Technical Annex – Part B

Advanced Radio Astronomy in Europe

Project full title	Advanced Radio Astronomy in Europe
Project acronym	RadioNet
Project coordinator	Prof. Dr. J. A. Zensus (MPG)
Call	Integrating and opening research infrastructures of European interest
Topic	INFRAIA–01–2016–2017: Integrating Activities for Advanced Communities
Domain	*Physical Sciences:* Research Infrastructures for advanced radio astronomy
Type of action	Research and Innovation Action (RAI)

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- ☐ Vaccine infrastructures.
- ☐ Experimental facilities for animal disease and infectiology (including zoonoses).
- ☐ Centres for replacement, reduction and refinement (3 Rs) of non-human primate testing.
- ☐ Facilities and resources for plant phenotyping.
- ☐ Marine biological stations.
- ☐ Research Infrastructures for the control of vector-borne diseases.

Energy

- ☐ Research Infrastructures for research on biomass conversion and biorefinery.
- ☐ Research Infrastructures for offshore renewable energy.

Environmental and Earth Sciences

- ☐ Research infrastructures for terrestrial research in the Arctic.
- ☐ Research Infrastructures for earthquake hazard.
- ☐ Mesocosms facilities for research on marine and freshwater ecosystems.
- ☐ Atmospheric simulation chambers.
- ☐ Research infrastructures for forest ecosystem and resources research.
- ☐ Sites, experimental platforms and data collections of anthropogenic impacts for ecosystem functioning and biodiversity research.
- ☐ Multidisciplinary Marine Data Centres for ocean and marine data management.

Mathematics and ICT

- ☐ Integrating activity for facilitating access to HPC (High Performance Computing) centers.

Material Sciences and Analytical facilities

- ☐ Research Infrastructures for advanced spectroscopy, scattering/ diffraction and imaging of materials.
- ☐ Synchrotron radiation sources and Free Electron Lasers.
- ☐ Facilities for research on materials under extreme magnetic conditions.
- ☐ Infrastructures for Neutron Scattering and Muon Spectroscopy.

Physical Sciences

- ☒ Research Infrastructures for advanced radio astronomy.
- ☐ Research Infrastructures for optical/IR astronomy.
- ☐ Research Infrastructures for hadron physics.
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- ☐ Access to European Social Science Data Archives and Official Statistics.
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1 Excellence

Research infrastructures are the cradle of world-class science, which is in turn the foundation of tomorrow's technologies, jobs, and well-being. These statements are particularly true for radio astronomy, where innovations in communication and ICT technology open new windows on the universe. Through the diverse programmes that the European nations funded in the past, Europe's radio astronomers can work with an impressively wide range of radio telescopes, covering a range of wavelengths spanning five decades, from [illegible]. Radio astronomy is a perfect example of a field in which national infrastructure providers have joined their efforts to establish and maintain world-class research facilities to develop, attract and retain research talents. From this, a vibrant community, spread out over even more nations, has developed. This community fosters scientific and technological innovations and contributes not only to the field of astronomy but also to interdisciplinary areas (like geodesy, fundamental physics, computing science) and the competitiveness of Europe at large.

Since 2000, the European Commission has supported an infrastructure cooperation network in radio astronomy. It started under the 5th Framework Programme (FP5) as a collaboration of partners from Europe, Australia and Canada. This collaboration continued successfully during FP6 (RadioNet) and FP7 (RadioNet2 and RadioNet3). The number of partners increased from 11 to 27, including global partners. Through this coordinated effort, Europe has successfully integrated a unique array of capabilities and made fantastic progress in radio astronomy. A world-leading position has resulted from this integration, which is for example demonstrated by the high proposal pressure for European time on the global ALMA telescope in Chile. Moreover, the ESFRI-listed SKA telescope is being developed as a global research infrastructure under European leadership. In order to make use of this advantage at a pivotal time in the development of radio astronomy, the RadioNet activities remain crucial.

The EC project contributions have allowed access for European scientists to a very complete range of radio astronomy infrastructures. At the same time, world-class technical development was initiated; European teams produced state of the art receivers for sub-millimetre telescopes, mastered the art of low frequency data processing, researched the use of aperture array receivers and implemented unique VLBI capabilities on the [illegible]. Nothing like this would have been possible without the formal collaborations that were initiated through the RadioNet projects. A small contribution (<10% of the operating cost of RadioNet infrastructures), has proven to be essential for bundling the efforts in European radio astronomy at all levels. This ensures that the required capacity building continues, which will be in high demand [illegible]It is also a crucial ingredient for involving more countries in radio astronomy. Moreover the developments for SKA and other ESFRI facilities offer synergetic opportunities to boost the science return of the past national investments in radio astronomy.

The proposed RadioNet work programme is structured into three types of activities: 3 Networking Activities (NA), 7 Trans-national access Activities (TA) and 3 Joint Research Activities (JRA). These activities are the outcome of a competitive selection process. The entire radio astronomy community was invited to submit applications, which were selected by independent experts based on excellence, implementation and impact criteria. Notably, an important criterion was that all selected activities would be measurable, realistic and achievable.

1.1 Objectives

Describe the specific objectives for the project, which should be clear, measurable, realistic and achievable within the duration of the project. Objectives should be consistent with the expected exploitation and impact of the project.

Against the backdrop of the development of the SKA and the operations of ALMA as global radio telescopes, we will focus on activities that maintain a strong European radio astronomy community, both scientifically and technically. There has been noticeable progress with the European-scale governance of radio astronomy through the establishment of JIVE-ERIC and the commitment to continue the existing collaborations. However, strong leadership of the RadioNet collaboration is much needed, with the following objectives:

1. to provide a governance structure for the collaboration of European radio astronomy institutes
2. to facilitate access to a complete set of key research infrastructures in Europe for advanced radio astronomy – open and free of charge,
3. to attract users of the wider astronomy community by providing an integrated, professional and consistent level of user support,
4. to equip scientists and engineers with the essential skills to take charge of existing and future radio astronomical infrastructures,
5. to provide a joint channel for the dissemination of scientific and technical achievements resulting from the collaboration,
6. to facilitate scientific and technical interaction among the radio astronomy community and with all partners , including industry and other stakeholders,
7. to develop state-of-the-art hardware and software necessary for the existing radio infrastructures and relevant for access to the future ,
8. to ensure that the joint technical development programme makes an impact on a European scale and connects with industry, reinforcing the H2020 mission,
9. to work towards establishing a long-term, self-supporting RadioNet structure, identifying the resources that will secure this collaboration on many levels
10. to contribute substantially to the implementation of the vision developed in the *ASTRONET Strategic Plan for European Astronomy* by providing key facilities and fostering a sustainable radio astronomical research community with world leading qualifications.

It is a strong point that this RadioNet proposal builds on its precursors and will continue to organize European radio astronomy. In some key places the RadioNet programme will make provisions to address the most important current issues. The user community will recognize the continuous commitment to provide a complete, innovative and accessible set of research facilities. In addition, RadioNet will continue to be the body representing the in the context of (*OBJECTIVE 1*).

Most importantly, RadioNet provides European astrophysicists with the most sensitive telescopes (*OBJECTIVE 2*) like the single dishes of APEX, Effelsberg 100m, and IRAM-PV, and unique interferometers probing high angular resolution such as e-MERLIN, EVN, IRAM-NOEMA, LOFAR, and WSRT. A so-called "open skies" policy is offered by all these radio telescopes, even though they are constructed and operated by national agencies, local institutes or limited collaborations. The European access is an essential ingredient for promoting the use of these facilities on a larger scale. In radio astronomy we proudly note that there has been substantial progress towards establishing an exchange of researchers as envisioned in the European Research Area (ERA). While traditionally the field was dominated by local specialists, an effective transition has been made by employing dedicated support staff at the telescopes. The nature of radio astronomy experiments are such that an adaptive level of assistance is key for allowing astronomers with a different background to make effective use of the radio astronomy infrastructures (*OBJECTIVE 3*).

A particular challenge in this respect is that radio astronomy rapidly new technologies, producing ever more voluminous and considerably more complex data. At the same time there is a demand from an increasing community of researchers to use the radio astronomy data. RadioNet is important for organising joint training events to attract new users, to provide with the essential tools to take full advantage of existing and future radio astronomical infrastructures. (Use of the archive will be included) The programme not only targets scientists, but also an international pool of engineers, who can update their skills and knowledge in exchange programmes. *(OBJECTIVE* 4). Dissemination of technical and scientific results will also benefit from a joint approach in order to maximise their impact. RadioNet will use the appropriate dissemination channels to promote the scientific and technical output of the project activities (e.g. publications, oral presentations at scientific conferences and workshops – *OBJECTIVE* 5). The audience will certainly not be restricted to radio astronomers, but it will include the broader scientific community, policy makers and industry. RadioNet will establish links with other EU projects (Europlanet, ASTERICS, AHEAD, OPTICON) and serve as an important point of contact for policy activities (ASTRONET, ESFRI initiatives). New links with industry will be explored by attending the specialised events, e.g. IEEE, communication meetings (*OBJECTIVE* 6).

Radio astronomy is big science with local, earth-bound telescopes. This continues to provide opportunities for innovation, as is demonstrated by the way our pioneering R&D activities have upgraded RadioNet facilities. The European partners will work on software that deploys modern parallel computing techniques, high in demand for instruments such as e-MERLIN, LOFAR, Apertif and the EVN. New digital equipment will allow radio astronomers to make more sensitive observations with the existing telescopes by increasing the observing bandwidth or the field of view. This possibility to design innovative receivers comes at a time when the increased data rates can be handled by new digital components. This particular programme has a direct link with the SKA; if these big data issues are not addressed for the upgraded RadioNet facilities, they will become a serious bottleneck for scientific progress. We envision that the developments will push the current norm for data processing and establish a new standard for radio astronomy performance (*OBJECTIVE* 7).

The topic of big data is a good example of the way radio astronomers are learning to mobilize the expertise that is available in industry. This interest has proven to be mutual, because the large data volumes and associated real-time analysis operations provide an interesting challenge for industry. All the JRAs proposed in the program have been selected to provide possibilities to combine our astronomical objectives with industrial partnerships (*OBJECTIVE 8*)

Concerning sustainability, RadioNet must make progress beyond current standards in terms of integration and services, technical development, expanding trans-national access and securing long-term services. In order to achieve this, we have to identify the core resources necessary to support the fundamental mission of European radio astronomy and secure this independently of EC funding (*OBJECTIVE* 9).

There is already a RadioNet vision on how the European radio astronomy community should formally organise itself in the coming decade (ASTRONET- ERTRC[1] Report & RadioNet3 White Paper). This vision now requires a sustainability plan for RadioNet beyond the grant lifecycle. Future R&D developments require a critical mass that can only be found on a European scale with respect to the needed resources (*OBJECTIVE* 10).

For all of European astronomy ASTRONET (an FP7 ERANet) has evaluated the strategic priorities for the next 5-25 years. The outcome of this exercise was reported in two documents: a Science Vision outlining the opportunities and priorities for European astronomy, and a Roadmap translating that Vision into a plan for establishing the required large-scale facilities. contributes substantially to the implementation of the *Strategic Plan for European Astronomy (OBJECTIVE 10)*:

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- RadioNet facilities make unique and essential contributions to our knowledge of the Universe,
- RadioNet performs coordinated efforts in technical development and in attracting and training of talent,
- RadioNet actively protects the radio frequencies for scientific use,
- RadioNet enables the delivery of excellent science due to its coordinating role and trans-national activities,
- RadioNet strengthens the competitive advantage while facilitating and expanding the access to radio astronomical infrastructures and data archives that facilitate excellent science.

This clear set of RadioNet objectives identified across the foreseen activities is addressing the requirements of the community of users, stakeholders and industry. The programme will make sure that European radio astronomy infrastructures remain competitive. The goals we define are ambitious but achievable; the RadioNet beneficiaries are experienced and professional, as the past activities have proven. Each activity has well-defined targets and plans to exploit the results for specific needs. RadioNet is the European body that will guard the standards for the R&D that is needed for European radio astronomy. The expected short term and long-term impacts of the project achievements have been identified and are described in Sec 2.1.

1.2 Relation to the work programme

Indicate the work programme topic to which your proposal relates, and explain how your proposal addresses the specific challenge and scope of that topic, as set out in the work programme.

WORK PROGRAMME TOPIC: The RadioNet proposal addresses the work programme topic INFRAIA–01–2016–2017: Integrated Activities for Advanced Communities – “Research Infrastructures for Radio Astronomy”.

SPECIFIC CHALLENGE: In the proposed TA programme, RadioNet offers a suite of specialised radio observatories that cover a range of wavelengths spanning five decades, from metre to sub-millimetre. The RadioNet telescopes and associated facilities, including laboratories and data repositories, are among the most powerful research infrastructures in the world, as needed to conduct cutting edge science and foster innovation. The accompanying RadioNet programme defines a range of activities that bring together researchers, policy makers and industry. The research infrastructures offered in RadioNet are open to anybody, with selection processes based only on scientific excellence.

SCOPE: The RadioNet partnership is rooted in earlier collaborations, with partners that are ready to make the next step in integrating their activities. Fostering the success and experience of the four precursor programs under FP5, FP6 and FP7, the RadioNet community has progressed to a very advanced degree of networking and coordination.

Although RadioNet was originally in essence an EC project, funding agencies and international project consortia nowadays recognise RadioNet as *the European entity* representing radio astronomy; its partners are jointly responsible for access to excellent facilities. Notably, the ASTRONET-ERTRC has stated in its recently published report (June 2015):

“We recommend that local and national radio institutes remain independent, as local support and expertise centres for radio astronomy, but that their joint activities, such as EVN and RadioNet, become more robustly and permanently organised and funded (but not through the same body that organises the European participation in the SKA).”

This conclusion is of paramount importance for consideration on the sustainability of coordinated approach to European radio astronomy.

RadioNet joins together 24 partners, amongst which are institutions operating world-class radio telescopes as well as organisations performing cutting-edge research, education and development in a wide range of technology fields that are important for radio astronomy. The consortium will establish strong links to complementary European initiatives by appointment of representatives in its Advisory Group. The consortium board will consider members from ESFRI initiatives (e.g. SKA), related scientific projects (e.g. ASTERICS, AHEAD, EUROPLANET), and key industries.

RadioNet dedicates a significant amount (42%) of the EC funding to support the Trans-national and Virtual access to the set of key radio astronomy facilities for researchers from European and Third Countries.

All selected TA facilities offer access based only on scientific excellence, using in almost all cases a common electronic application system (NorthStar, developed under RadioNet). The close cooperation established between the RadioNet facilities is an excellent starting point for TA leaders to identify the areas for further harmonisation and optimisation of the access procedures and interfaces. Collecting, calibrating and interpreting radio astronomical data is a challenging activity. , a certain number of black-belt users are crucial for pushing the radio telescopes to their limits, and for exploring new instruments and new techniques. On the other hand transparent and streamlined access for non-specialised users to the radio telescopes and their data will increase the range and impact of the science that is delivered. The projected full range of science capabilities drives the technological developments. (Arguments for including/offering Apertif Long-Term Archive under virtual access will be included)

, RadioNet dedicates a substantial budget (41%) to Joint Research Activities. These projects will develop equipment and software to improve the quality and variety of the services of our radio astronomy research infrastructures. The implementation of the delivered technology will , improve the bandwidth and quality of the data, simplify the use and maintenance, and reduce the operating cost and therefore increase the scientific productivity.

Thanks to RadioNet, the European radio astronomy community is now better connected than for example the US community, despite dealing with national and language barriers. In particular, effective platforms have been established for the interaction between European radio astronomers, engineers and the facility operators. For example, the European radio astronomers speak with one voice to keep the radio sky free from man-made interferences. The European radio astronomy engineers meet regularly in order to define new common standards and goals. As a consequence, duplication of effort is avoided and the technical developments are pushed forward effectively.

Previously, Networking Activities focused on specific audiences (scientist, engineers, policy makers), successfully addressing their particular needs. However, this autonomy of the Networking Activities was not designed to optimally support mutual interaction between the activities and their respective communities.

Now, RadioNet networking activities are proposed to be combined into three work packages with over-arching goals of dissemination, training and sustainability. This will be a significant improvement compared to previous incarnations of RadioNet. Each of these three topics involves the entire radio astronomy community; this facilitates interaction and synergy between researchers from the scientific community industry, engineers, technicians, policy makers, and other stakeholders. This way RadioNet will contribute to an efficient and attractive European Research Area.

RadioNet will organise the efficient curation, preservation and provision of access to the data collected or produced under the project. For this purpose, the repository of the Max Planck Society (MPG) will be used to establish a long-term archive for the preservation of results obtained by JRAs and NAs: software source-codes, technical design plans, publications, tutorials and oral presentations.

In the previous project, the RadioNet [illegible] alternative scenarios for addressing the issue of the governance of European radio astronomy. In the resulting White Paper the most credible scenario proposes the establishment of an entity called ‘RadioNet-work”. RadioNet-work shall be a body uniting all key European radio astronomy facilities and maintaining just the minimum level of basic activities, focusing on the continuity of the joint training effort only. [illegible].

[illegible]. At this moment, there is no need for [illegible] development of a new roadmap as one has been published recently by ASTRONET in the ERTRC report. However, a sustainability plan towards the next decade for European Radio Astronomy must be [illegible].

1.3 Concept and methodology

a) Concept

In the global arena, European Radio astronomy has played a predominant role for more than five decades, both in terms of outstanding scientific achievements and cutting edge technical work. However, the field of radio astronomy is changing rapidly and considerably, and we must adapt to those changes to remain at the forefront. New technologies can significantly improve the sensitivity, imaging quality and spectral coverage of telescopes and to maintain them at the forefront of the world, RadioNet must encourage investments in such technologies.

Beside the facilities themselves, the human capital of European radio astronomy is also a crucial factor in its success. Training skills like experiment design, data analysis, software tools and system engineering [illegible] needed to fully exploit the potential of radio telescopes. [illegible] to tackle the complexity of the Universe. Therefore the community of scientists able to use radio telescopes must grow. Consequently, the access methods to data must be adapted to meet the needs of non-specialised users through public archives and standard pipelines. RadioNet will offer the platform to address these needs.

Radio astronomy in Europe has a long history of successful cooperation; its primary examples are the European VLBI Network and the establishment of an “open sky policy” in 1980. Given the diversity of funding arrangements, agency and community requirements, these collaborations are often complex, sometimes fragile even. In RadioNet the entire radio astronomy community has been united under one umbrella. The funding agencies and international project consortia recognise, de facto, RadioNet as *the European entity* representing radio astronomy. Notably, RadioNet is seeking to become a self-supporting entity.

The RadioNet proposal defines a program for 4 years duration and with a total budget of 10M€. [illegible] to the operating cost of RadioNet facilities over the same period of time (146 M€). However, by invoking a common strategy this precisely targeted investment will capitalize on the opportunities with the most [illegible], addressing the most [illegible] needs of the users across Europe.

THE MAIN IDEAS, MODELS OR ASSUMPTIONS INVOLVED.

Building on the highly successful predecessors (FP5-FP7), this proposal aims at continuing the organization of European radio astronomy under the flag of RadioNet. Since its origin, RadioNet has become an effective driving force behind European radio astronomy and it has fundamentally re-shaped the radio astronomical scene in Europe into a complete, innovative and accessible set of research facilities. RadioNet activities have provided a sustainable and broad-based platform for the continued organisation of the European radio astronomy community, which is essential for securing lasting European leadership in all aspects of radio astronomy.

Over the years, the TA programme of RadioNet has stimulated the full exploitation of the open skies policy that has been at the core of the operations philosophy of most radio astronomical facilities for decades. In the same period, key investments in the been made. revolutionary opportunities to involve an even wider-range of astronomers, because of the new scientific fields these telescopes open up. The TA programme will certainly also attract users from Third Countries the European users. (Text on VA access will be added)

The Networking Activities (NA) of RadioNet have transformed the way science is conducted in Europe; they have provided a natural forum for developing European collaborations, for sharing both results and new ideas and for mobilizing the researchers themselves. Now, one of the main ideas is to mobilize the entire astronomy community , industry, and researchers from other academic disciplines (e.g. geodesy, fundamental physics and computing science). Another objective is to by providing a technical forum for supporting the Global Millimetre VLBI Array (GMVA). This is becoming even more relevant with the emergence of new, exciting research opportunities to include ALMA in the GMVA. Additional return will be generated by mobility in order to reinforce the contacts between the different groups: astronomers, engineers and industry.

It is rewarding to see that the Joint Research Activities (JRA) have contributed substantially to upgrades of all RadioNet facilities. JRA achievements led to the development of miniaturized detectors aimed at focal-plane array (FPAs) receivers for single-dish telescopes, to the development of new software and modern parallel computing techniques for interferometers, and to the development of new digital techniques allowing more efficient use of telescope hardware by increasing the observing bandwidth or the field of view of the dishes. Now, the JRAs will focus on the construction of large heterodyne FPA demonstrators, as well as on standardised instrumentation compatible with many of the European radio telescopes. Complementary to the hardware development, another JRA will deliver functionally superior, maintainable and computationally efficient calibration software that addresses the challenges and opportunities posed by new and future high sensitivity, wide-bandwidth, long-baseline radio interferometers.

INTER-DISCIPLINARY CONSIDERATIONS AND, WHERE RELEVANT, USE OF STAKEHOLDER KNOWLEDGE

Radio astronomy is a perfect example of how the interdisciplinary interaction between science and technology leads to applications that change our perception of the world, e.g. the VLBI observing technique is used daily to track the motion and orientation of the Earth in space as well as the movement of the tectonic plates. Moreover, RadioNet partners such as the Fraunhofer IAF have a long track record of transferring to industry. Another example is how receiver requirements are of integrated wide-band receivers. Finally, RadioNet research will have several industrial applications that rely on reciprocal imaging technology. Industry partners from geodesy, seismic imaging and radar imaging will be invited at the end of project to share the results for exploitation.

THE PROVISION OF OVERARCHING RESEARCH INFRASTRUCTURE SERVICE, ERA & GLOBAL COOPERATION

The RadioNet consortium involves 14 universities as direct partners. All other research institutes, which, together with associated universities, contribute of early stage researchers. Therefore, many more universities across Europe will benefit from RadioNet. The access to the RadioNet infrastructures and services is largely aimed at non-partner research groups. A broader community will profit from networking activities through training, dissemination of results, and access to facility archives. RadioNet will preserve and make them publicly accessible. This way RadioNet will help to develop a more efficient and attractive European Research Area.

Radio astronomy is already internationally cross-linked and RadioNet partners are involved in several European and global collaborations on research infrastructures (e.g. the European VLBI Network-EVN, GMVA, ALMA, EHT, SKA). Although RadioNet is not itself participating as a legal entity in those activities, the interest radio astronomy community is represented through the RadioNet partners. A strong RadioNet structure is deemed crucial to represent the European interests time when a number of global research infrastructures are (SKA, global VLBI, mm-VLBI).

LINKED NATIONAL AND INTERNATIONAL RESEARCH AND INNOVATION ACTIVITIES

which will be linked with the project, especially where the outputs from these will feed into the project;

New, revolutionary science capabilities often come within reach when new technologies become available. Therefore, a link to national and international research and innovation activities will be established in order to exploit the results in the most effective way.

CASA, the Common Astronomy Software Applications package, has been developed with the primary goal of supporting the data post-processing needs of the radio astronomical telescopes such as ALMA and JVLA. The package was developed by a global consortium of scientists based at the National Radio Astronomical Observatory (NRAO), the European Southern Observatory (ESO), the National Astronomical Observatory of Japan (NAOJ), the CSIRO Australia Telescope National Facility (CSIRO/ATNF), and the Netherlands Institute for Radio Astronomy (ASTRON) under the guidance of NRAO. The software developed in RadioNet will comply with CASA rules, and it will be integrated into in the CASA CORE software package. RadioNet will seek close interaction with the CASA team at NRAO for alignment of the activities.

IVS, International VLBI Service for Geodesy and Astrometry, is a global collaboration of 17 research organizations providing services for geodetic, geophysical, and astrometric research. Besides implementing several operational activities, it promotes the development of innovative geodetic and astrometric VLBI. RadioNet partners will continue their cooperation with the IVS technical development groups, notably where it concerns receiver development.

EUROPLANET, the Europlanet Advanced Research Infrastructure dedicated to planetary science funded by EC since September 1, 2015, aims to collaborate across EU space projects and develop links with other major EU projects. RadioNet will seek for collaborations with Europlanet, particularly in the media, outreach policy and industry links.

b) Methodology

RadioNet involves 25 partners who contribute to a total of 14 different work packages (1 Management, 3 NAs, 3 JRAs, 6 TAs and 1 VA). The first WP is to the overall management of the project, in which an experienced management team will centrally control the activities.

Joint Research Activities (WP5-WP7) are tailored to address over the full wavelength range of European radio astronomy infrastructures. under Trans-national Activities (WP8-WP13). A of the RadioNet programme is Long-Term Archive (WP14), which will be available by 2018. A detailed work package description is given in Table 3.1b. An efficient curation of the project results, defined in data management, will be realised by using the MPG repositories (see Sec.2.2a).

COHERENT AND COORDINATED SET OF ACTIVITIES

how the various types of activities will form a coherent and coordinated set of components contributing to the same objectives.

Together the 14 activities of RadioNet form a coherent and coordinated set with common objectives – to serve the needs of the radio astronomy infrastructures, enabling them to conduct excellent research and foster innovation.

NETWORKING ACTIVITIES – TO FOSTER A CULTURE OF CO-OPERATION

The networking activities aim specifically at timely and effective communication of results, by stimulating a continuous interchange of ideas. This we know to be crucial for the advance of cutting edge research programmes and the progress of science and technology. They also provide the environment for the personal interactions aimed at spreading good practices. In these opportunities for interaction on scientific and engineering topics can be identified. This will also ensure that the next generation of scientists and engineers are exposed to, and become familiar with, the capabilities of the radio astronomical infrastructures. Here, we propose a set of NAs that will significantly enhance the science (e.g. TA output) and technology (e.g. JRA developments) of the RadioNet infrastructures, but also of other relevant radio astronomical facilities. This will [illegible] that the RadioNet activities are indeed integrated and coherent. Specifically:

- WP2 (Dissemination) is designed to propagate the scientific and technological results within the context of the RadioNet infrastructures, in order to [illegible] their transfer in all directions (scientific, technical and industrial). This activity will foster the dialogue between science and technology, and reinforce the contact between European radio astronomy and industry,
- WP3 (Training) is dedicated to furnishing radio astronomers and engineers with the skills that are essential to take full advantage of the present and future radio astronomical infrastructures. A focussed set of training events will be offered, and inter-sectional mobility between the different groups: scientists, engineers, will be encouraged,
- WP4 (Sustainability) will strengthen the sustainability of future radio astronomical research in Europe by focusing on standardization of VLBI operations and equipment (EVN, but also GMVA), on protection and maintenance of the electromagnetic spectrum for radio astronomy, and on development of [illegible].

JOINT RESEARCH ACTIVITIES – TO IMPROVE THE INTEGRATED SERVICES

[illegible] The JRAs cover the entire frequency range of the RadioNet telescopes and arrays (see Fig.1.3b.1), delivering new equipment and software:

- WP5 ([illegible]) will develop novel technologies for receivers in the mm/sub-mm wavelength range aimed at IRAM 30m, APEX, IRAM-NOEMA and finally the ALMA. The novelty is to construct affordable, large focal plane array receivers (≥[illegible] pixels at 1-mm wavelength) and wide, intermediate frequency bandwidths (up to 24 GHz). These specifications would increase the telescope observing efficiency by two orders of magnitudes,

- WP6 (BRoad bAND EVN) will engineer a prototype broad-band digital receiver covering a frequency range from 1.5 GHz to 15.5 GHz, deployable at all EVN stations at a reasonable cost. This will boost the EVN observing efficiency and flexibility, and reduce the operating and maintenance cost considerably. These new receivers in the EVN enable a range of new science in the areas of VLBI imaging, spectroscopy, polarimetry, and astrometry, which at present can be tackled with only poor efficiency, if at all,
- WP7 (Radio Interferometry Next Generation Software) will deliver highly functional, maintainable and computationally efficient calibration software that addresses the challenges and opportunities posed by new and future wide bandwidth, long-baseline radio interferometers. These routines will empower much more accurate and thus effective processing of data from facilities such as ALMA, LOFAR, e-MERLIN, EVN, EHT, GMVA and SKA.

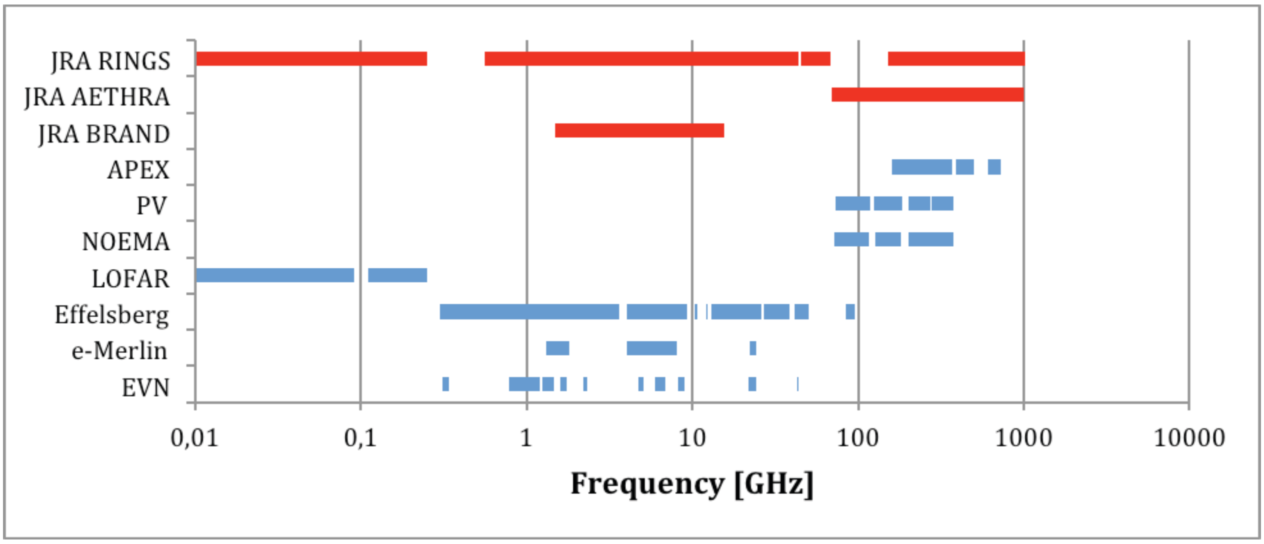


Fig.1.3b.1 The frequency coverage of the RadioNet TA facilities and the JRAs developments.

TRANS-NATIONAL AND VIRTUAL ACCESS – EXPLOITATION OF THE KEY RESEARCH INFRASTRUCTURES

Observations at radio wavelengths, from metre to sub-millimetre, offer a powerful and unique view on the Universe: they monitor the Solar System; they allow studying star formation in our own and other galaxies, they permit testing general relativity, and they contribute to precise astrometric and geodetic measurements. Many astronomers across Europe will be attracted to use the world's best facilities. Whether they are individual radio telescopes or international networks of antennas, they are all freely accessible due to the "open-skies" policy.

But, these facilities are diverse and highly specialised, thus their use requires specific assistance with planning, executing, analysing or interpreting the desired observations. The Trans-national Access programme provides access to these unique world-class facilities and at the same time guarantees the commitment of these observatories to offer an equally high level of professional support to both new and experienced users. The RadioNet facilities offer unique capabilities over an unprecedented range of radio wavelengths – from the largely uncharted territory of astronomy to the sub-millimetre range, occupied with many molecular transitions (see Fig 1.3b.1). RadioNet offers access to interferometers (EVN, e-MERLIN, IRAM-NOEMA, and LOFAR), and to single dish telescopes (Effelsberg, IRAM-PV, and APEX). Arguments for Virtual access will be added.

Continued technical development and substantial investments over the past years have pushed the global competitiveness of all these facilities and often gone beyond that by establishing truly unique capabilities. All RadioNet facilities take active steps in advertising their availability to the wide astronomical community, through email distribution lists, newsletters, webpages and meetings. All RadioNet TA facilities have an effective and fair procedure for the evaluation of the best proposals based on their scientific merit. Additionally, each TA infrastructure operates a dedicated team to support TA users at all stages: from the proposal submission through the observations up to distilling the scientific results (data reduction).

The RadioNet TA program has a fantastic record of attracting European users from many places. It turns national facilities into European research infrastructures. This result in excellent research, but also in the need to maintain and develop the facilities – they have to continuously improve in order to be attractive. We note that there is valuable return of investment here: the telescopes reinvest the EC support in the improvement of the professional user support, technical development and support of the “open sky” policy.

CONSIDERATION OF SEX AND GENDER ANALYSIS

Describe how sex and/or gender analysis is taken into account in the project’s content.

Females are particularly under-represented in the physical sciences, engineering, and in astronomy. The RadioNet community, aware of this situation, has actively taken steps to encourage female recruitment and participation. All institutes involved in RadioNet have a policy of promoting and developing their staff equally, regardless of gender. Therefore the RadioNet consortium has adopted in 2009 a diversity policy to hire personnel, regardless of sex, ethnic origin, physical handicap, sexual orientation or religion. This policy will continue to be applied in all steps of implementation of the RadioNet programme.

At present the RadioNet training and dissemination events have already an average of 30% of women, coming from all over the world. Although it is not totally satisfactory, it is encouraging compared to, for example, the USA (less than 20%). RadioNet will consider any steps to maintain this trend and to increase the participation of women.

Participants of the RadioNet events have come from all over the world, irrespective of culture, religion and gender (China, Ghana, Greenland, India, Iran, Japan, Korea, Russia, USA, etc.). They have been selected based [illegible]. In the next RadioNet we will continue this policy.

1.4 Ambition

Describe the advance your proposal would provide beyond the state-of-the-art, and the extent the proposed work is ambitious. In particular:

The [illegible] of RadioNet is to facilitate excellent science by offering access to the best radio astronomical facilities in the world, to enhance the infrastructure performance by updating them beyond the current state-of-the-art technology, to identify and exploit synergies between the partners in higher technical performance, to increase their utilisation by enabling new applications for astronomical and industrial purposes. By offering high quality research services to users from different countries and communities, attracting early stage researchers to astronomy and by networking the facilities, RadioNet will involve the scientific community and play a key role in the construction of an efficient research and innovation environment. Moreover, by coupling users, knowledge and investment, RadioNet will support the national, regional and European economic development.

NETWORKING ACTIVITIES - ENHANCEMENT OF THE PROVIDED SERVICES

Explain how the set of the "networking activities" will enhance the services provided by the research infrastructures in the proposed programme of activities. Indicate how the networking activities will foster a culture of co-operation between the participants in the project and the scientific communities benefiting from the research infrastructures.

RadioNet NAs are designed to foster a culture of cooperation between scientific and technical communities, linking for example with ASTRONET and SKA, and promoting cooperation with industry and policy makers. Thus RadioNet will help developing a more efficient and attractive European Research Area.

WP2-Dissemination will concentrate on broadcasting and advocating the scientific and technical results of the project through dedicated scientific and technical events. WP3-Training will attract especially early stage scientists to equip them with the essential skills to take full advantage of the present and future radio astronomical infrastructures, including the relevant instrumentation, observing techniques and technologies. This activity will also introduce exchange visits between RadioNet beneficiaries and other scientific and industrial partners, aiming at spreading good practices. WP4-Sustainability will focus on developing long-term perspectives for securing the fundamental mission of European radio astronomy community. RadioNet will interact with industry and policy makers for protecting radio astronomical frequencies. Finally, a formal platform will be provided, where European radio astronomy institutes and organisations come together and discuss the broad coordination of the field in areas related to strategic planning and other high-level policy matters. The platform will focus on joint activities, including the EVN, ALMA and the future SKA.

TRANS-NATIONAL AND VIRTUAL ACCESS ACTIVITIES - OVERALL COHERENCE OF THE SET OF INFRASTRUCTURES

On the basis of the set of the "trans-national and/or virtual access activities", explain the overall coherence of the set of infrastructures offering access. Indicate to what extent the activities will offer access to state-of-the-art infrastructures, high quality services, and will enable users to conduct high quality research

RadioNet infrastructures form a set of the most powerful radio/sub-mm astronomical research facilities, covering all wavelengths from metres to sub-mm and all angular scales from full-sky surveys to milli-arcsecond imaging (WP8-WP14, see Fig 1.3b.1). RadioNet infrastructures provide, in a coordinated way, "free of charge" trans-national access to individuals or groups from the scientific community. All offered facilities and their state-of-the-art equipment aim at obtaining fundamental scientific results and have a limited use for industrial applications; this link is provided when pushing the limit of their capabilities.

LOFAR (WP11) is the most powerful instrument in the world to offer high-resolution, wide-field imaging at metre wavelengths. The combination of EVN+e-MERLIN (WP8 and WP9) is the only instrument, which offers a complete range of baseline-lengths from 10km to 10,000km. IRAM-NOEMA (WP10) will be the only sub-mm array and the only mm-wave array capable of processing a total bandwidth of 32 GHz per antenna. Complemented by single-dish telescopes, such as the IRAM 30-m telescope (WP10) and APEX (WP13), one can combine sensitivity, angular, and spectral resolution to process molecular radiation into tomographic images of exceptional accuracy. The Effelsberg 100-m telescope (WP12) is unique in Europe and – together with the Green Bank telescope in the USA – one of the two flagship single dish telescopes worldwide. The ALTA (WP14) is a brand new facility offering free virtual access to data and scientific products produced from all sky surveys of the Northern sky that will be conducted with the Apertif frontend of the Westerbork Synthesis Radio Telescope (WSRT), as well as services to query, further exploit and perform in-depth data mining of these products adaptable to diverse research goals.

All RadioNet facilities have well-established peer review processes in place that ensure the selection of the highest quality of research, based on scientific merit only. Most of the facilities now use the Northstar proposal tool developed in FP6 RadioNet, simplifying the proposal procedures.

There is a joint effort to advocate their availability worldwide to the astronomical community. RadioNet will seek to enlarge the targeted group by establishing links to other astronomical communities, by publishing the call for proposals on the RadioNet webpage and by building up targeted mailing lists. By providing TA users with support at each stage of the observing process, they have the opportunity to interact with scientists and engineers at the facilities, and very often develop long-term collaborations in this process. This is the way to produce top-class science and to prepare the European community for the SKA at the same time. By having access to RadioNet infrastructures on one hand, and having a well-defined selection process of the best scientific observing proposals on the other hand, all conditions are met for TA users to conduct high quality research.

JOINT RESEARCH ACTIVITIES – CONTRIBUTION TO IMPROVEMENTS OF THE SERVICES

Looking at the set of the proposed "joint research activities" (JRAs) explain how these activities will contribute to quantitative and qualitative improvements of the services provided by the infrastructures

The set of RadioNet JRAs is innovative and aims at exploring new fundamental technologies and techniques to support the competitiveness of the RadioNet infrastructure.

Astronomy with mm/sub-mm-waves is the key observational tool for exploring cold and dense gas in the Universe. It has been revolutionised very recently by new and powerful interferometers such as ALMA and NOEMA. And yet, more technical enhancement is essential to realize the full potential of these facilities. The AETHRA (WP5) aims at exploiting these opportunities for the next generation instrumentation, at the same time reinforcing the European leadership in the field of mm/sub-mm astronomy. Reduced-size prototypes of focal-plane receiver arrays will include the interfaces needed to demonstrate their performance on the leading European telescopes, in particular on the IRAM 30-m telescope and APEX. The observing speed of the projected receiver will be boosted by widening the IF/RF receiver bandwidths and by increasing the instantaneous field of view through the implementation of focal plane arrays of heterodyne receivers with tens to hundreds of sky-pixels. As a result, an improvement of the telescopes operating in the millimetre regime by several orders of magnitude is envisaged.

The EVN, operating in the cm-range, competes only with the Very Long Baseline Array (VLBA) when it comes to accessibility, user support and quality of data. Today, the EVN uses separate receivers for the bands that are covered, leading to a loss of observing time of up to hours. In addition, the receivers require multiple, expensive cryogenic cooling systems. BRAND EVN will develop a prototype broad-band digital receiver, which will cover a frequency range from 1.5 GHz to 15.5 GHz for all EVN stations, making the very attractive frequency band at 15 GHz available in the EVN. The expected reduction in observing sensitivity will be compensated by the very wide frequency band and the very high output data rate. It will be needed to address the radio frequency interference, present in this very wide band, but this can be handled in the digital processing.

All long-baseline interferometer data must be corrected for differential, time-variable delays between array stations, which cannot be modelled a priori. Existing software to do this is limited to non-dispersive delays and functions poorly when the signal-to-noise ratio is low. This is problematic for millimetre wavelengths, where coherence times are very short, and for metre wavelengths, which are dominated by dispersive delays. Moreover, the current best- delay calibration routines are only available in AIPS, a software package whose support horizon is limited. The RINGS (WP7) work programme will deliver highly functional, maintainable and computationally efficient calibration software that addresses the challenges and opportunities posed by new and future high sensitivity, wide bandwidth, long-baseline radio interferometers. Crucial functional improvements will be the development of algorithms for full service fringe fitting solutions, accurately encompassing dispersive delay and full polarisation. These algorithms will be implemented in the existing CASA software package. The results delivered by RINGS target multiple national and international facilities (ALMA, SKA, LOFAR, e-MERLIN, EVN, EHT, and

GMVA). This will lead to an enhanced and more efficient exploitation of these facilities enabling new science (high image fidelity, large field of view, astrometry, polarimetry).

INNOVATION POTENTIAL

> *Describe the innovation potential* ***(e.g. ground-breaking objectives, novel concepts and approaches, new products, services or business and organisational models)*** *which the proposal represents. Where relevant, refer to products and services already available on the market. Please refer to the results of any patent search carried out.*

Radio astronomy R&D has yielded many innovative and wide-spread applications originally not foreseen by the developers. Examples can be found in communication antennas, transistor design, cryogenic coolers, medical and scientific imaging, time and frequency standards, GPS navigation, precision spacecraft navigation and cell phone location tracking. It is clear that radio astronomy expertise is a valuable resource that not only increases our fundamental knowledge of the universe, but also contributes significantly to European competitiveness.

However, the RadioNet technical developments will initially be of an astronomical nature and focus on opening new scientific possibilities for the scientific user. By equipping the RadioNet facilities with innovative technologies, RadioNet offers the users exciting tools for new discoveries.

The objective of AETHRA will be to produce reduced-size prototypes of heterodyne focal-plane receiver arrays (FPAs). [illegible] to FPAs of bolometric detectors that may consist of thousands of sky pixels, heterodyne FPAs, which are mandatory for spectral line and interferometric observations, so far have modest sizes (typically ≤10 sky pixels) and limited sensitivity. AETHRA will aim for high-sensitivity, large-size focal plane arrays (≥10^2 pixels at 1-mm wavelength) and wide bandwidths (up to 24 GHz), initially for single-dish telescopes, such as the IRAM 30-m telescope and APEX. Eventually, the AETHRA developments will have a major impact on interferometers such as NOEMA and in the longer term, ALMA. Note that a modest array of heterodyne receivers on the twelve 15-m diameter NOEMA antennas would boost the sensitivity of NOEMA for large scale mapping to a level that surpasses that of the ALMA 50 antenna interferometer in the most accessible bands. This would facilitate surveys for the most distant Luminous Infrared Galaxies, whose peak emission is redshifted to mm wavelengths – surveys that are confusion limited when carried out with single dish telescopes.

The prototype broad-band digital receiver to be delivered by BRAND will cover a frequency range from 1.5 GHz to 15.5 GHz. An implementation document with the installation requirements for each EVN station is part of the work. The project will make use of recent achievements in different fields: broad-band feeds and LNAs, back-ends with very high data rates of up to 128 Gbps (DBBC3, a result of RadioNet3), and data recorders for up to 64 Gbps as are being developed for the EHT (Event Horizon Telescope). The BRAND result will impact all EVN stations, and will be relevant for other astronomical communities (e.g. AVN – African VLBI Network). A capability to observe simultaneously 1.5 GHz to 15.5 GHz on the EVN would enable a range of science that at present can be hardly addressed. Key is the ability to make images at many frequencies simultaneously and have them phase referenced to each other. Applications span VLBI imaging, spectroscopy, polarimetry, astrometry and geodesy, and single-dish spectroscopy and polarimetry. The new frequency coverage will also be relevant for space applications in which spacecraft are observed.

The results of RINGS will be calibration software that addresses the challenges and opportunities posed by new and future high sensitivity, wide bandwidth, long-baseline radio interferometers. RINGS builds on the results of several projects such as RadioNet2, RadioNet3, BHC (BlackHoleCam), the LOFAR Long Baseline Working Group, the ALMA Phasing Project (APP), and Measurement Set Correct Polarization (MSCORPOL). RINGS will apply state of the art parallelization techniques and integrate the results in CASA CORE. The calibration solutions delivered by RINGS will facilitate ground-breaking science on all existing long baseline facilities (EVN, e-MERLIN, EHT, ALMA, LOFAR, and GMVA) enabling more sensitive imaging over larger fields, polarization imaging and measurements of proper motions and parallaxes. Notable science cases addressed by RINGS include: the direct detection of the event horizon around nearby super-massive black holes, jet formation by super-massive black holes, the formation of massive stars (in the mm-range); gas kinematics around active galactic nuclei, super-massive black hole binaries and multiples (in the cm range); and the low energy electron population associated with objects like active galactic nuclei, pulsar wind nebulae and neutron stars and truly spatially resolved studies of the emission processes at work in astrophysical systems, crucial for the interpretation of multi-frequency spectral energy distributions (in the m-domain).

Moreover, the RadioNet technical [illegible] for industry. [illegible] for future space projects such as STO2, GUSSTO and Millimetron. Additionally, low-cost mm/sub-mm heterodyne receivers and receiver arrays will have multiple applications beyond astronomy: Earth remote sensing, laboratory spectroscopy of molecules, high-resolution imaging (for medical, industrial or security applications). The frequency range of BRAND covers most of the frequency spectrum used by public/commercial services. The BRAND development extends the short-range communications with ultra-wideband capabilities (operating in the range 3-10 GHz) to a still broader range with potential additional applications on short and longer timescales, like for example [illegible] radar imaging. BRAND technology can be applied to the latest generation optical fibres network communication techniques, where increasing data rates are required, like 400 Gbps networks.

RINGS' goals have parallels with several industrial applications that rely on reciprocal imaging technology; in radar interferometry, phase calibrations are required to deal with instrumental, atmospheric and ionospheric effects. Another domain applying phase calibration and self-calibration is dynamic Magnetic Resonance Imaging (MRI). [illegible]. These applications will enhance the cooperation with industry and may foster the creation of new technology companies, active in the field of non-astronomical applications.

RadioNet networking and trans-national activities concentrate on users of the radio astronomical facilities. By offering access to those world-class facilities and providing assistance in doing the observations, it provides training to many scientists. For example, [illegible] And, as there is a continuous update of the facilities, the targeted training is expected to increase the number of TA users even more. This is a good investment in the next generation of scientists. [illegible] Current radio astronomy projects push for cutting-edge breakthroughs that can be applied to the engineering sciences and technologies. When astronomy is not the final career choice of astronomy students, they will be very well suited for careers in industry, such as medical processing or software development, because of the analytic skills and adaptive attitude that they have developed. The RadioNet activities will equip [illegible] with a wide-range of expertise, and this will enhance their market value. Thus, RadioNet's innovation potential regarding human capital goes well beyond radio astronomy.

2 IMPACT

2.1 Expected impact

Please be specific, and provide only information that applies to the proposal and its objectives. Wherever possible, use quantified indicators and targets. Describe how your project will contribute to each of the expected impacts:

Where relevant, any substantial impacts not mentioned in the work programme, that would enhance innovation capacity; create new market opportunities, strengthen competitiveness and growth of companies, address issues related to climate change or the environment, or bring other important benefits for society

Describe any barriers/obstacles, and any framework conditions (such as regulation, standards, public acceptance, workforce considerations, financing of follow-up steps, cooperation of other links in the value chain) that may determine whether and to what extent the expected impacts will be achieved.)

IMPROVING ACCESS

Researchers will have wider, simplified, and more efficient access to the best infrastructures they require to conduct their research, irrespective of location. They benefit from an increased focus on user needs.

The RadioNet Trans-national Access Programme (TA) is designed to provide the European astrophysics community with the most efficient access to the best astronomical research facilities covering all wavelengths from metres to sub-mm and all angular scales from full-sky surveys to milli-arcsecond imaging. The scientific results obtained by TA users are the testament to EC-funded transnational access over the last 10 years. These results are the outcome from the most technically challenging projects. The RadioNet proposal includes the development of initiatives and networking activities to ensure that TA facilities attract even more users to do even more demanding projects, resulting in a higher scientific impact. One step in this direction is to inform a broader scientific community about the TA programme. RadioNet will create a centralised mailing list (pooling all kind of astronomers and organisations), in order to provide information on all TA call for proposals and other events and opportunities.

All RadioNet TA facilities have a simple open access model, in which TA user groups and other users apply through the same channel. None of the facilities operate any kind of national quota. Almost all of the facilities (EVN, e-MERLIN, WSRT, LOFAR, Effelsberg and APEX) already use an identical electronic application procedure - NorthStar, developed under RadioNet1. In all cases, user groups submit a short scientific and technical observing proposal. An independent panel reviews all proposals before the observing time is awarded. The format, requirements and assessment criteria are simple across all RadioNet TA facilities, and in all cases the assessment is based entirely on scientific merit and technical feasibility rather than e.g. track record and experience with any given facility. This is a fair and open way to maximise the opportunities for new user groups and those from counties with less established radio astronomy communities.

No additional effort is required by groups seeking support through the TA programme - the individual facility administrations inform groups who are eligible for support with information about the nature and extent of this support. The RadioNet TA programme will further harmonise these access routes with measures to allow users to apply for multiple facilities in a single application. Additionally, special attention will be given to the feedback routine from the proposal committee to the applicants with the unsuccessful proposals, which is already a routine for EVN. The goal is to assist the denied applicants in the resubmission of their proposals. TA leaders, under the guidance of the TA coordinator and the Management, will perform these tasks.

All of the TA facilities in RadioNet have already invested in the development of dedicated user support teams and can provide face-to-face support and purpose-designed computing facilities for visiting users to prepare, execute, analyse and interpret their observations. As instruments continue to develop, as the projects proposed become increasingly technically demanding and as the breadth of the user communities increase, such a high level of sophisticated user support is becoming more and more important. An effective way to increase the output and productivity of these research infrastructures is a better direct support to the users to enable them to complete the processing and analysis of their data. Similarly an effective way to broaden the user community and to enable novel scientific experiments is to remove the perceived barriers and by improving the user support.

The JRAs in this proposal are directly targeted at improving the capabilities and efficiencies of the European research infrastructures providing trans-national access. Specifically, AETHRA will develop receivers with greatly enhanced observing and survey speed for mm and sub-mm telescopes and arrays (IRAM NOEMA, IRAM 30-m, APEX and ALMA). BRAND-EVN will develop truly broad-band receivers at cm wavelengths for the EVN (additionally Effelsberg, and possibly e-MERLIN), which will revolutionize the way EVN operates, make observing much more efficient and open up new scientific possibilities for wide-band science. RINGS will develop efficient and automated data processing routines for some of the stages of processing (especially fringe fitting). At present, users coming from other domains find the current processing routines to be the major difficulty in the use of radio astronomical instruments.

Taken together, the impacts of *these initiatives are aimed at broadening and simplifying the access to the RadioNet research infrastructures, and to respond to the needs of in terms of sensitivity, survey speeds, frequency coverage, and simplified data processing.* Technically the JRAs will lead to more homogeneous facilities, the NAs will keep the community well informed across national borders, and the TAs will upon past efforts to simplify and normalise access.

HARMONISING SERVICES

Operators of related infrastructures develop synergies and complementary capabilities, leading to improved and harmonised services. There is less duplication of services, leading to an improved use of resources across Europe. Economies of scale and saving of resources are also realised due to common development and the optimisation of operations

As a whole, the TA facilities provide a set of complementary capabilities across a broad range of wavelengths and angular scales, with almost no duplication. This facilitates the enormous breadth of scientific scopes of projects enabled by RadioNet.

Not surprisingly, users often want to combine data from different instruments to gain a multi-wavelength and/or a multi-scale view of astrophysical objects. Mechanisms to simplify and harmonise the application procedure are already in place in several important cases, and the common electronic submission software NorthStar has already been mentioned above. One of the most powerful combinations, e-MERLIN+EVN can already be proposed with a single application to the EVN Programme Committee. During the course of *RadioNet we will investigate and implement the procedures for single applications to multiple RadioNet telescopes more widely*. This harmonized access removes the difficulty encountered in such projects when different telescopes require separate applications at separate times and independent review by separate panels. The close cooperation established between the RadioNet TA facilities has already fostered considerable trust and understanding of how the various panels operate and we believe that such trust will a feasible approach.

The development of the BRAND-EVN receiver, for the first time, will provide a uniform receiver package with a very wide frequency range across the entire EVN. Until now, all EVN telescopes have developed their own receivers with different frequency ranges, different down conversion schemes and different characteristics. The owners of EVN stations Irbene, Effelsberg, Yebes and WSRT have already expressed an interest for purchasing the BRAND receiver. The JRA-RINGS will ensure that for the first time all the capabilities required to analyse data from radio interferometers at both high and low frequencies will exist in the same processing suite. Development of the technical cooperation between RadioNet facilities, labs and partner organisations has always been a priority for RadioNet and new ways to enhance cooperation continue to be sought. The introduction of the NA – Short Training Missions will provide a novel approach to directly supporting technical collaboration between scientists and engineers at different facilities focussed on particular technical issues. All *these harmonisation efforts will lead to less duplication and improve the use of European resources*.

FOSTERING INNOVATION THROUGH INDUSTRIAL PARTNERSHIPS.

Innovation is fostered through a reinforced partnership of research organisations with industry

The JRAs, AETHRA, BRAND-EVN and RINGS all involve industrial partners in addition to the universities and laboratories involved. In AETHRA these include TTI Norte (ES), which will be involved in the fabrication of the cryogenic amplifiers developed by IGN (ES) and digital electronics companies such as e2v (FR) who plan to work with IRAM on fast samplers. BRAND-EVN will involve partnership with the small company HAT-lab (IT) which itself was established for production of the digital back-ends developed by a previous EC-funded project. RINGS partners have established a research collaboration with SME's in the Netherlands (S&T, TriOpSys, KxA and MMPBI) on software for Big Science Data. partners in the field of radar, medical and seismic imaging on potential synergies with respect to the algorithms.

There are several past examples of these techniques having been developed into applications by SMEs including mobile phone location, deconvolution image recognition (both in Europe) in addition to well-known cases such as the development of the wi-fi protocol by Australian radio astronomers and engineers. In terms of hardware development, TTI Norte in the production of several hundred units of low-noise wide-band amplifiers developed by IGN for the ALMA and NOEMA projects. The production of the many mm/submm-wavelength heterodyne receiver needed for the construction of large FPAs and/or for non-astronomical applications, would similarly be transferred to SMEs, after those modules are developed by AETHRA.

This RadioNet proposal more general positive impacts in the following areas:

Enhancing innovation capacity: The three JRAs in this proposal are developing prototype hardware and techniques at the very leading edge of radio astronomy technology. There is a clear step-up in the ambition of the RadioNet partners to be more innovative: the hardware developments planned for AETHRA and BRAND represent major steps in capabilities of radio telescope instrumentation and are complementary to developments in digital and analogue electronics being driven by other markets such as telecoms. This represents a real contribution to enhancing innovation capacity.

: radio astronomy community, in Europe and world wide provides its own market for the new technologies being developed by RadioNet, especially the BRAND receiver, for which the market may reach 50 antennas. Outside radio astronomy there are potential markets for some of the component technologies, including MMIC receivers (AETHRA) , wide-bandwidth data acquisition (BRAND), and the robust operating at a low signal-to-noise ratio (RINGS).

: the BRAND receiver to be developed and prototyped in this project will be produced by existing SMEs such as HAT-Lab, which was created directly to produce a previous generation of digital radio astronomy companies created for the purpose. The new products will represent the very state-of-the-art for global radio astronomy and the technical competitiveness of these companies would be assured.

: the EC explicitly acknowledges the potential for radio astronomy to stimulate the economies of less developed countries by supporting and prioritising cooperation between Europe and Africa on radio astronomy. In the same way, RadioNet includes a range of European partners all of whom may benefit from the technology development, training/engineering interchange and improved access to research infrastructures proposed here.

EDUCATING THE NEXT GENERATION OF RESEARCHERS

A new generation of researchers is educated that is ready to optimally exploit all the essential tools for their research

Training, educating and building the next generation of astronomers and astrophysicists who are technically aware and capable of using the radio astronomy facilities effectively has always been a key focus of RadioNet. For astronomers and astrophysicists who have previously worked at other wavelengths, the techniques of radio astronomy and radio interferometry can present a significant barrier to their ability to use these instruments. The regular events, such as European Radio Interferometry School (ERIS), solar and single-dish schools, each of which attract up to 100 participants have already had a major impact on the development of the European radio astronomy community. They have enabled European students and researchers based in universities which do not have an established radio astronomy groups or their own radio astronomy facilities to conceive, design and execute radio astronomy observations on the world-leading telescopes to which the TA programme provides access

For many of today's active radio astronomers in Europe, their first and most effective practical introduction to the skills they needed to carry out their research was provided through schools such as ERIS. The high level of training provided and previous RadioNet projects complements the user support provided by the TA facilities. In this proposal we will extend the range of skills, which are covered at the training schools to include more advanced workshops aimed at sharing technical knowledge across disciplines and to include hardware and software engineering. Introductory schools (such as ERIS, Solar, Single Dish) will be developed and extended to cover all the technical developments and improvements in capabilities at the TA and other radio astronomy facilities. These schools are hosted at institutes with direct access to observing and data reduction facilities. Their faculty include staff who has worked on some of the most complex observational programmes but who are also directly involved in supporting inexperienced users. The schools use innovative hands-on teaching methods and always involve processing real data from state-of-the-art facilities. There is a natural focus on TA facilities and every effort is taken to ensure that all the most recent developments in these facilities are incorporated.

Spectrum management is becoming more and more important for radio astronomy as well as for other radio services; however, it is not part of any academic curriculum; radio astronomers have to learn it by doing it. NA-Sustainability supports CRAF, which is the European representation and consultation on radio spectrum management for radio astronomy. There is an increasing need to train and involve the astronomy community in issues of spectrum management and share expertise between RadioNet facilities and institutes. Therefore, the spectrum management subjects will be one of the basic agenda items of all RadioNet training events. Additionally there will be one dedicated international Spectrum Management School, which offers a comprehensive view of both technical and regulatory issues related to radio astronomers' use of the spectrum.

ALMA represents such a huge leap in sub-mm observational capabilities, with such wide scientific applications, that educating and training the community is a major challenge. The ALMA Regional Centre is provided by ESO to address this challenge at the European level with the actual face-to-face support being provided by a set of ARC nodes in individual countries. These ARC nodes are located at research institutes and RadioNet facilities. While the overall ALMA support is available at all nodes, specialized support in topics such as polarization, high dynamic range imaging, mosaicking are best provided by appropriate ARC nodes. The MARCUS WP3.2 provides the mobility and support for European ALMA users to take maximum advantage of the training and user support available across the whole set of European ARC nodes.

ENCOURAGING CROSS-DISCIPLINARY INTERACTIONS

Closer interactions between larger number of researchers active in and around a number of infrastructures facilitate cross-disciplinary fertilisations and a wider sharing of information, knowledge and technologies across fields and between academia and industry

Cross-disciplinary interactions in astronomy:

More than ever, astrophysicists need to address key science problems, using instruments at many wavelengths. The improved and simplified access being offered via the TA programme is designed to facilitate access to radio observatories to non-experts. Science-themed workshops are an effective way to reach out to the astrophysics research community to provide the awareness of the capabilities and applicability of radio and sub-mm facilities and the skills required to use them effectively. Within its NAs, RadioNet has defined a set of training schools and events to enable researchers to broaden their multi-wavelength expertise. The TA facilities maintain accessible data archives to allow maximum exploitation of observations of any one object or survey field.

Cross-disciplinary interactions with industry:

The technical workshops in WP2.2 are specifically designed to bring the work and results of developments within the JRAs but also more generally the work at RadioNet institutes and facilities to the attention of the broader engineering community.

Likewise, the Short Training Missions are a new feature of this RadioNet proposal specially designed to get together astronomers, engineers, and industrial partners to work on targeted problems in a novel and focused way. Such cooperation across countries and disciplines where the participants will be free to focus on a particular challenge and work together for a period of time allows RadioNet to build strong new partnerships in a much more responsive manner.

ENSURING SUSTAINABILITY

For communities, which have received three or more grants in the past, the sustainability of the integrated research infrastructure services they provide at European level is improved.

While the core services of the European do not depend on EC funding, the EC funding through RadioNet has provided a strong c among its partners, which will be maintained beyond the funding period.

European collaboration in radio astronomy is stronger than ever, with RadioNet being perhaps the most prominent and visible example. RadioNet has provided access to world-class facilities since FP5 (TA). The EC support has been playing a significant role in improving the radio astronomy facilities in Europe and their user support at the telescopes. RadioNet has made it possible to reduce costs by avoiding individual efforts, o develop equipment for all facilities (JRA). This collaboration and the development are not possible without external funding and centralised management. The support of CRAF in protecting the radio spectrum for scientific use

The RadioNet partners fully recognize the need a sustainable Europe-wide community based on research infrastructures, which are mainly funded at the national level, for both operations and development. This statement is in line with the ASTRONET-ERTRC recommendation "*… that joint activities, such as RadioNet, become more robustly and permanently organised and funded".*

RadioNet will examine, maintain and develop existing European radio astronomy research infrastructures in the era of SKA. SKA-operation needs to be developed. The RadioNet organisation will have a lean management based on in-kind of the partners. A few crucial activities such CRAF, TOG/GMVA and YERAC will be supported by contribution of the partners too. However, RadioNet will have to funding possibilities for the which are TA user support and the JRA projects. will be addressed in the leaner organisation to avoid this current strength becoming a threat for RadioNet sustainability.

The integration of major scientific equipment, sets of instruments and of knowledge-based resources

leads to a better management of the continuous flow of data collected or produced by these facilities and resources

The data obtained from the TA projects will be stored in the facility archives and available with open access.

Use Beyond Research and contribution to evidence-based policy making

When applicable, the integrated and harmonised access to resources at European level can facilitate the use beyond research and contribute to evidence-based policy making.

Radio astronomy in Europe is in a strong position but also at a crucial point for the future. RadioNet comprises directors of the RadioNet facilities with decades of experience in designing and operating facilities to meet the scientific demands of European radio astronomy. RadioNet contributed strongly to the ERTRC review. This review complements the ASTRONET Roadmap exercise, which highlighted by design the future needs of radio astronomy. RadioNet as an AERAP community member actively supports the development of the African-European Radio Astronomy and contributes to defining the framework programme for cooperation on thematic priorities such as research infrastructures, human capital development for radio astronomy, ICT and big data, renewable energy for radio astronomy. Thanks to the official RadioNet recommendation the Science Foundation Ireland will contribute to the building of a LOFAR station in Ireland in 2016.

Several of the countries involved in RadioNet are already investing significantly in the SKA. The majority of the SKA members are RadioNet partners; they are heavily engaged in the and technical development of SKA. RadioNet partners actively promote the SKA A growing user community is fundamental for the successful of the SKA project. (emerging) space powers (India and China). RadioNet will support EUROPLANET with exhibitions, joint brief papers, and education material.

RadioNet is therefore perfectly placed to contribute to evidence-based policy making.

THE SOCIO-ECONOMIC IMPACT OF PAST ESIF INVESTMENTS IN RESEARCH INFRASTRUCTURES

RadioNet partner VENT has profited from several projects financed from ESIF. The aim of the ICTSP – Centre project is to foster cooperation in fundamental and applied research in information and communication technologies and signal processing (ICTSP) via concentrating and integrating scientific infrastructure and intellectual resources to ensure scientific institutions' compatibility with EU excellence standards and rise of research competitiveness in research sector within European research community. The project resulted in the reconstruction and modernization of the radio telescopes RT-16 and RT-32, in the development of electronic equipment design and prototyping centre, in modernized infrastructure for satellite technology research, in the development of environment for cosmic data processing high-performance calculation, and in purchasing of 32 workplace equipment for scientific personnel. The ESIF support to Ventspils University College for the implementation of the master degree study program in natural sciences: Computer Sciences; aimed to prepare and support the competitive specialists in natural sciences with a master's degree in computer science. Within the project 15 scholarships were awarded that allowed students to fully dedicate their time to studies. Another ESIF project concentrated on signals related to Artificial Earth Satellites: Technologies of Receiving, Transmitting and Processing. Project results included publications in scientific and popular science journals, speeches in scientific conferences, and implemented technologies which will form the basis of the future EAS monitoring, control and signal processing centre in Latvia.

ASTRON together with the Dutch universities of Amsterdam, Groningen, Leiden and Nijmegen used the ESIF support in a LOFAR project. The aim was to build a generic sensor network, serving radio astronomy, geophysics and precision agriculture with ICT (in addition to the physical network) as the factor that binds these disciplines. The construction of parts of the physical infrastructure was carried out by a number of companies following public procurements. The impact of the project included: 30 jobs created directly in challenging economic circumstances, support of a number of SME's which would not have otherwise survived the economic conditions throughout the project period (2004-2009), the realisation of over 2M€ of investment of private capital in the course of the project, setting up a networking/business development organisation which brokered follow-up projects in the areas of sensor technology in the region, and setting up of a bachelor and masters degree programme in Sensor Technology at the Hanze University of Applied Sciences

ASTRON was also involved in a project TARGET, a public-private project in the area of large-scale data management and information systems. The project focused on research and development of innovative intelligent information systems that can efficiently process data and extract information from extremely large and structurally diverse datasets. [illegible] has been a partnership of ASTRON, research groups of the University of Groningen, and several local (Heeii, Target Holding), national (NSpyre), and international (IBM, Oracle) private partners. The developments and services developed by [illegible] targeted the associated (scientific) communities and the project provided an expertise centre to support growing national & international IT enterprises. For LOFAR, services were implemented that allow the astronomical community to interact with archived scientific data as well as enabling the operation and management of this archive. The TARGET project allowed (continued) employment of both existing and new highly educated personnel in the Northern region of the Netherlands. Through representational activities and through [illegible] Holding, it has shared and valorised knowledge and expertise and supports innovative startups and non-profit organisations.

2.2 Measures to maximise impact

a) Dissemination and exploitation of results

Provide a draft 'plan for the dissemination and exploitation of the project's results'. In the case of Integrating Activities, these are typically the results of the joint research activities to improve the infrastructure services, the enhanced access provision, and/or common standards, protocols etc. resulting from networking activities. Please note that such a draft plan is an admissibility condition, unless the work programme topic explicitly states that such a plan is not required. Show how the proposed measures will help to achieve the expected impact of the project. The plan, should be proportionate to the scale of the project, and should contain measures to be implemented both during and after the end of the project. Include a business plan where relevant

THE DISSEMINATION AND EXPLOITATION OF SCIENTIFIC RESULTS FROM THE PROJECT

In general, the dissemination of *scientific discoveries resulting from RadioNet actions* to the broader scientific community will be done in the normal way by the researchers themselves with the support of their host institutes. As expected, the scientists involved are highly motivated to publish their results in *peer-reviewed journals* with gold or green access (e.g. the astro-ph server) and through participation in *conferences* at the national and international level. Some of the most exciting results and those of a more general interest will be publicised through *press releases* using well-established media connections via host institutes and also through a project-wide *Newsletter and RadioNet Webpages.* New social media channels, including Facebook and Twitter are increasingly used by scientists across all fields as well as the general public as a natural means to keep up to date across a range of scientific fields and the use of these channels to disseminate RadioNet results will be supported and encouraged.

The work-package WP2-Dissemination will support all of these activities but will also provide specific financial and logistical support for the organisation, hosting and participation in large scientific conferences, which will focus on RadioNet scientific and technical activities.

RadioNet will assist scientists engaged in projects eligible for Trans-national Access support to disseminate their results by providing travel grants for participation in conferences, by posting the results on a project webpage and the RadioNet *newsletter*, by maintaining a publication list of RadioNet funded projects and by assisting in transnational *press releases*.

Increasingly the data products obtained by astronomers are being re-used by a wider community than the original proposers through accessible archives. All of the TA facilities maintain accessible archives of the raw and/or calibrated data products, which are available to other researchers according to facility-specific policies. In fact, in radio astronomy these policies are quite uniform and generally allow access to data products approximately one year after the observations were made. Although not funded specifically through this proposal, RadioNet facilities will work together to make their data products accessible in a uniform way, and provide Virtual Observatory compliant interfaces where possible.

THE DISSEMINATION AND EXPLOITATION OF TECHNICAL RESULTS FROM THE PROJECT

RadioNet has three JRAs, [illegible]

The result of the JRA AETHRA is a reduced-size prototype of focal-plane (sub-)mm receiver arrays, which can be used at mm and sub-mm observatories in and outside Europe. The prototypes will include the interfaces needed to demonstrate their performance on the leading European telescopes, in particular on the IRAM 30-m telescope and on APEX. The design of AETHRA will take into account the range of antennas which could host such arrays, with the aim of maximising the number of telescopes where they can be deployed. The documentation and descriptions, and the results of science verification will be published in the project wiki and also in technical proceedings (e.g. SPIE and ICMTT) and scientific journals (e.g. IEEE). A working group of the AETHRA management will explore with industry how the novel design elements of AETHRA can be used for other purposes, such as security, remote sensing, or medical imaging

The result of JRA BRAND EVN will be a standardized cm-wave receiver with extremely large bandwidth, designed to replace the multiplicity of narrow band receivers, which are currently used across RadioNet facilities. There are many more potential telescopes within, and outside, the RadioNet consortium that could use this technology. These telescopes have very different designs regarding their optical configuration and signal chains. BRAND-EVN includes specific tasks to survey the potential telescopes, which could adopt such a receiver and to develop a common design with maximum applicability. The product of this investigation will be a list of *specifications* and a *description of the interface* between the front-end and the antennas, naming adequate small companies for the production. These documents will be disseminated among the interested observatories before these commit to purchasing one or several BRAND receivers.

JRA RINGS will provide new algorithms for advanced calibration, as will be required by new instrumentation, including BRAND. The participants in the different work packages have state-of-the-art expertise in programming and data reduction. This ensures that the end product will *match the needs of the community*. The software will be written as *part of the widely available CASA data* reduction software. This ensures that it will be widely usable. The software will be properly documented and can be downloaded from servers at participating institutes.

For a full exploitation of the RINGS software, training courses will be offered in connection with the technical and scientific NAs. Institutes participating in RINGS will assign a scientist to serve as a link to the community in order to receive suggestions or complaints, and provide help. The software will be *maintained* at the participating institutes beyond the duration of RadioNet funding. RINGS software is written in Python and can be modified by users according to their needs. Phase calibration is a task that has also *applications outside astronomy*, for example in seismic imaging and radar. RINGS will seek discussions with those communities in order to create possible synergies between those domains.

THE DISSEMINATION OF POLICIES

A complex and coordinated project like RadioNet requires the definition of guidelines and policies. These will be of use even after RadioNet funding has ended. Examples are handbooks and procedures for managing different work packages (the management manual provided by Management) or to organize recurrent events (organisation manual for YERAC, ERIS schools etc. provided by the NAs). RadioNet will also define clear policies for the eligibility for TA projects and for the distribution of travel grants. Many of these policies will be useful and needed beyond the duration of RadioNet. They will therefore be made available to general community via the project wiki pages and RadioNet newsletter.

The policy issues involved in Spectrum Management for radio astronomy are a particularly important case. The increasing demand on spectrum for data transmission, especially mobile data and the future evolution of machine-to-machine communication is putting severe pressure on those bands which are protected for radio astronomy and other scientific use. RadioNet Spectrum managers from the observatories will participate in meetings organized and disseminate the results through the CRAF Newsletters and handbooks to all European radio astronomy institutes.

As the radio astronomy landscape enters a period of rapid change, and as large global facilities such as ALMA and the SKA begin to have a major impact on the field, it is essential to ensure that Europe speaks with a coherent voice and continues to develop a common strategic approach that maximizes our success. Additionally, European radio astronomy must support the development of radio astronomy in Africa. RadioNet coordinator and partners will proactively participate in the further development of the strategic plans for AERAP and SKA. In order to ensure that radio astronomy in Europe continues to thrive, senior representatives of the national observatories and other relevant stakeholders must continue to stay abreast of strategic developments in astronomy, and develop a vision of the future in which radio astronomy flourishes at a national, European and global level. RadioNet will provide an appropriate platform in which major strategic issues will be addressed.

RESEARCH DATA MANAGEMENT

*If you will take part in the pilot on **Open Research Data**, include information on how the participants will manage the research data generated and/or collected during the project, in particular addressing the following issues (For further guidance on research data management, please refer to the H2020 Online Manual on the Participant Portal.):*

- *What types of data will the project generate/collect? What standards will be used?*
- *How will this data be exploited and/or shared/made accessible for verification and re-use? If data cannot be made available, explain why.*
- *How will this data be curated and preserved? Include information about any open source software used or developed by the project*

RadioNet TA activities will not produce astronomical data, however they will allow astronomical data to be generated. Each of the RadioNet TA infrastructures possesses a data archive (see Table 2.2.1), and almost all of them offer open access to the raw observation data after a proprietary time, typically one year, depending on the [illegible] terms and conditions. Astronomical data is usually provided in FITS (Flexible Image Transport System) format – the standard originally developed for astronomy and now maintained under the auspices of the IAU.

RadioNet JRAs will generate software and simulated data products that will be available under open license, for example, via the GNU General Public License. This will make the routines and associated data readily available to any interested party. In particular, JRA RINGS will deliver highly functional, maintainable and computationally efficient calibration software that addresses the challenges and opportunities posed by new and future high sensitivity, wide bandwidth, long-baseline radio interferometers. Crucial functional improvements will be the development of algorithms for full service fringe fitting solutions, accurately encompassing dispersive delay and full polarisation. For re-use, these algorithmic developments will be implemented in the existing standard CASA software package (http://casa.nrao.edu/), which as well is published under a GNU General Public License.

For verification, the software source code will be published in a suitable open repository like the MPG research data repository Edmond (http://edmond.mpdl.mpg.de) or Github (https://github.com/) using Zenodo (http://zenodo.org/) to make certain states of research persistent and citable.

Technical design plans will be stored in an MPG long-term archive where they can be reviewed by entitled persons with a legitimate interest. These plans cannot be made publicly available because special IP rights apply to them, in case the results are capable of industrial or commercial application. Detailed information on the research data management actions will be described in the data management plan (DMP) that will be created in the beginning of the project.

TABLE 2.2.1 ARCHIVES OF THE RAW DATA OF THE RADIONET INFRASTRUCTURES

TA Name	Archive address	Access conditions
EVN	http://www.jive.nl/select-experiment	1 year
e-MERLIN	http://www.e-merlin.ac.uk/archive/	1 year
Effelsberg	http://www.mpifr-bonn.mpg.de/en/effelsberg	Contact the PI
LOFAR	http://lofar.target.rug.nl/	1 year
IRAM	http://www.iram-institute.org/EN/content-page-240-7-158-240-0-0.html; new to be ready in 2016	1 year currently
APEX	http://archive.eso.org/wdb/wdb/eso/apex/form	1 year

STRATEGY FOR KNOWLEDGE MANAGEMENT AND PROTECTION

*Outline the **strategy for knowledge management and protection**. Include measures to provide **open access** (free on-line access, such as the 'green' or 'gold' model) to peer- reviewed scientific publications which might result from the project. (Open access must be granted to all scientific publications resulting from Horizon 2020 actions. This obligation does not apply to trans-national access users.)*

Open Access will be ensured for all scientific publications from the RadioNet project. Papers resulting from TA projects would be encouraged but not required to become available open access.

RadioNet partners will be encouraged to adopt the 'gold' model by publishing in dedicated open access journals or by selecting open access options if applicable. We expect the RadioNet results to be published as articles in radio astronomical and multidisciplinary journals (A&A, ApJ, Nature, Science etc.) or in form of conference proceedings (several possibilities). In particular, the JRA results will often be published by [illegible], article processing charges for these publishers range from $5200 (Nature Communications, http://www.nature.com/openresearch/publishing-with-npg/nature-journals/) to $1750 (selected IEEE journals, http://open.ieee.org/) and RadioNet will [illegible] for this purpose at the WP1-Management.

However, the potential target audience of the publications will have high priority when selecting the appropriate journal and we expect that not all publishers will offer a 'gold' open access option [illegible] time of article submission. In these cases, the conditions of 'green' open access will be investigated by checking the individual author contract and consulting the openAIRE help desk if necessary.

RadioNet will deposit an electronic copy of the published version (e.g. the final peer-reviewed manuscript) of all scientific publications into MPG.PuRe (http://pubman.mpdl.mpg.de). This publication repository contains bibliographic description and numerous fulltexts of the publications of Max Planck researchers and associated projects. The repository is based on eSciDoc.PubMan, a software suite developed by the Max Planck Digital Library. MPG.PuRe is OpenAIRE compliant and therefore can be harvested by the OpenAIRE repository. Additionally the MPG.PuRe is open for several search engines, e.g. the MPG.PuRe records are indexed by Google and Google Scholar. Additionally the PuRe records are indexed by scientific search engine ‚Base', operated by University of Bielefeld (DE). 'Base' is one of the world's most voluminous search engines especially for academic open access web resources (https://www.base-search.net/). BASE is a registered Open Archive Initiative (OAI) service provider and contributed to the European project "Digital Repository Infrastructure Vision for European Research" (DRIVER).

b) Communication activities

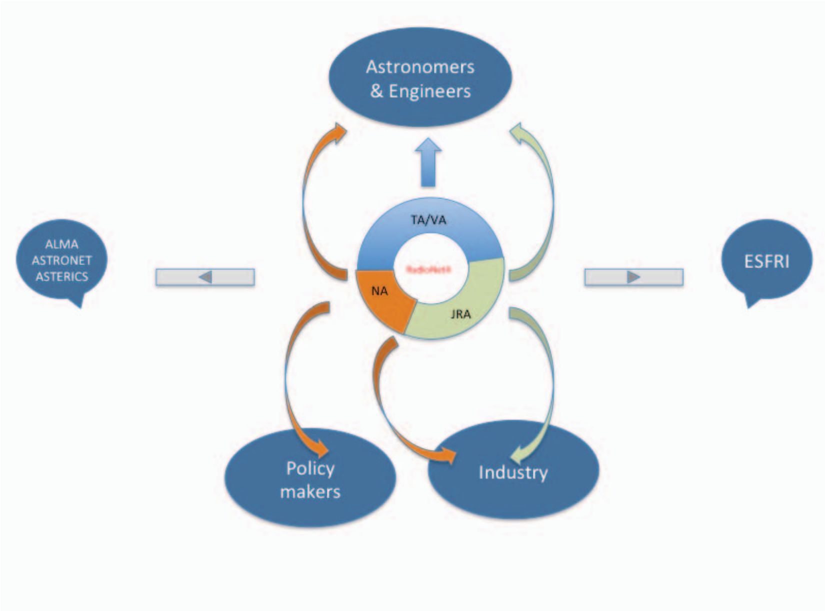
Describe the proposed communication measures for promoting the project and its findings during the period of the grant. Measures should be proportionate to the scale of the project, with clear objectives. They should be tailored to the needs of different target audiences, including groups beyond the project's own community. Where relevant, include measures for public/societal engagement on issues related to the project.

In a complex and transnational project like RadioNet, efficient communication is required i) within each WP and between the WPs (including Management), ii) between the RadioNet consortium and the rest of the scientific and technical community, iii) with industry, iv) with policy makers (such as national and international authorities, e.g. the ones that determine frequency allocations), v) complementary projects (such as ASTRONET, ESFRI related initiatives), and finally vi) with [illegible] general public.

Fig. 2.2b.1 depicts the [illegible] directions: obtaining feedback forms is an integral part of the communication tasks of RadioNet. All official [illegible] in RadioNet will be in English. The RadioNet project foresees internal communication between the different activities (MGT, NA, JRA, TA/VA) as well as between the consortium partners and bodies (Board, Exec). [illegible] Furthermore, each RadioNet activity will address [illegible]

The RadioNet project as a whole is in a constant dialog with the current (ALMA, ASTRONET) and future (SKA, Europlanet, OPTICON) astronomy organisations.

Each of them requires different communication channels described below individually.



FIGURES. 2.2b.1

Communication within the RadioNet Consortium

Objectives: Communication within the RadioNet consortium aims at providing transparent guidelines, the exchange of information to achieve scientific and technical goals, reaching consensus about decisions to be made, , in order to create synergy and to facilitate a common identity.

Methods: information relevant for RadioNet will be made available on web and wiki pages maintained by Management and the WP leaders. The Wiki is the administrative platform for the of the project. The access is in general open, however some of the information (contractual documents, budget, minutes etc.) restricted to RadioNet beneficiaries only. The project Wiki contains guidelines (e.g. in form of a Management Manual, to be prepared by Management), procedures, templates, minutes of meetings, information on imminent events and opportunities. Each WP maintains their own Wiki, to allow internal discussions, finding solutions to common problems, to store documents, define procedures. Management will provide guidelines and hands-on support how to set up Wikis for each WP. Communication exchange within the individual WPs will also be facilitated by face-to-face meetings and emails. Management will maintain an email distribution list in order to ensure an efficient spread of news.

Impact: that each project partner is always up-to date; . All documents are centrally stored and available at any time to all project partners. This communication structure the full traceability of all project steps (decision, documents, meetings etc).

COMMUNICATION BETWEEN RADIONET AND OTHER SCIENTIFIC AND TECHNICAL COMMUNITIES.

actions such as TA and NA, but also advertising JRAs. RadioNet will also provide a forum to announce events and opportunities at the individual partners. The feedback on TA and NA from these communities will be in particular used to improve TA and NA actions.

METHODS: Management will set up a web page where all relevant information of RadioNet actions and opportunities can be located, such as events or job offers. There will be clear directions how to contact Management and the other WPs. At regular intervals there will be an email digest of news (newsletter) and call for opportunities for support/organisation of scientific and technical events. A possibility to join the RadioNet mailing list will be offered at the registration page for each event supported by the project, also to TA users.

Management will also ask web content managers at the RadioNet partners to post this information on the institute websites. Events will be also announced by posters, and social media such as Twitter and Facebook. RadioNet will be represented at large national and international events by posters and talks. The feedback from the community to RadioNet will be via email and personal contact. In order to provide a RadioNet identity, a logo and a mission statement will be created and advertised at the supported events.

IMPACT: communication between the RadioNet project and other scientific and technical communities will the execution of the planned scientific and engineering events. This will foster cross-fertilisation and attract other communities. At the same time RadioNet results This is also a good opportunity for gaining new users for RadioNet facilities and creating new vibrant science.

COMMUNICATION WITH INDUSTRY

OBJECTIVES: Communication with industry serves to optimize the synergy necessary to develop state-of-the-art equipment and techniques and to optimize the fabrication phase of the developed instruments and methods.

METHODS: RadioNet representatives will make use of existing contacts and visit relevant fairs and conferences (e.g. IEEE, SPIE) in order to broaden and intensify such contacts. The industry experts relevant for RadioNet communities will be invited to technical events; also Short Training Missions will strengthen the ability of RadioNet to develop future collaborations with industry. The JRA partners will maintain close contact with respective industries to assure the marketing of the developed products. Industry representatives will be present in the RadioNet Scientific Advisory Board. RadioNet spectrum managers will exchange with industry the astronomy interests in relevant meetings (WRC-World Radio communication Conferences, ITU-International Telecommunication Union meetings, CEPT-European Conference of Postal and Telecommunications Administrations). RadioNet will develop policies in line with the contractual obligations for addressing intellectual property rights on the potential outcomes and future utilisations from the individual JRAs.

IMPACT: effective communication between the RadioNet project and industry will the promotion of the results, their exploitation within astronomy and beyond, and

COMMUNICATION WITH POLICY MAKERS AND COMPLEMENTARY PROJECTS

OBJECTIVES: Feedback to the European Commission and national policy makers is necessary in order to ensure the correct implementation of RadioNet and its transition toward a self-sustained action. RadioNet is playing an important role in the allocation of protected frequency ranges in order to minimize radio interference to scientific observations. In order to maximize the impact, to avoid duplication of efforts, and to provide a common, interdisciplinary vision, RadioNet will maintain contacts with complementary projects and organisations on European and international level, such as EVN, ASTRONET, AERAP, Europlanet, or ESFRI relevant initiatives such as SKA.

METHODS: Interaction with EC will be between the RadioNet Coordinator and the project officer in person or by email. RadioNet will support a synchronized strategy [illegible] CRAF issues. The RadioNet spectrum managers (CRAF) together with telecommunication administrations and industry will provide guidelines to the European Telecommunications Standards Institute (ETSI) for developing engineering standards. [illegible] will explore with the Board and other relevant bodies (EVN, SKA, ASTRONET) across Europe the best way forward into the next decade for European Radio Astronomy [illegible] will be done [illegible] of meetings and the development of policy documents. RadioNet will contribute to the development of policies for AERAP and Europlanet too. This will be realised in the form of meetings, organisation of joint conferences, development of material and policy documents. Individuals from complementary actions will be invited to become members of the RadioNet Advisory Board

IMPACT: [illegible] communication between the RadioNet project and policy makers will [illegible] a successful execution of the project and will lead to a self-standing RadioNet astronomy [illegible]

COMMUNICATION WITH [illegible] GENERAL PUBLIC

OBJECTIVES: Public outreach is already highly developed in the partner institutions. To [illegible] the highest impact it is mostly done by outreach offices in the local language(s), e.g. making use of visitor centres. Complementary actions exist at European and international level (e.g. by UNAWE and IAU). RadioNet will not duplicate these efforts, however it will support all those initiatives at any requested level. RadioNet will concentrate on efforts that maximize the impact of research resulting from TA, NA and JRA achievements of the project as a whole.

METHODS: A close connection to the RadioNet infrastructure public offices will be established by the Management in order to document and communicate the scientific discoveries resulting from TA use and the achievements of the project as a whole. RadioNet will [illegible] to a broader community via the project webpage, newsletter, the HORIZON2020 press office, and social networks. The project will support local efforts by preparing fact sheets on the actions and performance of RadioNet.

IMPACT: [illegible] communication between the RadioNet project and general public through the professional local outreach officers and dedicated initiatives [illegible]

3 IMPLEMENTATION

Please provide the following:

- brief presentation of the overall structure of the work plan;
- timing of the different work packages and their components (Gantt chart or similar);
- *You will be required to include an updated (or confirmed) '**plan for the dissemination and exploitation of results'** in both the periodic and final reports. This should include **a record of activities related to dissemination and exploitation** that have been undertaken and those still planned. In the case of Integrating Activities this should moreover **include dissemination of access opportunities and of the resulting use of the research infrastructure**, as well as **measures to assess or improve the innovation potential of the infrastructure**. A **report of completed and planned communication activities will also be required**.*
- *you must include a 'data management plan' as a distinct deliverable within the first 6 months of the project. A template for such a plan is given in the guidelines on data management in the H2020 Online Manual. This deliverable will evolve during the lifetime of the project in order to present the status of the project's reflections on data management.*
- graphical presentation of the components showing how they inter-relate (Pert chart or similar).

- detailed work description, i.e.:
    - a description of each work package (table 3.1a);
    - a list of work packages (table 3.1b);
    - a list of major deliverables (table 3.1c);

Give full details. Base your account on the logical structure of the project and the stages in which it is to be carried out. The number of work packages should be proportionate to the scale and complexity of the project.

You should give enough detail in each work package to justify the proposed resources to be allocated and also quantified information so that progress can be monitored, including by the Commission

*Resources assigned to work packages should be in line with their objectives and deliverables. Note that the primary deliverables of Integrating Activities are access provision, optimised use, and further improvement of the services offered by the participating research infrastructures. You are advised to include a distinct work package on '**management'** (see section 3.2) and on innovation, to indicate the type of activity (Networking: **NA**, trans-national or virtual access: **TA** or VA, Joint Research: **JRA**) for non-management work packages (see Part C of the section "Specific features for Research Infrastructures" in the 2016-2017 Research Infrastructures Work Programme), and to give due visibility in the work plan to 'dissemination and exploitation' and 'communication activities', either with distinct tasks or distinct work packages.*

*You will be required to include an updated (or confirmed) '**plan for the dissemination and exploitation of results'** in both the periodic and final reports. This should include **a record of activities related to dissemination and exploitation** that have been undertaken and those still planned. In the case of Integrating Activities this should moreover **include dissemination of access opportunities and of the resulting use of the research infrastructure**, as well as **measures to assess or improve the innovation potential of the infrastructure**. A **report of completed and planned communication activities will also be required**.*

If your project is taking part in the Pilot on Open Research Data, you must include a 'data management plan' as a distinct deliverable within the first 6 months of the project. A template for such a plan is given in the guidelines on data management in the H2020 Online Manual. This deliverable will evolve during the lifetime of the project in order to present the status of the project's reflections on data management.

RadioNet involves 25 partners who contribute to a total of 14 work packages (1 MGT, 3 NAs, 3 JRAs, 6 TAs and 1 VA, see Fig 3.1.1). The first WP is committed to the overall management of the project. An experienced management team will provide overall coordination of the activities and encourage and support self-management within the individual work packages, linking them together by transparent and efficient communication and decision processes. Networking Activities, WP2-WP4 aim at the multi-purpose approach to address the achievements, use and dissemination of results by any potential user. They will also address all sustainability issues for radio astronomy in Europe to minimise impact in the event that the important EC support is no longer available. Joint Research Activities (WP5-WP7) are tailored to address the technical development in all wavelength range of European radio astronomy infrastructures from metres to sub-mm, the comprehensive cluster of which will offer access under Transnational/Virtual Activities (WP8-WP14). A complete list of all work packages is given in Table 3.1b.

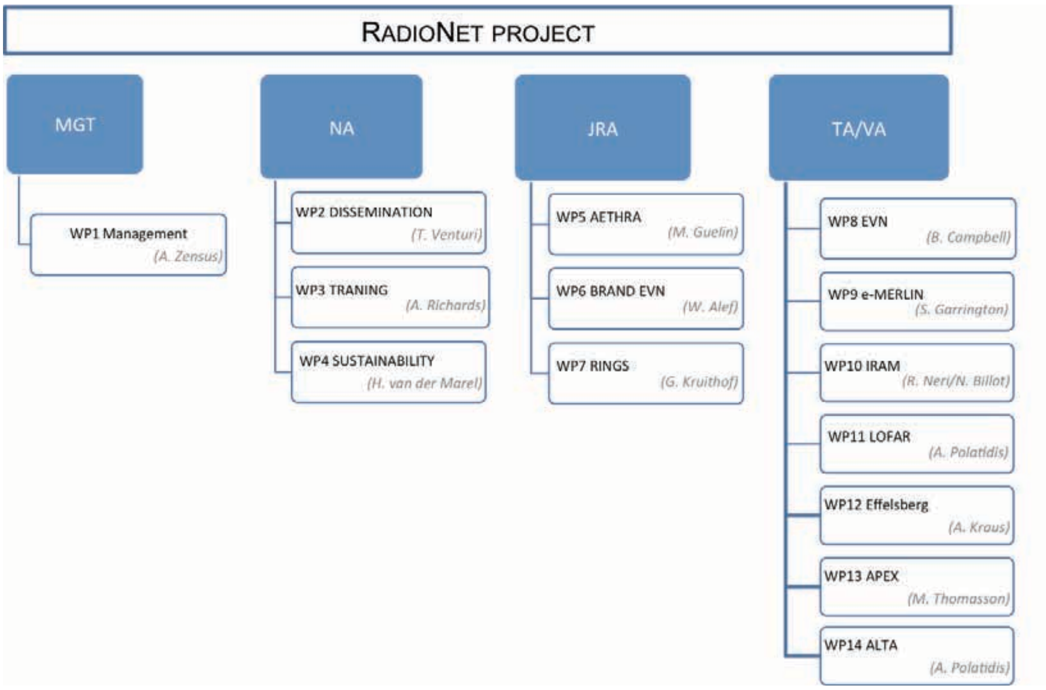


FIGURE 3.1.1 RadioNet Work Package structure

The RadioNet work packages are defined to be completely independent from each other, avoiding the danger of accumulation of risk for the project as a whole, should a specific work package encounter problems or delays. This independency covers the WP overall scope, goals and budget. This however does not prevent any cooperation between them, on the contrary the cooperation is planned and the most effective use of the resources and results is assured, for example tutorial for the use of the JRA results will be offered, the TA discoveries will be promoted at conferences, and awareness for technical issues at observatories will be created at training events.

The management structure of RadioNet will be ready to track and monitor the progress of the work packages in such a way that any problems that do require coordinated action, such as budget adjustments, are identified in a timely manner. The coordinator and his team can address this together with the work package leaders, seeking approval of the consortium Board and EC when needed.

All activities outline a plan for the dissemination and exploitation of results in the Data Management Plan (DMP); it will be updated regularly in periodic and final reports. For this purpose the project management supported by WP leaders will monitor and record all activities related to dissemination and exploitation that took place, are still foreseen or are judged to be beneficial.

This will be realised using management instruments including wiki pages and repositories. The records of activities, mostly in the form of reports, will moreover include dissemination of access opportunities and of the resulting use of the TA/VA infrastructures, as well as measures to assess their innovation potential. Furthermore, tracking of past and future communication activities will be performed.

The RadioNet coordinator will be assisted by qualified and experienced leaders of NAs and JRAs, and a TA/VA coordinator to monitor the progress with the programme and the budget. Each of the WP leaders will set up an effective task management for the implementation of work. It should be mentioned that the TA/VA coordinator supported by the Project Manager will additionally coordinate the accomplishing of the TA and VA tasks and the development of the TA related novelties. The NA and TA travel budget and execution of claims will be maintained centrally at the MGT. The centralisation of the TA/NA travel budgets has worked very well in the past. It assures an effective and routine performance, which is also substantially unburdening for the TA/VA and NA leaders, who contribute to RadioNet for free.

The MGT, NA and TA activities will run through the project duration. Not so the with the JRAs; their duration is restricted to maximum 42 months, in order to address already potential risks connected to the recruitment and to the use of the new technologies and to finalise their work within the total RadioNet lifetime. Additionally the virtual access to the newly developed archive of WSRT (ALTA) is expected to be fully operational in month 14.

In summary, RadioNet is efficiently set up as an action that coordinates comprehensively world-class research facilities and their science users and engineers. Since several decades, this distributed structure of RadioNet proved to be the most effective organization form for European radio astronomy. RadioNet will stimulate this diverse research and development community to optimally benefit from radio astronomy infrastructures and to be prepared for the development challenges and manifold research opportunities of the future.

The detailed description of each RadioNet work package (Table3.1a), the list of WPs (Table 3.1b), the timing of WPs and their components (Fig3.1.2) and the list of deliverables (Table3.1c) are presented in this section.

Table 3.1b: List of work packages

Work Package No	Work Package Title	Lead Participant No	Lead Participant Short Name	Person Months	Start Month	End Month
WP1	Management	1	MPG	90	1	48
WP2	NA – Dissemination		INAF	0	1	48
WP3	NA – Training		UMAN	0	1	48
WP4	NA – Sustainability		ASTRON	0	1	48
WP5	JRA – AETHRA		IRAM	169	1	42
WP6	JRA – BRAND EVN		MPG	185	1	42
WP7	JRA – RINGS		ASTRON	79	1	42
WP8	TA – EVN		JIV ERIC	0	1	48
WP9	TA – e-MERLIN		UMAN	0	1	48
WP10	TA – IRAM		IRAM	0	1	48
WP11	TA – LOFAR		ILT	0	1	48
WP12	TA – Effelsberg		MPG	0	1	48
WP13	TA – APEX		OSO	0	1	48
WP14	VA – ALTA		ASTRON	0	14	48
				523		

TIMING OF WORK PACKAGES AND THEIR COMPONENTS

All Gantt charts will be added.

Gantt Chart for JRA – RINGS

Taaknaam	Duur	Begindatum	Einddatum
State of the Art	132 dagen	zat 1-10-16	zat 1-4-17
Common Framework	132 dagen	zat 1-10-16	zat 1-4-17
Data sets for testing and verification	**197 dagen**	**zon 1-1-17**	**zon 1-10-17**
LOFAR	197 dagen	zon 1-1-17	zon 1-10-17
ALMA	197 dagen	zon 1-1-17	zon 1-10-17
EVN	197 dagen	zon 1-1-17	zon 1-10-17
GMVA	197 dagen	zon 1-1-17	zon 1-10-17
e-Merlin	197 dagen	zon 1-1-17	zon 1-10-17
First implementation	**305 dagen**	**zon 1-1-17**	**don 1-3-18**
Polarimetry conversio	305 dagen	zon 1-1-17	don 1-3-18
Multiband, Wideband	305 dagen	zon 1-1-17	don 1-3-18
Dispersive Delays	305 dagen	zon 1-1-17	don 1-3-18
Self Calibration	305 dagen	zon 1-1-17	don 1-3-18
Joint strategy	262 dagen	zon 1-10-17	maa 1-10-1
Final implementation	**262 dagen**	**don 1-3-18**	**vri 1-3-19**
Polarimetry conversion	262 dagen	don 1-3-18	vri 1-3-19
Multiband, Wideband	262 dagen	don 1-3-18	vri 1-3-19
Dispersive Delays	262 dagen	don 1-3-18	vri 1-3-19
Self Calibration	262 dagen	don 1-3-18	vri 1-3-19
Publication of results	153 dagen	vri 1-3-19	din 1-10-19
Final Report	153 dagen	vri 1-3-19	din 1-10-19

TABLE 3.1A: WORK PACKAGE DESCRIPTIONS

WP1– MANAGEMENT

WORK PACKAGE NUMBER	1		LEAD BENEFICIARY		MPG
WORK PACKAGE TITLE	RADIONET MANAGEMENT				
PARTICIPANT NUMBER	1				
SHORT NAME OF PARTICIPANT	MPG				
PERSON/MONTHS PER PARTICIPANT:	96				
START MONTH	1		END MONTH		48

OBJECTIVES

An effective, transparent and pro-active management (MGT) will guarantee the smooth implementation of the financial, administrative and scientific activities into the RadioNet project. The central management team will build on its experience and it will competently coordinate the overall progress, and the implementation of the work plan. The proposed management structure is capable of handling all management tasks and challenges of the RadioNet project. The MPG has all the necessary infrastructures in place.

DESCRIPTION OF WORK

The detailed implementation of the RadioNet management structure is described in Section 3.2. The RadioNet MGT will support the consortium bodies (Board, Exec, WP leaders and Advisory Board) in all aspects of implementing the project plan. The MGT will execute the work plan and decisions of the Board over the project lifetime. It will collect and provide all essential information from and to the partners on behalf of the Project Coordinator, respecting rules for rights and obligations defined in the CA (e.g. periodic reports, administrative and statistical records, deliverables and milestones, activities progress reports, financial-supported event reports).

The MGT will also be responsible for the well-organized curation, preservation and accessibility of the data collected or produced under the project. It will define a data management plan (DMP), addressing ethics and intellectual property rights. The management will fully support the project activities to foster the potential for social innovation and partnership with industry and project long-term sustainability.

The Coordinator and project partners with support from the MGT will ensure collaboration with other relevant scientific projects and organisations (e.g. ASTRONET, SKA, ALMA, ASTERICS, AHEAD, EUROPLANET), industrial stakeholders and national funding agencies.

The MGT will centrally coordinate the scientific dissemination of the project as a whole: via the project web/wiki page, social media tools, industry/EC platforms, press releases, and attendance at relevant meetings and events. This guarantees a professional, consistent and effective outreach of the project in the scientific and the political arena. RadioNet outreach will concentrate on the partners and their communities, especially facility users. The RadioNet outreach for the general public (pupils, teachers) will be the effort e.g. in the performance of local telescope visitor centres, IAU and in the EU projects EU-UNAWE). RadioNet will not duplicate those efforts but will foster the collaboration with these initiatives.

WP2 – Dissemination

Work package number	2		Lead beneficiary	INAF	
Work package title	NA – Dissemination				
Participant number	1				
Short name of participant	MPG	INAF			
Person/months per participant:	0	0			
Start month	1		End month	48	

Objectives

The Networking Activity – Dissemination is designed to:

- disseminate the scientific highlights and the development on the technological front within the context of the RadioNet infrastructures,
- avoid duplication of effort by developing procedural methods for the organisation of periodic events,
- provide a platform for the effective promotion of the ,
- perform a cross-disciplinary fertilization, especially transfer of scientific knowledge to the younger generations and to the less experienced institutes,
- foster dialogue between science and technology,
- strengthen the collaboration of European radio astronomy engineers with industry,
- broadcasting of knowledge in all directions (scientific, technical, industry).

Description of work

WP2.1: Science Dissemination [INAF]

The task will focus on supporting organization of scientific meetings, in the form of large conferences, topic-oriented smaller meetings and informal very small workshops/discussion forums. Most of those events will focus on scientific results achieved using the RadioNet facilities and/or technical developments of RadioNet activities. Additionally cross-disciplinary events will be supported every year, with the aim to feed the collaboration between radio astronomers and scientists working in other bands of the electromagnetic spectrum. This will disseminate the knowledge acquired in our field to the broader astronomical community and at the same time will broaden the scientific horizon of radio astronomers.

Moreover, special attention will be given to the younger generation of European radio astronomers. The Young European Radio Astronomers Conference (YERAC) has been held yearly since 1968, bringing together young radio astronomers working at European institutes, observatories, laboratories and universities in order to provide them with early opportunities for trans border interactions with peers. The Task 3.1 will actively support YERAC organisation by finding a suitable host, an organizing committee, additional to the financial support for the meeting organisation.

WP2.2: Technical Workshops [MPG]

This task will concentrate mainly on organization of a series of technical workshops (TWS). A special focus will be on the technical achievements and progress of the JRAs in this project in order to disseminate these results in the community. To bring the European radio astronomy engineering results and expertise to the attention of the broader engineering community, one or two special sessions at big international conferences outside the radio astronomy community will be co-organized. The objective will be to exchange ideas and new directions, and to attract the interest of researchers and industrial engineers in related fields to collaborate in the development of Radio Astronomy as well as industry applications with the aim to transfer knowledge in both directions. Furthermore it will foster the use of research infrastructures by industrial researchers and vice versa, and it will encourage the involvement of industrial associations in consortia or in advisory bodies.

In order to ensure the highest impact on the scientific and engineering communities, a Call for Events to be supported by the RadioNet WP2 will be released every 8 months, with the goal to collect all the requests at the same time and proceed with a comparable evaluation. A broad distribution of the Call will be ensured thanks to a detailed and exhaustive mailing list addressing the astronomical scientific and engineering communities at large, and use of other providers. The requests will be evaluated on the basis of the scientific or technical relevance, and of the impact they will have on the community at large. The evaluation will be made by a steering committee, to be appointed by the RadioNet Board.

All the activities of this WP play a major role in the radio astronomical community. Some of them are organised regularly, in particular the YERAC, the EVN Symposia and TWS. To avoid the duplication of work and to ensure their guidelines concerning the purpose and organization of those events will be developed together with the organisers. The guides will be made publicly available on a dedicated web site and will be updated regularly as an interactive document.

WP3 – Training

Work package number	3		Lead beneficiary	UMAN	
Work package title	NA – Training				
Participant number	1				
Short name of participant	MPG	UMAN	ESO		
Person/months per participant:	0	0	0		
Start month	1		End month	48	

Objectives

The Training activity is devoted to radio astronomers and engineers with the skills which are essential to take full advantage of the present and future radio astronomical infrastructures by:

- offering set of schools and forums, where specialist observatory personnel discuss engineering developments and exchange best practises, where users present cutting-edge results from RadioNet infrastructures, and where experienced astronomers train the next generation in the basics and finer of using radio astronomy infrastructures,
- providing a dedicated support program for visitors to the European ALMA Regional Centre nodes in order to strengthen and enlarge the user base,
- encouraging inter-sectional mobility so that the contacts between the different groups: astronomers, engineers and industry will be reinforced.

Description of work

WP3.1 Astronomical/Engineering Schools [UMAN]

This activity will foster the skills needed for exploitation of European radio astronomy facilities by researchers worldwide. It will enable radio astronomers to take advantage of global best practices and research opportunities and help newcomers to radio astronomy to learn current state-of-the-art techniques, and encourage them to stay in the field. The events are aimed at astronomers and engineers in order to communicate, and indeed develop techniques needed to plan observations, reduce and interpret data from present and next-generation facilities. This ensures that there will be sufficient experts in the market to support their communities in making use of new opportunities (ALMA, EHT and SKA, and the other rapidly-evolving RadioNet facilities). Each year a range of events catering to the whole community from beginners to experts will be offered addressing:

- Radio Interferometry – ERIS, which provide hands-on teaching of planning, calibration and imaging for data from RadioNet arrays and ALMA. There is a need for advanced workshops aimed at astronomers and software engineers with significant experience in order to share and develop techniques such as in mm VLBI (e.g. VLBI with ALMA) or wide-field, wide-band imaging at longer wavelengths to make use of the dramatic increases in sensitivity and survey opportunities afforded by SKA pathfinders,
- Single dish hands-on observing – the IRAM 30-m schools will continue biennially, additionally new cm-wave observatories to host single-dish training will be sought,
- Solar radio astronomy – events will be linked where appropriate to Community of European Solar Radio Astronomers (CESRA) and European Solar Physic Meetings. Two will be linked to new observing opportunities: Solar observing with ALMA and launching of Solar Orbiter (ESA) and Solar Probe (NASA) in 2018. A workshop on radio and space weather forecasting will strengthen co-operation between research infrastructure, scientific communities, modellers and observers, and the MetOffice UK.
- Radio interference – speakers on spectrum management issues will attend the training events of this NA, additionally an international Spectrum Management school will be organised in 2018,

requiring the participation of experts from around the world.

- Complementary topics – such as geodesy schools, CASA software training at the ARC nodes, science-themed schools and multi-wavelength workshops offering a radio session.

WP3.2 Mobility for ALMA Regional Centre Users – MARCUs [ESO]

The goal of this task is to strengthen and enlarge the user base, by means of supporting visits of European ALMA users to the European ARC nodes. The European ALMA Regional Centre (ARC) is a unique structure of user support in (sub-) millimetre astronomy. The ARC consists of a network of nodes and centres of expertise spread across Europe, plus the central coordinating node at the ESO headquarters in Garching, Germany. The ARCs network forms the interface between the ALMA observatory and the European astronomical community. ARC nodes provide face-to-face support at the proposal preparation stage in case of complicated observing programmes and/or novice users. They also provide support for archival research in order to ensure that the ALMA archive and ALMA itself is exploited to its full potential. Some of the individual nodes offer beside the overall ALMA support additional expertise, such as solar observations, very high frequencies, polarization, mosaicing, high-dynamic-range imaging. Encouraging mobility of the community across Europe will disseminate knowledge and enable innovative research partnerships.

This activity will support users from all European countries to take full advantage of the scientific and technical expertise from the most appropriate ARC node. In the past RadioNet3 has supported at least half of the requested visits to the ARCs. Some ARC nodes have limited funding available for visiting scientists, but this funding is by far not enough to cover all the requested visits in Europe. A large fraction of the astronomers who travel to the ARC nodes for face-to-face support are early career scientist (postdocs, students) who often do not have access to funding to support their trip. Now, when ALMA is in the full operational mode, it is crucial that new European ALMA users will receive any needed assistance – the mission of this activity.

WP3.3 Short Training Missions – STM [MPG, UMAN]

In an additional aspect of the training program, we will support mobility in order to reinforce the contacts between the different groups: astronomers, engineers and industry. This will allow young early career researchers to establish international, diverse collaboration. On the long perspective it will lay a foundation for the sustainability of the present and future infrastructures. The exchange programme will be open not only to the project partners but also to others, especially African countries will be encouraged. However, the visit must take place at the RadioNet beneficiaries. The call for applicants will be released every 8 months and the applications will be reviewed by the selection committee, whose members will be appointed by the RadioNet Board. The applicants will be expected to send a motivation letter, a CV, a brief summary of the proposed work, and the invitation of the host institution. The EC funding will support travel and accommodation costs. Typical duration of the visit will be one week. Each visit will be documented in an assessment report, clearly specifying the added value for the RadioNet community.

Potential hosts for training events will be invited to submit proposals for financial support, which will be evaluated by a WP3 selection committee appointed by the Board. The WP3 coordinators will ensure that major events such as ERIS occur at the appropriate intervals and receive guaranteed support. The calls of opportunity will be widely publicised. The financial support will subsidise travel costs for selected participants: e.g. early career, from less well-funded institutes or invited lecturers and tutors. Organisers will be encouraged to ensure the gender balance and diversity of attendees, both among participants and tutors. RadioNet will assist event hosts in publicising announcements, contacting experts and ensuring that lecture and tutorial material is maintained in open-access repositories. To assure the sustainability of the regular events, a manual for event organisers based on past experience and feedback from participants will be created. These will provide a checklist and ensure that lessons learnt are communicated, whilst being accessible for updating.

WP4 – SUSTAINABILITY

WORK PACKAGE NUMBER	4		LEAD BENEFICIARY		ASTRON
WORK PACKAGE TITLE	NA - SUSTAINABILITY				
PARTICIPANT NUMBER	1				
SHORT NAME OF PARTICIPANT	MPG	ASTRON	UAH	OBSPARIS	
PERSON/MONTHS PER PARTICIPANT:	0	0	0	0	
START MONTH	1		END MONTH		48

OBJECTIVES

To enhance the sustainability of future radio astronomical research in Europe with a focus on:

- standardization of VLBI operations and equipment at EVN and GMVA observatories to enhance the quality of the received data. Training and development are key elements, which will be shared by the TOG and GMVA technical groups on a regular .
- protection and maintenance of the radio spectrum infrastructure for radio astronomy to enable radio-astronomical observations which are sensitive enough to contribute significantly to relevant science goals. The Committee on Radio Astronomy Frequencies (CRAF) is this activity. It contains elements of training and collaboration with the industry to improve engineering standards.
- the establishment of a formal platform in which European radio astronomy institutes and organisations come together and discuss the broad coordination of the field in areas related to strategic planning and other high-level policy matters. The platform will focus on joint activities, including the EVN, ALMA and the SKA.

DESCRIPTION OF WORK

WP4.1: EVN TOG & GMVA Technical meetings [UAH, MPG]

EVN is a network of radio telescopes (Europe, Asia and South Africa) that performs simultaneous observations in the cm-wavelength regime. GMVA provides a complementary infrastructure that combines European and US telescopes, and ALMA to provide ultra-high resolution observations at mm-wavelengths. It is essential to maintain and improve these infrastructures in order to satisfy the requests for constantly increasing science goals and to sustain radio astronomy into the far future.

The success of the EVN is heavily based on standardisation of equipment and procedures across the network. The Technical & Operations Group (TOG) of the EVN is the platform for innovations and standardisation within the EVN and has been responsible for the maintenance of the technical and operational infrastructure of the EVN for the last 30 years. Regular technical meetings provide a crucial work platform for the TOG. In early 2016 the GMVA Technical Group (GTG) will be officially constituted to provide comparable services to the GMVA. Similarly, regular technical meetings are also planned for the GTG.

As there is considerable overlap between the EVN and GMVA infrastructures in terms of the participating stations, the technical personnel, as well as in the observing equipment it is intended to organize TOG and GTG technical meetings in conjunction with each other. The associated meetings will increase the synergy between both networks, and optimize the labour costs. These meetings allow staff from the stations to agree on common developments and share knowledge from which both networks will benefit. The TOG & GTG technical meetings will provide a crucial element of training and development, maintaining and enhancing the quality of the data received by EVN and GMVA users. The financial support provided in this project will boost these new combined meetings with the aim to make them an established part of the infrastructure at the end of the project.

The meetings will take place approximately every 8 months. Financial support will be provided to operators and engineers. The requests for financial support will be approved on an individual basis by the WP4 selection committee giving special consideration to participants from less well-funded institutes and external experts, and to gender diversity aspects. In particular, due to the fact of ALMA joining some of the GMVA observations starting 2017, inviting ALMA experts to GTG meetings will be of great importance. We also foresee the need for additional GTG meetings on request, addressing urgent GMVA-ALMA related issues. Meeting reports will be communicated to a diverse list including technicians and scientists from radio astronomy and other related communities (e.g. geodetic VLBI). The activity webpage will additionally hold action items from each meeting, lists of developments by the technical staff, status of the equipment and disk space resources, as well as the efficiency of the EVN and GMVA networks after each session to examine the evolution and the impact of the technical support. The main outcomes of the meetings will be reported to the governing bodies of EVN and GMVA respectively, to assure the continuation of the development processes

WP4.2: Spectrum Management [OBSPARIS]

In CRAF the European radio astronomy institutes collaborate to coordinate activities to keep the bands used by radio astronomy free from interference and to have a common voice in the international frequency management arena. The members of CRAF are delegated from radio astronomy institutes in 20 countries in Europe and from South Africa as well as from organizations such as SKA, ESA, IVS, and IRAM. They are involved in spectrum management for radio astronomy and as such represent their institutes in national and international issues to protect and maintain the radio spectrum infrastructure. The member institutes bring together the money to employ one frequency manager who represents radio astronomy at many international meetings.

CRAF holds up to two meetings per year, to report on the current interference issues and possible solutions, interactions with national administrations and anticipated developments related to scientific spectrum. Also information about international developments that may have an effect on radio astronomy is shared and discussed. During the meetings a coordinated strategy and common policy to address current and future issues is developed. CRAF meetings also have an educative aspect: attendees learn more about the techniques that are used in spectrum management.

On the global level, once every 3-4 years the World Radio communication Conferences (WRC) of the International Telecommunication Union (ITU) take far reaching and legally binding decisions on the allocation and use of radio spectrum for all services, including radio astronomy. Study Group 7 of the ITU (SG7) covers the science services and has a subsection dealing with radio astronomy. CRAF representatives are needed there to give evidence on the requirements of radio astronomy and to study the impact of decisions proposed by administrations. The next WRC is expected in 2019 and CRAF must attend this conference with enough representatives to cover all relevant meeting sessions.

The European Conference of Postal and Telecommunications Administrations (CEPT) makes binding decisions on European spectrum policy and use of the radio spectrum. There are at least seven committees, meeting two to four times a year, where issues involving scientific use of radio spectrum are discussed. Representatives of CRAF provide input on these issues and take part in the discussions. In many cases representatives from industry are also involved and together with telecom administrations, guidelines are provided to the European Telecommunications Standards Institute (ETSI) for developing engineering standards.

About 60% of the budget of this task will be used to subsidise the annual CRAF meetings: organisational cost, travel support for external experts and travel for CRAF members from less funded institutes. The remaining 40% of the budget will be used to provide financial support for travel to CRAF representatives at international spectrum management meetings at the ITU and CEPT. Funding will be assessed and approved on an individual basis by the WP4 selection committee. Written meeting reports will be distributed to CRAF members and stored on the password protected area. The reports contain decisions, action points and future reference. The summary is publicly available. The CRAF members discuss the outcomes with the appropriate people in their institutes.

WP4.3: RadioNet4 Strategy & Policy forum – SPOOR [ASTRON]

The SPOOR activities build upon the output of the previous RadioNet3 project and the recommendations of the ASTRONET ERTRC report. The SPOOR task will explore with the RadioNet Board, the EVN Board and other relevant bodies across Europe the best way forward into the next decade for European Radio Astronomy. The SPOOR will focus on recommendations 7 and 8 of the ERTRC report:

7. "We recommend that local and national radio institutes remain independent, as local support and expertise centres for radio astronomy, but that their joint activities, such as EVN and RadioNet, become more robustly and permanently organised and funded (but not through the same body that organises the European participation in the SKA)."
8. "We recommend that the European involvement in the SKA be organised through a treaty organisation that is robustly mandated and funded, to ensure the strongest impact of and participation in SKA by Europe. The ERTRC considers ESO to be a prime candidate to be that organisation."

Major strategic issues will be addressed by the RadioNet partners within SPOOR, including the need to arrive at a sustained approach for European collaboration. These include the EVN, SKA and CRAF, and go beyond the traditional sources of EC funding. A sustained platform for strategy and policy discussions under agreed governance beyond the RadioNet project will also be addressed. The results will be discussed by the RadioNet Board and published in the final report of this task. With this task financial support will be provided for the organization of several meetings and for travel support of participants, including external experts, to the respective meetings.

ASTRON will be the main leader of the WP4.

WP5 – AETHRA

Work package number	5			Lead beneficiary		IRAM	
Work package title	JRA - Advanced European Technologies for Heterodyne Receivers for Astronomy (AETHRA)						
Participant number	1						
Short name of participant	MPG	IRAM	FRAUNHOFER	UAH	OSO	UXOF	INAF
Person/months per participant:							
Participant number							
Short name of participant	RUG	SRON	OBSPARIS	TUD	UCO	ESO	STFC
Person/months per participant:							
Start month	1			End month			42

Objectives
AETHRA aims at exploiting new technologies, such as highly integrated microelectronic semi- or superconducting circuits, to significantly improve the next generation receivers of mm and sub-mm wavelength telescopes, reinforcing European technological and scientific leadership by considerably improving the receiver performance and observing speed of the European-owned world-leading facilities ALMA, APEX, NOEMA and PV. The most effective means to boost the observing speed of those instruments at a reasonable cost consist of: *a. <u>widening the IF/RF receiver bandwidths</u> and* *b. <u>implementing large focal plane arrays</u> (FPAs) of heterodyne receivers.* Both paths should be followed without degrading and as much as possible even improving the receiver. Precursor-developments have started via the JRA AETHER and have clearly demonstrated the potential available for facility upgrades. AETHER developed a range of high performance components for mm/sub-mm heterodyne receivers, mostly mixers and amplifiers. The receiver modules were fit to be assembled together in FPAs. However, their architecture of lumped mechanical elements meant poor homogeneity, reduced performance and high fabrication costs. Moreover, their footprint area (typically few cm^2 at 1-mm) limited the number of potential sky pixels to a few tens. Only a novel architecture, implying micro-devices, as much as possible integrated on planar substrates and fabricated in large quantities per foundry run, will open the way to spectral line imaging arrays with hundreds of sky-pixels. This will only be possible through a core understanding of the complete receiver system, in particular device physics, and through the application of industrial-type methods. ATHRA will make decisive steps along paths *a.* and *b.* and develop complete receiver prototypes, from RF antenna to IF signal digitization, that will provide ultra-high sensitivities across the entire mm/sub-mm wavelength spectrum readily observable from the ground, i.e. 70 GHz to 1 THz. – The receivers will be physically compact enough to be integrated into large FPAs. – Reduced size array demonstrators will be built and tested on the sky using e.g. the IRAM 30m and APEX telescopes. The four-octave RF band under consideration makes it necessary to choose, depending on wavelength, different technological solutions for detectors, LO and optics. Solutions for the detectors, the most critical component are: hybrid or MMIC low-noise cryogenic amplifiers (up to 3 mm), highly integrated 2SB or balanced SIS mixers (around 1 mm), and SIS and HEB mixers around 1 THz.

DESCRIPTION OF WORK

WP5.1: Semiconductor LNAs and MMIC receivers

5.1.1 Investigate the new 35 nm gate length mHEMT technology available at IAF to improve noise performance of cryogenic MMIC LNAs at W-band (72-116 GHz) [Fraunhofer, MPG]

Previous cryogenic GaAs mHEMT MMIC Low-Noise-Amplifiers (LNA) developments at W-band have relied on the well-established 100 nm and 50 nm gate length processes. Theory and experimental results on InP HEMT-based LNAs indicate the benefit of exploiting 35 nm mHEMT devices to obtain superior noise performance. Utilizing the latest transistor models, a 35-nm MMIC LNA for the W-band will be designed and fabricated at IAF.

5.1.2 Develop and build a W-band MMIC array demonstrator [MPG, IRAM, Fraunhofer]

Cryogenic part of the demonstrator will include a corrugated horn, an OMT and 2 W-band MMIC LNAs per pixel. A down conversion module will be designed which integrates full down conversion from RF to 4-12 GHz IF: a post-LNA at RF, a mixer, a LO-multiplier and an IF-LNA, possibly all on a single IAF GaAs MMIC. The module will be developed by MPG and IRAM. IRAM will make the receiver system design and assemble several of the cryogenic pixel modules into a test cryostat, which will allow for a demonstration of a small W-band FPA at the telescope.

WP5.2: Very large Focal Plan Array of SIS mixer receivers

5.2.1 Increase RF/IF bandwidths of SIS mixer receivers [OSO]

Work on solutions, and develop prototypes, to allow broadening RF band of 2SB SIS mixers beyond single-mode waveguide band: this includes OMT, substrate-to-waveguide transitions, RF 3DB wideband hybrids and power division circuits. On SIS mixer junction side, this task includes work on AlN tunnel barrier growth technology with focus on Nb/Al-AlN/Nb junction quality and reproducibility. The work will result in a prototype 2SB SIS mixer operating close to APEX Band 2 mixer and will be tested as part of SheFI APEX receiver.

5.2.2 Develop and build a 1mm FPA receiver demonstrator using highly integrated 2SB SIS mixer with large IF/RF bands [IRAM, UXOF, UAH, INAF]

Development of miniaturized single-chip 2SB SIS mixers, as much as possible integrated with RF/IF hybrids and first stage amplifiers, will be made by IRAM and UAH. The chip design and fabrication process will target top performance, reasonable cost and good reproducibility. The possibility to use planar OMTs will be explored by INAF. Novel solutions for the optics, LO injection and IF transport (e.g. minimalizing the use of coaxial cables) will be explored. Full receiver modules will be fabricated and integrated into an FPA demonstrator that will be tested on the sky on the IRAM 30-m telescope. The possibility to build FPAs for use on the NOEMA antenna will be explored.

WP5.3: FPA of receivers operating around 1 THz

5.3.1 Development of SIS mixers for 1 THz receivers [UOXF, RUG, UCAM, UCO]

In this task we will develop SIS tunnel junctions with a superconducting gap high enough to give good mixer noise temperature in a frequency range 780-950 GHz, which is suitable for ALMA band 10. The consortium will aim to improve on existing mixer performances by employing high gap superconductors such as NbN and AlN barrier. Mixer chips will then be fabricated using recent technologies such as SOI and beam-lead technology. Single pixel mixer tests will be performed to verify and compare the performances.

5.3.2 Development of highly integrated 2SB balanced SIS mixer array at around 1 THz [RUG, UOXF, UAH]

An up to 7-pixels receiver array module will be designed, fabricated and tested with a foot-print that can easily be integrated into telescope receivers. It will use highly integrated side-band separation mixers operating in the ALMA Band 10 frequency range. A smooth-walled horn array will be used to feed the mixers with integrated circular-to-rectangular transitions. Cryogenic amplifiers will be integrated to the mixer array as much as possible to reduce the IF noise contribution. We will also use efficient LO power injection in order to reduce the RF power required to pump the mixer array.

5.3.3 Explore new paths for enlarging the IF bandwidth of HEB devices [SRON, TUD]

While HEB mixers have shown excellent noise performance, their IF bandwidth has been limited to ~3.5 GHz. Increasing the IF bandwidth has become the outstanding issue in the HEB community, and is also known to be extremely challenging. In this subtask, new paths will be explored to double this bandwidth, while maintaining the lowest possible noise. One way is to make use the existing NbN thin film technology, but by introducing additional phonon cooling channels around the HEB.

5.3.4 Develop and build a HEB mixer FPA demonstrator [OBSPARIS, SRON, TUD]

NbN HEB mixers have great advantages of low LO power requirement, no magnetic fields, and no upper frequency limit. Therefore they are good candidates for a large array around 1 THz. We propose to build a HEB demonstrator array with a quasi-optical coupling scheme. We are going to explore an optical method to split a single LO for multi-pixels using a phase grating. In this task we will build a small array to prove the principle that could later be upscaled to larger arrays. The Observatory of Paris will develop, build and test the FPA demonstrator at LERMA. SRON and TUD will develop the final test setup, including preparing a cryostat with a large window, and will also be a backup supplier for the HEB devices.

WP5.4: Subtasks common to Tasks 5.1-5.3

5.4.1 Develop and build LO chains able to drive mixer arrays [STFC, OBSPARIS]

Develop new local oscillator generation schemes involving frequency harmonic up-conversion of baseband frequencies. Particular focus will be placed upon Schottky multiplier diode high power and high frequency operation enhancement, device integration, and structural compactness. Additionally, impact of the LO concept on 4K cooling requirements will be considered and device topology will be developed to mitigate adverse effects.

5.4.2 Develop and build large-bandwidth cryogenic IF amplifiers [UAH]

Work on increasing the bandwidth of cryogenic IF amplifiers, using MMIC or discrete HEMT design, and employing balanced layout. Work towards a prototype covering up to 16 GHz.

5.4.3 Establish networking on fabrication of superconducting circuits and micromachining facilities [UCO, OSO, RUG, TUD, IRAM, UCAM, UOXF]

Organize activity to share information on the clean rooms, thin-film deposition process, and other highly specialized equipment available in the partner institutes, in order to favour and support further collaborations between the partners and with external SMEs.

IRAM will perform the overall management of the WP5 AETHRA and will be the main contact point for the project management bodies (Board, Exec, MGT). Additionally, each of the subtasks have a defined leader (underlined), who will be responsible for the daily implementation of the task's work plan, the preparation and communication of the deliverables, publications and progress reports to the AETHRA leader, as well as their presentation at the AETHRA meetings.

The AETHRA partners will meet twice a year, at least once face-to-face. The progress reports, presentations at the face-to-face meetings, reports on the deliverables and publications will be made accessible at AETHRA wiki pages. The results and publications will be presented in international conferences such as SPIE and ICMTT as well as in specialized journals.

WP6 – BRAND EVN

WORK PACKAGE NUMBER	6		LEAD BENEFICIARY		MPG	
WORK PACKAGE TITLE	JRA - BROAD BAND EVN (BRAND EVN)					
PARTICIPANT NUMBER	1					
SHORT NAME OF PARTICIPANT	MPG	INAF	OSO	UAH	ASTRON	VENT
PERSON/MONTHS PER PARTICIPANT:						
START MONTH	1		END MONTH		42	

OBJECTIVES

The main objective of BRAND EVN is to develop and build a prototype broad-band digital receiver, which will cover a frequency range from 1.5 GHz to 15.5 GHz (1:10 maximum range, chosen to include the 2 cm VLBA band). The BRAND frontend can be adapted to different EVN antennas. The backend part can also be used for other receivers with a RF frequency or IF range between 0 GHz and 16 GHz. The BRAND receiver when deployed at a majority of EVN telescopes will:

- open a range of new scientific opportunities like multi-wavelength: VLBI mapping, spectroscopy, polarimetry, and single-dish, as well as geodetic VGOS compatibility, due to its enormous simultaneous bandwidth,
- catapult the EVN to new levels of performance not achievable with any other astronomical VLBI network,
- influence cost for maintenance and energy for cooling by replacing multiple VLBI receivers in the frequency range of 1.5-15 GHz,
- increase the available observing time offered by the EVN, as more than one frequency can be observed simultaneously,
- offer even greater sensitivity, as the reduction in sensitivity of such a broad-band receiver compared to narrow-band receivers will be more than compensated by the enormous data-rate resulting from the wide bandwidth,
- motivate non-EVN observatories for instance African telescopes to acquire a BRAND receiver as a relatively cheap means to co-observe with the EVN or even become a new EVN member,
- have an impact on the design of new telescopes, which could be optimized for a BRAND receiver, and would profit from a smaller number of required receivers.

The BRAND receiver might even become the next generation VGOS receiver due to its superior sensitivity, its wider bandwidth, and the possibility to choose parts of the spectrum still uncontaminated by RFI. In order to boost the utilisation of the new receiving system at a large number of the EVN telescopes the BRAND EVN project will provide a detailed implementation document that will contain all specifications to build a BRAND receiver, which will also include a list of suppliers and industrial partners who will be able to deliver parts or even complete frontend/backend systems. In addition each EVN station for which the BRAND specifications were collected will receive an interface document describing the specific local adaptations required to locally integrate the BRAND system.

The BRAND receiver prototype will be commissioned and tested at the 100m Effelsberg telescope.

DESCRIPTION OF WORK

WP6.1: Feasibility survey of EVN antennas [UAH, OSO, INAF]

The specifications for the installation of a BRAND receiver at the EVN antennas will be collected. All EVN stations will be contacted and encouraged to provide the required information about the optical configuration etc. as well as the local RFI situation. To mitigate the risk of low response, BRAND will assist at least the set of EVN stations, which committed purchasing of the BRAND receiver, in collecting the requirements and measuring the usable part of the spectrum with a set of standardised equipment. The feasibility survey will result in an implementation document for each EVN stations for which the information has been collected. The report will give recommendations with respect to the receiver layout, dewar specifications, optimal optical arrangements, IF cabling infrastructure, required HTS (High Temperature Superconducting) RFI filters, etc.

WP6.2: BRAND receiver frontend [MPG, INAF, OSO, UAH]

6.2.1: Primary focus feed including RFI filters

Different broad-band feeds for prime focus will be evaluated (e.g. Quad-ridge feed horn - QRFH, Eleven-feed, Dyson conical quad-spiral array - DYQSA). Possibilities for injecting noise-calibration signals at the feed level will be investigated. An optimal feed for the prototype Effelsberg system will be chosen. Appropriate filters for suppressing the strongest RFI, which would saturate the amplification chain, will be identified and the corresponding low-pass, high-pass and notch high-temperature superconductor (HTS) bandpass filters will be manufactured.

6.2.2: Solutions for secondary focus

Feed solutions for EVN telescopes, which will not be able to mount a BRAND receiver at primary focus will be investigated. The performance and suitability for available secondary focus feeds will be studied. Results and recommendations will be summarized in a report that will be available to all interested antennas.

6.2.3: Low Noise Amplifier (LNA)

An Indium Phosphide (InP) MMIC single broad-band LNA optimized for the 1.5-15.5 GHz frequency range will be designed and manufactured. The design will be based on the existing designs of, e.g. the RadioNet3 and VGOS receiving systems. It is planned to produce two LNA prototypes.

6.2.4: Cryostat and integration and testing of receiver frontend

A dewar for the prototype frontend system to be installed at the Effelsberg antenna will be manufactured. All frontend components will be integrated. Characterization and testing in the laboratory will be done.

WP6.3: BRAND backend [INAF, MPG, ASTRON, VENT]

6.3.1: Sampling board

Before the wide-band frontend signal can be sampled, it has to be amplified and equalized; an analogue board for this task has to be built. The BRAND backend will require sampling devices, which transfer the analogue signal to the numeric domain for a very wide band. Suitable sampling chips have just appeared on the market and are available in small numbers only. Demonstration boards, available from the manufacturer containing these chips, have already been tested and have shown to suffice for the BRAND project. Sampling boards making use of the sampling chips will be designed and manufactured. Additionally firmware for configuration and control of the boards will be developed.

6.3.2: High data rate processing board

A board with a single FPGA processor will be developed including the hardware platform with its firmware engine. The board will have an input data rate of 896 Gbps and 128 Gbps as output and will be one of the most powerful data processors available to radio astronomy in the next few years.

6.3.3 FPGA firmware

For processing linearly polarized feeds, digital linear to circular polarization conversion will be realized in firmware, starting from work previously done at ASTRON and MPIfR. Additional firmware will be developed for the various VLBI modes like direct sampling conversion (DSC), digital down-conversion (DDC), polyphase filterbank (PFB), etc. For this purpose the firmware developed under the RadioNet3 project (DBBC3) will be adapted and extended.

6.3.3 Backend integration and tests

All backend components will be integrated and tested in the laboratory. The firmware will be installed and tested on the integrated backend system. In order to test the VLBI capabilities a zero-baseline test between the two independent IF signal processing chains of the backend will be performed.

WP6.4: Control, recording and correlation software [INAF, MPG, OSO, ASTRON]

Control software for the BRAND frontend and backend system will be developed, which will allow users to perform various setup and configuration tasks, e.g. choose receiver setups, switch between processing modes etc. taking into account the compatibility with the VLBI Field System.

The BRAND receiving system will interface with various standard software components utilized when doing VLBI observations and adaptions to these will need to be made in order to allow processing of data produced by the BRAND receiver:

- VLBI Recording: existing VLBI recorders are limited in data rate and hence bandwidth that a single unit can record. Thus for very high bandwidth observations multiple recorders will have to be used in parallel to be able to record the huge output data rate of the BRAND receiver. This task will provide a software layer that will distribute the data stream and control and monitor the data recorders,
- Correlator input and output: the correlator software will be extended to allow unpacking of the data format delivered by the BRAND backend. In addition, the data products delivered by the correlator will need to be compatible with the post-processing software. In particular, post-processing of broad-band data as produced by BRAND will require special fringe-fitting capabilities as the ones, which will be provided by the WP7-RINGS (e.g. ionospheric treatment). Appropriate interfaces to the RINGS software will be defined.

WP6.5: Integration at telescope and test observation [INAF, MPG, OSO, UAH]

The BRAND prototype receiving system will be installed at the Effelsberg antenna. In the first step of commissioning the single-dish capabilities of the new system will be tested, including RFI mitigation capabilities. After the successful completion, the VLBI capabilities will be tested in a second step by performing test observations together with a second antenna equipped with a comparable receiver system. The first choice will be the VGOS receiver having four 1GHz-wide bands in the range of the BRAND receiver. Two of the activity partners will have VGOS antennas and will strive to participate in the proposed test observations. In case of unavailability of the VGOS antennas during the commissioning period a fallback position is to use several EVN stations where the different telescopes will use different receivers covering some parts of the BRAND frequency range.

The WP6 management will be located at MPG. The INAF project engineer will partly perform the work at MPG too, to optimise the efficiency and cost of the work. Each partner institute will appoint a central responsible person for the implementation of the local work, who will be in regular contact with the WP leader. Project controlling will be implemented via monthly teleconferences. Additionally BRAND face-to-face meetings will take place twice a year. A project wiki page will serve as project management platform, for sharing progress, problems, discussions and general information including minutes and other activity documents.

WP7 – RINGS

WORK PACKAGE NUMBER	7			LEAD BENEFICIARY		ASTRON
WORK PACKAGE TITLE	JRA – RADIO INTERFEROMETRY NEXT GENERATION SOFTWARE (RINGS)					
PARTICIPANT NUMBER	1					
SHORT NAME OF PARTICIPANT	MPG	ASTRON	JIVE	UMAN	OSO	DIAS
PERSON/MONTHS PER PARTICIPANT:	5	13	14	13	13	21
START MONTH	1			END MONTH		42

OBJECTIVES

The main objective for RINGS is to deliver advanced calibration algorithms for the next generation of radio astronomy facilities, characterized by a high sensitivity, a high bandwidth and long baselines:

- Deliver new functionality that allows the correct calibration of existing and upcoming high-sensitivity, wide-bandwidth, long-baseline radio interferometers, by extending existing fringe-fitting routines that solve for non-dispersive station-based delays,
- Deliver routines that allow robust self-calibration for low signal-to-noise-ratio sources,
- The functionality delivered by RINGS will be incorporated in the CASA CORE software package,
- Ensure continuity in the support of the software by incorporating the software in CASA (moving away from legacy software packages like HOPS-Haystack Observatory Post-processing System and AIPS),
- As a joint objective with the JRA BRAND: provide the capability to fringe fit an entire ~13 GHz wide band and be able to map the data with wide-band mapping software,
- Support the WP3 Training to provide a training workshop for radio astronomers in the use of the RINGS functionality,
- Organize interaction with the Radar and Seismic Imaging industry to exchange algorithmic approaches for phase calibration and enhance cross fertilization between these domains,
- The envisaged RINGS results will expectedly allow further valorization. The open-source S/W for antenna pattern description is likely to have benefits for industry and academia.

DESCRIPTION OF WORK

WP7.1 Polarimetry Conversion [OSO, DIAS]

Current interferometric observations are performed at very high data rates (several Gbps, at least) using wide fractional bandwidths. Hence, linear-polarization receivers will have to be used over such wide bands, due to the high instrumental polarization leakage resulting from the use of quarter-wave plates. Algorithms for an optimum calibration of the polarization response of wide-band receivers still need to be developed. This is especially true for very low frequencies, where Faraday rotation and depolarization must be taken into account, together with the receiver's leakage, and for long baselines, where the parallactic angles of the antennas are different, making it difficult to calibrate the phase delays and rates from observations on a linear-polarization basis.

WP7.1 will develop and test advanced algorithms for the polarization calibration of wide-band and long-baseline interferometric observations at both low frequencies (the case of LOFAR) and high frequencies (the case of mm-VLBI and ALMA). Additionally it is planned to implement full-polarization beam-modelling algorithms in our wide-band calibration software, for a high dynamic-range interferometric calibration. Currently there is a need in wide-field imaging for a proper mathematical framework for polarimetric beam models. The work builds on the Measurement Set Correct Polarization (MSCORPOL) project and work of the LOFAR Long Baseline Working Group as well as Polconvert (part of APP), which is software for the calibration/conversion of the ALMA mm-VLBI visibilities.

WP7.2: Multiband and Wide Band Fringe Fitting [JIVE, DIAS, MPG]

This task will handle the non-dispersive delays, phases and delay rates. Fringe fitting corrects an observation for atmospheric errors, which prevent the averaging of data in time and frequency, and therefore limit the sensitivity of a radio telescope. Multiband fringe fitting deals with datasets where the frequency coverage is cut into multiple bands with a large gap between them. Wideband fringe fitting handles datasets with continuous frequency coverage, where the bandwidth is of the same order as, or larger than, the observing frequency. Both cases require the inclusion of a frequency dependent sky model, handling of non-linear frequency dependence of delays, and ingestion of large volumes of data for a single processing step. Only CASA allows us to combine this functionality in a single software package.

WP7.3: Fringe Fitting with dispersive delays [UMAN, ASTRON, DIAS, MPG]

A dispersive delay (such as is caused by the Earth's ionosphere) leads to a phase change inversely proportional to frequency. Because of this inverse relationship, dispersive delays typically only become noticeable at low frequencies, especially below 1 GHz where instruments such as LOFAR operate. Over a sufficiently narrow bandwidth, the phase dependence on frequency can be approximated linearly, allowing a dispersive delay to be corrected with a traditional (non-dispersive delay only) solution, but this approximation breaks down when wide bandwidths are used. In this case (wide bandwidths, low frequency, such as for LOFAR) dispersive delay must be solved for; however, the problem space becomes exceedingly large, and any simple gradient-descent optimisation techniques inevitably become caught in local minima.

The approach taken by RINGS will be to use traditional techniques to constrain the solution space and 'guide' the overall phase solution (non-dispersive + dispersive delays) to the global minimum. The results of this task are also essential to achieve the maximum sensitivity in any radio telescope using the receiver to be developed by the WP6 BRAND.

Task 7.4: Advanced calibration algorithms for full-polarization interferometry data [OSO, DIAS]

Self-calibration is one of the most important calibration techniques in interferometry. It allows one to overcome dynamic-range limitations due mainly to atmospheric fluctuations, thereby decreasing the image noise to the theoretical limits. However, this technique is known to be problematic for low-SNR observations, due to the high probability of false detections. To date, there is no self-calibration algorithm able to deal with low-SNR data in a statistically robust way. WP7.4 will develop a robust, full-polarisation self-calibration algorithm incorporating direction dependent effects (WP7.1) and dispersive frequency dependent effects (WP7.3). This will be especially important for wide-field LOFAR images, as well as for ALMA mosaics and observations of extended polarized structures. The work in this task builds on previous work on UVMULTIFIT, a versatile library for fitting visibility data, implemented in a Python-based framework. UVMULTIFIT does simultaneous fitting of multiple source components to visibility data.

The WP7 will be managed by ASTRON leading the technical coordination and UMAN leading the scientific coordination. RINGS will use RadioNet wiki pages for sharing and archiving of all sorts of documents to support the ongoing work as well as the meetings. The wiki pages will have a public area in which early results will be shared with the community. The stakeholders for all the relevant facilities are well known, and therefore, direct communication of results to them and their involvement where necessary will be organised using an email distribution list. In particular, RINGS will

- organize with the WP3 a workshop on instructions on the application of the RINGS results,
- invite industry partners from geodesy, seismic imaging and radar imaging at the end of project to share the results for exploitation in industry at a workshop organised under WP2 Dissemination,
- seek close interaction with the CASA team at NRAO for alignment of the activities to ensure maximum uptake of the results on all facilities,
- actively communicate the activity mission and progress within and outside projects for instance the US (NRAO for the VLA, MIT Haystack), South Africa (SKA and the Meerkat Observatory), China (University of Shanghai), Australia (Murchison Wide Field Array) and KVN.

WP8 – EVN

WORK PACKAGE NUMBER	8					LEAD BENEFICIARY – JIVE
WORK PACKAGE TITLE	TA – EVN					
PARTICIPANT NUMBER	1					
SHORT NAME OF PARTICIPANT	MPG	ASTRON	JIVE	UMAN	OSO	
PERSON/MONTHS PER PARTICIPANT	0	0	0	0	0	
PARTICIPANT NUMBER						
SHORT NAME OF PARTICIPANT	UMK	AALTO	VENT	INAF	UAH	
PERSON/MONTHS PER PARTICIPANT	0	0	0	0	0	
	START – END MONTH					1 – 48

OBJECTIVES	PROVISION OF ACCESS TO EVN
	DESCRIPTION OF THE INFRASTRUCTURE
NAME	European VLBI Network – EVN
LOCATION	The EVN is a distributed network of radio telescopes located across Europe and beyond. European EVN telescopes include: Effelsberg (DE), Jodrell Bank (UK), Westerbork (NL), Onsala (SE), Medicina, Noto, Sardinia (IT), Yebes (ES), Torun (PL), Metsahovi (FI), and Irbene (LV). The central processing facility – (correlator) is Dwingeloo (NL).
WEB SITE ADDRESS	www.evlbi.org
ANNUAL OPERATING COSTS	€

DESCRIPTION OF THE INFRASTRUCTURE *Give a brief general description of the infrastructure to which access is offered. Illustrate, in particular, its state-of-the-art equipment and services offered to users that make it rare or unique in Europe. Outline the areas of research normally supported by the infrastructure, as well as new areas opening to users, if any. If the infrastructure is composed of several installations, describe these including their specific features. If parts of the infrastructure are still under construction, specify the starting date of construction and indicate the date when access can realistically be made available.*

The EVN is a cooperative effort among ten institutes in eight EU countries, plus Russia, China, South Korea, South Africa, and Puerto Rico. Five telescopes larger than 60-m provide unmatched sensitivity to the array. The telescopes in Asia and Africa create baselines longer than 8000 km, providing milliarcsecond resolution at cm wavelengths. The EVN also observes in conjunction with telescopes in the USA and Australia to provide significantly more baselines in the range up to 11000 km and to boost sensitivity further, and is working towards being able to include the individual telescopes of the UK *e*-MERLIN array to introduce baselines as short as 10 km. The EVN central processing facility is located at the Joint Institute for VLBI ERIC (JIVE). Advanced capabilities of software correlator (SFXC) provides since 2012 innovative features, such as pulsar binning/gating (including coherent de-dispersion if required), multiple phase-centre output within a single wide-field correlation, near-field correlation for solar-system targets, use of orbiting satellite-borne antennas, and a phased-up mode for high time-resolution applications. Connectivity upgrades at most telescopes have led to routine 1Gbps data rates in real-time e-EVN, in which telescopes stream data via optical fibre directly into the correlator. These rates enable higher sensitivity in projects studying transient sources, which benefit from this more dynamically responsive mode of operation. The e-EVN is a SKA pathfinder.

The EVN is an entirely open-sky instrument, in that there is no time pre-allocated for any group, whether related to an EVN institute or not. Nor is there any fraction of the total time reserved for competition from sub-sets of applicants (i.e., no national/institutional quotas).

SERVICE CURRENTLY OFFERED BY THE INFRASTRUCTURE *Describe the services offered by the infrastructure and its research environment, and demonstrate how it will enable scientists to carry out high-quality research. You should summarise some of the most interesting scientific achievements already obtained by users. Demonstrate that there is a widespread interest from users in other countries to conduct research at the infrastructure (or make otherwise use of its services), e.g. by indicating the number of international users currently using the facility per year.*

There are three 3-week EVN observing sessions per year, plus 10-15 days of real-time e-EVN observations. Since 2013, 144 hours of observation have been eligible to move to out-of-session dates specified by the PI, in order to promote observations with other instruments. Target-of-Opportunity (ToO) observations permit response to extremely rare and unpredictable events where there is an urgency to conduct high-impact science. The EVN's combination of sensitivity and angular resolution, the advent of SFXC, and the maturation of the e-EVN provide European researchers with a flexible instrument they can use to make significant advances in a wide variety of astronomical topics. The ASTRONET-ERTRC report has concluded that the EVN delivers a wide range of excellent science with respect to the ASTRONET Science Vision and will remain the premier VLBI instrument during the SKA1 era. The ERTRC has also noted that the contribution of the smaller radio telescopes in Europe to the Science Vision is greatly enhanced by their collective participation in the EVN.

- A highlight of extra-galactic astronomy conducted by EVN TA users include determining the relative contributions of active galactic nuclei and star-bursts to the overall energy budget of luminous infra-red galaxies or dusty active galaxies out to redshifts corresponding to the peak of cosmic star formation (TA project, Romero-Canizales et al. 2012, A&A, 543, A72; Ramirez-Olivencia, 2015, Highlights of Spanish Astrophysics VIII, 378).

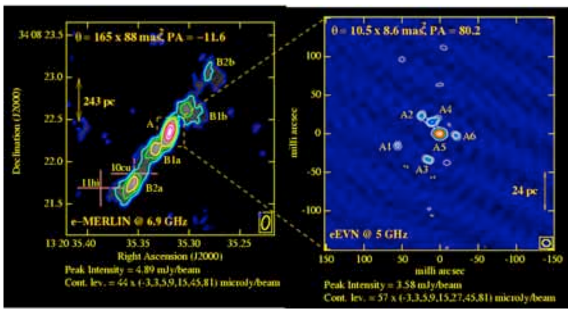
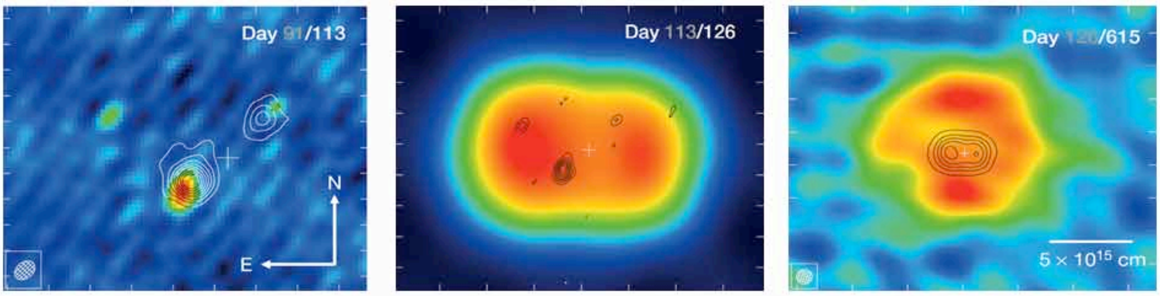


Fig. WP8.1 e-MERLIN image at 6.9 GHz (left) and e-EVN image at 5 GHz (right) of the LIRG IC883

- ToO e-EVN observations have successfully responded to an outburst of V959 Mon, a gamma-ray loud nova, only the third ever known (TA project, Chomiuk et al. 2014, Nature, 514, 339).



Figs.WP8.2 The evolution of the gamma-ray loud nova V959 Mon. Left: two epochs of 6 GHz EVN observations, 91 days (contours) and 113 days (colour) after the gamma-ray discovery. Middle: the 113-day EVN structure as contours under a colour-scale 36.5 GHz JVLA image 13 days later. Right: the longer-term E-W to N-S "flip" of outflow direction of the ejecta, with VLA structure at day 126 (contours) and 615 (colour).

Observed projects over the period 2012-2015 have had 482 different astronomers participating in the user groups, including among them 49 students. About 37% of the users worked at institutes outside of the EU & associated states. These statistics illustrate the appeal of the EVN to a wide international user base that also contains a significant cohort of young astronomers just starting their careers. The oversubscription factor (the ratio of proposed to observed network hours) for the EVN is on the order of 2.5.

DESCRIPTION OF WORK

Modality of access under this proposal

Outline how a user, or user group, will be given access to the infrastructure or to its services (e.g. type of equipment/service used, expected output/deliverables, etc.). For trans-national access indicate the typical location and duration of work (estimated number of days spent at the infrastructure), and, where relevant, how the users will be integrated into the scheduling of the infrastructure and the degree of independence they will experience with respect to the normal research activity of the infrastructure. Define clearly, for each installation, the ***unit of access*** *being offered and indicate what is covered and included (e.g. preparatory work, specific training courses) in one unit. This is essential for monitoring the access provided under this project, but also to justify the corresponding costs (see section 3.4b of this document). Indicate for each installation which modality will be used to declare access costs (on the basis of unit cost, as actual cost, or as a combination of the two) and justify your choice.*

A Call for Proposals is issued three times per year via e-mail distribution lists and web pages that reach the main body of radio astronomers in Europe and beyond. The EVN provides a web-based proposal tool to facilitate submission. Following the review of proposals by the EVN Program Committee (PC), the EVN scheduler places observations into the EVN block schedule at the next available opportunity, based on the proposals' consensus grades and their technical requirements. There are expedited proposal procedures for urgent ToO experiments to request observing time outside the scheduled sessions. When granted, the PI creates an observing schedule to drive the telescopes with assistance from JIVE. The telescopes forward observed data to JIVE for correlation. Observation and correlation proceed in absentia. Reduction of the data can be performed at JIVE (especially in case of first-time users) or at other EVN institutes.

The unit of access will be a network-observing hour on the EVN, as documented by the EVN block schedules for the EVN sessions, e-EVN days, out-of-session observations, and ToO observations. The network observing hours will be understood to comprise beside the observation also the correlation, post-correlation quality review, pipelining, and archiving, plus any eventual help with scheduling or data analysis particularly requested by new users. No access will be counted to the projects waived because of problems at network telescopes. Access costs will be calculated on a network-observing hour basis.

Support offered under this proposal

Describe the scientific, technical and, for trans-national access, logistic support that would be offered to the users. Where relevant, emphasise the quality of the scientific environment in which the users will be working and explain how this might stimulate their research. Explain to what extent such support is already routinely provided to external users.

All steps of using the EVN, from proposing to data analysis, are discussed in the EVN Users' Guide on the EVN web page. Extensive assistance at each stage is available from the JIVE support scientists. With a successful TA program, the EVN will continue to offer this full range of support. The Call for Proposals prompts new or inexperienced users to request help from JIVE in the course of proposal writing, practical scheduling advice and also reviewing the benefits and responsibilities of TA eligibility if applicable. Following correlation, JIVE support scientists review the output data to ensure the highest possible quality, run the EVN pipeline that calibrates the data and produces preliminary images, and place the resulting FITS files, pipeline output, and diagnostic plots on the EVN Archive. The PI receives a one-year proprietary period, unless the PC chairman has approved an extension. The EVN Archive is fully open-access and its content is searchable. The correlated data are distributed to the PI with an accompanying cover letter raising the possibility of data analysis visits. In the past four years, there have been 36 such visits from 158 TA eligible projects (27 to JIVE, 9 to other EVN institutes), 30% of the visits were by new users.

The EVN strives to continue providing high-level support, but without the backing of the TA program, especially the assignment of JIVE support scientists is at risk. This would affect the non-black belt users reducing the number of new EVN users. The ERTRC has recognized the role played by the JIVE support scientists, the EVN pipeline, and the EVN Archive in increasing the user base and optimizing their scientific output.

OUTREACH TO NEW USERS

State what measures are taken to attract new potential users (e.g. web page, call for proposals, etc.), including specific user groups such as users coming from SMEs or representing new areas of research, if appropriate. Indicate why and to which extent the EU funding of this trans-national and/or virtual access activity will provide European research teams with new opportunities of access to the infrastructure. Indicate whether the number of trans-national users is expected to increase as a result of this proposal, and how you will monitor such an increase. If the infrastructure is being opened to users other than those from the host country of the infrastructure for the first time, what evidence is there that there will be sufficient demand for the access being offered under this proposal?

The distribution of the EVN Call for Proposals reaches the body of radio astronomers in Europe and beyond through the VLBI and EVN e-mail distribution lists and inclusion in the EVN and NRAO newsletters (more than 1600 addresses). The EVN organises biennial symposia, which bring together users to discuss their science, and enable them to learn about recent developments in the EVN. An associated EVN Users' Meeting focuses on more operational issues, and provides a forum for lively feedback. Seasoned EVN astronomers provide hands-on tutorials at ERIS, covering aspects underlying successful VLBI experiments. At topical scientific meetings, EVN astronomers promote the VLBI science and engage new users from other communities. The success of real-time e-EVN observations provides a clear example in which the EVN has become attractive to a new community of astronomers—those studying transient objects for which rapid mas-scale images can be crucial, to inform and plan the on-going observations at other wavelengths.

Over the past four years, there have been 39 first-time PIs leading EVN projects (50% students). These projects comprise 20% of the total number of projects. The EVN has demonstrated over the past four years that with an active TA program it can attract proposals from teams composed predominantly from non EVN-institute astronomers, especially young researchers.

REVIEW PROCEDURE UNDER THIS PROPOSAL

For trans-national access activities, describe the peer review procedure that will be used to select users under this proposal. Outline the composition of the User Selection Panel. Demonstrate that the selection of users will follow the principles of transparency, fairness and impartiality. As the selection will be based on the evaluation of scientific merit of the applications, but with priority to new users and users coming from countries where such infrastructure is not available, indicate any additional selection rule that you would like to add. For virtual access activities, describe how and when the periodical assessment of the services offered to the scientific community will be carried out (e.g. by an international review panel). The corresponding assessment reports must be defined as deliverables to the EC.

The EVN PC comprises 13 experienced astronomers, representing a broad spectrum of scientific and technical expertise and meets typically one month after proposal deadline. Four at-large members are not affiliated with any EVN institute; two are from EVN institutes that are not RadioNet beneficiaries). The EVN consortium board of directors approves PC members, keeping in mind the need to cover the full range of scientific avenues that the EVN can pursue. At large members are often from outside the radio astronomy community. Since the EVN comprises all of the European radio astronomy observatories, most of the recognised experts will be drawn from its institutes. It has to be mentioned that the PC affords no intrinsic advantage to proposals from EVN institutes, nor is there any observing quota allocated for them.

The PC evaluates proposals based on their scientific merit and technical feasibility. Each proposal is discussed until a consensus judgment is reached. This review results in a numerical grade and a recommended time allocation. The PC meetings are a notable strength of the procedures, to ensure the combined expertise of the full committee will identify the strengths and weaknesses of each proposal uniformly. Agreeing on a consensus grade after the discussion enables the final grade to incorporate any improvement in the understanding of the proposal. Keeping the PC to a reasonable size is a key for the success of this approach. The PI receives the consensus grade, summary comments, and comments from individual PC members. These are helpful in cases where the PI is requested to resubmit the proposal after addressing specific points.

WP9 – E-MERLIN

Work package number	9	Lead beneficiary – UMAN
Work package title	TA – e-MERLIN	
Participant number		
Short name of participant	UMAN	
Person/months per participant:	0	
	Start – End month	1– 48

OBJECTIVES	PROVISION OF ACCESS TO e-MERLIN
	Description of the infrastructure
Name	*e*-MERLIN
Location	The seven e-MERLIN telescopes are located at Jodrell Bank, Darhall, Pickmere, Knockin, Defford and Cambridge (UK). The collected data are transmitted via a dedicated fibre network for data correlation and processing to Jodrell Bank (UK).
Web site address	http://www.e-merlin.ac.uk
annual operating costs	

Description of the Infrastructure

e-MERLIN is an operational network of 7 radio telescopes in the UK operated by the UMAN and STFC. With a maximum baseline of 217 km and receiver bands at 1.5, 6 and 23 GHz it provides imaging, spectroscopy and polarimetry at resolutions of 10-150 mas. The large collecting area of the 76-m Lovell Telescope (Jodrell Bank) together with upgraded state-of-the art receivers and a maximum bandwidth of 2 GHz (per polarization) provides micro-Jansky sensitivity in typical observations. It is a unique facility in the world, filling the gap between VLBI arrays such as the EVN and smaller single-site arrays such as WSRT. By combining e-MERLIN and EVN we can offer a single array with baselines from 10km to 10000km capable of imaging with high fidelity and sensitivity on scales from 1 mas up to 1 arcmin. The technical capability to operate both arrays together has been demonstrated and will be ready for general use by 2016.

e-MERLIN has a very broad range of scientific interest and the current project spans the whole range from the formation of planets stars, the evolution of galaxies and cosmological experiments on the nature of dark matter and dark energy.

Service currently offered by the Infrastructure.

Globally e-MERLIN is a unique radio imaging facility providing state-of-the-art observations with resolutions ranging from 10-150mas, which can be applied to a very wide range of astrophysical research. e-MERLIN is operated as a national facility with an open skies policy. The ASTRONET-ERTRC report confirms that the capabilities and scientific applications of e-MERLIN make it a key instrument for European astrophysics groups.

Current highlights and projects include:

- resolving the uJy extragalactic source population (Beswick, SKA Key Science Workshop, Stockholm 24-27 Aug 2015);
- detection (and important non-detection) of supernovae in nearby galaxies (e.g. Perez Torres et al ApJ 792, 38, 2014);

- the detection of rocky material in the planet formation zone around a young star (Greaves et al – press release 2015 https://www.ras.org.uk/news-and-press/2656-astronomers-see-pebbles-poised-to-make-planets);

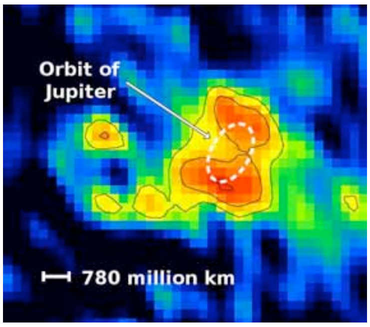


Fig WP9.1. e-MERLIN image of DG Tau showing possible detection of rocky material.

A legacy programme of 12 key projects involving over 300 scientists is under way; over the last 4 years of operations, e-MERLIN has had a mean oversubscription rate of all proposals was 3.0, and 6.8 for proposals requesting the inclusion of the Lovell telescope in the array. Each open proposal round typically receives ~35-50 proposals, with between 200-400 investigators involved in each round. Between 2012-2015, 56% of proposing scientists were based outside the UK and 63% of which were from Europe

DESCRIPTION OF WORK

MODALITY OF ACCESS UNDER THIS PROPOSAL

Access for scientists to use e-MERLIN follows a well-defined and supported mechanism. Proposed scientific projects are evaluated through a transparent independent process, which allocates the available resources (telescope time) required for each project. These are returned to the facility where these projects are observed in a dynamically scheduled, service mode by e-MERLIN operational staff. This service mode mechanism maximises the efficiency and scientific productivity of the facility. Expert e-MERLIN operational staff will undertake all observations, data collection and quality assessment of the scientific data products on the PI's behalf. During these stages detailed consultation with the science PI is undertaken as required. Following these initial steps the data, and any resultant products, are distributed to the external science user for advanced analysis and scientific exploitation. Full user support is offered and provided to the PI or their team at all stages of this process – from proposal and project preparation through to science interpretation. This support is tailored to the individual requirements of the user. The science PI has exclusive access to these data for a standard 18 months proprietary period before being made open for archival use to any scientist. Archival use of these unique data products results in a significantly increased science output for the facility.

The unit of access being offered is defined as the unit time duration (hours) of observations, which are correlated (i.e. offered time for the user to undertake experiments on the full facility). Each project is allocated an amount of observing dependent on project needs and full support including any necessary preparatory work, technical support and user training provided to all project. Access costs will be declared on the basis of unit cost.

SUPPORT OFFERED UNDER THIS PROPOSAL

A dedicated user support team based on the main University of Manchester Campus and also at Jodrell Bank Observatory (JBO) provide a high level of support throughout all stages of project preparation and planning, proposal submission, scheduling, execution of observations, data reduction and analysis. A data reduction suite on the main campus has dedicated workstations and office space, which can be booked for observing, data reduction and science team visits.

Visiting TA scientist can interact with a wide range of scientists and engineers in Manchester and at JBO. The Jodrell Bank Centre for Astrophysics (JBCA) in Manchester is the second largest astrophysics research group in the UK with over 180 staff and postgraduate students working on all areas of astrophysics. JBCA combines e-MERLIN, VLBI, the UK ALMA regional centre node, and three of the SKA design groups, as a recognised hub of expertise in interferometry. The University of

Manchester also hosts the SKA Organisation HQ at JBO. The group is highly respected for the quality of its research programme. For example, over the four-year period from 2010-2013, JBCA researchers published 707 research articles, which received 10108 citations (data obtained via Scopus March 2015).

Visiting scientists are encouraged to give short talks, or longer colloquia as well as informal discussion with staff and students. Visits will be publicised so that JBCA staff are aware of the opportunities to meet visitors. At Jodrell Bank, visitors can interact with operations staff, engineers and technicians with expertise in all aspects of radio astronomy, in addition also wit the SKA staff.

OUTREACH TO NEW USERS

The availability of e-MERLIN to European user groups and the support available via the TA programme will be advertised via a number of channels including major astronomy meetings, websites, social media etc. Each proposal round is widely advertised via meetings, websites and email exploders, including distribution to in excess of 2000 individual researchers globally. All email lists are regularly updated to include new or potential users.

Access to TA support has proven to be essential for a number of European users who because of local budget limitations would otherwise be unable to fully access all of the support that is available, including face-to-face user support and data retrieval. In addition to these outreach methods the e-MERLIN science team regularly organise specific science meetings or parallel sessions at large science meetings, and training workshops which are open to the international community to provide the opportunity for newer or less experienced users to obtain firm background in the techniques and science that is feasible with e-MERLIN. These events are well attended, typically limited by venue size, and from experience typically result in a number of new users applying for access to the facility.

e-MERLIN already has a large community of international users situated beyond Europe. The extended eligibility of TA support to include third countries will help to further facilitate this. As a facility we intend to concentrate this limited support on countries where this further support will have the highest impact. UMAN and e-MERLIN staff is actively involved in several projects to develop astronomical research in Africa and central and southern America, notable via UK government funded Newton initiatives. These training initiatives are being used to train new scientists and promote the utilisation of European research infrastructures. These channels will be used to promote these new TA supported activities.

All user groups must apply for time through a well-established procedure with regular deadlines for proposals. Successful applicants are informed of awarded time and eligibility for TA support. Observations are normally dynamically scheduled and carried out by e-MERLIN staff but groups can request scheduling at a particular time and can request to carry out the scheduling themselves and take part in the observations. User groups must normally travel to either Manchester or JBO to access and process the raw data where they will receive help and training from a dedicated support scientist. Travel funding will be available to support a significant number of visits: preference will be given to new users and those who would find it hard to fund such visits without assistance. This TA assistance enables eligible user to fully access all levels of expert assistance provided. This allows supported teams to undertake the most technically demanding, and often highest scientific impact, projects.

REVIEW PROCEDURE UNDER THIS PROPOSAL

User groups must apply for time through a well-established procedure with regular deadlines for proposal submission (indicate the months if they are fixed or how often the calls are released). Proposals are assessed by an independent science committee (Time Allocation Group: TAG) including external experts and a broad panel of independent external referees. The e-MERLIN TAG is independently appointed by STFC. The TAG members are rotated with other senior members of the community every few years. Proposal review is based on scientific merit and technical feasibility and there is no discrimination or quota based on country of origin. Successful applicants are informed of time awarded to their proposal and eligibility for TA support.

WP10 – IRAM

WORK PACKAGE NUMBER	10	LEAD BENEFICIARY - IRAM
WORK PACKAGE TITLE	TA – IRAM	
PARTICIPANT NUMBER		
SHORT NAME OF PARTICIPANT	IRAM	
PERSON/MONTHS PER PARTICIPANT	0	
	START – END MONTH	1– 48

OBJECTIVES	PROVISION OF ACCESS TO	IRAM: NOEMA & 30-M
	DESCRIPTION OF THE INFRASTRUCTURE	
NAME	Institut de Radioastronomie Millimétrique (IRAM) operates two facilities, the NOrthern Extended Millimeter Array (NOEMA) and the 30-m telescope.	
LOCATION	NOEMA on the Plateau de Bure (FR), the 30-m telescope in the Sierra Nevada (ES).	
WEB SITE ADDRESS	http://www.iram-institute.org	
ANNUAL OPERATING COSTS		

DESCRIPTION OF THE INFRASTRUCTURE *Give a brief general description of the infrastructure to which access is offered. Illustrate, in particular, its state-of-the-art equipment and services offered to users that make it rare or unique in Europe. Outline the areas of research normally supported by the infrastructure, as well as new areas opening to users, if any. If the infrastructure is composed of several installations, describe these including their specific features. If parts of the infrastructure are still under construction, specify the starting date of construction and indicate the date when access can realistically be made available.*

NOEMA is the most sensitive millimetre-wave interferometer of the northern hemisphere. The interferometer currently consists of seven 15m antennas, all equipped with low-noise heterodyne receivers for the 3mm, 2mm, 1mm and 0.8mm atmospheric windows. The SSB receivers provide a bandwidth of 4 GHz in each polarization. With baselines up to 800 meters NOEMA allows sensitive imaging down to 0.2" resolution. The signals from the 7 antennas are processed by two IRAM-developed digital correlators that allow for a large variety of observing modes and the possibility to phase up the antennas for VLBI experiments. By the end of 2019, NOEMA will see a dramatic performance increase. The interferometer will have 12 antennas, offer the ability to correlate 32 GHz of bandwidth for regular observations, provide sensitivities very close to ALMA and high quality imaging with a spatial resolution down to 0.1arcsec. NOEMA's unique capabilities will make it possible to help unlocking the complexities of star- and planet-formation processes in the Milky Way and in nearby galaxies, developing a better under-standing of star formation in the Universe, and along the way help understanding the emergence of life on Earth.

The IRAM 30m telescope is by far the most sensitive millimetre-wave single-dish for observations in the 3mm, 2mm, 1mm and 0.8mm atmospheric windows. It provides sensitive imaging down to 8" resolution and offers unique observing capabilities with several low-noise wide-band heterodyne receivers (EMIR) and a dual polarization 9-channel heterodyne array (HERA), and in the longer-term receiver technology developed in the frame of the RadioNet3-JRA AETHER. NIKA2, a wide-field-of-view continuum camera built by a European consortium, is also at the forefront of technology and will be opened to the community in 2016. The camera will be equipped with three focal plane arrays to perform simultaneous observations in the 1mm atmospheric window (in two polarizations) and in the 2mm window. NIKA2, the current and the future suite of heterodyne multi-beam receivers are in the process of rejuvenating wide-field astronomy in the millimetre range, and allow the international community to have access to a unique facility to conduct cutting-edge research, including large surveys of galactic star-forming regions, nearby galaxies, investigations of the SZ flux-mass scaling relations in galaxy clusters, and to prepare forthcoming cosmological experiments like CORE+ that aim at measuring the polarization of the CMB. The 30m-telescope is heavily used for complementing interferometer maps with short-spacing information, mostly for NOEMA, but also for completing data for the CARMA and ALMA interferometers.

SERVICE CURRENTLY OFFERED BY THE INFRASTRUCTURE *Describe the services offered by the infrastructure and its research environment, and demonstrate how it will enable scientists to carry out high-quality research. You should summarise some of the most interesting scientific achievements already obtained by users. Demonstrate that there is a widespread interest from users in other countries to conduct research at the infrastructure (or make otherwise use of its services), e.g. by indicating the number of international users currently using the facility per year.*

IRAM operates two well-established astronomical millimetre-wave observatories equipped with cutting-edge technology, most of which is designed, developed and built in-house. The continual improvement of the instrumentation and software at the IRAM facilities places the research infrastructure at the forefront of astronomical research in the millimetre-wave bands, as has been the case for decades. One remarkable achievement, among many others, is that one third of the molecules known to be present in space have been discovered using the IRAM facilities. The institute counted a total of more than 230 peer-reviewed publications per year, over the years 2010 to 2013, mostly in leading journals such as A&A, ApJ, MNRAS, Nature, Science and SPIE.

Some of the most interesting scientific achievements already obtained by the TA users are:

- ***ISM chemistry in metal rich environments: molecular tracers of metallicity***

E. Bayet (University of Oxford, UK) and T. Davis (ESO) investigated the effect of changes in the molecular abundances on the chemistry of metal rich and alpha-enhanced galaxies. Their study suggests that in the future it may be possible to calibrate a metallicity indicator for the molecular interstellar medium. This is the first study of its type, and the results are encouraging, the ultimate goal being to calibrate a metallicity indicator for the molecular interstellar medium.

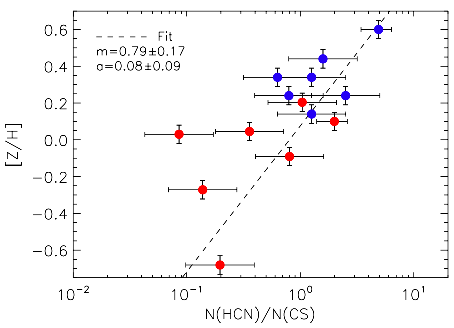


Fig. WP10.1 The relation between metallicity and the HCN/CS column density ratio for spiral (blue) and ETG (red) galaxies.

- ***The quest for Black Holes in the Early Universe***

S.Gallerani (SNS, Italy) in collaboration with University of Cambridge (UK) and IRAM (France), has recently discovered in one of the most distant quasars known to date the emission line of ^{12}CO in the highest millimetre transition ever detected so far. The detection of this line has promising potential to open a new pathway for the discovery and the study of the evolution of the first black holes in the early Universe.

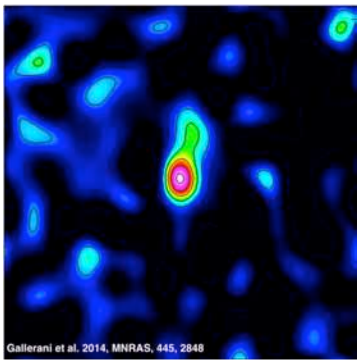


Fig. WP10.2 A map of the 12CO(17-16) emission in SDSS J1148+5251 at z = 6.4

Face to face support through experienced and hands on staff provides users with an invaluable tool not only to gather the best possible data from their successful observations but also to increase knowledge for future proposals and observing runs. The observing capabilities offered to the scientific community are relevant to hundreds of European users. The interest from the community in using the IRAM telescopes keeps growing, and over the past year we have received about 470 observing proposals from over 1250 unique users originating from 43 countries. The high oversubscription rates of NOEMA (3.4 on average in 2014) and the 30m-telescope (a factor of 2 in 2014) testify to the excellence of the IRAM facilities but lead to situations where significant fractions of high quality proposals are rejected due to the lack of telescope time.

DESCRIPTION OF WORK

Modality of access under this proposal

Outline how a user, or user group, will be given access to the infrastructure or to its services (e.g. type of equipment/service used, expected output/deliverables, etc.). For TA indicate the typical location and duration of work (estimated number of days spent at the infrastructure), and, where relevant, how the users will be integrated into the scheduling of the infrastructure and the degree of independence they will experience with respect to the normal research activity of the infrastructure. Define clearly, for each installation, the unit of access being offered and indicate what is covered and included (e.g. preparatory work, specific training courses) in one unit. This is essential for monitoring the access provided under this project, but also to justify the corresponding costs (see section 3.4b of this document). Indicate for each installation which modality will be used to declare access costs and justify your choice.

[illegible]. This amount of telescope time is allocated to observing programs submitted by principal investigators, regardless of institutional affiliation. Submission deadlines are currently in mid-March and mid-September each year for the summer (01 Jun – 30 Nov) and winter (01 Dec – 31 May) scheduling periods.

The Principal Investigator (PI) of an accepted project is notified when his/her project is scheduled either at the 30m-telescope or NOEMA. For the 30m, the PI is expected to visit the observatory to carry out the observations with support from the local staff. The PIs of NOEMA projects do not run the observations on-site due to the complexity of the scheduling of NOEMA programs, and instead telescope operators and local astronomers run the observations. PIs are then invited to the IRAM headquarters in Grenoble to reduce and calibrate the interferometer data. In either case, the typical stay duration for users of the IRAM facilities is about one week.

Based on our experience in the previous RadioNet project, we propose to provide access under this proposal to about 50 TA eligible research programs (NOEMA and 30m-telescope), equivalent to about 840 hours of observing time for the benefit of about 200 astronomers from TA eligible institutions. We estimate that this will lead to about 50 peer-reviewed publications over the duration of this project, not counting abstracts and conference proceedings.

The unit of access to IRAM will be Telescope hours (this time can include also pointing and calibration checks made for the particular project additionally to the observing time). The access costs will be declared on the basis of unit cost.

Support offered under this proposal

Describe the scientific, technical and, for trans-national access, logistic support that would be offered to the users. Where relevant, emphasise the quality of the scientific environment in which the users will be working and explain how this might stimulate their research. Explain to what extent such support is already routinely provided to external users.

IRAM provides all the necessary logistics and the best possible environment for users to ensure that their research projects are successful, at the time of the proposal preparation before the submission deadline, during the data acquisition phase, and later on throughout the data reduction/analysis stage. Be it at the 30m-telescope or during visits at the IRAM headquarters for the analysis of NOEMA data, users of the facilities benefit from a high-quality administrative and high-level scientific support. In addition IRAM has established an ALMA user support centre (ARC) and has a strong record of training astronomers and specialists in millimetre-wave astronomy through the IRAM summer schools and the IRAM Visiting Astronomer Program. By the end of 2016, IRAM will also provide the necessary infrastructure and best possible support to access the raw data archives of both IRAM research infrastructures.

Outreach to new users

State what measures are taken to attract new potential users including specific user groups such as users coming from SMEs or representing new areas of research, if appropriate. Indicate why and to which extent the EU funding of this activity will provide European research teams with new opportunities of access to the infrastructure. Indicate whether the number of trans-national users is expected to increase as a result of this proposal, and how you will monitor such an increase.

IRAM makes publicity for RadioNet via webpages and informs users of the IRAM facilities about the possibility of TA funding in the Call for Proposals and in the project reports resulting from the IRAM Program Committee meetings. IRAM provides the most powerful millimetre-wave facilities of the northern hemisphere. IRAM's overarching purpose is to provide an invaluable resource for cutting-edge research, foster opportunities for young scientists to engage in millimetre-wave research, promote interdisciplinary research collaborations, increase researchers productivity, and last but not least, to strengthen and widen the European millimetre-wave community. In particular, the new generation of European researchers, not necessarily originating from the millimetre-wave community but used to the multi-wavelength approach to problem solving in astrophysics, will benefit from this initiative by developing a high-value experience with millimetre-wave facilities and the qualified support and training of IRAM staff astronomers. While RadioNet3, for instance, has been very successful in starting interdisciplinary collaborations between European theoretical chemists, laboratory chemists, spectroscopic physicists and astronomers (e.g. SOLIS consortium with researchers from France, Germany, Italy and United Kingdom), we expect the impact of RadioNet to be paramount to strengthen the impact of RadioNet3 and widen collaborations across research networks to address key and future challenges of astronomical research, like the formation and destruction routes of complex organic compounds in the Universe, the formation of the solar system and the emergence of life in the universe.

Since 2006, IRAM is facing the challenge of an ever-increasing demand pressure on observing time and resources from TA eligible research programs (NOEMA has seen an increase of over 30% in the number of participants from TA programs during the period covered by RadioNet3). Hence, the number of trans-national users is expected to further increase as a result of this proposal. IRAM runs a continuous program to monitor and analyse users statistics. According to current figures, the impact of the RadioNet TA program has been key to developing the interest of the European scientists i.e. the number of TA eligible users that apply for observing time at the IRAM facilities is suggestive of a continued positive impact over the next period.

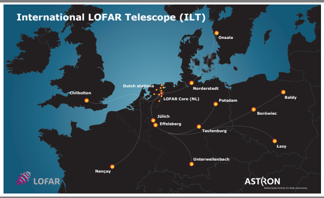
REVIEW PROCEDURE UNDER THIS PROPOSAL

describe the peer review procedure that will be used to select users under this proposal. Outline the composition of the User Selection Panel. Demonstrate that the selection of users will follow the principles of transparency, fairness and impartiality. As the selection will be based on the evaluation of scientific merit of the applications, but with priority to new users and users coming from countries where such infrastructure is not available, indicate any additional selection rule that you would like to add.

The fundamental principle for allocating observing time at the IRAM observatories is the scientific merit of the proposals. A program committee (PC) reviews the proposals and issues recommendations to the IRAM Director based on scientific merit, technical feasibility and availability of the resources required. The selection and the priority given to proposals by the PC are not affected by the national or institutional affiliations of the principal investigators. IRAM takes all possible care and attention to ensure an objective, transparent and independent proposal reviewing process. For proposals of the same scientific merit and urgency, priority is given to proposals of new users. A complete feedback is provided to all applicants in the form of a written report, a few weeks after the Program Committee meeting. For proposals received under the TA scheme, the same procedure is applied, with the same peer review process in place.

IRAM PC members are chosen from amongst the best-qualified and most renowned millimetre-wave experts in the field of galactic and extragalactic research. They are elected for a renewable three-year term and serve the international astronomical community without financial compensation. Their replacement is staggered over the years to ensure continuity of work and transfer of knowledge. The current composition of the IRAM PC reflects the RadioNet work programme requirements of at least 50% of members being independent of the IRAM partner organizations (62%, as of January 2016).

WP11 – LOFAR

Work package number	11		Lead beneficiary – ILT
Work package title	TA – LOFAR		
Participant number			
Short name of participant	ILT	ASTRON	
Person/months per participant	0	0	
	Start – End month		1– 48

Objectives	Provision of access to	LOFAR
	Description of the infrastructure	
Name	Low Frequency Array – LOFAR	
Location	Antennae centred in Exloo (NL), data processor in Groningen (NL), Control and User Support Centre in Dwingeloo (NL)	
Web site address	www.astron.nl	
annual operating costs		

Description of the Infrastructure *Give a brief general description of the infrastructure to which access is offered. Illustrate, in particular, its state-of-the-art equipment and services offered to users that make it rare or unique in Europe. Outline the areas of research normally supported by the infrastructure, as well as new areas opening to users, if any. If the infrastructure is composed of several installations, describe these including their specific features. If parts of the infrastructure are still under construction, specify the starting date of construction and indicate the date when access can realistically be made available.*

The International LOFAR Telescope (ILT) operates the Low Frequency Array (LOFAR), a uniquely powerful telescope operating at low frequencies, 30—240 MHz, which offers state-of-the-art observing capabilities thanks to its phased-array technology with digital beam-forming. The array extends over 2000 km in Europe, with 38 antenna stations in the Netherlands, 6 in Germany, 3 in Poland, and 1 each in France, Sweden, and the UK, connected by fibre to the high-performance central data processing and archive facilities in Groningen, and further distributed systems. These, separately owned, facilities are jointly operated by the ILT. ASTRON provides the central operating organization; individual owners are responsible for the operation of their stations and data connections.

LOFAR is a transformational facility providing simultaneous interferometric and beam-formed data, at a multitude of resolutions on different directions on the sky, yielding sensitivity orders of magnitude better than previous telescopes. Furthermore, its ground-breaking ability to buffer large amounts of data at the element level provides a unique capability to perform retrospective imaging of the sky on short timescales. It is currently the largest radio interferometer in the world both in collecting area and number of elements, a feature that will be unsurpassed in the next decade. Already one of the most prominent pathfinders for the SKA, and as the only operational prototype of the mega radio-interferometers of the 21st century, the ILT has pioneered the field of scientific observation analysis involving huge data volumes. While thus allowing the user community to break important new scientific ground in a wide range of areas of astrophysics ranging from the near Earth environment to the early Universe, it is challenging concepts of data analysis, taking a step further in the exploitation of powerful, shared, computing facilities, distributed data analysis and use of vast archival datasets. Finally the legacy of the Long Term Archive will multiply the scientific impact of LOFAR data

Service currently offered by the Infrastructure *Describe the services offered by the infrastructure and its research environment, and demonstrate how it will enable scientists to carry out high-quality research. You should summarise some of the most interesting scientific achievements already obtained by users. Demonstrate that there is a widespread interest from users in other countries to conduct research at the infrastructure (or make otherwise use of its services), e.g. by indicating the number of international users currently using the facility per year.*

The ILT has now been in operation for more than five years. Over time, the sophistication of the processing pipelines and the analysis techniques continue to improve. Observing and processing of concurrent interferometry and beam formed observing modes, handling data flow through high-speed networks and powerful computing facilities, and archiving of large data volumes to high capacity remote infrastructures are fully operational. Successive observing semesters have seen increasing sophistication in automated pipelines for the initial processing and the further data reduction using powerful computer clusters. These pipelines are also available to run in several computer architectures on facilities that may be available to individual users. Furthermore, ASTRON's software engineers develop and implement complex analysis pipelines, based on novel methods and algorithms proposed by users.

With its versatility and its unique spectral coverage, LOFAR offers new capabilities into a wide area of scientific subjects not available to the astronomical community before. LOFAR has already opened up new areas of study in solar physics, planetary and exo-planetary science, cosmic ray physics, pulsar astronomy, has offered new perspectives in active galaxies and clusters, and is providing a unique probe of the early universe. Consequently interest by large, international collaborations, who were either not previously users of radio interferometers, or based in countries with a lesser tradition in radio astronomy, has surged. Examples of access provided to new users are, the significant interest by solar physics groups based in Ireland or Germany, unique studies in planetary and exoplanetary physics proposed by groups in France, studies of the transient universe by groups active in other wavelengths.

Formal bi-annual proposal calls to the global community have been issued since December 2012. Until now, 1600 hours of observing time were offered per semester – this was constrained mostly by the data throughput and processing pipelines that deliver the data in a form where users are able to carry out their science. On average 41 proposals were accepted each semester with an oversubscription rate of 1.6. In each semester these involved about 194 individual researchers, of whom 78% have affiliation outside the Netherlands. As a result, 40-50% of the approved proposals are TA eligible. A study of the demographics of ILT users shows that most proposals involve several graduate students or young researchers (representing a ratio of 50% or more in each proposal).

Since the start of operations in 2010, LOFAR has led to the publication of 194 refereed papers, which yielded a total of 2390 citations corresponding to an h-index of 28.

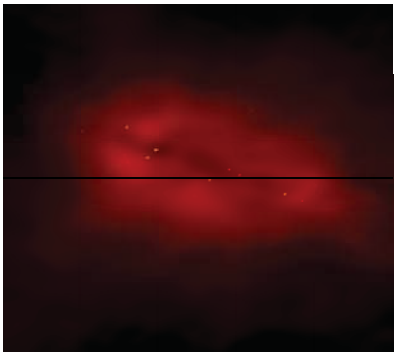


Fig. WP11.1 M82 illustrating the relative brightness between the compact and extended emission at 154MHz (Varenius et al, 2015)

Highlights of results obtained from TA projects are De Gasperin et al's (2012, A&A, 547, A56) high dynamic range image of the active galaxy M87 whose unprecedented spatial and spectral resolution provided an accurate estimate of the source's magnetic field, age and energetics. Furthermore, the ultra-high resolution afforded by LOFAR's long baselines allowed Varenius et al (2015, A&A, 574, A114) to simultaneously imaged the diffuse and compact emission in the nearby galaxy M82.

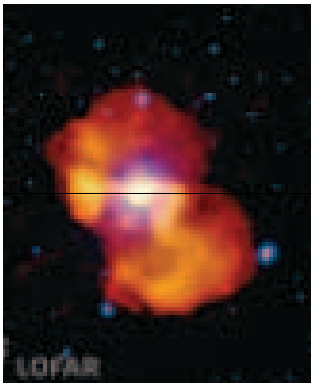


Fig. WP11.2 140MHz image of M87 (De Gasperin et al, 2012)

DESCRIPTION OF WORK

MODALITY OF ACCESS UNDER THIS PROPOSAL

Outline how a user, or user group, will be given access to the infrastructure or to its services (e.g. type of equipment/service used, expected output/deliverables, etc.). For trans-national access indicate the typical location and duration of work (estimated number of days spent at the infrastructure), and, where relevant, how the users will be integrated into the scheduling of the infrastructure and the degree of independence they will experience with respect to the normal research *activity of the infrastructure. Define clearly, for each installation, the* ***unit of access*** *being offered and indicate what is covered and included (e.g. preparatory work, specific training courses) in one unit. This is essential for monitoring the access provided under this project, but also to justify the corresponding costs (see section 3.4b of this document). Indicate for each installation which modality will be used to declare access costs (on the basis of unit cost, as actual cost, or as a combination of the two) and justify your choice.*

Access starts with proposal submission through the web-based tool NorthStar, following the bi-annual Call for proposals. The Call encourages users to obtain further information from the online documentation and advice from the Science Support Group (SSG). Each proposal receives a unique code, perpetuated throughout its implementation along with relevant information on uses and access provided. In a successful proposal, users use documentation and specification tools, available online, for designing observing projects. The large initial volume of the raw data necessitates timely initial reduction through the ancillary powerful cluster computers using automated pipelines. This procedure requires careful resource management and is performed by experts at ASTRON who monitor the state of the entire system, inspect the data quality and provide feedback for the user as well as for the engineering staff involved in maintenance. Processed data are stored in LOFAR's Long Term Archive (LTA) facilities. Powerful computational facilities, enabling investigators to further process the data are available and administered by ASTRON's Science Support Group (SSG), which also maintains the archive and facilitate open access to it. Archive use may in its own right require substantial use of ILT processing resources, and thus require allocation through a proposal and intervention by ILT staff. Data processing software and automated data reduction pipelines are under continuous development, and are available to all users, to use either at ILT's computing facilities or to install at their facilities. Successful proposals obtain access to all these services, which are quantified by the amount of observing hours awarded.

The unit of access to LOFAR is defined as an observing hour. The access cost will be declared on the basis of unit cost.

SUPPORT OFFERED UNDER THIS PROPOSAL

Describe the scientific, technical and, for trans-national access, logistic support that would be offered to the users. Where relevant, emphasise the quality of the scientific environment in which the users will be working and explain how this might stimulate their research. Explain to what extent such support is already routinely provided to external users.

ASTRON's Science Support Group (SSG) communicates and advises all users at all stages of their projects, starting with technical advice and support in proposal preparation. At proposal acceptance, the SSG informs users to use online documentation and offers extensive advice during observing specification, data evaluation and initial data processing.

Powerful computing facilities for further data analysis and consultation for data analysis at the users' computing facilities, are available to all users. ILT experts provide additionally extensive consultation on data analysis techniques and algorithms. Facilities to access and process data in the Long Term Archive are also provided. While observing and processing are done in absentia, users can visit ASTRON in Dwingeloo/NL at any stage of their work and use office, computing facilities and accommodation at ASTRON. The cost of the visits will be at least partially covered by the TA travel budget.

OUTREACH TO NEW USERS

State what measures are taken to attract new potential users (e.g. web page, call for proposals, etc.), including specific user groups such as users coming from SMEs or representing new areas of research, if appropriate. Indicate why and to which extent the EU funding of this trans-national and/or virtual access activity will provide European research teams with new opportunities of access to the infrastructure. Indicate whether the number of trans-national users is expected to increase as a result of this proposal, and how you will monitor such an increase. If the infrastructure is being opened to users other than those from the host country of the infrastructure for the first time, what evidence is there that there will be sufficient demand for the access being offered under this proposal?

Calls for proposals are issued twice yearly, two months in advance of the submission deadlines. The Call is emailed to a list of 900 addresses, which include individual researchers, institutes and also other email exploders, hence reaching additional researchers. Moreover, these recipients further post the Call to other email exploders, and display it in notice-boards and astronomical meetings. An increasing interest by new user groups is indicated in current proposal statistics.

In a rigorous programme to present scientific results, capabilities and availability of LOFAR to the wider astronomical community, LOFAR Science Workshops have been held annually since 2011. LOFAR Users' Meetings, held in the same context, provide the opportunity to present the current instrument status, receive input and discuss future development plans with the whole community. Biennial LOFAR Data Analysis schools alternate with special sessions on LOFAR in ERIS to introduce astronomers to the insights of LOFAR data and analysis software. The latest progress in the observatory status, analysis techniques and new results are streamed bi-weekly in the interactive LOFAR Status Meetings and are summarised bi-monthly in the electronically distributed Newsletters. Furthermore, LOFAR scientific results are presented in various specialised conferences, as well as in large astronomical meetings like the IAU general assembly, the EWASS, and the American Astronomy Society.

REVIEW PROCEDURE UNDER THIS PROPOSAL

For trans-national access activities, describe the peer review procedure that will be used to select users under this proposal. Outline the composition of the User Selection Panel. Demonstrate that the selection of users will follow the principles of transparency, fairness and impartiality. As the selection will be based on the evaluation of scientific merit of the applications, but with priority to new users and users coming from countries where such infrastructure is not available, indicate any additional selection rule that you would like to add.

Proposals are invited each semester (in March and September) from the worldwide community. The independent Programme Committee (PC) is directly mandated by the ILT Board to set final allocations. This panel consists of 10-16 scientists with staggered three-year tenure, selected from the international community based on individual expertise (the Chair is currently from the USA; only 1 of the current 12 members, is from the Netherlands). The PC reviews all proposals, assesses scientific merits and produces a uniform ranking. The PC, taking also into account observatory advice on technical, logistical, and scheduling constraints, then composes the final observing program, by allocating from the direct PC (Open Skies) share of time (increasing from 10% to 45% over last 5 years), and amalgamating pre-assignments from partial shares by the national consortia involved in the ILT.

Proposal evaluation is based only on scientific merit. Extensive advice in the proposal preparation stage is offered particularly to new users. Furthermore new users that are not successful in a proposal stage, are approached and offered help, so that they can improve the quality and hence the competitiveness of their proposal.

WP12 – EFFELSBERG

WORK PACKAGE NUMBER	12	LEAD BENEFICIARY – MPG
WORK PACKAGE TITLE	TA – EFFELSBERG	
PARTICIPANT NUMBER	1	
SHORT NAME OF PARTICIPANT	MPG	
PERSON/MONTHS PER PARTICIPANT	0	
	START – END MONTH	1 – 48

OBJECTIVES	PROVISION OF ACCESS TO	EFFELSBERG
	DESCRIPTION OF THE INFRASTRUCTURE	
NAME	100-meter Radio Telescope Effelsberg	
LOCATION	Bad Münstereifel-Effelsberg (DE)	
WEB SITE ADDRESS	http://www.mpifr-bonn.mpg.de/en/effelsberg	
ANNUAL OPERATING COSTS		

DESCRIPTION OF THE INFRASTRUCTURE *Give a brief general description of the infrastructure to which access is offered. Illustrate, in particular, its state-of-the-art equipment and services offered to users that make it rare or unique in Europe. Outline the areas of research normally supported by the infrastructure, as well as new areas opening to users, if any. If the infrastructure is composed of several installations, describe these including their specific features. If parts of the infrastructure are still under construction, specify the starting date of construction and indicate the date when access can realistically be made available.*

The 100-m Radio Telescope Effelsberg of the Max-Planck-Institut für Radioastronomie (MPIfR) is a unique European astronomical facility that combines superb sensitivity and wide frequency coverage with distinct versatility. The telescope can be used to observe radio emission from celestial objects in a wavelength range from 1 m (300 MHz) down to 3.5 mm (86 GHz). The high surface accuracy of the reflector (the mean deviation from the ideal parabolic form is of the order of 0.5 mm rms) together with the construction principle of “homologous distortion” (i.e., the reflector in any tilted position has a parabolic shape with a well-defined, but shifted, focal point) enables very sensitive observations even at the highest frequencies (the sensitivity at K-band is about 1 K/Jy, corresponding to a telescope gain of 83 dB – the system temperature is in the range of 40-65 K, frequency and weather dependent).

With its specifications, the Effelsberg 100-m telescope is unique in Europe and – together with the Green Bank telescope in the USA – one of the two flagship single dish telescopes worldwide.

Currently, the telescope’s receiver suite is undergoing a major upgrade: with the support of the Max-Planck-Society, seven new wide-band, state-of-the-art receiver systems are currently replacing the older receivers – together with modern FPGA-based data acquisition systems. Within the next two years, this will result in nearly continuous frequency coverage of the telescope between 1-50 GHz in combination with highest possible time and frequency resolution. Furthermore, with the planned installation of a phased array feed (presumably in winter 2016/2017), the telescope serves as a test-bed for emerging and future (SKA-like) technology.

SERVICE CURRENTLY OFFERED BY THE INFRASTRUCTURE *Describe the services offered by the infrastructure and its research environment, and demonstrate how it will enable scientists to carry out high-quality research. You should summarise some of the most interesting scientific achievements already obtained by users. Demonstrate that there is a widespread interest from users in other countries to conduct research at the infrastructure (or make otherwise use of its services), e.g. by indicating the number of international users currently using the facility per year.*

The large number of high-quality receivers together with several specialized backends and newly developed data analysis software, dedicated to different observing modes, provide excellent conditions for spectroscopic observations (atomic and molecular transitions over a wide frequency range), for high time-resolution measurements (pulsar and transient observations), mapping of extended areas of the sky, for polarimetry and participation in a number of interferometer networks (such as mm-VLBI, EVN, and global VLBI). The observed data are usually published in peer-reviewed journals as well as in conference proceedings. Since 2013, there were more than 350 refereed publications which made use of recent data from the 100-m telescope or referred to the older ones (numbers from ADS). The data is also used in a number of Master's and PhD theses. Some of the most important results obtained with the telescope in the last years include:

- the finding of the constancy of the electron-to-proton mass ratio in the early universe (*Bagdonaite et al., 2013, Phys. Rev. Lett. 111, id. 231101, TA project*),
- the discovery of a magnetar in the Galactic center (*Eatough et al., 2013, Nature 501, p. 391*),
- the first data release of a complete northern hemisphere HI survey (*Winkel et al., in press, to be published by January 2016*),
- the sensitive mapping of the radio emission in the light of the ammonia molecule in the Orion molecular cloud (*Hacar et al., 2016, TA project*).

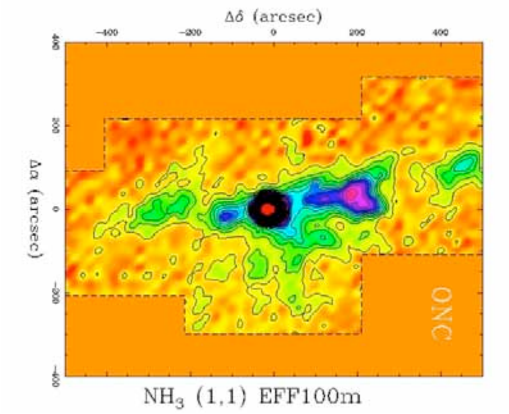


Fig. The radio emission in the light of the ammonia molecule in the Orion molecular cloud (Hacar et al., 2016)

As the 100-m Radio Telescope is a unique astronomical instrument, it has always been in strong demand by local astronomers as well as by scientists from abroad (the institute supports the "Open Skies" policy). With an over-subscription factor of up to 3, about 40% of observing requests are received from PIs outside Germany. The demand of observing time per proposal ranges from a few hours for very specific requests to more than several hundred hours in case of survey or monitoring projects. The number of these large proposals has been increasing recently; hence, a special proposal category of "Key Science Projects" has been introduced in 2010 and was requested six times since then.

All observed data are archived in database. A possibility to archive the data in a hierarchical data storage system at the MPG HPC centre in Garching is under investigation. All data are stored in the well-defined MBFITS format. Software for the analysis of MBFITS data sets is available and documented. The policy of the data access for external users is currently under discussion within the MPIfR. Financial and technical solutions for access are being investigated. Currently, it is recommended to contact the scheduler and/or the PI of the project to arrange for data access.

DESCRIPTION OF WORK

MODALITY OF ACCESS UNDER THIS PROPOSAL

Outline how a user, or user group, will be given access to the infrastructure or to its services (e.g. type of equipment/service used, expected output/deliverables, etc.).For trans-national access indicate the typical location and duration of work (estimated number of days spent at the infrastructure), and, where relevant, how the users will be integrated into the scheduling of the infrastructure and the degree of independence they will experience with respect to the normal research activity of the infrastructure. Define clearly, for each installation, the ***unit of access*** *being offered and indicate what is covered and included (e.g. preparatory work, specific training courses) in one unit. This is essential for monitoring the access provided under this project, but also to justify the corresponding costs (see section 3.4b of this document). Indicate for each installation which modality will be used to declare access costs (on the basis of unit cost, as actual cost, or as a combination of the two) and justify your choice.*

Observer's access to the 100-m Radio Telescope is awarded on the basis of successful observing proposals, subject to a peer review procedure. The proposers are informed about the success of their application soon after the meeting of the program committee. Proposals selected for observation are scheduled as soon as possible (normally within a year, depending on the target visibility and logistical constraints like receiver availability). The PI is responsible for the preparation, execution and analysis of the proposed observations. Usually, it is expected that at least one of the investigators is present at the observatory for the scheduled observing time, although remote observations are possible and have become more common recently. For high frequency observations, dynamic scheduling is employed to ensure the usage of optimum weather conditions, whenever possible.

In one year, the total observing time available is about 6000 hours (excluding technical test observations). We expect to host about 5 TA user groups per year with an average observing time per proposal being about three nights (~40-50 hours). Assuming that there are average 3 scientists per TA group, that amounts in 20 projects, 924 hours observing time and 40-50 users for the project duration. Therefore, we expect at least one refereed publication per project appearing in astronomical journals. Since most of the astronomical publications are usually published on "astro-ph" first, an open-access to these results will be granted. Additionally, data gathered with the 100-m Radio Telescope will be used in a number of Master's and PhD theses.

The unit of access are defined as observing hours; including time for system test and calibration. The access cost will be declared based on the basis of the unit cost.

SUPPORT OFFERED UNDER THIS PROPOSAL

Describe the scientific, technical and, for trans-national access, logistic support that would be offered to the users. Where relevant, emphasise the quality of the scientific environment in which the users will be working and explain how this might stimulate their research. Explain to what extent such support is already routinely provided to external users.

External users of the telescope will receive full advice and support for optimizing the utilization of the 100m radio telescope. The experienced staff of the observatory (scientists, acting as "friends of the telescope", engineers and telescope operators) offers support to the observers in planning observations, selection of observing modes, observing itself, and first state data analysis. The TA users can count also on the help of scientific staff from the institute's headquarters in Bonn, who are experienced in using the 100m Radio Telescope for spectroscopy, continuum, pulsars and VLBI observations. A workspace and the accommodation at the telescope will be offered to the TA users, also the transport from Bonn to the observatory will be provided (approx. 40km). Especially young scientists are encouraged to visit the telescope to gain observational experience. If necessary, absentee-observations are carried out by the staff of the observatory. A collection of all information necessary for observers can be found on the observatory wiki pages (https://eff100mwiki.mpifr-bonn.mpg.de/doku.php), publicly available and constantly updated.

OUTREACH TO NEW USERS

State what measures are taken to attract new potential users (e.g. web page, call for proposals, etc.), including specific user groups such as users coming from SMEs or representing new areas of research, if appropriate. Indicate why and to which extent the EU funding of this trans-national and/or virtual access activity will provide European research teams with new opportunities of access to the infrastructure. Indicate whether the number of trans-national users is expected to increase as a result of this proposal, and how you will monitor such an increase. If the infrastructure is being opened to users other than those from the host country of the infrastructure for the first time, what evidence is there that there will be sufficient demand for the access being offered under this proposal?

Potential observers are informed about the proposal deadlines and recent developments by the institute's web pages and the "Effelsberg Newsletter" (http://issuu.com/effelsbergnewsletter). The latter contains the Call for Proposals as well as information about news for the observers; additionally, it reports on recent scientific results. This newsletter is sent out three times a year, about one month prior to the proposal deadlines. It is posted to the research institutes in the fields of radio astronomy and astrophysics, and distributed by electronic mail to a wide group of astronomers and astronomical institutes in Europe (more than 100 addressees).

Since 2002, the "International Max Planck Research School for Radio and Infrared Astronomy" (IMPRS) is established at the MPIfR offering interested students scholarships and dissertation projects in radio astronomy. Many of the students attending the IMPRS in the past years used the 100 m telescope on a regular basis. Experience shows that these students often act as "multipliers" in later stages of their career: they promote the instrument and initiate observing projects with their own students.

Since 2013 the TA program indeed allowed six new user groups with an average 5 users per group to observe with the telescope. Based on this we can expect at least around 50 new users under TA program in RadioNet.

REVIEW PROCEDURE UNDER THIS PROPOSAL

For trans-national access activities, describe the peer review procedure that will be used to select users under this proposal. Outline the composition of the User Selection Panel. Demonstrate that the selection of users will follow the principles of transparency, fairness and impartiality. As the selection will be based on the evaluation of scientific merit of the applications, but with priority to new users and users coming from countries where such infrastructure is not available, indicate any additional selection rule that you would like to add.

The Programme Committee (PKE) currently consists of 8 members, established scientists thereof 5 are external. The PKE meets face-to-face three times per year (about one months after the deadlines) to select the best proposals judging their scientific merit and technical feasibility. If necessary, a reduction in observing time is decided. Preferential treatment is given to student projects, if the PKE can identify the needs of gathering Effelsberg data necessary for completing their theses in time. Members of the PKE who are co-investigators on a project are not participating in the assessment of the corresponding proposal. After the meeting, the proposers receive a notification about the assessment including the grade, the comments of the referees and if successful also the amount of time granted, and scheduling information.

The aspects of the allocation process and of the usage of the telescope are reviewed biannually by the International Scientific Advisory Committee of the MPIfR.

WP13 – APEX

Work package number	13	Lead beneficiary – OSO
Work package title	TA - APEX	
Participant number		
Short name of participant	OSO	
Person/months per participant	0	
	Start – End month	1 – 48

OBJECTIVES	PROVISION OF ACCESS TO	APEX
	Description of the infrastructure	
Name	Atacama Pathfinder Experiment (APEX)	
Location	Llano Chajnantor (CL) at 5100 m altitude in the Atacama Desert; the base camp is located in Sequitor, close to the town San Pedro de Atacama.	
Web site address	www.chalmers.se/en/centres/oso/radio-astronomy/apex/Pages/default.aspx	
Annual operating costs		

Description of the Infrastructure *Give a brief general description of the infrastructure to which access is offered. Illustrate, in particular, its state-of-the-art equipment and services offered to users that make it rare or unique in Europe. Outline the areas of research normally supported by the infrastructure, as well as new areas opening to users, if any. If the infrastructure is composed of several installations, describe these including their specific features. If parts of the infrastructure are still under construction, specify the starting date of construction and indicate the date when access can realistically be made available.*

Onsala Space Observatory (OSO) is the Swedish National Facility for Radio Astronomy. It operates several radio telescopes at Onsala, and it is one of three partners (the other are MPIfR and ESO), in the Atacama Pathfinder Experiment (APEX) project, a 12m sub-mm telescope in Chile. OSO share of the total APEX costs is 23% and hence the same amount of the observing time, thereof 10% is offered to host country Chile. According to the present legal status APEX will operate until the end of 2017, however an extension of the APEX project until 2022 is foreseen. The prolongation of APEX operation time will be most probably connected with reduction of the Swedish share of the observing time to 13%, corresponding to about 500–600 hours per year. In this proposal, we will offer access to APEX Swedish share.

The APEX telescope is of excellent quality (15 µm rms surface accuracy) and the site as proven by the successful operation at 1.5 THz. Observations are carried out from early April to late December (excluding the Bolivian winter).

APEX is currently equipped with bolometer cameras and single-pixel heterodyne receivers as facility (common-user) instruments. Users of Swedish APEX time also have access to the partner instruments ArTeMiS (a bolometer array) and SEPIA (a heterodyne receiver). There are spectrometers with up to 4x4 GHz bandwidth. At present all of the facility instruments and ArTeMiS are available on Swedish APEX time to PIs and observing teams without restriction on nationality. For ESO/OSO PI instruments (SEPIA) there is a requirement on having a Swedish co-I.

Both SHeFI and SEPIA were built by OSO. The SEPIA instrument, installed in 2015, contains an ALMA Band 5 receiver. An ALMA Band 9 (602–720 GHz) receiver will be installed in the SEPIA cryostat in early 2016. There are also plans to replace the present SHeFI instrument with an upgraded version possibly in 2018. On the bolometer side, a revolutionary new large-format (>20000 pixels at 850 µm) bolometer array (A-MKID) is being developed by MPIfR as a PI instrument, with access for the ESO and OSO under negotiation.

Table: Current APEX common-user receivers, plus ArTeMiS and SEPIA available on Swedish time. It is expected that the 1x4 GHz facility spectrometer will be upgraded to 4x4 GHz by 2017 or early 2018.

Name	*Frequency range*	*Receiver temperature or sensitivity*	*Receiver type*	*Spectrometer*
SEPIA B5	159–211 GHz	55 K (SSB)	SIS	FFTS, 4x4 GHz
SHeFI	211–270 GHz	125–190 K (SSB)	SIS	FFTS, 4 GHz
SHeFI	270–370 GHz	135 K (SSB)	SIS	FFTS, 4 GHz
SHeFI	385–500 GHz	100 K (DSB)	SIS	FFTS, 4 GHz
LABOCA	345 GHz	60–100 mJy $Hz^{0.5}$	295 pixel bolometer array	n/a
ArTeMiS	856 GHz	600 mJy $Hz^{0.5}$	2304 pixel bolometer array	n/a

The APEX telescope and its instruments provide a rare opportunity for European astronomers to observe southern sky objects including the centre of our Galaxy and the Magellanic Clouds, at sub-mm wavelengths. Now that ALMA is operational but highly over-subscribed, the demand for APEX remains high and is increasing, partly in order to make preparatory observations to support ALMA proposals or add very short spacings.

APEX is used to investigate many fundamental questions in astronomy, such as: how do planets, stars and galaxies form and evolve, how do complex molecules form in the interstellar medium, and what did the early universe look like. The bolometer cameras enable studies of the distribution and luminosity of high-z galaxies as well as the properties of the dusty surroundings of very young stellar objects. The spectral line instruments provide information on the interstellar and circumstellar physics and chemistry taking place in our Galaxy as well as in distant galaxies.

SERVICE CURRENTLY OFFERED BY THE INFRASTRUCTURE *Describe the services offered by the infrastructure and its research environment, and demonstrate how it will enable scientists to carry out high-quality research. You should summarise some of the most interesting scientific achievements already obtained by users. Demonstrate that there is a widespread interest from users in other countries to conduct research at the infrastructure (or make otherwise use of its services), e.g. by indicating the number of international users currently using the facility per year.*

Swedish time on APEX is currently open to scientists from all countries. A few examples of interesting results, based on observations by TA eligible groups, are summarized below.

- Miettinen et al. (A&A 553, A88, 2013 and A&A 555, A41, 2013) observed the starforming region Orion B9 in continuum emission and spectral lines. The structures observed are likely the result of cylindrical Jeans-type gravitational fragmentation. In the region SMM 6 in Orion B9, several condensations were identified. They are in an advanced stage of chemical evolution and near the onset of gravitational collapse, and will form stars or brown dwarfs,

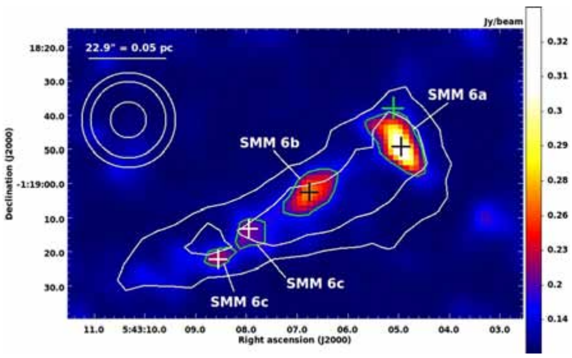


Figure APEX/SABOCA 350 µm image of the fragmented prestellar core SMM 6 in Orion B9.

- Wampfler et al. (A&A 572, A24, 2014) observed nitrogen fractionation in protostars. In our solar system, the terrestrial planets, comets, and meteorites are significantly enriched in 15N compared to the Sun and Jupiter. While the solar and jovian nitrogen isotope ratio is believed to represent the composition of the protosolar nebula, a still unidentified process has caused 15N-enrichment in the solids. APEX observations of nearby protostars revealed 15N-enrichment in two of three sources, consistent with the chemical fractionation scenario,

- Groenewegen (A&A 561, L11, 2014) used APEX and IRAM to study mass loss from evolved stars. For stars with masses below about one solar mass, most of the mass loss occurs early during their giant phase. Five such “red giant branch” stars were observed in two rotational CO lines, and for one the first such detection ever was made, raising new questions about the mass loss mechanism and paving the way for future studies with ALMA.

The demand for observing time on APEX Swedish time is high, with an oversubscription ratio (between requested and observed time) of 1.5–2.2. The annual number of proposals for Swedish APEX time increased almost 40% in the last 4 years. More than half of them had only non-Swedish authors. During the same years, the number of unique international PI and co/PI of Swedish APEX time increased from 164 to 233 per year. Recently there are in average 65 publications per year based on APEX data. This includes all entire APEX observing time.

DESCRIPTION OF WORK

MODALITY OF ACCESS UNDER THIS PROPOSAL

Outline how a user, or user group, will be given access to the infrastructure or to its services (e.g. type of equipment/service used, expected output/deliverables, etc.). For trans-national access indicate the typical location and duration of work (estimated number of days spent at the infrastructure), and, where relevant, how the users will be integrated into the scheduling of the infrastructure and the degree of independence they will experience with respect to the normal research activity of the infrastructure. Define clearly, for each installation, the unit of access being offered and indicate what is covered and included (e.g. preparatory work, specific training courses) in one unit. This is essential for monitoring the access provided under this project, but also to justify the corresponding costs (see section 3.4b of this document). Indicate for each installation which modality will be used to declare access costs (on the basis of unit cost, as actual cost, or as a combination of the two) and justify your choice.

Access to APEX is carried out through a proposal and peer review process (see below). The Call for Proposals is widely advertised. The observations at APEX are complicated by the high altitude of the telescope, 5100 m, which prevents the use of a regular visiting-astronomers scheme. APEX observations are therefore made in semi-service mode through a scheme where the APEX staff and selected visiting astronomers carry out the observations. All observers must pass a high-altitude physical test. The observed data is validated by the APEX staff before it is archived. Swedish APEX data is archived in the ESO archive (http://archive.eso.org/). The proprietary time is one year, after which the data becomes freely available.

The unit of access is telescope observing hour, including time for pointing and calibration checks made for the particular project additionally to the observing time. Access costs will be declared on the basis of unit cost, since the access cost (per telescope hour) is similar for all users.

SUPPORT OFFERED UNDER THIS PROPOSAL

Describe the scientific, technical and, for trans-national access, logistic support that would be offered to the users. Where relevant, emphasise the quality of the scientific environment in which the users will be working and explain how this might stimulate their research. Explain to what extent such support is already routinely provided to external users.

The observations are carried out in semi-service mode as described above. TA-eligible users may, if they wish and pass the physical test, act as visiting astronomers at the expense of OSO. TA users will then get practical experience of using a world-class sub-mm telescope and will interact with other astronomers and telescope experts. TA users not visiting APEX will get experience in planning sub-mm observations, reducing and analysing the data. OSO offers help, via its APEX project scientist, both during the proposal phase and the data reduction phase, to those who need it. This type of support has worked successfully for many years.

Outreach to new users

State what measures are taken to attract new potential users (e.g. web page, call for proposals, etc.), including specific user groups such as users coming from SMEs or representing new areas of research, if appropriate. Indicate why and to which extent the EU funding of this trans-national and/or virtual access activity will provide European research teams with new opportunities of access to the infrastructure. Indicate whether the number of trans-national users is expected to increase as a result of this proposal, and how you will monitor such an increase. If the infrastructure is being opened to users other than those from the host country of the infrastructure for the first time, what evidence is there that there will be sufficient demand for the access being offered under this proposal?

Call for proposal is issued twice per year, with deadlines usually on 15 October and 15 April, and is available at the OSO web page. Additionally the call is sent by email to more than 300 addresses. An extension of the explorer list to other communities is envisaged. By providing clear guidelines and on-line tools for estimating observing time, a simplification for proposal process for new users is striven. Proposals are submitted through the NorthStar system common for most radio astronomical telescopes. Astronomers at OSO are at disposal in the proposal preparation and data reduction issues.

The demand on APEX is high; the TA programme will allow more transnational users to access APEX. The possibility for European astronomers to use APEX under the TA programme will be clearly advertised in the Calls for proposals. Based on the results of previous TA programmes, we can expect that the demand for access from TA groups will be higher than the amount of observing time offered under this proposal. In fact, in the previous RadioNet more than six times the available TA access was requested by TA groups. Between 2012 and 2014, the number of TA users was on average 95 per year and shows steady increase. In fact, the EC support under TA programme to APEX will be used to increase the Swedish observational staff support and therefore to extend the daily operation. Apex operation under Swedish time is must be operated by the Swedish staff.

Review procedure under this proposal

For trans-national access activities, describe the peer review procedure that will be used to select users under this proposal. Outline the composition of the User Selection Panel. Demonstrate that the selection of users will follow the principles of transparency, fairness and impartiality. As the selection will be based on the evaluation of scientific merit of the applications, but with priority to new users and users coming from countries where such infrastructure is not available, indicate any additional selection rule that you would like to add.

Observing proposals for Swedish time on APEX are evaluated by a Swedish Time Allocation Committee (with five members from several Swedish universities and from abroad; the majority is from outside OSO and RadioNet). The grading of a proposal is done solely on scientific merit. In the case that several proposal receives a similar grade, priority will be given to TA eligible proposals with new users. PI of each proposal is informed about the outcome of the review procedure, including comments and feedback on the proposal from the committee. The PI also receives instructions on how to proceed with the observations, information about archiving of the data, and contact information to the APEX project scientist at OSO for additional support.

WP14 – ALTA

WORK PACKAGE NUMBER	14	LEAD BENEFICIARY – ASTRON
WORK PACKAGE TITLE	VA - ALTA	
PARTICIPANT NUMBER		
SHORT NAME OF PARTICIPANT	ASTRON	
PERSON/MONTHS PER PARTICIPANT	0	
	START – END MONTH	14 – 48

OBJECTIVES	PROVISION OF ACCESS TO
	DESCRIPTION OF THE INFRASTRUCTURE
NAME	Westerbork Apertif Long Term Archive (ALTA)
LOCATION	Westerbork (NL)
WEB SITE ADDRESS	www.astron.nl
ANNUAL OPERATING COSTS	€

DESCRIPTION OF THE INFRASTRUCTURE *Give a brief general description of the infrastructure to which access is offered. Illustrate, in particular, its state-of-the-art equipment and services offered to users that make it rare or unique in Europe. Outline the areas of research normally supported by the infrastructure, as well as new areas opening to users, if any. If the infrastructure is composed of several installations, describe these including their specific features. If parts of the infrastructure are still under construction, specify the starting date of construction and indicate the date when access can realistically be made available.*

The Westerbork Apertif Long Term Archive (ALTA) is a brand new facility offering to the world-wide astronomical community free virtual access to data and scientific products produced from all sky surveys of the Northern sky that will be conducted with the Apertif frontend of the WSRT, as well as services to query, further exploit and perform in-depth data mining of these products adaptable to diverse research goals.

The ALTA is a complete Centre of Expertise. It creates a scientific research environment in which varied astronomical research programs can be conducted by offering a complete set of Services and extensive User Support, to exploit the central information system whose main goal is to allow transparent and distributed access, to Apertif data and processed data products in its long-term storage.

The data collection (surveying) strategy that will populate the ALTA has specific strengths for a number of science areas, including: the use of imaging of *resolved* or faint HI structures to study the role of gas (dynamics, interactions, accretion) in galaxy evolution and investigate the properties of the smallest gas-rich galaxies in the local Universe, the study of magnetic fields in galaxies and of the large-scale structures in which they are embedded, the study the role of cold gas, feedback activity, star formation in bright and faint AGN. Furthermore, the surveys will also detect, characterize and localize fast radio bursts (FRBs) over the Northern sky (in a much larger volume than hitherto available surveys), perform a census of intermittent and normal pulsars along the Galactic Plane as well as study afterglows of Gamma Ray Bursts and Tidal Disruption Events.

The ALTA addresses its products, services and the associated user support (documentation, personal help, analysis algorithms) to both specialists and non-experts in radio interferometry. In a quantum leap from the paradigm of supplying only observations, it takes the onus of performing data analysis <u>on their own</u> from the majority of the users. Offering a range of high quality science-ready products and tools to perform intensive and in-depth data mining on them, the ALTA will enable astronomers not only to reach the wide range of scientific goals set by the design of the surveys, but also to engage in more sophisticated multi-wavelength and multi-instrument studies, availing themselves of appropriate combinations of data from large scale facilities, to explore novel cutting-edge science.

The ALTA will be populated with data in regular public releases, growing by a rate of 2 Petabyte/year for the four years the survey completion. Allowing a buffer period for processing and quality assessment by the observing team, fully open access to the ALTA is planned to kick off in January 2018 with the first data release.

SERVICE CURRENTLY OFFERED BY THE INFRASTRUCTURE *Describe the services offered by the infrastructure and its research environment, and demonstrate how it will enable scientists to carry out high-quality research. You should summarise some of the most interesting scientific achievements already obtained by users. Demonstrate that there is a widespread interest from users in other countries to conduct research at the infrastructure (or make otherwise use of its services), e.g. by indicating the number of international users currently using the facility per year.*

The ALTA is an integral part of the Apertif system designed to make its unique scientific products accessible to all users in a transparent way. Apertif is the new observing system of the WSRT, consisting of phased-array feeds and digital beamformers, with a digital correlator and Tied Array beamformer to match. It transforms the WSRT to a cutting-edge survey interferometer with unique coverage of the northern hemisphere sky, not only as an important SKA pathfinder in focal-plane-array technology but also as the first to offer all its scientific products in a freely accessible virtual archive.

The ALTA will contain a uniform set of survey products of assured quality: the raw visibilities; the calibration information and continuum and spectral line data cubes; time-domain data of varied time-resolution and higher level data products such as source lists, moment maps, and data cubelets containing objects of interest. These products will be supplied by the Apertif Survey Team a collaboration of several groups from the international astronomical community that will conduct a few very large-scale Apertif surveys in the period 2017-2020, namely:

- A large-area, shallow imaging survey of HI and polarised radio continuum emission covering ~3500 deg^2;
- A medium-deep imaging survey of HI and polarised radio continuum emission covering ~ 450 deg^2;
- A time-domain survey for pulsars and fast transients over 15,000 deg^2 .

ALTA personnel cater for data integrity and scientific quality and the overall archive maintenance. Further User Support is provided through a Helpdesk, manned by instrument and data handling experts.

The ALTA is accessible through the web and for advanced uses, a software interface. Designed according to International Virtual Observatory Alliance standards, its products are discoverable through Virtual Observatory interfaces developed in various astronomical research programs. Its catalogues and metadata can be queried anonymously. Access to the archive is open to all users who may download data to process them further according to their own scientific needs. Users are also able to search and download science-ready products (images and spectra, source catalogues) and use provided tools to perform intensive and in-depth data mining suitable for their research goals.

DESCRIPTION OF WORK

MODALITY OF ACCESS UNDER THIS PROPOSAL

Outline how a user, or user group, will be given access to the infrastructure or to its services (e.g. type of equipment/service used, expected output/deliverables, etc.).

The ALTA will utilize disk based online storage in combination with tape based offline storage allowing sustained upload and download data throughput at a level of not less than two gigabits per second and peak loads (for 24 hours or more) of one gigabyte per second. Descriptive data, location pointers, unique ID's, as well as catalogue information will be stored in a central database.

Any astronomer can access the ALTA. Users will be able to query anonymously, the ALTA’s fully indexed and Virtual Observatory (VO) compatible catalogues, using web-based frontend archive infrastructures. For IT security purposes, access to data and scientific products is available by obtaining a free, individual account. User accounts are administered by the ALTA helpdesk.

Access to the ALTA will be through web services. Users are able to download raw or calibrated data (visibilities, time domain data) and perform their own further analysis. Furthermore, finalised science-ready data (images, spectral cubes, spectra) and catalogues, fully documented with respect to their quality and analysis history are also available to download and be used directly as suited for the users' scientific purpose.

The Apertif Survey Team will collectively be responsible for regular, public releases to the ALTA. These releases will involve all standard data products stored in the Archive: the initial uncalibrated visibilities and beam-formed FITS time series will be followed by the derived data products, Data releases will be accompanied with documentation, with regard to observing, processing procedures and key quality characteristics. The release schedule will be published and updated regularly. Data instalments are scheduled according to the requirements for quality assurance and the effort involved in releases.

SUPPORT OFFERED UNDER THIS PROPOSAL

Describe the scientific, technical and, for trans-national access, logistic support that would be offered to the users. Where relevant, emphasise the quality of the scientific environment in which the users will be working and explain how this might stimulate their research. Explain to what extent such support is already routinely provided to external users

Extensive documentation on the usage of the archive will be available on the ASTRON web pages. All steps from obtaining access, querying and downloading raw data and data products are described there. Further documentation on analysis methods and special algorithms developed for Apertif data will also be available. The ALTA Helpdesk is available via the internet to provide easy access to assistance and referral to radio astronomy and data specialists in areas ranging from ALTA data access, retrieval, or handling issues, to queries on the quality and ways of scientific mining of the data.

Further documentation on analysis methods, special processing algorithms and pipelines developed for Apertif data is available through the ALTA web pages; additional help can be obtained through the ALTA Helpdesk. This will enable users to improve their analysis techniques and ensure the maximum scientific return out of their effort.

ALTA Application support engineers are available to refine services available to users, maintain and adapt the quality of the ALTA services to developing technologies in a matter transparent to the users. To optimize and balance the use of the available computer resources, access to the archive and the use of its data is monitored. This process will also provide an assessment of the offered services.

OUTREACH TO NEW USERS

State what measures are taken to attract new potential users (e.g. web page, call for proposals, etc.), including specific user groups such as users coming from SMEs or representing new areas of research, if appropriate. Indicate why and to which extent the EU funding of this trans-national and/or virtual access activity will provide European research teams with new opportunities of access to the infrastructure. Indicate whether the number of trans-national users is expected to increase as a result of this proposal, and how you will monitor such an increase. If the infrastructure is being opened to users other than those from the host country of the infrastructure for the first time, what evidence is there that there will be sufficient demand for the access being offered under this proposal?

Availability, access methods to the ALTA and the extensive documentation on ASTRON's website will be advertised by special announcements issued with every release, on the internet and emailed to a large list of more than 900 addresses including individuals, institutes and other astronomical email exploders, hence reaching additional researchers. Preceding the first release, the Apertif Survey Team will publish a paper describing in detail the properties of the data on offer in ALTA.

Access to the ALTA will also be advertised at conferences and at larger meetings of national and international astronomical societies. Special sessions on the use of the ALTA will be included in various radio-astronomical data analysis schools, offering new users a view of the opportunities available and a view towards future arrays like the SKA.

Free availability of the science-ready products and their associated data will lower the threshold for accessing the results of the unique, large-scale surveys of the northern sky conducted by Apertif. It is expected that a large number of users, particularly non-specialists in radio astronomy, will benefit from this. In the coming years, exploitation of the ALTA for data mining and large-scale studies will pave the way to the next generation of major survey instruments.

REVIEW PROCEDURE UNDER THIS PROPOSAL

For virtual access activities, describe how and when the periodical assessment of the services offered to the scientific community will be carried out (e.g. by an international review panel). The corresponding assessment reports must be defined as deliverables to the EC.

The independent Science Advisory Committee of ASTRON will monitor and review the usage of the ALTA and its impact to the worldwide astronomical community. The panel consists of members of the (inter)national community outside ASTRON selected for their field of expertise.

Archival usage statistics such as the number of users, types of query, data volume traffic, as well as feedback from user questionnaires will be employed to evaluate the quality of the archive services. The scientific impact of the use of the archive, mirrored in the number of publications will also be considered. The panel is empowered to suggest improvements or changes in the modus operandi of the ALTA to ensure that the best scientific results are obtained from the use of the archive.

3.1 Management structure, milestones and procedures

The organisational structure and decision-making mechanisms of RadioNet will [illegible] on the successful consortium organisation and procedures of [illegible] predecessors, which has proven to be appropriate for the complexity and scale of the project. However, some [illegible] will be [illegible] address the experience gained. [illegible] Fig. 3.2.1 shows the overall management structure of RadioNet. Three bodies form the [illegible] of RadioNet: Board, Executive Committee and WP leaders, [illegible] The Coordinator is the contact person between the project and European Commission. The project will receive well-founded analyses and recommendations from an Advisory Group. The Management Team will support all governance bodies.

The overall project will be governed by the Consortium Board, which consists of one representative per project partner. The Board will be the decision making body. The execution of the Board decisions will be coordinated by the Executive Committee (consisting of Board Chair, Manager, NA and JRA leaders, and TA coordinator) and overseen by the Coordinator. The management team will perform the day-to-day management of the project, and support the consortium bodies. The consortium´s rules will be defined in the consortium agreement (CA) following the appropriate DESCA model (Development of a Simplified Consortium Agreement). To address the future needs, an Advisory Group will be introduced, composed of external advisors to provide feedback from the community at large and advise the project on strategic decisions.

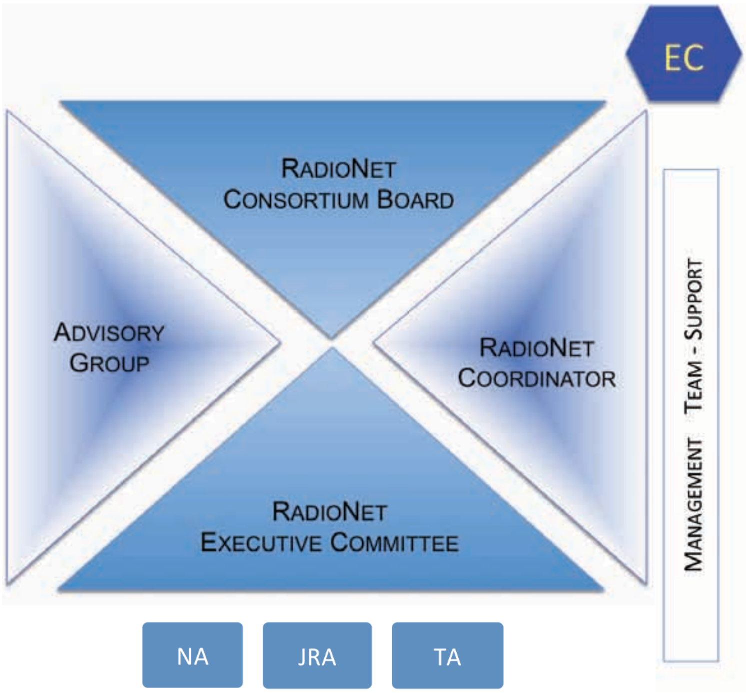


FIGURE 3.2.1: RadioNet organisational structure.

Consortium Board (Board)

will be the governing and ultimate deciding body. It will consist of one representative of each project beneficiary, who will attend the Board meeting in person or be represented by a nominated proxy. The Board will meet twice a year, at least once face to face. The Board meetings will be chaired by the Chair or Vice-Chair, who will be elected for the period of 2 years from the Board members. The Chair supported by the Coordinator and Management team, will ensure the procedure of Board meetings in accordance with the Consortium Agreement, e.g. following the deadlines for agenda, voting rules, and minutes. The Board will only deliberate if two-thirds of its members are present or represented. Decision will be in most cases by trying to reach a consensus, and else taken by a majority of two-thirds of the votes. The Chair can invite WP leaders to report on the status and progress, and other guests in order to foster the collaboration with other communities. These guests will not have voting rights.

EXECUTIVE COMMITTEE (Exec)

will be the supervisory body of the execution of the project, which will report to the Board and be accountable to this Body. The Exec will consist of the Board Chair and Vice-chair, the Coordinator, Project Manager, the NA and JRA leaders, and the TA coordinator. The TA coordinator (Prof. S. Garrington) will be representing all TA activities, report their development and advise on any TA budget reallocation. The Exec meetings, which are led by the Chair of the Board, will be held 3 times a year, at least once face to face. The written minutes will be distributed to the Exec and Board members, as well as to the Project Officer.

COORDINATOR

will be the intermediary between the Parties and the European Commission. The Coordinator (Prof. J. A. Zensus) will be responsible for the overall scientific and management coordination, complying with all regulatory and scientific requirements of EC and Horizon 2020; assuring good communication on all levels, mediating in conflict resolution, assuring project visibility and impact in the astronomical and general community. In this role, J. A. Zensus will be assisted by his scientific staff when necessary (MPG in-kind contribution). The Coordinator will dedicate up to 20% of his working time, which is an in kind contribution of the MPG.

MANAGEMENT TEAM (MGT)

will be proposed by the Coordinator and appointed by the Board. The MGT will assist and facilitate the work of the Consortium bodies. It will coordinate the timely workflow, the distribution of finances, the project internal and external communication. It will ensure the project visibility in the global community. The team will act in a professional, transparent and responsible fashion on the partners' behalf, maintaining effective communication on all levels. The MGT will meet bi-weekly with the Coordinator and it will consist of:

- PROJECT MANAGER (I. Rottmann, 9PM/yr): responsible for the day-to-day business; timely and fiscally sound implementation of the contract; identification and solution of issues; definition and maintenance Data Management Plan, and first contact point of the travel reimbursement,
- PROJECT ASSISTANT (MPG, 9PM/yr): responsible for documentation and support of the management work; maintenance of the project management platform (wiki); assistance for tracing the publications,
- OUTREACH ASSISTANT (MPG, 4PM/yr): maintaining of the web pages and social media, responsible for the directly related project outreach,
- TRAVEL ASSISTANT (MPG, 4 PM/yr): responsible of the processing of the MGT, NA and TA travel claims.
- FINANCIAL CONTROLLER (E. Schwetz, in-kind contribution): responsible for the timely and correct distribution of the EC payments and financial performance of the partners.

WORK PACKAGE LEADERS

will be appointed by the Board. They will be responsible for the day-to-day implementation of the WP work plan and decisions of the Board. WP leaders will report at the Exec meetings the progress and any deviations including the solutions. Nevertheless, any discrepancies with the work plan will have to be promptly reported to the Coordinator.

THE ADVISORY GROUP (AG)

will be composed of a pool of maximum 6 external advisors – from scientific and industrial environment, gender balanced. There was no Advisory Group in the previous RadioNet projects, which somewhat restricted our reaching out to fellow communities. The assignment of the AG will maximize interactions and optimize complementarities not only with astronomical community (e.g., ALMA, ASTRONET, OPTICON, AHEAD) and relevant ESFRI initiatives (e.g., SKA, ASTERICS), but also with the industry.

The Board will appoint the AG members upon the Coordinator's nomination. The Coordinator will be authorised to execute a non-disclosure agreement (defined in the CA). The AG summits will be associated with the face-to-face Board meetings, allowing their attendance, in order to provide feedback from the community at large and advice about strategic decisions. The Coordinator will provide administration for the AG summits (organisation, minutes, implementation of the decisions). AG may invite guests (e.g. Board members, WP leaders) to attend their summits, but without voting rights.

CONSORTIUM AGREEMENT (CA)

will be an agreement between the project partners, concerning the reciprocal rights and obligations, in particular the structure of the management bodies, allocation of the financial contribution, mutual confidentiality and non-disclosure agreement, liabilities and intellectual property rights. In order to pursue market opportunities arising from the project's results (e.g. JRA results) the ownership and access to generated knowledge will be not only defined but also communicated to all involved project participants. Given the academic nature of most of the partners, the CA will be based on a DESCA model (http://www.desca-2020.eu/). The CA will play a key role in the project implementation by providing the coherent and practical operation framework for all project parties, from Board via Exec, MGT and WP leaders up to individual scientists and administrative persons. The CA will ensure that the project achievements are accomplished in the most effective way. All project beneficiaries will be provided with the actual version of the CA, and they will be aware of its content and implications for their contribution. The current CA version will be always available, password protected, on the project wiki page.

CONTINGENCY BUDGET

It is envisaged that a contingency budget, approximately 5% of the TA budget, will be kept at the coordinator´s institution in a common fund. This will allow a quick reaction to unforeseen developments by limited budget reallocation. The creation of the budget and its reallocation will be subject for a Board decision and afterwards, subject to the approval of the European Commission. However, the project duration, the Coordinator can decide without any Board decision, but upon the approval of the EC.

OUTREACH

Project outreach will concentrate on the communication of the opportunities, current scientific and technological discoveries, as well as the achievements on other platforms (e.g. political platform). To avoid the duplication of effort, the general public is already addressed by each partner's outreach office (e.g. visitors centres at the telescopes), as well as by European projects such as UNAWE, and international such as IAU. office and partners will stay in close contact with all those outreach activities to maximise their impact.

[illegible] a close connection to the outreach offices of the RadioNet telescopes will be established and maintained. This way the Management receives information about all scientific discoveries resulting from TA programme and it will disseminate them together with other project achievements and the current radio astronomical issues through several channels such as the project webpage, news including Horizon2020 news at the EC, social networks, attendance at relevant events, and by email. RadioNet will create an e-mail list for the dissemination of project related topics. A possibility to join this list will be offered at the registration page of each supported event. Additionally, TA users will be encouraged to subscribe for this list.

Describe, where relevant, how effective innovation management will be addressed in the management structure and work plan. Innovation management is a process, which requires an understanding of both market and technical problems, with a goal of successfully implementing appropriate creative ideas. A new or improved product, service or process is its typical output. It also allows a consortium to respond to an external or internal opportunity.

INNOVATION MANAGEMENT

Based on the experience of the previous RadioNet3 project, to assure the Continuous Improvement Process (CIP), all administrative and regulatory issues will be consolidated in the MGT. This applies in particular for the development of processes and their execution, the selection criteria for the financial support of events, the reimbursement process, the documentation and monitoring of the internal system, the monitoring of budget. This centralisation will allow the identification of systematic problems and the introduction of appropriate solutions. All management processes will be formally defined in the management manual.

The technical developments proposed by the JRAs require adopting cutting edge novel technologies in order to achieve scientific breakthroughs. Therefore an innovation management will be necessary to consider any potential problems of market and technology. Partners involved in RadioNet JRAs are experienced in recognising and implementing potential [illegible] state-of-the-art enhancements. Therefore an investment in outdated technologies could be prevented and the associated risk can be addressed.

A good example is the successful development of the UniBoard^2 under the RadioNet3. It created a generic, high-performance computing platform for radio astronomy, along with a number of firmware personalities (digital receiver, pulsar binning machine, VLBI correlator). The activity started using state-of-the-art FPGAs built on 40nm technology, but shortly after, a possibility to use [illegible]. This led to an amendment to the contract. Thanks to the close contact with the industry partners Xilinx and Altera, the production of the UniBoard^2 with 20nm technology (compatible with the next 14nm devices) was brought about.

Also partners of the RadioNet3 JRA AETHER successfully solved a problem in the production of SIS junction mixers operating up to 1 THz. [illegible] European laboratory originally planned fo the development could not be used, t[illegible]to [illegible]

The RadioNet3 JRA DIVA updated the planned frequency range from 1-4GHz to 1.6-6GHz in the development of a low-noise wide-band integrated amplifier for VLBI antennas, to respond to the decision of the SKA Wide Band Single Pixel Feed (WBSPF) consortium concerning the new receiver bands being now 1.6- 5.2GHz and 4.6-24 GHz. This decision made possible the use of the RadioNet3 developments not only for the EVN, but also for the SKA.

CRITICAL RISK

Describe any critical risks, relating to project implementation, that the stated project's objectives may not be achieved. Detail any risk mitigation measures. Please provide a table with critical risks identified and mitigating actions (table 3.2b)

There is only a limited risk in the performance of the NA and TA activities. Based on the previous RadioNet experiences it seems very unlikely that TAs would not fulfil their contractual obligations. The oversubscription rate of TA projects was at least 50% and increases continuously. The scheduled events of the NA activities address the key-topics and were over-booked in the past, it is therefore unlikely that there could be either no host institute or to little demand to perform the NA events. However, critical [illegible] relating to project implementation has been identified in performing the JRA work programmes. Details on [illegible] risks and their mitigation measures are given in Table 3.2b.

TABLE 3.2B: CRITICAL RISKS FOR IMPLEMENTATION

DESCRIPTION OF RISK	WORK PACKAGE INVOLVED	PROPOSED RISK-MITIGATION MEASURES
No feedback on Call for Topics Level of likelihood: low	WP2	Early announcements, broad spreading, suggestion of topics to the community
Finding no local organizer for events Level of likelihood: low	WP2	Addressing partners personally, organize at home institute
Overspending of budget Level of likelihood: low	WP2	Strictly restrict budget for each topic event, controlling of budget
Underspending of budget Level of likelihood: low	WP2	Organize additional events
Difficult to find host for major event Level of likelihood: low	WP3	Provide detailed guidance from organisers of previous events
Low uptake of ARC Node visits Level of likelihood: low	WP3	Advertise to new ALMA users outside traditional community
Hard to get observatory staff released for visits Level of likelihood: low	WP3	Discuss specific benefits with individual observatory managements
35nm gate length process decreases the performance of mHEMT MMICs at W-band Level of likelihood: Low	WP5	Use proven 50 nm gate length process for cryogenic W-band LNAs instead
Integration of down conversion module in single chip not feasible Level of likelihood: Low	WP5	Decrease level of integration (more chips per module)
Integration of 2SB mixer and hybrids on a single chip gives poor results Level of likelihood: Low	WP5	Turn to lumped elements configuration
Difficulties to fabricate SIS junctions with the very high current density needed for operation around 1 THz Level of likelihood: Medium	WP5	Explore different superconductive materials
Developed LO chain has not enough power to drive several mixers for the FPA (especially at 1 THz) Level of likelihood: Low	WP5	Reduce number of pixel per LO and fabricate more LOs
No ADC with sampling rate of 32 Gbps available Level of likelihood: Low	WP5	Multiplex signal and use a smaller sampling rate.
General risk to achieve the design specifications Level of likelihood: low	WP6	The present state of the art of VGOS and RadioNet3 DIVA receivers as well

		as DBBC3 backend are a solid basis for achieving the design goals.
Broad band sampler availability Level of likelihood: low	WP6	Existing broad-band sampler from a different manufacturers will be used as multi-device.
VLBI test of BRAND receiver with VGOS telescopes (OSO & UAH) Level of likelihood: low	WP6	Using other VGOS antennas, or using EVN antennas with single-band VLBI.
Firmware for polarisation conversion Level of likelihood: medium	WP6	Previous work by ASTRON and MPG are a good basis for this work. Fall-back: convert polarisation after correlation.
Loss of key personnel Level of likelihood: medium	WP7	Support knowledge transfer between partners by staffing all tasks with 2-3 institutes.
Algorithmic development is too ambitious for the budgeted time/manpower. Level of likelihood: medium	WP7	Apply regular reviews. Enforce prioritisation of key goals.
Lack of consistency between tasks Level of likelihood: low	WP7	Joint analysis of algorithms at the start. Use a common development framework. Mid-term JRA meeting to analyse joint calibration strategies.
Low requests from the scientific community Level of likelihood: medium	WP14	Increasing the advertisement of the virtual access to the archive and its prominence.

Level of likelihood *to occur:* **Low/medium/high**
The likelihood is the estimated probability that the risk will materialise even after taking account of the mitigating measures put in place.

TABLE 3.1C: LIST OF DELIVERABLES

DELIVERABLE (NUMBER)	DELIVERABLE NAME	WORK PACKAGE NUMBER	SHORT NAME OF LEAD PARTICIPANT	TYPE	DISSEMI-NATION LEVEL	DELIVERY DATE (MONTHS)
WP1.1	Assembling the web/wiki pages	1	MPG	R	PU	3
WP1.2	Data Management Plan	1	MPG	R	PU	6
WP1.3	Data Management Plan - update	1	MPG	R	PU	42
WP2.1	Technical Workshop 1 – report including oral presentation for download	2	MPG	R	PU	12
WP2.2	YERAC– report including oral presentation for download	2	INAF	R	PU	16
WP2.3	Large Radio Astronomical Conference – proceedings	2	INAF	R	PU	16
WP2.4	Technical Workshop 2 – report including oral presentation for download	2	MPG	R	PU	27
WP2.5	YERAC	2	INAF	R	PU	28
WP2.6	Large Radio Astronomical Conference – proceedings	2	INAF	R	PU	32
WP2.7	Technical Workshop 3 – report including oral presentation for download	2	MPG	R	PU	43
WP2.8	Large RadioNet Conference – proceedings	2	INAF	R	PU	47
WP3.1	Specialised training event (e.g. ERIS, single-dish etc)	3	UMAN	R	PU	13
WP3.2	Update of the ‘Guide to the European ARC network’	3	ESO	R	PU	14
WP3.3	Spectrum management school	3	OBSPARIS	R	PU	24
WP3.4	Specialised training event (e.g. ERIS, single-dish etc)	3	UMAN	R	PU	29
WP3.5	Update of the ‘Guide to the European ARC network’	3	ESO	R	PU	30
WP3.6	Specialised training event (e.g. ERIS, single-dish etc)	3	UMAN	R	PU	45
WP3.7	Update of the ‘Guide to the European ARC network’	3	ESO	R	PU	46
WP4.1	Report Technical Meeting	4	UAH	R	PU	12
WP4.2	CRAF Meetings	4	OBSPARIS	R	PU	12
WP4.3	1st progress report SPOOR	4	ASTRON		PU	18
WP4.4	Report Technical Meeting	4	UAH	R		24
WP4.5	CRAF Meetings	4	OBSPARIS	R	PU	24
WP4.6	Report Technical Meeting	4	UAH	R	PU	36
WP4.7	CRAF Meetings	4	OBSPARIS	R	PU	36
WP4.8	2nd progress report SPOOR	4	ASTRON	R	PU	36
WP4.9	Final report of SPOOR	4	ASTRON	R	PU	47
WP4.10	Report Technical Meeting	4	UAH	R	PU	48
WP4.11	CRAF Meetings	4	OBSPARIS		PU	48
WP5.1	Low noise, cryogenic 35 nm mHEMT MMIC amplifiers	5	IAF	DEM	CO	42

WP5.2	Multipixel W-band FPA demonstrator composed of cryogenic module and down conversion module	5	IRAM	DEM	PU	42
WP5.3	Very wideband RF/IF SIS receiver	5	OSO	R	PU	42
WP5.4	Single-chip 2SB SIS mixer operating near 1 mm	5	IRAM	R	PU	36
WP5.5	Multipixel FPA demonstrator composed of miniaturized 2SB receivers operating near 1 mm	5	IRAM	DEM	PU	42
WP5.6	SIS junction mixer operating around 1 THz	5	UOXF	R	PU	36
WP5.7	Multipixel FPA demonstrator composed of 2SB SIS mixer receivers operating around 1 THz	5	RUG	DEM	PU	42
WP5.8	Multipixel demonstrator of FPA of HEB mixer receivers	5	OBSPARIS	DEM	PU	42
WP6.1	Report on recommendations for individual EVN antennas.	6	UAH	R	PU	6
WP6.2	Description and evaluation of the analogue part of the prototype (frontend) of the BRAND receiver for one selected antenna	6	OSO	R	PU	36
WP6.3	Description and evaluation of the digital part of the BRAND receiver (backend)	6	INAF	R	PU	36
WP6.4	Description and evaluation of the Control, Recording & Correlation software.	6	ASTRON	R	PU	36
WP6.5	Test results of the integrated BRAND receiver.	6	MPG	R	PU	42
WP7.1	Report State of the Art on Algorithms	7	ASTRON	R	PU	6
WP7.2	Common Framework for Development	7	ASTRON	OTHER	PU	6
WP7.3	Data sets for testing and verification	7	ASTRON	OTHER	PU	12
WP7.4	First implementation on algorithms in Python	7	ASTRON	DEM	PU	18
WP7.5	Report on the strategies to combine results of tasks 7.1-7.4	7	ASTRON	R	PU	24
WP7.6	Final implementation of algorithms in CASA CORE	7	?	R	PU	30
WP7.8	Final Report	7	ASTRON	R	PU	36
WP14.1	ALTA assessment report	14	ASTRON	R	PU	24
WP14.1	ALTA assessment report	14	ASTRON	R	PU	36
WP14.1	ALTA assessment report	14	ASTRON	R	PU	48

LIST OF THE MILESTONES IS GIVEN IN THE TABLE 3.2A.

MILESTONE NUMBER	MILESTONE NAME	RELATED WORK PACKAGE	DUE DATE (IN MONTH)	MEANS OF VERIFICATION
2.1	Technical Workshop 1	2	10	Organisation of the event
2.2	YERAC	2	14	Organisation of the event
2.3	Large Radio Astronomical Conference	2	14	Organisation of the event
2.4	Technical Workshop 2	2	25	Organisation of the event
2.5	YERAC	2	26	Organisation of the event
2.6	Large Radio Astronomical Conference	2	30	Organisation of the event
2.7	Technical Workshop 3	2	40	Organisation of the event
2.8	Large Radio Astronomical Conference	2	44	Organisation of the event
3.1	Training events	3	10	Reports, web pages published
3.2	ARC Guide update/STM reports	3	12	Guide/report published
3.3	Training events	3	26	Reports, web pages published
3.4	ARC Guide update/STM reports	3	27	Guide/report published
3.5	Training events	3	43	Reports, web pages published
3.6	ARC Guide update/STM reports	3	43	Guide/report published
4.1	CRAF meeting 1	4	8	Meeting web-page
4.2	TOG meeting 1	4	10	Meeting web-page
4.3	Annual SPOOR meeting 1	4	12	Meeting web-page
4.4	CRAF meeting 2	4	20	Meeting web-page
4.5	TOG meeting 2	4	22	Meeting web-page
4.6	Annual SPOOR meeting 2	4	24	Meeting web-page
4.7	CRAF meeting 3	4	32	Meeting web-page
4.8	TOG meeting 3	4	34	Meeting web-page
4.9	Annual SPOOR meeting 3	4	36	Meeting web-page
4.10	CRAF meeting 4	4	44	Meeting web-page
4.11	TOG meeting 4	4	46	Meeting web-page
4.12	Delivery of final SPOOR report	4	46	Publication
5.1	Low-noise cryogenic MMIC amplifiers operating in W-band	5	34	Test report
5.2	W-band downconversion module based on a semiconductor MMIC	5	34	Test report
5.3	Multipixel demonstrator of FPA of MMIC receivers	5	40	Report on test on telescope
5.4	Single-chip 2SB SIS mixer operating around 1 mm wavelength	5	40	Test report
5.5	Multipixel demonstrator of FPA of miniaturized 2SB SIS mixer receivers operating around 1 mm	5	40	Report on test on telescope
5.6	Fabrication of SIS junction with very high current density for operation around 1 THz	5	34	Test report
5.7	Demonstrator of FPA of 2SB SIS mixer receivers operating around 1 THz	5	40	Test report

5.8	Multipixel demonstrator of FPA of HEB SIS mixer receivers operating around 1 THz	5	40	Operating
5.9	LO chain with high output power around 1 THz	5	34	Operating
6.1	Completion for primary focus feed prototype for a selected station	6	24	Report complete
6.2	Prototype feed evaluation	6	30	Operating
6.3	Completion of the report describing the secondary focus solution	6	24	Report complete
6.4	Completion of the HTS filter prototype	6	18	Report complete
6.5	HTS filter evaluation	6	24	Operating
6.6	Completion of the LNA prototype	6	24	Report complete
6.7	LNA testing results	6	30	Operating
6.8	ADC converter prototype ready	6	26	Report complete
6.9	ADC converter prototype testing with the basic functionalities	6	32	Operating
6.10	Processing board prototype ready	6	26	Report complete
6.11	Processing board testing with the basic firmware	6	32	Operating
6.12	Basic software initial version ready	6	26	Report complete
6.13	Basic software testing for the basic functions	6	32	Released and validated
6.14	Laboratory integration	6	40	Operating
7.1	End of RINGS preparatory phase	7	6	Report complete
7.2	First implementations of RINGS algorithms in Python	7	18	Test report
7.3	Strategy for single calibration approach	7	24	Minutes of the WP7 meeting
7.4	Final Implementation of algorithms in CASA	7	30	Released and validated
7.5	Final report and publication	7	36	Final report and publication submitted.

SUMMARY OF THE TRANS-NATIONAL ACCESS IS PROVIDED IN TABLE 3.2C.

------ to be provided in Draft 3 ---------------------

3.2 Consortium as a whole

Describe the consortium. How will it match the project's objectives? How do the members complement one another)? In what way does each of them contribute to the project? How will they be able to work effectively together?

The participants of RadioNet bring together a wide range of relevant expertise in the field of radio astronomy. The consortium involves 25 organisations, including all of the major radio observatories in Europe. In addition, institutes with state-of-the-art knowledge in advanced electronics are also valued partners in the programme. Strong collaborations exist with large international organisations and associations such as ESO, ALMA and the SKA project. The competence of the participants spans the areas of fundamental astrophysical research, operations of large-scale radio telescope facilities, scientific support, and innovative technology development for astronomical instrumentation. This distributed knowledge base reflects the diverse set of activities proposed within this proposal.

The consortium collectively has significant experience in managing large projects. The consortium is based on the previous *RadioNet* FP6 and FP7 partnerships; the long-standing collaboration and trust that exist between the participant guarantees good communication and an easy exchange of information.

TABLE3.3A – PARTNER INVOLVEMENT

	Partner	MGT	NA			JRA			TA						VA
	No/Name	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	WP10	WP11	WP12	WP13	WP14
1	MPG														
2	ASTRON														
3	IRAM														
4	INAF														
5	JIV ERIC														
6	UMAN														
7	OSO														
8	TCD														
9	STFC														
10	SRON														
11	OBSPARIS														
12	UOXF														
13	UAH														
14	TUD														
15	ESO														
16	Fraunhofer														
17	RUG														
18	DIAS														
19	ILT														
20	UMK														
21	UCO														
22	VENT														
23	AALTO														
24	U.Turku														
25	GLA														

Each WP is led by a particular institute and individuals, chosen by the consortium on the basis of their expertise. In this area, the experience of the consortium in producing high quality data products and making them available to the international astronomical community is considerable. The consortium operates most of the largest and best equipped telescopes in the world for single dish observations as well as in close collaboration for European and Global VLBI. The consortium also boasts significant expertise in the area of fundamental research and education. Partners include some of the largest universities and research institutes in Europe. They address problems in fundamental astrophysics and enjoy an international reputation in the development of advanced and innovative technology. The members of this consortium are responsible for a large fraction of all publications (both scientific and technical) associated with the field of radio astronomy.

In summary, the RadioNet consortium consists of internationally leading institutes with complementary and overlapping expertise, spread both within and across the partners. The consortium is mature and stable, but also flexible in terms of embracing new partners and ideas. In fact, this consortium has all the skills and competencies needed to handle the wide range of different activities and associated deliverables, as described in this proposal. The Table 3.3a shows the partner involvement in the RadioNet activities:

INDUSTRIAL/COMMERCIAL INVOLVEMENT

If applicable, describe the industrial/commercial involvement in the project to ensure exploitation of the results and explain why this is consistent with and will help to achieve the specific measures, which are proposed for exploitation of the results (see sec 2.3).

The main objectives of the RadioNet JRAs are to produce prototypes of highly specialised equipment and software for forefront astronomical research. Although there is no direct role for industrial partners within the project, many of the participants are closely connected to industrial parties (e.g. INAF) or have commercial business units (e.g. the Fraunhofer Institute for Applied Solid-State Physics). It is also expected that the JRA partners will make use of local SMEs for the manufacture of specialised passive components. In fact RadioNet JRA partners have not only studied , but also additionally they have studied the potential use of the results in other fields: scientific and industrial.

The laboratories involved in AETHRA have already close working relations with SMEs, such as TTI norte (Spain), which fabricates the low noise cryogenic amplifiers developed by IGN Yebes, Radiometer Physics (Germany), e2v (France) that collaborates with IRAM on the development of fast AD converters, Low Noise Factory (Sweden), STTproducts (the Netherlands), MECON BV (the Netherlands) and MM microwave (UK). Low-cost mm/sub-mm heterodyne receivers (AETHRA) will also have multiple applications beyond astronomy: Earth remote sensing, laboratory spectroscopy of molecules, high-resolution imaging (for medical, industrial or security applications). These applications will enhance the cooperation with industry, and may foster the creation of new technology companies active in the field of non-astronomical applications.

In case of BRAND EVN, there is already a small company HAT-Lab (http://www.hat-lab.com/), which agreed to manufacture and market sampler and processing unit. The analogue part is more difficult — horn, cryostat, and receiver control have to be adapted for each antenna. The LNAs might be produced by one of the partners (OAN) or small specialised companies like Low Noise Factory (http://www.lownoisefactory.com/) in Sweden.

RINGS will organize interaction with the Radar and Seismic Imaging industry to exchange algorithmic approaches for phase calibration and enhance cross fertilization between these domains. The envisaged RINGS results will expectedly allow further valorisation. The open-source S/W for antenna pattern description is likely to have benefits for industry and academia.

OTHER COUNTRIES:

At present, the RadioNet project does not involve partners from countries non-eligible for EU funding.

3.3 Resources to be committed

European radio astronomical collaboration in R&D was always strongly supported by the participating institutes, with the ultimate aim of promoting the excellence of European radio astronomy. The EC funds played permanently a crucial role in supporting those initiatives. The European radio astronomical community has worked together in several projects under the European Research Framework Programmes for the past three decades (in particular RadioNet, SKA-related or DG-Connect EXPRES projects).

MGT BUDGET

The MGT of the project will be centralised at the MPG. The management team has been identified to ensure the and most economic performance. The members of MGT team and their duties described in the Sec.3.2, generate the major part of the expected cost – personnel cost of the manager and assistants of the project (see Tabl3.4c). A small part of the budget has been reserved for PC-equipment for the management team. The remaining budget will be use for the support of the organisation of consortium meetings and support for travel costs of the members of the governing bodies, advisory groups and invited guests. Approximately 25000€ will be reserved for the production of project outreach material and purchasing open access for publications in journals like IEEE.

The total MGT budget is 9% of the project cost, which is justified by the size of the project, its complexity and the responsibility of management functions. The management plays a critical role, not only for the execution of the overall project, but also by taking over the administrative aspects of the individual NA and TA tasks.

TABLE 3.4C MGT AND NA BUDGETS, INCLUDING A TA TRAVEL BUDGET

Management and centralised NA and TA travel budgets					
Beneficiary	WP1	WP2	WP3	WP4	WP8-14
MPG	Management	Dissemination	Training	Sustainability	TA travel budget
Personnel cost	600.000,00	0,00	0,00	0,00	0,00
Travel	90.000,00	180.000,00	220.000,00	140.000,00	125.000,00
Equipment	5.000,00				
Other	25.000,00				
Total other cost	120.000,00	180.000,00	220.000,00	140.000,00	125.000,00
Subcontracting	0,00	0,00	0,00	0,00	0,00
Indirect cost	180.000,00	45.000,00	55.000,00	35.000,00	31.250,00
Total cost	900.000,00	225.000,00	275.000,00	175.000,00	156.250,00
EC contribution	**900.000,00**	**225.000,00**	**275.000,00**	**275.000,00**	**156.250,00**

900.000,00	775.000,00	156.250,00
MGT	NA	TA travel

NA/TA TRAVEL BUDGET

Based on earlier experiences, the NA and TA travel budget including support for the event organisation will be centrally allocated at MPG (see Table 3.4.c). Each NA activity has an individual budget, which will be mostly used to support the events organisational cost and its participants. A support of each NA will be allocated by a selection committee, whose members will be appointed by the Board upon the suggestion of the NA leader. The selection of supported events and its participants will be based on the scientific excellence and its relevance for the radio astronomy community at large, and will follow the principles of transparency, fairness and impartiality. However, priority will be given to participants coming from countries without radio astronomical infrastructures, early career scientists and females.

In contrast to NAs, there will be only one TA travel budget of 125.000€ allocated at MPG, to be shared between the TA activities. Each TA leader will be responsible for the allocation of the travel support. The priority will be given to the telescope users, when possible some of the cost of the Proposal Committee and TA leader meetings could be reimbursed. The central TA budget will allow for effective and flexible use addressing the demand without unnecessary delay. The demand at each TA infrastructure will be defined and monitored regularly, and changed when needed.

The settlement of the TA/NA reimbursement will be done by the MPG, based on its national financial rules. Only costs that are reasonable, justified and that comply with the principles of sound financial management, in particular regarding economy and efficiency (i.e. be in line with good housekeeping practice when spending public money and not be excessive) will be reimbursed. A preliminary number of expected events and users travelling to the TA infrastructures are given in the individual NA and TA descriptions (Table 3.1a).

Templates for the reimbursement forms including the financial regulations will be created and provided by the MGT to the affected parties and stored for download at the project webpage. A regular updates on the spending of the NA/TA travel budget will be provided quarterly to the respective WP leaders. It will ensure that any reallocation of the budget can be addressed directly following the project rules (e.g. upon approval of the Board and EC).

JRA BUDGET

The resources to be committed in the Joint Research Activities (WP5 – WP7) are presented in Table 3.4d. As could be expected from a development project, the main part of the total budget requested for the JRAs is related to personnel costs. Some of the activities have allocated budget for equipment and material. These costs are summarised in the category “other”. As WP internal meetings are foreseen on a regular basis, a fraction of the JRA budget has been allocated for travel. In case of WP6 BRAND significant amount of travel costs is needed by the partner UAH to allow a team to travel to the European EVN telescopes to obtain of the antenna specifications. The WP5 AETHRA requires budget of 160.500€ for purchase of components and other consumables (see the WP5 description). Additionally, a budget for use of the clean-room facilities at Fraunhofer is foreseen (102.000€).

The JRAs have an ambitious, but feasible scope. The EC contribution to the programme is important, but is also seen as a co-fund to the real cost. To enable the timely realisation of the work plan, the partners will commit additional resources. This contribution will be offered by manifold means: some partners will contribute with additional manpower, others will provide access to their facilities.

Additionally, Table 3.4A person-months required for the action and Table 3.4B lists other items only for MPG, participant which provides trans-national access and has allocated travel budget for the visit of the selected users. The Table 3.4B includes also justification of cost for each participant, if the sum of the costs for travel, equipment, and goods and services exceeds 15% of the personnel costs for that participant.

TABLE 3.4D JRA RESOURCES TO BE COMMITTED

Beneficiary	PM	Personnel cost	Travel	Equipment	Other cost	Total other cost	Subcontracting	Indirect cost	Total cost	EC contribution
WP5 AETHRA										
IRAM	40	323.000,00	5.000,00	20.000,00	20.000,00	45.000,00		92.000,00	460.000,00	**460.000,00**
MPG	6	63.000,00	3.000,00	11.000,00	11.000,00	25.000,00		22.000,00	110.000,00	**110.000,00**
Fraunhofer	6	54.500,00	3.000,00		102.500,00	105.500,00		40.000,00	200.000,00	**200.000,00**
OSO	9	67.500,00	3.000,00		9.500,00	12.500,00		20.000,00	100.000,00	**100.000,00**
RUG	16	120.000,00	3.000,00	10.000,00	3.000,00	16.000,00		34.000,00	170.000,00	**170.000,00**
SRON	14	105.000,00	3.000,00	12.000,00		15.000,00		30.000,00	150.000,00	**150.000,00**
TUD	0									**0,00**
STFC	6	61.000,00	3.000,00	10.000,00	6.000,00	19.000,00		20.000,00	100.000,00	**100.000,00**
UOXF	15	76.500,00	3.000,00		8.500,00	11.500,00		22.000,00	110.000,00	**110.000,00**
UCO	6	41.500,00	3.000,00		11.500,00	14.500,00		14.000,00	70.000,00	**70.000,00**
OBSPARIS	10	64.000,00	3.000,00		13.000,00	16.000,00		20.000,00	100.000,00	**100.000,00**
INAF	4	21.100,00	2.900,00			2.900,00		6.000,00	30.000,00	**30.000,00**
UAH	31	113.500,00	3.000,00		3.500,00	6.500,00		30.000,00	150.000,00	**150.000,00**
WP5	169	1.136.100,00				303.900,00		360.000,00	1.800.000,00	1.800.000,00
WP6 BRAND EVN										
MPG	55	389.583,33	9.000,00			9.000,00		99.645,83	498.229,17	**498.229,17**
INAF	52	372.666,67	7.000,00			7.000,00		94.916,67	474.583,33	**474.583,33**
OSO	27	193.500,00	6.000,00			6.000,00		49.875,00	249.375,00	**249.375,00**
UAH	42	175.000,00	25.000,00			25.000,00		50.000,00	250.000,00	**250.000,00**
ASTRON	9	63.750,00	6.000,00			6.000,00		17.437,50	87.187,50	**87.187,50**
VENT	0	0,00	0,00			0,00		0,00	0,00	**0,00**
WP6	185	1.194.500,00				53.000,00		311.875,00	1.559.375,00	**1.559.375,00**
WP7 RINGS										
MPG	5	39.583,33	3.000,00			3.000,00		10.645,83	53.229,17	**53.229,17**
JIVE	14	102.666,67	5.000,00			5.000,00		26.916,67	134.583,33	**134.583,33**
ASTRON	13	102.916,67	10.000,00			10.000,00		28.229,17	141.145,83	**141.145,83**
UMAN	13	102.916,67	5.000,00			5.000,00		26.979,17	134.895,83	**134.895,83**
OSO	13	94.250,00	5.000,00			5.000,00		24.812,50	124.062,50	**124.062,50**
DIAS	21	82.250,00	5.000,00			5.000,00		21.812,50	109.062,50	**109.062,50**
WP7	79	524.583,33				33.000,00		139.395,83	696.979,17	**696.979,17**

TABLE 3.4A SUMMARY OF STAFF EFFORT (IT WILL BE UPDATE IN DRAFT 3)

Participant number / short name		WP 1	WP 2	WP 3	WP 4	WP 5	WP 6	WP 7	WP 8	WP 9	WP 10	WP 11	WP 12	WP 13	WP 14	Total
1	MPG	90	0	0	0	6	55	5	0	0	0	0	0	0	0	156,0
2	ASTRON	0	0	0	0	0	9	13	0	0	0	0	0	0	0	22,0
3	IRAM	0	0	0	0	40	0	0	0	0	0	0	0	0	0	40,0
4	INAF	0	0	0	0	4	52	0	0	0	0	0	0	0	0	56,0
5	JIV ERIC	0	0	0	0	0	0	14	0	0	0	0	0	0	0	14,0
6	UMAN	0	0	0	0	0	0	13	0	0	0	0	0	0	0	13,0
7	OSO	0	0	0	0	9	27	13	0	0	0	0	0	0	0	49,0
8	UCAM	0	0	0	0	6	0	0	0	0	0	0	0	0	0	6,0
9	STFC	0	0	0	0	6	0	0	0	0	0	0	0	0	0	6,0
10	SRON	0	0	0	0	14	0	0	0	0	0	0	0	0	0	14,0
11	OBSPARIS	0	0	0	0	10	0	0	0	0	0	0	0	0	0	10,0
12	UOXF	0	0	0	0	15	0	0	0	0	0	0	0	0	0	15,0
13	UAH	0	0	0	0	31	42	0	0	0	0	0	0	0	0	73,0
14	TUD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,0
15	ESO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,0
16	Fraunhofer	0	0	0	0	6	0	0	0	0	0	0	0	0	0	6,0
17	RUG	0	0	0	0	16	0	0	0	0	0	0	0	0	0	16,0
18	DIAS	0	0	0	0	0	0	21	0	0	0	0	0	0	0	21,0
19	ILT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,0
20	UMK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,0
21	UCO	0	0	0	0	6	0	0	0	0	0	0	0	0	0	6,0
22	VENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,0
23	AALTO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,0
	Total person / month	90,0	0,0	0,0	0,0	169,0	185,0	79,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	523,0

TABLE 3.2B: SUMMARY OF TRANS-NATIONAL/VIRTUAL ACCESS PROVISION (WILL BE UPDATED IN DRAFT 3)

Access provider short name	Short name of infrastructure	Installation		Installation country code	Type of access	Unit of access	Unit cots (UC) (€)	Min. quantity of access to be provided	Access cost	Estimated number of users	Estimated number of user projects
		Nr	Short name						On the basic of UC		
JIVE	EVN	1	JIVE	IO	TA-uc	Network observing hours					
UMAN	EVN	2	JBO	UK	TA-uc	Network observing hours					
MPG	EVN	3	Eff	DE	TA-uc	Network observing hours					
ASTRON	EVN	4	WSRT	NL	TA-uc	Network observing hours					
OSO	EVN	5	On	SE	TA-uc	Network observing hours					
INAF	EVN	6	Mc	IT	TA-uc	Network observing hours					
INAF	EVN	7	Nt	IT	TA-uc	Network observing hours					
INAF	EVN	8	SRT	IT	TA-uc	Network observing hours					
UAH	EVN	9	Yb	ES	TA-uc	Network observing hours					
AALTO	EVN	10	Mh	FI	TA-uc	Network observing hours					
UMK	EVN	11	Tr	PL	TA-uc	Network observing hours					
VENT	EVN	12	Ib	LV	TA-uc	Network observing hours					
UMAN	e-MERLIN			UK	TA-uc	Observing hours					
IRAM	IRAM	1	NOEMA	FR	TA-uc	Observing hours					
IRAM	IRAM	2	PV	ES	TA-uc	Observing hours					
ASTRON	LOFAR			NL	TA-uc	Observing hours					
ASTRON	WSRT			NL	TA-uc	Observing hours					
MPG	Effelsberg			DE	TA-uc	Observing hours					
OSO	APEX			CL	TA-uc	Observing hours					

____The TA costs, access hours, number of users and projects will be given in Feb 2016, when the cost/hour will be calculated____

TABLE 3.4B OTHER DIRECT COST' ITEMS (TRAVEL, EQUIPMENT, OTHER GOODS AND SERVICES)

Please complete the table below for each participant which provides trans-national access and foresees costs for travel and subsistence needed to support the visits of the selected users.
Please also complete the table below for each participant if the sum of the costs for' travel', 'equipment', and 'goods and services' exceeds 15% of the personnel costs for that participant (according to the budget table in section 3 of the proposal administrative forms).
This table will be provided later on.

MPG	Cost (€)	Justification
Travel & subsistence for trans-national access	125000€	A central TA travel budget will be created. This will unburden the TA leaders and their institutes. An efficient handling of the claim will be assured. The use of the budget will be a subject for agreement between the TA leaders and it will depend on the TA users demands.
Other Travel	90.000€ (MGT)	Organisational cost and support for travel cost of the participants and guest for 4 meetings of the Board (40.000€), 4 Exec meetings (20.000€), 4 NA leader meetings (8000€), 6 TA leaders meetings (8.000€). Additionally the cost of the MGT participation in the JRAs annual meetings, scientific conferences including booth, meetings with the project officer (19.000€)
	540.000€	Events organised and supported by the project NAs (for the details see WP descriptions). 180.000€ for the NA-Dissemination, 220.000€ for the NA-Training, and 140.000€ for the NA-Sustainability
	17.000€	Cost of the JRA activity meetings: JRA-AETHRA (5000€), JRA-BRAND EVN (9000€, including travel of the activity leader), and JRA-RINGS (3000€).
Equipment	16.000€	Equipment for the MGT team (5000€) and the JRA AETHRA (11.000€).
Other goods and services	36.000€	Production of the project outreach material, audit costs and the cost for the open access to the project publications 25.000€). ???? in AETHRA (11.000€).

UCAM	Cost (€)	Justification
Travel & subsistence for trans-national access		
Other Travel		
Equipment		
Other goods and services		

STFC	Cost (€)	Justification
Travel & subsistence for trans-national access		

Other Travel		
Equipment		
Other goods and services		

OBSPARIS	Cost (€)	Justification
Travel & subsistence for trans-national access		
Other Travel		
Equipment		
Other goods and services		

Fraunhofer	Cost (€)	Justification
Travel & subsistence for trans-national access		
Other Travel		
Equipment		
Other goods and services		

UCO	Cost (€)	Justification
Travel & subsistence for trans-national access		
Other Travel		
Equipment		
Other goods and services		