

VLBI in Cycle-4

OBSMODE Meeting
May 5-7, Socorro NM
G. Crew & L. Matthews
for the ALMA Phasing Project



Topics in this Presentation

- History of the ALMA Phasing Project
- **Technical Implementation Status**
- Operational Approach
- Path to Cycle 4

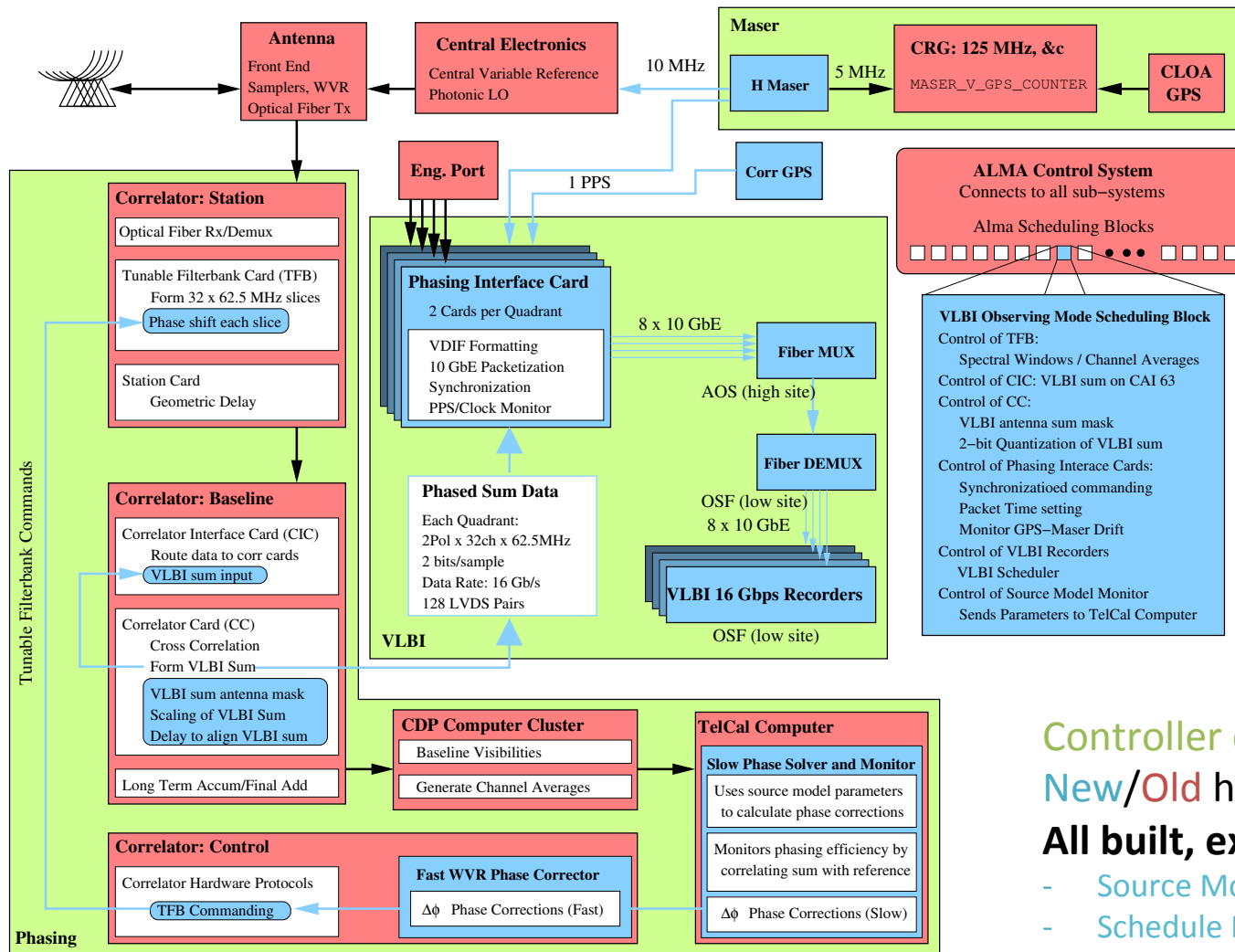
ALMA Phasing Project, a brief history

- A development project to phase-up ALMA and record the summed signal for mm/sub-mm VLBI:
 - Project accepted in 2012, CDR in May 2013:
 - Complete h/w & s/w designs & development plans
 - Rigorous adherence to ALMA standards and requirements
 - Commissioning plan
 - Operations plan proposal
 - Hardware Accepted: Dec 2014 (with minor RIDs)
 - S/W implemented in R10.4-R2014.6 (R2015.2++)
 - Commissioning: Jan 2015-(August 2015)
- Nominal completion of “phase 1” Aug 2015.
- The road to Cycle-4 is “phase 2”.

Why VLBI?

- Two general white papers and workshops
 - I.e. Not **just** the EHT
 - Future mmVLBI Research with ALMA: A European vision
 - R.P.J. Tilanus, T.P. Krichbaum, J.A. Zensus, A. Baudry, M. Bremer, H. Falcke, G. Giovannini, R. Laing, H. J. van Langevelde, W. Vlemmings, Z. Abraham, J. Afonso, I. Agudo, A. Alberdi, J. Alcolea, D. Altamirano, S. Asadi, K. Assaf, P. Augusto, A-K. Baczko, M. Boeck, T. Boller, M. Bondi, F. Boone, G. Bourda, R. Brajsa, J. Brand, S. Britzen, V. Bujarrabal, S. Cales, C. Casadio, V. Casasola, P. Castangia, J. Cernicharo, P. Charlot, L. Chemin, Y. Clenet, F. Colomer, F. Combes, J. Cordes, M. Coriat, N. Cross, F. D'Ammando, D. Dallacasa, J-F. Desmurs, R. Eatough, A. Eckart, D. Eisenacher, S. Etoaka, M. Felix, R. Fender, M. Ferreira, E. Freeland, S. Frey, C. Fromm, L. Fuhrmann, K. Gabanyi, R. Galvan-Madrid, M. Giroletti, C. Goddi, J. Gomez, E. Gourgoulhon, M. Gray, I. di Gregorio, R. Greimel, et al. (103 additional authors not shown)
 - High-Angular-Resolution and High-Sensitivity Science Enabled by Beamformed ALMA
 - Vincent Fish, Walter Alef, James Anderson, Keiichi Asada, Alain Baudry, Avery Broderick, Chris Carilli, Francisco Colomer, John Conway, Jason Dexter, Sheperd Doleman, Ralph Eatough, Heino Falcke, Sándor Frey, Krisztina Gabányi, Roberto Gálvan-Madrid, Charles Gammie, Marcello Giroletti, Ciriaco Goddi, Jose L. Gómez, Kazuhiro Hada, Michael Hecht, Mareki Honma, Elizabeth Humphreys, Violette Impellizzeri, Tim Johannsen, Svetlana Jorstad, Motoki Kino, Elmar Körding, Michael Kramer, Thomas Krichbaum, Nadia Kudryavtseva, Robert Laing, Joseph Lazio, Abraham Loeb, Ru-Sen Lu, Thomas Maccarone, Alan Marscher, Iván Mart'i-Vidal, Carlos Martins, Lynn Matthews, Karl Menten, Jon Miller, James Miller-Jones, Félix Mirabel, Sebastien Muller, Hiroshi Nagai, Neil Nagar, et al. (21 additional authors not shown)
 - Recent workshop (Jan 2015)
 - http://www.alma.inaf.it/index.php/Workshop_on_mm-VLBI_with_ALMA

Technical Implementation Status, cartoon

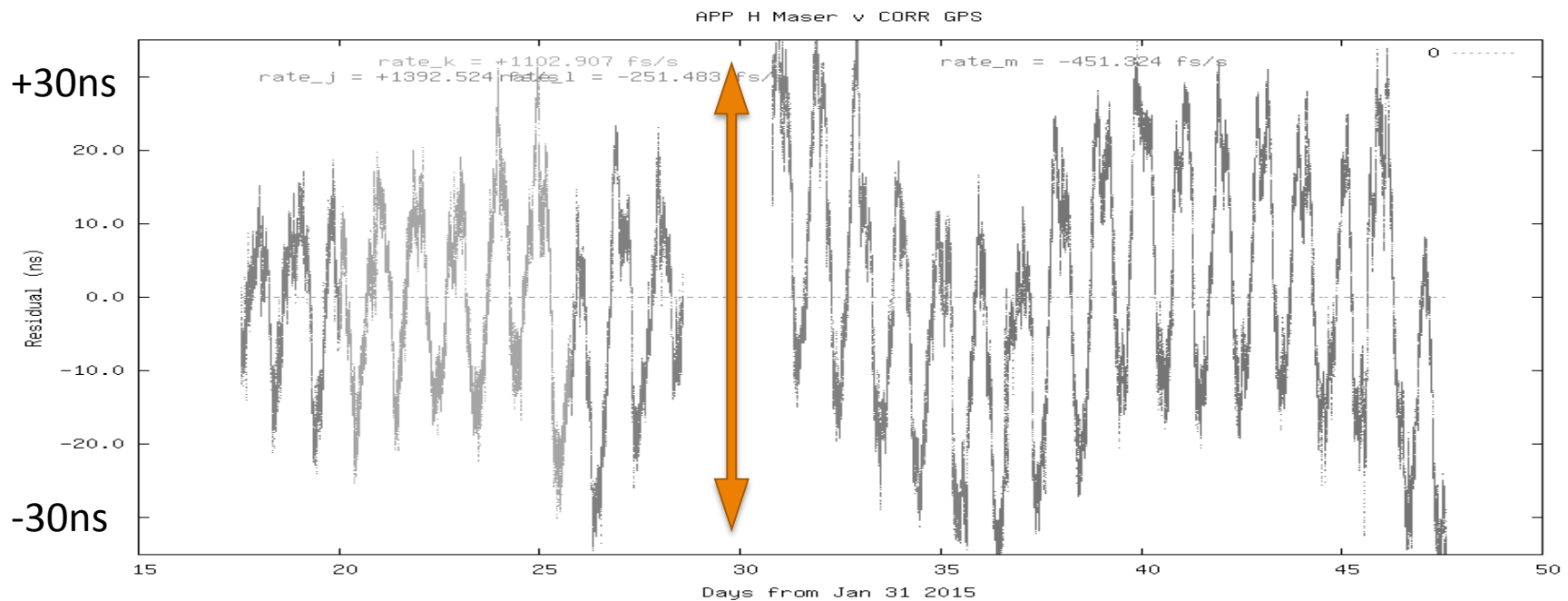


Controller domain
New/Old h/w & s/w
All built, except for:

- Source Modeler
- Schedule Block

Hardware Status, Maser, done

- H Maser accepted Nov 2014
- Power-cycled during Feb. Maintenance
- Works fine (residuals of GPS-Maser fit: **ionospheric TEC variations**)



5/4/15

Days after power-cycling completed

1 month

6

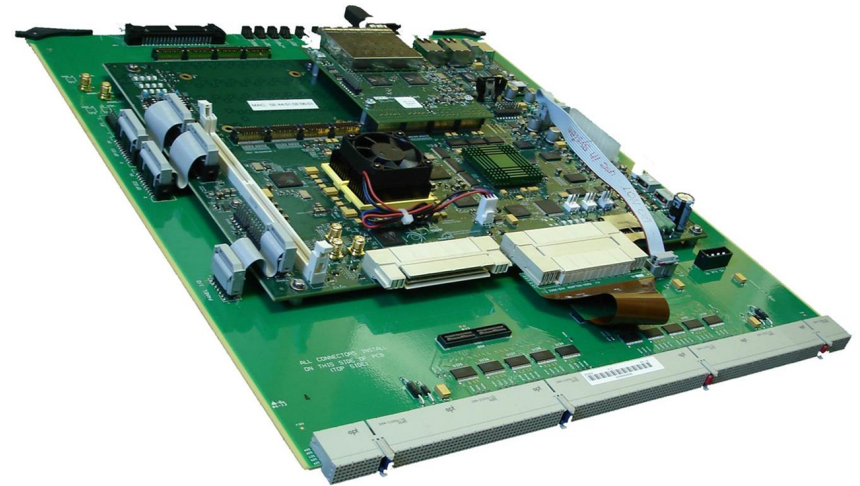
Hardware Status, OFLS + Recorders, done

- Delivery complete 2014
- Mux (AOS) + DeMux (OSF)
- 4 Recorders + 1 spare
- KVM switch and monitor
- Modules tested for 2900m
- ~ PB of test recordings onto 24TB and 32TB modules; 48TB modules current state-of-art
- Used in Jan 2015 VLBI test with APEX (about ~2hrs x 2d)
- System error rate ~ 1ppm on every 8 data streams
- V1.2j of s/w installed



Hardware Status, Phasing Interface Cards, done

- 4 PIC pairs installed in 4 quadrants, June 2014
- TTL to LVDS converter for (Correlator GPS and Maser) PPS monitoring
- Many additional signal cables (2b x 32 ch/PIC) installed and checked.



Software Status, overview

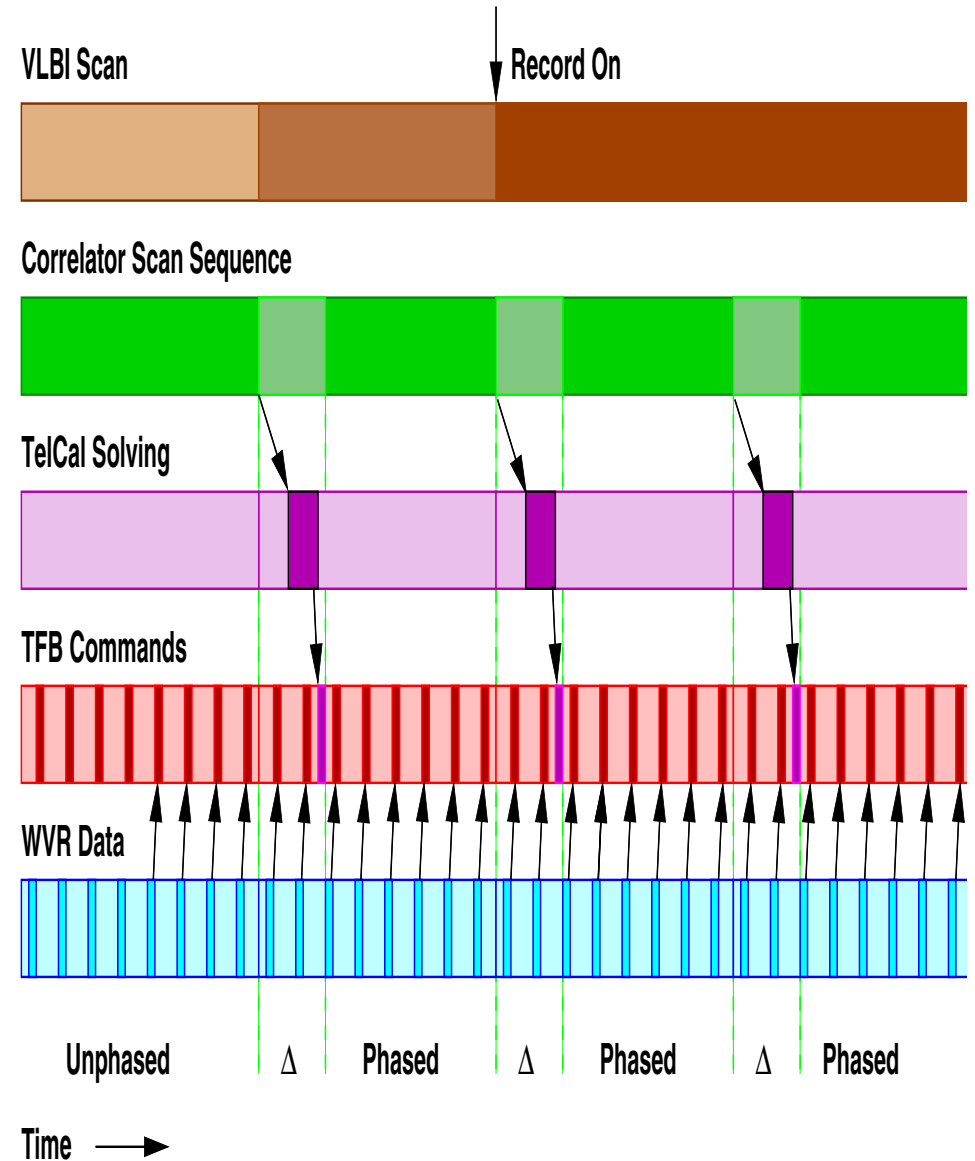
- New observing mode (VOM) derived from standard interferometry (Interferometry controller) w/new controllers (Phasing Controller & VLBI Controller)
- Basic interface changes in place since R10.6
- Verification/Validation missions:
 - Jan 2014: Basic phasing system (R10.6)
 - Jul 2014: VLBI hardware integration (R10.8, R2014.2)
 - Oct 2014: Slow + Fast phasing loops (R2014.4)
 - Jan 2015: Single-dish VLBI with APEX (R2014.4)
 - Mar 2015: Phasing commissioning (R2014.6)

Software Status, continued

- ICT Task Status:
 - 67 **Closed** (*i.e.* work completed)
 - 15 *Submitted, In Progress or Implemented*
 - **Relatively minor effort required for these**
 - SSR refactoring of test observing script
 - VEX2VOM (convert VEX to SB/support)
 - GUIs for monitoring VOM activity
 - 5 **Verified, awaiting validation**
 - Making very good progress on commissioning
 - March mission produced some good data in expected mode
 - Still need more data to complete commissioning
 - There are some issues with the current implementation
 - Commissioning plan includes non-ICT-task items

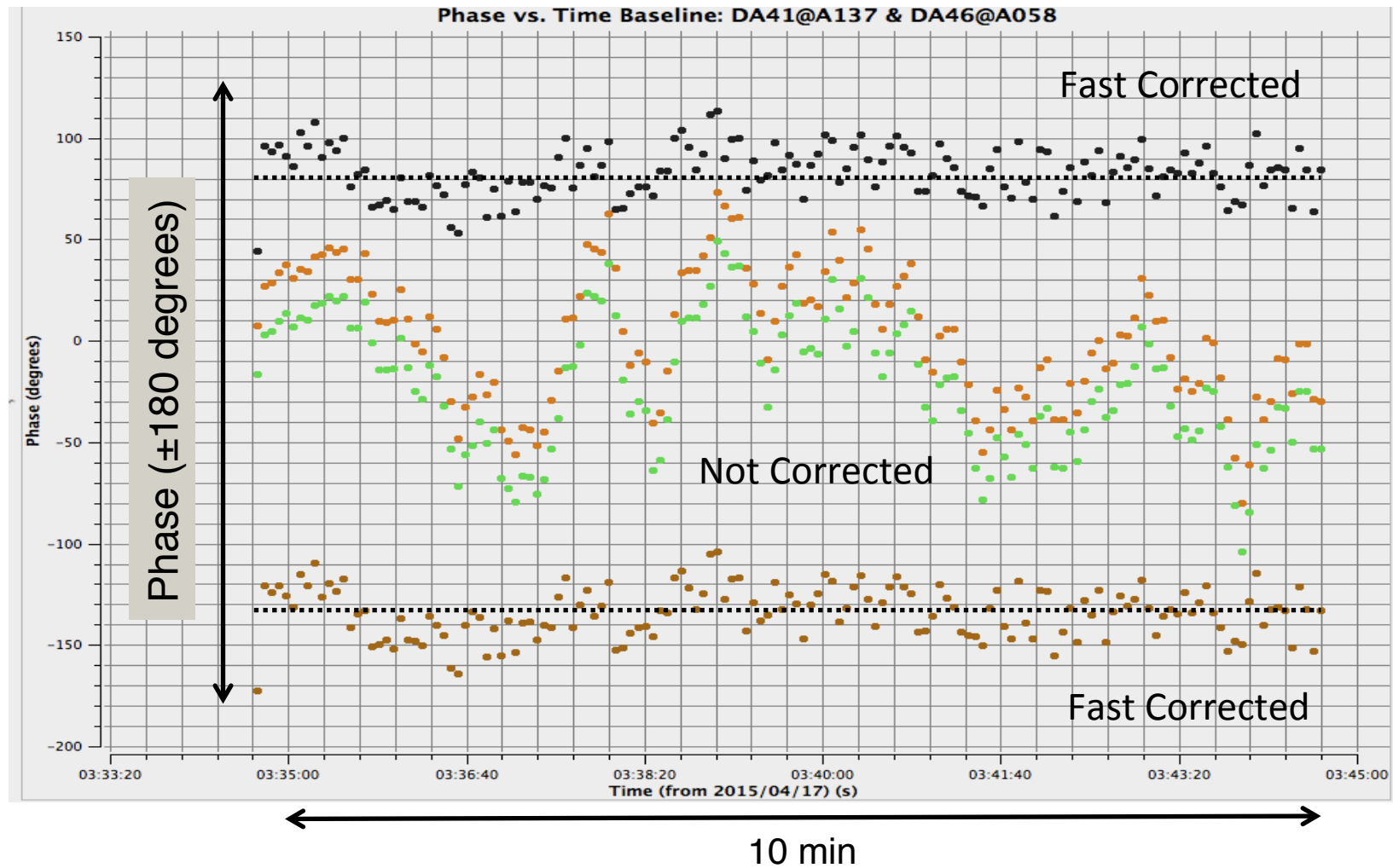
Some Results, Phasing system

- Timeline of “scans”
- Two time-scales for adjusting the phases in the TFBs
 - “Slow” phasing loop
 - “Fast” adjustments
- Proper tuning of Slow and Fast can be used to better manage weather



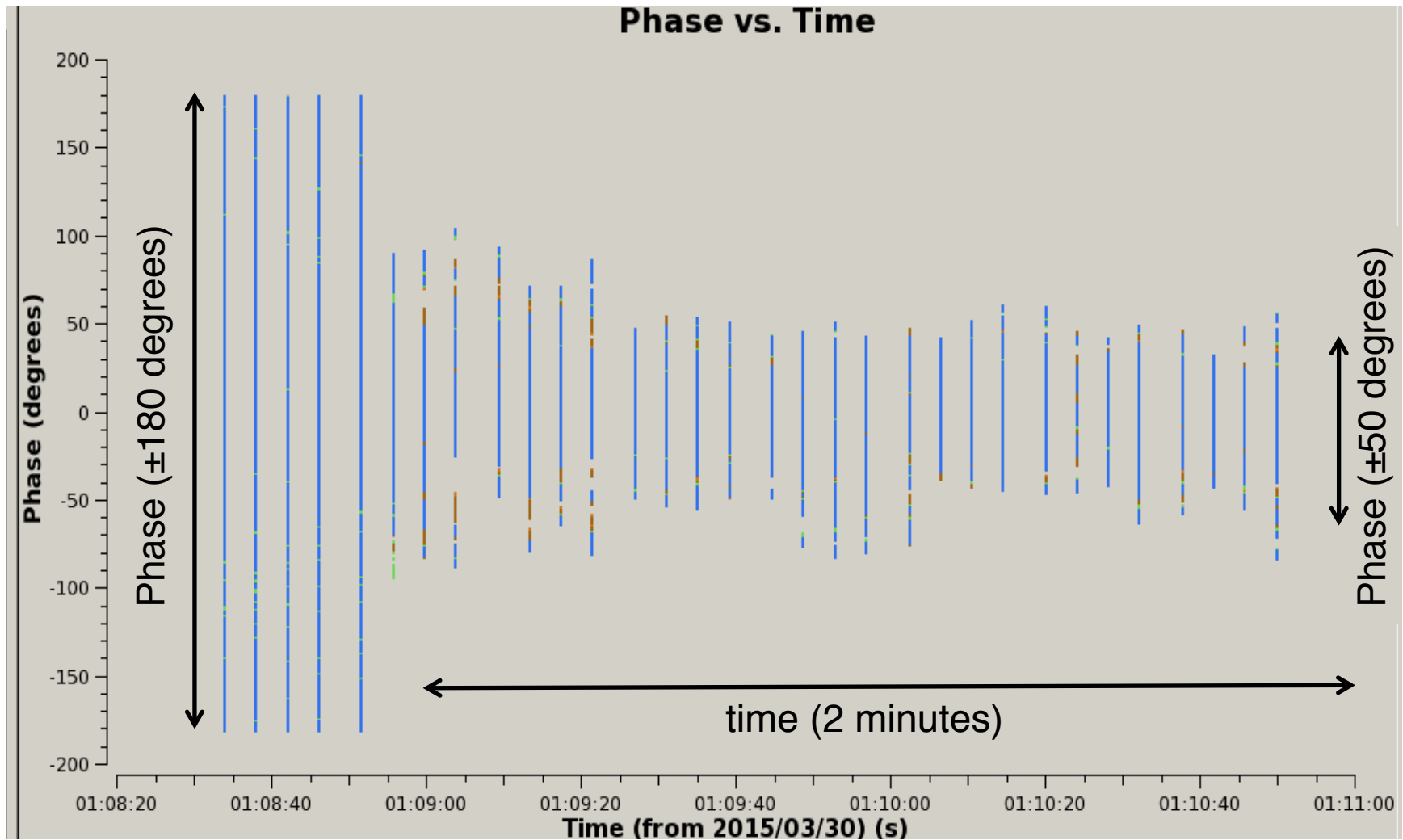
Fast WVR Correction

4 SWs in parallel, band 6; 2 SWs corrected , 2 SWs un-phased; one baseline



“It works” – Band 3 phasing from March 2015

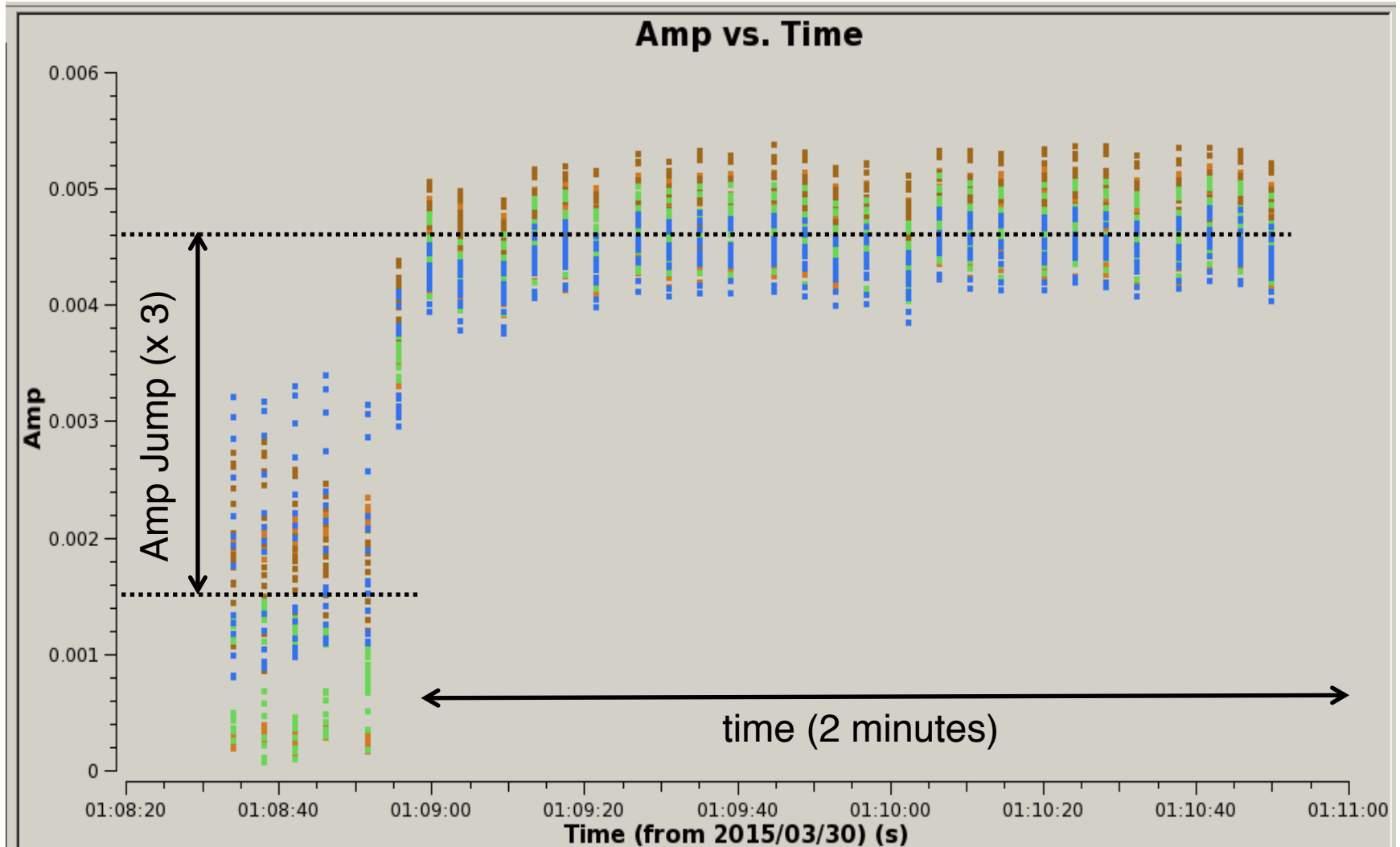
All 4 quadrants, both pols, 8 ChAvs/SW; 16-s scans with 4-s integrations

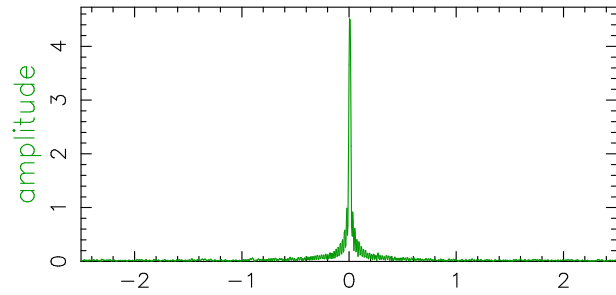
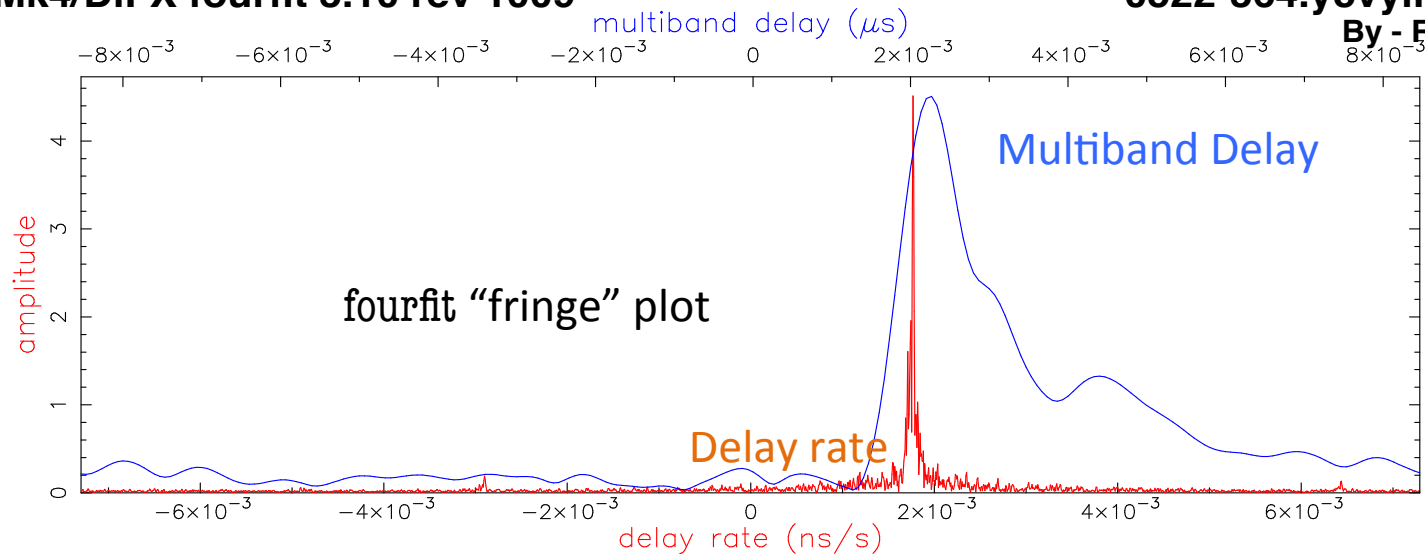


“It works” – Band 3 amplitude

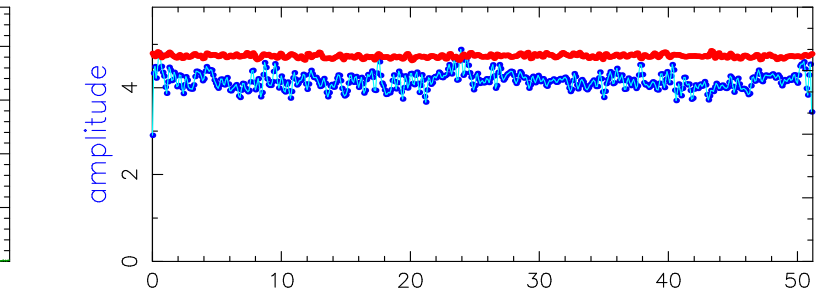
Have similar Band 6 results

9 antennas, Sum “Antenna” v Comparison antenna, **All** baselines/pols/Ch.Avs





Singleband Delay



Ave Cross Power Spectrum

Fringe quality 3

SNR 391.2

Int time 299.970

Amp 4.730

Phase 110.7

PFD 0.0e+00

Delays (us)

SBD 0.007200

MBD 0.002250

Fringe rate (Hz)

0.377732

Ion TEC 0.00

Ref freq (MHz)

214055.6969

AP (sec) 0.320

Exp. Jan13B1e

Exper # 7187

Yr:day 2015:013

Start 063000.00

Stop 063500.16

FRT 063230.00

Corr/FF/build

2015:113:203411

2015:113:203948

2015:113:083619

RA & Dec (J2000)

05h22m57.9846s

VLBI with APEX, 0522-364 on Jan 13 2015, Y polarization of Quadrant 1

Array was un-phased in Band 6 due to delay issue (rather severe for quadrant 1). The baseline to APEX was 2 km and the ALMA array reference center is sufficient for a fringe. (The analysis has yet to be done on fine-tuning the position; no "phase cal" corrections applied.) The bandwidth in each TFB channel was trimmed to 51.2 MHz for 32 channels. Similar results (on 2 days) were obtained for 3c279, 1246-257, Cen-A (1322-427) as well as 0522-364

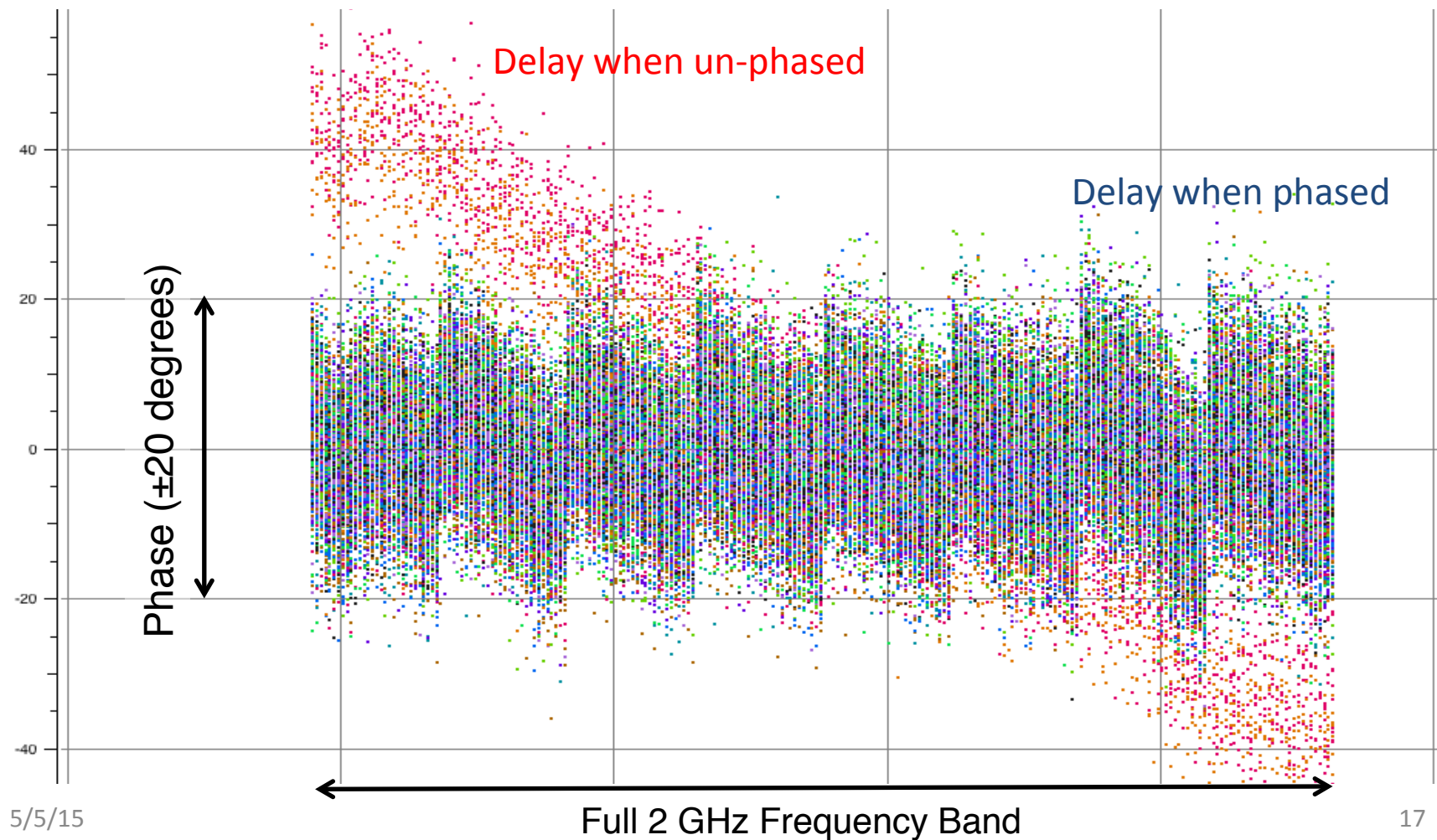
Some Issues (delay)

- Delay issue (found and solved in February)
 - Phase sum is constructed **prior** to baseband delay corrections made within CDP processing nodes
 - Sum is phased by TelCal, then un-phased by the missing delay correction (hence Jan12/13 fringes are effectively single dish)
 - Understood and partially fixed in Feb: baseband delay processing in CDP must be turned off so that TelCal sees what the antenna **summer** sees
 - Consequence: delay correction is not done by CDP processing for archived data (CASA).
- Other solutions may be possible but have not yet been explored

Phase of Comp. Ant Relative to Ref. Antenna

Example DA58 (reference antenna) & DV11
(phased in most scans; un-phased for some)

The maximum of eight
Channel Averages were used



Some Issues (channelization)

- Not enough spectral windows to allow full use of current channelized peer systems in band 3 (VLBA or GMVA)
 - Need 16 or more to match PFBs of DBEs
 - Sampling mismatch (2^N MHz v 4000 MHz)
 - ICT-3852 can be an ALMA development priority
- Not enough channel averages in band 6 (EHT)
 - Current EHT DBE is single channel
 - 8 is the maximum allowed by APDM (ICT-4656)
 - Loss of SNR (quite a bit more than a few percent)

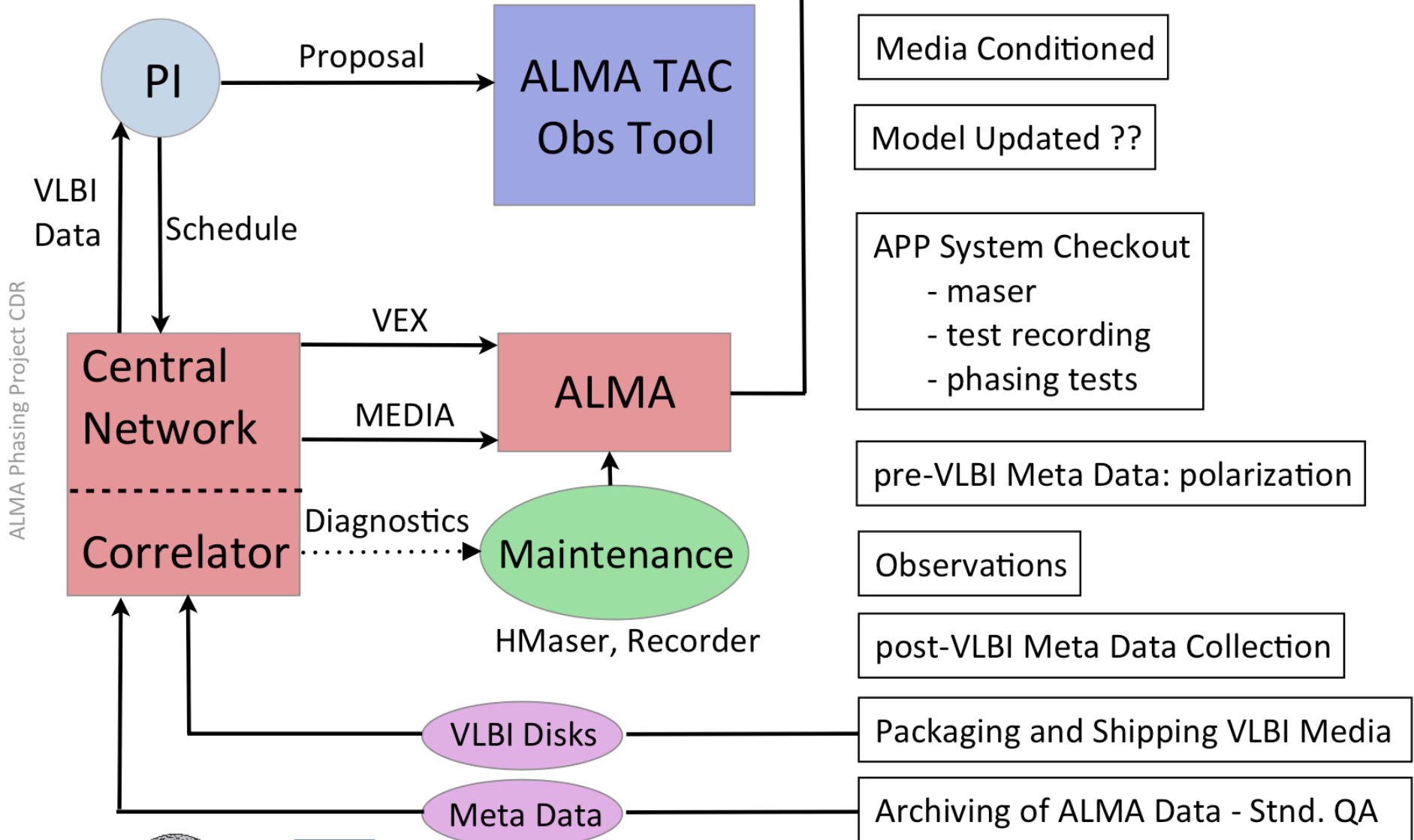
Some Issues (performance)

- TelCal performance
 - WVR corrections in R2014.6 take too long with many antennas (presently)
 - APP Phase results available quickly (1-2 sec) but must wait for full meta-data to be published
 - (A fix to work around these was *just* implemented)
- Scheduling campaigns for Band 3 or 6
 - Must align with EOC weeks and peer observatory sessions and weather
- VLBI (linear to circular transform) relies on ALMA polarization calibration. Have a tool for this, but it needs more work.

Discussion Topics

- **Operational Approach**
- Path to Cycle 4

VLBI Observation Flow:



ALMA Phasing Project CDR



5/4/1

Some Operational Comments

- VBLI hardware probably mothballed between observations:
 - Power-up & check-out procedures
 - Supporting test scripts
- Observation via schedule block
- **Sub-arrays cannot be active**
- Post-observation activities
 - Gather logs for correlation
 - Power-down & mothball procedures
- VLBI Correlation at Haystack/Bonn (Mk6 units)
- Module shipment

Discussion Topics

- Operational Approach
- **Path to Cycle 4**

OT Considerations

- VOM derived from Standard Interferometry
 - OT can be used as for continuum or line projects
 - “check box” for:
 - Full VLBI (Phasing and Recording)
 - Phasing alone (or Recording alone)
 - Need to capture enough of SB for planning
 - VLBI session(s) will need to be subdivided into shorter observations
- VEX2VOM tool must reconcile final VEX with project SB to generate execution instances

SSR Implementation

- CalAPPTarget started
- Need to refactor test script functions into form more suitable for invocation via SB
- Still need to develop “smarts” for transforming VEX inputs to specific run parameters based on conditions at time of execution.
- Calibration items

Pipeline & Archive

- Process as for interferometry
- Current Delay implementation poses some problems which may be left for the observer
- “non-standard forever...so don't care”
- Archive of VLBI products...

UN-SORTED, BACKUP MATERIAL

VLBI works in AIPS too.

