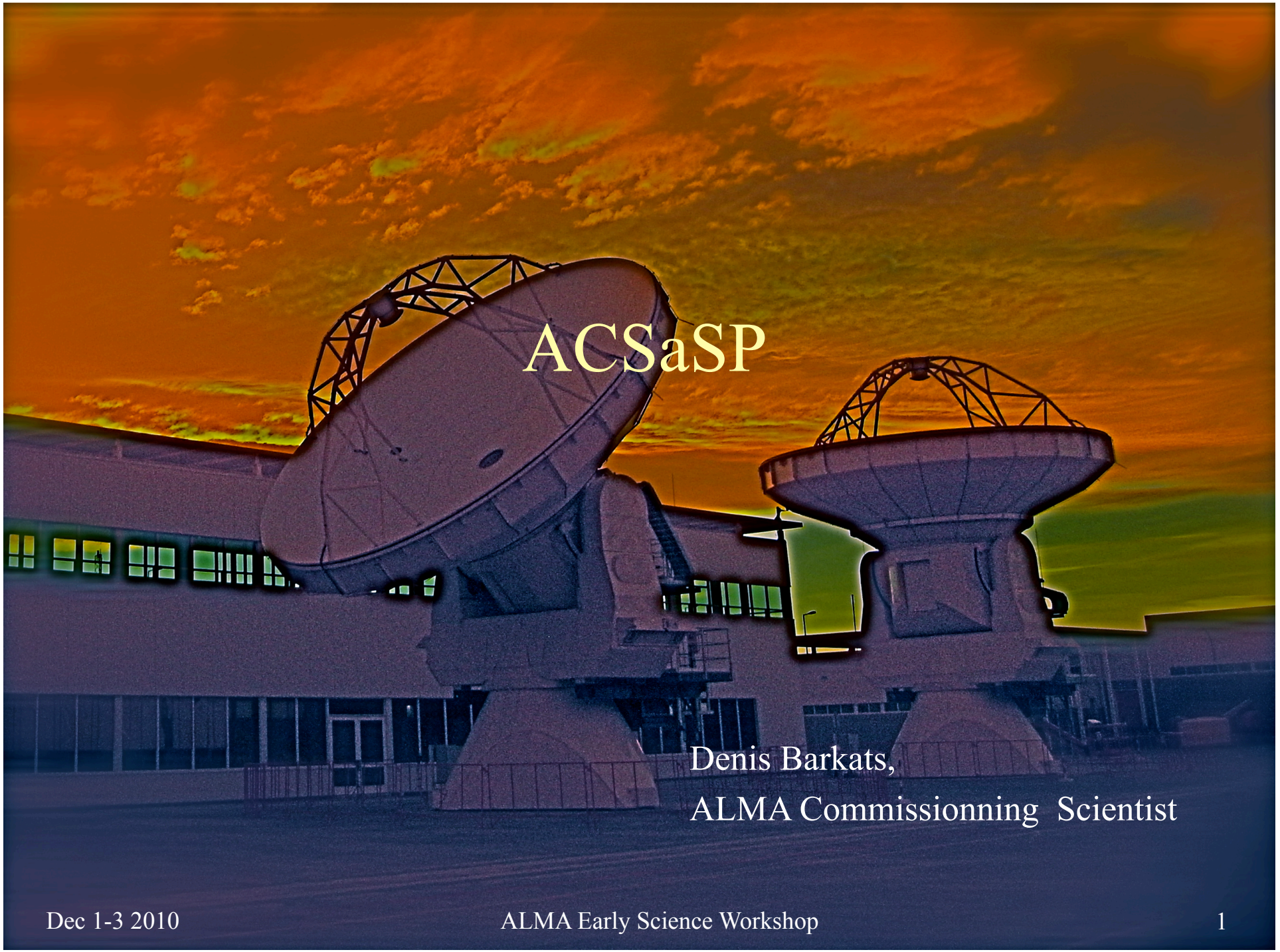
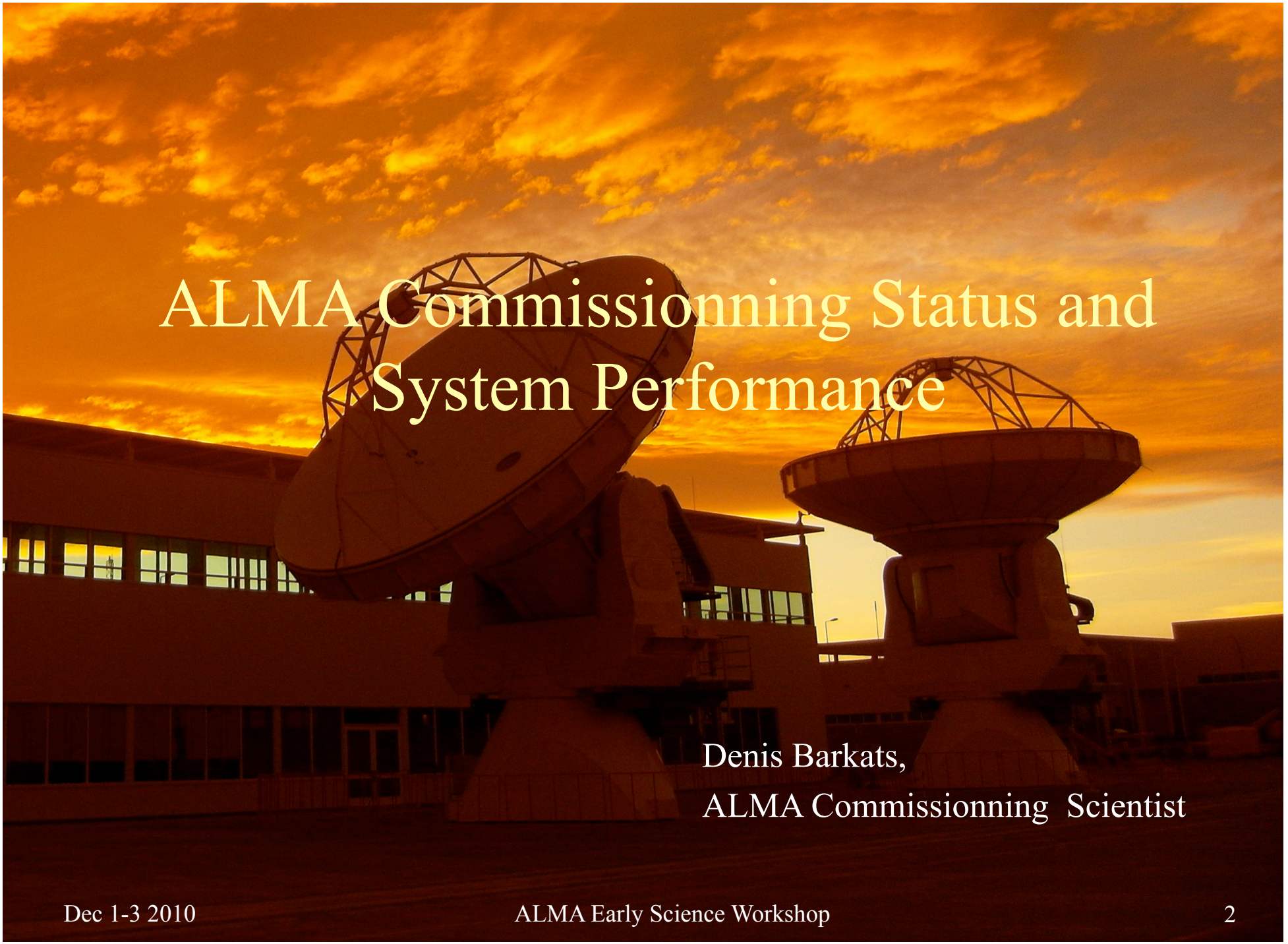


ACSaSP

Denis Barkats,
ALMA Commissionning Scientist



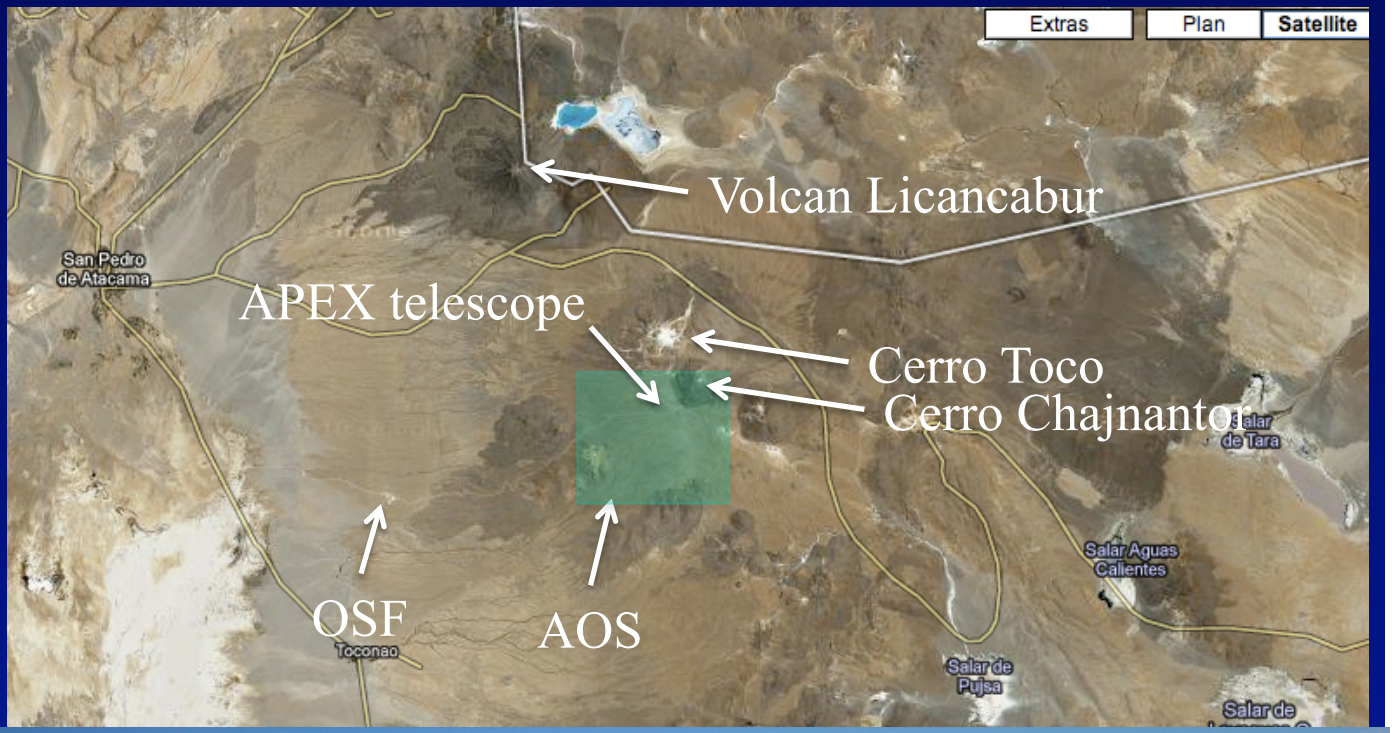
ALMA Commissionning Status and System Performance

Denis Barkats,
ALMA Commissionning Scientist

Outline

- What is CSV and Organization
- Deliveries: Antenna integration process
- Deliveries: Control Software basics (see RL talk)
- Yearly Perspective Summary
- System Status as of October 2010
- System Performance
- Recent commissionning test images
- http://www.almaobservatory.org/

Geographic Location



What is CSV

- Antennas, Receivers, Front Electronics, BackEnd electronics, Correlator, Photonic LO system, cablings, site infrastructure, Control System, Computer network, archive…
- CSV is the glue between all the different sub-systems
- Lots of constraints
- Lots of documentation, meetings, coordination
- Intrinsically dirty job: all aspects of debugging and troubleshooting
- + of course Science verification

CSV team

- Richard Hills, Alison Peck, Robert Lucas, Stuartt Corder, Denis Barkats, Tsuyoshi Sawada, Antonio Hales, Rainer Mauersberger, Daniel Fulla, Gianni Marconi, Diah Gunawan, Eric Villard, Tim van Kempen, Kengo Tachihara, Shinya Komugi, and Takeshi Kamazaki

  = 15 CSV-scientists +

  2-3 Santiago-based Operation astronomers +

  2 ESO fellows +

  3 ARC liaisons (~3months) +

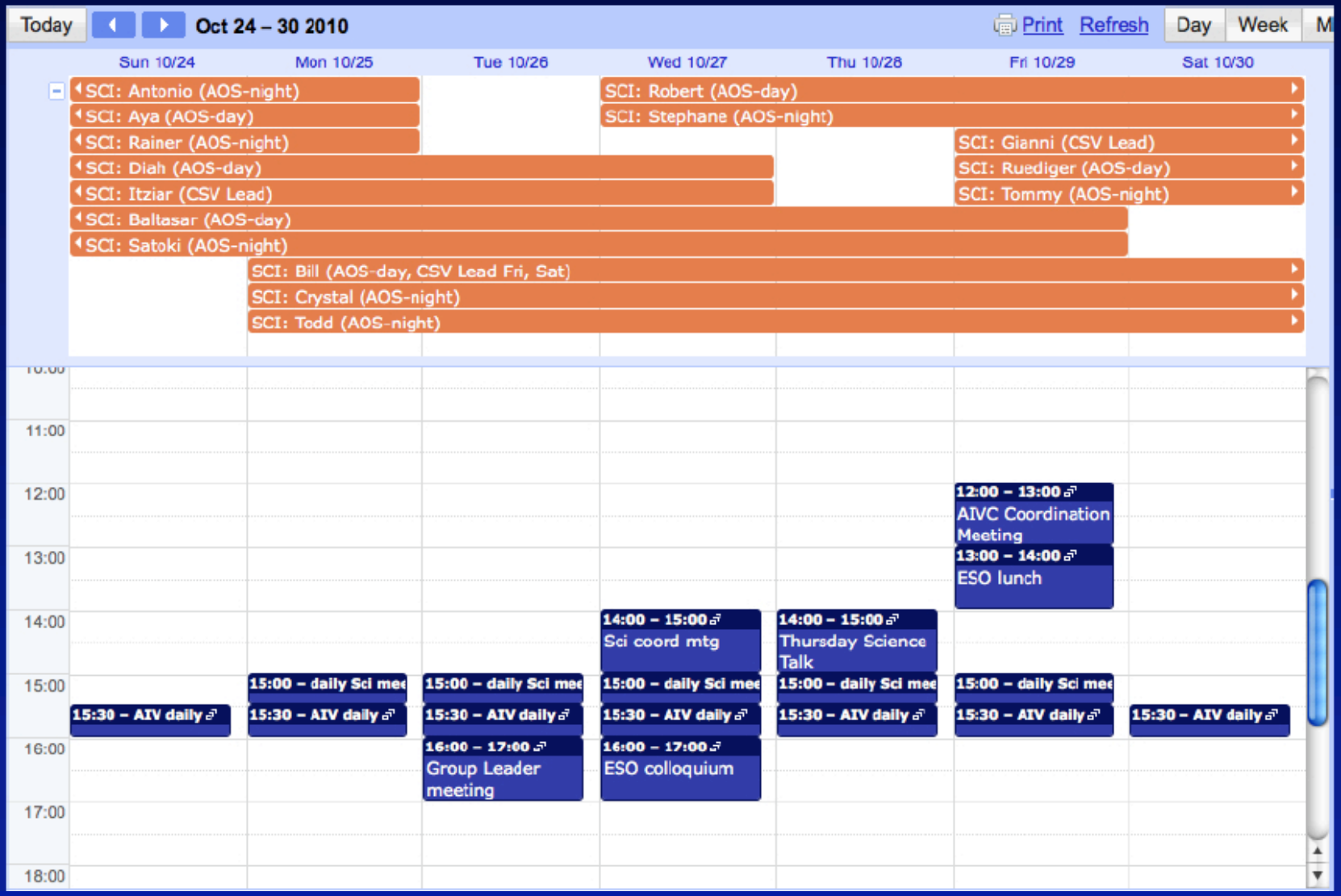
  2-3 visitors, specialized ARC staff (~3months)

  Total = 21 in October 2010
- Modified Turno System (8/28)
- Coordination and Communication is CRITICAL
- CSV groups (Correlator, Systems, Calibration, Antenna, Imaging, Observing modes, Documentation)

One day in the life…

- 24 hr operations
- CSV shift 4PM → 6:30AM, Engineering/Computing shift 8AM → 4PM
- Scientists in daytime: 2+CSV Lead
- Scientists at night: 2-3
- Array Operators: 2
- Computing support in daytime: 6
- Computing support at night: 2
- Engineering support in daytime: 18
- Engineering support at night: on-call only

Sample Week


Today
Oct 24 – 30 2010
Print
Refresh
Day
Week
Sun 10/24
Mon 10/25
Tue 10/26
Wed 10/27
Thu 10/28
Fri 10/29
Sat 10/30
SCI: Antonio (AOS-night)
SCI: Aya (AOS-day)
SCI: Rainer (AOS-night)
SCI: Diah (AOS-day)
SCI: Itziar (CSV Lead)
SCI: Baltasar (AOS-day)
SCI: Satoki (AOS-night)
SCI: Robert (AOS-day)
SCI: Stephane (AOS-night)
SCI: Gianni (CSV Lead)
SCI: Ruediger (AOS-day)
SCI: Tommy (AOS-night)
SCI: Bill (AOS-day, CSV Lead Fri, Sat)
SCI: Crystal (AOS-night)
SCI: Todd (AOS-night)
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
12:00 – 13:00
AIVC Coordination Meeting
13:00 – 14:00
ESO lunch
14:00 – 15:00
Sci coord mtg
14:00 – 15:00
Thursday Science Talk
15:00 – daily Sci mee
15:30 – AIV daily
16:00 – 17:00
Group Leader meeting
16:00 – 17:00
ESO colloquium

Site Infrastructure Operations and Support Facility (OSF)

OSF Technical Facility Control Room

Site Infrastructure: Array Operations Site (AOS)

- AOS Technical Building and support infrastructure completed in 2008
- Construction of the 192 concrete antenna foundations completed end 2009
- Infrastructure needed is underway
  - Network of access roads
  - Power distribution
  - Fiber optic signal connection

Antenna Processing

ALMA antennas are manufactured to a common specification by three contractors

North American

12m antenna

European

12m antenna

East Asian

12m antenna on transporter in foreground

Contractor camp construction

Assembly, Integration and Verification

Four-station process

Station 1: Surface setting and verification using beacon holography and pointing verification using optical pointing telescope

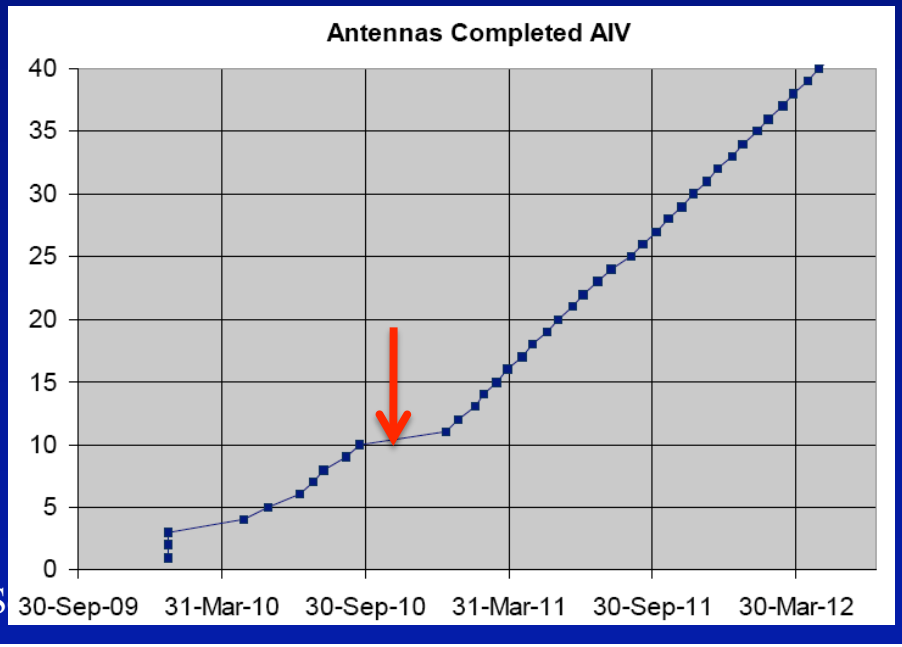
Station 2: FE and BE and other subsystems (WVR, ACD) integration and system verification

Stations 3: Complete antenna system verification at OSF, including 2-antenna interferometer

Station 4: transport to AOS and verification at 5000m

ALMA Antennas

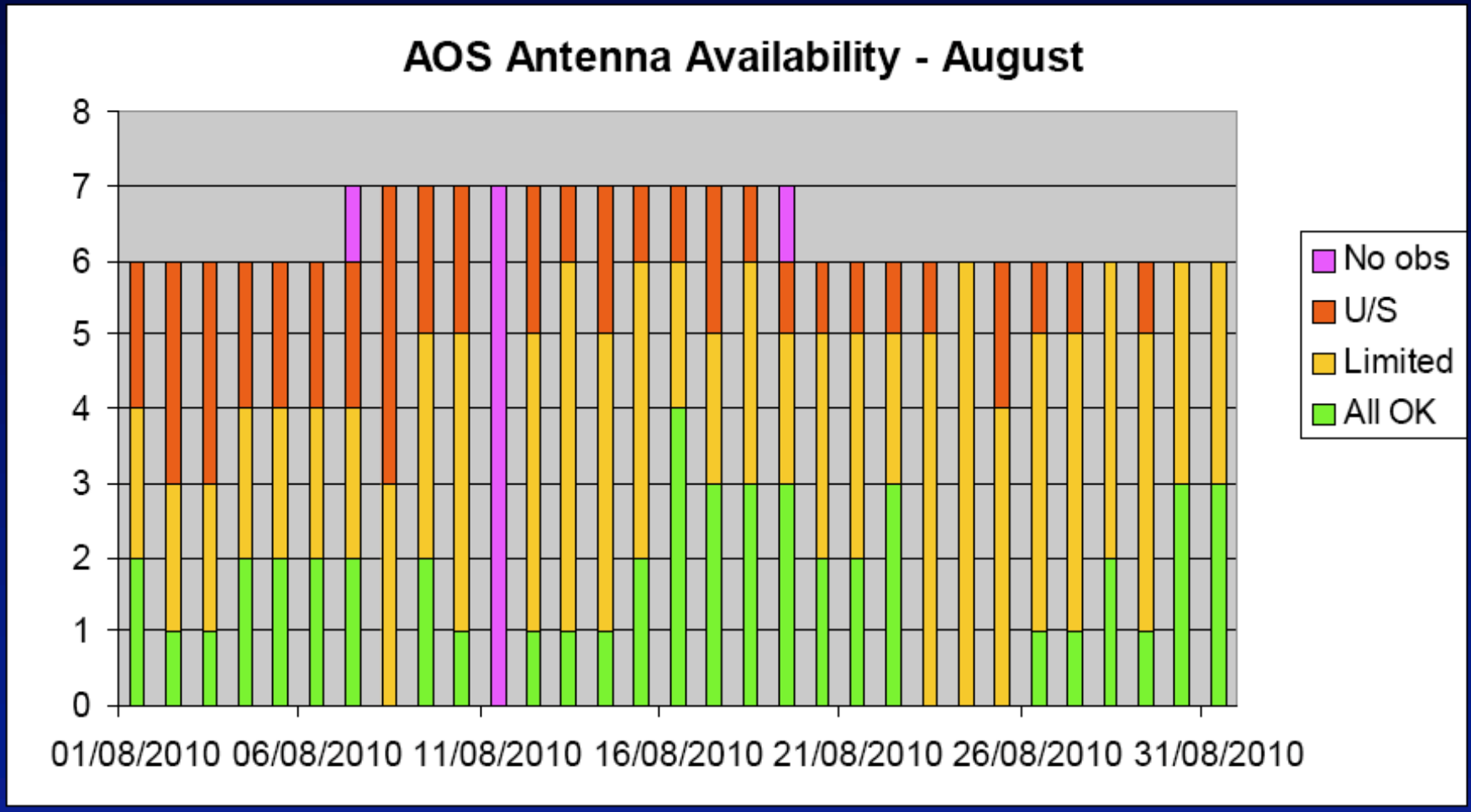
Partner/Contractor	*Number to be supplied*	*Delivered to **Site***	*Delivered to **AIV***	*Delivered to **CSV***
North American/ Vertex	25 x 12m	16	10	8
European/ TAS-EIE-MTM Consortium	25 x 12m	5+	Mar 2011	0
East Asian/ Mitsubishi Electric Corp (MELCO)	4 x 12m 16 x 7m	4 4	3 Feb 2011	2 0



Commissioning on the fly.

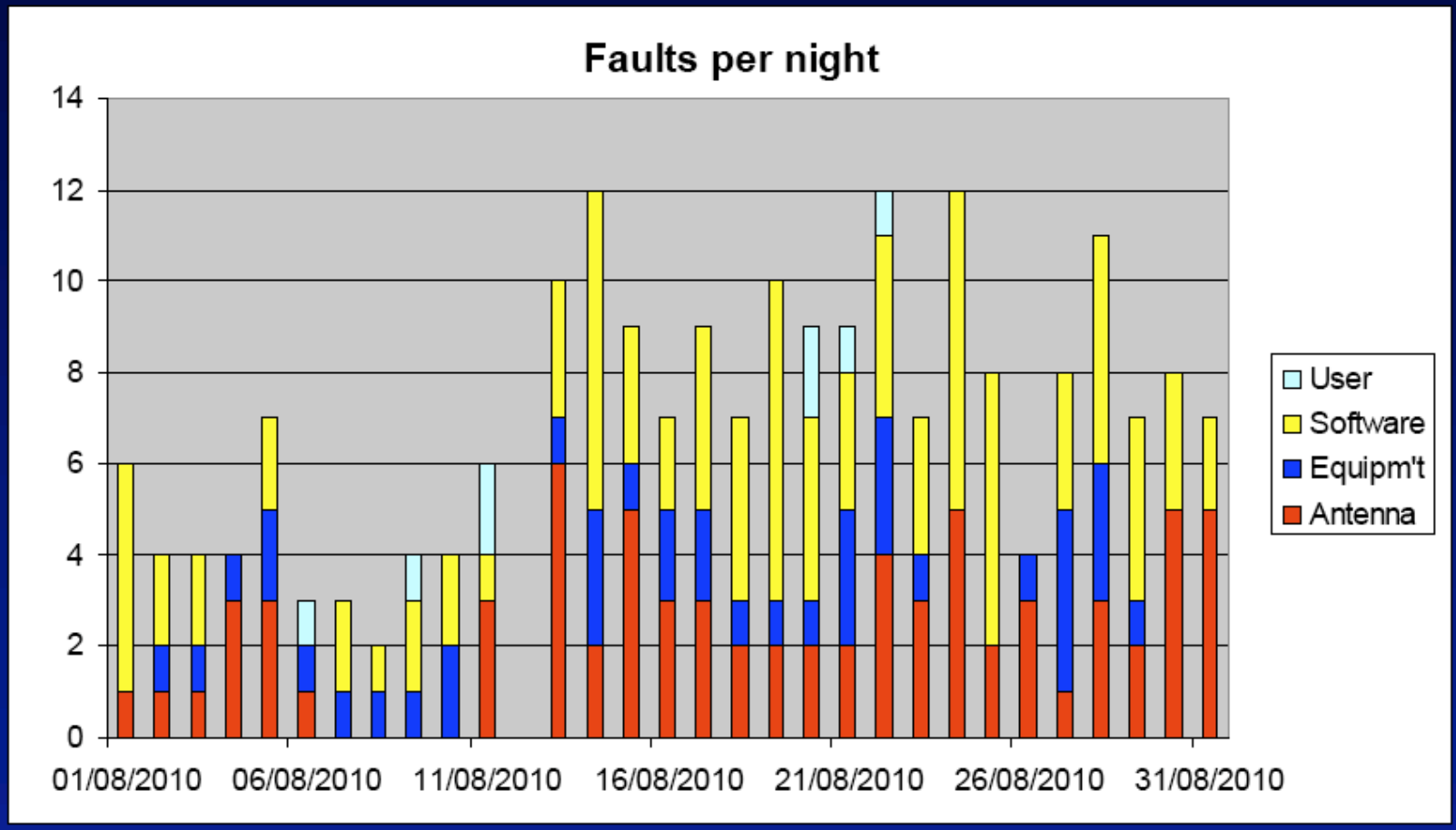
- Everything is changing (improving) as we are commissioning it. Makes troubleshooting very hard.
- The commissioning work is being done in a difficult environment: ALMA is still very much under construction – even at the level of providing basic infrastructure.
- There is a basic mismatch between the approach construction contractors and the needs of people making delicate scientific measurements.
- Even on the established sub-systems there are frequent changes going in – daily software patches, firmware in numerous items, cabling changes…
- Commissioning is working on the fine line between more functionality and more stability
- Expect the un-expected.

Night by night antenna status



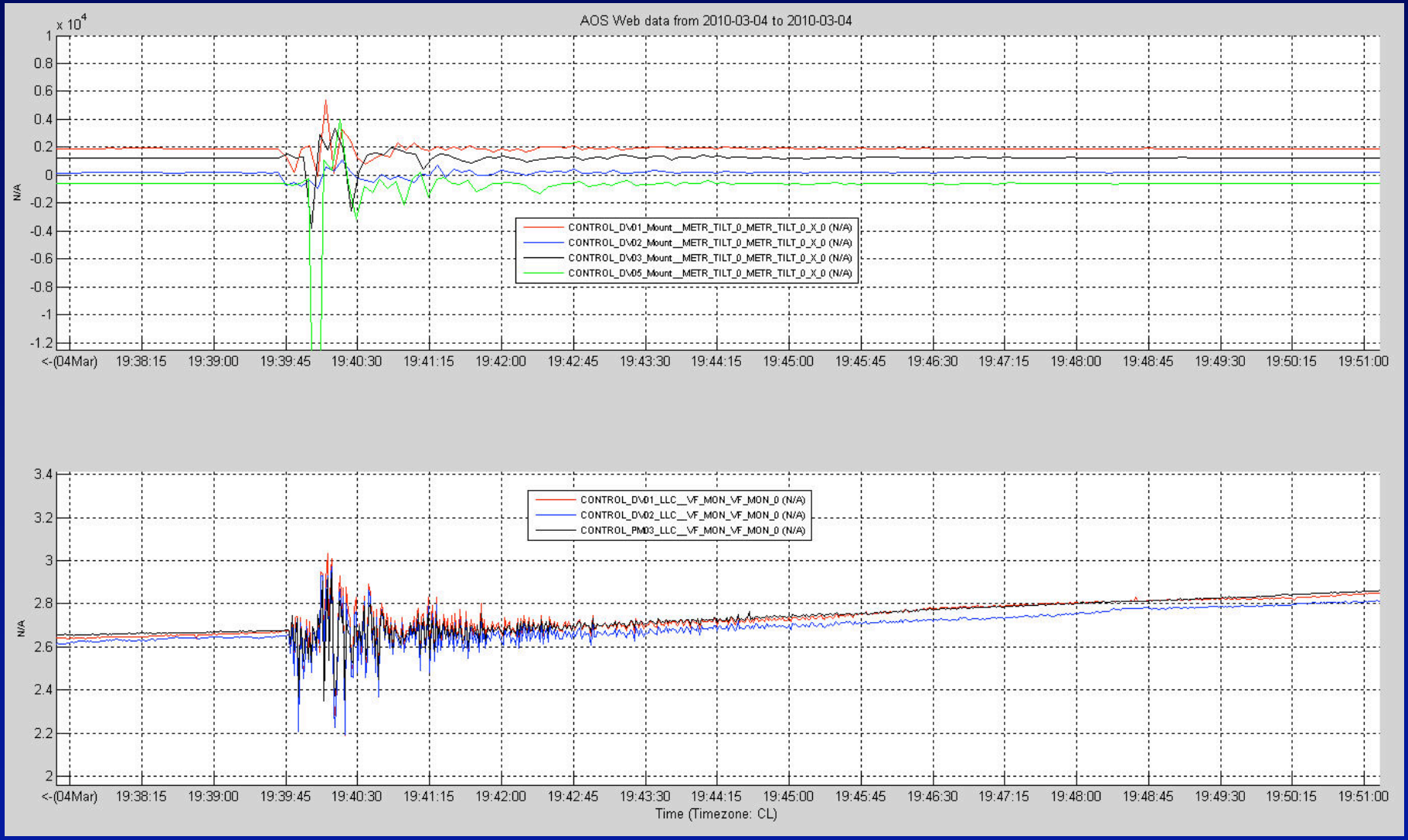
- Overall figures for 2010 are ~50% fully operational, 20% reduced, 20% U/S
- But these have got worse since ~July.

Faults that stopped operation



- Detailed analysis for August. Time lost 58 minutes per fault. 4.5 faults per night.
- Many are repeats of same fault:

Earthquakes in Chile



Yearly progress summary

Oct 2009 – early OSF-AOS interferometry plans

- Check coherence loss (LO phase noise) using auto- and cross-correlation
- Check that we observe atmospheric phase as predicted by WVR
- Compare bandpasses in various bands in detail
- Interferometric beam maps (amplitude and phase: astronomical holography)
- Return to phase after a frequency change
- Interferometry with full capabilities (2 polar., 2 basebands, 2 sidebands: relative amp./phase stability)
- Two targets, phase and amplitude stability - characterize slow variations
- LO offsetting (for side band separation)

☒ - on-going task

✔ - routine observation

☒ - on-going task

✔ - routine observation

☒ - on-going task

✔ - routine observation

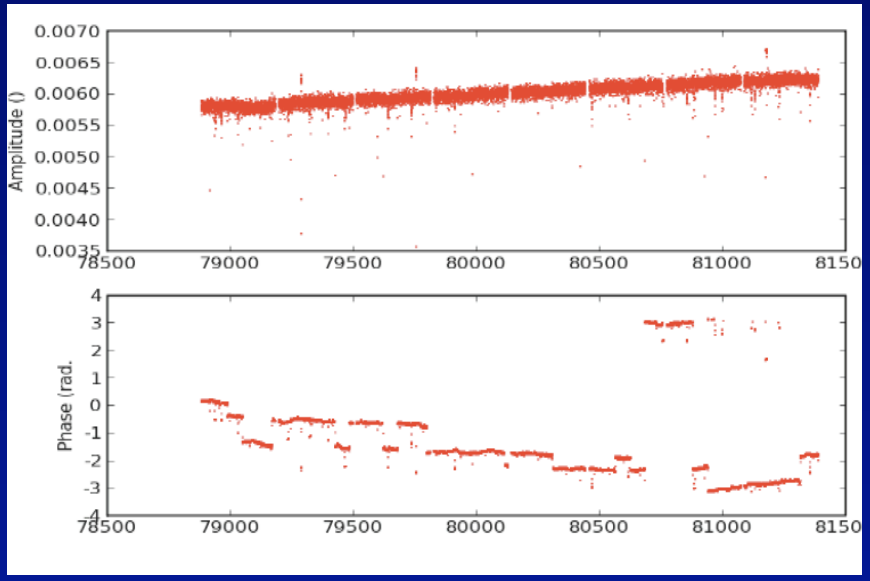
☒ - on-going task

✔ - routine observation

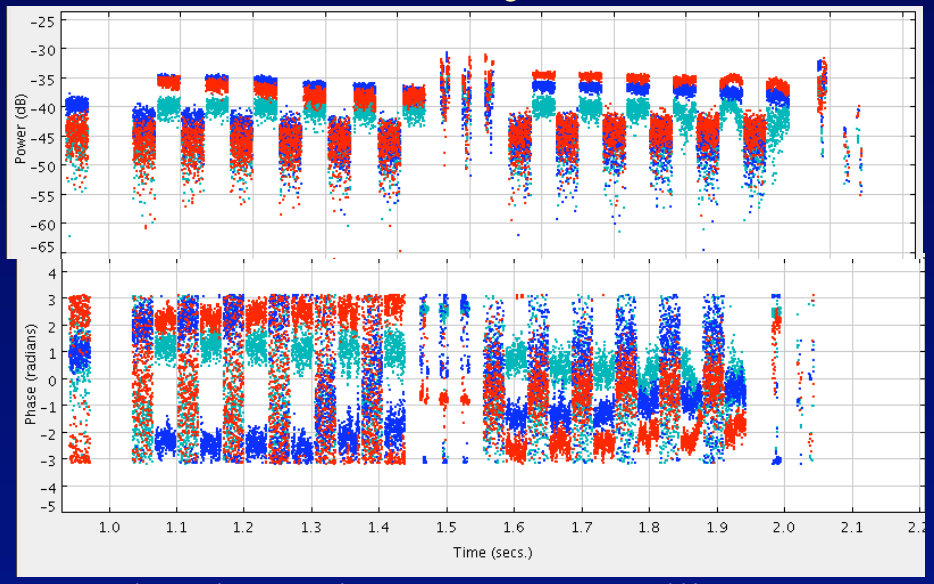
- Check radio pointing (planets) using OSF pointing models
- Get first fringes at band 3 (SiO maser, then continuum)
  - New correlator (first quadrant)
  - New central LO
- Get first baselines using delays / phases
- Get good pointing using band 3 interferometry
- Check accuracy of fringe tracking at low elevations
- Check phase closure (with 3 antennas)
- ... and other tests better done at AOS, or not done at OSF.
  - Band 9 tests, with image side band rejection

✔ - routine observation

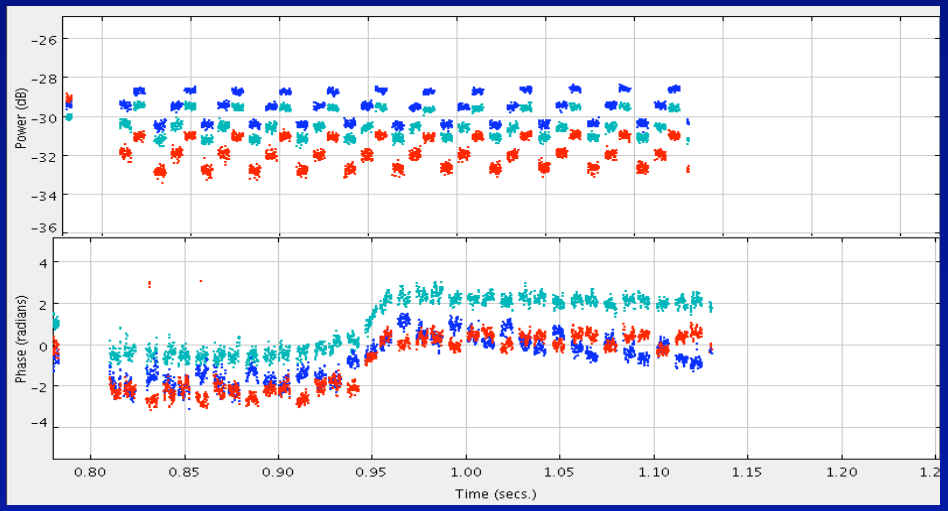
Yearly progress summary



Band 3 1hr track on bright qso, Aug2009



Band 9 2hr track on ngc253 + callisto, Aug2010



Band 6 1hr on bright qso triplet Aug2010

System Status (ie. what's in progress as of Oct 2010)

- 8 antennas with 4 receiver bands (3 ~3mm, 6 ~1.3mm, 7 ~0.9mm, 9 ~0.5mm)
- Good antenna performance: surface accuracy, pointing, focus, tracking
- Single Field Interferometry, Single Dish spectral lines
- Baselines from 20m to 91m (250m)
- Correlators (BL, ACA, OSFI) with basic set of correlator modes (~20 tested)
- Control Software
- Online and Offline data calibration tools + CASA data reduction
- Preliminary Phase, Amplitude, Flux, Bandpass calibration strategies (ACD +WVR)
- Preliminary full polarization Single Field tracks.
- Systems all stable/efficient enough to observe a few hours in a row without failures or system restarts.

What is still needed

Deliveries of equipment

- Completed antennas - ~continuous
- New subsystems: LO, correlator - discrete
- Infrastructure: roads, power, comms

New functionality

- Software releases
- Working out the detailed procedures (scheduling blocks, calibration, polarization, …
- Documentation

Focus less on troubleshooting/debugging and more into quantitative scientific verification

Discontinuities in Deliveries (ie. known disruptions)

- Photonic Local Oscillator system 16 → 64 antennas ~ Mar 2011 (1wk + 3wks)
- Correlator Q1 → Q2 + Q3 ~ Mar 2011 (1wk)
- OSF/ AOS Communications: microwave → fiber ~ Nov 2010
- OSF Control Room HVAC ~ ?? Mar 2011
- Foundations ACA > Central Cluster ~ continuous from now to April 2011
- Software Rev 8.0 ~ Dec-Jan 2011
- Software Rev 8.1 ~ Jul 2011
- Archive transitions (new hardware in OSF, + SCO archive) ~Jan 2011
- Power: generators at OSF → generators at AOS ~Aug 2011 (possibly earlier)
- + probably several small power outages

ALMA phase correction strategy

Fast-switching

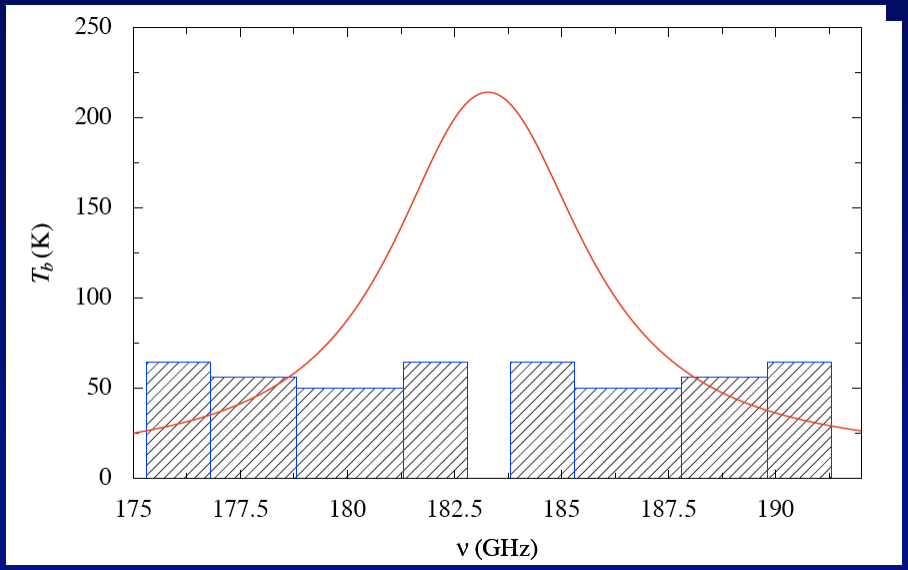
- Observe quasar next to science target (~2 deg)
- Measure antenna phase error
- Calibration cycles of 10-15s (fast antennas)
- Can be done slowly (slow phase calibration ~ minutes)
- Can calibrate a 90GHz and transfer to higher band (Band7/9) = Frequency transfer

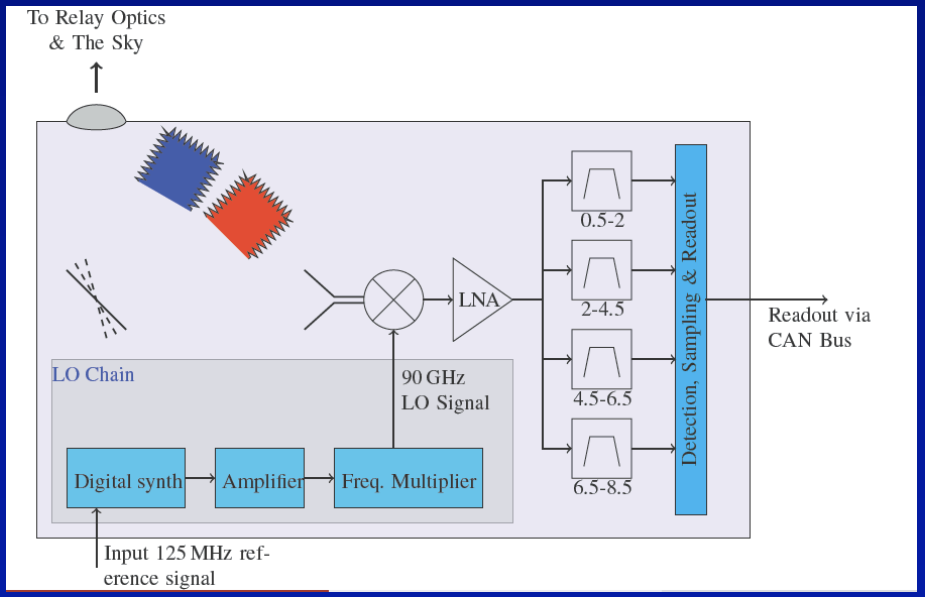
+

Water Vapor Radiometry

- Measure atmospheric properties along the line of sight of each telescope
- Use dedicated 183GHz radiometers in each telescope
- Measurements at ~1Hz
- Derive excess path length
- Correct either in correlator or post-processing

Phase calibration – WVR correction



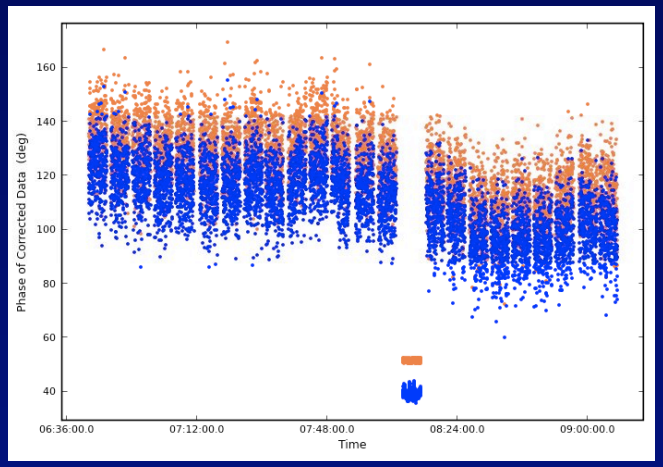


183GHz Water Vapor Radiometer

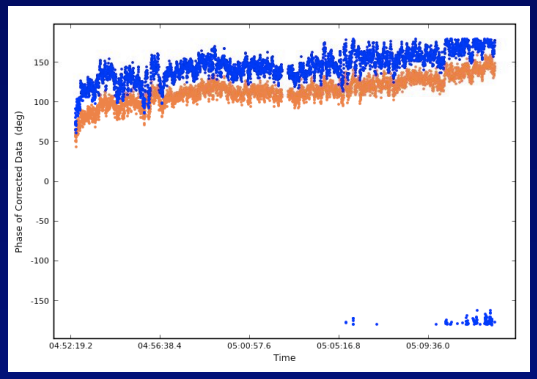
- Warm DSB Mixer, Trx ~1000K
- 18GHz bandwidth split into 4 DSB channels
- Dicke-switched against chopper wheel hot/cold load allows continuous calibration
- 0.1K /channel RMS
- 0.1K pp stability (10mn, 10deg tilt)
- Absolute Accuracy ~ 1%
- 1 unit in each antenna + planned freestanding WVR for continuous operation
- Provided by Cavendish labs, U. of Cambridge (B Nikolic, E Curtis)

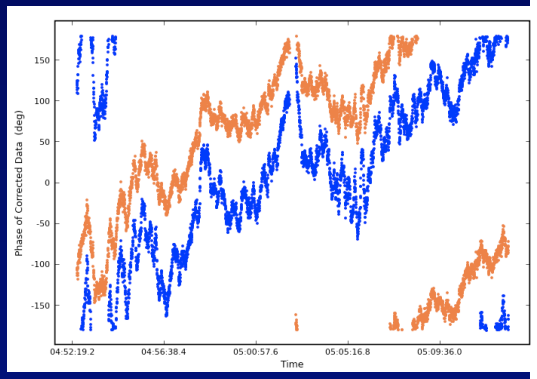
Phase calibration – WVR correction

Phase calibration – WVR correction

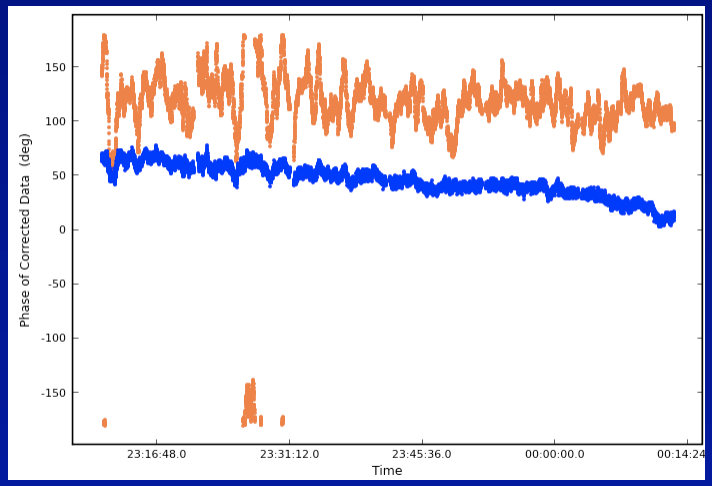


86GHz, PWV = 0.5mm, BL = 200m, 2 hr track (Jan 2010) (rms = 8.1° → 8.7°)

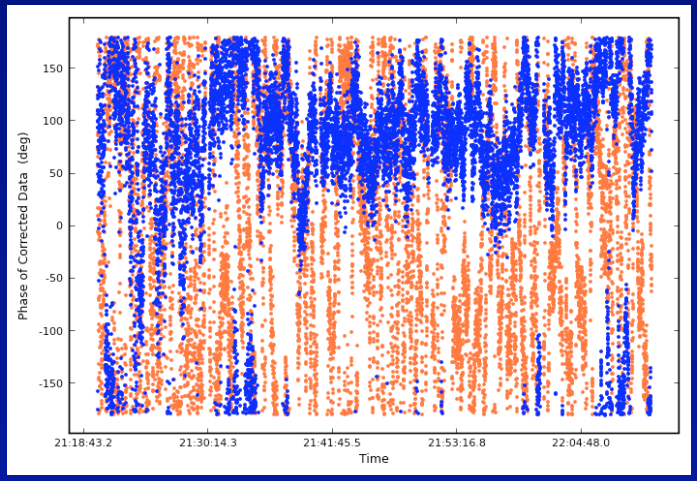




345GHz, PWV = 0.6mm, BL = 25m - 550m , 0.5 hr track (rms = 21° → 12°)



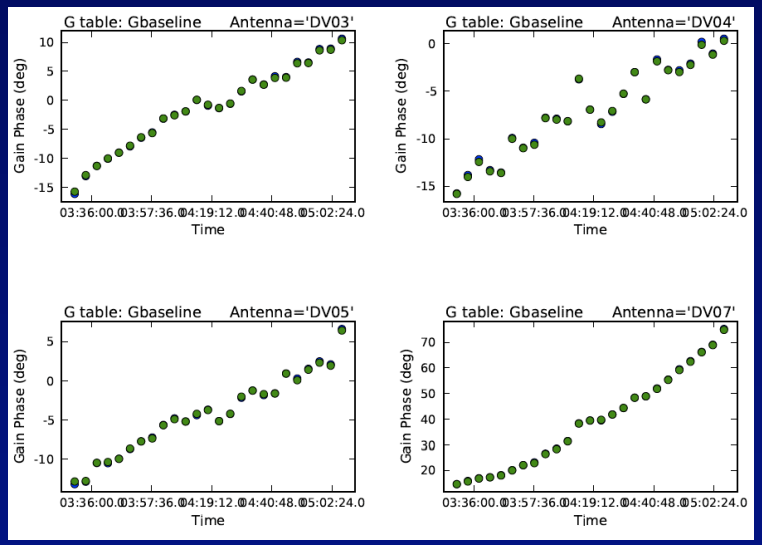
86GHz, PWV = 3.0 mm, BL = 200m, 1hr track (rms = 17° → 4.1°)

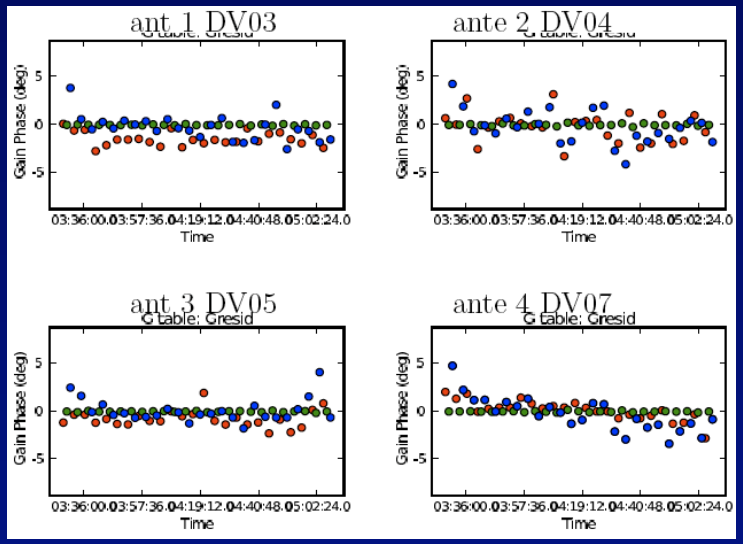


230GHz, PWV = 9.1mm, BL = 200m, 1hr track (Mar 2010) (rms = 61° → 42°)

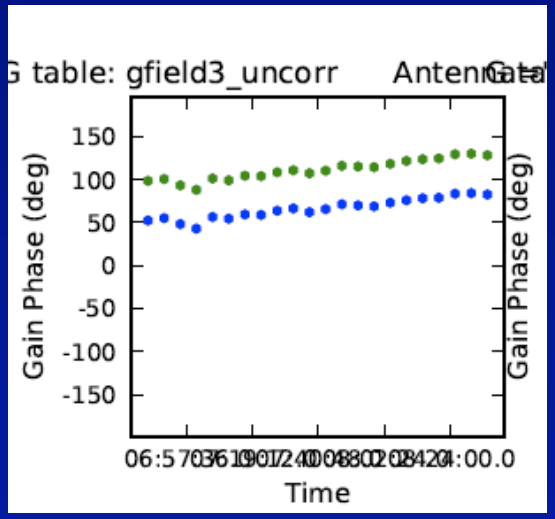
“Slow” Fast-switching

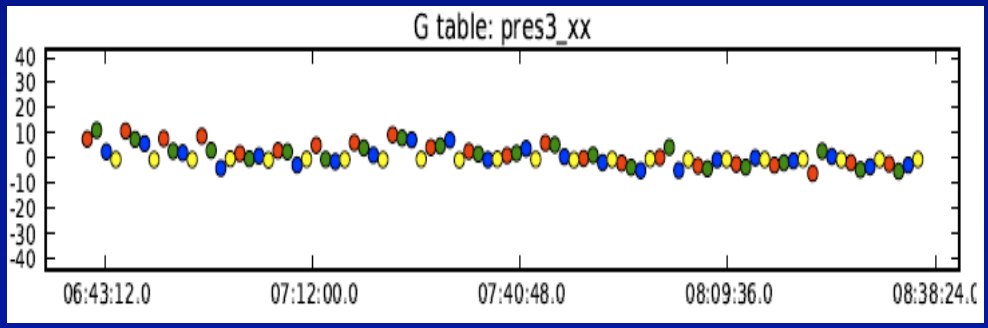
Band 3,
3 quasar
switching





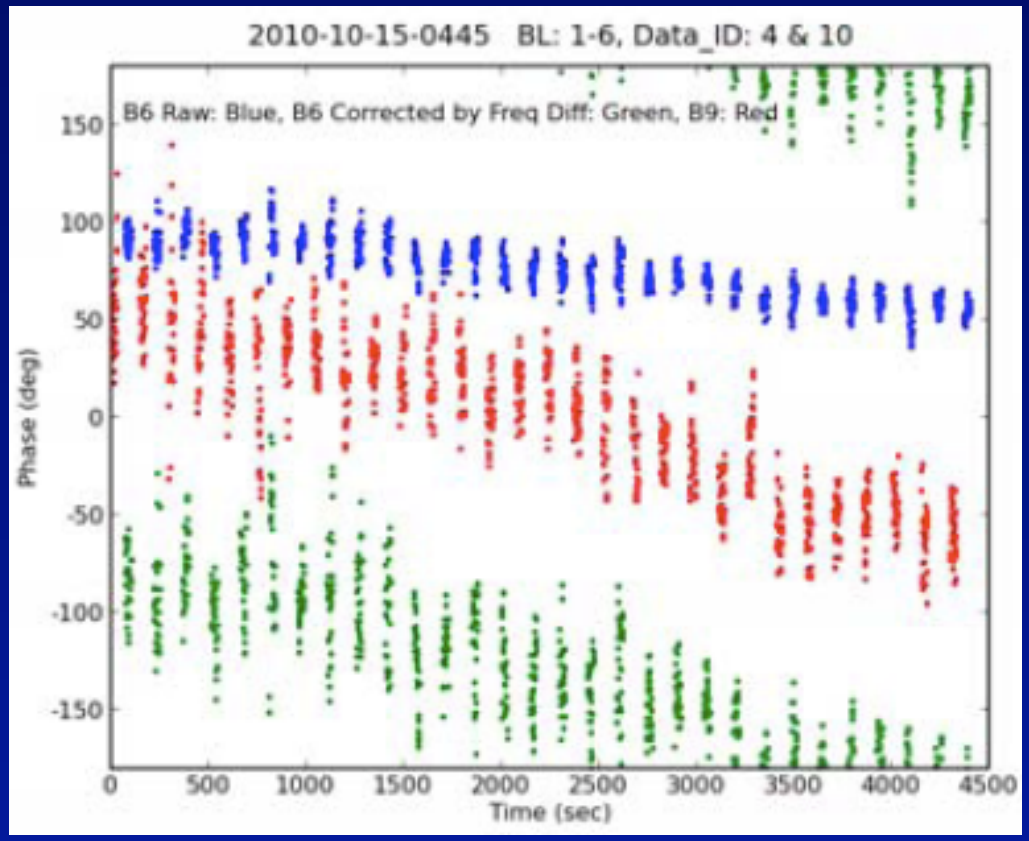
Band 7,
4 quasar
switching





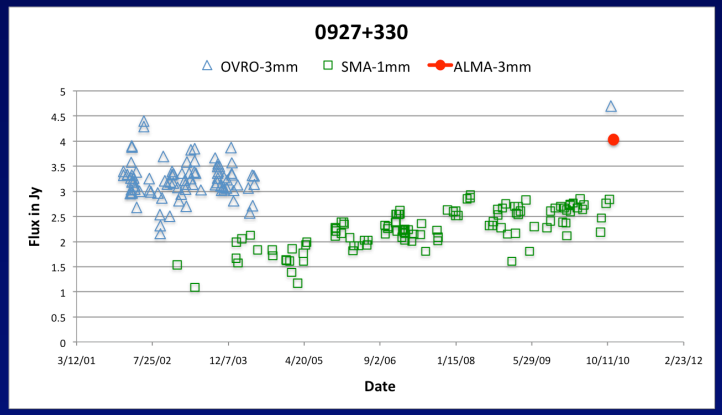
“Slow” Frequency-referencing

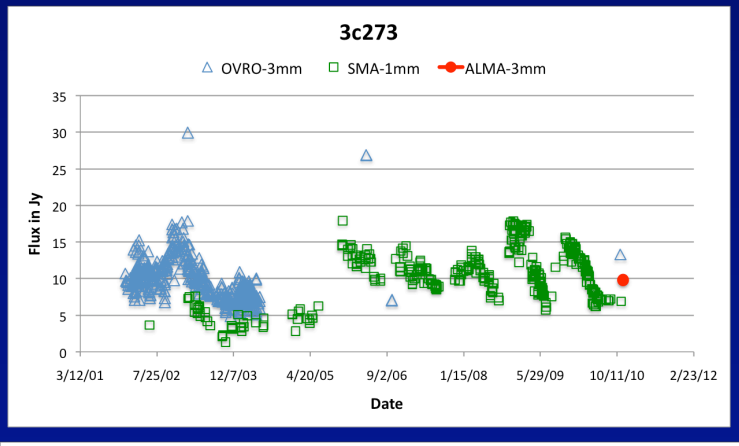
- PRELIMINARY results (Oct 2010)
- Band6 – Band9 1 qso switching
- Blue = Band 6 measured phase
- Green = Band 9 measured phase
- Red = Band 9 calculated phase

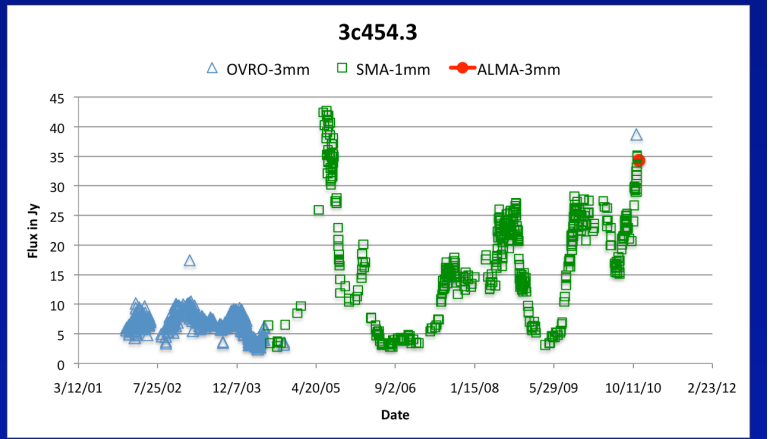


Amplitude/Flux calibration

- PRELIMINARY results (Nov 2010)
- A looooong road to get to this point
- 3% repeatability over a few days
- No sideband ratio correction
- No pointing/focus error correction
- No temporal or spectral phase variation correction (decorrelation)

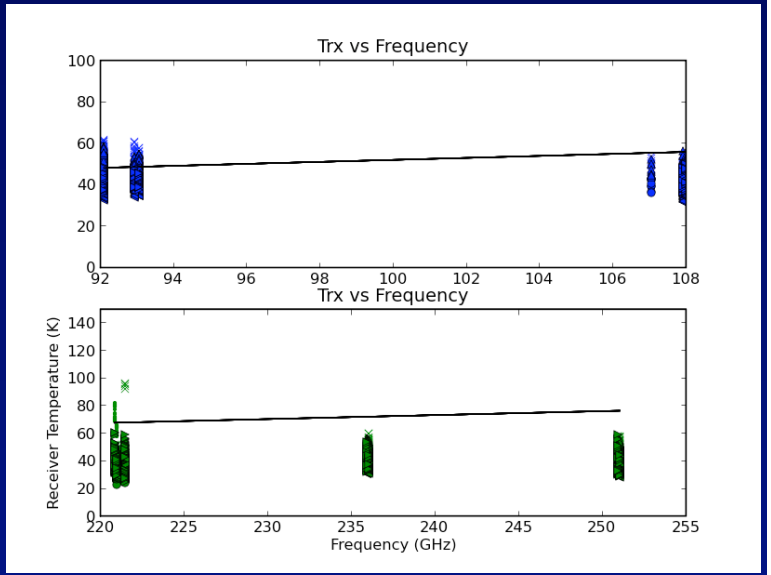


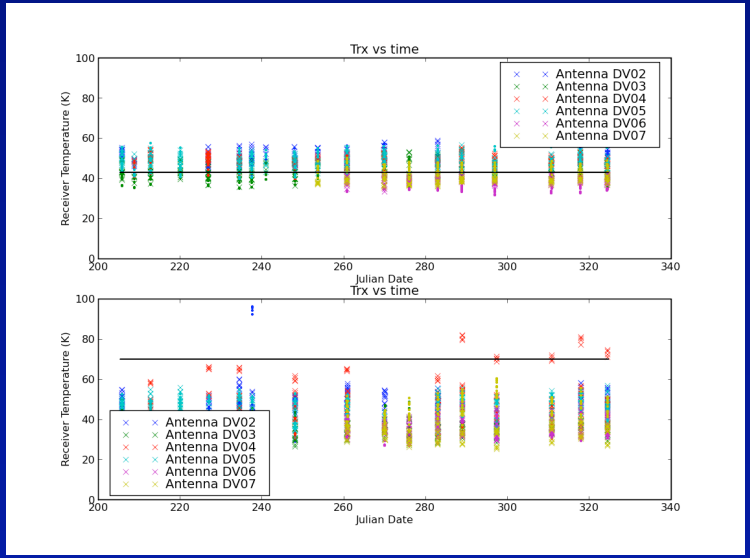




Amplitude/Flux calibration

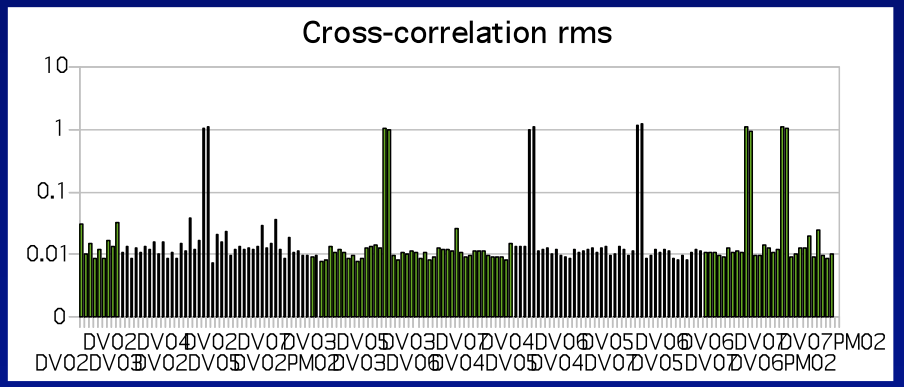
- PRELIMINARY results (Nov 2010)
- A looooong road to get to this point
- 3% repeatability over a few days
- No sideband ratio correction
- No pointing/focus error correction
- No temporal or spectral phase variation correction (decorrelation)

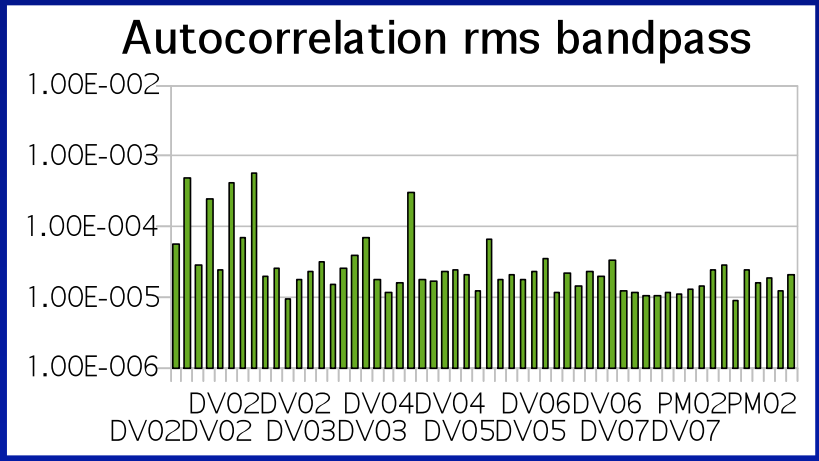




Bandpass stability

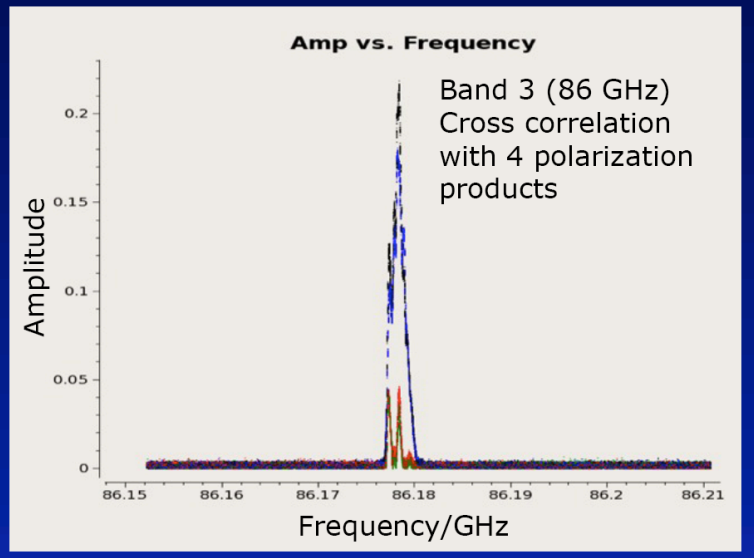
Specifications
Autocorrelations: 0.01%/mn change in bandpass shape
Cross-correlations: 0.1%/hr change in amplitude shape
0.01deg/hr change in phase shape

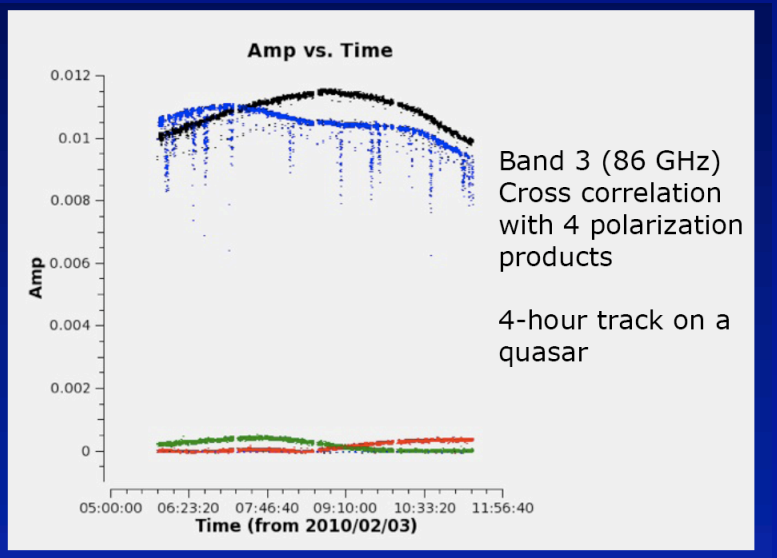




Polarization observations

- From Feb 2010
- CASA linear polarization analysis functionality from June 2010
- Planning installation of a beacon polarized source for polarization calibration
- Repeat/concentrate on Band7
- Specific polarization work campaign Feb 2010

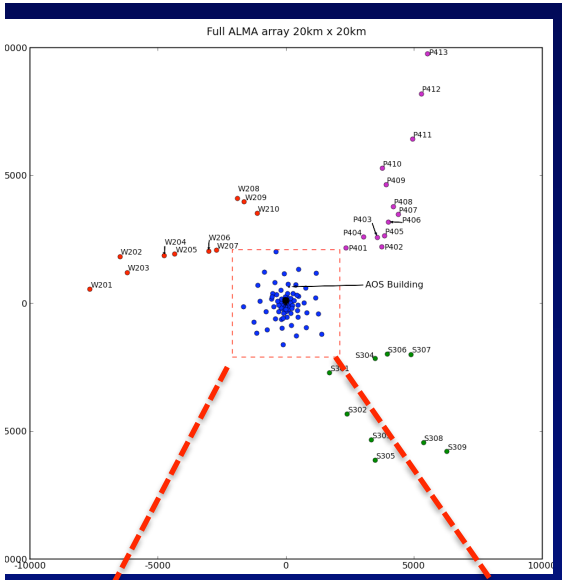


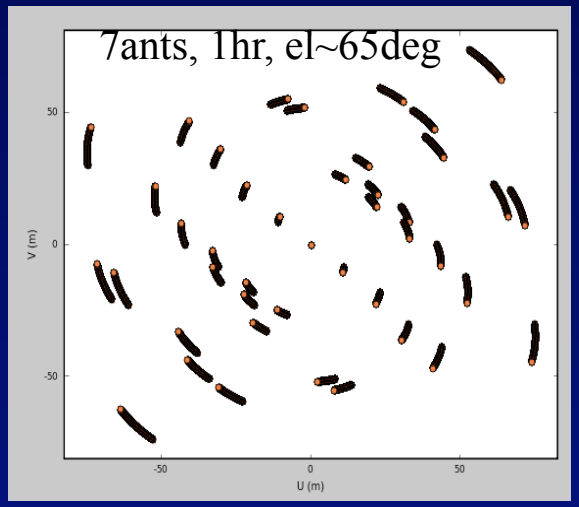


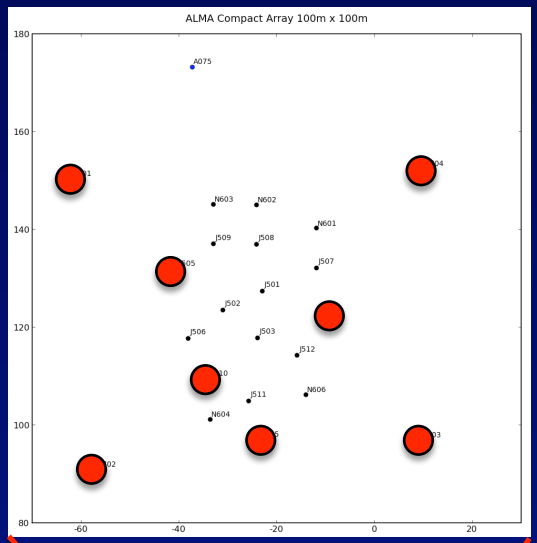
Latest Test Data

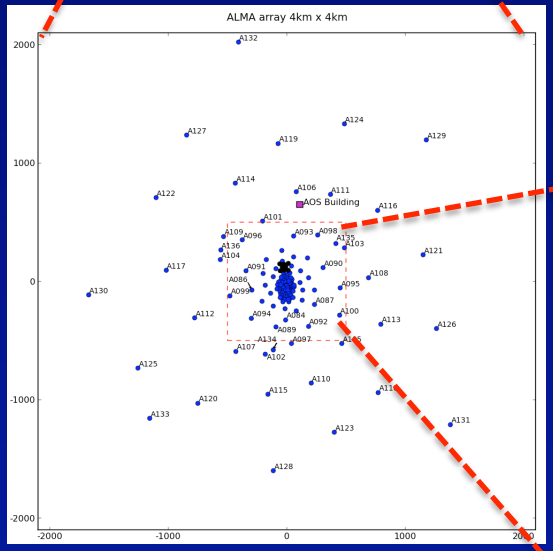
Credits

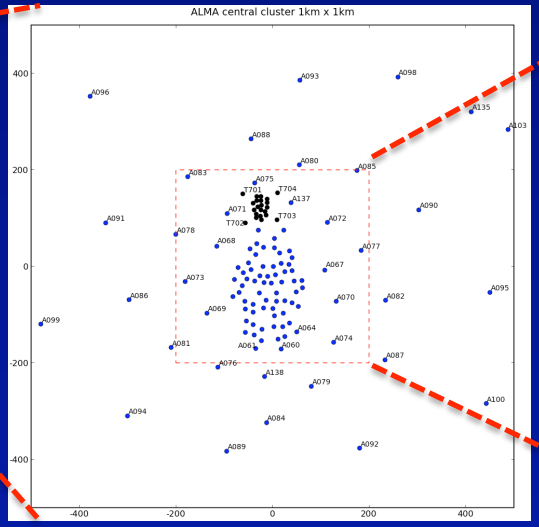
- It is important to emphasize that what is being shown here is the result of years of hard effort by very many people working on the design, construction and assembly as well as the management of ALMA.
- In particular the AIV team did an outstanding job in getting eight antennas into operation on schedule and, perhaps even more important, their engineers and software people have worked extraordinarily hard to fix the problems and to keep the systems running.
- Until recently the CSV team has been focussed on Commission tests – trying things out and seeing what does not work.
- We are now getting started on Scientific Verification – demonstrating what does work by observing well-known objects.

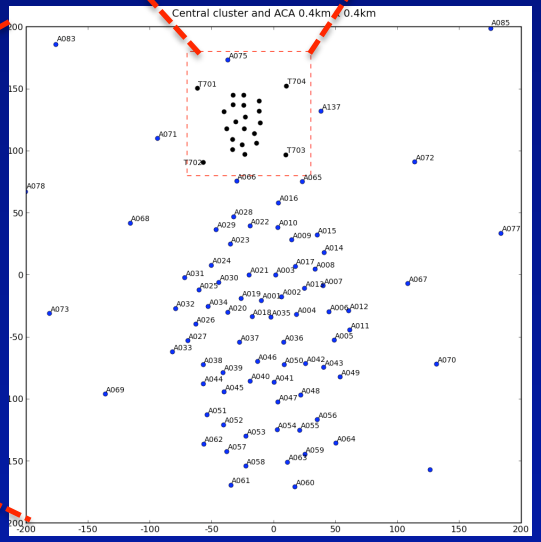

Full ALMA array 20km x 20km
AOS Building


7ants, 1hr, el~65deg
V (m)
U (m)


ALMA Compact Array 100m x 100m


ALMA array 4km x 4km
AOS Building

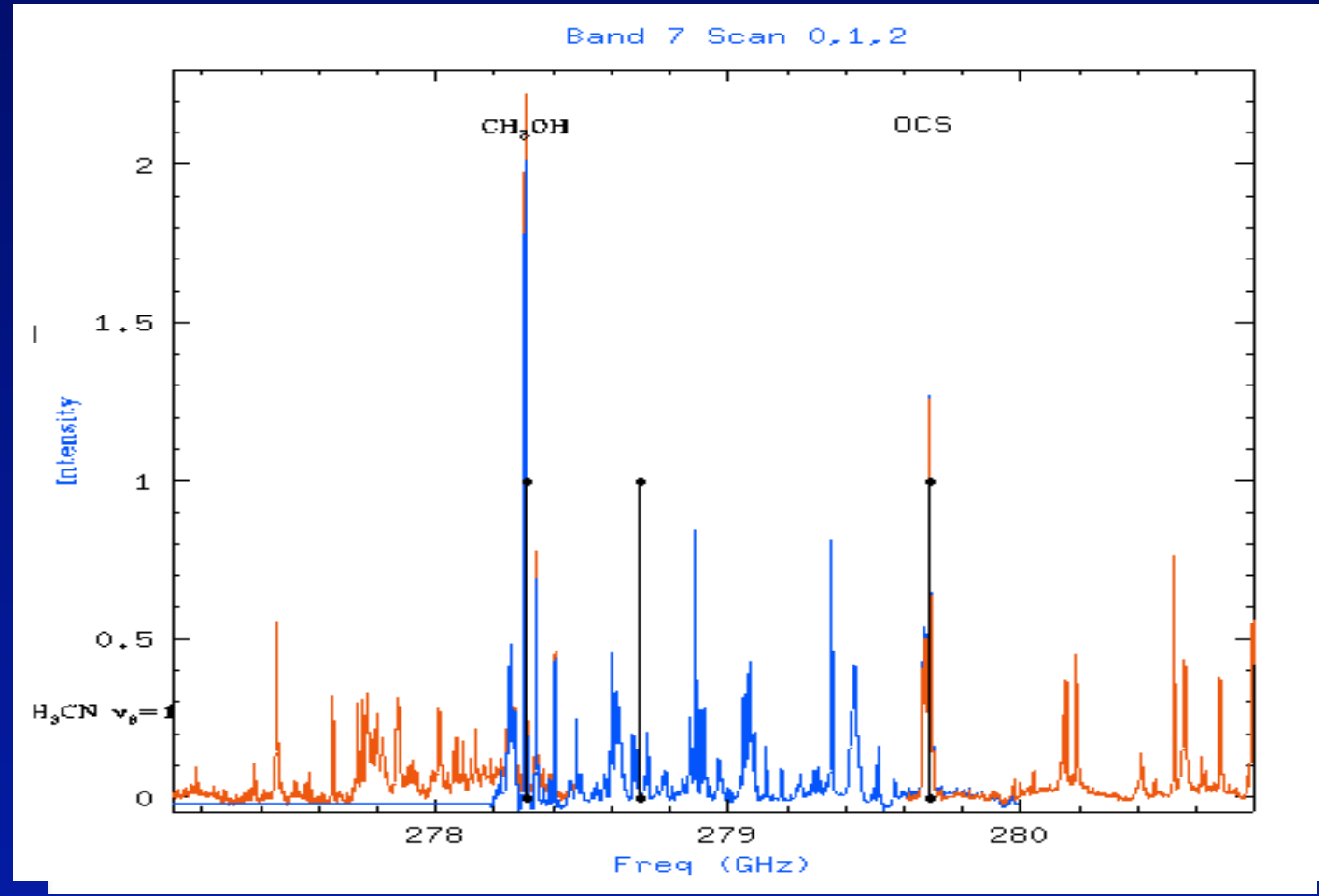

ALMA central cluster 1km x 1km


Central cluster and ACA 0.4km

Recent Results from Commissioning

Band 7 (345 GHz) spectrum of Orion

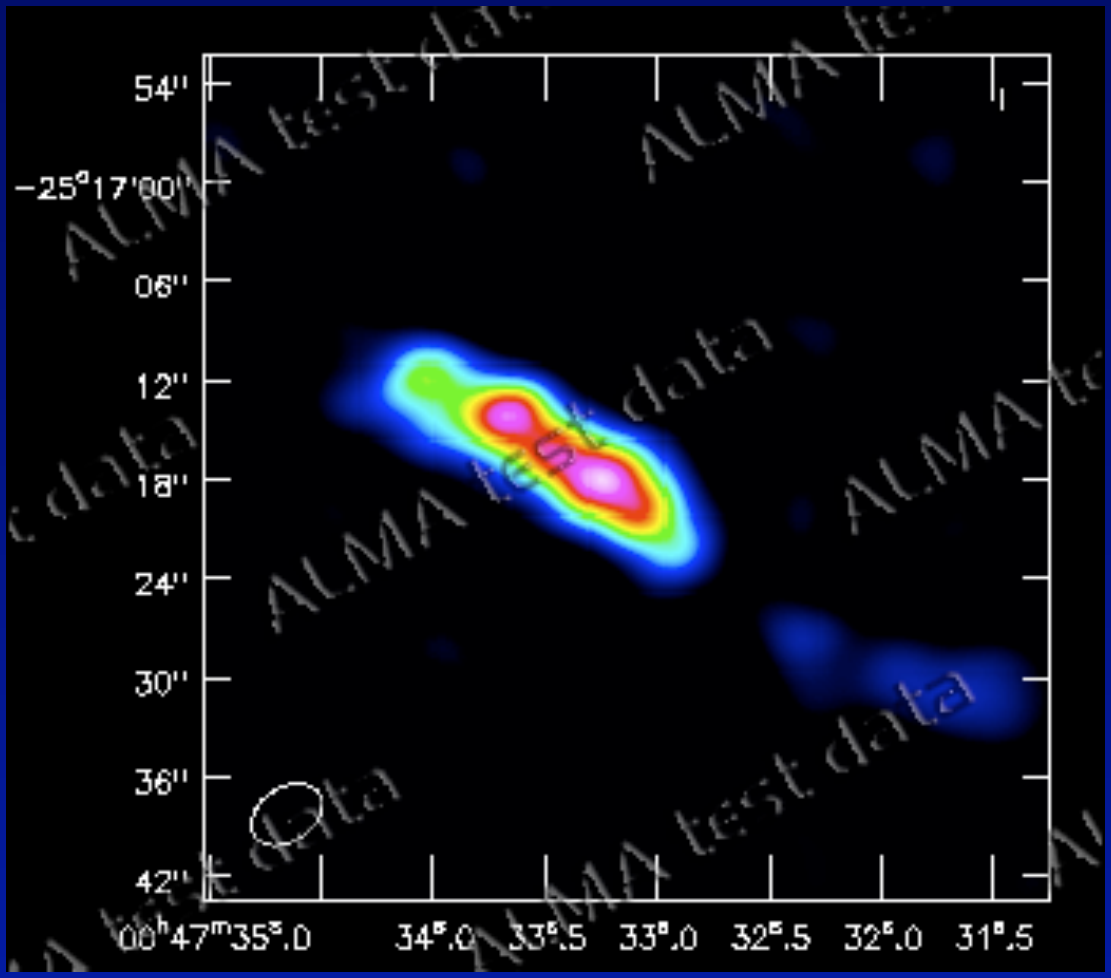
- Color: ALMA
- B/W: IRAM 30m



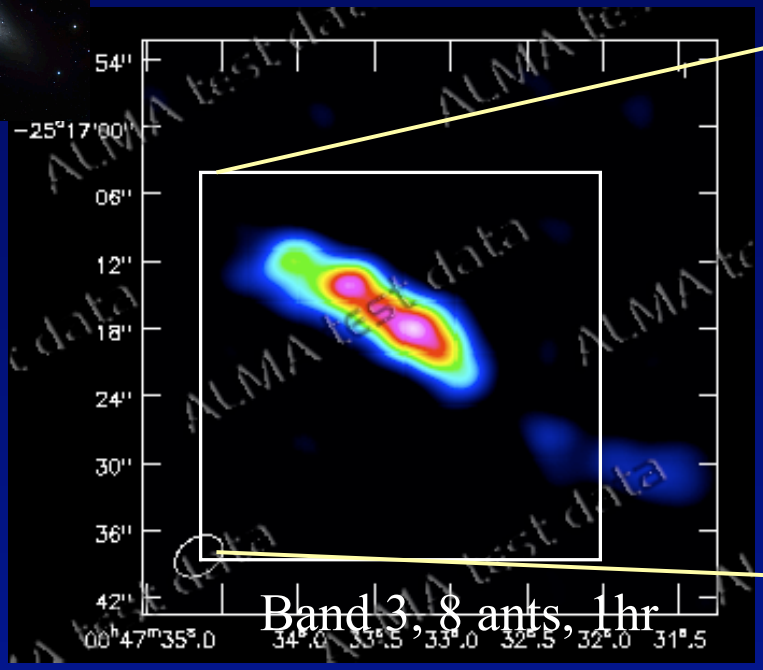
First Eight-Antenna Test Image

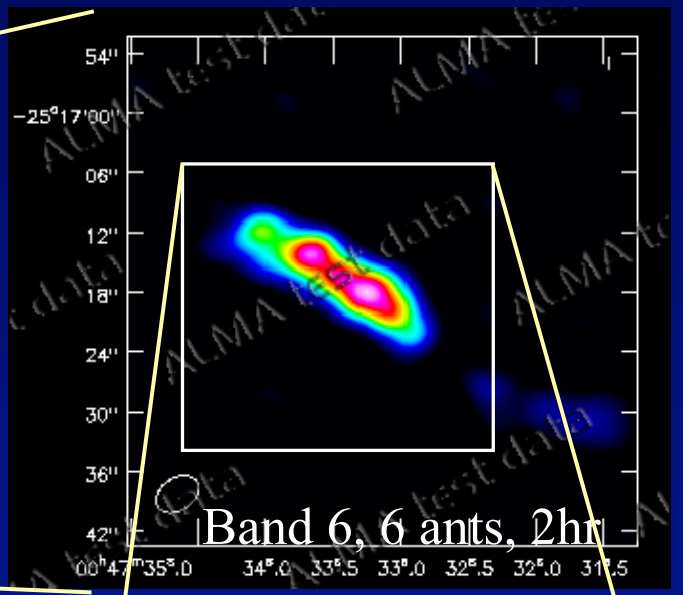
- NGC 253 CO J = 1-0
- Edge-on spiral
- 1hr track at Band 3
- 0.8mm PWV

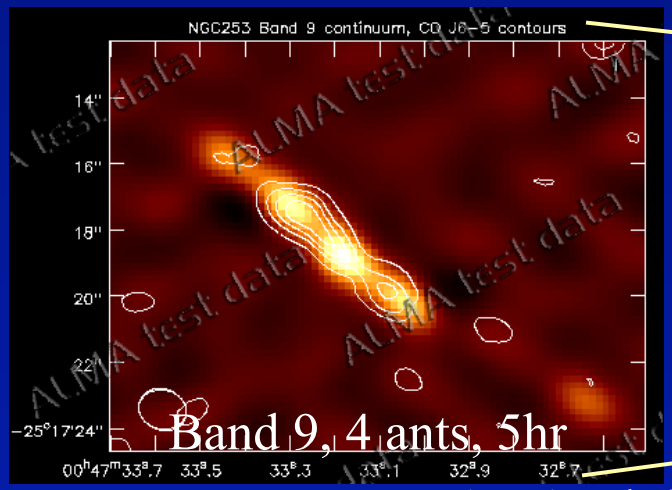
(Oct 1st 2010)

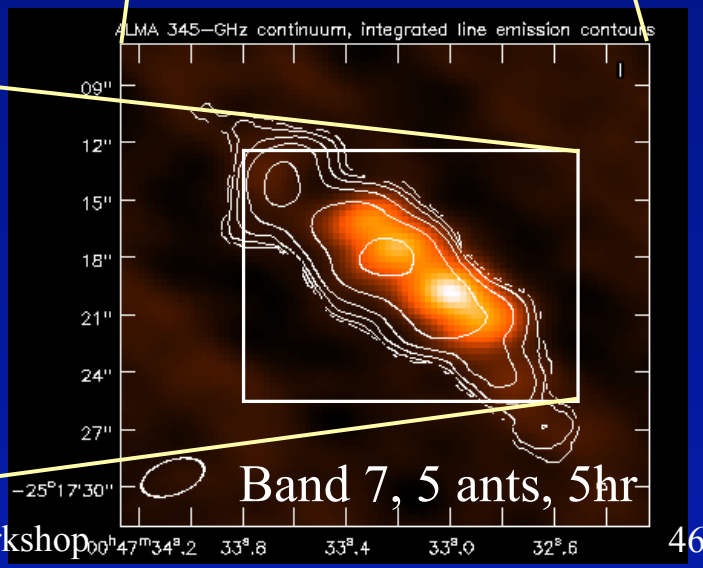


All four available bands work



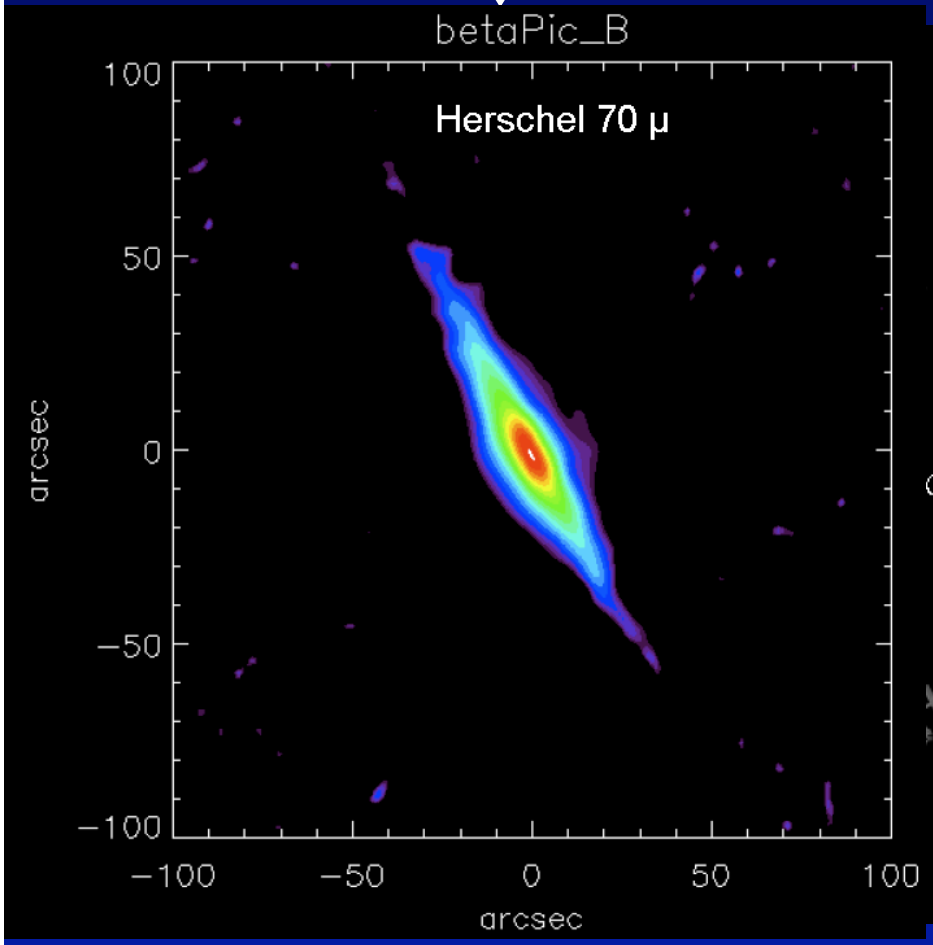


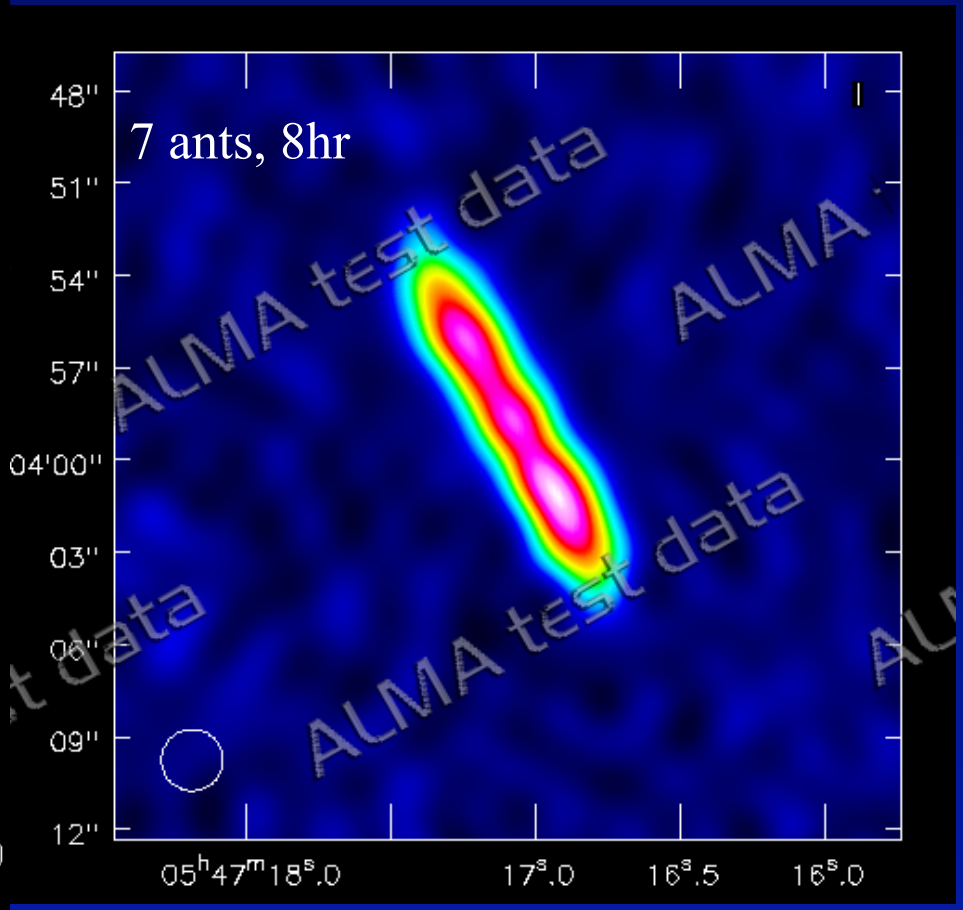




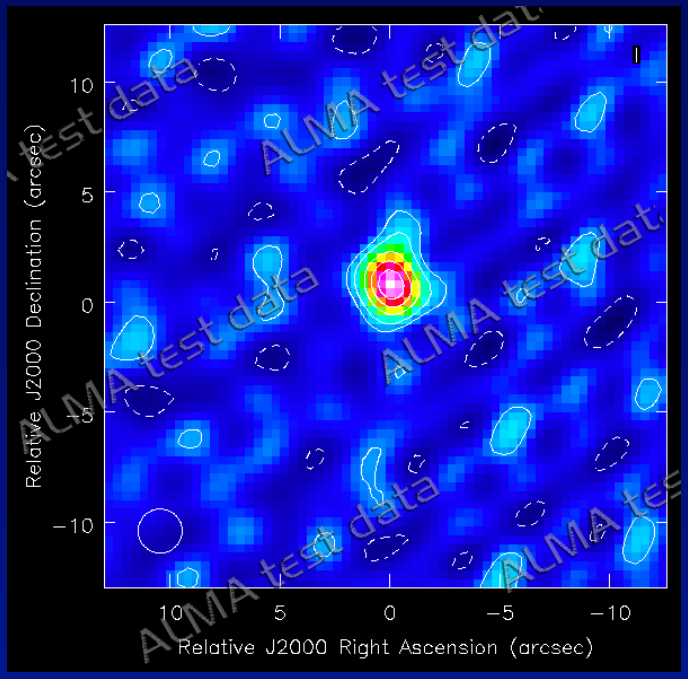
Beta-Pictoris Debris Disk

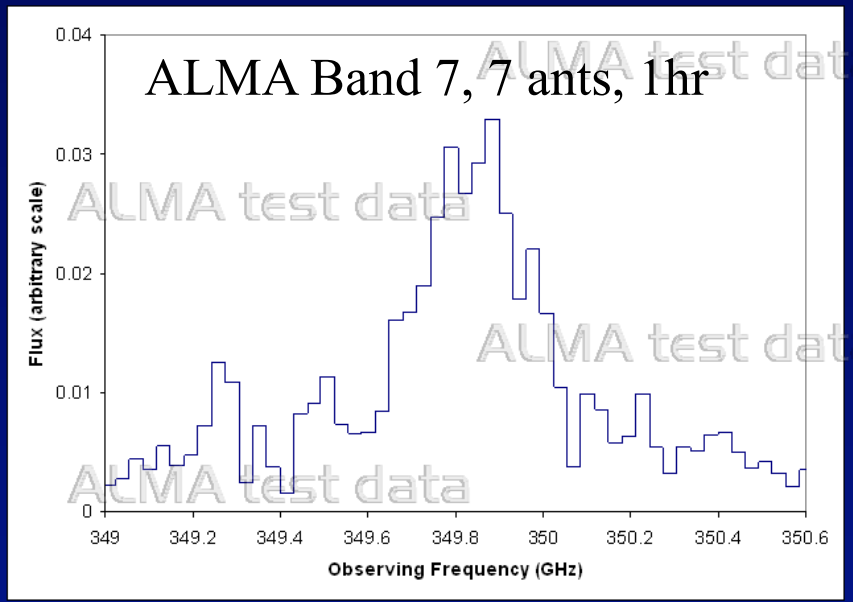
- Herschel ↓ 70 microns ALMA Band 7 ↓ (11th Nov)

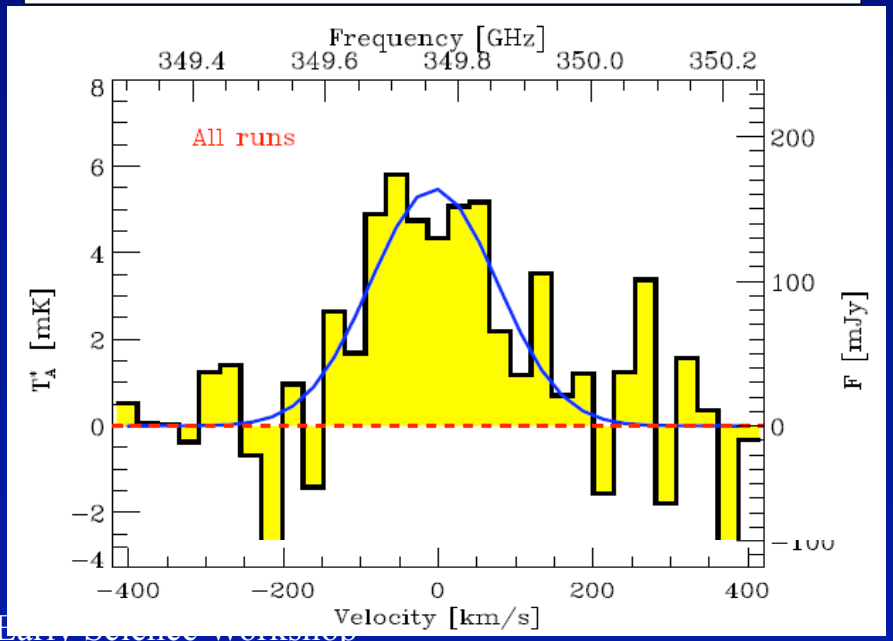




C+ line in BRI 0952 (z=4.4 QSO) (16th Nov)







APEX, 349.77 GHz, 22hrs (1.6hrs) →
Astro-ph: 0904.3793v1