ALMA Development Studies Call NA

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Small Development Projects & Upgrade Studies

NA Development Studies: FY2016 Call

- Overview: Describe Call, priorities recently endorsed by ALMA Board ('ALMA2030'), current studies and projects, other opportunities
- New NA Call for Studies published March 2015
  - FY2016 funding, dependent upon budget
  - Funding would begin 1 October 2015
  - Deadline mid-June 2015
- Goal: Develop new ideas for study, consistent with the ALMA 2030 vision, outcomes of previous studies

A ROAD MAP FOR DEVELOPING ALMA

ASAC Recommendations for ALMA 2030

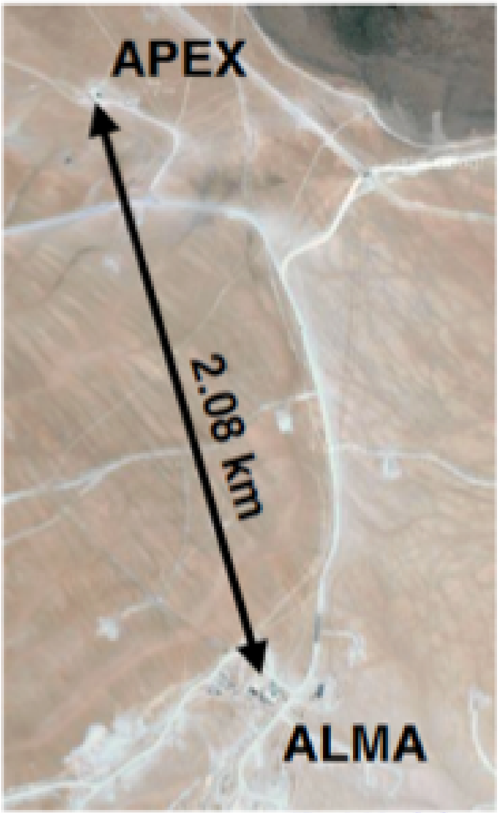
- Finish the Scope of ALMA (receivers, VLB capability)
- Recommended development paths
  - 1. Improvements to the ALMA Archive: enabling gains in usability and impact for the observatory.
  - 2. Larger bandwidths and better receiver sensitivity: enabling gains in speed.
  - 3. Longer baselines: enabling qualitatively new science.
  - 4. Increasing wide field mapping speed: enabling efficient mapping.

Current and Past ALMA Development Programs

Thematically ordered

- Projects from the First (2010, 2011) Calls are now reaching fruition:
  - Band 5 (163-211 GHz) receivers
  - Fiber optic connection from ALMA to the World
  - ALMA Phasing Project (VLB)
  - Several from subsequent Calls continue
- Studies from a number of Calls nearing completion

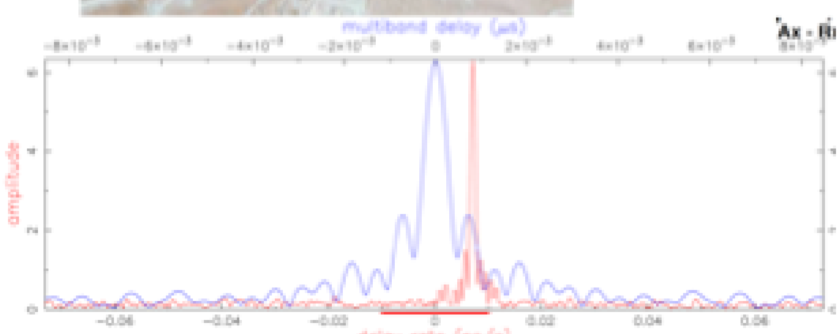
ALMA Phasing Project (APP)

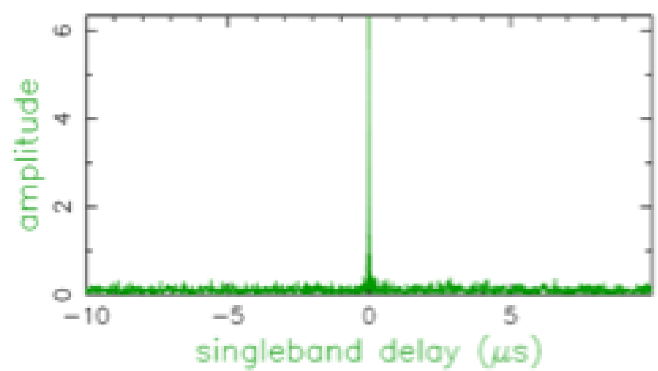


ALMA VLBI 'First Light'

Both APEX and ALMA used completely independent Hydrogen Masers, electronics and backends, making this a true VLBI experiment.

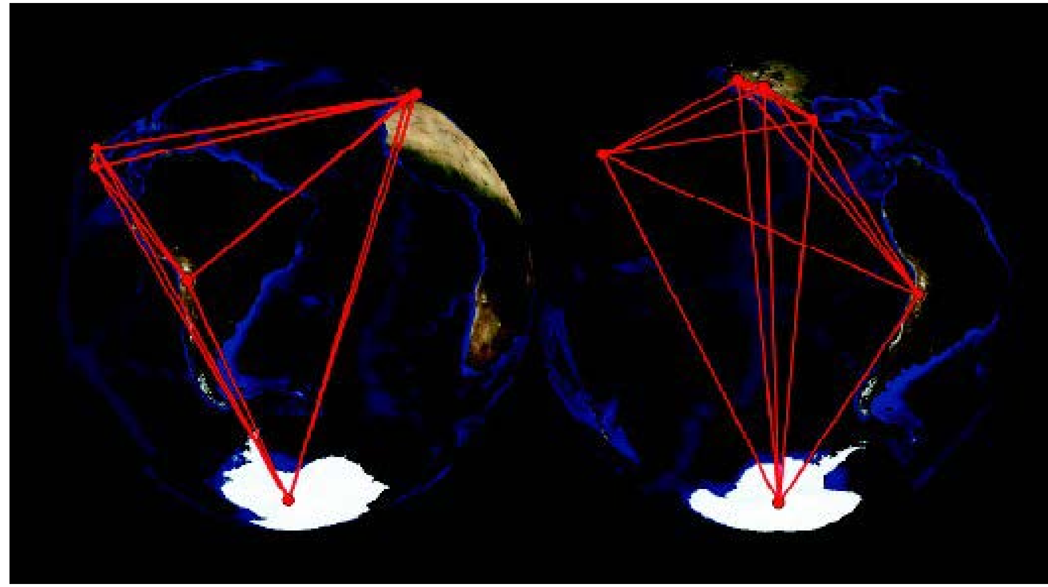
The high signal to noise of the detection is evident from the clear peaks in delay rate, and both multi-band and single-band delay (plots below).





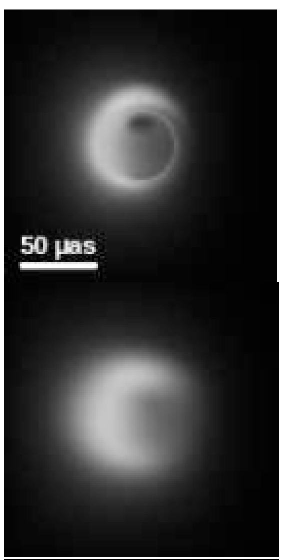
Longer Baselines: Enabling Qualitatively New Science

APEX—AOS fringes demonstrated 13 Jan 2015



24-31 March mission for APP: MIT: Matthews (APP), JAO-EOC: Phillips, Remijan

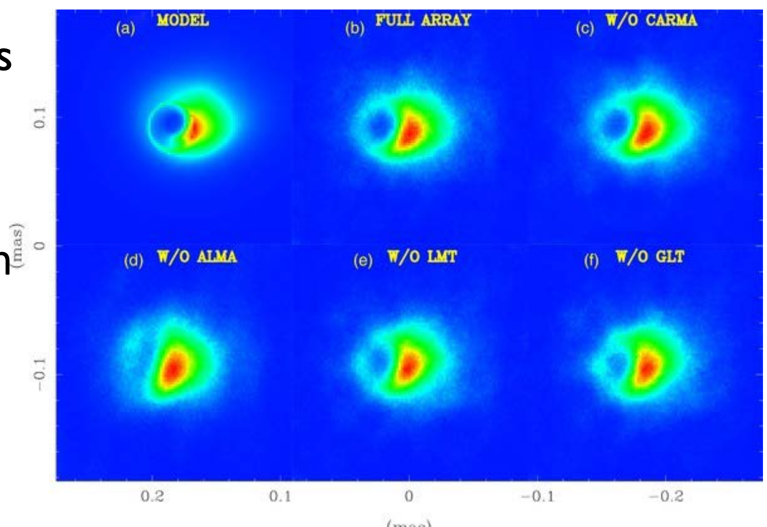
Discussion/work regarding execution sequences and integration with nominal observing modes



(Left) Image of SgrA* (top) as viewed by the array shown right above at 1.3mm (bottom)

1.3mm stations

M87 simulation
230 GHz
Lu et al. (2014)



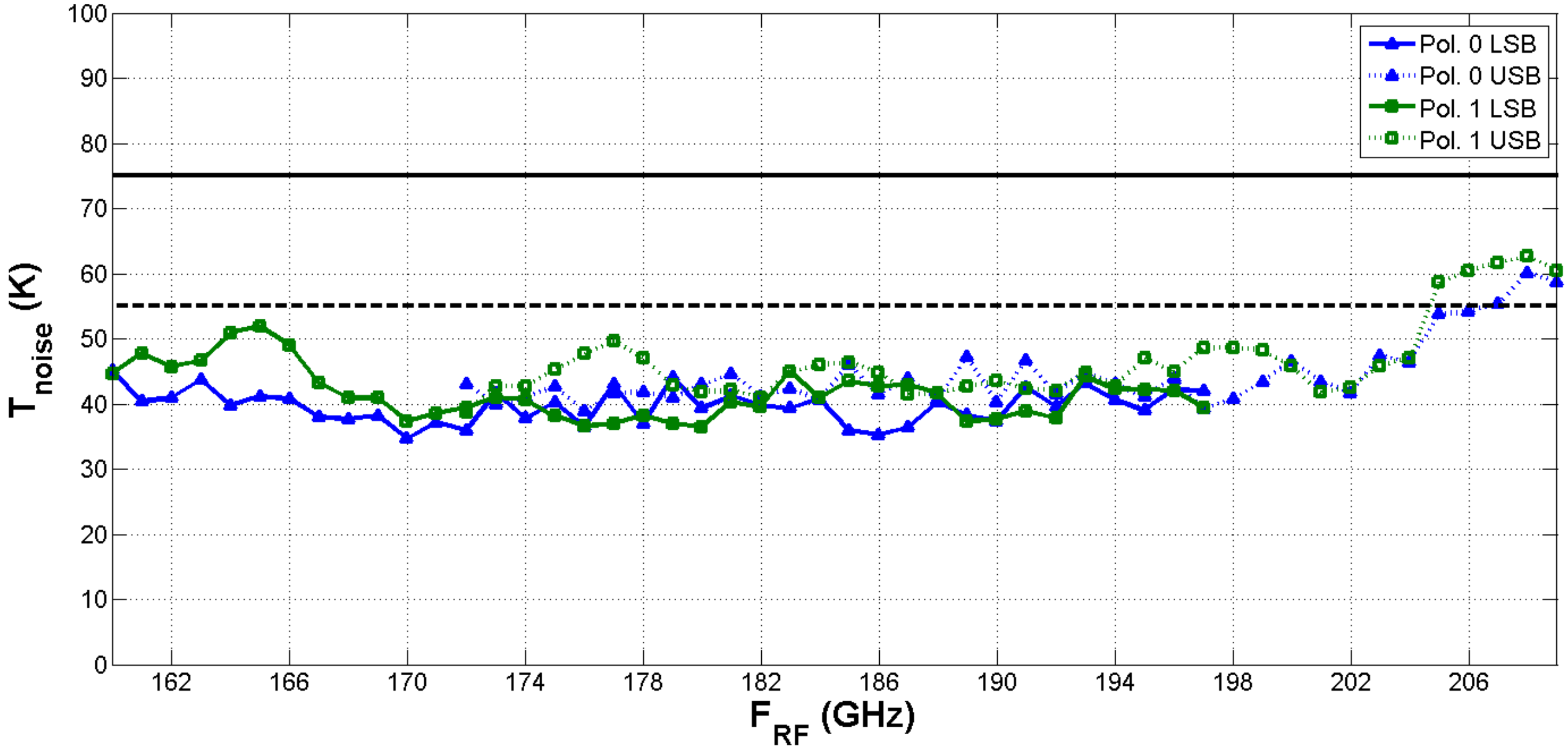
EU Led Projects/Studies Underway: Band 5

- 1 Feb 2013 – Kick-off meeting
- 2013/14 – Design optimized for series production
- Manufacturing Readiness Review (May 2014)
- Two production type CCAs built, being tested
- Decision to produce 73 units (up from 67)
  - Exactly same hardware, no mix with pre-production units
  - Cost difference small compared to refurbishment
- Band 5 integration at OSF to start in April 2015
  - Using experience from B4/8/10 integration
  - Last cartridge integrated Q2-2017
  - Funded by ESO & NRAO, plan agreed with JAO
  - ESO/NRAO/JAO team testing equipment at OSF now

Band 5 – Technical Status

- Tightened specs as compared to ALMA baseline
  - Receiver noise temperature
    - 80 % of RF band (163 – 211 GHz): 65 K → 55 K (15% better)
    - Whole RF band (163 – 211 GHz): 108 K → 75 K (30% better)
  - Extended LO tuning range (WCA by NRAO)
    - 166 – 203 GHz instead of 171 – 203 GHz (16% wider)
- First Band 5 production cartridge shows good noise temperature performance
- Science case summary: Laing et al 2010 Msngr 141, 14L

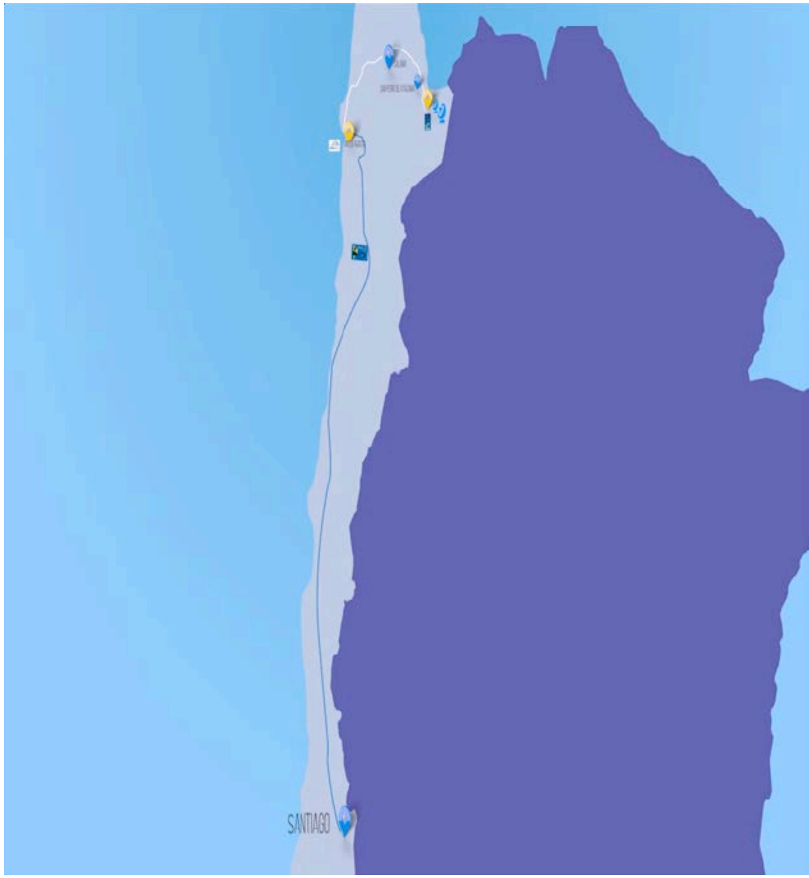
Band 5 – Sensitivity



ALMA's Connection to the World

150km of fiber connects ALMA/AOS to Chilean Internet backbone (REUNA) thence to the World

Data transmission speeds increased by more than a factor of ten over the current microwave link



NRAO NSF Associated Universities, Inc.

Improvements to the ALMA Archive
Three studies, two projects target this

- Studies
  - *NA FY2014* (Reports available)
    - Community Science Tool Development (Leroy et al.)
      - Development of spectral cube-domain analysis tools for use with ALMA data
    - New Calibration algorithms, refinements better long baseline imaging (Wilson)
      - correct for atmospheric influences on the image quality
    - Eu: Advanced data analysis and archive enhancement: Develop enhanced data analysis software system for CASA (UzK, Allegro, NBI)
      - MAGIX opt package, Auto-line-ID, Radiation transfer

ALMA NA Development Projects: Archive

Continuing for another year

- Projects
  - ADMIT (Lee Mundy, U. Md.) **Science Objective**:
    - ADMIT provides easy, organized, immediate access to the science data in the cubes
    - provides tools for discovering and mining science from the data
    - provides efficient access to the science in archival data to empower data reuse
  - Next Generation ALMA Viewer: (E. Rosolowsky, U. Alberta) **Science Objective**:
    - To provide a visualization solution for ALMA/CASA that will meet long-term needs for (1) big data, (2) archive exploitation, and (3) extensibility.

Larger Bandwidths; Better Receiver Sensitivity

Improving sensitivity and spectral grasp

- Construction/Upgrade of receivers to provide increased bandwidth to the digital system—there are Studies and Projects toward this end
  - New receiver Projects for uninstrumented ALMA Bands
    - Band 5 Project (Eu & NA): First of 73 of 8 GHz x 2 polzn 163-211 GHz receivers on ALMA in April; installation continues for ~2 years.
    - Band 2 (NA) Project: a 67-90 GHz prototype will present two 8 GHz sidebands, 2 polarizations to the system (currently of course only 16 GHz of this bonanza can be processed at once) Note Eu Study, below
    - Band 1 (EA & CL & NA) Project a prototype 35-50GHz, 8 GHz x 2 polzn receiver is under construction.

Larger Bandwidths; Better Receiver Sensitivity

- Currently there are several studies moving in this direction:
  - Band 6 Study: (NA) Kerr is studying a 2nd generation B6 (211-270 GHz) receiver incorporating balanced sideband-separating SIS mixers providing flatter gain and noise characteristics over a full 4-12 GHz IF band.
  - Band 10 Study: (NA) B10 (787-950 GHz) currently DSB 8 GHz; Kerr is studying a 2nd generation B10 SSB receiver over a full 4-12 GHz IF band.
  - Band 2+3 Study: (Eu) Band 2+3 development:
    - Prototypes of horn and OMT meet specs over 67-116 GHz
    - LNA development:
      - » UMan: excellent design over full range (being prototyped)
      - » Other LNAs (EU foundries) and packaging (IRAM,INAF & RAL)
    - Bench system test by end of year, full prototype in 2 yrs w/ 16GHz/pol
  - Combination of B2+3 would leave a cryostat slot, Studies for B11?
    - An Eu study investigated B11 science and the ALMA site
    - An EA study: Hot Electron Bolometer mixer with SiGe HBT low noise amplifier has been tested and a new SIS device (Nb/Al-AlOx-Al/Nb) has been fabricated.

Larger Bandwidths; Better Receiver Sensitivity

- Upgrade of existing Receivers:
  - Band 3 (84-116 GHz, NA) Project: Addition of deflux heater, magnets to improve stability, sensitivity
  - Band 3 (84-116 GHz, NA) Study of TKIP (traveling-wave kinetic inductance parameter) amplifier over the 55-175 GHz
  - Band 9 (602-720 GHz, (Eu) Study: upgrading Band 9 to 2SB with wider IF ready for implementation
- Upgrades to backends
  - Digital Study (Eu): Upgrade of the digital system to process increased bandwidth--developing next generation digitizers
  - NAASC Memo 114: suggests upgrade of the correlators to process the increased bandwidth –future Study?

Gains in Usability

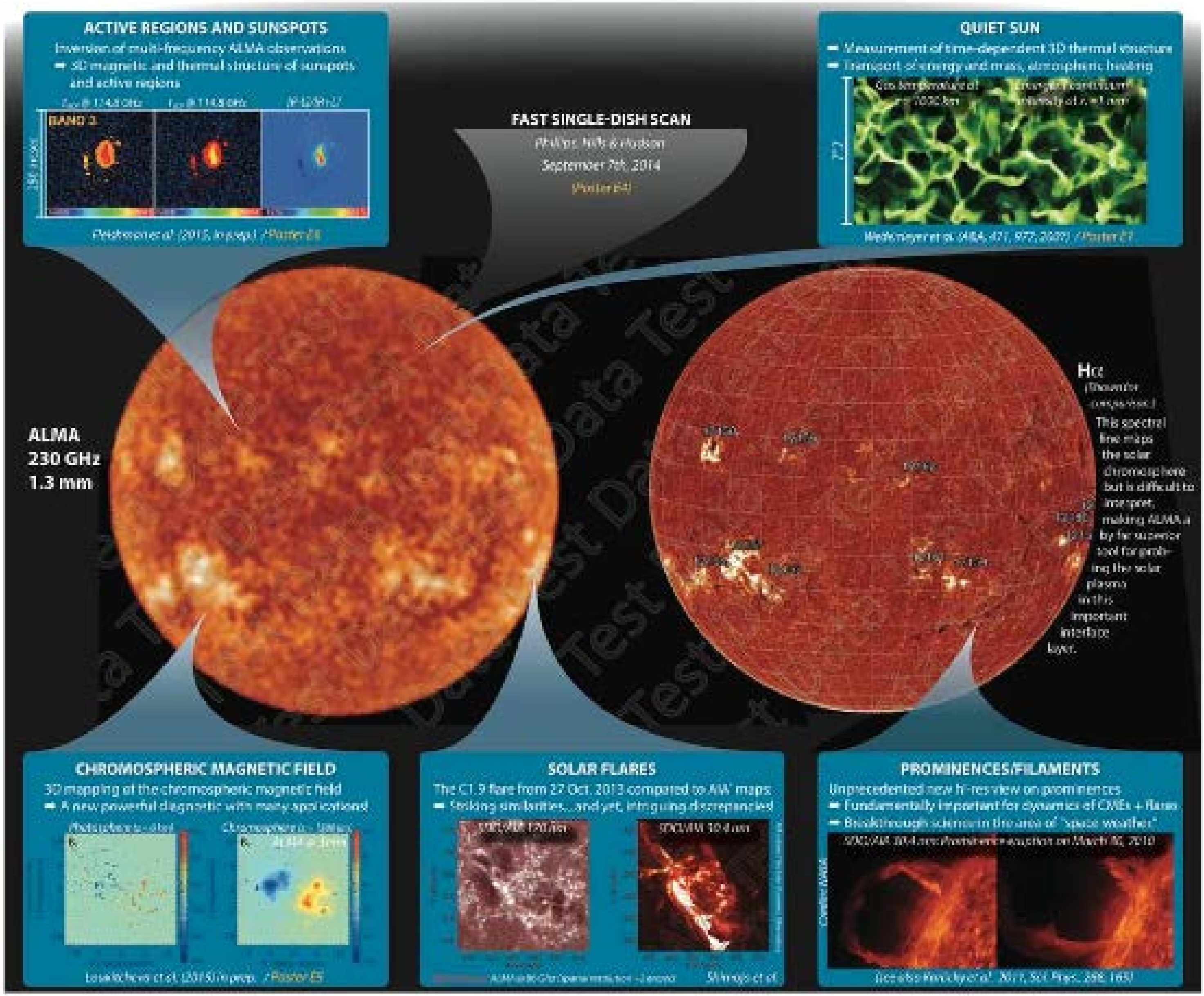
- Optical Fiber Project near completion (NA & Eu)
  - Data currently moves from ALMA to JAO via microwave link
  - *Fiber provides an order of magnitude increase in data volume transmission, better reliability*
  - Dec 2014: fiber completed. Equipment installed in all nodes. System ready for end-to-end testing. 3-month penalty applied.
  - Jan 2015 end-to-end-end (i.e., AOS/OSF ↔ SCO) performed. Result confirms specification, namely two full-duplex channels of 1Gbps each.
  - Full operational use of the link awaits permits
- Cryostat cooling upgrade Study (Eu, cost saving on power consumption)

Gains in Usability (continued)

- **Artificial Source at AOS** Project (EA with JAO)
  - Upgrade of the optical comb generator and the optical noise source for wider bandwidth (800 GHz to 1.4 THz) is going on.
  - J-band (WR03) photomixer test at Band 8 frequency range is under preparation.
- **Expansion of the Central LO Article to 5 Subarrays** Project (NA)
  - **Objective:** Add a 5th complete subarray, identical in every way to the four currently installed, completing the original subarray design specification of ALMA and allowing additional simultaneous engineering and scientific observing activities

Increasing Wide Field Imaging Speed

- Concept Study of a Millimeter Camera for ALMA Study (NA)
  - Examines the construction of a focal-plane array instrument for Band 3 wavelengths to be installed on one of the antennas within the Total Power Array (TPA). Improve efficiency of TPA observations which provide data on large scales for combination with 12-m Array and 7-m Array data.
- Solar Observing strategies Study (NA, Eu, EA): *new science area*
  - Open ALMA up for solar studies through the definition of total power and interferometric ALMA solar observing modes; development of detailed use cases, supported as appropriate by modeling; develop online/offline software requirements for solar observing modes, solar data calibration, and solar data reduction; development of solar observing modes to the ALMA operations to be implemented for Cycle 3 observing.



ACTIVE REGIONS AND SUNSPOTS
Inversion of multi-frequency ALMA observations
➡ 3D magnetic and thermal structure of sunspots and active regions
BAND 3
FAST SINGLE-DISH SCAN
September 7th, 2014
QUIET SUN
➡ Measurement of time-dependent 3D thermal structure
➡ Transport of energy and mass, atmospheric heating
ALMA
230 GHz
1.3 mm
Hα
This spectral line maps the solar chromosphere but is difficult to interpret, making ALMA a by far superior tool for probing the solar plasma in this important interface layer.
CHROMOSPHERIC MAGNETIC FIELD
3D mapping of the chromospheric magnetic field
➡ A new powerful diagnostic with many applications
SOLAR FLARES
The C1.9 flare from 27 Oct. 2013 compared to AIA maps
➡ Striking similarities... and yet, intriguing discrepancies
PROMINENCES/FILAMENTS
Unprecedented new hi-res view on prominences
➡ Fundamentally important for dynamics of CMEs + flares
➡ Breakthrough science in the area of "space weather"

Pathways to ALMA Development!

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- Collection of possible development possibilities
  - For each possibility:
  - Science motivation
  - Readiness level
  - Timescale for development
  - Impact
  - Rough expected cost
- Informed by Development Studies and observatory experience
  - No prioritization
  - Some limited cross-linking of items

Examples from Matrix

No.	Improvement Area	Item	Degree	Speed/Difficulty	Fabrication Cost	Target Science	Note	Operation effects
01	Sensitivity	More 12m antennas	incremental	Known	High to Very High	All	Correlator, IF transfer	More power generation
02		More ACA	incremental	Known	High to Very High	Large scales	ACA correlator/IF	More power generation
03		New digital system	×2 bandwidth in some cases, otherwise needs new Rxs	Moderate, some research	Moderate to High	All	See also 33, 43	Some power, array downtime
04		2SB B9/B10	×2 for B9/B10	Research/Known	Moderate	High frequency	~20% of all observing time	Downtime for installation
05		Lower noise Rxs	20%-200%, more at high frequency	Research	Moderate	All		Downtime for installation
06		New technology devices for Rxs	Potentially large	Long scale research	Moderate to High	All	Quantum-limited amps, ultra-wideband	

11	Resolution	Longer baselines	×2-3, or up to 300 km	Requires construction	Moderate to Very High	SMBHs, photospheres of stars, high-z BH	Need more experience with long baselines	Snow cleanup and recovery
12		Better phase correction	~10%-30%, more for high frequencies. Increasingly important for long baselines	Software, research, maybe some new hardware	Very low	Disks, exgal. All science fields that require high resolution.	Need statistics on current performance of WVR	
13		mmVLBI	VLBI operations for general users	Ongoing	Low to Moderate	High resolution/non-thermal	Need good operation model	Low Agreements with other observatories/networks
21	FOV	Multi-beam Rxs	×N	Extensive; modifications to cryostat, LO, potentially IF transport, correlator	Very high	Nearby galaxies, local SF regions, Galactic surveys	Biggest gain at higher frequencies	Downtime for deployment and testing. Data rate increase, archive cost. Software/pipeline/algorithms development needed
22		Under-illuminated feed	×a few for mapping of bright sources	Not clear how to share with normal system	Moderate	Solar science, GMC mapping	Easier to implement independent subarrays	Downtime for installation

31	Spectral Coverage	B2	New capability	Similar to other bands	Moderate to High	Disks, high-z, SZ, molecules	Could be combined with upgraded B3 and wide band	Downtime for installation
32		B11	New capability	Research, long commissioning	High	Very high-z H_2, FIR, local NII 205 um	Very small fraction of time available	Downtime for installation
33		Extend IF for Rxs	×2-3, maybe more?	New Rx, new digital system/IF transport	Moderate to High	Simultaneous isotopologues , line surveys	More correlator to improve sensitivity and spectral coverage	Data rate/Volume increase
34		Correlator	×2 bandwidth in some cases, otherwise needs new Rxs	Moderate, some research	Moderate to High	line surveys	See also 03, 33	Data rate/Volume increase

41	Simultaneous frequency coverage	B2+3	New capability	Some research	Moderate	As B2	Saves a 4K cryo slot for B11	Downtime for installation
42		Multi freq. feeds	×2.2	Research	Moderate	SLEDs, multi-transition studies	Requires system wide modifications	Data rate/Volume increase
43		Dual feed use?	×2 for large scale mapping	Quick?	Low to moderate?	Galactic GMCs, nearby galaxies	Requires system wide modifications	Data rate/Volume increase
51	Imaging quality and calibration	Deconvolution, combination software	Important for extended /complex srcs.	Quick, some research	Low	Complex sources	Need to understand the best way to add 12m array with ACA	None
52		Better phase calibration	~10-30%, maybe more at high freq.	Research	Low	High frequency, high resolution (e.g. disks)		Data gathering
53		Better sidelobe calibration	Better image fidelity in	Measurements	Low	Large mosaics,		Data gathering
54		Better amplitude calibration	×2?	Calibration source	Low to moderate?	High precision line ratios, absolute calibration		Data gathering
55		Better passband calibration	Very high spectral resolution?	Noise injection device	Low	m/s velocity resolution		Data gathering
56		Better polarization calibration and purity		External wire grids, OMT development	Moderate	High precision/ dynamic range pol.		Data gathering
61	Flexibility	Subarrays	×2-3 speedup for shallow mapping or multifreq. or simultaneous multi-wl monitoring	More LO reference systems	Low	Galactic GMC, nearby galaxies, variable phenomena	Pretty much implemented	None
62		Increase in data rates	Resolution, archival value	Infrastructure	Moderate	Galactic, nearby gals., high time resolution	Increase in processing time, data transmission	Archive space and cost

71	Usability	Better automatic pipeline calibration and imaging heuristics	Better archival products, long term science value	Software	Low	All		None
72		Automatic Analysis and Enriched Archive	Added value products, cube descriptions	Software	Low to moderate	All		None
73		Visualization	Quick first look tools, better 3D visuals	Software	Low to moderate	Complex sources		None
74		Cube analysis tools (source finding, line ids, source decomposition, property measurements)	Better analysis for experts and non experts	Software	Low to moderate	All		None
81	Reliability & efficiency	Remote power recovery	Fast recovery from power or weather	Infrastructure	Low	All	Partially implemented	Increased efficiency, low cost
82		Upgrade of power delivery system	Increased reliability	Infrastructure	?	All		Increased efficiency
83		Cryo cooling improvements	Cheaper reliable cooling systems	Infrastructure	Moderate	All		Refurbish all antennas, downtime
84		Remote inspection for weather recovery	Fast recovery from weather	Infrastructure	Low to Moderate	All		Installing and maintaining cameras