CASA Scientific Priorities

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formerly known as cabal

CASA

Science requirements for CASA are based on ALMA, EVLA, +Single Dish applications

Single Dish part is now managed by NAOJ:
NAOJ project manager and
project scientist will be nominated soon

This talk will focus on ALMA and EVLA

EVLA

Current state of ALMA and EVLA:

EVLA

- WIDAR correlator is now in operation,
  old VLA correlator: RIP

- WIDAR modes are currently being
  implemented and tested

- 3 main steps forward:
  (a) OSRO modes
  (b) RSRO modes (current)
  (c) 3-bit sampler 8GHz wideband mode

I. "OSRO1": A configuration for continuum applications, to comprise two independently tunable sub-bands, full polarization, each of which has 128 MHz bandwidth with 64 channels, with the possibility of smoothing in frequency to reduce dataset sizes or to improve spectral response offlin In this configuration it will also be possible to decrease the bandwidth by powers of two, keeping t same number of channels, to provide the spectro-polarimetry capabilities in Table 1.

Table 1: Correlator capabilities per sub-band for full-polarization continuum applicatio and spectro-polarimetry (OSRO1)

Sub-band BW (MHz)	Number of poln. products	Number of channels/poln product	Channel width (kHz)	Channel width (km/s at 1 GHz)	Total velocity coverage per sub-band (km/s at 1 GHz)
128	4	64	2000	600/ν(GHz)	38,400/ν(GHz)
64	4	64	1000	300	19,200
32	4	64	500	150	9,600
16	4	64	250	75	4,800
8	4	64	125	37.5	2,400
4	4	64	62.5	19	1,200
2	4	64	31.25	9.4	600
1	4	64	15.625	4.7	300
0.5	4	64	7.813	2.3	150
0.25	4	64	3.906	1.2	75
0.125	4	64	1.953	0.59	37.5
0.0625	4	64	0.977	0.29	18.75
0.03125	4	64	0.488	0.15	9.375

OSRO1

II. "OSRO2": A higher resolution configuration for spectral line applications, to comprise one tunable sub-band, dual polarization, with 128 MHz bandwidth and 256 channels, again with the possibility of smoothing in frequency to reduce dataset sizes or to improve spectral response offline. It will be possible to decrease the bandwidth by powers of two, keeping the same number of channels, to provide the capabilities in Table 2.

Table 2: Correlator capabilities for spectral line applications, dual polarization (OSRO2)

Sub-band BW (MHz)	Number of poln. products	Number of channels/poln product	Channel width (kHz)	Channel width (km/s at 1 GHz)	Total velocity coverage (km/s at 1 GHz)
128	2	256	500	150/v(GHz)	38,400/v(GHz)
64	2	256	250	75	19,200
32	2	256	125	37.5	9,600
16	2	256	62.5	19	4,800
8	2	256	31.25	9.4	2,400
4	2	256	15.625	4.7	1,200
2	2	256	7.813	2.3	600
1	2	256	3.906	1.2	300
0.5	2	256	1.953	0.59	150
0.25	2	256	0.977	0.29	75
0.125	2	256	0.488	0.15	37.5
0.0625	2	256	0.244	0.073	18.75
0.03125	2	256	0.122	0.037	9.375

OSRO2

The maximum bandwidth available will be 2 GHz, implemented as 2x1 GHz basebands that can be tuned independently within a given receiver band. Recirculation (trading sub-band bandwidth for an increase in the number of channels per sub-band) will be enabled in the correlator, to give the capabilities per sub-band pair shown in Table 3 below. There will be 64 independently-tunable sub-band pairs, which can have identical bandwidths, number of channels, and number of polarization products, although it will also be possible to trade sub-bands for channels. The number of polarization products can be traded for an increase in the number of channels, up to a maximum of 16,384 channels per polarization product per sub-band pair.

Table 3: Correlator capabilities per sub-band with recirculation; the number of polarization products may be traded for number of channels

Sub-band BW (MHz)	Number of poln. products	Number of channels/poln product	Channel width (kHz)	Channel width (km/s at 1 GHz)	Total velocity coverage per sub-band (km/s at 1 GHz)
128	4	64	2000	600/v(GHz)	38,400/v(GHz)
64	4	128	500	150	19,200
32	4	256	125	37.5	9,600
16	4	512	31.25	9.4	4,800
8	4	1024	7.813	2.3	2,400
4	4	2048	1.953	0.59	1,200
2	4	4096	0.488	0.15	600
1	4	8192	0.122	0.037	300
0.5	4	16384	0.031	0.0092	150
0.25	4	16384	0.015	0.0046	75
0.125	4	16384	0.0076	0.0023	37.5
0.0625	4	16384	0.0038	0.0011	18.75
0.03125	4	16384	0.0019	0.00057	9.375

RSRO

EVLA

- 3bit samplers (8GHz BW capability) have been delayed due to technical problems.

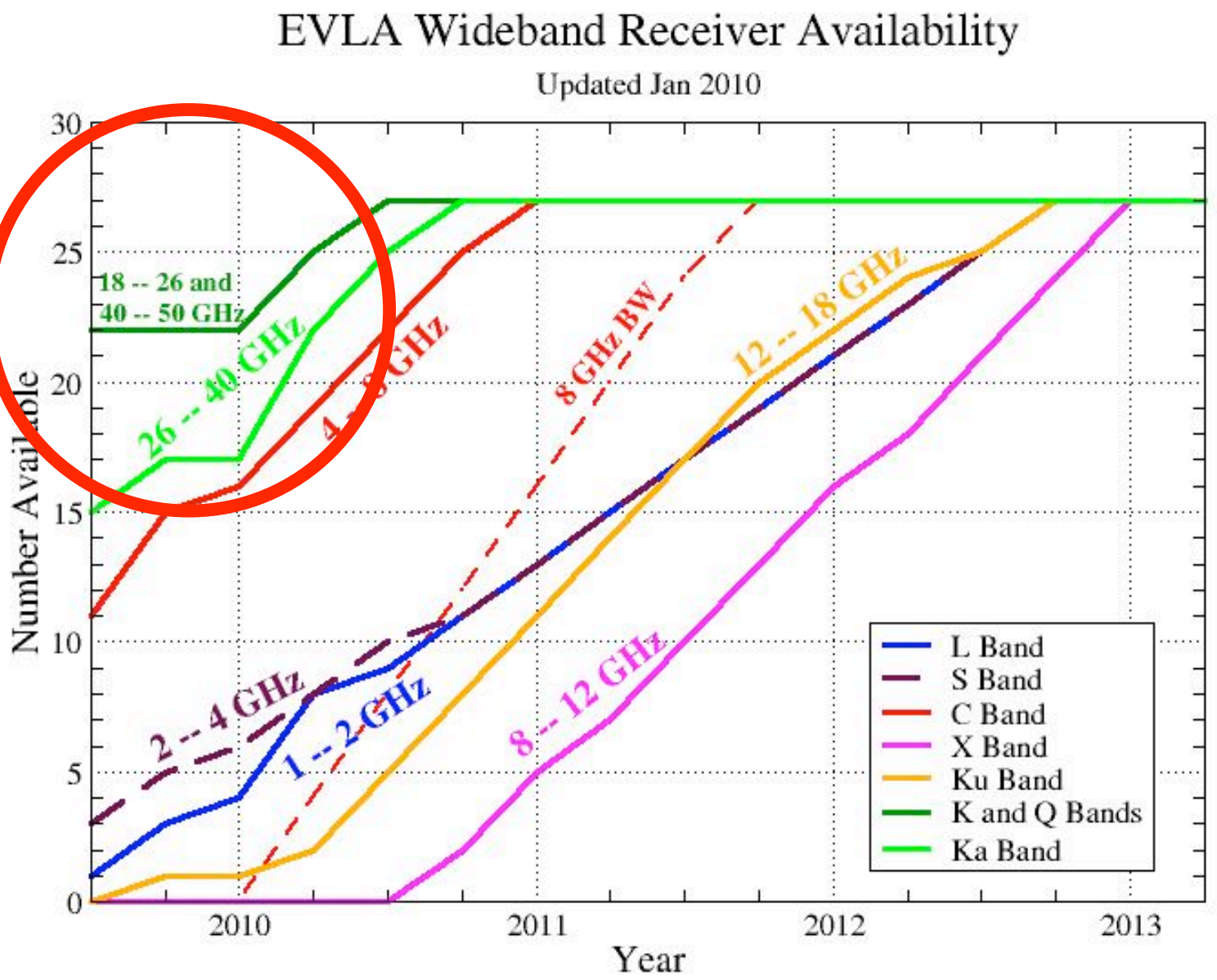
- Availability about 1 year from now.

➔ CASA needs to be able to follow the wideband requirements imposed by this schedule

The data rates will also increase as the array configurations expand

D until Jul ➔ **C** Aug-Nov ➔ **B** Dec-Feb ➔ **A** Mar-Jun 2011

EVLA


EVLA Wideband Receiver Availability
Updated Jan 2010
Number Available
Year
2010
2011
2012
2013
0
5
10
15
20
25
30
18 -- 26 and
40 -- 50 GHz
26 -- 40 GHz
8 GHz BW
12 -- 18 GHz
2 -- 4 GHz
1 -- 2 GHz
8 -- 12 GHz
L Band
S Band
C Band
X Band
Ku Band
K and Q Bands
Ka Band

ALMA

- Currently mainly antenna commissioning (holography, pointing, Rx testing, polarization Properties; linear feeds!, …) and

- first correlations between few antennas/baselines

- Number of operating antennas will change quickly as new antennas are shipped and assembled ➔ 6 ants in July!

- Call for first ALMA science end of 2010 with science data being taken in 2011 (w/ 16 antennas)
Receivers will be available in the 3, 1, 0.9 and 0.45 mm bands (3, 6, 7 and 9) and possibly other bands.

➔ Submm capabilities needed from very start

ALMA

Highest priority correlator modes for Early Science (the mode numbers are those from ALMA Memo 556).

Mode	Total Bandwidth	Number of Spectral Points	Spectral Resolution	Polarization
7	2 GHz	4096	488 kHz	Dual
9	500 MHz	4096	122 kHz	Dual
12	62.5 MHz	4096	15 kHz	Dual
18	62.5 MHz	2048	30 kHz	Full
70	2 GHz	64	31.25 MHz	Full

The Atacama Large Millimeter Array (ALMA) Quick Reference

Bands:	3	4	5	6	7	8	9	10
Frequency (GHz)	84-116	125-163	163-211	211-275	275-373	385-500	602-720	787-950
Wavelength (mm)	3.57-2.59	2.40-1.84	1.84-1.42	1.42-1.09	1.09-0.80	0.78-0.60	0.50-0.42	0.38-0.32

	Early Science	ALMA Inauguration
Antennas	≥ 16 x 12m	≥ 50 (12m & 7m)
Bands	≥ 3 bands (Bands 3,6,7,9 likely)	Bands 3,6,7,9 (+ 4,8 & 10 on some)
Maximum Bandwidth	16 GHz (2 polarizations × 8 GHz)	
Correlator Configurations	≥ 5	0.01 - 40 km/sec, 71 configurations
Maximum Angular Resolution	$0.02'' \left(\frac{\lambda}{1\ \mathrm{mm}}\right) \left(\frac{10\ \mathrm{km}}{\mathrm{max\ baseline}}\right)$	
Maximum Baseline	At least 250m (may reach 1km)	15.3 km
Continuum Sensitivity (60 sec, Bands 3—9)	~0.2 — 4.2 mJy	~0.05 — 1 mJy
Spectral Line Sensitivity (60 sec, 1 km/sec, Bands 3—9)	~30 — 250 mJy	~ 7 — 62 mJy

Sensitivity Calculator: http://science.nrao.edu/alma/tools.shtml

ALMA

01 December 2009 Phase Closure with three antennas at AOS.
01 March 2010 *Solicitation of Ideas for Science Verification Targets.*
01 June 2010 Aperture Synthesis Image with Six or more antennas.
15 July 2010 Demonstration of Phase Correction with WVR's.
01 October 2010 Continuum Total Power Image using a 12m antenna with a nutating subreflector.
01 November 2010 Release of first Science Verification data.
01 December 2010 *Call for Early Science.*
01 January 2011 First sub-millimetre wavelength synthesis image.
01 February 2011 *Proposal due date*
01 March 2011 Astronomical Signal with an ACA 7m Antenna.
01 April 2011 Release of First Public Images.
01 May 2011 First image at a frequency higher than 850 GHz.
01 June 2011 Polarization Images.
01 July 2011 Phase closure with 3 ACA 7m antennas.
01 August 2011 *Start of Early Science*

01 November 2011 Aperture synthesis image with Six or more 7m antennas.
01 February 2012 Maps combining 12-m and ACA antennas.
01 April 2012 Maps combining zero-spacing with 12-m and ACA.
01 June 2012 High resolution images using baselines of ~4km.

01 August 2012 "Extreme" resolution images with the longest baselines.

01 September 2012 *Inauguration*

ALMA relies almost entirely on CASA!!

- QSOs weak at high frequencies, best calibrators are planets, moons, asteroids but they are sparse, extended, have seasons, phases, they move, have strange shapes, …
➔ accurate models are needed

- ALMA needs novel techniques for phase stability over long baselines and at high frequencies

- Different calibration techniques (loads not diodes, atmosphere, etc)

-Small primary beam! ➔ mosaicing will be a major mode of operation

- ACA+ main array combination

Users

Users!!
There's a growing community using CASA.

What they expect:

- consistency
- user friendliness
- publication quality output
- reliability of the code
- speed
- EVLA and ALMA data to be calibrated & imaged properly
- basic analysis tools now and
- more advanced analysis tools in the future

What we can gain:
- Bug finding
- suggestions for improvements
- collect scripts for wider use
- establish a forum where users help users

Can’t avoid it: the shopping list

Priority 0.5:

- EVLA Import/Export switched/total power/Tsys data from SDM to MS to UVFITS
- ALMA Import/Export switched/total power/Tsys data from SDM to MS to UVFITS
- Online Flag.xml from SDM to MS to UVFITS
- ALMA Linear polarization: joint estimation of instrumental and source linear pol
- Way to generate baseline dependent planet model for use in calibration, setjy etc

Can't avoid it: the shopping list

Priority 1 & 1.5:

Interface & Visualization:

- plotms: Add major capabilities as outlined in JIRA 1415 (multipanel, overplotting, iteration, averaging in velocity, plot weights, plot Tsys). Force redraw data, robust unzoom. Add connectiong dots with lines and histograms. Add hard copy.

- plotms: move plotcal functionality into plotms

- ms viewer: planning of refactoring (in plotms, data caching, new capabilities)
  –design

- viewer: hardcopy quality improvements (publication quality)
- viewer: full scriptability
- viewer: ergonomic improvements (tapedeck, menus, registration)

- viewer: refactoring/replacement (e.g. kvis, ds9)

Can’t avoid it: the shopping list

Priority 1 & 1.5:

Data Handling:

- The Package must be able to handle data taken in standard ALMA and EVLA modes for the Sun and Solar System objects, including moving targets.
Note: this mostly consists of not making extra sources or frequencies due to the changing positions and Doppler. handle stepped doppler-tracked data with frequency offsets - design & implementation

- SDM and MS handling of OTF mosaicing observations - planning

Can’t avoid it: the shopping list

Priority 1 & 1.5:

Flagging and UV Data Manipulation:

- flagdata: improvements to speed and useability (cleanup of options)
- flagdata: apply online flags (e.g. from FLAG_CMD table)
- flagdata: improvements to autoflagging for simple RFI
- cvel: add sinc function (FFT shift) gridding, improve hanning smoothing

Can't avoid it: the shopping list

Priority 1 & 1.5:

Calibration:

- make scratch columns fully optional throughout calibration
- setjy improvements (setting of simple models, channel dependent spectra)
- incorporate EVLA antenna gain curves (as a function of frequency over EVLA bands)
- atmospheric optical depth support as function of frequency (Owen/Marvil models)
- applycal: interpolation improvements (box-car,median,timerange,scan)
- uvcontsub: improvements from uvcontsub2 (e.g. cross-spw solving)
- EVLA parallel hand polarization correcting/solving - development
- package up delay fitting (as opposed to a full-fledged fringe)

Can’t avoid it: the shopping list

Priority 1 & 1.5:

Imaging:

- clean: correct outlier/inlier field use
- clean: functioning mfs nterms > 1 (MFS and MSMFS)
- clean: add hanning smoothing and sinc function (FFT shift) gridding
- clean: multi-ms support
- clean: resolve mosaic “flat-noise” issue; meaningful threshold

Can’t avoid it: the shopping list

Priority 1 & 1.5:

Image and Data Analysis:

- specfit task: spectral profile fitting (to a pixel or average over region)
- immath: polarization improvements (use of stokes cube, easy pola thresholding)
- immath: spectral index using cube channels (from single or multiple images)
- immath: rotation measures (using cube channels and/or multiple images)

Can’t avoid it: the shopping list

Priority 1 & 1.5:

Algorithm Development:

- wide-field image-plane polarization correction - prototyping
- "Narrow field, wide-band imaging of confused sources” - prototyping

Can’t avoid it: the shopping list

Priority 1 & 1.5:

HPC:

- Complete parallelization tests of prototype processing cluster
  multi-threading/shared-memory use of casa applications - planning
- multi-threading/shared-memory use of casa applications - implementation
- Complete software for parallelized processing cluster
- Define details of scheme to pass jobs from workstation to cluster
- Implement scheme to pass jobs from workstation to cluster

Can’t avoid it: the shopping list

Priority 1 & 1.5:

Simulation:

- Fix issue that results in multiple applications of noise
- Promote polarization sim to task level
- Simulate target/cal cycle

Priority 2-3:

Interface & Visualization

- ms viewer: time and channel averaging and rms
- listvis/listcal: speed and output improvements
- viewer: box/region handling cleanup and improvements (incl. resizing)
- viewer : multipanel improvements (specify plot panel padding or spacing, display axes along outermost axes only)
- viewer: user selection of step range and increment (tapedeck)
- plotms/viewer: report cursor info in logger/term (e.g. with button/hotkey)
- plotms/viewer: The user shall be able to change between different time and coordinate units and formats (e.g. hours, hhmmss, radians, ddmmss.s) for axes.
- SDM and MS handling of OTF mosaicing observations
- The Package shall be able to import a user-supplied ephemeris in tabular form of the same format used by the Observation Preparation Tool.
- The Package must be able to calculate and apply phase offsets based on the difference between observed and imported ephemerides.
- Support in measurement set for ecliptic/galactic coordinates
- Support in measurement set for ‘apparent place’; geocentric coordinates of date

Priority 2-3:

Data Handling
- uvaveraging: baseline-dependent averaging (e.g. Owen, Cotton)
- fixvis: add aberration correction

Calibration
- EVLA parallel hand polarization correcting/solving - implement
- gencal: add opacity corrections
- gencal: add gaincurve corrections
- gencal: retrieve EVLA online updated antenna positions, analogous to AIPS VLANT
- Correct handling of correlation dependent flags when calibrating
- Add phase center shifts to gencal or fixvis or cvel
- ALMA Linear polarization: constraints on mean D
- ALMA Linear polarization: 2nd order effects/non-linearized solutions

Imaging
- allow combination of components and model images in clean
- clean: correct/flexible handling of correlation dependent flags
- clean: output cubes (equally spaced) in optical velocity
- clean: make boxit capability accessible from within interactive
- clean implement MEM deconvolution with clean-task capabilities (incl. mosaics, widefield)

Priority 2-3:

Image and Data Analysis
- region handling cleanup and improvements
- imfit: improvements (improved errors,deconvolve beam)
- imstat: improvements (histogram fitting for noise) line transition syntax definition (e.g. restfreq, splatalogue access, specfit)
- boxit: speed and robustness improvements (e.g. code in c++ if needed)
- imregrid: rotation by arbitrary angle for rotation axes aligned with the cube axes

- widefield image-plane polarization correction - task implementation

Algorithm Development
- "Narrow Field, wide-band imaging of confused sources" - task implementation
- RFI excision algorithm development (e.g. GMRT, Pen, Kogan)
- RFI excision algorithm implementation (e.g. GMRT, Pen, Kogan)

Simulation
- Make simdata more modular Incorporate SD sim
- Incorporate SD sim
- Simulate pointing errors
- Specify resolution instead of configuration

CASA

Final Remarks:

EVLA and foremost ALMA are projects that cannot fail. ALMA is one of the biggest multi-national astronomical facilities ever built.

The success or failure of this project will be critical for future large, multi-national facilities in general, and in particular to the partner institutes involved.

The data reduction package is the observer's interface to the data they receive from the facilities.

The quality of CASA imaging and reduction, and analysis tools is critical for all scientific breakthroughs expected from both telescopes.

And imaging quality will also be in the public eye through EPO