ALMA: Early Science
& synergies with other facilities

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Perth 28 April 2011

ALMA
EUROPEAN ARC
ALMA Regional Centre || Italian

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

ALMA basics

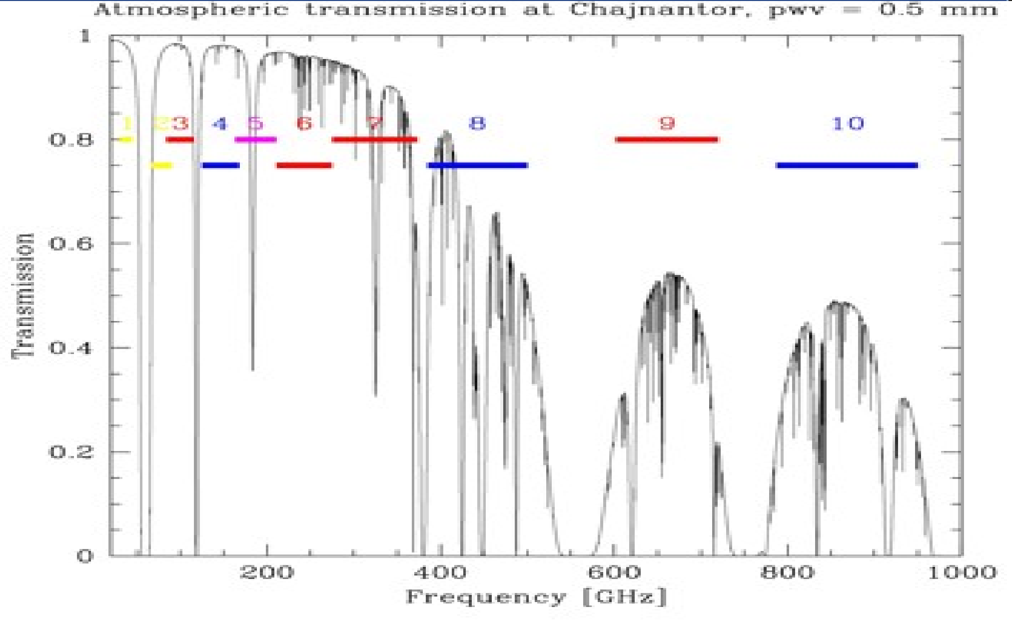
ALMA Early Science

Calibrating ALMA

ALMA+Planck+ATCA+...

ALMA numbers

- The Atacama Large Millimeter Array is a **mm-submm reconfigurable interferometer**
- Under construction on the Chajinantor plain (**5000m**, Chile)
- Frequency range: **10 bands between 30-900 GHz** (0.3-10 mm)
- Antennas: **50x12m** main array + (**12x7m + 4x12m**) ACA



- **World wide collaboration:**
  Europe: ESO (14 countries),
  North America: NRAO (USA, Canada),
  East Asia: NAOJ (Japan, Taiwan),
  Chile
- Contributors share the observing time

ALMA numbers

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- Frequency range: **10 bands between 30-900 GHz** (0.3-10 mm)
- Antennas: **50x12m** main array + (**12x7m + 4x12m**) ACA
- Baselines length: **15m ->150m-16km** + **9m->50m**
- Resolution: **0.2” x (300/freq_GHz)x(1km/max_baseline)**
- FOV 12m array: **20.3”/(300/freq_GHz)**
- Bandwidth: **2 GHz x 4basebands for each of 2 polarisations**
- **70 correlator modes**: 31MHz-2GHz / 8192 ch / single, dual, full polarisation product
- **Mosaic** capability

ALMA numbers

Noise in the image

$$\sigma_{image} = \frac{k_b T_{sys}}{A\eta}\sqrt{\frac{2}{t\ \Delta\nu\ n_{pol}\ N(N-1)}}$$

Angular resolution

$$\theta = 1.33\frac{\lambda}{b_{max}}$$

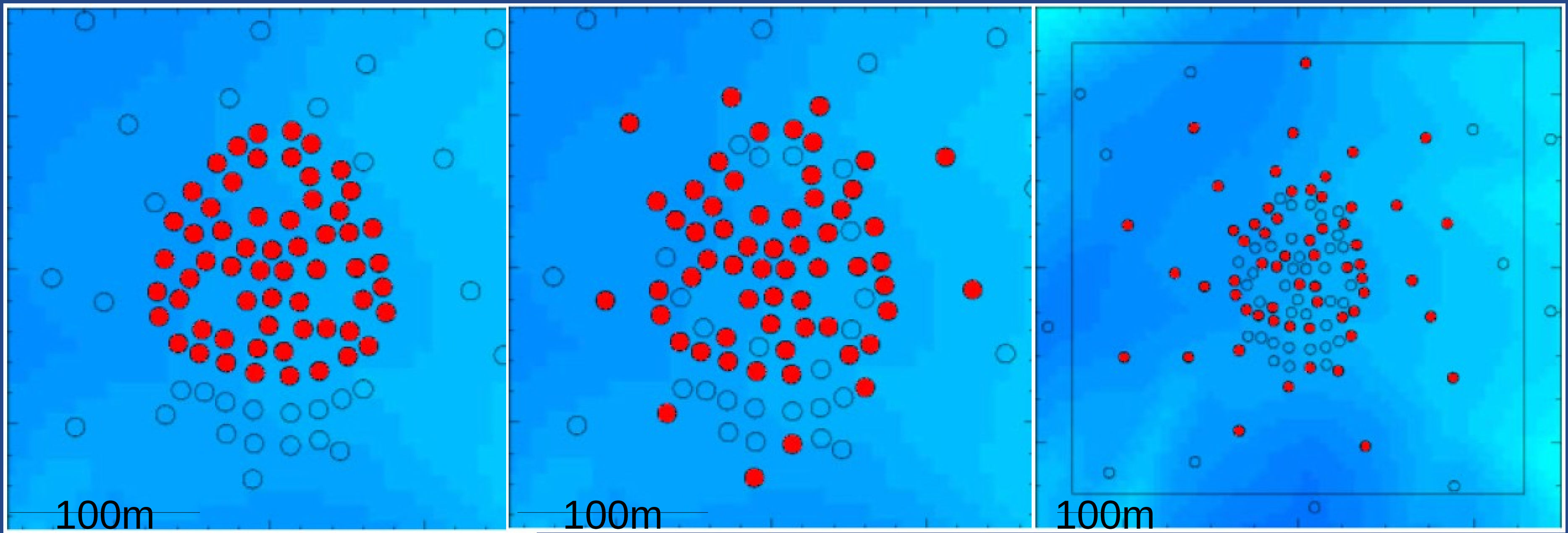
Dry site, low pwv, low Tsys, high sensitivity also at submm frequencies

>6500sqm of effective area and 1225 baselines for the 12m array
+ Short spacings with ACA
Excellent instantaneous uv coverage & high sensitivity
<0.05mJy @100 GHz in 1 hr

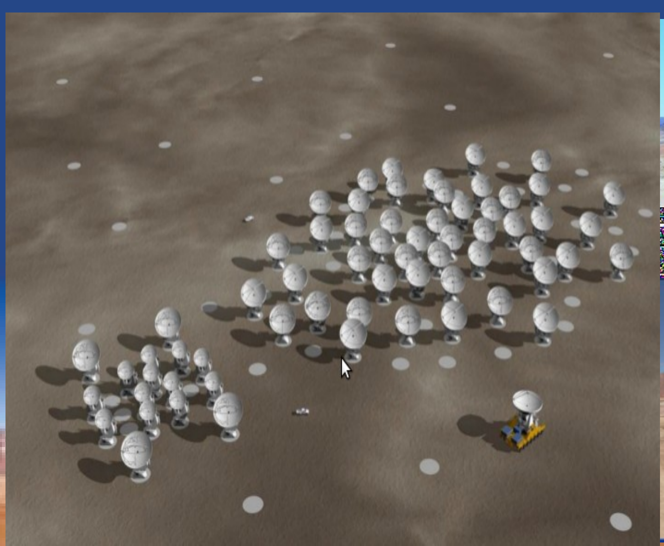
Up to 16km baselines, subarcsec resolution
40 mas @ 100 GHz,
5 mas @ 900 GHz

Flexibility in spectral and spatial studies

ALMA reconfiguration

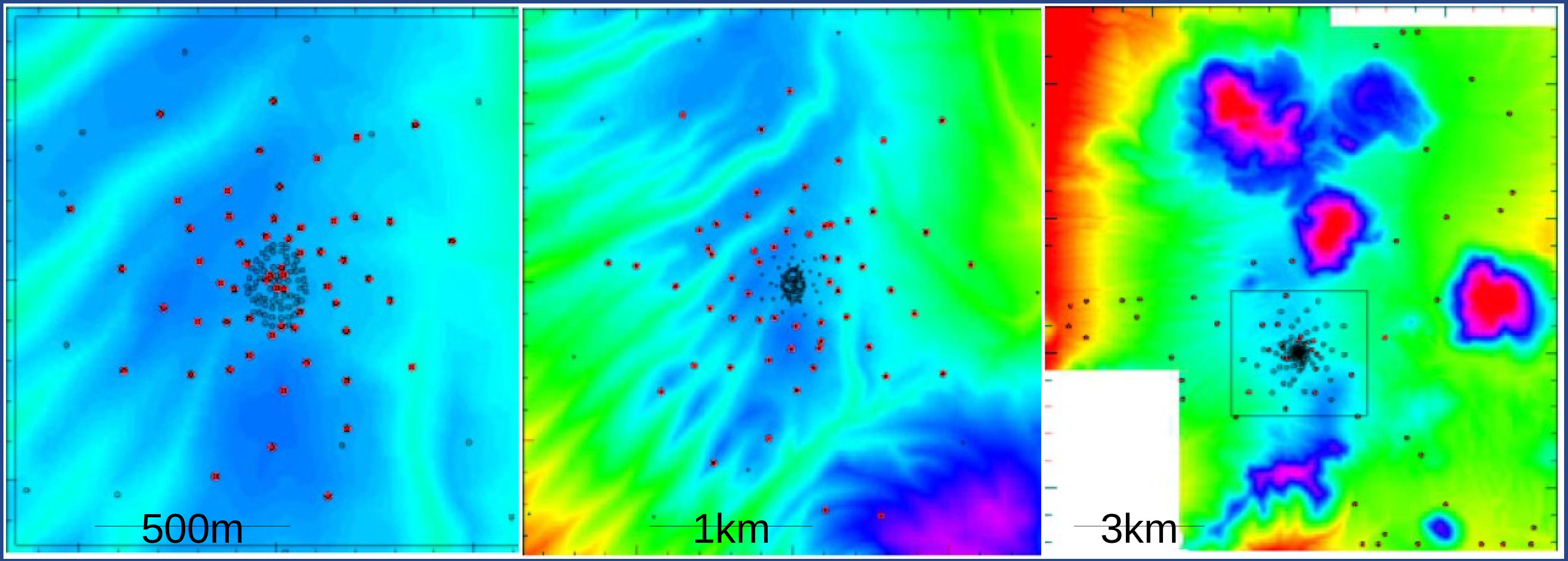


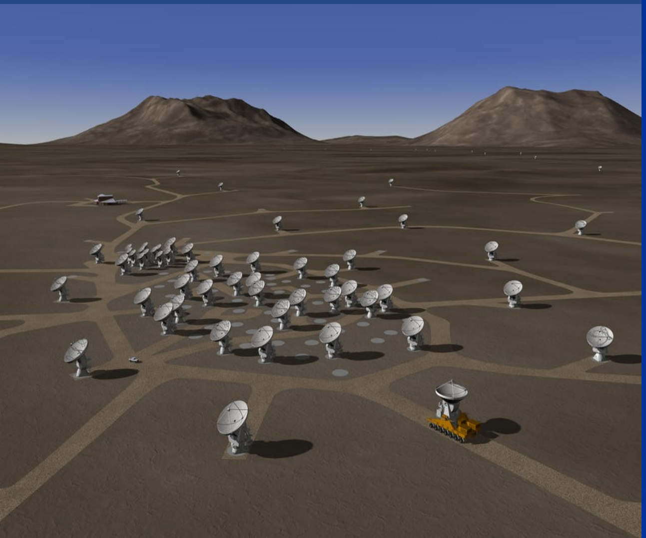
Antenna transporter



Antenna stations at 5000m

ALMA reconfiguration





ALMA organization

- 3 sites in Chile
  - AOS: ALMA operations site (5000 m)
    - Antennas, correlator
  - OSF: Operations support facility (2900 m)
    - Labs, antenna assembly and maintenance
    - Operators, astronomers
  - SCO: Santiago central office
    - JAO (Joint ALMA observatory)
      - » Calls for proposals
      - » Running ALMA
      - » Data reduction pipeline
      - » Quality assessment
    - Archive
- ALMA Regional Centers

The ALMA Regional Centers (ARC)

- **Interface between JAO and users**
- 1 ARC per Partner:
  - NRAO for North America
  - NAOJ for East Asia
  - ESO for Europe
- Operation support
  - Archive replication
  - Astronomer on duty
  - Software tools

- User support
  - Community formation and outreach (schools, workshops, tutorials, ...)
  - Phase 1 (proposal preparation)
  - Phase 2 (scheduling block preparation)
  - Data analysis
  - Archive mining

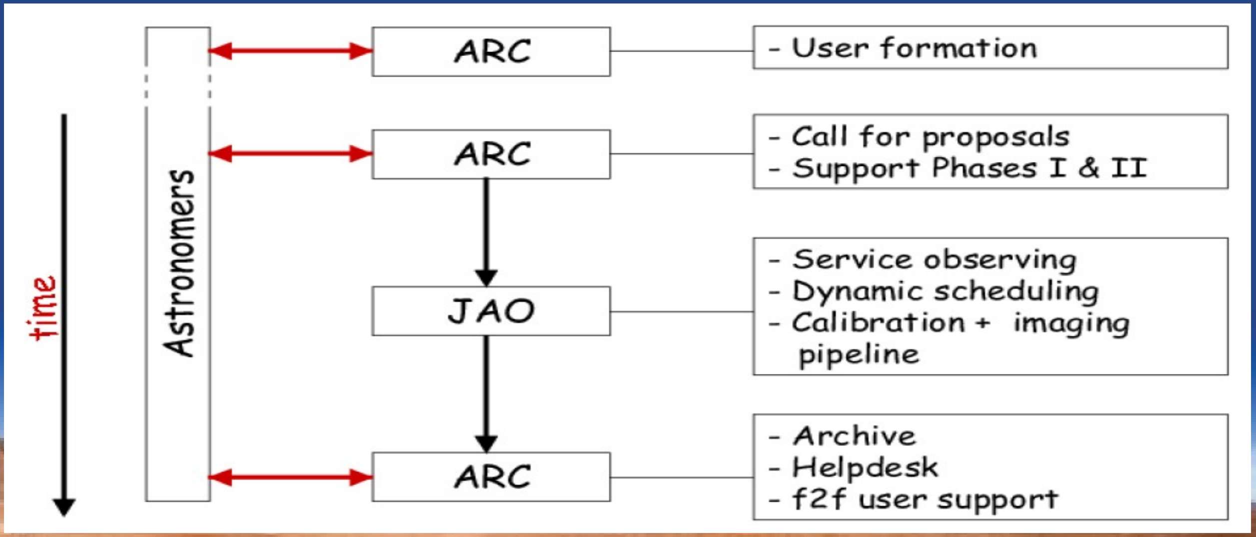
ALMA project checklist

Have a good idea!
Estimate required configuration (CASA, Splatalogue, OST, OT)
Write the proposal idea in pdf docs
(max 5 page)
Register to the User Portal (UP)

PHASE I – Proposal submission (OT, UP, Helpdesk)
TAC evaluation
PHASE II – Observing program submission for accepted proposals (OT, UP, Helpdesk)

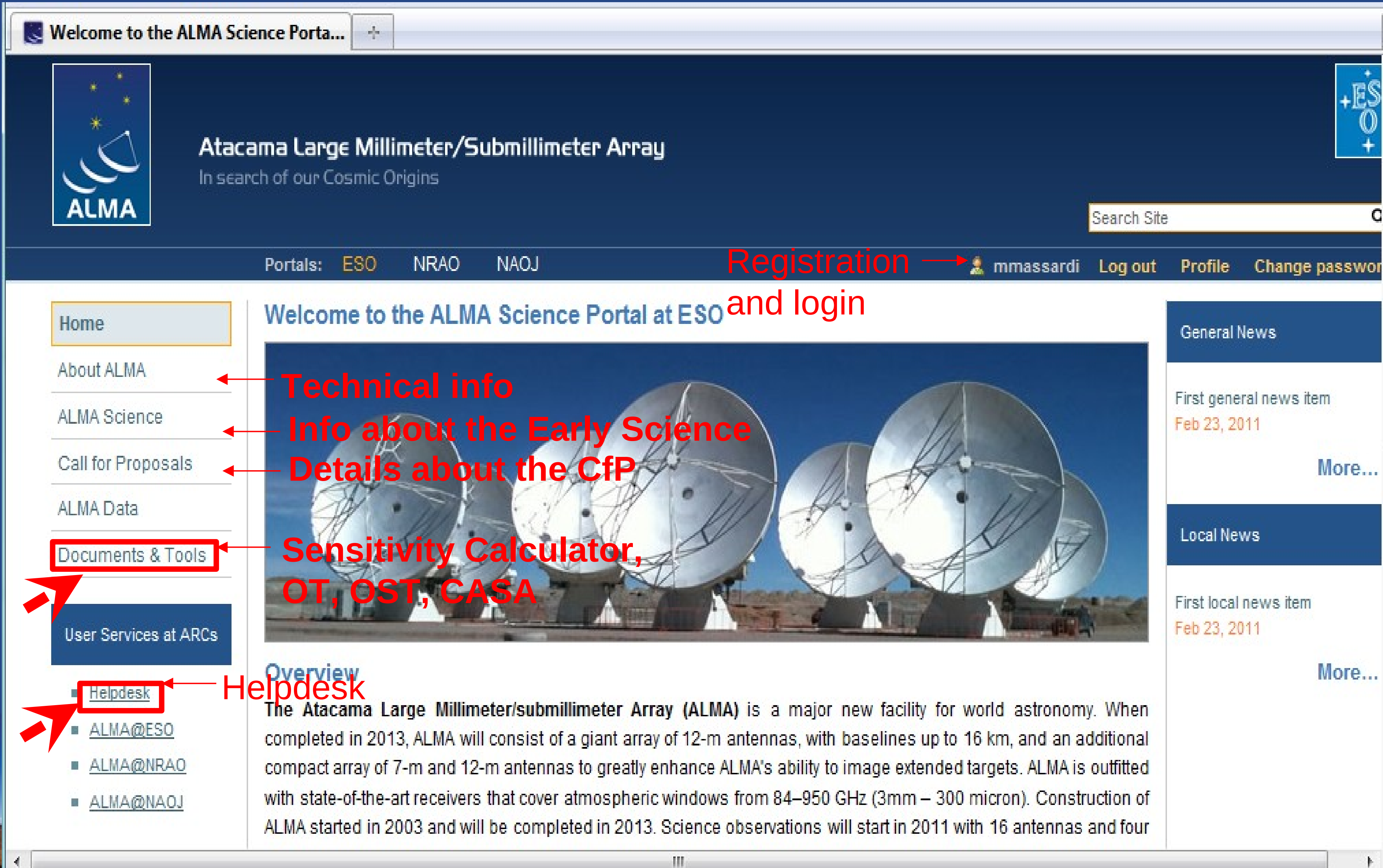
Observations

Data reduction and analysis (CASA)

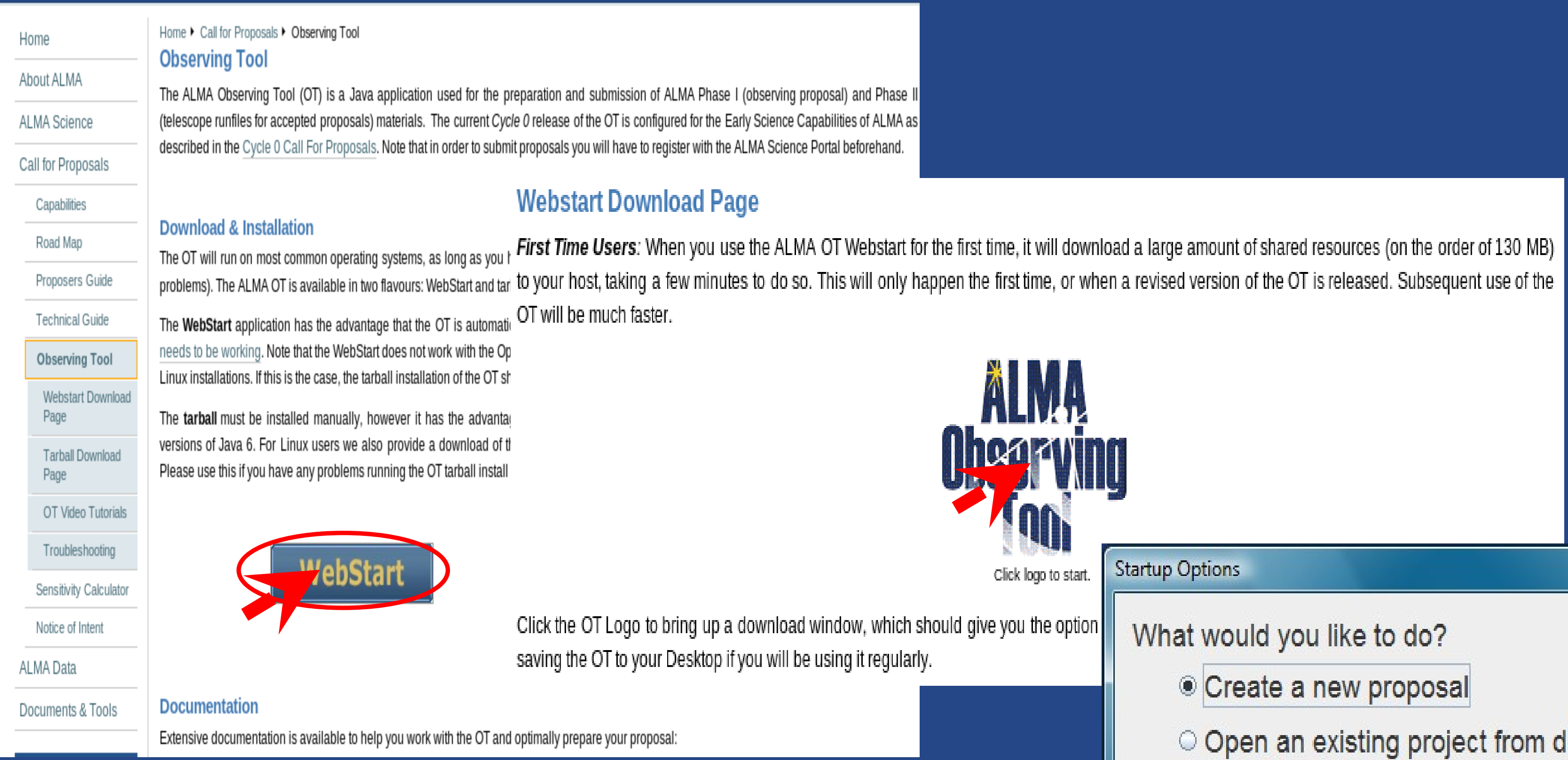


The ALMA User Portal

http://almascience.org/



The ALMA Observing Tool



Home ‣ Call for Proposals ‣ Observing Tool

Observing Tool

The ALMA Observing Tool (OT) is a Java application used for the preparation and submission of ALMA Phase I (observing proposal) and Phase II (telescope runfiles for accepted proposals) materials. The current *Cycle 0* release of the OT is configured for the Early Science Capabilities of ALMA as described in the Cycle 0 Call For Proposals. Note that in order to submit proposals you will have to register with the ALMA Science Portal beforehand.

Download & Installation

The OT will run on most common operating systems, as long as you h problems). The ALMA OT is available in two flavours: WebStart and tar

The **WebStart** application has the advantage that the OT is automati needs to be working. Note that the WebStart does not work with the Op Linux installations. If this is the case, the tarball installation of the OT sh

The **tarball** must be installed manually, however it has the advanta versions of Java 6. For Linux users we also provide a download of t Please use this if you have any problems running the OT tarball install

WebStart

Documentation

Extensive documentation is available to help you work with the OT and optimally prepare your proposal:

Home

About ALMA

ALMA Science

Call for Proposals

Capabilities

Road Map

Proposers Guide

Technical Guide

Observing Tool

Webstart Download Page

Tarball Download Page

OT Video Tutorials

Troubleshooting

Sensitivity Calculator

Notice of Intent

ALMA Data

Documents & Tools

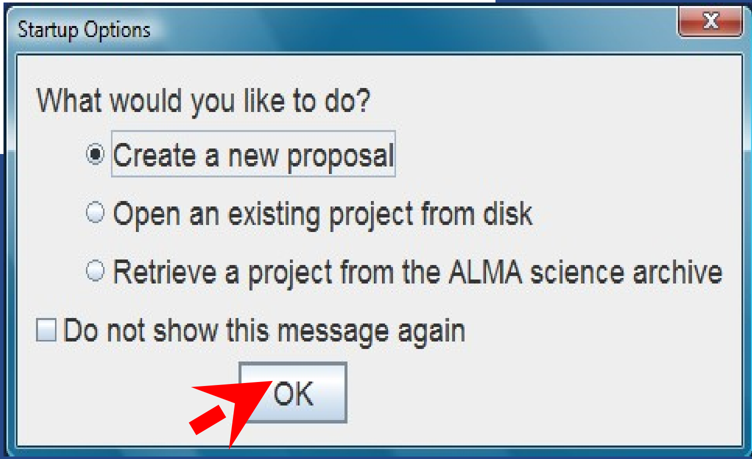
Webstart Download Page

First Time Users: When you use the ALMA OT Webstart for the first time, it will download a large amount of shared resources (on the order of 130 MB) to your host, taking a few minutes to do so. This will only happen the first time, or when a revised version of the OT is released. Subsequent use of the OT will be much faster.

ALMA Observing Tool

Click logo to start.

Click the OT Logo to bring up a download window, which should give you the option saving the OT to your Desktop if you will be using it regularly.



Startup Options

What would you like to do?

- Create a new proposal
- Open an existing project from disk
- Retrieve a project from the ALMA science archive

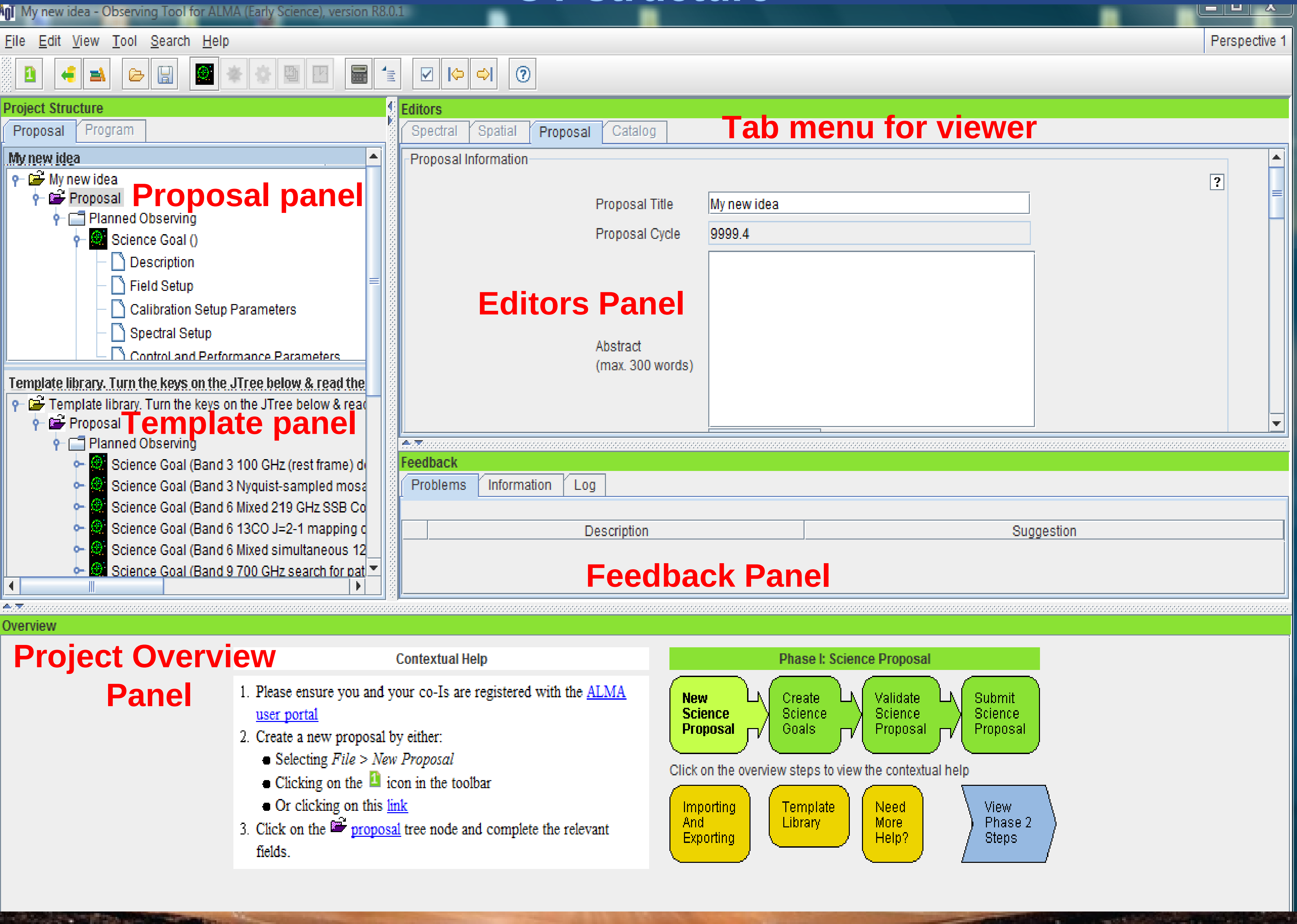
Do not show this message again

OK

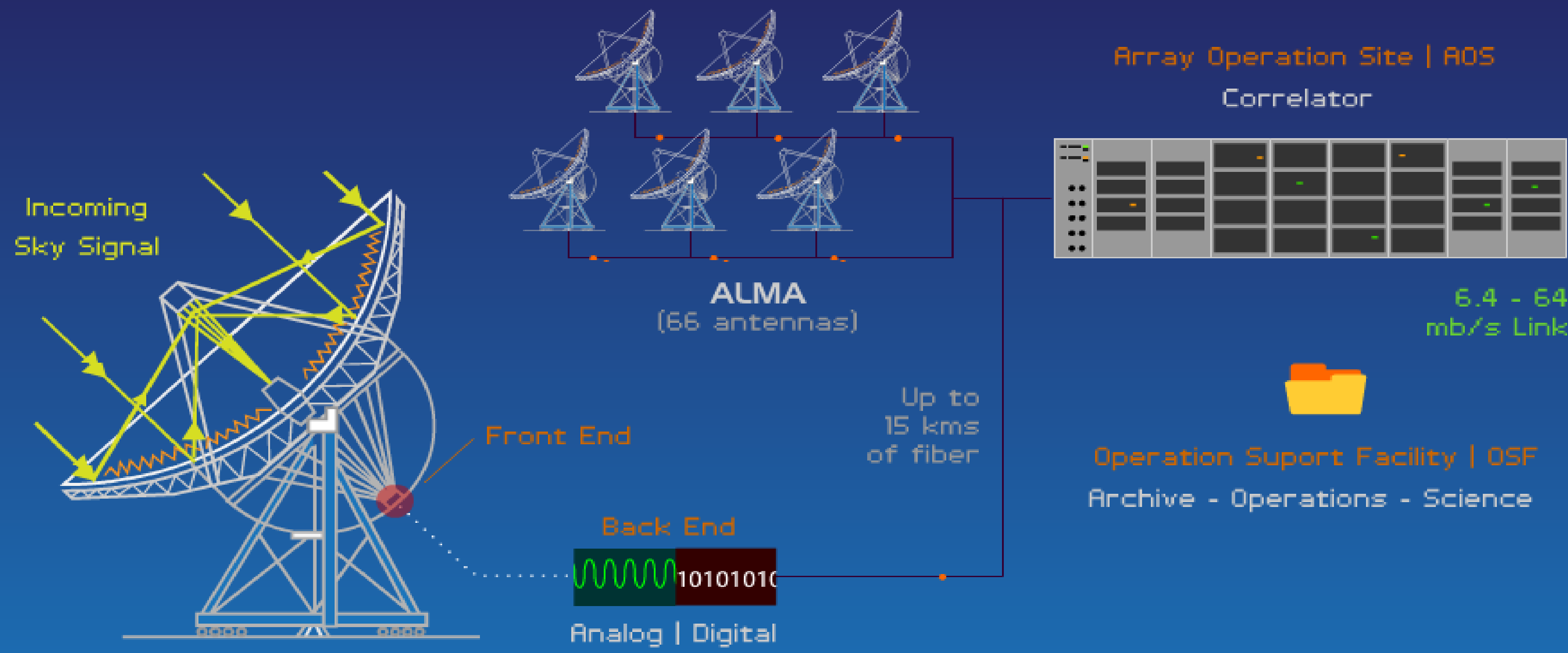
OT is a java-based client program, requires Java 1.6 (currently), runs on Linux (various distr.), MacOS (10.5-10.6), Windows (>XP).

The graphic interface allows one to get help/feedback and hints even with small knowledge of the system.

OT structure



ALMA data flow



ALMA receivers

Heterodyne Receiver sensitive to Upper and Lower Side Bands (USB and LSB). Sidebands are mapped to a lower frequency band by mixing the sky signal with a Local Oscillator (LO). Varying LO1 changes the sidebands position.

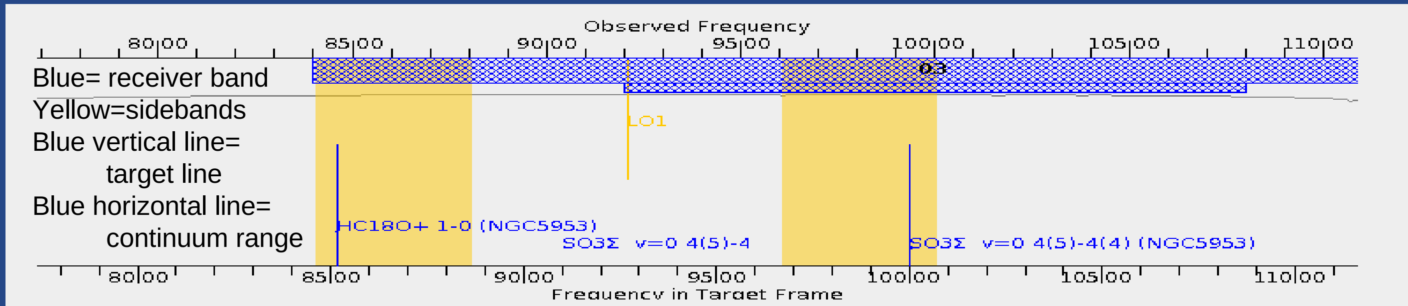
ALMA receivers are
- 2SB (separated in the receiver):

Bands 3, 4, 5, 7, 8	sidebands 4 GHz wide separated by 8 GHz
Band 6	sidebands 5 GHz wide separated by 10 GHz

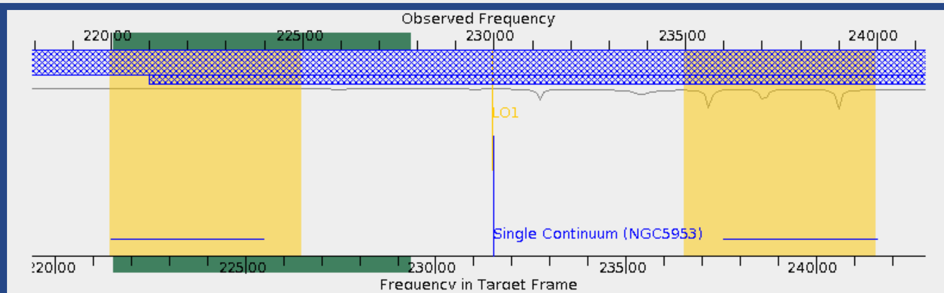
- DSB (separated in the correlator):

Bands 9, 10	sidebands 8 GHz wide separated by 8 GHz

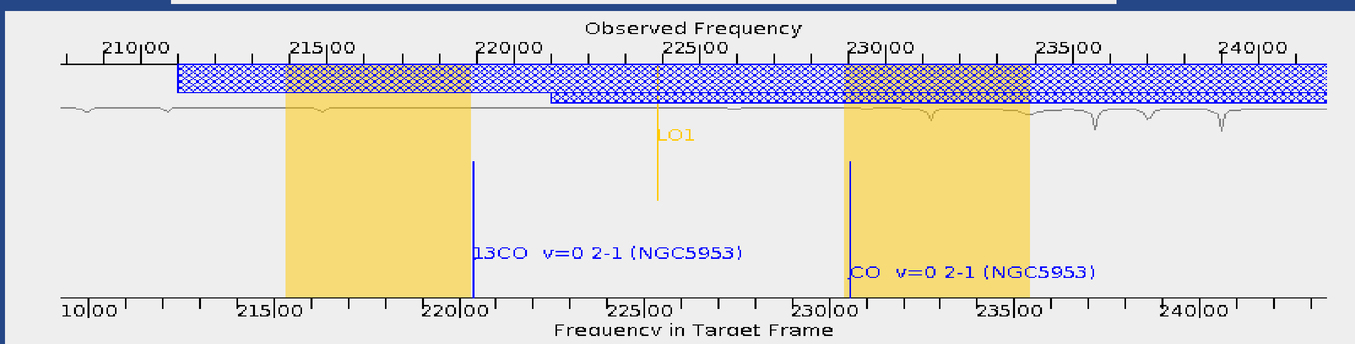
ALMA frequency setup



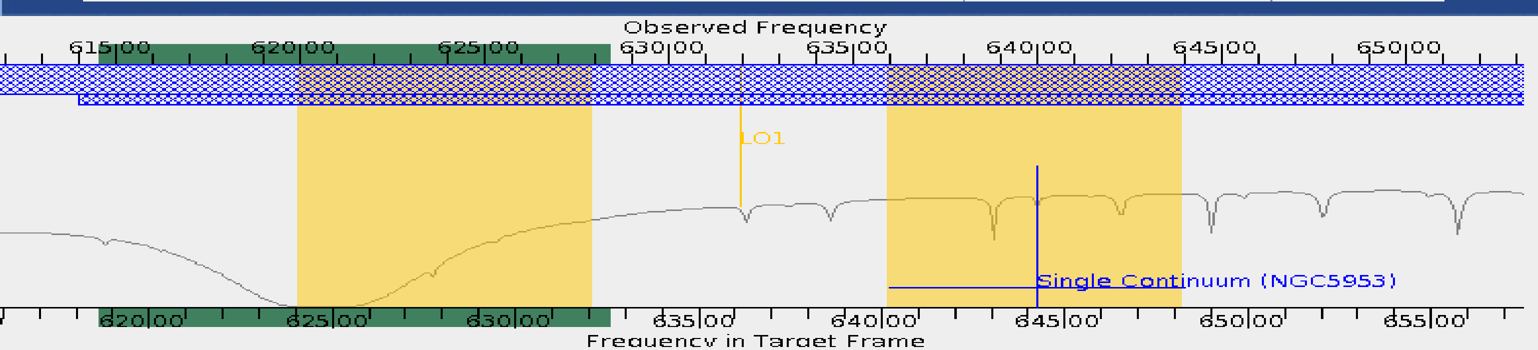
Band 3:
2 sidebands to
see target lines



Band 6:
2 sidebands for
2SB continuum



Band 6:
5-10GHz
separation
allows 13CO
and 12CO



Band 9:
DSB continuum

ALMA correlator

INPUT from front ends

CORRELATOR split in 4 quadrants

OUTPUT from each baseband

...

8 GHz for each of 2 pol

N antennas

1quadrant= 1baseband= 2GHz

1quadrant= 1baseband =2GHz

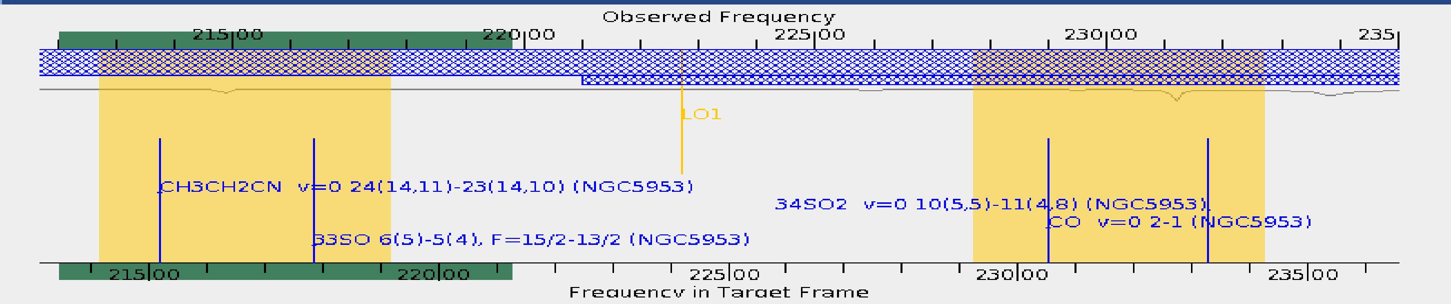
1quadrant= 1baseband =2GHz

1quadrant= 1baseband =2GHz

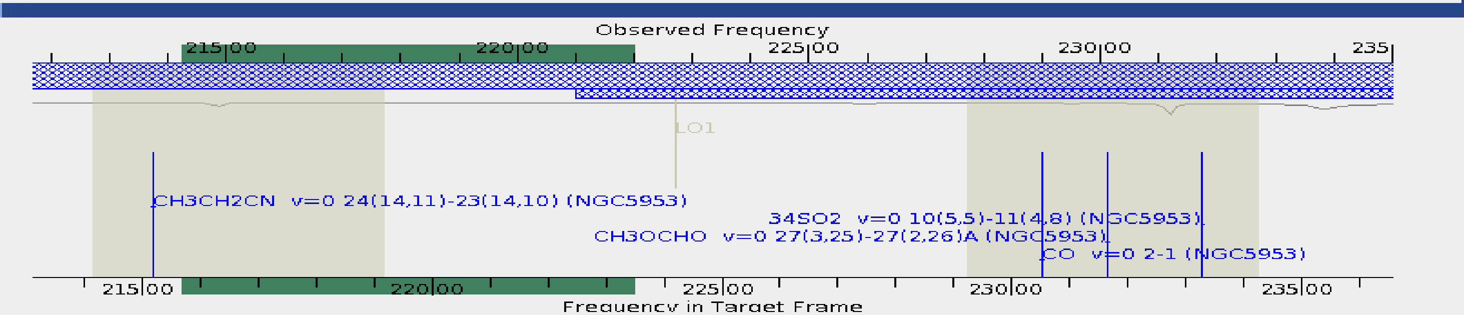
8192 channels
1,2 or 4 polarisations
Spectral window:
31MHz-2GHz

The 4 basebands can be setup independently
Highly flexible correlator:
>70 modes

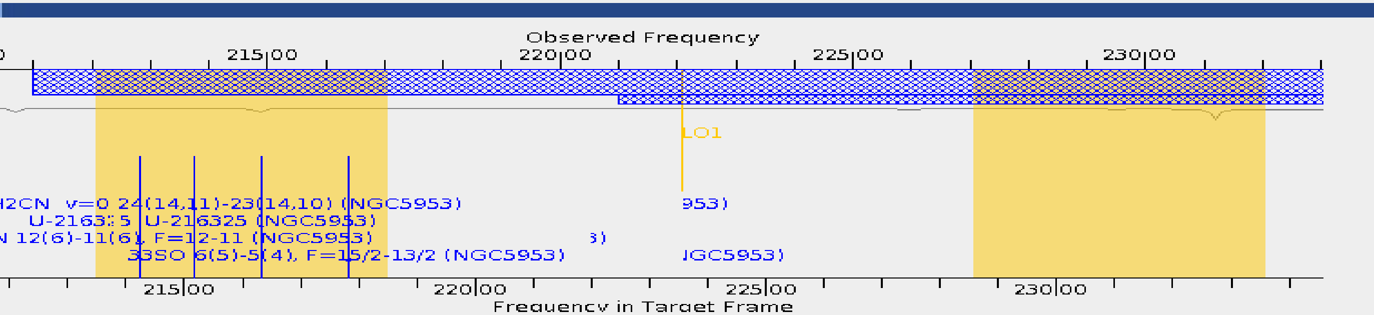
ALMA spectral windows setup



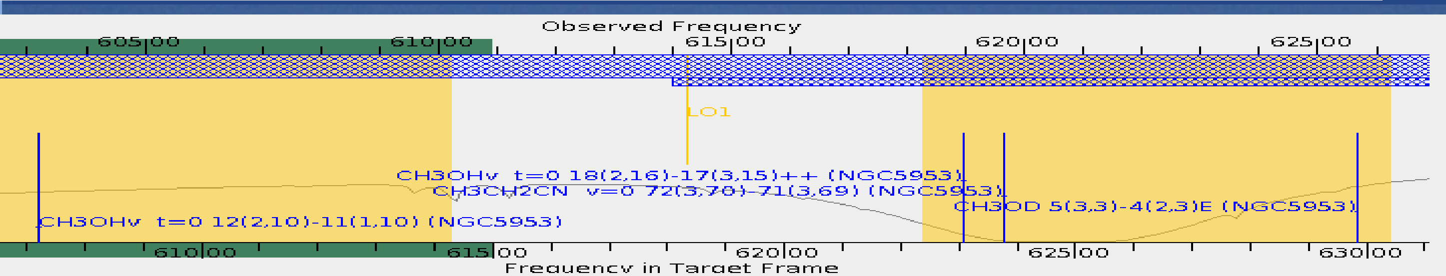
2SB:
2 basebands per sideband



2SB:
3 basebands per sideband
NOT ALLOWED



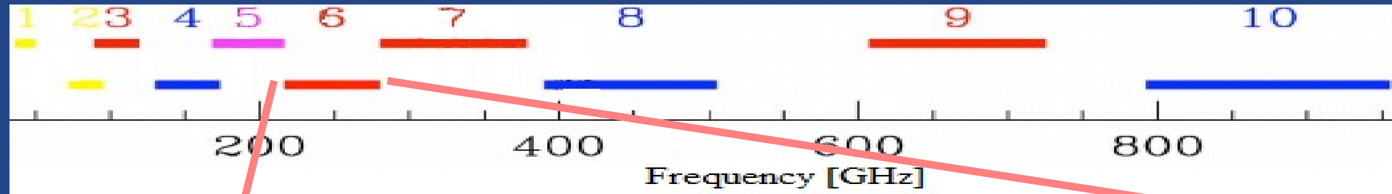
2SB:
4 basebands per sideband



DSB:
3 basebands per sideband
ALLOWED

ALMA frequency settings summary

Select the band
(i.e. choose the receiver)



RECEIVERS

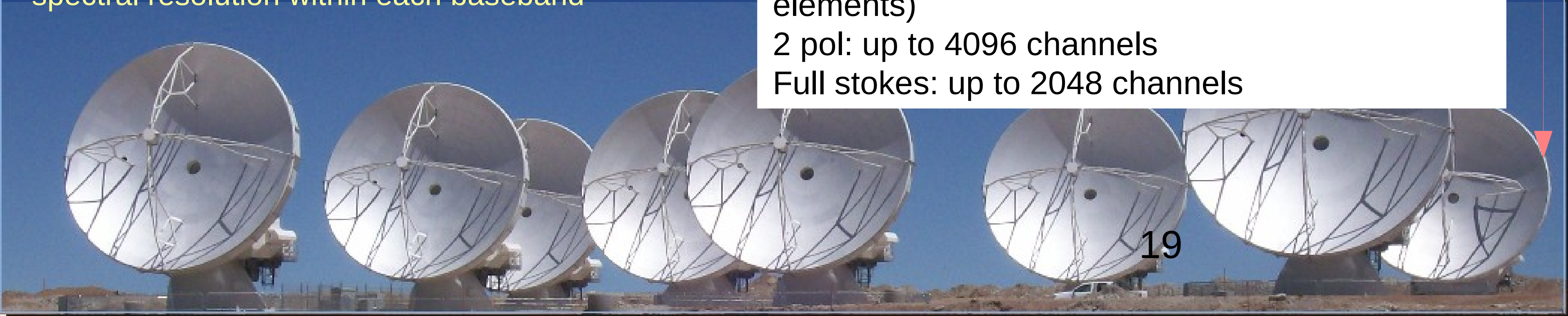
Fix LO1 to define the **2 sidebands**

Fix LO2 to define the 4 **basebands**

CORRELATOR

Chose your polarisation and
spectral resolution within each baseband

1 pol: up to 8192 channels (=resolution elements)
2 pol: up to 4096 channels
Full stokes: up to 2048 channels

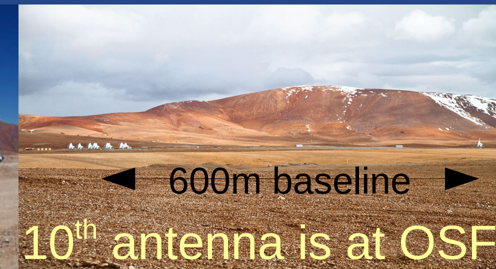


ALMA correlator summary

- 4 independent basebands
- ~70 modes:
  - 2 GHz to 31 MHz bandwidth / 8192 channels / 1,2 or 4 pol products
  - Varying sampling options (better sensitivity with degraded resolution)
  - Continuum mode
- Possibility to observe many spectral windows/baseband (with same or different resolution/width, polarisation properties...)

ALMA status & next milestones





Science Verification

- On-going to observe known sources to validate the output of ALMA
- Data made public (in June): not for science

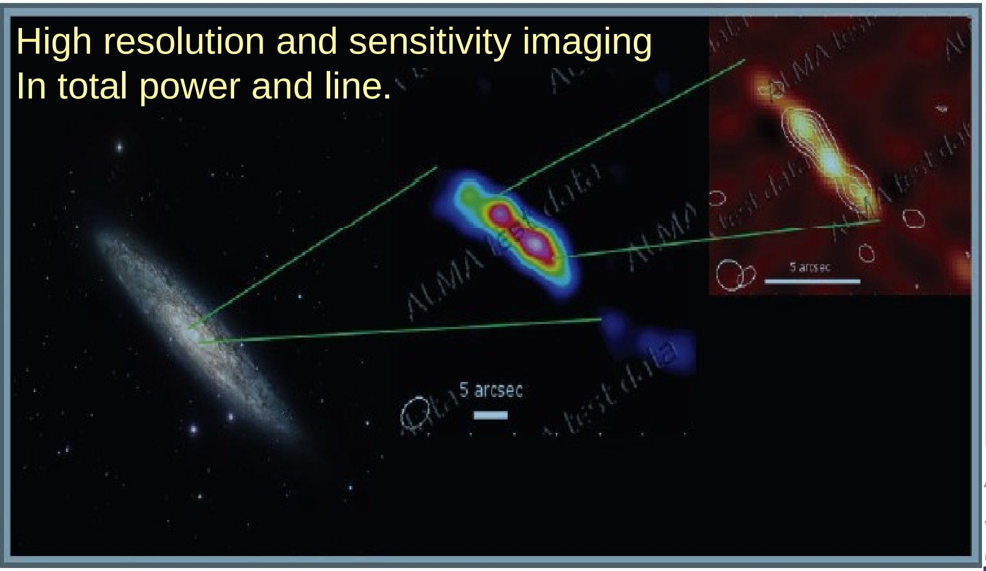
Early Science

- 31 March: call for proposals and ALMA Science Portal opening
- 1 June: opening of the archive for proposal submission
- 30 June: proposal submissione deadline
- 30 September 2011 - 30 June 2012:

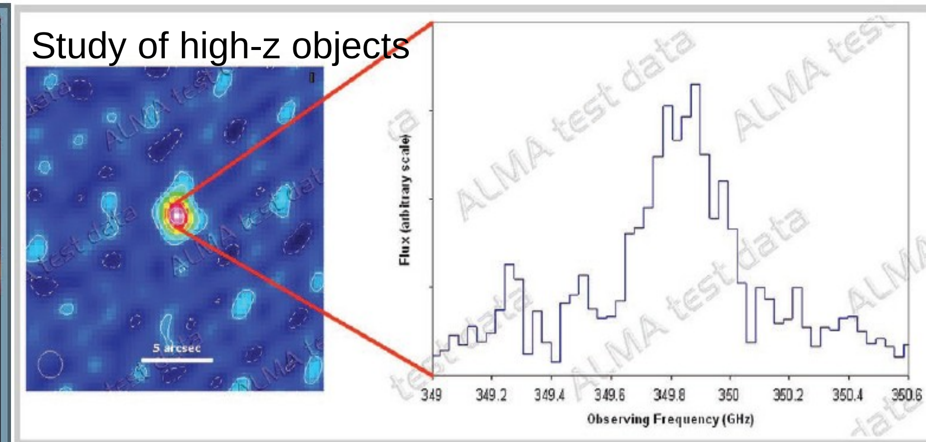
ES Phase 0 observations (500-700 h)

http://almascience.eso.org/call-for-proposals

First tests of science with ALMA



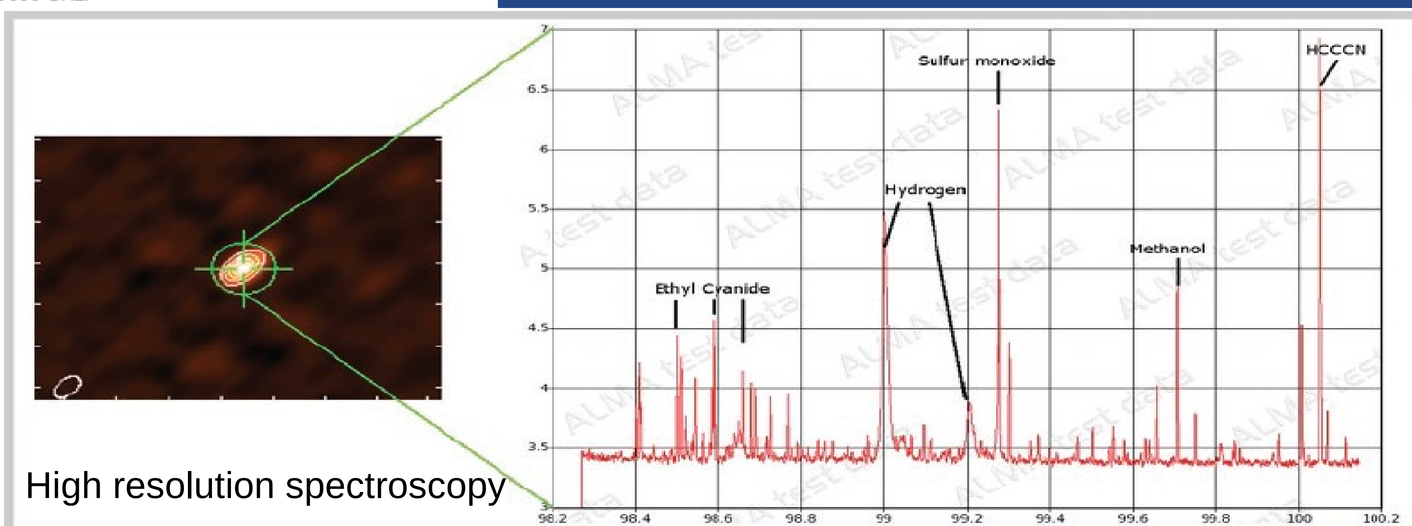
This shows the well-known spiral NGC253, with an optical image of the whole galaxy on the left (credit: ESO). The ALMA test images show dense clouds of gas in the central regions of the galaxy: (middle) the CO J = 2-1 line at 230 GHz and (right) the continuum and CO J = 6-5 line at 690 GHz.



As a test of ALMA's ability to observe broad spectral lines, we observed the quasar BRI 0952-0115, which is at a red-shift of z = 4.43. The object is again unresolved on short baselines, but the 158 micron line from ionized carbon is clearly detected in the spectrum, which is impressive given that this observation took only one hour in total.

ALMA 8 antennas hw/sw tests mid 2010

An example of ALMA's potential as a spectroscopic instrument: on the left is the map of the molecular "hot core" G34.26+0.15, which is unresolved with the short baselines that we are presently using, so the "image" is not very interesting whereas a section of the spectrum near 100 GHz shows a "forest" of molecular lines. A few of the chemical species that are responsible for the emission lines are identified on the plot.



	Full array	**Early Science**
Frequency range:	**10 bands 30-900 GHz**	**4 bands (3, 6, 7, 9)**
Antennas:	**50x12m +** ACA	**16x12m** (no ACA)
Sensitivity	**0.15 mJy in 1 min at 230 GHz**	**0.5 mJy in 1 min at 230 GHz**
Max baseline:	150**m-16km**	**2 configs: 18-125m** **36-400m**
Resolution:	**20 mas @ 230 GHz** **70 correlator modes**	**1000 mas @ 230 GHz** **20 correlator modes**
	Mosaic capability	**Limited mosaic** capabilities
	Pipeline reduction in Chile	Reduction @ ARCs

Care about resolution and sensitivity limits in ES

Band	Frequency [GHz]	Angular Resolution ["]	Maximum Scale ["]	T_{bc} [mK]	Flux [mJy]	T_{bl} [K]	Field of View ["]
Properties of the Compact Configuration (baselines of ~18 m to ~125 m)							
3	100	5.3	21	0.65	0.14	0.030	62
6	230	2.3	9	1.0	0.20	0.029	27
7	345	1.55	6	1.8	0.37	0.043	18
9	675	0.80	3	15	3.2	0.27	9
Properties of the Extended Configuration (baselines of ~36 m to ~400 m)							
3	100	1.56	10.5	7.6	0.14	0.35	62
6	230	0.68	4.5	11	0.20	0.34	27
7	345	0.45	3.0	20	0.37	0.50	18
9	675	0.23	1.5	175	3.2	3.1	9

Band	Lower frequency [GHz]	Upper frequency [GHz]	Type
3	84	116	2SB
6	211	275	2SB
7	275	373	2SB
9	602	720	DSB

ALMA-ES correlator summary

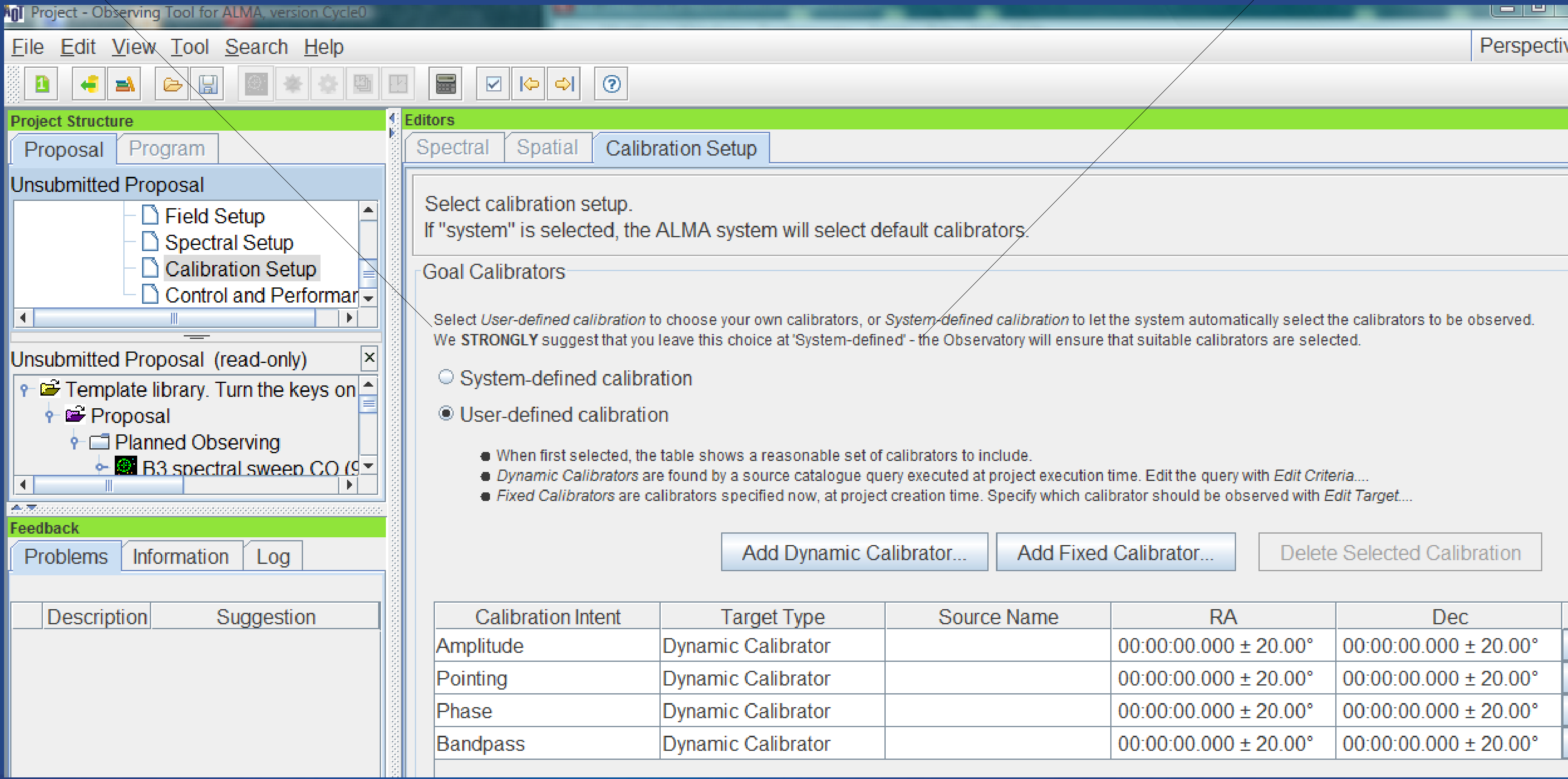
- ~~4 independent basebands~~ Same mode for all the basebands
- ~~~70 modes~~: 14 modes
  - 2 GHz to 31 MHz bandwidth / 8192 channels / 1,2 or 4 pol products
  - ~~Varying sampling options (better sensitivity with degraded resolution)~~
  - Continuum mode
- ~~Possibility to observe many spectral windows/baseband (with same or different resolution/width, polarisation properties...)~~ Only one spectral window per baseband

Care about the limitations in resolution
and sensitivity for the ES!
ALMA ES is ok for few hours, limited scope projects!
Furthermore, experience in mm interferometry is needed
among investigators because data won't pass through the pipeline
Calibration quality is being assessed!

The Calibration setup in the observing tool

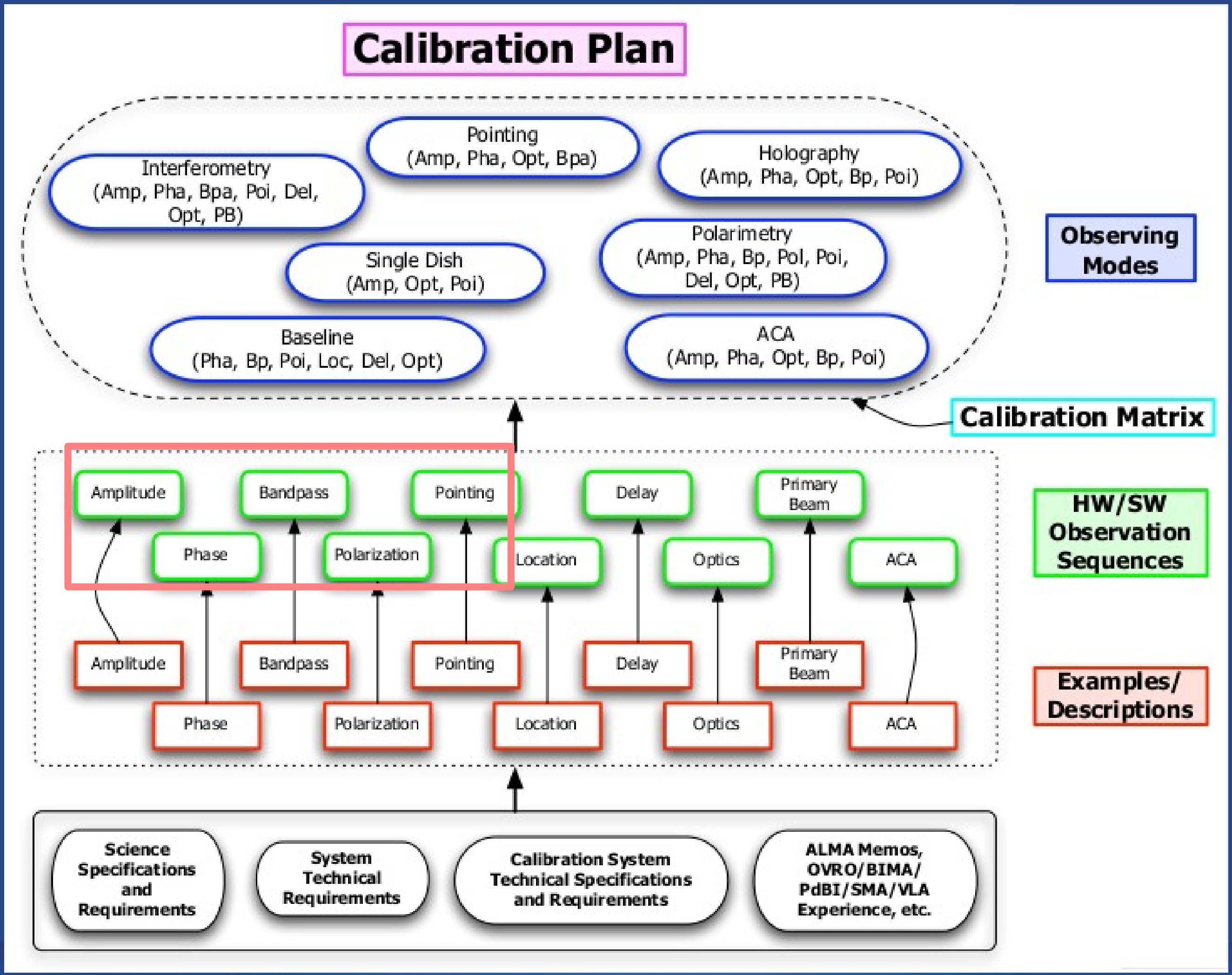
"...We STRONGLY suggest that you leave this choice at 'System-defined'..."

at least for the ES Phase 0



If user-defined calibration is necessary, care to justify it in the proposal!!!

The plan



Requirements & experience feed the description of the various kinds of calibration which drived the HW/SW developement.
The descriptions generate the sequences of observations that constitute the various observing modes.
Reference doc in Mangum (2006)'s memo

Remember that:
- **ALMA has unprecedented sensitivity & resolution at mm-submm frequencies**
- Projects are dynamically scheduled.
- PI (in FullALMA) receive the calibrated, reduced data.
- ALMA structure is (in FullALMA) also for not expert.

ALMA calibration summary

Phase calibration

- Bright unresolved sources (mostly quasars from AT20G, Planck ...)
- Fast switching on calibrators within 2° every few min
- Water vapour radiometry (emission at 183GHz atmospheric line, deduce phase fluctuations on 1s timescale)
- positional accuracy <1/10 synthesized beam-width

Flux density scale (primary)

- Planets/moons can be used (Neptune, Titan)
- Asteroids, Radio stars, quasars depends on quality of models, frequency, configuration...
- Initial expected accuracy <5% B3, <10% B6-7, <20% B9

Bandpass calibration

- Bright unresolved sources (mostly quasars from Planck catalogues)

Polarisation calibration

- Well known polarized or unpolarized sources (edges of planets/moons?). Still under characterization.

Existing calibrator databases

- ATCA, SMA, VLA **calibrator pages** including planetary data

- **Herschel catalogues**

- **Planck Early Release Compact Source Catalogue** (Planck collaboration 2011)
  30, 44, 70, 100, 143, 217, 353, 545, 817 GHz allsky

- **AT20G** *(Murphy et al. 2010) 4.8, 8.6, 20 GHz Southern sky >50mJy @20GHz +pol*
- ***PACO*** *(MM et al. 2011) 4.5-40GHz Southern sky 463 sources +pol*
  BS>500mJy in AT20G
  FS>200mJy in AT20G
  + inverted & upturning +ATCA calibrators
- ***SiMPlE*** *(Procopio et al.2011, Righini et al. In prep) 5,8,20 GHz Northern sky WMAP sources*

All the ALMA observations will update the ALMA calibrator catalogue.

Reasons for new databases

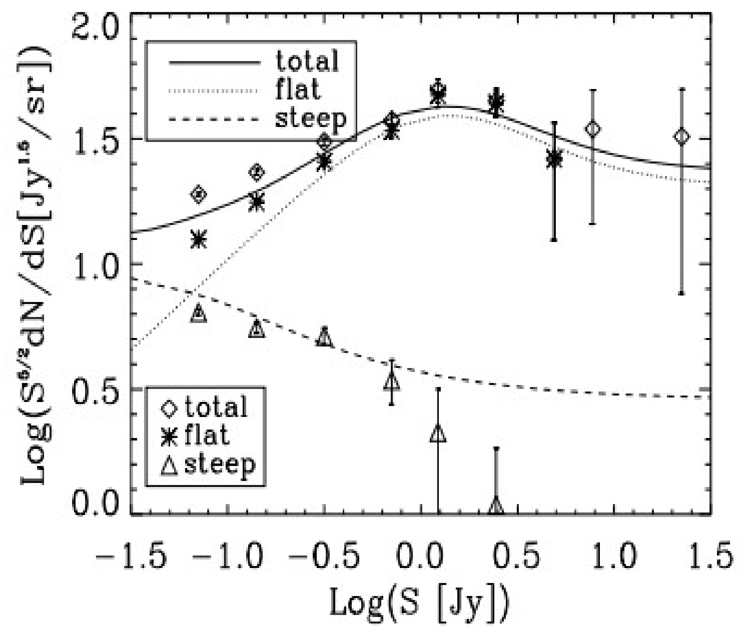
The knowledge of the properties of extragalactic radio source populations at frequencies >10 GHz is poor because large-area high-frequency surveys are very time-consuming with high sensitivity ground-based diffraction-limited telescopes.

To date, **the Australia Telescope 20 GHz** (AT20G, Murphy et al. 2010) is the largest ground-based sample of the high radio frequency sky: it is 93% complete above 100 mJy at 20 GHz over the whole Southern sky with follow-up (within a few weeks time) at 4.8 and 8.6 GHz. No comparable samples exist for the Northern hemisphere.

It demonstrated that (MM et al. 2010):

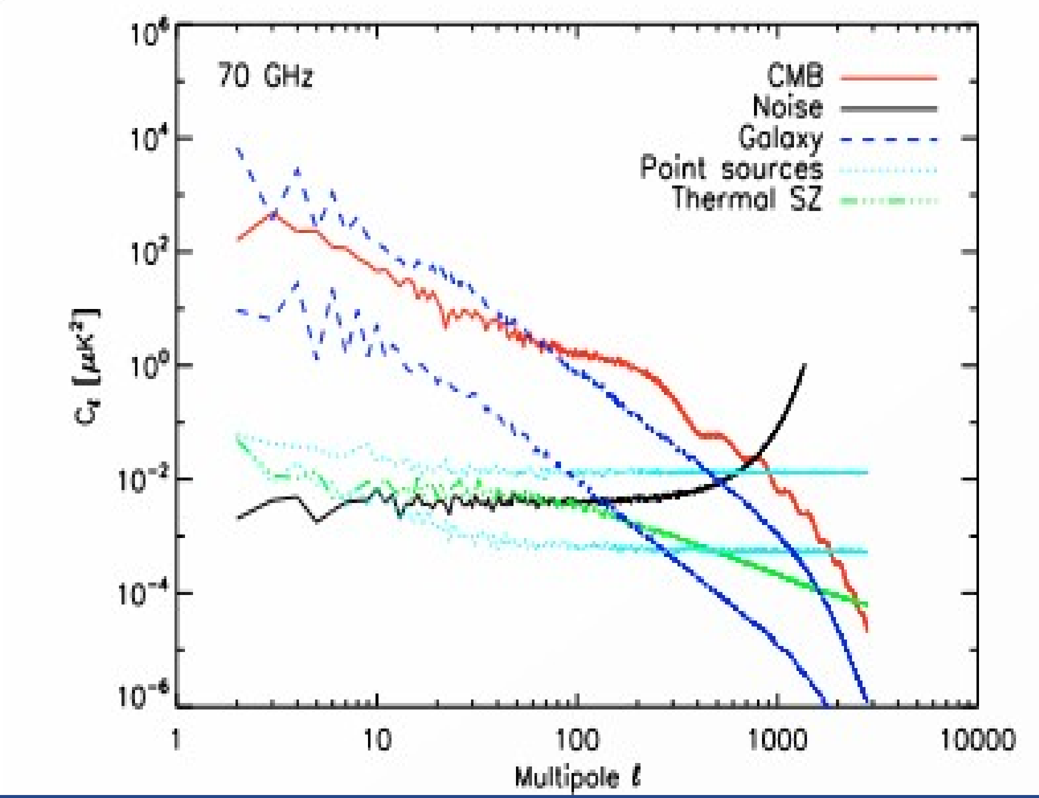
- **The bright samples are dominated by flat-spectrum sources**
- **Steep-spectra sources grew important at lower flux densities and higher frequencies**
- **The spectral behaviour cannot be easily described by a power law**
- **The spectral index distribution changes with flux density and frequency**
- **The median 1yr variability at 20GHz is 6.9% increasing with frequency** (Sadler et al. 2006)

20 GHz sourcecounts



Sources as CMB contaminants

Foregrounds power spectra (Leach et al. 2008)



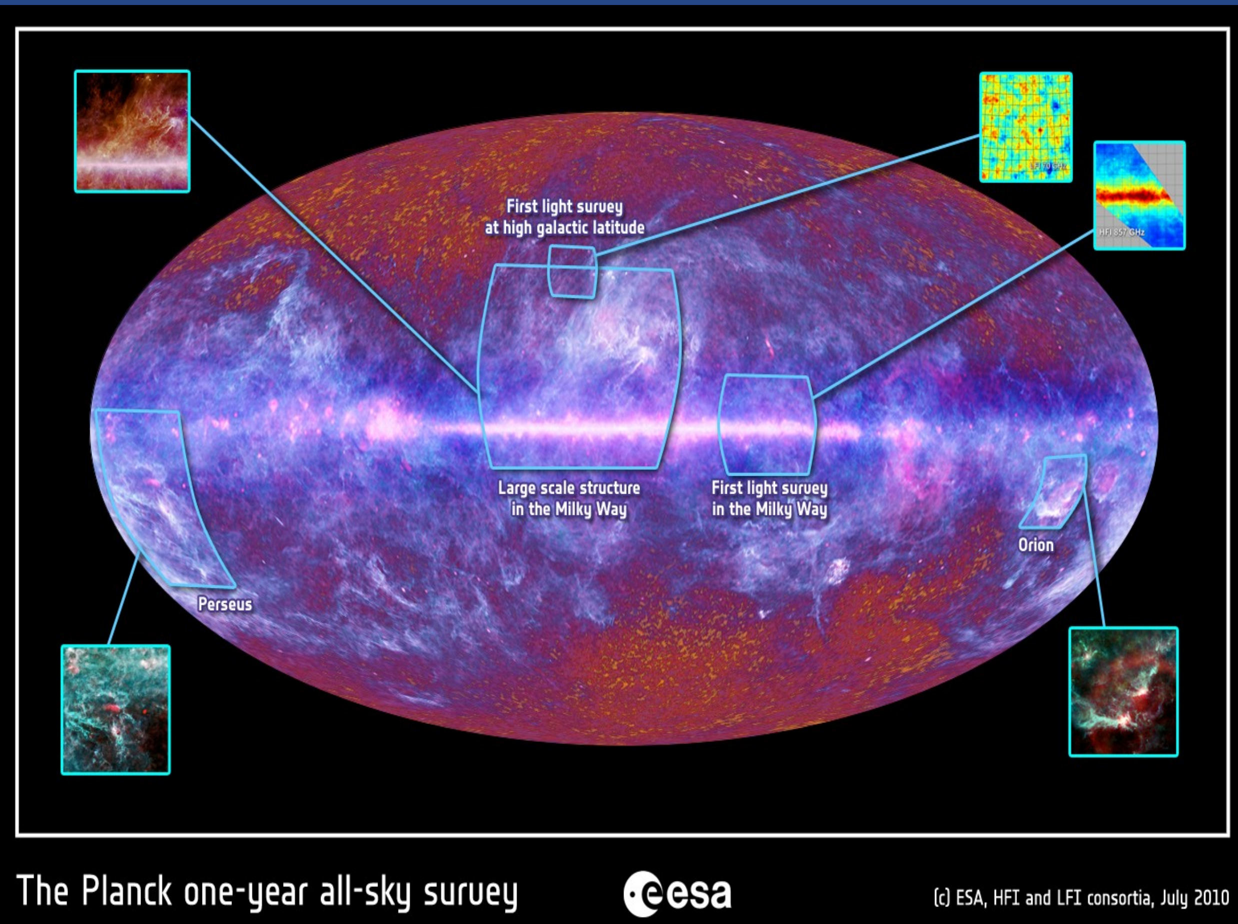
Fluctuations due to radio sources are **the main contaminants of the CMB signal on scales smaller than 30 arcmin** (De Zotti et al. 1999, Toffolatti et al. 2005).

They need therefore to be carefully subtracted to avoid biasing the estimates of cosmological parameters.

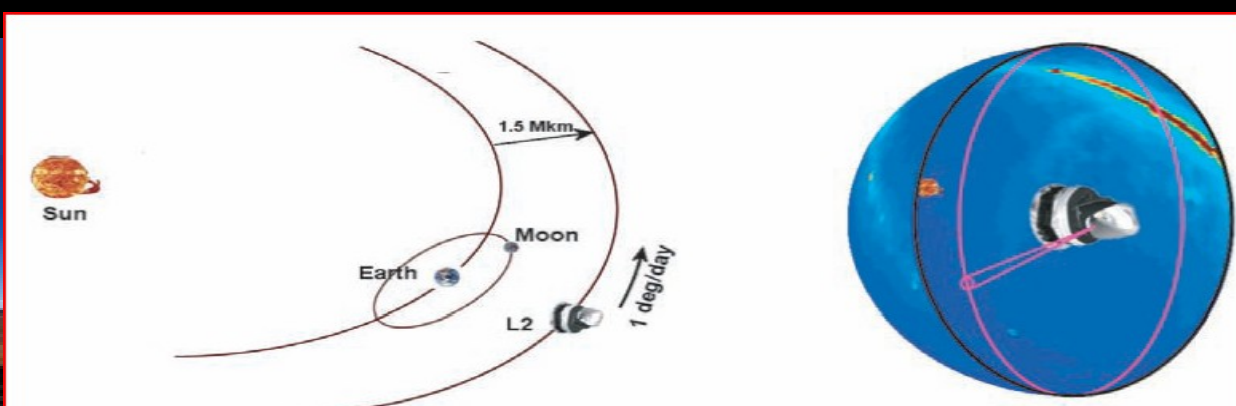
Extrapolation from low frequencies are highly unreliable and modelization of source population is extremely challenging.

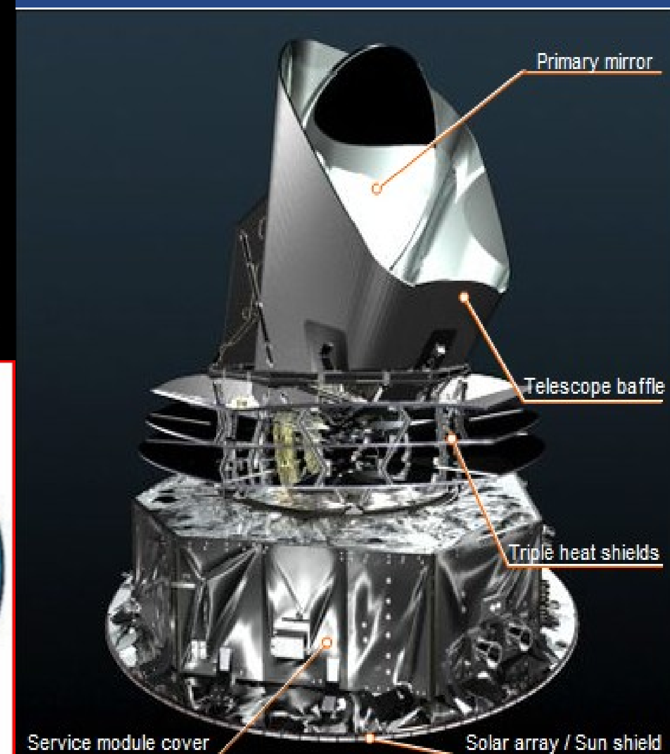
Planck offers a unique opportunity to carry out an unbiased investigation of the spectral properties of radio sources in a poorly explored frequency range, partially unaccessible from the ground before ALMA.

The Planck satellite



Main target: imaging the CMB anysotropies.
Allows all sky survey of foregrounds In the frequency range 30-857 GHz.
First release in Jan 2011.
Cosmological results due to come in 2013. Scanning strategy fully predictable (the POFF tool, MM & Burigana 2010).





The Planck Early Release Compact Source Catalogue

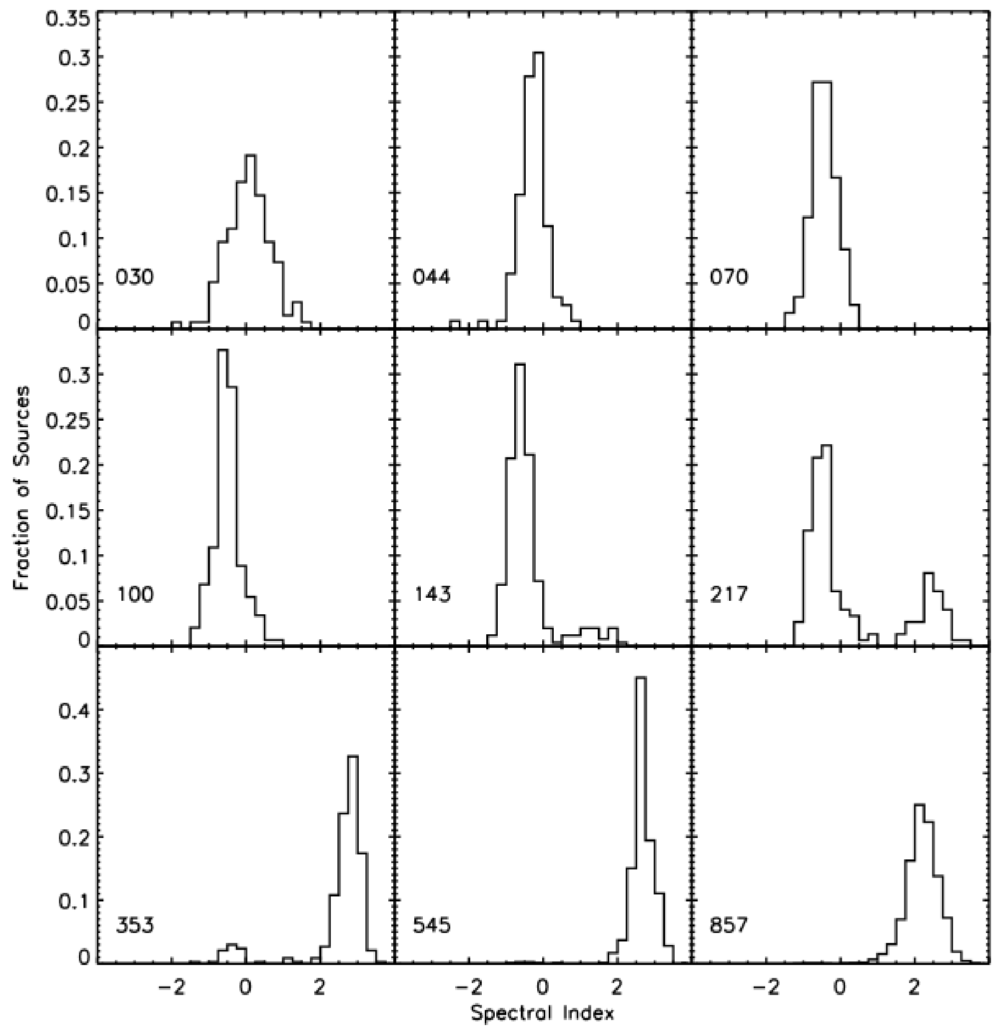
The ERCSC (Planck collaboration 2011) is a list of high reliability (>90%) sources, both Galactic and extragalactic, derived from the data acquired by Planck between August 13 2009 and June 6 2010. (~1.6 full sky surveys). It consists of:

- **9 lists of sources, extracted independently from each of Planck's nine frequency channels**.
- 2 additional lists extracted using multi-channel criteria:
  - the Early Cold Cores catalogue (ECC), consists of galactic dense and cold cores, selected mainly on the basis of their temperature
  - the Early Sunyaev-Zeldovich catalogue (ESZ), consists of galaxy clusters selected by the spectral signature of the Sunyaev-Zeldovich effect.

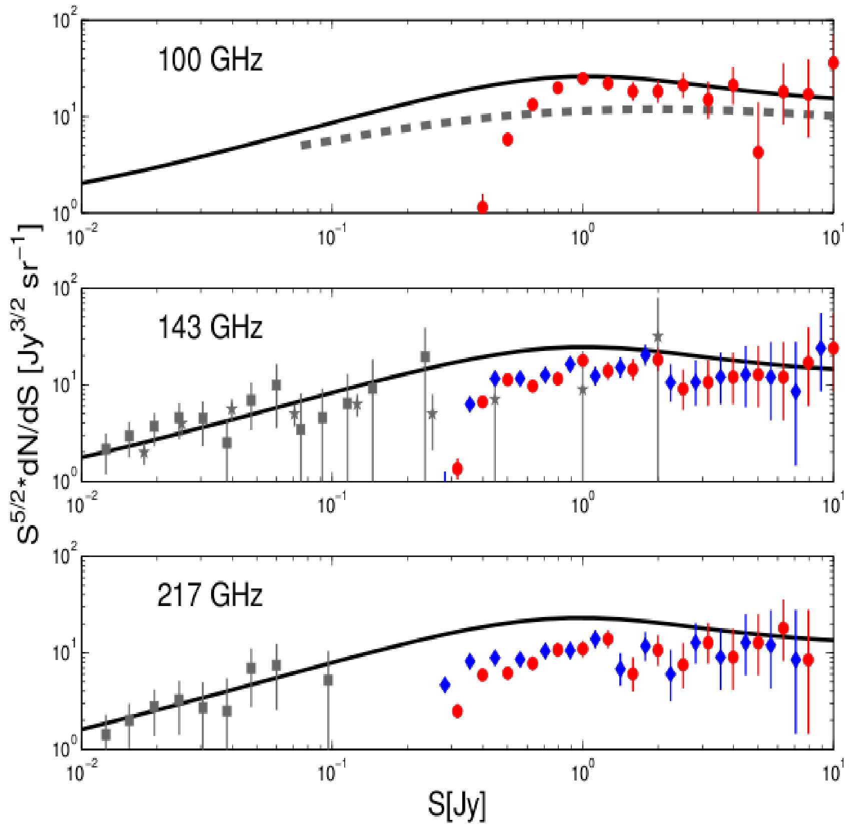
Freq [GHz]	30	44	70	100	143	217	353	545	857
$\lambda(\mu m)$	10000	6818	4286	3000	2098	1382	850	550	350
Sky Coverage (%)	99.96	99.98	99.99	99.97	99.82	99.88	99.88	99.80	99.79
Beam FWHM (′)[a]	32.65	27.00	13.01	9.94	7.04	4.66	4.41	4.47	4.23
# of Sources	705	452	599	1381	1764	5470	6984	7223	8988
# of $\|b\| > 30°$ Sources	307	143	157	332	420	691	1123	2535	4513
10σ[b] (mJy)	1173	2286	2250	1061	750	807	1613	2074	2961
10σ[c] (mJy)	487	1023	673	500	328	280	249	471	813
Flux Density Limit[d] (mJy)	480	585	481	344	206	183	198	381	655

Notes. [(a)] The precise beam values are presented in Planck Collaboration (2011e) and Planck Collaboration (2011f). This table shows the values which were adopted for the ERCSC. [(b)] Flux density of the median $>10\sigma$ source at $|b| > 30°$ in the ERCSC where σ is the photometric uncertainty of the source. [(c)] Flux density of the faintest $>10\sigma$ source at $|b| > 30°$ in the ERCSC. [(d)] Faintest source at $|b| > 30°$ in the ERCSC.

The Planck Early Release Compact Source Catalogue



Spectral index distribution for ERCSC sources with dec>30deg and radio sources source counts up to 217GHz



A population of bright flat/inverted spectrum objects is suitable up to high frequencies. An issue for ALMA is their size, not given by the confusion limited ERCSC.

The databases sensitivity

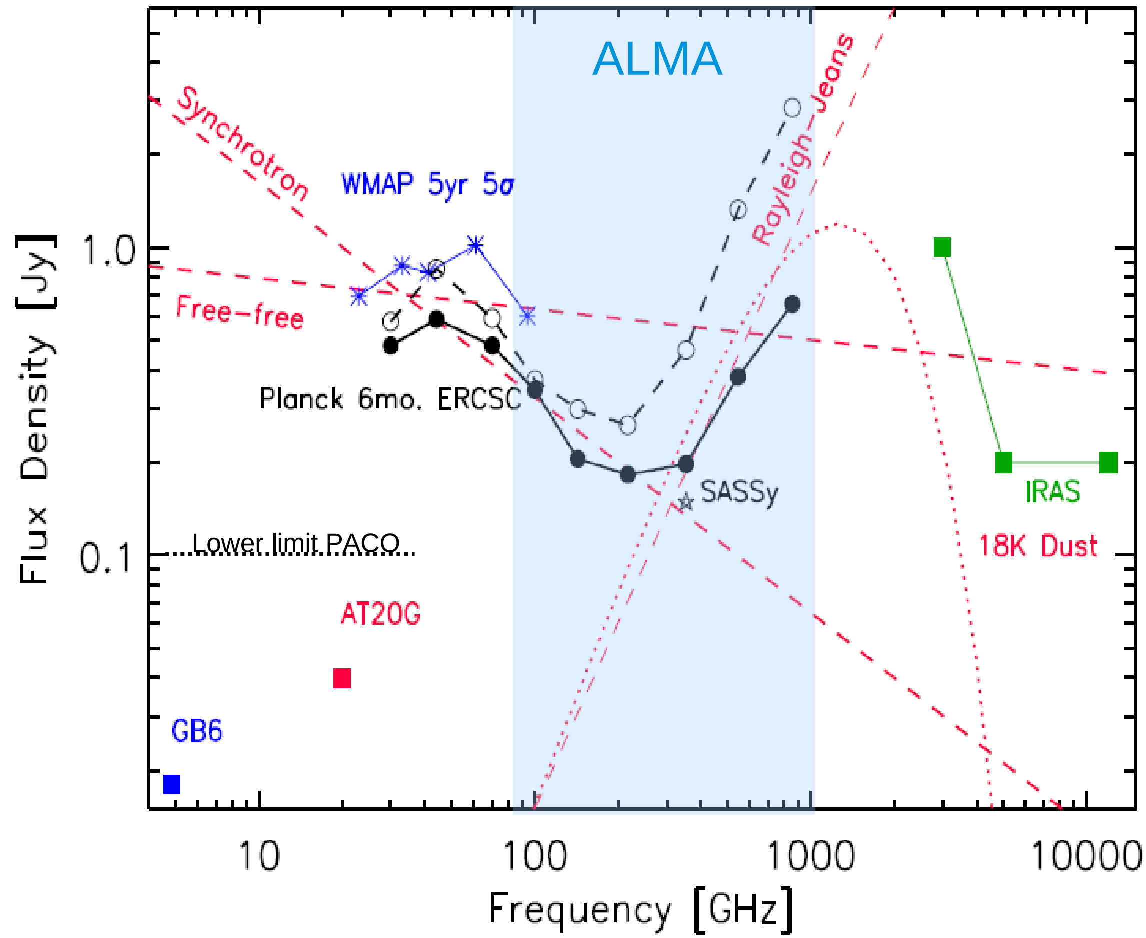
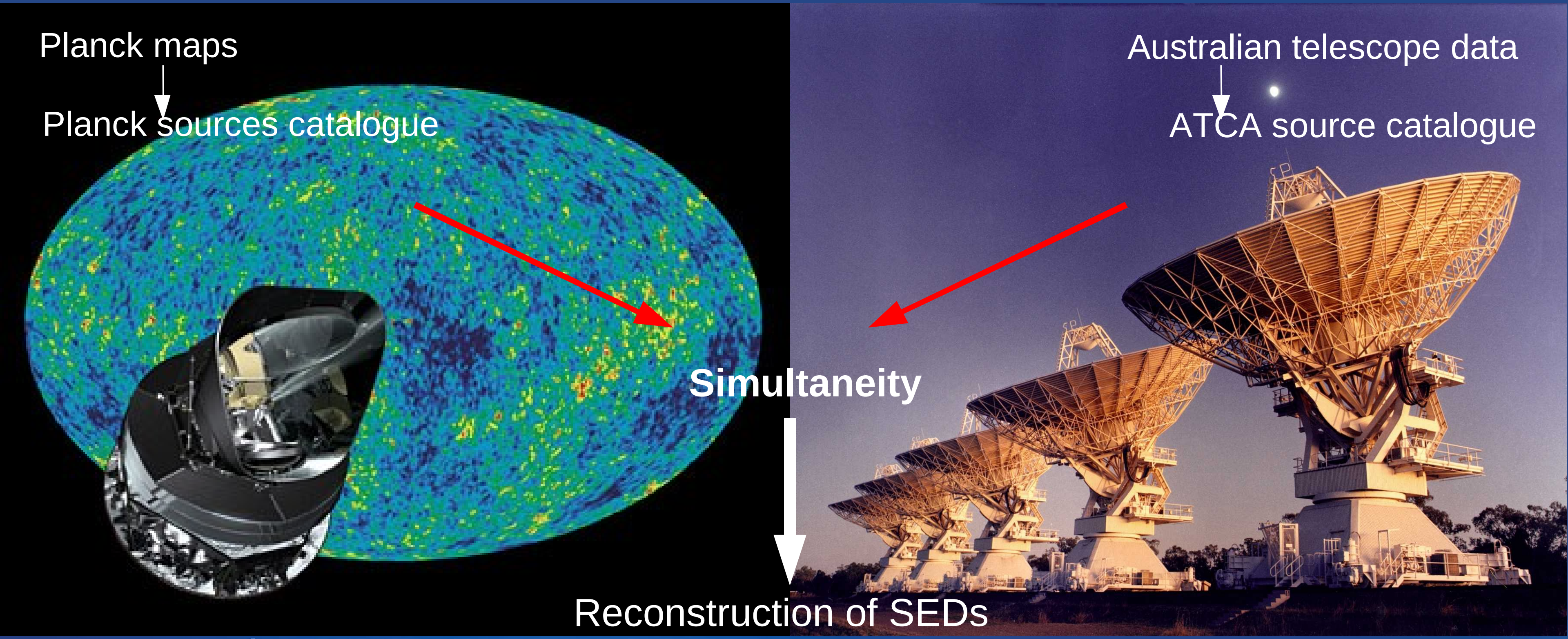


Fig. 5. The *Planck* ERCSC flux density limit both at $|b| < 10°$ (dashed black line) and at $|b| > 30°$ (solid black line) is shown relative to other wide area surveys. Also shown is the spectrum of known sources of foreground emission with red lines. The ERCSC sensitivity is worse in the Galactic Plane due to the strong contribution of ISM emission especially at submillimetre wavelengths. In the radio regime, the effect is smaller. The WMAP 5σ values are derived from the NEWPS catalogue of González-Nuevo et al. (2008).

The Planck ATCA Coeval Observations project

Nearly simultaneous (within 10 days from Planck observations) with ATCA multi-frequency observations (from 4.5 to 40 GHz) in total intensity and polarisation.



The Planck ATCA Co-eval Observations database

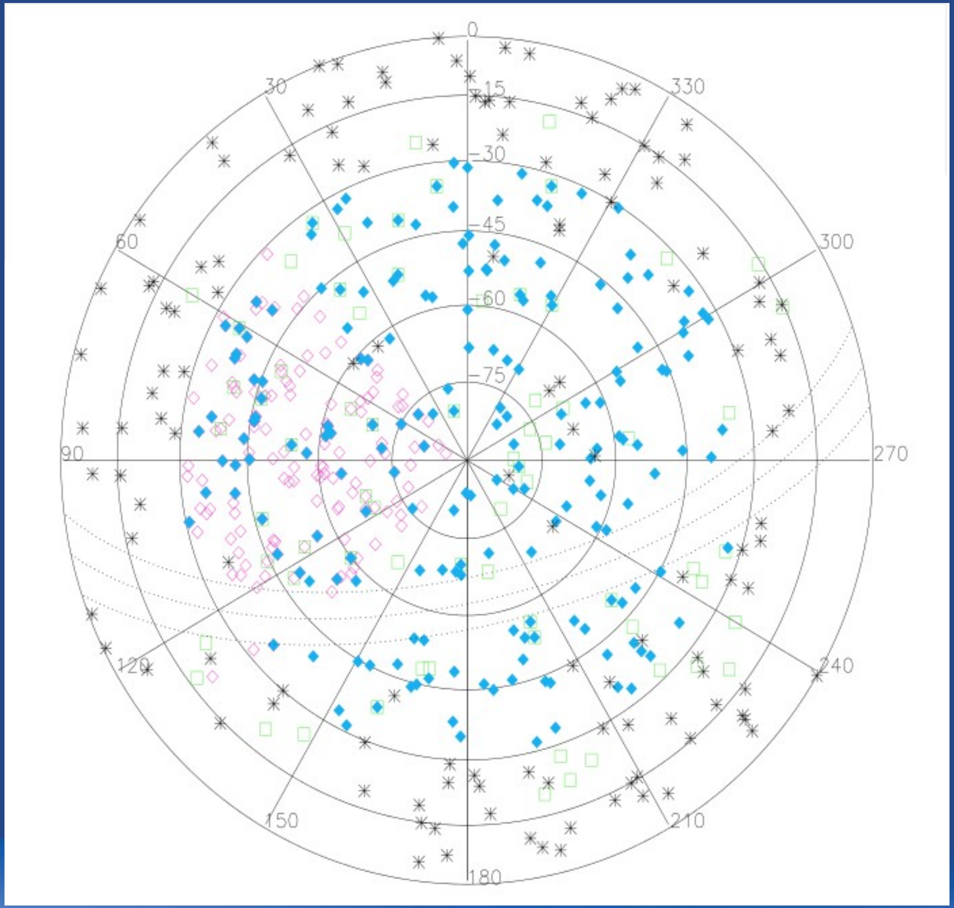
The selection was done in the AT20G catalogue + long term observations data

Complete sample of **inverted and upturning sources** between 5 and 20 GHz (69)

Complete sample of **flux density selected**:
162 S(@20GHz)>200 mJy (Bonavera et al. In prep)
189 S(@20GHz)>500 mJy (MM et al. 2011)

Variable sources (in ATCA observations)

63 **known Blazars** observed with APEX



Total number of sources: 483

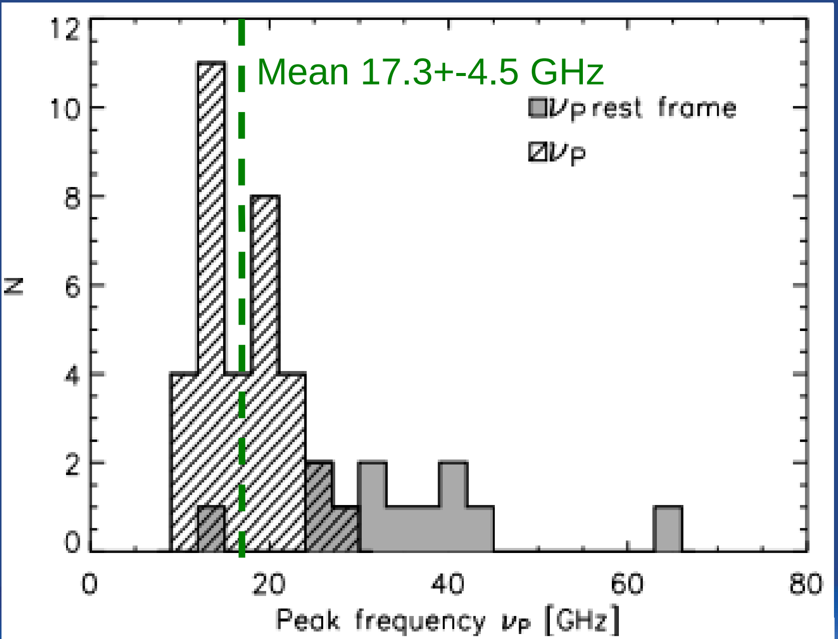
The Planck ATCA Co-eval Observations database

174 bright sample compact sources

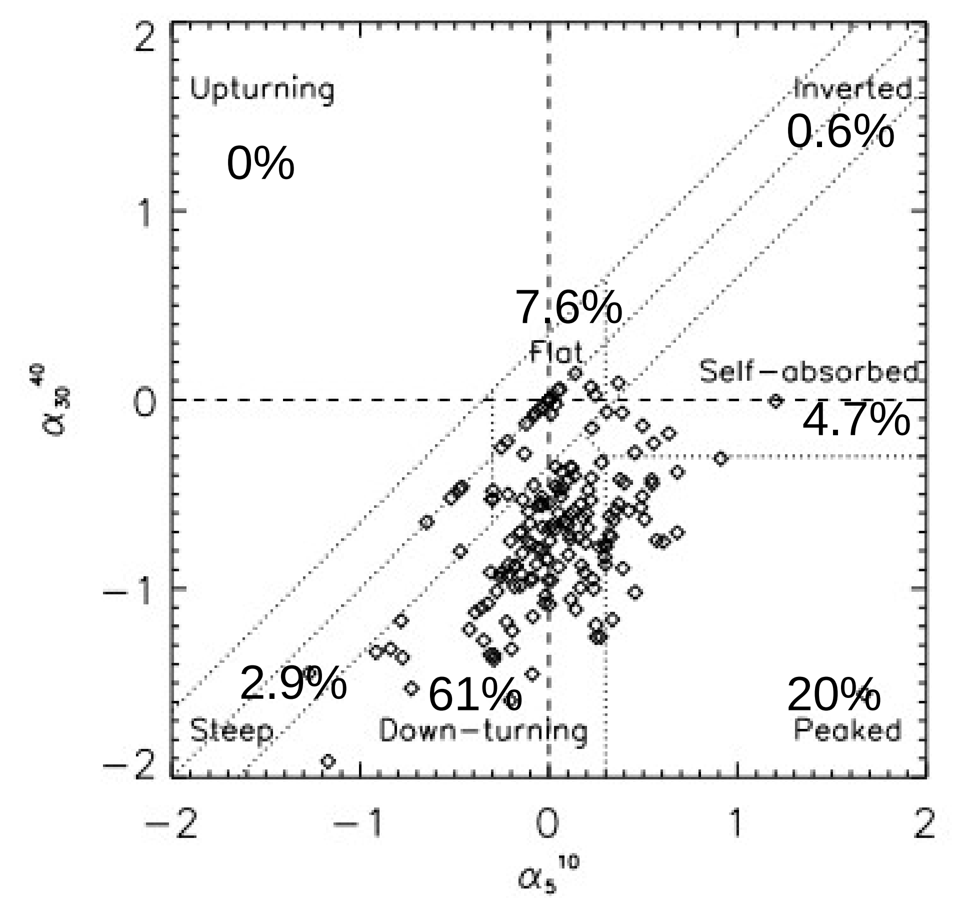
Fit with a double power law

$$S(\nu) = S_0/[(\nu/\nu_0)^{-a} + (\nu/\nu_0)^{-b}]$$

- estimation of spectral indices on the fit
- source classification
- estimation of peak frequency for the peaked



Distribution of peak frequency in obs and rest frame



Radio colour-colour plot between 5-10 and 30-40 GHz:

-11% single power law – mostly flat

- few low freq rising probably self-absorbed

- 20% peaking

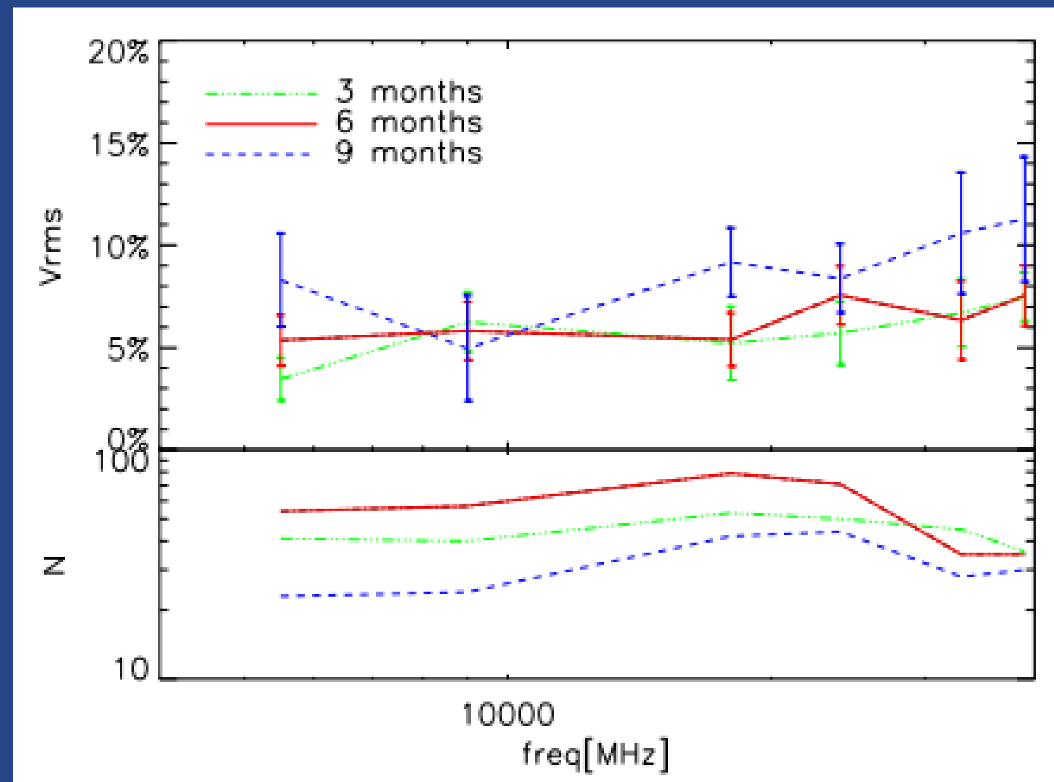
The Planck ATCA Co-eval Observations database

The variability index

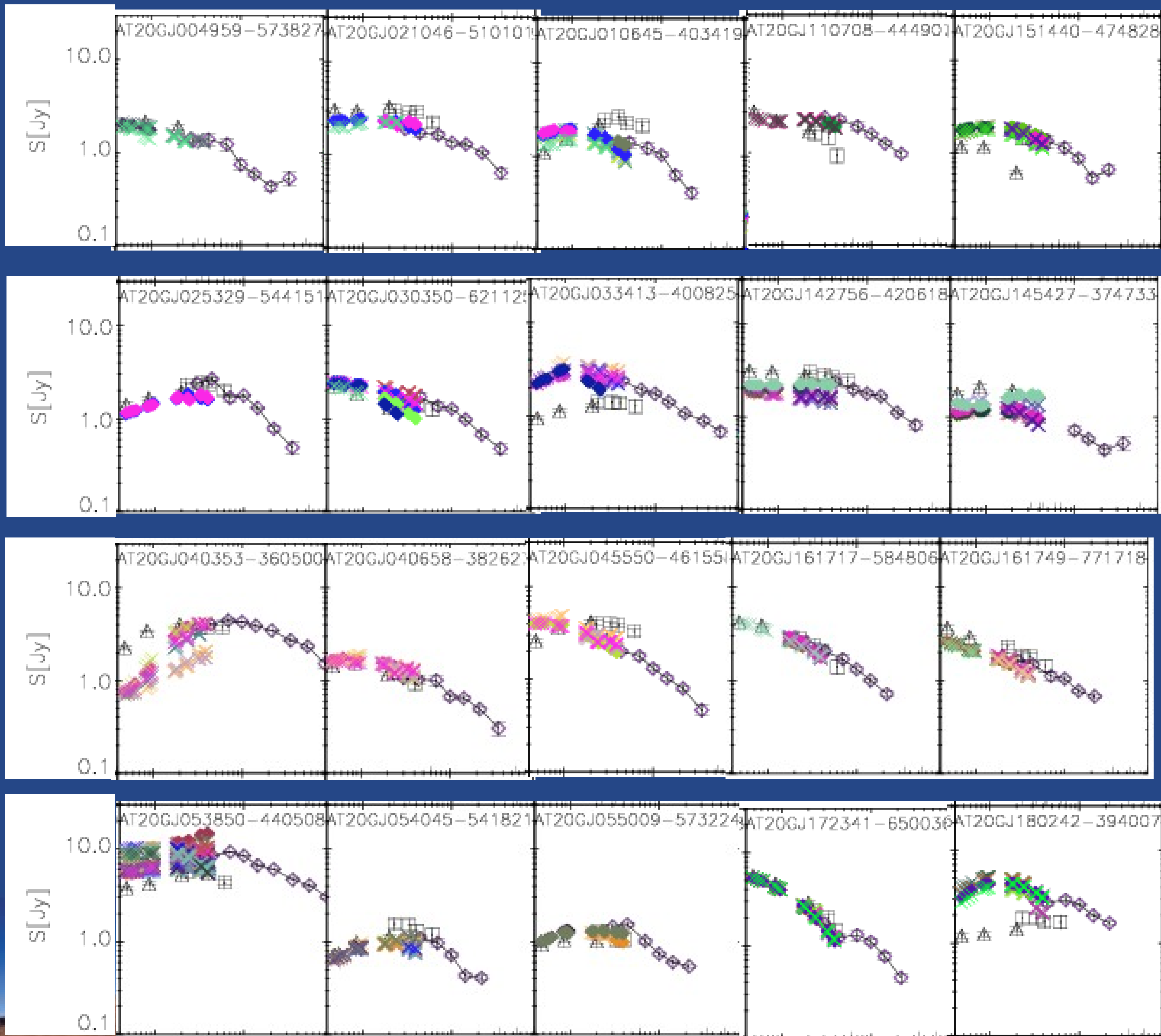
$$V_{\rm rms} = \frac{100}{\langle S \rangle} \sqrt{\frac{\sum [S_i - \langle S \rangle]^2 - \sum \sigma_i^2}{n}}$$

Has been estimated for the best couple of observations for each source.
We confirmed the trend towards an **increase of variability with frequency and a marginal indication of a larger variability on longer time scales**

The median variability at 20GHz on 9 months is about 9%



The Planck ATCA Co-eval Observations database



SEDs between 4.5 and 857 GHz

PACO, asterisks (different colours= different epochs)
ERCSC, diamonds
AT20G, triangle
NEWPS, squares

ATCA+Planck shows that these objects are pointlike and still bright enough to be suitable ALMA calibrators up tosubmm freqs.

(MM et al. 2010, Bonavera et al. 2011)

Absolute Amplitude Calibration

- **ALMA absolute calibration goal is 1 %**

- Relative amplitude accuracy of 1 % is needed for high dynamic range images (up to 10^4).

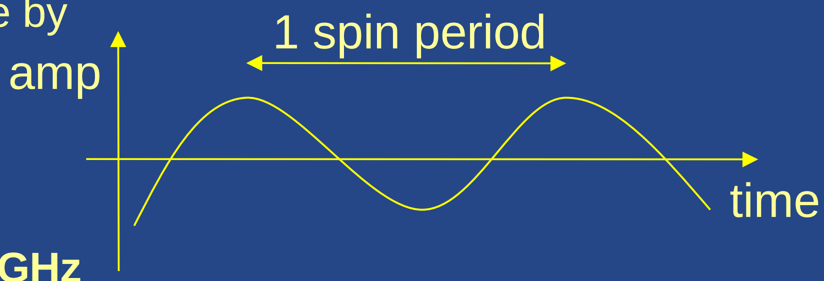
- So far, "**absolute" calibration is hardly ever performed**: most arrays (even at cm wavelengths) rely on so-called primary amplitude calibrators, which have been measured in an absolute way once (or twice) and are assumed constant since then.

- **At mm wavelengths, the primary calibrators are the solar system planets**. However, they have not yet been measured or modeled with better than 5% accuracy.

- At sub-mm wave-lengths, the situation is even worse. The IRAM interferometer currently achieves about 5 % accuracy at 3 mm, and 10 % at 1.3 mm.

Telescopes absolute & cross calibration

Absolute calibration of the Planck detectors (up to 353 GHz) is derived from the annual modulation of the CMB dipole by the Earth’s orbit around the Sun.



Absolute dipole measurement is obtained by differentiating along a spin period. Flux density calibration is expected as accurate as 1% up to 353 GHz

By exploiting the CMB dipole-based Planck calibration we can:

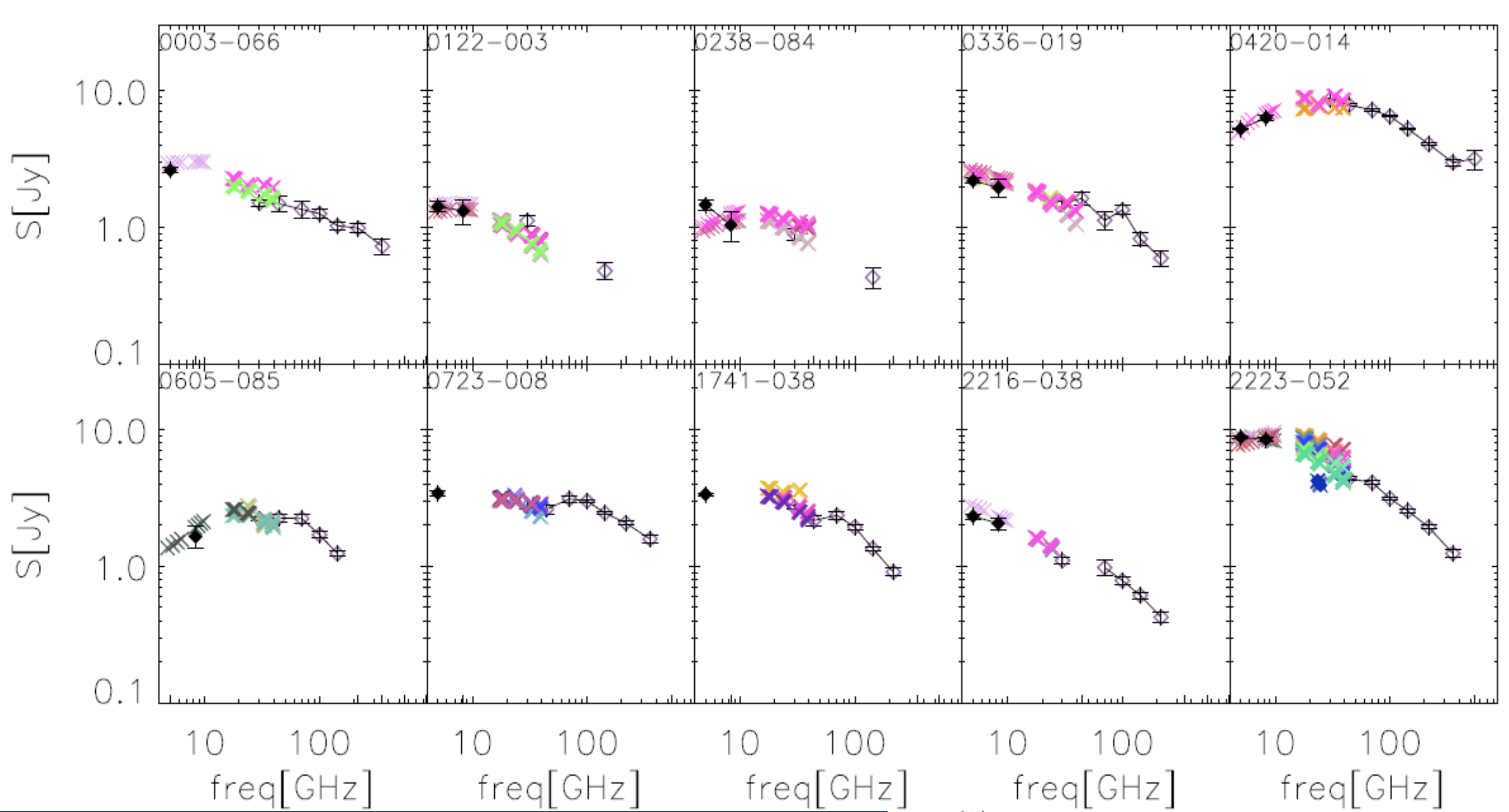
- establish the relative flux scale between Planck and ground-based tel at mm freq

- define an absolute calibration for all the telescope

The fluxes can be both transferred to the primary calibrators and used to **improve the models** for planets and calibrator sources

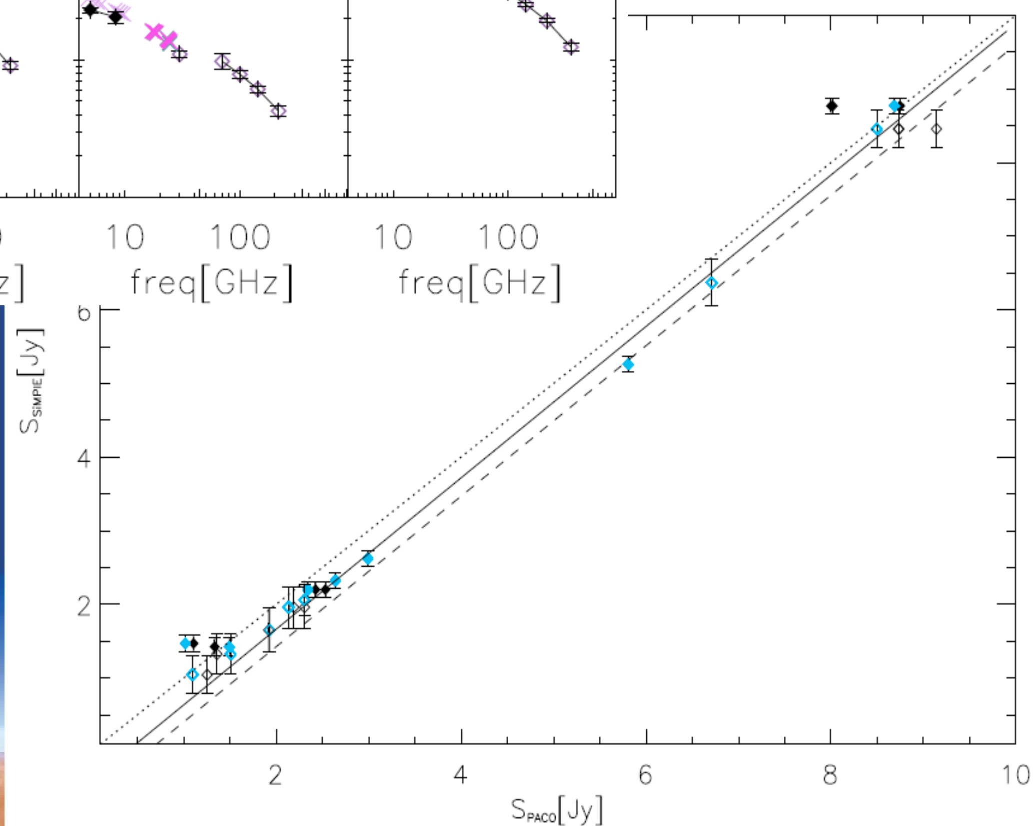
An observing project for cross-comparisons is observing about 20 bright sources simultaneously (i.e. within few days) with ATCA, Medicina and AMI at 3-6cm and 12mm, at 7mm between ATCA and VLA + Planck, at 3mm between ATCA, ALMA and CARMA + Planck.

SiMPlE+PACO+Planck



Cross-calibration of ATCA and the Medicina radiotelescope at 5 and 8GHz (...preiiminary results of the project)
Soon to come ALMA+ATCA at 3mm...

(Procopio et al. 2011)



Summary

- **ALMA is a unique instrument in the (sub-)mm (0.3 to 10 mm) range**
  - Unequaled sensitivity
    - Large collecting area (7200 m^2), excellent dry site (5000 m altitude)
    - e.g. 6 uJy in 6h @ 230 GHz
  - Great imaging capabilities
    - 50 antennas +ACA, variable configuration
    - High resolution (15km = 40 mas @ 100 Ghz,5 mas @ 900GHz)
  - Flexible spectral configuration
  - Pipeline reduced data
- **Early Science proposal submission deadline on 30th of June**

  (care for the limited capabilities !!!)
  - 16 antennas, baselines up to 450m, reduced number of spectral modes
- **Tools are designed to help the experienced AND non experienced user to use ALMA.**
  - Access to the ALMA world through the Science Portal and the ALMA Observing Tool
- **Calibration accuracy is beng improved, also exploiting synergies and simultaneous observations with other facilities, like Planck, ATCA, ...**

Enjoy your ALMA proposals !!!!!

Contact the Helpdesk and
your ARC node for support

Useful links:
ALMA UP: http://almascience.org/
ALMA PRIMER FOR ES: http://almatelescope.ca/ALMAPrimer.pdf
ALMA CfP: http://almascience.eso.org/call-for-proposals
Helpdesk: https://alma-help.nrao.edu/