

ALMA Science: a review of (sub)mm band science and instruments in the ALMA era



Marcella Massardi

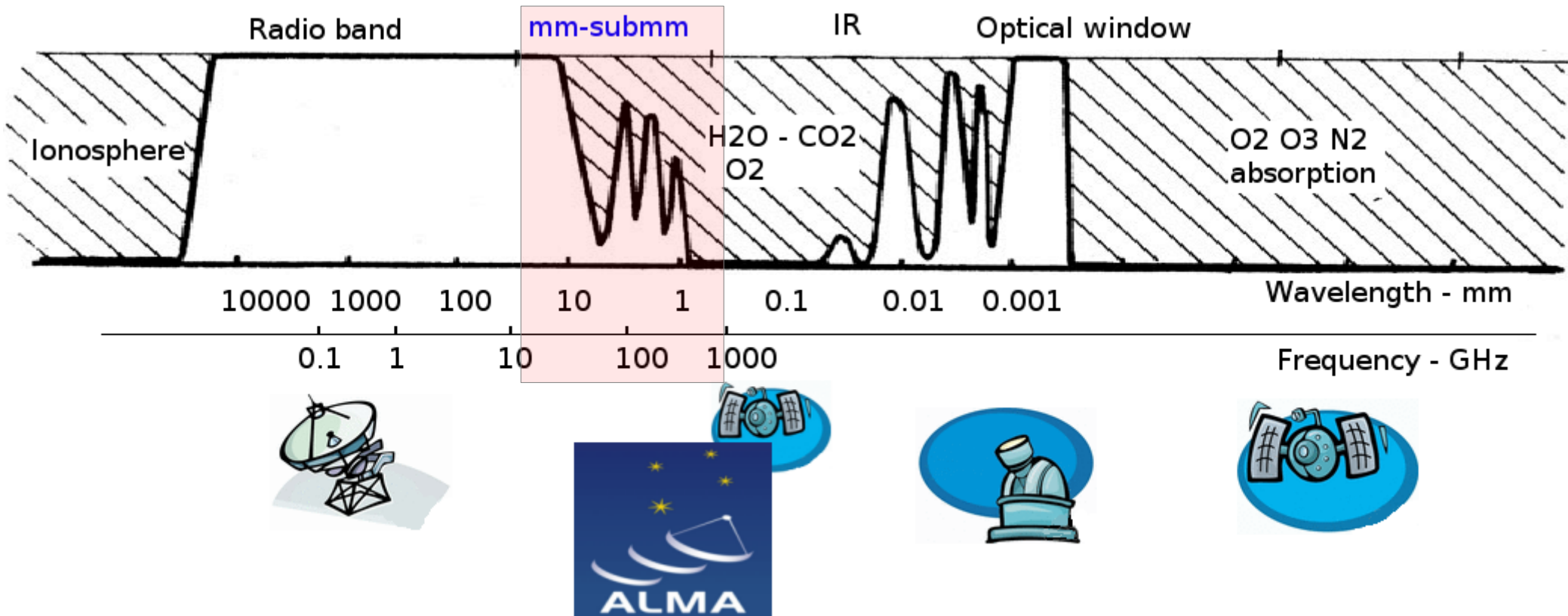
INAF- Istituto di Radioastronomia
Italian node of European ALMA Regional Centre



EUROPEAN ARC
ALMA Regional Centre || Italian

SISSA – February 2014

Outline



Signals in (sub)mm band

The reasons for ALMA

Galactic Science

Extragalactic Science

What can we get out of them?

Pills of interferometry
ALMA properties
Writing a proposal

From planets to our Galaxy

AGNs
Submm galaxies
Galaxy clusters

Observing in the sub(mm)

Issues in the sub(mm)

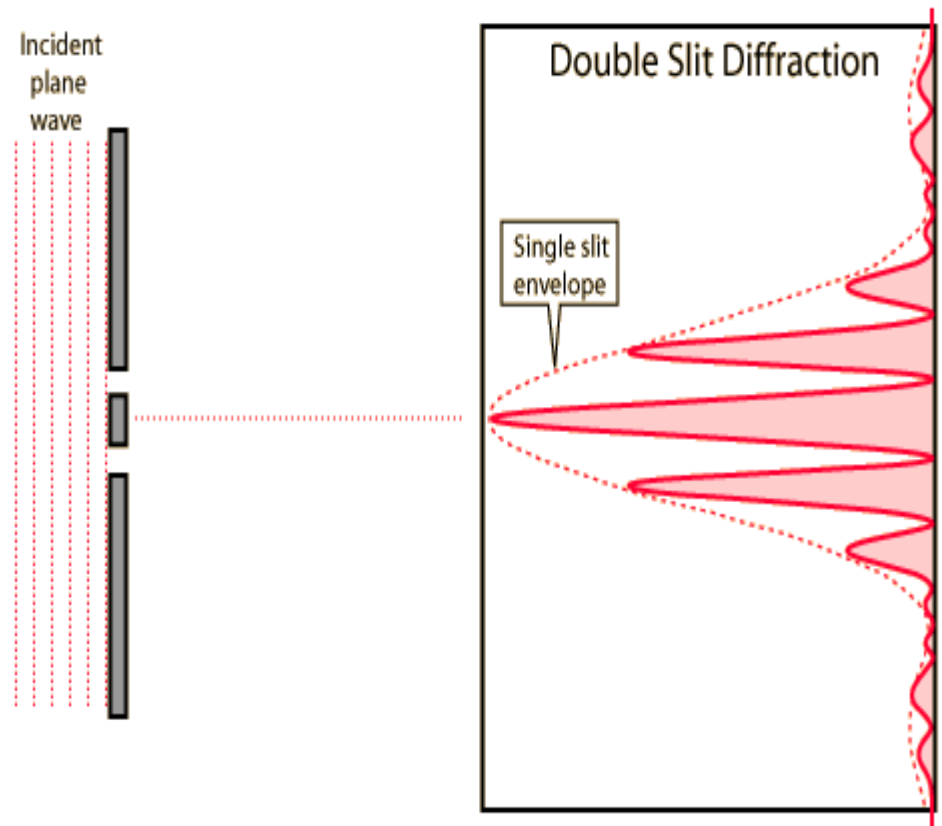
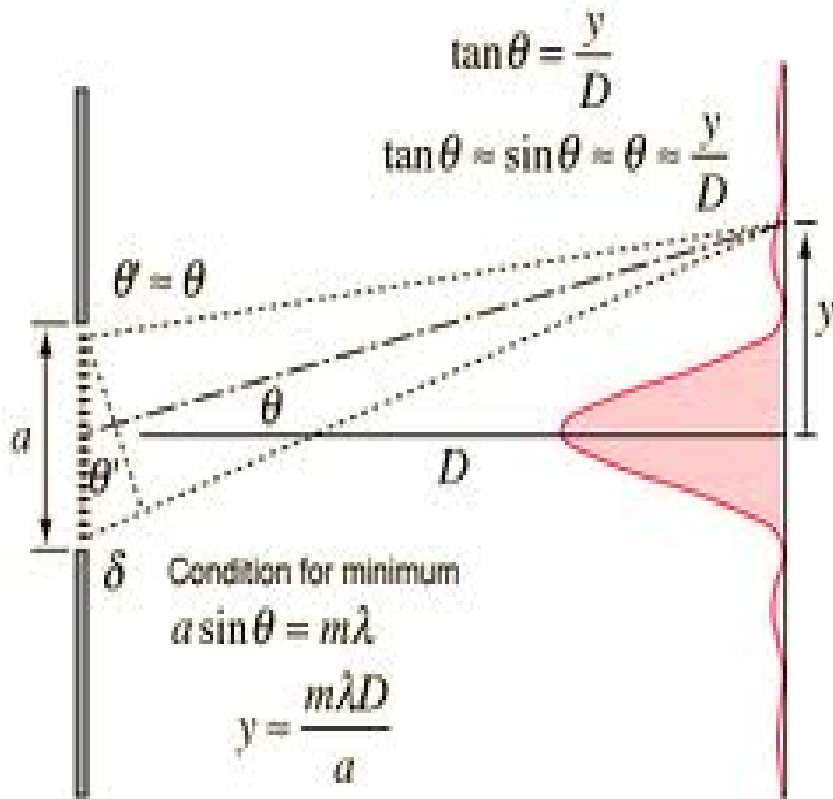
Resolution for a radiotelescope of diameter D at wavelength λ and $k \sim 1$

$$\theta = k \lambda / D$$

Hence, **resolution decreases as the wavelengths decreases.**

Larger telescopes are needed to reach higher resolutions:

from space small instruments give large areas but low resolution
from ground larger instruments are possible.



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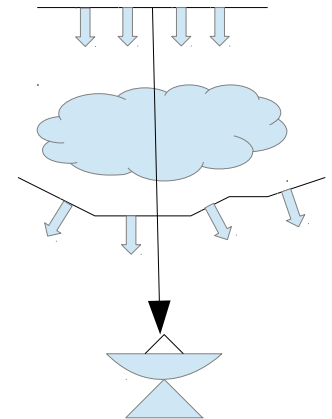
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Atmospheric effects: scattering of signal, absorption

Instrumental effects: surface accuracy must be higher at lower wavelengths



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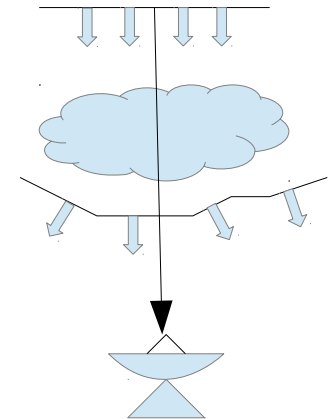
Atmospheric effects: scattering of signal, absorption

Instrumental effects: surface accuracy must be higher at lower wavelengths

The rms noise in the signal (sensitivity):

T_{sys} is the brightness temperature equivalent to the flux received from the antenna, including source, atmosphere, instrumental noise.

$$\Delta S_\nu = 2 k \frac{T_{\text{sys}}}{A_e \sqrt{2t \Delta \nu}}$$



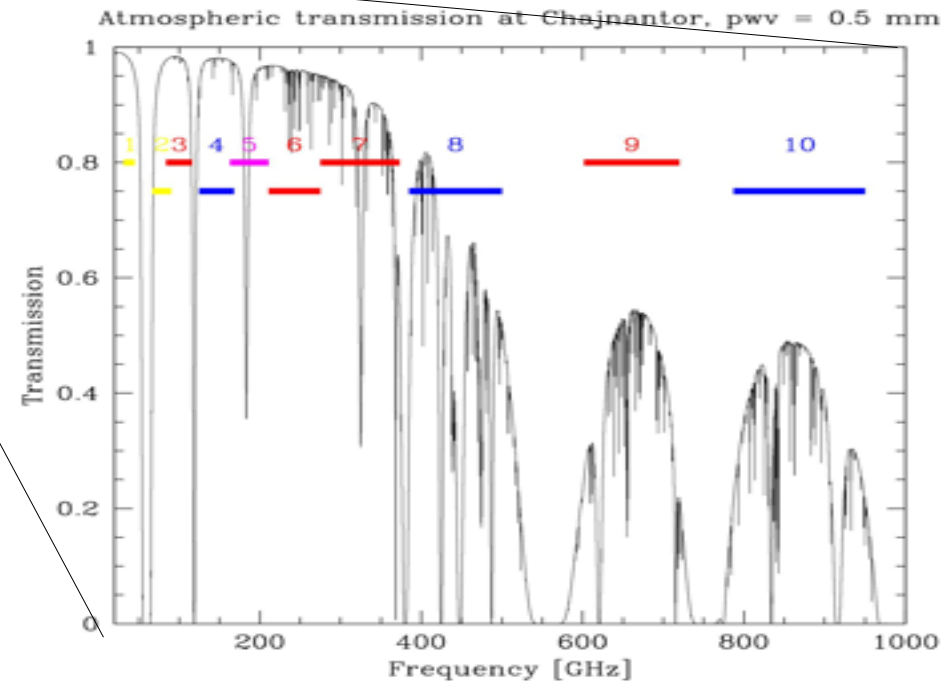
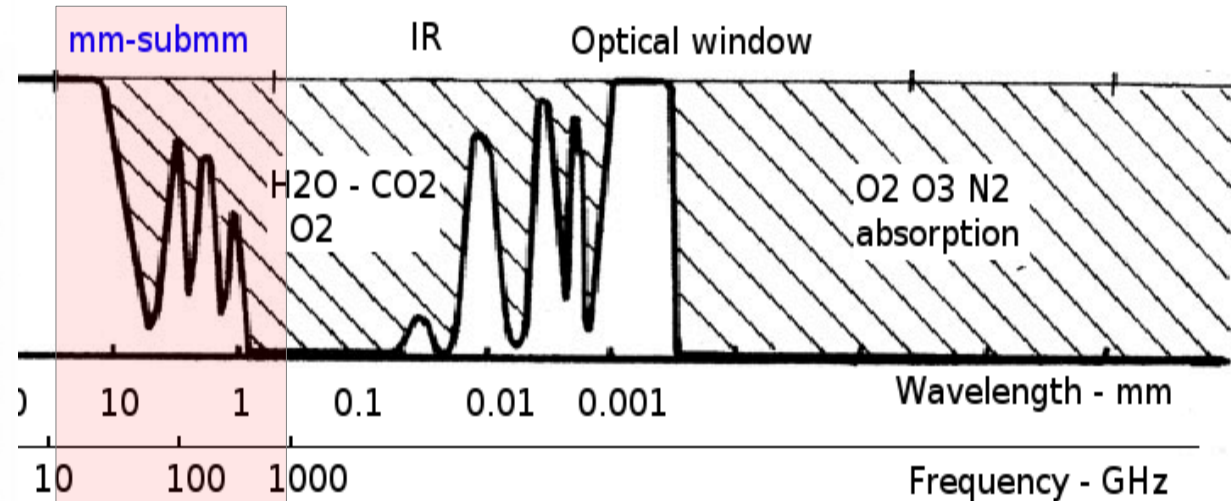
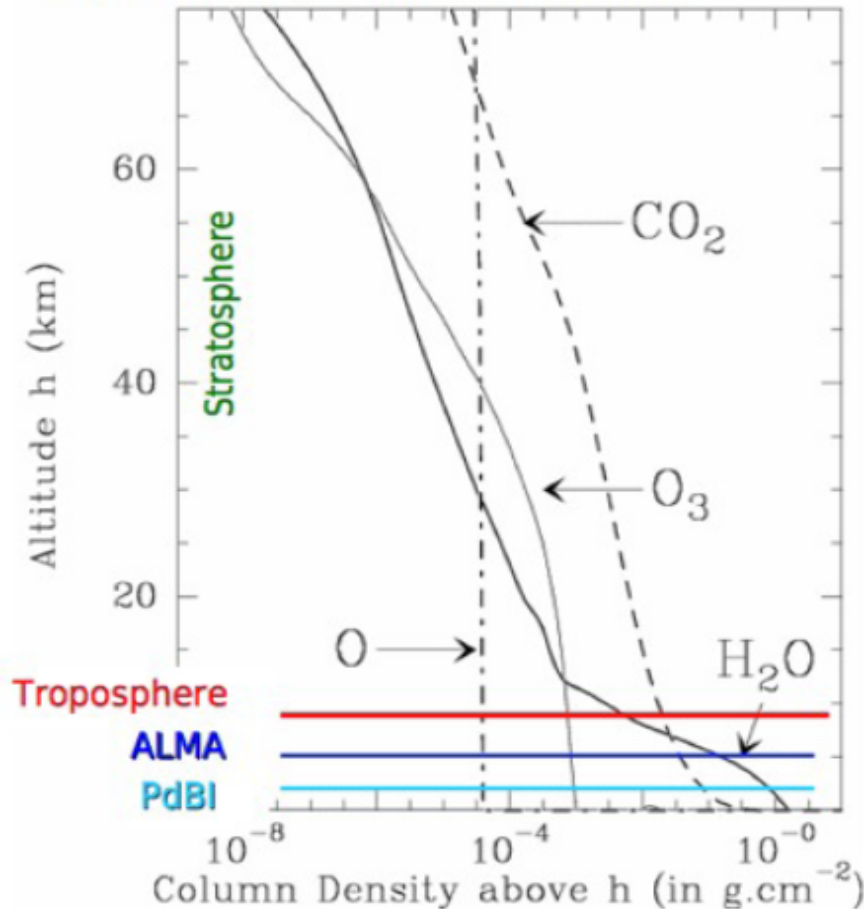
Sensitivity can be improved by

- getting lower T_{sys} (= lowering the instrumental noise
choosing sites with low water vapour levels)
- increasing the collecting area
- increasing the bandwidth and/or the integration time

Receiving system: ATMOSPHERE + ANTENNA + RECEIVER + BACKEND

Instruments: selecting the site

Column density as function of altitude



Chemical components in the atmosphere absorb the signal.
Only some transmission bands are available and only from high and dry sites.

Receiving system: **ATMOSPHERE** + ANTENNA + RECEIVER + BACKEND

Instruments: bolometers

An incident radiation changes the temperature of the receiver that absorb it.

The temperature variation is a measure of radiation intensity.

Bolometers are intrinsically broadband because the thermal effect is independent of frequency.

They are less sensitive to atmospheric variations.

Filters are needed for frequency determination.

They are usually mounted on single dish, hence limited in resolution to the antenna diameter.

To cover larger areas they are packed in arrays to increase the instantaneous Field Of View.

Instrument	Wavelength (microns)	F-o-V (sq-arcmins)	NEFD (mjy)	FWHM (arcsec)	Confusion (mjy)
SCUBA	450	4.2	400	7.5	0.25
	850	4.5	80	14	0.5
SCUBA-2	450	50	100	7.5	0.25
	850	50	30	14	0.5
Laboca-S	350	4	250	7	0.3
Laboca	850	11	110	18	0.8
SPIRE	250	32	29	18	2.6
	350	32	34	25	3.8
	500	32	37	35	5.4
AzTec	1100	2.4	3.5	5.5	0.06
MAMBO-2	1200	10	30	10	0.2

100 pc at $z>1$ appear on arcsec scales

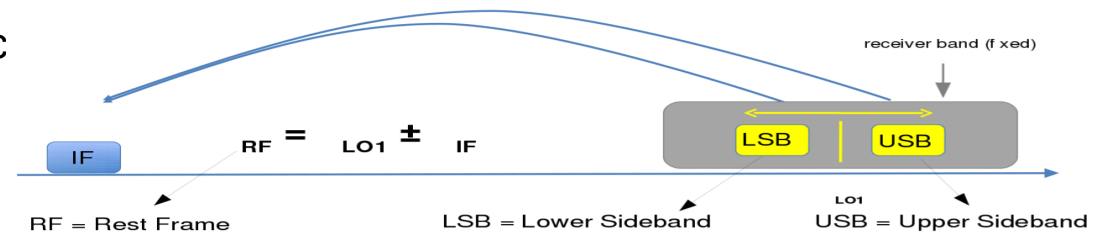
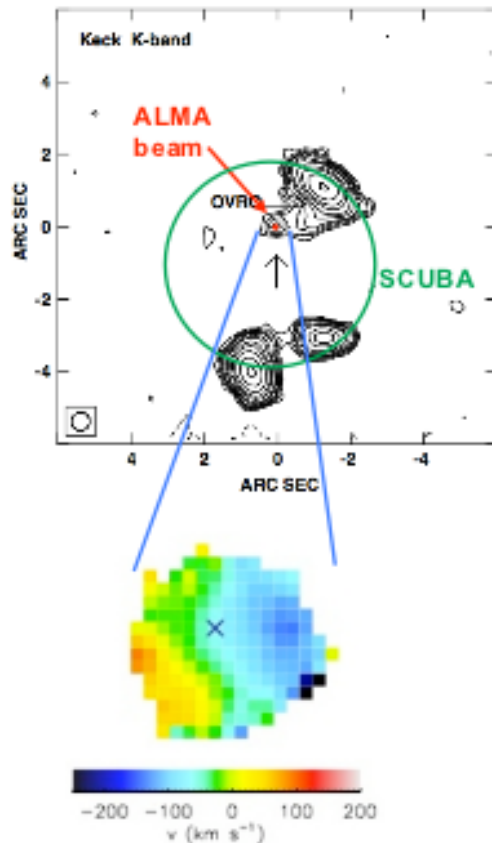
Receiving system: ATMOSPHERE + ANTENNA + RECEIVER + BACKEND

Instruments: Coherent receivers

Coherent receivers preserve the phase of the signal: can be mounted on interferometers

Furthermore, by mean of heterodyne principles the frequency is shifted to fixed lower values, without changing any other property of the signal, by combining the received signal with that of a tunable **Local Oscillator**.

This allows to have the whole electronic chain working at the same frequency.



Name	Antennas [# × Diameter]	$\Delta\lambda$ [mm]	Max ang. resol. [asec]	Total area [m ²]
IRAM-PdBI	6 × 15m	1.2–3	0.35	1060
CARMA ^a	6 × 10.4m + 10 × 6m	1.2–3	0.1	792
NMA	6 × 10m	1.2–3	1	471
SMA	8 × 6m	0.35–1.2	0.1	226
eSMA ^b	SMA + 15m + 10.4m	0.87–1.2	0.2	488
ATCA ^c	6 × 22m ^d	3–12	2.	2280 ^d

Notes:

^a CARMA is the merging of the former OVRO (6×10.4m antennas) and BIMA (10×6m antennas) arrays.

^b eSMA is the combination of SMA with the JCMT and CSO.

^c ATCA can observe at much lower frequencies, down to $\lambda = 20\text{cm}$, the specifications given here only refer to the observing capabilities at mm wavelengths.

^d At $\lambda = 3\text{mm}$ only 5 of the ATCA antennas can be used, for a total collecting area of 1900 m².

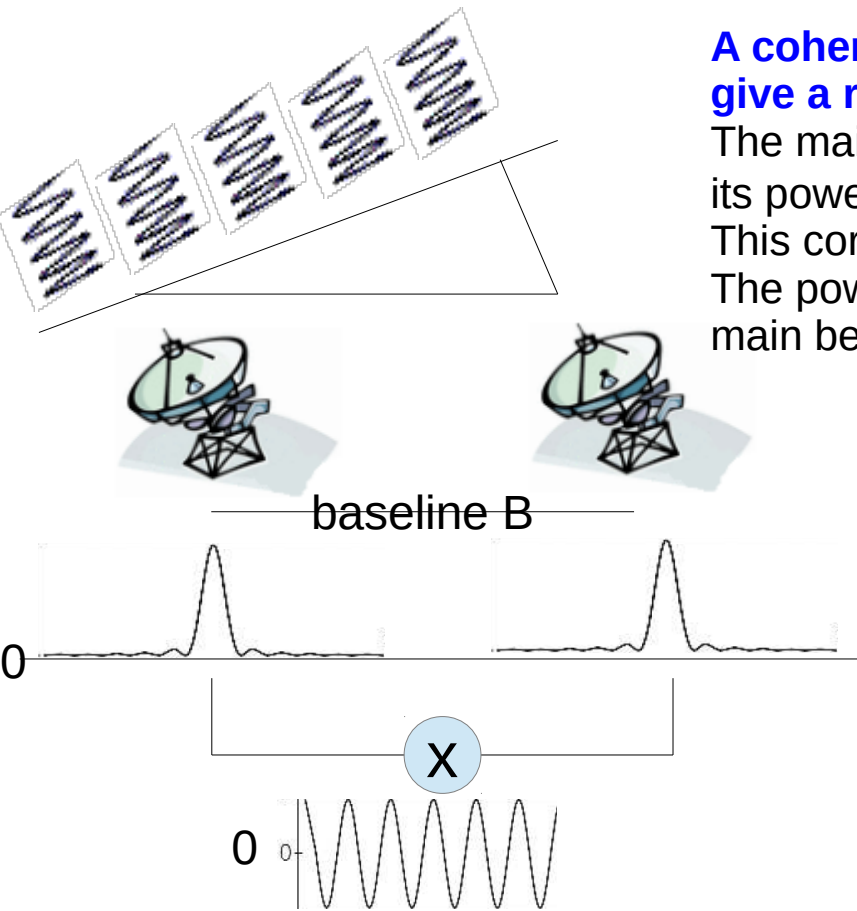
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A coherent combination of reflectors of diameter d at distance $B(>>d)$ give a resolution equivalent to that of a single reflector of diameter B .

The main (primary) beam (FOV) of an antenna is the solid angle where its power pattern (assuming to use it as a transmitter) is larger ($\theta=\lambda/d$). This correspond to the range where it is more sensitive as a receiver. The power pattern in case of a far away point source is given by the main beam shape with amplitude equal to the source flux (total power).

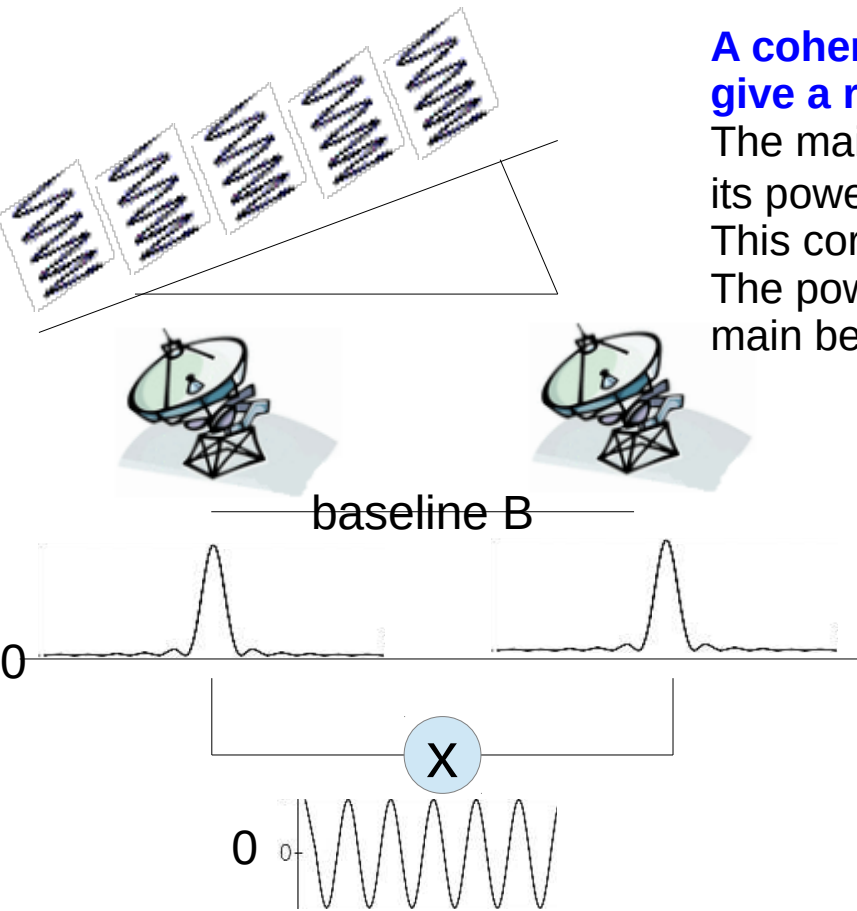
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After correcting for geometrical delays, allowing the comparison of two points of the same wavefront coming from a far away point source the output of the correlation of two signals is a fringes pattern centered around 0 (total power is lost).

Only the spatial component corresponding to $\theta=\lambda/B$ is preserved.

Baselines equal to $2D$ identifies angular scales of the order of $\theta/2$. **The interferometer works as a filter in spatial scales.**

Signals on multiple baselines can be combined to retrieve information on source structure (= aperture synthesis).

Receiving system: ATMOSPHERE + ANTENNA + RECEIVER + BACKEND

The visibility function

The incoming wave induces a electromagnetic voltage in the antennas (E is the wave amplitude)

The geometrical delay in the direction $s=s_0+ds$

The correlator works as a multiplier and time integrator with output

$$U_1 \propto E e^{i\omega t}$$

$$U_2 \propto E e^{i\omega(t-\tau)}$$

$$\tau = \frac{1}{c} \mathbf{B} \cdot \mathbf{s}$$

$$R(\tau) \propto \frac{E^2}{T} \int e^{i\omega t} e^{-i\omega(t-\tau)} dt$$

$$R(\tau) \propto \frac{\omega}{2\pi} E^2 \int_{-\pi/\omega}^{\pi/\omega} e^{i\omega\tau} dt$$

$$R(\tau) \propto \frac{1}{2} E^2 e^{i\omega\tau}$$

$$dP = I_\nu \cos\theta d\Omega d\sigma d\nu$$

$$= A(s) I_\nu(s) d\Omega d\nu$$

If $t \gg 2\pi/\omega$

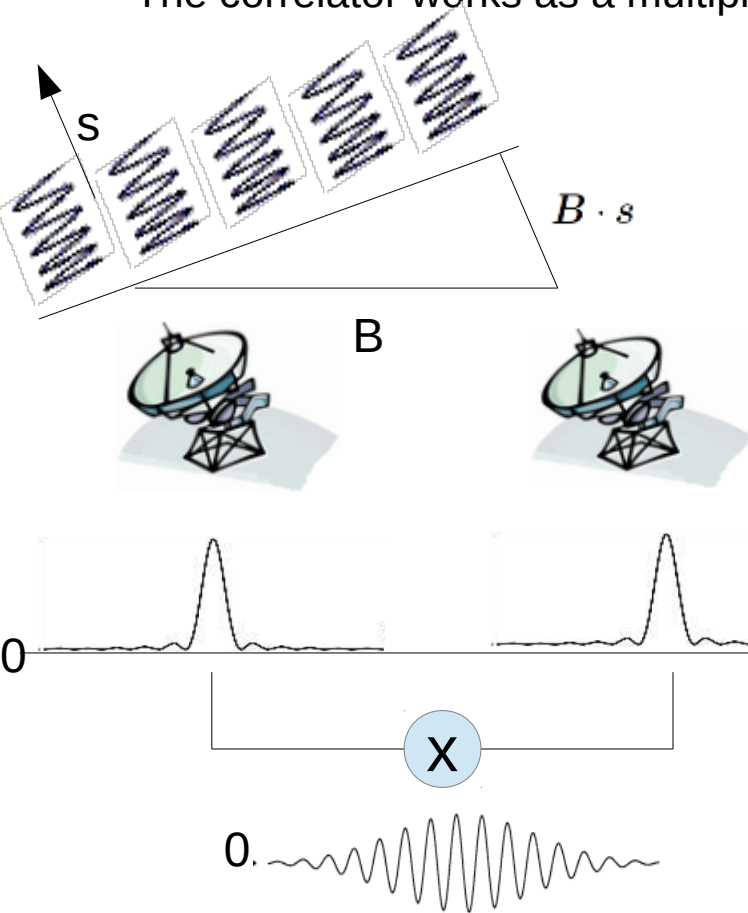
that results in

The power induced by the source in terms of I and effective area from in the direction s ($P \propto E^2$)

$$r_{12} = A(s) I_\nu(s) e^{i\omega\tau} d\Omega d\nu$$

The output of the correlator integrated over the source is the visibility function

$$R(\mathbf{B}) = \iint_{\Omega} A(\mathbf{s}) I_\nu(\mathbf{s}) \exp \left[i 2\pi \nu \left(\frac{1}{c} \mathbf{B} \cdot \mathbf{s} \right) \right] d\Omega d\nu$$



Receiving system: ATMOSPHERE + ANTENNA + RECEIVER + BACKEND

The visibility function: properties

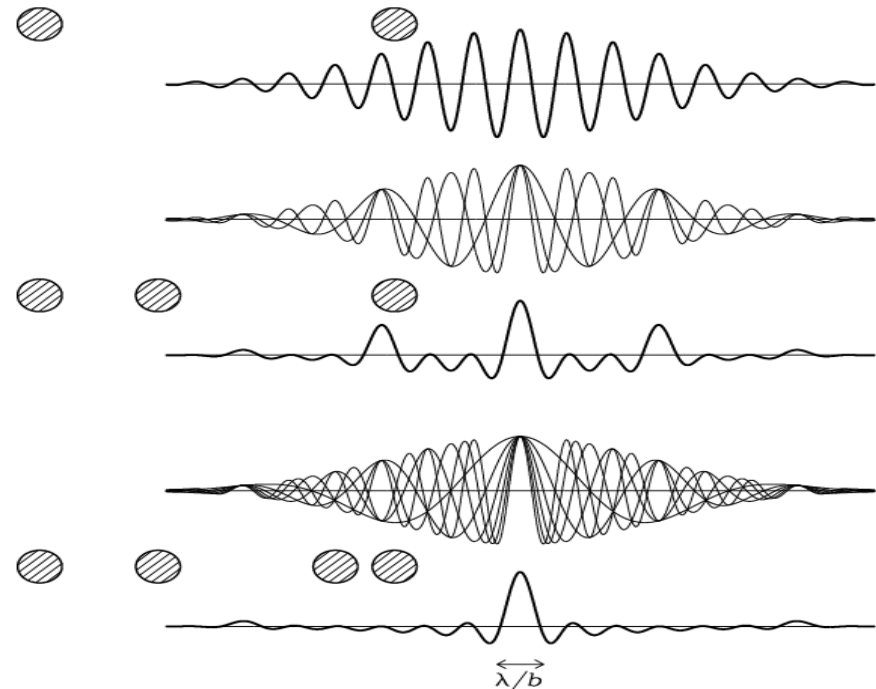
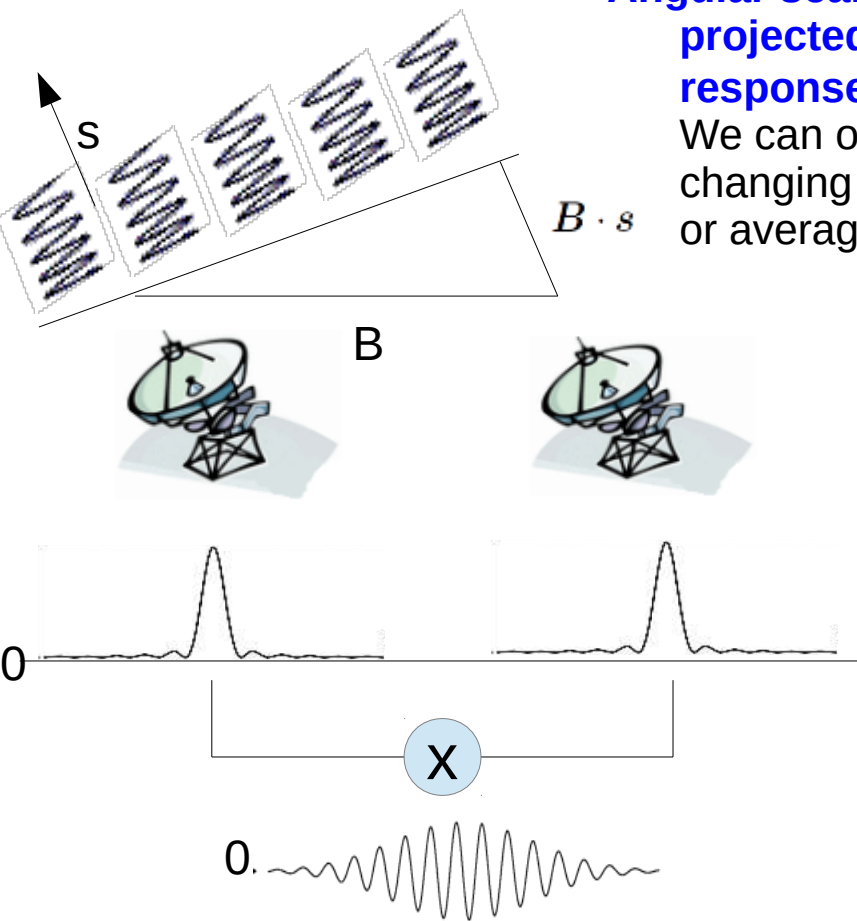
Some **visibility function** properties:

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- **Amplitude is modulated by the main beam shape**
- **The phase is strictly connected with the source position**
- **Angular scales on the sky are associated with the size of the projected baseline needed to observe them and the FWHM of the response function width is the synthesized beam λ/B .**

We can observe more angular scales either
changing the baseline

or averaging the signal from N Antenna couples $(N(N-1)/2)$



Receiving system: ATMOSPHERE + ANTENNA + RECEIVER + BACKEND

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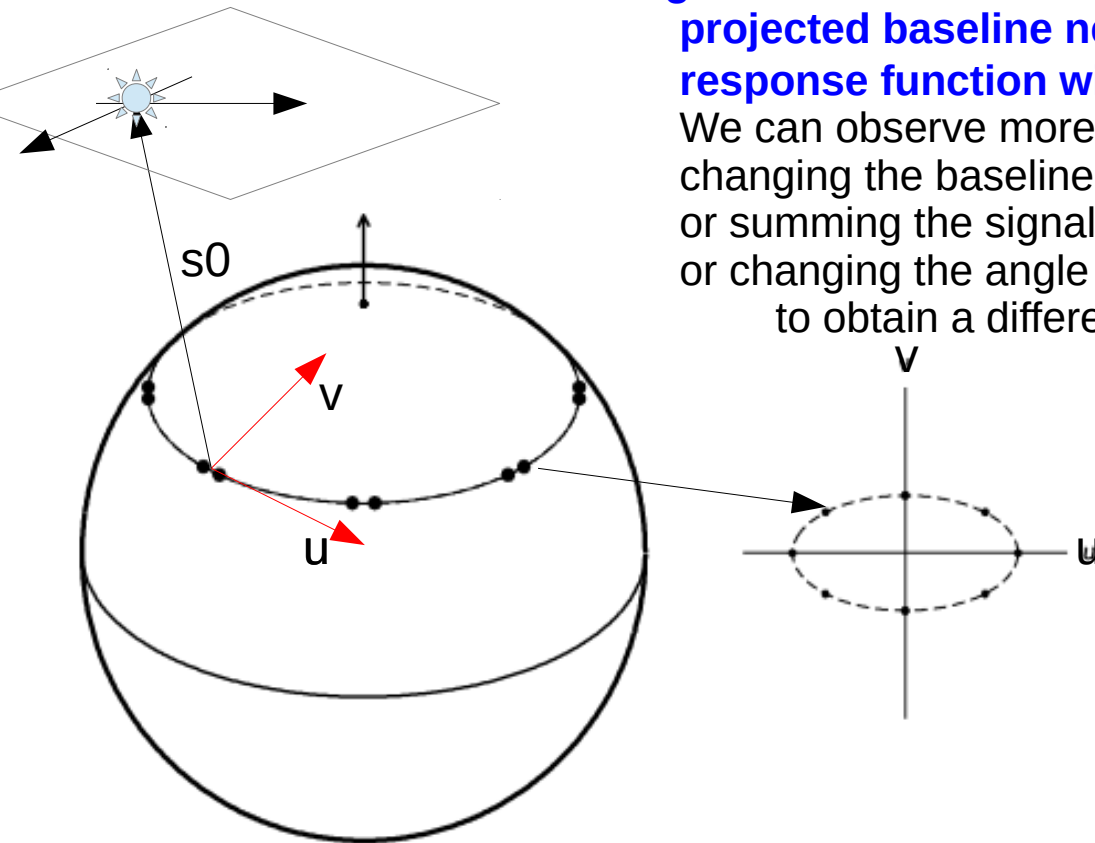
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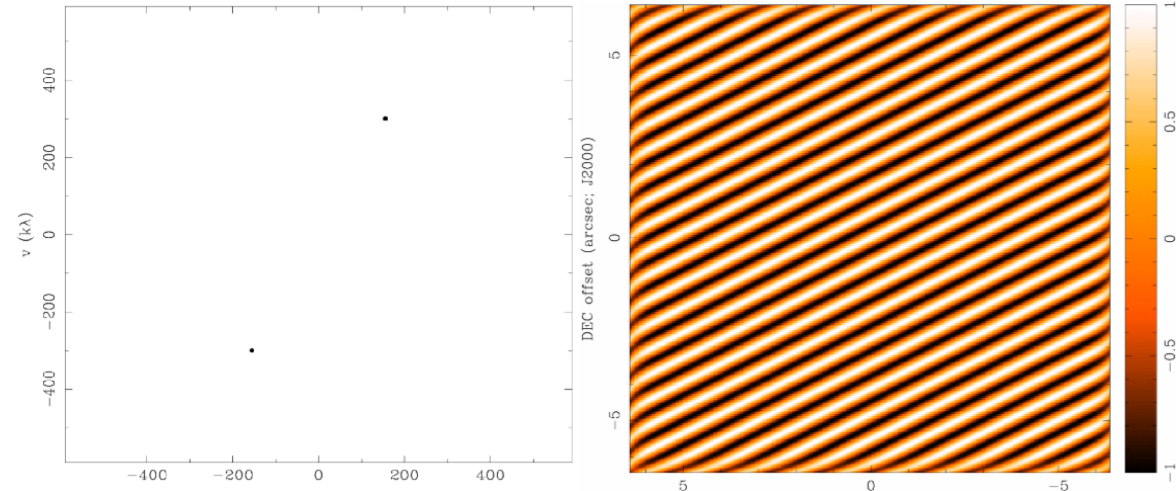
or changing the angle towards the target (exploiting the Earth rotation) to obtain a different projection of the same baseline.



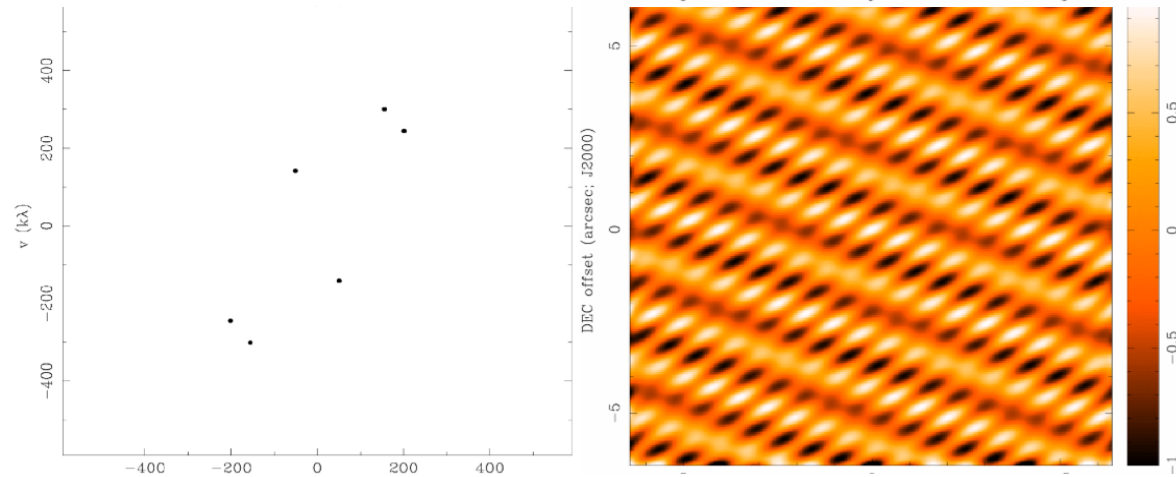
The projected baseline is described over the uv plane perpendicular to the direction to the phase center (s_0) with u and v towards E and N. The earth rotation generates elliptical loci on the uv plane in 12 hr which ellipticity depends on the telescope latitude and source declination.

Receiving system: ATMOSPHERE + ANTENNA + RECEIVER + BACKEND

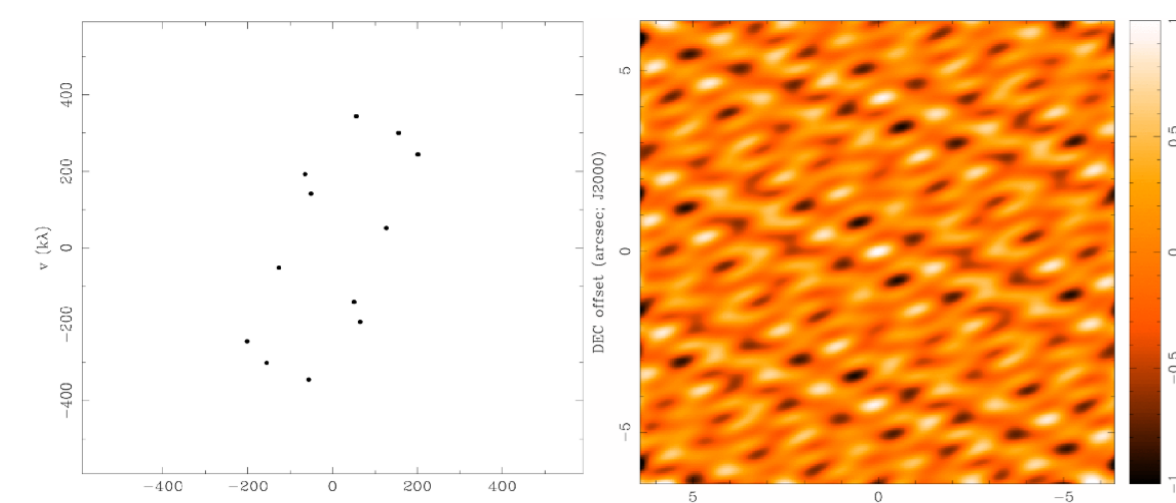
The visibility function: the uv plane



2 antennas

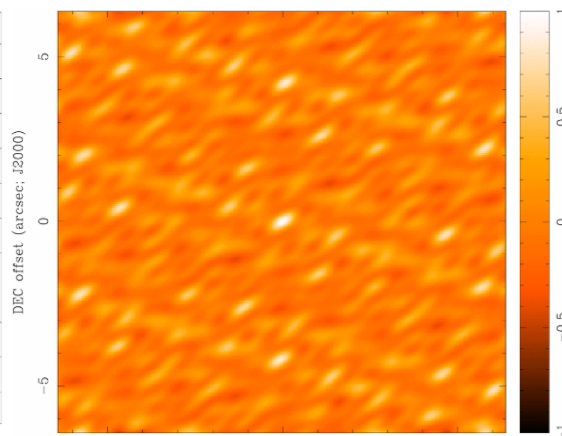
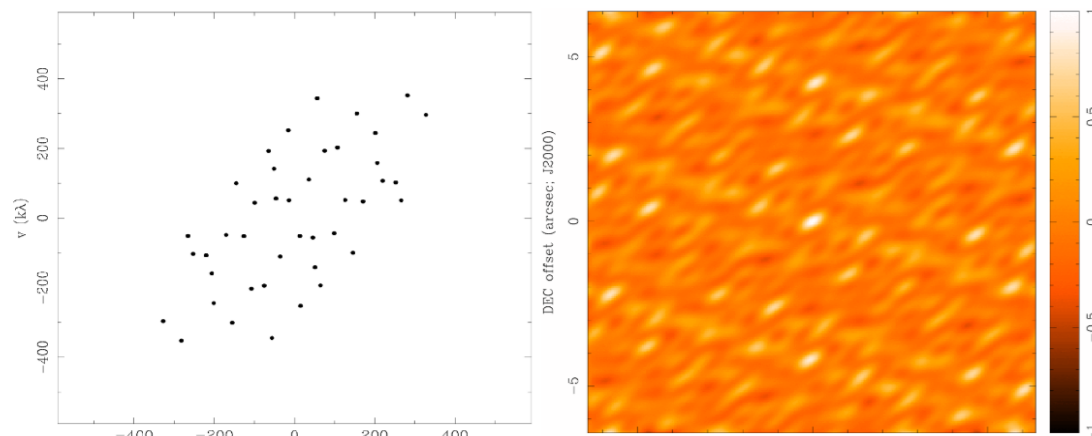


3 antennas



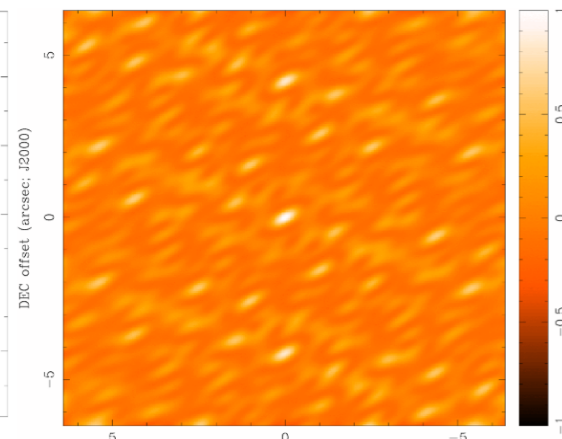
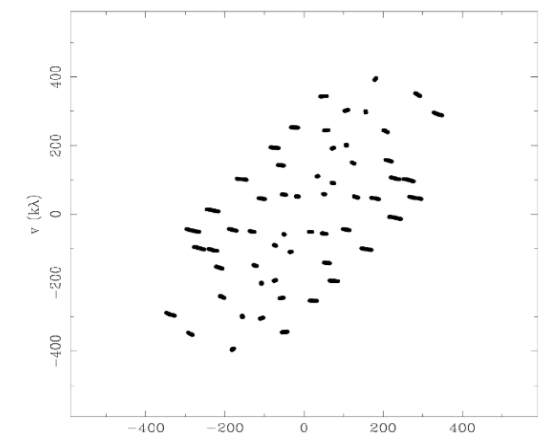
5 antennas

The visibility function: the uv plane

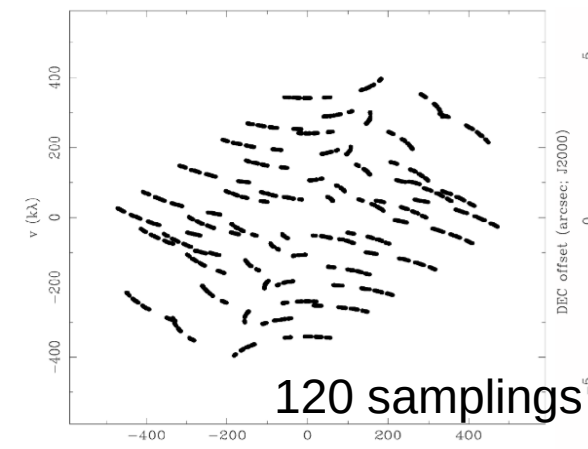


8 antennas

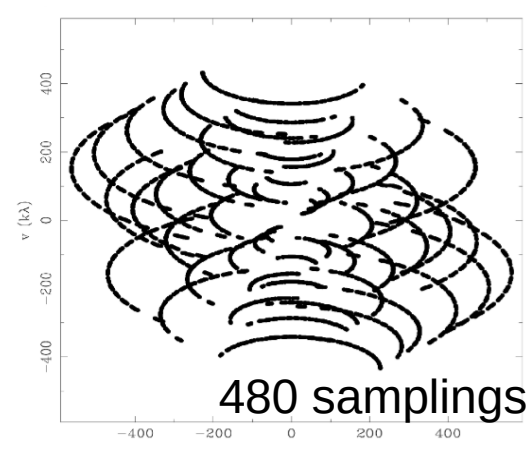
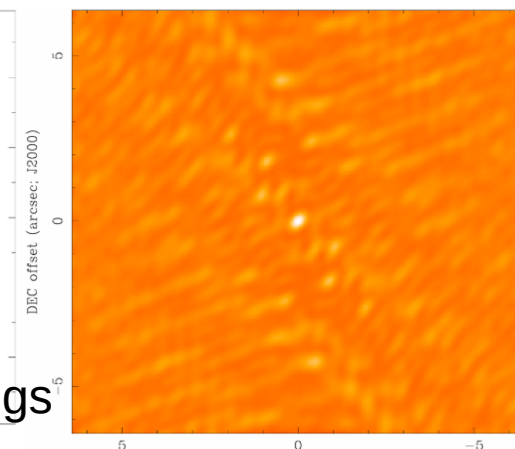
1 sampling



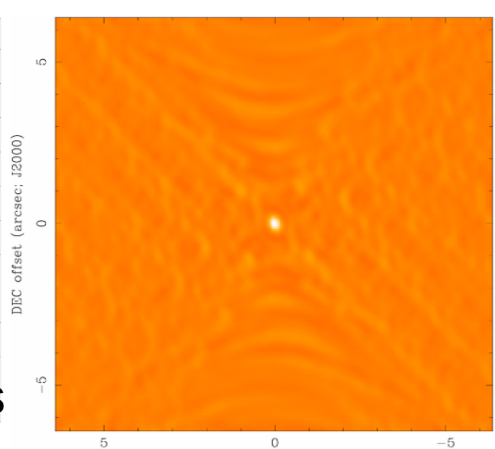
30 samplings



120 samplings



480 samplings



The visibility function: properties

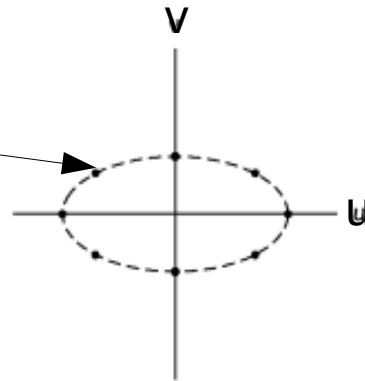
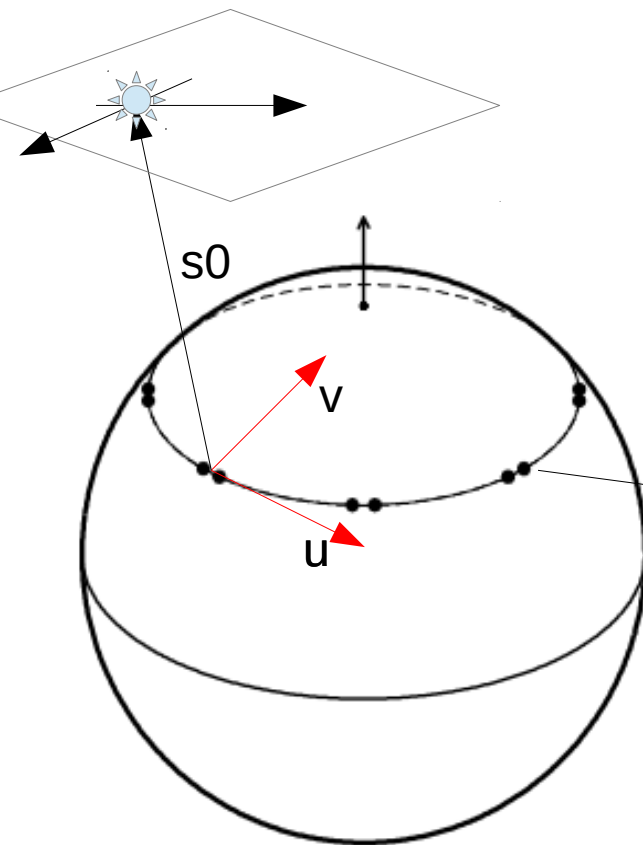
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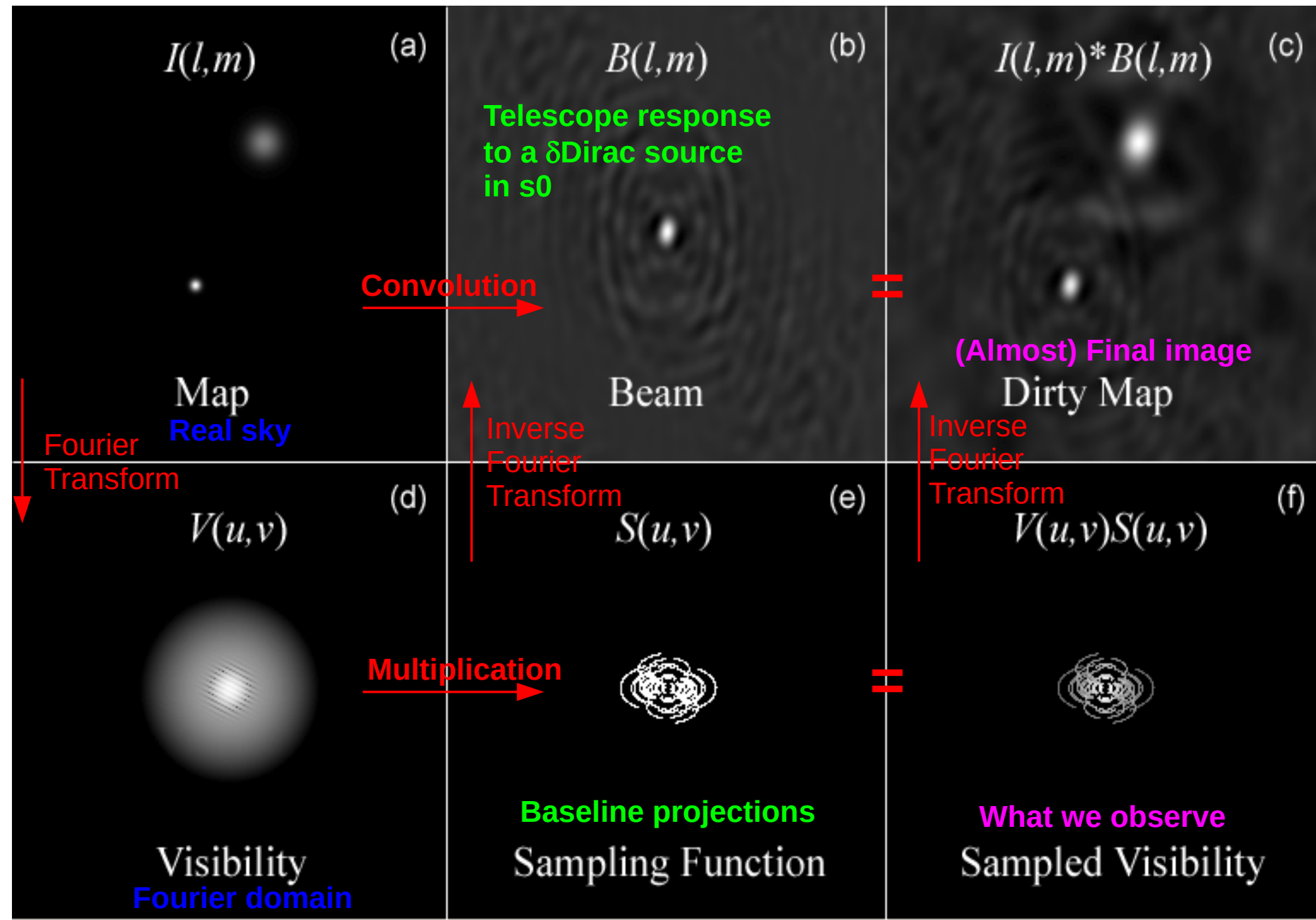
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- **Van Cittert- Zernike theorem: the visibility pattern is the Fourier transform of the brightness pattern**

Hence the inverse transformation of the uv plane gives the image of the real plane (filtered for the observed angular scales).

Receiving system: ATMOSPHERE + ANTENNA + RECEIVER + BACKEND

From the sky to the image



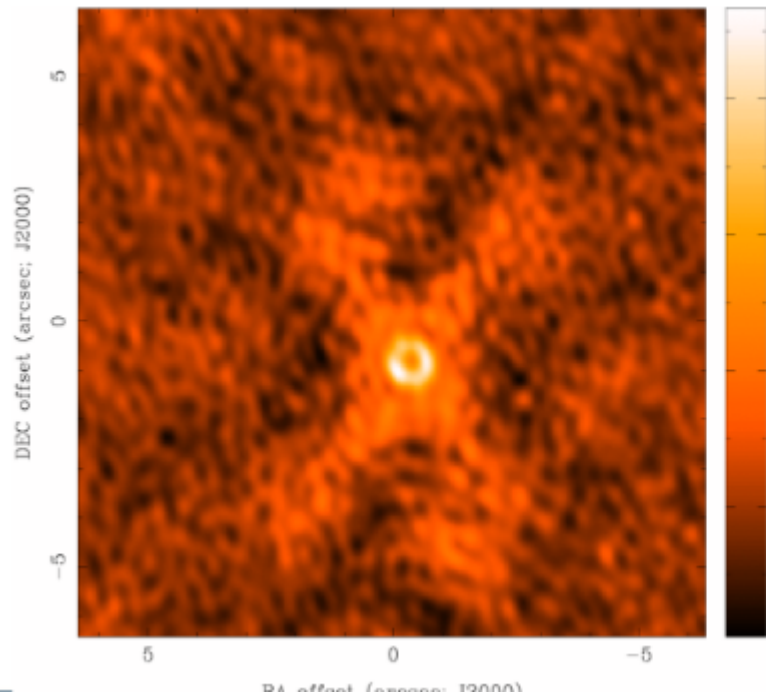
Deconvolution

$$R(\mathbf{B}) = \iint_{\Omega} A(\mathbf{s}) I_{\nu}(\mathbf{s}) \exp \left[i 2\pi \nu \left(\frac{1}{c} \mathbf{B} \cdot \mathbf{s} \right) \right] d\Omega d\nu$$

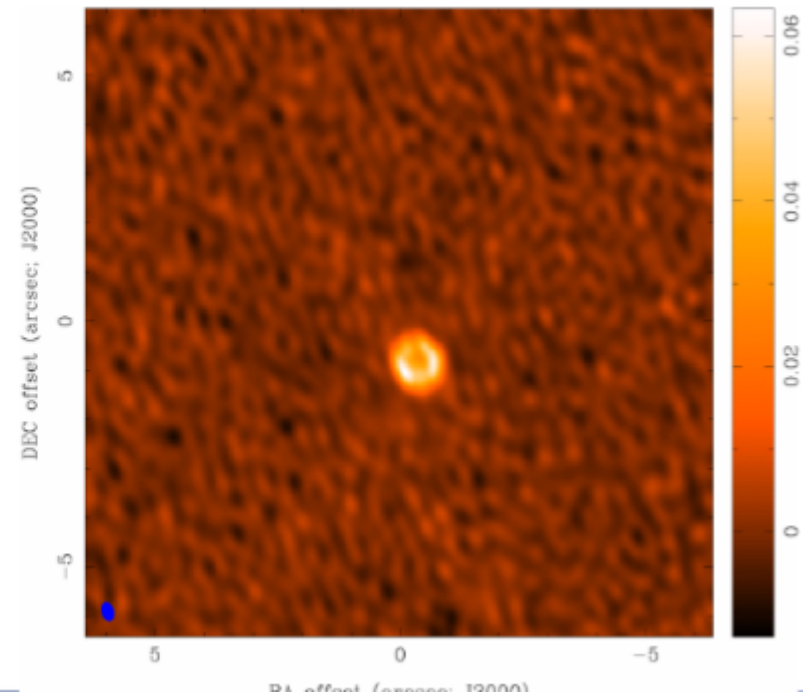
- Aims to find a sensible model of $I(\mathbf{s})$ compatible with data without sidelobes
- Uses non-linear techniques to interpolate/extrapolate samples of $R(u,v)$ into unsampled regions of the (u,v) plane
- Requires knowledge of beam shape $A(\mathbf{s})$ and a priori assumptions about $I(\mathbf{s})$

One of the most common algorithms in radio astronomy is the algorithm CLEAN (Hogbom 1974)

Dirty
Image



Cleaned
Image



The Atacama Large Millimeter Array

ALMA rationale

- The Atacama Large Millimeter Array is a **mm-submm reconfigurable interferometer**
- Inaugurated March 2013 on the Chajnantor plain (**5000m**, Chile)
- **The design of ALMA is driven by three key science goals:**

- The ability to detect spectral line emission from CO or [CII] in a normal galaxy like the Milky Way at a redshift of $z=3$, in less than 24 hours,

- > frequency bands, high sensitivity
- > study of star formation in galaxies up to high redshift, galaxy formation, Lensing, ...

- The ability to image the gas kinematics in protostars and in protoplanetary disks around young Sun-like stars in the nearest molecular clouds (150 pc),

- > high and low angular resolution, high spectral resolution
- > study of processes of star and planet formation, stellar evolution and structure, astrochemistry, ...

- The ability to provide precise high dynamic range ($=|\text{image max}/\text{image min}|$) images at an angular resolution of 0.1 arcsec.

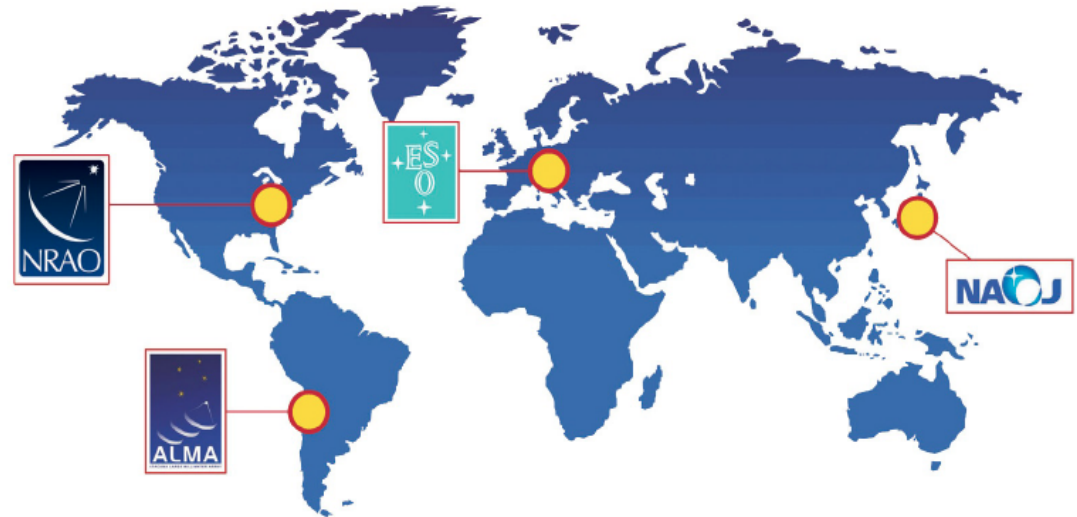
- > high angular resolution and sensitivity
- > galaxy dynamics, AGN core mechanisms, imaging of exoplanets, comets, asteroids, ...

ALMA organization

World wide collaboration

- Europe: **ESO** (14 countries)
- North America: **NRAO** (USA, Canada)
- East Asia: **NAOJ** (Japan, Taiwan)
- Chile

Contributors share the observing time

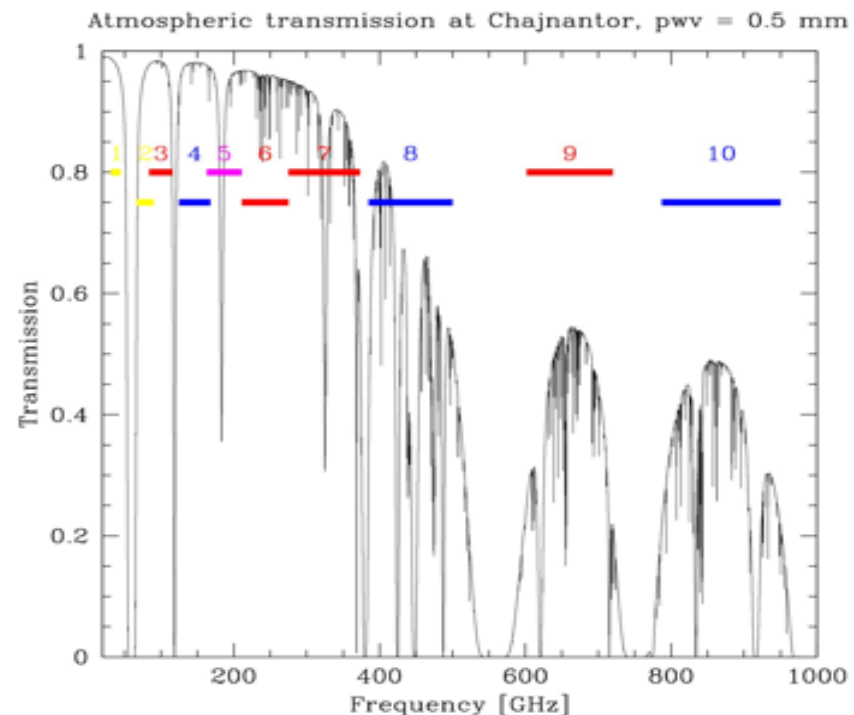


3 Sites in Chile

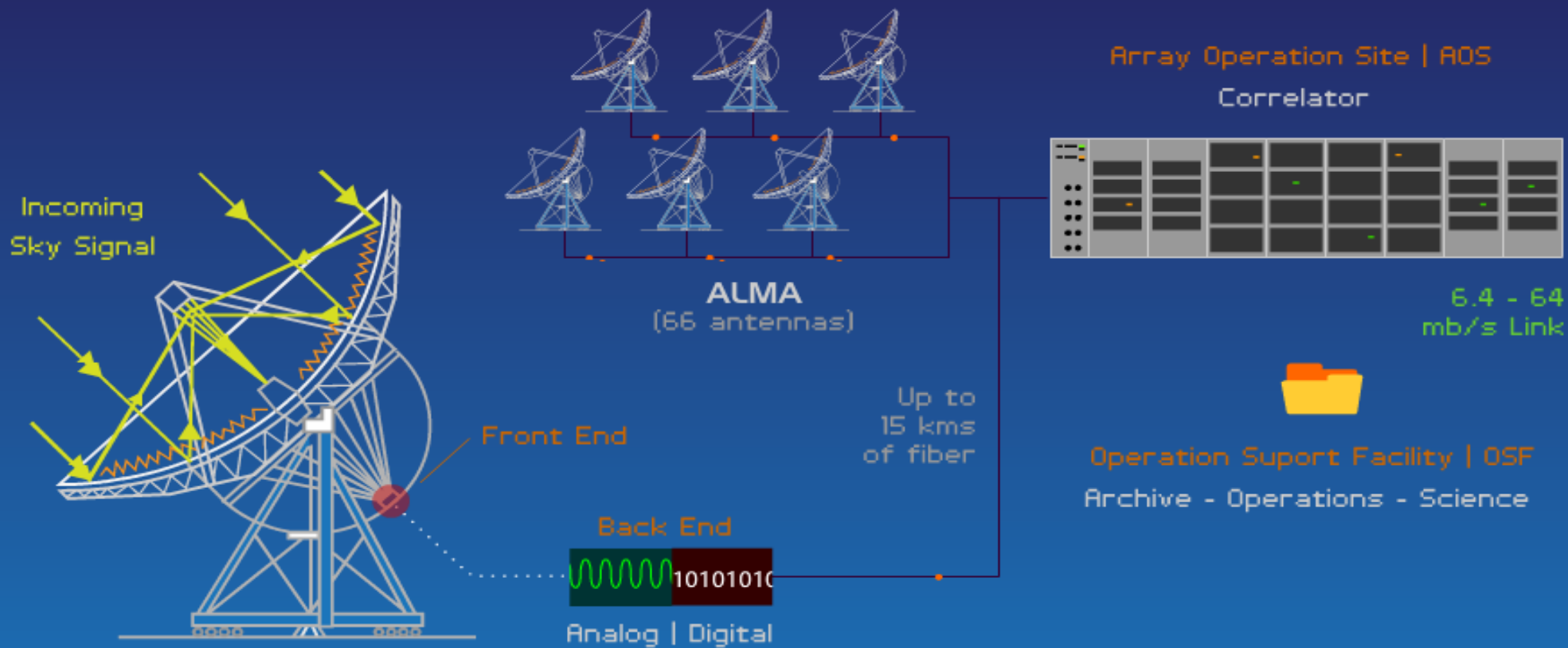
- **AOS**: ALMA Operations Site (5000m): Antennas, Correlator
- **OSF**: Operations Support Facility (3000m):
Labs, Antenna Assembly & Maintenance Operators, Astronomers
- **SCO**: Santiago Central Office:
 - Call for Proposals
 - Running ALMA
 - Data Reduction Pipeline
 - Quality Assessment



ALMA sites

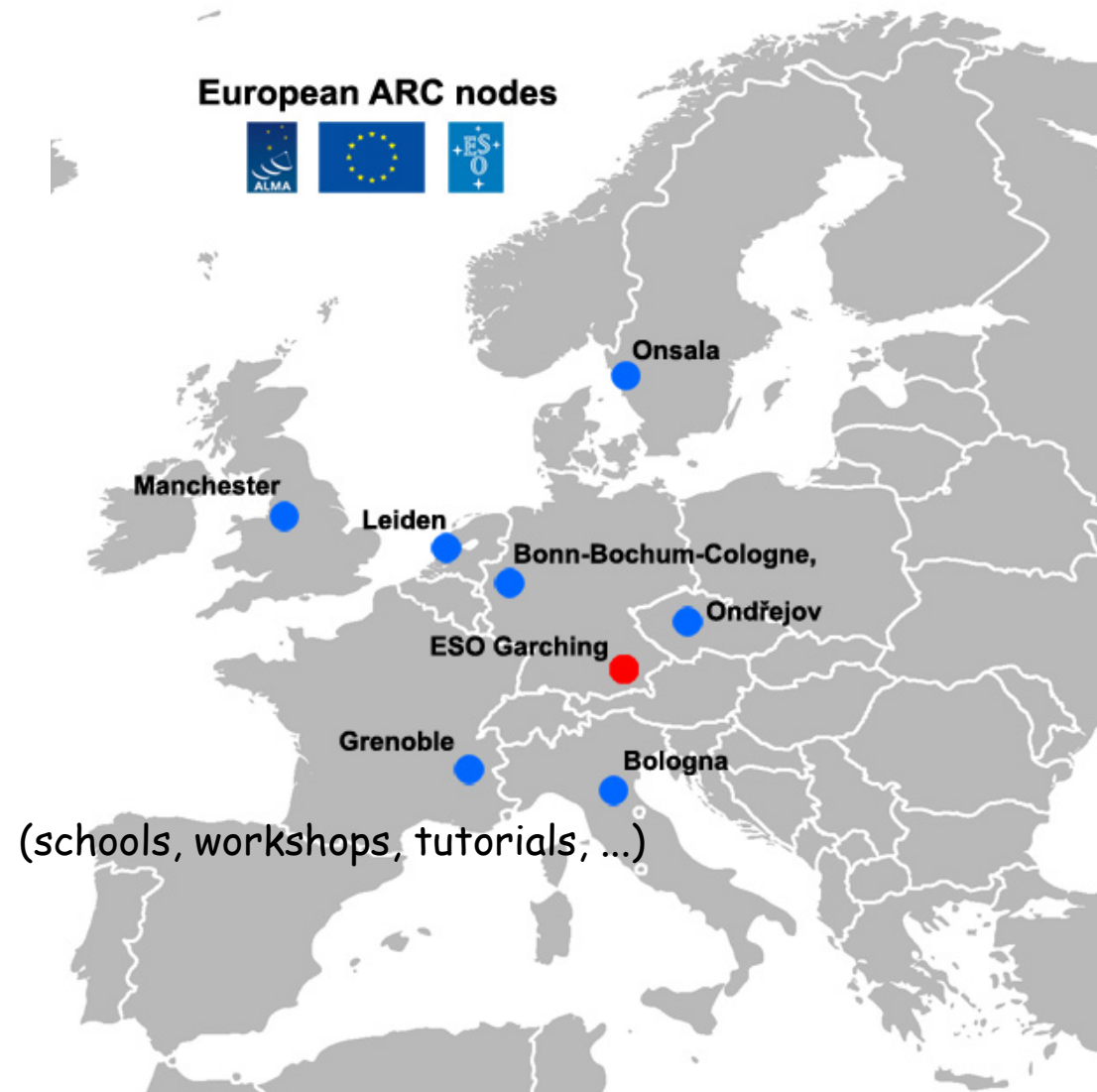


ALMA data flow



The ALMA Regional Centres (ARCs)

- **Interface between JAO and users**
- 1 ARC per Partner:
 - NRAO for North America
 - NAOJ for East Asia
 - **ESO for Europe (split in 7 nodes)**
- Operation support
 - Archive replication
 - Astronomer on duty
 - Software tools
- User support
 - Community formation and outreach
 - Phase 1 (proposal preparation)
 - Phase 2 (scheduling block preparation)
 - Data analysis, Archive mining
 - F2F user support, Helpdesk



Enter the ALMA world through the ALMA Science Portal

<http://almascience.eso.org/>

The screenshot shows the ALMA Science Portal homepage. The header features the ALMA logo and the text "Atacama Large Millimeter/submillimeter Array" and "In search of our Cosmic Origins". A navigation bar includes links for ESO, NRAO, and NAOJ. A search bar is located on the right. A red circle highlights the "Log in | Register | Reset Password | Forgot Account" links. A red text overlay states "All PI and CoI must be registered". The main content area has a banner image of ALMA antennas with a red text overlay: "Current call Tools and info". Below this, another red text overlay reads: "All the documents and tools Cycle 2 primer, Proposer Guide, OT Guide". A red circle highlights the "Proposing" link in the left sidebar. Another red circle highlights the "Documents & Tools" link. A third red circle highlights the "Helpdesk" link under "User Services at ARCs". The right sidebar contains a "General News" section with several news items.

Atacama Large Millimeter/submillimeter Array
In search of our Cosmic Origins

ESO NRAO NAOJ

Search Site

Log in | Register | Reset Password | Forgot Account

You are here: Home

Welcome to the Science Portal at JAO

Current call Tools and info

All the documents and tools
Cycle 2 primer, Proposer Guide, OT Guide

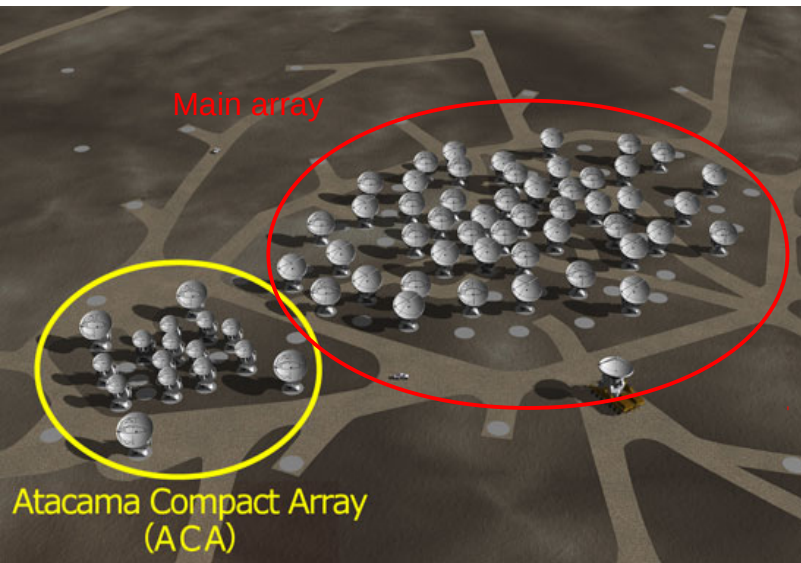
from one of the **ALMA Regional Centers (ARCs)** of the ALMA partner organizations, ESO, NRAO or NAOJ. You may switch between the different instances of the portal through the links to the appropriate ALMA partner at the top banner. Through this portal you can find details about the technical capabilities of ALMA, how to propose for observing time, and how to access ALMA data. It includes links to all official

General News

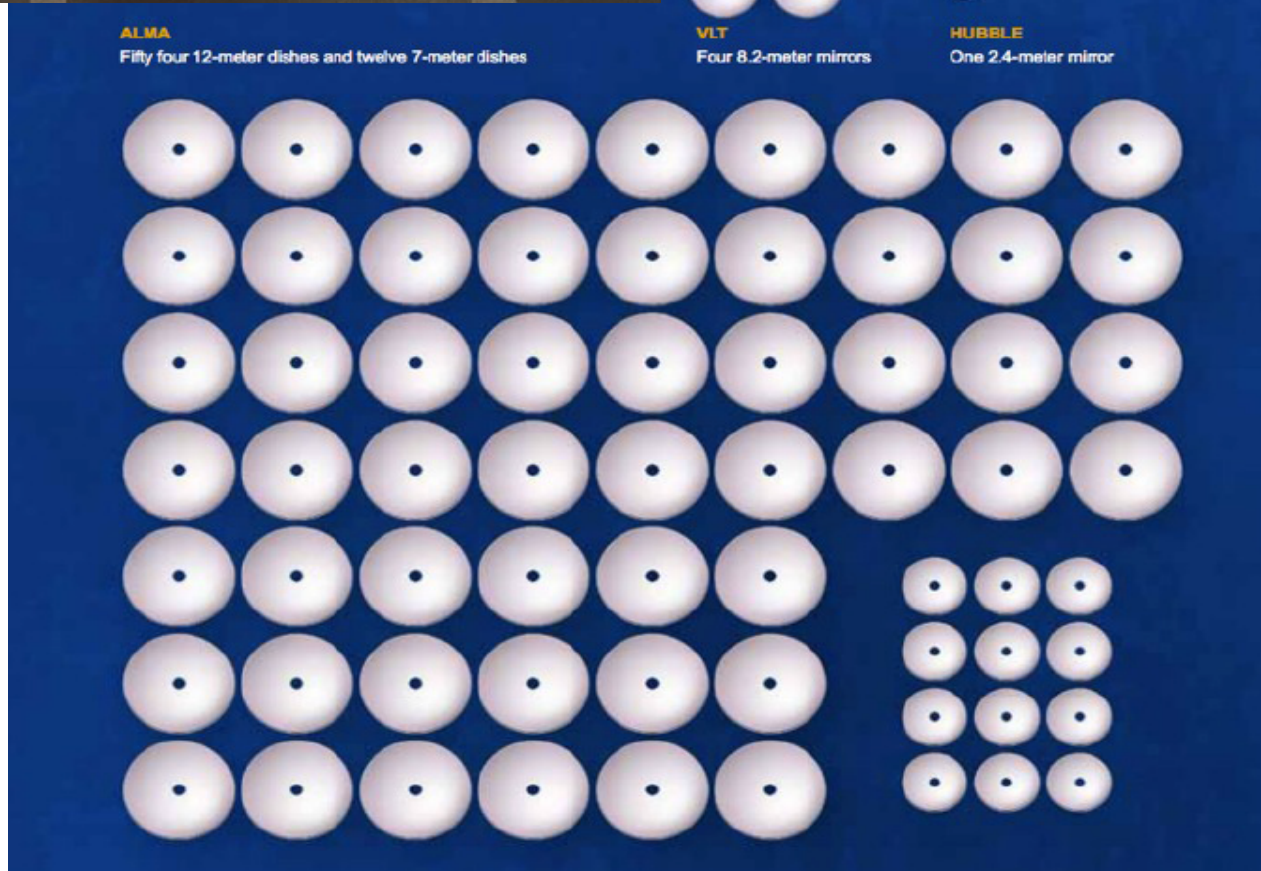
- ALMA Cycle 2 Call for Proposals is now open
Oct 19, 2013
- Cycle 1 Update and Transfer to Cycle 2
Oct 07, 2013
- ALMA Cycle 2 Pre-announcement
Sep 17, 2013
- ALMA Cycle 1 Status Update
Sep 10, 2013
- ALMA Cycle 0 final report
Jun 19, 2013

Access to Helpdesk for any request (FAQ, problems, F2F...)

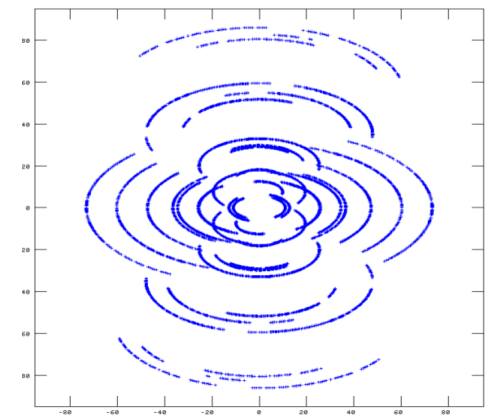
ALMA array(s)



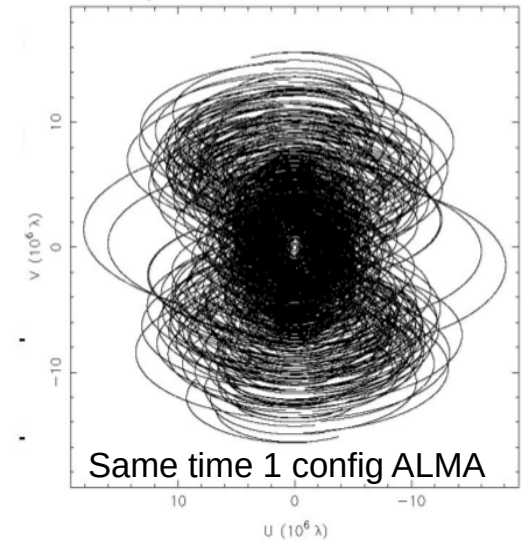
Antennas : **50x12m** main array + **(12x7m + 4x12m TP)** ACA
 Baselines : **15m ->150m-16km** + **9m->50m**



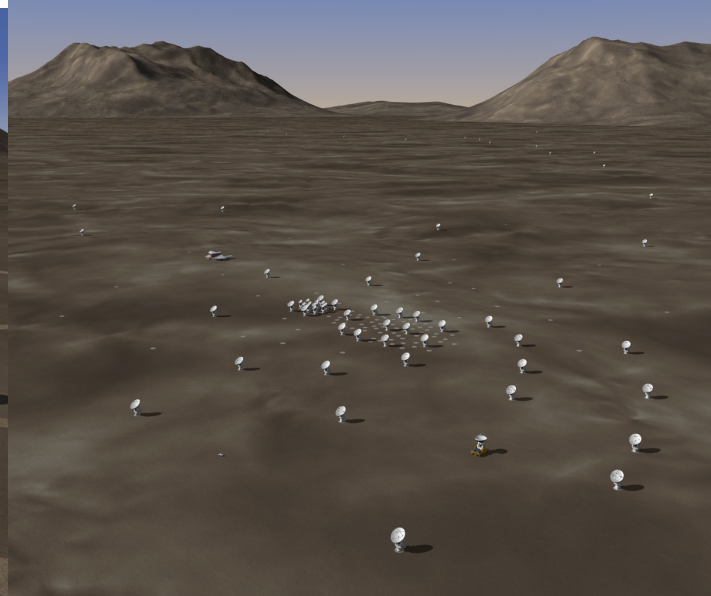
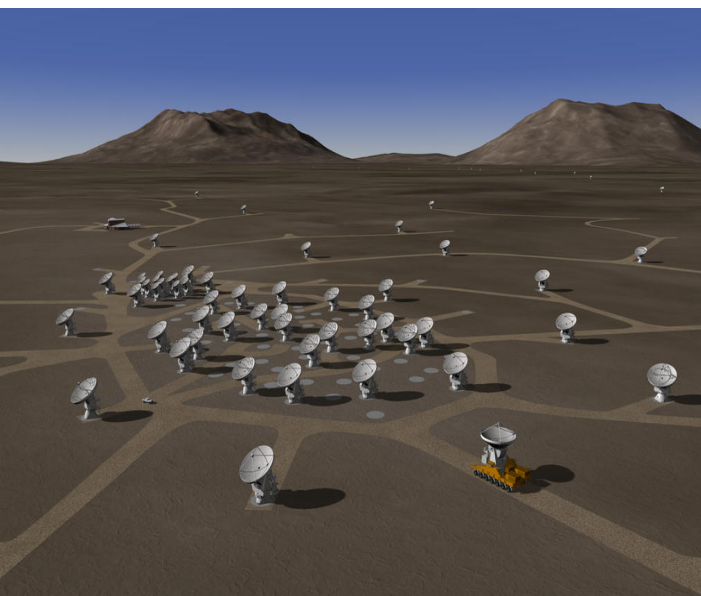
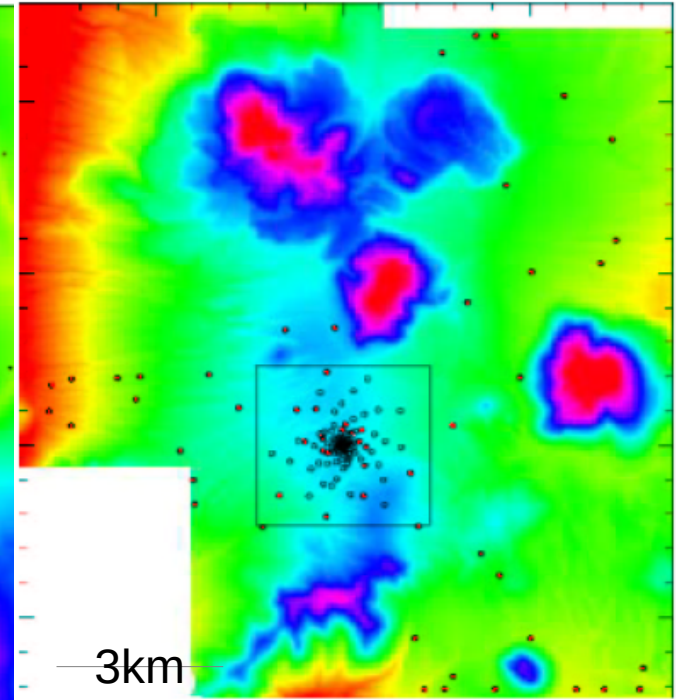
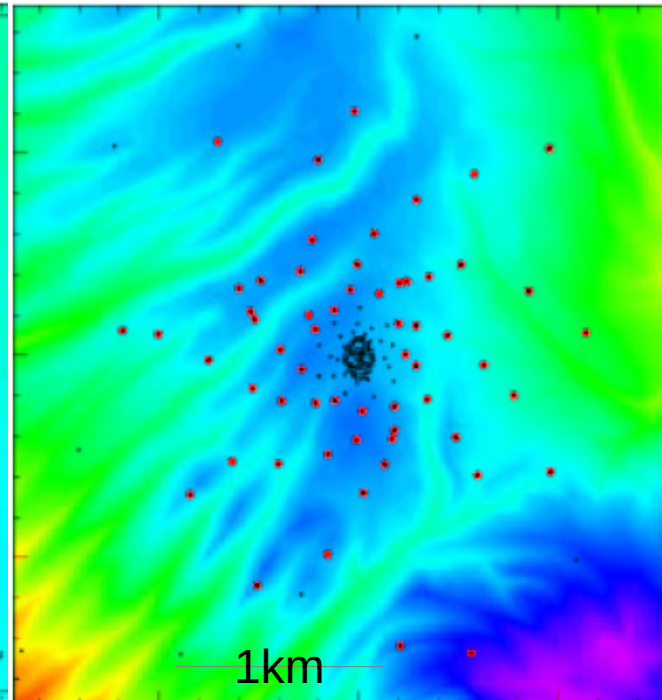
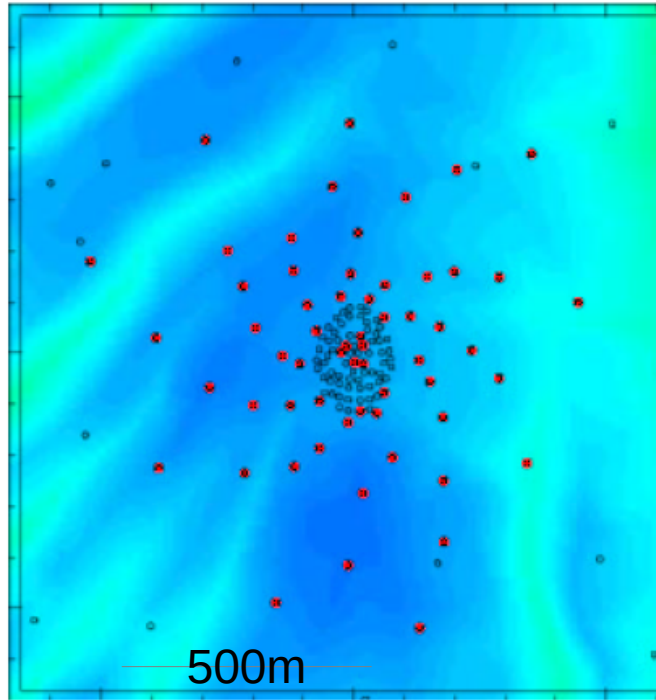
Few hr 2 config OVRO



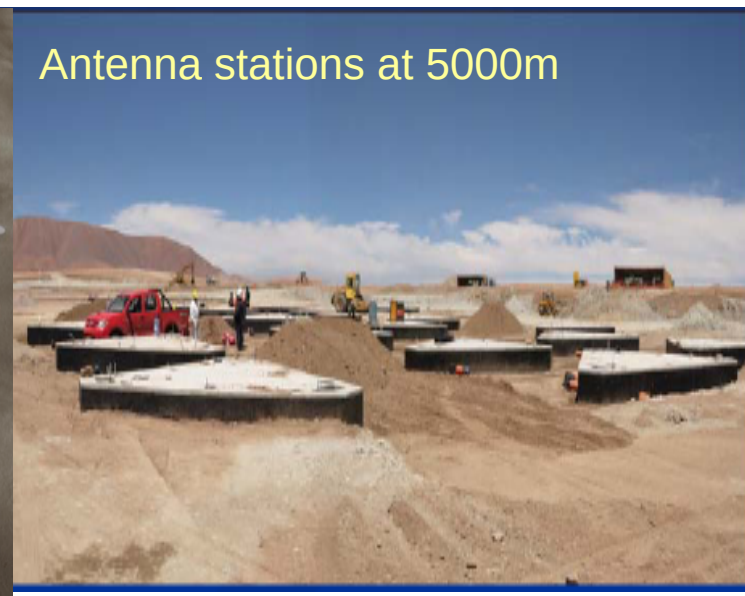
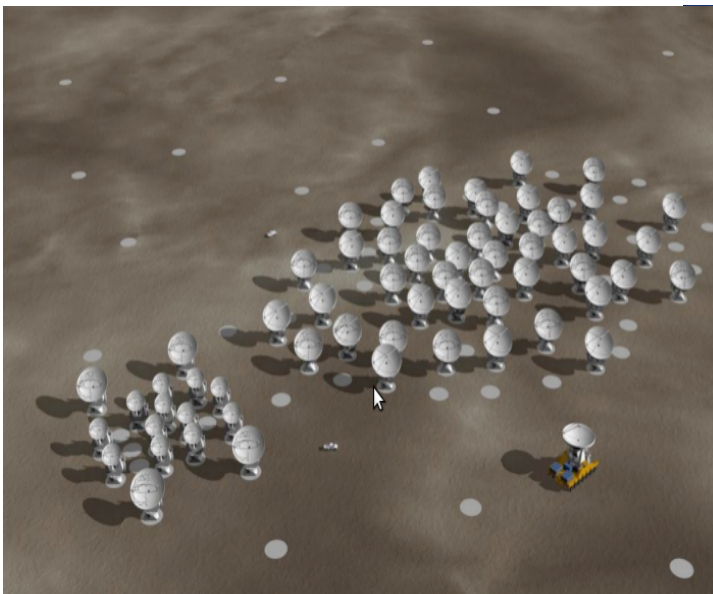
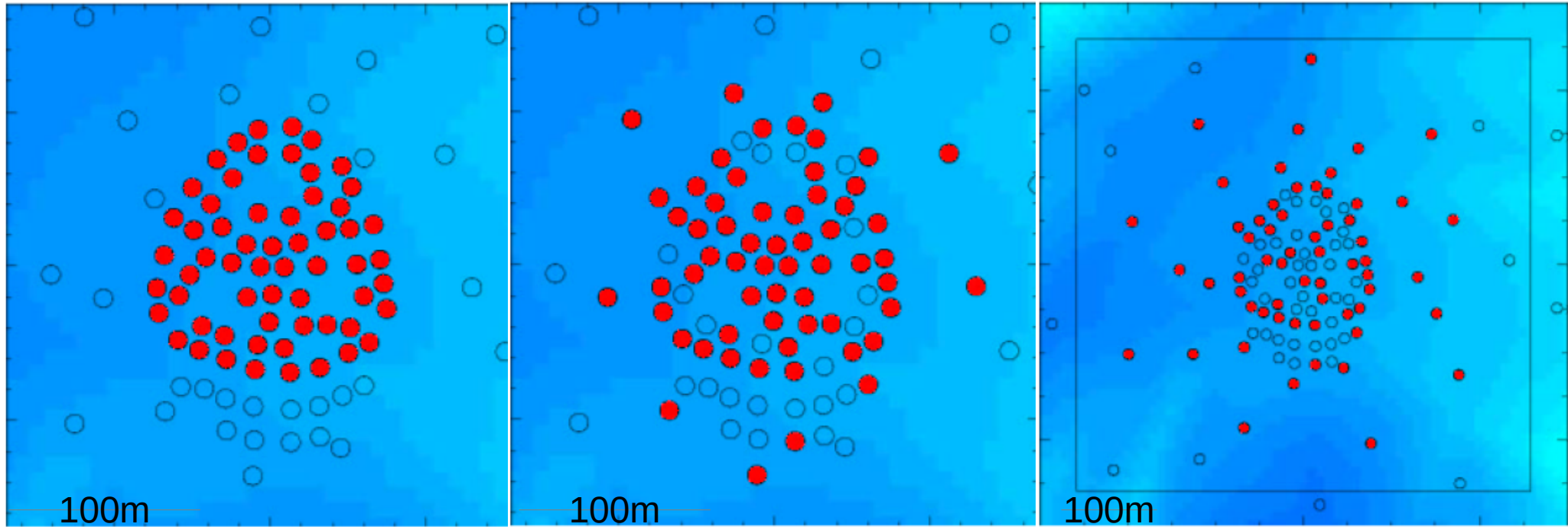
900GHz_50pc_ws_8 at 896.000 GHz in XX 2012 Jun 21



ALMA reconfiguration

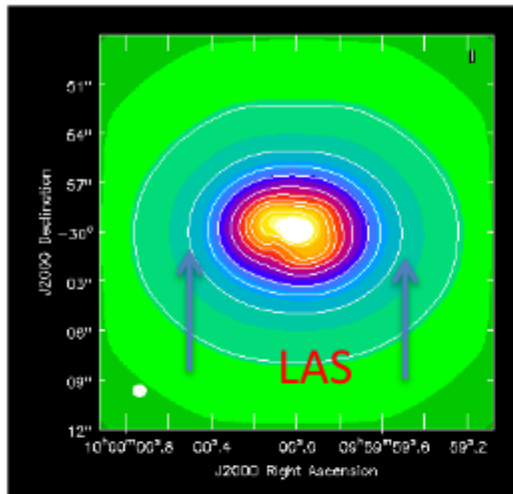


ALMA reconfiguration



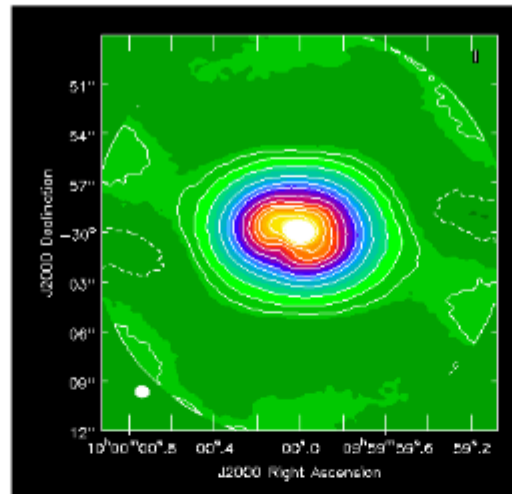
ALMA array(s)

MODEL



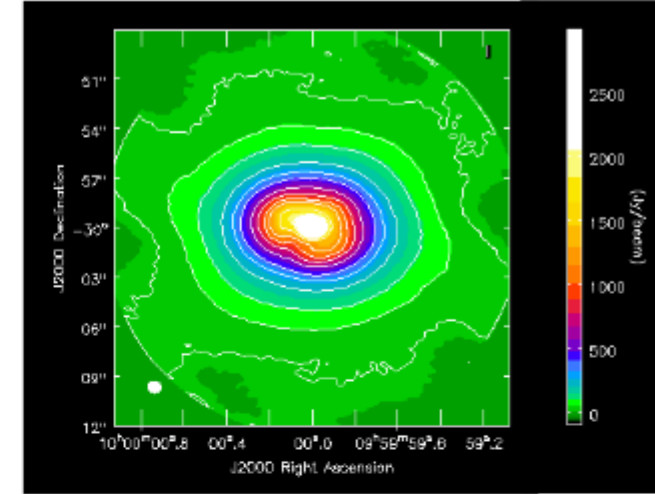
Restored flux 11000 Jy

12-m image



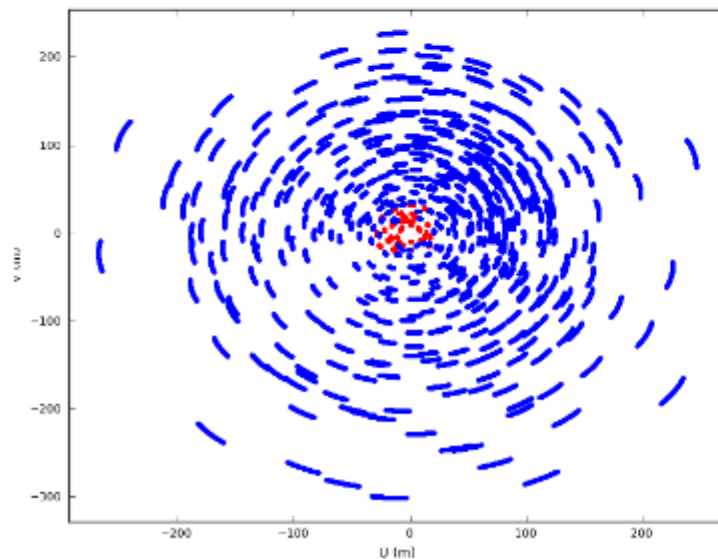
7000 Jy

12m+7m Image



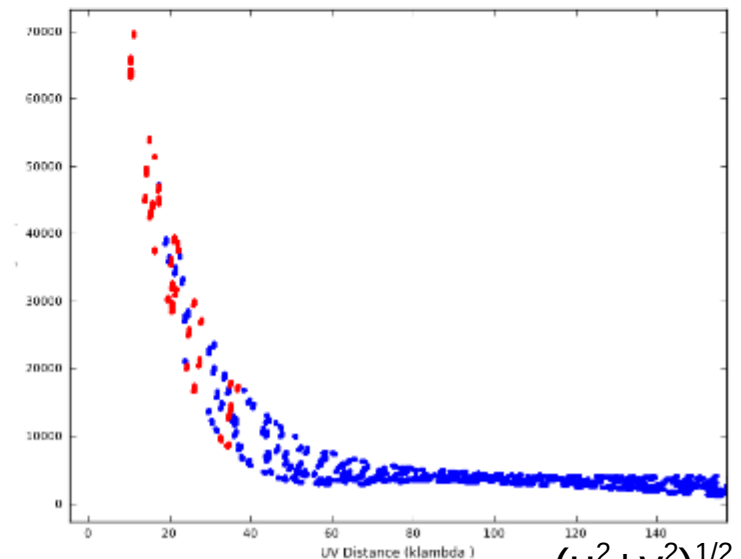
9000 Jy

Primary beam corrected: 20% cutoff: Contours: -20,20,50,100,200,300,400,600,800,1000,1200,1600,2000



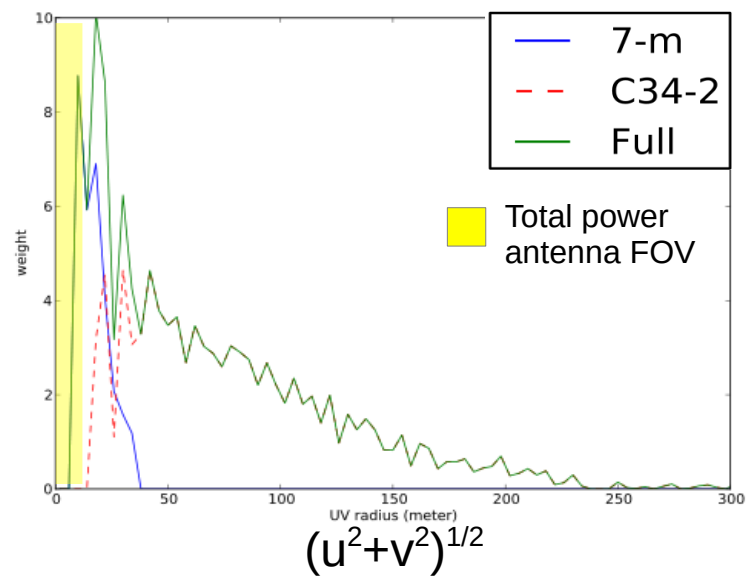
U-V coverage

(red=ACA, blue=ALMA12m)

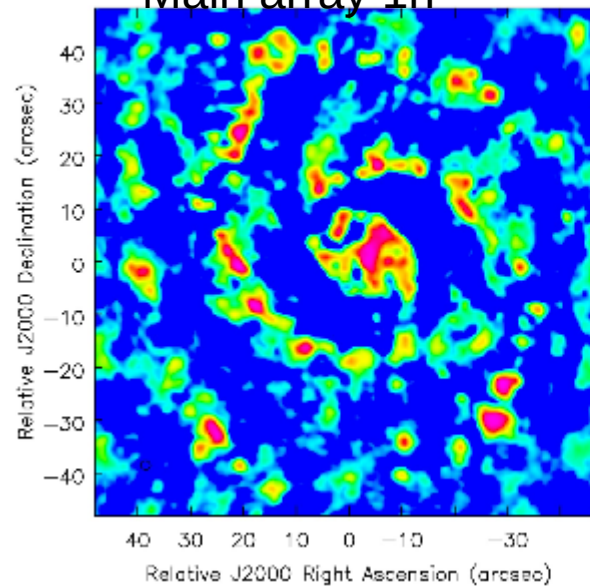


Amplitude vs uv-distance

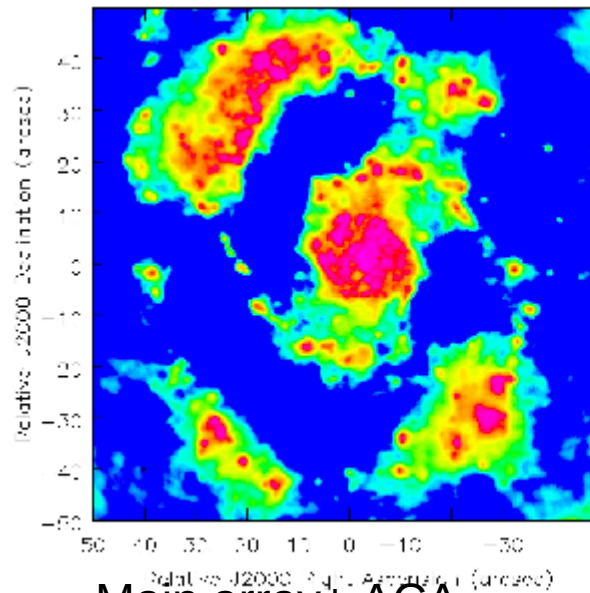
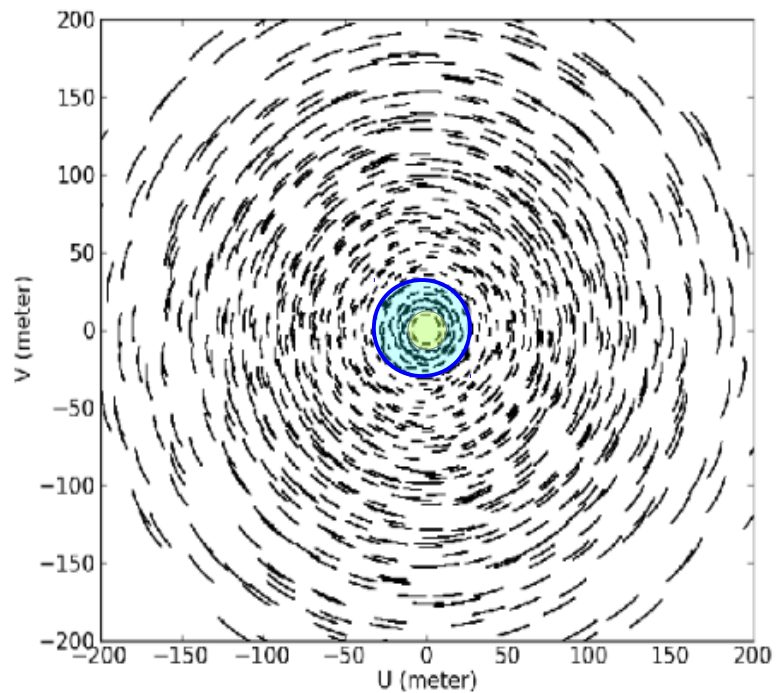
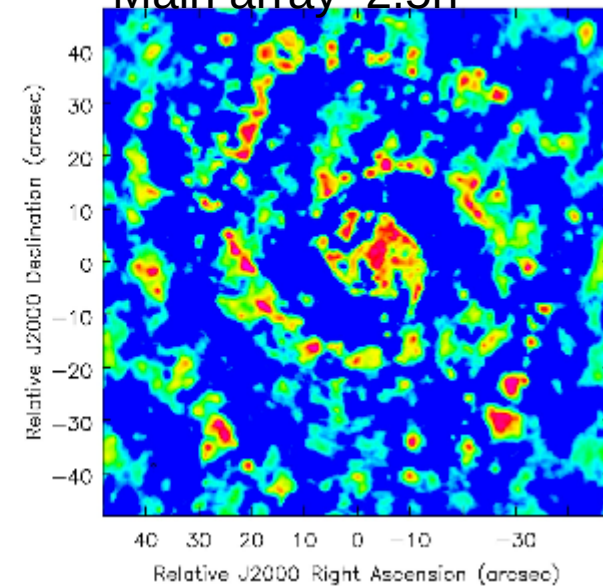
ALMA array(s)



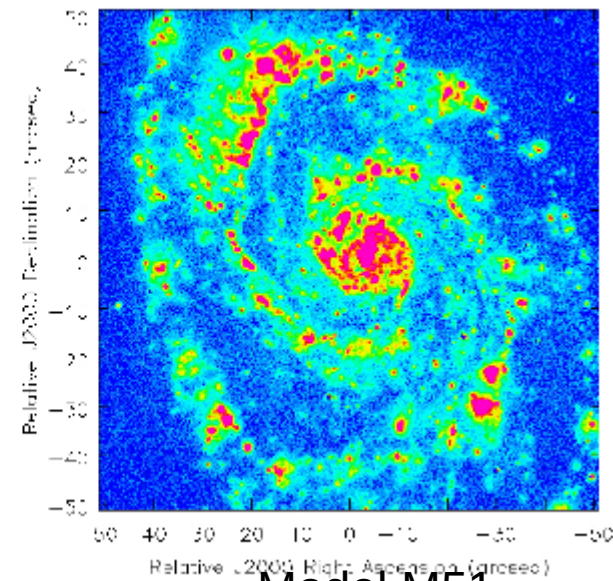
Main array 1h



Main array 2.5h



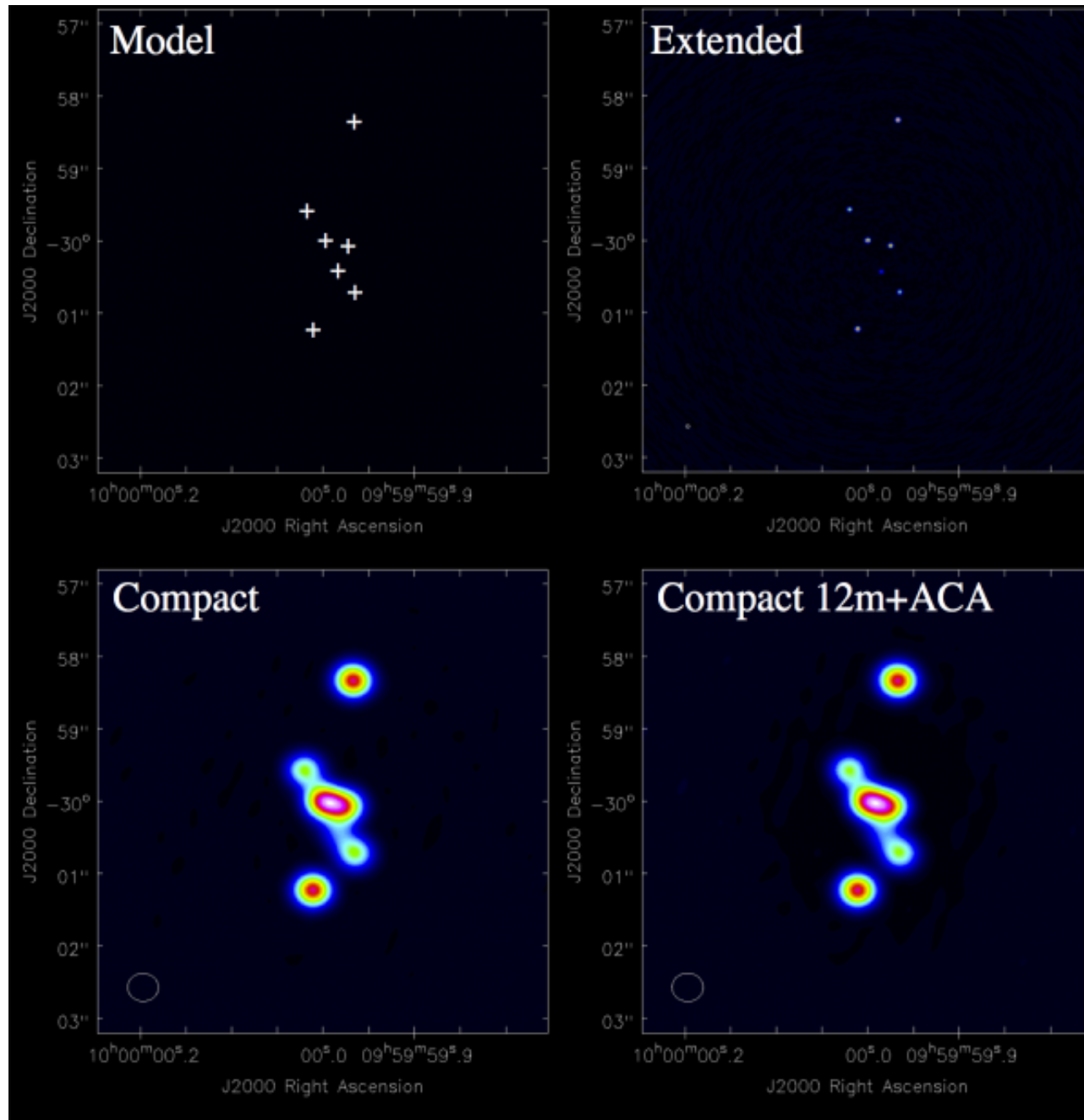
Main array+ ACA



Model M51

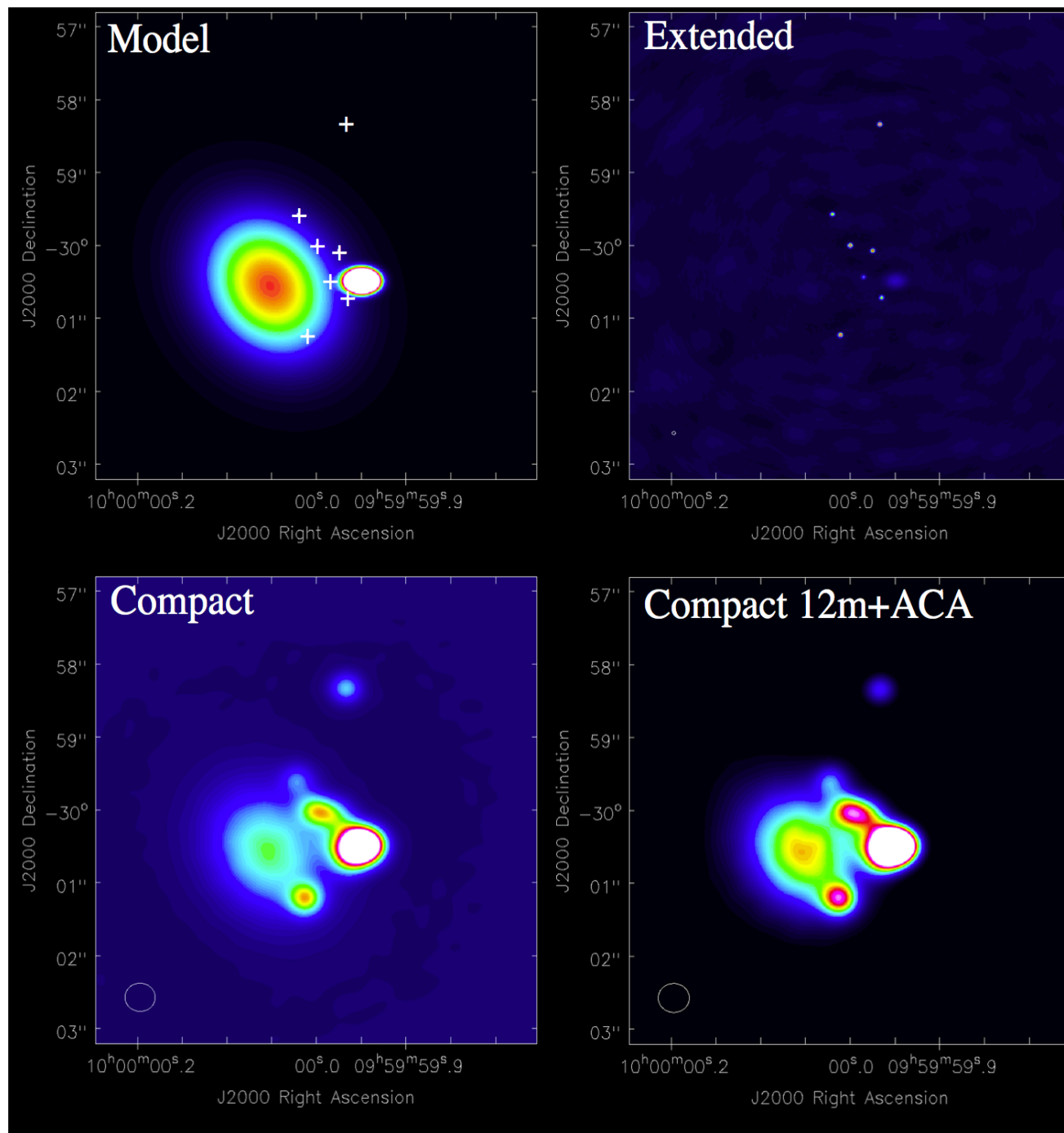
ALMA array(s)

Main array
for compact
objects



ALMA array(s)

ACA
for extended
objects



Make your ALMA simulations (Observation Support Tool)

<http://almaost.jb.man.ac.uk/>



Submit a request for a full simulation of ALMA capabilities for your target
Receive the results via e-mail

Array	Instrument	ALMA	Queue Status • Help
Sky Setup	Source model	OST Library: Central point source	Choose a library source model or
	Upload a FITS file	Browse...	You may upload your own model
	Declination	-35d00m00.0s	Ensure correct formatting of this s
	Image peak / point flux in mJy	0.0	Set to 0.0 for no rescaling of sour
Observation Setup	Central frequency in GHz	90	The value entered must be within
	Bandwidth in MHz	32	Use broad for continuum, narrow
	Required resolution in arcseconds	1.0	OST will choose config if instrumen
	Pointing strategy	Single	Selecting single will apply primary
	Start hour angle	0.0	Deviation of start of observation f
	On-source time in hours	3	Maximum duration is 24 hours
	Number of visits	1	How many times the observation i
	Number of polarizations	2	This affects the noise in the final n
Corruption	Atmospheric conditions	Good (PWV = 0.5 mm)	Determines level of noise due to v
Imaging	Imaging weights	Natural	This allows a resolution / sensitiv
	Perform deconvolution?	No (Return dirty image)	Apply the CLEAN algorithm to deconv



EUROPEAN ARC
ALMA Regional Centre || UK

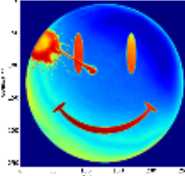
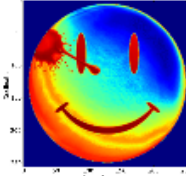


ALMA Observation Support Tool

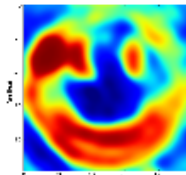
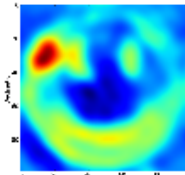
Job ID: 20110330175645 / Submitted by: casasola@ira.inaf.it

Overview

Click thumbnails to view full-size images. Left: linear colour scale, right: with histogram equalization.

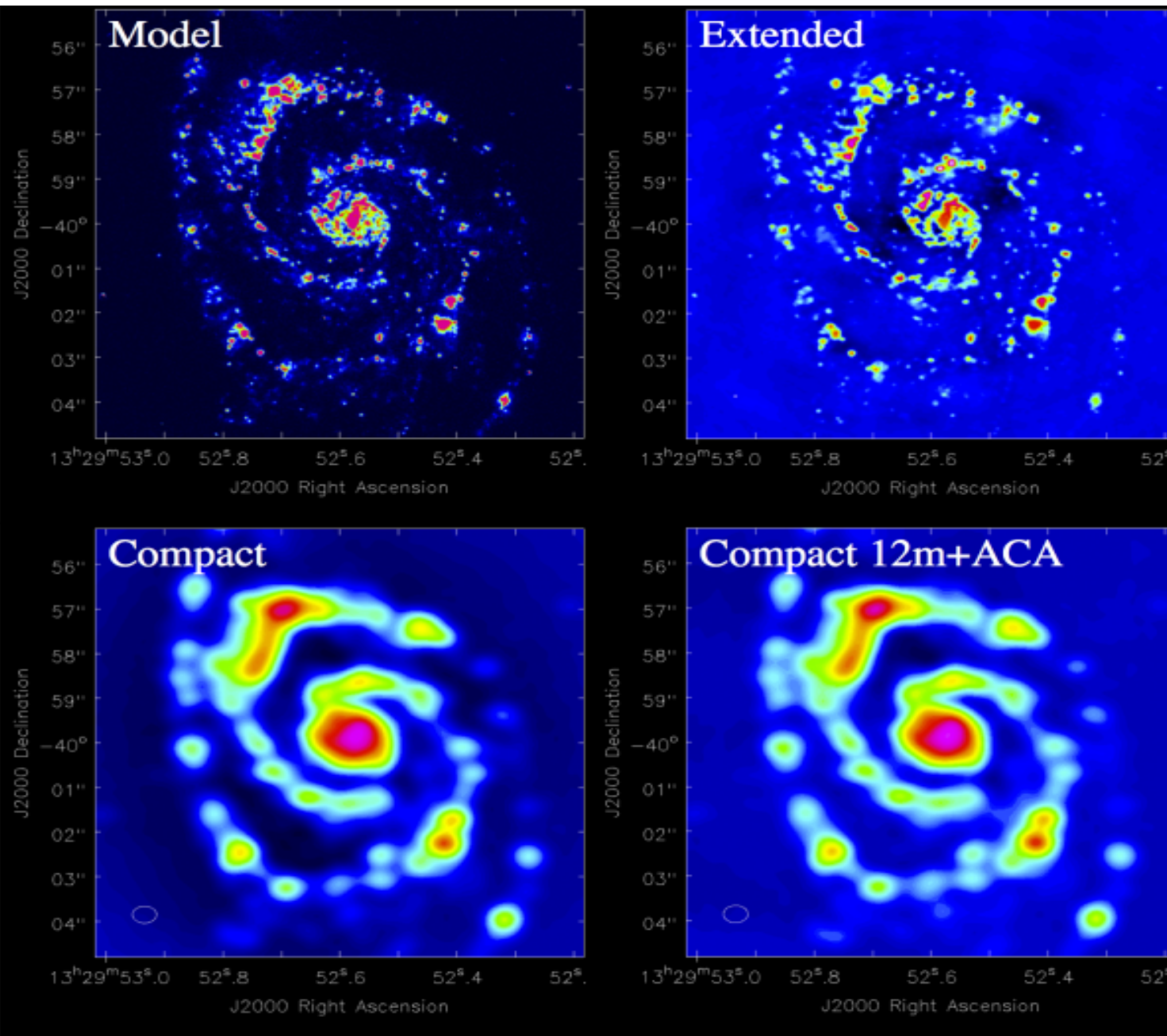
Array configuration	Early Science ALMA (Compact Cycle 0, 125 m baseline)
Source model	All we ever see of stars are their old photographs
	 
Maximum elevation	77.88 degrees
Central frequency	90 GHz = Band 3
Bandwidth	0.032 GHz
Track length	3 hours x 1.0 visits
System temperature	Tsys = Trec + Tsky = 37.0 + 4.42 = 44.15 K
PWV	0.5 mm
Theoretical RMS noise	0.000103323597098 Jy (in naturally-weighted map)
Restoring beam (resolution)	Major axis = 6.229 arcsec, minor axis = 5.176 arcsec, PA = 55.607 deg

Data products



Your simulated image
[Download FITS file](#)

Make your ALMA simulations (CASA simalma, simobserve, and simanalyze)



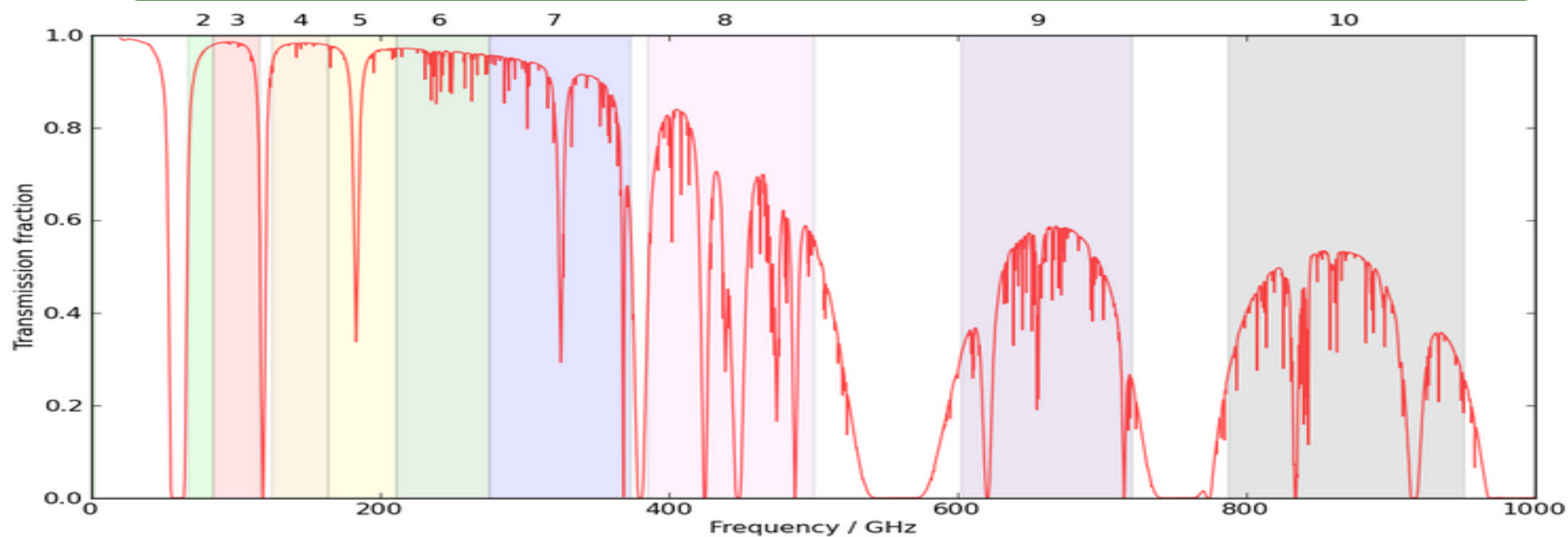
The task **simobserve** generates a data set with simulated visibilities based on an input model image.

The task **simanalyze** produces a cleaned image based on the simulated visibilities, and it generates some diagnostic images.

CASA also provides the task **simalma** that simplifies the steps needed to simulate ALMA observations that combine data from multiple arrays or multiple configurations.

ALMA bands

<i>Full Science Capabilities</i>					Most Compact		Most Extended	
Band	Frequency (GHz)	Wavelength (mm)	Primary Beam (FOV _{1/2} ")	Continuum Sensitivity (mJy/beam)	Angular Resolution (")	Spectral Sensitivity ΔT_{line} (K)	Angular Resolution (")	Spectral Sensitivity ΔT_{line} (K)
1	31.3-45	6.7-9.5	197-137	0.04	13-9	0.006	0.12-0.08	255
2	67-90	3.3-4.5	92-69	0.06	6-4.4	0.009	0.06-0.04	413
3	84-116	2.6-3.6	73-53	0.07	4.8-3.4	0.04	0.045-0.032	430
4	125-163	1.8-2.4	49-38	0.06	3.2-2.4	0.048	0.030-0.023	330
5	163-211	1.4-1.8	38-29	0.11	2.5-1.9	0.06	0.027-0.021	641
6	211-275	1.1-1.4	29-22	0.085	1.9-1.5	0.05	0.018-0.014	490
7	275-373	0.8-1.1	22-16	0.15	1.5-1.1	0.08	0.014-0.01	814
8	385-500	0.6-0.8	16-12	0.28	1.04-0.8	0.28	0.01-0.008	1900
9	602-720	0.4-0.5	10-8.6	1.1	0.66-0.55	0.9	0.006-0.005	8900
10	787-950	0.3-0.4	7.8-6.5	1.2	0.51-0.42	1.6	0.005-0.004	—



ALMA resolution

- Baselines length: **15m ->150m-16km + 9m->50m**
- Resolution: **$0.2'' \times (300/\text{freq_GHz}) \times (1\text{km}/\text{max_baseline})$**
- FOV 12m array: **$17''/(300/\text{freq_GHz})$**
- FOV 7m array: **$29''/(300/\text{freq_GHz})$**

Up to 16km baselines, subarcsec resolution

40 mas @ 100 GHz,

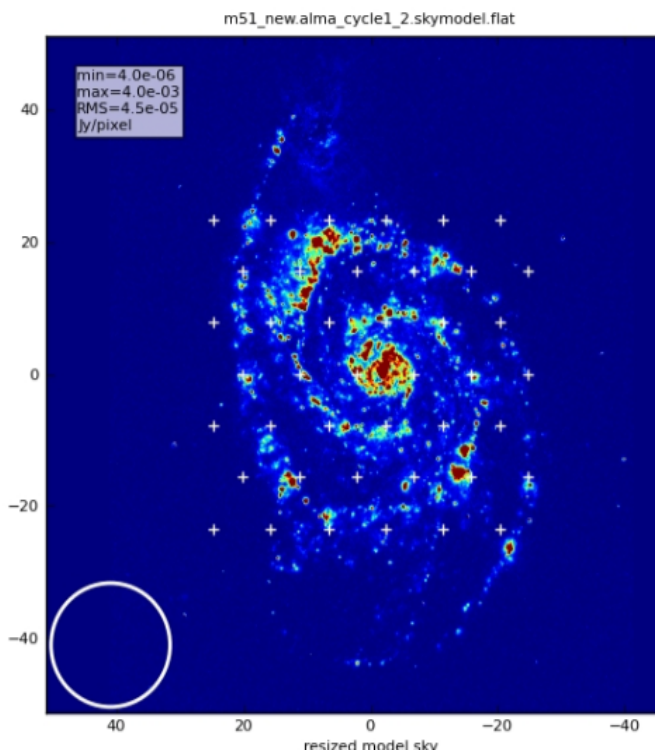
5 mas @ 900 GHz

$$\theta = k \lambda / D$$

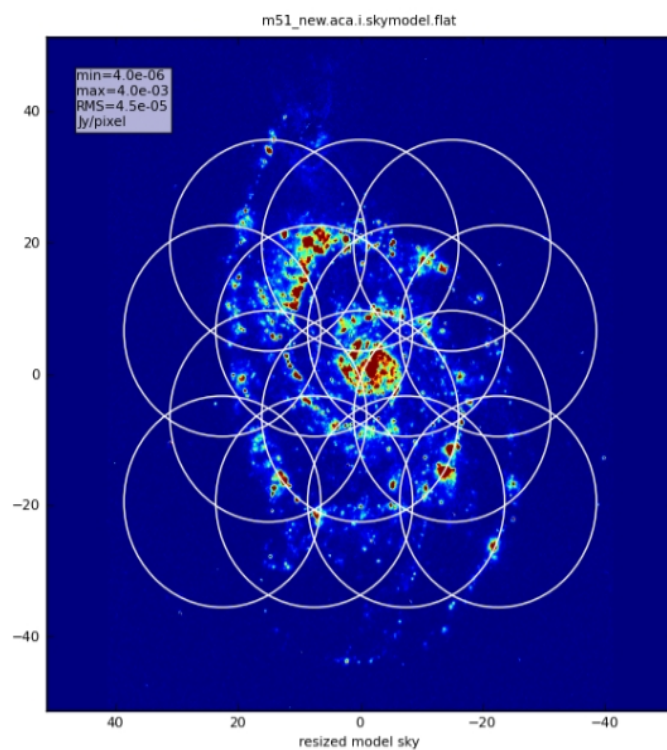
Mosaicking

Largest angular scales than that available to the shortest baseline cannot be observed.

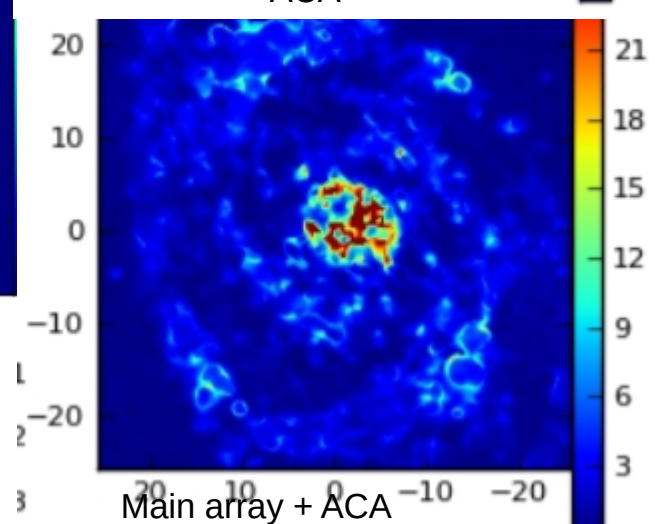
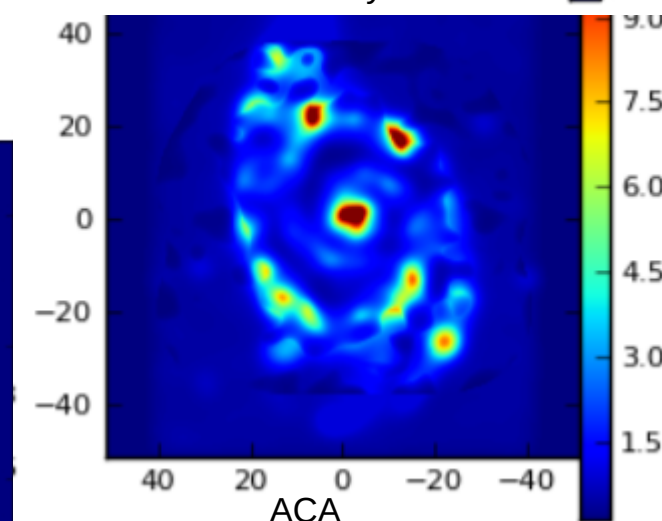
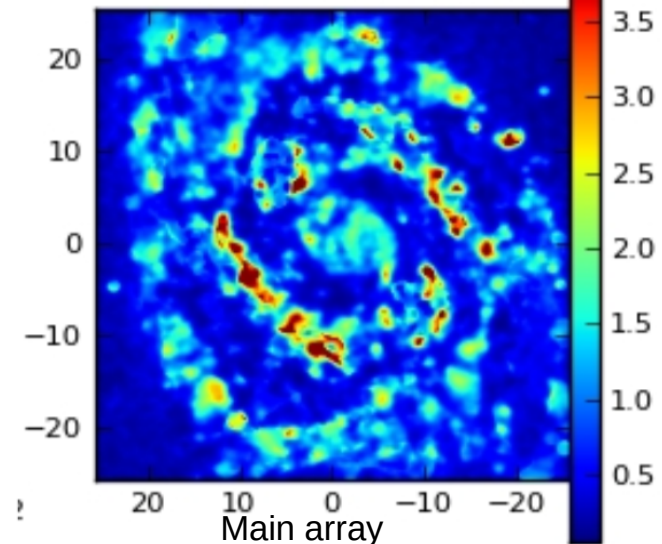
Details in the ranges available to the given baselines can be observed on larger region of the sky by mosaicking the region.



Model & 12m FOV



ACA Pointing map



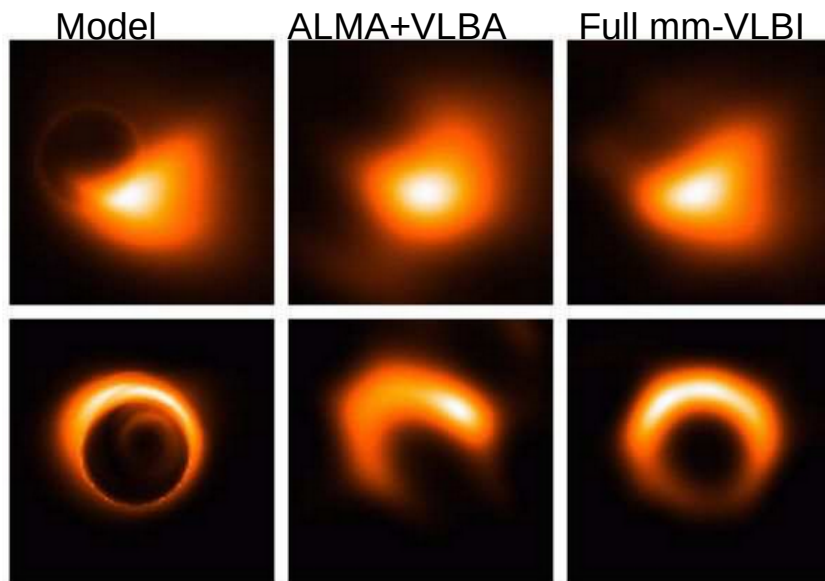
mm-VLBI with ALMA

Higher and higher resolutions can be obtained with longer baselines. **VLBI is a worldwide network of telescopes that matches simultaneous observations in different sites, exploiting the phase information to construct a world-wide interferometer.**

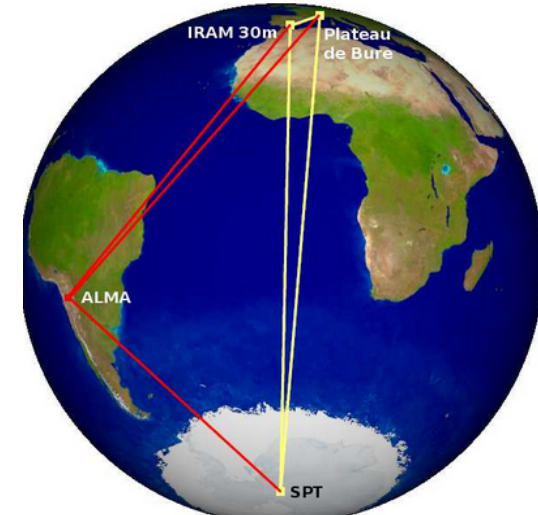
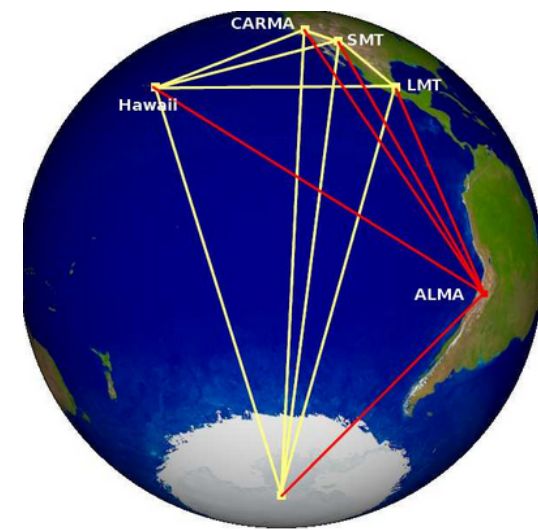
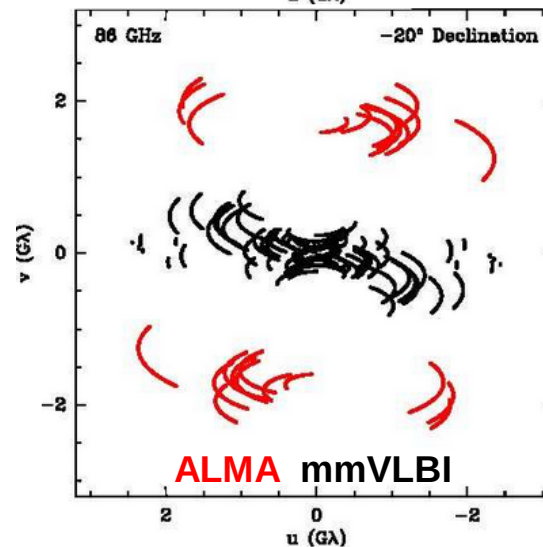
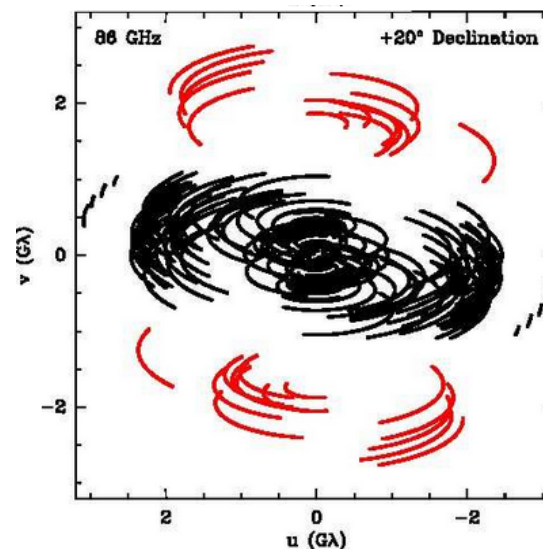
At 1 mm and a baseline of 9000 km offers resolution of about 20 microarcseconds

ALMA will be operating in the mm-VLBI since 2017 adding a strength in sensitivity. **Only sources with flux densities >100 mJy have been observable so far; ALMA will reduce it by more than an order of magnitude.**

This capability will allow the shadow of the event horizon in the black hole at the Galactic Centre, the relativistic jet flows in AGN and the dusty winds near stellar surfaces to be imaged



M87 models of different basis of the jet as observed by ALMA+CARMA+SMA+ SMT and by adding also PdBI



ALMA sensitivity

Dry site, low pwv, low T_{sys} , high sensitivity also at submm frequencies

>6500sqm of effective area and 1225 baselines for the 12m array

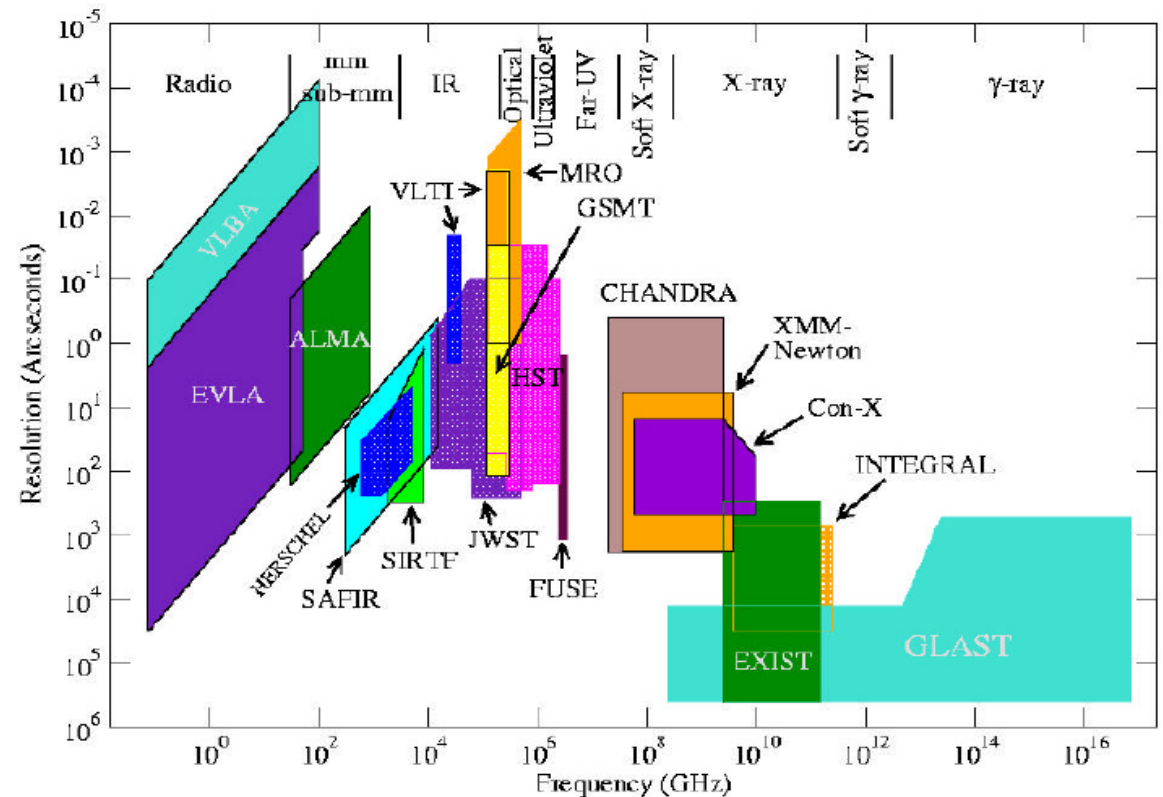
+ Short spacings with ACA

Excellent instantaneous uv coverage & high sensitivity

<0.05mJy @100 GHz in 1 hr

$$\Delta S_{\nu} = 2k \frac{T_{\text{sys}}}{A_e \sqrt{2t \Delta\nu}}$$

Receivers are couple of dipoles,
so split the signal into 2 polarizations
By combining the independent
polarizations chains it can reconstruct
all the Stokes parameters



The Science Goal: Sensitivity Calculator

<http://almascience.eso.org/call-for-proposals/sensitivity-calculator>

Common Parameters

Dec	00:00:00.000	
Polarization	Dual ▼	
Observing Frequency	345.00000	GHz ▼
Bandwidth per Polarization	0.00000	GHz ▼
Water Vapour Column Density	☒ Automatic Choice ☐ Manual Choice	
tau/Tsky	0.913mm (3rd Octile)	
Tsys	tau0=0.158, Tsky=39.538	
	157.027 K	

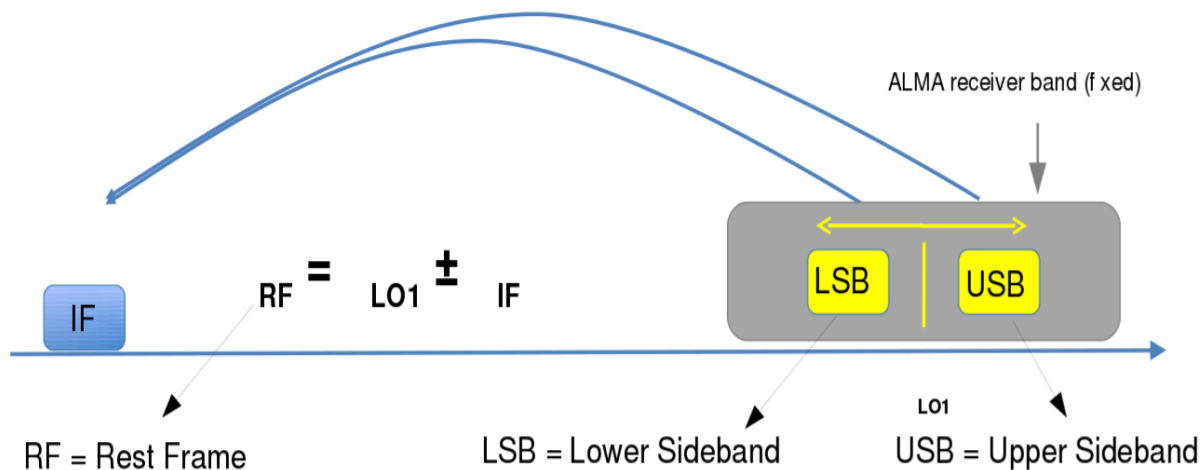
Individual Parameters

	12m Array		7m Array		Total Power Array	
Number of Antennas	34		9		2	
Resolution	0.00000	arcsec ▼	5.974554 arcsec		17.923662 arcsec	
Sensitivity(rms)	0.00000	Jy ▼	0.00000	Jy ▼	0.00000	Jy ▼
(equivalent to)	Infinity	K ▼	0.00000	K ▼	0.00000	K ▼
Integration Time	0.00000	s ▼	0.00000	s ▼	0.00000	s ▼
Integration Time Unit Option Automatic ▼						

Calculate Integration Time

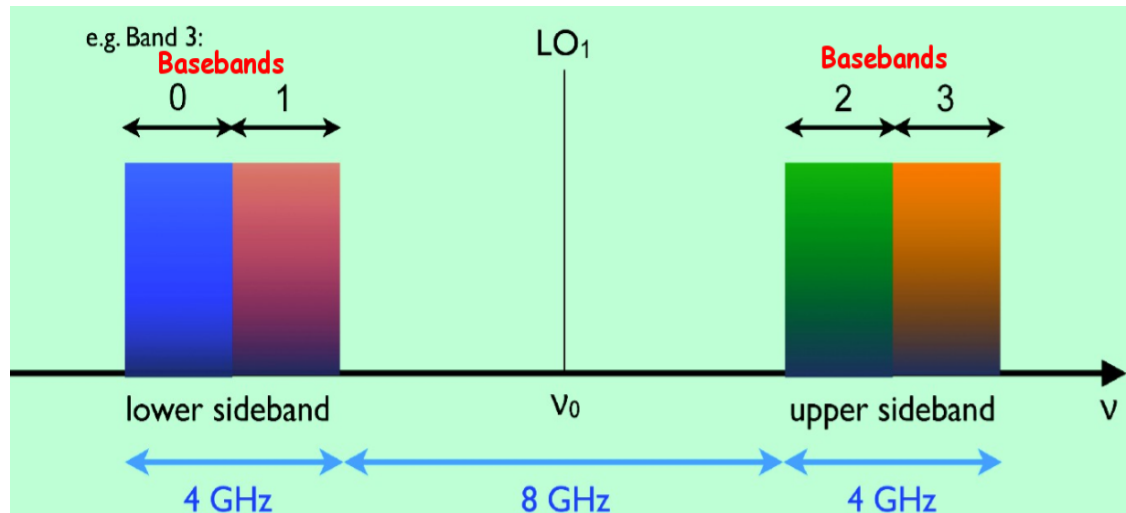
Calculate Sensitivity

ALMA spectral properties



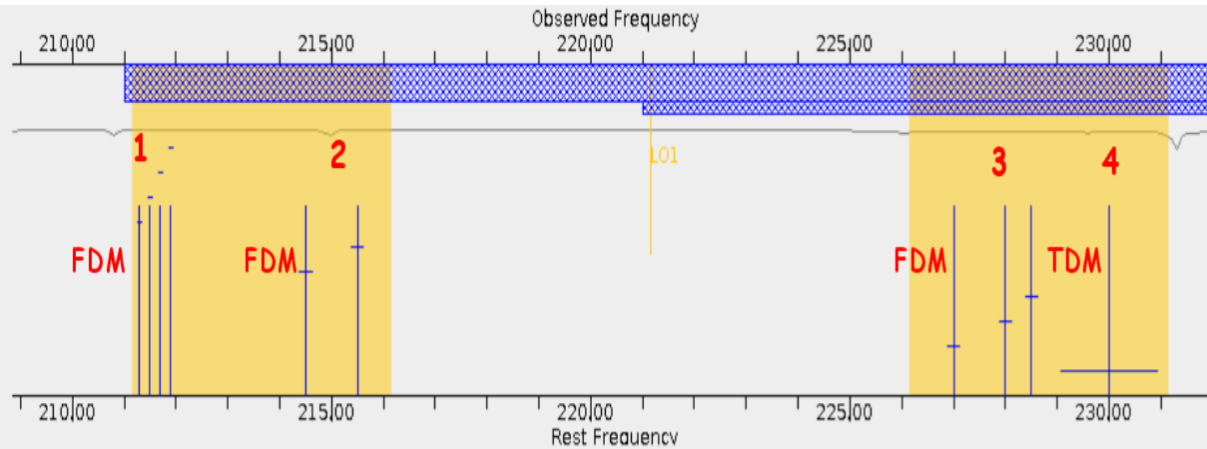
The coherent receivers map two frequency regions to an Intermediate Frequency by mixing the signal with a Local Oscillator.

The receivers allow up to **4 x 2 GHz-wide Basebands** that can be placed in one sideband or distributed between the 2 Sidebands.



A maximum available 8 GHz bandwidth is achieved when the 4 basebands are chosen not to overlap.

ALMA spectral properties



Each baseband may be divided into one or more spectral windows by allocating a fraction of the correlator resources to each window.

Resolution

Typical purposes:

Spectral scans

Targeted imaging of moderately narrow lines: cold clouds / protoplanetary disks

“Continuum” or broad lines

Mode	Polarization	Bandwidth per baseband (MHz)	Number of channels per baseband	Channel Spacing (MHz)	Velocity width at 300 GHz (km/s)
7	Dual	1875	3840	0.488	0.48
8	Dual	938	3840	0.244	0.24
9	Dual	469	3840	0.122	0.12
10	Dual	234	3840	0.061	0.06
11	Dual	117	3840	0.0305	0.03
12	Dual	58.6	3840	0.0153	0.015
6	Single	58.6	7680	0.00763	0.008
69	Dual	2000	128	15.625	15.6
71	Single	2000	256	7.8125	7.8

Frequency division mode: small bandwidth
High resolution
(spectral lines)

Time division mode: large bandwidth
low resolution
(continuum)

Quick Picker

- | | |
|--|--|
| ☒ CO $v=0$ | ☐ $^{13}\text{CO } v=0$ |
| ☐ C^{17}O | ☐ C^{18}O |
| ☐ $\text{CH}_3\text{OH } v_t=0$ | ☐ H_2CO |
| ☐ HCN $v=0$ | ☒ HNC $v=0$ |
| ☐ $\text{H}^{13}\text{CN } v=0$ | ☐ $\text{HC}^{15}\text{N } v=0$ |
| ☐ DCN $v=0$ | ☒ $\text{HCO}^+ v=0$ |
| ☐ CS | ☐ H^{13}CO^+ |
| ☐ NH_3 | ☐ C I |
| ☒ C II | ☐ O I |
| ☐ O III | ☐ N II |
| ☐ $\text{H}_2\text{O } v=0$ | ☐ HDO |
| ☐ $\text{SiO } v=0$ | |



Search:

Telescope Bands:

- Any
- ALMA Band 3 (84-116 GHz)
- ALMA Band 4 (125-163 GHz)

Redshift:

Energy Range: Min Max ☒ E_L (cm^{-1}) ☐ E_L (K)

Frequency Range:

Frequency Unit: GHz

Min Max

+ Frequency

- Frequency

Search

Astronomical Filters

(Double click to unselect)

- ☐ Top 20 list
- ☐ Planetary Atmosphere
- ☐ Hot Cores
- ☐ Dark Clouds
- ☐ Diffuse Clouds
- ☐ Comets
- ☐ AGB/PPN/PN
- ☐ Extragalactic



Scan to Mobile Splat

Found 22 lines from 84 - 750 GHz, showing 1 - 22
Click on the chemical formula below for more information about that species.

	Species	Chemical Name	Ordered Freq (GHz) (rest frame, redshifted)	Resolved QNs	CDMS/JPL Intensity	Lovas/AST Intensity	E_L (cm^{-1})	E_L (K)	Linelist
1	HCO⁺ v=0	Formylum	89.18853, 89.18853	1 - 0	0.00000	10.8	0.0000	0.0000	SLAIM
2	HNC v=0	Hydrogen Isocyanide	90.66356, 90.66356	J= 1 - 0	0.00000	1.6	0.0000	0.0000	SLAIM
3	CO v=0	Carbon Monoxide	115.27120, 115.27120	1 - 0	0.00000	60.0	0.0000	0.0000	SLAIM
4	HCO⁺ v=0	Formylum	178.37507, 178.37507	2 - 1	0.00000		2.9750	4.2803	SLAIM
5	HNC v=0	Hydrogen Isocyanide	181.32473, 181.32473	J= 2 - 1	0.00000		3.0240	4.3508	SLAIM
6	CO v=0	Carbon Monoxide	230.53800, 230.53800	2 - 1	0.00000	70.	3.8450	5.5321	SLAIM
7	HCO⁺ v=0	Formylum	267.55763, 267.55763	3 - 2	0.00000	12.	8.9250	12.8410	SLAIM
8	HNC v=0	Hydrogen Isocyanide	271.98111, 271.98111	J= 3 - 2	0.00000	10.	9.0730	13.0539	SLAIM
9	CO v=0	Carbon Monoxide	345.79599, 345.79599	3 - 2	0.00000	70.00	11.5350	16.5962	SLAIM
10	HCO⁺ v=0	Formylum	356.73424, 356.73424	4 - 3	0.00000	17.40	17.8500	25.6820	SLAIM
11	HNC v=0	Hydrogen Isocyanide	362.63030, 362.63030	J= 4 - 3	0.00000	3.0	18.1450	26.1065	SLAIM
12	HCO⁺ v=0	Formylum	445.90291, 445.90291	5 - 4	0.00000		29.7490	42.8019	SLAIM
13	HNC v=0	Hydrogen Isocyanide	453.26991, 453.26991	J= 5 - 4	0.00000		30.2410	43.5098	SLAIM
14	CO v=0	Carbon Monoxide	461.04077, 461.04077	4 - 3	0.00000	60.	23.0690	33.1910	SLAIM
15	HCO⁺ v=0	Formylum	535.06164, 535.06164	6 - 5	0.00000		44.6230	64.2022	SLAIM
16	HNC v=0	Hydrogen Isocyanide	543.89755, 543.89755	J= 6 - 5	0.00000		45.3600	65.2625	SLAIM
17	CO v=0	Carbon Monoxide	576.26793, 576.26793	5 - 4	0.00000		38.4480	55.3178	SLAIM
18	HCO⁺ v=0	Formylum	624.20846, 624.20846	7 - 6	0.00000	14.3	62.4710	89.8813	SLAIM
19	HNC v=0	Hydrogen Isocyanide	634.51082, 634.51082	J= 7 - 6	0.00000	14.8	63.5030	91.3661	SLAIM
20	CO v=0	Carbon Monoxide	691.47308, 691.47308	6 - 5	0.00000	100.	57.6700	82.9738	SLAIM
21	HCO⁺ v=0	Formylum	713.34137, 713.34137	8 - 7	0.00000	24.7	83.2920	119.8379	SLAIM
22	HNC v=0	Hydrogen Isocyanide	725.10732, 725.10732	J= 8 - 7	0.00000		84.6680	121.8177	SLAIM

ALMA status

ALMA Current status:

All the antennas have completed Assembly, Integration and Verification at the OSF at 3,000m and almost all have been transported to the AOS at 5,000m

ALMA Early Science:

allows community to observe with incomplete, but already superior array, on best effort basis:

- **Cycle 0: Sep. 2011 - Jan. 2013**
- **Cycle 1: Jan. 2013 - May. 2014**
- **Cycle 2 call for proposals: 24 October 2013, Deadline: 5 December 2013**

	Cycle 0 Sep. 2011 - Jan. 2013	Cycle 1 Jan. 2013 - May. 2014	Cycle 2 Jun. 2014 - Oct.2015
Telescope			
Hours dedicated to Science	800	800	2000 (incl. some Cycle 1)
Antennas	> 12x12-m no ACA	> 32x12-m+9x7m+2TP	> 34x12-m+9x7m+2TP
Receiver bands	3, 6, 7, 9	3, 6, 7, 9	+4, 8
Wavelengths [mm]	3, 1.3, 0.8, 0.45	3, 1.3, 0.8 0.45	+2, 0.7
Baselines	up to 400 m	up to 1000 m	up to 1500
Polarisation	single-dual	single dual	+full (with limitations)

Cycle 0:

- 111 Highest-priority + 51 filler proposals (out of 919 submissions)
- 108 (98%) Highest-priority PIs received some data

A proposal checklist

Have a good idea!

Estimate required configuration (CASA, Splatalogue, OST, OT)
Write the proposal idea in pdf docs (max 5 page)

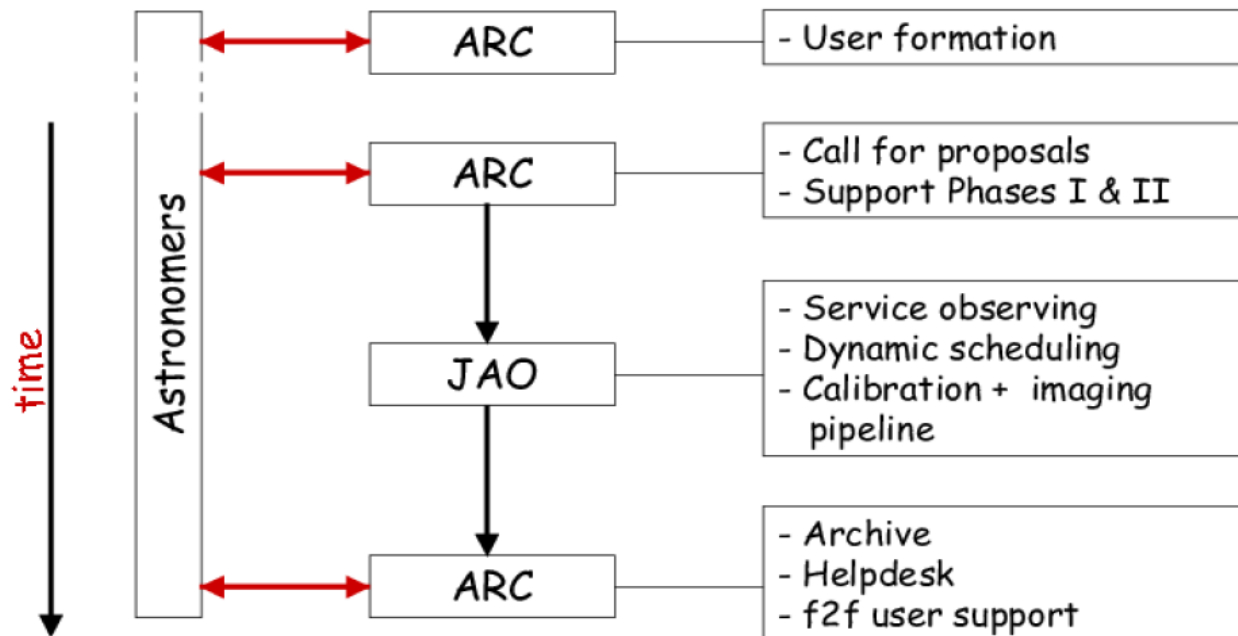
Register to the Science Portal (SP)

PHASE I – Proposal submission (OT, SP, Helpdesk)
TAC evaluation

PHASE II – Observing program submission for accepted proposals (OT, SP, Helpdesk)

Observations

Data reduction and analysis (CASA)



Phase II and ALMA observations

Investigators will be notified of the result of the ALMA Proposal Review process via email and successful investigators will be invited to submit a detailed observing plan.

The ALMA Observing Tool (OT) is used to prepare individual Scheduling Blocks

Dynamic schedule: the best SBs at any moment will be observed (science, weather, project...)

These will be used by the ALMA Scheduling Software to ensure that the observations are carried out under the required weather conditions.

The ALMA Regional Centers (ARC) will provide support to investigators in the Phase II process.

Once the Phase II preparation is finished the Scheduling Blocks will be submitted to the ALMA site and scheduled according to rank and requested observing conditions.

Investigators will be able to track the status of their project with the **ALMA Project Tracker**.

Once observations are completed and pass the quality controls the Principal Investigator receives a link to his/her data including a minimal data reduction.

The CASA (Common Astronomy Software Applications) is the standard tool for ALMA data reduction.

The ALMA Observing Tool

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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 have Java installed (and no known problems). The ALMA OT is available in two flavours: WebStart and tarball.

The **WebStart** application has the advantage that the OT is automatically updated when a new version is released. Note that the WebStart does not work with the OpenJDK Linux installations. If this is the case, the tarball installation of the OT should be used.

The **tarball** must be installed manually, however it has the advantage that it can be run on older versions of Java 6. For Linux users we also provide a download of the tarball. Please use this if you have any problems running the OT tarball installation.

Documentation

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

Webstart Download Page

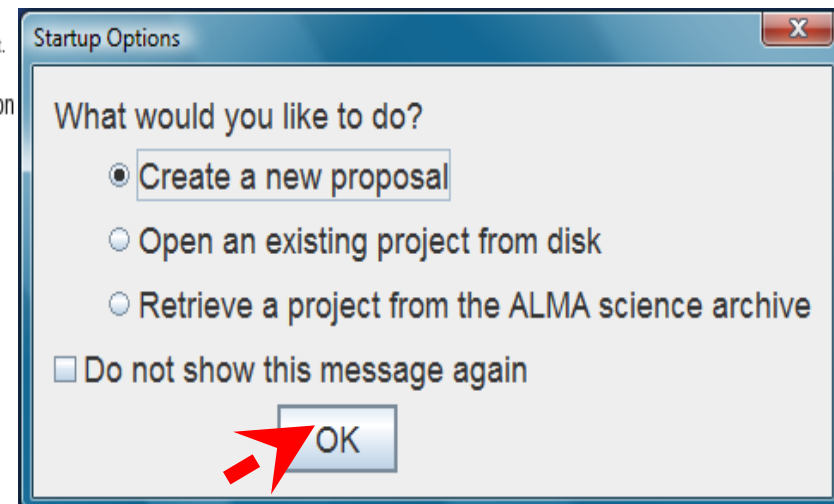
First Time Users: When you use the ALMA OT Webstart for the first time, it will download a large amount of shared resources (on the order of 130 MB) to your host, taking a few minutes to do so. This will only happen the first time, or when a revised version of the OT is released. Subsequent use of the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



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

OT is a java-based client program,
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.



Proposals with the ALMA Observing Tool

My new idea - Observing Tool for ALMA (Early Science), version R8.0.1

File Edit View Tool Search Help

Perspective 1

Project Structure

Proposal Program

My new idea

- My new idea
 - Proposal
 - Planned Observing
 - Science Goal ()
 - Description
 - Field Setup
 - Calibration Setup Parameters
 - Spectral Setup
 - Control and Performance Parameters

Template library. Turn the keys on the JTree below & read the

- Template library. Turn the keys on the JTree below & read
 - Proposal
 - Planned Observing
 - Science Goal (Band 3 100 GHz (rest frame) d
 - Science Goal (Band 3 Nyquist-sampled mosa
 - Science Goal (Band 6 Mixed 219 GHz SSB Co
 - Science Goal (Band 6 13CO J=2-1 mapping c
 - Science Goal (Band 6 Mixed simultaneous 12
 - Science Goal (Band 9 700 GHz search for pat

Editors

Spectral Spatial Proposal Catalog

Tab menu for viewer

Proposal Information

Proposal Title: My new idea

Proposal Cycle: 9999.4

Editors Panel

Abstract (max. 300 words)

Feedback

Problems Information Log

Description	Suggestion

Feedback Panel

Project Overview

Contextual Help

- Please ensure you and your co-Is are registered with the [ALMA user portal](#)
- Create a new proposal by either:
 - Selecting *File > New Proposal*
 - Clicking on the  icon in the toolbar
 - Or clicking on this [link](#)
- Click on the  [proposal](#) tree node and complete the relevant fields.

Phase I: Science Proposal

New Science Proposal → Create Science Goals → Validate Science Proposal → Submit Science Proposal

Click on the overview steps to view the contextual help

Importing And Exporting Template Library Need More Help? View Phase 2 Steps

(see Viviana & Rosita's talks)

Tips to write a proposal

The proposal review process

Proposals will be reviewed by an international peer review committee.

The peer review by committee is a group of hopefully well informed peers examines your proposal, ranks it against other proposals, and then allocates resources to the highest ranked proposals.

There will at least one Review Panel for each of the **main themes**:

Cosmology and the High Redshift Universe

Galaxies and Galactic Nuclei

ISM, Star Formation/protoplanetary Disks and their Astrochemistry, Exoplanets

Stellar Evolution, the Sun and the Solar System

The ranked proposals from the different panels and sub-panels will be merged into a single ranked list in the ALMA Proposal Review Committee (APRC) and assigned a letter grade A through D:

A the proposal will be carried over to the following cycle if it is not finished

B the proposal should be finished during the current cycle but will not be carried over to the next cycle.

C are 'filler' programs observed when no A or B can be scheduled

D proposals will not be observed.

Now, this process is NOT perfect,

BUT it is NOT a lottery, or fundamentally flawed and/or fixed.....

DO NOT let that idea impact on how you write ..

Everything you can do to give your proposal a broader context, make it easier to read, more enjoyable, more clear, ... all will help your chances

What should a proposal look like?

- Should have a good, readable **“Executive Summary”** that sets the research in context, sets out the big issues in a field, says what you will do, and how the results from that will address the big issues.
- Should have a **well set out background** that expands on the context and big questions in the field.
- Should clearly **explain why the observations you propose are critical** for answering those questions
- Should clearly **demonstrate the observations / research is technically feasible**, that the time / resources requested are appropriate
- Should clearly **demonstrate that your team will be able to do the work**, and/or has a track-record for having done similar work in the past.
- Should include **“only” useful figures**
- **Must be readable and should be pleasurable to read.**

The technical justification

The Technical Justification should fully justify the technical aspects of the requested observations and should address the following aspects:

- **sensitivity**
- **resolution**
- **array configuration**
- **imaging**
- **correlator setup**
- **calibration**
- **scheduling/time constraints**
- **special constraints on standard observing mode**
- **any non-standard choices**

The technical justification must be very, very clear – say what your assumptions, required S/N, number of pointings etc are, so your reasoning can be reproduced by the technical assessors.

Try to know/understand the telescope or ask to someone who knows it

What to never do

- Do not ignore the grading or funding criteria.
- Don't submit proposals that are badly written – if English is not your first language, get a collaborator to proof read or rewrite it for you.
- Don't ask for the wrong instrument, the wrong amount of time, or the wrong semester.
- Don't rage at the panels - its not their fault they didn't have enough money or telescope time last time
- Don't waffle - less is more
- **Don't use jargon & acronyms**
- **Don't assume everyone knows this scientific area is the most compelling thing ever done.**

Few tips

- **Tell a story.** Make your proposal and enjoyable narrative that leads the reader from point to point.
- **“Close the Loop”**
- **Frame your project as an experiment** (“Hypothesis and Testing”) rather than data gathering.
- Think seriously about the risks of a “new class of object” discovery project.
- Avoid the evil “Constrain”
- **The more you “quantify” the better you get the point** (i.e. avoid generic “more, much, less, few” but give numbers to give the idea that you have already dirty hands on the matter)

WAA

RS

RV

VLM

SMBH

AGN

FIR

FR II

ULIRG

ERO

SMG

CDFS

PCCS

EMU

APEX

SCUBA

WTHDIM

Ask yourself...

- Would you want to read this proposal? Late at night? On a plane? Along with 80 others just like it?
- Would you be able to read and understand this proposal in under 5m per page?
- Can you FIND the main points in the proposal without reading the whole thing in all its gory detail?
- Imagine its your hard earned money, would you pay for this project?

**It's not the reader's job to understand your proposal
... its your job to make them understand it.**

**Readers are looking for enjoyable,
understandable proposals to read that
present innovative ideas for new research**

Useful hints/contact details

ALMA primer for Early science:
www.almascience.eso.org/
->proposing

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