Archive tips and tricks

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How to check if a target is in the archive?

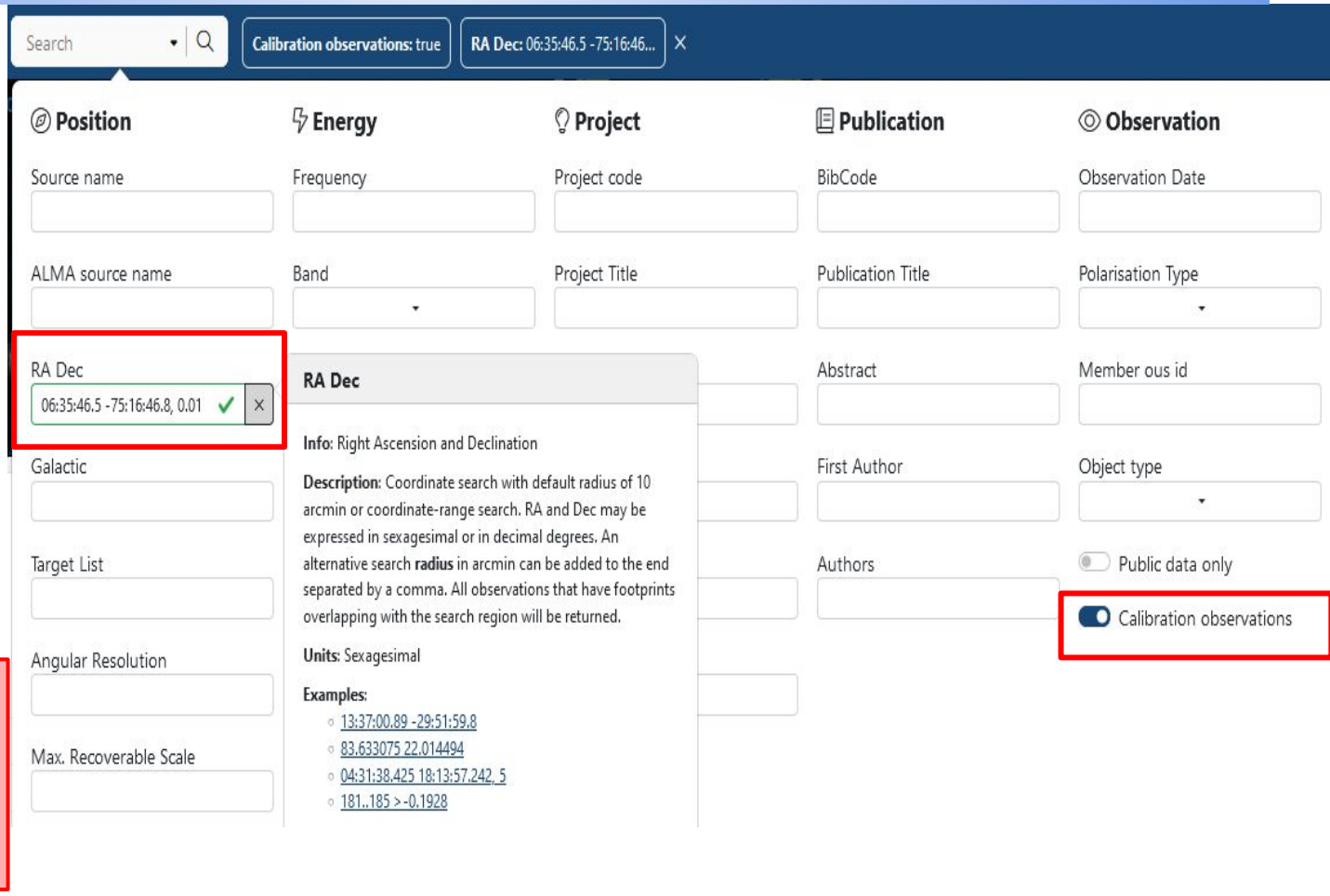
Search
06:35:46.5 -75:16:46.8
including also calibrators images
At 30 arcsec there is
PKS 0637-752
(06:35:46.5 -75:16:16.8)

FACTS

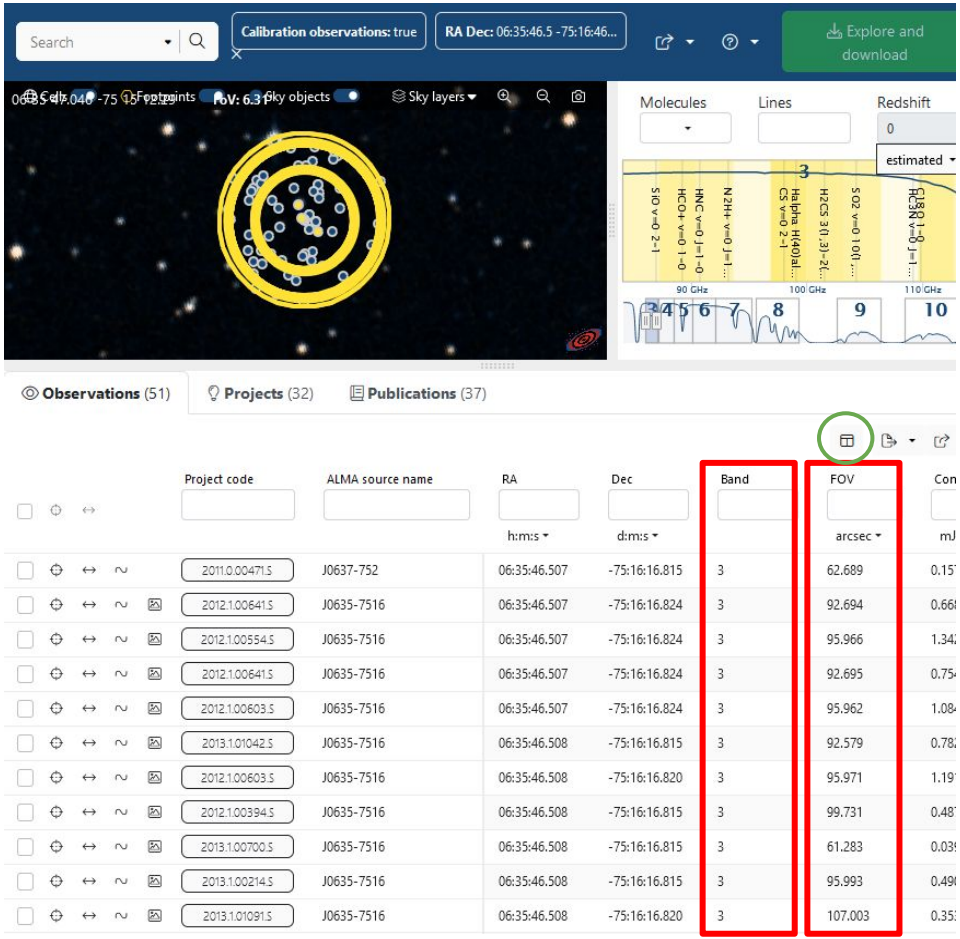
The archive lists the observations which footprint overlaps with the searching region (default radius 10 arcmin)

TIPS

Make the searching radius as small as possible (0.01 arcmin) to search if a position is within the footprints!!!



How to check if a target is in the archive?



TRICKS

Note that for sake of readability in the following examples I will resort the columns and change the size of the top part of the interface to the best convenience

A small searching areas selects only observations for which the FOV or the mosaicked area is larger than the distance between the searched position and the observed pointing position.

That might prefer lower bands with 7m array where the beam is larger

FOV= 21" *(300GHz/freq)*(12m/ant diam)
~x2 @ 7m
~x3 @ 100GHz=B3
~/3 @ 900 GHz=B10
Resolution ~ FOV/100-1000

How to check if a target is in the archive?

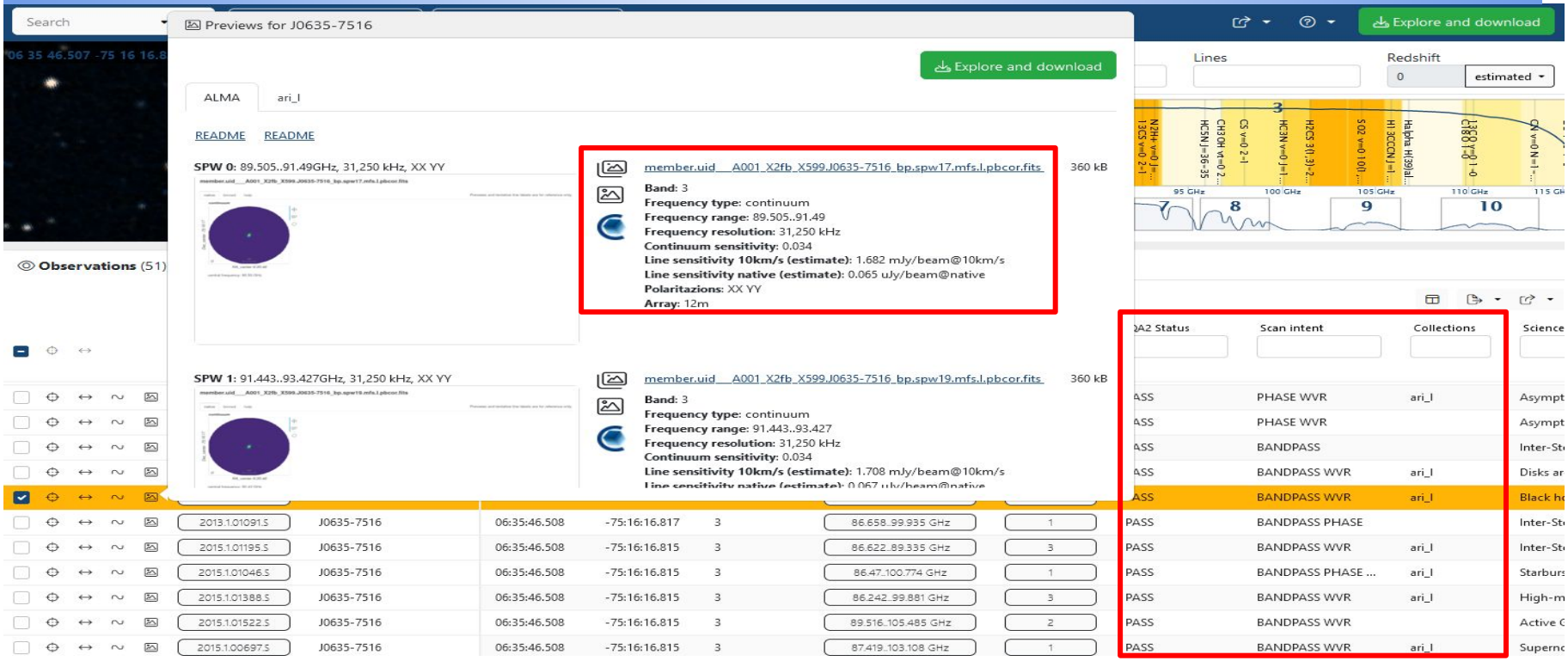
Observations (51) | Projects (32) | Publications (37)

Project code	ALMA source name	RA (h:m:s)	Dec (d:m:s)	Band	FOV (arcsec)	Cont. sens. (mJy/beam)	Frequency support	↑ Release date	Publications	Ang. res. (arcsec)	Min. vel. res. (km/s)	Array	Max. reco. scale (arcsec)	Collections	Scient
2015.1.01195.S	J0635-7516	06:35:46.508	-75:16:16.815	3	66.186	0.0575	86.622..89.335 GHz	2017-06-08	3	2.206	0.239	12m	20.442	ari_l	ISM ar
2015.1.01046.S	J0635-7516	06:35:46.508	-75:16:16.815	3	62.196	0.0377	86.47..100.774 GHz	2017-06-17	1	2.390	3.322	12m	34.222	ari_l	Active
2015.1.01388.S	J0635-7516	06:35:46.508	-75:16:16.815	3	62.571	0.0638	86.242..99.881 GHz	2017-07-12	3	1.966	0.216	12m	20.905	ari_l	ISM ar
2015.1.01522.S	J0635-7516	06:35:46.508	-75:16:16.815	3	59.722	0.0336	89.516..105.485 GHz	2017-09-06	2	0.653	181.016	12m	14.402		Active
2015.1.00697.S	J0635-7516	06:35:46.508	-75:16:16.815	3	61.125	0.0357	87.419..103.108 GHz	2017-09-19	1	1.087	92.650	12m	11.105	ari_l	Stars a
2015.1.01522.S	J0635-7516	06:35:46.508	-75:16:16.815	3	59.722	0.0332	89.516..105.485 GHz	2018-02-28	2	0.430	181.016	12m	9.008		Active
2015.1.01522.S	J063546-751616	06:35:46.330	-75:16:16.800	3	59.722	0.0322	89.516..105.485 GHz	2018-02-28	2	0.377	181.016	12m	11.687		Active
2015.1.01522.S	J0635-7516	06:35:46.508	-75:16:16.815	3	59.722	0.0296	89.516..105.485 GHz	2018-02-28	2	0.375	181.016	12m	12.057		Active
2015.1.00748.S	J0635-7516	06:35:46.508	-75:16:16.815	3	62.665	0.0304	84.998..100.846 GHz	2018-03-17	0	0.463	94.770	12m	9.676	ari_l	Stars a
2015.1.00697.S	J0635-7516	06:35:46.508	-75:16:16.815	3	63.387	0.0356	84.026..99.701 GHz	2018-03-29	1	1.118	95.880	12m	11.274	ari_l	Stars a

Furthermore, remember that **the query lists one row for each source (inc calibrators) per MOUS. The reported values are an estimate of what would be achievable on the basis of the observing conditions.**

Then, **the publications refer to the project a target belong to, not necessarily to the target listed in the query** (so it is possible that even if there are >3 pubs for a row or 37 in total, no one has yet published the data for that specific source in those observing conditions).

Searching for calibrators



Typically, calibrators do not have an image nor a preview in the early cycles.

Search for ari-l images if available in column “Collections” but only if column “Scan Intent” is BANDPASS, CHECK, PHASE or TARGET (and for projid 2013*, 2015*, 2016*).

Also in the preview info you can find the expected sensitivity of an image!

Searching for calibrators

ALMA Calibrator Source Catalogue

Query Form | Result Table | Result Plot

https://almascience.eso.org/alma-data/calibrator-catalogue

Search | Reset

Position

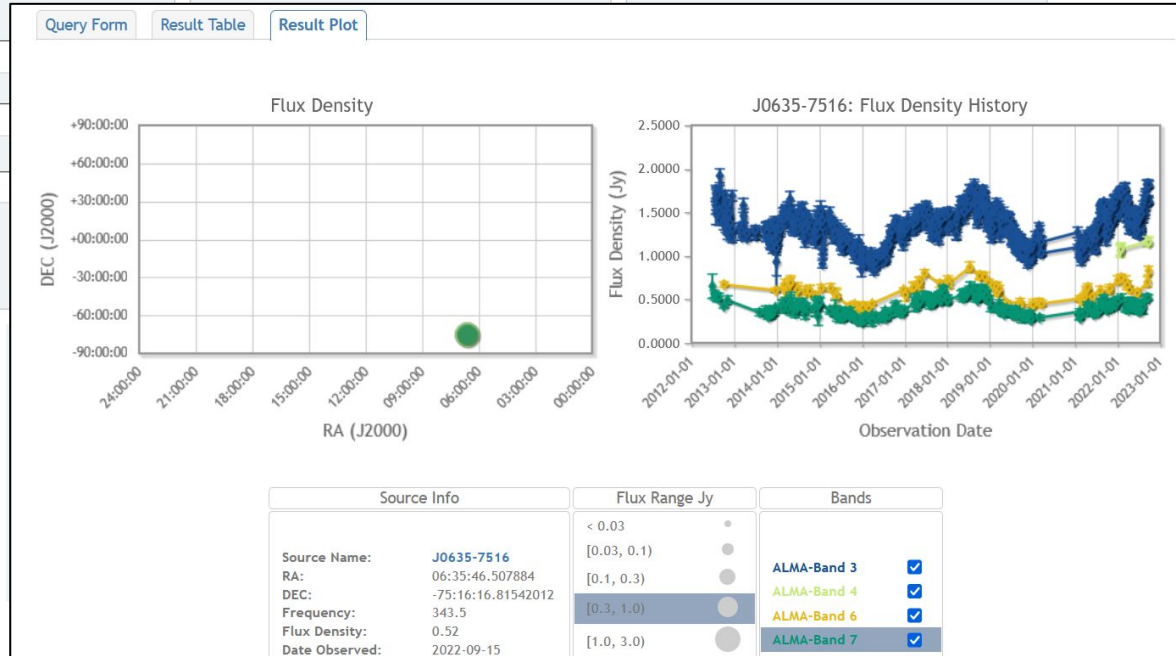
Source name (resolved by ALMA)
J063542-751615
RA
06:35:46.50788
Dec
-75:16:16.8154
Search radius

Energy

Band
Frequency
Flux Density

Time

Polarisation



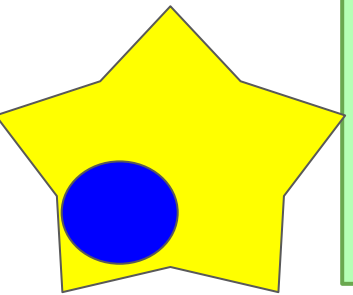
The calibrator catalogue lists the value observed in the calibrator monitoring program
It does not include images, nor the values observed during science observations

How to measure a flux?

$$1Jy = 10^{-23} erg/s/cm^2/Hz$$

Jy measures all the energy per time, per frequency bin and per detector area coming from a given solid angle. The solid angle is typically the synthesized beam

Each pixel of an image provides the flux within a beam area centered in that pixel



For a source smaller than the synthesized beam all the flux is within the solid angle

Peak flux[Jy/beam] = Integrated Flux[Jy]

For a source larger than the synthesized beam integrate over the whole source region and correct for the number of pixels in a beam

$$\textbf{IntegratedFlux[Jy]} = \sum_{\text{Pixels}} \textbf{Flux}_{\textbf{pixel}}\textbf{[Jy/beam]}\textbf{A}_{\textbf{beaml}}/\textbf{A}_{\textbf{pixel}}$$

Statistics: Region 1 (Active)

Image: Active Region: Active

Statistic	Value
NumPixels	7.830000000000e+2 pixel(s)
Sum	9.766996445512e+1 Jy/beam
FluxDensity	2.955533659228e+0 Jy
Mean	1.247381410666e-1 Jy/beam
StdDev	2.418775028509e-1 Jy/beam
Min	-1.629138924181e-2 Jy/beam
Max	1.291243910789e+0 Jy/beam
Extrema	1.291243910789e+0 Jy/beam
RMS	2.720103147893e-1 Jy/beam
SumSq	5.793386568843e+1 (Jy/beam)^2

“FluxDensity” in CARTA “Sum” in CARTA

How to measure a flux?

$$1Jy = 10^{-23} erg/s/cm^2/Hz$$

Jy measures all the energy per time, per frequency bin and per detector area coming from a given solid angle. The solid angle is typically the synthesized beam

Each channel of a spectrum provides the flux within a range of frequency

For a line narrower than the channel width
all the flux is within the channel

Line Flux[Jy/beam*km/s]=
Peak flux[Jy/beam]*channel_width[km/s]

For a line wider than the channel size
integrate over the whole line and correct for the channel width

Line Flux[Jy/beam*km/s] =

$$\sum_{\text{Channels}} \textbf{Flux}_{\textbf{ch}}\textbf{[Jy/beam]*channel\_width[km/s]}$$

Statistics: Region 2 (Active) mom 0 map

Image: Active Region: Active

Statistic	Value
NumPixels	5.400000000000e+1 pixel(s)
Sum	-8.848474074155e+0 Jy/beam.km/s
FluxDensity	-2.651730261824e-1 Jy.km/s
Mean	-1.638606310029e-1 Jy/beam.km/s
StdDev	1.167055398779e-1 Jy/beam.km/s
Min	-3.685683012009e-1 Jy/beam.km/s
Max	8.852740377188e-2 Jy/beam.km/s
Extrema	-3.685683012009e-1 Jy/beam.km/s
RMS	2.005449175270e-1 Jy/beam.km/s
SumSq	2.171786253079e+0 (Jy/beam.km/s)^2

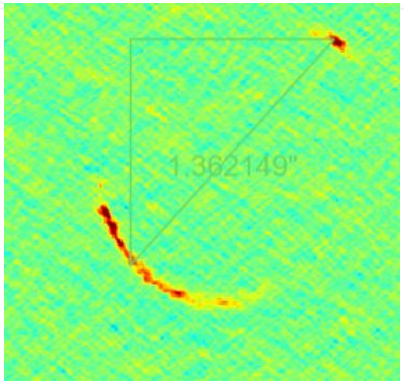
How to measure a size or a width?

Search SDP9 a lensed star forming galaxy at redshift 1.5
typical size of Einstein ring < 2 arcsec, typical linewidth few*100km/s

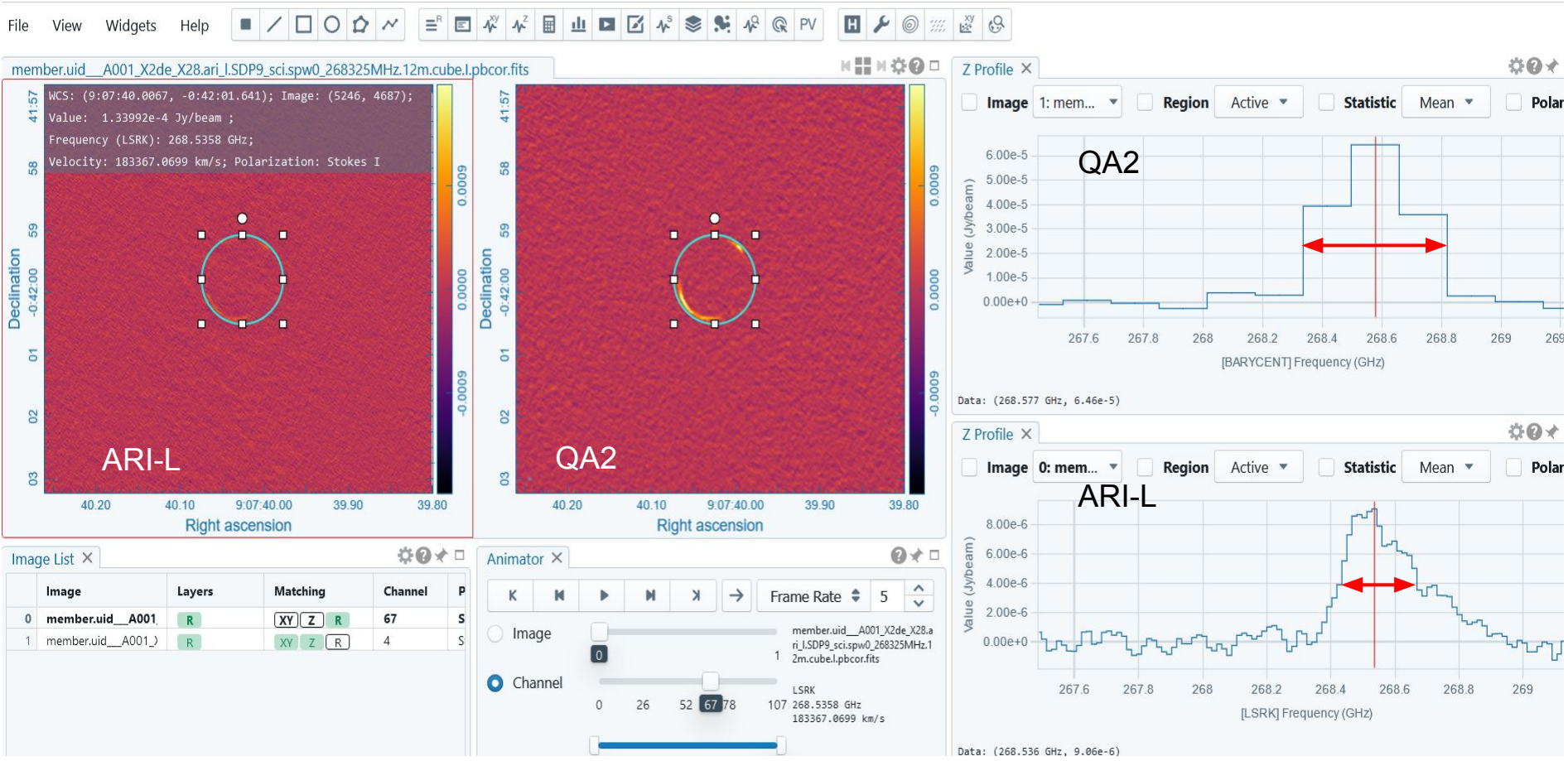
Project code	ALMA source name	Band	Cont. sens. (mJy/beam)	Ang. res. (arcsec)	Min. vel. res. (km/s)	Array	Max. reco. scale (arcsec)	FOV (arcsec)
2011.0.00661.S	HATLAS J090740.0-004...	3	0.0183	1.706	2.754	12m	20.034	59.128
2012.1.00915.S	H-ATLAS_J090740.0-00...	3	0.0175	1.443	2.754	12m	23.333	59.125
2015.1.00415.S	SDP9	6	0.0129	0.020	35.042	12m	0.355	22.404
2016.1.01340.S	SDP.9	4	0.0249	1.302	2.268	12m	12.032	43.681
2016.1.01340.S	SDP.9	3	0.0205	1.836	3.388	12m	17.988	62.992

To measure a size choose an angular resolution <size/5

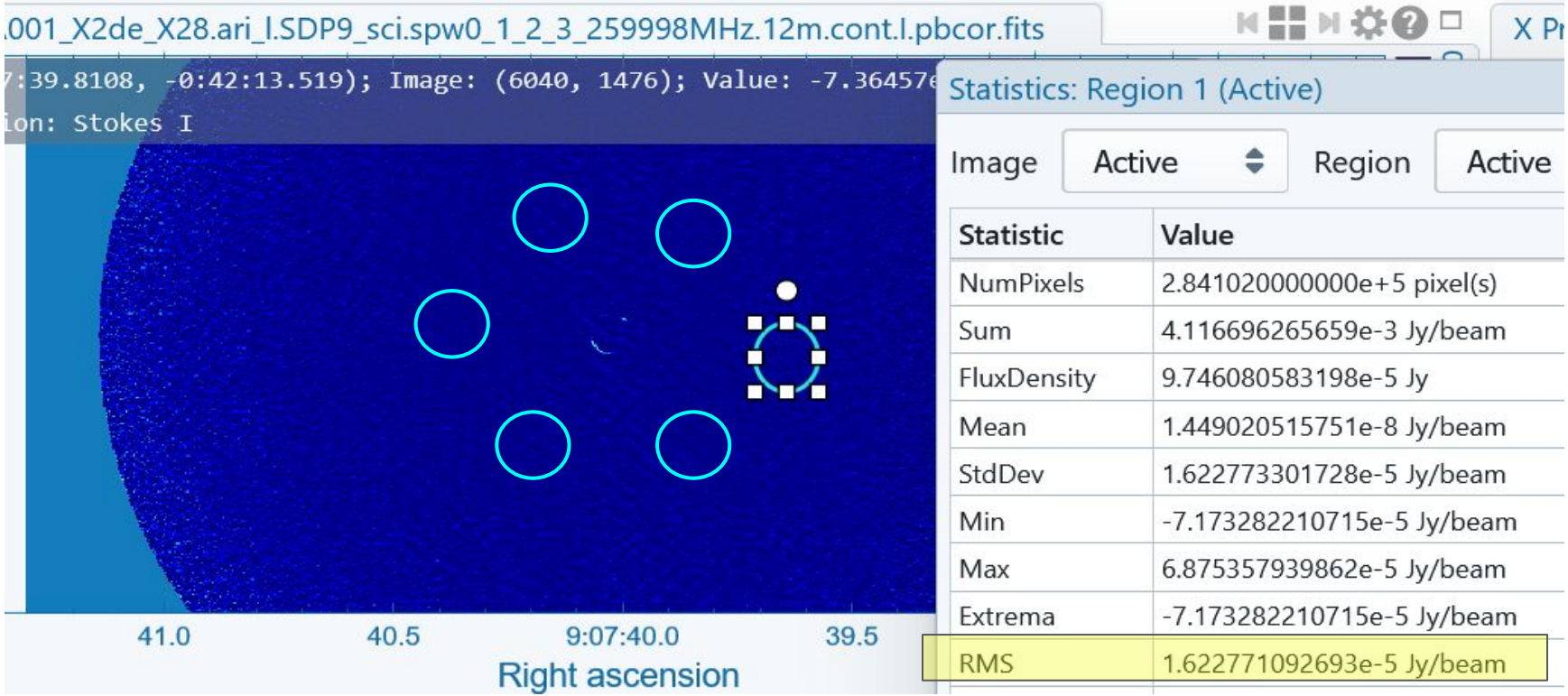
To measure a line width choose an spectral resolution <size/3



How to measure a size or a width?



How to measure noise?



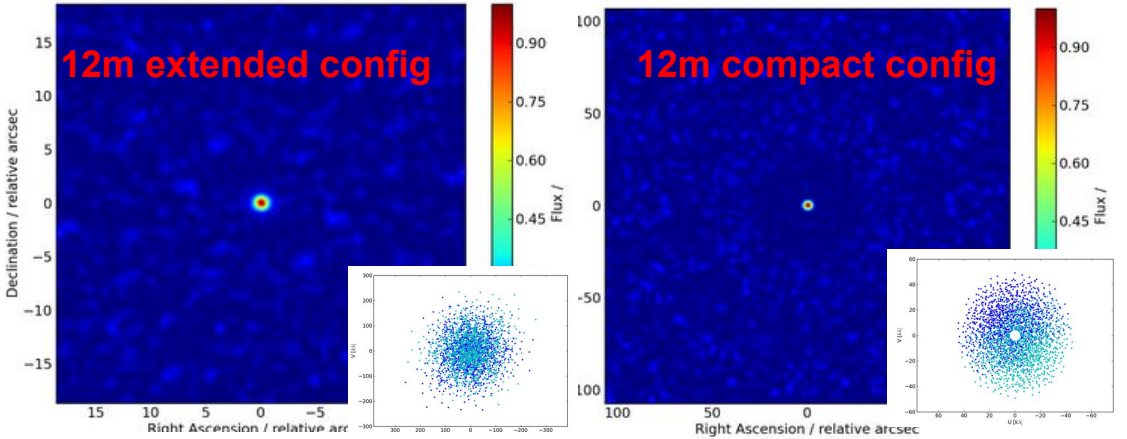
Draw regions far from the source, but not too far because of the pbcorrection
Get the rms from CARTA and average them…

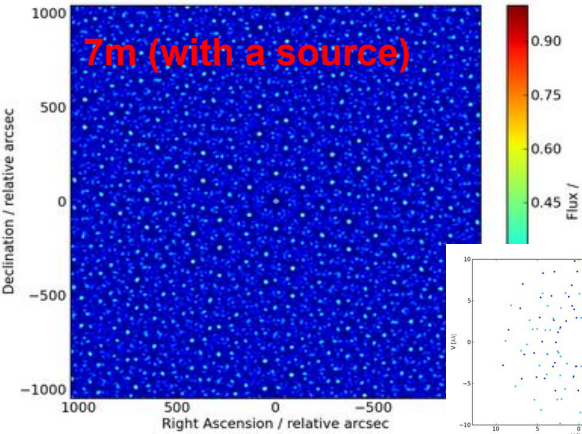
compare with the 0.0129 mJy/beam of the query interface!!!!

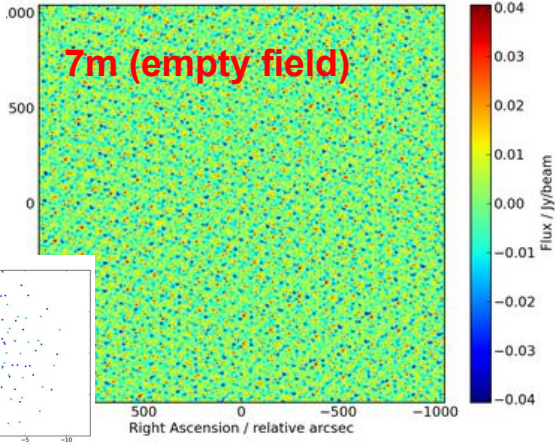
Questions?

When a spurious detection is a detection?

SIMULATIONS



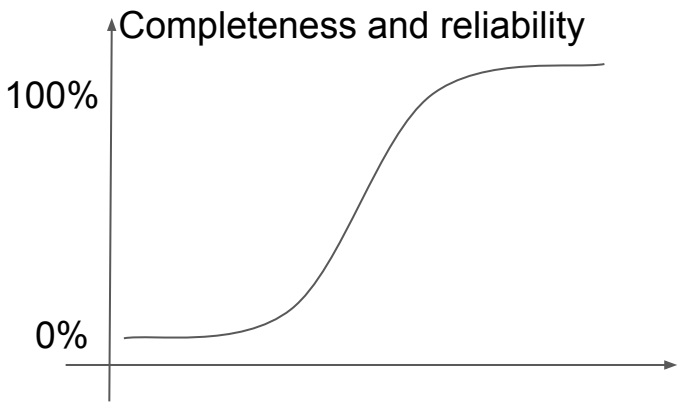




The noise of an interferometric image is not Gaussian because it is the result of a non linear process.

For this reason it is recommended to measure the noise by averaging over various regions where there is no source (this minimizes the pattern effects).

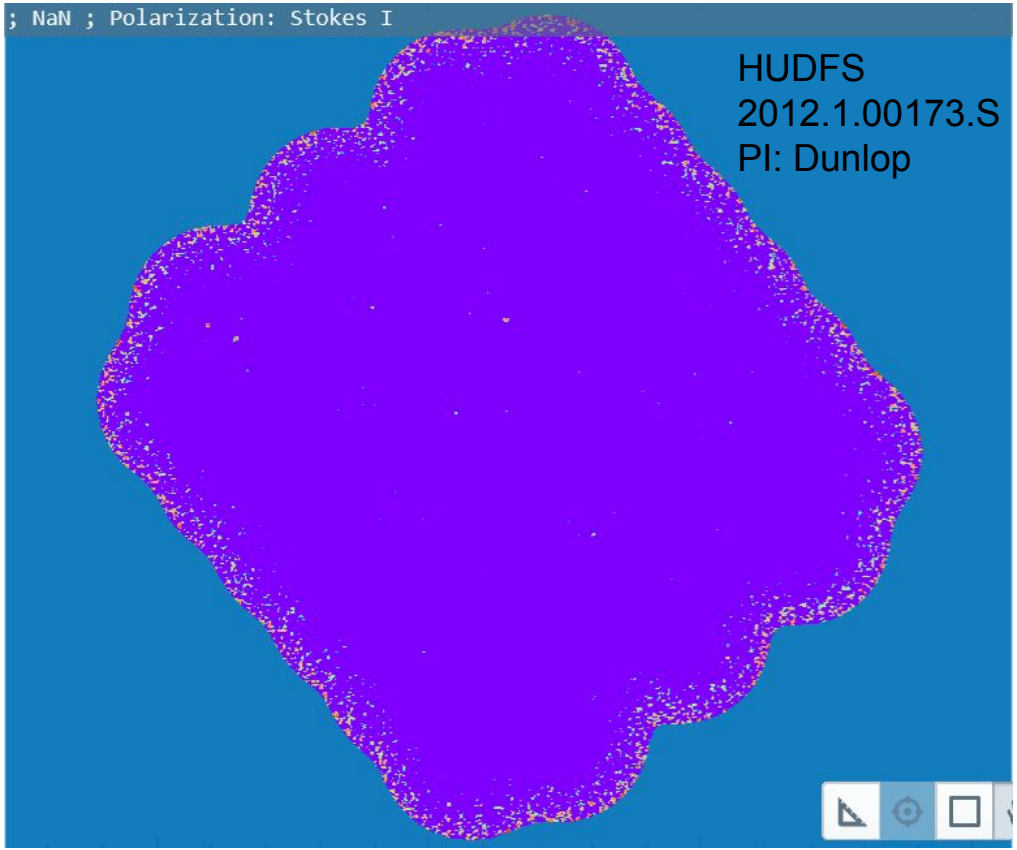
When a spurious detection is a detection?



Completeness = fraction of all the source above a given flux level that have been detected

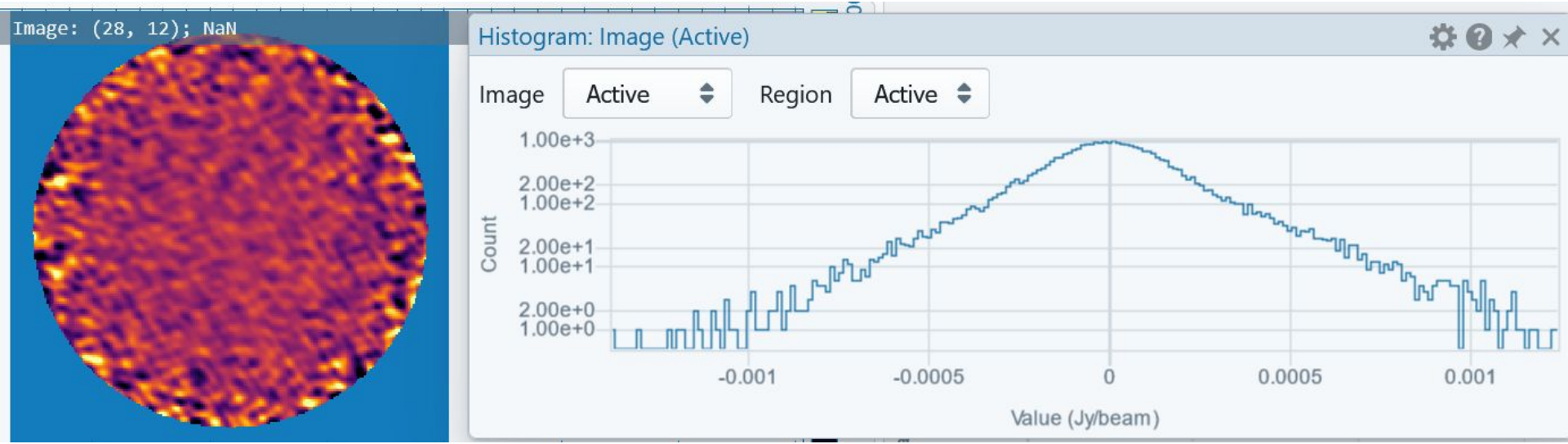
Reliability = fraction of real sources above a given flux level

Select pixels going down in flux density … but pay attention to the limit of it



When a spurious detection is a detection?

ARCHIVED 12m PB CORRECTED IMAGE (VERY FAINT SOURCE IN THE CENTER)



Typically the negative side of the pixel values distribution is used as tracer of the Gaussian noise…
But not in an interferometric image!!!!

The pixel distribution is asymmetrical (both in pb and non pb corrected images!!!)
so detection significance is not just given by the Gaussian fit of the negative pixels distribution.

When a spurious detection is a detection?

In case of spurious detections in a given field, reproduce the observation conditions with **simulations** to estimate completeness and reliability:

ALMA Observing Support Tool: https://almaost.jb.man.ac.uk/
I-TRAIN #5 tutorial: https://almascience.eso.org/tools/eu-arc-network/i-train

Simulating ALMA with CASA: https://casaguides.nrao.edu/index.php/Guide_To_Simulating_ALMA_Data
I-TRAIN #15 tutorial: https://almascience.eso.org/tools/eu-arc-network/i-train

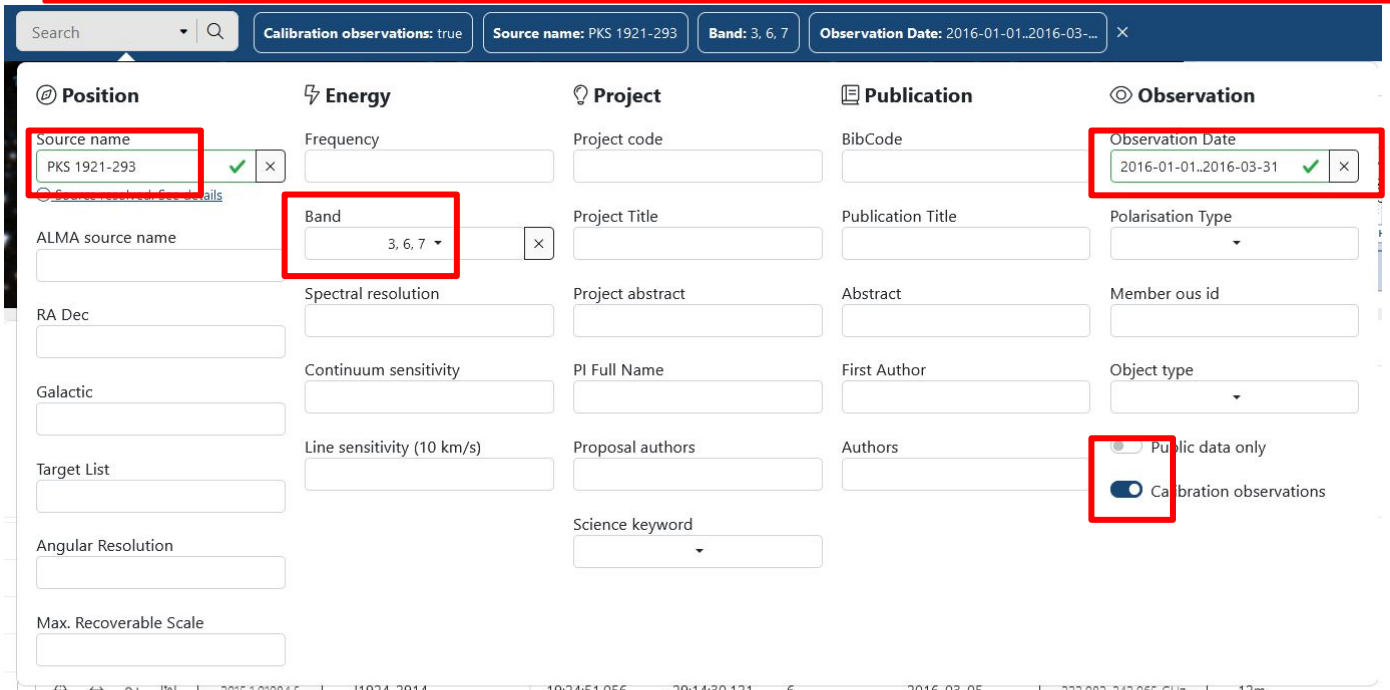
APSYNSIM: https://github.com/onsala-space-observatory/APSYNSIM
I-TRAIN #16 tutorial: https://almascience.eso.org/tools/eu-arc-network/i-train

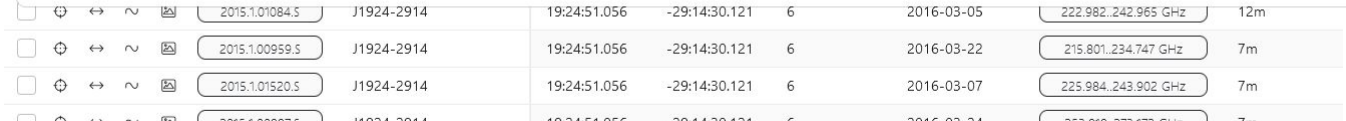
Another possibility to verify if a detection is real is to consider
other observations of the same target
assuming reliable conditions of variability or spectral behaviours.

Questions?

How to build a SED or a timecurve for a source?

If you need to build time series data should refer to the same scales.
If you are sure that the source is a point source choose your data and open images with CARTA to grab the peak flux.





Search for all the observations of the calibrator PKS1921-293 in the first 3 months of 2016.

Select one obs for frequency in january and march.

Select only the columns you want

Export the table to save the info only on the selected rows

How to build a SED or a timecurve for a source

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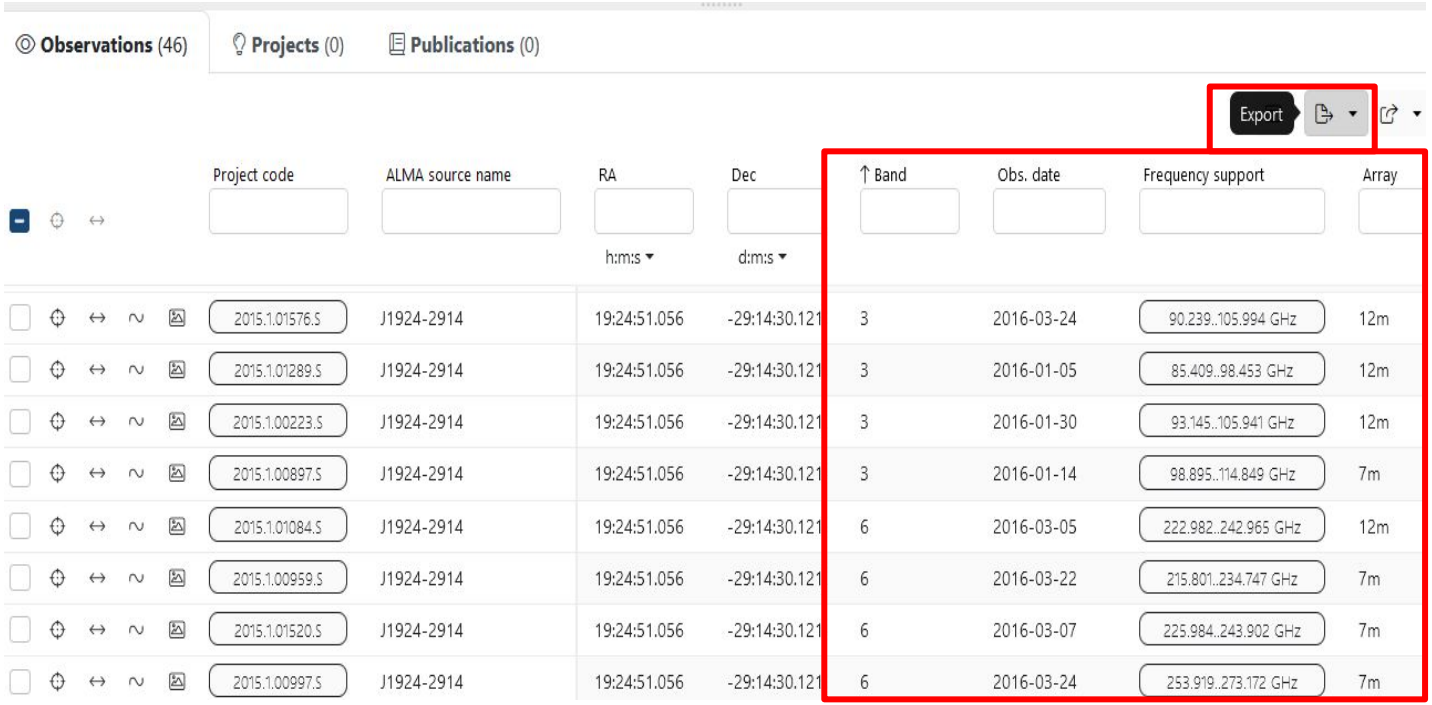


Search for all the observations of the calibrator PKS1921-293 in the first 3 months of 2016.

Select one obs for frequency in january and march.

Select only the columns you want

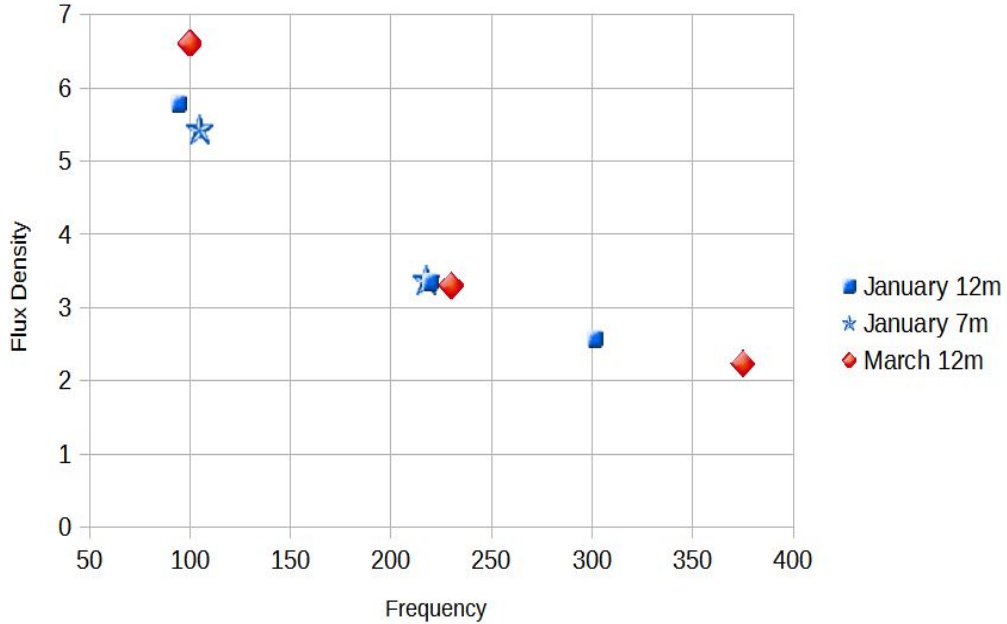
Export the table to save the info only on the selected rows

How to build a SED or a timecurve for a source

	Project code	ALMA source name	Ra	Dec	Band	Cont. sens.	Frequency support
1							
2	2015.1.01329.S	J1924-2914	291.2127331541667	-29.241700286111115	3	0.05292610005178721	[95.03..96.91GHz,488.28k
3	2015.1.00149.S	J1924-2914	291.2127331541406	-29.241700286121656	6	0.3148528980746554	[214.69..216.71GHz,1128.
4	2015.1.00897.S	J1924-2914	291.21273315419273	-29.241700286116405	3	0.28161504855196734	[98.89..100.90GHz,1938.4
5	2015.1.00149.S	J1924-2914	291.2127331541667	-29.241700286111115	6	0.04764062061852789	[214.77..216.65GHz,1128.
6	2015.1.00150.S	J1924-2914	291.2127331541667	-29.241700286111115	7	0.05540846408255419	[301.19..303.07GHz,976.5
7	2015.1.01003.S	J1924-2914	291.2127331541667	-29.241700286111115	7	0.07376011393820256	[341.95..343.82GHz,1938.
8	2015.1.00658.S	J1924-2914	291.2127331541667	-29.241700286111115	9	0.9151276372140352	[673.00..674.98GHz,3125
9	2015.1.01312.S	J1924-2914	291.2127331541667	-29.241700286111115	6	0.04612907160174198	[224.24..226.12GHz,1128.
10	2015.1.01404.S	J1924-2914	291.2127331541331	-29.241700286125223	3	0.31524396288382583	[89.92..91.91GHz,31250.0
11	2015.1.01344.S	J1924-2914	291.2127331541187	-29.24170028612161	3	0.05560090068515236	[91.93..92.05GHz,141.11k
12							

The exported csv files can easily be managed as tables

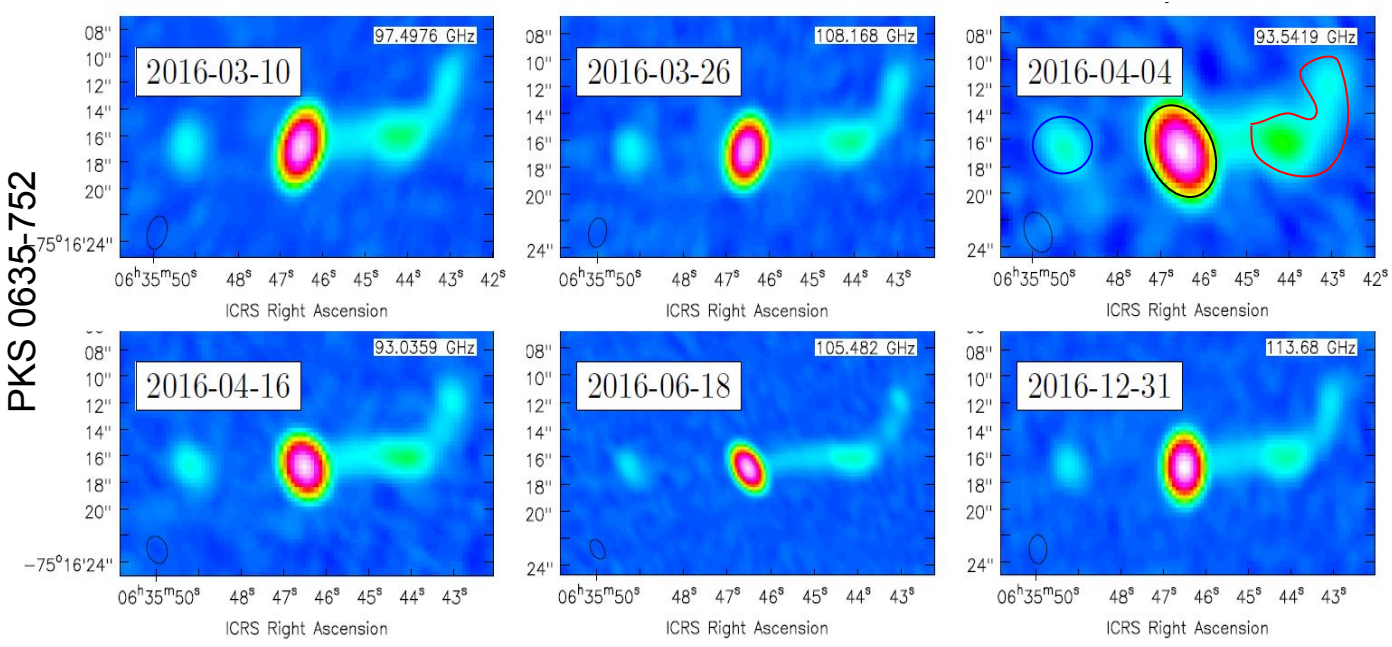
SEDs and timelines for point sources can be reasonably built by extracting peak flux densities from CARTA on archival images
(remember that they are only representative!).

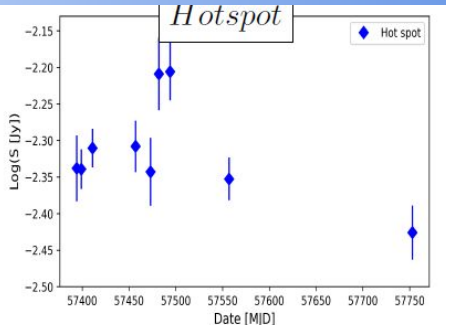


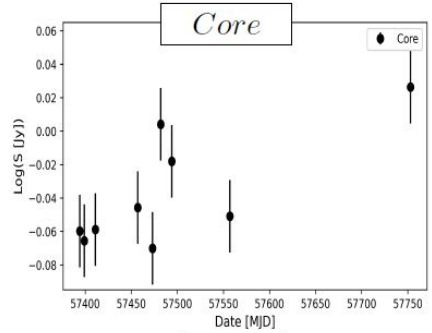
How to build a SED or a timecurve for a source

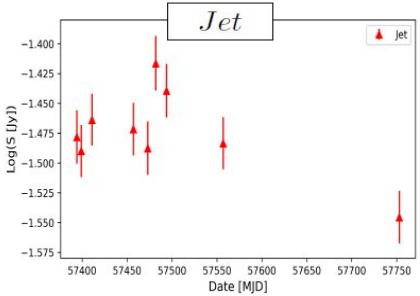
If you need to build SED data should refer to the epochs and scales.

If a source is extended wrt the image resolution a region has to be defined to collect the flux density.

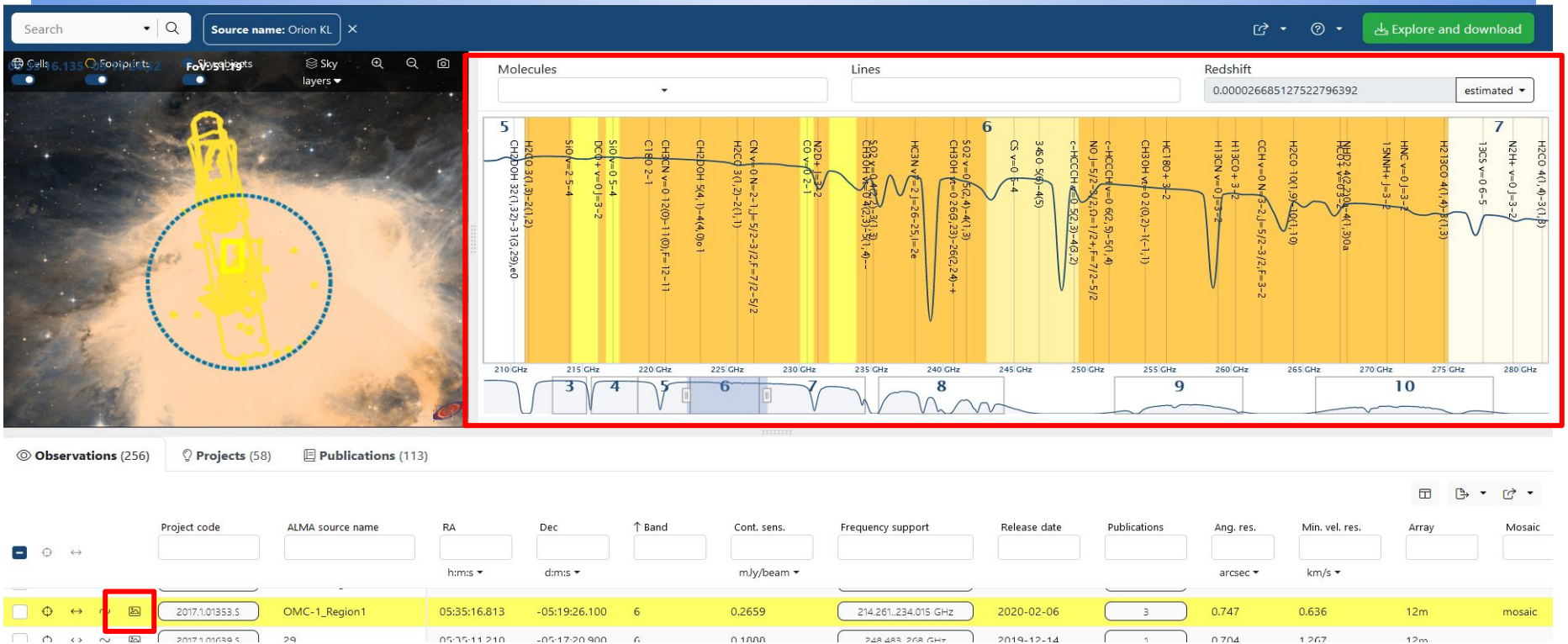








How to search for lines in a source?

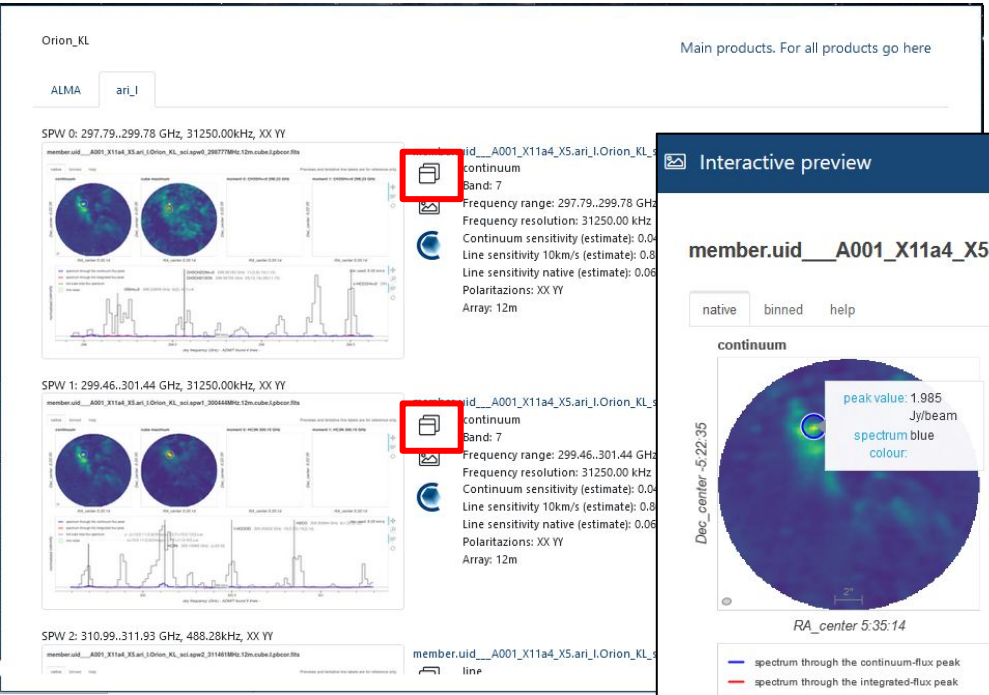


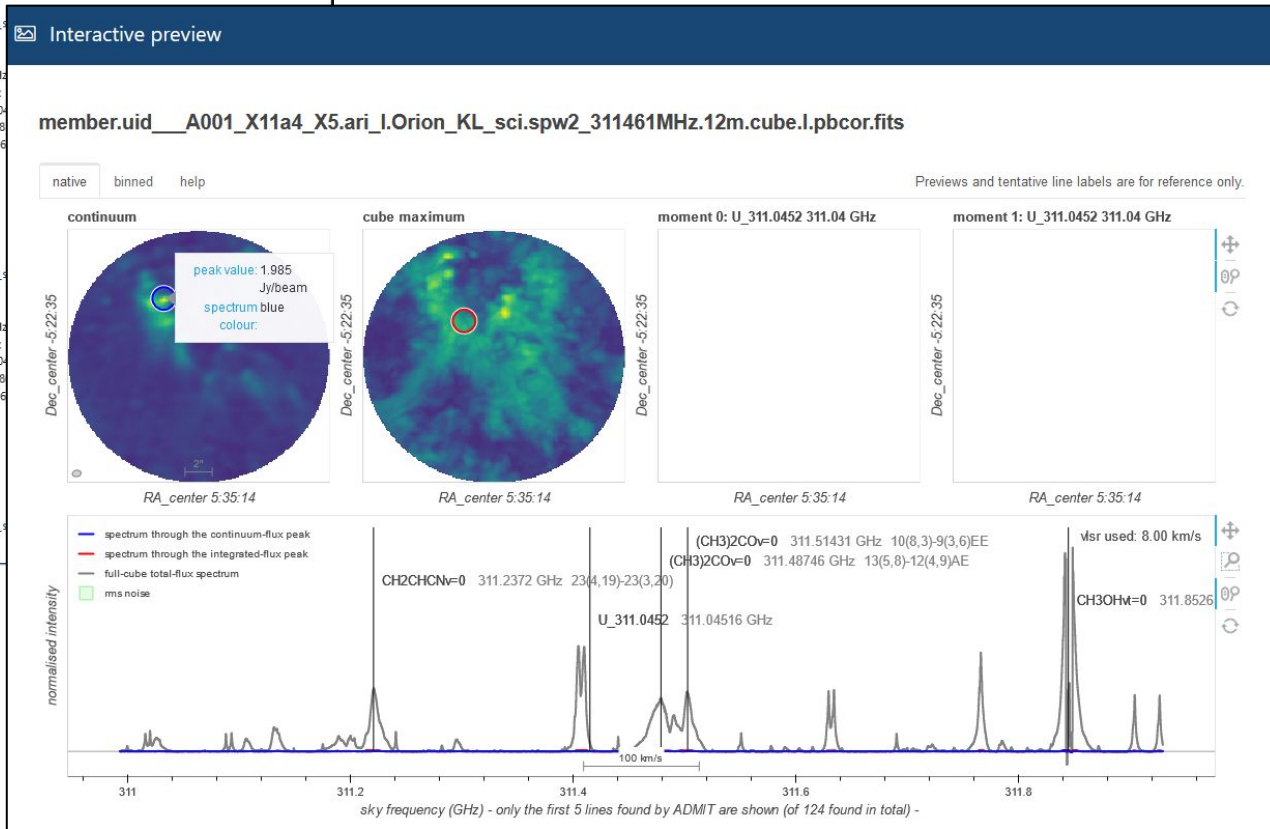
Search for Orion KL

The spectral window give indications of which lines fall in the selected observed frequency range (no indication of detection here! It lists all the lines as given by splatalogue https://splatalogue.online// or selected by archive user)

The preview helps in identifying which lines can be detected

How to search for lines in a source?



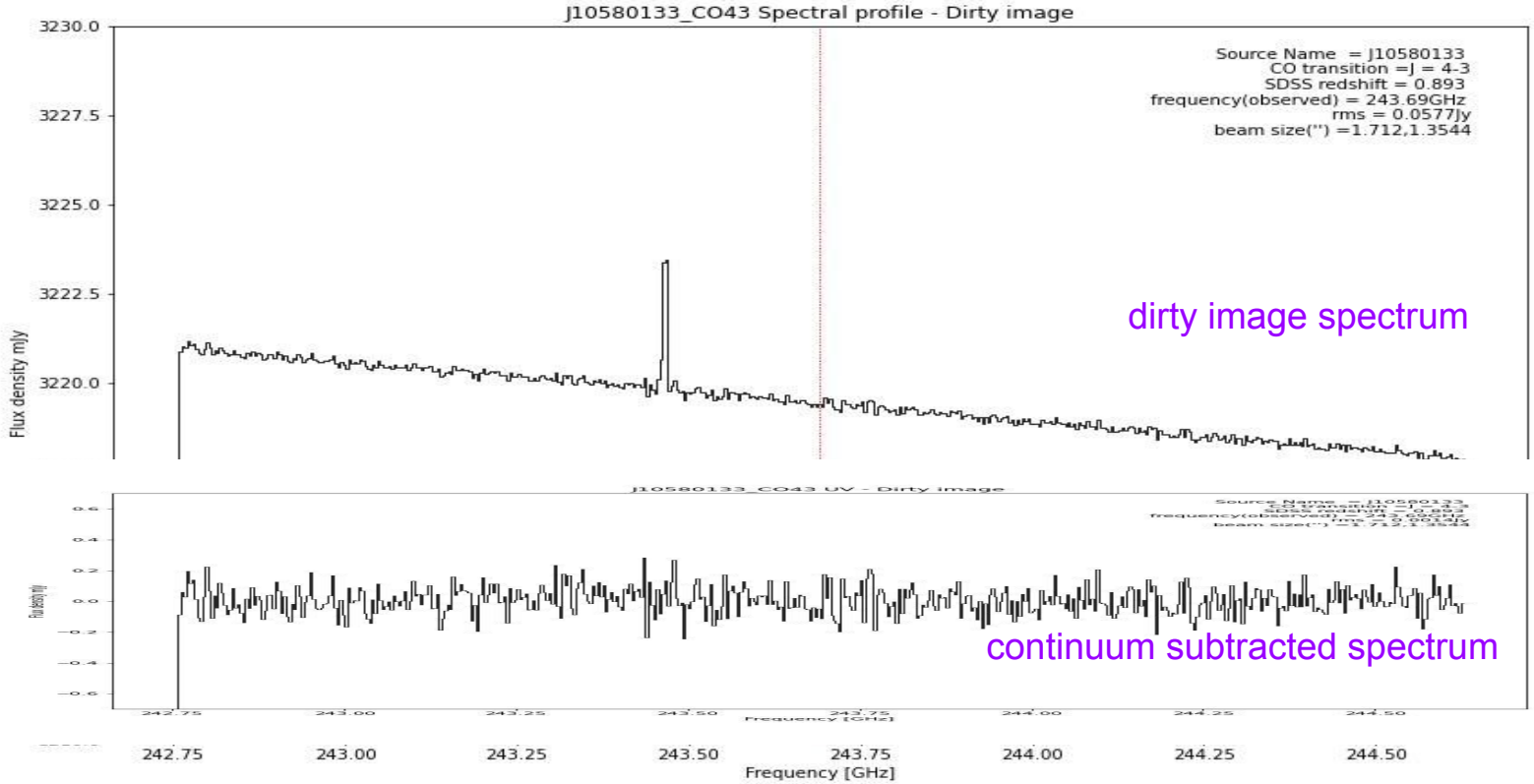


Interactive preview allows
to bin spectra.
Remember they are supposed to be previews, not final spectra for science

When a line is a line?

A bandpass calibrator observed in cycle 4.

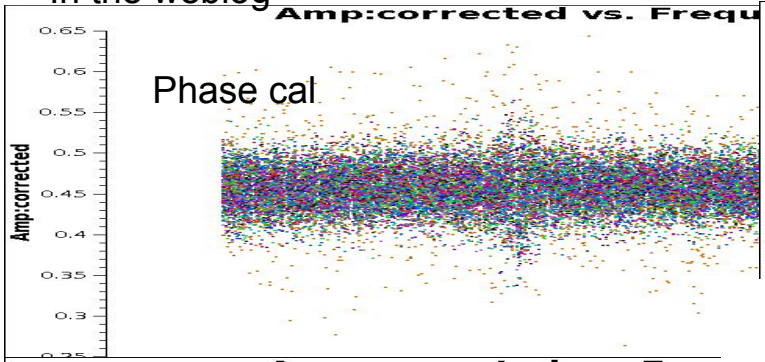
Courtesy Chandana Hedge

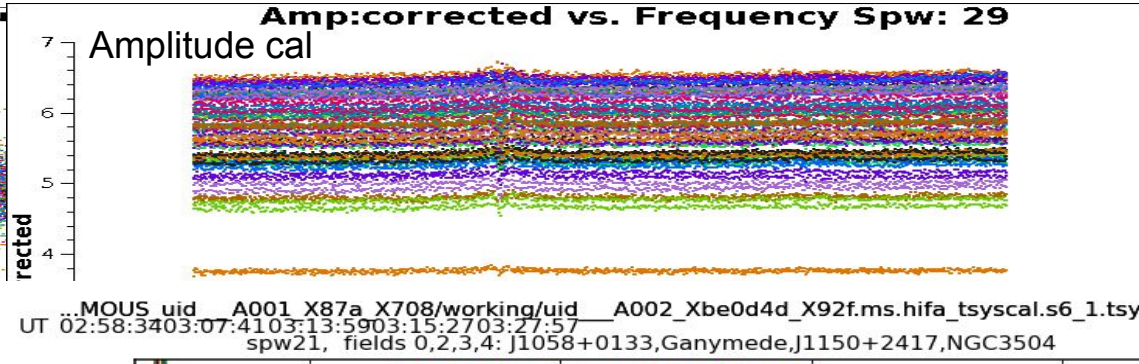


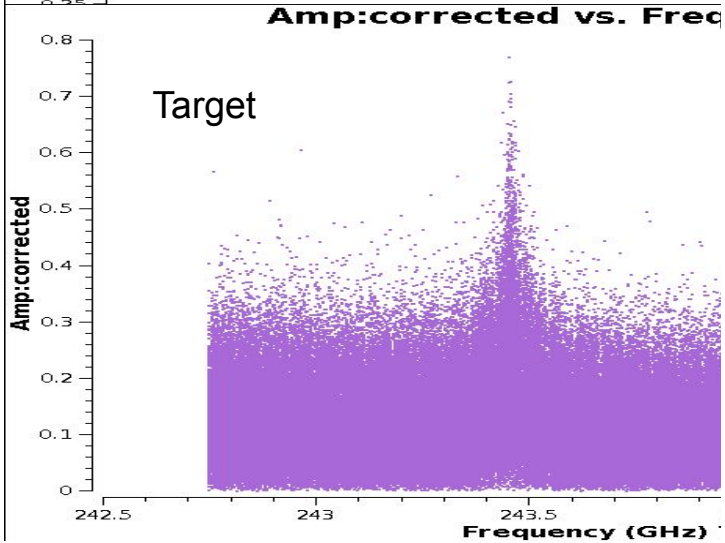
In the calibrated MS plot the Real part of visibilities: that shows also negative fluctuations due to noise

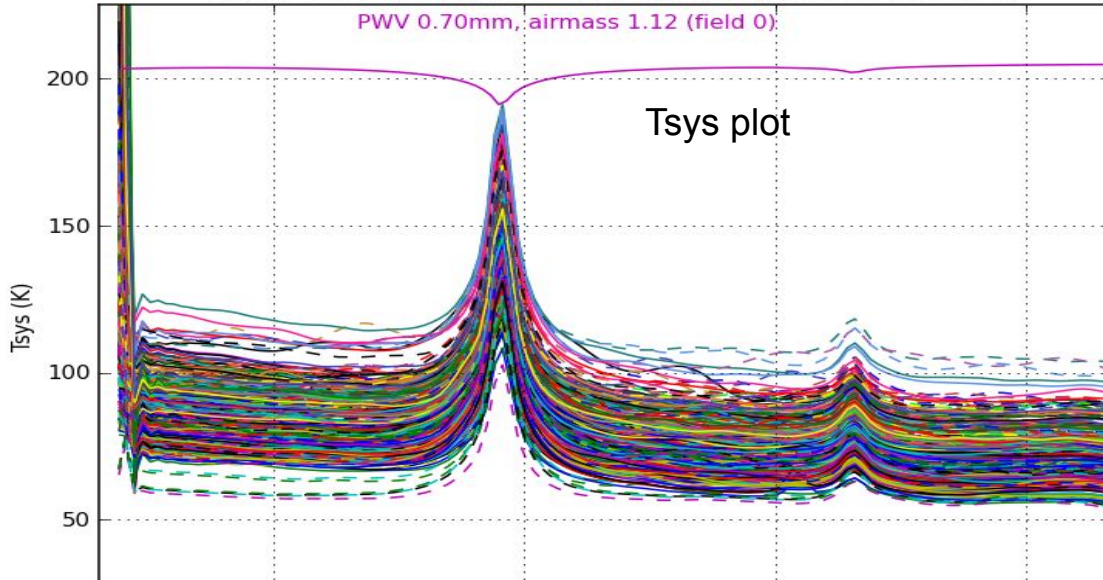
When a line is a line?

In the weblog





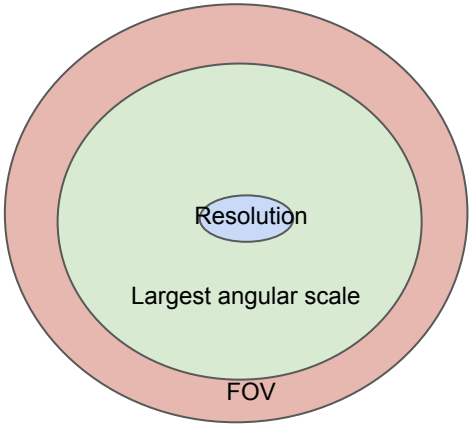




Questions?

The interferometer is a filter in angular scales

The interferometer is a filter in angular scales:
scales smaller than resolution are smoothed,
scales larger than the maximum recoverable scale are not observed.

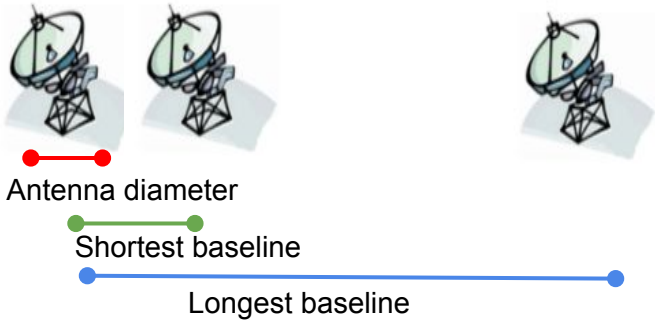


Remember that observed angular scales are associated to array lengths and observed wavelength according to

$$\theta \propto \lambda / D$$

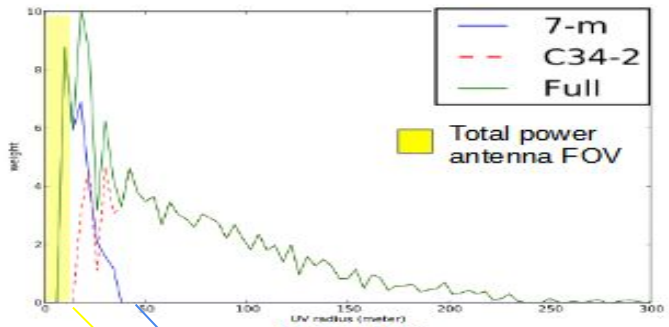
Angular scale ∝ Wavelength / Physical scale

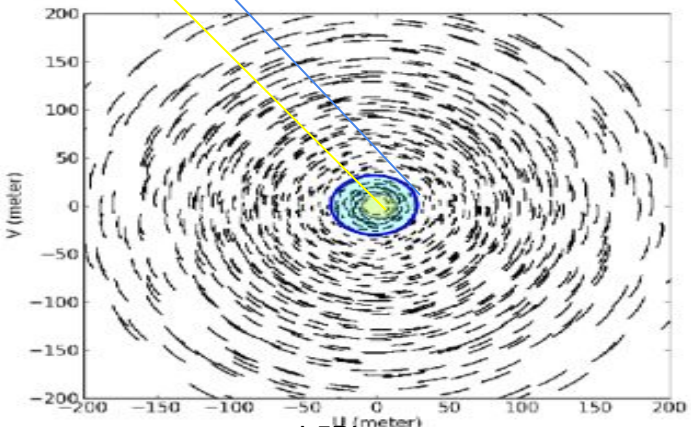
Field of View	Antenna Diameter
Angular Resolution	Longest Baseline
Largest Angular Scale	Shortest Baseline



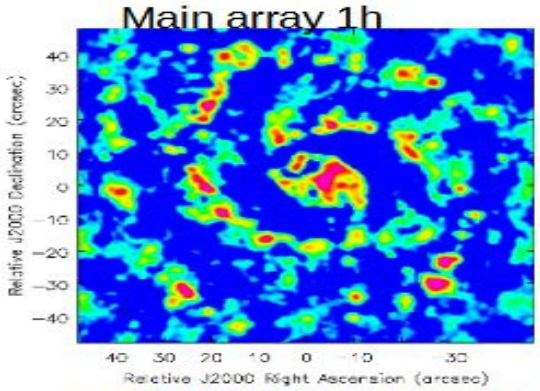
and that noise decrease with increasing the observing time

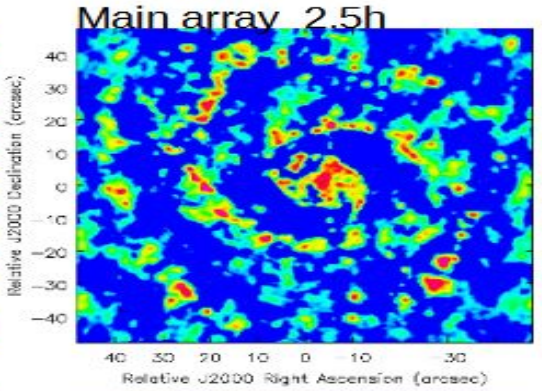
The interferometer is a filter in angular scales

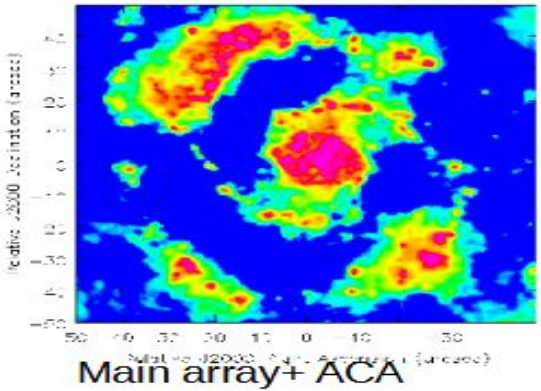


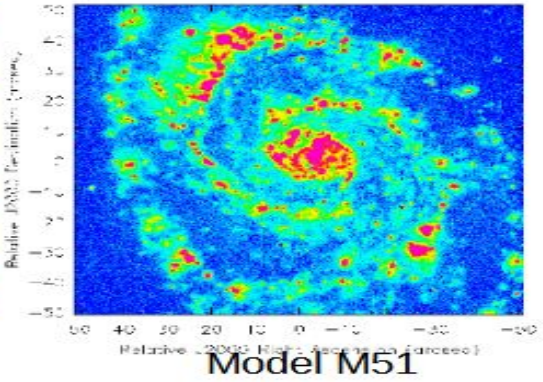


L5BL
L80BL
Longest Baseline









Data on the same scales improve sensitivity on those scales. Data on different scales reconstruct different structures/emission

How to combine data?

Mind the gaps in scales when choosing the data

To improve a detection -> combine images or ms on the same scales

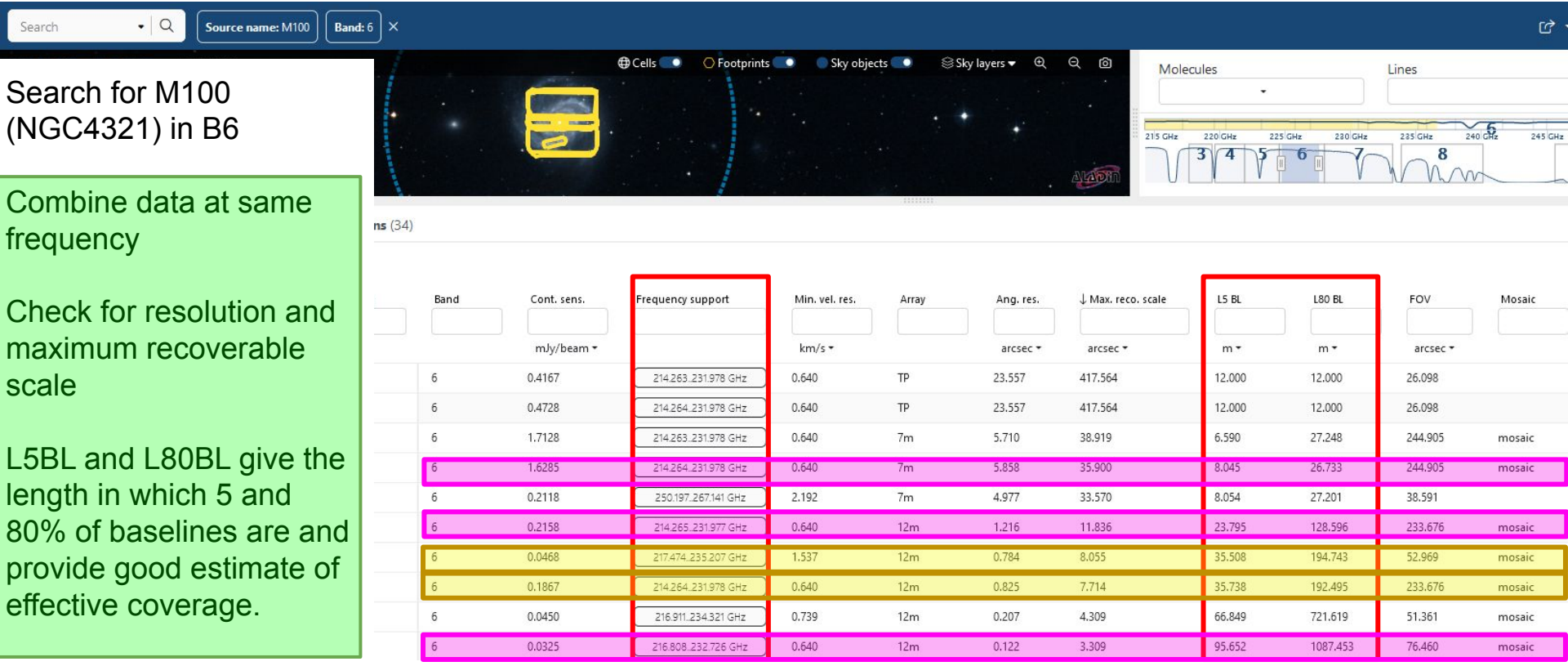
To build an image over a broader range of scales -> combine ms on different scales

Search for M100 (NGC4321) in B6

Combine data at same frequency

Check for resolution and maximum recoverable scale

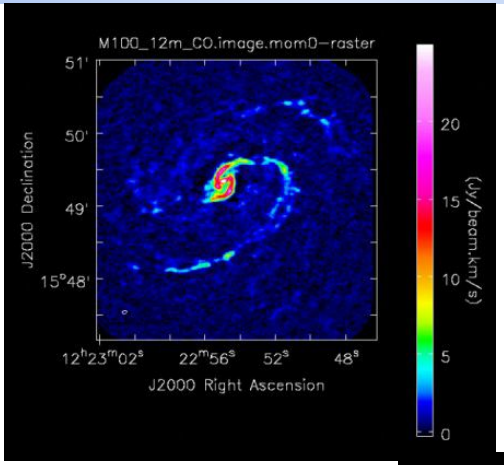
L5BL and L80BL give the length in which 5 and 80% of baselines are and provide good estimate of effective coverage.

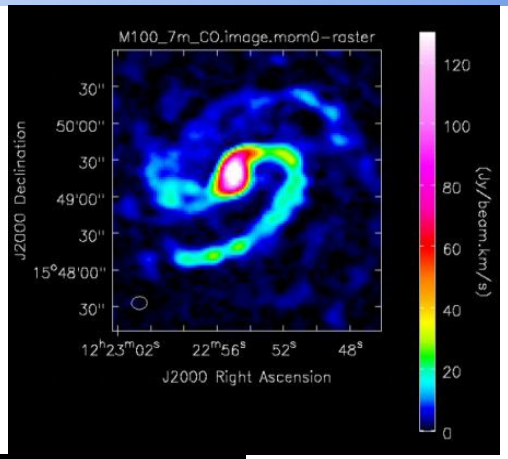


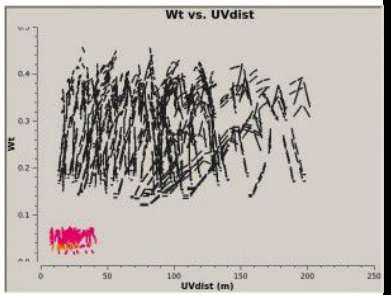
	Band	Cont. sens.	Frequency support	Min. vel. res.	Array	Ang. res.	↓ Max. reco. scale	L5 BL	L80 BL	FOV	Mosaic
		mJy/beam		km/s		arcsec	arcsec	m	m	arcsec	
	6	0.4167	214.263..231.978 GHz	0.640	TP	23.557	417.564	12.000	12.000	26.098	
	6	0.4728	214.264..231.978 GHz	0.640	TP	23.557	417.564	12.000	12.000	26.098	
	6	1.7128	214.263..231.978 GHz	0.640	7m	5.710	38.919	6.590	27.248	244.905	mosaic
	6	1.6285	214.264..231.978 GHz	0.640	7m	5.858	35.900	8.045	26.733	244.905	mosaic
	6	0.2118	250.197..267.141 GHz	2.192	7m	4.977	33.570	8.054	27.201	38.591	
	6	0.2158	214.265..231.977 GHz	0.640	12m	1.216	11.836	23.795	128.596	233.676	mosaic
	6	0.0468	217.474..235.207 GHz	1.537	12m	0.784	8.055	35.508	194.743	52.969	mosaic
	6	0.1867	214.264..231.978 GHz	0.640	12m	0.825	7.714	35.738	192.495	233.676	mosaic
	6	0.0450	216.911..234.321 GHz	0.739	12m	0.207	4.309	66.849	721.619	51.361	mosaic
	6	0.0325	216.808..232.726 GHz	0.640	12m	0.122	3.309	95.652	1087.453	76.460	mosaic

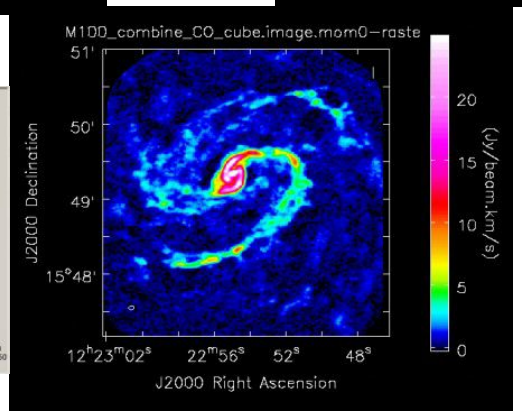
How to combine data from different arrays?

- Download raw data and calibrated them separately
- Concatenate data and select the same frequency range
- Properly weight the different datasets
- Perform imaging of concatenated data









CASA Guide on array combination
https://casaguides.nrao.edu/index.php?title=M100_Band3_Combine_6.2

How to stack images?

IF you know the distribution of emission as a function of angular scales (e.g. for a point source)
or
IF you know you are combining data on the same angular scales (e.g. from data observed in the same array conditions, but on different time otherwise also noise non-gaussianity would sum)
then
it is possible to do stacking of the images to improve the sensitivity of the detections

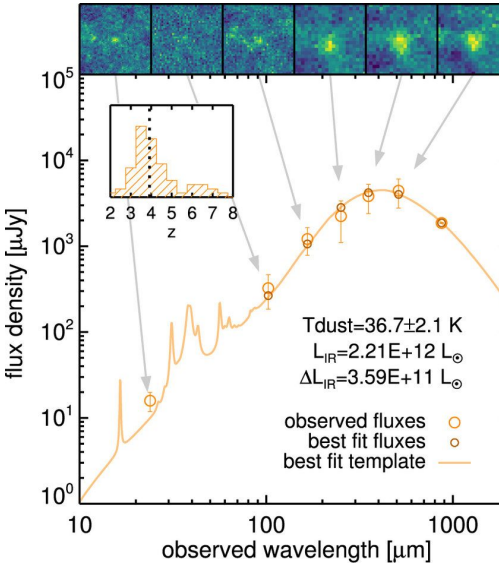
- Download the images
- Rebin the cubes to the same rest frame frequency grid
- Smooth the images to the same pixelization grid
- Average the images per pixel and channel

CAVEATS!!!!

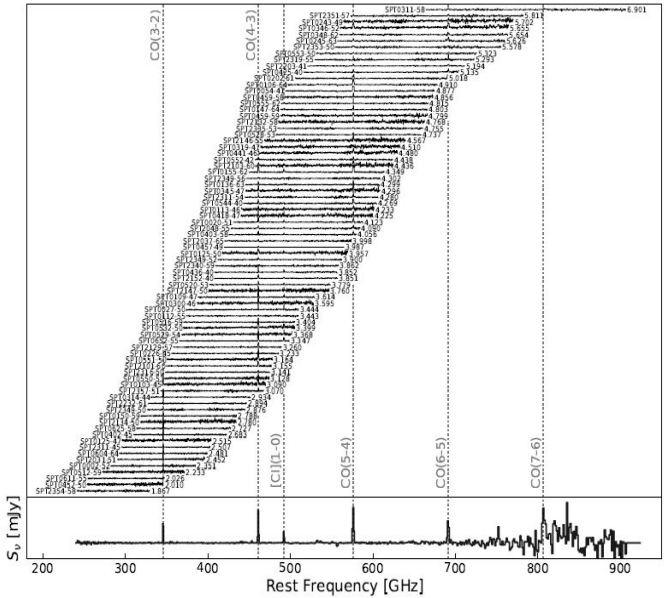
Rebinning channels in a cube is not equal to make a cube with a different spectral resolution (as uv coverage varies with the observed wavelength)
-> it can be an approximation in case of flat spectra and compact objects
-> better to start with high resolution images

Smoothing pixels in the image (=averaging close pixels) is not equal to make an image with lower resolution (=selecting/weighting baselines)
-> it can be an approximation in case the source size is always smaller than the observed largest angular scale.
-> consider that the observed scales are the same among images

How to stack images?



Wang et al. 2019
stacking of 39 H-dropouts



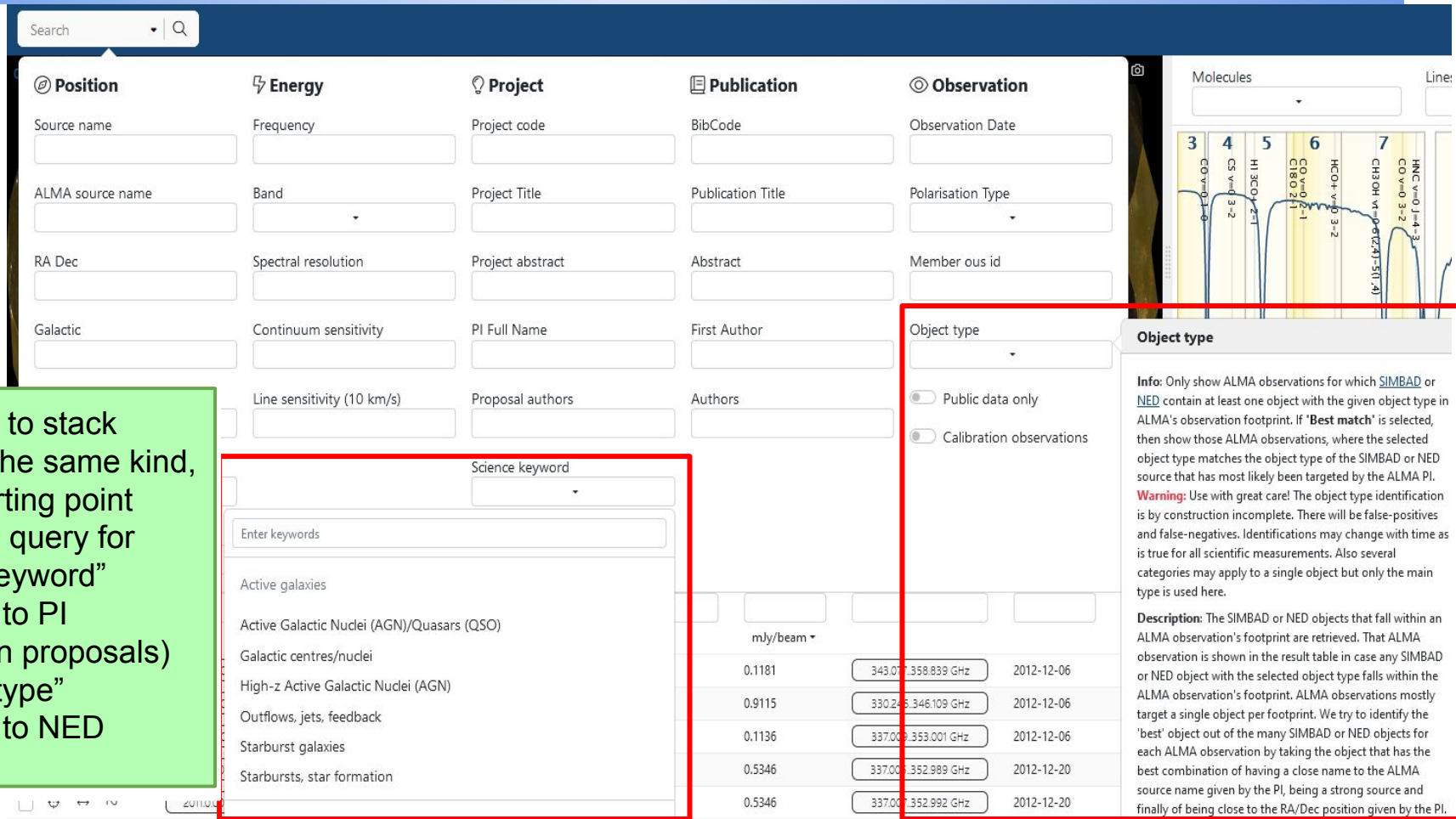
Reuter et al. 2020
stacking of 57 lensed galaxies

Typically stacking is performed on sources from the same project to guarantee the same observing conditions.

However, as it should be performed in the same rest-frame archival data from different projects might work as well.

Linestacker: https://jbjolly.github.io/LineStacker/ (Jolly et al. 2020)
I-TRAIN #9 tutorial: https://almascience.eso.org/tools/eu-arc-network/i-train
https://www.youtube.com/watch?v=1WtImPA0jcY

How to stack images?



If you want to stack objects of the same kind, a good starting point could be to query for “Science keyword” (according to PI indication in proposals) or “Object type” (according to NED definition).

Questions?

For any ALMA related issue remember that you can always contact us

https://help.almascience.org/

Now let's try to…

1) … search if a position/source has been observed as target, calibrator or spuriously in other observations (try with your favourite source, giving coordinates and/or source name…
one of my favourite is Centaurus A at 13:25:27.60 -43:01:09.4)

2) … choose a target field and identify candidate sources in the field using CARTA
(try with projID= "2013.1.00718.S" PI= "Dunlop"
or projID= "2013.1.00718.S" PI= "Aravena"
or projID= "2018.1.00035.L" PI= "Kohno")

3) … build the SED and/or a time series for a source
(try with Centaurus A, PKSJ1921-293, 3C273, 3C279)

4) … select a set of images that could be averaged or ms that could be combined
(try with local galaxies as Centaurus A, NGC5135 or NGC2992, or 3C273 and 3C279)

5) … select a set of images that could be stacked
(try searching all the "high-z Active Galactic Nuclei", of which you know the redshift)