Frequently Asked Questions

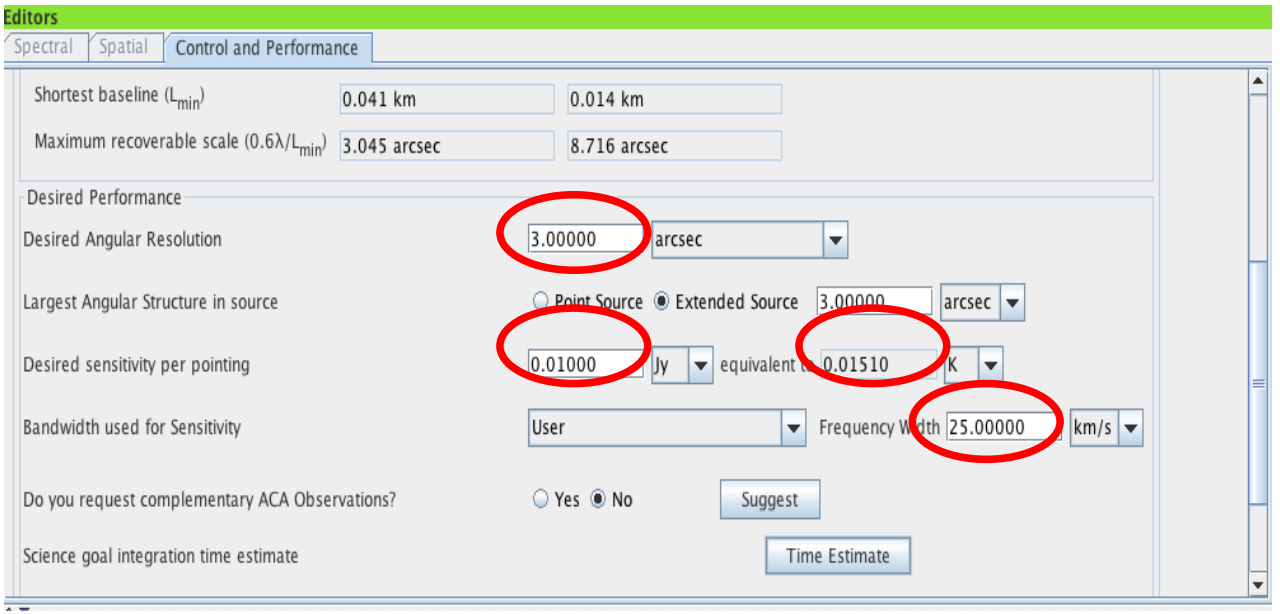
AM, EL, JB

Italian ARC, Tutorial per ALMA Cycle 2

21 November 2013, Bologna

AIM

- Provide tips to fill in the Observing Tool Fields
  - Field Setup: expected source properties
    - Peak continuum flux density per beam
    - Peak line flux density per beam
  - Control and performance
    - Largest angular scale
    - Use of ACA
  - Spectral line issues



Flux and Brightness Temperature

- Temperature and Fluxes (Rayleigh-Jeans)
  - S = Flux density (Jy, Jy per beam)
  - T = brightness temperature (K)
  - k Boltzmann constant
  - Ω_S solid angle (steradian)
  - θ_b HPBW of a gaussian

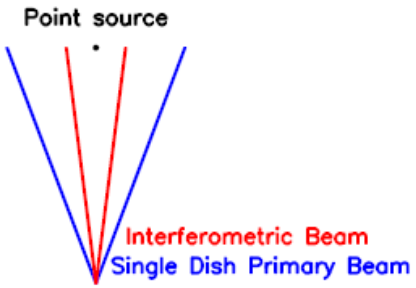
$$S = \frac{2\,k\,T\,\Omega_S}{\lambda^2}$$

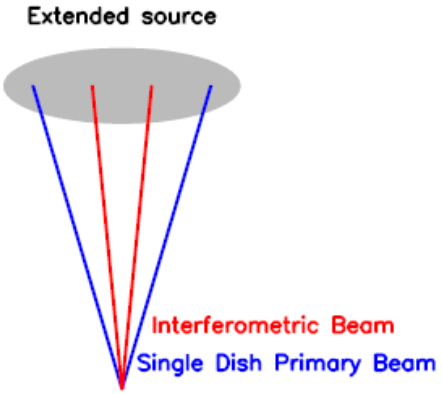
$$T = \frac{\lambda^2\,S}{2\,k\,\Omega_S}$$

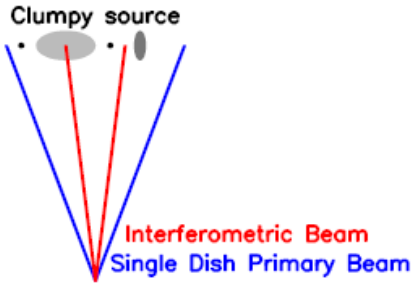
$$\Omega_S = \frac{\pi\,\theta_b^2}{4\,ln2}$$

Peak Flux estimation

- From observations at different resolution
  - Point source:
    - Flux (Jy or Jy/beam) independent of the Beam
    - $T\,(K) \propto 1/\mathrm{BeamSize}^2$
  - Extended uniform source
    - T independant of the beam
    - Flux (Jy /beam) $\propto \mathrm{BeamSize}^2$
      - [if brightness is uniform over the source]
    - Largest recoverable angular scale !
      - Flux loss because a part extended emission is filtered out by the interferometer
  - Fragmented/Clumpy source
    - Number of clumps, size, relative strength, positions ?

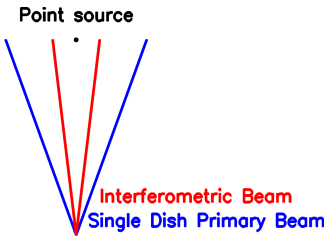




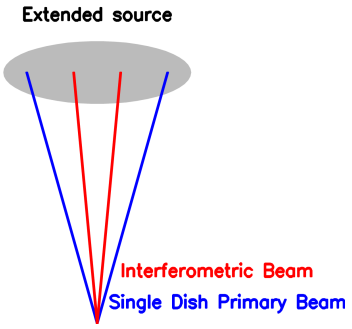


Peak Flux estimation

single dish vs. interferometry



- From Single Dish (10") to Interferometry (1")
  T_{mb} = 1 K in 10" @ 300 GHz
  Flux = 7.36 Jy in 10" @ 300 GHz



- Point source
  - Flux is constant! $F_{int}=F_{SD}$
  - $T_{int} = T_{SD}*(Beam_{SD}/Beam_{int})^2$
    - F = 7.36 Jy/beam
    - T_{MB}= 100K

- Extended (uniform) source
  - T is constant
  - $F_{int} = F_{SD}*(Beam_{int}/Beam_{SD})^2$
    - F = 0.0736 Jy/beam
    - !! Largest recoverable scale !!

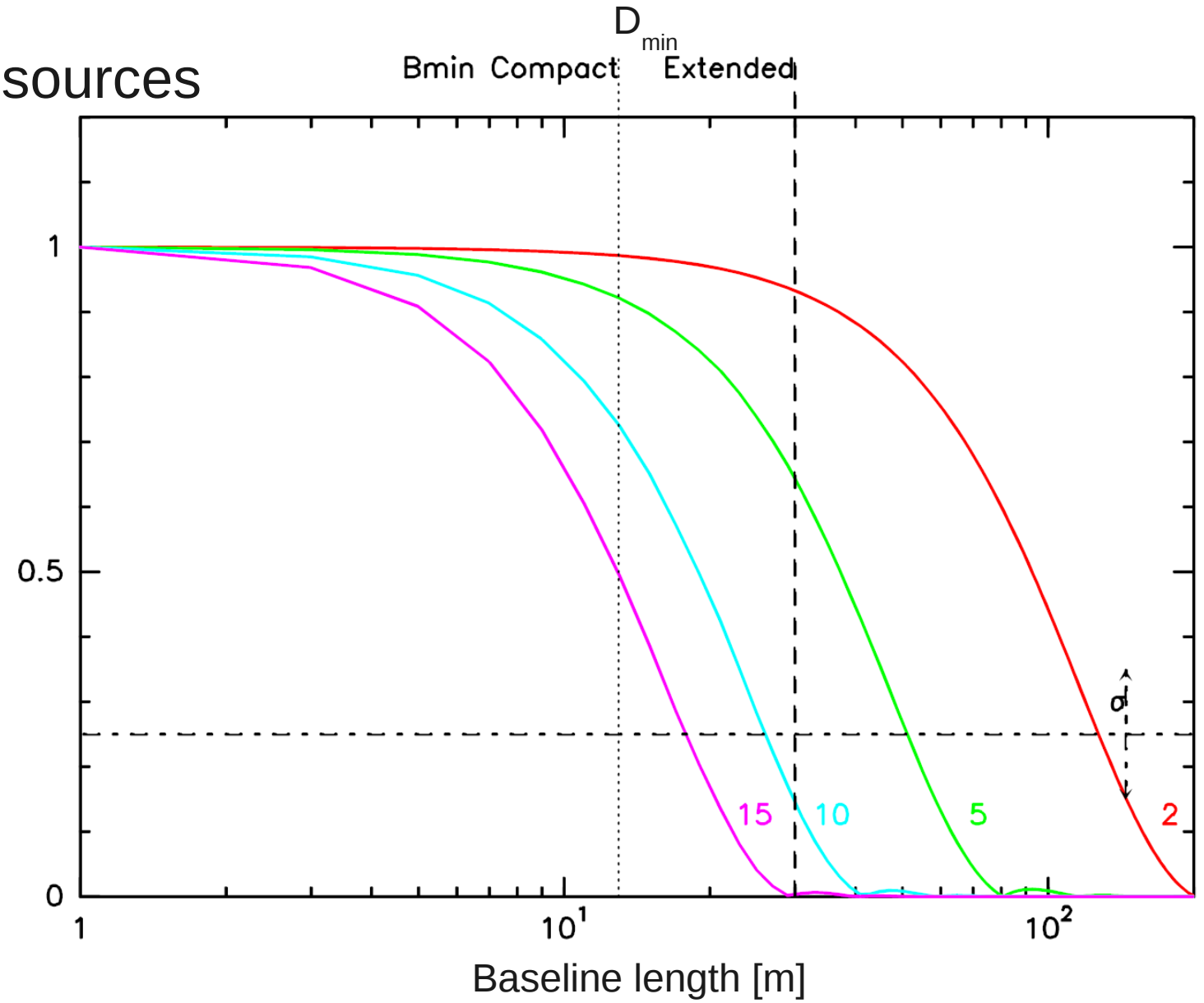
2 different assumptions lead to a factor 10000 in exp time!

Largest Recoverable Scale

- Baselines > antenna size
  - Short spacing are missing in interferometry
  - Filtering of large scale emission
- LRS [´´] = 37200/D_{min}[m]/υ[GHz]
- ALMA (Main Array) Cycle 2 at 300 GHz
  - Compact configurations LRS ~ 7-8"
  - Most extended configurations LRS ~ 2-3"

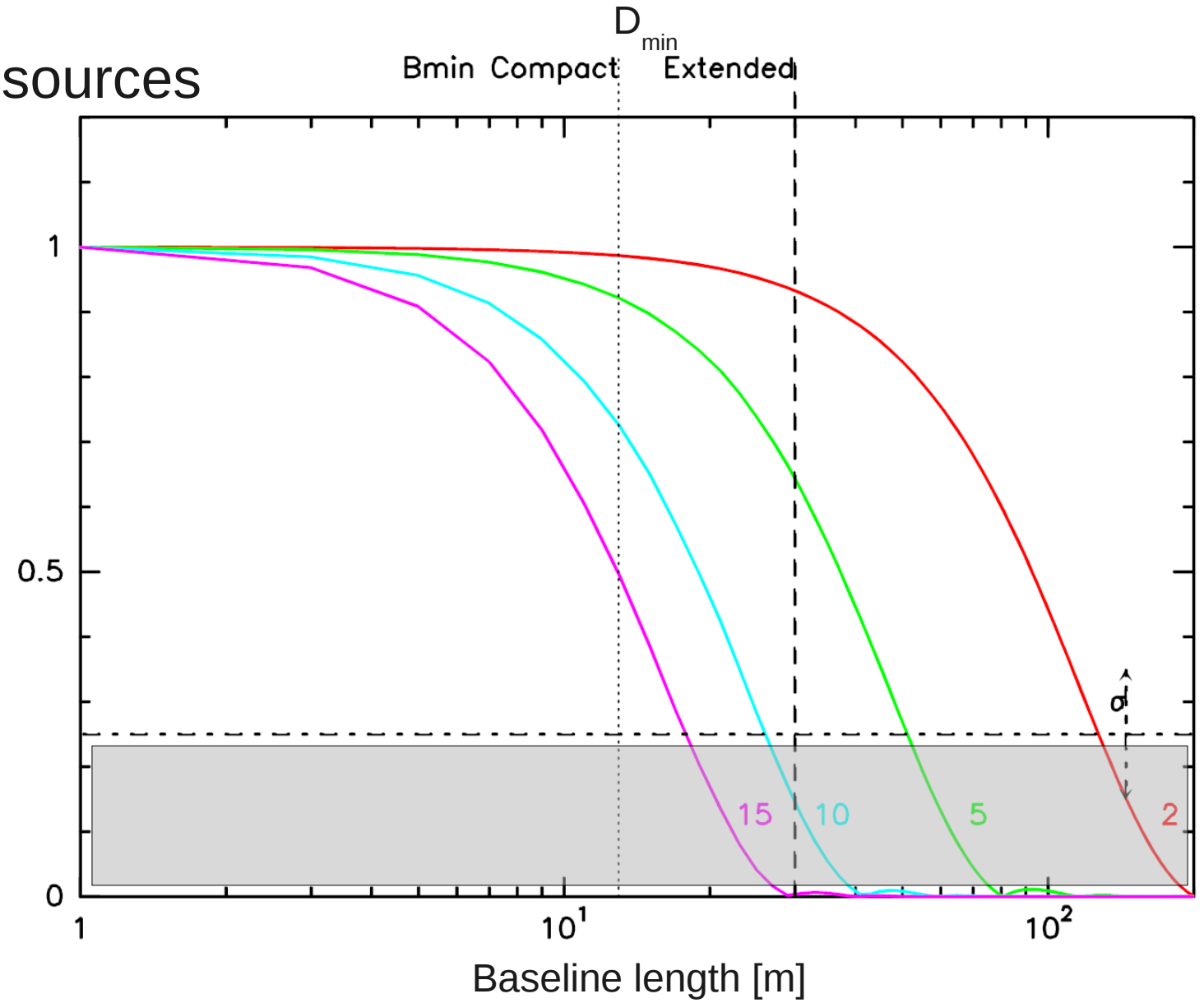
Largest Recoverable Scale

- Gaussian sources



Largest Recoverable Scale

- Gaussian sources



Largest Recoverable Scale

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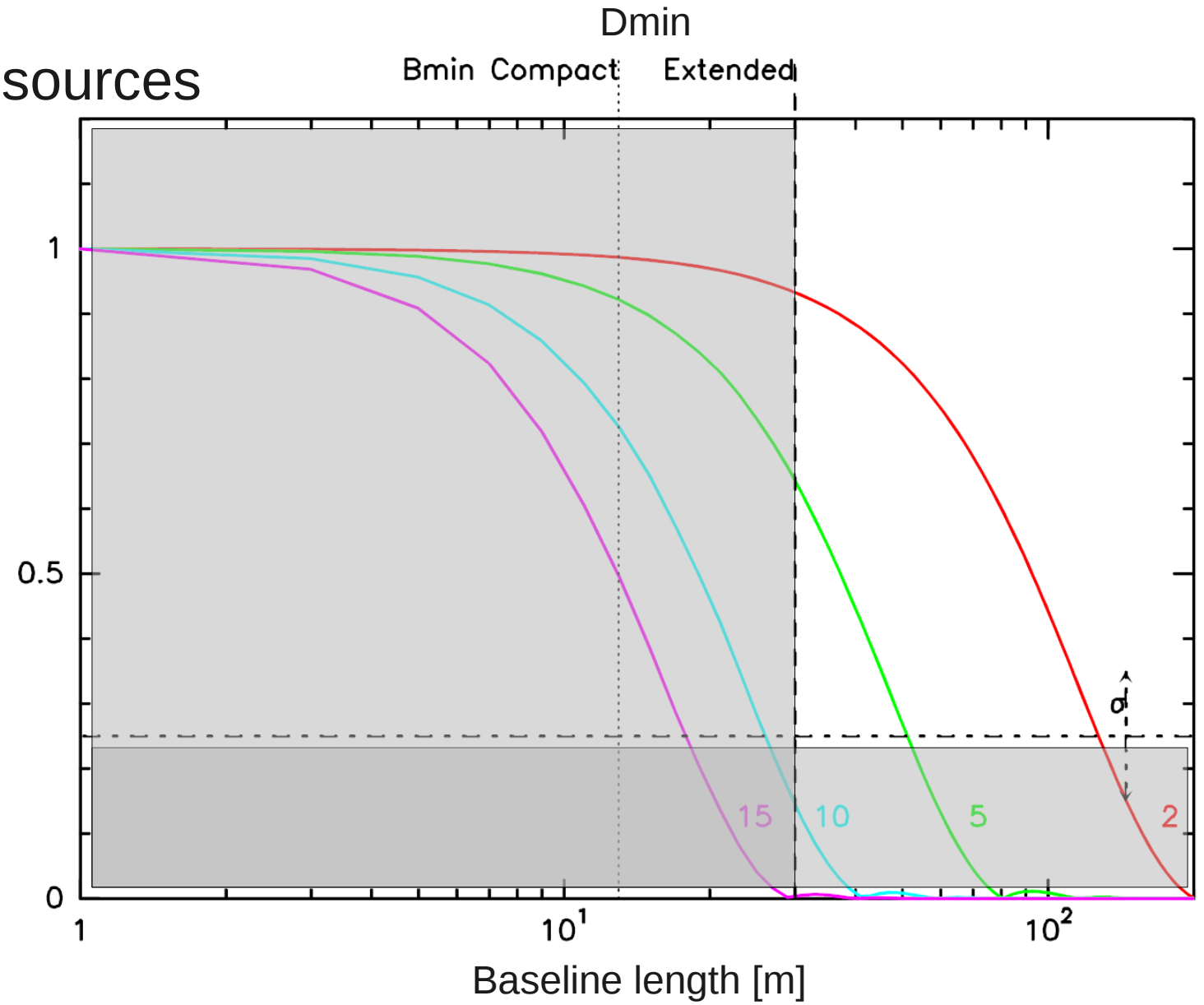
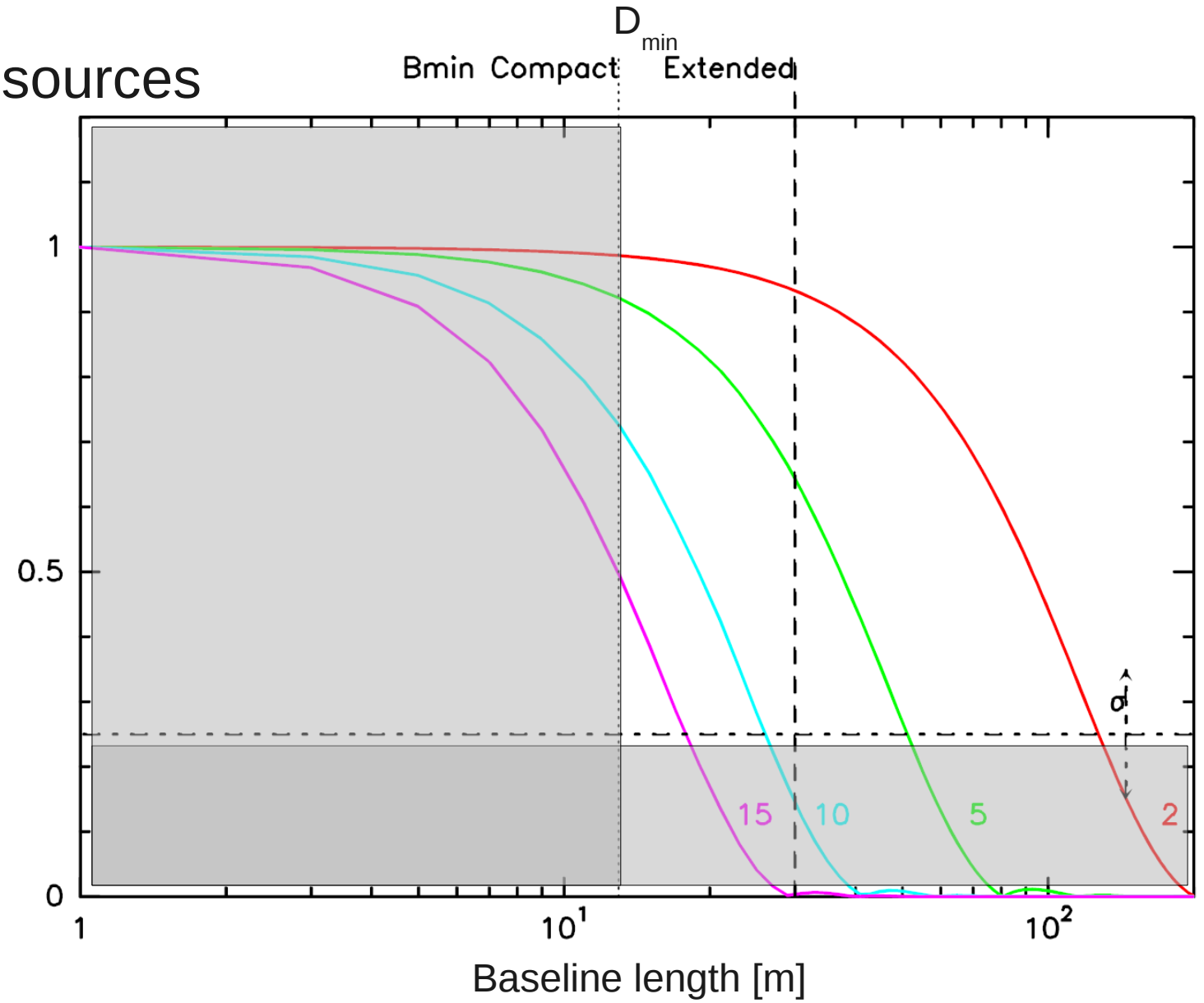


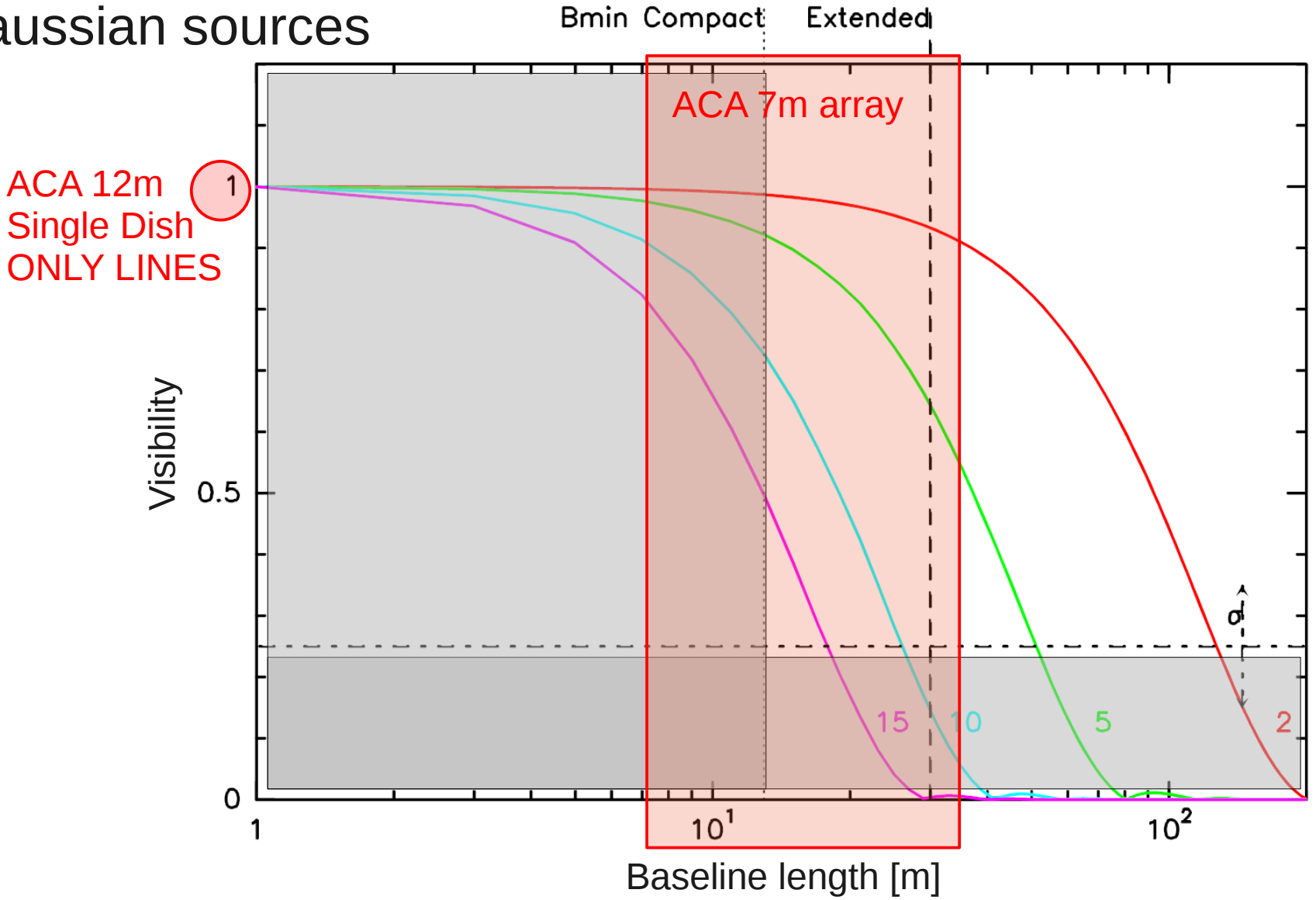
Largest recoverable scale

- Gaussian sources



Largest recoverable scale and ACA

- Gaussian sources



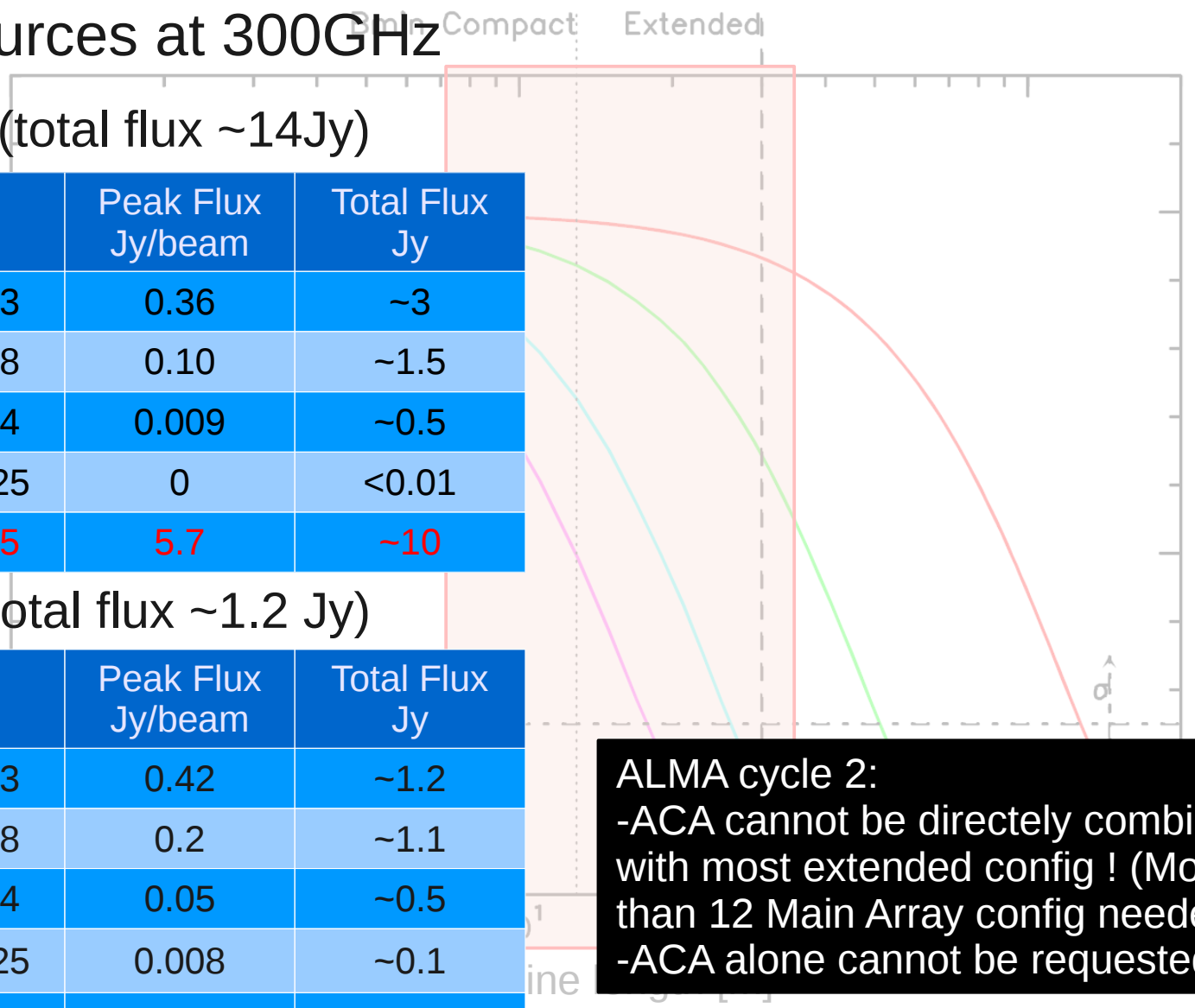
Largest Recoverable Scale and ACA

- Gaussian sources at 300GHz
  - FWHM 10" (total flux ~14Jy)

Config.	Beam "	Peak Flux Jy/beam	Total Flux Jy
1	1.4 x 1.3	0.36	~3
2	0.9 x 0.8	0.10	~1.5
4	0.6 x 0.4	0.009	~0.5
6	0.5 x 0.25	0	<0.01
ACA alone	5.8 x 5.5	5.7	~10

  - FWHM 3" (total flux ~1.2 Jy)

Config.	Beam "	Peak Flux Jy/beam	Total Flux Jy
1	1.4 x 1.3	0.42	~1.2
2	0.9 x 0.8	0.2	~1.1
4	0.6 x 0.4	0.05	~0.5
6	0.5 x 0.25	0.008	~0.1
ACA alone	5.8 x 5.5	1.13	~1.2

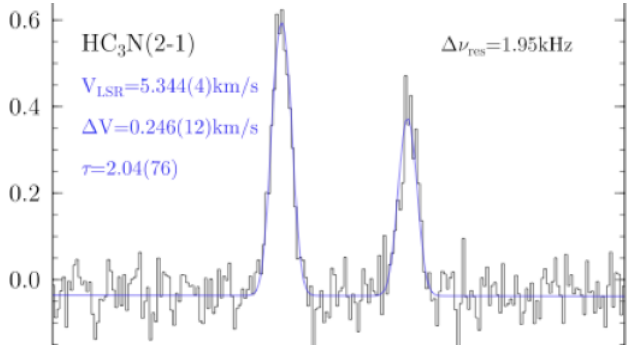


ALMA cycle 2:
-ACA cannot be directely combined with most extended config ! (More than 12 Main Array config needed)
-ACA alone cannot be requested

Spectral lines issues

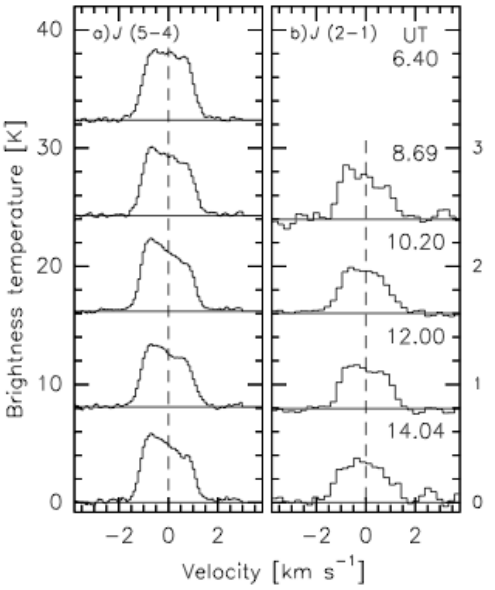
- Gaussian profile
  - Area(Jy kms^{-1}), FWHM (kms^{-1}) → Flux Peak (Jy)
    - SN on the peak

$$rms(Jy) = \frac{Area(Jy \cdot kms^{-1})}{FWHM(kms^{-1}) \cdot SN}$$

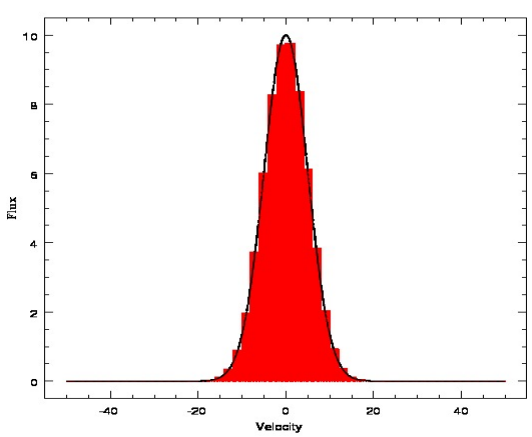


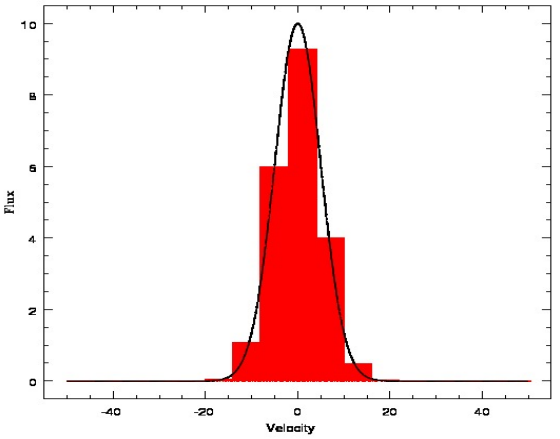
- Undefinied Profile
  - SN on the area (>SN on the peak)

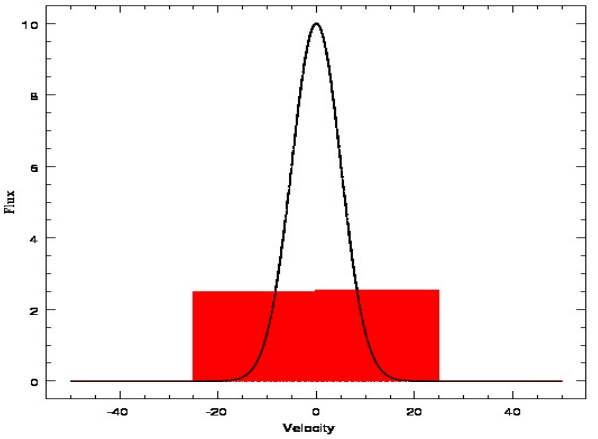
$$rms(Jy) = \frac{Area(Jy \cdot kms^{-1})}{N_{chan}^{1/2} \cdot \Delta\nu(kms^{-1}) \cdot SN}$$



- Peak Flux doesn't depend on channel spacing (when FWHM > chan width)







- Sensitivity depends on channel spacing

$$\Delta S \propto \frac{T_{sys}}{D^2\left[n_p N(N-1)\Delta\nu\Delta t\right]^{1/2}} Wm^{-2}Hz^{-1}$$

… and now a practical example

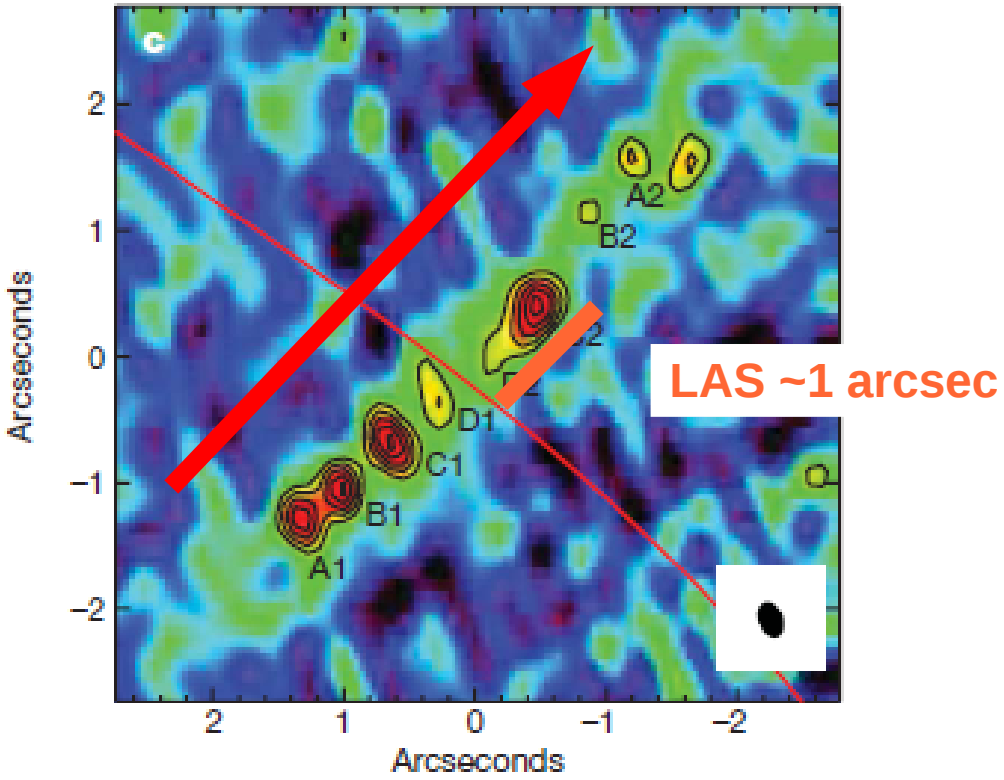
Resolve at high frequency the continuum and molecular gas in a distant (z=2,3) lensed starburst galaxy: Cosmic Eyelash

- **New ALMA observations** in band 7 (312 GHz): CO (9-8) + continuum

- **Previous observations:**

SMA at 850 μm (Band 7) continuum:

Ext = 5 arcsec



Angular resolution: θ_{SMA}=0.2 "

Multiple components

Source angular size = 5 "

LAS = 1"

S(tot)=86 mJy

f.c= 6 mJy= 3 rms

Before you propose

- A science case
- Source coordinates, radial velocity, proper motion
- **Observing frequency, bandwidth, spectral resolution**
- **Angular resolution and LAS**
- **Required sensitivity**
- Dynamic range

Resolve the continuum and molecular gas in distant lensed starburst galaxy

- Previous observations: CO(3-2) with SMA, resol. ~
- Receivers: Band 7 (CO(9-8) + continuum)
- Angular resolution: 0.3 arcsec to resolve components detected by SMA.
  ACA is not needed.
- Spectral resolution: TDM --> one sideband for CO(9-8) + 3 for continuum
- Spectral sensitivity: CO(9-8) peak flux density is expected 10 mJy,
  S/N~20 at the peak in 100 km/s is required
- --> rms= 0.5 mJy for line emission
- --> average channels
- --> rms = 70 μJy for continuum
- --> S/N>15 (1 mJy continuum emission expected)

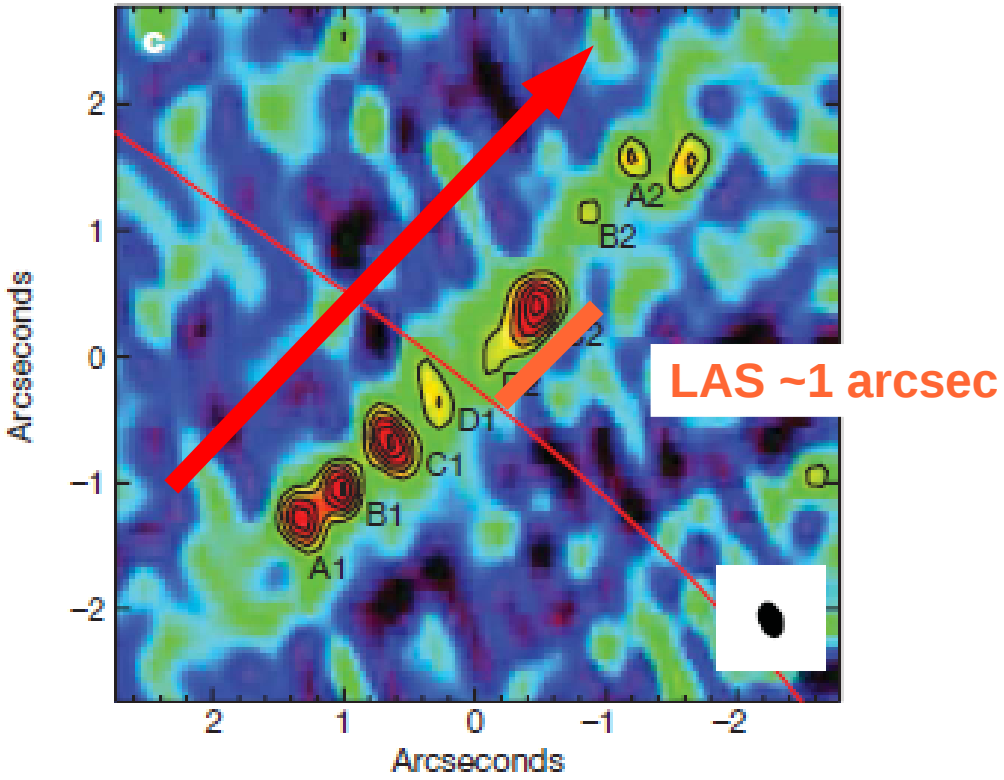
Resolve at high frequency the continuum and molecular gas in a distant lensed starburst galaxy: Cosmic Eyelash

- **New ALMA observations** in band 7 (350 GHz): CO (9-8) + continuum

- **Previous observations:**

SMA at 850 µm (Band 7):

Ext = 5 arcsec



LAS ~1 arcsec

Angular resolution: θ_{SMA}=0.2 "

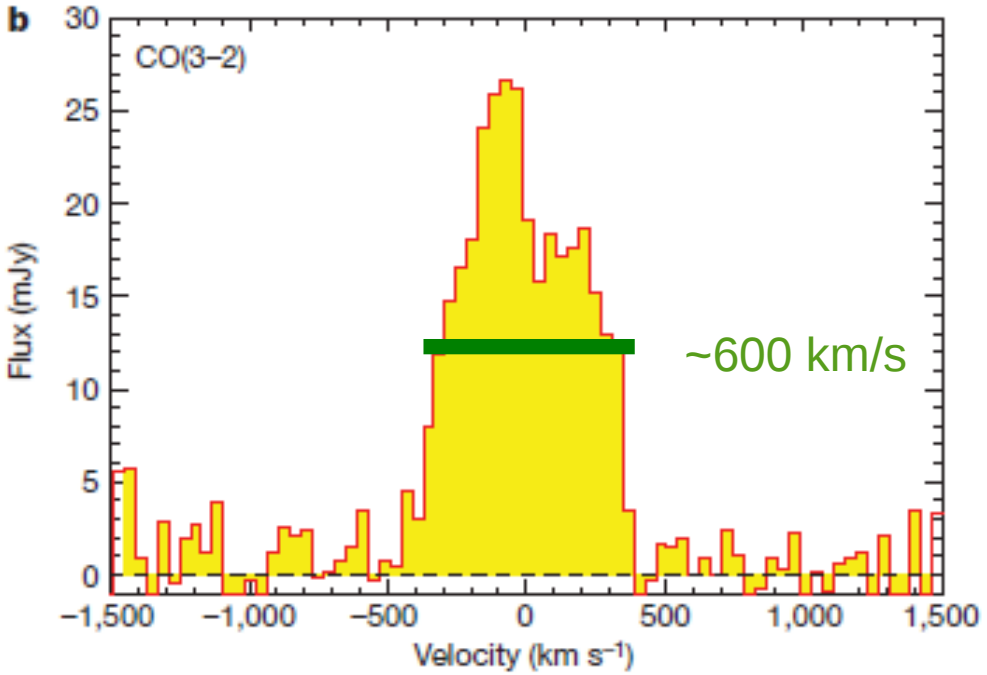
Multiple components

Source angular size = 5 "

LAS = 1"

Resolve at high frequency the continuum and molecular gas in a distant (z=2,3) lensed starburst galaxy: Cosmic Eyelash

- **Previous observations:** PdB at 104.5 GHz (Band 3):CO(3-2)



Gaussian Profile

FWHM$_{[CO(3-2)]}$= 600 km s^{-1}

F$_{[CO(3-2)]}$= 13.8 Jy km s^{-1}

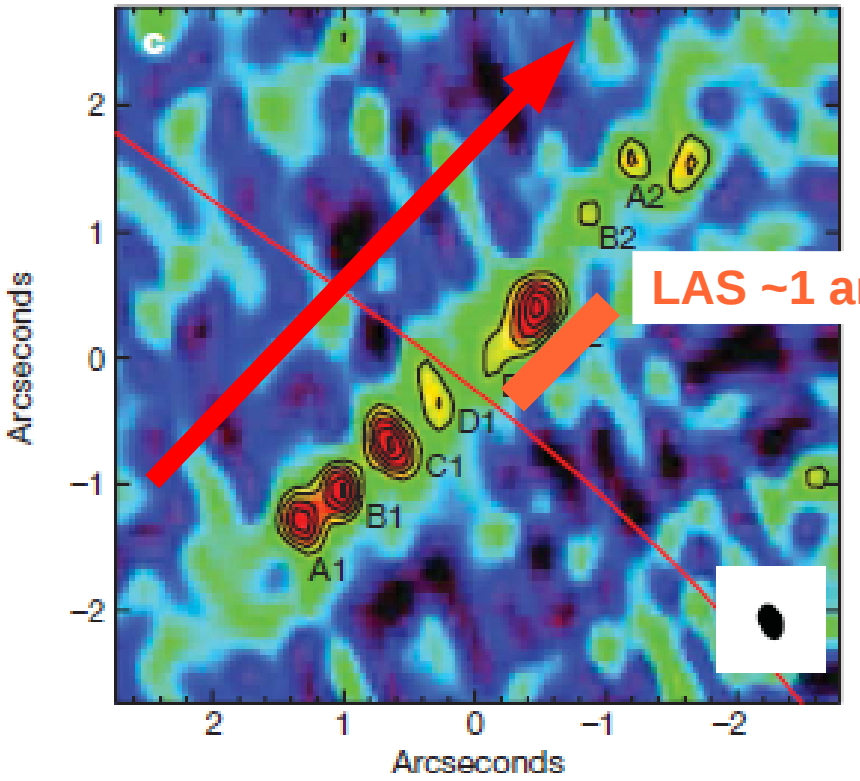
F$_{peak}$$_{[CO(3-2)]}$= F$_{[CO(3-2)]}$/ FWHM$_{[CO(3-2)]}$ = 23 mJy

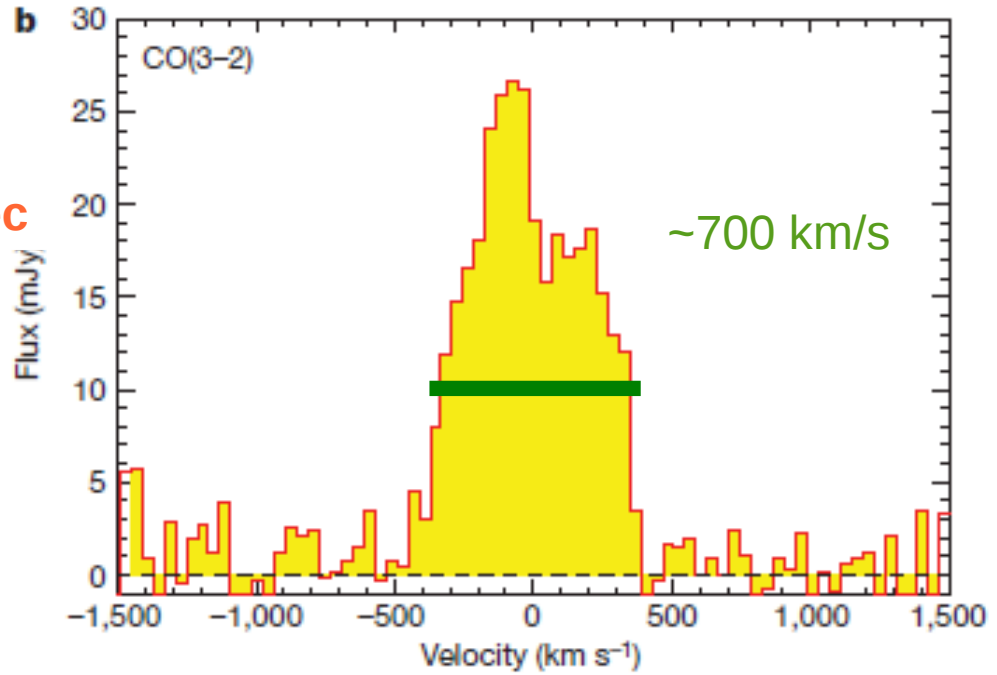
Angular resolution: θ_{PdBI}=1 "

Resolve at high frequency the continuum and molecular gas in a distant lensed starburst galaxy: Cosmic Eyelash

- Previous observations:

Ext = 5 arcsec





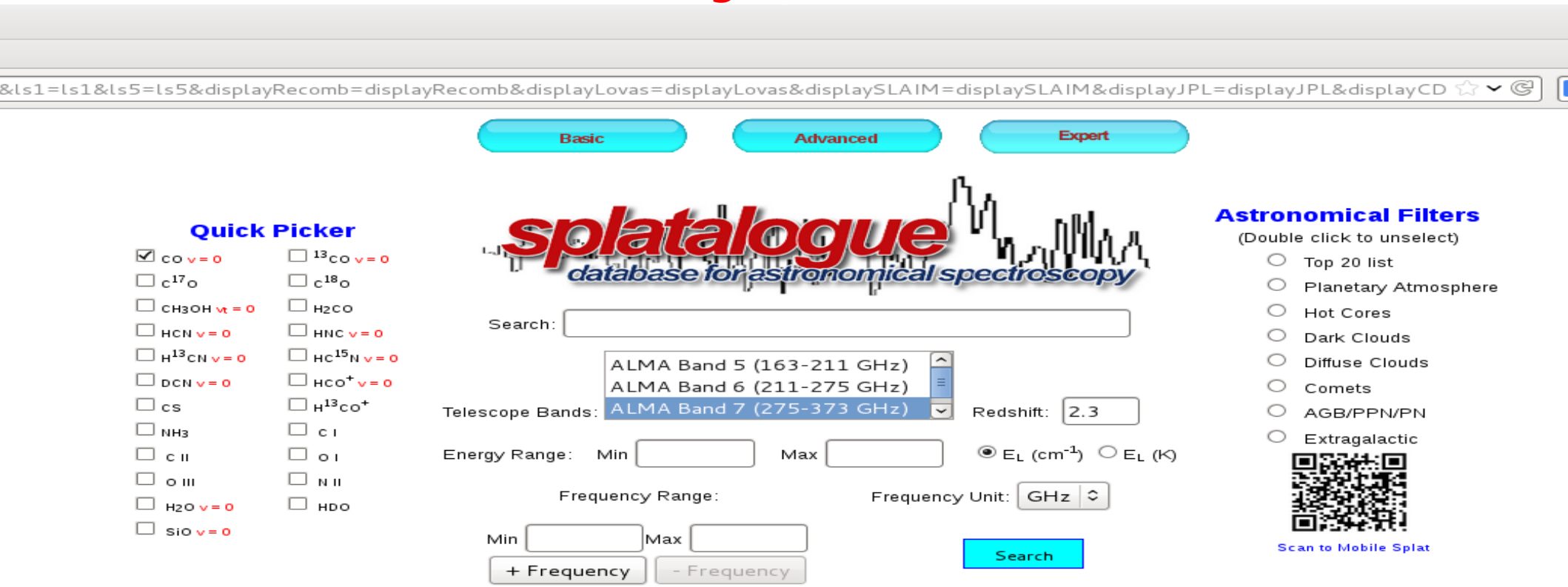
SMA at 850 μm (Band 7):
0.2 arcsec of resolution,
S=86 mJy
f.c= 6 mJy

PdB at 104.5 GHz (Band 3):
CO(3-2)

Which CO line at given z and band?

http://www.cv.nrao.edu/php/splat/

Which CO line at given z and band?



Found 3 lines in ALMA Band 7 (275-373 GHz), showing 1 - 3

	Species	Chemical Name	Ordered Freq (GHz) (rest frame, redshifted)	Resolved QNs	CDMS/JPL Intensity	Lovas/AST Intensity	E_L (cm^{-1})	Linelist
1	CO v = 0	Carbon Monoxide	921.79970, 279.33324	8- 7	0.00000		107.64200	SLAIM
2	CO v = 0	Carbon Monoxide	1036.91239, 314.21587	9- 8	0.00000	17.5	138.39000	SLAIM
3	CO v = 0	Carbon Monoxide	1151.98544, 349.08650	10- 9	0.00000		172.97800	SLAIM

Query took 0 seconds

Export current fields
Export current fields without Resolved QNs
Export CASA fields

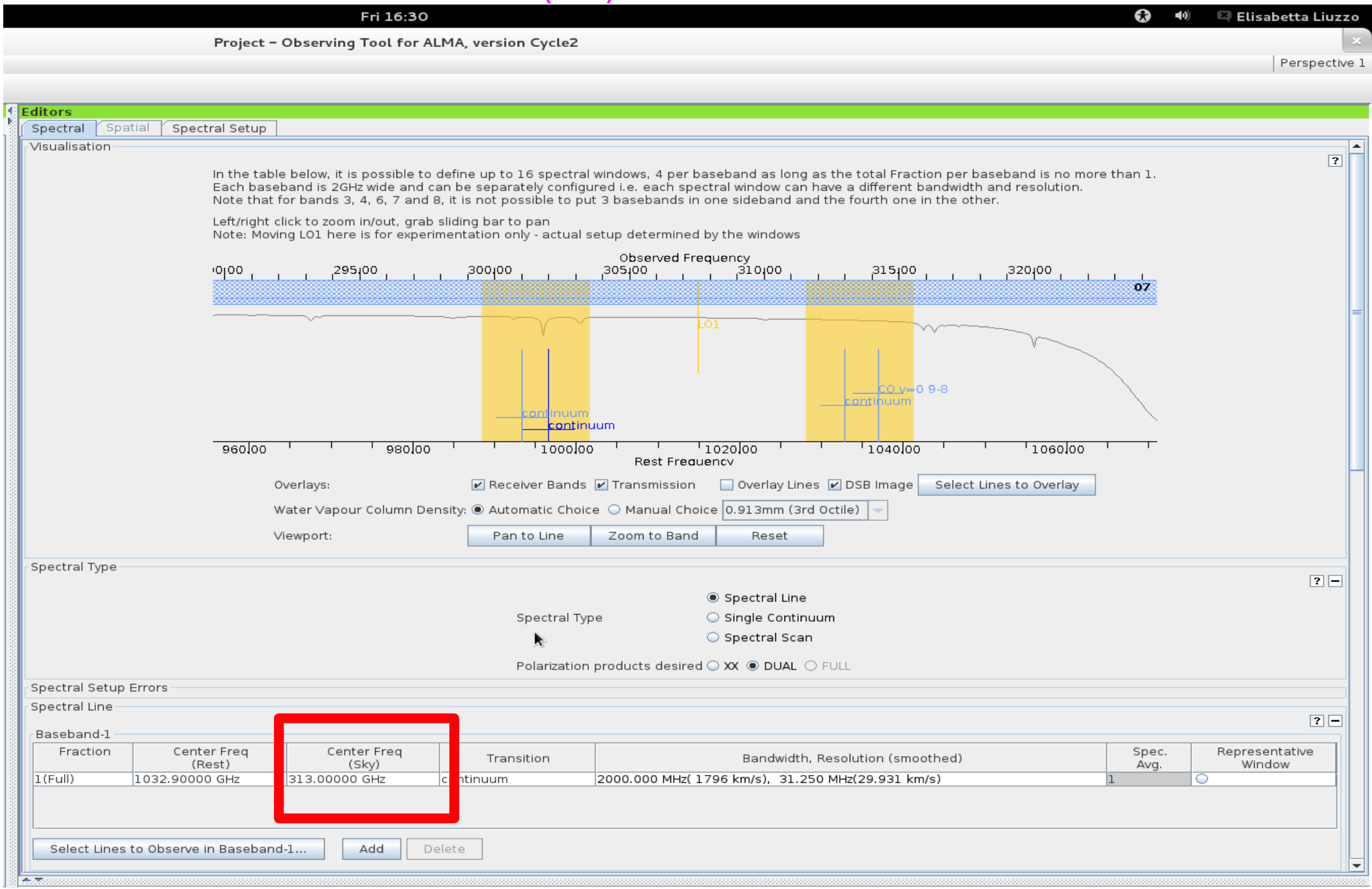
Field Separator
Tab
Colon

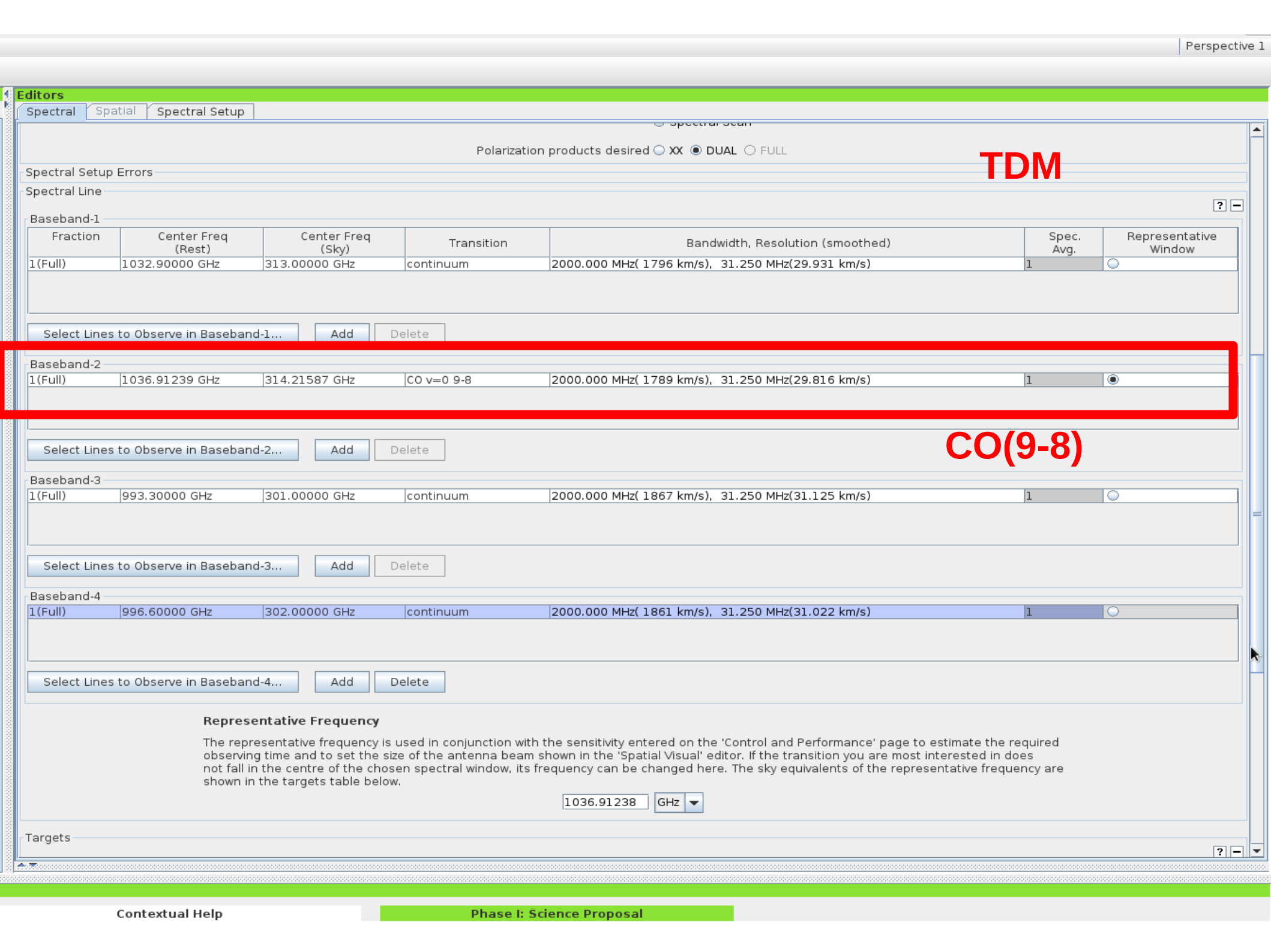
Range
All Records
Current Page

Export

New ALMA observations in band 7 (312 GHz): CO (9-8) + continuum in 1 SG

1 baseband for CO (9-8) + 3 basebands for continuum




Perspective 1
Editors
Spectral
Spatial
Spectral Setup
Polarization products desired XX DUAL FULL
TDM
Spectral Setup Errors
Spectral Line
Baseband-1
Fraction
Center Freq (Rest)
Center Freq (Sky)
Transition
Bandwidth, Resolution (smoothed)
Spec. Avg.
Representative Window
1(Full) 1032.90000 GHz 313.00000 GHz continuum 2000.000 MHz(1796 km/s), 31.250 MHz(29.931 km/s) 1
Select Lines to Observe in Baseband-1...
Add
Delete
Baseband-2
1(Full) 1036.91239 GHz 314.21587 GHz CO v=0 9-8 2000.000 MHz(1789 km/s), 31.250 MHz(29.816 km/s) 1
CO(9-8)
Select Lines to Observe in Baseband-2...
Add
Delete
Baseband-3
1(Full) 993.30000 GHz 301.00000 GHz continuum 2000.000 MHz(1867 km/s), 31.250 MHz(31.125 km/s) 1
Select Lines to Observe in Baseband-3...
Add
Delete
Baseband-4
1(Full) 996.60000 GHz 302.00000 GHz continuum 2000.000 MHz(1861 km/s), 31.250 MHz(31.022 km/s) 1
Select Lines to Observe in Baseband-4...
Add
Delete
Representative Frequency
The representative frequency is used in conjunction with the sensitivity entered on the 'Control and Performance' page to estimate the required observing time and to set the size of the antenna beam shown in the 'Spatial Visual' editor. If the transition you are most interested in does not fall in the centre of the chosen spectral window, its frequency can be changed here. The sky equivalents of the representative frequency are shown in the targets table below.
1036.91238
GHz
Targets
Contextual Help
Phase I: Science Proposal

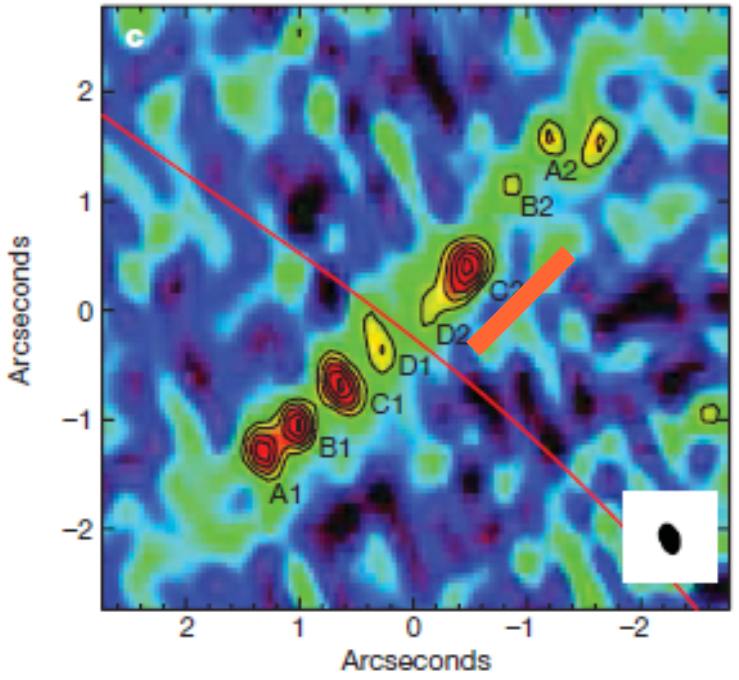
Resolve at high frequency the continuum and molecular gas in a distant (z=2,3) lensed starburst galaxy: Cosmic Eyelash

- **New ALMA observations** in band 7 (350 GHz): CO (9-8) + continuum

- **Required angular resolution?**

In band 7, ALMA allows 0.13 – 1.19 '' -->e.g. ask $\theta_{ALMA} \sim \theta_{SMA} = 0.2$ ''

MRS permitted is 2,9 arcsec for the extended config and 8,3 arcsec for the most compact configuration --> LAS **estimated** is 1 arcsec < MRS from SMA continuum image → ok, no ACA!



SMA Band 7 continuum

θ_{SMA}=0.2 ''

LAS ~1 arcsec

Resolve at high frequency the continuum and molecular gas in a distant lensed starburst galaxy: Cosmic Eyelash

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- **Required angular resolution?**

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  MRS permitted is 2,9 arcsec for the extended config and 8,3 arcsec for the most compact configuration --> LAS **estimated** is 1 arcsec from SMA continuum image → ok no ACA!

- **Required sensitivity?**

  - for CO(9-8) line and continuum observations;

  - Do estimations on CO(9-8) profile, $\mathbf{F}_{[CO(9-8)]}$ or $\mathbf{F}_{\mathbf{peak}[CO(9-8)]}$, FWHM and morphology (resolved, unresolved, N components, components size, etc), SN, spectral resolution, continuum emission of the faintest component.

Resolve at high frequency the continuum and molecular gas in a distant lensed starburst galaxy: Cosmic Eyelash

- **Required sensitivity for CO(9-8) line?**

- If you **know/assume** CO(9-8) gaussian profile

- If you **know/assume** CO(3-2)/CO(9-8) = 2.5,
  derive **$F_{[CO(9-8)]}$** = **$F_{[CO(3-2)]}$** / (2.5) = 5.52 Jy km s^{-1}

- If you **know/assume** $FWHM_{[CO(9-8)]} \sim FWHM_{[CO(3-2)]}$ = 600 km s^{-1}
  derive **$F_{peak[CO(9-8)]}$**=**$F_{[CO(9-8)]}$** / $FWHM_{[CO(9-8)]}$ = 9.2 mJy

- if you request **SN=20**

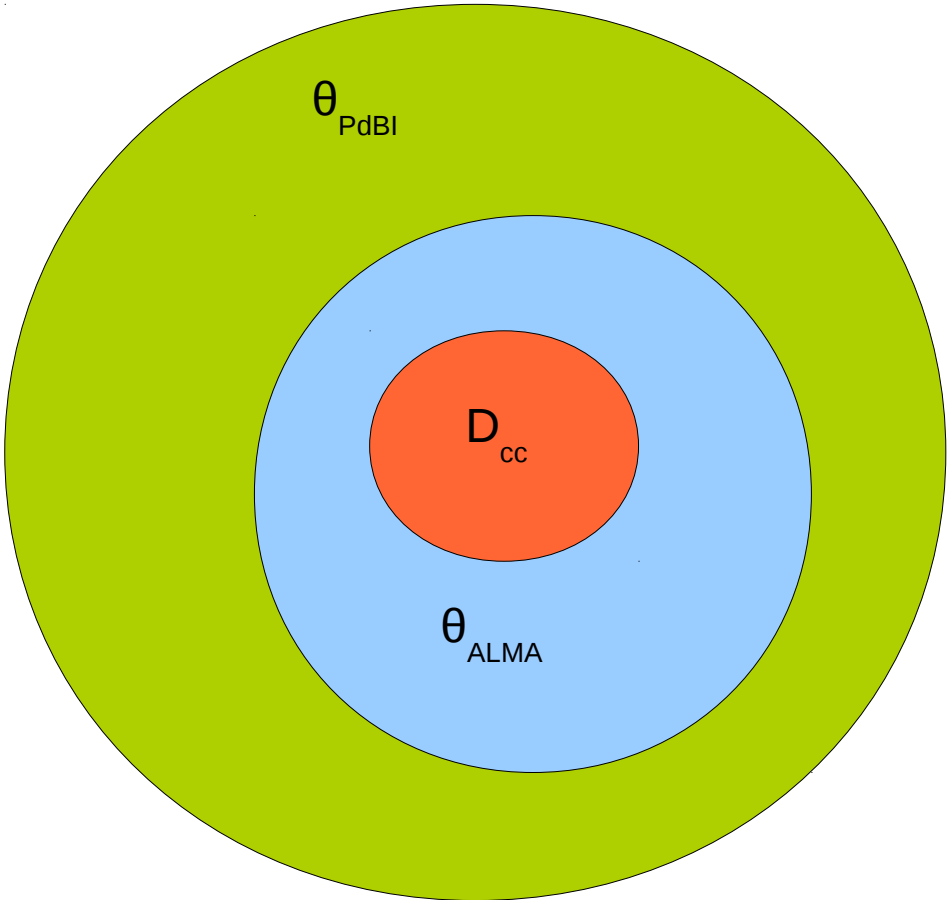
Required sensitivity for CO(9-8) line?

Using the estimations: CO(9-8) **gaussian profile**, **$F_{[CO(9-8)]}$** = 5.52 Jy km s^{-1} , **$F_{peak[CO(9-8)]}$**= 9.2 mJy, and requesting **SN=20...**

...which morphology you know/assume??

- source unresolved in PdBI data and it will be **unresolved** with $\theta_{ALMA} \sim 0.2$ ''

--> **rms = $F_{peak[CO(9-8)]}$ / SN**~0.5 mJy



Required sensitivity for CO(9-8) line?

Using the estimations: CO(9-8) **gaussian profile,** $F_{[CO(9-8)]} = 0.92$ Jy km s^{-1} , $F_{peak[CO(9-8)]} = 9.2$ mJy, and requesting **SN=20**

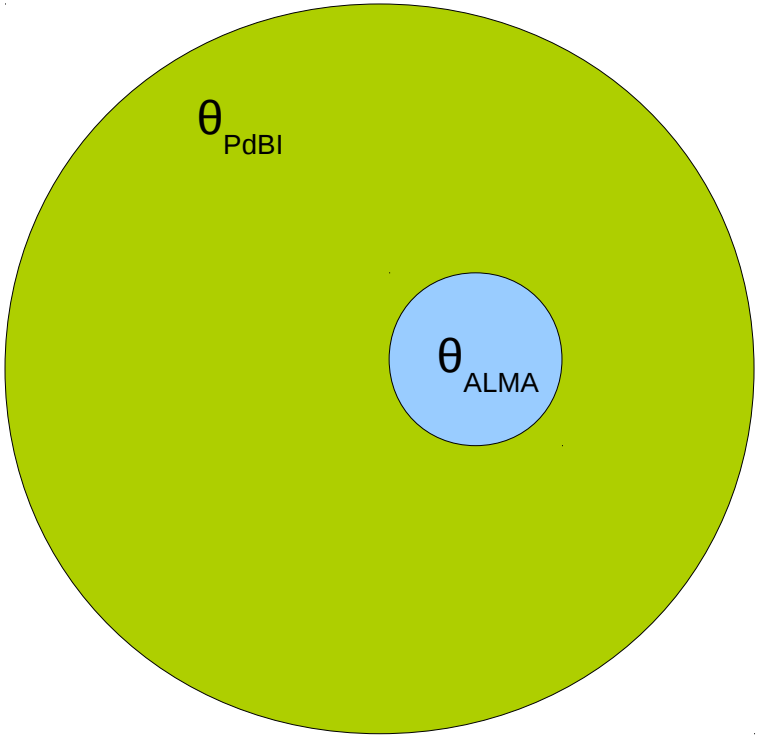
...what morphology you assume??

- source unresolved in PdBI data and it will be **resolved** with $\theta_{ALMA} \sim 0.2$ '' in:

1 component with angular size $D_{cc} \sim \theta_{PdBI}$ and uniformly distributed in D_{cc}

--> $\mathbf{rms = F_{peak[CO(9-8)]} * R_1 / SN} \sim 0.02$ mJy

where $\mathbf{R_1 = (\theta_{ALMA} / \theta_{PdBI})^2 = (0.2/1)^2}$



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Using the estimations: CO(9-8) **gaussian profile,** $F_{[CO(9-8)]} = 0.92$ Jy km s^{-1} , $F_{peak[CO(9-8)]} = 9.2$ mJy, and requesting **SN=20**

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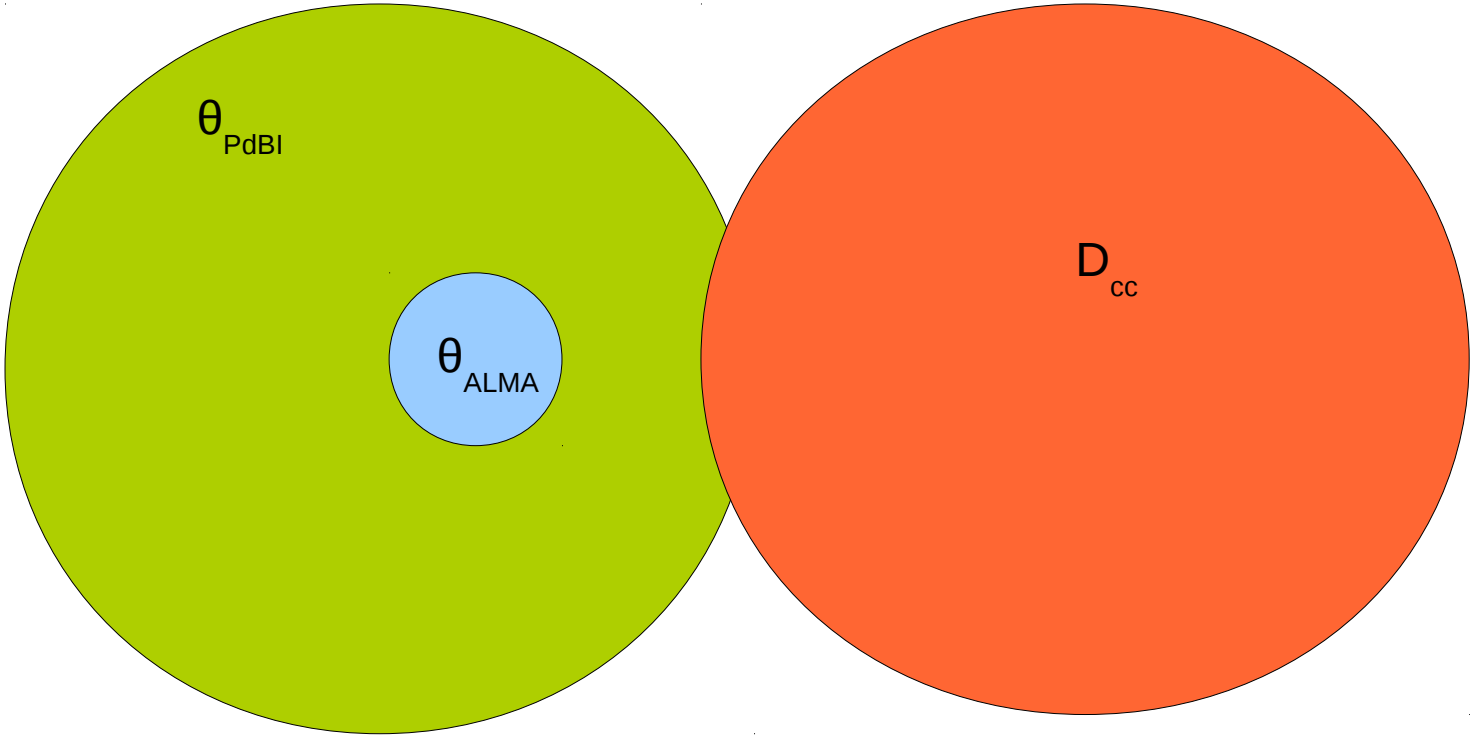

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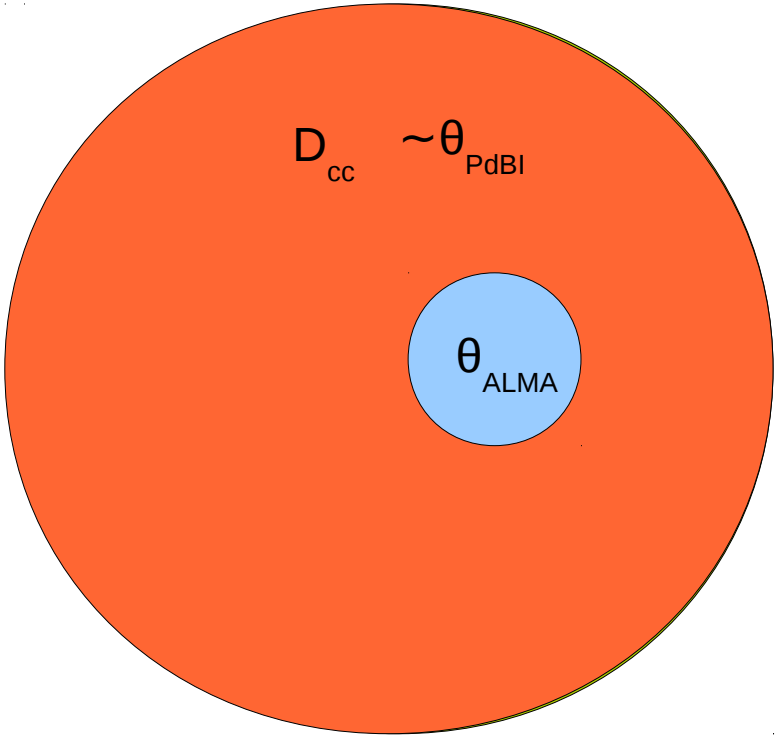
- source unresolved in PdBI data and it will be **resolved** with $\theta_{ALMA} \sim 0.2$ '' in:

1 component with angular size $D_{cc} \sim \theta_{PdBI}$ and uniformly distributed in D_{cc}

--> $\mathbf{rms = F_{peak[CO(9-8)]} * R_1 / SN} \sim 0.02$ mJy

where $\mathbf{R_1 = (\theta_{ALMA} / \theta_{PdBI})^2 = (0.2/1)^2}$



Required sensitivity for CO(9-8) line?

Using the estimations: CO(9-8) **gaussian profile, F[CO(9-8)]** = 0.92 Jy km s^{-1} , **F_{peak}[CO(9-8)]**= 9.2 mJy, and requesting **SN=20**

...what morphology you assume??

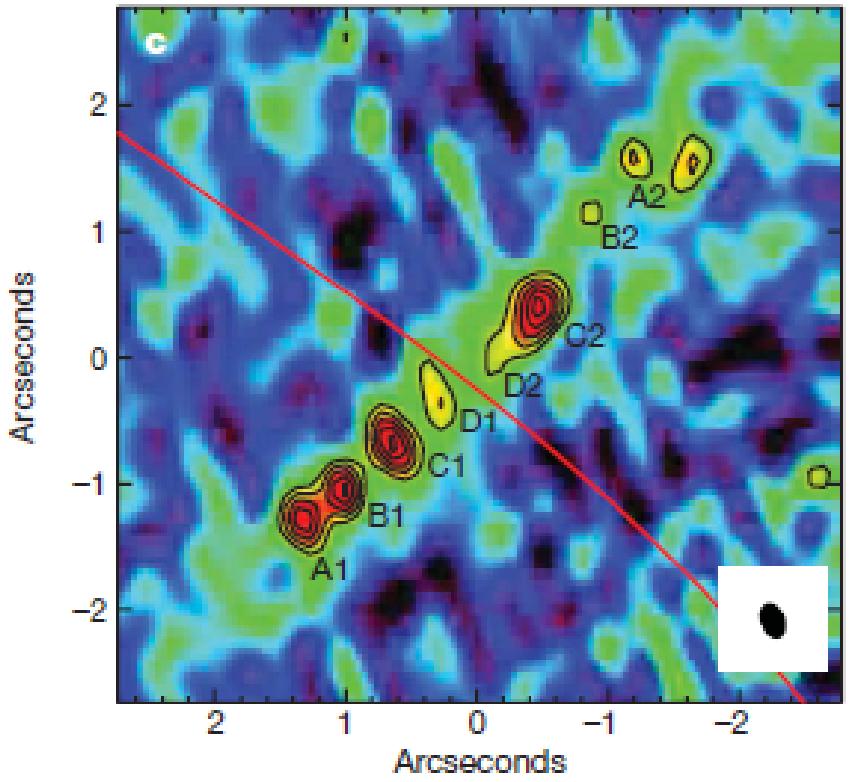
- source resolved in PdBI data and it will be **resolved** with θ_{ALMA} ~ 0.2 '' in

N components with angular size **D_{cc} > θ_{ALMA}**

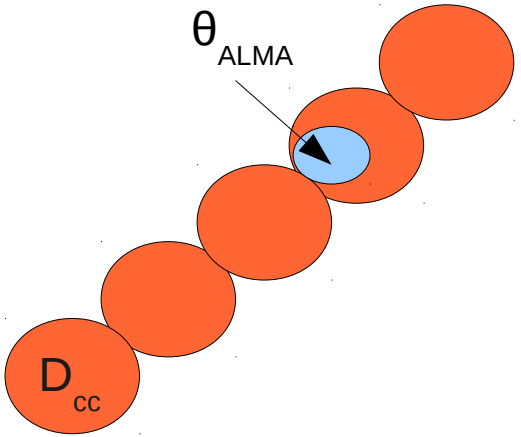
(From SMA data, **assumptions**: 1) CO(9-8) traces the continuum --> N = 5, 2) the estimated CO(9-8) flux is equally and uniformly distributed among them, 3) mean D_{cc} = 0.8 '')

rms = (F_{peak}[CO(9-8)]/N)* R_N / SN ~ 0.006 mJy

where **R_N = (θ_{ALMA} / D_{cc})^2 = (0.2/0.8)^2**



3 assumptions!!



Required sensitivity for CO(9-8) line?

Using the estimations: CO(9-8) **gaussian profile, F[CO(9-8)]** = 0.92 Jy km s^{-1} , $\mathbf{F_{peak}[CO(9\text{-}8)]}$= 9.2 mJy, and requesting **SN=20**

What morphology you assume??

- source unresolved in PdBI data that will be **unresolved** with θ_{ALMA} ~ 0.2 ''

--> $\mathbf{rms = F_{peak}[CO(9\text{-}8)] / SN \sim 0.5\ mJy}$

- source unresolved in PdBI data that will be **resolved** with θ_{ALMA} ~ 0.2 '' in: 1 component with angular size $\mathbf{D_{cc} \sim \theta_{PdBI}}$ and uniformly distributed in $\mathbf{D_{cc}}$

--> $\mathbf{rms = F_{peak}[CO(9\text{-}8)] * R_1 / SN \sim 0.02\ mJy}$

where $\mathbf{R_1 = (\theta_{ALMA} / \theta_{PdBI})^2 = (0.2/1)^2}$

- source resolved in PdBI data that will be **resolved** with θ_{ALMA} ~ 0.2 '' in **N** components with angular size $\mathbf{D_{cc} > \theta_{ALMA}}$

(From SMA data, **assumptions**: 1) CO(9-8) traces the continuum --> N = 5, 2) the emission line flux is equally and uniformly distributed among them, 3) mean D_{cc} = 0.8 '')

$$\mathbf{rms = (F_{peak}[CO(9\text{-}8)]/N) * R_N / SN \sim 0.006\ mJy}$$

where $\mathbf{R_N = (\theta_{ALMA} / D_{cc})^2 = (0.2/0.8)^2}$

Resolve at high frequency the continuum and molecular gas in a distant lensed starburst galaxy: Cosmic Eyelash

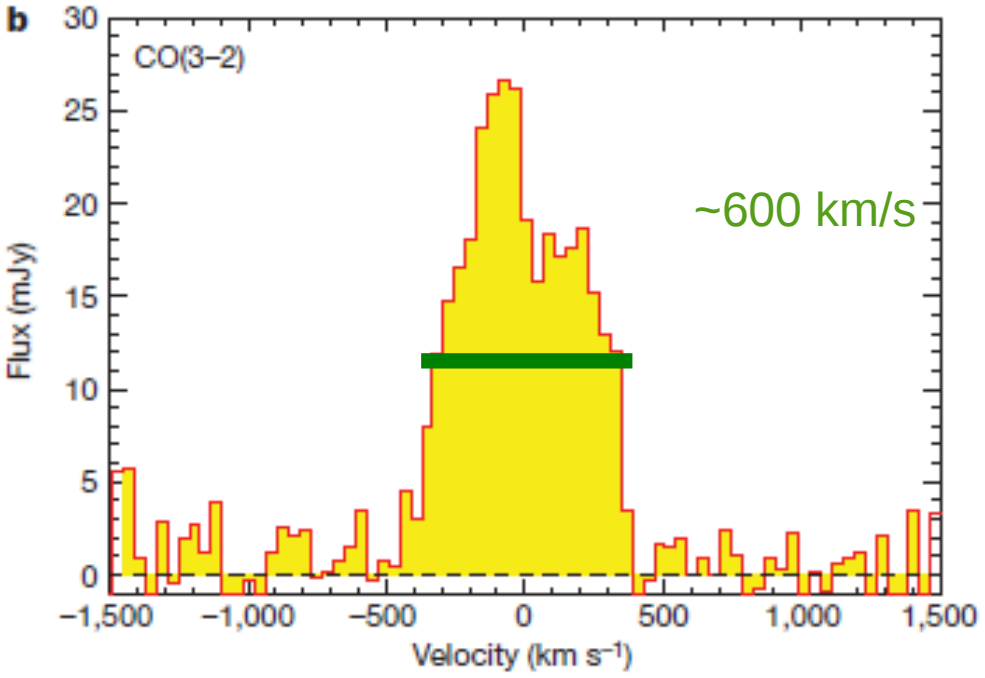
- **bandwidth used for line sensitivity**

- How many times do you want to sample the line width?

  → it depends on your SG: mapping, kinematics, ...

  → it depends on your estimated/known FWHM

  → integration time on source to achieve the requested rms changes



If you need 6 points → 100 km /s bandwidth

Perspective 1

Editors

Spectral | Spatial | Control and Performance

These parameters are used to control various aspects of the observations, including the required antenna configurations and integration times.

Control and Performance

Configuration Information

Antenna Beamsize (1.2 * λ / D)	12m	19.680 arcsec	7m	33.737 arcsec		
Number of Antennas	12m	34	7m	9	TP	2

	Most extended 12m configuration	Most compact 12m configuration
Longest baseline (L_{max})	1.508 km	0.166 km
Synthesized beamsize (λ/L_{max})	0.131 arcsec	1.188 arcsec
Shortest baseline (L_{min})	0.041 km	0.014 km
Maximum recoverable scale ($0.6\lambda/L_{min}$)	2.908 arcsec	8.322 arcsec

Desired Performance

Desired Angular Resolution: 0.20000 arcsec

Largest Angular Structure in source: ○ Point Source ◉ Extended Source 1.00000 arcsec

Desired sensitivity per pointing: 0.50000 mJy equivalent to 0.15480 K

Bandwidth used for Sensitivity: User Frequency Width 100.00000 km/s

Do you request complementary ACA Observations? ○ Yes ◉ No Suggest

Science goal integration time estimate: Time Estimate

Is more time required due to u,v coverage issues? (must be justified) ○ Yes ◉ No

Are the observations time-constrained? ○ Yes ◉ No

Required rms →
1st case assumed

Resolve at high frequency the continuum and molecular gas in a distant (z=2,3) lensed starburst galaxy: Cosmic Eyelash

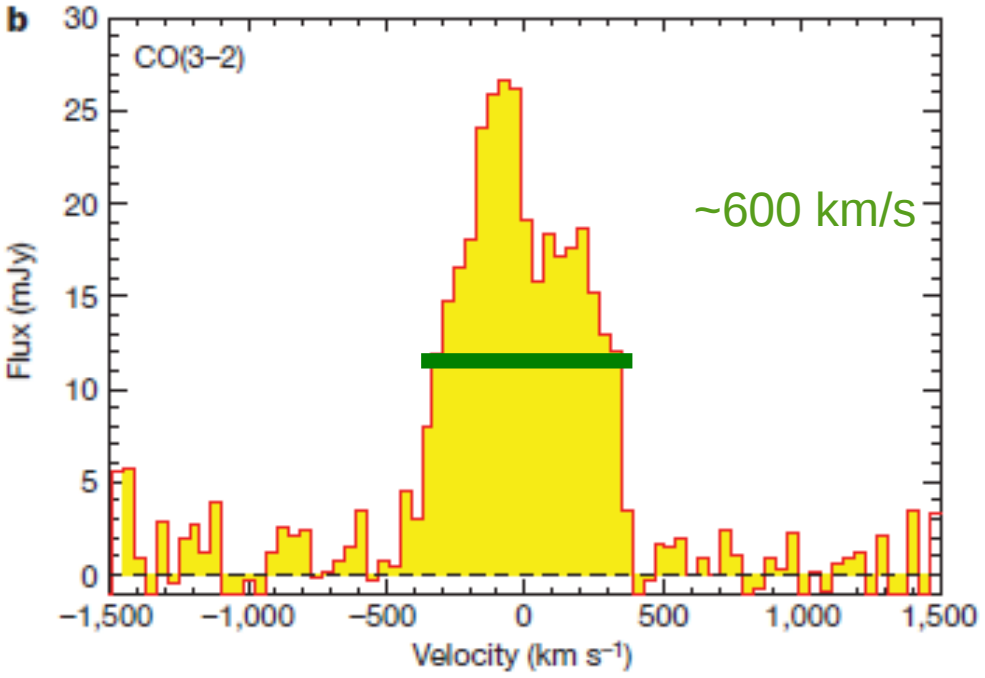
- **bandwidth used for line sensitivity**

- How many times do you want to sample the line width?

  → it depends on your SG: mapping, kinematics, ...

  → it depends on your estimated/known FWHM

  → integration time on source to achieve the requested rms changes

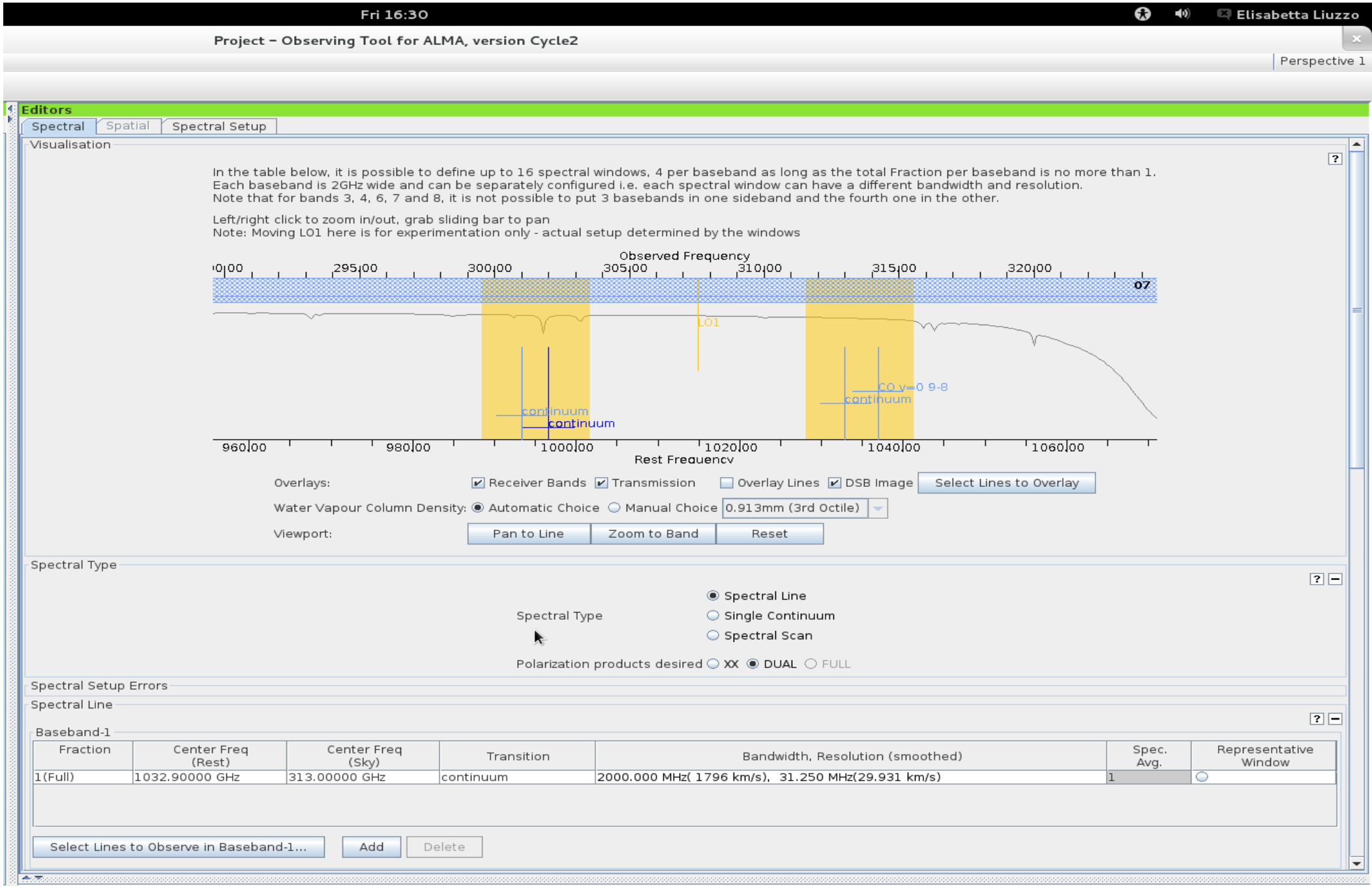


If you need 6 points → 100 km /s bandwidth

...**for the continuum emission**

→in our case with 3 basebands

→aggregate bandwidth --> ~6 GHz

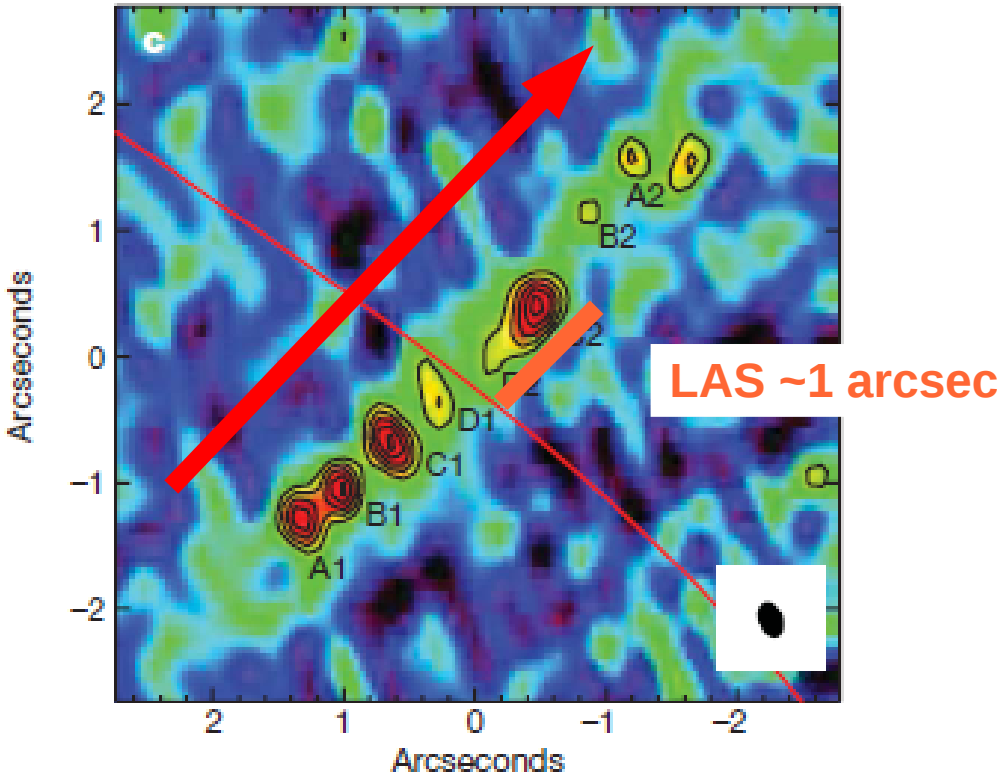


Resolve at high frequency the continuum and molecular gas in a distant (z=2,3) lensed starburst galaxy: Cosmic Eyelash

- **New ALMA observations** in band 7 (312 GHz): CO (9-8) + continuum

- **Previous observations:** SMA at 850 µm (Band 7) continuum:

Ext = 5 arcsec



Angular resolution: θ_{SMA}=0.2 "

Multiple components

Source angular size = 5 "

LAS = 1"

S(tot)=86 mJy

f.c= 6 mJy

--> if requested 6 times deeper observ

--> 1mJy peak flux density required

Perspective 1

Editors

Spectral | Spatial | Technical Justification

Enter a Technical Justification for this Science Goal, paying special attention to the parameters reproduced below.

Relevant science parameters

Sensitivity	0.50 mJy	Angular Resolution	0.20 arcsec
Bandwidth for sensitivity	104.81 MHz	Largest angular structure	1.00 arcsec
Representative frequency	314.22 GHz	ACA	No

Expected source properties

Continuum:

Aggregate bandwidth	5.97 GHz	Sensitivity	0.07 mJy
Peak flux density	1.00 mJy	SNR	15.09

Line:

Peak flux density	10.00 mJy	SNR	20.00
Line width	400.00 km/s	Resolutions per FWHM	13
Dynamic Range (cont. peak/line rms)	2.00		

Non-standard choices

Field setup:

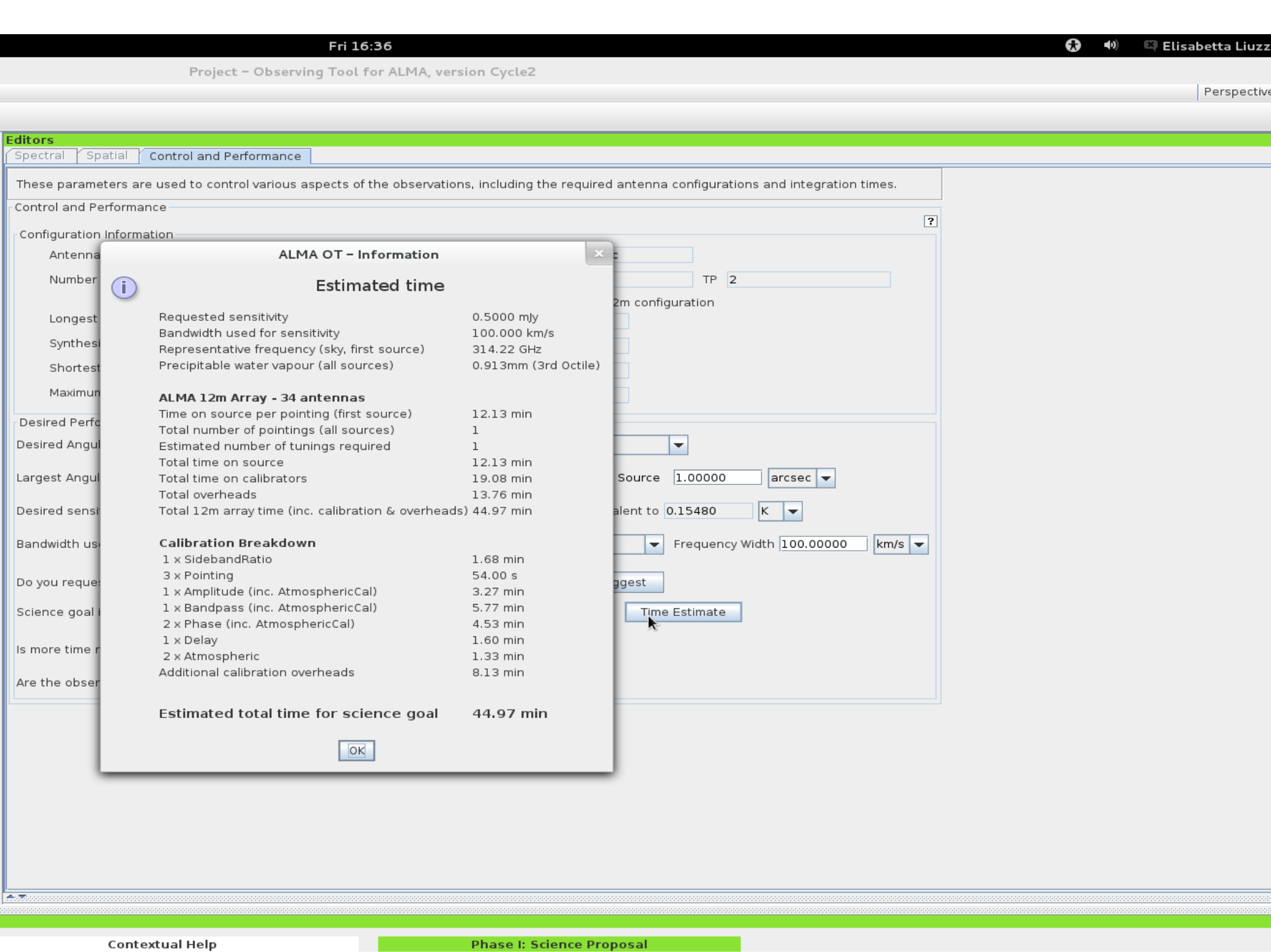
Spectral Setup:

Calibration:

Control and Performance:

Justification text (max 4000 characters)

Launch Editor


Fri 16:36
Elisabetta Liuzz
Project – Observing Tool for ALMA, version Cycle2
Perspective
Editors
Spectral
Spatial
Control and Performance
These parameters are used to control various aspects of the observations, including the required antenna configurations and integration times.
Control and Performance
Configuration Information
Antenna
Number
TP
2
2m configuration
Longest
Synthesi
Shortest
Maximun
Desired Perfo
Desired Angul
Largest Angul
Source
1.00000
arcsec
Desired sensi
alent to
0.15480
K
Bandwidth us
Frequency Width
100.00000
km/s
Do you reque
ggest
Science goal i
Time Estimate
Is more time r
Are the obser
ALMA OT – Information
Estimated time
Requested sensitivity 0.5000 mJy
Bandwidth used for sensitivity 100.000 km/s
Representative frequency (sky, first source) 314.22 GHz
Precipitable water vapour (all sources) 0.913mm (3rd Octile)
ALMA 12m Array - 34 antennas
Time on source per pointing (first source) 12.13 min
Total number of pointings (all sources) 1
Estimated number of tunings required 1
Total time on source 12.13 min
Total time on calibrators 19.08 min
Total overheads 13.76 min
Total 12m array time (inc. calibration & overheads) 44.97 min
Calibration Breakdown
1 x SidebandRatio 1.68 min
3 x Pointing 54.00 s
1 x Amplitude (inc. AtmosphericCal) 3.27 min
1 x Bandpass (inc. AtmosphericCal) 5.77 min
2 x Phase (inc. AtmosphericCal) 4.53 min
1 x Delay 1.60 min
2 x Atmospheric 1.33 min
Additional calibration overheads 8.13 min
Estimated total time for science goal 44.97 min
OK
Contextual Help
Phase I: Science Proposal