EUROPEAN ARC
ALMA Regional Centre

ALMA QA

What is quality assurance, what should I look for or look at?

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SPANISH

ALMA Days

18-20 February 2025, La Laguna, Tenerife, Spain

Outline

- **INTRO : Interferometric Imaging**
  - basics overview
  - image parameters

Sorry means I have to do a little more talking….

- **PART 2 : Imaging Weblog**
  - what images were made for my target(s)
  - can I use Pipeline images or do I need to do more

This session with ‘hands-on’

- **OPTIONAL : Imaging with Pipeline**
  - use CASA with ALMA pipeline to try some image commands

last 30-40min

Basics of imaging synthesis

- Interferometers sample the sky in the Fourier Domain (the ‘Visibilities’) which are complex quantities (amplitude and phase) -> *think “flux and position”*
- Imaging is an inverse Fourier transform
  - We have sampled particular **U, V** coordinates with given baselines at given times. These must be ‘converted’ into physical parameter space onto an ***l, m*** grid

https://casaguides.nrao.edu/index.php/First_Look_at_Imaging

Recommended (i) : https://science.nrao.edu/science/meetings/2018/16th-synthesis-imaging-workshop/talks/Wilner_Imaging.pdf

Recommended (ii) : https://www.iram-institute.org/medias/uploads/file/PDFs/IS-2018/pety-single-field.pdf

Basics of imaging synthesis

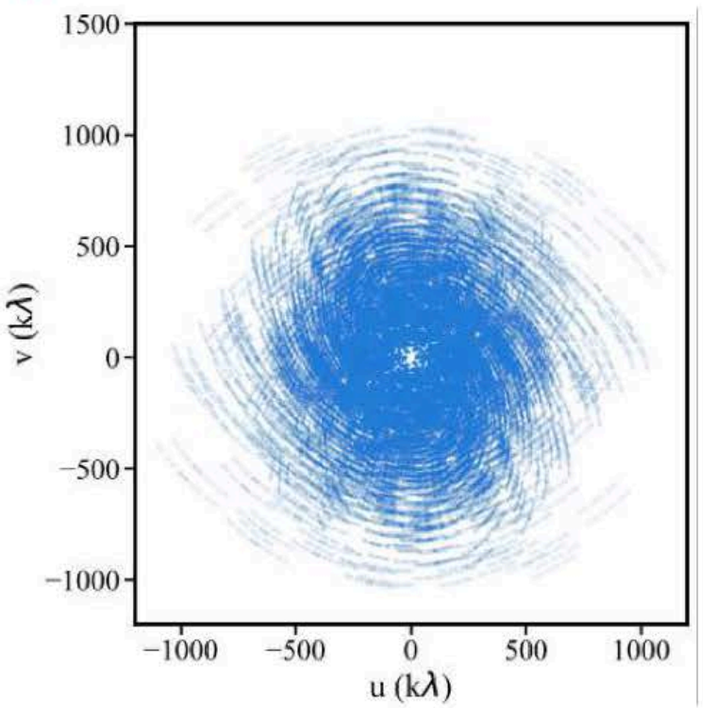
- Mathematical transforms change U,V into image plane
  - $\boldsymbol{V}(U,V) = 2D\ FT\ \{\boldsymbol{B}_{primary}.\boldsymbol{I}_{source}\}$ (*Visibilities*)
  - $\boldsymbol{S}(U,V)$ = 1 where U,V are sampled, = **0 if not** (*Sampling function*)
  - $\boldsymbol{B}_{dirty}(l,m) = 2D\ FT^{-1}\{S\}$ (*Dirty Beam*)
  - $\boldsymbol{I}_{meas}(l,m) = 2D\ FT^{-1}\{S.V\}$ (*Measured image*)
    - —> $\boldsymbol{I}_{meas} = \boldsymbol{B}_{dirty} * \{\boldsymbol{B}_{primary}.\boldsymbol{I}_{source}\}$
- So we doing a Fourier Transform, then must deconvolve to ‘remove’ the dirty beam

We are doing aperture synthesis we do not have a filled U,V

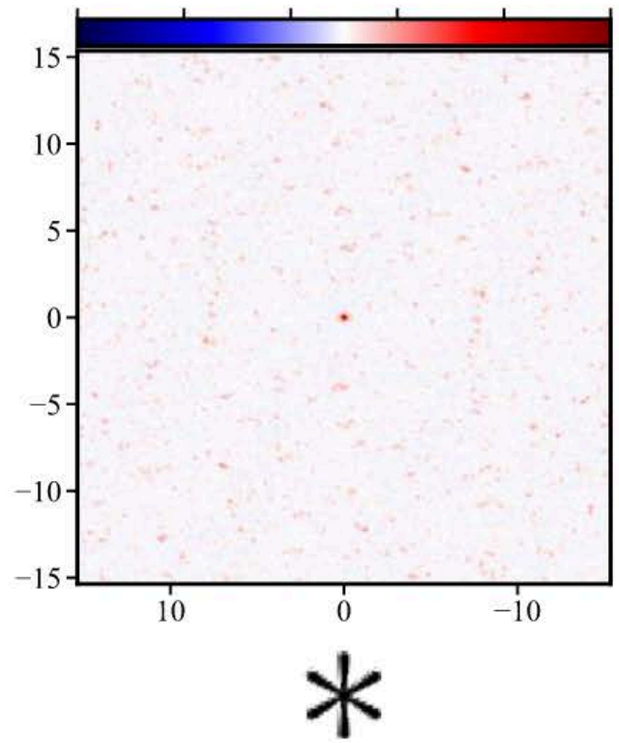
Credits- J.Pety IRAM

Basics of imaging synthesis

$S(u,v)$



$\mathcal{F} \rightarrow$

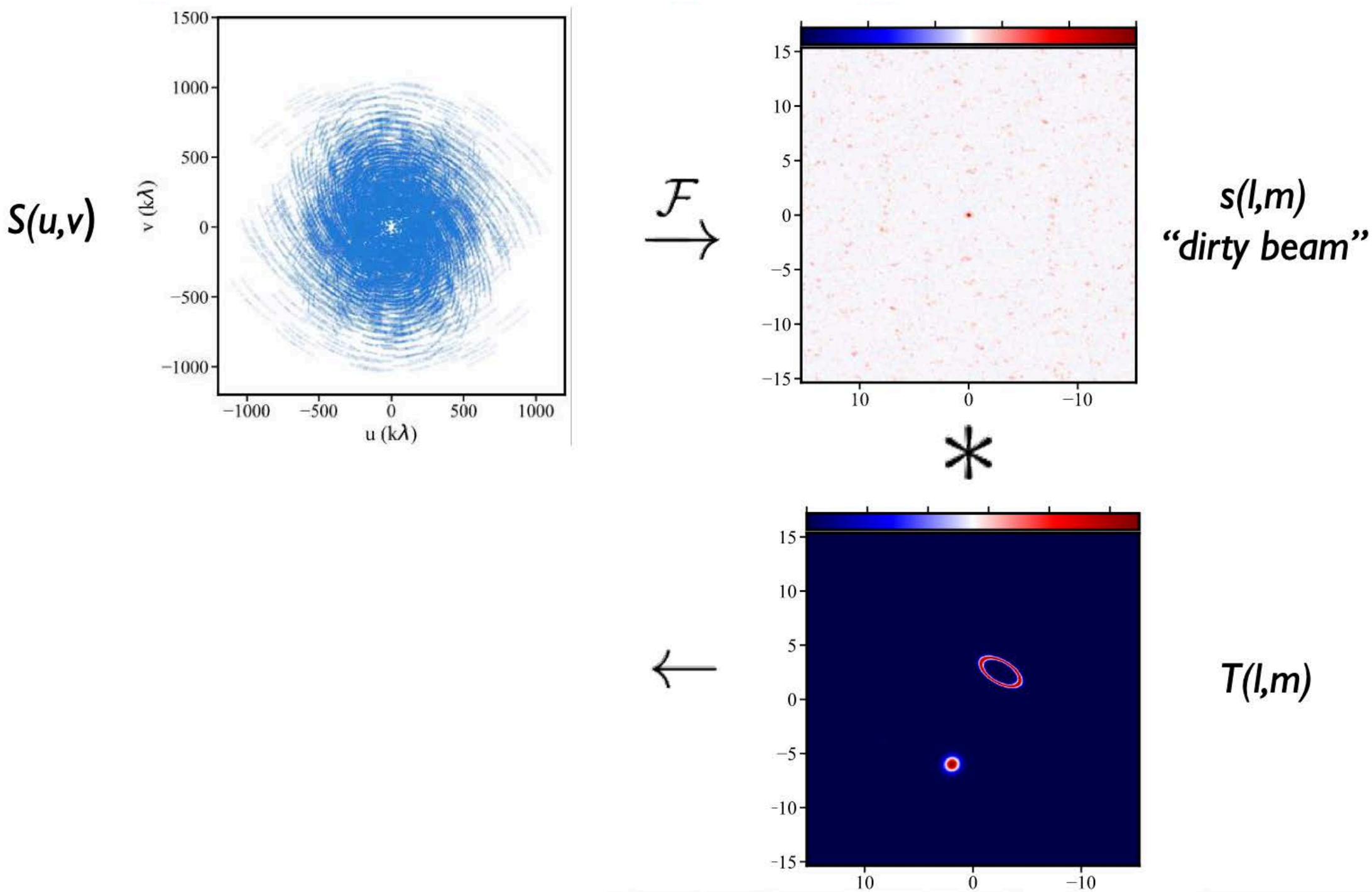


$s(l,m)$
"dirty beam"

$*$

Credits: Wilner - SMA

Basics of imaging synthesis



Credits: Wilner - SMA

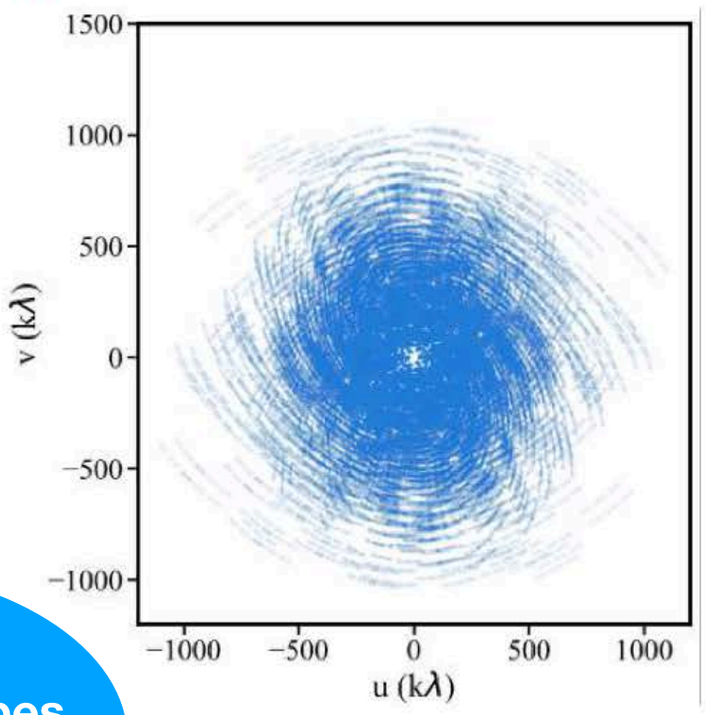
INTRO

Basics of imaging synthesis

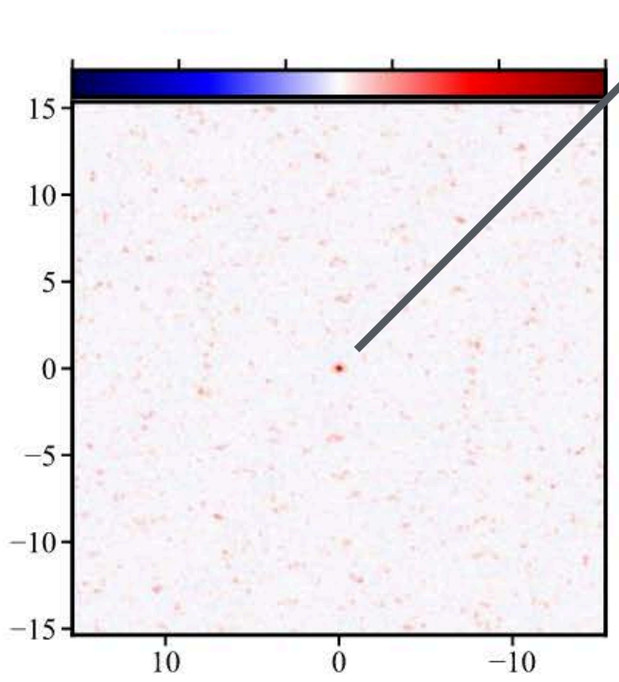
'Clean beam' - fit of central 'gaussian' component

Note - needs good U,V coverage and continuity - important for merging data poorly merged arrays do not conform to a 'gaussian' clean beam

$S(u,v)$



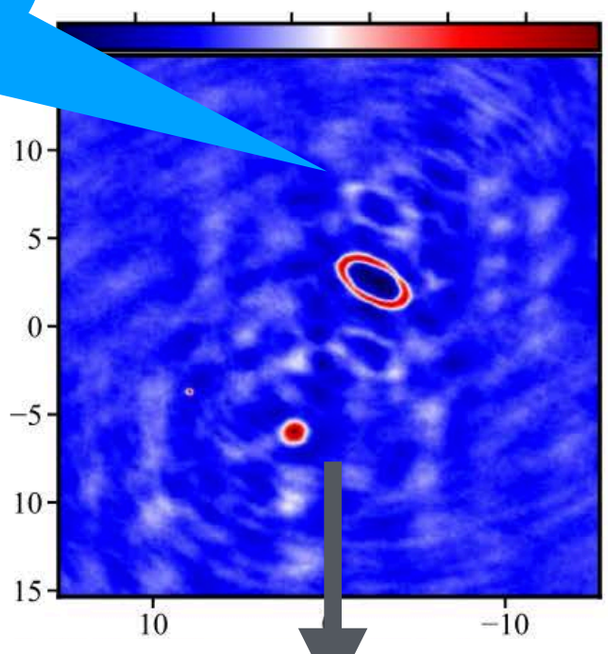
$\mathcal{F}$ →



$s(l,m)$
"dirty beam"

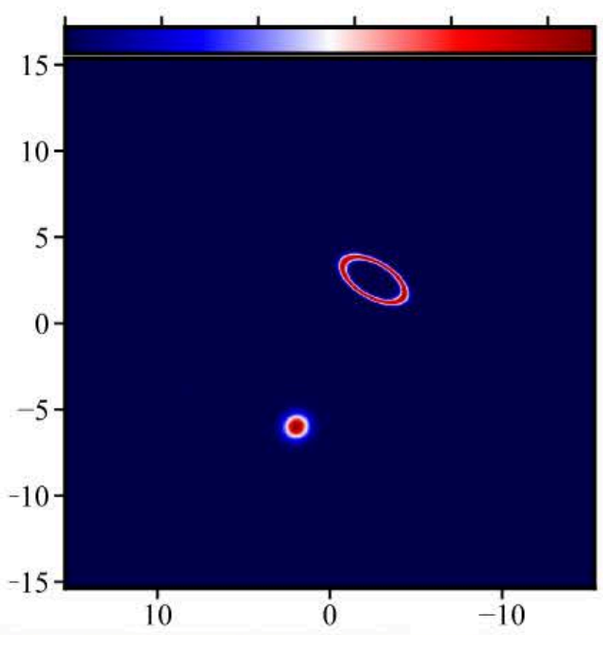
*

caused by sidelobes, i.e side of the 'beam'



$T^D(l,m)$
"dirty image"

←

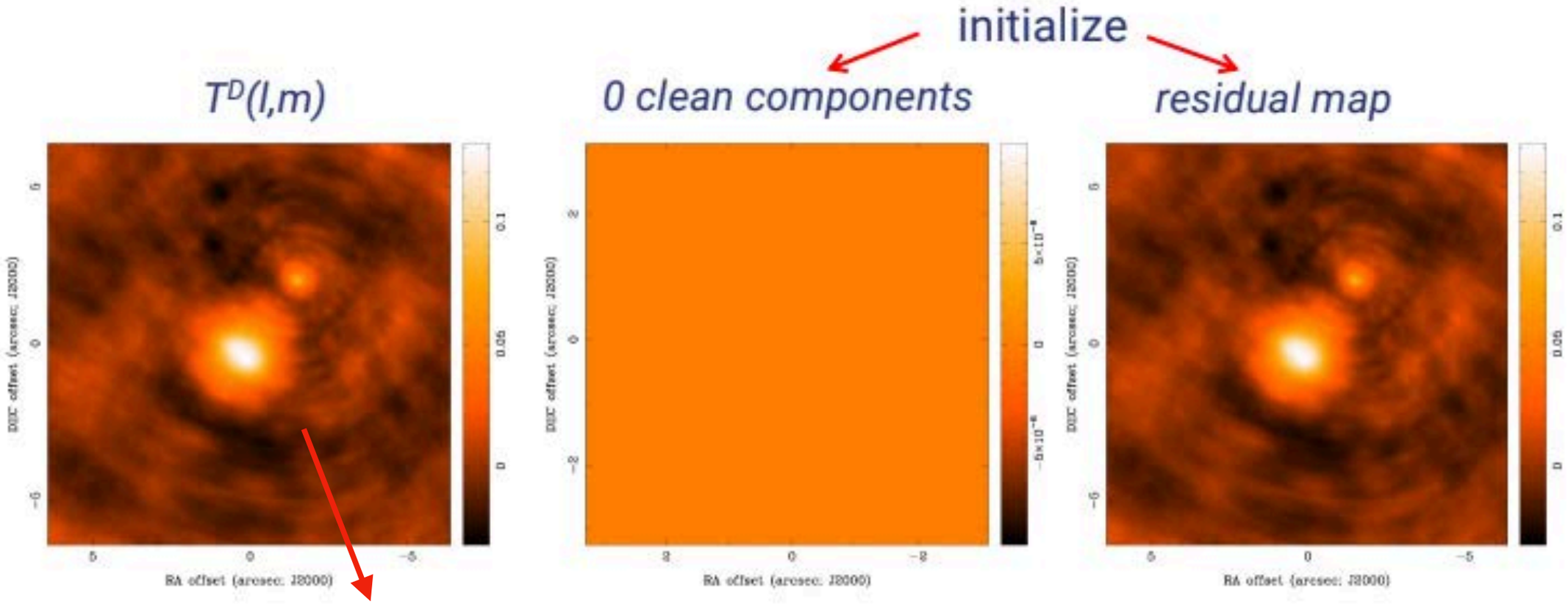


$T(l,m)$

Now Deconvolve

Credits: Wilner - SMA

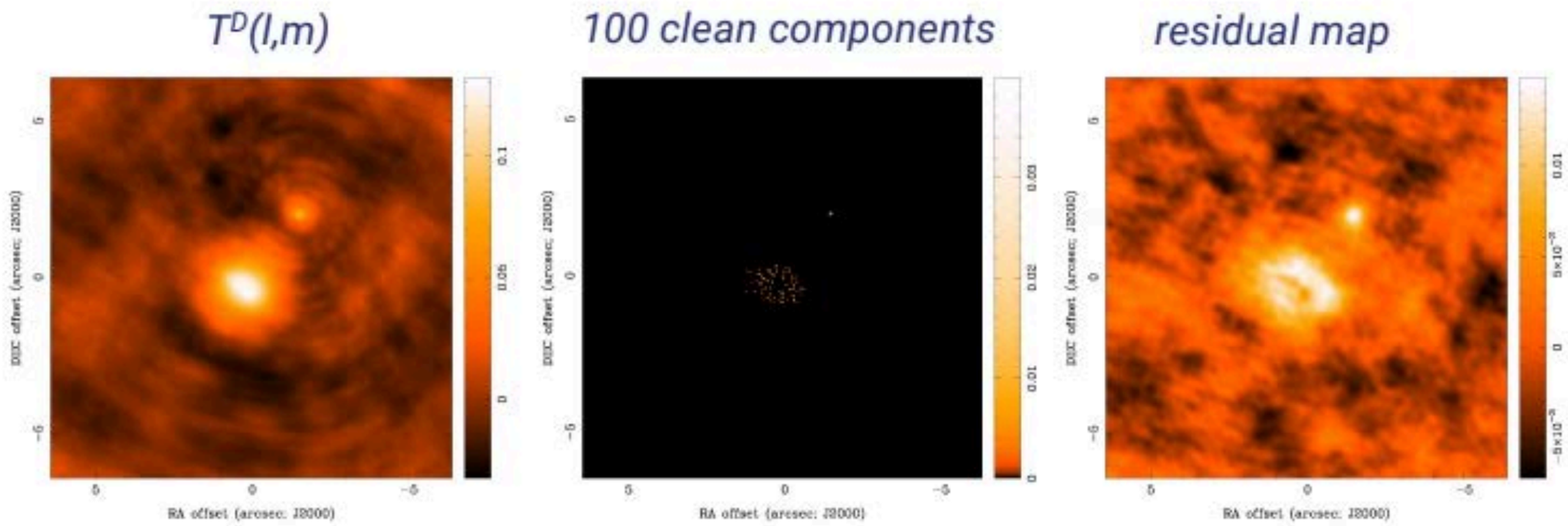
Brief note on Cleaning



Usually apply a mask

Credits: Wilner - SMA

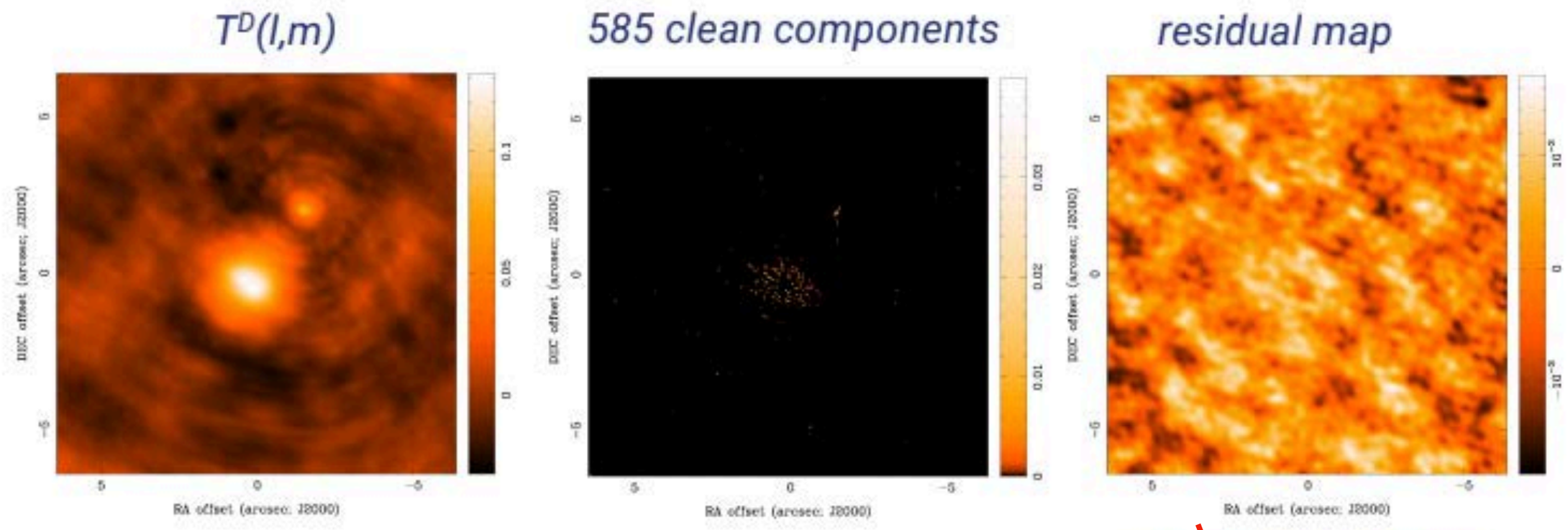
Brief note on **Clean**ing



Could ‘interactively’ refine the mask

Credits: Wilner - SMA

Brief note on Cleaning



Should look like noise - then we are done

Credits: Wilner - SMA

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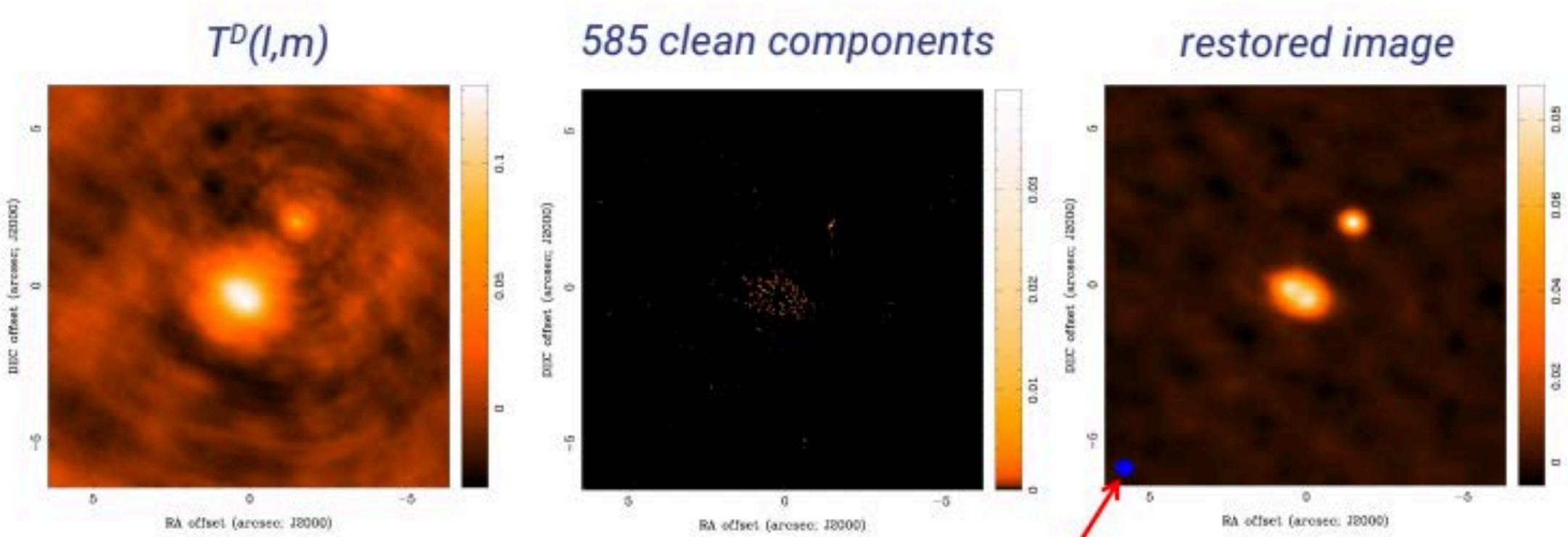
Brief note on **Clean**ing



‘clean’ beam

Credits: Wilner - SMA

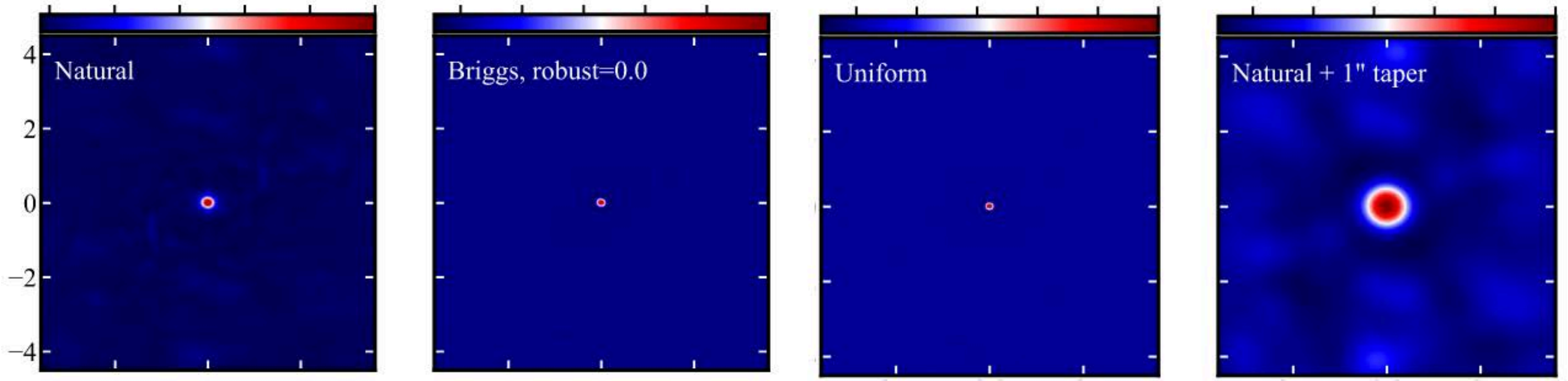
Imaging parameter selection

- When imaging a number of parameters need to be used:
  - **Cell (pixel) size**: clean beam / 5 - i.e. at least 5 cells (pixels) per clean beam *(you know AR)*
    - Required to grid correctly, ascribe flux to ‘correct’ locations within a ‘clean beam’
    - Pixels too large - blocky image flux build up in ‘wrong’ places, poor clean beam ‘fit’
    - Pixels too small - hard for the Fourier transform, cells ‘empty’, could affect weightings
  - **Image Size**: Cover the Primary Beam
    - If emission is not large scale, image to HPBW or smaller *(long baselines which can be huge images)*, for mosaics *always* extend past the edges
  - **Specmode**: ‘mfs’ (multi-frequency synthesis) or ‘cube’ spectral line cube
    - ALMA/CASA Pipeline specific ‘cont’ - merges all SPWs
  - **Cleaning type**: `CLEAN`ing - **Hogbom**, Clark, Multi-Scale; (but also Max Entropy MEM)
    - **niter / threshold** - how much to clean by before stopping

Imaging parameter selection

- When imaging a number of parameters need to be used:
  - **Robust**: Numerical Value from +2 *Natural* to -2 *Uniform (between is 'Briggs Robust')*
    - **+ve**, weights towards shorter baselines (each baselines is equally weighted and more shorter ones are always sampled - lower AR, but maximised sensitivity)
    - **-ve**, weights towards longer baselines (gives more power to least sampled visibilities - inversely proportioned, increasing noise but best AR)
    - Default = 0.5, 'middle-ground' between resolution and sensitivity
  - **Taper**: Make the beam larger (worse AR) by Apodizing the U,V by a Gaussian
    - Like smoothing the image with a Gaussian but not 'exactly' the same
  - **uvrange**: optional method to limit the range of visibilities in the image, e.g. if a few shorter baseline are causing a striping, you can exclude them from the time (uvrange = '800~16000' - default meters, or specify klambda - obeys list rule for multiple MS)

Imaging parameter selection



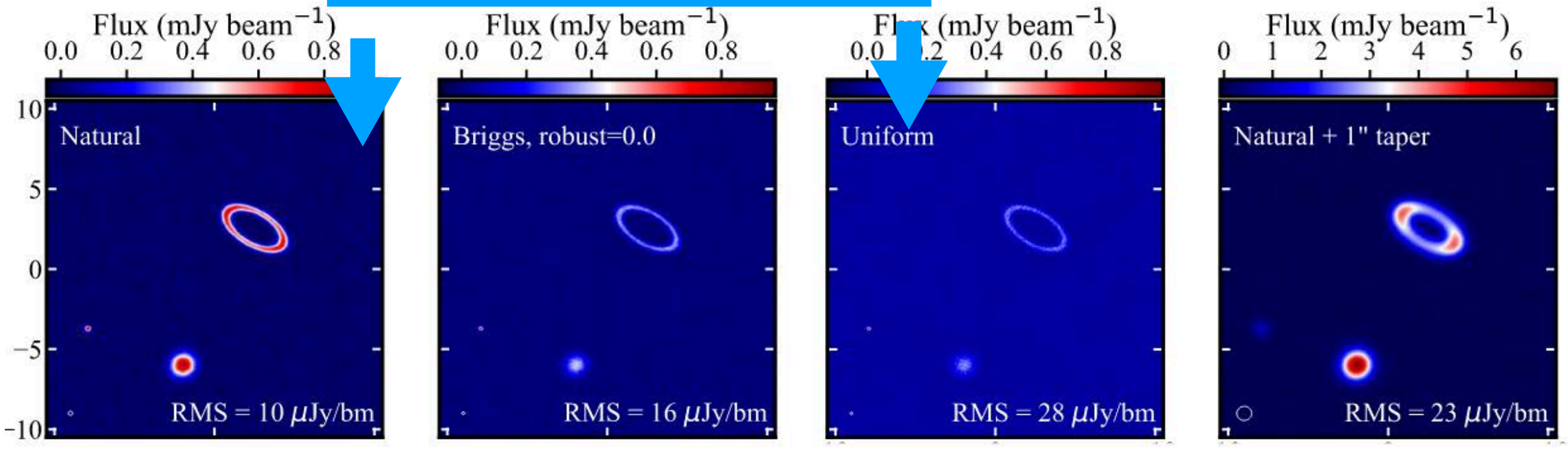
natural | robust=0 | uniform | natural + 1” taper

	Robust/Uniform	Natural	Taper
resolution	higher	medium	lower
sidelobes	lower	higher	depends
point source sensitivity	lower	maximum	lower
extended source sensitivity	lower	medium	higher

Credits: Wilner - SMA

Imaging parameter selection

factor ~2.5 change in beam ‘area’

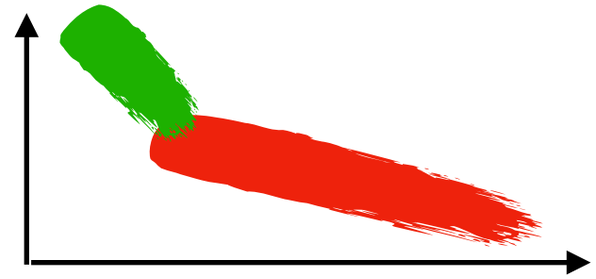


natural	robust=0	uniform	natural + 1” taper
0.29x0.25 p.a. -81	0.19x0.17 p.a. -78	0.17x0.15 p.a. -87	0.93x0.88 p.a. -86

	Robust/Uniform	Natural	Taper
resolution	higher	medium	lower
sidelobes	lower	higher	depends
point source sensitivity	lower	maximum	lower
extended source sensitivity	lower	medium	higher

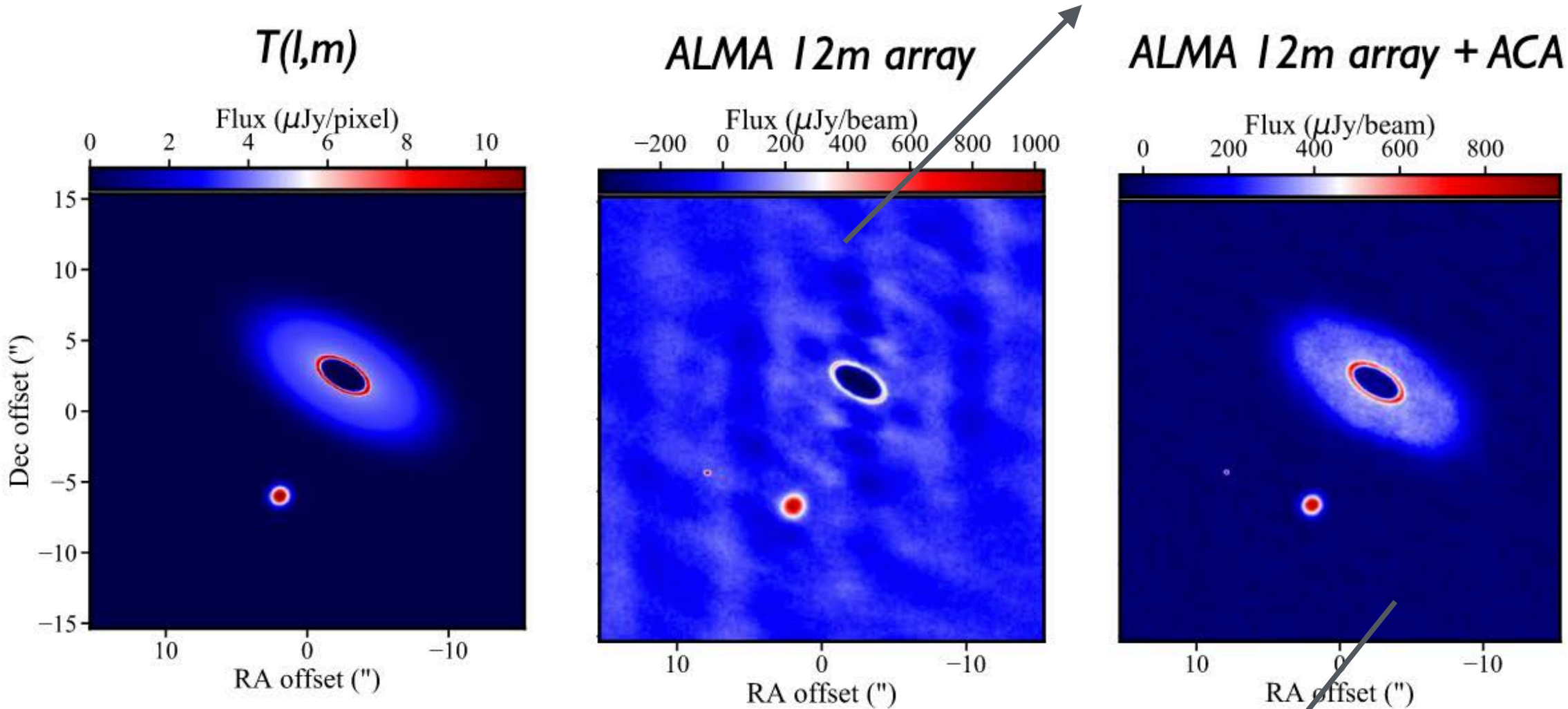
Credits: Wilner - SMA

Merging Data



Merging ACA and 12m to recover extended scales

Misses all extended structure, no U,V to sample this - so cannot image it



Recovers much of the extended structure

Credits: Wilner - SMA

INVESTIGATING THE IMAGING WEBLOG

may continue from the calibration weblog or be a stand alone

28. **hif_mstransform**: Create science target MS		1.00	1:25:19
29. **hifa_flagtargets**: ALMA Target flagging		1.00	0:08:49
30. **hif_makeimlist**: Set-up parameters for target per-spw continuum imaging		1.00	0:34:25
31. **hif_findcont**: Detect continuum frequency ranges		1.00	0:00:53
32. **hif_uvcontsub**: UV continuum fit and subtraction		1.00	0:21:04
33. **hif_makeimages**: Make target per-spw continuum images		1.00	0:00:54
34. **hif_makeimlist**: Set-up parameters for target aggregate continuum imaging		1.00	10:04:05
35. **hif_makeimages**: Make target aggregate continuum images		N/A	0:00:14
36. **hif_makeimlist**: Set-up parameters for target cube imaging		N/A	0:00:11
37. **hif_makeimages**: Make target cubes		N/A	2:03:38
38. **hif_makeimlist**: Set-up parameters for representative bandwidth target cube imaging	No clean targets expected	1.00	0:00:54
39. **hif_makeimages**: Make representative bandwidth target cube	Nothing to image	1.00	0:28:12
40. **hif_selfcal**: Selfcal	No QA	1.00	0:00:57
41. **hif_makeimlist**: Set-up parameters for target per-spw continuum imaging		1.00	0:54:37
42. **hif_makeimages**: Make target per-spw continuum images		1.00	0:00:57
43. **hif_makeimlist**: Set-up parameters for target aggregate continuum imaging		1.00	7:51:27
44. **hif_makeimages**: Make target aggregate continuum images		N/A	0:00:15
45. **hif_makeimlist**: Set-up parameters for target cube imaging		N/A	0:00:12
46. **hif_makeimages**: Make target cubes		1.00	0:35:42
47. **hif_makeimlist**: Set-up parameters for representative bandwidth target cube imaging	No clean targets expected	N/A	0:00:15
48. **hif_makeimages**: Make representative bandwidth target cube	Nothing to image	N/A	0:00:12
49. **hifa_exportdata**: Prepare pipeline data products for export		1.00	0:35:42

INVESTIGATING THE IMAGING WEBLOG

may continue from the calibration weblog or be a stand alone

all TARGET imaging is AFTER mstransform

finds the continuum for subtraction

loops of "**hif_makeimlist**" and "**hif_makeimages**" form the imaging process

28. **hif_mstransform**: Create science target MS			
29. **hifa_flagtargets**: ALMA Target flagging			
30. **hif_makeimlist**: Set-up parameters for target per-spw continuum imaging			
31. **hif_findcont**: Detect continuum frequency ranges		1.00	1:25:19
32. **hif_uvcontsub**: UV continuum fit and subtraction		1.00	0:08:49
33. **hif_makeimages**: Make target per-spw continuum images		1.00	0:34:25
34. **hif_makeimlist**: Set-up parameters for target aggregate continuum imaging		1.00	0:00:53
35. **hif_makeimages**: Make target aggregate continuum images		1.00	0:21:04
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49. **hifa_exportdata**: Prepare pipeline data products for export		1.00	0:35:42

PART 2

What images were made for my targets

- **Key Points**

  - Pipeline can change imaging parameters

  - aims to make images of *mfs*, *cont*, *cube* for all SpWs and science targets

  - needs to achieve the **Angular Resolution** so can slightly adjust **Robust**

- **Caveats**

  - Pipeline is *designed to facilitate QA2* - not necessarily make every single science product

  - so-called *mitigation* can occur:

    - change image size, cell size, choose SpW, limit number of sources imaged, if the products are too big

INVESTIGATING THE IMAGING WEBLOG

hifa_imageprecheck - done in runs for PI data to "**check**" and "**set**" the **robust weighting** scheme for obtaining the **requested** spatial resolution

These estimates should always be considered as the BEST CASE SCENARIO. These estimates account for Tsys, the observed uv-coverage, and prior flagging. The estimates DO NOT account for (1) subsequent science target flagging; (2) loss of continuum bandwidth due to the hif_findcont process (i.e. removal of lines and other spectral features from the data used to image the continuum); (3) Issues that affect the image quality like (a) poor match of uv-coverage to image complexity; (b) dynamic range effects; (c) calibration deficiencies (poor phase transfer, residual baseline based effects, residual antenna position errors, etc.). *It is also important to note that both the repBW and aggBW beam calculations are intrinsically multi-frequency synthesis continuum calculations, using the relevant spws as described above. The synthesized beam for a single channel in a cube will typically be larger and can be significantly larger depending on the details of uv-coverage and channel width.*

robust	uvtaper	Synthesized Beam	Cell	Beam Ratio	Bandwidth	BW Mode	Effective Sensitivity
0.0	[]	0.260 x 0.227 arcsec @ -73.3 deg	0.045 x 0.045 arcsec	1.15	15.62 MHz	repBW	0.000355 Jy/beam
0.0	[]	0.[illegible] x 0.206 arcsec @ -81.9 deg	0.041 x 0.041 arcsec	1.15	6854 MHz	aggBW	2.75e-05 Jy/beam
0.5	[]	0.276 x 0.252 arcsec @ -82.2 deg	0.05 x 0.05 arcsec	1.10	15.62 MHz	repBW	0.000263 Jy/beam
0.5	[]	0.268 x 0.233 arcsec @ -87.7 deg	0.047 x 0.047 arcsec	1.10	6854 MHz	aggBW	2.05e-05 Jy/beam
1.0	[]	0.306 x 0.286 arcsec @ 77.5 deg	0.057 x 0.057 arcsec	1.07	15.62 MHz	repBW	0.000239 Jy/beam
1.0	[]	0.300 x 0.268 arcsec @ 83.1 deg	0.054 x 0.054 arcsec	1.07	6854 MHz	aggBW	1.87e-05 Jy/beam
2.0	[]	0.322 x 0.300 arcsec @ 67.7 deg	0.06 x 0.06 arcsec	1.07	15.62 MHz	repBW	0.000237 Jy/beam
2.0	[]	0.317 x 0.285 arcsec @ 78.0 deg	0.057 x 0.057 arcsec	1.07	6854 MHz	aggBW	1.85e-05 Jy/beam

INVESTIGATING THE IMAGING WEBLOG

hif_checkproducts - done in runs for PI data to "**check**" and "**set**" the what **products** will be made - if there are many source or many 'large' cubes there can be **mitigation** - i.e. **reduced** products made to avoid long processing

- 22. hif_makeimlist (checksrc)
- 23. hif_makeimages (checksrc)
- 24. hifa_imageprecheck
- 25. hif_checkproductsize
- 26. hifa_renorm
- 27. hifa_exportdata
- 28. hif_mstransform
- 29. hifa_flagtargets
- 30. hif_makeimlist (mfs)
- 31. hif_findcont
- 32. hif_uvcontsub
- 33. hif_makeimages (mfs)
- 34. hif_makeimlist (cont)
- 35. hif_makeimages (cont)
- 36. hif_makeimlist (cube)
- 37. hif_makeimages (cube)
- 38. hif_makeimlist (cube_repBW)

25. Check Product Size

QA Score: 1.00 No size mitigation needed

Allowed maximum cube size: 40 GB
Allowed cube size limit: 100 GB
Predicted maximum cube size: 14.2 GB
Mitigated maximum cube size: 14.2 GB
Allowed product size: 500 GB
Initial predicted product size: 62.3 GB
Predicted product size after cube size mitigation: 62.3 GB
Mitigated product size: 62.3 GB

everything made as per default - 5 pixels per beam, imaged size out to 0.2 PB, all fields, all SpWs

Size mitigation parameters for subsequent hif_makeimlist calls

nbins	hm_imsize	hm_cell	field	spw
default	default	default	default	default

INVESTIGATING THE IMAGING WEBLOG

hif_checkproducts - done in runs for PI data to "**check**" and "**set**" the what **products** will be made - if there are many source or many 'large' cubes there can be **mitigation** - i.e. **reduced** products made to avoid long processing

Task notifications

QA Size had to be mitigated (hm_imsize,nbins,hm_cell,spw)

Warning! The separation between U_Her field centers across EBs is 0.001252 arcseconds (larger than the limit of 200.0 microarcseconds). This is only normal for an ephemeris source or a source with a large proper motion or parallax.

Allowed maximum cube size: 60 GB
Allowed cube size limit: 80 GB
Predicted maximum cube size: 542 GB
Mitigated maximum cube size: 44.2 GB
Allowed product size: 400 GB
Initial predicted product size: 4.34e+03 GB
Predicted product size after cube size mitigation: 88.5 GB
Mitigated product size: 88.5 GB

some mitigation - smaller image size, only 3 pixels per beam, **only one** SpW

Size mitigation parameters for subsequent hif_makeimlist calls

nbins	hm_imsize	hm_cell	field	spw
25:1,31:1,27:1,29:1	0.7pb	3ppb	default	27

PART 2

can I use Pipeline images or do I need to do more

“Pipeline is designed to allow QA2 - not necessarily make every single science product”

- **Yes:**

  - you have *mfs*, *cont*, *cube* for all SpWs and targets

  - the image size, and robust used are good for your science

  - cleaning and making was done (*close to*) ideally

- **No:**

  - want to see how things change with robust, or taper etc

  - missing SpWs or targets

  - cleaning mask not optimal

  - “**findcont**” might not be optimal, continuum not fully subtracted

  - merge with other data

PART 2

Hands-on weblog viewing

https://almascience.eso.org/arcdistribution/ALMAschool/**-NAME-**/html

- **Investigate some weblogs:**

  - **dataset 1** (from calibration) - Low Mass protostar

  - **PHANGS** - Mosaic of nearby galaxies

  - **ALMAGAL_ACA** data of sample of High Mass star forming Regions

  - **ALMAGAL_12m** main array data of same set of targets

  - DECO

  - **ARKS_TM1** - Looking for exo-Kuiper belt structures in YSOs

  - **ARKS_TM2** - same disk different array

  - **GLASS** - High Z detection aligned with JWST

lots of sources

- **OR - your own selected from Archive**

PART 2

Hands-on

- **Considerations:**

  - is everything imaged

  - is the imaging good

  - can you find the noise levels and beam sizes

  - did continuum subtraction work

  - can you see the science already

  - what else might you want to do…..

Any questions?

OPTIONAL

Work through re-imaging with ALMA Pipeline

- **Need:**

  - you downloaded the data 2018.1.01201.S

  - you have ALMA Pipeline version of CASA (6.6.1) is latest now

  - your CASA is **working**

- **Important points**

  - Pipeline calibrated data generally should be **restored** with the exact version that was used originally

  - Imaging can use the latest ALMA specific CASA version the ‘ms’ structure did not change and latest CASA is always **better**

OPTIONAL

Work through re-imaging with ALMA Pipeline

BASIC SEQUENCE FOR IMAGING

```
 1 hifa_importdata(vis=MyVis,dbservice=False)
 2 hif_mstransform(pipelinemode="automatic")
 3 hifa_flagtargets(pipelinemode="automatic")
 4 hifa_imageprecheck(pipelinemode="automatic")
 5 hif_makeimlist(specmode='mfs')
 6 hif_findcont(pipelinemode="automatic")
 7 hif_uvcontsub(pipelinemode="automatic")
 8 hif_makeimages(pipelinemode="automatic")
 9 hif_makeimlist(specmode='cont')
10 hif_makeimages(pipelinemode="automatic")
11 hif_makeimlist(specmode='cube')
12 hif_makeimages(pipelinemode="automatic")
13 hifa_exportdata(imaging_products_only=True)
```

import and prepare the data

find and subtract the continuum

make images and cubes

exports to fits files

OPTIONAL

Work through re-imaging with ALMA Pipeline

BASIC SEQUENCE FOR IMAGING

We will be changing some options

```
 1 hifa_importdata(vis=MyVis,dbservice=F
 2 hif_mstransform(pipelinemode="autom    ic
 3 hifa_flagtargets(pipelinemode="au  omat    )
 4 hifa_imageprecheck(pipelinemode="auto  tic")
 5 hif_makeimlist(specmode='mfs')
 6 hif_findcont(pipelinemode="automati  ")
 7 hif_uvcontsub(pipelinemode="automatic")
 8 hif_makeimages(pipelinemode="automatic")
 9 hif_makeimlist(specmode='cont')
10 hif_makeimages(pipelinemode="automatic")
11 hif_makeimlist(specmode='cube')
12 hif_makeimages(pipelinemode="automatic")
13 hifa_exportdata(imaging_products_only=True)
```

import and prepare the data

find and subtract the continuum

make images and cubes

exports to fits files

OPTIONAL

Work through re-imaging with ALMA Pipeline

move to your working directory, with the untarred package download (2018.1.01201.S) - navigate to bottom directory -> **calibrated** -> **working**

start CASA, pipeline version (minus minus pipeline)

```
optional configuration file config.py not found, continuing CASA startup without it

IPython 7.33.0 -- An enhanced Interactive Python.

Telemetry initialized. Telemetry will send anonymized usage statistics to NRAO.
You can disable telemetry by adding the following line to the config.py file in your rcdir (e.g. ~/.ca
fig.py):
telemetry_enabled = False
--> CrashReporter initialized.
2024-06-12 07:57:23 INFO: Environment is not MPI enabled. Pipeline operating in single host mode
2024-06-12 07:57:24 INFO: Environment variable FLUX_SERVICE_URL not defined.  Switching to backup url.
2024-06-12 07:57:24 INFO: Environment variable FLUX_SERVICE_URL_BACKUP not defined.
2024-06-12 07:57:25 INFO: Pipeline version 2023.1.0.125 running on ma024396.ads.eso.org
2024-06-12 07:57:25 INFO: Host environment: 16.0 GiB memory, 8 x Intel(R) Core(TM) i7-8559U CPU @ 2.70
nning MacOS 14.5
2024-06-12 07:57:25 INFO: Initializing cli...
2024-06-12 07:57:25 INFO: Loaded Pipeline commands from package: h
2024-06-12 07:57:25 INFO: Loaded Pipeline commands from package: hif
2024-06-12 07:57:25 INFO: Loaded Pipeline commands from package: hifa
2024-06-12 07:57:25 INFO: Loaded Pipeline commands from package: hifas
2024-06-12 07:57:25 INFO: Loaded Pipeline commands from package: hifv
2024-06-12 07:57:25 INFO: Loaded Pipeline commands from package: hsd
2024-06-12 07:57:25 INFO: Loaded Pipeline commands from package: hsdn
CASA 6.5.4.9 -- Common Astronomy Software Applications [6.5.4.9]

CASA <1>:
```

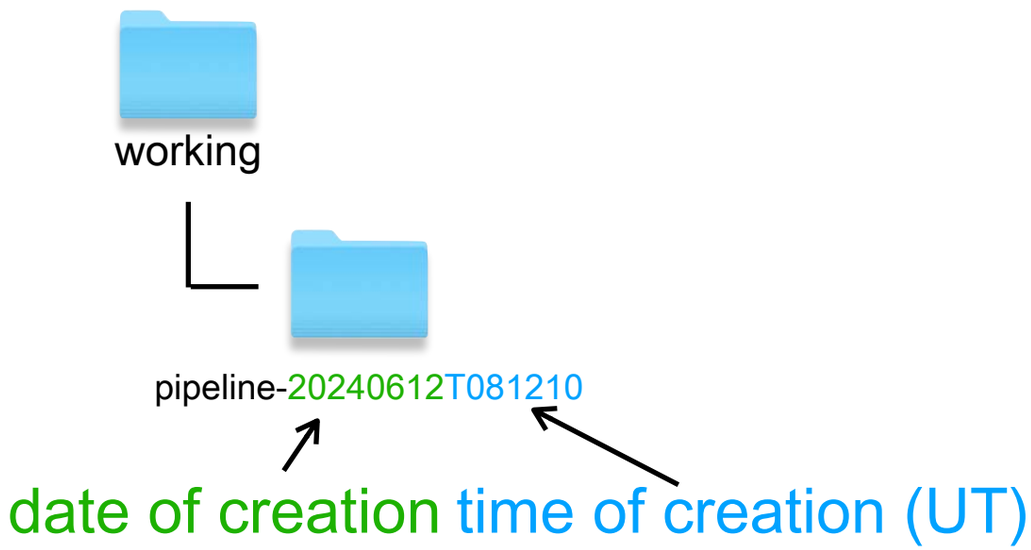
OPTIONAL

Work through re-imaging with ALMA Pipeline

But first we have to initialise the pipeline “context” so it knows what it is doing and keeps track of stages

```
CASA <1>: __rethrow_casa_exceptions = True

CASA <2>: h_init()
2024-06-12 08:12:10 INFO: Tracking execution duration for context: pipeline-20240612T081210
2024-06-12 08:12:10 INFO: Setting plot level to 'default'
Out[2]: <Context(name='pipeline-20240612T081210')>
```



OPTIONAL

Work through re-imaging with ALMA Pipeline

now just define a list for the Measurement sets, so we don't have to type all the time

```
CASA <7>: import glob

CASA <8>: MyVis = glob.glob('*.ms')

CASA <9>: MyVis
Out[9]: ['uid___A002_Xd2b681_Xa1c2.ms', 'uid___A002_Xd2b681_Xb99d.ms']

CASA <10>:
```

OPTIONAL

Work through re-imaging with ALMA Pipeline

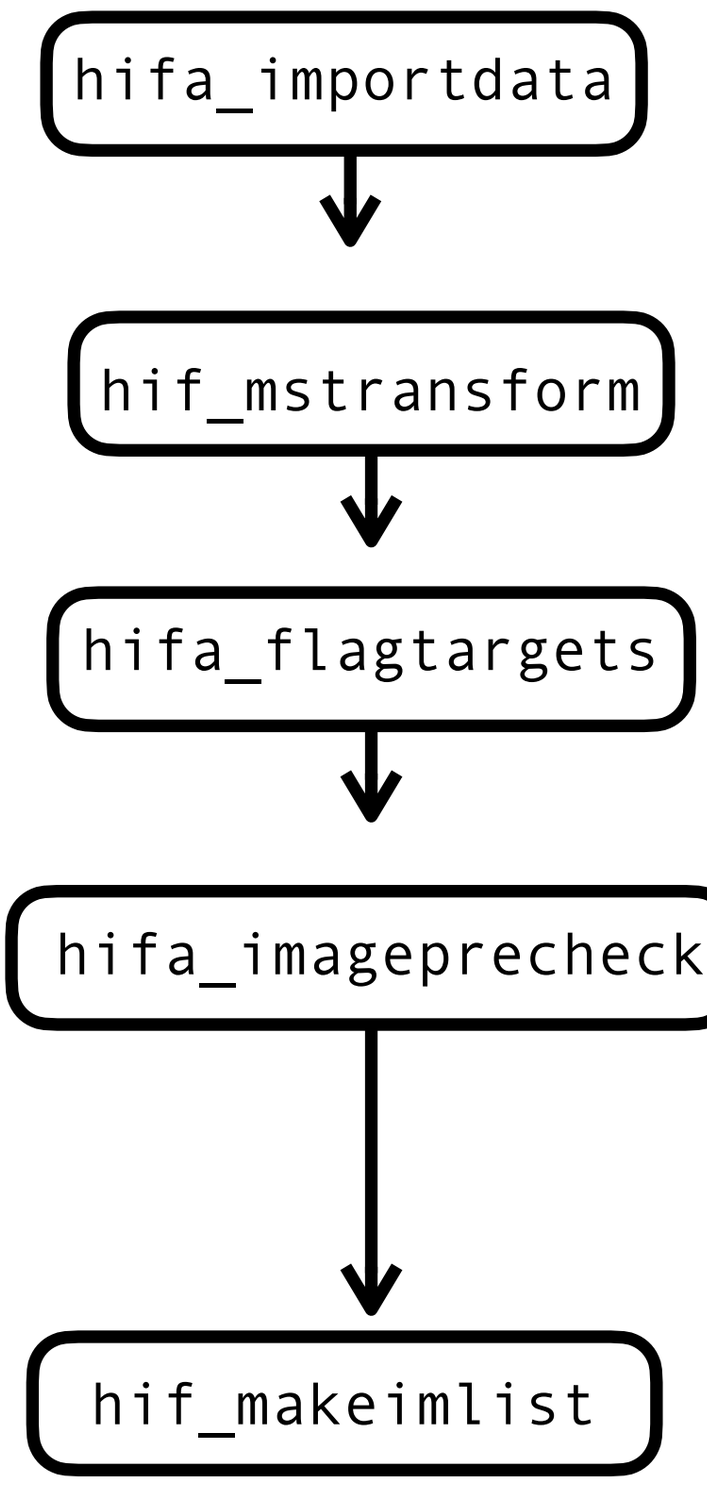
we don't need this set, we are importing data

```
[CASA <10>: hifa_importdata(vis=MyVis, dbservice=False)
2024-06-12 08:18:29 INFO: Starting execution for stage 1
2024-06-12 08:18:29 INFO: Equivalent CASA call: hifa_importdata(vis=['uid___A002_Xd2b681_Xa1c2.ms', 'uid___A
002_Xd2b681_Xb99d.ms'], dbservice=False)
2024-06-12 08:18:29 INFO: Creating pipeline objects for measurement set(s) /Users/lmaud/Work/QA2_offlineWL/P
Ltutorial/2018.1.01201.S/science_goal.uid___A001_X133d_X2c85/group.uid___A001_X133d_X2c86/member.uid___A001_
X133d_X2c8b/calibrated/uid___A002_Xd2b681_Xa1c2.ms
2024-06-12 08:18:29 INFO: Analysing uid___A002_Xd2b681_Xa1c2.ms
2024-06-12 08:18:29 INFO: Populating ms.antenna_array...
2024-06-12 08:18:29 INFO: Populating ms.spectral_windows...
```

processing output

this will take a few minutes so let me explain the next points while it processes

Required Steps before continuum subtraction:



will apply Binary Data Flags, and will calculate some properties of the MSs.

will create the measurement sets of the target for imaging.

will create flags for the science target data.

will use the representative source and spw containing the representative frequency selected by the PI in the OT to calculate the synthesized beam and to make sensitivity estimates for the aggregate bandwidth and representative bandwidth for three values of the robust parameter.

will determine image parameters (image size, cell size, etc) in automatic mode to be used in the subsequent `hif_makeimages` stage.

Required Steps before continuum subtraction:

`hifa_importdata`

will apply Binary Data Flags, and will calculate some properties of the MSs.

`hif_mstransform`

will create the measurement sets of the target for imaging.

`hifa_flagtargets`

will create flags for the scie

we will skip the check now, this will go to defaults w.r.t expected settings:
- image size to 20% of PB and robust = 0.5

`hifa_imageprecheck`

will use th
the representative frequen
OT to calculate the synthesized
sensitivity estimates for the aggregate bandwidth and representative bandwidth for three
robust parameter.

this is the first call - BEFORE findcont and uvcontsub - nesscary to then later do 'cont' and 'cube' images

`hif_makeimlist`

will determi
size, etc) in automatic
subsequent `hif_makeima`

OPTIONAL

Work through re-imaging with ALMA Pipeline

once the import data is done, and you have saved the context, then the weblog can be viewed

- h_save()
- h_weblog()

saves the pipeline "context" all information about the Pipeline tasks you are running

OR

- open a new terminal
- **navigate** to the pipeline-2024…/html/…. directory

```
python3 -m http.server 8080 --bind localhost
```

- open the browser

```
http://localhost:8080/
```

OPTIONAL

Work through re-imaging with ALMA Pipeline

LETS LOOK AT THE WEBLOG CREATED

guess what - there is one stage, the import data

Task Summaries

Task		QA Score	Duration
1. **hifa_importdata**: Register measurement sets with the pipeline	Flux catalog service not used. Source.xml is the origin.	0.30	0:08:12

CASA logs and scripts

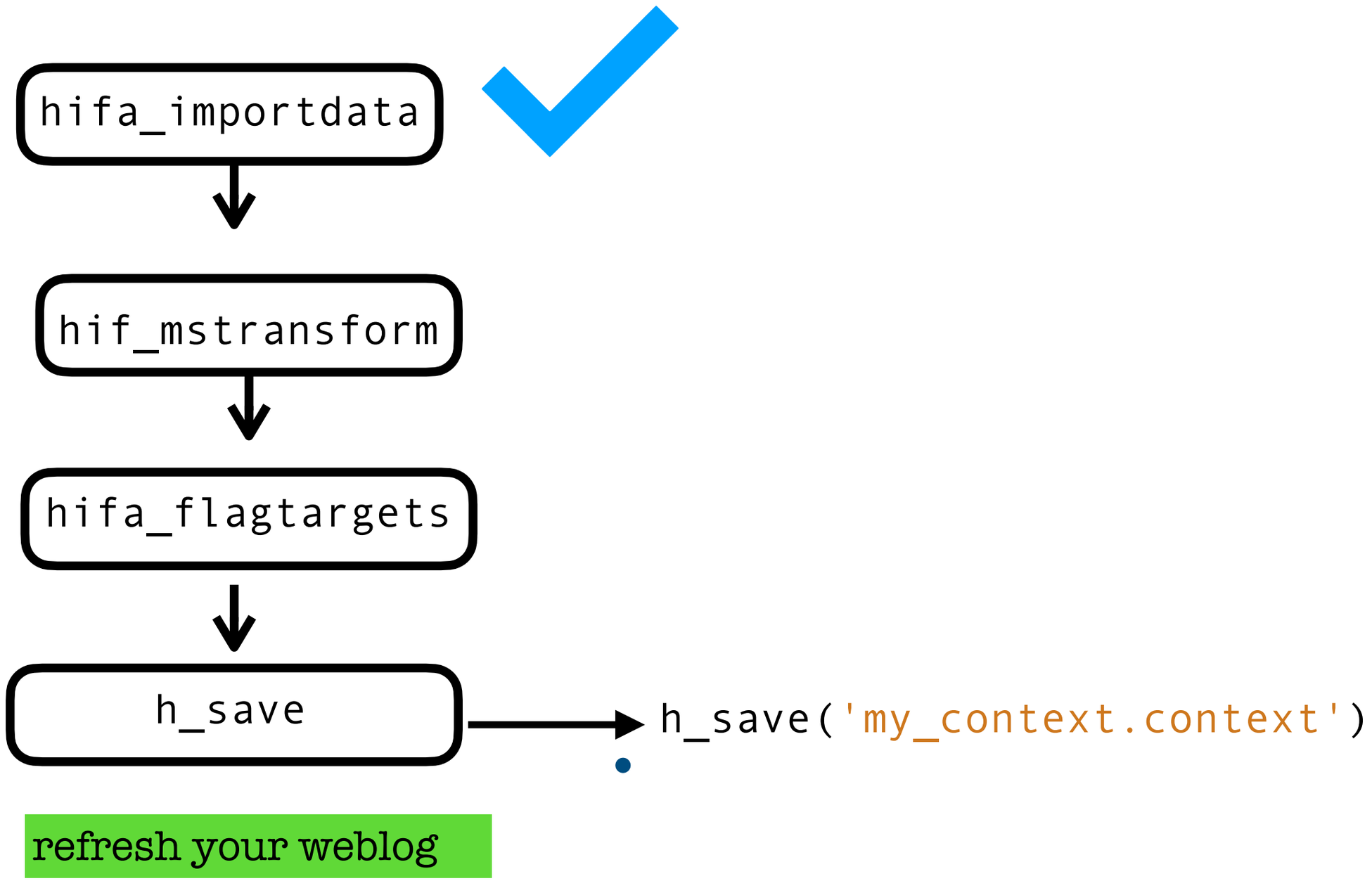
- View, view in new tab or download casa-20240612-085750.log (116.4 KiB)
- View, view in new tab or download casa_commands.log (815 bytes)
- View, view in new tab or download casa_pipescript.py (152 bytes)
- View, view in new tab or download (608 bytes)

this score is ok, we told it not to look at the flux service. And we are not doing calibration

OPTIONAL

Work through re-imaging with ALMA Pipeline

OK, THE NEXT STEPS

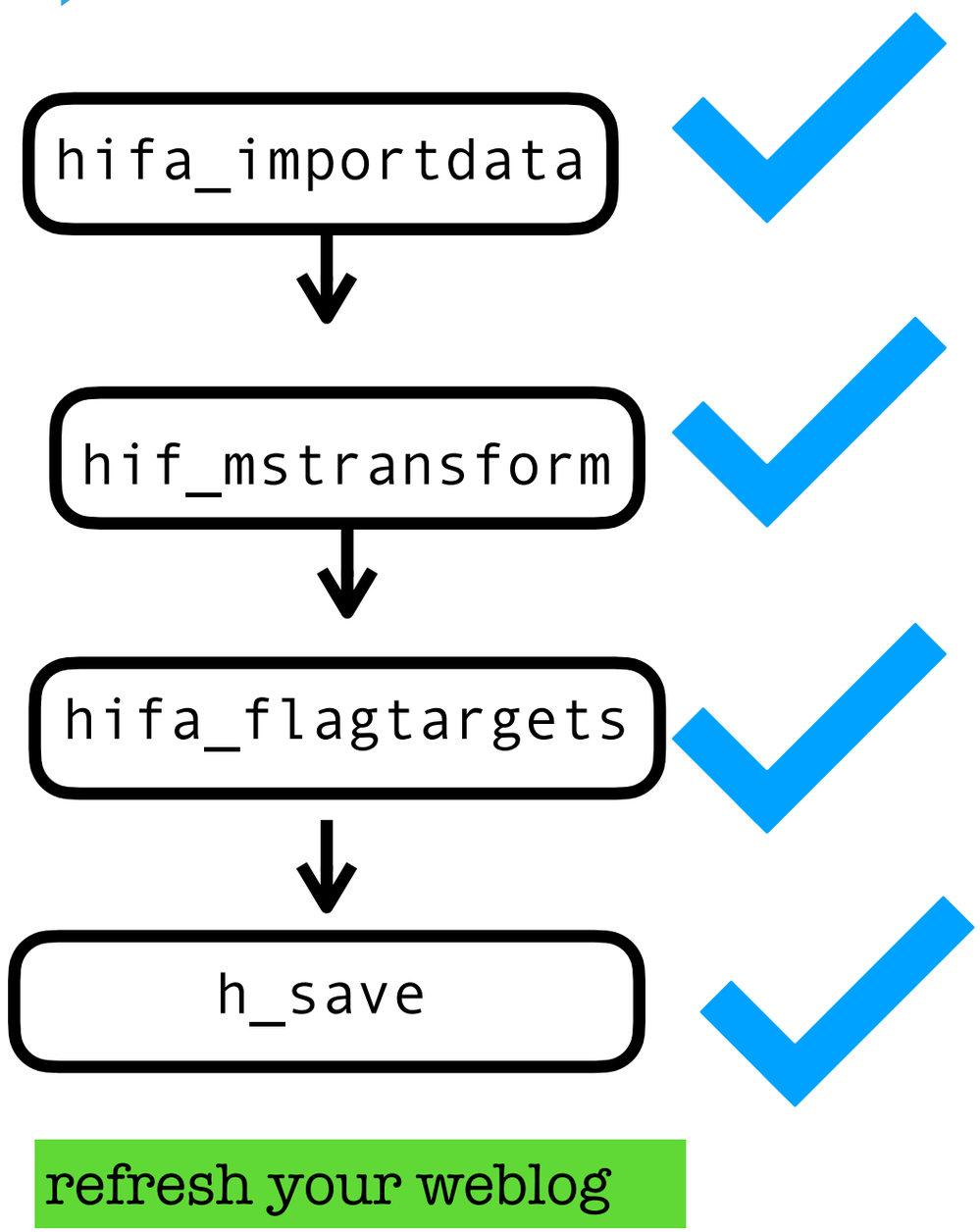


refresh your weblog

OPTIONAL

Work through re-imaging with ALMA Pipeline

OK, THE NEXT STEPS



- now we will image a custom image
  - we miss the precheck as we will setup images ourselves and its more a guide for data analysts
  - otherwise as part of a ‘standard’ imaging pipeline run the stage takes - 6-8min for these data on a laptop

OPTIONAL

Work through re-imaging with ALMA Pipeline

ready to actually image

ensure **ALL** SpW are listed at a minim, before findcont stage otherwise that won't work - maybe the first **hif_makeimlist** can also be left only with - spec mode = 'mfs' - option

```
CASA <10>: hif_makeimlist(specmode='mfs')
```

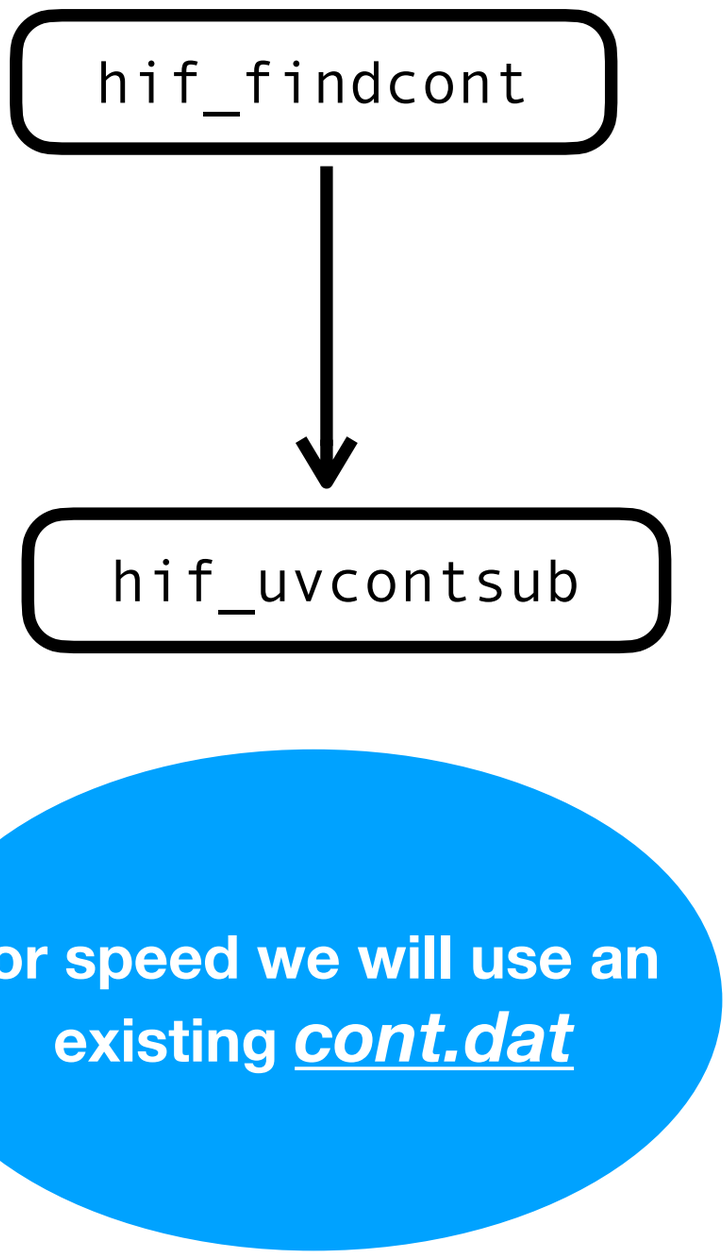
- image all SpW with robust parameters will be AUTOMATICALLY set

later we will do some changing of the parameters

OPTIONAL

Work through re-imaging with ALMA Pipeline

BEFORE GOING ON WE NEED TO 'FINDCONT'



will make dirty image cubes for each spectral window of each science target. It will generate and evaluate the mean spectrum of a masked region. It will calculate frequency ranges that are the least likely to contain any line emission or absorption. Efforts are made to get at least a wid spread over the spectral window and some channel lining can occur related to the PI's requested spectral resolution

Does the continue subtraction in the UV domain. After this step (since Cycle 9 pipeline, CASA 6.4.1), the original continuum + line emission is contained in the **DATA** column of the MS, will first be split out such that a **new MS** is made where the DATA column contains **LINE ONLY**

OPTIONAL

Work through re-imaging with ALMA Pipeline

```
[CASA <13>:

[CASA <13>: !cp ../products/cont.dat .

[CASA <14>:
```

```
[CASA <14>: hif_findcont
2024-06-12 21:49:34 INFO: Starting execution for stage 5
2024-06-12 21:49:34 INFO: Equivalent CASA call: hif_findcont()
2024-06-12 21:49:34 INFO: Using data type REGCAL_CONTLINE_SCIENCE for continuum finding.
2024-06-12 21:49:34 INFO: Using existing selection [{'range': (219.526413327, 219.553776531), 'refer': 'LSR
'}, {'range': (219.559456839, 219.570756377), 'refer': 'LSRK'}, {'range': (219.573382756, 219.5843769), 're
er': 'LSRK'}] for field RU_Lup, spw 24
Out[14]:
FindCont:
 Source RU_Lup
  SpW 24:    Ranges: 219.5264133270~219.5537765310GHz;219.5594568390~219.5707563770GHz;219.5733827560~219.58
3769000GHz LSRK
   Status: OLD
```

Pipeline knows we are using a table we gave

CAREFUL - format changes between newer versions

OPTIONAL

Work through re-imaging with ALMA Pipeline

BEFORE GOING ON WE NEED TO 'FINDCONT' & 'UVCONTSUB'

```
[CASA <13>:

[CASA <13>: !cp ../products/cont.dat .

[CASA <14>:
```

```
[CASA <14>: hif_findcont
2024-06-12 21:49:34 INFO: Starting execution for stage 5
2024-06-12 21:49:34 INFO: Equivalent CASA call: hif_findcont()
2024-06-12 21:49:34 INFO: Using data type REGCAL_CONTLINE_SCIENCE for continuum finding.
2024-06-12 21:49:34 INFO: Using existing selection [{'range': (219.526413327, 219.553776531), 'refer': 'LSR
'}, {'range': (219.559456839, 219.570756377), 'refer': 'LSRK'}, {'range': (219.573382756, 219.5843769), 're
er': 'LSRK'}] for field RU_Lup, spw 24
Out[14]:
FindCont:
 Source RU_Lup
  SpW 24:   Ranges: 219.5264133270~219.5537765310GHz;219.5594568390~219.5707563770GHz;219.5733827560~219.58
3769000GHz LSRK
   Status: OLD
```

```
[CASA <16>: hif_uvcontsub
2024-06-12 21:53:37 INFO: Starting execution for stage 6
2024-06-12 21:53:37 INFO: Equivalent CASA call: hif_uvcontsub()
2024-06-12 21:53:37 INFO: Selecting representative target source RU_Lup for data set uid___A002_Xd2b681_Xa
2_targets.ms
```

OPTIONAL

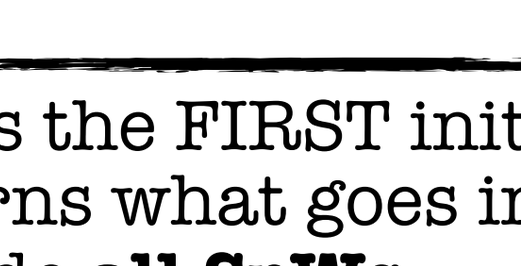
Work through re-imaging with ALMA Pipeline

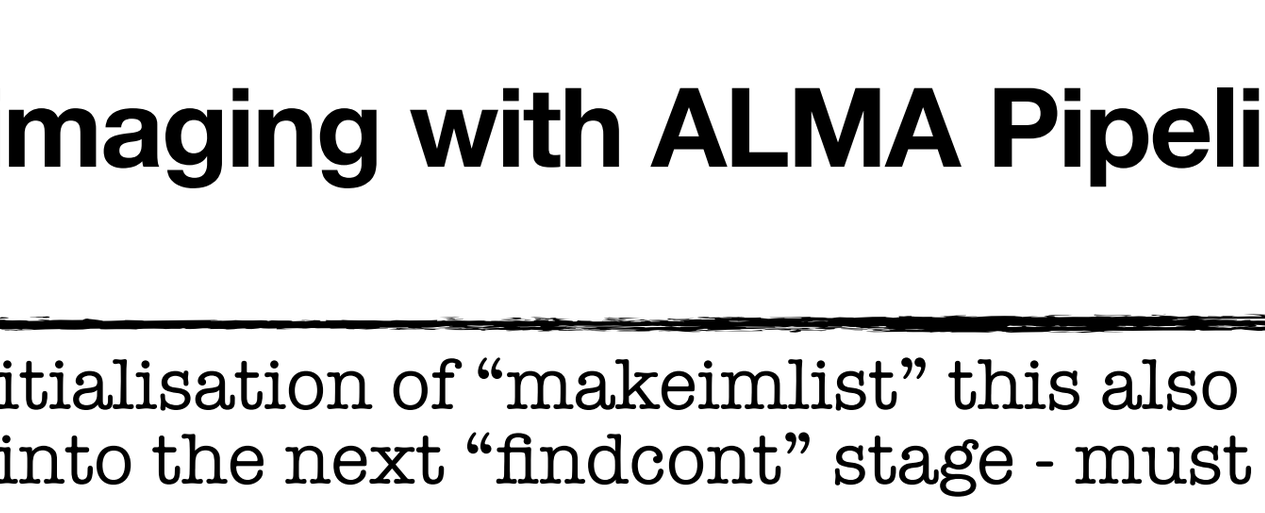
this is the FIRST initialisation of “makeimlist” this also governs what goes into the next “findcont” stage - must include **all SpWs**

```
CASA <10>: hif_makeimlist(specmode='mfs')
```

```
CASA <16>: h_save()

CASA <17>: hif_makeimages()
```





now we are free to do imaging as we want

OPTIONAL

Work through re-imaging with ALMA Pipeline

LOOPS OF MAKEIMLIST TO MAKE IMAGES

imaging from this point can just continue in loops of "**makeimlist**" and then "**makeimages**"

```
hif_makeimlist(specmode='xxxx')
```

- specmode="mfs', 'cont', 'cube'
- robust (-2.0 to 2.0)
- spw = 'X'
- hm_cell = 'x.xarcsec'
- hm_imsize = xx
- uvtaper = ['XXarcsec']
- **cube mode:**
  - start = '219.553GHz'
  - nchan = 200
  - nbins = 'spw:n,spw:n'

dont make this too big, the imaging heuristics in PL can fail as most of the image is 'blank'

```
hif_makeimages()
```

care with formats

```
h_save()
```

remember to regularly save the context and also check your weblog

OPTIONAL

Work through re-imaging with ALMA Pipeline

```
CASA <120>: hif_makeimlist(specmode='mfs',robust=-0.5,spw='22,24,26',hm_imsize=60)

CASA <121>: hif_makeimages()

CASA <122>: h_save()
```

- changed robust
- sub-selection of some SpWs
- changed the image size

OPTIONAL

Work through re-imaging with ALMA Pipeline

```
CASA <120>: hif_makeimlist(specmode='cube',robust=2.0,spw='22,26',hm_imsize=80,
            nbins='22:8,26:4')

CASA <121>: hif_makeimages()

CASA <122>: h_save()
```

- changed robust
- sub-selection of some SpWs
- changed the image size
- different binning of cube

OPTIONAL

Work through re-imaging with ALMA Pipeline

```
CASA <25>: hifa_exportdata(imaging_products_only=True)
```

- Export the images to fits files.

OPTIONAL

Work through re-imaging with ALMA Pipeline

SUPER EXPERT MODE

`hif_makeimages`

the call to ‘make the images’, this will use all pre-set parameters as checked and benchmarked to perform for (almost) all ALMA data…the threshold for cleaning and auto masking are all included…

these can be changed - BUT - with caution as the effects might be somewhat unexpected or cause very long runtimes if you have larger data

OPTIONAL

Work through re-imaging with ALMA Pipeline

SUPER EXPERT MODE

```
tclean(vis=['uid___A002_Xd2b681_Xa1c2_targets_line.ms', 'uid___A002_Xd2b681_Xb99d_targets_line.ms'], field='RU_Lup',
spw=['22', '22'], antenna=['0,1,2,3,4,5,6,7,8,9,10&', '0,1,2,3,4,5,6,7,8,9,10,11&'], scan=['6,8,11,13,16', '7,10'],
intent='OBSERVE_TARGET#ON_SOURCE', datacolumn='data', imagename='oussid.s32_0.RU_Lup_sci.spw22.cube.regcal.I.iter0',
imsize=[100, 100], cell=['0.89arcsec'], phasecenter='ICRS 15:56:42.2942 -037.49.15.995', stokes='I', specmode='cube',
nchan=126, start='216.0782155800GHz', width='0.4886236MHz', outframe='LSRK', perchanweightdensity=True,
gridder='standard', mosweight=False, usepointing=False, pblimit=0.2, deconvolver='hogbom', restoration=False,
restoringbeam='common', pbcor=False, weighting='briggsbwtaper', robust=0.5, npixels=0, niter=0, threshold='0.0mJy',
nsigma=0.0, interactive=False, fullsummary=False, usemask='auto-multithresh', sidelobethreshold=1.25, noisethreshold=5.0,
lownoisethreshold=2.0, negativethreshold=0.0, minbeamfrac=0.1, growiterations=75, dogrowprune=True, minpercentchange=1.0,
fastnoise=False, savemodel='none', parallel=False)
```

`hif_makeimages`

- hm_cyclefactor
- hm_sidelobethreshold
- hm_noisethreshold
- hm_lownoisethreshold
- hm_negativethreshold

help hif_makeimages, some parameters are changeable - some note and get overwritten

look at your logs to see the typical parameters

can use a similar copy of “tclean” and run own calls - but no more weblog

Automasking parameters for Pipeline

Array	*sidelobethreshold*	*noisethreshold*	*minbeamfrac*	*lownoisethreshold*	*negativethreshold*
12m (short) b75<300m	**2.0**	**4.25**	**0.3**	**1.5**	**0.0 (continuum) 15.0 (line)**
12m (long) b75>300m	**3.0**	**5.0**	**0.3**	**1.5**	**0.0 (continuum) 7.0 (line)**
7m (continnum/line)	**1.25**	**5.0**	**0.1**	**2.0**	**0.0**
12m + 7m combined **TENTATIVE**	**2.0**	**4.25**	**0.3**	**1.5**	**0.0**

MUST READ - NRAO guide: https://casaguides.nrao.edu/index.php/Automasking_Guide

Some Schools and Material *(not exhaustive)*

- IRAM summer school: https://www.iram-institute.org/EN/content-page-399-7-67-367-399-0.html
- European Radio interferometry school - ERIS: https://www.jive.eu/eris2022/
- SMA interferometry school: https://lweb.cfa.harvard.edu/sma-school/program/
- NRAO synthesis imaging workshop: https://science.nrao.edu/science/meetings/2018/16th-synthesis-imaging-workshop/16th-synthesis-imaging-workshop-lectures
- Myers - Imaging in CASA: https://slideplayer.com/slide/7964345/
- UK ARC node - line imaging tutorial: https://www.alma.ac.uk/index.php/meeting-supplemental-material/286-spectral-line-imaging-tutorial
- ALMA primer series basic concepts videos: https://www.youtube.com/channel/UCwTfiIlYuUQr4sRc5iSJaRg/videos
- Lecture course: https://www.astron.nl/astrowiki/doku.php?id=uva_msc_radioastronomy_2013

Extra Slides

Brief image analysis

- Some analysis can be done in the CARTA

Image Information

- **imhead** — summarize and manipulate the "header" information in a CASA image

Image Manipulation

- **imsubimage** — Create a (sub)image from a region of the image
- **imcontsub** — perform continuum subtraction on a spectral-line image cube
- **imfit** — image plane Gaussian component fitting
- **immath** — perform mathematical operations on or between images
- **immoments** — compute the moments of an image cube
- **impv** — generate a position-velocity diagram along a slit

Image Information

- **imstat** — calculate statistics on an image or part of an image
- **imval** — extract the data and mask values from a pixel or region of an image

Image Reformatting

- **imtrans** — reorder the axes of an image or cube
- **imcollapse** — collapse image along one or more axes by aggregating pixel values along that axis
- **imregrid** — regrid an image onto the coordinate system of another image
- **imreframe** — change the frame in which the image reports its spectral values
- **imrebin** — rebin an image
- **specsmooth** — 1-dimensional smooth images in the spectral and angular directions
- **imsmooth** — 2-dimensional smooth images in the spectral and angular directions

Spectral line related

- **specfit** — fit 1-dimensional Gaussians, polynomial, and/or Lorentzians models to an image or image region
- **specflux** — Report details of an image spectrum.
- **plotprofilemap** — Plot spectra at their position
- **rmfit** — Calculation of rotation measures
- **spxfit** — Calculation of Spectral Indices and higher order polynomials
- **makemask** — image mask handling
- **slsearch** — query a subset of the Splatalogue spectral line catalog
- **splattotable** — convert a file exported from Splatalogue to a CASA table

Image Import/Export

- **importfits** — import a FITS image into a CASA image format table
- **exportfits** — write out an image in FITS format

CREDITS: Imaging Analysis in CASA by Feng Long - SMA school 2022 (older viewer commands): https://lweb.cfa.harvard.edu/sma-school/program/

Brief image analysis

- **imval**(imagename, region='', box='', chans='', stokes='')

- **imstat**(imagename, region='', box='' chans='', stokes='')

box = '512,512' - one pixel
box = 'blcX, blcY, trcX, trcY' - box region

region = 'circle[[512pix, 512pix], 50pix]'
region = 'circle[[04h35m28.15s, +22d32m14.24s], 1.5arcsec'

- **immath**(imagename='name', expr='IM0^2', outfiile='')

will square all data in image 0

- **immath**(imagename=['name1', 'name2'], expr='IM0-IM1', outfile='')

will subtract image 0 from image 1 (of input list)

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CREDITS: Imaging Analysis in CASA by Feng Long - SMA school 2022 (older viewer commands): https://lweb.cfa.harvard.edu/sma-school/program/

Brief image analysis

- myfit = **imfit**(imagename, region='', chans='', stokes='')

>print(myfit)

- **imsubimage**(imagename, outfile='', chans='5~10', region='', box='')

takes channels 5 to 10 out of a cube

- **immoments**(imagename='name', moments=[0], chans='10~50, outfile='image_mom0')

integrated intensity using channels 10 to 50 (Jy/beam.km/s units)

- **immoments**(imagename='name', moments=[1], chans='10~50, outfile='image_mom1', includepix=[3*0.05])

if sigma = 0.05Jy/bm, this is >3sigma

('range=[-20km/s,10km/s], restfreq=230.5GHz')

CREDITS: Imaging Analysis in CASA by Feng Long - SMA school 2022 (older viewer commands): https://lweb.cfa.harvard.edu/sma-school/program/

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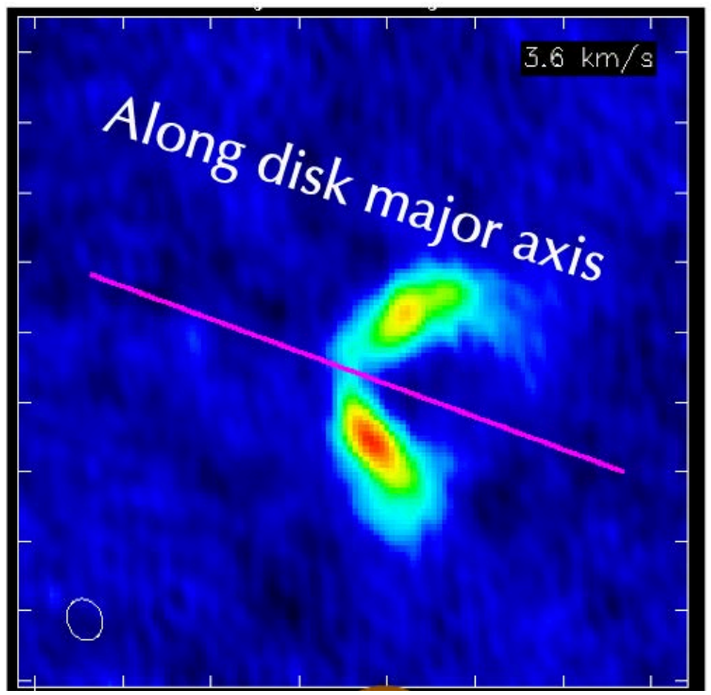
Brief image analysis

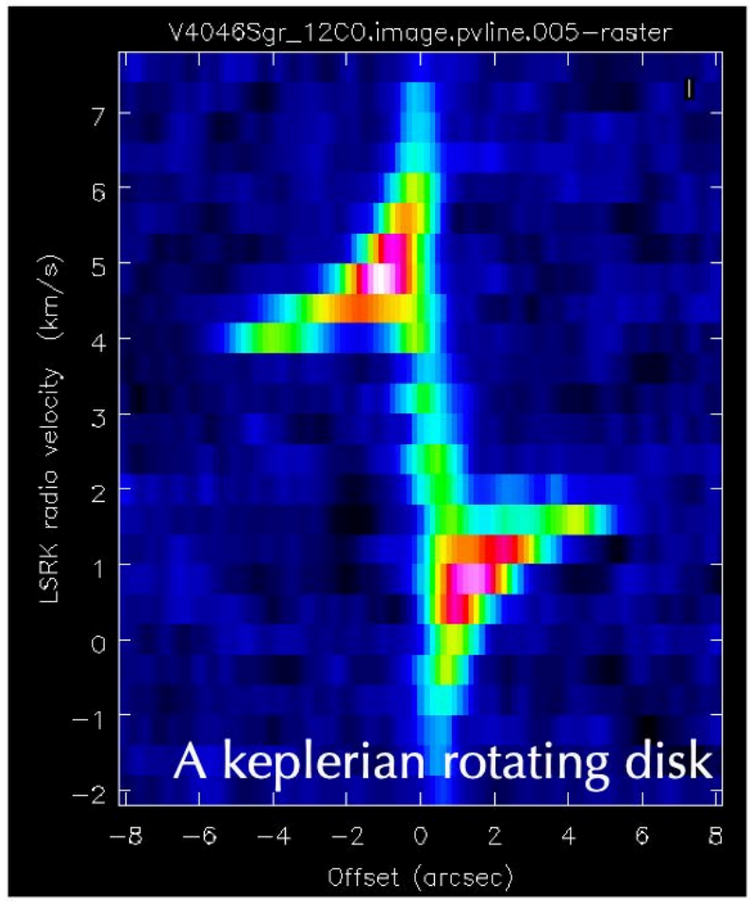
- **impv**(imagename, outfile='source_line_PV.image', chans='', mode='length', center=['18h14m10.5s, '-32d47m35.27s'],length='15arcsec', pa='70deg')

pix units also

Single channel



PV image - rotating disk



CREDITS: Imaging Analysis in CASA by Feng Long - SMA school 2022 (older viewer commands): https://lweb.cfa.harvard.edu/sma-school/program/

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