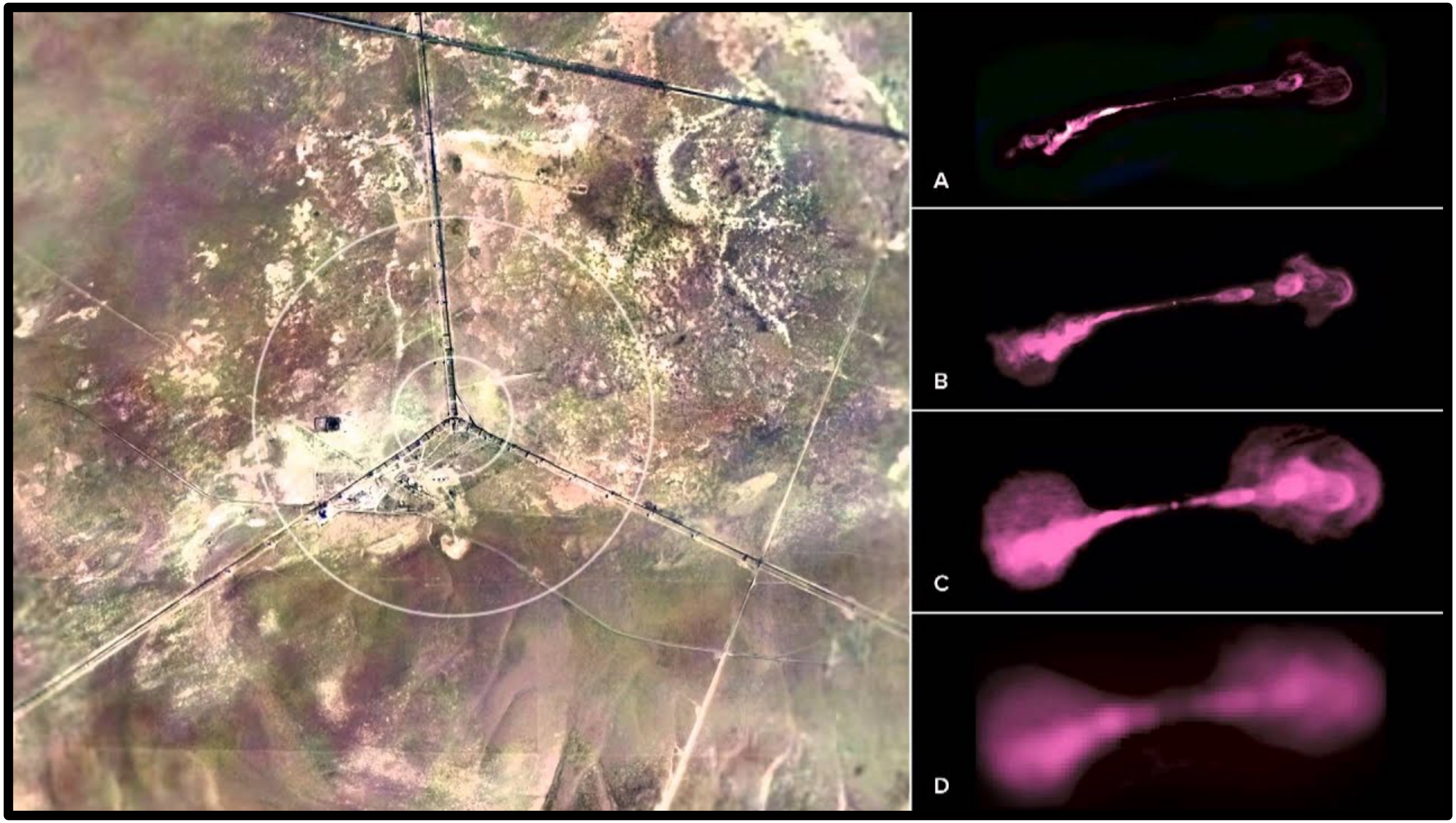
Simulating ALMA data

Angus Mok

Credits:
Remy Indebetouw (NRAO)
Andrew McNichols (NRAO)

Why simulate ALMA observations?

Proposed resolution / array configuration



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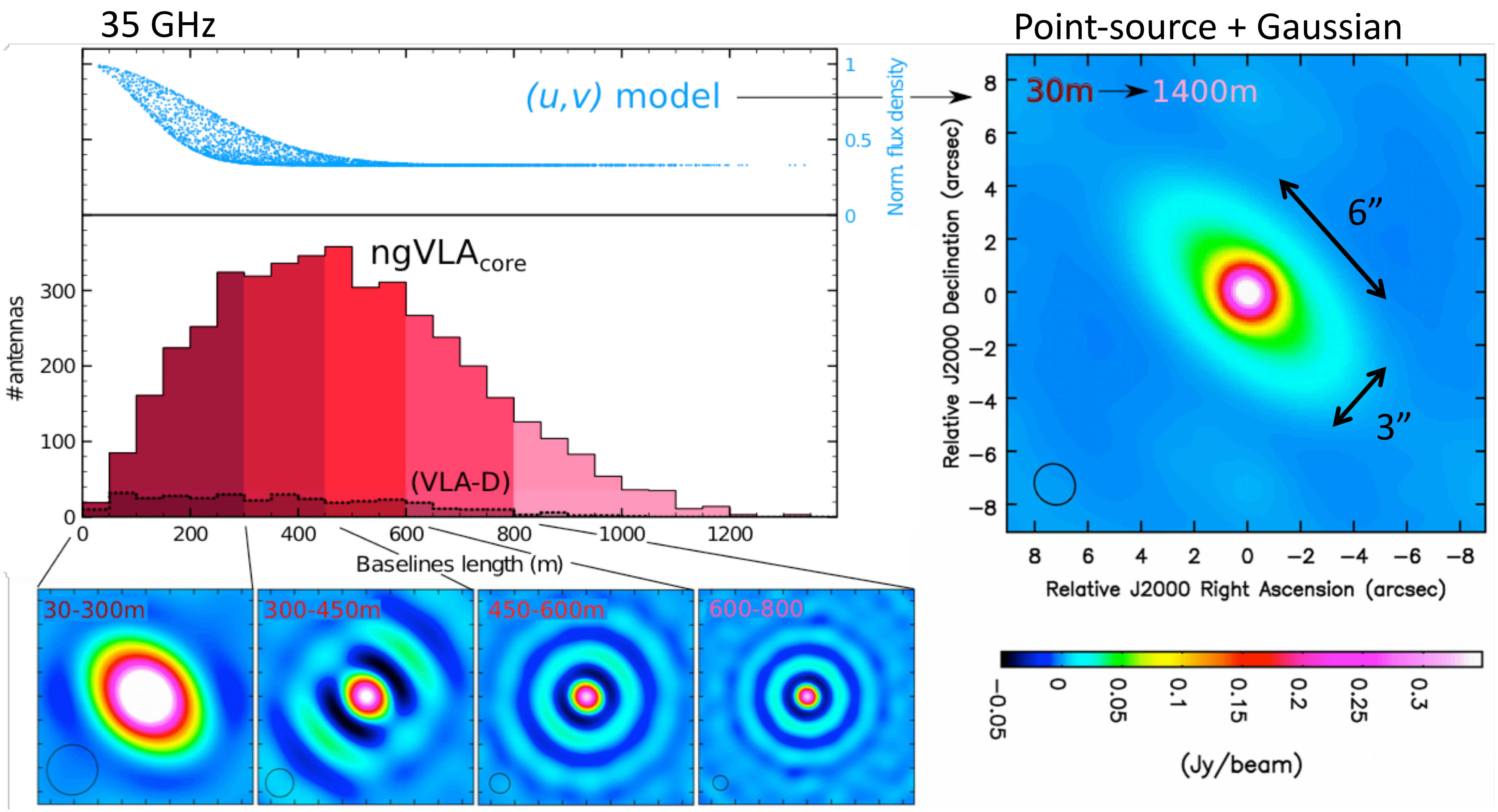

Emonts et al 2018, ASPC, 517, 587

Why simulate ALMA observations?

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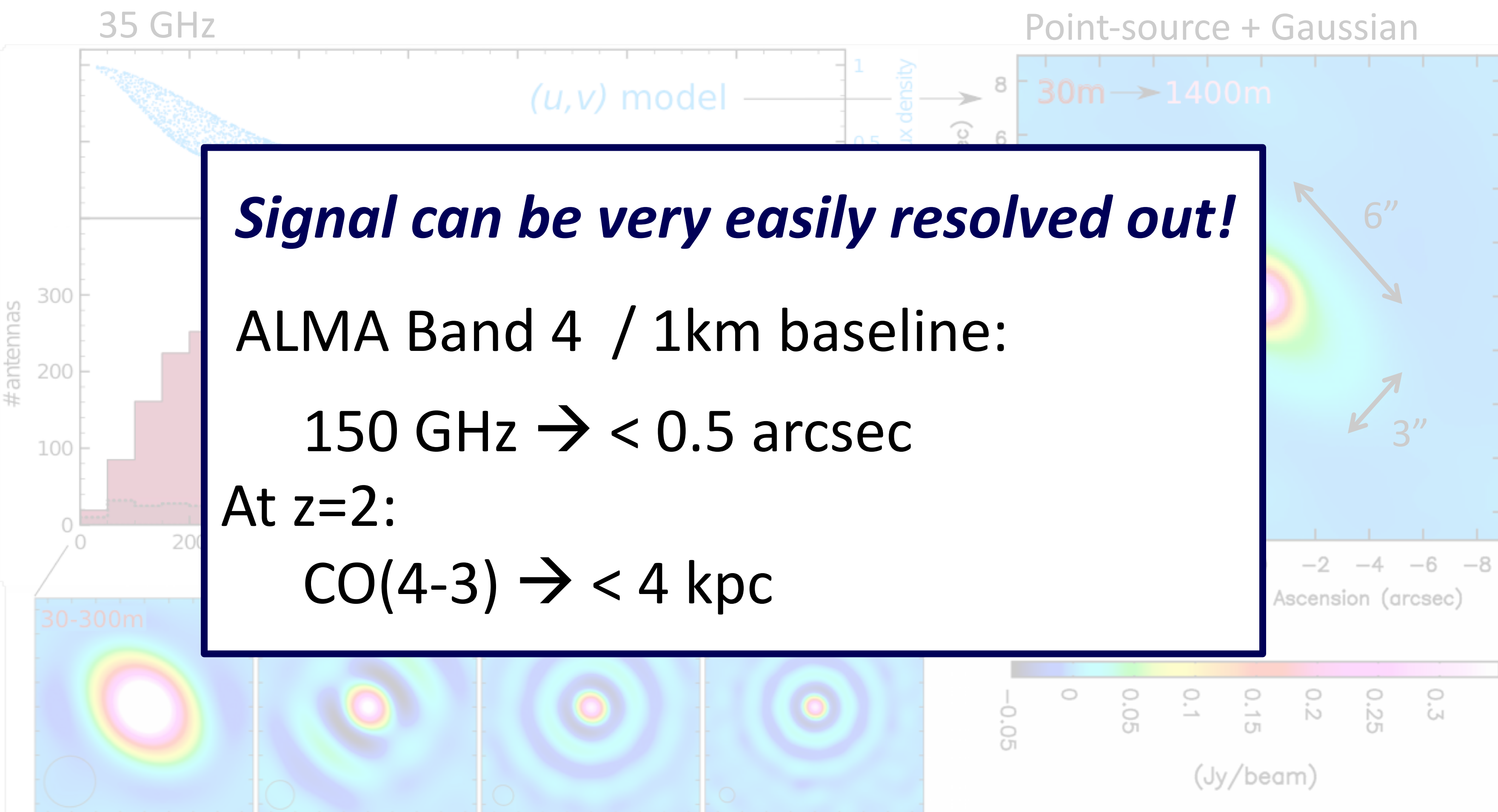


Signal can be very easily resolved out!

ALMA Band 4 / 1km baseline:

150 GHz → < 0.5 arcsec

At z=2:

CO(4-3) → < 4 kpc

Emonts et al 2018, ASPC, 517, 587

How to simulate ALMA observations?

CASA simulation tasks:

- simobserve
- simanalyze

(simobserve + simanalyze → simalma)

Configuration files:

ALMA + ACA

VLA, ngVLA, ATCA, PdbI, WSRT,
CARMA, MeerKAT, SMA, VLBA

Note: ALMA Cycle-7 config files → CASA 5.5
identical to Cycle-6 config files in CASA 5.4!

How to simulate ALMA observations?

CASA

Search Site | Search

Home | CASA 5.5.0 | Latest | CASA 5.4.1 | CASA 5.4.0 | CASA 5.3.0 | CASA 5.1.2 | CASA 5.1.1 | CASA 5.1.0 | CASA 5.0.0

CASA Documentation

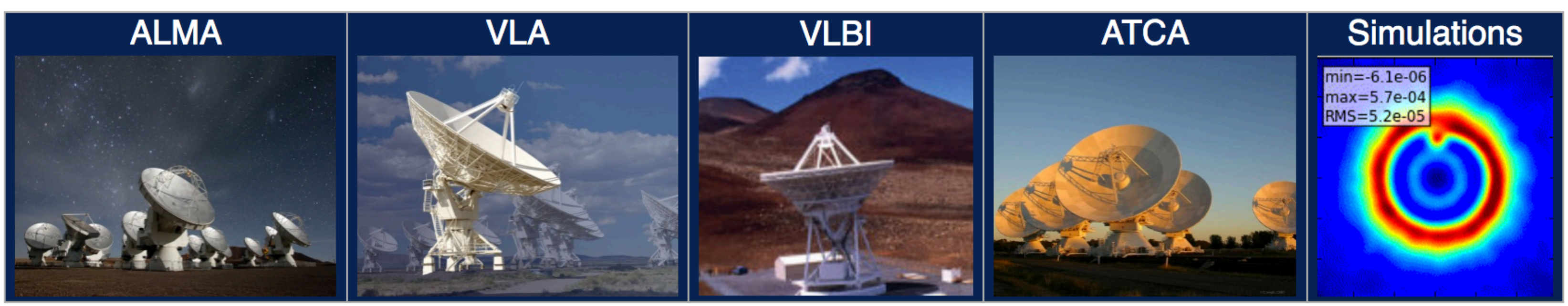
CASA Docs

Official CASA documentation
https://casa.nrao.edu/casadocs/

CASA Guides

Telescope-specific CASA strategies
https://casaguides.nrao.edu/

CASA Tutorials



SIMALMA Tutorial

https://casaguides.nrao.edu/index.php/Simalma_(CASA_5.4)

CASA Guides:
https://casaguides.nrao.edu/

1. Go to CASA Guides website
2. Click on Simulations and then on the SimALMA tutorial
3. Start up CASA on your computer
4. Follow the steps and use copy + paste to insert commands on your own version of CASA

SIMALMA Tutorial

https://casaguides.nrao.edu/index.php/Simalma_(CASA_5.4)

CASA Guides:
https://casaguides.nrao.edu/

```
# Set simalma to default parameters
default("simalma")
# Our project name will be "m51", and all simulation products will be placed in a subdirectory "m51/"
project="m51"
overwrite=True
```

```
# Model sky = Halpha image of M51
os.system('curl https://casaguides.nrao.edu/images/3/3f/M51ha.fits.txt -f -o M51ha.fits')
skymodel         =  "M51ha.fits"
```

```
# Set model image parameters:
indirection="J2000 23h59m59.96s -34d59m59.50s"
incell="0.1arcsec"
inbright="0.004"
incenter="330.076GHz"
inwidth="50MHz"
```

```
antennalist=["alma.cycle6.3.cfg","aca.cycle6.cfg"]
```

```
totaltime="1800s"
tpnant = 2
tptime="7200s"
pwv=0.6
mapsize="1arcmin"
```

SIMALMA

```
inp
```

```
go
```

IPython: CASA_testing/Simulations

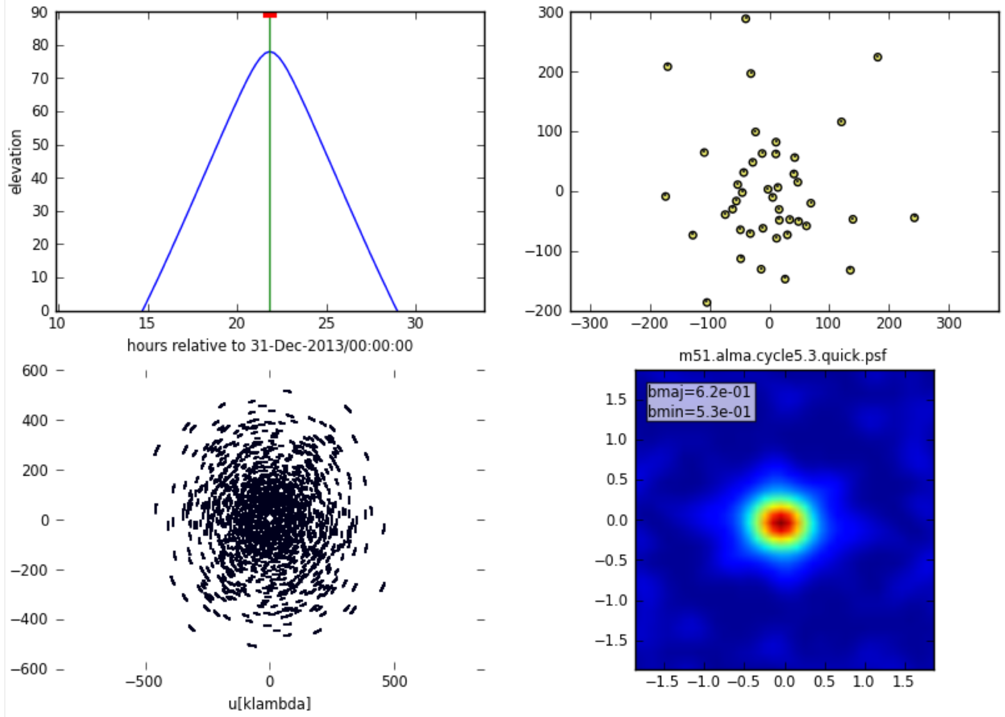
File Edit View Search Terminal Help

```
---------> inp()
#  simalma :: Simulation task for ALMA
project             =      'm51'        #  root prefix for output file names
dryrun              =      False        #  dryrun=True will only produce the
                                        #   informative report, not run
                                        #   simobserve/analyze
skymodel            = 'M51ha.fits'      #  model image to observe
     inbright       =    '0.004'        #  scale surface brightness of brightest
                                        #   pixel e.g. "1.2Jy/pixel"
     indirection    = 'J2000 23h59m59.96s -34d59m59.50s' #  set new direction
                                        #   e.g. "J2000 19h00m00 -40d00m00"
     incell         = '0.1arcsec'       #  set new cell/pixel size e.g.
                                        #   "0.1arcsec"
     incenter       = '330.076GHz'      #  set new frequency of center channel
                                        #   e.g. "89GHz" (required even for 2D
                                        #   model)
     inwidth        =     '50MHz'       #  set new channel width e.g. "10MHz"
                                        #   (required even for 2D model)

complist            =           ''      #  componentlist to observe
setpointings        =         True
     integration    =        '10s'      #  integration (sampling) time
     direction      =           ''      #  "J2000 19h00m00 -40d00m00" or "" to
                                        #   center on model
     mapsize        =   '1arcmin'       #  angular size of map or "" to cover
                                        #   model

antennalist         = ['alma.cycle6.3.cfg', 'aca.cycle6.cfg'] #  antenna
                                        #   position files of ALMA 12m and 7m
                                        #   arrays
hourangle           =    'transit'      #  hour angle of observation center e.g.
                                        #   -3:00:00, or "transit"
totaltime           =      '1800s'      #  total time of observation; vector
                                        #   corresponding to antennalist
tpnant              =            2      #  Number of total power antennas to use
                                        #   (0-4)
     tptime         =      '7200s'      #  total observation time for total
                                        #   power

pwv                 =          0.6      #  Precipitable Water Vapor in mm. 0 for
                                        #   noise-free simulation
image               =         True      #  image simulated data
     imsize         =            0      #  output image size in pixels (x,y) or
                                        #   0 to match model
     imdirection    =           ''      #  set output image direction,
                                        #   (otherwise center on the model)
     cell           =           ''      #  cell size with units or "" to equal
                                        #   model
     niter          =            0      #  maximum number of iterations (0 for
                                        #   dirty image)
     threshold      =     '0.1mJy'      #  flux level (+units) to stop cleaning

graphics            =       'both'      #  display graphics at each stage to
                                        #   [screen|file|both|none]
verbose             =        False
overwrite           =         True      #  overwrite files starting with
                                        #   $project
```

SIMALMA

1. Simobserve

Simulate visibilities (MS) for each configuration



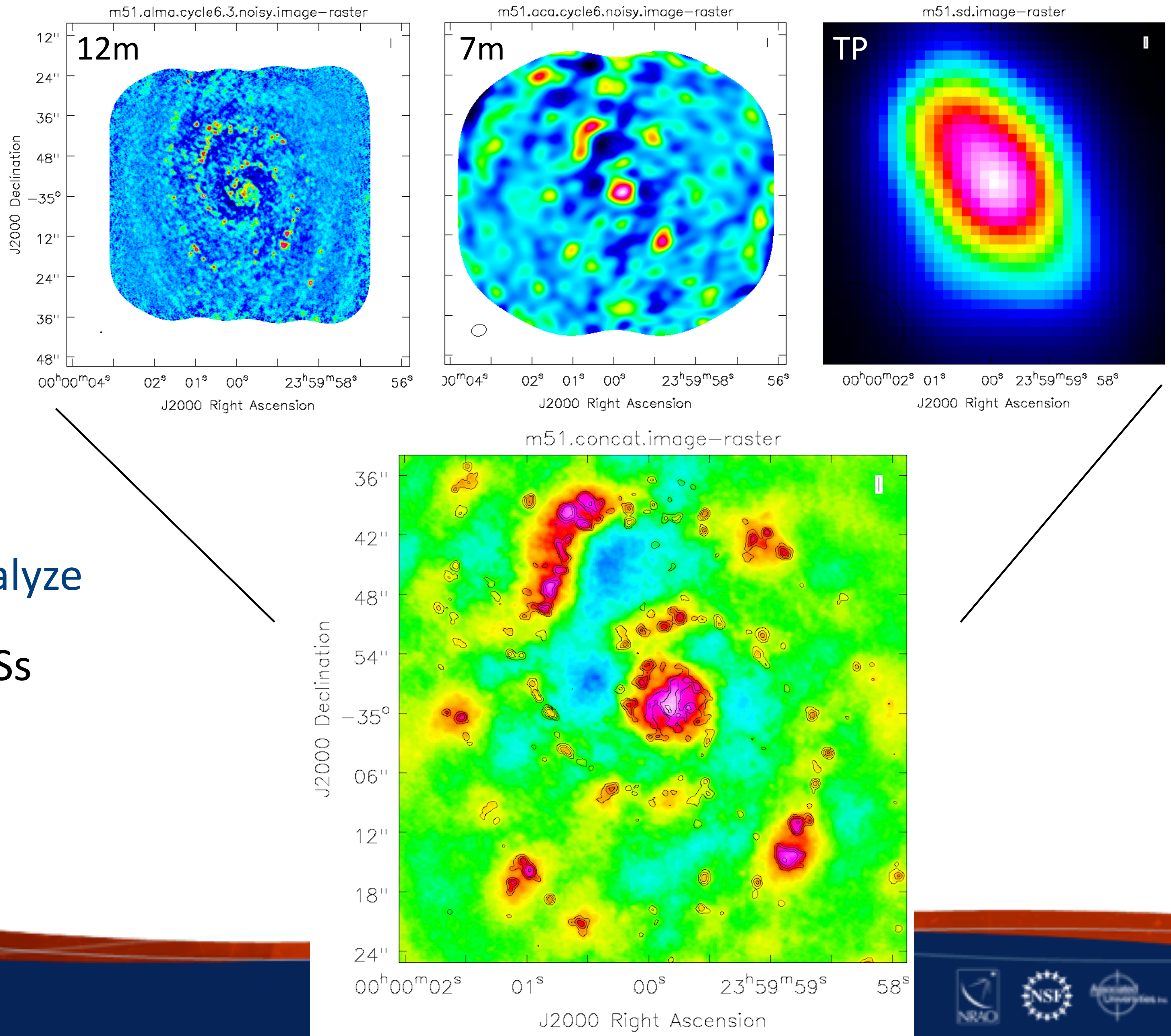
2. Simanalyze

Image MSs

SIMALMA

1. Simc

Simula
each c



2. Simanalyze

Image MSs

Questions?

CASA Guides

https://casaguides.nrao.edu/

ALMA Data –
what to expect after your observations are made

Angus Mok

Authors: Sarah Wood, Devaky Kunneriath, Sabrina Stierwalt, Erica Keller, Catarina Ubach

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array

The Condensed Version

- Data delivered after passing Quality Assurance (QA)
- Download data from *Archive Query* and *Request Handler* tools on the ALMA Science Portal
- Delivered data include:
  - Calibration tables and diagnostics
  - Preliminary images (*better products may be possible with more careful continuum identification & interactive cleaning*)
- Sections 11, 12, 14, and Appendix C of ALMA Technical Handbook

Goals of Quality Assurance (QA) Process

- Ensure reliable final data product
  - Desired sensitivity (as specified by PI)
  - Desired resolution (as specified by PI)
- Ensure calibration and QA imaging free from major artifacts
- Warning: Errors in PI-supplied parameters are outside scope of QA process, including:
  - Incorrect source coordinates
  - Inadequate frequency specification
  - Inadequate sensitivity limits

During Observations – QA0

- Monitoring of on-the-fly calibration and system performance
- Rapidly-varying parameters checked
  - Atmospheric effects
  - Antenna issues
  - Front-end issues
  - Connectivity issues
  - Back-end issues

Between Observations – QA1

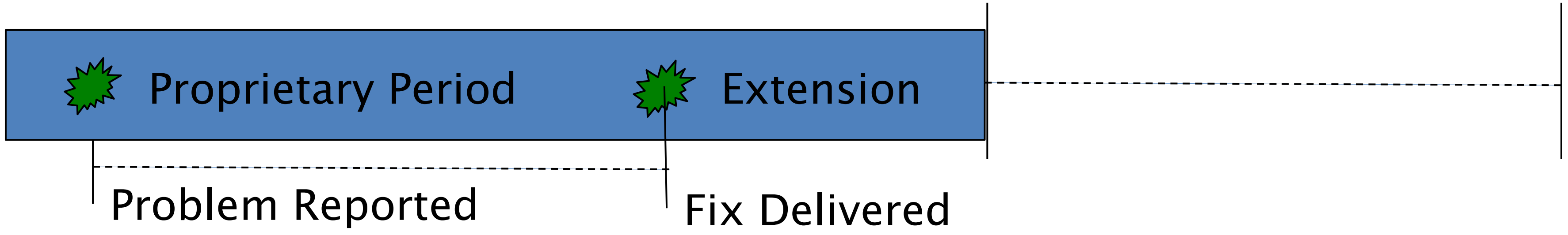
- Slowly Varying Parameters
- General array calibration
  - Baseline measurements
  - Delays
- Antenna Calibrations
  - All-sky pointing
  - Focus curves
  - Beam patterns

After Observations – QA2

- Final QA checks include:
  - RMS of complex antenna-based gains
  - Absolute flux calibration scale
  - T_{sys} within acceptable range
  - Proper phase transfer cadence
  - Proper bandpass corrections
- Assessment of Imaging Products
  - Signal-to-noise and angular resolution
  - No strong artifacts
  - Performed on the reference source/spectra

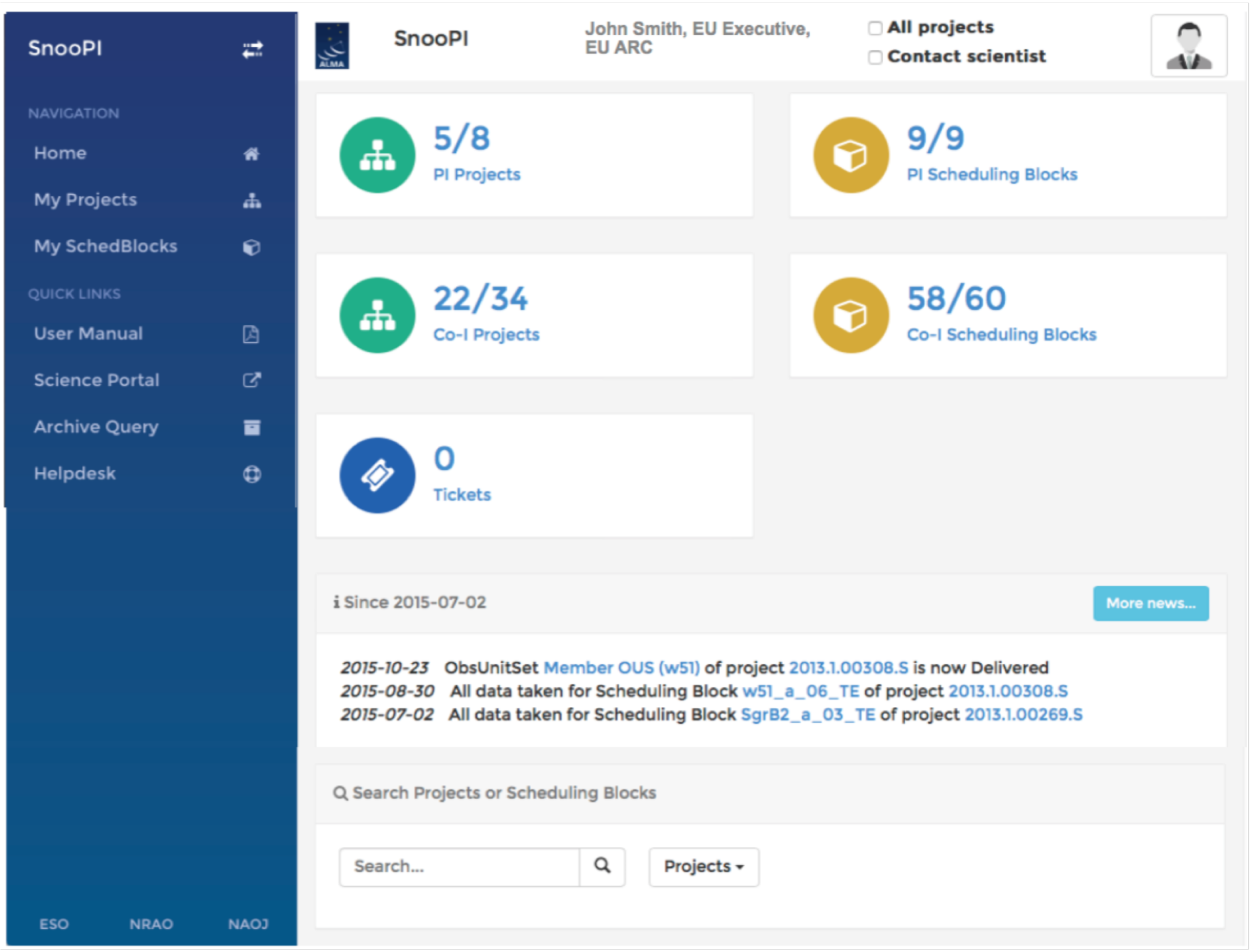
After Delivery – QA3

- Additional QA stage possibly triggered by PI reporting any issues underlying:
  - Data, observing procedure, calibration
- Re-evaluation of calibrated data products
- Proprietary period extension *(within two months of delivery)*



Monitor Project Status: *SnooPI*

https://almascience.eso.org/observing/snoopi



Data Delivery Email

- NA PIs get two delivery emails
  1. From JAO with links:
     - Archive query for MOUS package
  2. From NAASC:
     - Fully-calibrated MS (North America Only)
     - Calibration and Imaging Report (weblog)
     - ADMIT products

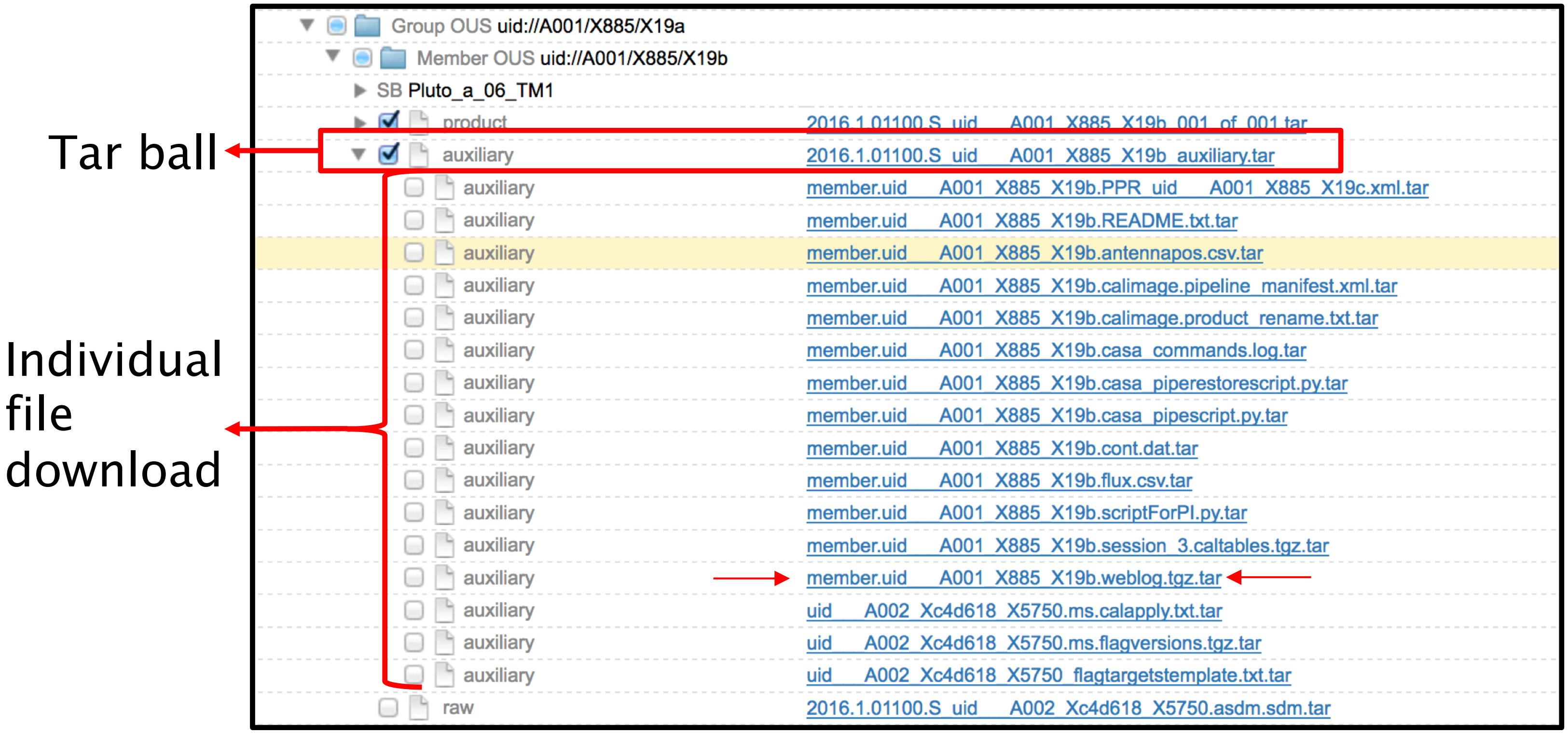
Data Delivery

- Publication Requirements:
  - ALMA acknowledgement
  - ARC specific acknowledgement

- Additional Support:
  - Funded face-to-face reduction visits to your home ARC
  - Contact info for ARC Helpdesk

Hands on: (http://almascience.nrao.edu/aq/)

Cycles 5-Present



QA2 Data Products Package: the processed data

After un-tarring the processed data we have a directory tree:

Science goal

Project code

```
2017.1.05267.S/
`-- science_goal.uid___A001_X1299_X2z
    `-- group.uid___A001_X1299_X25
        `-- member.uid___A001_X1299_X39
            |-- calibration
            |-- log
            |-- member.uid___A001_X1299_X39.README.txt
            |-- product
            |-- qa
            |-- script
```

Group OUS: combination of member OUS's

Member OUS: may contain 12-m array, ALMA Compact Array (ACA), or Total Power observation

Data delivery products…

QA2 Data Products Package: the processed data

Calibration Directory:

Calibration tables generated by the pipeline

Contains manual flagging commands, continuum selection, flux measurements for calibrators

```
|-- calibration
|    |-- member.uid___A001_X1299_X39.hifa_calimage.auxproducts.tgz
|    |-- member.uid___A001_X1299_X39.session_1.auxcaltables.tgz
|    |-- member.uid___A001_X1299_X39.session_1.caltables.tgz
|    |-- uid___A002_Xc8ed15_X1a9.ms.calapply.txt
|    |-- uid___A002_Xc8ed15_X1a9.ms.flagversions.tgz
|    `-- uid___A002_Xc8ed15_X1a9_target.ms.auxcalapply.txt
```

All flags will be restored during calibration

QA2 Data Products Package: the processed data

Calibration Products:

Log of equivalent CASA commands (non-executable)

```
|
|-- log
|   `-- member.uid___A001_X1299_X39.hifa_calimage.casa_commands.log
|-- member.uid___A001_X1299_X39.README.txt
|-- product
|   |-- member.uid___A001_X1299_X39.SOURCE_sci.spw25_27_29_31.cont.I.pb.fits
|   |-- member.uid___A001_X1299_X39.SOURCE_sci.spw25_27_29_31.cont.I.pbcor.fits
|   |-- member.uid___A001_X1299_X39.SOURCE_sci.spw25.cube.I.mask.fits
|   |-- member.uid___A001_X1299_X39.SOURCE_sci.spw25.cube.I.pbcor.fits
|   |-- member.uid___A001_X1299_X39.SOURCE_sci.spw25.cube.I.pb.fits.gz
|   |-- member.uid___A001_X1299_X39.J0117p1418_ph.spw31.mfs.I.pbcor.fits
|   `-- member.uid___A001_X1299_X39.J0117p1418_ph.spw31.mfs.I.pb.fits.gz
|
```

Directions to access QA comments and restoration instructions

Calibration and Target images produced during reduction (may be representative)

QA2 Data Products Package: the processed data

Calibration Scripts and Weblog:

Weblog contains plots and images from reduction and imaging. Unpack this for lots of information!

```
|-- qa
|   `-- member.uid___A001_X1299_X39.hifa_calimage.weblog.tgz
`-- script
    |-- member.uid___A001_X1299_X39.calimage.pipeline_manifest.xml
    |-- member.uid___A001_X1299_X39.calimage.product_rename.txt
    |-- member.uid___A001_X1299_X39.hifa_calimage.casa_piperestorescript.py
    |-- member.uid___A001_X1299_X39.hifa_calimage.casa_pipescript.py
    |-- member.uid___A001_X1299_X39.hifa_calimage.pprequest.xml
    `-- member.uid___A001_X1299_X39.scriptForPI.py
```

Run scriptForPI.py to restore calibration

Commands to re-run the pipeline

Introduction to Imaging in CASA

With contributions from Amanda Kepley, Crystal Brogan, David Wilner, Urvashi Rau, and others

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array

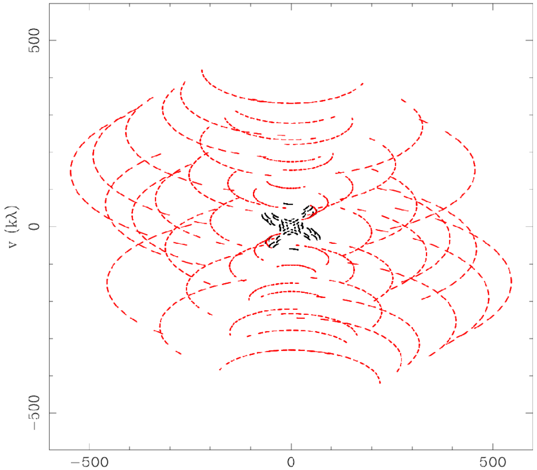
NRAO

Goals of this talk

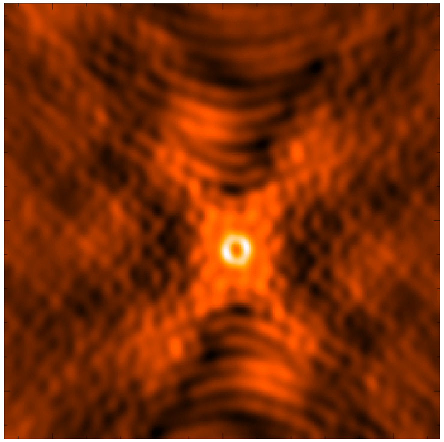
- Gain some intuition for interferometric imaging
- Delve into the theory underlying the imaging process.
- Tour of main deconvolution task in CASA: tclean

The observed (AKA dirty) image is the true image convolved with the PSF.

B(u,v)
(sampled visibilities)

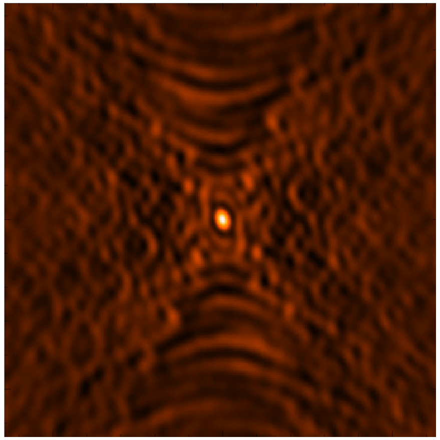


TD(x,y)
(dirty image)

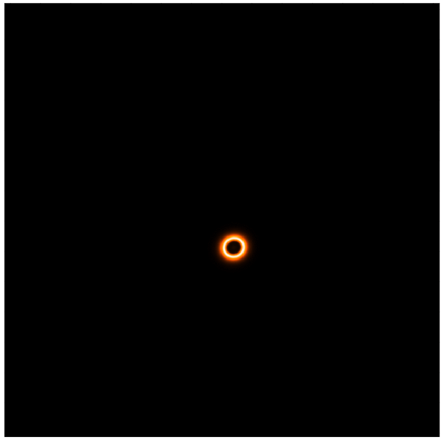


⇌ (Fourier Transform)

b(x,y)
(dirty beam or psf)



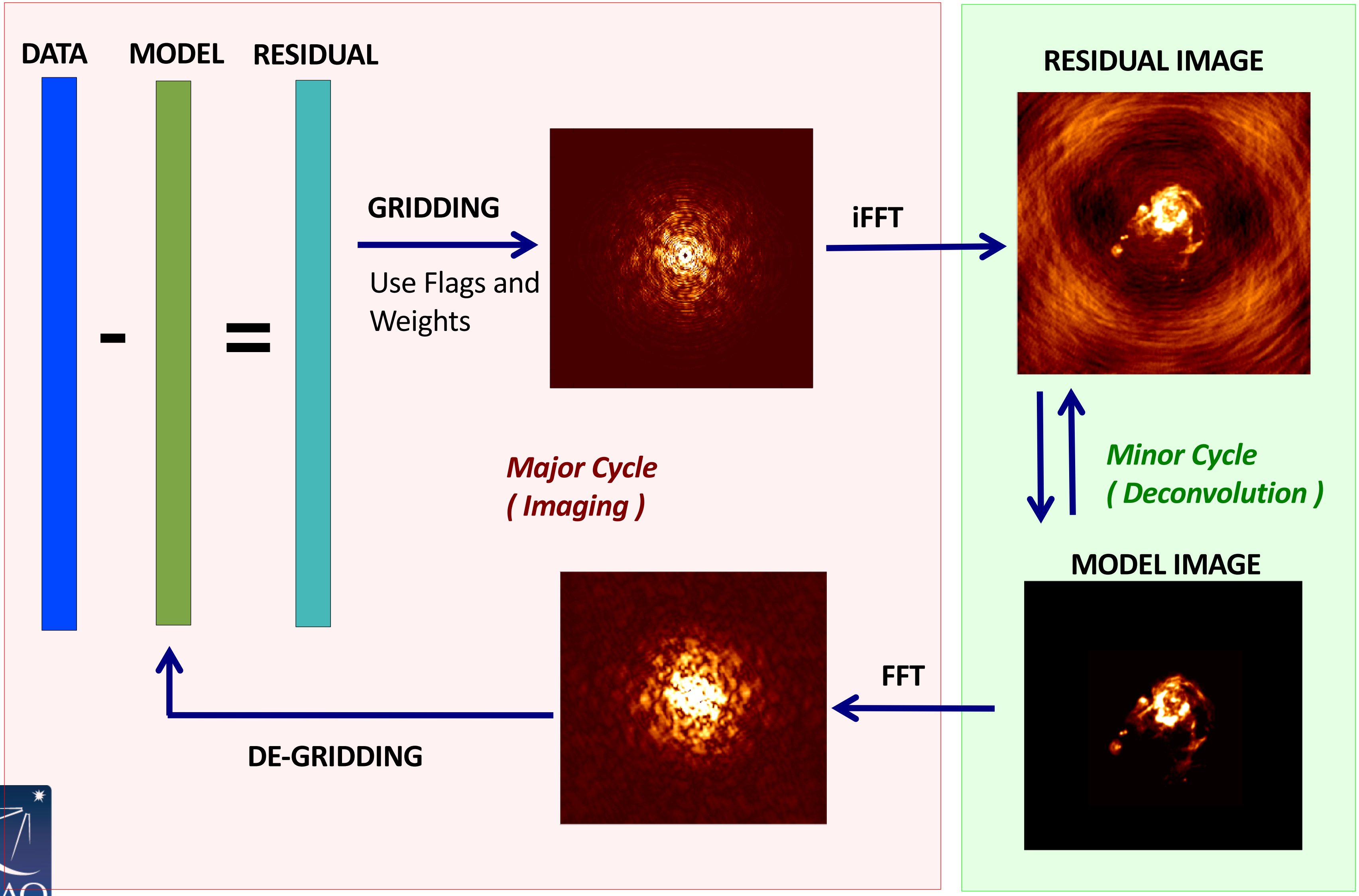
⊗
Convolve



T(x,y)
(True sky brightness)

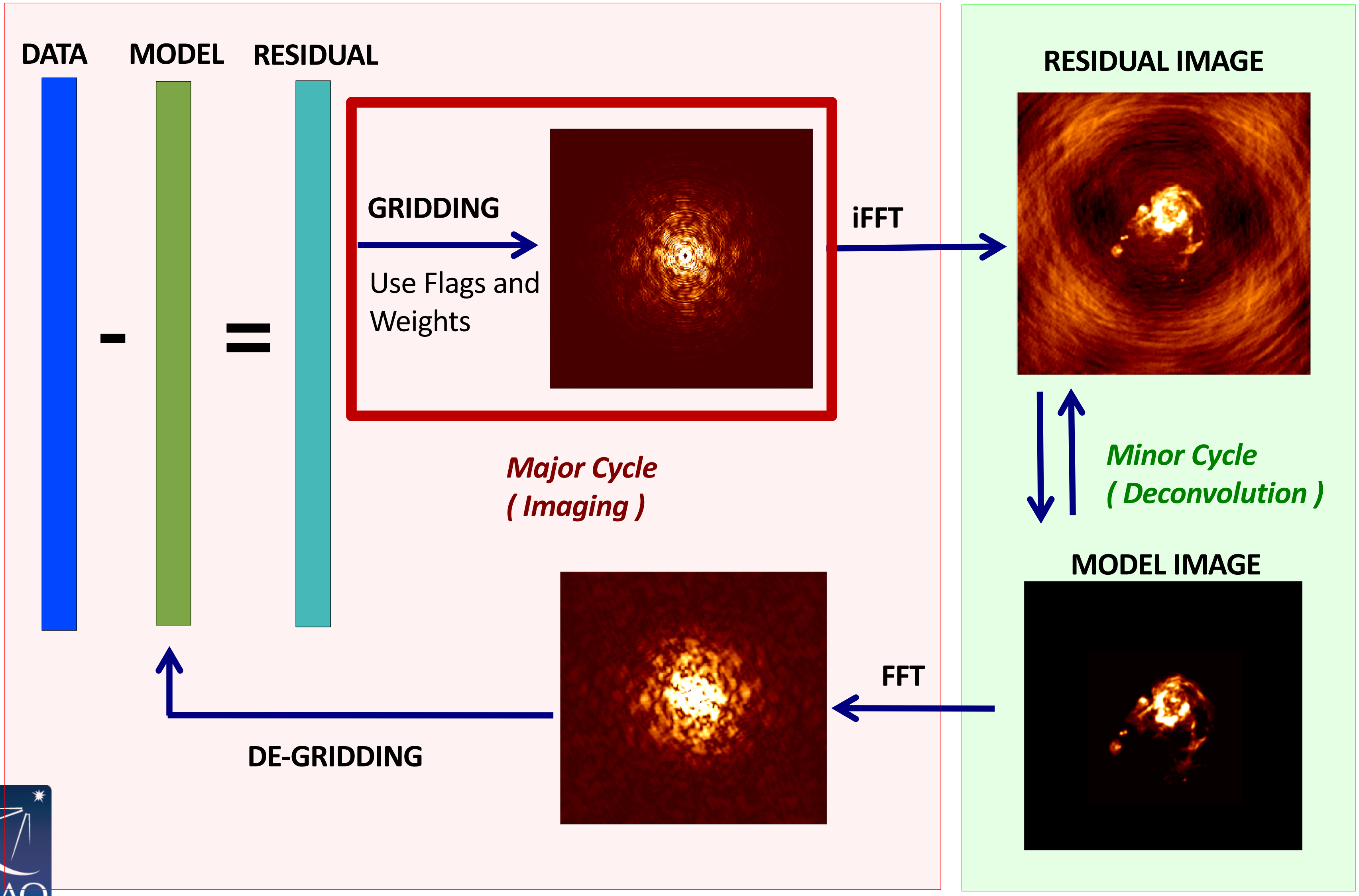
- **Fourier transform of sampled visibilities yields the true sky brightness convolved with the point spread function ("dirty beam").**
- **You need to deconvolve the PSF from the dirty image to reconstruct the source. A commonly used way to do this is called cleaning.**

This is a iterative process where the data is gridded, deconvolved, and de-gridded.



Slide courtesy Urvashi Rau

The gridding step requires pixel and image size as well as weighting scheme.



Slide courtesy Urvashi Rau

Gridding: Visibility Weighting

- "Natural" weighting
  - $1/\sigma^2$ in occupied cells, where σ^2 is the noise variance
  - maximizes point source sensitivity and lowest rms in image
  - more weight to short baselines, so the angular resolution is degraded
- "Uniform" weighting
  - Enhanced angular resolution, but can have trouble with sparse *uv* coverage
  - Rarely used because of this
- "Robust" (or "Briggs") weighting
  - An adjustable parameter allows for continuous variation between maximum point source sensitivity and resolution (uniform -> natural)

NRAO

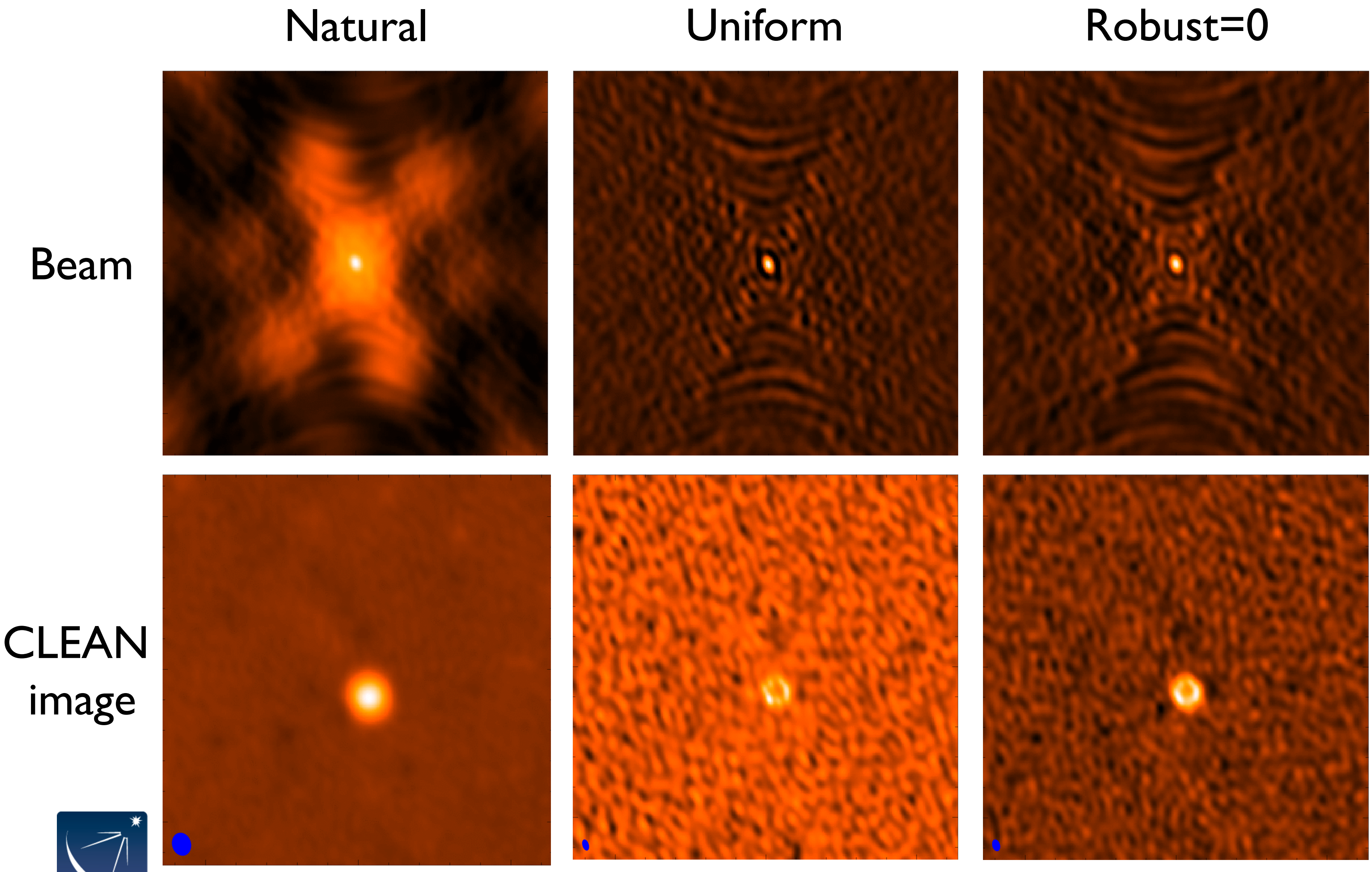
Slide courtesy David Wilner

Gridding: Visibility Weighting

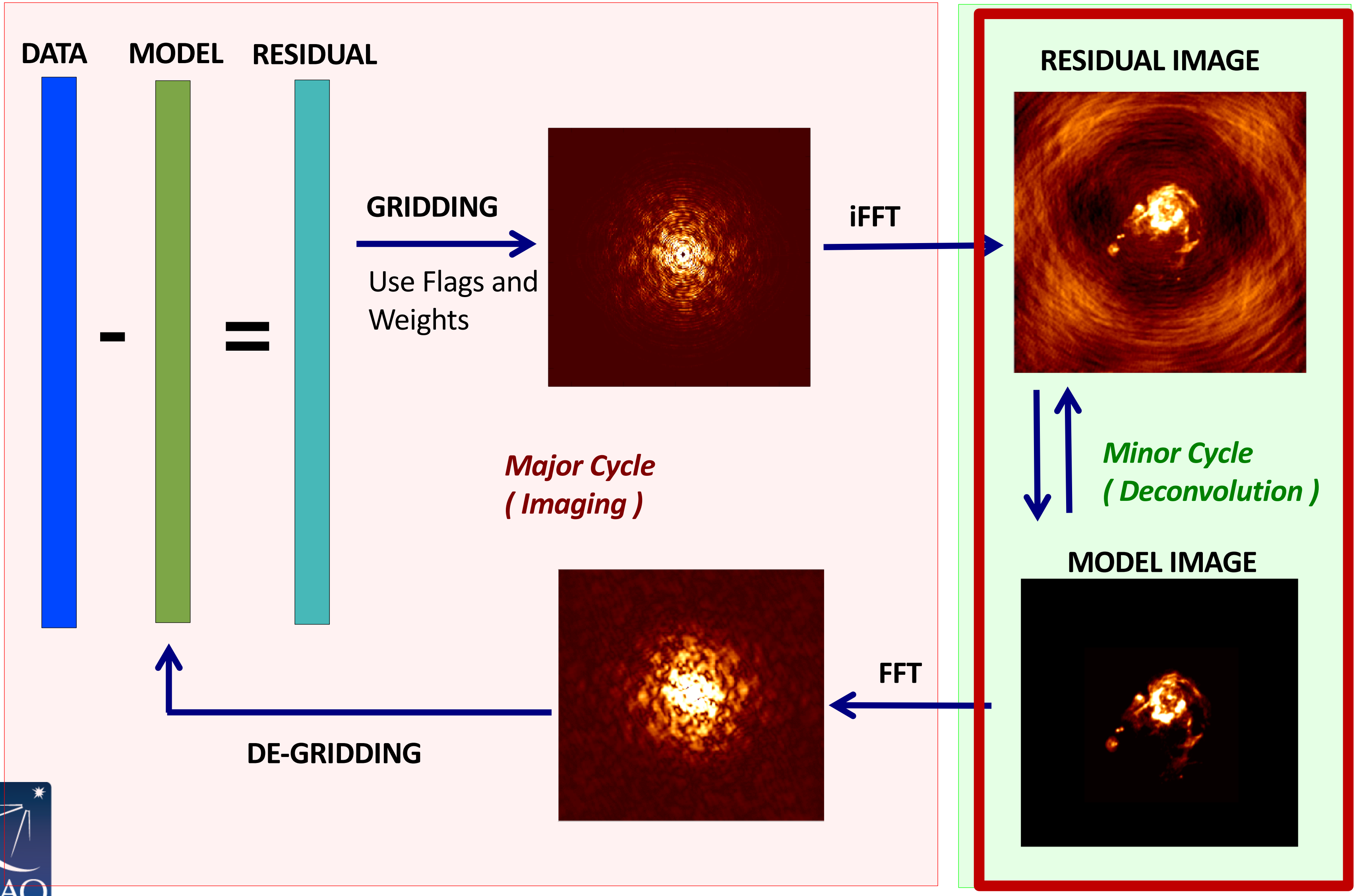
- Good first try is **robust** = 0.5. It's a nice balance between resolution and noise.
- Detection experiment or weak extended source: try **natural** (maybe even with a taper)

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

Adapted from slide by David Wilner


Natural
Uniform
Robust=0
Beam
CLEAN
image

Deconvolution requires specifying how you want to create and subtract the model.



Slide courtesy Urvashi Rau

Clean is the most common deconvolution algorithm.

Sky Model : List of delta-functions

(1) Construct the observed (dirty) image and PSF

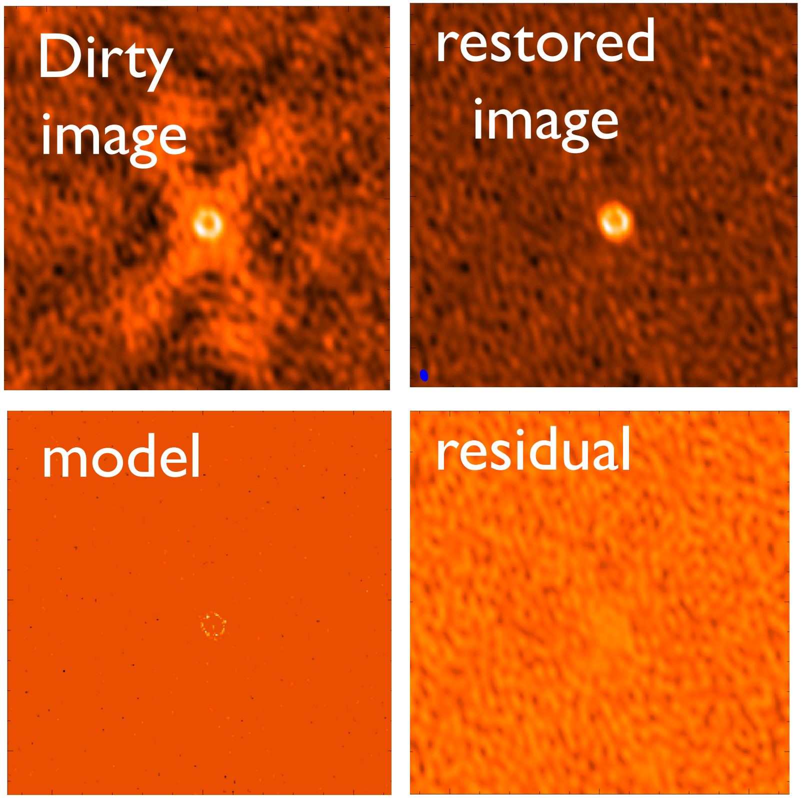
(2) Search for the location of peak amplitude.

(3) Add a delta-function of this peak/location to the model

(4) Subtract the contribution of this component from the dirty image - a scaled/shifted copy of the PSF

Repeat steps (2), (3), (4) until a stopping criterion is reached.

(5) Restore : Smooth the model with a 'clean beam' and add residuals



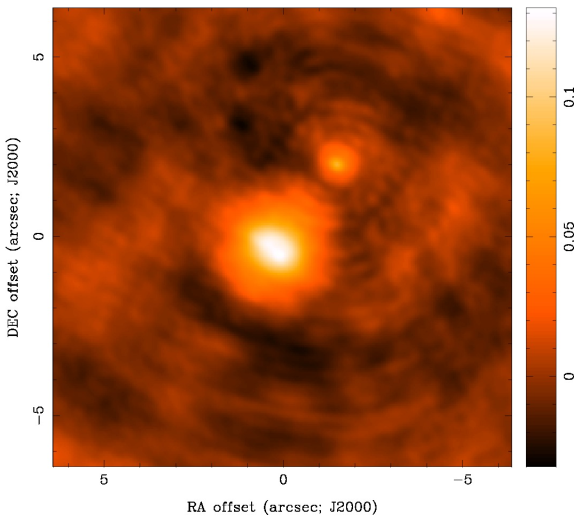
Choices: what and how much PSF to subtract and when to stop

Adapted from slide by Urvashi Rau

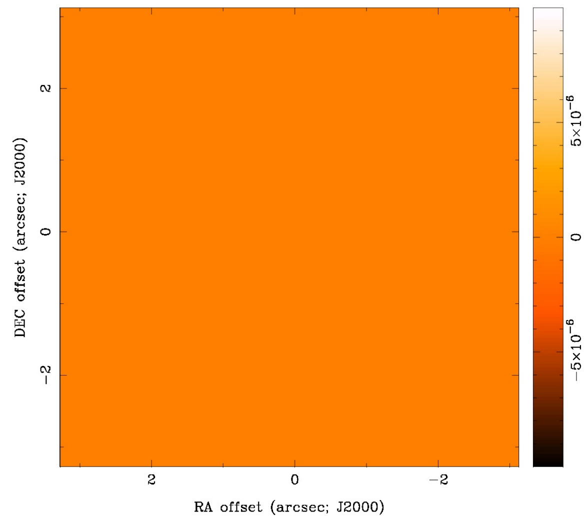
clean example

initialize

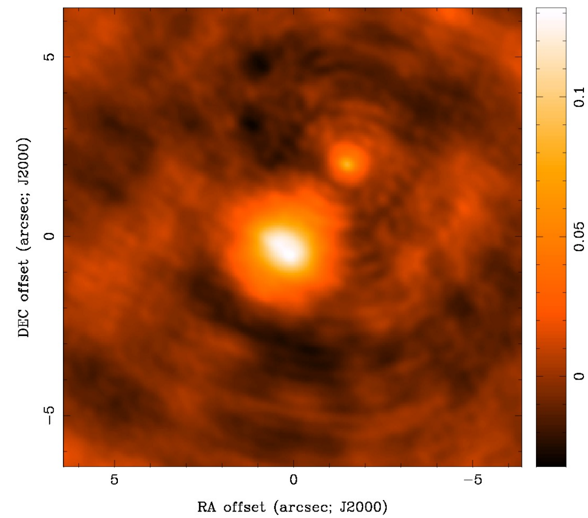
$T^D(l,m)$



0 clean components

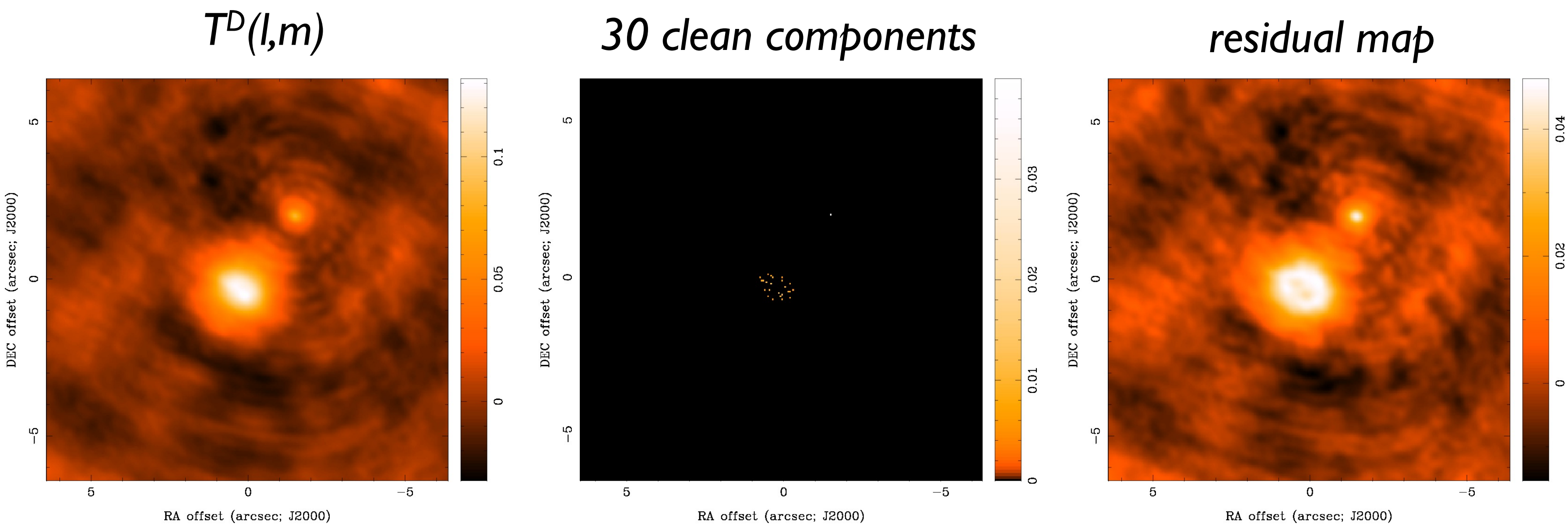


residual map



Slide courtesy David Wilner

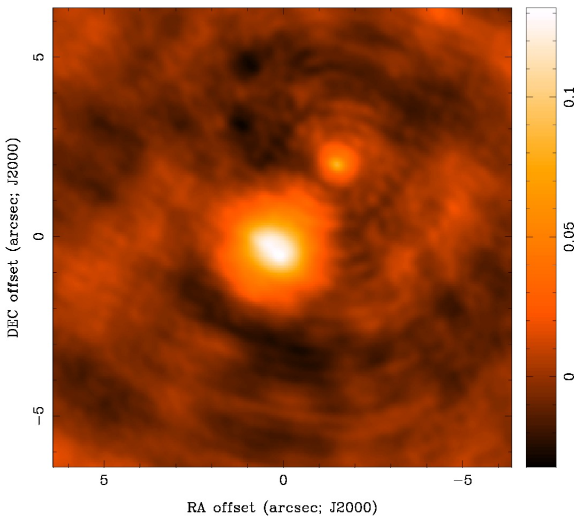
clean example



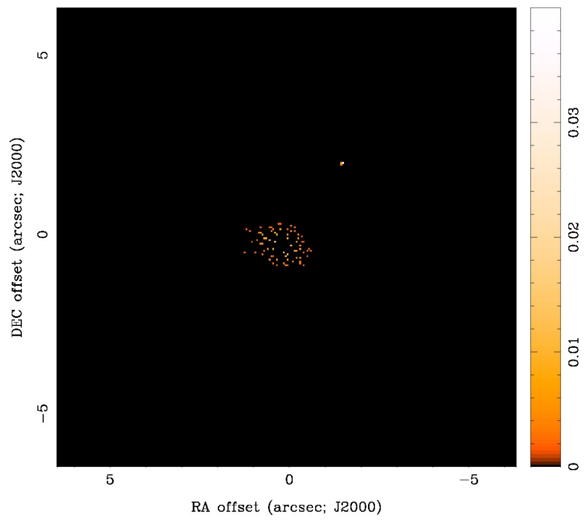
Slide courtesy David Wilner

clean example

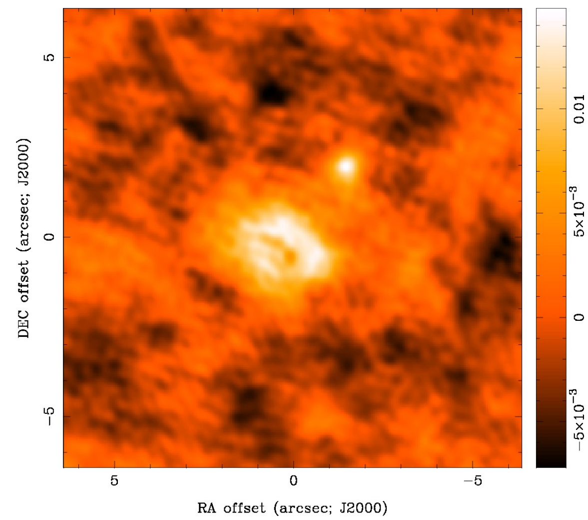
$T^D(l,m)$



100 clean components



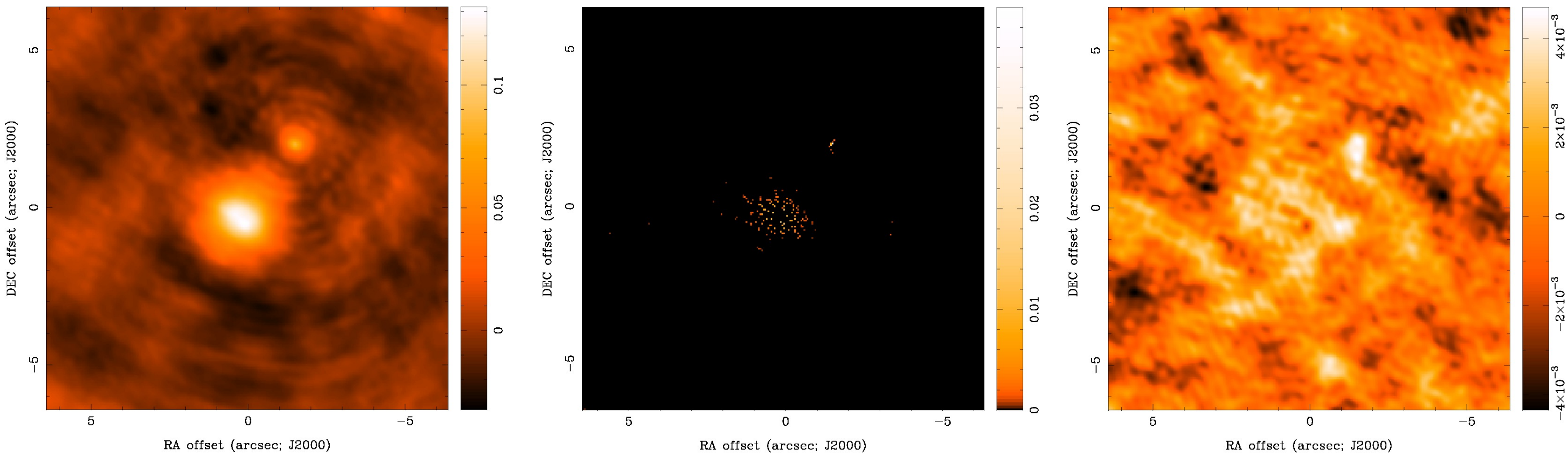
residual map



Slide courtesy David Wilner

clean example

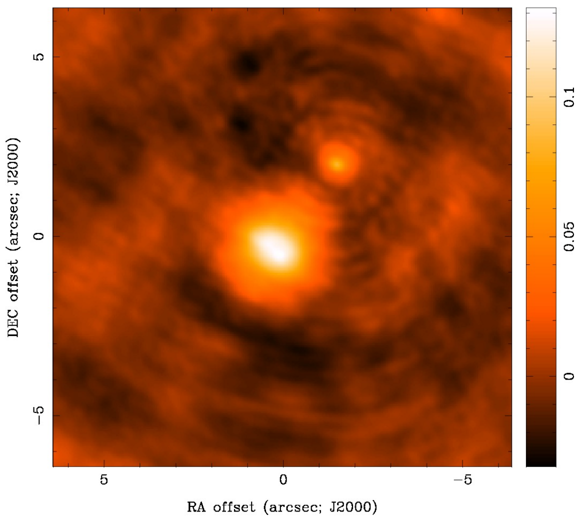
$T^D(l,m)$ | *300 clean components* | *residual map*



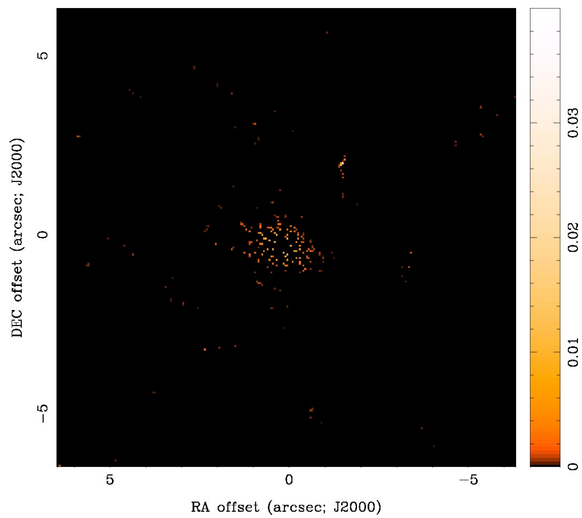
Slide courtesy David Wilner

clean example

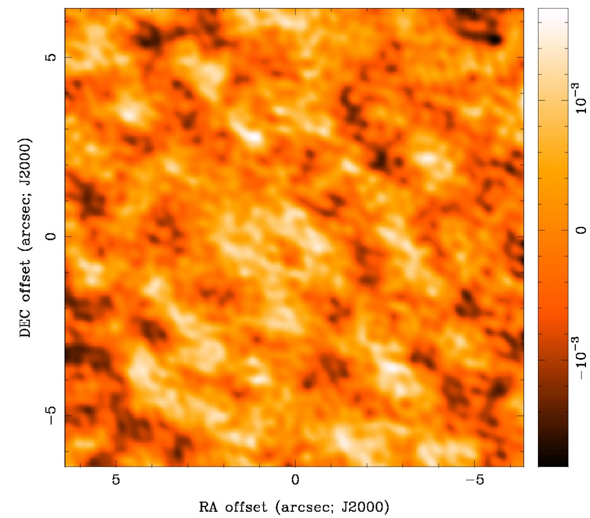
$T^D(l,m)$



583 clean components



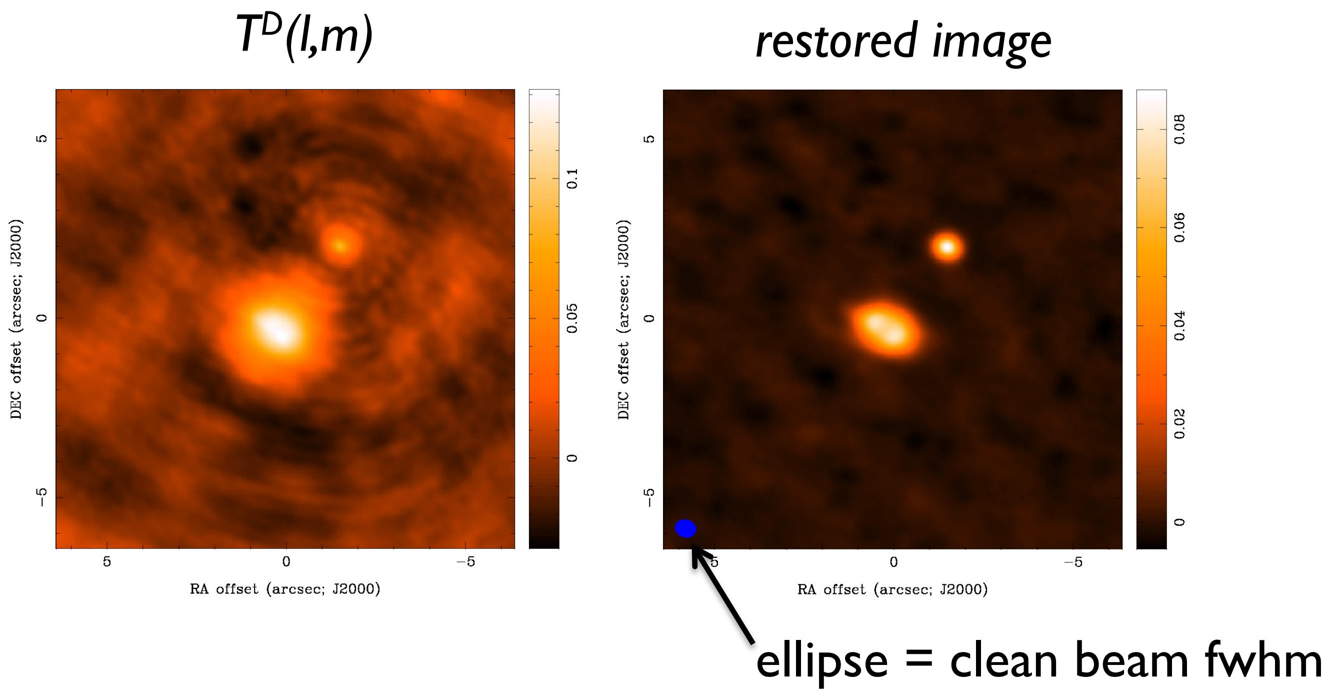
residual map



threshold reached

Slide courtesy David Wilner

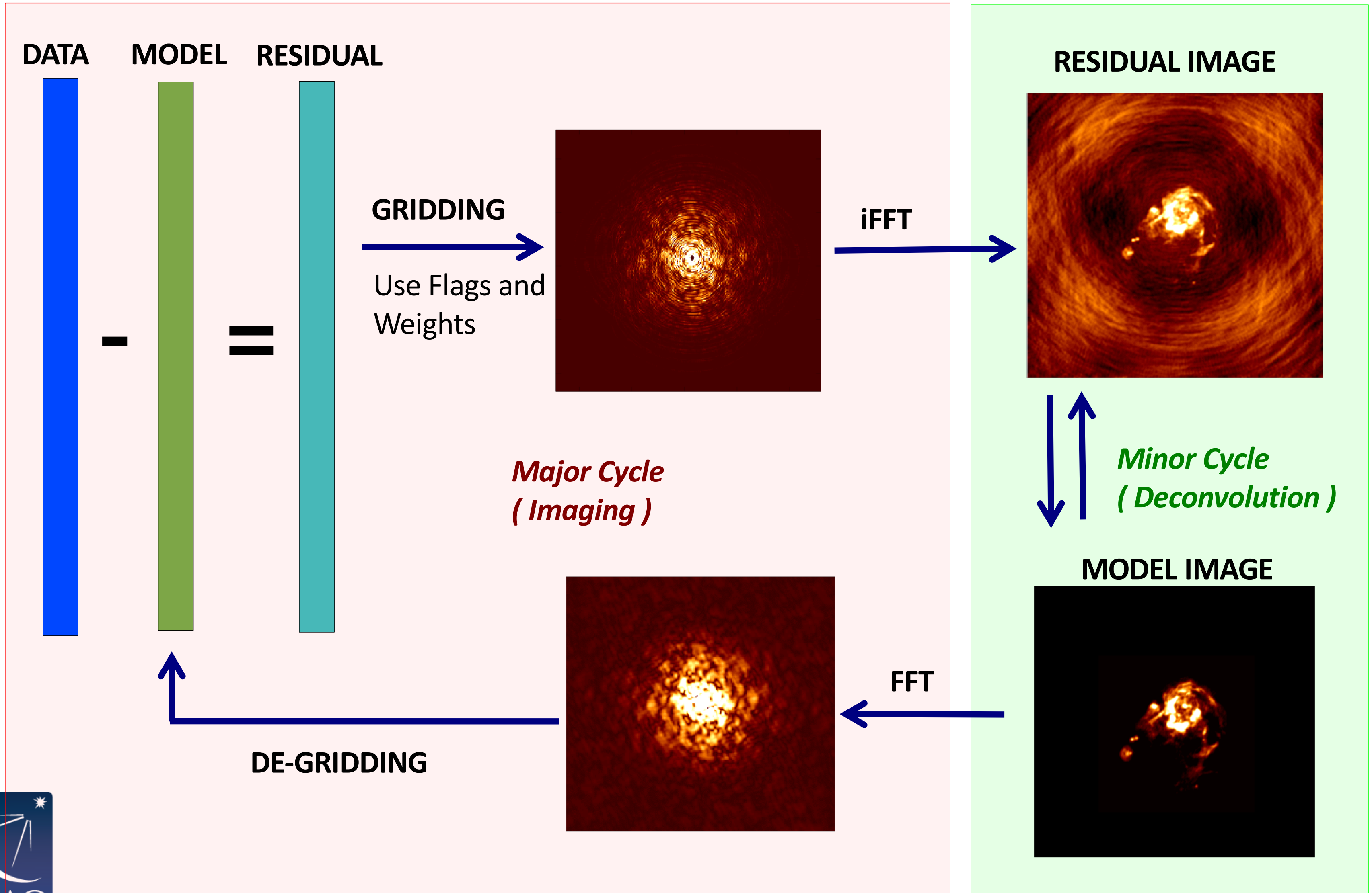
clean example



final image depends on

imaging parameters (pixel size, visibility weighting scheme, gridding) and deconvolution (algorithm, iterations, masks, stopping criteria)

How do we do all this in practice?



Slide courtesy Urvashi Rau

The main imaging task in CASA is tclean

- **clean** is the original imaging task.
- **tclean** (i.e., test clean) is a new version of clean that has been refactored to make it easier to maintain and add new options.
- The task **tclean** is used by Cycle 5 pipeline and all development including bugfixes is only being done in **tclean**.
- Major syntax and usage changes from **clean** → **tclean** are summarized here: https://casaguides.nrao.edu/index.php/TCLEAN_and_ALMA

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TCLEAN in CASA:

There can be an intimidating number of parameters!

There are many sources of help with data reduction, including guides, helpdesk, and visits to NRAO.

```
CASA <6>: inp tclean
--------> inp(tclean)
#  tclean :: Radio Interferometric Image Reconstruction
vis                 =          ''        #  Name of input visibility file(s)
selectdata          =        True        #  Enable data selection parameters
     field          =          ''        #  field(s) to select
     spw            =          ''        #  spw(s)/channels to select
     timerange      =          ''        #  Range of time to select from data
     uvrange        =          ''        #  Select data within uvrange
     antenna        =          ''        #  Select data based on antenna/baseline
     scan           =          ''        #  Scan number range
     observation    =          ''        #  Observation ID range
     intent         =          ''        #  Scan Intent(s)

datacolumn          = 'corrected'        #  Data column to image(data,corrected)
imagename           =          ''        #  Pre-name of output images
imsize              =       [100]        #  Number of pixels
cell                = ['1arcsec']        #  Cell size
phasecenter         =          ''        #  Phase center of the image
stokes              =         'I'        #  Stokes Planes to make
projection          =       'SIN'        #  Coordinate projection (SIN, HPX)
startmodel          =          ''        #  Name of starting model image
specmode            =       'mfs'        #  Spectral definition mode
                                         #   (mfs,cube,cubedata)
     reffreq        =          ''        #  Reference frequency

gridder             =  'standard'        #  Gridding options (standard, wproject,
                                         #   widefield, mosaic, awproject)
     vptable        =          ''        #  Name of Voltage Pattern table
     pblimit        =         0.2        #  >PB gain level at which to cut off
                                         #   normalizations

deconvolver         =    'hogbom'        #  Minor cycle algorithm (hogbom,clark,m
                                         #   ultiscale,mtmfs,mem,clarkstokes)
restoration         =        True        #  Do restoration steps (or not)
     restoringbeam  =          []        #  Restoring beam shape to use. Default
                                         #   is the PSF main lobe
     pbcor          =       False        #  Apply PB correction on the output
                                         #   restored image

outlierfile         =          ''        #  Name of outlier-field image
                                         #   definitions
weighting           =   'natural'        #  Weighting scheme
                                         #   (natural,uniform,briggs)
     uvtaper        =          []        #  uv-taper on outer baselines in uv-
                                         #   plane

niter               =           0        #  Maximum number of iterations
usemask             =      'user'        #  Type of mask(s) for deconvolution
                                         #   (user, pb, auto-thresh, auto-
                                         #   thresh2, or auto-multithresh)
     mask           =          ''        #  Mask (a list of image name(s) or
                                         #   region file(s) or region string(s) )
     pbmask         =         0.0        #  primary beam mask

restart             =        True        #  True : Re-use existing images. False
                                         #   : Increment imagename
savemodel           =      'none'        #  Options to save model visibilities
                                         #   (none, virtual, modelcolumn)
calcres             =        True        #  Calculate initial residual image
calcpsf             =        True        #  Calculate PSF
parallel            =       False        #  Run major cycles in parallel

CASA <7>:
```

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Output of TCLEAN

Minimally:

- my_image.pb — Primary beam model
- **my_image.image** — Cleaned and restored image (Jy/clean beam)
- my_image.mask — Clean "boxes"
- my_image.model — Clean components (Jy/pixel)
- my_image.psf — Dirty beam
- my_image.residual — Residual (Jy/dirty beam)
- my_image.sumwt — Sum of weights

Wide-field imaging, multi-term, and parallel imaging will produce additional products.

Information about advanced usages (parallel, restarting, automasking…) can be found in the CASA Guide website.

Hands-on Session (https://casaguides.nrao.edu)

ALMAguides

How to use these CASA Tutorials

Imaging Tutorials for CASA beginners

If you are new to CASA, start with the following tutorials. ALMA data are delivered with standard calibrations applied and they are ready for imaging. These guides cover the basic steps required for imaging and self-calibration.

- A first look at imaging in CASA This guide gives a first look at imaging and image analysis in CASA.
- A first look at self-calibration in CASA This guide demonstrates continuum self-cal.
- A first look at spectral line imaging in CASA This guide shows imaging of a spectral line.
- A first look at image analysis in CASA This guide demonstrates moment creation and basic image analysis.

Guides for reducing ALMA Science Verification data

The links below lead to overview pages for each science verification observation. The guides themselves are linked from the overview pages. These guides are a useful tools for those who would like to learn the process of calibration and imaging in detail.

The following ALMA science verification guides have been validated for CASA version 4.3. They should also work for CASA version 4.4, and they will be validated for version 4.4 soon.

- TWHydraBand7: The protoplanetary disk source TW Hya at Band 7 (0.87 mm)
- NGC3256Band3: The galaxy merger NGC 3256 at Band 3 (3 mm)
- AntennaeBand7: Mosaic of the galaxy merger NGC 4038/4039 (Antennae) at Band 7 (0.87 mm)
- IRAS16293Band9: Mosaic of the protostellar cluster IRAS16293-2422 at Band 9 (0.45 mm)
- File:BR1202 SV Band7 Calibration notes.pdf: Supplemental notes on the calibration of Science Verification target BR1202-0725 in CASA 3.3
- ALMA2014_LBC_SVDATA: Imaging scripts and details for the 2014 ALMA Long Baseline Campaign science verification data for Juno, Mira, HL Tau, and SDP.81.
- M100_Band3: Demonstration of combining 12m-array, 7m-array, and Total Power data for M100 using CASA 4.3.1
- 3C286_Polarization: Demonstration of the reduction of ALMA continuum polarization toward the quasar 3C286

A Guide to CASA Data Weights and How to Ensure They are Correct for Data Combination

A Guide to Processing ALMA Data for Cycle 0

This page takes you through the steps of processing Cycle 0 data from the ALMA data archive. The guide describes some helpful hints for downloading the data, and describes the process all the way through imaging and self-calibration, and image analysis.

You can also get a look at example data calibration scripts used for Cycle 0 data at the following links. These were written for CASA version 3.4.

- TDM (128 channels/spw) File:TDM.example.ms.scriptForCalibration.py
- FDM (3840 channels/spw) File:FDM.example.ms.scriptForCalibration.py
- If you need to update 3.4 scripts to 4.2, see more information here

A Tutorial for Simulating ALMA Data.

Start here to learn about simulations. The CASA 4.3 simulation examples in the above tutorial should also work for version 4.4, and they will be validated for version 4.4 soon. Jump directly to the simulations examples with the following links.

- Simulation Examples in CASA 4.3
- Examples for older versions of CASA: 4.2 4.1 4.0 3.4 3.3

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Hands-on Session (https://casaguides.nrao.edu)

Alternatively, if you do not want to download the full 4.1G data package, you can download just the smaller data file (600M) needed specifically for this tutorial as follows:

```
# In bash
mkdir MyTutorial
cd MyTutorial
wget -r -np -nH --cut-dirs=4 --reject "index.html*" https://bulk.cv.nrao.edu/synth/dred_workshops/sis14/working_data/sis14_twhya_calibrated_flagged.ms/
```

Or you can download the file via your browser at the following links: https://bulk.cv.nrao.edu/almadata/public/working/sis14_twhya_calibrated_flagged.ms.tar

```
# In CASA
plotms(vis='sis14_twhya_calibrated_flagged.ms', xaxis='u', yaxis='v', avgchannel='10000', avgspw=False, avgtime='1e9', avgscan=False,
coloraxis="field", showgui=True)
```

```
# In CASA
os.system('rm -rf twhya_smoothed.ms')

split(vis='sis14_twhya_calibrated_flagged.ms', field='5', width='8', outputvis='twhya_smoothed.ms', datacolumn='data')

listobs('twhya_smoothed.ms')
```

```
# In CASA
os.system('rm -rf phase_cal.*')

tclean(vis='sis14_twhya_calibrated_flagged.ms',
       imagename='phase_cal',
       field='3',
       spw='',
       specmode='mfs',
       deconvolver='hogbom',
       gridder='standard',
       imsize=[128,128],
       cell=['0.1arcsec'],
       weighting='natural',
       threshold='0mJy',
       niter=5000,
       interactive=True)
```

```
# In CASA
os.system('rm -rf twhya_cont_auto.*')

tclean(vis='twhya_smoothed.ms',
       imagename='twhya_cont_auto',
       field='0',
       spw='',
       specmode='mfs',
       gridder='standard',
       deconvolver='hogbom',
       imsize=[250,250],
       cell=['0.08arcsec'],
       mask='box [ [ 100pix , 100pix] , [150pix, 150pix ] ]',
       weighting='briggs',
       robust=0.5,
       threshold='15mJy',
       niter=10000,
       interactive=False)

imview('twhya_cont_auto.image')
```

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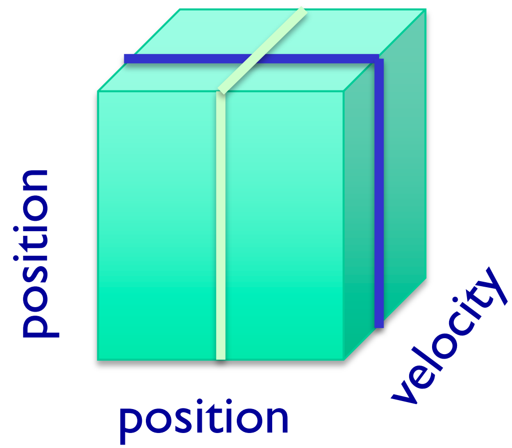
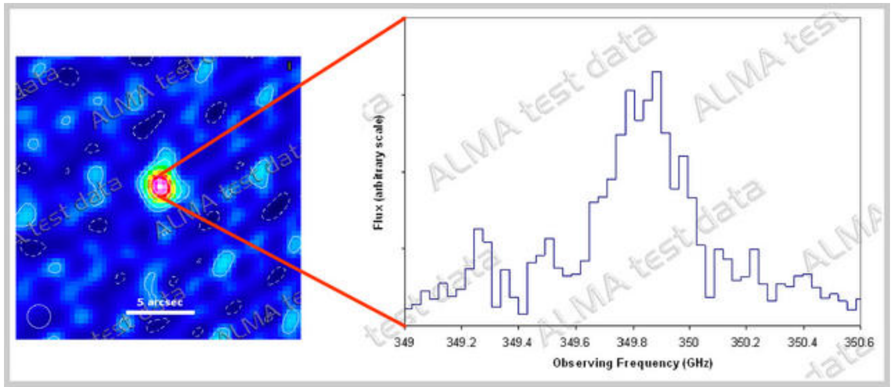
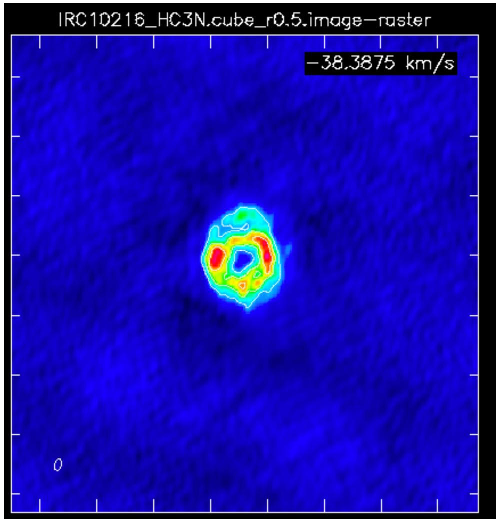
Extensions: Imaging spectral lines



Spectrum

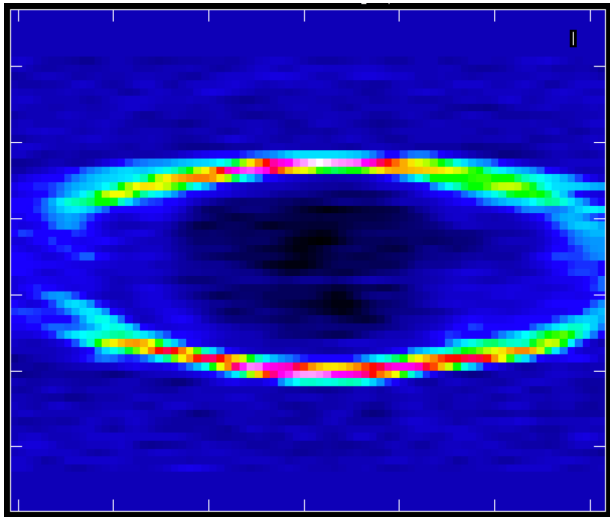


Channel map



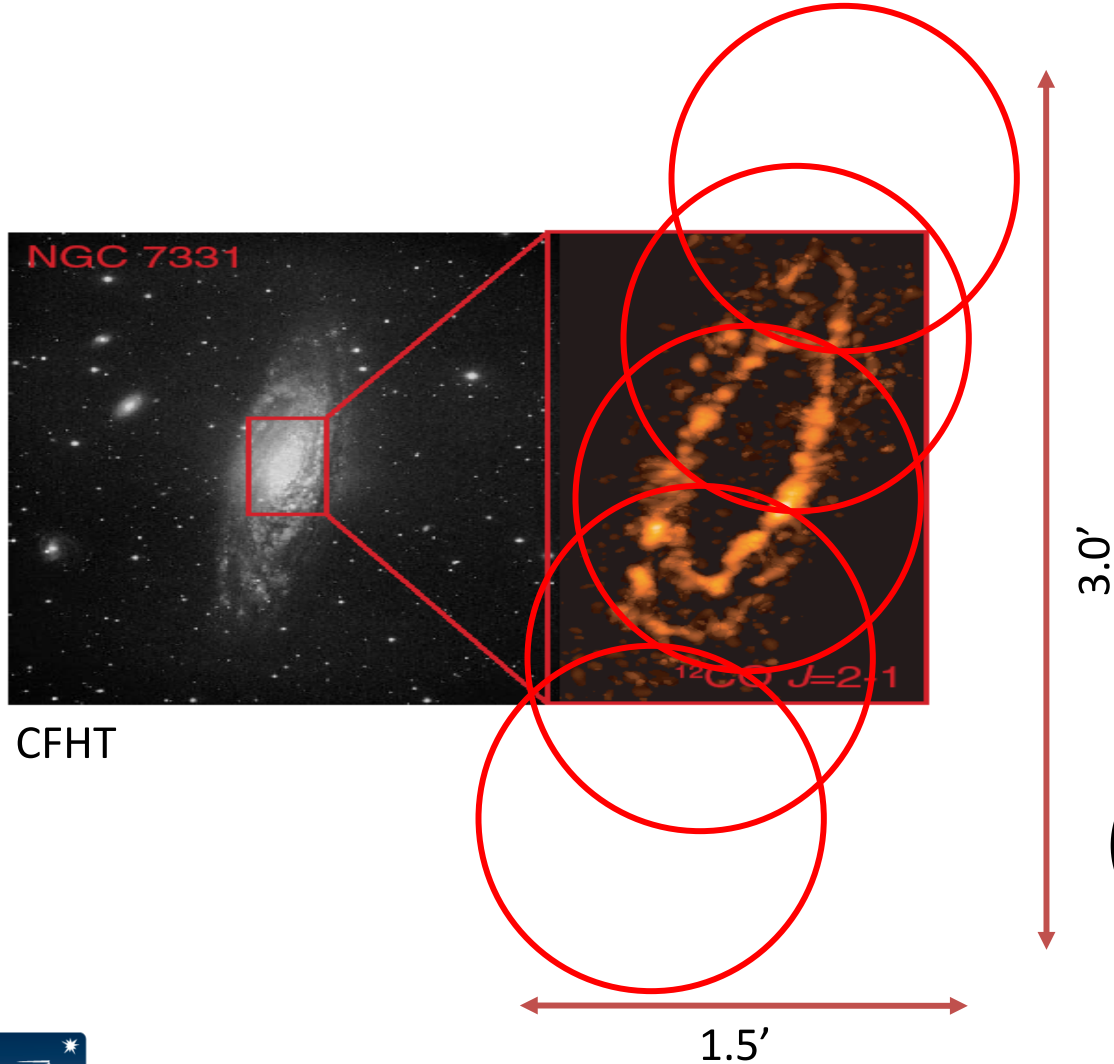
Fixed velocity, polarization, etc.

Position-velocity map



One fixed position, polarization, etc.

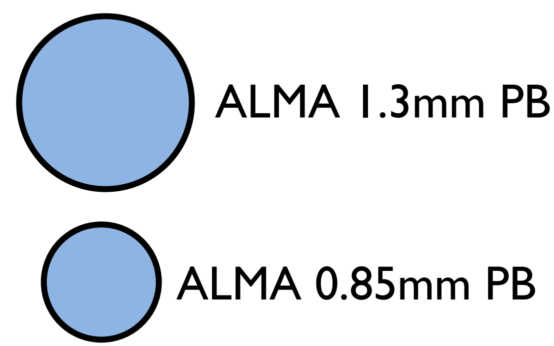
Extensions: Mosaics



Mosaics are common with ALMA particularly at high frequencies

Example: SMA 1.3 mm observations: 5 pointings

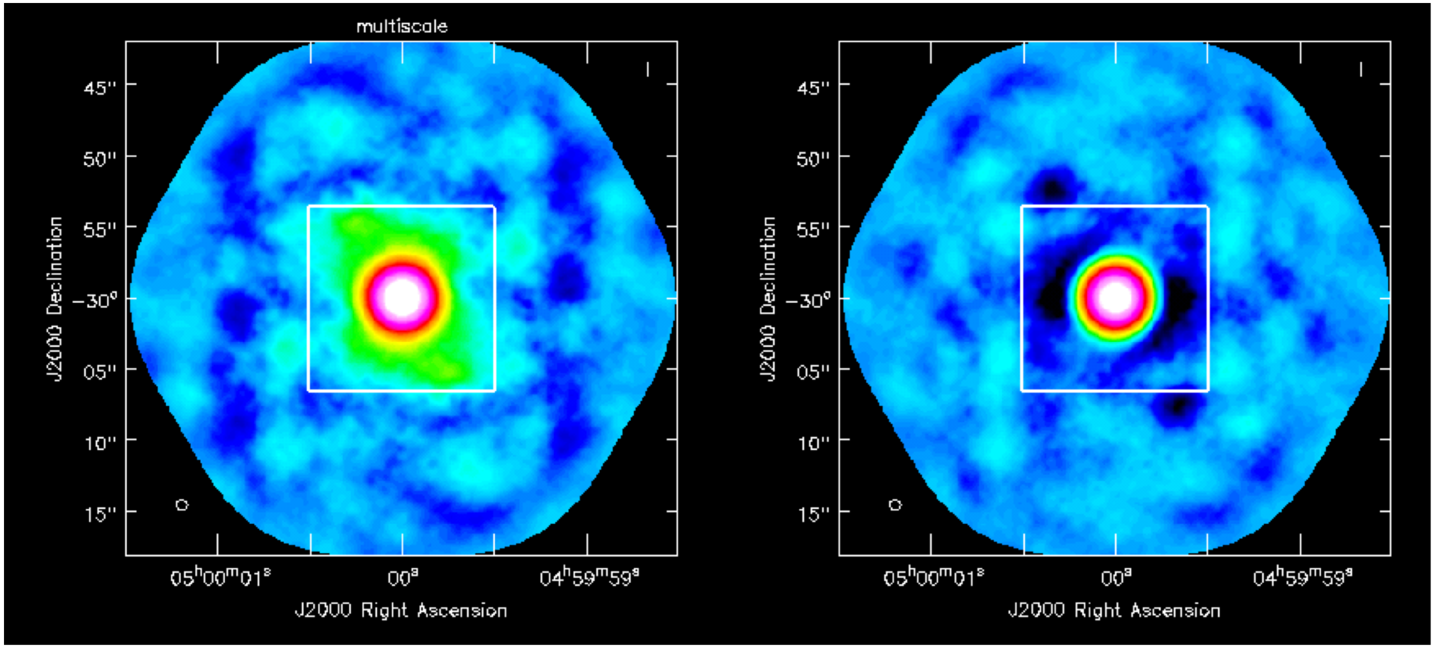
- Primary beam ~1'
- Resolution ~3"



Petitpas et al.

Extensions: Multi-scale CLEAN

multi-scale "classic" scale



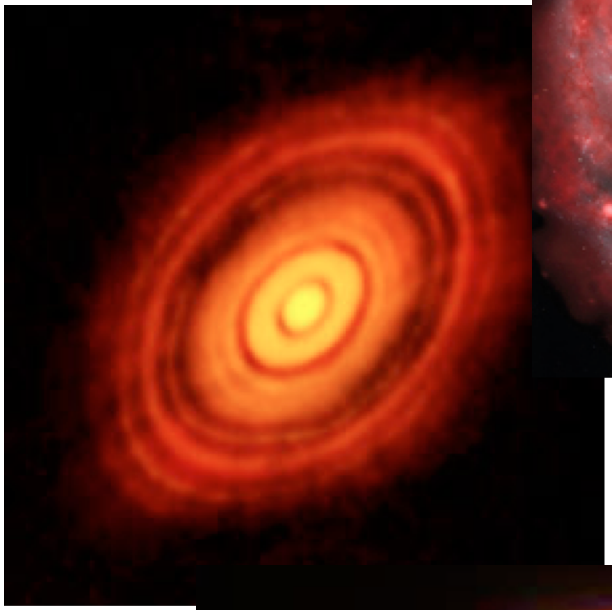
Instead of using delta functions like hogbom or clark, one can use extended clean components to better match emission scales (multiscales, typically paraboloids)

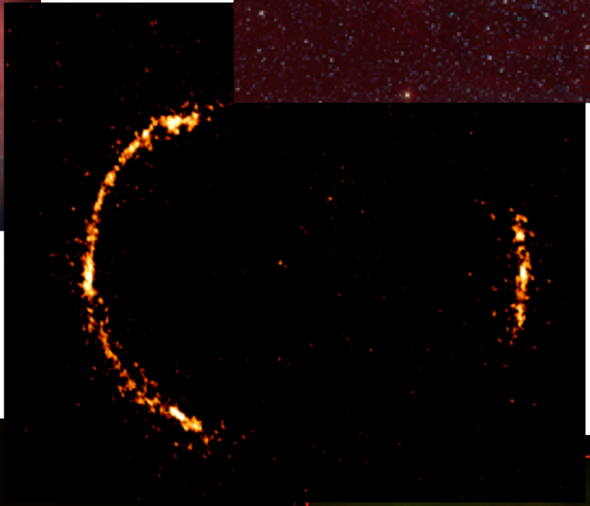
Suggested scale parameter choice : point source, the second the size of the synthesized beam and the third 3-5 times the synthesized beam, etc.

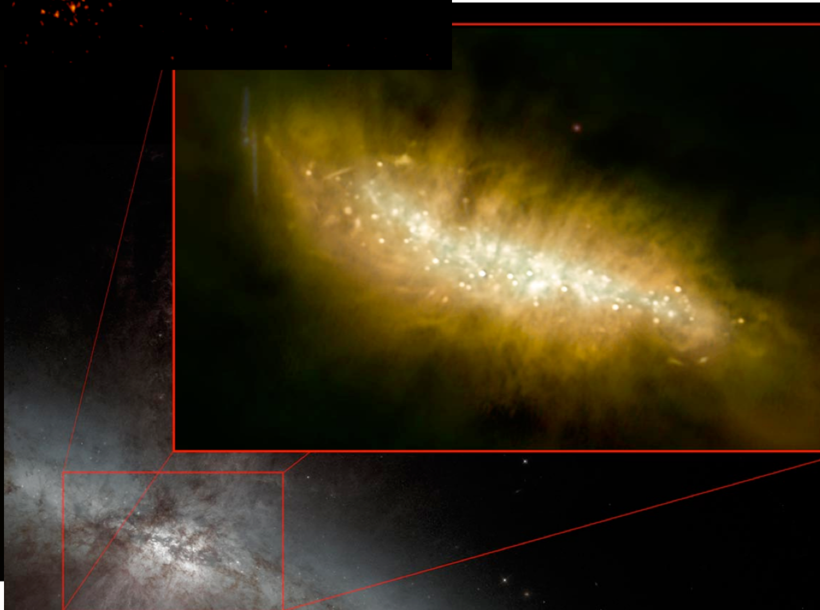
Extensions: Combining with single-dish or other interferometric maps

- If you have only images:
  - feather (or "casafeather")
- If you have an image and an MS:
  - use CLEAN with the image as the model
  - and/or feather
- If you have multiple MS plus an image:
  - input to clean will be all the MS'es
- See GBT Memo 300 for information on how combining GBT cubes with ALMA data.

Cool ALMA images…







For more info:

http://www.almaobservatory.org

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