

ALMA Cycle 8 2021 Proposal Planning Talk Date



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Introduction to Imaging with CASA

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Robert C. Byrd Green Bank Telescope



Very Long Baseline Array



ALMA Cycle 8 2021 Proposal Planning



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



Visibility and Sky Brightness

V(u,v), the complex visibility function, is the 2D Fourier transform of T(l,m), the sky brightness distribution (for an incoherent source, small field of view, far field, etc.) [see TMS for derivation]

mathematically $V(u,v) = \int \int T(l,m)e^{-i2\pi(ul+vm)}dldm$ $T(l,m) = \int \int V(u,v)e^{i2\pi(ul+vm)}dudv$ u,v are E-VV, N-S spatial frequencies [wavelengths] l,m are E-VV, N-S angles in the tangent plane [radians] $(\text{recall } e^{ix} = \cos x + i \sin x)$

$$V(u,v) \xrightarrow{\mathcal{F}} T(l,m)$$





Interferometry Basics

Single dish: diameter gives resolution

Interferometer: diameter gives FOV and the separation gives resolution





Interferometers discretely sample the uvplane.



- Small uv-distance: short baselines (measures extended emission)
- Long uv-distance: long baselines (measures small scale emission)
- Orientation of baseline determines orientation in the uv-plane
- Antennas can only physically be so close together leaving a hole in the center of the uv-plane (missing short spacings)



Missing Short Baselines: Demonstration

T(l,m)



ALMA 12m array



much improved

ALMA 12m array + ACA

n.b. clean does not reach theoretical rms due to poorly sampled extended structure

NRAO

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





- 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.

How do we recover the true image?

Cleaning!



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



Slide courtesy Urvashi Rau

A note on terminology



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



Slide courtesy Urvashi Rau

Gridding: Pixel and Image Size

• pixel size: satisfy sampling theorem for longest baselines



- in practice, 5 to 8 pixels across dirty beam main lobe to aid deconvolution
- Beam size [arcsec] = 206265.0/(longest baseline in wavelengths)
- image size: natural choice often full primary beam A(I,m)
 - For single fields:
 - I2m : FOV[arcsec] = 6300 / nu[GHz]
 - 7m: FOV[arcsec] = 10608 / nu[GHz]
 - nu[GHz] is the sky frequency.
 - For mosaics:
 - You can get the imsize from the spatial tab of the OT. The parameters "p length" and "q length" to specify the dimensions of the mosaic. If you're imaging a mosaic, pad the imsize substantially to avoid artifacts.



Gridding: Visibility Weighting

- introduce weighting function *W*(*u*,*v*)
 - modifies sampling function
 - $S(u,v) \rightarrow S(u,v)W(u,v)$
 - changes s(l,m), the dirty beam





Natural Weighting

- $W(u,v) = 1/\sigma^2$ in occupied cells, where σ^2 is the noise variance
- generally gives more weight to short baselines, so the angular resolution is degraded
- maximizes point source sensitivity
- lowest rms in image



Weighting Schemes and Noise

- natural = equal weight for all visibilities [lowest noise]
- uniform = equal weight for filled (u,v) cells [highest noise]
- robust/Briggs = continuous variation between natural and uniform
- taper = decrease resolution, increase surface brightness sensitivity

NRAC

The weighting you choose depends on your science goals.

- 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)
- Finer detail of strong sources: try **robust**

	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

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

30 clean components

residual map ŝ 0.04 ŝ 0.1 0.03 DEC offset (arcsec; J2000) DEC offset (arcsec; J2000) 0.02 0.05 0.02 0 0 0.01 0 9 ĥ -5 -5 5 -5 5 0 5 0 0 RA offset (arcsec; J2000) RA offset (arcsec; J2000) RA offset (arcsec; J2000)

ιΩ

DEC offset (arcsec; J2000)

0

ŝ

100 clean components

300 clean components

DEC offset (arcsec; J2000)

threshold reached

 $T^{D}(l,m)$

ellipse = clean beam fwhm

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.

- Tclean is a refactored version of the original clean task
 - The original clean task is deprecated and SHOULD NOT BE USED.
- Tclean task
 - takes the calibrated visibilities
 - grids them on the UV-plane
 - performs the FFT to a dirty image
 - deconvolves the image
 - restores the image from clean table and residual
- Major syntax and usage changes from clean \rightarrow tclean are summarized here:

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

TCLEAN in **CASA**:

There can be an intimidating number of parameters!

Start simple and make it more complicated as you need to.

> inp(tclea	n)	
<pre># tclean :: Radio</pre>	Interfe	rometric I
vis	=	_ · · ·
selectdata		True
snw		
timerange		
uvrange		
antenna		
scan		
observation		
intent		
datacolumn	= 'cor	rected!
imagename	=	11
imsize		[100]
cell	= ['1a	ircsec']
phasecenter		
stokes		'I'
projection		'SIN'
startmodel	-	1-1-1
specmode	-	'MTS'
reffreq		
gridder	= 'sta	indard'
vntable		
oblimit		0.2
potrare		0.1
deconvolver	= 'h	ogbom'
restoration	-	True
restoringbeam	=	[]
pbcor		False
outlierfile		
weighting	= 'na	itural'
uvtaper		п
niter usemask	-	θ 'user'
mask		
pbmask		Θ.Θ
restart		True
savemodel		'none'
colores		
catores		True
calcpsf		True True

<6>> inn trlean

CASA <**7**>:

Select data based on antenna/baseline
Scan number range
Observation ID range
Scan Intent(s)
Data column to image(data,corrected)
Pre-name of output images
Number of pixels
Cell size
Phase center of the image
Stokes Planes to make
Coordinate projection (SIN, HPX)
Name of starting model image
Spectral definition mode

Name of input visibility file(s)

Enable data selection parameters

- # (mfs,cube,cubedata)
- # Reference frequency

age Reconstruction

field(s) to select spw(s)/channels to select Range of time to select from data Select data within uvrange

- # Gridding options (standard, wproject,
- # widefield, mosaic, awproject)
- # Name of Voltage Pattern table
- # >PB gain level at which to cut off
- normalizations
- # Minor cycle algorithm (hogbom,clark,m
- # ultiscale,mtmfs,mem,clarkstokes)
- # Do restoration steps (or not)
- # Restoring beam shape to use. Default
 # do the DSE main labo
- # is the PSF main lobe
 # Apply PB correction on the output
- restored image
- # Name of outlier-field image
 # definitions
- Weighting scheme
- # (natural,uniform,briggs)
- # uv-taper on outer baselines in uv-
- # plane
- Maximum number of iterations Type of mask(s) for deconvolution (user, pb, auto-thresh, auto-
- # thresh2, or auto-multithresh)
- # Mask (a list of image name(s) or
- # region file(s) or region string(s) ;
- # primary beam mask
- # True : Re-use existing images. False
- # : Increment imagename
- # Options to save model visibilities
- # (none, virtual, modelcolumn)
 # Calculate initial
- # Calculate initial residual image
 # Calculate DSE
- # Calculate PSF
- # Run major cycles in parallel

TCLEAN in CASA

vis = ms file (can be multiple ms'es)

imagename = whatever you want

> inp(tclear	n)
vic	= "
v is Selectriata	
field	= 11
SDW	
timerange	
uvrange	
antenna	
scan	
observation	
intent	
datacolumn	= 'corrected'
imagename	= ''
TIIISTZE	- [100]
cell	= ['larcsec']
phasecenter	=
stokes	= 'I'
projection	= 'SIN'
startmodel	=
specmode	imts'
rettreq	
aniddor	- Intendend
gridder	Stanuaru
votable	
phimit	= 0.2
portante	- 0.2
deconvolver	- 'hoghom'
	no Boom
restoration	 True
restoringbeam	= []
<u> </u>	
pbcor	= False
outlierfile	
weighting	<pre>= 'natural'</pre>
uvtaper	= []
	-
niter	
usemask	user'
ma als	
mask	
n hma c k	- 00
pomask	- 0.0
restart	= True
restart	ii ue
savemode1	= 'none'
	none
calcres	= True
calcpsf	= True
parallel	= False

/find tology

age Reconstruction

- Name of input visibility file(s) Enable data selection parameters
- # field(s) to select
- spw(s)/channels to select Range of time to select from data
- Select data within uvrange
- Select data based on antenna/baseline
- Scan number range #
- Observation ID range
- Scan Intent(s)
- Data column to image(data,corrected)
- Pre-name of output images
- Number of pixels
- # Cell size
- # Phase center of the image
- # Stokes Planes to make
- Coordinate projection (SIN, HPX)
- Name of starting model image Spectral definition mode
- #
- (mfs,cube,cubedata) Reference frequency #
- # Gridding options (standard, wproject,
- widefield, mosaic, awproject)
- Name of Voltage Pattern table
- # >PB gain level at which to cut off
- normalizations
- Minor cycle algorithm (hogbom, clark, m #
- ultiscale,mtmfs,mem,clarkstokes)
- Do restoration steps (or not)
- Restoring beam shape to use. Default
- is the PSF main lobe Apply PB correction on the output
- restored image
- Name of outlier-field image #
- definitions #
- Weighting scheme
- (natural, uniform, briggs)
- uv-taper on outer baselines in uv-
- plane
- Maximum number of iterations #
- Type of mask(s) for deconvolution
- (user, pb, auto-thresh, auto-
- thresh2, or auto-multithresh)
- Mask (a list of image name(s) or
- region file(s) or region string(s)) # primary beam mask
- # True : Re-use existing images. False : Increment imagename
- Options to save model visibilities (none, virtual, modelcolumn)
- Calculate initial residual image #
- Calculate PSF #
- Run major cycles in parallel

TCLEAN in **CASA**

imsize = size of image in pixels = typically primary beam (i.e., FOV)

cell = size of pixels in angular units = typically 5-8 pixels across synthesized beam (resolution)

See slide 17 more details.

CASA <6>: inp tclea	an		
> inp(tclea	in)		
# tolean :: Kaulo	101	terrerometric in	la
selectdata	=	True	
field	=		
spw			
timerange			
uvrange			
antenna			
observation			
intent			
datacolumn		'corrected'	
imcizo		[100]	
cell		['larcsec']	
phasecenter	_	1	
stokes		'I'	
projection		'SIN'	
startmodel	=		
specmode	=	'mfs'	
reffren			
renneg			
gridder	=	'standard'	
vptable			
pblimit		0.2	
deconvolver	=	'hogbom'	
restoration	=	True	
restoringbeam		[]	
nhear		Falsa	
pucor		raise	
outlierfile			
	_		
weighting	=	'natural'	
uvtaner		n	
aveaper			
niter	=	Θ	
usemask	=	'user'	
mask			
IIIdSK			
pbmask		0.0	
restart		True	
s avemode 1		Inonel	
Savemouel		none	
calcres		True	
calcpsf		True	
parallel		False	

CASA <7>:

e Reconstruction

#

#

#

#

field(s) to select spw(s)/channels to select Range of time to select from data Select data within uvrange

Scan number range Observation ID range Scan Intent(s)

Number of pixels

normalizations

restored image

primary beam mask

Calculate PSF

: Increment imagename

definitions Weighting scheme

plane

is the PSF main lobe

Cell size

Name of input visibility file(s) Enable data selection parameters

Select data based on antenna/baseline

Data column to image(data,corrected)

Pre-name of output images

Phase center of the image Stokes Planes to make

Coordinate projection (SIN, HPX) Name of starting model image Spectral definition mode (mfs,cube,cubedata) Reference frequency

Gridding options (standard, wproject, widefield, mosaic, awproject) Name of Voltage Pattern table

Minor cycle algorithm (hogbom,clark,m

>PB gain level at which to cut off

ultiscale,mtmfs,mem,clarkstokes) Do restoration steps (or not) Restoring beam shape to use. Default

Apply PB correction on the output

Name of outlier-field image

(natural,uniform,briggs) uv-taper on outer baselines in uv-

Maximum number of iterations Type of mask(s) for deconvolution

(user, pb, auto-thresh, autothresh2, or auto-multithresh) Mask (a list of image name(s) or region file(s) or region string(s))

True : Re-use existing images. False

Options to save model visibilities (none, virtual, modelcolumn) Calculate initial residual image

Run major cycles in parallel

Key tclean parameters

The **specmode** parameter controls whether you image the continuum or line emission.

The **gridder** option is used to specify what sort of gridding you will be doing (standard, mosaic, widefield, wproject, or awproject). The first two are most common with ALMA. The rest more common with the VLA.

The **deconvolver** options gives you access to different deconvolution options (hogbom, clark, mtmfs, multiscale,

clarkstokes)

ASA <23>: inp				
tclean :: Radio	Int =	terferometric	Image R	econstruction Name of input visibility file(s)
electdata	_	True	#	Enable data selection parameters
field	=		#	field(s) to select
SDW			#	spw(s)/channels to select
timerange			#	Range of time to select from data
uvrange			#	Select data within uvrange
antenna			#	Select data based on antenna/basel
scan			#	Scan number range
observation			#	Observation ID range
intent			#	Scan Intent(s)
atacolumn		'corrected'	#	Data column to image(data,corrected
magename			#	Pre-name of output images
msize		[100]	#	Number of pixels
ell		['larcsec']	#	Cell size
hasecenter			#	Phase center of the image
tokes		'I'	#	Stokes Planes to make
rojection	=	'SIN'	#	Coordinate projection (SIN, HPX)
pecmode	=	'mfs'	#	Spectral definition mode
			#	(mfs,cube,cubedata)
reffreq			#	Reference frequency
ridder	=	'standard'	#	Gridding options (standard, wprojed
			#	widefield, mosaic, awproject)
vptable			#	Name of Voltage Pattern table
pblimit		0.2	#	>PB gain level at which to cut off
			#	normalizations
econvolver	=	'mtmfs'	#	Minor cycle algorithm (hogbom,clar
			#	ultiscale,mtmfs,mem,clarkstokes)
scales		[]	#	List of scale sizes (in pixels) for
			#	multi-scale algorithms
nterms		2	#	Number of Taylor coefficients in th
			#	spectral model
estoration	=	True	#	Do restoration steps (or not)
restoringbeam		[]	#	Restoring beam shape to use. Defau
			#	is the PSF main lobe
pbcor		False	#	Apply PB correction on the output
			#	restored image
				Name of outling field image
utilerinte				definitions
oighting	_	Insturall		Weighting scheme
ergnung	-	naturat		(natural uniform brigge)
untanor		-		(naturat, uniform, or iggs)
uvcaper		u .	#	nlane
				prone
iter	=	Θ	#	Maximum number of iterations
semask	=	'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
				Taur - De une autobles des ser
estart		True	#	True : Re-use existing images. Fals
avenadal		Inerel	#	: increment imagename
avellique	_	none	#	options to save model visibilities

True

True

False

calcpsf

initial residual image

Calculate PSF

Run major cycles in parallel

Imaging spectral lines: continuum subtraction

- Generally would like to subtract continuum emission prior to imaging line data.
 - We will see how to identify line-free channels in hands-on session.
- Current best practice is to use uvcontsub to do the subtraction in uv plane.

CASA <11>: inp > inp(0			
# uvcontsub ::	: Contin	uum fitting and s	subtr	raction in the uv plane
vis	=	'ngc3256_co.ms'	#	Name of input MS. Output goes to vis + ".contsub"
field	=	11	#	Select field(s) using id(s) or name(s)
fitspw	=	'0:20~53:71~120'	#	Spectral window:channel selection for fitting the continuum
combine	=		#	Data axes to combine for the continuum estimation (none, or spw and/or scan)
solint	=	'int'	#	Continuum fit timescale (int recommended!)
fitorder	=	0	#	Polynomial order for the fits
spw	=		#	Spectral window selection for output
want_cont	=	False	#	Create vis + ".cont" to hold the continuum estimate.
async	=	False	#	If true the taskname must be started using uvcontsub()

Gridder options: mosaics

Mosaics are common with ALMA particularly at high frequencies

Example: SMA 1.3 mm observations: 5 pointings

- Primary beam ~I'
 - Resolution \sim 3"

ALMA 1.3mm PB ALMA 0.85mm PB

Gridder options: mosaics

gridder='mosaic' mosweight=True conjbeams=False specify field for data, e.g., field='1~6'

Setting mosweight=True weights each field in the mosaic independently to avoid issues with non-uniform sensitivity for more uniform Briggs weighting values and poor uv-coverage.

ALMA recommends conjbeams=False (do not take into account the primary beam scaling with frequency).

There's a tool ("ia.linearmosaic") to stitch all pointings together entirely in the image domain after cleaning each pointing individually.

	> inn()			
# tcle	an :: Radio I	nterferometric	Image R	Reconstruction
vis		= ''	#	Name of input visibility file(s)
selectd	ata	True	#	Enable data selection parameters
fi	eld		#	field(s) to select
sp	W		#	<pre>spw(s)/channels to select</pre>
ti	merange	= ''	#	Range of time to select from data
uv	range	= ''	#	Select data within uvrange
an	tenna	= ''	#	Select data based on antenna/baseline
sc	an	= ''	#	Scan number range
OD	servation	= ''	#	Observation ID range
10	tent	=	#	Scan Intent(s)
datacol	ump	= 'corrected'	#	Data column to image(data corrected)
imagena	me	= ''	#	Pre-name of output images
imsize	inc :	= [100]	#	Number of nixels
cell		= ['larcsec']	#	Cell size
phasece	nter	= ''	#	Phase center of the image
stokes		= 'I'	#	Stokes Planes to make
project	ion	= 'SIN'	#	Coordinate projection (SIN, HPX)
startmo	del	= '''	#	Name of starting model image
specmod	e	'mfs'	#	Spectral definition mode
			#	(mfs,cube,cubedata)
re	ffreq		#	Reference frequency
gridder		= 'mosaic'	#	Gridding options (standard, wproject,
			#	widefield, mosaic, awproject)
по	rmtype	= 'flatnoise'	#	Normalization type (flatnoise,
	table		#	Tlatsky) Name of Voltors, Dottorn toble
vp	ldDLe	- 0.2		Name of vollage fallern lable
po	LIMIL	- 0.2	*	pormalizations
60	nibeams	= Ealco	#	lise conjugate frequency for wideband
0	njucans	- raise	#	A-terms
				A COMING
deconvo	lver	'hogbom'	#	Minor cycle algorithm (hogbom,clark,m
		_	#	ultiscale,mtmfs,mem,clarkstokes)
restora	tion	True	#	Do restoration steps (or not)
re	storingbeam	= []	#	Restoring beam shape to use. Default
			#	is the PSF main lobe
pb	cor	= False	#	Apply PB correction on the output
			#	restored image
	641.0			Name of outling field image
outtier	rite	-		Name of outlier-field image
				00110111006
Waighti	0.0	Instural!		definitions Weighting scheme
weighti	ng	'natural'	#	Weighting scheme (natural uniform briggs)
weighti	ng taper	'natural' = []	# # #	Weighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv-
weighti uv	ng taper	= 'natural' = []	* # # #	Weighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv- plane
weighti uv	ng taper	inatural'	* # # #	Weighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv- plane
weighti uv niter	ng taper	'natural' = [] 0	* # # # #	Weighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv- plane Maximum number of iterations
weighti uv niter usemask	ng taper	'natural' = [] 0 'user'	* # # # # #	Weighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv- plane Maximum number of iterations Type of mask(s) for deconvolution
weighti uv niter usemask	ng taper	'natural' = [] 0 'user'	* # # # # # #	Meighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv- plane Maximum number of iterations Type of mask(s) for deconvolution (user, pb, auto-thresh, auto-
weighti uv niter usemask	ng taper	'natural' = [] 0 'user'	* # # # # # # # #	Meighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv- plane Maximum number of iterations Type of mask(s) for deconvolution (user, pb, auto-thresh, auto- thresh2, or auto-multithresh)
weighti uv niter usemask ma	ng taper sk	'natural' = [] 0 'user' = ''	****	Meighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv- plane Maximum number of iterations Type of mask(s) for deconvolution (user, pb, auto-thresh, auto- thresh2, or auto-multithresh) Mask (a list of image name(s) or
weighti uv niter usemask ma	ng taper sk	'natural' = [] 0 'user' = ''	****	<pre>definitions Weighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv- plane Maximum number of iterations Type of mask(s) for deconvolution (user, pb, auto-thresh, auto- thresh2, or auto-multithresh) Mask (a list of image name(s) or region file(s) or region string(s))</pre>
weighti uv niter usemask ma pb	ng sk	'natural' = [] 0 'user' = '' = 0.0	****	Weighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv- plane Maximum number of iterations Type of mask(s) for deconvolution (user, pb, auto-thresh, auto- thresh2, or auto-multithresh) Mask (a list of image name(s) or region file(s) or region string(s)) primary beam mask
weighti uv niter usemask ma pb	ng taper sk mask	'natural' = [] - 0 'user' = '' = 0.0	****	Weighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv- plane Maximum number of iterations Type of mask(s) for deconvolution (user, pb, auto-thresh, auto- thresh2, or auto-multithresh) Mask (a list of image name(s) or region file(s) or region string(s)) primary beam mask
weighti uv niter usemask ma pb restart	ng taper sk mask	<pre>'natural' = [] = 0 'user' = '' = 0.0 = True</pre>	****	<pre>definitions Weighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv- plane Maximum number of iterations Type of mask(s) for deconvolution (user, pb, auto-thresh, auto- thresh2, or auto-multithresh) Mask (a list of image name(s) or region file(s) or region string(s)) primary beam mask True : Re-use existing images. False . Increment imagename</pre>
weighti uv niter usemask ma pb restart	ng taper sk mask	'natural' = [] 'user' = '' = 0.0 = True	****	<pre>definitions Weighting scheme (natural,uniform,briggs) uv-taper on outer baselines in uv- plane Maximum number of iterations Type of mask(s) for deconvolution (user, pb, auto-thresh, auto- thresh2, or auto-multithresh) Mask (a list of image name(s) or region file(s) or region string(s)) primary beam mask True : Re-use existing images. False : Increment imagename</pre>
niter uv niter usemask ma pb restart savemod	ng sk	'natural' = [] o'user' = '' = 0.0 = True = 'none'	****	<pre>definitions Weighting scheme (natural, uniform, briggs) uv-taper on outer baselines in uv- plane Maximum number of iterations Type of mask(s) for deconvolution (user, pb, auto-thresh, auto- thresh2, or auto-multithresh) Mask (a list of image name(s) or region file(s) or region string(s)) primary beam mask True : Re-use existing images. False : Increment imagename Options to save model visibilities (none virtual medalcolumn)</pre>
meighti uv niter usemask ma pb restart savemod	ng taper sk mask el	'natural' = [] 'user' = '' = 0.0 = True = 'none' = True	****	<pre>definitions Weighting scheme (natural, uniform, briggs) uv-taper on outer baselines in uv- plane Maximum number of iterations Type of mask(s) for deconvolution (user, pb, auto-thresh, auto- thresh2, or auto-multithresh) Mask (a list of image name(s) or region file(s) or region string(s)) primary beam mask True : Re-use existing images. False : Increment imagename Options to save model visibilities (none, virtual, modelcolumn) Calculate indicate the section of t</pre>

Deconvolver options: PSF sampling choices

- deconvolver='hogbom'
 - Subtracts shifted and scaled full PSF from residual image
 - More accurate but can be computationally expensive.
- deconvolver='clark'
 - Subtracts small patch of shifted and scaled PSF from residual image
 - Does the major cycle more often to compensate for the above
 - Potentially less accurate, but also less computationally expensive.
- deconvolver='clarkstokes'
 - Does the thing as clark, but doing each polarization product separately.

> inn()			
tclean :: Radio I	nterferometric	Image R	econstruction
is	= ''	#	Name of input visibility file(s)
electdata	 True 	#	Enable data selection parameters
field	= ''	#	field(s) to select
spw		#	Spw(S)/Channels to select from data
uvrange			Select data within uvrange
antenna		#	Select data based on antenna/baselir
scan		#	Scan number range
observation		#	Observation ID range
intent	= '''	#	Scan Intent(s)
atacolumn	- Icorrected!		Data column to image(data corrected)
atacolumn	= corrected	#	Pre-name of output images
msize	= [100]	#	Number of pixels
ell	= ['larcsec']	#	Cell size
hasecenter		#	Phase center of the image
tokes	= 'I'	#	Stokes Planes to make
rojection	= 'SIN'	#	Coordinate projection (SIN, HPX)
nacmode	- Imfel		Name of Starting model image
peciliode	111 5		(mfs.cube.cubedata)
reffreq		#	Reference frequency
ridder	<pre>'standard'</pre>	#	Gridding options (standard, wproject
		#	widefield, mosaic, awproject)
vptable	- 0.2	#	Name of Voltage Pattern table
potimit	- 0.2	#	normalizations
			normat rzac rons
econvolver	= 'hogbom'	#	Minor cycle algorithm (hogbom,clark,
			uttiscate, mumis, mem, ctarkstokes)
estoration	True	#	Do restoration steps (or not)
restoringbeam	= U	#	is the PSE main lobe
pbcor	= False		Apply PB correction on the output
		#	restored image
utlierfile	=	#	Name of outlier-field image
	- Instant I	#	definitions
ergnung	naturat	#	(natural uniform briggs)
uvtaper	= n		uv-taper on outer baselines in uv-
		#	plane
iter	= 1	#	Maximum number of iterations
threshold	- 0.1	#	Stopping threshold
cvcleniter	= -1	#	Maximum number of minor-cvcle
		#	iterations
cyclefactor	= 1.0	#	Scaling on PSF sidelobe level to
		#	compute the minor-cycle stopping
	- 0.05	#	threshold.
minpstfraction	= 0.05	#	of cleaning in the minor cycle
maxosffraction	= 0.8		PSF fraction that marks the minimum
manportraction		#	depth of cleaning in the minor cycl
interactive	= False	#	Modify masks and parameters at
		#	runtime
	- I was at		The standard for the second of the
semask	'user'	#	lype of mask(s) for deconvolution
			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
			True - De use suisting income Data
estart	- True	#	The interview in the second se
avemodel	= 'none'	#	Options to save model visibilities
		#	(none, virtual, modelcolumn)
alcres	= True	#	Calculate initial residual image
alcpsf	= True	#	Calculate PSF
arallel	= False	#	Run major cycles in parallel

Deconvolver options: 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)

NRAO *

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

Selecting scales that are close to the size of your source can lead to poor modeling and divergence in clean.

Deconvolver options: Multi-scale CLEAN

deconvolver='multiscale'

- only do multiscale
- line or narrow bandwidth continuum

deconvolver='mtmfs'

- multiscale+multi-terms
- wide-fractional bandwidth continuum
- For both need to set scales
 - Note that scales is in pixels

# tolean :: Radio	Interferometric	: Image Reconstruction
V15	True	# Name of input visibility file(s)
fiold	- Irue	# Enable data selection parameters
Tieta		# Tield(S) to select
timerange		# Spw(s)/Challers to select from data
Limerange		# Select data within uvrange
antenna		# Select data based on antenna/base
scap		# Scan number range
observation		# Observation ID range
intent		# Scan Intent(s)
incene		
datacolumn	= 'corrected'	# Data column to image(data.correct
imagename		<pre># Pre-name of output images</pre>
imsize	= [100]	<pre># Number of pixels</pre>
cell	= ['larcsec']	# Cell size
phasecenter		# Phase center of the image
stokes	= 'I'	# Stokes Planes to make
projection	= 'SIN'	<pre># Coordinate projection (SIN, HPX)</pre>
startmodel	=	# Name of starting model image
specmode	= 'mfs'	# Spectral definition mode
		<pre># (mfs,cube,cubedata)</pre>
reffreq		# Reference frequency
gridder	<pre>= 'standard'</pre>	# Gridding options (standard, wproj
		<pre># widefield, mosaic, awproject)</pre>
vptable	= ''	# Name of Voltage Pattern table
pblimit	= 0.2	# >PB gain level at which to cut of
		# normalizations
decentrelues	- Invittional a	# Minor sucle election (becher ele
deconvolver		# withor Cycle algorithm (nogbom,cla # withiscale mtmfs mem clarkstokes)
ccoloc		# lict of ccole cirec (in nivels)
scales	- 11	# multi-scale algorithms
smallscalebias	= 0.6	# A bias towards smaller scale size
Silla Ersea Ecoras	0.0	# A bras conditas sinderer scare size
restoringbeam	= []	# Restoring beam shape to use. Defa
		<pre># is the PSF main lobe</pre>
pbcor	= False	# Apply PB correction on the output
		<pre># restored image</pre>
outlierfile		# Name of outlier-field image
		# definitions
weighting	<pre>= 'natural'</pre>	<pre># Weighting scheme</pre>
		<pre># (natural,uniform,briggs)</pre>
uvtaper	= []	# uv-taper on outer baselines in uv
		# plane
a da an		M. Maulaum number of the setters
niter		# maximum number of iterations
usemask	- user	# Type of mask(s) for deconvolution
		# (user, pp, auto-thresh, auto-
mask		# thresh2, or auto-multithresh)
mask		# mask (a list of image name(s) or
phmack	- 00	# region file(s) of region string(
politask	0.0	+ primary beam mask
restart	= True	# True : Re-use existing images Fa
- cocar c	riue	# : Increment imagename
savemode1	= 'none'	# Options to save model visibilitie
	none	<pre># (none, virtual, modelcolumn)</pre>
calcres	= True	# Calculate initial residual image
calcosf	= True	# Calculate PSF
parallel	= False	<pre># Run major cycles in parallel</pre>

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Restoration options: Primary beam correction

pbcor=True

- Correct the output image for the primary beam (i.e., the beam pattern of the telescope)
- You want to measure things from a primary beam corrected image because it includes the response of the telescope.
- The noise will no longer be flat across the image.

For multi-term mfs primary beam corrections (i.e., nterms=2) use the **widebandpbcor** task instead.

	:: Radio	Int	terferometric	Image	Recon
	a		True	#	Ena
	d			- #	fie
	a			#	Snw
	range			#	Ran
	nge			#	Se1
	nna			#	Sel
				#	Sca
	rvation			#	Obs
	ent			#	Sca
datacolu	mp	_	[corrected]	#	Dat
imagenam	A	_	con ected	#	Pre
imsize	C	_	[100]	#	Num
cell		-	['larcsec']	#	Cel
nhasecen	tor	_	[Iai CSec]	#	Pha
stokes	cer	_	1.1.1	#	Sto
projecti	00		'STN'	#	
startmod	el	_		#	Nam
specmode		_	'mfs'	#	Sne
speemode	_			#	(1
ref	freq			#	Ref
gridder		_	'standard'	#	Gri
				#	wi
vot	able			#	Nan
obl	imit		0.2	#	>PB
				#	no
deconvol	ver	=	'multiscale'	l #	Min
				#	. ut
sca	Les		LI	#	LIS
sma	llscalebias		0.6	#	Ab
			_		_
restorat	100	=	True	#	Do
res	toringbeam		- U	#	Res
nha			Falsa	#	15
рос	or		False	#	Арр
				#	re
outtien	TLC.			#	Nell
				#	de
weightin	g	=	'natural'	#	Wei
				#	(n
uvt	aper		L1	#	- uv
					pi
niter		=	Θ	#	Max
usemask		=	'user'	#	Тур
				#	(u
				#	th
mas	k			#	Mas
				#	re
pbm	ask		0.0	#	pri
restart			True	#	Tru
				#	
savemode	1		'none'	#	Ont
				#	(n
calcres			True	#	Cal
colonef			True		Cal

False

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ag	e Re	econstruction
	#	Name of input visibility file(s)
	#	Enable data selection parameters
	#	field(s) to select
	#	spw(s)/channels to select
	#	Range of time to select from data
	#	Select data within uvrange
	#	Select data based on antenna/baseli
	#	Scan number range
	#	Observation ID range
	#	Scan Intent(s)
		Sean Incenc(S)
	#	Data column to image(data.corrected)
	#	Pre-name of output images
	#	Number of pixels
	#	Cell cize
	#	Phase center of the image
	4	Stokes Planes to make
	#	Coordinate projection (STN HPV)
	*	None of starting model image
	#	Name of Starting model image
	#	spectral definition mode
	#	(mrs,cube,cubedata)
	Ŧ	Reference frequency
		Calddan and an interdent surveyer
	#	Gridding options (standard, wproject
	#	widefield, mosaic, awproject)
	#	Name of Voltage Pattern table
	#	>PB gain level at which to cut off
	#	normalizations
	#	Minor cycle algorithm (hogbom,clark
	#	ultiscale,mtmfs,mem,clarkstokes)
	#	List of scale sizes (in pixels) for
	#	multi-scale algorithms
	#	A bias towards smaller scale sizes
	#	Do restoration steps (or not)
	#	Restoring beam shape to use. Default
	#	is the PSF main lobe
	#	Apply PB correction on the output
	#	restored image
	ŧ.	Name of outlier-field image
	#	definitions
	#	Weighting scheme
	#	(natural,uniform,briggs)
	#	uv-taper on outer baselines in uv-
	#	plane

#	Maximum number of iterations
#	Type of mask(s) for deconvolution
#	(user, pb, auto-thresh, auto-
#	thresh2, or auto-multithresh)
#	Mask (a list of image name(s) or
#	<pre>region file(s) or region string(s))</pre>
#	primary beam mask
#	True : Re-use existing images. False
#	: Increment imagename
#	Options to save model visibilities
#	(none, virtual, modelcolumn)
#	Calculate initial residual image
#	Calculate PSF
	Run major cycles in parallel

Restoration options: restoringbeam

restoringbeam='common'

- gives same beam across an entire cube.
- Recommended to run this in serial mode because of how parallel cube mode is currently implemented.
- Can clean cube in parallel mode, then restart in serial mode with restoringbeam='common' to get a common beam.

:: Radio In	iterferometric	Image Reconstruction
	True	# Name of input visibility f
d	i i ue	# field(s) to select
ŭ		<pre># field(s) to select # spw(s)/channels to select</pre>
range		# Range of time to select fr
nge		# Select data within uvrange
nna =		# Select data based on anten
=		# Scan number range
rvation =		# Observation ID range
		<pre># Scan Intent(s)</pre>
atacolumn	'corrected'	# Data column to image(data
magename =		# Pre-name of output images
msize =	[100]	# Number of nivels
ell =	['larcsec']	# Cell size
hasecenter =	= ''	# Phase center of the image
tokes =	· ' I '	# Stokes Planes to make
rojection =	'SIN'	# Coordinate projection (SIN
tartmodel =		# Name of starting model ima
pecmode =	'mfs'	# Spectral definition mode
		<pre># (mfs.cube.cubedata)</pre>
reffreq =		<pre># Reference frequency</pre>
riddor -	'standard'	# Gridding options (standard
ridder -	Scandaru	# widefield mosaic awarai
vntable =		# Name of Voltage Pattern ta
oblimit =		# Name of Voltage rattern ta # >PR gain level at which to
portinite	0.12	<pre># normalizations</pre>
	1	
econvolver =	'multiscale'	# Minor cycle algorithm (hog
		# Ultiscale,mtmts,mem,clark
scales =	• U	# LIST OF SCALE SIZES (IN PI
smallscalebias =	.6	# Multi-Scale algorithms # A bias towards smaller sca
	-	
estoration =	True	# Do restoration steps (or n
restoringbeam -	· U	# Kestoring beam snape to us
phoor -	Ealco	# Apply PP correction on the
pucor -	- raise	# Apply PB correction on the
		# rescored image
utterrite -		# Name of Outlier=fretu fillag
o labting -	Inchungli	# definitions
eighting =	natural	# weighting scheme
uutenen -		# (natural, uniform, briggs)
uvtaper =	·	# uv-taper on outer baseline
		# plane
iter =	0	<pre># Maximum number of iteratio</pre>
semask =	'user'	<pre># Type of mask(s) for deconv</pre>
		<pre># (user, pb, auto-thresh, a</pre>
		<pre># thresh2, or auto-multithr</pre>
mask =		# Mask (a list of image name
		<pre># region file(s) or region</pre>
pbmask =	= 0.0	<pre># primary beam mask</pre>
estart =	True	# True : Re-use existing ima
	Thuc .	# : Increment imagename
avemodel =	inone'	# Options to save model visi
		<pre># (none, virtual, modelcolu</pre>
alcres =	True	<pre># Calculate initial residual</pre>
alcpsf =	True	<pre># Calculate PSF</pre>
arallel =	False	# Run major cycles in parall

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m data

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HPX)

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cut off

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Default

output

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image

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Stopping parameters

- Setting niter>0 exposes stopping parameters
- tclean stops when it completes the maximum number of iterations or when residuals go below the threshold level, whatever comes first.
 - Set niter to a large, but not too large, number
 - 1000 is a decent starting point
 - The more complex your image is the larger niter you will need
 - threshold='3mJy'
 - Usually some multiple of your noise level (1-3 sigma)
- Interactive=True
 - Allows you interactive control of tclean through the viewer
 - Choice of niter and threshold can be controlled through viewer
- Other parameters largely for power users
 - Gain can be useful for cases with extended emission (although see multiscale clean)
 - cyclefactor, cycleniter, minpsffraction,maxpsffraction all control how often the minor cycle happens.

[CASA < 21 >: inp > inp()			
<pre># tclean :: Radio</pre>	Interferometr	: Image Reconstruction	4144 #414(a)
selectdata	- True	# Name of input visit # Enable data select	on parameters
field	= "	<pre># field(s) to select</pre>	
spw	= ''	<pre># spw(s)/channels to</pre>	select
timerange		<pre># Kange of time to se # Select data within</pre>	Lect from data
antenna		# Select data based o	n antenna/baselin
scan		<pre># Scan number range</pre>	
observation		# Observation ID rang	;e
intent		# Scan Intent(s)	
datacolumn	= 'corrected	# Data column to imag	e(data,corrected)
imagename		<pre># Pre-name of output</pre>	images
imsize	= [100]	<pre># Number of pixels # Collector</pre>	
phasecenter	= ['larcsec']	# Cell Size # Phase center of the	image
stokes	= 'I'	# Stokes Planes to ma	ike
projection	= 'SIN'	# Coordinate projecti	on (SIN, HPX)
startmodel	= Infel	# Name of starting mo # Spectrol definition	del image
specilioue	mis	# (mfs.cube.cubedata)
reffreq		# Reference frequency	
gridder	'standard'	<pre># Gridding options (s # widefield mossic</pre>	tandard, wproject
votable		# Name of Voltage Pat	tern table
pblimit	= 0.2	# >PB gain level at w	hich to cut off
		<pre># normalizations</pre>	
deconvolver	hoghom'	# Minor cycle algorit	hm (hoghom clark
acconvolver	nogoom	# ultiscale.mtmfs.me	m.clarkstokes)
restoration	True	# Do restoration step	os (or not)
restoringbeam	= []	<pre># Restoring beam shap</pre>	e to use. Default
nhcor	= Ealce	# is the PSF main Lo	be
pocor	- raise	# restored image	on the output
outlierfile		<pre># Name of outlier-fie # definitions</pre>	ld image
weighting	<pre>'natural'</pre>	# Weighting scheme	
		<pre># (natural, uniform, t</pre>	riggs)
uvtaper	= []	# uv-taper on outer t	aselines in uv-
		# plane	
niter	= 1	<pre># Maximum number of i</pre>	terations
gain	= 0.1	# Loop gain	
cvcleniter	= 0.0	# Stopping threshold # Maximum number of m	inor-cycle
cycremiter	1	# iterations	inior-cycle
cyclefactor	= 1.0	# Scaling on PSF side	lobe level to
		<pre># compute the minor- # threshold</pre>	cycle stopping
minpsffraction	= 0.05	# PSF fraction that n	arks the max dept
		# of cleaning in the	minor cycle
maxpsffraction	0.8	<pre># PSF fraction that m</pre>	arks the minimum
interactive	- Falca	<pre># depth of cleaning # Modify macks and no</pre>	in the minor cycl
interactive	- raise	# runtime	allecers at
usemask	user'	# Type of mask(s) for # (user ph auto-th	deconvolution
		# thresh2, or auto-n	ultithresh)
mask		<pre># Mask (a list of image)</pre>	ge name(s) or
nhmaek	- 0.0	<pre># region file(s) or # primary beam meril</pre>	region string(s)
pomask	- 0.0	# primary beam mask	
restart	= True	# True : Re-use exist	ing images. False
		# : Increment imager	ame
savemodel	= 'none'	# Uptions to save mod # (none virtual mod	del visibilities
calcres	= True	# Calculate initial	esidual image
calcpsf	= True	# Calculate PSF	
parallel	= False	# Run major cycles ir	parallel

Running TCLEAN interactively

- residual image in viewer
- define a mask with defining a mouse button on shape type
- define the same mask for all channels
- or iterate through the channels with the tape deck and define separate masks

Continue for next major cycle and display residual

Stop

Exit interactive mode, but continue cleaning. Dangerous if control parameters not set sensibly!! Using Ctrl+C can corrupt your ms.

Output of TCLEAN

Minimally:

- my_image.pb
- my_image.image
- my_image.mask
- my_image.model
- my_image.psf
- my_image.residual
- my_image.sumwt

Primary beam model
Cleaned and restored image (Jy/clean beam)
Clean "boxes"
Clean components (Jy/pixel)
Dirty beam
Residual (Jy/dirty beam)
Sum of weights

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

Together images can be used in subsequent tclean runs if necessary. It's good practice not to delete subsets of images.

Advanced usage: tclean can be restarted

- restart=True
 - If tclean is started again with same image name, it will try to continue deconvolution from where it left off. Make sure this is what you want. If not, give a new name or remove existing files with rmtables('my_image.*')
- restart=False
 - If tclean is started again with same image name, increment the image name, and start the clean process from the beginning.
- calcpsf and calcresid
 - Controls whether or not tclean calculates the psf and residual or uses what's on disk.

 Also: try NOT to do CTRL+C as it could corrupt your MS when it touches the visibilities in a major cycle.

Advanced Usage: parallel mode

- Tclean can be run in parallel to speed up processing of images and cubes.
- Setting this up requires a few extra steps:
 - Start casa in mpi mode: mpicasa –n 8 casa
 - The –n parameter specifies how many cores you have available. One will be used for control and n-1 will be used for processing
 - In your tclean command, set parallel=True (not necessary in CASA 6.2 for cubes)
 - Run your tclean command.

Advanced usage: automasking

- usemask='auto-multithresh'
- Used by the ALMA Pipeline starting in Cycle 5. Also available to users as a tclean option.
- Default parameters generally good for ALMA 12m data
- General purpose algorithm so works for ALMA, VLA, ATCA, etc.
- casaguide:

https://casaguides.nrao.edu/index.php/Auto masking_Guide

Paper: <u>Kepley et al. 2020, PASP, 132, 1008</u>, 02405

Combining with single-dish or other interferometric maps

- If you have only images:
 - feather (or "casafeather")
- If you have an image and an MS:
 - Can use CLEAN with the image as the model and/or feather
- If you have multiple MS plus an image:
 - Same as above, input to clean will be all the MS'es
- See <u>GBT Memo 300</u> for information on how combining GBT cubes with ALMA data.
- New single dish and interferometric deconvolution task coming in CASA 6.1. See <u>Rau, Naik, & Braun, AJ,</u> <u>158, 1</u> for details of algorithm.
- Useful info from 2019 image combination workshop: <u>https://github.com/teuben/dc2019</u>

Figure 1: *uv*-coverage of the ALMA 12m+7m array for the data used in this memo with the GBT (green) and ALMA TP (purple) coverages overlaid. The GBT data has significant overlap with the ALMA 12-m array uv-coverage.

From GBT Memo 300 (Hoffman and Kepley)

Combining with other data: feather

#	feather	::	Combine	two	images	using	their	Fourier	transforms	

ımagename	=	
nighres	=	
lowres	=	
async	=	False

- # Name of output feathered image
- # Name of high resolution (interferometer) image
 - Name of low resolution (single dish) image
- # If true the taskname must be started using feather(...)

We also have a graphical tool: CASAfeather

Combining with other data: model for clean

In tclean, set startmodel='mymodel.model' Units for model image: Jy/pixel

Be careful to mask a large enough region!

... some CASA images...

Looking ahead ...

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 re 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 in ging 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 Vernication 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

For more info:

http://www.almaobservatory.org

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of the European Organisation for Astronomical Research in the Southern Hemisphere (ESO), the U.S. National Science Foundation (NSF) and the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Republic of Chile. ALMA is funded by ESO on behalf of its Member States, by NSF in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and by NINS in cooperation with the Academia Sinica (AS) in Taiwan and the Korea Astronomy and Space Science Institute (KASI). ALMA construction and operations are led by ESO on behalf of its Member States; by the National Radio Astronomy Observatory (NRAO), managed by Associated Universities, Inc. (AUI), on behalf of North America; and by the National Astronomical Observatory of Japan (NAOJ) on behalf of East Asia. The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.

