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Simulating ALMA Observations

Pamela Klaassen

Jan 24 2013

Why

Why

- Why would you want to simulate observations?

Why

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  - ➡ In a proposal:
    - To show you've thought about filtering, sensitivity and observability

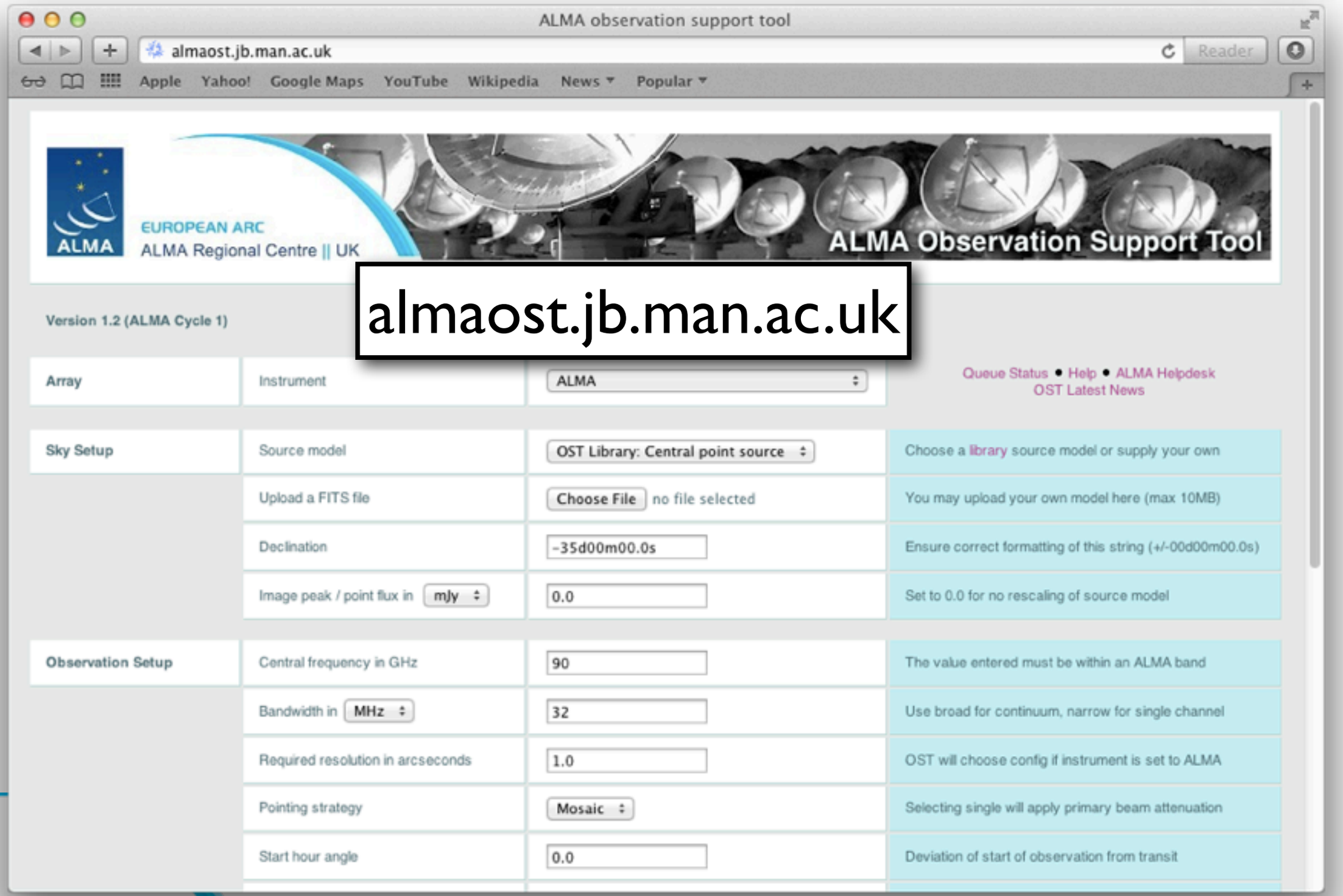
Why

- Why would you want to simulate observations?
  - ➡ In a proposal:
    - To show you've thought about filtering, sensitivity and observability
  - ➡ In a paper:
    - To compare simulations with observations

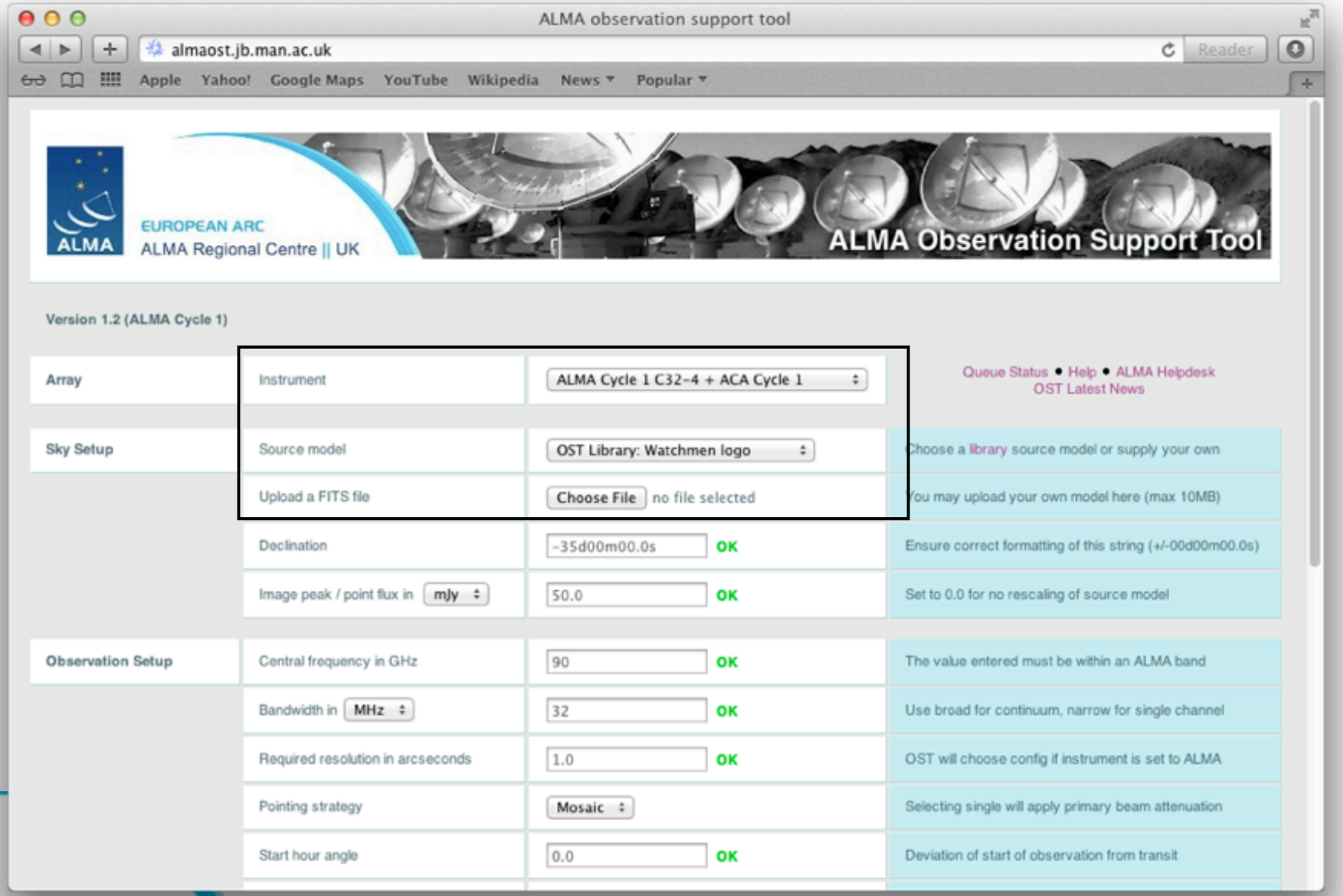
How

- Two tools you can chose from
  - ➡ Single plane, first look
    - ALMA Observation Support Tool (OST)
  - ➡ More robust, including noise estimates
    - Modelling tasks built into CASA

ALMA OST


ALMA observation support tool
almaost.jb.man.ac.uk
Reader
Apple
Yahoo!
Google Maps
YouTube
Wikipedia
News
Popular
EUROPEAN ARC
ALMA Regional Centre || UK
ALMA Observation Support Tool
almaost.jb.man.ac.uk
Version 1.2 (ALMA Cycle 1)
Array
Instrument
ALMA
Queue Status • Help • ALMA Helpdesk
OST Latest News
Sky Setup
Source model
OST Library: Central point source
Choose a library source model or supply your own
Upload a FITS file
Choose File
no file selected
You may upload your own model here (max 10MB)
Declination
-35d00m00.0s
Ensure correct formatting of this string (+/-00d00m00.0s)
Image peak / point flux in
mJy
0.0
Set to 0.0 for no rescaling of source model
Observation Setup
Central frequency in GHz
90
The value entered must be within an ALMA band
Bandwidth in
MHz
32
Use broad for continuum, narrow for single channel
Required resolution in arcseconds
1.0
OST will choose config if instrument is set to ALMA
Pointing strategy
Mosaic
Selecting single will apply primary beam attenuation
Start hour angle
0.0
Deviation of start of observation from transit

ALMA OST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Sky Setup
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Upload a FITS file
Choose File
no file selected
You may upload your own model here (max 10MB)
Declination
-35d00m00.0s
OK
Ensure correct formatting of this string (+/-00d00m00.0s)
Image peak / point flux in
mJy
50.0
OK
Set to 0.0 for no rescaling of source model
Observation Setup
Central frequency in GHz
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The value entered must be within an ALMA band
Bandwidth in
MHz
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OK
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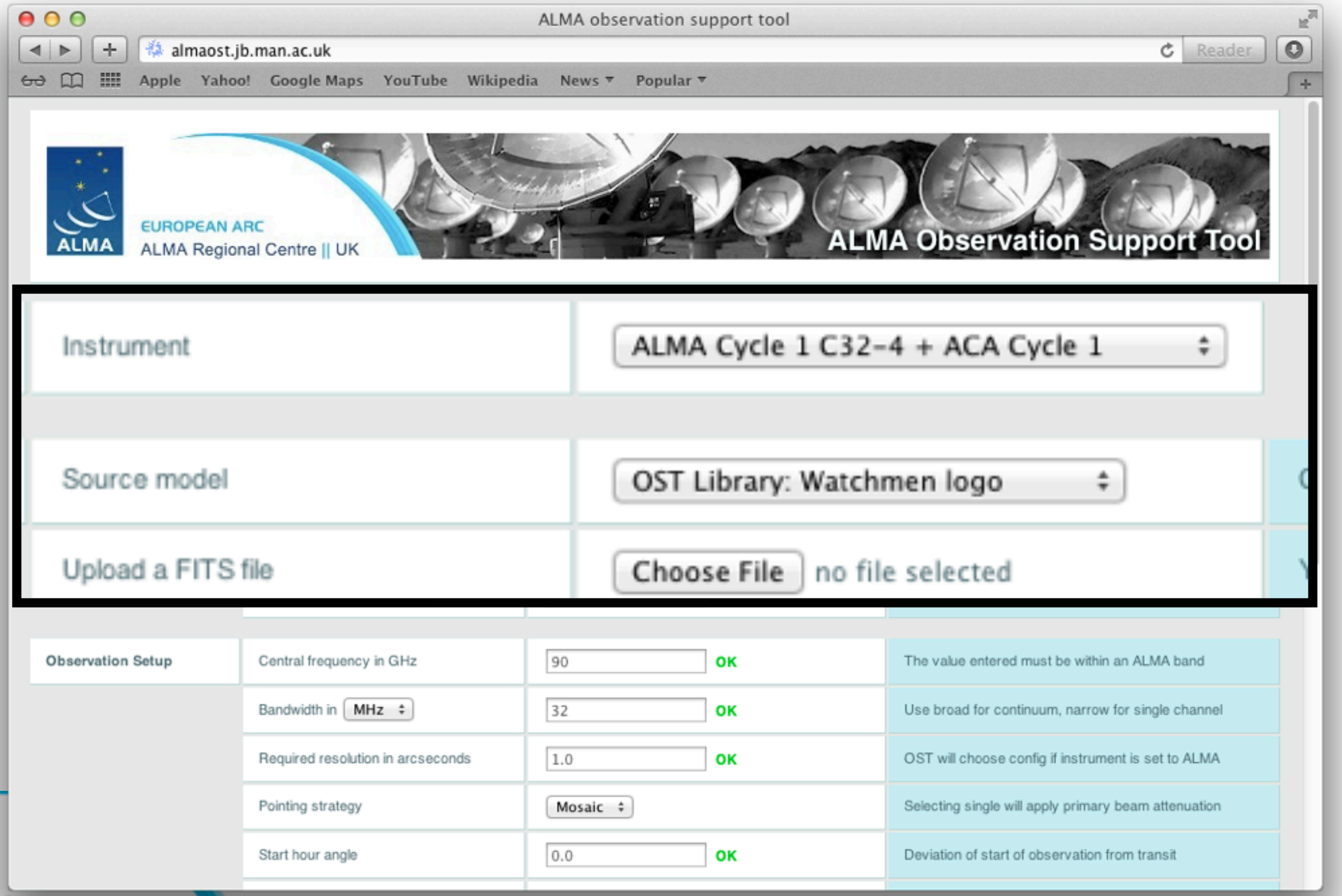
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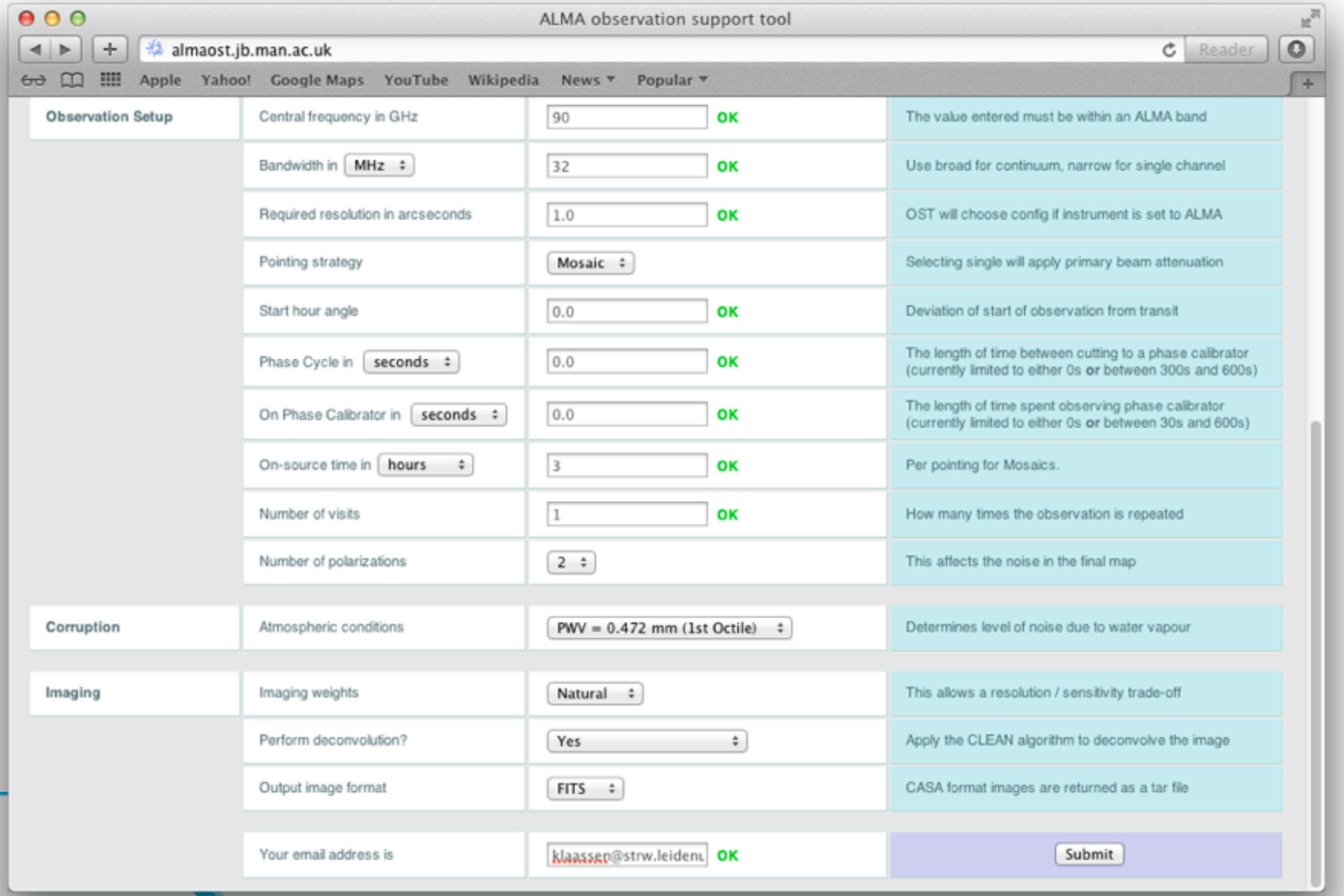
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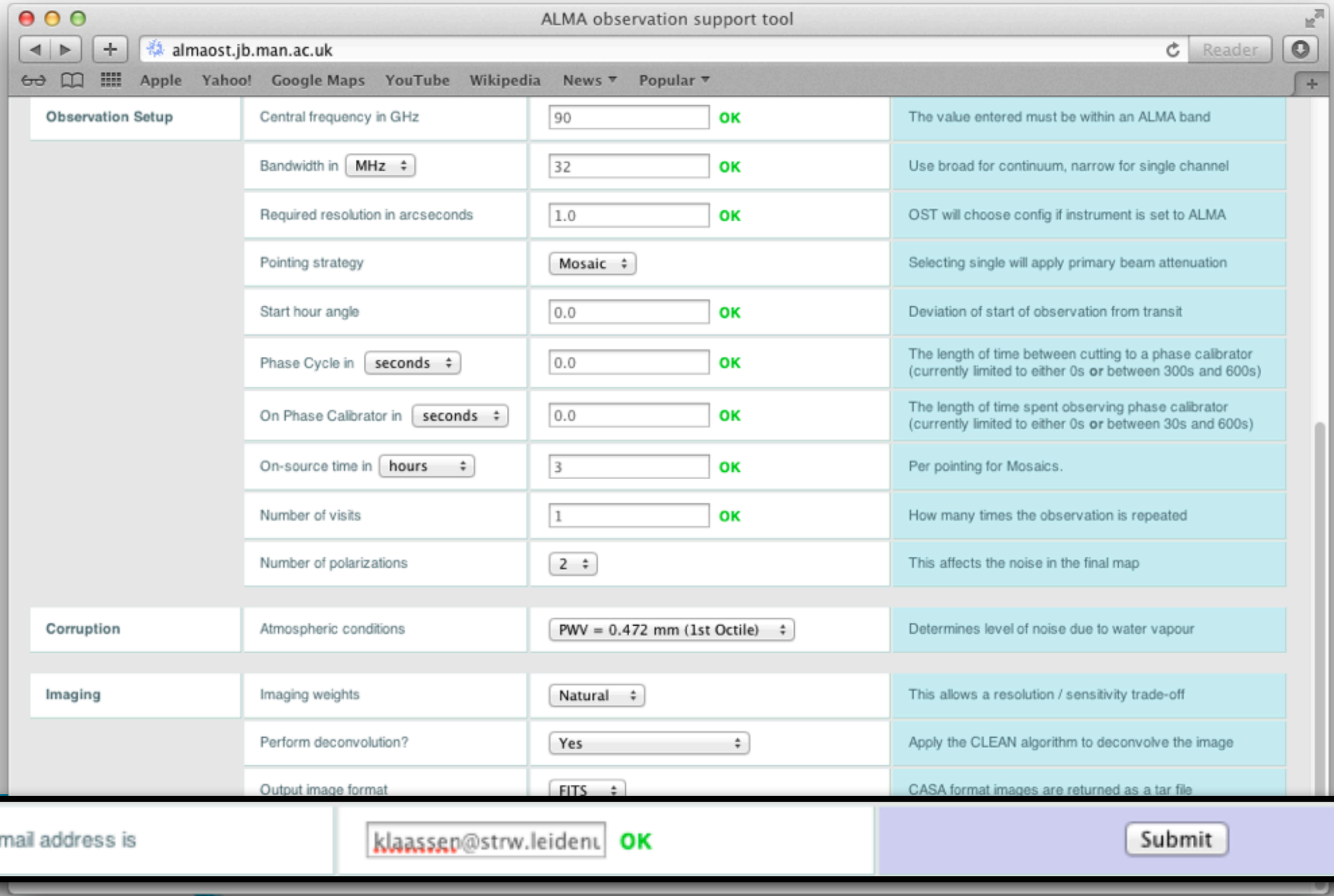
Start hour angle
0.0
OK
Deviation of start of observation from transit
Phase Cycle in
seconds
0.0
OK
The length of time between cutting to a phase calibrator (currently limited to either 0s or between 300s and 600s)
On Phase Calibrator in
seconds
0.0
OK
The length of time spent observing phase calibrator (currently limited to either 0s or between 30s and 600s)
On-source time in
hours
3
OK
Per pointing for Mosaics.
Number of visits
1
OK
How many times the observation is repeated
Number of polarizations
2
This affects the noise in the final map
Corruption
Atmospheric conditions
PWV = 0.472 mm (1st Octile)
Determines level of noise due to water vapour
Imaging
Imaging weights
Natural
This allows a resolution / sensitivity trade-off
Perform deconvolution?
Yes
Apply the CLEAN algorithm to deconvolve the image
Output image format
FITS
CASA format images are returned as a tar file
Your email address is
klaassen@strw.leiden
OK
Submit

ALMA OST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klaassen@strw.leidenu
OK
Submit

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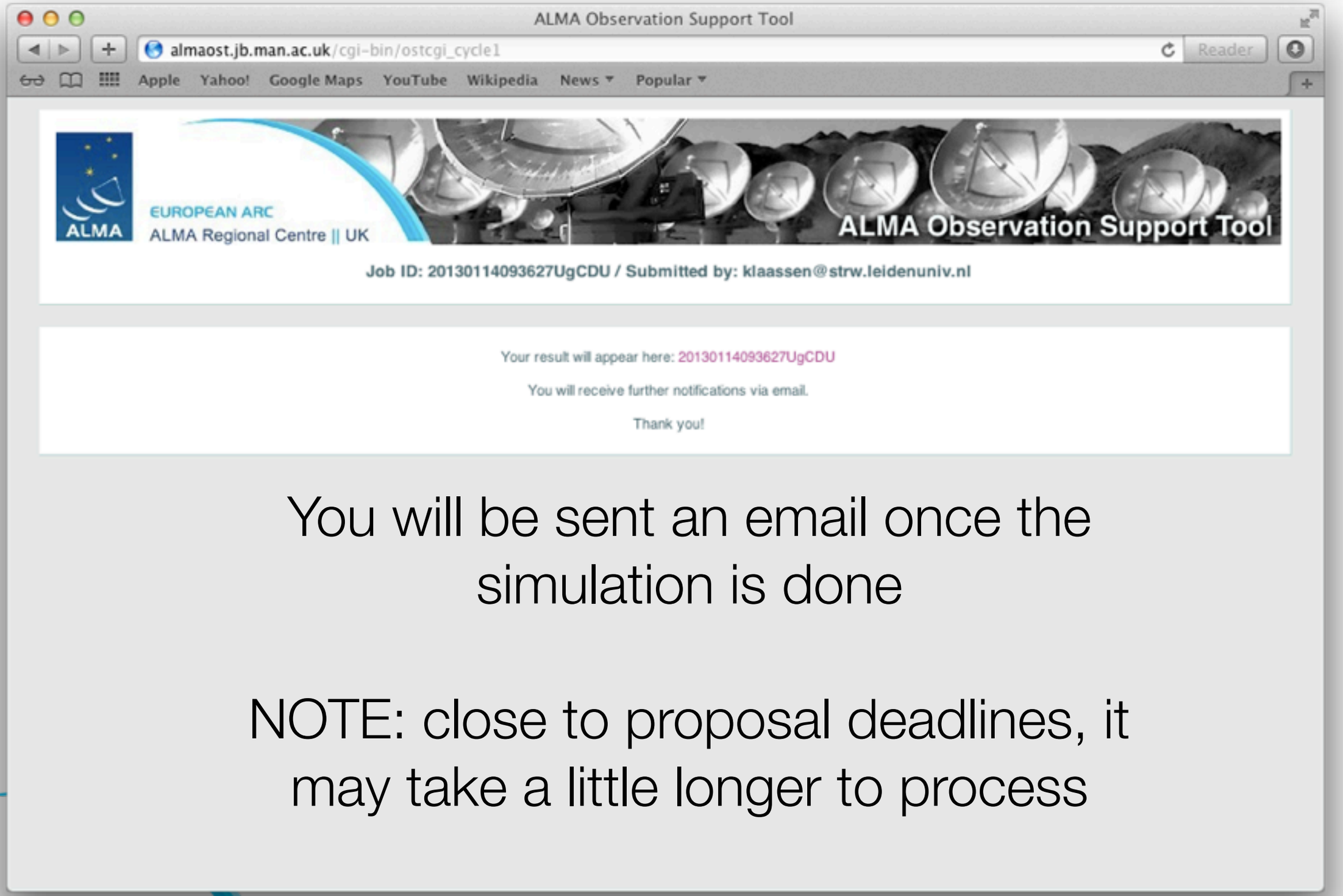
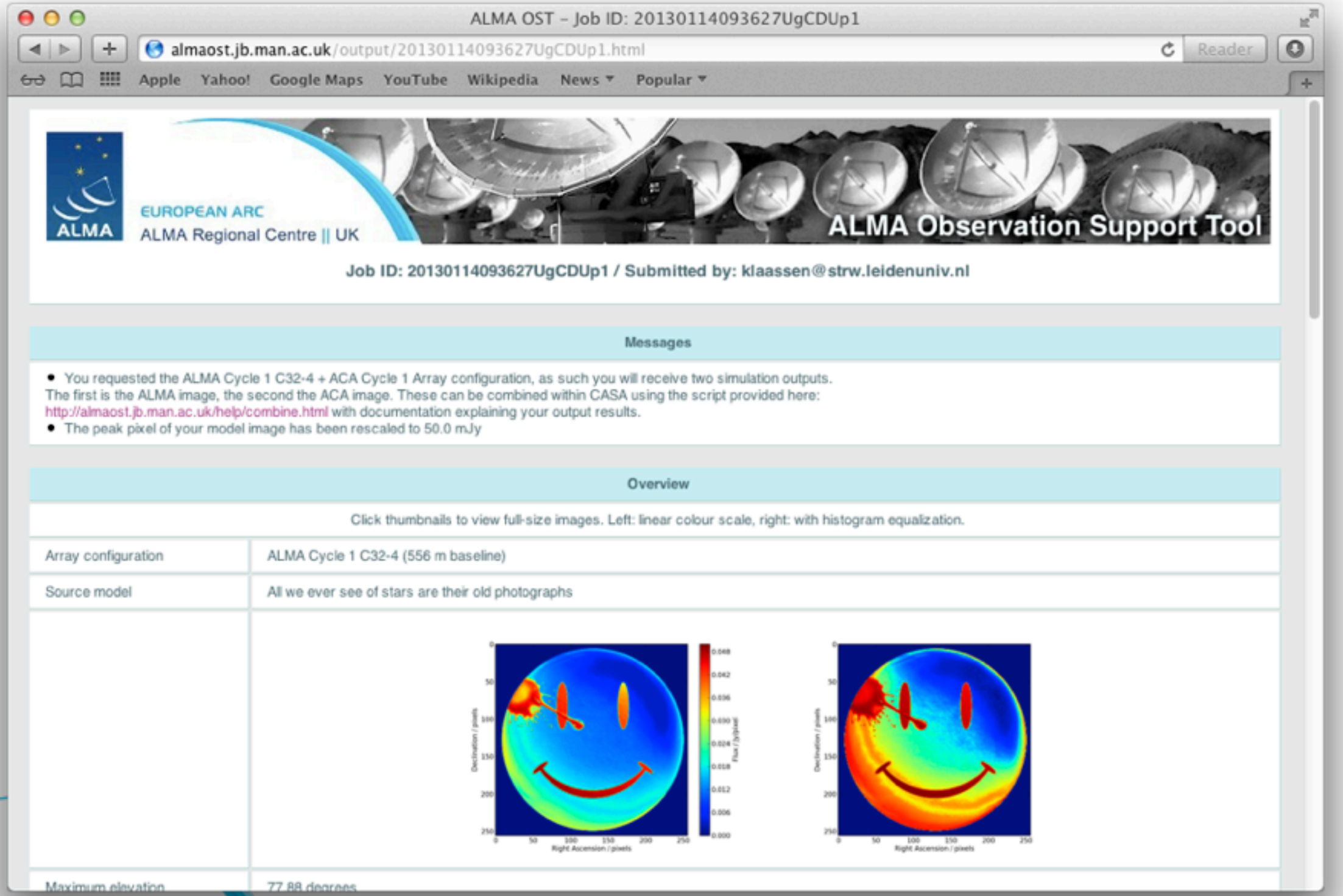


You will be sent an email once the simulation is done

NOTE: close to proposal deadlines, it may take a little longer to process

ALMA OST


ALMA OST – Job ID: 20130114093627UgCDUp1
almaost.jb.man.ac.uk/output/20130114093627UgCDUp1.html
Reader
Apple
Yahoo!
Google Maps
YouTube
Wikipedia
News
Popular
ALMA
EUROPEAN ARC
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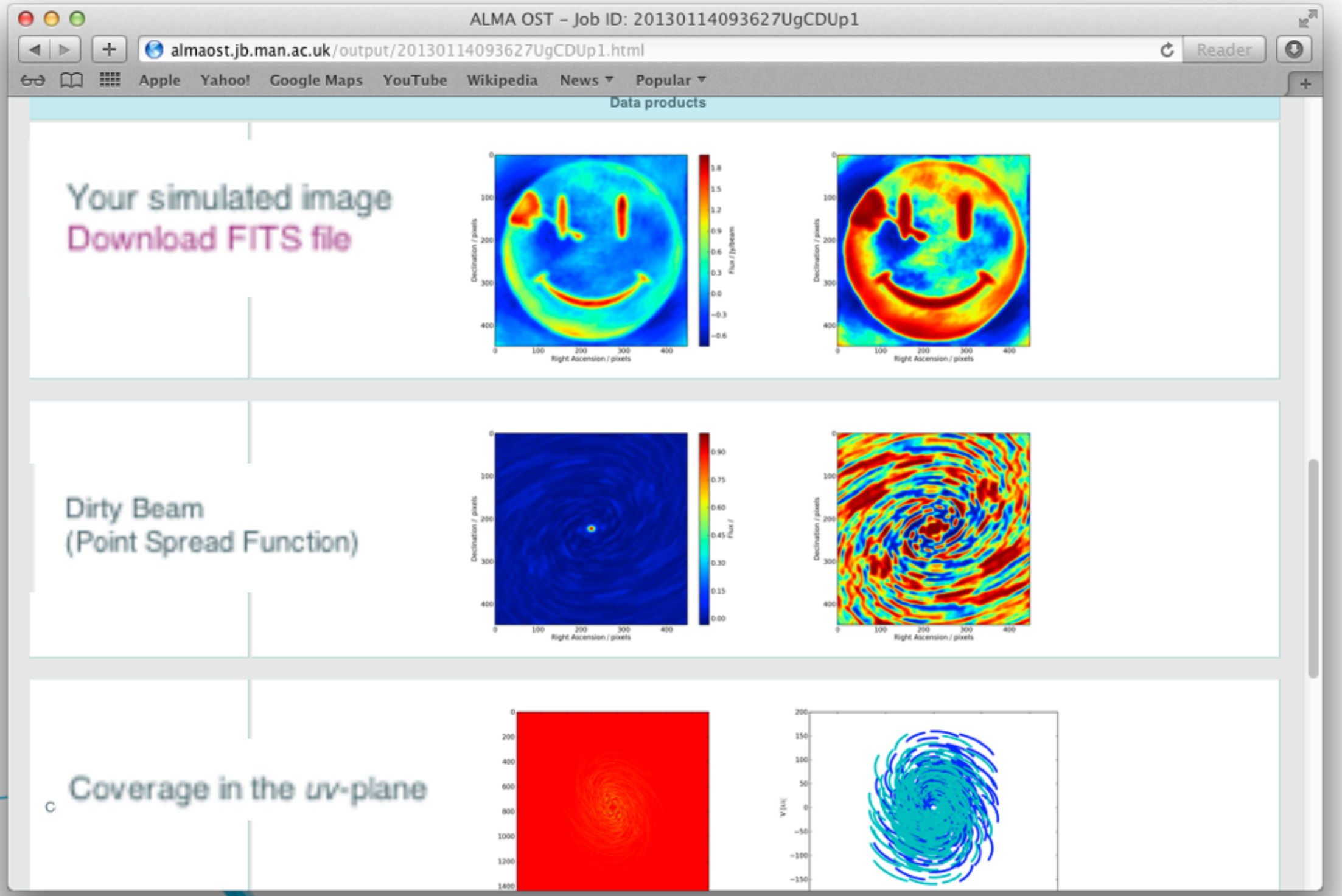
ALMA Observation Support Tool
Job ID: 20130114093627UgCDUp1 / Submitted by: klaassen@strw.leidenuniv.nl
Messages
You requested the ALMA Cycle 1 C32-4 + ACA Cycle 1 Array configuration, as such you will receive two simulation outputs.
The first is the ALMA image, the second the ACA image. These can be combined within CASA using the script provided here:
http://almaost.jb.man.ac.uk/help/combine.html with documentation explaining your output results.
The peak pixel of your model image has been rescaled to 50.0 mJy
Overview
Click thumbnails to view full-size images. Left: linear colour scale, right: with histogram equalization.
Array configuration
ALMA Cycle 1 C32-4 (556 m baseline)
Source model
All we ever see of stars are their old photographs
Declination / pixels
Right Ascension / pixels
Flux / Jy/pixel
Maximum elevation
77.88 degrees

ALMA OST


ALMA OST – Job ID: 20130114093627UgCDUp1
almaost.jb.man.ac.uk/output/20130114093627UgCDUp1.html
Reader
Apple
Yahoo!
Google Maps
YouTube
Wikipedia
News
Popular
Data products
Your simulated image
Download FITS file
Declination / pixels
Right Ascension / pixels
Flux / Jy/beam
Dirty Beam
(Point Spread Function)
Flux /
Coverage in the uv-plane
V [kλ]

The Next Step

	For use with CASA simdata
Input sky model	Download processed model in FITS format
Download simdata.last file	20130114093627UgCDUp1.simdata.last
Download pointing file	20130114093627UgCDUp1.ptg.txt

- What you did in the OST, can act as a starting point for more robust simulations in CASA (***if*** you need to!)

http://almaost.jb.man.ac.uk/help/

CASA Simulator

- There is a CASA guide for the simulator
  - ➡ There are a variety of step by step tutorials
    - (one including the ACA)

http://casaguides.nrao.edu/

Following example is in CASA 3.4

CASA Simulator

- simobserve
  - ➡ Take input image into UV plane
  - ➡ (add noise if applicable)

- simanalyze
  - ➡ Take visibilities into image plane
  - ➡ Using simple cleaning algorithms

CASA Simulator

SIMOBSERVE

- A number of parameters to be set
  - ➡ Most of which have good default settings
- Create visibilities of your input image
  - ➡ **2D or 3D**

thermal noise

qcasaviewer

```
CASA <6>: inp
--------> inp()
#  simobserve :: mosaic simulation task:
project             =       'sim'        #  root prefix for output
skymodel            =         ''         #  model image to observe
complist            =         ''         #  componentlist to observ
setpointings        =       True
     integration    =       '10s'        #  integration (sampling)
     direction      =         ''         #  "J2000 19h00m00 -40d00m
                                         #   center on model
     mapsize        =   ['', '']         #  angular size of map or
                                         #   model
     maptype        =     'ALMA'         #  hexagonal, square, etc
     pointingspacing =       ''         #  spacing in between poin
                                         #   "0.25PB" or "" for 0.5

obsmode             =       'int'        #  observation mode to sim
                                         #   erferometer)|sd(single
                                         #   ]
     antennalist    = 'alma.out10.cfg'   #  interferometer antenna
     refdate        = '2012/05/21'       #  date of observation - n
                                         #   unless concatting simu
     hourangle      =  'transit'         #  hour angle of observati
                                         #   -3:00:00, or "transit"
     totaltime      =     '7200s'        #  total time of observati
                                         #   of repetitions
     caldirection   =         ''         #  pt source calibrator [e
     calflux        =       '1Jy'

thermalnoise        =         ''         #  add thermal noise: [tsy
                                         #   manual|""]
leakage             =        0.0         #  cross polarization (int
                                         #   only)
graphics            =     'both'         #  display graphics at eac
                                         #   [screen|file|both|none
```

CASA Simulator

SIMANALYZE

- Simple cleaning of the visibilities generated in SIMOBSERVE
  - ➡ Non-interactive
- Alternatively, take the visibilities and clean them manually
  - ➡ (can be interactive)

```
pythonw

CASA <7>: inp simanalyze
--------> inp(simanalyze)
#  simanalyze :: image and analyze simulated datasets
project             =      'sim'        #  root prefix for output
image               =       True        #  (re)image $project.*.ms
                                        #   $project.image
     vis            =  'default'        #  Measurement Set(s) to i
     modelimage     =         ''        #  prior image to use in c
                                        #   existing single dish i
     imsize         =          0        #  output image size in pi
                                        #   0 to match model
     imdirection    =         ''        #  set output image direct
                                        #   (otherwise center on t
     cell           =         ''        #  cell size with units or
                                        #   model
     niter          =        500        #  maximum number of itera
                                        #   dirty image)
     threshold      =  '0.1mJy'         #  flux level (+units) to
     weighting      =  'natural'        #  weighting to apply to v
     mask           =         []        #  Cleanbox(es), mask imag
                                        #   region(s), or a level
     outertaper     =         []        #  uv-taper on outer basel
                                        #   plane
     stokes         =        'I'        #  Stokes params to image

analyze             =      False        #  (only first 6 selected
                                        #   be displayed)
graphics            =     'both'        #  display graphics at eac
                                        #   [screen|file|both|none
verbose             =      False
overwrite           =       True        #  overwrite files startin
                                        #   $project
async               =      False        #  If true the taskname mu
                                        #   using simanalyze(...)
```

CASA Simulator

SIMOBSERVE

- Modify (as required):
  - ➡ Pointing direction
  - ➡ Size
  - ➡ Frequency
  - ➡ Set Pointings
- Predict visibilities
- Corrupt the ms

qcasaviewer

```
CASA <6>: inp
--------> inp()
#  simobserve :: mosaic simulation task:
project             =      'sim'        #  root prefix for output
skymodel            =        ''         #  model image to observe
complist            =        ''         #  componentlist to observ
setpointings        =      True
     integration    =      '10s'        #  integration (sampling)
     direction      =        ''         #  "J2000 19h00m00 -40d00m
                                        #   center on model
     mapsize        =  ['', '']         #  angular size of map or
                                        #   model
     maptype        =    'ALMA'         #  hexagonal, square, etc
     pointingspacing =       ''         #  spacing in between poin
                                        #   "0.25PB" or "" for 0.5

obsmode             =      'int'        #  observation mode to sim
                                        #   erferometer)|sd(single
                                        #   ]
     antennalist    = 'alma.out10.cfg'  #  interferometer antenna
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                                        #   unless concatting simu
     hourangle      =  'transit'        #  hour angle of observati
                                        #   -3:00:00, or "transit'
     totaltime      =    '7200s'        #  total time of observati
                                        #   of repetitions
     caldirection   =        ''         #  pt source calibrator [e
     calflux        =      '1Jy'

thermalnoise        =        ''         #  add thermal noise: [tsy
                                        #   manual|""]
leakage             =       0.0         #  cross polarization (int
                                        #   only)
graphics            =    'both'         #  display graphics at eac
                                        #   [screen|file|both|none
```
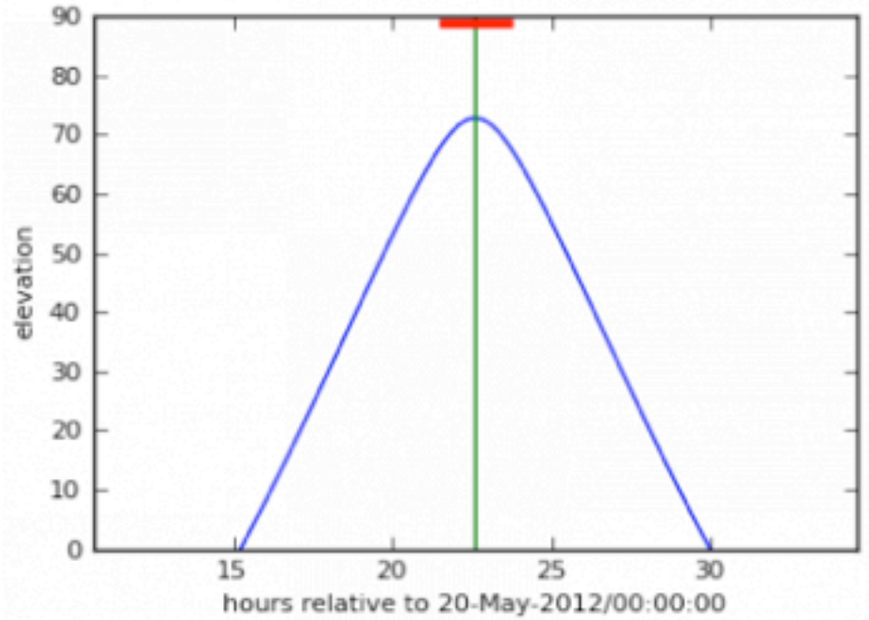
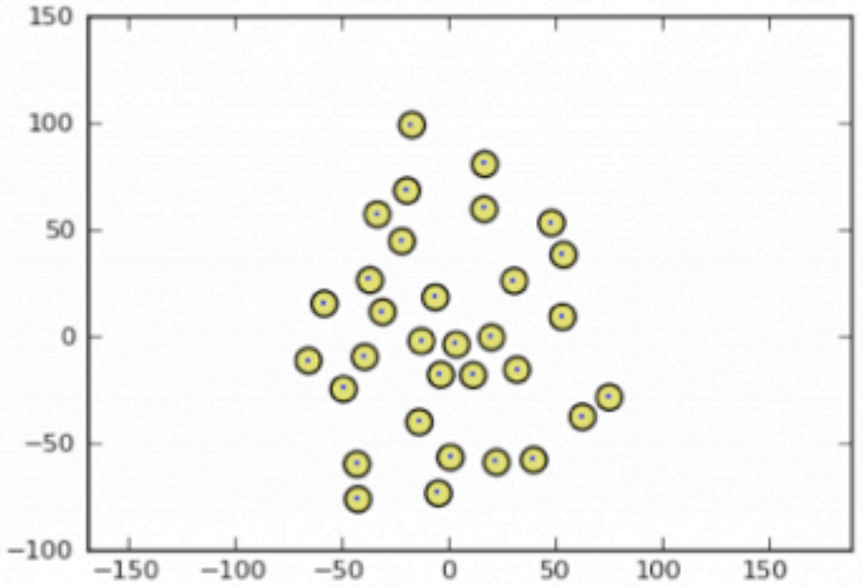
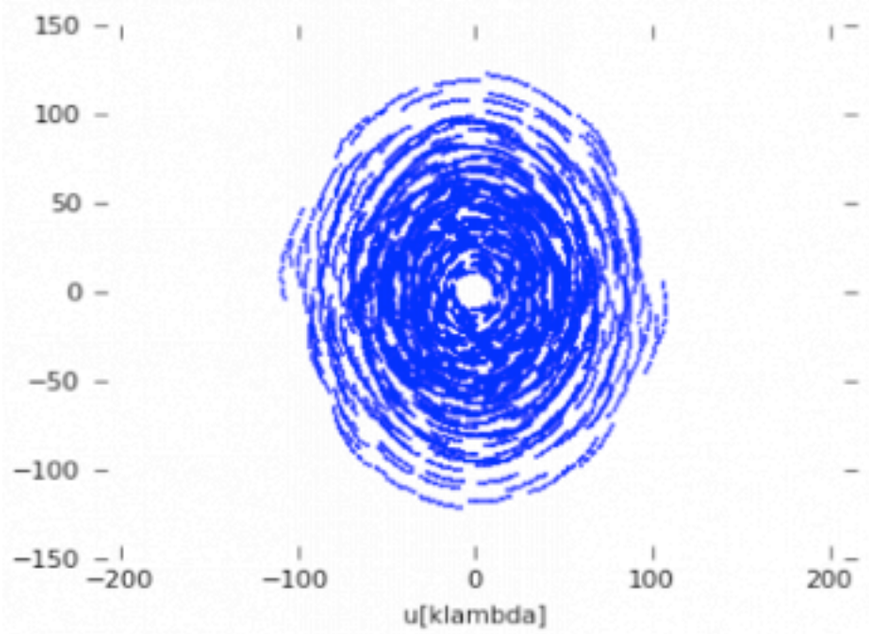

CASA Simulator

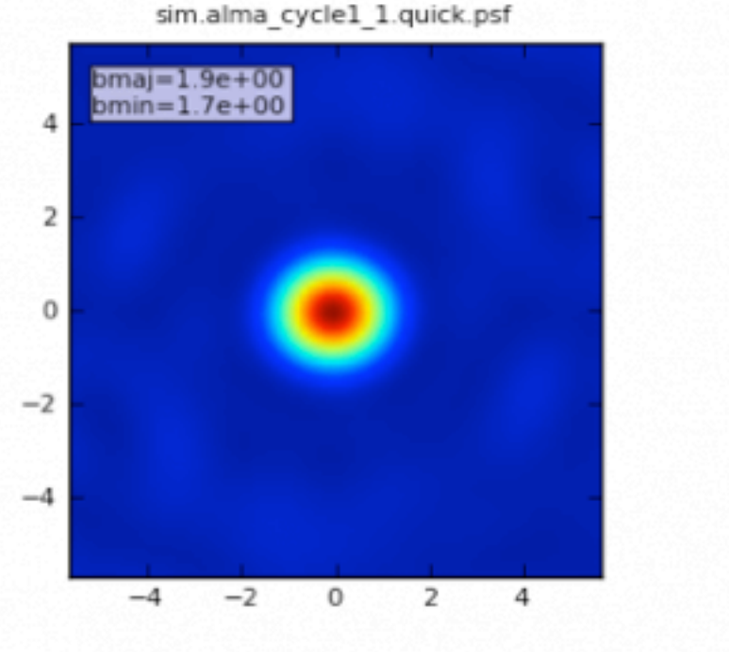
Outputs useful diagnostic plots...

and a measurement set!



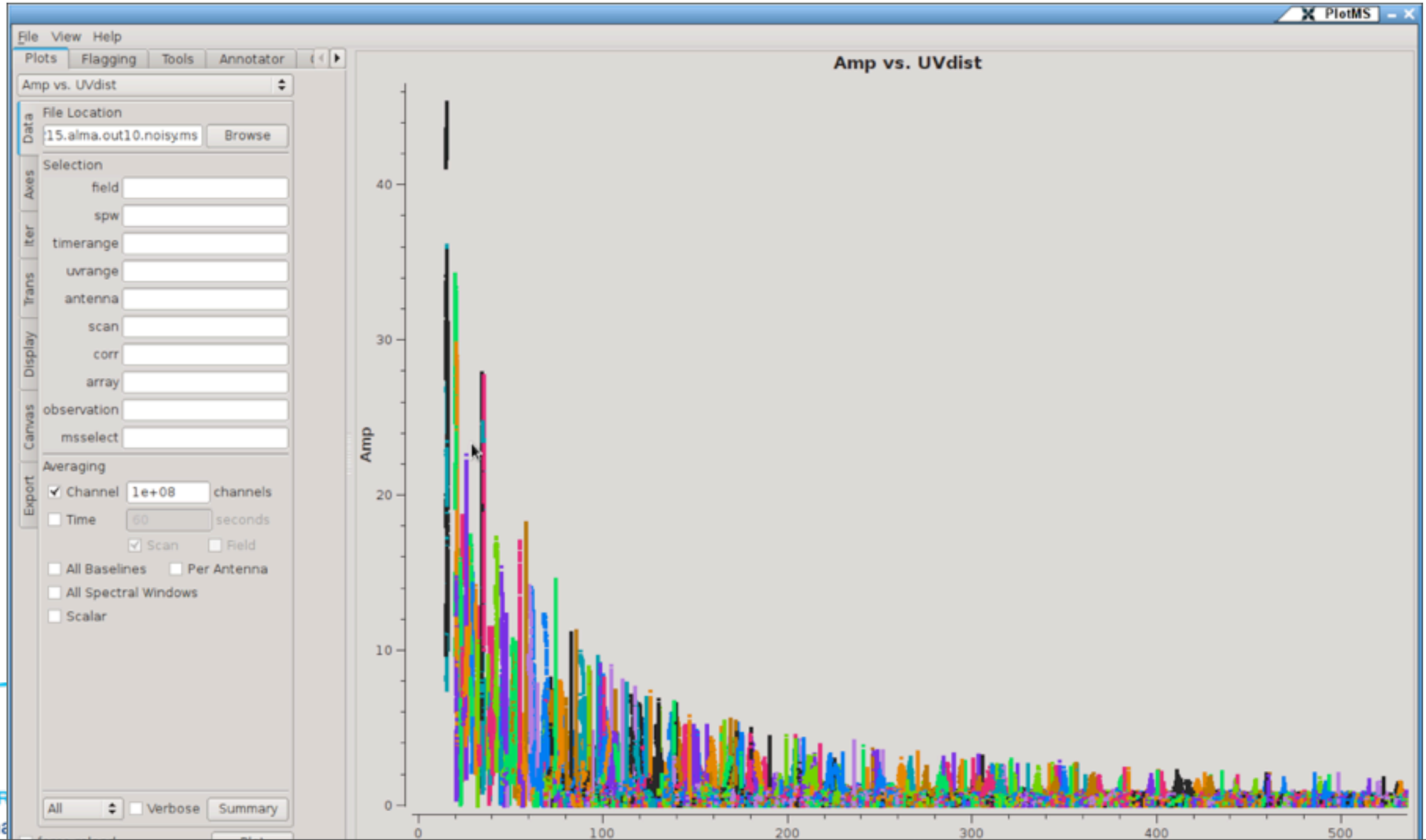






CASA Simulator

Now you've got a model measurement set!



CASA Simulator

Now you've got a model measurement set!

- At this point:
  - ➡ Run again with different configuration (e.g. ACA)
  - ➡ Clean the images manually
  - ➡ Continue to simanalyze

CASA Simulator

SIMANALYZE

- Image the visibilities
- Assess the output data quality

```
pythonw

CASA <7>: inp simanalyze
--------> inp(simanalyze)
#  simanalyze :: image and analyze simulated datasets
project             =      'sim'        #  root prefix for output
image               =       True        #  (re)image $project.*.ms
                                        #   $project.image
     vis            =  'default'        #  Measurement Set(s) to i
     modelimage     =         ''        #  prior image to use in (
                                        #   existing single dish i
     imsize         =          0        #  output image size in pi
                                        #   0 to match model
     imdirection    =         ''        #  set output image direct
                                        #   (otherwise center on t
     cell           =         ''        #  cell size with units or
                                        #   model
     niter          =        500        #  maximum number of itera
                                        #   dirty image)
     threshold      =   '0.1mJy'        #  flux level (+units) to
     weighting      =  'natural'        #  weighting to apply to v
     mask           =         []        #  Cleanbox(es), mask imag
                                        #   region(s), or a level
     outertaper     =         []        #  uv-taper on outer basel
                                        #   plane
     stokes         =        'I'        #  Stokes params to image

analyze             =      False        #  (only first 6 selected
                                        #   be displayed)
graphics            =     'both'        #  display graphics at eac
                                        #   [screen|file|both|none
verbose             =      False
overwrite           =       True        #  overwrite files startin
                                        #   $project
async               =      False        #  If true the taskname mu
                                        #   using simanalyze(...)
```

Levels of Complexity

- OST
  - ➡ 2D, generic noise calculations
- Simobserve / simanalyze
  - ➡ 3D, basic cleaning algorithms
- Simobserve / independent clean
  - ➡ 3D, interactive cleaning
  - ➡ Large scale structures

The simpler, the smaller the disk footprint

Example

THE ASTROPHYSICAL JOURNAL, 760:91 (8pp), 2012 November 20 doi:10.1088/0004-637X/760/1/91

ARE MOLECULAR OUTFLOWS AROUND HIGH-MASS STARS DRIVEN BY IONIZATION FEEDBACK?

THOMAS PETERS[1,2,7], PAMELA D. KLAASSEN[3,4], MORDECAI-MARK MAC LOW[5], RALF S. KLESSEN[1], AND ROBI BANERJEE[6]

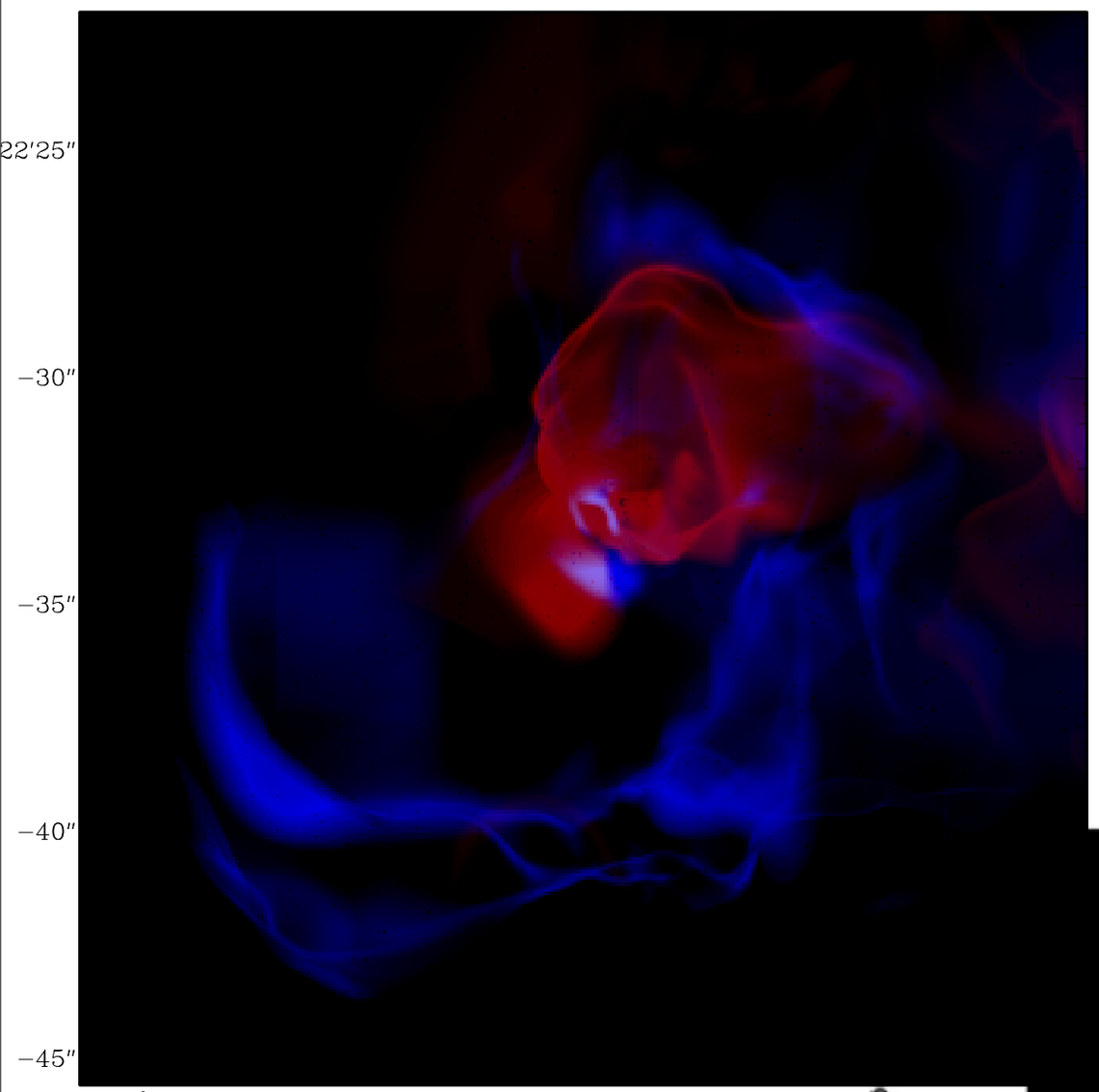
- Outflows from Peters et al. (2010a)
- Ray-traced with RADMC-3D (CO J=2-1)
- Filtered using the CASA Simulator
  - ➡ *with* noise

http://www.ita.uni-heidelberg.de/~dullemond/software/radmc-3d/

Example

- Added typical weather conditions for Band 6 observations (pwv = ~1.2mm)
  - ➡ Towards the direction of G5.89 (dec = -24 deg)
- Observation parameters
  - ➡ 4 hours on source (in 6 pointings)
  - ➡ 0.5” final resolution (input = 0”.038)
  - ➡ Spectral resolution = 1 km/s

What it does

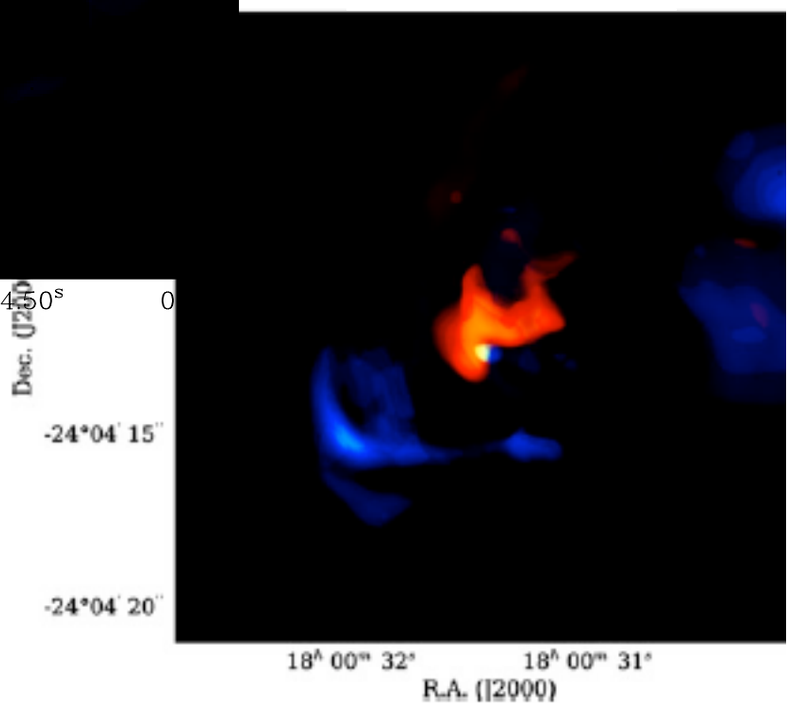


Output cube from RADMC-3D

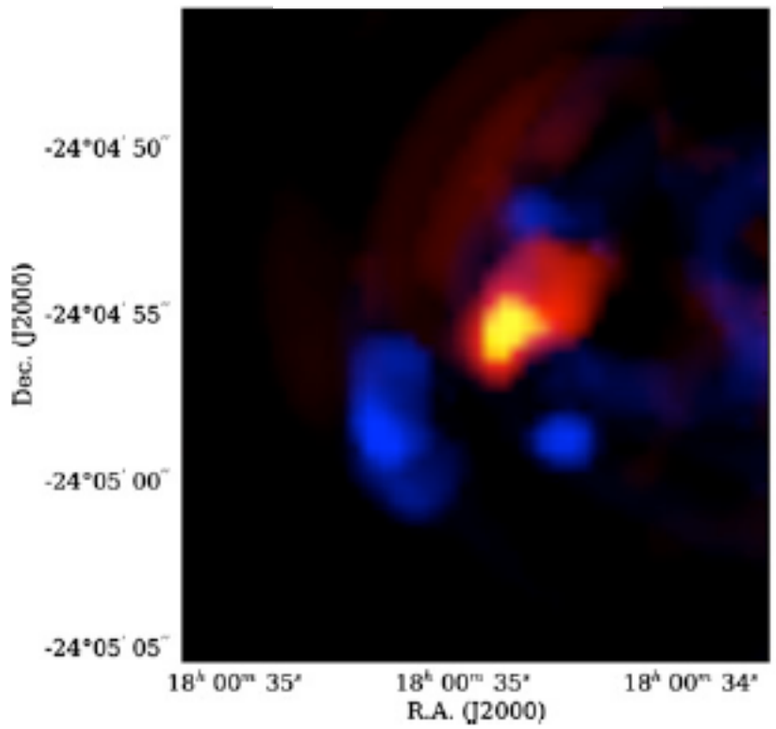
(Red & Blue shifted CO outflow)

From CASA Simulator

ALMA



CARMA



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What it did

- We were able to determine outflow properties from the simulated observations

➡ Realistic method for comparing simulations with observations

To Get Quality Results…

- To make quantitative comparisons, understanding your methods is key!

➡ Make sure each step is done properly

- Use the right weather conditions for your band

➡ If you're modifying your model

- Make sure to scale the fluxes properly
- That your sizes and structures are realistic

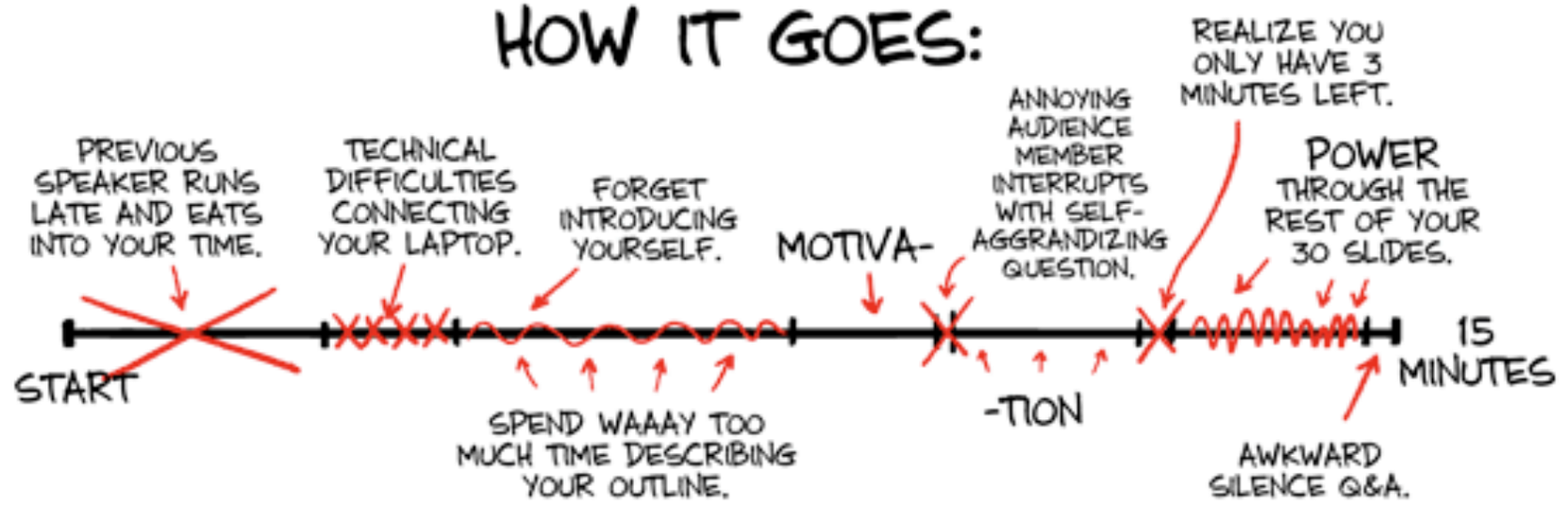
Conclusions

- Simulating observations *may* strengthen your observing proposals
  - ➡ But don’t over complicate things!
- Comparing simulations to observations
  - ➡ This way direct comparisons are possible!

YOUR CONFERENCE PRESENTATION

HOW YOU PLANNED IT:

HOW IT GOES:



YOUR CONFERENCE PRESENTATION

HOW YOU PLANNED IT:

HOW IT GOES: