Introduction to CASA

Common Astronomy Software Application

Dan Walker

EUROPEAN ARC
ALMA Regional Centre || UK

What is CASA?

Common Astronomy Software Application

- Used for calibration, imaging and analysis of interferometric data
- Used via the command line using an iPython interface
- Available for Linux and Mac OS
- Current general version is CASA 6.6.3
- Current pipeline version is CASA 6.5.4 (this is what we will use)
- Latest and previous releases can always be found here: https://casa.nrao.edu/casa_obtaining.shtml

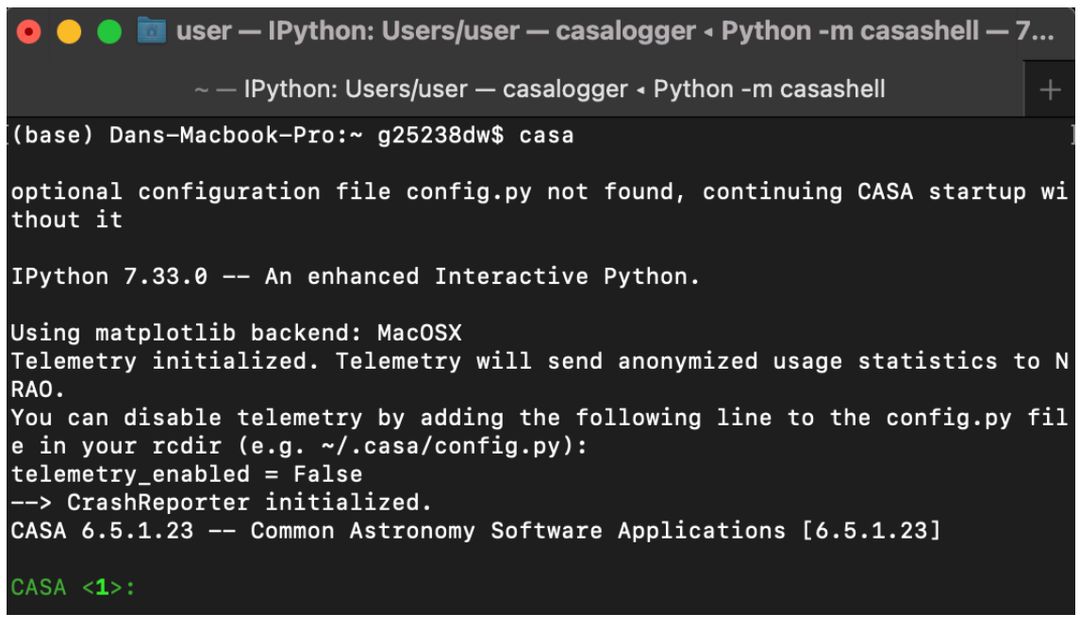
Launching CASA

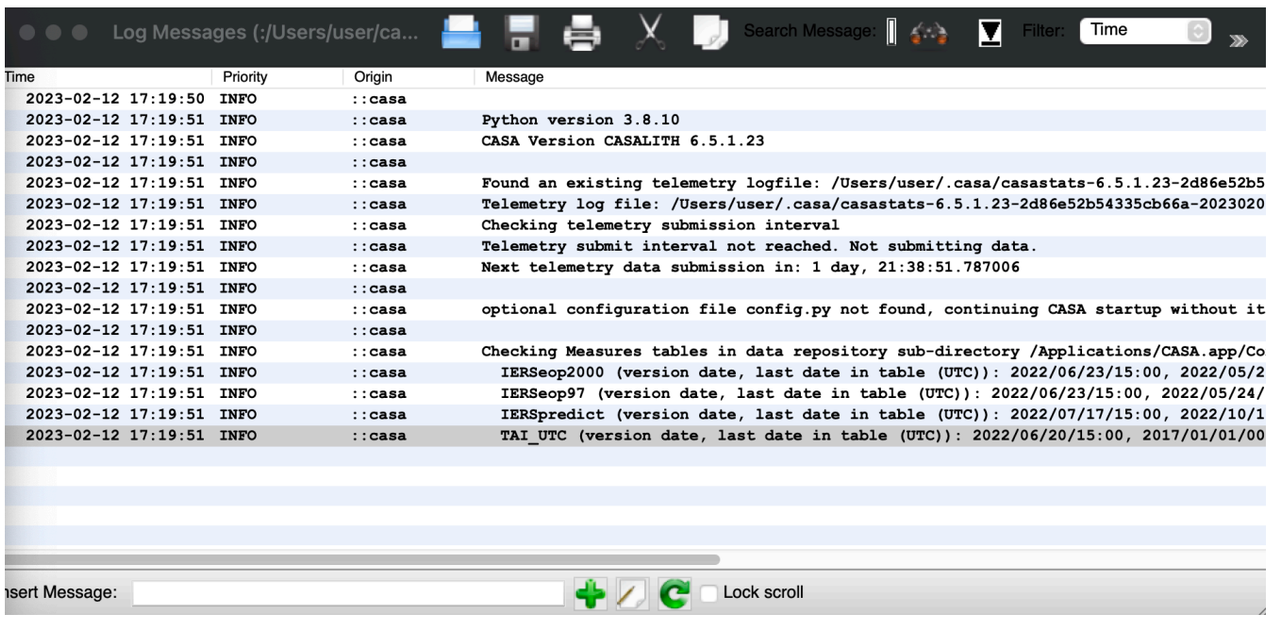
- If you have set up an alias, simply type `casa` on the command line. Otherwise, enter the full path, e.g.:

  ```
  ~/path-to-casa/bin/casa

  ~/CASA.app/Contents/MacOS/casa
  ```

- This will launch the IPython session in the terminal, along with the CASA logger GUI:





Tip: use `casa --nologger` if you don't need the logger GUI

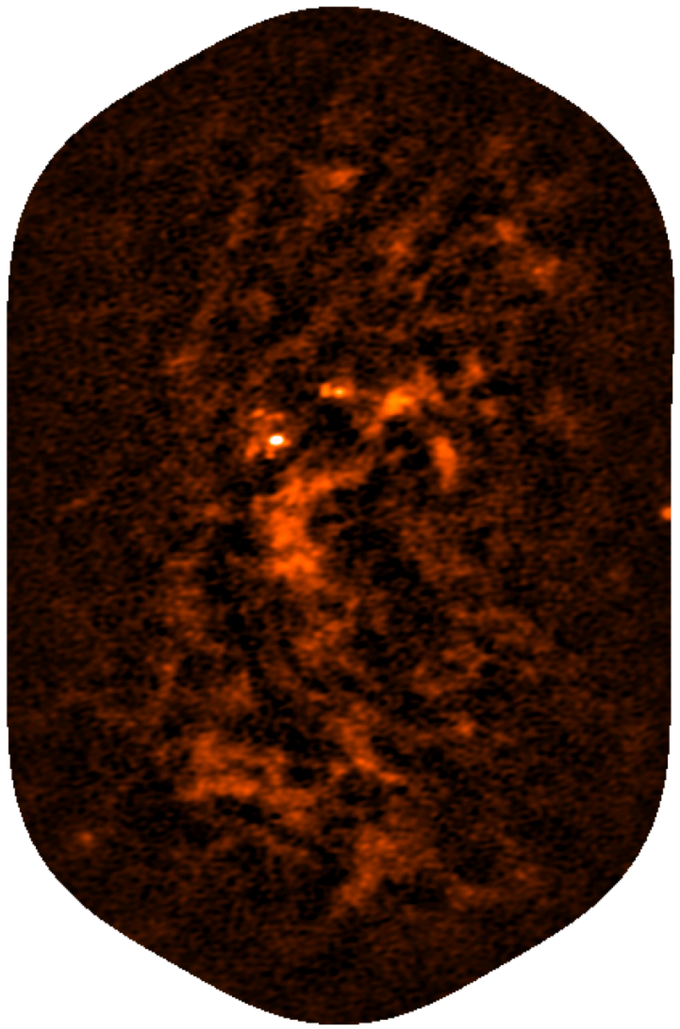
CASA tasks

- CASA tasks are an interface to the underlying toolkit
- Tasks perform a single job such as loading or plotting data
- Each task contains a set of user-defined parameters
- A complete list of available tasks can be found here: https://casadocs.readthedocs.io/en/stable/api/casatasks.html
- Example: change the coordinate system of an image using `imregrid`

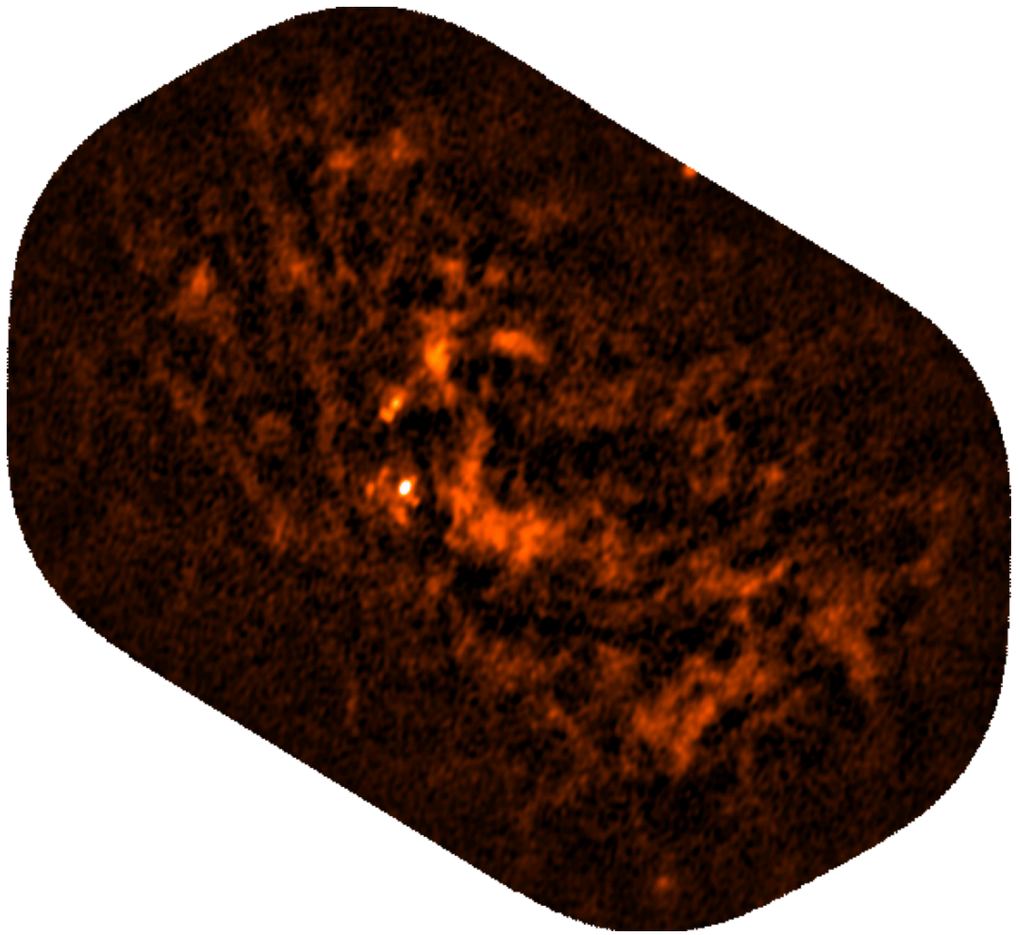
```
imregrid(imagename = 'input_image.fits',
         template  = 'GALACTIC',
         output    = 'output_image.galactic')
```

`imregrid` task example

Input: J2000



Output: Galactic



`imsubimage` task example

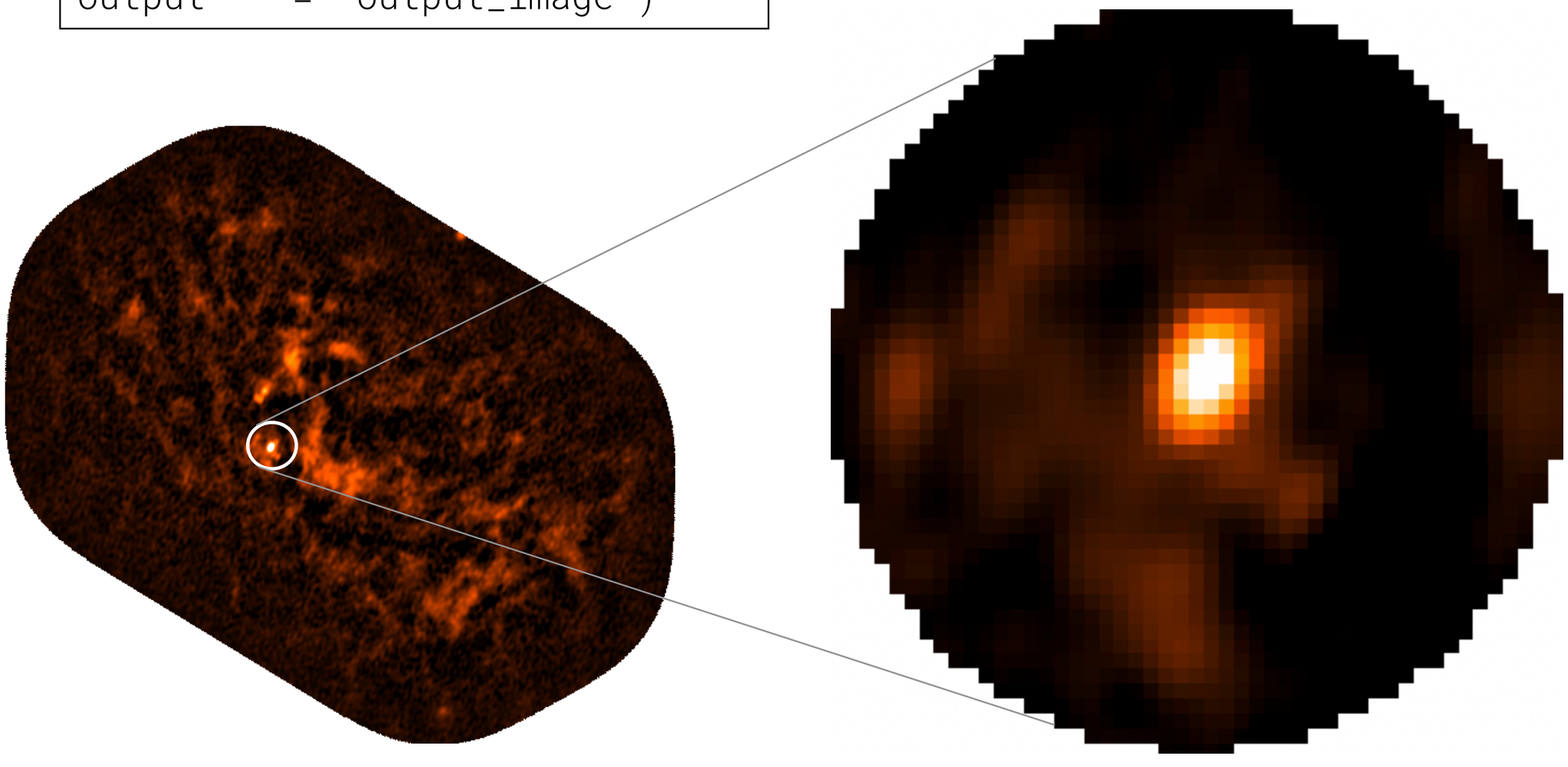
```
imsubimage(

imagename = 'input_image.fits',

region    = 'crop_region.crtf',

output    = 'output_image')
```

Note: .crtf extension means 'casa region text format' (see here)



CASA tasks

- You can also specify the parameters in turn, and run the task later:

```
default(imregrid)

imagename = 'input_image.fits'

template  = 'GALACTIC'

output    = 'output_image.galactic'

imregrid()
```

Beware! This method defines parameters globally, so be sure to run `default(task)` for other tasks to avoid potential issues.

CASA tasks

- You can also write tasks in a Python script, which can be executed with CASA. This is good practice for keeping track of your analyses, and making your work repeatable/reproducible.

- Within CASA: `execfile(script_name.py)`

- In terminal: `casa -c script_name.py`

- Script example:

```
import glob

fns = [x for x in glob.glob('*.fits')]

for fn in fns:

   imregrid(imagename = fn, template='GALACTIC',
   output=fn.replace('.fits','.galactic'))
```

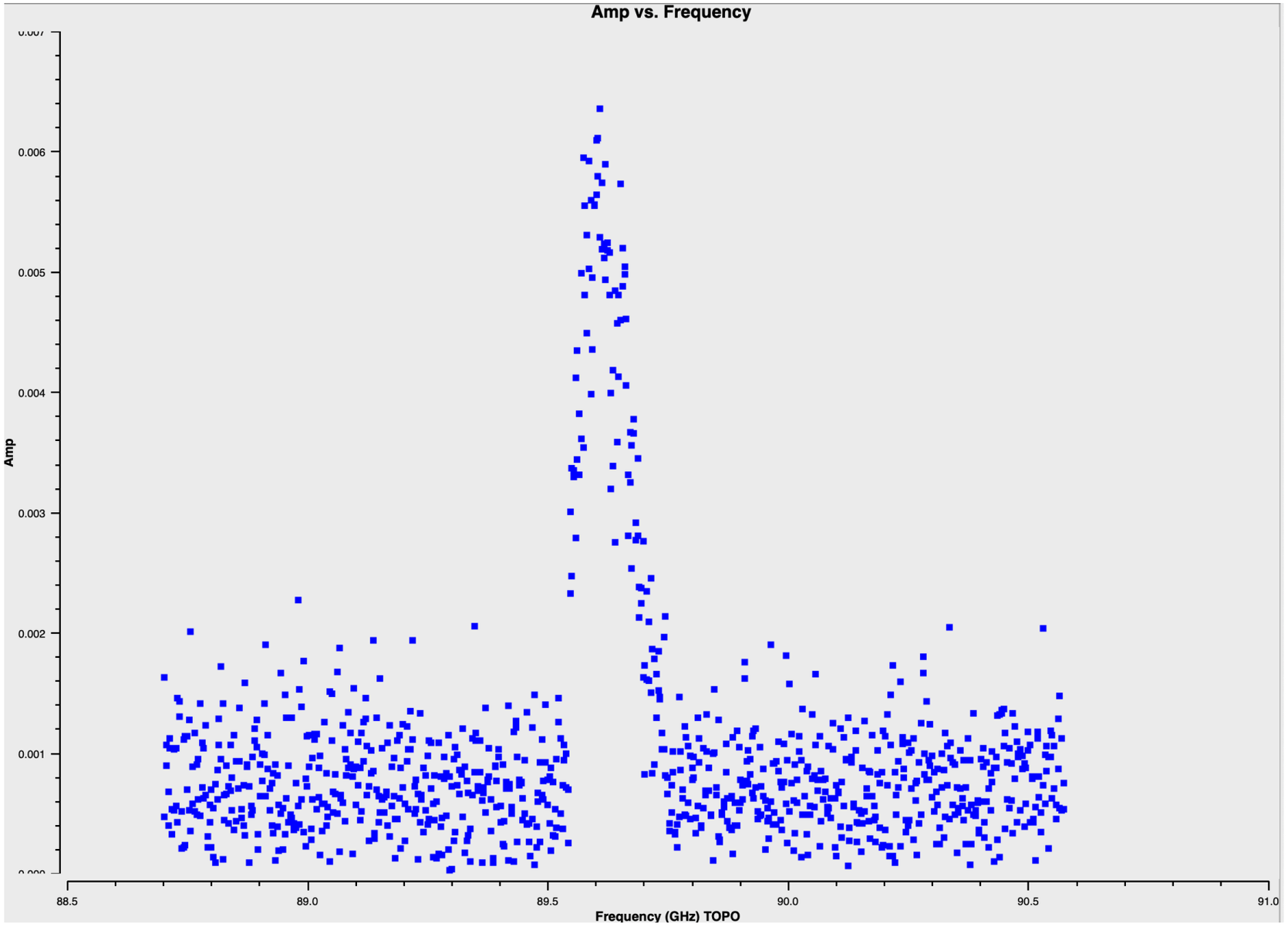
CASA tasks: *listobs*

- Use to inspect key details of the observation and setup
- Live view in casa logger, or output to text file

```
Time                    Priority  Origin          Message
   2024-02-18 20:04:21  INFO      …obs::::casa    ################################################
   2024-02-18 20:04:21  INFO      …obs::::casa    ##### Begin Task: listobs            #####
   2024-02-18 20:04:21  INFO      …obs::::casa    listobs( vis='/Users/user/UK_ALMA_Workshop_24/imaging/uid___A002_Xf396d6_X45bb.target.ms', selectdata=True, spw='', field='', antenna='', uvrange='', timerar
   2024-02-18 20:04:21  INFO      …ms::summary    ================================================================================
   2024-02-18 20:04:21  INFO      …s::summary+            MeasurementSet Name:  /Users/user/UK_ALMA_Workshop_24/imaging/uid___A002_Xf396d6_X45bb.target.ms      MS Version 2
   2024-02-18 20:04:21  INFO      …s::summary+    ================================================================================
   2024-02-18 20:04:21  INFO      …s::summary+       Observer: pkamieneski     Project: uid://A001/X1525/X705
   2024-02-18 20:04:21  INFO      …s::summary+    Observation: ALMA
   2024-02-18 20:04:21  INFO      …Properties     Computing scan and subscan properties...
   2024-02-18 20:04:35  INFO      …ms::summary    Data records: 42631006       Total elapsed time = 3033.5 seconds
   2024-02-18 20:04:35  INFO      …s::summary+       Observed from   04-Dec-2021/12:31:58.1   to   04-Dec-2021/13:22:31.6 (UTC)
   2024-02-18 20:04:35  INFO      …ms::summary
   2024-02-18 20:04:35  INFO      …s::summary+       ObservationID = 0         ArrayID = 0
   2024-02-18 20:04:35  INFO      …s::summary+    Date        Timerange (UTC)          Scan  FldId FieldName             nRows     SpwIds   Average Interval(s)     ScanIntent
   2024-02-18 20:04:35  INFO      …s::summary+    04-Dec-2021/12:31:58.1 - 12:32:15.3     6      0 PJ113921.7              321172  [4,13,14,15,16,17,18,19,20,21,22,23,24]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                12:32:20.0 - 12:37:23.1     7      0 PJ113921.7             5003098  [4,13,14,15,16,17,18,21,22,23,24,25,26]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                12:38:17.1 - 12:43:19.9     9      0 PJ113921.7             5003052  [4,13,14,15,16,17,18,21,22,23,24,25,26]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                12:44:15.4 - 12:44:34.1    11      0 PJ113921.7              321172  [4,13,14,15,16,17,18,19,20,21,22,23,24]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                12:44:39.6 - 12:49:42.2    12      0 PJ113921.7             5003052  [4,13,14,15,16,17,18,21,22,23,24,25,26]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                12:50:35.5 - 12:55:38.7    14      0 PJ113921.7             5003098  [4,13,14,15,16,17,18,21,22,23,24,25,26]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                12:56:33.8 - 12:56:50.1    16      0 PJ113921.7              321172  [4,13,14,15,16,17,18,19,20,21,22,23,24]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                12:56:58.0 - 13:02:01.1    17      0 PJ113921.7             5003098  [4,13,14,15,16,17,18,21,22,23,24,25,26]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                13:02:55.1 - 13:07:57.9    19      0 PJ113921.7             5003052  [4,13,14,15,16,17,18,21,22,23,24,25,26]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                13:08:52.2 - 13:09:10.1    21      0 PJ113921.7              321126  [4,13,14,15,16,17,18,19,20,21,22,23,24]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                13:09:15.3 - 13:14:18.1    22      0 PJ113921.7             5003052  [4,13,14,15,16,17,18,21,22,23,24,25,26]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                13:15:12.4 - 13:20:15.1    24      0 PJ113921.7             5003052  [4,13,14,15,16,17,18,21,22,23,24,25,26]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                13:21:08.4 - 13:21:25.6    26      0 PJ113921.7              321172  [4,13,14,15,16,17,18,19,20,21,22,23,24]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …s::summary+                13:21:30.2 - 13:22:31.6    27      0 PJ113921.7             1000638  [4,13,14,15,16,17,18,21,22,23,24,25,26]  [1.15, 0.016, 0.016, 0.016, 0.016
   2024-02-18 20:04:35  INFO      …ms::summary              (nRows = Total number of rows per scan)
   2024-02-18 20:04:35  INFO      …ms::summary    Fields: 1
   2024-02-18 20:04:35  INFO      …s::summary+    ID   Code Name                RA               Decl           Epoch   SrcId      nRows
   2024-02-18 20:04:35  INFO      …s::summary+    0    none PJ113921.7          11:39:21.742000 +20.24.50.90000 ICRS    0       42631006
   2024-02-18 20:04:35  INFO      …ms::summary    Spectral Windows:  (15 unique spectral windows and 2 unique polarization setups)
   2024-02-18 20:04:35  INFO      …s::summary+    SpwID  Name                                      #Chans   Frame   Ch0(MHz)  ChanWid(kHz)  TotBW(kHz) CtrFreq(MHz) BBC Num  Corrs
   2024-02-18 20:04:35  INFO      …s::summary+    4      WVR#NOMINAL                                    4    TOPO  184550.000   1500000.000   7500000.0 187550.0000        0  XX
   2024-02-18 20:04:35  INFO      …s::summary+    13     X1620027342#ALMA_RB_03#BB_1#SQLD               1    TOPO   87878.312   2000000.000   2000000.0  87878.3124        1  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    14     X1620027342#ALMA_RB_03#BB_2#SQLD               1    TOPO   89639.062   2000000.000   2000000.0  89639.0616        2  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    15     X1620027342#ALMA_RB_03#BB_3#SQLD               1    TOPO  100062.031   2000000.000   2000000.0 100062.0312        3  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    16     X1620027342#ALMA_RB_03#BB_4#SQLD               1    TOPO  101618.562   2000000.000   2000000.0 101618.5616        4  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    17     X1620027342#ALMA_RB_03#BB_1#SW-01#FULL_RES   128    TOPO   88870.500    -15625.000   2000000.0  87878.3124        1  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    18     X1620027342#ALMA_RB_03#BB_1#SW-01#CH_AVG       1    TOPO   87862.687   1796875.000   1796875.0  87862.6874        1  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    19     X1620027342#ALMA_RB_03#BB_2#SW-01#FULL_RES   128    TOPO   90631.249    -15625.000   2000000.0  89639.0616        2  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    20     X1620027342#ALMA_RB_03#BB_2#SW-01#CH_AVG       1    TOPO   89631.249   1875000.000   1875000.0  89631.2491        2  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    21     X1620027342#ALMA_RB_03#BB_3#SW-01#FULL_RES   128    TOPO   99069.844     15625.000   2000000.0 100062.0312        3  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    22     X1620027342#ALMA_RB_03#BB_3#SW-01#CH_AVG       1    TOPO  100046.406   1796875.000   1796875.0 100046.4062        3  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    23     X1620027342#ALMA_RB_03#BB_4#SW-01#FULL_RES   128    TOPO  100626.374     15625.000   2000000.0 101618.5616        4  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    24     X1620027342#ALMA_RB_03#BB_4#SW-01#CH_AVG       1    TOPO  101602.937   1796875.000   1796875.0 101602.9366        4  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    25     X1620027342#ALMA_RB_03#BB_2#SW-01#FULL_RES   480    TOPO   90574.608    -3906.250   1875000.0  89639.0616        2  XX  YY
   2024-02-18 20:04:35  INFO      …s::summary+    26     X1620027342#ALMA_RB_03#BB_2#SW-01#CH_AVG       1    TOPO   89638.817   1875000.000   1875000.0  89638.8175        2  XX  YY
   2024-02-18 20:04:35  INFO      …ms::summary    Sources: 15
   2024-02-18 20:04:35  INFO      …s::summary+    ID   Name               SpwId RestFreq(MHz)  SysVel(km/s)
```

CASA tasks: *plotms*

- Use to plot and interact with visibility data
- Critical for calibration and flagging stages of data reduction



Link to full documentation

CASA data formats

- Raw visibility (*uv*) data from ALMA comes in *ALMA Science Data Model (ASDM)* format
- Once imported into CASA this is stored as a Measurement Set (*MS*)
- These are structured as directories containing many (sub-)tables, *not* individual files, e.g.:

```
dwalker2@iris3 /raid/dwalker2/UK_workshop/uid___A002_Xf396d6_X45bb.ms > ls
ANTENNA              POINTING             table.f17       table.f23_TSM1
ASDM_ANNOTATION      POLARIZATION         table.f17_TSM1  table.f23_TSM2
ASDM_ANTENNA         PROCESSOR            table.f17_TSM2  table.f24
ASDM_CALATMOSPHERE   SOURCE               table.f17_TSM3  table.f24_TSM1
ASDM_CALPOINTING     Source.xml           table.f17_TSM4  table.f24_TSM2
ASDM_CALWVR          SPECTRAL_WINDOW      table.f18       table.f24_TSM3
ASDM_EXECBLOCK       SpectralWindow.xml   table.f19       table.f24_TSM4
ASDM_RECEIVER        STATE                table.f2        table.f3
ASDM_SBSUMMARY       SYSCAL               table.f20       table.f4
ASDM_SOURCE          SYSPOWER             table.f20_TSM0  table.f5
ASDM_STATION         table.dat            table.f21       table.f6
CALDEVICE            table.f1             table.f21_TSM1  table.f7
DATA_DESCRIPTION     table.f10            table.f21_TSM2  table.f8
DataDescription.xml  table.f11            table.f21_TSM3  table.f9
FEED                 table.f12            table.f21_TSM4  table.info
FIELD                table.f13            table.f22       table.lock
FLAG_CMD             table.f14            table.f22_TSM1  WEATHER
HISTORY              table.f15            table.f22_TSM2
OBSERVATION          table.f16            table.f23
```

- Any image files produced by a CASA task will also be stored in this format
- Use task `exportfits` to convert CASA image files to FITS format

Getting help with CASA

- Type `inp taskname` to get an overview of a given task and its input parameters

```
CASA <4>: inp imregrid
# imregrid -- regrid an image onto a template image
imagename     = ''                        # Name of the source image
[redacted]    'get'                       # A dictionary, refcode, or name of an image that provides the output
                                          # shape and coordinate system
output        = ''                        # Name for the regridded image
asvelocity    = True                      # Regrid spectral axis in velocity space rather than frequency space?
axes          = [-1]                      # The pixel axes to regrid. -1 => all.
interpolation = 'linear'                  # The interpolation method. One of "nearest", "linear", "cubic".
decimate      = 10                        # Decimation factor for coordinate grid computation
replicate     = False                     # Replicate image rather than regrid?
overwrite     = False                     # Overwrite (unprompted) pre-existing output file?
```

- Type `help taskname` to get a detailed description of a given task and its input parameters (use arrow keys to continue, press q to exit)

```
Help on _imregrid in module casashell.private.imregrid object:

class _imregrid(builtins.object)
 |  imregrid ---- regrid an image onto a template image
 |
 |
 |  Imregrid will regrid an input image onto a new coordinate system from a template image
 |  or to a new directional reference frame. If a template image is used, then the input and
 |  template images must have the same coordinate structure.
 |
 |  --------- parameter descriptions ---------------------------------------------
 |
 |  imagename     Name of the source image
 |  template      A dictionary, refcode, or name of an image that provides the output shape and coordinate system
 |  output        Name for the regridded image
 |  asvelocity    Regrid spectral axis in velocity space rather than frequency space?
:
```

Getting help with CASA

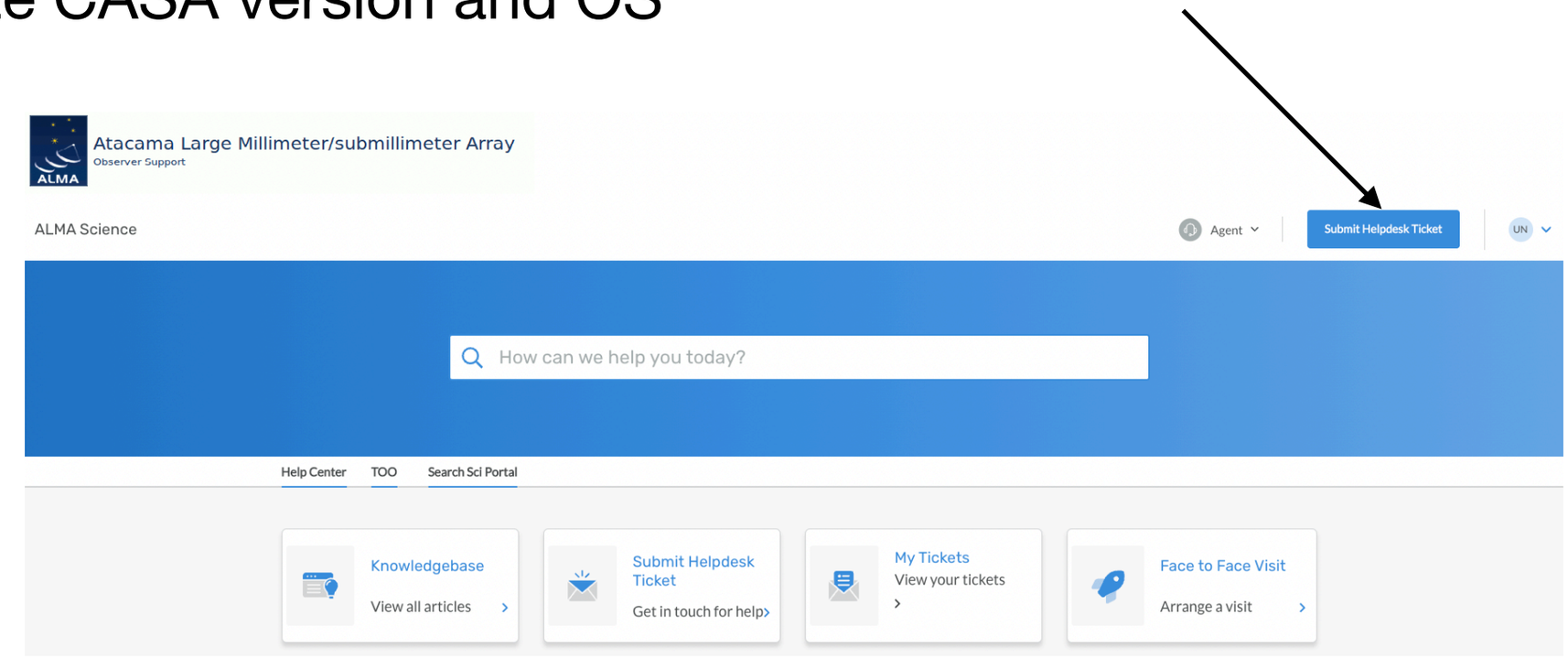
- For the most detailed information, refer to the latest CASA documentation: https://casa.nrao.edu/casadocs/latest

- If you are still having issues, you can submit a Helpdesk ticket, and someone will happily assist you!

  - Visit https://help.almascience.org/

  - Submit to the Data Reduction department

  - State CASA version and OS



CASA Guides

- Go to https://casaguides.nrao.edu/index.php?title=Main_Page for a suite of examples to guide you through using some CASA tasks (mostly imaging related).