

Data products analysis

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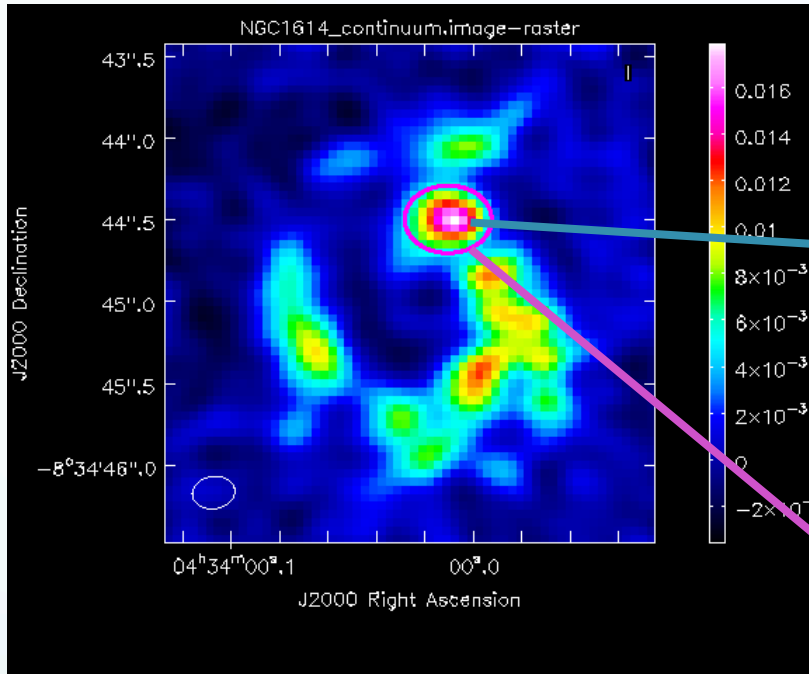


EUROPEAN ARC
ALMA Regional Centre || Italian

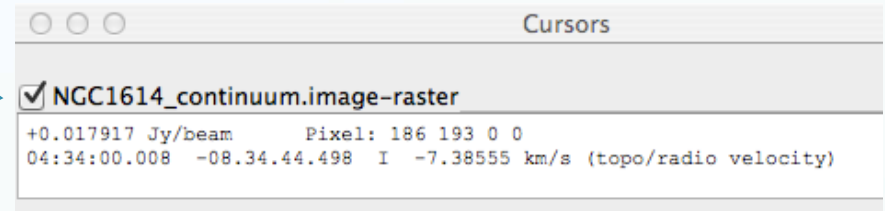
Data analysis tools

- In the image plane:
 - Obtain intensities, noise, etc.
 - 2d source fitting
- In the spectral axis:
 - Line identification and line fitting
 - PV diagrams
 - Moment maps

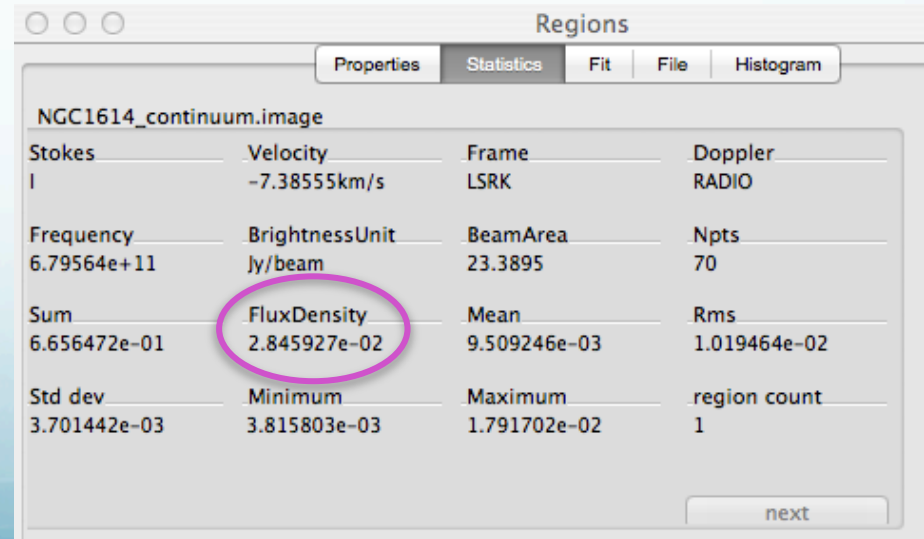
Peak flux and flux density



In each pixel we measure the integrated flux in the synthesized beam (Jy/beam)



The flux density is the integrated flux over the selected area (Jy)



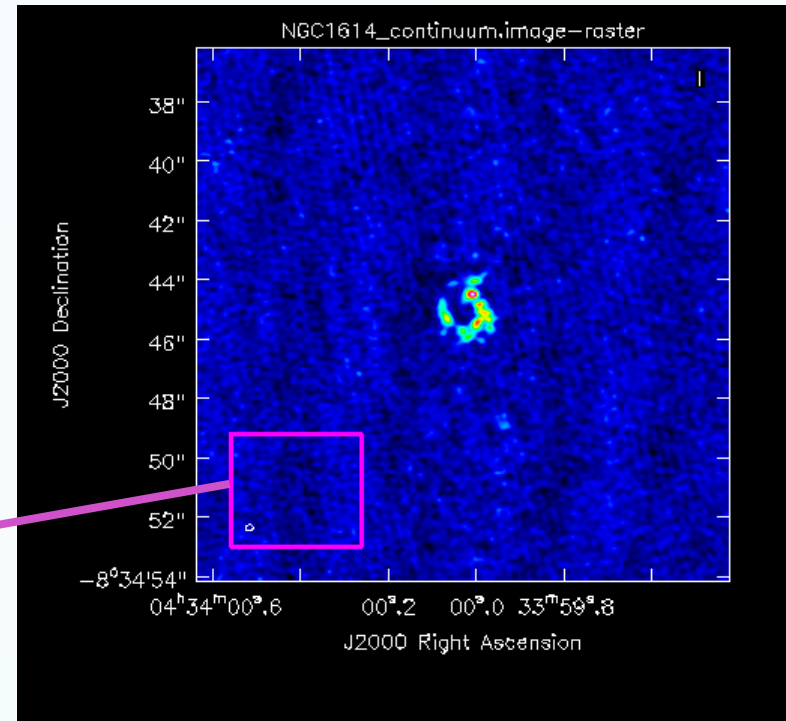
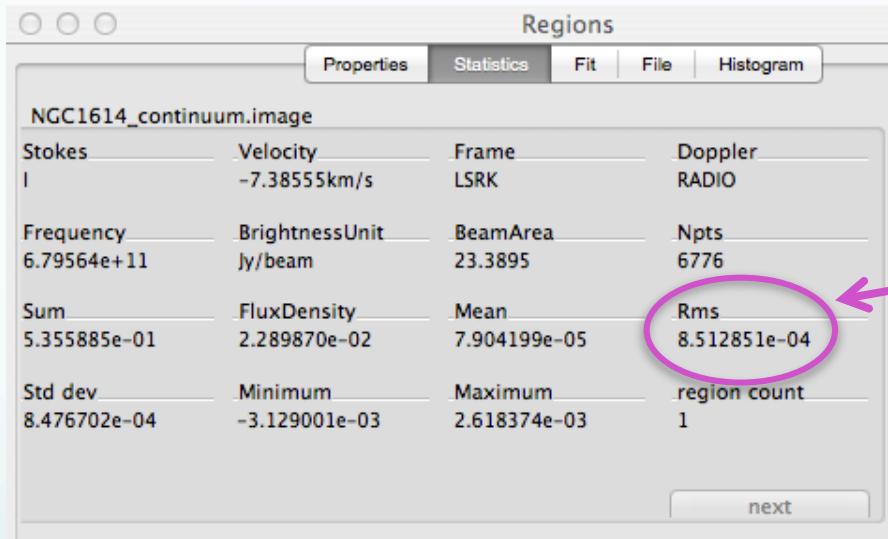
We measure:

$$F \pm 0.10 \times F$$

for a 10% flux calibration accuracy

Image noise and flux errors

Measure the rms (Jy/beam)
in an empty region:



The uncertainty in
the measured flux is:

$$\sqrt{(\text{rms})^2 + (0.10 \times F)^2}$$

Image statistics: *imstat*

```
CASA <8>: inp imstat
-----> inp(imstat)
# imstat :: Displays statistical information from an image or image region
imagenname      =      ''      # Name of the input image
axes            =      -1      # List of axes to evaluate statistics
                                # over. Default is all axes.
region         =      ''      # Image Region or name. Use Viewer
box            =      ''      # Select one or more box regions
chans          =      ''      # Select the channel(spectral) range.
                                # See "help par.chans" for examples.
stokes         =      ''      # Stokes params to image
                                # (I,IV,IQU,IQUV). Default "" =>
                                # include all
listit         =      True     # Print stats and bounding box to
                                # logger?
verbose        =      True     # Print additional messages to logger?
mask           =      ''      # Mask to use. See help par.mask.
                                # Default is none.
logfile        =      ''      # Name of file to write fit results.
algorithm      =      'classic' # Algorithm to use. Supported values
                                # are "chauenet", "classic", "fit-
                                # half", and "hinges-fences". Minimum
                                # match is supported.
clmethod       =      'auto'   # Method to use for calculating
                                # classical statistics. Supported
                                # methods are "auto", "tiled", and
                                # "framework". Ignored if algorithm is
                                # not "classic".
```

Image statistics: *imstat*

```
> imstat(imagename = 'source2.continuum.fits')
```

- Measure flux on strongest region:

```
> mystats=imstat(imagename = 'source2.continuum.fits',  
                 box = '182,190,189,195')
```

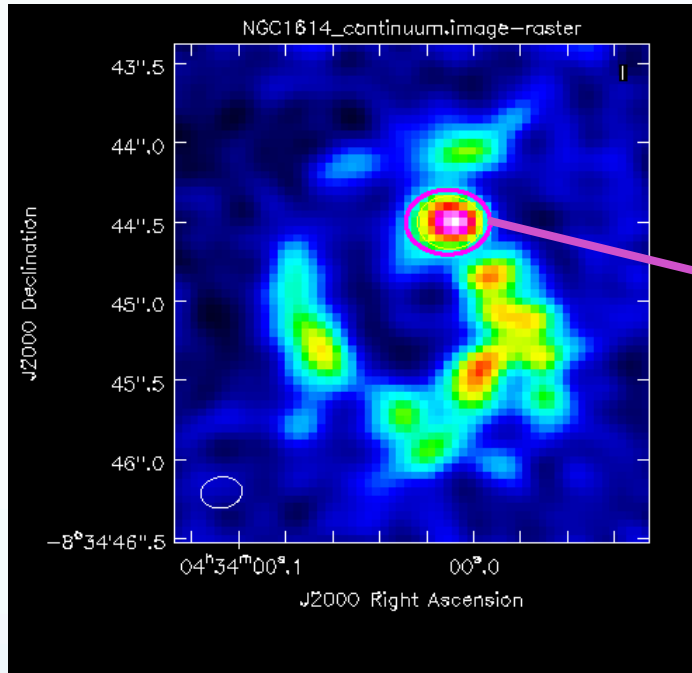
```
> mystats['flux'][0]
```

- Measure rms (signal-free region)

```
> mystats=imstat(imagename = 'source2.continuum.fits',  
                 box='25,25,100,100')
```

```
> mystats['rms'][0]
```

Fitting sources



2D Gaussian fitting
Note the interactive tool is still under development !!

```
Image component size (convolved with beam) ---  
--- major axis FWHM: 430 +/- 88 marcsec  
--- minor axis FWHM: 368 +/- 70 marcsec  
--- position angle: 43 +/- 49 deg  
  
Clean beam size ---  
--- major axis FWHM: 0.26 arcsec  
--- minor axis FWHM: 0.20 arcsec  
--- position angle: -81.66 deg  
  
Image component size (deconvolved from beam) ---  
--- major axis FWHM: 373 +/- 145 marcsec  
--- minor axis FWHM: 271 +/- 126 marcsec  
--- position angle: 31 +/- 60 deg  
  
Flux ---  
--- Integrated: 45 +/- 12 mJy  
--- Peak: 14.8 +/- 2.9 mJy/beam  
--- Polarization: I
```

Sizes convolved (deconvolved) with a gaussian of the beam size

Fitting sources: *imfit*

```
> myfit = imfit(imagename = 'source2.continuum.fits',  
               region = 'circle [ [ 185pix , 193pix] , 8pix ]')
```

```
> myfit['results']['component0']['flux']
```

```
> myfit['results']['component0']['shape']['majoraxis']
```

```
Out[27]: {'unit': 'arcsec', 'value': 0.43005500189354}
```

```
> myfit['deconvolved']['component0']['shape']  
['majoraxis']
```

```
Out[29]: {'unit': 'arcsec', 'value': 0.37321385202232604}
```


Knowing our images: *imhead*

- mode='summary' (default), prints out a summary of the image properties in the logger

```
> imhead('source2.continuum.fits')
```

```
> imhead('NGC1614_C06-5.image')
```

- mode='list', prints out a list of the header keywords and values to the terminal

```
> imhead('source2.continuum.fits', mode='list')
```

```
> myhead=imhead('source2.continuum.fits', mode='list')
```

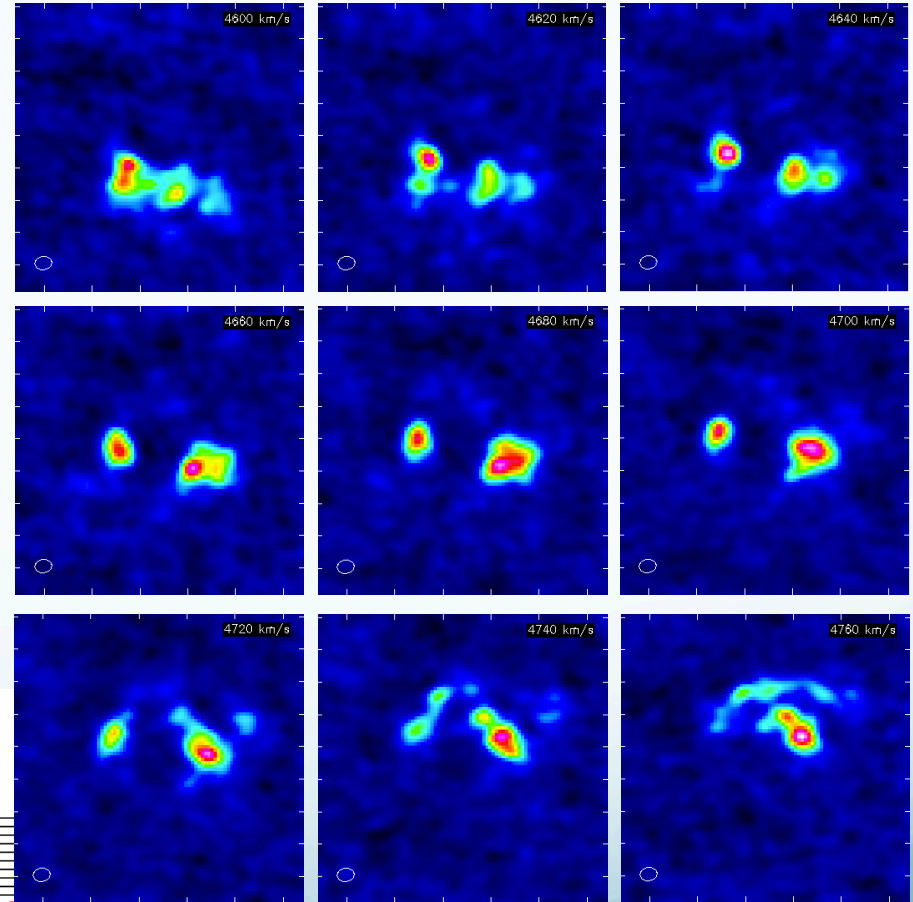
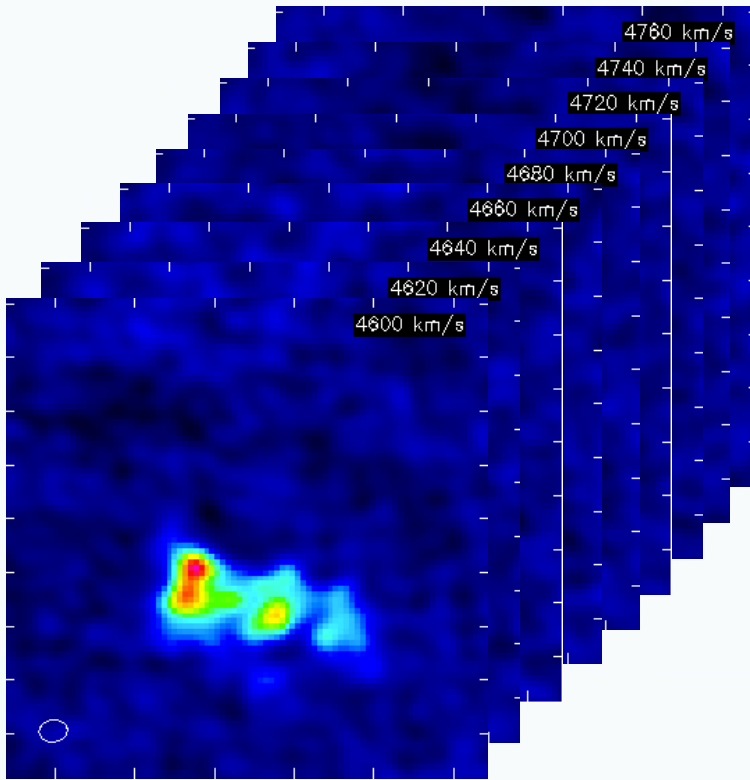
```
> myhead['beammajor']
```

Knowing our images: *imhead*

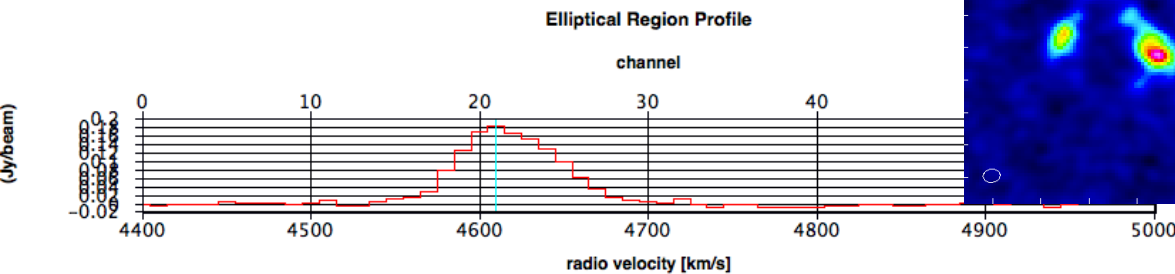
- mode='get', allows the user to retrieve the current value for a specified keyword hdkey
 - > `mybmaj = imhead('source2.continuum.fits', mode='get', hdkey='beammajor')`
 - > `mybmaj`
 - mode='put', allows the user to replace the current value for a given keyword
- Use with caution: it does not transform the image !

Spectral line images

2D slices in each chan/freq/velo:

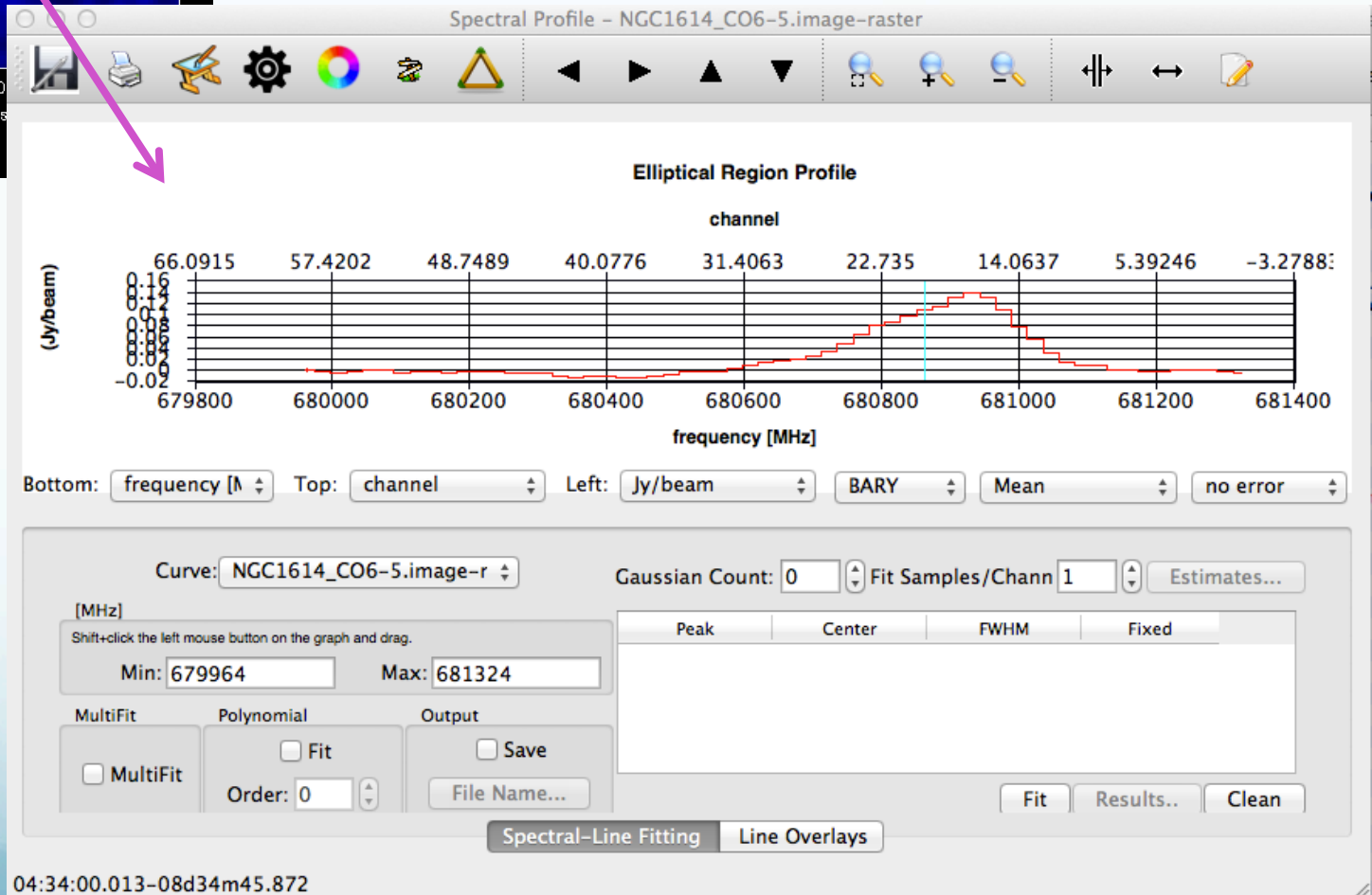
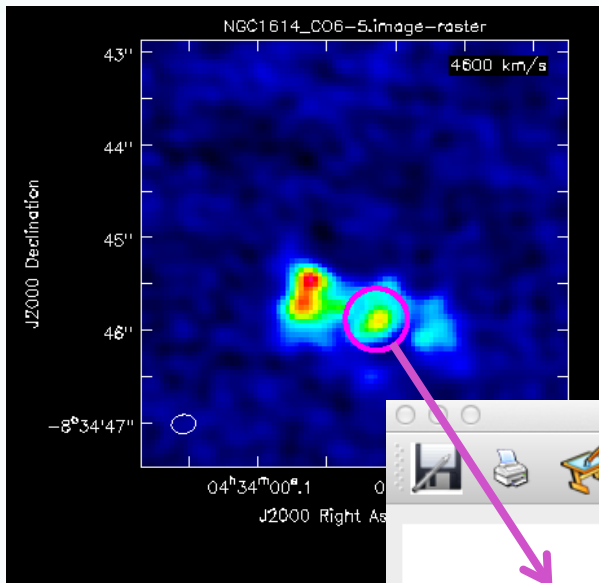


1D slice along the chan/freq/velo axis:



NGC1614_CO6-5.image

The spectral viewer



Line identification

Chemical

Name Formula

CO

Astronomical Filters: None

Range

Min: 680.2

Max: 681.3

GHz

Doppler Shift

Doppler Type: Radio

Redshift Velocity

4600 km/s

Reference Frame: BARY

Search

Save Lines... Clear Lines

Spectral-Line Fitting Line Overlays

Click the right mouse button on a known line on the graph to find the redshift.

Always specify the source velocity!!

Will search on the splatalogue database (splatalogue.net), incorporated into CASA.

Line identification: catalogues

- Splatalogue:

<http://www.cv.nrao.edu/php/splat/advanced.php>

- Cologne Database for Molecular Spectroscopy:

<http://www.astro.uni-koeln.de/cdms/>

- Jet Propulsion Laboratory:

<http://spec.jpl.nasa.gov/>

- NIST Recommended Rest Frequencies

<http://physics.nist.gov/cgi-bin/micro/table5/start.pl>

Line id.: *slsearch* and *splattotable*

- slsearch: searches in splatalogue the molecules/lines matching the selection. Prints results in the CASA log or writes a table:

```
> slsearch(freqrange=[freq1,freq2], verbose=True)
```

```
> slsearch(outfile='mylines.tbl',  
           freqrange=[freq1,freq2])
```

```
> slsearch(tablename = 'mylines.tbl',  
           freqrange = [freq1,freq2], species = ['mymolecule'],  
           verbose=True)
```

- splattotable: converts txt files in to CASA tables

```
> splattotable(filenamees = ['splatalogue.tsv'],  
              table = 'splatalogue.tbl')
```

Export spectra



- Will save a txt file table with frequencies and intensities as selected in the viewer
- NOTE intensity scale may not be correct !
- NOTE frequencies will be sky frequencies !
It is necessary to convert to rest frequencies using the source velocity, if one wants to use other tools to plot the spectra and identify lines using rest frequencies from catalogues

Export spectra: *imval*

```
> xval = imval(imagename='NGC1614_CO6-5.image',  
              box='184,165', chans='0~40')
```

```
> xval
```

```
Line peak is at: > xval['data'][17]
```

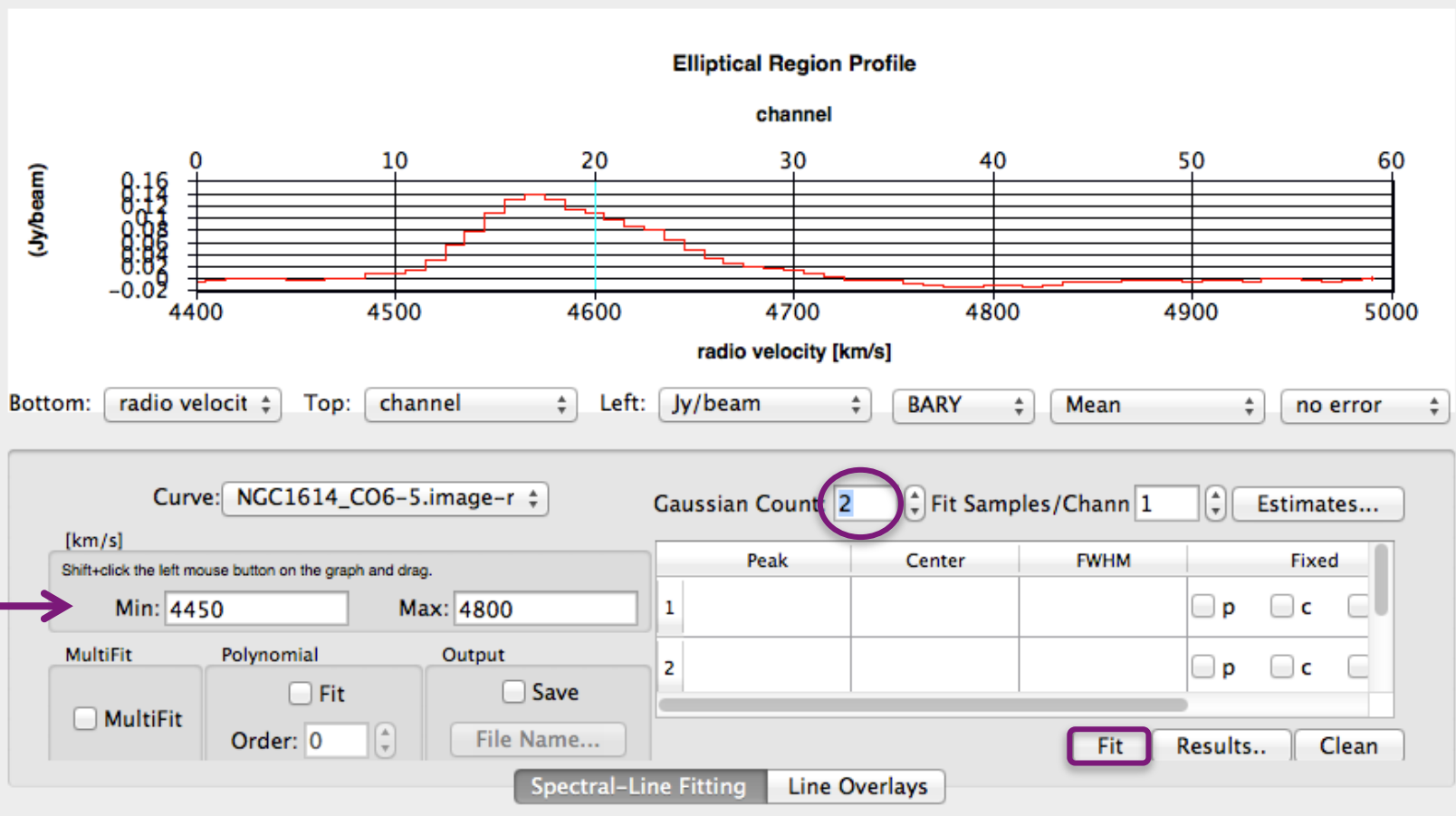
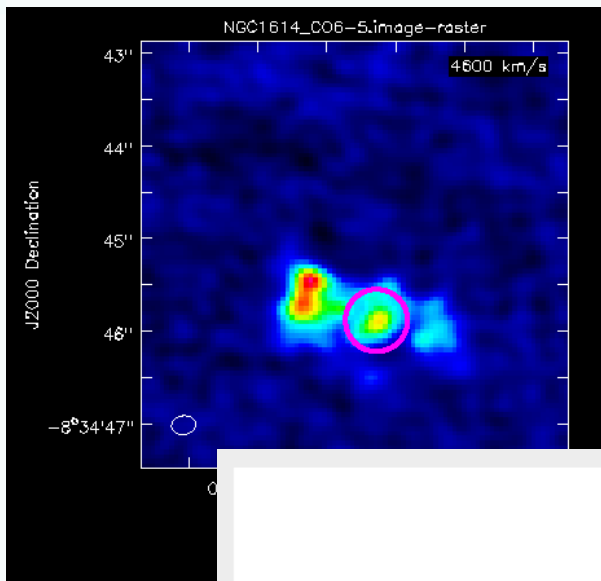
```
And the frequency is: > xval['coords'][17][3]
```

NOTE frequencies are sky frequencies !

$$V_{\text{radio}} = c \Delta\nu / \nu_0$$

Spectral line fitting

Note some features of the spectral viewer are still under development !!



Spectral line fitting: *specfit*

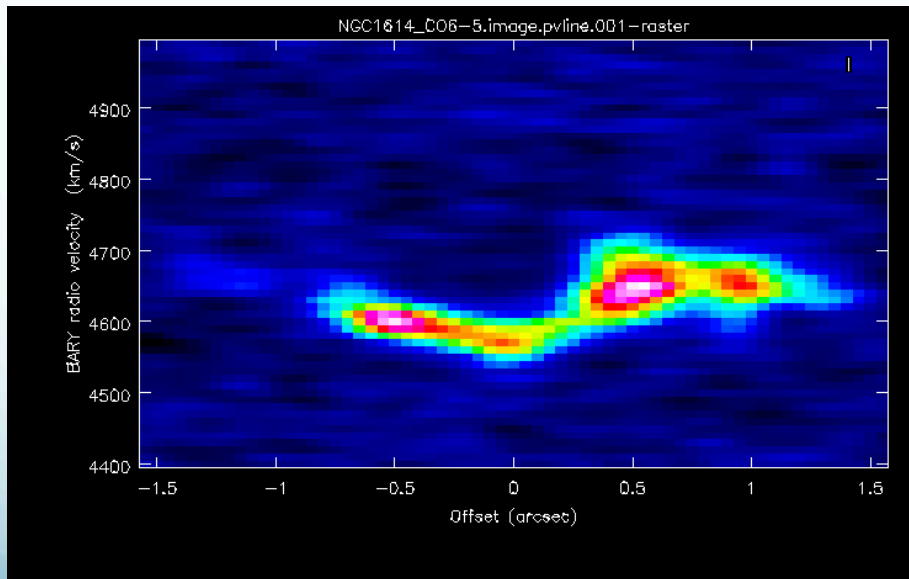
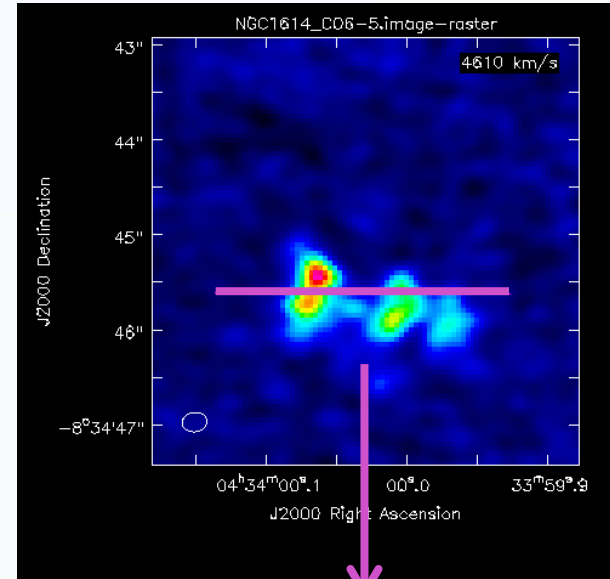
```
> specfit(imagename=' NGC1614_C06-5.image',  
          box='178,159,191,172', chans='5~40',  
          ngauss=2, multifit=False, logfile='myfit.txt')
```

- `multifit=False`: average the axis pixels and do a single fit to that average profile
- `multifit=True`: fit a profile along the desired axis at each pixel in the region. It is possible to save the solution and error images (e.g. area, velocity, etc.) and explore them in the viewer.

Position-velocity diagrams



Slice along the selected direction, to inspect the velocity distribution



Regions

Properties pV File Histogram

NGC1614_CO6-5.image

end point coordinates

pixel	147.8 171.0	J2000	04:34:00.137 -8.34.45.601
	210.1 170.7		04:33:59.926 -8.34.45.614

position angle 89.76° length 3.115 arcsec

averaging width 1

Generate P/V Next



Position-velocity diagrams: *impv*

```
> impv(imagename='NGC1614_C06-5.image',  
       outfile='NGC1614_C06-5_pv.image',  
       chans='', mode='length',  
       center= ['04h34m00.0s', '-08d34m45.6s'],  
       length='2.8arcsec', pa='90deg')
```

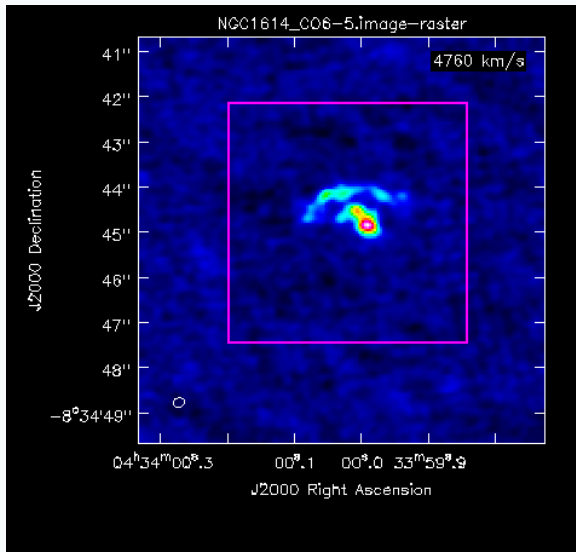
Moment maps

Useful to visualize 3D images: collapsing in one axis.

The most common are the moment maps: Intensity-weighted sums along the velocity axis, yielding images of:

- moment 0
(integrated emission) $\rightarrow \Delta v \sum S_v = I_{\text{tot}}$
- moment 1 (velocity) $\rightarrow \frac{\sum v S_v}{\sum S_v} = \langle v \rangle$
- moment 2
(velocity dispersion) $\rightarrow \frac{\sum (v - \langle v \rangle)^2 S_v}{\sum S_v} = \langle v^2 \rangle^{1/2}$

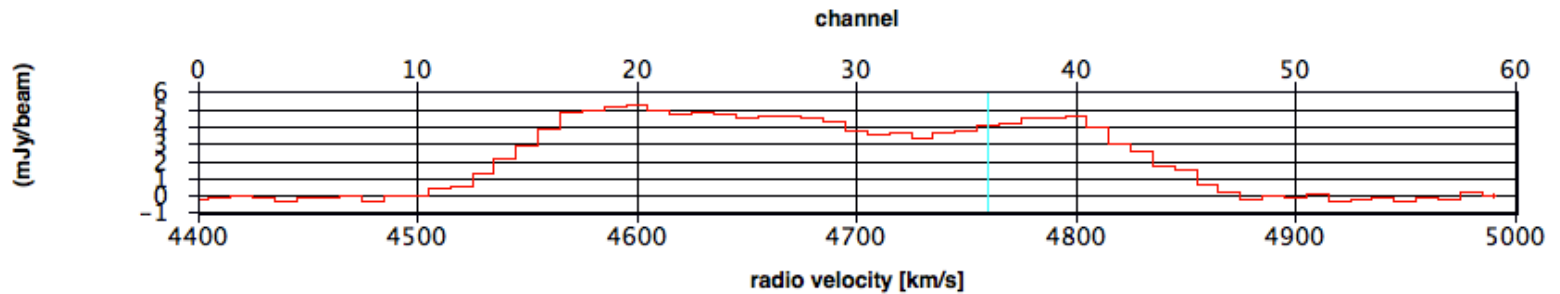
Moment maps



Spectral Profile: Collapse/Moments - NGC1614_CO6-5.image-raster



Rectangle Region Profile



Bottom: radio velocit ▾ Top: channel ▾ Left: Jy/beam ▾ BARY ▾ Mean ▾ no error ▾

[km/s]

Select a table row then shift-click the graph with the left mouse and drag.

Interval Count: 1 ▾

	Min	Max
1	4450	4950

- Moment(s):
- (-1) Mean Value, Mean Intensity
 - (0) Integrated Value, Sum**
 - (1) Weighted Mean, Velocity Field
 - (2) Intensity-Weighted Dispersion of Spectral Co
 - (3) Median Value, Median Intensity
 - (4) Spectral Coordinate of Median, Median Veloci
 - (5) Standard Deviation About Mean, Noise, Intens
 - (6) Root Mean Square Intensity
 - (7) Absolute Mean Deviation

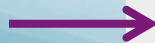
Thresholding

Include Exclude None (All)

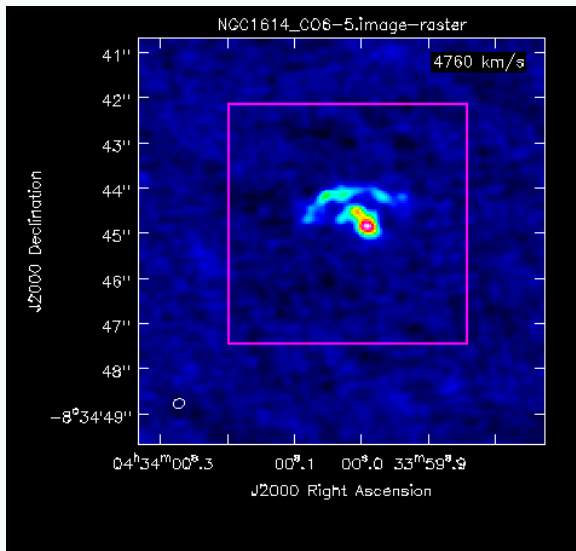
Symmetric Interval

Start:

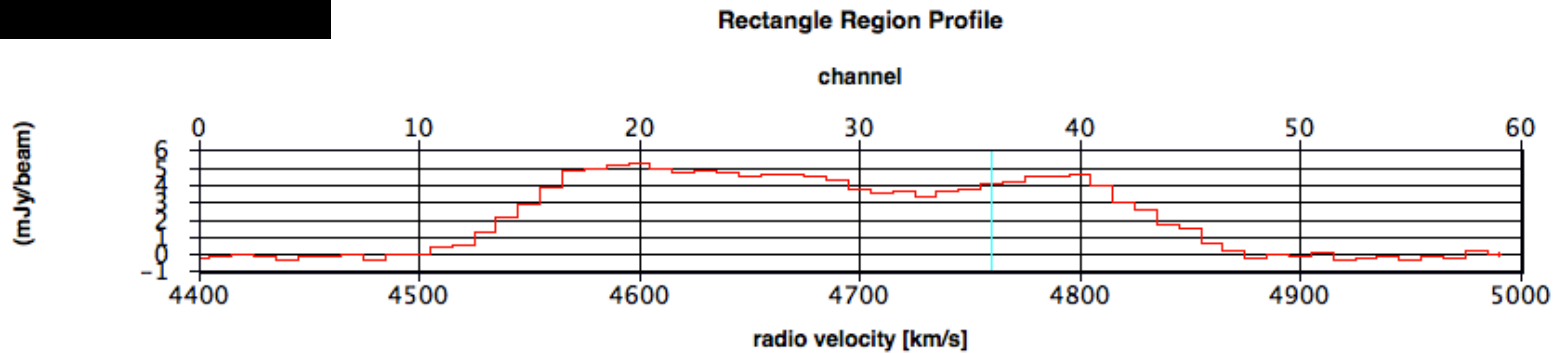
End:



Moment maps



Spectral Profile: Collapse/Moments - NGC1614_CO6-5.image-raster



Bottom: radio velocit Top: channel Left: Jy/beam BARY Mean no error

[km/s]

Select a table row then shift+click the graph with the left mouse and drag.

Interval Count: 1

	Min	Max
1	4450	4950

- Moment(s):
- (-1) Mean Value, Mean Intensity
 - (0) Integrated Value, Sum
 - (1) Weighted Mean, Velocity Field
 - (2) Intensity-Weighted Dispersion of Spectral Co
 - (3) Median Value, Median Intensity
 - (4) Spectral Coordinate of Median, Median Veloci
 - (5) Standard Deviation About Mean, Noise, Intens
 - (6) Root Mean Square Intensity
 - (7) Absolute Mean Deviation

Thresholding

Include Exclude None (All)

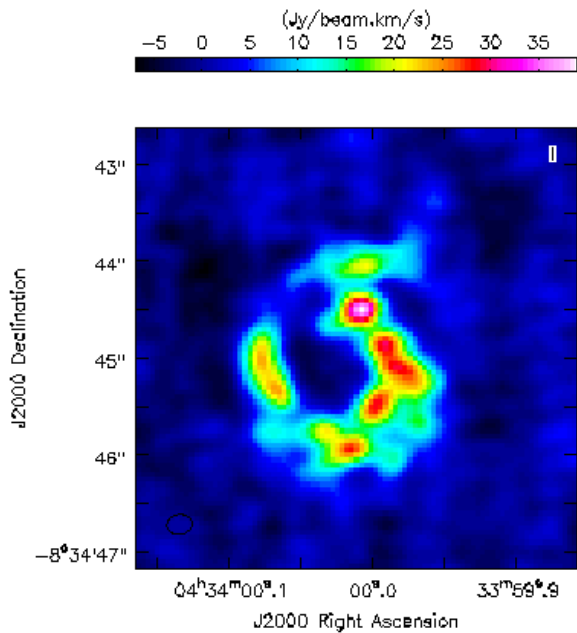
Symmetric Interval

Start: 0.08

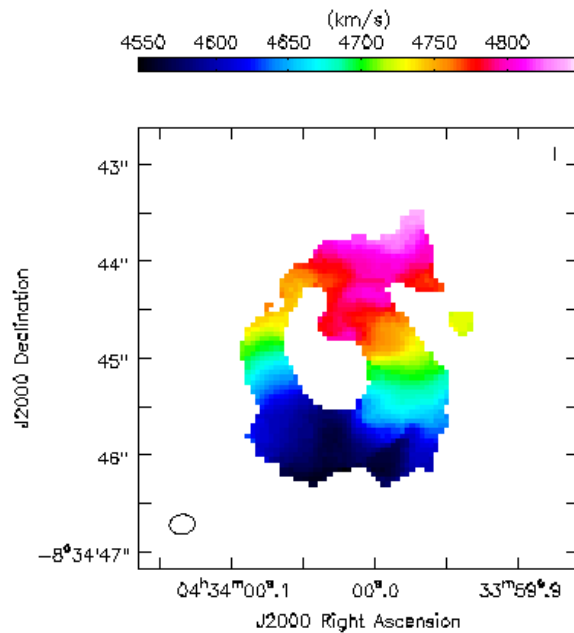
End: 1000

Select Root Output File... Collapse

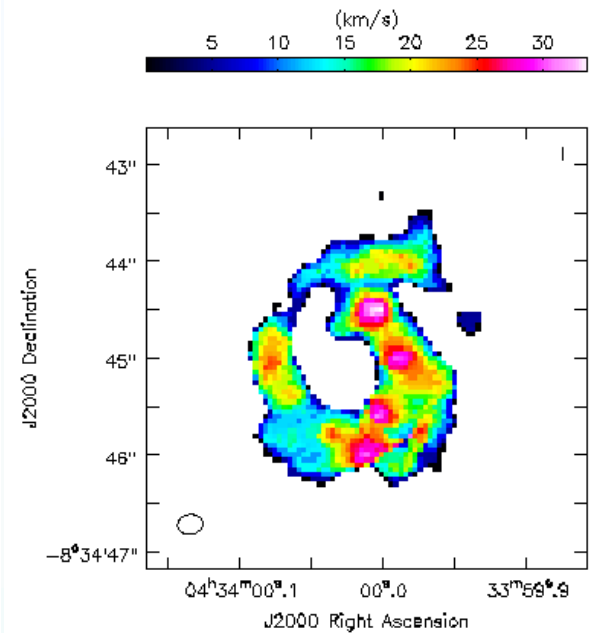
Moment maps



Moment 0
Integrated emission



Moment 1
Intensity weighted
mean velocity



Moment 2
Intensity weighted
velocity dispersion

Moment maps: *immoments*

- Moment 0 (no threshold needed):

```
> immoments(imagename = 'NGC1614_C06-5.image',  
            moments = [0],  
            box = '130,135,235,240', chans = '5~55',  
            outfile = 'NGC1614_C06-5.mom0')
```

- Use a threshold for moments 1 and 2:

```
> immoments(imagename = 'NGC1614_C06-5.image',  
            moments = [1,2], includepix = [0.08,1000],  
            box = '130,135,235,240', chans = '5~55',  
            outfile = 'NGC1614_C06-5.mom')
```

CASA manual and CASA ALMA guides:

<http://casa.nrao.edu/docs/UserMan/UserMan.html>

<https://casaguides.nrao.edu/index.php/ALMAGuides>

More tools...

- CASA to GILDAS:

<http://www.iram.fr/IRAMFR/ARC/documents/filler/casa-gildas.pdf>

<http://www.iram.fr/IRAMFR/GILDAS/>

- XCLASS:

<http://www.astro.uni-koeln.de/projects/schilke/XCLASSInterface>

- Software Tools for Radio Astronomy:

<http://radio-astro-tools.github.io/>