Data products analysis

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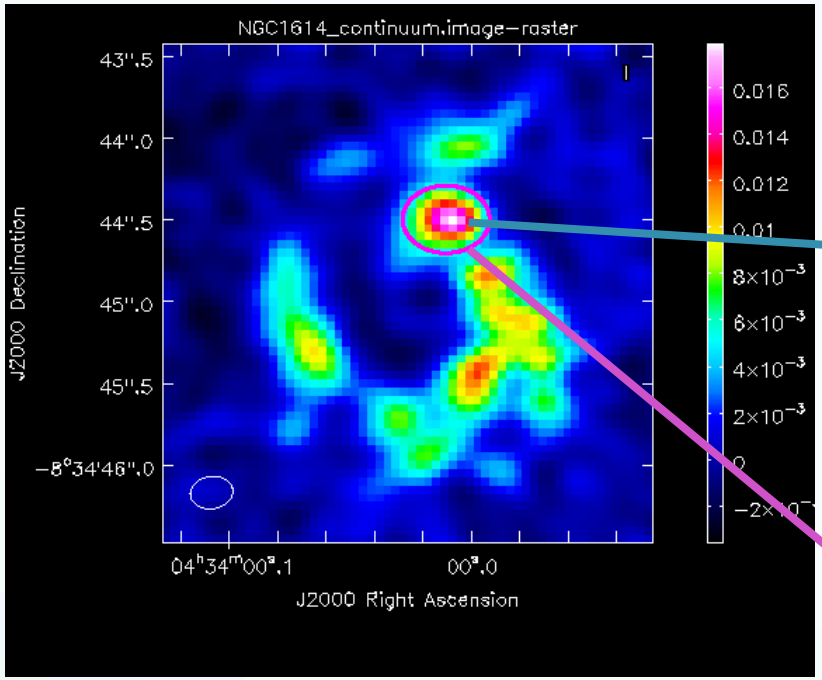
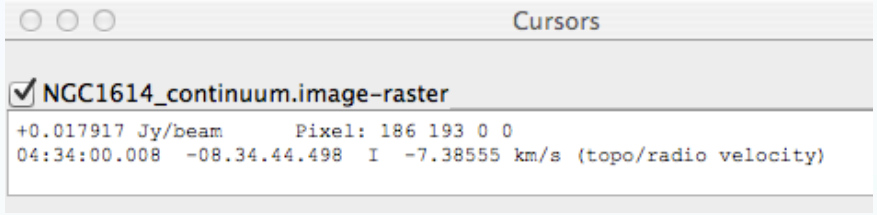
Data analysis tools

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

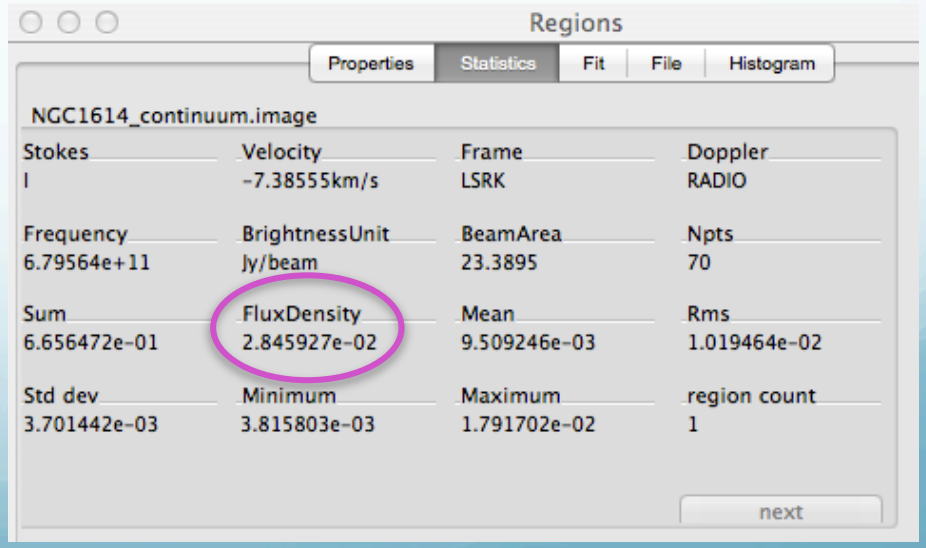
Peak flux and flux density



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)

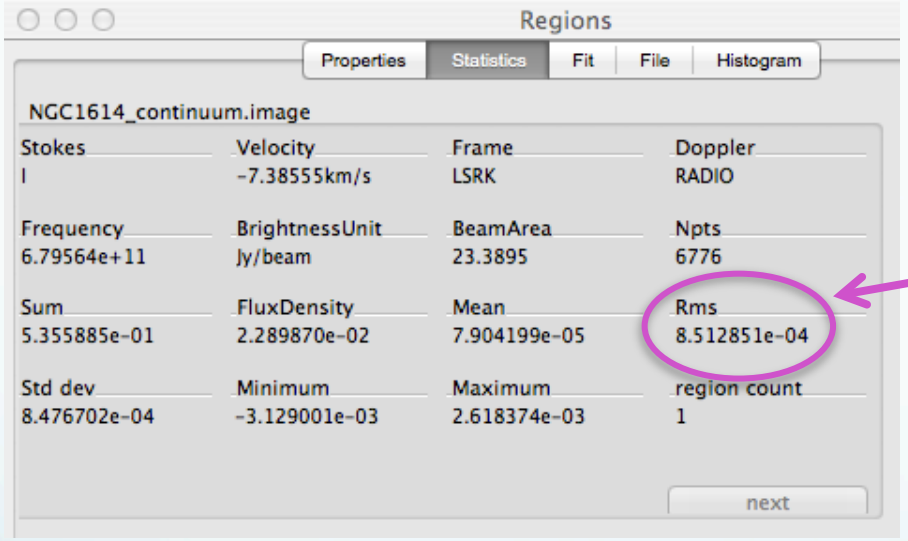


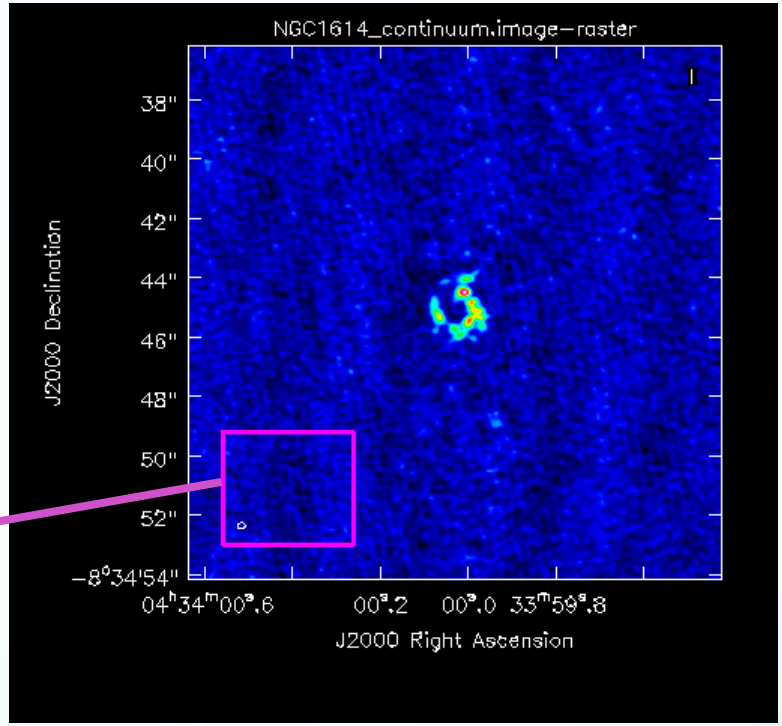
We measure: $F \pm 0.10 \times F$

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
imagename            =          ''          #  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 "chauvenet", "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’)

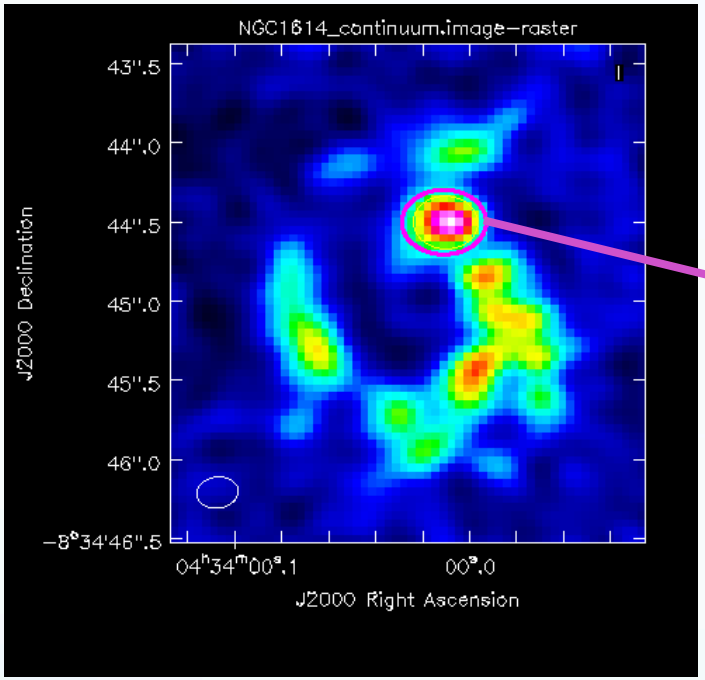
> mystats[‘flux’][0]

- 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_CO6-5.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*

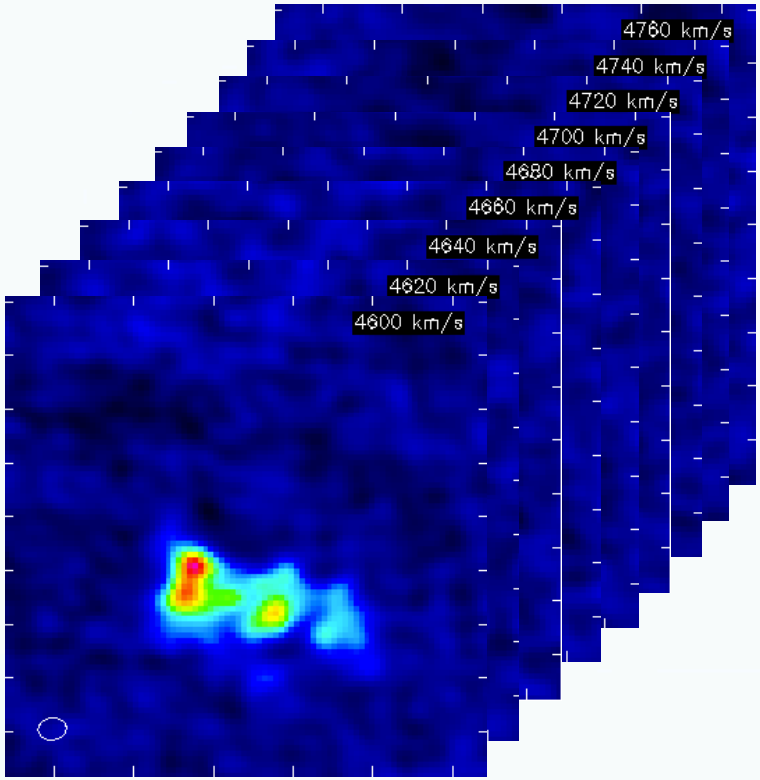
- mode='get', allows the user to retrieve the current value for a specified keyword hdkey

```
> mybmaj = imhead('source2.continuum.fits',
                  mode='get', hdkey='beammajor')

> mybmaj
```

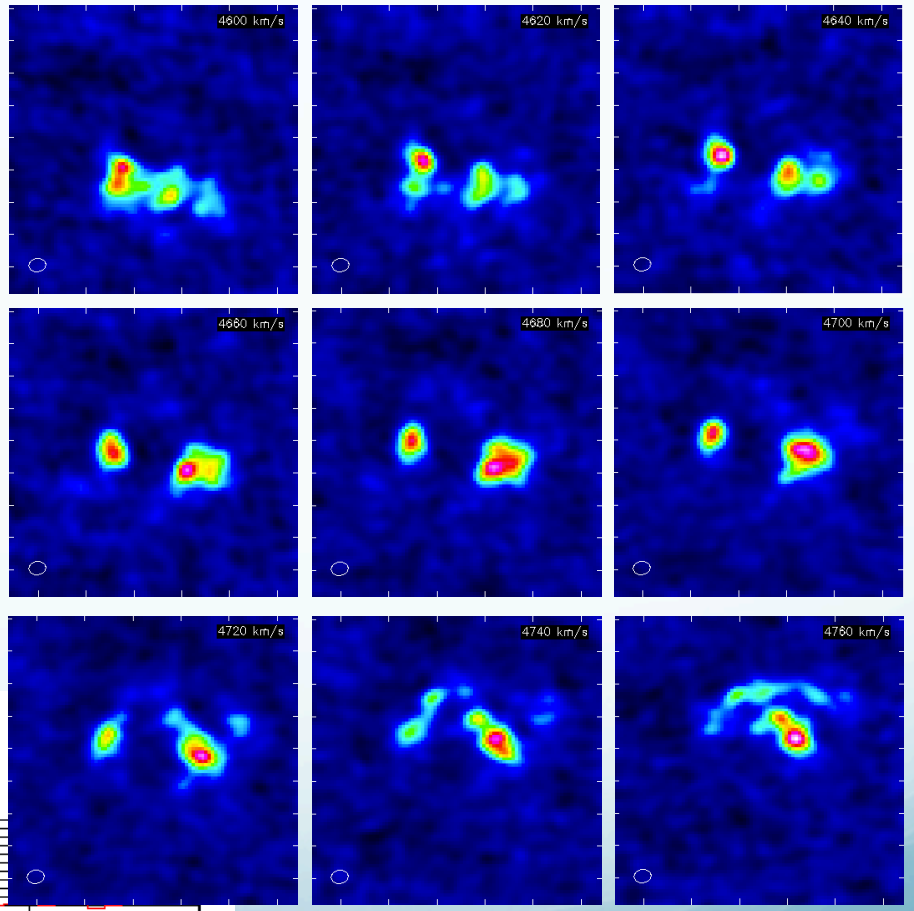
- mode='put', allows the user to replace the current value for a given keyword

→ Use with caution: it does not transform the image !

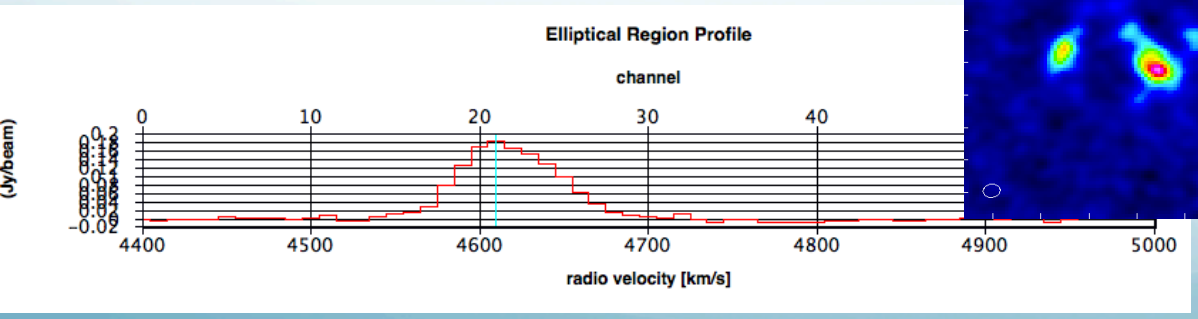
Spectral line images



2D slices in each chan/freq/velo:

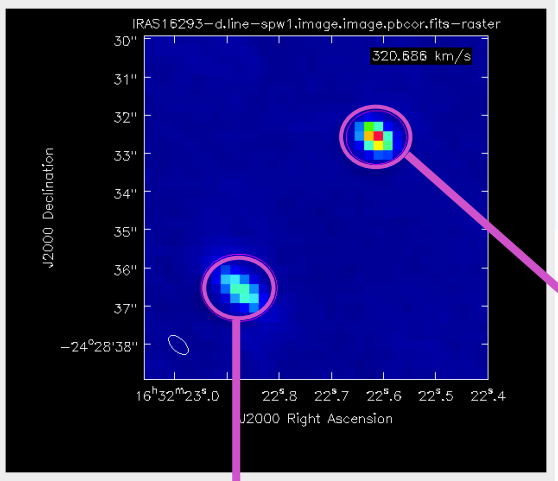


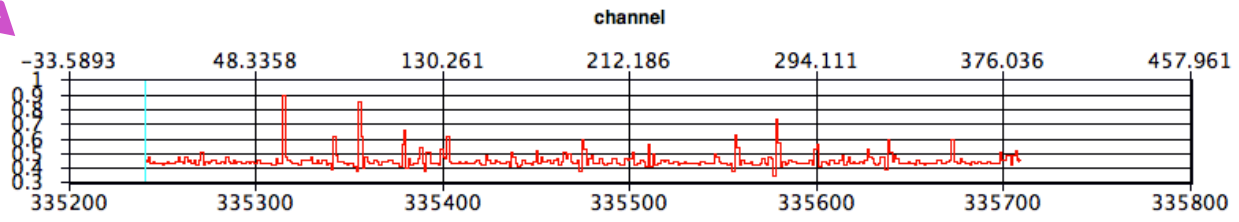
1D slice along the chan/freq/velo axis:

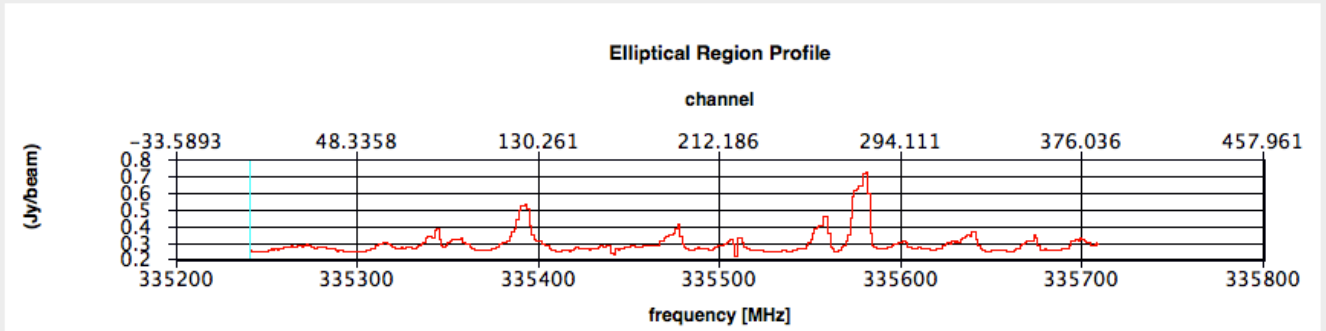


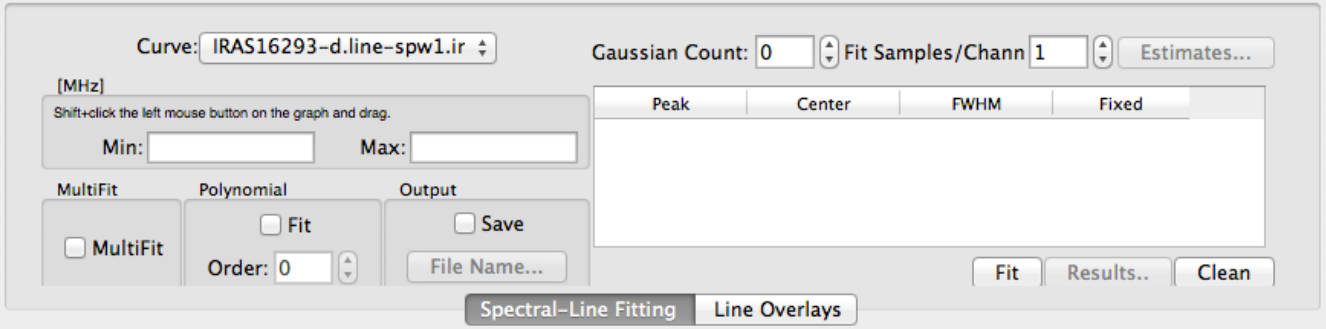
NGC1614_CO6-5.image

The spectral viewer

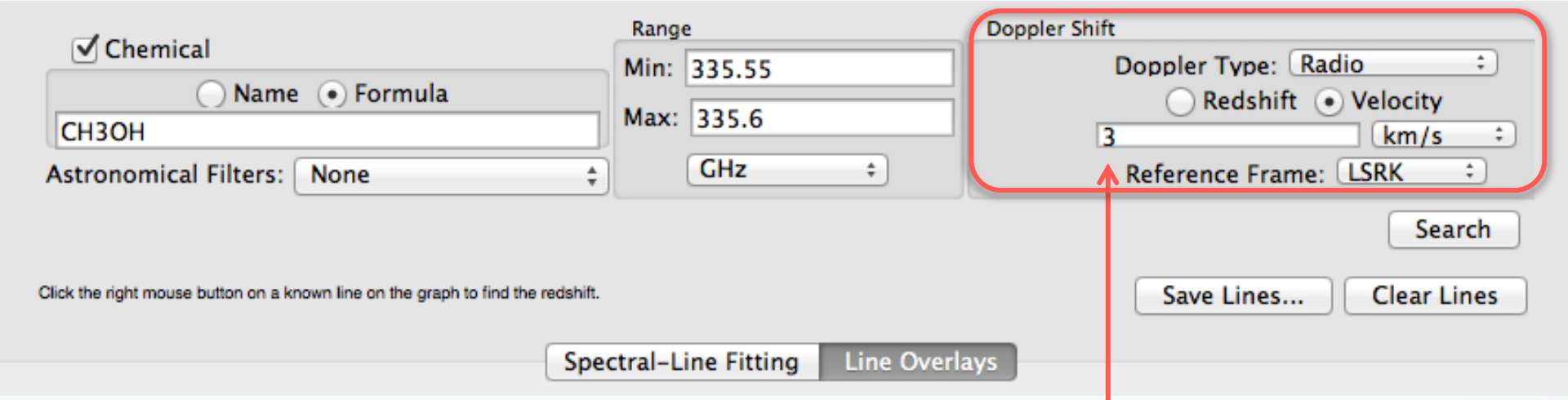








Line identification



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=[335.3,335.4], verbose=True)

> slsearch(outfile='lines_335.3-335.4.tbl',
                freqrange=[335.3,335.4])

> slsearch(tablename = 'lines_335.3-335.4.tbl',
freqrange = [335.3, 335.4], species = ['HDO'], verbose=True)
```

- splattotable: converts txt files in to CASA tables

```
> splattotable(filenames = ['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*

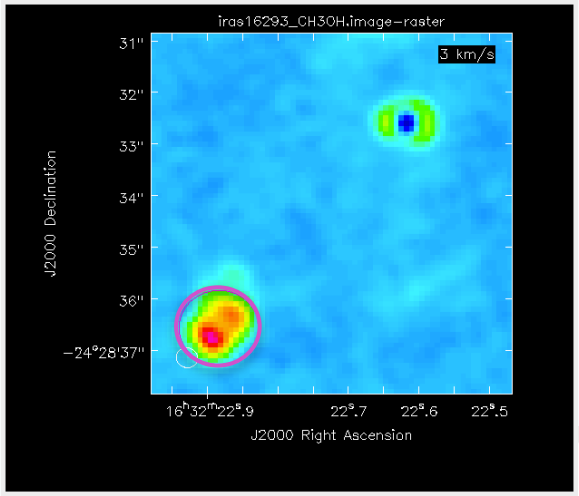
```
> xval = imval(imagename = 'IRAS16293-d.line-spw1.image.image.pbcor.fits', box = '61,61', chans='100~150')

> xval
```

Line peak is at: `> xval['data'][15]`

And the frequency is: `> xval['coords'][15][2]`

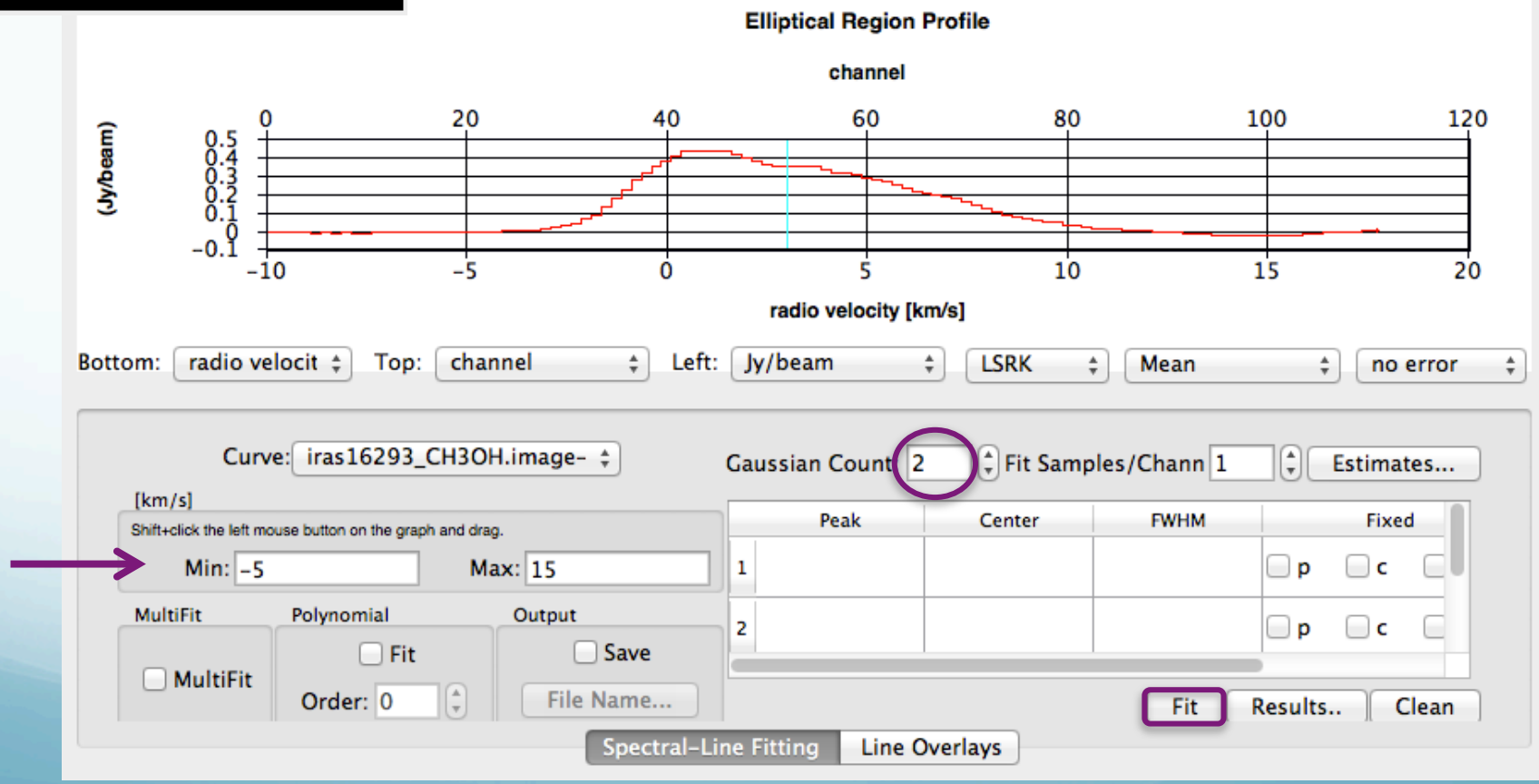
NOTE frequencies are <u>sky frequencies</u> !

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



Spectral line fitting

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



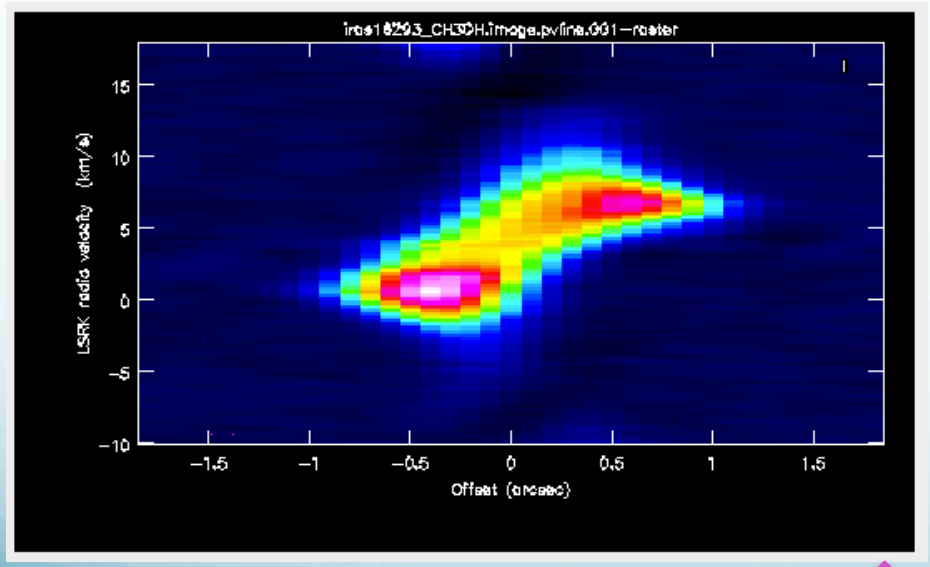
Spectral line fitting: *specfit*

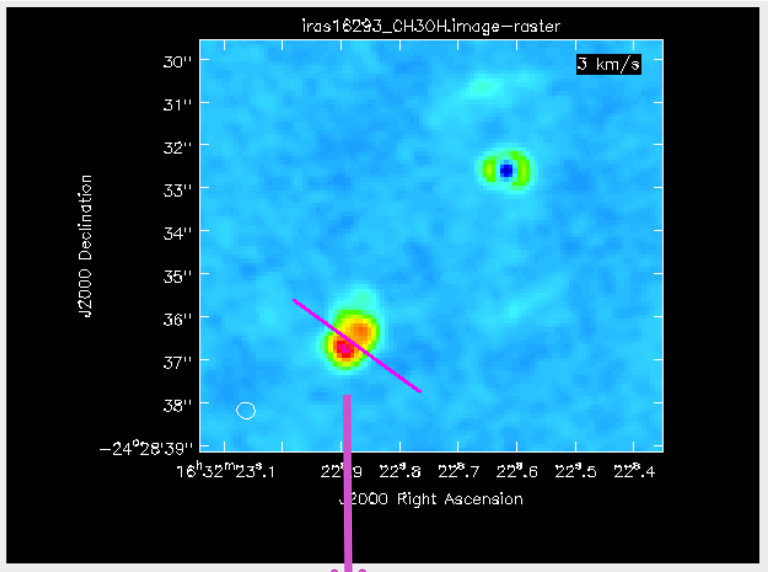
```
> specfit(imagename='iras16293_CH3OH.image',
          box='111,111,125,125', chans='20~90',
          ngauss=2, multifit=False, logfile='myfit.txt')
```

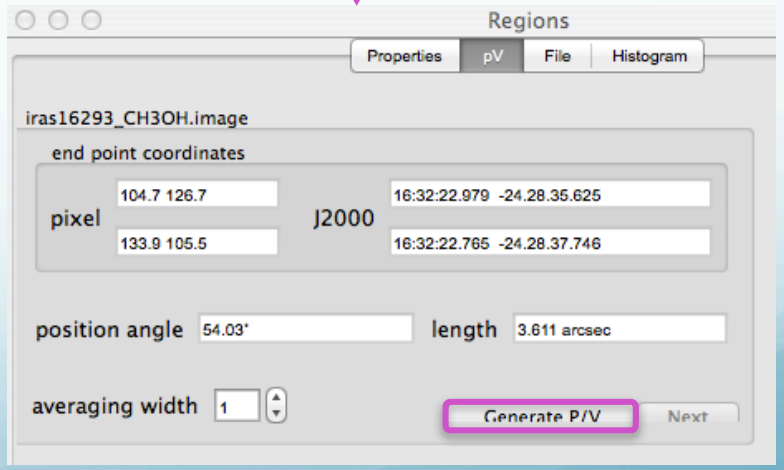
- multifit=False: average the axis pixels and do a single fit to that average profile
- multifit=True: fit a profile along the desired axis at each pixel in the region. It is possible to save the solution and error images (e.g. area, velocity, etc.) and explore them in the viewer.

Position-velocity diagrams

Slice along the selected direction, to inspect the velocity distribution







Position-velocity diagrams: *impv*

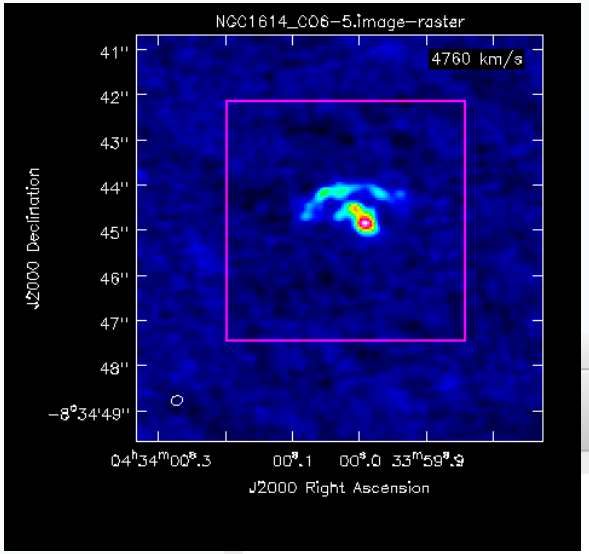
```
> impv(imagename='iras16293_CH3OH.image',
                outfile='iras16293A-ch3oh_pv.image',
                chans='20~90', mode='length',
                center=['16h32m22.9s','-24d28m36.6s'],
                length='3.6arcsec', pa='54deg')

> impv(imagename='iras16293_CH3OH.image',
                outfile='iras16293B-ch3oh_pv.image',
                chans='30~70', mode='length',
                center=['16h32m22.6s','-24d28m32.6s'],
                length='3arcsec', pa='90deg')
```

Moment maps

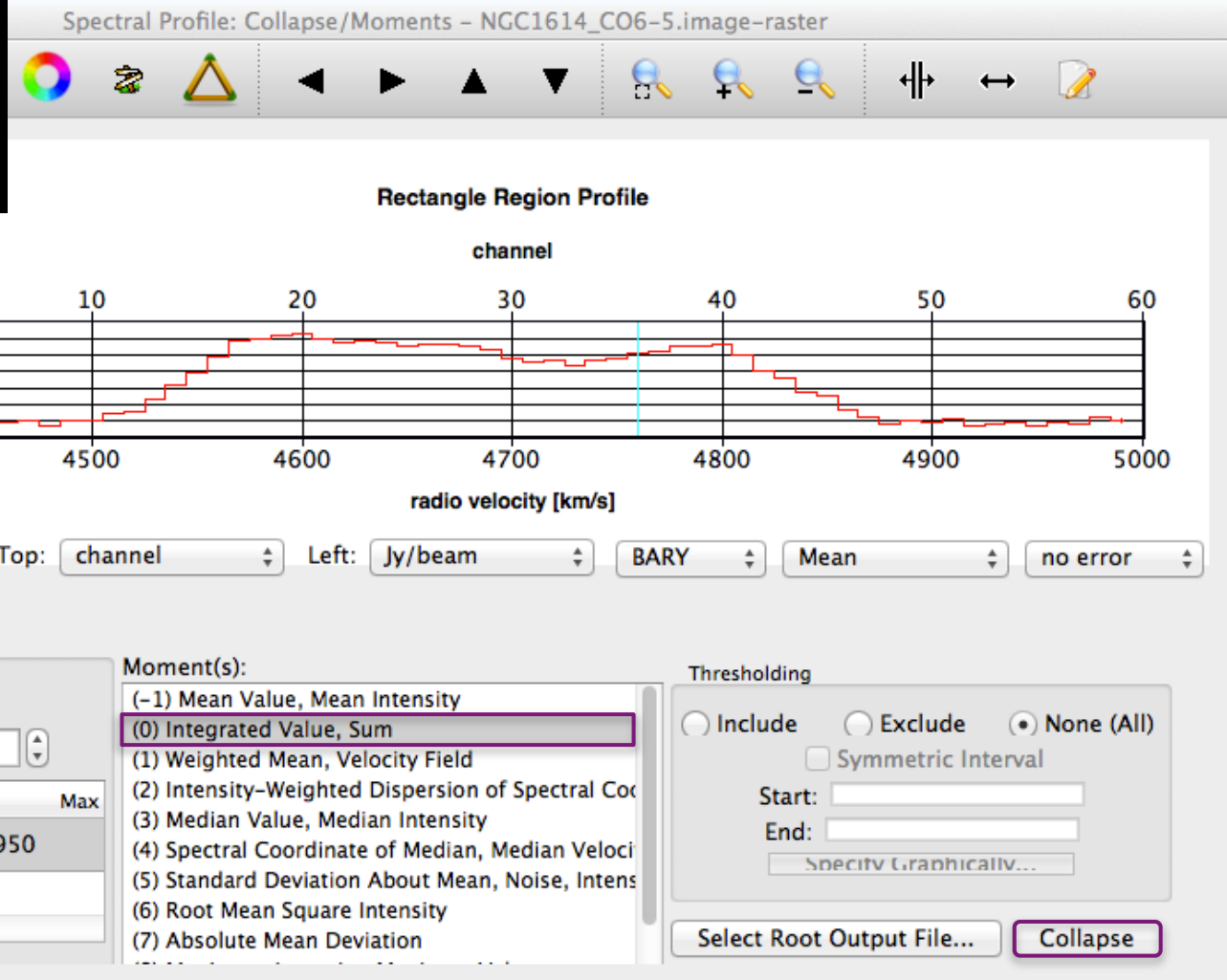
Useful to visualize 3D images: collapsing in one axis.

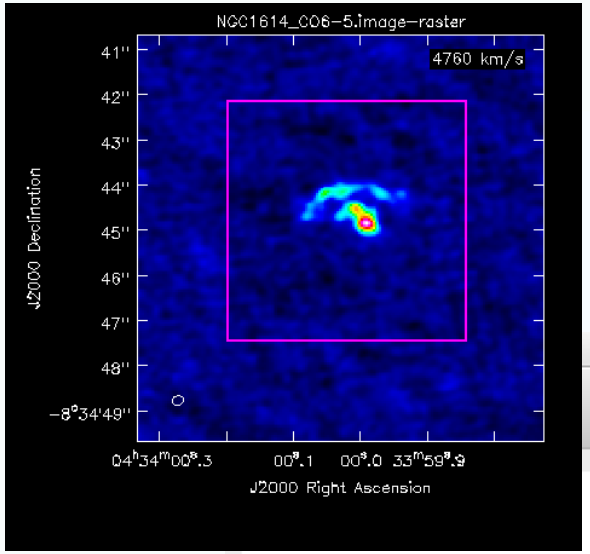
The most common are the moment maps: Intensity-weighted sums along the velocity axis, yielding images of:

- moment 0 (integrated emission) → $\Delta v \sum S_\nu = I_{tot}$
- moment 1 (velocity) → $\frac{\sum v S_\nu}{\sum S_\nu} = < v >$
- moment 2 (velocity dispersion) → $\frac{\sum (v - <v>^2) S_\nu}{\sum S_\nu} = < v^2 >^{1/2}$

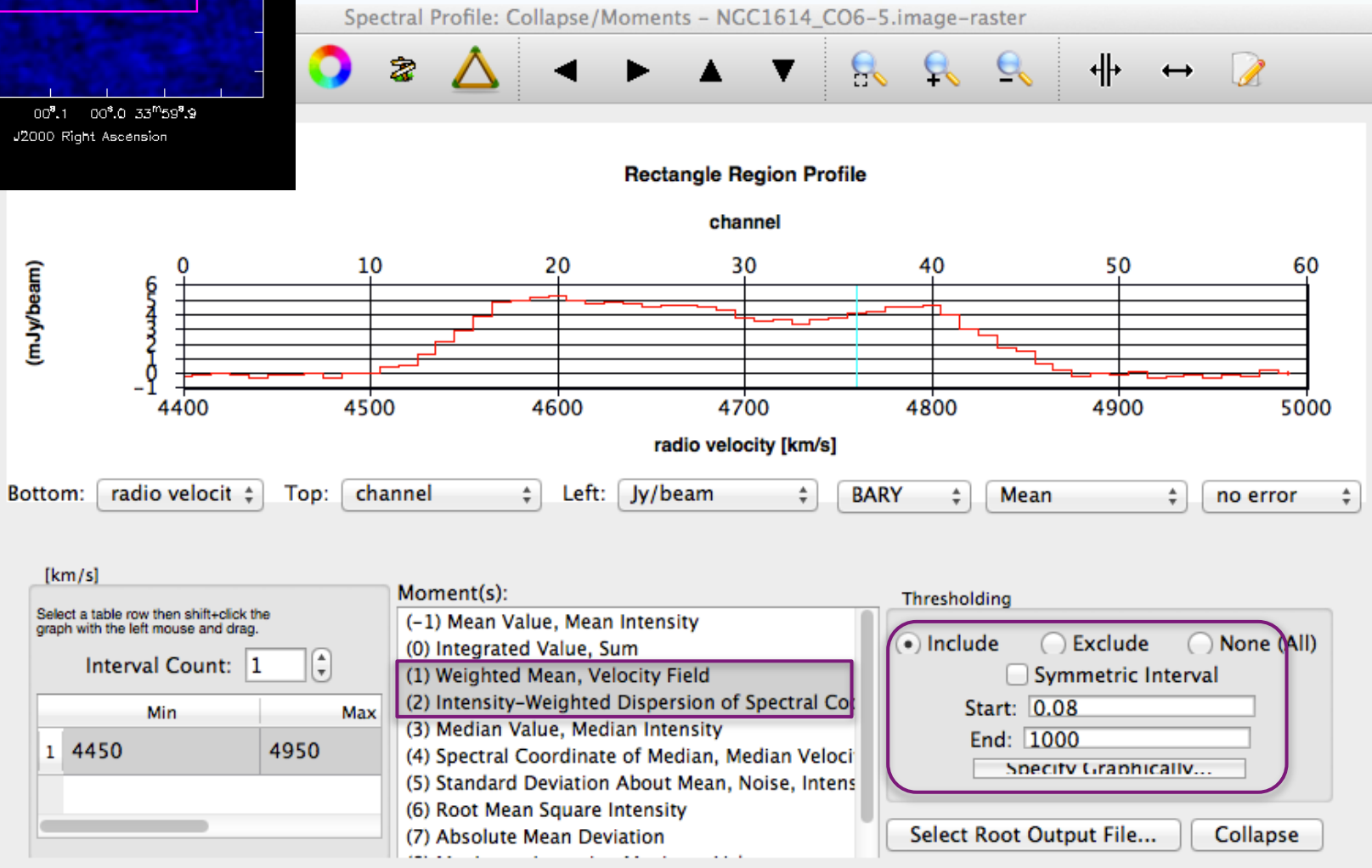

NGC1614_CO6-5.image-raster
4760 km/s
41''
42''
43''
44''
45''
46''
47''
48''
-8°34'49''
J2000 Declination
04h34m00s.3
00s.1
00s.0
33m59s.9
J2000 Right Ascension

Moment maps

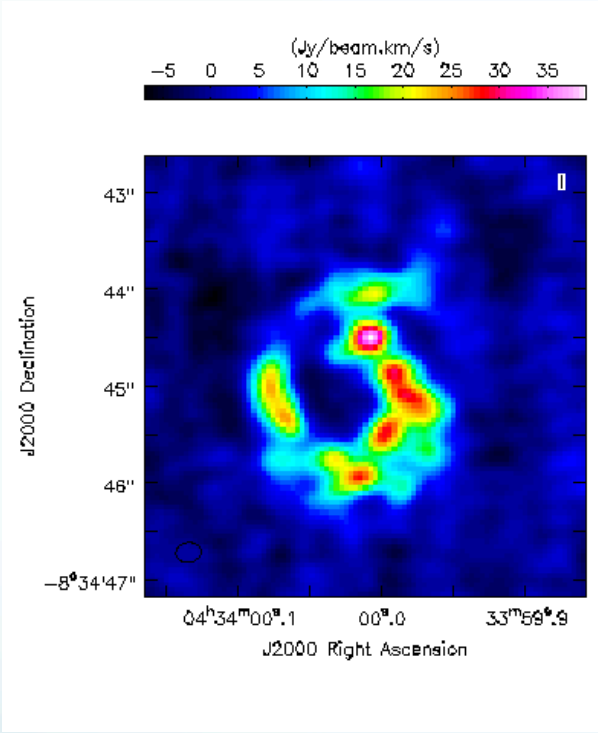

Spectral Profile: Collapse/Moments - NGC1614_CO6-5.image-raster
Rectangle Region Profile
channel
(mJy/beam)
0
10
20
30
40
50
60
6
4
2
0
-1
4400
4500
4600
4700
4800
4900
5000
radio velocity [km/s]
Bottom: radio velocit
Top: channel
Left: Jy/beam
BARY
Mean
no error
[km/s]
Select a table row then shift+click 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 Coc
(3) Median Value, Median Intensity
(4) Spectral Coordinate of Median, Median Velocit
(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:
Specify Graphically...
Select Root Output File...
Collapse


NGC1614_CO6-5.image-raster
4760 km/s
41''
42''
43''
44''
45''
46''
47''
48''
-8°34'49''
J2000 Declination
04h34m00s.3
00s.1
00s.0
33m59s.9
J2000 Right Ascension

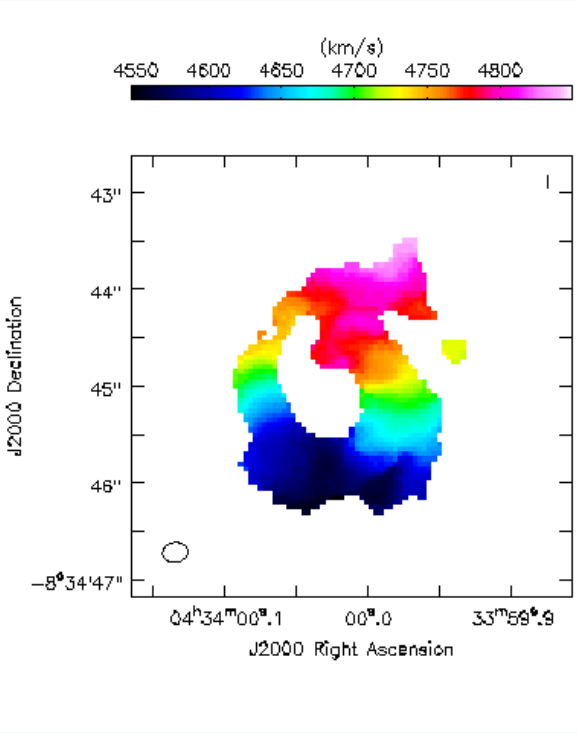
Moment maps


Spectral Profile: Collapse/Moments - NGC1614_CO6-5.image-raster
Rectangle Region Profile
channel
(mJy/beam)
0
10
20
30
40
50
60
4400
4500
4600
4700
4800
4900
5000
radio velocity [km/s]
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 Velocit
(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
Specify Graphically...
Select Root Output File...
Collapse

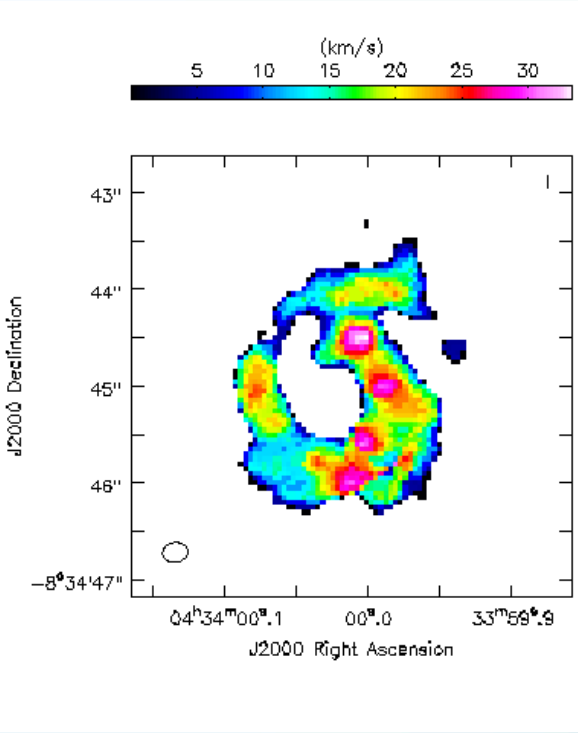
Moment maps



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_CO6-5.image',
                moments = [0],
                box = '130,135,235,240', chans = '5~55',
                outfile = 'NGC1614_CO6-5.mom0')
```

- Use a threshold for moments 1 and 2:

```
> immoments(imagename = 'NGC1614_CO6-5.image',
                moments = [1,2], includepix = [0.08,1000],
                box = '130,135,235,240', chans = '5~55',
                outfile = 'NGC1614_CO6-5.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/