Analysis Tools

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Prepare for the exercises

In your analysis folder
- mkdir analysis_tools

Copy the data
- cp -r ../../archive/DRT2023/TW_hydra/twhya_n2hp.image analysis_tools/.
- cp -r ../../archive/DRT2023/TW_hydra/sis14_twhya_cont.image analysis_tools/.

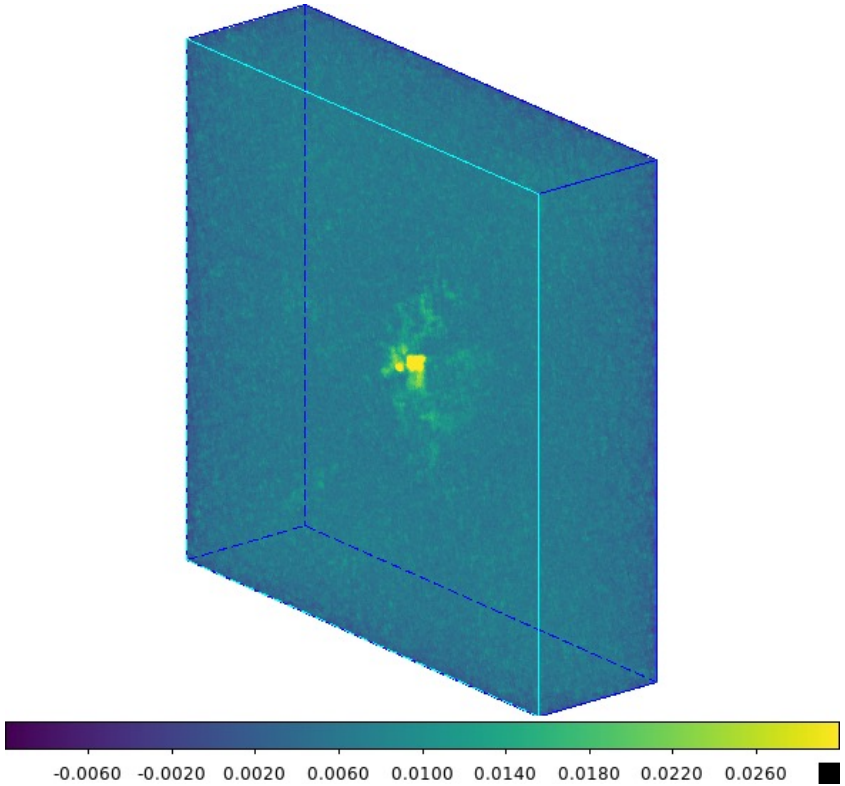
Copy scripts from the ‘scripts’ folder to your own folder
- > cp ../../scripts/analysis_tools_script.py analysis_tools/.

Start CASA
- nice +10 env -u PYTHONPATH -u LD_LIBRARY_PATH casapy-660

- If you already did all this:
  - cd ../analysis_tools
  - Start CASA

Datacubes

- 3D data product:
  - 2 spatial dimensions (RA, DEC)
  - 1 velocity dimension
- We will look at a few datacube analysis methods



Analysis tools

- We will look at analysis in CASA
- CASA - https://casa.nrao.edu/casa_obtaining.shtml

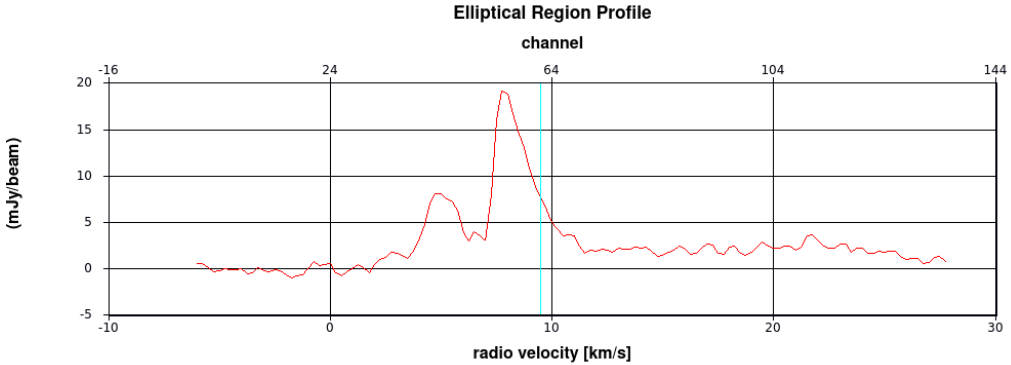
- Many others tools are available! We have many of these available on our computers
- **Contact us at alma@strw.leidenuniv.nl with questions about or requests for assistance with analysing your alma data**

Analysis Techniques

- To visualize the information we usually make 1-D or 2-D projections providing different visualisation/analysis methods:
  - Spectral profiles (1-D slices along the velocity axis)
  - Channel maps (2-D slices along the velocity axis)
  - Moment maps (integration along the vel. axis)
  - Position-velocity plots (slices along spatial dimension)
  - Movies (series of 2-D slices along velocity axis)

Spectral profiles

- Spectral profiles are 1-D slices along the velocity axis
- They can be created with the CASA viewer



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- Spectral profiles are 1-D slices along the velocity axis
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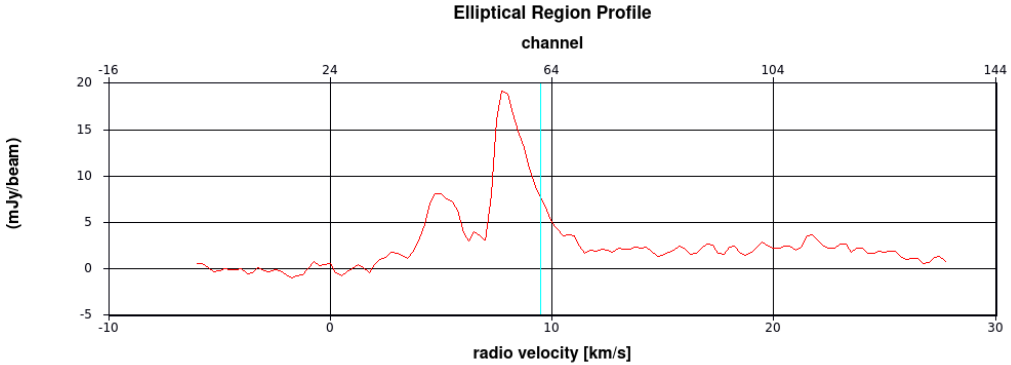


Exercise – start up CASA

- Use the “nice” command to prevent taking up all the CPU power for example for CASA
  - In (ba)sh shell: `> nice -n 10 env -u PYTHONPATH -u LD_LIBRARY_PATH casapy-660`
  - In (t)csh shell: `> nice +10 env -u PYTHONPATH -u LD_LIBRARY_PATH casapy-660`

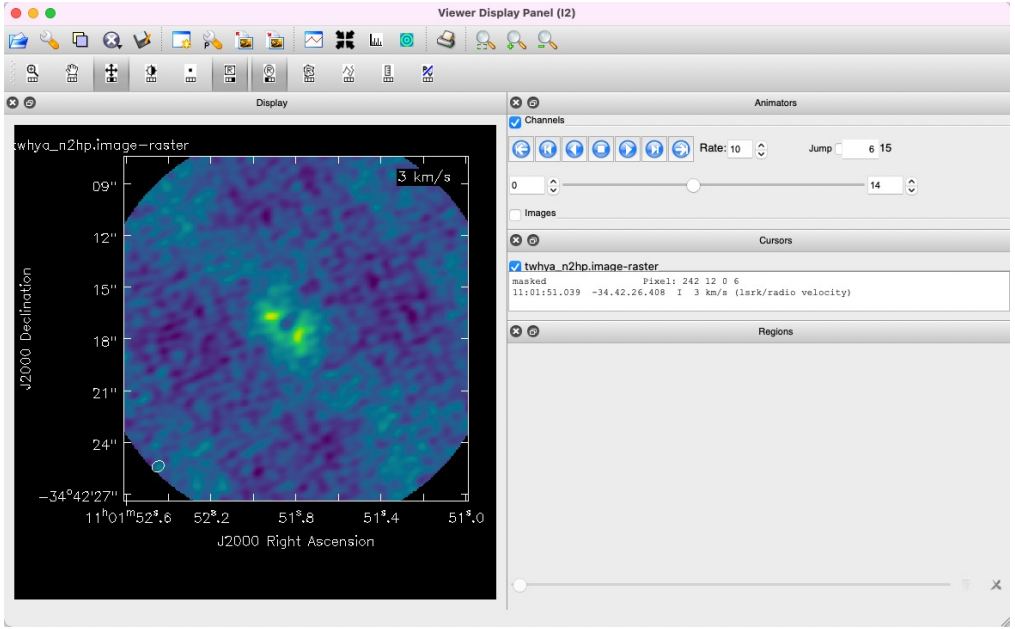
Spectral profiles

Open the casa viewer:

- CASA <1>:
  imview('twhya_n2hp.image')

NB: Also works with .fits images

- CASA <1>: imview('my_image.fits')



Exercise – Run the script

Open the casa viewer:

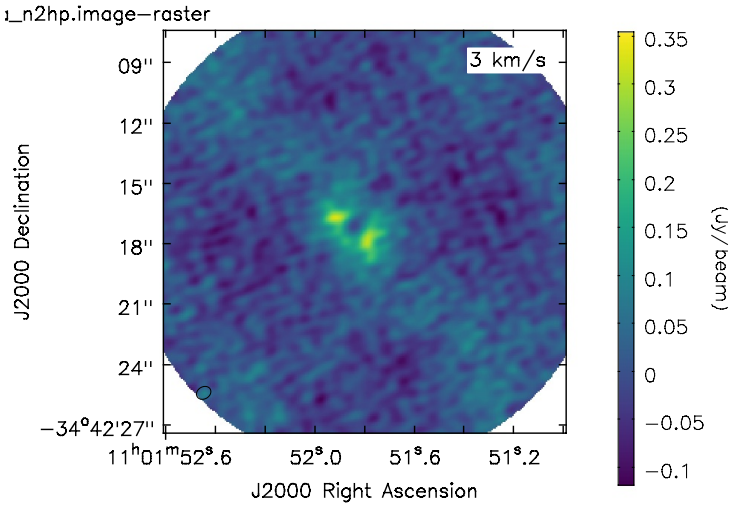
- CASA <1>: mysteps = [1]

- CASA <2>: execfile('analysis_tools_script.py')

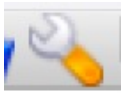
Channel maps

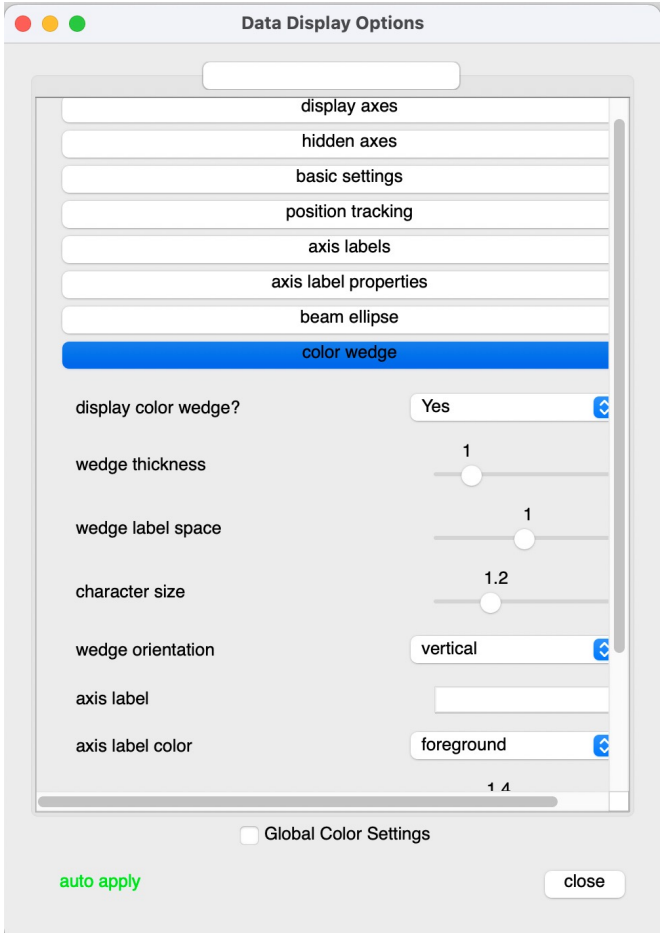
- Channels are 2D slices along the velocity axis
- Channel maps and other plots can be created in the CASA viewer

- First open the image in the viewer and select the channel you want to plot
  - `imview('twhya_n2hp.image')`

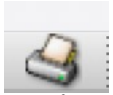


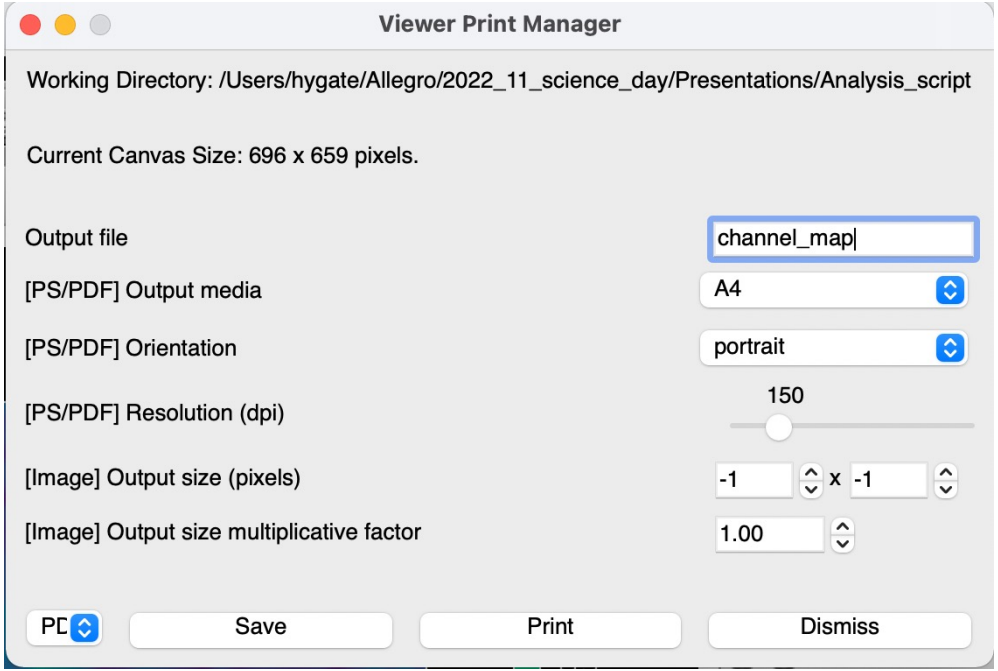
Channel maps

- Click the spanner button 
- Select options to customsise your plot
  - e.g. set “display color wedge” to true



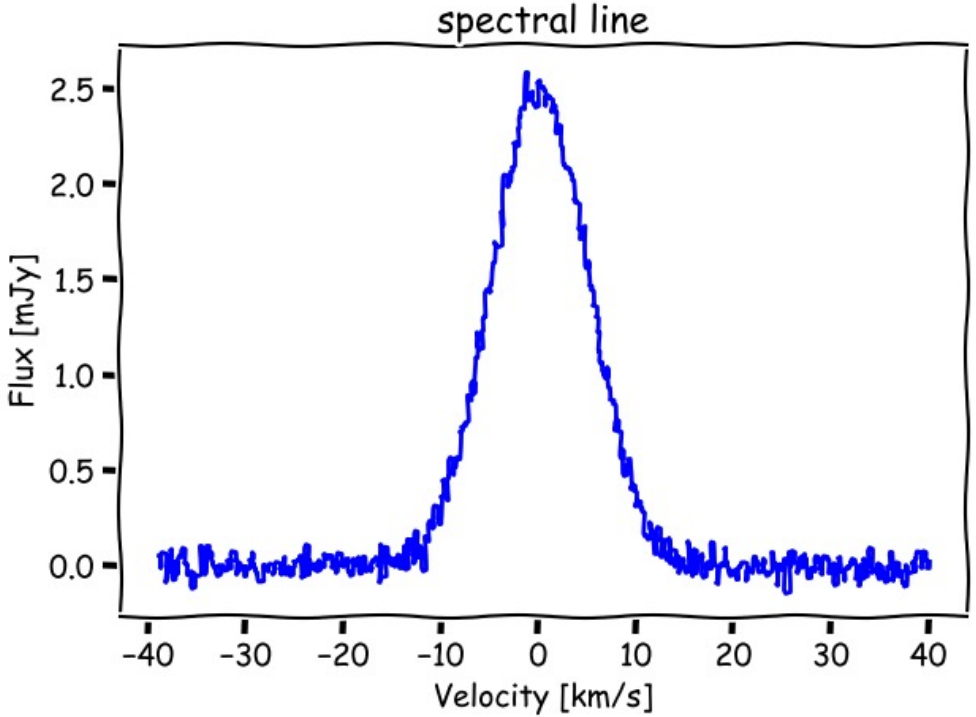
Channel maps

- Click the printer button 
- Select “pdf” (or your favourite format) from the drop down menu in the bottom left
- The same process works for any image in casa
- But you can make nicer plots with e.g. matplotlib!



Moment analysis

- Moments allow us to characterise a spectral line



Moment analysis

- **-1**: the mean value of the spectrum
- **0:** the integrated value of the spectrum
- **1:** the intensity weighted coordinate – used for velocity fields
- **2:** the intensity weighted dispersion of the coordinate – used for velocity dispersion fields
- **3:** the median of the spectrum
- **4:** the median velocity
- **5:** the standard deviation about the mean of the spectrum
- **6:** the root mean square of the spectrum
- **7:** the absolute mean deviation of the spectrum
- **8:** the maximum value of the spectrum
- **9:** the coordinate of the maximum value of the spectrum
- **10:** the minimum value of the spectrum
- **11:** the coordinate of the minimum value of the spectrum

Moment analysis

- **-1**: the mean value of the spectrum
- **0:** the **integrated value** of the spectrum
- **1:** the intensity weighted coordinate – used for “**velocity**” fields
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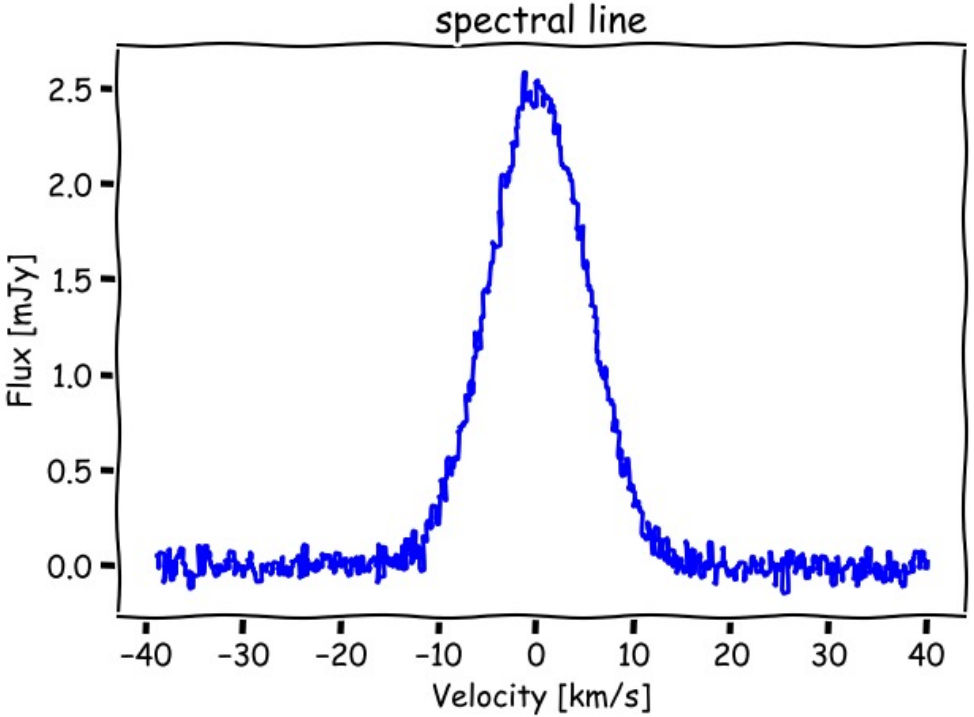
- **7:** the absolute mean deviation of the spectrum
- **8:** the maximum value of the spectrum
- **9:** the coordinate of the maximum value of the spectrum
- **10:** the minimum value of the spectrum
- **11:** the coordinate of the minimum value of the spectrum

Moment analysis

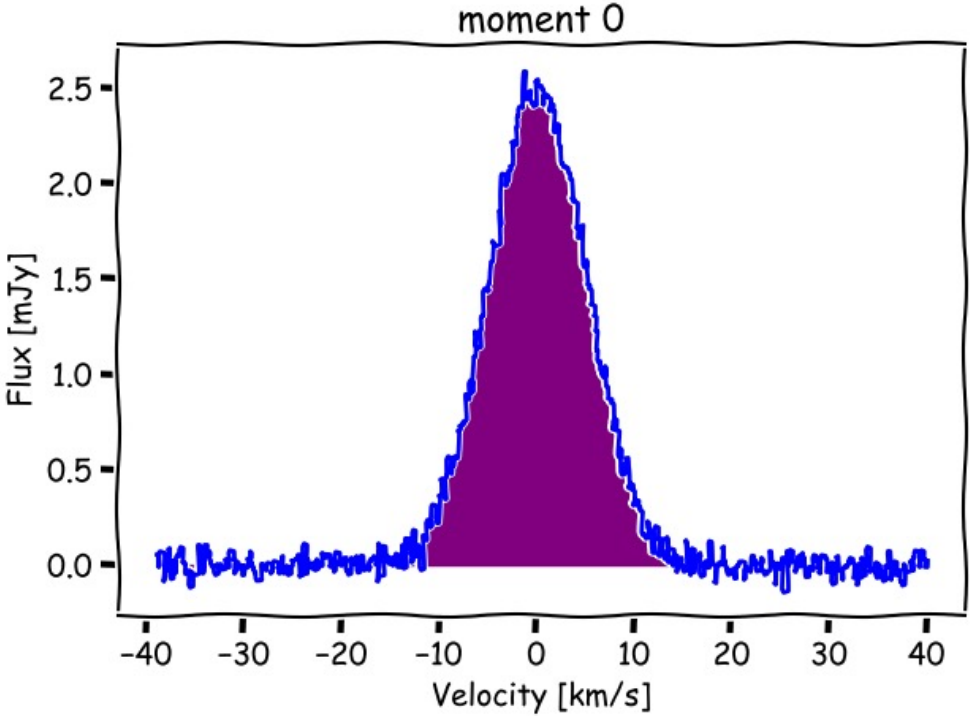
- immoments task in CASA: https://casa.nrao.edu/casadocs/latest/global-task-list/task_immoments/about
- Generally no threshold for moment 0
- Exclude noise with threshold from moment 1 or higher maps



Moment 0 – integrated flux

- CASA <1>: immoments(axis='spec', imagename='my_image', moments=[0], outfile='my_mom0')
- Normally no threshold

$$M_0 = \Delta v \sum I(v)$$

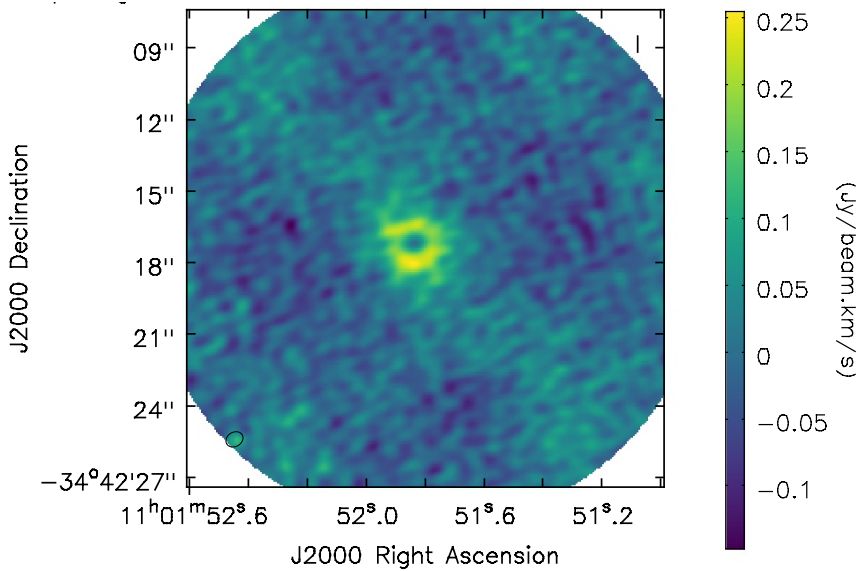


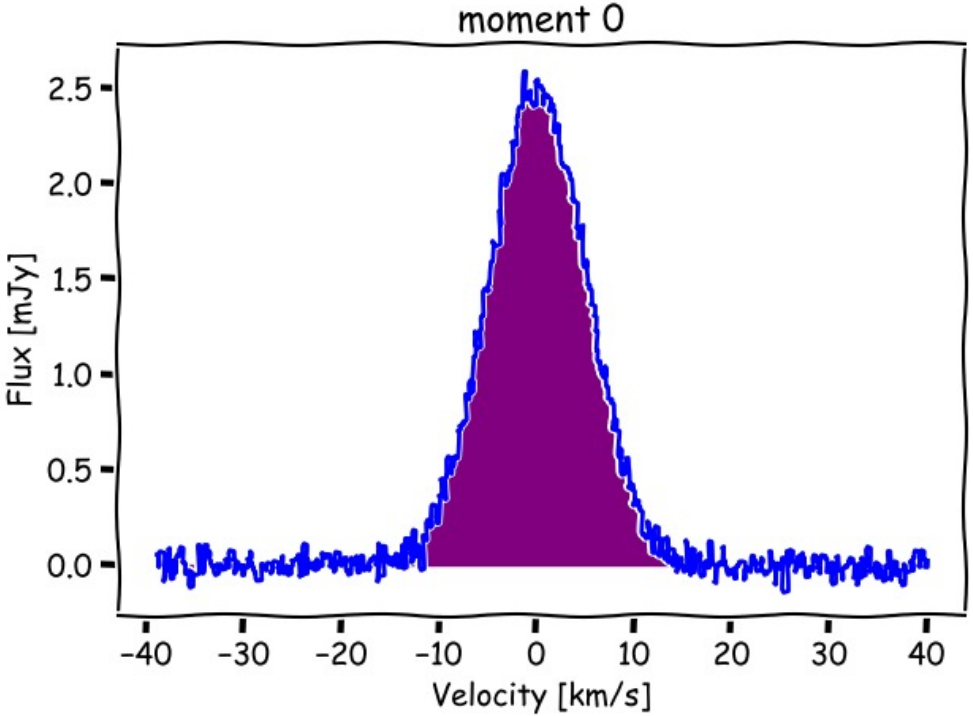
Exercise – Run the script

- CASA <1>: mysteps = [2]
- CASA <2>: execfile('analysis_tools_script.py')

- CASA <1>: mysteps = [3]
- CASA <2>: execfile('analysis_tools_script.py')

Moment 0 – integrated flux

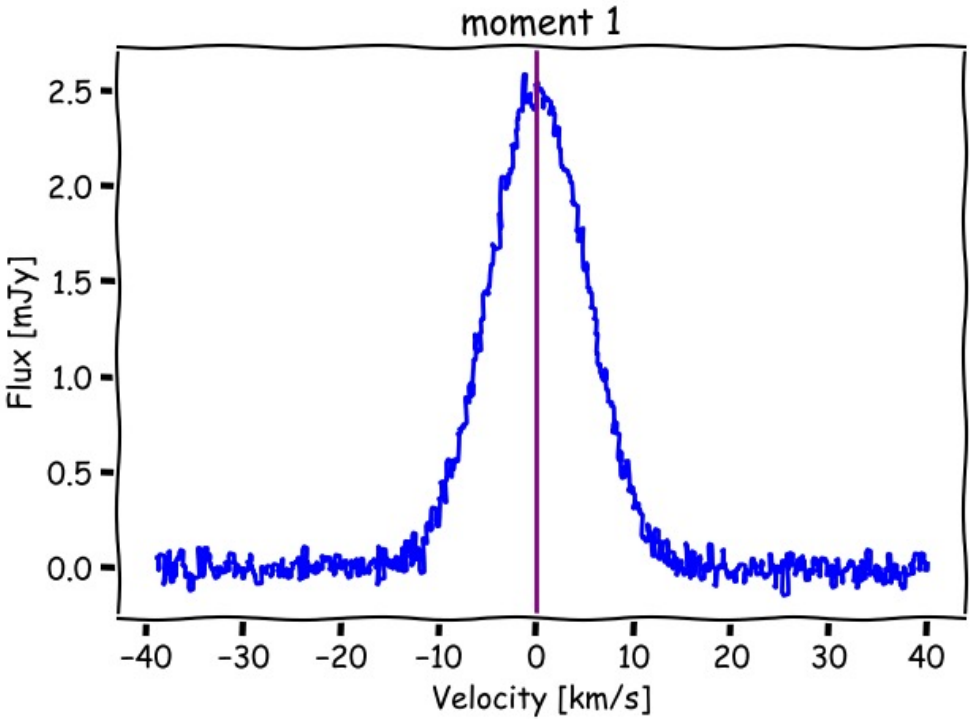




Moment 1 - Velocity

- CASA <1>: immoments(axis='spec', imagename='my_image', includepix= [3 ∗ sigma, maxpix] moments=[1], outfile='my_mom1')
- use “includepix” for thresholding. E.g. from 3σ to the maximum pixel value

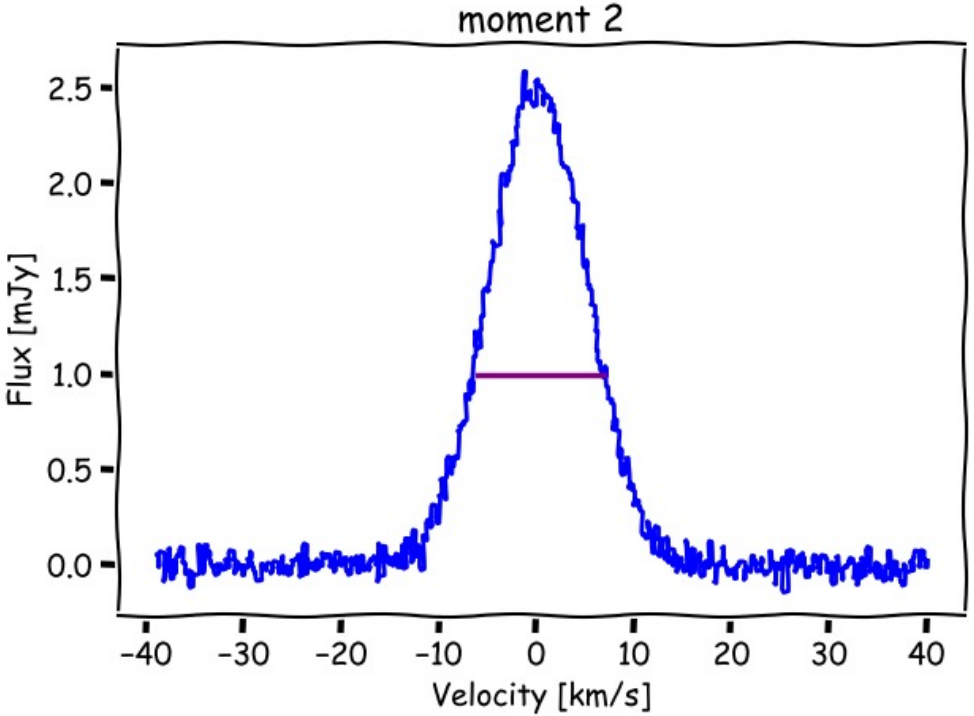
$$M_1 = \frac{\sum v\, I(v)}{\sum I(v)}$$



Moment 2 - Velocity dispersion

- CASA <1>: immoments(axis='spec', imagename='my_image', includepix= [3 ∗ sigma, maxpix] moments=[2], outfile='my_mom2')
- use “includepix” for thresholding. E.g. from 3σ to the maximum pixel value

$$M_2 = \sqrt{\frac{\sum (v - M_1)^2 \, I(v)}{\sum I(v)}}$$



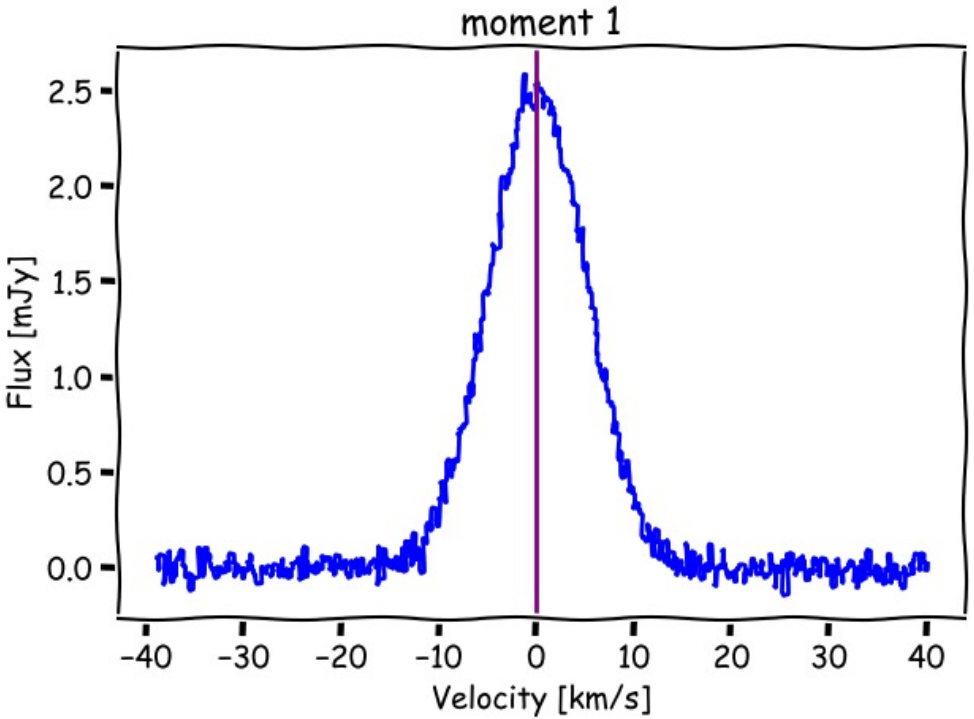
Exercise – Run the script

- CASA <1>: mysteps = [4]
- CASA <2>: execfile('analysis_tools_script.py')

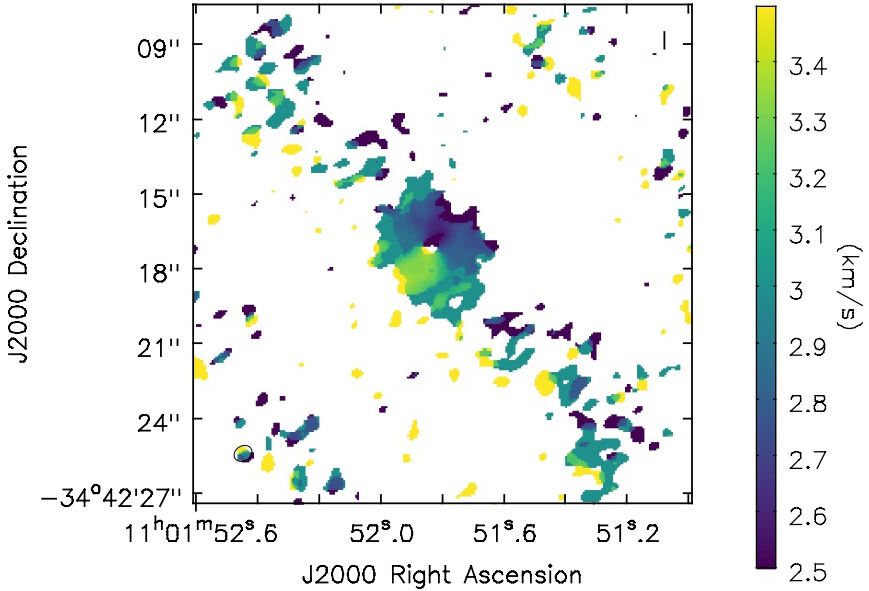
Moment 1 - Velocity

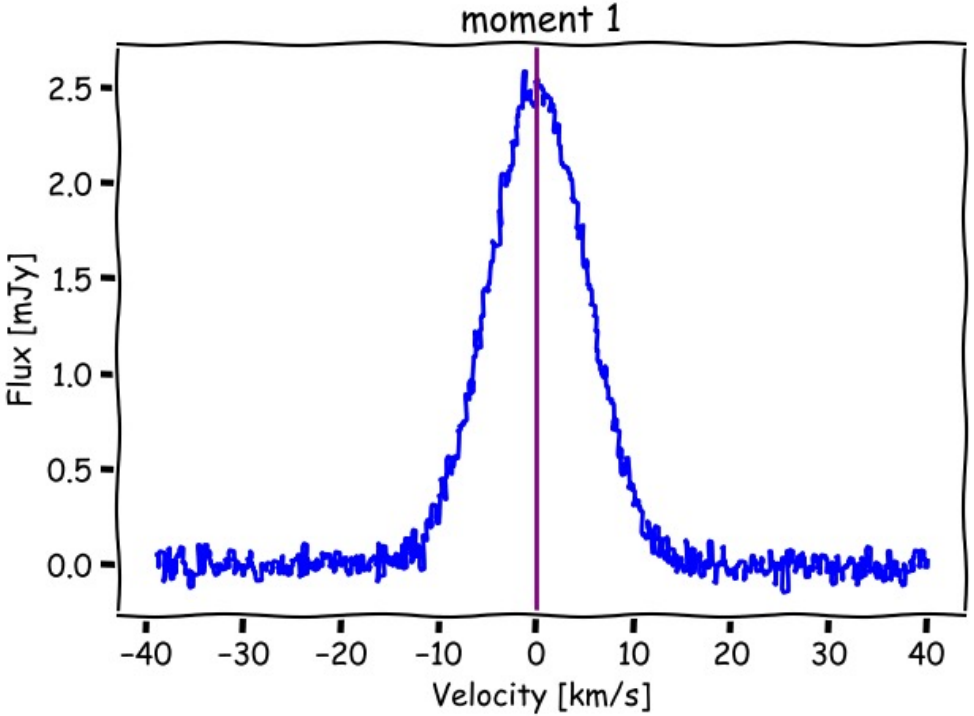
- CASA <1>: immoments(axis='spec', imagename='my_image', includepix= [3 ∗ sigma, maxpix] moments=[1], outfile='my_mom1')
- use “includepix” for thresholding. E.g. from 3σ to the maximum pixel value

$$M_1 = \frac{\sum v\, I(v)}{\sum I(v)}$$



Moment 1 - Velocity





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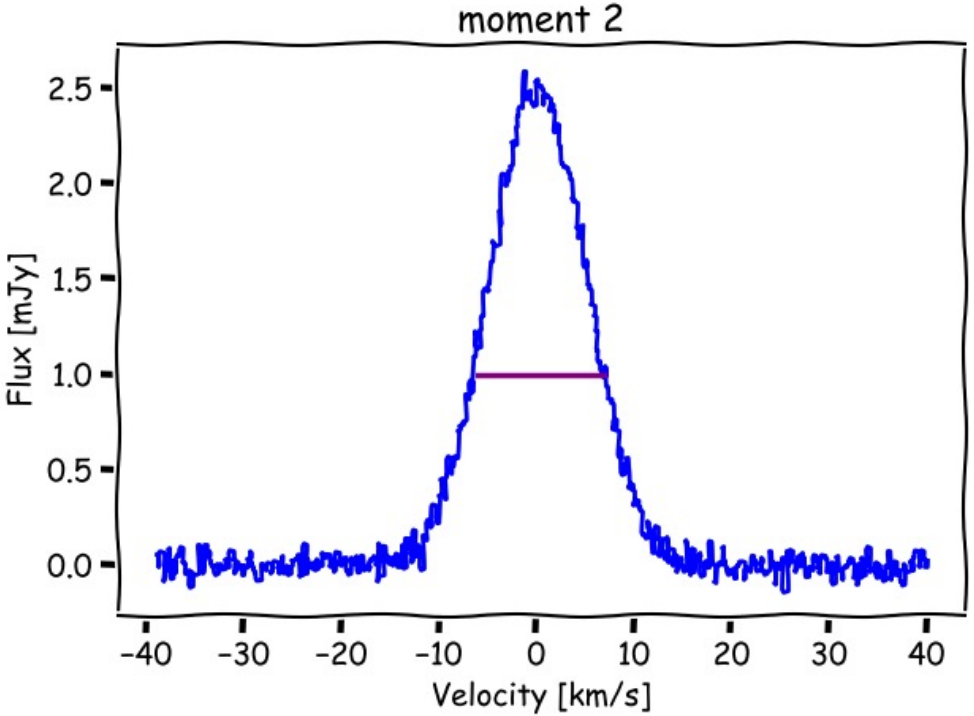
- use “includepix” for thresholding. E.g. from 3σ to the maximum pixel value

$$M_2 = \sqrt{\frac{\sum (v - M_1)^2 \, I(v)}{\sum I(v)}}$$



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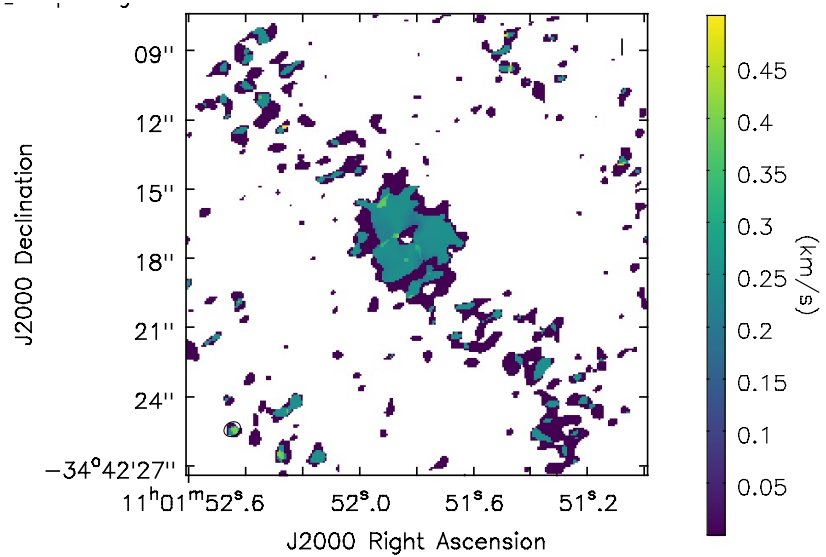
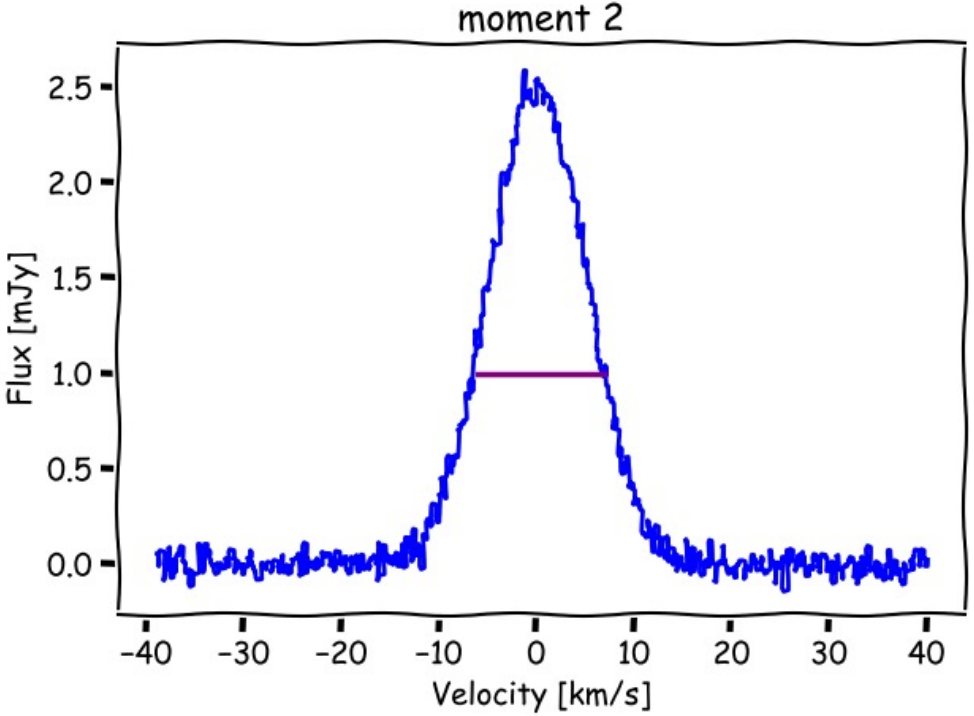




Exportfits

- Export your image to a .fits file for use with other software (e.g. ds9, python…)

- CASA <1>: exportfits(imagename='twhya_n2hp.image',
- …: fitsimage='twhya_n2hp.image' + '.fits')

Exercise – Run the script

- CASA <1>: mysteps = [5]
- CASA <2>: execfile('analysis_tools_script.py')

Modelling - imfit

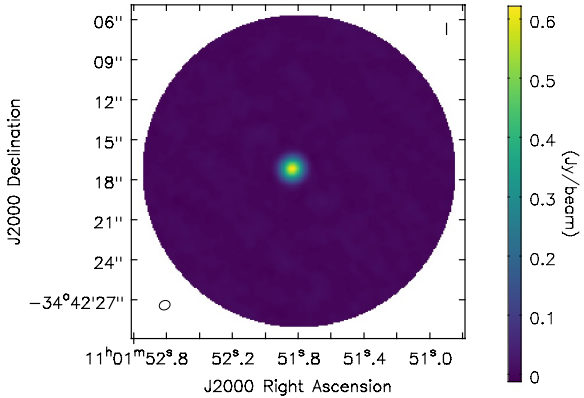
- CASA <15>: imfit(imagename="sis14_twhya_cont.image",
- ...: region="imfit_region.crtf", logfile="contin_fit.log",
- ...: model="sis14_twhya_cont.image.imfit",
- ...: residual="sis14_twhya_cont.image.fitresid")

Exercise – Run the script

- CASA <1>: mysteps = [6]
- CASA <2>: execfile('analysis_tools_script.py')

Modelling – assessing results

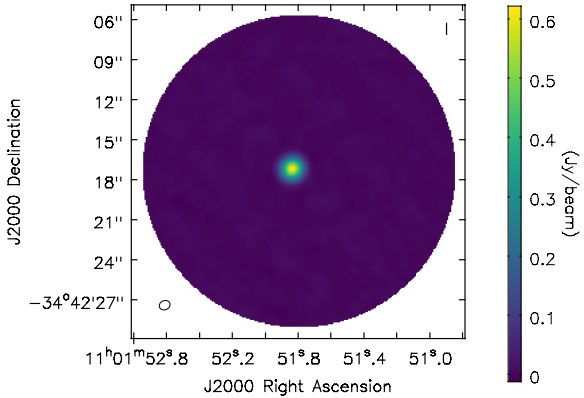
Image



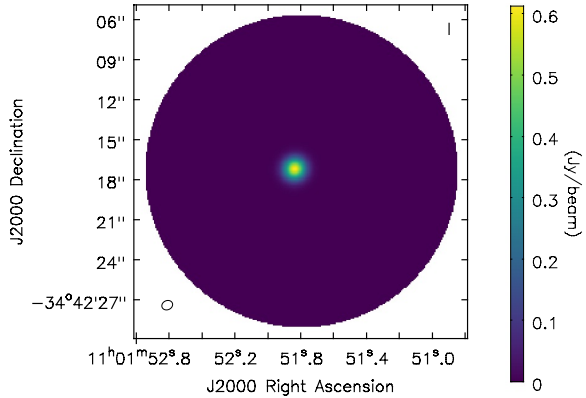
Let's check our model

Modelling – assessing results

Image



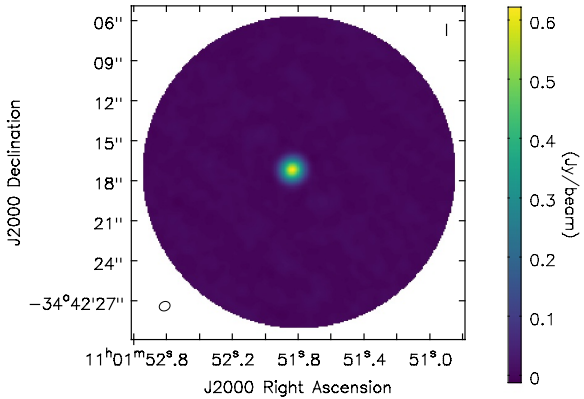
Model



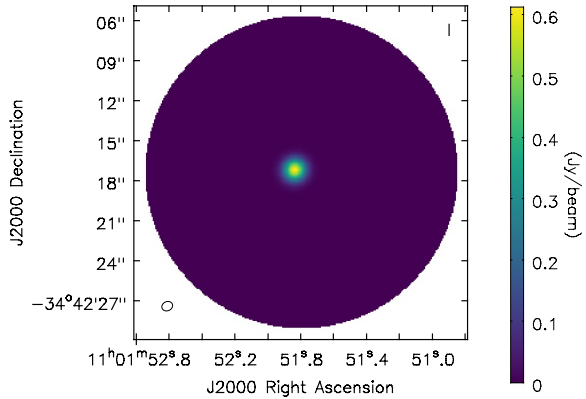
Looks like a reasonable fit… but let's check the residuals…

Modelling – assessing results

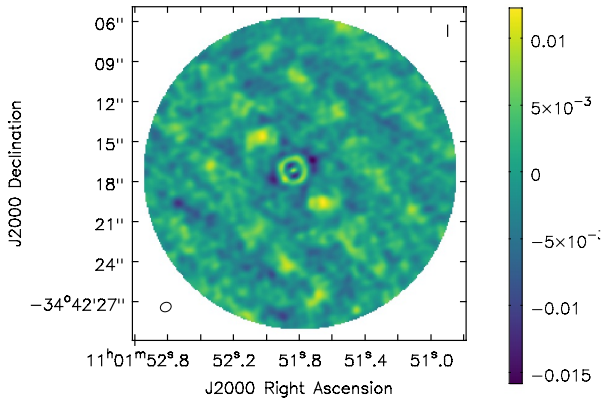
Image



Model



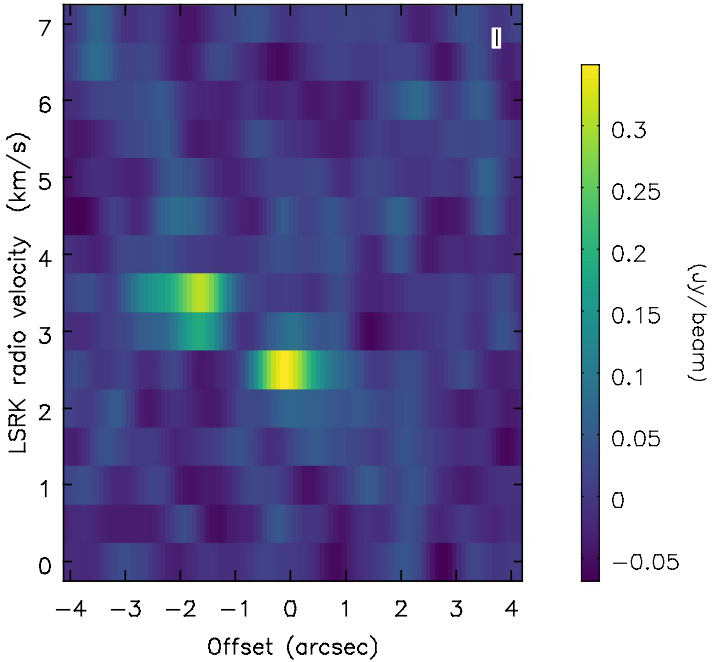
Residual



Position-Velocity (P-V) Diagrams – Interactive

- CASA <1>: mysteps = [7]
- CASA <2>:
  execfile('analysis_tools_script.py')

- Click the pv button



Position-Velocity (P-V) Diagrams – automatic

- CASA <1>: mysteps = [8]
- CASA <2>: execfile('analysis_tools_script.py')

Re-gridding images – run the script

- CASA <1>: mysteps = [9]
- CASA <2>: execfile('analysis_tools_script.py')

- imregrid(imagename='twhya_n2hp.image',
- template='GALACTIC',
- output='twhya_n2hp.image' + '.galactic')

Bonus - Movies

- **ds9** my_cube.fits **-cmap** viridis **-scale** limits min max **-movie** slice gif movie.gif **–exit**

- http://ds9.si.edu/doc/ref/command.html#movie
- If this fails update DS9, or for a worse-looking movie try:
  - **-cmap** bb
  - **-movie** slice movie.mpeg

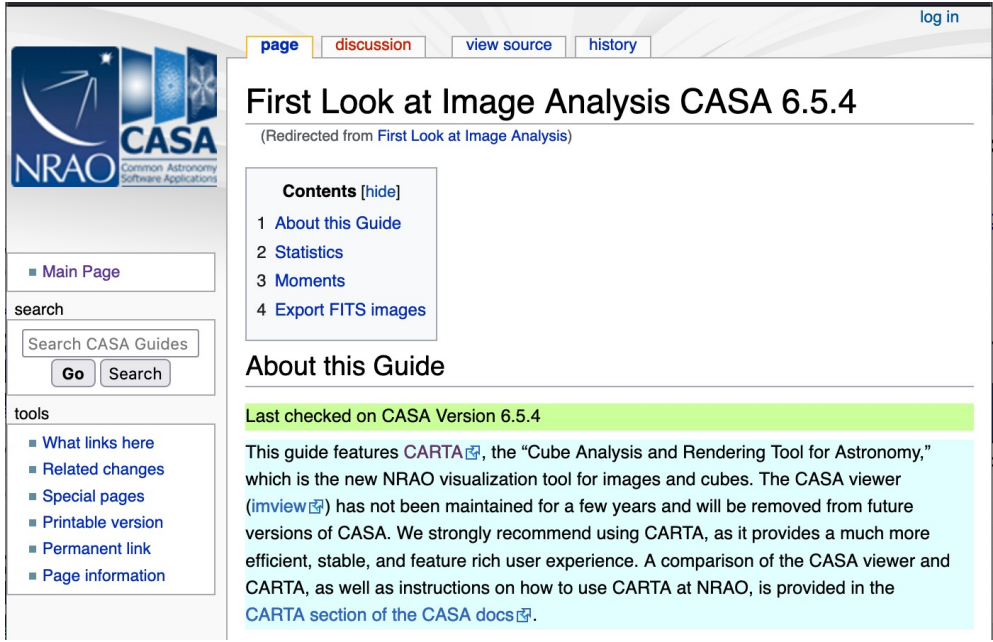
Exercise – Run the script

- CASA <1>: mysteps = [10]
- CASA <2>: execfile('analysis_tools_script.py')

Where next? CASA guides

https://casaguides.nrao.edu/index.php?title=First_Look_at_Image_Analysis_CASA_6.5.4

- Short tutorial on image analysis in CASA



Where next? Itrain

https://almascience.eso.org/tools/eu-arc-network/i-train

- Video tutorials for some packages, for example:
  - I-TRAIN #3: UVMultiFit
  - I-TRAIN #9: Stacking spectra in the image domain with LineStacker

Where next? Allegro software list

- List of ALMA-related software tools hosted by allegro.
- Will be announced soon – sign up to our newsletter to stay informed
- Newsletter: http://bit.ly/AllegroNews

Resources

- CASA documentation: https://casa.nrao.edu/casadocs/latest/
- CASA guides: https://casaguides.nrao.edu/index.php?title=First_Look_at_Image_Analysis
- CASA cookbook: https://casa.nrao.edu/Doc/Cookbook/casa_cookbook.pdf
- Download CASA: https://casa.nrao.edu/casa_obtaining.shtml
- Download DS9: https://sites.google.com/cfa.harvard.edu/saoimageds9
- EU arc network tools: https://almascience.eso.org/tools/eu-arc-network-tools

- Allegro maintains a number of analysis tools on our computers
- **Contact us at alma@strw.leidenuniv.nl with questions or requests for assistance with your alma data**