Moment maps of neutral gas in emission

MSc - II Practical

I. The data

Spectral cubes contain information about the spatial extent and brightness of a celestial object, with wavelength/velocity acting as the third axis of the cube. These data cube files are stored in the astronomical-standard FITS format. Further details may be obtained from the header.

This exercise will use the H I 21 cm line emission data from the HI4PI survey (HI4PI Collaboration 2016). This transition occurs due to the flipping of the electron spin in a hydrogen atom. The parallel spins of the nucleus and electron become anti-parallel with respect to each other after the flip in the electron spin. The energy given out in this process is the 21 cm radiation. Such radiation mainly comes from cool gas in the Galaxy and elsewhere in the Universe.

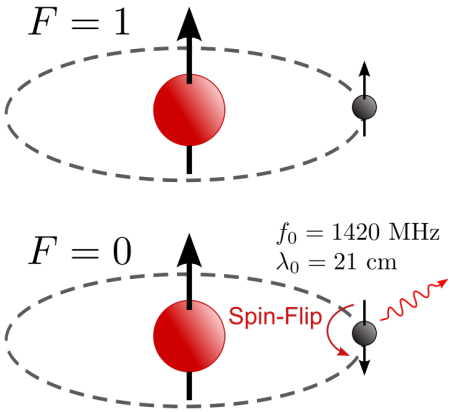

Figure 1: H I 21 cm transition; Credit: `https://en.wikipedia.org/wiki/Hydrogen_line`

II. Moment maps

Moments help extract spectroscopic details from the data cube. For example, the 0th moment yields the integrated intensity over a spectral line (unit: K km s^{-1}). The 1st and 2nd moments provide insight into the intensity-weighted velocity of the spectral line (unit: km s^{-1}) and its velocity dispersion (unit: km^2 s^{-2}) respectively. Mathematically, these are obtained through the following integrals:

$$M_0 = \int I_\nu d\nu \tag{1}$$

$$M_1 = \frac{\int \nu I_\nu d\nu}{\int I_\nu d\nu} \tag{2}$$

$$M_N = \frac{\int I_\nu (\nu - M_1)^N d\nu}{\int I_\nu d\nu} \tag{3}$$

III. Practical exercise

- Download the FITS file: `http://cdsarc.u-strasbg.fr/vizier/ftp/cats/J/A+A/594/A116/CUBES/GAL/TAN/TAN_C14.fits`

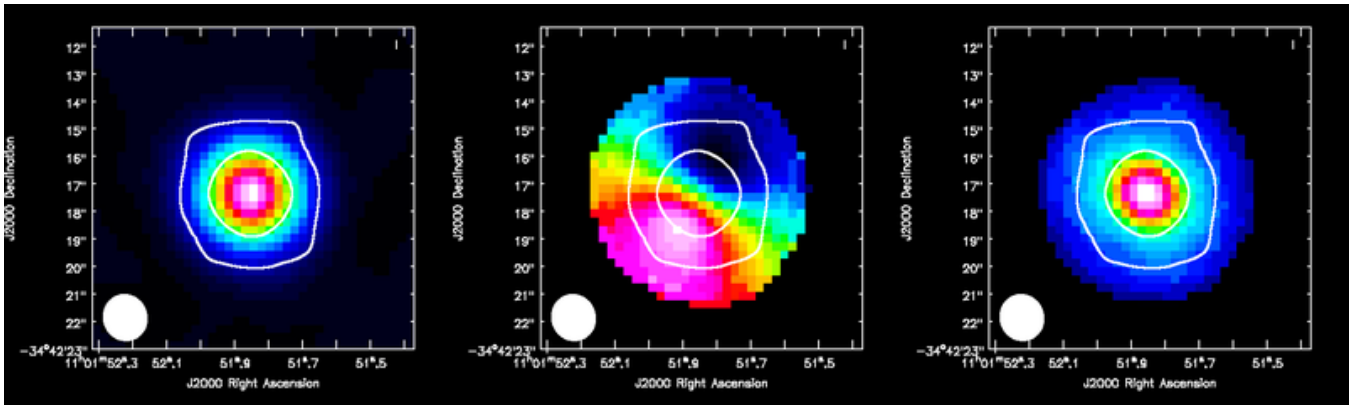

Figure 2: Moment maps using ALMA observations of HCO^+; Credit: `https://casaguides.nrao.edu/index.php/TWHydraBand7_Imaging_4.2`

- Open the FITS file and read the data using the appropriate function with the package SpectralCube.
- Use the *quicklook()* method to slice through the data cube in different ways. Slice the cube along the spectral axis and capture the output for 4-5 such cases. Extract a spectrum from the cube and capture the output for 4-5 such cases.
- Use the *world()* method followed by *subcube()* and *spectral_slab()* to cut out a small part of the entire datacube. For this the latitude, longitude and velocity details will need to be provided.
- Execute the *moment()* commands that compute the 0th and 1st moments.
- Using the World Coordinate System (WCS), display the moment maps.

IV. References

`https://spectral-cube.readthedocs.io/en/latest/moments.html`
`https://notebook.community/adrn/tutorials/notebooks/FITS-cubes/FITS-cubes`
`https://ui.adsabs.harvard.edu/abs/2016A%26A...594A.116H/abstract`

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