Dealing with low S/N high-redshift Integral Field Spectroscopic (IFS) Data

After this exercise you would:

- Get more comfortable with IDL coding
- Learn how to manipulate 3D datacubes
- Grasp the concept of co-adding data and characterising the errors of the co-added datacube

Background of the data you are going to deal with:

In 2011 we reported the metallicity gradient of a gravitationally lensed high-redshift spiral galaxy. The data you are going to use is from Yuan et al. (2011, ApJ, 732). The data were collected from the adaptive-optics aided Integral Field Spectrograph (IFS) instrument OSIRIS at KECK. Don't worry, we are not going to let you reduce the raw data. You are mostly going to experience some of the fun processes that we have to go through in order to dig out the signal from noise-dominated high-redshift data. This project will give you a good feeling of what the challenges are in analysing low S/N, high-redshift IFS data. It is also a good practice for your IDL coding skills.

The assignment datacubes can be downloaded from here:

https://www.mso.anu.edu.au/~chfeder/teaching/astr_4004_8004/material/high_z_galaxy/high_z_galaxy.tar.gz

Steps:

1. You are given 19 3D datacubes of a lensed spiral galaxy that are obtained from 19 individual exposures in the observations. Read in one of these cubes in IDL (note that these are .fits files). Learn how to extract the spatial and wavelength information from the datacube.
2. For the original datacube, which dimension is the wavelength, which is RA and which is Dec? How did you come up with the answer?
3. Now transpose each datacube such that the first dimension is RA, the 2nd dimension is Dec, and the third dimension is the wavelength.
4. Please install ds9 or qfitsview if you want a more intuitive look at the IFS data. After you understand the IFS data, you should be able to generate a wavelength-collapsed (see hint *h1 below) 2D image for any of the 18 datacubes.
5. The redshift of the galaxy is about 1.489. Now generate a 2D H-alpha image from each datacube? Also please describe how you generated the H-alpha image.
6. Co-add the 18 datacubes and generate a final co-added 3D datacube that has the best S/N in the H-alpha emission line detection. (see hint *h2 for help)
7. (optional) Calculate the associated error cube from the above steps.

Please send us your IDL codes as well as a short description of how you did each step (you can add those descriptions in your IDL codes)

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Hints:

*h1: wavelength-collapsed: take the median in the wavelength direction

*h2: the datacube is dominated by sky noise, cosmic rays, and instrument background (imperfect flat-fielding). To get the best S/N in emission lines (in our case H-alpha), please fit a linear function to the continuum in the spectral direction for each spatial pixel, and subtract it out from each spaxel (pixel in wavelength direction). This will help you subtract the imperfect flat-fielding for the price of losing the first-order continuum of the science object (however, we don't care so much about the continuum of the science object anyway).

*h3: (optional) There may be some spatial shift among the 18 data cubes, i.e., the center of the spiral galaxy could have some offsets among the 18 datacubes. If you can find a way to determine the offset, the S/N of the co-adding can be improved by correcting for the offsets.