Spectroscopy Notes

From talk given by Hugh Allen, 23/04/16

Capturing a Spectrum

1) Pick a target – start with A or B class stars with nice clean obvious spectra.
    a. Double stars look awesome but make sure spectra can be distinguished.
    b. Comets, Supernovae, variable stars, quasars, even planets are good.
       Shelyak –double whose motion can be measured using spectroscopy over a few days !
    c. Build a database of targets, thinking about what will be visible at different seasons.
    d. See what others are imaging – Yahoo groups, FB groups. (OAS Spectroscopy)
       Look for science projects – eg BESS database

2) Find it – might be easy with gotos, but learn your sky!
    a. Use SIMBAD to find fainter objects
    b. Use MPC to find domets and asteroids (MPCES)
    c. Use AAVSO to monitor variable stars

3) Position it correctly in the FOV = left hand side, spectrum going to right
    a. Make sure spectra don't overlap – watch out for faint stars in line with your target!
    b. Can image two objects at once but spectra must be vertically above each other

4) Find a reference star.
    a. For every session you need a reference star.
    b. You cannot reuse between sessions, as air quality etc change.
    c. The ref star should be an A/B type star with strong H lines
    d. Should be close to your target so you get similar air effects
    e. Capture it at around the same time, so the air quality is the same
    f. MILES database useful to find reference stars

5) FOCUS!
    a. With an SA, focus on the spectrum – will be slightly different to the star.
    b. Use a bahtinov mask to get close.
    c. With the SA, capture several spectra to find the best focused one
    d. Practice !!!!

       (Alpy is different, you focus offline then focus the guide camera off the slit then move the slit onto the target.)

6) Exposure – aim for 80% saturation at peak
    a. Use Rspec pixelmap to check saturation – aim for 80% saturation by ADU.
    b. So for an 8-bit camera, aim for 200
    c. For a DSLR (14-bit) aim for 13000
    d. For a 16-bit camera aim for 52000
    e. It doesn't matter if the zero order is saturated

7) Exposure for faint targets
    a. Will have light pollution hot pixels etc
    b. So take darks and flats, as per normal astroimaging
    c. Stack 6-10 frames.
    d. Watch out for background stars !!

8) Binning, Bias, Darks and Flats
    a. The usual image processing to remove artefacts and noise
    b. Rspec vertically bins between the yellow lines
    c. Can also bin horizontally – will smooth out noise but lose resolution

9) Saving the data
    a. Use a good naming scheme
    b. As ref stars are specific to session, recommend date then star name eg
       2016-04-23\Altair
       2016-04-23\Vega-ref

Using RSpec

1) Load the image

2) Adjust till horizontal

3) Move yellow lines to +/- 10 pixels of the spectrum – use zoom fn if needed

4) Check saturation is ~ 80% using the pixelmap

5) Subtract background.

6) CALIBRATE
    a. Draw box round a peak
    b. Control-drag to cover a line
    c. Click on a pixel and enter a wavelength value
    d. Repeat for 3 or 4 more lines at least
    e. Choose 3rd order fit
    f. Click calculate
    g. Save the calibrated curve
    h. Then Apply.
    i. Set as the Reference Curve

    j. Look up the star's spectral class
    k. Load an ideal curve from the Rspec reference library
    l. Crop off out of range data (outside 4000-7000A typically)
    m. Delete absorbtion lines
    n. Use spline smoothing to determine continuum of the ideal reference curve
    o. This creates a smoothed ideal continuum.
    p. Divide the reference star by the ideal continuum
    q. Again remove all lines then smooth
    r. This generates a curve for correcting the target stars.
    s. Save this curve!

    We now have a calibrated continuum which we can apply to the targets

Background information and notes

Robin Ledbetter is the UK expert = threehillsobservatory.co.uk

Basics

SA 200 is a blazed diffraction grating – throws more light to one side than the other, so positioning is important.
Alpy is a slit spectroscope – creates nonlinear spectrum.

The length of the spectrum depends on grating spacing and camera-grating distance. Use online calculator on rspec site to check optimal

$$m\lambda = \sigma \sin\theta$$

Where

m = order of spectrum
sigma = spacing in lines/mm
lambda = wavelength of light in mm
and theta is the angle the light will be thrown to

Diffraction gratings are pretty linear though the spectrum is slightly curved (projected onto a sphere?).

You will <u>always</u> get Sodium lines... its everywhere....

Setup

The spectrum should be arranged with the zero order (star) on the left side of the screen, the spectrum stretching horizontally across the sensor.

Rspec bins the data vertically, so spectrum should run horizontally. Try to get it right on camera then adjust if necessary in Rspec, but you will lose some resolution

Make sure the whole spectrum = ~4000A – fits on the chip.

To calibrate you will need to know the physical dimensions of your sensor – width and pixel size.

Dispersion and Resolution

Dispersion – low is better

SA 200 = 7.5 A/pixel

Resolving power = $\lambda/\delta\lambda$

Target resolution is delta-lambda = 3 pixels to allow two adjacent lines to be distinguished (ie you want one light pixel between the two dark ones where the lines are)

So the best you can get from an SA200 is 3x7.5 = 22 Angstroms.

Hence resolving power is about 200 (4000A / 22A)

SA200 resolution affected by focal length – best is ~ F/5 to F/6 – so with the RC8,the Focal Reducer might be helpful? But then get the camera further from the grating.

Typical exposure time – alderamin 2 seconds

Shape of lines

Depth is a fraction of the continuum
Need to normalise the spectrum wrt this continuum
Equivalent Width EW = width of rectangle that has the same area as the line but extended from the continuum down to zero.
FWHM – usual meaning
To resolve lines, they must be separated by at least 1x FWHM
Width of lines depends on many factors – gas pressure in the star (so red giants narrower?)
This makes it hard to measure spectra of nebulae with SA200 – need a slit spectroscope really
Nebulae will be mostly narrow emission lines

To calibrate

1) Need to adjust for the Quantum Efficiency curve of your camera (QE curve). This shows the response of your camera at different wavelengths.

2) Need to adjust for atmospheric effects – absorbtion by water, CO_2 etc - which also depends on the elevation of the object. Easier to correct if the target is > 30 degrees up.

   Aside: Air mass = mass of air between observer and star – depends on sine of elevation. So at zenith, AM=1 whereas at 34 degrees, AM=1.8

3) Need to account for any nonlinearity of the spectrum, so calibrate nonlinearly – less important with SA200 than with spectrographs