Practical Spectroscopy **K M Harrison**

Gratings – Introduction

Never touch the surface of a grating – death is imminent
Different lines/ mm (l/mm) give different dispersion
Diffraction gratings deviate different wavelengths by different angles
The difference in the deviation angles gives the dispersion (A/pixel (CCD), A/mm (film)
Dispersion is not the same as resolution
Resolution is approx x2-3 the dispersion (10A/pixel = 20-30A)
R value = wavelength/ delta
Gratings produce multiple spectra – Zero order plus 1st order (brightest), 2nd Order etc.
Blazed gratings provide a bright 1st Order spectrum
The dispersion per order is almost constant. 2nd order dispersion is x2 the 1st order
Spectral orders start to “overlap” around 7800A – Free spectral range/ sort filters
Any telescope, any camera – almost!
Reflecting telescopes - no chromatic issues
Mono cameras give better performance
Use the bright (blazed) 1st order spectrum
Similar set-ups give similar dispersions
Align the spectrum across the horizontal axis of the chip.
Focus on the spectrum, not the zero order star image
Faint objects require LONG exposures (>60 mins)
Don’t over expose the subs (clipping)
Aim for maximum SNR (maximum signal)
Use darks (flats optional?)
NO “pretty picture” processing!

Transmission Gratings

Usually the Star Analyser (100/200 l/mm)
Available 100, 200, 300, 600 l/mm
Sizes up to 50mm square
Slit-less operations – shape of zero order determined by source (star size)
Resolution determined by source size – usually 20-30A
Normally shows the full visible spectrum (4000-7000A)
Higher resolution when used as objective grating – lenses>50mm fl
Converging beam arrangement – spacing/ f ratio/ camera pixel/ frame size
Suitable for all telescopes but “sweet spot” f4-f5
Increasing spacing (dispersion) doesn’t increase resolution
Can be “upgraded” with grism (best with l/mm > 200)
Can be adapted to use a slit arrangement (ALPY, CCDSpec)

Reflection Gratings

Used in a spectrograph – slit/ collimator/grating/imaging/camera
Commercial instruments: LhiresIII, LISA, DADOS
Available 150, 300, 600, 1200, 2400 l/mm
Sizes up to 50mm square
Normally used with >f7 telescopes
Narrow spectral coverage – grating rotation to centre wavelength

Slit gap defines the resolution (x2-3 pixel size)
Needs telescope guiding to hold target on slit gap
Reflective slit plate/ beam splitter allows effective guiding
Focus target on slit gap
Allows the use of reference lamp for calibration (Neon/ RELCO)

<u>Setting up the Grating/ spectrograph</u>
NEVER touch the grating surface!
Rigid spacers (transmission)
Using the blazed 1^{st} order
Problems using filter wheels (transmission)
Alignment of spectral image (transmission)
Exposures – maximum signal
Drift in Dec – widen the spectral image (transmission)

Focus – camera to slit/ telescope to slit (slit)
Calibration of the grating rotation (slit)
Adaptors/alignment/balance (slit)
Finding the target/ target on slit/ guiding on target (PHD2/ AstroArt etc.) (slit)
Image acquisition software – Darks/lights/stacking

Spectral Image Processing
Object: To produce a usable, calibrated, corrected 1D FITS profile

Freeware software – BASS Project, ISIS, VSpec (Midas/ IRAF)
Payware - RSpec – nice but limited
RTFM

<u>Pre-Processing</u>
Standard AP imaging processing packages – AstroArt, Maxim etc.
Darks/ Lights/ stacking
Crop spectrum (+/- 50 pixel)
Check for clipping (quick profile)
Always work with blue to LHS (flip image if necessary)
If using reference lamp –use same grating setting/ don't over expose
Crop reference to match spectral image
Save as FITS

<u>Initial Processing (target and reference)</u>
Tilt removal
Slant removal (slit)
Smile removal (slit)
Select spectral height
Select background removal zones
Note interfering bright star images!
Save as FITS

<u>Calibration</u>
Use Zero image and at least one know feature (transmission)
Use Zero order and known dispersion (transmission)

Use known reference lines (slit)
Aim for minimum RMS error (Quadratic solution)
Normalise (rescale)
Measure R value/ SNR
Save as FITS 1D

<u>Instrument Response</u>
IR corrects for camera/ grating response curve
Use either a Pickles/ Miles reference spectrum or known reference star (at similar altitude)
Divide target by reference
Smooth the data (IR curve) if necessary
Watch for crappy "end" results – crop limits to suit.
Divide target by IR to confirm results.
Note: the IR can be re-used on other spectra
Save as FITS
BESS data submissions/ FITS headers

<u>Analysis</u>
Very difficult!
Good sources required
Reading compulsory
Start with OBAFGKMRNS sequencing
Recognise the Balmer series!
Understand effects of temperature, Doppler and rotation of spectrum
Be stars, variable stars, Novae, Campaigns and ProAm

Digital Spectroheliograph (SHG)
SHG invented by Hale/ Deslandres in the 1890's
Means of recording the solar chromosphere
Used a scanning slit and imaging slit combo
Uses the solar spectrum to present a series of line scans which when combined build up an image (spectroheliogram)
Digital revolution – CCD/ webcams around 2000 - no more imaging slit
Smaller compact instruments
Telescope/slit/spectrograph/camera
Use the sidereal rotation to scan the Sun (120 seconds)
Any wavelength, any bandwidth
High resolution allows "science" – Zeeman effects, Doppler effects, Magnetograms