Variable Star Section

British Astronomical Association

Spectroscopy Workshop
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Download from dropbox at http://tinyurl.com/NLO-workshop

How we do Spectroscopy

An Overview

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HOW WE DO SPECTROSCOPY OVERVIEW

- Project
- Equipment
- Observations
- Data Reduction
- Measurements

The Project

- What is the target and what are we trying to find out about it ?
- What do we need to measure ?
  - Wavelengths, resolution, SNR
  - What precision and accuracy do we need ?
- How often and how long for ?
- Will data from several observers be combined ?
  - Use common procedures and measure a standard reference
  - Set up a group to coordinate observations and compare results

Armed with this information we can then plan how best to proceed, identifying what will perhaps need particular attention, and what does not matter.

The Equipment

- The Spectrograph
  - The universal spectrograph does not exist so may need to concentrate on specific project areas eg resolution/magnitude (or own two or more spectrographs !)
- Ancilliary equipment
  - Cameras, wavelength calibration and flat lamps, control software
- The telescope and mount
  - Match the spectrograph and telescope focal ratio
  - Beware of chromatic aberrations
  - Good tracking and guiding capability
  - May need to consider load carrying capacity
- The Observatory
  - Spectroscopy is much easier with a permanent setup
  - Some spectrographs can be controlled remotely

Paton Hawksley
Star Analyser
~50A £100

Shelyak ALPY
10 A
£500-1100-1600

Shelyak
LHIRES III
10-0.3A
£2300

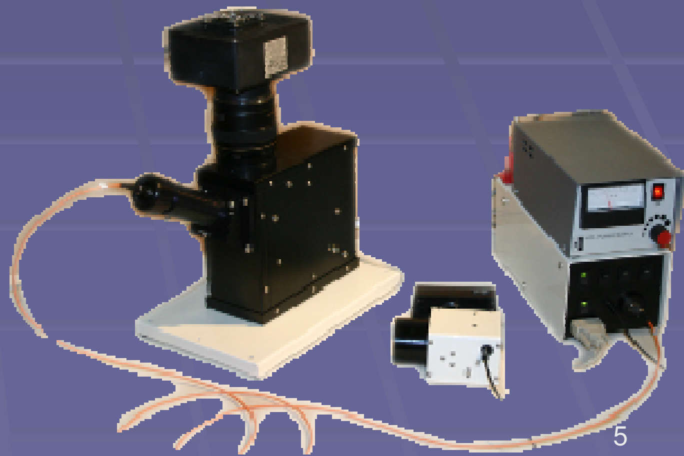
JTW
L200
12-0.9A
£1300

Shelyak
LISA
6 A
£2300

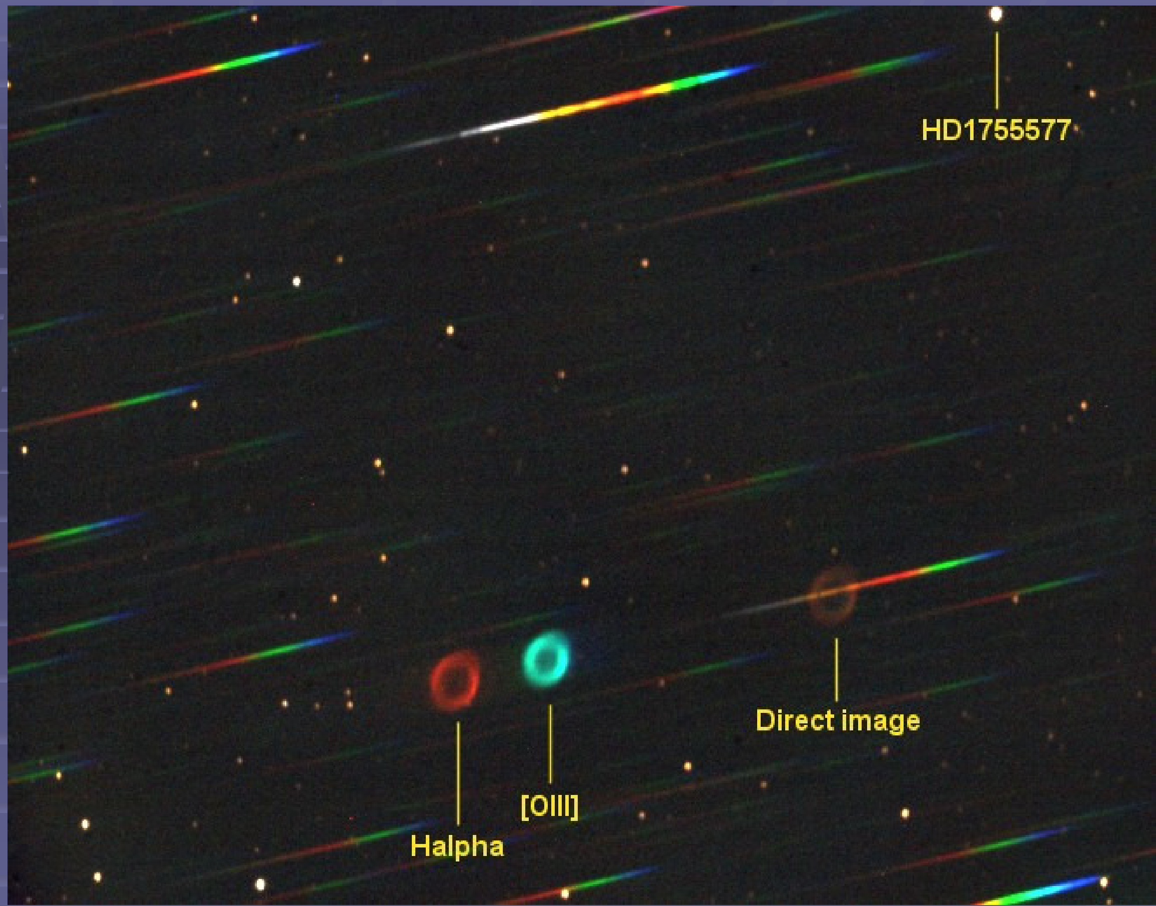
Elliot Inst
CCDSpec
15 A
£1300

Baader
DADOS
15/2A
£1400

Shelyak
eShel
0.6A
£11000



A spectrograph produces a line of images of the light source at each wavelength



Buil http://www.astrosurf.com/buil/staranalyser/obs.htm

The resolution depends on:-

The width of the light source image (eg FWHM of star image)

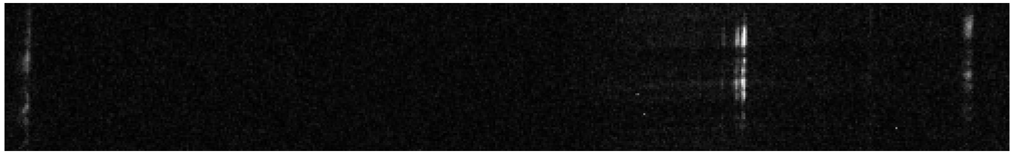
How far the light is spread out (the linear dispersion)

Adding an entrance slit allows the width of the light source (and hence the resolution) to be controlled and kept constant

SA200 M57

With the slit wide open the emisison lines in the spectrum appear as separate images. (The two main images are from O[III]/Hbeta) and N[II]/Halpha

Individual emission lines appear as the slit is closed.
Note also how the skly background is reduced



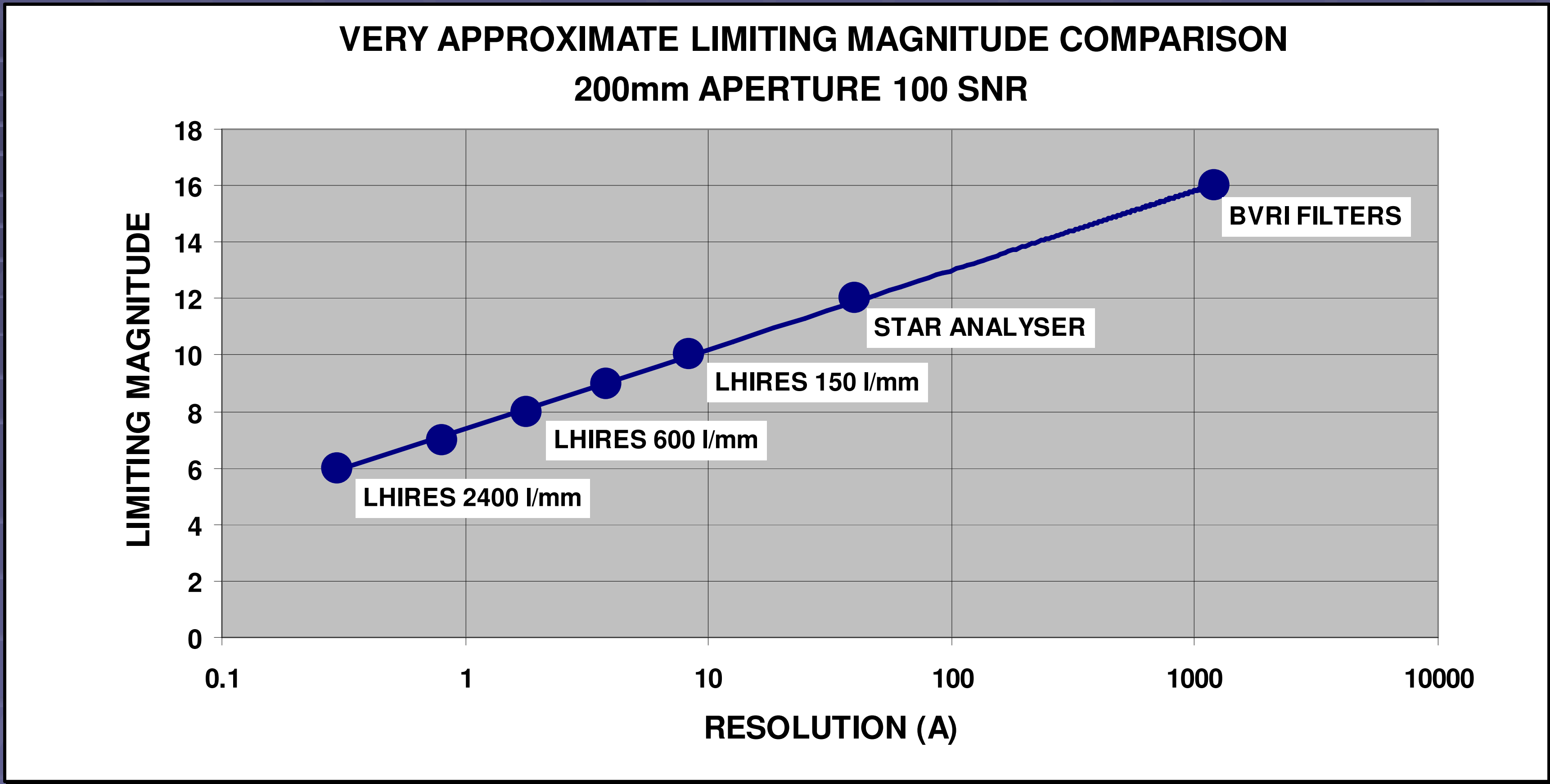
The resolution increases as the slit is narrowed but the amount of light passing through the slit is also reduced

The addition of a slit increases the complexity (and cost) of the instrument significantly compared with a simple slitless non objective grating spectrograph

With this simple insight we can immediately understand for example:

- Why higher resolution needs brighter targets
- How the spectrograph performance is affected by the telescope aperture and focal ratio
- How we can use slit width to trade sensitivity for resolution, particularly with extended objects
- Why poor seeing reduces resolution with slitless spectrographs but reduces throughput with slit spectrographs.

Resolution can be increased by increasing the dispersion
But there is a trade off between resolution and sensitivity

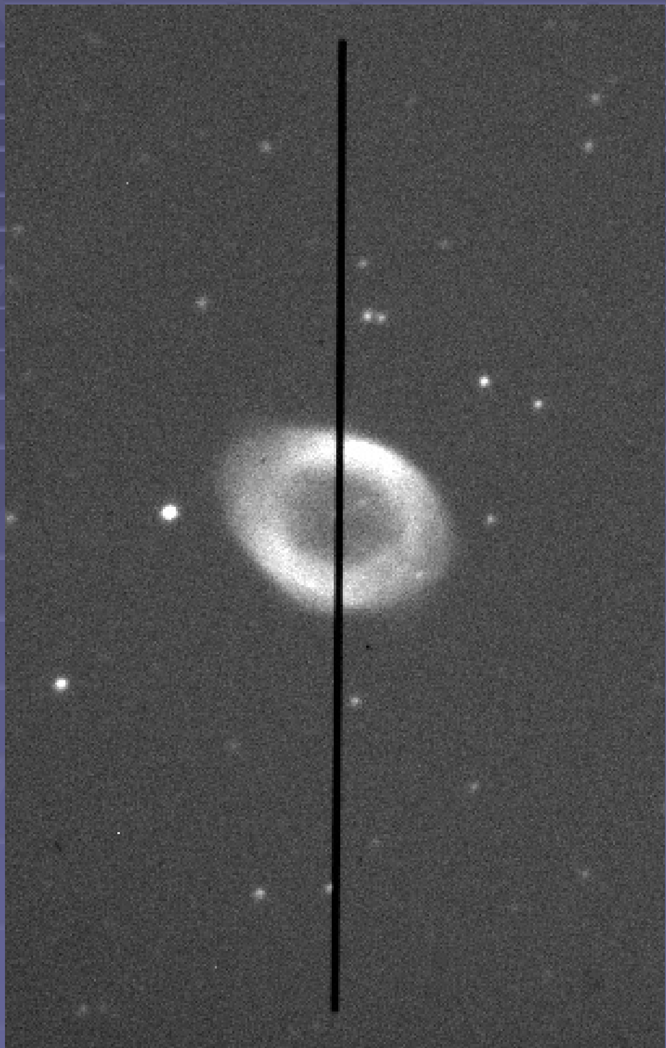


The more the spectrum is spread out (higher dispersion)
the brighter the target needs to be

(Note this is for continuum spectra.
High dispersion can be beneficial in the detection of narrow emission lines)

Spectroscopy needs a lot of light and anything done to maximise the number of photons ending up the spectrum can have a big payback.

http://www.astrosurf.com/buil/alpy600/performances.htm



http://www.astrosurf.com/aras/slit/method.htm

Focusing and Guiding are crucial here - For commercial slit (and fibre fed) spectrographs for the amateur the mirror slit guider is now the (almost) universally adopted solution to this problem.

(Self builders take note !)

Some other factors to consider

- Stability (thermal and flexure)
- Wavelength coverage
  - resolution at the extreme ends of the spectrum (edge of field aberrations and chromatism in the optics can limit the useful wavelength range)
- Efficiency
  - The efficiency and spectral response of a diffraction grating can vary from that published depending on the geometry
  - Take care that that the spectrograph optics do not vignette the beam from the telescope.
  - Camera QE and noise figure

The Observation

- Try to time the observations so the target and reference stars are measured close to the same air mass
- Take care not to saturate (combine multiple exposures to get enough signal in faint parts of spectrum)
- If your spectrograph shows thermal drift or flexure, take frequent wavelength calibration lamp spectra
- Don’t forget matching darks, flats. Can use cloudy nights if spectrograph is not disturbed (Average a large number to avoid adding noise)

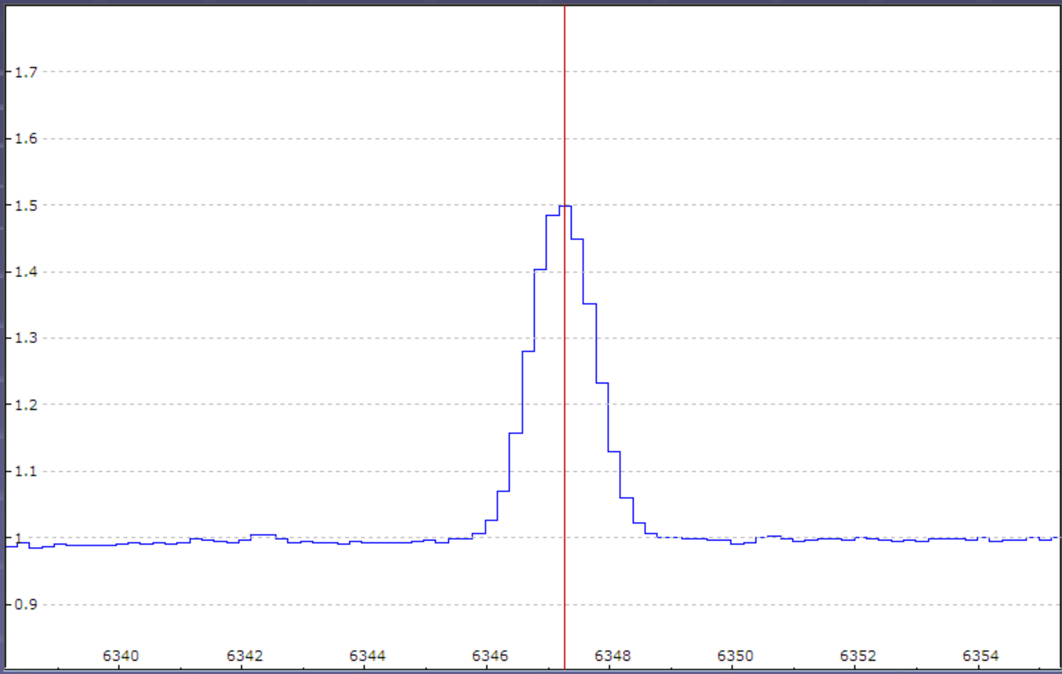
Data Reduction

Use fits files with completed headers from images to calibrated spectrum

- Pre-processing
  - Darks, Flats
  - Geometric corrections (tilt, slant, smile)
  - Sky background removal
- Digitising (binning)
  - Summing the pixel counts in each column for rows where there is spectrum data
- Wavelength calibration
  - Calibration light source
  - Heliocentric correction
- Flux calibration
  - Rectification
  - Instrument response (reference star)
  - Atmospheric extinction (air mass)
  - Radiometric (Spectrophotometry)

Measurements

- Using all the pixel values in the line to measure the line parameters not just the peak significantly increases precision



- Wavelength can be measured to small fraction of the resolution
- The area of the line gives a measure of the line strength which is more precise than the peak and independent of the spectrograph resolution (eg Equivalent Width)