High Resolution Spectroscopy

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Spectroscopic Terms

• Spectral resolution, Resolving Power: 
  \[ R = \frac{\lambda}{\Delta\lambda}, \quad \text{in physical terms } R = \frac{c}{\Delta v} \]
  – \( \lambda \) is the wavelength of interest
  – \( \Delta\lambda \) is the smallest wavelength interval that can be resolved
  – \( c \) the speed of light
  – \( \Delta v \) the doppler shift of the object

• Dispersion – \( \Delta\lambda / \text{pixel} \) or \( \Delta\lambda / \text{Å} \) (informal)
Resolution $\lambda/\Delta\lambda$ Ranges

$10 < R < 1000 \rightarrow$ low
$1000 < R < 10000 \rightarrow$ medium
$10000 < R < 100000 \rightarrow$ high
$100000 < R < ... \rightarrow$ ultra high
Slit Spectrographs

- **Entrance Aperture**: A slit, usually smaller than that of the seeing disk
- **Collimator**: converts a diverging beam to a parallel beam
- **Dispersing Element**: sends light of different colors into different directions
- **Camera**: converts a parallel beam into a converging beam
- **Detector**: CCD, IR array, photographic plate, etc.
Long Slit Spectroscopy

The higher the resolution
→ the smaller the wavelength band covered.
Diffraction Gratings

• Multi-slit diffraction
• reflection gratings and transmission gratings

• most astronomical gratings are reflection gratings
Limitations for High Dispersion

• **Problem**: detector size, shape
  – generally square or 1x2 format
  – a conventional grating spectrograph produces a very LONG high dispersion spectrum that won’t fit on a CCD

• **Solution**: the echelle grating
  – works in high orders (n=100)
  – a second dispersing element spreads the light in a perpendicular direction
Echelle Gratings

- To increase spectral resolution, increase the order at which a grating is used.
- For high orders, must increase $a$ and $b$ in the grating equation (to ~50-75°).
- The spectral range for each order is small so the orders overlap.
- Separate the orders with a second disperser (cross disperser) acting in a perpendicular direction.

C. R. Kitchin, *Optical Astronomical Spectroscopy*
High resolution spectroscopy requires:

- Gratings with larger number of lines per mm
- Larger dispersion
- Larger Detector
- More complex Optics