# Astronomical Techniques I

## Lecture 11

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# DN to magnitude conversion - Zero Point

The zero point of an instrument, by definition, is the magnitude of an object that produces one count (or data number, DN) per second. It is the setting of the zeropoint, then, which determines the connection between observed counts and a standard photometric system (such as Gunn *ugriz*), and in turn between counts and astrophysically interesting measurements such as the flux incident on the telescope. The magnitude of an arbitrary object producing DN counts in an observation of length EXPTIME is therefore:

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$m = -2.5 \times \log_{10}$(DN / EXPTIME) + ZEROPOINT + colorterm + extinction + galactic extinction + K correction + cosmological dimming + intrinsic dust correction + intergalactic attenuation + aperture correction + bad pixel correction

# for more details

Astronomical photometry by Henden & Kaitchuk
Introduction to astronomical photometry by Budding & Demircan

# Spectral resolution

Spectral resolution is usually quoted as $R = \frac{\lambda}{\Delta\lambda}$ where $\lambda$ is observing wavelength and $\Delta\lambda$ is the smallest wavelength interval that can be isolated from its neighbors.

In the UVOIR, spectral resolution is provided by:

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2. prisms
3. diffraction gratings

# Spectral resolution regimes

- low resolution $R \sim 100$
- medium resolution $R \sim 1000$ IFOSC 190 to 3700, SDSS 1800
- high resolution $R \sim 10000$ Keck HIRES upto 67000

# GMRT Resolution for the HI line

In its high resolution mode, GMRT hardware backend sampled 16 MHz of bandwidth through 256 channels. What is spectral resolution *R* if you are observing HI line emission at $\lambda = 1420$ MHz? Is GMRT a low, medium or high spectral resolution telescope?

# GMRT Resolution for the HI line

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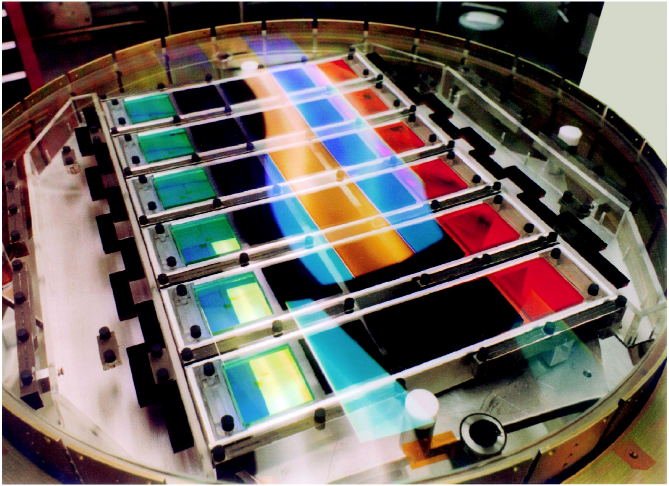
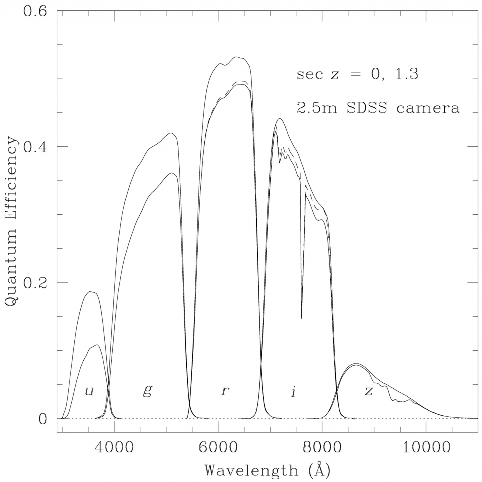
# Broadband filters - colored glass



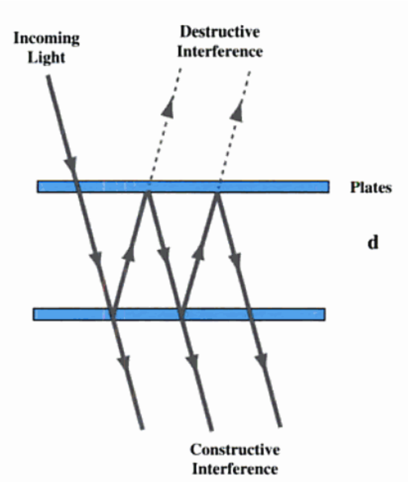
# Broadband filters

Transmissive/absorptive properties of glasses depend on their solid state band structure. Tunable by selecting materials or dyes. Colored glasses have broad (500 Å), slowly changing transmission curves. $R \sim 10$ Dozens of types of glass filters are used in astronomy, forming different standard systems such as Johnson UBVRI, Gunn *ugriz* systems.

# Sloan survey filter transmission functions



# Interference filters




Thin film layers (thickness $\sim$ 100 Å) of metals and dieletrics deposited on glass substrates in vacuo produce constructive interference effects through multiple internal reflections.

# Throughput and Spectral Resolution

The throughput of the interference filter is

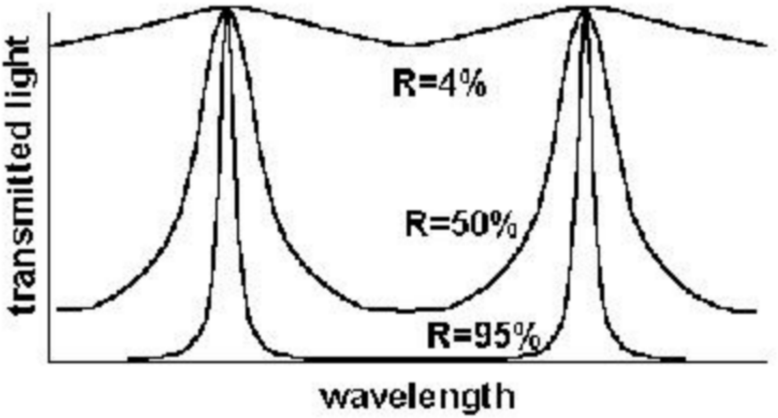
$$I/I_0 = \frac{1}{1 + \frac{4R\sin^2(\delta/2)}{(1-R)^2}}$$

where $\delta = \frac{2\pi}{\lambda} 2d\cos\theta$, $R$ is the reflection coefficient, $d$ is the spacing between layers, and $\theta$ is the angle of incidence. The spectral resolution of the etalon (defined by half-power points on the response curve) is:

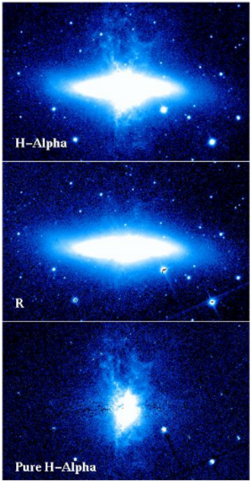
$$\Re = \frac{2\pi d\sqrt{R}}{\lambda(1-R)}$$

- For fixed-band interference filter, colored glass (or additional layering) used to suppress unwanted higher orders in the throughput.
- Typical bandwidths for astronomy are in the 10-500 Å range, with $\Re$ 10-500.
- widely used for emission line isolation (e.g. H$\alpha$), Prominent stellar absorption features (e.g. Mg I, Ca II), intermediate-band diagnostics of stellar abundance, gravity: e.g. the Stromgren filters;
- eg. COMBO-17 project, and WFC3 on HST
- Classic two-layer etalon is also used in astronomy as a Fabry-Perot Interferometer, where gas pressure or pizeo-electric positioners are used to adjust *d* in order to create a tunable, high resolution 2D imaging filter.

# How reflectivity changes filter transmission



# Procedure for narrow band imaging



# Prisms

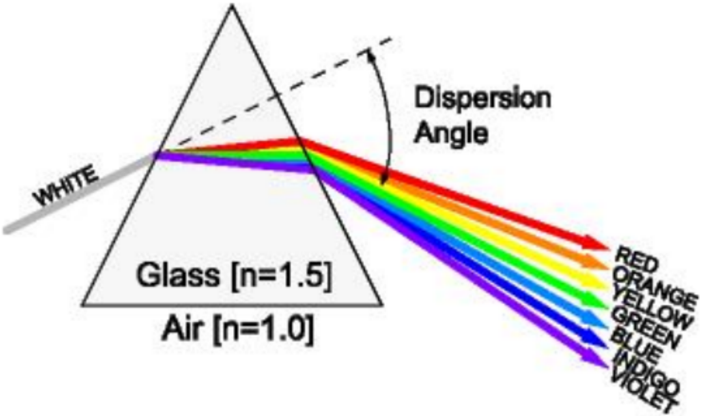



Fig. 4.8 Refraction through a prism.

$$\Re = B\frac{dn}{d\lambda}$$

where B is the length of the prism base.

# Advantages of prism spectrographs

- High throughput; useful for faint-object spectroscopy
- Wide field possible for multiobject samples
- Cheap, simple; predominant in early astronomical spectroscopy, rare nowadays e.g. IMACS on Megallan I Baade has a prism observing mode.

# Disadvantages of prisms

- $\Re$ can be a strong function of wavelength, yielded crowding at long wavelength end of response.
- Internal absorption limits use in UV
- More complex data reduction because of variable dispersion

# Objective prism imagers: place prism over telescope primary