Observational Astronomy

Direct Imaging Photometry

Kitchin pp. 329-340, 357-366;

Chromey pp. 133, 316-368.

Astronomical Imaging

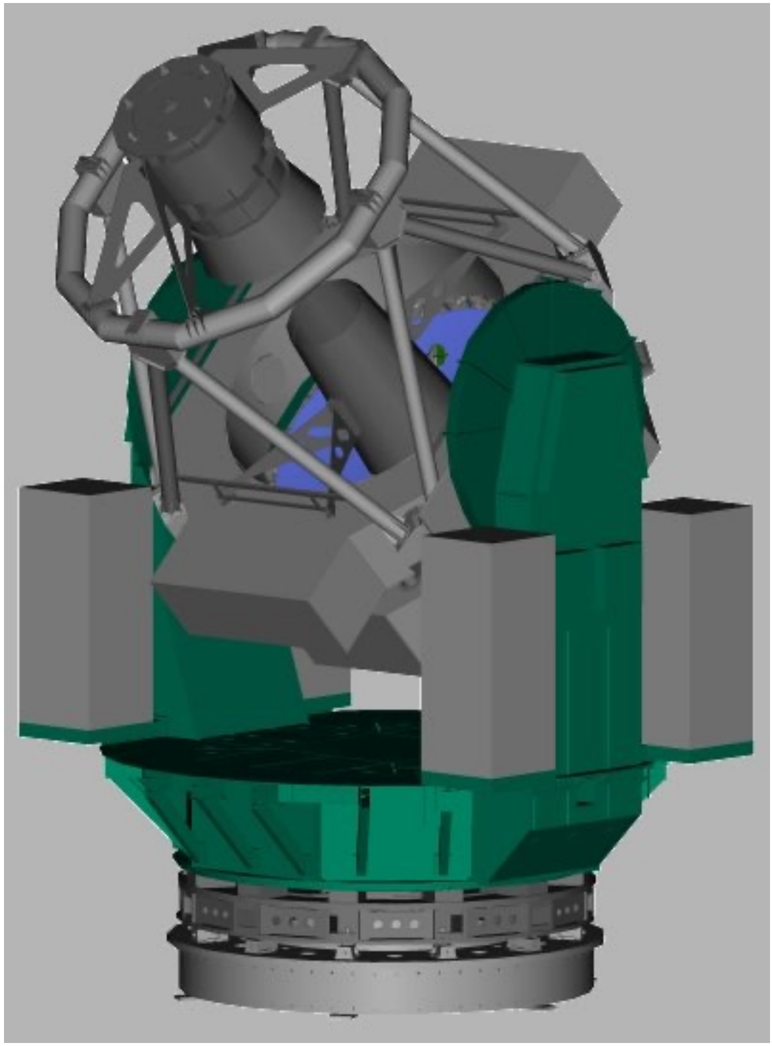
Wide versus **Deep** field

Specific goals:

- Cover as many objects as possible (e.g. clusters, star-forming regions) *Field of View, Angular resolution.*
- The most distant objects possible (e.g. early galaxies) *Sensitivity.*

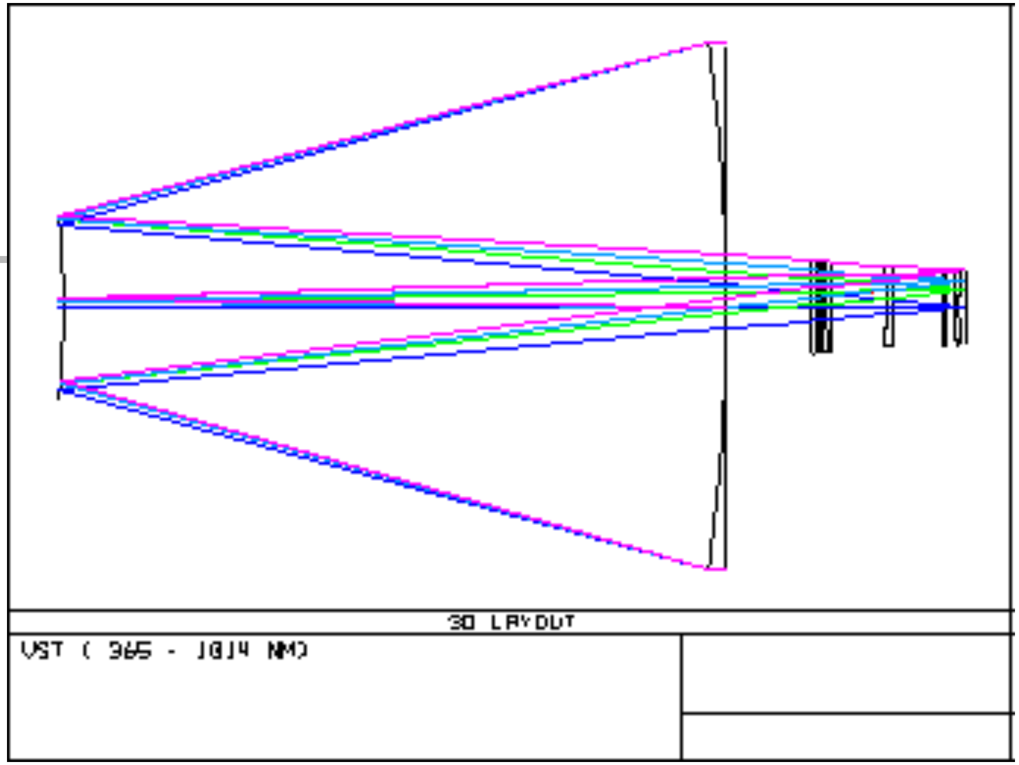
Wide Field Imager: VST

- The VST is a 2.6m f/5.5 Cassegrain telescope
- Corrected FoV is 1.5º square with angular resolution of 0.5"
- Focal plane is equipped with a 16kx16k CCD mosaic camera with a 15μ pixel




VST

VST Optics



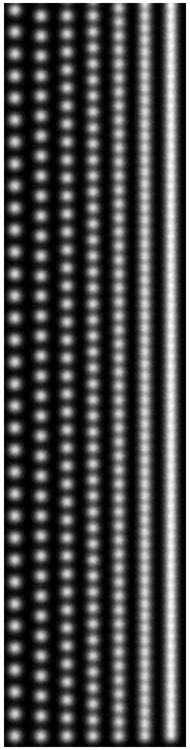
- Optical layout including ADC, field corrector etc.
- Plate scale:
  - focal length=2.6m$\times$5.5=14.3m
  - 1”= π /180º/3600$\approx$5$\times$10^{-6} rad
  - Resolution element: 0.5” $\Rightarrow$ 0.5 $\times$ 5$\times$10^{-6} rad $\times$ 14.3m $\approx$ 35μ

    $\approx$ 2.3 CCD pixel (nearly perfect Nyquist sampling)

Sampling Theorem
(Whittaker-Nyquist-Kotelnikov-Shannon sampling theorem)

The sampling frequency must be at least twice the highest frequency of the signal.

What should be the spacing between two Gaussians given their width so that we can tell them apart?
For 1D Gaussian:

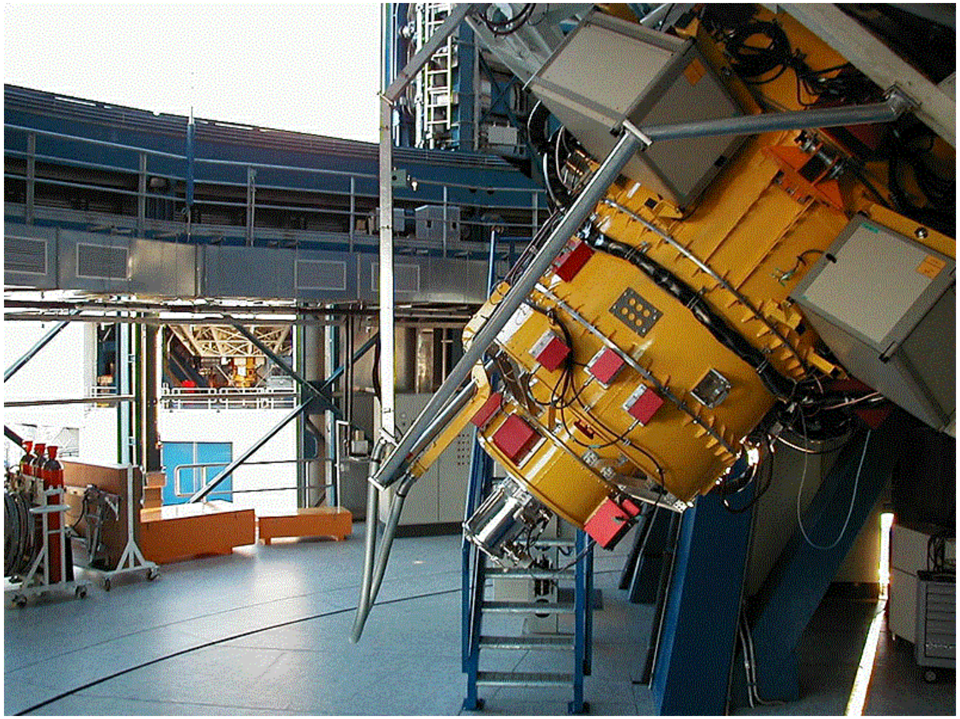


PSF $\propto e^{\frac{-x^2}{2\sigma^2}} = 1/2 \Rightarrow x \equiv \delta = \sqrt{2 \ln 2}\sigma$

and the separation $= 2\delta = 2 \cdot \sqrt{2 \cdot \ln 2}\sigma \approx 2.355 \cdot \sigma$

A general purpose telescope

VLT+FORS

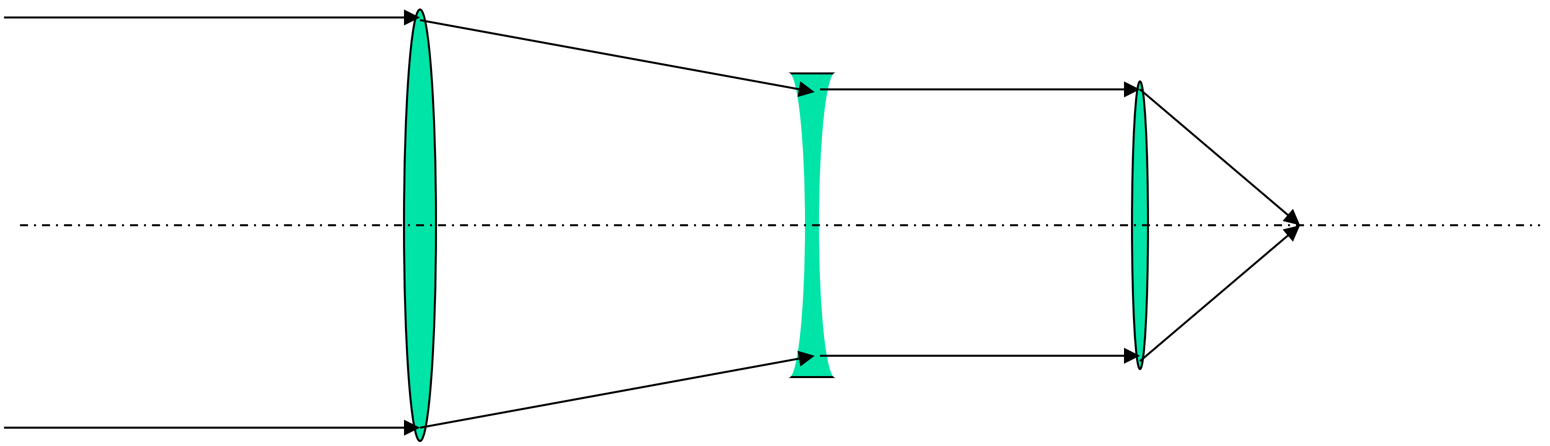


FOcal Reducer/low dispersion Spectrograph

VLT UT (8.2m f/13.4):
focal length=8.2m×13.4=108.8m
Plate scale in Cassegrain:
5×10^{-6} rad × 108.8m ≈ 530μ/arcsec

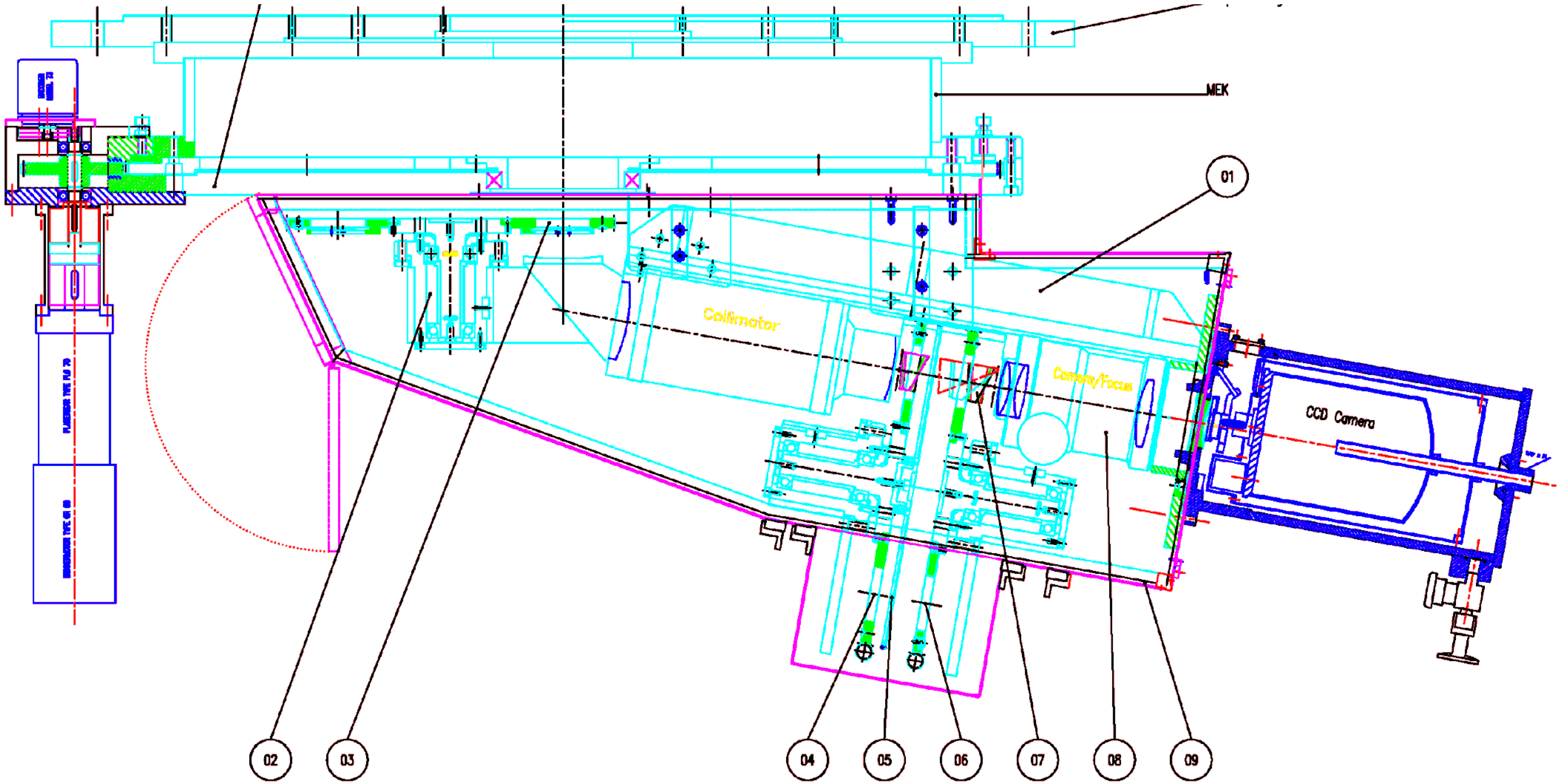
Focal Reducers

- Purpose: adjusting plate scale

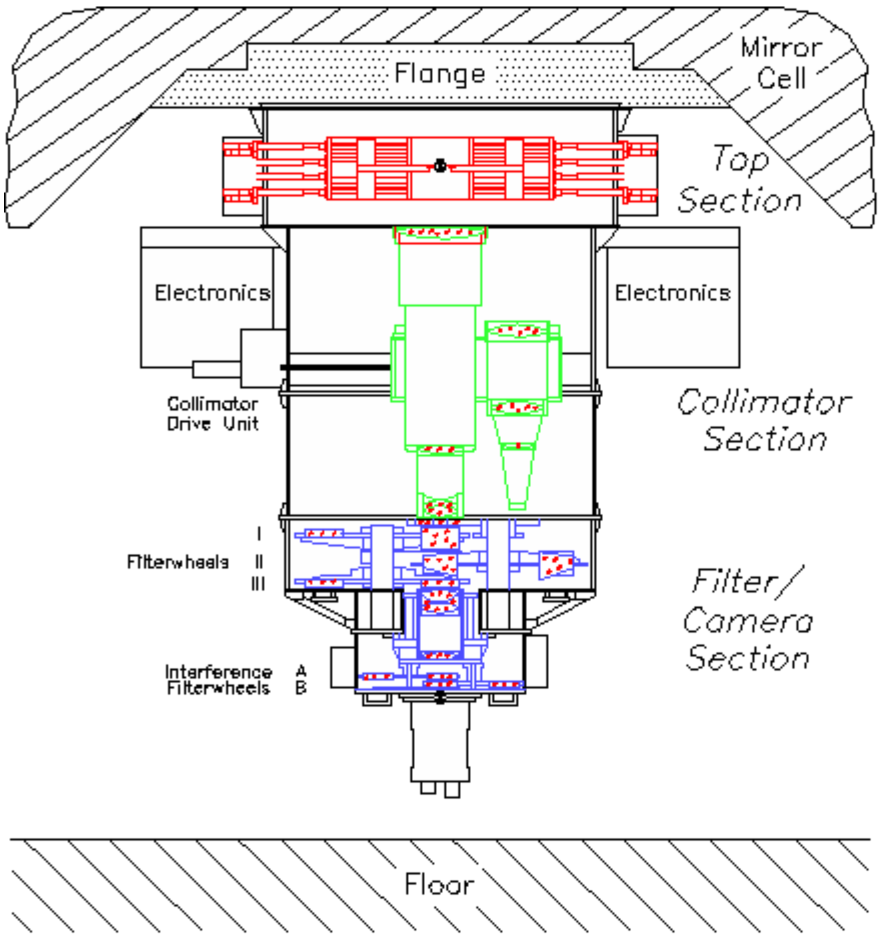


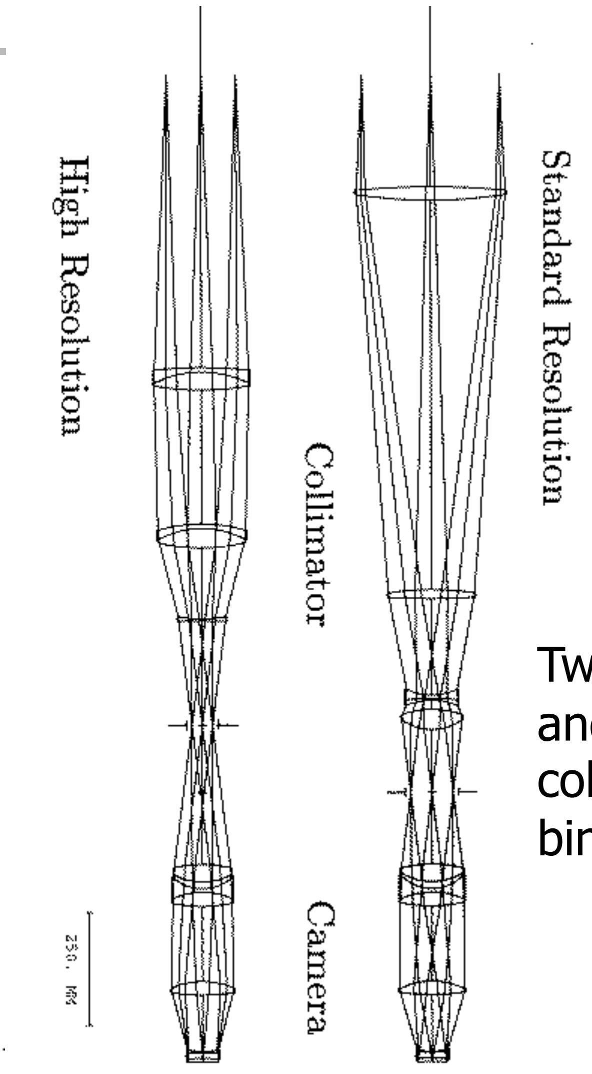
- Side benefits: collimated beam is good for filters

NOT workhorse: ALFOSC



Unconventional instrument: FORS

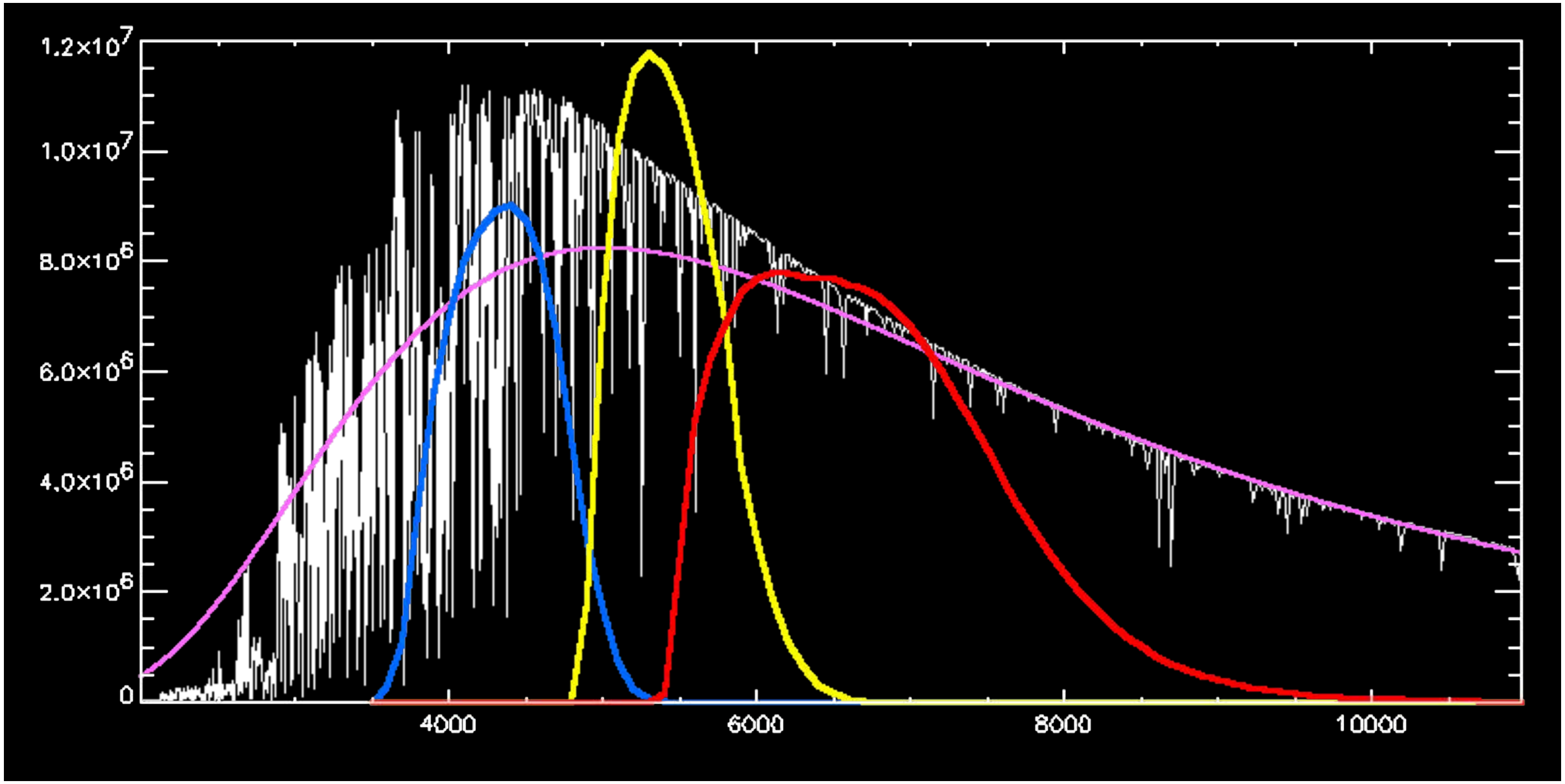




Two resolutions: 0.2” and 0.1” by changing collimators and CCD binning

Filters

- Broad band filters (UBV system, Johnson H.L. & Morgan W.W.: 1953, ApJ, **117**, 313)



Broad-Band Filter Technology

Color absorption glasses:

- *blocking* (high absorption shorter than certain wavelength while highly transparent at longer wavelengths) or
- *bell-curve* (sharp cut-off at shorter wavelength and gradual drop towards longer wavelength)
- Transmission is high, up to 75-90%

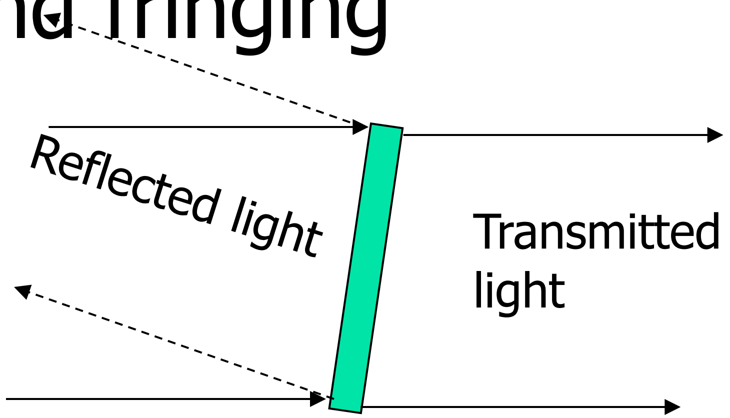
Narrow-Band Filter Technology

Interference coatings:

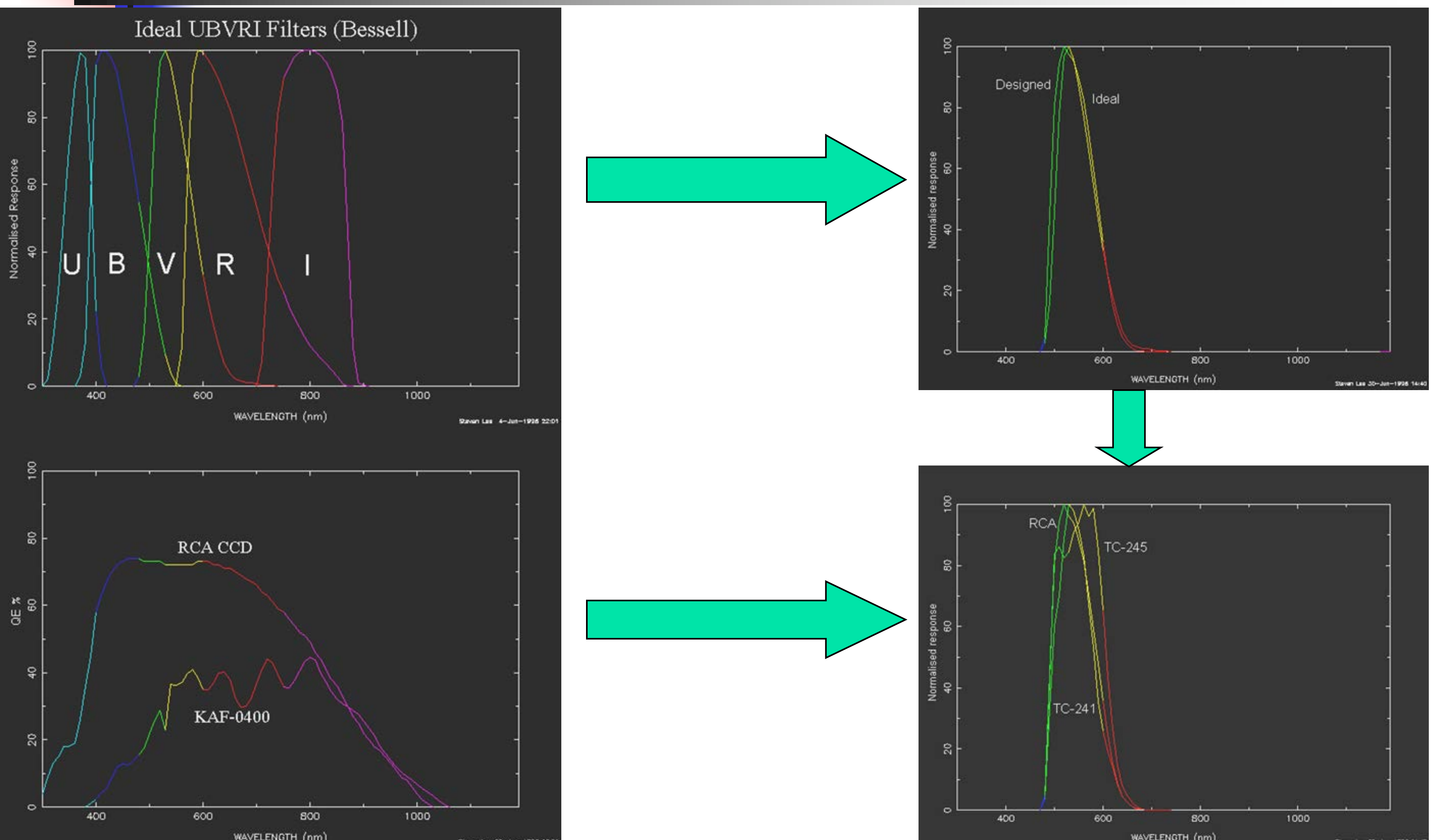
- Multiple (up to 20) dielectric layers producing interference between internal reflections
- Create multiple transparency windows at different wavelengths
- Must be combined with broad-band filters
- Transmission is low, around 20-30%

Chromatism and other problems

- Filters are best used in parallel beam, otherwise they introduce chromatism
- They also shift focal plane (transparent glass plates)
- Slight tilt is used to avoid ghosts (shift of optical axis) and fringing

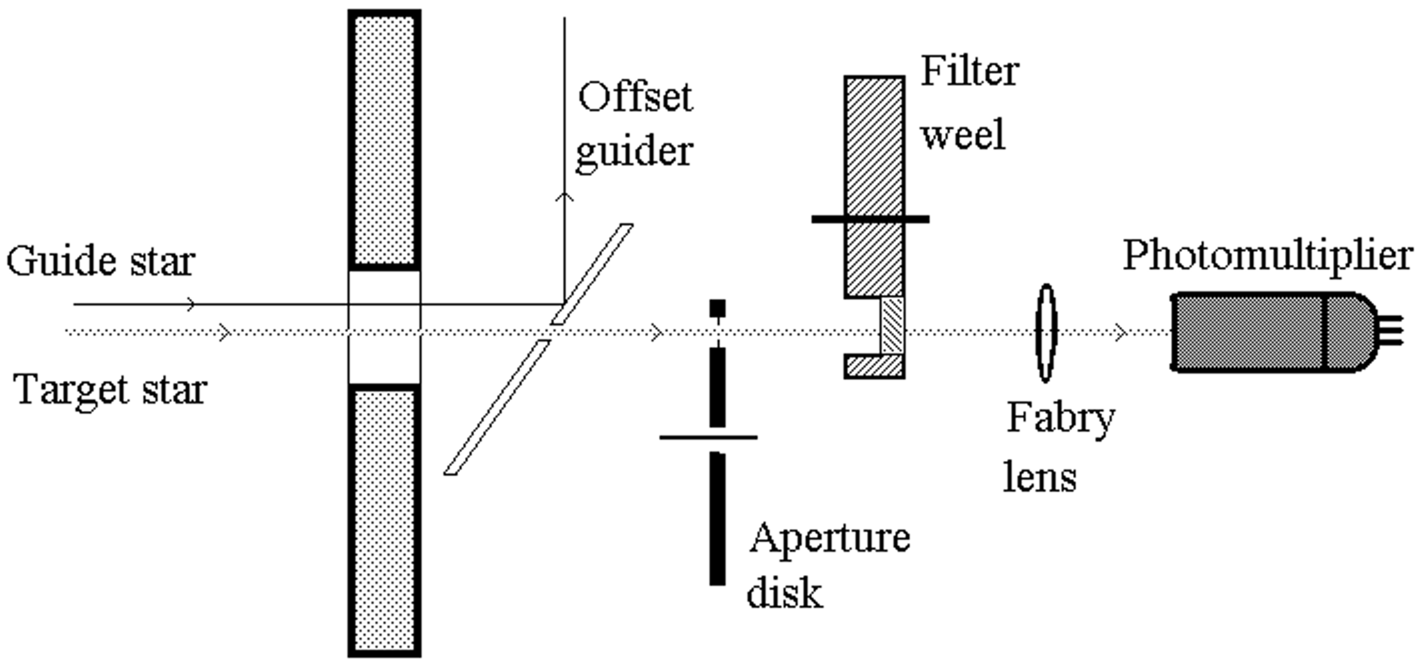


Transmission Function



Photometry

Classical one-channel photometer:



Farbry lens creates an image of the primary mirror on the detector

What do we measure and how?

- Magnitudes: $\Delta m = -2.5 \log \left(I_\lambda / I_\lambda^{\mathrm{ref}} \right)$
- Filters:

$$\Delta m_v = -2.5 \log \frac{a \int f^v(\lambda) I_\lambda d\lambda}{b \int f^v(\lambda) I_\lambda^{\mathrm{ref}} d\lambda}$$

- a and b are selected such that Vega will be 0 magnitude in all colors
- Interstellar extinction: objects with the same SED located in different direction and distances appear to have different magnitudes.

  The main source of extinction is the scattering and absorption-heating of the dust particles. The main effect is to "redden" the energy distribution. Color excess:

$$E(\lambda_2 - \lambda_1) = [m(\lambda_2) - m(\lambda_1)] - [m(\lambda_2) - m(\lambda_1)]_0$$

Absolute and differential photometry

- Radiation in a given band is affected by the atmosphere, telescope, photometer and detector. All of these must be calibrated.
- Absolute photometry is done against an absolute calibrator e.g. a black body radiation standard.

Absolute and differential photometry (cont'd)

- Once absolute measurements are done for a few objects they can be used as standards.
- Differential photometry measures flux difference in a given band between a target and a standard.
- Observations should be close on the sky and in time to account for the atmosphere and interstellar extinction (scales with distance).
- Classical sequence:
  <selecting band>:<standard> - <target> - <standard>

CCD Photometry

- Many objects at once (standards and targets simultaneously)
- Large dynamic range
- PSF is spread over several pixels with different sensitivity
- Photometry of extended sources

Next time…

Astronomical detectors