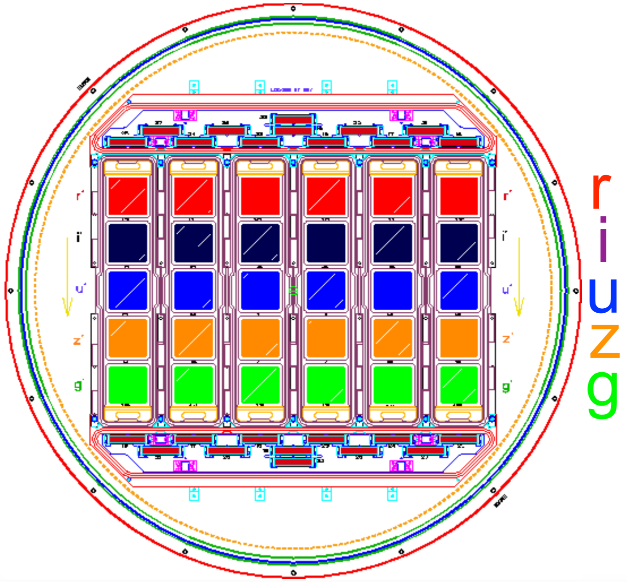
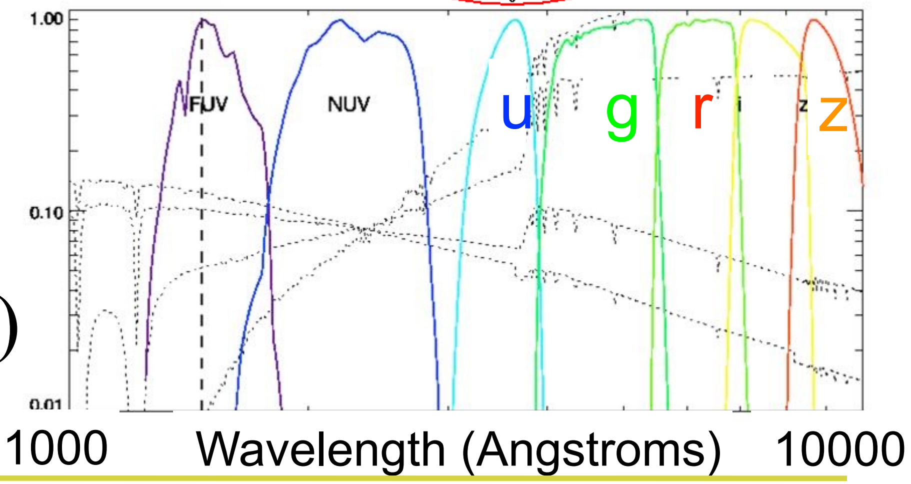
Magnitude Systems

Observing the sky through filters (passbands)

- Objects in the sky have different energy signatures
  - i.e. different fluxes as a function of wavelength
- So, to categorize astronomical sources , we observe the sky through different filters or "passbands"
  - which allow light to pass at different wavelengths
- e.g., the SDSS (and GALEX) passbands to the right

SDSS camera assembly from http://www.astro.princeton.edu/PBOOK/camera/camera.htm



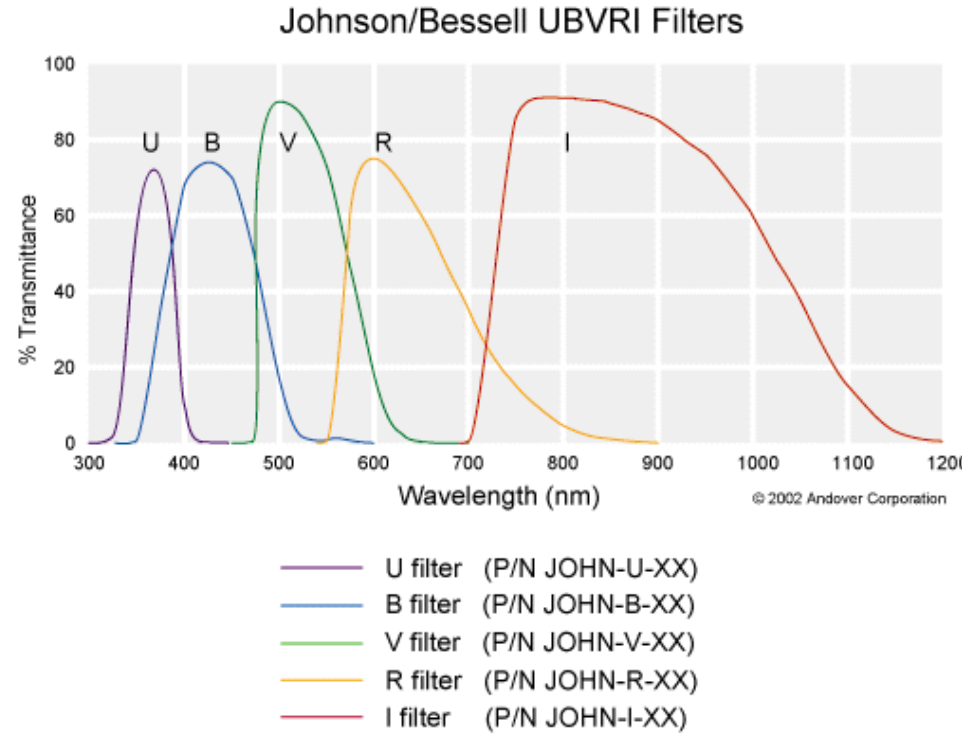


Flux measurements and the Vega system

- In each passband (integrated over wavelength), we measure the "flux" (the total amount of energy per unit area arriving at the telescope's detector per second)
- To create a standard system of how *relatively* bright sources appear to be, astronomers created a system of *magnitudes*. For magnitude (m) and flux (f)
  - $m - m_0 = -2.5\log10(f/f_0)$
  - where the 0 subscript, here, refers to a measure relative to some "standard" star that calibrates the zero-point of the system
- For a long time, the zero-point was chosen to be the star Vega (i.e. f_0 is the flux of Vega in a given band and $m_0 = 0$ is the magnitude of Vega in a given band)

Flux measurements and the Vega system

- The main early standard system in use was the Johnson *UBV* system
  - see syllabus links
- This system was extended to redder filters (*RI* by Cousins)
  - and extended to a system of cheaper glass filters by Bessell



- In this system (calibrated by flux measurements of many stars) Vega's magnitude is close to 0 in every passband:
  - $U_{Vega} = 0$; $B_{Vega} = 0$; $V_{Vega} = 0$; $R_{Vega} = 0$; $I_{Vega} = 0$

AB magnitudes

- Using Vega in this manner to calibrate a magnitude system is problematic for a number of reasons
- Vega does *not* have a flat spectral energy distribution (SED...the flux-wavelength relation) so it doesn't make much sense to *force* it to be flat
- This becomes even more problematic for UV and IR surveys (surveys outside of the optical), where Vega deviates substantially from a flat SED
- Vega may be a δ-scuti star, which vary in brightness!
- A solution is to calibrate the system using the absolute physical flux from Vega (in $WHz^{-1}m^{-2}$) across Vega's SED...this system is the AB system (see syllabus links)

AB magnitudes

- Modern systems of passbands, such as the SDSS *ugriz* filter system are on the AB magnitude system
- In this system, the zero-point source is a theoretical source *defined* such that it *truly* has a flat SED
- In the AB system, the flux zero-point in *every* filter is *defined* to be 3631 Jy (Janskys; 1 Jy = 10^{-26} $WHz^{-1}m^{-2}$)
- Thus, AB magnitude in any passband is given by
  - $m = -2.5 \log10 f + 8.9$ (magnitude *m* and flux in Jy)
  - $m = -2.5 \log10 f - 56.1$ (flux in $WHz^{-1}m^{-2}$)
- Conversions between the *UBVRI* Vega system and the *ugriz* AB system are linked from the syllabus

Nanomaggies and model vs PSF fluxes

- In recent weeks we have been working with the SDSS sweeps files. These files store SDSS fluxes as, e.g.,
  - *PSFFLUX* (*ugriz* flux as measured fitting a profile that assumes the source is a point source)
  - *MODELFLUX* (*ugriz* flux as measured using the best-fitting profile)
- These fluxes are in a unit of nanomaggies, a system where the zero-point flux is (3631 x 10^9) Jy or $10^9 f_0$
  - Thus $m = -2.5\log10(f/10^9 f_0)) = -2.5\log10(f/f_0) +2.5\log10\ 10^9 = 22.5-2.5\log10(f/f_0)$
- So, in the sweeps, to convert the FLUX tags to magnitudes, simply take $m = 22.5-2.5\log10(FLUX)$

asinh magnitudes

- The official (online) SDSS magnitudes are stored in a unit called *luptitudes* or *asinh magnitudes*
- This unit was designed to improve magnitudes for very faint objects (for very low signal-to-noise measurements)
- In this system, $m = -(2.5/ln10)[asinh((f/f_0)/2b) + ln(b)]$ instead of $m = -2.5log10(f/f_0)$
- *b* is a "softening parameter" designed to improve magnitudes as *f* approaches 0 (see syllabus links)
- We won't study asinh magnitudes as I suspect they won't be used outside of the SDSS (*b* changes with survey depth, which makes *b* hard to calibrate)
  - but it's worth nothing that *asinh magnitudes* differ slightly from *magnitudes* for very *faint objects*

Python tasks

1. Consider the star PG1633+099A, the discussion on how to convert between *UBVRI* and SDSS *ugriz*, and the *SDSS DR16 Navigate Tool*, all linked from the syllabus
    - use the *UBVRI* to *ugriz* transformations to show that the *g* magnitude displayed for PG1633+099A in the *SDSS DR16 Navigate Tool* is near the expected value
    - grab *ugriz* for PG1633+099A from the SDSS sweep files...show they agree with the *Navigate Tool* values
    - Don't forget the *sweepdir* (as should be passed to my *sdss_sweep_data_index.py* code) is */astro/astr8020/dr15/eboss/sweeps/dr13_final*

Python tasks

2. Find a faint object in the *Navigate Tool* image...show that *ugriz* for *this* object *differs* between the sweeps and the *Navigate Tool* values. Why might this be the case?
    - Make sure you choose something of type ‘star’ and not ‘galaxy’. Think about why this is true.