Angular Measures

Degrees, arcminutes, arcseconds: $1° = 60' = 3600''$

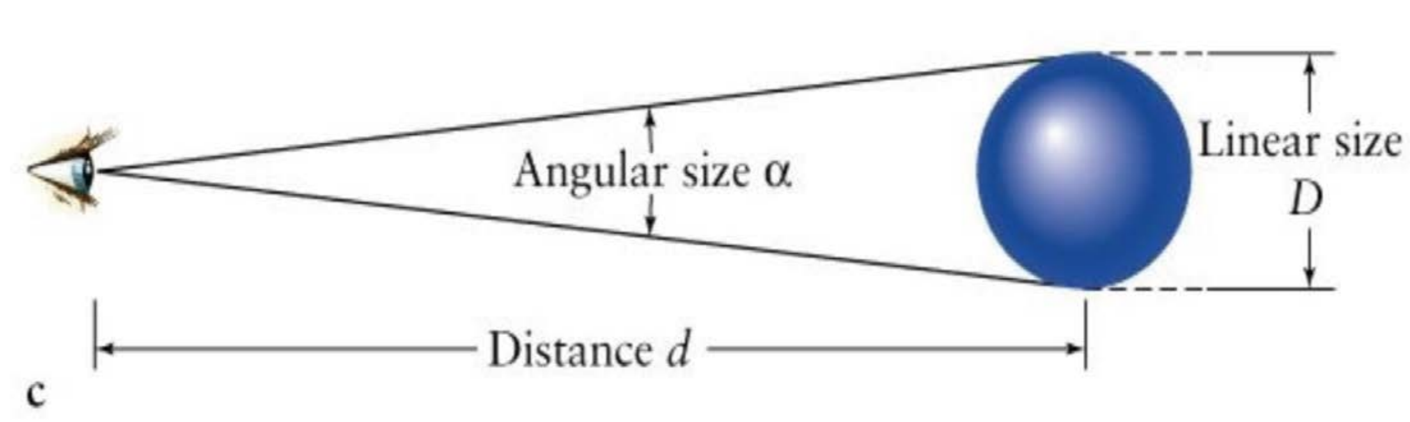
(Area in square degrees, square arcmin, square arcsec)

Radians: 2π radians $= 360°$, so 1 radian $\approx 57.3° = 206265''$

(Area: steradians, 4π steradians = whole sky)

Small Angle Approximation:

$$D = d \tan \alpha \approx d\alpha_{rad} \approx d\alpha_{arcsec}/206265$$



Object	Size
Sun and Moon	$\approx 0.5°$
Naked eye resolution	$\approx 1'$
Jupiter (max)	50”
Ground-based resolution	$\approx 1''$
Hubble resolution	$\approx 0.1''$
M101 (nearby spiral)	$\approx 20'$
Distant Galaxies	$< 1'$
Really Distant Galaxies	$< 2''$
Virgo Cluster	$\approx 8°$
Coma Cluster	$\approx 1°$

Coding tip: make sure to get units correct when using trig functions! They usually assume radians. If an angle is in degrees, do this:

```
np.sin(np.radians(theta))
```

Apparent Magnitude *(a measure of observed flux)*

Apparent magnitude (m) is the apparent brightness (flux) of an object as seen in the sky.

$$m = -2.5\log_{10}(f) + const$$

$$m_1 - m_2 = -2.5\log_{10}(f_1/f_2)$$

So:

- $\Delta m = 1$ mag → factor of ≈ 2.512 in flux
- $\Delta m = 5$ mag → factor of exactly 100 in flux
- $\Delta m = 10$ mag → factor of 100^2 = 10,000 in flux

Object	m_V
Sun	≈ -27
Moon	≈ -13
Jupiter (max)	-2.9
Vega	0.03
Aldebaran (RGB)	0.9
Naked Eye Limit	≈ 6
Bright galaxies	$\approx 8-10$
SDSS faint limit	≈ 23
Aldebaran in LMC	≈ 18
Aldebaran in Virgo	≈ 30
Hubble UDF limit	≈ 31

Coding tip: remember, mags use log10.

🙁 `np.log()   : natural log`
🙂 `np.log10(): base 10 log`

Absolute Magnitudes *(and distances)*

Absolute magnitude (M) is the apparent magnitude an object would have **if** it were at a distance of 10 pc.

$$m - M = 5\log_{10}(d) - 5$$

- Distance (d) ***must*** be measured in parsecs.
- $m - M$ is known as the distance modulus

Object	Distance	Modulus
α Centauri	1.3 pc	-4.4
star @ 10pc	10 pc	0.0
Orion Nebula	415 pc	8.1
Galactic Center	8.2 kpc	14.6
Large Magellanic Cloud	50 kpc	18.5
Andromeda Galaxy	750 kpc	24.4
Virgo Cluster	16.5 Mpc	31.1
Coma Cluster	100 Mpc	35.0

Absolute Magnitudes *(and luminosity)*

Since absolute magnitude is the apparent magnitude at a fixed distance (10pc), it is a measure of luminosity.

$$M_1 - M_2 = -2.5\log_{10}(L_1/L_2)$$

If we take object #2 to be the Sun, we have

$$M - M_\odot = -2.5\log_{10}\left(L/L_\odot\right)$$

or

$$L = 10^{-0.4(M-M_\odot)}L_\odot$$

Object	M_V	$L_V/L_{V,\odot}$
Sun	+4.83	1.000
Vega	+0.58	80
Betelgeuse	−5.8	17,000
Large Magellanic Cloud	≈ −18.0	1.5×10^{9}
Andromeda Galaxy	≈ −21.7	4.0×10^{10}
M87 (giant E)	≈ −22.5	8.0×10^{10}

*Remember, magnitudes are generally defined in a filter bandpass, so the luminosity refers to the luminosity **in that bandpass**.*

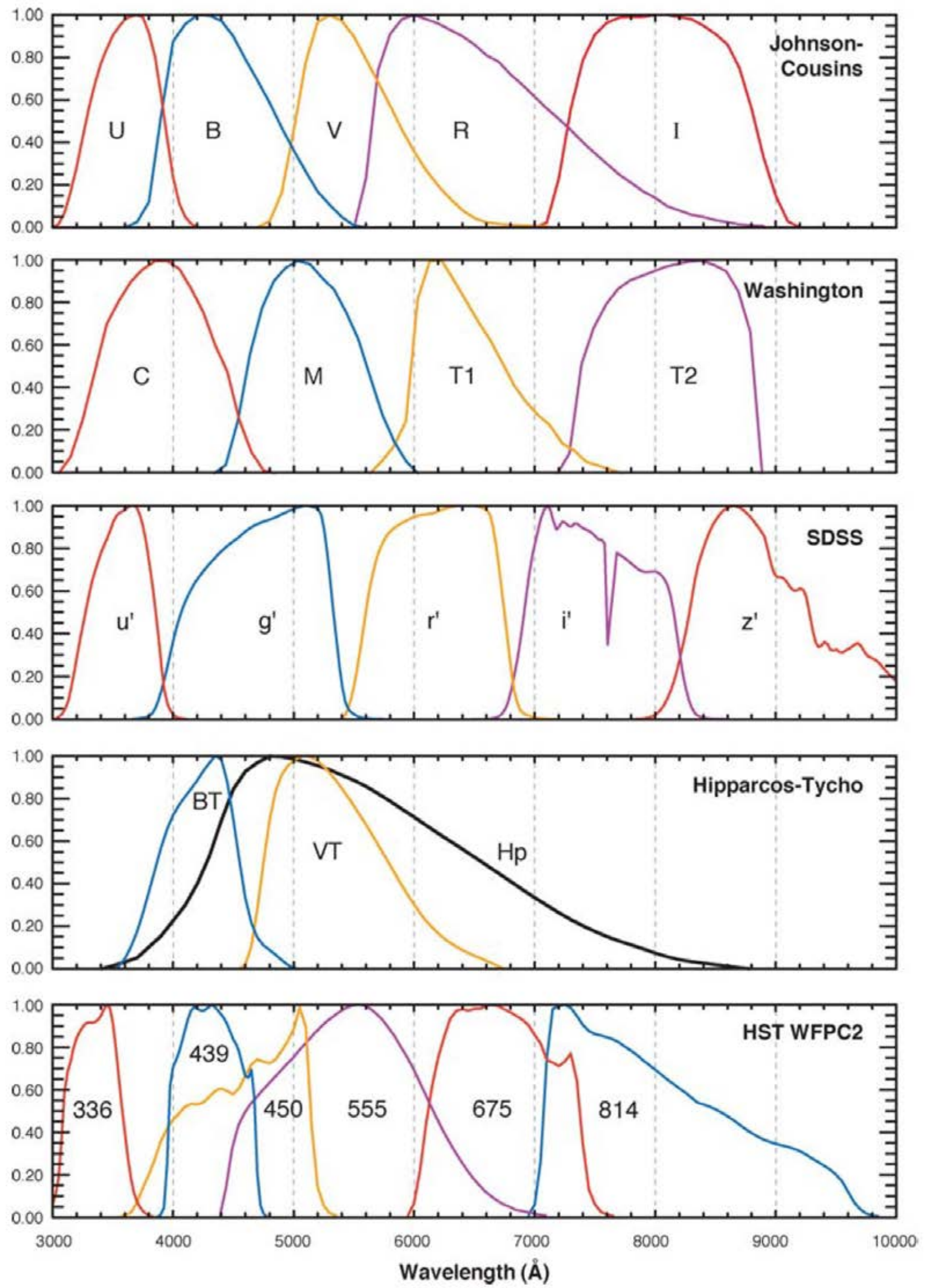
*Total luminosity summed over all wavelengths is called the **bolometric luminosity**, and is almost never what we work with.*

Filters and Colors

We measure fluxes/magnitudes through different filter bandpasses and define colors as the difference in magnitudes.

$$B - V = m_B - m_V = M_B - M_V$$

Convention: always list the bluer filter first, then smaller or more negative colors mean bluer objects.



Bessell ARAA 2005

Color-Magnitude Diagrams (CMDs)

The key to understanding stars and stellar populations.

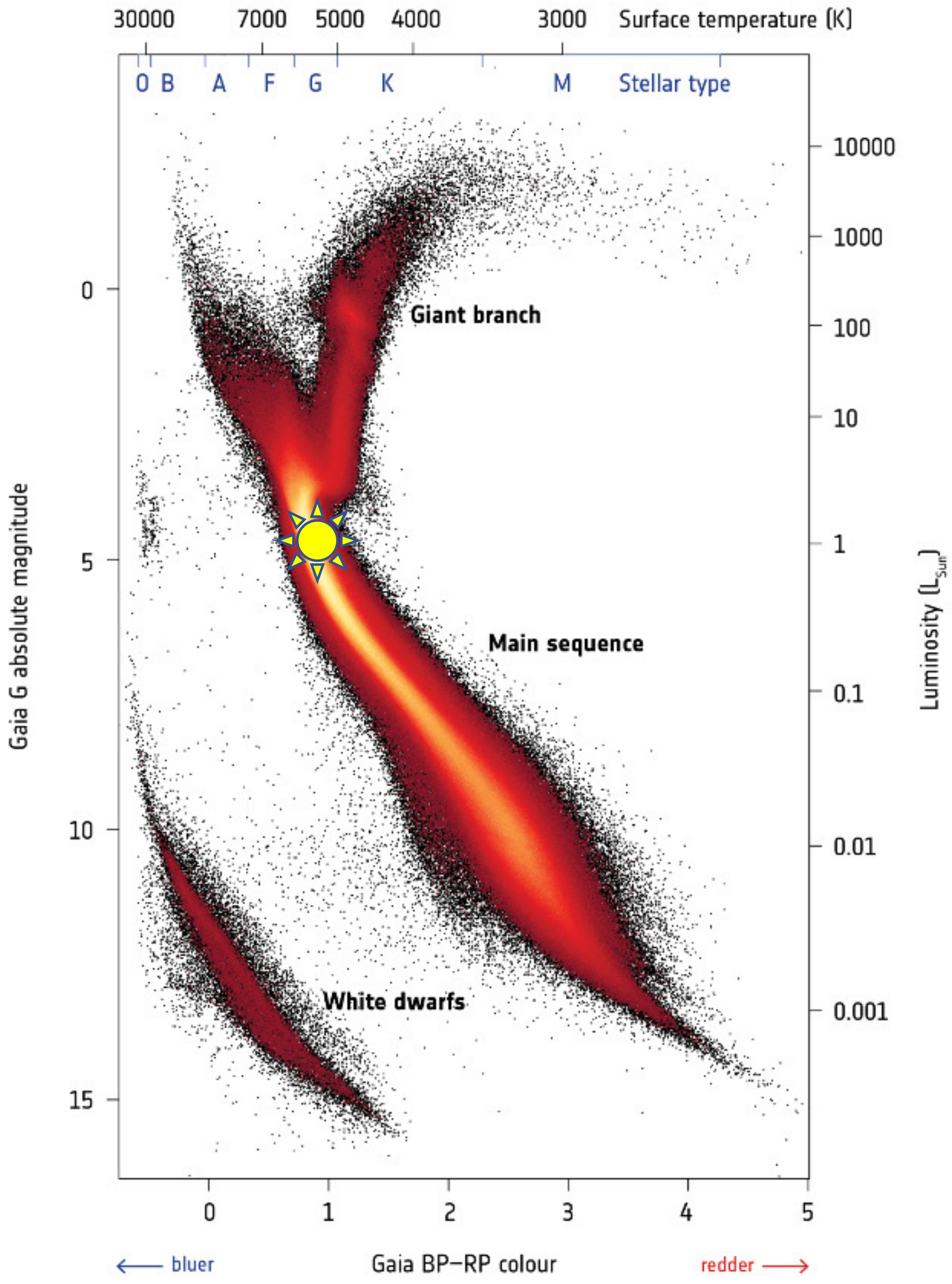
Stars live most of their lives on the main sequence.

Massive stars:

- bright and blue on the MS; live fast, die young (< 100 Myr)
- at end of life, evolve across the CMD to become red supergiants, then go supernova

Low mass stars:

- fainter and redder on the MS; live for 10+ Gyr
- at end of life evolve up the CMD to become red giants, then eject outer layers and become a white dwarf.



CMD of the solar neighborhood from Gaia

Units and Conversions

I beg you, please don't use SI units.

Natural units for Galactic and extra-galactic astronomy:

- distance: parsecs [pc], kiloparsecs [kpc], megaparsecs [Mpc]
- time: years [yr] or millions of years [Myr]
- mass: solar masses [$M_\odot$]
- speed: km/s

Handy "close-enough" conversions:

- 1 year $\approx \pi \times 10^7$ seconds
- 1 km/s $\approx$ 1 pc/Myr

Constants:

- G $\approx 4.43 \times 10^{-3}$ if using pc, $M_\odot$, km/s, Myr

Coding tip: learn astropy's units functionality:

https://docs.astropy.org/en/stable/units/