Australian National University

ASTR2013 – *Foundations of Astrophysics*

Week 6: Practical Astronomical Observations and Coordinate Systems

An introduction to concepts that will be important on the field trip.

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Revision - The End of a Massive Star

- As the inert Fe core approaches the Chandrasekhar mass and collapses, there is much more than enough energy to completely reverse nuclear fusion processes.
- If neutron stars were supported simply by neutron degeneracy pressure their radius would be:

$$r_{\rm ns} \approx 2.3 \times 10^9\ {\rm cm}\ \frac{m_e}{m_n}\left(\frac{Z}{A}\right)^{5/3}\left(\frac{M}{M_\odot}\right)^{-1/3} \approx 11\ {\rm km}\left(\frac{M}{1.4M_\odot}\right)^{-1/3}.$$

- Forming a neutron star is a factor of ~10 more energetic than fusion in forming the Fe core, resulting in a massive supernova explosion, with luminosity dominated by Neutrinos.
- Most supernovae (type II, and also type Ibc) are caused by massive stars collapsing, but type Ia are caused by white dwarfs merging or otherwise approaching the Chandrasehkar mass and fusing CNO to Fe in an explosion.

Week 6 Summary

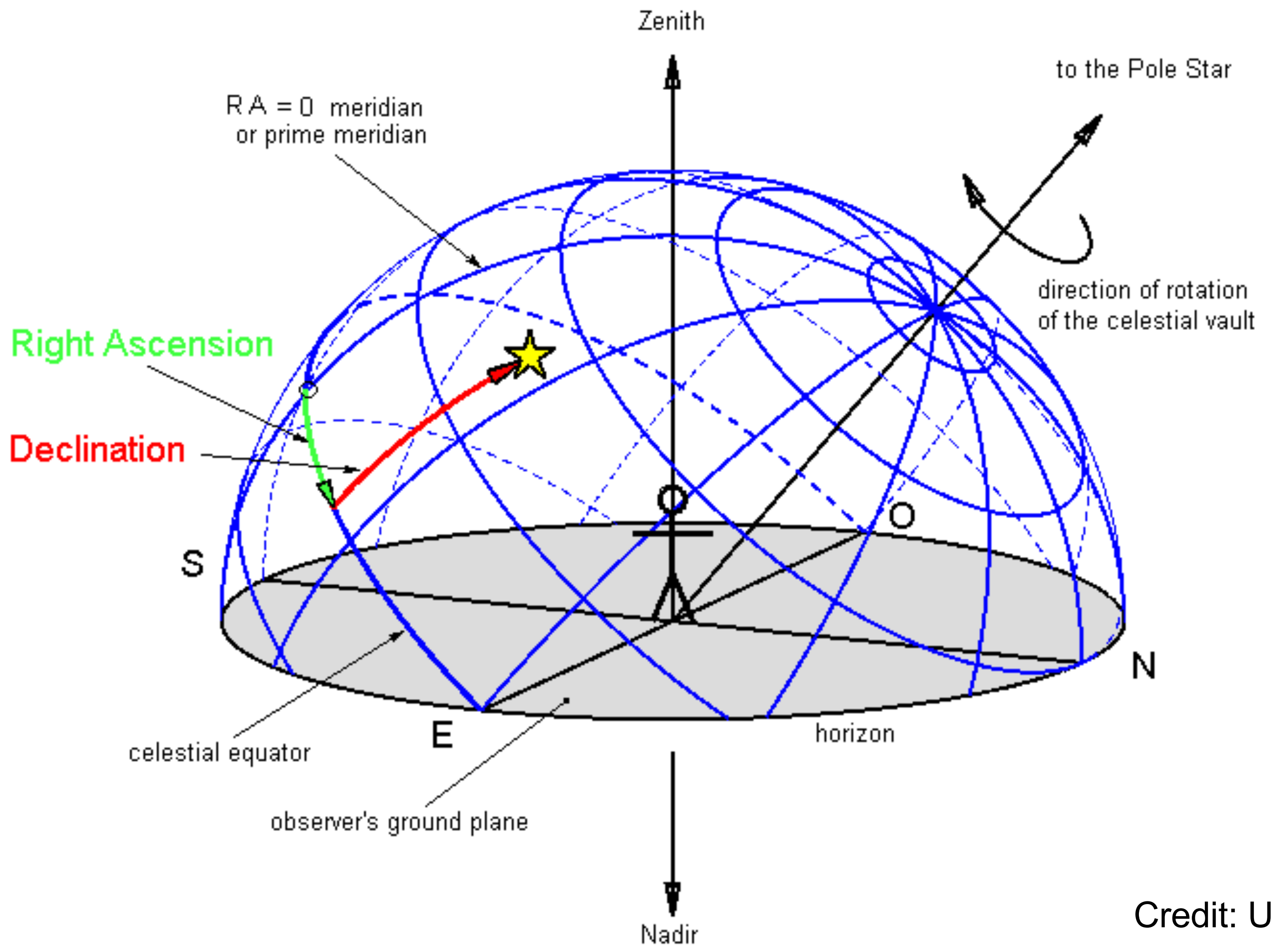
Textbook: Only Chapters 1 and 2 again, plus these notes, links and tutorial exercises.

1. Astronomical Coordinate Systems and catalogs.
2. The Magnitude Scale(s) and distance modulus.
3. Types of telescopes and instruments.
4. Signal to noise: beyond target shot noise.

Equatorial Co-Ordinates

- Imagine you're inside the globe looking out. *Right Ascension* (RA, α) is like longitude (in an East direction).
- RA is measured in hours or degrees : 1 hour = 15 degrees. From 0 to 24 hours, or 0 to 360°.
- Declination (Dec, δ) is like latitude, i.e. running from -90° to +90°.
- The co-ordinate system precesses with the earth, so has to be defined at a given *equinox*. Modern convention is to use the equinox of the J2000.0 *epoch*.
- Zero degrees RA is (roughly) the sun at noon at the northern spring equinox, one of two points where the *ecliptic* and *equatorial* equators cross.

Equatorial Co-Ordinates

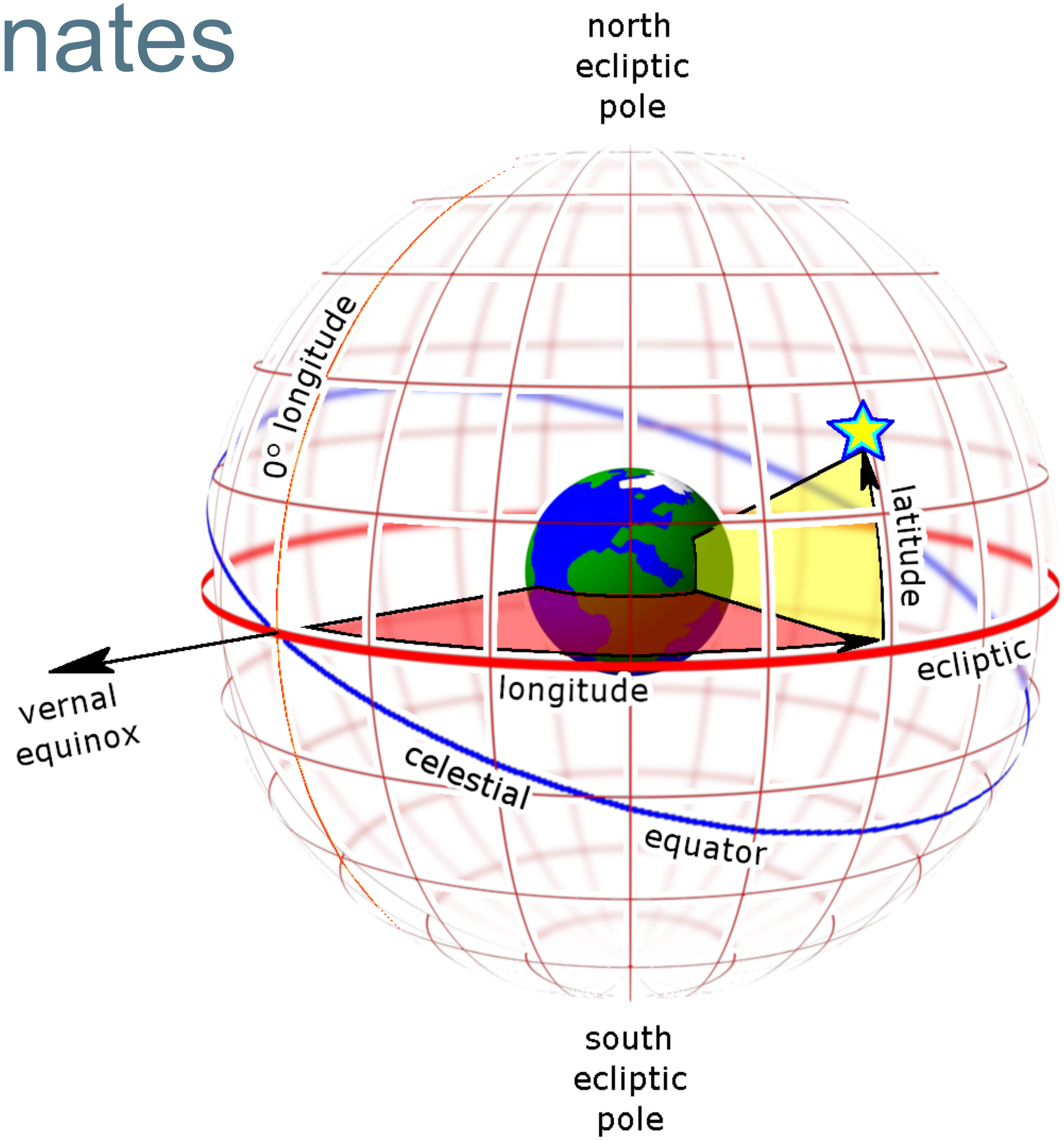


Go through this on board and with examples…

Credit: University of Michigan

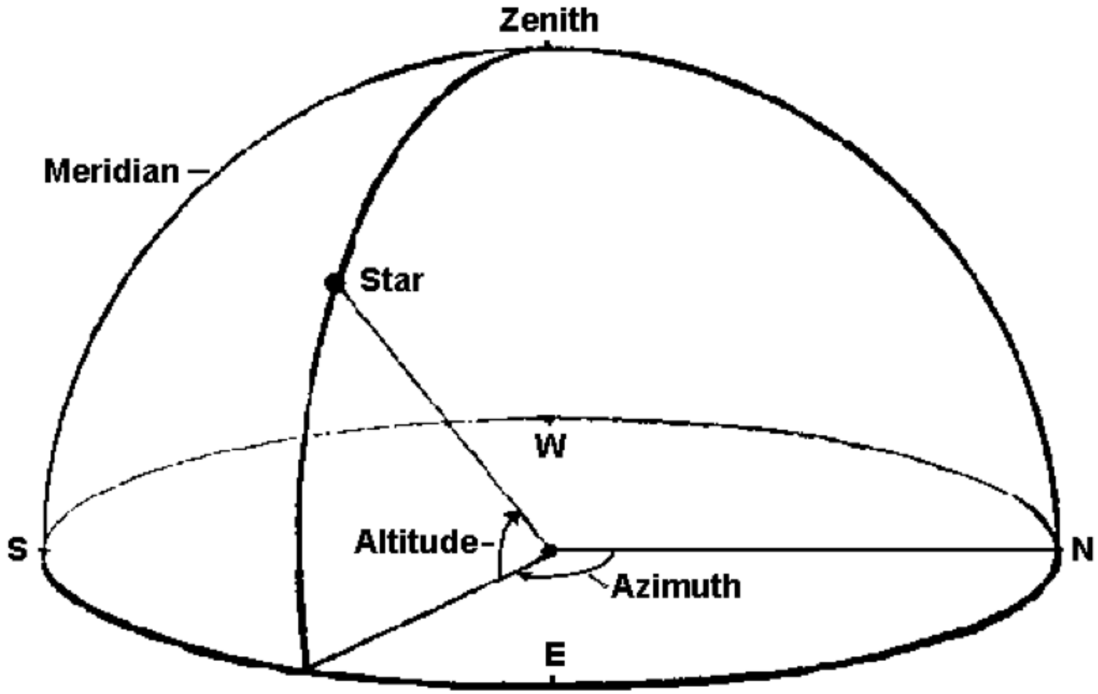
Ecliptic Co-Ordinates

Ecliptic Co-ordinates has its equator on the *ecliptic plane* (the earth's orbit) and not the equatorial plane.



Alt-Az Coordinates

- Easily understandable but always changing
- Azimuth: degrees E of N following the horizon.
- Altitude=90° is *zenith* i.e. straight up. 90°-Altitude is the *zenith distance* (or zenith angle).
- *Airmass* ≈ secant (zenith distance).



Key Online Resources

- NED for extragalactic objects.
- Simbad for (bright) stars.
- SkyView and Aladin for images and images overlayed with object catalogs.
- StarAlt and the ESO observability tool for seeing where objects are at particular times.
- Astropy (python – in tutorial) does some co-ordinate transforms, as does the NED coordinate transform webpage.

The Magnitude Scale

- Many astronomers (e.g. me) use a historical scale called *Vega magnitudes*.
- These were once defined relative to the brightest star in the Northern hemisphere, α Lyrae or Vega. For any filter F , we have:

$$
\begin{aligned}
m_F &= -2.5 \log_{10} \frac{f_F}{f_{F,\mathrm{Vega}}} \\
f_F &= f_{F,\mathrm{Vega}} 10^{-0.4 m_F}.
\end{aligned}
$$

- In practice, Vega doesn't have a Vega magnitude of exactly 0. It has a magnitude of 0.03 in the visible region of the spectrum [See Bessell and Murphy (2012) and Bessell (2005)]

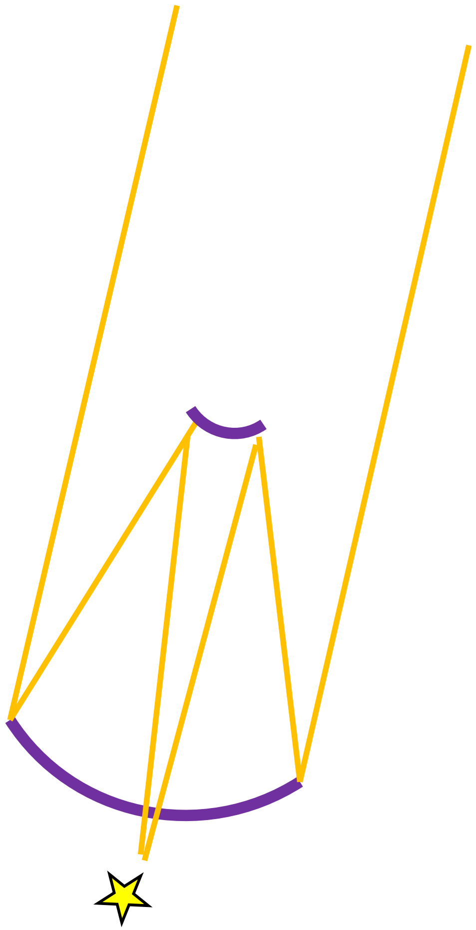
Absolute Magnitudes

- Observed magnitudes are called *apparent magnitudes, m*. The same object has a different magnitude at different distances.
- By convention, the *absolute magnitude, M* of an object is the magnitude it would have if placed at 10pc.
- The inverse square law enables us to define the *distance modulus:*

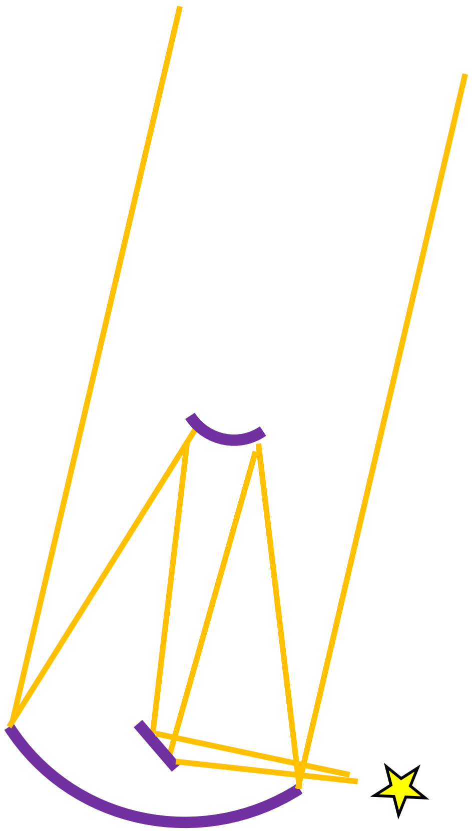
$$m - M = 5\log_{10}\left(\frac{d}{10\,\mathrm{pc}}\right)$$

Telescope Foci

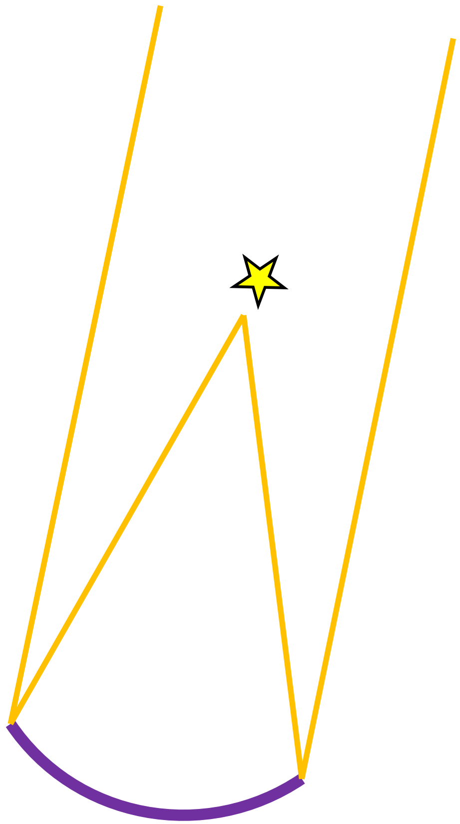
Cassegrain



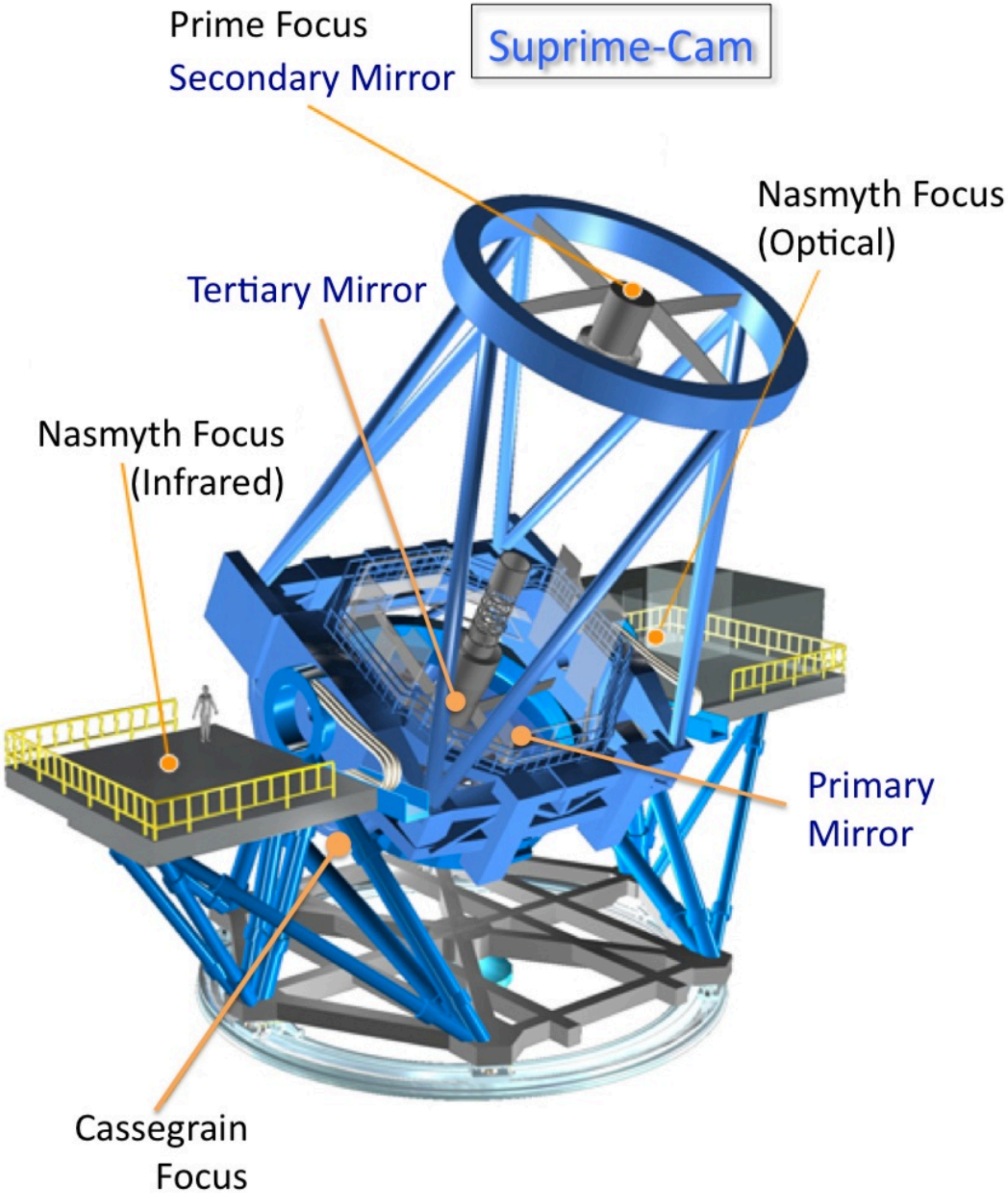
Nasmyth
(Coudé with an extra fold)



Prime Focus

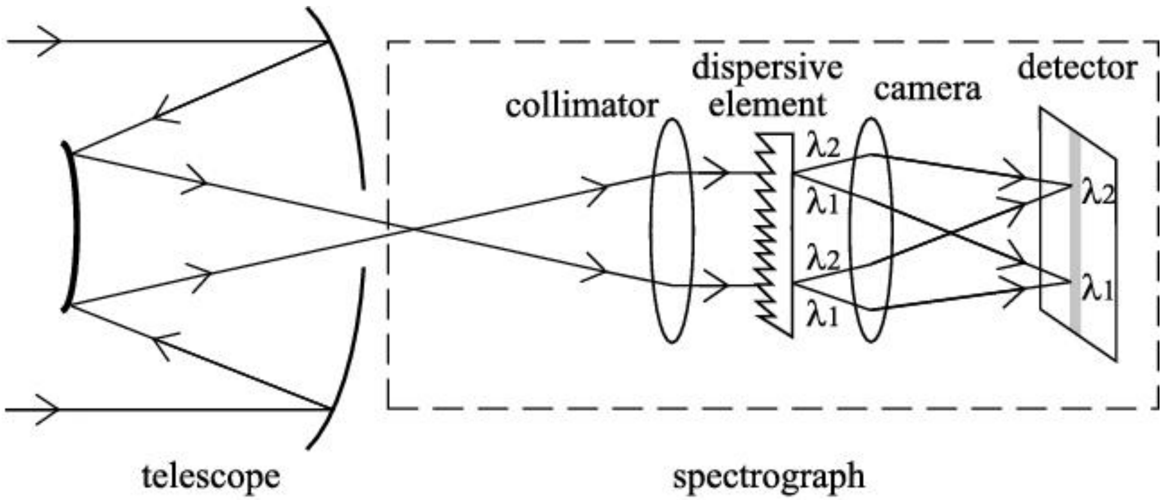


Example – Subaru has all 3 foci accessible

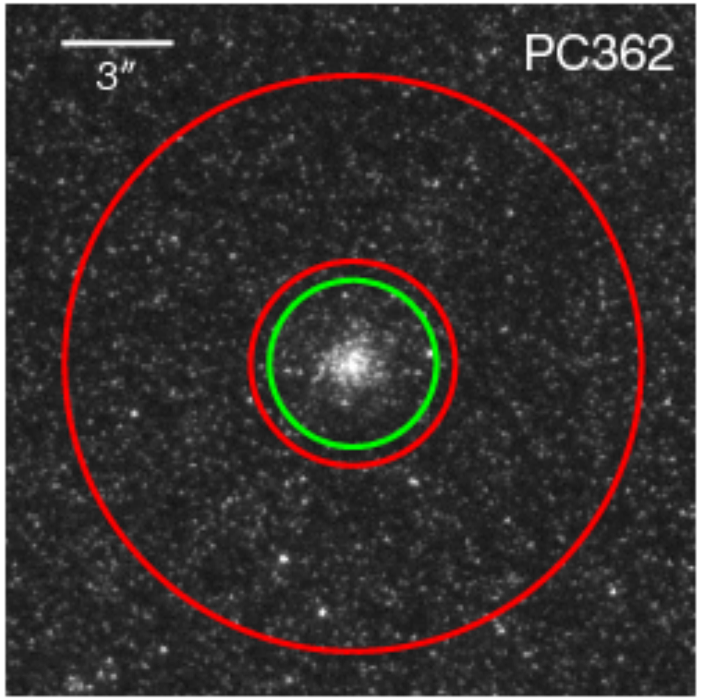


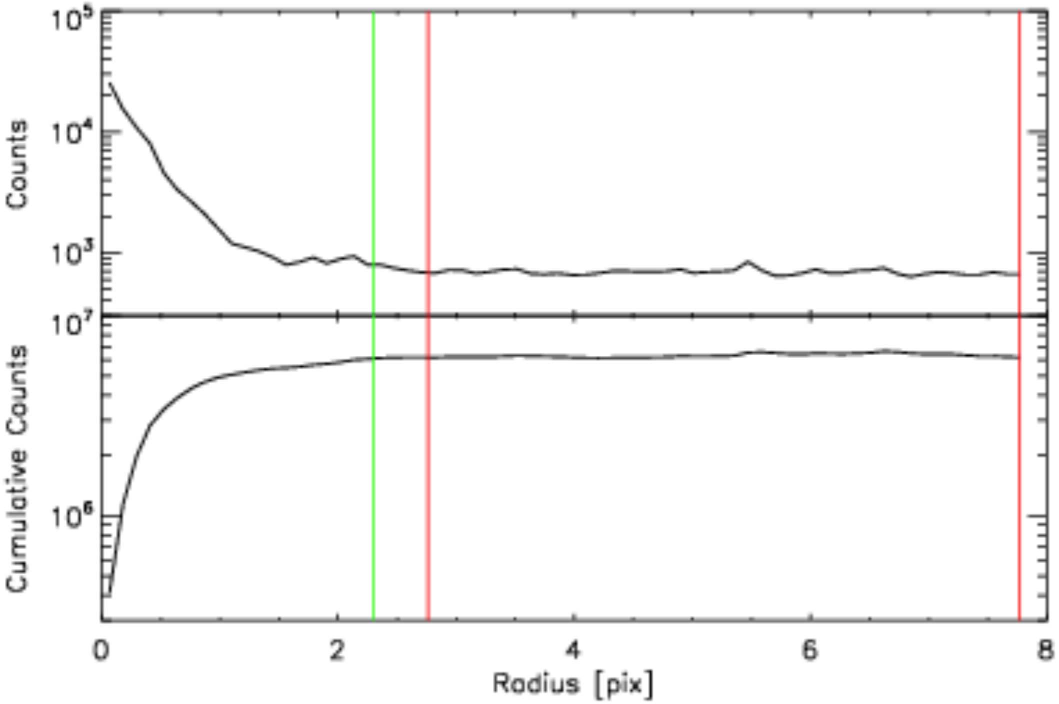
Different Foci for Different Purposes

- At Prime and Cassegrain focus, instruments have a variable gravity vector – not the best place for stable spectrographs.
- Spectrographs are best at Nasmyth, or fed by fibers. Some are *integral field units* – taking a spectrum of ever pixel, called a “spaxel”
- Refractive telescopes have a limited aperture size – only good for wide fields of view.



Aperture Photometry





- Measure the total counts ($\Sigma C(i.j)$) in green circle.
- Estimate sky background (sky/pixel) between two annulus

$$C = \Sigma C(i.j) - \text{Npixel} * \text{sky/pixel}$$

N_{pixel} is total pixel number in the green circle

Signal-to-noise

- Remember back in week 1: $S/N = \sqrt{r} \approx \sqrt{N}$
- In practice, counting photons from a target is not always the dominant source of noise.
  - Observations are *background limited* if the sky is brighter than the target, when averaged over the solid-angle *aperture* of the target.
  - If image size (”seeing”) is larger, then the aperture is larger and an background noise is larger.
  - Observations are *readout noise* limited if the detector noise, rather than target shot noise or background shot noise limits an observation.

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