Tópicos

Close binary stars

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Lecture 4

21/08

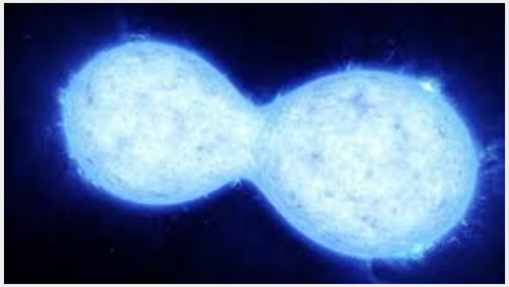
Classification of binary stars

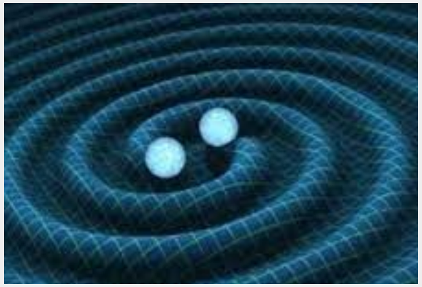
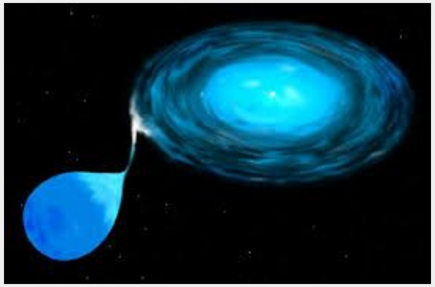
Classification of binary stars

→ Based on **phenomenology**:
- by discovering “striking” cases and name similar ones to them (e.g. Beta Lyrae, Algol)
- or a physical process (X-ray binaries, novae…)

→Based on **observational techniques** (visual, spectroscopic, astrometric, eclipsing)

→Based on physical **Roche model**



Types based on observational techniques

Depends on our instruments, the distance to us + orbital parameters, and the orbit configuration with respect to us (face on, edge on…)

→ **Visual** binary: a pair orbiting each other far enough apart (or close enough to us) that we can see the two stars.

→ **Astrometric** binary: only one star can be seen, but the wobble of its proper motion indicates the existence of another star in orbit around it.

→ **Spectroscopic** binary: evidence for two different stars in the spectra, or radial velocity (RV) variations.

→ **Eclipsing** (or photometric) binary: the orbital plane is nearly edge-on with respect to our line of sight. We see partial or total eclipses.

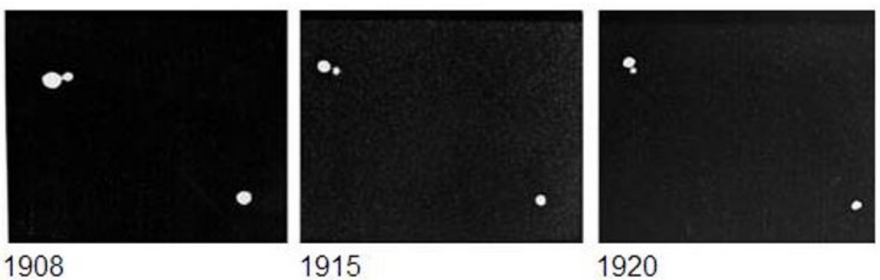
A binary star may be a member of one or more of these classes. For example, an eclipsing binary may also be a spectroscopic binary if it is bright enough

Visual Binaries

- Both stars resolved
- Near to the earth, with long period only.

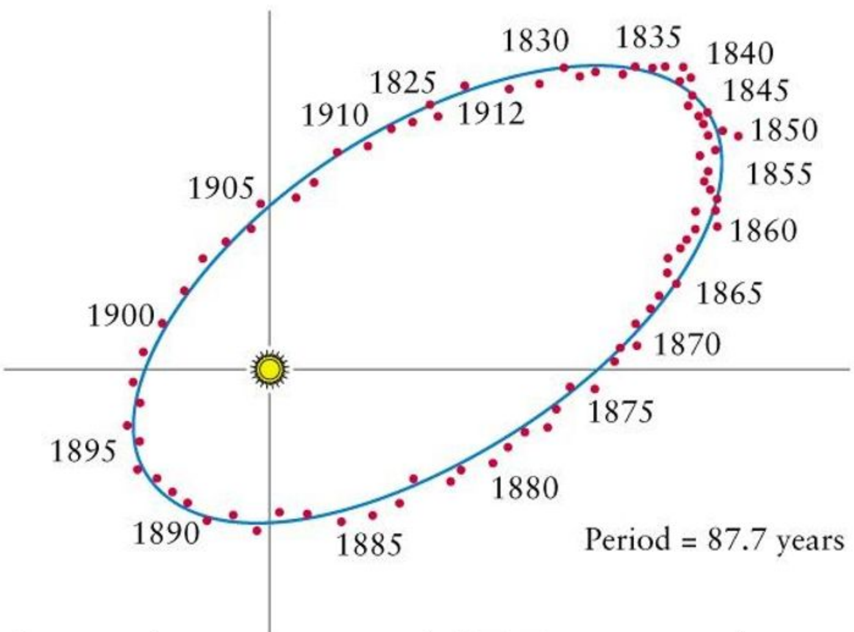
Examples:

Kruegar 60



From 1908 to 1920 the visual binary completed about 1/4 of a revolution.

70 Ophiuchi

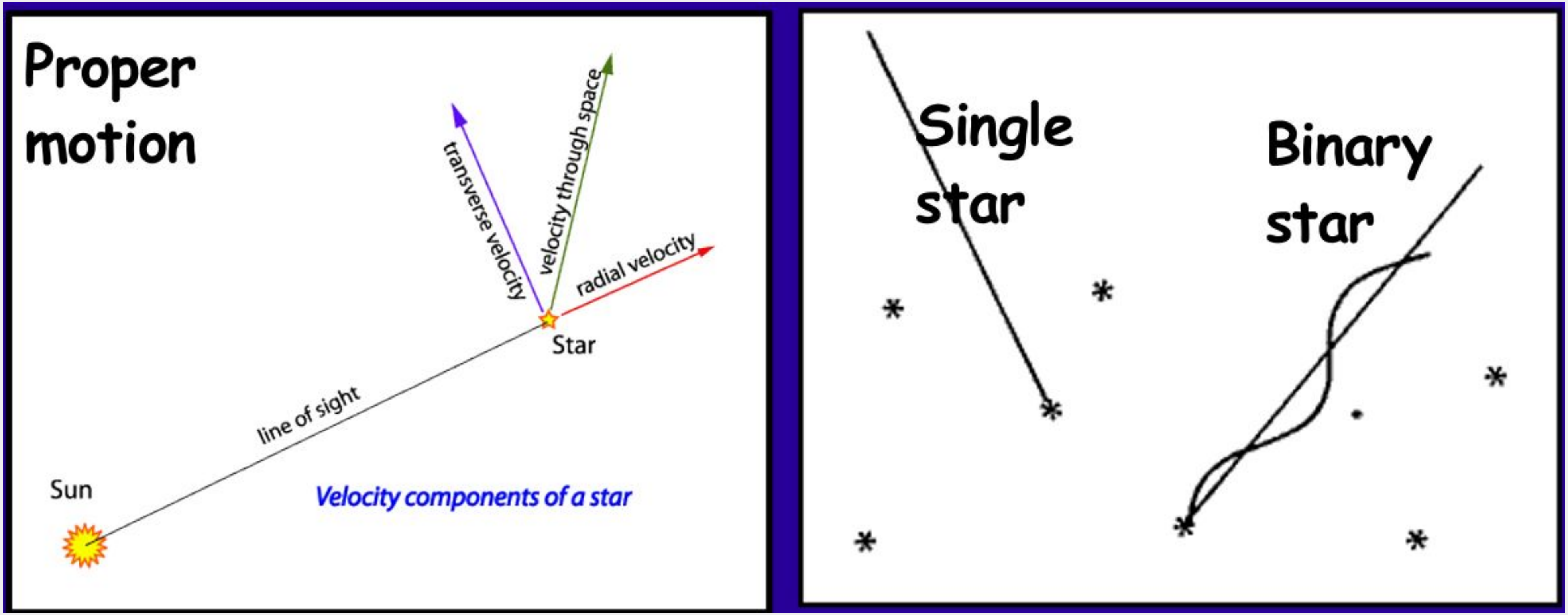


Over the course of 87.7 years, the star makes one full orbit.

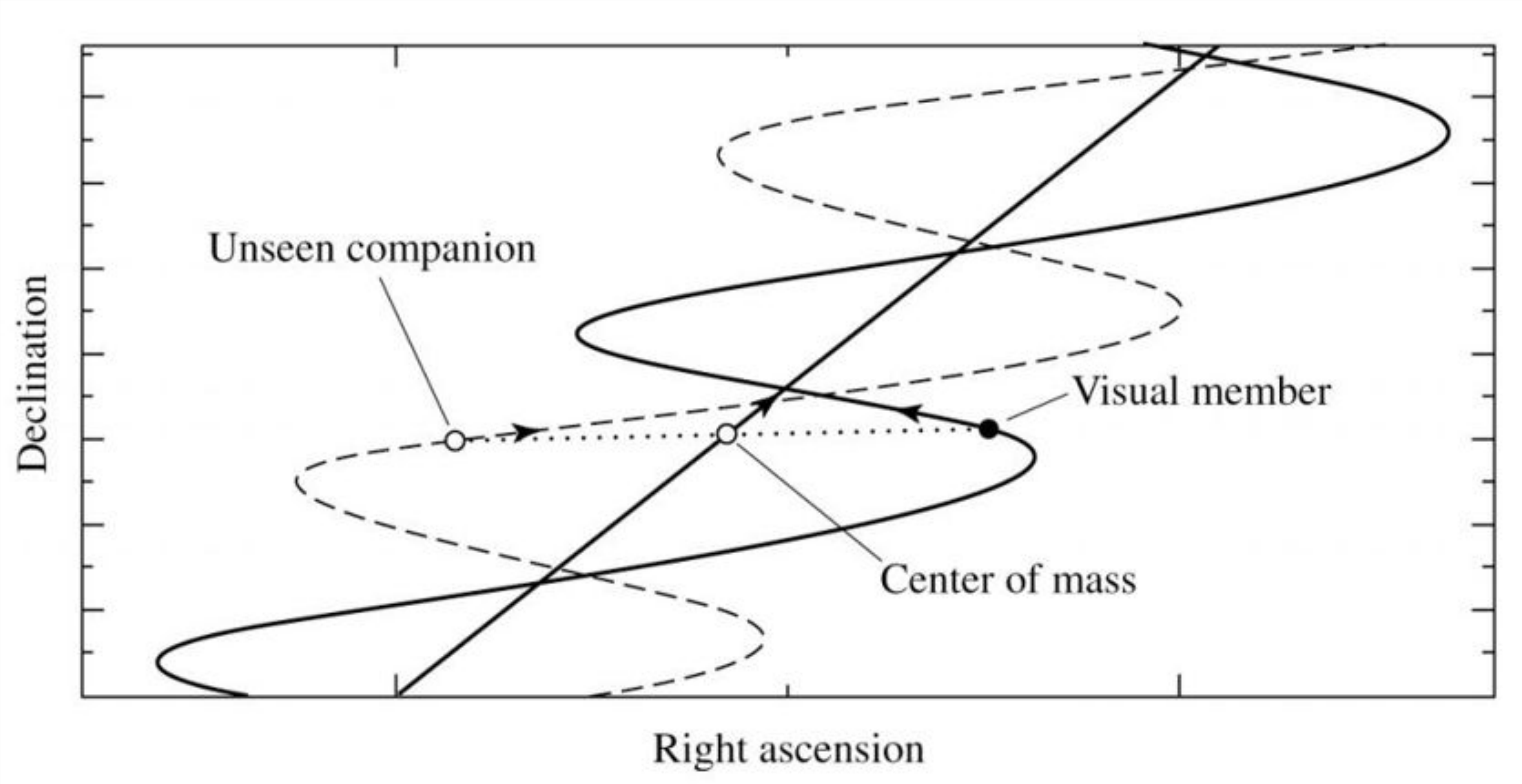
Astrometric Binaries

Binary nature revealed by proper motion.

Only one star is visible, but we can detect that it wobbles about an unseen centre-of-mass.

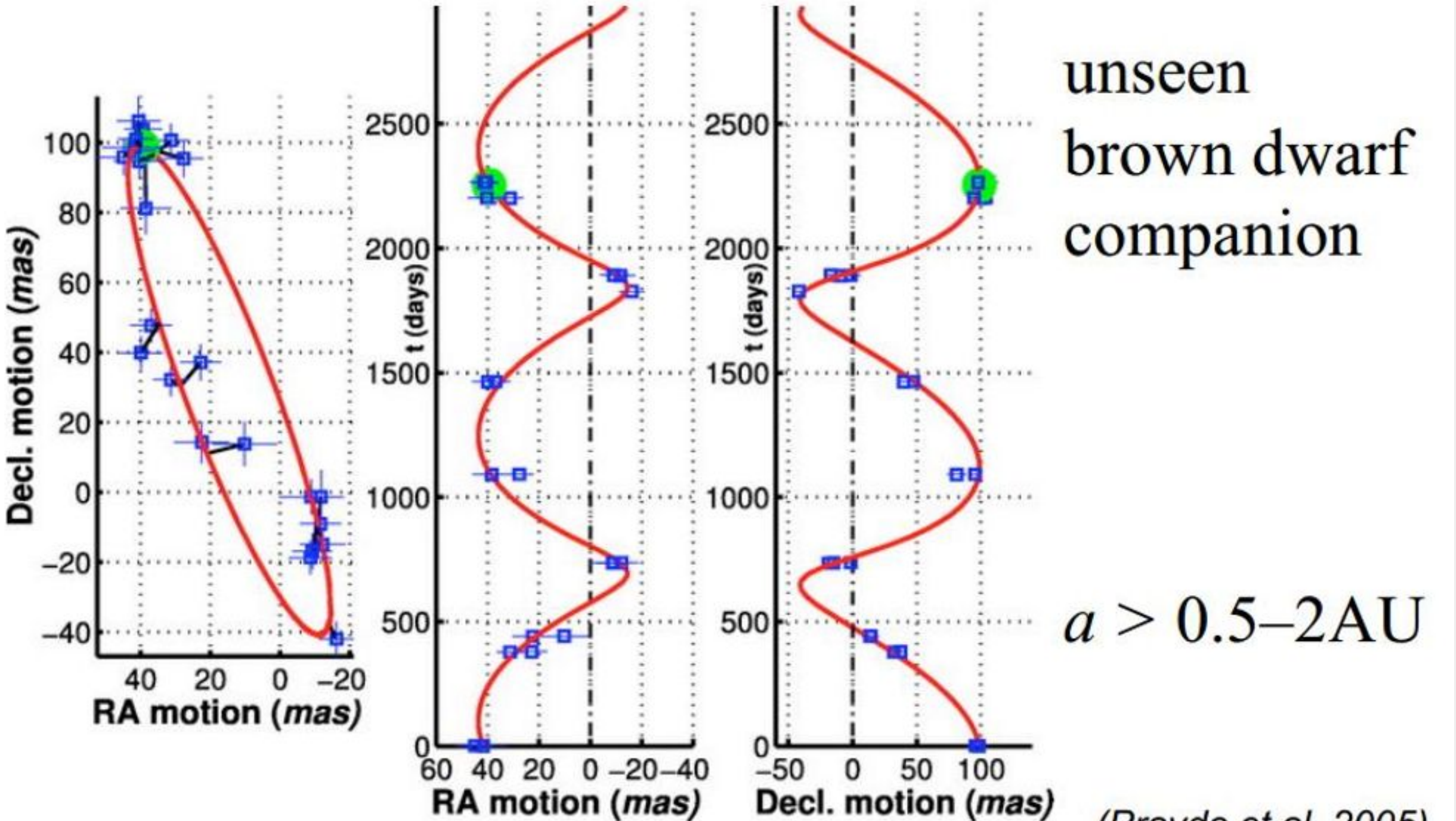


Astrometric Binaries



Astrometric Binaries

Example: GJ 802AB



(Pravdo et al. 2005)

Astrometric Binaries

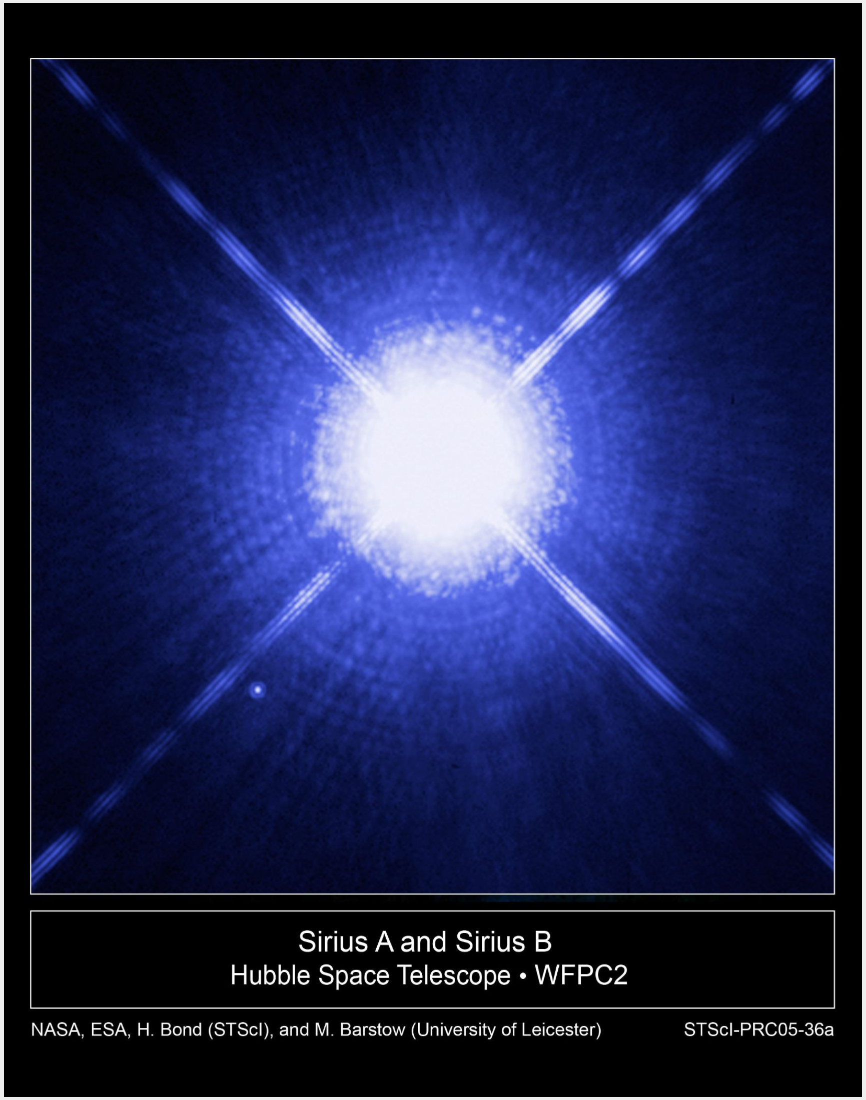
Example: Sirius A (~2$M_\odot$ MS star) + Sirius B (~ 1$M_\odot$ WD)

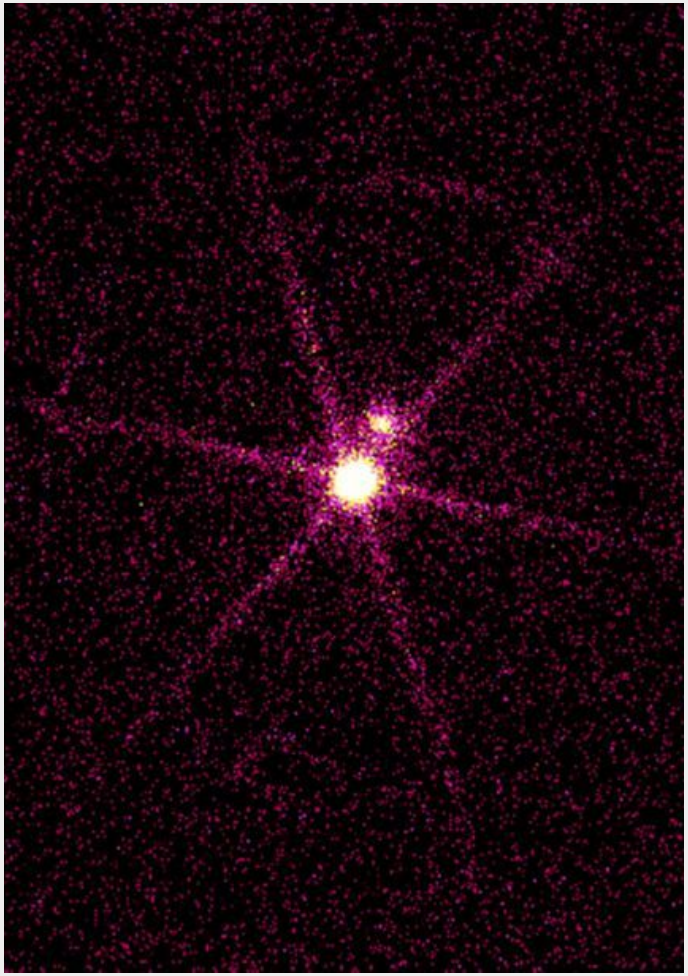
Sirius A is much brighter than Sirius B.

Sirius B was first detected by observing the proper motion of the brighter Sirius A.

Sirius A/B

With the current instruments, it is also a visual binary.





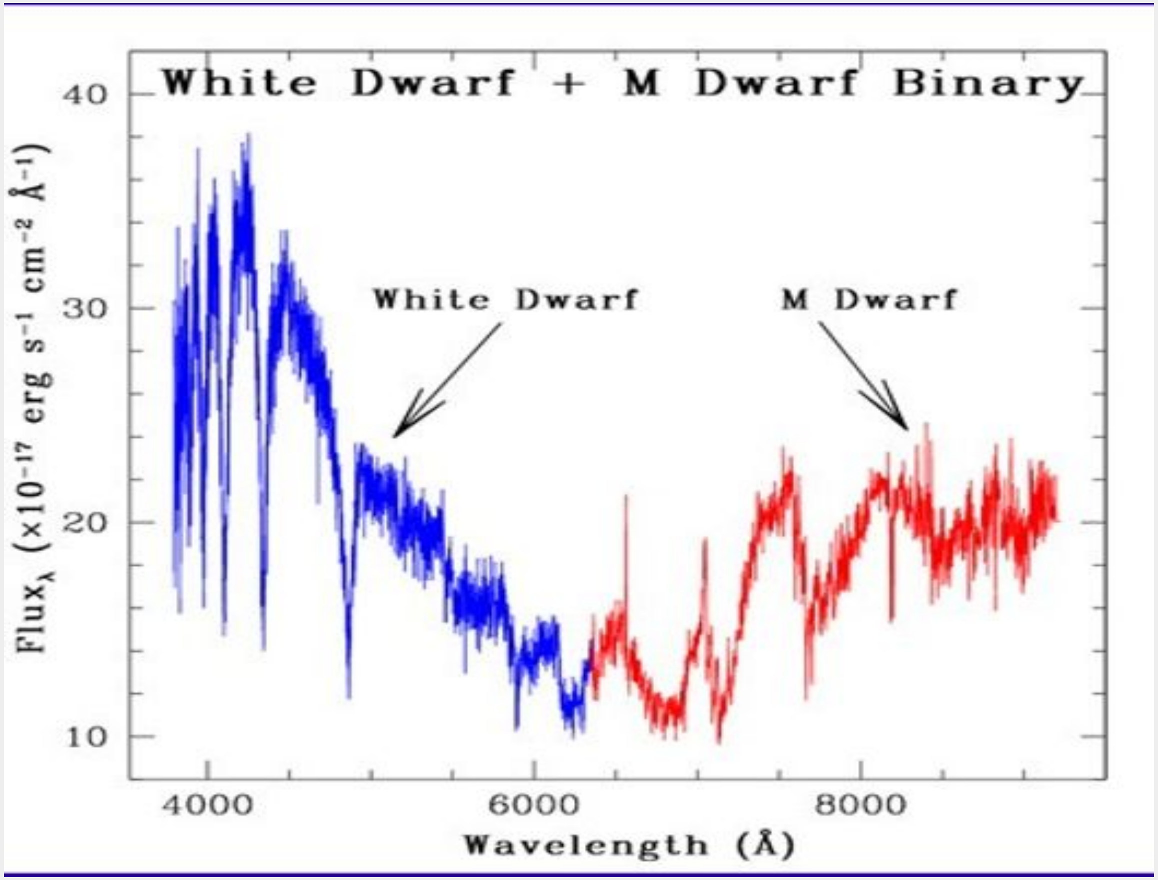
Chandra image (X-rays)

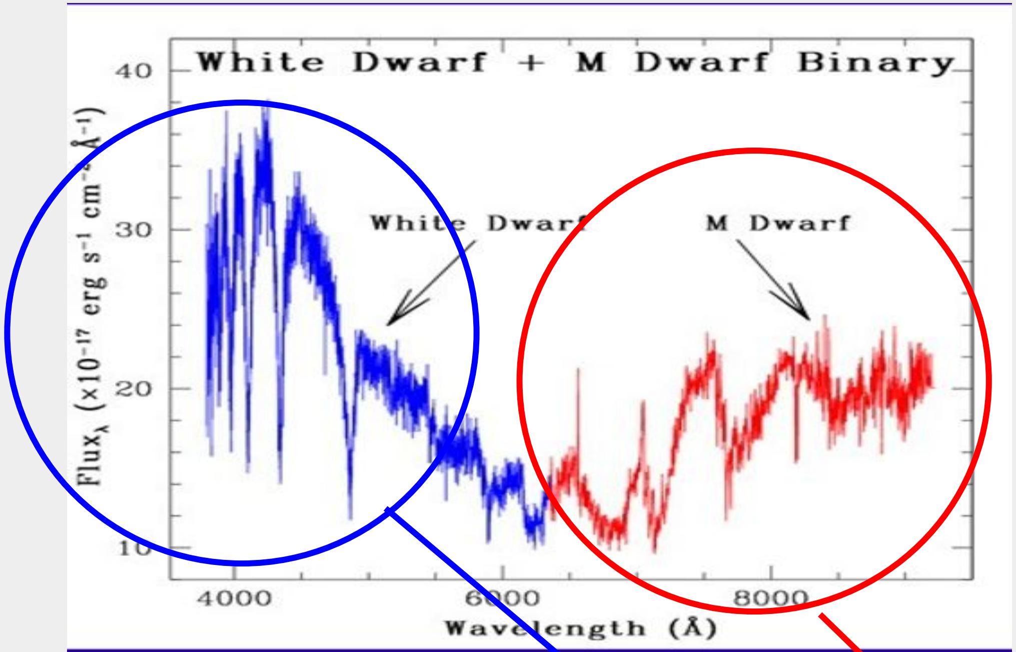
Spectroscopic binary (SB)

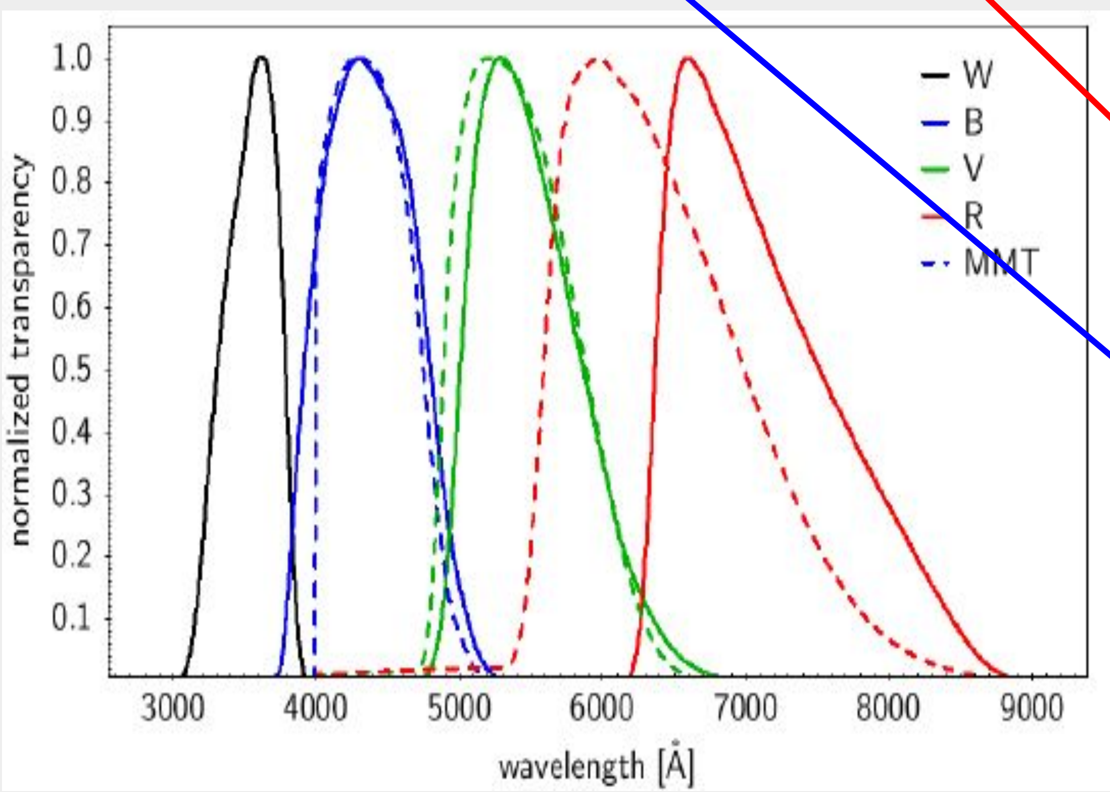
Two stars in orbit around each other but generally too close to each other (and/or far from us), fall in the same slit → not resolved.

Binary nature is revealed by the spectra.

Example:
composite spectra in a close WD + low -mass MS binary







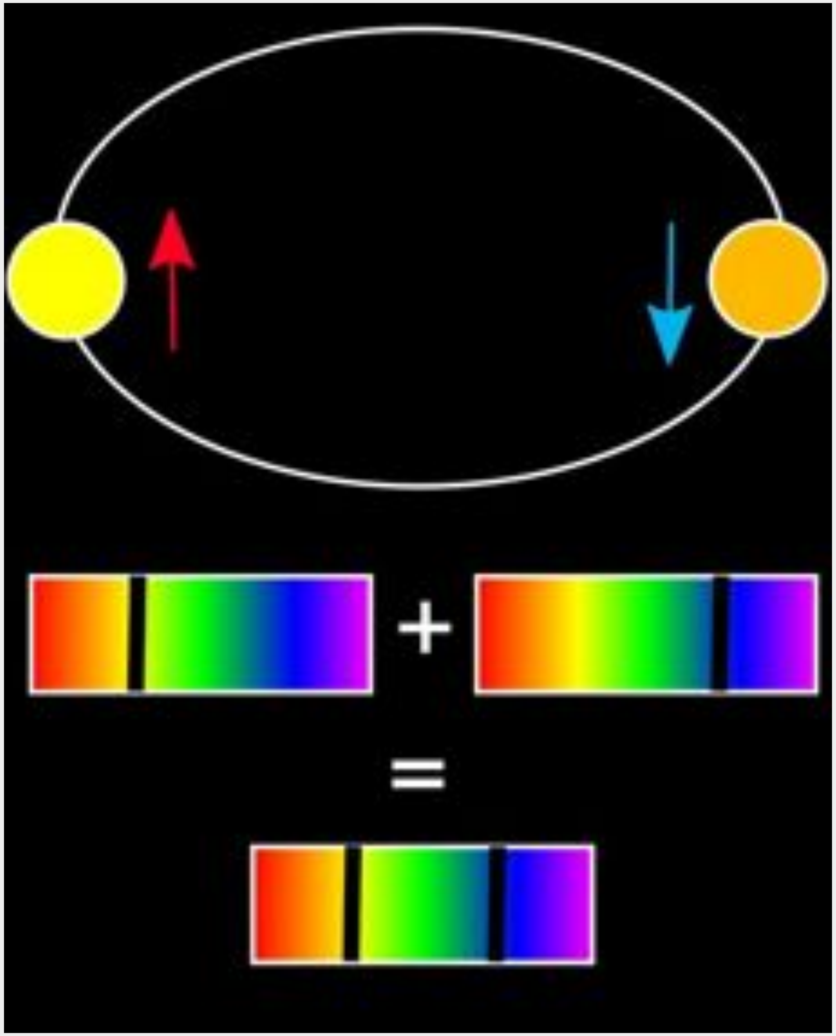
Not always you can see the composite spectra.

Depends on T_{eff} for bot stars, and wavelength range coverage.

Dominates in red and IR

Dominates in blue and UV

Spectroscopic binary (SB)



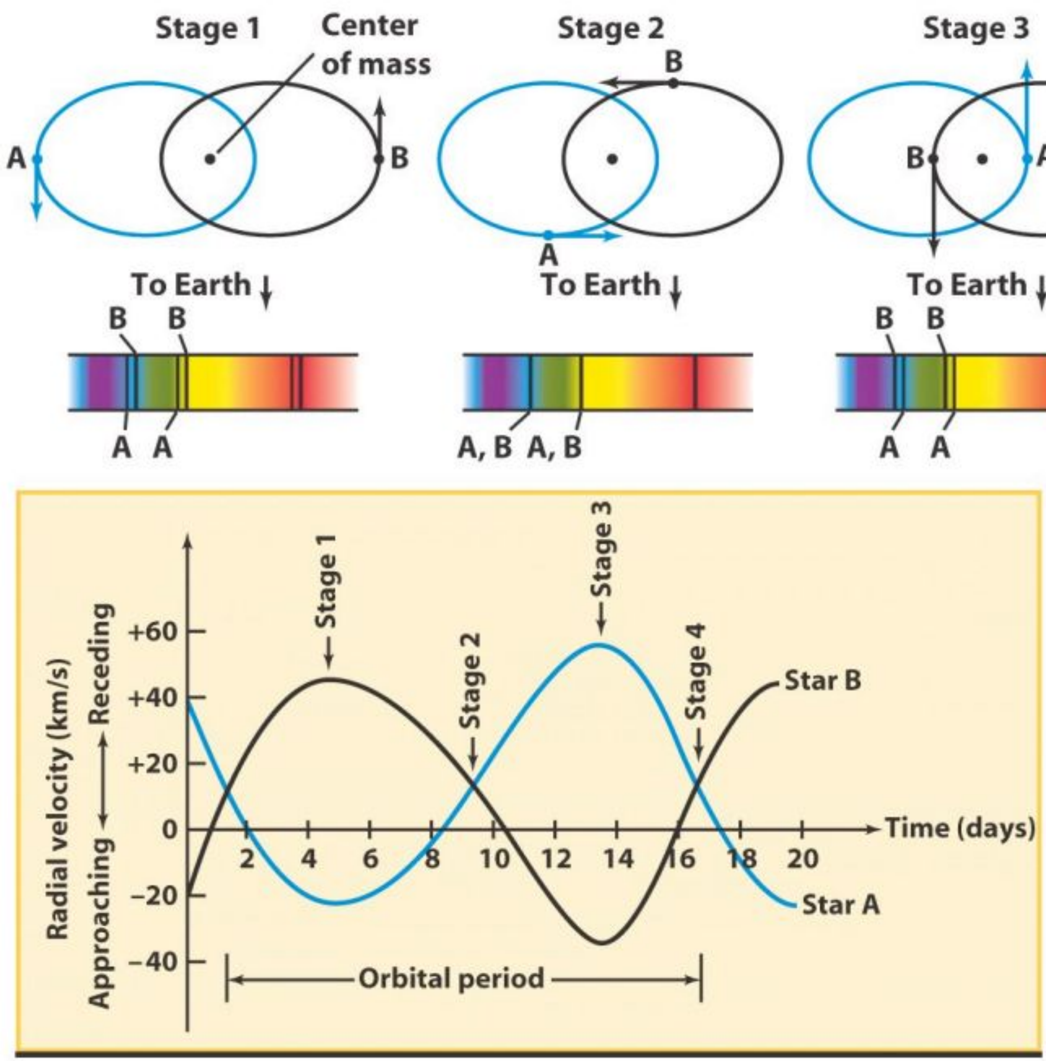
Even if you see only one component in the spectra, the binary nature can still be revealed by doppler shifted lines (periodical shift to blue and red during orbital phases, if inclination is enough to detect RV variations)

- SB1: lines from one star

- SB2: lines from both stars (they move in antiphase)

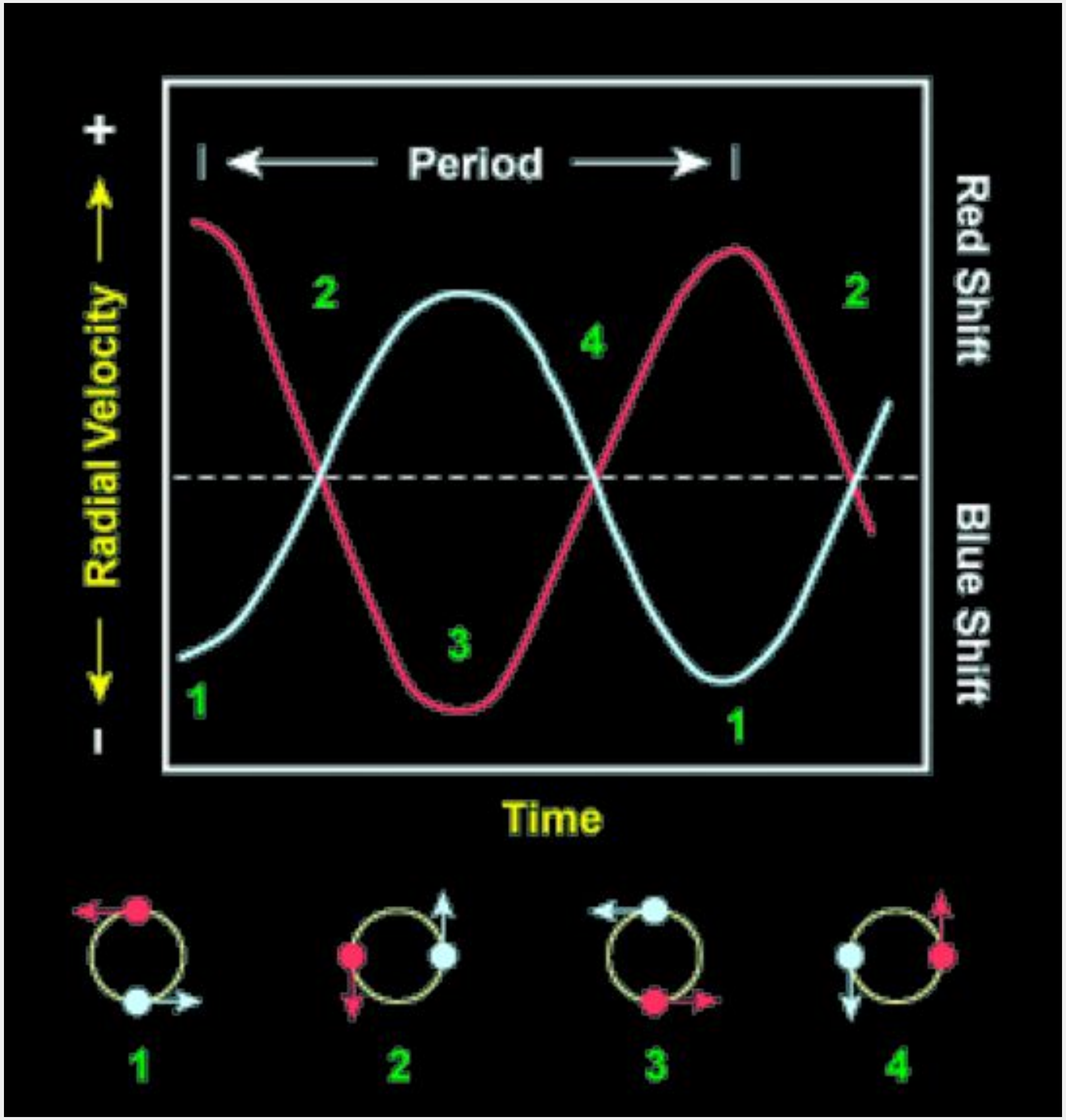
Spectroscopic binary (SB)

From the Doppler shift data, we can reconstruct the component of the stars velocities in our line of sight (Radial Velocity).



Velocity curves for a spectroscopic binary

Spectroscopic binary (SB)



In SB2s it is possible to measure the RV curves of both components.

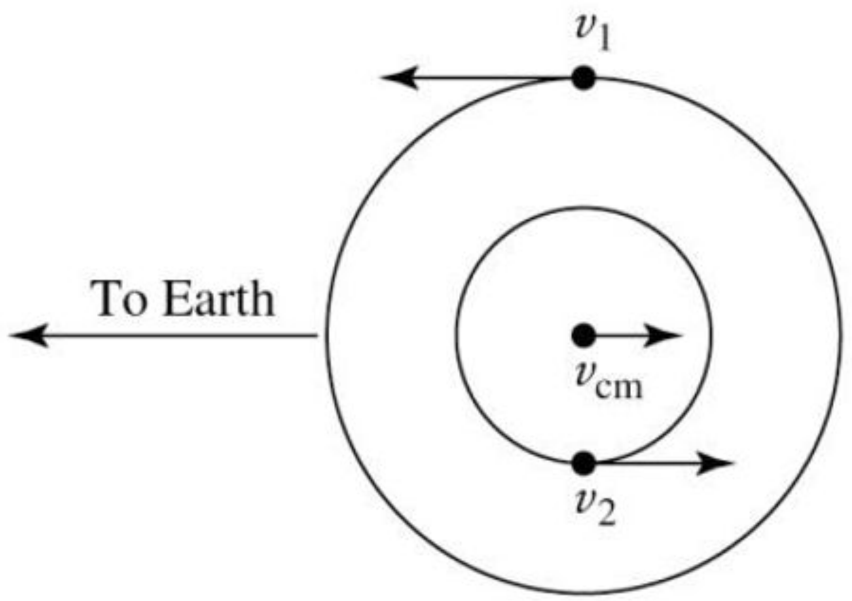
The true velocities are only known if the inclination angle with our line of sight is known.

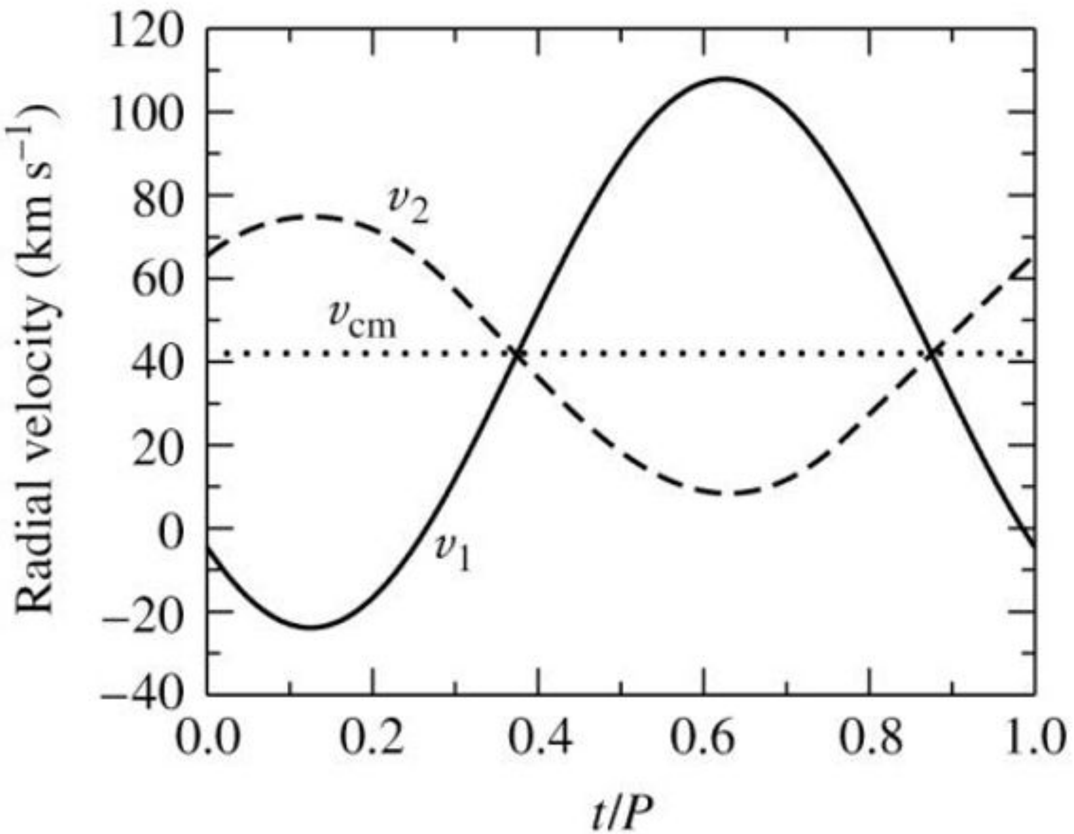
$$v_R = v \sin(i)$$

EXTREME CASES:
face-on orbit: $i = 0$ (no RVs, except by the systemic velocity of the system with respect to us)
edge-on orbit: $i = 90°$, $v_r = v$

Spectroscopic binary (SB)

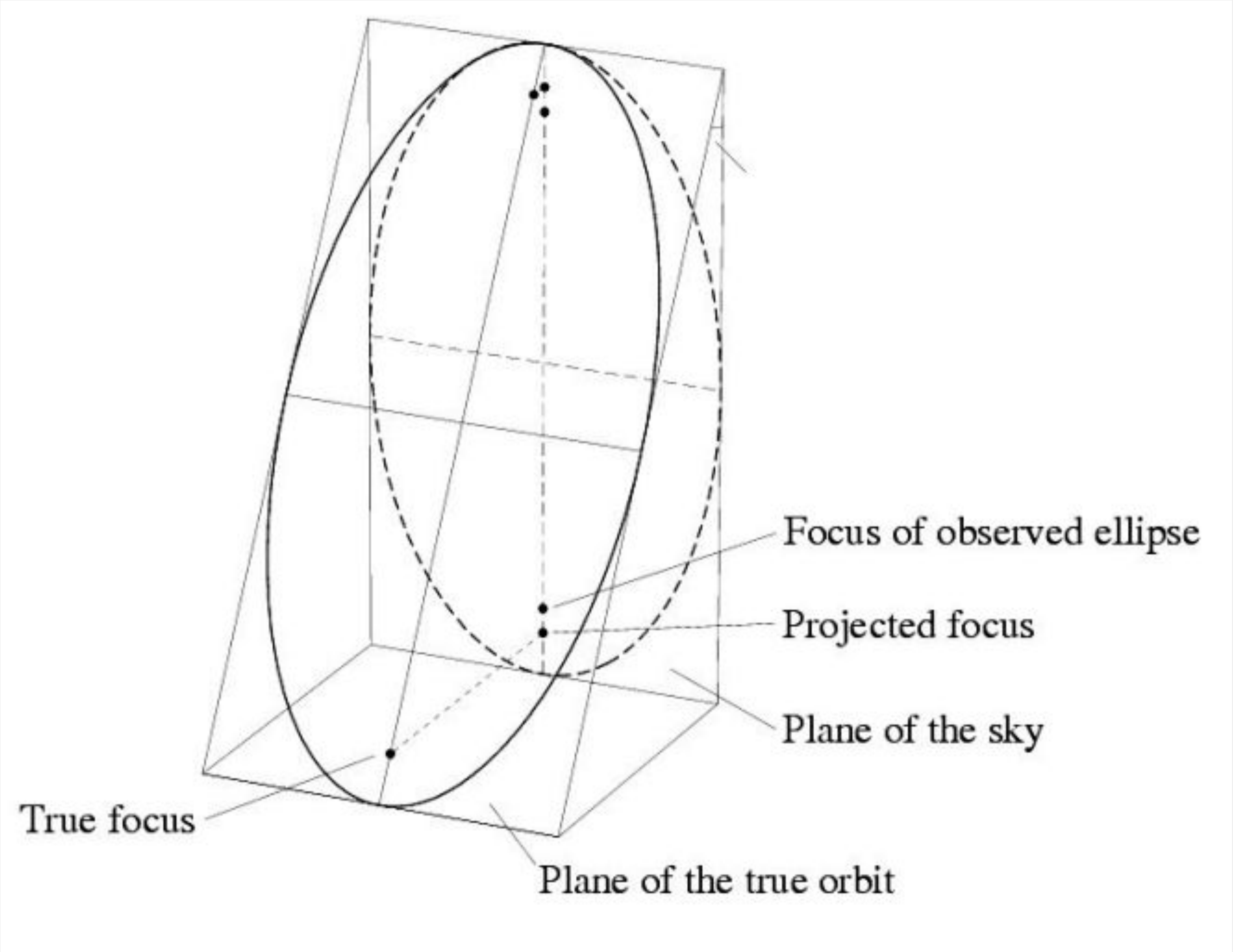
A simple orbit geometry (circular orbits) and edge-on (i=90°) orientation leads to a simple and easy way to interpret the RV curves





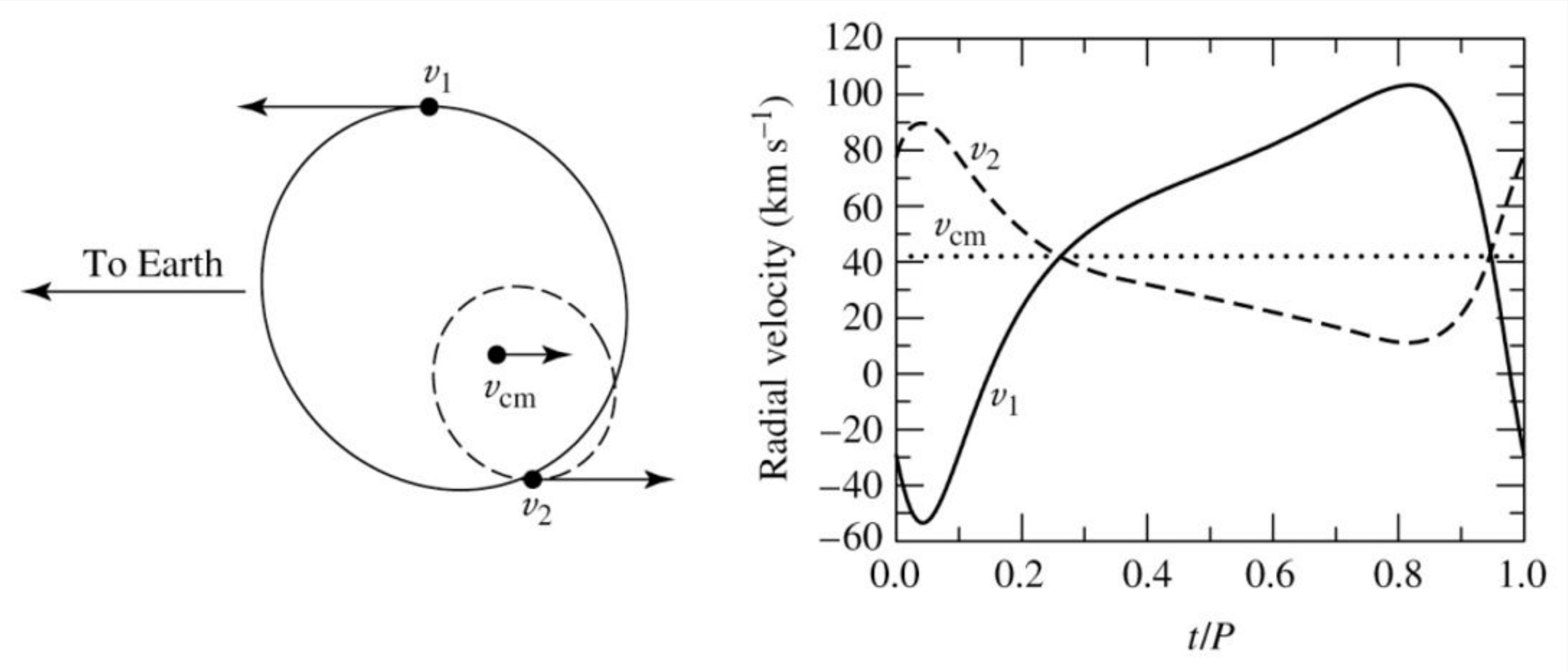
Spectroscopic binary (SB)

But commonly, orbits are not circular, not edge-on, and the orbital plane is tilted relative to the plane of the sky, leading to a more complex shape of the RV curves, which could be used to constrain the orbit orientation.



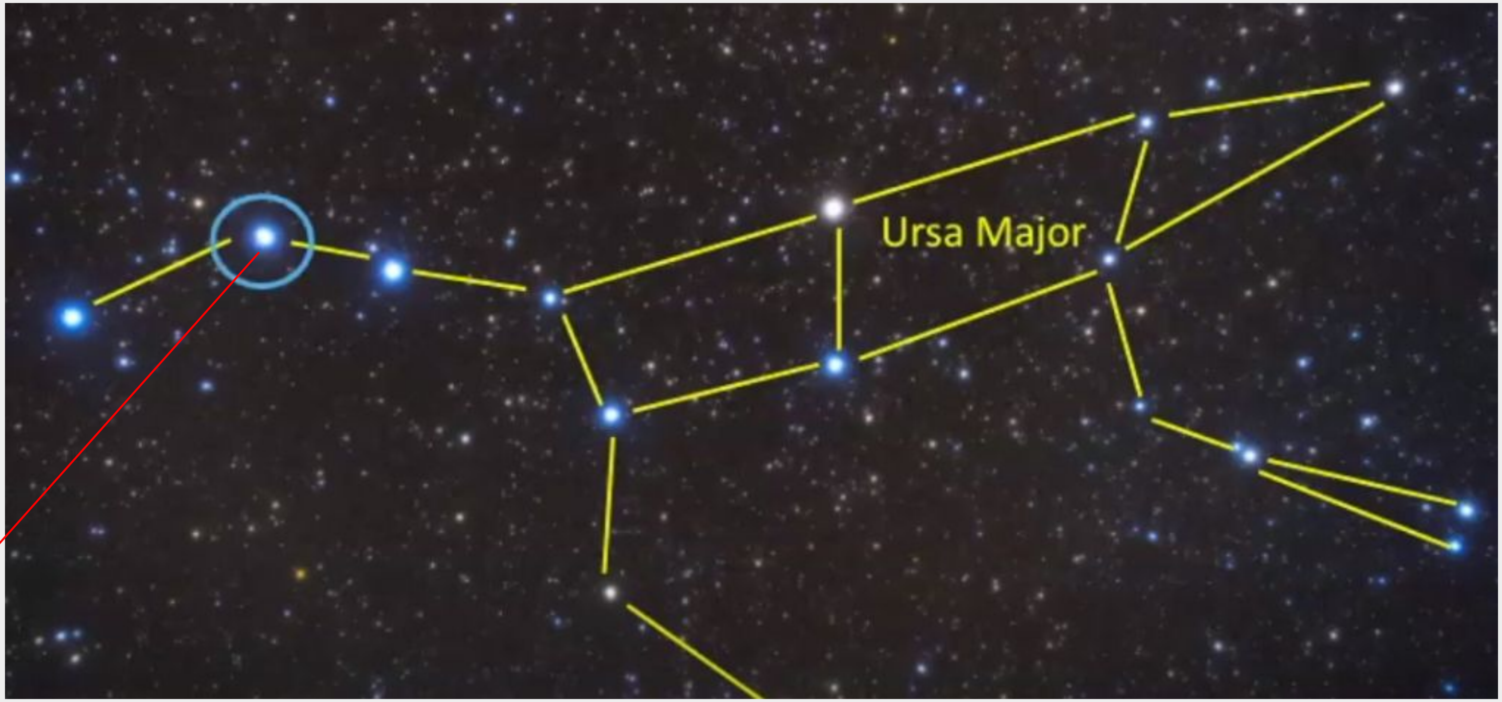
Spectroscopic binary (SB)

Example, RV curve for a SB2 in an elliptical orbit (e = 0.4)



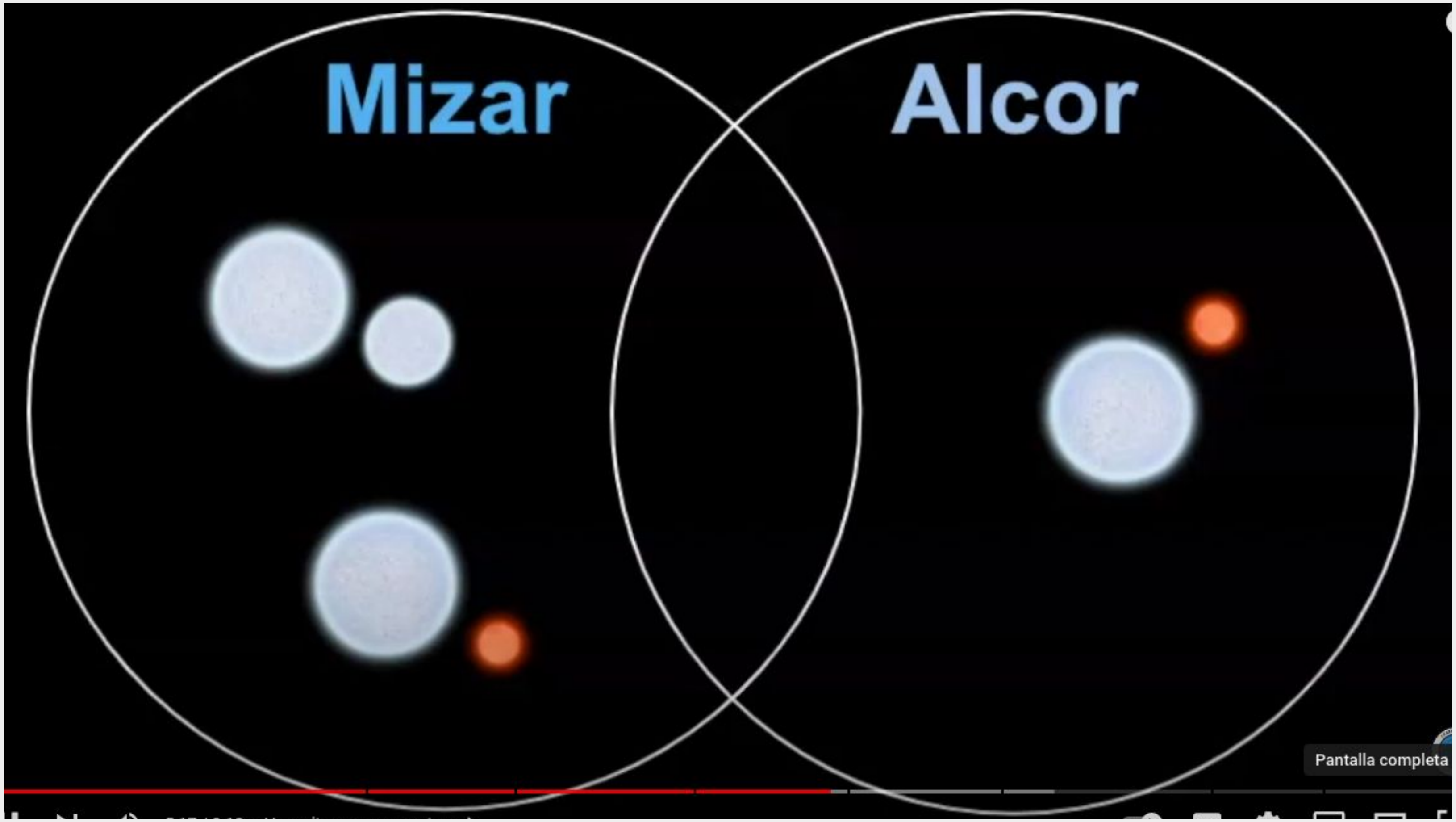
Spectroscopic binary (SB)

The first spectroscopic binary system was discovered by E. C. Pickering in August, 1889, and remarkably it was one of the components of the first visual binary, namely Mizar (the brightest) and Alcor (the dimmer)



Spectroscopic binary (SB)

Now we now that it is a sextuple system.
What we see as “Mizar” is indeed a quadruple and what we see as “Alcor” is a binary

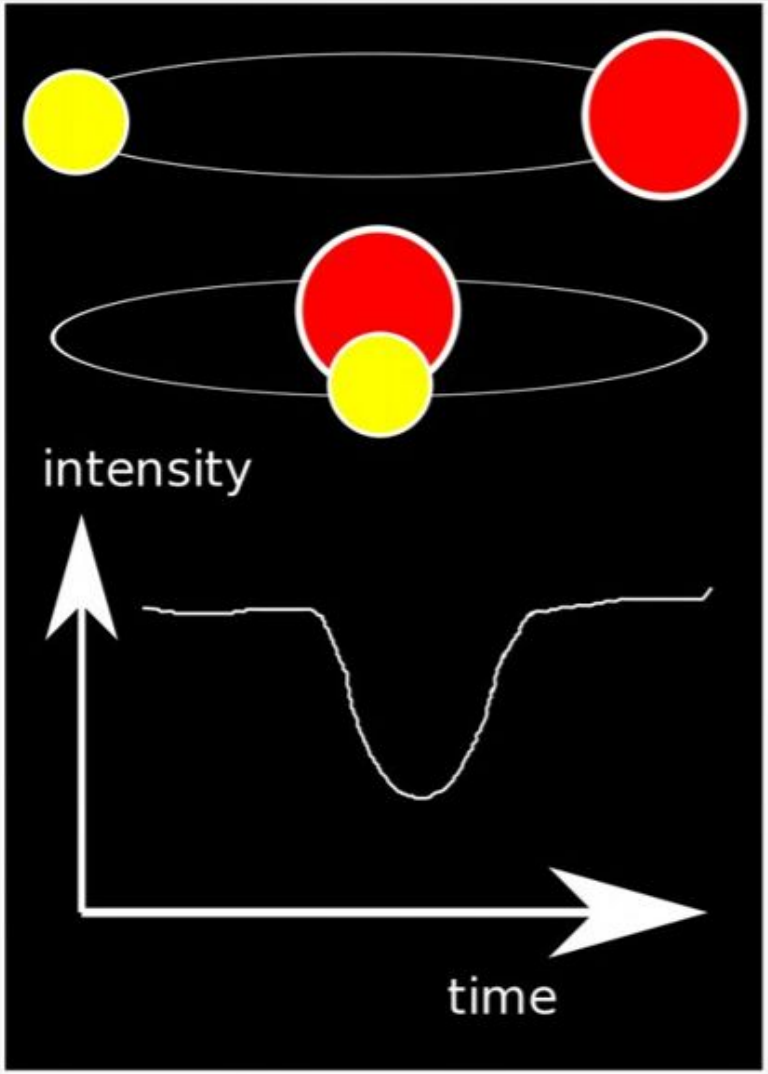


Eclipsing Binary

Light curve shows regular light variations due to one of the stars passing in front of its companion, as viewed from the Earth.

Light curve variability:

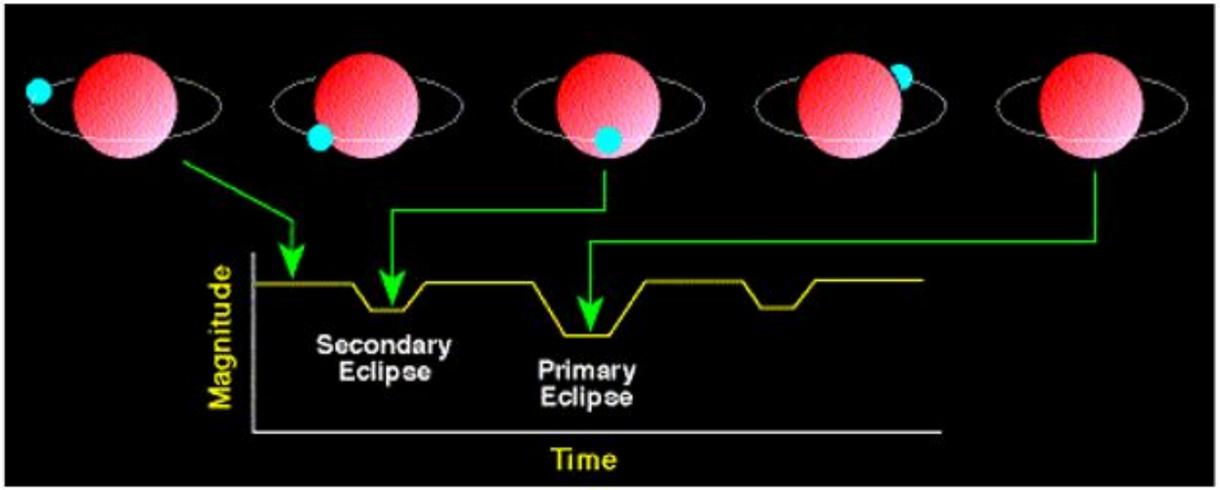
- Eclipses
  (requires high-inclination, nearly edge-on)

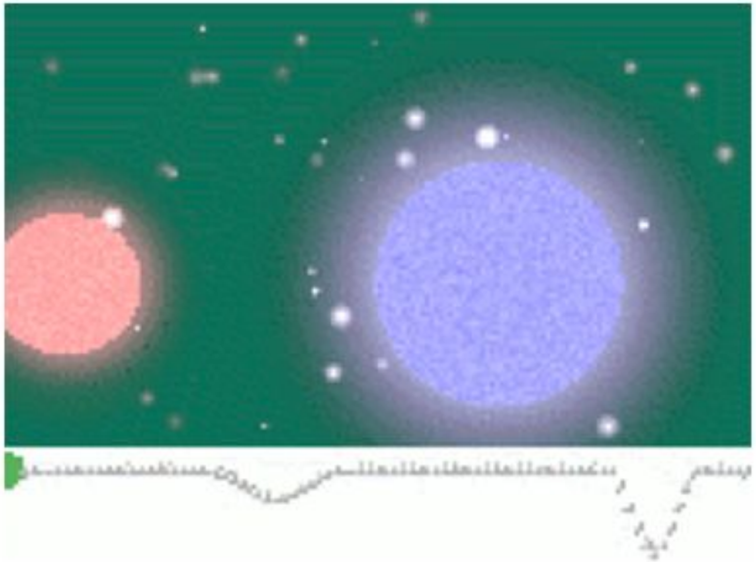


The first eclipsing binary, Algol, was discovered by Goodericke in 1782.
In 1889, H. C. Vogel found that Algol was also a spectroscopic binary.

Eclipsing Binary

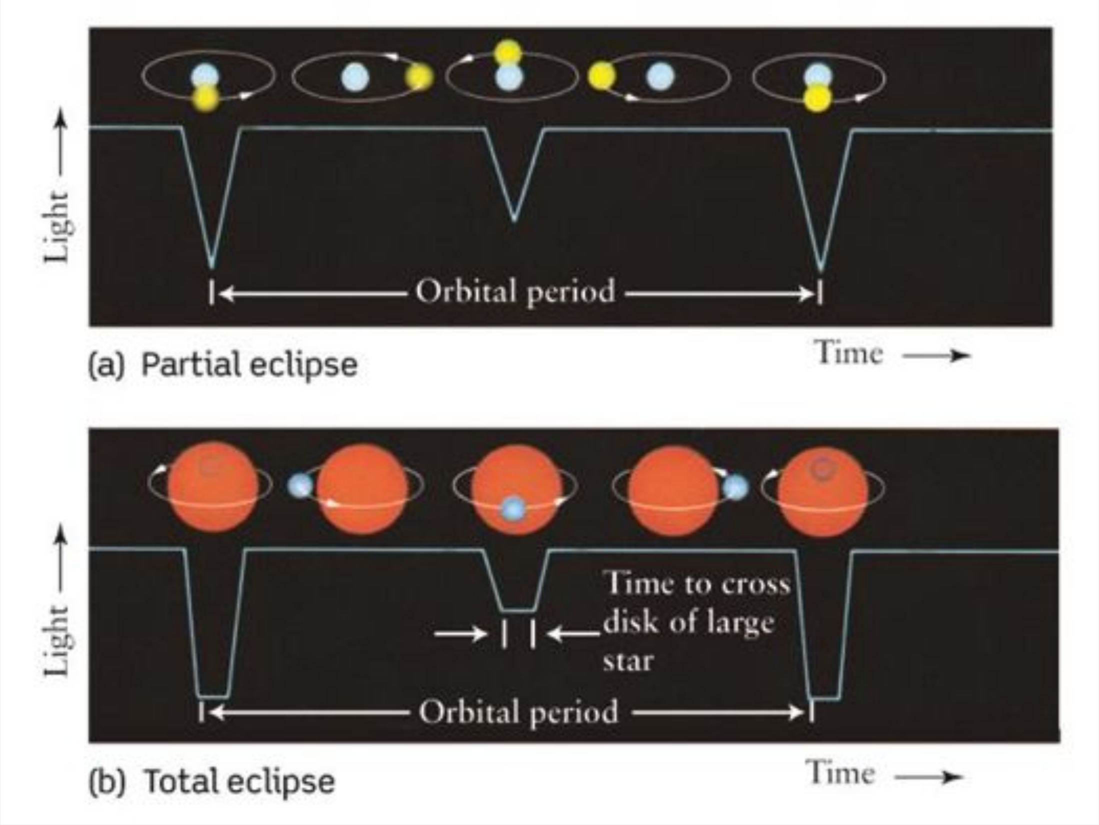
Orbital period = time between two primary or secondary eclipses





Primary eclipse is always when the brightest star, in the observed filter, is covered by it's companion.

Eclipsing Binary

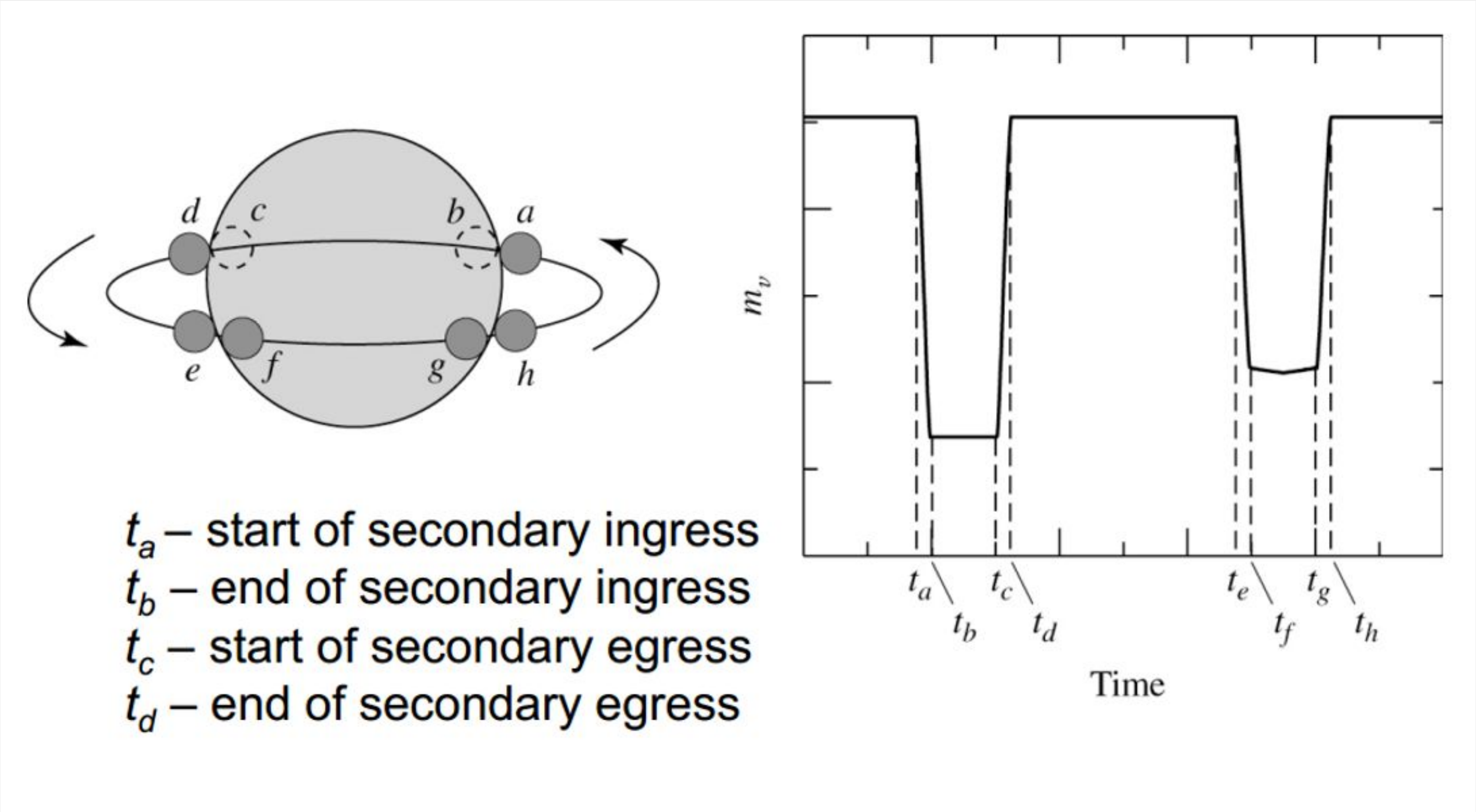


By studying the shape of the eclipses, in conjunction with a knowledge of their radial velocity curves, it is possible to determine the masses and radii of the stars in the binary.

Eclipsing binaries are hence extremely useful systems.

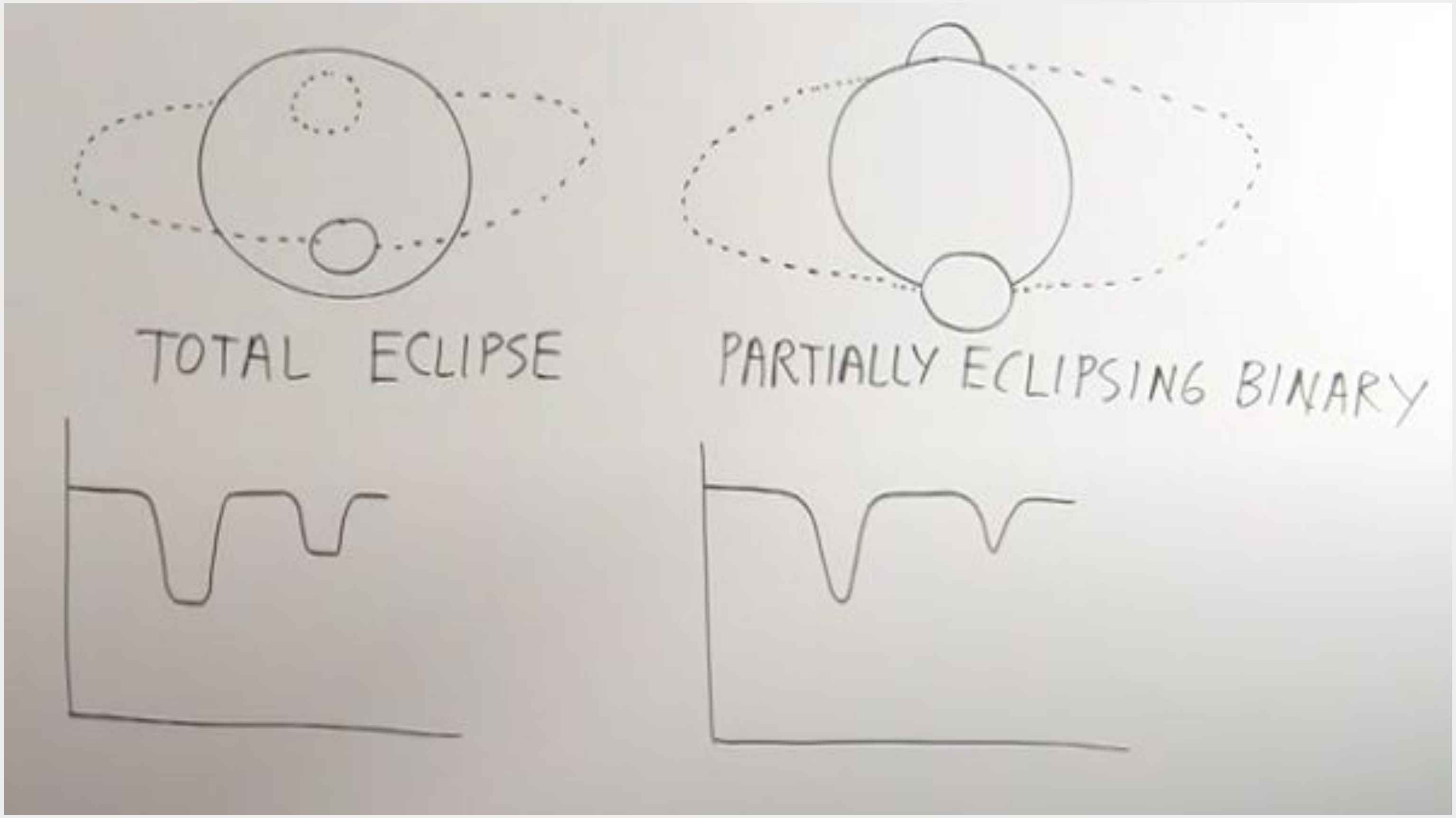
Totally eclipsing Binary

The “best” systems are those with clear **total** eclipses where we can measure the duration of ingress and egress, as well as the duration of the total eclipse



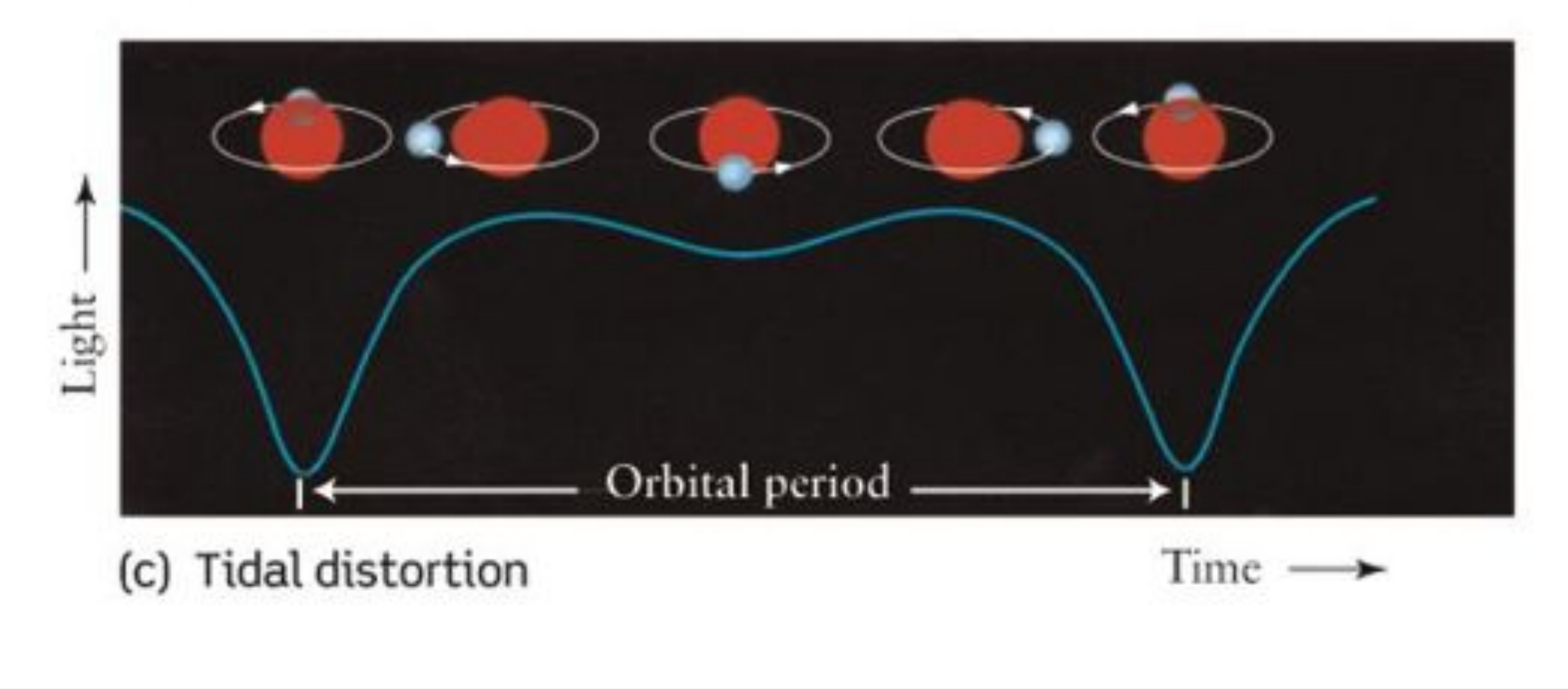
Partial eclipses

When the orbital plane of the two stars is not perfectly aligned with our line of sight, we can have the stars only partially eclipsing each other during their orbit.
This results in a shallow dip in the light curve as opposed to the deeper, more pronounced dips seen in total eclipses.



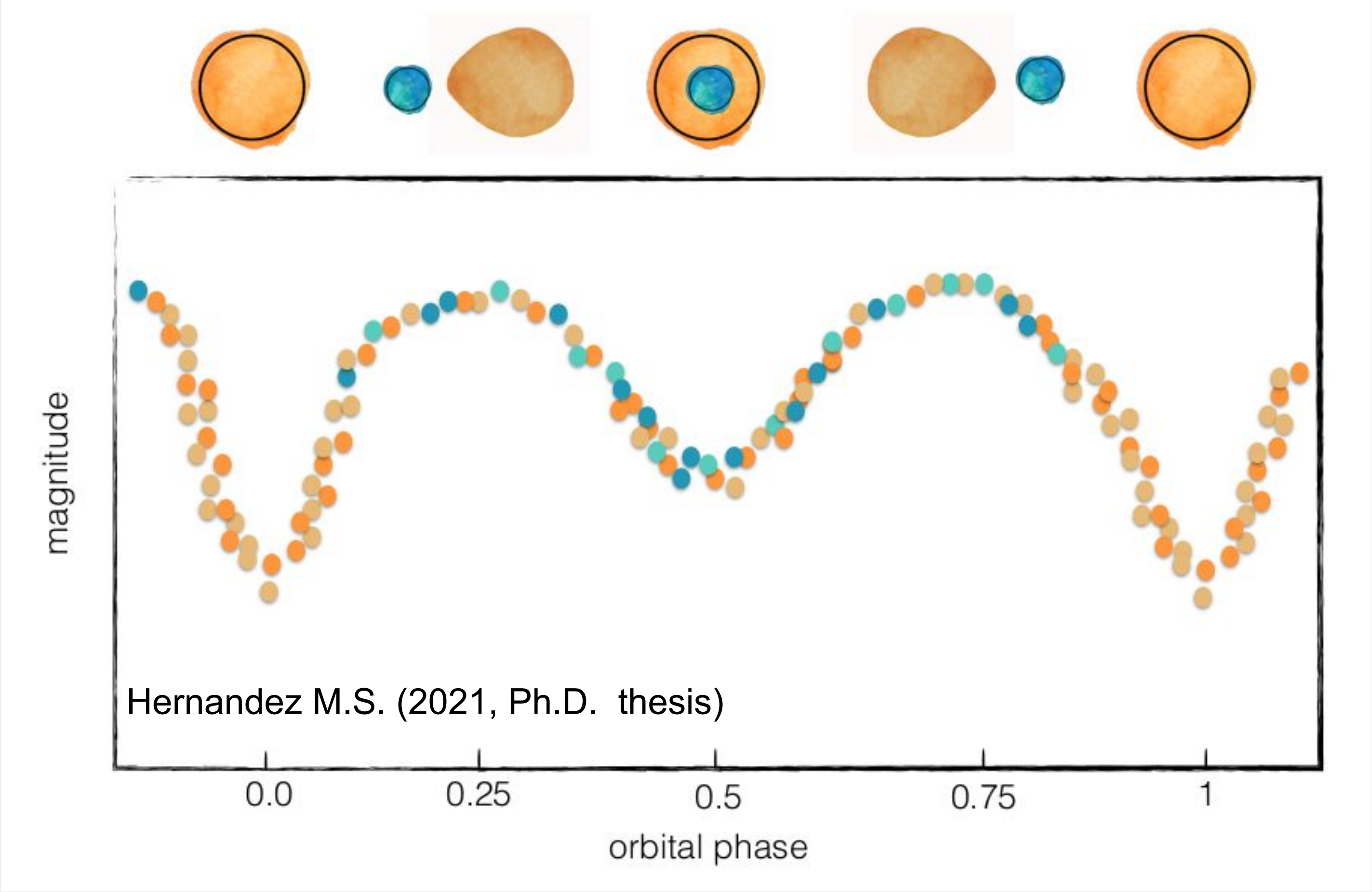
Eclipsing Binaries with ellipsoidal modulation

- For close binaries we can also see: Ellipsoidal modulation (requires at least one of the two stars to be tidally distorted, i.e. non-spherical)



Eclipsing Binaries with ellipsoidal modulation

The distorted (non-spherical) shape of a star in a close binary is often detectable in the light curve of the binary system.
The distorted star presents maximum surface area to us and appears to be brighter when it is seen side-on, which occurs a quarter of the cycle before and after the eclipse. When the elongation lies along our line of sight, the star looks fainter. This phenomenon is called *ellipsoidal modulation*



Next: Newton and Kepler’s law