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1 Intro

Importance of binaries

- Plays a key role in the evolution of massive stars
- first presumed to exist because of Algol Type stars. These stars were explained with mass transfer
- Mergers are a key source of strongest GW rad, GrBs, and have r-process elements. (i.e. in Kilonova)
- Likely cause of SNe Ia, Ib, Ic (SN with a lack of hydrogen in their spectra)
- cause of low-intermediate mass stars with odd chemical compositions, ex. barium stars.

2 Visual binaries and the universal validity of the laws of physics

2.1 Visual binaries

- Visual binary $\rightarrow$ two in proximity through a telescope
- Physical $\rightarrow$ gravitonalty bound orbits
- Optical $\rightarrow$ happen to be close together in the sky
- Visual binaries have longer orbits
- the proof of physical binaries (and not just coincidence) was proved in 1767 by John Michell
- Shows that Newton's law of gravity applied outside just our solar system

2.2 Astrometric Binaries

Wide binaries

- Binaries where one of the stars is too faint to directly observe
- Can still be detected by the following Proper Motion of the visible component
- Center of mass moves along, star orbits this center, showing a periodic wiggle in its apparent motion (I wonder how this can be muddled with and/or separated from parallax. I'm guessing they are in different planes?? (next graphic helped(it wiggles slightly due to yearly parallax, however, the proper motion is much greater and over a much longer duration, so it sort of just becomes "noise" relative)))

2.3 Spectroscopic Binaries

Spectroscopic Binaries

- A binary which is determined to be a binary due to its spectra
- double-lined binary (SB2) $\rightarrow$ when both sets of spectral lines can be observed redshifting and blueshifting
- single-lined (SB1) $\rightarrow$ when only set of spectral lines can be observed redshifting/blueshifting
- this is due to Doppler shifting when one of the binaries is relativistically coming towards us and the other away
- Doppler shift ($\Delta\lambda$) can be related to the radial velocity (the component of the velocity on our line of sight)
- $$\frac{\Delta\lambda}{\lambda} = \frac{v_{rad}}{c}$$

2.4 Eclipsing Binaries

Binaries where one star passes in front of the other at some point during its period

- A partial eclipse will happen if
- $$\sin(\phi) < \sin(\phi_0) = \frac{R_1 + R_2}{a}$$
- where inclination i is defined as the angle between the orbital plane and the plane of the sky $\rightarrow \phi = 90° - i$ and a is the orbital radius

- and a total eclipse will occur if

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$$\sin(\phi) < \sin(\phi_1) = \frac{R_1 - R_2}{a}$$

- We assume that the angles between line of sight and orbital planes are random, the probability of having an angle between 0 and ϕ_0 is the fraction of the surface area of the half sphere between the pole and the circle at an angle ϕ_0 from the pole, which is equal to $2\pi(1 - \cos(\phi_0)$. While the area of the half sphere is 2π[1]. Thus the probability of having an eclipse is

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$$\mathcal{F}_{eclipse} = (1 - \cos\phi_0)$$

- Assuming ϕ_0 small

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$$\sin\phi \simeq \phi_0 \simeq \frac{(R_1 + R)_2}{a}$$

- due to series expansion[2]

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$$\cos\phi_0 \simeq 1 - \frac{(R_1 + R_2)^2}{2a^2}$$

- Thus

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$$\mathcal{F}_{eclipse} = \frac{(R_1 + R_2)^2}{2a^2}$$

- Because $R_1 + R_2 < a$, eclipses are most likely for either dwarf stars with a very close orbital radius, or wide binaries where at least one star is a giant

[1] Try this myself and verify that this makes sense
[2] for sure do this at some point

Glossary

Algol Type Type of eclipsing binary with properties similar to the Algol system. It appears paradoxical because the more evolved star has a smaller mass, explained by mass transfer. 1

Kilonova A merger of either a NS+NS (DNS) binary or a NS+BH binary. Results in a bright signal resulting from the rapid decay the the NS material. Results in a peak brightness around 1000x that of a standard nova, hence the name. Likely a standard candle. 1

Proper Motion The motion of a star in the sky relative to more distant stars. Allows us understand the velocity of a star relative to the earth 2