Binary Stars in Astronomy

Most of our knowledge of stars’ **Masses** comes from **binary stars**

In a **binary star** system, two stars orbit each other. (In and “Optical Double”, they don’t)

*Alberio, a double star in Cygnus*

*Alpha Centauri A & B, The nearest star system to the Sun*
Binary Stars in Movies

Tatooine, a planet orbiting a binary star, in *Star Wars*
Types of Binary Stars

Binary Stars are common. More than half of the stars are in a binary (or multiple) system. Types of binary:

**Visual Binary:** both stars can be resolved  
(orbital period may be determined by long term monitoring)

**Astrometric Binary:** only one star is seen, and it wobbles  
(its motion is detected via *astrometry*)

**Eclipsing Binary:** One star passes in front of the other  
(lucky orientation of orbital plane)

**Spectrum Binary:** One star is seen, but its spectrum is doubled!  
(these two spectra doppler shift in opposite directions)

**Spectroscopic Binary:** One star, one spectrum which is shifting  
(The second star is very dim...and might even be a planet)
Mizar & Alcor: a naked eye Double Star...and more
With a telescope, we see that Mizar is a **Visual Binary**: Mizar A & Mizar B

And with a spectrograph, we see that *both* Mizar A & Mizar B are **Spectrum Binaries**
View from a hypothetical planet in the Mizar system
So, Mizar is 4 stars. Alcor is at about the same distance, but wasn’t thought to orbit Mizar because Alcor’s velocity exceeds the escape velocity.

But... Recent surprise: Alcor also has a companion!

Alcor A’s large velocity is due to its orbit around Alcor B!

The Alcor system (A&B) has low velocity and now appears gravitationally bound to Mizar.

So Alcor & Mizar are really a sextuple system!

In fact, they are part of the young “Ursa Major Moving Group”, investigated in 1950 by Nancy Roman.
The center of mass (CM), is a “balance point” that both stars orbit. It is always closer to the more massive star.

\[ m_1 r_1 = m_2 r_2 \]

Where is the CM of the Sun-Jupiter System? Inside the Sun?

\[ r_{JUP} \sim 5 \text{ AU} \quad ; \quad m_{JUP} = 0.001 \; m_{\text{SUN}} \]

(recall: 1 AU \sim 200 \; R_{\text{SUN}})
The mass of each star determines its distance, \( r \), from the CM ...which is just the semimajor axis of its circular orbit (\( a_1 \) or \( a_2 \))

Combined with the measured velocity of either star, these give the orbital period:

\[
v_i = \frac{2 \pi r_i}{P}
\]

The full separation of the stars is: \( a = a_1 + a_2 \)

The Total mass can then determined by Kepler’s 3rd Law:

\[
P^2 = \frac{4\pi^2}{G (m_1 + m_2)} a^3, \quad \text{(S.I. Units)}
\]
\[
P^2 = \frac{a^3}{(m_1 + m_2)} \quad \text{(Solar System Units)}
\]
Parsecs & AU in Binaries

Recall this triangle from parallax:

It is useful in measuring the size of binary star orbits!

Side: 1 Parsec = 206265 AU \((d)\)
Side: 1 AU
Angle: 1 arc second. \((p)\)

eg.: Binary @ 1pc. Stars are separated by 5”
How many AU apart are the stars?