ASTR 1020

Lab 12: Eclipsing and Spectroscopic Binary Stars

What Are Binary Stars?

A binary star is a system of two stars orbiting each other. Fun fact: Most stars in the universe may be binary stars! That is, most stars in the universe travel in pairs.

Eclipsing Binary

SS Boötis is an eclipsing binary. That is, as the stars orbit, one goes in front of the other from time to time. When this happens, we see a dip in the overall light coming from the star system. This should make sense: If we count all the photons coming at us from the stars, we get more when they're both visible than when one star is blocking all or part of the other star.

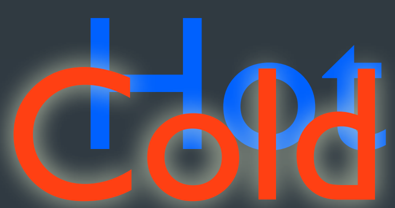
More light

Less light

Primary and Secondary Eclipse

The definition is based solely on temperatures. Primary is cold star in front of hot star, and secondary is hot star in front of cold star.

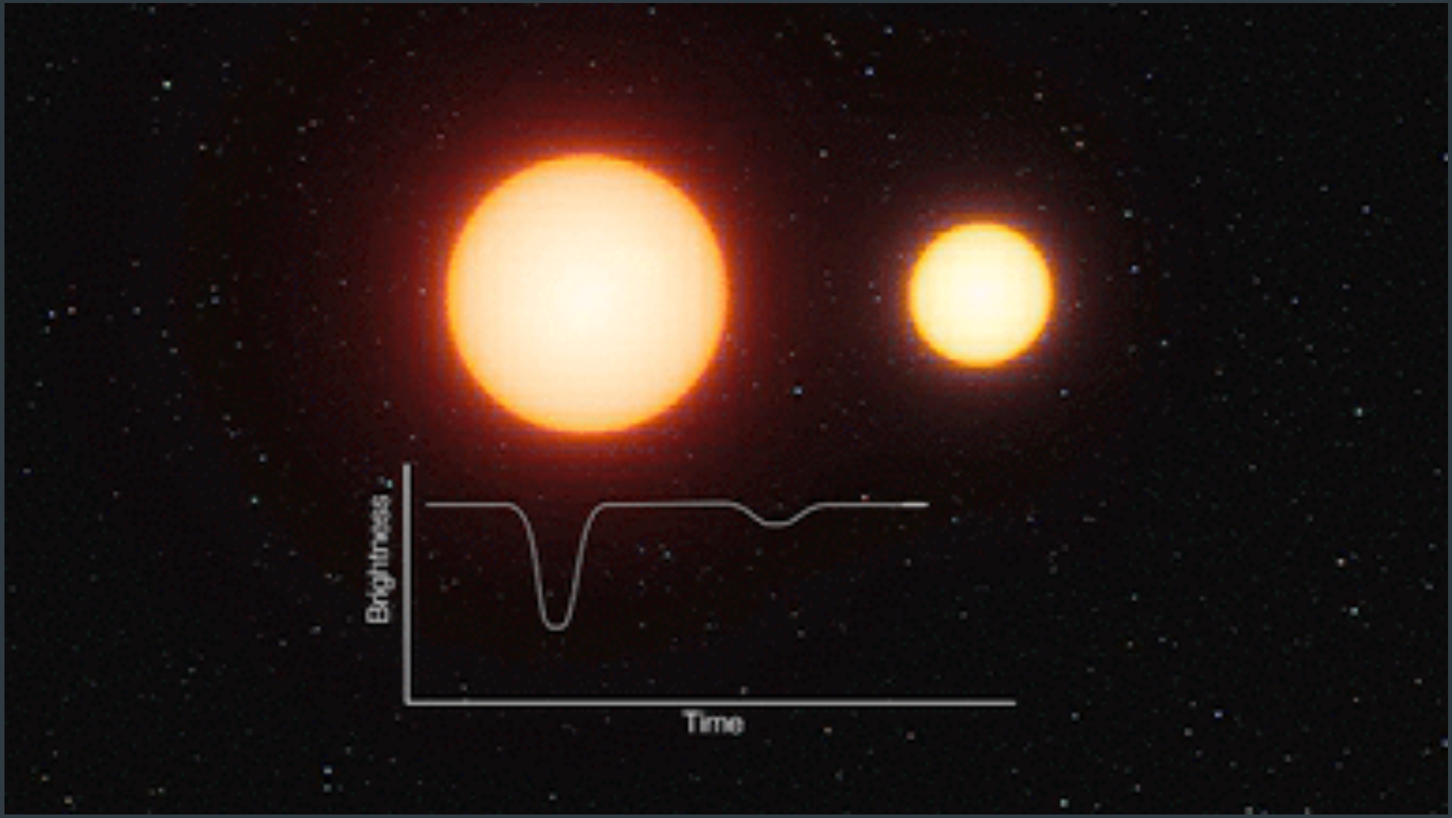
Primary eclipse



Secondary eclipse

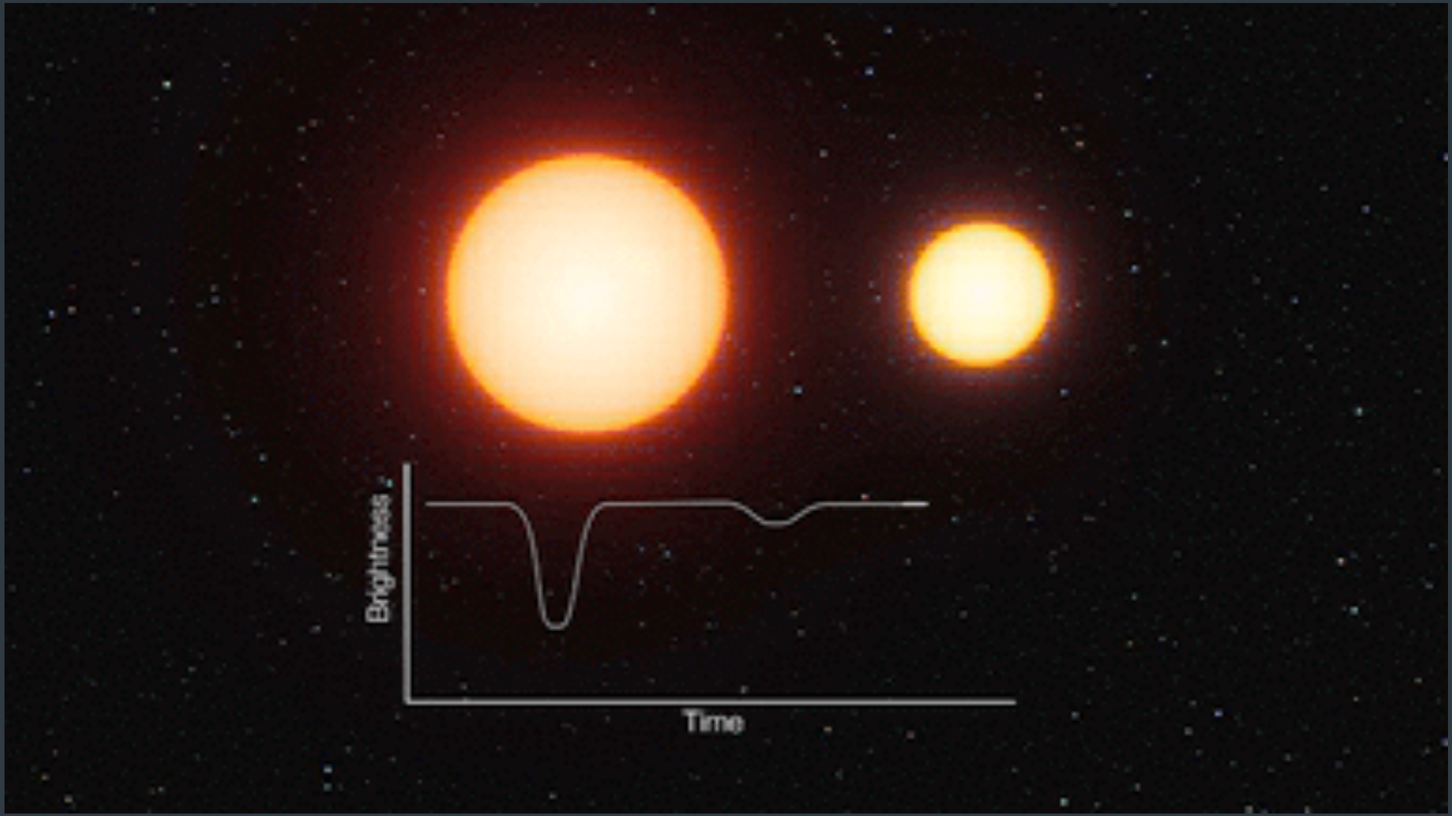
SS Boötis

We will spend today's lab fully analyzing the binary star (two stars) SS Boötis. We will find the relative brightnesses of the two stars, their masses, and their sizes, all from photometric and spectroscopic data.



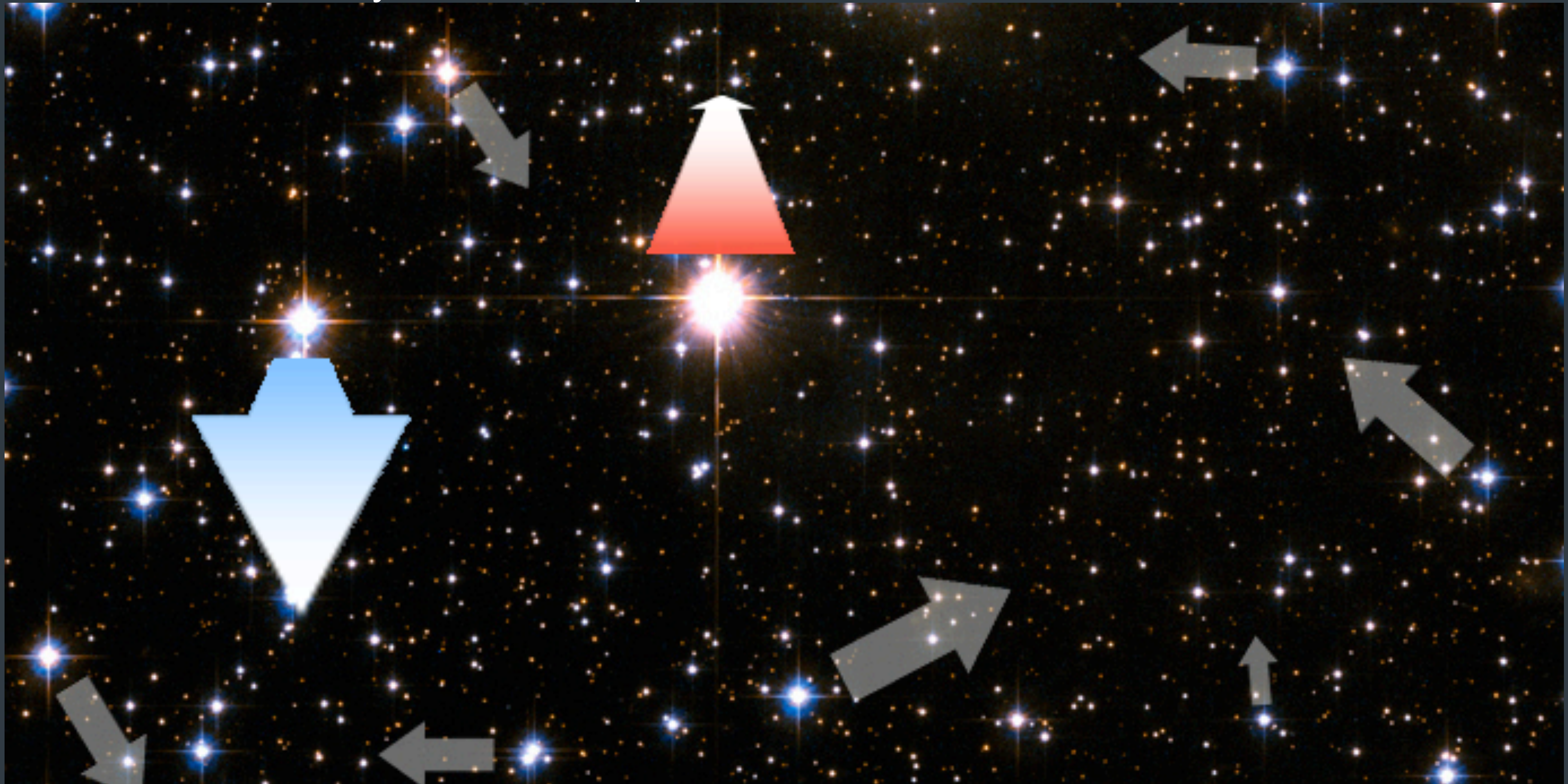
Photometry

Photometry is the measure of light. Put basically, how much light is there? There is more light when both stars are visible and less light when one star blocks all or part of the other star. Watch the marker on the light curve as the animation plays.



Doppler Shift

Everything in the universe is moving around, left, right, towards you, away from you. When a source of light, such as a star, moves towards you, its wavelength gets squished (bluenned). When the star moves away from you, its wavelength gets stretched (reddenned). This is the Doppler shift, and from how big the shift is, we can figure out how fast the star is moving towards us ($v_{rad} < 0$) or away from us ($v_{rad} > 0$). Note that this effect on the color is usually slight, and the color of a star comes mostly from its temperature.



Physics Magic: Ratios

From here you apply various physics equations to deduce the sizes and masses of the stars. First we deduce ratios, and then we deduce actual values in relation to the size and mass of the sun.

Relative stellar radii:
(ratio of stellar radius to orbital radius)

$$r_c = \frac{\pi(t_3 - t_1)}{P}$$

$$r_h = \frac{\pi(t_2 - t_1)}{P}$$

Center of mass velocity:
(velocity of pair as a whole, towards or away from you)

γ = velocity where stars' velocity curves intersect, in km/s

Mass ratio:
(ratio of stellar masses, from orbital speeds)

$$\frac{M_h}{M_c} = \frac{\alpha_c + \beta_c}{\alpha_h + \beta_h}$$

Note: Ratios are **unitless**.

Physics Magic: Actual Values

From here you apply various physics equations to deduce the sizes and masses of the stars. First we deduce ratios, and then we deduce actual values in relation to the size and mass of the sun.

Stellar separation:
(distance between stars, in AU)

$$a = \frac{0.211 \times V \times \frac{P}{365.25}}{2\pi}$$

Total stellar mass:
(sum of masses of stars, in solar masses ($M_\odot$))

$$M_c + M_h = \frac{a^3}{\left(\frac{P}{365.25}\right)^2}$$

Stellar radii:
(radius of each star, in solar radii ($R_\odot$))

$$R_c = r_c \times a \times 214.95$$

$$R_h = r_h \times a \times 214.95$$

Stellar mass algebra: You have two unknowns (M_c and M_h), and two equations (total mass $M_c + M_h$ and mass ratio M_h/M_c). Substitute information from one equation into the other and solve for each of the masses.

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