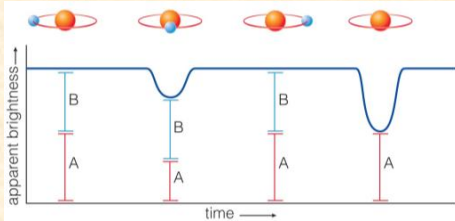


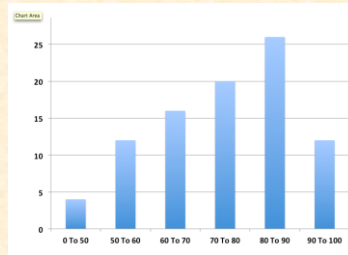
## ASTR 1020: Stars & Galaxies

September 30, 2013

- Reading: Chapter 15, section 15.1.
- *MasteringAstronomy* Homework on **Properties of Stars** is due October 4.
- Extra chances for Naked Eye Observing: Sep. 30 & Oct. 1.



## Results from Exam 1



Mean = 75%  
 Median = 76%  
 Stand. Dev. = 14%  
 Max = 102%  
 Min = 29%

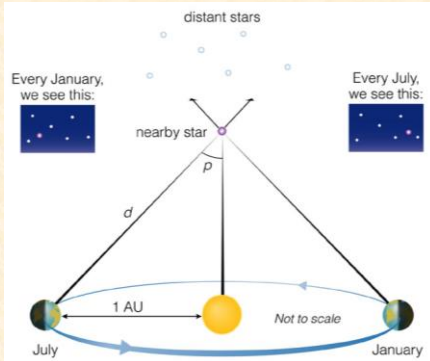
## Astronomy Picture of the Day



Young stars only several million years old in NGC 7129. 3000 light years away in Cepheus.

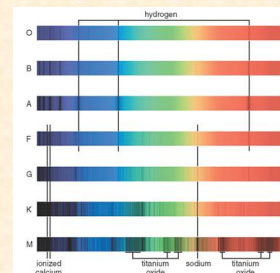
## Today's Class: Stellar Masses

- Quick Review of
  - Parallax (distance)
  - Temperature measurements
- Measuring stellar masses via binary stars.



How do we measure distances to stars?

## How do we measure stellar temperatures?



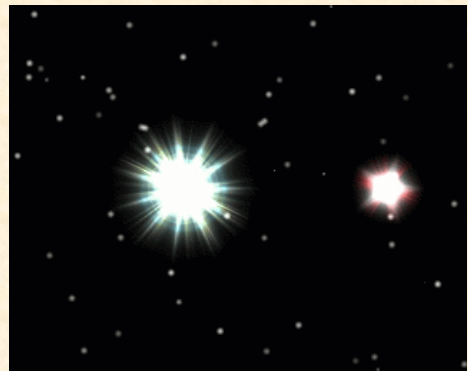
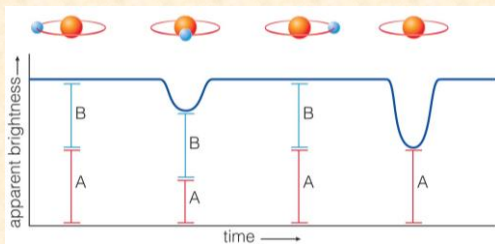
Reading Clicker Question: What properties of a binary star system are needed to determine the masses of the stars?

- A. stellar size and orbit size
- B. orbit size and spectral type
- C. stellar size and spectral type
- D. orbit size and orbit period
- E. orbit period and stellar size

Reading Clicker Question: What properties of a binary star system are needed to determine the masses of the stars?

- A. stellar size and orbit size
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- C. stellar size and spectral type
- D. orbit size and orbit period**
- E. orbit period and stellar size

How do we measure stellar masses?



The orbit of a binary star system depends on strength of gravity

Animation of Binary Stars



Albireo: A bright and beautiful double (actually triple) star system. 380 light years distant. Stars are 4000 AU apart.

Clicker Question

What percentage of all Sun-like (G) stars in our galaxy are thought to be binaries?

- A) 10%
- B) 30%
- C) 50%
- D) 75%
- E) 95%

## Clicker Question

What percentage of all Sun-like (G) stars in our galaxy are thought to be binaries?

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## Types of Binary Star Systems

- Visual Binary
- Eclipsing Binary
- Spectroscopic Binary

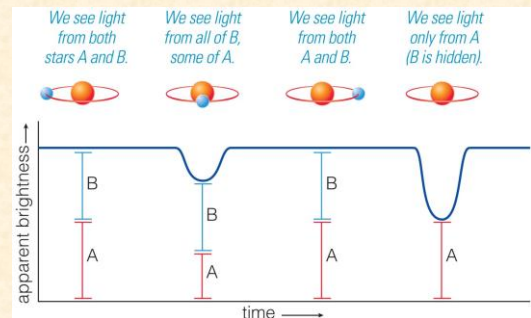
*Many stars are in binary systems so we have lots of stars to work with.*

## Visual Binary



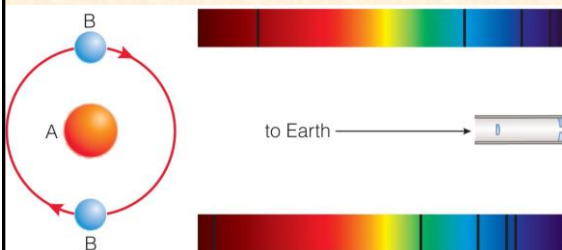
We can directly observe the orbital motions of these stars.

## Eclipsing Binary



Above is called a **light curve**.  
We can measure periodic eclipses.

## Spectroscopic Binary



We determine the orbit by measuring Doppler shifts

We measure mass using gravity.



Isaac Newton

Direct mass measurements are possible only for stars in binary star systems. Use Newton's version of Kepler's 3<sup>rd</sup> Law:

$$p^2 = \frac{4\pi^2}{G(M_1 + M_2)} a^3$$

$p$  = period

$a$  = average separation

$M_1, M_2$  = masses of stars

### Clicker Question

What 2 pieces of information do you need to measure the mass of stars in an *eclipsing binary system*?

- Time between eclipses & distance between stars.
- Period of binary system & its distance to the Earth.
- Velocities of the stars & the Doppler shifts of absorption lines.

### Clicker Question

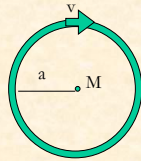
What 2 pieces of information do you need to measure the mass of stars in an *eclipsing binary system*?

- Time between eclipses & distance between stars.**
- Period of binary system & its distance to the Earth.
- Velocities of the stars & the Doppler shifts of absorption lines.

### Need 2 out of 3 observables to measure mass:

- Orbital Period ( $p$ )
- Orbital Separation ( $a$ )
- Orbital Velocity ( $v$ )

For circular orbits,  $v = 2\pi a/p$



Most massive stars:  
 $100 M_{\text{Sun}}$

Least massive stars:  
 $0.08 M_{\text{Sun}}$

( $M_{\text{Sun}}$  is the mass of the Sun)

### What have we learned?

- **How do we measure stellar masses?**
  - Newton's version of Kepler's third law tells us the total mass of a binary system, if we can measure the orbital period ( $p$ ) and average orbital separation of the system ( $a$ )