Binary Stars

- There are different types of binaries which can be useful
- **Visual Binary**
  - Stars where we actually see the orbit –
- **Spectrum Binaries**
  - Single-Line Spectroscopic Binary
  - Double-Line Spectroscopic Binary
- **Eclipsing Binaries**

Return to Kepler’s Laws

- We can now determine an orbit
  - Semi-major Axis: \( a \)
  - Period: \( P \)
  - Kepler’s law as modified by Newton is
    - \( M_1 + M_2 = \frac{a^3}{P^2} \)
- If we can find \( a \) and \( P \) we can get the sum of the masses
- All of our direct information about stellar masses comes from the study of binaries

**Double Stars Systems**

- **Double Stars**
  - Stars that appear together in the sky
- **Optical Doubles**
  - Stars that are only along the same line of sight
  - Not Gravitationally bound
- **Binaries or Binary Stars**
  - Two stars orbit each other
  - We are interested in these gravitational binary systems

**Individual Masses?**

- Can we find the individual masses?
  - Yes, If we can plot both orbits around a common center of mass.
Orbits of Binary Stars

Individual Orbits

- If we can plot both orbits we can get a ratio of the masses
- \( \frac{M_1}{M_2} = \frac{a_2}{a_1} \)
- Combine with Kepler's law and we can get the masses

Other kinds of Binary Stars

- **Spectrum Binaries**
  - One spectrum is seen, but it doesn't make sense
  - For example: TiO molecular bands and strong H lines
  - IMPOSSIBLE FOR A SINGLE STAR!
  - This a combined spectrum of two stars
    - TiO bands from an M star
    - Strong Hydrogen lines from an A star

Other kinds of Binary Stars

- **Spectroscopic Binaries**
  - Seen by shifts in the spectral features
- **Single-Line Spectroscopic Binary**
  - 1 set of lines seen to move
- **Double-Line Spectroscopic Binary**
  - 2 sets of lines shifting in opposite directions

Single-Line Spectroscopic Binary

Double-Line Spectroscopic Binary
Masses from a Spectroscopic Binary

- Spectroscopic Binaries can be used to determine mass ratios
  - tip or inclination of the system is a problem
- We can only really determine the inclination of Eclipsing Binaries

Eclipsing Binaries

- One star passes in front of the other
- Extrinsic Variable Stars
- We must look at the light curve to see the binary nature of the system

Varieties of Eclipsing Binaries

- Different light curves based on a number of factors
  - The relative sizes of the two stars
  - The relative brightness of the two stars
  - Shape of the two stars
  - The inclination
  - The distance between the stars
  - Orbital period
- Let’s look at some of the various types

Eclipse

Partial eclipses

- Hotter, more luminous star eclipsed

Total eclipses

- Cooler, less luminous star eclipsed

<table>
<thead>
<tr>
<th>Time</th>
<th>Brightness</th>
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<tbody>
<tr>
<td>Hotter, more luminous star eclipsed</td>
<td>A</td>
</tr>
<tr>
<td>Cooler, less luminous star eclipsed</td>
<td>B</td>
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More Complex Systems

• We have learned that as stars evolve they tend to get larger
• The size change effects binary systems
  http://instruct11.cit.cornell.edu/courses/astro101/java/binarybinary.htm

Roche Lobes

• Named for Edouard Roche
• Calculated the Gravitational field
  – If stars are far apart they are nearly spherical
  – If stars are close together they become egg shaped
• Eventually Roche found a figure-eight shape

Roche Lobes

• Each half of the figure-eight is called a Roche Lobe
• If the material passes into a Roche Lobe it falls onto the star
• Material moving from one star to the other passes through the central point

Detached Binary Systems

• Here neither star has filled its Roche Lobe
• These are what we were talking about earlier

Semi-Detached Binary

• One star expands to fill its Roche Lobe
• Material flows from one to the other star
<table>
<thead>
<tr>
<th>Two Types of Semi-Detached Eclipsing Systems</th>
<th>Contact Binaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Algol Variable - No Accretion Disk formed</td>
<td>• Both Stars fill their Roche Lobes</td>
</tr>
<tr>
<td>• β Lyrae - Accretion disk formed</td>
<td></td>
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<table>
<thead>
<tr>
<th>Overcontact Binary</th>
<th>Neutron Binaries</th>
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<tbody>
<tr>
<td>• So much overflow that one atmosphere is formed around both stars</td>
<td>• X-ray Bursters</td>
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</tbody>
</table>

![Diagram of a neutron binary system](image-url)