Astro 8501 – 6944

Binary Stars

Thursdays 9am
AIfA 0.008

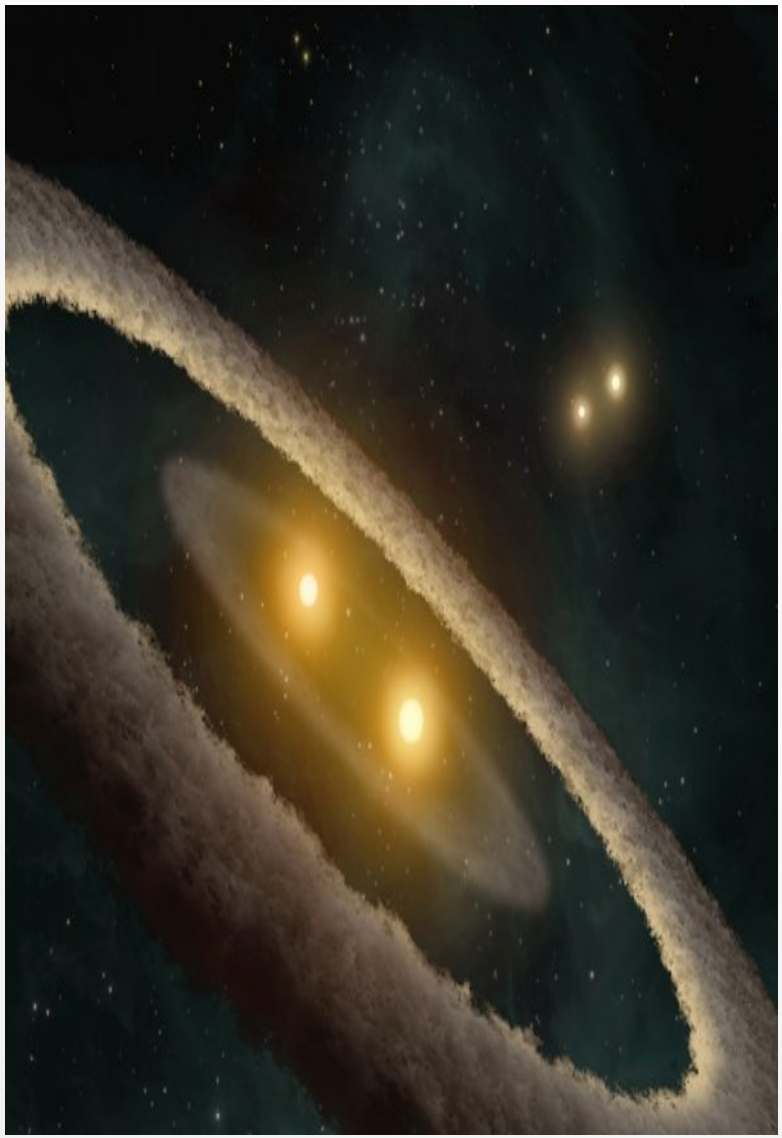
Argelander Institut für Astronomie

Robert Izzard izzard@astro.uni-bonn.de

http://www.astro.uni-bonn.de/~izzard/binary_stars.html

Class 1: An Introduction

- A bit of history
- Famous binary stars
- Bright stars and binaries
- Types of binaries
- Basic nomenclature
- Resources at your disposal



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Binaries in History

- 148AD Ptolemy
- Telescopic discovery started around 1650 Italy: Castelli/Galileo

  It's one of the beautiful things in the sky and I don't believe that in our pursuit one could desire better

- Riccioli (Bologna)

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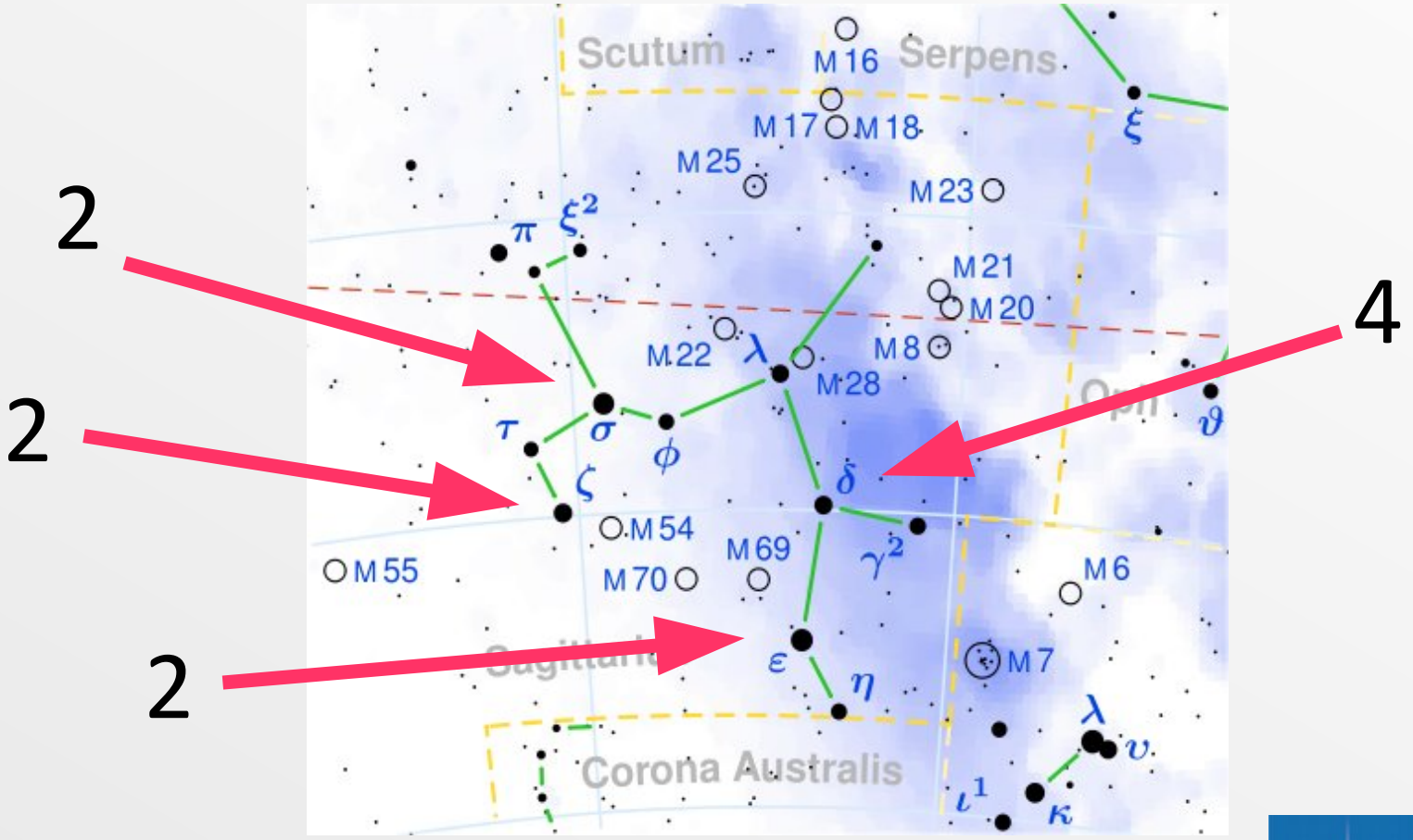
History

Almagest of Ptolemaios, 150AD

"double star at the eye of Sagittarius"



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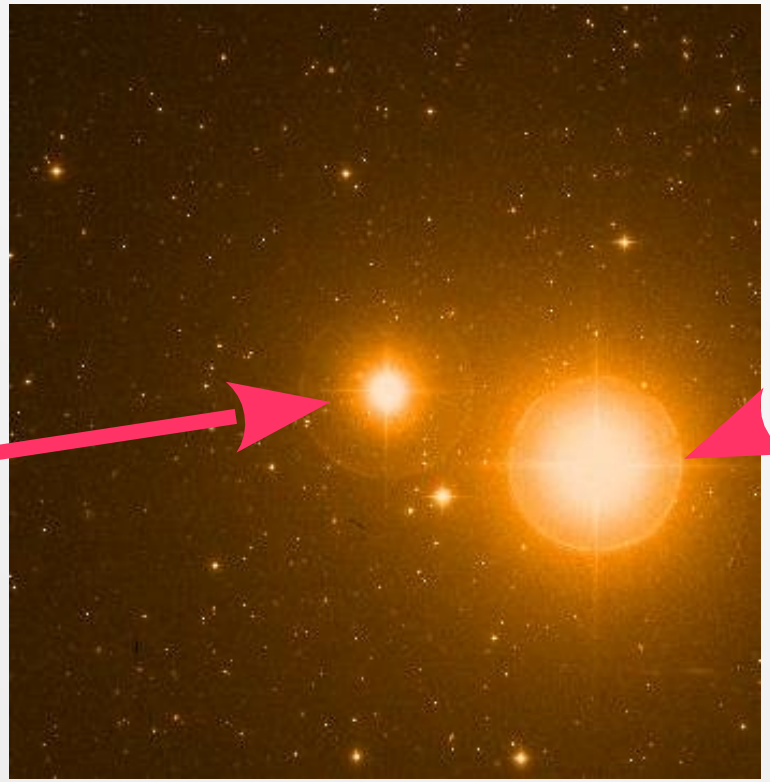
Telescopic Binary

- 1617 Galileo observed Mizar: Binary!



Mizar
(quadruple)

Alcor
(binary)

Telescopic Discovery

- 1656 q Orionis O6V+? (Huygens)
- 1685 a Cru (Acrux) B1V+B1V, 430 AU (Foutenay)
- 1689 a Cen G2V+K1V, 24.4AU (Richaud)
- 1718 g Vir F0V+F0V (Bradley)
- 1719 Castor (a Gem) A1V+A2V (Pound)
- 1753 61 Cygni K5V+K7V (Bradley)
- … etc. …

Are binaries real?

Duplicity could be duplicitous

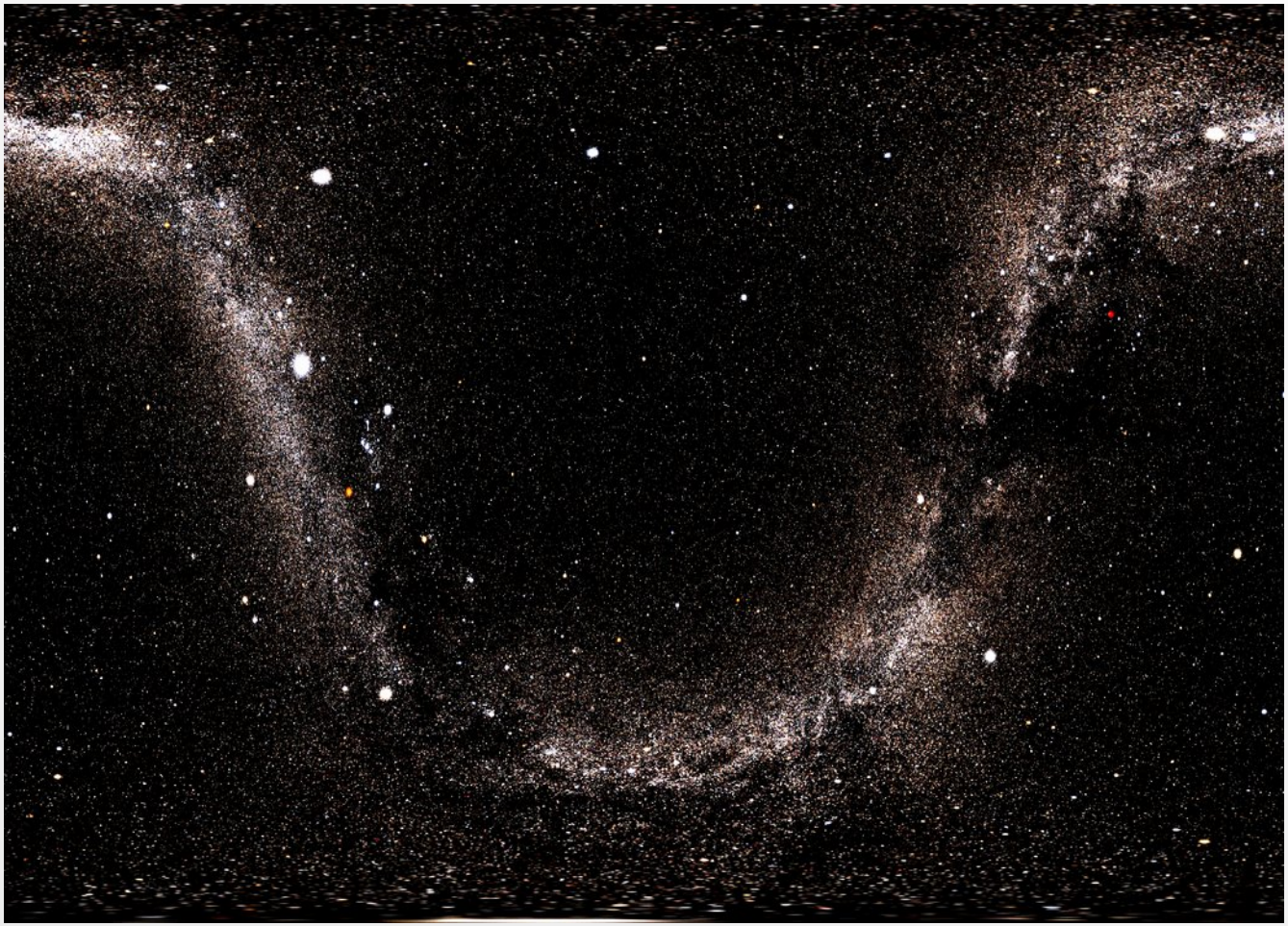
If two stars should really be situated very near each other, and at the same time so far insulated as not to be materially affected by the attractions of neighbouring stars, they will then compose a separate system, and *remain united by the bond of their own mutual gravitation towards each other*.

This should be called a real double star; and any two stars that are thus mutually connected, form the binary system which we are now to consider.

Herschel (1802)

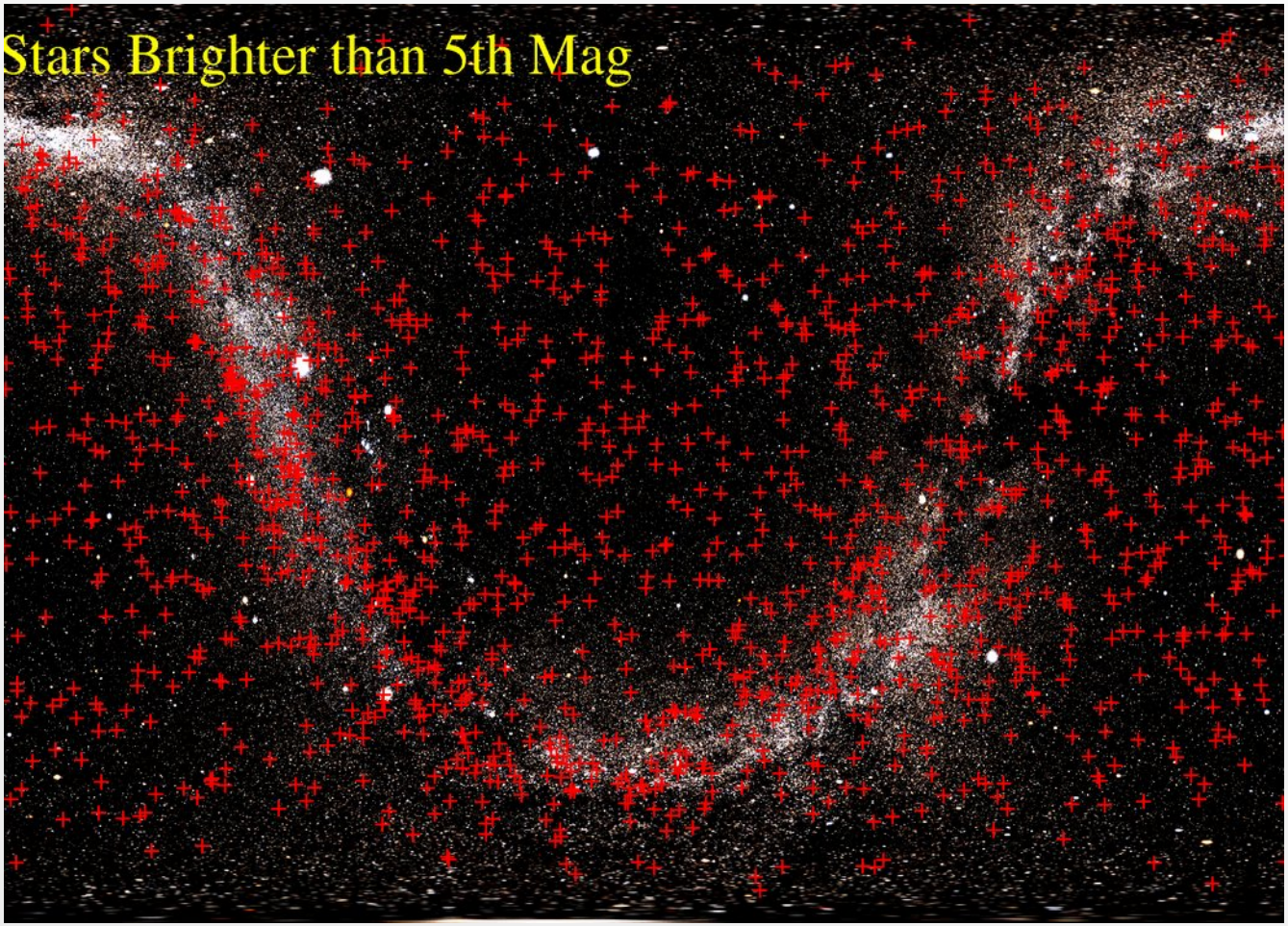
The Night Sky

Composite Tycho image (from NASA)



The Bright Star Catalogue

https://secure.wikimedia.org/wikipedia/en/wiki/Bright_Star_Catalogue



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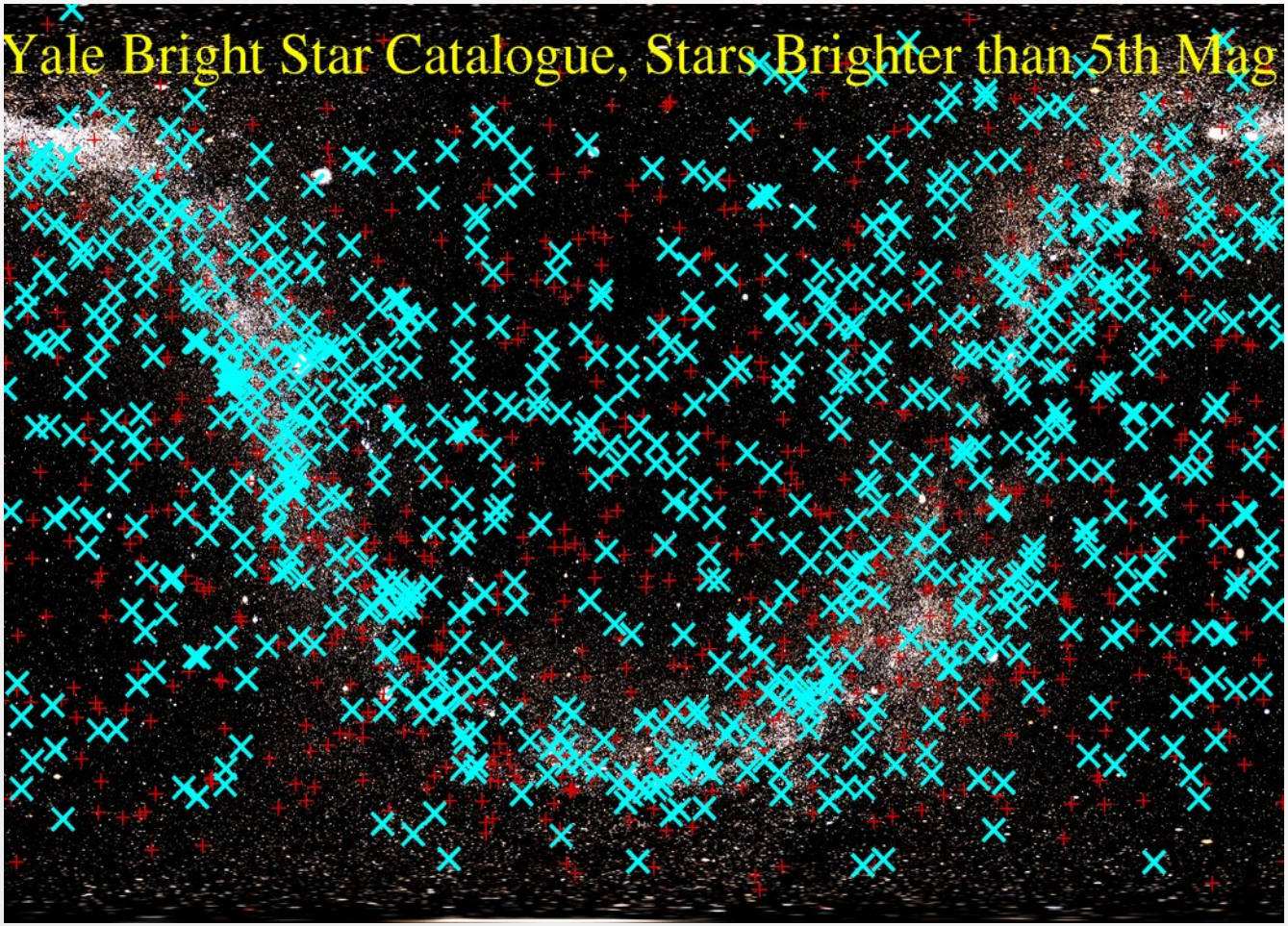

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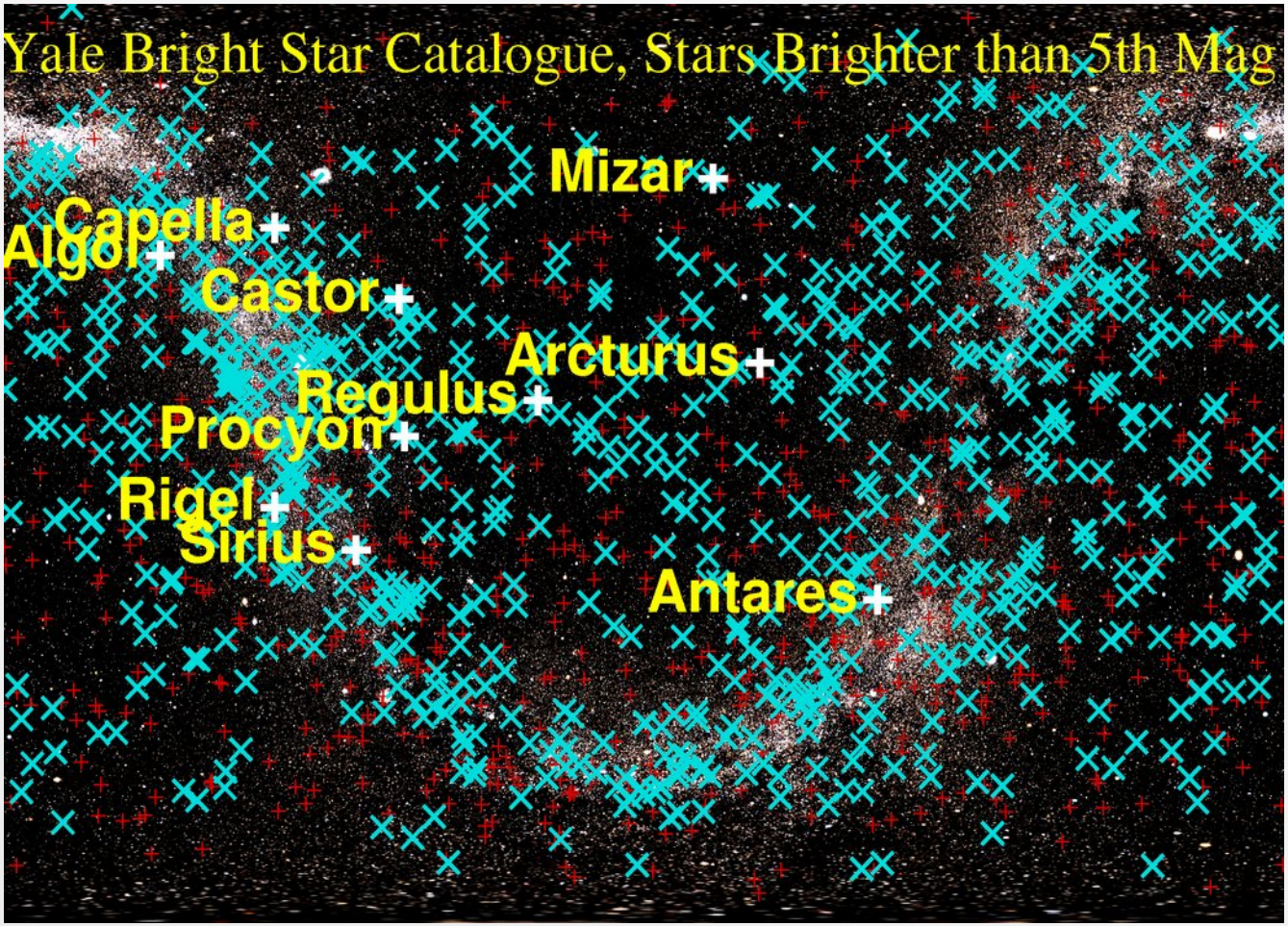
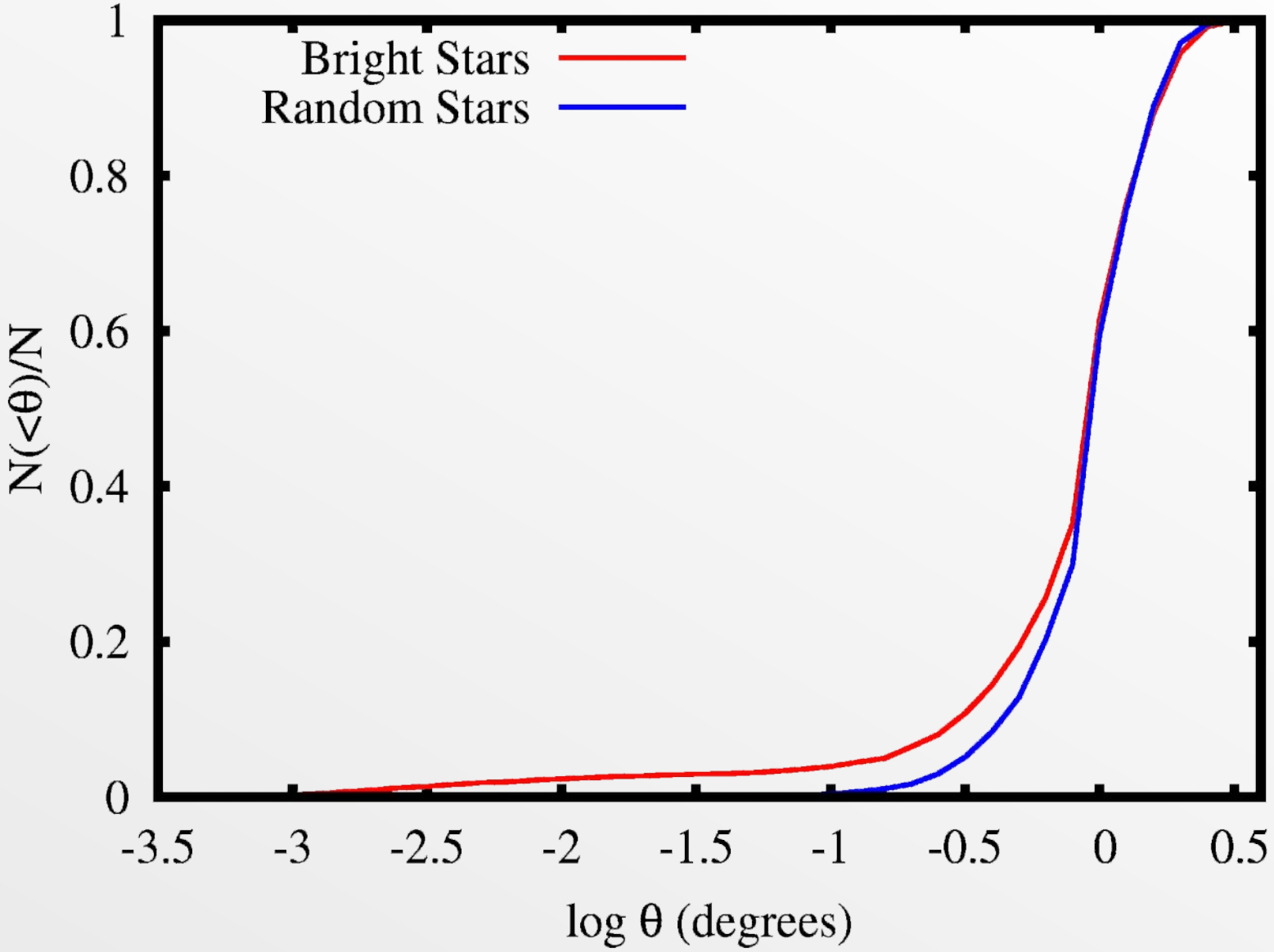
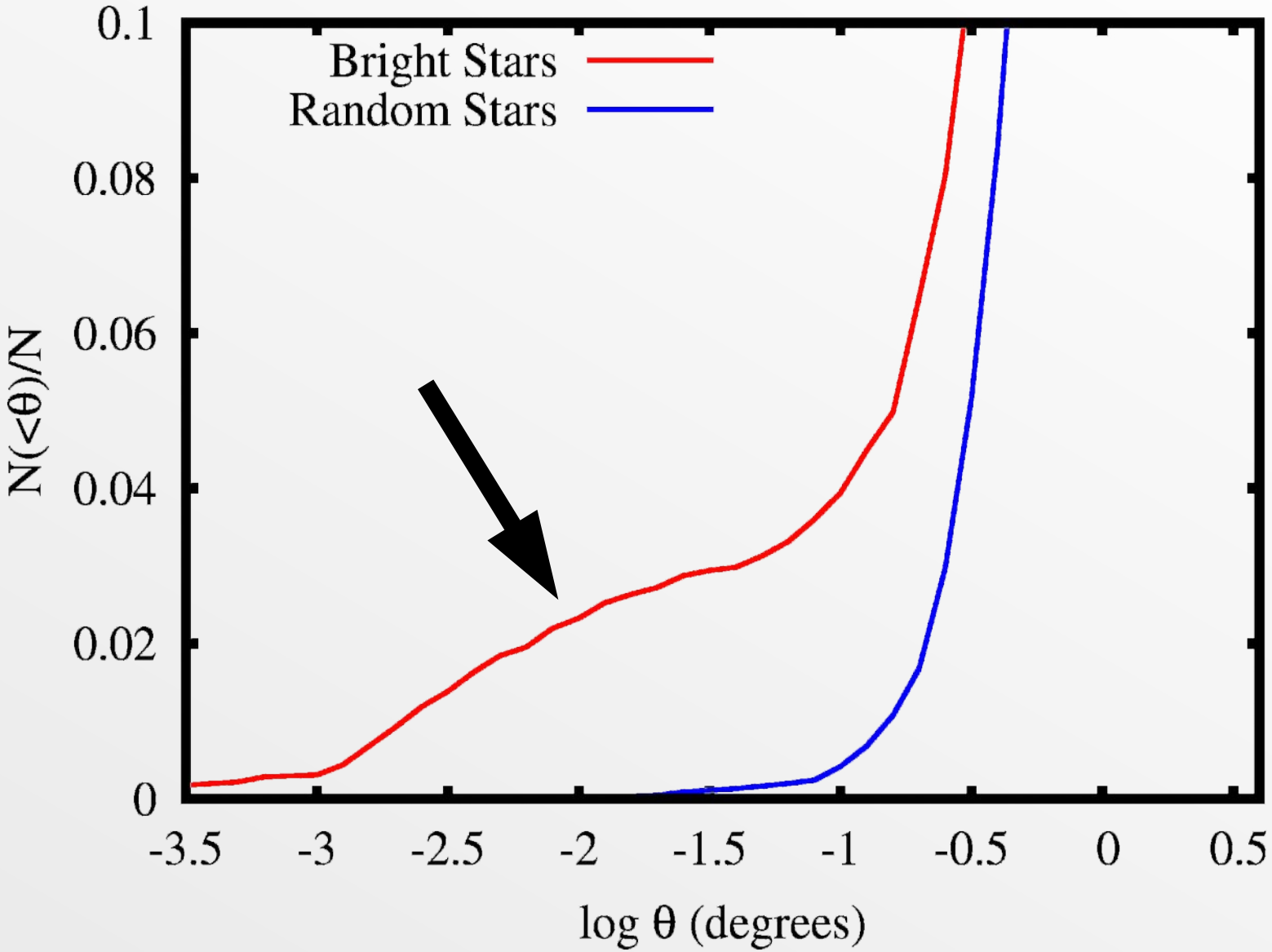


Testing the Binary Hypothesis



- Use the Bright Star Catalogue

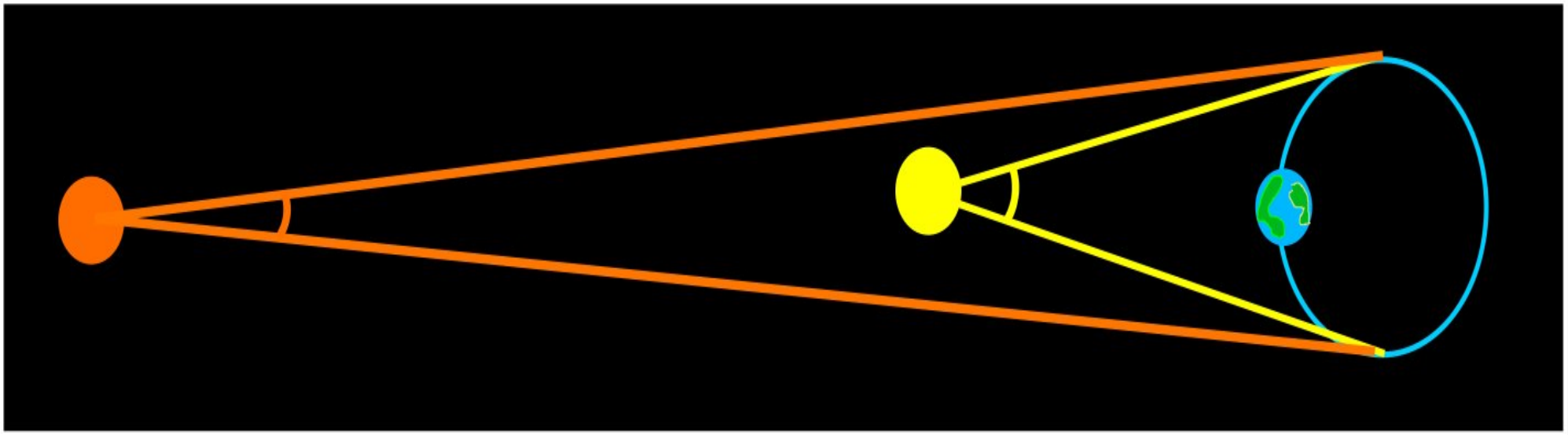
Testing the Binary Hypothesis



- cf. Michell 1767

Michell 1767

Parallax proves it

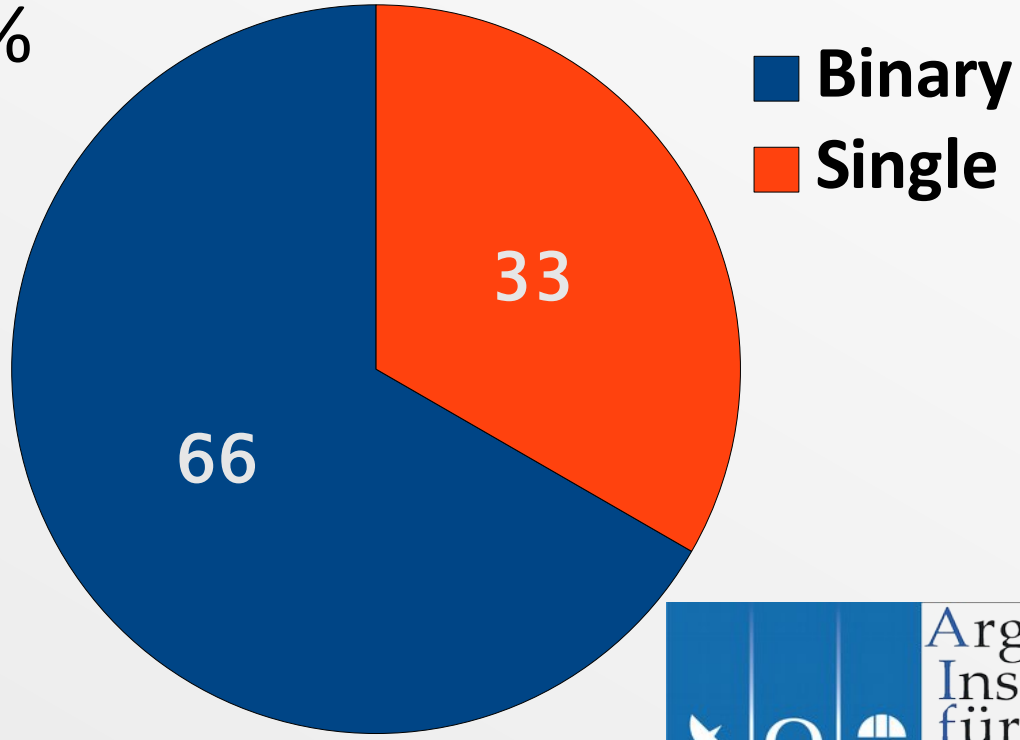


Coincident “binaries” have different parallax

Binary Fraction

- Stars brighter than 5th Magnitude:
- 1618 systems
- 825 Single-star Systems
- 793 Binary-star Systems
- Binary System Fraction 49%
- Binary *Star* Fraction >66%

Massive stars more likely to be binary



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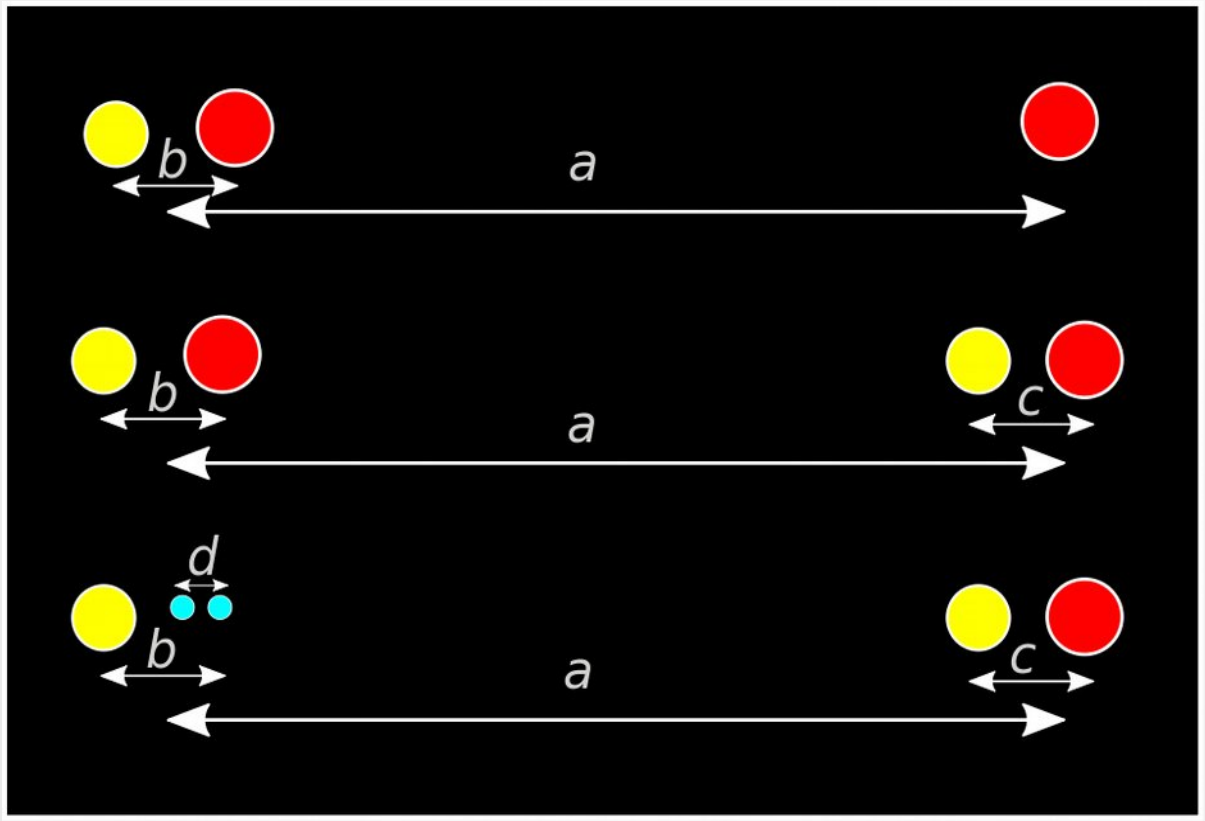
Higher order multiples

- Previous picture neglects triples, quadruples etc.
- These are ***at least*** 10% of systems, 17% of stars
- Must be hierarchical to be stable: treat as binaries



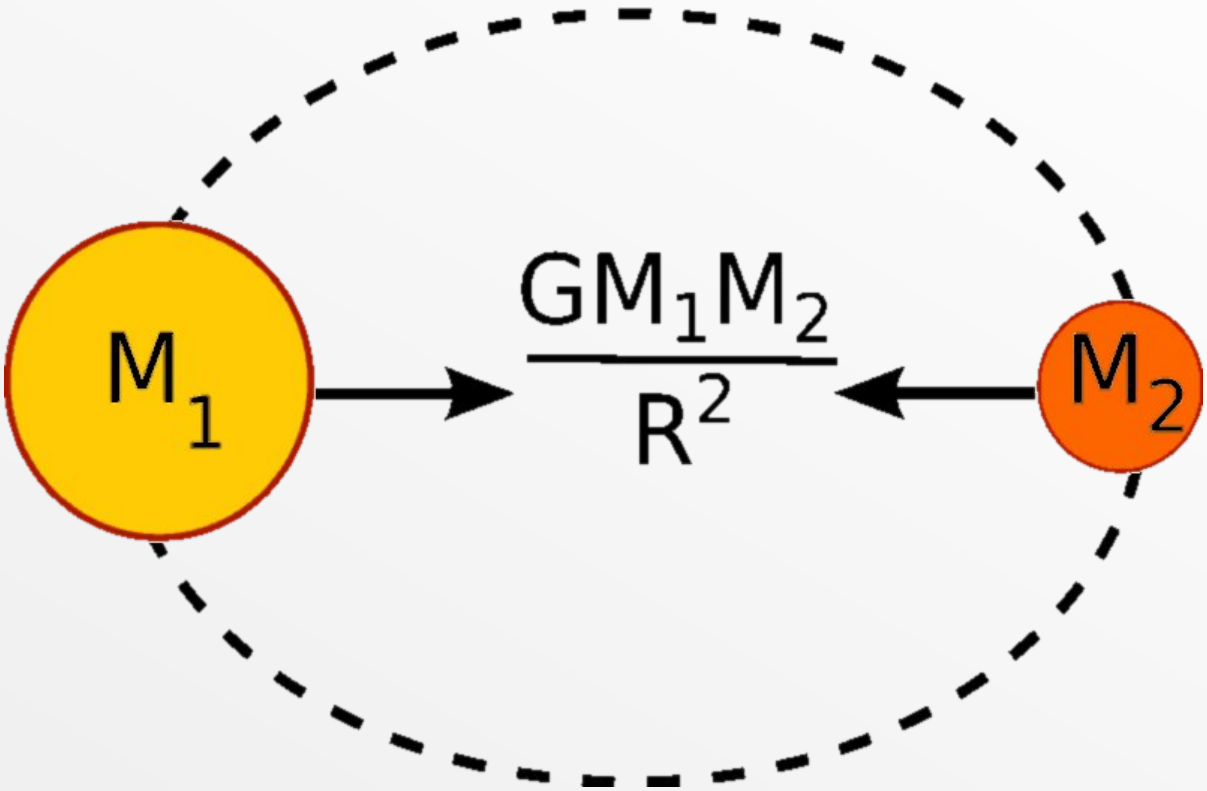
$a>10b$

$a > 10b, 10c$

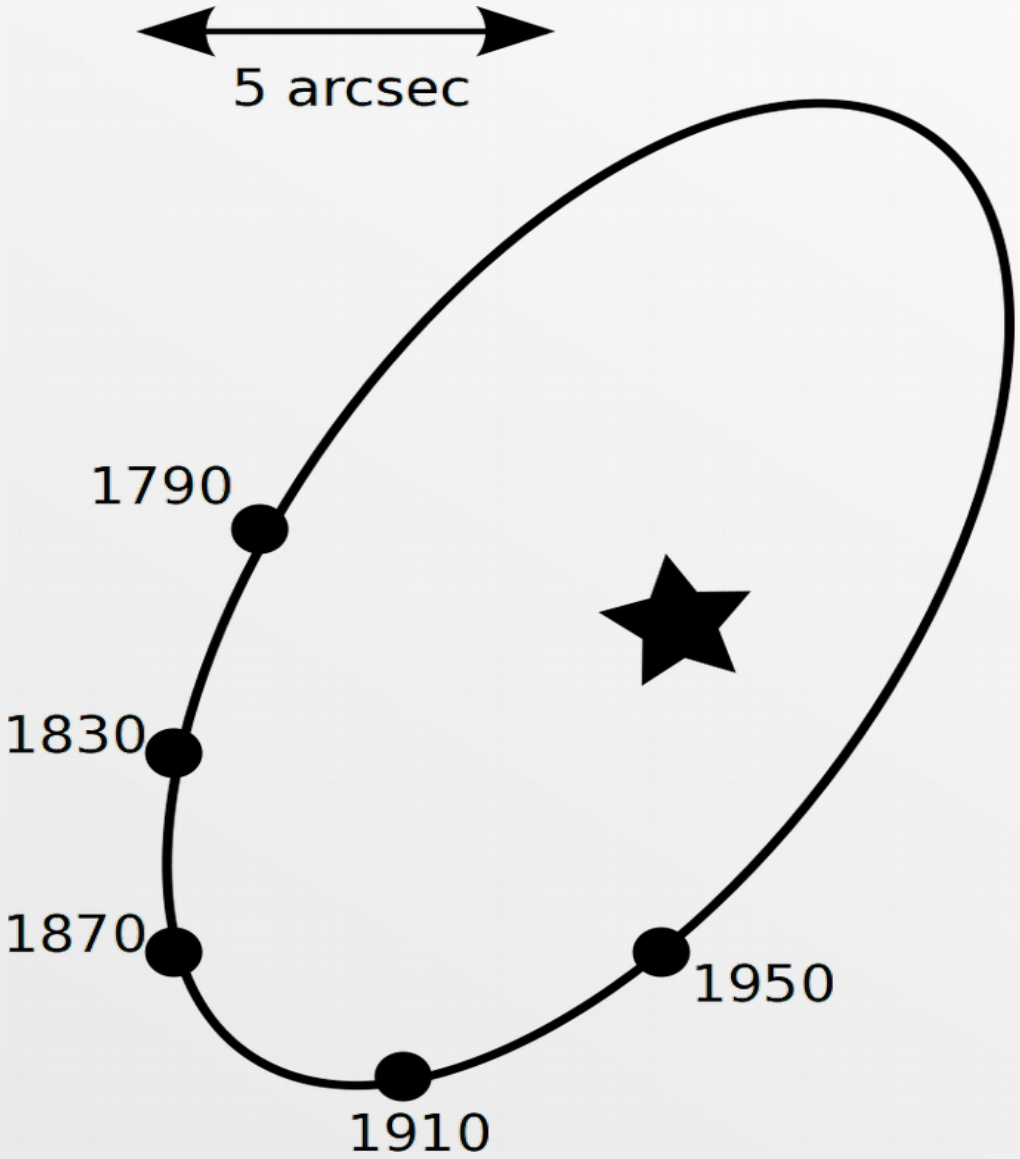
$b>10d\ a>10b\ a>10c$

Types of Binary Star

- Visual Binary
- Spectroscopic Binary
  - 1
  - 2
- Eclipsing Binary



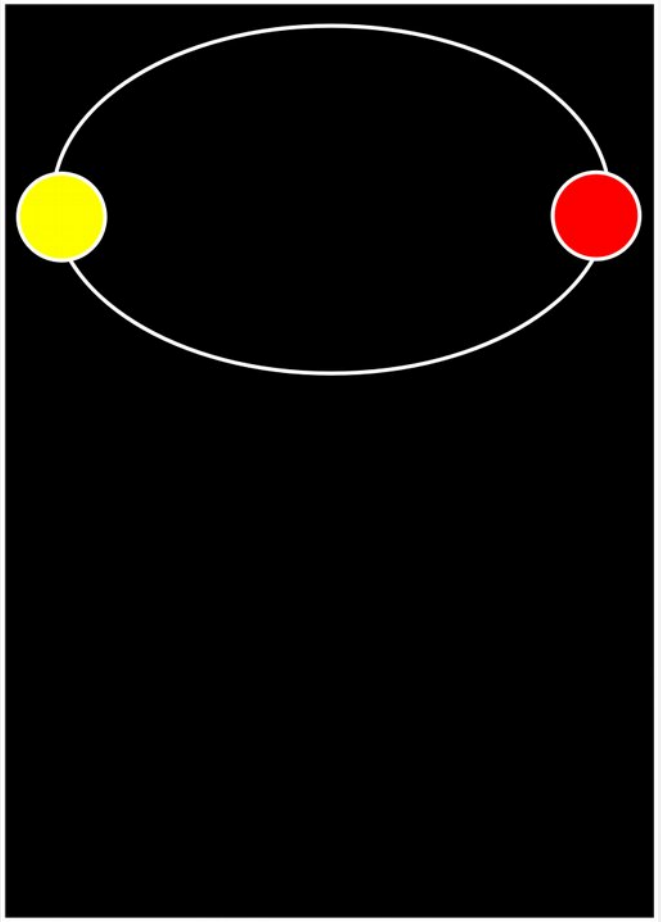
Visual Binaries



- Stars resolved
- Close:

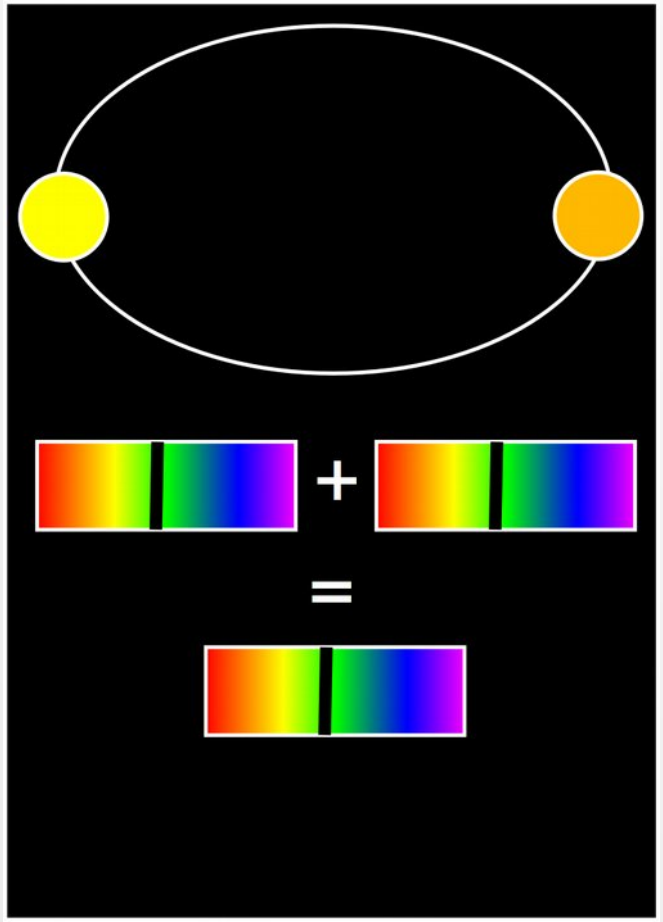
  gravitationally bound?
- Orbit:
  - *Circular or Ellipsoidal*
- e.g. Castor
- Near, long period only
- >0.01'

Spectroscopic binary



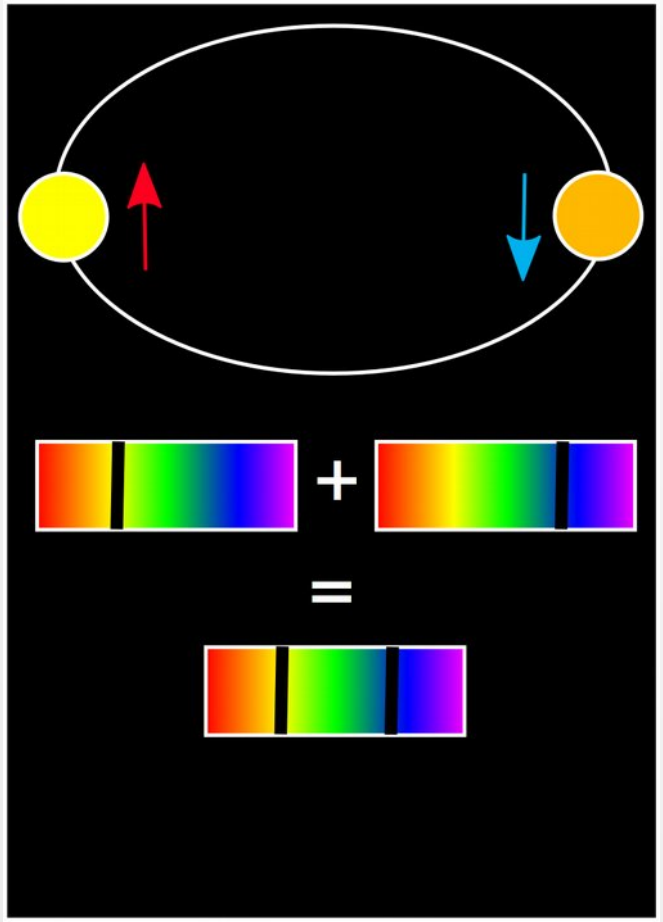
- Not resolved

Spectroscopic binary

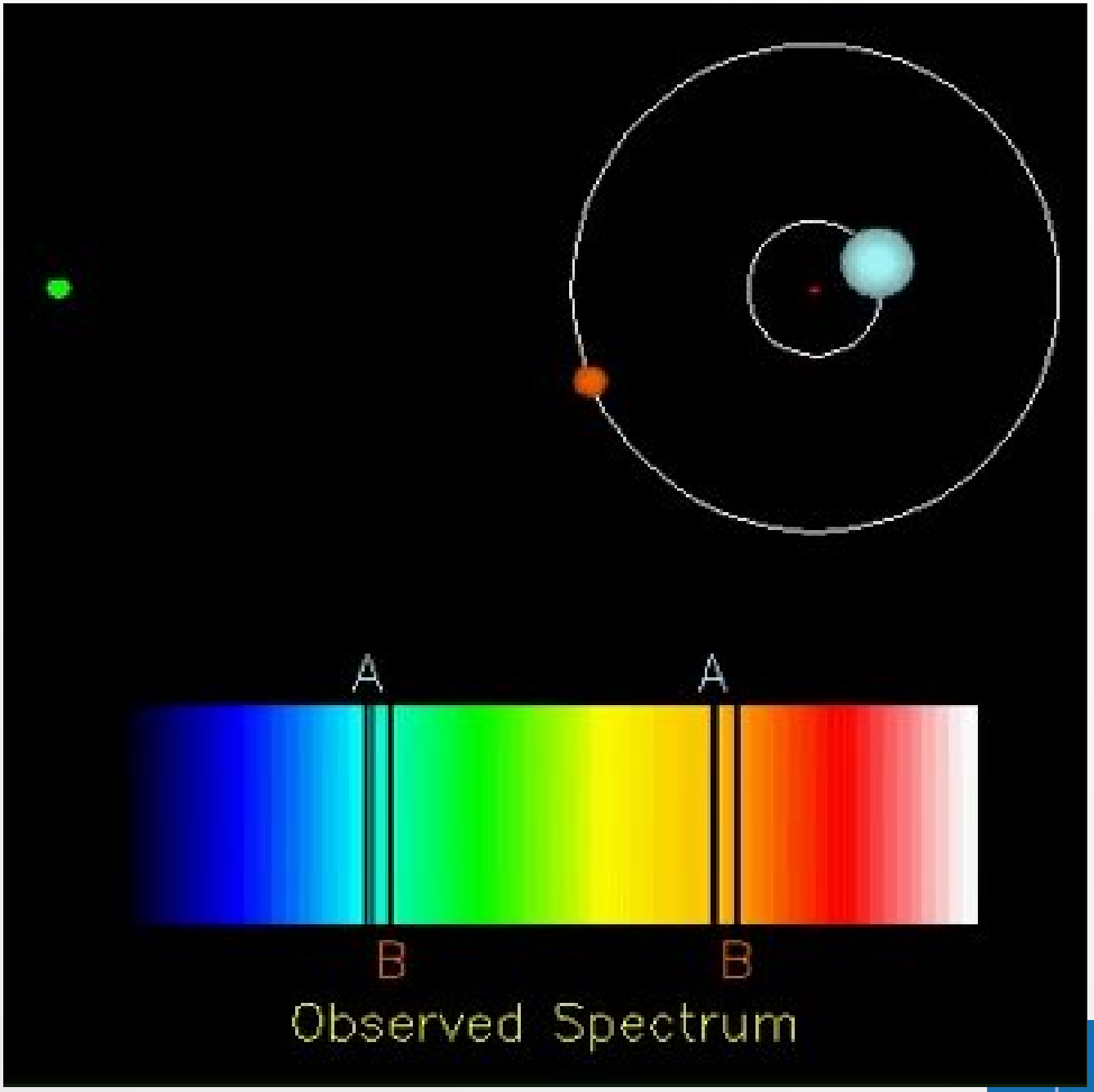


- Not resolved
- Take spectra
- Identify lines

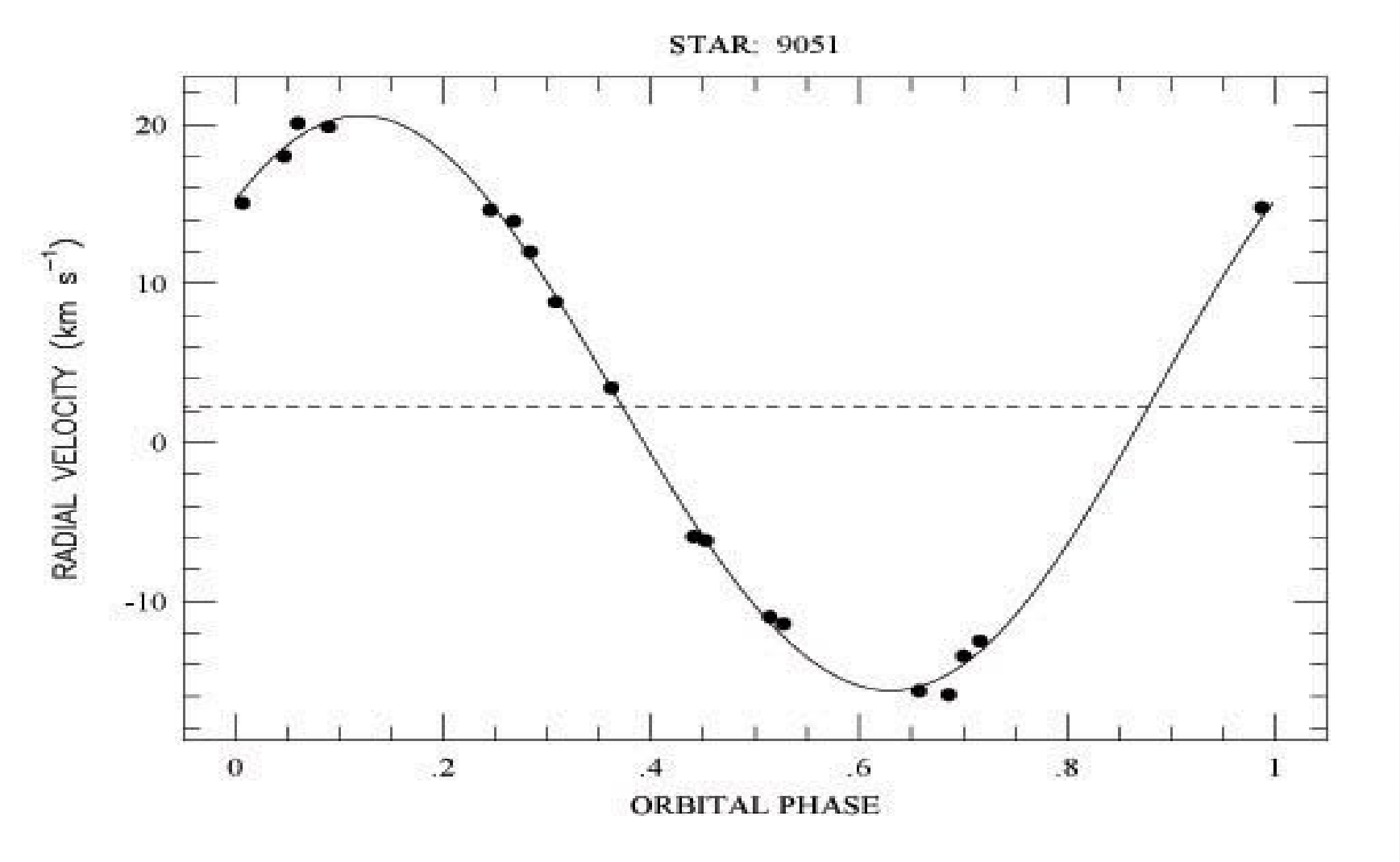
Spectroscopic binary



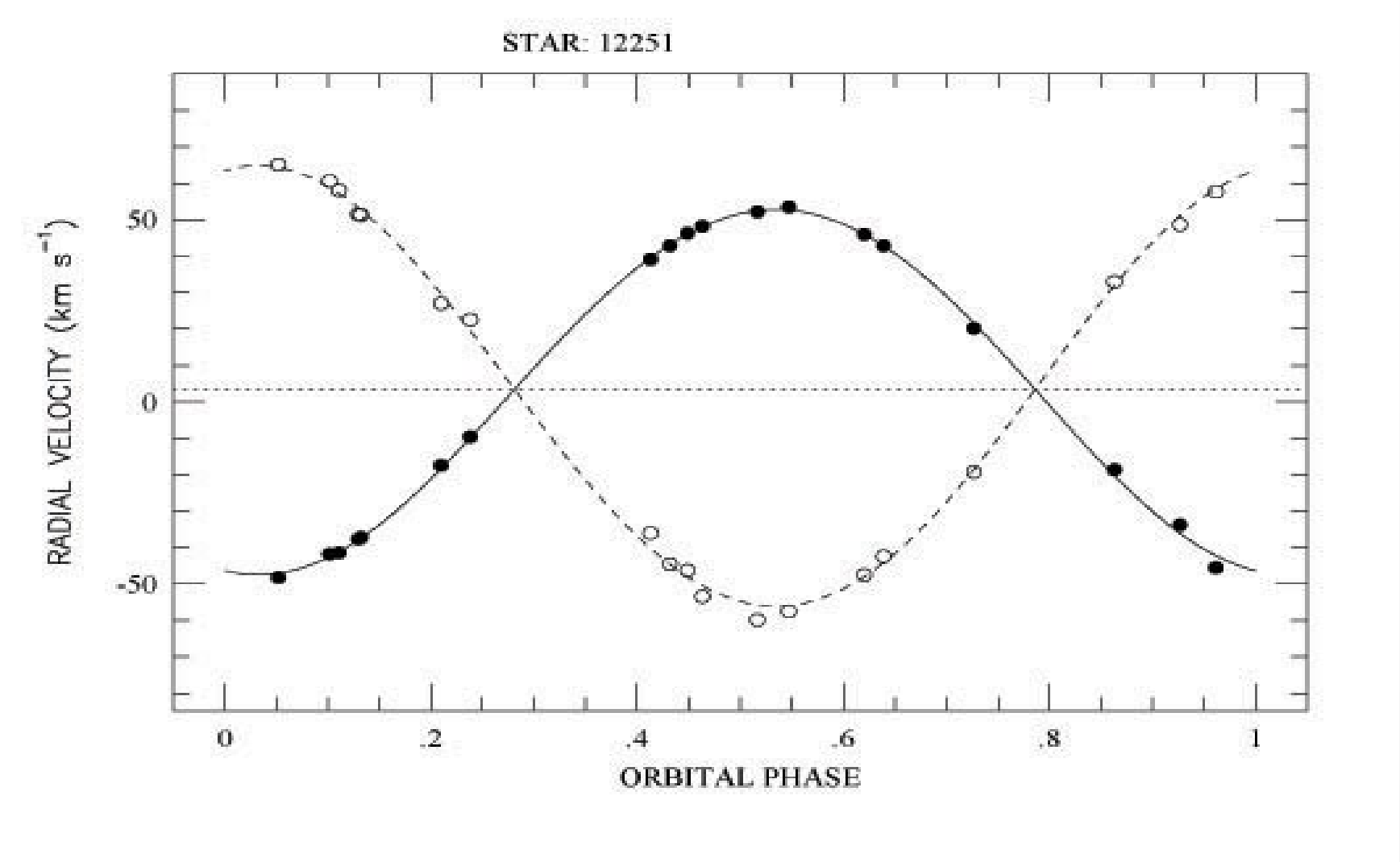
- Not resolved
- Take spectra
- Identify lines: Doppler
- SB1 : one star
- SB2 : both stars
- Short period
- Large distance


A
A
B
B
Observed Spectrum

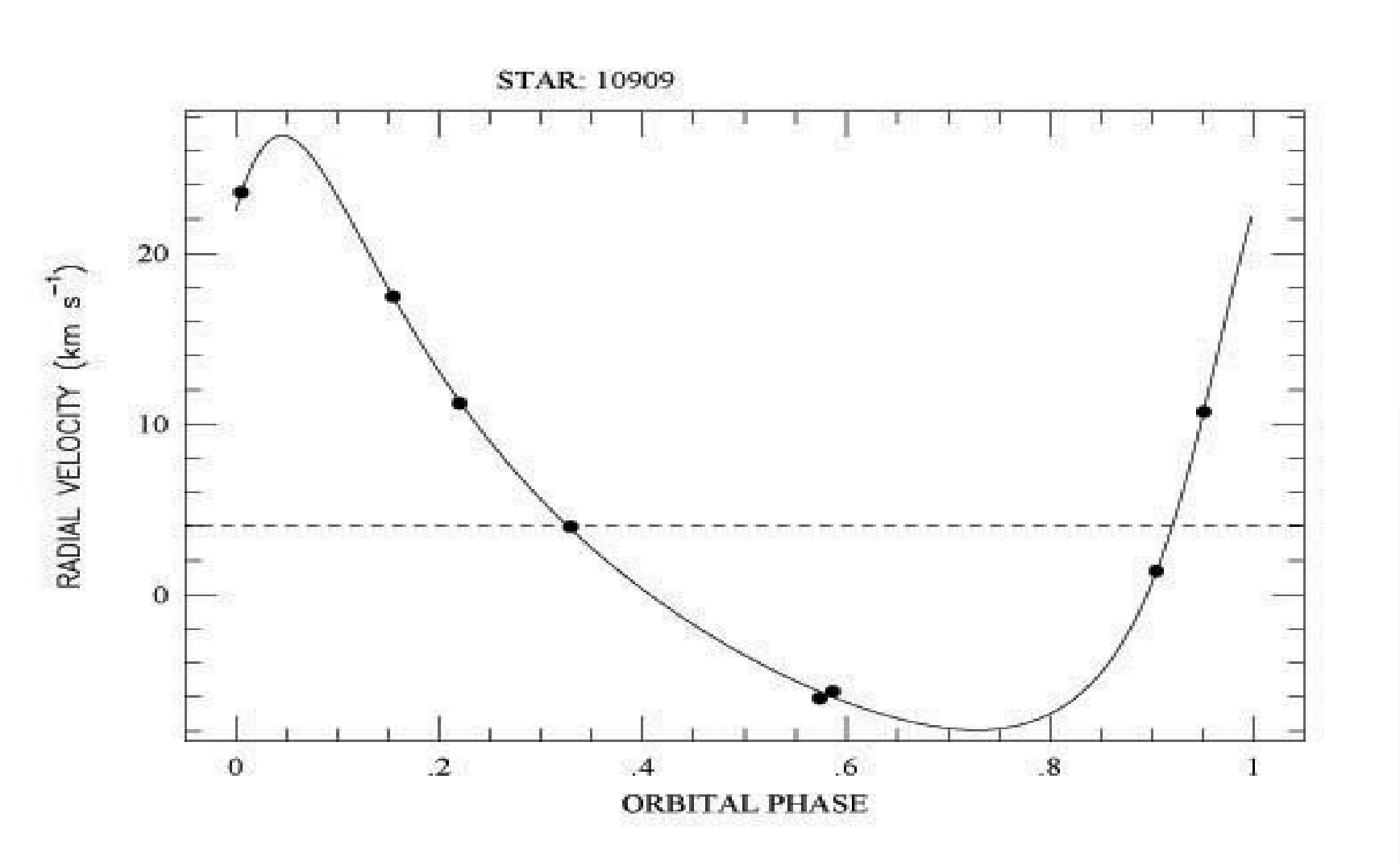
SB1



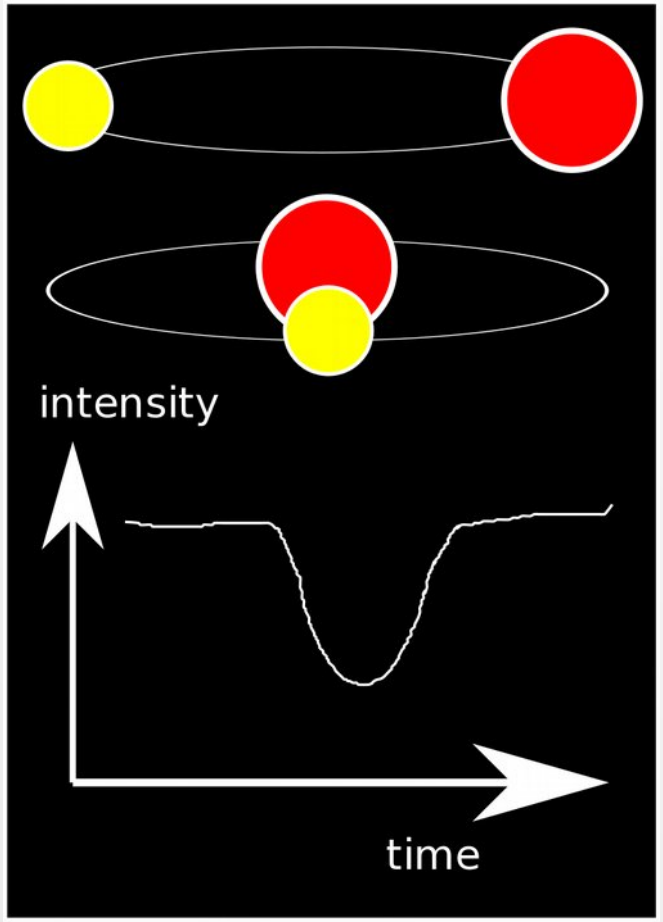
SB2



Eccentric SB1

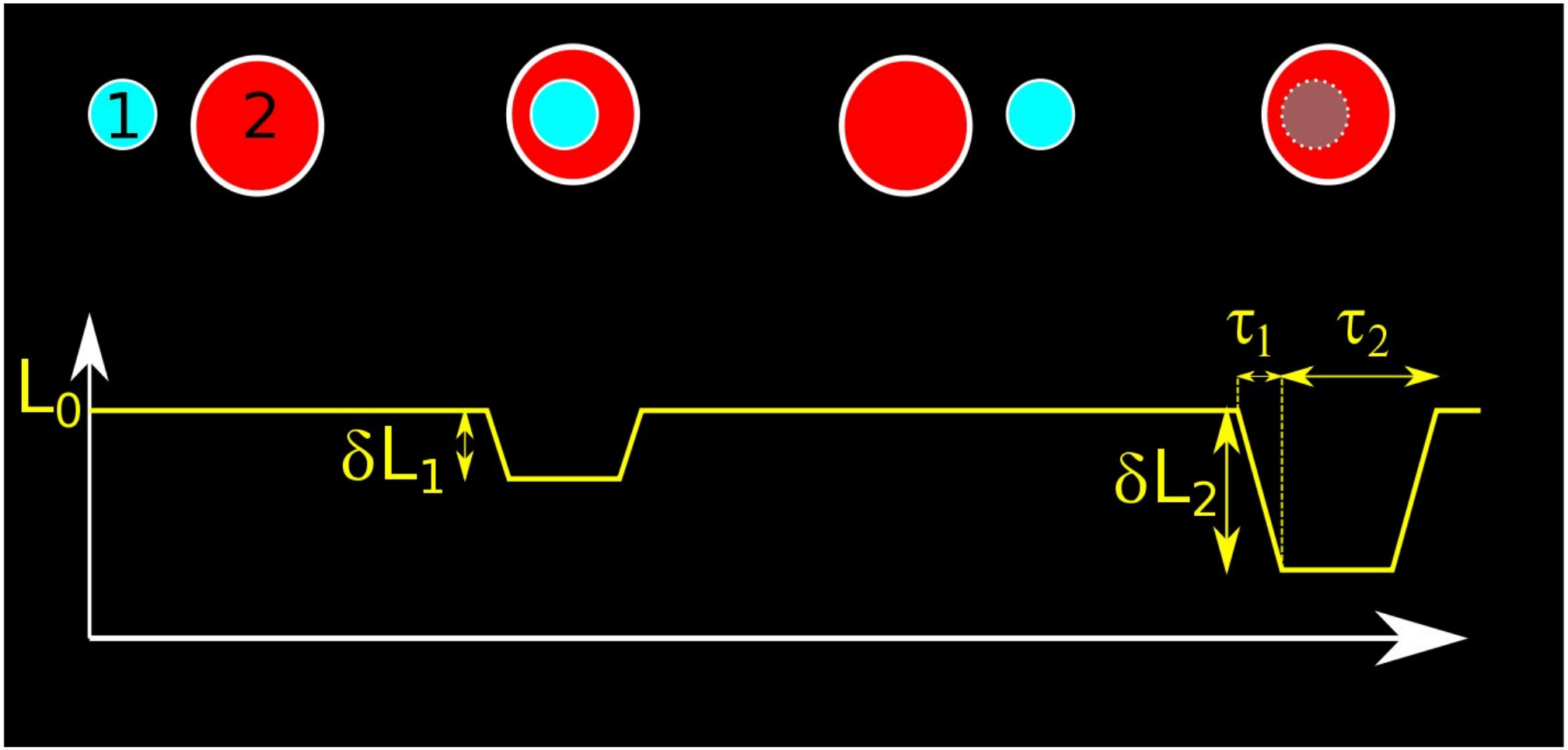


Photometric Binary



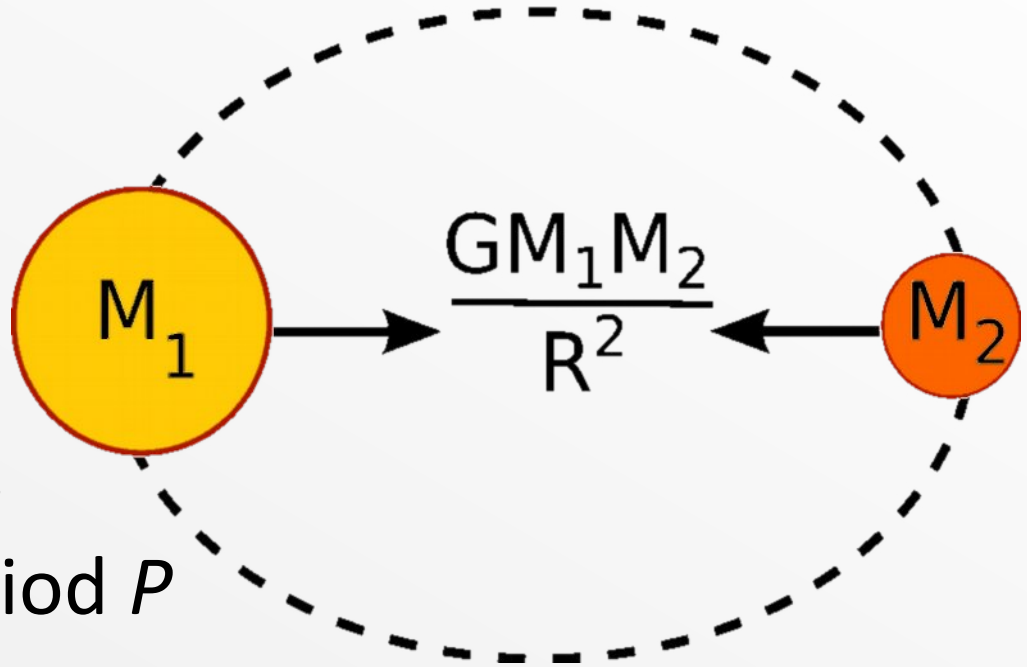
- Stars not resolved
- Light curve variability
- Eclipses
  - *Inclination*
- Non-spherical stars
- Colour variation

Eclipsing binary



Nomenclature

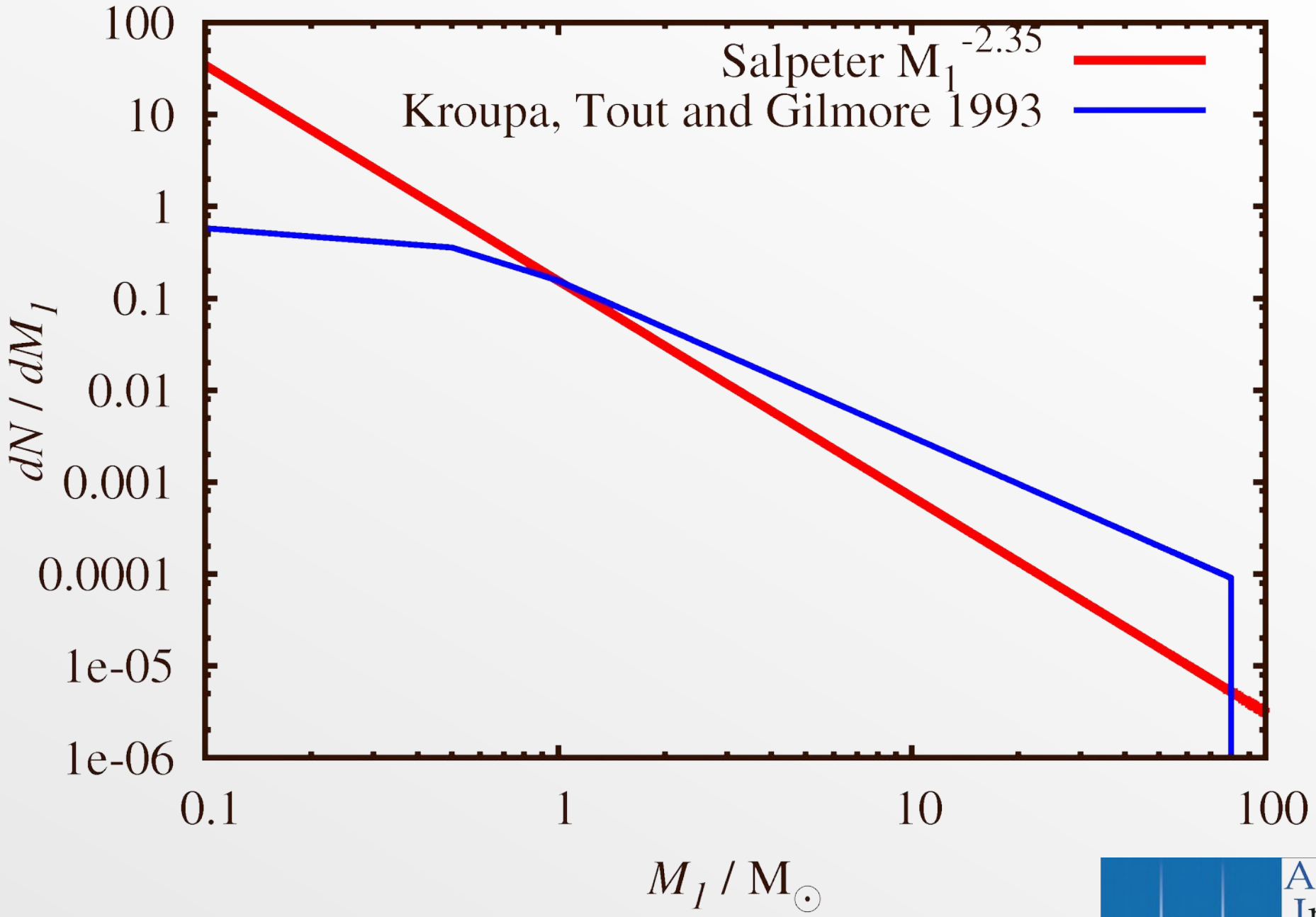
- Mass of more massive star primary: M_1
- Mass of less massive star secondary: M_2
- Mass ratio $q = M_2/M_1$
- Separation a – Orbital Period P
- Orbital Eccentricity e
- Inclination i (edge on=90 degrees)



Initial parameter distributions

- How many binaries have a given
  - Primary mass M_1
  - Secondary mass M_2
  - Orbital period P or separation a
  - Eccentricity e
- Important for statistical comparisons between models and observational data

Primary mass



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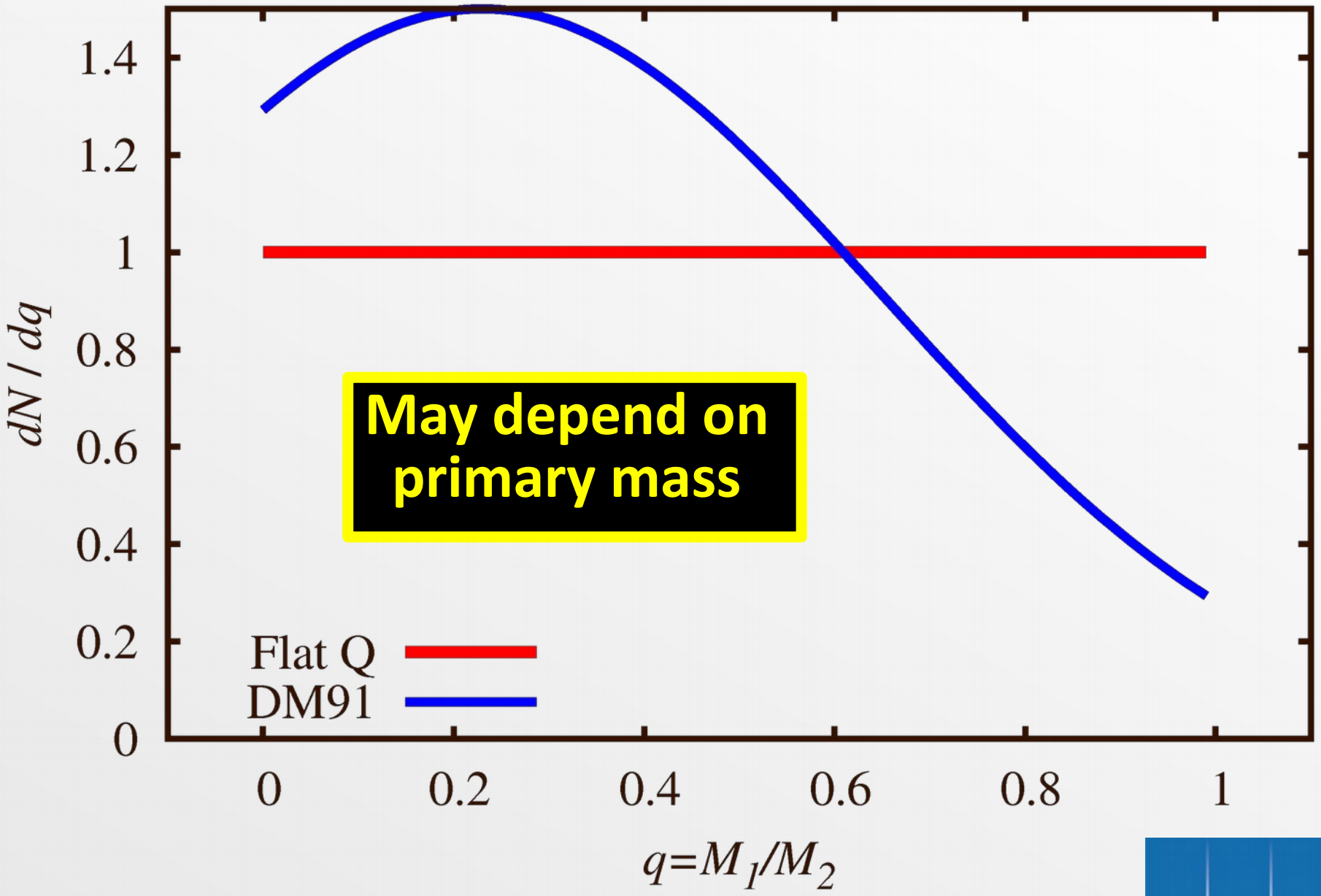
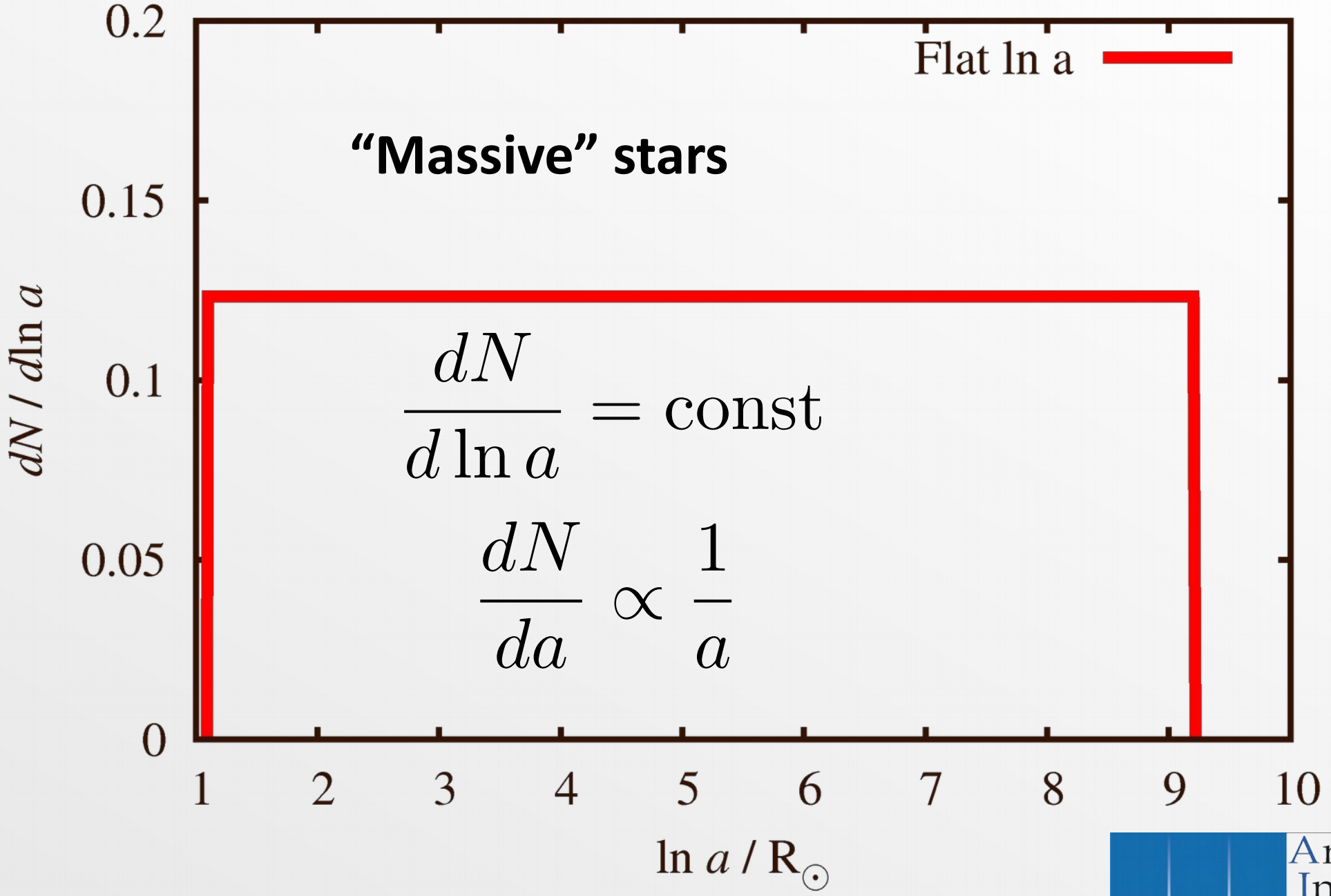
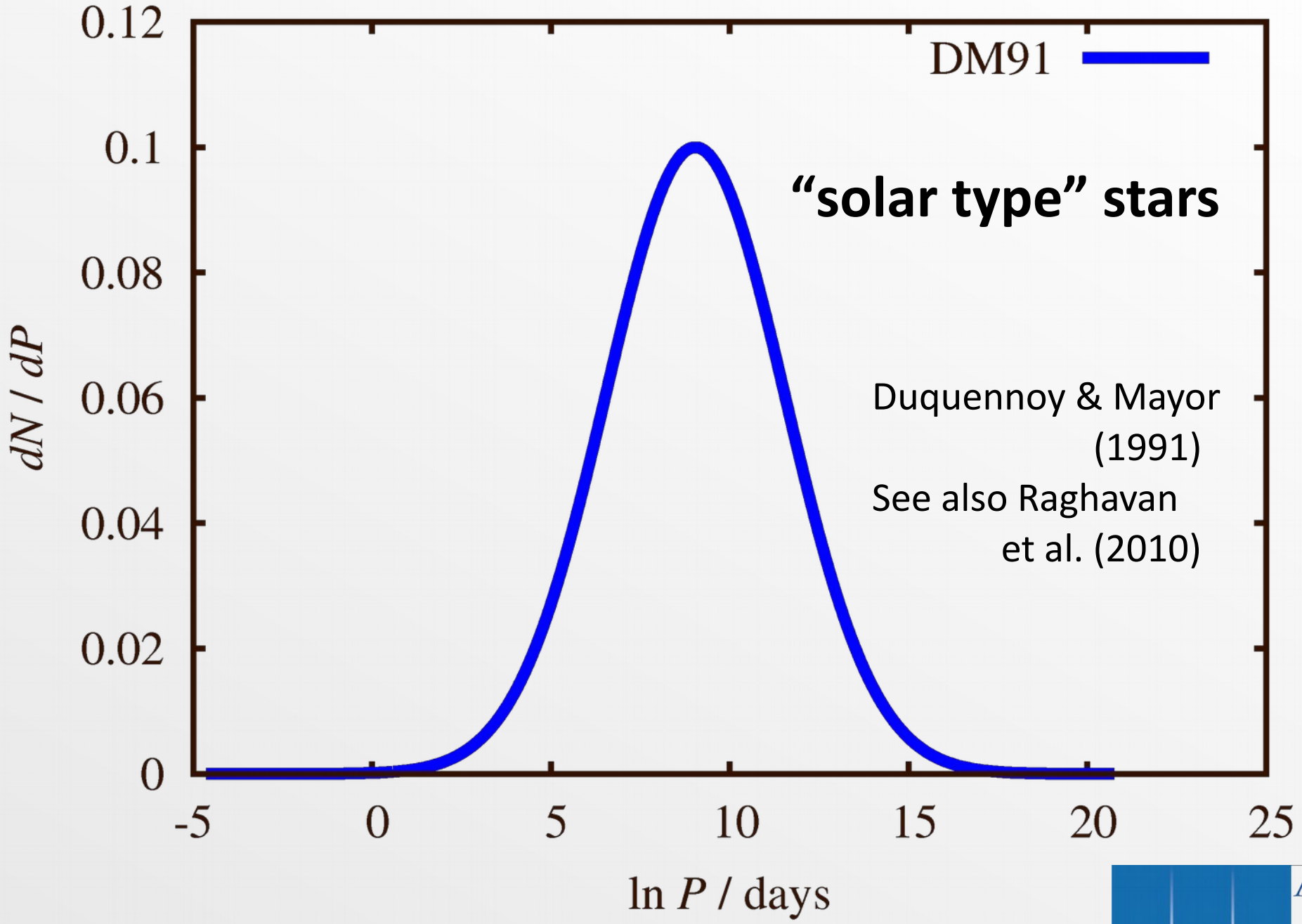
Secondary mass



Separation



Orbital Period



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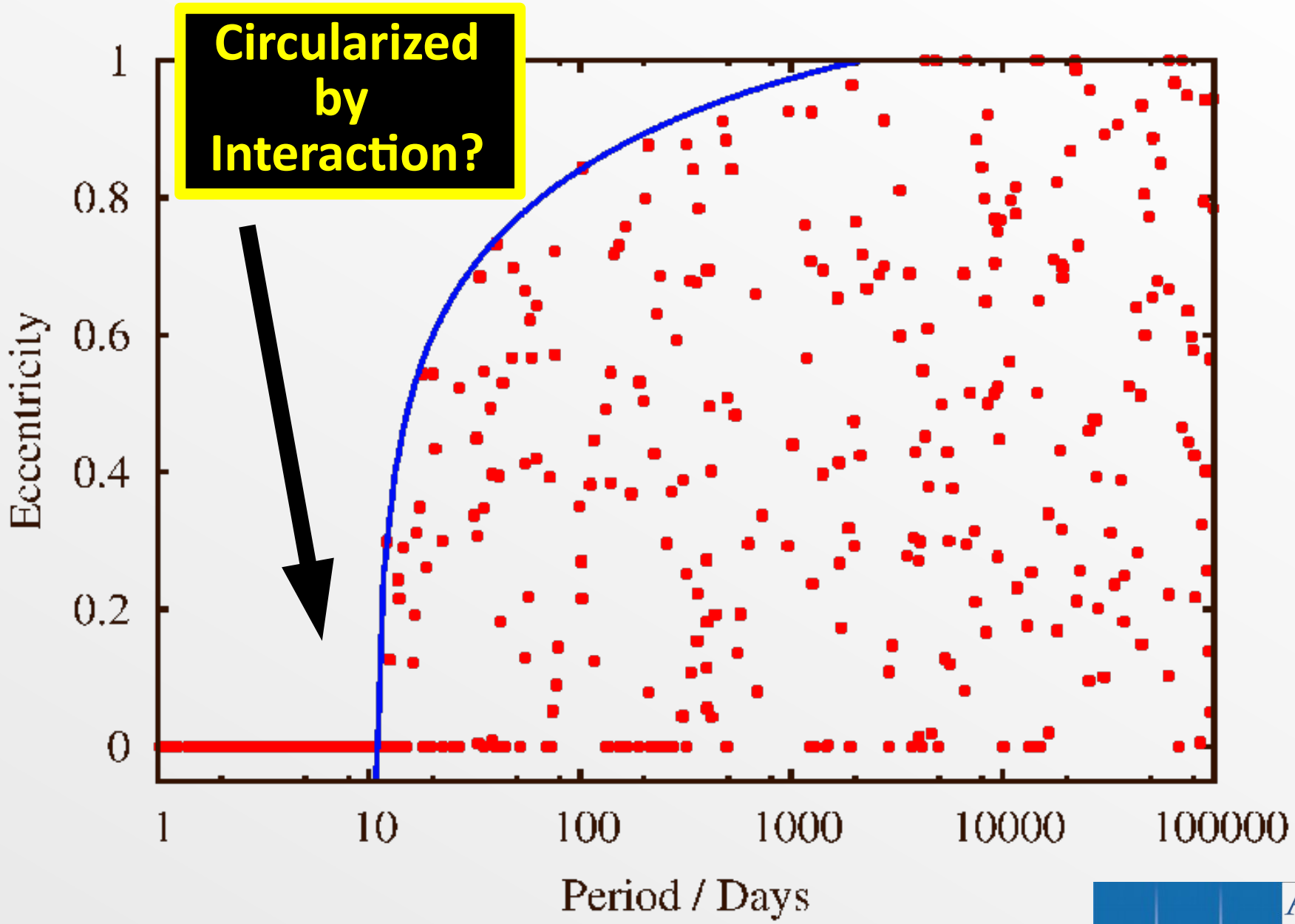
Eccentricity

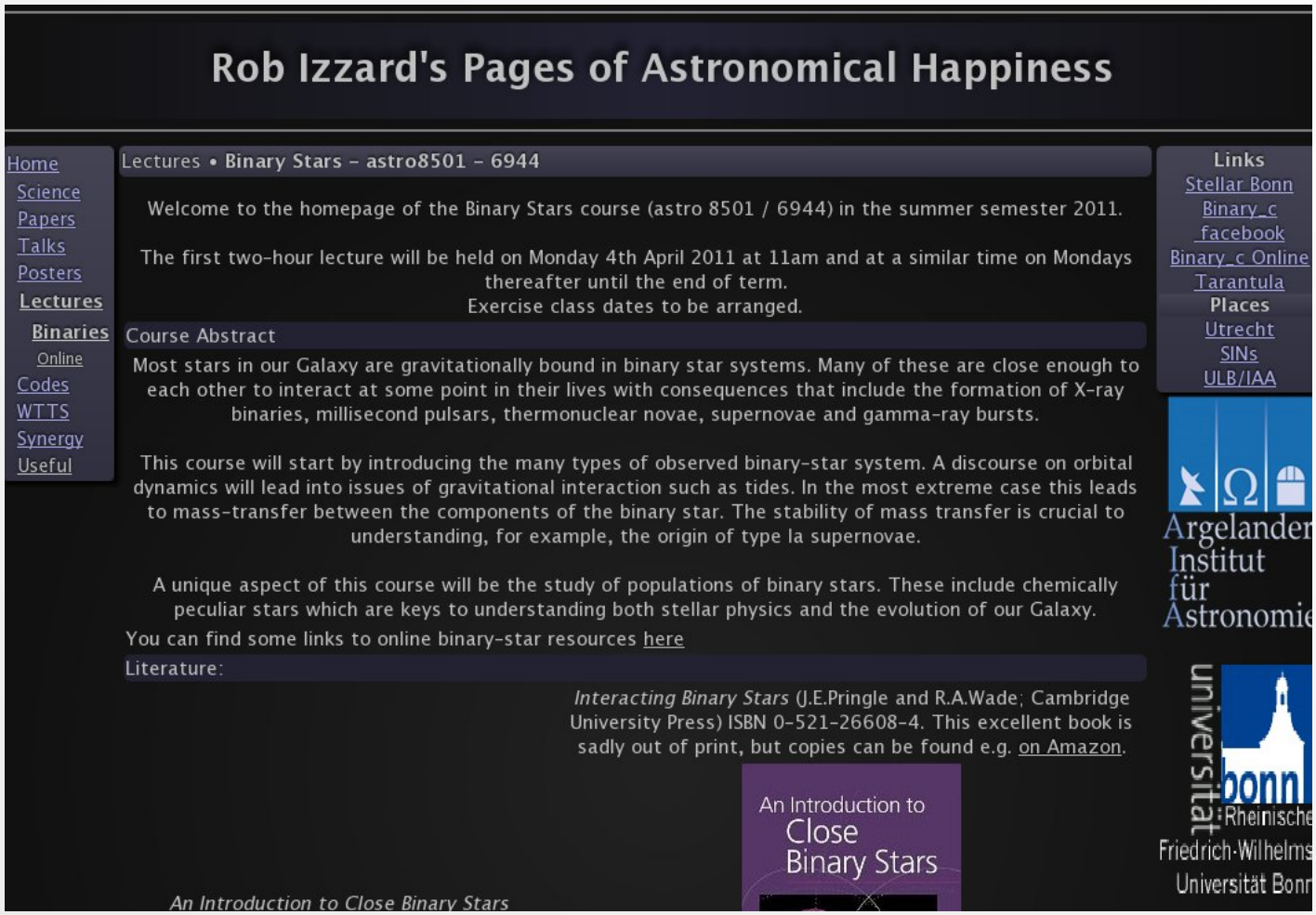


Binary naming schemes

- Named after the prototype system
  - *e.g. Algol, W-Uma*
- Chemistry e.g. barium star, carbon star
- Accretion: Symbiotic star
- Emission: X-ray binary
- Double WD, “double degenerate”
- Outbursts: nova, supernova

Online Resources

http://www.astro.uni-bonn.de/~izzard/binary_stars.html



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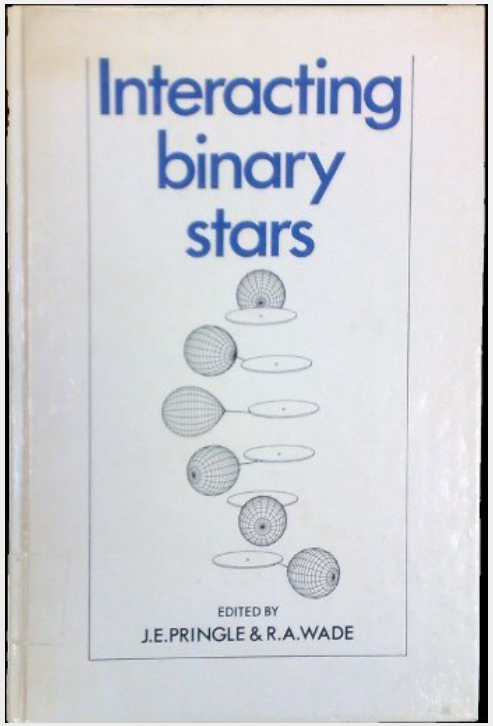
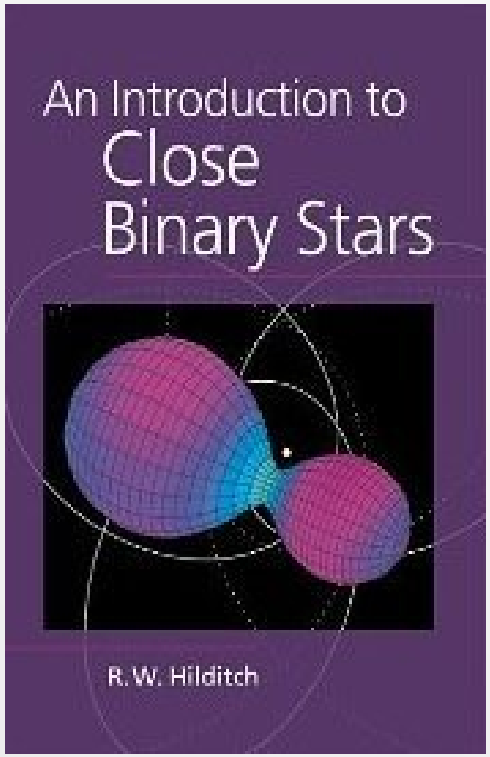
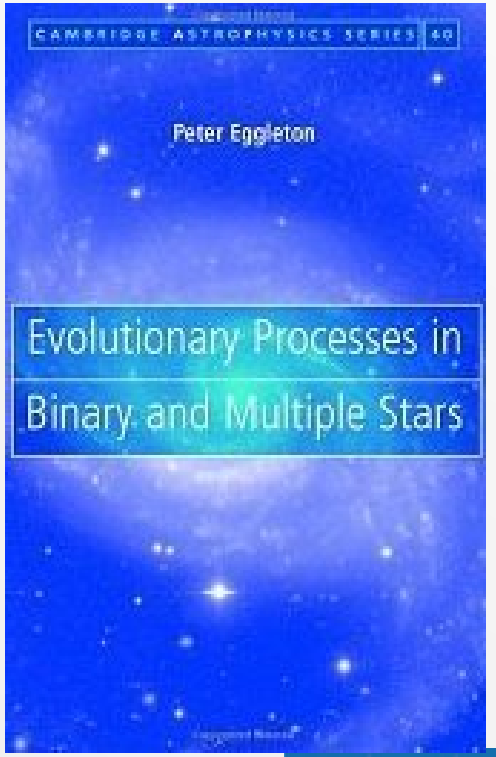
Textbooks

- Interacting Binary Stars (Pringle and Wade)
- An Introduction to Close Binary Stars (Hilditch)
- Evolutionary Processes in Binary and Multiple Stars (Eggleton)







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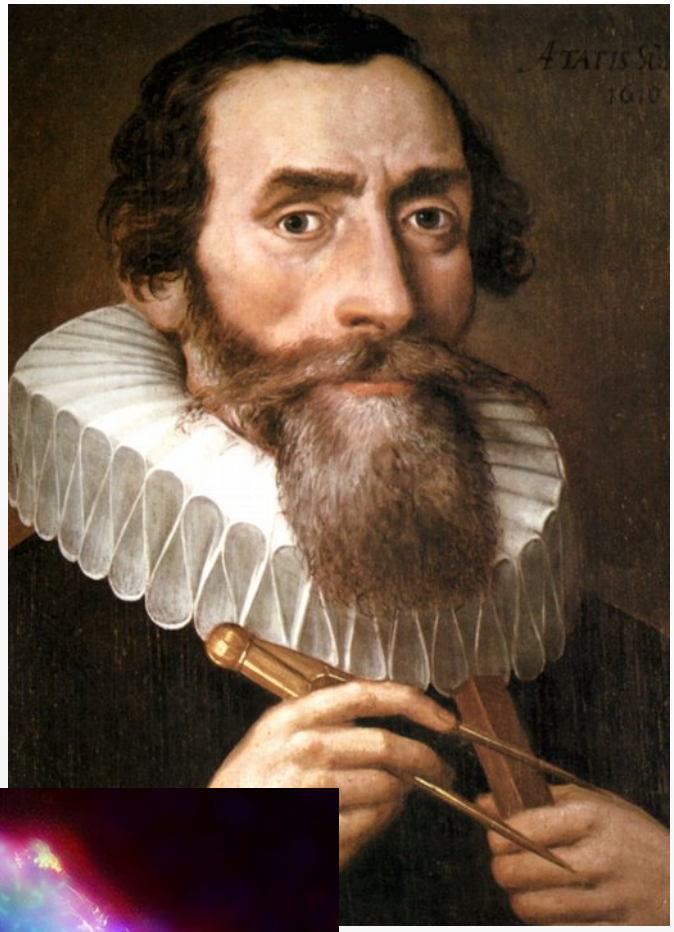
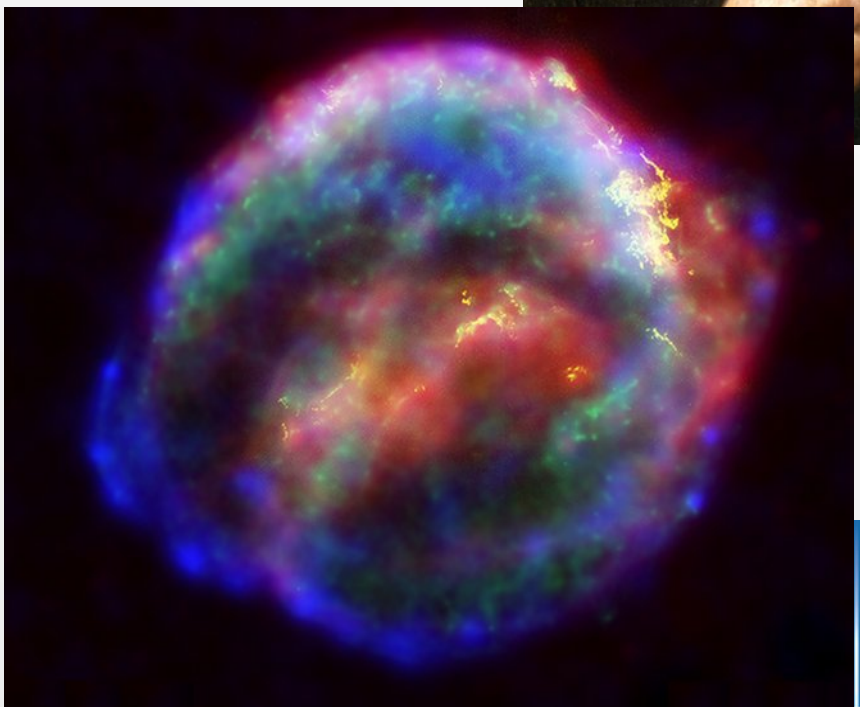
Kepler's Laws



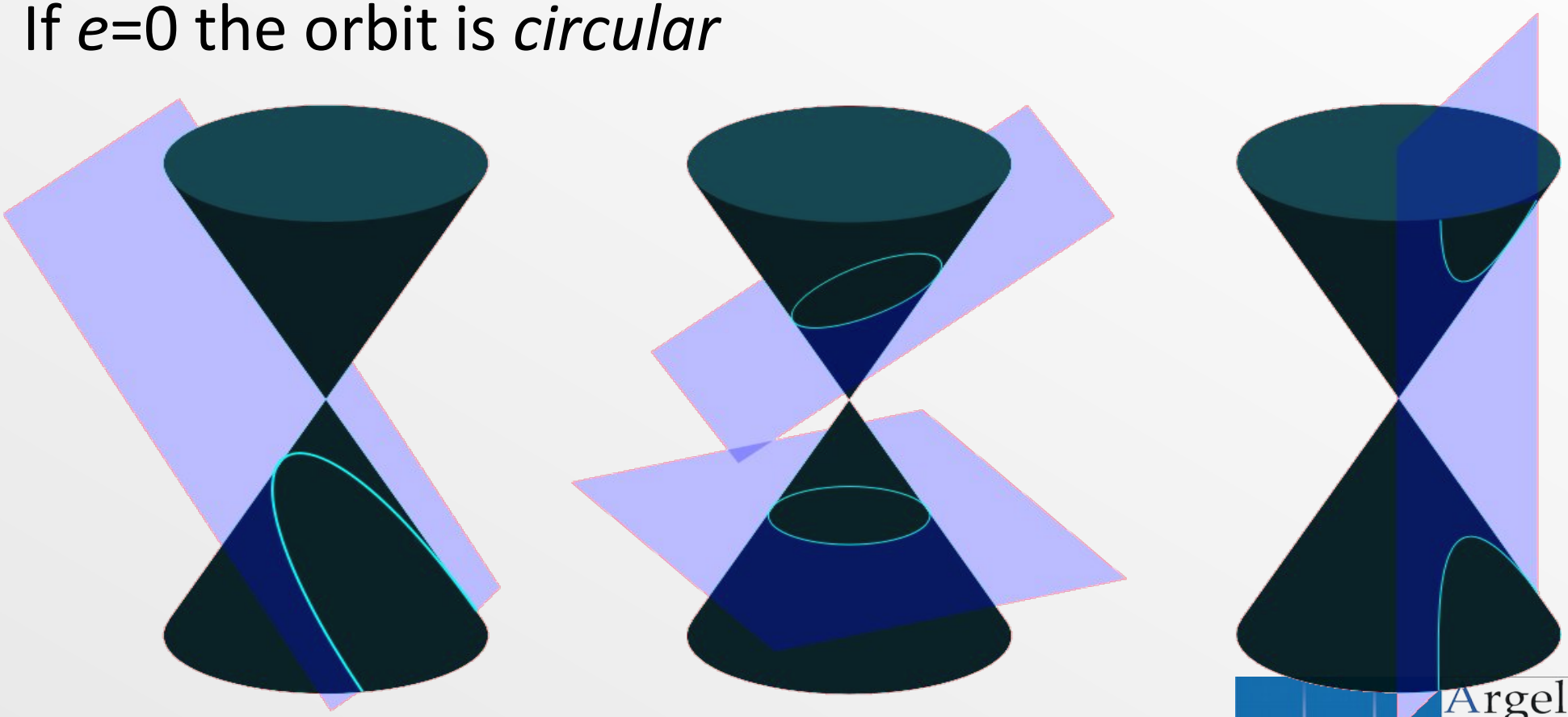
- German!
- 1571-1630
- Worked with

  Tycho Brahe

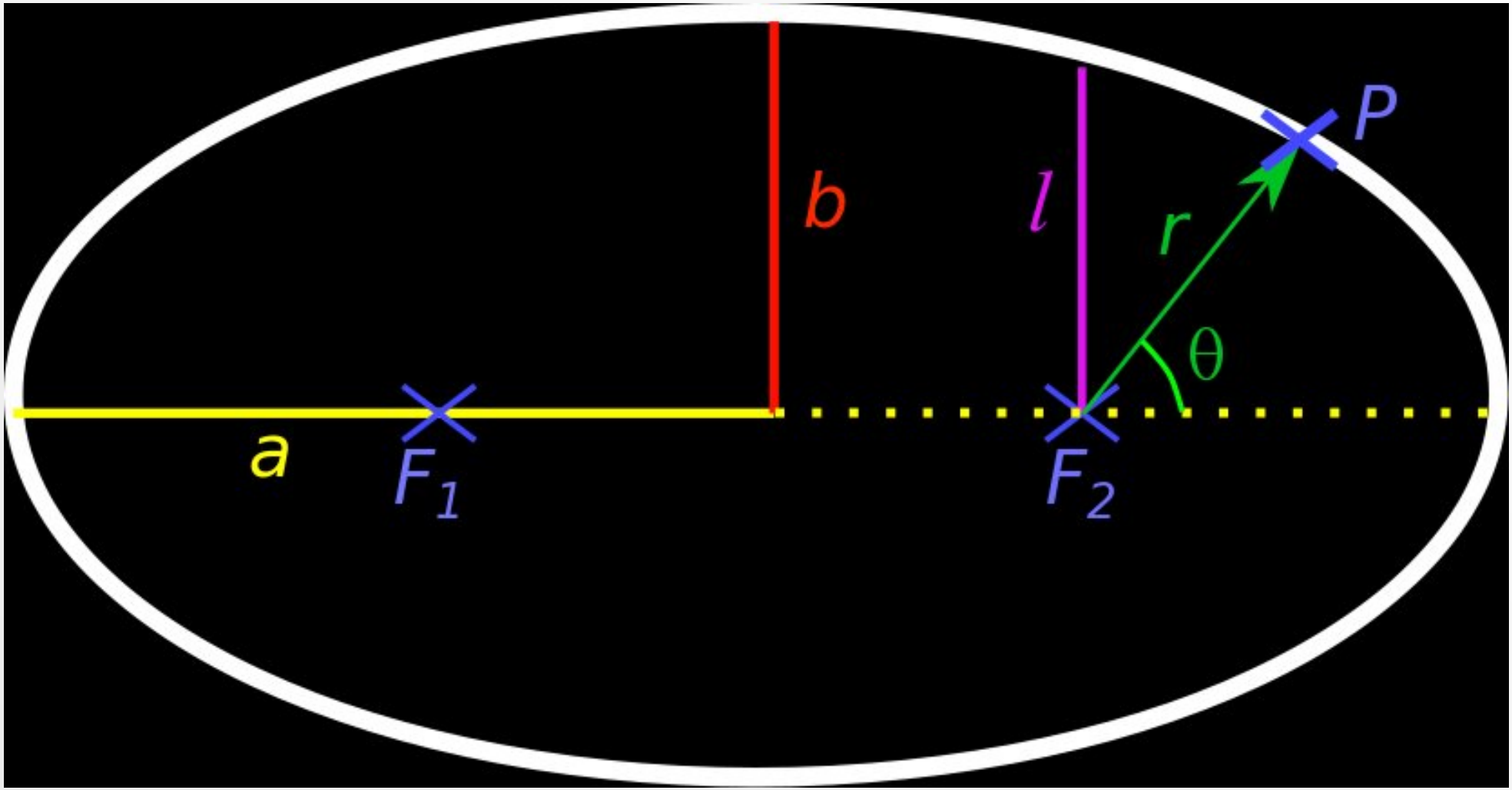


Kepler's First Law

- The orbits of binary stars are *conic sections*
- *Bound* orbits are ellipses
- If *e*=0 the orbit is *circular*

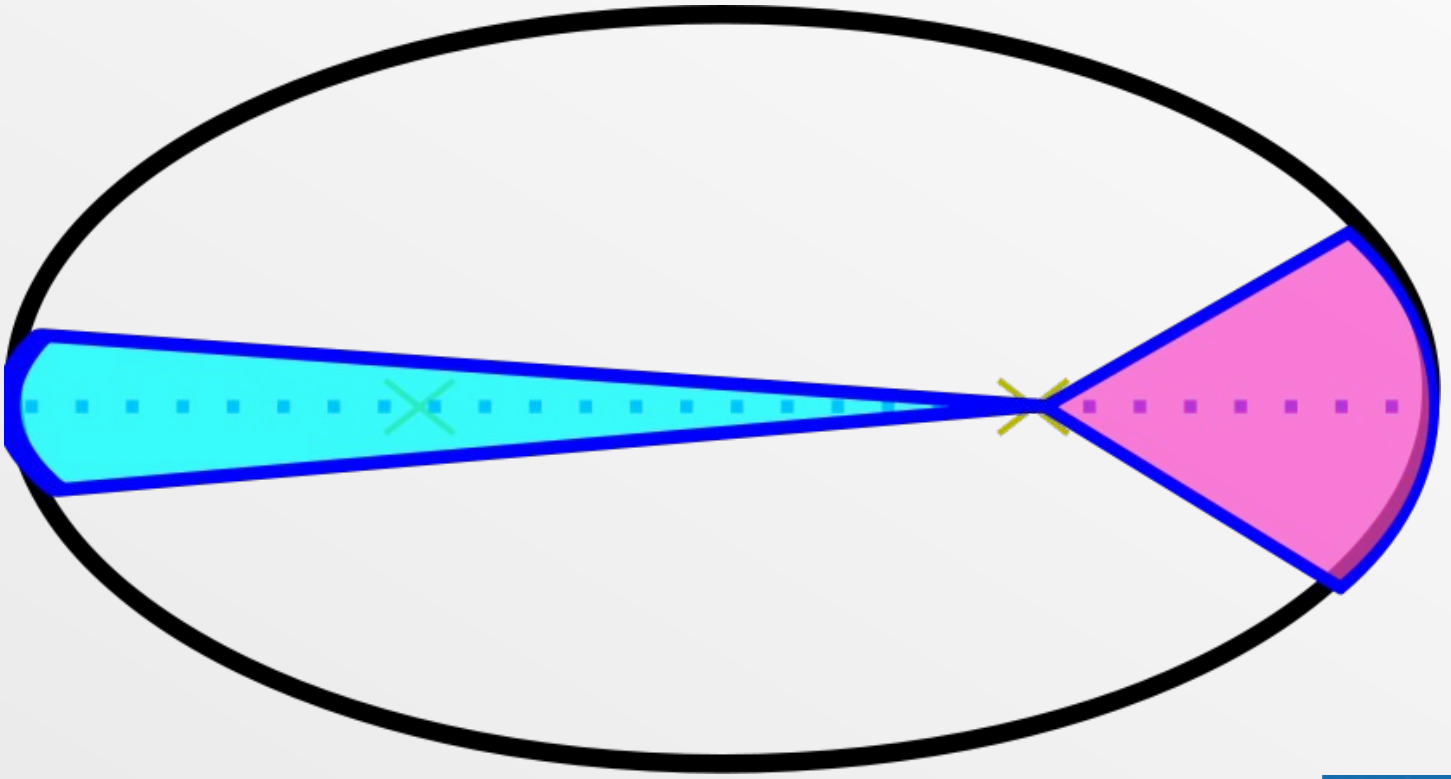


Elliptical Motion



Kepler's Second Law

- The line connecting the two stars sweeps out *equal areas* in *equal times*



Kepler's Third Law

- Period and separation are related by

$$P^2 \propto a^3$$

- Independent of eccentricity
- Define *mean* angular velocity $\omega = \frac{2\pi}{P}$

Kepler's Laws

- Bound Orbits are ellipses
- Equal areas swept in equal times

$$P^2 \propto a^3$$

- All consequences of Newton's law

$$F = \frac{GM_1M_2}{r^2}$$