

Astro 8501 – 6944

Binary Stars

Thursdays 9am
Alfa 0.008



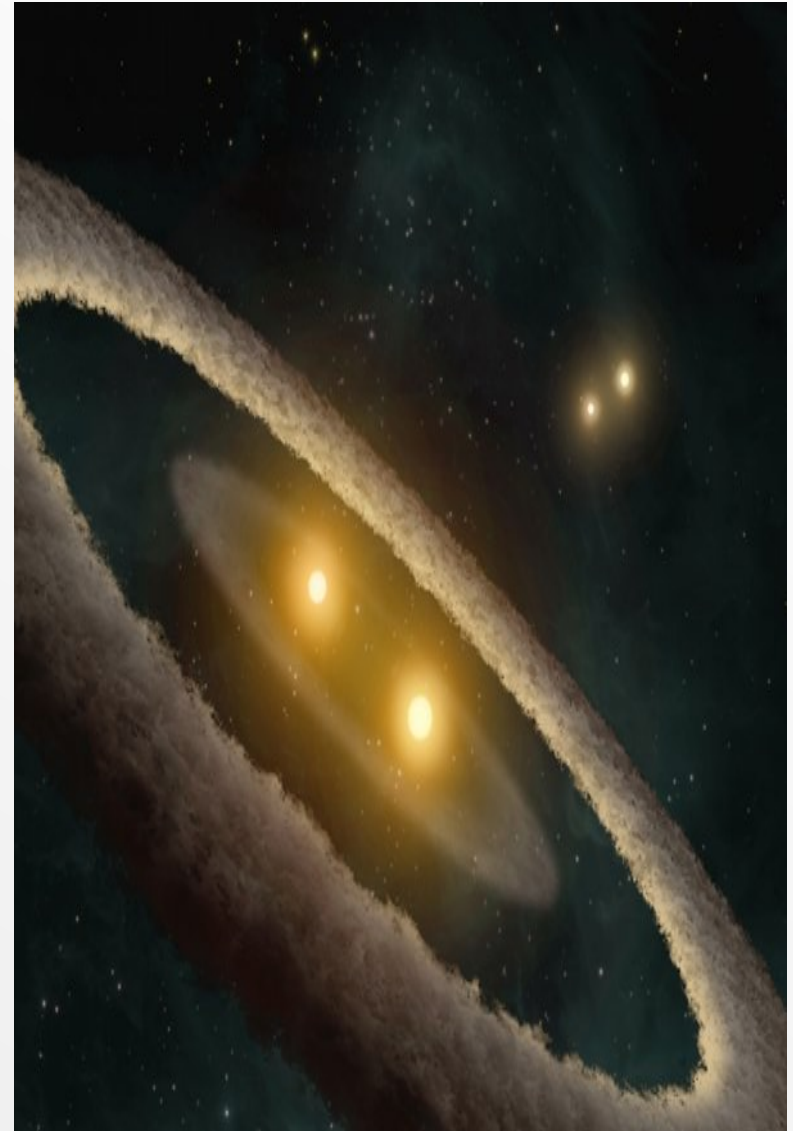
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http://www.astro.uni-bonn.de/~izzard/binary_stars.html

Class 1: An Introduction

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



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

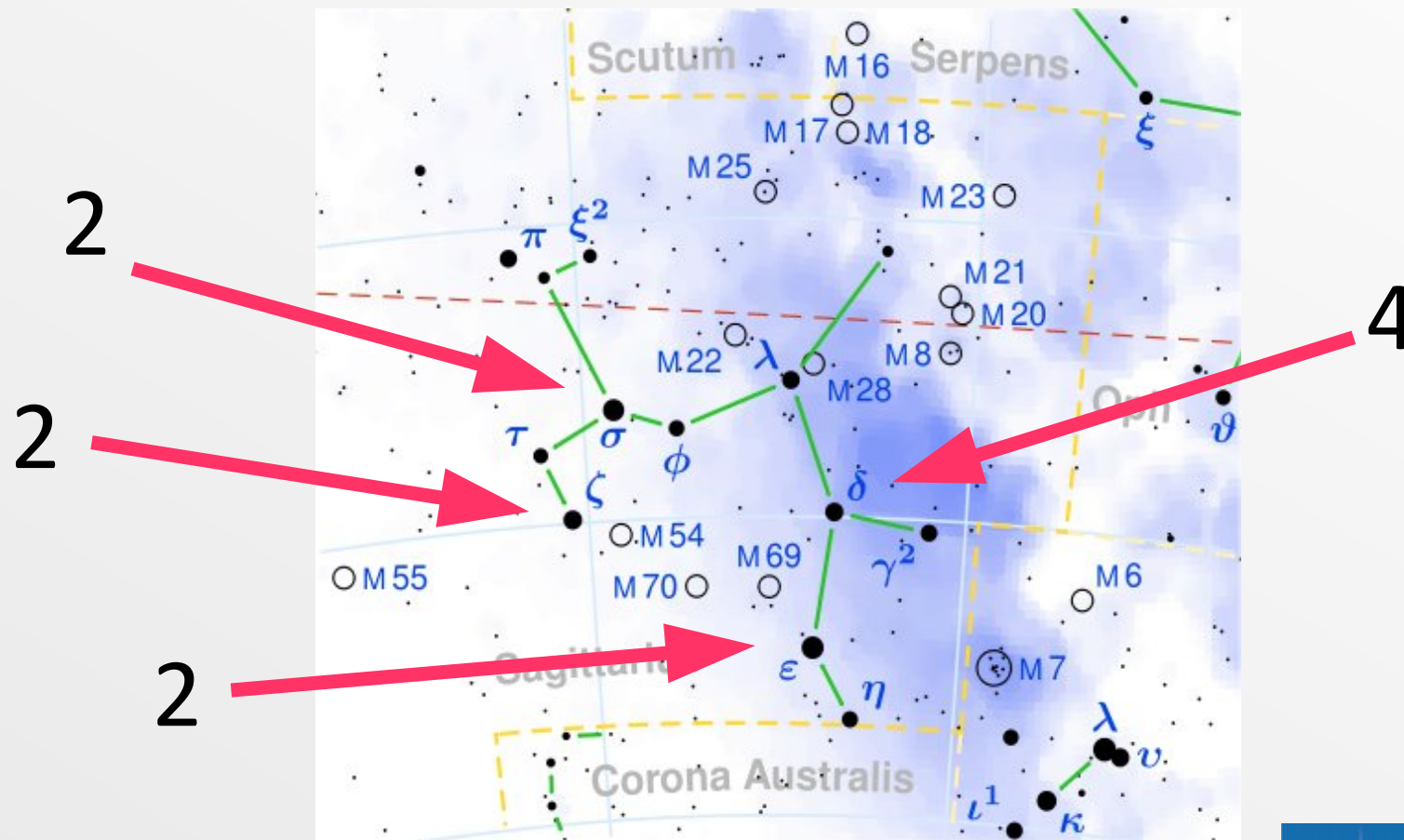
- Riccioli (Bologna)



History

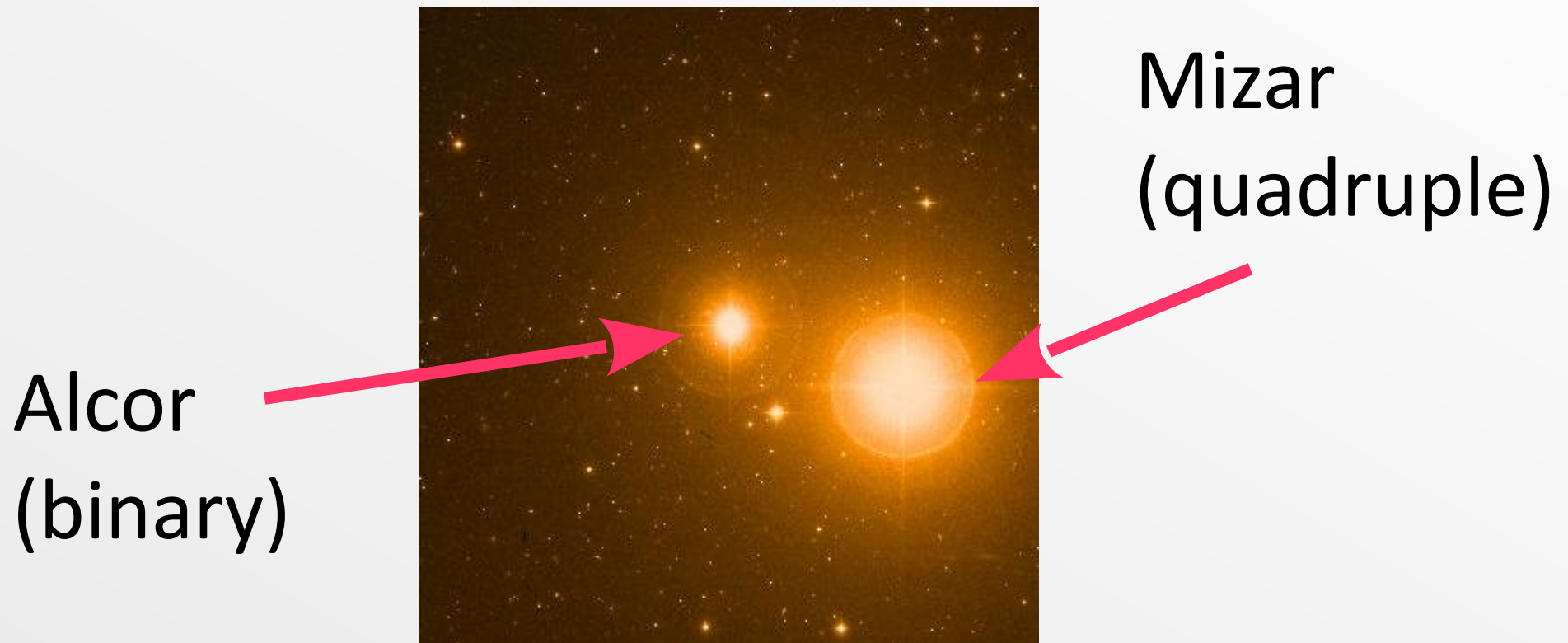
Almagest of Ptolemaios, 150AD

“double star at the eye of Sagittarius”



Telescopic Binary

- 1617 Galileo observed Mizar: 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)

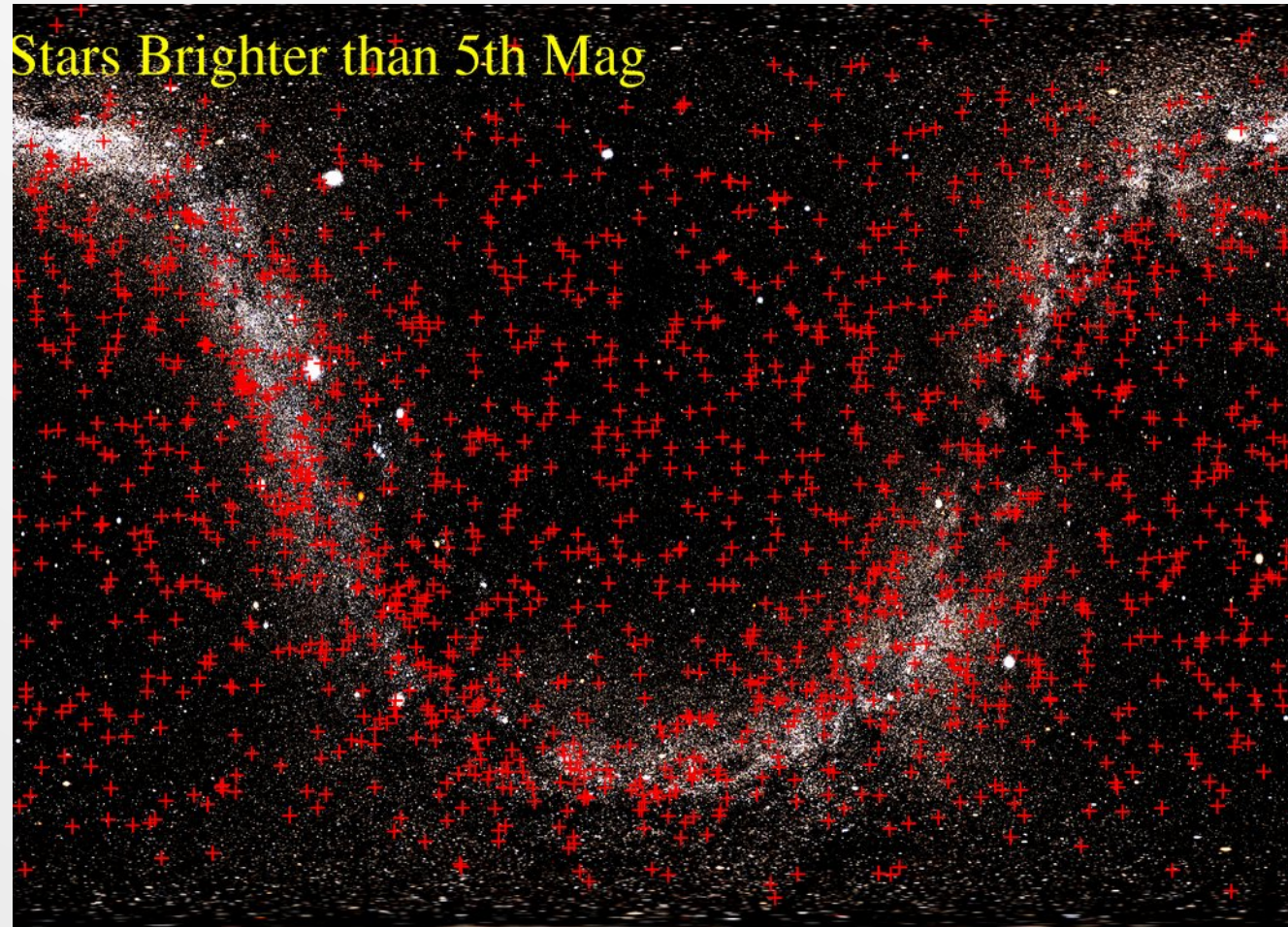
The Night Sky

Composite Tycho image (from NASA)



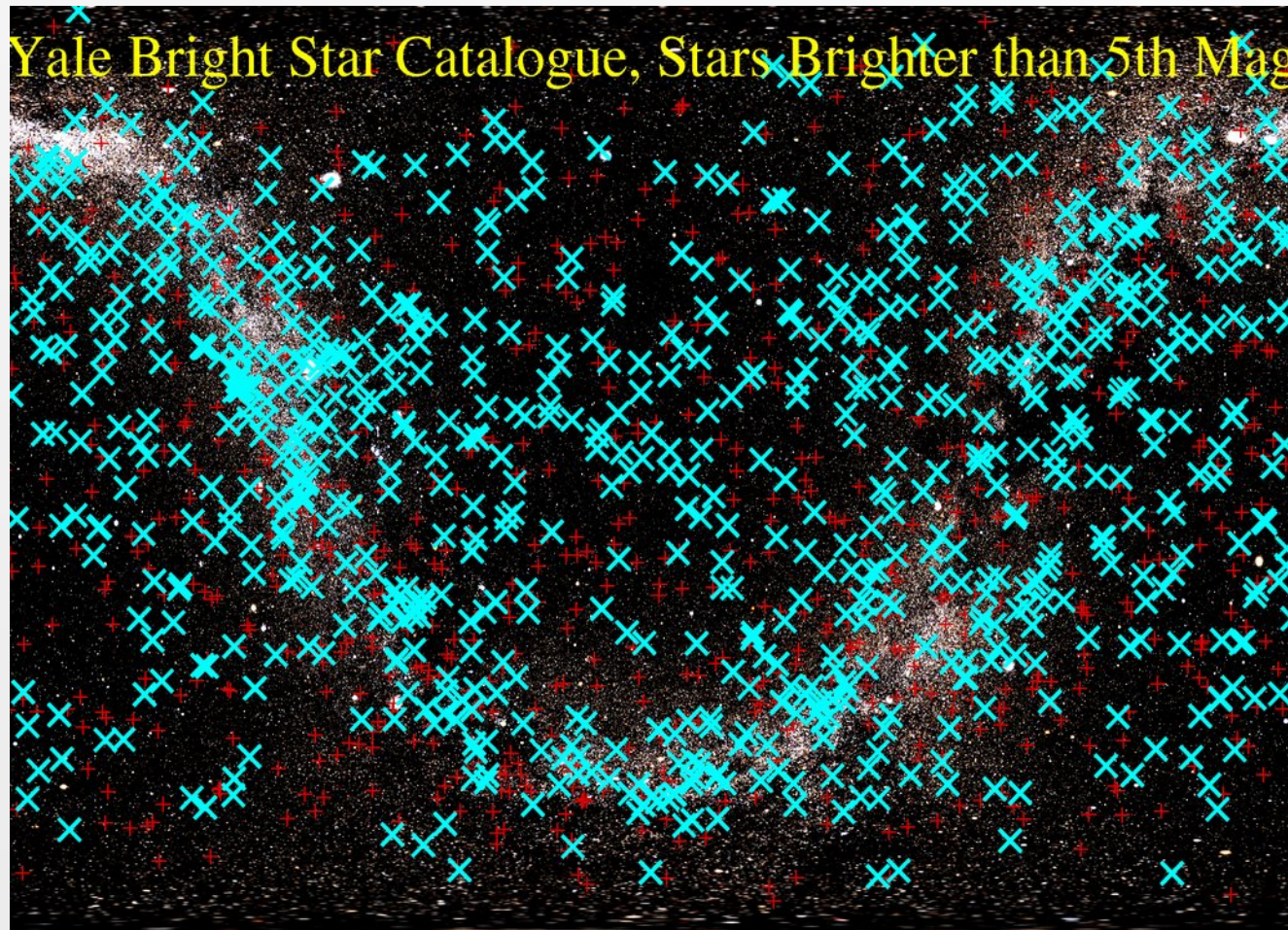
The Bright Star Catalogue

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



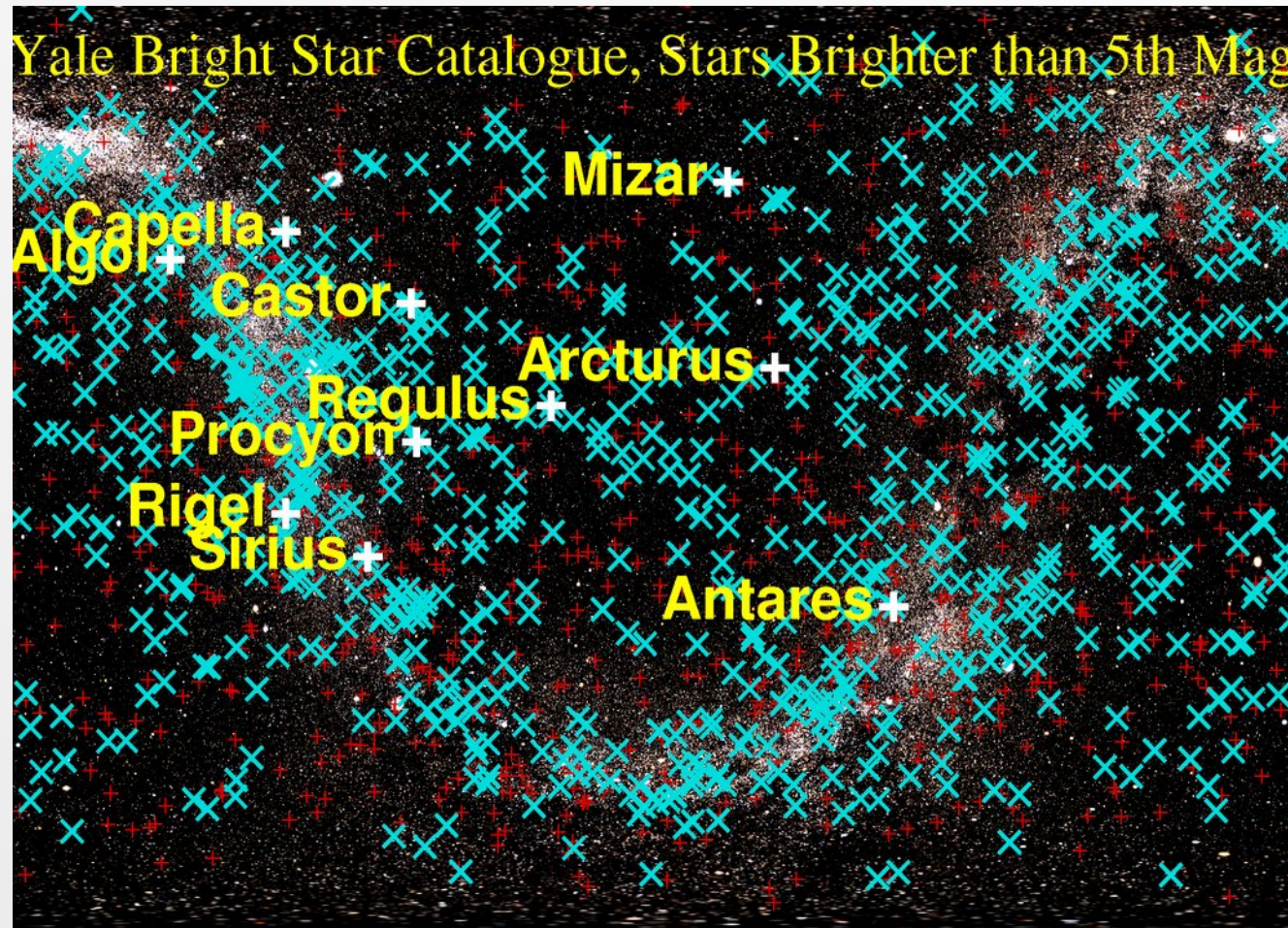
The Bright Star Catalogue

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

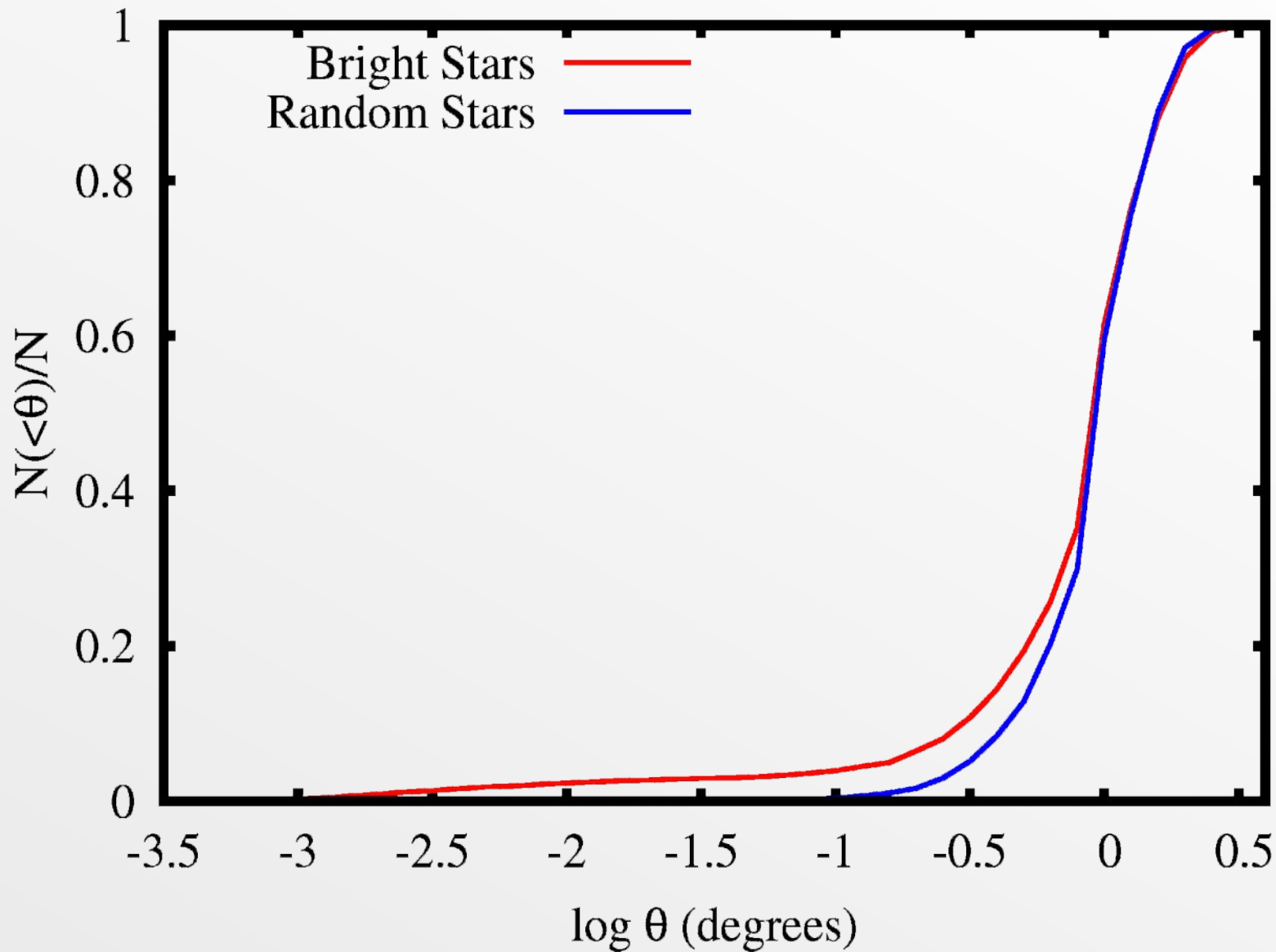


The Bright Star Catalogue

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

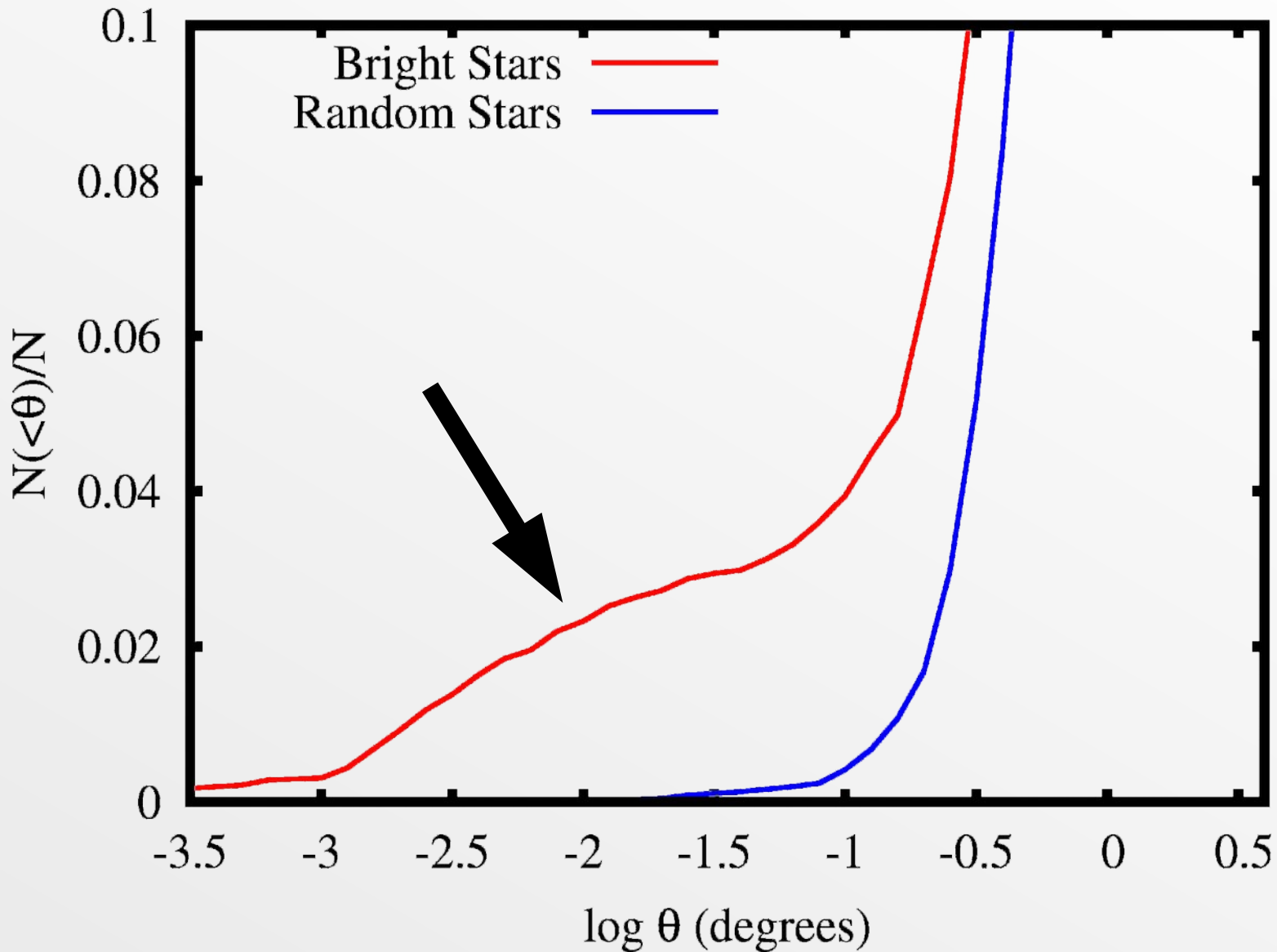


Testing the Binary Hypothesis



- Use the Bright Star Catalogue

Testing the Binary Hypothesis

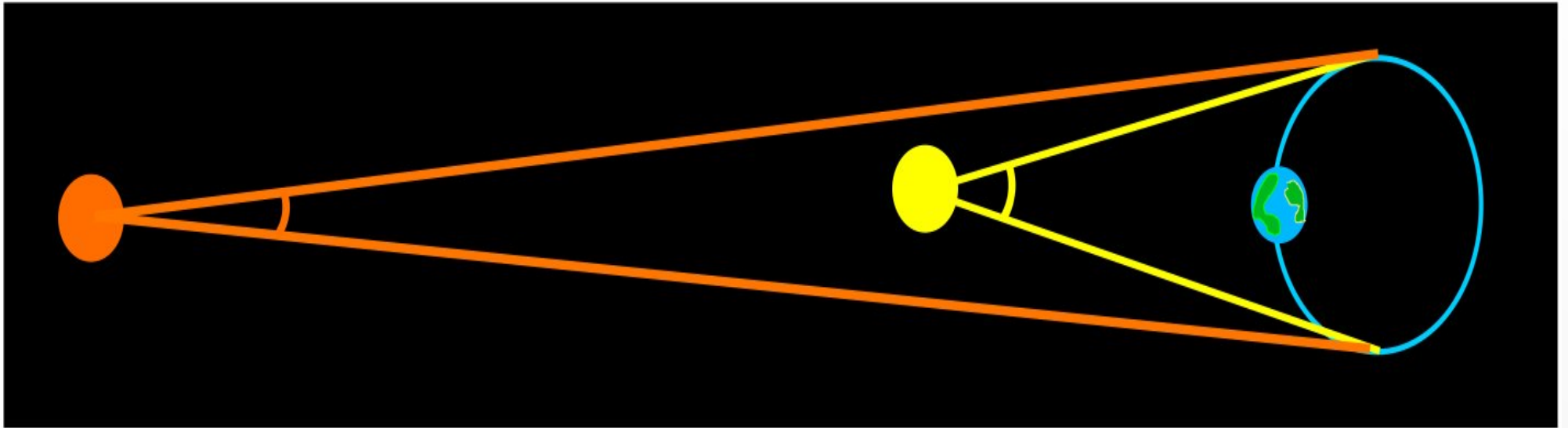


• cf. Michell 1767

Michell 1767



Parallax proves it

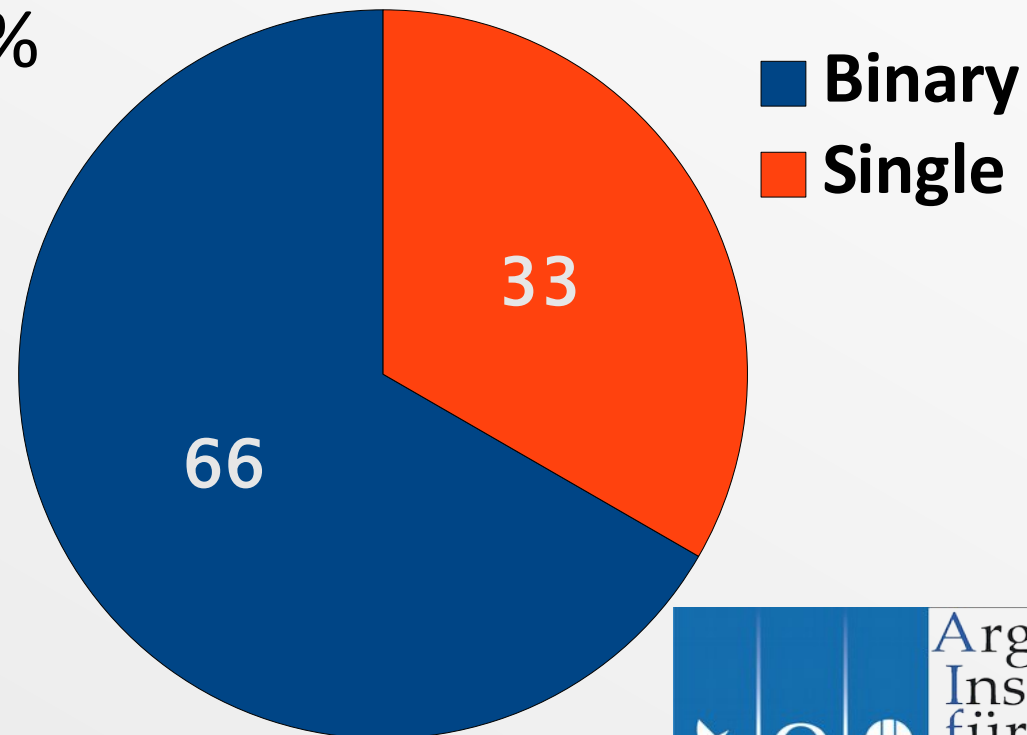


Coincident “binaries” have different parallax

Binary Fraction

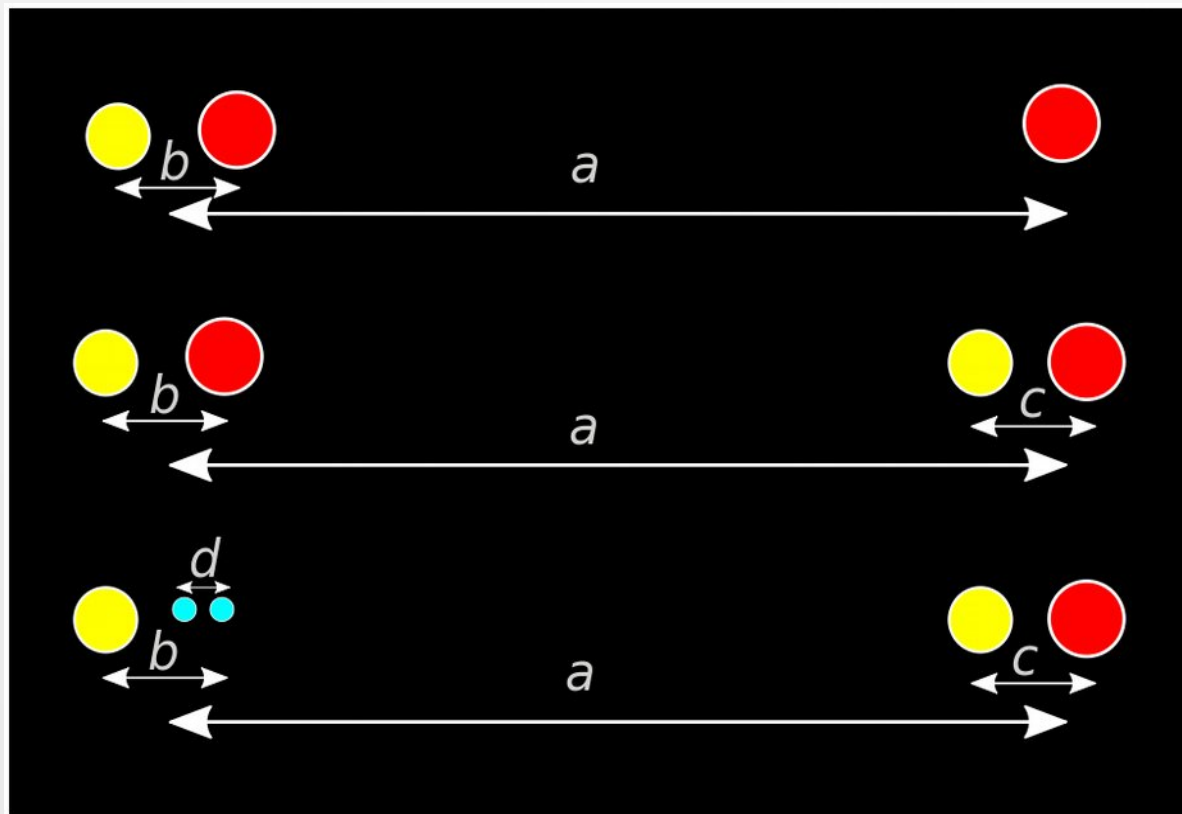
- Stars brighter than 5th Magnitude:
- 1618 systems
- 825 Single-star Systems
- 793 Binary-star Systems
- Binary System Fraction 49%
- Binary *Star* Fraction >66%

**Massive stars
more likely to be
binary**



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



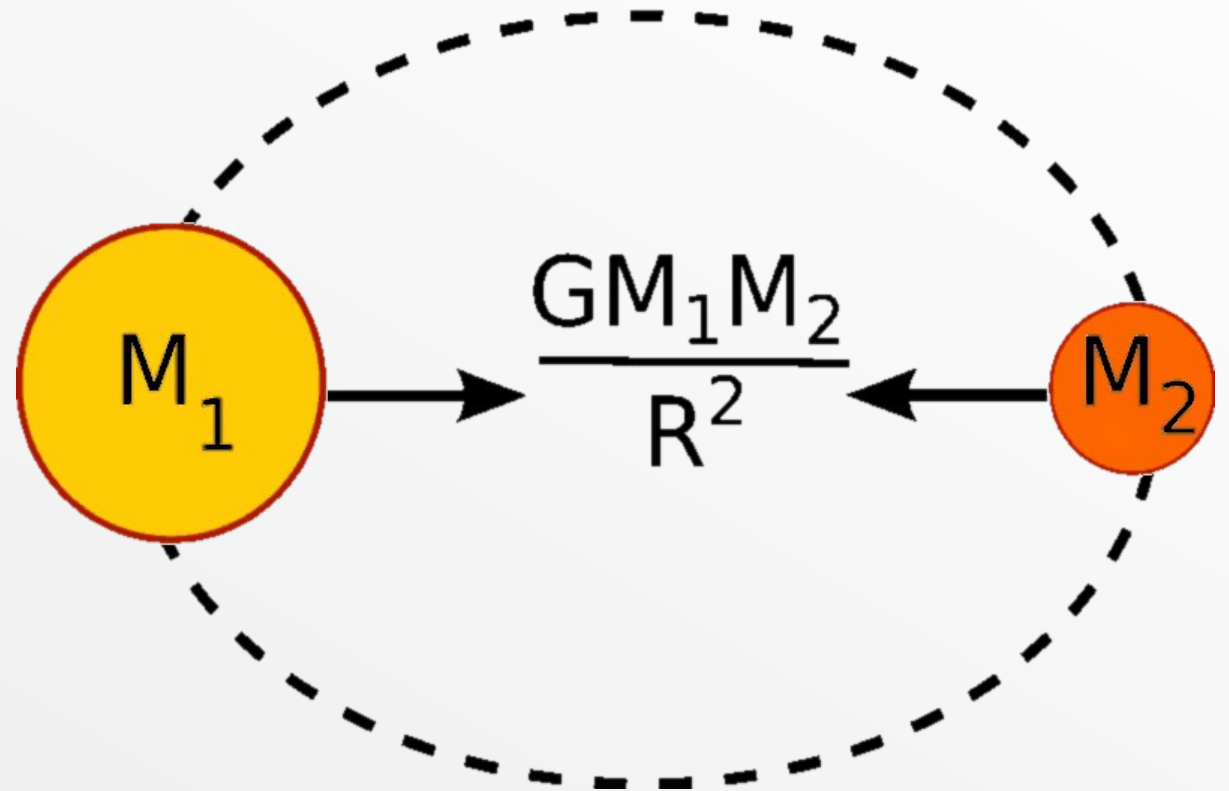
$$a > 10b$$

$$a > 10b, 10c$$

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

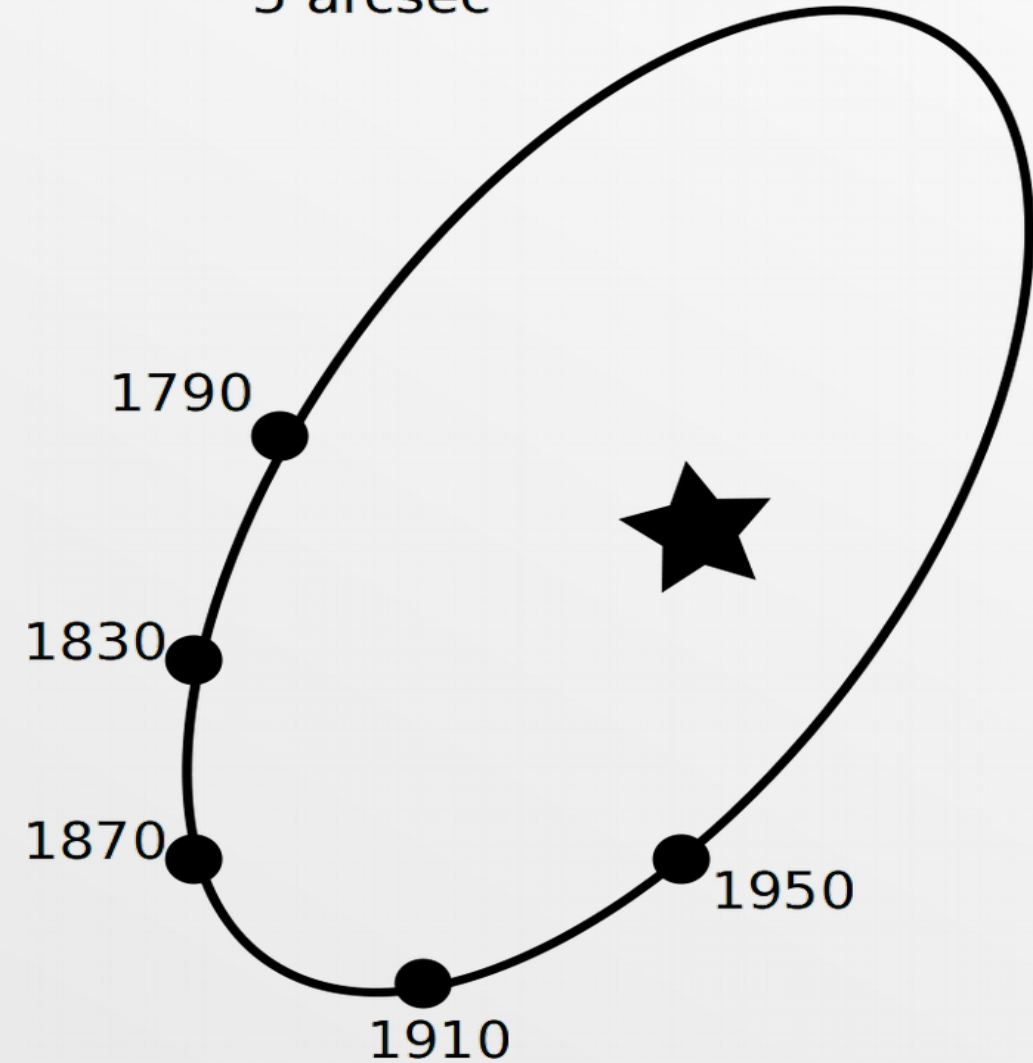
Types of Binary Star

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



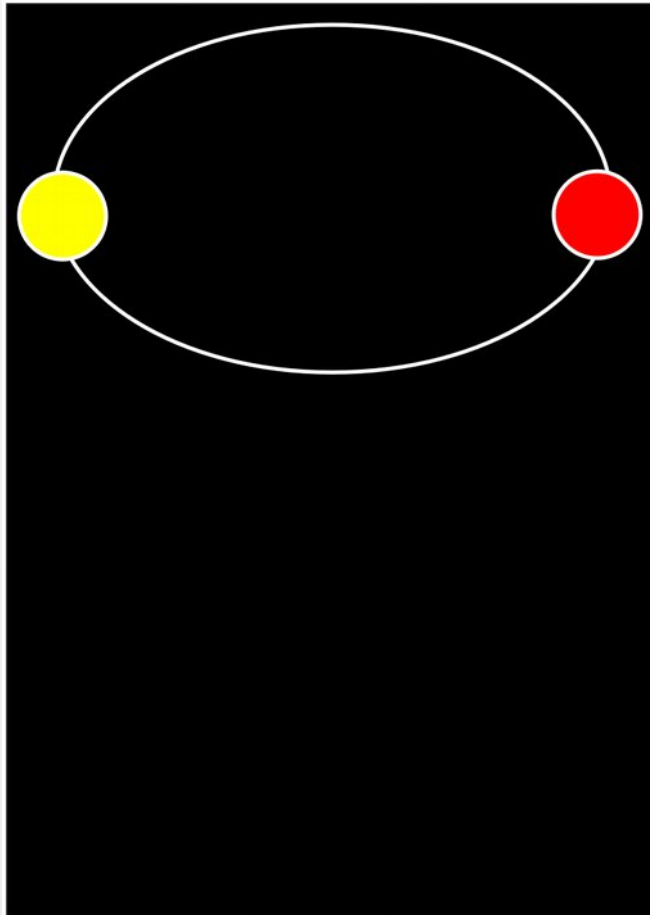
Visual Binaries

5 arcsec



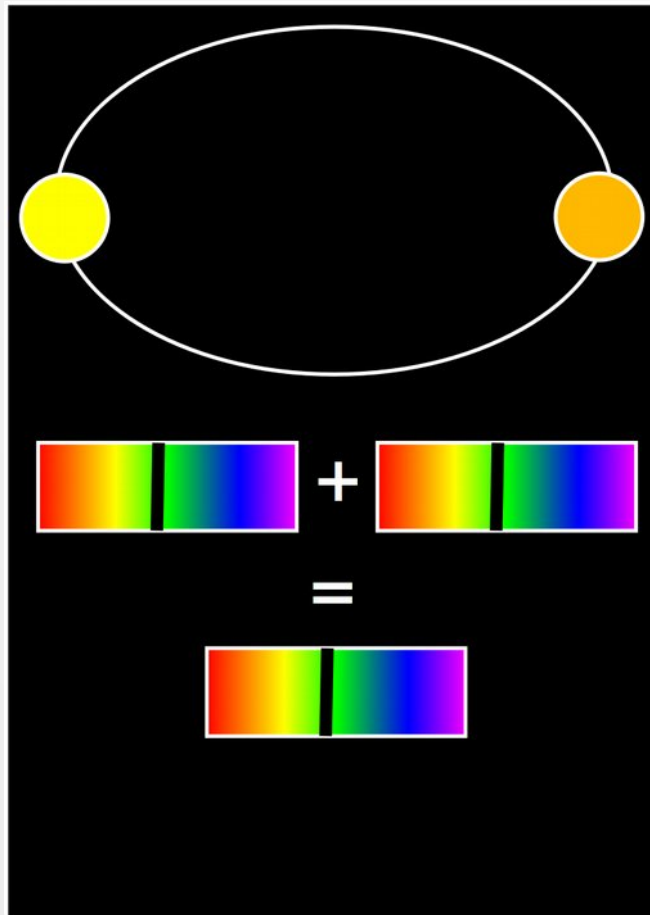
- Stars resolved
- Close:
 - gravitationally bound?
- Orbit:
 - *Circular or Ellipsoidal*
- e.g. Castor
- Near, long period only
- $>0.01'$

Spectroscopic binary



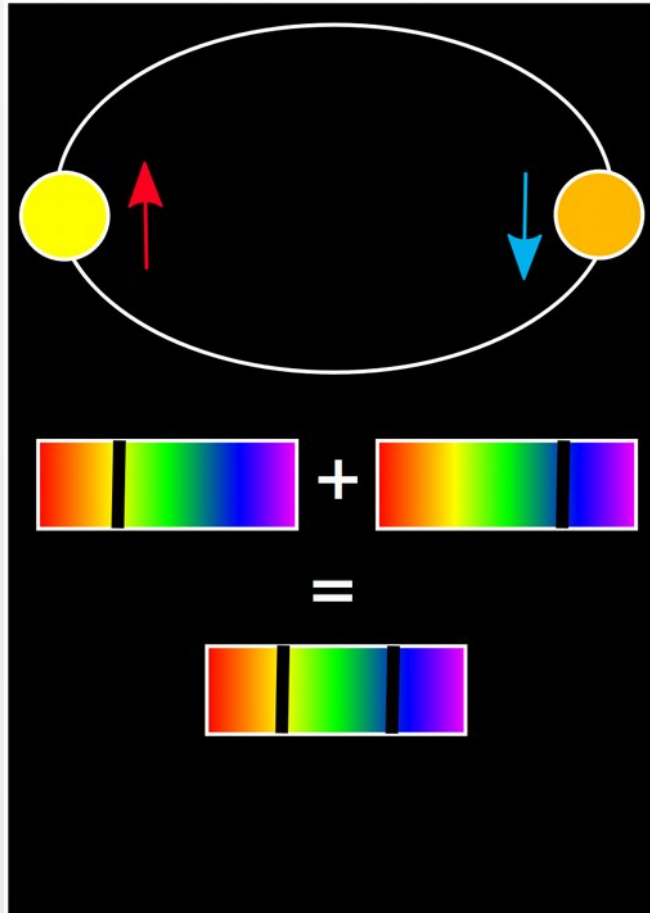
- Not resolved

Spectroscopic binary

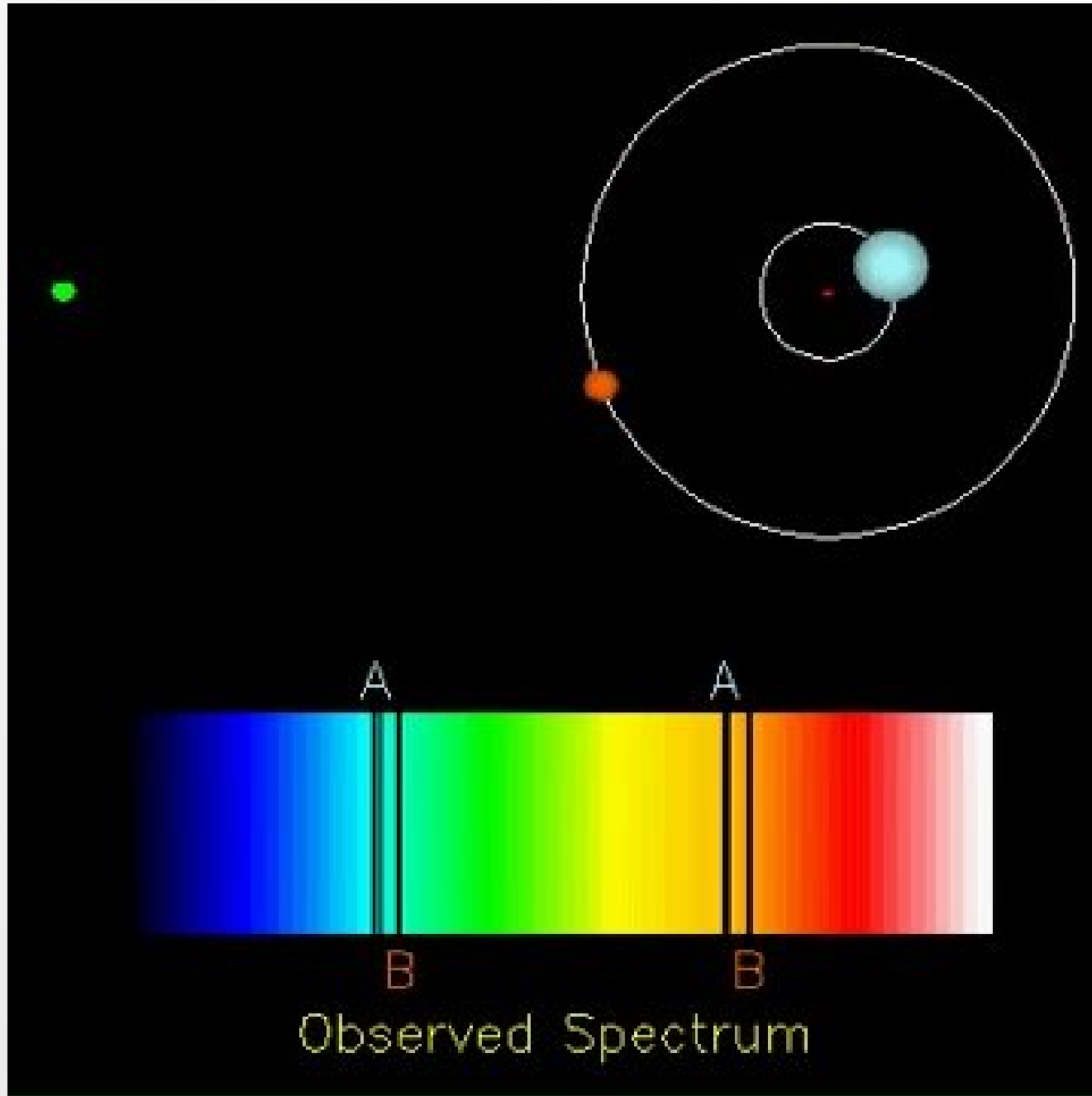


- Not resolved
- Take spectra
- Identify lines

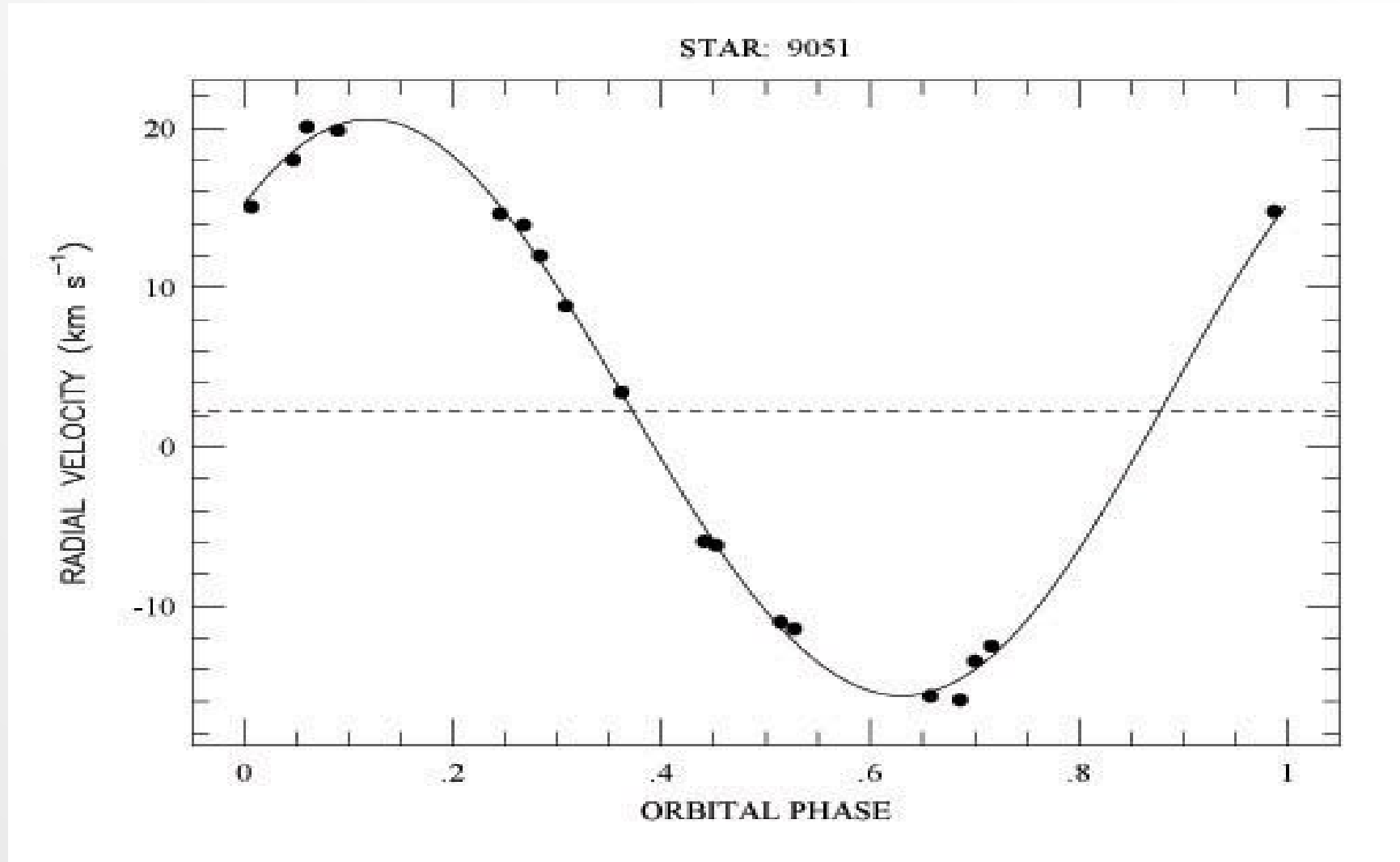
Spectroscopic binary



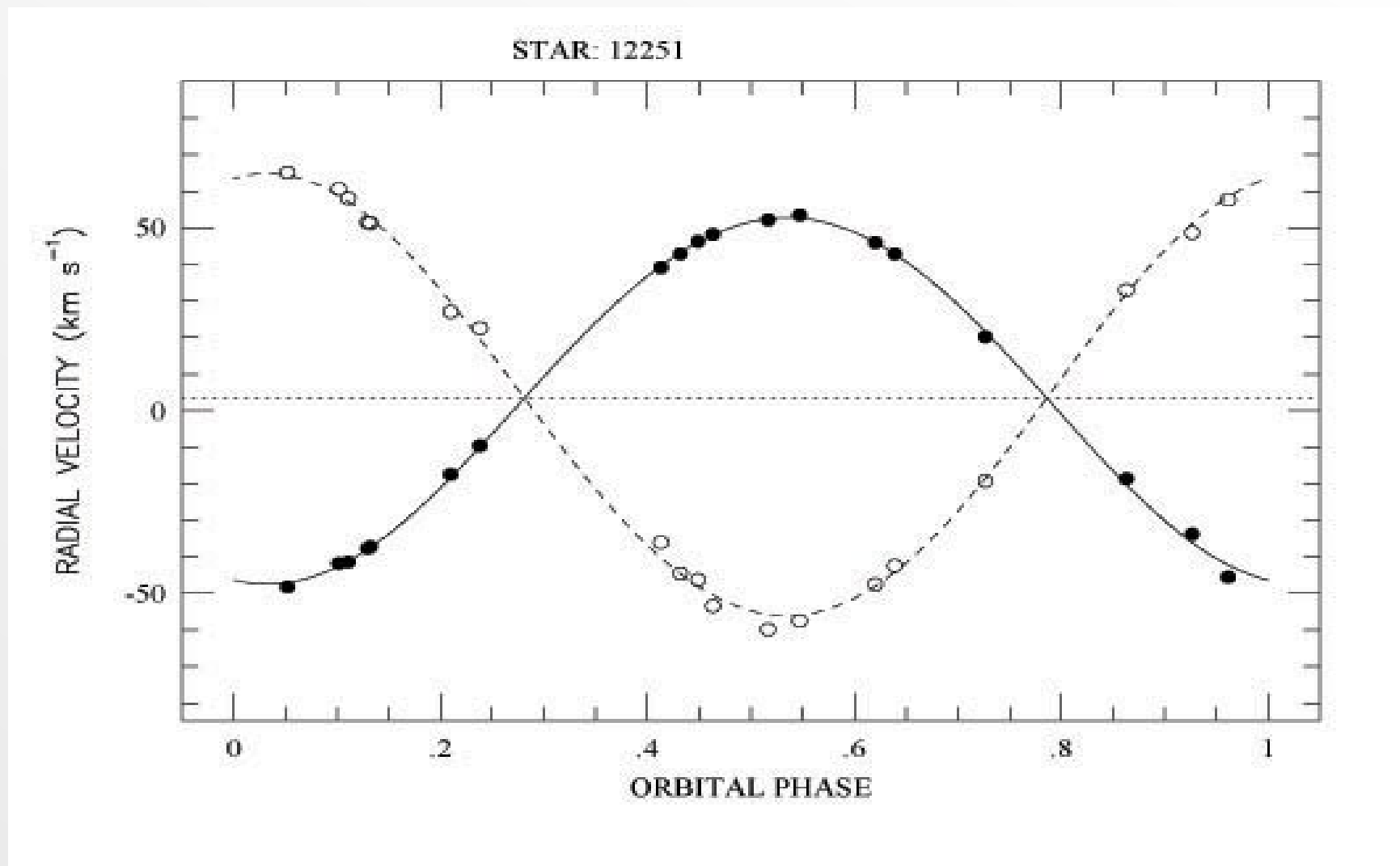
- Not resolved
- Take spectra
- Identify lines: Doppler
- SB1 : one star
- SB2 : both stars
- Short period
- Large distance



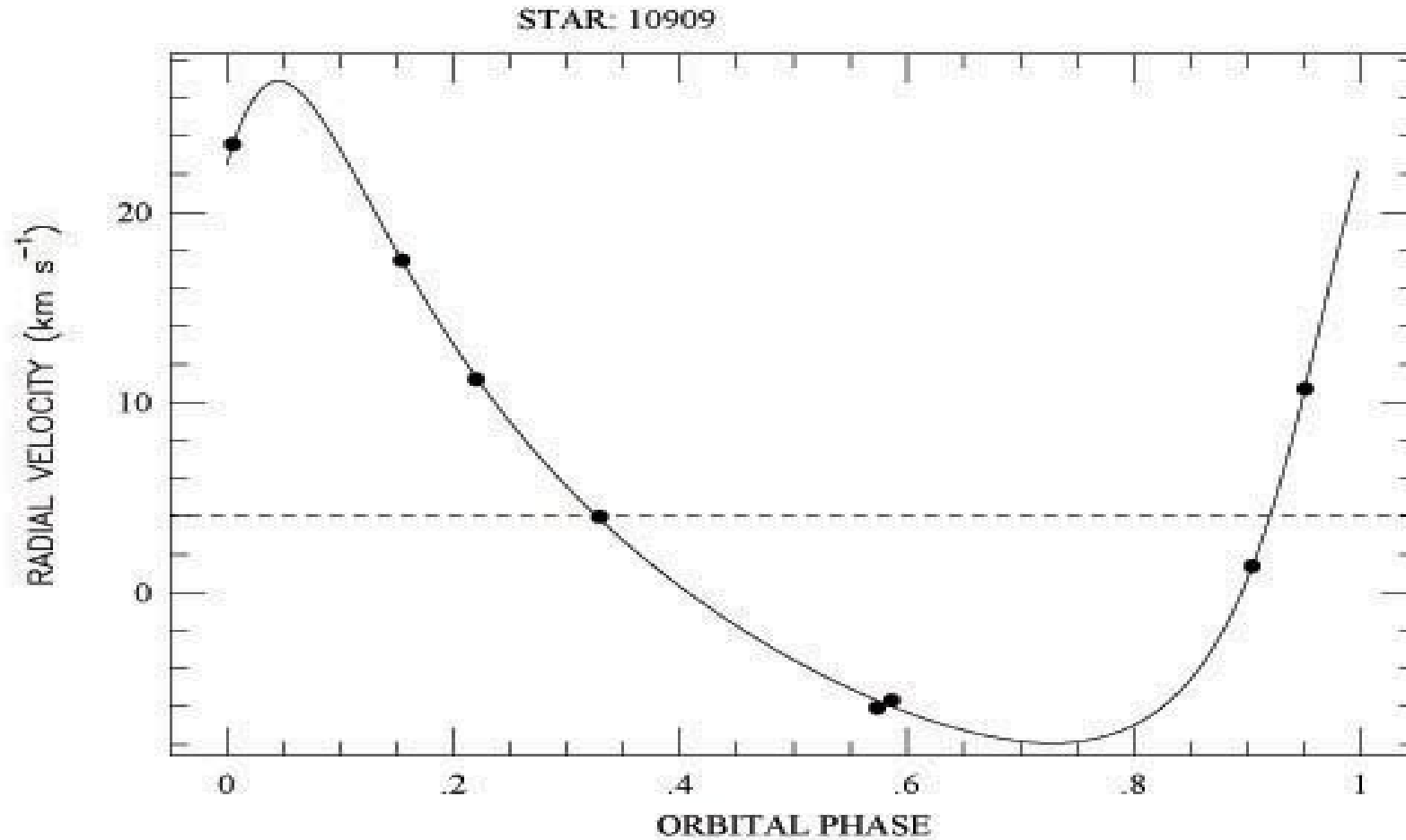
SB1



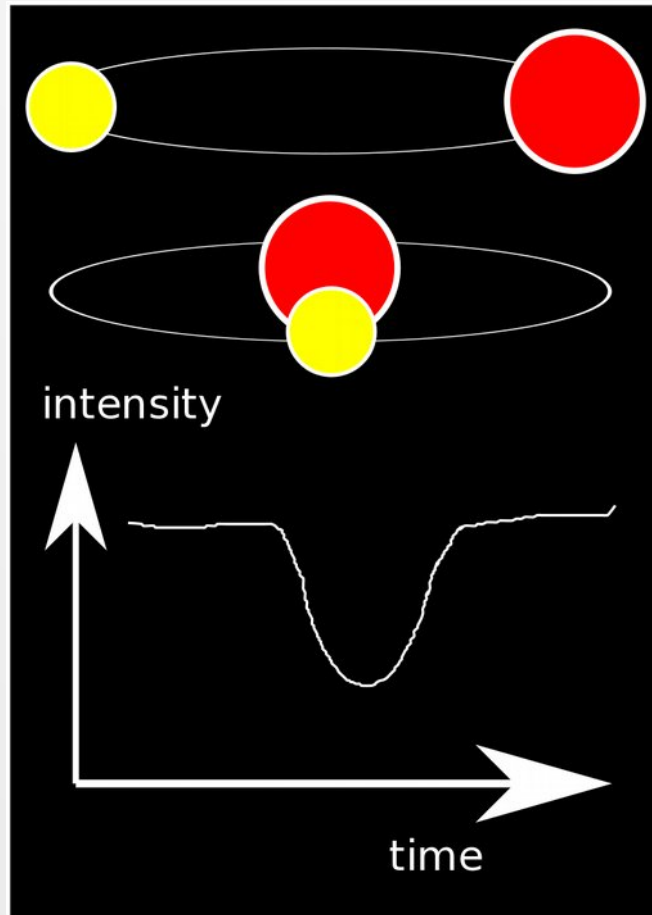
SB2



Eccentric SB1

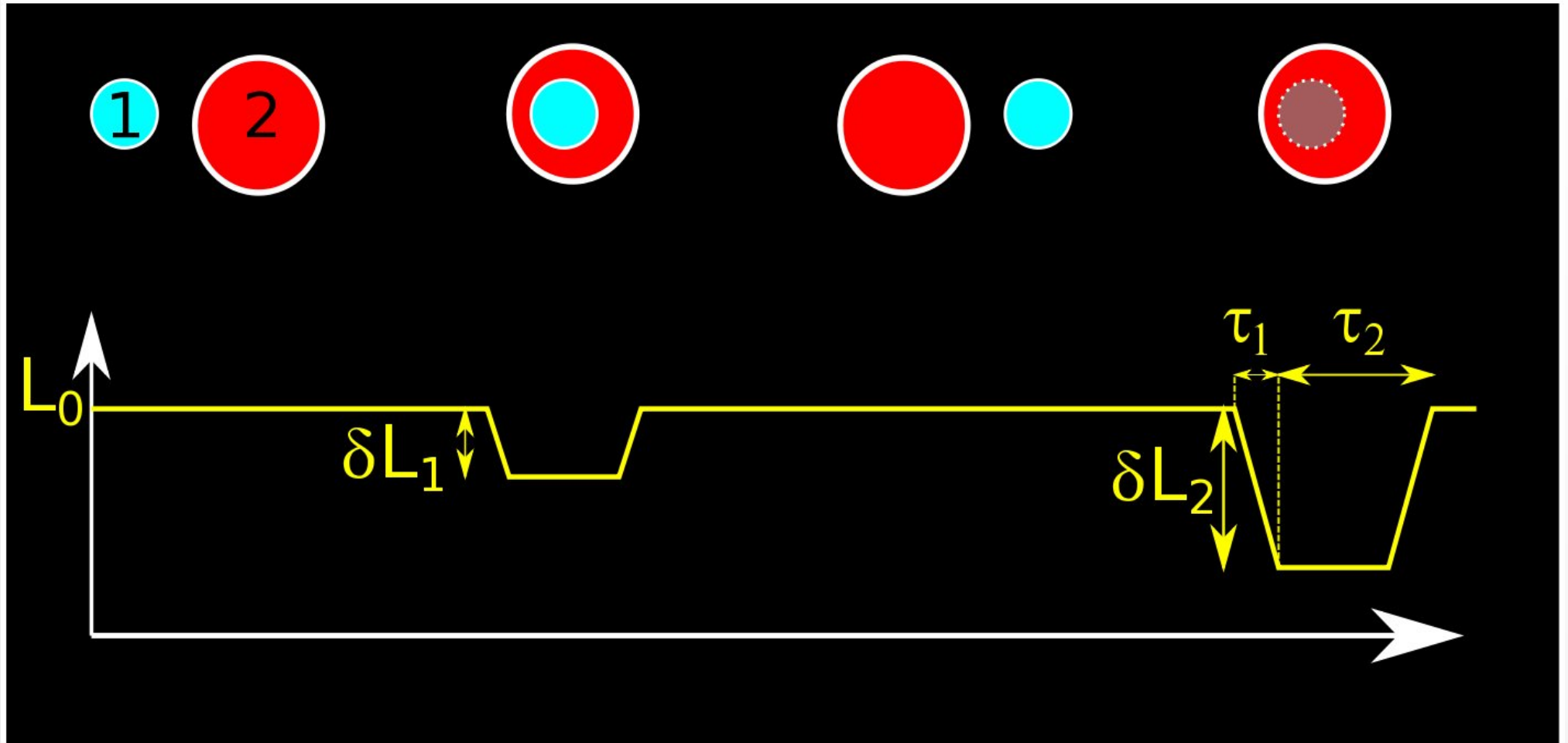


Photometric Binary



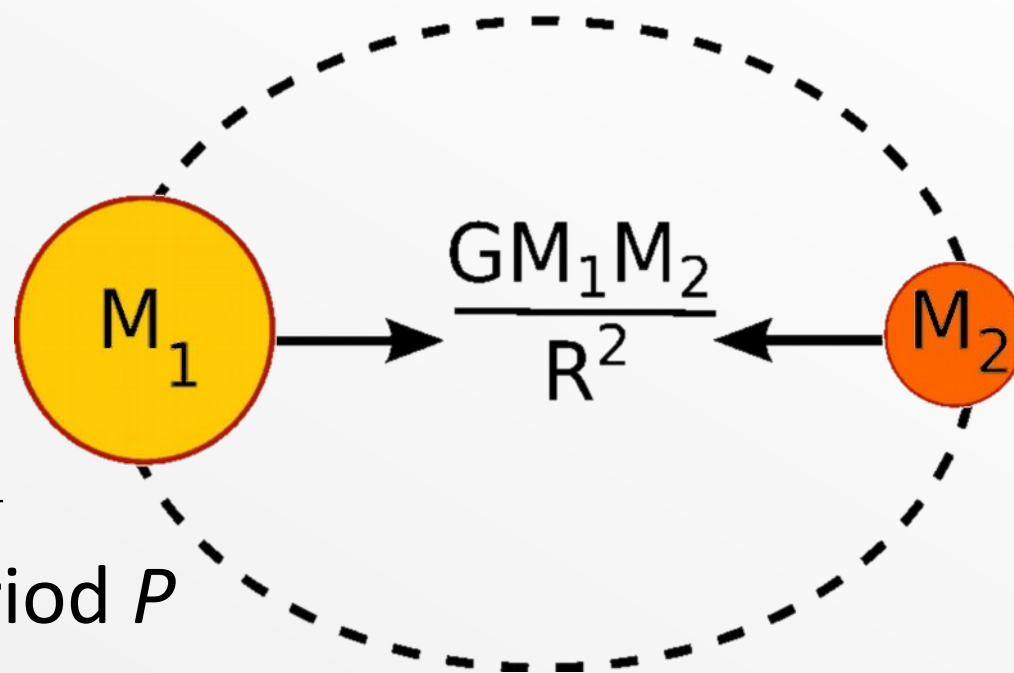
- Stars not resolved
- Light curve variability
- Eclipses
 - *Inclination*
- Non-spherical stars
- Colour variation

Eclipsing binary



Nomenclature

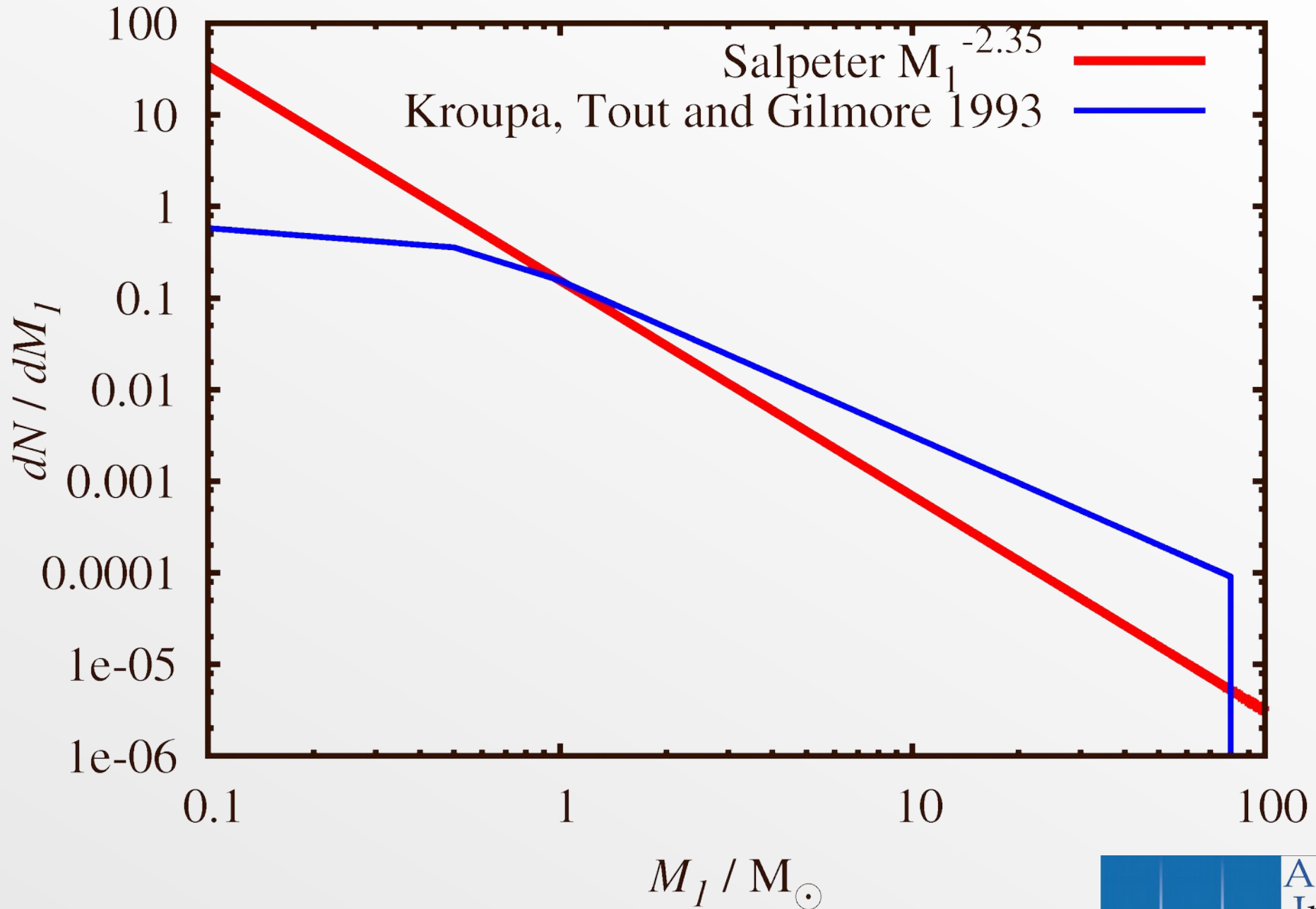
- Mass of more massive star primary: M_1
- Mass of less massive star secondary: M_2
- Mass ratio $q = M_2/M_1$
- Separation a – Orbital Period P
- Orbital Eccentricity e
- Inclination i (edge on=90 degrees)



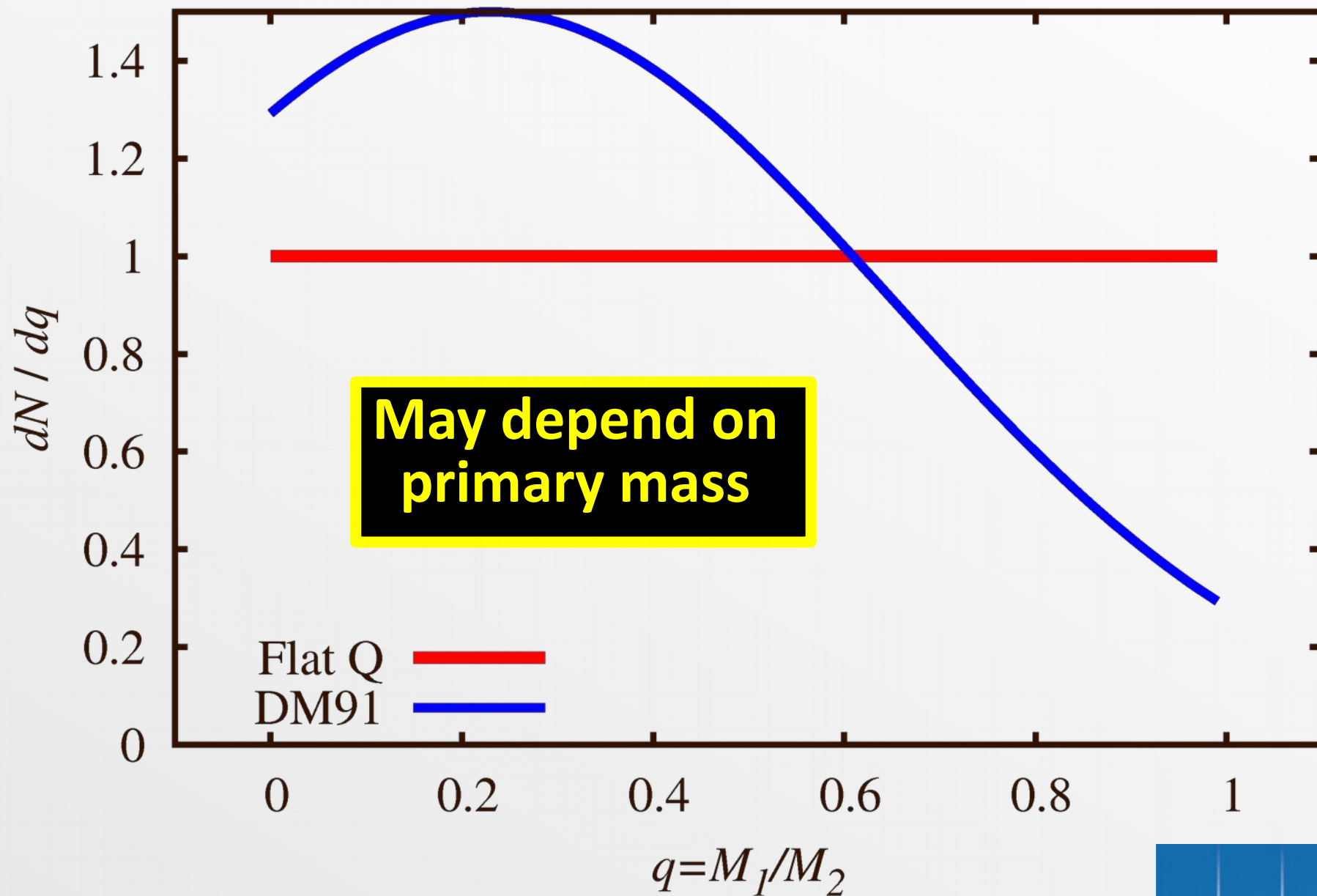
Initial parameter distributions

- 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

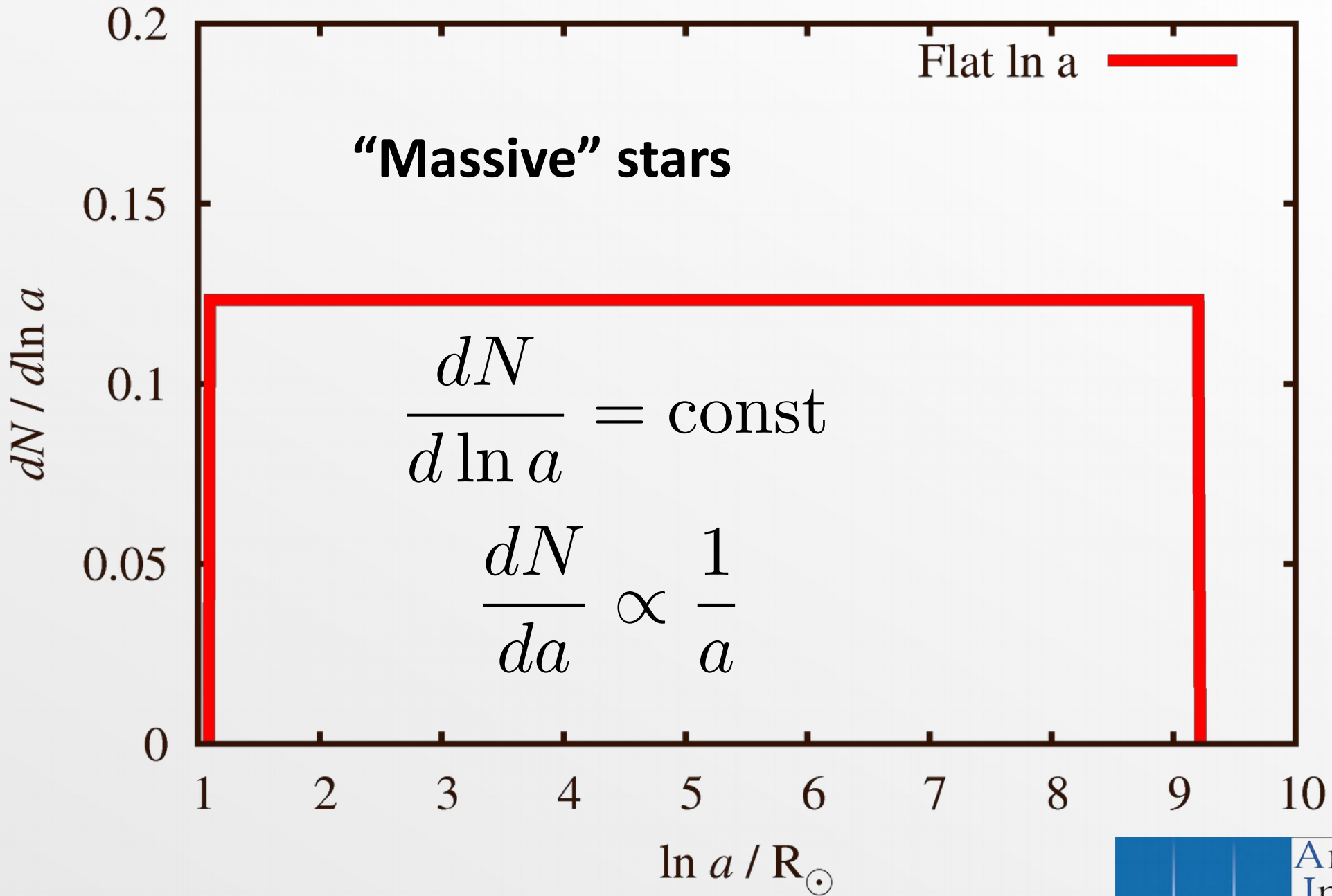
Primary mass



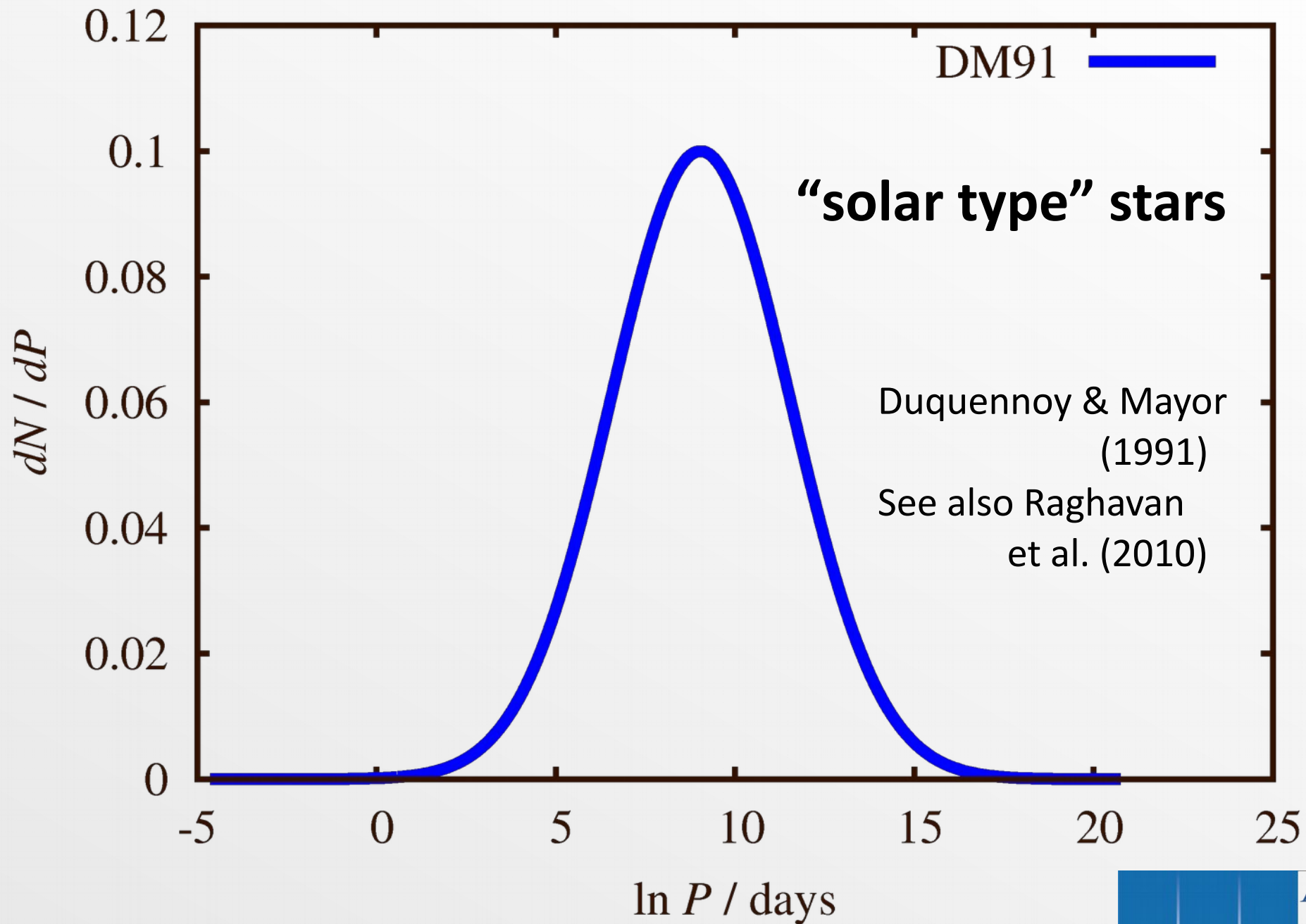
Secondary mass



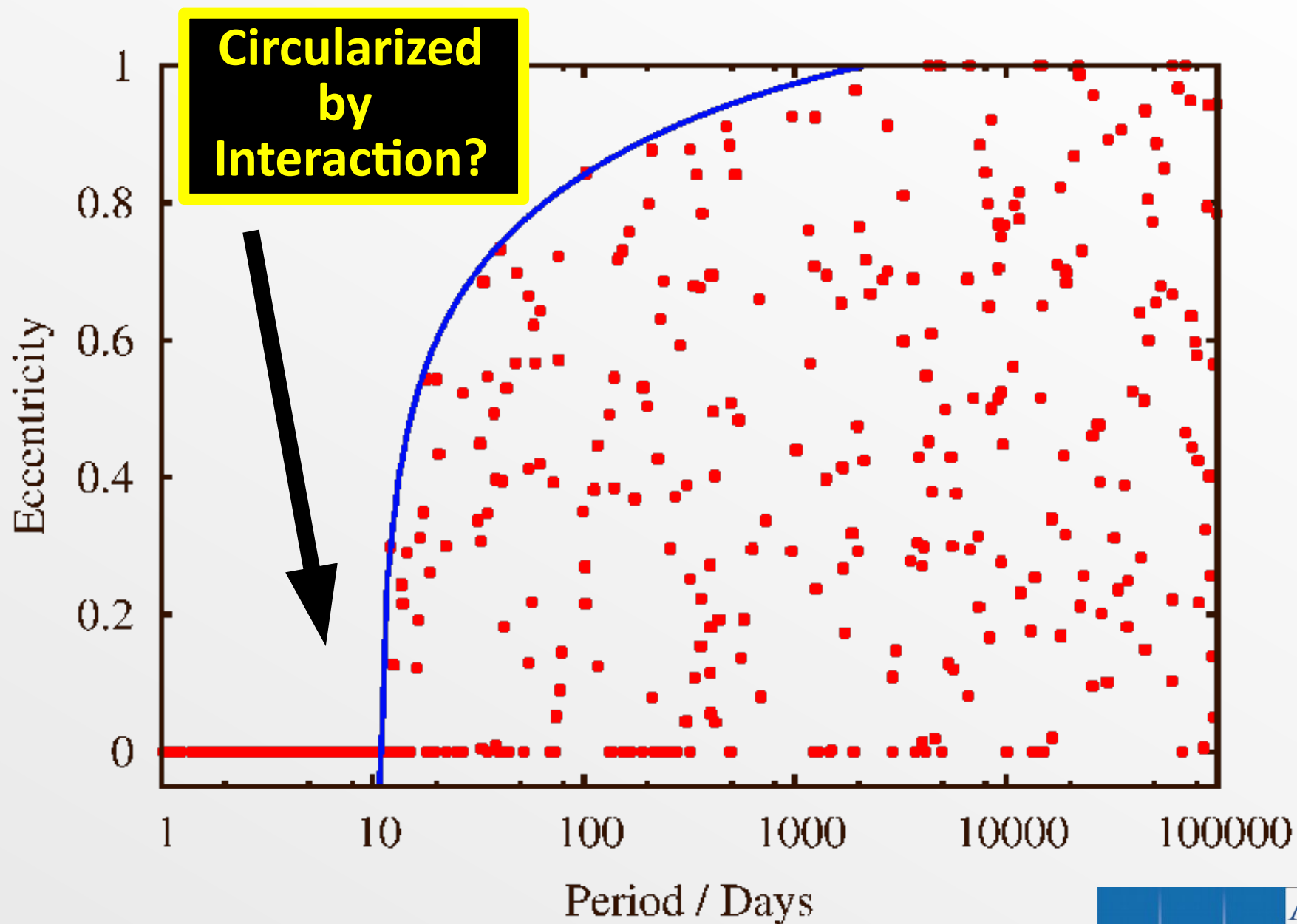
Separation



Orbital Period



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

Rob Izzard's Pages of Astronomical Happiness

Lectures • Binary Stars – astro8501 – 6944

Welcome to the homepage of the Binary Stars course (astro 8501 / 6944) in the summer semester 2011.

The first two-hour lecture will be held on Monday 4th April 2011 at 11am and at a similar time on Mondays thereafter until the end of term.
Exercise class dates to be arranged.

Course Abstract

Most stars in our Galaxy are gravitationally bound in binary star systems. Many of these are close enough to each other to interact at some point in their lives with consequences that include the formation of X-ray binaries, millisecond pulsars, thermonuclear novae, supernovae and gamma-ray bursts.

This course will start by introducing the many types of observed binary-star system. A discourse on orbital dynamics will lead into issues of gravitational interaction such as tides. In the most extreme case this leads to mass-transfer between the components of the binary star. The stability of mass transfer is crucial to understanding, for example, the origin of type Ia supernovae.

A unique aspect of this course will be the study of populations of binary stars. These include chemically peculiar stars which are keys to understanding both stellar physics and the evolution of our Galaxy.

You can find some links to online binary-star resources [here](#)

Literature:

Interacting Binary Stars (J.E.Pringle and R.A.Wade; Cambridge University Press) ISBN 0-521-26608-4. This excellent book is sadly out of print, but copies can be found e.g. [on Amazon](#).

Links

- [Stellar Bonn](#)
- [Binary_c](#)
- [facebook](#)
- [Binary_c Online](#)
- [Tarantula](#)
- [Places](#)
- [Utrecht](#)
- [SINs](#)
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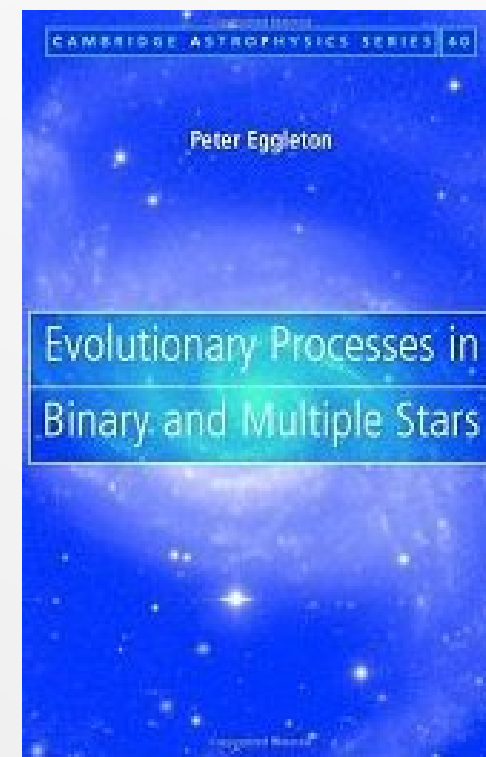
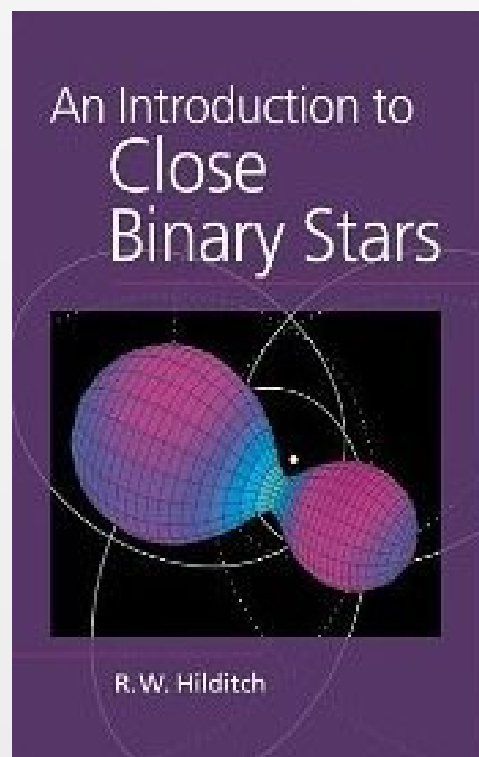
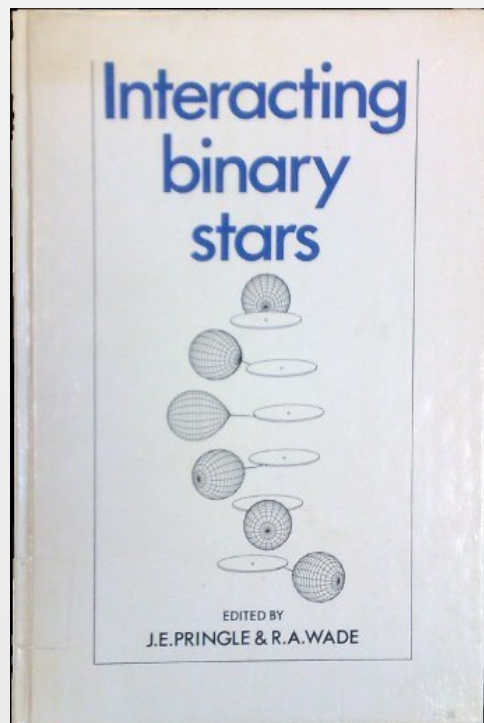
Logos: Argelander Institut für Astronomie, universität bonn, Rheinische Friedrich-Wilhelms Universität Bonn

Book Cover: An Introduction to Close Binary Stars

An Introduction to Close Binary Stars

Textbooks

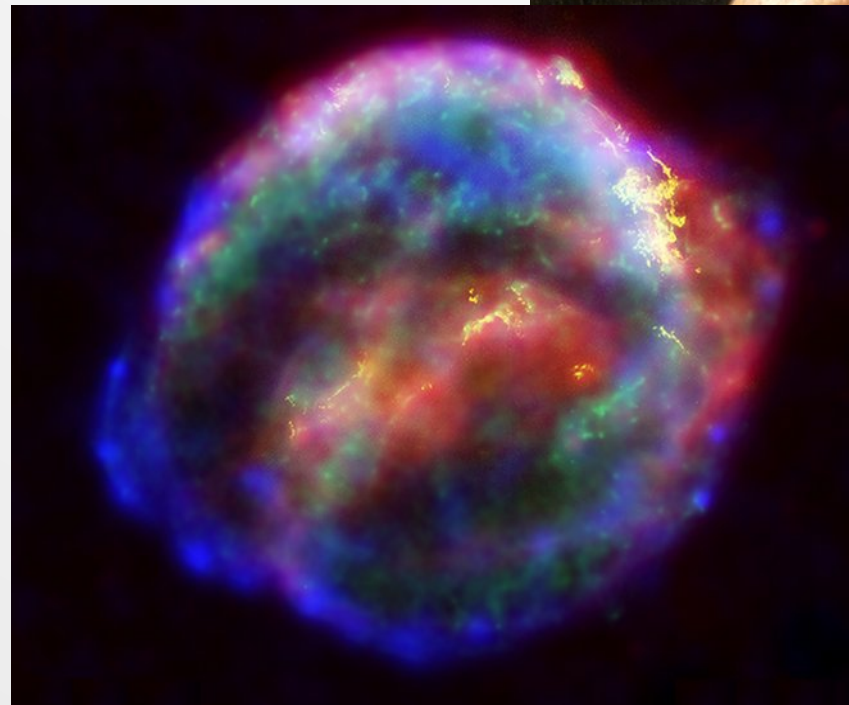
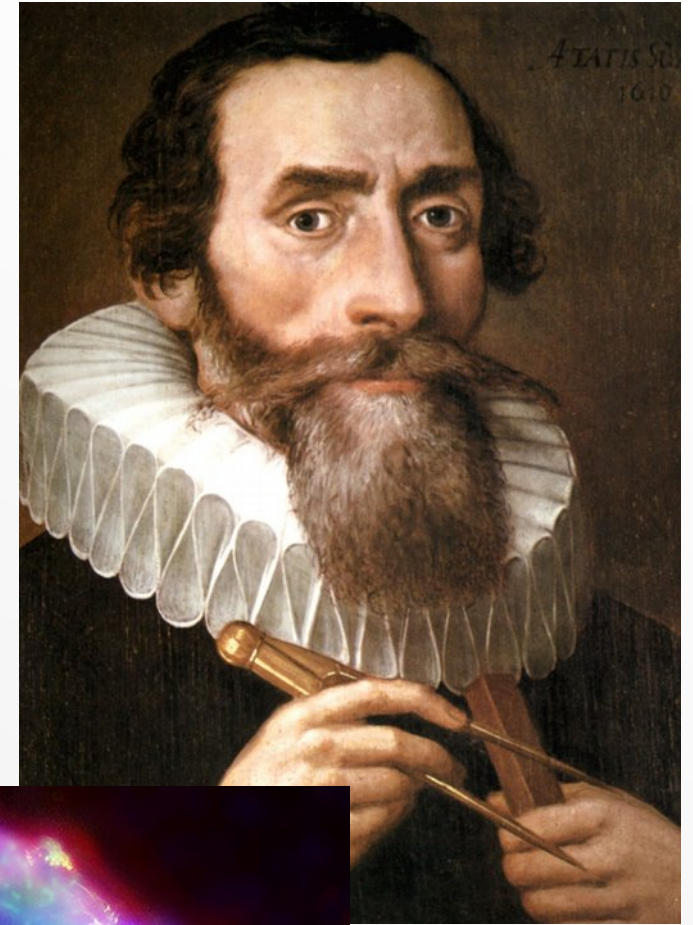
- Interacting Binary Stars (Pringle and Wade)
- An Introduction to Close Binary Stars (Hilditch)
- Evolutionary Processes in Binary and Multiple Stars (Eggleton)



Kepler's Laws

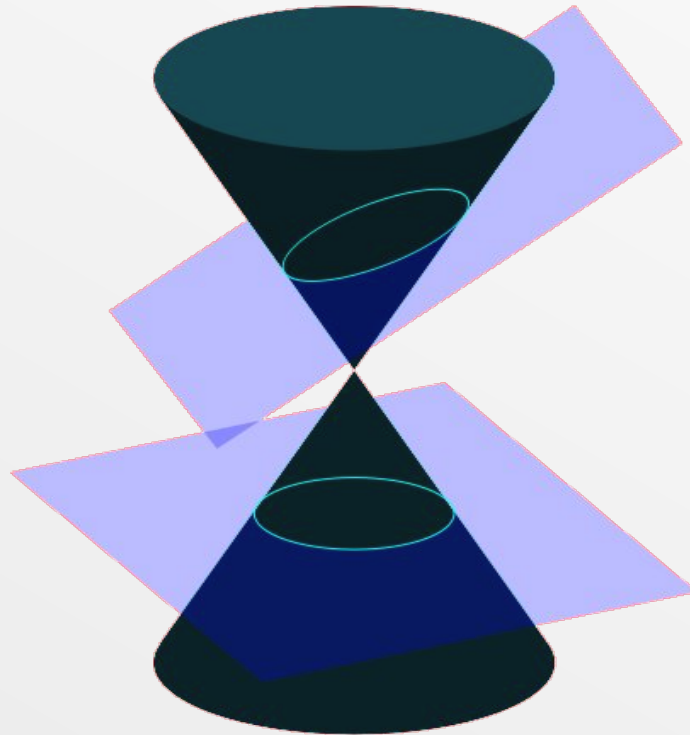
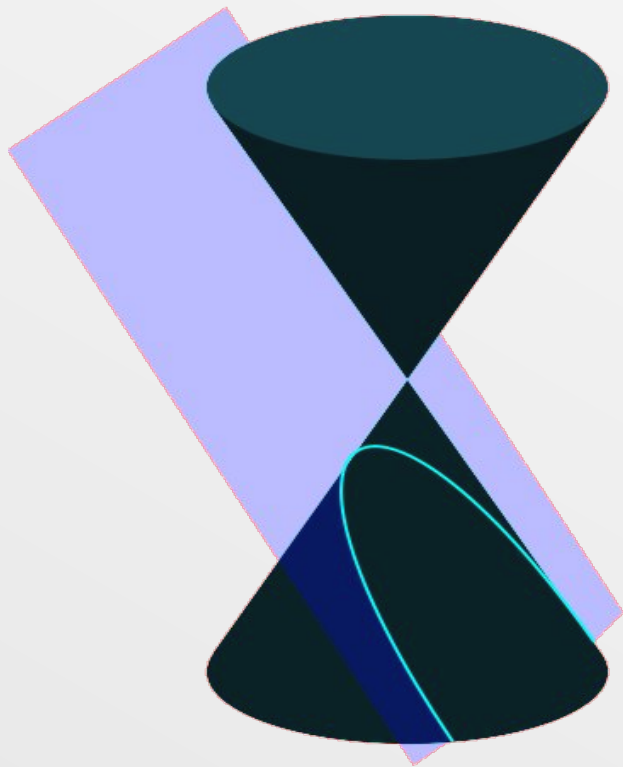
- German!
- 1571-1630
- Worked with

Tycho Brahe

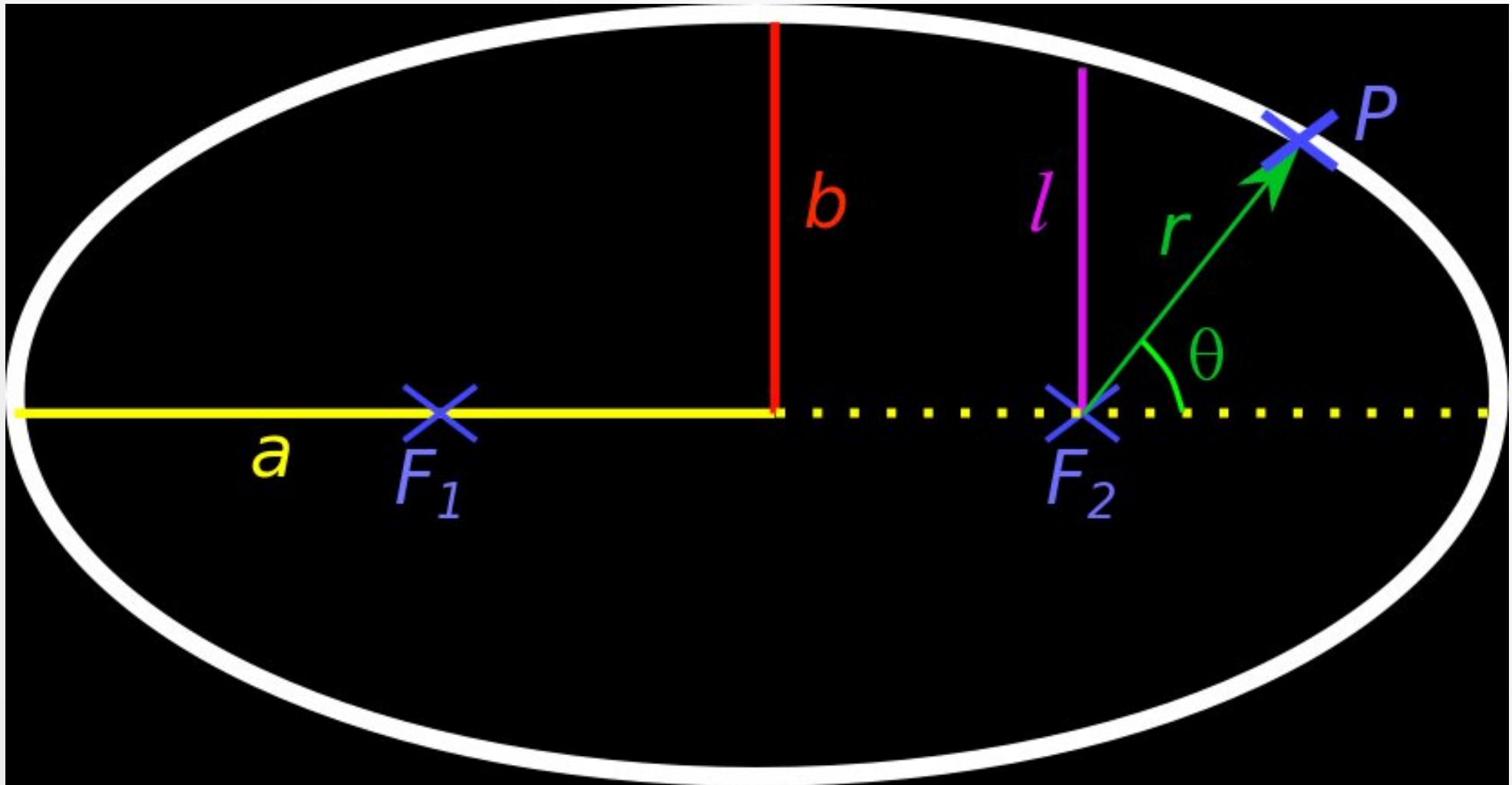


Kepler's First Law

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



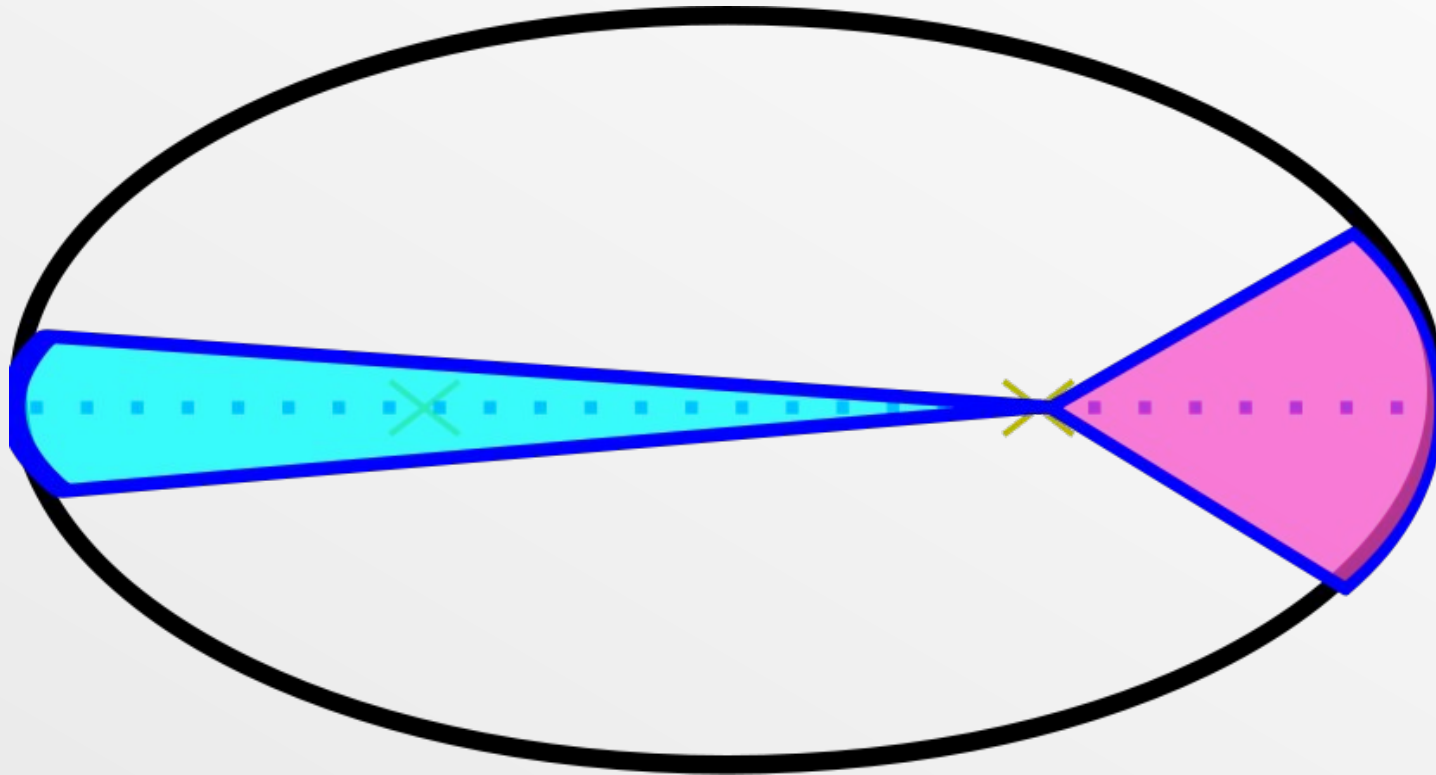
Elliptical Motion



Kepler's Second Law

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

$$\frac{1}{2} r^2 \dot{\theta} = \frac{2\pi a^2 \sqrt{1-e^2}}{P}$$



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

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