AS 4024: Binary Stars and Accretion Disks

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Web Page:

http://star-www.st-and.ac.uk/~kdh1/bsad.html

Outline (provisional)

- **Binary Stars**
- **Text: R. Hilditch: Close Binary Stars**
  - **Two body motion**
  - **Orbits and perturbations**
  - **Roche lobes and mass transfer**

- **Accretion Disks**
- **Text: Frank, King and Raine: Accretion Power**
  - **Steady Disks**
  - **Time-Dependent Disks**
  - **Disks in Binary Binary Stars**
  - **(Disks in Active Galactic Nuclei)**
  - **(Disks in Protostars)**

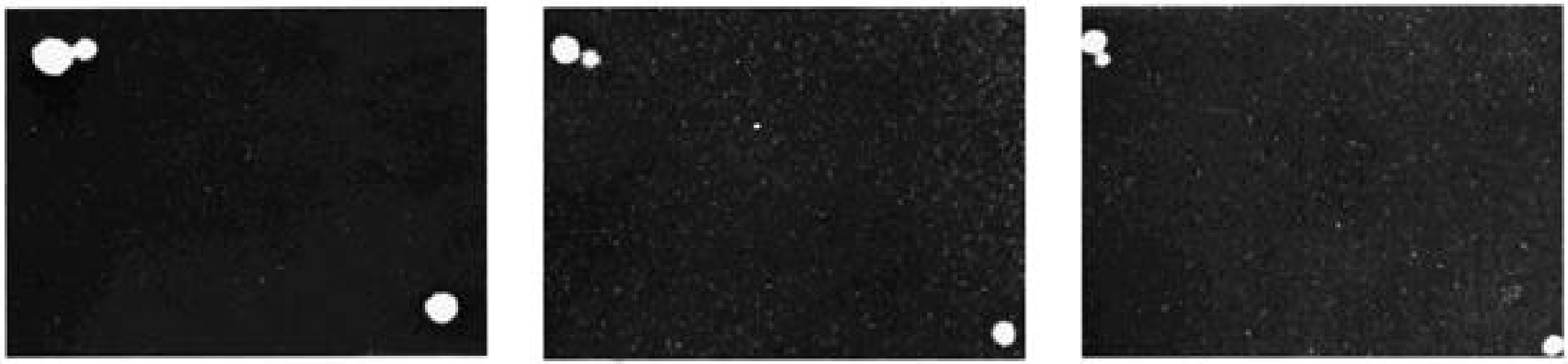
Binary Stars

- **Most stars are in binary or multiple systems**
  - **> 50 % of solar type stars G,K,M**
  - **alters star/planet formation theories**
- **Useful**
  - **measure**
    - **masses**
    - **radii**
  - **test**
    - **stellar evolution**
    - **stellar atmospheres**
    - **general relativity -- pulsars timing**
  - **micro-arcsec tomography (eclipse / doppler / zeeman)**
    - **stellar surfaces**
    - **accretion discs**

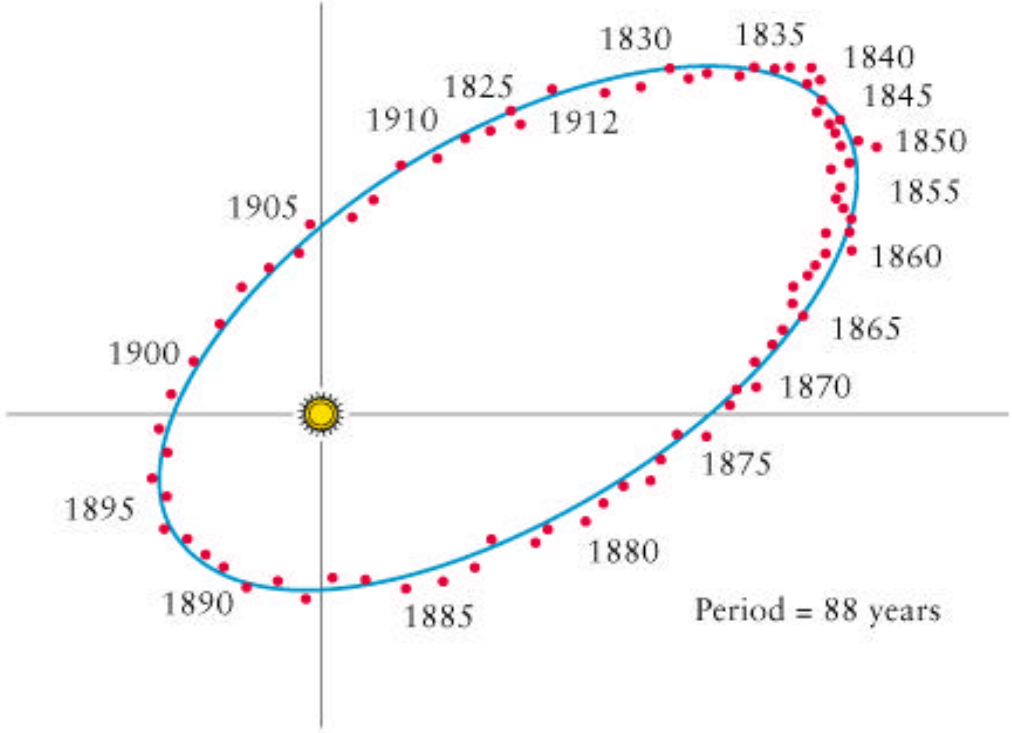
Types of Binaries

- **Visual Binaries (Herschel 1802)**
  - **>0.2 arcsec**
  - **both stars seen, orbital motion**
- **Interferometric Binaries**
  - **speckles - > 0.03 arcsec**
  - **lunar occultation - > 0.003 as = 3 milli-arcsec (mas)**
  - **interferrometry ~ 0.2 mas, improving**
- **Close Binaries**
  - **not resolved (yet)**
- **Spectroscopic Binaries**
  - **composite spectra, doppler-shifted lines**
  - **SB1, SB2 = spectra from 1 or both stars**
- **Photometric Binaries**
  - **eclipses, tidal distortion, heating effects**

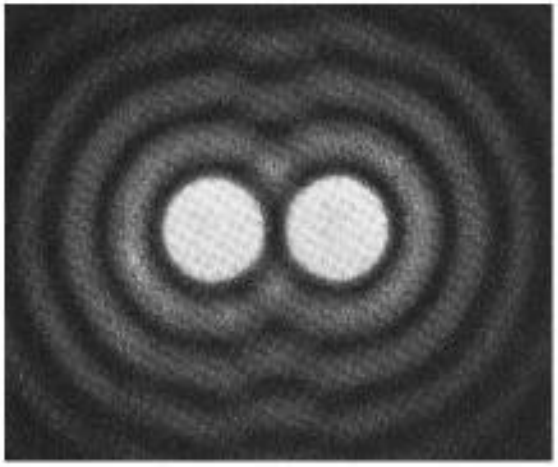
Visual binary



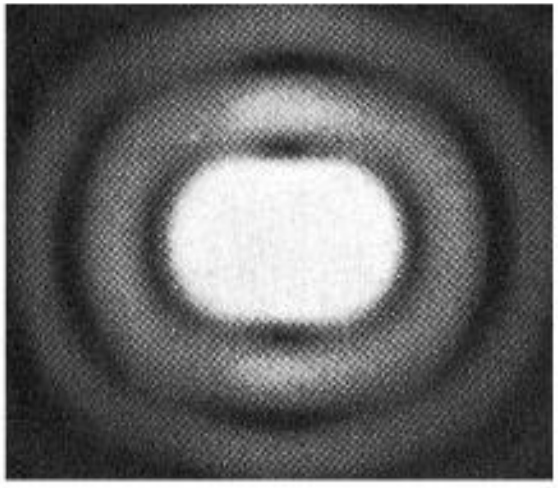
1908 1915 1920



Resolving a close double star

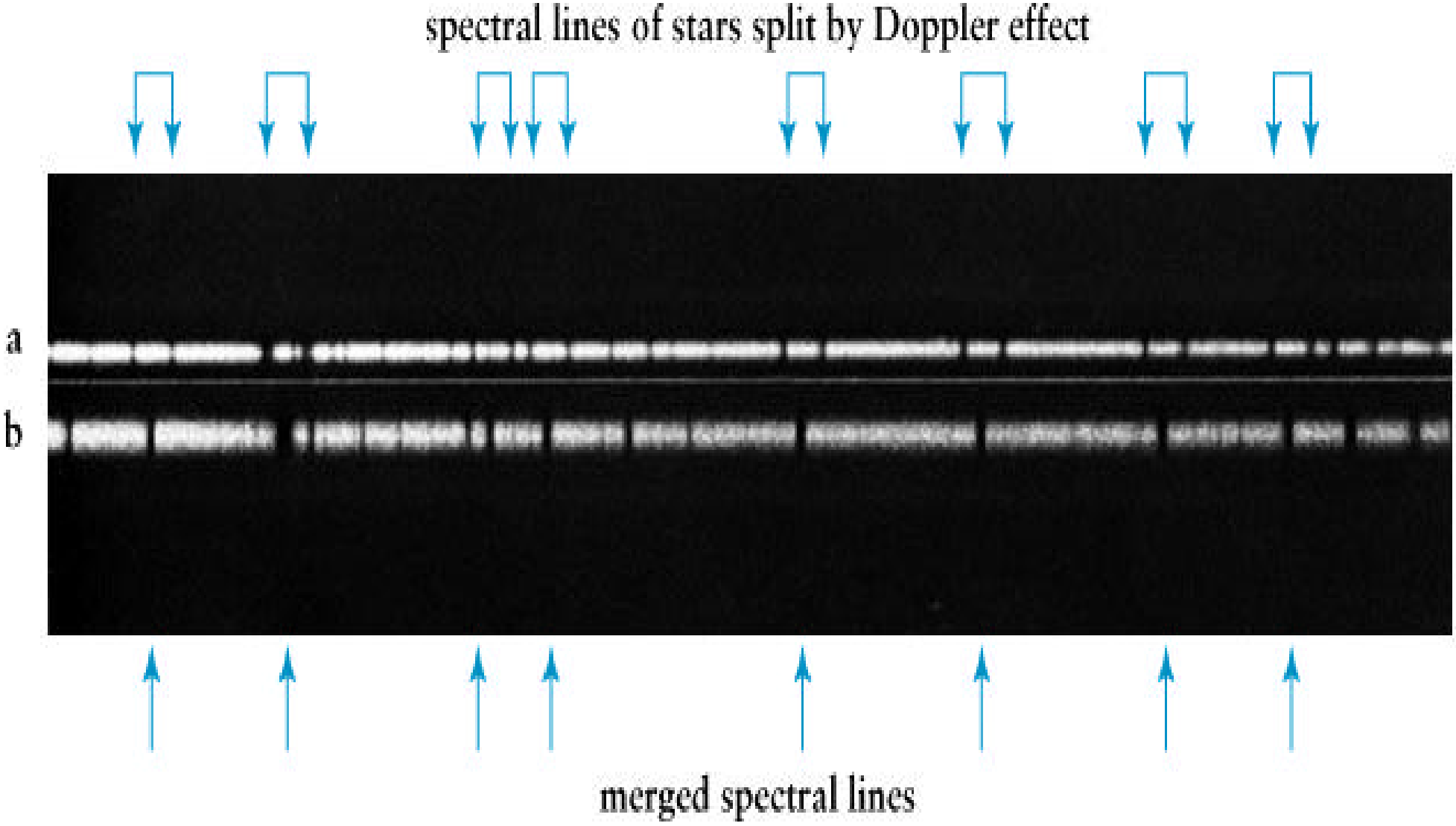


a

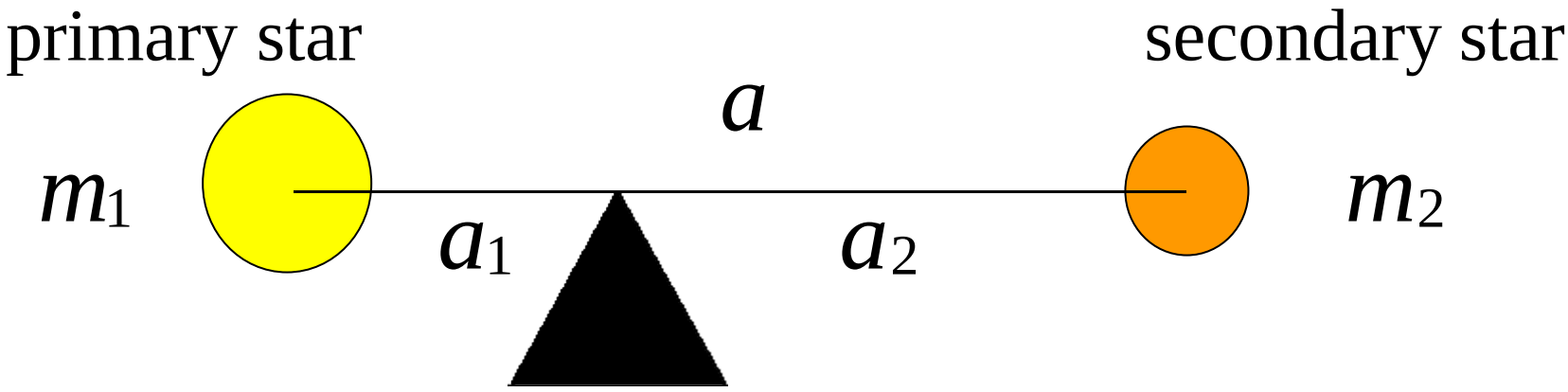


b

Spectroscopic binary



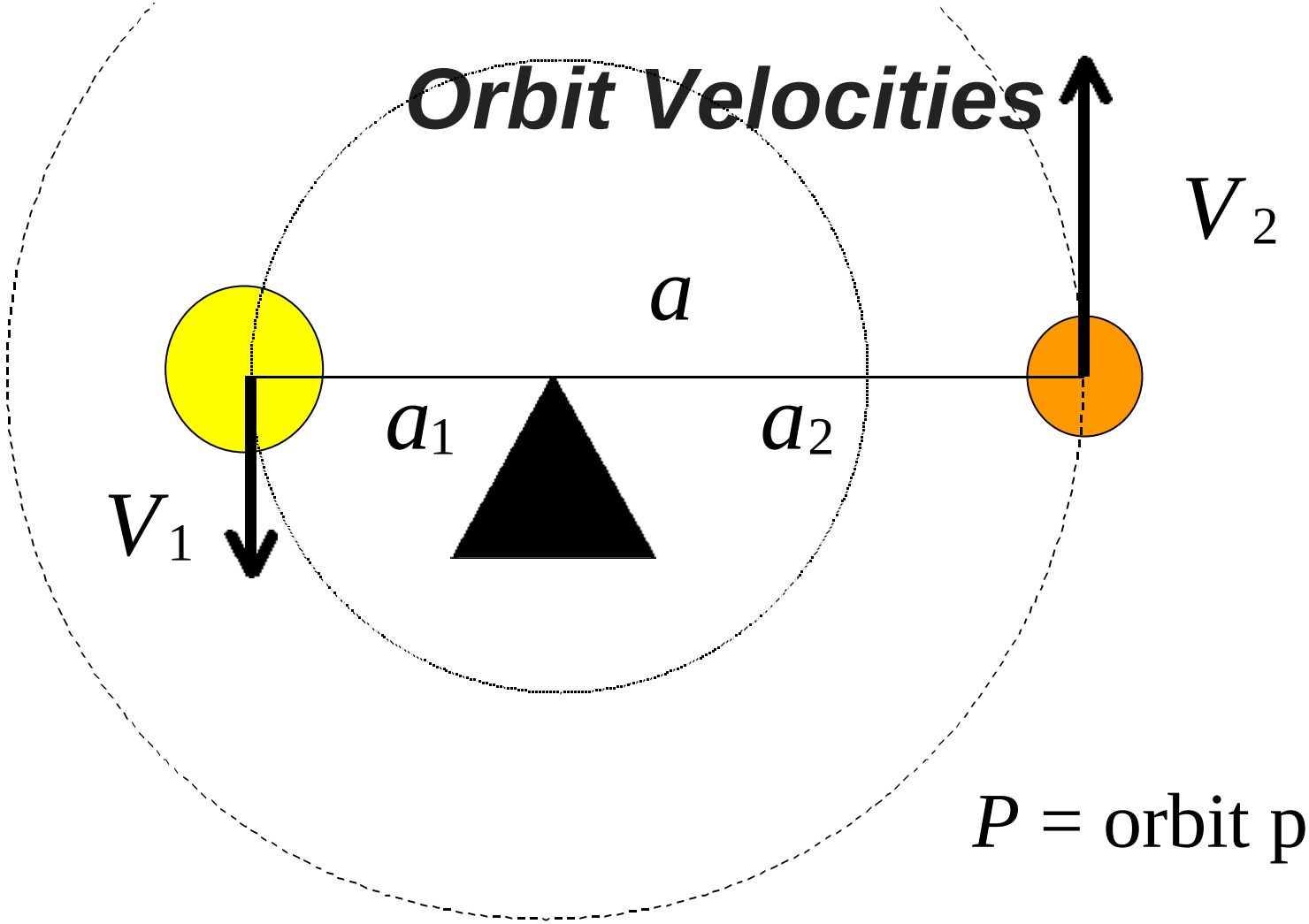
Centre of Mass



$$a_1 m_1 = a_2 m_2$$

$$\frac{a_1}{a} = \frac{m_2}{m_1 + m_2} \qquad \frac{a_2}{a} = \frac{m_1}{m_1 + m_2}$$

Orbit Velocities



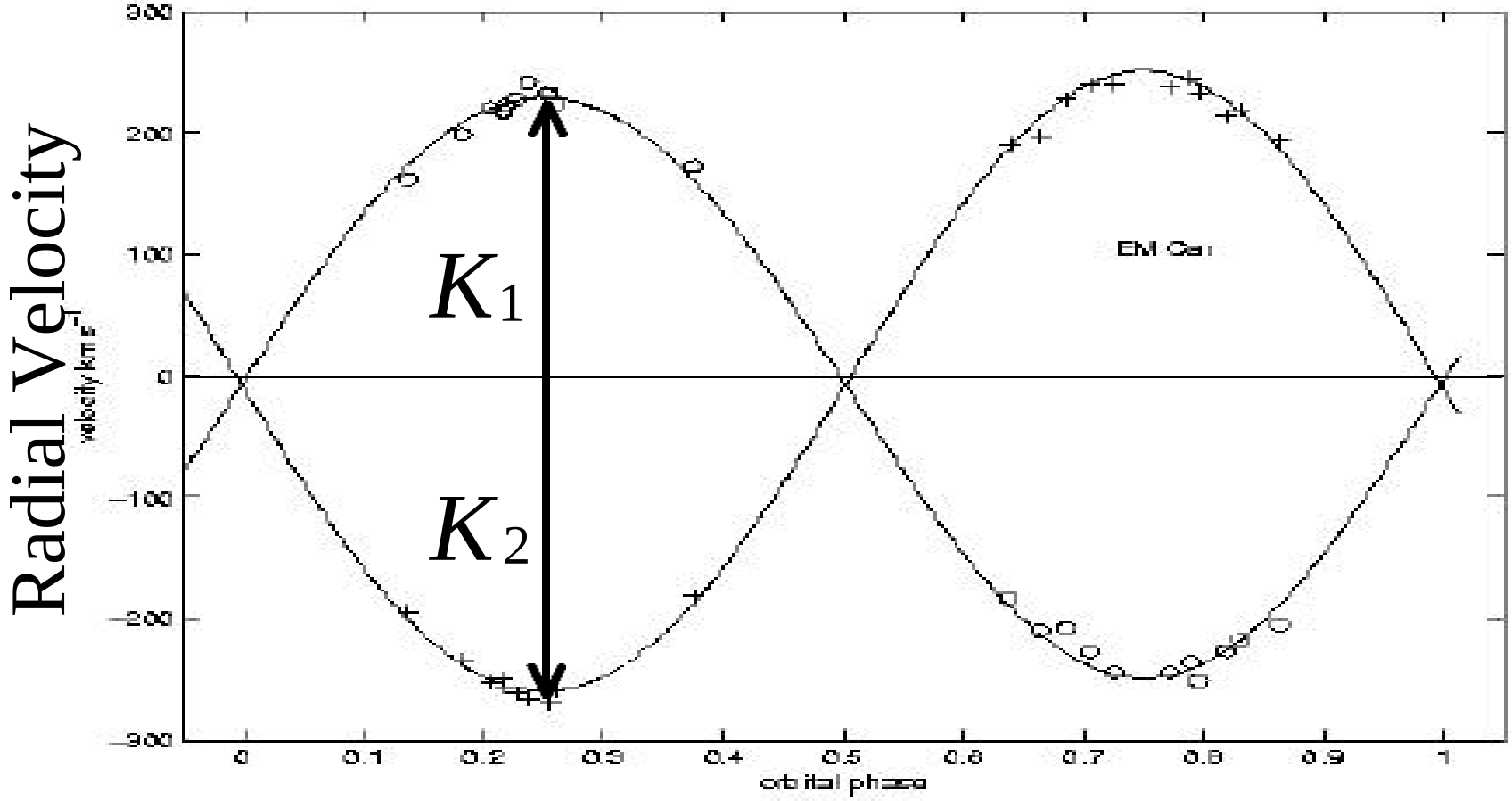
P = orbit period

$$\frac{V_1}{V_2} = \frac{a_1}{a_2} = \frac{m_2}{m_1}$$

$$V_1 + V_2 = \frac{2p\ a}{P}$$

Velocity Curve

observe : $K = V \sin i$



Orbital Phase

Masses

observe: P $\quad K_1 = V_1 \sin i$ $\quad K_2 = V_2 \sin i$

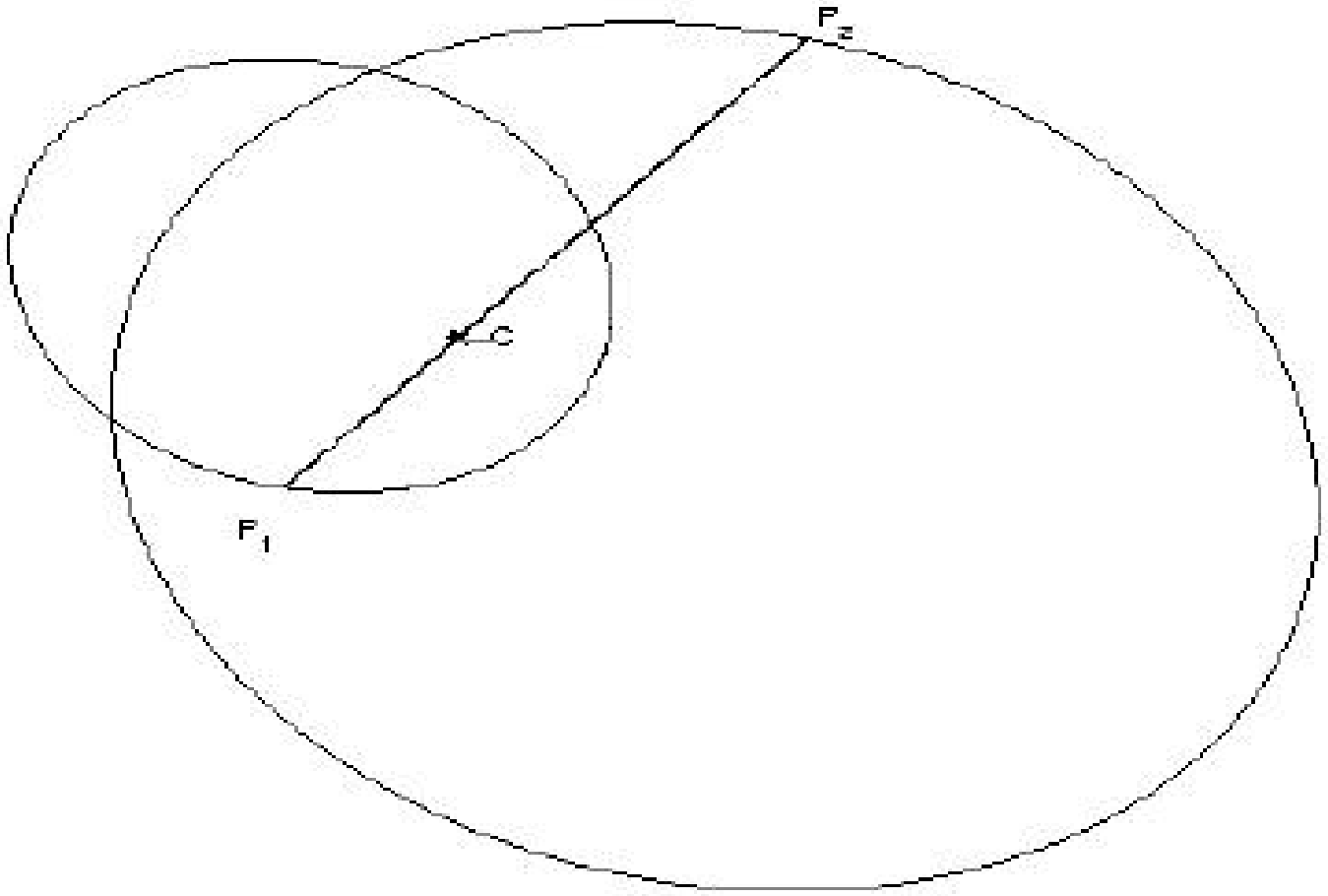
mass ratio: $q = \frac{m_2}{m_1} = \frac{a_1}{a_2} = \frac{K_1}{K_2}$

orbit size: $2p\ a \sin i = (K_1 + K_2)\ P = K\ P$

Kepler's Law: $m_1 + m_2 = M = \frac{4p^2\ a^3}{G\ P^2}$

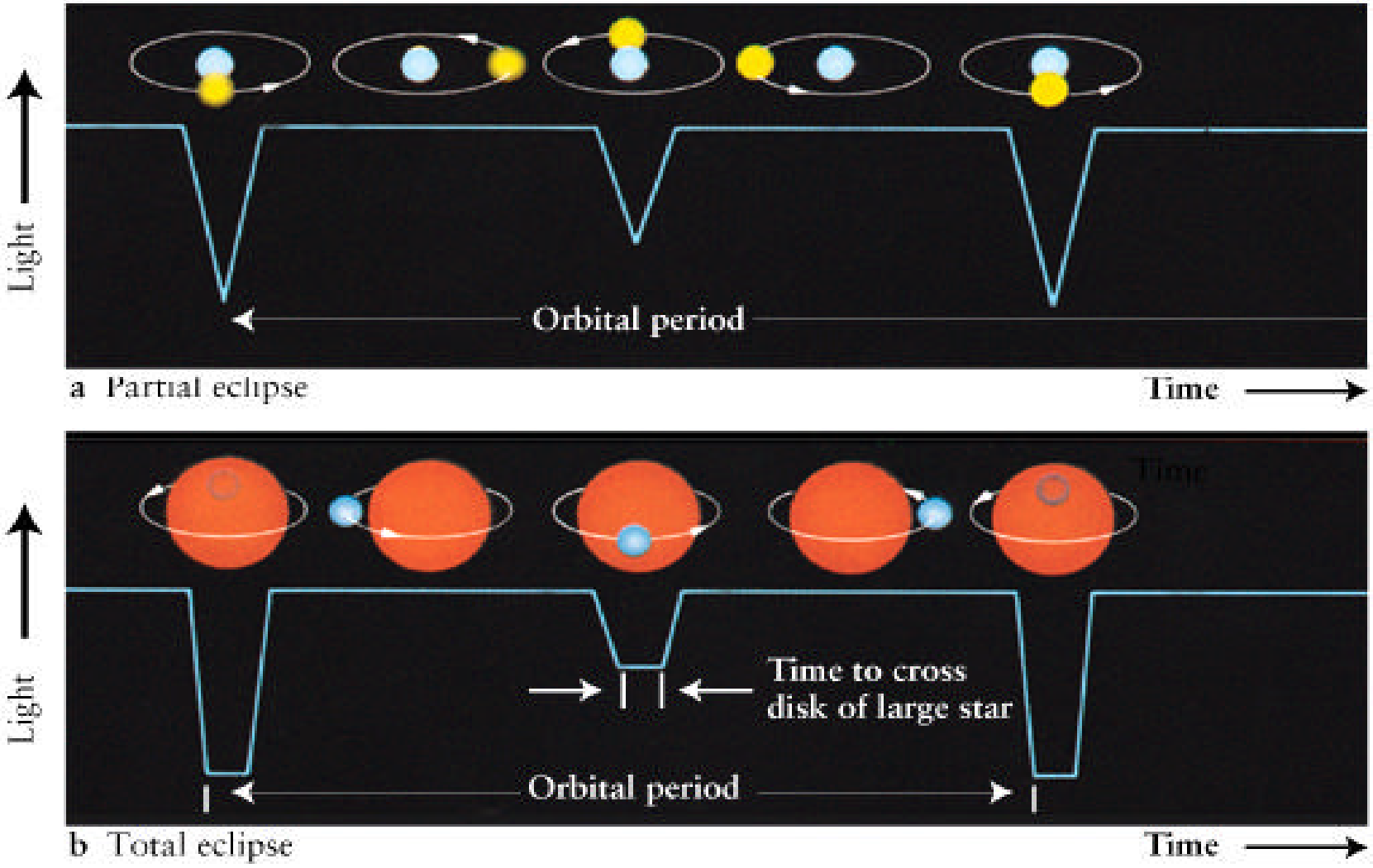
minimum mass: $M \sin^3 i = \frac{P\ K^3}{2p\ G}$

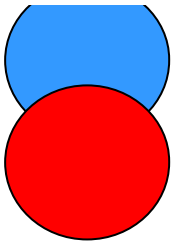
Elliptical Orbits

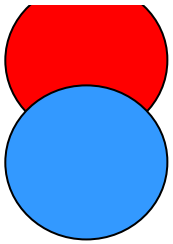


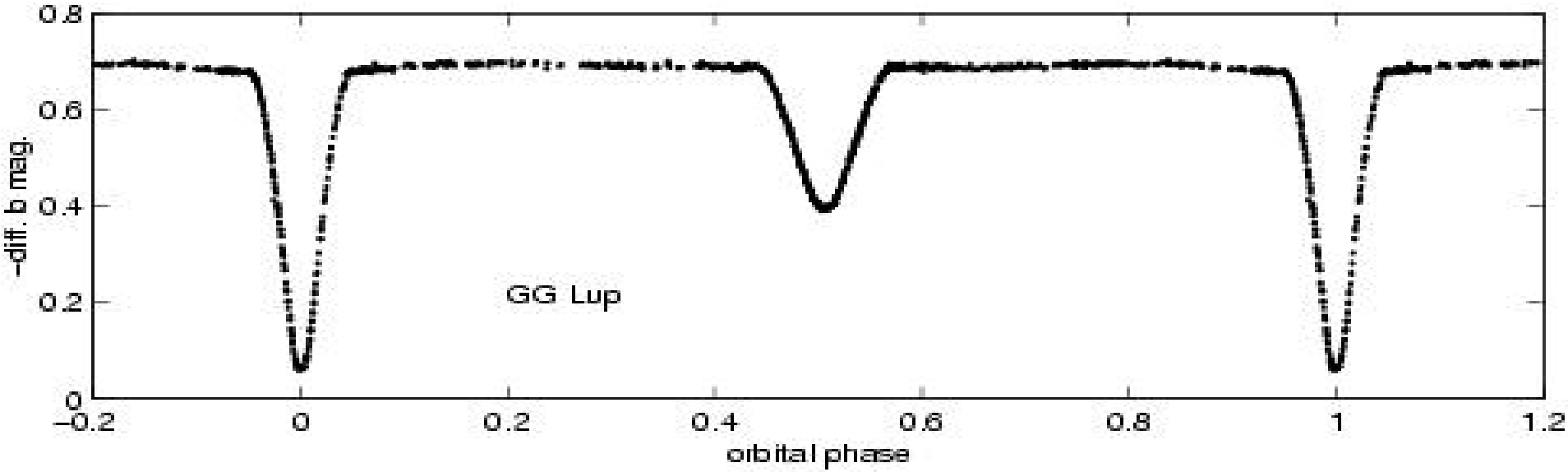
Eclipsing binaries

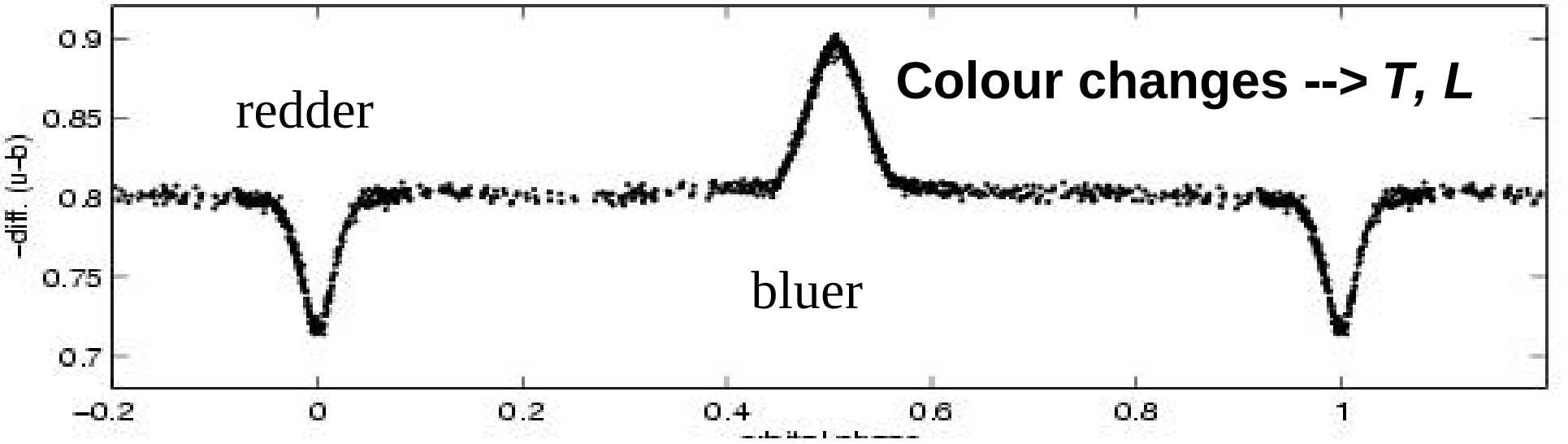
timing+velocities --> sizes





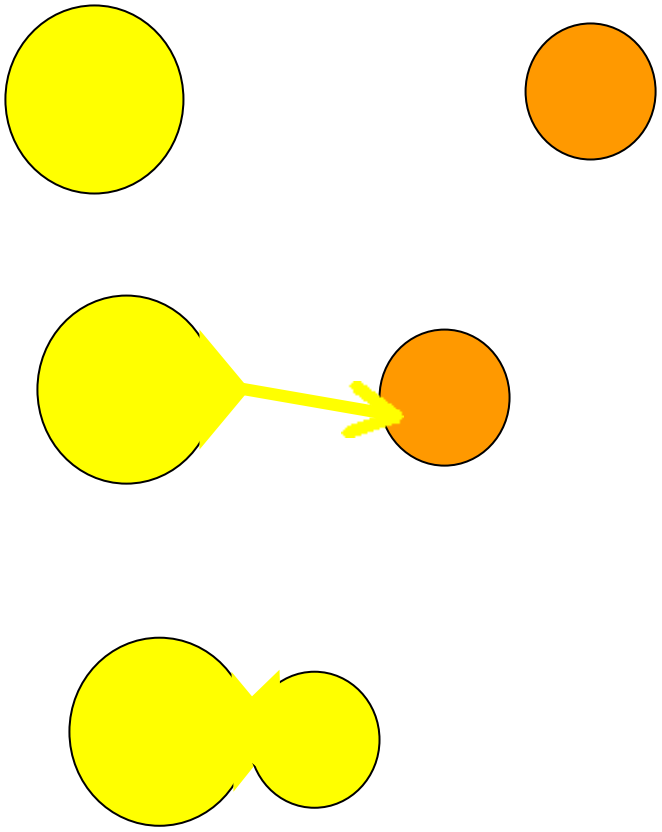



0.8
0.6
0.4
0.2
0
−diff. b mag.
GG Lup
−0.2
0
0.2
0.4
0.6
0.8
1
1.2
orbital phase


0.9
0.85
0.8
0.75
0.7
−diff. (u−b)
redder
bluer
Colour changes --> T, L
−0.2
0
0.2
0.4
0.6
0.8
1

Types of Close Binaries

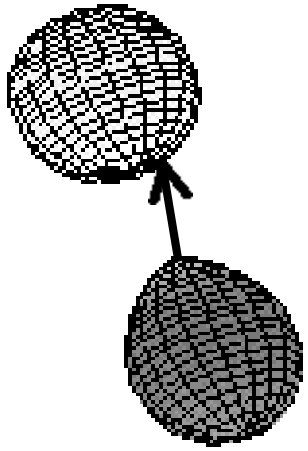
- **Detached**
  - stars inside Roche lobes
  - tidal distortions, irradiation
- **Semi-detached**
  - one star fills its Roche lobe
  - mass transfer
- **Contact**
  - stars touch at inner Lagrange point L_1
  - overfill Roche-lobes
  - joined by a neck of material
- **Common Envelope**
  - two stars embedded in a common envelope
  - near-spherical if R >> a



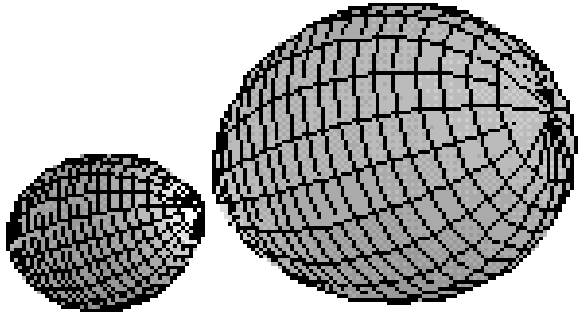
Binaries in Roche-Lobes

detached

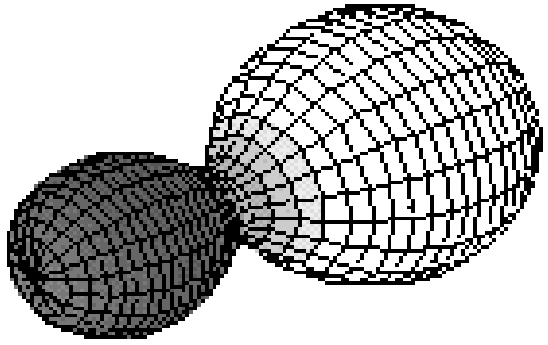
semi-detached (Algol)



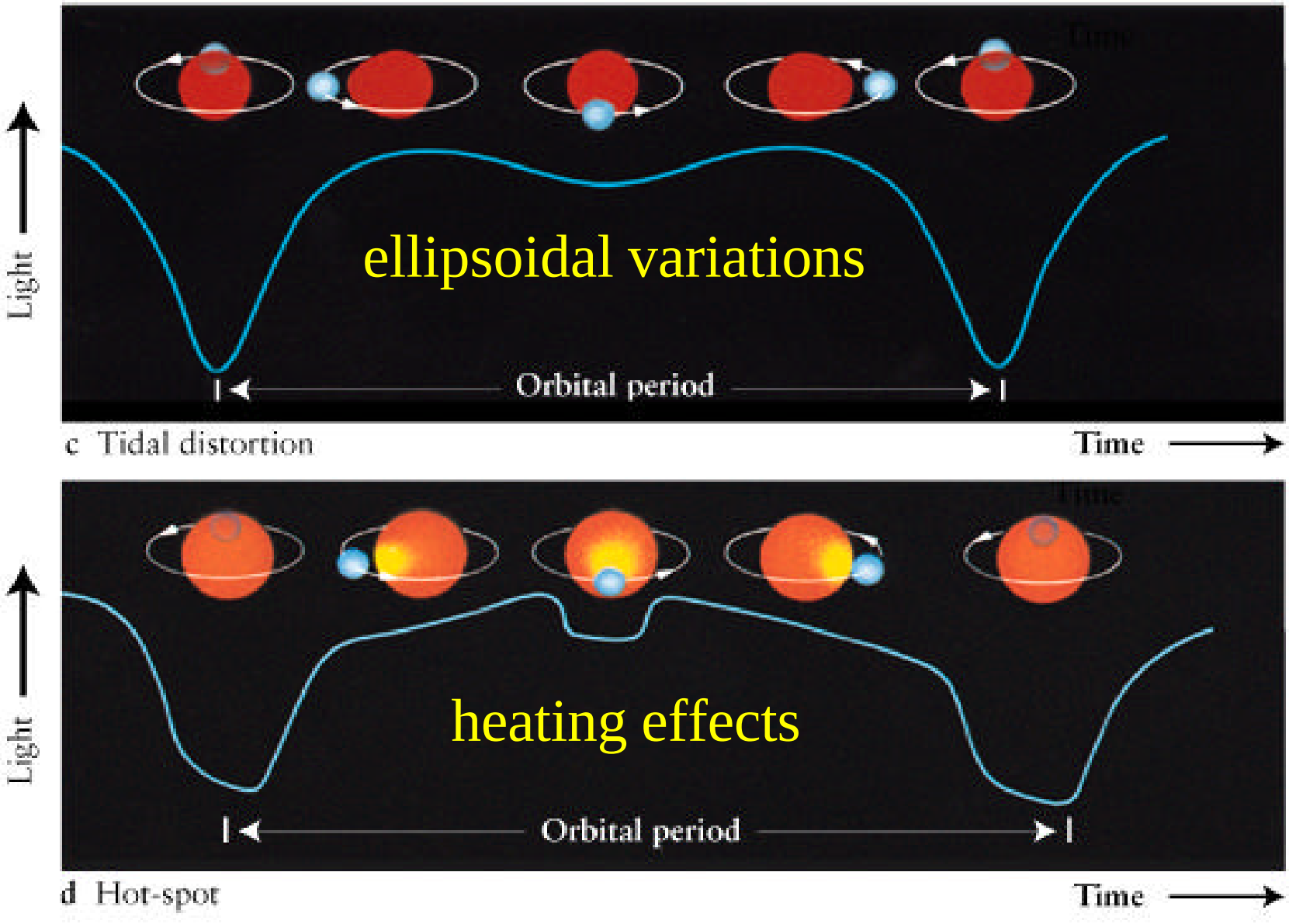
close to contact



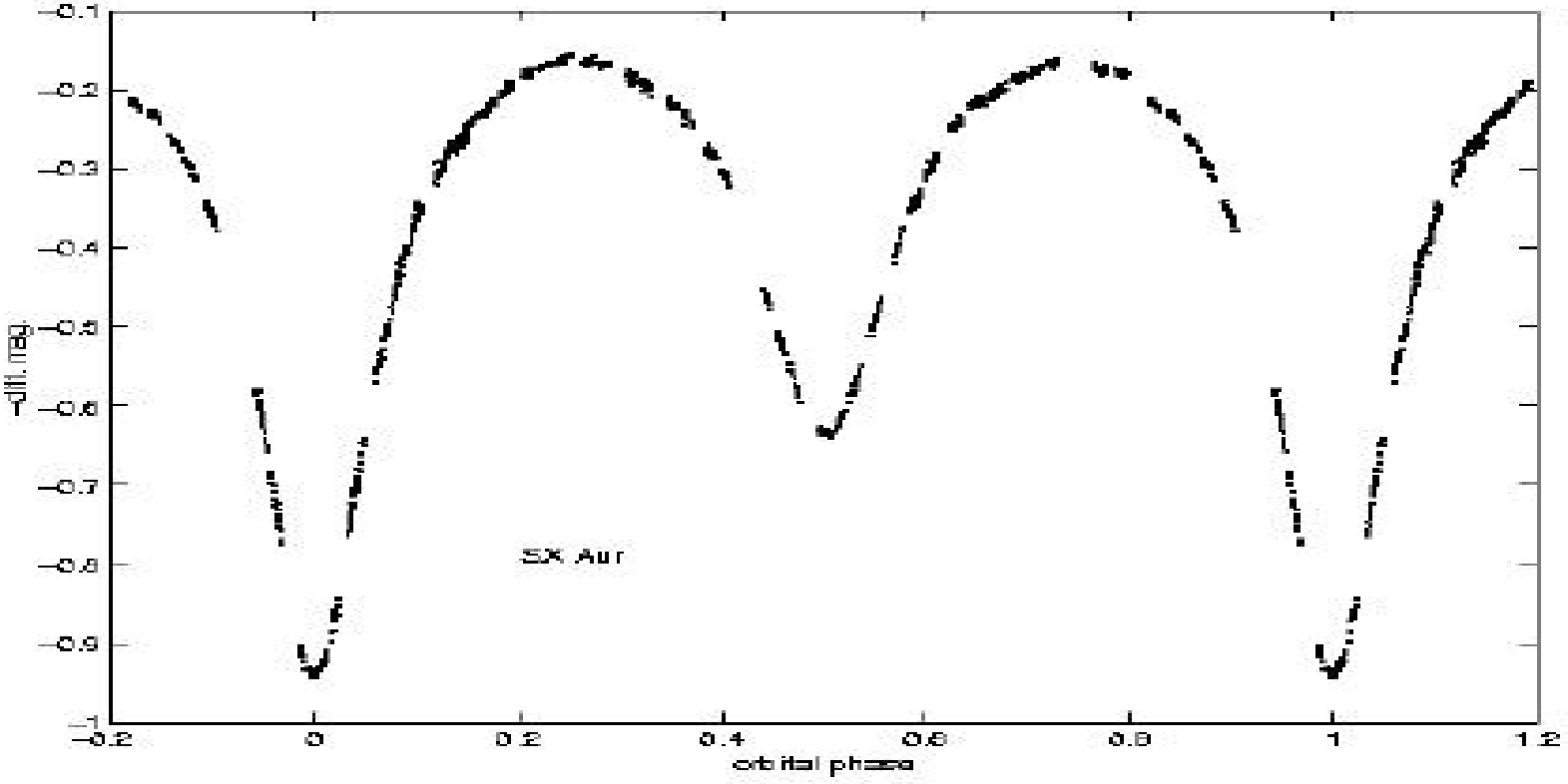
contact (W UMa)



Proximity Effects



Light curve of Contact Binary

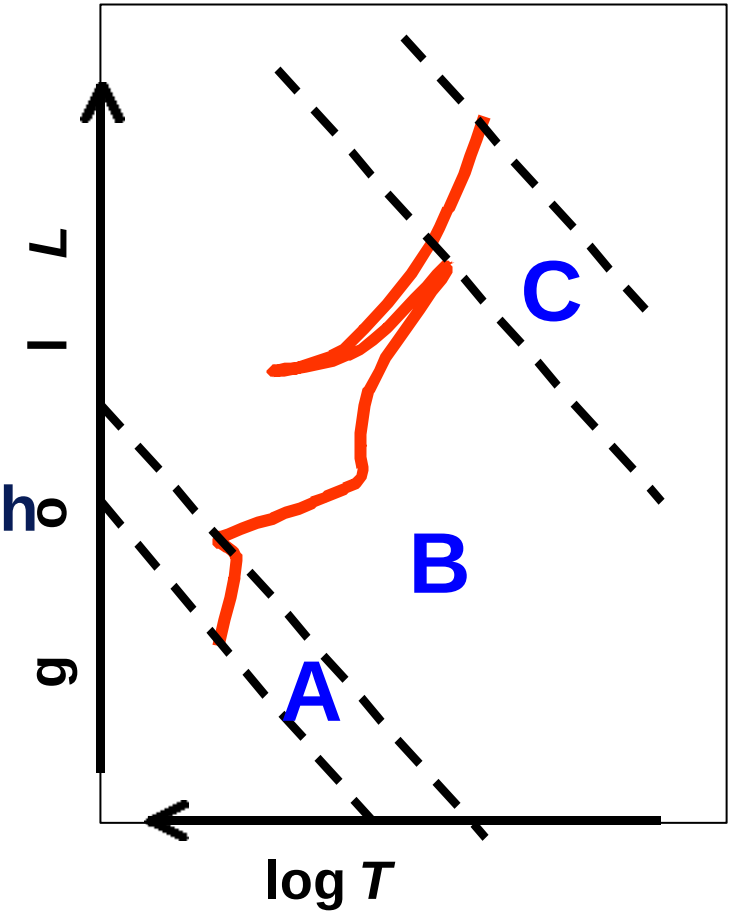


Orbital Phase

Binary Star Evolution

$$R \propto L^{1/2} T^{-2}$$

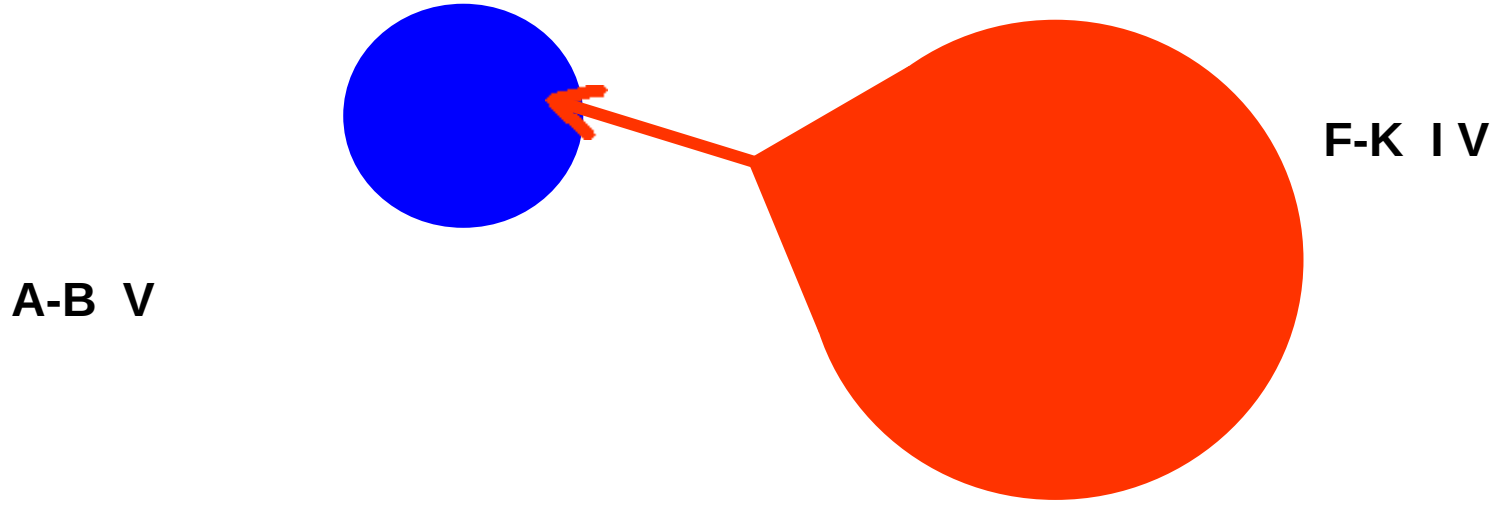
- **Roche lobes limit star sizes**
  - **mass transfer between stars**
  - **mass loss from system**
  - **common envelope**
- **Case A: main sequence**
- **Case B: giant branch**
- **Case C: asymptotic giant branch**



The Algol Paradox

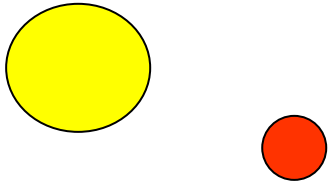
- **Semi-detached, gas stream hits primary star**

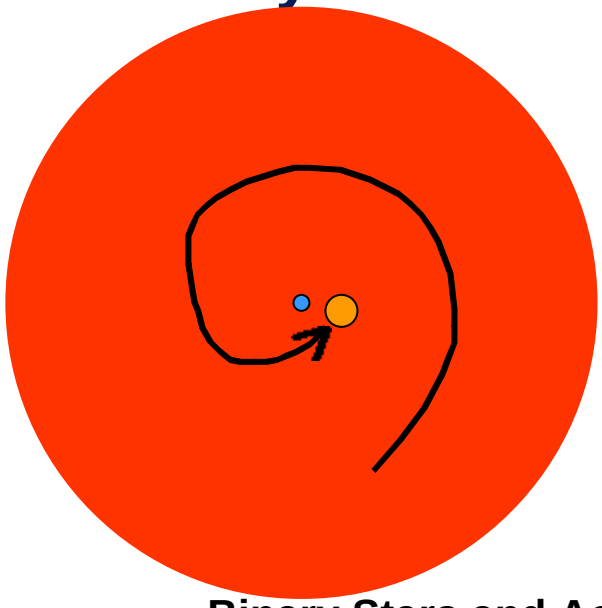
- **less massive secondary star (F-K IV)**
- **is evolving off main sequence**
- **before the more massive (A-B V) primary**



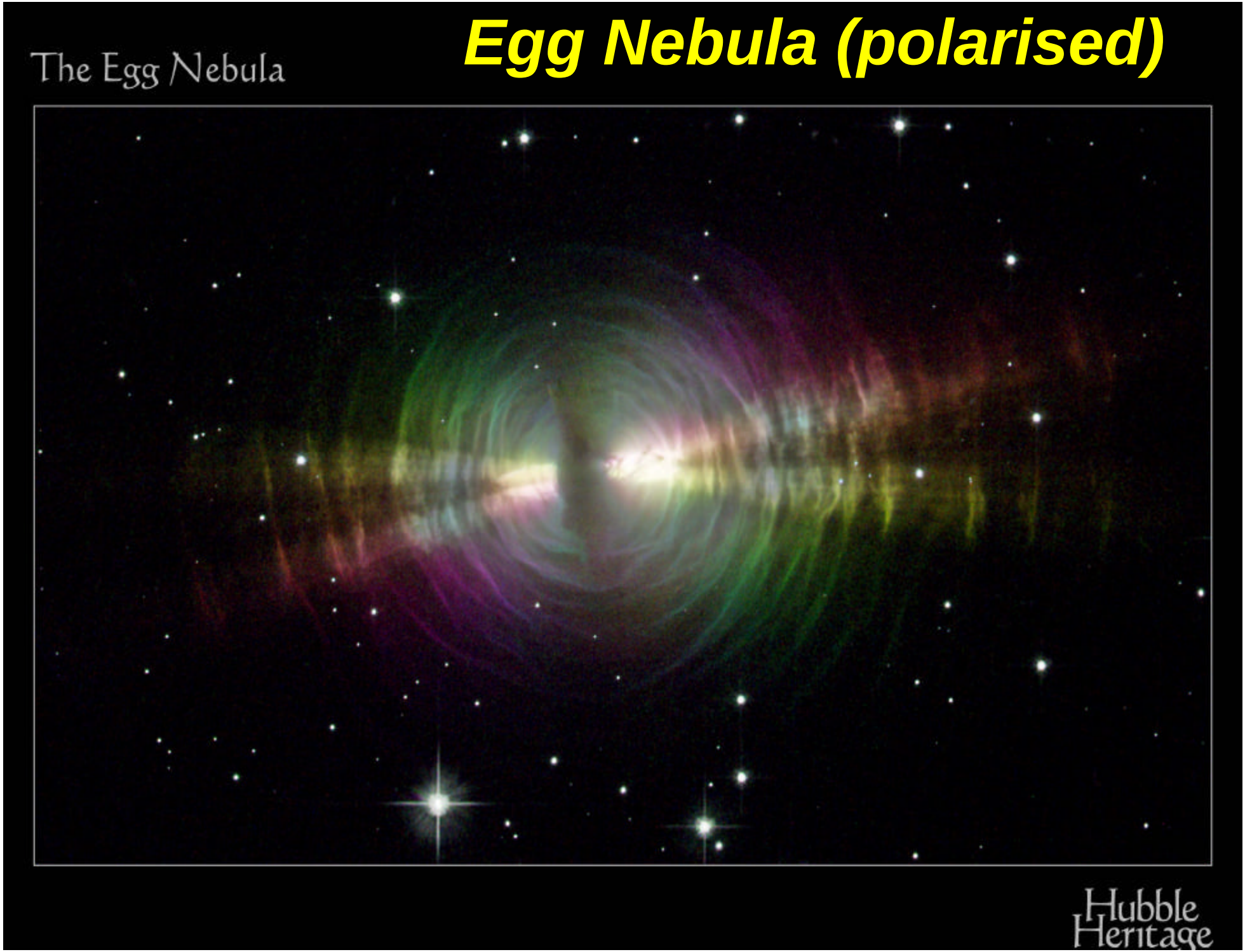
Common Envelope Phase

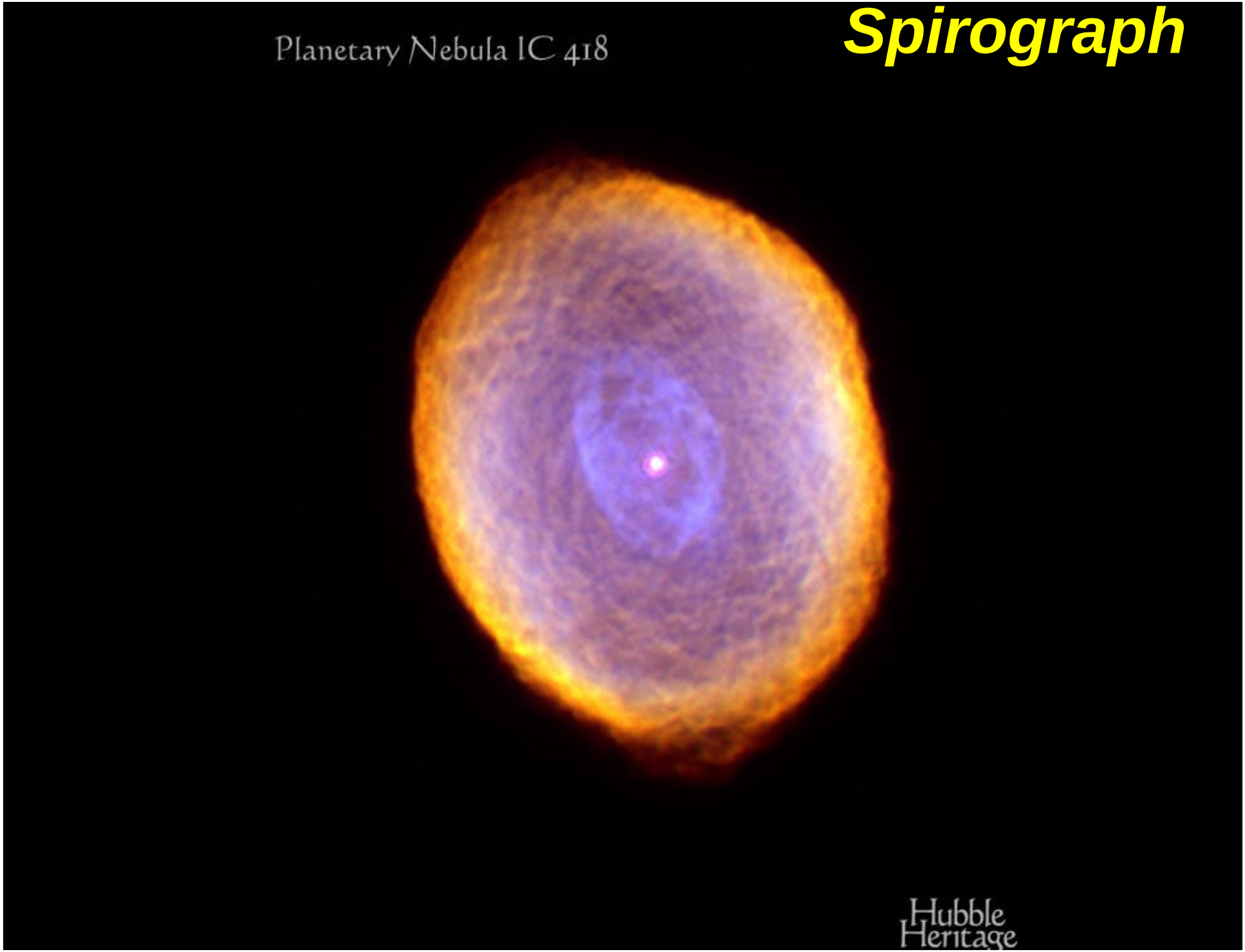
- **Initial wide MS+MS (e.g. P ~100d)**
- **Primary -> red giant,**
- **swallows low-mass companion.**
- **Stellar cores spiral inward.**
- **Orbital energy / angular momentum**
- **transfers to the envelope.**
- **Envelope ejects --> bi-polar Planetary Nebula**
- **Final MS+WD (P <1 day)**

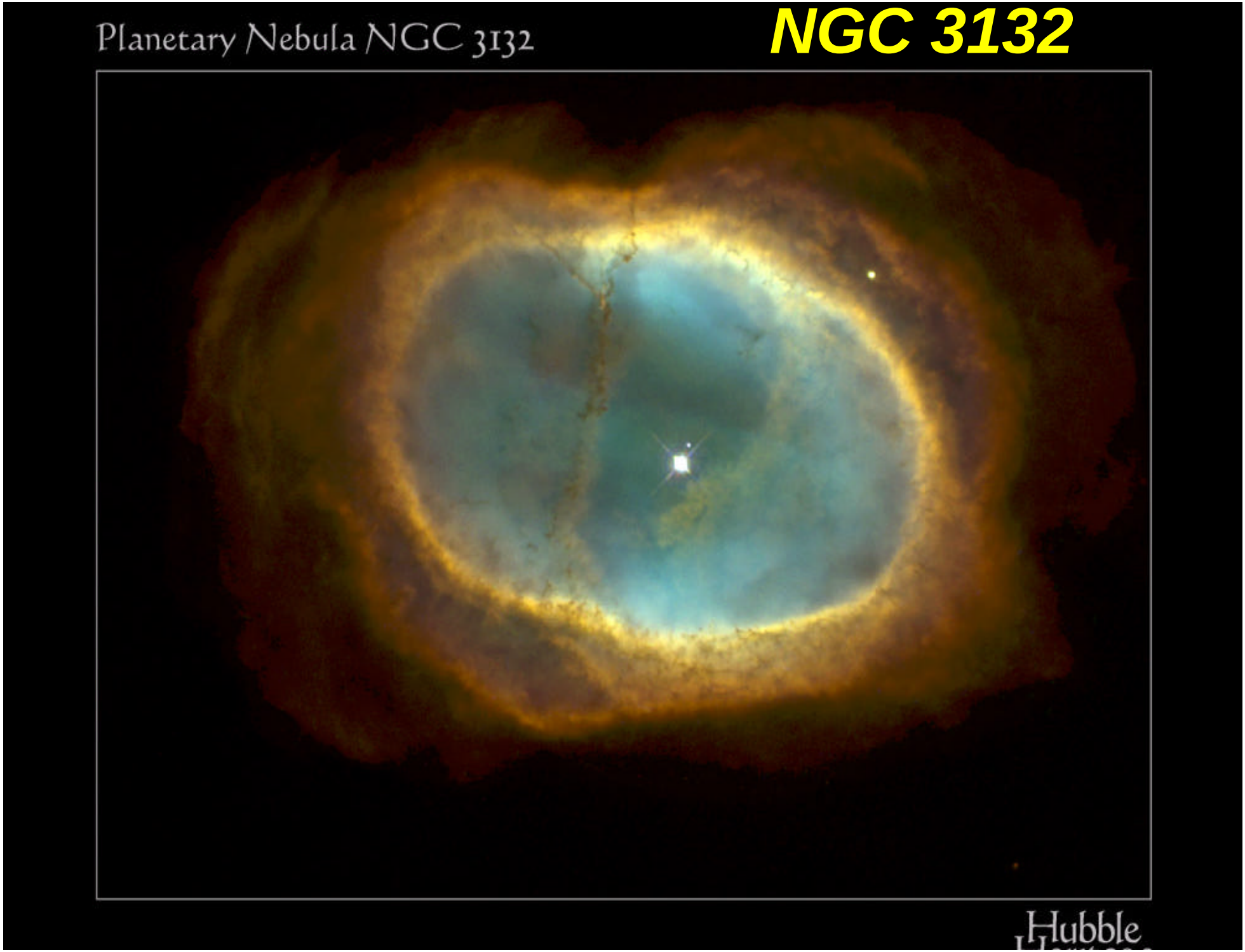




Egg Nebula (polarised)

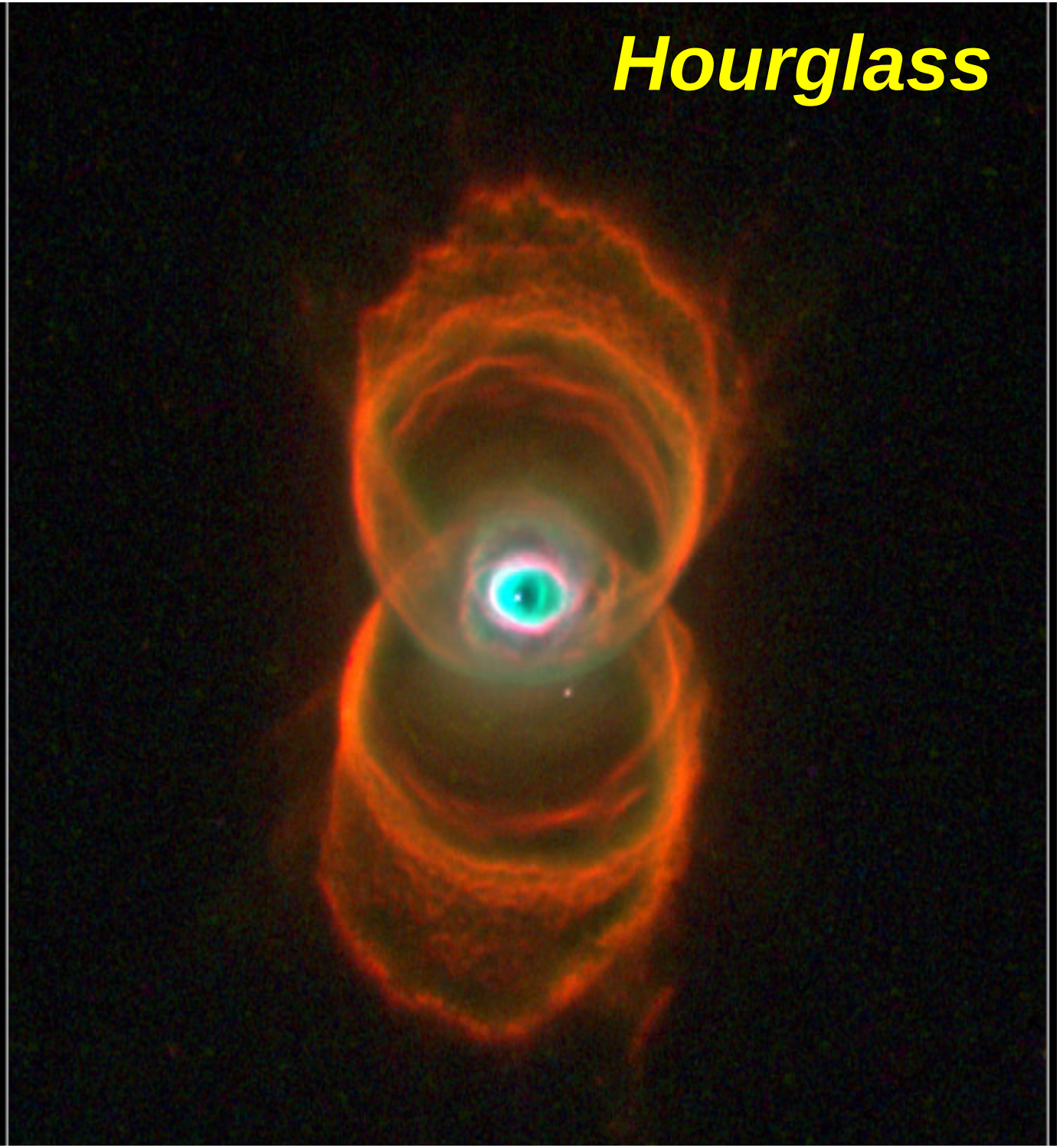



Planetary Nebula IC 418
Spirograph
Hubble Heritage

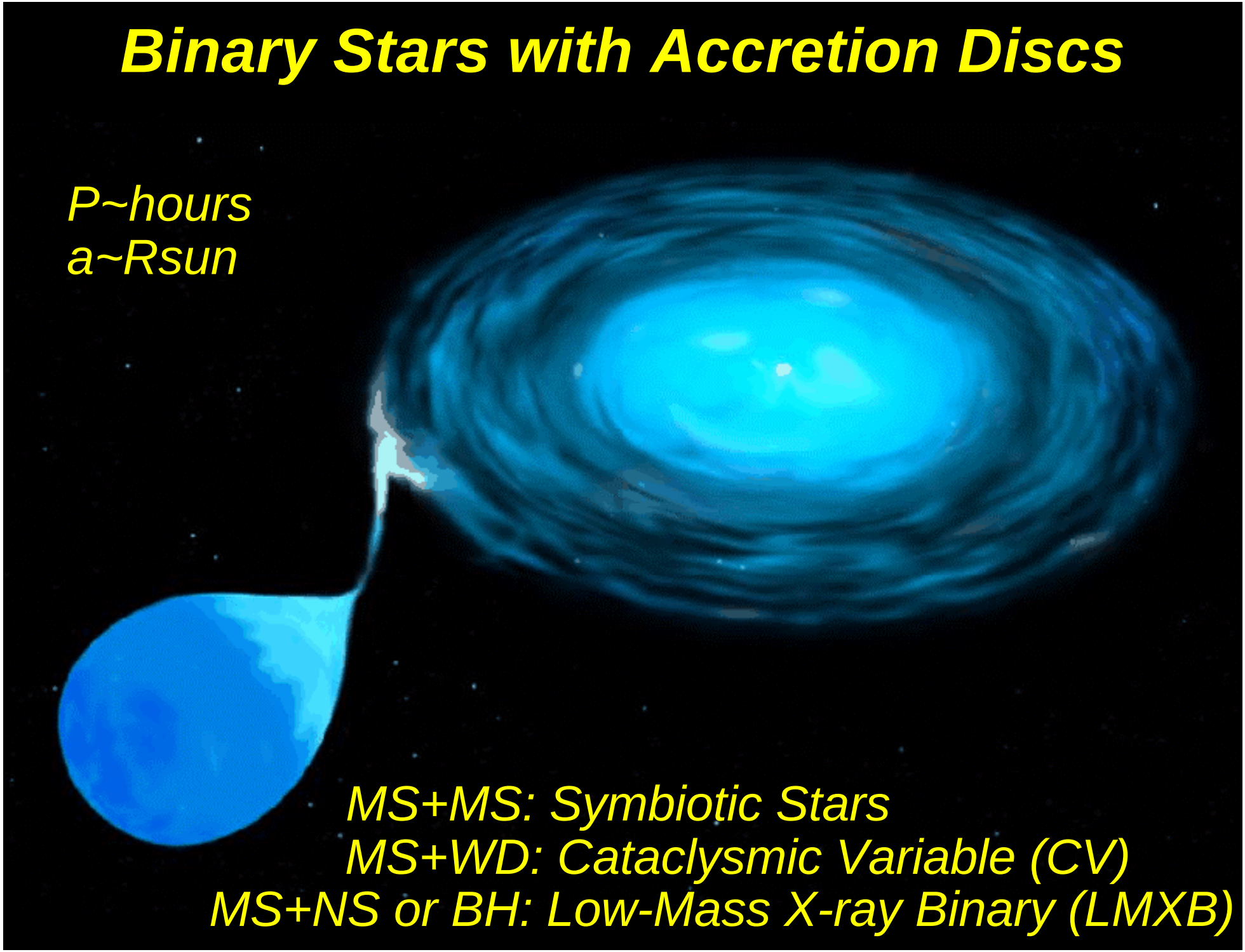

Planetary Nebula NGC 3132
NGC 3132
Hubble


The Egg Nebula
Hubble Heritage


Planetary Nebula NGC 3132
Hubble Heritage


Hourglass

Binary Stars with Accretion Discs



P~hours
a~Rsun

MS+MS: Symbiotic Stars
MS+WD: Cataclysmic Variable (CV)
MS+NS or BH: Low-Mass X-ray Binary (LMXB)

Accretion Disks in CVs

- **Eclipses of Disk**
  - **measure T(R) , accretion rate**
- **Dwarf Novae and Black-Hole X-ray Binaries**
  - **disk accretion flow unstable**
  - **spiral shocks in disks**
  - **precessing elliptical disks**

Magnetic CVs

- **Polars**
  - **white dwarf strongly magnetic (B~1e7-1e9 gauss)**
  - **prevents disk formation**
  - **matter funnels down field lines (like aurorae)**
  - **x-ray emission**
- **Intermediate Polars**
  - **weakly magnetic white dwarf (B~1d6-1e7 gauss)**
  - **disrupts inner disk**
  - **pulses from rotating magnetosphere Pspin<Porbit**