AS 4024: Binary Stars and Accretion Disks

Keith Horne (for Ron Hilditch)
kdh1@st-and.ac.uk

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)

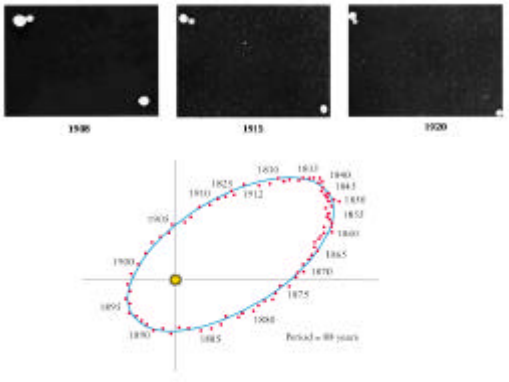
Binary Stars

- **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

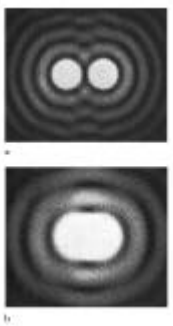
Types of Binaries

- **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

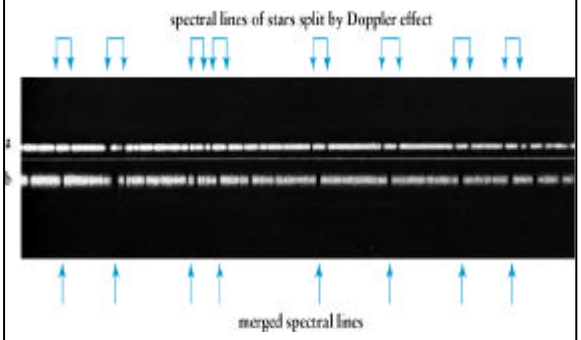
Visual binary



Resolving a close double star

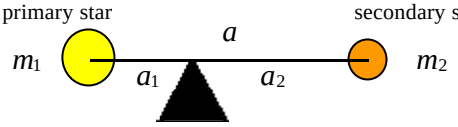


Spectroscopic binary



Centre of Mass

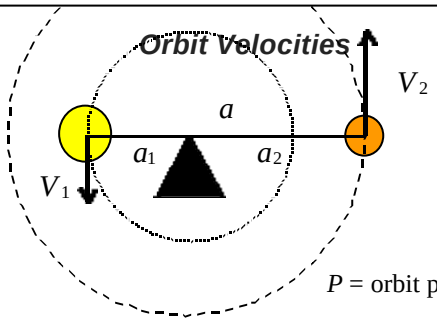
primary star — secondary star



$$a_1 m_1 = a_2 m_2$$

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

Orbit Velocities

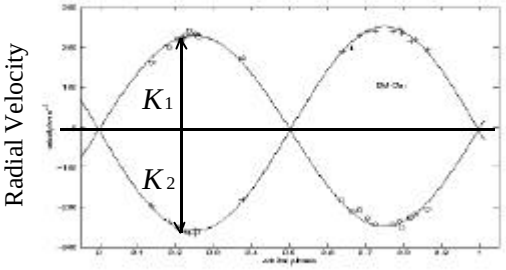


P = orbit period

$$\frac{V_1}{V_2} = \frac{a_1}{a_2} = \frac{m_2}{m_1} \qquad V_1 + V_2 = \frac{2p\ a}{P}$$

Velocity Curve

observe : $K = V \sin i$



Orbital Phase

Masses

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

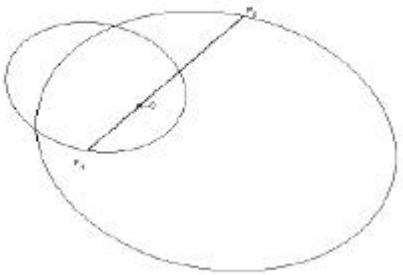
mass ratio: $q = \frac{m_2}{m_1} = \frac{a_1}{a_2} = \frac{K_1}{K_2}$

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

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

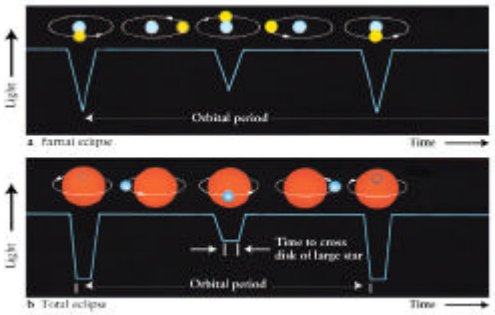
minimum mass: $M \sin^3 i = \frac{P\ K^3}{2p\ G}$

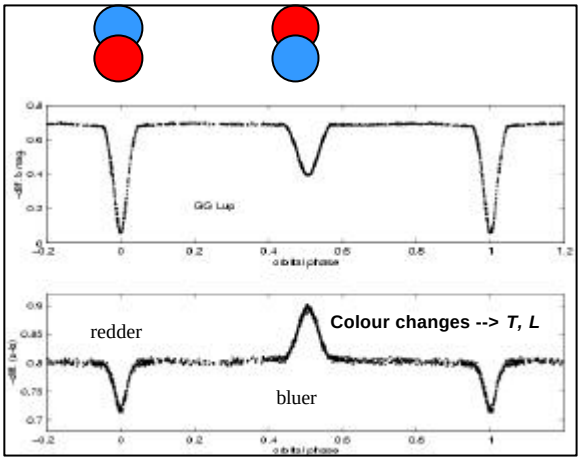
Elliptical Orbits



Eclipsing binaries

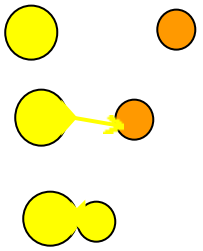
timing+velocities --> sizes



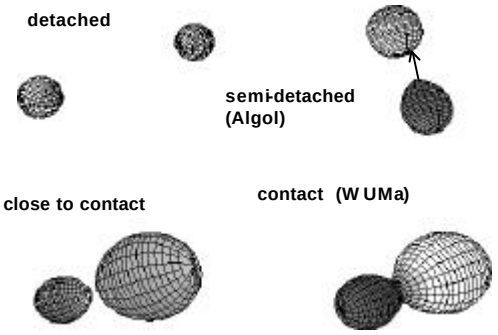


Types of Close Binaries

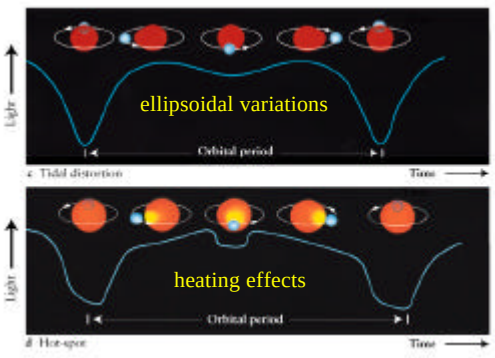
- **Detached**
  - stars inside Roche lobes
  - tidal distortions, irradiation
- **Semi-detached**
  - one star fills its Roche lobe
  - mass transfer
- **Contact**
  - stars touch at inner Lagrange point L_1
  - overfill Roche-lobes
  - joined by a neck of material
- **Common Envelope**
  - two stars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



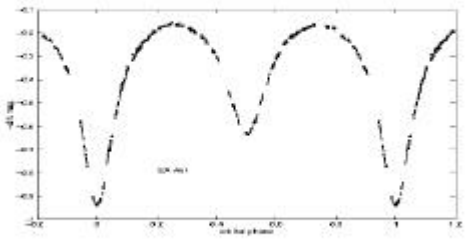
Binaries in Roche-Lobes



Proximity Effects



Light curve of Contact Binary

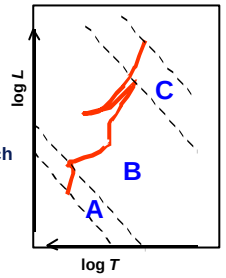


Orbital Phase

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



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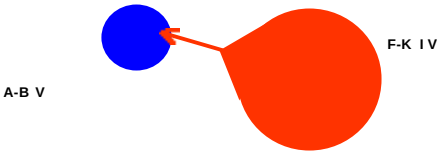
The Algol Paradox

- 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



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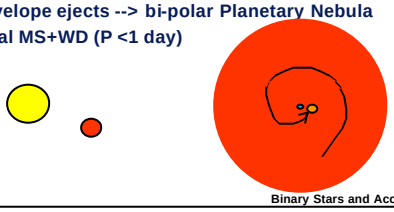
Common Envelope Phase

- 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)



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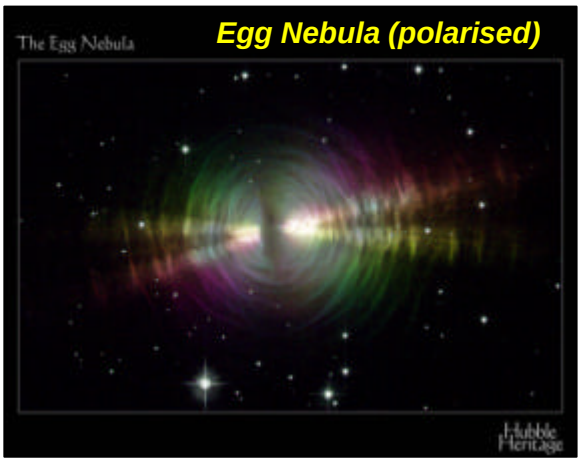

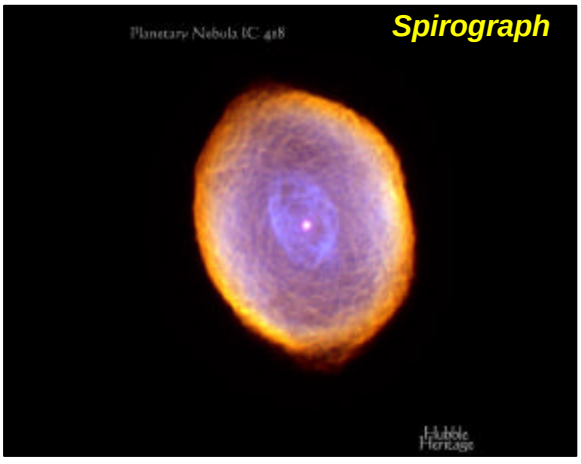

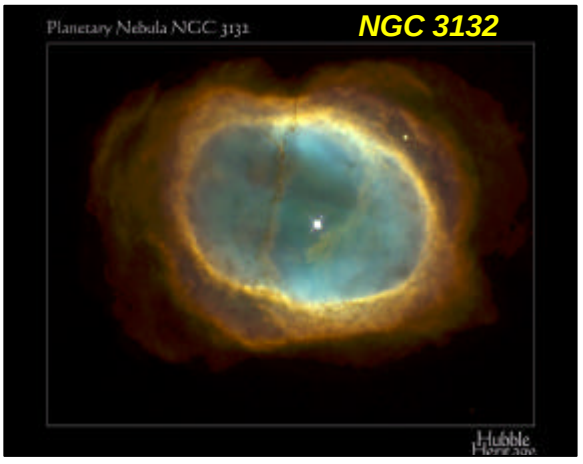

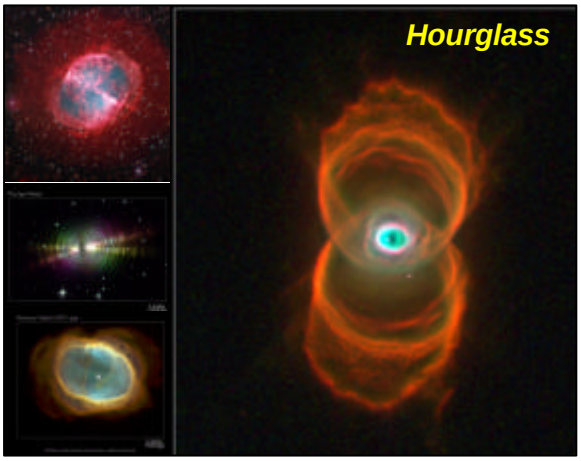

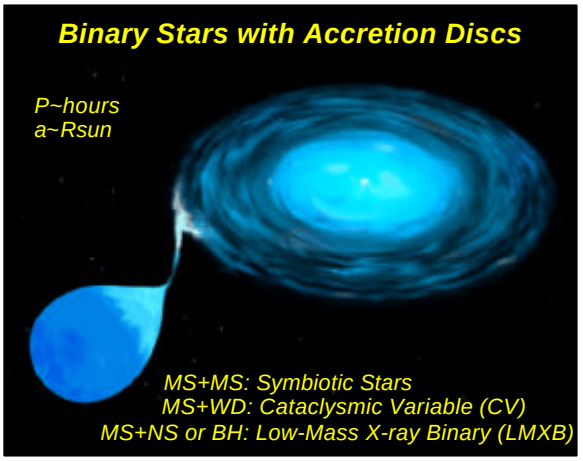

Accretion Disks in CVs

- **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