Evolution of Close Binary Systems

- There are many multiple star systems in the Galaxy
- For the vast majority, the separation of the stars is large enough that one star doesn't affect the evolution of the other(s)

m_p [$M_\odot$]	f_{bin}	Source
$0.10 \leq m_p < 0.45$	0.34	Janson et al. (2012b)
$0.45 \leq m_p < 0.84$	0.45	Mayor et al. (1992)
$0.84 \leq m_p < 1.20$	0.46	Raghavan et al. (2012)
$1.20 \leq m_p \leq 3.00$	0.48	De Rosa et al. (2012, 2014)
$m_p > 3.00$	1.00	Mason et al. (1998)
		Kouwenhoven et al. (2007)

The Algol Mystery

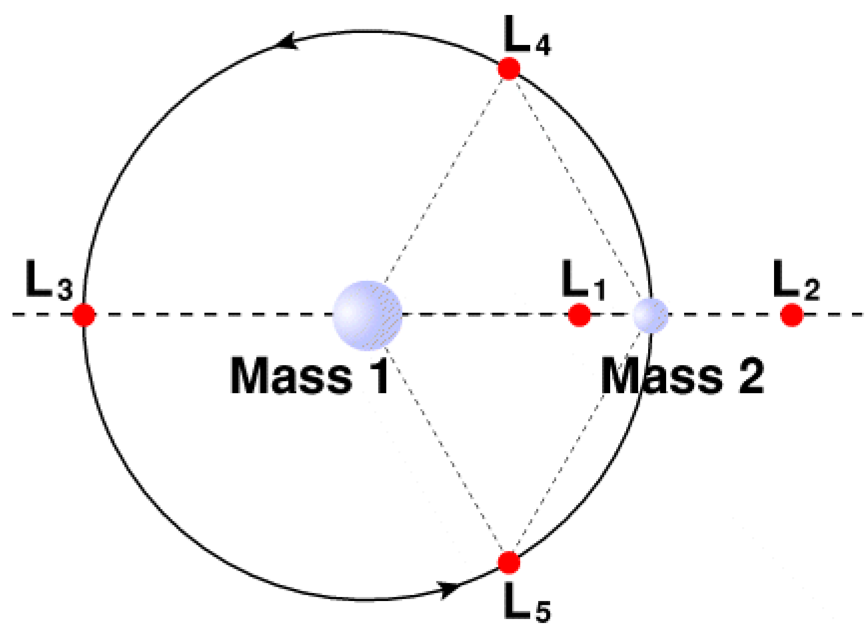
- Algol is a double-lined eclipsing binary system with a period of about 3 days (very short). The two stars are:
  - Star A: B8, 3.4 $M_{\odot}$ main-sequence star
  - Star B: G5, 0.8 $M_{\odot}$ subgiant star
- What is wrong with this picture?

The Algol Mystery

- The more massive star (A) should have left the main sequence and started up the RGB before the less massive star (B).
- What is going on here?
- The key is the short-period orbit.

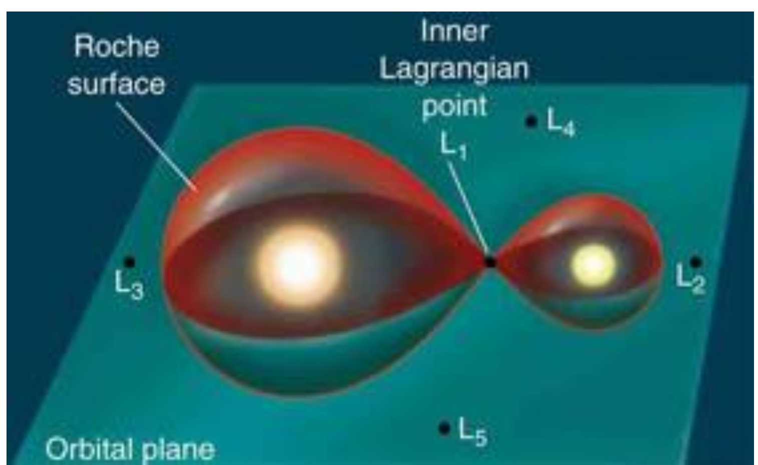
The Algol Mystery

- Originally the system contained Star A at 1.2 $M_\odot$ and Star B at 3.0 $M_\odot$
- Between the two stars is a point where the gravitational forces of the two stars balance. This is called a Lagrange point.



The Algol Mystery

- As Star B evolves and expands as it heads up the RGB
- When its radius equals the distance of the L1 point (called the Roche Radius) the material in Star B's envelope feels a stronger attraction to Star A and there is mass transferred from B to A.

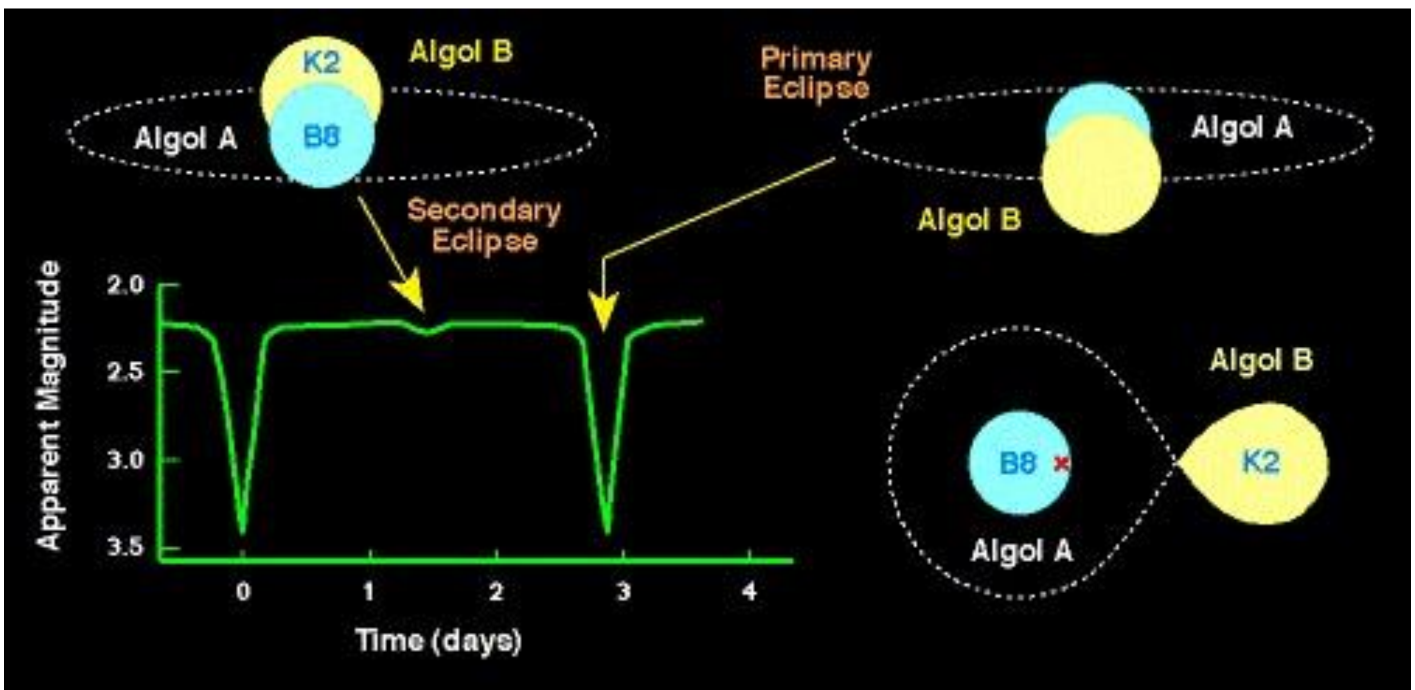


The Algol Mystery

- In the case of Algol, Star B transferred 2.2 $M_\odot$ of material to Star A

    Star A: 1.2 $M_\odot$ => 3.4 $M_\odot$

    Star B: 3.0 $M_\odot$ => 0.8 $M_\odot$



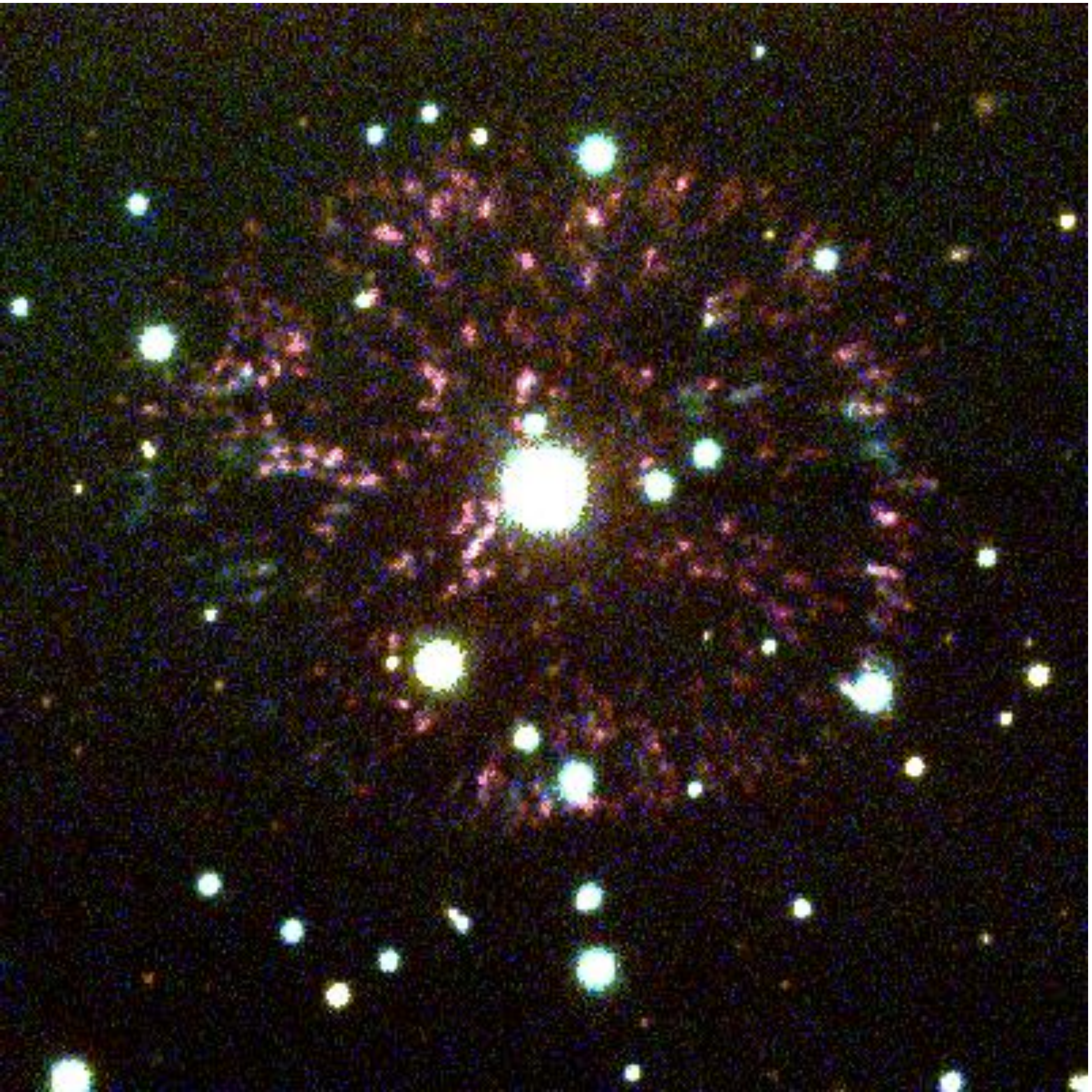
Mass Transfer Binaries

- Think about the continued evolution of Algol and you have the explanation for ***novae***.
- If the original primary transfers most of its mass to the original secondary, you are left with a massive main-sequence star and a White Dwarf.
- When the original secondary starts to evolve up the RGB, it transfers some material back onto the White Dwarf.

Nova: white dwarf re-ignition in a binary system

- A ***Nova*** is a faint star suddenly brightens by a factor of 10^4 to 10^8 over a few days or hours
- It reaches a peak luminosity of about $10^5\ L_{\odot}$
- A nova is different from a supernova (luminosity of $10^9\ L_{\odot}$)
- Material from an ordinary star in a close binary can fall onto the surface of the companion white dwarf
- Because of strong gravity, the transferred hydrogen mass is compressed into a dense layer covering the while surface
- When the temperature reaches about 10^7 K, hydrogen fusion ignites through the surface layer, producing the sudden increase in luminosity

Novae

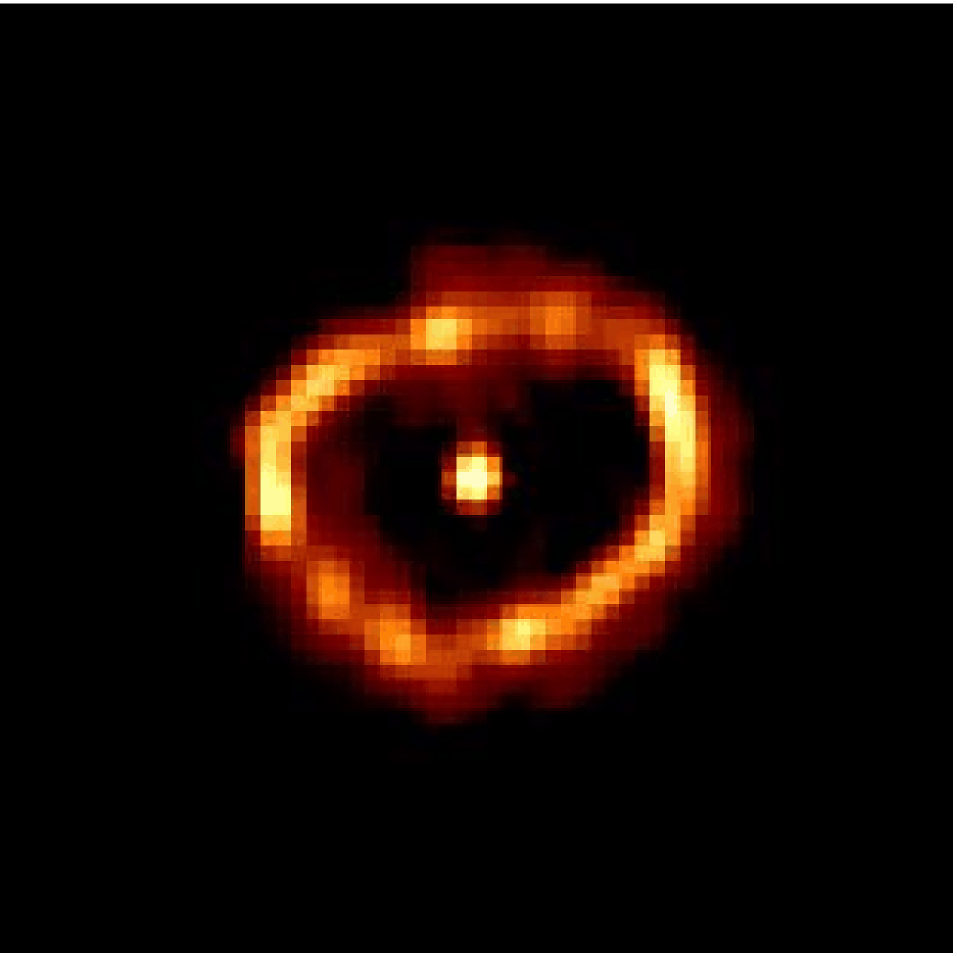


- Nova Persei became one of the brightest stars in the sky in 1901. There is an expanding shell from the explosion. The velocity of the material is about 2000 km/sec

Novae

- Nova Cyg (1992) illuminated a cloud of nearby hydrogen gas
- The expanding shell of the nova could be seen a few years later with HST

Novae



- Nova Cyg in 1994.
- Most nova are recurrent
- Every year there are 20 - 30 novae observed in the Milky Way. “Naked eye” nova occur more likely one per decade.

Light curves of Novae