Introductory Astronomy

Week 5: Stellar Evolution

Clip 10: Mass Transfer

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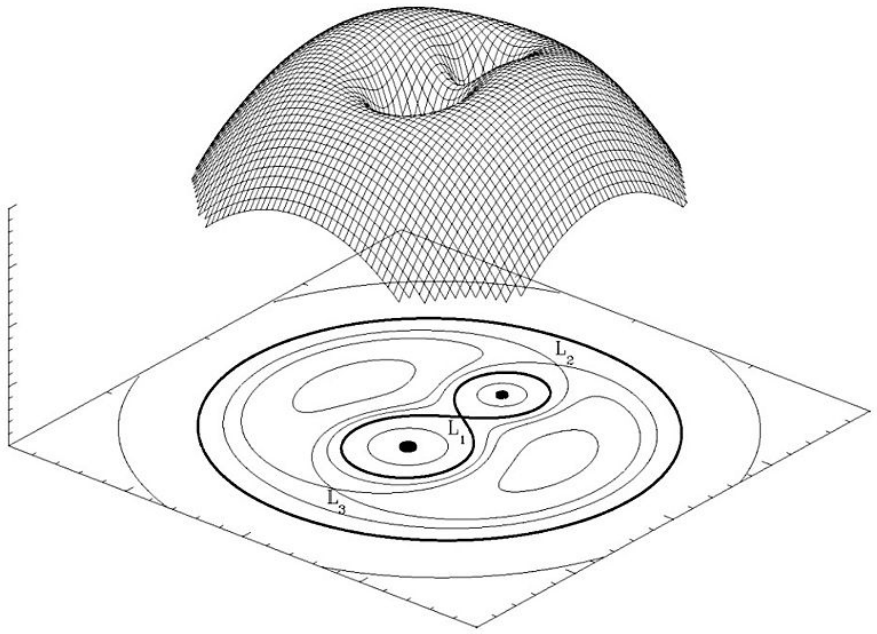
Roche Potential

- In a binary system matter orbits both stars
- Entire system rotates. If dropped from (rotating) rest, where will a stone fall?
- Combined gravity and rotation described by Roche potential
- Inside each star's Roche lobe orbits stay close to that star



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Algol

- Eclipsing binary Algol is a puzzle:

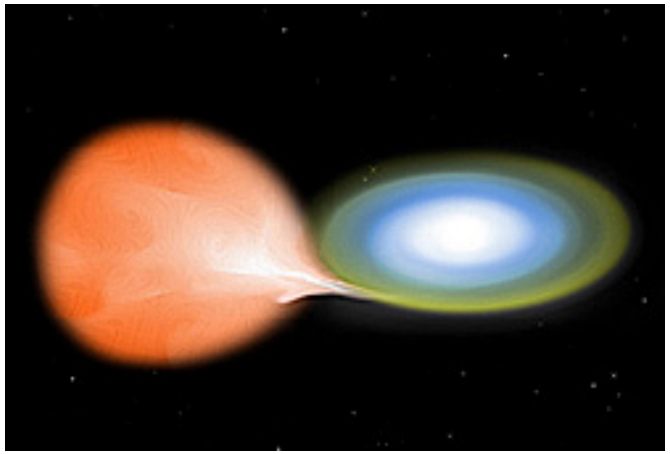
  $M_A = 3.59 M_\odot$ MS

  $M_B = 0.79 M_\odot$ subgiant

- Massive A should have evolved earlier?

  $R = 0.062\ \mathrm{AU}$

- B started out as the more massive star
- In its subgiant phase, atmosphere leaked out of its Roche lobe
- Gas lost by B forms accretion disk around A



White Dwarf Nova

- White dwarves in close binaries can accrete Hydrogen at $10^{-8}\,M_\odot/\mathrm{yr}$ from partner when it overflows its Roche lobe
- Infalling gas compressed to degeneracy and heated by immense surface gravity
- Enriched with CNO by turbulent mixing at base
- When $10^{-4}M_\odot$ accumulates, base temperature $10^7\,\mathrm{K}$
- CNO fusion explosively heats gas to$10^8\,\mathrm{K}$ and luminosity $10^5\,L_\odot$
- Radiation pressure ejects accreted material
- Total energy released $10^{38}\,\mathrm{J}$ over months
- Can recur in $10^5\,\mathrm{yr}$
- Ejected matter glows at initial $T \sim 9000\,\mathrm{K}$
- 30/yr in M31

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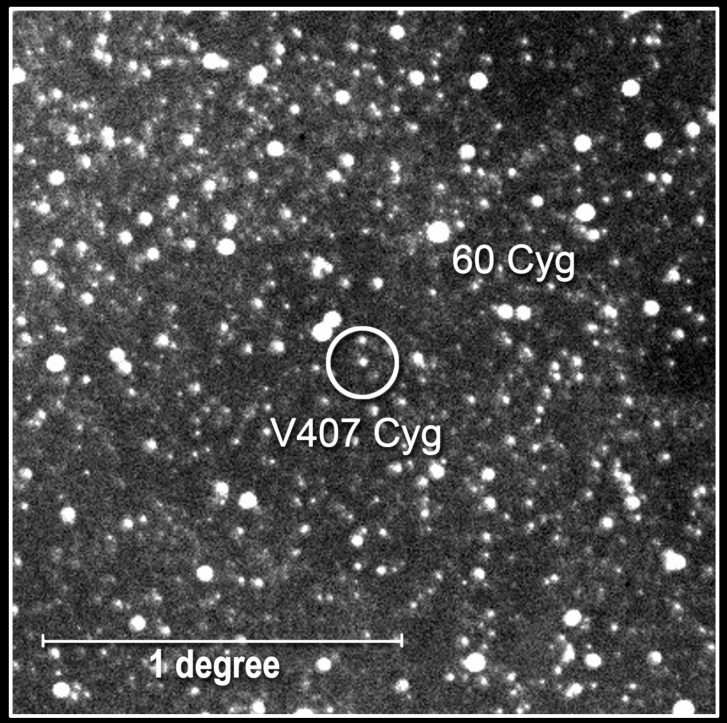
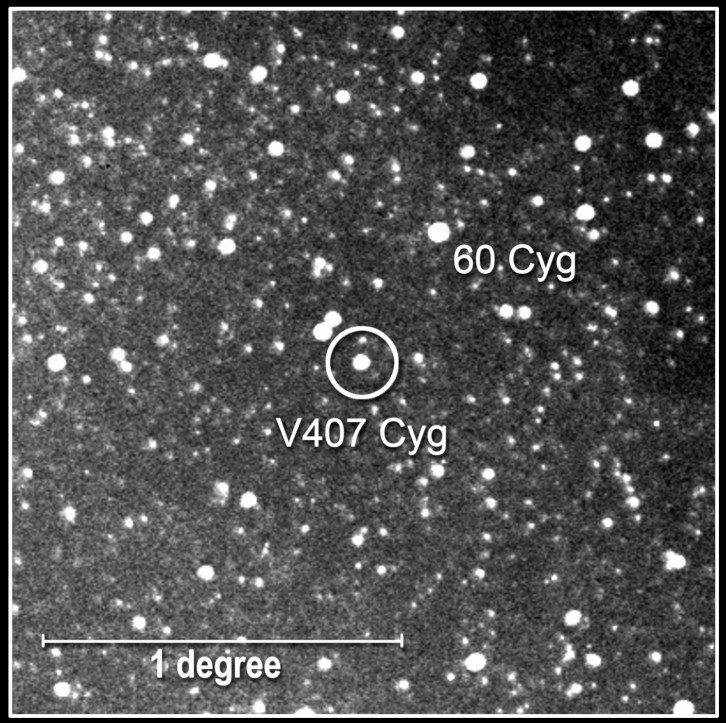
Nova Cygni 2010 in Visible Light



March 7, 20:36 UT



March 10, 19:08 UT

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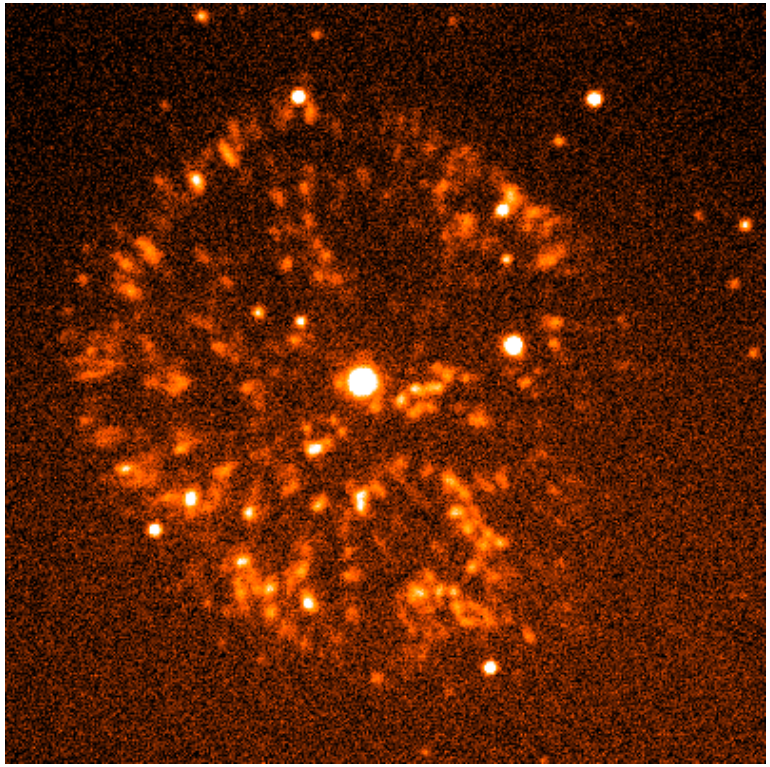
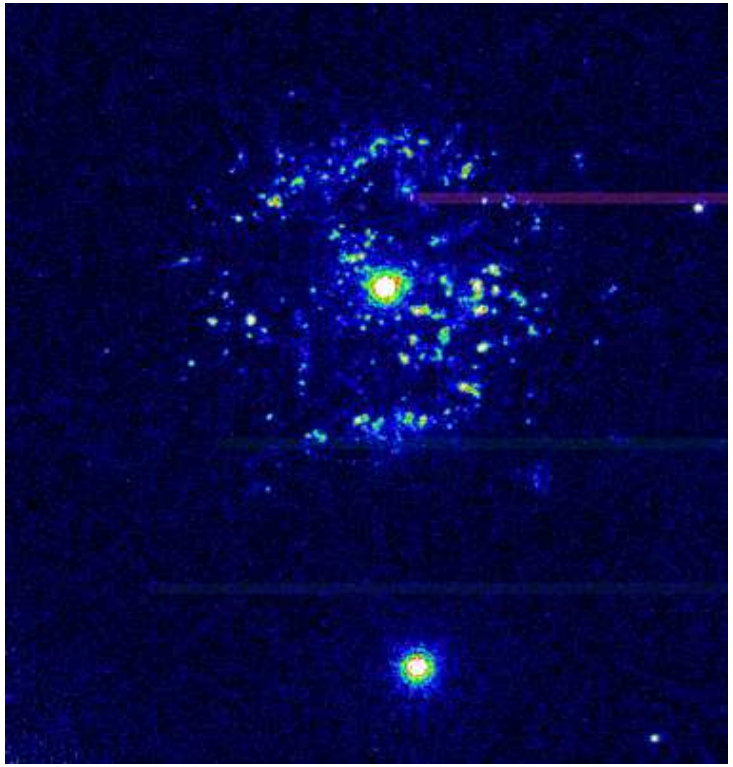
Nova Remnants





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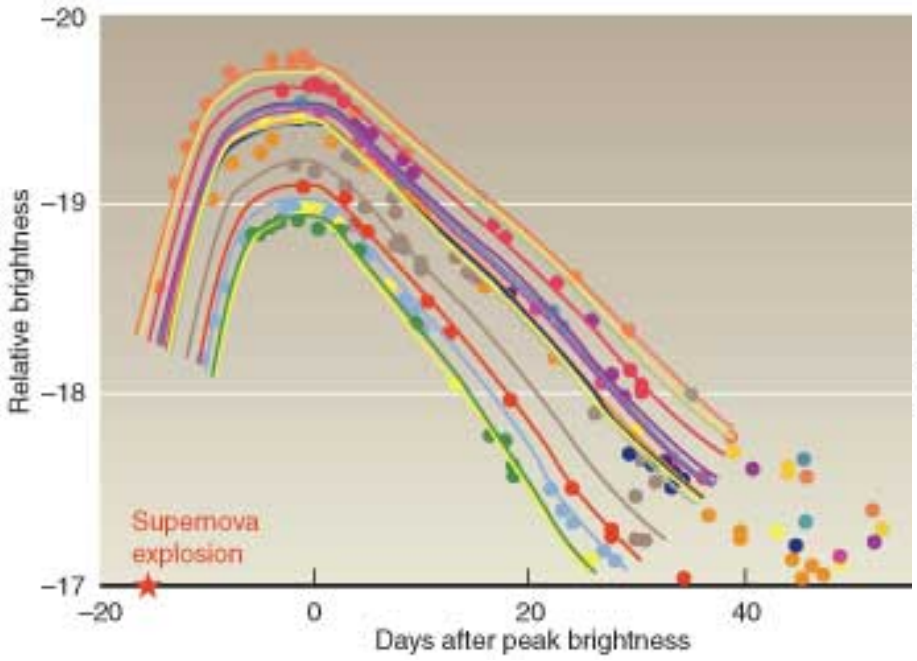
Type-Ia Supernova

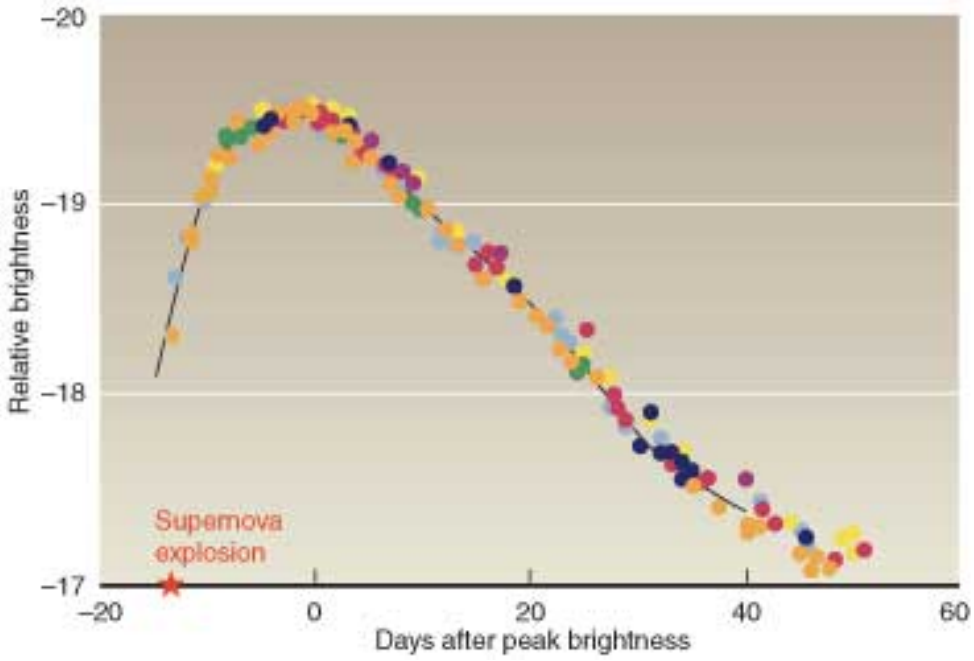
- Accretion adds to white dwarf mass. What if it exceeds Chandrasekhar limit?
- It doesn't. As increased mass compresses dwarf, pressure and temperature increase
- A turbulent convection phase leads to ignition of Carbon fusion
- In degenerate dwarf heating does not lead to expansion so violent explosive process fuses substantial fraction of star in a few seconds
- Oxygen fusion less complete
- Internal temperature exceeds $10^9\ \mathrm{K}$
- Fusion releases $10^{44}\ \mathrm{J}$ blowing star apart completely releasing shock wave ejecting matter at high speeds
- Luminosity reaches $10^{9-10} L_\odot$ decays over months
- Spectrum has absorption lines of Si but little H He
- Decay of readioactive fusion products near iron mass in shell contributes to luminosity at late times

What We Know

- Nature of Mass donor unclear
  - Single Degenerate: Donor is MS or giant
  - Double Degenerate: Donor is White dwarf ripped apart by tidal forces in merger
- Likely both occur
- Nature of explosion also debated: deflagration or detonation? Degenerate Helium flash trigger or internal CO ignition
- Fact: Luminosity (corrected by light curve) almost the same for all Ia Supernovae: Standard Candles!

A Standard Candle





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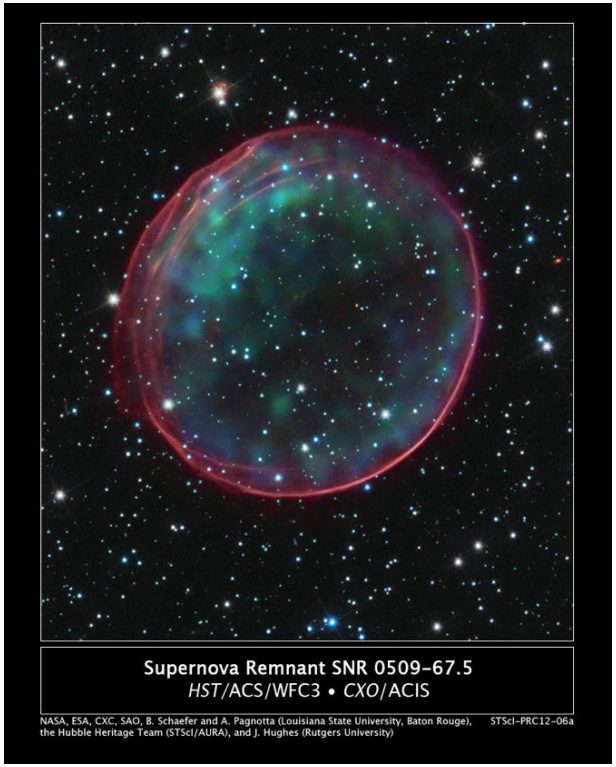
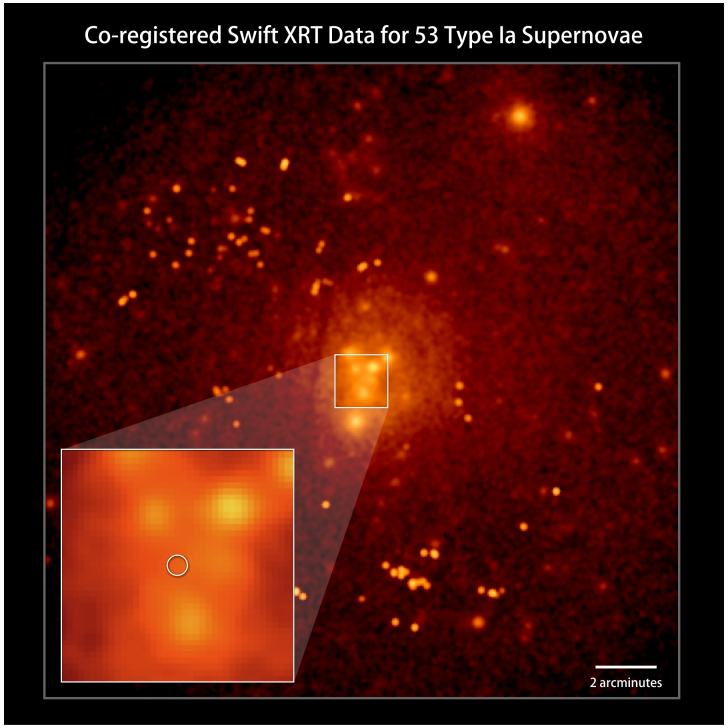
Evidence for DD Model





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Credits

- Nova Cygni 2010: K. Nishiyama and F. Kabashima/H. Maehara, Kyoto Univ. http://www.nasa.gov/mission_pages/GLAST/news/shocking-nova.html
- GkPer: WIYN/NOAO/NSF http://www.noao.edu/image_gallery/html/im0008.html
- T Pyxidis: Mike Shara, Bob Williams, and David Zurek (Space Telescope Science Institute); Roberto Gilmozzi (European Southern Observatory); Dina Prialnik (Tel Aviv University); and NASA http://hubblesite.org/newscenter/archive/releases/1997/29/
- SN Light Curves: From LLNL Science&Technology Review https://www.llnl.gov/str/SepOct08/hoffman.html
- SNR-0509-67.5: NASA, ESA, CXC, SAO, the Hubble Heritage Team (STScI/AURA), J. Hughes (Rutgers University) http://www.nasa.gov/mission_pages/hubble/science/supernova-source.html
- Co-Registered X-ray Images: NASA/Swift/Stefan Immler http://www.nasa.gov/mission_pages/swift/bursts/supernova-narrowing.html

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