Nuclear Shell Burning Triggered by an Accretion-Disk Instability

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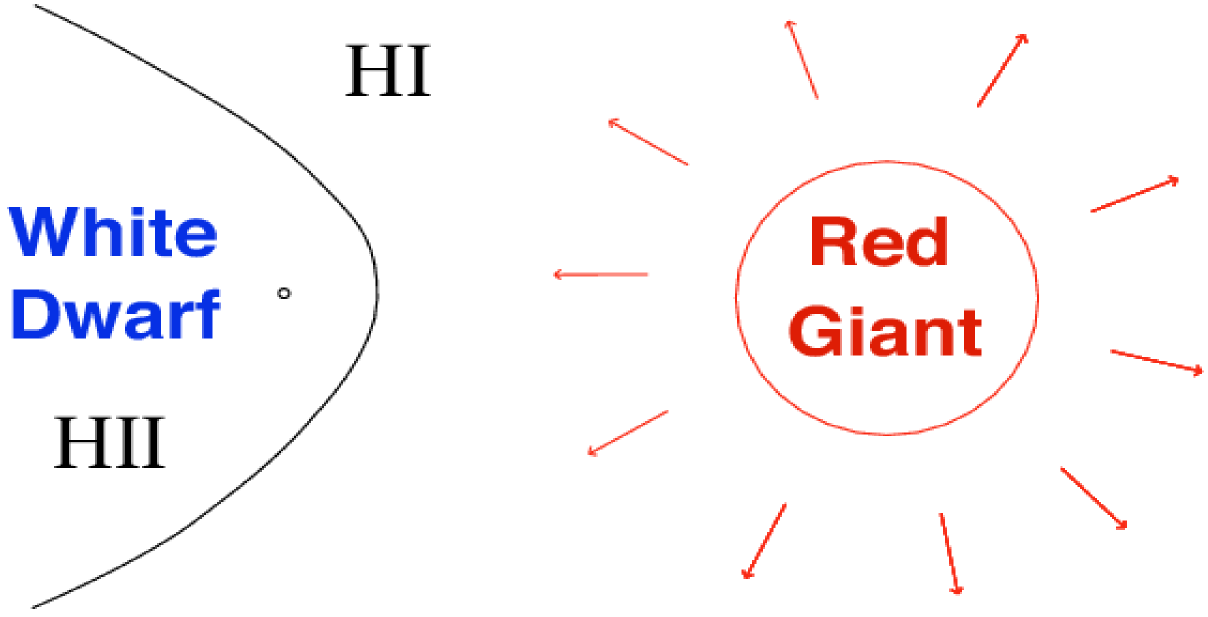
Outline

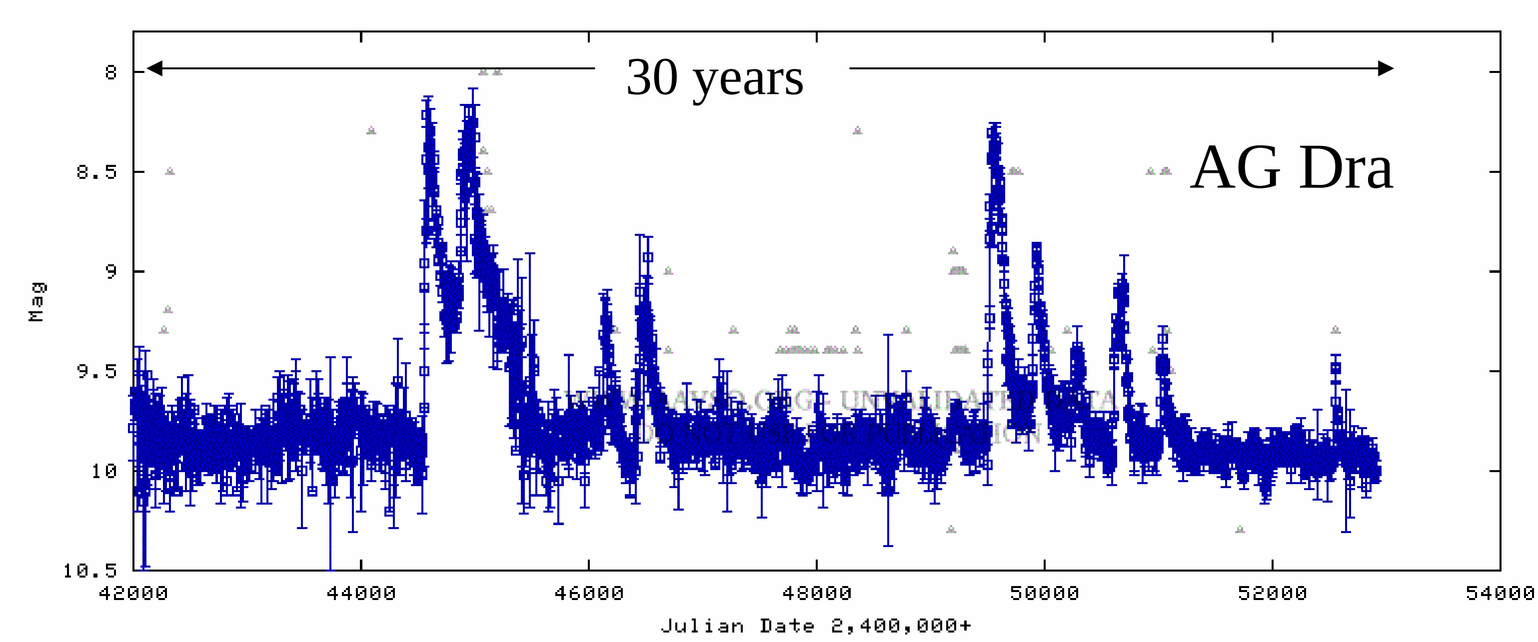
1. Background
   A. Symbiotic stars as possible SN Ia progenitors
   B. Mass loss and classical symbiotic outbursts
2. In-depth study of a symbiotic-star outburst
   A. Unsteady accretion onto a steady-burning layer
   B. Ejection of a shell plus collimated jet
3. Conclusions and questions

Symbiotic Binaries: Possible SN Ia Progenitors



- Wide: AU separations, P_{orb} order of years
- Wind-Fed Accretion
- Emission Nebula
- ➡ Quasi-steady Nuclear Burning on WD

Classical Symbiotic Outbursts



- Typically 1 - 3 mag
- Every few years to decades

- Too frequent to be recurrent novae
- Too large to be dwarf novae

Symbiotic Stars and Outbursts

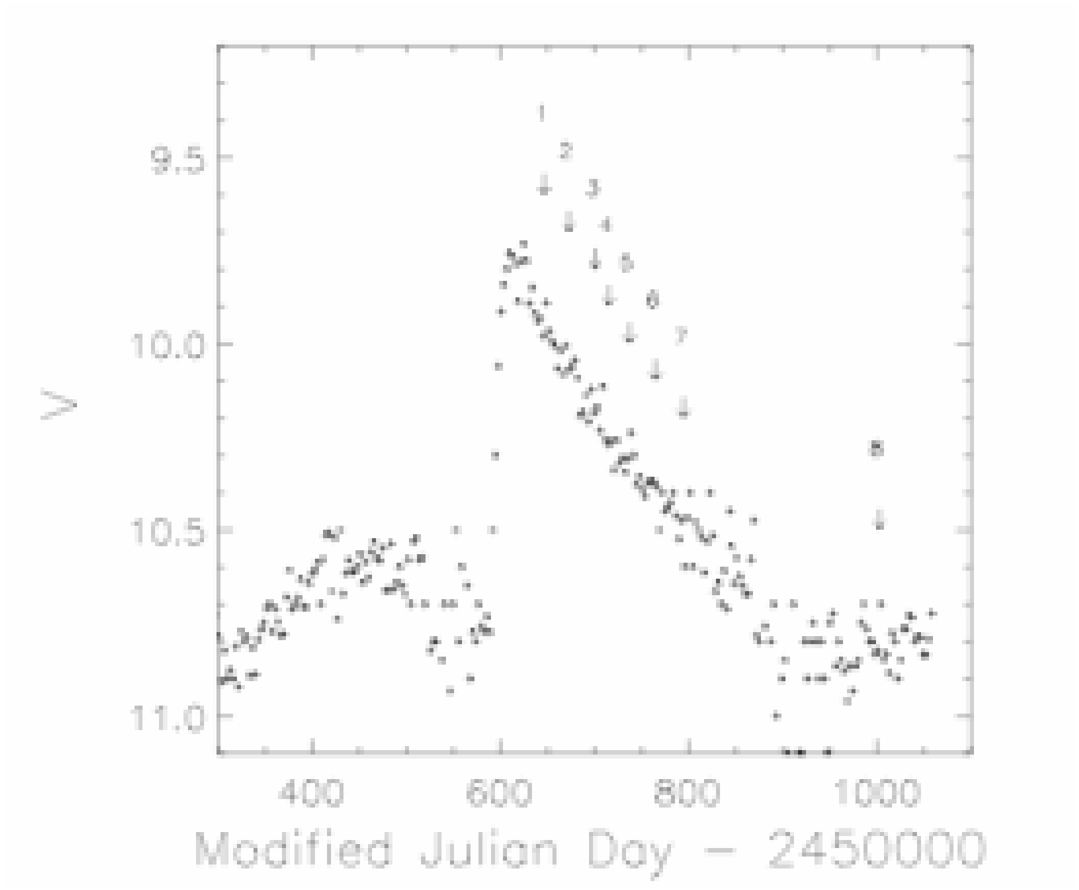
QuickTime™ and a YUV420 codec decompressor are needed to see this picture.

http://www.ing.iac.es/conferences/symbiotics/

Case Study: Z Andromedae

- Class prototype
- Quasi-steady shell burning on the white dwarf
- Classical symbiotic outbursts
- Strong white-dwarf magnetic field

Evidence for a Disk Instability

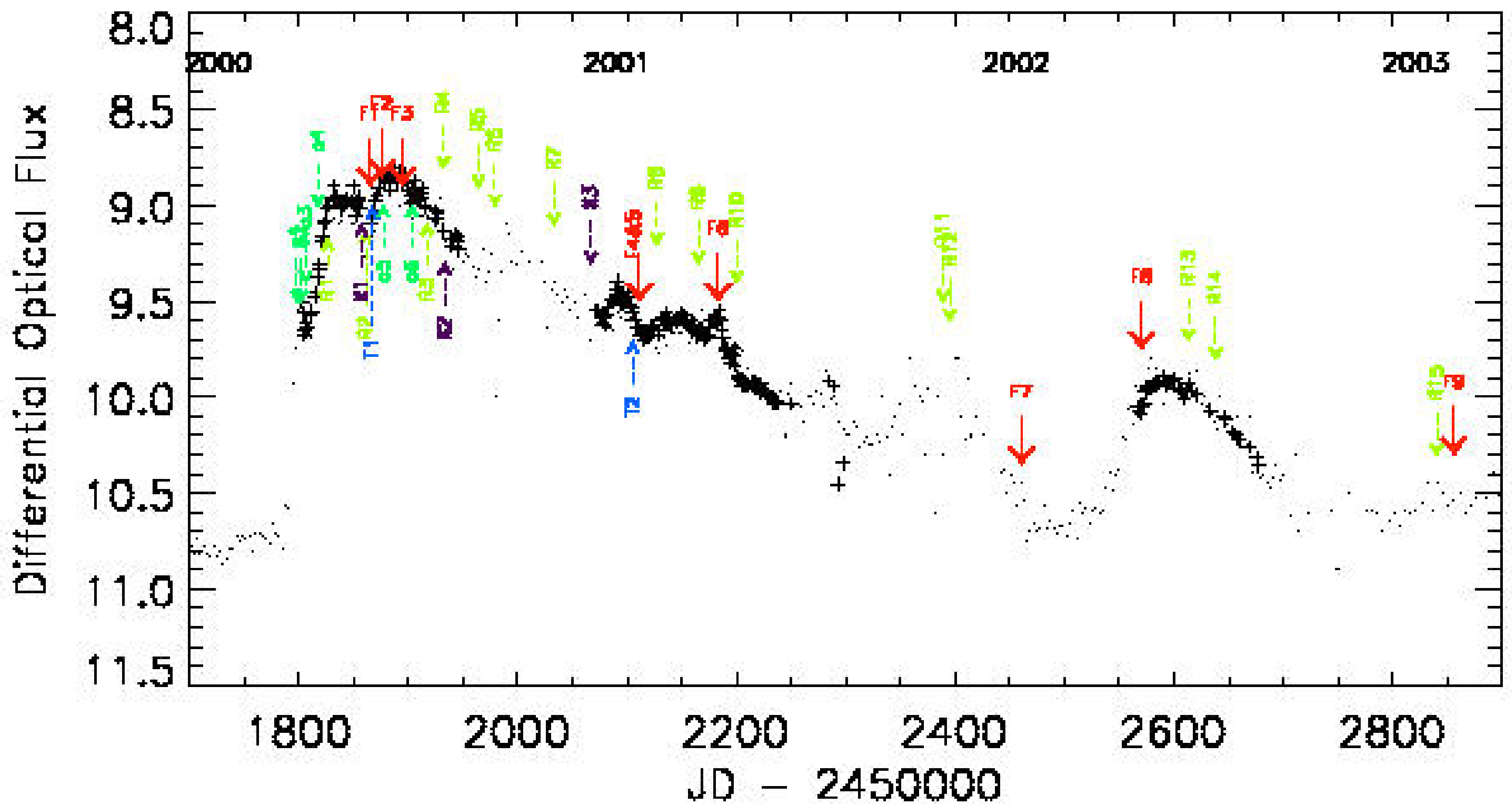


During 1997 Outburst:

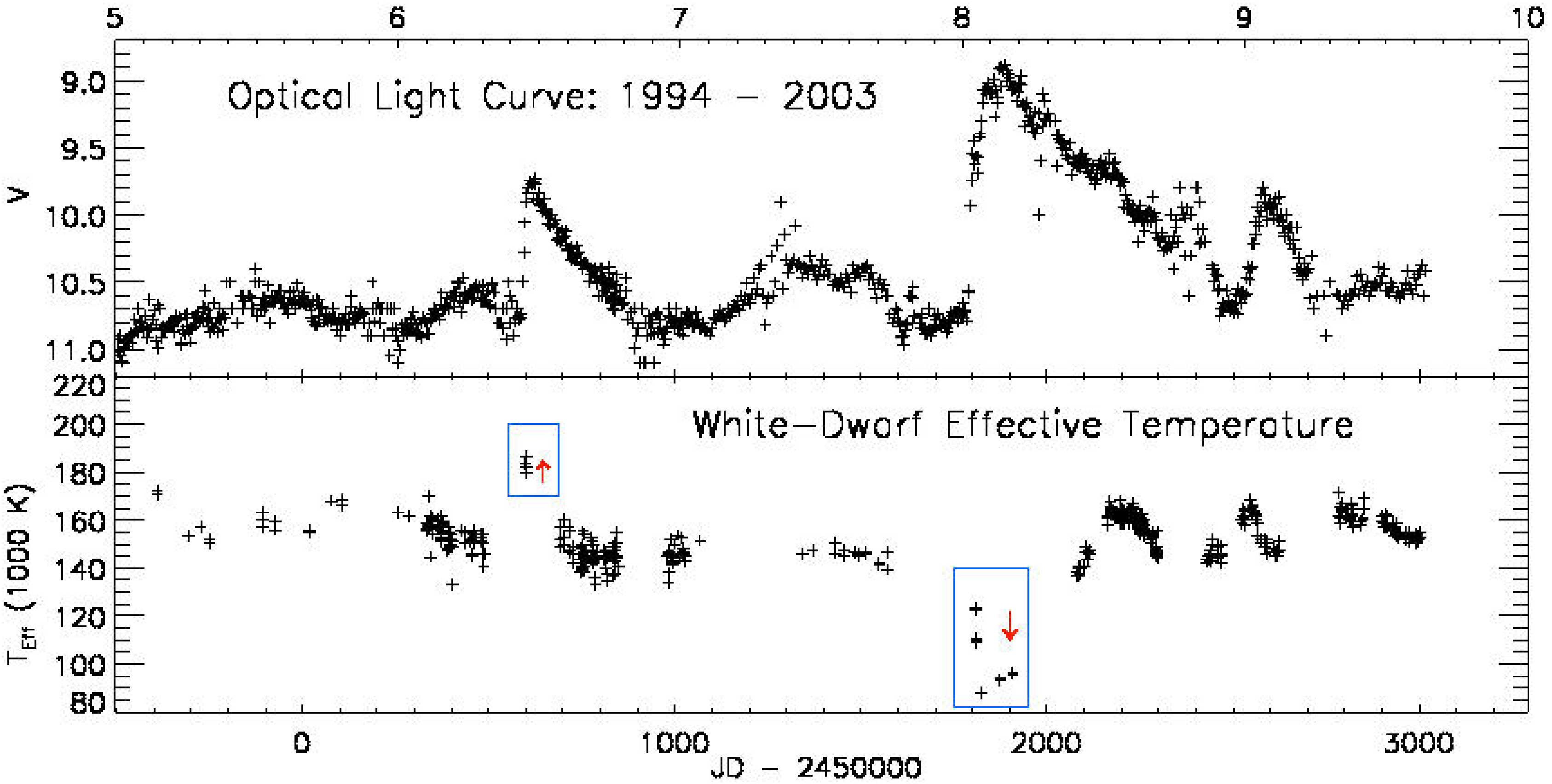
- Hot component effective temperature increased
- Hard X-ray flux increased
- Amplitude of 28-minute oscillation increased (Sokoloski & Bildsten 1999)

Multi-wavelength Monitoring

We observed Z Andromedae with the VLA, MERLIN, 3 ground-based optical telescopes, FUSE, XMM, and Chandra

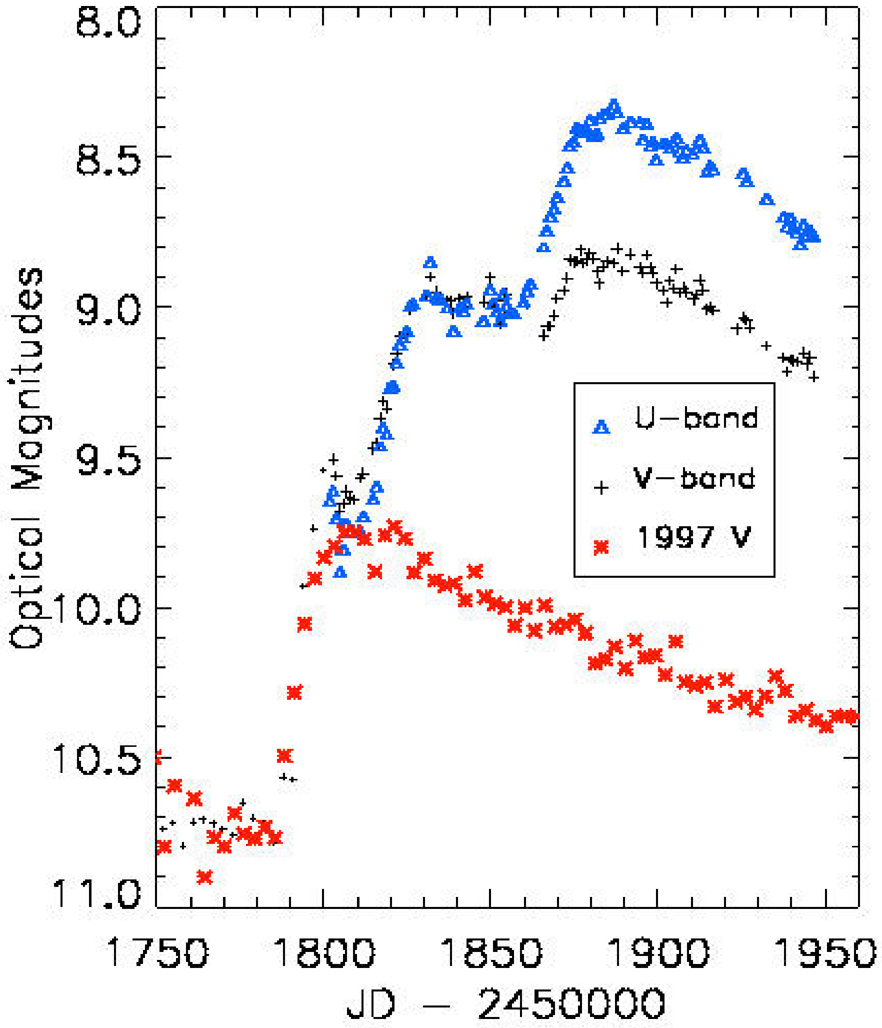


Results I: White-Dwarf T_{eff}



- The 1997 outburst was a dwarf nova.
- The 2000 outburst was something different.

Results II: Three-Stage Rise



- First stage: similar to 1997 event
- Second stage: shell ejection
- Third stage: shell clears to reveal a hot, luminous white dwarf

Results III: White-Dwarf Luminosity

Quiescence: $L_{WD} \sim 10^3 L_{sun}$ (Murset et al. 1991)

Outburst: $L_{WD} \sim 10^4 L_{sun}$ (from FUSE fluxes and WD photospheric model fitting)

➡ If 2000-2002 outburst entirely accretion powered:

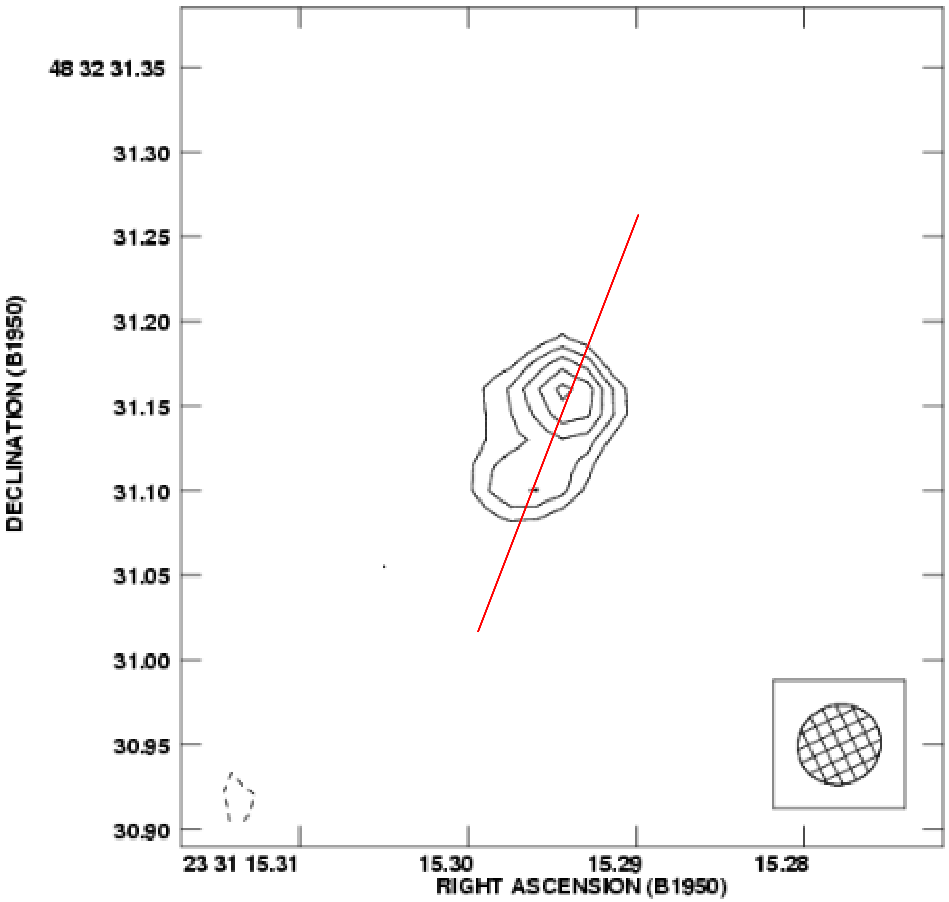
$$\dot{M} = \frac{LR_{WD}}{GM_{WD}} \approx 5 \times 10^{-5} \frac{M_{sun}}{yr} \left(\frac{L}{10^4 L_{sun}}\right) \left(\frac{R_{WD}}{0.1 R_{sun}}\right) \left(\frac{M_{WD}}{0.65 M_{sun}}\right)^{-1}$$

If nuclear powered, $\Delta M \approx few \times 10^{-7} - 10^{-6} M_{sun}$

➡ Outburst powered by nuclear burning

$$t_{nuc} = \left(\frac{C_P T}{E_{nuc}}\right) \left(\frac{\Delta M}{\dot{M}}\right) \approx 1 mo \left(\frac{T}{4 \times 10^6 K}\right) \left(\frac{\Delta M}{2 \times 10^{-5} M_{sun}}\right) \left(\frac{\dot{M}}{5 \times 10^{-8} M_{sun} / yr}\right)^{-1}$$

Mass Loss During Outburst



- Both spherical and collimated outflows
- As much as $3 \times 10^{-7} M_{sun}$ ejected in the collimated outflow (Brocksopp et al 2004)
- Unclear how much mass was lost in the shell ejection

Conclusions

- The amount of material ejected in classical symbiotic-star outbursts may determine whether symbiotics can be SNe Ia progenitors.
- To investigate classical symbiotic-star outbursts, we observed the 2000-2002 event in Z Andromedae. It was triggered by a dwarf-nova-like disk instability. The addition of fresh fuel then increased the rate of nuclear shell burning on the white dwarf.
- The outburst led to the ejection of a shell of material, as well as the production of a collimated outflow, or jet.

Questions

The discovery of a “combination nova” in Z And raises several questions:

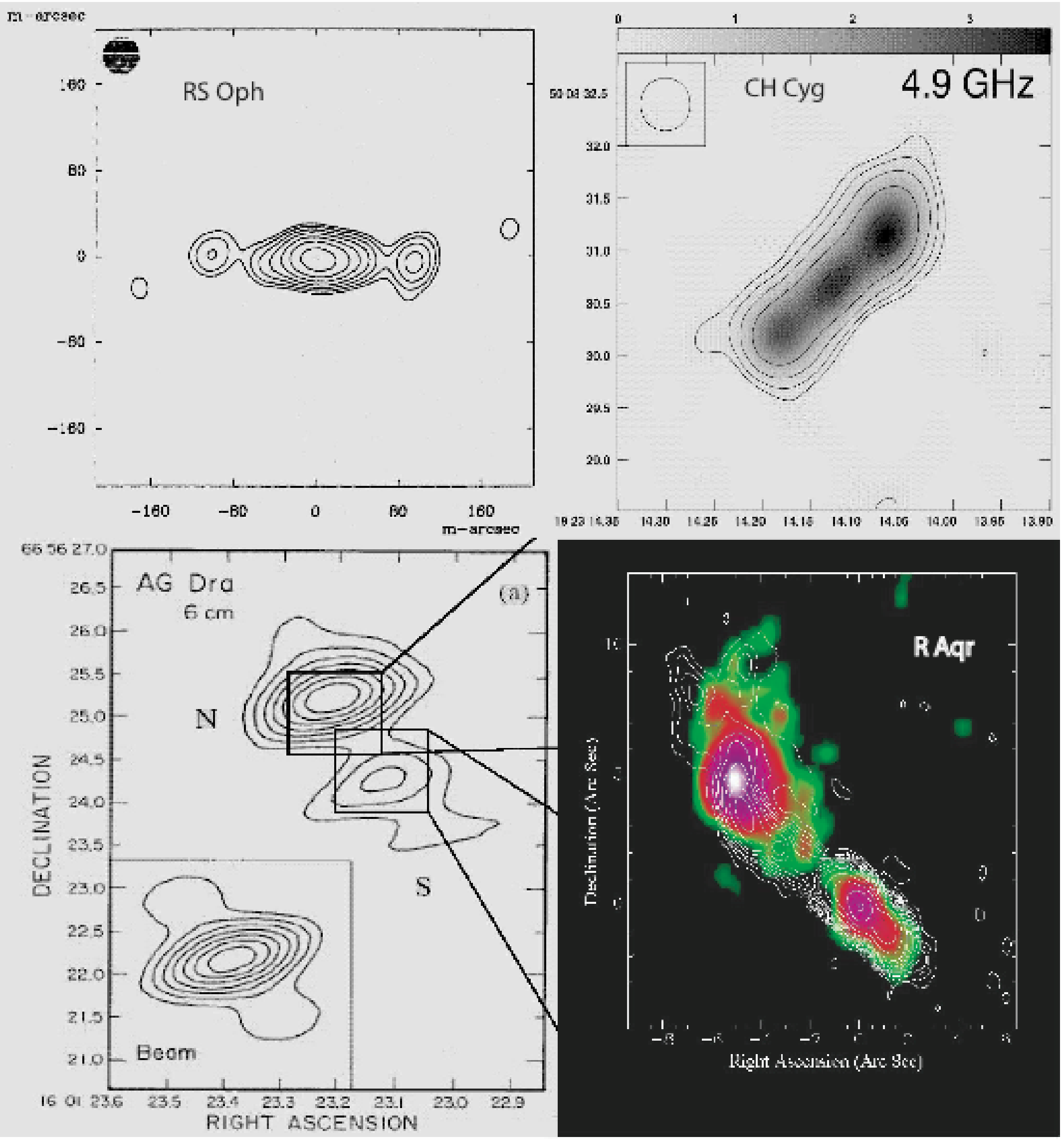
1. What happens when you suddenly dump fresh fuel onto a white dwarf experiencing quasi-steady nuclear shell burning?
2. How much mass is expected to be ejected in such an event?
3. What fraction of classical symbiotic-star outbursts are combination novae?

Gallery of Symbiotic-Star Jets

Angular sizes: tens of mas to tens of arcsec.

Physical sizes: tens to thousands of AU

Wide variety of symbiotics represented



Acknowledgments

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