Better off-line reviews

- Warner’s CV book (‘95)
- Bode & Evans nova book (‘89); new version coming next year (Shafter’s extragalactic nova review came from this)

What’s a nova look like?

\[ \mu = 10.5 \]

Fall: days - months
(Duerbeck ‘81)

\[ \mu = 9.1 \]

Rise: hours

- M31 & LMC novae (Della Valle & Livio ‘95)
- Galactic novae (Downes & Duerbeck ‘00)

• “Faster-brighter” and “slower-fainter” (opposite of Ia’s)
• Not great for doing distance measurements
Luminosity specific nova rate (LSNR)

- Pop. synth. (Yungelson et al. ‘97; Matteucci et al. ‘03) predicts dependence on SFR
- Observed LSNR pretty consistent with being constant…
- …but maybe higher for irregulars / dwarf ellipticals
- Optical surveys will clean up here!
How many classical novae will we see with new optical surveys? LOTS.

- Typical nova: $M_V \sim -8$
- $V \sim 24$ survey (Pan-Starrs / LSST) will see novae out to 25 Mpc (Virgo: 20 Mpc)
- $\sim 2$ novae per $10^{10} L_{\odot, K}$ per yr
- $\sim 5 \times 10^8 L_{\odot, K}$ per Mpc$^3$
- Depending on seeing / cadences / sky coverage, that’s $\sim 3000$ novae per yr!
Outcomes of H-accretion on WDs

1.0 $M_\odot$ WD

Classical novae

Supersoft sources

Stable H burning

(Classical novae)

(Townsley & Bildsten '05)
Accretion phase

- Thermal conditions set by compressing material:
  - accretion energy released in boundary layer (Piro & Bildsten ‘04) & nuclear burning negligible for now
  - calculation shows that $t_{th} \sim t_{acc}$ at the base of the layer, so profile set by conditions inside envelope

- Entropy equation yields

\[ L_{\text{comp}} = \dot{M} \int_{P_{\text{base}}}^{0} T \frac{dP}{dP} \, dP = \frac{7}{4} \dot{M} \frac{k_B T_{\text{base}}}{\mu m_p} \]

- Radiative diffusion gives trajectory of envelope base:

\[ T_{\text{base}} = 2 \times 10^7 \, \text{K} \left( \frac{\dot{M}_{-8} \rho_3^2}{M_1} \right)^{2/11} \]
Ignition conditions

- Layer follows that trajectory until nuclear burning becomes non-negligible:

\[
\left. \frac{\partial \epsilon_{\text{nuc}}}{\partial T} \right|_P > \left. \frac{\partial \epsilon_{\text{cool}}}{\partial T} \right|_P ,
\]

- First nuclear reaction to go is \( p + ^{12}\text{C} \) (neglecting my current research)
- Rough scaling:

\[
M_{\text{ign}} \propto \dot{M}^{-1/2} M^{-1/2} R^3
\]

- Also depends on \( T_{\text{core}} \) (see Townsley & Bildsten ‘04 for self-consistent \( T_{\text{core}} \) calculations; Yaron et al. ‘05 for grid)
Nova cycle

• Radiation can’t transport heat away anymore, so convection sets in
• Convective phase lasts long time (10’s of years), but $M_{\text{ign}}$ already set
• Once convective zone reaches surface, $L_{\text{bol}}$ jumps
• Super-Eddington due to convective transport of unstable $\beta$-nuclei ($^{13}\text{N}$, $^{14}\text{O}$, $^{15}\text{O}$, $^{17}\text{F}$; Starrfield et al. ‘72)
• Optical peaks during expansion (larger photosphere) and then falls during constant $L_{\text{bol}}$ phase

(Prialnik ‘86)
Mass loss

• Shock?
  – possibly in very energetic novae (Sparks ‘69), although MLT handling of convection isn’t ideal
  – even if it exists, it doesn’t play a huge role
• Optically thick wind (Kato & Hachisu ‘94):
  – radiation-driven wind from within photosphere
  – enabled by new OPAL opacities (‘92); actually predicted by Kato & Iben (‘92)
• Common envelope (e.g., MacDonald ‘80):
  – in CV, binary separation is roughly

\[ a \sim 10^{11} \text{ cm} \left( \frac{P_{\text{orb}}}{5 \text{ h}} \right)^{2/3} \left( \frac{M}{M_\odot} \right)^{1/3} \]

  – interesting that novae might be only practical way to observe CE’s in real-time (“hey, look at me!”)
Constant bolometric luminosity phase

- Just like max Mdot for stable burning (Fujimoto ‘82) and RG $M_{\text{core}}$-L relationship (Paczynski ‘71), there is a max $M_{\text{env}}$ and L for given $M_{\text{WD}}$
  - can think of this as an Eddington argument, but for the whole envelope (actually, it’s hydrostatic equilibrium)
  - also depends on envelope composition

Also a min $M_{\text{env}}$; once fuel consumption and mass loss get here, burning stops, and cycle starts again
Constant bolometric luminosity phase

- Given $M_{\text{env}}$ and $L$, can calculate length of phase: months to years (and not decades, as might be expected if $M_{\text{ign}}$ used)

- What does this look like? Photosphere recedes back, so spectrum becomes harder, optical falls
  - $L \sim 10^4 L_\odot$, $R \sim 10^9$ cm: 10’s of eV’s
  - shows up in EUV / soft X-rays

- Current M31 campaign (Pietsch et al. ‘05, ‘07) finding plenty of supersoft sources where optical novae occurred: bingo!

(Kahabka & van den Heuvel ‘97)
M31 Red Variable (‘88; Rich et al. ‘89) and V838 Mon (‘02; Munari et al. ‘02)

M31 RV much slower for its high $L$…big H shell? (Iben & Tutukov ‘92); V838 Mon had 3 separate peaks

Tylenda & Soker (‘06) argue against nova (no way for nova to stay cool) and argue for stellar mergers