What stars create Type Ia Supernova? Now a big-money question.

Recurrent novae (RN) are a likely progenitor. But two big problems…

Archival data is the only way to answer the big question

Now, huge & comprehensive set of archival RN data
Perennial problem:

WHAT IS THE PROGENITOR SYSTEM FOR TYPE Ia SUPERNOVAE?

SUDDENLY A VITAL BIG-MONEY PROBLEM:
- Must know progenitor to calculate change in SN Ia $M - \Delta t_{15}$ relation
- Evolution of metallicity in old Universe change Hubble Diagram shape
- SNAP cannot achieve goal without progenitor/evolution solution
**PROPOSED PROGENITORS:**
- Recurrent Novae
- Symbiotic stars
- Super-soft sources
- Double White Dwarf Binaries

**RECURRENT NOVAE:**
- Recurrent Novae are just a subset of ordinary novae that happen to go off more than once per century
- As such, they are binary systems with matter flowing off a companion star onto a white dwarf, accumulating on its surface until the pressure gets high enough to trigger a thermonuclear runaway (like an H-bomb) that is the nova
- Only 10 known in our Milky Way galaxy, including:
  - T Pyx (1890, 1902, 1920, 1944, 1967)
  - T CrB (1866, 1946)

**RECURRENT NOVAE ARE LIKELY SOLUTION:**
To recur with $\tau_{\text{rec}} < 100$ years, RNe must have:
- High WD mass ($1.2M_{\odot} < M_{\text{WD}} < M_{\text{Chandra}}$)
- High accretion rate ($M \sim 10^{-7} M_{\odot}/\text{yr}$)

$M_{\text{WD}}$ will exceed $M_{\text{Chandra}}$ any year now…
SN Ia
TWO PROBLEMS:

• Does the White Dwarf eject more mass each eruption than it gains between eruptions?
  \[ M_{\text{ejecta}} < \tau_{\text{rec}} \dot{M} \]

• Are there enough RNe to produce the observed Type Ia SN rate?
  \[ R_{\text{RNdeath}} = R_{\text{SNIa}} \]

\[ R_{\text{RNdeath}} = \frac{N_{\text{RN}}}{(0.2M_\odot)} \]

SOLUTION NEEDS GOOD RN DEMOGRAPHICS:

• \( \tau_{\text{rec}} \) - recurrence time scale

• \( N_{\text{RN}} \) - number of RNe in Milky Way

• \( \dot{M} \) - mass accretion rate onto white dwarf

• \( M_{\text{ejecta}} \) - mass ejected in eruption
CAN GET THESE ONLY FROM HISTORICAL/ARCHIVAL DATA:

• $\tau_{\text{rec}}$ - can only look in archival plate collections

• $N_{\text{RN}}$ - archival plates and AAVSO data only way to measure discovery efficiency

• $M$ - changes on all time scales, but we need average over the last century

• $M_{\text{ejecta}}$ - must have pre-eruption eclipse timings
PRODUCTS:  [also, see http://www.phys.lsu.edu/recurrentnova/]

• Modern measures of all comparison stars
• Remeasure all archival plates [only data for half the eruptions]
• Complete light curves for all 37 known RN eruptions
• B & V light curve templates for each RN in eruption
• 10,000 CCD magnitudes during quiescence [essentially only data for 7 RNe]
• Year-by-year discovery efficiencies for all RNe
• Recurrence time scales and predicted next dates of eruption
• Best distances and extinctions for all 10 RNe
• Intrinsic absolute magnitudes and colors at peak and quiescence
• UBVRIJHK spectral energy distribution for all 10 RNe

HIGHLIGHTS:

• 6 newly-discovered RN eruptions
• 1 newly-discovered RN
• 5 newly-discovered orbital periods
• U Sco will next erupt any month now
• Horrifyingly low nova discovery efficiencies
• 5 accurate distance measures (based on companion stars)
RESULTS: [also, see my Poster 491.04 on Wednesday]

- U Sco will go off any month now…
  - First time a nova eruption has been predicted for a given star and year
  - Great opportunity to prepare; large international USCO2009 collaboration

- Discovery efficiencies ~ 4% for average nova
  - Huge opportunity for amateurs to discover the missing novae
  - ~80 of ‘classical novae’ now in catalogs are really recurrent

- Discovery of sudden sharp drop in eruption light curves
  - Mystery for theorists

- $M_{\text{ejecta}} < \tau_{\text{rec}} M$ for CI Aql and U Sco
  - White dwarves are gaining mass → RNe will collapse as Type Ia SNe

- $R_{\text{RNe death}} \sim R_{\text{SN Ia}}$ for Milky Way, M31, & LMC
  - There are enough RNe to supply the Type Ia events
STORYLINES:

MOST NOVA ERUPTIONS ARE NOT DISCOVERED
- Discovery efficiency is <10%
- This opens up a tremendous opportunity for enterprising amateurs to use the latest in off-the-shelf cameras and a nightly observing cadence to discover many novae
- Roughly a third of so-called ‘Classical Novae’ are actually recurrent novae with multiple eruptions in the last century (all but one of which were missed)

RECURRENT NOVAE AS LIKELY PROGENITORS OF TYPE Ia SUPERNOVAE
- Long-lasting progenitor problem of vital importance for supernova cosmology & SNAP
- Recurrent novae must have high-mass white dwarfs and high accretion rates, so they are a likely solution to the progenitor problem
- Two big questions, for which the only solution can come from archival data
- I have collected a huge and exhaustive database from Harvard plates and the AAVSO
- Results show that white dwarf is gaining mass and there are ~10,000 RN in the Milky Way

ARCHIVAL DATA HAS FRONT-LINE ASTROPHYSICS
- Archival data sources (e.g., the Harvard Plates and the AAVSO data base) have wonderful discoveries and front-line astrophysics tucked away.
- Archival material is often the only way to get coverage in the time domain longer than a few years, and this is often critical for astrophysics
- Worldwide collections of archival astrophotos need conservation and digitization
- The younger generation of astronomers needs to learn how to use the archival data, and to realize that the riches are there for the taking