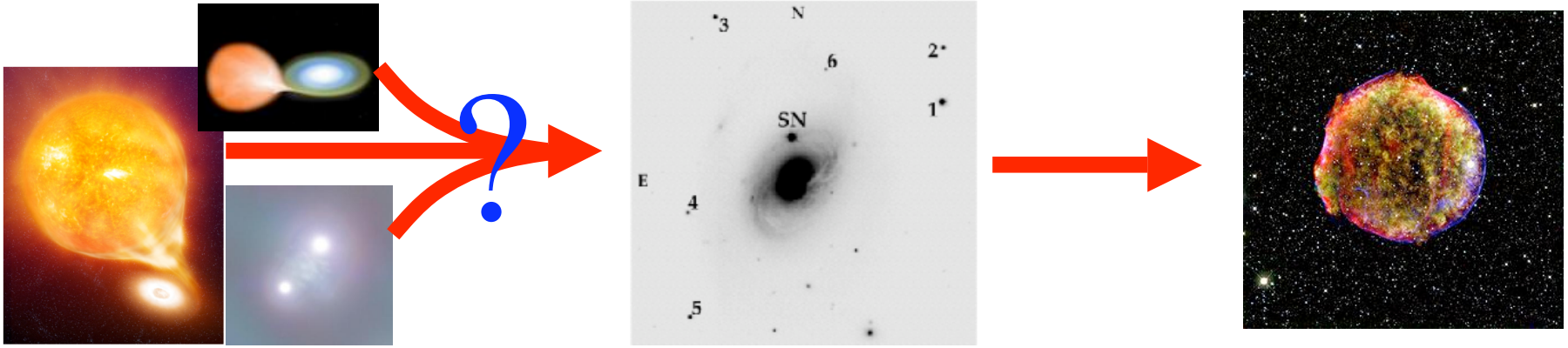
FRONT-LINE RECURRENT NOVA SCIENCE REQUIRES CENTURY-OLD DATA

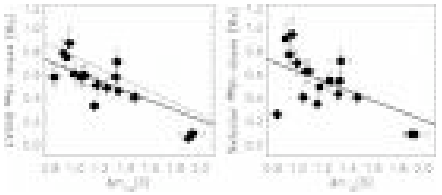
Bradley E. Schaefer (Louisiana State University)

Perennial problem:

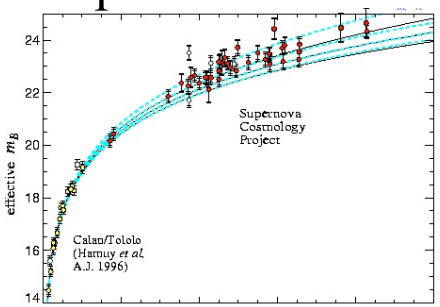
WHAT IS THE PROGENITOR SYSTEM FOR TYPE Ia SUPERNOVAE?



SUDDENLY A VITAL BIG-MONEY PROBLEM:

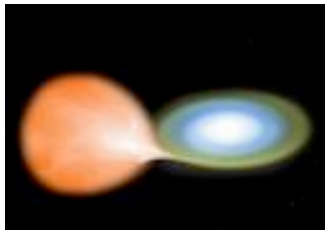


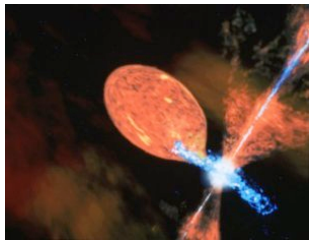
- Must know progenitor to calculate change in SN Ia M-Δt_{15} relation
- Evolution of metallicity in old Universe → change Hubble Diagram shape
- *SNAP* cannot achieve goal without progenitor/evolution solution



PROPOSED PROGENITORS:

- Recurrent Novae
- Symbiotic stars
- Super-soft sources
- Double White Dwarf Binaries






RECURRENT NOVAE ARE LIKELY SOLUTION:

To recur with τ_{rec}<100 years, RNe must have:

- High WD mass ($1.2M_{\odot}<M_{WD}<M_{Chandra}$)
- High accretion rate ($\dot{M}\sim10^{-7}\ M_{\odot}$/yr)

M_{WD} will exceed $M_{Chandra}$ any year now… → SN Ia

TWO PROBLEMS:

- Does the White Dwarf eject more mass each eruption than it gains between eruptions?

  $M_{ejecta} < \tau_{rec}\ \dot{M}$?

- Are there enough RNe to produce the observed Type Ia SN rate?

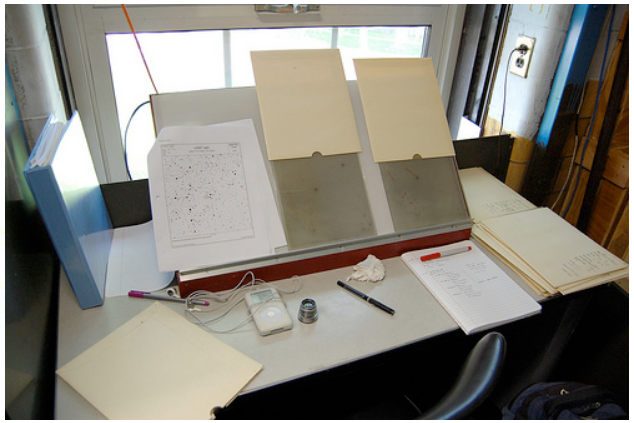
  $R_{RNdeath} = R_{SNIa}$? $R_{RNdeath} = N_{RN} / (\dot{M} 0.2M_{\odot})$

RN DEMOGRAPHICS REQUIRED TO ANSWER THE FRONT-LINE QUESTIONS:

- τ_{rec} - recurrence time scale
- N_{RN} - number of RNe in Milky Way
- $\dot{M}$ - mass accretion rate onto white dwarf
- M_{ejecta} - mass ejected in eruption

CAN GET THESE ONLY FROM HISTORICAL/ARCHIVAL DATA:

- τ_{rec} - can only look in archival plate collections
- N_{RN} - archival plates and AAVSO data only way to measure discovery efficiency
- $\dot{M}$ - changes on all time scales, but we need average over the last century
- M_{ejecta} - must have pre-eruption eclipse timings



τ_{rec} = Average Recurrence Time Scale:

Most RN eruptions are *not* discovered:

- Undirected searches: <efficiency> = 4% (0.6%-19% full range)
- Directed searches: <efficiency> = 60% (30%-100% full range)

Missed eruptions make for errors of ~3X in τ_{rec}:

- CI Aql: Old τ_{rec}=83 years [2000-1917]
  - -But I found 1941 eruption
  - -Steady brightness 1941-2000 shows eruption ~1975 missed
    - ➔ τ_{rec}=27 years (3X error)
- U Sco: Old τ_{rec}=24 years [6 eruptions since 1863]
  - -But I found 1917, 1945, & 1969 eruptions
  - -Steady eruptions every 10±2 years (lost behind Sun in 1927 and 1957)
    - ➔ τ_{rec}=10±1 years (2.4X error)
- V2487 Oph: Naive τ_{rec}=98 years [1998-1900]
  - -But <efficiency>=30% 1890-2008 with two eruptions found
    - ➔ τ_{rec}=18 years (5.4X error)
- RS Oph: Old τ_{rec}=23 years [5 eruptions since 1890]
  - -But new-found eruptions in 1907 & 1945 plus new eruption in 2006
    - ➔ τ_{rec}=14 years (1.6X error)

N_{RN} = Number of RN in our Milky Way:

(and in M31 and LMC)

- $N_{RN} = N_{known} / (F_{discoverable}\, \varepsilon_{RN})$

  $N_{known} = 10$

  $F_{discoverable} \approx 0.2$ (Shafter 2002)

  ε_{RN} = Discovery efficiency for finding 2-or-more nova eruptions

$<\varepsilon_{discovery}>=4\%$ For one event →

	3 eruptions
Most never seen at all	88.5%
A few with 1 event (labeled 'CN')	11%
Rarely, 2 or more events seen	0.5%

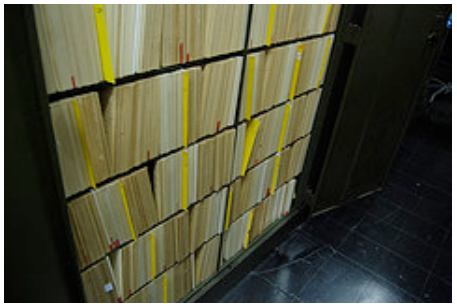
$\varepsilon_{RN}=1/200$

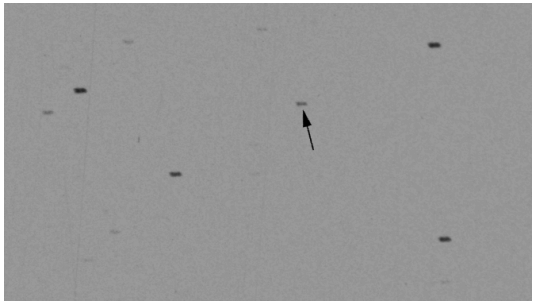
$\sim 10 \times N_{known}$ RNe are hiding as cataloged 'Classical Novae'

$N_{RN} = 10 / (0.2/200) = 10{,}000$ RNe in our galaxy!

- TEST: Seek old eruptions of 'Classical Novae': Success - Nova Oph 1998 erupted in 1900

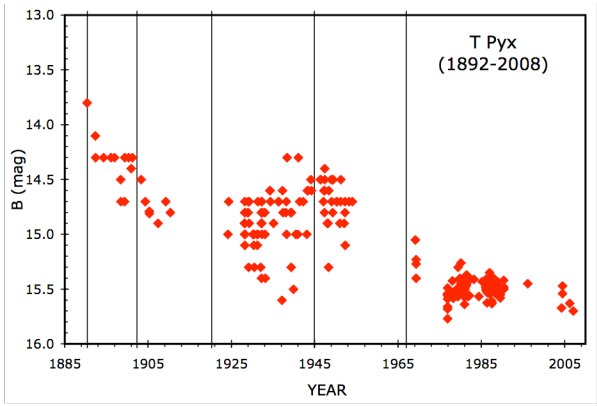
(Pagnotta, Schaefer, & Xiao; 2008)

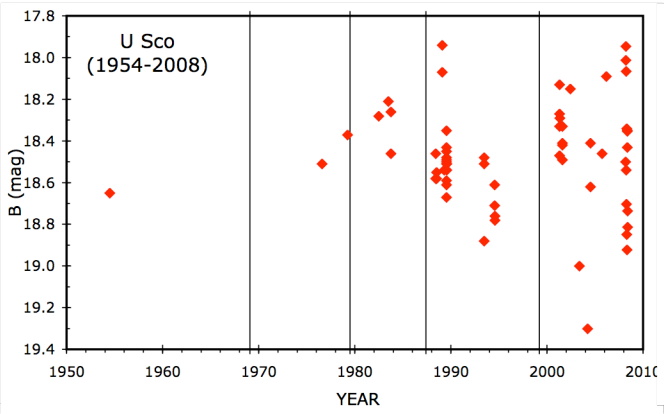


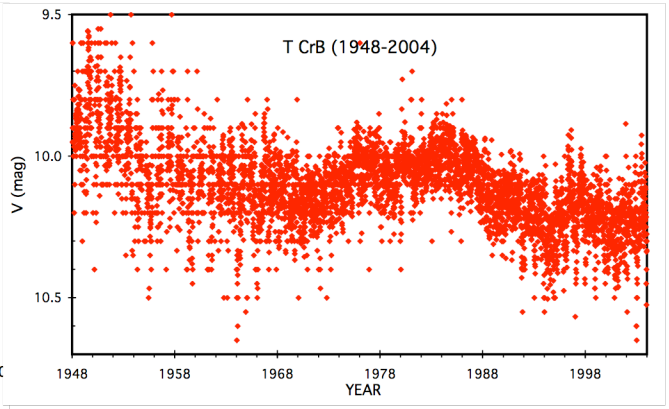


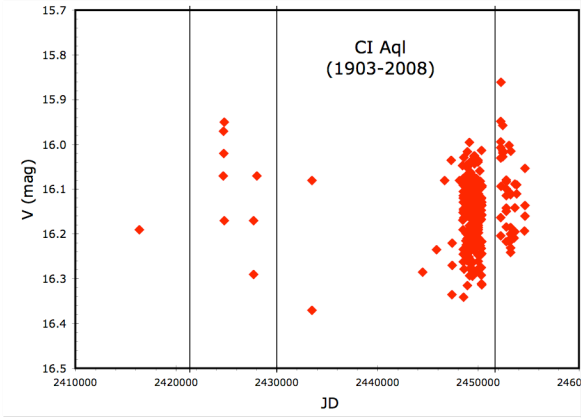
$\dot{M}$ = Average Mass Accretion Rate:

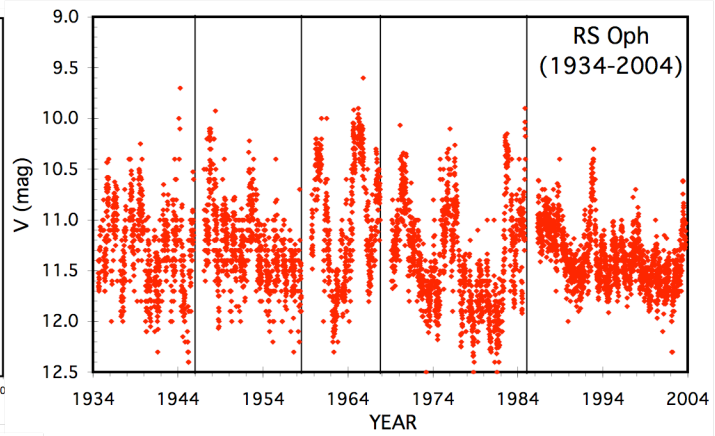
$\dot{M} \propto F_{blue}^{1.5}$

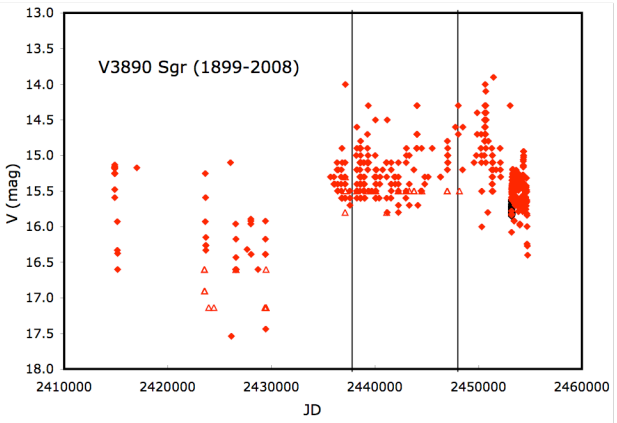


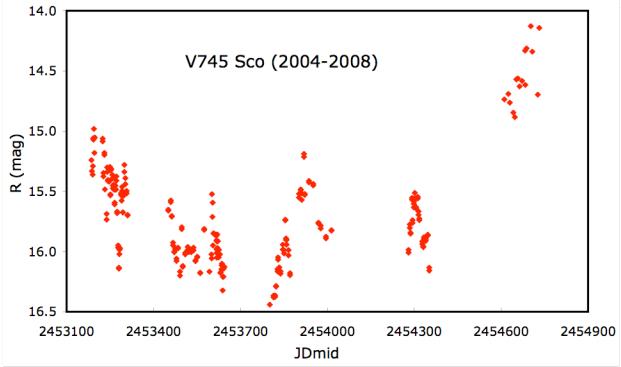


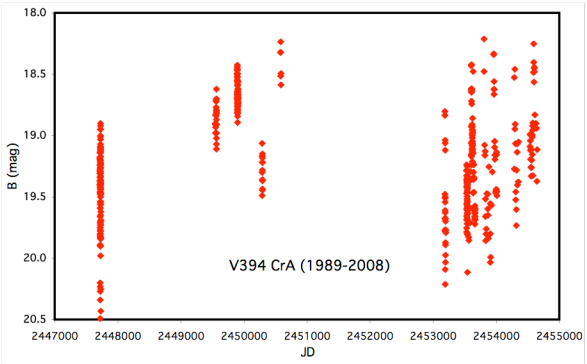












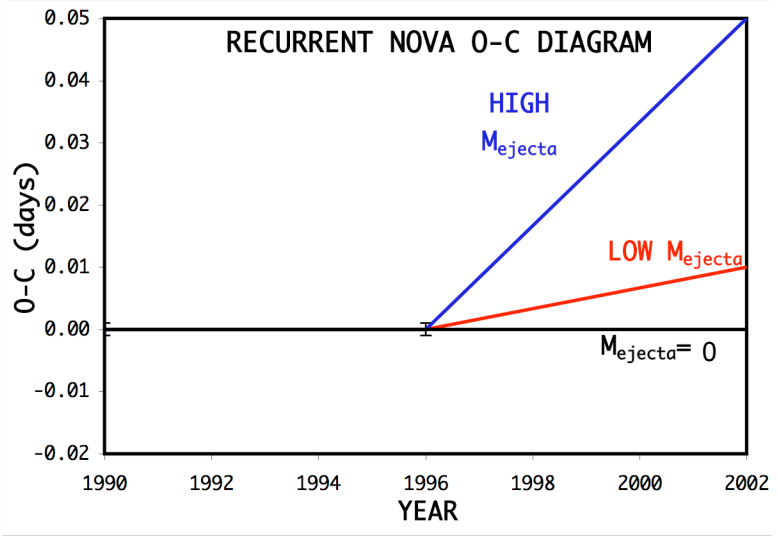
- $\dot{M}$ varies by 10X on all timescales
- Archival data (from Harvard & AAVSO) allow for correct measures

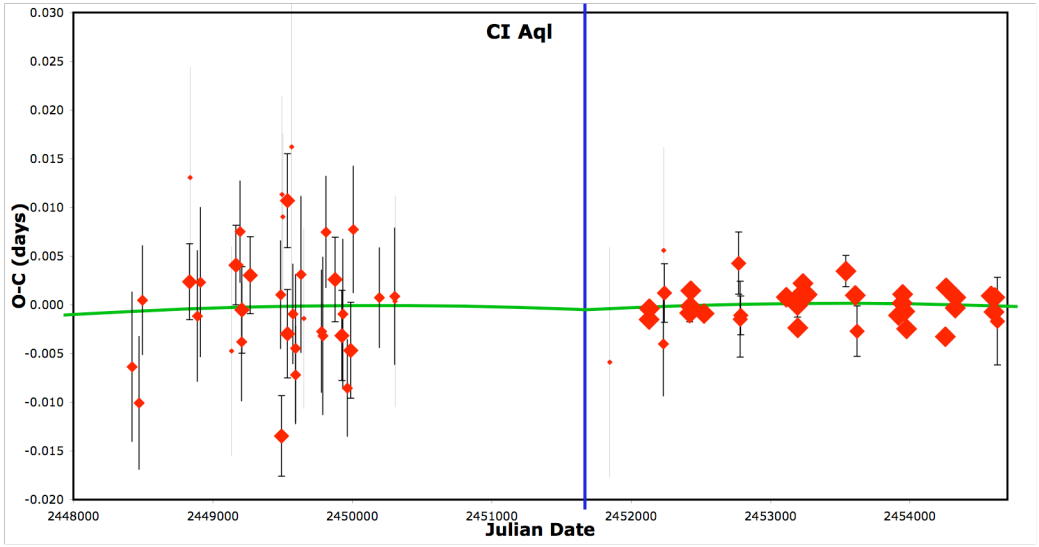
M_{ejecta} = Mass ejected by nova eruption:

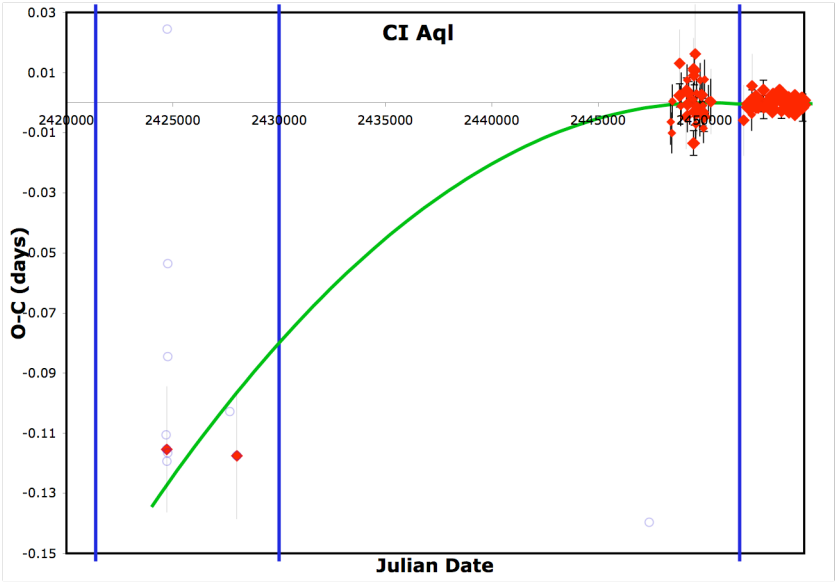
Orbital period change across an eruption (ΔP)
will give the ejected mass: $M_{ejecta} = 0.91\ M_{WD}(\Delta P/P)$

Need *pre*-eruption eclipse times:

- Harvard plates
- AAVSO archives
- Archival light curves (mine and Roboscope)







Results for CI Aql:

$\Delta P = (8 \pm 4) \times 10^{-7}$ days

$M_{ejecta} = (1.5 \pm 0.7) \times 10^{-6}\ M_{\odot}$

RESULTS:

[see also my Poster 491.04 on Wednesday]

- $R_{RNdeath} \sim R_{SNIa}$ for Milky Way, M31, & LMC
- $M_{ejecta} << \tau_{rec} \dot{M}$ for CI Aql and U Sco

LESSONS:

- Most nova events are missed ➔ Great opportunity for observers
  ➔ ~30% of 'Classical Novae' are RNe with multiple eruptions in the last century
- Harvard plates should be digitized
  [see Poster 427.07 by Tang, Grindlay, Los, & Laycock]
- Front-line science is laying around in archival data
- Science unique and unobtainable with modern telescopes
  [cf. Special Session on Monday]