Classical Nova Rates and Properties

A. W. Shafter

San Diego State University

Outline of Talk

I. Extragalactic Nova Rates

II. Nova Properties

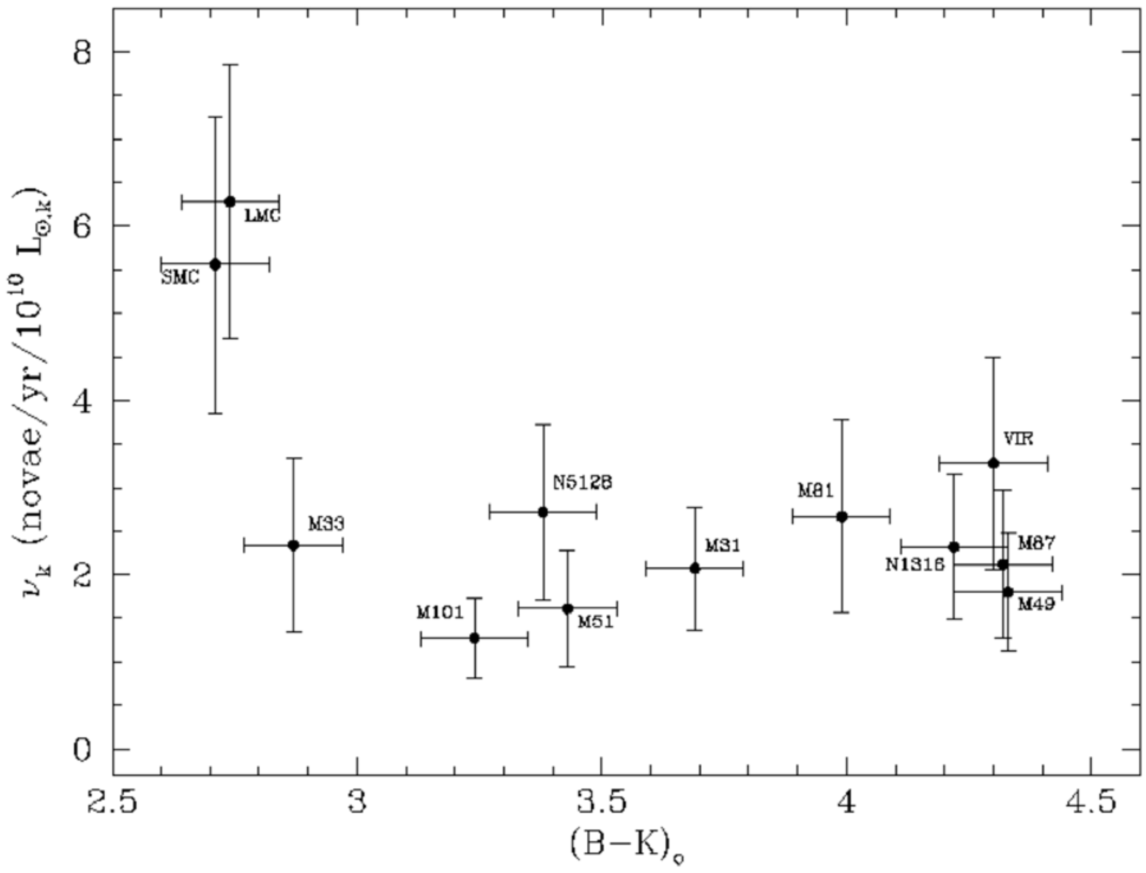
- Nova Population Differences
- Spectroscopic Classes of Novae

III. Recurrent Novae in M31

- Are RNe a significant progenitor of SNe Ia?

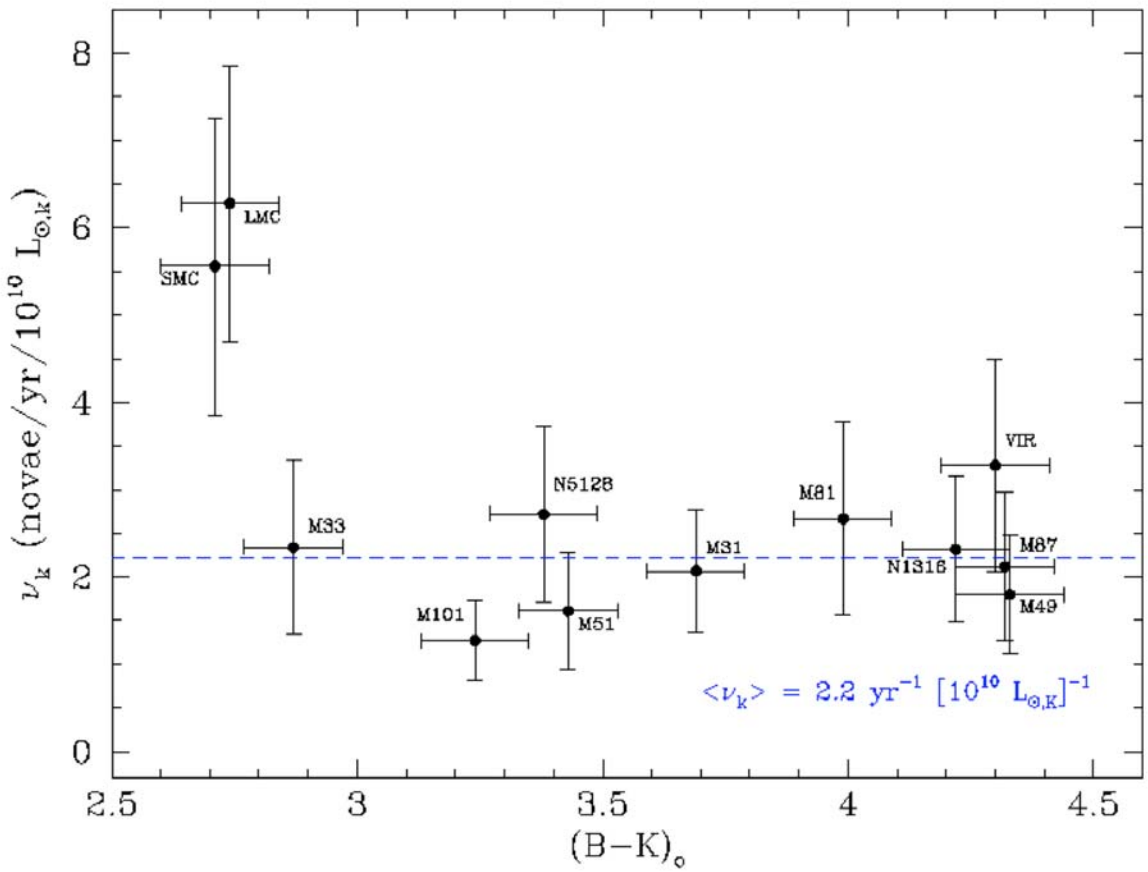
Luminosity-Specific Nova Rates

From Williams & Shafter (2004)



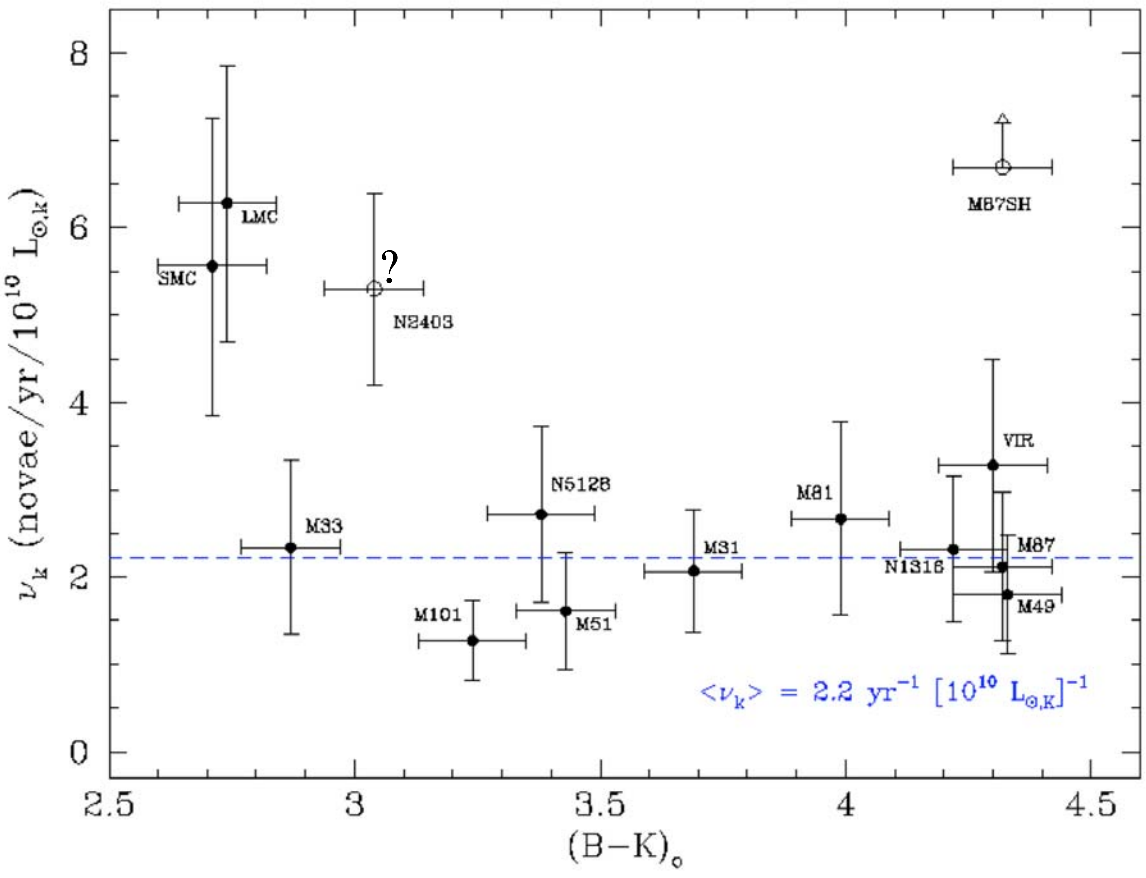
Luminosity-Specific Nova Rates

From Williams & Shafter (2004)

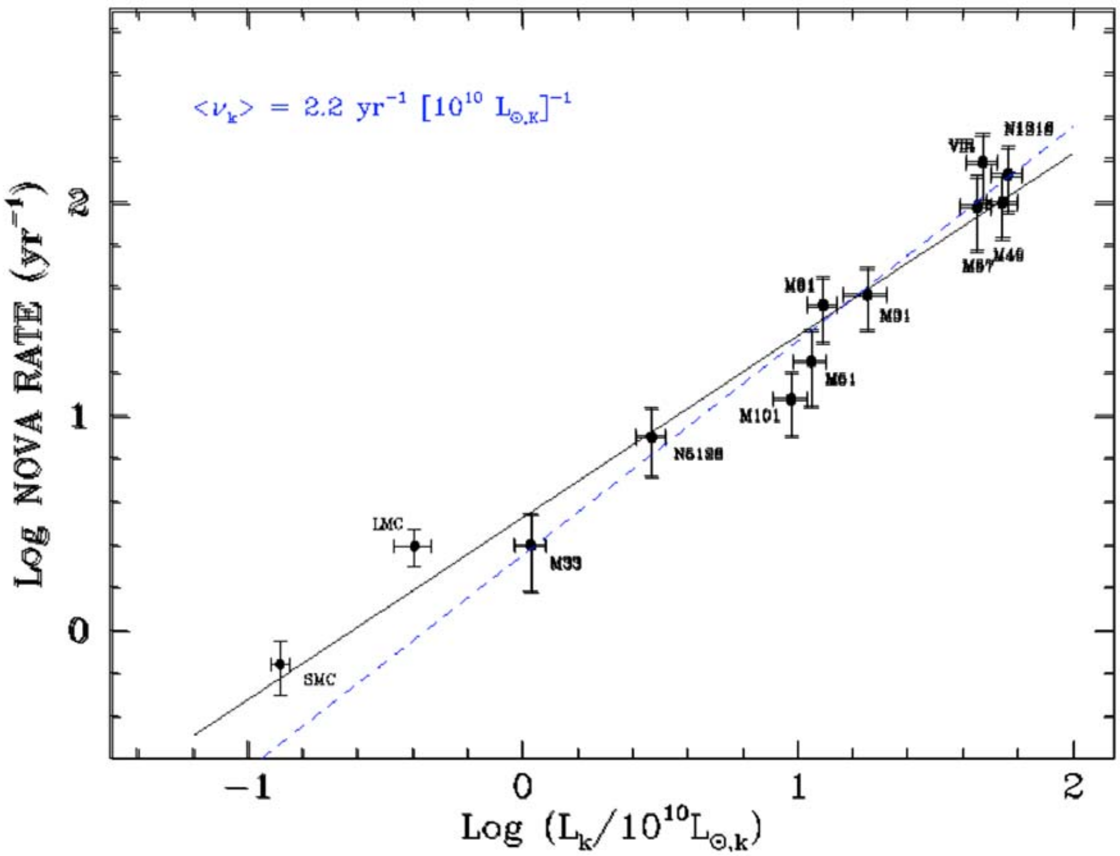


Luminosity-Specific Nova Rates

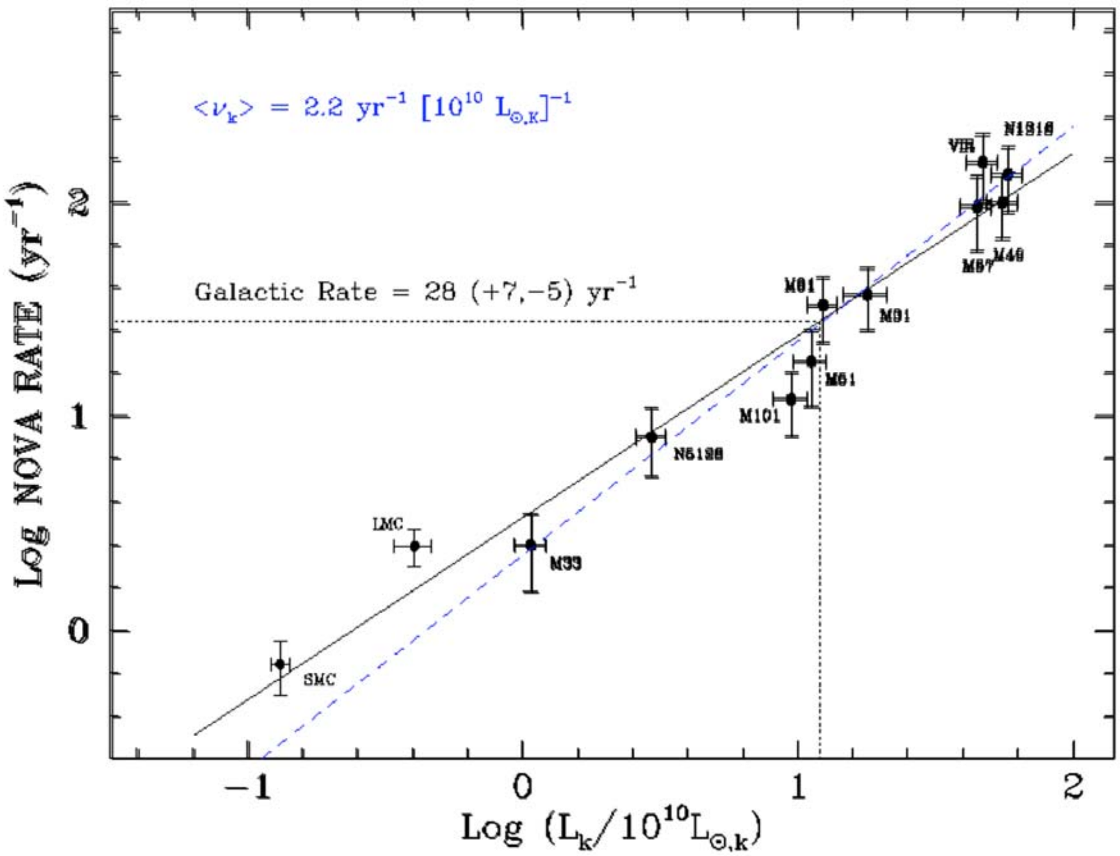
From Williams & Shafter (2004)



Nova Rates vs Galaxy *K*-band Luminosity



Nova Rates vs Galaxy *K*-band Luminosity



M31: Principal Historical Target

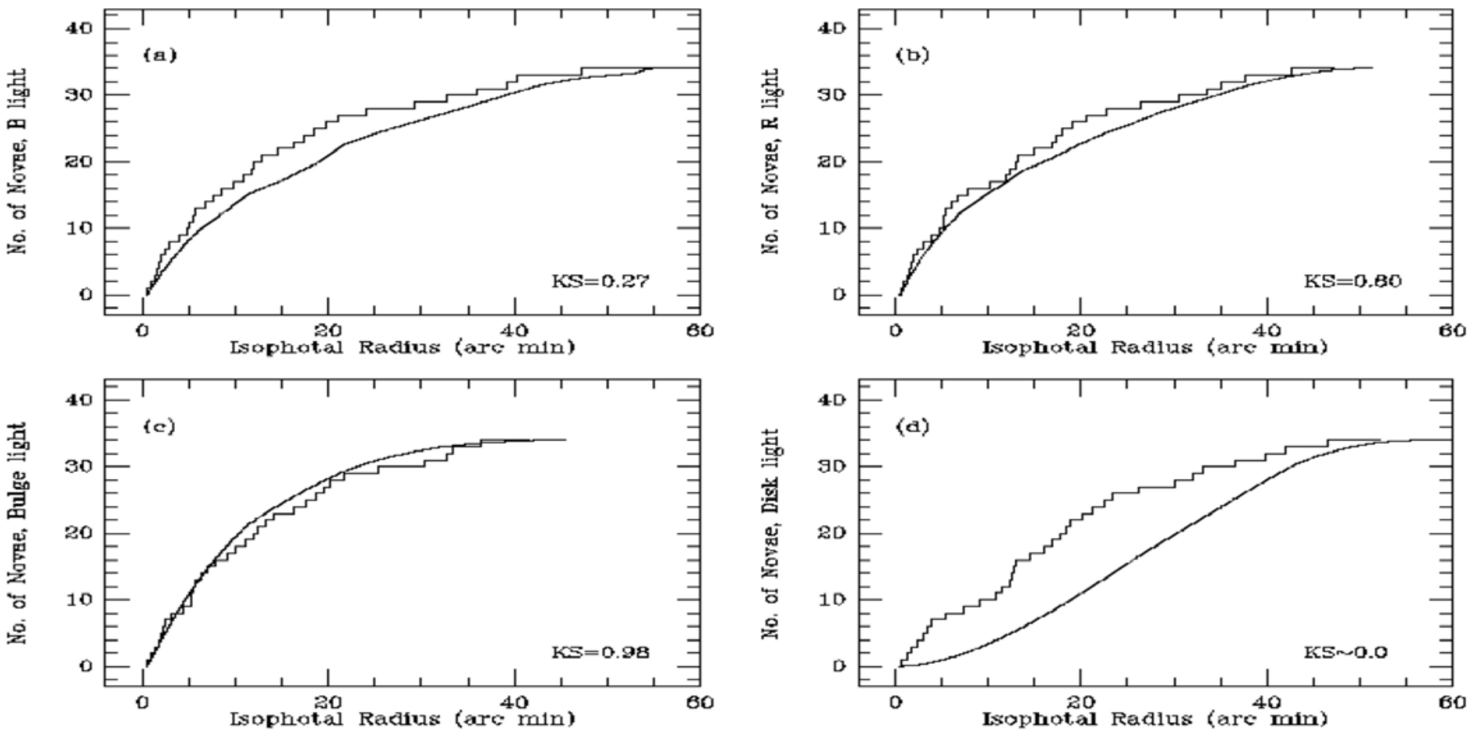
Major Studies:	Novae
• Hubble (1929)	85
• Arp (1956)	30
• Rosino (1964;1973)	142
• Ciardullo et al. (1987)	40
• Shafter & Irby (2001)	82
• Darnley et al. (2006)	20
• Others (inc. amateurs)	>400
Total:	>800

Principal Conclusions:

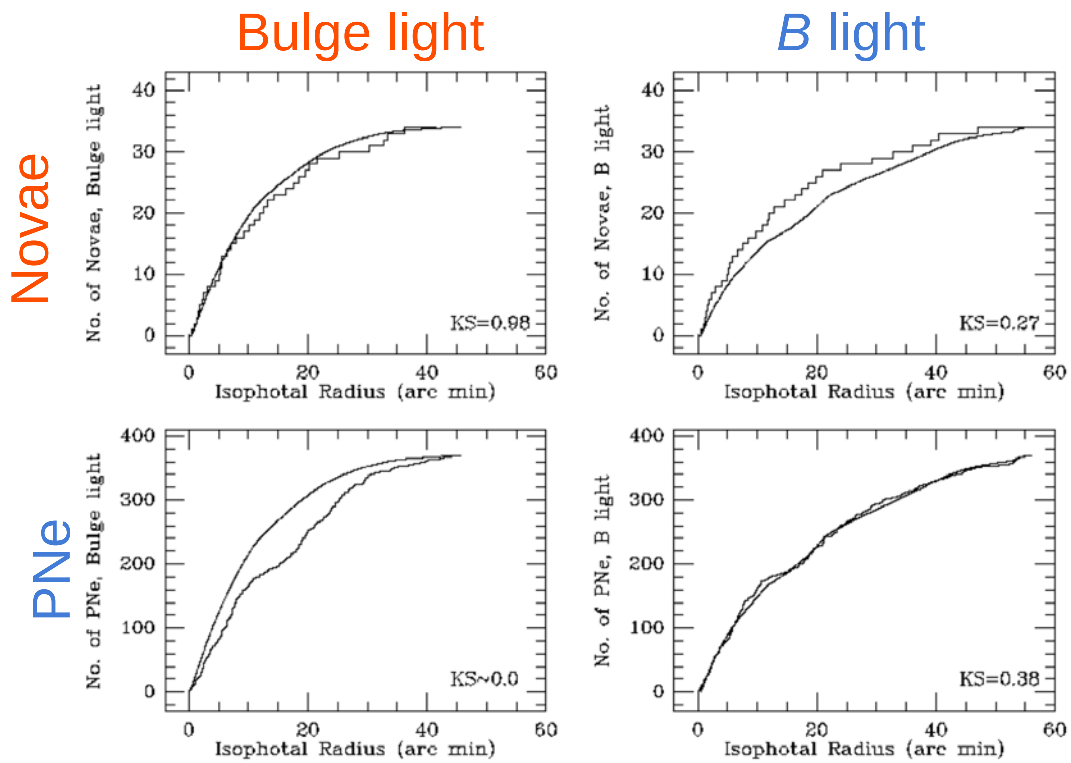
- Nova Rate ~30-40 (65!?) yr^{-1}
- ***Appear consistent with a mainly bulge population***

Cumulative Distribution of Novae vs Isophotal Radii

- The radial distribution of novae matches the Bulge light significantly better than the galaxy's disk light, or total broadband light (Shafter & Irby 2001).
- Is extinction in the disk a problem?



Cumulative Distributions of M31 Novae and PNe



- Novae are clearly more centrally concentrated than are PNe in M31.
- This result is robust in that it is not affected by the degree of extinction in the disk of M31.
- It appears that novae in M31 are primarily associated with the bulge population.

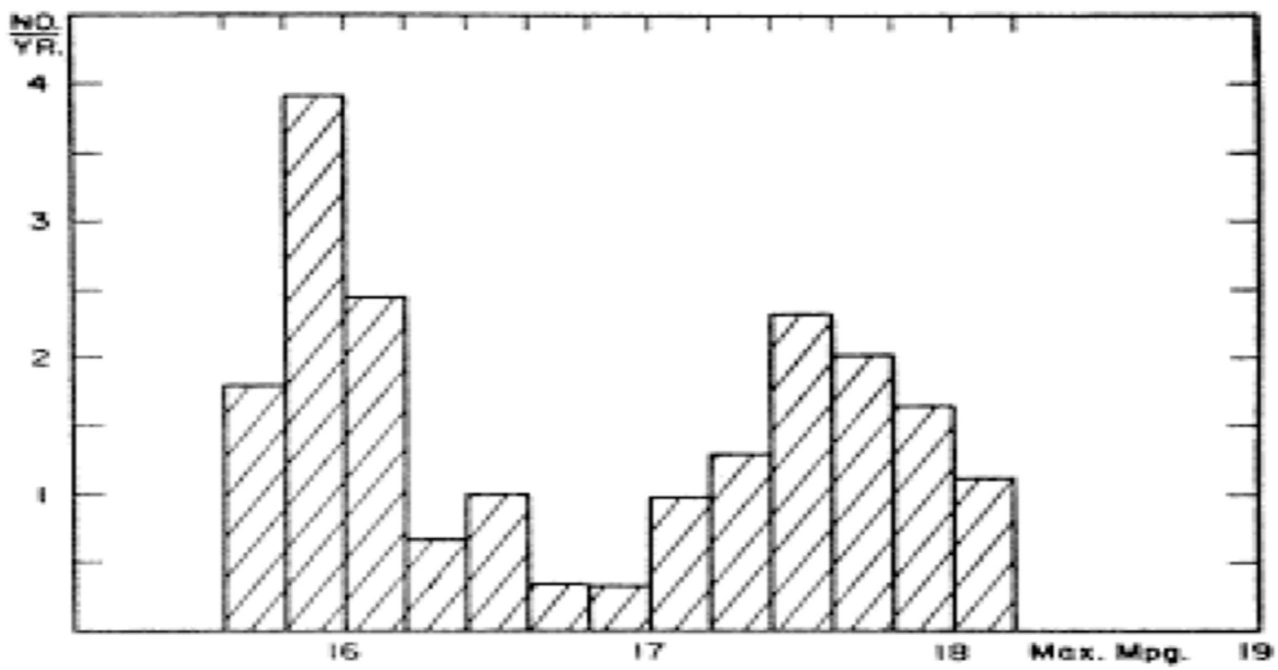
Nova Populations

- Could the relatively high M31 bulge rate result from an additional formation mechanism?
  (e.g., could some fraction of bulge novae be spawned in globular clusters?)
  M87 rate may be ~3 times M49, as is the GC population!

- Are there two distinct populations of Novae?

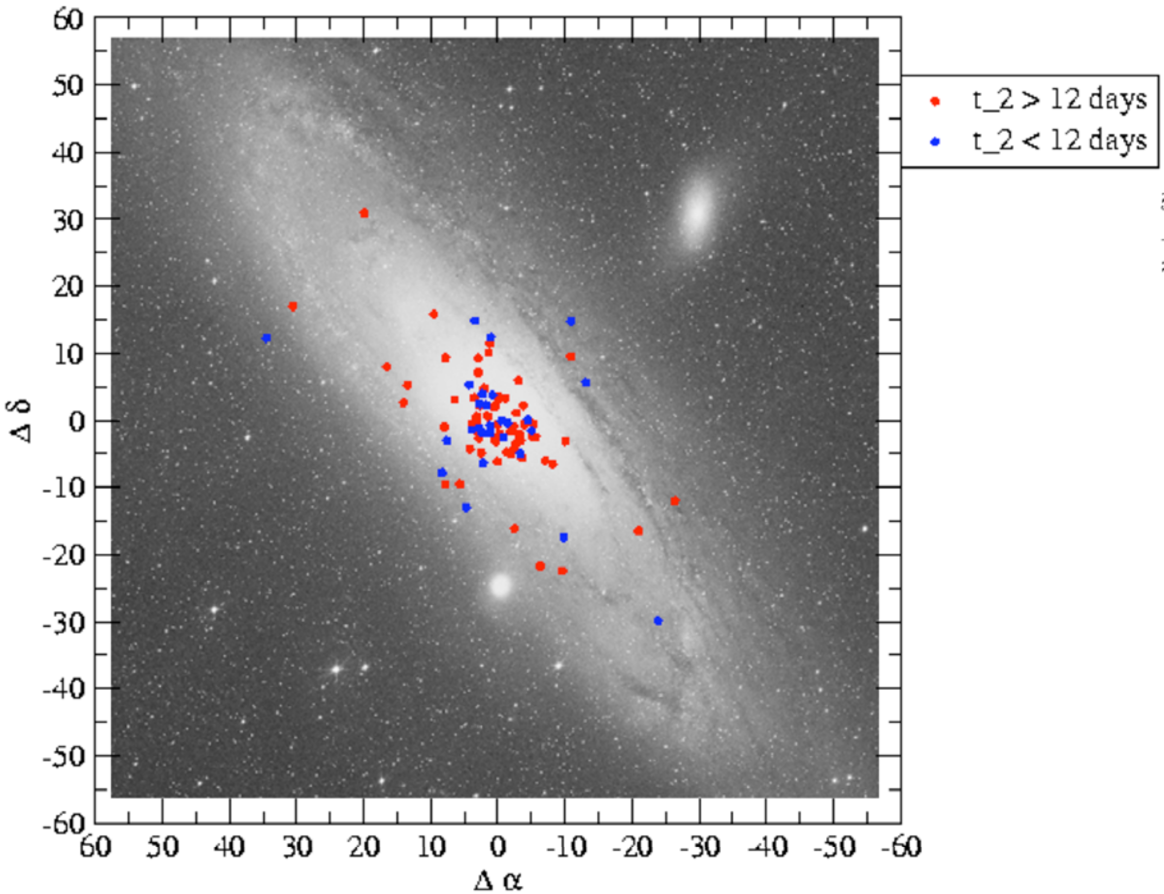
- If so, do their observed properties (maximum magnitude, rate of decline) differ?

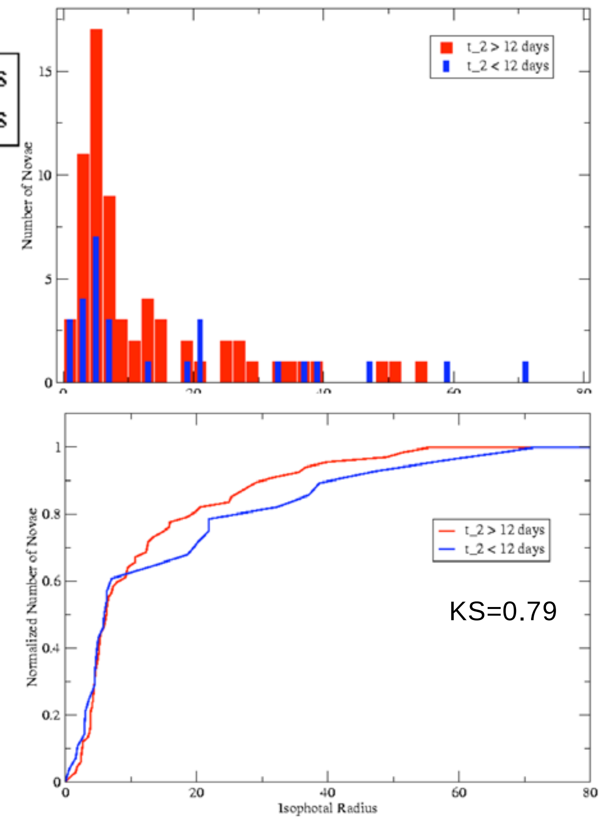
Maximum Magnitude Distribution for Arp's M31 Novae



Distribution is bimodal with peaks near m_{pg}=16.0 and m_{pg}=17.5, which corresponds to $M_{pg} \cong -7$ and $M_{pg} \cong -8.5$, respectively.

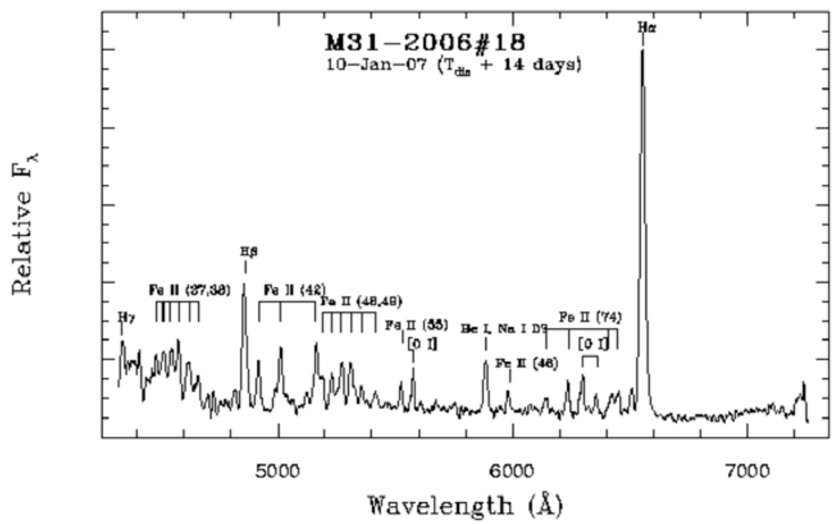
Variation of Speed Class with Spatial Position

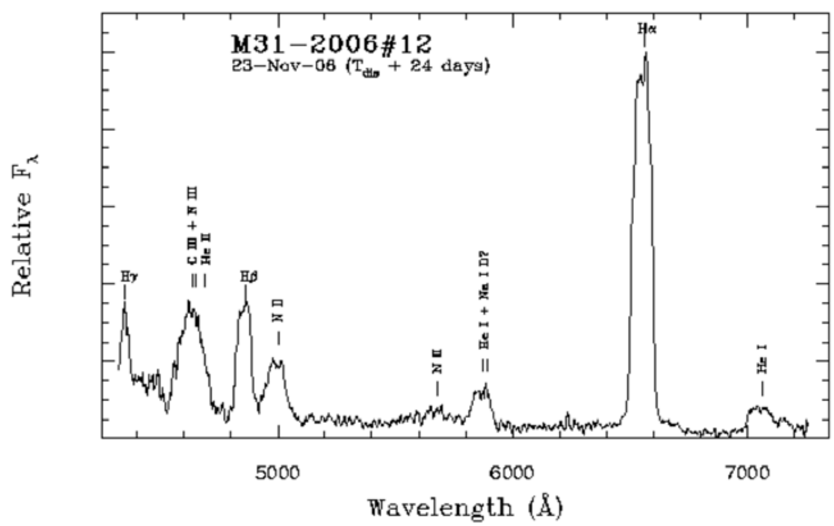




Light curve data from Hubble-Arp-Rosino (Capaccioli et al. 1998) nova sample reveals no compelling dependence of speed class with spatial position in M31. Fast novae maybe slightly more extended.

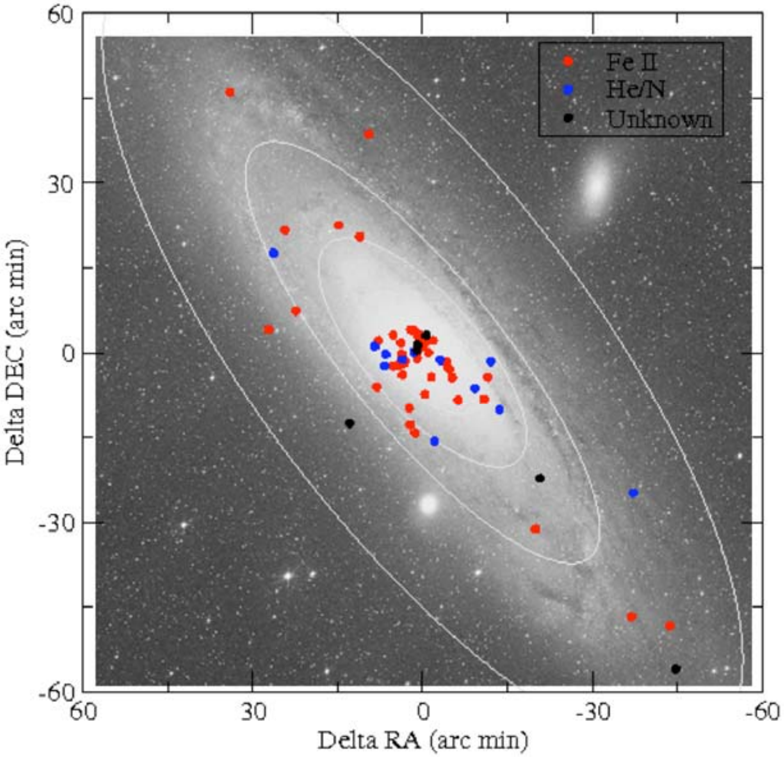
New Approach to Studying Nova Populations: Spectral Classification of Novae in M31

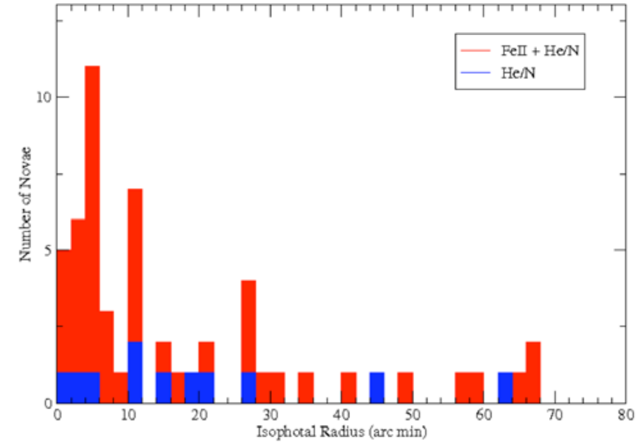


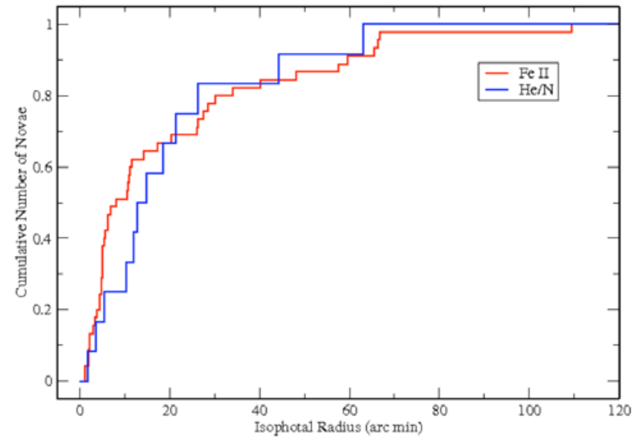


- Williams (1992) proposed that novae can be divided into two classes “Fe II” and “He/N” based on observed emission lines.
- Fe II novae evolve slower, have lower expansion velocities, and lower levels of ionization compared with the He/N novae.
- Della Valle & Livio (1998) argued that Galactic He/N novae are faster, more luminous, and located at lower Galactic latitudes than Fe II novae.
- Until recently, only 17 M31 nova spectra available. We (Bode, Darnley, Misselt, and I) are involved in a spectroscopic major survey of M31 novae with the HET; now more than 50 M31 novae with spectroscopic classifications.
- He/N novae represent ~15% of the total.

Radial Dependence of Nova Spectral Class in M31



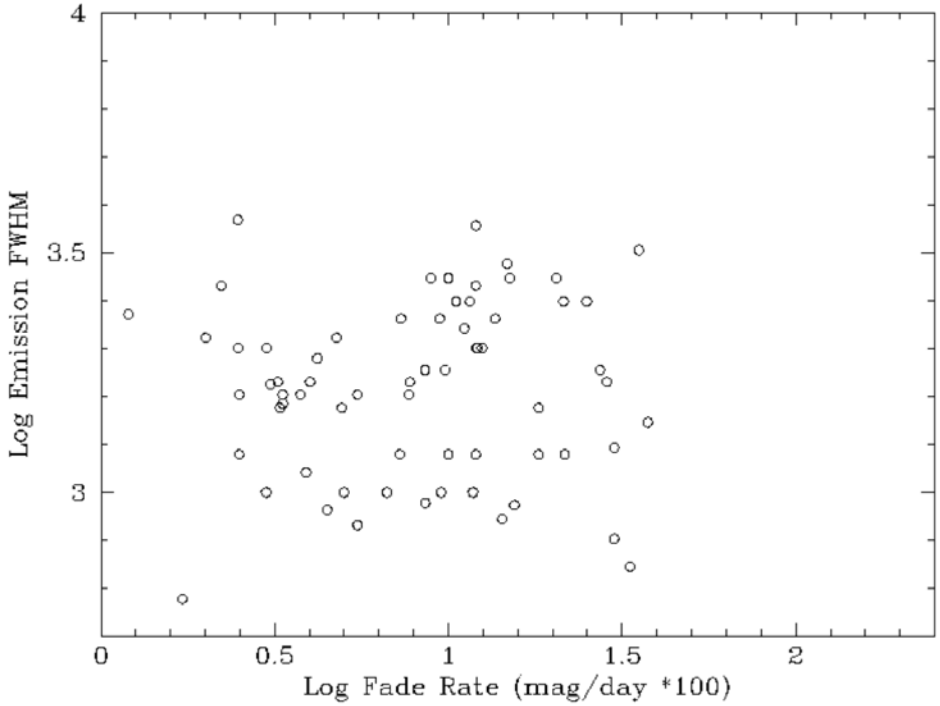




- The scanty data available suggest that the distribution for the He/N novae may be slightly more extended than that for the Fe II novae.
- Spectroscopic classifications for additional novae will be required before definitive conclusions can be reached.

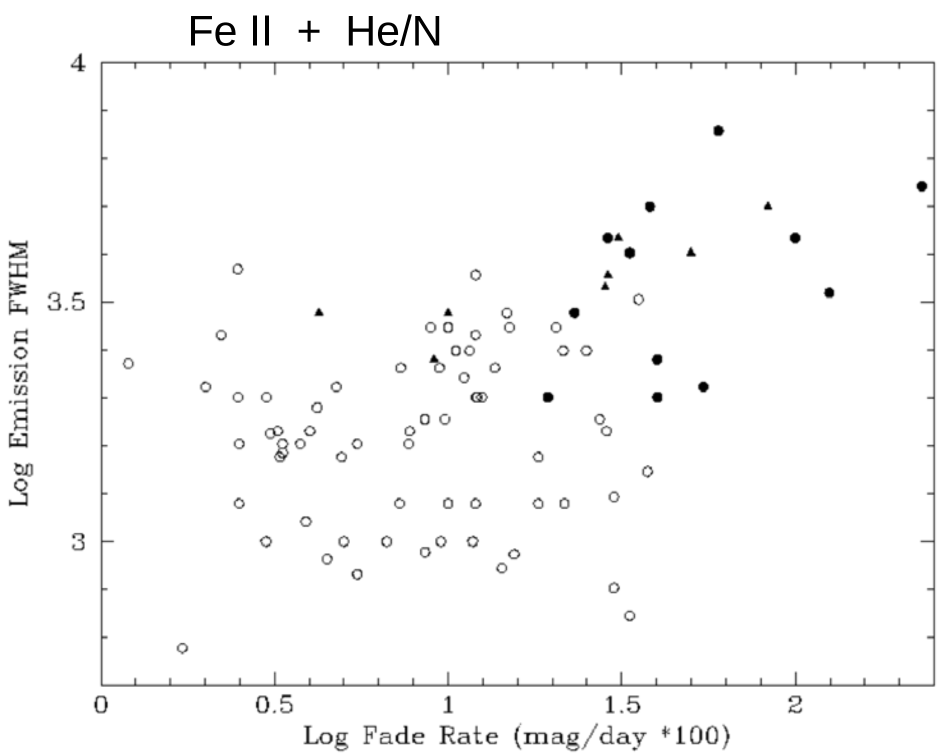
Expansion Velocity vs Fade Rate for Galactic Fe II and He/N Novae

Fe II



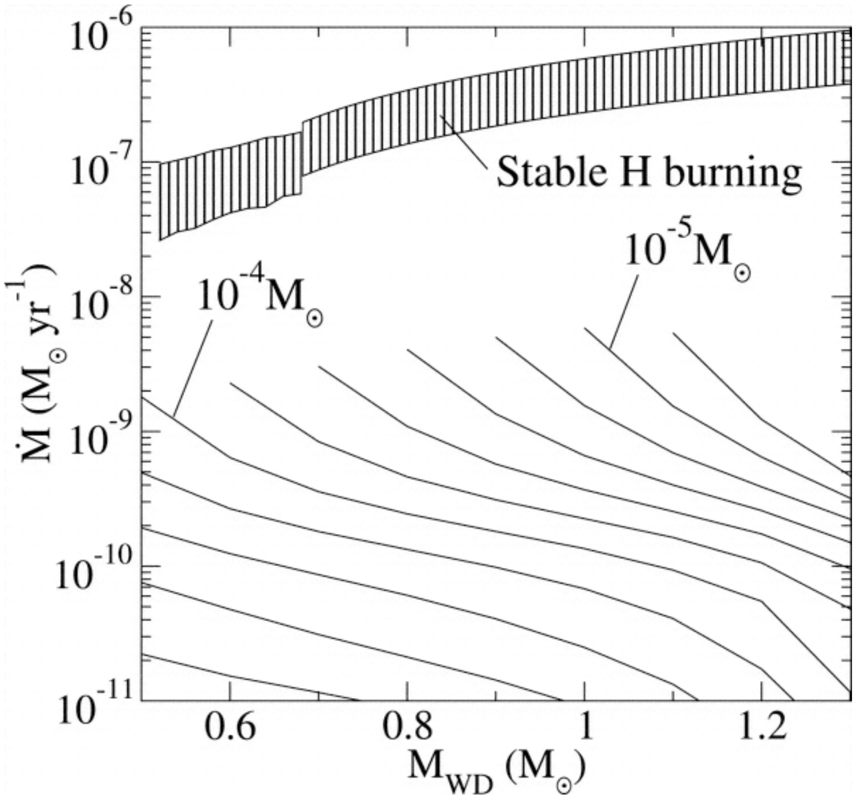
- Following an earlier study by Della Valle & Livio (1998), Shafter (2008) has compiled a list of 94 Galactic novae for which spectroscopic classes can be tentatively defined.

Expansion Velocity vs Fade Rate for Galactic He/N and Fe II Novae



- Following an earlier study by Della Valle & Livio (1998), Shafter (2008) has compiled a list of 94 Galactic novae for which spectroscopic classes can be tentatively defined.
- The He/N and Fe IIb (hybrid) objects are clearly “faster” and have generally higher expansion velocities than the Fe II systems.
- **What fundamental parameter(s) determine spectroscopic class?**

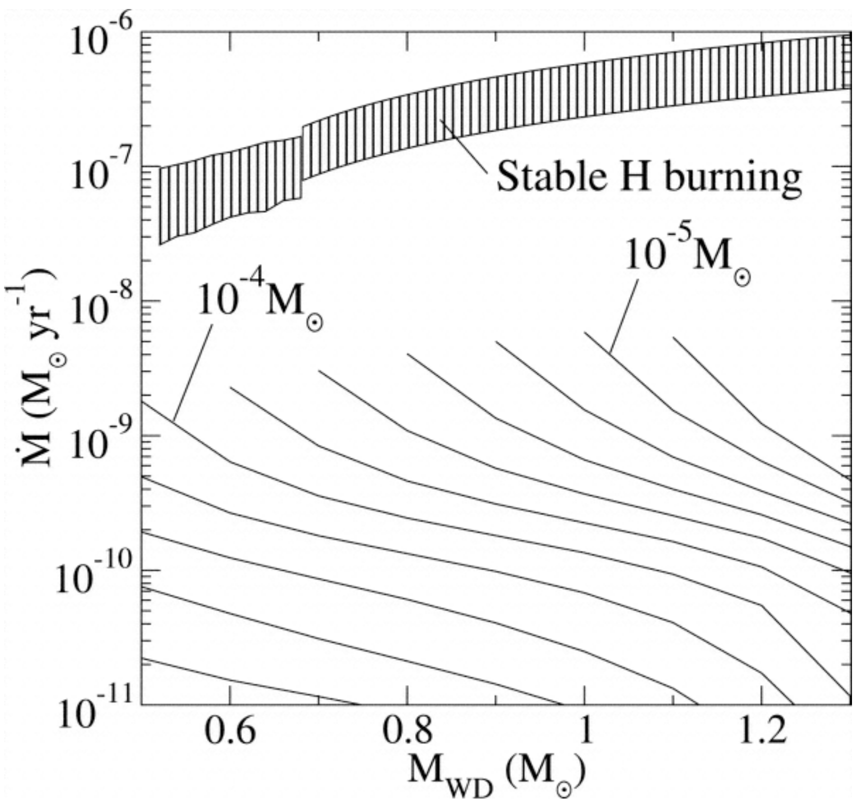
Classical Nova Ignition Masses



Townsley & Bildsten (2005)

- Ignition masses depend not only on M_{WD}, but also on T_{WD} and hence dM/dt.

Classical Nova Ignition Masses

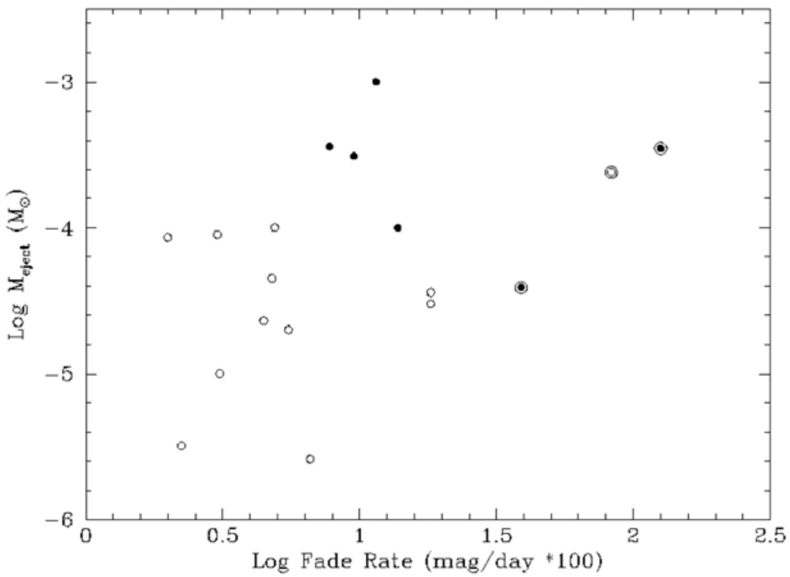


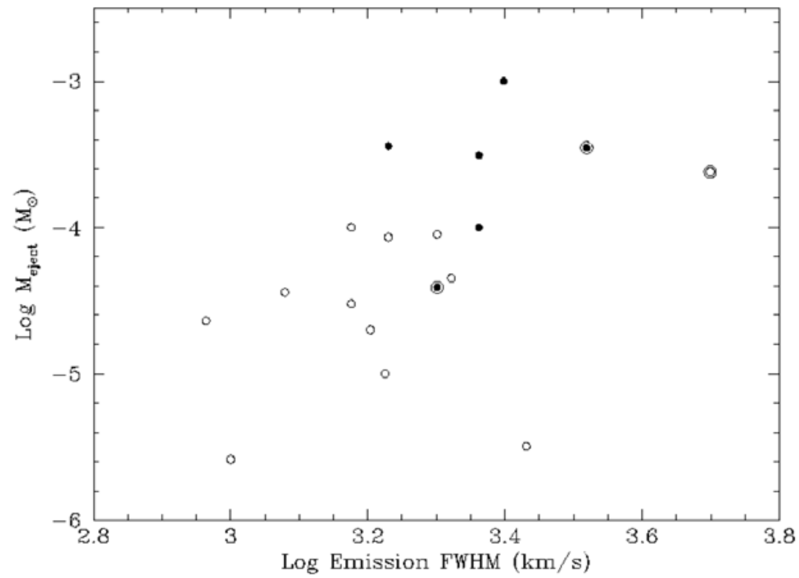
Townsley & Bildsten (2005)

- Ignition masses depend not only on M_{WD}, but also on T_{WD} and hence dM/dt.

- **Predictions:** For a given accretion rate, a higher M_{WD} implies a lower M_{env} (and hence a lower M_{ej}), a higher V_{exp}, a more rapid photometric evolution, and a He/N spectroscopic type.
- Since dM/dt increases with P_{orb}, for a given M_{WD} the ejected mass should generally decrease with P_{orb}.
- Systems below the period gap should generally have higher M_{ej} ($>10^{-4}$) compared to systems above the gap.

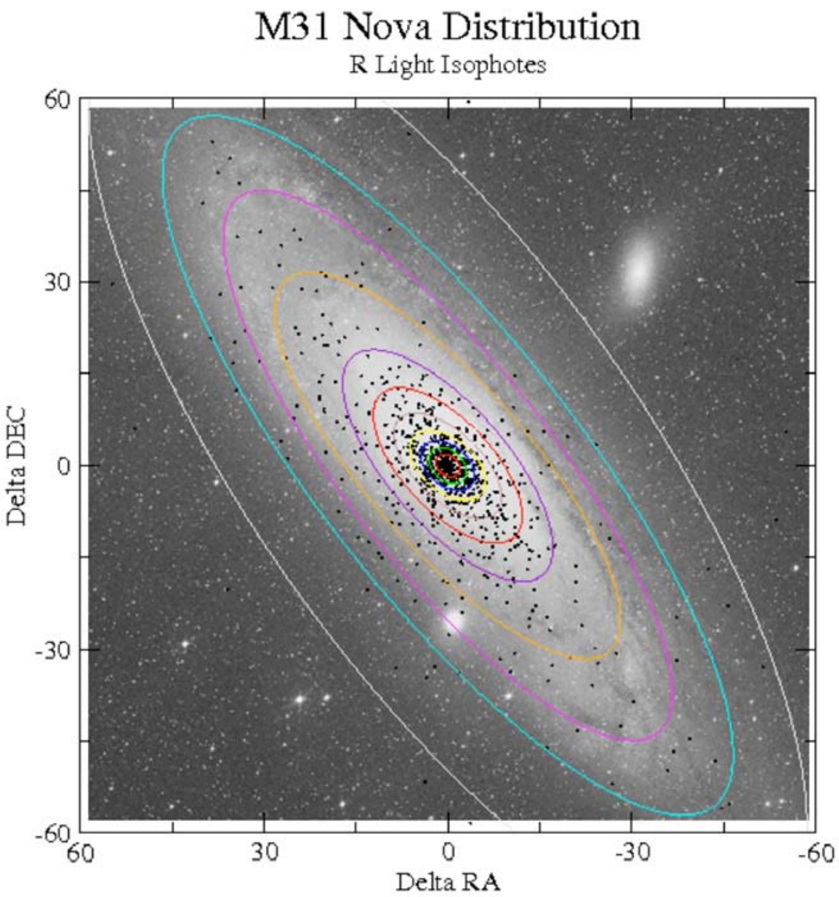
Ejected Masses vs White Dwarf Mass





- Filled circles represent systems thought to contain ONeMg WDs.
  Large open circled points represent He/N spectroscopic type.
- ***Contrary to expectations, systems with the most massive white dwarfs appear to have the most massive ejecta…***
- Statistics are poor, so confirmation of this result is needed.

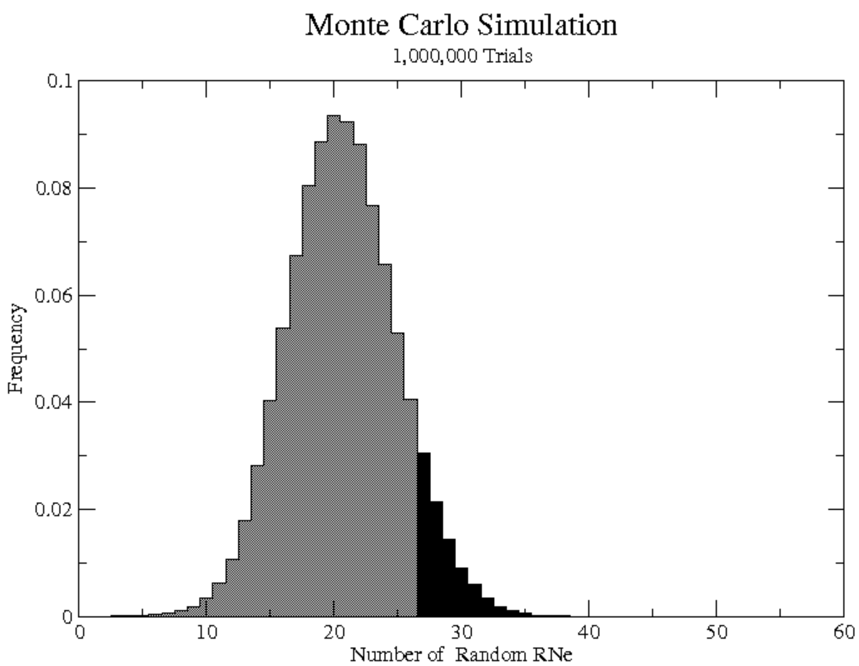
Estimating the RNe population in M31

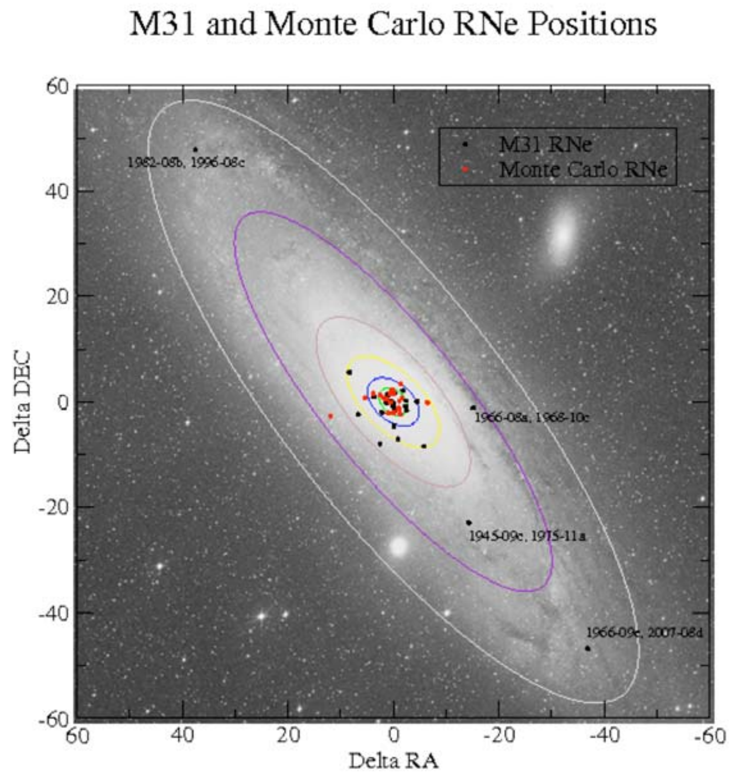


- Pietsch et al. (2007) has compiled the positions of >800 M31 novae.
- From these there are a total of 23 pairs, 3 triples, and 1 quad with separations < 5''.
- Of these 27 RNe candidates, many are likely chance positional coincidences.
- To estimate what fraction, we have conducted a Monte Carlo simulation.

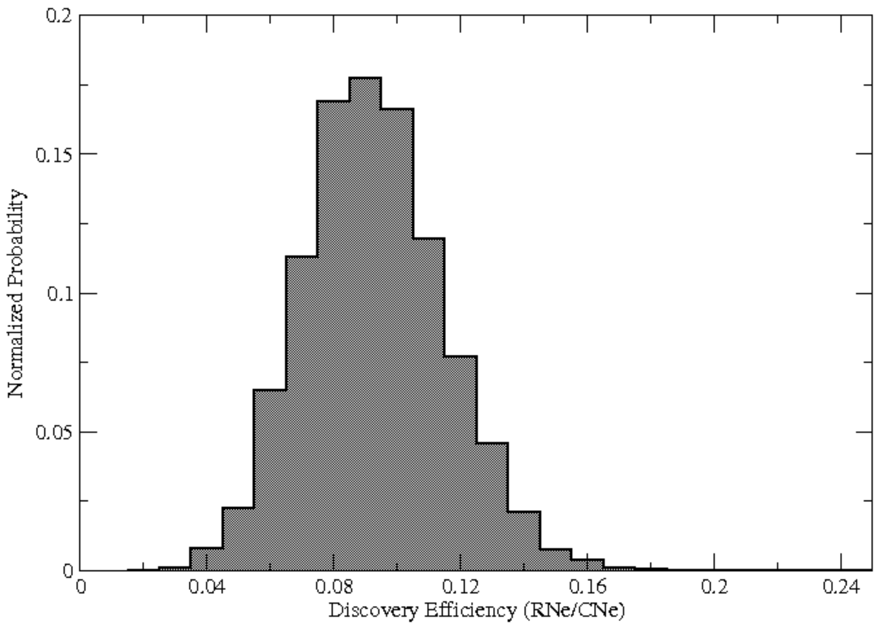
Monte Carlo RNe Simulations

- We randomly distribute synthetic novae with the same spatial distribution as the observed nova distribution and check for chance positional coincidences.
- The most likely number of chance coincidences is 20, suggesting that ~7 of the RNe candidates are likely real (6% chance none are).
- Not surprisingly, the chance coincidences are concentrated near the nucleus where the nova density is highest.





Can RNe be a significant channel for SNe Ia?



- 814 outbursts of which we estimate 14 are from an estimated 7 RNe. Raw $N_{RNe}/N_{CNe} \sim 0.018$
- Discovery efficiency is much lower for RNe than for CNe

  (observed twice, faster evolution).
- A Monte Carlo simulation shows that RNe discovery efficiency ~0.09 CNe.
- Thus, corrected $N_{RNe}/N_{CNe} \sim 0.2$
- If $R_{CN+RN} \sim 60\ yr^{-1}$ then

  $R_{RN} \sim 10\ yr^{-1}$
- If average RN has ~30 yr recurrence time, $M_{WD} \sim 1.3 M_{sun}$, and $dM/dt \sim 10^{-7}\ M_{sun}\ yr^{-1}$

  --> D.R. $\sim 3.0 \times 10^{-4}\ yr^{-1}$
- ~10% of the SNe Ia B.R.?

Conclusions & Future Work

- The best estimate of the Galactic nova rate is ~30-35 per year.
- The LSNR of galaxies with differing Hubble types appears roughly constant, but this needs to be more definitively established.
- Any variation in the properties of novae (luminosity, fade rate) from differing stellar populations remains uncertain.
- The frequent and deep surveying of nearby galaxies made possible by Pan-Starrs and the LSST will be of great help in addressing the above!
- Are a significant fraction of novae spawned in globular clusters? Compare the nova rates in M87 and M49… and other galaxies with different GC populations.
- Contrary to expectations, the mass ejected from novae appears higher for systems with the most massive WDs…
- The white dwarf mass is believed to be the most important fundamental property in determining outburst characteristics (expansion velocity, speed class, and spectroscopic class).
- It appears that RNe could account for as many as 10% of the SNe Ia rate in a galaxy like M31.