# The Stellar Populations of Extragalactic Novae

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# Basic Nova Properties

- Close Binary System consisting of a late-type, usually near M.S. star transferring mass to its white dwarf companion.
- TNR on surface of WD leads to a nova eruption
- Luminous! $M_V \sim -6$ to $-9$
- Peak luminosity & fade rate depend mainly on $M_{WD}$, but also on $T_{WD}$, dM/dt (and stellar population?)
- All novae are recurrent at intervals of $\sim 10^1$ - $\sim 10^5$ yr.

# The Role of Extragalactic Nova Studies

I. Equidistant sample of novae makes it possible to study relative nova luminosities and fade rates

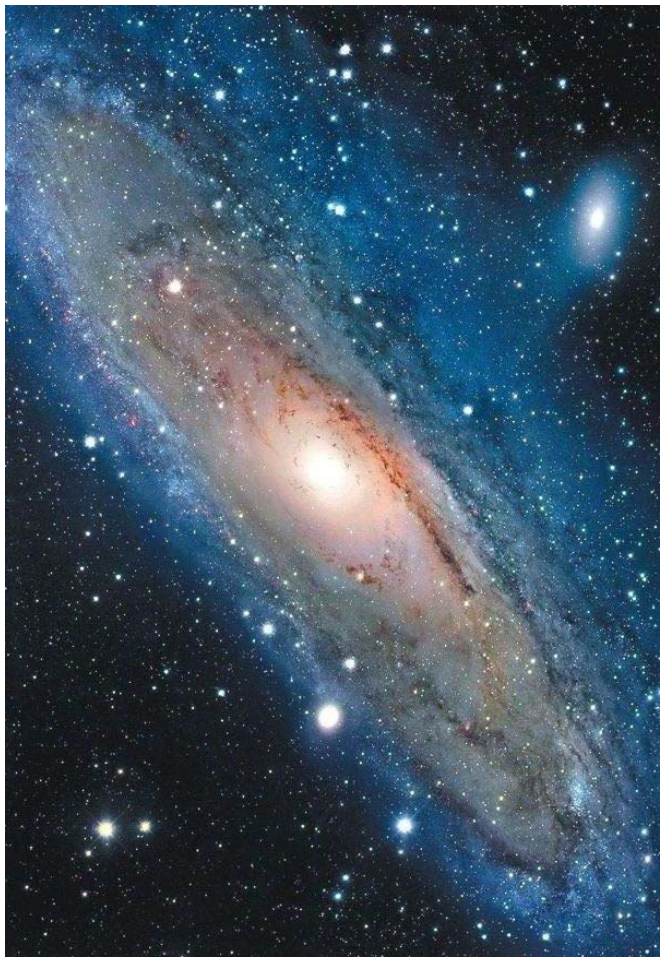
II. Stellar population of novae can be more easily studied

- Study TNRs in novae from different populations
- Estimate mean WD masses in novae from different populations

III. Useful as distance indicators

- $M_V \sim -9$ for brightest (fastest) novae
- MMRD relation (brighter novae fade faster)
- Telescope-time intensive

# M31: Principal Historical Target

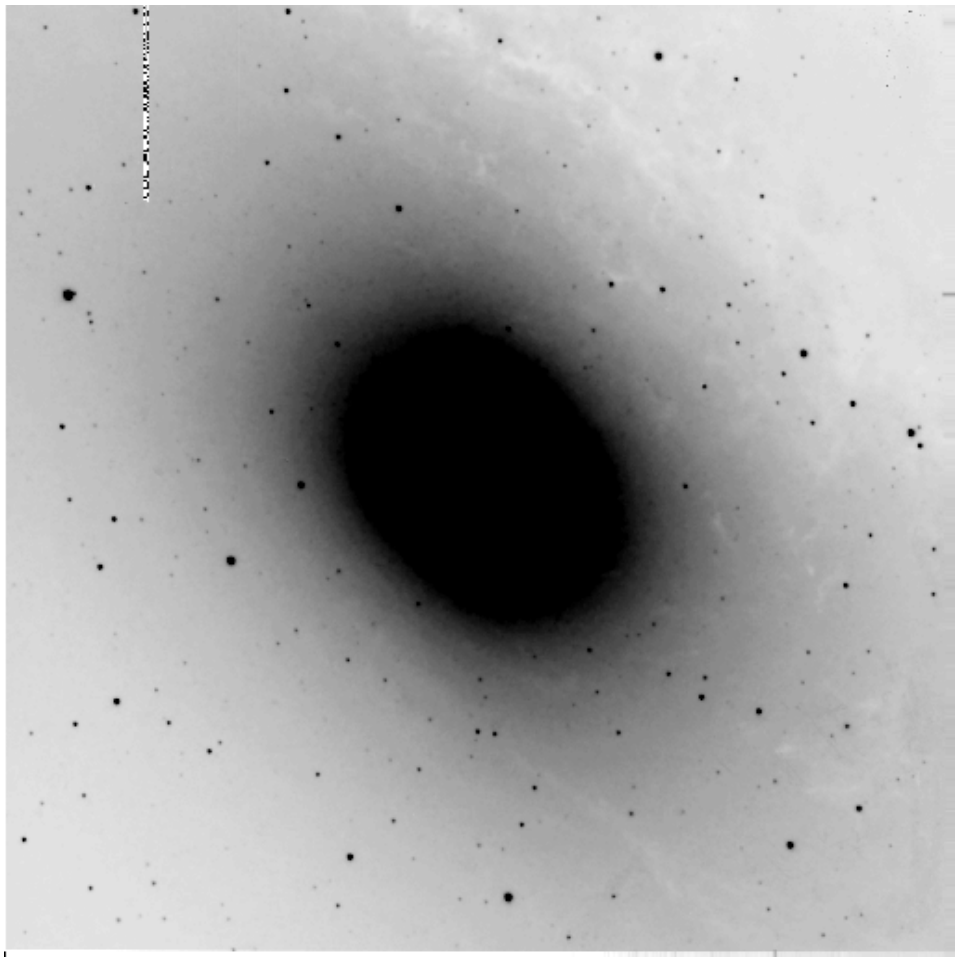


| **Major Studies:** | **Novae** |
|---|---|
| • Hubble (1929) | 85 |
| • Arp (1956) | 30 |
| • Rosino (1964;1973) | 142 |
| • Ciardullo et al. (1987) | 40 |
| • Shafter & Irby (2001) | 82 |
| • Darnley et al. (2006) | 20 |
| • Others (e.g. amateurs) | >300 |
| Total: | >700 |

**Principal Conclusions:**

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

# M31 Bulge: 29Dec03 – 23Jan05 Comparison



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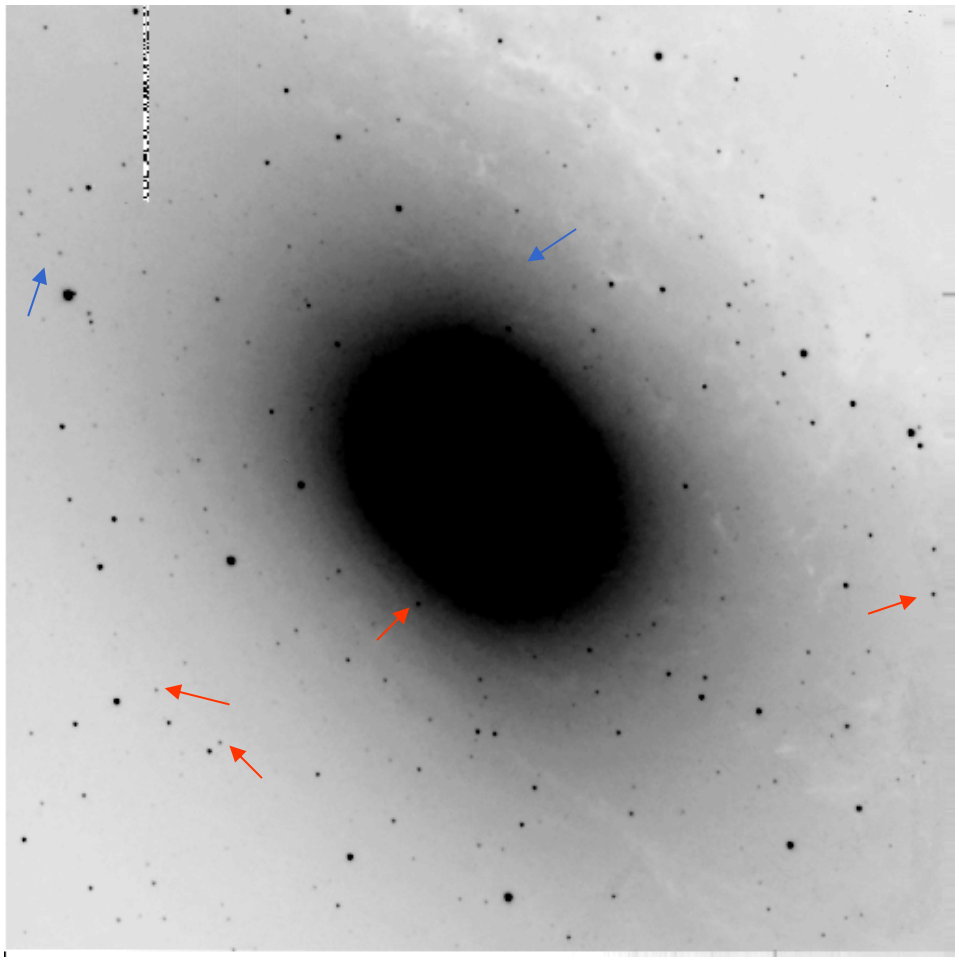
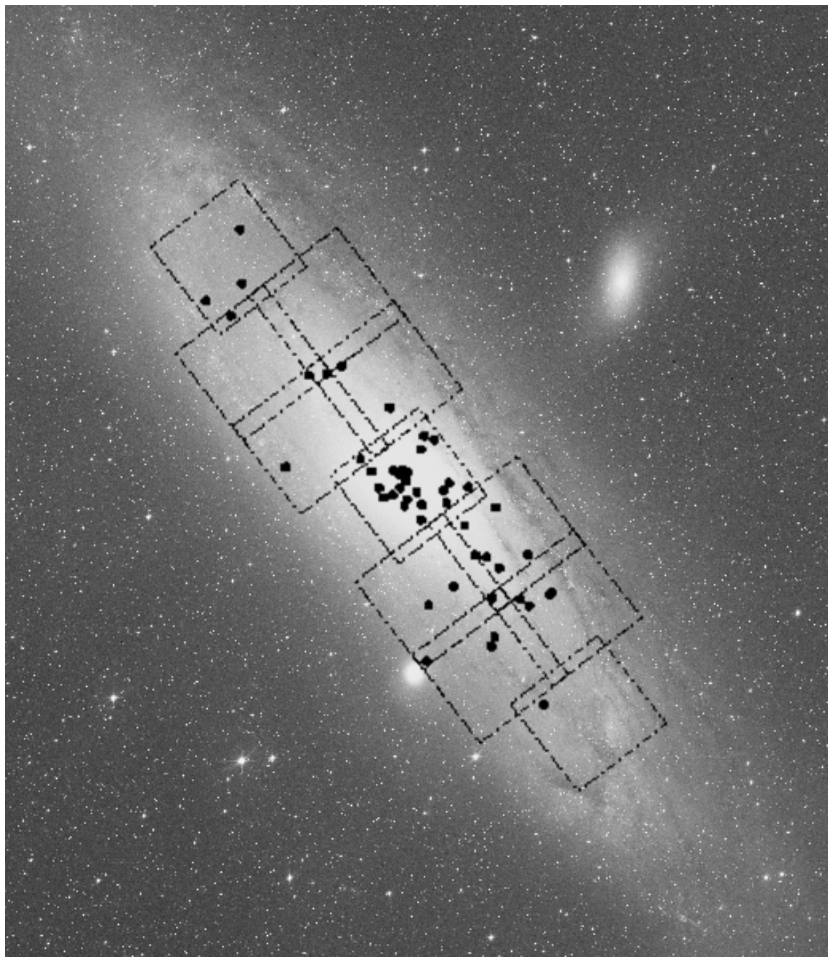
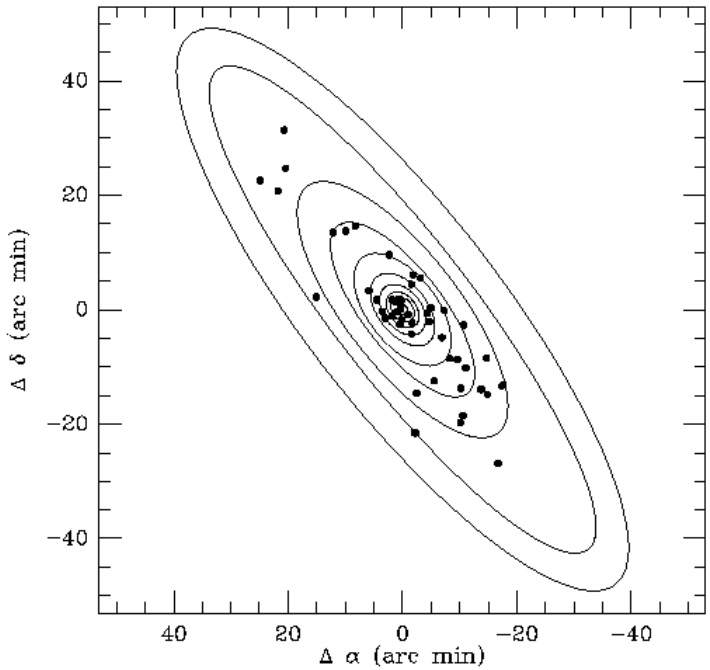


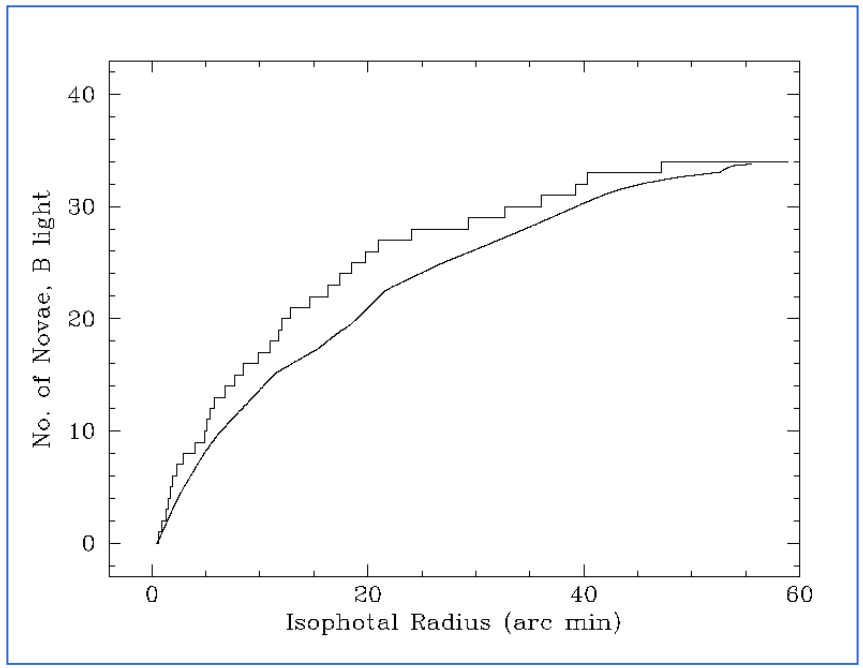
# M31 Nova Spatial Distribution



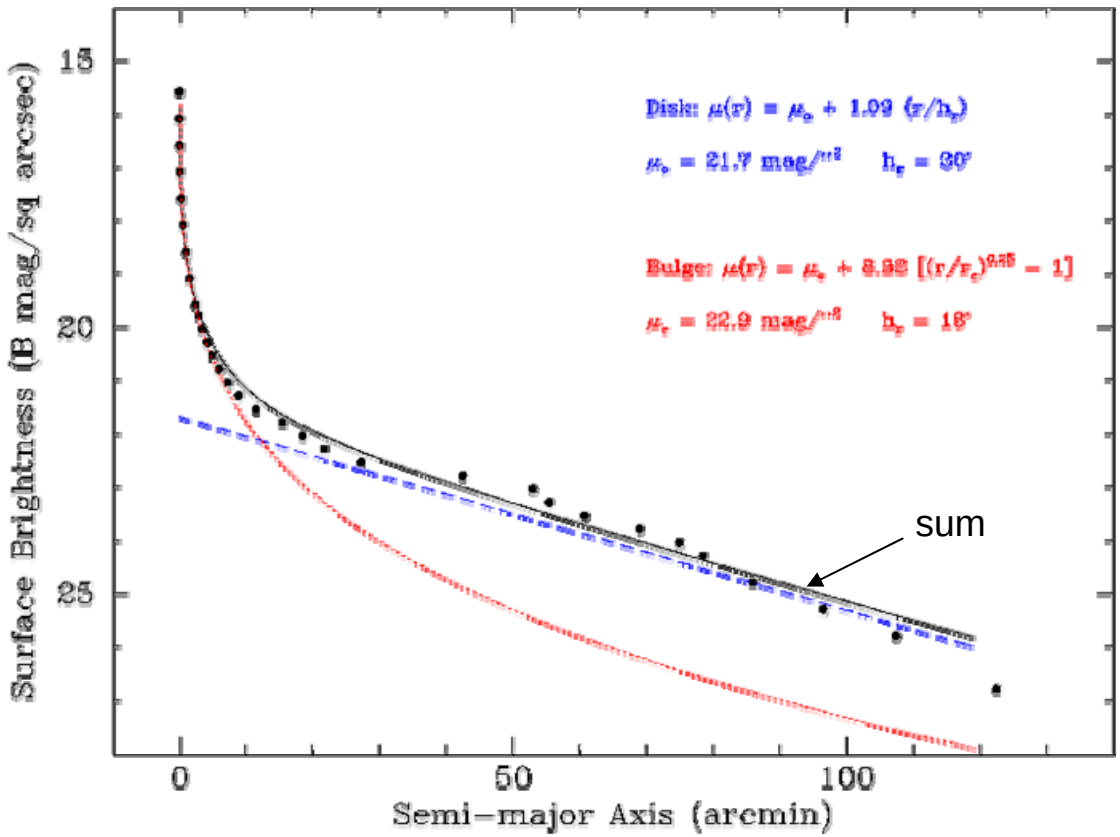
- Shafter & Irby (2001) H$\alpha$ survey at MLO.
- 11 13’ X 13’ CCD fields
- 53 Novae detected in Survey A
- Novae centrally concentrated

# Cumulative Nova Distribution vs *B*-band Light

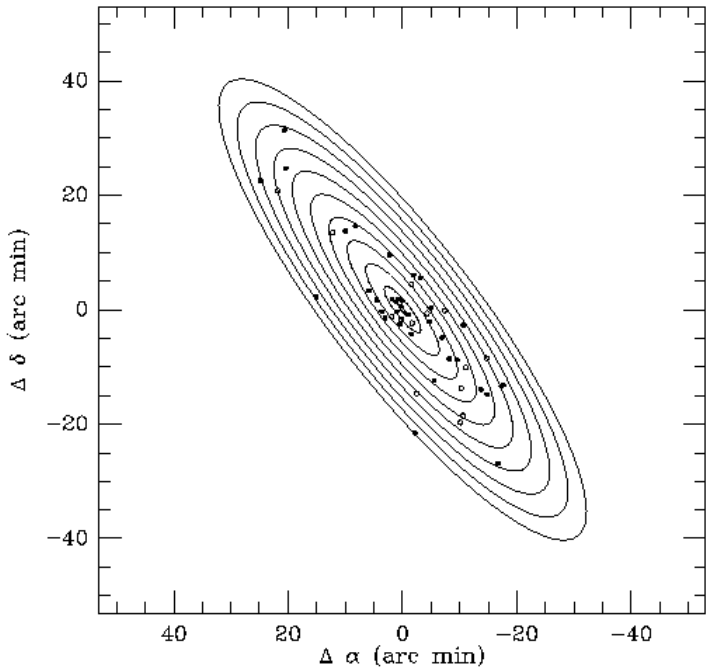


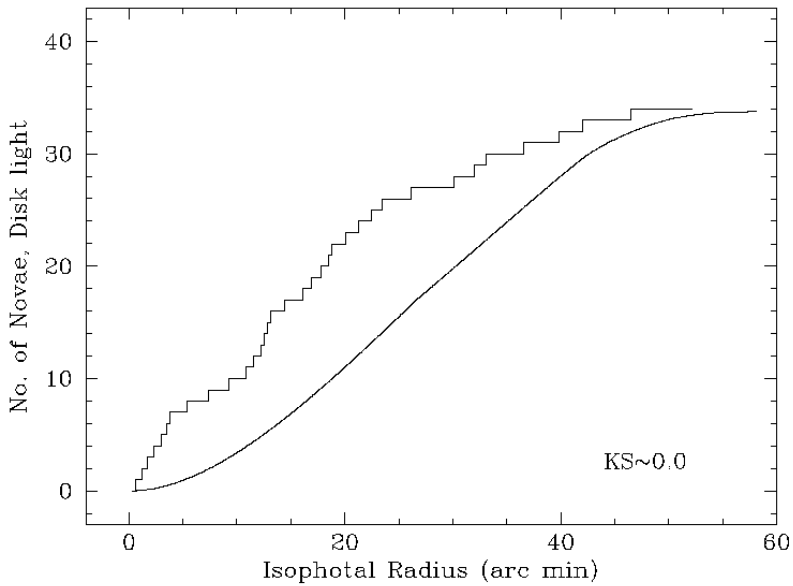



# Radial Surface Brightness Profile of M31 *B* Light

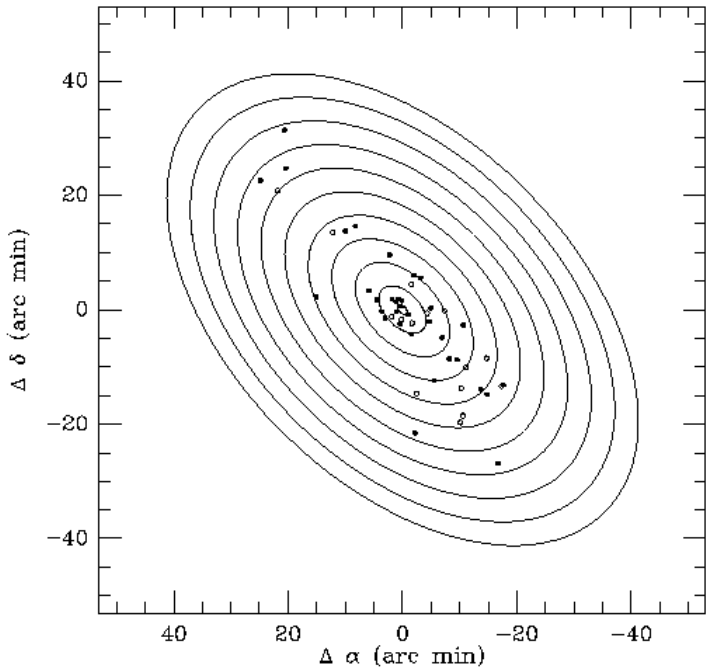


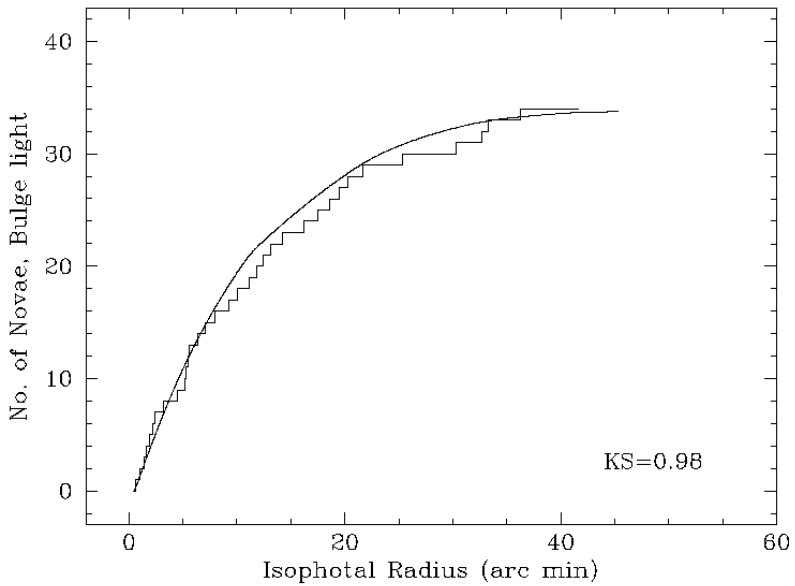
# Cumulative Nova Distribution vs Disk Light



# Cumulative Nova Distribution vs Bulge Light

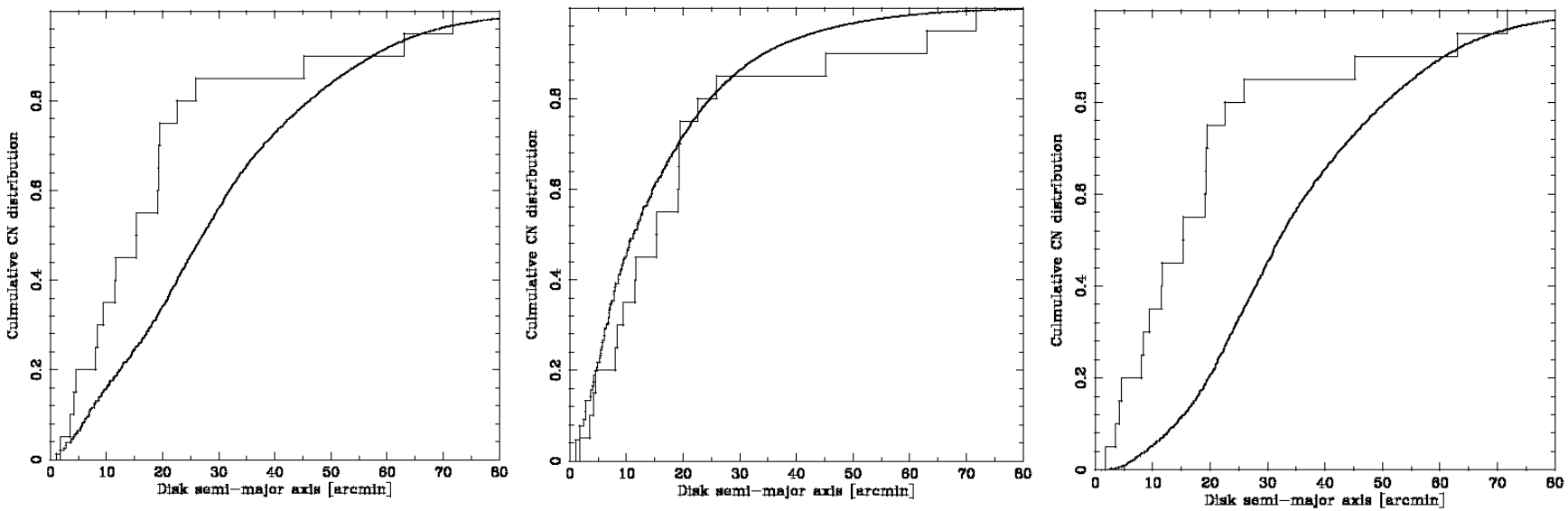


# Nova Spatial Distribution from Darnley et al. Survey

Darnley et al. (2004, 2006) argued completeness is a problem in earlier M31 surveys – Revised nova rate ~65 per year, but no change in spatial distributions…

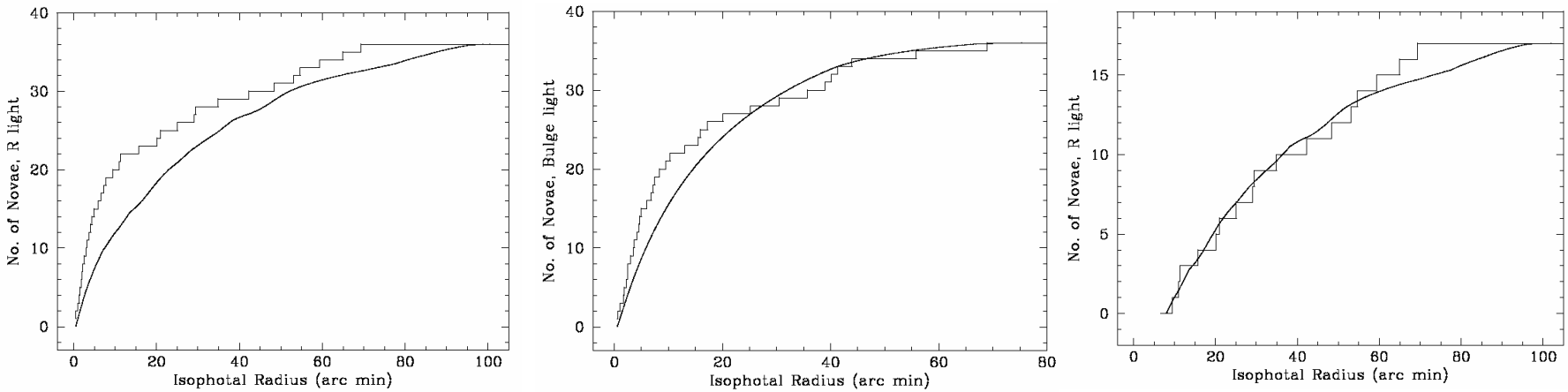
***Left panel:*** cumulative nova distribution poor fit to background *R* light.
***Middle panel:*** cumulative nova distribution good fit to bulge light.
***Right panel:*** cumulative nova distribution poor fit to disk light.



# M31 Extended Spatial Distribution from ROTSE IIIb Data at McDonald Observatory (Quimby et al.)

The ROTSE IIIb program has surveyed M31 every clear night since 11/04, covering the entire galaxy, and is complete to 18$^{th}$ magnitude outside 8 arcmin from the nucleus. The ROTSE data can be augmented with similar bulge surveys over the same period to study the extended spatial distribution of novae in M31.

***Left panel:*** ROTSE+Bulge survey compared with background *R* light
***Middle panel:*** ROTSE+Bulge survey compared with Bulge light
***Right panel:*** ROTSE data compared with *R* light for r>8'



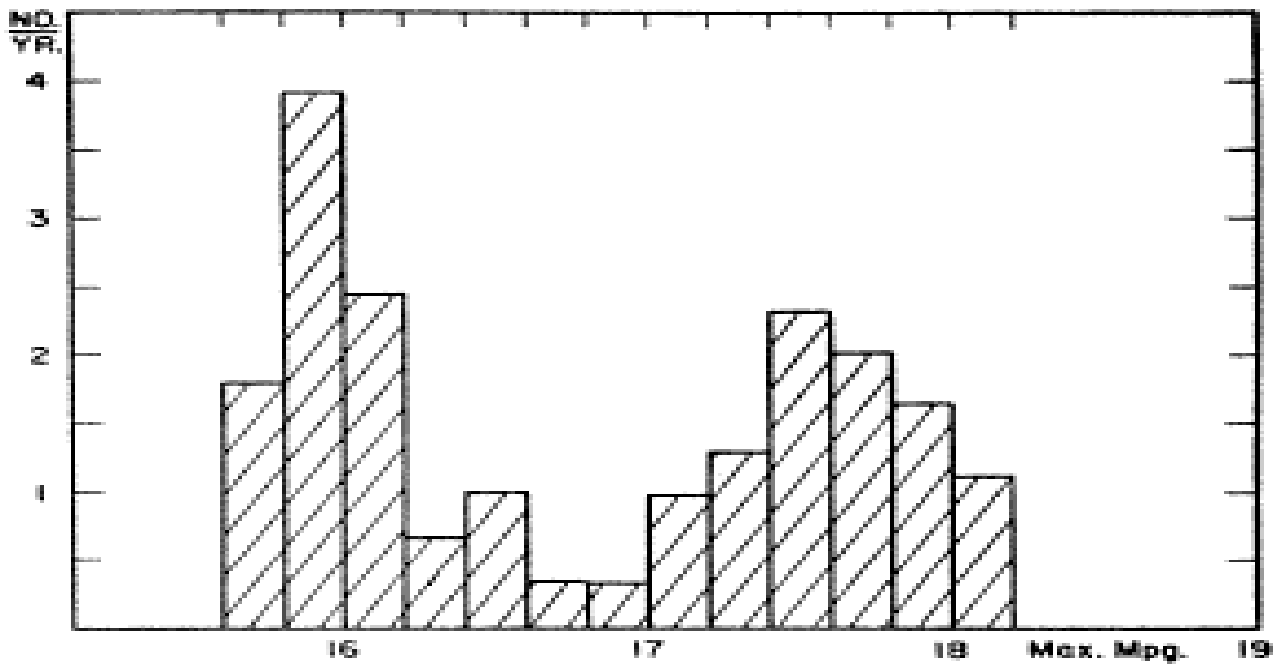
# Are Novae Primarily a Bulge Population?

- Relatively high M31 bulge rate results from:
  (1) Shorter recurrence times for bulge novae? Seems unlikely
  (2) Higher specific density of bulge novae?
  ***(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!***
  (3) Observational selection bias, extinction in disk, etc.
  Steward Obs deep H$\alpha$ survey will help address this question.

- Are there two distinct populations of Novae?

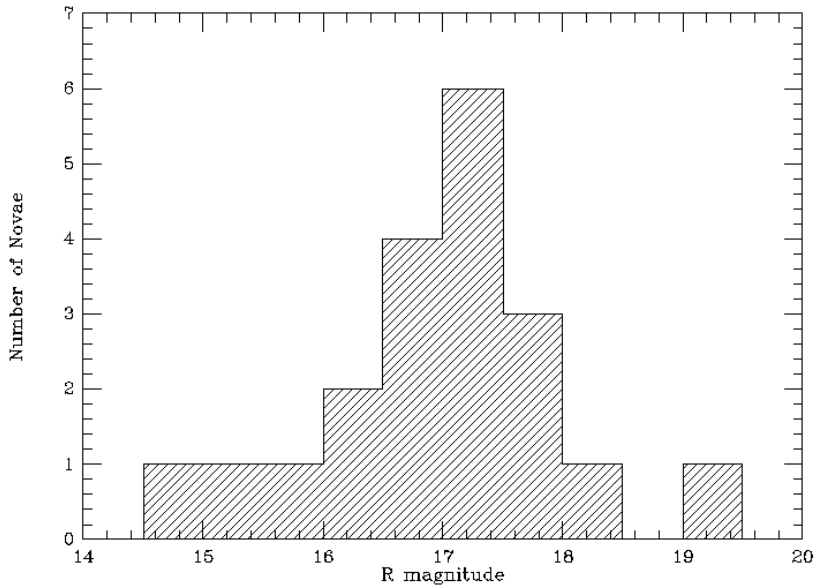
- If so, do their observed properties (maximum magnitude, rate of decline) differ?

# Maximum Magnitudes for Arp's M31 Novae



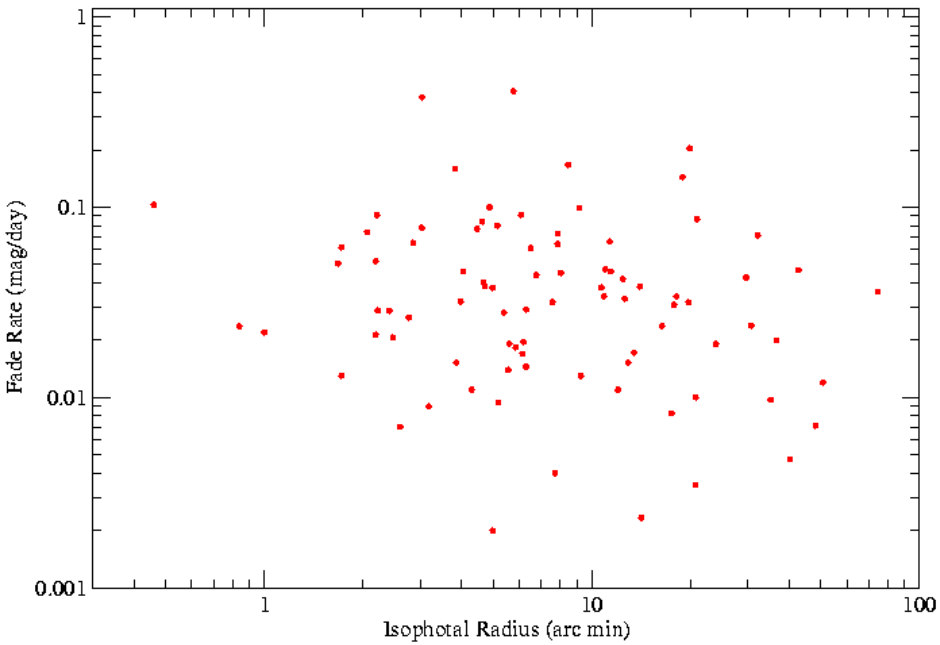

Distribution is bimodal with peaks near $m_{pg}$=16.0 and $m_{pg}$=17.5, which corresponds to $M_{pg} \cong -7$ and $M_{pg} \cong -8.5$, respectively.

# Maximum magnitude Distribution for Darnley et al.'s Point Agape Sample of 20 M31 Novae




<M> ~ -7.5 with no evidence for a bimodal distribution corresponding to different populations of novae

# Radial Dependence of Nova Fade Rate in M31




- Red points represent data for 87 novae with measured R and Hα decline rates (Shafter & Irby 2001, Pietsch et al. (2006), Ciardullo et al. 1990, Darnley et al. 2004), LOSS M31 data.

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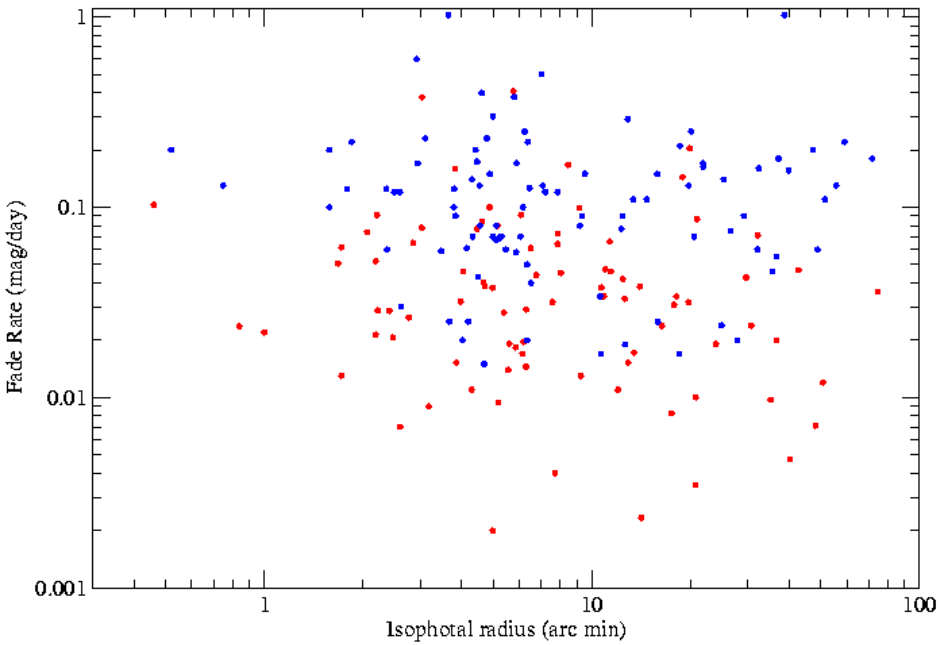
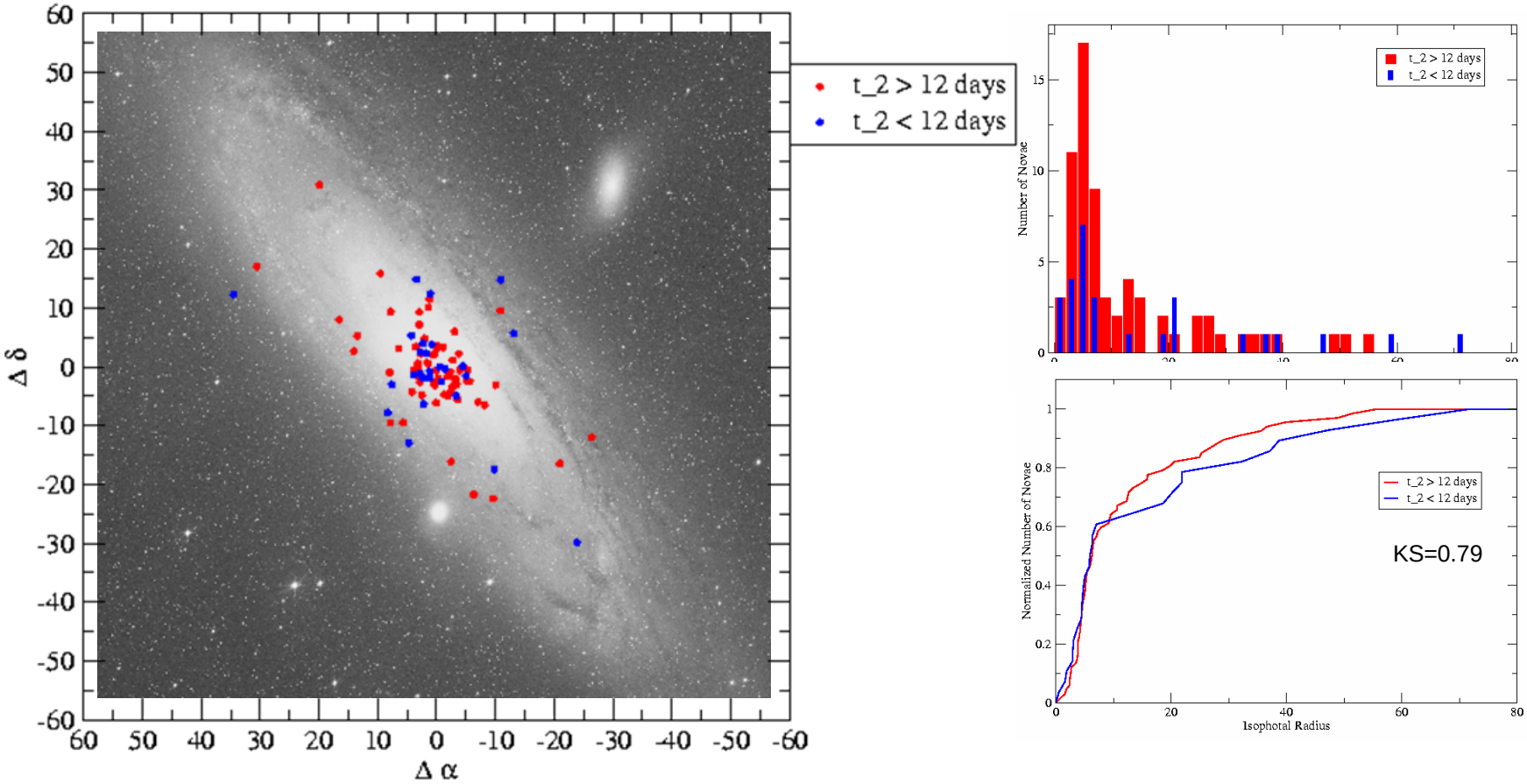


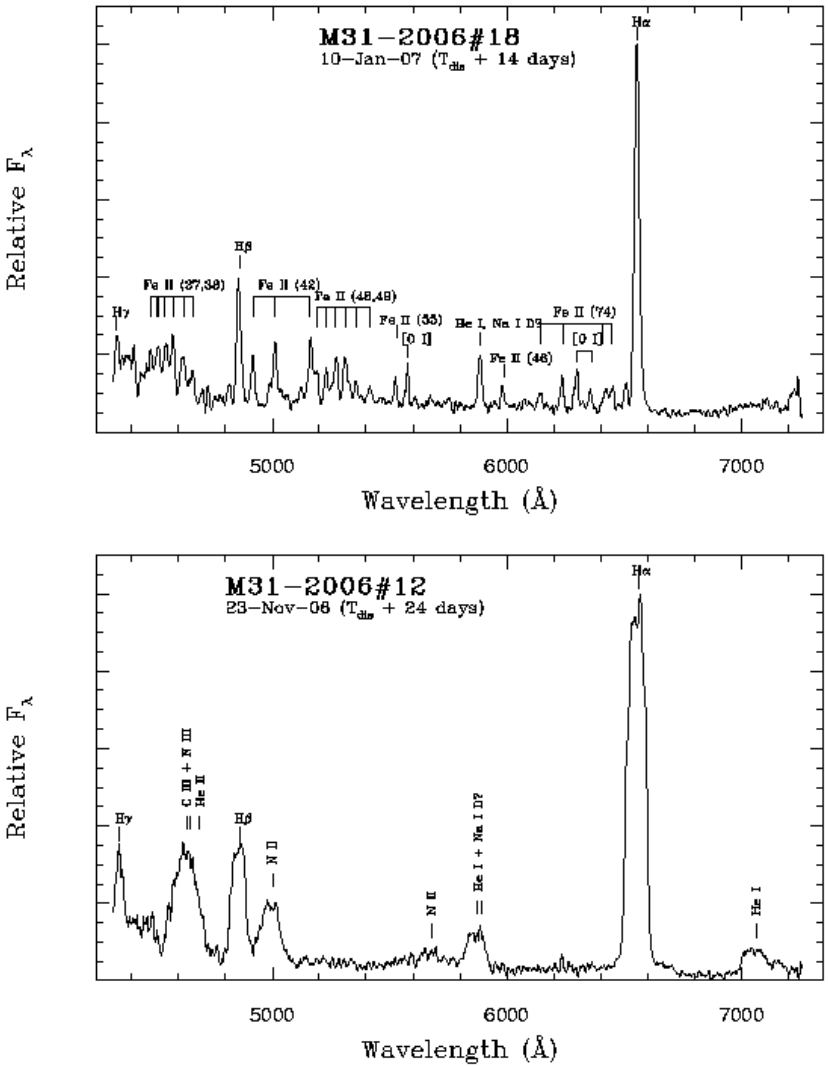

- Red points represent data for 87 novae with measured R and Hα decline rates (Shafter & Irby 2001, Pietsch et al (2006), Ciardullo et al. 1990, Darnley et al. 2004), LOSS M31 data.
- Blue points represent data for 95 novae with measured B decline rates (Capaccioli et al 1989.)
- No obvious evidence that the nova fade rate varies with distance from nucleus.

# Variation of Speed Class with Spatial Position



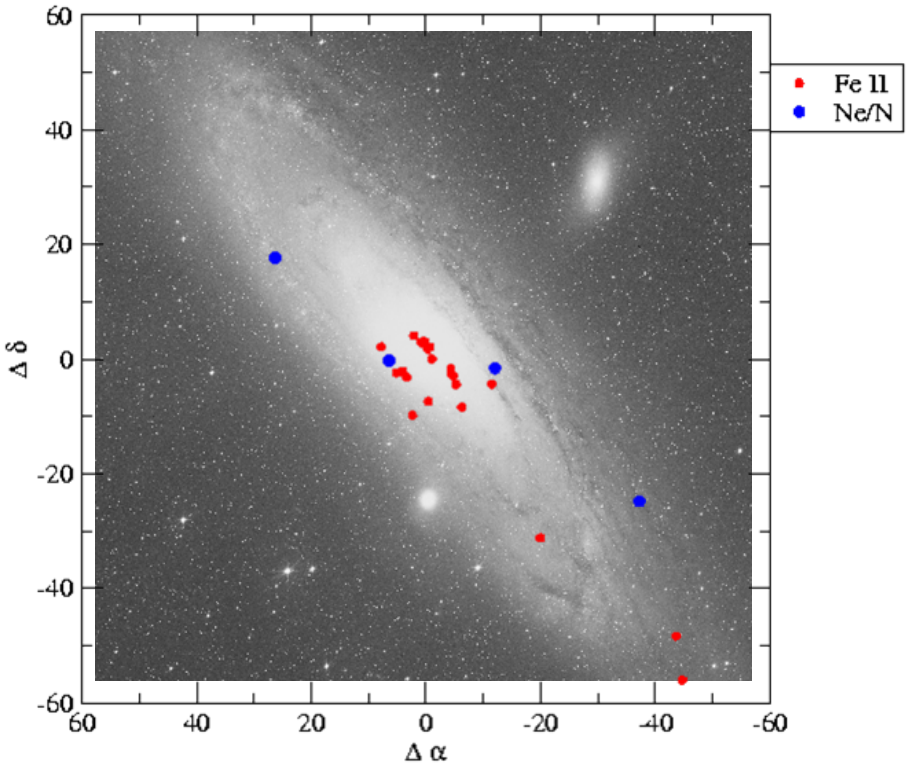

Light curve data from Hubble-Arp-Rosino (Capaccioli et al. 1998) nova sample reveals no compelling dependence of speed class with spatial position in M31. Fast novae maybe slightly more extended.

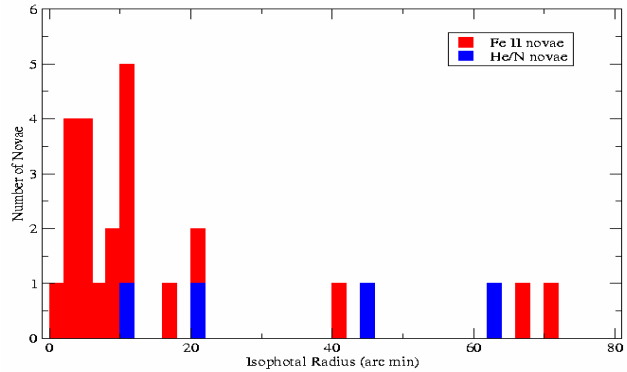
# New Approach to Studying Nova Populations: Spectral Classification of Novae in M31

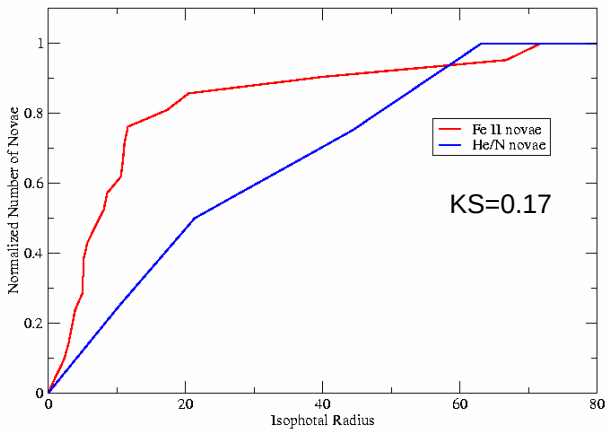



- Williams (1992) proposed that novae can be divided into two classes “Fe II” and “He/N” based on observed emission lines.
- Fe II novae evolve slower, have lower expansion velocities, and lower levels of ionization compared with the He/N novae.
- Della Valle & Livio (1998) showed that Galactic He/N novae are faster, more luminous, and located at lower Galactic latitudes than FeII 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 raising the number of spectra available from 17 to 25.
- He/N novae represent ~15%

# Radial Dependence of Nova Spectral Class in M31



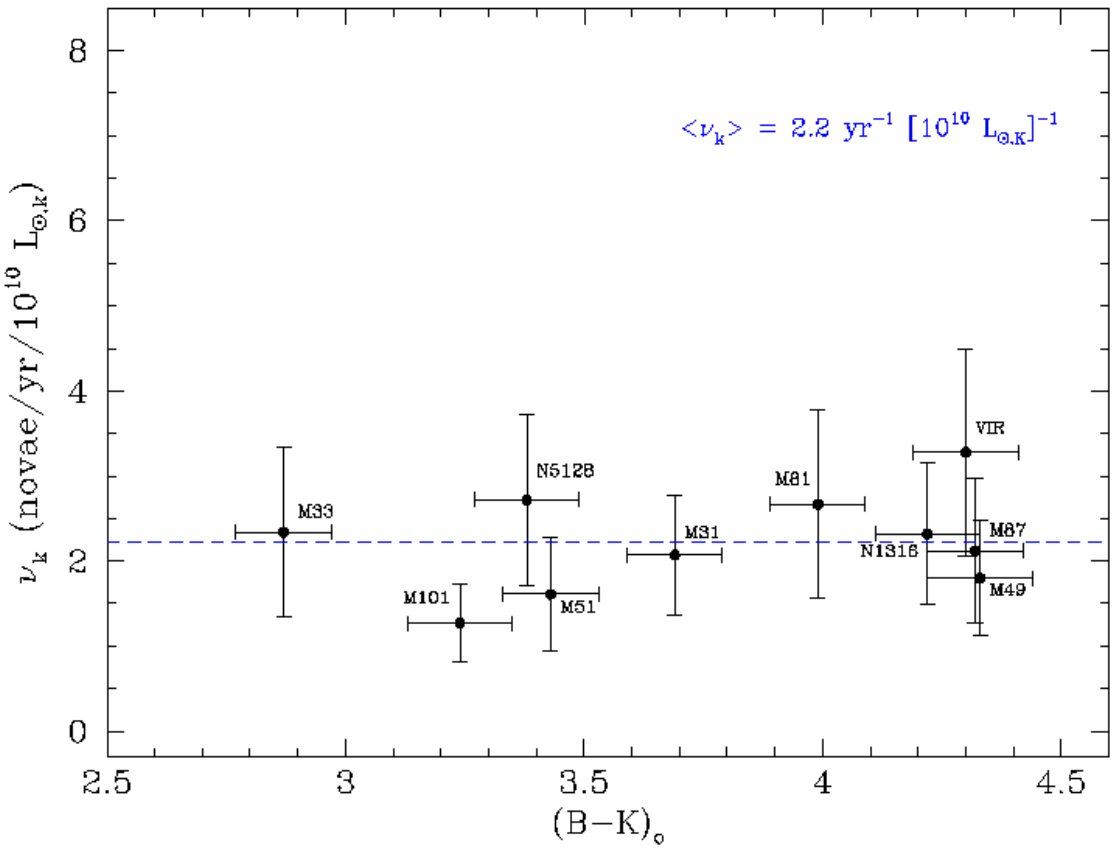

- The scanty data available suggest that the distribution for the He/N novae may be slightly more extended than that for the Fe II novae.
- Spectroscopic classifications for additional novae will be required before definitive conclusions can be reached.

# Nova Rates in Different Hubble Type Galaxies

- Nova rates have been measured in a dozen external galaxies.
- The population synthesis models of Yungelson et al. (1997) predict that the luminosity-specific nova rate should be higher in galaxies with a recent history of active star formation (e.g. spirals and irregulars, particularly low mass systems).
- Nelson et al. (2004) suggest that the nova frequency should be lower in an older population containing CVs with cooler white dwarfs.
- Thus, the LSNR should vary with the Hubble type of the galaxy.

# Luminosity-Specific Nova Rates

From Williams & Shafter (2004)



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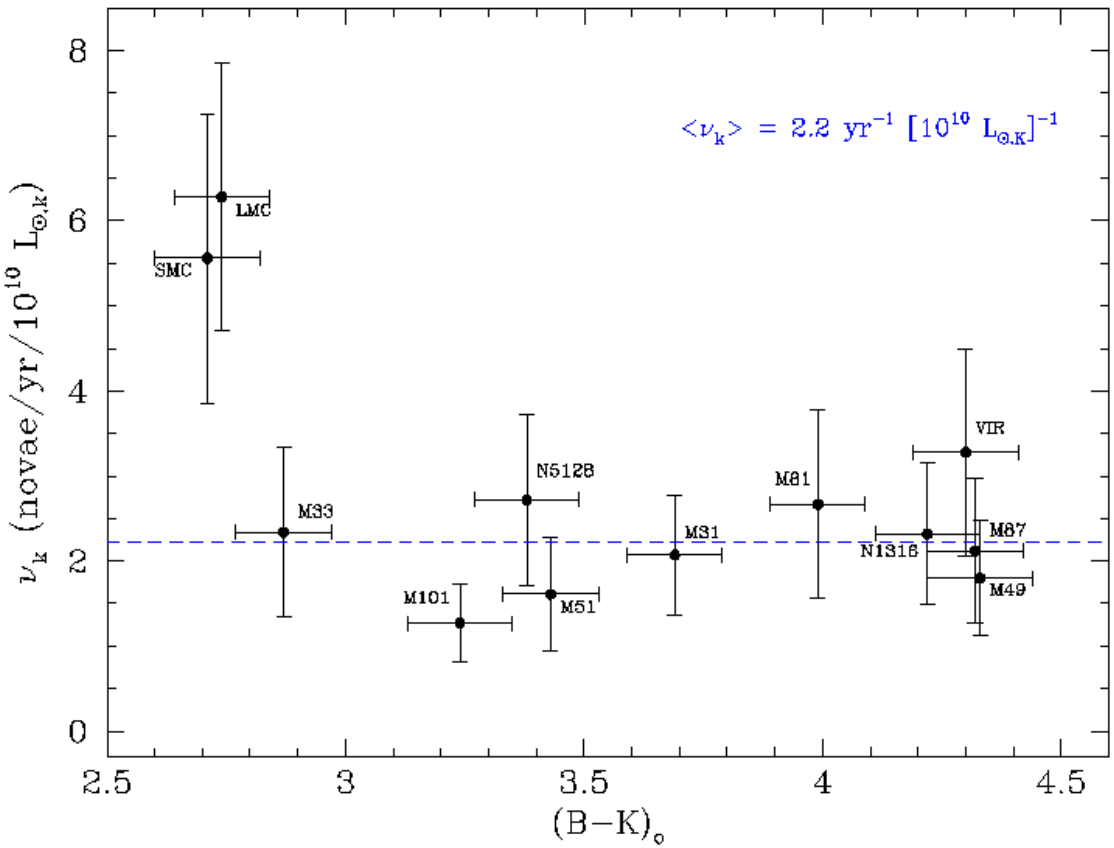
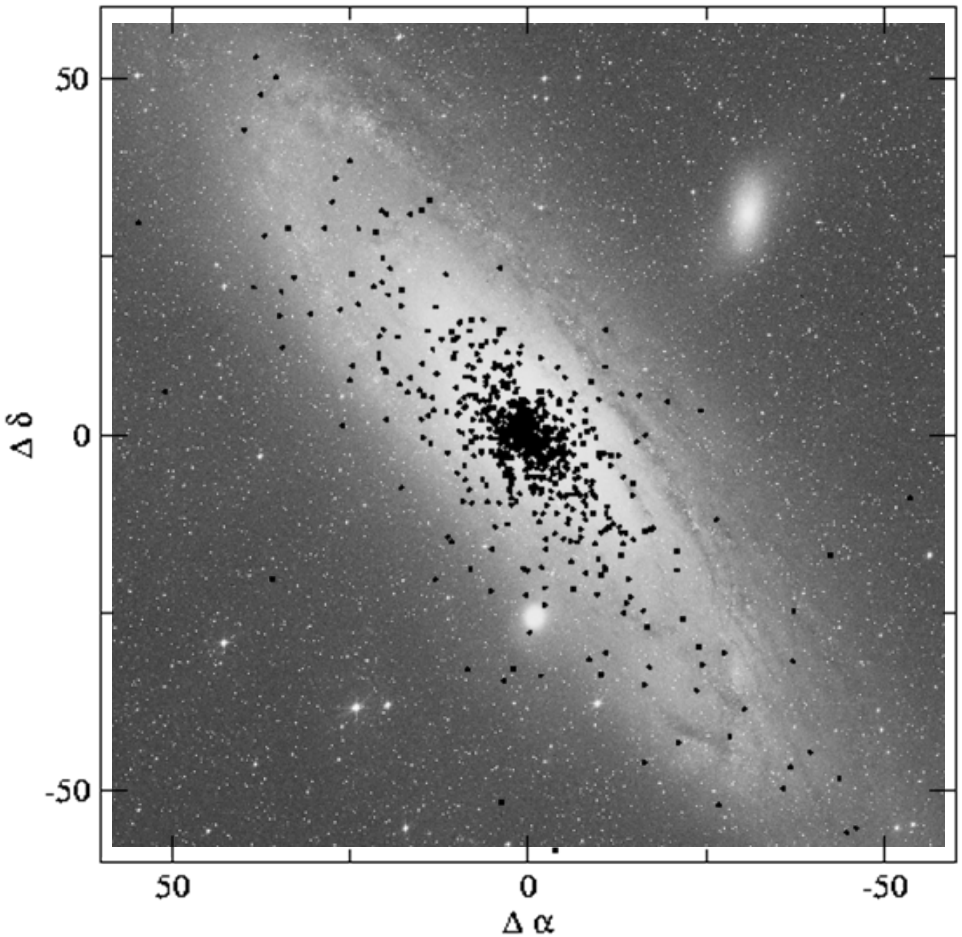


# M31 Recurrent Nova Search Underway




- Jahrese Reed at SDSU compiled positions for all M31 nova to date.

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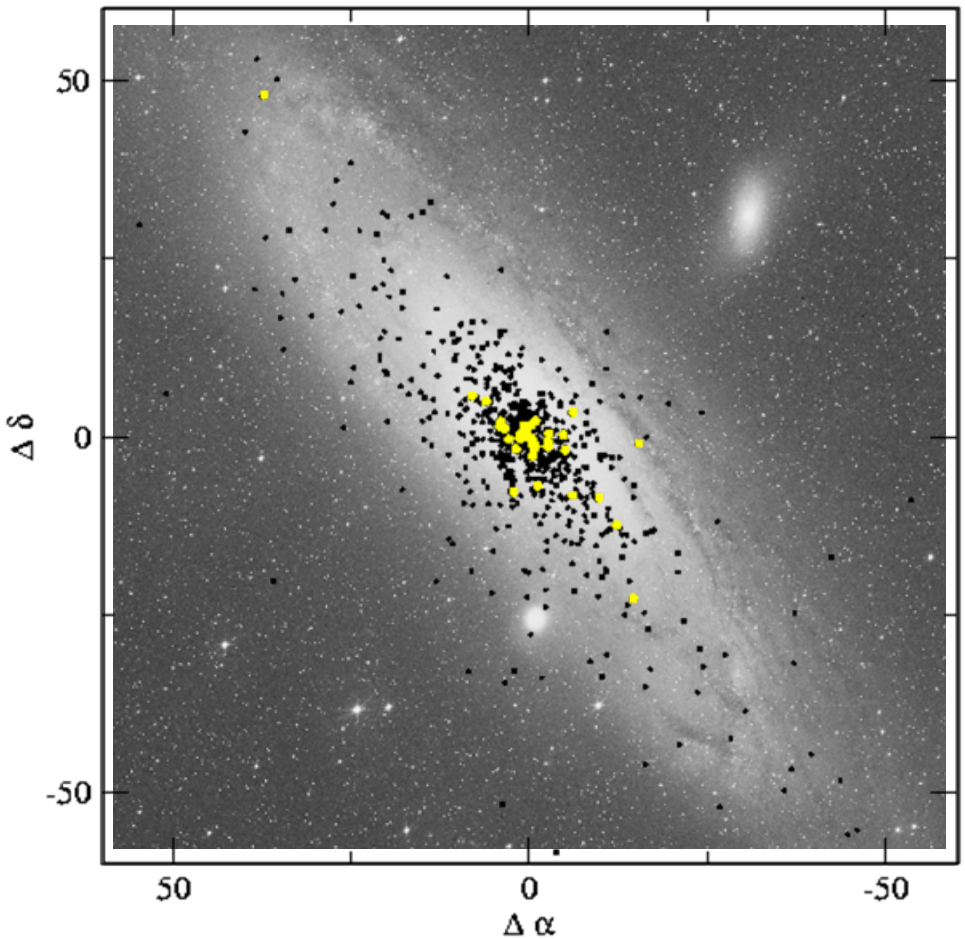


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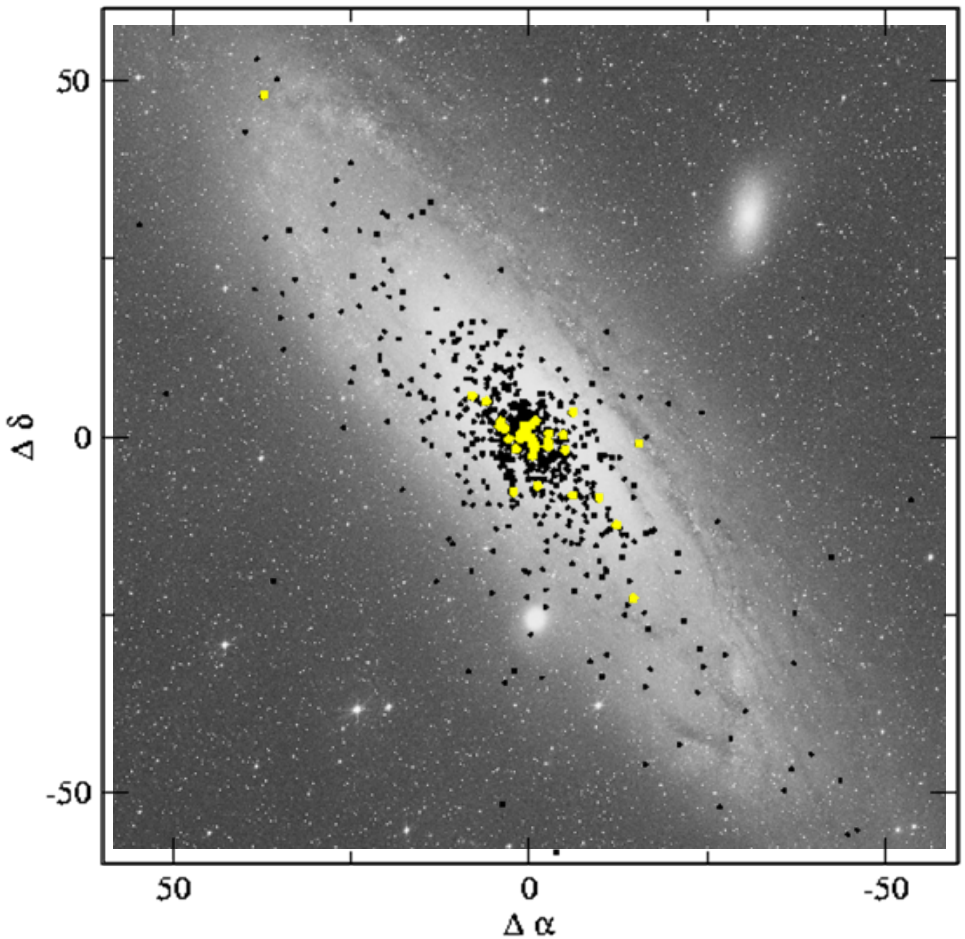


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- 738 outbursts of which 85 are from 40 RNe candidates (at most!).
- $N_{RN}/N_{CN} \sim 0.13$
- If $R_{CN+RN} \sim 65\ yr^{-1}$ then $R_{RN} \sim 7\ yr^{-1}$
- ~30 yr recurrence with $dM/dt \sim 10^{-7}\ M_{sun}\ yr^{-1}$ -> D.R. ~ $1 \times 10^{-4}\ yr^{-1}$
- ~2% of the SNe Ia B.R.

# Conclusions & Future Work

- There is mounting evidence that the extragalactic nova rates have been systematically underestimated due to infrequent sampling and incompleteness in searches.
- The properties of novae (luminosity, fade rate) from differing stellar populations remains uncertain.
- The possible variation of the LSNR of galaxies with differing Hubble types needs to be more definitively established.
- 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!
- Population synthesis models need to address the relatively high nova rates observed in older stellar populations.
- 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.
- SNe Ia birth rate is about a factor of 50 higher than death rate of RNe.