A Brief Review of Extragalactic Novae

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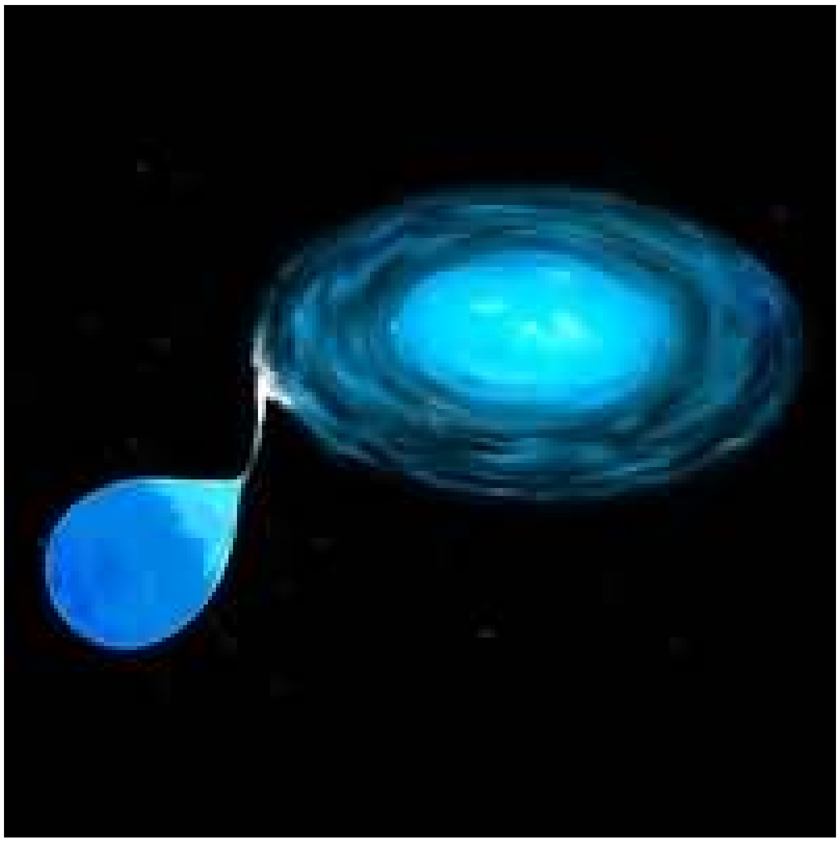
Outline of Review

- Why Study Extragalactic Novae?
- Brief History of Nova Surveys in M31
- Nova Populations
- Nova Rates in Different Hubble-Type Galaxies
- Recurrent Novae as SNe Ia Progenitors
- Summary
- Suggestions for Future Work

What's a Nova?



- Close Binary System consisting of a late-type, near M.S. star transferring mass to a white dwarf companion.
- TNR on surface of WD leads to a nova eruption
- M_V ~ -6 to -9
- Luminosity, fade rate depends on M_{WD}, T_{WD}, dM/dt, and stellar population?
- All novae are recurrent at intervals of ~10^1 - ~10^5 yr.

The Role of Extragalactic Nova Studies

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

II. Stellar population of novae can be more easily studied

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

III. Useful as distance indicators

- $M_V \sim -9$ for brightest (fastest) novae
- MMRD relation (brighter novae fade faster)
- Expensive of telescope time

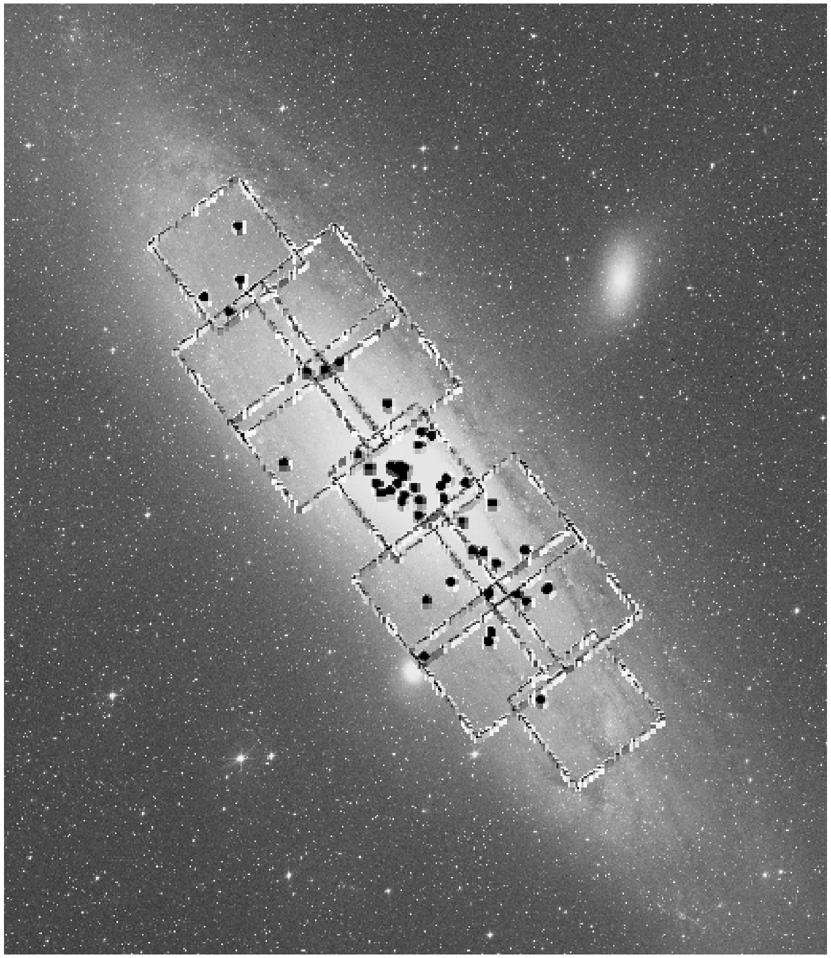
M31: Principal Historical Target

Major Studies:	**<u>Novae</u>**
• Hubble (1929)	85
• Arp (1956)	30
• Rosino (1964;1973)	142
• Ciardullo et al. (1987)	40
• Shafter & Irby (2001)	72
• Darnley et al. (2006)	20

Principal Conclusions:

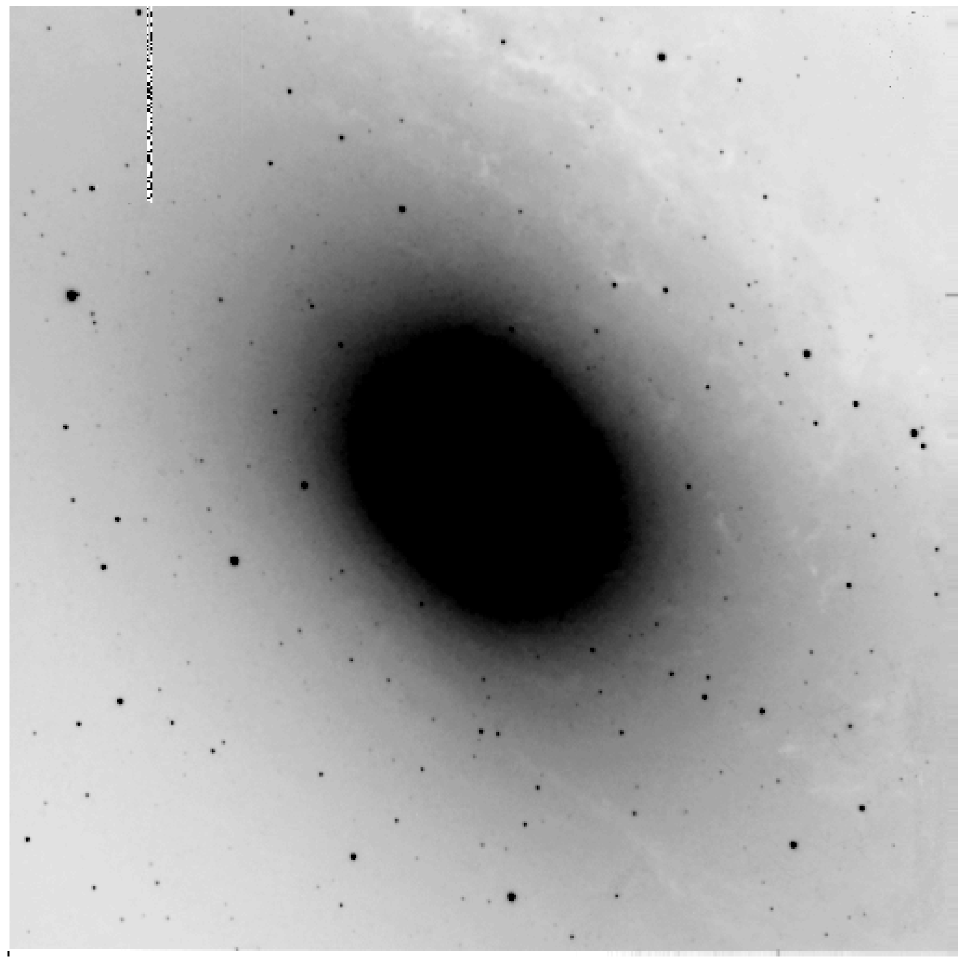
- Nova Rate ~30-40 (65!?) yr^{-1}
- Novae centrally concentrated
- ***Appear consistent with a mainly bulge population***

Recent M31 Nova Survey Results

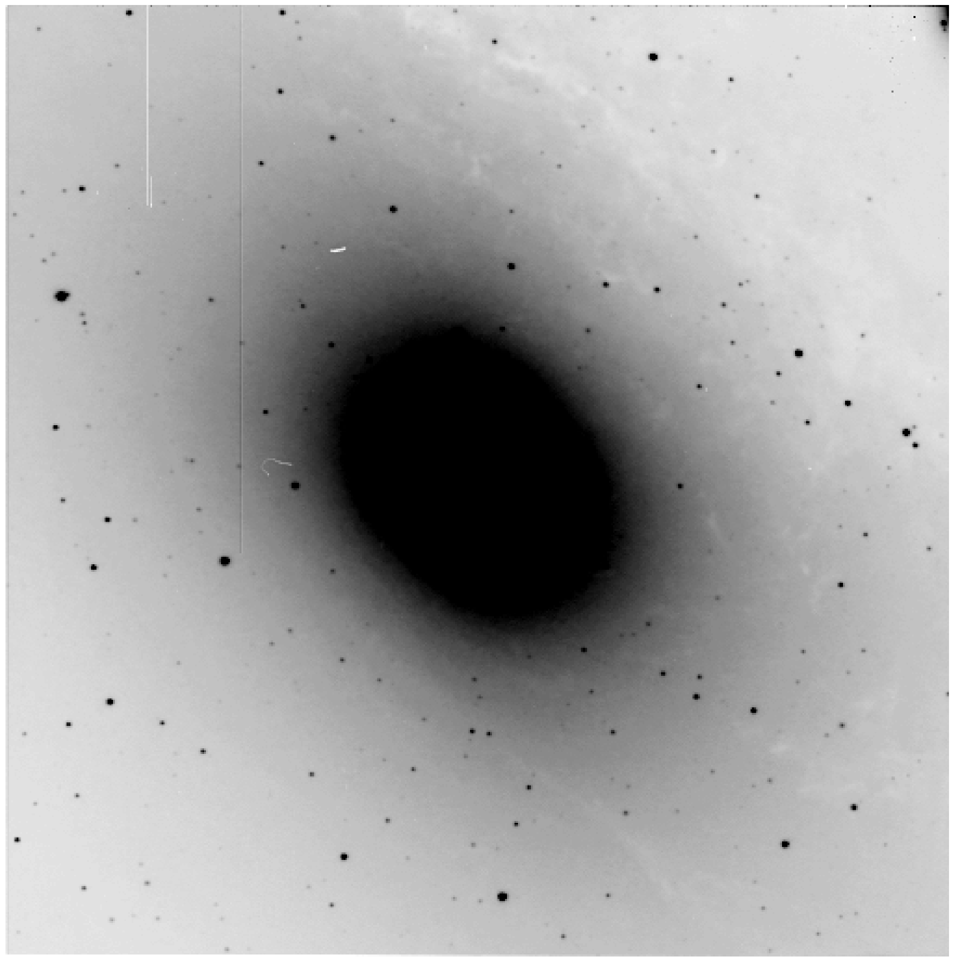


- Shafter & Irby (2001) Hα survey at MLO.
- 11 13’x13’ CCD fields
- 53 Novae detected in Survey A
- Novae centrally concentrated

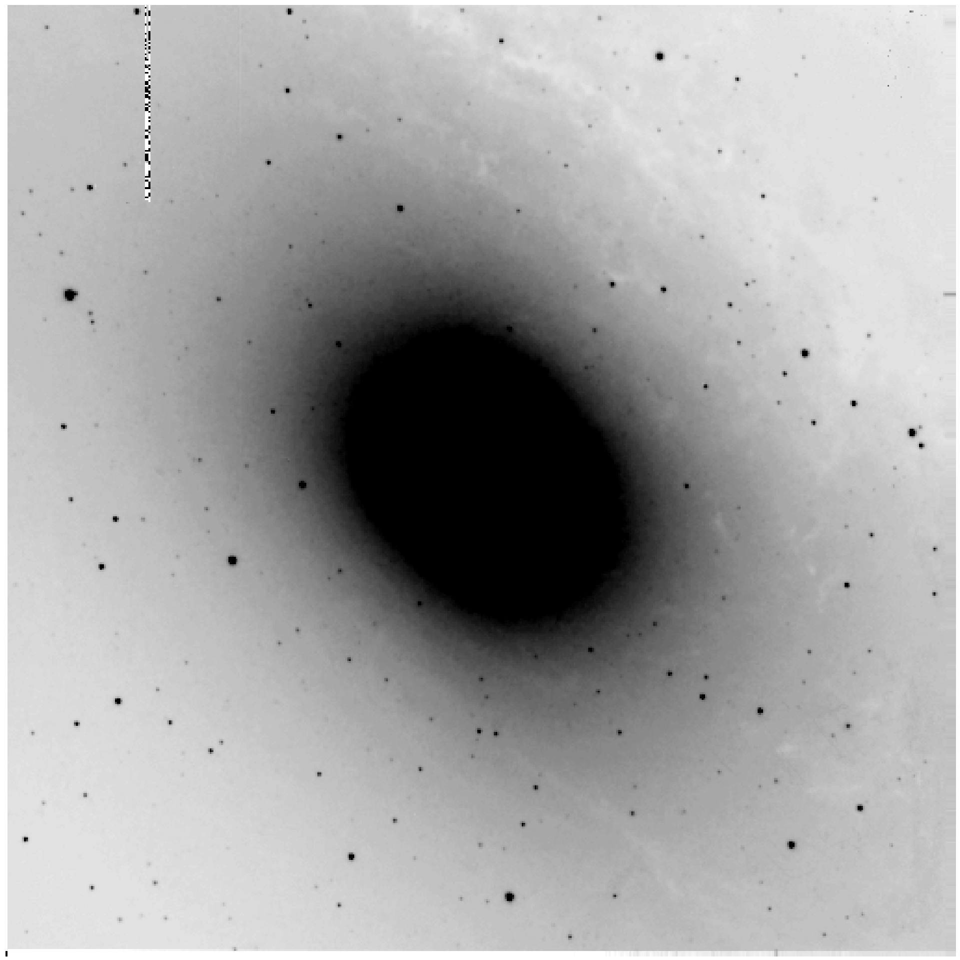
M31 Bulge Hα 29Dec03



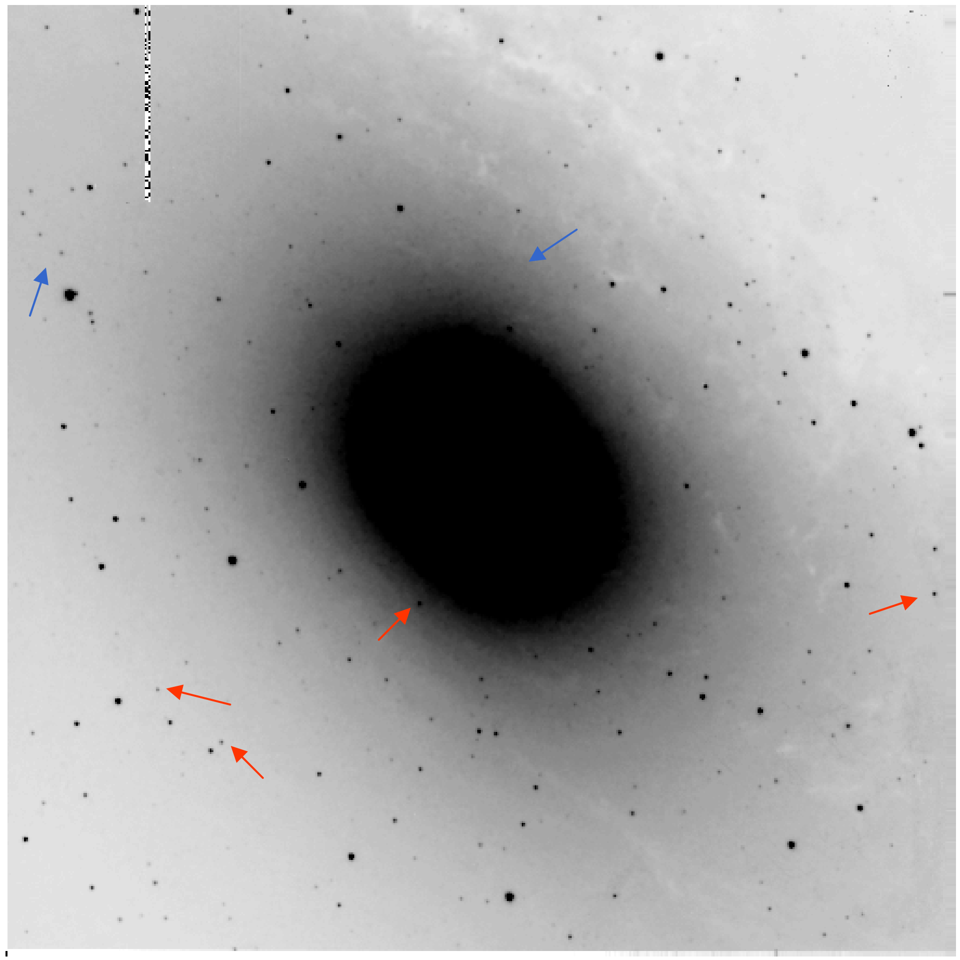
M31 Bulge: Hα 23Jan05



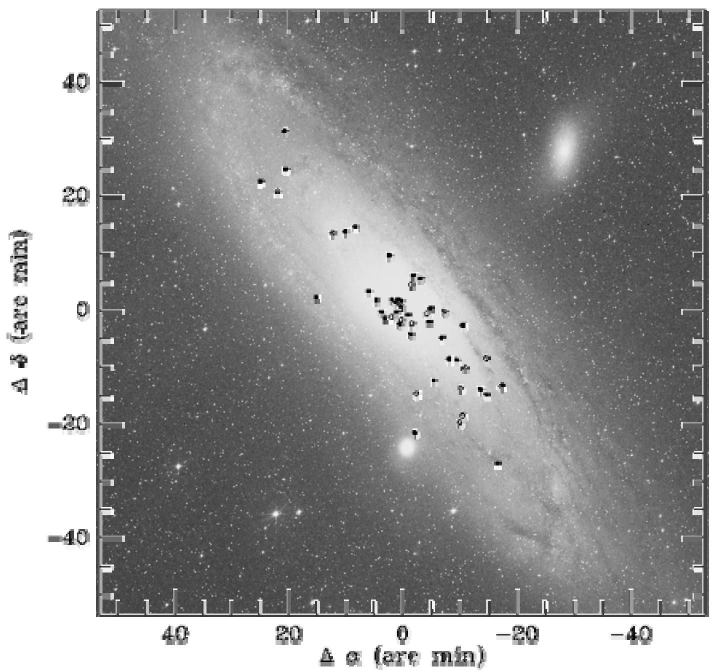
M31 Bulge: 29Dec03 – 23Jan05 Comparison



M31 Bulge: 29Dec03 – 23Jan05 Comparison

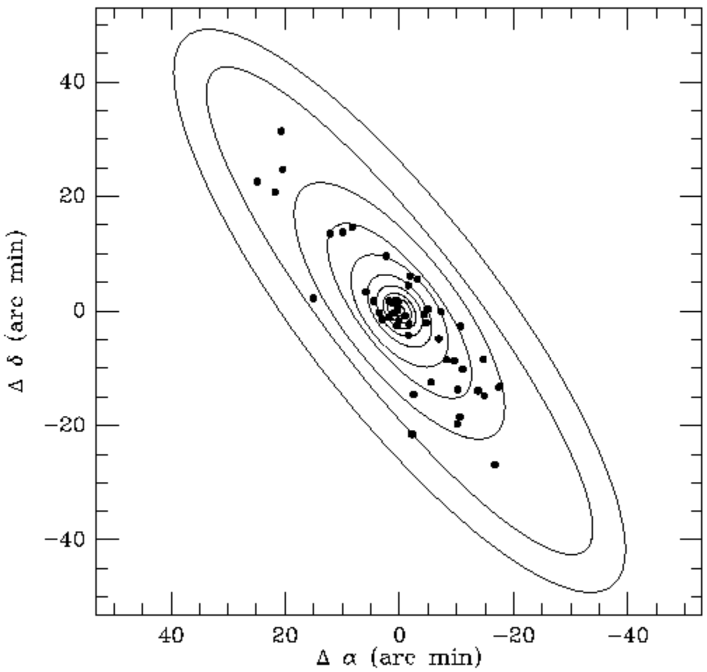


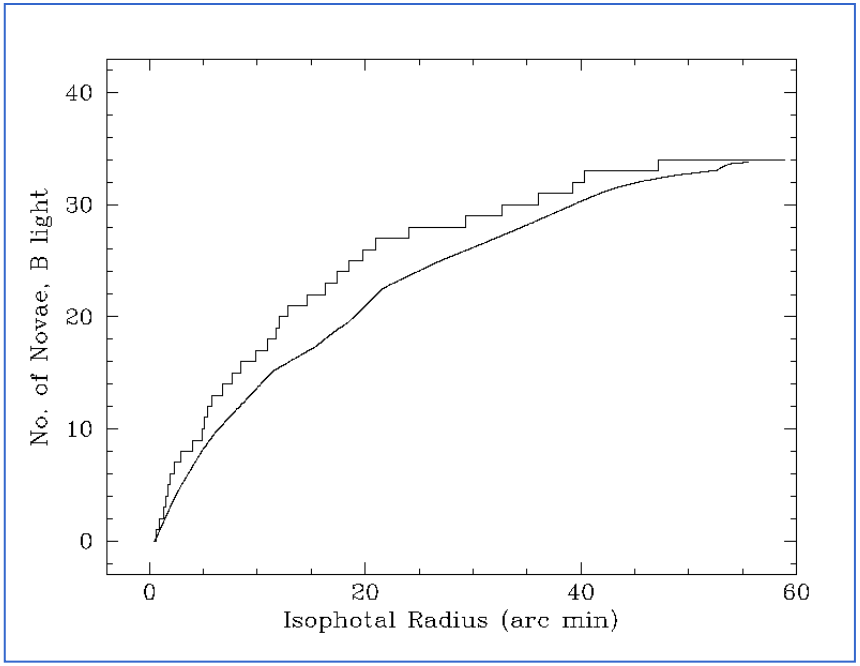
Nova Isophotal Radius Distributions



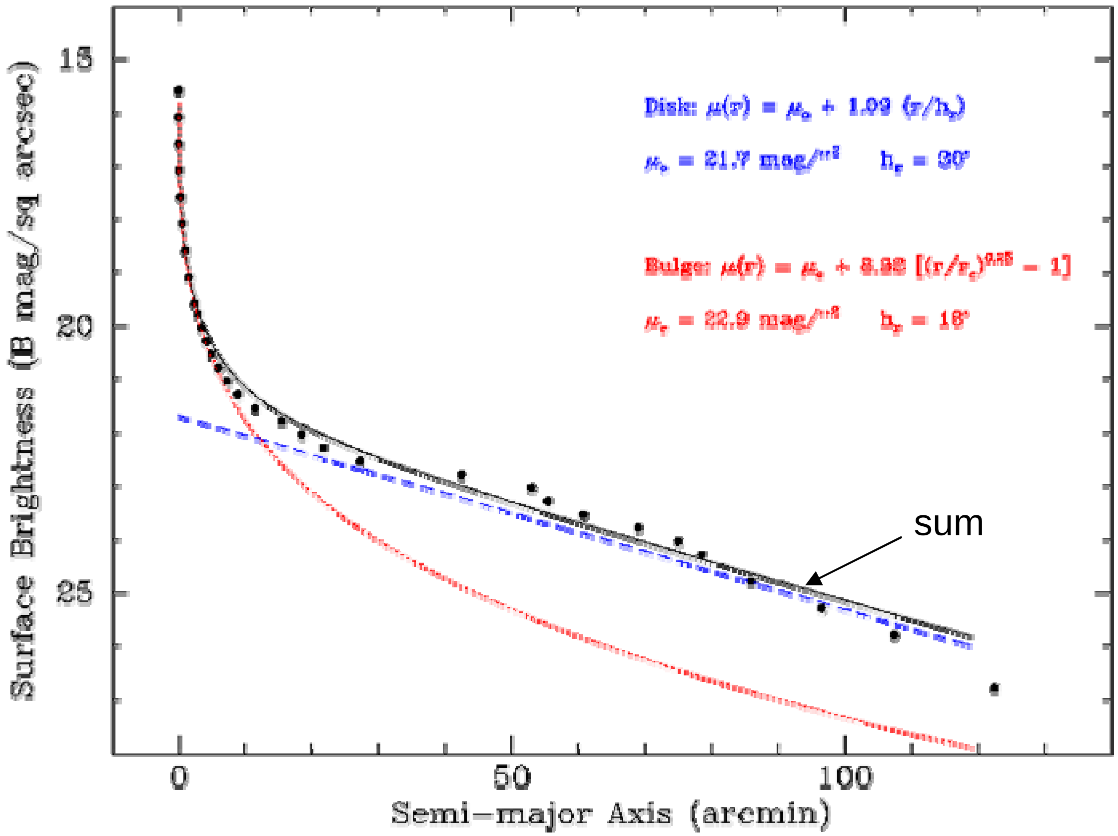
- Radial distributions of the 53 novae are computed based on the background *B* band light.
- Radial distributions are also computed based on background light from bulge-disk separations of the M31 *B* band surface brightness.

Cumulative Nova Distribution vs *B*-band Light

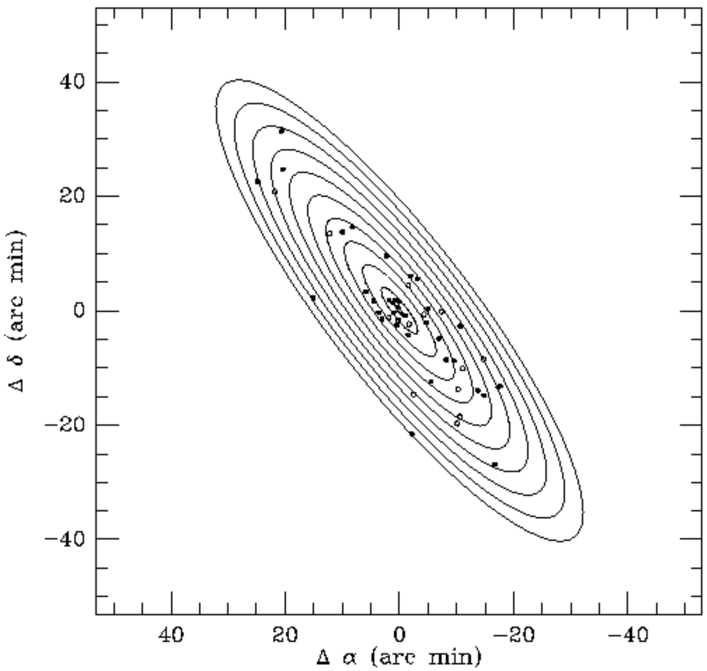


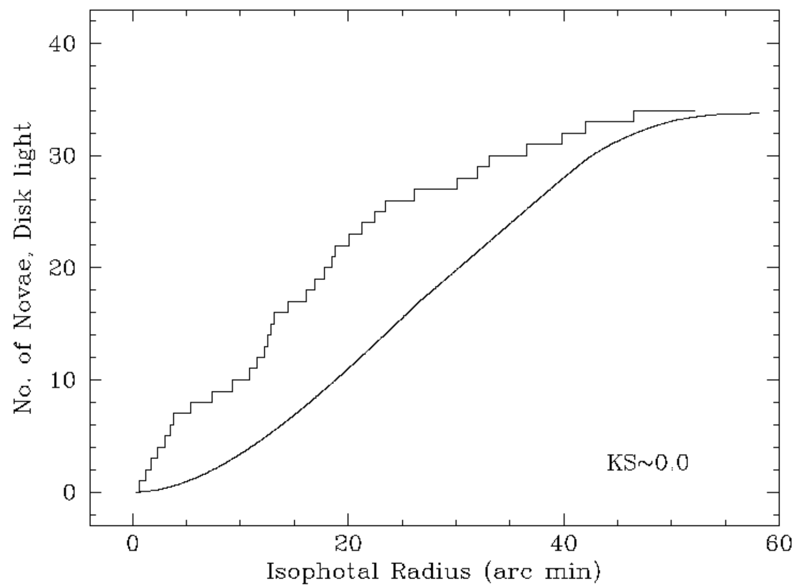


Radial Surface Brightness Profile of M31 *B* Light

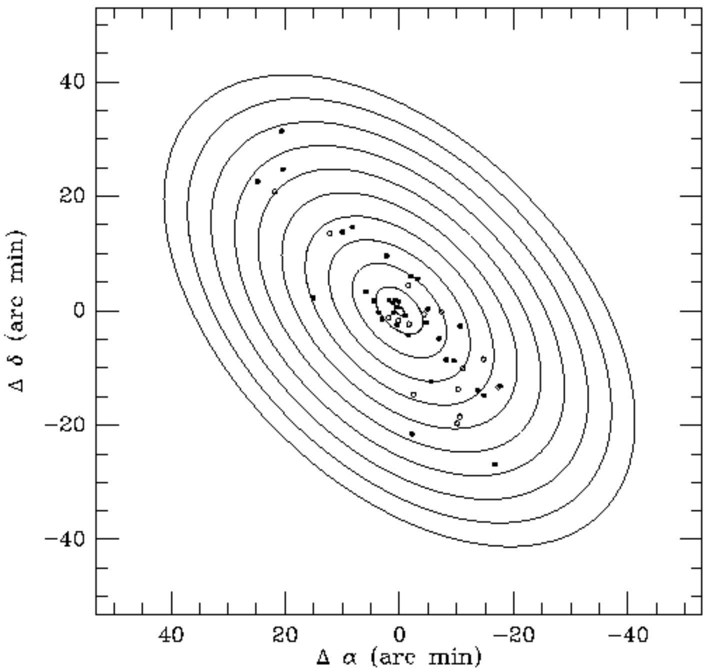


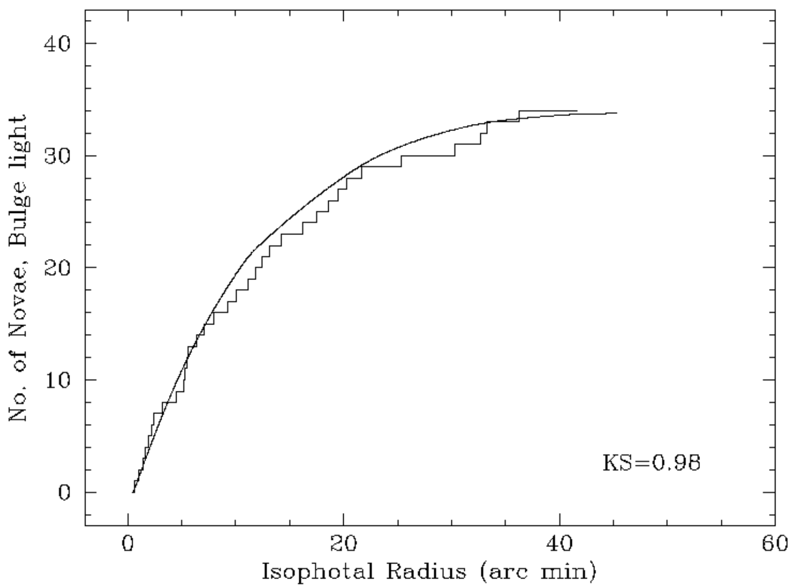
Cumulative Nova Distribution vs Disk Light





Cumulative Nova Distribution vs Bulge Light





Nova Populations

- Relatively high M31 bulge rate results from:

  (1) Shorter recurrence times for bulge novae?

  (2) Higher specific density of bulge novae?

  (e.g., could some fraction of bulge novae be spawned in globular clusters?)

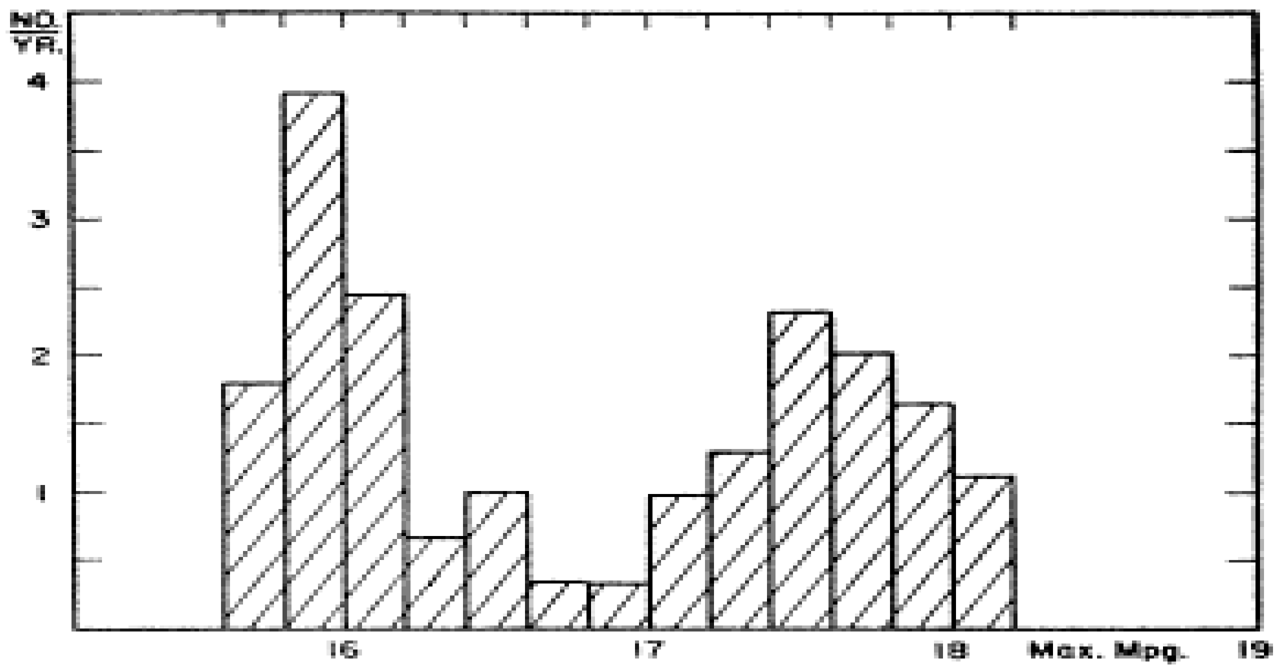
  (3) ***M87 rate may be ~3 times M49, as is the GC population!***

  (4) Observational selection bias, Extinction, etc.

- Are there two distinct populations of Novae?

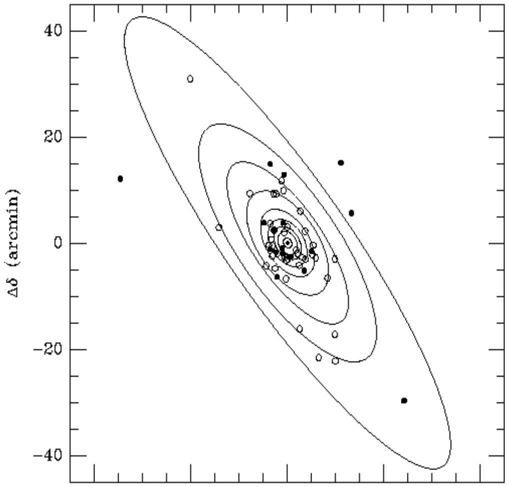
- If so, do their observed properties (maximum magnitude, rate of decline) differ?

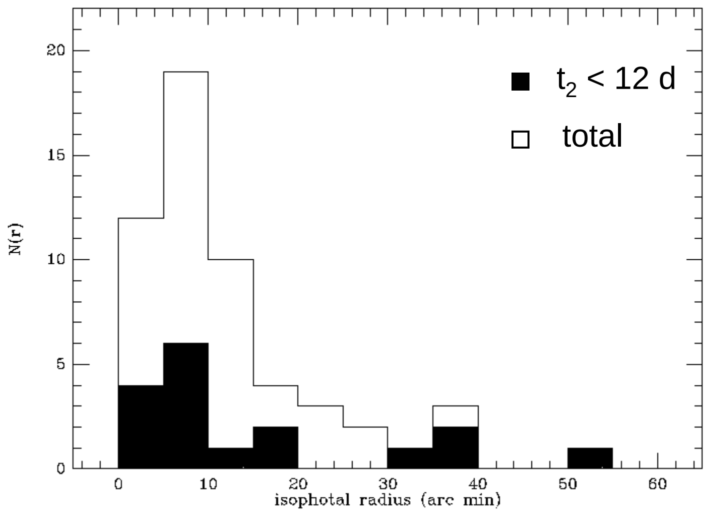
Maximum Magnitude for Arp's M31 Novae



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.

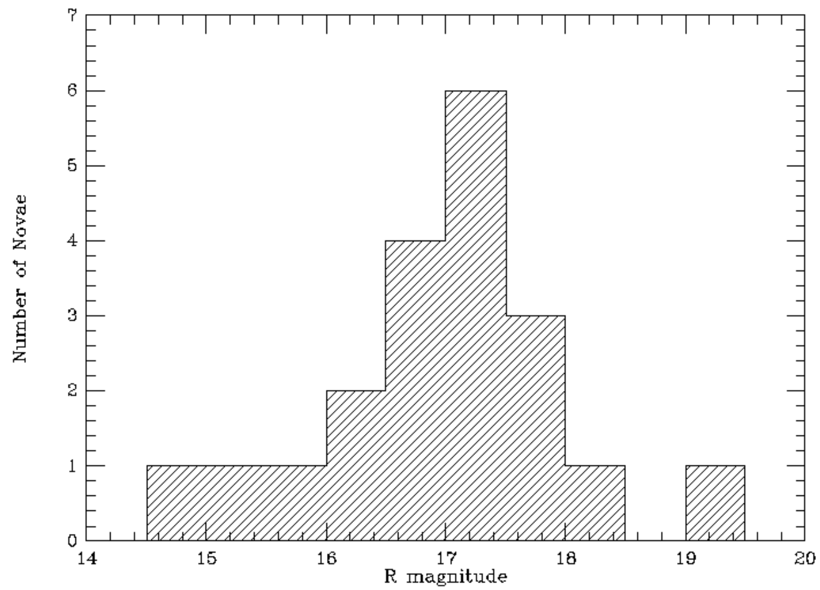
Variation of Nova Speed Class with Spatial Position





- Light curve data from Arp (1956) nova sample reveals no obvious dependence of nova speed class with spatial position in the galaxy.
- Limited nova sample and high inclination of M31 make it difficult to draw definitive conclusions from the Arp nova sample.

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

Distribution of Nova Decline Rates in Differing Galaxies

- The fade rates of Galactic and M31 novae have long been known to be slower than novae from the younger stellar populations found in the LMC.

From Della Valle et al. (1995)

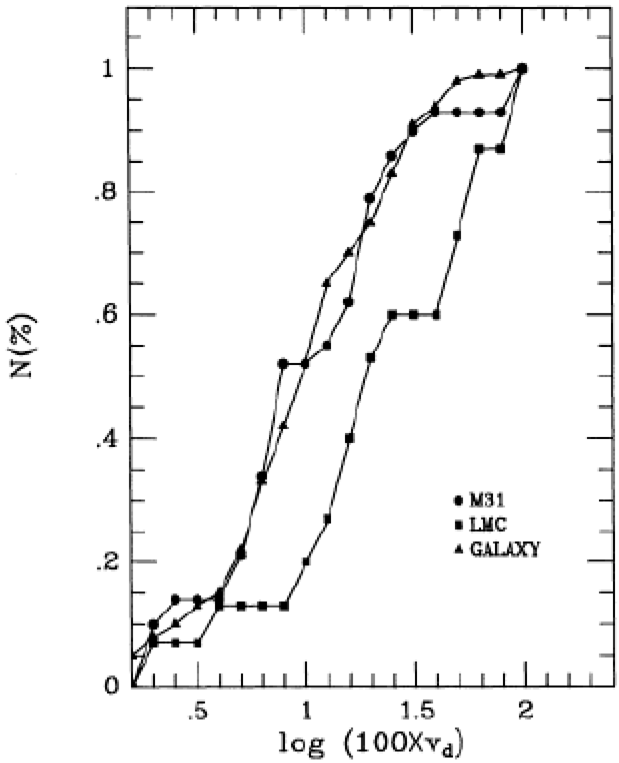


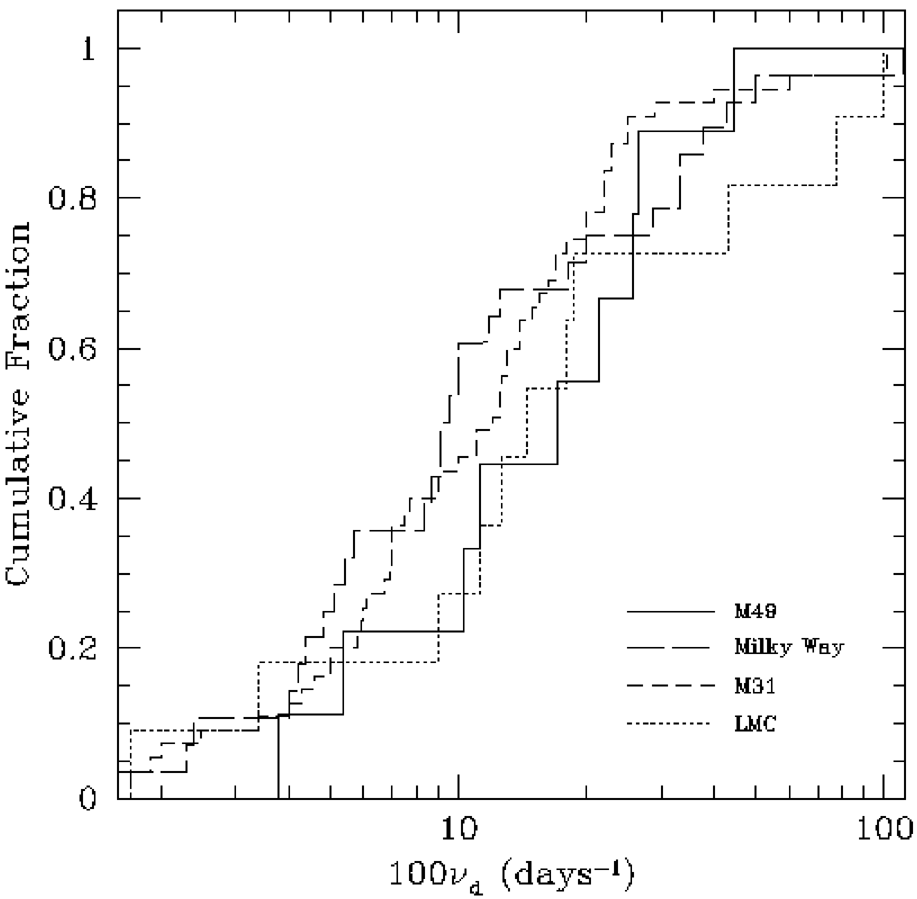
Fig. 1. Cumulative distributions of the rates of decline for M31, Galaxy and LMC. The M31 data come from Arp (1956) and Capaccioli et al. (1989), Galaxy data from Della Valle (1988), and LMC data from Capaccioli et al. (1990)

Distribution of Nova Decline Rates in Differing Galaxies

- The fade rates of Galactic and M31 novae have long been known to be slower than novae from the younger stellar populations found in the LMC.

- However, Ferrarese et al. (2004) have shown that the fade rate for a sample of M49 novae (Pop II) are comparable to novae in the LMC (Pop I).

From Ferrarese et al. (2004)



Nova Rates in Different Hubble Type Galaxies

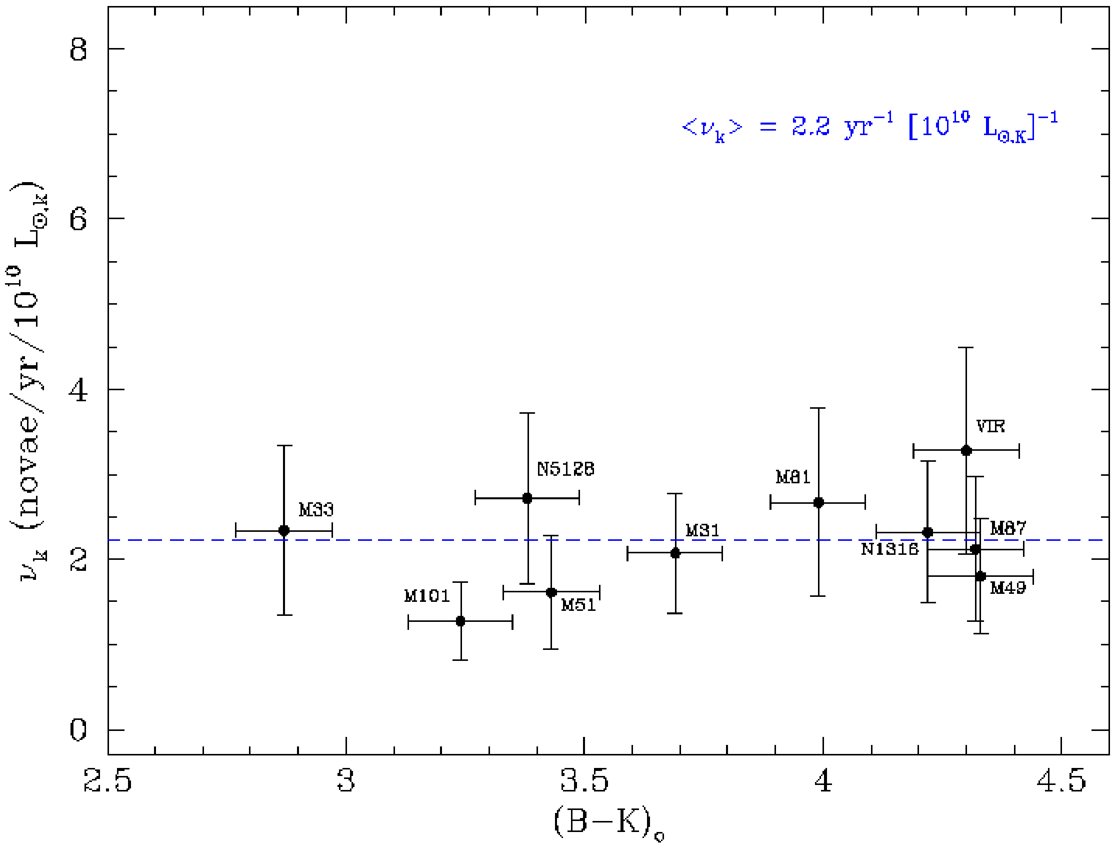
- Nova rates have been measured in a dozen external galaxies.

- 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).

- Thus, the LSNR should vary with the Hubble type of the galaxy.

Luminosity-Specific Nova Rates

From Williams & Shafter (2004)



Luminosity-Specific Nova Rates

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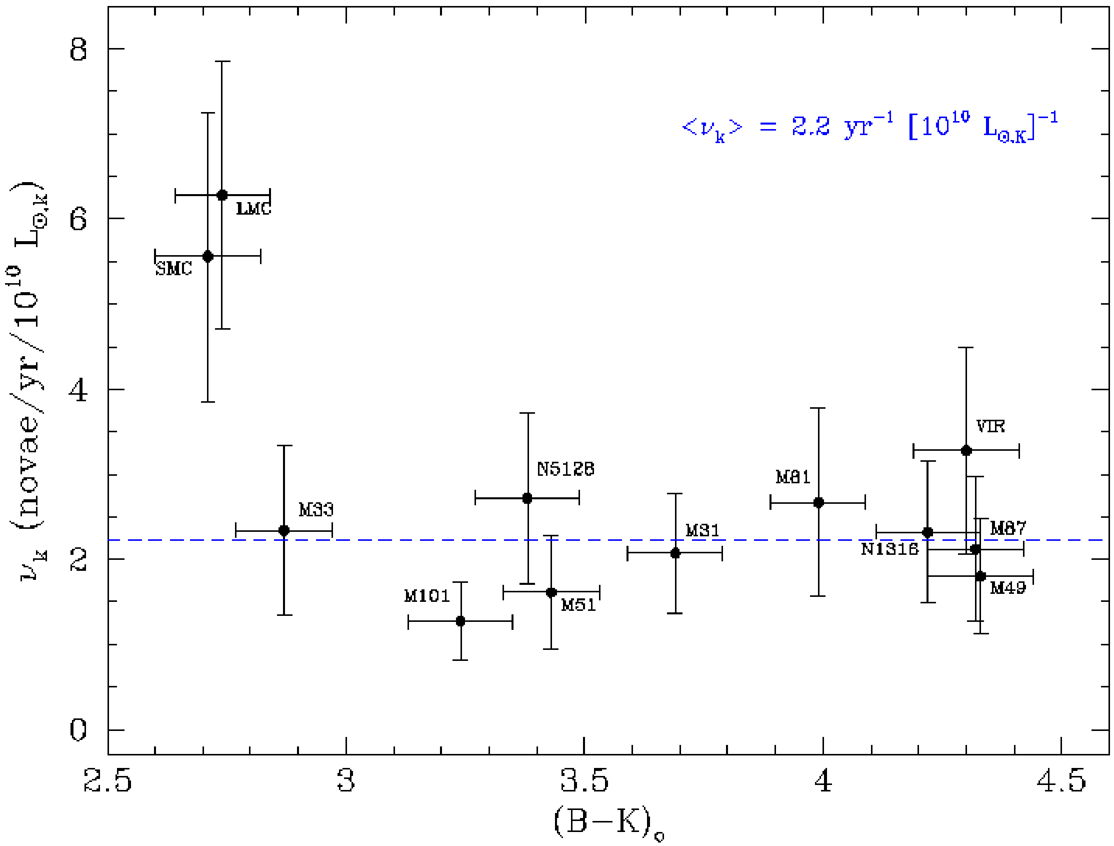
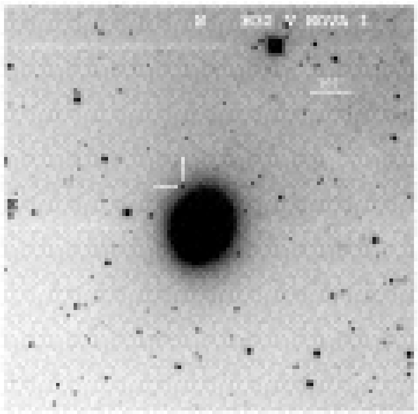
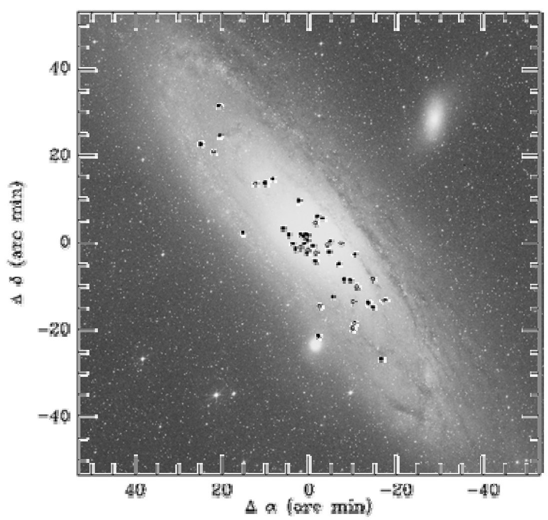


A High M32 Nova Rate?

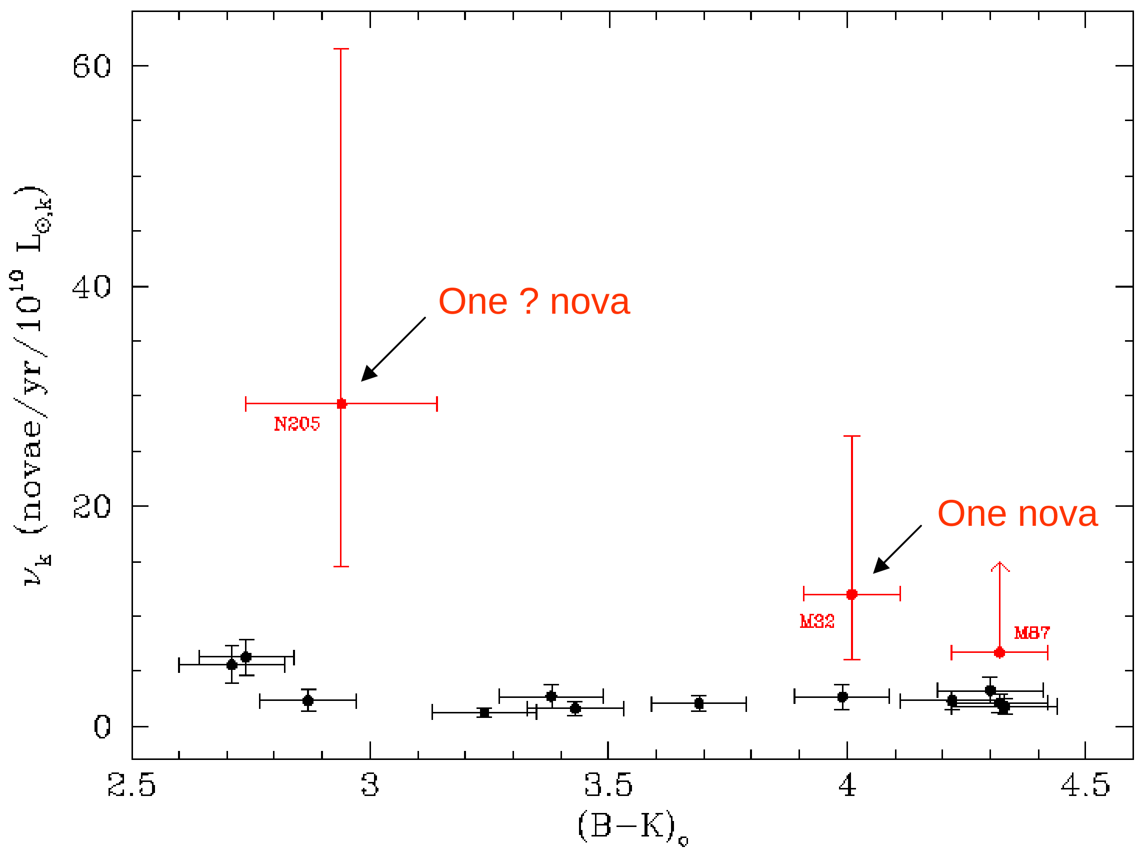




- Neill & Shara (2005) discovered a nova in the field of M32 during a 4.5 mo survey.
- They derive rate of $2^{+2.4}_{-1.0}$ novae per yr for M32.
- LSNR~12
- Contamination from M31 is a problem.

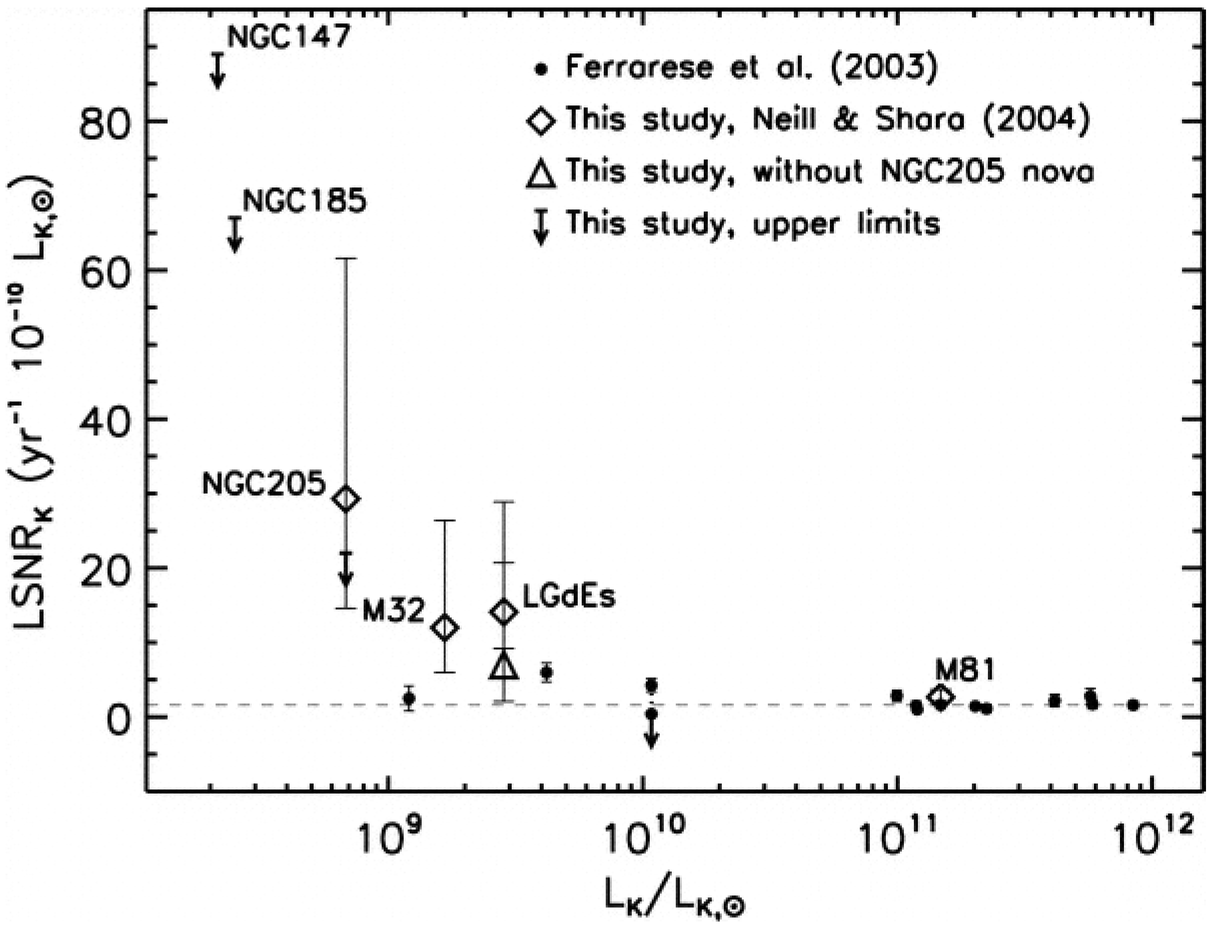
LSNRs with addition of Neill & Shara (2005) ellipticals

Potentially high LSNRs in low mass dwarf ellipticals

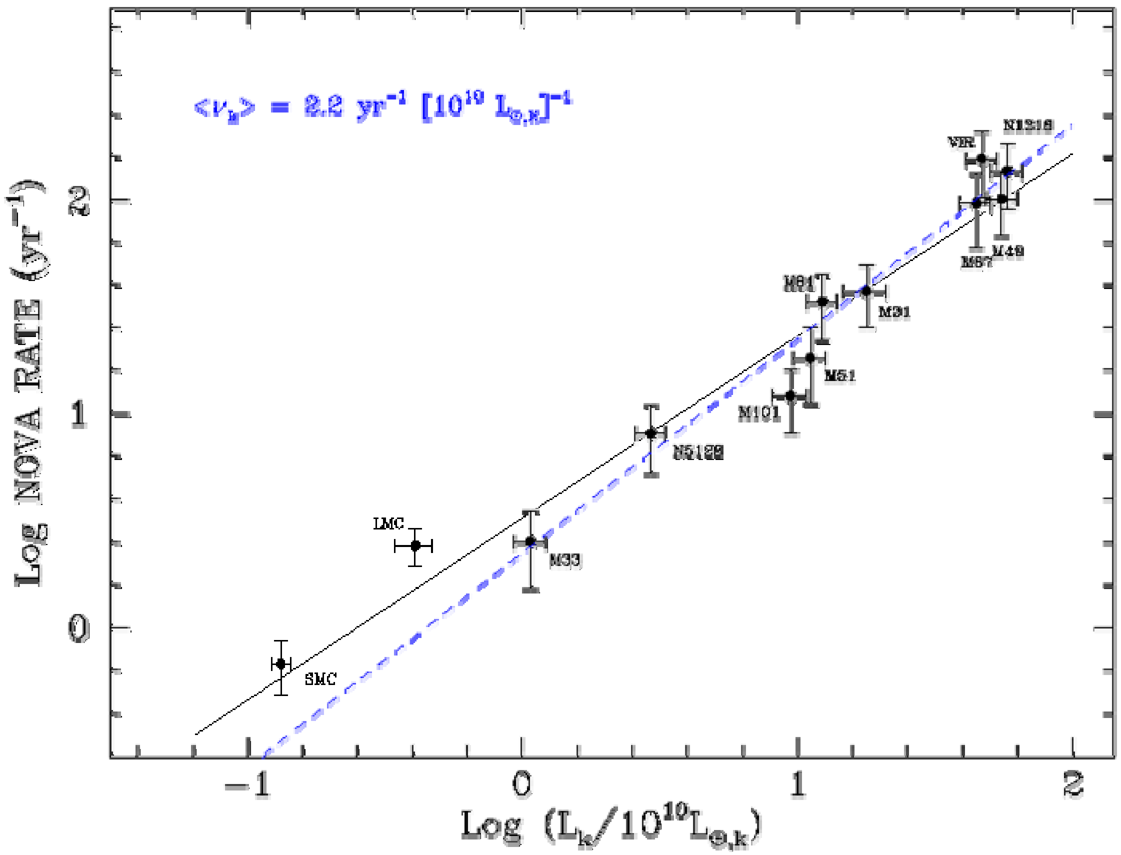


LSNR as a function of galaxy mass (*K* luminosity)

Neill & Shara (2005)



Nova Rates vs Galaxy *K*-band Luminosity



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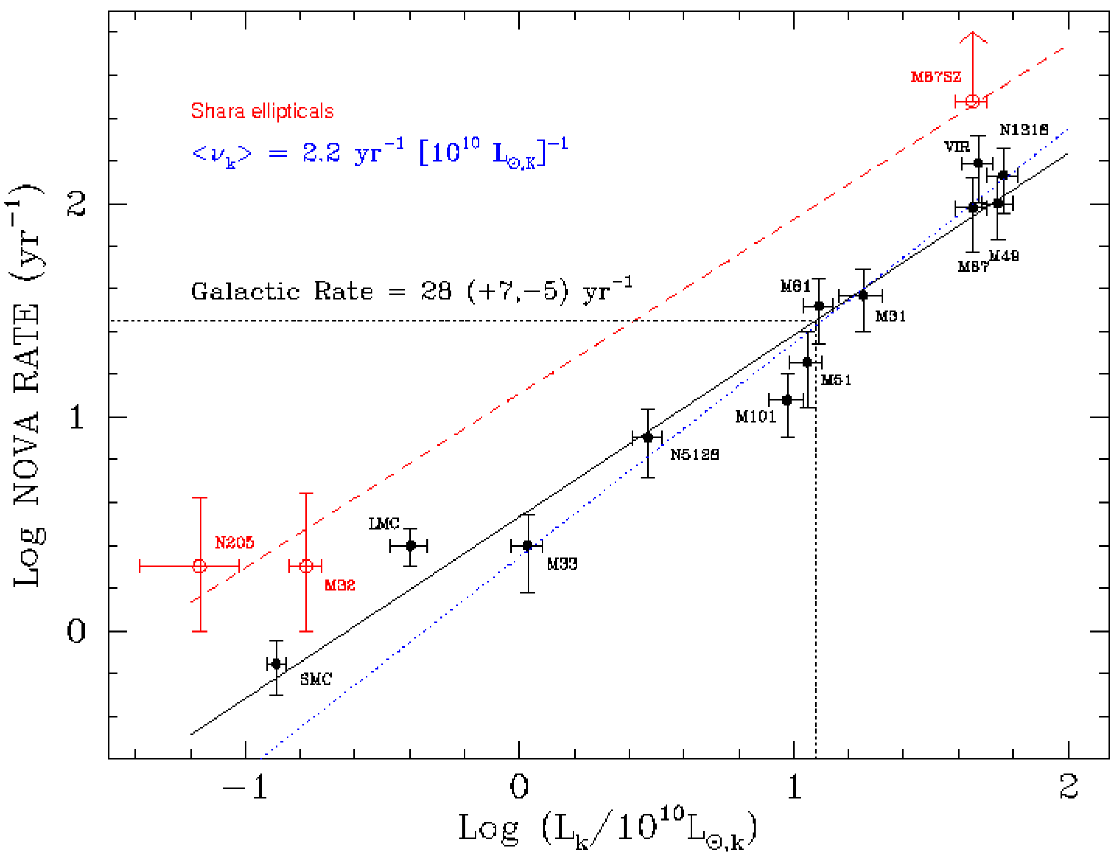

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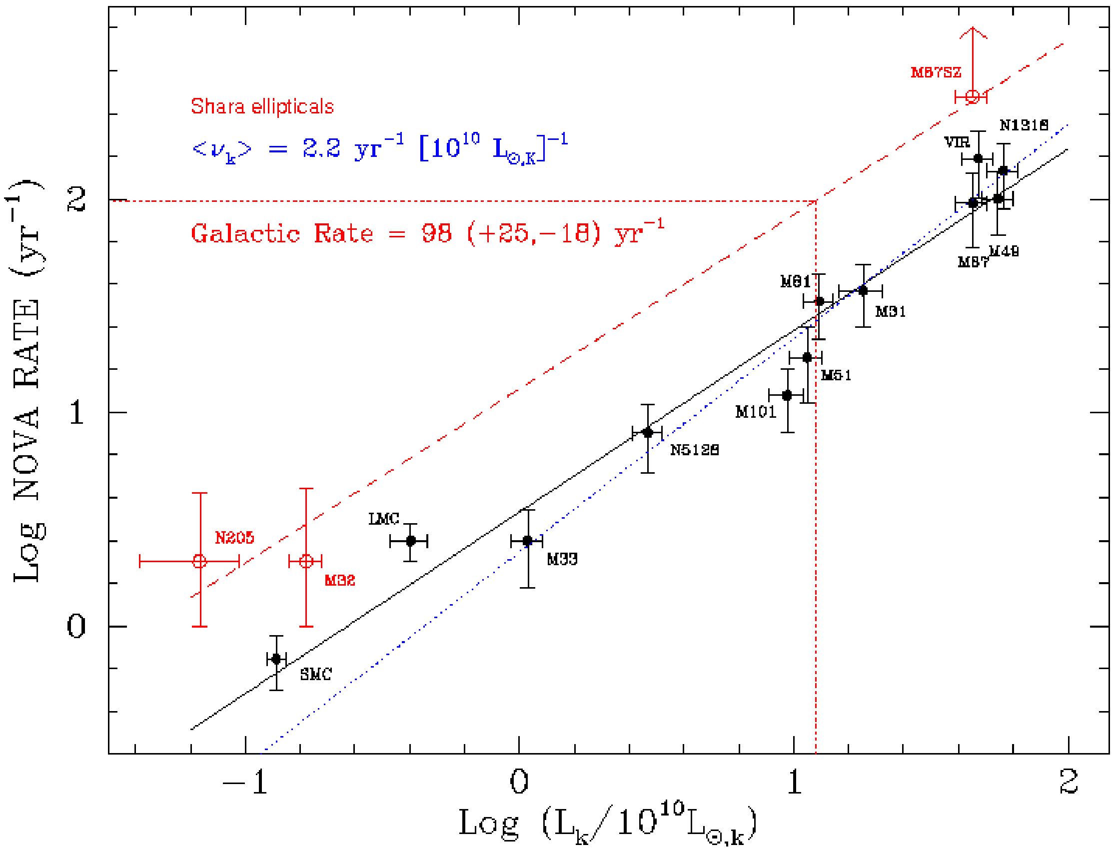
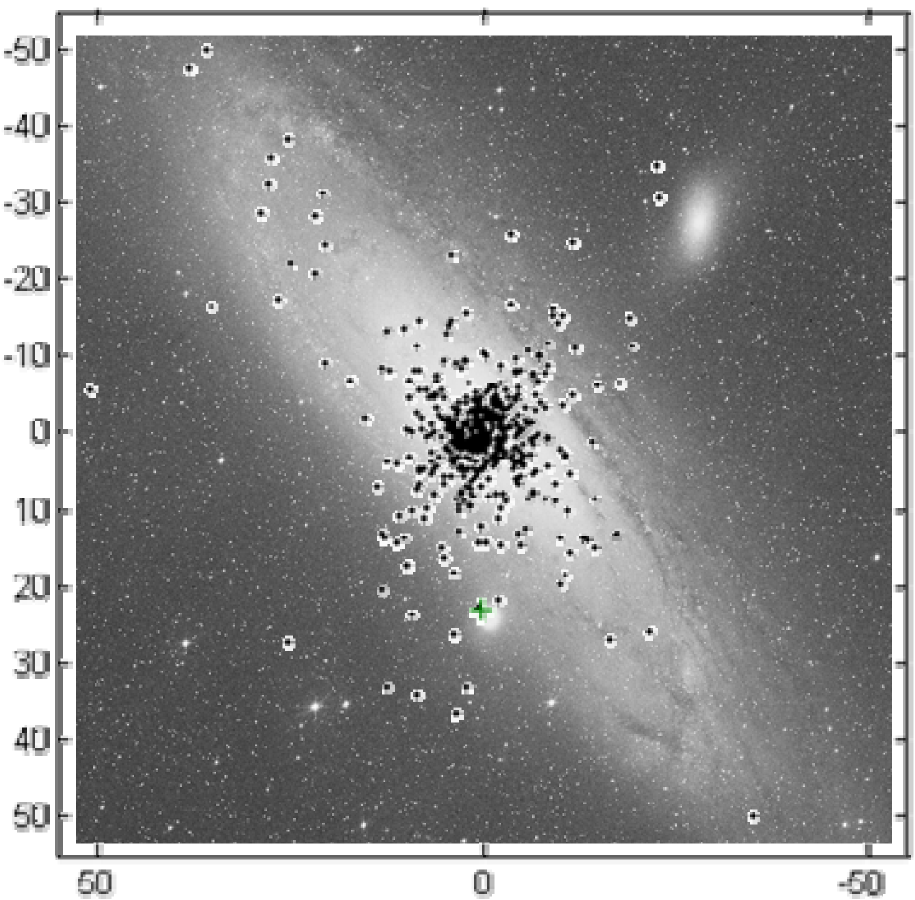


M31 Recurrent Nova Search Underway



- Jahrese Reed at SDSU compiled positions for all M31 nova to date.
- 507 outbursts of which 48 are from 22 RNe candidates.
- $N_{RN}/N_{CN} \sim 0.11$
- If $R_{CN} \sim 65\ yr^{-1}$ then $R_{RN} \sim 7\ yr^{-1}$

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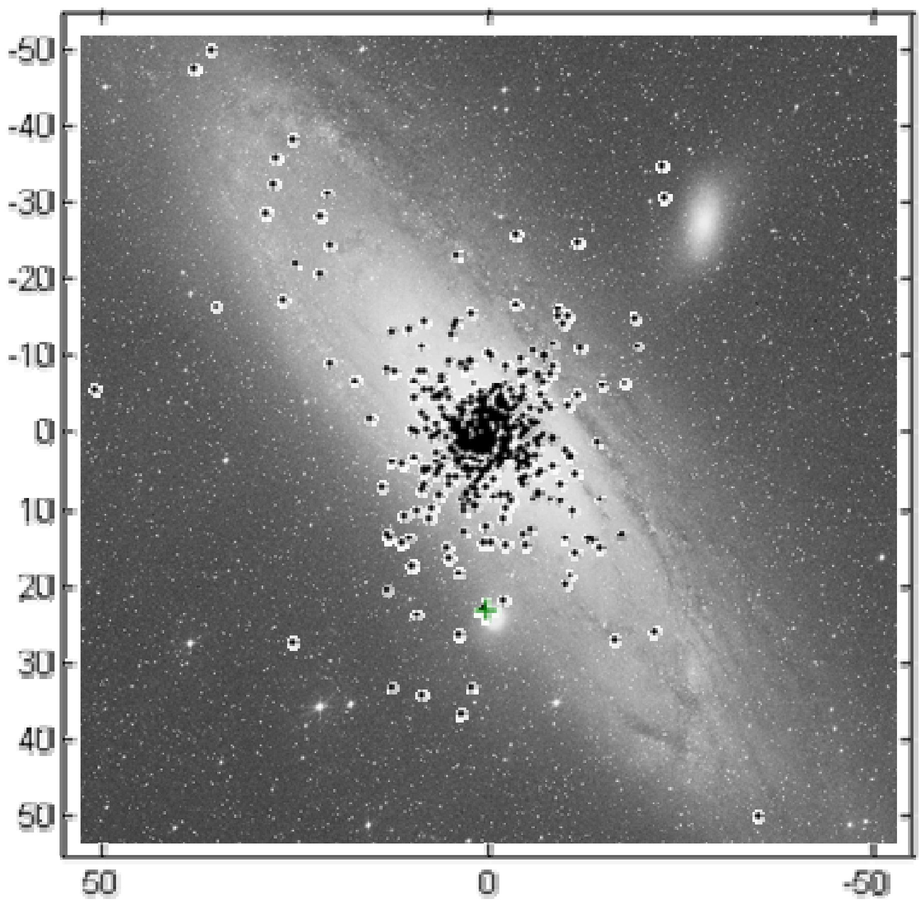

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- $N_{RN}/N_{CN} \sim 0.11$
- If $R_{CN} \sim 65$ yr^{-1} then $R_{RN} \sim 7$ yr^{-1}
- ~30 yr recurrence with $dM/dt \sim 10^{-7}$ M_{sun} yr^{-1} -> D.R. ~ 1-2 x 10^{-4} yr^{-1}
- ~2% of the SNe Ia B.R.

Conclusions

- There is mounting evidence that the extragalactic nova rates have been systematically underestimated due to infrequent sampling and incompleteness in searches.
- The nova rate per unit mass (*K* luminosity) appears to be at least as high, and maybe higher, in older stellar populations, which is in conflict with expectations from population synthesis models.
- A significant fraction of nova binaries may be spawned in a galaxy's gloublar cluster system.
- Scaling from extragalactic surveys suggest a Galactic nova rate of 25-35 per year in excellent agreement with the Galactic estimate. (*but*, see Neill & Shara 2005).
- SNeIa birth rate is about a factor of 50 higher than death rate of RNe.

Future Work

- The properties of novae (luminosity, fade rate) from differing stellar populations must be explored further.
- Pan-Starrs and the LSST will be of great help here!
- The possible variation of the LSNR of galaxies with differing Hubble types needs to be more definitively established.
- Population synthesis models need to be improved to address the 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.