Measuring Galactic and Extragalactic NOVA Rates

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Methods of Determining the Galactic Nova Rate

I. Direct: Extrapolation of Observed Spatial Distribution of Novae to the Entire Galaxy

Problems Include:

- Distribution strongly affected by patchy interstellar absorption
- Distances to individual novae uncertain
- Azimuthal Asymmetry of Galaxy (i.e. presence of a bar)
- ***Possible variation in nova luminosity and frequency in differing stellar populations***

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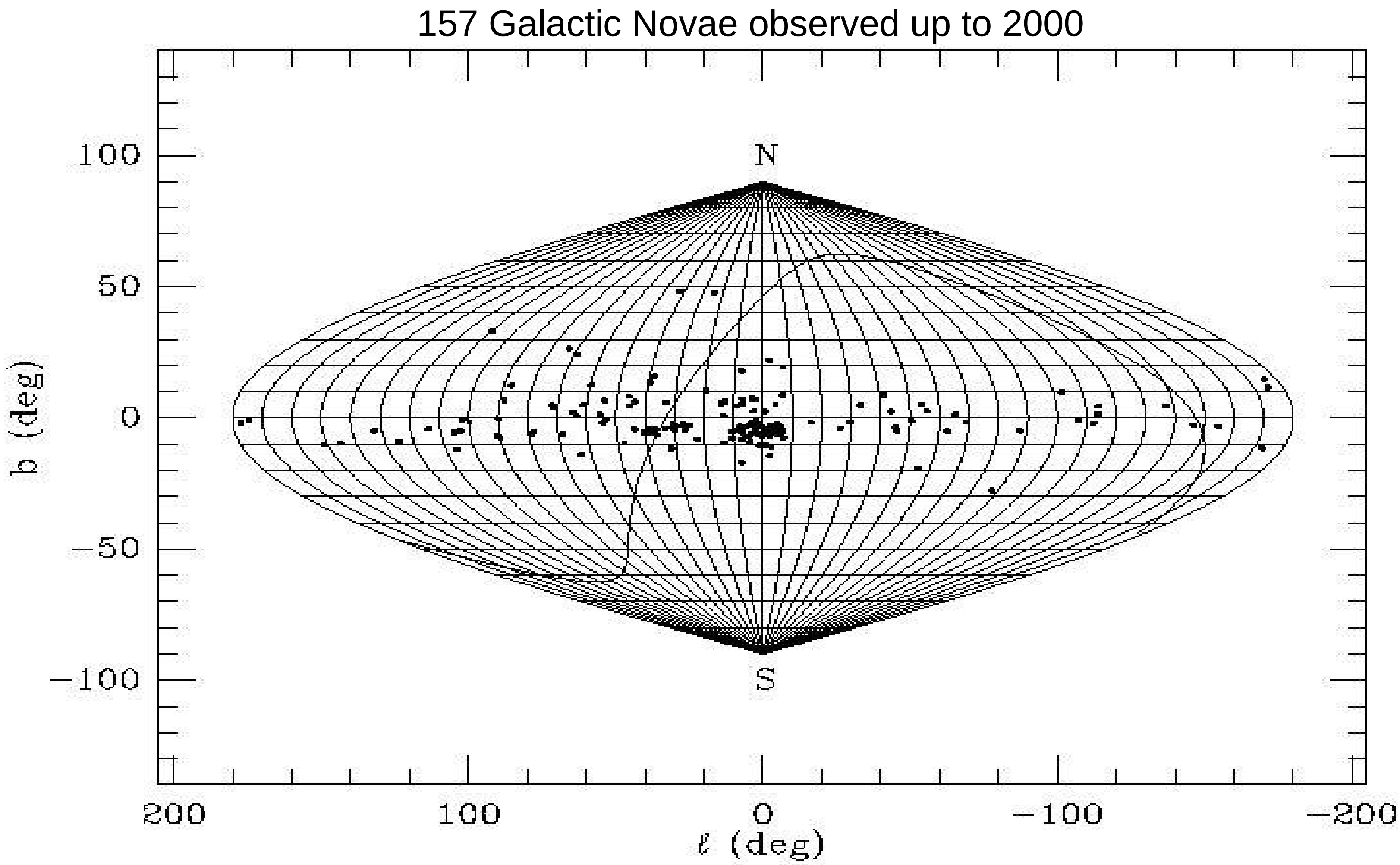
II. Indirect: Estimation Based on Extragalactic Rates

Problems Include:

- Uncertainty in Extragalactic Nova Rates (incompleteness)
- ***Possible variation in nova properties in differing stellar populations***

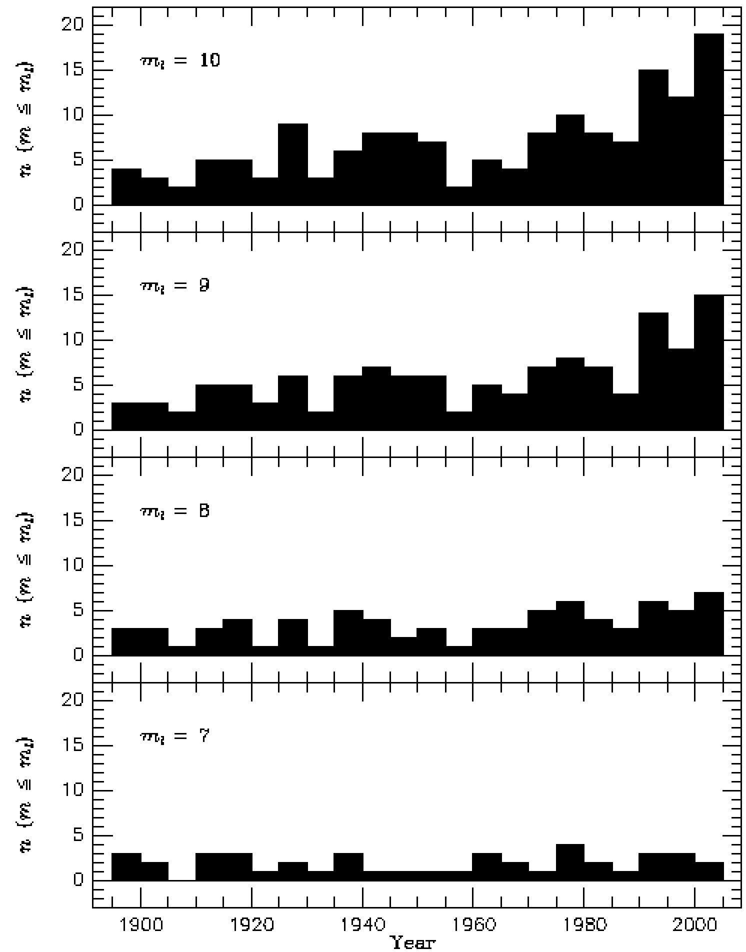
Galactic Distribution of Classical Novae



Galactic Nova Discovery Rate (1895-2005)

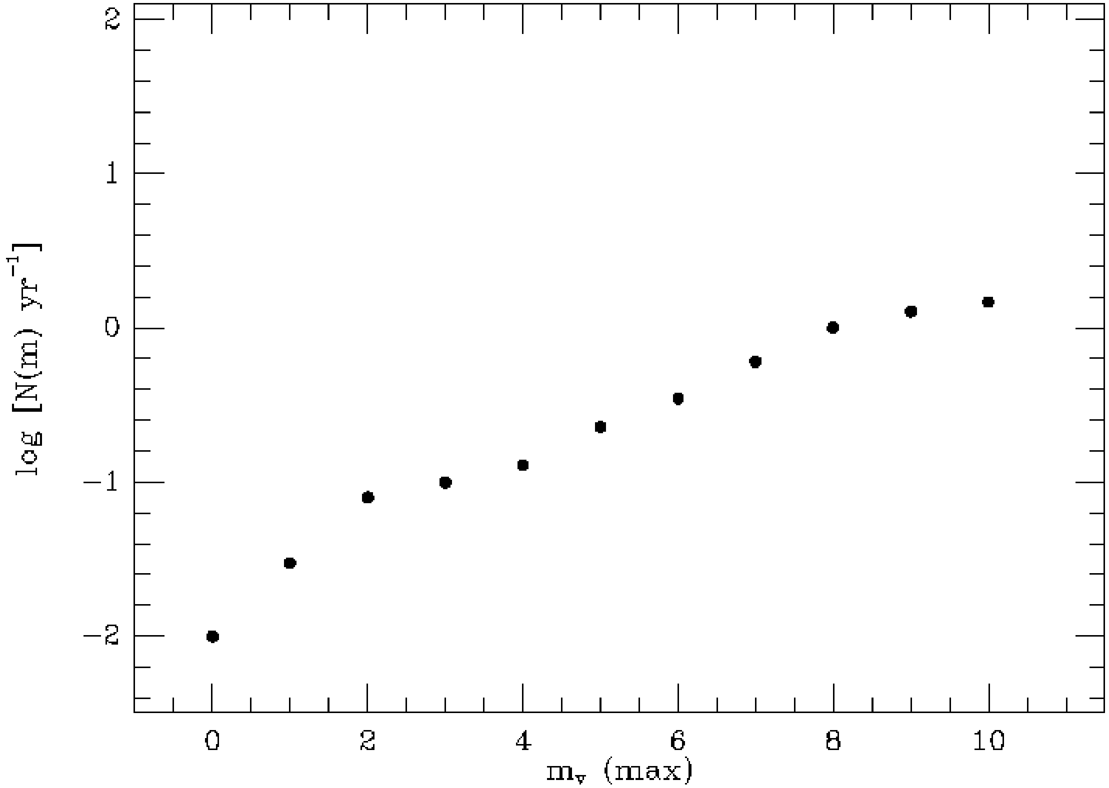
The discovery rate for novae brighter than $m_V = 7$ has been relatively constant at ~0.6 yr^{-1} for more than a century.

Not surprisingly, an increasing number of fainter novae have been discovered in recent years.



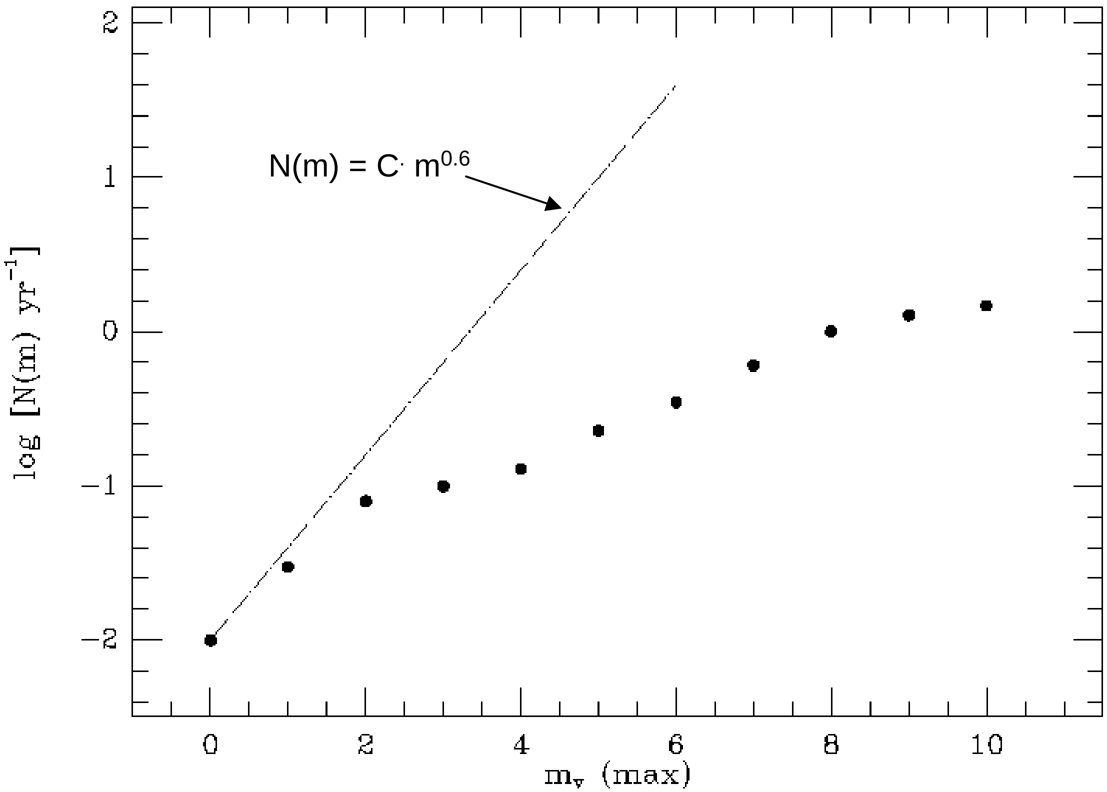
Observed Number Counts of Galactic Novae (1900-2000)

149 novae brighter than V=10



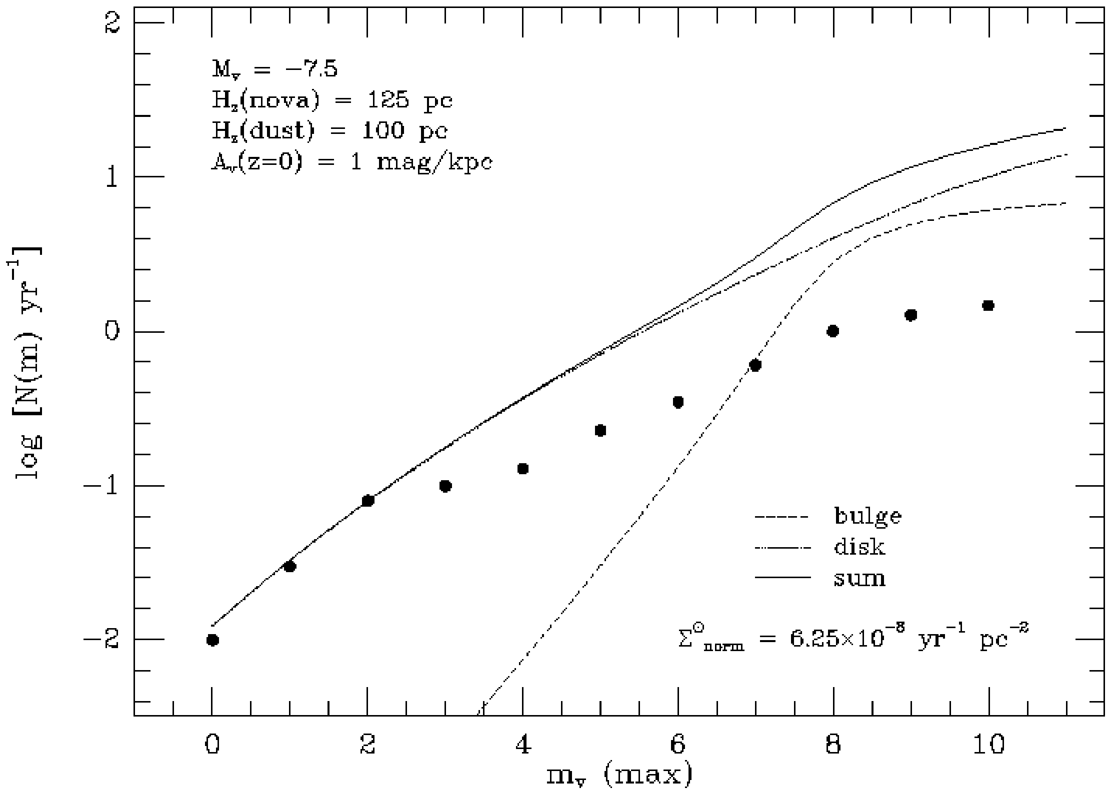
Shafter (2002)

Observed Number Counts of Galactic Novae (1900-2000)



Shafter (2002)

Expected Nova Counts From Galactic Luminosity Model of Bahcall & Soneira (1980)



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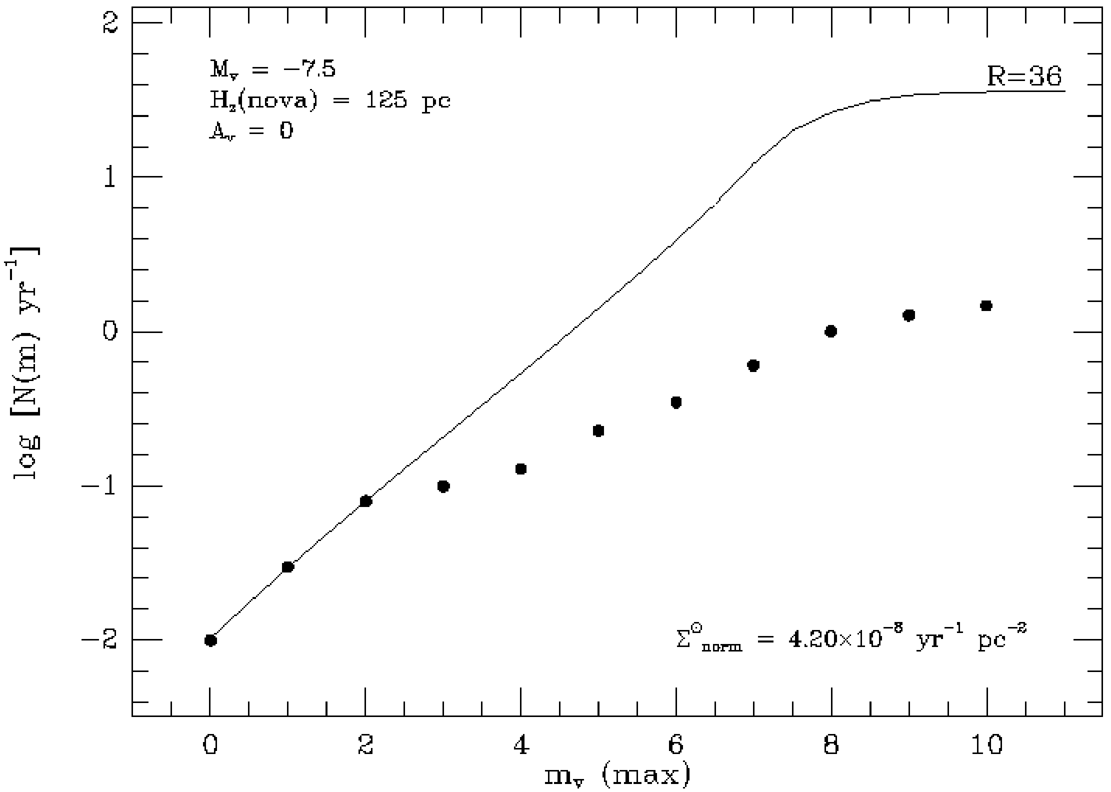
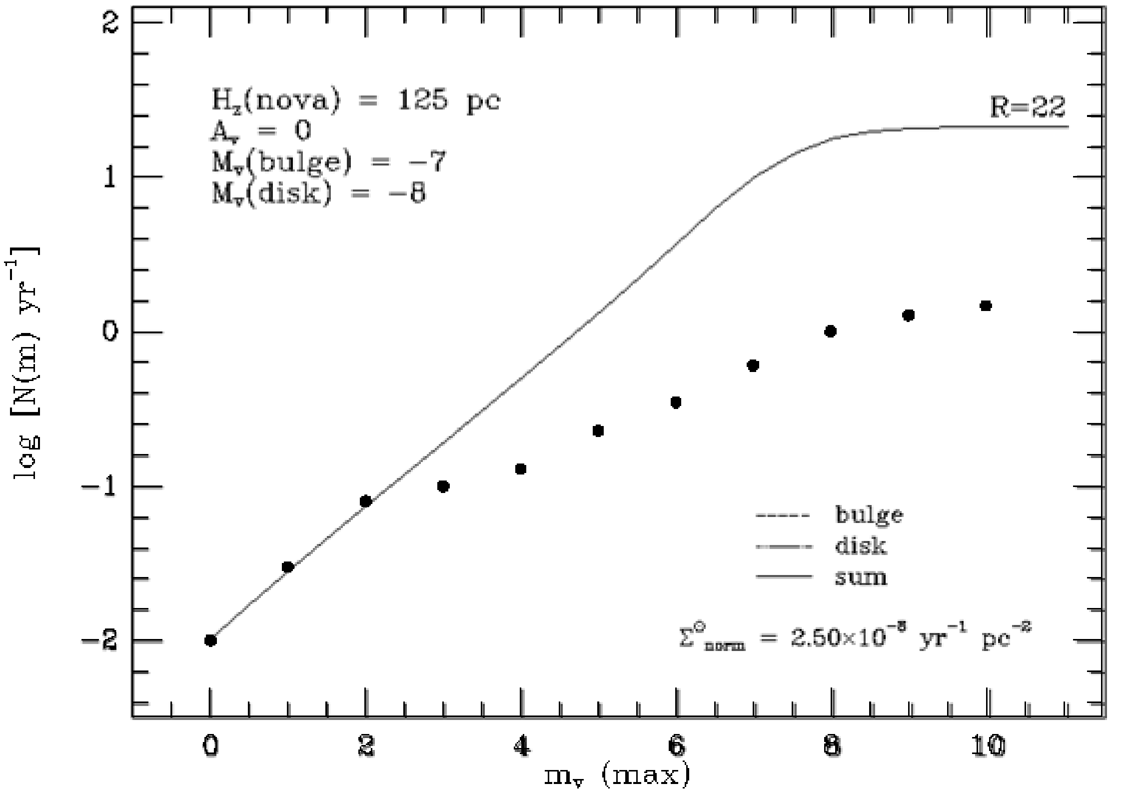


Shafter (2002)

Expected Nova Counts From Galactic Luminosity Model of Bahcall & Soneira (1980)

Two Nova Population Model



Shafter (2002)

Summary of Galactic Nova Rate Estimates

Estimates of Galactic nova rate:

- Single population, $\langle M_V \rangle = -7.5$: 36 per year
- Two population, $\langle M_V \rangle = -7$ (bulge), -8 (disk): 22 per year
- Shafter (1997): 35+/-11 per year
- Best estimate: ~30 per year

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Large uncertainty due to two principal factors:

1. Large extrapolation from solar neighborhood
2. Uncertainty in nova luminosities across differing stellar populations

Must turn to Extragalactic Studies…

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

- $M_V = -9$
- MMRD relation
- Expensive of telescope time

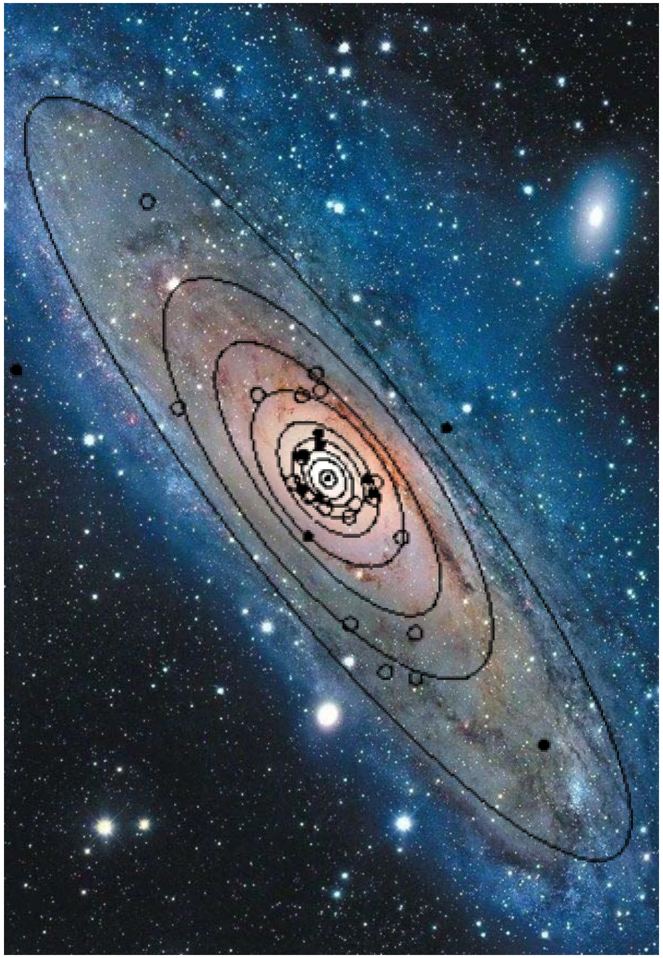
M31: Principal Historical Target

Principal Studies:	**Novae**
• Hubble (1929)	85
• Arp (1956)	30
• Rosino (1964;1973)	142
• Ciardullo et al. (1987)	40
• Shafter & Irby (2001)	72

Principal Conclusions:

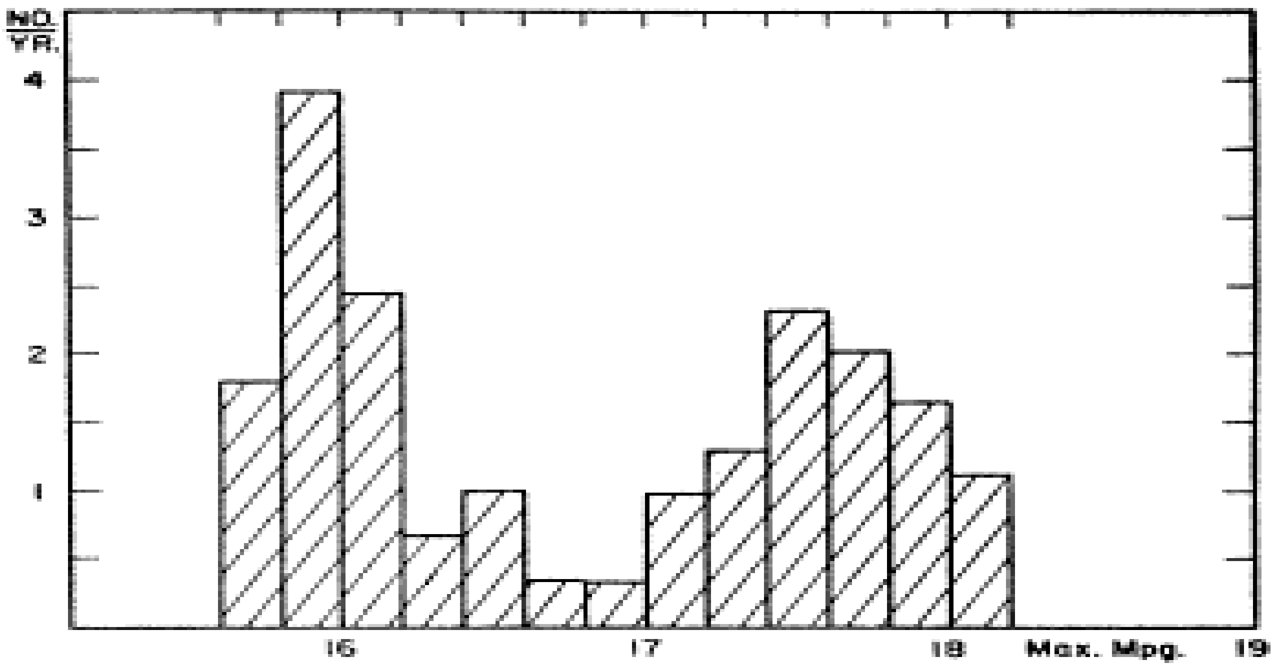
- Nova Rate ~30-40 per year
- Novae centrally concentrated
- Appear consistent with mainly bulge population

Arp Survey



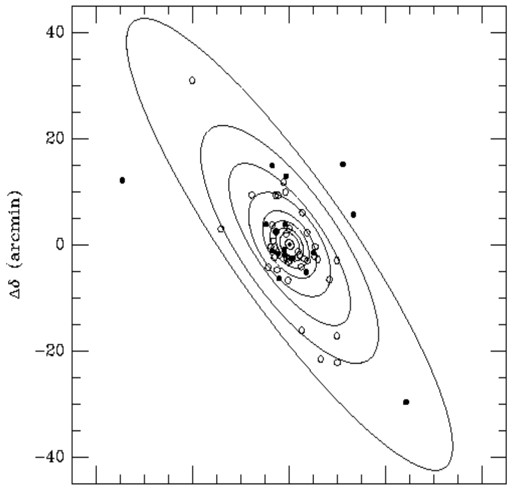
- Arp (1956) discovered a total of 30 novae during a *B* survey using the Mount Wilson 60 and 100-in reflectors.
- Survey was incomplete within ~5’ of nucleus.
- Nova rate est. ~29 per yr
- Evidence for two populations of novae

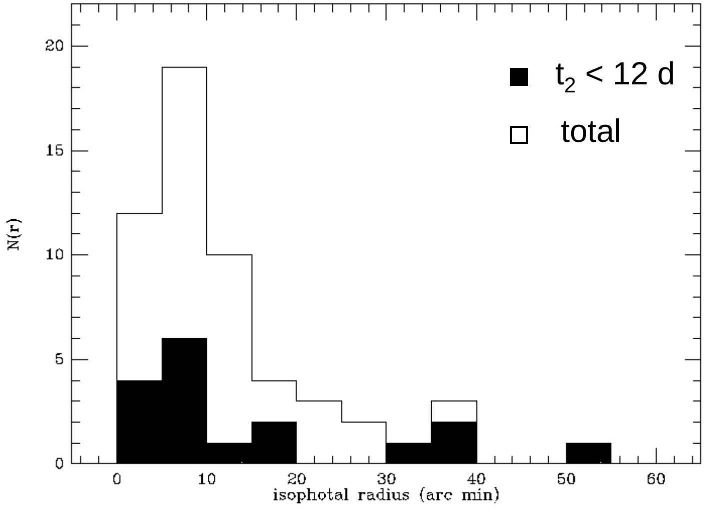
Maximum Magnitude Distribution for Arp's M31 Novae



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 Nova Speed Class with Spatial Position

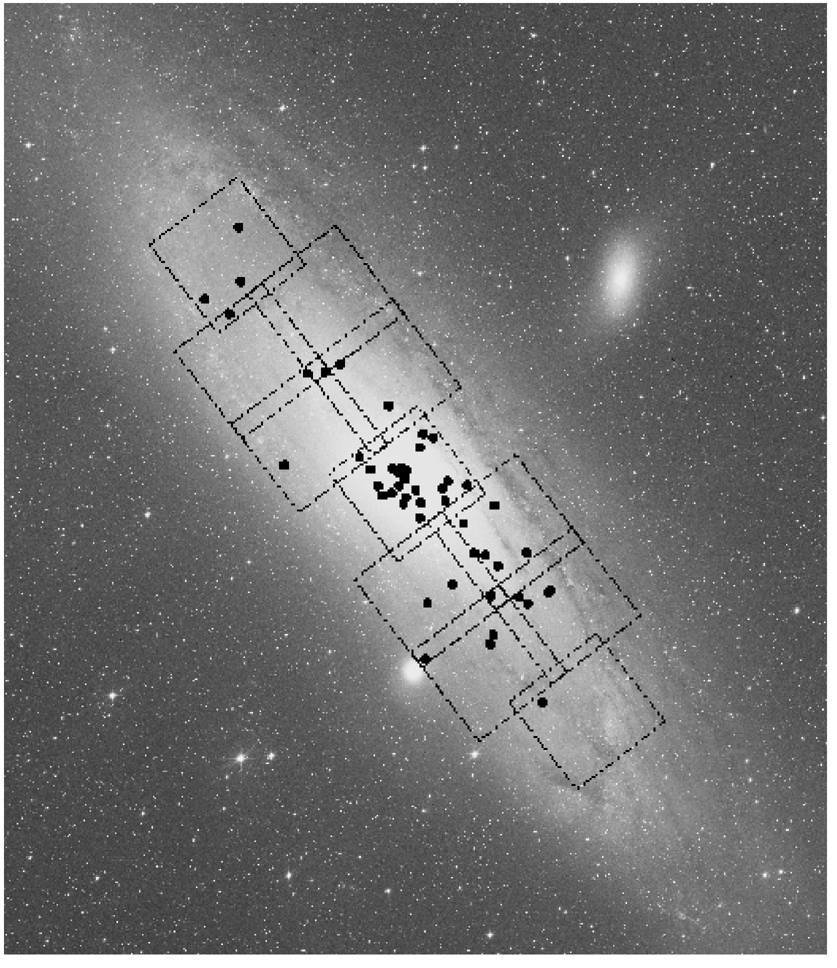




- Light curve data from Arp (1956) nova sample reveals possible weak dependence of nova speed class with spatial position in the galaxy.

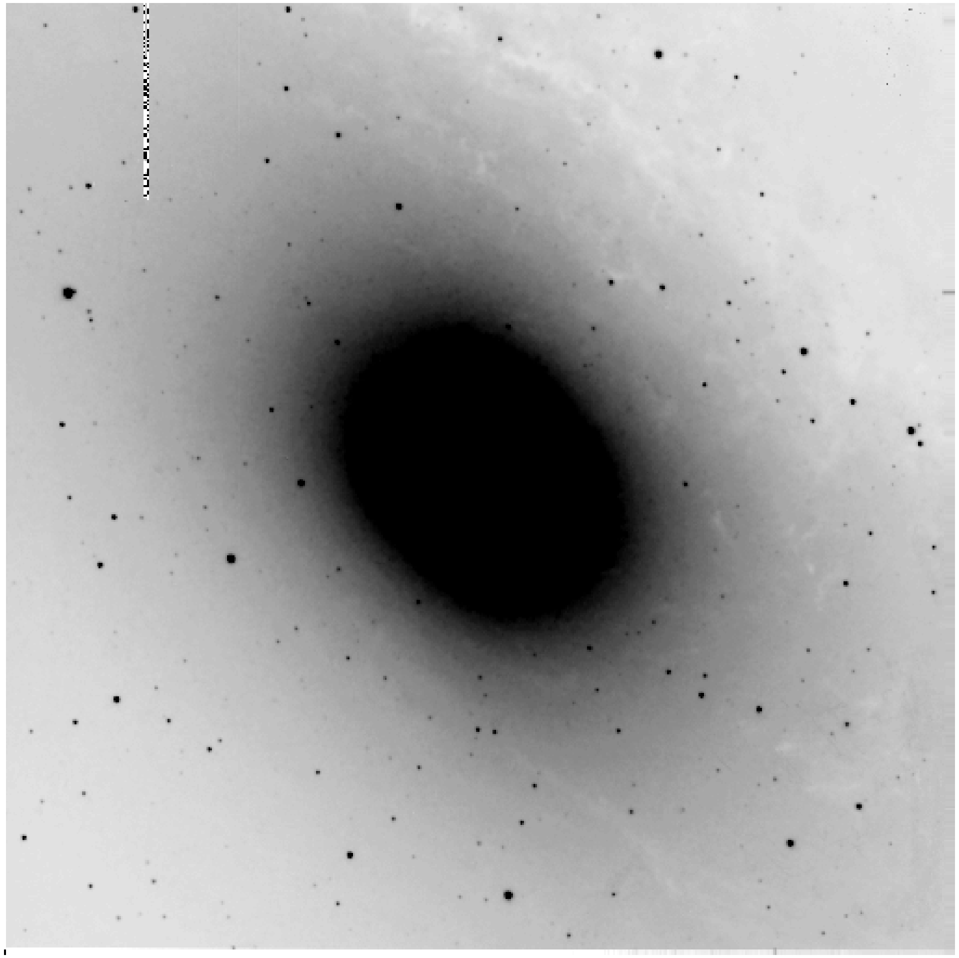
- Limited nova sample and high inclination of M31 make it difficult to draw definitive conclusions from the Arp nova sample.

Recent M31 Nova Survey Results

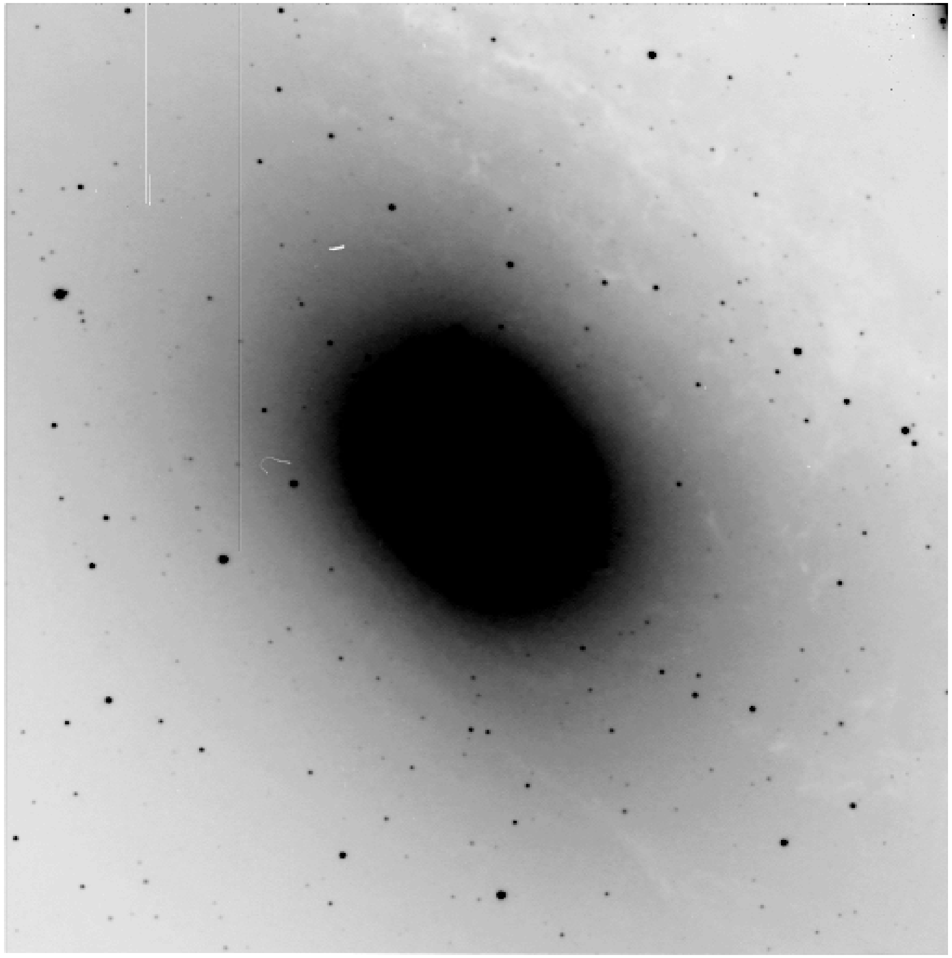


- Shafter & Irby (2001) Hα survey at MLO
- 11 13'x13' CCD fields
- 53 Novae detected in Survey A
- Novae centrally concentrated

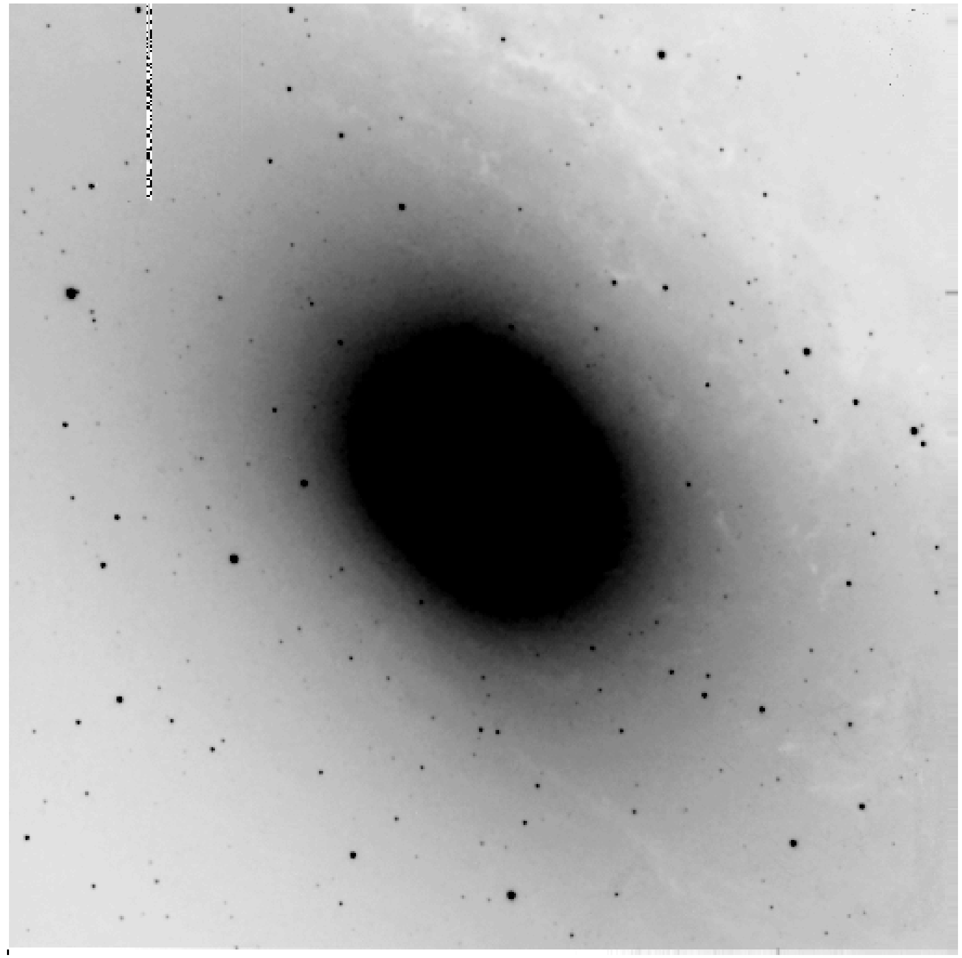
M31 Bulge Hα 29Dec03



M31 Bulge: Hα 23Jan05



M31 Bulge: 29Dec03 – 23Jan05 Comparison



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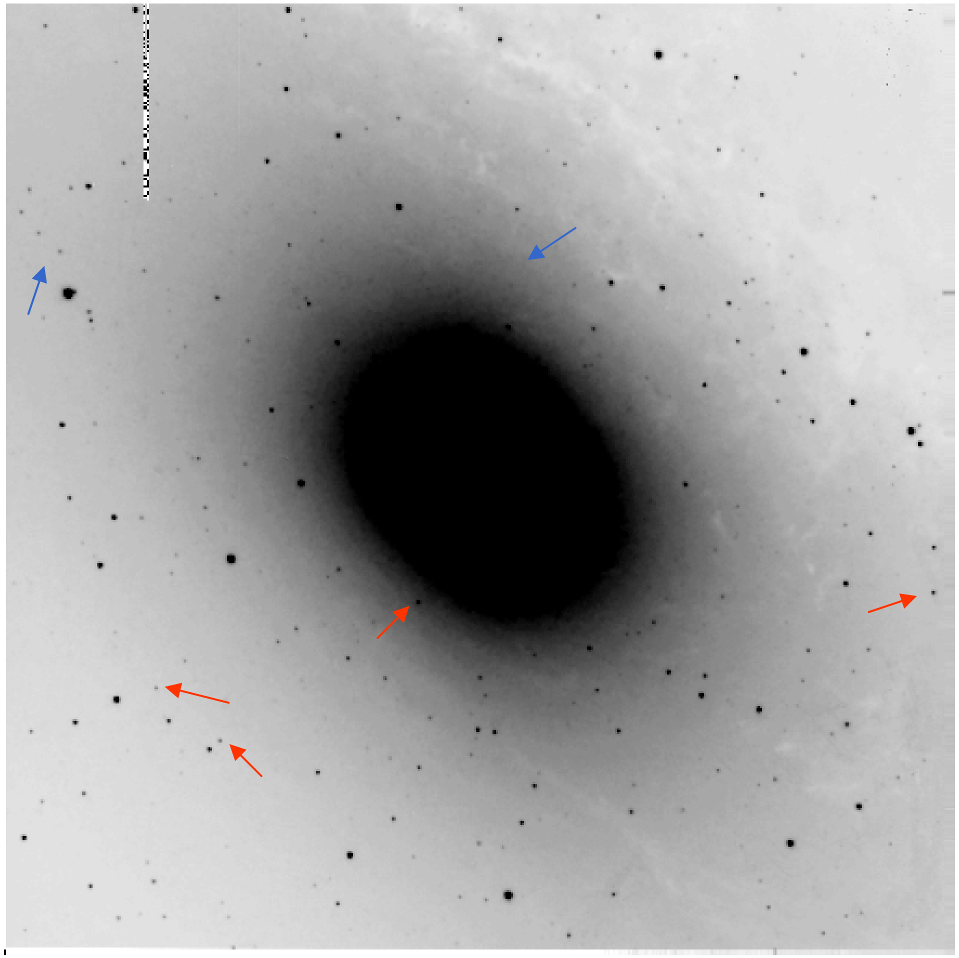
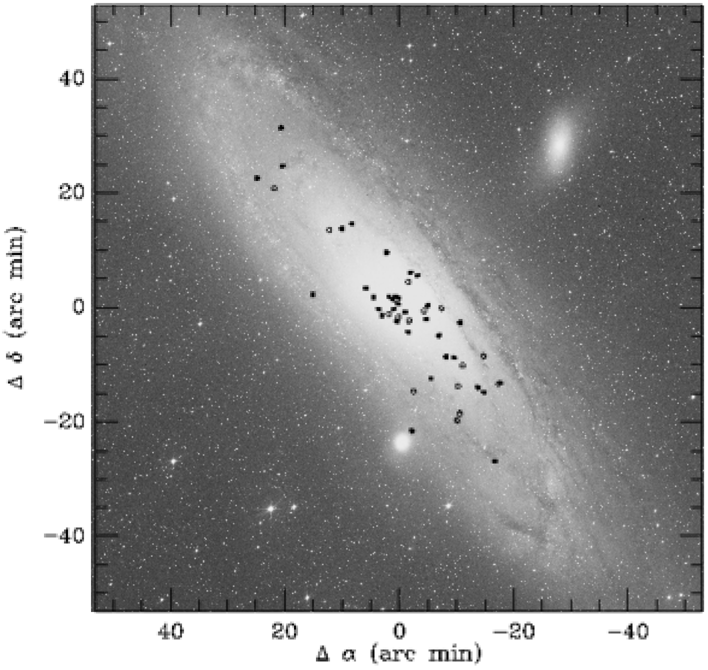
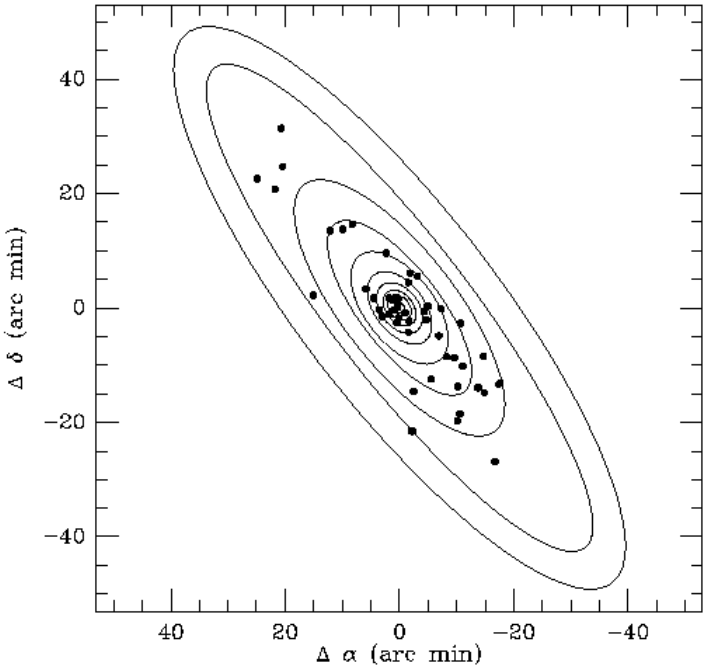


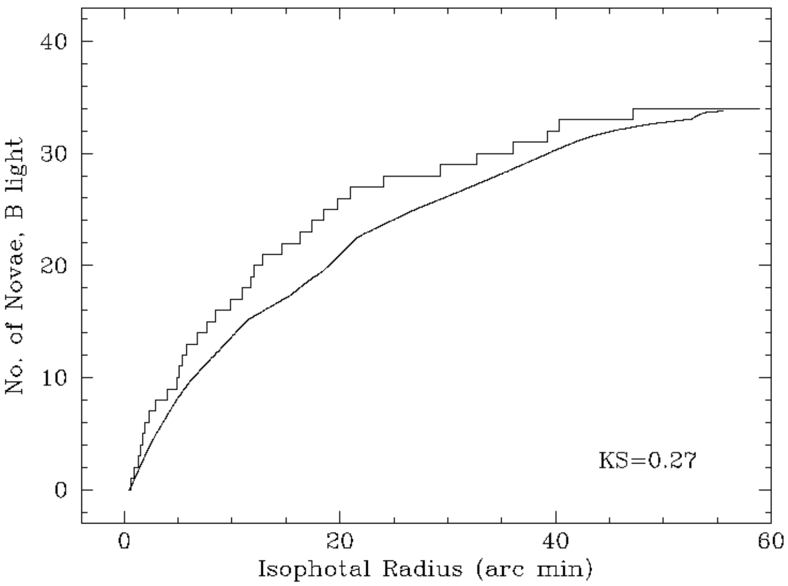
Nova Isophotal Radius Distributions



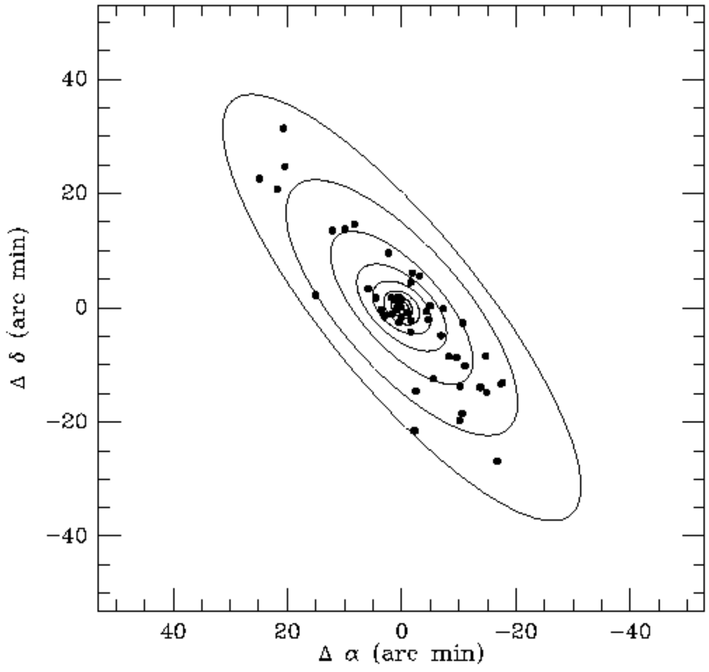
- Radial distributions of the 53 novae are computed based on the background *B* and *R* band light.
- Radial distributions are also computed based on background light from bulge-disk separations of the M31 *B* band surface brightness.

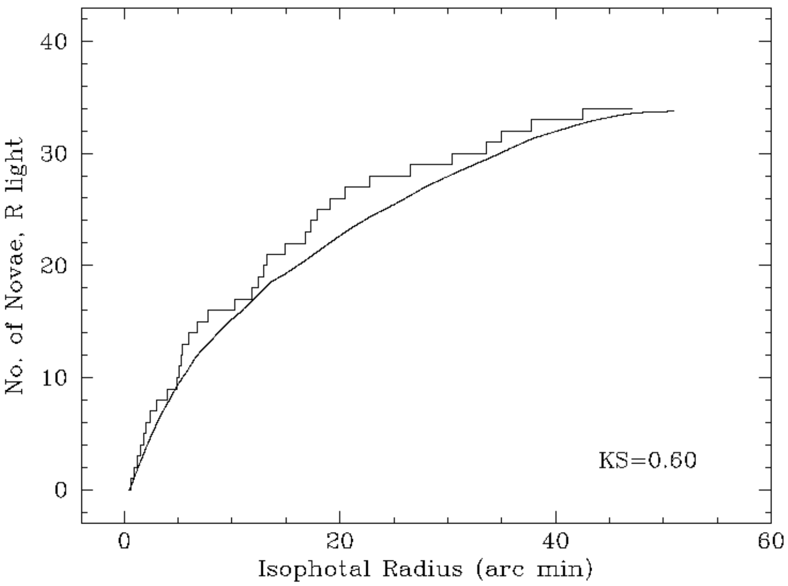
Cumulative Nova Distribution vs *B*-band Light





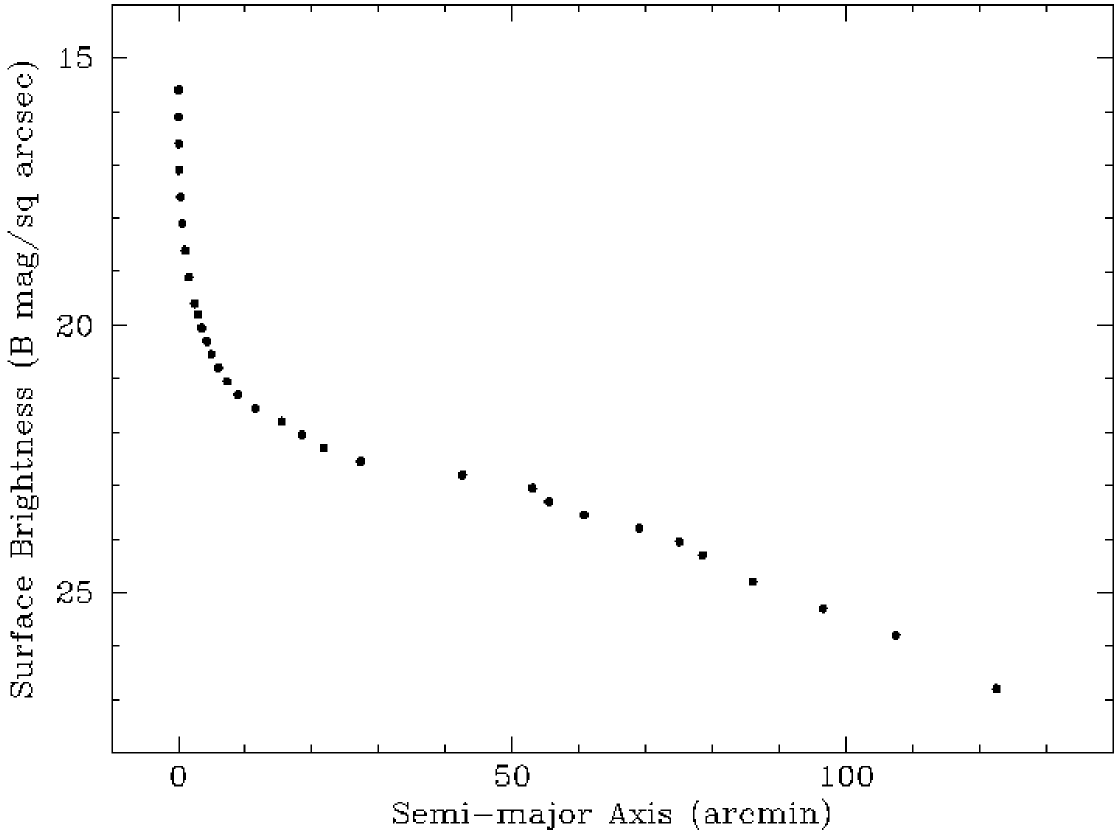
Cumulative Nova Distribution vs *R*-band Light





Radial Surface Brightness Profile of M31 *B* Light

From de Vaucouleurs (1958)



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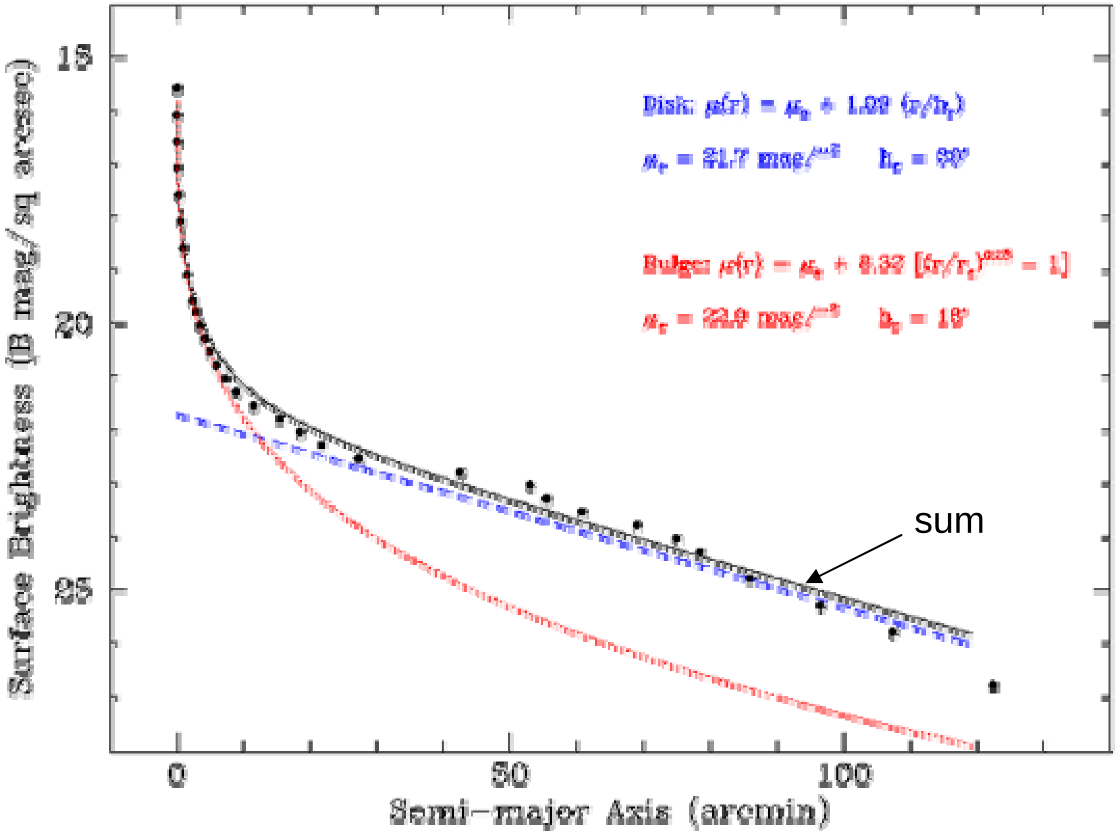
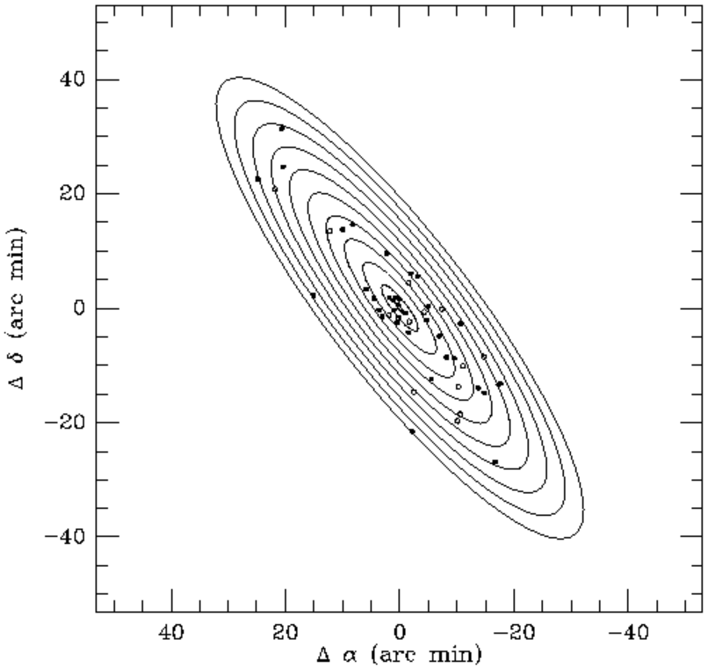
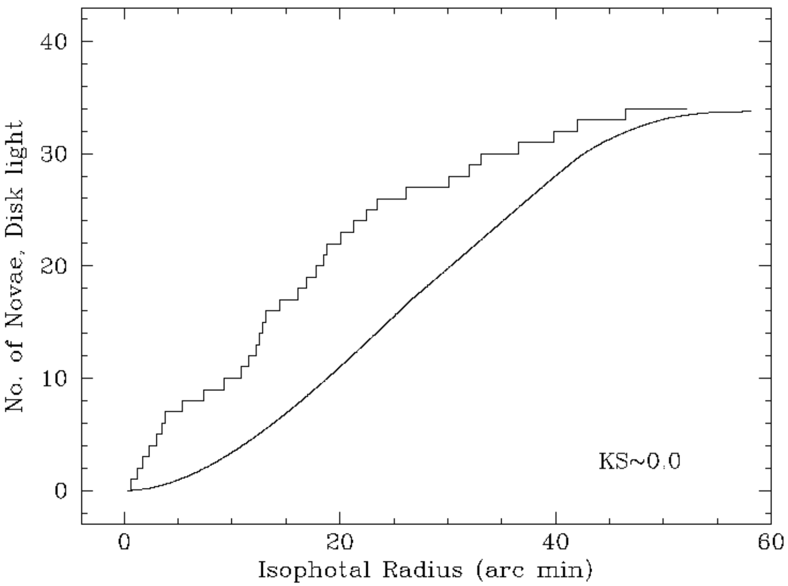
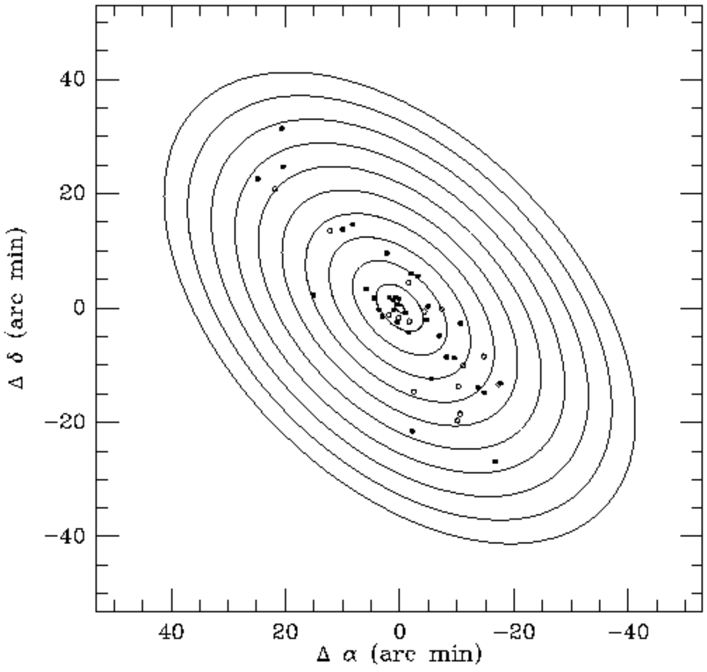


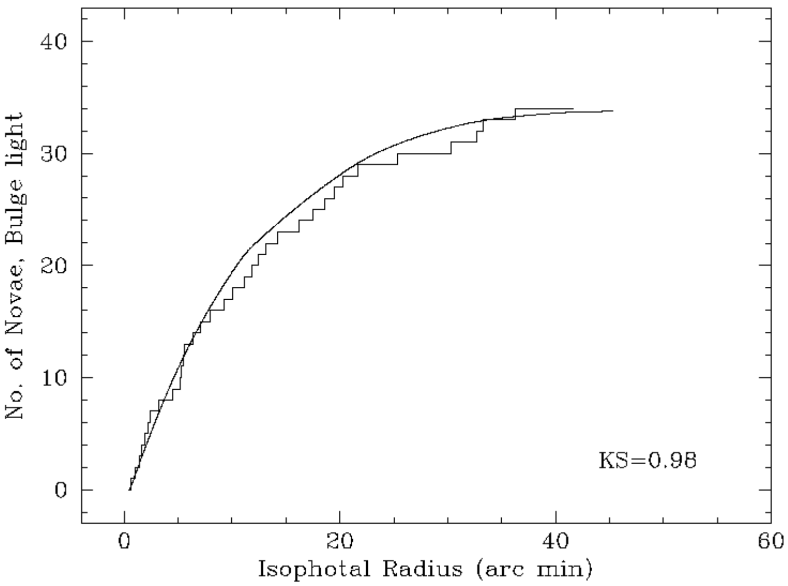
Cumulative Nova Distribution vs Disk Light





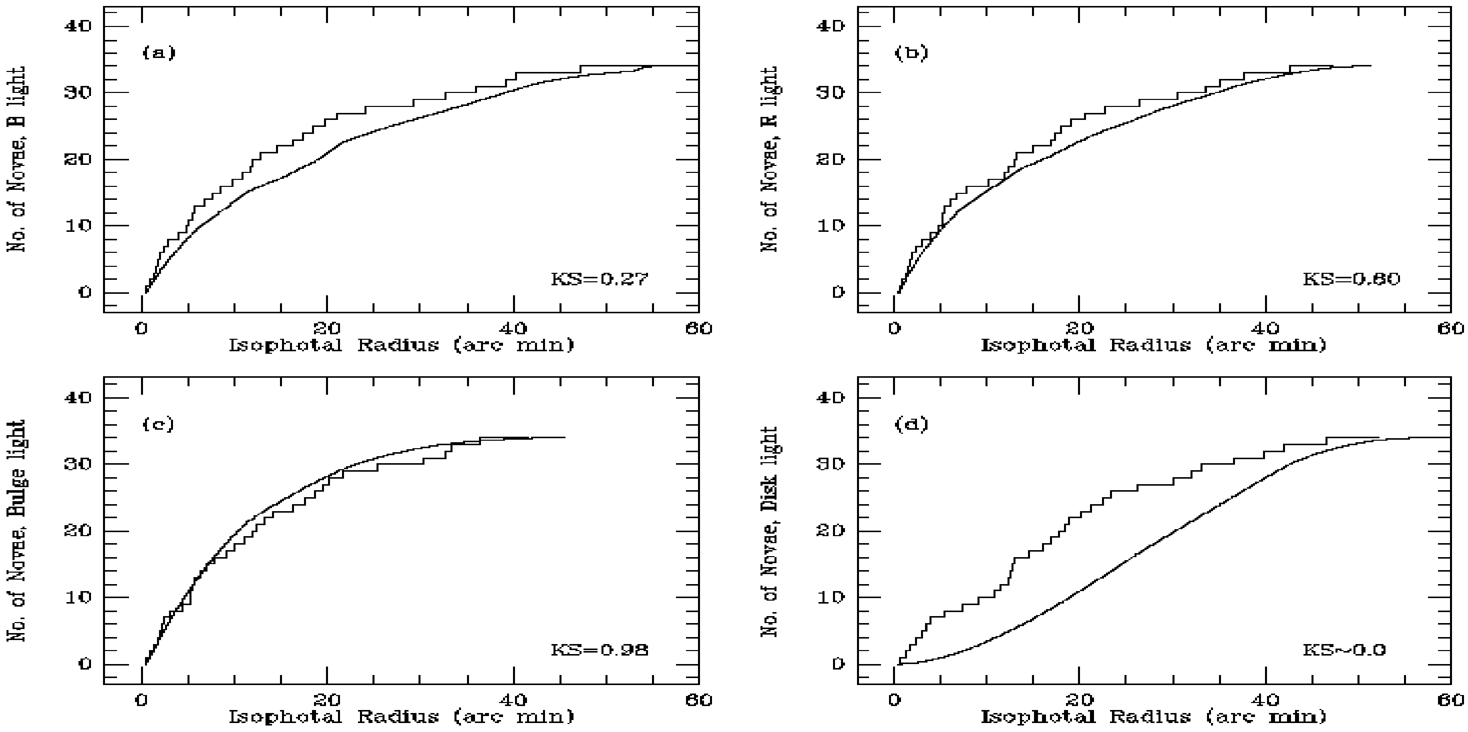
Cumulative Nova Distribution vs Bulge Light





Cumulative Distribution of Novae vs Isophotal Radii

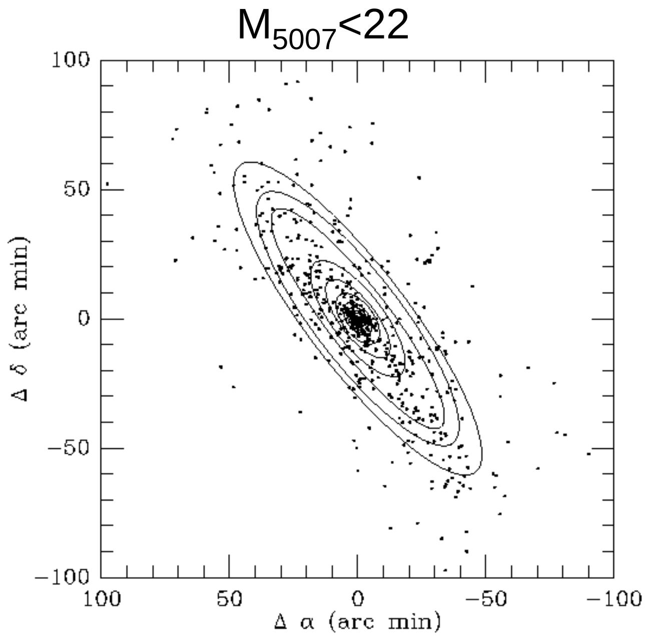
- The radial distribution of novae matches the Bulge light significantly better than the galaxy's disk light, or total broadband light.
- Is extinction in the disk a problem?

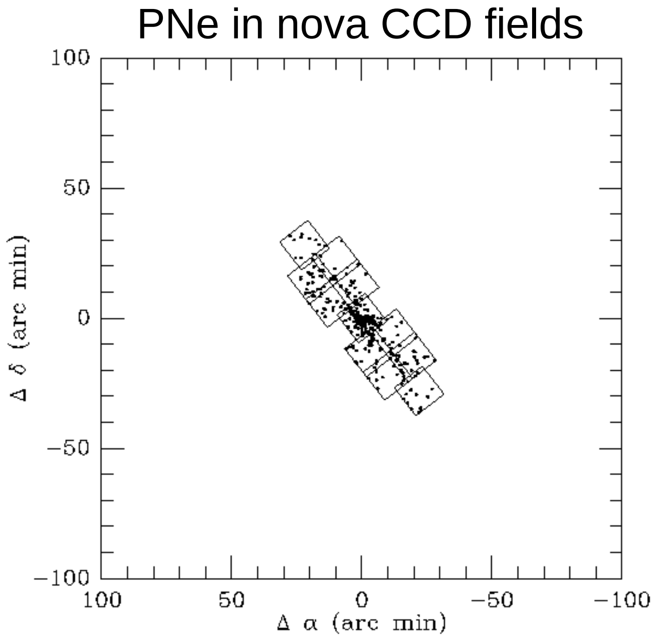


M31 Planetary Nebula Distribution

- M31's PNe Distribution can provide a check on the possibility that disk novae in M31 are being obscured by extinction in the disk (*Unpublished PNe data courtesy of R. Ciardullo).*
- Luminosity-specific stellar death rate (η) is relatively insensitive to the age of the stellar population for populations older than 1Gyr.

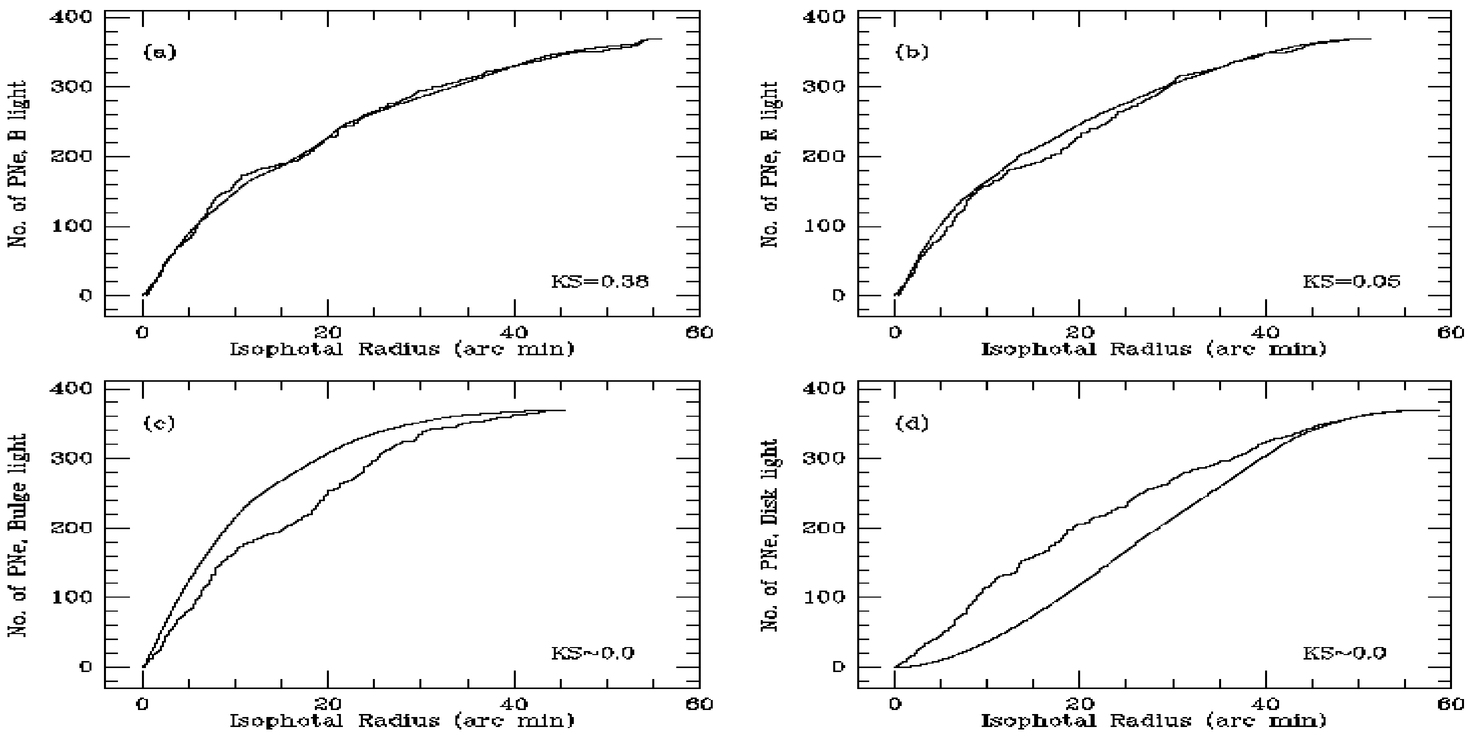
$\eta \cong 2 \times 10^{-11}$ stars yr $^{-1}$ L_{sun}^{-1} (Renzini & Buzzoni 1986)



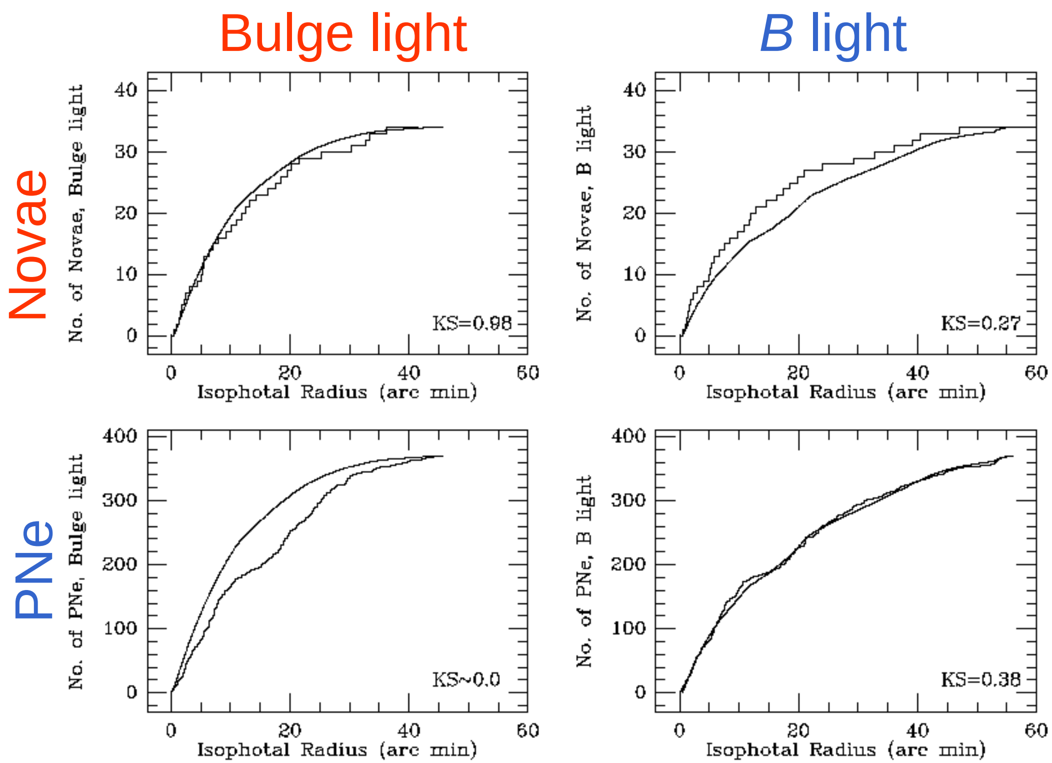


Cumulative Distribution of M31 PNe vs Isophotal Radii

- The radial distribution of M31 PNe matches the total B-band light significantly better than the bulge or disk light.
- Since PNe are discovered via their [OIII] λ5007 emission, they should be at least as affected by extinction as the novae in Hα.



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.
- What about the Galaxy?

Hatano et al. (1997) Monte Carlo Simulation

Observed rate (m < 11) = 11.8 yr^{-1}
(Liller & Mayer 1987)

Model Fraction (m < 11) = 0.29

N_G = 11.8/0.29 = 41 novae per year

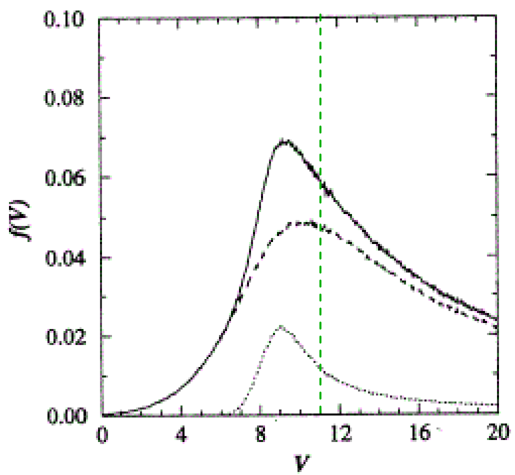


Figure 5. The standard-model *V* distribution. Dotted line: bulge novae; dashed line: disc novae; solid line: total.

Obs

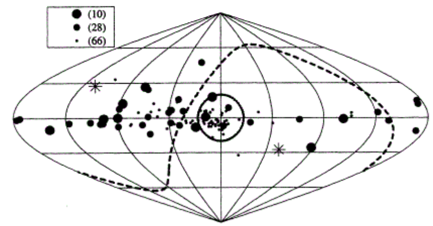


Figure 3. As Fig. 1, but for 104 novae having $V < 8$ (disc novae) or $V < 9$ (bulge novae).

f_b = 1/8

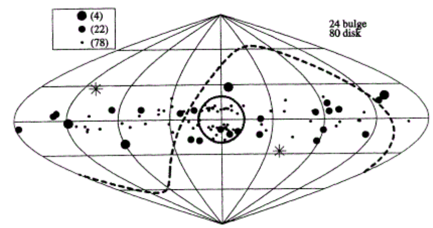


Figure 4. The distribution of 104 standard-model novae having $V < 8$ (disc) or $V < 9$ (bulge). In the standard-model the true bulge fraction is 1/8. This figure is to be compared to Fig. 3.

f_b = 1/2

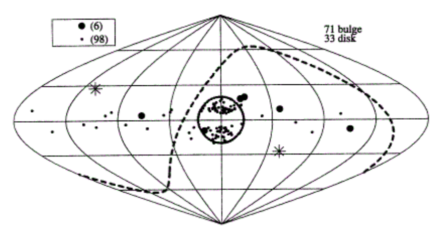


Figure 6. Like Fig. 4, but for a true bulge fraction of 1/2 instead of 1/8.

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) Observational Selection Bias

- Are there two distinct populations of Novae?

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

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)

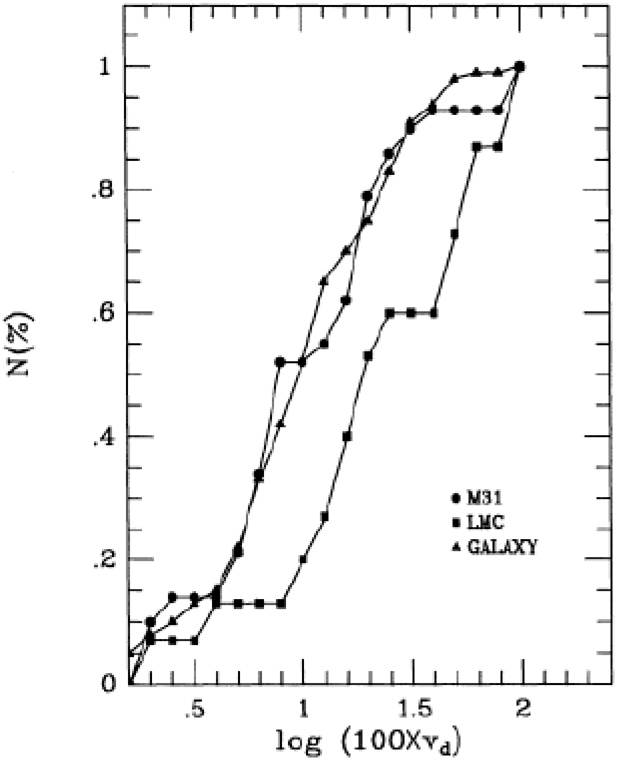


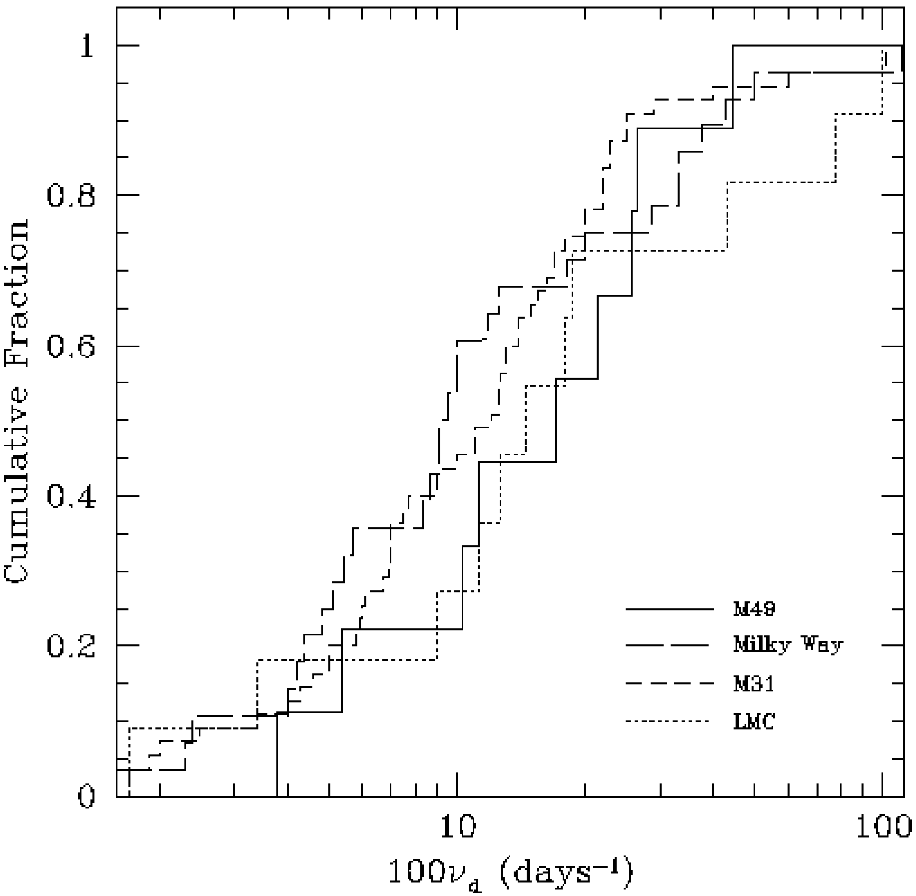
Fig. 1. Cumulative distributions of the rates of decline for M31, Galaxy and LMC. The M31 data come from Arp (1956) and Capaccioli et al. (1989), Galaxy data from Della Valle (1988), and LMC data from Capaccioli et al. (1990)

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

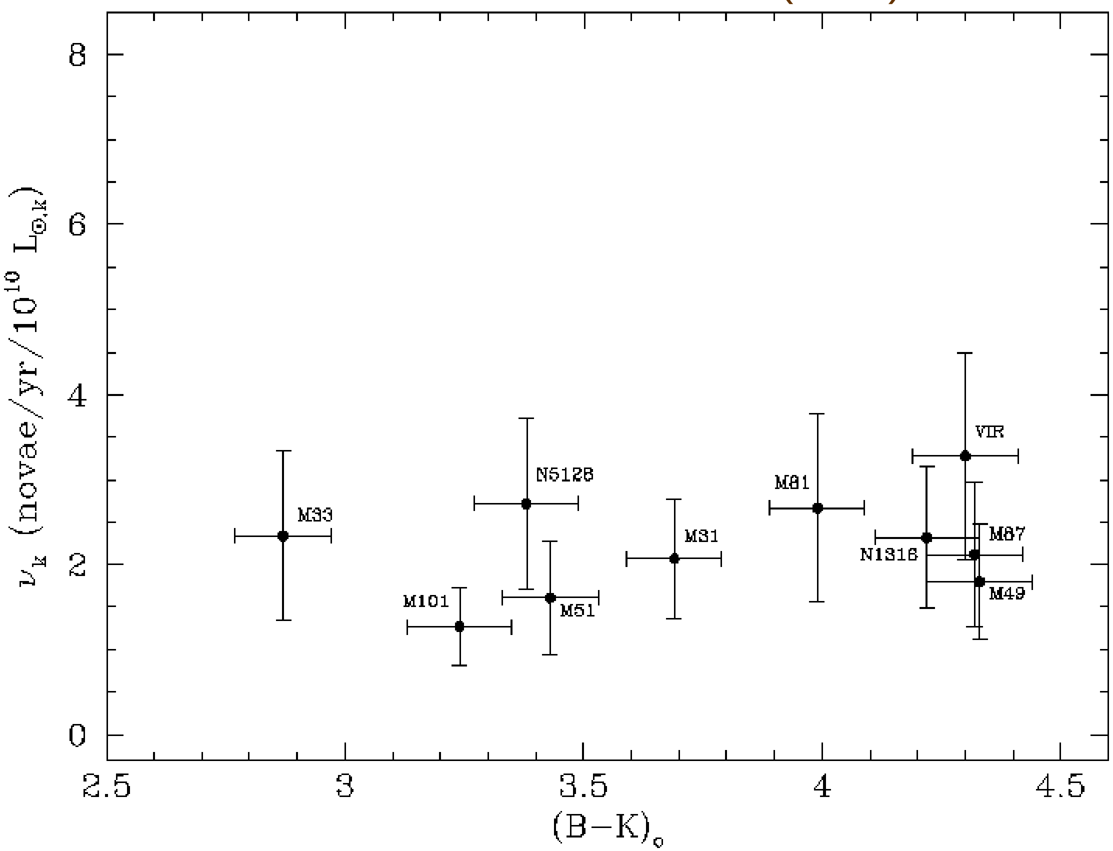
- Nova rates have been measured in a dozen external galaxies.

- 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)



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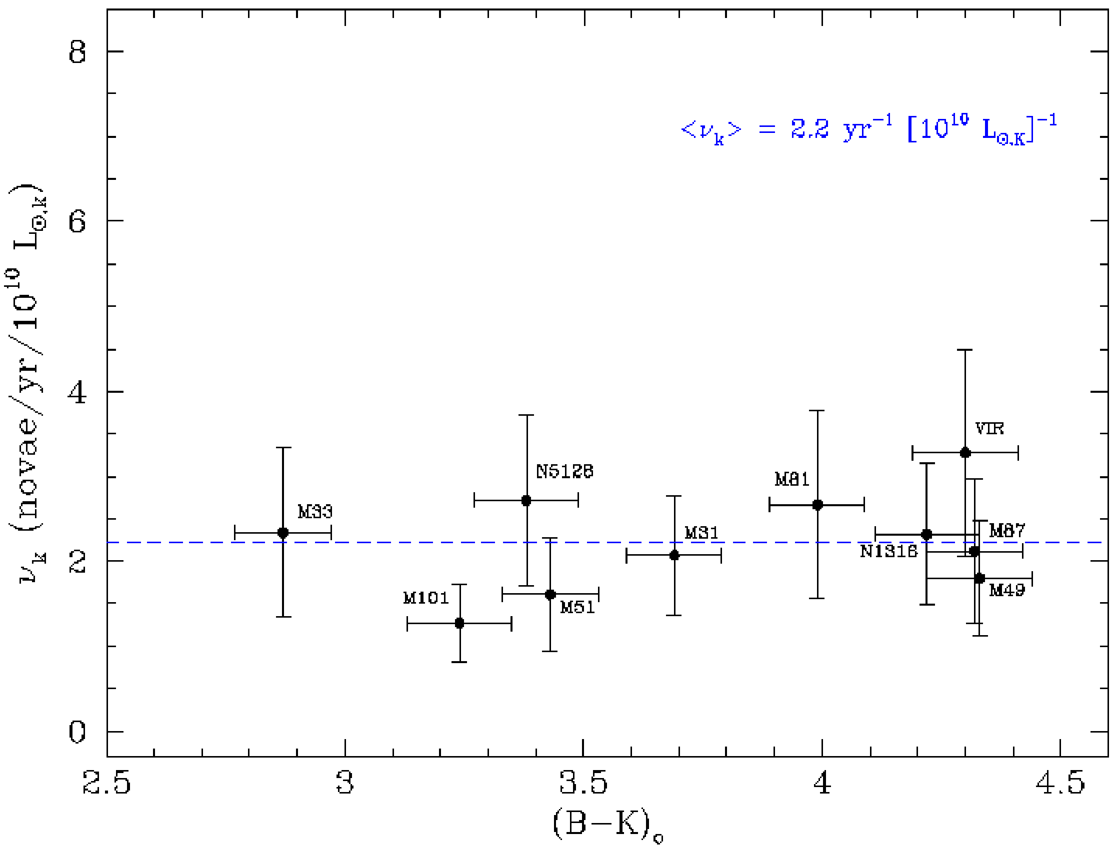

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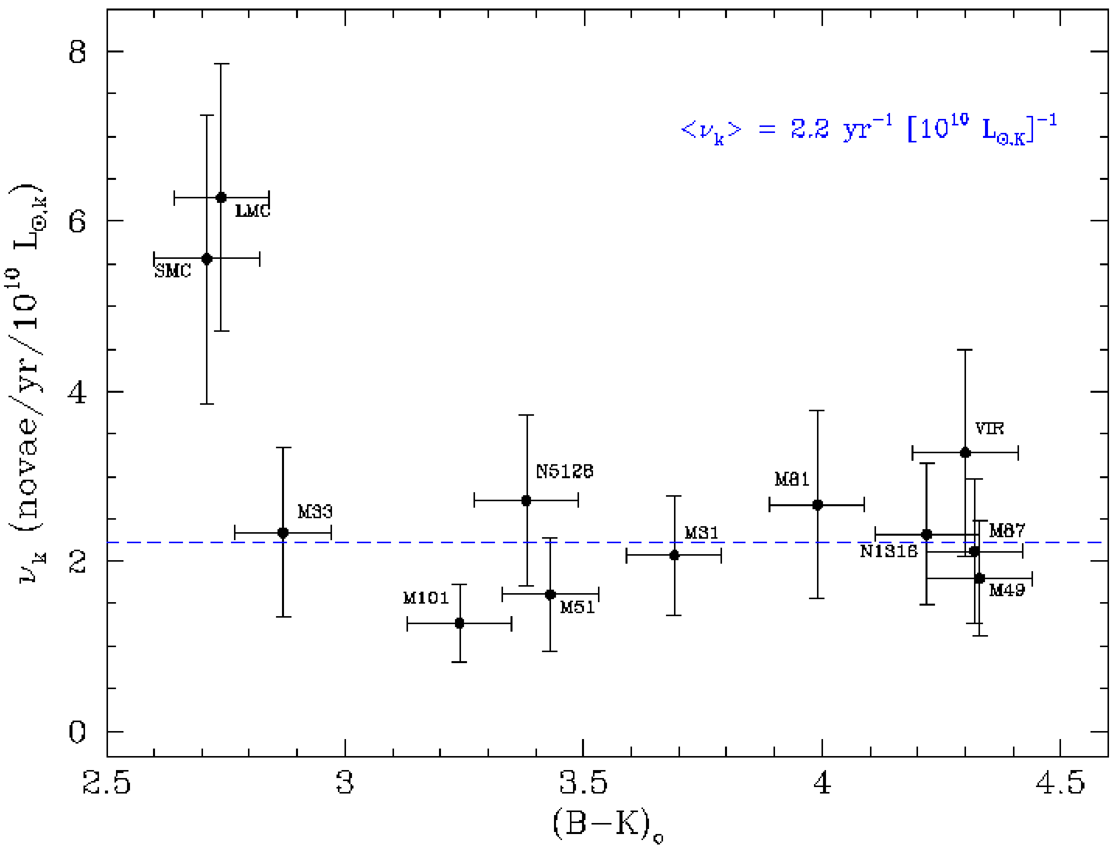
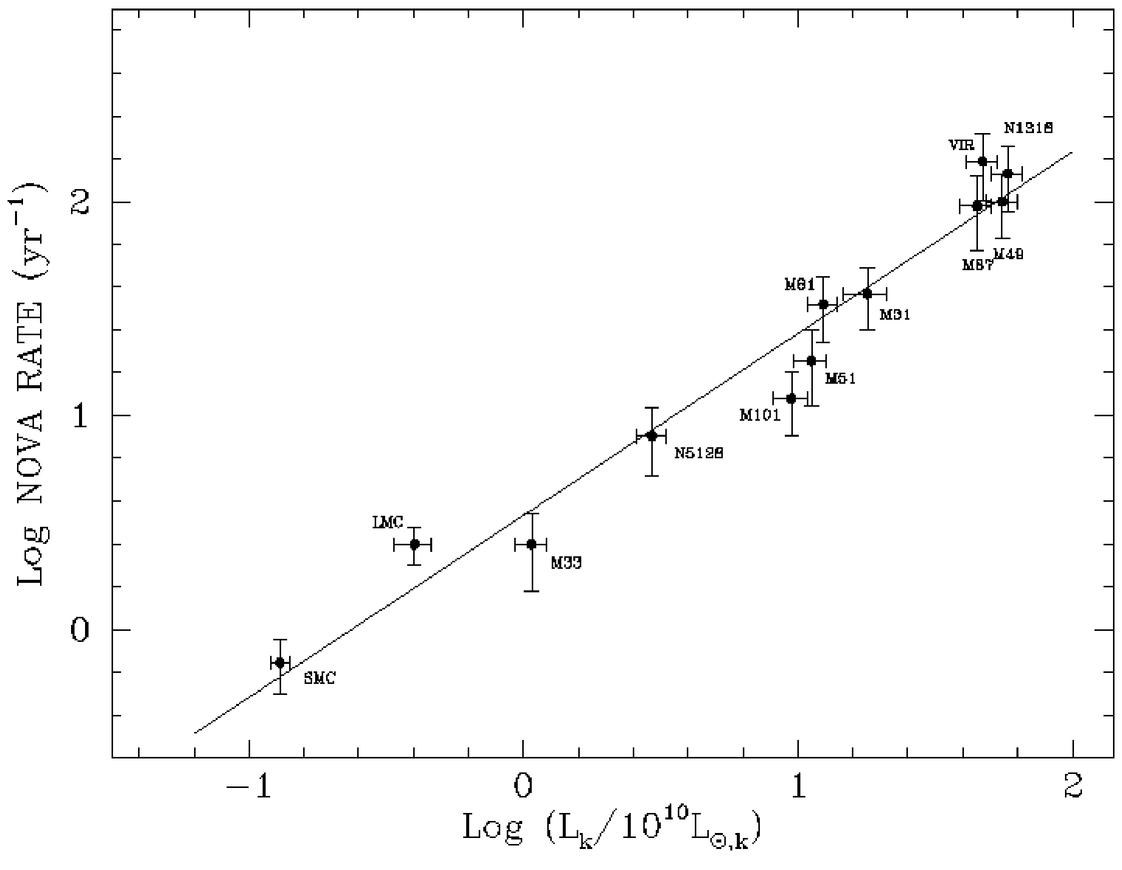


Nova Rates vs Galaxy *K*-band Luminosity



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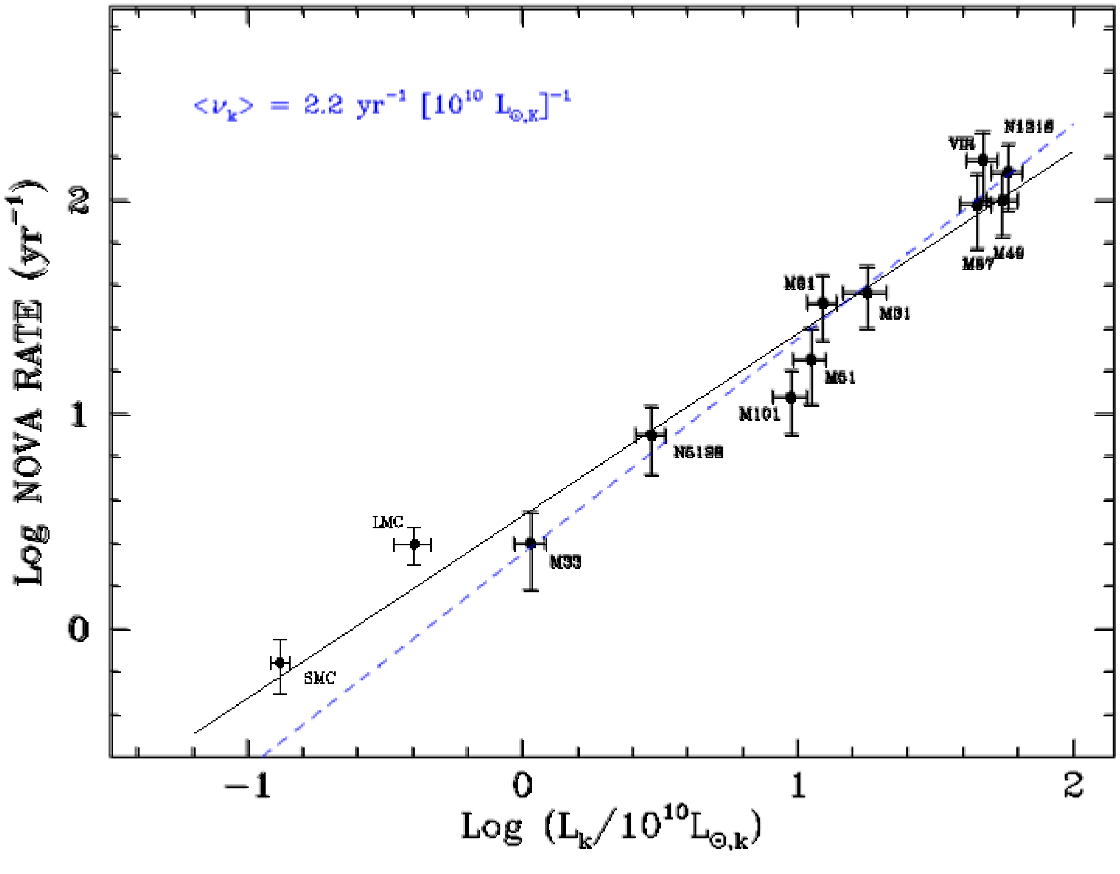

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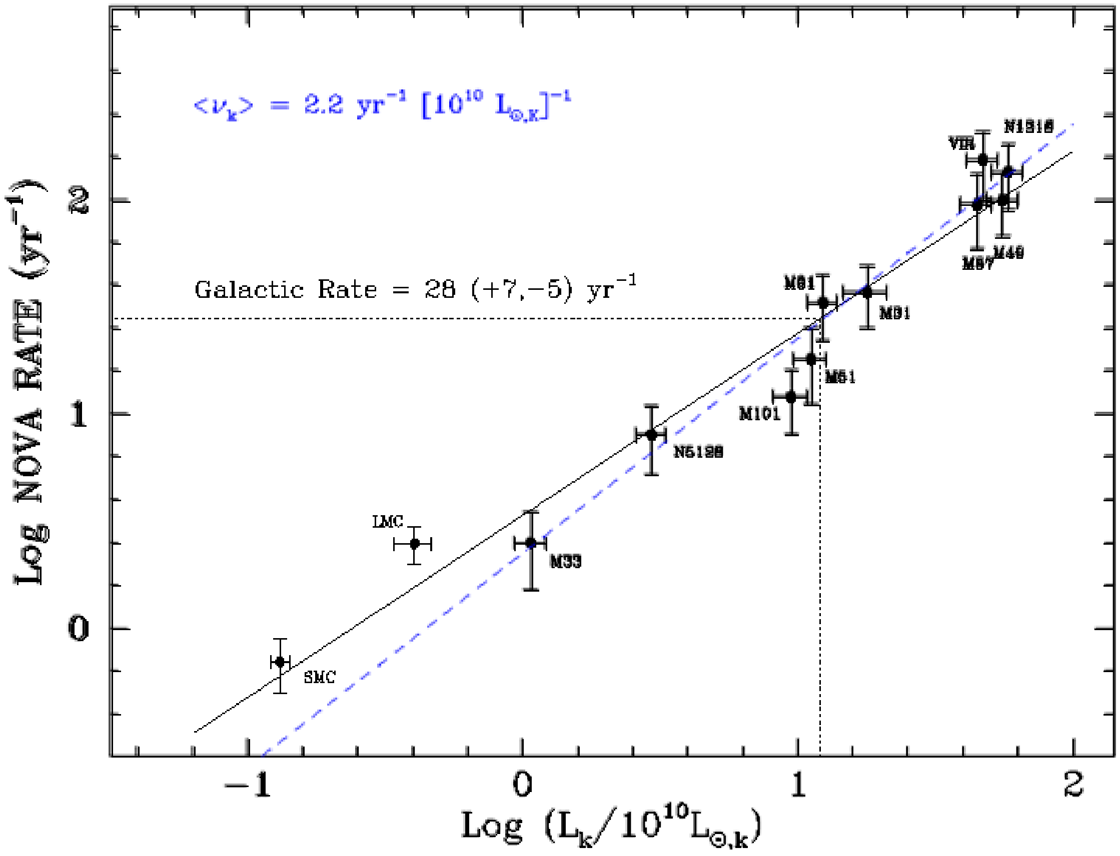
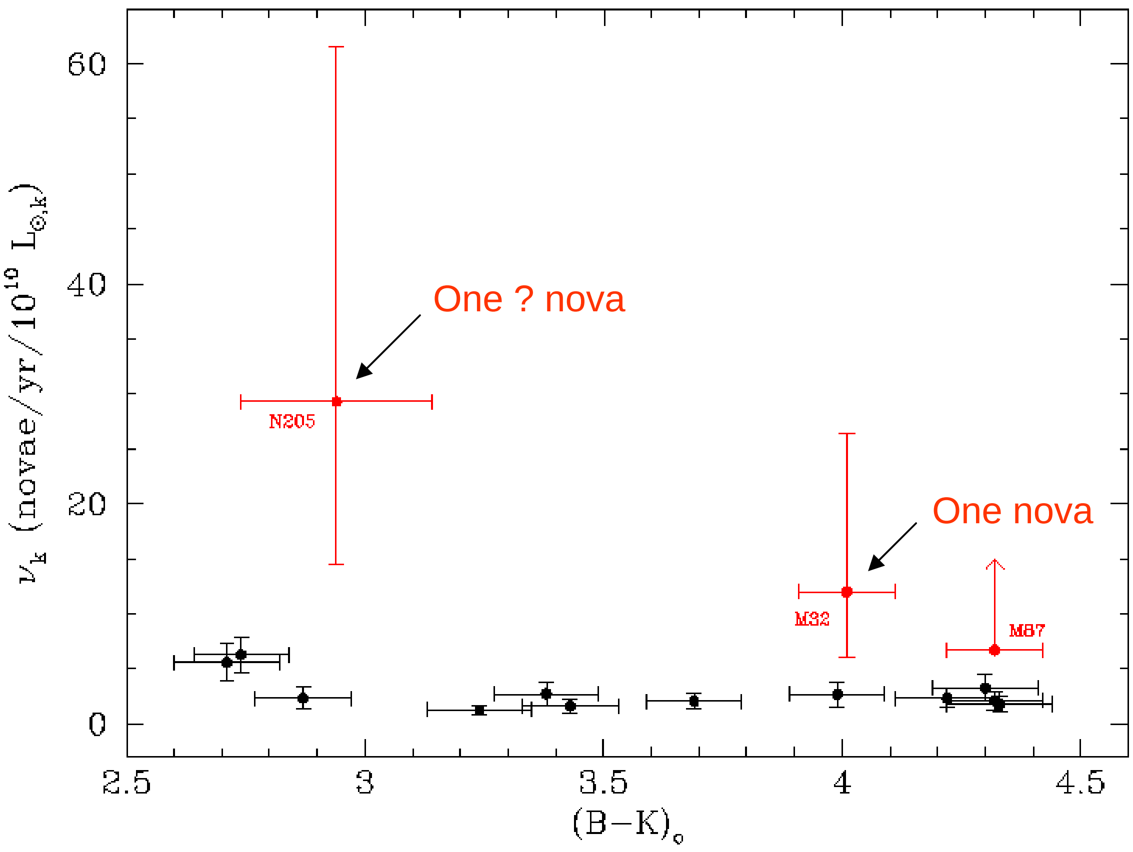


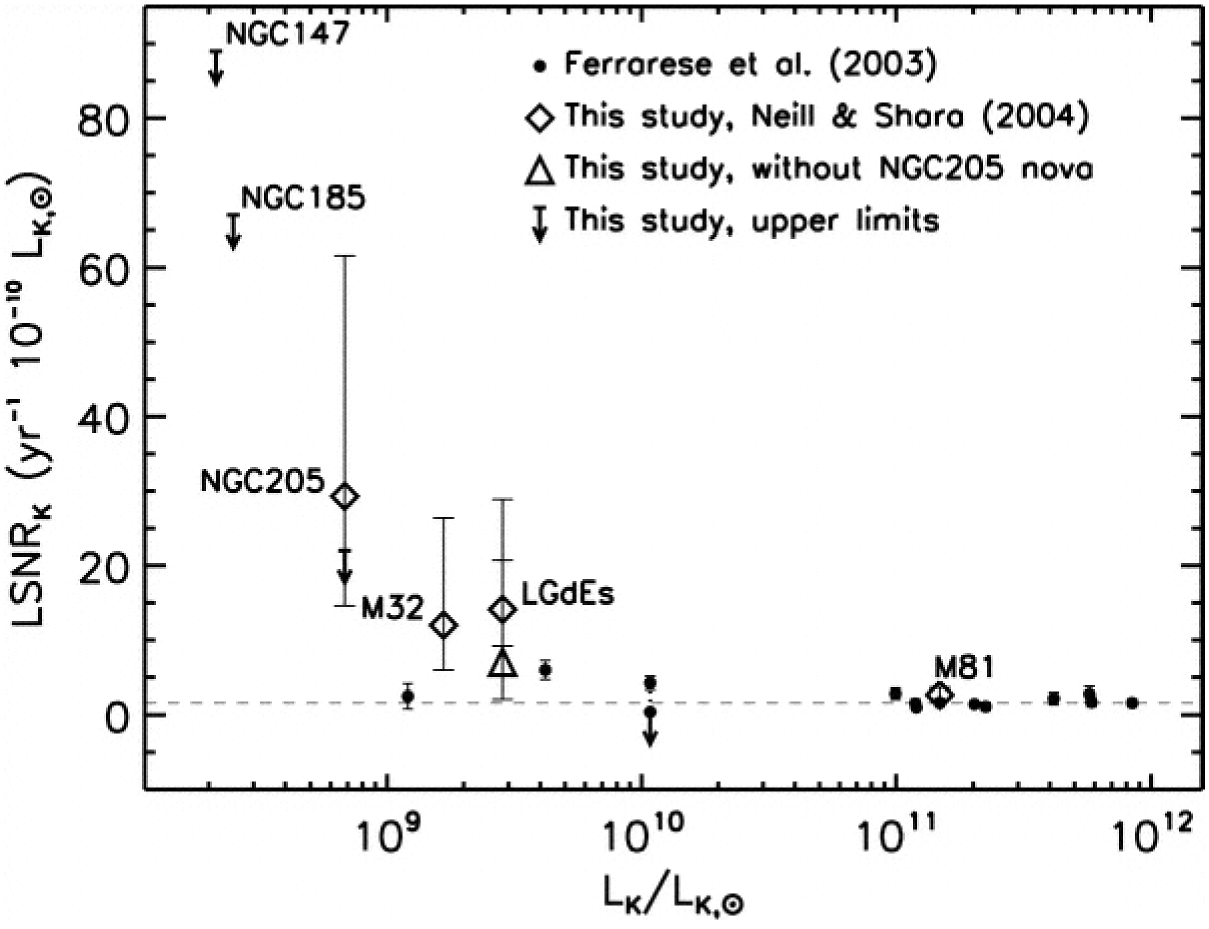
LSNRs with addition of Neill & Shara (2005) ellipticals

Potentially high LSNRs in low mass dwarf ellipticals



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

Neill & Shara (2005)



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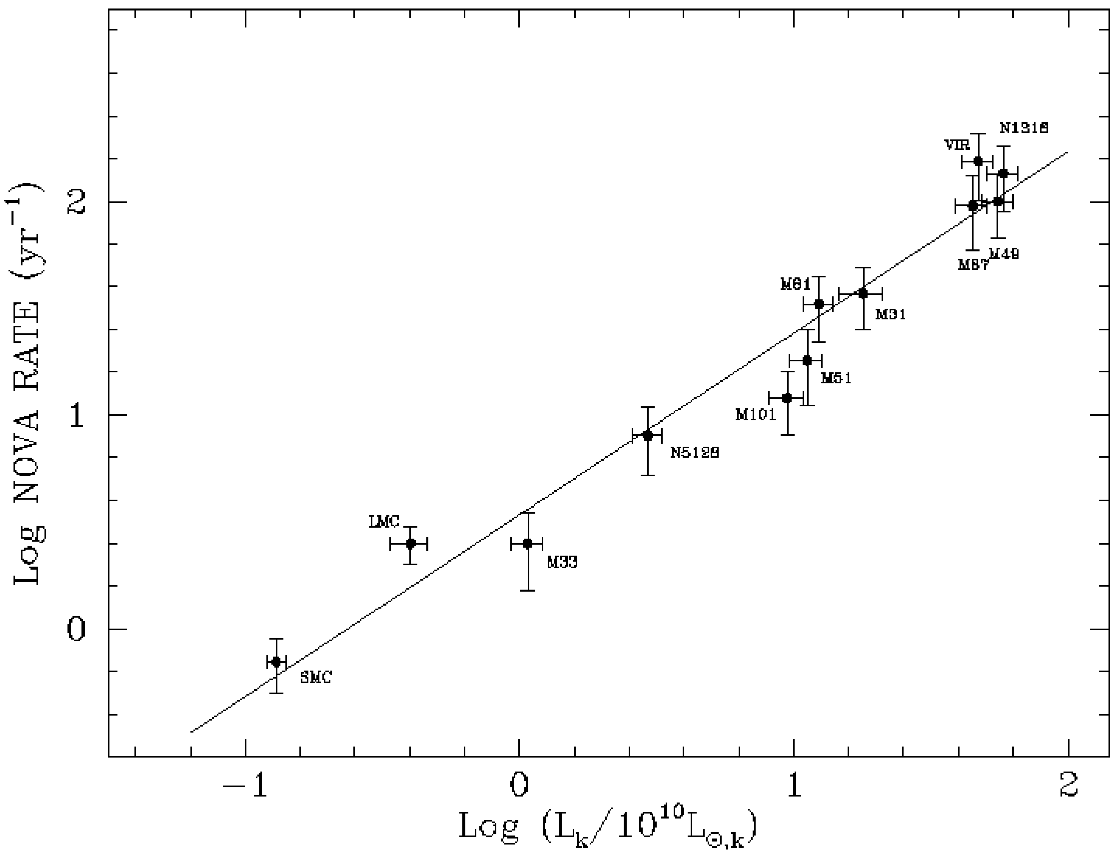

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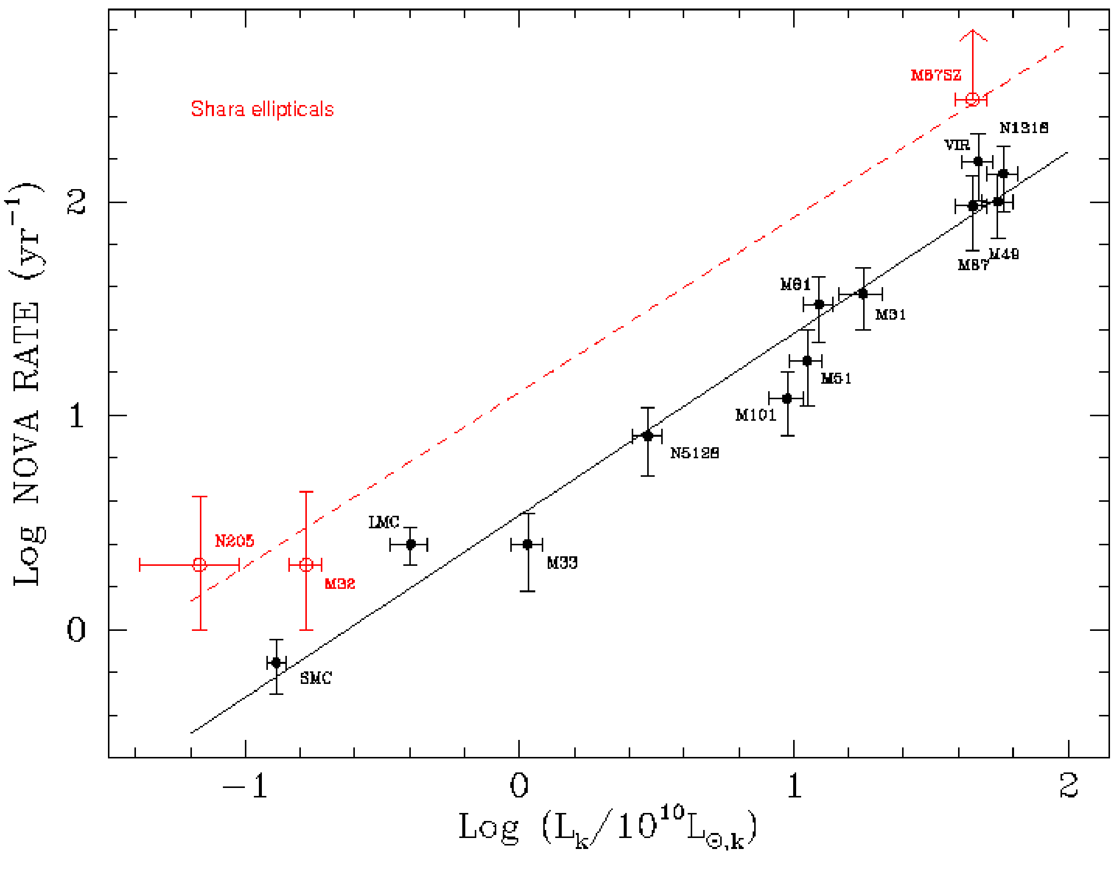

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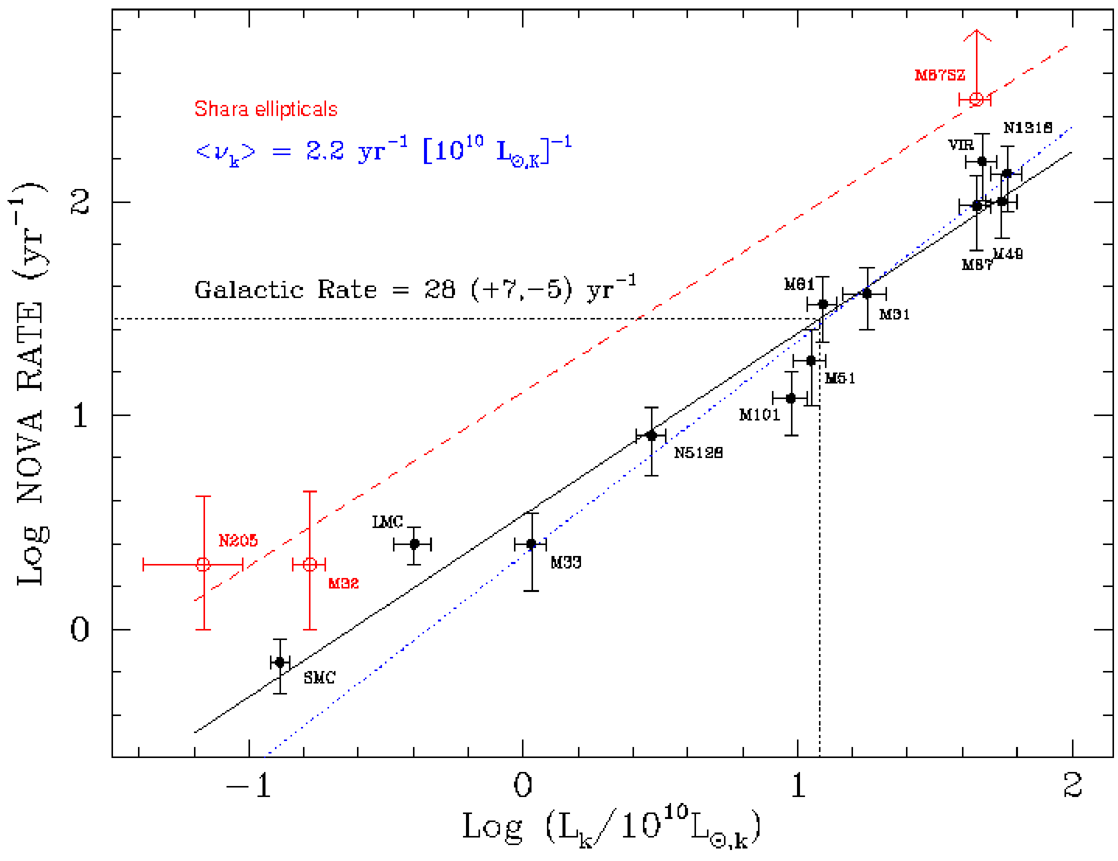

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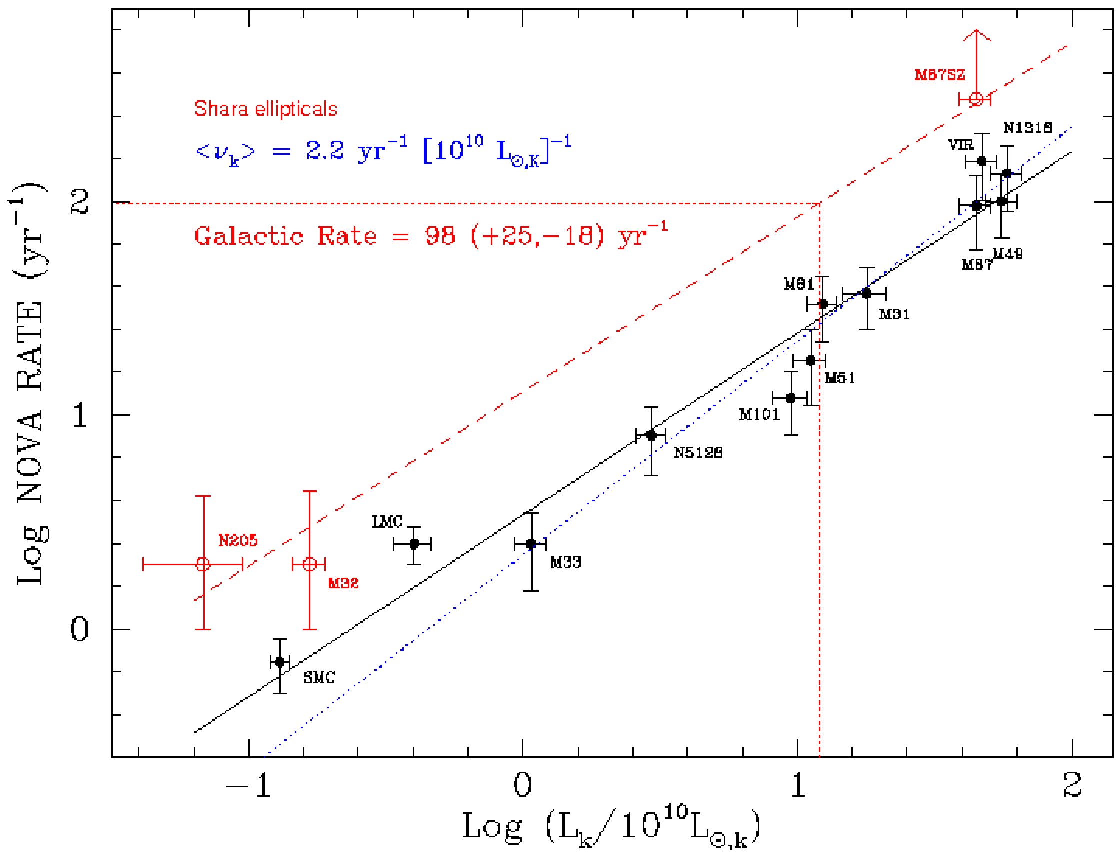

Conclusions

- The Galactic Nova Rate is ~36 per year based on extrapolation of the nova rate in the solar vicinity.
- If bulge novae are systematically fainter than disk novae then the nova rate can be much lower (~20 per year)
- Scaling from Extragalactic surveys suggest a Galactic nova rate of 23-35 per year in excellent agreement with Galactic estimates. (*but*, see Neill & Shara 2005)
- There is mounting evidence that that the nova rate per unit mass (*K* luminosity) is at least as high, and maybe higher, in older stellar populations, in conflict with population synthesis models.

Future Work

- The observed properties of novae (luminosity, fade rate) from differing stellar populations must be explored.
- The possible variation of the LSNR of galaxies with differing Hubble types must 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 rates in M87 and M49…