The Nova Rate of M101

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Outline

1 Overview: Nova Progenitor Systems

2 Motivations: Understanding Nova Populations

3 Data Reduction: Finding Novae in M101

4 Deriving a Nova Rate

5 Conclusions
Nova Progenitors

Nova Outbursts

- Increase in magnitude of 10 – 20 mag
- Peak luminosities up to \( M_V \sim -9 \)
- Brighter novae fade more quickly than faint novae
- Decline in H\(\alpha\) more slowly than in B or V
## Tentative Properties of Nova Populations

<table>
<thead>
<tr>
<th>Property</th>
<th>Bulge Population</th>
<th>Disk Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Population II</td>
<td>Population I</td>
</tr>
<tr>
<td>Light-curve evolution</td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td>Williams (1992) spectral class</td>
<td>Fe II</td>
<td>He/N</td>
</tr>
<tr>
<td>White dwarf composition</td>
<td>CO</td>
<td>ONe</td>
</tr>
<tr>
<td>Mean recurrence times</td>
<td>Longer</td>
<td>Shorter</td>
</tr>
</tbody>
</table>

Shafter & Quimby (2007)
Recurrence time $\rightarrow$ LSNR

- Higher mass white dwarf = Shorter recurrence time = Higher Nova Rate
- Lower mass white dwarf = Longer recurrence time = Lower Nova Rate
- Use infrared K light as a proxy for mass
- Normalize the nova rate by total K light to get LSNR
- Compare Luminosity Specific Nova Rates (LSNRs) from different galaxies
Instrumentation

★ Bok 90” Prime Focus Imager
★ Operated by Steward Observatory, University of Arizona
★ Array of four 4096 × 4096 pixel CCDs
★ H\(\alpha\) filter: \(\lambda_o = 6580\) Å, FWHM = 80 Å
## Summary of Observations

<table>
<thead>
<tr>
<th>Epoch</th>
<th>UT Date</th>
<th>Julian Date (2,400,000+)</th>
<th># of Exposures</th>
<th>Integration Time (hrs)</th>
<th># of nights</th>
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<tbody>
<tr>
<td>1</td>
<td>2005 May 02</td>
<td>53493</td>
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<tr>
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<td>53845</td>
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<td>53880</td>
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<td>7</td>
<td>2006 Dec 13</td>
<td>54083</td>
<td>4</td>
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<td>8</td>
<td>2007 Jan 28</td>
<td>54129</td>
<td>13</td>
<td>3.25</td>
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<td>9</td>
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<td>54171</td>
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<td>54244</td>
<td>18</td>
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</table>
Image Reduction

- Standard Reduction: apply bias, dark, and flat field corrections
- Assign coordinates using field stars from USNO A2 Catalog
- Align in IRAF\(^1\) with IMALIGN or SREGISTER
- Median combine with IMCOMBINE

\(^1\) IRAF (Image Reduction and Analysis Facility) is distributed by the National Optical Astronomy Observatories, which are operated by AURA, Inc., under cooperative agreement with the National Science Foundation
A Master Image of M101

North is up and East is to the left. FOV is 22.5′ × 22.5′
Median Subtracted Image

North is up and East is to the left. FOV is 26.3′ × 26.3′
## Nova Positions & Magnitudes

<table>
<thead>
<tr>
<th>Nova</th>
<th>R.A. h m s</th>
<th>decl. ° ′ ′′</th>
<th>∆ R.A. ′′</th>
<th>∆ decl. ′′</th>
<th>$m_{H\alpha}$ (mag)</th>
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<tr>
<td>2005-1...</td>
<td>14 03 27</td>
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<td>339</td>
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<td>356</td>
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<td>163</td>
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<td>14 03 12</td>
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<td>20.2</td>
</tr>
<tr>
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<td>14 03 19</td>
<td>54 19 56</td>
<td>57</td>
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<td>19.9</td>
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<tr>
<td>2007-5...</td>
<td>14 03 05</td>
<td>54 24 27</td>
<td>-65</td>
<td>214</td>
<td>22.6</td>
</tr>
</tbody>
</table>

Offsets are measured from the center of M101 at

\[
\text{R.A.} = 14^h03^m12.51^s, \quad \text{decl.} = 54^\circ20^\prime53.1^\prime\prime \quad (J2000.0).
\]
Survey Completeness

![Graph showing survey completeness as a function of Hα magnitude.](image)
Isophotes represent 10% of the total K light as derived from 2MASS data (Jarrett et al. 2003).
Red circles are novae found in current study, open circles were fainter than the limiting magnitude. Black squares are novae from Shafter et al. (2000).
The cumulative distribution of 10 novae detected above the limiting magnitude along with 10 novae from 2000 study compared to the total distribution of K-band light. The radial distribution of novae follows the galactic light very well (KS = 99%).
Monte Carlo Method

★ Make an initial guess for $N_t$
★ $N_{obs}(N_t) = \int C(m)N(m, N_t)dm$
★ Record the number of times that $N_{obs}(N_t)$ matches $n_{obs}$
★ Repeat $10^4$ times
★ Simulation was run with Fortran code NEWRATES3.f
The most probably nova rate is $N_t = 10.4^{+1.6}_{-1.5}$. 
Mean Nova Lifetime Method

\[ \log \tau_c (\text{days}) = -4.78 - 2.10M_c - 0.162M_c^2 \]

\[ T(M < M_c) = \tau_c + \sum_{i=2}^{n} \min(t_i - t_{i-1}, \tau_c) \]

\[ R = \frac{N(M < M_c)}{T(M < M_c)} \]
Mean Nova Lifetime Method

$$M_c = -7.13 \pm 0.24$$

$$\tau_c = 90.7 \pm 11.2 \text{ days}$$

Effective survey time, \( T(M < M_c) = 578 \pm 31 \text{ days} \)

$$R = \frac{10}{578} \times 365.25 \text{ yr}^{-1}$$

* Nova rate in surveyed region of 6.3 \( \pm 2.0 \text{ yr}^{-1} \).
Mean Nova Lifetime: Global Nova Rate

★ Corrects for survey incompleteness (over $\sim 15\%$ of M101)
★ Yields a nova rate of $9.7 \pm 2.9 \text{ yr}^{-1}$. 
Luminosity Specific Nova Rate

- Use infrared K light as a proxy for mass
- Monte Carlo LSNR = $(1.10 \pm 0.25) \times \left\{10^{10} \, L_\odot\right\}^{-1} \, \text{yr}^{-1}$
The Nova Rate of M101

<table>
<thead>
<tr>
<th>Study</th>
<th>GNR (yr⁻¹)</th>
<th>LSNR (yr⁻¹ {10^{10}}⁻¹ L⊙,K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>10.4⁺¹.⁶₋₁.₅</td>
<td>(1.10 ± 0.25)</td>
</tr>
<tr>
<td>2000</td>
<td>12 ± 4</td>
<td>(1.27 ± 0.46)</td>
</tr>
</tbody>
</table>

The global nova rate (GNR) of the 2000 study is from Shafter et al. The LSNR is a revised value from Williams & Shafter (2004).
Luminosity Specific Nova Rates of External Galaxies

Luminosity Specific Nova Rates of External Galaxies

![Graph showing nova rates of various galaxies with different (B - K) values.](image-url)
Conclusions

- \( \text{LSNR}_K = (1.10 \pm 0.25) \times \left\{ 10^{10} \, \text{L}_{\odot, K} \right\}^{-1} \, \text{yr}^{-1} \), robust!
- Currently there appears to be no correlation between LSNR and Hubble type

Future Work

- Nova rates should be determined for a larger number of external galaxies.
- Light curves should be obtained for more novae outside of the Galaxy and M31
Acknowledgments

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References