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Constraining the role of novae as progenitors of type Ia supernovae

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Abstract

 With the progenitors of type Ia supernovae (SNe Ia) still eluding direct detections, various types of accreting white dwarfs (WDs) have been proposed as prospective candidates. One of the possibilities are WDs undergoing unstable nuclear burning on their surfaces. Although observations and theoretical modeling of classical novae generally suggest that more material is ejected during the explosion than is accreted, there is growing evidence that in certain accretion regimes of novae, appreciable mass accumulation by the WD in the course of unstable nuclear burning may be possible. We propose that statistics of novae in nearby galaxies may be a powerful tool to determine the role these systems play in producing SNe Ia. Methods. We used multicycle nova evolutionary models to compute the number and temporal distribution of novae that would be produced by a typical SN Ia progenitor before it reached the Chandrasekhar mass limit (Mch) and exploded, assuming that it experienced unstable nuclear burning during its entire accretion history. We then used the observed nova rate in M 31 to constrain the maximal contribution of the nova channel to the SN Ia rate in this galaxy. Results. The M 31 nova rate measured by the POINT-AGAPE survey is ≈ 65 yr-1. Assuming that all these novae will reach Mch, we estimate the maximal SN Ia rate novae may produce, which is ≲ 0.1-0.5 × 10-3 yr-1. This constrains the overall contribution of the nova channel to the SN Ia rate at ≲ 2-7%. However, if all POINT-AGAPE novae do eventually reach Mch, a significant population of fast novae (t2 ≲ 10 days) originating from the most massive WDs is expected, with a rate of ~200-300 yr-1, which is significantly higher than currently observed. We point out that statistics of such fast novae can provide powerful diagnostics of the contribution of the nova channel to the final stage of mass accumulation by the single-degenerate (SD) SN Ia progenitors. To explore the prospects of their use, we investigated the efficiency of detecting fast novae as a function of the limiting magnitude and temporal sampling of a nova survey of M 31 by a PTF class telescope. We find that a survey with the limiting magnitude of mR ≈ 22 observing at least every second night will catch ≈ 90% of fast novae expected in the SD scenario. Such surveys should be detecting fast novae in M 31 at a rate on the order of ≳ 103 × f per year, where f is the fraction of SNe Ia that accreted in the unstable nuclear burning regime while accumulating the final ΔM ≈ 0.1 M⊙ before the supernova explosion.

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Keywords

Galaxies: individual: M 31, Novae, cataclysmic variables, Supernovae: general, Surveys