ASTRONOMY

Rebirth of Novae as Distance Indicators Due to Efficient, Large Telescopes

M. Della Valle[1] and R. Gilmozzi[2]

A nova is a close binary system, where one component is a white dwarf. A nova exhibits a sudden and rapid increase in its brightness because of thermonuclear reactions on the surface of the white dwarf that is accreting hydrogen-rich material from its smaller mass companion star. These explosions liberate about 10^{45} ergs of energy within a few weeks, thus making novae some of the most luminous transient sources in the sky and, therefore, powerful standard candles for measuring intergalactic distances (*1*, *2*). In addition, nova surveys in external galaxies can be used to determine the average number of nova outbursts per year, the nova rate, and this rate can be used to estimate the contribution of novae to the chemical evolution of the parent galaxy (*3*) and their potential to be gamma-ray producers (*4*). Despite the importance of novae, they are difficult to detect and observe in external galaxies with 2- to 4-m class telescopes. Here we used the 8.2-m Very Large Telescope (VLT) to search for novae in NGC 1316, the parent galaxy of the type Ia supernovae 1980N and 1981D. The observations were performed during nine nights between 25 December 1999 and 19 January 2000. They were carried out in service mode at the VLT equipped with the FORS-1 instrument (focal reducer/low-dispersion spectrograph) and a 2048-by-2048 charged-coupled device (CCD) camera with a projected pixel size of 0.2 arc sec and a field of view of 6.8 by 6.8 arc min. Each 20-min exposure was imaged with filter B (in the Bessel photometric system), sometimes complemented by V and I. The background light due to the galaxy was removed by applying a median filter to each image, which was successively subtracted from the original frame. This procedure generates images containing only stars and the faint galaxy. The novae were discovered by comparing each background-subtracted B frame with the one obtained on 25 December. Photometric measurements have been performed with Sextractor (*5*), and the aperture photometry was corrected to account for seeing variations. We found four transient objects (Fig. 1) with blue colors, (B-V) ~0, which are typical for novae observed around the maximum of their brightness. The time scale of the apparent brightness and the color variability of these objects (Fig. 2) are inconsistent with other types of variable stars, such as Mira, cepheids, Hubble-Sandage variables, or foreground objects like RR Lyr and flare stars. These four novae in NGC 1316, at a distance of ~19.5 Mpc, are the first detected beyond the Virgo cluster. The sampling of the light curves is adequate to estimate the distance to the galaxy with the Buscombe–de Vaucouleurs relation. Because the last data points of the light curves were obtained within 20 days of the brightness maximum, the corresponding apparent magnitudes allow us to set an upper limit to the distance of the galaxy of 20 Mpc ± 2.4 (1 σ). Nova A was caught during its early decline from maximum brightness; therefore, the last data point can only be used to set a lower limit to the distance, i.e., 18.2 Mpc ± 2.2. The estimated distances imply an absolute magnitude at maximum brightness (M_B) of $M_B \geq -19.20 \pm 0.35$ and $M_B \geq -19.10 \pm 0.35$ for supernova 1980N and supernova 1981D, respectively. This result is consistent with the existence of a ~0.2 to 0.3 mag deficiency in the luminosity at maximum of type Ia supernovae found in early type galaxies compared with supernovae found in spirals (*6*). Simulated VLT observations of novae in the Fornax cluster (*7*), where NGC 1316 is located, showed that our novae sample might be incomplete by as much as 20%. With this in mind and by applying the control time technique (*8*), we estimate a nova rate for NGC 1316 of about 90 to 180 novae per year. After normalizing this rate to the infrared luminosity of the galaxy, we find that NGC 1316 tends to produce novae less prolifically than some type of spiral galaxies (*9*, *10*). Novae can be used as distance indicators like cepheids by studying the Zwicky and Buscombe–de Vaucouleurs relationships in parent galaxies with well-observed type Ia supernovae. Novae that can be rapidly and easily detected with larger telescopes such as the VLT have another important advantage over cepheids because they can be observed in all types of galaxies.

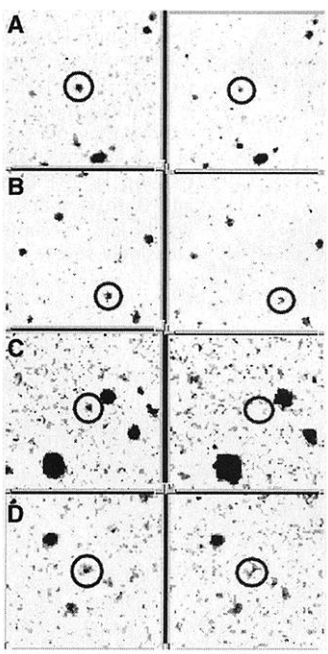

Fig. 1. Novae in B light during the bright and faint states: nova **A** (9 and 13 January 2001), nova **B** (26 December 2000 and 12 January 2001), nova **C** (26 December 2000 and 12 January 2001), and nova **D** (9 and 12 January 2001).

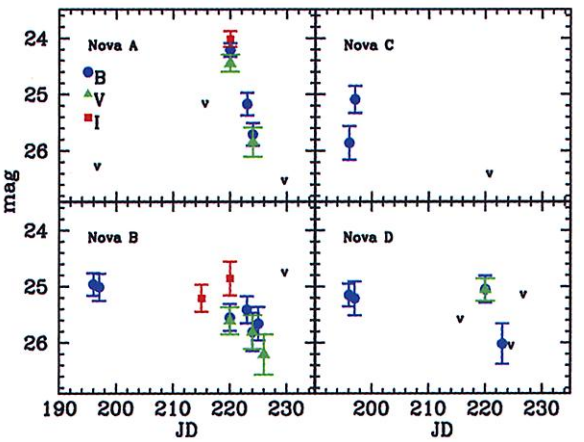

Fig. 2. Photometric evolution of the novae. Filled circles, observed B magnitudes; filled triangles, observed V magnitudes; filled squares, observed I magnitudes. V symbols represent upper limits.

References

1. S. van den Bergh, C. J. Pritchet, *Publ. Astron. Soc. Pac.* **98**, 110 (1986).
2. M. Della Valle, M. Livio, *Astrophys. J.* **452**, 704 (1995).
3. R. D. Gehrz *et al.*, *Publ. Astron. Soc. Pac.* **110**, 3 (1998).
4. J. Gomez-Gomar, M. Hernanz, J. Jose, J. Isern, *Mon. Not. R. Astron. Soc.* **296**, 913 (1998).
5. E. Bertin, S. Arnouts, *Astron. Astrophys. Suppl. Ser.* **117**, 393 (1996).
6. D. Branch *et al.*, *Astrophys. J.* **465**, 73 (1996).
7. M. Della Valle, R. Gilmozzi, in *The Early Universe with VLT*, J. Bergeron, Ed. (Springer, Berlin, 1997), p. 380.
8. F. Zwicky, *Astrophys. J.* **96**, 28 (1942).
9. M. Della Valle *et al.*, *Astron. Astrophys.* **287**, 403 (1994).
10. L. Yungelson *et al.*, *Astrophys. J.* **481**, 127 (1997).

[1]Arcetri Astrophysical Observatory, Largo E. Fermi 5, Firenze, Italy. [2]European Southern Observatory, Paranal, Antofagasta, Chile.