New Astronomy 37 (2015) 9–14

Contents lists available at ScienceDirect

New Astronomy

journal homepage: www.elsevier.com/locate/newast

Early spectroscopic observations of four extragalactic novae

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HIGHLIGHTS

- We performed spectroscopic observations of four extragalactic novae in M31 and M33.
- Nova M31 2009-10b is one of the most luminous novae ever observed in M31.
- Nova M33 2010-07a is the first recorded nova in M33 that underwent a second mass ejection.

ARTICLE INFO

Article history:
Received 10 July 2014
Received in revised form 28 October 2014
Accepted 11 November 2014
Available online 20 November 2014
Communicated by E.P.J van den Heuvel

Keywords:
Novae
Cataclysmic binaries

ABSTRACT

We report the spectroscopic observations of four extragalactic novae in M31 and in M33, secured at Loiano Observatory, Italy. Nova M31 2009-10b is a luminous nova that needed some days to achieve the peak brightness. We confirm that it is a Fe II nova and we show that it is one of the most luminous novae ever observed in M31, showing an evolution close to that of the bright extragalactic novae M31 2007-11d, LMC 1991 and SN 2010U. The novae M31 2010-07a and M31 2011-07b are standard Fe II novae. Nova M33 2010-07a is a Fe II nova that showed a peculiar rebrightening, during which we observed emission lines with P Cyg profiles: we suggest that it is the first observed nova in M33 that underwent a second mass ejection.

1. Introduction

Classical novae are a subset of cataclysmic variable where a thermonuclear runaway of the material accreted from the secondary star on the white dwarf occurs (Warner, 1995; Bode and Evans, 2008). Galaxies with different stellar populations could show different nova rates or different evolutionary paths of novae. Observations of novae in M31 and M33 offer the opportunity to understand the nova population, avoiding the variable interstellar reddening affecting galactic novae. The first systematic study of novae in M31 dates back to Hubble who estimated a nova rate of about 30 per year. The survey by Arp et al. (1956) suggested a rate of 26 ± 4 novae per year. The surveys by Rosino (1973); Rosino et al. (1989) discovered more than one hundred novae in M31. The Hα survey performed by Ciardullo et al. (1987) showed that novae could appear in any part of M31, despite previous claims of concentration far from bulge. In fact, novae are mostly associated with the M31 bulge, when extinction effects are included, according to Capaccioli et al. (1989), who estimated a rate of $29 \pm 4\,\mathrm{yr}^{-1}$. The rates estimated by Arp et al. (1956) and by Capaccioli et al. (1989) are consistent with the recent estimation of $37^{+12}_{-8}\,\mathrm{yr}^{-1}$ by Shafter and Irby (2001). Darnley et al. (2006) estimated a larger rate, $65^{+16}_{-15}\,\mathrm{yr}^{-1}$, suggesting also the existence of two nova populations, in bulge and in disk. Two distinct nova populations exist in the Milky Way. Della Valle et al. (1992) suggested that fast novae are closer to the galactic plane than slow novae. In addition, they belong to two distinct spectral classes, He/N and Fe II (Williams et al., 1991; Williams, 1992), with the former being faster and more luminous (Della Valle and Livio, 1995). The most part of novae in the Milky Way or in M31 belongs to the Fe II class. While the nova population in M31 is bulge dominated, in M33 it is disk dominated. The nova rate in M33 should be larger than in M31, since M33 is an early type galaxy (Della Valle et al., 1994). The estimated rate ranges from less than $0.4\,\mathrm{yr}^{-1}$ (Sharov, 1993) to $4.7 \pm 1.5\,\mathrm{yr}^{-1}$ (Della Valle et al., 1994), including a recent estimation of $2.5^{+1.0}_{-0.7}\,\mathrm{yr}^{-1}$ (Williams and Shafter, 2004). The first spectroscopic survey of M31 novae has been performed by Tomaney and Shafter (1992), who suggested a similarity with galactic novae. The recent survey by Shafter et al. (2011) has monitored about fifty novae in M31, showing that most of them belong to the Fe II spectral class. The investigation by Shafter et al. (2012) on the spectroscopic classes of M33 novae has reported that 5 out of 8 classified novae are He/N or hybrid novae, in contrast with the

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http://dx.doi.org/10.1016/j.newast.2014.11.003
1384-1076/

Galaxy and M31 where novae mostly belong to Fe II class. A possible explanation is the different stellar population that leads to more massive white dwarfs. To date, there are more than nine hundreds and about forty identified novae in M31 and M33, respectively (Pietsch et al., 2007; Pietsch, 2010),[1, 2] but only a few detailed spectroscopic surveys of novae in M31 and M33 have been performed (Tomaney and Shafter, 1992; Shafter et al., 2011; Shafter et al., 2012). Extensive coverage of extragalactic novae is difficult, due to their transient nature and the large distance of host galaxies. However, the typical magnitudes of novae in M31 and M33 at maximum and during the early decline make them suitable candidate targets for medium size telescopes, that in principle can secure timely observations. Some extragalactic novae could show the peculiar photometric and/or spectroscopic behaviors sometimes observed in galactic novae: high brightness, secondary outbursts, oscillations etc. Such anomalous behaviors deserve further investigation, triggering observations as the ones reported here to assess possible spectroscopic peculiarities.

We present spectroscopic observations performed at the Loiano Observatory, Italy, of four extragalactic novae, M31 2009-10b, M31 2010-07a, M31 2011-07b, M33 2010-07a. The observations extend an ongoing monitoring program of galactic novae by the same author (Poggiani, 2012). Two objects out of four showed a peculiar behavior. We will show that M31 2009-10b is one of the most luminous novae ever observed in M31 and that it evolved as other very bright extragalactic novae and that M33 2010-07a underwent a rebrightening that could be explained by a second mass ejection.

2. Observations

We secured optical spectra of M31 2009-10b, M31 2010-07a, M31 2011-07b, M33 2010-07a at the Cassini 1.52 m telescope, Loiano Observatory, Italy, using the BFOSC imager and spectrograph. We have used grism #4 to achieve a wide spectral coverage, 3800–8700 Å, with a resolution of 3.97 Å/px. The spectra frames have been corrected with the bias and flat frames. The spectra have been extracted with the optimal extraction algorithm by Horne (1986), calibrated in wavelength using HeNeAr lamps and corrected with an instrumental response curve. Time and weather constraints prevented securing more than one spectrum per nova.

3. Results

3.1. Nova M31 2009-10b

The extragalactic nova M31 2009-10b was independently discovered on 2009 October 11 by K. Itagachi, K. Nishiyama, F. Kabashima (Nakano and Yusa, 2009; Podigachoski et al., 2009; Nakano and Itagaki, 2009). Optical spectroscopy secured by Yamaoka and Ayani (2009) on 2009 October 15 showed a featureless blue continuum and Balmer lines with P Cyg profile. The observations by Di Mille et al. (2009) from October 15 to 19 initially showed a blue continuum with lines in absorption flanked by weak emissions, then a red continuum with Balmer lines in emission. On October 19 Barsukova et al. (2009) observed Balmer lines with red wings and Fe II transitions. A similarity with the slow rising Fe II nova 2007-11d (Shafter et al., 2009) was suggested by Di Mille et al. (2009). M31 2009-10b was classified as a Fe II nova, according to the spectral classes defined by Williams et al. (1991); Williams (1992). M31 2009-10b has been observed in the UV domain by the Swift satellite on 2009 October 22 and 25 (Henze et al., 2009).

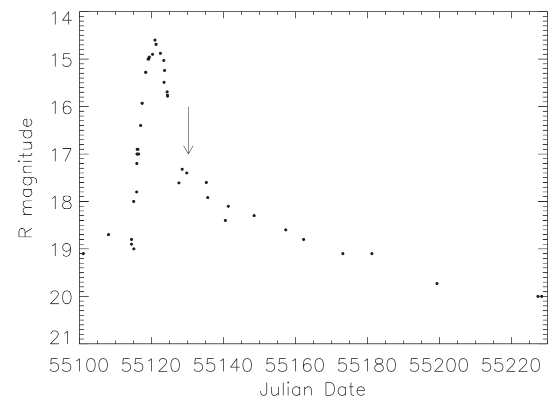

Fig. 1. R band light curve of M31 2009-10b.

3.1.1. Photometry

We have built the R band light curve of nova M31 2009-10b using the data of IAU circulars [3], VSNET database [4] and the photometry provided by Shafter et al. (2011). The light curve is reported in Fig. 1. The arrow marks the epoch of our observation.

The rise to maximum lasted off about five days. According to Cao et al. (2012), the UV peak of M31 2009-10b preceded the optical one by a few days. M31 2009-10b achieved a maximum magnitude of $R = 14.6$ on 2009 October 16 (MJD = 55121.0), while the maximum V magnitude was 15.0. The peculiar high brightness triggered our spectroscopic observation. We have estimated a decline time by two magnitudes of 6 days in the R band. Thus M31 2009-10b is a very fast nova, according to the speed classes defined by Payne-Gaposchkin (1957). The absolute magnitude at maximum can be estimated following the approach by Shafter et al. (2009). Using a value of 0.062 for E(B-V) (see Schlegel et al. (1998), Appendix C), an intrinsic color $(V-R)_0$ of about 0.16 at two magnitudes from maximum (Shafter et al., 2009) and a distance module of 24.38 for M31 (Freedman et al., 2001), we estimate an absolute magnitude at maximum of $M_V = -9.8$.

3.1.2. Spectroscopy

We have secured a spectrum of M31 2009-10b on 2009 October 25. The spectrum is reported in Fig. 2. The P Cyg profiles typical of novae around maximum have disappeared. The spectrum is dominated by intense Balmer and Fe II, O I lines in emission, typical of a Fe II nova in the early decline at the evolutionary stage P_{fe}, according to the classes by Williams et al. (1991); Williams (1992). Our spectrum is very similar to the spectrum of M31 2007-11d secured by Shafter et al. (2009) 14 days after maximum, confirming the similarity between the two objects suggested by Di Mille et al. (2009).

The ratios between the integrated fluxes of some relevant transitions to Hβ flux and the equivalent widths are reported in Table 1. Assuming nebular conditions of the case B and the optically thin medium, the ratio of O I 8446 to O I 7773 is expected to be 0.6 (e. g. Munari et al. (2008)). At the epoch of our spectrum we observed a ratio of 2.39. The inversion of the line ratio is explained by the fluorescence pumped by absorption of Lyβ photons (Bowen, 1947). The fluorescence mechanism is effective when the optical depth of Hα is large. In optically thin and low ionization conditions we would expect a ratio of O I 8446 to Hα of about 10^{-3} (Strittmatter et al., 1977). We observe a ratio of about 0.27, confirming that Hα had a large optical depth at the epoch of observation.

[1] http://www.mpe.mpg.de/~m31novae/opt/m31/index.php.
[2] http://www.mpe.mpg.de/~m31novae/opt/m33/index.php.
[3] http://cfa-www.harvard.edu/iau/services/IAUC.html.
[4] http://ooruri.kusastro.kyoto-u.ac.jp/mailman/listinfo/vsnet-alert.