### $BVR_CI_CH\alpha$ PHOTOMETRIC EVOLUTION OF NOVA 2007 IN M33

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**Abstract.**  $BVR_{\rm C}I_{\rm C}$  and H $\alpha$  lightcurve of Nova 2007, located in M33, is presented. It displayed the fastest decline ever observed for a nova in this galaxy ( $\Delta B$ =0.40 ±0.01 mag day<sup>-1</sup>), and its colors match those of galactic counterparts. The nova was discovered when it was already two magnitudes down from maximum (estimated to have occurred on Sept. 13 at B=15.5 mag).

Key words: stars: novae

## 1. INTRODUCTION

The recorded appearance of a nova in the Pinwheel Galaxy (M33) is a rare event. Sharov (1983) summarized the only 14 novae discovered to date in M33. Williams and Shafter (2004) in a carefully planned search in H $\alpha$  from 1995 to 2002 found just six novae. Estimates of the M33 nova production rates are quite uncertain and range from 0.45 (Sharov 1993), to 2.5 (Williams and Shafter 2004), to 4.6 yr<sup>-1</sup> (Della Valle et al. 1994). Most of M33 novae have very poorly sampled light-curves, frequently containing just a couple of single-band photometric points (e.g. Carpenter 1929, Rosino and Bianchini 1973, Williams and Shafter 2004), and even fewer have spectroscopic information. Nova 2007 (hereafter M33-N2007) was discovered in M33 by F. Kabashima and K. Nishiyama (cf. Nakano 2007) on unfiltered CCD images exposed on September 18.63 UT. Spectroscopic confirmation was provided by Wagner et al. (2007), who found that the spectrum was dominated by broad Balmer and HeI emission lines. Later a similar, though more detailed, description of the spectrum was provided by Shafter et al. (2007).

### 2. OBSERVATIONS

A  $BVR_{\rm C}I_{\rm C}$  comparison sequence around M33-N2007 was calibrated against Landolt's equatorial standards by observations obtained on three independent pho-

to metric nights with the Sonoita Research Observatory (Arizona) 0.35-m Celestron C14 robotic telescope using Optec filters and an SBIG STL-1001E CCD camera, 1024×1024 array, 24 µm pixels  $\equiv 1.25''$ /pix. The sequence is identified in Fig. 1 and listed in Table 1.

 $BVR_{\rm C}I_{\rm C}{\rm H}\alpha$  observations of M33-N2007 were obtained with the 0.50m f/8 Ritchey-Cretien telescope operated on top of Mt. Zugna by Museo Civico di Rovereto (Trento, Italy) and equipped with Optec filters and Apogee Alta U42 CCD camera,  $2048 \times 2048$ array, 13.5  $\mu$ m pixels  $\equiv 0.70''/pix$ .  $BVR_{\rm C}$  observations were acquired also with the 60-cm, f/3.3 robotic telescope of the Črni Vrh Observatory (Slovenia), equipped with Omega filters and a Finger Lake Instruments 1024S CCD camera, 1024 × 1024 array, 24  $\mu$ m pixels  $\equiv$ 2.5''/pix. The nova photometry has been calibrated against the photometric sequence of Table 1, and it is reported in Table 2, together with  $BR_{\rm C}$ photometry from Nakano (2007a,b) recalibrated against the same photometric sequence (the original data used



Fig. 1.  $R_{\rm C}$ -band image identifying the nova in the center and the comparison sequence listed in Table 1.

USNO-B1 data for surrounding field stars).

Two H $\alpha$  observations were also obtained through a 50 Å wide interference filter centered at 6560 Å. Assuming  $m(\text{H}\alpha)-R_{\rm C}=0.0$  for the stars of the photometric sequence in Table 1, we obtained for the nova  $m(\text{H}\alpha)=17.50\pm0.02$  on September 21.035, and  $m(\text{H}\alpha)=17.40\pm0.03$  on September 23.877 UT. They confirm the Williams and Shafter (2004) findings that M33 novae decline very slowly in H $\alpha$ and show  $B-m(\text{H}\alpha)\approx 2$  mag.

Table 1: Photometric comparison sequence identified in Fig. 1

	V (±)		$B–V~(\pm)$		$V\!\!-\!\!R_{ m C}~(\pm)$		$V\!\!-\!\!I_{ m C}~(\pm)$	
a b c d f g h i j	$\begin{array}{c} 14.081\\ 14.164\\ 14.558\\ 15.502\\ 15.594\\ 16.300\\ 16.459\\ 16.739\\ 17.005\\ 17.519\end{array}$	$\begin{array}{c} 0.018\\ 0.013\\ 0.013\\ 0.013\\ 0.019\\ 0.031\\ 0.036\\ 0.041\\ 0.017\\ 0.036\\ \end{array}$	$\begin{array}{c} 1.124\\ 0.651\\ 0.807\\ 0.754\\ 0.514\\ 0.695\\ 1.035\\ 0.113\\ 0.521\\ 0.140\end{array}$	$\begin{array}{c} 0.030\\ 0.033\\ 0.092\\ 0.047\\ 0.039\\ 0.093\\ 0.088\\ 0.088\\ 0.084\\ 0.066\\ 0.096\\ \end{array}$	$\begin{array}{c} 0.694\\ 0.364\\ 0.448\\ 0.430\\ 0.341\\ 0.385\\ 0.630\\ 0.149\\ 0.327\\ 0.284 \end{array}$	$\begin{array}{c} 0.012\\ 0.011\\ 0.012\\ 0.039\\ 0.031\\ 0.033\\ 0.045\\ 0.033\\ 0.064\\ 0.027\\ \end{array}$	$\begin{array}{c} 1.285\\ 0.726\\ 0.858\\ 0.834\\ 0.670\\ 0.835\\ 1.158\\ 0.334\\ 0.728\\ 0.172 \end{array}$	$\begin{array}{c} 0.014\\ 0.012\\ 0.010\\ 0.021\\ 0.034\\ 0.040\\ 0.068\\ 0.063\\ 0.025\\ 0.029\\ \end{array}$

HJD	date (UT)	B (±)	V (±)	$R_{ m C}~(\pm)$	$I_{\rm C}~(\pm)$	
$\begin{array}{c} \text{HJD} \\ 63.001 \\ 64.006 \\ 64.440 \\ 64.540 \\ 64.631 \\ 65.417 \\ 65.417 \\ 65.430 \end{array}$	date (U1) 09-19.501 09-20.506 09-20.935 09-21.035 09-21.126 09-21.912 00-21.912	$\begin{array}{c} B & (\pm) \\ 17.6 \\ 18.3 \\ 18.51 & 0.03 \\ 18.49 & 0.02 \\ 18.52 & 0.03 \\ 18.43 & 0.05 \\ 18.57 & 0.03 \end{array}$	V (±) 18.50 0.08 18.32 0.02 18.35 0.03 18.64 0.13 18.45 0.03	$\begin{array}{c} R_{\rm C} (\pm) \\ 16.7 \\ 17.0 \\ 17.56 \\ 0.07 \\ 17.53 \\ 0.01 \\ 17.53 \\ 0.04 \\ 17.68 \\ 0.05 \\ 17.69 \\ 0.02 \end{array}$	$I_{\rm C}$ (±) 17.48 0.03	a a b c b b c
$\begin{array}{c} 65.430\\ 66.561\\ 66.629\\ 67.382\\ 67.631\\ 76.357 \end{array}$	$\begin{array}{c} 09\text{-}21.923\\ 09\text{-}23.056\\ 09\text{-}23.124\\ 09\text{-}23.877\\ 09\text{-}24.126\\ 10\text{-}02.852 \end{array}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	17.55       0.03         17.69       0.03         17.86       0.03	с с b с b b

Table 2:  $BVR_{\rm C}I_{\rm C}$  photometry of the nova. a = Nakano (2007a,b), b = Črni Vhr and c = Mt. Zugna observations. HJD = heliocentric JD - 2454300

#### 3. RESULTS

The lightcurve of M33-N2007 is presented in Fig. 2. It is one of the best ever obtained for a nova in M33, and the only multi-band one.

It is characterized by a very fast decline, amounting to  $\Delta B = 0.40 \pm 0.01$  mag day<sup>-1</sup> (which is the slope of the least-squares fit plotted as a solid line in Fig. 2). This agrees with the the optical spectrum being characterized by HeI and NII and not FeII emission lines (cf. Williams 1992). None of the previously observed M33 novae declined faster than M33-N2007 (their decline rates show a bimodal distribution, centered at  $\Delta B = 0.06$  and 0.25 mag day<sup>-1</sup>). Using calibrations summarized by Warner (1995), a  $\Delta B = 0.40 \pm 0.01$  mag day<sup>-1</sup> rate corresponds to an absolute magnitude  $B \sim -9.3$ . At the M33 distance and foreground reddening (840 kpc and  $E_{B-V}=0.08$ , cf. Mateo 1998), M33-N2007 should have peaked to  $B \sim 15.5$ . The dashed line in Fig. 2 is a hand drawn extrapolation to a  $B_{\rm max} = 15.5$  maximum, that could have occurred around September 13, i.e. five days before the nova was actually discovered. The mean colors of M33-N2007 during the period of our observations (on average 8 days past and  $\Delta B=3$  mag down from estimated maximum) are  $B-V=+0.20\pm0.02$ ,  $V-R_{\rm C}=+0.80\pm0.03$ ,  $V-I_{\rm C}=0.96\pm0.05, R_{\rm C}-I_{\rm C}=0.22\pm0.06$  (the uncertainty is the error of the mean). The reddening corrected color  $(B-V)_{\circ} = -0.05$  is in good agreement with van den Bergh and Younger (1987), who found for galactic novae on average  $(B-V)_{\circ} = +0.23$  $\pm 0.06$  at maximum, and  $(B-V)_{\circ} = -0.02 \pm 0.02$  two magnitudes down from it.

The last observation (October 2) in Fig. 2 shows a flattening of the decline and blueing of the colors. Other M33 novae have been observed to glitch, even rebrighten, in their late-time *B*-band (or equivalent  $m_{\rm pg}$ ) light-curves, for ex. Novae 1974 and 1982 (cf. Della Valle et al. 1994). The M33-N2007 astrometric position (with respect to UCAC stars in the field) is (J2000)  $\alpha$ =01 33 58.65,  $\delta$ = +30 57 34.3 (±0.2 arcsec on both coordinates).



**Fig. 2.**  $BVR_CI_C$  light-curves of the nova. 'V" symbol marks the negative observation reported by Nakano (2007), and the arrow the date of discovery. a, b, c as identified in Table 2.

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