# Novae search in M 31 with Rozhen NAO telescopes: June - December 2010

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**Abstract.** We present BVR photometric data for 9 novae and one long-period Mira variable in M 31, observed in 2010. This work is part of a series of papers based on observations taken with the 2-m RCC telescope and the 50/70-cm Schmidt telescope at Rozhen NAO, Bulgaria, obtained by the Bulgarian novae search team. Light curves of 7 novae are constructed using Rozhen NAO data and data from the literature. We estimated the rate of decline $t_2$ = 25.6 days and 38.3 days for M31N2010-05a and M31N2010-10d, respectively. Our photometric measurements are made few weeks before the observed maximum of M31N2010-10b and few months after the last published data point for M31N2010-06d and M31N2010-10d.
**Key words:** Novae, light curves, M 31, Mira variables

## Introduction

Classical novae surveys are very important for using novae as standard candles and for better understanding the physics of this subclass of the cataclysmic variable stars. Observations of Galactic novae are limited due to high extinction in the disk, but the nearby galaxy M 31 gives an excellent opportunity for novae surveys. The number of searching teams grows and the discovered novae in M 31 increased in the last few years. More than 800 novae have been discovered (Pietsch et al. 2007; Shafter et al. 2011, and references therein) over the past century. Moreover, possible recurrent novae are known recently (Pietsch 2010; Cao et al. 2012; Lee et al. 2012).

Most of major surveys of M 31 novae (Darnley et al. 2004, 2006; Cao et al. 2012; Kasliwal et al. 2010; Shafter et al. 2011) and also small telescope monitoring programs (Hatzidimitriou et al. 2007, Valcheva et al. 2010) make possible the construction of optical light curves, covering long interval of time for dozens novae and wide range of magnitudes. This is one of the most important aims in the novae monitoring campaigns, as it makes possible the estimation of the nova rate of decline, and the specification of the maximum mgnitude rate of decline (MMRD) relationship (Zwicky 1936, della Valle and Livio 1995).

Here, we present BVR photometric data for 9 novae and one Mira variable, firstly recognized as nova in M 31 (Ovcharov et al. 2007; Taneva et al. 2010). This paper is organized as follows: Section 1 describes Rozhen NAO observations, data reduction and photometry data; Section 2 presents some discussion about light curves and the Mira variable star; Section 3 contains our conclusion.

## 1. Observations and data reduction

The observations are carried out during 15 nights from June to December 2010 at Rozhen NAO, Bulgaria with the 2-m RCC telescope and the 50/70-cm Schmidt telescope, equipped with VersArray1300B and FLI PL16803 CCD cameras, respectively. They are part of our M 31 novae monitoring program (Valcheva et al. 2010; Ovcharov et al. 2010). The novae sample and the Mira-like variable, firstly recognized as nova M 31 N 2007-11g, are described in Table 1. First column is for the object name, then coordinates, discovery date, magnitudes at the discovery, spectral type and references are given.

**Table 1.** Sample of objects

| Nova name | RA | DEC | Discovery date | Magnitudes | Type | Reference |
|---|---|---|---|---|---|---|
| | hh:mm:ss | dd:′:″ | yyyy/mm/dd | mag | | |
| M31N 2010-05a | 00:42:35.88 | +41:16:37.4 | 2010/05/28.035 | 17.6(R) | FeII | 1 |
| M31N 2010-06a | 00:43:07.56 | +41:19:49.0 | 2010/06/28.014 | 18.1(R) | FeII | 2 |
| M31N 2010-06b | 00:44:22.46 | +41:28:14.5 | 2010/06/28.014 | 19.1(R) | FeII | 3 |
| M31N 2010-06c | 00:44:04.48 | +41:28:34.2 | 2010/06/26.084 | 17.8(R) | ... | 4 |
| M31N 2010-06d | 00:42:55.61 | +41:19:26.0 | 2010/06/24.02 | 19.5(Swift uvw1) | FeII | 5 |
| M31N 2010-09b | 00:43:45.53 | +41:07:54.7 | 2010/09/30.412 | 17.7(R) | FeII | 6 |
| M31N 2010-10a | 00:42:45.84 | +41:24:22.2 | 2010/10/05.551 | 17.6(R) | FeII | 7 |
| M31N 2010-10b | 00:42:41.51 | +41:03:27.3 | 2010/08/19.055 | 18.9(R) | FeII | 8 |
| M31N 2010-10d | 00:42:36.91 | +41:19:29.6 | 2010/10/29.478 | 17.8(U) | FeII | 9 |
| Mira variable: | | | | | | |
| M31N 2007-11g | 00:44:15.88 | +41:13:51.1 | 2007/10/28.716 | 18.73(R) | Mira | 10 |

References – (1) Hornoch et al. 2010i; (2) Hornoch et al. 2010c,h,a,f,e; Henze et al. 2010; Pietsch et al. 2010d; (3) Hornoch et al. 2010b,a,g; (4) Burwitz et al. 2010a; Pietsch et al. 2010a; Hornoch 2010; Hornoch et al. 2010a,e; Burwitz et al. 2010b; (5) Pietsch et al. 2010b; Hornoch et al. 2010g; Pietsch et al. 2010c; Henze et al. 2010; Barsukova et al. 2010; Pietsch et al. 2010d; (6) Yusa 2010a; Pietsch et al. 2010e; Shafter et al. 2010b,c; (7) Yusa 2010b; Shafter et al. 2010c; Pietsch et al. 2010d; (8) Corral-Santana et al. 2010; Shafter et al. 2010d; (9) Nishiyama & Kabashima 2010; Sun et al. 2010; Hornoch et al. 2010d; Hornochova & Wolf 2010; Shafter et al. 2010a; (10) Ovcharov et al. 2007;

Data reduction and aperture photometry of the objects are performed using standard IRAF routines. The total integration time was split into a few separate frames (typical exposure time of 3×300 or 5×300 sec). Secondary standards in the field of M 31 (Stanev et al. 2010) are used for the magnitude calibration of the objects. Table 2 presents the BVR photometric data for the 9 novae and the Mira-like variable. First column is for the nova name, followed by observing date, standard magnitudes, errors and telescope.

## 2. Discussion

All novae from the sample, except M31N 2010-05a, are also observed as a part of the Palomar Transient Factory (PTF) monitoring of M 31 (Law et al. 2009; Rau et al. 2009) and the light curves are discussed by Cao et al. (2012). Our BVR photometric data are a good complement to the last one.

Fig. 1 presents light curves of 7 novae from our sample and the Mira-like variable, based on our data and on the already published (Cao et al. 2012, M 31 (Apparent) Novae Page - *www.cbat.eps.harvard.edu/CBAT_M31.html*).

**M31N2010-05a** This nova is discovered by Hornoch et al. (2010i) in May 28.035 UT. It is spectroscopically confirmed by Pietsch et al. (2010d) and the

**Table 2.** BVR photometric data

| Nova name | UT start 2010 | B mag | err mag | V mag | err mag | R mag | err mag | Telescope |
|---|---|---|---|---|---|---|---|---|
| 2010-05a | 14.045 June | | | | | 17.666 | 0.018 | 2-m RCC |
| 2010-05a | 15.007 June | | | | | 17.695 | 0.017 | 2-m RCC |
| 2010-05a | 14.991 June | 17.862 | 0.019 | | | | | 2-m RCC |
| 2010-05a | 14.999 June | | | 17.968 | 0.016 | | | 2-m RCC |
| 2010-05a | 17.012 June | | | | | 18.207 | 0.349 | 50/70 |
| 2010-05a | 07.039 July | 19.499 | 0.244 | | | | | 50/70 |
| 2010-05a | 07.012 July | | | | | 19.603 | 0.511 | 50/70 |
| 2010-05a | 07.027 July | | | 19.657 | 0.424 | | | 50/70 |
| 2010-06a | 04.990 July | | | | | 17.303 | 0.035 | 50/70 |
| 2010-06a | 04.999 July | | | 17.279 | 0.048 | | | 50/70 |
| 2010-06a | 05.003 July | 17.495 | 0.053 | | | | | 50/70 |
| 2010-06a | 07.039 July | 18.348 | 0.047 | | | | | 50/70 |
| 2010-06a | 07.012 July | | | | | 18.108 | 0.062 | 50/70 |
| 2010-06a | 07.027 July | | | 18.254 | 0.059 | | | 50/70 |
| 2010-06b | 04.990 July | | | | | 18.602 | 0.075 | 50/70 |
| 2010-06b | 04.999 July | | | 19.118 | 0.208 | | | 50/70 |
| 2010-06b | 05.003 July | 19.877 | 0.412 | | | | | 50/70 |
| 2010-06b | 07.039 July | 20.395 | 0.232 | | | | | 50/70 |
| 2010-06b | 07.012 July | | | | | 19.377 | 0.112 | 50/70 |
| 2010-06b | 07.027 July | | | 19.500 | 0.121 | | | 50/70 |
| 2010-06b | 13.993 Sept | | | | | 20.144 | 0.164 | 50/70 |
| 2010-06b | 14.030 Sept | 20.220 | 0.192 | | | | | 50/70 |
| 2010-06b | 14.033 Sept | | | 19.940 | 0.219 | | | 50/70 |
| 2010-06b | 15.925 Sept | | | | | 20.013 | 0.167 | 50/70 |
| 2010-06b | 15.960 Sept | 20.690 | 0.211 | | | | | 50/70 |
| 2010-06b | 15.956 Sept | | | 20.703 | 0.382 | | | 50/70 |
| 2010-06c | 04.990 July | | | | | 18.601 | 0.083 | 50/70 |
| 2010-06c | 04.999 July | | | 19.242 | 0.241 | | | 50/70 |
| 2010-06c | 05.003 July | 19.892 | 0.404 | | | | | 50/70 |
| 2010-06c | 07.039 July | 19.489 | 0.103 | | | | | 50/70 |
| 2010-06c | 07.012 July | | | | | 18.688 | 0.071 | 50/70 |
| 2010-06c | 07.027 July | | | 19.284 | 0.109 | | | 50/70 |
| 2010-06d | 04.990 July | | | | | 18.013 | 0.078 | 50/70 |
| 2010-06d | 04.999 July | | | 18.077 | 0.115 | | | 50/70 |
| 2010-06d | 05.003 July | 18.288 | 0.111 | | | | | 50/70 |
| 2010-06d | 07.039 July | 20.158 | 0.327 | | | | | 50/70 |
| 2010-06d | 07.012 July | | | | | 20.006 | 0.478 | 50/70 |
| 2010-06d | 07.027 July | | | 20.289 | 0.506 | | | 50/70 |
| 2010-06d | 13.993 Sept | | | | | 19.479 | 0.239 | 50/70 |
| 2010-06d | 14.030 Sept | 19.412 | 0.154 | | | | | 50/70 |
| 2010-06d | 14.033 Sept | | | 19.932 | 0.441 | | | 50/70 |
| 2010-06d | 15.925 Sept | | | | | 19.705 | 0.317 | 50/70 |
| 2010-06d | 15.960 Sept | 19.452 | 0.126 | | | | | 50/70 |
| 2010-06d | 15.956 Sept | | | 19.905 | 0.385 | | | 50/70 |
| 2010-09b | 10.953 Oct | | | | | 18.848 | 0.129 | 50/70 |
| 2010-10a | 10.953 Oct | | | | | 17.938 | 0.073 | 50/70 |
| 2010-10b | 13.993 Sept | | | | | 19.319 | 0.083 | 50/70 |
| 2010-10b | 14.033 Sept | | | 19.583 | 0.145 | | | 50/70 |
| 2010-10b | 15.925 Sept | | | | | 19.418 | 0.103 | 50/70 |
| 2010-10b | 15.956 Sept | | | 19.572 | 0.131 | | | 50/70 |
| 2010-10b | 10.953 Oct | | | | | 18.520 | 0.478 | 50/70 |
| 2010-10b | 12.759 Nov | | | | | 18.826 | 0.094 | 50/70 |
| 2010-10b | 13.752 Nov | | | | | 18.940 | 0.067 | 50/70 |
| 2010-10b | 14.765 Nov | | | | | 18.927 | 0.072 | 50/70 |
| 2010-10b | 15.820 Nov | | | | | 19.106 | 0.098 | 50/70 |
| 2010-10d | 12.759 Nov | | | | | 18.168 | 0.122 | 50/70 |
| 2010-10d | 13.752 Nov | | | | | 18.314 | 0.125 | 50/70 |
| 2010-10d | 14.765 Nov | | | | | 18.337 | 0.126 | 50/70 |
| 2010-10d | 15.820 Nov | | | | | 18.492 | 0.157 | 50/70 |
| 2010-10d | 15.857 Nov | 18.710 | 0.107 | | | | | 50/70 |
| 2010-10d | 15.849 Nov | | | 18.390 | 0.125 | | | 50/70 |
| 2007-11g | 13.993 Sept | | | | | 19.843 | 0.107 | 50/70 |
| 2007-11g | 15.925 Sept | | | | | 19.636 | 0.095 | 50/70 |
| 2007-11g | 15.956 Sept | | | 20.047 | 0.183 | | | 50/70 |
| 2007-11g | 10.953 Oct | | | | | 18.975 | 0.145 | 50/70 |
| 2007-11g | 12.759 Nov | | | | | 18.963 | 0.096 | 50/70 |
| 2007-11g | 13.752 Nov | | | | | 19.041 | 0.056 | 50/70 |
| 2007-11g | 14.765 Nov | | | | | 19.040 | 0.065 | 50/70 |
| 2007-11g | 15.820 Nov | | | | | 19.157 | 0.090 | 50/70 |
| 2007-11g | 14.927 Nov | | | | | 18.903 | 0.015 | 2-m RCC |
| 2007-11g | 14.933 Nov | 21.365 | 0.058 | | | | | 2-m RCC |
| 2007-11g | 14.929 Nov | | | 19.800 | 0.019 | | | 2-m RCC |
| 2007-11g | 06.685 Dec | | | | | 18.856 | 0.017 | 2-m RCC |
| 2007-11g | 08.682 Dec | | | 20.009 | 0.024 | | | 2-m RCC |

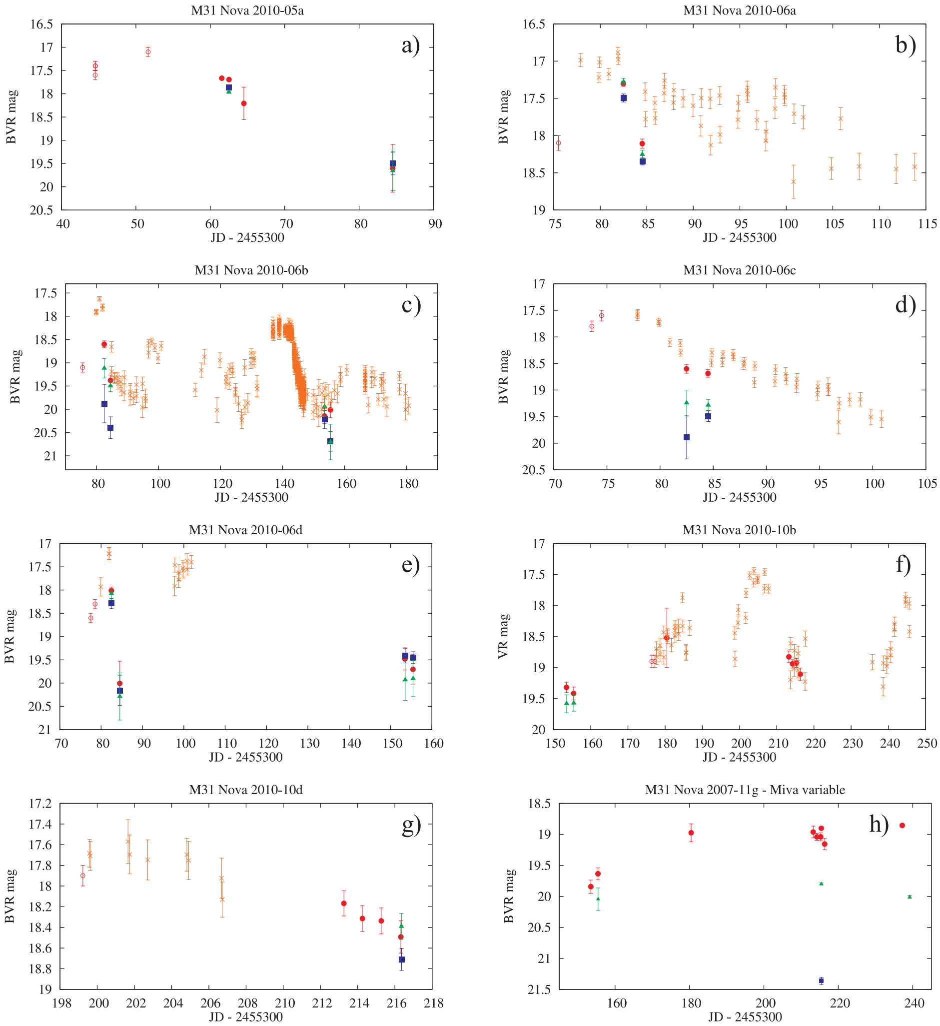


**Fig. 1.** Filled circles present our R-band data, triangles are V- and squares are B-band data. The empty circles present the R-band data from the M 31 (Apparent) Novae Page (*www.cbat.eps.harvard.edu/CBAT_M31.html*) and the crosses – R-band data from Cao et al. (2012).

derived type is FeII. Fig. 1a illustrates the nova light curve which is published here for the first time. The decline rate estimate by using the R-band data is $t_2 = 25.6$ days. It seems that this nova is with smoothly declining light curve.

**M31N2010-06a and M31N2010-06b** These two novae are with jittering decay and have a well-sampled light curves in Cao et al. (2012). Fig. 1b and Fig. 1c present our data added to the published ones.

**M31N2010-06c** This is a smoothly declining nova (Fig.1d) as it is defined by Cao et al. (2012). Our data fall in the gap of the constructed light curve of Cao et al. (2012) and demonstrate a break in the declining part of the curve, indicating to possible dust dip, typical for the D class novae. Such possibility is confirmed by the red colors measured by us on both sides of the suspected dip. However, its too short occurrence after the maximum light presumes a shallower dip, if any.

**M31N2010-09b and M31N2010-10a** We add one photometric measurement (see Table 2) for each of these two smoothly declining novae (Cao et al. 2012).

**M31N2010-10b** Although this nova is with well-sampled rise stage of the light curve in Cao et al. (2012), our data expand the light curve before the moment of maximum with more than 20 days (see Fig.1f).

**M31N2010-06d and M31N2010-10d** Rozhen NAO data complement the under-sampled light curves in Cao et al. (2012) (Fig.1e and Fig.1g). It seems that M31N2010-06d is a nova with jittering decay and M31N2010-10d is a smoothly declining nova. The decline rate for M31N2010-10d estimated by using our R-band magnitudes and the ones from Cao et al. (2012) is $t_2$=38.3 days.

The properties of the discussed novae are presented in Table 3. First column is the nova name, then rate of decline $t_2$, decline morpholgy and reference are shown. $S$ indicates smoothly declining light curves and $J$ – jittering decay.

**Table 3.** Properties of the novae light curves

| Nova name | $t_2$ (days) | Decline Morphology | Ref. |
|---|---|---|---|
| M31N 2010-05a | 25.6 | S | 1 |
| M31N 2010-06a | $>$31 | J | 2 |
| M31N 2010-06b | 8 | J | 2 |
| M31N 2010-06c | 19 | S | 2 |
| M31N 2010-06d | ? | J | 1 |
| M31N 2010-09b | 10 | S | 2 |
| M31N 2010-10a | $>$9 | S | 2 |
| M31N 2010-10b | $>$41 | ? | 2 |
| M31N 2010-10d | 38.3 | S | 1 |

References – (1) this work, (2) Cao et al. (2012)

In Fig. 1h we present Rozhen NAO data for the observed in 2010 maximum of the Mira-like variable, firstly recognized as nova M31N 2007-11g by our team in 2007 (Ovcharov et al. 2007). The colour evolution of the variable is noticeable. The brightness in the V-band decreases with the rise of the R-band magnitude.

## Conclusion

This paper presents the photometric measurements of 9 novae and one Mira-like variable, observed by the Bulgarian novae search team (Valcheva et al. 2010, Ovcharov et al. 2010). Light curve for M31N2010-05a is constructed for the first time and we estimated its rate of decline $t_2 = 25.6$ days. For 7 novae we present R-band light curves when combining our data and the data from Cao et al. (2012). For M31N2010-10d we estimated the rate of decline $t_2 = 38.3$ days. When taking into account all available data we determined the decline morphology for three of the novae. The light curve for the Mira-like variable demonstrates colour evolution with time.

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