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## The light curves of the type Ia Supernova 2004fu

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### Abstract

CCD *UBVRI* photometry is presented for the type Ia supernova 2004fu in NGC 6949. The light and colour curves are typical for this class of objects, the absolute magnitude at maximum and decline rate are in agreement with the relationship between these parameters established for SNe Ia.

SN 2004fu was discovered by Arbour (2004) on unfiltered CCD images taken with a 0.3-m Schmidt-Cassegrain reflector on 2004 November 4.87 (approximately at 16<sup>m</sup>8) and 5.81 (approximately at 16<sup>m</sup>5). The new object was located at  $\alpha = 20^{\text{h}}35^{\text{m}}11^{\text{s}}.54$ ,  $\delta = +64^{\circ}48'25''.7$  (equinox 2000.0), which is 29'' east and 15'' north of the center of the Sc galaxy NGC 6949.

Modjaz et al. (2004) report that a spectrum (range 350–740 nm) of SN 2004fu, obtained on November 10.17 UT with the F. L. Whipple Observatory 1.5-m telescope, shows it to be a type Ia supernova, several days before maximum light.

We started photometric observations of SN 2004fu immediately after discovery, on November 6, with the 60-cm reflector of the Crimean Observatory of the Sternberg Astronomical Institute (C60) equipped with a Roper Scientific VersArray1300B CCD camera, and continued monitoring nearly each night until November 25. On November 22, images were obtained at the 38-cm reflector of the Crimean Astrophysical Observatory (C38) with an Apogee AP-47p CCD camera. Between 2004 December 29 and 2005 March 26, we observed SN 2004fu on four nights at the 70-cm reflector in Moscow (M70) with an AP-47p CCD camera, and on 2005 May 4, the last images were obtained at C60.

The reductions and photometric techniques were described by Tsvetkov (2006) and Tsvetkov et al. (2006). The image of SN 2004fu with comparison stars is shown in Fig. 1. The supernova is far away from the center of the galaxy and from the spiral arms, and the galaxy background does not affect the measurements. The magnitudes of the comparison stars are presented in Table 1, and photometry of the SN is reported in Table 2.

The light curves are shown in Fig. 2, where we also plotted the data obtained by amateur observers in the *BVR* bands as reported at

<http://www.astrosurf.com/snweb2/2004/04fu/04fuMeas.htm>. Their data in *B* are in good agreement with our results, while in the *V* and *R* bands some systematic differences can be found. We achieved excellent photometric coverage of the premaximum rise and first few days of brightness decline, but later only sporadic observations were obtained. We can derive dates and magnitudes of maximum light:  $B_{\text{max}} = 15.87$  on JD 2453326.3 (November 16.8),  $V_{\text{max}} = 15.42$  on JD 2453327.2,  $R_{\text{max}} = 15.18$  on JD 2453327.4. The date of maximum light in *I* is difficult to estimate with the same accuracy, as the light curve is quite flat near the maximum, with  $I_{\text{max}} = 15.19$ . Using the amateur data, we can derive the decline rate parameter  $\Delta m_{15}(B) = 1.3$ . We fitted the data to the light curves of the well studied SN Ia 1994D (Richmond et al., 1995, Altavilla et al., 2004) with nearly the same value of  $\Delta m_{15}(B)$ . The agreement between the light curves of SN 2004fu and

1994D is nearly perfect in the  $B$  and  $V$  bands near maximum, while in  $R$  and  $I$  some differences are evident. At late stages, the difference between these objects is prominent in all bands except  $I$ .

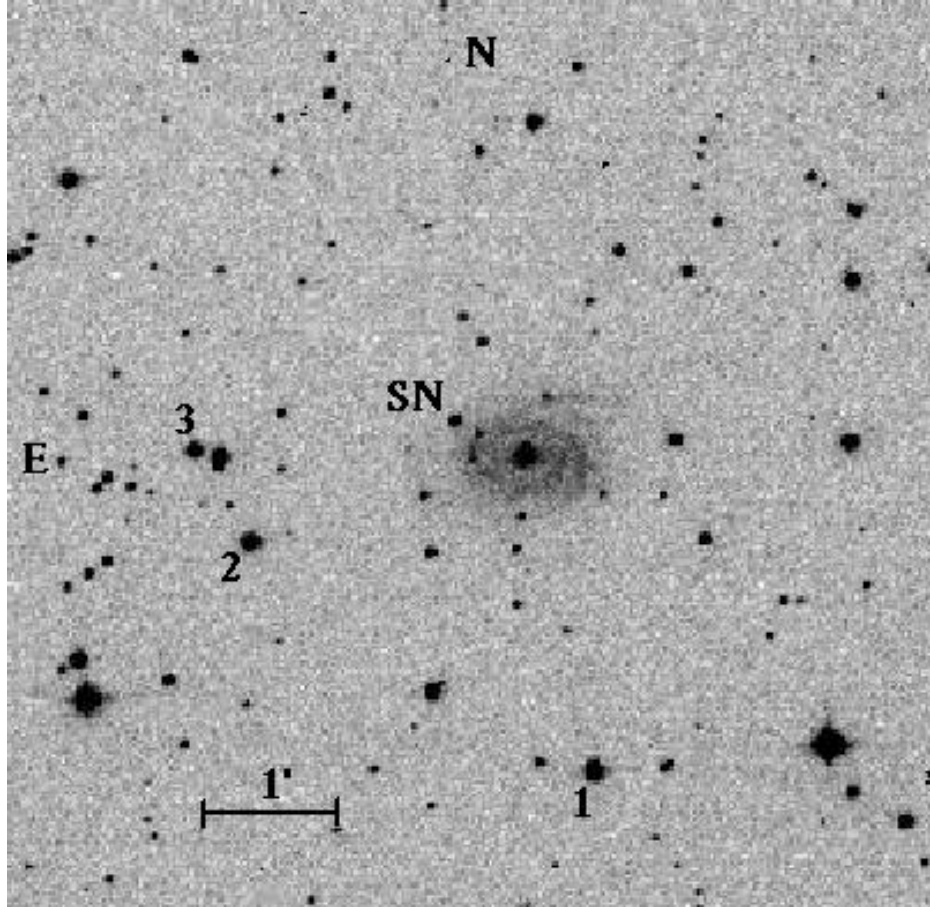
The colour curves for SN 2004fu are shown in Fig. 3 and are compared to those for SN 1994D. We see a very good agreement between SN 2004fu and SN 1994D in  $(B - V)$  and some differences in  $(V - R)$ . We shifted the  $(U - B)$ ,  $(B - V)$ , and  $(V - R)$  colour curves of SN 1994D by 0.5, 0.41 and 0.25 mag, respectively. As the light of SN 1994D suffered negligible extinction both in the Galaxy and in the host galaxy (Altavilla et al., 2004), these values represent the total colour excess for SN 2004fu. Comparing these data with the estimates of galactic extinction from Schlegel et al. (1998):  $A_U = 2.10$ ,  $A_B = 1.67$ ,  $A_V = 1.28$ ,  $A_R = 1.03$ , we conclude that all extinction towards SN 2004fu originated in the Galaxy. Using these values for extinction along with the distance modulus  $\mu=33.19$  from the LEDA database, we can derive the absolute magnitudes at maximum light:  $M_B = -18.99$ ,  $M_V = -19.05$ ,  $M_R = -19.04$ . These values are slightly fainter than the average luminosity for SNe Ia and are in a good agreement with the relationship between the decline rate parameter and absolute magnitude for SNe Ia as presented by Phillips (2005) and Altavilla et al. (2004).

We conclude that SN 2004fu is a typical object for its class regarding photometric behavior, with the rate of decline after maximum slightly faster, and the maximum luminosity lower than average, in accordance with the relationship between these parameters for SNe Ia.

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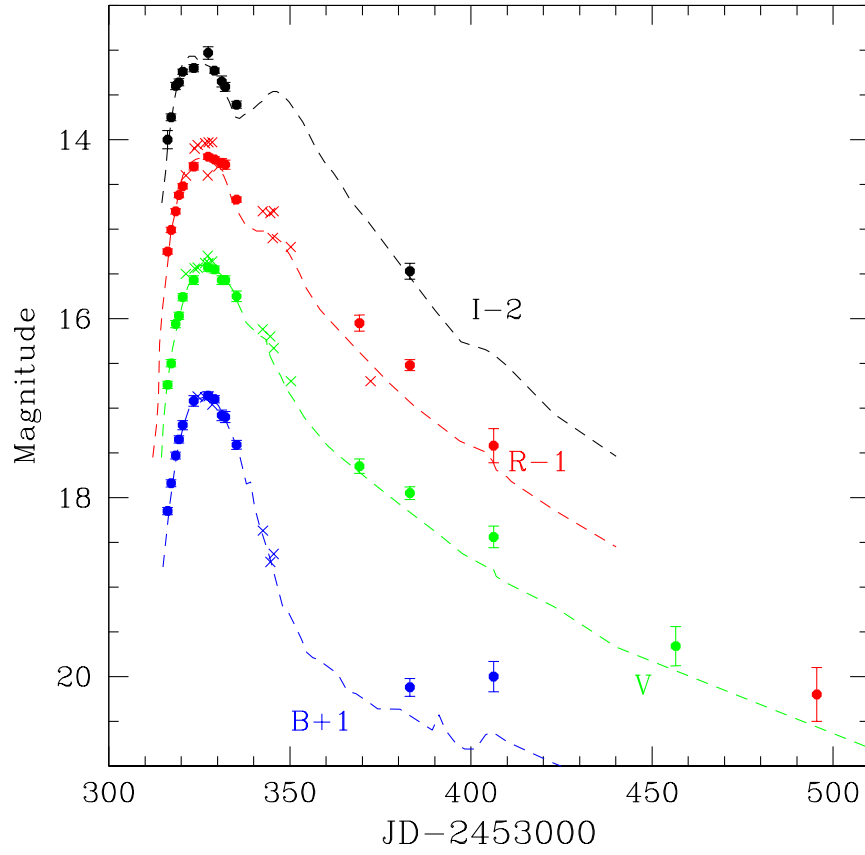
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**Figure 1.** SN 2004fu in NGC 6949 with comparison stars

Table 1: Magnitudes of comparison stars

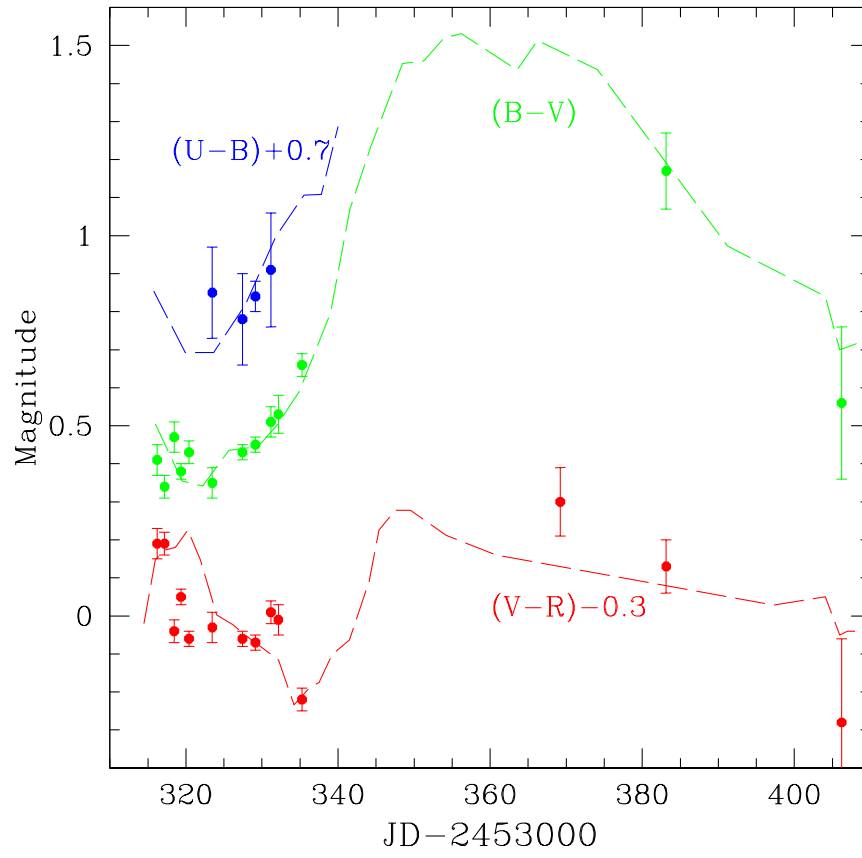
Star	$U$	$\sigma_U$	$B$	$\sigma_B$	$V$	$\sigma_V$	$R$	$\sigma_R$	$I$	$\sigma_I$
1	14.66	0.06	14.59	0.03	13.85	0.04	13.34	0.02	12.92	0.02
2	16.00	0.04	15.25	0.04	13.96	0.03	13.19	0.03	12.55	0.02
3	15.73	0.07	15.25	0.04	14.22	0.04	13.59	0.03	13.12	0.02



**Figure 2.** *BVRI* light curves of SN 2004fu, showing our photometry (dots) and that of amateur observers (crosses). The dashed curves are the light curves of SN 1994D

Table 2: Photometry of SN 2004fu

JD 2453000+	<i>U</i>	$\sigma_U$	<i>B</i>	$\sigma_B$	<i>V</i>	$\sigma_V$	<i>R</i>	$\sigma_R$	<i>I</i>	$\sigma_I$	Tel.
316.22			17.15	0.04	16.74	0.04	16.25	0.03	16.00	0.10	C60
317.19			16.84	0.04	16.50	0.04	16.01	0.03	15.75	0.04	C60
318.45			16.53	0.04	16.06	0.04	15.80	0.03	15.40	0.04	C60
319.35			16.35	0.04	15.97	0.04	15.62	0.03	15.36	0.04	C60
320.41			16.19	0.05	15.76	0.04	15.52	0.03	15.24	0.03	C60
323.47	16.07	0.12	15.92	0.06	15.57	0.05	15.30	0.04	15.20	0.04	C60
327.42	15.94	0.12	15.86	0.04	15.43	0.04	15.19	0.03	15.03	0.07	C60
329.15	16.04	0.05	15.90	0.04	15.45	0.04	15.22	0.03	15.23	0.03	C60
331.17	16.29	0.15	16.08	0.06	15.57	0.05	15.26	0.05	15.35	0.06	C60
332.15			16.10	0.06	15.57	0.05	15.28	0.05	15.41	0.05	C38
335.25			16.41	0.05	15.75	0.06	15.67	0.03	15.61	0.04	C60
369.22					17.65	0.08	17.05	0.09			M70
383.15			19.12	0.10	17.95	0.07	17.52	0.06	17.47	0.09	M70
406.21			19.00	0.17	18.44	0.12	18.42	0.19			M70
456.54					19.66	0.22					M70
495.49							21.20	0.30			C60



**Figure 3.**  $(U - B)$ ,  $(B - V)$  and  $(V - R)$  colour curves of SN 2004fu. The dashed curves are the colour curves of SN 1994D