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SPECTROSCOPIC AND PHOTOMETRIC OBSERVATIONS OF SN 2004dj

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The supernova SN 2004dj in NGC 2403 was first reported by Nakano et al. (2004). It has been classified as a normal type II-P supernova (Patat et al. 2004). We present spectroscopic and photometric observations of the supernova SN 2004dj obtained at the Ondřejov observatory and Lelekovice private observatory during August, September, and October 2004.

We obtained a total of 15 spectra of the supernova during 8 nights between 3rd August and 1st September 2004 at the Ondřejov 2m reflector using the Coudé spectrograph (for a description see Škoda et al. 2002) with a spectral range 6330 to 6773 Å. The resolution power of the spectrograph in the Hα region is about 13 000. We used the Coudé 700mm camera with the SITe CCD 2030×800 15μ pixels. Spectra were obtained as a series of exposures during the same night were co-added. The development of the Hα profile is shown in Fig 1. All spectra were normalized to 1 using the continuum near 6330 Å. All spectra were analysed using principal component analysis (PCA) combined with our own version of robust regression (Mikulášek et al. 2003), where all 8 observed Hα line profiles are expressed as a linear combination of basic mutually orthonormal functions, i.e., principal components. After a careful analysis we concluded we could confine ourselves to the first three terms of the PCA decomposition, since the amplitude of higher order terms being negligible with respect to the errors. Telluric lines were removed prior to the analysis.

The Hα line is described by the radial velocities of the minimum and maximum of the broad P Cygni profile and by the ratio of the maximum and minimum line intensity of the profile (see Tab. 1, Fig. 2). The radial velocities are calculated relative to the frame coupled with supernova. Measured values of radial velocities were corrected for the radial velocity of the host galaxy NGC 2403, which is 129 km/s (Ho et al. 1997). The positions of the line minimum and maximum were found to decrease from 6960±20 to 4890±40 km/s and 1273±4 to 772±5 km/s, respectively. The initial change in radial velocities is steep, however it flattens out with time (see Fig. 2a). We found only a small change in the ratio of the maximum and minimum line intensities. Initially, the ratio was 5.29±0.10, then it reached 6.3±0.2 at JD 24453234.6±0.5 before it dropped down to 4.9±0.2 (Fig. 2b). The blue edge of the absorption part of the line profile remained more or less constant: 10 300 km/s.

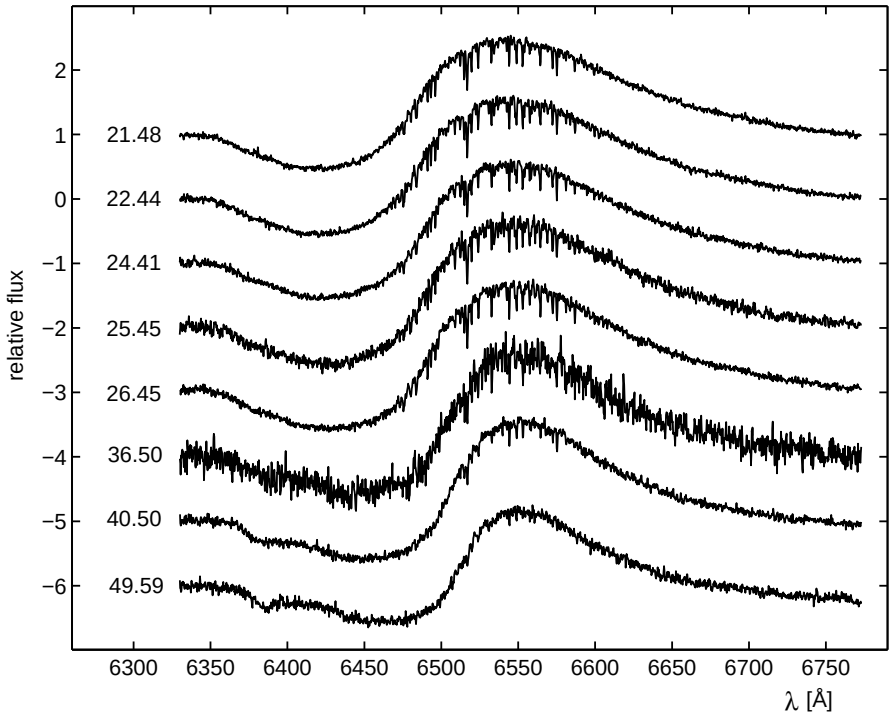

Figure 1. Spectra of SN 2004dj obtained at the Coudé spectrograph of the Ondřejov 2m telescope. The y axis denotes the relative flux, individual spectra are shifted and labeled with the Julian date at the middle of the exposure of co-added spectra ($JD-2453200$).

Table 1: The Hα line characteristics of SN 2004dj. The JD given is the mid-exposure time of co-added spectra, N is the number of co-added spectra, $RV_{\rm max}$ and $RV_{\rm min}$ are the radial velocities of the maximum and minimum of the Hα profile corrected for the radial velocity of the host galaxy ($RV_{\rm g} = 129$ km/s, Ho et al., 1997), respectively, $I_{\rm max}/I_{\rm min}$ is the ratio of the maximum and minimum intensities, $RV_{\rm abs}$ is the corrected radial velocity of the blue absorption feature and $I_{\rm cabs}$ is its central depth.

JD-2450000	N	$RV_{\rm max}$ [km/s]	$RV_{\rm min}$ [km/s]	$I_{\rm max}/I_{\rm min}$	$RV_{\rm abs}$ [km/s]	$I_{\rm cabs}$
3 221.48	2	6955±25	1275±5	5.3±0.2	9090±70	0.030±0.011
3 222.44	2	6840±30	1206±5	5.5±0.2	9040±90	0.023±0.011
3 224.41	2	6530±60	1091±6	5.3±0.2	8750±60	0.040±0.013
3 225.49	2	6340±110	1028±9	5.9±0.3	8730±130	0.035±0.024
3 226.45	1	6210±50	970±6	6.0±0.2	8720±230	0.012±0.014
3 236.50	2	5590±120	707±9	5.8±0.6	8300±150	0.07±0.05
3 240.50	2	5250±50	687±5	6.1±0.2	8310±50	0.070±0.017
3 249.59	2	4890±40	672±5	4.9±0.2	8290±30	0.130±0.020

We want to draw attention to the absorption feature in the blue part of the absorption wing of the Hα P Cygni profile (see Fig. 1). The center of the absorption feature was to move towards the red, similarly to the maximum of the main Hα line profile (see Fig. 1). The depth at the center of the feature increases from 0.021 ± 0.006 to 0.112 ± 0.015 with respect to undisturbed Hα profile. A similar feature was observed in SN 1999em (see Fig. 13 in Leonard et al. 2001). However, it remains uncertain whether the absorption feature belongs to the Hα line profile or whether it can be attributed to absorption of some other chemical element.

Ondřejov photometric observations have been carried out with the 0.65-m f/3.6 telescope equipped with an AP7 CCD camera (SITe 512×512 pixels) at the primary focus, in

BVR Johnson-Cousins standard photometric bands (Bessell 1990). Stars GSC 4120:685 and GSC 4120:725 served as the comparison and check stars, respectively (see Figure 3).

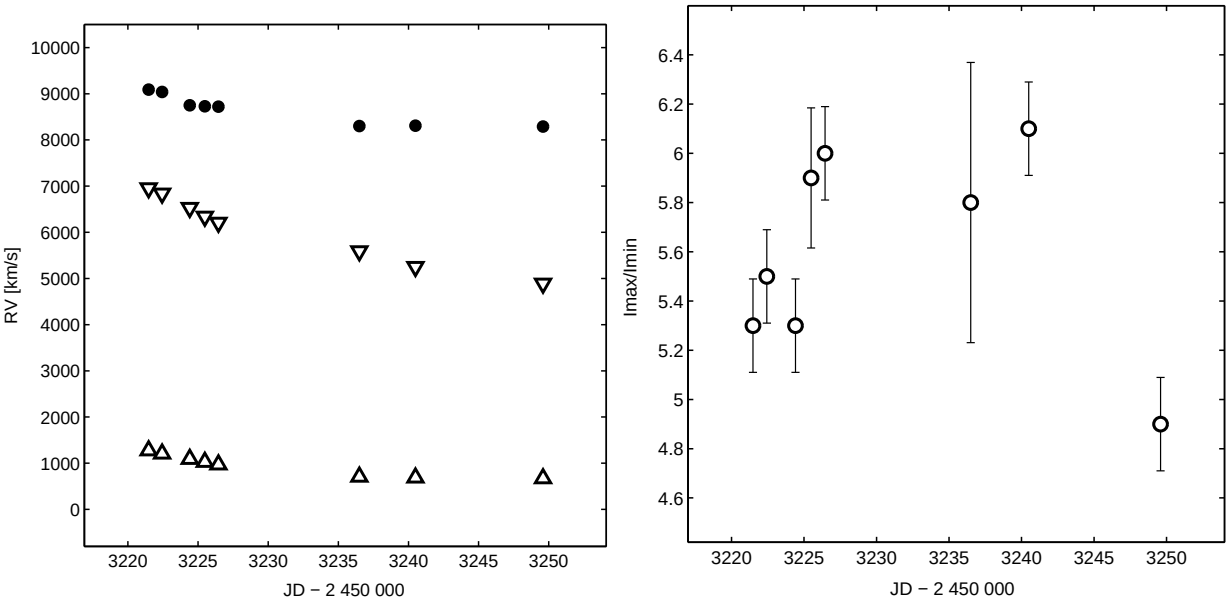

Figure 2. (a) Time dependence of radial velocities of Hα's profile maximum (Δ) and minimum (∇). Dots ($\bullet$) denote the radial velocity of the absorption feature center found in the blue part of the wing. (b) Time dependence of the ratio of maximum and minimum intensity of the Hα's profile.

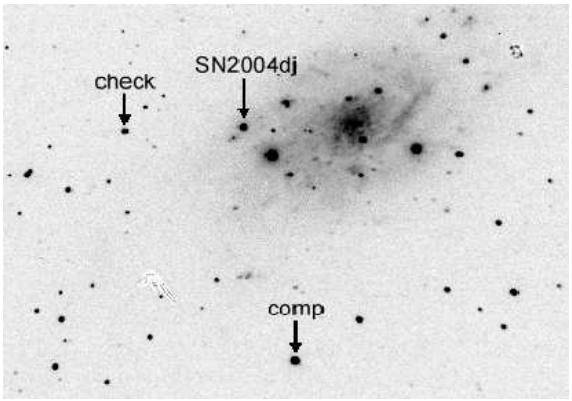

Figure 3. An image taken at Ondřejov showing the position of SN 2004dj, the check star (GSC 4120:725, 13.085 R) and the comparison star (GSC 4120:685, 11.48 R).

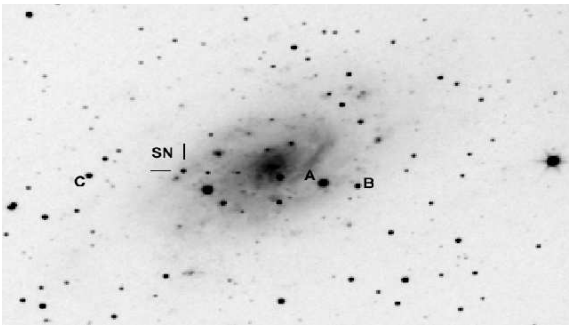

Figure 4. An image taken at Lelekovice showing the position of SN 2004dj and the comparison stars, GSC 4120:764 (A, 10.205 R), GSC 4120:718 (B, 13.165 R) and GSC 4120:725 (C, 13.085 R).

In Lelekovice, we obtained photometry in the R Johnson-Cousins standard photometric band using the 0.35-m f/4.7 telescope equipped with the SBIG ST-6V CCD. We co-added 6-10 individual images with exposure times of 60 seconds to improve the signal-to-noise ratio. We used the comparison star GSC 4120:764 and the two check stars, GSC 4120:718 and GSC 4120:725 (see Fig. 4) to obtain the Lelekovice R light curve.

The comparison stars from both Ondřejov and Lelekovice posts were calibrated using the calibration fields near M31 and M13, which have already been well calibrated using the

standard fields measured by Landolt (1992). The comparison stars and calibration fields near M31 and M13 were observed during two nights under average conditions with an estimated accuracy of 0.05 mag in R. All data except of the last one: JD=2453297.406, R=13.91 mag, have been reported in Hornoch (2004a,b). The results of photometric observations are shown in the Fig. 5 and Table 2 (only in electronic version).

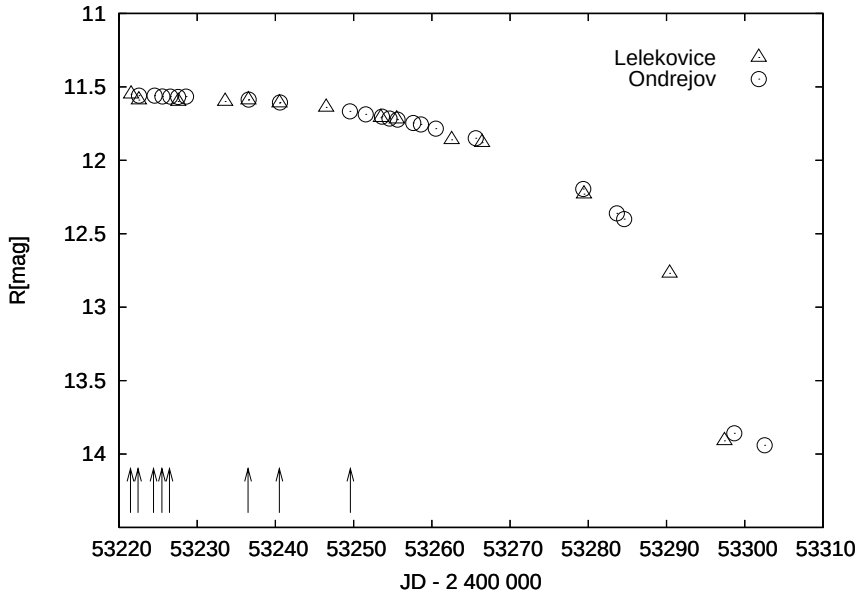

Figure 5. The R light curve from both Lelekovice (triangles) and Ondřejov (circles) observatories. Arrows indicate nights when the spectra in Fig. 1. were obtained. All of them were taken during the phase of the very slow decrease after the brightness maximum.

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