COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 5584

Konkoly Observatory
Budapest
21 December 2004

HU ISSN 0374 – 0676

DISCOVERY OF SPECTRAL VARIABILITY OF POST-AGB STAR SAO 40039

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We present the first results obtained in the course of spectroscopic monitoring of the poorly-studied post-AGB star SAO 40039. A high-luminosity star SAO 40039 ($B = 10^{m}.1$ (Fujii et al., 2002)) is located close to the galactic plane in the direction close to the anticenter of Galaxy ($l = 159^{\circ}.8$, $b = 4^{\circ}.8$). Based on BVRIJHK photometry, Fujii et al. (2002) classified the star as A4 Ia. It is identified with the IR-source IRAS 05040 + 4820. Its double-peaked spectral energy distribution and its position in the IRAS color-color diagram confirm the post-AGB status. There is no H_2O, SiO or CO maser associated with the source IRAS 05040 + 4820 (Wouterloot & Brand, 1989; Wouterloot et al. 1993). According to the Lewis (1989) chronological sequence, this means that SAO 40039 is close to the PN stage. This conclusion is also confirmed by the sufficiently high temperature of the central star and a low temperature of the dusty envelope (Fujii et al., 2002).

Our spectral observations of SAO 40039 were made at the 6-m telescope of the Special Astrophysical Observatory with the echelle-spectrograph NES (Nasmyth focus, 2K×2K CCD-chip, $R \geq 60000$ (Panchuk et al. 2002, `http://www.sao.ru/hq/ssl/NES.html`). The journal of observations is presented in Table 1. The data reduction process (cosmic ray trace removal, background subtraction, and spectral order extraction) were done under the standard ECHELLE context of the MIDAS package. The cosmic ray traces were removed by median averaging of two subsequent spectra. A hollow cathode Th-Ar lamp was used for wavelength calibration. The radial velocities were measured by matching the original and mirrored profiles of individual lines. A typical error in the V_r measurements for a single line is about $1\,\mathrm{km\,s^{-1}}$.

Table 1: Observing log for SAO 40039

Date	Exposure time, s	Spectral range Å	Resolving power, R	$\overline{S/N}$
02/12/2002	2×3600	4520–6000	60000	75
09/09/2003	2×3600	4520–6000	60000	100
10/01/2004	2×3600	5280–6760	75000	85
08/03/2004	2×3600	5280–6760	75000	115

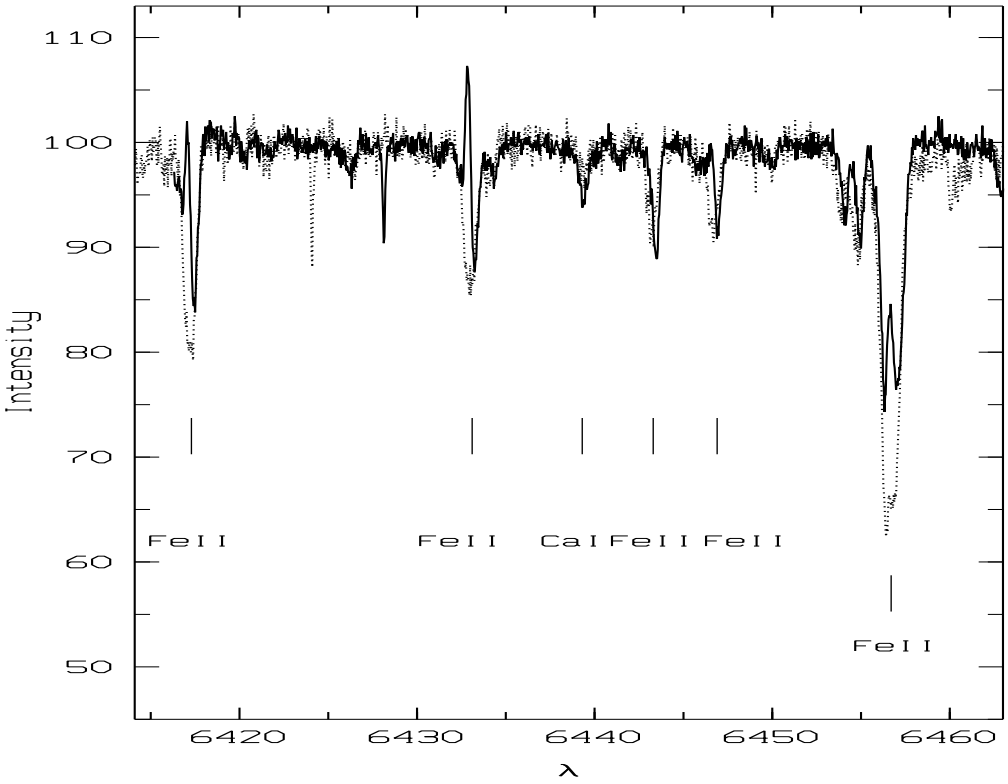

Figure 1. A fragment of two spectra of SAO 40039: 08/03/2004 – solid line, 10/01/2004 – dotted.

The main peculiarity of the SAO 40039 spectrum is the presence of complex emission-absorption profiles of Hα and some metallic lines. In addition, comparing spectra obtained at different epochs, we reveal strong variability both in numerous metallic lines (Fig. 1, Fig. 2) and in Hα (Fig. 3).

Table 2: Heliocentric V_r (km s^{-1}) in the spectra of SAO 40039

Ion (Mult.)	02/12/2002	09/09/2003	10/01/2004	08/03/2004
Cores of absorption lines:				
Fe II, Cr II, etc. (r $\rightarrow$ 1)	-14.8	-6.8	-15.3	-8.2
Hα	—	—	-27	-28
Hβ	-14.8	-10.6	—	—
Wings of weak absorptions				
at r = 0.90 $\div$ 0.95	-14	-9.5	-15.5	-13.0
Maximum extension of blue wings:				
Fe II(42)	-70	-61	-65 :	-70
Hα	—	—	-65 :	-57 :
Emission lines:				
Fe II(40, 46)	—	—	—	-18
Hα	—	—	-15	-13 :
I.S. NaI (1)	-25, -3	-26, -2	-27, -2.5	-28, -2
DIB	—	—	-3 :	-2.5 :

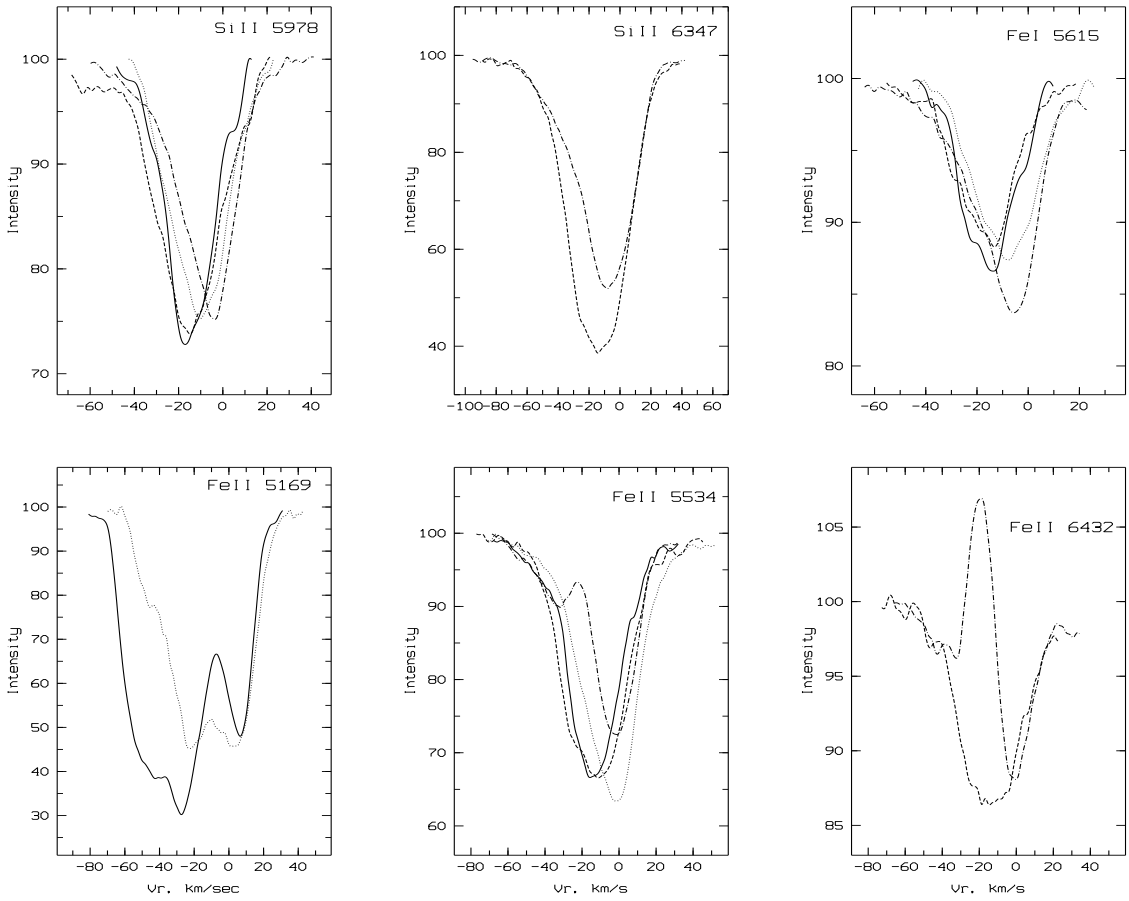

Figure 2. Temporal variability of selected lines in the SAO 40039 spectra. 02/12/2002 – solid line, 09/09/2003 – dotted, 10/01/2004 – dashed short, 08/03/2004 – dash-dot.

The heliocentric V_r values derived from absorption and emission lines and/or their components at different epochs are shown in Table 2. Our present time coverage does not allow us to comment on possible reasons for the variability found. Significantly variable V_r were revealed in most of the absorption lines (except for V_r values determined on the wings of the weak absorptions at depth $r = 0.90 \div 0.95$). As seen in Fig. 2, variability in the central part of the line profiles ($V_r \approx -20\,\mathrm{km\,s^{-1}}$) could be caused by variable emission. These variations are especially remarkable in the Fe II (40) lines. In the blue wings of the strongest Fe II (42) lines, however, variability is caused by variable absorption along the line of sight. As a first approximation, the value $V_r \approx -13\,\mathrm{km\,s^{-1}}$ that follows from the wings of weak ($0.75 < r < 0.92$) absorption lines could be adopted as a systemic velocity V_{sys} ($V_{lsr} \approx -20\,\mathrm{km\,s^{-1}}$).

Using high resolution spectra, we classified SAO 40039 as a A4 Ib star ($Mv \approx -5^m$), which is consistent with the result published by Fujii et al. (2002). The determination of the stellar luminosity leads us to the distance value of $d \approx 4\,\mathrm{kpc}$. This distance fits very well with the systemic velocity of $V_{lsr} \approx -20\,\mathrm{km\,s^{-1}}$. Besides, as follows from Table 2, a velocity component of $V_r \approx -25 \div -28\,\mathrm{km\,s^{-1}}$ is present in the interstellar NaD lines (Fig. 3). According to Münch (1957), distant stars HD 232299, BD + 43°1168 and HD 232947 which exist at galactic latitudes close to SAO 40039, have similar double-peaked NaD line profiles with components at $V_r \approx -(20 \div 38)$ and $-(1 \div 3)\,\mathrm{km\,s^{-1}}$ having

intensities approaching those in the SAO 40039 spectra.

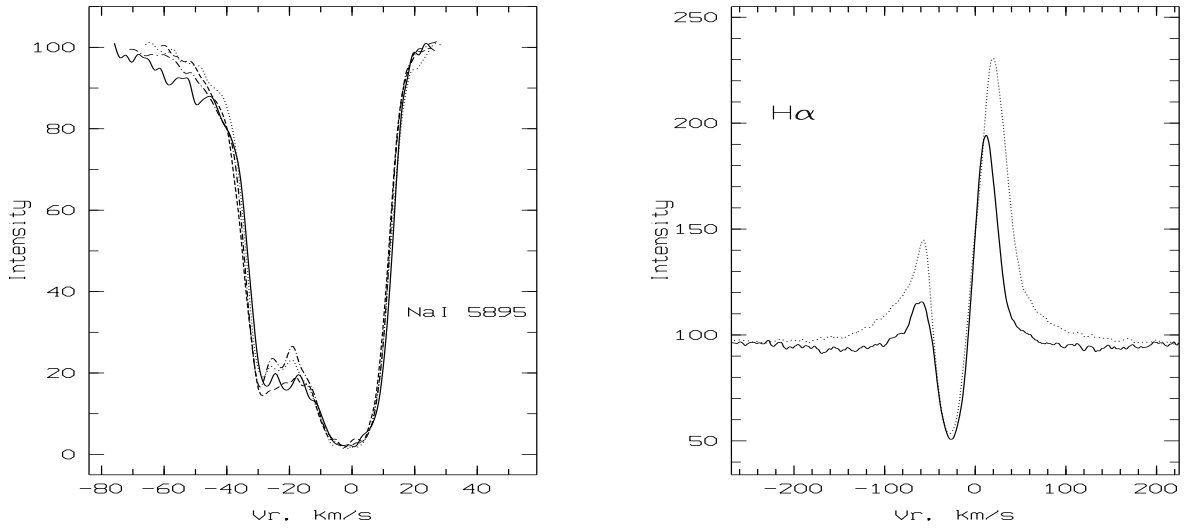

Figure 3. The same as in Fig. 2 but for Na I 5895 Å and Hα.

Since the spectrum of SAO 40039 contains many absorption lines without visible emission components, it is possible to estimate metalicity and abundances of selected chemical elements in its atmosphere. However, we have to keep in mind that both the model parameters and chemical composition, determined for such a luminous star with the unstable and extended gaseous-dusty envelope in the framework of a static plane-parallel atmospheric model under the LTE approach, can be considered as a first approximation only. The comparison of spectra of SAO 40039 with a grid of theoretical spectra that were calculated by us permits us to obtain the following model parameters for the star: $T_{\rm eff} \approx 8000$ K, $\log g \approx 1.0$, $\xi_{\rm t} \approx 6$ km s^{-1}, $[{\rm Fe/H}]_\odot = -0.3$ and C, O overabundances. In summary, stellar parameters and chemical abundances pattern of SAO 40039 resemble to a PPN candidate HD 187885 = IRAS19500−1709 (Van Winckel et al., 1996).

Acknowledgements: We acknowledge financial support from the Russian Foundation for Basic Research (project No. 02–02–16085), from the Department of Physics Sciences of RAS and from the Russia President's Foundation for young scientists (No. MK-874.2004.2).

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