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The variability of hot protoplanetary objects and the stellar wind from central stars of planetary nebulae

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Abstract. The results of longtime systematic UBV-observations of 6 hot protoplanetary nebulae (PPN) with early B spectra are given. Fast stochastic brightness variations in the range of $0.^m2$-$0.^m4$ (in V-band) have been found. The minimal time scale of the oscillations is from several hours to one day. The repeated spectral observations of hot protoplanetary nebulae have shown obvious variability in the hydrogen emission lines. It is suggested that the stellar wind from the future planetary nebula nucleus with variable $\dot{M}$ is responsible for variations observed in hot PPNs.

Keywords. protoplanetary nebulae, photometry, variability

In 1990 we began a program of variability search for possible protoplanetary objects (PPNe) on the basis of systematic photoelectric UBV-observations, carried out with a 60-cm telescope at the Crimean Station of Sternberg Institute. Among the program objects, there were 6 hot PPNe with temperatures above 20000 K, namely: V886 Her, V1853 Cyg, LS IV -12°111, IRAS 19200+3457, IRAS 07171+1823 and OY Gem (HD 51585). We found fast irregular variations in the range of $0.^m2$- $0.^m4$ for all 6 sources (Arkhipova *et al.* (1999), Arkhipova *et al.* (2001), Arkhipova *et al.* (2002), Arkhipova *et al.* (2004)). The minimal time scale of the oscillations is from several hours to one day. The typical time scales are in the range of several days. The variability type is very similar in all cases. The color indices almost do not correlate with the star's brightness. Slower variations of the mean star brightness were found only for OY Gem and V886 Her. OY Gem may have a quasiperiod of about 2800 days (Arkhipova *et al.* (2006)), V886 Her systematically decreases its brightness at a rate of $0.^m015$ per year, probably due to its fast evolution along a horizontal track in the H-R diagram towards hotter stars (Arkhipova *et al.* (1999)).

The spectral observations of all 6 PPNe obtained by us from 1990 to 2005 show noticeable variability of the equivalent widths of hydrogen emission lines and, in some cases, also of He I lines. Most stars have He I lines with P Cyg profiles of variable intensity. Forbidden lines belong to atoms and ions of low excitation: [NII], [SII], [OII], [OI], and [FeII]. Very weak nebular lines of [OIII] are seen only in the spectrum of OY Gem.

We have derived the parameters of the central star and of the gaseous envelope for several studied stars and also have used data from other authors for other stars (Moehler & Heber (1998); Mooney, Rolleston, Keenon *et al.* (2002); Ryans, Dufton, Mooney *et al.* (2003)). The summary of the parameters of hot PPNe is shown in Table 1 where we present, in succession: the spectral class, the temperature and $\log g$ for the central star, the electron density of the nebular component, color excess, determined from the mean observed $B-V$ color index, and its circumstellar and interstellar parts, the amplitude

Table 1. The parameters of 6 hot PPNe

	LSIV-12°111	V1853 Cyg	IRAS 19200	V886 Her	IRAS 07171	HD 51585
Sp	B0Ie	B1.5Iabe	Be	B1IIe	Be	B[e]
T_{eff}, K	20500-24000	19000	20000	20750-23000	25000	28000
lg g	2.35-2.7	2.5-3.0		2.35-2.6		
n_e	$5 \cdot 10^3$	10^4		$2 \cdot 10^4$	$3.1 \cdot 10^3$	10^6
T_e, K	7800			10000	20000	20000
$E(B-V)$	0.35	0.38	0.30	0.30	0.20	0.60
I.S.	0.15	0.25	0.14	0.14	0.10	0.30
C.S.	0.20	0.13	0.16	0.16	0.10	0.30
ΔV	0.4	0.3	0.3	0.3	0.2	0.1
$\Delta(U-B)$	0.15	0.2	0.2	0.2	0.15	0.1
$W(\mathrm{H}_\alpha)$, Å	45	11.5-16.2	20-26	25-50	120	750-1000
T_d, K	120	100	140	230	180	125

of variations in V band and that of $U-B$. The last lines of the table give the W_λ of the H_α emission and the dust temperature in the IRAS range. Two stars – OY Gem and IRAS 07171+1823 – were found to have also hot dust with a temperature above 1000 K.

Fluctuations in the mass outflow rate at the photospheric level must cause changes of the density and optical depth of the extended stellar atmosphere. A possible consequence can be variations of the star's brightness and of the line intensities, in particular, of the equivalent lines of the emissions formed in the upper atmosphere. This is confirmed by observations of the H_α equivalent width in the spectrum of OY Gem, namely, the brighter the star, the lower is $\mathrm{W}(\mathrm{H}_\alpha)$. Quite similar considerations in favor of the explanation of fast variability in the planetary nebula nucleus IC 418 by variations in stellar mass loss were suggested by Mendez, Forte & Lopez (1986). The authors of this paper attribute brightness modulations to fluctuations in the effective radius of the star with an extended atmosphere. The observed variations in the planetary nebula IC 4997, have been studied in detail by Kostyakova (1999), they also may be caused by the activity of the central star evoked by unstable stellar wind. We think that this mechanism of variability may be the most probable one at initial stages of the planetary nebula ionization (apparently all our 6 objects are in such a phase). An important factor producing relatively large photometric variations can be the existence of a sufficiently extended stellar atmosphere. Our PPNe quite satisfy this condition. It may also be that the amplitude of photometric variations depends on the mass (luminosity) of PPNe as well, but the observational data are scanty to verify this suggestion.

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