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LS II +22°8 – A NEWLY RECOGNIZED CLASSICAL Be STAR

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LS II +22°8 was discovered by Stock et al. (1960) as a possible luminous early-type star with emission in the Hα line. Later it was listed in the Henize (1976) catalog of emission-line stars as Hen 1764. Pesch (1963) estimated its spectral type as B9 Ia or B2–5 V (with less likelihood) from his UBV photometry (see Table 1), which also implies the interstellar extinction $A_V \sim 2\overset{m}{.}0$ assuming no circumstellar contribution. Allen (1973) obtained near-IR photometry of the star ($H = 9\overset{m}{.}90, K = 9\overset{m}{.}60$). These data indicate a very weak near-IR excess radiation (see Fig. 1) taking into account the above A_V, a total-to-selective interstellar extinction ratio, R =3.1, and intrinsic color-indices for the above spectral types (Strajzhys 1977). This excess can be explained by free-free emission of the circumstellar gas or of a faint cool companion. Its weakness and shape ($E_{V-K} \sim 0\overset{m}{.}2$, dereddened $H - K = 0\overset{m}{.}15$) rules out the presence of hot dust around the star.

Dong & Hu (1991) identified LS II +22°8 with the IRAS PSC source 19381+2224. However, the IRAS fluxes detected at 12, 25, and 60 μm (10.43, 7.10, and 3.64 Jy respectively) imply a very strong flux rise between 2 and 12 μm, which is inconsistent with the assumption about a late-type companion (see Fig. 1). Such a rise might be due to the radiation of dust with the highest temperature of nearly 300–500 K. Moreover, a steep decrease of these IRAS fluxes with wavelength is consistent with either a small extent of the dusty structure or with a different illuminating source for the dust. The first suggestion along with the absence of the hot dust leads to a conclusion that the dust is concentrated in a rather thin remote shell, while the second one points that either the optical object is a binary system or it is not associated with the IRAS source.

Thé et al. (1994) pointed out that there is a 54″ offset between the optical position of LS II +22°8 and that of the IRAS source. This is well outside the IRAS positional error ellipse, which has major axes of 22″ and 5″ and a position angle of 70°. A faint star, that is located very close to the position of IRAS 19381+2224, is seen in the Space Telecope Institute Digital Sky Survey image of a field around LS II +22°8. It seems to be a more appropriate optical counterpart of this IRAS source. The mid-IR spectrum of IRAS 19381+2224 taken by the IRAS Low-Resolution Spectrometer (LRS) shows a weak emission feature at 11.3 μm (Olnon et al. 1986), which is probably due to the SiC dust particles usually observed in the spectra of carbon stars. Therefore, LS II +22°8 and IRAS 19381+2224 are most likely different sources.

The simultaneous $UBVRI$ observations of LS II +22°8 in the Johnson photometric system were obtained with two 1-meter telescopes at the Assy and Tien-Shan Observatories of the Fesenkov Astrophysical Institute in Kazakhstan equipped with a two-channel photometer-polarimeter (Bergner et al. 1988) between June 1993 and August 1998 through the 26″ diaphragm (Table 1). Its brightness varies with an amplitude of $\sim 0\overset{m}{.}3$ in the VRI-bands, while it reaches $0\overset{m}{.}6$ in the U-band. Such a behaviour might be due to free-bound emission of the circumstellar gas which gives the strongest contribution shortward of the Balmer jump and manifests itself by the peculiar spectrum (see below). The averaged color-indices $U-B$ and $B-V$ are consistent with those of a reddened B8±1 giant or dwarf ($A_V = 2.3 \pm 0\overset{m}{.}2$, R =3.1), which displays an excess radiation longward of 0.5 μm. The latter increases from about $0\overset{m}{.}1$ in the R-band to $0\overset{m}{.}4$ in the K-band (according the data by Allen 1973). It can be explained by free-free emission of the envelope as in classical Be stars (e.g. Dougherty et al. 1991).

Table 1. Photometric observations of LS II +22°8.

JD 2400000+	V	$U-B$	$B-V$	$V-R$	$R-I$
[a]	11.78	0.37	0.54		
49165.39	12.04	0.38	0.68	0.69	0.41
49232.33	12.05	0.27	0.70	0.66	0.45
49612.14	11.97	0.20	0.72	0.58	0.32
49942.28	11.95	0.21	0.57	0.69	0.36
49944.26	11.81	0.43	0.63	0.58	0.34
49960.20	12.02	0.17	0.59	0.69	0.36
51043.28	11.74	0.09	0.54	0.61	0.45
51052.25	11.73	0.11	0.57	0.58	0.40

[a] data from Pesch (1963)

The spectroscopic observations were obtained at the 6-meter telescope of the Russian Academy of Sciences with a photoelectric TV-scanner (Balega et al. 1979) on 1993 July 10 in the spectral regions 3933–4960 and 5852–6900 Å with a resolution of 2 Å. The most prominent features in the spectrum are a double-peaked Hα emission (Fig. 2) and Fe II absorption lines. The Hβ line is mostly filled in with emission, while Hγ and Hδ show only weak signs of it. Other emission lines, which are seen in the spectrum, can be identified with Fe I transitions, usually blends of several lines. The Na I $D_{1,2}$ and Si II 6347 and 6371 Å absorption lines certainly contain circumstellar contribution as their equivalent width ratios are different from those of pure interstellar and photospheric, 1.33 and 1.22, respectively. The observed diffuse interstellar bands at 6278 and 6283 Å are rather strong and are consistent with the reddening derived above from the photometric data.

The strong influence of the circumstellar material makes it difficult to estimate the MK type of the star from our spectral data. The observed Hδ line wings are consistent with the theoretical ones for the temperatures not higher than 12000 K, that corresponds to a B8 spectral type. Since the Hα emission line is not very strong and hardly affects the Balmer jump (Doazan 1982), we can assume that our photometric estimate of the object's MK type is correct.

The Hα line profile and strong Fe II absorption lines are similar to those of classical Be-shell stars, where they are formed in a dense circumstellar disk viewed at a high inclination angle (close to edge-on, Hanuschik 1994). The observed ratio of the Hα peak intensities $V/R > 1$ is also seen in many classical Be stars and is thought to be due to rotating one-armed density waves in the disk (e.g. Okazaki 1991). The optical brightening accompanied with the blueing observed in August 1998 (two last lines in Table 1) may be due to the shell strengthening, which is usual for classical Be stars (e.g. Doazan 1982).

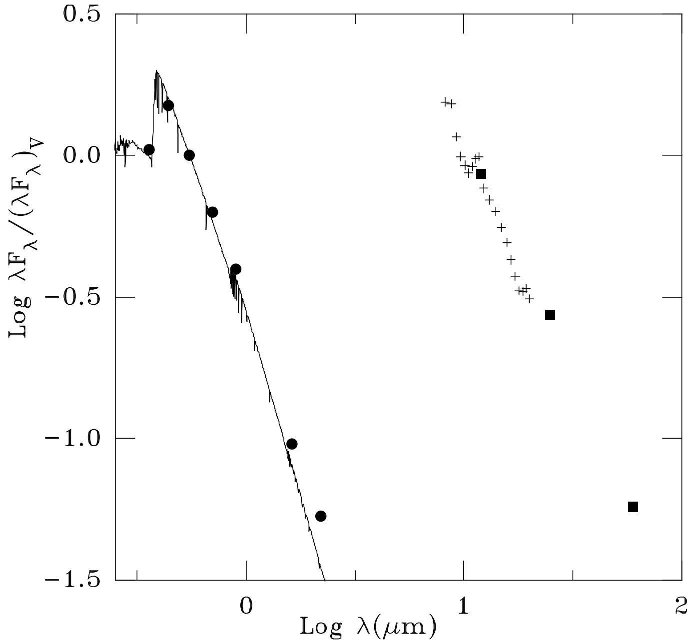

Figure 1. The dereddened SEDs of LS II +22°8 constructed from the averaged *UBVRIHK* photometric data (filled circles) along with that of IRAS 19381+2224 (filled squares – IRAS photometry, crosses – IRAS LRS spectrum). A Kurucz (1994) model atmosphere for T_{eff} = 12000 K and log g = 3.5 is shown by a solid line.

The separation between the Hα emission peaks, 290±60 km s^{-1}, implies a rotational velocity of the envelope of at least 100 km s^{-1} if one assumes that rotation is the main mechanism of the line formation. Subtraction of the photospheric profile from the observed Hβ line profile reveals a double-peaked emission similar to that in the Hα line.

If we suggest a typical luminosity of a late B-type classical Be star for the object, log $L_{bol}/L_{\odot} \sim 2.5$ (e.g. Zorec & Briot 1991), a distance of ~ 2 kpc can be derived. An assumption that the object is a supergiant is not consistent with the derived spectral type and intrinsic color-indices of the star. Furthermore, the presence of a disk-like gaseous envelope is a feature of B[e] supergiants (Zickgraf et al. 1986), which also exhibit a strong near-IR excess not seen in LS II +22°8. Balmer line profiles similar to those of the object also display pre-main-sequence Herbig Ae/Be stars (Finkenzeller & Mundt 1984). However, such a strong emission-line spectrum in these stars is usually acompanied by a noticeable near-IR excess that rules out the pre-main-sequence nature of LS II +22°8. The collected observational data do not allow us to consider other possible options (e.g., binary system with different types of the secondary component).

Thus, both photometric and spectroscopic properties of LS II +22°8 suggest that it is most likely a classical Be-shell star. Its emission in the Hα line is one of the strongest among those of Be stars with nearly similar spectral types. It is similar to that of Pleione during its shell phase (Doazan 1982). New photometric and spectroscopic variations of

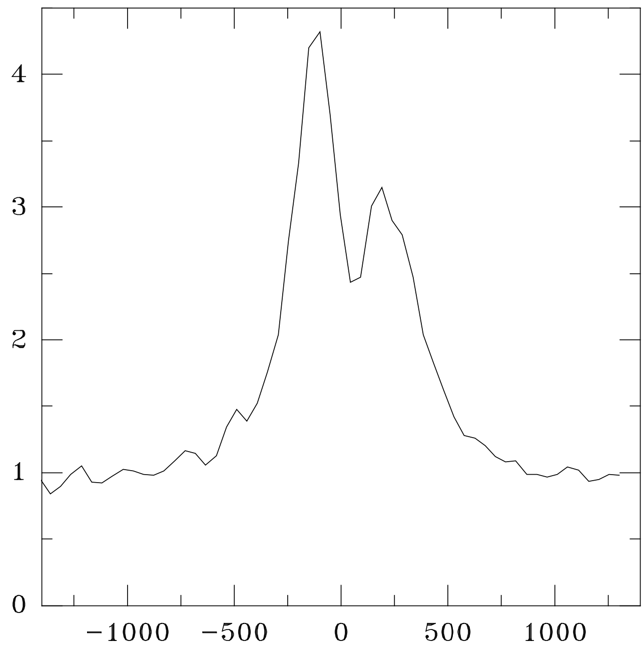

Figure 2. The Hα line profile in the spectrum of LS II +22°8. The heliocentric velocity is given in km s^{-1}, the intensity is normalized to the continuum.

LS II +22°8 are, therefore, expected in the future. The IRAS source 19381+2224 is most likely associated with a cool nearby star.

References:

Allen, D.A., 1973, *MNRAS*, **161**, 145
Balega, I.I., Vereschagina, R.G., Markelov, S.V., et al., 1979, *Izvestia Spec. Astroph. Obs.*, **11**, 248
Bergner, Yu.K., Bondarenko, S.L., Miroshnichenko, A.S., et al., 1988, *Izvestia Glavn. Astron. Obs. v Pulkove*, **205**, 142
Dong, Y.S., Hu, J.Y., 1991, *Chin. A&A*, **15**, 275
Doazan, V., 1982, in *The B Stars with and without Emission Lines*, A.B. Underhill, V. Doazan (eds.), NASA SP-456
Dougherty, S.M., Taylor, A.R., Clark, T.A., 1991, *AJ*, **102**, 1753
Finkenzeller, U., Mundt, R., 1984, *A&AS*, **55**, 109
Hanuschik, R.W., 1994, *Proc. IAU Symp. 162*, (eds.) L.A. Balona, H.F. Henrichs, and J.M. Le Contel, Kluwer Acad. Publ., p. 358
Henize, K.G., 1976, *ApJS*, **30**, 491
Kurucz, R.L., 1994, *Smithsonian Astrophys. Obs.*, CD-ROM No. 19
Okazaki, A.T., 1991, *PASJ*, **43**, 75
Olnon, F.M., Raymond, E., and IRAS Science Team, 1986, *A&AS*, **65**, 607
Pesch, P., 1963, *ApJ*, **137**, 547
Stock, J. et al., 1960, Luminous Stars in the Northern Milky Way, Part II
Strajzhys, V., 1977, in *Multicolor Photometry of Stars*, Vilnius, Mokslas
Thé, P.S., de Winter, D., Pérez, M.R., 1994, *A&AS*, **104**, 315
Zickgraf, F.-J., Wolf, B., Stahl, O., et al., 1986, *A&A*, **163**, 119
Zorec, J., Briot, D., 1991, *A&A*, **245**, 150