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

Number 4661

Konkoly Observatory
Budapest
19 January 1999

HU ISSN 0374 – 0676

THE SPECTRUM OF FG SAGITTAE IN 1998

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The interest in the variable star FG Sge has considerably increased after 1992 when it underwent dramatic photometric variations not seen before. These variations have continued up to the present time. Wallerstein (1990) and Jurcsik (1993) were the first who noted similarities between low–amplitude variations and sharp brightness declines of FG Sge and those of R CrB stars. At present, the universally accepted paradigm is that in the case of FG Sge we witness the result of a final helium shell flash after the star had departed from AGB (Iben 1984). After the discovery of another late helium flash star — Sakurai's object (Nakano, Benetti & Duerbeck 1996) the interest to both stars is higher still. For the latest reviews see Kipper (1996) and Gonzalez et al. (1998).

We have continued our routine monitoring of FG Sge and starting from 1996 also Sakurai's object trying to obtain some spectra every year in order to detect possible changes in their spectra. Two sets of spectra of FG Sge were obtained in 1998, on June, 19 and July, 11 with the prime focus echelle spectrometer of RAS 6–m telescope. The resolution of these spectra is 12,000. The spectral coverage is $\lambda\lambda 4200 \div 7700$ for the first set and $\lambda\lambda 4700 \div 8600$ for the second one. Both sets are usable redwards from $\lambda 4800$. The reduction of the spectra was performed using the image reduction system IRAF†. At the time of our observations a deep brightness drop was in an advanced stage and the star was as faint as it was during the previous deep minimum 2 years ago when Gonzalez et al. (1998) observed rich emission–line spectrum. The light–curve for dates near to our observations is depicted in Fig. 1. The data for this figure were taken from the AAVSO International Database (Mattei 1998). The moments of our observations are indicated by vertical lines.

The spectra of the first set which were observed about 60 days after the onset of brightness decline are very rich emission–line spectra with narrow lines. The rich photospheric absorption spectrum characteristic of light maxima is absent. Due to moderate resolution the lines are not fully resolved but are not wider than 29 $\mathrm{km\,s^{-1}}$. Such a spectrum is referred to as E1 by Alexander et al. (1972). In R CrB stars the E1 lines are usually blueshifted by some 10 $\mathrm{km\,s^{-1}}$ relative to stellar radial velocity. We, however, found, that these lines give the velocity $v_\mathrm{r} = 41 \pm 3$ $\mathrm{km\,s^{-1}}$ close to the velocity we found from absorption lines during relative light maxima $v_\mathrm{r} = 44.4$ $\mathrm{km\,s^{-1}}$ (Kipper & Kipper 1993). The lines correspond mostly to low excitation ($\epsilon_\mathrm{u} < 4$ eV) of singly ionized rare earths

†IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

and few lines of Fe I, K I, Na I, Mg I, Ca I and Ca II. Selected regions of the spectra are illustrated in Fig. 2 and Fig. 3.

The lines of Ti II, which are usually observed in the spectra of R CrB stars in minima, were not identified in FG Sge spectrum at this resolution. Of usually strong Sc II lines only few weak ones were found. In the second set of spectra, obtained 20 days later, the emission lines are much weaker or absent. The remaining lines were initially stronger with the tendency of lower excitation lines ($\epsilon_u < 3$ eV) being more persistent.

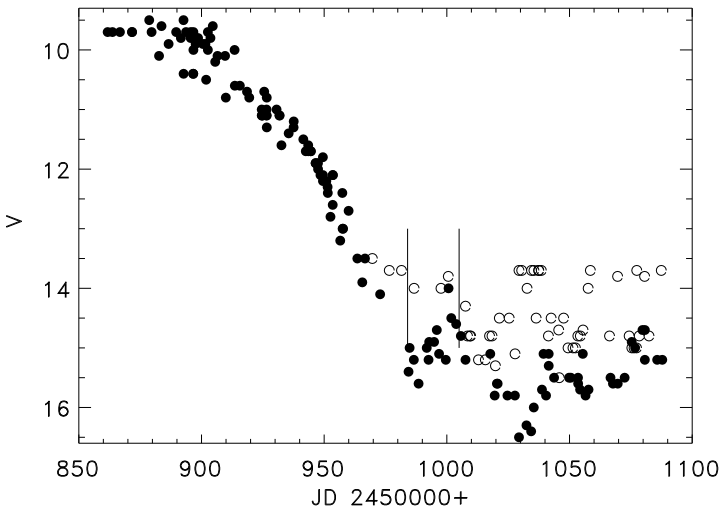

Figure 1. Light curve of FG Sge for summer 1998 (Mattei 1998). Open symbols indicate the upper limits. Vertical lines indicate the moments of spectral observations

Two of Ca II ($\epsilon_u = 3.15$ eV) IR triplet lines at λ8498 and λ8542, which are close to the red wavelength limit of our second set of spectra, remained quite strong with the line ratio 1:2.1 corresponding to optically thick case.

The Mg I b triplet lines at 5167.3, 5183.6 and 5183.6 Å, which usually belong to broad line category during R CrB stars minima, are narrow and weaken considerably between the two observation sets.

C_2 Swan bands of $\Delta v = 0, 1, 2$ sequences are strongly in emission in our first set of spectra. We could not, however, see the bands of CH and CN. In the case of FG Sge this phenomenon was first observed by Gonzalez et al. (1998) during the deep brightness decline in May, 1994 and then again in June, 1996. In the case of V854 Cen (R CrB star) Rao & Lambert (1993) found that C_2 bands in emission were not rotationally resolved and the bandheads were somewhat blueshifted. No such shift is observable in our spectra and some rotational structure of bands is visible. In the second set of spectra the C_2 bands are considerably weaker and the $\Delta v = 2$ sequence is no more visible.

The only broad lines in the spectra are the Na I D doublet lines and K I doublet lines at 7664.9 and 7699.0 Å. The Na I D lines are also the most prominent features in the entire visible spectrum.Their profile is depicted in Fig. 3. The interstellar absorption, which has been present in all FG Sge spectra observed so far, is indicated in the figure. Broad and sharp emission features are visible. Both broad and narrow emission components are nearly at the photospheric velocity. The half–width of the broad emission is

around 180 km s^{-1}. The K I doublet shows the same behaviour with broad and narrow components.

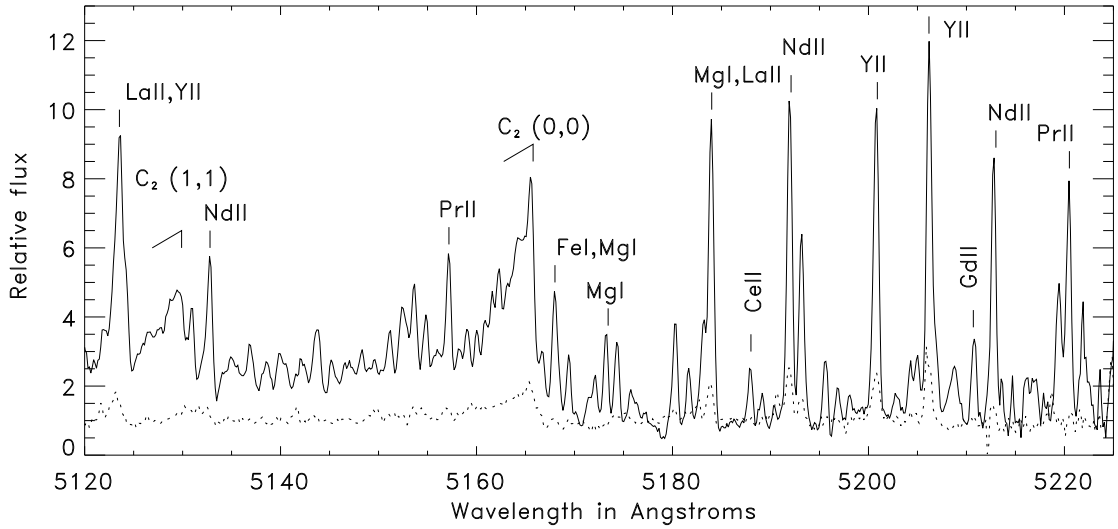

Figure 2. A part of the spectra of FG Sge on June, 19 (full line), and on July, 11, 1998 (dotted line). The relative flux is given in continuum units

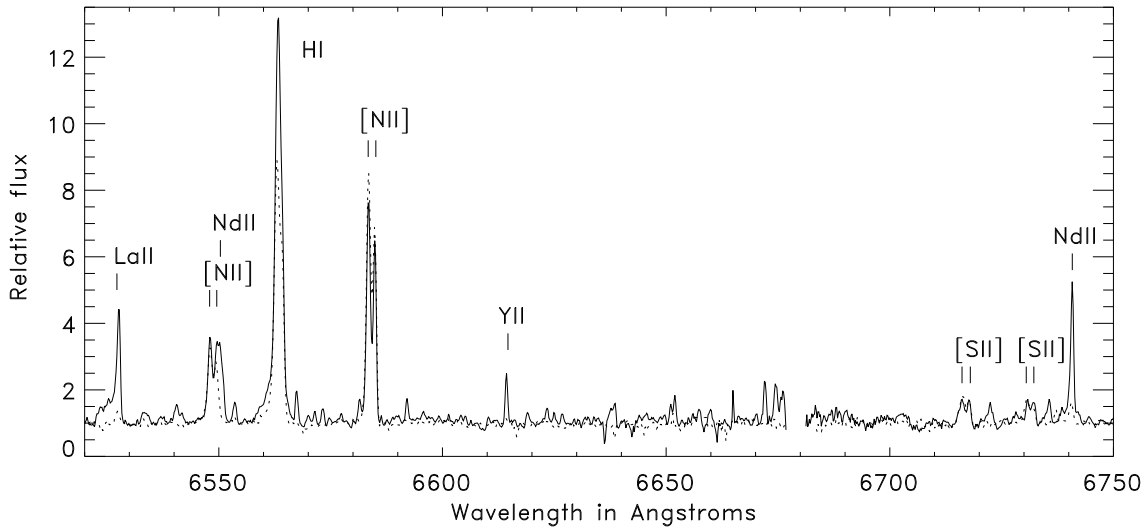

Figure 3. The same as in Fig. 2 for another wavelength interval

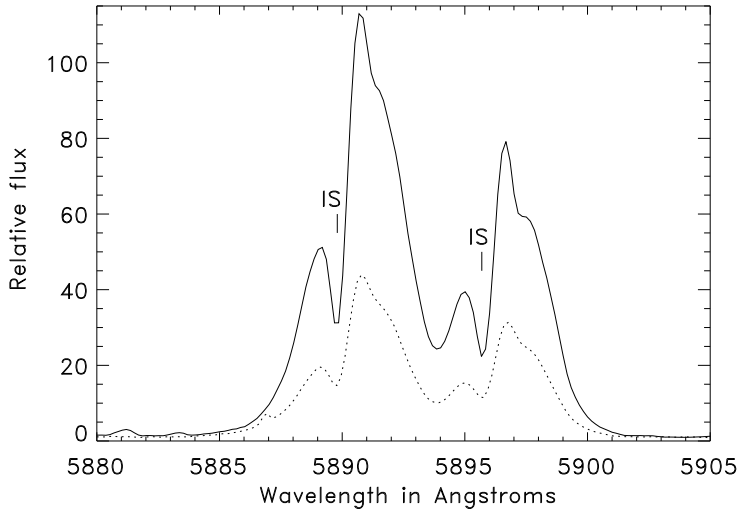

Figure 4. Na I doublet in the spectrum of FG Sge on June, 19 (full line), and on July, 11, 1998 (dotted line)

Some of the lines formed in FG Sge nebula (He 1–5) are also visible. Part of those lines (H_α, H_β, λ6548.05 [N II]) seem to be contaminated by stellar ("chromospheric") emission lines and their intensities are decreasing as the other stellar emission lines do. Several lines (λ5007.57 [O III], λ6583.45 [N II], λ6716.4 and λ6730.8 of [S II]) are quite free from stellar emission lines and their intensity does not change during our observations. All nebular lines and especially the lines with stellar contribution show two–peaked profiles with the red component weaker than the blue one. The radial velocity of the nebula inferred from these lines is 45 ± 4 km s^{-1}, in good accordance with the stellar velocity, and the expansion velocity of the nebula 33 ± 1 km s^{-1} is again close to the value of 35 ± 1 km s^{-1} found by Gonzalez et al. (1998).

Acknowledgements. In this note, we have used, and acknowledge with thanks, data from the AAVSO International Database. T.K. acknowledges support by Estonian Science Foundation grant 3166.

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