Heavy Element Abundances In FG Satittae

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ABSTRACT. The spectrogram of FG Sge obtained by the 6-m telescope in 1986 is analyzed. The iron peak elements are underabundant relative to the sun, and the heavy elements (Z>39) have abundances up to 3 dex (1,000 times) higher than in the Sun.

1. Introduction

The spectrum of the variable star FG Sge has been intensively observed in recent years as its spectral type has been rapidly changing, and since 1955 growing progressively later, while its atmosphere has become very strongly enriched with heavy elements. The authors have tried to follow the changes in FG Sge in every possible case (Kipper and Kipper 1977; Kipper 1978, 1981, 1984). In this note we report line identifications in the spectrum of FG Sge in the yellow-red spectral region and our estimates of elemental abundances in its atmosphere in 1986.

2. Observations

In 1986 (August 21) at the 6-m telescope a 14 Å/mm spectrogram of FG Sge was obtained with the main stellar spectrograph. The spectral region registered was λλ 5200-6700. As the star was quite faint ($m \sim 9.3$) for that spectrograph-telescope combination and due to rather bad weather conditions, the signal-to-noise ratio at the continuum level was not much higher than 10. But as the possible changes in the spectrum of FG Sge are of great interest, this spectrogram was nevertheless analyzed.

3. Analysis of the Spectrum

The spectrum was reduced using the semiautomatic spectrophotometric reduction system developed at the Tartu Astrophysical Observatory (Kipper 1986).

There are no great changes in the spectrum compared with that in 1980. At that time we estimated the spectral type of FG Sge as K0 Ib - K2 Ib. The recent infrared photometric observations (1.25 - 3.5 μm) by Taranova (1986, 1987) show that the much earlier spectral type G2 I and even F5 I should be assigned to FG Sge for the moment of maximum light. Differences in spectral types determined using the visual and infrared spectral regions are obviously caused by the extremely heavy blanketing at shorter wavelengths due to the unusual chemical composition. Taranova also estimated, at minimum light, the effective temperature,

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Tmin = 5500 K and the bolometric absolute magnitude Mbol = -5.12, if the distance of FG Sge was 4.1 kpc. Using these rather reliable data and the estimates by Fadeyev and Tutukov (1981), on the basis of the stellar evolution theory, of r = 4.2 kpc and Mbol = -5.73, we adopted for the following analysis the model atmosphere with Teff = 5500 K and log g = 1.0.

Table 1

Z	Element	Solar abundance	[ε] 1980	[ε] 1986	Number of lines	References for log gf
11	Na	-5.7		-0.6	4 Na I	3
12	Mg	-4.4		-1.1	1 Mg I	20
20	Ca	-5.7	-0.7	-0.7	5 Ca I	20
21	Sc	-8.9	0	-0.5	6 Sc II	8
22	Ti	-7.0	-1.5	-0.2	9 Ti I	3
23	V	-7.9	-1.5	0.4	8 V I	15
24	Cr	-6.3	-1.5	-0.6	2 Cr I	3
25	Mn	-6.6	-1.0	-0.5	2 Mn I	15
26	Fe	-4.4	-1.6	-2.1	8 Fe I	15
				-0.7	9 Fe II	15
27	Co	-7.0	-1.0	-0.4	5 Co I	5
28	Ni	-5.7	-1.0	-1.2	3 Ni I	3
38	Sr	-9.1		1.8	2 Sr I	3
39	Y	-9.9	2.2	2.0	3 Y I	9
				1.8	10 Y II	9,5
40	Zr	-9.2	2.1	1.2	4 Zr I	7
42	Mo	-9.8	2.1	2.0	6 Mo I	2
44	Ru	-10.1	2.0	3.4	4 Ru I	3
45	Rh	-10.5		3.1	2 Rh I	3
50	Sn	-10.0		3.3	1 Sn I	3
56	Ba	-9.9	2.4	0.5	2 Ba II	15
57	La	-10.9	2.2	2.7	30 La II	3
58	Ce	-10.4	2.1	1.8	26 Ce II	3
59	Pr	-11.2	2.2	1.4	12 Pr II	1
60	Nd	-10.8	2.1	1.7	59 Nd II	5
62	Sm	-11.3	2.4	2.3	12 Sm II	3
63	Eu	-11.3	2.6	1.6	4 Eu II	3
64	Gd	-10.9	2.7	1.4	16 Gd II	3
70	Yb	-11.8		3.1	6 Yb II	3
71	Lu	-11.2	3.0	1.6	4 Lu II	3
72	Hf	-11.1	2.0	2.7	1 Hf II	3
90	Th	-11.8		1.8	1 Th II	4
92	U	-11.4		2.1	1 U II	5

As the spectrogram obtained in 1986 has twice the dispersion of any of our previously analyzed spectra, we had to re-identify the lines. This was done by using the list of lines in the solar spectrum (Moore et al., 1966) and the tables by Meggers et al. (1975). A line was considered to be identified if it followed reasonably well the curve of growth for the given element. As most of the found lines have not been classified, and we do not know their transition probabilities, the number of reliably identified lines is small. Even a cursory examination of the results of identifications reveals that most of the lines belong to heavy elements, and there is a very small number of iron-peak-element lines. The largest number of identified lines belong to Nd II.

The abundances of elements were estimated from the curves of growth computed for the model (5500/1.0). Using the lines of Nd II, we estimated the microturbulent velocity to be ξ_t = 10 km/s. This value coincides with the result found for FG Sge in 1980 (Kipper 1981). The radial velocity of FG Sge estimated from the tracings was -41 ± 5 km/s.

4. Results

The results of the abundance determination are given in the table. The errors in the abundances obtained are quite large, reaching 1 dex as can be seen by comparing the results for the first and second spectra of Fe and Y. Such a low precision is due to the errors in equivalent widths derived from the low signal-to-noise spectrum and especially to the errors in identifications and the oscillator strengths used. If these errors are considered, it appears that the abundances in FG Sge have not changed since 1980. Thus one can see the underabundances of metals up to Ni and the large overabundances for the heavy elements beginning with Sr.

The Na I lines D1,2 have strong circumstellar components which are shifted bluewards by approximately 46 km/s. If one assumes that the ionization in the circumstellar shell corresponds to that at the top of the atmosphere and the radius of FG Sge is around 100 $R_\odot$, one can estimate the lower limit to the mass loss of $\dot{M} \sim 5.10^{-7}$ $M_\odot$/year. Fadeyev and Tutukov (1981) estimated from the modeling of the FG Sge pulsations an upper limit to the mass loss rate of 10^{-5} $M_\odot$/year.

References

1. Biemont, E., Grevesse, N., Hauge, O. 1979, Solar Phys. 61, 17.
2. Biemont, E., Grevesse, N., Hannaford, P., Lowe, R.M., Whaling, W. 1983, Astrophys. J. 275, 889.
3. Corliss, C.H., Bozman, W.R. 1982, NBS Monograph No. 53.
4. Corliss, C.H. 1979, Monthly Not. Roy. Astron. Soc. 189, 607.
5. Cowley, C.R., Corliss, C.H. 1983, Monthly Not. Roy. Astron. Soc. 203, 651.
6. Fadeyev, Yu.A., Tutukov, A.V. 1981, Monthly Not. Roy. Astron. Soc. 195, 811.
7. Gurtovenko, E.A., Kostik, R.I. 1980, Ukrainian Acad. Sci., preprint ITF-79-138P.
8. Gurtovenko, E.A., Kostik, R.I., Orlova, T.F. 1985, Kinematika Fiz. Nebesn Tel. 1, 75.
9. Hannaford, P., Lowe, R.M., Grevesse, N., Biemont, E., Whaling, W. 1982, Astrophys. J. 261, 736.
10. Kipper, T.A., Kipper, M.A. 1977, Sov. Astron. Lett. 3, 410.
11. Kipper, T.A. 1978, Sov. Astron. Lett. 4, 280.
12. Kipper, T.A. 1981, Sov. Astron. Lett. 7, 428.
13. Kipper, T.A. 1984, Sov. Astron. Lett. 10, 219.

14. Kipper, T.A. 1986, Estonian Acad. Sci., Preprint A-2.
15. Kostik, R.I. 1987, private communication.
16. Meggers, W.F., Corliss, C.H., Scribner, B.F. 1975, NBS Monograph No. 145.
17. Moore, Ch.E., Minnaert, M.G.J., Houtgast, J. 1966, NBS Monograph No. 61.
18. Taranova, O.G. 1986, Astrofizika **25**, 453.
19. Taranova, O.G. 1987, Sov. Astron. Lett. **13**, 891.
20. Wiese, W.L., Smith, M.W., Miles, B.M. 1969, Atomic Transition Probabilities NSRDS-NBS, 2.

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