FG SAGITTAE, A TEST OF THE THEORY OF EVOLUTION OF DOUBLE SHELL SOURCE STARS

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FG Sge is a unique stellar object possessing a number of unusual properties which are as follows: (1) FG Sge is a core of a planetary nebula, (2) at least since 1894 this star has crossed the HR diagram from the left to the right, (3) the atmosphere of FG Sge was enriched in s-elements, (4) FG Sge is a pulsating variable the period of which progressively increases from 15 days in 1962 to 110 days in 1980.

As it was primarily supposed by Paczyński (1971) FG Sge moves in the HR diagram along the horisontal loop due to a helium shell flash in its interior. This hypothesis provides not only the explanation of enriched surface abundances of s-elements but allows also to estimate both the distance and the age of the planetary nebula surrounding FG Sge. According to Flannery and Herbig (1973) the expansion velocity and the angular radius of the planetary nebula are 34 km/s and 18 arcsec, respectively. Thus, the age of the planetary nebula τ is related to the distance d by

$$\log \tau \text{ (yr)} = 0.400 + \log d \text{ (pc)} \qquad (1)$$

Supposing that the planetary nebula was formed at the preceding helium flash, the interflash period - core mass relation (Paczyński, 1975) and the core mass - luminosity relation (Paczyński, 1970) can be used for obtaining another relation between the age of the planetary nebula and its distance:

$$\log \tau = 5.201 - 4.79 \cdot 10^{-8} d^2. \qquad (2)$$

The relations (1) and (2) are shown in Fig. 1 by the curves (1) and (2), respectively. From equations (1) and (2) it follows that the distance is d = 4.83 kpc and the age is τ = 12100 yr. Thus, FG Sge's luminosity is L = 14 700 $L_\odot$.

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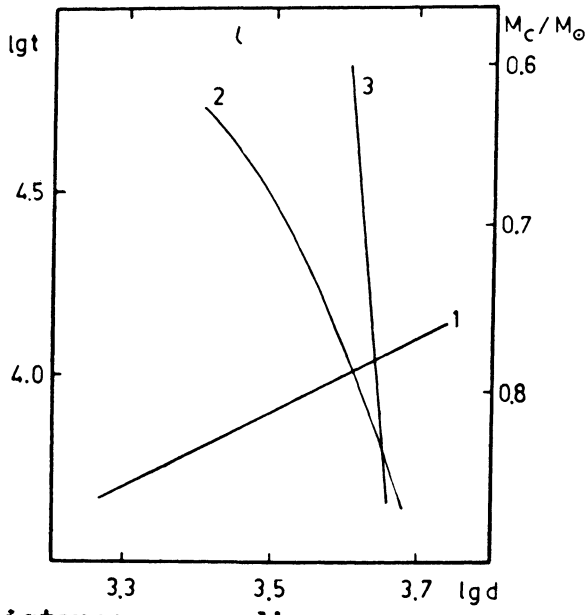

Fig 1 The distance - age diagram.

It should be noted that this estimate of the distance by 2 times exceeds the one observed.

Pulsation of FG Sge provides another way for estimating its distance by using the period - mean density relation. Expressing the stellar radius in terms of the effective temperature T_e and the distance and fixing time of observation we find that d depends on the total stellar mass M, only. The hydrodynamic computations for the models of pulsating yellow supergiants showed that the appropriate value of the pulsation constant is Q = 0.045 days (Fadeyev, 1982). Neglecting the envelope mass and using the interflash period - core mass relation we show this dependence in Fig. 1 by the curve (3) corresponding to t=1977 when P=90 days. The solution of this dependence and the relation (1) coincides with that of (1) and (2) within the interval 0.15 mag.

To decrease influence of uncertainties in observable parameters on the luminosity estimation averaging over the time interval is more preferable. Combining the period - mean density relation with the core mass - luminosity relation we get the period - luminosity relation for double shell source stars:

$$P=4.707\cdot 10^{13}Q(L/L_\odot)^{3/4}T_e^{-3}(L/L_\odot+30930)^{-1/2} \qquad (3)$$

where the approximation $M_c=M$ is used. The decrease of T_e

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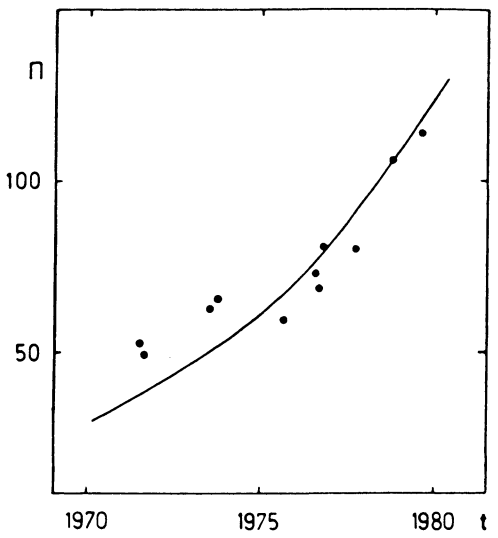

Fig. 2 Observational (filled circles) and theoretical (solid line) temporal dependence of FG Sge's period.

as a function of time is known from the scanning observations (Stone, 1979), so the relation (3) with Q=0.045 days gives the temporal dependence of FG Sge's period as P=P(t,L), where L is an unknown parameter. The observational estimates of FG Sge's period obtained in the interval from 1971 to 1979 are best fitted by the relation (3) for L=19 500 $L_{\odot}$(see Fig. 2).

Thus, the estimate of FG Sge's luminosity infered from the relations for double shell source stars is in a close agreement with that obtained from the period - mean density relation for pulsating stars. The difference between these estimates is about 0.3 mag and may be caused by uncertainties in the interstellar extinction and the bolometric correction as well as period variability of semiregular pulsation.

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