

## THE STRANGE BEHAVIOR OF FG SAGITTAE

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Abstract

FG Sagittae is a peculiar variable star surrounded by a planetary nebula. The star has undergone a steady increase in brightness over the past 80 years. Recently, the spectrum was discovered to be changing, as well. There is a suggestion that FG Sge could be in the process of releasing another nebulous shell.

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FG Sagittae originally appeared to be a simple irregular variable of small amplitude and short duration--not particularly exciting, relatively speaking. Later, the irregular variations were seen to be superimposed on a long, steady magnitude increase--more interesting. Then the 100-inch telescope at Mount Wilson revealed a nearly circular planetary nebula surrounding FG Sge--certainly something to think about, but not quite the complete picture. The final touch was that the spectrum of FG Sge was discovered to have become progressively later (cooler) since it was first observed--very interesting, indeed. All of this leads to the fundamental question: What has been happening with FG Sagittae?

The observational history of this peculiar star is relatively short. In 1944, C. Hoffmeister announced the discovery of an irregular variable in Sagitta by Sonneberg observers. They had found, after examining plates covering a relatively short period of time, that the star had irregular variations, up to  $0^m5$ , lasting as long as one hundred days. G. Richter (1959), one of the observers, reported that observations from 780 Sonneberg plates covering the period JD 2425502 - 2436724 (September 12, 1928 - June 4, 1959) showed a continuous brightening from  $12^m4$  to  $10^m3$  pg. A further study of the light curve of FG Sge revealed that the star had gradually but steadily brightened from  $13^m6$  pg in 1894 to  $9^m6$  B in 1965. Several of the observations prior to 1910 were from Harvard plates measured by J. Ashbrook and reported by Richter.

I made magnitude estimates of FG Sge on 250 Harvard patrol plates covering the years 1929 through 1975, with gaps from 1952 to 1962 and from 1962 to 1967. The plates are primarily blue sensitive, IIA-0 emulsion, with the exception of the Damon plates, which begin in 1967 and are in three colors: red, 103a-F; yellow, IIA-D; blue, IIA-0. For my measurements on the blue plates, I used the comparison stars for which Richter (1959) had published magnitudes, but it was necessary to use two comparison stars from the AAVSO FG Sge preliminary d-chart for the red and yellow magnitudes.

Figure 1 is the light curve of FG Sge in which the photographic magnitude is plotted versus Julian Date. The light curve shows a slow brightening from  $12^m5$  in 1930 to  $9^m7$  in 1968, with several irregular variations superimposed. This is in agreement with previously published light curves of FG Sge (Richter 1959, Herbig and Boyarchuk 1968). After 1968, the light curve shows a marked decline in photographic brightness. This supports the findings of Wenzel and Fürtig (1972), that the U and B brightnesses have been falling.

Figure 2 is a three-color plot of the magnitude of FG Sge during the period 1968-1975. AAVSO visual observations for this period are also plotted. While the blue brightness has decreased, there has been a slight increase in the red brightness, with fluctuations in all three colors from a few tenths to half of a magnitude. The AAVSO visual observations, which are ten day means, confirm the irregular short term variations. They also support the indication of a small decrease in the yellow brightness.

This odd optical behavior has been accompanied by a continuous change in spectrum in the sense that the spectral type has become

later since the star was first observed spectroscopically in 1955. At that time, K. G. Henize (1961), who had obtained the spectrogram at Mount Wilson, did not classify the star, but noted that the spectrum indicated that the object might be a "variable shell star similar to  $\gamma$  Cassiopeiae in which ejected matter is sufficient to produce a visible nebulosity." Herbig and Boyarchuk (1968) studied the spectrum of FG Sge during the years 1960 - 1967. They found that during that period the spectrum changed from that of a B9 Ia supergiant to an A5 Ia supergiant. In order to determine how long the spectrum had been varying, they examined the spectrogram taken by Henize in 1955, and classified the type as B4 I supergiant. From this they knew that the spectral type had been becoming later, at least since 1955. A later study of the spectrum by Langer, Kraft, and Anderson (1974) showed that by 1972 the spectrum had advanced to that of an F6 Ip supergiant, while Smolinski, Climenhaga, and Kipper (1976) describe it as G2 or even later in 1975.

How can the optical and spectral variations be explained? It is probable that they are linked with the nebulosity around FG Sge, which was first discovered by Henize in 1955 and mentioned in his list of new planetary nebulae (1961). The nebulosity was independently discovered by Herbig in 1960 and by Fürtig and Wenzel in 1962.

Herbig and Boyarchuk (1968) suggested that, although the recent activity of this object is unrelated to the existing planetary nebula, it is possible that it is related to a repetition of the ejection of the nebula. In this case, the deep shell of material would temporarily hide the hot central star, and in the process of expanding, eventually become more and more transparent. This would account for the changes in spectral type and brightness. This idea is supported by other astronomers who have worked with this object.

What has been happening with FG Sge is still not certain. We have only the facts of this star's activity over the past 80 years to work with. We know that sometime in the past, 6000 years ago according to Flannery and Herbig (1973), the star ejected a planetary nebula. We know that in recent years the star has undergone definite changes in brightness and spectrum. Whether or not we are seeing the ejection of a second planetary nebula is a question which can be considered theoretically, but which requires the proof of further observation.

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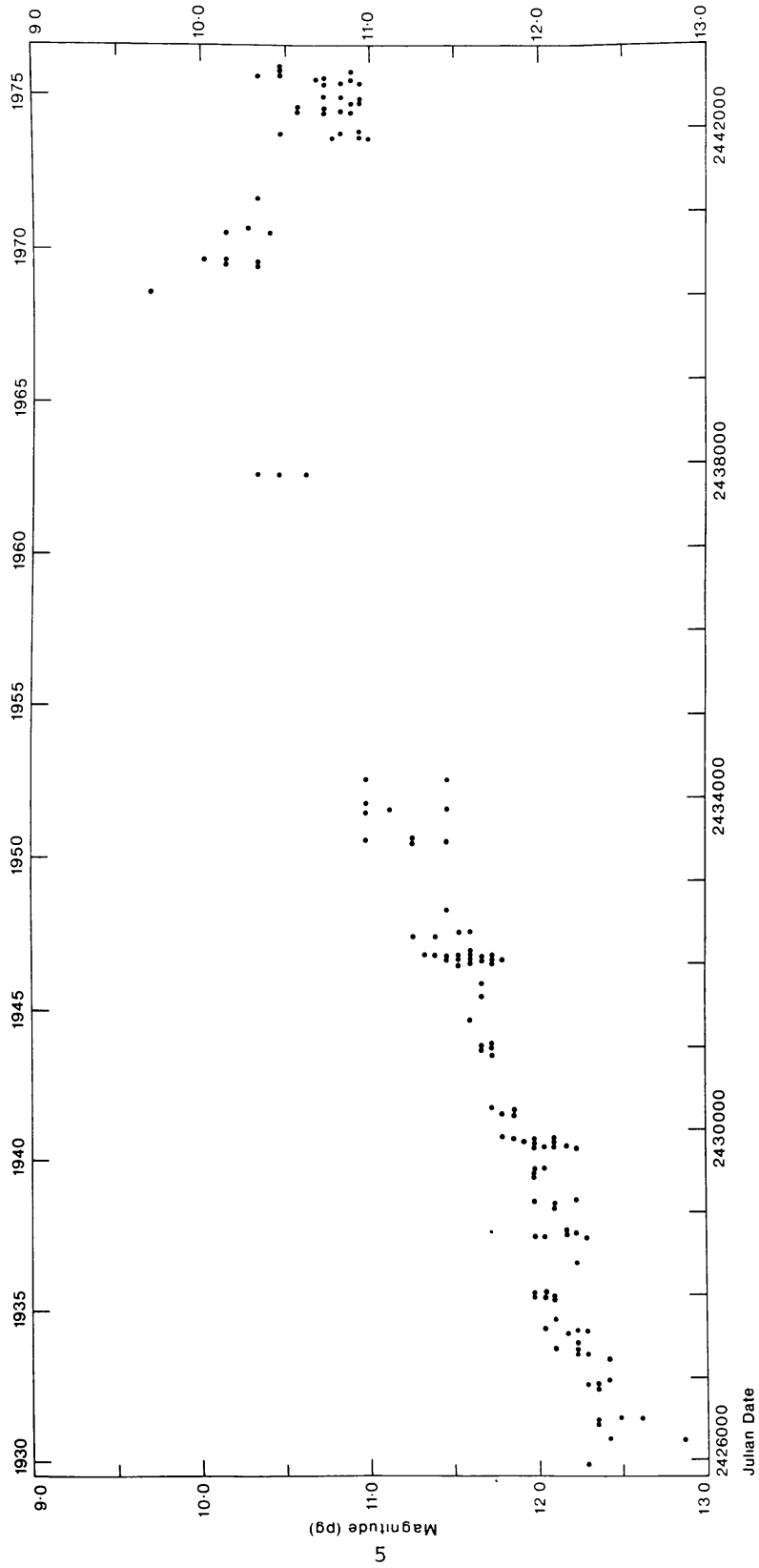


Figure 1. Photographic light curve of FG Sagittae from 1930 to 1975. All observations are from blue sensitive, IIA-0 emulsion plates.

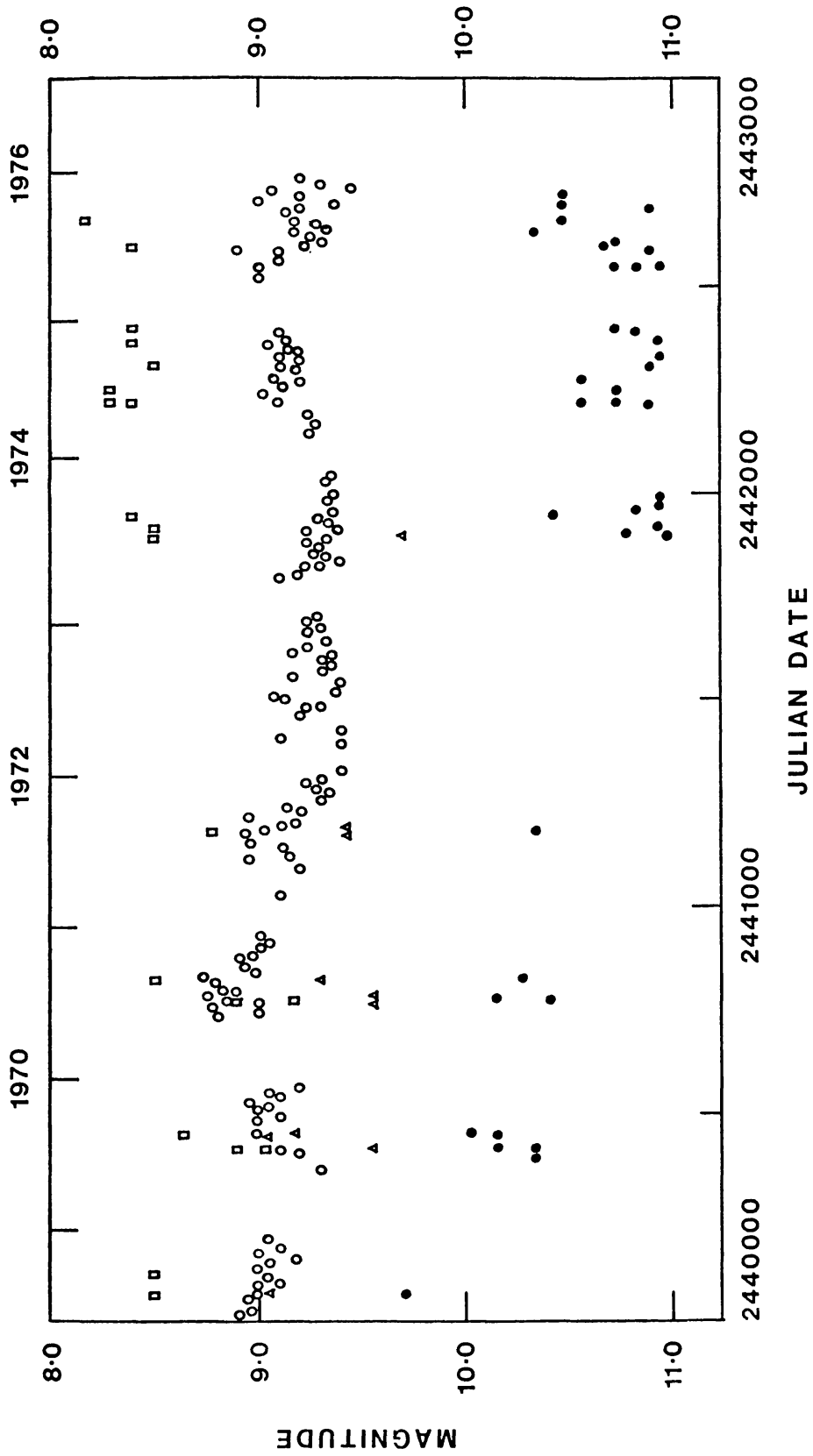


Figure 2. Three-color light curve of FG Sagittae from 1968 to 1975.  $\square$  are red brightnesses;  $\Delta$  are yellow;  $\bullet$  are blue;  $\circ$  are visual.