THE 1988 BRIGHTENING OF S PERSEI: OPTICAL AND WATER MASER VARIABILITY

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Abstract

The 22.2 GHz water maser fluxes in S Persei are graphed as a function of Julian Day and compared to the visual data compiled by the AAVSO. The features of the complex water maser spectra vary in intensity but not in unison. One set of features peaked about 35 days after the peak of the visual maximum, a second set of features peaked about 120 days after the visual maximum, while a third set of features shows little variation in flux. The changes in intensity of the features correlate with their position relative to the star. The features closer to the star react sooner.

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We have been observing water maser emission at 22.2 GHz in S Persei since April, 1987, at Haystack Radio Observatory[1]. The emission has been monitored approximately once a month. S Persei, an M3 supergiant, is a semiregular variable star ranging in visual magnitude from 8.3 to 11.8 (Cox and Parker 1978) with two periods estimated at 807 and 968 days (Leung and Stothers 1977). Visual data compiled by AAVSO observers for the same period of time as the maser observations show that a decline in brightness of S Per was followed by an increase in brightness during the first half of 1988. The visual peak occurred at approximately JD 2447370 (Figure 1).

S Per has a complex water maser spectrum usually showing about 11 distinct features that range in velocity from -32 km/s to -47 km/s. The features vary in intensity, but not in unison. We have identified six of the most distinct features and labeled them with letters from A to F, increasing in velocity. We have plotted the individual features on a graph of flux versus Julian Date (JD). This allowed us to separate the features into four groups. Figure 2 illustrates the first group, Features A and B. Both features remain fairly constant throughout the observing period, fluctuating around a mean intensity of 50 Jy. Features D and F, shown in Figure 3, mimic the decline and increase in the visual light curve, although the rise and decline time covers a larger time interval. The intensity for D and F varies from about 25 Jy at the minimum to about 120 Jy at the maximum for D and 90 Jy for F. These features are estimated to peak about JD 2447470, a hundred days after the visual peak. Feature E, shown in Figure 4, most closely resembles the brightening of the visual light curve. At the beginning of our observations E fluctuates around a mean intensity of 25 Jy, rises very rapidly to a maximum of 190 Jy at JD 2447393 (35 days after the visual peak), and falls as rapidly to its minimum value of about 25 Jy. Feature C fluctuates around a mean value of 150 Jy before

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the brightening but its intensity rapidly declines to about 45 Jy right after the visual maximum.

To obtain a better understanding of the total power emitted by the maser in comparison to the visual light curve, we measured the integrated area of each spectrum, or the total area underneath the combined features, expressed in units of (km s^{-1} K), and plotted this against time. Figure 5 shows that the integrated area mimics the visual data. More interestingly, the overall brightening is divided into two peaks which are separated by a drop in intensity a month after the visual peak. The first area peak correlates in time with Feature E, and the second area peak with the peaks of Features D and F.

A map of the water maser spots observed around S Per at the Very Large Array (VLA) is shown in Figure 6 (Diamond et al. 1987). Each circle on the map represents the location of detected maser emission, with more intense emission designated with larger circles. Using the velocities for the features we observed and the velocities listed above the circles, we were able to estimate the locations of some but not all of the observed spots. Feature E, the most dramatically changing feature, was not observed by Diamond et al. (1987) but may lie relatively close to the star and is quite intense. Features A, B, C, and D are placed farther from the star.

We were surprised that Feature E, which showed the greatest change in intensity, lagged the visual maximum by less than one month. The water maser emission associated with Mira variables lags the visual light curve often by the same length of time, 1 to 3 months (Webb, Benson, and Little-Marenin 1988), even though the water maser emission around the supergiant S Per is approximately ten times farther from the star than the maser emission associated with the giant Mira variables (Lane and Johnston 1987).

In conclusion, we observe a relationship between the visual light curve and the maser emission. We estimate that the regions of water maser emission can be divided roughly into three groups: a close-lying spot (Feature E), which responds very quickly to the changes in visual light; a spot lying farther from the star (Feature D), which responds more slowly to the changes in the visual light, up to three months later; and spots which may be farthest out, yet which have shown a response to the variations in visual light (Feature C).

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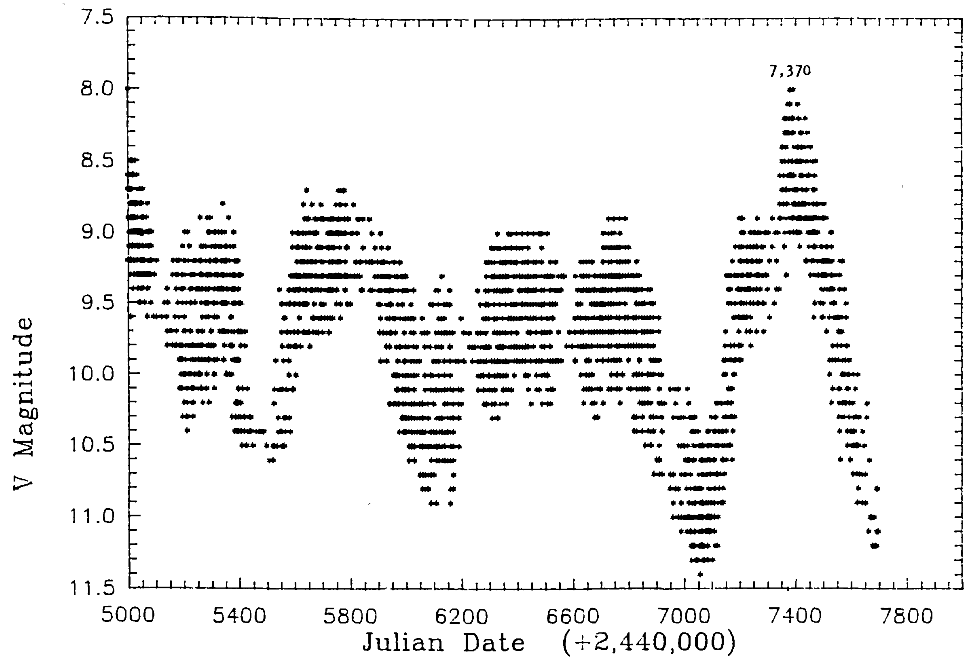

Figure 1. AAVSO Data for S Per plotted vs. Julian Day.

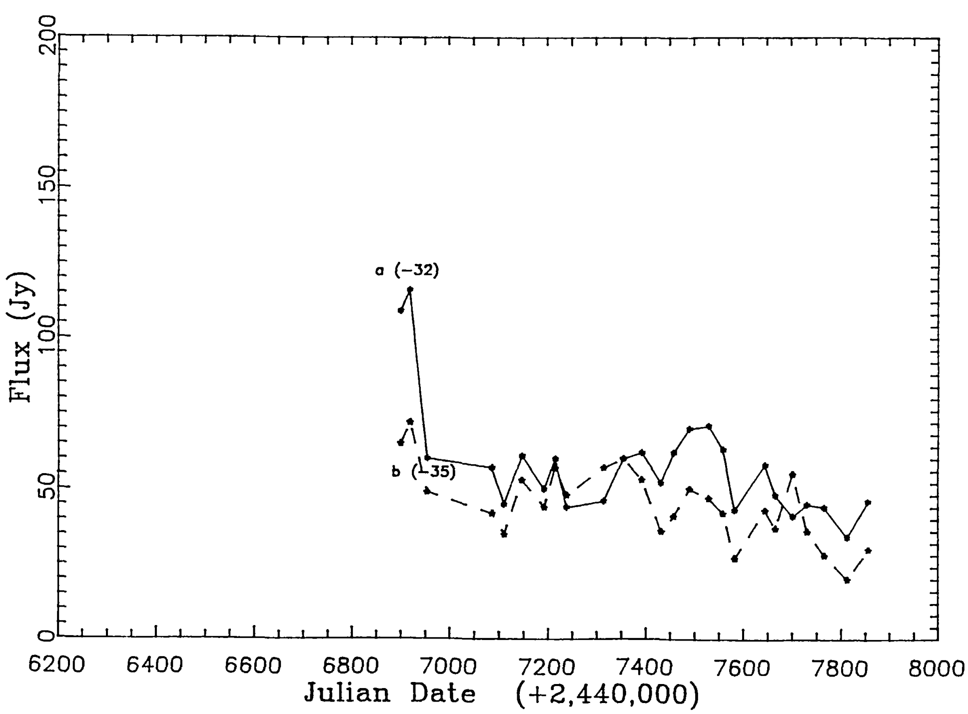

Figure 2. Water maser flux vs. Julian Day for Features A and B.

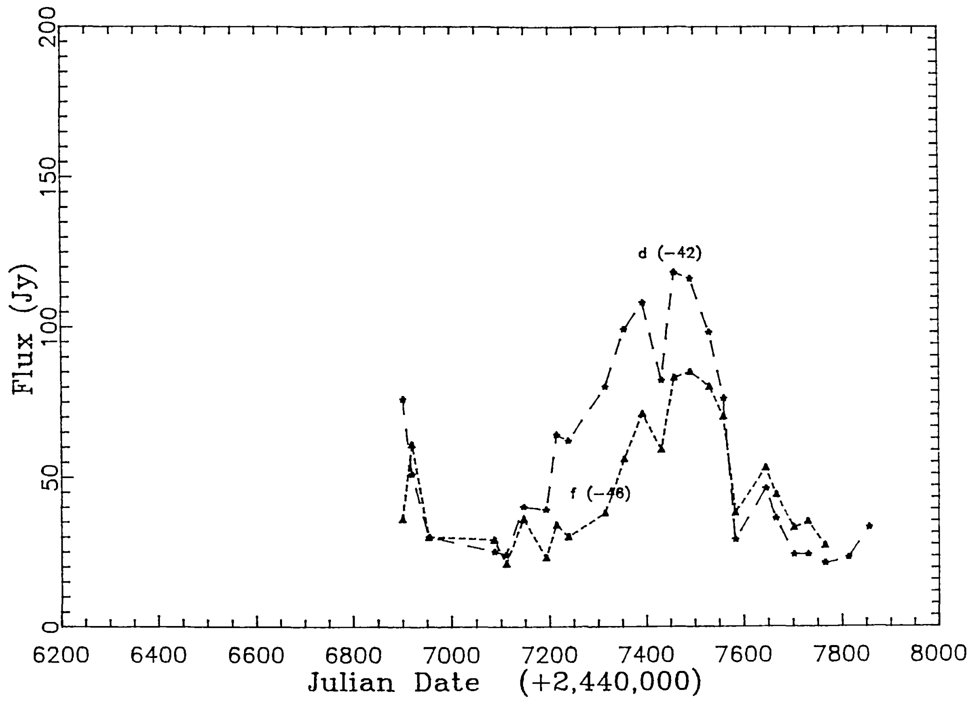

Figure 3. Water maser flux vs. Julian Day for Features D and F.

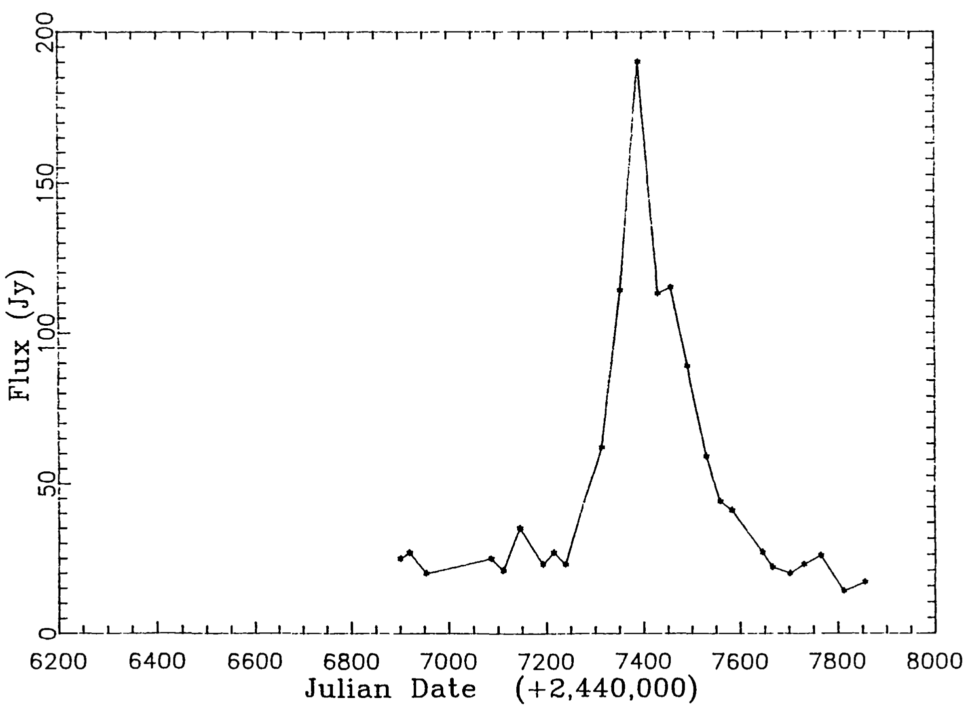

Figure 4. Water maser flux vs. Julian Day for Feature E.

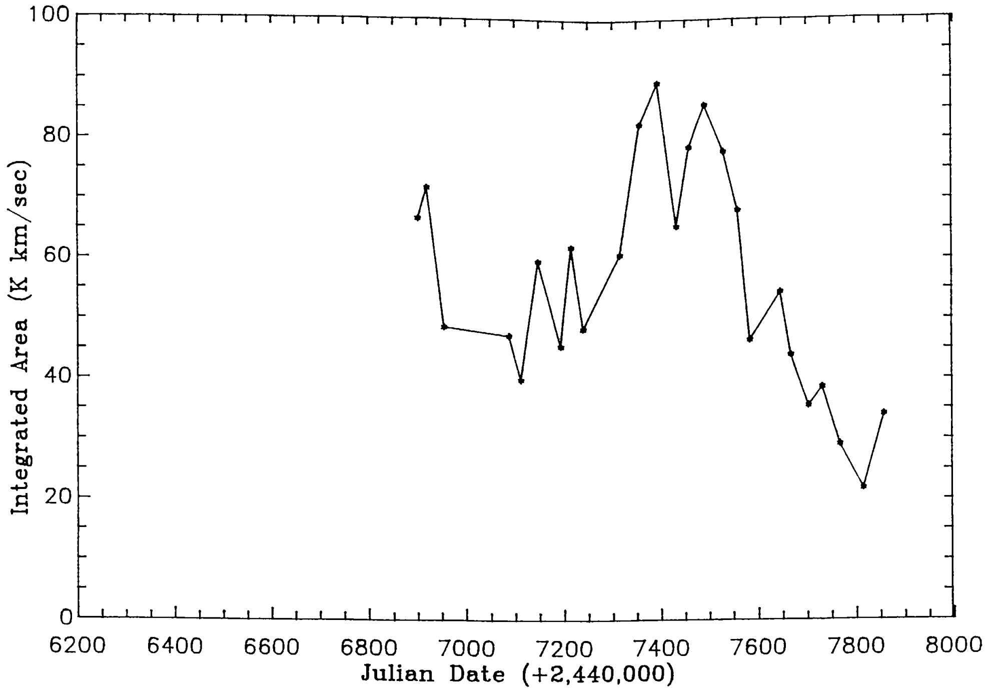

Figure 5. The integrated water maser flux for S Per vs. Julian Day.

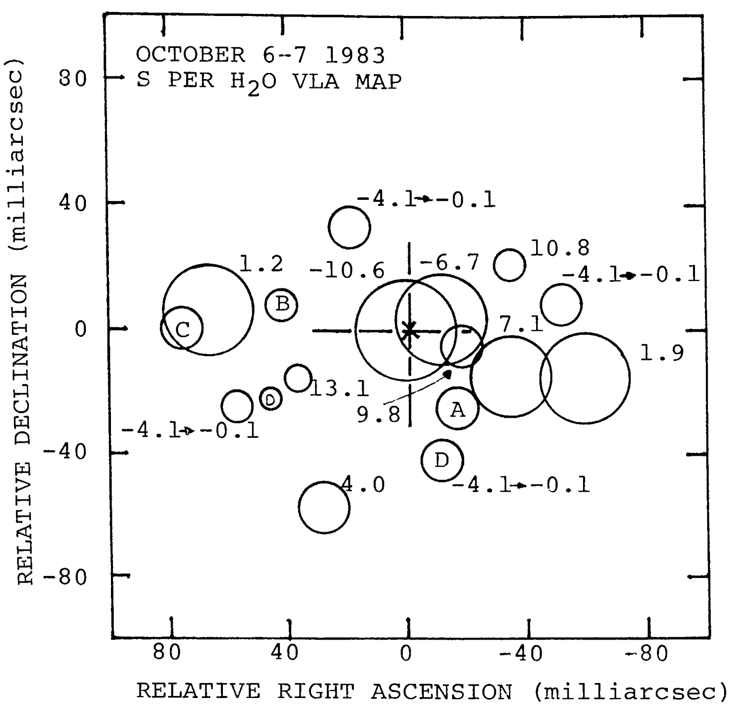

Figure 6. Very Large Array map of water maser emission plotted relative Dec vs. relative R.A. The sizes of the circles are proportional to the intensities of the water maser emission. The numbers above the circles are the spots' velocities relative to the V_{LSR} of S Per. Adapted from Diamond, P. J., Johnston, K. J., Chapman, J. M., Lane, A. P., Bowers, P. F., Spencer, J. H., Booth, R. S.: 1987, **Astron. and Astrophys. 174**, 97.