RADIO OBSERVATIONS OF HD 193793

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ABSTRACT: Radio observations of the Wolf-Rayet star HD 193793 are presented. Most of the observations were made during a large outburst in the infrared. The radio observations are consistent with the suggestion that a circumstellar dust shell recently formed.

As part of a radio survey of Wolf-Rayet stars, radio emission from HD 193793 was first detected in October, 1975 (Florkowski and Gottesman 1977). This detection was followed up by further radio observations which are presented here. They were made at the National Radio Astronomy Observatory using the Green Bank interferometer and the completed portion of the Very Large Array. Aperture synthesis observations have an important advantage over observations made with a single antenna. Since early type stars are located close to the galactic plane, they are often near H II regions. Thus, confusion effects can often be important. As a result of its higher resolution an interferometer is able to distinguish between radio emission from the star and radio emission from other sources adjacent to the star. In the case of HD 193793 several other sources are nearby.

The Green Bank observations were made simultaneously at 3.7 cm and 11.1 cm using the three element interferometer. The measurements were made in a differential fashion using a nearby, unresolved radio source as a flux density and phase standard. Aperture synthesis maps for each wavelength were made using the calibrated visibility data from each observing run. The standard NRAO mapping programs were used to form the maps. Since a given observing run consists of data for only three baselines, the sidelobe response of the synthesized beam was relatively strong. The effect of the sidelobes was removed from the map using the CLEAN method of Hogbom. The flux densities for HD 193793 were obtained from cleaned maps and thus the contamination by the sidelobes of nearby radio sources was greatly reduced.

The flux densities determined from the Green Bank data are given in the table below. The values for October, 1975 are slightly different from those published by Florkowski and Gottesman. In the previous work

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the flux densities were determined by fitting a point source model to the calibrated visibility data. This method assumes that sidelobes from nearby sources are insignificant. Later observations, made with the same antenna spacings, showed that this is not the case. The values given here were determined from cleaned maps.

Table 1: Flux Densities at 3.7 cm and 11.1 cm

Date	S(3.7cm) mJy	S(11.1cm) mJy
Oct 23-25, 1975	20.6 ± 1.8	25.6 ± 1.8
Mar 16-23, 1977	2.6 ± 1.0	<1.6
Jan 6-9, 1978	2.0 ± 1.6	<1.6
Apr 6-9, 1978	1.6 ± 1.6	<1.6
May 18-20, 1978	2.3 ± 1.6	<1.6
Jun 11-14, 1978	2.9 ± 1.6	<1.6
Jul 15-17, 1978	1.0 ± 1.6	<1.6

In aperture synthesis nonrandom effects are important in determining the noise level of a map (e. g. Hamaker 1979). I have adopted, on semi-empirical grounds, to represent the actual uncertainties in the flux density by twice the value of the rms. of the (random) system noise. One can see from the table that the values of the 3.7 cm flux density are not reliable during 1977-1978.

The observations with the Very Large Array were made at 6 cm and, on one occasion, at 20 cm. Since the VLA was not yet completed, the number of antennas available for observing depended on the status of the array. Between eight and thirteen antennas were used to observe HD 193793. The measurements were made in the same manner as the Green Bank observations and comparable calibration and mapping procedures were used. The table below gives the flux densities determined from the VLA observations.

Table 2: Flux Densities at 6 cm and 20 cm

Date	S(6cm) mJy	S(20cm) mJy
Jul 22-24, 1978	1.4 ± 0.3	
Oct 11-12, 1978	1.7 ± 0.4	
Dec 17, 1978	1.5 ± 0.3	<1.
Feb 16, 1979	1.5 ± 0.4	

These observations cover a time interval when HD 193793 was exhibiting unusual behavior in the infrared. Sometime between November, 1976

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and June, 1977 its infrared flux brightened by a factor of ten (Hackwell, Gehrz, and Grasdalen 1979). One would like to examine the radio observations made after 1976 for evidence of variability. Unfortunately the Green Bank data are not reliable. In order to improve their precision data from several observing runs were combined to form a single map. The reduced sidelobes and the better signal to noise ratio would make the cleaning procedure more reliable. The values of the flux density at 3.7 cm were determined to be 3.6 mJy ± 0.7 mJy for the March, 1977 and January-April, 1978 observations and 2.3 mJy ± 1.1 mJy for the May-June, 1978 observations. The upper limit for the flux density at 11.1 cm was 1 mJy for both groups of observations. These values as well as the VLA data indicate that the radio emission was roughly constant during this time interval. The flux densities at 3.7 cm and 6 cm can be combined to form a spectral index, having a value of 1.7. This value is very uncertain because of the small wavelength interval and the large uncertainties in the flux densities. It does suggest that the spectral index mav be larger that the 0.6 value expected for a stellar wind with a r^{-2} density distribution. Further multiwavelength observations are needed to check this result.

The absence of variability in the radio spectral region during 1977-1979 is consistent with the formation of a dust shell as proposed by Williams et al. (1978) and Hackwell, Gehrz, and Grasdalen. A factor of ten decline in the radio emission and a large change in the spectral index did occur between 1975-1977. This suggests that variations in the rate of ejection of ionized material can occur. Evidently HD 193793 shows complex behavior in the radio and infrared. This star is relatively well observed. It is not known if other early type stars show similar variability. This is a very important question because the rates of mass loss derived from radio observations have been used as standards in calibrating the rates determined by other methods.

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DISCUSSION

Williams: During the time span of your observations and right up to this summer, I have been monitoring HD 193793 in the infrared. The flux has continued to decline. Determination of the temperature of the grains from the infrared colours needs knowledge of grain chemistry; assuming graphite grains with opacity proportional to $\lambda^{-1.7}$, the temperature has declined steadily from about 900K in September 1977 to 500K in May 1981. From thermal equilibrium on the grains we can determine their distance from the star. This has increased by a factor of 4 over the same period. The intermediate data (see transparency) show that the expansion has been linear with time and the grains have not been further accelerated by radiation pressure since September 1977.

Cassinelli: Fitzpatrick and Savage looked at HD 193793 in the UV to see if there is any evidence for peculiar moleculiar species that might be associated with dust grain formation. They saw no unusual molecular species and found a very ordinary visual and UV continuum consistent with T_{eff} = 43000K.

Panagia: In the table showing the individual NRAO measurements at 3.7 cm all values were lower than 3 mJy and most even lower than 2 mJy. How can it be that the combination of all measurements gives an average value of 3.6 mJy ?

Florkowski: The value of 3.6 mJy is not an average value, but rather a value obtained from a map formed from several observing runs. Not all of the runs have the same baseline sample. The combined map had a much better spatial frequency distribution and thus a much weaker side-lobe response. This improvement made the map easier to clean and the resulting flux density more reliable.