Radio Observations of Flare Stars

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Observations of the radio emission from the red dwarf flare stars in the solar neighbourhood have been made at Jodrell Bank since 1958. In Australia, observations have been made both of these flare stars and of the early type flare stars in stellar aggregates. Observations in both Britain and Australia have been hampered by the difficulties involved in obtaining radio and optical coverage at the same time.

In the initial Jodrell Bank programme, at a frequency of 240 mhz, between 1958 and 1960, 474 hours of observations were obtained, mostly on UV Ceti, and 13 events compatible with bursts of radio emission from the star were seen, but due to poor seeing conditions at the Cambridge Observatories the correlation between radio and optical flares could not be established, although the rate of occurence of radio events was similar to the reported rate for optical events of a few magnitudes.

In the next programme, between 1960 and 1963, the optical coverage was improved by using the Baker-Nunn cameras of the Smithsonian satellite tracking network, with which stellar magnitude changes greater than 0.3 magnitudes could be measured. During the first year 166 hours of good optical-radio coverage were obtained, again mostly on UV Ceti. No major optical flare was observed, but 23 minor flares, of less than one magnitude were seen. Since there was no obvious radio signal, the records were integrated by superimposing the radio records aligned on the epoch of the peak of the photographic event (Lovell et al. 1963 Nature 198 p. 228). The result of the integration showed an increase in radio emission over the interval -2 min to $+8$ min about the epoch of the optical flare maximum.

The programme of simultaneous radio and optical observations only became really efficient when several optical observatories in the Soviet Union, including the Crimean Astrophysical Oberservatory, using photoelectric equipment, agreed to cooperate. Programmes were then carried out regularly until December 1969, and in 36 separate programmes 4000 hours of observing time were accumulated. Many cases of radio-optical correlations of individual flares were found.

For the minor flares observed the mean radio emission at 240 mhz was of the order of 5 flux units per magnitude change in the optical flare. In one or two cases however, a larger change per magnitude was observed, for instance, for a strong flare observed on UV Ceti in October 1963, the flux change per magnitude was 13 flux units. This flare was also observed at 408 mhz.

The Australians have reported on a joint radio-optical programme (HIGGINS et al. 1968 Aust. J. Phys. 21 p. 725) during September—October 1967. 21 optical events were observed, 6 of which were monitored at radio frequencies. Of these 6 events 5 gave emission at 150 mhz, and the strongest of these was also detected at 80 mhz. The sensitivity at 80 mhz was such that one would probably not have expected to detect the other 4 events. Optical flares of 1—2 magnitudes gave 4—25 flux units of radio emission at 150 mhz.

Information on the frequency spectrum of the radio emission is limited. Observations have been made by the Australians at 80 mhz, 150 mhz, 2650 mhz and in England at 240 mhz, and 408 mhz, but in few cases has a flare been observed at more than one frequency. There are some indications that the radiation my be sharply concentrated in the region of a hundred or so mhz, as in some solar outbursts.

Early measurements at Jodrell Bank on 240 mhz, and 408 mhz gave results ranging from $S \propto f^{-0.5}$ to $S \propto f^{-1.5}$.

Frequency dispersion has been observed in the radio observations. In at least one case the peak of the emission on 408 mhz occured 2 min after the optical flare, and on 240 mhz 1 min after the peak on 408 mhz. This indicated a drift rate of 2.8 mhz per sec. (For type II solar bursts drift rates of up to 1 mhz per sec are recorded).

The Jodrell Bank 1963 results show a tendency for the radio emission to reach a maximum after the optical peak.

In order to discover the mechanism responsible for the radio emission, many more radio measurements of flares at different frequencies are required, both to establish the frequency spectrum and to measure any frequency dispersion. Optical measurements with good time resolution taken at the same time as the radio measurements are needed, and so co-operation between radio and optical observers in joint programs is very important.

Another parameter of the emission which should be measured is the polarization. An attempt has been made to measure this at Jodrell Bank, but unfortunately there was no flare during the observing period.

The intention is that in the next flare star program at Jodrell Bank, which will probably take place in the spring of 1972, measurements will be made on at least two radio frequencies, and an attempt will be made to measure the polarization parameters of the emission.

Estimates of physical parameters of the emitting region may be made from the radio observations. Where radio emission at a particular frequency is seen an upper limit may be placed an the electron density in the emitting region by saying that the frequency emitted must be greater than the plasma frequency. This gives upper limits of 7.10^8 electrons per cc, and 2.10^9 electrons per cc, at 240 mhz 408 mhz respectively.

If the decay of the radio signal after the flare maximum is due to collisional damping in the stellar atmosphere, an estimate of the effective temperature of the flare region may be made. (For an electron the collision time t is calculated to be

$$t_c = 7.6 \times {}^5 \; T^{3/2} \nu^{-2}).$$

The temperatures obtained from this calculation, using the decay times of minutes to hours observed, are of the order of 10^9 deg K, several orders of magnitude greater than is compatible with the gravitational stability of the star. Reasonable temperatures would only be obtained from decay times of the order of seconds. One must conclude that in the observed flares we are not seeing an isolated event, and that perhaps the decay in the flare intensity is related to the decay of the energy-producing pocesses.

Do the flare stars contribute significantly to the generally distributed galactic emission?

At 240 mhz the observed brightness temperature T of the radio emission from the galaxy varies from 50 deg K in the anticentre to several hundred degrees along the disc towards the galactic centre. The brightness temperature which would be observed from an isotropic distribution of flare stars modelled on UV Ceti has been calculated. A general distribution of flare stars out to distances ranging from 1 kpc to 100 kpc gives values for the brightness temperature contribution of 0.13—13.0 deg K. It can be seen that the contribution from the flare stars would be negligible even if it were permissible to continue the integration out to say 10 kpc.

Discussion to the paper of WILSON

KUNKEL: Could you make some remarks on the ratio of optical to radio energies, with a view to comparing solar with stellar flares?

WILSON: The latest work I know on the subject is the result obtained by you that if the energy loss in the optical was calculated correctly the ratio of optical to radio energies for the red dwarf stars was the same as for solar flares. You also concluded that this was strange as the red dwarf stars were such different objects from the sun.

KUNKEL: My earlier result assumed hydrogen recombination as the only emission process. Since other processes may be active, other values may be applicable.

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