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A SEARCH FOR ISOLATED RADIO PULSES FROM THE CRAB NEBULA AT 151·5 MHz

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SUMMARY

A search has been made for large bursts of radio emission at 151·5 MHz from the direction of the Crab Nebula. In 605 hr of observation, no events exceeding a flux of $1{\cdot}4 \times 10^{-22}$ W m^{-2} Hz^{-1} were detected. This therefore sets an upper limit for the energy in radio pulses from the direction of the Crab Nebula which might be associated with the events recorded in the gravitational wave experiments of Weber. Implications of the results with regard to ' strong pulses ' and phase fluctuations in the periodic emissions from the pulsar NP 0532 are also examined.

1. INTRODUCTION

Weber (**1**) has reported that he is detecting pulses of gravitational radiation of extraterrestrial origin. The sidereal anisotropy (**2**) in his event rate is consistent with a source lying near the direction of the Galactic Centre or, alternatively, of the Crab Nebula (which is near the Galactic Anticentre). For this reason, we have extended our general search for isolated radio pulses to specific observations of the Galactic Centre and the Crab Nebula. The results of the study of the Galactic Centre have been reported elsewhere (**3**), and we describe here the Crab Nebula experiment. The original intention was to search for radio pulses which might be emitted in association with Weber's events, but the generally restless behaviour of the Crab Pulsar NP 0532 also made extended radio observation of this object worthwhile, in view of the possibility of obtaining information on the strong pulses (**4**)–(**8**), and radio emission associated with the phase fluctuations (**9**) and frequency jumps (**10**)–(**12**) in the pulsed emission from NP 0532.

2. OBSERVATIONS

Three groups took part in the experiment, with observing stations at Cambridge, Glasgow and Harwell. As before (**3**), only pulses arriving simultaneously at two or more stations were considered, so as to discriminate against local interference. The directional antenna arrays used in the Galactic Centre observations were repositioned so that the Crab Nebula could be observed simultaneously at all three stations for several hours a day. The observations were carried out between 1970 September 23 and 1971 March 3. The radio systems at the three stations operated at or near to 151·5 MHz, with bandwidths between 1·0 MHz and 1·2 MHz, and integration times of between 0·27 s and 2·9 s. Only those pulses having an amplitude of at least three times the ' peak to peak ' noise on the records and of duration less than 5 min were considered. This amplitude corresponds to a minimum flux of $3 \cdot 6 \times 10^{-23}$ W m^{-2} Hz^{-1} for unpolarized radio pulses of width substantially greater than the integration time. However, since the antennae were fixed, the sensitivity to radio pulses from the direction of the Crab varied with sidereal time. This meant that for most of the observing period, the sensitivity was poorer than that quoted above. In order to make a more useful statement about the effective observing time and sensitivity, a less demanding flux value of $1 \cdot 4 \times 10^{-22}$ W m^{-2} Hz^{-1} was chosen as a 'threshold sensitivity'. Any pulses exceeding this flux during the observing time would definitely have been detected. The periods of time during which various combinations of stations observed the Crab Nebula simultaneously with a sensitivity at least as good as the threshold sensitivity are given in Table I.

TABLE I

Observing periods on Crab Nebula

Stations observing Crab Nebula simultaneously	Observing time (hr)
All stations	178
Cambridge and Glasgow	224
Glasgow and Harwell	442
Cambridge and Harwell	295

The charts were scanned for pulses which occurred in coincidence between the different stations. A coincidence was said to have occurred if events at the different stations were detected within 1 min of each other. During the 178 hr that all three stations were simultaneously sensitive to pulses arriving from the Crab Nebula, no three-fold coincidences caused by pulses from its direction were detected. A separate examination of pulses occurring in coincidence at only two stations (two-fold coincidences) were also carried out. The Crab Nebula was observed by at least two stations simultaneously for 605 hr with a sensitivity better than the threshold sensitivity. In this time, no pulses originating in the direction of the Crab Nebula were detected. It should, however, be pointed out that owing to the integration times, the sensitivity to pulses of very short duration was poorer than the threshold sensitivity.

3. DISCUSSION

Weber has divided his events into four classes (1), dependent on the amplitude of the pulses making up each event, relative to the noise near the time of the event. His first class contains his largest coincident pulses and comprises 5 per cent of all his coincidences. The probability of at least one of these rare events occurring in our observing time of 605 hr is 56 per cent. We therefore cannot rule out the possibility that there occur radio pulses associated with these unusually large events. However, the rate of occurrence of Weber's events outside his first class is such that 13 would have been expected in 605 hr. It therefore seems probable that for 95 per cent of Weber's events, there are no associated radio pulses at $151 \cdot 5$ MHz emitted by a source in the direction of the Crab Nebula and having a flux exceeding the threshold sensitivity. Weber has estimated that the flux of gravitational radiation during an event is 10 W m^{-2} at a frequency of 1660 Hz in a bandwidth of $0 \cdot 016$ Hz. The limits on the associated radio emission are $1 \cdot 4 \times 10^{-16}$ W m^{-2} at a frequency of $151 \cdot 5$ MHz in a bandwidth of about 1 MHz.

We note that energy considerations make it extremely improbable that the flux in Weber's events could be generated by the Crab unless some very efficient beaming mechanism is involved.

The upper limits on the rate of large, isolated radio pulses from the Crab Nebula can also be viewed with regard to phenomena such as 'strong' pulses (**4**)–(**8**), phase fluctuations (**9**), and frequency jumps (**10**)–(**12**) in the pulsed radio emission from NP 0532.

TABLE II

Summary of VHF observations of 'strong' pulses from NP 0532

Frequency (MHz)	Pulse energy threshold (10^{-26} J m^{-2} Hz^{-1})	Approximate rate above threshold (hr^{-1})	Reference
74	20	120	Comella *et al.* (**4**)
146	10	23	Gower & Argyle (**5**)
111	15	14	Heiles & Rankin (**6**)
160	28	6	Sutton *et al.* (**7**)
170	14	4	Goldstein & Meisel (**8**)
146	65	0·5	Gower & Argyle (**5**)
151·5	4000	$\gtrsim$0·002	Present work
* * *	* * *	* * *	* * * * *
151·5	0·4	$1{\cdot}2\times10^5$	Rankin *et al.* (**14**)

The last entry in the Table is an interpolated value for the average pulsed energy per period at 151·5 MHz.

Table II summarizes the VHF measurements available at present on the 'strong' pulses from NP 0532. The 2·9 s time constant of the Cambridge system rendered it unsuitable for the study of such short pulses, in spite of the known dispersion of 0·135 s MHz^{-1} at 151·5 MHz. The sensitivity of the Glasgow and Harwell systems, having time constants of about 0·3 s, to pulses of this type was $\sim 4\times10^{-23}$ J m^{-2} Hz^{-1}. The corresponding upper limit on the rate of 'strong' pulses $\gtrsim 10^4$ times the average pulsed energy per period is given in Table II.

We can also conclude that if NP 0532 undergoes small, sudden fluctuations in phase more often than about once every 25 days, then there is probably no radio emission of a flux exceeding our threshold sensitivity associated with these changes. No major changes in period were reported as having occurred during our Crab Nebula observations, and so we can say nothing with regard to radio emission during such events.

An unsuccessful search for *microwave* pulses from the Crab Nebula has recently been reported by Partridge & Wrixon (**13**) who used receivers 100 km apart operating at frequencies of 16 GHz and 19 GHz.

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NOTE ADDED IN PROOF

A pulse height distribution for strong pulses from NP 0532 at 146 MHz has recently been published by Argyle & Gower (15). They find that the number N of strong pulses of energy exceeding a threshold S associated with the main pulse component is given approximately by $N = 500S^{-2.5}$ per min where S is measured in units of the average pulse energy. The expression was only tested for values of S up to about 300, but if it is extrapolated to our threshold ($S \sim 10^4$) it predicts a pulse rate of the order of 1 in 3×10^5 hr which is certainly consistent with our negative result.