LETTERS TO THE EDITOR

PHYSICAL SCIENCES

Pulsar Io Effect?

Burbidge and Strittmatter[1] have suggested that a small orbiting companion of a neutron star might trigger pulses of radio emission, in a way analogous to the Io effect in Jupiter. They propose a satellite of mass $m < 10^{27}$ g, to avoid difficulties with gravitational radiation, orbiting at a distance $R = 10^8$ cm to give a period of the order observed in pulsars.

At this distance the tidal stresses impose a minimum (the Roche limit) on the satellite density ρ, given by

$$\rho > 14{\cdot}8\ (R/r)^3\ \rho_c$$

where r and ρ_c are the radius and mean density of the central body. With $r = 10$ km, $\rho_c = 10^{14}$ g cm^{-3}, this condition gives

$$\rho > 1{\cdot}4 \times 10^9 \text{ g cm}^{-3}$$

Such a density implies a highly degenerate configuration. Neutron stars, however, have a lower mass limit because they can only be stable if

$$\frac{Gm_nM}{r'} > \Delta$$

where r' is the radius and M is the mass of the star, m_n is the mass of the neutron, and Δ is the difference in binding energy per nucleon between neutron and atom (say iron)[2]. With smaller mass the formation of atomic nuclei is energetically favoured. Oppenheimer and Volkoff[3] give the limit as $0{\cdot}1\ M_\odot$; Landau and Lifshitz[2] give it as $1/3\ M_\odot$. A neutron star of mass 10^{27} g is therefore thermodynamically impossible. A white dwarf electron degenerate configuration is also inadmissible for such a low mass.

The gravitational radiation from a binary star gives a characteristic decay time for the orbit of[4]

$$\tau = c^5\ [(m_1 + m_2)/(G^5\omega^8)]^{1/3} \times 1/128 \times 1/(m_1m_2)$$

Saslaw *et al.*[4] give $\tau = 10^8$ s for $m_1 = m_2 = 0{\cdot}5\ M_\odot$. For $m_1 = 0{\cdot}10\ M_\odot$, $m_2 = 0{\cdot}5\ M_\odot$ and identical period, the characteristic time is still only

$$\tau = 4 \times 10^8 \text{ s}$$

Thus any orbiting mechanism for pulsars appears to be excluded, unless Bondi's[5] suggestion of non-radiating states in free-fall motion is accepted.

D. H. DOUGLAS-HAMILTON

Harvard College Observatory,
Cambridge, Massachusetts.

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[1] Burbidge, G. R., and Strittmatter, P. A., *Nature*, **218**, 433 (1968).
[2] Landau, L. D., and Lifshitz, E. M., *Stat. Phys.*, 341 (1958).
[3] Oppenheimer, J. R., and Volkoff, G., *Phys. Rev.*, **55**, 374 (1939).
[4] Saslaw, W. C., Faulkner, J., and Strittmatter, P. A., *Nature*, **217**, 1222 (1968).
[5] Bondi, H., *Proc. Roy. Soc.*, A, **269**, 21 (1962).

Observations of Pulsating Radio Sources at 11 cm

THE four known pulsating radio sources[1,2] have all been observed at wavelengths down to 32 cm (ref. 3). For the source *CP* 1919 an upper limit to the flux density at 21 cm (ref. 4), a positive detection at 13 cm (ref. 5), and an upper limit at 11 cm (ref. 6) have been published. The previous observations at 11 cm wavelength have now been extended to all four sources, and positive results are reported here for two of them.

The observations were made with the Mark 2 telescope at 2,695 MHz on May 8, 9 and 10, 1968. The receiver bandwidth was 8 MHz, the system temperature 170° K and the aperture efficiency 50 per cent. The observing technique, using superposition of the receiver output over a number of cycles of the pulse repetition period by means of a computer, has been described previously[6]. Observations were averaged for 80 min on *CP* 0950 and for 60 min on each of the other sources.

Pulses from *CP* 0950 and *CP* 1133 were clearly detected. Their arrival times agreed with those expected from comparison with simultaneous observations at 408 MHz using established dispersion delays[3,6]. Fig. 1 illustrates this for *CP* 0950. The signal-to-noise ratio was not sufficient to determine definite pulse profiles, but the durations appeared similar to those reported at lower frequencies[3]. For *CP* 0834 and *CP* 1919 only upper limits could be placed on 11 cm emission. Details of the average pulses are given in Table 1. Mean pulse energy is estimated by assuming an effective pulse duration of 30 ms at peak flux density.

Table 1. DETAILS OF THE FOUR SOURCES

Source	Peak flux density (W m^{-2} Hz^{-1})	Mean pulse energy (J m^{-2}Hz^{-1})
CP 0834	$\leq 0{\cdot}1 \times 10^{-26}$	$\leq 3 \times 10^{-29}$
CP 0950	$0{\cdot}15 \times 10^{-26}$	$4{\cdot}5 \times 10^{-29}$
CP 1133	$0{\cdot}3 \times 10^{-26}$	9×10^{-29}
CP 1919	$\leq 0{\cdot}1 \times 10^{-26}$	$\leq 3 \times 10^{-29}$

CP 1919 would not be expected to be above the detection limit of either these or the previous observations[6] at 11 cm wavelength, assuming the mean pulse energy at 13 cm is 10^{-29} J m^{-2} Hz^{-1} (ref. 5). This source apparently has a spectral index between 73 cm and 13 cm of 3·2 (ref. 5). If this spectral index were characteristic of all the sources over this wavelength range, then none should have been detected at 11 cm. In fact, for both *CP* 0950 and *CP* 1133 the spectral index over this range is not signifi-

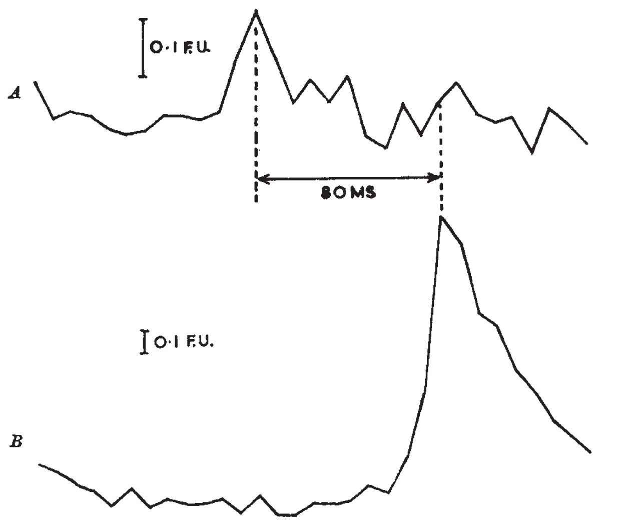

Fig. 1. *CP* 0950. *A*, 2,695 MHz data integrated 80 min. *B*, 408 MHz data integrated 5 min. Expected dispersion delay, 75 ms. Effective time resolution, 8 ms.