PSR 1055−52—A PULSAR RESEMBLING THE CRAB NEBULA PULSAR

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SUMMARY

Mean pulse profiles of the pulsar PSR 1055−52 have been measured at frequencies of 308, 400, 635 and 1400 MHz; in addition measurements have been made of the strong linear polarization at 1400 MHz. The pulse shape is found to be complex with a strong interpulse approximately midway between the main components. The average pulse from PSR 1055−52 displays certain remarkable similarities to that of the Crab Nebula pulsar PSR 0531+21.

The pulsar PSR 1055−52 was discovered by Vaughan & Large (1972) and subsequently observed by McCulloch et al. (1973), who obtained more precise values for the declination, period and dispersion measure. Vaughan & Large on one occasion observed a strong interpulse and they suggested that the true period for this pulsar may be half the 197 ms quoted in their paper. Observations with the Parkes 64-m radio telescope at frequencies of 308, 400, 635 and 1400 MHz between 1972 May and November have confirmed the 197-ms period and the presence of a strong interpulse which occurs approximately midway between the main pulses. The relative separations of the components are found to be remarkably similar to those of PSR 0531+21, the pulsar in the Crab Nebula.

Figure 1 shows the mean pulse shape of PSR 1055−52 at the four observing frequencies, obtained by combining many superposed epoch integrations made at orthogonal polarizations. Three pulse components are readily recognized in each profile; these are labelled A, B and C in the diagram. The separation of components C and A is approximately 0.4 period (i.e. ≈ 79 ms). The average flux density of component A is approximately half that of components B and C combined, which makes PSR 1055−52 the second pulsar known to have two well-separated components of comparable amplitude. Component A has an irregular shape and is difficult to define accurately but has a mean width of approximately 10 per cent of a period. Component B is the narrowest of the three components, occupying about 1.3 per cent of a period. The ratio of the amplitude of B to C decreases monotonically with increasing frequency, implying that the spectrum of B falls off more rapidly than the spectrum of C. The third component, C, has a duration of about 4 per cent of a period and appears to be composed of two sub-components of different spectral index so that the first of these dominates at 308 MHz while the second is more significant at 1400 MHz. All components are
very erratic, showing strong amplitude fluctuations with a time scale of a few minutes. These fluctuations are more marked and of shorter time scale at the lower frequencies.

Mean pulse profiles were obtained simultaneously at the four observing frequencies and subsequently analysed to provide the mean spectrum of each component. Data obtained with orthogonal feed polarizations were combined to give the total energy at each frequency. The signal-to-noise ratio on these records was poor compared to the signal-to-noise on the data presented in Fig. 1 so that it was not possible to resolve peaks B and C. Estimates of the energies of these components were made by dividing their combined energy in proportion to their relative energies as determined from the data of Fig. 1. The resultant spectra are plotted in Fig. 2. The spectrum of component A is well defined with a spectral index of about
The spectrum of component B appears to be similar to A while there is some indication of the spectrum of C being flatter.

Linear polarization was measured at $1400\,\text{MHz}$ by making a series of superposed epoch integrations with the position angle of the feed advanced by $45^\circ$ between integrations. The results, shown in Fig. 3, indicate that all three pulse components are highly polarized ($\sim 80$ per cent). The relative position angle remains fairly constant throughout each individual component, with mean values of about $25^\circ$ for A, $-55^\circ$ for B and $-30^\circ$ for C. Thus the position angles for components A and B are almost orthogonal, a conclusion which is supported by successive observations at orthogonal feed angles at lower frequencies which show that component A is weak when B is strong and vice versa.

The complex pulse shape of PSR $1055-52$ is similar to that of the Crab Nebula pulsar as observed at frequencies near $300\,\text{MHz}$ (Rankin et al. 1970). This similarity is illustrated in Fig. 4, where component A has been identified with the interpulse, component B with the precursor, and component C with the main pulse. The relative separations of the three components of these pulsars are in remarkable agreement, the separation of the interpulse and main pulse agreeing within $1$ per cent of a period.

However, there are notable differences between these pulsars: (1) The precursor of PSR $0531+21$ is the widest of its three components. For PSR $1055-52$ the 'precursor' is the narrowest component. (2) The spectrum of the PSR $0531+21$ precursor is much steeper than that of either the main pulse or interpulse, with the result that the precursor is barely detectable at $606\,\text{MHz}$ (Rankin, Heiles & Comella 1971). The amplitude of the PSR $1055-52$ precursor is still comparable.
Fig. 3. Average linear polarization of PSR 1055 - 52 at 1400 MHz. The full curve gives the total flux density while the dashed curve gives the linearly-polarized flux density. The position angle of the linearly-polarized component is drawn for each of the pulse components. The origin of the position angle data is arbitrary.

Fig. 4. Comparison of the relative pulse shapes and separations for PSR 1055 - 52 and 0531 + 21. The data for PSR 0531 + 21 are taken from Rankin et al. (1970) at 318 MHz while the data for PSR 1055 - 52 are a smoothed representation of the 635 MHz data.
with the other components at 1400 MHz. (3) All components of PSR 1055−52 are highly polarized while in PSR 0531+21 only the precursor is significantly polarized. Nevertheless, the remarkable similarity between the pulse components of these two pulsars (which are the only two pulsars which have interpulses of similar amplitude to the main pulse) suggests that the magnetic field geometry and orientation with respect to the observer’s line-of-sight of these pulsars may be similar.

The currently accepted theories of pulsar emission all involve the rapid rotation of a magnetized neutron star together with strong beaming of the emitted radiation. Most explanations of the optical and X-ray emission from PSR 0531+21 rely on the very rapid rotation of this object (period ≈33 ms). However, our current understanding of pulsar emission mechanisms does not rule out the possibility that the optical and X-ray emissions from PSR 0531+21 are due to an unusual magnetic field geometry and orientation. If this is the case the similarity between PSR 0531+21 and PSR 1055−52 suggests that the same situation might be found in PSR 1055−52. Hence a search for optical and X-ray pulsations from the direction of PSR 1055−52 could result in narrowing the field of possible pulsar theories.

Backer, Boriakoff & Manchester (1973) have discussed pulsars which have wide integrated pulse profiles. They present data on four pulsars (PSR 0832+26, 0904+77, 0950+08 and 1929+10) with relatively weak interpulses and suggest that there is a class of pulsars which emit over a significant fraction of a period. If so, PSR 1055−52 must be counted as a member of this class.

REFERENCES