TIME ASYMMETRIES IN PULSAR SIGNALS

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ABSTRACT

The average shape of micropulses in two pulsars is highly symmetric, unlike the subpulse emission which is skewed in the same sense as the average profiles. These conclusions stem from a third-order correlation analysis of the emission from PSR 0950+08 and PSR 2016+28. The symmetric micropulses may be produced either by temporal modulation or angular beaming of the radiation. If due to temporal modulation, this average symmetry implies a distribution of time-scales in the emission process: the difference between the rise time-scale (τ_r) and the decay time-scale (τ_d) must be small compared to $\Delta\tau_r$ and/or $\Delta\tau_d$. Subpulses in PSR 0950+08 are narrower than and have the same sense of asymmetry as the average profile. In PSR 2016+28 the two subpulses typically present in a pulse are both tapered toward the outside edge of the pulse. In both pulsars, the skewness of the subpulses contributes significantly to the skewness of the average profile; a symmetrical distribution of these subpulses within the pulse window could then give rise to an asymmetrical profile.

ASYMMETRY ANALYSIS OF TWO PULSARS

We have developed a statistical analysis technique for investigating time asymmetry or skewness in random processes. This technique is closely analogous to second-order correlations such as the autocorrelation function and contains information about the skewness of features on a wide range of time scales. We form the skewness function of a random process by crosscorrelating the square of the given time series with the time series itself. The positive and negative lag halves of this function are not identical. In fact, the difference between them is a measure of the asymmetry present in the time series of a given time scale. We normalize this skewness function by the zero-lag value of the third-moment crosscorrelation, a choice that limits the range of the function to [-1, 1].

W. Sieber and R. Wielebinski (eds.), Pulsars, 197–198.

When we apply this technique to high-resolution, dedispersed intensity data from PSR 0950+08 and PSR 2016+28 we find a number of interesting results. The micropulse emission from both of these (quite different) pulsars is highly symmetric in its temporal profile. Although this symmetry could arise in either a beaming or a temporal discharge model of micropulses, we explore its implications in the latter model. We prefer this interpretation primarily because micropulse widths do not seem frequency dependent as are subpulse and average profile widths.

The measured micropulse symmetry, then, places strong constraints on the time scales governing the rise and decay of the emission process. Since the rise time scale (which is probably that of a plasma instability) and the decay time scale (which indicates the coupling time between the original instability and a radiative or plasma quenching mechanism) are determined by different physical processes, there is a need to understand their equality. Since either or both the rise and decay mechanisms may be stochastic, the distribution widths, $\Delta\tau_r$ and $\Delta\tau_d$, may be large compared with $|\tau_r - \tau_d|$. If either the rise or the decay process is noisy enough, the measured symmetry could be that of the time scale distribution shape instead of the difference between τ_r and τ_d. Since the measured micropulse symmetry is an average quantity it may or may not arise from individually symmetric micropulses.

The subpulse skewness results are particular to the individual pulsars. Subpulses from PSR 0950+08 occur with a wide range of intensities and with no drifting subpulse pattern. We have found that these subpulses have the same sense of asymmetry as the average profile — they rise to peak intensity more slowly than they decay. For PSR 2016+28 the drifting subpulse pattern and the double-humped (430 MHz) average profile complicate the analysis. The initial subpulse skewness feature indicates, though, that of the two subpulses that are typically present in a pulse, the one that rises more slowly than it decays is usually the stronger of the two. The large time-lag values are consistent with these subpulses being tapered toward the outside of the pulse window, the inner edges of the subpulses being cut off more abruptly than the outer. The skewness of the subpulses in both of these pulsars is similar to that of their respective average profiles, implying that the subpulse asymmetry at least helps in building up the asymmetry of the average profile.

We would like to thank V. Boriakoff and T. Hankins for use of their data and R. Lovelace, R. Isaacman, and J. Weisberg for helpful discussions. The Arecibo Observatory is part of the National Astronomy and Ionosphere Center, which is operated by Cornell University under contract with the National Science Foundation.