Drifting subpulses galore

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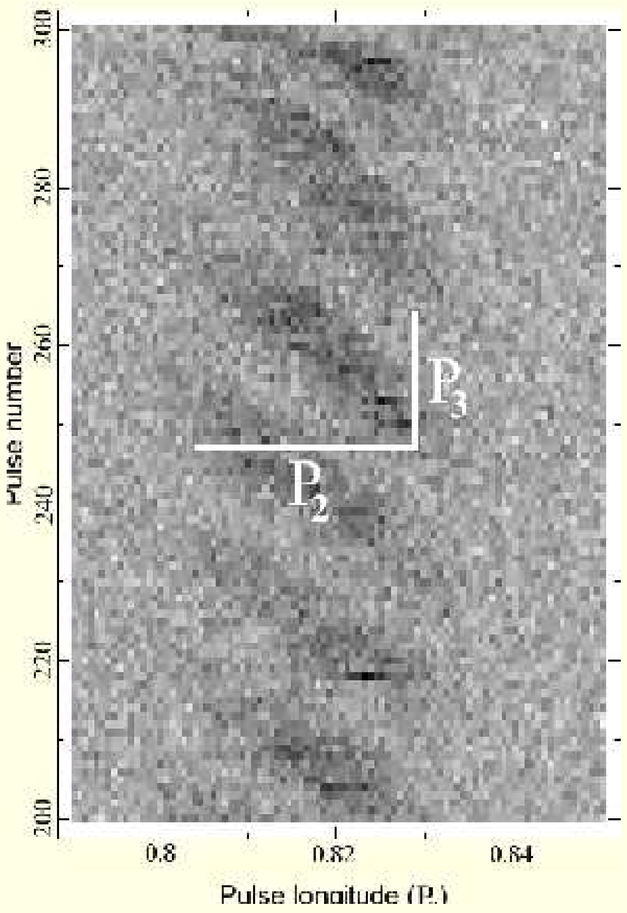
ABSTRACT

Using the Westerbork Synthesis Radio Telescope (WSRT) and a powerful new detection method we have undertaken a systematic, unbiased survey for pulsar subpulse modulation. This allows us, for the first time, to do meaningful statistics on the drifting phenomenon, which give insight into the still unknown emission mechanism. We have found an unexpected high number of new drifters that indicates that drifting is a common phenomenon for radio pulsars and we have found a number of correlations that should be explained by emission models.

WHAT ARE DRIFTING SUBPULSES?

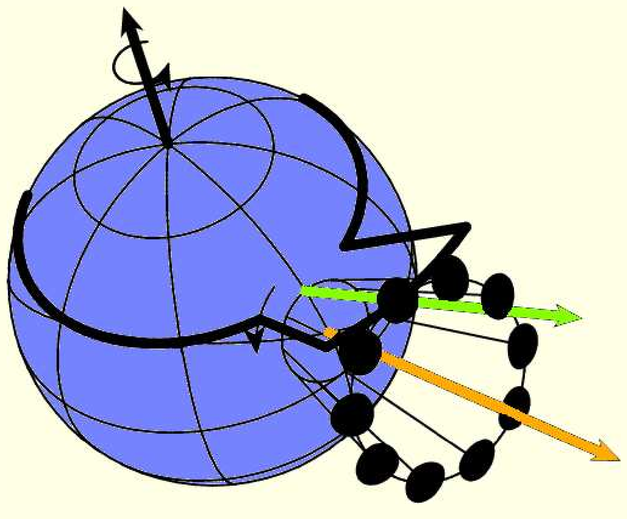
The pulses of some pulsars consist of subpulses and for some pulsars these subpulses drift systematically in phase. This is beautifully demonstrated by PSR B1819−22 in the so-called "pulse stack":



Here successive pulses are stacked on top of one another. One can see that the pulses consist of subpulses and that they drift in time, causing the diagonal "drift bands". This pulsar is one of the new drifters we have found.

WHAT PRODUCES DRIFTING SUBPULSES?

In the standard model for drifting subpulses the radio emission is produced in emission entities around the magnetic axis. These entities rotate around the magnetic axis due to an $\mathbf{E} \times \mathbf{B}$ drift.

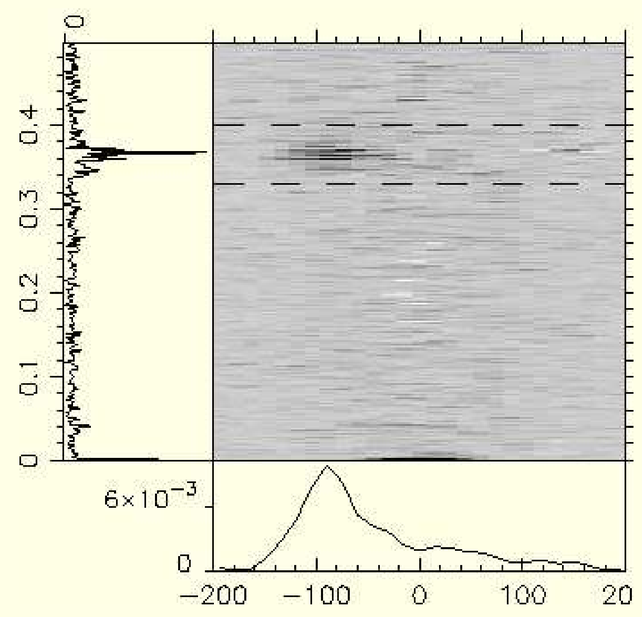


WHY PERFORM THIS SURVEY?

Drifting subpulses are known in great detail for only a small number of well studied pulsars. Because drifting is most likely linked to the still unknown emission mechanism, we learn about the physics of the emission mechanism by studying drifting subpulses.
We have undertaken a large, systematic survey for subpulse drifting. Our sample is also not biased on any particular pulsar characteristics as were previous studies. This allowed us to do, for the first time, meaningful statistics on the drifting phenomenon. Therefore this study could serve as an excellent observational foundation for a new improved emission model.

THE SENSITIVE DETECTION METHOD

Previous studies of drifting subpulses often used tracking of individual subpulses through time and therefore can only be carried out on a limited number of bright pulsars. We therefore use the integrated Two-Dimensional Fluctuation Spectrum (Edwards & Stappers 2002), which can be used to detect drifting subpulses even when the pulsar is too weak to see single pulses. This Fourier method is sensitive for both horizontal and vertical periodicities in the pulse-stack:



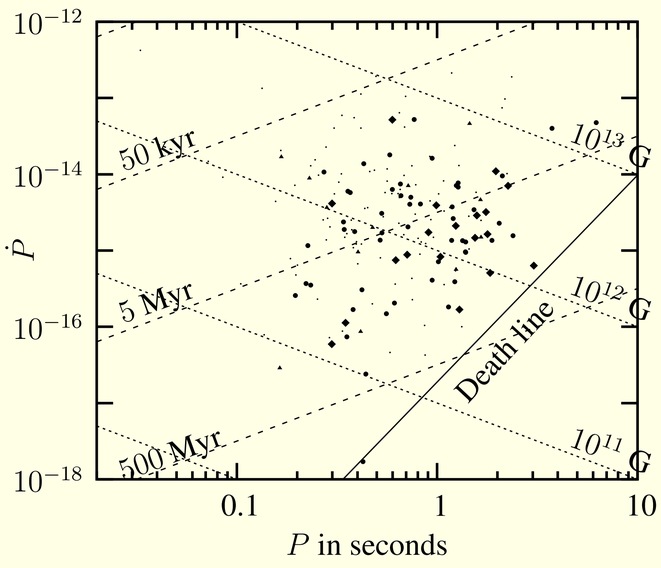
The horizontal and vertical axis are $1/P_2$ and $1/P_3$, which are the horizontal and vertical drift band separation respectively. Drifting subpulses are identified by a "feature" in this fluctuation spectrum.

IS DRIFTING INTRINSIC TO THE EMISSION MECHANISM?

Of the 187 analyzed pulsars 71 are shown to exhibit the drifting phenomenon. If the observations that had an insufficient S/N to detect drifting are ignored, we have shown that at least about 60% of the pulsars drift. This implies that the physical conditions required for the drifting mechanism to work cannot be very different than the required physical conditions for the emission mechanism of radio pulsars. It could well be that the drifting phenomenon is an intrinsic property of the emission mechanism, although drifting could in some cases be very difficult or even impossible to detect.

CORRELATIONS FOUND

The physical properties of radio pulsars can be estimated from its position in the P-$\dot{P}$-diagram, which is a diagram of the pulse period versus its slowing down rate. The non-drifters are the small dots and the drifters are larger symbols. Lines of equal age and magnetic field strengths are shown as well.



We find that

- Drifters are average older:
- Drifting is more regular for the oldest pulsars.
- Drifting is independent of the magnetic field strength.
- The vertical drift band separation P_3 is not correlated to any other pulsar parameter, as was reported in the past. This is difficult to explain in the standard model.

MAGNETIC ALIGNMENT?

The evolutionary trend found seems to suggest that the mechanism that generates the drifting subpulses gets more and more stable as the pulsar ages. This could be because the magnetic axis and the rotation axis becomes more aligned for older pulsars. An more aligned magnetic axis could possibly imply more stable electrodynamical conditions in the magnetosphere of the pulsar.

REFERENCES

Edwards, R.T. & Stappers, B.W. 2002, A&A, 393, 733
Weltevrede, P., Edwards, R.T., Stappers, B.W. 2005, Subm.

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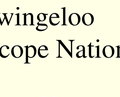

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