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Observations of rotational instabilities in Radio Pulsars

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Abstract. Two kinds of irregularities are observed in the rotation rates of pulsars – timing noise and glitches. A study of these irregularities is useful as a probe for the internal structure of these stars. We present the distribution of fractional change in the rotation rate of pulsars as obtained from all available data.

Radio pulsars are the most remarkable clocks. The successive pulses received from the star provide a measurement of its rotation. A model of rotational parameters is usually fitted to the pulse arrival time measurements for this purpose. In many pulsars, the residuals obtained from such a fit reveal a highly stable rotation rate, which decreases gradually at a fixed rate. However, long term monitoring of pulse arrival times in some pulsars reveals small fluctuations or irregularities, which are of two types. Many pulsars exhibit a continuous wandering of the rotation rate called timing noise. On the other hand, a few pulsars exhibit a sudden increase in the rotation rate, often followed by a period of relaxation and this phenomenon is called a glitch. Glitches are believed to be due to differential rotation between the superfluid, which forms the core of the star, and its crust. Models have been proposed to explain this interaction (Alpar et al. 1993; Ruderman, Zhu & Chen 1998), but the details of this phenomenon are still uncertain. Glitches are a useful probe for the internal structure of pulsars or neutron stars. Lyne, Shemar and Smith (2000) place constraints on the fraction of moment of inertia associated with the interacting components by carrying out a statistical analysis of 48 glitches. The analysis of glitches also provides constraints for Equation of state of neutron stars (Datta & Alpar 1993; Link, Epstein & van Riper 1993).

In the last decade, continuous and extensive monitoring of more than 270 pulsars have been carried out at Jodrell Bank Observatory and a study of this timing database has revealed many new glitches (Shemar & Lyne 1996). We have extended this study by a further two years and work is in progress to analyse all the available data to date. Figure 1 shows some of the new glitches discovered in this extended analysis. In this study, an improved analysis procedure was followed, which resulted in the detection of glitches with three orders of magnitude smaller fractional change in rotation rate as compared to the usual pulsar glitches. A database of 97 glitches based on these measurements as well as glitches reported in the literature has been assembled by the authors. A distribution of the fractional change in the rotation rate for all the glitches in this database is presented in Figure 2. The smallest glitch in the database occurred in PSR B1907–03 with a fractional change in frequency of 0.6 x 10^{-9} (Krawczyk et al. 2002), whereas

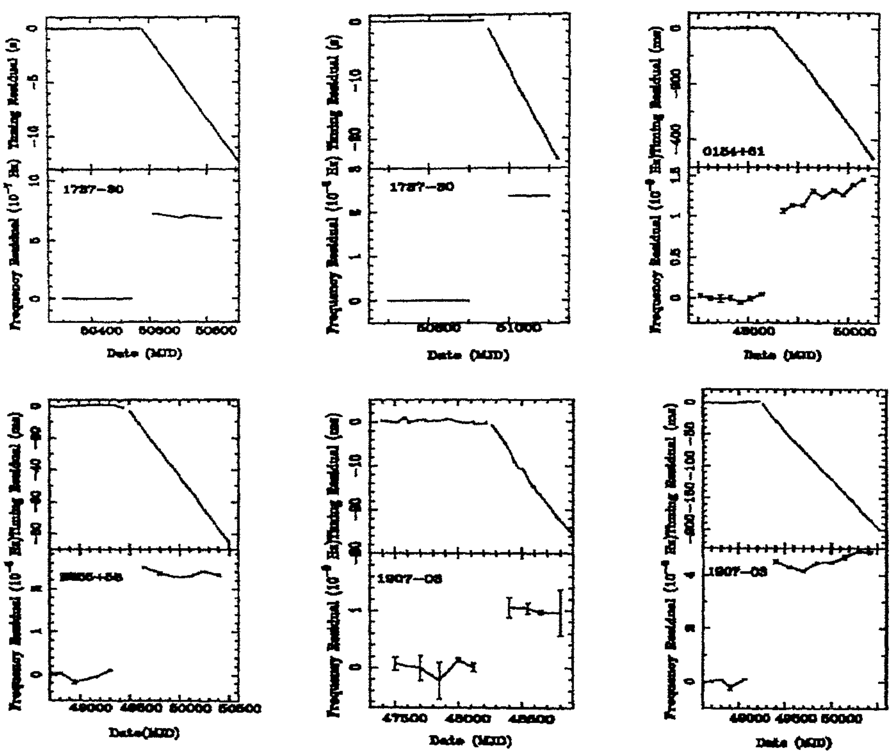

Figure 1. Six new glitches in four pulsars detected in the Jodrell timing database.

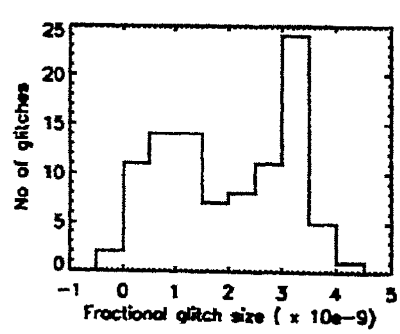

Figure 2. The distribution of fractional change in the rotation rate.

the corresponding value for the largest glitch in PSR J1806–2125 is 1.6×10^{-5} (Hobbes et al. 2002) indicating the large of glitch sizes.

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