Binary Radio Pulsars
ASP Conference Series, Vol. 328, 2005
F. A. Rasio and I. H. Stairs

Timing Instabilities in Millisecond Pulsars

D. C. Backer

Astronomy Department & Radio Astronomy Laboratory
University of California, Berkeley, CA 94720-3411

Abstract. The class of pulsars with millisecond rotation periods have often been used, and advertised, as "precision celestial clocks" for experiments in relativity and gravitational-wave astrophysics. However, several of these stars exhibit timing instabilities. I review this topic summarizing the work of a number of primary observers[1] who have been carefully monitoring these pulsars over the past 20 years.

1. Timing Noise

Kaspi et al. (1984) first showed that PSR B1937+21 displayed an instability of a few microseconds over time scales of 8 years. The form was a roughly cubic residual from the best-fit model. A reasonable hypothesis was that this was "timing noise" similar to, but much smaller amplitude than, that observed in slow period pulsars. The reasonableness comes from the simple fact that as a neutron star slows down, it needs to adjust to a new equilibrium figure. The solid crust of neutron stars can prevent smooth adjustment as mechanical configuration energy can be stored in this crust and released unevenly. While Lommen (2001) has considered other contributions for this instability (gravitational radiation and a planet), internal noise in the neutron star remains likely.

Various authors have correlated a metric of timing noise variance with the rotational period slowdown rate, $\dot{P}$ for pulsars reaching down to the millisecond domain (MSPs). This started with Dewey & Cordes (1989) and was updated by Arzoumanian et al. (1994). I present in Figure 1 a version of the timing noise diagram from Arzoumanian et al. with updates for the millisecond period population. There are new upper limits that are significantly lower than in 1994. There are objects for which timing noise had been reported, but which later have turned out to be other effects (e.g., B1257+12 and dispersion measure fluctuations). The most significantly established, "not white noise residuals" pulsars remain B1937+21 first reported by Kaspi et al. and B1821−24 first reported by Cognard et al. (1996). The latter has been left out of some studies owing to its location in the globular cluster M28, which means that gravitational buffeting by the granular potential in the cluster will lead to some level of timing noise. But this level is largely excluded by the known density and population of stars in this system as discussed by Cognard et al. and other authors.

A more complete presentation of the data in Figure 1 will be presented in a future publication. G. Hobbs has completed a PhD thesis on analysis of timing all pulsars in the Jodrell Bank archive (2002). We can look forward to a richer study of the dependence on timing noise on spindown and other parameters. For example, he finds that the highest correlative parameter is not $\dot{P}$, which can be translated into torque, but rather age, which might be translated into temperature.

[1]Particular thanks in this talk to I. Cognard, A. Lommen, A. Lyne, and G. Hobbs for their contributions.

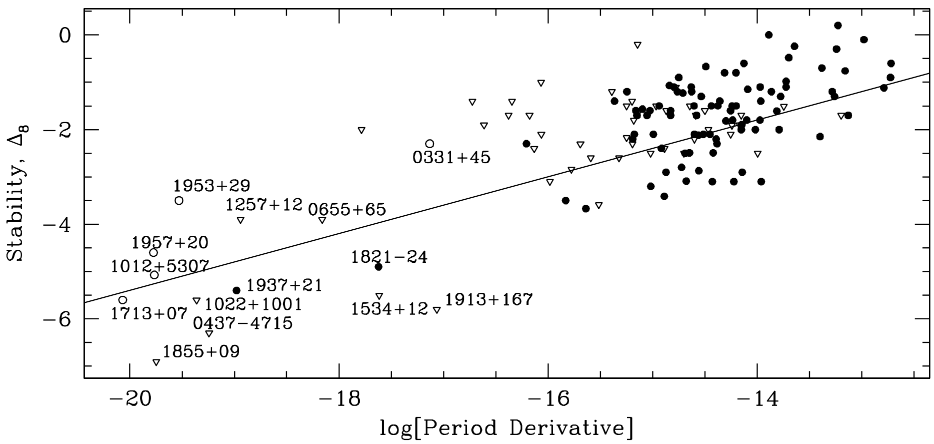

Figure 1. Timing noise in pulsars *vs* spindown rate.

2. A Glitch in PSR B1821-24

Timing observations of B1821-24 and other MSPs at Nançay (France) have been made continuously since 1989 October apart from a gap between 1999 November and 2000 July owing to the upgrade of the telescope (Cognard et al. 1996). Observations of B1821-24 were also conducted with the 140 ft Green Bank telescope between 1989 and 1997, and briefly with the new 100 m Green Bank Telescope (GBT) during 2002 and 2003.

A few months after 2001 March, the standard model of B1821-24 became inadequate. Figure 2 shows the timing residuals based on a model up to 2001 March, and the abrupt change in slope – a glitch in the rotation frequency. Various checks were done regarding the instrumentation. The most convincing evidence for a real effect came from the lack of any similar effect in the analysis of timing observations of other millisecond pulsars in the Nançay program. A full report on this first glitch in an MSP will be presented elsewhere. B1821−24 is now the noisiest of the MSPs and has, perhaps not surprisingly, the only glitch in the MSPs.

3. Summary

Pulsars B1821−24 and B1937+21 are more clearly defining the extremes of instability in these otherwise marvelous celestial clocks.

References

Arzoumanian, Z., et al. 1994, ApJ, 422, 671

Cognard, I., et al. 1996, A&A, 311, 179

Dewey, R., & Cordes, J.M. 1989, NATO ASI CS, 262, 119

Hobbs, G. 2002, PhD thesis, University of Manchester

Lommen, A. 2001, PhD thesis, Univerisity of California, Berkeley

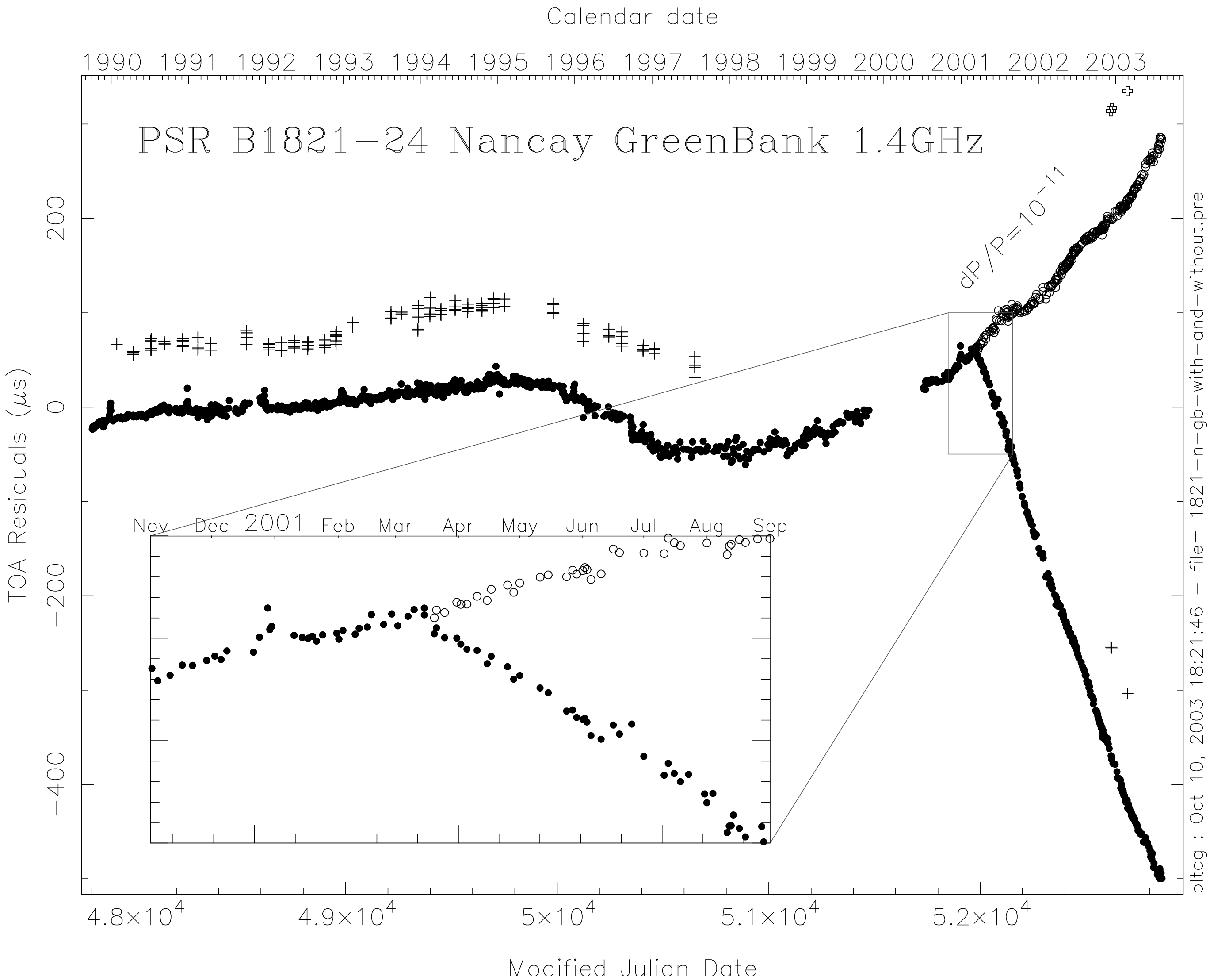

Figure 2. Small glitch in the 3-ms pulsar B1821−24, which is in the globular cluster M28, as reported by Cognard et al.