Is PSR B0656+14 a very nearby RRAT?

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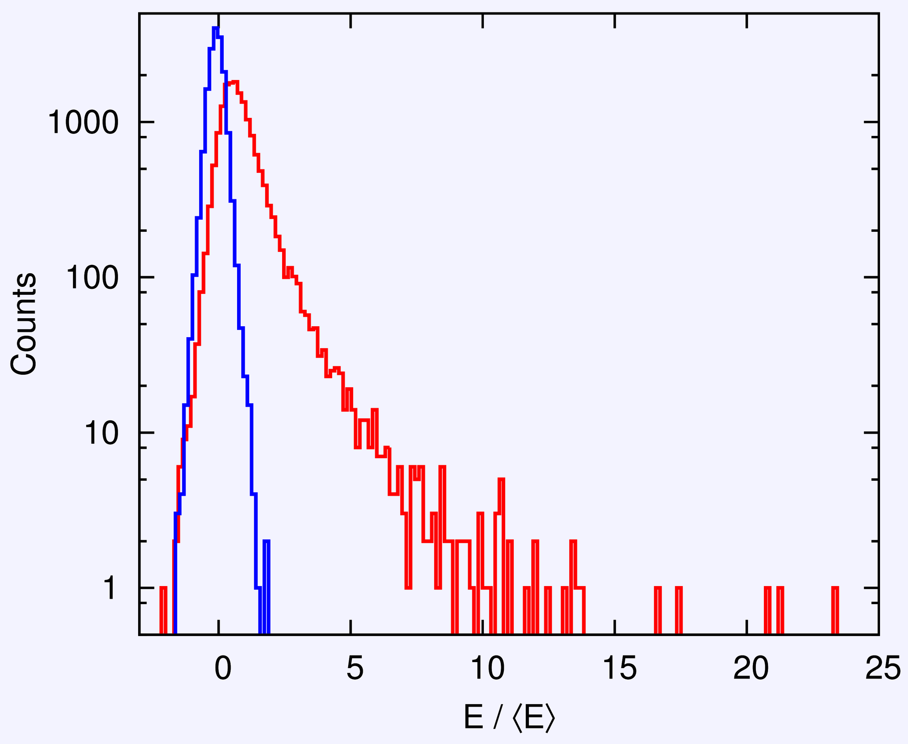
Exceptionally powerful pulses

Exceptionally powerful bursts of radio emission were found for PSR B0656+14 in a recent extensive survey of subpulse modulation by Weltevrede et al. (2006a). The results presented here are based on 40,000 pulses recorded in two 327-MHz observations using the 305-meter Arecibo telescope. In the following figure you see a pulse-energy distribution of PSR B0656+14 (red line) and the off-pulse distribution (blue line).



The brightest recorded pulse was about 116 times stronger than the average, which is outside the plotted energy-range and the highest measured peak-flux was 420 times the average peak-flux of the pulsed emission. Pulses this bright are very exceptional for radio pulsars.

Very bright, yet not "giants"

Based on the energy of the brightest pulses alone, PSR B0656+14 would fit into the class of pulsars that emit so-called giant pulses. However, the bright pulses of PSR B0656+14;

- have timescales much longer than the nanosecond timescale observed for giant pulses
- do not show a power-law energy-distribution
- are not confined to a narrow pulse window
- are not associated with an X-ray component
- are much brighter than giant micropulses.

This suggests differing emission mechanisms for the classical giant pulses and the bursts of PSR B0656+14.

References

McLaughlin, M. A., Lyne, A. G., Lorimer, D. R., et al., 2006, Nature, 439, 817

Weltevrede, P., Edwards, R. T. & Stappers, B. W., 2006a, A&A, 445, 243

Weltevrede, P., Stappers, B. W., Rankin, J. M. & Wright, G. A. E. 2006b, ApJ., 645, L149

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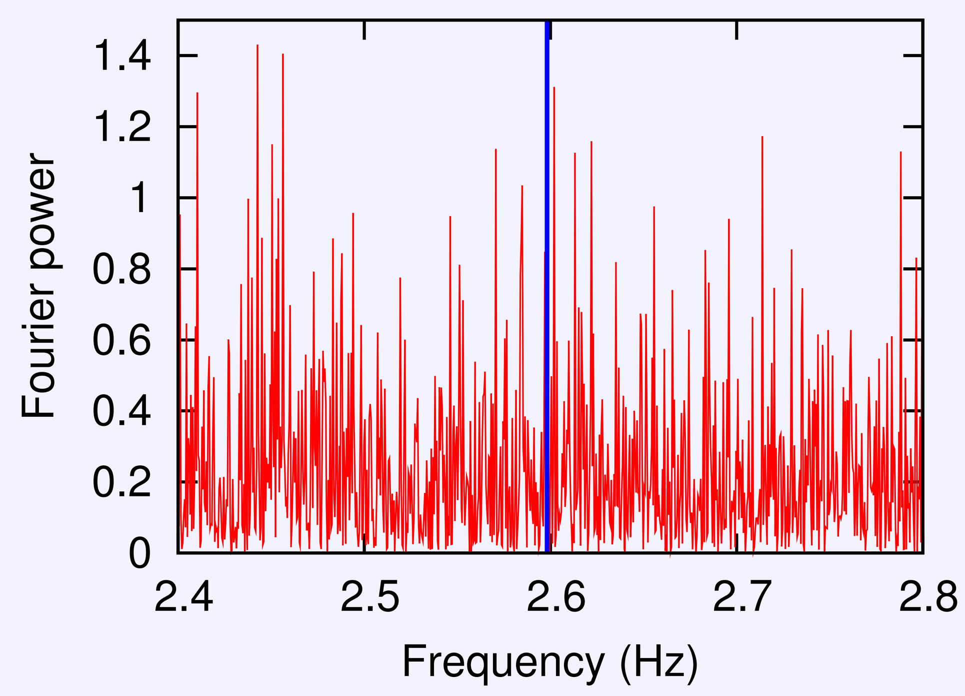
What are RRATs?

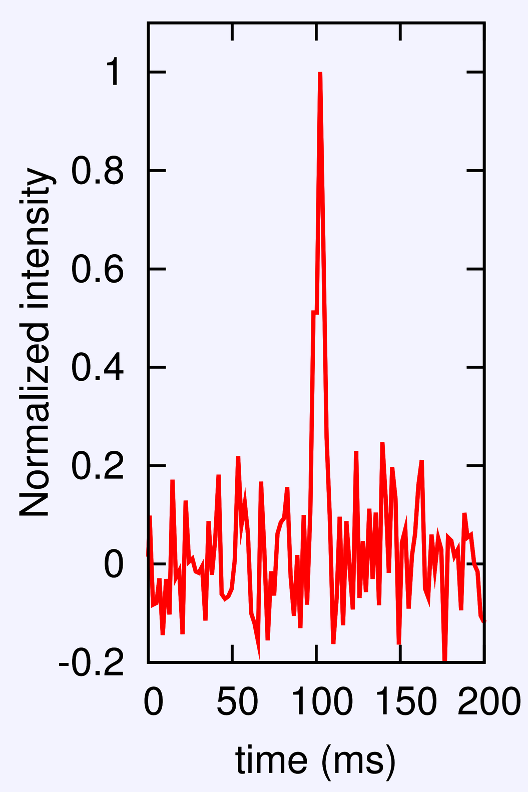
Recently a new population of bursting neutron stars were discovered. These Rotating RAdio Transients (RRATs; McLaughlin et al. 2006) typically emit detectable radio emission for less than one second per day, causing standard periodicity searches to fail in detecting the rotation period.

Why PSR B0656+14 is RRAT-like

The very nearby PSR B0656+14 (288 pc) occasionally emits extremely bright bursts of radio emission with luminosities typical for RRATs (Weltevrede et al. 2006b). When gaussian-distributed noise is added to the data, we can simulate what a more distant PSR B0656+14 would look like. Were PSR B0656+14 located twelve times farther away (at more typical distance), we would find no sign of the pulsar's (2.6-Hz) rotation frequency in 35-minute segments of the data:



However in the same data the brightest pulse would still be clearly detected (18σ).



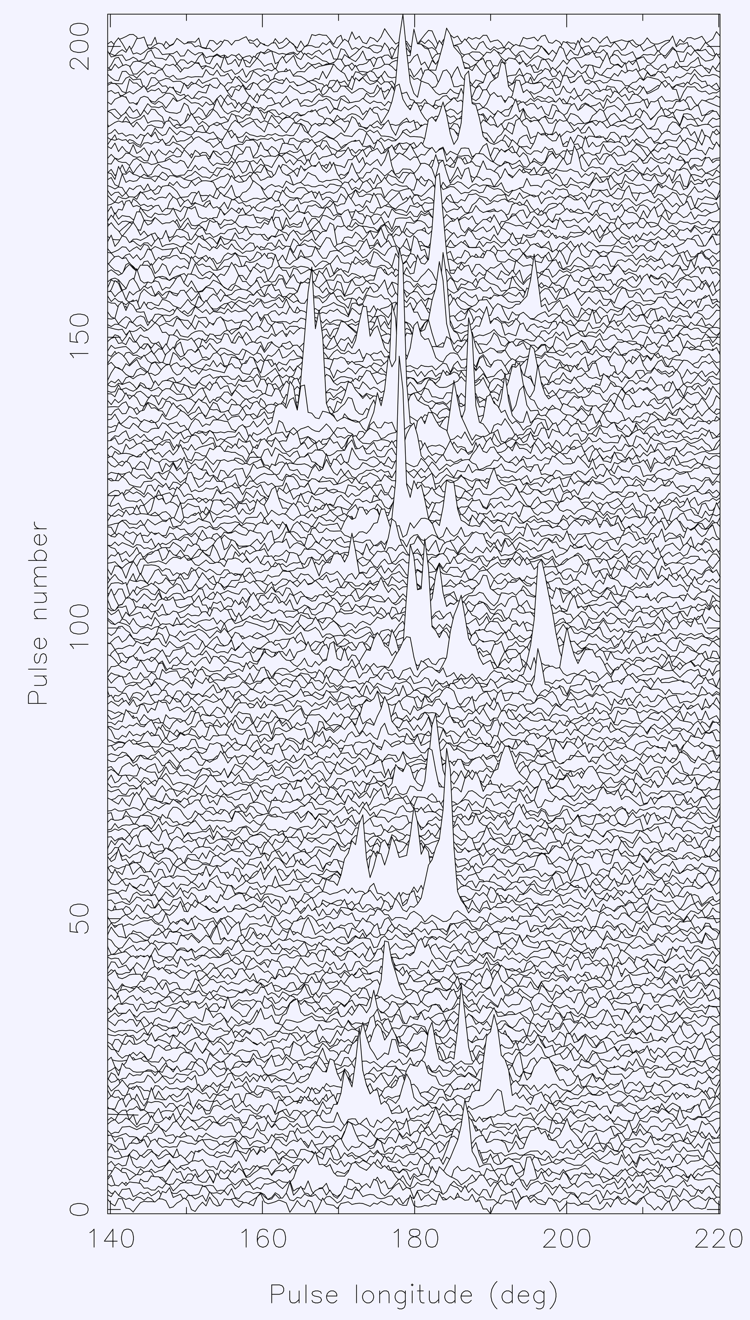
We estimate that at this distance only one burst per hour would be detectable. With burst rates found for the RRATs ranging from one burst every 4 minutes to one every 3 hours, this is a typical value.
Only in the spectrum of the whole 1.8-hour observation would the periodicity of a twelve times more distant PSR B0656+14 be marginally detectable for Arecibo. This means that a distant PSR B0656+14 could only be found as a RRAT in a survey using Arecibo, unless the pointings were unusually long.

Implications

Our identification of PSR B0656+14 with RRATs implies that at least some RRATs could be sources which emit pulses continuously, but over an extremely wide range of energies. This is in contrast to a picture of infrequent powerful pulses with otherwise no emission. Therefore, if it indeed turns out that PSR B0656+14 (despite its relatively short period) is a true prototype for an RRAT, we can expect future studies to demonstrate that RRATs emit much weaker pulses among their occasional bright bursts.
We would also predict, as we have found for PSR B0656+14, that their integrated profiles will be far broader than the widths of the individual bursts and will need many thousands of bursts to stabilize.

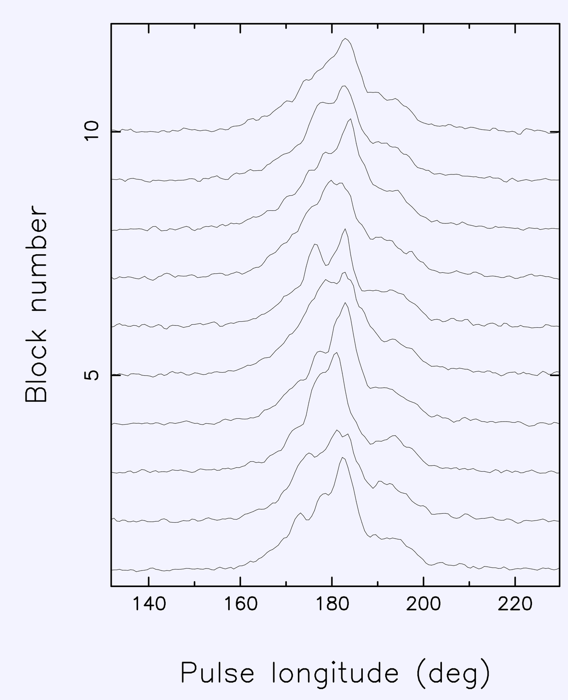
Spiky emission

Weltevrede et al. 2006c find that the emission of PSR B0656+14 can be characterized by two different types: "spiky" and weak emission. The bright pulses consist of short quasi-periodic bursts with microstructure and have a narrow "spiky" appearance, in contrast to the underlying weaker broad pulses. In the following pulse-stack there is about three times more energy in the weak emission (hidden below the noise) than the spiky emission.



Profile instability

The shape of the pulse profile requires an unusually long timescale to achieve stability (over 25,000 pulses at 327 MHz) caused by the spiky emission. This instability is illustrated in the following plot in where profiles of ten successive blocks of one thousand pulses each are plotted.



If this kind of spiky emission is typical for RRATs, their integrated profiles will be far broader than the widths of the individual bursts and will need many thousands of bursts to stabilize.

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