Pulsar Astrophysics the Next Fifty Years
Proceedings IAU Symposium No. 337, 2017
P. Weltevrede, B.B.P. Perera, L.L. Preston
& S. Sanidas, eds.

doi:10.1017/S1743921317009164

Mode changing in the Black Widow Pulsar

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Abstract. Mode changing is a phenomenon where a pulsar's emission abruptly changes between two or more quasi-stable modes. We have discovered mode changing in the Black Widow Pulsar (PSR B1957+20), a first detection of mode changing in a millisecond pulsar. On average, a mode change occurs every 1.7 seconds. Multiple components across the pulse profile participate in the mode changing, indicating that this is likely caused by a global change in the pulsar's magnetosphere.

Keywords. (stars:) pulsars: individual (PSR B1957+20), stars: neutron

1. Overview

Some pulsars are known to exhibit mode changing behaviour in their radio pulse emission. Mode changing is a phenomenon where a pulsar's mean pulse profile abruptly changes between two or more quasi-stable modes and has been observed in about a dozen or so slow pulsars (Backer (1970), Wang *et al.*, 2007). In our Arecibo observations (at 327 MHz) of PSR B1957+20, the Black Widow Pulsar, we have made a first detection of mode changing in a millisecond pulsar. The specifics of these observations are described in detail in Main *et al.*, 2017. In Figure 1, we show our results.

We have detected the pulse profile of PSR 1957+20 switching between two modes of emission, a High Mode and a Low Mode, where the latter is the mode exhibiting lower flux. The average length of time between mode changes is 1.7 seconds, much faster than mode changing phenomena observed previously in other pulsars (see the *Top* panels of Figure 1). We define a "metric function" that determines which mode a specific individual pulse is in by multiplying the pulse profile of an individual pulse by the difference profile (shown in the *Bottom Left* panel of Figure 1). This "metric function" is then used to determine which individual pulses belong to which mode. A histogram of this metric clearly shows a bimodal distribution, indicating the presence of two emission modes. The pulse profiles of the two modes show that the interpulse, the main pulse and additional pulse components exhibit changes between the modes. This is further evidence that mode changing is likely a global process in the pulsar's magnetosphere (as posited by Cordes (2013) and Timokhin (2010)).

A more in-depth analysis of the mode changing in PSR B1957+20 can be found in a forthcoming paper (Mahajan *et al.*, in prep).

References

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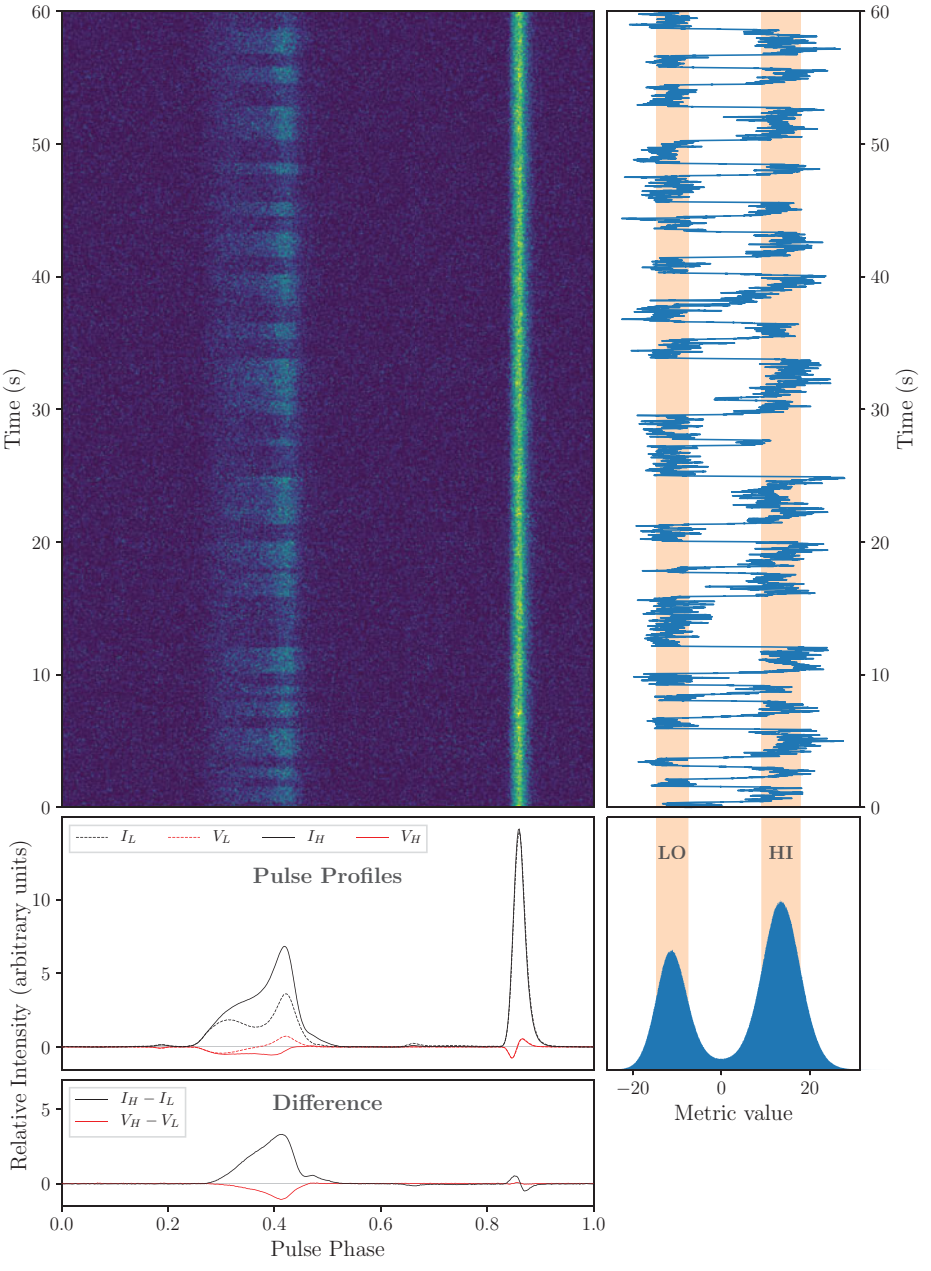

Figure 1. Mode changing in the Black Widow Pulsar. *(Top Left):* Phase-time plot for 60-second chunk of data. Every horizontal row of pixels represents the average pulse profile over 50 pulse periods. The colour-scale is linear in intensity. *(Middle Left):* The pulse profile of the pulse emission in the High Mode (H) and Low Mode (L). The I and V Stokes parameters are plotted. *(Bottom Left):* The difference between the two modes in both I and V. *(Top Right):* The "metric function" for the 60s chunk of data displayed to the left (with a uniform filter of length 50 pulses applied to suppress the noise). *(Bottom Right):* A histogram of the metric function (over the entire dataset). The faint vertical bars represent the 1σ range about the two peaks if the histogram was fit by a sum of two Gaussian peaks. The High Mode (HI) on the right and the Low Mode (LO) on the left.