

An ESE Event For PSR 0329+54

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Abstract. Space Very Long Baseline Interferometry observations of PSR 0329+54 which, by luck, occurred during an interstellar fringing event are presented. Multiple images of the pulsar were not detected. However, the pulsar was observed to have enhanced angular broadening during this event. The angular broadened size of PSR 0329+54 during this event is 1.88×1.67 mas with a position angle of 30° East of North, which is larger than the expected value of < 0.1 mas from the observations of Britton, Gwinn & Ojeda (1998).

Keywords: plasmas – scattering – turbulence – pulsars: individual: PSR 0329+54
- - ISM: general

1. Introduction

Extreme scattering events (ESEs) are thought to occur when a “plasma lens” lies nearly along the line of sight to a radio source (Clegg, Fey and Lazio, 1998). It is generally believed that interstellar fringing in pulsar dynamic spectra are also the result an ESE event in which two or more dominant ray-bundles reach the Earth from the pulsar (Rickett, Lyne, & Gupta, 1997). Under such conditions, two or more images of the pulsar should be present when mapped at an angular resolution of a few milli-arcseconds or less (Rickett, Lyne, & Gupta, 1997). The observations presented in this paper are the first high angular resolution images made of a pulsar during an interstellar fringing event. Multiple images of PSR 0329+54 are not observed. However, “enhanced” angular broadening is observed.

2. Observations

The pulsar PSR 0329+54 was observed on August 22, 1998 from 6^h to 18^h UTC using Space Very Long Baseline Interferometry (SVLBI) (Hirabayashi, *et al.*, 1998). The NRAO’s 140 Foot telescope was also used to make simultaneous “single dish” observations of PSR 0329+54 during the SVLBI observations. The single dish observations had a total bandwidth of 70 MHz with a resolution of 0.078125 MHz. The SVLBI observations have a total bandwidth of 32 MHz and a resolution of



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0.125 MHz. The SVLBI observations were correlated using the “pulsar gating” mode of the VLBA correlator. The gate had a width of 15% of the pulsar period and was centered on the center of the main pulse.

3. Interstellar Fringing Event

The dynamic spectrum of the peak of the pulsar emission from the 140 Foot observations is shown in Figure 1a. The normalized auto-correlation function of the dynamic spectrum is shown in Figure 1b. The interstellar fringes can be seen as the periodic bright “scintles” that go from the lower right to the upper left in Figure 1a. A solid line is shown in Figure 1a which indicates the direction of the fringes. The expected drift of the scintillation pattern is also obvious – being from the lower left to the upper right in Figure 1a.

The measured scintillation bandwidth and timescale during this observation were found to be $\nu_d = 5.1 \pm 0.1$ MHz (HWHM at $\delta t = 0$) and $\tau_d = 1100 \pm 50$ seconds (e^{-1} half width at $\delta f = 0$), respectively. The fringe periods for the peak of the pulse profile were determined to be 3223 ± 170 seconds along the time axis and -3.18 ± 0.06 MHz along the frequency axis from the auto-correlation function. Since the fringe periods and the diffractive scintillation timescales and frequencies are similar in magnitude, it is not possible to use the “secondary spectrum” (Rickett, Lyne, & Gupta, 1997) to find the fringe peak since it is confused with the DISS. The auto-correlation function was thus used to determine the fringe periods since the fringe peak and the DISS are not confused in this function. Following the arguments in Rickett, Lyne, & Gupta and using $D \sim 1.43$ kpc (Taylor, Manchester, & Lyne, 1993), it can be estimated that the multiple images producing the fringing during the August 22, 1998 PSR 0329+54 observations should have a separation $\delta\theta \geq 0.35$ mas.

In Figure 2a, I show the image derived from the entire SLVBI data set after self-calibration. The SVLBI data set has a resolution of 1.67×1.12 mas with a position angle of -5.7° (East of North). Figure 2b shows the flux versus UV distance for the data set. Multiple images of PSR 0329+54 are not observed at this resolution. However, PSR 0329+54 is not a point source either. A single elliptical Gaussian is able to provide a good fit to the image. The best fit elliptical Gaussian has a major axis of 1.88 ± 0.01 mas, a minor axis of 1.67 ± 0.01 mas and a position angle of $30^\circ \pm 3$ (E of N).

If the extended source size of PSR 0329+54 is the result of multiple images of the pulsar which are not resolved then the image separation is $\delta\theta \lesssim 0.5$ mas.

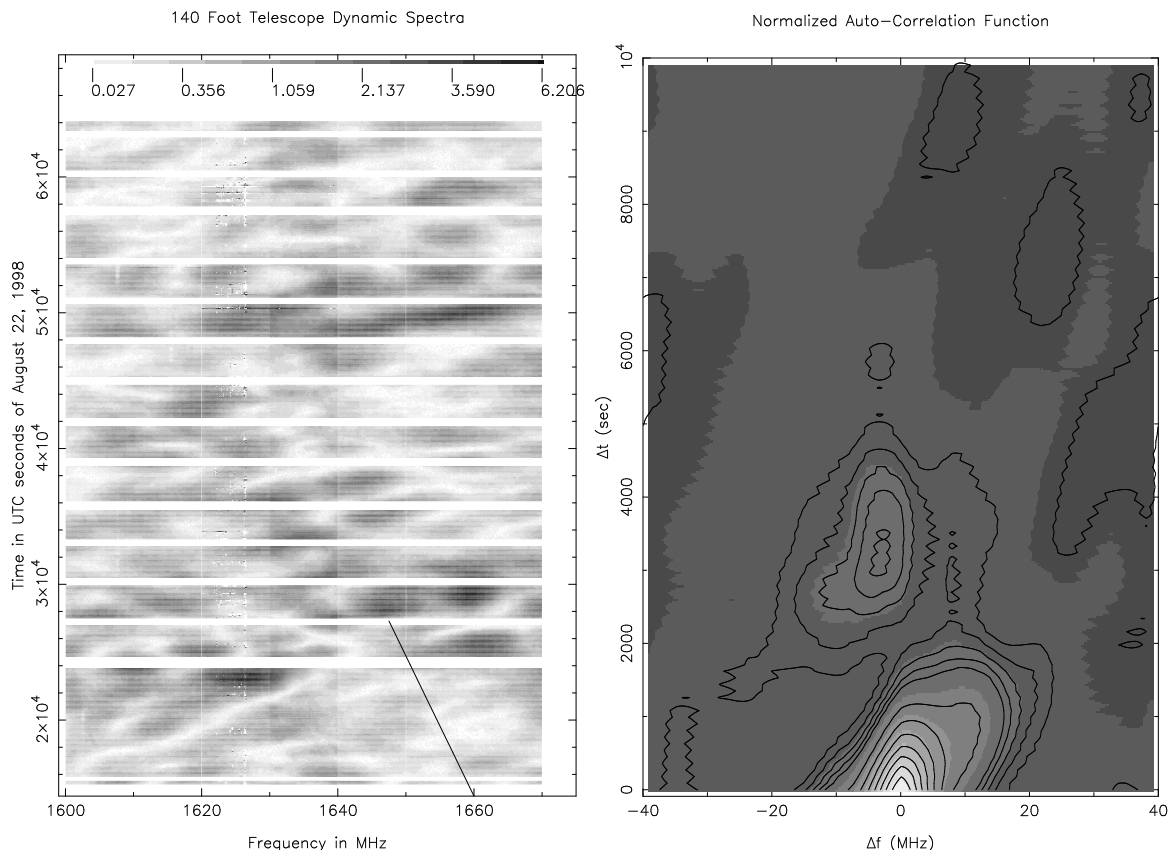


Figure 1. Dynamic spectra from the 140 Foot single dish data (a) and its normalized auto-correlation function (b). The line in the dynamic spectra indicates the direction of the fringes. The flux scale, in Jy, is given in the upper portion of (a). Interference from the Iridium satellites is clearly visible in (a). The contours in (b) are 0.0, 0.1, 0.125, 0.15, 0.175, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 0.9.

Britton, Gwinn & Ojeda (1998) determined that the angular broadening of PSR 0329+54 was < 3.4 mas at 330 MHz. Scaling this to 1650 MHz, the Britton, Gwinn & Ojeda angular broadening limits corresponds to < 0.1 mas. If the extended source size of PSR 0329+54 during the fringing event is due to DISS, then we are observing enhanced angular broadening during the ESE. This is also what was observed for PKS 1741-038 during an ESE (Lazio, Fey & Gaume, 2000).

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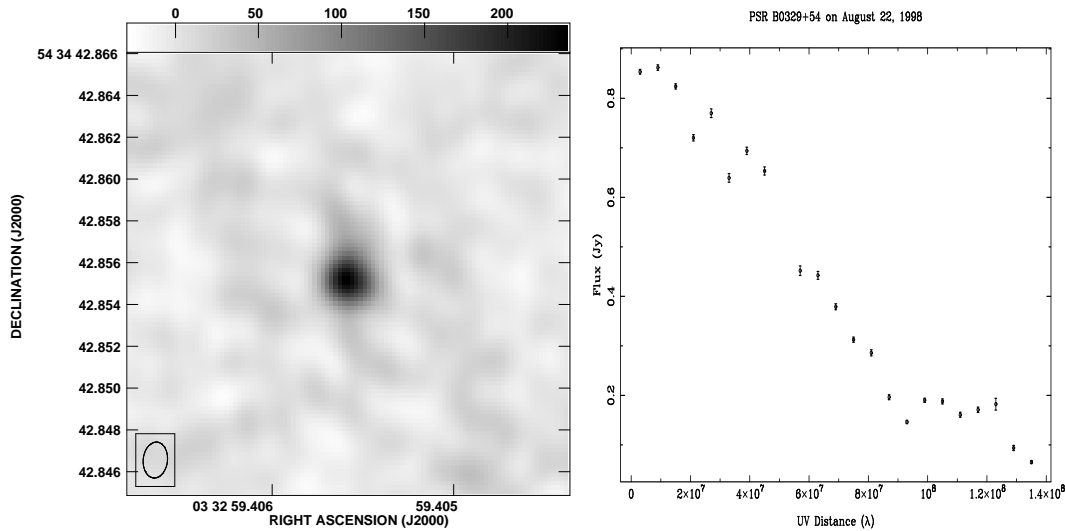


Figure 2. Image of PSR 0329+54 from the Space-VLBI observations during the interstellar fringing event (a). Flux vs. UV distance (b) determined from averaging within equally spaced radial bins in UV distance.

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