T.J. Galama, J. van Paradijs, A.G. de Bruyn, L. Hanlon and K. Bennett

Unusual Increase in the 325 MHz Flux Density of PSR B0655+64

Abstract

We detected a large amplification of the flux density of PSR B0655+64 at 325 MHz (a factor of $\sim$ 43) lasting about one hour and restricted to a very narrow bandwidth (3.6 ± 0.4 MHz). The decorrelation bandwidth and duration are in agreement with the values expected for diffractive interstellar scintillation. However, the observed amplification of the flux density of PSR B0655+64 is too large. The extreme flux density amplification of PSR B0655+64 might be explained in terms of caustics.

I Introduction

Irregular plasma refraction by the interstellar medium between the source and the observer cause scintillation of the source. The scintillation occurs on two distinct scales. Variations on time scales of minutes to hours are caused by the familiar diffractive interstellar scintillation (DISS). Variations on time scales of days to months are produced by refractive interstellar scintillation (RISS). Apart from "ordinary" scintillation strongly non-Gaussian "spikes" have been reported in long-term pulsar flux monitoring (e.g., Cole et al. 1970; Helfand et al. 1977). Goodman et al. (1987) argued that these might be due to strong focusing events or caustics. Another type of strong refractive focusing, so-called Fiedler events, have been observed in radio quasars (Fiedler et al. 1987). In the most dramatic event Fiedler et al. observed intensity increases of roughly threefold on refractive time scales.

In this paper we report on the discovery of a very large amplification of the flux density of PSR B0655+64 at 325 MHz. A more extensive treatment can be found in Galama et al. (1997).

II Observations and data reduction

The event was discovered serendipitously in data taken in a GRB follow-up project with the Westerbork Synthesis Radio Telescope. The data cover a period of three

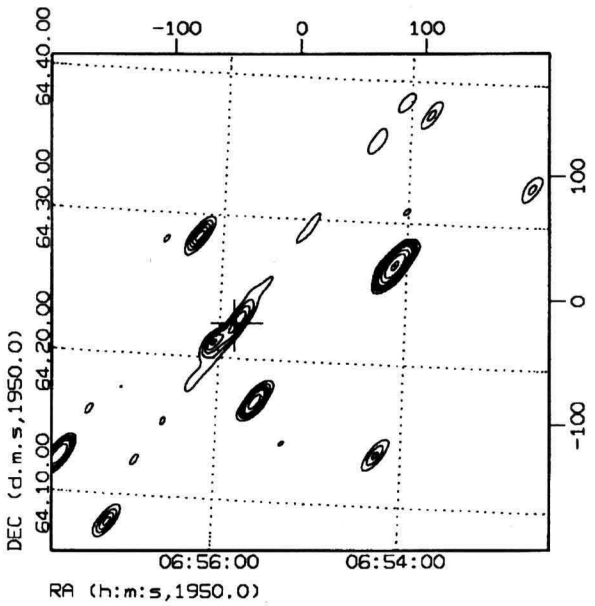

Figure 1. Contour plot of a WSRT image at 325 MHz. The position of PSR B0655+64 is indicated by the cross. The plot shows the elongated structure of PSR B0655+64 in the image of June 25. Contour levels are 15, 30, 45, 60, 75, 120, 240, 480, 960, and 1075 mJy. Map noise is 3.6 mJy (1σ).

months (April–June 1994; additional observations January 15 and 16, 1996). The WSRT is an East-West array consisting of 14 parabolic dishes, each 25 m in diameter. The data were reduced using the Netherlands East-West Synthesis Telescope Array Reduction package (NEWSTAR).[1]

III Results

In a map obtained from data of June 25, 1994, we noticed a faint straight elongated structure, repeating itself at the grating response distances (see Figure 1). The feature was detected with all interferometers. The elongated image response is that of an object that flared for only a short period of time. The feature and the binary pulsar PSR B0655+64 coincide to within $1\farcs3$ in the direction perpendicular to the elongation. Smoothed light curves of PSR B0655+64 are shown in Figure 2. The phenomenon

[1] See URL `http://www.nfra.nl:80/newstar/`.

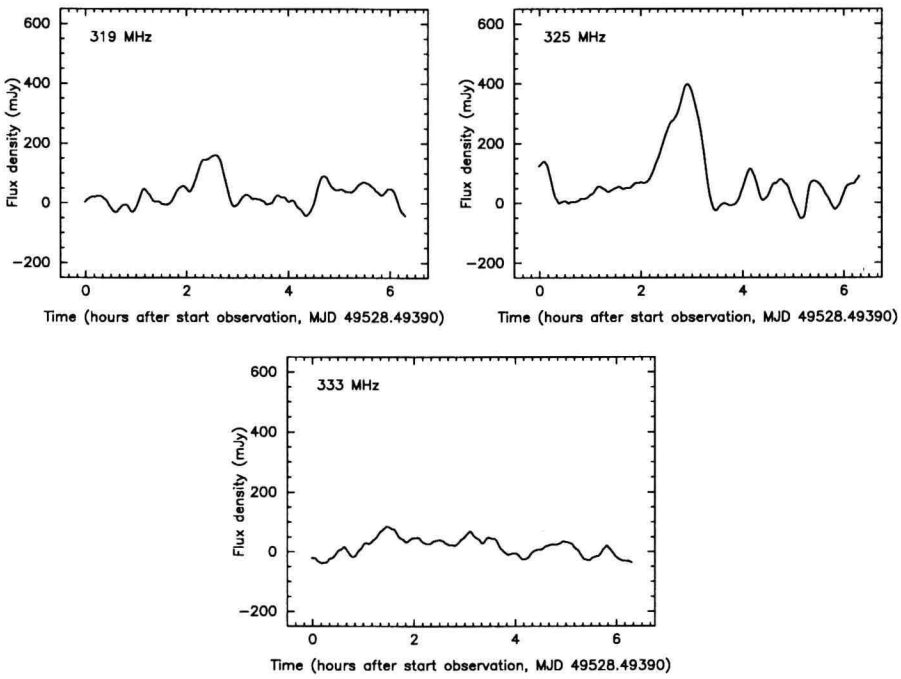

Figure 2. Light curves of the source at the position of PSR B0655+64 from the 92 cm observations of June 25, smoothed with a triangular function of 14 min. full-width at half maximum. From upper-left to lower-right corner: 319.3, 325, and 333 MHz. R.M.S. noises are 40, 55 and 35 mJy (1σ), respectively.

is restricted to a very narrow bandwidth (see Fig. 2). The decorrelation bandwidth was derived to be 3.6 ± 0.4 MHz (see Galama et al. 1997). A non-smoothed (1 min. integration) 325 MHz light curve of PSR B0655+64 shows a peak of 580 mJy (5.8σ), and a duration of about one hour. This yields an amplification of a factor 43 ± 9 (compared to an average derived from the data, excluding the observation of June 25; compared to Lorimer et al.'s 1995 flux density values we have a factor of 69 ± 23).

IV Discussion

The decorrelation bandwidth and characteristic time scale of the variation are in good agreement with the values expected for diffractive interstellar scintillation (compared with Lyne's 1984 values, assuming a Kolmogorov spectrum of the interstellar turbulence). However, the observed amplification of the flux density of PSR B0655+64 is too large to be explained by this mechanism. Perhaps the observed flux density amplification can be explained in terms of a caustic (strong focusing event; Goodman

et al. 1987). Caustics can explain a larger amplification (a factor < 40). Caustics are rare events, lasting about a refractive time scale ($\sim$ 3 days for PSR B0655+64). This explains the lack of similar events on other days. However, even caustics, as produced by a "normal" interstellar medium (e.g., the model of Goodman et al. 1987) can not satisfactorily explain the huge increase we observed.

Acknowledgements

We thank Prof. Narayan for a fruitful discussion on caustics and Dr. Ramachandran for comments. We are grateful for the assistance of the WSRT telescope operators T. Spoelstra and R. de Haan.

References

Cole, T.W., Hesse, H.K. & Page, C.G. 1970, Nature, 225, 712
Fiedler, R.L. et al. 1987, Nature, 326, 675
Galama, T.J. et al. 1997, A&A, 325, 631
Goodman, J.J. et al. 1987, MNRAS, 229, 73
Helfand, D.J., Fowler, L.A. & Kuhlman, J.V. 1977, AJ, 82, 701
Lorimer, D.R. et al. 1995, MNRAS, 273, 411
Lyne, A.G. 1984, Nature, 310, 300

Authors' Addresses

T.J. Galama & J. van Paradijs: Astronomical Institute 'Anton Pannekoek'. Kruislaan 403, 1098 SJ, Amsterdam, the Netherlands

A.G. de Bruyn: NFRA. Postbus 2, 7990 AA, Dwingeloo, the Netherlands

L. Hanlon & K. Bennett: Astrophysics Division, ESTEC. Noordwijk, the Netherlands