# PULSAR INTERFEROMETRY WITH MICROARCSECOND RESOLUTION

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ABSTRACT. An 'interstellar interferometer' related to a double imaging of the pulsar PSR 1237+25 by refraction in the interstellar medium has been used to resolve the pulsar magnetosphere for the first time. With an interferometer baseline $\sim 1\ AU$, we have measured a typical transverse separation between the emitting regions of PSR 1237+25 to be $\sim\ 10^8$ cm, or an angular separation $\sim 0.02\ \mu$as.

Refractive effects can significantly modify the interstellar scintillation patterns arising from diffractive scatter of pulsar signals propagating through the interstellar medium (e.g. Hewish et al. 1985; Cordes and Wolszczan 1986). Strong refraction events sometimes split the apparent pulsar image into two or more distinct subimages. The resultant dynamic spectra (intensity as a function of time and frequency) are the superposition of separate patterns from each subimage combined with oscillatory cross terms caused by beating between subimages. The oscillatory terms are equivalent to fringes obtained with an interferometer baseline $\sim 1\ AU$, sufficiently large to potentially resolve the pulsar magnetosphere (Cordes et al. 1986).

The dynamic spectra of PSR 1237+25 observed in December 1986 at 430 MHz with the Arecibo radiotelescope and with the 3-level, 40 MHz correlation spectrometer are shown in Fig. 1a. They display a strikingly periodic intensity modulation as a function of time and frequency. A model to explain this modulation (Wolszczan and Cordes 1987 and references therein) consists of a thin screen in which refractive phase variations are strong enough to give rise to a pair of diffracted subimages of the pulsar. Beating between subimages leads to oscillations (fringes) in the dynamic spectra, best characterized by the oscillation period in frequency, $P_\nu$. The transverse displacement of a source by a distance $\delta x_s$ shifts the observed fringes by approximately $\delta\phi \approx 3 \cdot 10^{-5}\nu\delta x_s[(D/D_s - 1)/DP_\nu]^{1/2}$ radians, where $\nu$ is the observing frequency, D is the pulsar distance and $D_s$ is the distance between the pulsar and the screen. Fringe shifts may arise, if different pulse components are emitted from locations that are separated in the transverse direction (e.g. Cordes et al. 1983). We have resolved such separations by detecting fringe phase shifts in the dynamic spectra of PSR 1237+25 at different pulse longitudes (one pulsar period equals 360° longitude) as shown in Fig. 1b,c. The range of spatial separations of the emission regions calculated for $D = 2D_s$ is indicated on the right hand side of Fig. 1c. For a dipolar magnetic field and emission at a constant altitude,



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the fringe phase should be *symmetric* with respect to the pulse centroid and it should monotonically increase through the origin. This is in contradiction to the measurements, suggesting that the magnetic field of PSR 1237+25 may deviate strongly from a dipolar form in the emission region and emission altitudes may vary such that transverse separations are much larger for a given pulse longitude than implied by the dipole model. Alternatively, the refracting screen may be located much nearer the pulsar than the Earth ($D \gg D_s$), which would lead to transverse separations much smaller than for the screen that is midway ($D = 2D_s$).

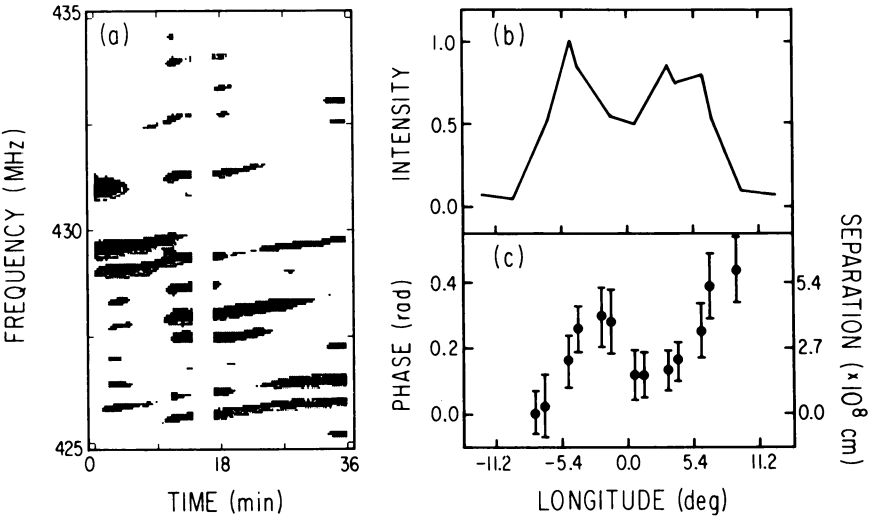


Fig. 1. PSR 1237+25: *(a)* Dynamic spectrum, *(b)* integrated pulse profile and *(c)* fringe phase as a function of pulse longitude.

In addition to resolving the pulsar magnetosphere, our measurements suggest that a discrete refracting structure of size $> 1$ AU crossed the line of sight, producing a predominantly double image of the pulsar with a splitting angle between subimages of about 3.3 mas. This episode may be similar in origin to recent caustic events seen in the light curves of compact extragalactic radio sources (Fiedler *et al.* 1987).

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