INTERSTELLAR SCATTERING TOWARDS CYG X-3

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MERLIN observations at 0.408 GHz of the December 1985 outburst of Cyg X-3 have enabled us to characterise the angular broadening, caused by interstellar scattering, very accurately. The scattering along the line of sight towards Cyg X-3 is exceeded by only two other lines of sight through the Galaxy: towards the Galactic centre (see e.g. Lo et al. 1985. Nature, **315**, 124) and towards NGC 6334 (Rodriguez et al. 1982. Astrophys.J., **225**, 103); as a result quite short baselines are needed to study the scattering disk at 73 cm wavelength (0.408 GHz). The projected MERLIN baselines for our observations cover the range from a few km (on which the source was unresolved and had a correlated flux density ∿3.6 Jy) to ∿130 km (on which the source was totally resolved i.e. a correlated flux density $\leq$0.030 Jy). The basic result from these observations is that over this range of baselines the scattering appears to be purely diffractive in character. The scattering disk is, to quite a good approximation, a circular gaussian and shows no evidence of fine scale substructure. Model fitting to the visibility amplitudes, assuming circular symmetry, yields $\theta_{0.408\mathrm{GHz}} = 2.85\pm0.05$ arcsec (FWHM).

However a detailed examination of the data reveals deviations from this simple picture. There is a hint of dipolar distortion (axial ratio 0.93±0.03) in the N-S direction and a slight but significant deviation from a gaussian profile. We have characterised this latter effect quantitatively as follows: for a power law spectrum of turbulence the normalised fringe visibility $\gamma = \exp - (\mathrm{baseline})^n$ thus a plot of $\log(-\ln(\gamma))$ against log (baseline) should yield a straight line with slope n. Here the baseline is measured in wavelengths and the usual power law index β corresponds to n+2 (see the review article by Rickett and Coles in this volume). The MERLIN 0.408 GHz data were plotted in this way out to 100,000 wavelengths (i.e. ∿73 km) at which point the fringe amplitude drops below the noise and the data begin to deviate sharply from a straight line. The data with good signal-to-noise ratio are well fitted by a line with slope $n = 1.88\pm0.05$ (i.e. $\beta = 3.88\pm0.05$). This is to be compared with $n = 1.67$ (i.e. $\beta = 11/3$) for the classical Kolmogorov spectrum.

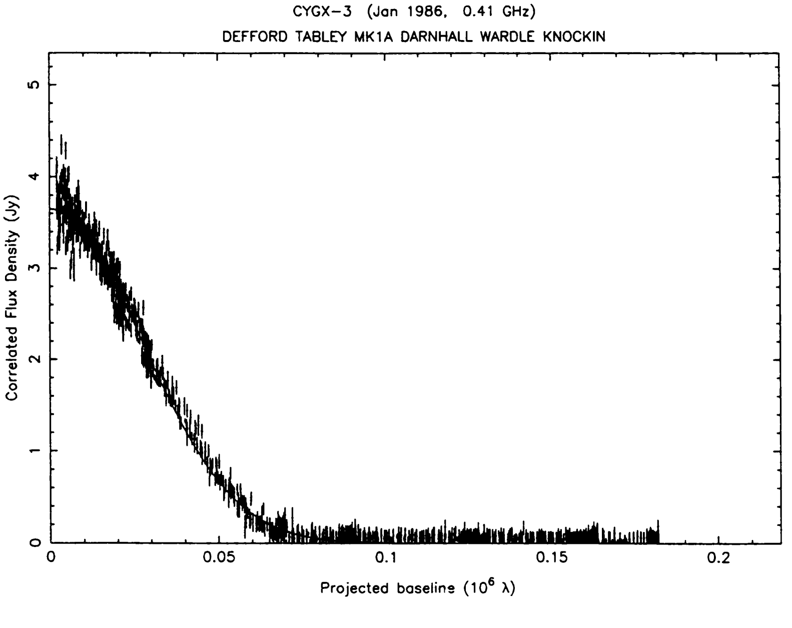
On the basis of diffractive scattering theory the wavelength dependence of the scattering diameter is $\lambda^{\beta/(\beta-2)}$ (e.g. Romani et al.,

M. J. Reid and J. M. Moran (eds.), The Impact of VLBI on Astrophysics and Geophysics, 305–306.

1986, Mon.Not.R.astr.Soc., 220, 19) the predicted dependence is, therefore, $\lambda^{2.06\pm0.03}$. MERLIN observations of Cyg X-3 at 1.66 GHz enable us to measure this wavelength dependence directly even though we were only able to observe the source in its quiescent mode (flux density 0.057 Jy). Fitting a circular gaussian model to the visibility amplitudes yields $\theta_{1.66GHz}$ = 0.154±0.010 arcsec (FWHM) from which we infer that the exponent of the wavelength dependence is 2.08±0.05 i.e. consistent with the value derived from the shape of the scattering disk at 0.408 GHz alone. Note that the expected size at 1.66 GHz for the β = 4.00 case is 0.172±0.003 arcsec while that for β = 11/3 is 0.130±0.002 arcsec. Both are inconsistent with the present 1.66 GHz data, especially the β = 11/3 case.

Re-analysis of the Jodrell Bank data taken at the time of the 1972 outburst (Anderson et al. 1972, Nature Phys.Sci. 239, 117) yields $\theta_{0.408GHz}$ = 2.7±0.3 arcsec. The size of the scattering disk has not changed by more than ∿10% in the last 15 years.

MERLIN observations of Cyg X-3 during future outbursts should enable us to image the scattering disk directly at 0.408 and 1.66 GHz and to constrain β even more closely.



The MERLIN fringe amplitude at 0.408 GHz (in Jy) plotted against projected baseline (in Mλ). The larger scatter on the short baseline data is due to confusion from the Cygnus X region. The signal-to-noise ratio falls below unity just before 0.1 Mλ and so the right hand half of the plot represents only thermal noise. The solid line shows the Fourier transform of a circular gaussian of total flux 3.65 Jy and diameter (FWHM) 2.85 arcsec.