Limits on Refractive Interstellar Scattering of H_2O Masers

C.R. Gwinn, J.M. Moran, M.J. Reid and M.H. Schneps
Harvard-Smithsonian Center for Astrophysics

We limit the spectral index of density fluctuations in the interstellar plasma by comparing maser sizes, due to small-scale fluctuations, with wander of masers from constant velocity, possibly due to refraction by large-scale fluctuations. The wander of the masers about constant-velocity motion limits power-law spectra of the fluctuations to indices less than 4.0.

1. INTRODUCTION

Refractive effects in interstellar scattering have recently attracted much interest, motivated by the possibility that they may explain low-frequency variability of quasars and pulsars, and flicker of quasars at decimeter wavelengths (Rickett, Coles and Bourgois 1980). Large-scale ($\approx 10^{14}$ cm) density fluctuations could produce the observed effects by focusing or defocusing radiation from the sources. Such fluctuations should also act as prisms, producing an apparent time-variable deflection of the source. We place limits on such deflections.

2. OBSERVATIONS AND ANALYSIS

The data discussed here were obtained from three VLBI observations of the water masers in Sgr B2(N) over a period of six months. We used antennas at Haystack, Green Bank, the VLA and Owens Valley. The minimum fringe spacing was 700 microarcseconds (μas). We phase-referenced all frequency channels to a reference channel, and mapped the masers with fringe-rate mapping. We determined sizes and more precise positions by fitting in the (u, v) plane. We then removed differential precession and nutation, and fitted for proper motions. Since the beam was elongated in declination, our fits were much more accurate in right ascension, and we discuss that coordinate here. Estimated random and systematic errors were less than 10 μas.

The fitted sizes of the masers in Sgr B2(N) ranged upward from a sharp cutoff at 300 μas (FWHM), which we ascribe to interstellar scattering. It is consistent with sizes of OH masers in Sgr B2 at 18 cm and the scaling of size θ with wavelength λ as $\theta \propto \lambda^2$ expected for interstellar scattering (Moran 1968), and is larger than minimum sizes in closer maser clusters.

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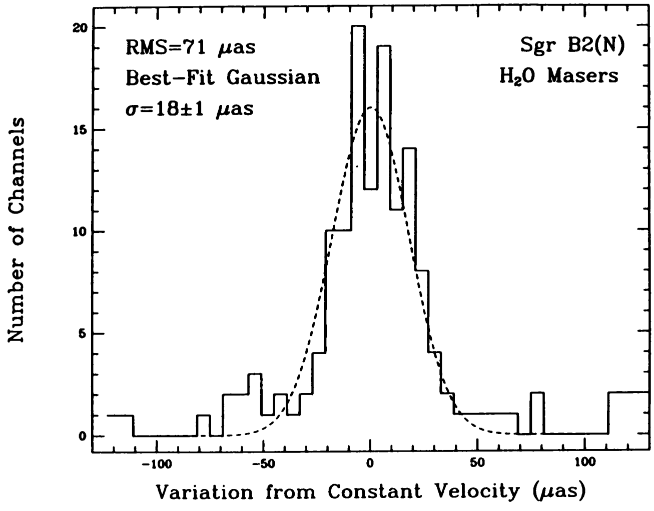

Figure The histogram shows residuals for the fits to constant-velocity motions for H_2O masers in Sgr B2(N); the dashed line shows the best-fitting Gaussian distribution.

We fit constant-velocity motions to positions of maser features in 49 frequency channels and positions on the sky, which appeared at all three epochs with flux densities of 3 Jy or more. The fitted motions are consistent with physical motions of the masing clouds (Reid *et al.* 1987). The figure shows a histogram of the residuals, corrected for the reduction in rms by the fit. The best-fitting Gaussian, which is sensitive to the width of the central peak, has a standard deviation of $18 \pm 1\mu$as. Maser wander due to refractive effects is generally taken to be a Gaussian process, as would result from the incremental effects of many scattering screens along the line of sight. We can place an upper limit of 20 μas on any such wander. The wander is expected to be of the order of the scattering disk size for power-law density fluctuation spectra with indices greater than 4.0 (Rickett 1986), so the index must be less than that. Comparison with quantitative theory favors the Kolmogorov index of 3.67 (Romani, Narayan and Blandford 1986).

3. CONCLUSIONS

The scattering size and observed wander for H_2O masers in Sgr B2 require any power law spectrum to have an index of less than 4.0, and are consistent with a Kolmogorov spectrum of density fluctuations.

4. REFERENCES

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