INTERSTELLAR BROADENING OF COMPACT LOW GALACTIC LATITUDE RADIO SOURCES

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1. INTRODUCTION

Scattering of radio waves off inhomogeneities in electron density in the interstellar medium can produce an apparent broadening in the angular diameter of an intrinsically compact background radio source. The magnitude and distribution of this effect at low galactic latitudes ($|b|<5^{\circ}$) is not well known, although several cases suggest substantial broadening in certain directions, such as the Cygnus X region (Anderson et al. 1972), and the galactic center (Davies, Walsh, and Booth 1976). Large scattering in the plane is consistent with the scintillation properties of pulsars seen through substantial thicknesses ($\gtrsim$ 1 kpc) of the galactic disk.

2. SURVEY RESULTS

To further study interstellar broadening and its galactic longitude dependence, we recently surveyed 30 low-latitude compact extragalactic sources using the Bonn 100-m radiotelescope and the Jodrell Bank Mk IA radiotelescope as a VLB interferometer at 408 MHz. Most of the sources were taken from the Clark and Crawford (1974) survey of small-diameter, low-latitude sources. In preliminary NRAO Green Bank interferometer observations, we identified for special emphasis those Clark and Crawford sources which are unresolved on baselines of $\sim 3 \times 10^5$ λ and $\sim 10^6$ λ at 2695 and 8085 MHz. (The Bonn-Jodrell Bank baseline is $\sim 10^6$ λ at 408 MHz). The VLBI results for these sources are shown in Fig. 1.

The sources are grouped in two ranges of galactic longitude. In the longitude range, $195^{\circ} < \ell < 235^{\circ}$ we found two measurably broadened sources (as evidenced by their gaussian visibility curves), eight cases in which the effects of broadening were not apparent in the visibility data (either because the sources were unresolved, or complex in structure), and one completely resolved source (in which fringes were not detected with any projected spacing). The completely resolved source is seen through a major HII region (IC 2177), in which heavy scattering is probably occurring.

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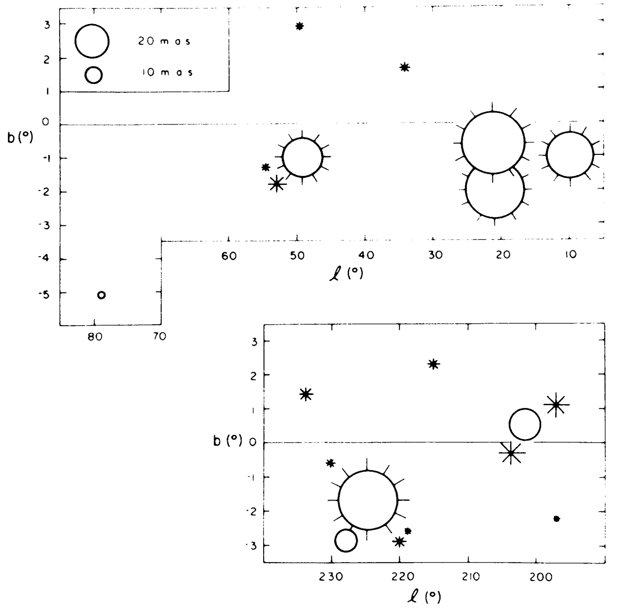

Fig. 1 - Measured Angular Broadening Diameters and Limits, plotted in galactic coordinates. Circles denote broadening measurements. Circles with exterior rays denote lower limits, and stars significy upper limits. Diameters shown are proportional to measured or limited angular broadening diameters (FWHM).

Significantly, four of eight sources observed in the range $10^{\circ} < \ell < 60^{\circ}$ were completely resolved. Binomial statistics confirm an excess of resolved sources in this longitude range, with 93% statistical confidence. This is interpreted as due to angular broadening, since these same sources were unresolved on baselines having comparable angular resolution at 2695 and 8085 MHz. (The results obtained using the larger sample of sources, including those partially resolved at 2695 and 8085 MHz, further support this conclusion. However, since these sources have not been shown to be intrinsically compact for a 10^6 λ interferometer, they are not included in this discussion.)

The magnitude of the scattering occurring in the 10°-60° longitude range is appreciable, well in excess of an extrapolation of the formula shown to be valid at latitudes $> 10^{\circ}$ by Duffett-Smith and Readhead (1976). We therefore postulate that a separate,low-scale height, distribution of scattering material is responsible for the observed broadening at low latitudes. Major path-to-path variations in the observed broadening suggest that the scattering material occurs in clouds. We have therefore investigated models in which such clouds are distributed with low scale height a) in a screen in the inner Galaxy and b) throughout the galactic disk. Interception by one or more clouds would produce heavy scattering such that an intrinsically compact source would appear totally resolved in our observations.

In Fig. 2, we show the area covering factor as a function of galactic latitude for the models best fitting the data. Although the free parameters (scale height of scattering clouds, areal cloud density at $b=0^{\circ}$) are not highly constrained (due to the limited amount of data) it is likely that the area covering factor at very low latitudes ($|b| \lesssim 1^{\circ}$) is

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appreciable. This is particularly true if the scale height of scattering clouds is comparable to that of population I phenomena (~80 pc), as might be expected.

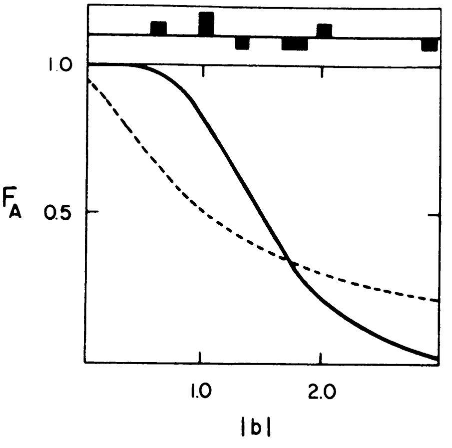

Fig. 2 - Covering factor versus galactic latitude for models in which the scattering occurs in clouds in the inner Galaxy (solid line), and in clouds distributed throughout the galactic disk (dashed line). The results from the sources in the range $10^{\circ}<\ell<60^{\circ}$ are shown at the top, above the line if resolved, and below the line if not.

III. IMPLICATIONS FOR COMPACT LOW-LATITUDE RADIO SOURCES

This result has important consequences for low-latitude sources (e.g. masers) seen through the inner Galaxy or large extents of the galactic disk. Our data strongly suggest (but do not prove conclusively) that the spot sizes observed in distant OH maser sources are significantly broadened by interstellar scattering (Burke et al. 1968). Bowers et al. (1980) noted that five of six OH/IR stars seen through the inner galaxy are lacking small scale structure often found in these objects. This result, if it is due to scattering, is completely consistent with our data and the models depicted in Fig. 2.

This survey provides an indication as to how much scattering is to be expected along various lines of sight in the galaxy, and thus has applicability to studies of compact sources seen at low latitudes. The broadening of CL 4 (Geldzahler and Shaffer 1981) is surprisingly large for its latitude of 8°, and is probably due to the Cygnus Loop.

Geldzahler and Shaffer (1981, 1982) have studied the compact radio source G127.11+052 which appears very close to the center of the SNR G127.1+0.5. The lack of scattering in G127.11+052 ($\lesssim$ 0.15 mas at 10.65 GHz - Geldzahler and Shaffer 1982) is not too surprising in view of our results in the 195° - 235° longitude range. It is somewhat surprising that heavy broadening does not occur in the SNR. A possibility that should be investigated is that the scattering is suppressed at 10 GHz because the rms phase fluctuation is $\lesssim$ 1 radian. At lower frequencies the scattering could be quite heavy, however, if the effective turbulent scale is quite small.

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More thorough low-latitude broadening surveys, involving better matched resolution, and much greater dynamic range are in progress.

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