MEASUREMENTS OF INTERSTELLAR SCATTERING IN THE CYGNUS REGION

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ABSTRACT

We report progress on a study of interstellar scattering in the direction of the constellation Cygnus. A high quality, 1663 MHz VLBI image has been obtained of the radio source 2013+370, whose structure at this frequency is dominated by scattering. The visibility function indicates that the spectral index of the interstellar density irregularities is between 3.7 and 4.0, with the higher value being somewhat more likely. Another project consists of multifrequency observations of eight sources in this region. Pronounced changes in the scattering are observed for sources separated by only a few degrees.

1. GENERAL REMARKS

Many types of radioastronomical observations reveal the presence of plasma turbulence in the interstellar medium. Since angular broadening is one of the phenomena resulting from wave propagation through a random medium, VLBI observations can assist in the study of interstellar turbulence. A VLBI observation of angular broadening gives us a measurement of the path-integrated "strength of scattering". Comparison of different lines of sight therefore permits us to identify astronomical objects or regions characterized by particularly heavy scattering. This allows us to discriminate between turbulence distributed along the line of sight and that which is concentrated in one or a few regions. Furthermore, the interferometric visibility of a point source viewed through a turbulent medium is directly related to the structure function of the density irregularities. A careful measurement of a compact radio source may therefore permit us to deduce the spatial spectrum of the density irregularities. This, in turn, provides valuable information on the physical processes operative in forming the irregularity spectrum.

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2. VARIABILITY OF SCATTERING ON CLOSE LINES OF SIGHT

We are in the process of obtaining three-frequency scattering measurements for nine sources in the direction of Cygnus. For one of the sources (2013+370, see below) the observations are complete. For the remaining eight objects, observations at 5 and 1.6 GHz have been acquired and partially analysed. Observations at 0.61 GHz are awaiting scheduling. The nine sources are 1923+210, 1954+513, 2005+403, 2013+370, 2021+317, 2022+542, 2023+336, 2048+313, and 2113+293. We believe we have detected interstellar scattering for five of the sources: 2005+403, 2013+370, 2021+317, 2023+336, and 2048+313. Interstellar scattering is manifest by a λ^2 dependence of the angular size on wavelength, and a size which is much larger than observed for high-latitude sources with similar spectra and variability characteristics.

A striking result of our preliminary investigations is that the amount of angular broadening changes substantially for lines of sight separated by only a couple of degrees, suggesting that the scattering is dominated by a single region. However, the nature of these regions is uncertain. The sources 2013+370 and 2048+313 lie behind the Cygnus OB1 association and the Cygnus Loop supernova remnant, respectively, yet are less scattered than nearby sources whose lines of sight do not intersect such obvious "extreme Population I" objects.

3. SCATTERING OF THE RADIO SOURCE 2013+370

In previous observations it was found that the source 2013+370 displayed broadening due to interstellar scattering. We therefore undertook a six-station observation at 1663 MHz to obtain a good map of this object and to acquire information on the form of the density irregularity spectrum.

The image of the source revealed two striking attributes. The first is its asymmetry. A Gaussian fit to the Cleaned map yields a major axis of 17 milliarcseconds, a minor axis of 12 milliarcseconds, and a position angle of 14 degrees. Since this is the same position angle as observed for the intrinsic structure at a higher frequency, it seems likely that this asymmetry reflects underlying intrinsic structure. However, this statement is not completely certain. The second noteworthy feature of the image is its smoothness; there is no evidence of multiple images, as might be expected if the irregularity spectrum were quite steep, with attendant strong refractive effects. Comparison of the observed visibility with that given by power law turbulence indicates a best fit for a power law index of between 3.7 and 4.0.