Probing Turbulence in the Interstellar Medium using Radio-Interferometric Observations

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Abstract

In this thesis we use radio-interferometric observations to probe the intensity fluctuation power spectrum of the neutral hydrogen (H I) 21-cm emission from the interstellar medium (ISM) of the external galaxies. We develop a visibility based power spectrum estimator to probe the power spectrum directly from the interferometric observations and also estimate the errors in it. A numerical simulation of synthetic observations is also performed to access the efficacy and limitations of this estimator. We use this estimator to evaluate the power spectrum of three individual spiral galaxies, a dwarf galaxy sample and THINGS [1] spiral galaxies. In each case, the power spectrum is found to follow a power law $P_{\rm HI}(U) = AU^{\alpha}$ over a specific length scale range. The estimated value for the slope α ranges from ~ -1.5 to ~ -2.6 for the sample of dwarf galaxies. We interpret this bi-modality as arising due to 2D turbulence on length scales much larger than the scale-height of the galaxy disk and 3D otherwise. The power law slope also show a weak correlation with the surface density of star formation rate for these galaxies. We found for the external spiral galaxies the power spectrum is a power law up to a length scale of 10 to 16 kpc, indicating turbulence to be operational at these large length scales. We measure the scale-height of the external nearly face-on spiral galaxy NGC 1058 to be ~ 500 pc interpreting a change in the slope observed in it's power spectrum. Power spectrum of the harassed galaxy NGC 4254 is found to be affected by galaxy harassment. For 18 spiral galaxies derived from the THINGS sample we found no correlation between the power law slope and the different dynamical parameters of these galaxies. For most of the dwarf and spiral galaxies, the intensity fluctuation power spectrum is found to be a direct probe of the density fluctuation and not affected by the velocity fluctuations in ISM. We would attempt to understand these new observations in terms of physical models of the ISM in future.

[1] THINGS: The HI Nearby Galaxy Survey