Abstract

Supernova remnants (SNRs) have a variety of overall morphology as well as rich structures over a wide range of scales and across the entire electromagnetic band of frequency. Quantitative study of these structures can potentially reveal fluctuations of density and magnetic field originating from the interaction with the interstellar medium (ISM) and turbulence in the expanding ejecta. In this thesis, we use the power spectrum technique for the investigation of observed intensity fluctuations from four Galactic SNRs in radio and X-ray.

We have used the archival VLA data and observed GMRT data to estimate the angular power spectrum C_ℓ of the synchrotron emission fluctuations of Cas A, Kepler, Crab and Tycho SNR respectively. This is done using the novel, visibility based, Tapered Gridded Estimator. In addition, we present C_ℓ measured from archival Chandra X-ray data of Cas A, Kepler and Tycho SNR in two separate energy ranges A $\sim (0.5-1.0)$ keV and B $\sim (4.2-6.0)$ keV, both of which are continuum dominated. The different emissions all trace fluctuations in the underlying plasma and possibly also the magnetic field, and we expect them to be correlated. We quantify this using the cross angular power spectrum between the different emissions.

For the chosen SNRs, the auto and cross C_ℓ are found to follow a power law over a specific range of inverse angular scale ℓ. We note that the best fit values of the power law slope largely lie between -1.5 and -3.5. For shell-type SNRs like Cas A, Kepler, the broken power law C_ℓ has been identified with the transition from 2D turbulence at large scales to 3D turbulence at smaller scales occurring at an angular scale corresponding to the shell thickness. Alternatively, this can also be explained as 2D inverse cascade driven by energy injection from knot-shock interactions. In contrast, the angular scale of the observed break for shell-type Tycho SNR does not coincide with the shell thickness. We do not find a significant change in the power law of radio C_ℓ for Crab SNR which is possibly related to its filled-centre geometry.

The estimated cross C_ℓ quantify the ℓ dependence of the correlation. We further evaluate their dimensionless cross correlation coefficients which measure the strength of the correlations among the three bands considered here. For Cas A and Tycho, the qualitatively analogous result of correlation of X-ray B data with both radio and X-ray A suggests the emission in X-ray B to be a mix of thermal and non-thermal. The scenario is slightly different for Kepler SNR where the radio data is better correlated with X-ray A than X-ray B. However, the observed strong correlation between X-ray A and B for all three SNRs indicates relatively similar characteristics of the emission in these bands. These findings from auto and cross C_ℓ provide observational inputs regarding the nature of turbulence and the emission mechanisms of the SNRs.

Keywords: Interstellar medium (ISM): supernova remnants - methods: data analysis - radio and X-ray - statistical: power spectrum - auto and cross - turbulence - (magnetohydrodynamics) MHD - radiation mechanisms: thermal and non-thermal