

Gamma-Ray Bursts as Distance Anchors for a Multi-Wavelength View of the Interstellar Medium

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Abstract

The interstellar medium (ISM) is a mixture of gas, dust and cosmic rays that drives star formation. Its components cycle between phases, but key processes remain unclear, particularly how magnetic fields regulate the ISM and how its structures are arranged in three dimensions (3D) given distance uncertainties. This challenge will be addressed using gamma-ray bursts (GRBs) as natural background beacons. Their X-ray emission, scattered by dust clouds along the line of sight, produces expanding X-ray rings that give precise geometric distances to dust layers (Tiengo & Mereghetti 2006). Since only seven GRBs with X-ray rings are currently known (Šiljeg et al. 2023), archival Swift-XRT observations will be reanalysed, combined with 3D dust-extinction maps (Lallement et al. 2022; Edenhofer et al. 2024), to expand the sample.

Combining these X-ray ring distances with LOFAR Faraday tomographic data (Erceg et al. 2022, 2024), Planck dust polarisation maps (Planck Collaboration 2020) and HI4PI data (HI4PI Collaboration 2016) can reveal the multiphase, magnetised nature of the ISM toward GRBs and constrain the distribution of neutral and ionised gas, using the independent, geometry-based GRB distances as anchors to break the distance degeneracy inherent to Faraday tomography.

We will argue that integrating GRB X-ray rings, 3D dust-extinction maps, LOFAR Faraday tomography, Planck polarisation and HI4PI data will provide a more comprehensive, distance-resolved view of the ISM, improving the prediction and identification of new X-ray rings while refining the understanding of interstellar dust and magnetic fields.

Keywords: interstellar dust, magnetic field, gamma-ray bursts, X-ray scattering, Faraday tomography, neutral hydrogen