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Fermi and eROSITA Bubbles as ”by-products” of Galactic Evolution

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The Fermi and eROSITA bubbles (FBs and eRBs) are the largest gamma-ray and X-ray emitting objects in the sky, respectively. They look like nearly symmetrical pairs of bubbles rising above and below the center of our Galaxy. The FBs extend about 50°, and their emission mechanism is under debate, whether the leptonic scenario (inverse Compton scattering by relativistic electrons) or the hadronic scenario (decay of π^0 particles produced by collisions between relativistic protons and target nuclei in thermal gas). The eRBs extend up to $\sim 80^\circ$ and are dominated by thermal X-ray emission. In the last decade, most of the literature suggested that the FBs and eRBs were formed by ~ 10 Myr past Galactic Center (GC) burst-like activities, implying that the bubbles are evanescent structures of the Milky Way Galaxy (MW). However, the actual formation mechanisms are still unknown.

Linearly polarized radio observations have also reported such bilobal giant structures (hereafter Giant Radio Lobes, GRLs, Carretti et al. 2013). Several bright filamentary substructures in the GRLs trace the corresponding parts of the FBs and eRBs very well. The polarization observations also show that the magnetic fields above and below the Galactic disk are perpendicular to the disk everywhere. These facts strongly support the existence of outflows from the disk. However, the filamentary substructures may rule out a simple bubble-like morphology of the outflow.

The outflow from the Galactic disk is also strongly motivated to explain the total amount of metals in the current disk, $\sim 10^7\ M_\odot$, which is estimated with the typical metallicity of $Z_\odot \sim 0.01$ and the total mass of gaseous matter within the star-forming region of the disk $\sim 10^9 M_\odot$ (e.g., Misiriotis et al. 2006). Without the outflow from the Galactic disk, the metal amount would be much larger than the above estimate: The star formation in the MW has continued at a rate of $\dot{M}_{\rm sf}$
$gtrsim 3 M_\odot$ yr^{-1} during the cosmic-age of $t_{\rm age} \sim 14$ Gyr (Haywood et al. 2016). The Salpeter initial mass function gives a fraction of massive stars as $f_{\rm ms} \sim 0.1$. From the ratio of the metal mass of the supernova ejecta to the mass of the progenitor star as $f_{\rm ej} \sim 0.1$ (e.g., Sukhold et al. 2018), we obtain the total mass of metals ejected by the supernovae during the cosmic-age as $M_Z \sim f_{\rm ej} f_{\rm ms} \dot{M}_{\rm sf} t_{\rm age}$
$gtrsim 4 \times 10^8 M_\odot \gg 10^7 M_\odot$. Thus,
$gtrsim 97$ % of the ejected metals should be removed from the disk by the outflow (Shimoda et al. 2024). The observed mid-infrared large structure around the GC (Bland-Hawthorn et al. 2003) may be the evidence of the outflow that removes ‘missing’ metals.

To be motivated by the above scenario of the MW evolution scenario, we construct a simplified model for the FBs and eRBs. We find that the Galactic wind scenario can reproduce the bubbles during
$gtrsim 1$ Gyr as ‘by-products’ of the MW evolution. This result also implies that the bubbles are “by-products” of the Galactic evolution, and gamma-ray emissions above the Galactic disk can be important clues for the Galactic evolution.

Collaboration(s)

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