Mapping the Local Bubble's Magnetic Field in 3D

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Abstract

We present a 3D map of magnetic field orientation on the surface of the Local Bubble. This map is the first of its kind to fully chart magnetic fields over an observed superbubble. Recent work mapping the 3D shape and dynamics of the Local Bubble has revealed that the formation of all young stars within 200 pc of the Sun was triggered by the Bubble's rapid expansion. The exact mechanics of this expansion, and the role that magnetic fields in the surrounding interstellar medium have played in regulating its evolution, is not yet clear. By combining detailed models of the Bubble's geometry (derived from 3D dust mapping) with the assumption that magnetic field vectors are tangent to the Bubble's surface, we are able to infer the 3D magnetic field orientation from Planck plane-of-the-sky dust polarization orientations. We analyze the relationship between the Bubble's inferred magnetic field and background starlight polarimetry observations, and discuss how magnetic fields may have affected the dynamics of the Local Bubble and other nearby structures in the ISM.

Introduction

Star formation is typically clustered, so expanding, low-density superbubbles ~100s of parsecs in diameter generated by sequential supernovae are common throughout the interstellar medium (ISM) in the Milky Way (Zucker et al. 2022) and beyond (JWST papers). These superbubbles are expected to play a significant role in concentrating and distributing the effects of stellar feedback (missing citation); (missing citation) and in triggering the formation of dense gas and stars (missing citation); (missing citation).

Numerical and hydrodynamical simulations predict that magnetic field orientation has a significant impact on the direction of superbubble expansion (missing citation); (missing citation), but the overall role of magnetic fields in regulating the formation, expansion, and effects of superbubbles is unclear. It has recently become possible to map the 3D magnetic field structure of individual molecular clouds within superbubbles (missing citation); (missing citation), but while measurements of magnetic field strength over entire superbubbles have been obtained (missing citation); (missing citation); (missing citation); (missing citation); (missing citation), efforts to map the 3D orientations of magnetic fields over the entire surfaces of superbubbles have been limited by uncertainties on their 3D geometries.

The Local Bubble is an an expanding, low-density superbubble centered roughly near the Sun's present day location. Due to its proximity and well-studied nature, the Local Bubble is an ideal candidate to map magnetic field structures in 3D across a superbubble's surface for the first time. The Local Bubble was likely generated by a series of supernovae within the last ¡15 Myr and is highly irregular in shape, being surrounded by a thin shell of cold dust and gas extending up to a few hundred parsecs from the Sun (missing citation); (missing citation); (missing citation); (missing citation). Efforts to map the surface field structure of the Local Bubble have been limited by the uncertainties in the geometry of the cavity in the ISM around the Sun. Recent work mapping the 3D geometry of the Local Bubble (missing citation) has enabled detailed analysis of its relationship to molecular clouds and star-forming regions adjacent to its surface, and suggested that nearly all local star formation within 200 pc of the Sun was triggered by the Bubble's expansion (missing citation).

However, the exact mechanics driving the Local Bubble's formation and expansion are not yet entirely clear. Additionally, information on how magnetic fields may effect the bubble's dynamics and evolution, and by extension local star formation, is limited. B-field orientations inferred from polarization measurements are generally oriented parallel to the Galactic plane, but the B-field in the local ISM has been observed to depart from this ordered behavior (missing citation); (missing citation); (missing citation). Studies of the Local Bubble have suggested that it could be responsible for the nearby variations from this trend. An accurate 3D map of the Local Bubble's magnetic field structure would then not only be a useful probe of the nearby history of star formation and general relationship between superbubbles, but also serve to constrain the variations between the local and larger-scale Galactic magnetic fields.

(missing citation) modeled magnetic fields on the surface of the Local Bubble at high latitudes ($|b|$¿60○) with the simplifying assumption that the shell has an ellipsoidal geometry, and concluded that variations in the B-field in these polar regions would be sufficient to distort measurements of Galactic field by a significant amount. (missing citation) and (missing citation) extended this work with a more physically motivated geometry enabled by 3D dust mapping of the Local Bubble's surface by (missing citation), and reached similar conclusions that the Local Bubble's surface makes a large contribution to the total observed sub-mm dust polarization at high latitudes. (missing citation) studied magnetic field strength and grain alignment on the Local Bubble's surface using archival optical polarimetry observations, and found that the strength of the Bubble's magnetic field as well as grain alignment efficiency varies significantly across its surface.

In this work, we create a true three-dimensional map of the Local Bubble's magnetic field structure. Specifically, we constrain the Local Bubble's magnetic field structure by combining its known surface geometry with *Planck* polarization observations and background starlight polarization measurements. We assume that the magnetic field's inclination is tangent to the surface of the Local Bubble, and that the observed plane-of-sky magnetic field is primarily generated by a polarizing layer on the surface of the Local Bubble. Combining these assumptions with polarization observations constraining the plane-of-sky field orientations results in a complete set of 3D B-field vector orientations. This enables a full characterization of the B-field orientation over the surface to create the first-ever 3D map of a magnetic field over a superbubble.

In §**??** we describe the data used in our analysis. We describe the construction of the 3D magnetic field map from *Planck* dust polarization data in §**??**, and discuss the association between the field and the Local Bubble's surface and local environment in §**??**. We compare the *Planck*-derived magnetic field to background starlight polarization measurements in §**??** before concluding in §**??**.

References