

The Solar Journey: Modeling Features of the Local Bubble and Galactic Environment of the Sun

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Abstract

The objective of the “Solar Journey” project is to give context to “empty” space by reconstructing and visualizing the three-dimensional (3D) distribution of interstellar material surrounding the Sun and nearby stars, and by applying state-of-the-art visualization techniques to the task of comparing and interpreting multispectral data sets containing complementary information on cloud physics.

Summary

Three-Dimensional Reconstructions are required to understand the shadowing properties of the ISM, energy transfer between stars and the ISM, the heliosphere and astrospheres of external stars, and the general distribution and physical properties of cold and warm, neutral and ionized, interstellar clouds.

Reliable modeling of three-dimensional structures is one of the more challenging tasks in the analysis of astronomical

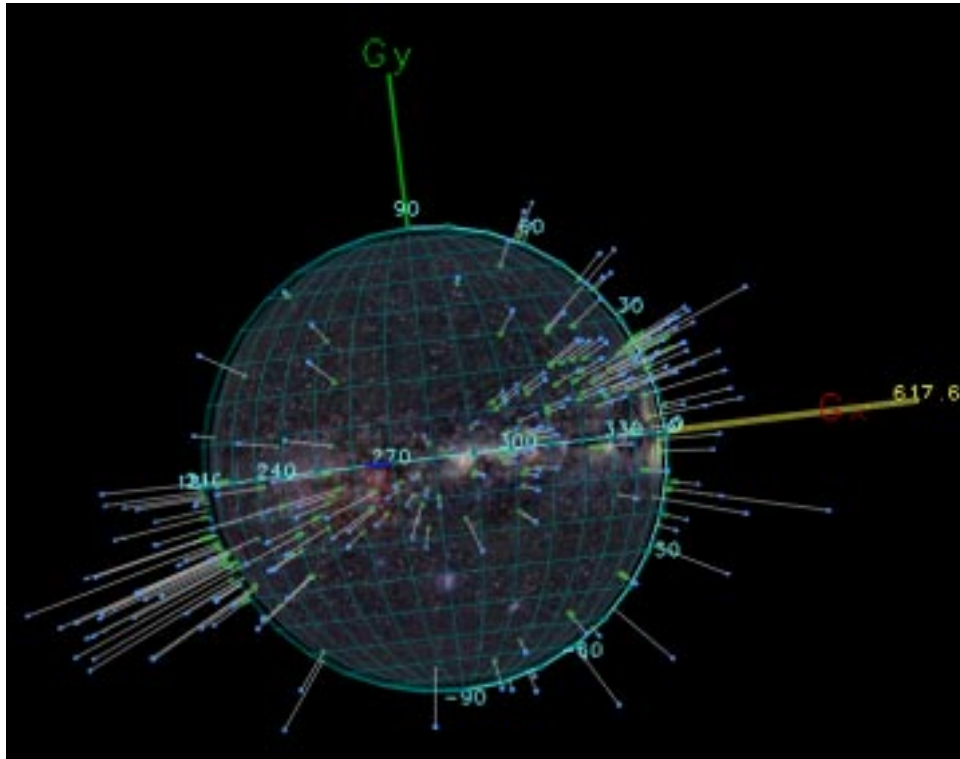
data, and is required for understanding the relation between multispectral observations of the ISM. It is also an essential task for visualization scientists working with astronomers to develop scientifically accurate simulations of complex spatial structures.

We report on a method for combining the shadowing properties of the interstellar medium (ISM) with astrometric data to visualize and derive the three-dimensional distribution of nearby ISM. This methodology is applied to the case study of the three-dimensional structure of the [Local Bubble](#) over

distance scales of ~ 500 pc. The DistEdTool software reconstructs 3D models of the volume distribution of any interstellar material causing absorption, providing the background star distances are known.

Local Bubble and Goulds Belt

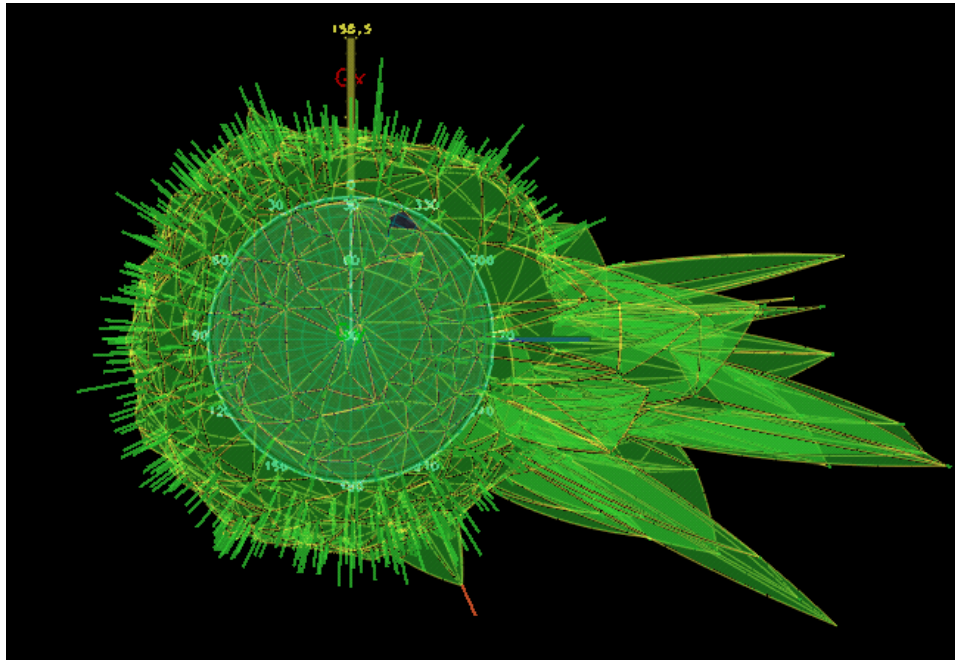
- The Sun is located inside of a “ring” of massive hot OB stars, known as Gould’s Belt (see Figure). Since Gould’s Belt hot stars dominate the distribution of ISM within ~ 500 pc, there is a void in the ISM around the Sun known as the Local Bubble, and extending hundreds of parsecs in the third Galactic quadrant ($180^\circ \rightarrow 270^\circ$) (e.g. Frisch 1995). Gould’s Belt is tilted by $\sim 15\text{--}20^\circ$ with respect to the Galactic plane, which introduces an asymmetry into the distribution of nearby ISM that is difficult to represent using two-dimensional (2D) map projections.



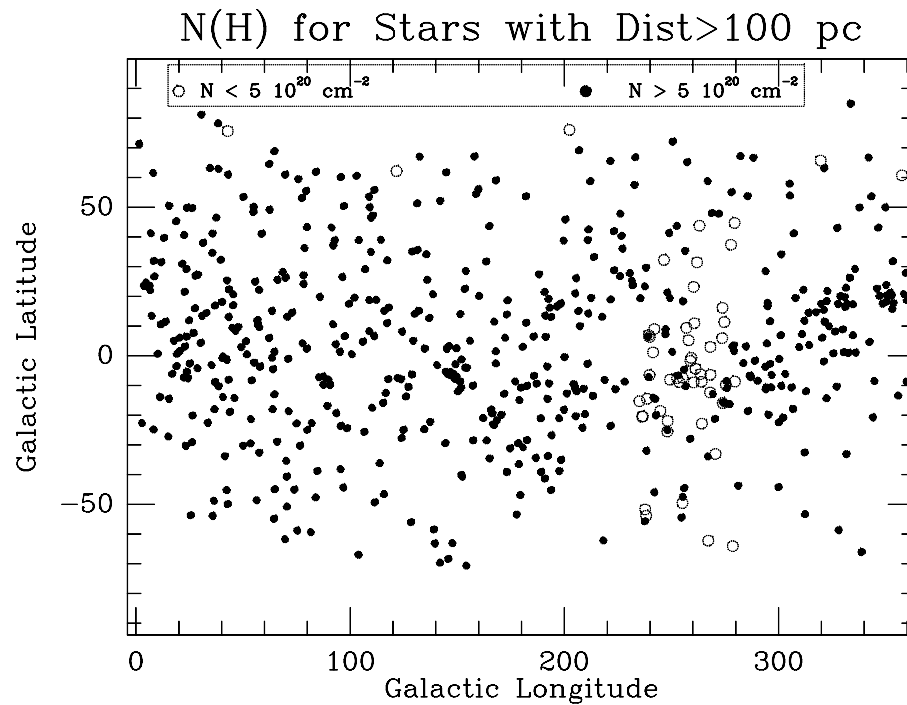
Caption: O,B stars with $V < 5$ mag display the asymmetrical distribution associated with Gould's Belt. Longitude 270° is at the image center, with the galactic center to the right. Note $15\text{--}20^\circ$ tilt of Gould's Belt stars, long noted in the literature. The background texture is the Mellinger image of the Milky Way. (From DistEdTool display, using Hipparcos data. Blue dots are stars; length of green 'bead' $\sim N(H)$; line length gives star distance.)

- **Finding the Walls of Local Bubble from E(B-V):** The 3D volume distribution of ISM forming the “walls” of the Local Bubble can be visualized by using 3D analysis tools designed to combine information from one- or two-dimensional data sets for reconstructing 3D volume information, and rendering that information using state-of-the-art computer visualization techniques. **Local Bubble “walls”** are determined by the locations of stars with color excesses $E(B-V) > 0.08$ mag (or $N(H) = 4.6 \times 10^{20} \text{ cm}^{-2}$, Bohlin et al. 1978), corresponding to the column density where the fractional abundance of H_2 makes the transition from $f(H_2) < 0.01$ to $f(H_2) > 0.01$. For a nominal density $n = 10$

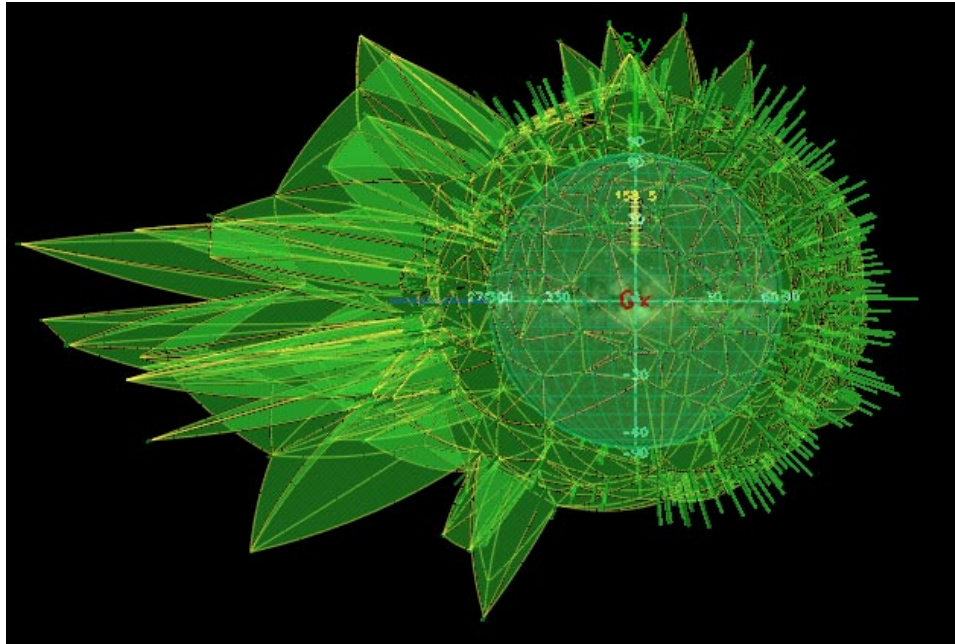
cm^{-3} , this corresponds to a 14.2 pc cloud length. We use the parallax and spectral data contained in the Hipparcos catalog, for early-type stars (O, B, A). Star selection is restricted to stars with trigonometric distances that agree to within 15–25% with spectral parallax values, and that are brighter than $V \sim 7$ mag,



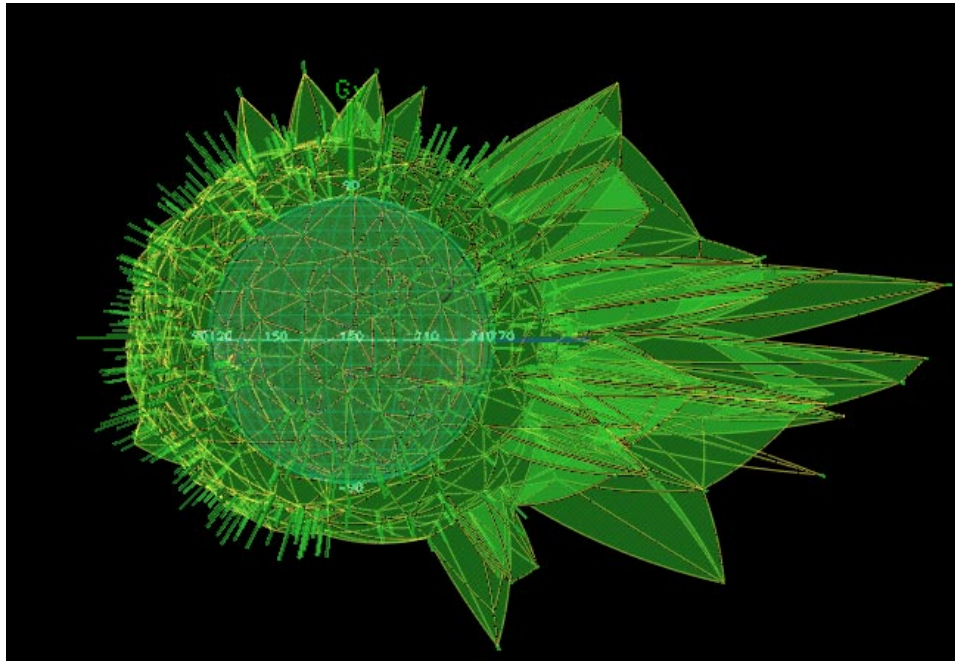
Caption: View of Local Bubble (LB) from North Galactic Pole (Galactic center at top, $l=270^\circ$ to right). The location of the “walls” of the Local Bubble are reconstructed from $E(B-V)$ reddening data for ~ 700 stars in the Hipparcos Catalog. The large distance to the Local Bubble wall in the third galactic quadrant corresponds results from low interstellar column densities in that region (long known), while the spiked features elsewhere show the patchiness of the LB walls at ~ 80 pc.



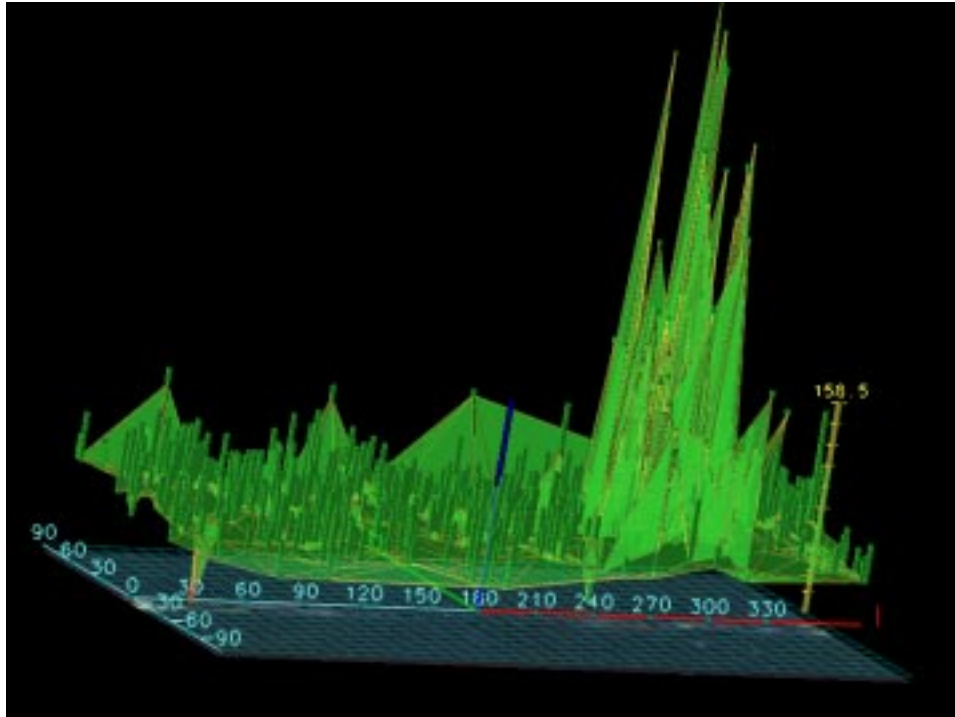
Caption: For contrast, the positions and column densities of all stars with distances greater than 130 pc are plotted as a function of galactic coordinates. Open circles represent stars with column densities $N(H) < 5 \times 10^{20} \text{ cm}^{-2}$, while filled circles are stars with $N(H) > 5 \times 10^{20} \text{ cm}^{-2}$. Note the deficit of material in the interval $l=245^\circ \rightarrow 280^\circ$, corresponding to a viewpoint through the elongated direction of the Local Bubble.



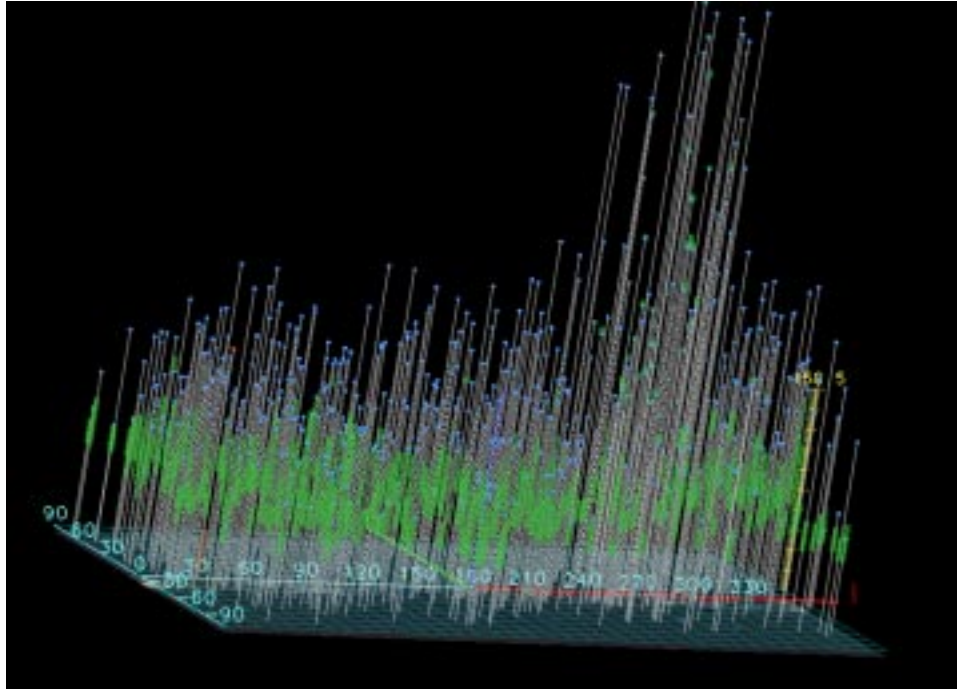
Caption: Local Bubble from $l=0^\circ$ viewpoint ($l=90^\circ$ to right). DistEdTool displays stellar positions and cloud column density (based on $E(B-V)$), and allows adjustment of cloud distance. The cloud layer is then reconstructed using Delauney triangulation, and a transparent surface wrapped around the triangulation.



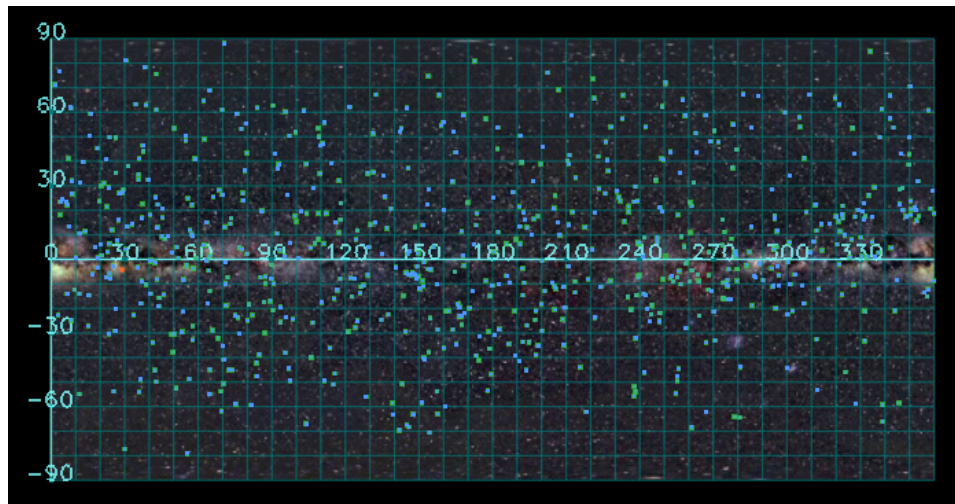
Caption: Local Bubble from $l=180^\circ$ viewpoint ($l=90^\circ$ to left). These results are based on data in the Hipparcos catalog. Note that either incorrect spectral classifications or incorrect photometric data will yield incorrect $N(H)$ values. Stars of spectral type A_m were omitted because of these uncertainties, since $\sim 50\%$ of the A_m stars yield anomalously large $N(H)$ (i.e. $E(B-V)$) values.



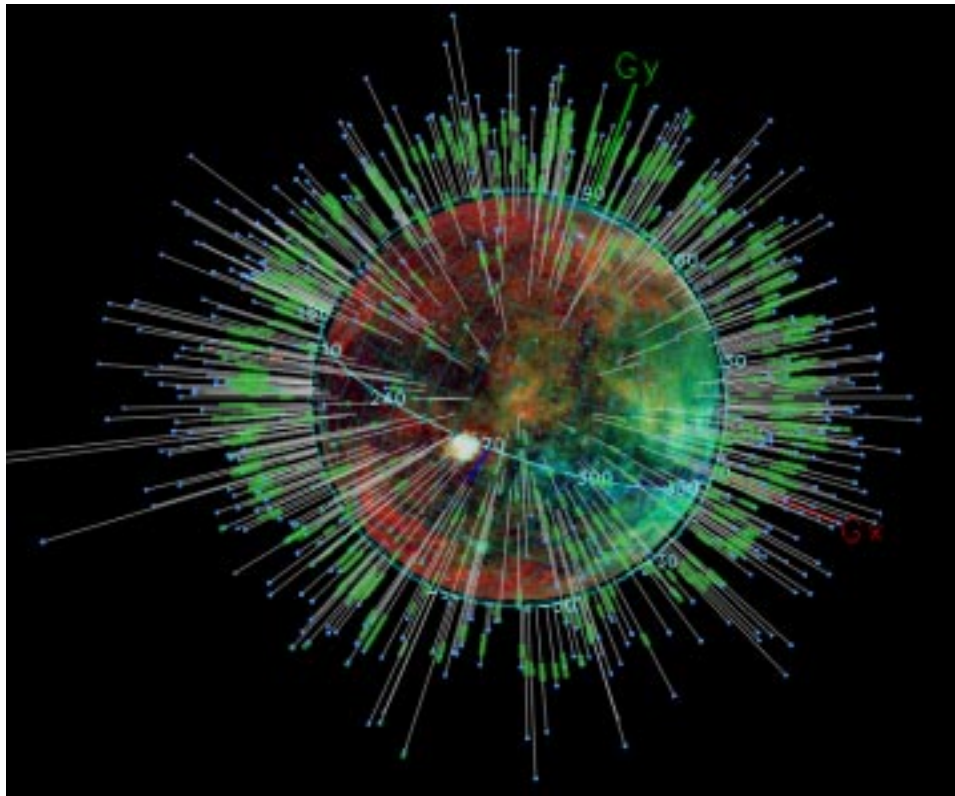
Caption: Local Bubble Delaunay triangulation for planar projection. $l=0^\circ$ to left.



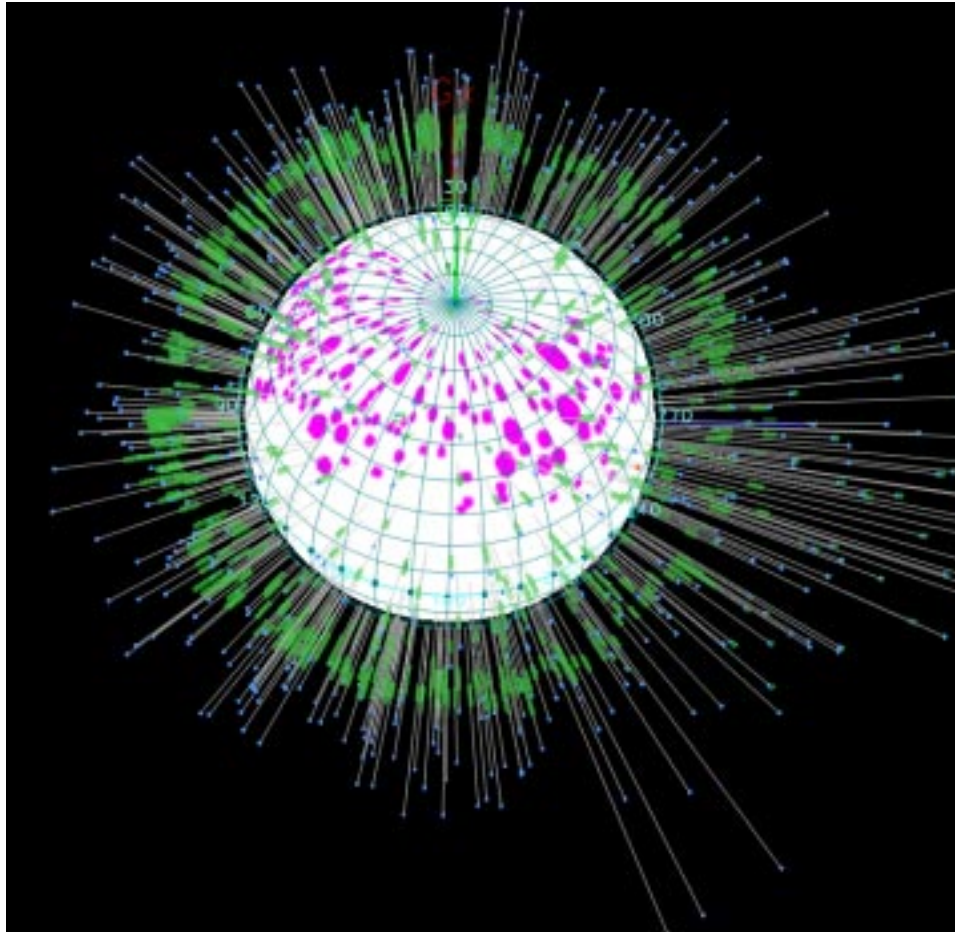
Caption: Stars and interstellar matter columns used to create Delauney triangulation (planar projection). Blue dot: star. Green bead: ISM column (length in pc, and $\propto E(B-V) \propto N(H)$ using $n=10 \text{ cm}^{-3}$). $l=0^\circ$ to left.



Caption: Locations of stars used for 3D modeling, using Mellinger Milky Way Galaxy image as background texture. A range of texture images are available with DistEdTool, and any survey with positional data can be used as a texture image. DistEdTool offers a simple way for comparing star locations with cloud positions, including velocity dependent information. $l=0^\circ$ to left.



Caption: Stars plotted against ROSAT soft X-ray data (red = 0.25 keV). The bright emission source near center is the Vela supernova remnant, near $l \sim 270^\circ$. Multiple display options are incorporated into DistEdTool, including background texture images of all-sky multispectral data from millimeter to Angstrom wavelengths.



Caption: Stars plotted against ROSAT soft X-ray shadows (from Snowden et al. 2001). The figure is centered near $l=180^\circ$, $b=+50^\circ$.

Historical Notes

- **The Discovery** and most extensive mapping of the Local Bubble void in ISM around the Sun has relied on reddening data of O–A0 stars by foreground interstellar dust (Eggen 1963, Fitzgerald 1968, Lucke 1978, Perry 1982a, Perry 1982b). These data outline a vacant region surrounding the Sun extending ~ 100 pc in the directions of the Galactic center and anti-center, and ~ 50 pc in the directions of Galactic rotation ($l \sim 90^\circ$) and anti-rotation.
- **Other maps of the Local Bubble** have been based on UV (Bohlin et al. 1978, Frisch and York 1983) and optical absorption lines (Na⁰, Sfeir et al. 1999, Vergely et al.

2001), polarization of starlight (Leroy 1999), and the distribution of EUV sources ($<912 \text{ \AA}$, white dwarfs and cool stars, Warwick et al. 1993, Welsh et al. 1999).

Software Development

The Distance Editing Tool (DistEdTool) is part of a suite of software tools developed for the purpose of modeling and visualizing multispectral data sets useful for reconstructing the physical properties of the Galactic Environment of the Sun. DistEdTool reconstructs the 3D volume distribution of any material giving rise to absorption phenomena, provided the distances of the background target objects are known. DistEdTool is implemented on three platforms: Silicon Graphics O2 (SGI), Windows based PC's with state-of-the-art game boards, and SUN Sparc workstations.

Among the other software tools developed for the Solar Journey project are: (a) [Image Alignment Tool](#) which precisely aligns images (e.g. photographs) containing stellar point sources with star positions from a fiducial catalog such as Hipparcos; (b) [Tools](#) for modeling and rendering ISM data as a resource for the National Virtual Observatory; (c) [Star rendering](#), visualization, and editing tools; (d) [Interactive animation tools](#) for rendering and visualizing large data sets.

Software Demonstrations

Software demonstrations accompanying this poster paper include demonstrations of DistEdTool on a PC laptop, a three-minute video 'Solar Journey', and a three-minute video 'Cosmic Clock'. The Cosmic Clock video can be purchased as part of the published proceedings of the SIGGRAPH 2000 conference.