

The Journey of the Sun **A Virtual Reality Simulation**

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Abstract

Give **context** to the “empty” space around us by reconstructing and visualizing the Galactic surroundings of the Sun and nearby stars, using state-of-the-art visualization techniques applied to the task of comparing and interpreting multispectral data sets.

Goals of Our Work

- **Virtual Reality Simulation:** Support interactive visualization, modeling, and pedagogical animation of multispectral data sets.
- **Science Applications:** Apply modeling tools to Solar neighborhood, Local Bubble, Astrospheres and Space Motions of Stars and Clouds, and especially Galactic Weather.

Resources

- **Software** developed under this and other programs.
- **NASA and ESA Data Sources.** MAST, ADS, GSFC, NED, ROSAT, etc.
- **Models and Data** from colleagues and individual databases on the Web.

Our Recent Results

- **Software:** VRML DistEdTool, GLUI DistEdTool, StarViewer, Large Spacetime Scale Navigation, Movie Animation Tools, Image Alignment Tool.
- **Hardware Targets:** System-independent desktop applications, CAVE applications, Elumens Kiosk, and Video.
- **Outreach and Education:** Produce pedagogical movies, provide resources for Adler Planetarium

Outline of Following Slides

- **Modeling Methods:** Strategy, Kinematics, Stars, Data Sources
- **Tool Development:** Distance Editing Tool, Star and interstellar material simulation, Alignment Tool.
- **Demonstrations:** Editing Tool, Interactive Movie Scenes.

Synthesize 3D Models from Multispectral Data

Model distribution of interstellar matter in the Local Bubble (out to ~ 500 pc)

- **Strategy:** Use emission maps to establish 2D positions and cloud types, use absorption lines in stars of known distance to establish distance and physical properties of emission feature.
- **Kinematics:** Compare 3D space motions of stars and clouds for nearby stars.

... 3D Models from Multispectral Data ...

- **Interstellar (IS) Dust:** Reddening of starlight (A_V , $E(B-V)$, $E(b-y)$), polarization of starlight, infrared emission, heated dust.
- **Molecular Clouds (CO/H₂):** 1–0 CO rotational line (115 GHz); survey in galactic plane, selected regions out of plane.
- **Hot ($\sim 10^6$ K) plasma:** Soft X-ray emission (0.1–1.5 keV), UV absorp. lines (OIV, CIV, NV, SiIV).

... 3D Models from Multispectral Data ...

- **IS Neutral Gas:** UV, optical, EUV absorption in both lines and EUV continuum. All-sky maps of H° 21-cm emission & absorp. X-ray shadows.
- **IS Ionized Gas:** H^{+} $\text{H}\alpha$ emission (partial velocity data), all-sky radio continuum (408 MHz), pulsar dispersion, UV absorption.
- **Stars:** Distances, proper motions (Hipparcos), Nearby stars (Gliese: 3800 stars within 25 pc).

Tool Summary

3D Interstellar Material Modeling — Distance Editing Tool —	
Project Description	Capabilities
Version 1.0 (VRML)	Utilize stellar spectral lines to deduce intervening gas structure
Version 2.0 (VRML)	Enhanced to support additional data types and formats
Version 3.0 (GLUI)	Essential new features, improved performance, platform independence, and OpenGL button/box user interface

Tool Summary ...

Star Image Rendering and Simulation	
Star Viewer	Instrumental and artistic imaging characteristics of stars, interactivity
Interactive Visualization at Large Spacetime Scales	
Large Spacetime Scale Navigation	Support interactive exploration of data exceeding the capabilities of built-in computer graphics hardware
Tools for Registering Data Sources	
Image alignment tool (alpha)	Place cropped or distorted images at true position, etc.

Tool Summary ...

Outreach and Educational Materials	
Movie animation tools	Customize movie path planning and interpolation to overcome limitations of traditional systems. Unique problems for earth-fixed-camera views.
Museum Inter. Graphics Kiosk Animation	Provide interactive versions and custom enhancements of pre-stored movie sequences for individual planetarium attendees.

Tools for Interpreting and Visualizing Data

Working inward with large-scale navigation:

- ⇒ **Galaxy** — Data Alignment Tool, Large Scale Navigation, etc.
- ⇒ **Local Bubble** — DistEdTool
- ⇒ **Local Fluff** — DistEdTool
- ⇒ **Heliosphere** — Visualize theoretical models

Synergistic Activities

- **Computer Science.** Hierarchical Methods in Visualization (published). Reports on star rendering and editing tools (in preparation).
- **“Solar Journey” & “Cosmic Clock”:** short pedagogical computer animations; rendering, modeling, and interactivity enhancements in progress.
- **Adler Planetarium.** Resource provider for “Sun-Earth Connection” show. Delivered interactive movie software for adaptation to Elumens kiosks.

SUMMARY

- **Data sets.** Assembled, aligned, analyzed local galactic environment data sets for use in simulations and movies.
- **Interactive systems.** General tools for 3D analysis, alignment, and interactive movie scenes at all scales. CAVE applications for very large scales.

Future Work

- Distance Editing Tool and Data Alignment Tool for release to astronomical community
- Develop advanced gas and star rendering methods, incorporate into interactive movie tools
- Improve modeling and rendering methods for “Solar Journey” interactive and film simulations
- Modeling and rendering ISM data as a resource for the NVO.

Supplementary Appendix Material:

Using Multispectral Data to create 3D Model of Interstellar Matter in the Local Bubble:

Process:

Synthesize the distribution of interstellar matter in the local Solar environment out to ~500 pc.

- **Stars:** Place distances on interstellar clouds seen in absorption towards stars of known distances (Hipparcos data, 10% accuracy at 100 pc). Sampling interval: 118,000 stars and — >one star per 0.5 square degree; 20,500 O, A, B, F

stars within 500 pc. (Gliese catalog: 3800 stars within 25 pc.)

- **Optical Absorption Data.** Ca^+ , Na^0 lines. Put distances on maps of cold ISM (H^0 21-cm emission, CO emission, dust infrared emission at $100 \mu\text{m}$)
- **UV Absorption Data.** Give physical conditions of clouds identified in optical absorption lines and multispectral emission data. “Walls” of Local Bubble.

- **UV and EUV Absorption Data.** Map distribution of ISM in the Local Fluff (where column densities are too low for optical lines or 21-cm emission).
- **H⁰ 21-cm Emission.** 2D distribution of clouds with $\text{Log } N(\text{H}^0) > 19.5 \text{ cm}^{-2}$.
- **CO 1=0 rotational transition, 115 GHz.** Distribution of CO and H₂ molecular clouds, for $\text{Log } N(\text{H}_2) > 19.5 \text{ cm}^{-2}$.

- **Soft X-ray Diffuse Emission, 0.1–1 keV.** Distribution of supernova remnants and hot (10^6 K plasma, fills 80% space).
- **UV Absorption Data.** OIV, CIV, SiIV, NV absorption lines in stars (>100 pc) give distance of hot plasma.
- **H α emission:** Gives 2D distribution of warm ($\sim 10,000$ K) ionized gas, distances fixed by UV absorption lines. (WHAM data, Gaustad data).

APPENDIX: Data Summary Tables: I

Interstellar Dust

A_V , $E(B-V)$, $E(b-y)$	Reddening of starlight	Lucke:1978
Polarization of stars	Polarization of starlight by interstellar dust	Leroy:1999
Dust infrared emission	Cleaned all-sky maps compiled from infrared and microwave data	Schlegel, Finkbeiner, Davis:1998
Heated dust	Hot stars heating nearby dust	Gaustadvan, Bu- ren:1993

Data Summary Table II

Interstellar Neutral Gas		
N(H ⁰)	UV, optical, and EUV absorption (both lines and EUV continuum)	FrischYork:1983, Paresce:1984, Warwicketal:1993, Diamondetal:1995, Welshetal:1999, Sfeiretal:1999
H ⁰ 21-cm data	All-sky maps with cloud velocity, resolution <0.5 ^o	ColombPoppelHeiles:1980, Hartmann:1997

Data Summary Table II ...

Interstellar Neutral Gas			
X-ray shadows	shadows -rays	Shadows in soft X-ray background, caused by ISM with $\log N(\text{H}^0) > 19.5 \text{ cm}^{-2}$	Snowetal:2000
X-ray emission	emission	ROSAT 1/4 keV PSPC all-sky survey	Snowdenetal:1995

Data Summary Table III

Interstellar Ionized Gas

<p>H^+ $H\alpha$</p> <p>emission</p>	<p>All-sky $H\alpha$ emission (northern hemisphere with velocities)</p>	<p>Haffner, Reynolds, Tufte:1999, Gaus- tad:1997</p>
<p>Radio con- tinuum</p>	<p>All-sky 408 MHz emis- sion, ionized gas, cos- mic ray synchrotron emission</p>	<p>Berkhuijsen:1971</p>

Data Summary Table IV

Molecular Clouds		
CO/H ₂ distribution	Galactic plane, high and low latitudes	Dame:1987, Magnani-etal:2000, Hartman-netal:1998
Stars		
Hipparcos catalog	Distances (10% accuracy at 100 pc) and photometry for 118,000 stars, or up to one star per ~0.5 square degrees on the sky	Perryman:1997
Nearby stars (Gliese)	Complete catalog of stars within 25 pc (3800 objects with small astrometric distances)	Gliese:1991

