

# **The Journey of the Sun**

## **A Virtual Reality Simulation**

**A.J. Hanson and P.C. Frisch**

*Computer Science, Indiana University*

*and*

*Department of Astronomy and Astrophysics*

*University of Chicago*

**AISRP 2000, Boulder, CO**

# OVERVIEW

- **Local Solar Environment Model:** ISM, molecular clouds, loops, stars, local fluff, heliosphere
- **Distance Editing Tool:** 2D maps, point sources, and absorption data  $\Rightarrow$  3D models
- **NASA Data:** dust, plasma, atoms, ions
- **Implementations:** CAVE, Tools, *Cosmic Clock*

# Big Picture of Local Solar Environment

*Working inward from ~500pc:*

- **Local Bubble.**
- **Local Fluff.**
- **Heliosphere.**

## Components of Solar Environment [*See Figs*]

- **Interstellar clouds of gas and dust.**
- **Molecular clouds.** H<sub>2</sub> clouds traced by CO
- **Supernova remnants.** Radio Continuum Loops
- **Stars and Associations.** Massive stars, nearby stars, white dwarfs, and pulsars
- **Local Fluff.**
- **Heliosphere.** Heliopause, bow and term. shock

## 3D Modeling of Interstellar Matter

Synthesize the distribution of interstellar matter in the local Solar environment out to  $\sim 500$  pc.

- **Absorption Data.** Put distances on features in emission maps
- **Emission Maps.** Establish 2D positions and cloud types (neutral, warm ionized, molecular,...)
- **3D Structure.** From combining star distances with absorption data and emission maps

# Cloud Types and Tracers

- **CNM/WNM.** Warm and cold neutral matter ( $H^0$  21-cm emission; optical and UV absorption lines)
- **WIM.** Warm ionized matter (H-alpha emission, pulsar dispersion measure, UV absorption lines)
- **HIM.** Hot ionized material (soft X-ray emission, UV absorption lines)
- **Molecular Clouds.** (CO emission)

# Resources

- **NASA Data Sources.** Need to select the useful data from enormous quantity available.
- **Models and Data from Colleagues and Databases.**
- **Distance Editing Tool.** Combine data sources for analysis.

# Distance Editing Tool [*Demo*]

- **Multiple sources.** Combine 2D maps, point sources, and absorption line data  $\Rightarrow$  3D distance information
- **2D Data.** Texture maps give context
- **Distance Data.** Sources with known distances, absorption line data
- **Sliding Tubes.** Interactive manipulation of absorption data to deduce distances

# Analysis Method: Sliding Tube

- **Sliding tube** represents cloud thickness (interstellar material absorbing starlight)
- **Texture maps on grid** suggest the underlying material ( $10^6$ -degree plasma, heated dust, neutral H, molecular cloud).
- **Point sources:** stars, etc, provide background 3D constraints on the 2D image data

# Combining Multispectral Data

- **Dust.**

- *Emission = infrared data (e.g. IRAS, DIRBE)*
- *Absorption = color excess of stars*

- **CNM.** Cold neutral material

- *Emission = H<sup>0</sup> 21-cm*
- *Absorption = stellar UV & optical absorption lines*

## *Combining Multispectral Data, contd*

- **WIM.** Warm ionized material
  - *Emission = H-alpha data, radio continuum (loops)*
  - *Absorption = absorp. lines, pulsar dispersion*
- **WNM.** Warm neutral material
  - *Emission = H<sup>0</sup>.*
  - *Absorption = UV, optical absorption lines*
- **HIM.** Hot ionized material
  - *Emission = soft X-ray background*
  - *Absorption = UV absorption lines in disk and halo stars*

# Local Fluff

- **Absorption Line Data.**
- **Column Densities:** Use col. densities in Distance Editing Tool to find geom. of Local Fluff
- **Fine Structure.** Determine geometry of cloudlets in Local Fluff

# Kinematics of Local Fluff

- **Interstellar Gas Flow velocity.** Find systematic 3D motions
- **Cloudlet properties.** Get kinematics of individual local cloudlets
- **Solar environment.** Establish kinematics of Sun relative to nearby cloudlets
- **Relative motions of nearby stars.**

# Heliosphere

Interaction of Solar System with the Local Fluff.

- **Heliopause.** (discontinuity between plasmas)
- **Termination Shock.** (solar wind goes subalfvenic)
- **Bow Shock.** (interstellar flow goes subsonic)

# Interstellar medium and the Interplanetary Environment

- **Interstellar neutral gas.**
- **Interstellar dust and micrometeorites.**
- **Planetary magnetospheres.**
- *Future:* **Solar cycle and time varying heliosphere.**

# Implementation Activities

Related work on interactive astrophysical visualization:

- **Computer Science.** Dagstuhl 2000 Workshop, Amsterdam Visualization Symposium, NSF/DoE Lake Tahoe Workshop on Hierarchical Methods in Visualization.
- **Adler Planetarium.** Resource provider for “Sun-Earth Connection” show.
- **“Cosmic Clock.”** 3-1/2 minute computer animation. One of 39 selected from 630 entries for Siggraph 2000 graphics conference. Cosmological causality and the Hubble expansion (physical vs comoving coordinates).

# SUMMARY

- **Data sets.** Assembling and analyzing unified local galactic environment data sets.
- **Interactive systems.** General tools for 3D analysis, CAVE applications for very large scales, “Cosmic Clock” movie.
- **Future Work.** Continue with new data sources and analysis applications.