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3D TOMOGRAPHY OF LOCAL INTERSTELLAR GAS AND DUST

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Abstract. Interstellar absorption data and Strömgren photometric data for target stars possessing a Hipparcos parallax have been combined to build a 3D tomography of local gas and dust. We show the latest inverted 3D distributions within 250 pc, compare gas and dust maps and discuss the present limitations and work in progress. Gaia extinction data and follow-up ground-based stellar spectra (e.g. with GYES at the CFHT) will provide a far larger database that should allow a 3D tomography of much higher quality and extended to much larger distances.

Keywords: galaxy: solar neighborhood, ISM: atoms, ISM: clouds

1 Introduction

The nearby interstellar medium plays several important roles in astrophysics. It is a tool for studying the evolution of the ISM, it provides the local conditions for photons and particles transport, it is a foreground which needs to be removed for studying specific objects, it is the ambient medium which governs limit conditions for a specific object and also the context environning such an object, etc. We present here studies of the gas and dust 3D distribution in the local interstellar medium (by local we mean here the interstellar medium within 250 pc).

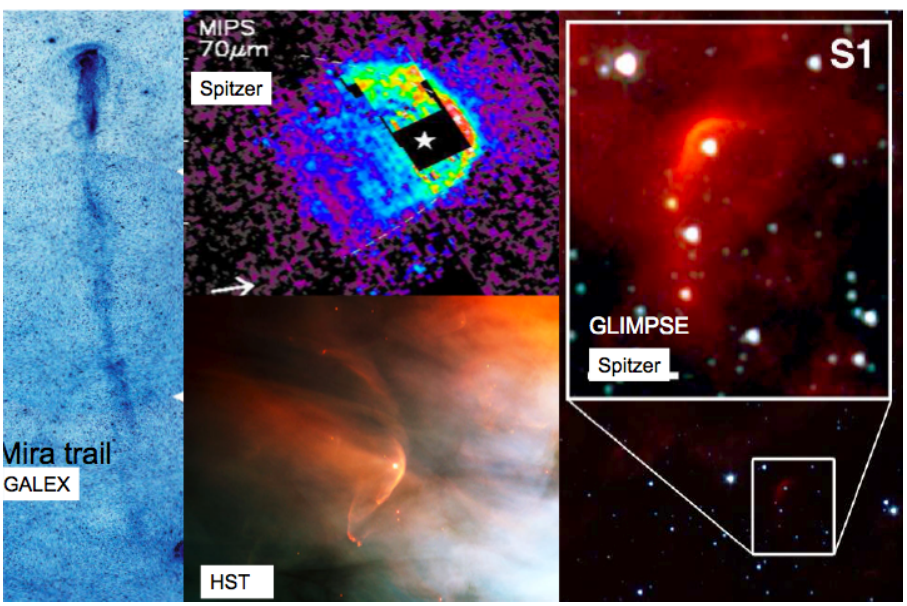

Fig. 1. Examples of interaction regions between stars and their surrounding environment. Stars collide the surrounding gas inducing a compression area. The knowledge of the ambient medium helps modeling the interaction.

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2 Means of study

This work is based on NaI and CaII interstellar absorption lines in nearby star spectra and extinction obtained by Strömgren photometry. Both types of data can be inverted to get a 3D tomography of gas and dust. In addition, absorption lines assembled in an interstellar absorption database are a tool to distinguish between foreground absorption and local lines when studying objects by means of spectroscopy.

Fig. 2 illustrates an example of typical absorption lines.

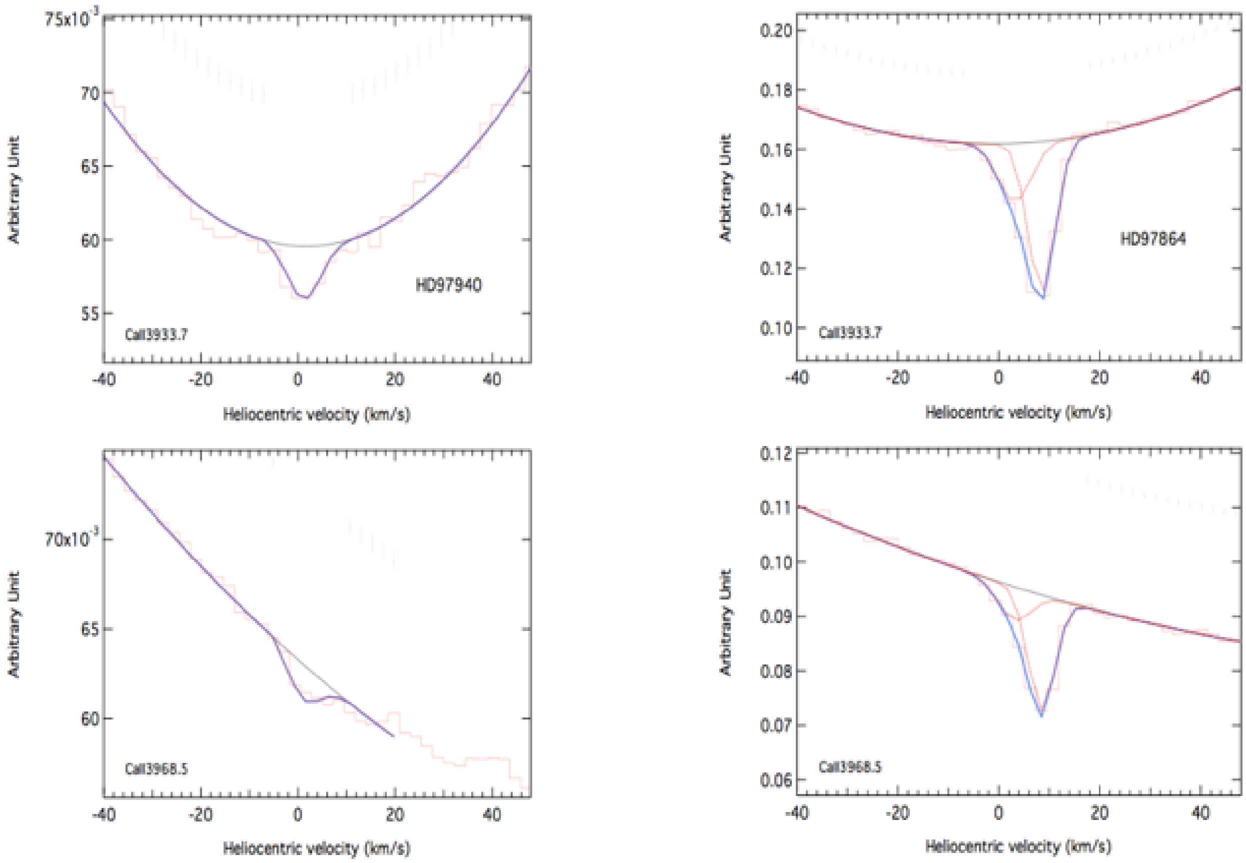

Fig. 2. Examples of CaII absorption lines of two stars in the same line of sight (the K line at 3934Å is on the top and the H line at 3968Å is on the bottom). On the left, HD97940 located at 85pc. A line is observed at about 2 km/s therefore a cloud begins before 85pc at this velocity. On the right, HD97864 located at 92pc. The same line is observed at about 2 km/s and a new one is detected around 9 km/s so the cloud beginning before 85pc is still present and another one at a velocity of about 9 km/s begins between 85 and 92pc.

3 Comparison of the different tracers

Gas and dust data can be combined with distances to the target stars to reconstruct by means of sophisticated inversion tools the gas and dust distributions in three dimensions. The obtained maps of the local interstellar medium reveal the so-called *Local Bubble*, a region devoid of dense gas that surrounds the Sun. Because of the difficulty to represent these distributions in three dimensions we show several cuts in the data cubes.

The different tracers are NaI, CaII and extinction. NaI is the tracer of dense and neutral gas, CaII is the tracer of dense neutral and also ionized gas and extinction locates the dust. We compare the results obtained with the different tracers in the meridian plane, i.e. the plane perpendicular to the galactic plane containing the Sun and the galactic center. These are shown in Fig. 3.

In all the cases, the Local Bubble surrounding the Sun is about 200pc wide in the galactic plane. This cavity is surrounded by large dense clouds: Ophiucus, Chamaeleon, Coalsack or Taurus. The maps reveal two chimneys towards the halos and the cavity is tilted perpendicularly to the plane of the Gould Belt which is a ring of young stars and star forming regions tilted of about 20° towards the Galactic Center.

Within the Local Bubble neither NaI nor dust significant concentration is present, however it contains many diffuse clouds revealed in the CaII maps. These clouds are too ionized for being visible in NaI and too tenuous to be visible in extinction but they are detected thanks to CaII which traces the ionized gas.

The maps present strong similarities but also differences that may reflect gas states but also poor precision due to the limited amount of stars available for the inversion. Two articles are based on these maps, one comparing NaI and CaII (Welsh et al. 2010) and the other comparing NaI and extinction (Vergely et al. 2010).

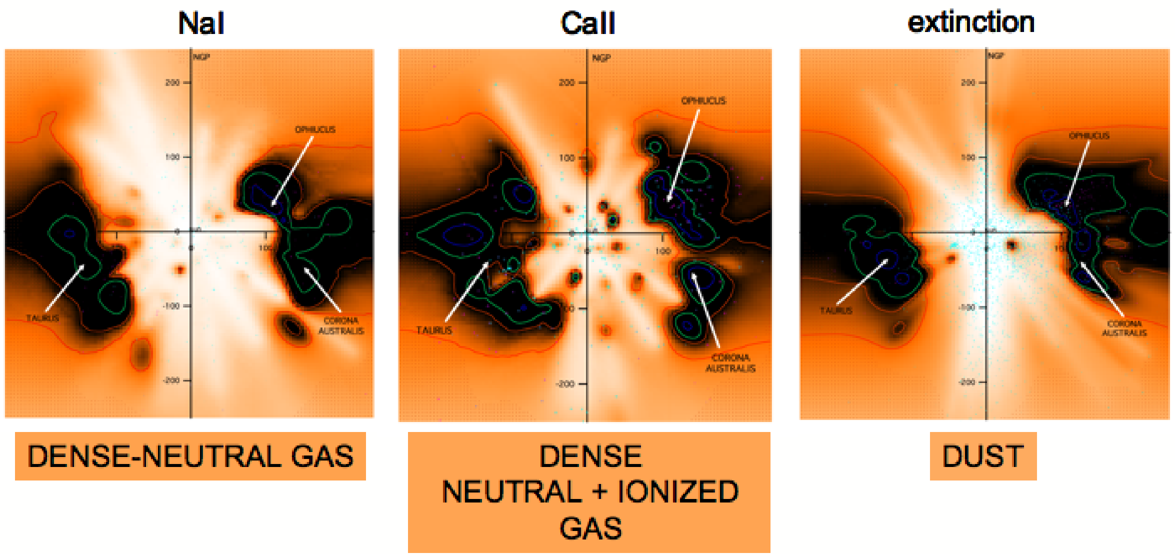

Fig. 3. Comparison of the local interstellar medium in the meridian plane. In each cut, the Galactic Center is on the right and the North Galactic Pole is on the top. Black indicates an important density whereas white represents diffuse regions. On the left, the map with NaI. On the middle, the map with CaII. On the right, the map with extinction.

4 Comparison between integrated gas and dust

In Fig. 4 neutral gas (on the left) and dust (on the middle) integrated back within the 3D cubes between the Sun and 200 pc are represented in aitoff projection. Important similarities are visible between the total columns of neutral gas traced by neutral sodium and dust opacities. On the right of Fig. 4, dotted lines representing integrated dust until 200pc are superimposed on the map showing the dust emission integrated to infinity derived from infrared data (Finkbeiner et al. 1999). Firstly, isocontours correspond very well with the map, showing that the inversion method is robust in spite of the limited amount of stars. Secondly, since the isocontours are well matching the map at moderate and high latitude, this means that the majority of the dust observed on the map of Finkbeiner et al. 1999 is located within 200pc.

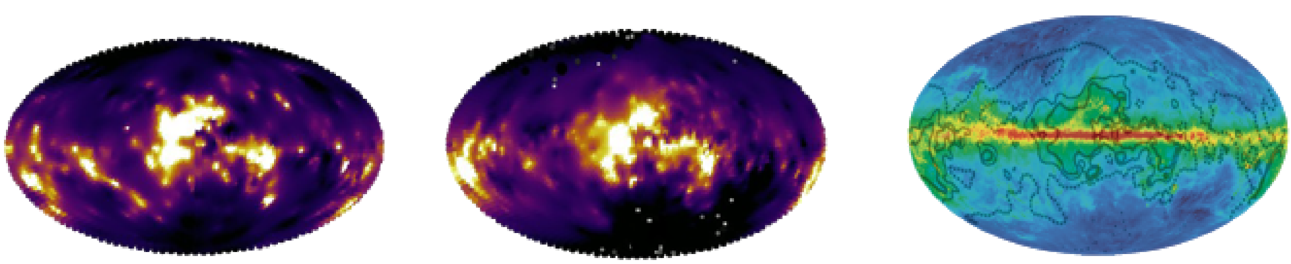

Fig. 4. Neutral gas (on the left) and dust (on the middle) integrated between the Sun and 200pc. On the right, map of the total column of dust, i.e. integrated to infinity (Finkbeiner et al. 1999). Dotted lines representing integrated dust until 200pc are superimposed.

5 Determination of the distance towards nearby structures

One of the interests of these inversions is the possibility to identify nearby structures seen in 2D maps and obtain an information on their distance, based on the kinematics. In particular, some clouds seen in the 21 cm HI data maps from the LAB Survey (Kalberla et al. 2005) are studied by compairing HI emission and NaI absorption velocities of the stars belonging to the database in the direction of the clouds. An example is presented in Fig. 5.

The map on the left in Fig. 5 presents a structure seen in HI emission between -10 and 0 km/s LSR. In order to define its distance, all the stars in this region are superimposed on the map and for each of them, we note the distance of the star and whether or not NaI is observed in absorption in this velocity interval.

We remark in this example that until 75pc, the stars don't present NaI absorption on their line of sight whereas from 75pc, all of them present NaI absorption lines around -3 km/s LSR. This means that the structure at -3 km/s LSR begins at around 75pc .

The spectra of the top and of the bottom of Fig. 5 illustrate respectively the NaI absorption spectrum of a star more distant than 75pc in the region and the HI emission spectrum in the same direction. This is an example showing that gas in the structure has a velocity around -3 km/s LSR. It would be the same with the NaI absorption and HI emission spectra of each star more distant than 75pc.

The cut on the right in Fig. 5 shows the structure seen in the same sky region in the NaI cube. It begins at 75pc, which is consistent with the distance found previously from the kinematics and allows the identification. Indeed, by using two methods based on different data, the first being the localization by velocity criteria and the second being the localization in the NaI cube only by absorption growth with distance criteria, the same result is obtained.

This identified region corresponds to the high latitude molecular clouds known as MBM53, MBM54 and MBM55 (Magnani et al. 1985). (Magnani et al. mapped the sky looking for high latitude clouds emitting CO and named them MBM.) Their initial estimated distance was 150pc (Welty et al. 1989). At that time, the stars did not have Hipparcos parallax, so the distance of the cloud was badly estimated. Here we have improved the localization of the structure and shown that it is much closer than previously thought.

This analysis is currently extended to other dense clouds by comparing the NaI interstellar absorptions and the HI emission and by searching the clouds in the data cubes.

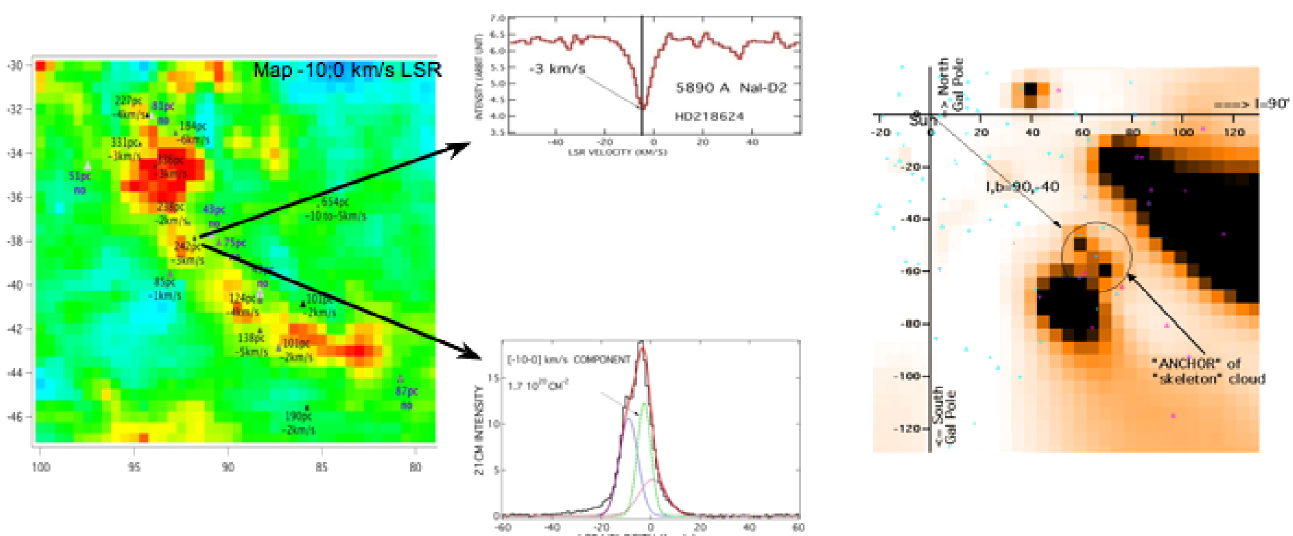

Fig. 5. Determination of the distance of a structure located at $l = 90°$ and $b = -40°$. On the left, the structure seen in HI emission in the velocity interval between -10 and 0 km/s LSR. On the top, NaI absorption spectrum of one of the stars more distant than the cloud with an absorption velocity around -3 km/s LSR. On the bottom, HI emission spectrum in the same direction with one of the peak around -3 km/s LSR. On the right, cut in the NaI cube at the good coordinates. The structure is visible and begins at 75pc.

6 Perspectives

Tomographic methods applied to local ISM dust and gas have been tested and validated on the current available absorption and extinction databases. In order to improve the accuracy and spatial resolution of the 3D maps, it is mandatory to increase the stellar databases, and have access to corresponding reliable parallaxes for the target stars. The GAIA mission and follow-up ground-based spectroscopic data with GYES will provide such considerably larger and better data sets. Combinations of the 3D distributions with 2D spectral maps should in addition allow to replace the roughly spherical clouds obtained by inversion by more realistic shapes.

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