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Dynamical ISM with Gaia and ground-based massive spectroscopic stellar surveys

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Abstract. The ongoing Gaia mission of ESA will provide an accurate spatial and kinematical information for a large fraction of stars on our side of the Galactic centre. Interstellar extinction and line absorption studies toward a large number of stars at different distances and directions can give a 3-dimensional distribution map of interstellar absorbers, and thus reach a similar level or spatial and kinematic perfection. Specifically, under certain morphologies (e.g. geometrically thin absorption curtains and sheets) one can infer a complete velocity vector from its radial velocity component and so obtain a dynamical information comparable to stars. For that, observations of large number of stars at different distances are needed to determine where (along the line of sight) are the absorption pockets. Therefore, techniques to measure interstellar absorptions towards (abundant) cool stars are needed. A complex mix of colliding absorption clouds in found in the Galactic plane. Thus, one would wish to start with deep observations to detect the weak, but much more simple interstellar absorptions at high Galactic latitudes. Finally, interstellar atomic line absorption studies toward cool stars in the optical are largely limited to Sodium and Potassium doublets, not covered by many surveys, including Gaia. Diffuse interstellar bands (DIBs) can be important, as their measurement can give the same type of information as interstellar atomic absorption lines. A combination of both may also point to differences in dynamics of different components of the interstellar medium. In particular, Gaia spectra can be used to study the DIB at 8620 Å, and build 3-dimensional absorption maps, as already demonstrated by RAVE. Additionally, several the survey ground-based surveys (e.g APOGEE in the infrared, Gaia-ESO and Galah) that are pursuing this approach will be discussed in this contribution. The use of this new information can change our understanding in many areas (e.g. determination of membership of stars in clusters, studies of a few Myr old supernova remnants and investigations of Galactic fountains).

Key words. Galaxy: local interstellar matter – Surveys – Interstellar medium: lines and bands – Techniques: spectroscopic – Interstellar Medium: kinematics and dynamics

1. Introduction

In 2020, the Gaia mission (launched in December 2013) is expected to release astrometric distances and velocity vectors for a significant fraction of stars on our side of the Galactic centre, thus allowing a computation of stellar orbits and of evolution of the Galaxy as a whole. Studies of the interstellar medium (ISM) cannot yield information equivalent to stars, as they lack proper motion components of the velocity vector. Radial velocity shifts could be measured for ∼ 500 diffuse interstellar bands (DIBs) identified as absorptions in the optical and infra-red spectra of background stars accumulated along the line of sight (Hobbs et al. 2009). By observing a given DIB toward many stars which are nearly in the same direction but at different and known distances one can reconstruct absorption sites along the line of sight. Joining observations in many directions on the sky finally leads to their spatial distribution. So we get a 4-dimensional picture of the ISM for each DIB measurable in individual spectra.

Interstellar absorption lines of neutral atoms yield information equivalent to DIBs, but most lines are in the UV and blue part of the spectrum, so their study is limited to hot stars. An exception are sodium and potassium doublets. These lines are sharp, so measurement of their radial velocity is easy. Absorptions by ions are mostly limited to the UV and blue domains. Interstellar emission lines lack information on the distance of the emitting clouds unless they lie in the disk and we assume they follow its rotational curve or they originate in known ISM complexes. Interstellar dust absorptions can have their spatial distribution reconstructed similarly to DIBs but they lack any velocity information, which is a prerequisite for time evolution studies.

Here we discuss the challenge of using massive spectroscopic stellar surveys to obtain a multidimensional information on ISM, mostly based on observations of DIBs. We start with a brief overview of DIB properties and show that the ongoing surveys are reaching over a dozen DIBs in up to a million lines of sight, mostly toward stars away from the Galactic plane and with known spectrophotometric distances. ISM is the place of violent collisions of supernova shells, plus winds from asymptotic giant branch stars and hot-star associations. Head-on collisions in the Galactic plane are difficult to interpret. But many of the ongoing surveys observe away from the plane where interactions generally result in a net motion perpendicular to the plane. If any shells of absorbing material are identified we can assume that their motion is perpendicular to shell surfaces and reconstruct a complete velocity vector from its radial velocity component. Such information for ISM is then equivalent to the one collected for stars by Gaia.

2. Diffuse interstellar bands

Diffuse interstellar bands were first discovered nearly a century ago by Mary Lea Heger (1922) who noted the absorption bands at 5780 and 5797Å and considered them stationary in her study of early-type spectroscopic binaries McCall & Griffin (2013). They were not clearly recognised as interstellar until the work of Merrill (1934; see Herbig 1995; Sarre 2006). The label diffuse differentiates between the somewhat hazy appearance of DIBs compared with the relative sharpness of atomic transitions in the interstellar medium. Their physical carriers are still unidentified (Galazutdinov et al. 2011; Krełowski et al. 2010; Salama et al. 1999; Snow & McCall 2006; Iglesias-Groth et al. 2010; Maier et al. 2011). They are mostly found in the optical and near infra-red spectral bands, with the DIB with the longest wavelength discovered at 1.793 μm (Geballe et al. 2011). DIBs were also observed in nearby galaxies (Vidal-Madjar et al. 1987; Cox et al. 2007; Cox & Patat 2014; Cordiner et al. 2008a,b, 2011) and at cosmological distances (e.g. York, et al. 2006; Monreal-Ibero et al. 2015), but most of the studies rely on high resolution and high S/N spectra of hot stars in our Galaxy. Because the DIBs are weak (the strongest one at 4428Å having a typical equivalent width of 2Å in a E(B-V)=1 sight-line) and easily blended with stellar lines, high S/N spectra of nearly featureless hot stars are most appropriate for studying DIBs. Therefore most of the surveys include few thousand stars at most (Snow et al. 1977; van Loon 2014; Lan et al. 2015), or around a hundred stars, if weaker DIBs are observed (e.g. Friedman et al. 2011).

Individual DIBs do not show large variations in the peak position and profile, even between sight-lines with very different dust properties (e.g. grain size, see Tielens 2005).

Table 1. Properties of selected ongoing large stellar spectroscopic surveys. The last column refers to spectra suitable for DIB measurements.

Survey	D(mirror) [m]	λ range(s) [nm]	R	Mag range	Stars
RAVE	1.2	841–877	7500	$9 < I < 12$	459k
SEGUE	2.5	390–900	1800	$14 < g < 20.3$	240k
SEGUE-2	2.5	380–920	1800	$15.5 < g < 20.3$	118k
LAMOST	4.0	365–900	1000	$r < 14$	$\gtrapprox$ 100k
APOGEE	2.5	1510–1700	22500	$7 < H < 13.8$	100k
Gaia-ESO	8.0	~ 80 @ 403–900	20000	$V < 19$	~ 100k
GALAH	4.0	97 @ 472–789	28000	$12 < V < 14$	> 185k
Gaia-RVS	1.45 × 0.5	847–874	11500	$V \lesssim 13$	$\lessapprox$4M

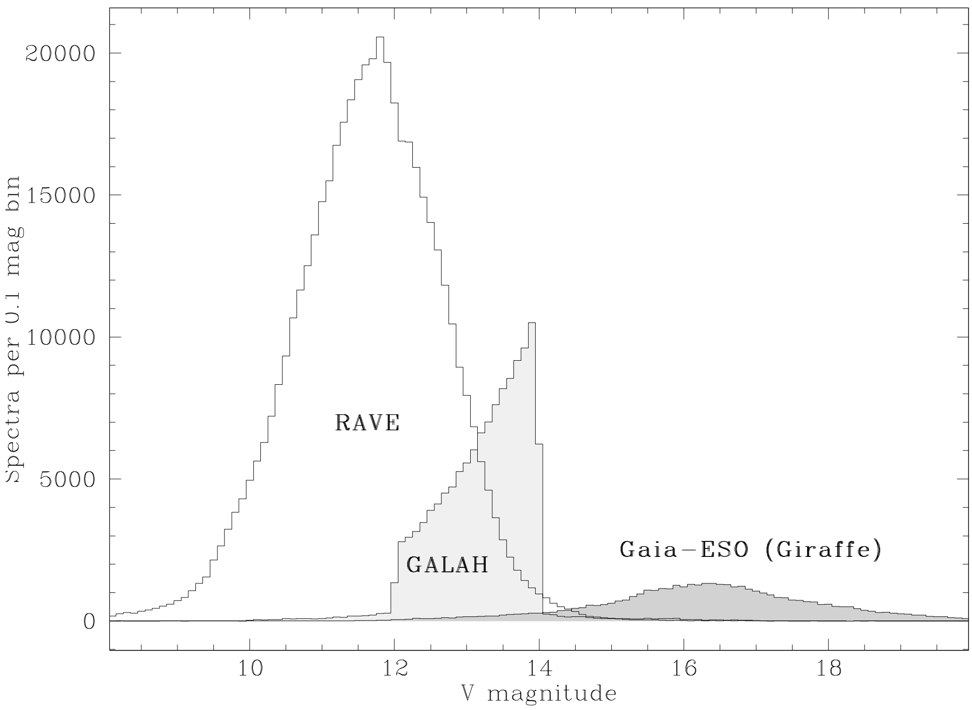

Fig. 1. Apparent V magnitude distributions of RAVE, GALAH, and Gaia-ESO survey observations, the latter only for the Giraffe instrument. Only targets already observed are plotted (see text).

Shapes of some DIBs are reminiscent of the rotational contours of a large molecule (see e.g. Sarre et al. 1995). DIB abundances are correlated with interstellar extinction and with abundances of some simple molecules (Thorburn et al. 2003). These arguments show that DIBs are probably associated with carbon-based molecules (Sarre 2006; for a general review on carbon role see Henning & Salama 1998). DIBs show no polarisation effects

(Herbig 1995) and are likely positively charged (Milisavljević et al. 2014), as suggested by the relatively low energies of absorbed photons (Tielens 2005). Until recently no known transition of any molecule or atom has yet been found to match the central wavelengths of the DIBs (Steglich et al. 2011; Huisken et al. 2014; Kokkin et al. 2014; Rouillé et al. 2014), a consequence of very low densities and huge absorption volumes in the ISM. Their origin and chemistry are thus unknown, a unique situation given the distinctive family of many absorption lines within a limited spectral range. Some of the DIBs have composed profiles which have the appearance of partially resolved P (ΔJ = 1), Q ($\Delta J = 0$), and R ($\Delta J = +1$) rotational branches of a large molecule, where J is the molecular rotational quantum number (Sarre 2014). So relative positions of the components are fixed, while their relative intensities may vary. Like most molecules in the ISM that have an interlaced chemistry, DIBs may play an important role in the life-cycle of the ISM species and are the last step in fully understanding the basic components of the ISM. The problem of their identity is more intriguing given the possibility that the DIB carriers are carbon-based molecules. A recent claim of identification of DIBs at 9633 Å and at 9578 Å with absorption bands of C_{60}^{+} (Campbell et al. 2015) may be however changing this unsatisfactory situation.

DIBs are more numerous than absorption lines of other ISM species in the optical and near infra-red bands and are therefore ideal to be studied in general spectroscopic surveys, as they are present across the whole optical and near-IR range. Having observations of multiple DIBs also allows the study of different parameters (Kos & Zwitter 2013) of the ISM apart from observing the spatial distribution of a single species. Even without the knowledge of the carriers, DIBs can be used to trace unobserved or hard to observe properties of the ISM toward the stars in a spectroscopic survey. All extensively studied DIBs correlate at least vaguely with reddening and HI abundance (Herbig 1995; Munari et al. 2008; Raimond et al. 2012; Penadés Ordas et al. 2013), ratios of different DIB strengths correlate with the UV radiation field (Krełowski et al. 1992; Kos & Zwitter 2013) and widths of some DIBs correlate with H2 abundances (Gnacinski & Krełowski 2014). It must be noted, however, that the correlation between different species of molecules can be poorly coincidential and does not indicate relations between DIBs and other species, as is often the case in the ISM.

3. Spectroscopic surveys

The main goal of stellar spectroscopic surveys is to study Galactic structure and evolution. But the collected spectra allow for a significant auxiliary science where observations of DIBs in a vast number of sight-lines are a typical example. Such ongoing surveys include RAVE (Steinmetz et al. 2006; Zwitter et al. 2008; Siebert et al. 2011; Kordopatis et al. 2013), SEGUE (Yanny et al. 2009), SDSS-III (Eisenstein et al. 2011), Gaia-ESO (Gilmore et al. 2012; Randich et al. 2013), APOGEE (Zasowski et al. 2013), Gaia (Prusti 2014), Hermes-GALAH (Freeman 2012; De Silva et al. 2015) and LAMOST (Deng et al. 2012; Yuan et al. 2014; Luo et al. 2015). Observations of 100,000s of stars bring new possibilities to the study of DIBs, to map the distribution of carriers in the Galaxy and to search for peculiar environments with unusual DIB properties. All this can contribute to the big goal of identifying the carriers.

Table 1 lists basic properties of the ongoing large stellar spectroscopic surveys. For reasons of efficiency the exposure time per target is usually limited to $\approx$ 1 hour, and most of the listed surveys use modern fiber-fed spectrographs with a high throughput. So a combination of telescope mirror diameter (D) and resolving power (R) can be used to obtain a rough estimate of the S/N ratio as a function of apparent magnitude. The number of observed stars quoted in the last column will increase with time for most of the surveys. Quoted numbers are collected from the literature for the first 5 surveys, and are current estimates for Gaia-ESo, GALAH and Gaia-RVS (counting only stars brighter than $V \sim 13$ in the latter case).

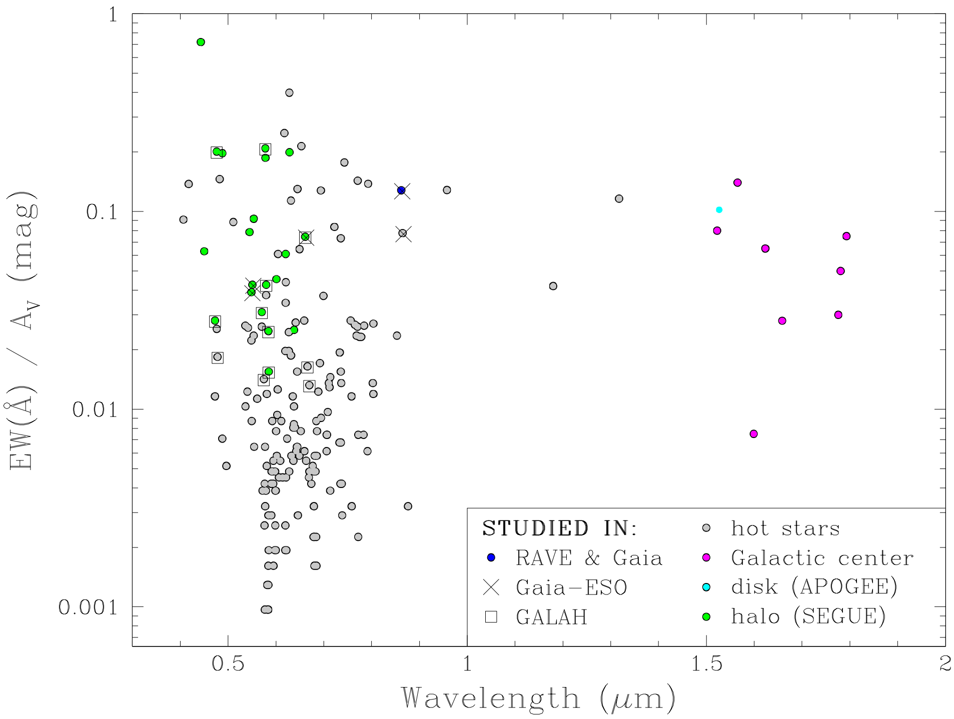

Fig. 2. Distribution mean equivalent width-to-extinction (EW_{DIB}/A_V) ratios and wavelength for 196 optical and NIR DIBs. Symbols mark DIBs which are being studied by individual spectroscopic surveys.

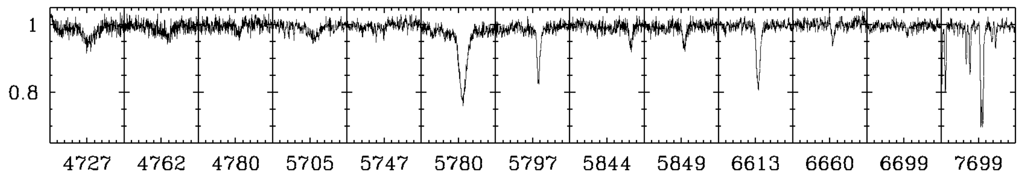

Fig. 3. Preliminary data on diffuse interstellar bands and on the K I interstellar atomic line at 7699 Å as observed by the GALAH survey. Each 20 Å wide panel is centered on the DIB wavelength as listed in Jenniskens & Désert (1994). Plotted wavelengths are heliocentric.

Figure 1 plots V magnitude histograms for stars already observed by three of the surveys listed in Table 1. Histogram for RAVE includes stars from DR4 (Kordopatis et al. 2013). Their V magnitudes have been estimated from the 2MASS J and K magnitudes using the relation:

$$V = K + 2(J - K) + 0.28 + 0.382e^{2(J-K)-0.4} \quad (1)$$

Histogram of the GALAH survey includes stars observed until 10-apr-2015, and data for Gaia-ESO survey are the ones from iDR4 obtained with the Giraffe instrument. Another ~ 6.5% of the Gaia-ESO targets are observed with the UVES instrument and are not plotted in Figure 1. Most of the UVES targets are in the 12.5 < V < 15.5 magnitude range.

DIBs are distributed over a wide range of wavelengths, so surveys with a large wavelength coverage generally include a larger number of DIBs. But on the other hand most of the DIBs are very faint, so a high S/N spectrum is needed for their detection and measurement. In this sense one can note the importance of the GALAH survey which is obtaining hundreds of thousands of high resolution spectra with $S/N \sim 100$ per resolution element.

Figure 2 plots mean equivalent width to extinction ratio and wavelength of close to 200 confirmed DIBs. Grey symbols are DIBs that were studied only in individual spectra of hot stars. Their plotted intensities are from Jenniskens & Désert (1994), Krełowski & Sneden (1995), and Jenniskens et al. (1996). Blue dot is the DIB at 8620 Å observed by RAVE and Gaia surveys (Munari 1999; Munari et al. 2008). Pink dots are infra-red DIBs reported in spectra of stars toward the Galactic center by Geballe et al. (2011). Light blue is the DIB at 1527 nm observed by APOGEE (Zasowski et al. 2015), green dots are 20 DIBs observed by SEGUE (Lan et al. 2015). DIBs studied by Gaia-ESO are crossed-out, while the ones measured by GALAH are embedded in squares. It is clear that the current surveys are studying only the brightest DIBs within their wavelength intervals. Some of the DIBs, notably the one at 6614 Å are studied by more than one survey, but generally this is not the case.

Figure 3 illustrates the most prominent DIBs in the GALAH survey spectra. A number wavelength ranges from a spectrum of TYC 4011-102-1, a hot star with strong interstellar absorptions close to the Galactic plane, are plotted. Individual panels show a dozen DIBs, while the right-most panel plots the interstellar atomic K I line. The latter in fact reveals the presence of two interstellar clouds with K I absorption at different radial velocities. For a majority of GALAH targets which lie away from the Galactic plane such complications are rare (but can be detected).

4. DIB measurement

Traditional measurements of DIBs have been limited to hot stars with spectra having only a small number of stellar spectral lines which are thermally or rotationally broadened. Measurement of DIBs in such high S/N spectra is relatively easy, as the DIBs usually lie on a nearly featureless stellar continuum (for a discussion of its automation see Puspitarini et al. 2013). But observations of DIBs in large stellar spectroscopic surveys draw their strength from a huge number of studied objects. So DIBs should be measured also in spectra of cooler stars, as hot objects are too scarce for the task. As an illustration we note that in a magnitude limited (but otherwise randomly sampled) RAVE survey only 1% of observed stars are hotter than 8100 K and only 1 star in 1000 is hotter than 16000 K.

Spectra of cool stars are rich in lines with widths that are comparable to those of DIBs. So the latter are almost always superimposed on a rich intrinsic stellar spectrum. Subtraction of the stellar contribution which is needed prior to DIB measurement can be done in two ways. Either we use a theoretical model of stellar atmosphere to compute it or we infer the stellar contribution from other stars' spectra that are very similar but have a different or even negligible presence of the DIB feature. The former approach was used by Puspitarini et al. (2015) for Gaia-ESO data, and by Zasowski et al. (2015) for the APOGEE set. Unfortunately line lists, values of oscillator strengths, non-LTE effects and the three-dimensional nature of dynamics in stellar atmospheres is still a challenge for theoretical models. Observational apparatus with its residuals of interference fringes, and uncertain level of continuum makes the computation of a realistic stellar spectrum even more difficult. So the studies using this approach understandably focused on sight-lines with strong DIB features, usually these are distant objects close to the Galactic plane.

An alternative approach, introduced by Kos & Zwitter (2013), exploits a core strength of large spectroscopic surveys, namely that they observe many stars with very similar intrin-

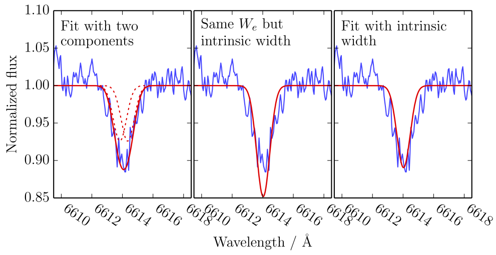

Fig. 4. Example of a DIB indicating presence of two absorbing clouds at different radial velocities as observed by the Gaia-ESO survey. The left panel is a fit with two absorbing clouds, the middle one keeps the same equivalent width but uses a single cloud, while right panel is an unconstrained fit using a single cloud.

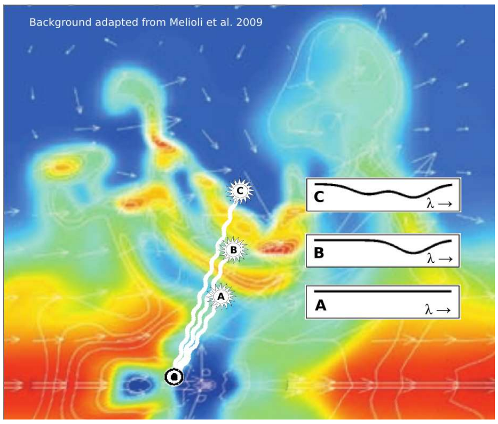

Fig. 5. Concept of a multi-dimensional localisation of DIB absorption clouds in the ISM.

sic spectra. Such close neighbours are identified by morphological comparison of restframe spectra in the wavelength ranges that do not include the studied DIB. So one can assume that these spectra are very similar also within the DIB's wavelength range. The measured difference is then attributed to DIB's contribution. This approach does not depend on physical modelling of stellar atmospheres, even systematic effects of the observational setup tend to cancel out, though a better renormalisation of the star-subtracted spectrum is often needed. Note that a large sample of stellar spectra is needed to find the matching spectra unaffected by the interstellar medium. Nearest neighbour algorithms are applied to the spectra themselves with minimal reliance on stellar parameters, so the results do not require generation of synthetic spectra. In magnitude limited surveys with an otherwise random selection of observed spectra the sample size should be close to a hundred thousand or more for a satisfactory performance of the nearest neighbour algorithm. Note that several surveys listed in Table 1 satisfy this requirement.

Diffuse interstellar bands are resolved features, as their name implies. In Section 2 we mentioned that their profiles can be, in fact, quite complex, due to the presence of partly resolved molecular rotational branches of implied complex molecular carriers. So the spectrum of DIBs obtained after division by the underlying stellar spectrum can be written as

$$F(\lambda) = \prod_{i=1}^{D} \prod_{j=1}^{C} \prod_{k=1}^{P} [1 - G(A_{ijk}, \lambda c_{ik}, \sigma_{ik}, v_j)(\lambda)] \tag{2}$$

where the products go over D DIBs, C interstellar clouds with distinct radial velocities along the line of sight, and P components of the profile of each DIB. G is the adopted shape of the DIB absorption component, e.g. a Gaussian with a given amplitude A, rest wavelength λc, width σ, and radial velocity v. Here we assume that only radial velocity and amplitudes of individual components of a given DIB change from cloud to cloud, while the relative position of components stays fixed which is true if components are partially resolved branches in the electronic transition of a large molecule.

Complexity of DIB profiles, as described by eq. 2, is usually not supported by the data. For noisy observations one usually starts with a simplistic assumption of a single Gaussian and allows for more complicated choice only if a sufficient S/N and resolving power justify it. Kos & Zwitter (2013) for example used asymmetric Gaussian profiles, and Figure 4 shows evidence for two absorbing clouds at different radial velocities.

DIBs are weak absorptions, so saturation effects which can be very important e.g.

for interstellar absorption in Sodium doublet (Munari & Zwitter 1997) are usually negligible. Zasowski et al. (2015) present an impressive example of linearity for the DIB at 1.57 μm even for interstellar extinctions of $A_V \approx 10$ mag. Puspitarini et al. (2015) obtain a similar result for optical DIBs observed by the Gaia-ESO survey in a few sight-lines close to the Galactic plane.

5. Toward a multi-dimensional picture

Observation of a single star places the observed DIB absorption somewhere along the line of sight towards the star, but does not fix its exact location. But an ensemble of stars observed in a similar direction and at different distances allows for a spatial localisation of absorbing clouds. In figure 5 it is clear that while there is no absorption closer than star A we have an absorbing cloud between stars A and B, and yet another one till star C, in this case detected both by an increased equivalent width and by the radial velocity shift of the absorbing cloud. By joining a large number of lines of sight one can finally assemble their distance-resolved clouds into a full 3-dimensional distribution, eventually even measuring radial components of their velocity vector.

Two points should be mentioned when speaking about ISM in multiple-dimensions. First, distances should be known with sufficient accuracy, and clearly this will be a significant contribution of Gaia. At the moment we should resort to spectro-photometric distances, an example are results from a Bayesian approach for the RAVE survey by Binney et al. (2014). Errors on spectrophotometric distances are typically around 20%. If location of a certain absorbing cloud is revealed by a number of stars their individual distance errors would partially cancel out. So errors in spectrophotometric distances are important but not really a single most important limiting factor in building of a multi-dimensional picture of ISM absorptions.

The second point is a requirement for a sufficient density of lines of sight. In the GALAH survey there are some 400 optical fibers placed within a field of view of π square degrees. So a mean distance between fibers is around 5 arc minutes, corresponding to 1.6 pc at a distance of 1 kpc. So a combination of accurate astrometric distances from Gaia and a large number of high S/N spectra from surveys like GALAH will allow a 3-dimensional study of ISM at a $\sim$ 1 pc resolution. We did not reach this goal yet, both because the distances are not accurate enough, and because in surveys before Gaia-ESO or GALAH the achieved S/N of collected spectra was frequently too low for measurement of DIBs in individual spectra, so that results for many stars at similar distances had to be joined together to improve the reliability of DIB measurement.

At the moment there are two quasi 3-dimensional maps of the Galactic DIB absorptions. We call them quasi, because they take the distance, the hardest to measure parameter, into account – but a good distance sampling is compensated by a poor sampling of one of the other dimensions. In the case of Kos et al. (2014) this is the Galactic latitude, where the distribution is given only by two independent coeficients and the measured scale height. Two existing maps are covering the southern skies away from the Galactic plane (Kos et al. 2014) and the northern skies close to the Galactic plane (Zasowski et al. 2015). The first one studies the DIB at 8620 Å, as revealed by the RAVe survey, while the second is an APOGEE study of the DIB at 1.57 μm. Figure 6 illustrates the results of the former study. Clearly, absorption increases with distance, as expected, but the picture is not the same for stars above or below the Galactic plane. This shows that DIB absorbers are not completely mixed in the vertical direction, which indicates that their where-abouts are related to relatively recent events in the ISM, e.g. supernova explosions not older than a fraction of the vertical oscillation time of $\approx$ 10 Myr. The same study also shows that the vertical scale-height of carriers for the DIB at 8620 Å is 118 ± 5 pc, which is significantly smaller than the vertical scale-height of dust (209 ± 12 pc). Study of Zasowski et al. (2015) finds a very similar vertical scale height of 108 ± 8 pc for the DIB at 1.57 μm. They also construct a spatial map of DIB absorptions projected to the Galactic plane. Their

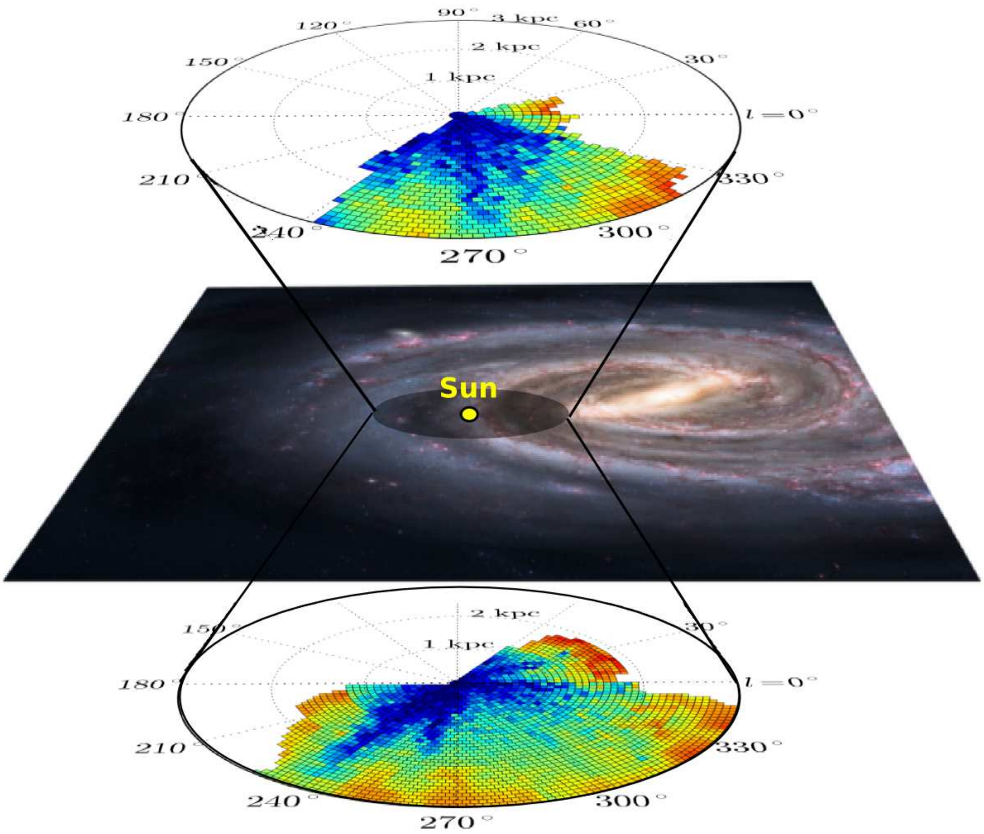

Fig. 6. Projected equivalent width of the DIB at 8620 Å for regions on both sides of the Galactic plane, as revealed by the RAVE survey. The color scale is linear with the darkest red tones reaching an equivalent width of ~ 1.5 Å. Adapted from Kos et al. (2014).

map reaches ~ 3-times larger distances than the map of RAVE, but at a lower spatial resolution. On the other hand they were able to map a general velocity variation of the DIB across the sky and confirm that it follows the general differential rotation pattern of the disk. Lan et al. (2015) constructed a 2-dimensional map of DIB absorptions off the plane based on SDSS data. All these studies are complementary to each other, as they sample different hemispheres and different distance ranges.

Construction of 3-dimensional maps of DIB absorptions assumes that the carriers are distributed smoothly in the general ISM. This assumption is generally true, the only exception seem to be particular environments of Herschel 36 (Dahlstrom et al. 2013; Oka et al. 2013; but see Bernstein et al. 2015), and the Red Square Nebula (MWC 922 Zasowski et al. 2015a). There is also a recent statement of DIB at 6613 Å to be detected in emission in the field (Burton et al. 2015). The argument about DIB absorptions not being related to circumstellar environments can be turned around by saying that the ISM sampled along a closely spaced set of lines of sight until a given distance should exhibit very similar DIB properties. An example for such a case are stellar clusters, where spectra of all cluster members should include nearly identical DIB absorptions. Kos et al. (2015) used the Gaia-ESO data to demonstrate that this is indeed true for most stars considered to be members. A few stars which were considered to be cluster members based on their position in the sky, proper motion, radial velocity, and values of stellar atmosphere parameters, however showed a significantly different strength and/or radial velocity of the DIBs in their spectra, compared to other cluster members. This implies that they are foreground or background stars. So DIBs can present an important additional rejection criterion for cluster membership. On the other hand rich clusters can be used to study granulation of DIB properties in directions perpendicular to the line of sight and on sub-parsec scales.

6. Dynamical interstellar medium

Local bubble is a cavity in the ISM with a size of at least 100 pc in the Galactic plane which contains also our Solar system (for a recent review see Lallement et al. 2014). Density of neutral hydrogen in the bubble is 0.05 atoms/cm^3, which is about 10 times less than typical for ISM in the Galactic plane. Hot X-ray emitting diffuse gas in the bubble has been recently discussed by Galeazzi et al. (2014), while far-UV radiation has been observed by CHIPSat (Hurwitz et al. 2005). A survey of both hemispheres in Na I and Ca II lines has been done by Welsh et al. (2010). The bubble is filled with ionised hydrogen gas at a million degrees embedded in a wall of dense cold gas. It is worth probing such a medium with absorptions in Ca II, Na I and K I atomic absorptions, and also with DIBs which are seen even in relatively harsh environments (van Loon et al. 2009). The latter has been attempted for the northern hemisphere by Farhang et al. (2014). Berghöfer & Breitschwerdt (2002) provide evidence that the Local bubble must have been created and shaped by multi-supernova explosions. They analysed the trajectories of moving stellar groups in the solar neighbourhood and found that about $\sim$ 19 supernovae must have occurred during the past $\sim$ 14 million years since bubble's creation. Fuchs et al. (2006) show that their implied energy input is sufficient to excavate a bubble of the presently observed size. For a review of recent events connected to the Local bubble see Lallement (2015).

The ongoing large stellar spectroscopic surveys permit to widen our view beyond the Local bubble. ISM is the place of violent collisions of supernova shells, plus winds from asymptotic giant branch stars and hot-star associations. A typical line of sight of the current surveys which lies close to the Galactic plane penetrates many of these structures, so it is difficult to present an interpretation which reaches beyond the expected increase of the DIB strength with distance and its general correlation with dust extinction. Interpretation of ISM dynamics is even harder, as one can expect that each line of sight samples several head-on collision regions in the Galactic plane. So it is important to note that observations of the on-going GALAH and partly Gaia-ESO surveys are away from the Galactic plane where interactions generally result in a net motion perpendicular to the plane. If any shells of absorbing material are identified we can assume that their motion is perpendicular to shell surfaces and reconstruct a complete velocity vector from its radial velocity component. Such information for ISM is then equivalent to the one collected for stars by Gaia.

This information can be used to study past events in the interstellar medium. They could also identify and characterise Galactic fountains blown away by supernovae in the last million years. Such flows are thought to sustain star formation in the disk by entraining fresh gas from the halo, so they provide a mechanism which explains why star formation in our and other similar galaxies did not stop when gas present in the disk has been used up (Bland-Hawthorn 2009; Fraternali 2014). So dynamical spatial mapping of DIBs observed in the ongoing large stellar spectroscopic surveys is likely to provide an observational calibration of the recent ever more realistic simulations of dynamical evolution of the ISM (Khoperskov & Shchekinov 2014; Girichidis et al. 2015).

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References

Berghöfer, T.W., and Breitschwerdt, D. 2002, A&A, 390, 299
Bernstein, L.S., et al. 2015, ApJ, 801, 6
Binney, J., et al. 2014, MNRAS, 439, 1231
Bland-Hawthorn, J. 2009, in The Galaxy Disk in Cosmological Context, J.Andersen et al. eds. (CUP, Cambridge), IAU Symp., 254, 241
Campbell, E.K., et al. 2015, Nature, 523, 322
Burton, W.T., et al. 2015, IAU GA Meeting 29, 2255619
Cordiner, M.A., et al. 2008a, A&A, 480, 13
Cordiner, M.A., et al. 2008b, A&A, 492, 5
Cordiner, M.A., et al. 2011, ApJ, 726, 39
Cox, N.L.J., et al. 2007, A&A, 470, 941
Cox, N.L.J. & Patat, F. 2014, A&A, 565, 61
Dahlstrom, J., et al. 2013, ApJ, 773, 41
De Silva, G.M., et al. 2015, MNRAS, 449, 2604
Deng, Li-Cai, et al. 2012, Research in Astronomy and Astrophysics, 12, 735
Eisenstein, D.J., et al. 2011, AJ, 142, 72
Farhang, A., et al. 2014, in The Diffuse Interstellar Bands, J. Cami and N.L.J. Cox eds. (CUP, Cambridge), IAU Symp., 297, 84
Fraternali, F. 2014, in Setting the Scene for Gaia and LAMOST, S. Feltzing et al. eds. (CUP, Cambridge), IAU Symp., 298, 228
Freeman, K.C. 2012, in Galactic Archaeology, ed. W. Aoki et al. (ASP, San Francisco), ASP Conf. Ser., 458, 393
Friedman, S.D., et al. 2011, ApJ, 727, 33
Fuchs, B., et al. 2006, MNRAS, 373, 993
Galazutdinov, G., et al. 2011, MNRAS, 412, 1259
Galeazzi, M., et al. 2014, Nature, 512, 171
Geballe, T.R., et al. 2011, Nature, 479, 200
Gilmore, G., et al. 2012, The Messenger, 147, 25
Girichidis, P., et al. 2015, `arXiv:1508.06646`
Gnacinski, P. & Krełowski, J. 2014, in The Diffuse Interstellar Bands, J. Cami and N.L.J. Cox eds. (CUP, Cambridge), IAU Symp., 297, 125
Heger, M.L. 1922, Lick Obs. Bull., 10, 146
Henning, T. & Salama, F. 1998, Science, 282, 2204
Herbig, G. 1995, ARAA, 33, 19
Hobbs, L.M., et al. 2009, ApJ, 705, 32
Huisken, F., et al. 2014, in Diffuse Interstellar Bands, J. Cami and N.L.J. Cox eds. (CUP, Cambridge), IAU Symp., 297, 265
Hurwitz, M., et al. 2005, ApJ, 623, 911
Iglesias-Groth, S., et al. 2010, MNRAS, 407, 2157
Jenniskens, P. & Désert, F.-X. 1994, A&AS, 106, 39
Jenniskens, P., et al. 1996, A&A, 313, 649
Kokkin, D.L., et al. 2014, in The Diffuse Interstellar Bands, J. Cami and N.L.J. Cox eds. (CUP, Cambridge), IAU Symp., 297, 286
Khoperskov, S. A., and Shchekinov, Yu. A. 2014, `arXiv:1403.7075`
Kordopatis, G., et al. 2013, AJ, 146, 134
Kos, J. & Zwitter, T. 2013, ApJ, 778, 86
Kos, J., et al. 2014, Science, 345, 791
Kos, J., et al. 2015, in preparation
Krełowski, J., et al. 1992, MNRAS, 258, 693
Krełowski, J., and Sneden, C. 1995, in The Diffuse Interstellar Bands, A. G. G. M. Tielens and T. P. Snow eds. (Springer, Dordrecht), Astroph. and Space Sci. Library, 202, 13
Krełowski, J., et al. 2010, ApJL, 714, L64
Lallement, R., et al. 2014, MemSAI, 85, 339
Lallement, R., 2015, J. of Physics, Conf. Ser., 577, 12016
Lan, T.-W., Ménard, B., Zhu, G., 2015, MNRAS, 452, 3629
Luo, A.-Li, et al. 2015, Research in Astronomy and Astrophysics, 15, 1095
Maier, J.P., et al. 2011, ApJ, 729, 20
McCall, B.J. & Griffin, R.E. 2013, Proc. R. Soc. A, 469, 20120604
Merrill, P.V. 1934, PASP, 46, 206
Milisavljević, D., et al. 2014, ApJL, 782, L5
Monreal-Ibero, A., et al. 2015, A&A, 567, L3
Munari, U., and Zwitter, T. 1996, A&A, 318, 269
Munari, U. 1999, Baltic Astronomy, 8, 73
Munari, U., et al. 2008, A&A, 488, 969
Oka, T., et al. 2013, ApJ, 773, 42
Penadés Ordas, M., et al. 2013, Highlights of Spanish Astrophysics, VII, eds. J. C. Guirado, et al. 600

Prusti, T. 2014, EAS Pub. Ser., 67, 15
Puspitarini, L., et al. 2013, A&A, 555, 25
Puspitarini, L., et al. 2015, A&A, 573, 35
Raimond, S., et al. 2012, A&A, 544, A136
Randich, S., et al. 2013, The Messenger, 154, 47
Rouillé, G., Jäger, C., Huisken, F., Henning, T. 2014, in The Diffuse Interstellar Bands, J. Cami and N.L.J. Cox eds. (CUP, Cambridge), IAU Symp., 297, 276
Salama, F., et al. 1999, ApJ, 526, 265
Sarre, P.J., Miler, J.R., Scarrott, S.M. 1995, Science, 269, 674
Sarre, P.J. 2006, J. Molecular Spectroscopy, 238, 1
Sarre, P.J. 2014, in The Diffuse Interstellar Bands, J. Cami and N.L.J. Cox eds. (CUP, Cambridge), IAU Symp., 297, 34
Siebert, A., et al. 2011, AJ, 141, 187
Snow, T. P., Jr., York, D.G., Welty, D.E. 1977, AJ, 82, 113
Snow, T.P., McCall, B.J. 2006, ARAA, 44, 367
Steglich, M., Bouwman, J., Huisken, F., Henning, Th. 2011, ApJ, 742, 2
Steinmetz, M., et al. 2006, AJ, 132, 1645
Thorburn, J.A., et al. 2003, ApJ, 584, 339
Tielens, A.G.G.M. 2005, The Physics and Chemistry of the Interstellar Medium (CUP, Cambridge)
van Loon, J. T.h. 2014, in The Diffuse Interstellar Bands, J. Cami and N.L.J. Cox eds. (CUP, Cambridge), IAU Symp., 297, 79
van Loon, J. T. h., et al. 2009, MNRAS, 399, 195
Vidal-Madjar, A., et al. 1987, A&A, 177, L17
Welsh, B.Y., et al. 2010, A&A, 510, 54
Yanny, B., et al. 2009, AJ, 137, 4377
York, B.A., et al. 2006, ApJ, 647, L29
Yuan, H.-B., et al. 2014, in Setting the scene for Gaia and LAMOST, S. Feltzing et al. eds. (CUP, Cambridge), IAU Symp., 298, 240
Zasowski, G., et al. 2013, AJ, 146, 81
Zasowski, G., et al. 2015, ApJ, 798, 35
Zasowski, G., et al. 2015a, arXiv:1508.07015
Zwitter, T., et al. 2008, AJ, 136, 421