Tracing Galactic Arm with 6614 Å Diffuse Interstellar Band and Gaia DR2 Distances

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Abstract. Enigmatic problem in astronomical spectroscopy is diffuse interstellar bands (DIBs). DIBs are ∼500 weak and broad absorption features seen in the spectra of stars or other astronomical objects located behind interstellar materials. Despite the unknown ions or molecules that caused the absorptions, except for two near infrared DIBs, DIBs can be used as a potential interstellar medium (ISM) tracer to map Galactic structure. Gaia is a mission of the European Space Agency (ESA) which was launched on 2013. It provides precise distances which greatly improve our knowledge of the structure and history of our Galaxy. In this work, we used previously determined DIB equivalent width (EW) measurements by means of DIB fitting that is a combination of a synthetic stellar spectrum, a synthetic telluric transmission, and empirical DIB profile to the Gaia–ESO Large Public Spectroscopic Survey data. From DIB measurements from stellar spectra of distributed target stars and together with Gaia DR2 distances, we investigated the ISM distribution along particular line of sight, i.e., (l,b)∼(213°, -2°) which probes Local and Perseus Arm.

1. Introduction
Diffuse interstellar bands (DIBs) are a large number of weak and broad unidentified absorption features seen in the spectra of stars or other astronomical objects located behind interstellar materials. DIBs behave like interstellar lines in regard to their occurrence, strength, and Doppler shift. Rather being narrow and sharp, they are widened (diffuse width), but weak (not easily saturated). Currently, we do not know clearly which ion(s) or molecule(s) that caused DIBs, except for two near infrared DIBs that recently discovered to be related to C60⁺ [2]. DIBs can be used as potential ISM tracer because: (1) they are ubiquitous (more than 400 cataloged DIBs in optical and IR domain) [8, 9, 10]; they are not easily saturated; and they have correlation with other interstellar parameters, i.e. reddening [3].

Gaia is a mission of the ESA which was launched on 2013. It provides precise distances which improve our knowledge of the structure of our Galaxy. Gaia Data Release (DR) 2 was released on April 2018 and is available through the archive [5, 6]. Spectroscopic data (DIB measurements) and Gaia distances can help to trace the Galactic interstellar structures.
2. Data
The stellar spectra were taken from the Gaia-ESO Spectroscopic Survey (GES) [7], a public
spectroscopic survey that started in 2011 and aims at recording VLT/FLAMES spectra of \( \sim 100 \)
000 stars in our Galaxy. In this works, we used target stars on field \((l,b)\sim(213^\circ, -2^\circ)\) with the
H665 (HR15N) setting, which has spectral resolution of \( R_{\text{Giraffe}} \sim 17000 \) and spectral range
of 5822 to 6831 Å. We therefore used the 6614 Å DIB, which is the strongest DIB presented in
the spectral range of our data. The target stars are located about the Galactic plane and are
widely distributed in distances, which allow us to trace ISM distribution along the line of sight.
The DIBs study with GES have been previously performed by [13].

3. Method and Results

![Figure 1](image)

**Figure 1.** The 6614 Å DIB equivalent width measurements vs. Gaia DR2 stellar distances.
Colors show longitude of the stars. Abrupt increase of the equivalent width corresponds to the
crossing of dense interstellar materials, i.e. Galactic arm.

As mentioned in [13], we used DIB fitting to measure the strength (i.e., equivalent width or
EW) of DIB. For the DIB fitting, an observed spectrum was fitted with a triple combination
of DIB Model (fit in strength and shift), telluric transmission model (fit in strength and shift),
and synthetic stellar spectrum (fit in shift). The Levenberg-Marquardt algorithm in IGOR Pro
6.2 was used to search for coefficient values of the fitting. We allowed multi-component DIBs
that were guessed by using velocity prior values from HI emission spectra [4].

The DIB model is an average profile of a DIB from series of observations of nearby stars [12].
In this case we ignored sub-structures seen in DIB profile as they are very small. The synthetic
Figure 2. Planck extinction map for the \((l,b)\sim(213^\circ, -2^\circ)\) field. The map shows different extinction values along the longitude.

Figure 3. Distribution of target stars in XY plane, superimposed with illustration of Galactic map by R. Hurt (SSC/Caltech)
telluric transmission was taken from the Transmissions of the AtmosPhere for AStromomical data (TAPAS) web-based service (see [1] and references therein).

We updated the analysis from [13] by using Gaia DR2 distances [5, 6] to build the DIB strength radial profile along the line of sight (see Fig. 1). Figure 1 shows the plot between the measured DIB equivalent width vs. stellar distances. The colors show different longitude of the target stars. Green shows the stars with Galactic longitude \( l < 212.8^\circ \), whereas purple shows target stars with \( l > 212.8^\circ \). Abrupt increase of the DIB equivalent width corresponds to the crossing of dense interstellar materials, i.e. Galactic arm. From the figure, we found that there are two spatial structures in the field. The first one is for \( l < 212.8^\circ \) (see black trace in Fig. 1), another one is for \( l > 212.8^\circ \) (see dash line). The structures for \( l > 212.8^\circ \) and \( l < 212.8^\circ \) are in agreement with the extinction map of Planck [11]. The Planck map shows more interstellar extinction for \( l > 212.8^\circ \) (Fig. 2). From the Fig. 1, the abrupt increases of DIB strength at a distance of less than 2 kpc might correspond to Local Arm, whereas at 2-4 kpc might correspond to Perseus Arm. However, we also found a very abrupt increases at about 3 kpc. Thus, interstellar clouds in Perseus Arm in this line-of-sight (of the field) might be complex or inhomogenous.

In addition we have compared the distribution of the target stars to a face-on map of our Galaxy illustrated by R. Hurt (SSC/Caltech) based on HI data (see Figure 3). The color scale shows the DIB strength measurement. The abrupt increase of DIB is in agreement with the location of the Galactic Arm.

4. Conclusions and Future Works

We show that spectroscopic data (DIB EW) and precise stellar distances can be used to trace the Galactic structures. We detected Local (at \( < 2 \) kpc) and Perseus arm (at 2-4 kpc) in the radial profile between DIB strength and stellar distances as seen from the abrupt increase trend. The field \((l, b) \sim (213^\circ, -2^\circ)\) shows complex (different) interstellar structures for \( l < 212.8^\circ \) and for \( l > 212.8^\circ \).

5. Acknowledgements

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