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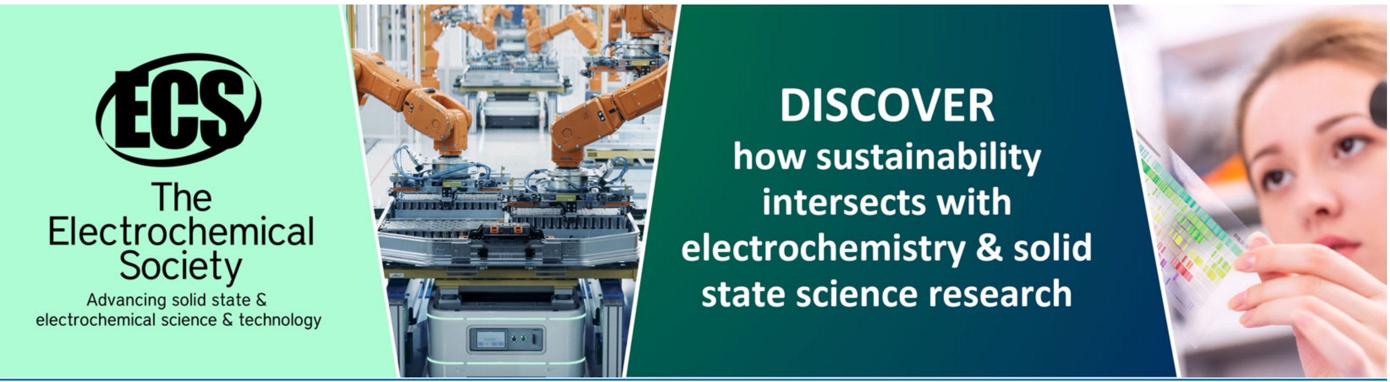

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A Search for Extragalactic Diffuse Interstellar Bands: SAMI Data

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Abstract. Diffuse interstellar bands (DIBs) are puzzling absorption features that can be found in the spectra of reddened objects in our Galaxy, as well as in other observed galaxies. Although we still know too little of the carriers of DIBs, the numerous features along the optical and near infrared wavelengths and the consistency of their measured properties make DIBs potentially promising interstellar material tracers. DIBs studies are mostly based on stellar spectra in our Galaxy, but since DIBs can also be found in other galaxies, we search for DIBs in the spectra of nearby galaxies by perusing Sydney-AAO Multi-object Integral-field unit (SAMI) data. We demonstrate DIB measurement by performing an automated fitting of a combination of a smooth continuum and a model of DIB profile to the spectrum. This preliminary result will be an important input to consider in drawing conclusion about DIBs and their environments.

1. Introduction

Diffuse interstellar bands (DIBs) are puzzling weak interstellar absorption features that can be found in the spectra of reddened objects in our Galaxy as well as in other galaxies. DIBs indicate interstellar origin as seen from their occurrence, strength, and kinematics. Unlike interstellar lines with narrow and sharp profiles, DIBs profiles are often broad (diffuse). DIBs were firstly identified in 1922 by [1]. Although it has been almost a century, the carriers of DIBs are still unknown, except for the two infrared ones (λ 9632 and 9577 Å DIBs) that relate to $C60^+$ molecules [3]. Identifying DIBs carriers is a challenging task and is a subject of active research (see [9, 8, 15] and references therein). Despite the unknown carriers, DIBs can be a potential ISM tracer because they are ubiquitous ($\sim$500 DIBs in optical and infrared [11, 10, 12]) and have correlation with other interstellar parameters, i.e., color excess (see [7] and references therein).

Most of the DIBs studies are within our own Galaxy. However, our Galaxy is just one among hundreds of billions in the observable universe. Therefore, there have been questions about DIBs existance and properties in other galaxies. The first extragalactic DIB observations were made by [17], who measured DIBs in Magellanic Clouds. From supernova observations in Large Magellanic Cloud (LMC), [18] found that the extragalactic DIBs are quite similar to that of our Galaxy in terms of the DIBs present, profiles, and strengths. There are, however, still many other unexplored galaxies with DIBs carriers.

At present, large galaxy surveys, in particular with integral-field unit (IFU) spectroscopy, have been or are being conducted. This provides not only spectral information but also spatially resolved information. This may improve our knowledge about DIBs distribution and properties in other galaxies. In this preliminary work, we aim at demonstrating extragalactic DIB detection and extraction from IFU data.

2. Data

We used spectra of galaxies observed by using the Sydney-AAO Multi-object Integral-field (SAMI) that feeded the AAOmega spectrograph [5]. SAMI was installed at the ∼4m Anglo-Australian Telescope (AAT) at Siding Spring Observatory. SAMI combined the power of multi-object spectrograph together with the spatial multiplex advantage of an integral field spectrograph.

SAMI taken data for SAMI Galaxy Survey [2] from 2013 until 2017. The SAMI Galaxy Survey is a spatially resolved spectroscopic survey of a large sample of nearby galaxies ($z \lesssim 0.1$). The main aim is a survey of ∼3400 galaxies across a wide range of environments and stellar masses. The SAMI Galaxy Survey was setted up to have resolutions of $R \simeq 1730$ in the blue arm (spectral range of 3750-5750Å) and $R \simeq 4500$ in the red arm (spectral range of 6300-7400Å). However, due to the low resolution of the blue arm, and thus it is more difficult for DIB detection, we focus on spectra with the red arm setting. The spectra with red arm setting allow us to investigate strong DIB, i.e., λ 6283 Å DIB. The detection of 6283 Å DIB in other galaxy has been shown before by [4] (see Fig. 3 in their article about DIBs in Small Magelanic Cloud (SMC)).

The SAMI Galaxy Survey sample consisted of two different samples, i.e., SAMI-GAMA sample from GAMA survey [6] and additional cluster sample. However, those GAMA galaxies are located away from Galactic Plane ($l \simeq 50°$). Thus, we could not expect to detect strong Milky Way DIBs in the spectra. The Milky Way DIBs will be very weak or negligible in this case because of the lack of ISM above our Galactic disk. The Milky Way DIBs and extragalactic DIBs can be disentangle thanks to the significant redshift. In the case of SAMI data, the redshift information were pre-determined and given in the catalog. In addition, the Milky Way 6283 Å DIB could not be detected because of the spectral range of our data. Thus, we confirmed that there is no contamination from the Milky Way DIB in the data.

We used SAMI data (DR2) [16] that can be accessed via the AAO's Data Central (https://datacentral.org.au/). The data in SAMI DR2 are divided into core data, produced directly from the SAMI data reduction pipeline, and value-added data products from SAMI Galaxy Survey science analysis pipelines. The core data consist of cubes, binned cubes, and and aperture spectra. Figure 1 shows an illustration of SAMI data for galaxy 177518. The image on the left indicates spatial information or distribution of 6283 Å DIB in the galaxy 177518. Darker region corresponds to stronger absorption by the DIB, thus more abundant. However, careful study has to be performed in order to derive conclusion.

3. Method and Results

In order to increase the S/N of the galaxy spectrum, we have conducted several tests, i.e. stacking (summing) galaxy spectra from the selected high S/N spaxels in SAMI cubes. However, the resulting spectrum did not yield significant improvement compared to the aperture spectra provided by the SAMI DR2. We therefore used the elliptical aperture spectra provided by the DR2 for the fitting.

We measured DIB equivalent width (EW) by performing automated fitting to the galaxy spectrum in the spectral range of the DIB feature. The equivalent width is defined as the area between the line profile and the continuum, proportional to the number of absorbers. We

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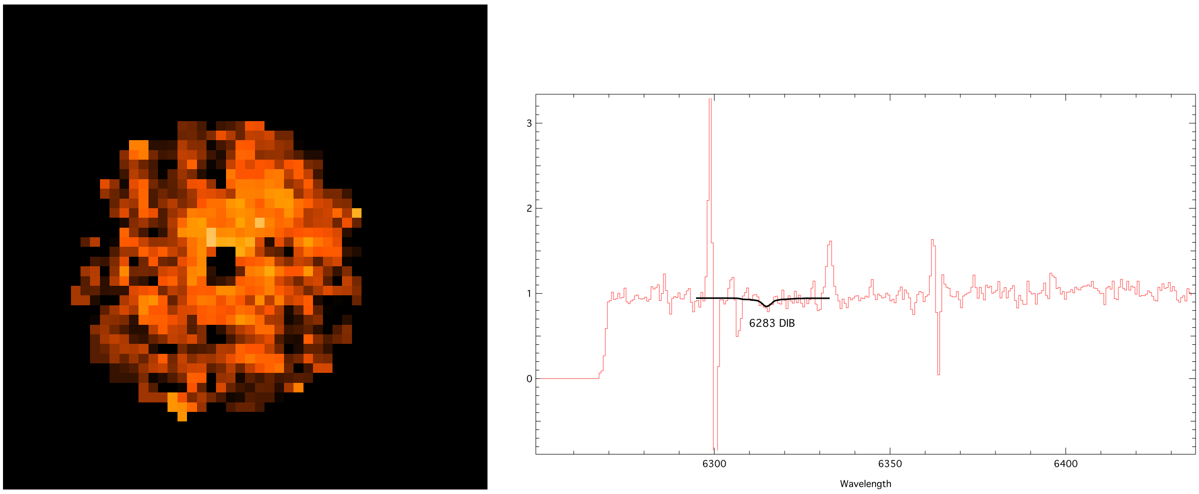

Figure 1. Left: An example of SAMI cube, spatial information of galaxy 177518 at 6314 Å. The wavelength is the location of 6283 Å DIB following the galaxy redshift. Right: Spectrum of galaxy 177518. Red line shows the galaxy spectrum and black line shows a model of 6283 Å DIB.

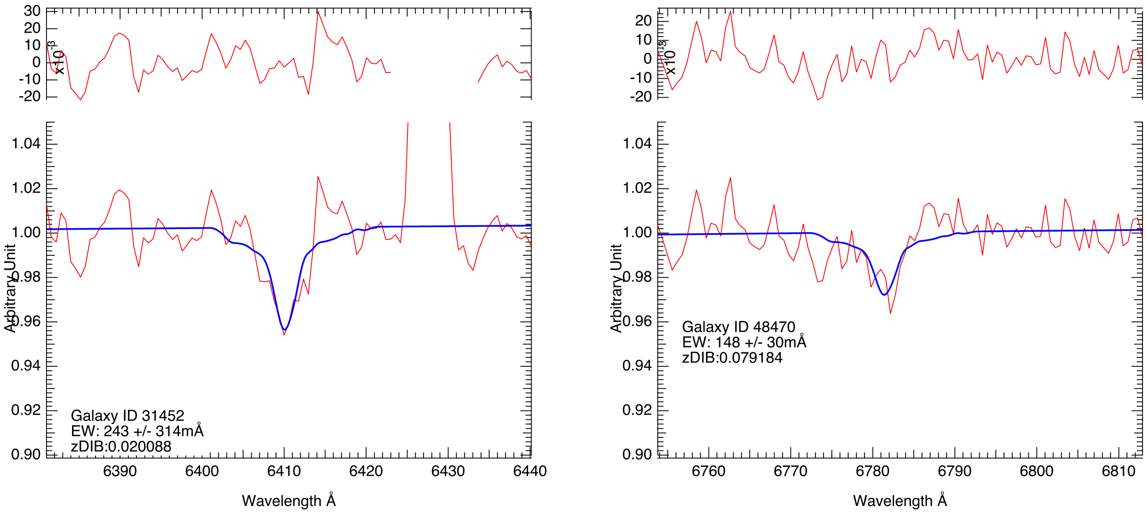

Figure 2. Two examples of the DIB fitting in the galaxy spectrum 31452 (left) and 48470 (right). Red line in the lower panels shows the galaxy spectrum and blue line shows the fitting result (a combination of smooth continuum and DIB model). Upper panels show fitting residuals.

fitted the spectrum with a combination of smooth continuum (polynomial function) and a DIB model simultaneously. The fitting used Levenberg-Marquardt algorithm in IGOR Pro 8 software (WaveMetrics, Inc.). Galactic or stellar features were masked if necessary.

The λ 6283 Å DIB model is an empirical (average) profile from series of observations of nearby stars in our Galaxy by [13, 14]. The spectral resolution of the DIB model was adapted to the current SAMI spectral resolution by convolution with instrumental function. Predetermined galaxy redshift was used as an initial guess for DIB detection, in addition to the cross relation operation with the DIB model. Some examples of DIB fitting can be found in Fig. 2.

4. Conclusions and Future Works

From this study, we have shown that DIB carriers are present in other galaxies. The SAMI Galaxy Survey data can be used to study extragalactic DIBs, in particular for the strong 6283 Å DIB with the red arm setting. The IFU is very potential, not only it can provide spectral information, but also spatial information. We have developed spectral tool to fit DIB in a spectrum of galaxy by using a combination of smooth continuum (polynomial function) and a DIB model. For the future works, the DIB fitting tool can be applied for all SAMI data and DIB measurement results can be compared to the galaxies properties. This will help in drawing general overarching conclusion about DIBs and their environments.

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