Correlation between diffuse interstellar bands (DIBs) and interstellar extinction using data from Bosscha Compact Spectrograph

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Correlation between diffuse interstellar bands (DIBs) and interstellar extinction using data from Bosscha Compact Spectrograph

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Abstract. A longstanding challenge in astronomical spectroscopy is to uncover the carriers of diffuse interstellar bands (DIBs). They are broad absorption features due to the interstellar matter (ISM). They are seen in stellar spectra of background stars or other astronomical objects. Although we do not know utterly the carriers of the DIBs, they can be a promising tracer of the ISM. One of the interesting properties is their correlations with the interstellar (IS) extinction. For each band, the correlation has considerable dispersion and differences that possibly due to the IS physical conditions. Some DIBs are sensitive to the stellar radiation field, and some are not. To study the effect, we measured the DIB observed in Be/B stars spectra. The stars were observed by using Bosscha Compact Spectrograph at the Bosscha Observatory, Lembang, Indonesia. We performed an automated fitting of a combination of a smooth stellar continuum, the DIB profile, and a synthetic telluric transmission to the spectrum. The DIB measurements were compared to the general DIBs-extinction relationship. The correlation is found to be in good agreement with previous determinations.

1. Introduction

Diffuse interstellar bands (DIBs) are mysterious absorption features seen in a spectrum of a star (or other astronomical object). DIBs behave like interstellar (IS) lines with regard to occurrence, strength, and Doppler shift. As a matter of fact, they are caused by the absorption of light by the interstellar matter (ISM). Instead of being narrow and sharp, as the well-known interstellar lines, DIBs profiles are widened (diffuse width) and irregular.

Despite the unknown origin/carrier, DIBs can be a promising tracer of the ISM. (1) DIBs are numerous. Around 500 DIBs are identified in optical, IR, and UV domain [3, 4, 7]. Identifying their carriers is a subject of active research for many years. (2) DIBs are not easily saturated. They can be used to trace distant Galactic IS structures (see[9]). (3) DIBs are correlated with interstellar extinction (AV) or reddening (E(B-V)) with some dispersion. Interstellar extinction or reddening occurs because interstellar dust absorbs and scatters the light. The relationship between DIBs and interstellar extinction can be used for extinction estimation of an unknown

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region in the sky; and to indicate interstellar physical conditions because some DIBs are sensitive to the stellar radiation field, and some are not.

Observation Program of Be Stars has been conducted in Bosscha Observatory, Lembang, Indonesia for many years [6]. Be stars are B-type stars surrounded by gaseous disks which exhibit (variable) Balmer line emission and an infrared excess. These stars may contribute to the interstellar environment through the stellar wind and the stellar radiation that may destroy or favor the DIB carrier(s). We are aiming at studying the effect of stellar radiation field through the correlation between DIBs and interstellar extinction.

2. Data

For the analysis, we used 34 target stars (Be and B-type star) that are part of Be Stars Observation Program ([6]; Aprilia, priv. comm.). The stellar spectra were observed by using Bosscha Compact Spectrograph [5] with $R \simeq 8000$ and spectral range of 6350-6800 Å. For the analysis we focus on the 6613.62 (6614) Å DIB that are strong enough to ensure a detection in most targets. Stellar parallaxes of the target stars were obtained using SIMBAD Astronomical Database, whereas interstellar extinction data were obtained using a computerized model by [2].

3. Method

Our goal is to extract and measure DIB equivalent width (EW) in series of stellar spectra in an automated way. The equivalent width is defined as the area between the line profile and the continuum. It corresponds to the measure of the strength of spectral features.

We fit the stellar spectra (data) to a triple combination of DIB Model (fit in strength and shift), telluric transmission model (also fit in strength and shift), and smooth continuum (with a polynomial function). The fitting uses the LevenbergMarquardt algorithm in the IGOR Pro software (WaveMetrics, Inc.).

The DIB Model is an empirical profile (see [8]), whereas a synthetic telluric transmission computed using the line-by-line radiative transfer model (LBLRTM) code and the HIgh-Resolution-TRANsmission molecular absorption (HITRAN) spectroscopic database [1, 10].

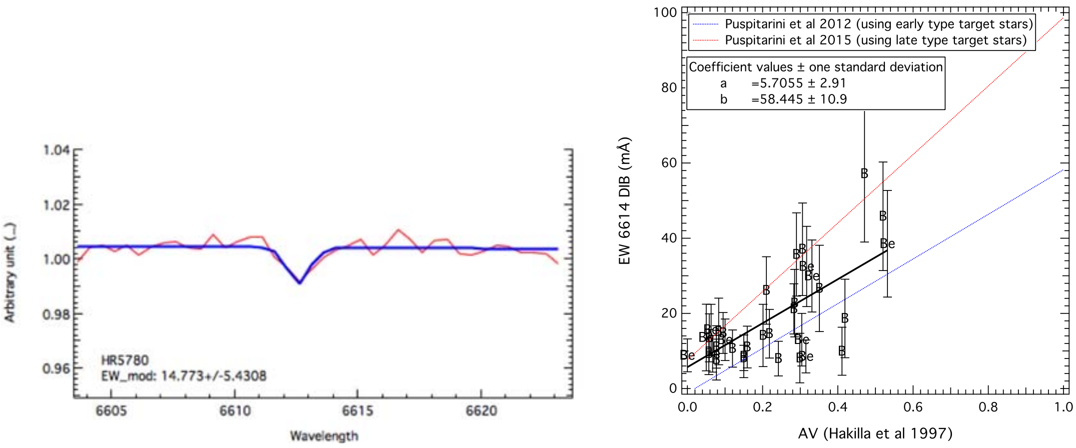

Figure 1. Left: An example of DIB fitting in the spectrum of HR5780 star. Red shows the stellar spectrum, whereas blue shows the fitting result. Right: The equivalent width measurements of the 6614 DIB vs. the interstellar extinction (AV) from [2]. The correlation is found to be in good agreement with previous determinations.

4. Results and Discussions

An example of the DIB fitting can be found in Fig. 1 (left). From the fitting, we can measure the equivalent width of 6614 DIB profile which corresponds to abundance of its carrier. We then plot the equivalent width measurements of the 6614 DIB vs. the interstellar extinction (AV) from [2] (see Fig. 1 right). We remark that the interstellar extinction in this case is totally independent from our data. It is mainly derived from photometric data and model [2].

The plot in Fig. 1 right shows that there is a positive correlation between the strength of the DIB and interstellar extinction. The Pearson correlation coefficient (V_{pr}) that we obtained is 0.7. The interstellar extinction itself is reddening and dimming that are mainly caused by dust. The positive correlation indicates that DIB's carrier and interstellar dust are quite well mixed in the interstellar cloud. However, one of the explanation we don't obtain perfect correlation (V_{pr}=1) is because of the stellar radiation field. The stellar radiation in this case tends to destroy the 6614 DIB carrier.

This correlation that we obtained is in good agreement with previous determinations, i.e., [8] that used hot O-type target stars and [9] that used cool or late-type target stars. The gradient of the correlation is found to be in between the ones derived from hot and cool target stars. This may indicate typical stellar radiation field from Be/B stars that is moderate (not too strong and not too weak). However, we notice some dispersions in the measurements. The dispersions could come from the measurement error (S/N of the low resolution data), blending with diffuse nearby DIB, i.e. 6607.07 Å, or the stellar radiation field itself.

5. Conclusions

We conclude from this study that 6614 DIB has been correctly extracted from our spectroscopic data of B/Be stars. The positive correlation between DIB's equivalent width (abundance) and interstellar extinction indicates that the mysterious DIB's carrier and interstellar dust are well-mixed in the interstellar cloud. The correlation parameter (V_{pr} = 0.7) is found to be in good agreement with previous determinations ([8] and [9]), within uncertainties. When compared with [8], our Pearson coefficient is higher. We believe that this is due to the smaller stellar radiation field influences, because our targets (B/Be) are cooler than those used by [8] (O-type stars). In reverse, our Pearson coefficient is smaller than the ones in [9] that used cooler stars (G, K, M type stars). Because these cooler stars produce smaller stellar radiation field influences that favor the carrier of 6614 DIB.

Acknowledgments

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