Detecting extragalactic diffuse interstellar bands (DIBs) in supernova spectra by using ESO data

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Abstract. Diffuse Interstellar Bands (DIBs) are weak and wide absorption features due to interstellar matter. DIBs are interesting to study because until now their chemical identifications are still unclear. DIBs can be found in reddened spectrum of celestial bodies in our Galaxy and other galaxies. Detecting extragalactic DIBs is challenging, one of the ways is by using an extragalactic supernova spectrum. The supernova acts as a background source to probe interstellar matter in a galaxy. We studied extragalactic DIBs by using the SN 2006X spectrum. The spectrum was observed by using the UVES instrument and the La Silla telescope at the European Southern Observatory (ESO) and was accessed from ESO archives. Detection of DIBs was performed by predicting the central wavelengths of DIBs in the supernova spectrum by taking the galaxy redshift (z) into account and observing DIBs profiles. Small shift variations in the wavelength are allowed. The detection of extragalactic DIBs indicates that DIBs are universal.

1. Introduction

Interstellar matter (ISM) is a “rich laboratory” contains of atoms, molecules, ions, or solid particles in a wide range of temperature and pressure, among of them are not fully understood. Diffuse Interstellar Bands (DIBs) are a set of weak and wide absorption features due to ISM that are seen in optical and infrared region of a reddened spectrum of celestial bodies. DIBs are interesting to study because until now their chemical identifications are still unclear and under investigation (see [2],[3],[8] and references therein).

Most of the studies about DIBs are “Galactic DIBs” or within our Milky Way. However, our Galaxy is just one among hundreds of billions in the universe. There have been questions about DIBs. Are DIBs present in other galaxies? Are their wavelengths and profiles like those found in the Milky Way? [7].

However, detecting extragalactic DIBs is challenging. One of the ways to detect extragalactic DIBs is by using an extragalactic supernova spectrum. Supernova (SN) is a powerful and luminous stellar explosion. It occurs during the last evolutionary stages of a massive star or when a white dwarf is triggered into runaway nuclear fusion. Supernova is bright enough and can be used to detect DIBs in other galaxies. The supernova can act as a background source to probe ISM in a galaxy. One of the first extragalactic DIBs in supernova spectra was observed by [9].

At present, many spectroscopic surveys have been or are being conducted and the data are available publicly in achieve. This may improve our knowledge about DIBs. In this preliminary work, we aim at...
detecting extragalactic DIBs in a supernova spectrum by using European Southern Observatory (ESO) data.

2. Data
We used spectrum of SN 2006X. SN 2006X was a Type Ia supernova in Messier 100 or NGC 4321, a spiral galaxy in the constellation Coma Berenices. The supernova was discovered in early February 2006. It is located at (l,b)= (271.15,+76.89) in Galactic coordinate. The redshift of the supernova is 0.0036395 (see Table 1). The host galaxy, Messier 100, is an active galaxy nucleus. It is a SABc type galaxy and has an inclination of 31° ± 0.7° [4]. The redshift of Messier 100 is 0.005251.

| Object  | Coordinate (l,b) | Redshift (z) | Notes              |
|---------|------------------|--------------|--------------------|
| SN2006X | (271.15, +76.89) | 0.0036395    | Messier 100 / NGC4321 |

Table 1. Basic data of SN 2006X from SIMBAD Astronomical Database.

The supernova was observed by using the ESO UVES Spectrograph. UVES is the high-resolution optical spectrograph of the Very Large Telescope (VLT) located at the Nasmyth B focus of UT2. The spectrum was accessed in ESO science archive interfaces (http://archive.eso.org/). An example of the spectrum can be found in figure 1. It was observed on February 18, 2006. The spectral resolution and S/N are 42310 and 50.9, respectively. The spectral range is from 4727-6835 Å with a gap from 5753-5784 Å.

Figure 1. An example of SN2006X spectrum from ESO Science Archive.

3. Method and Results
We searched for two strong DIBs: 6283 Å and 6614 Å, in the spectrum of SN 2006X. We predicted the DIBs location by using the redshift information and the Doppler Spectroscopy Formula: \( \lambda = \lambda_0 (1 + z) \), where \( \lambda \) is the predicted DIBs location, \( \lambda_0 \) is the central wavelengths of DIBs from Hobbs Catalog [5], and \( z \) is the redshift information. We then searched the DIBs in the predicted wavelength and allowed small variations. Figure 2 shows the detection of DIBs. Interestingly, the DIBs locations were not the same as the supernova redshift prediction, but similar to the redshift of Messier 100 (the host galaxy). The 6283 Å DIB was found at 6319 Å which corresponds to \( z=0.0055 \). This shows that the supernova and the interstellar gas, which contains DIBs carrier(s), have different kinematics. DIBs are not caused by circumstellar matter of the supernova but are caused by the ISM in the host galaxy. We
then compared the extragalactic DIBs profile with the ones in our Galaxy [6]. Our measurement results agree with [1].

![Image of DIBs](image-url)

**Figure 2.** The detection of 6284 Å and 6614 Å DIBs in the spectrum of SN 2006X.

4. Conclusions and Potential Future Works

We have shown that DIBs are present in other galaxies. We have demonstrated that supernova spectrum can be used to study extragalactic DIBs. High S/N and high-resolution spectrum is favorable for DIBs detection because DIBs are weak features (line opacity (τ) less than 0.03). In our case, spectrum with S/N ~ 50 is good enough to detect strong DIB for example the 6283 Å DIB.

We detected the 6283 Å and 6614 Å DIBs in the SN 2006X spectrum. From our measurement, the redshift of the DIBs is about 0.0055, which differ from the SN redshift, i.e. 0.0036, but similar to the redshift of Messier 100 (the host galaxy), i.e. 0.0053. Thus, DIBs are caused by the ISM in the host galaxy and are not circumstellar (supernova) materials. By comparing with Galactic DIBs, we found that the extragalactic DIBs are quite similar to that of our Galaxy in terms of the profiles, but more studies are needed to investigate their characteristics.

Recent studies indicate that DIBs are probably caused by complex organic molecules. Detection of extragalactic DIBs in different galaxies at different cosmological distances may give a hint on the cosmic chemical evolution. The Central Bureau for Astronomical Telegrams (CBAT) has listed thousands of supernovae and there are several hundred new supernovae each year. Supernova can be bright and may outshine its host galaxies. Therefore, it can be used as a potential background source to study extragalactic DIBs to understand DIBs properties and the cosmic chemical evolution. At present, many spectroscopic surveys have been or are being conducted. This may improve our knowledge about DIBs.

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