論文の内容の要旨

A Study of Near-infrared Diffuse Interstellar Bands

(近赤外 DIB 吸収バンドの研究)

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In this thesis, I present a first comprehensive survey of diffuse interstellar bands (DIBs) in 0.91-1.32 μm with the newly developed near-infrared (NIR) spectrograph, WINERED, mounted on the Araki 1.3 m Telescope in Japan. The DIBs in the NIR wavelength range are expected to be electronic transitions of ionized large-sized carbon molecules, such as polycyclic aromatic hydrocarbons (PAH) and fullerenes. The NIR wavelength range is also useful in exploring the DIBs toward the stars with heavy interstellar extinction because of its higher transmittance in interstellar clouds compared with the optical wavelength range. Despite the potential importance of the DIBs in NIR wavelength range, they have been no systematic search while exceeding 500 DIBs have been detected mainly in the optical wavelength range. WINERED offers a high resolution of R =~ 28,300 with high sensitivity in wide wavelength coverage of 0.91-1.36 μm, where only four DIBs have been confirmed till now. With the survey, I aimed to extensively search for NIR DIBs and to reveal their properties. I present following three studies on NIR DIBs in this thesis.

The search for NIR DIBs

I obtained high-resolution (R=28,300) spectra of 25 early-type stars with color excesses of 0.07<E(B-V)<3.4. I searched for the absorption lines originating from interstellar gas clouds by comparing the obtained spectra with the stellar model spectra. Consequently, in addition to the five DIBs previously identified in the wavelength coverage of WINERED, I identified 15 new DIBs, eight of which were reported as DIB ``candidates'' by Cox. Figure 1 shows the equivalent width (EW) distribution of DIBs as a function of the wavelength. Figure 2 shows the spectra of three strong DIBs for the all targets in this survey.

The properties of NIR DIBs

I analyzed the correlations among NIR DIBs, strong optical DIBs, and the reddening of the stars. Consequently, I found that all NIR DIBs show weaker correlations with the reddening rather than the strong optical DIBs, suggesting that the equivalent widths of NIR DIBs depend on some physical conditions of the interstellar clouds, such as UV flux. Three NIR DIBs, λλ10780, 10792, and 11797, are found to be classifiable as a "family," in which the DIBs are well correlated with each other, suggesting that the carriers of these DIBs are connected with some chemical reactions and/or have similar physical properties such as ionization potential. I also found that three strongest NIR DIBs λλ10780, 11797, and 13175 are well correlated with the optical DIB λ 5780.5, whose carrier is proposed to be a cation molecule with high ionization potential, indicating that the carriers of the NIR DIBs could be cation molecules.

The environmental dependence of NIR DIBs in the Cyg OB2 association

In order to reveal the environmental dependence of NIR DIBs, I obtained the NIR high-resolution spectra of seven early-type stars in the Cyg OB2 association, toward which the gas clouds are known to have complex gaseous structures exposed to the strong flux of ionizing photons. Cyg OB2 association contains a number of bright early-type stars with large extinction, toward which strong DIBs can be detected. I could detect all 18 NIR DIBs toward all the observed stars with large EWs. I examined the relations between the DIBs and the column densities of C_2 molecules in the literature. Consequently, I could not find any clear relations between DIBs and C_2 column densities toward the Cyg OB2 association, suggesting that NIR DIB carriers are distributed mainly in the diffuse component rather than in the dense component. Such properties of NIR DIBs are common to those of "classical" strong DIBs in the optical wavelength range. It is also found that the EW ratios of DIBs λ λ10504 and 5780.5 to DIBs λ λ10780, 10792, 11797, 12623, and 13175 in the Cyg OB2 association are lower than those in the interstellar environment by a factor of two. I suggest that the environmental dependence of DIB ratios illustrates some difference in the properties of the DIB carriers, such as the stability to the high-energy photons and the ionization potential.

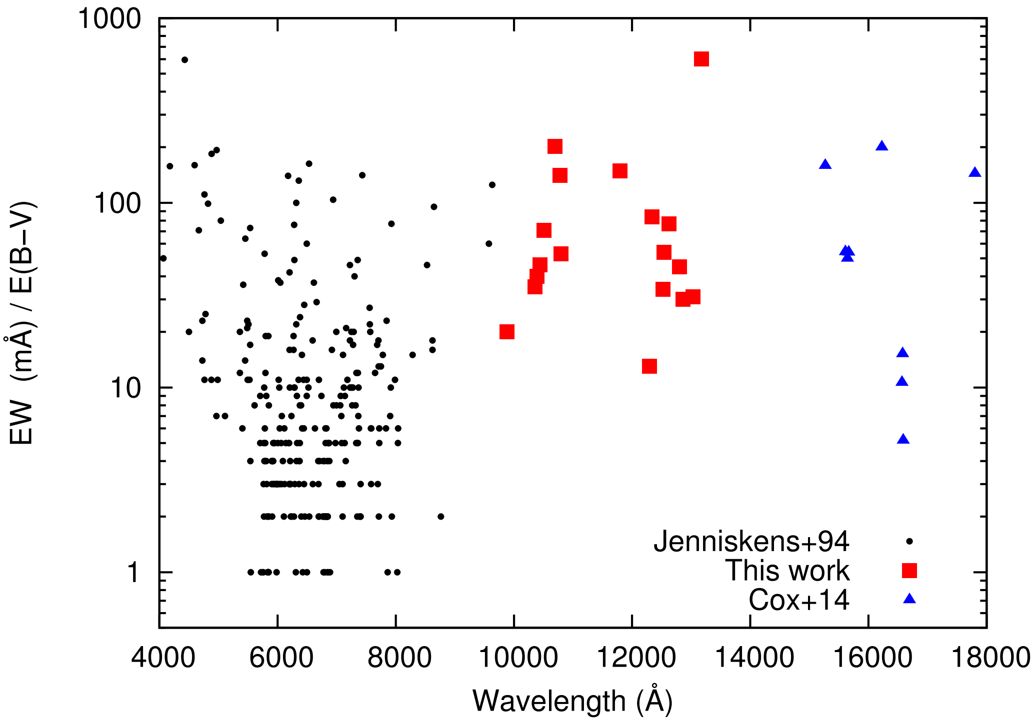

Figure 1: Distribution of the ratios of the EWs to E(B-V) as a function of the wavelength for all DIBs in optical and near-infrared. Black circles, red squares, and blue triangles represent the points of optical DIBs from Jenniskens et al. (1994), NIR DIBs found in this study, and DIBs in the H-band from Cox et al. (2014), respectively.

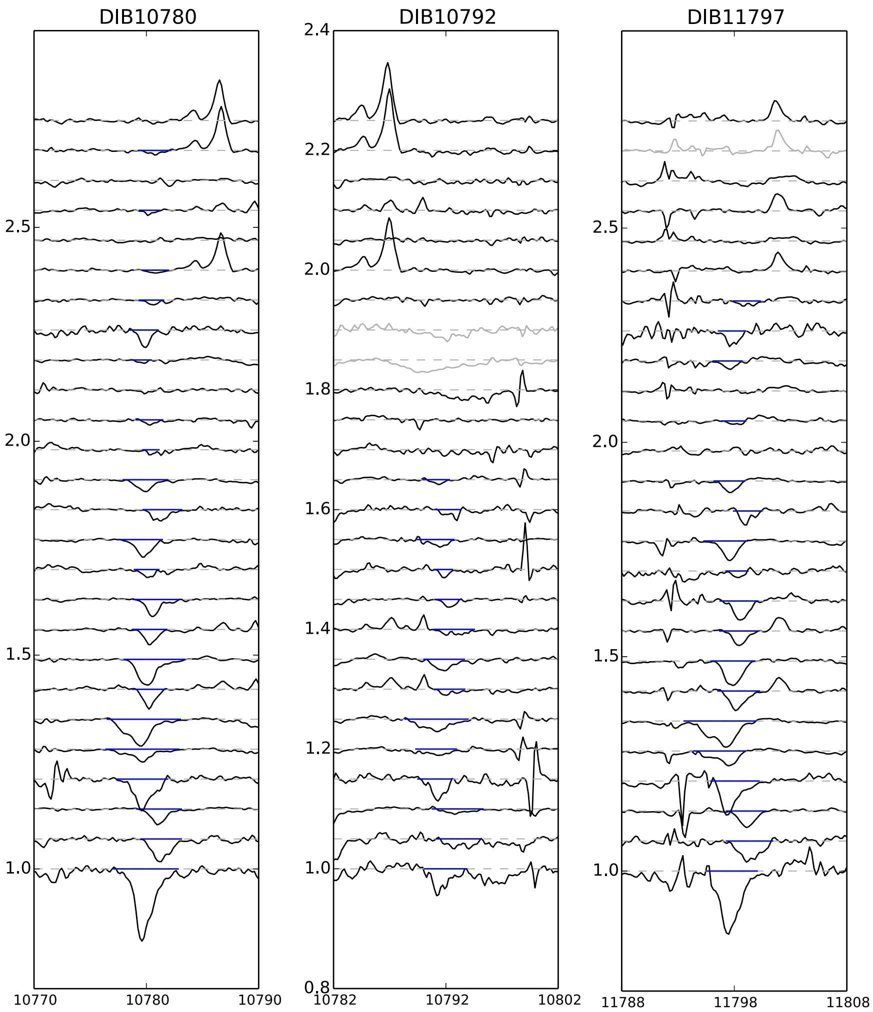

Figure 2: Spectra of three DIBs, λλ10780, 10792, and 11797, for all targets plotted in increasing order of E(B − V) from top to bottom. The spectra are normalized and plotted with arbitrary offsets. The continuum level of each stars is shown by a dashed thin line. The spectra of the stars, in which the EWs or upper limits of the DIBs cannot be evaluated due to overlapped stellar and/or telluric absorption lines, are plotted with gray lines. The integrated ranges used in the calculation of the EWs are shown as thick blue lines.