DEVELOPMENTS OF OPTICAL SPECTROMETERS AS APPROACHES TO DIFFUSE INTERSTELLAR BANDS

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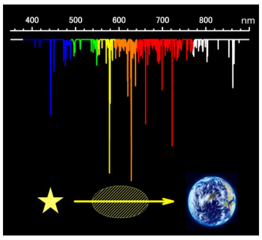
Abstract

To be able to solve the diffuse interstellar bands (DIBs) problem, we have developed a discharge-emission spectrometer and a cavity ringdown spectrometer. Hollow cathode discharge cell was installed in the spectrometers to generate molecular ions, which are probable DIBs candidates. Recently the electronic transition of the butatriene cation $H_2CCCCH_2^+$ was observed in the discharge emission. The observed frequency of the transition enables the comparison of the absorption feature of $H_2CCCCH_2^+$ with DIBs.

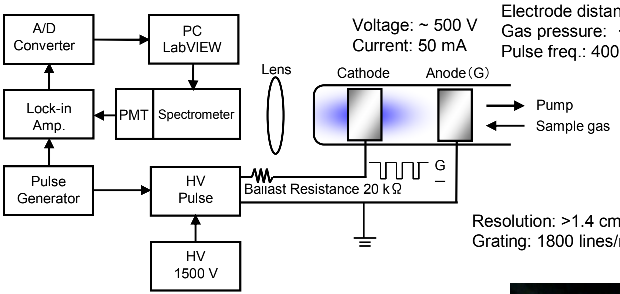
Introduction

Diffuse Interstellar Bands (DIBs) are absorption bands of optical stellar light by unknown interstellar matters. DIBs were first discovered in the optical absorption spectra on stars in about 1920. Although several hundreds DIBs were detected already, DIBs still remain the longest standing unsolved problem in spectroscopy and astrochemistry. To identify the carriers of DIBs, candidate molecules need to be generated in the laboratory for evaluating the frequencies of electronic transitions, which can be eventually compared with astronomical DIB spectra.



Diffuse Interstellar Bands

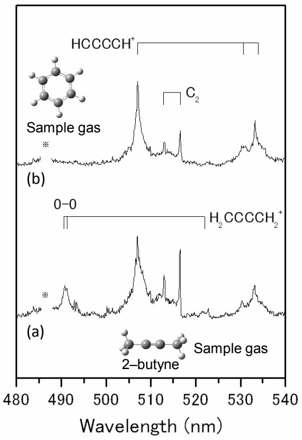
Discharge-Emission Spectrometer

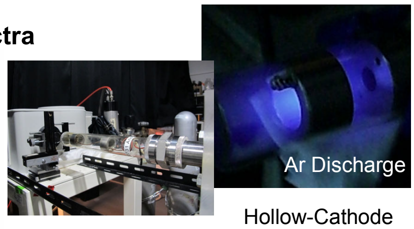


Cell inside diameter: 3.3 cm
Electrode distance: 10 cm
Gas pressure: ~ 0.2 Torr
Pulse freq.: 400 Hz

Resolution: >1.4 cm^{-1}@501 nm
Grating: 1800 lines/mm

Discharge Emission Spectra

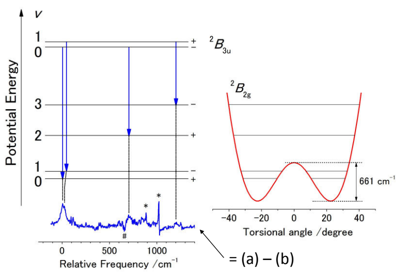




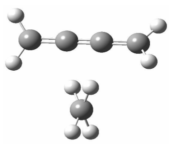
Hollow-Cathode Discharge System

The bands at 20381 cm^{-1} (4905Å) was assigned to the $^2B_{3u}$ – X $^2B_{2g}$ transition of $H_2CCCCH_2^+$ based on the reported photo-electron spectrum [1].

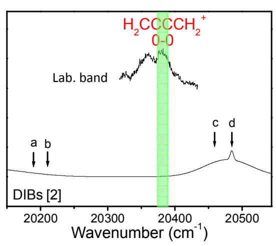
Torsional Vibrational Levels and Potential Curve



Butatriene cation
$H_2CCCCH_2^+$



Comparison with DIBs



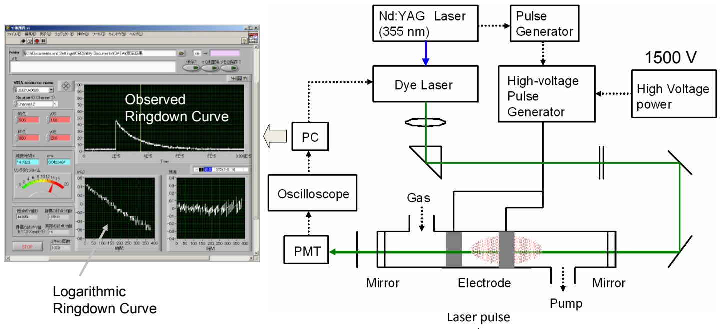
Comparison with DIBs (cm^{-1})

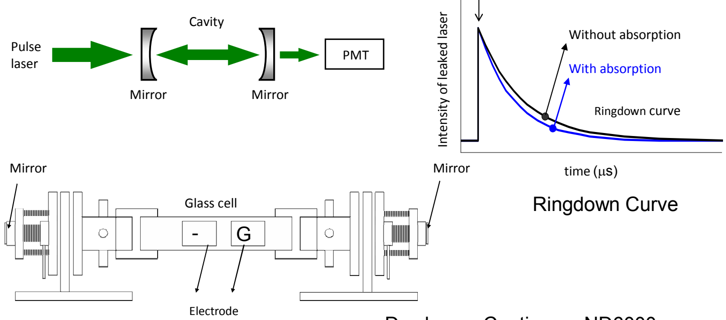
Lab. band	DIBs [2,3]
	a 20192 (4951Å)
	b 20209 (4947Å)
20381 (4905Å)	
	c 20456 (4887Å)
	20478 (4882Å)
	d 20486 (4880Å)

No DIBs agree with the $^2B_{3u}$ – X $^2B_{2g}$ 0-0 band of $H_2CCCCH_2^+$

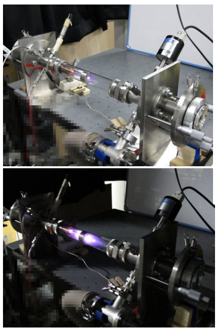
Araki *et al.*, *Chemical Physics Letters, submitted.*

Cavity Ringdown Spectrometer [4,5]





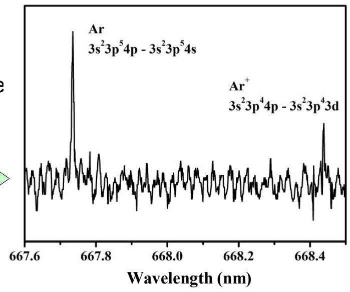
Ringdown Curve

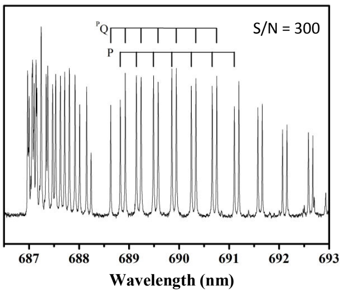


Dye laser: Continuum ND6000
YAG laser: Continuum Surelite II
Line width: 0.07 cm^{-1}
Laser power: 0.2~2 mJ/pulse
Repetition rate: 10 Hz

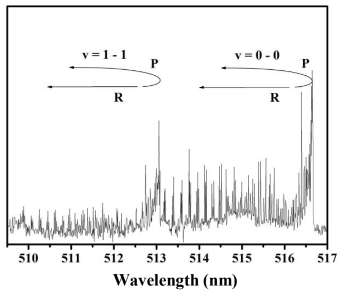
Air Discharge
Ar^+/Ar ~ 0.1

Hollow-Cathode Discharge in Cavity Ringdown Cell





O_2: $b^1\Sigma_g$-$X^3\Sigma_g$ (1-0) band



C_2: $d^3\Pi_g$–$a^3\Pi_u$ Swan band

Summary

- To be able to solve DIBs problem, we have developed the discharge-emission spectrometer and the cavity ringdown spectrometer.
- The band observed at 20381 cm^{-1} (4905Å) in the discharge of 2-butyne with the discharge-emission spectrometer was assigned to the $^2B_{3u}$–X^2B_{2g} transition of the butatriene cation $H_2CCCCH_2^+$ based on the sample-gas dependences.
- Torsional vibrational levels and potential curve were analyzed by the double minimum potential.
- By comparison of the band with DIBs, no related DIBs were found.
- The test observations of cavity ringdown spectrometer using Ar, Ar^+, O_2, and C_2 were successfully achieved.

[1] Brogli *et al.*, *Chem. Phys.*, **4**, 107 (1974), [2] Jenniskens *et al.*, *Astron. Astrophys. Suppl.*, **106**, 39 (1994), [3] Bondar, *Mont. Not. R. Astron. Soc*, **423**, 725 (2012), [4] Linnartz *et al.*, *J. Chem. Phys.*, **109**, 3819 (1998), [5] Motylewski and Linnartz, *Rev. Sci. Instrum.*, **70**, 1305 (1999)