POTENTIAL LINE STRUCTURE VARIABILITY IN DIB FEATURES OBSERVED IN PATHFINDER TRES SURVEY

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Diffuse Interstellar Bands

Figure 1: Gas-phase laboratory spectra of $C_{60}^+$ at 5.8 K.

Campbell, E. K., et al. 2015, Nature, 523, 322
Heger, M.L. 1922 LicOB, 337, 141
Where are the DIB carriers?

- Generally believed to be in the Interstellar Medium
- No spectroscopic shift indicative of a binary star system
- Previous search attempts for DIBs in circumstellar shells were mostly unsuccessful or inconclusive

Temporal variation found in observation of extragalactic supernova type Ic

Possible explanation: DIBs carriers are local to the star and were produced by mass loss pre-Supernova

Findings suggest that some carriers might be in circumstellar shells.
Motivation and Hypothesis

- Findings suggest that some carriers might be in circumstellar shells
- Are carriers produced by or associated with mass loss events in progenitor stars?
Findings suggest that some carriers might be in circumstellar shells.

- Are carriers produced by or associated with mass loss events in progenitor stars?
- Can temporal variation be seen towards similar massive stars?
O and N-rich Massive Stars

- N-rich and O-rich stars previously identified as possibly containing DIB carriers in circumstellar shells
- Wolf Rayet stars favored, possible SNe I b/c progenitors

1.5 m Tillinghast telescope and Tillinghast Reflector Echelle Spectrograph at Fred L. Whipple Observatory

For each star, observations were made 2-5 times between June and November 2013
17 Star Pathfinder Survey
17 Star Pathfinder Survey
17 Star Pathfinder Survey
Potential Variation in Line Structure

- MT-59 DIB 5797, **Sept 26.1** and **Nov 26.1**
- MT-59 DIB 6614, **Sept 11.3** and **Sept 19.2**
Potential Variation in Line Structure

Flux (+ offset)

WR2

MT59

MT145

DIB $\lambda_{5780}$

DIB $\lambda_{5797}$

Wavelength [Å]
Potential Variation in Line Structure

- SNR ~ 5-15
- Short integration period
- $^2\Pi - ^2\Pi$ transition
- Linear, polar molecule
- 5-7 heavy atoms

Table 1. Model input values for the $\lambda 5797.1$ DIB (see Figure 2).

<table>
<thead>
<tr>
<th>Model</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_r$ (K)</td>
<td>2.73</td>
<td>2.73</td>
<td>3.50</td>
</tr>
<tr>
<td>$B$ (MHz)</td>
<td>1300</td>
<td>1200</td>
<td>1000</td>
</tr>
<tr>
<td>$B'/B$</td>
<td>0.98</td>
<td>0.97</td>
<td>0.99</td>
</tr>
<tr>
<td>$A' - A$ (MHz)</td>
<td>19,000</td>
<td>27,000</td>
<td>17,000</td>
</tr>
<tr>
<td>$\lambda_0$ (Å)</td>
<td>5797.10</td>
<td>5797.15</td>
<td>5797.10</td>
</tr>
<tr>
<td>$\Delta t$ (ps)</td>
<td>50</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>$\rho$</td>
<td>2.50</td>
<td>3.00</td>
<td>2.50</td>
</tr>
</tbody>
</table>

Huang, J., & Oka, T. 2015, Mol. Phys, 8976, 1
Extended Tails towards Red (ETR) are produced by increase in rotational distribution of a polar molecule.

Rotational constants decrease in electronic excited state, causing decrease in transition frequency when higher rotational states are populated.

Figure 2. Comparison between the extraordinary DIBs toward Her 36 (in black) and ordinary DIBs toward 9 Sgr (red). The deep absorption near 100 km s$^{-1}$ for λ5797 of 9 Sgr is stellar and should be ignored.

Maybe what we’re seeing is time variability in rotational distribution?

Figure 2. Comparison between the extraordinary DIBs toward Her 36 (in black) and ordinary DIBs toward 9 Sgr (red). The deep absorption near 100 km s$^{-1}$ for λ5797 of 9 Sgr is stellar and should be ignored.
Comparing Huang & Oka models and data

- Model is decent fit for 11/26 epoch
- Can we find a better fit for the 9/26 model on the red side?

11/26 spectrum

9/26 spectrum
Making models with higher rotational distribution

- Made synthetic spectra with higher temperatures using PGOPHER
- Mixed with the original Huang and Oka models with different ratios
- \( \text{Total} = (\alpha \times \text{cold}) + [1 - (\alpha \times \text{hot})] \)
  - \( 0 \leq \alpha \leq 1 \)

http://pgopher.chm.bris.ac.uk/
Making models with higher rotational distribution
Making models with higher rotational distribution
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Making models with higher rotational distribution
Found RMS of residuals between models and data

RMS plots:
- y-axis is increasing ratio of “hot” spectra
- x-axis is increasing temperature
RMS Comparison

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RMS plots

Model A

9/26

11/26

Model C

9/26

11/26

Trend: 9/26 epoch with ETR is “warmer” than 11/26 without ETR
RMS plots

Model A

Model C

- Trend: 9/26 epoch with ETR is “warmer” than 11/26 without ETR
Results

9/26, “warmer”

11/26, “cooler”
Results

- Rotational distribution of earlier epoch appeared “warmer”
  - Potentially an increased collisional excitation due to interaction with mass loss from the star
  - Suggests carrier of 5797 may be located close to MT-59, not in ISM
A change in rotational distribution might explain the line substructure changes we saw

Potentially caused by interaction of carrier with stellar winds

Supports carriers being in circumstellar shells

Low quality data due to low SNR and short integration periods

Ideally, this work will motivate other, higher quality observations in order to search for time variability in DIBs

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