Correlations Among the Diffuse Interstellar Bands

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The APO DIB Survey

- Apache Point Observatory 3.5-meter
- 3,500–10,200 Å; $\frac{\lambda}{\Delta \lambda} \sim 37,500$ (8 km/s)
- S/N (@ 5780Å) > 500 for 160 stars
- 119 nights, from Jan 1999 to Jan 2003
Understanding the DIBs

- Ideal: match with laboratory spectrum
  - after 70+ years, no luck yet

- Correlations with other species
  - C₂, C₃ (Oka, next talk)
    - insights into chemistry
  - H, H₂ (Snow, following talk)
    - insights into environment

- Correlations among the DIBs
  - identify chemically related DIBs?
  - identify DIBs caused by common carrier?
  - pick out spectrum of a single carrier?
Search for a Common Carrier

- Assumptions:
  - gas phase molecules
  - DIBs are vibronic bands
  - low temperature
    - carriers all in ground vibrational state
  - relative intensities fixed
    - Franck-Condon factors
    - independent of temperature and density
  - rotational structure may vary with temperature
  - low-lying splittings (e.g. spin-orbit) will foil this
DIB Correlations

- Star #1: A
- Star #2: B
- Star #3

Intensity
Wavelength

Strength of DIB A

Strength of DIB B

Fixed ratio

1
2
3
Example: Bad Correlation

\[ r = 0.55 \]
Example: Good Correlation

$r = 0.985$

measurement errors could be causing deviations?
Statistics of Correlations

- Pairs of DIBs observed in >40 stars
- 1218 pairs
- 58 DIBs included
- Histogram of $r$
- Generally well correlated
- Few very good correlations
  - 19 with $r > 0.95$
  - 118 with $r > 0.90$
DIB "Families"

- Look for sets of DIBs in which all correlation coefficients are high

![Diagram showing correlation coefficients and sets of DIBs]
False Positives?

- Most sightlines sample multiple clouds
- DIBs broader than velocity differences
- Conditions may be different in each cloud
- Uncorrelated DIBs may "wash" into correlation?
6196 vs. 6613 in Detail

entire sample
N=114
r=0.985

E_B-V < 0.6
N=89
r=0.977

E_B-V < 0.4
N=64
r=0.962

E_B-V < 0.2
N=35
r=0.918
## Trends with $E_{B-V, \text{max}}$

<table>
<thead>
<tr>
<th>$E_{B-V, \text{max}}$</th>
<th>r(6196,6613)</th>
<th>r(6204,6284)</th>
<th>r(5797,6284)</th>
<th>r(4963,5780)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>0.918</td>
<td>0.847</td>
<td>0.818</td>
<td>0.200</td>
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<tr>
<td>0.3</td>
<td>0.945</td>
<td>0.896</td>
<td>0.738</td>
<td>0.238</td>
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<td>0.4</td>
<td>0.962</td>
<td>0.903</td>
<td>0.649</td>
<td>0.375</td>
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<tr>
<td>0.5</td>
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<td>0.939</td>
<td>0.779</td>
<td>0.409</td>
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<tr>
<td>0.6</td>
<td>0.977</td>
<td>0.944</td>
<td>0.798</td>
<td>0.333</td>
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<tr>
<td>1.0</td>
<td>0.977</td>
<td>0.959</td>
<td>0.806</td>
<td>0.432</td>
</tr>
<tr>
<td>all</td>
<td>0.985</td>
<td>0.976</td>
<td>0.860</td>
<td>0.623</td>
</tr>
</tbody>
</table>

"correlated DIBs"

"uncorrelated DIBs"
Conclusions

• Two families of chemically related DIBs
  – $\lambda 6196, 6613, 5487, 5780, 6204, 6284$ ["normal" DIBs]
  – $\lambda 4963, 4727, 4984, 5418$ ["C$_2$ DIBs"]

• Few, if any, strong DIBs share a common carrier
  – many many different DIB carriers!

• Constraint on carriers of most strong DIBs
  – Must have strong (origin) band, other bands weaker

• As we measure weaker DIBs, we hope to find some "perfect" correlations
  – vibronic progressions
  – one strong DIB, many weak DIBs