A Study of the CO$_2$ Absorption Feature at 15.2 µm of Several Young Stellar Objects

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Spectroscopy and YSOs

- Surrounded by envelope of gas and dust particles
- Ice mantles form on dust particles
- Each ice molecule leaves a feature in the YSO’s radiation at certain wavelengths
- Studying these features reveals much about the YSO’s environment
- \( \text{CO}_2 \) absorption feature at 15.2 µm (infrared radiation)
Sources

• Elias 16
Data

- Data was taken from the Spitzer Space Telescope
- Infrared Spectrograph (IRS)
- Short-High Module
Spectra

IRAS04154+2823
(+0.30)
IRAS04365+2535
(+0.20)
Elias 16
(-0.30)

TDC041834.4
Optical Depth Plots

- Indicate the amount of radiation absorbed in the line of sight between the observer and the source
- Optical Depth ($\tau$):
  $$\tau = -\ln \left( \frac{I}{I_0} \right)$$
  - $I$ is the observed flux of the source
  - $I_0$ is the flux of the source without the ice
  - Must fit polynomial over ice feature
Fitting Laboratory Spectra

• Ices surrounding stars usually consist of a mixture of different ices
• The different mixtures give rise to different shapes of the feature
• A database was constructed with the laboratory optical depth spectra of ices of different mixtures and temperatures
• Two lists of ice mixtures: polar and apolar
• Used a program that scaled a mixture from each list to find the best fitting pair to the source’s optical depth spectra by calculating the $\chi^2$ value
Optical Depth Plots of Sources and Lab Spectra
Column Densities

• Measures the amount of ice in the line of sight
• Column Density ($N$):
  \[ N = \int \tau \, dv/A \]

• Integral is taken over a specific wavelength range, including the feature
• $\tau$ is the optical depth for the source
• $v$ is frequency
• $A$ is the band strength of the feature as measured in the laboratory
• $A$ for the CO$_2$ absorption feature is 15.2 µm is $1.1 \times 10^{-17}$ cm/molecule
Ice Mixtures and Temperatures

- For the most part, sources contain fairly similar ice mixtures
- All sources have a polar ice component dominated by cold H2O and CO$_2$ ice
  - IRAS04154+2823 has same general shape, so probably has same general mixture of ices
- Apolar ices more varied
  - Several contain CO dominated ice
  - Some contain equal amounts of CO$_2$ and another ice
- Cannot determine exact mixtures and ratios of ice, as well as exact temperature
Results ~ L1551 IRS5

- previous studies of other ice features
  - CO (polar and apolar), H$_2$O, and “XCN”
- Evaluated amount of CO$_2$ ice by calculating the abundances of the other ices relative to water
### Column Densities and Abundances of L1551 IRS5

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Absorbance A (cm molecule⁻¹)</th>
<th>Column Density N (molecules cm⁻²)</th>
<th>Abundance *100</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O</td>
<td>2.0 X 10⁻¹⁶</td>
<td>3.5 E18</td>
<td>100</td>
</tr>
<tr>
<td>CO₂</td>
<td>1.1 X 10⁻¹⁷</td>
<td>1.2 E18</td>
<td>34</td>
</tr>
<tr>
<td>CO (4.67 µm)</td>
<td>1.1 X 10⁻¹⁷</td>
<td>4.4 E17</td>
<td>12</td>
</tr>
<tr>
<td>XCN</td>
<td>5.0 X 10⁻¹⁷</td>
<td>2.9 E17</td>
<td>8.3</td>
</tr>
<tr>
<td>CO (4.68 µm)</td>
<td>1.1 X 10⁻¹⁷</td>
<td>1.5 E17</td>
<td>4.2</td>
</tr>
</tbody>
</table>
Further Study ~ L1551 IRS5

- There is a large amount of CO$_2$ ice in front of L1551 IRS5
- Recently, several low mass objects have been found to have a high CO$_2$ abundance similar to L1551 IRS5 (taken from Nummelin, A., Whittet, D.C.B., Gibb, E.L., Gerakines, P.A., & Chiar, J.E. 2001, ApJ, 558, 185)
- Possibly due to increased efficiency in CO$_2$ production toward low mass objects
- More work is needed to investigate this
Acknowledgements

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Questions?