COMPOSITION OF THE ORION NEBULA

Using the Hubble Space Telescope Faint Object Spectrograph

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Motivation

• Analyze elemental abundances in the Orion Nebula with HST FOS data
• Ability to analyze data from UV and visible regions with the **same instrument** observing the **same position** in the nebula
• UV data enables determination of carbon abundances
HII regions

- Clouds of ionized gas
- Regions of recent star formation
- Orion Nebula is the closest H II region (1344 light years)
Collisionally excited lines

• “Forbidden” lines
  – Transitions produce lines not observed in the lab; very unlikely under normal conditions
  – Observed in low-density gases where atomic collisions are infrequent, like H II regions!
  – Notated by square brackets: O++ $\rightarrow$ [O III]

• Measure the intensities of these lines to learn about conditions in the nebula
Measuring Line Intensities

![Graph showing absorption lines with intensity values on the y-axis and wavelength on the x-axis. The graph displays multiple absorption lines at different wavelengths with intensity values ranging from 1.0E-14 to 3.0E-14.]
Reddening Correction

\[ \frac{I(\lambda)}{I(H\beta)} = \frac{F(\lambda)}{F(H\beta)} \times 10^{c[\,f(\lambda) - f(H\beta)\,]} \]

- reddening-corrected flux
- measured flux
- extinction correction parameter that varies with wavelength

\[ c = \frac{\log_{10}(2.86) - \log(H\alpha/H\beta)}{-0.274} \]

H\alpha, H\beta: Balmer lines of hydrogen
nebular

- Package in Space Telescope Science Data Analysis System
- Shaw & Dufour (1995)
- Calculate temperatures, densities, and abundances in IRAF
Temperature and Density Calculations

• Strength of the forbidden lines is very sensitive to temperature
• Due to weak/noisy lines needed to determine temperature, values presented here are from the literature

\[
Te(OIII) = \frac{(4959 + 5007)}{4363}
\]

\[
Te(NII) = \frac{(6548 + 6584)}{5755}
\]

\[
Ne(SII) = \frac{6716}{6731}
\]
Abundance Calculations

Ionic abundances  Total elemental abundances

\[ \frac{O}{H} = \frac{(O^+ + O^{++})}{H^+} \]
\[ \frac{S}{H} = \frac{(S^+ + S^{++})}{H^+} \]
\[ \frac{N}{H} = \frac{(N^+/O^+)}{(O/H)} \]
\[ \frac{Ne}{H} = \frac{(Ne^{++}/O^{++})}{(O/H)} \]
\[ \frac{C}{H} = \frac{(C^{++}/O^{++})}{(O/H)} \]

- Where possible, sum the contribution from multiple excitation states
- Otherwise, take advantage of similar ionization potentials and use O/H correction factor
- \(- \log(X/H) + 12\)
Elemental Abundances

\[ \log(X/H) + 12 \]

<table>
<thead>
<tr>
<th>Object</th>
<th>C</th>
<th>N</th>
<th>O</th>
<th>Ne</th>
<th>S</th>
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<tbody>
<tr>
<td>Orion 1SW</td>
<td>8.66</td>
<td>7.88</td>
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<td>7.76</td>
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<td>6.95</td>
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<td>7.62</td>
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<td>Solar*</td>
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<td>7.92</td>
<td>8.69</td>
<td>8.08</td>
<td>7.32</td>
</tr>
</tbody>
</table>

Conclusions

• Determined elemental abundances in the Orion Nebula from collisionally excited spectral lines
• Found consistent abundances with FOS spectra
  – Oxygen consistent with literature
  – Carbon within reasonable limits
• Not able to determine temperatures precisely enough with HST FOS