Fine Structure Lines toward NGC 2024

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Strong $^{12}\text{C}\text{II}$ & $^{13}\text{C}\text{II}$ emission

$^{12}\text{C}\text{II}$ & $8\ \mu\text{m (MSX)}$

$^{13}\text{C}\text{II}$ & $^{12}\text{C}\text{II}$

$^{12}\text{C}\text{II}$ & $^{13}\text{C}\text{II}$ mapped in Early Science

Graf et al. 2012

NGC 2024
Standard source model: 2 emission components

- Cold foreground @9 km/s
- Warm background @11 km/s

Graf et al. 1993
Revisited in January 2015:

- 1.5' x 1' maps in
  - [OI]
  - [^{12}CII], [^{13}CII]
- 3' x 2' maps in
  - [^{12}CII], [^{13}CII]
  - \(^{12}\)CO 13→12
  - \(^{13}\)CO 13→12
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- 1.5' x 1' maps in
  - [OI]
  - $^{12}\text{CII}$, $^{13}\text{CII}$
- 3' x 2' maps in
  - $^{12}\text{CII}$, $^{13}\text{CII}$
  - $^{12}\text{CO} \ 13 \rightarrow 12$
  - $^{13}\text{CO} \ 13 \rightarrow 12$
Two step line modelling:

1: $[^{13}\text{CII}]$ - HFS - fit

Fit optically thin $[^{13}\text{CII}]$ HFS components with $[^{12}\text{CII}]$ blanked.

Yields

- $T_{\text{ex}} \times \tau([^{12}\text{CII}]) = 962 \text{ K}$
Two step line modelling: 2: 3-component full line fit

<table>
<thead>
<tr>
<th>Component</th>
<th>$T_{ex}$ [K]</th>
<th>$\tau$</th>
<th>$V_{LSR}$ [km/s]</th>
<th>$\Delta V$ [km/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>481.0</td>
<td>2.0</td>
<td>10.30</td>
<td>3.14</td>
</tr>
<tr>
<td>broad emission</td>
<td>40.7</td>
<td>0.2</td>
<td>9.56</td>
<td>6.50</td>
</tr>
<tr>
<td>Foreground</td>
<td>0.0</td>
<td>1.8</td>
<td>10.21</td>
<td>2.86</td>
</tr>
</tbody>
</table>

Fixed values in RED

$N_{BG}(^{12}\text{C}^+) > 10^{19}$ cm$^{-2}$

$N_{FG}(^{12}\text{C}^+) > 10^{18}$ cm$^{-2}$

Note: Rest frequencies of HFS-components revised
Peaks just north of ionization front - as expected, but...
[OI] channel maps

essentially NO emission between 9 km/s and 11 km/s!
[O I] sample spectrum

Fixed values in RED

Massive foreground absorption
Foreground absorption artificially removed

>60% of [CII] emission is obscured by foreground

~85% of [OI] emission is obscured by foreground
Resolving power matters!

[CII] self-absorption disappears at $R < 100000$
[OI] self-absorption disappears at $R < 30000$
$^{13}\text{CO} \ 13\rightarrow 12 \ \text{on} \ [^{13}\text{CII}]$
Summary

• High resolution spectroscopy reveals strong foreground absorption in [OI] and [CII]:
  - ~85% of background [OI] emission obscured
  - >60% of background [CII] emission obscured

• Consistent with FG hydrogen column density of $10^{22}$ cm$^{-2}$

• Background [OI] / [CII] intensity ratio ~ 5 indicates substantial density and radiation field

• Fine structure emission peaks just north (or wraps around) dense condensation (seen in $^{13}$CO 13→12)

Finally: High spectral resolution is crucial for accurate line intensities and to disentangle line of sight source structure