The Formation of IRDCs

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From Stars To Galaxies
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CO Mass Density Comparison: CO isotopologues vs. Extinction

- IRAM 30m telescope:
  - $^{13}$CO(1-0)
  - $^{13}$CO(2-1)
  - C$^{18}$O(1-0)
  - C$^{18}$O(2-1)
  - Beam sizes:
    - 22" (1-0)
    - 11" (2-1)
  - Spectral Resolutions:
    - 0.05 km/s (1-0)
    - 0.1 km/s (2-1)

$^{16}$O/$^{18}$O = 327
Wilson & Rood 1994

$^{12}$C/$^{13}$C = 54
Milam 2005

$^{12}$CO/H$_2$ = 2x10$^{-4}$
Lacy et al. 1994
A 5 K increase in $T_{\text{ex}}$ would lead to a factor of two increase in column density.
Virial Mass Estimates

- Ellipsoidal Virial Mass assumes a depth equal to width (Bertoldi & McKee, 1992)

\[ \alpha_{\text{obs}} = \frac{5\sigma^2 R_{\text{obs}}}{GM} \]

<table>
<thead>
<tr>
<th>$^{13}$CO $M_\odot$</th>
<th>Virial $M_\odot$</th>
<th>Ext $M_\odot$</th>
</tr>
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<tbody>
<tr>
<td>420</td>
<td>2100</td>
<td>570</td>
</tr>
</tbody>
</table>

$\alpha_{\text{obs}} \sim 4$ for IRDC Filament H
IRDC Rotation and Associated GMCs

- Catalog 1:
  - Simon et al. (2006)
  - Use IRDCs as GMC tracers:
    - ~300 sources

- Catalog 2:
  - Koda 2006 GMC catalog
  - ~550 GMCs

- Method:
  - 10, 20, and 30 pc GMC radii.
  - $dv = \pm 15$ km/s
  - Identify cloud center of mass in l,b,v space
  - Measure rotation about CM.
Prograde vs. Retrograde:

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<tr>
<th></th>
<th>Pro</th>
<th>Retro</th>
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<tbody>
<tr>
<td>Simon Cat</td>
<td>0.49</td>
<td>0.51</td>
</tr>
<tr>
<td>Koda Cat</td>
<td>0.51</td>
<td>0.49</td>
</tr>
<tr>
<td>Koda et al. 2006</td>
<td>0.52</td>
<td>0.48</td>
</tr>
<tr>
<td>Tasker &amp; Tan 2009</td>
<td>0.49</td>
<td>0.51</td>
</tr>
</tbody>
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$\rightarrow$ No statistical difference between catalogs. KS probability ~0.25 (Tasker and Tan 2009)

(Tasker and Tan 2009)
Are GMCs Virialized?

\[ \alpha_{\text{obs}} = \left( \frac{M_o}{M_{13CO}} \right)^{\eta} \]

BM92:
Log\((M_o) = 3.32\n\eta = 0.59\)

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<tr>
<td>(\alpha_{\text{pro}})</td>
<td>1.10</td>
<td>1.09</td>
</tr>
<tr>
<td>(\alpha_{\text{retro}})</td>
<td>1.17</td>
<td>1.11</td>
</tr>
<tr>
<td>Log((M_o))</td>
<td>6.50</td>
<td>6.32</td>
</tr>
<tr>
<td>(\eta)</td>
<td>0.64</td>
<td>0.60</td>
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No correlation between virial parameter and direction of rotation.
Conclusions

• **Filament H:** Comparisons of mass surface density from molecular line emission and extinction indicate possible gas depletion onto dust grains or a $T_{\text{ex}}$ gradient. Though not conclusive.

• **IRDC virial analysis:** Large $\alpha_{\text{obs}}$ suggest that Filament is not gravitationally bound. Large turbulent motions maybe due to shocks as indicated by SiO emission (Jiménez-Serra et al. 2009)

• On larger scales, virial analysis on GMCs indicate large $\alpha_{\text{obs}}$ and no preferred direction of rotation. This finding is consistent with GMC interaction models (Tasker & Tan 2009)