Star formation

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Lecture 1: Star formation in the Milky Way

Where did the Sun come from?
What kind of stars are in this galaxy?
The Milky Way

“dark clouds” where light is blocked by interstellar dust

Interstellar dust

- consists mostly of Silicon, Carbon (“household fluff” produced by stars)
- sublimes (ie. melts) at $T > 1000K$
- at what wavelength do we expect blackbody emission?

$$\lambda_{max} = \frac{2.9 \times 10^6 \text{ nm K}}{T}$$

$T < 1000K \Rightarrow \lambda_{max} > 1\mu \text{m}$

i.e. INFRARED
The Milky Way in Infrared

Credit: AKARI mission/ JAXA
Orion
“Most star formation within 0.5 kpc lies in Gould's Belt, a ring around the sky containing star-forming molecular clouds centred on a point 200 pc from the Sun and tilted at 20 degrees to the Galactic Plane”
Ophiuchus
Perseus Molecular Cloud at sub-mm wavelengths

Note how star formation is concentrated in small, clustered regions

Hatchell et. al. (2007)

Spitzer (IR) cores-to-discs (c2d) survey

Evans et al. (2008)
(Nearby) Molecular clouds: in numbers

Table 1

<table>
<thead>
<tr>
<th>Cloud</th>
<th>Solid angle (deg$^2$)</th>
<th>Distance (pc)</th>
<th>Area (pc$^2$)</th>
<th>$\Delta v$ (km s$^{-1}$)</th>
<th>Mass$^a$ (M$_{\odot}$)</th>
<th>$(n)_b$ (cm$^{-3}$)</th>
<th>Refs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cha II</td>
<td>1.08</td>
<td>178 ± 18</td>
<td>1000 ± 20</td>
<td>1.2</td>
<td>426 ± 86</td>
<td>340</td>
<td>3.7</td>
</tr>
<tr>
<td>Lupus</td>
<td>3.10</td>
<td>150 ± 20$^c$</td>
<td>28.4 ± 6.5</td>
<td>1.2</td>
<td>816 ± 188</td>
<td>381</td>
<td>4.7</td>
</tr>
<tr>
<td>Perseus</td>
<td>3.86</td>
<td>200 ± 50</td>
<td>73.6 ± 20.4</td>
<td>1.54 ± 0.11</td>
<td>4814 ± 1925</td>
<td>206</td>
<td>7.8</td>
</tr>
<tr>
<td>Scorpius</td>
<td>0.85</td>
<td>200 ± 10</td>
<td>17.5 ± 1.4</td>
<td>2.16 ± 0.01</td>
<td>2016 ± 135</td>
<td>707</td>
<td>27.6</td>
</tr>
<tr>
<td>Ophiuchus</td>
<td>6.04</td>
<td>125 ± 25</td>
<td>31.4 ± 12.6</td>
<td>0.94 ± 0.11</td>
<td>2182 ± 878$^c$</td>
<td>318</td>
<td>8.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15.457</strong></td>
<td><strong>1649 ± 51.9</strong></td>
<td><strong>10254 ± 3228</strong></td>
<td><strong>...</strong></td>
<td><strong>...</strong></td>
<td><strong>...</strong></td>
<td></td>
</tr>
</tbody>
</table>

- mostly consist of molecular hydrogen, but also other molecules e.g. carbon monoxide, ammonia, NH$_3$, methanol, water.
- size $\sim$ 0.1pc - 100pc (0.3ly - 300ly)
- density $\sim$ 10$^3$ - 10$^4$ particles/cm$^3$ $\sim$ 10$^{-21}$ - 10$^{-20}$ g/cm$^3$
- size + density implies mass $\sim$ 10 to 10$^6$ Msun
- temperature $\sim$ 10K
- lifetime? (1 million - 10 million yrs)
- formation?

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Taurus Molecular Cloud

T-Tauri and surrounds (optical) credit: NOAO

Taurus molecular cloud in $^{12}$CO emission
Fig. 11.— Image showing H$_2$ column density overlaid with the eight well-known regions of high column density as designated by Onishi et al. (1996). These regions define the masses and areas given in Table 4.

<table>
<thead>
<tr>
<th>Region</th>
<th>Mass (M$_\odot$)</th>
<th>Area (pc$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1495</td>
<td>2616</td>
<td>31.7</td>
</tr>
<tr>
<td>B213</td>
<td>1095</td>
<td>13.7</td>
</tr>
<tr>
<td>L1521</td>
<td>1584</td>
<td>17.6</td>
</tr>
<tr>
<td>HCl2</td>
<td>1513</td>
<td>15.8</td>
</tr>
<tr>
<td>L1498</td>
<td>373</td>
<td>5.7</td>
</tr>
<tr>
<td>L1506</td>
<td>491</td>
<td>7.7</td>
</tr>
<tr>
<td>B18</td>
<td>1157</td>
<td>14.5</td>
</tr>
<tr>
<td>L1536</td>
<td>978</td>
<td>16.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9807</strong></td>
<td><strong>123.3</strong></td>
</tr>
</tbody>
</table>

*Regions defined in Figure 11*

*Includes correction for He*
H-R diagram (for Taurus MC)

T-Tauri stars

Why is there a “bump” on top of the blackbody curve?
Initial mass function

Massive stars are rare, but they have a disproportionate influence

Luhman et al. (2006)
Disproportionate influence of massive stars: radiation

Taurus  Ophiuchus  Orion

Credit: APOD / Rogelio Bernal Andreo (Deep Sky Colors)
Credit: C. O’Dell/HST/NASA
Credit: Mark McCaughrean/HST/NASA
“Pillars of creation” (the Eagle nebula).