The Herschel view of the on-going star formation in the Vela-C molecular cloud

T. Giannini (OAR), D. Elia (IAPS), D. Lorenzetti (OAR), and the HOBYS team
The Vela–C cloud

- it is the cloud “C” of the Vela Molecular Ridge (Murphy & May, 1991), \( l = 263^\circ - 265^\circ, b = 0^\circ - +2^\circ \)

- distance = 700 ± 200 pc (Liseau et al. 1992)

- site of star formation on a wide range of masses (Massi et al. 2003; Baba et al. 2006)
Herschel observations

- Vela – C observed with PACS and SPIRE in parallel mode as part of the Herschel key-program HOBYS (Herschel imaging survey of OB Young Stellar OBjects)

- Simultaneous photometry at five wavelengths between 70 μm and 500 μm

Giannini et al. 2012 A&A, 539, 156
SPIRE sensitivity ~ 20 times better than BLAST

- catalogue of 1686 sources (5σ)
- sources spatially associated to obtain a band merged catalogue
- peak of source number at 250 μm (loss of sensitivity at longer wavelengths)
- multiple associations at λ ≥ 160 μm

⇒ 268 objects selected for SED fitting

<table>
<thead>
<tr>
<th>Band</th>
<th>N</th>
<th>Sens. limit (Jy)</th>
<th>90% Compl. limit (Jy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>1686</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70 μm</td>
<td>658</td>
<td>0.04</td>
<td>0.21</td>
</tr>
<tr>
<td>160 μm</td>
<td>871</td>
<td>0.09</td>
<td>0.67</td>
</tr>
<tr>
<td>250 μm</td>
<td>966</td>
<td>0.11</td>
<td>1.07 (BLAST : 17)</td>
</tr>
<tr>
<td>350 μm</td>
<td>697</td>
<td>0.33</td>
<td>1.32 (BLAST : 22)</td>
</tr>
<tr>
<td>500 μm</td>
<td>416</td>
<td>0.46</td>
<td>1.95</td>
</tr>
</tbody>
</table>

Herschel HPBW (500 μm) = 35.7”, ALMA (870 μm) : FoV = 18”, ang.res. : 0.45”-1.55”

ALMA sensitivity at 870 μm : ~ 0.1 Jy (5σ, 1 min)
SED fitting

- SED fitted with a modified black-body function
- Grid of models: $8 \, \text{K} \leq T \leq 40 \, \text{K}; \ 10 \, \mu\text{m} \leq \lambda_0 \leq 40 \, \mu\text{m},$ nfor $\lambda > \lambda_0$
- the emission is optically thin
- Derived parameters: T,M,d, L

**STARLESS:**
- sources not detected at $70 \, \mu\text{m}$

**PROTOSTELLAR:**
- sources with a $70 \, \mu\text{m}$ flux above the best fit by more than $3 \, \sigma$ or
- detected at $\lambda < 70 \, \mu\text{m}$ by other surveys

$\Rightarrow 218$ starless sources
$\Rightarrow 48$ protostellar sources
Physical parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Starless (218)</th>
<th>Protostellar (48)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>median</td>
<td>average</td>
</tr>
<tr>
<td>$M$ ($M_\odot$)</td>
<td>3.3</td>
<td>5.5</td>
</tr>
<tr>
<td>$T_\sigma$ (K)</td>
<td>10.0</td>
<td>10.3</td>
</tr>
<tr>
<td>$D$ (pc)</td>
<td>0.064</td>
<td>0.067</td>
</tr>
<tr>
<td>$L_{\text{FIR}}$ ($L_\odot$)</td>
<td>0.17</td>
<td>0.22</td>
</tr>
</tbody>
</table>

**RED: starless**
**BLUE: protostellar**

- Sizes from 0.025 pc to 0.13 pc: mixture of cores and clumps
- On average, protostellar sources are more compact and warmer than the starless ones. Both colder than interstellar medium ($T \sim 14$ K, Hill et al. 2011)
- Wide range of masses; 8 sources have $M > 20 M_\odot$
Prestellar sources

To determine if a starless core is gravitationally bound (then pre-stellar), a comparison of its mass with the corresponding Bonnor-Ebert mass has been performed ($M_{\text{pre}} > 0.5M_{\text{BE}}$).

Effects of turbulence and magnetic field discarded.

206 out of 218 (~94%) starless cores have been recognized as pre-stellar, (69% in the Aquila Rift).

In a mass vs size plot, all the unbound sources are close to the mass detection limit (~0.05 $M_\odot$).

⇒ Need of much higher sensitivity to effectively probe the ratio of the bound/unbound sources.
The Source Mass Distribution

- The prestellar source mass distribution was fitted as $N(\log M) \propto M^{-\gamma}$

- Fit from the completeness mass limit of $4M_\odot \Rightarrow \gamma = 1.1 \pm 0.2$

- With BLAST: $\gamma = 1.9 \pm 0.2$ for $M > 14M_\odot$ (Netterfield et al. 2009)

- This value is intermediate between $\gamma = 0.7$ of large CO clumps (Kramer et al. 1998) and $\gamma = 1.3$ of the IMF
  ... but if we consider only sources with $d < 0.08$ pc $\Rightarrow \gamma = 1.4$

- Possible flattening at masses close to the completeness limit?

⇒ at the Vela-C distance the Herschel spatial resolution is not sufficient to probe cloud cores
The Herschel-HOBYS survey of Vela-C in the FIR has revealed a numerous population of pre- and proto-stellar cores ....

......but

need of higher sensitivity to :

- probe the faintest and much numerous population
- understand whether or not the very high percentage of bound cores is real or not
- probe the mass distribution up to subsolar masses

need of higher spatial resolution to :

- resolve the high degree of multiplicity in the largest Herschel beams
- probe the core mass distribution without contamination of larger structures
Collaboration with Northwestern University, Osservatorio di Arcetri

- **Aim:** to study the role of the magnetic field in the gravitational collapse through similarities between cloud magnetic fields (30000 AU) and infall morphologies (1000 AU).

- In a magnetically dominated scenario a flattened inner core forms with its symmetric axis parallel to the local B-field.

- The 'Axehead' in Vela-C is the ideal target since it was observed with BLAST-Pol at 250 μm (50 hr, data under reduction)
Method: sample of Herschel selected prestellar and protostellar cores: sources in different evolutionary stages selected based on the $250 \, \mu m$/mid-IR flux (Akari, MSX, Wise) (e.g. $F(250 \, \mu m)/F(9 \, \mu m) > 100 \Rightarrow$ Class 0 protostar, Enoch et al. 2009)

Direction of the B-field from BLAST-Pol

Core morphology from ALMA observations at 345 GHz

CASA simulation of a Class 0:
- **left:** original $350 \, \mu m$ data (from SHARC-II of the B-field/SHARP at CSO);
- **right:** simulated ALMA 345 GHz image at the distance of Vela-C.

⇒ Despite some artifacts, the position angle of the inner core's major and minor axes are preserved.

....Grazie !!