Young embedded clusters in Cygnus-X

E. Moraux
F. Maia, I. Joncour
Cygnus X

- One of the richest SFR
- 2 large molecular clouds (Cygnus X North and South)
- Cyg OB2 association in the middle
- Is there any connection?
- Studies difficult due to high extinction (foreground molecular cloud at 500-800pc)
- In the local spiral arm: structures at different distances
- Age spread of ~10 Myr

Previous embedded cluster identification from 2MASS data (Le Duigou & Knödlseder 2002; Bica+ 2003)
→ New deep NIR images of CygX North with WIRCAM (1 sq.deg.) down to $K\sim20$
WIRCAM data

- J, H, K filter
- Photometry calibrated on 2MASS
- Source extraction using SExtractor + PSFEx
- Stellar density maps built from the K-band catalogue using different kernel sizes and then stacked
- Confirmation of the emerged, more populous clusters
Membership analysis

• Cluster CMD obtained from the substraction of control field CMD derived in an area close to the cluster, with same surface.

• Probability using stellar density in multi-colour space:

\[
P_{\text{phot}} = \frac{\rho_{\text{clu}} - \rho_{\text{fld}}}{\rho_{\text{clu}}}
\]

• Cutoff at 50%

(Maia+ 2010, 2014)
For a given age, estimation of each stellar extinction minimizing the dispersion of the global extinction distribution.
Then the distance modulus (DM) for each star is inferred using Av.
Cluster parameters

- Maximization of the sharpness $S$ of the $Av$ and $DM$ distributions
  
  $$S \left( \log t \right) = \left[ \frac{N_{\text{max}}}{W} \right]_{Av} \times \left[ \frac{N_{\text{max}}}{W} \right]_{DM}$$

  → « best » isochrone
  → Most probable age, average $Av$ and $DM$
Completeness

- Incompleteness expected due to crowding in the center and extinction
- Completeness estimated by adding artificial stars into the images and computing the recovery fraction
Mass distribution

Luminosity distribution corrected from incompleteness

Mass function \((M_j \rightarrow \text{mass})\)

Fit by a lognormal + power-law above 1M\(_{\odot}\)

Maia, Moraux, Joncour 2016
### Several layers of star formation

<table>
<thead>
<tr>
<th>Region</th>
<th>Dist. (pc)</th>
<th>Average Av (mag)</th>
<th>Age (Myr)</th>
<th>Alpha [1-10 Mo]</th>
<th>Total mass (Mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDB57</td>
<td>809</td>
<td>24.4</td>
<td>1.4</td>
<td>1.4 ± 0.1</td>
<td>163 ± 28</td>
</tr>
<tr>
<td>BDB59</td>
<td>1367</td>
<td>12.9</td>
<td>1.6</td>
<td>1.4 ± 0.3</td>
<td>197 ± 27</td>
</tr>
<tr>
<td>BDB58</td>
<td>2937</td>
<td>13.5</td>
<td>2.0</td>
<td>1.5 ± 0.3</td>
<td>610 ± 56</td>
</tr>
<tr>
<td>LK15</td>
<td>1729</td>
<td>11.2</td>
<td>2.2</td>
<td>1.7 ± 0.1</td>
<td>367 ± 31</td>
</tr>
<tr>
<td>BDB56</td>
<td>1458</td>
<td>9.8</td>
<td>2.8</td>
<td>1.8 ± 0.1</td>
<td>140 ± 21</td>
</tr>
<tr>
<td>LK13</td>
<td>487</td>
<td>7.2</td>
<td>4.5</td>
<td>-</td>
<td>&gt;40</td>
</tr>
<tr>
<td>LK12</td>
<td>751</td>
<td>8.7</td>
<td>5.6</td>
<td>2.4 ± 0.1</td>
<td>305 ± 29</td>
</tr>
<tr>
<td>FSR249</td>
<td>1690</td>
<td>7.0</td>
<td>10</td>
<td>1.8 ± 0.1</td>
<td>312 ± 30</td>
</tr>
<tr>
<td>LK14</td>
<td>968</td>
<td>8.5</td>
<td>14</td>
<td>2.1 ± 0.1</td>
<td>433 ± 24</td>
</tr>
<tr>
<td>Bica3</td>
<td>4613</td>
<td>15.1</td>
<td>501</td>
<td>-</td>
<td>&gt;3000</td>
</tr>
</tbody>
</table>

**Older background cluster**

**The youngest have a top heavy MF**
Why is the MF top heavy in younger clusters?

Have we missed the low mass stars?

• Confusion? No
• Extinction? I don’t think so but may be possible
• Star formation still ongoing? But low mass stars would form last...
• Mass segregation?

→ Need to look at larger areas and other regions to confirm the trend