The Loneliest O Stars

Joel Lamb
Sally Oey
Jessica Werk
(University of Michigan)
Motivation

• Massive star formation
  – Competitive accretion vs. Core accretion
    – Competitive: $m_{\text{max}} \propto M_{\text{cl}}^{2/3}$ (Bonnell et al. 2004)
    – Core: massive stars may form with few companions (Krumholz et al. 2010)

• IGIMF effect
  – Predict $m_{\text{max}} - M_{\text{cl}}$ relation steepens IGIMF (Weidner & Kroupa 2004, 2005)
  – Non-universal stellar IMF

• Cluster mass function vs. stellar clustering law (Maschberger & Clarke 2008)
  – $n(M_{\text{cl}}) dM_{\text{cl}} \propto M_{\text{cl}}^{-2} dM_{\text{cl}}$ vs. $n(N_*) dN_* \propto N_*^{-2} dN_*$
Sample & Observations

- SMC field OB stars \((Oey \textit{et al.} \ 2004)\)
  - Friends of friends algorithm
  - Isolated in ground-based imaging \((Zaritsky \textit{et al.} \ 2002)\)
- New \textit{HST ACS SNAP} observations
  - 8 isolated OB stars imaged in F814W and F555W
• Two algorithms to identify companions
  – Stellar density analysis
  – Friends of friends algorithm

3 clustered OB stars
3 isolated OB stars
2 runaways
Cluster Modeling

- Monte Carlo simulations
  - Cluster mass function
    - \( n(M_{\text{cl}}) \, dM_{\text{cl}} \propto M_{\text{cl}}^{-2} \, dM_{\text{cl}}, \quad 10 \, M_{\odot} \leq M_{\text{cl}} \leq 10^6 \, M_{\odot} \)
  - Stellar clustering law
    - \( n(N_{\ast}) \, dN_{\ast} \propto N_{\ast}^{-2} \, dN_{\ast}, \quad 1 \leq N_{\ast} \leq 10^6 \)
  - Kroupa (2001) IMF

- Compare with SMC and Galactic field massive star statistics (Oey et al. 2004; de Wit et al. 2005)
Galactic clusters compiled by Weidner et al. (2010)

$10^0 \leq N_* < 10^1$

$10^1 \leq N_* < 10^2$

$10^2 \leq N_* < 10^3$

$10^3 \leq N_* < 10^4$

$10^4 \leq N_* < 10^5$

$10^5 \leq N_* < 10^6$
**$M_{cl}$ or $N_\star$?**

- SMC massive star clustering \cite{Oey2004} 
- Galactic field O stars \cite{deWit2005}

### Table

<table>
<thead>
<tr>
<th>Sample</th>
<th>1 O star</th>
<th>1 OB star</th>
<th>Iso. O Star</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMC Observed</td>
<td>0.61±0.08</td>
<td>0.65±0.04</td>
<td>-</td>
</tr>
<tr>
<td>Galactic Observed</td>
<td>-</td>
<td>-</td>
<td>0.04±0.02</td>
</tr>
<tr>
<td>$M_{cl}^{-2}$</td>
<td>0.667±0.004</td>
<td>0.651±0.003</td>
<td>0.072 ± 0.001</td>
</tr>
<tr>
<td>$N_\star^{-2}, N_\star \geq 40$</td>
<td>0.700±0.006</td>
<td>0.607±0.004</td>
<td>0.083 ± 0.001</td>
</tr>
</tbody>
</table>

- Best agreement with observations
  - $n(M_{cl}) \, dM_{cl} \propto M_{cl}^{-2} \, dM_{cl}$
  - $n(N_\star) \, dN_\star \propto N_\star^{-2} \, dN_\star, \text{ with } N_{\star, \text{min}} = 40$
$M_{\text{cl}}^{-2}, N_0=1$

$10^0 \leq N_* < 10^1$
$10^1 \leq N_* < 10^2$
$10^2 \leq N_* < 10^3$
$10^3 \leq N_* < 10^4$
$10^4 \leq N_* < 10^5$
$10^5 \leq N_* < 10^6$
• Inconsistent with $m_{\text{max}} - M_{\text{cl}}$ relation
  – competitive accretion
  – steepened IGIMF
• Support universal stellar IMF, including $m_{\text{up}}$
Plot from Maschberger & Clarke (2008)
Red points from Testi et al. (1997, 1999)
Conclusions

• Minimal O star groups fit well within simplistic
  \[ n(M_{cl}) \, dM_{cl} \propto M_{cl}^{-2} \, dM_{cl} \quad \text{OR} \quad n(N_*) \, dN_* \propto N_*^{-2} \, dN_*, \quad N_{*,\text{min}} = 40 \]
  plus universal IMF
  - Both cluster MF and truncated stellar clustering law consistent with SMC and Galactic massive field star observations

• Minimal O star groups inconsistent \( m_{\text{max}} - M_{cl} \) relation
  - Support core accretion models
  - Inconsistent with steepened IGIMF