Constraining star cluster disruption laws through population statistics: The case of M33

Iraklis Konstantopoulos - Penn State*
Nate Bastian - Exeter
Mark Gieles - Cambridge
Henny Lamers - Utrecht

*research undertaken at ESO

Gainesville, 9 April 2010
DISCLAIMER

This talk contains just one pretty picture
DISCLAIMER

This talk contains just one pretty picture.
Context

Why do we care about cluster disruption?
Context

Why do we care about cluster disruption?

All stars form in a clustered fashion

_The Gospel according to Lada & Lada (2003)_
Why do we care about cluster disruption?

All stars form in a clustered fashion

Why do we see more stars in the field?

Why are there so few old clusters?
Cluster disruption

The ultimate driver of cluster evolution
Cluster disruption

The ultimate driver of cluster evolution

- Gas expulsion
- Encounters with GMCs
- Interaction with the tidal field

Physical factors?  Observation?
Disruption mechanisms

What is on offer?
Disruption mechanisms

What is on offer?

Two flavours: key point is cluster Mass
Disruption mechanisms

What is on offer?

lose 70-90% of population every age
dex

random process

Antennae
Disruption mechanisms

What is on offer?

MID
lose 70-90% of population every age dex
random process
Antennae

MDD

$T_{\text{dis}} \propto M^\alpha$

selection on physical criterion
MCs, M51, M33

Fall+ 05
Chandar+ 06
Whitmore+ 07

Boutloukos & Lamers 03
Lamers+ 05
Gieles+ 06
Thing 1 (physics)

The motivation for mass dependence
Thing 1 (physics)

The motivation for mass dependence

Spitzer 1958, Ostriker 1972 & many more: density is the crucial factor
Thing I (physics)

The motivation for mass dependence

Spitzer 1958, Ostriker 1972 & many more: density is the crucial factor

NO mass-radius relation among young clusters
Spitzer 1958, Ostriker 1972 & many more: density is the crucial factor.

NO mass-radius relation among young clusters

mass becomes the expression of density

(ie M~ρ)
Thing 2 (observations)

Environmental confusion
Thing 2 (observations)

Environmental confusion

CFR

6 \rightarrow \log \tau \rightarrow 9
Thing 2 (observations)

*Environ-mental confusion*

- CFR
- $\log N$
- Loads
- A bunch
- Nuffin

- Fairly simple
Thing 2 (observations)

Environmental confusion

<table>
<thead>
<tr>
<th>CFR</th>
<th>log N</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>log τ</td>
</tr>
<tr>
<td></td>
<td>9</td>
</tr>
<tr>
<td>loads</td>
<td>nuffin</td>
</tr>
</tbody>
</table>

fairly simple
Thing 2 (observations)

*Environ-mental confusion*

![Graph of CFR vs logN](image)
Observations

*The M33 cluster population*
Observations

The M33 cluster population

KPNO 4m UBVI imaging

Local Group Survey
Massey & al. 06 (M06)
Observations

*The M33 cluster population*

**KPNO 4m UBVI imaging**

**Local Group Survey**

**Massey et al. 06 (M06)**
Observations

The M33 cluster population

KPNO 4m UBVI imaging

Local Group Survey
Massey & al. 06 (M06)

Chandar, Bianchi & Ford 99, 01
Bedin et al. 05
Sarajedini & Mancone 07
Park & Lee 07
San Roman et al. 09
Measurements

Age dating
Measurements

Age dating

3DEF algorithm
(Bik et al. 2003)
Measurements

Age dating

3DEF algorithm (Bik et al. 2003) → BC03

$X^2$ minimisation in all bands
Measurements

Age dating

3DEF algorithm (Bik et al. 2003)

BC03

$X^2$ minimisation in all bands

Age

Mass
Measurements

Age dating

3DEF algorithm (Bik et al. 2003)
Analysis

Our results
Analysis

Our results
Analysis

Our results
Simulations

Reproducing the M33 population

$\text{MID} + \text{Power-law cIMF}$

$\text{MDD} + \text{Schechter cIMF}$

\[ f_{\text{MID}} = [0.5, 0.8, 0.9] \]

\[ M(t)/M_i \propto \{\mu_{\text{ev}}(t) - \gamma t/t_0\}^{1/\gamma} \]
Simulations

Reproducing the M33 population

MID + Power-law cIMF
MDD + Schechter cIMF

\[ f_{\text{MID}} = [0.5, 0.8, 0.9] \]
\[ \frac{M(t)}{M_i} \propto \left\{ \mu_{\text{ev}}(t) - \frac{\gamma t}{t_0} \right\}^{1/\gamma} \]

dep $M_i$  
dep environment

(Lamers et al. 05)
It’s all about the slopes

\[ MDD + \text{Schechter cIMF} \quad \text{MID} + \text{Power-law cIMF} \]
It’s all about the slopes

MDD + Schechter cIMF

MID + Power-law cIMF
It’s all about the slopes

$\text{MDD} + \text{Schechter cIMF}$

$\text{MID} + \text{Power-law cIMF}$

- Observed $\tau^{-0.9}$
- $f_{\text{MID}} = 50\%$
It’s all about the slopes

\[ \text{MDD + Schechter cIMF} \]

\[ \text{MID + Power-law cIMF} \]
It’s all about the slopes

**MDD + Schechter cIMF**

**MID + Power-law cIMF**
Conclusions

This is where you stop snoozing (for a sec)
Conclusions

This is where you stop snoozing (for a sec)

• Investigated cluster age distributions in a quiescent environment, where the SFR~constant over 1 Gyr
• Found models of mass-dependent disruption to amply emulate the observed distribution
• Mass-independent models produce much steeper distribution slopes than the ones observed
• (WARNING: fading curves are tricky!)
• (Will add constraints relating to the fraction of stars forming in clusters given the SF properties of the galaxy – but gimme a couple of days)