Young stellar clusters

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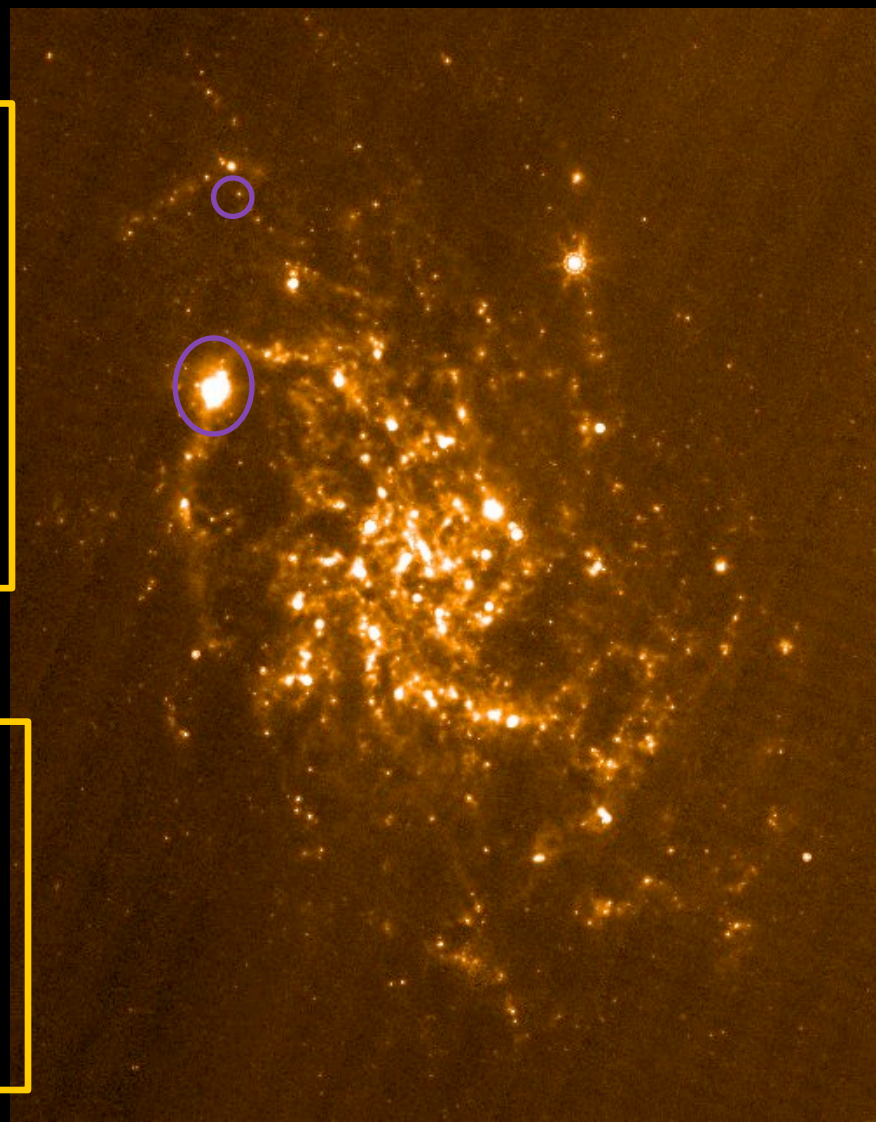
Star forming regions in M33:
Observable over 4 orders of magnitude in L

1. Embedded phase

- Thermal radio continuum: free free emission from ionized gas. *Non-thermal emission*
  Timescales: 0-5 Myr
  (Negative result by Buckalew et al. 2006 suggest to use MIR).
- Dust emission: thermal IR emission from dust grains . *Dust abundance, evolved stars.*
  Timescales: 0-10 Myr + 0-10 Gyr

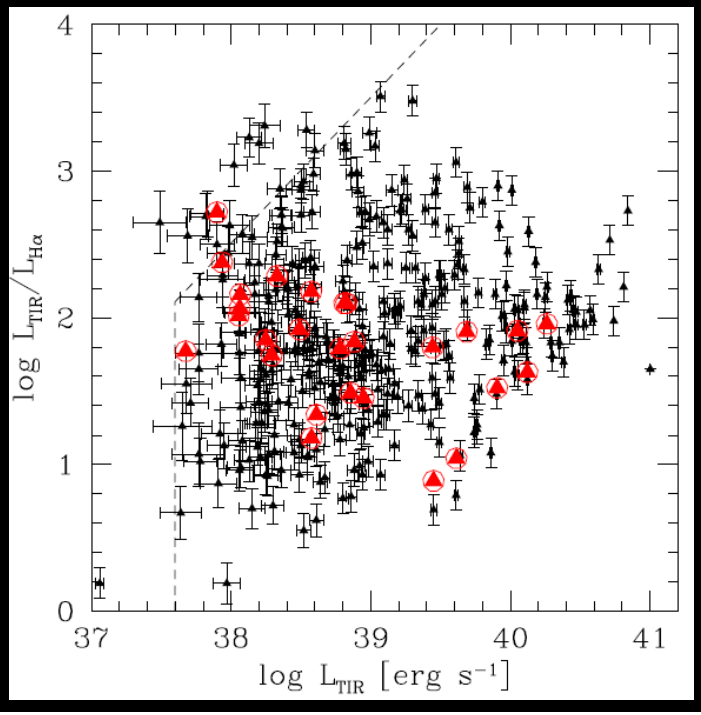
2. Young phase

- UV continuum emission stellar radiation from young massive stars. *Extinction-age degeneracy.*
  Timescales: 0-200 Myr
- Emission lines: nebular emission from HII regions powered by massive stars. *Leakage, stochastic IMF.*
  Timescales: 0-5 Myr



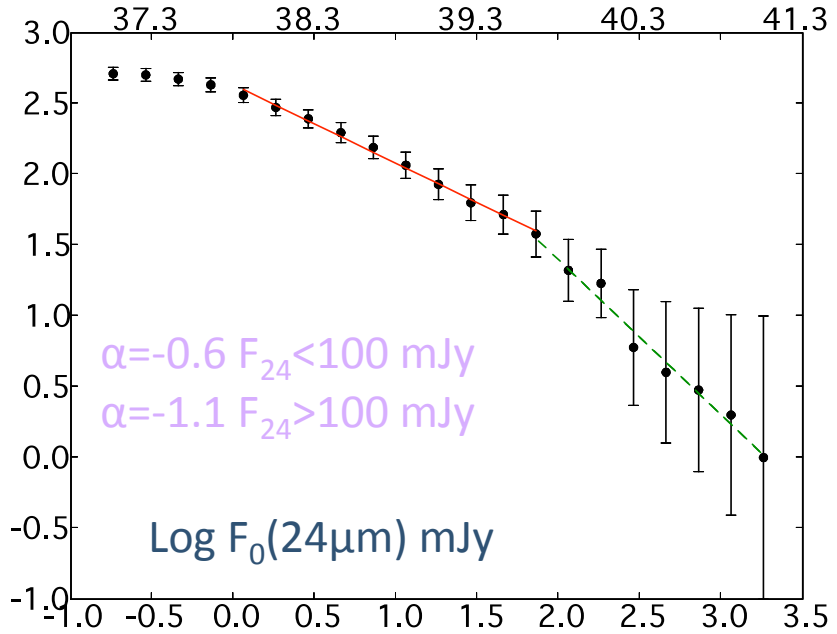
The Local Group Power: resolving individual SF sites

- 500 sources extracted from 24μm Spitzer map of M33
- None of GMCs have IR sources with no Hα
- Half of 500 sources have Hα counterpart
- What are the other half ?
- The scatter between F(Hα) and F(24) is large and increases towards faint sources



Log N (F>F_0)

Log L(TIR) ergs/s



1. Embedded phase

IRAM-30m deep observations of 20 isolated sources

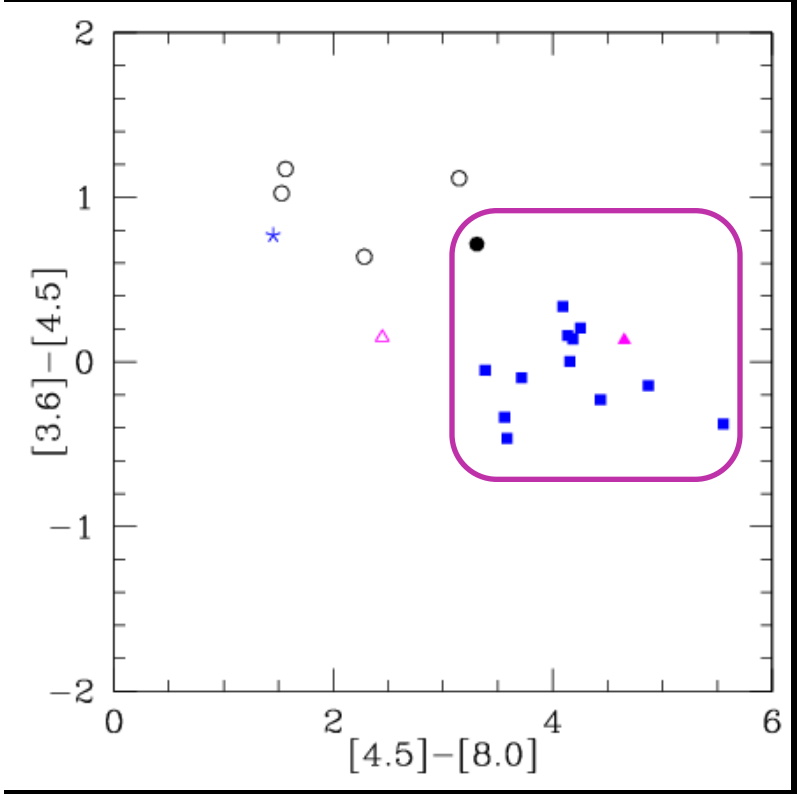
-14 with Hα counterpart have detectable CO lines (filled symbols)

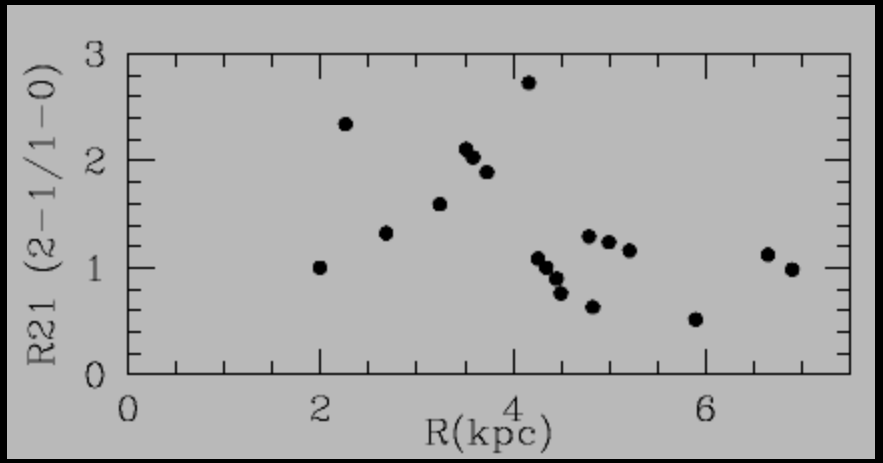
-4 with no Hα counterpart have no or dim CO lines (open circles)

-CO mass correlated with cluster age

-IRAC colors can be used to find clusters associated with MCs

-Clouds properties change radially (GMCs are not ubiquitous). The CO J=2-1/1-0 ratio varies around SF sites!



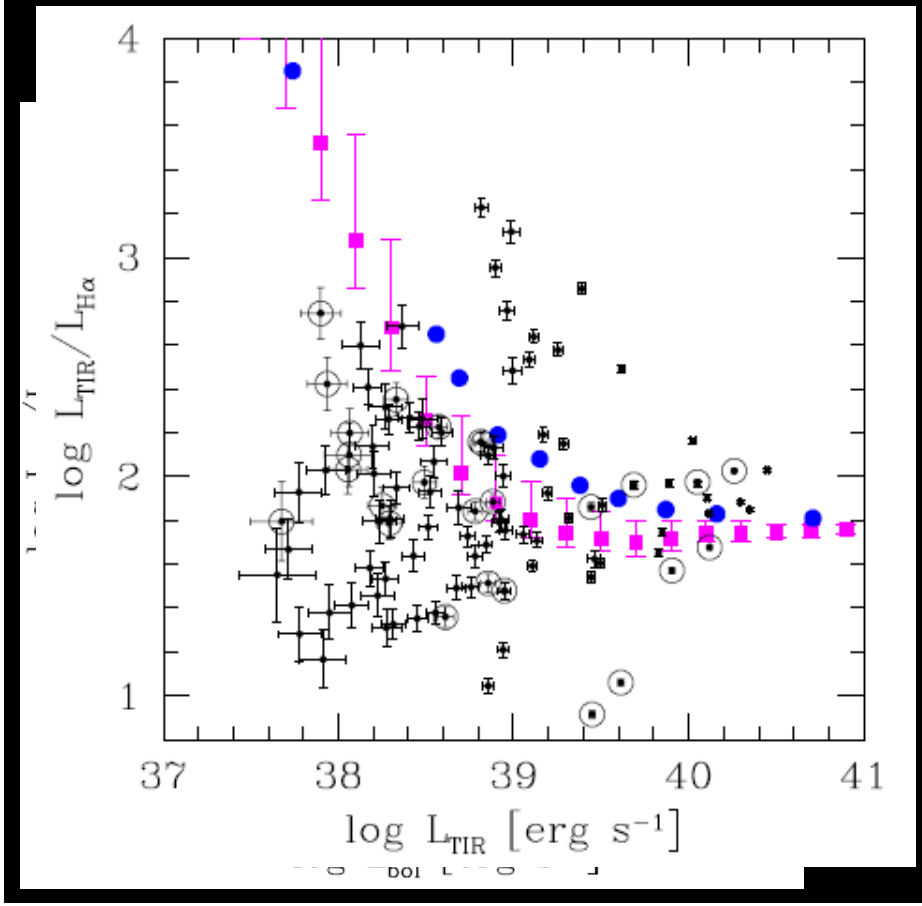


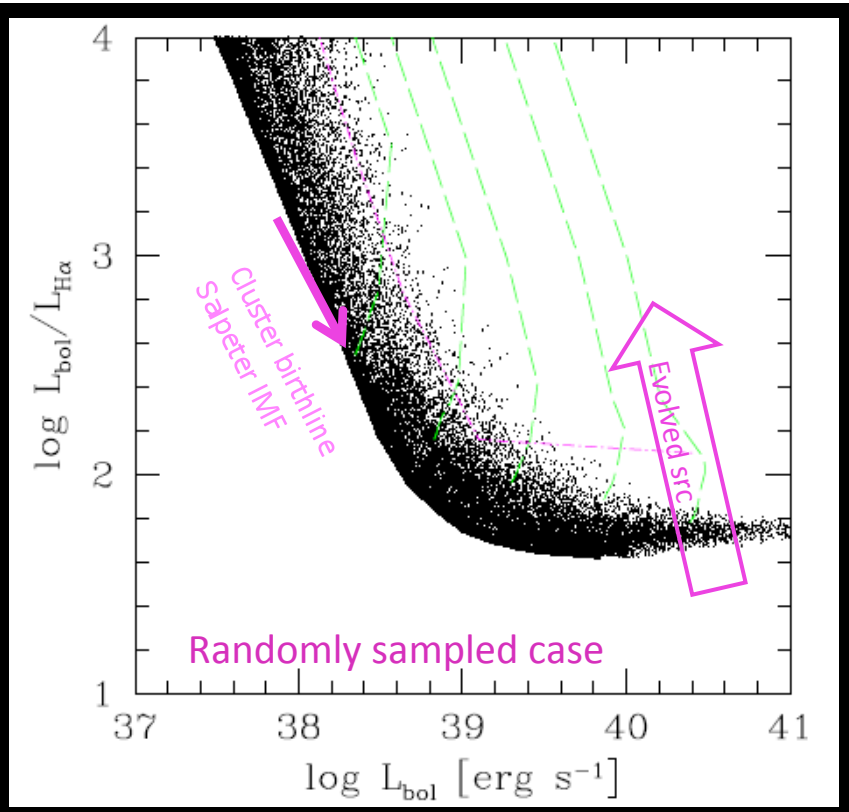
NO deeply embedded clusters found !

2. Young phase

The IMF **and the cluster birthline**

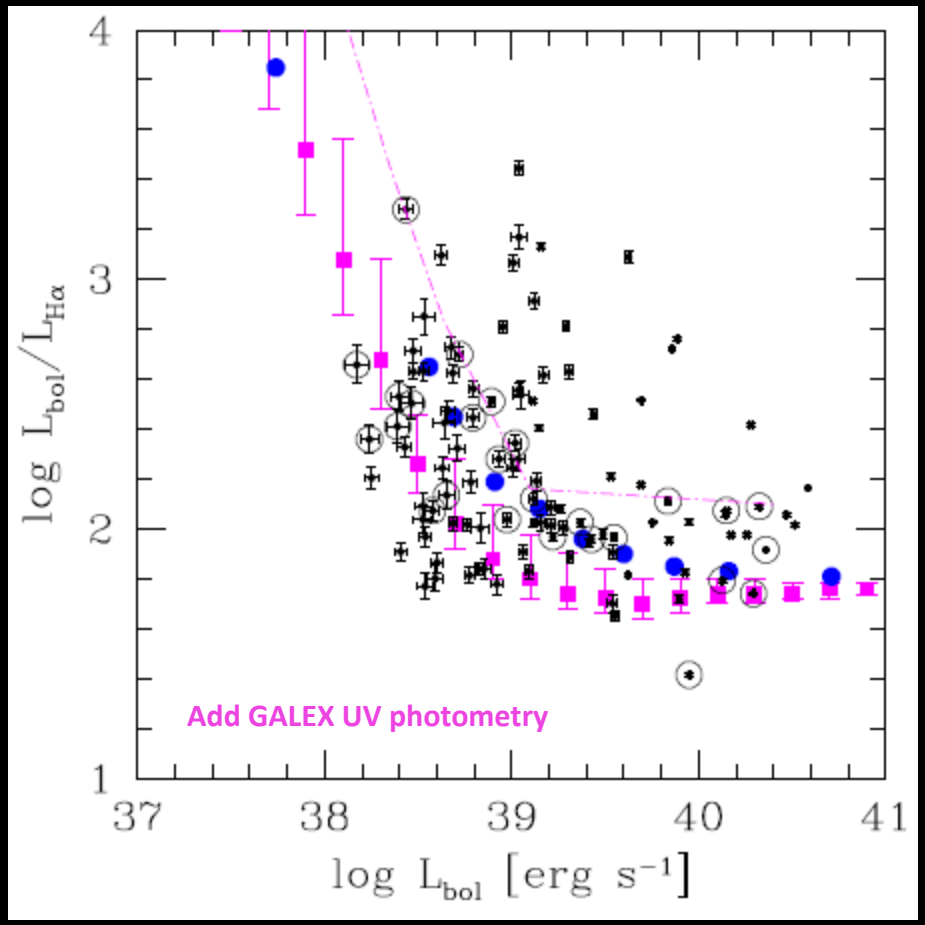
- Can L(TIR) be close to L(Bol) as for embedded clusters?
- Young faint clusters should follow a non linear relation L(Bol)-L(Hα) IMF dependent. UV colors confirm their young ages

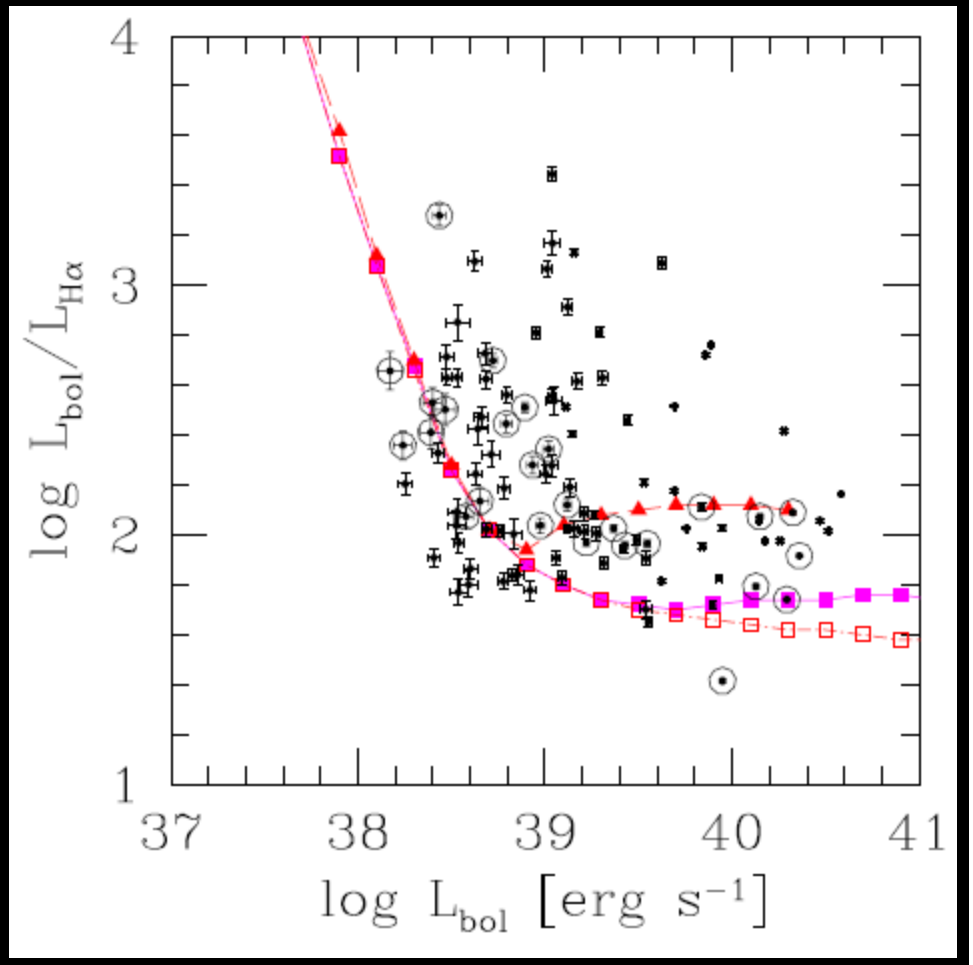




(from Corbelli, Verley, Elmegreen, Giovanardi 2009 A&A 495, 479) .

Clusters are below the birthline ! => L (Bol) > L (TIR); next step: add GALEX luminosities !





- Upper end Salpeter OK, in clusters IMF is stochastically sampled!
- Low & patchy dust/gas ratio requires multiwavelength analysis. MCs are small and fade away easily
- O3 seems the most massive stars in M33 clusters

2. Young phase

Fits to the Spectral Energy Distribution

Sample selection: *Hα emitters, known metallicity, 24μm counterpart*
Method: *SED model fitting, from UV to mid-IR. Single burst model*
Results: *stellar masses, ages, metallicity, extinction, bolometric L*

32 Clusters selected

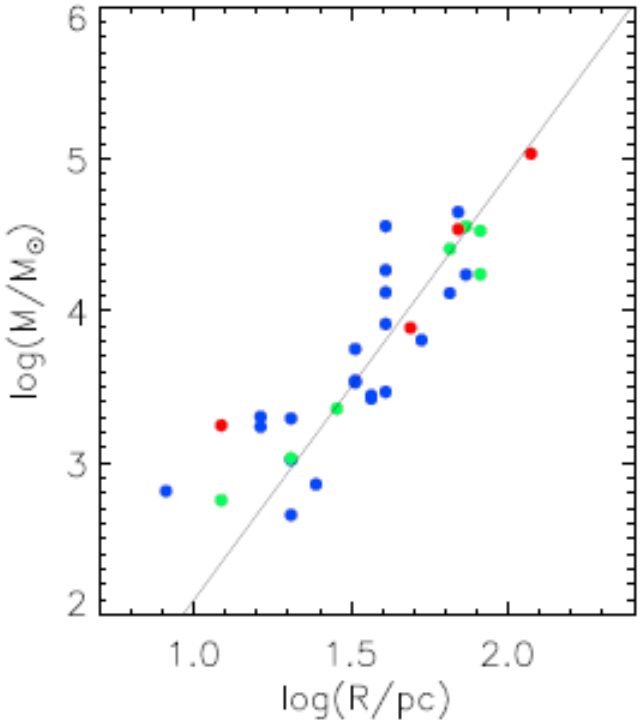
Ages: 7-7.5 → 4 ; 6.5-7 → 7; 6.2-6.5 → 21

Visual Extinction: 0.2 → 1.2 mag

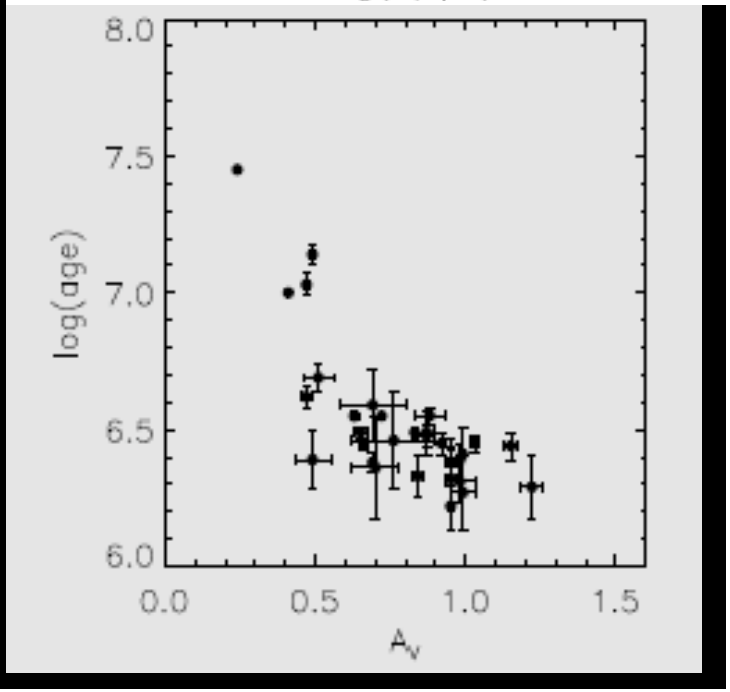
Masses: 500 → 10^5 Msun

Non shocking relations.....

$M = C \; R^3 \Rightarrow$ constant density



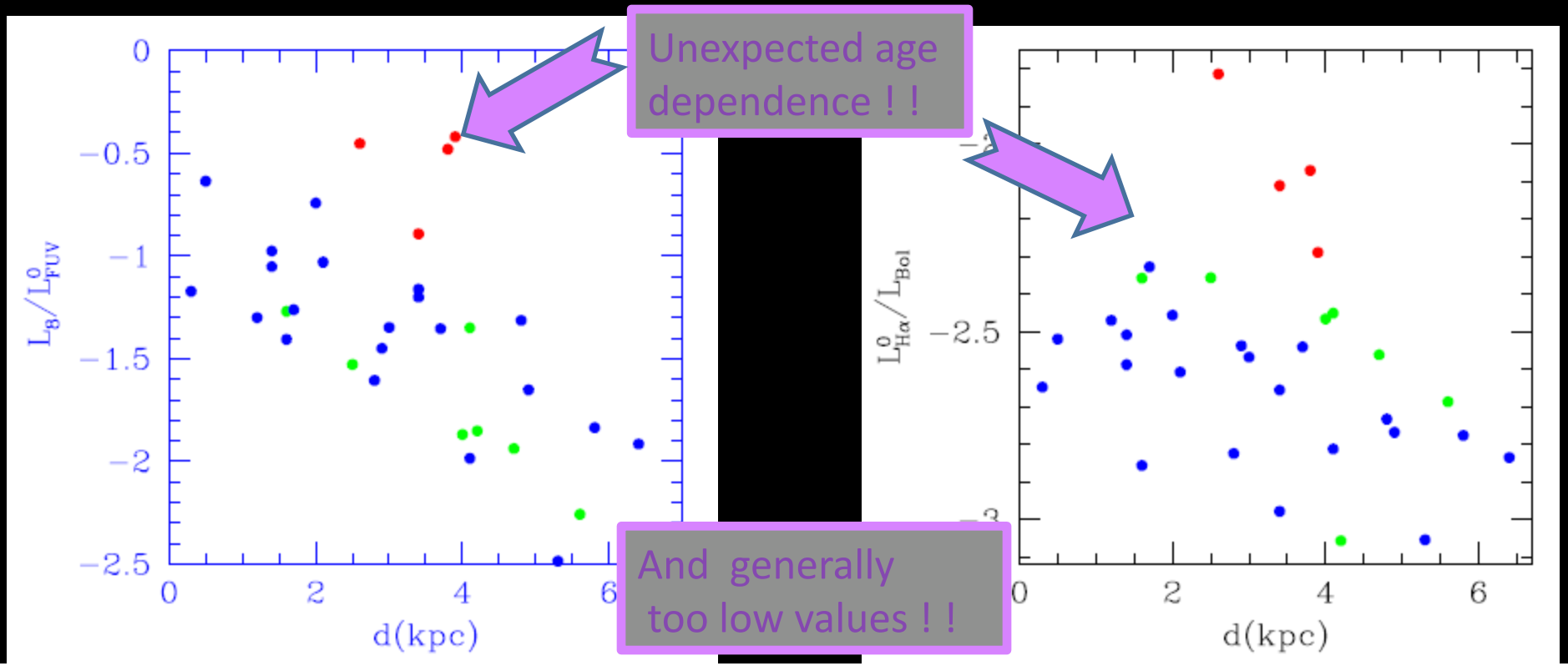
Extinction decreases with cluster age



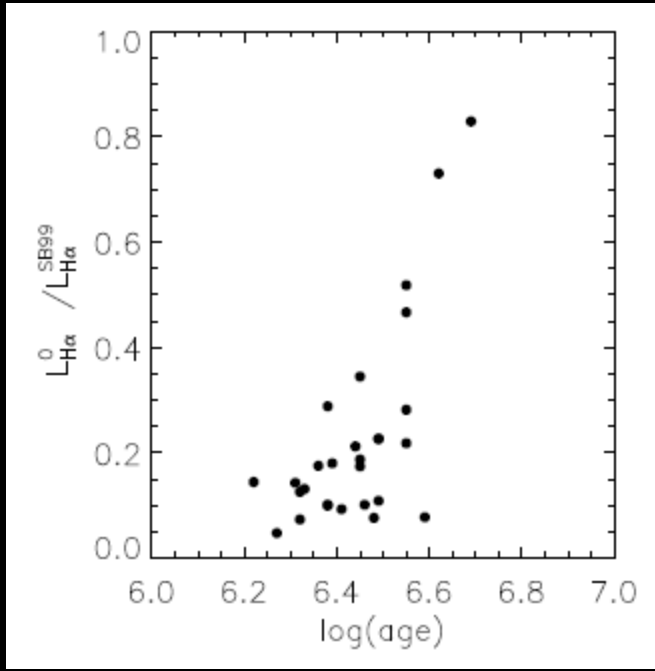
.....Shocking relations and non-relations

A_{FUV} does NOT correlates with L_{24} / L_{bol} , N_{HI} , Z, d ....

L_{mid-IR} / L^{0}_{FUV} , $L_{H\alpha}{}^{0} / L_{Bol}$ correlates with d ! But .....



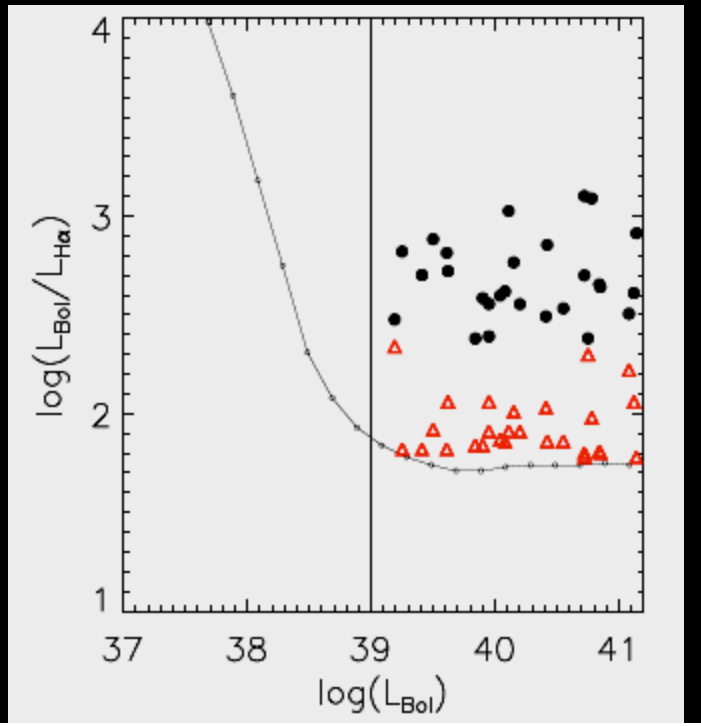
Hα emission is much lower than SED models predicts!
IR emission is too low compared to derived extinction!



Many ionizing photons are missing, especially in young clusters

L_{IR} ($12xL_{MIR}$) low => A^{0}_{FUV} << A_{FUV}

L_{bol} >> L_{FUV} + L_{NUV} + L_{IR}



Leakage or wrong IMF ?

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Leakage:
It explains the high diffuse fraction in the disk and the low IR emission

Leakage:
It should increase with age
It is stronger than model predicts

IMF:
If massive stars are missing models overestimate extinction !
HII extinction decreases with d.

IMF:
Stochstic effects? Most of our clusters should have a complete IMF
Steeper? It does not explain the trend with age

The age problem can be solved if there is a delayed formation of the most massive stars

In any case the solution implies very small dust masses around young clusters

Open questions:

- Is there an embedded phase in SF regions of M33? How to find it?
- Can we sample the Cluster Birthline to see if small clusters form outliers ?
- What are the MIR sources with no Hα emission?
- What to use as local SFR indicator ?