Two populations of star clusters - a feature at all ages

Susanne Pfalzner[1] & Avon Huxor[2]

1 Max-Planck-Institut für Radioastronomie

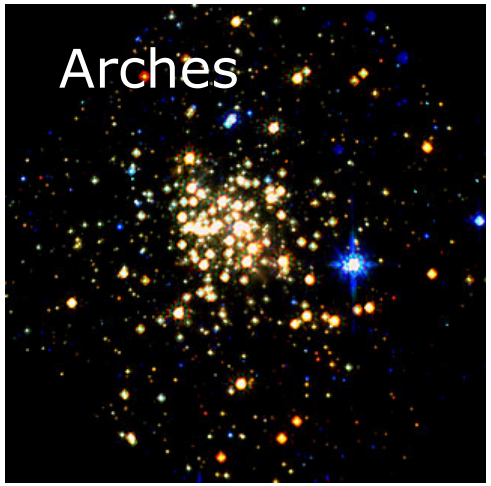
2 Astronomisches Recheninstitut

Young clusters

Most stars form not in isolation, but groups of stars

Group of spacially correlated stars

Group members of fairly equal age



Clusters Associations

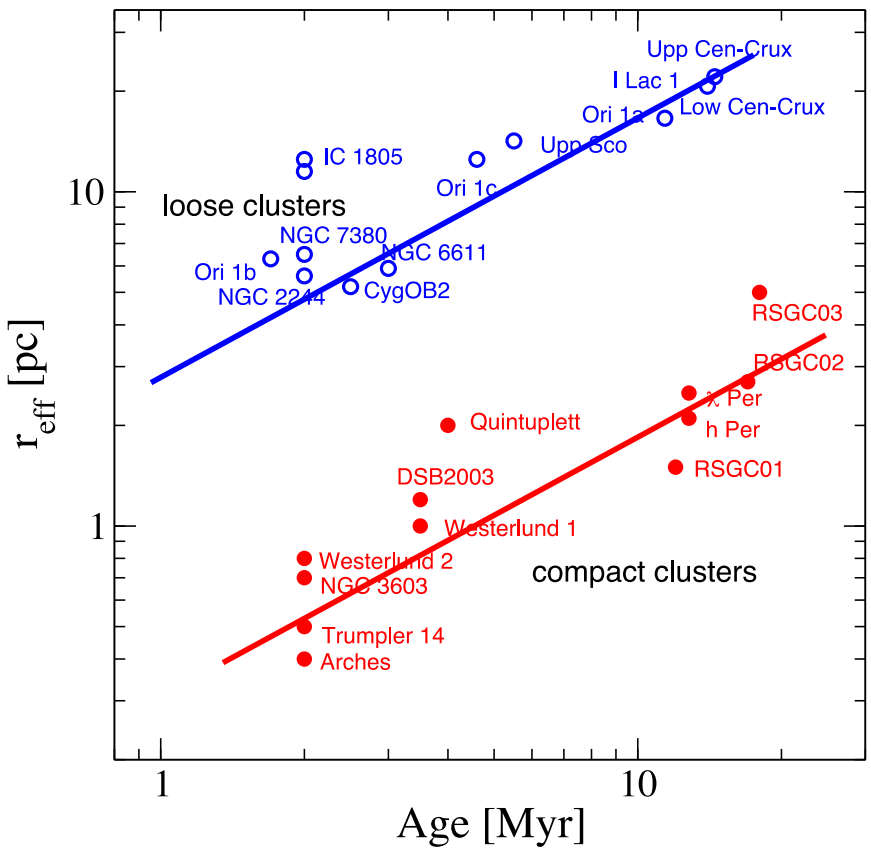
Cluster vs. associations

Initial idea

Clusters	Associations
small size	large size
bound	unbound
large mass	small mass
can exist for a long time	dissolve on short timescales

(Victor Ambartsumian 1947)

Size development over first 10-20 Myr



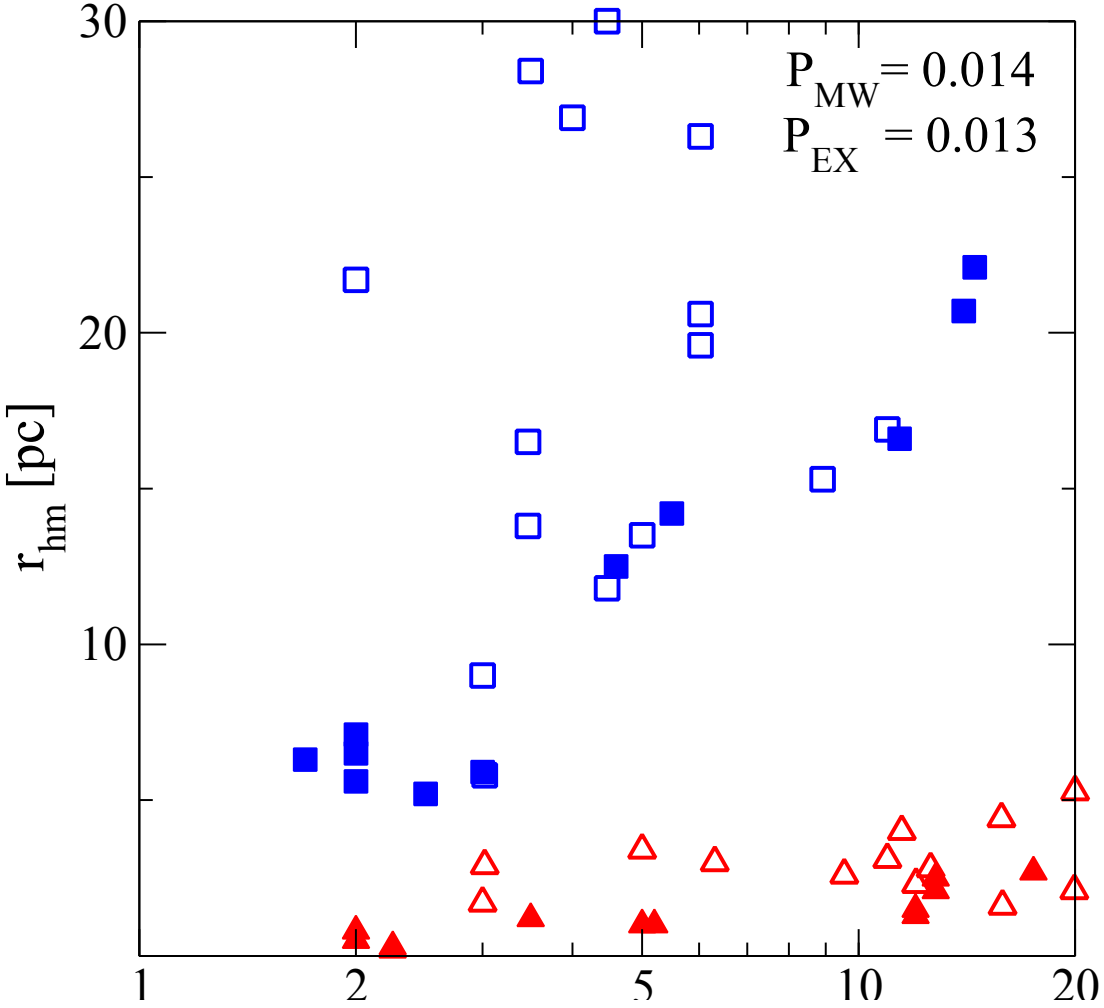
Pfalzner A&A 2009, Portegeis Zwart et al. 2010, Gieles & Portegies Zwart 2011

Clusters and associations expand by factor 5-10

Clusters due to stellar encounters

Associations due to gas expulsion

Young Clusters in nearby galaxies

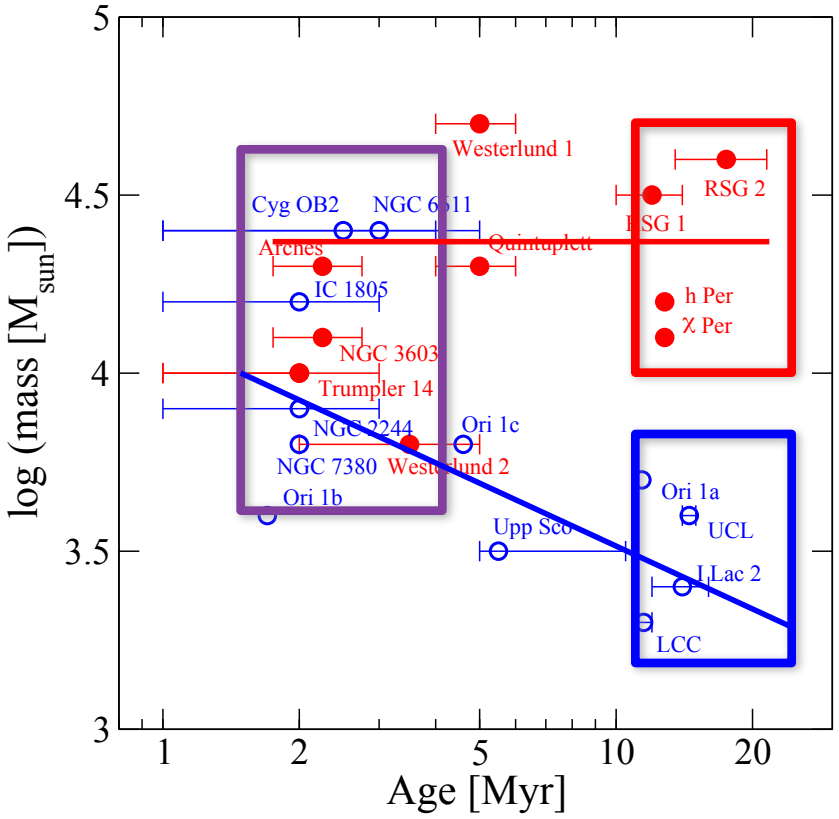


Same situation

Associations

Clusters

Mass development



Reason:

Clusterss
retain most of their mass

SFE_C= 60-70%

Associations
loose 80-90% of their mass

SFE_A up to 30%

Pfalzner A&A 2009

Cluster vs. associations

Modern idea

Clusters	Associations
Small size	extended
But strong development over first 10-20 Myr	
bound	unbound
Large mass retain it over time	~~Small mass~~ Initially large, quick mass loss
Can exist for a long time	Dissolve on short timescales

Cluster vs. associations

Modern idea

Clusters	Associations
Small size	extended
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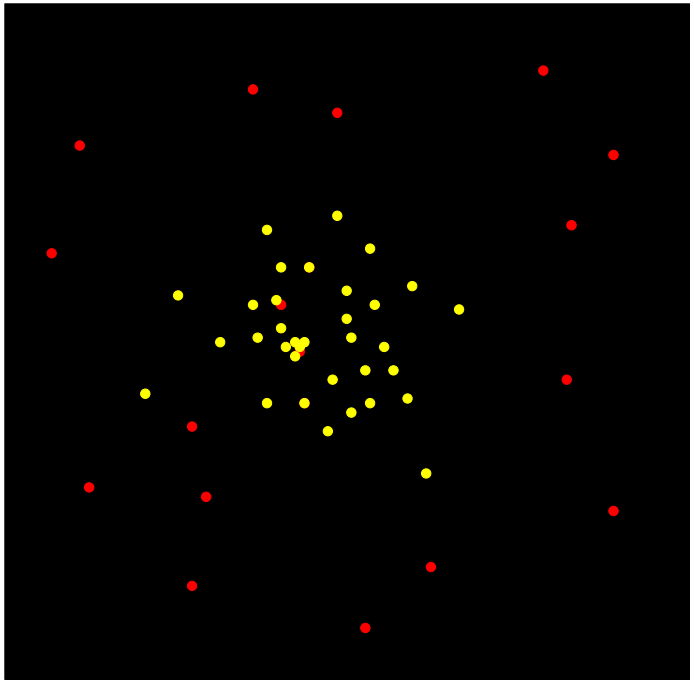
Gas expulsion in associations



- Size at onset of gas expulsion: 1-3pc
- Form mostly with ~30% SFE
- A single massive OB associations feeds 15000-25000 stars within 10-20Myr into the field population
- Remnant: cluster consisting of ~1000-3000 stars within 20pc - leaky cluster
- Full cluster expansion only observed for $M > 10\,000\ M_{sun}$

How important is gas expulsion?

Different points of view

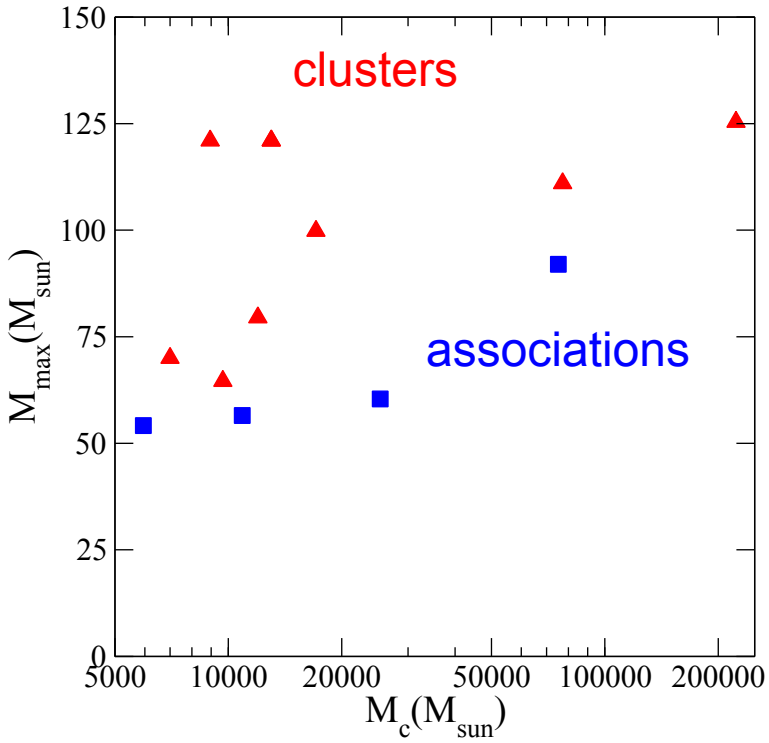
- Lada & Lada 2003: **Gas expulsion very important!**

  Number counts of embedded and exposed cluster:
  Infant mortality:
  90% of all clusters dissolve before they are 10 Myr old

- Bastian (2011): **Gas expulsion in clusters is not important**

(multiepoch high-resolution spectroscopy
NGC 3603, Westerlund 1, Arches, R136)

Most massive stars in cluster vs. associations



Adapted from Weidner et al. 2010

In clusters
more massive than in
associations

Errors are relatively large,
but so far there seems to be no
exception from this
trend

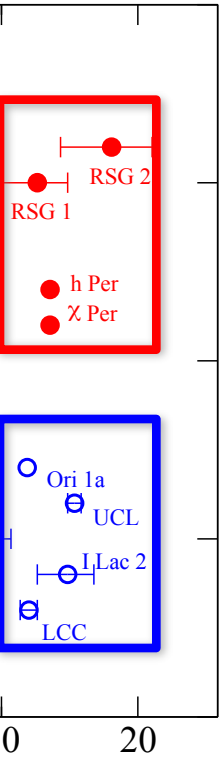
Star formation process different in clusters and associations

Cluster vs. associations

Modern idea

Clusters	Associations
Small size But strong development over first 10-20 Myr	extended
Initial Mass retained	Initially large, quick mass loss
Higher masses	Lower masses
Can exist for a long time	**Can only be detected, if remnant cluster massive**

Situation at 20 Myr



Clusters		Associations
1-2 pc		15-20 pc
	10 times more massive	
Cluster	10 000 times denser	than associations
	more massive stars	
	different stellar distributions	

Expectation, if cluster developed in isolation

Clusters		Associations	
1-2 pc	2-3 pc	15-20 pc	20 pc

10 times more massive

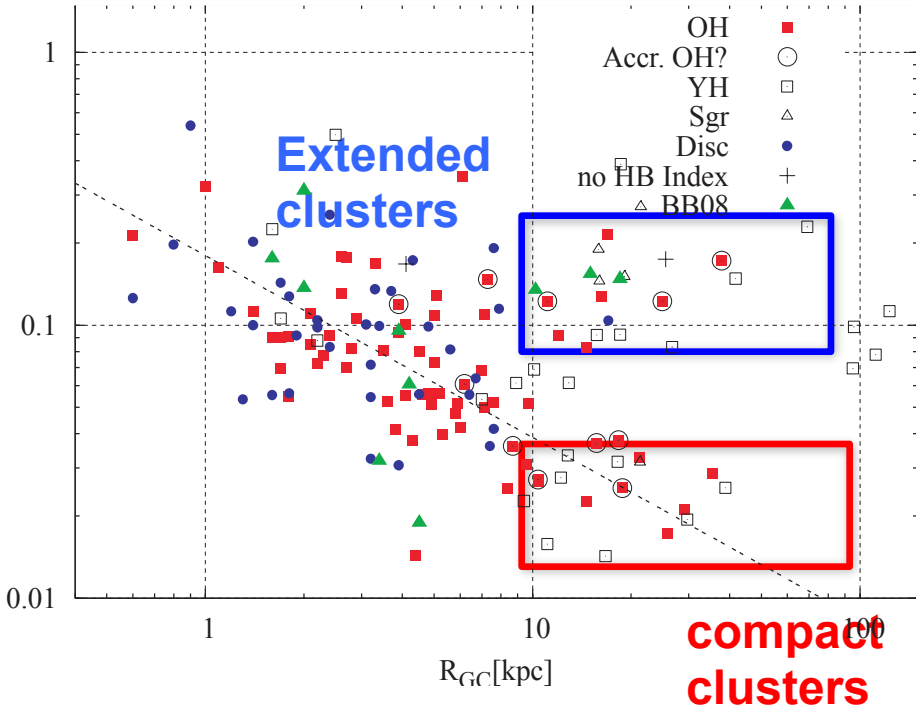
Cluster **10 000 times denser** than associations

more massive stars

different spatial distribution

Additional differences resulting from difference in stellar densities

Two groups of GC clusters



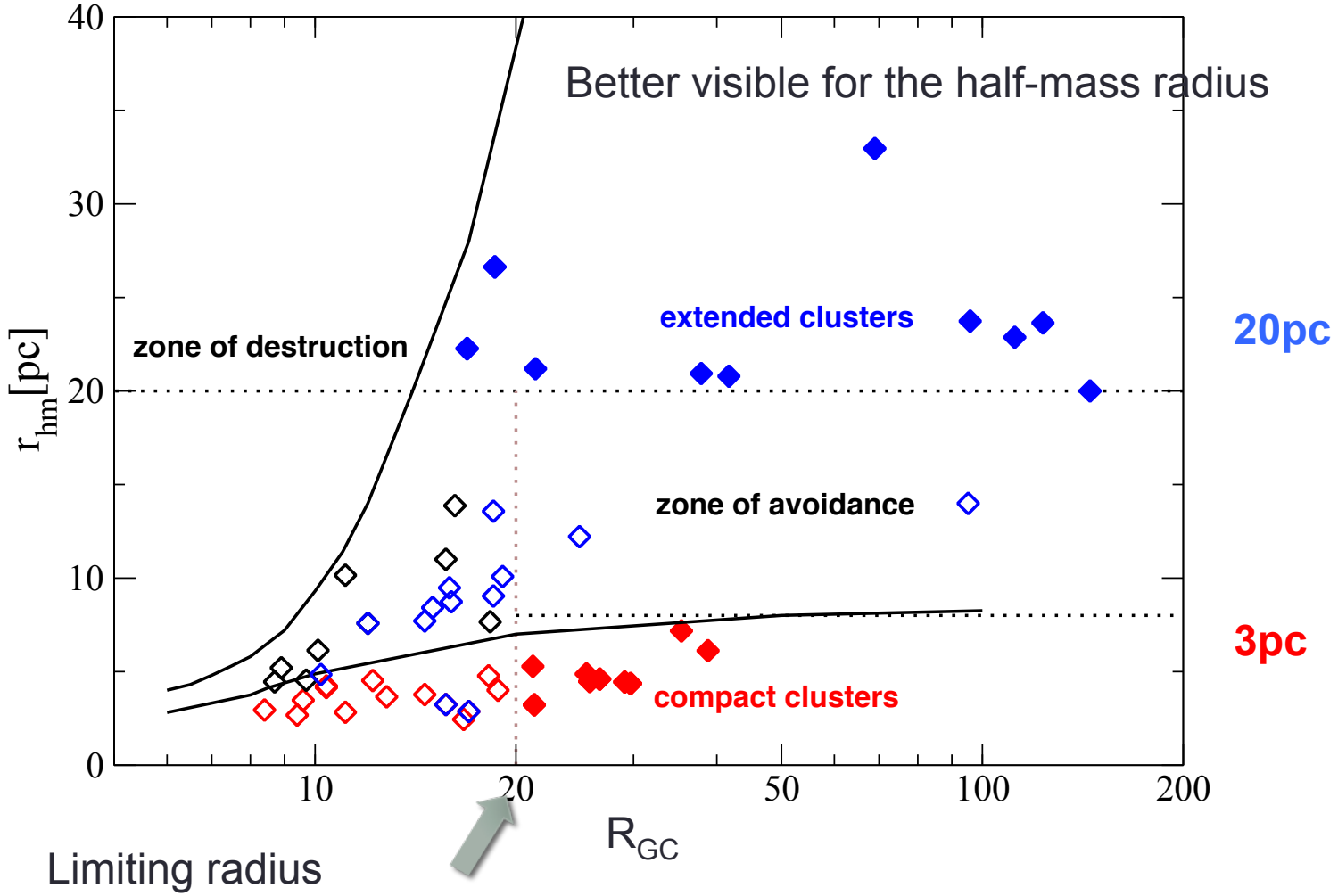
Baumgardt et al. 2010

Evidence for two populations of Galactic globular clusters from the ratio their half-mass to Jacobi radii

Standard theory:
Extended clusters were accreted

Problem:
It is difficult to extend once compact cluste that size

Globular clusters in MW



Limiting radius
20 kpc

Expectation, if cluster developed in isolation

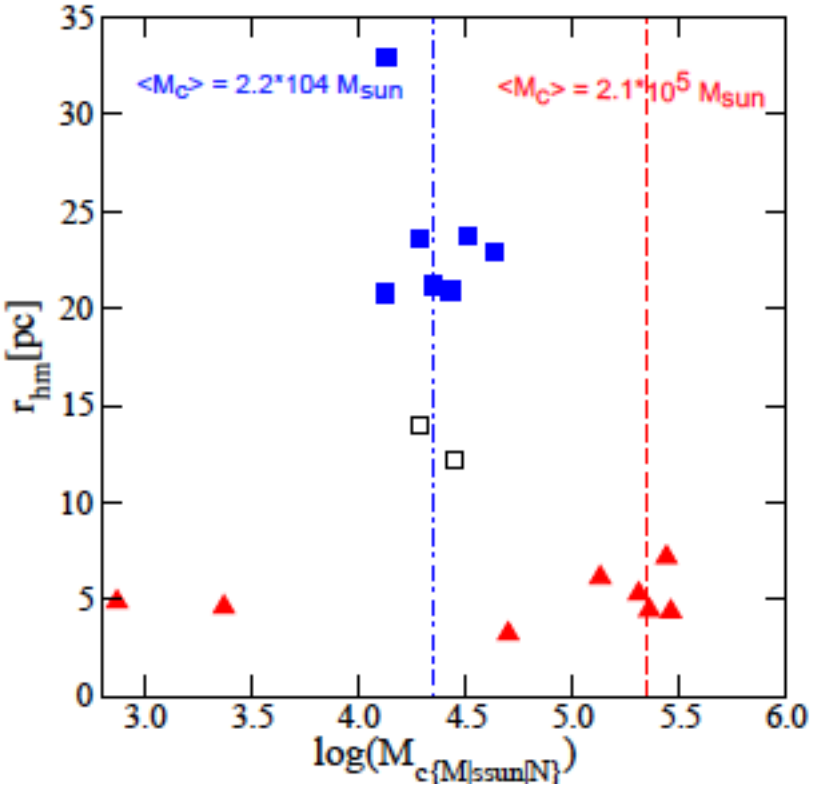
Clusters	**ok**	**Associations**	**ok**
1-2 pc	2-3 pc	15-20 pc	20 pc

10 times more massive

Cluster **10 000 times denser** than associations

more massive stars

Masses – extended vs. compact

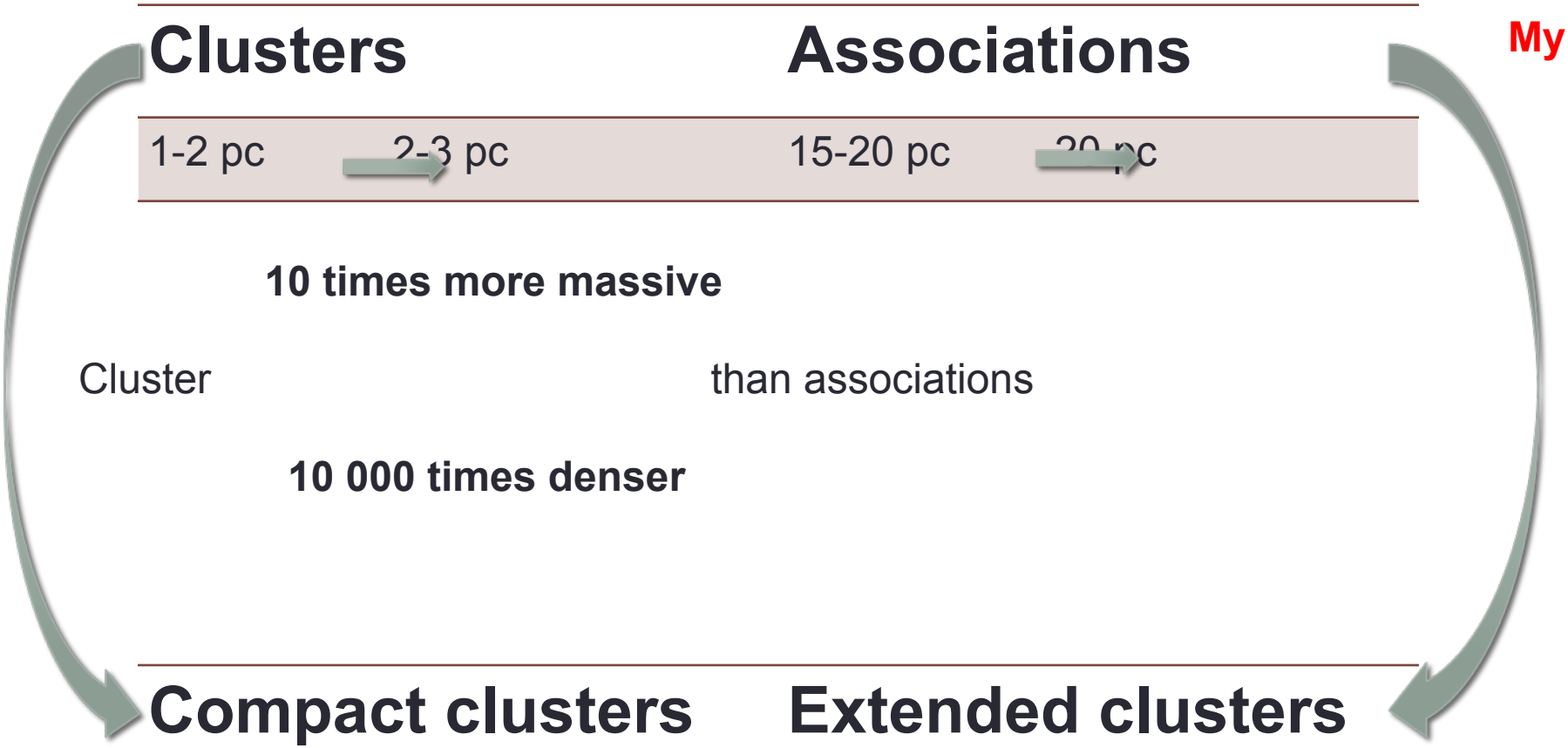


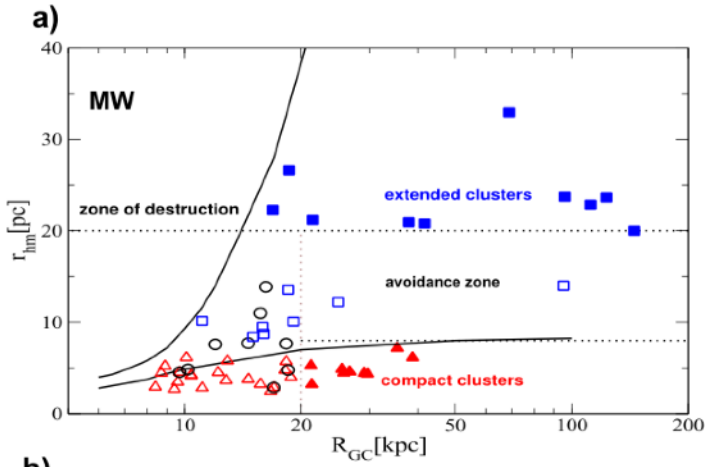
Compact clusters are 10 times more massive than extended clusters

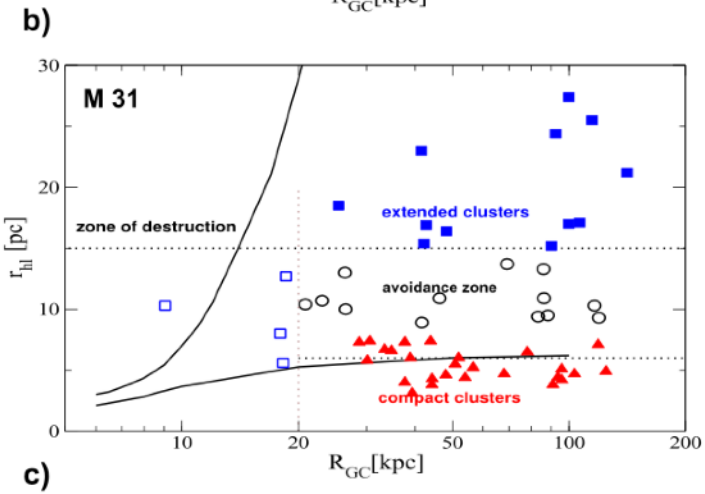
In addition, differe in:

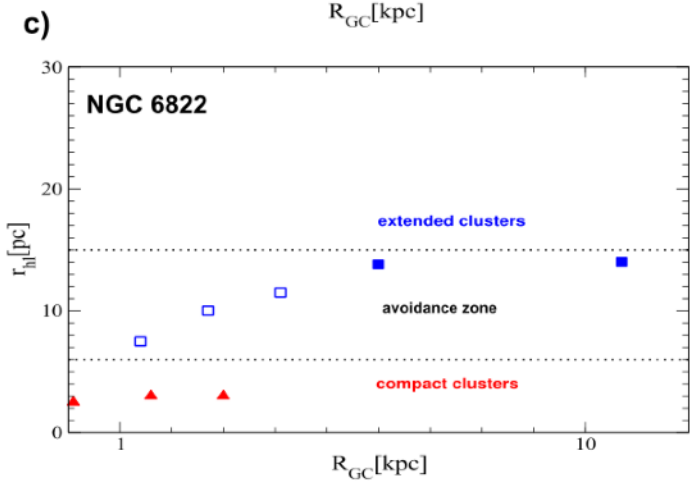
- **mass distribution**
- **blue straggler and pulsar**
- **properties**
- **metallicity**
  (Talk of Florent Renaud)

Cluster formation the same since 10 Gyr?









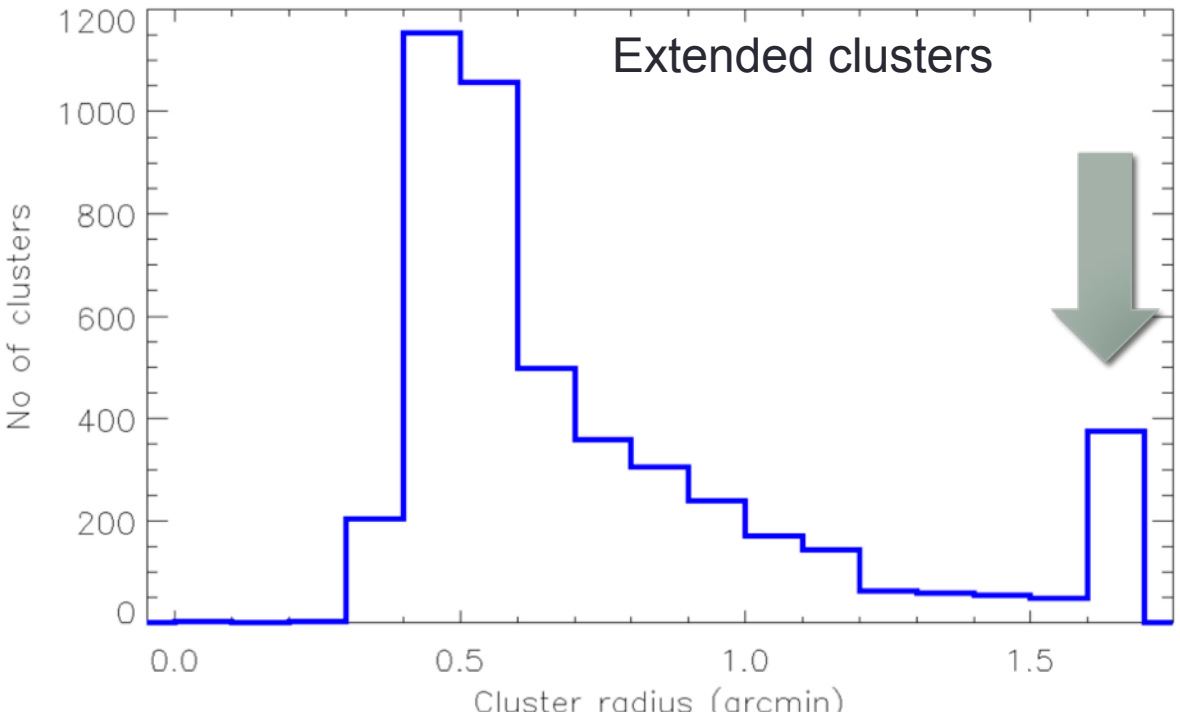
How about two types of clusters in other galaxies?

Spiral and dwarf galaxies
Compact and Extended clusters

Location of clear distinction depends on Galaxy mass

Elliptical galaxies
Only compact clusters

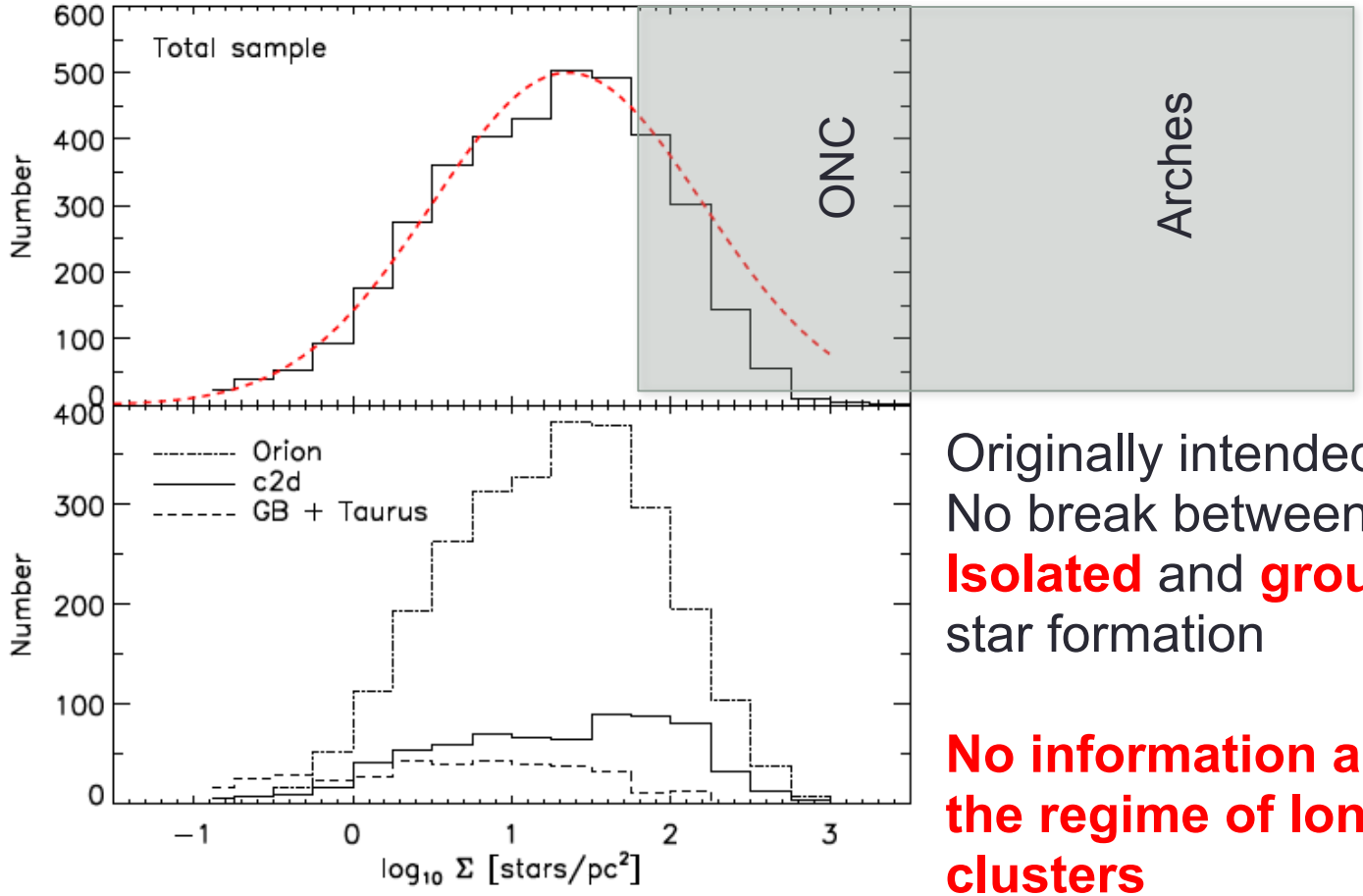
Same applies for LMC



20 pc

From
Theodore Bitsakis
talk

One or more modes of clustered star formation?

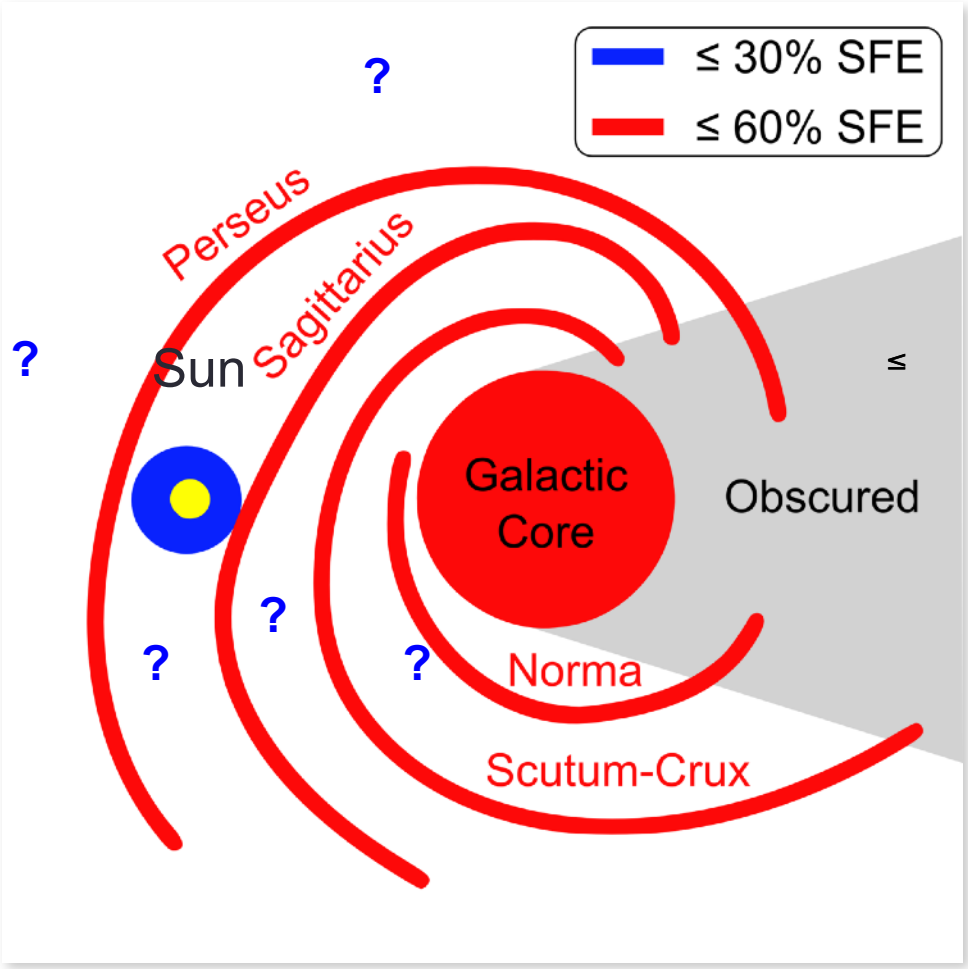


Bressert et al. 2010

Originally intended to show No break between **Isolated** and **grouped** star formation

No information about the regime of long-lived clusters

Why two types of clusters through the ages?



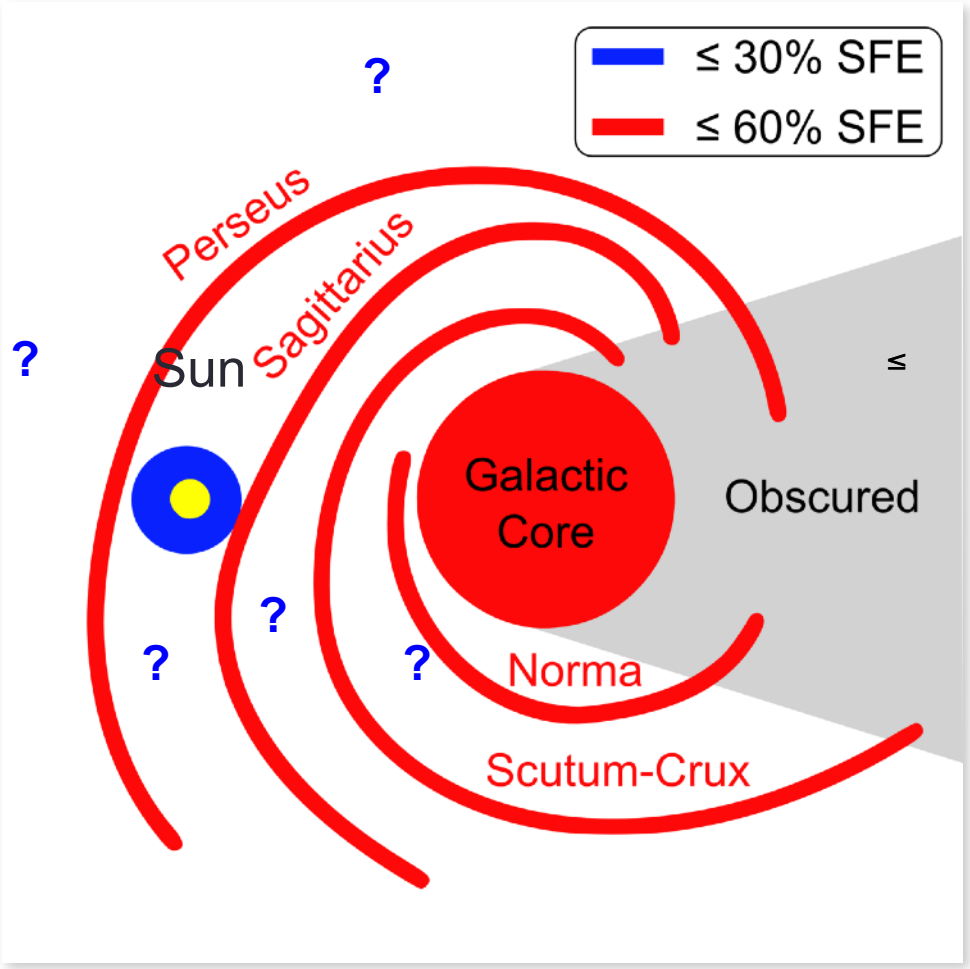
If two types of clusters exist over 10 Gyr, we need to understand why this happens!

Solar neighbourhood:
Extended cluster
up to 30% SFE

Close to Galactic center and in spiral arms
Comapct cluster
+ extended clusters?
up to 60% SFE

Areas of different SFE in the Milky Way?

Why two types of clusters through the ages?

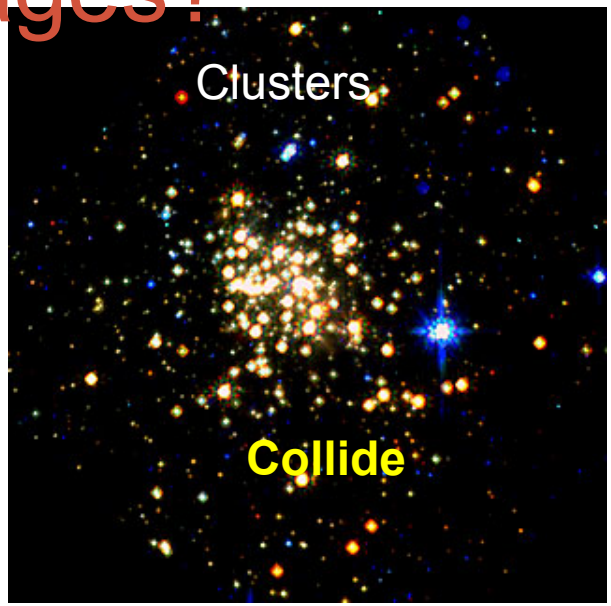


If two types of clusters exist over 10 Gyr, we need to understand why this happens!

A variety of processes could lead to two distinct modes of cluster formation.

Compact clusters only in areas of high density

Why two types of clusters through the ages?



Westerlund 2
NGC 3603
Arches
Quintuplett
30 Dor
(Zeidler et al. 2016, Fukui et al. 2014, Stolte et al. 2014)

show signs of formation by cloud-cloud collisions

57% of the entire known population

Would explain the location in spiral arms and Galactic centre

Consequences of two types of clusters

Independent of the meachnism, we have to

- Find explanation for the origin of two types of clusters
- Find explanation for more massive stars in compact clusters
- Different IMFs in both types clusters?
- If different mechanisms, than different types of simulations
- Determine relative abundance of both types

Advantage, easy explanation for

- Break in Kennicutt-Schmitt-Law
- Low SFE in Galactic Centre: Too high collision speed

Summary

- You find two types of „clusters“ in young and old populations
- The properties in mass, radius and other properties correspond to each other

young clusters  **compact clusters**

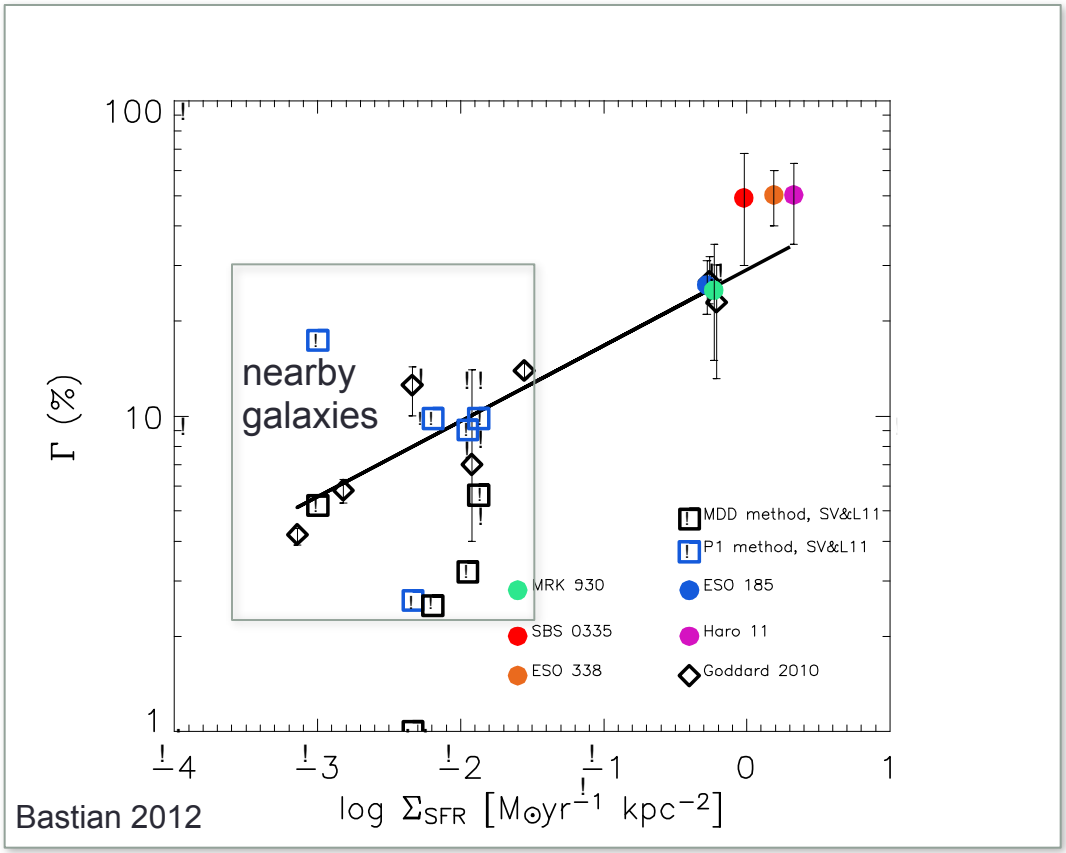
associations **extended clusters**

- young cluster formation requires high density
- Possible explanation:

collaps vs. collide formation scenario

Relative abundancies of cluster types

Percentage of stars born in long-lived clusters



Nearby galaxies:

Only ~ 10% of stars formed in long-lived clusters

90% in clusters that dissolve quickly

Extended clusters representative for early history of field star population