Violent Star Formation

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Summary

- VSF and Massive Young Clusters (MYC/YMC)
- HII galaxies. Self-gravity and the Fundamental Plane
- MYC. Mass Segregation. Equipartition
- The ages of HII galaxies

In the last few years we have witnessed a revolution in observational cosmology as a result of combining an old QSO discovery technique with Keck spectroscopy. Now we have spectra of thousands of emission line galaxies at redshifts similar to those that until only few years ago were exclusively populated by QSOs.

The spectral similarities between high z emission line galaxies and "local" starforming galaxies is amazing (although some differences are present). The fact that we can now obatain spectra of young stellar clusters up to very high redshifts has produced an enormous increase of interest in the subject of young stellar clusters and massive stars.

The hope is that by comparing nearby and high redshift examples of star-forming regions we will learn about galaxy formation and evolution at Cosmological scales.

Because we can observe them over this huge range of distances and look-back time, the study of the largest star-forming regions is of great interest.

Why? Because we are interested in EVOLUTION

The concept of Violent Star Formation includes a variety of systems that are believed to have formed large numbers of new stars in a very short time.

There is a wide variety of names related to regions of Violent Star Formation

OB associations
super-associations
HII regions
Giant HII regions
HII galaxias
Super star clusters
Young super star clusters
Massive Young Clusters
Young Masive Clusters
Massive star clusters
Extremely Massive star clusters
YoDeCs
Starbursts
VSF regions
Fuzzy clusters
(young globular clusters)
...
...

Clearly we do not believe that these are different systems or that they respond to different physics. More likely that they are different manifestations of the same phenomenum: cluster formation and evolution in a variety of environments and with a range of initial conditions (Mass, Rotation, velocity dispersion, size, IMF, chemical composition, internal gradients, etc). The names to me represent aspects of the same basic scenario: Cluster formation and evolution from massive molecular clouds.

From a molecular cloud characterized by its mass, size, chemical composition and through processes like fragmentation, coagulation, ... (role of turbulence?) leading to gravitational instability and collapse of the gaseous fragments,

a young cluster is born with initial conditions that are not arbitrary but linked to the parent cloud properties and the conditions for star formation.

The cluster evolves dynamically mainly affected by mass loss initially and binary action later. Many clusters will fully evaporates some will have a long and healthy life

I suggest that we can locate most VSF types in a 3-Dimensional diagram with axes

Mass, size, age

and that we will find large volumes in common between the different types.

The concept of OB associations as groups of tens of OB stars and that of super-associations indicating a more luminous and massive system whose prototype is 30-Doradus were developed by Ambartzumian and co-workers from the late 30s to the 70s.

One of the first comprehensive list of super-associations in external galaxies was compiled by Markarian an co-workers using the 1m Byurakan Schmidt and a methodology developed in Mexico by Haro and co-workers at the Tonantzintla observatory Schmidt telescope equiped with an low dispersion objective prism.

Using similar techniques, during the 80s other surveys followed, i.e. Tololo and University of Michigan plus several imaging surveys of starforming systems in external galaxies. Their spectral characteristics being identical to those of superassociations.

Perhaps the youngest and more massive VSF systems are the HII Galaxies.

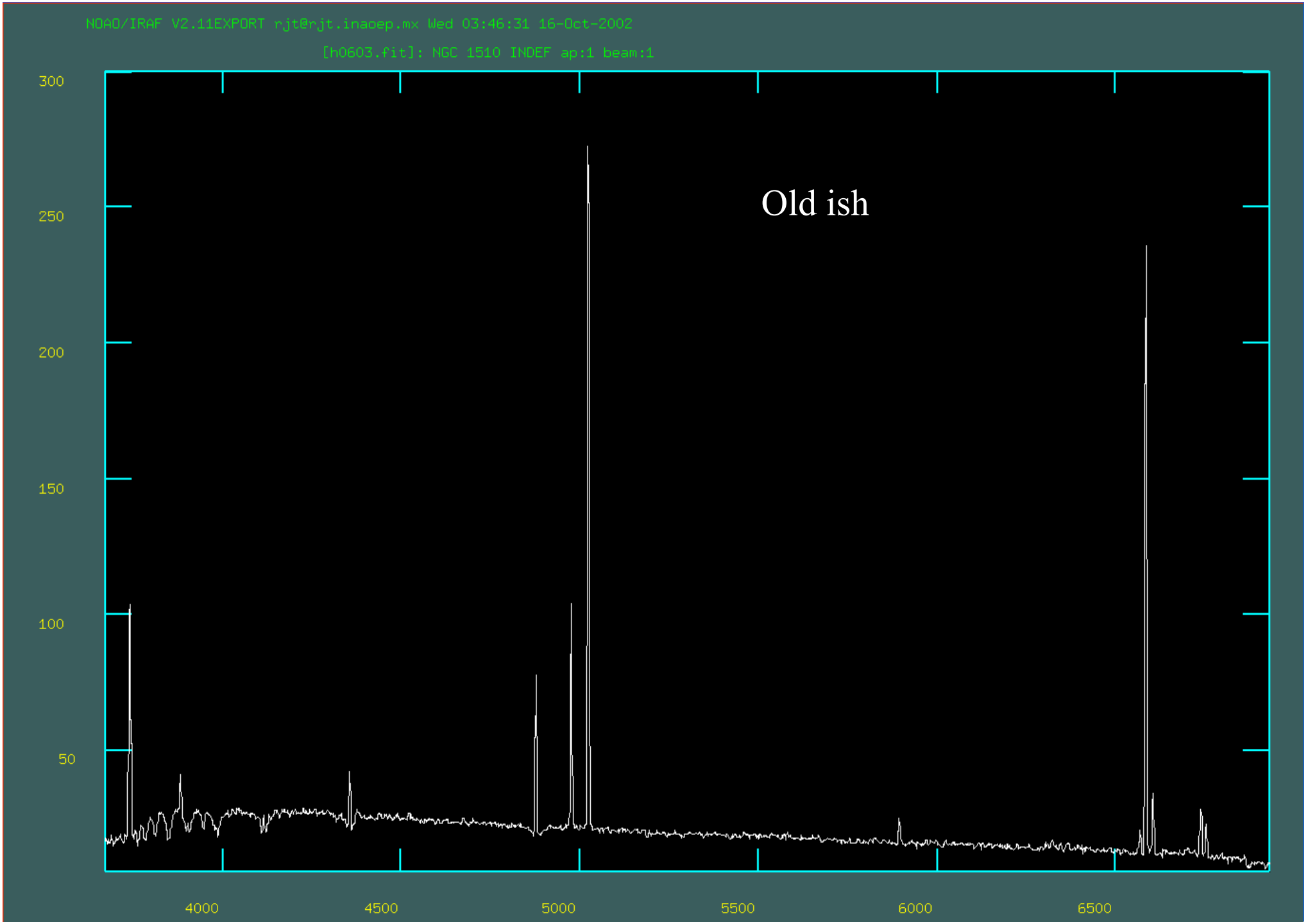
HII Galaxies are selected because their optical spectrum resembles that of Superassociations like 30-Doradus in the LMC or NGC 604 in M33.

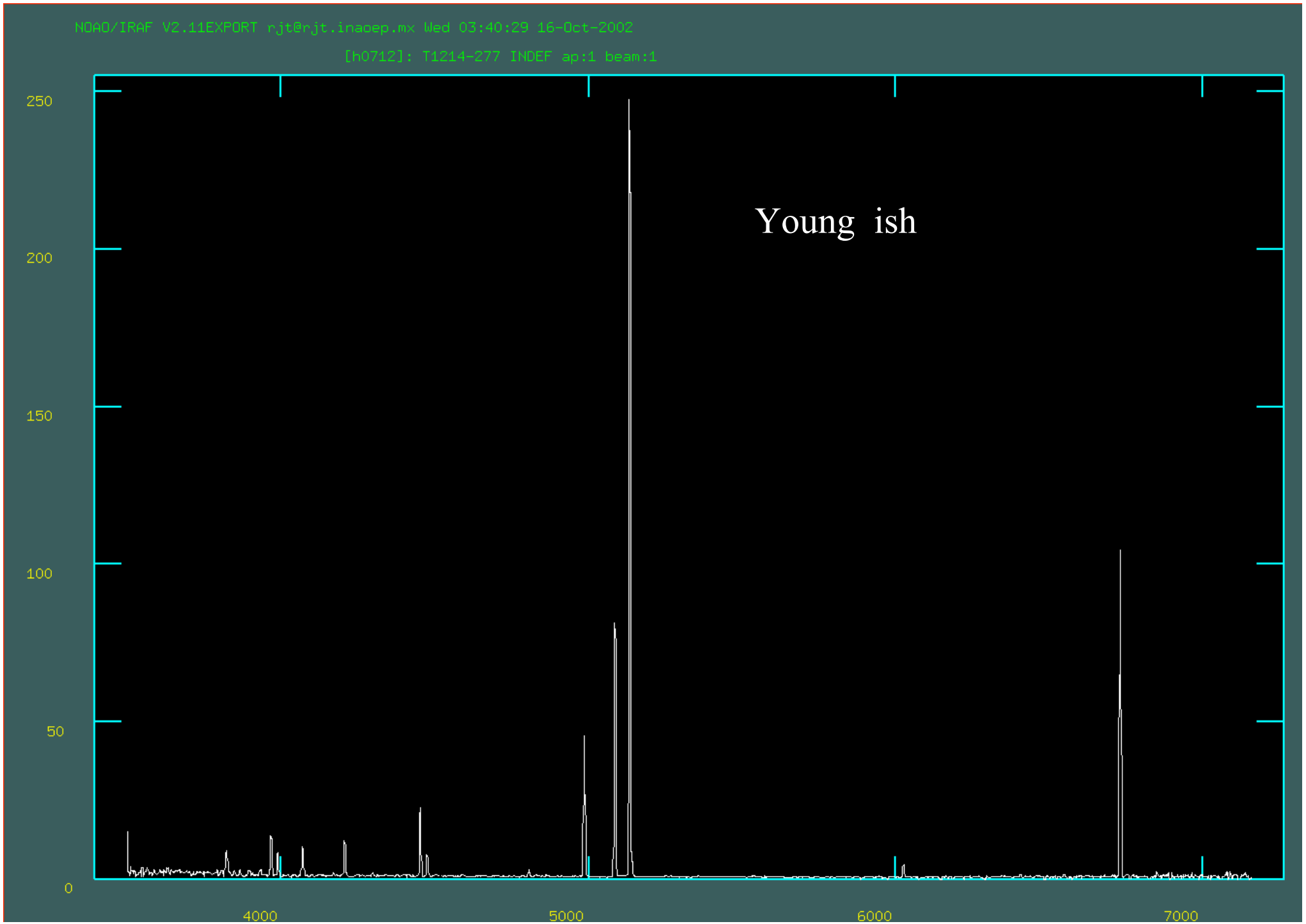
HII galaxies tend to be luminous and compact bursts of star formation in low surface brightness dwarf irregular galaxies.

The stellar make-up indicates a very young stellar population.

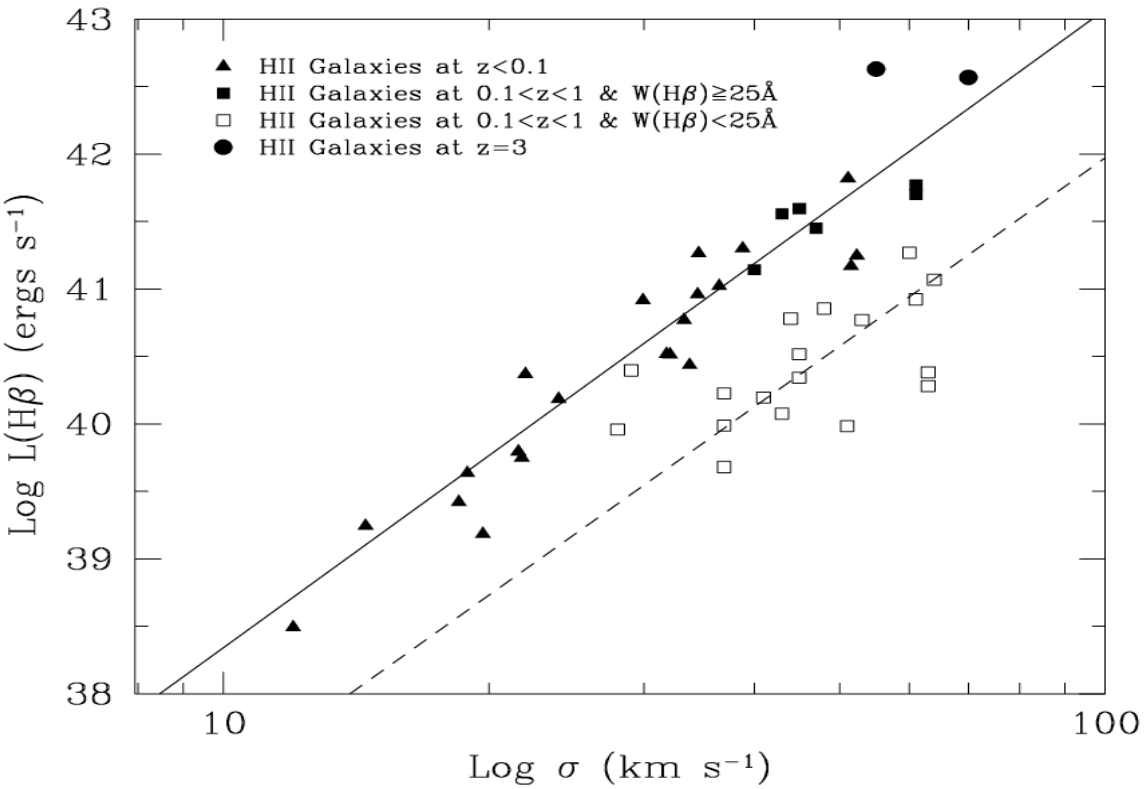
Their strong emission lines makes them ideal for studies of chemical abundances and chemical evolution.

Basically, HII galaxies are among the youngest stellar systems that can be studied in any detail.


NOAO/IRAF V2.11EXPORT rjt@rjt.inaoep.mx Wed 03:46:31 16-Oct-2002
[h0603.fit]: NGC 1510 INDEF ap:1 beam:1
300
250
200
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4000
4500
5000
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6000
6500
Old ish


NOAO/IRAF V2.11EXPORT rjt@rjt.inaoep.mx Wed 03:40:29 16-Oct-2002
[h0712]: T1214-277 INDEF ap:1 beam:1
250
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Young ish

Are HII Galaxies gravitationally bound?



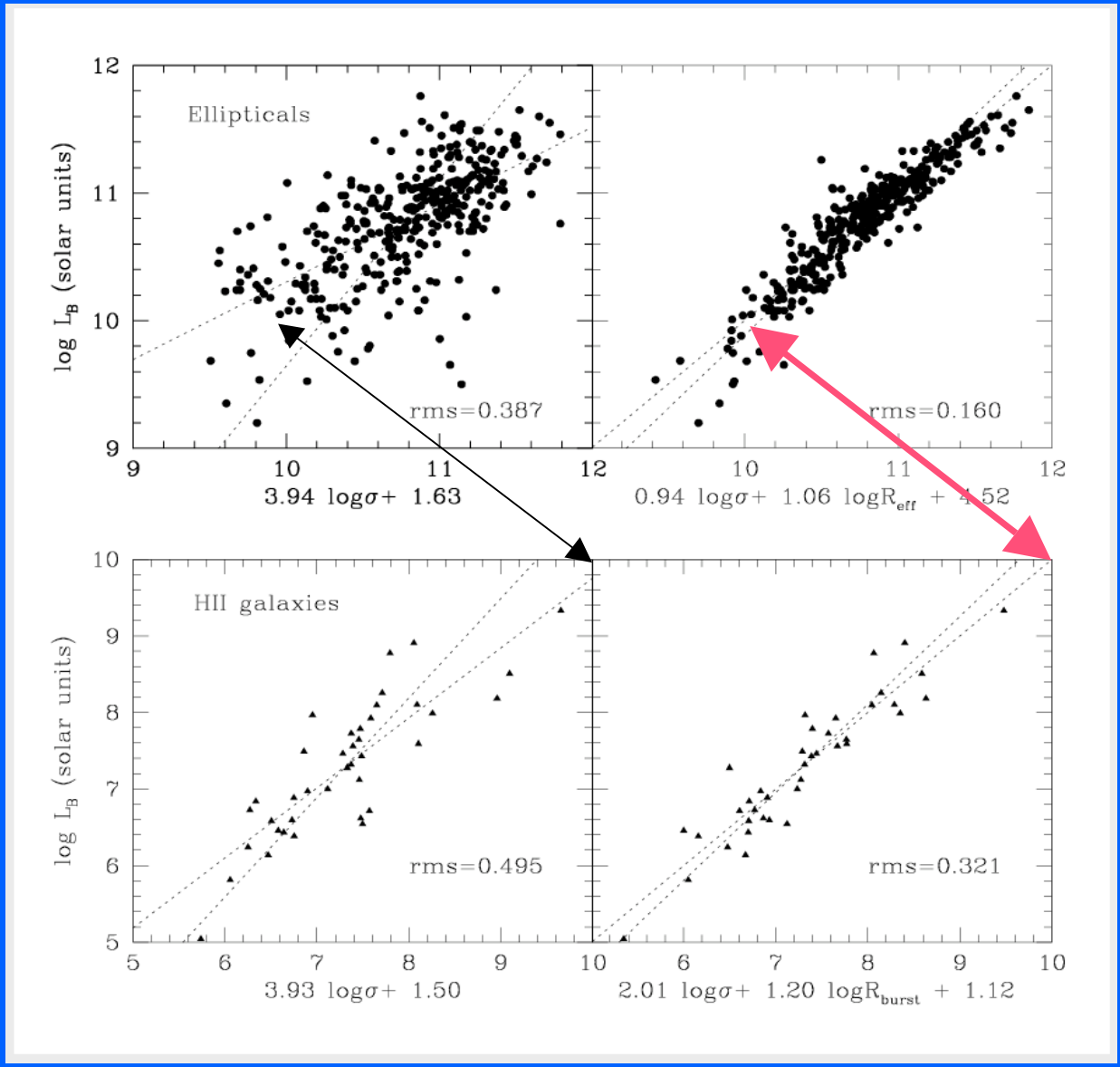
If HII Galaxies are bound then a Fundamental Plane for MC has to exist for those systems were the M/L is the same, i.e. The youngest clusters when all stars are still in the main sequence.

Melnick, Terlevich and Terlevich 2002

The youngest clusters when all stars are still in the main sequence are the HII galaxies.

There is a FP for nearby HII galaxies.

Moreover after evolving for a Hubble time they occupy the same FP as Ellipticals and bulges but shifted toward luminosities typical of GC and dwarf spheroidals.



Telles 1998

Studies of the IMF, mass and chemical composition of YMC are central to our understanding of some of the fundamental problems in star and cluster formation.

The IMF and the mass segregation in YMC .

Mass segregation has been detected in 30~Dor and other very young clusters,

Massive stars preferentially populate the core of the young cluster while low mass stars have a more extended radial distribution.

Therefore, the half light radius is smaller than the half mass radius.

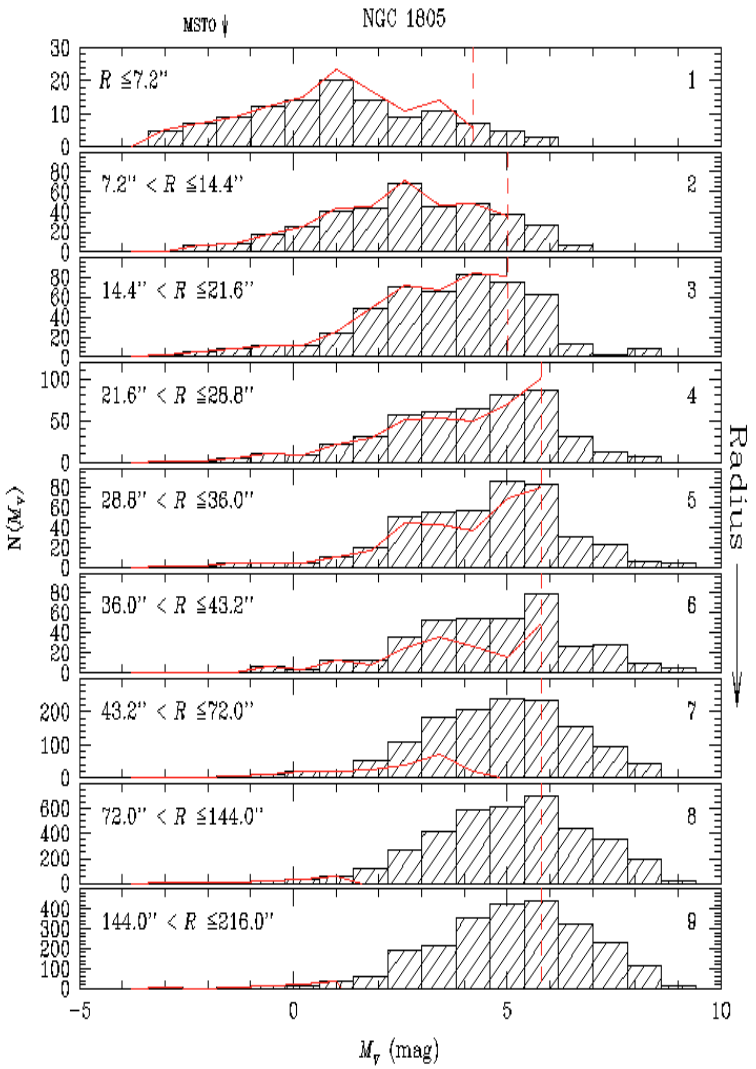


Figure 4. Observational total LFs from our WFPC2 data in annuli at increasingly large radii from the NGC 1805 cluster centre (histograms). The thick solid lines are the actual cluster star distributions, after correction for the background field star contribution and the effects of incompleteness; the 50 per cent completeness limits are indicated by the vertical dashed lines. The numbers on the right-hand side in each panel refer to the corresponding annular LFs in Fig. 6. The main-sequence turn-off magnitudes ('MSTO') are indicated by the arrows.

de Grijs et al 2002

Mass segregation is also detected in NGC 1818 in the LMC

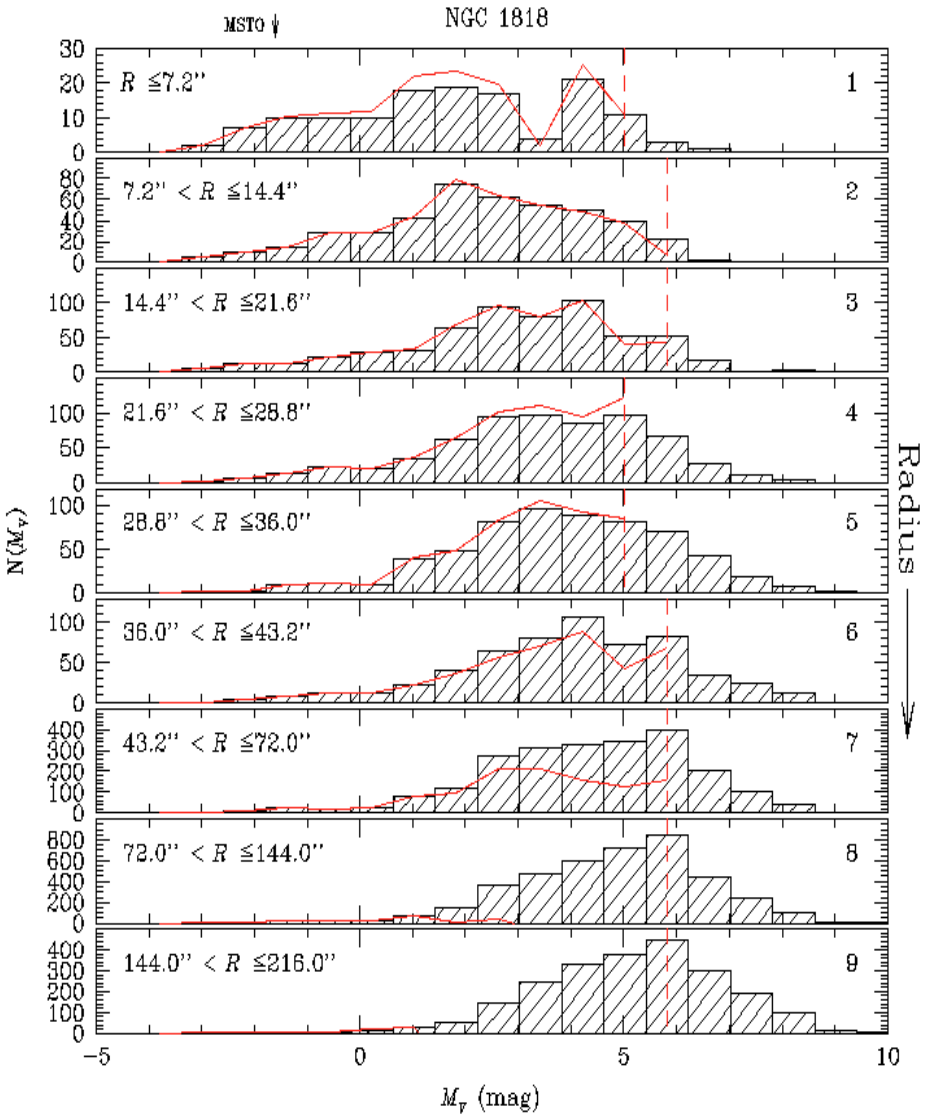


Figure 5. Same as in Fig. 4, but for NGC 1818.

de Grijs et al 2002

Mass segregation was also detected in 30-Doradus from NIR imaging.

(Brandl etal 1996)

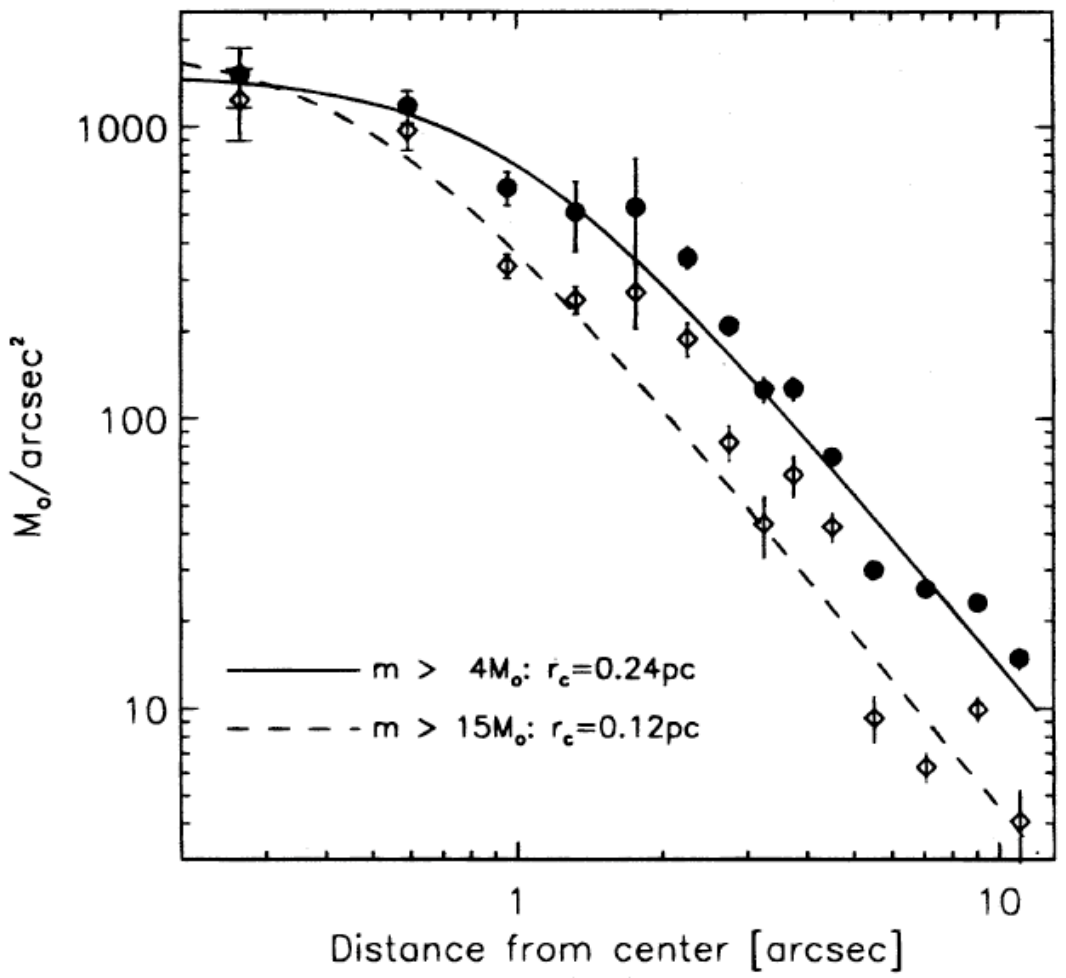
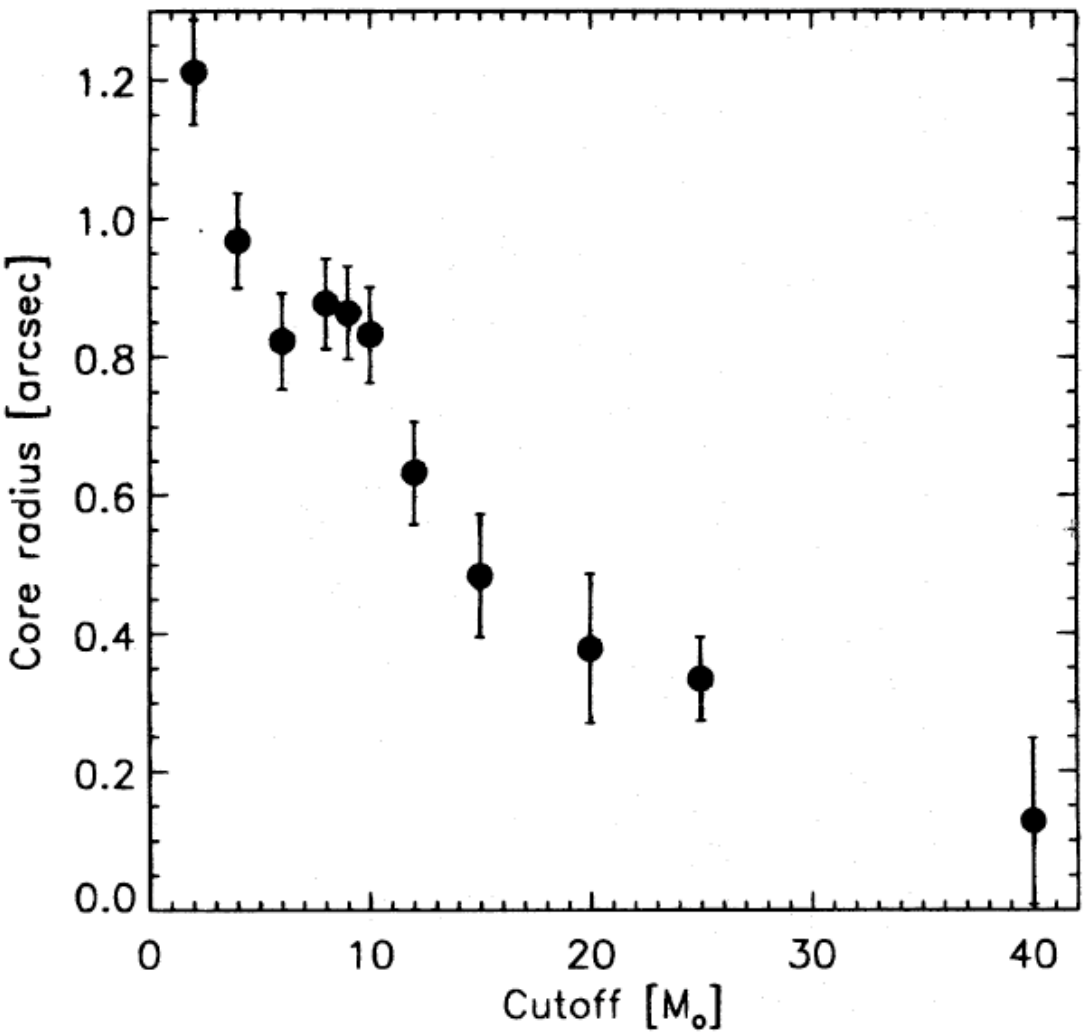


FIG. 15.—Fit to the mass density distribution of stars with $m > 4\,M_\odot$, which is the mass range that we covered by the completeness correction (*solid line*). Fitting a standard King profile yields $r_c = 0''.97 \pm 0''.07$ (0.24 pc). If we restrict the fit to stars with $m > 15\,M_\odot$, the number of stars drops significantly, but the core radius also shrinks to $r_c = 0''.48 \pm 0''.09$ (0.12 pc) (*dashed line*). Going to even higher cutoff values, a pure power-law fit yields approximately the same χ^2 as the King fit. The first data point was not included in the fit.

(Brandl etal 1996)

A different way of showing the mass segregation in the central regions of 30-Doradus



But the evidence for mass segregation is not restricted to the central regions

But mass segregation affects the whole of 30-Doradus

Also dynamical segregation

Table 2. Mass segregation.

Mass range	Mean mass	Velocity dispersion
$>23.5\ M_\odot$	$49.6\ M_\odot$	$27.8\ \mathrm{km\ s^{-1}}$
$<23.5\ M_\odot$	$19.4\ M_\odot$	$36.7\ \mathrm{km\ s^{-1}}$

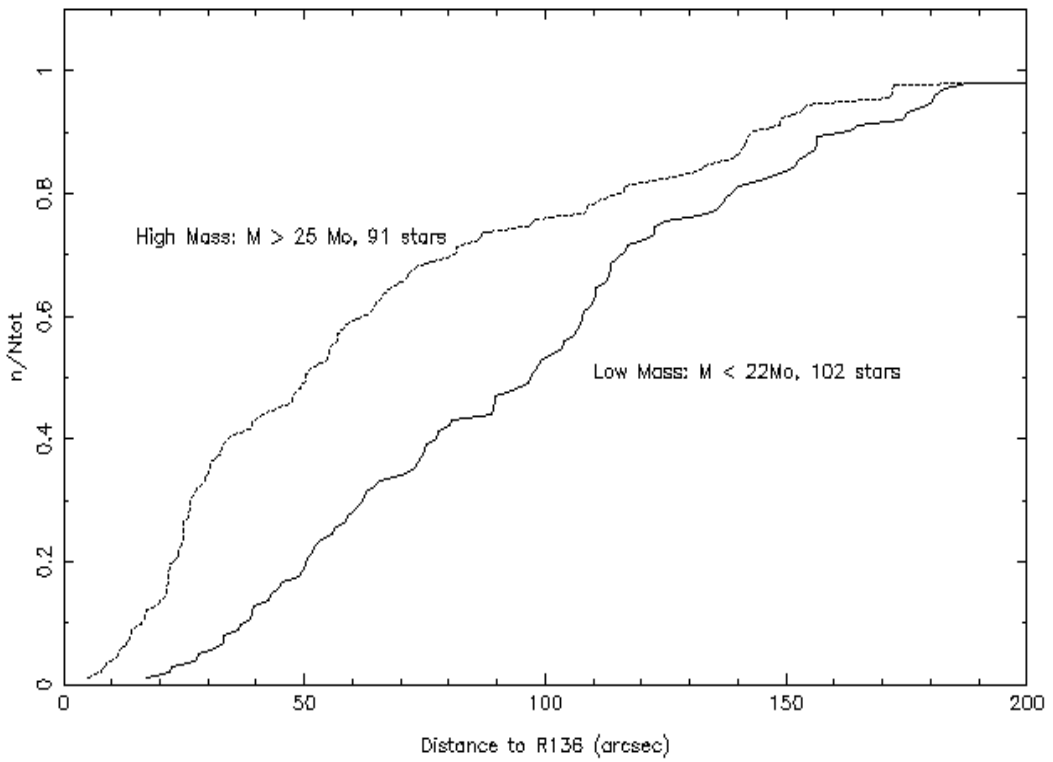


Fig. 27. Cumulative radial distribution of stars according to masses determined from their spectral types. Both distributions are plotted with dashed and continuous line styles, for the high-mass and low-mass stars respectively. The different distribution for both subsets indicates the presence of mass segregation

30-Dor seems close to Equipartition

In 30-Dor the dynamical relaxation time is much longer than the age of the stars(2Myr).

This suggest that much of the relaxation is related to the star formation process itself

(Bosch, Melnick, Selman, Terlevich)

And for 30-Doradus the IMF is Salpeter

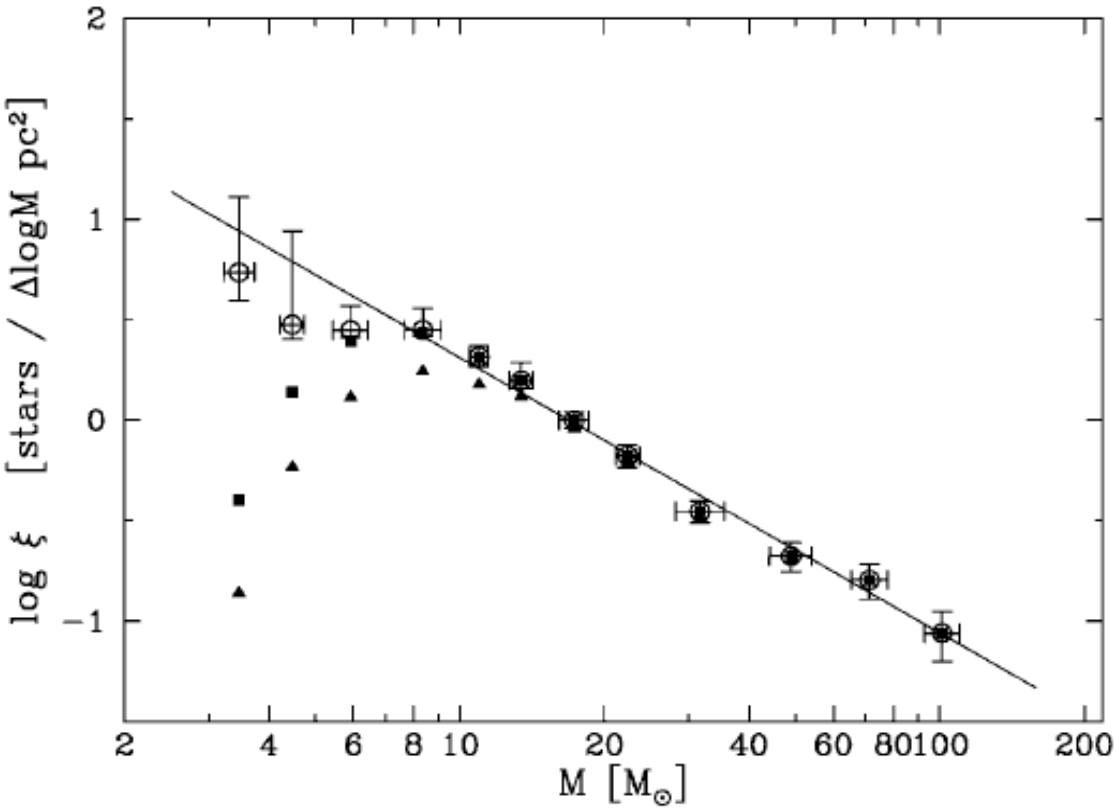


Fig. 10. The IMF of 30 Doradus for the sample of stars with $r > 15''$, calculated assuming equally likely isochrones below 3My. The line is a least squares fit to the data which gives $dN \propto M^{-2.37\pm0.08}dM$. The error bars consider counting statistics together with the errors in the incompleteness and magnitude-limit corrections.

Selman etal 1999

Because the dynamical relaxation time in YMC (i.e. 30-Doradus, NGC1805, NGC1818) is much longer than the age of its stellar population, the observed mass segregation raises some important points :

-- The mass and dynamical segregation in YMC can be understood if it occurrs previously to the star formation itself, i.e. at a time when the system was mainly gaseous and binary interactions between gasous fragments were frequent. After the fragments in the parent cloud collapsed to form stars, the system becomes less dissipative and the kinematics is basically frozen. This argument suggests the possibility that the structure and kinematics we see today in very YMC may be closely related to the structure and kinematics of the last stages of fragmentation and star formation in the parent cloud. Clearly more detailed observations in resolved systems are needed.

-- Given that it is very difficult to determine the size or to measure the velocity dispersion of the low mass stars that make the bulk of the mass,in a segregated cluster presently we have no method to determine accurately the dynamical mass of a segregated cluster .

-- Mass segregation could be indirectly responsible for the claims (Rieke and Lebofsky 1981) of low M/L or top-heavy IMFs in Starbursts? (size underestimation)

-- Radial age gradients in YMC could also be the consequence of mass segregation

Do YMC evolve into young GC?

It has been argued that because YMC have masses and sizes similar to GC, YMC are the progenitors of GC.

A caviat is that in the presence of mass/dynamical segregation in YMC, dynamical evolution should be taken into account when comparing the mass and light distribution of an old stellar cluster with the mass/light distribution of a very young one:

Leaving aside the accion of massive binaries scattering low mass stars to large radii, the large mass loss in the form of stellar winds and SN ejecta from the central region of the cluster will strongly affect its dynamical evolution in less than a Hubble time.

A cluster with a Salpeter IMF loses about 25 percent of its initial mass during its first 100 Myr of evolution.

Slow mass loss will produce an adiabatic ***expansion*** proportional to the mass loss (Richstone and Potter ,1982), while abrupt mass loss of a small fraction of the cluster mass is twice as effective as the same amount of slow mass loss in puffing up the cluster (Biermann and Shapiro 1979).

The combination of initial mass segregation and dynamical evolution can produce (after few Gigayears) a mass distribution that has an effective radius several times larger than the initial light distribution.

And for 30-Doradus the IMF is Salpeter

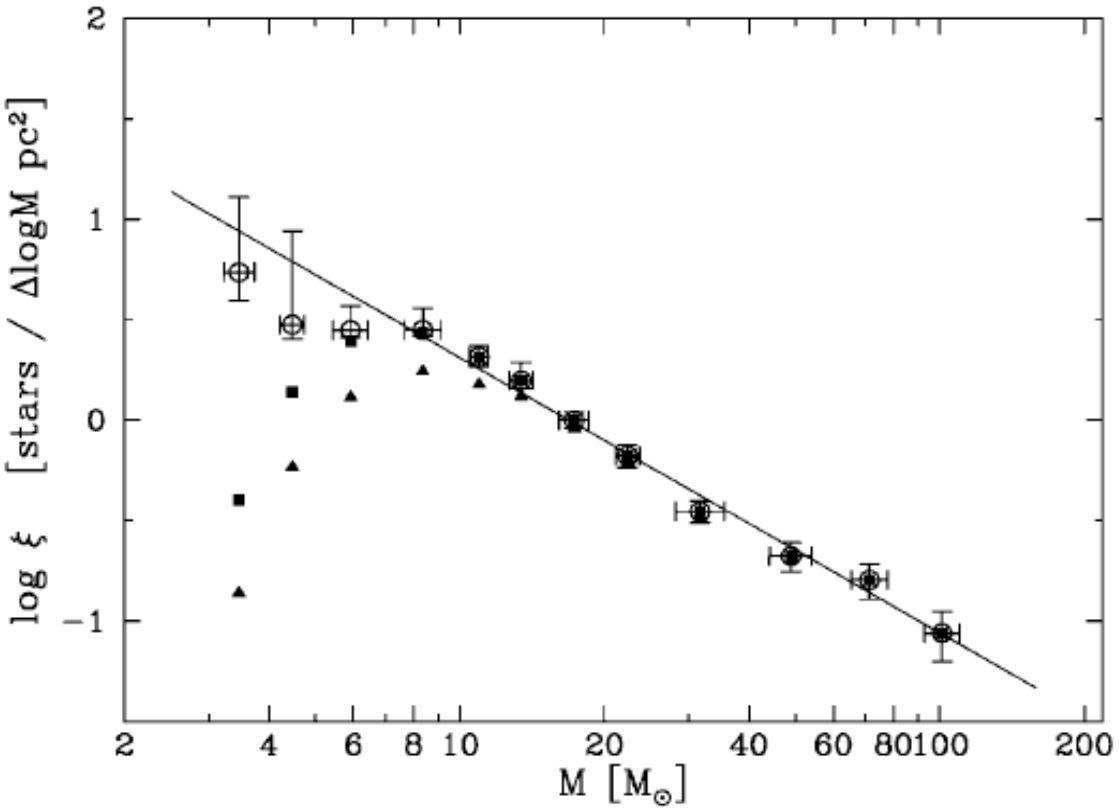


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Selman etal 1999

HII galaxies or very YMC are probably gravitationally bound and have a FP that after evolution coincides with the FP of old spheroidal galaxies.

YMC are relaxed!!! Large ammount of dissipation and relaxation seems to be associated with the processes of fragmentation and star formation in YMC. Young clusters in the LMC show strong mass segregation and indications of equipartition of energy. *Young clusters are probably born with initial conditions that are not arbitrary but linked to the parent cloud properties and the conditions for star formation.*

Systems like 30-Doradus will probably evolve into clusters that are not as dense as galactic GC

The detailed study of the light and mass distribution plus the kinematical mapping of the nearest YMC (NGC3603, 30-Dor, NGC 604 and 594 in M33, Hubble V and X in NGC 6822) will provide important clues to the structure of these systems during the active star-formation stage.

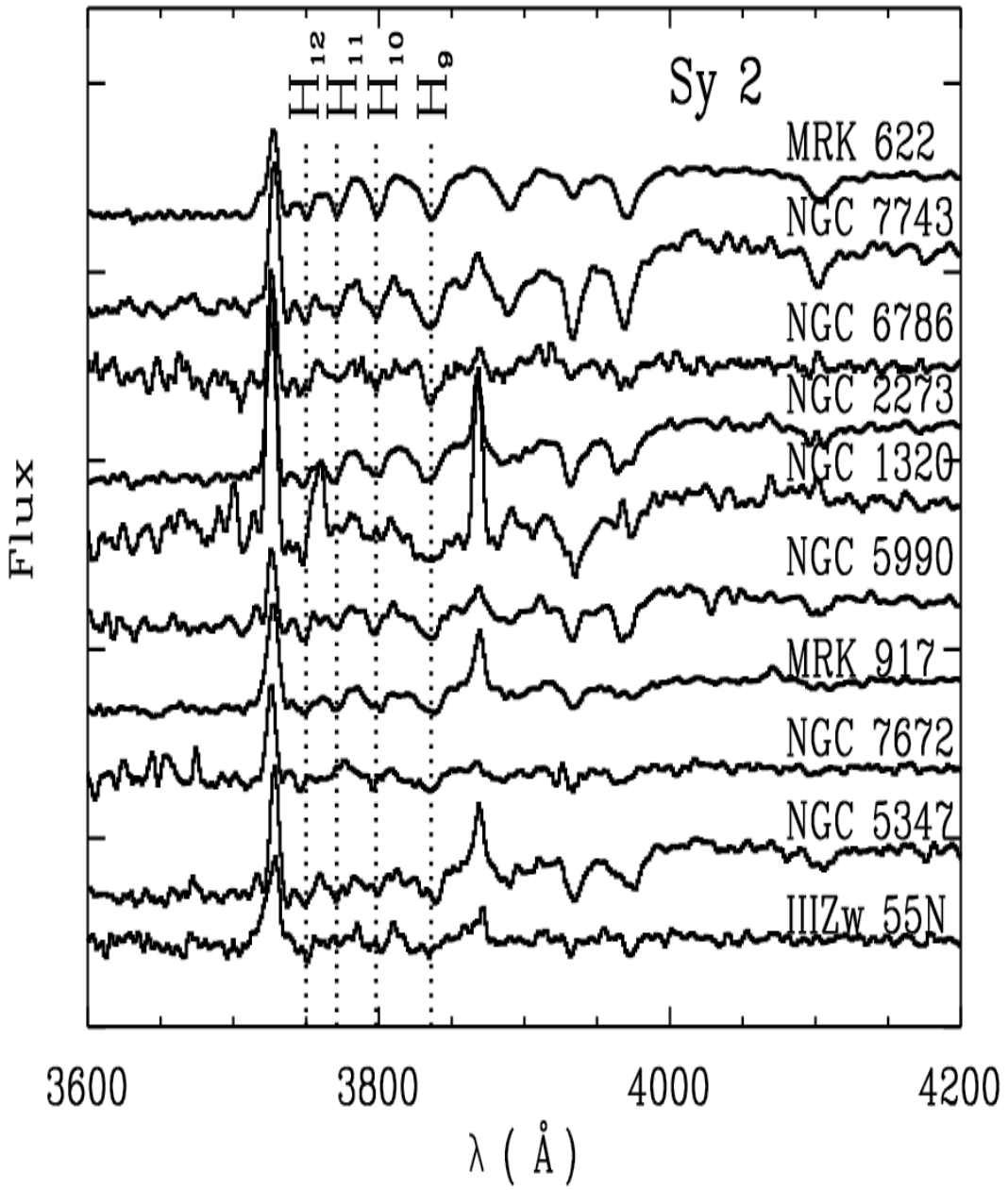
Another recent advance regarding VSF involves perhaps the most massive and luminous young stellar clusyters in the Near Universe.

Nuclear SB are present in many radio quiet and radio loud AGN.

At least,

1/3 of nearby luminous FRII radio galaxies,
1/2 of nearby type 2 Seyferts, and
1/5 of nearby type 1 Seyferts

have a nuclear powerful SB producing as much or larger luminosity than the AGN itself.



YMC in Type 1 Seyferts

These nuclear YMC in Seyferts are very luminous, with luminosities up to 10^11 Solar Luminosities

Their study is bound to bring new information and insights into bulge Formation and evolution and the relation between VSF and AGN activity.

