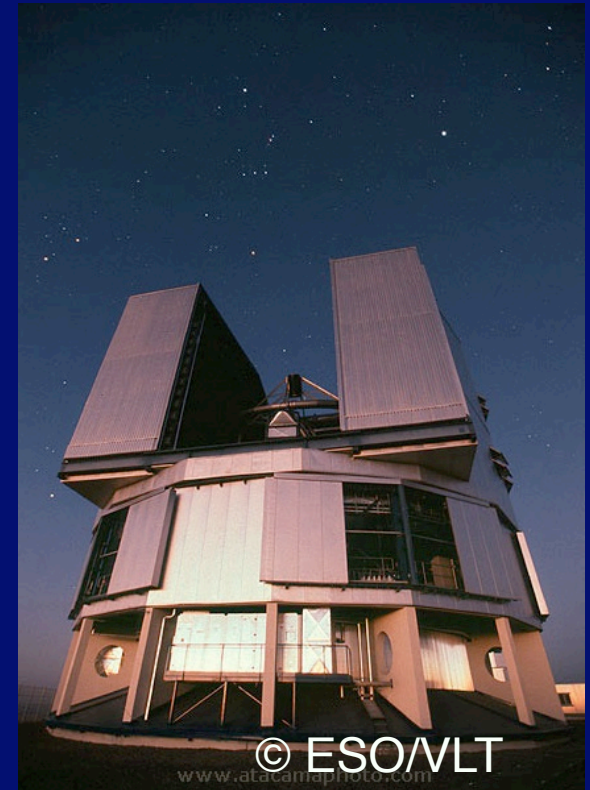


Starburst clusters with E-ELT - the harvest beyond the Milky Way



Andrea Stolte

*I. Physikalisches Institut
Universität zu Köln*



E-ELT Science

May 2009

ESO Garching

Starburst clusters with E-ELT - the harvest beyond the Milky Way

1. Starburst clusters in the Milky Way

2. Starburst cluster science cases

Part I: the extragalactic science case

(Part 2: Milky Way - tomorrow)

3. Outlook for EELT instruments

1. Starburst clusters in the Milky Way

Why do we care ?

The Milky Way Starburst Cluster Zoo

Galactic center

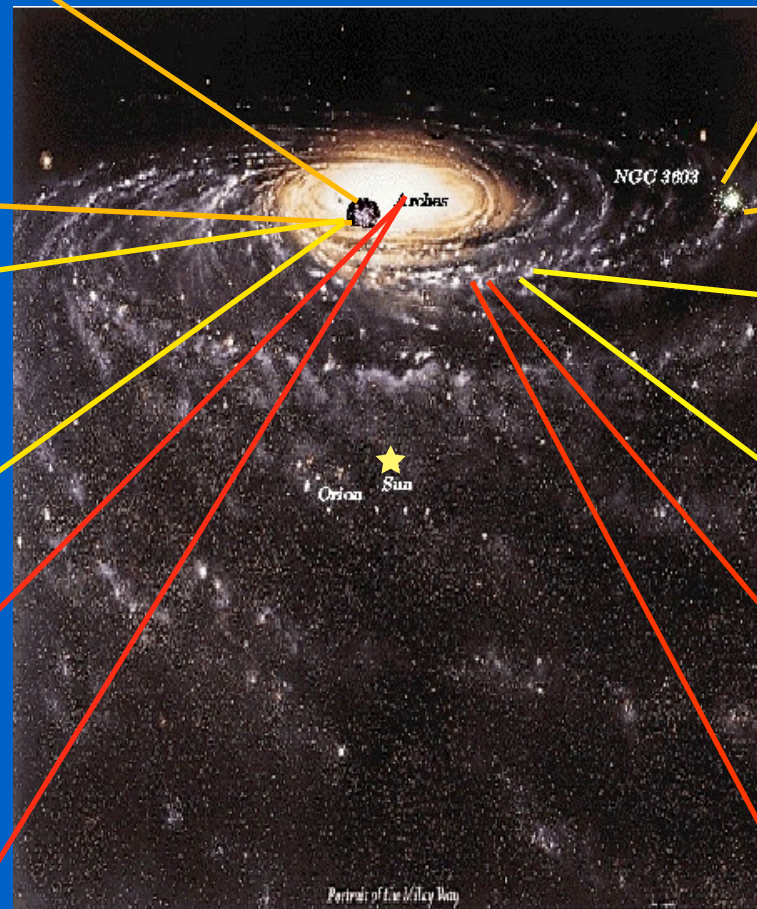


GC Arches
Stolte et al. 2005

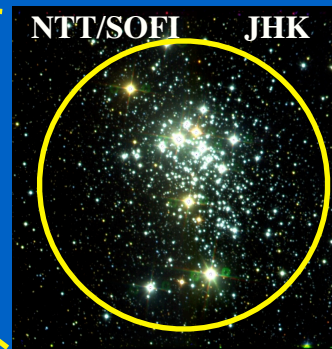
Spiral arms



NGC 3603 YC
Stolte et al. 2004



Portrait of the Milky Way Jon Lomberg



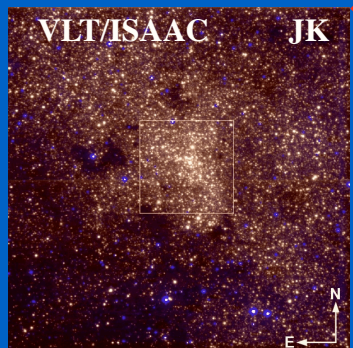
Westerlund 1
Brandner et al. 2008



Westerlund 2
Ascenso et al. 2007



GC Quintuplet
Stolte et al., in prep



Nuclear cluster
Schoedel et al. 2007

1. Starburst clusters in the Milky Way

The birth place of high-mass stars

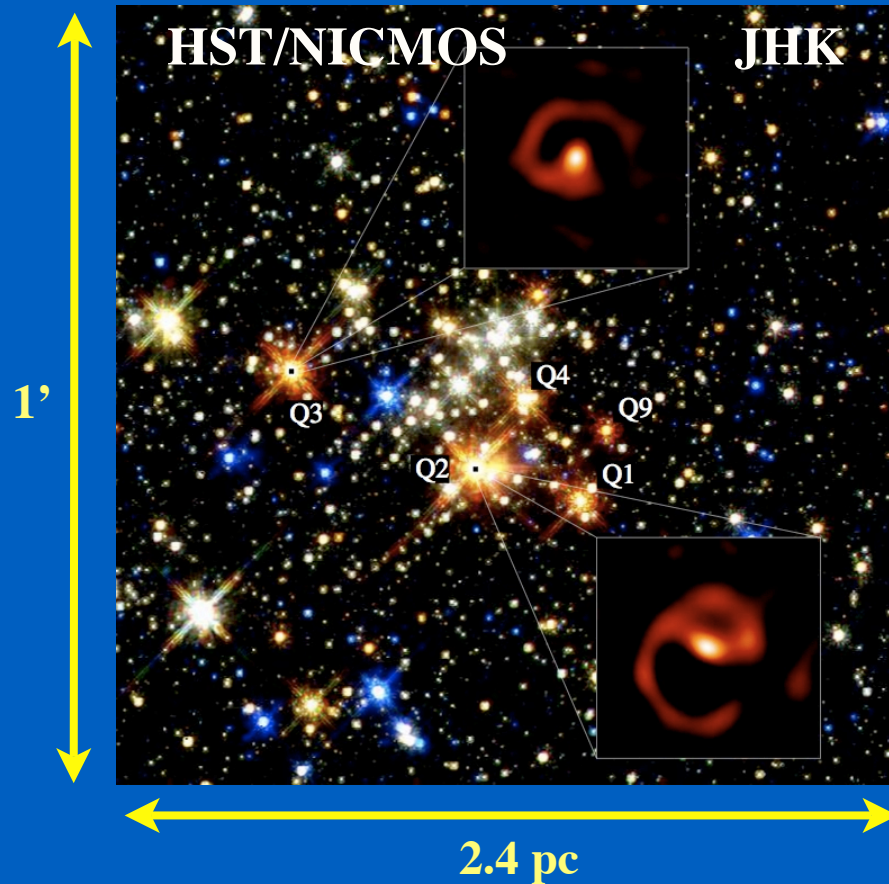
 Massive stars $M > 40 M_{\text{sun}}$ exclusively form in starbursts

 Starburst clusters sample the high-mass IMF

$\Rightarrow$ *Stellar evolution, wind & SN feedback, Wolf-Rayet stars*

$\Rightarrow$ *chemical enrichment (e.g. centers of galaxies)*

Quintuplet - a unique laboratory for high-mass stellar evolution



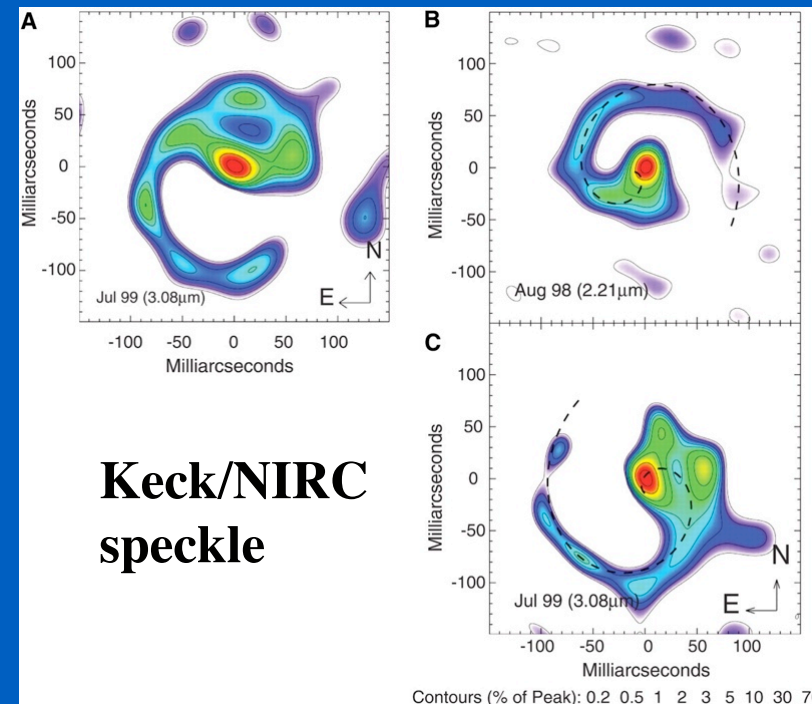
Tuthill et al. 2006

The cocoon stars:

- featureless MIR spectra
not YSO, not late-type AGB/WC

Moneti et al. 2001

- interacting wind binaries

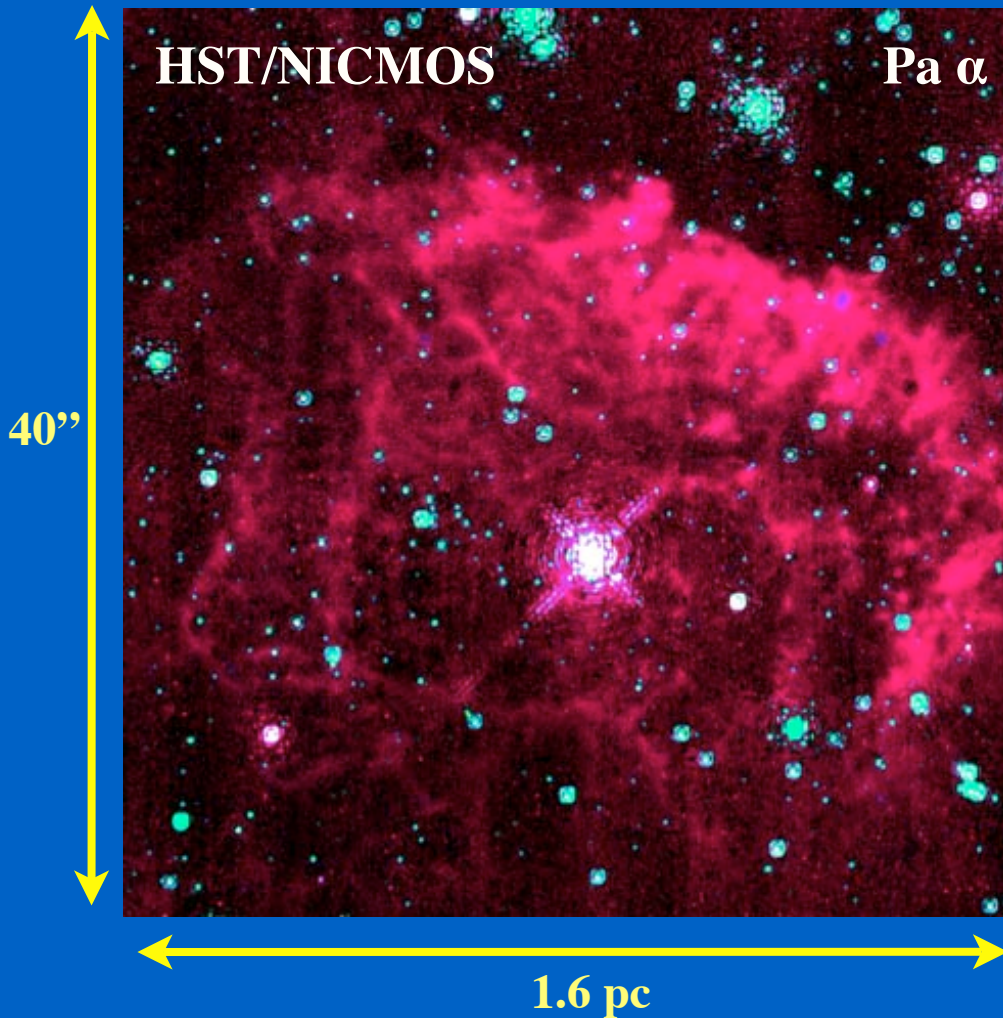


**Keck/NIRC
speckle**

Contours (% of Peak): 0.2 0.5 1 2 3 5 10 30 70

Quintuplet - host of the most massive star in the Galaxy?

Pistol star



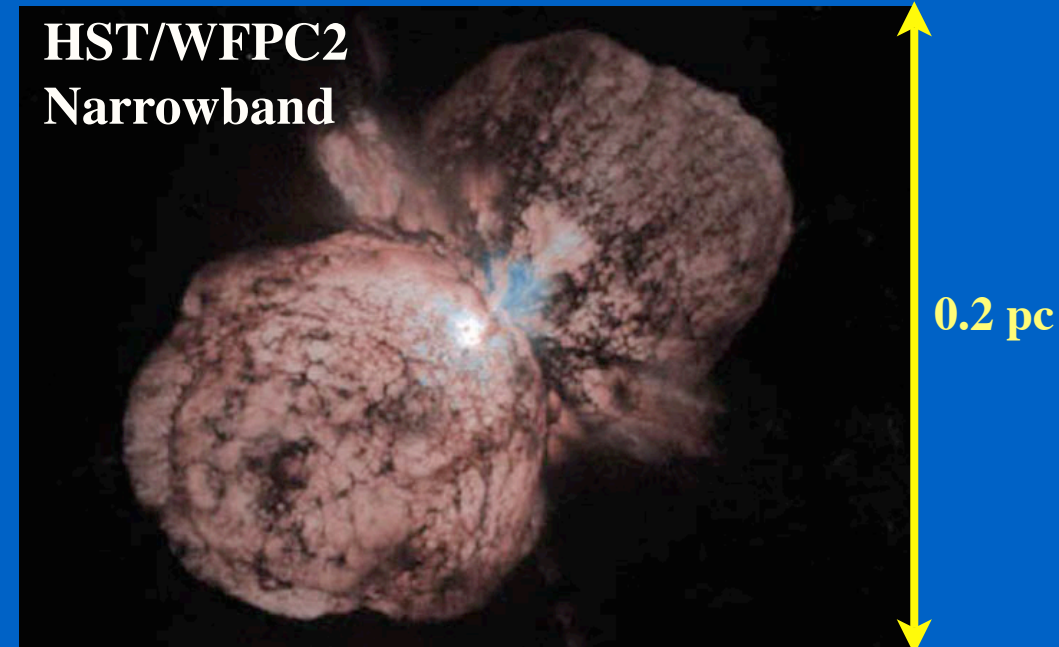
Figer et al. 1999, STScI, NASA

- LBV
- initial mass $\sim 200 M_{\text{sun}}$

Yungelson et al. 2008

- age $\sim 2 - 4 \text{ Myr}$ *Figer et al. 1999*

eta Carinae



Morse, Davidson, STScI, NASA

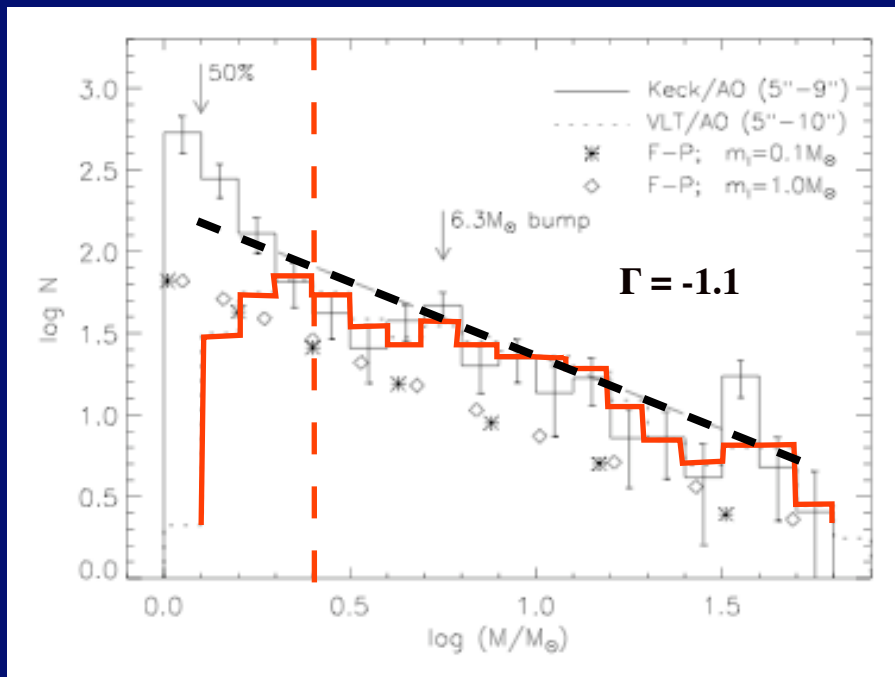
2. Science cases

The question of the upper stellar mass limit will not be answered without EELT

Outstanding questions in the Milky Way starburst sample

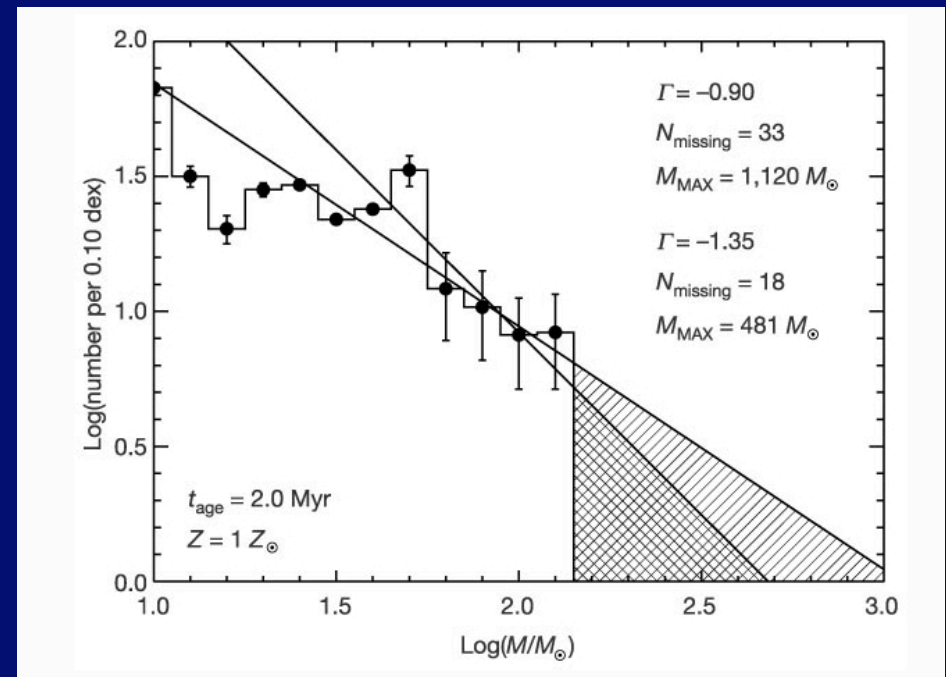
- Initial stellar mass function -- biased to high-mass stars or universal ?
- Upper mass limit -- real or sampling effect ?
- From young starbursts to globulars --
can more massive clusters survive the tides of time ?

Present-day Arches MF $0.2 < R < 0.4$ pc



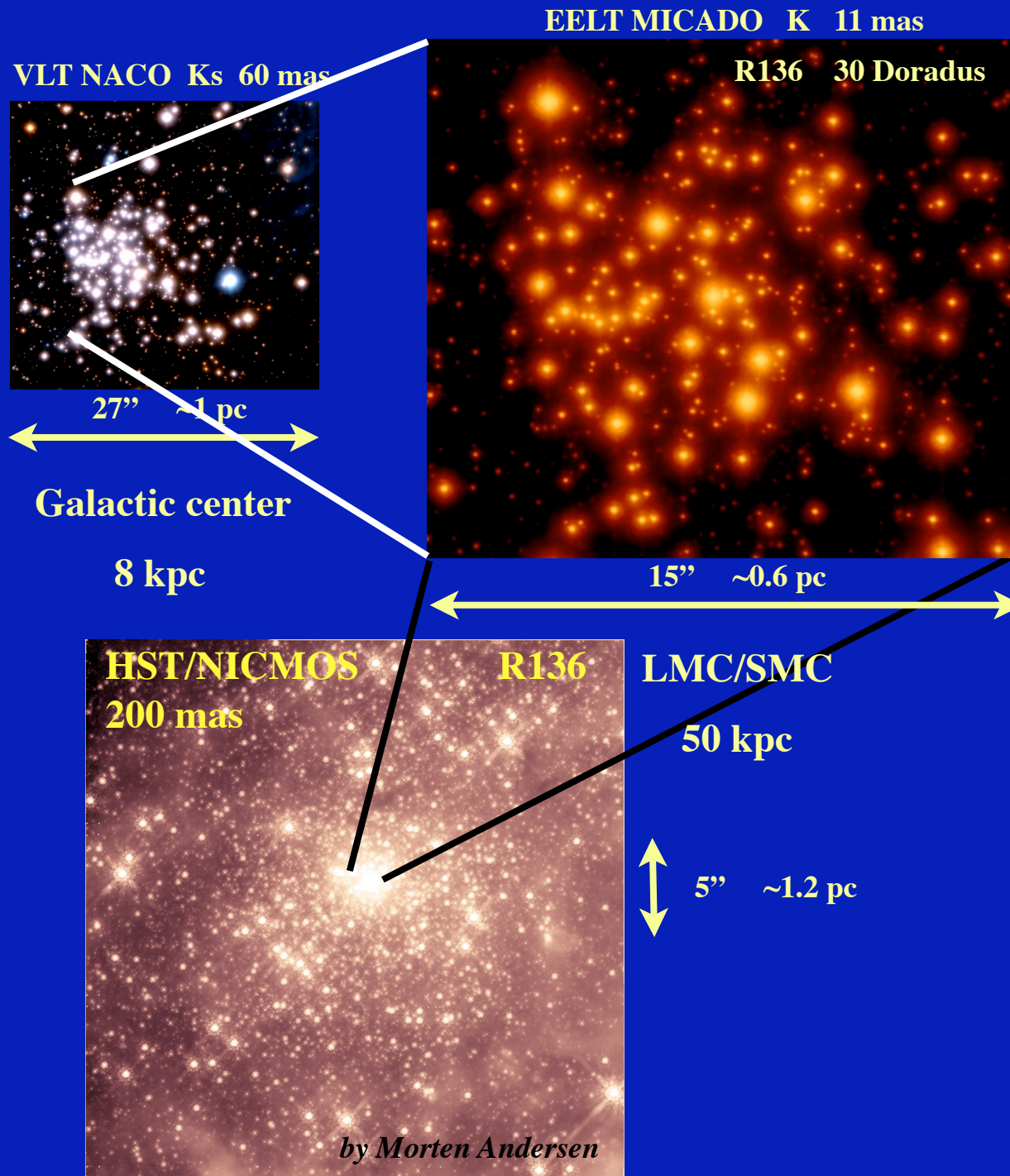
Stolte et al. 2005, Kim et al. 2006

Suggested upper mass limit

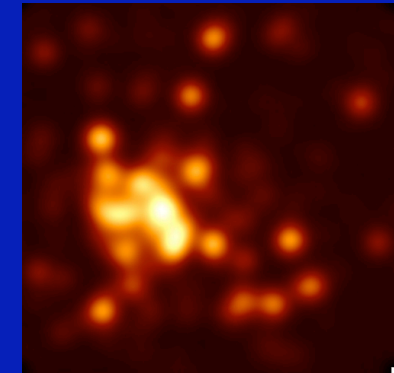


Figer et al. 2005

Extragalactic starburst clusters in nearby galaxies



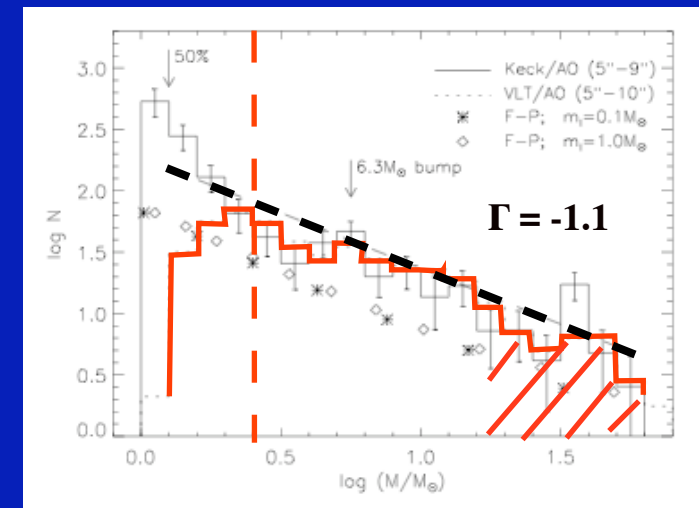
EELT MICADO K 11 mas



0.27" ~ 1 pc

M31 / M33

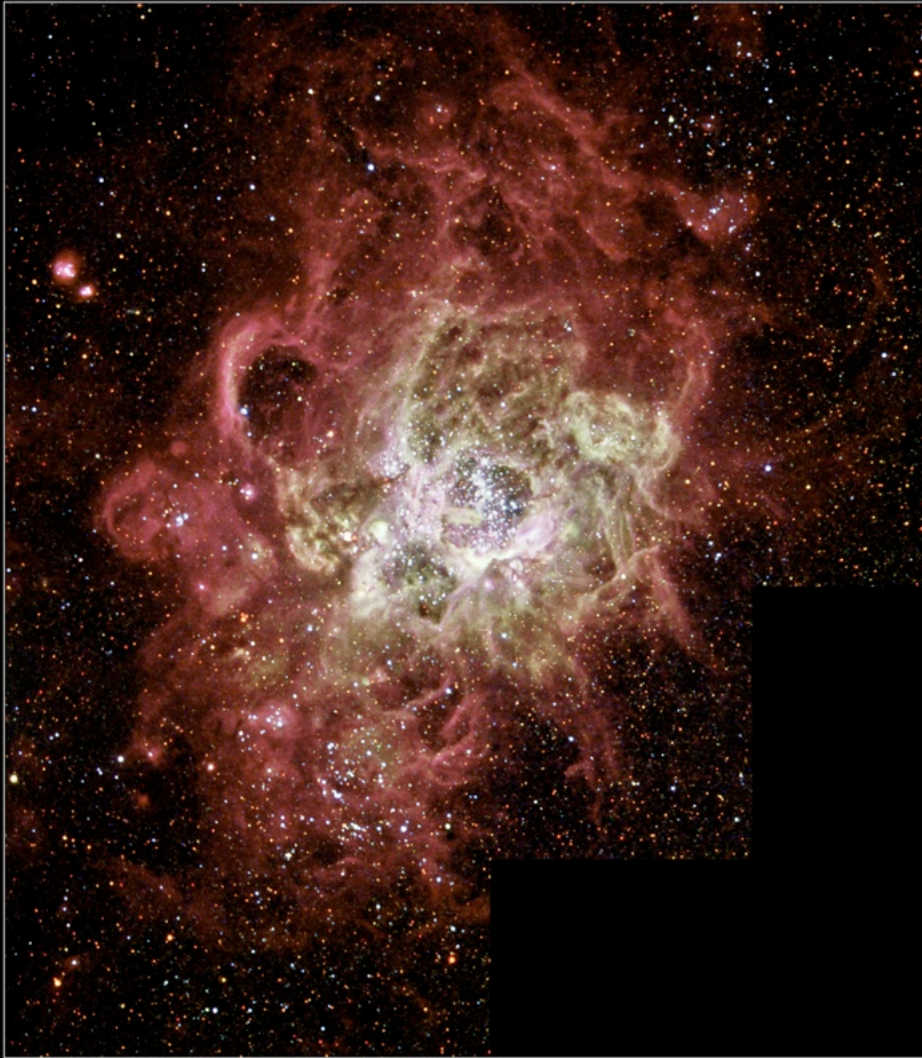
800 kpc



20 Msun K = 21.4 mag @ M31
J = 21.3 mag

Resolving extended cluster-forming regions in M33

NGC 604 in Spiral Galaxy M33



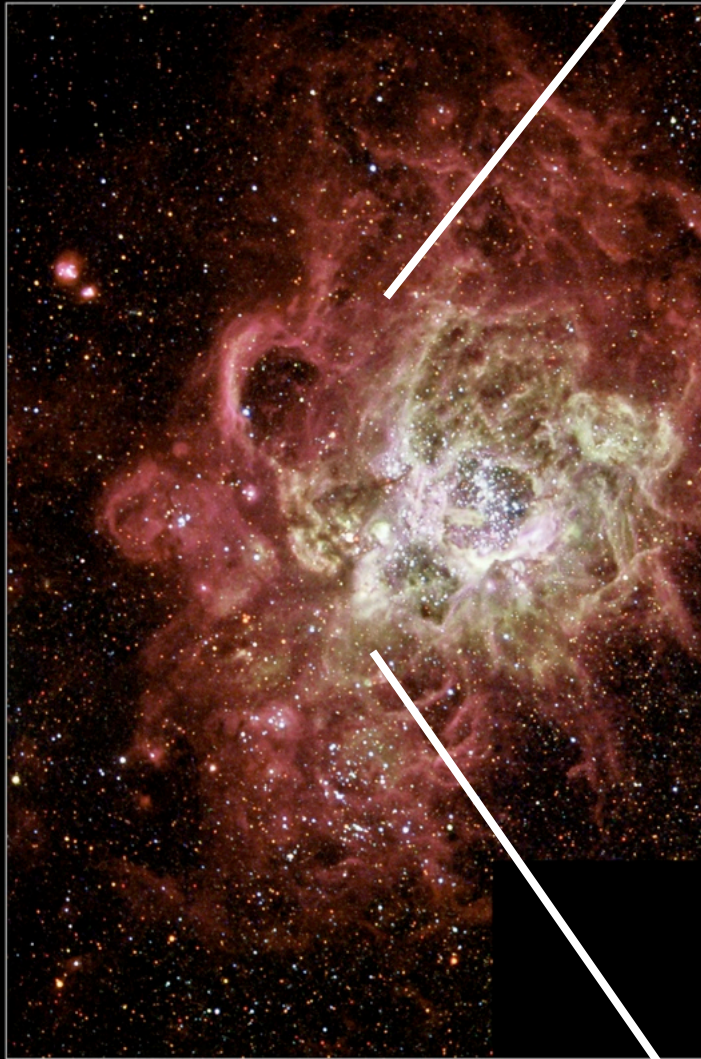
Hubble
Heritage

NASA and The Hubble Heritage Team (STScI/AURA) • Hubble Space Telescope WFPC2 • STScI-PRC03-30



Resolving extended cluster-forming regions in M33

NGC 604 in Spiral Galaxy M33

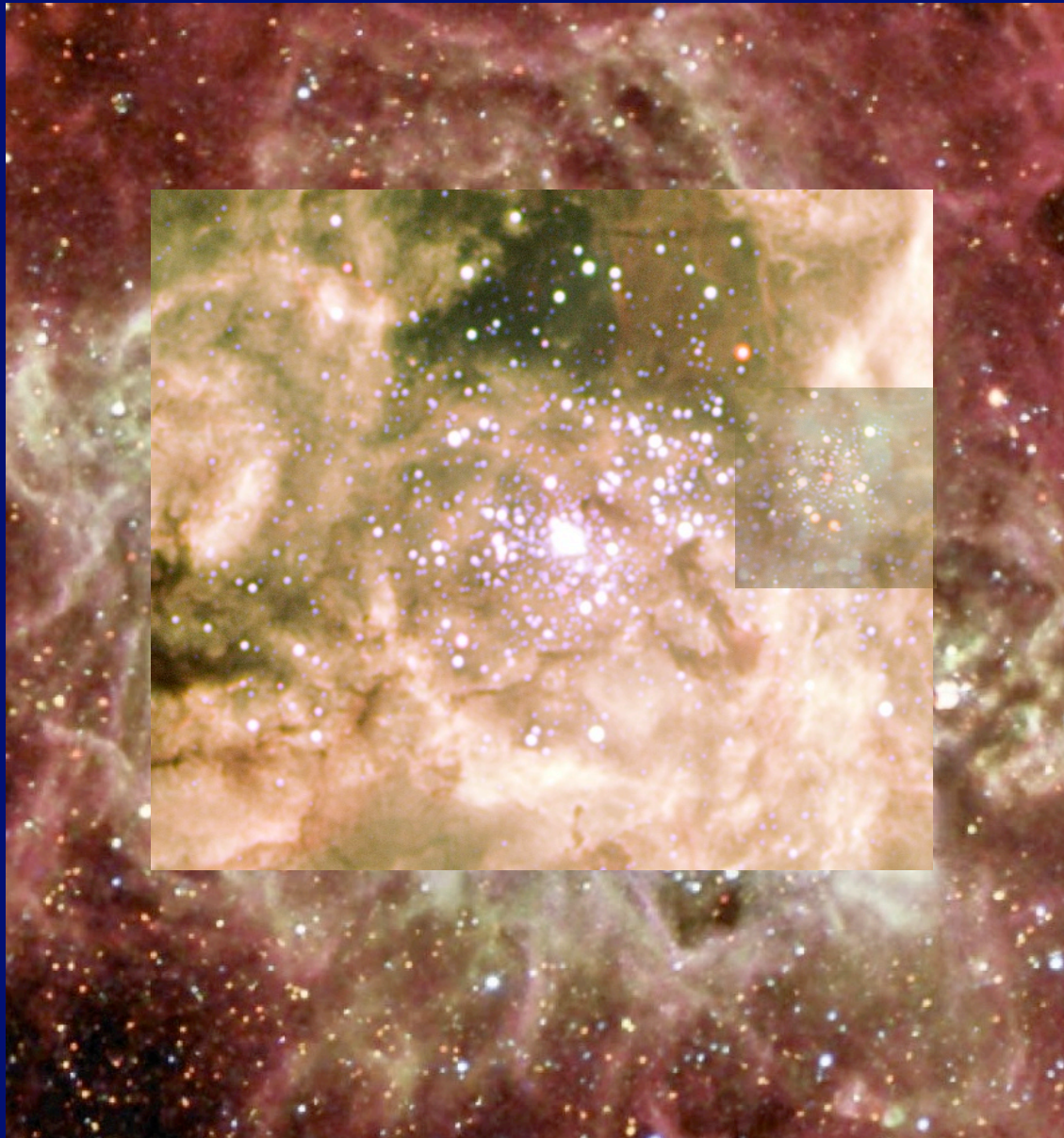


NASA and The Hubble Heritage Team (STScI/AURA) • Hubble Space Telescope WFPC2 • STScI-PRC03-30

Resolving extended cluster-forming regions in M33

~400 pc

90''



NGC 604

M33

914 kpc

Hubble Heritage WFPC2

WFPC2

EELT

V 0.4 pc

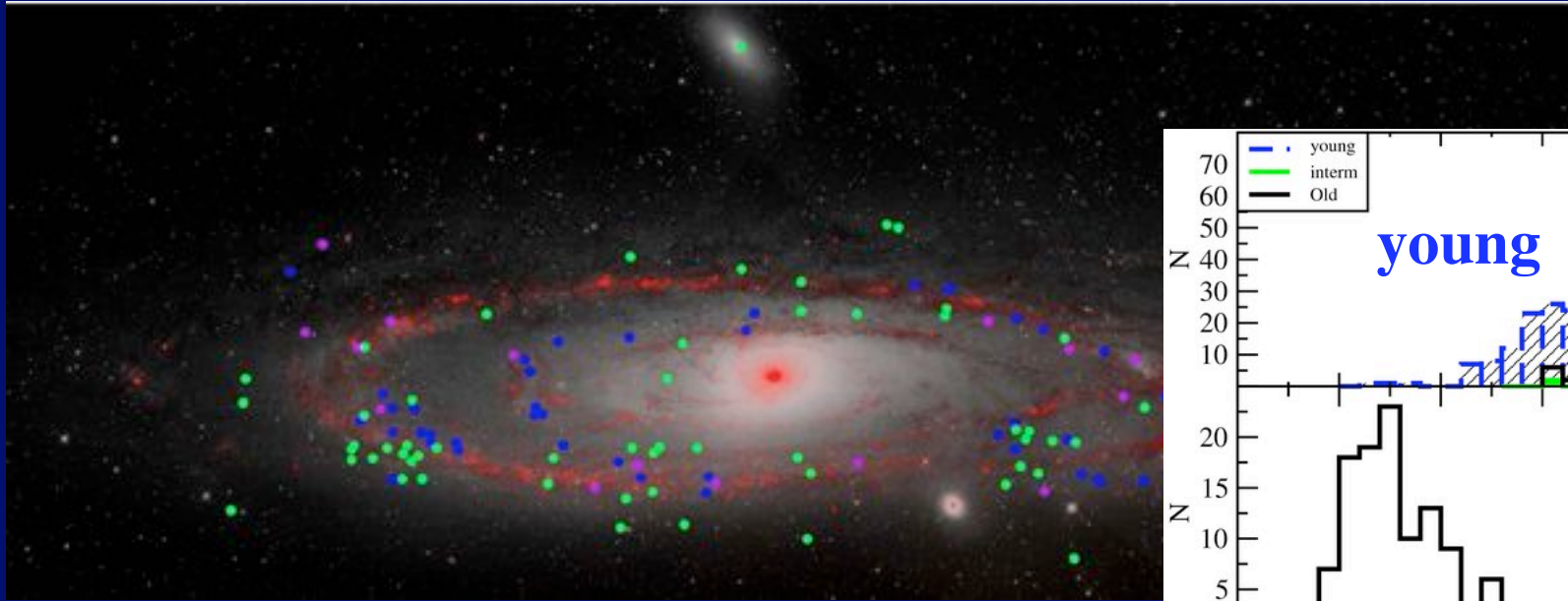
J 0.026 pc

typical core radius 0.2 pc

=> 10 % of core size

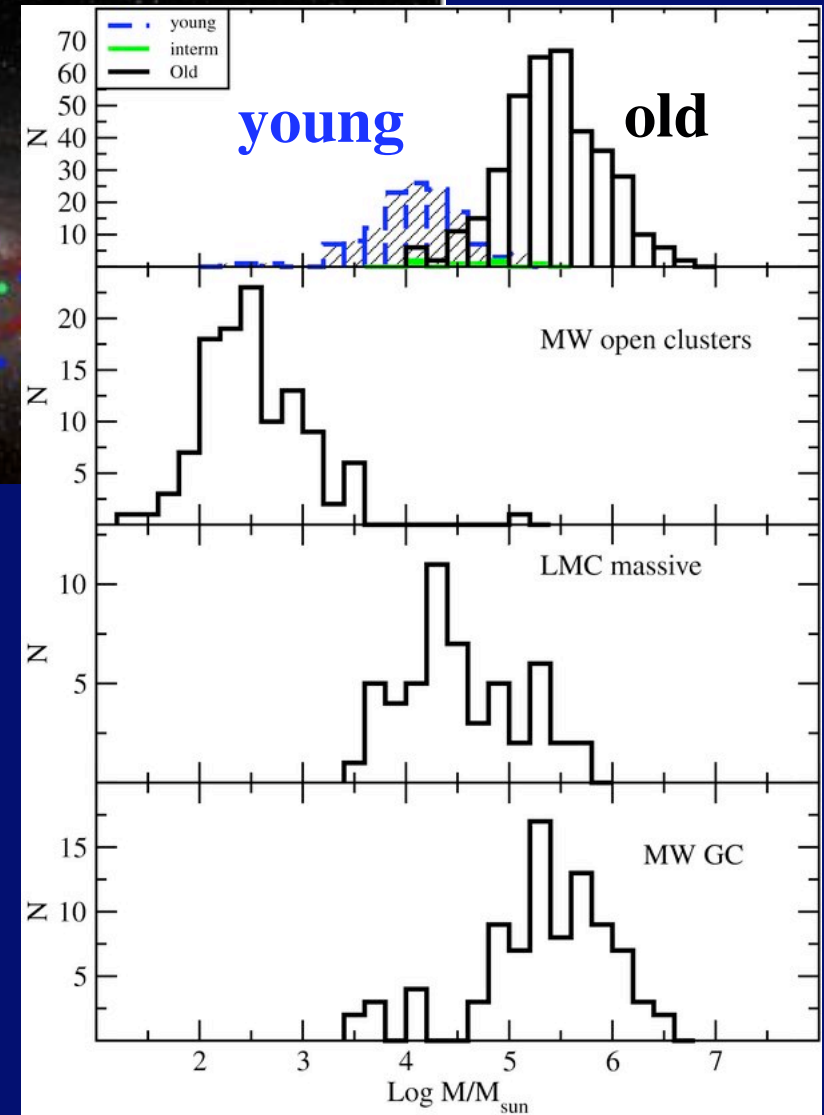
No such clusters in the Milky Way today !!!

Cluster distribution in M 31



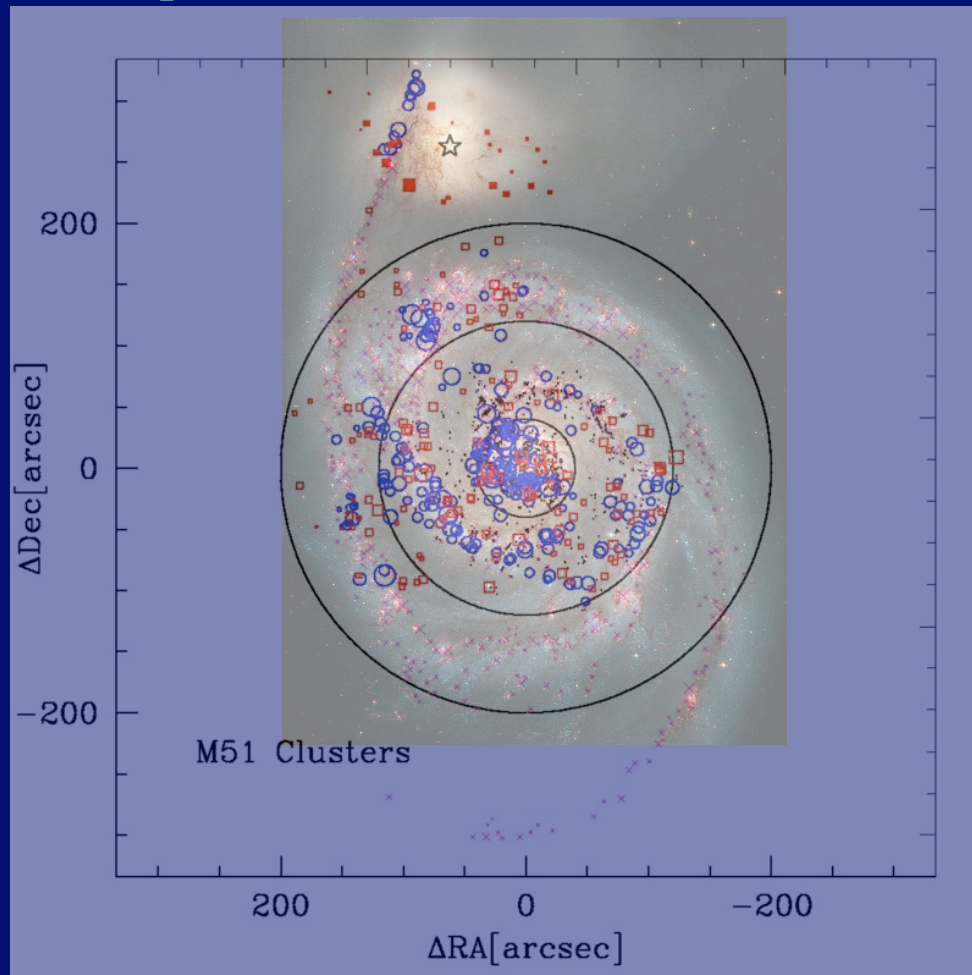
Caldwell et al. 2009

- young < 100 Myr
- 100 < 320 Myr
- 320 < 2 Gyr



Extragalactic young cluster sizes - M51 young cluster system

Spatial cluster distribution in M 51



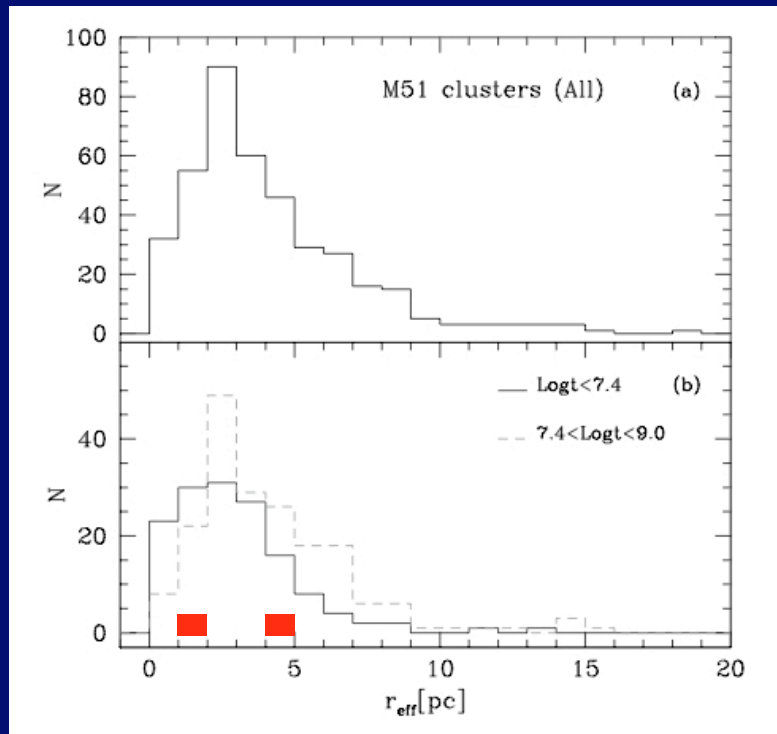
- blue young < 100 Myr
- red young < 100 Myr
- older clus > 100 Myr
- × spiral arm HII regions

Whirlpool galaxy M 51
credit: NASA/ESA

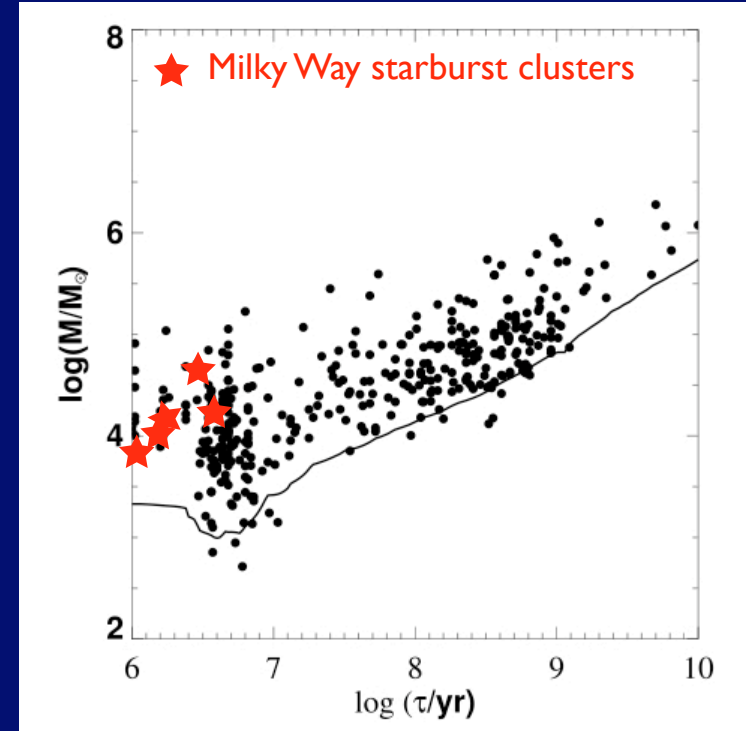
Lee et al. 2005

Extragalactic young cluster sizes - M51 young cluster system

Cluster size distribution in M 51



Cluster mass distribution in M 51



Multiply the Milky Way cluster sample by factor of 10 at least

Whirlpool galaxy M 51
credit: NASA/ESA



Lee et al. 2005

Starburst galaxies in the Southern Sky - M83

Distance 3.7 Myr

Rich cluster sample:

55 blue, very young clusters

96 red, more evolved clusters

=> cluster statistics



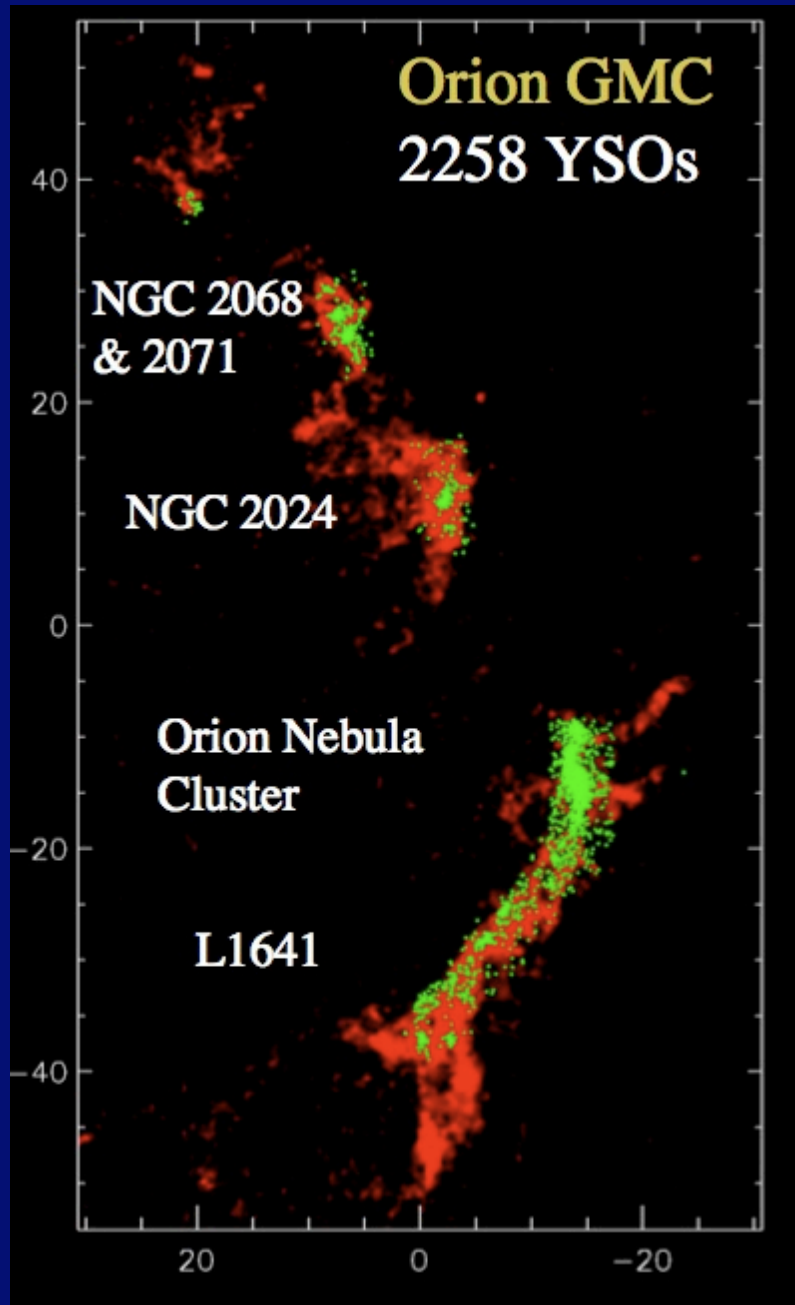
APOD/ESO De Martine 2008

Outlook into space.....

	Distance	VLT 8m <i>60 mas</i>	EELT 42m <i>11 mas</i>
Gal. Center	8 kpc	480 AU	87 AU
LMC	50 kpc	3000 AU / 0.01pc	550 AU
M31	800 kpc	48000 AU / 0.23 pc	8250 AU / 0.04 pc
M51	~4 Mpc	1.2 pc	0.2 pc

=> Resolve down to scales of the most compact Milky Way cluster cores

Outlook into space.....



16 pc in K-band:

400 resolution elements @ M31

200 resolution elements @ M83

80 resolution elements @ M51

~16 pc

2 deg

Megeath et al.

Science cases by instrument

<u>Instrument</u>	<u>wavelength</u>	<u>Science case</u>
MICADO	1.6-2.2 micron	- extragalactic starburst clusters - high-mass IMF & max stellar mass - Milky Way - the far side population
METIS	3.5-13 micron	- disk survival in starburst environment
HARMONI	1.6-2.2 micron	- distances, metallicities, ages - internal velocity dispersion - the most massive stars: - winds, mass loss, evolution

Approaching the outstanding questions with E-ELT

- Initial stellar mass function -- biased to high-mass stars or universal ?
 - cover full cluster extend (wide-field mode)
 - extend the sample to more ages, cluster masses, densities...
- Upper mass limit -- real or sampling effect ?
 - increase the *resolved* cluster sample to more massive clusters
- From young starbursts to globulars --
 - can more massive clusters survive the tides of time ?
 - more massive clusters
 - more evolved clusters > 10-20 Myr
 - dynamical cluster evolution in different environments

Thanks!