

# The Formation and Gas Dynamics of the young SMC Cluster NGC 346

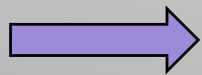
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Dynamics of Low-Mass Stellar Systems, Santiago, Chile, 4-8 April 2011

# Overview

NGC 346 appears to be a young cluster that has formed through hierarchical fragmentation

- Discuss stellar population and sub-cluster structure
- Discuss the dynamics of the ionized gas



what we can learn about cluster formation processes and the expulsion of residual gas

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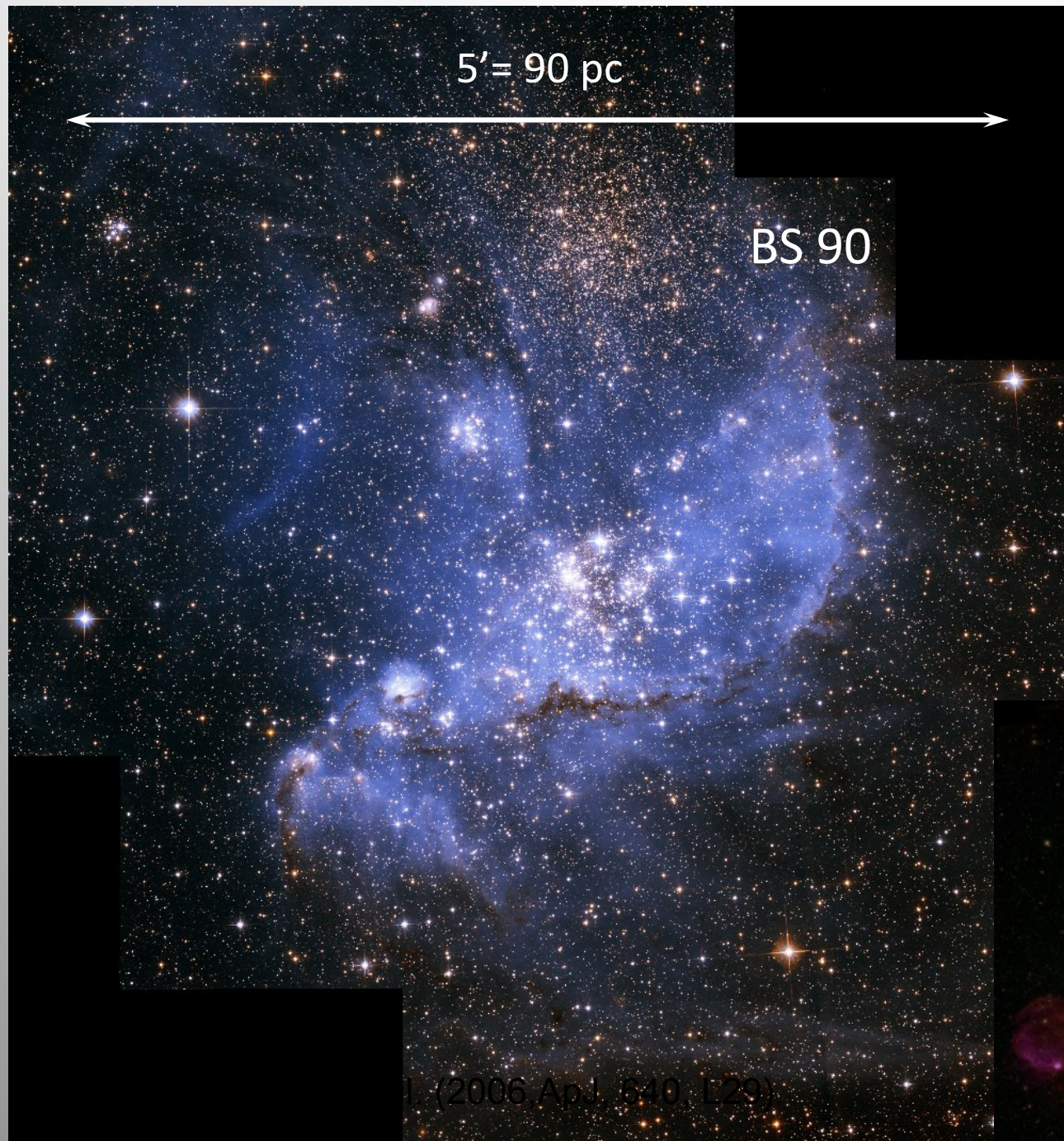
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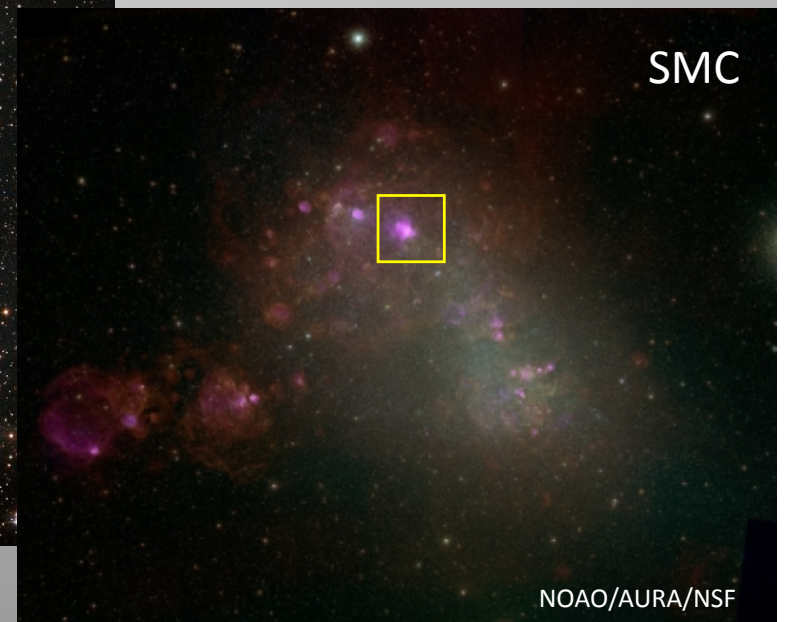
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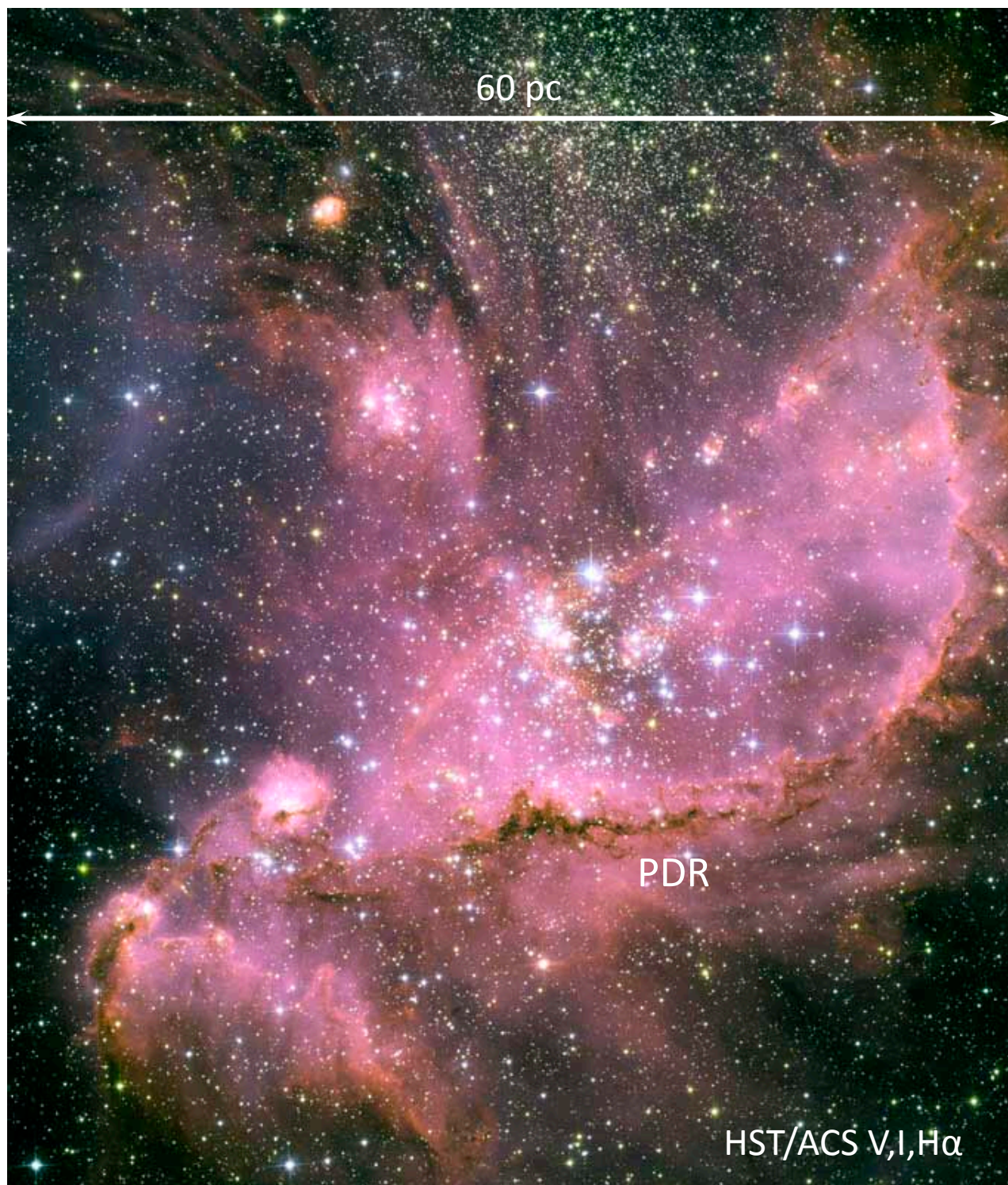
## NGC 346:

- Most massive star-forming region in the SMC
- Contains largest sample of O stars in the SMC  $\sim 33$
- Large population of pre-MS stars in many sub-clusters
- Age  $\sim 3$  Myr



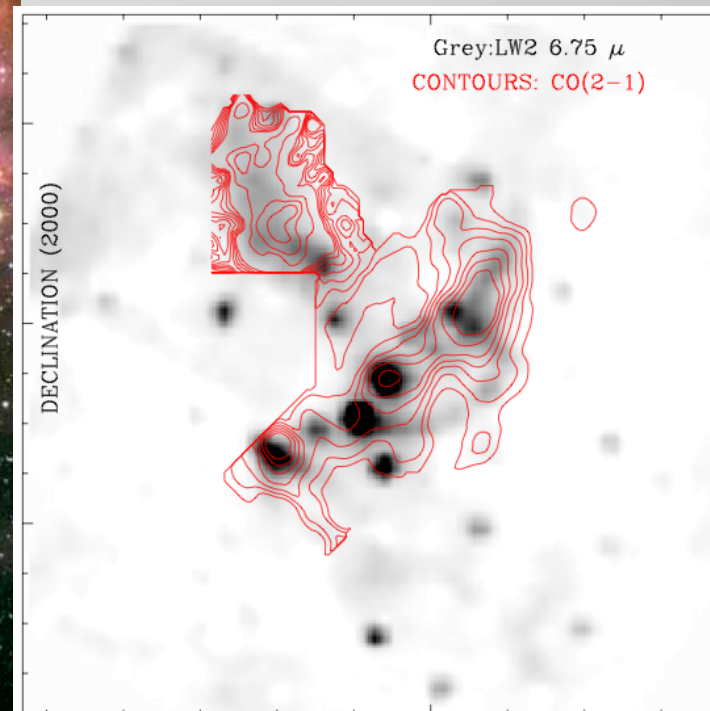
V,I HST/ACS Nota et al. (2006,ApJ, 640, L29)

NOAO/AURA/NSF



## LHA 115-N66:

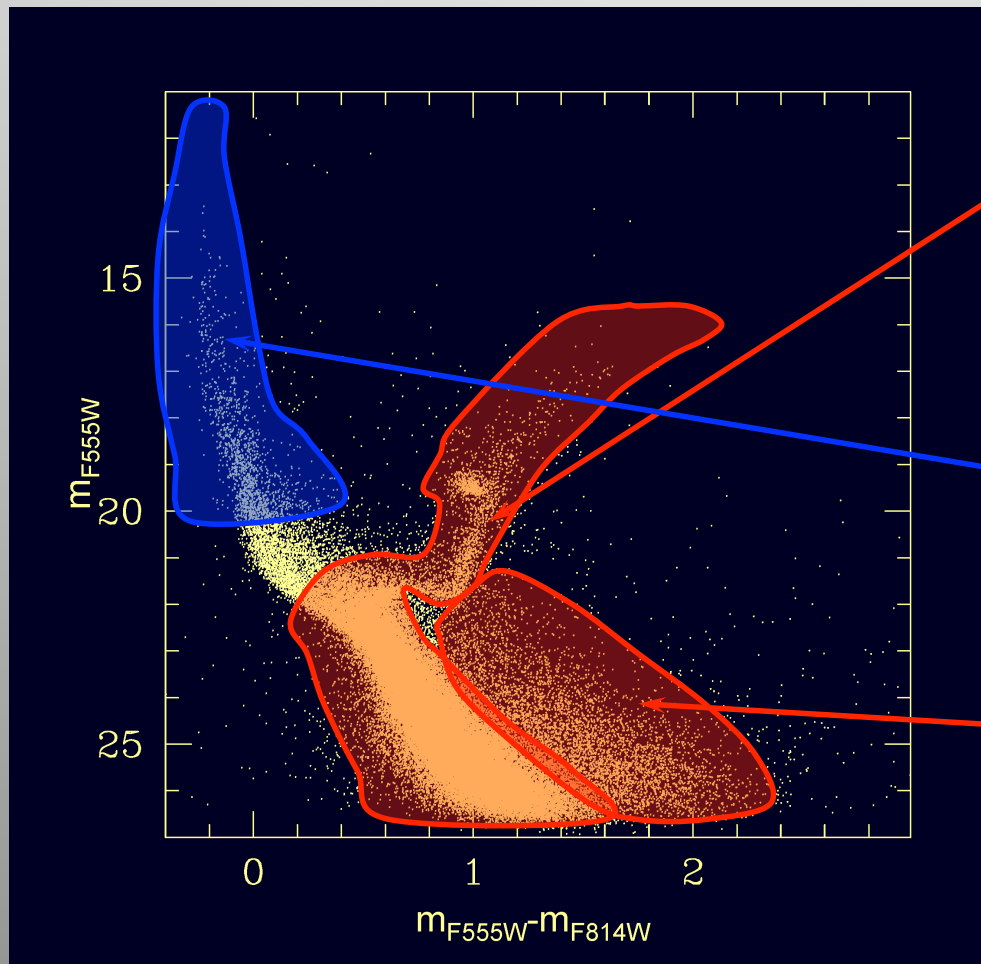
- Most luminous H II region in the SMC
- $L(\text{H}\alpha) \sim 60 \times \text{Orion}$
- Filamentary structure
- Molecular gas is present



Rubio et al (2000): some CO remains in molecular clumps

# The CMD

(Sabbi et al. 2007, AJ, 133, 44)

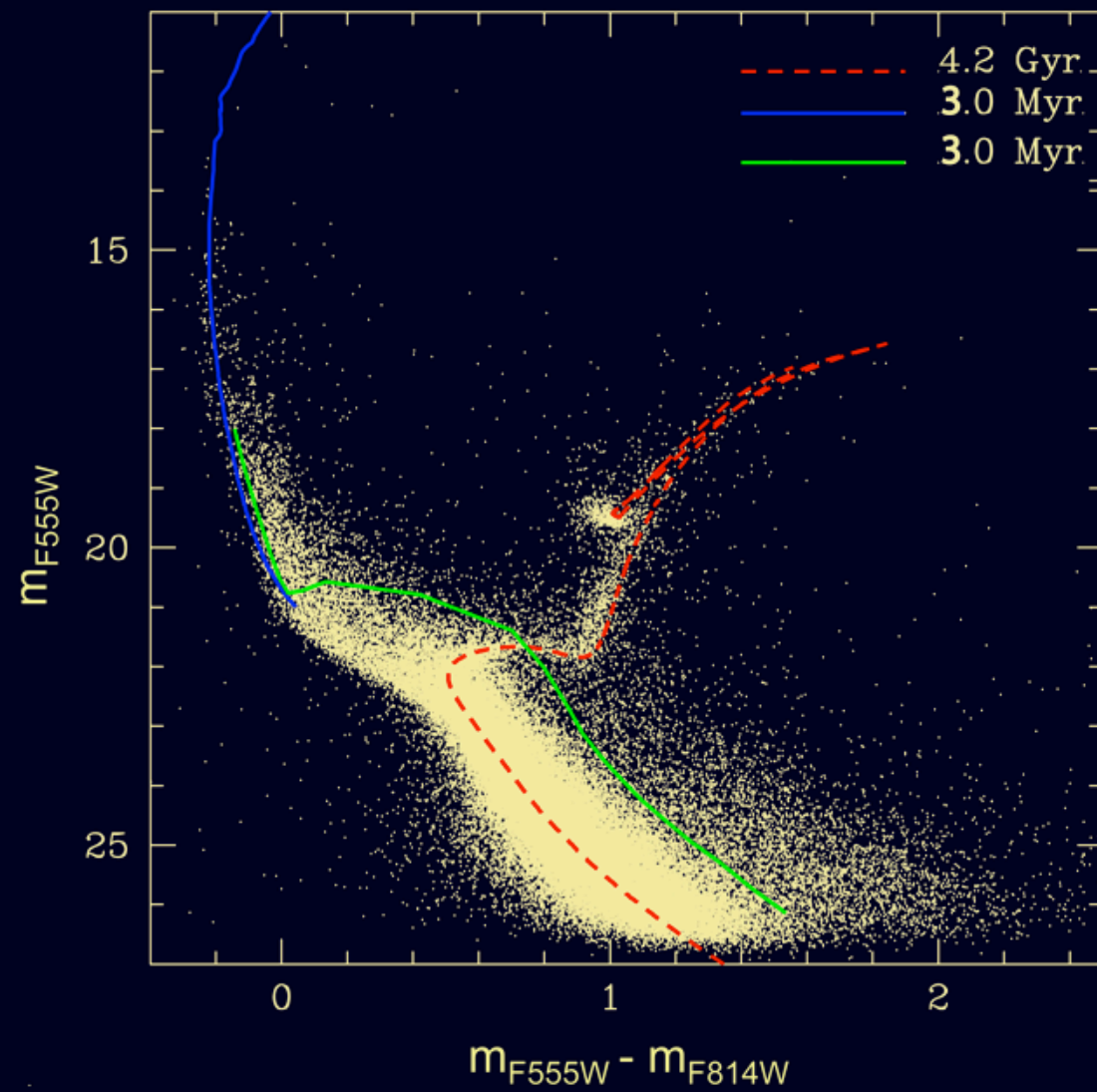


Old SMC population + BS90  
contribution

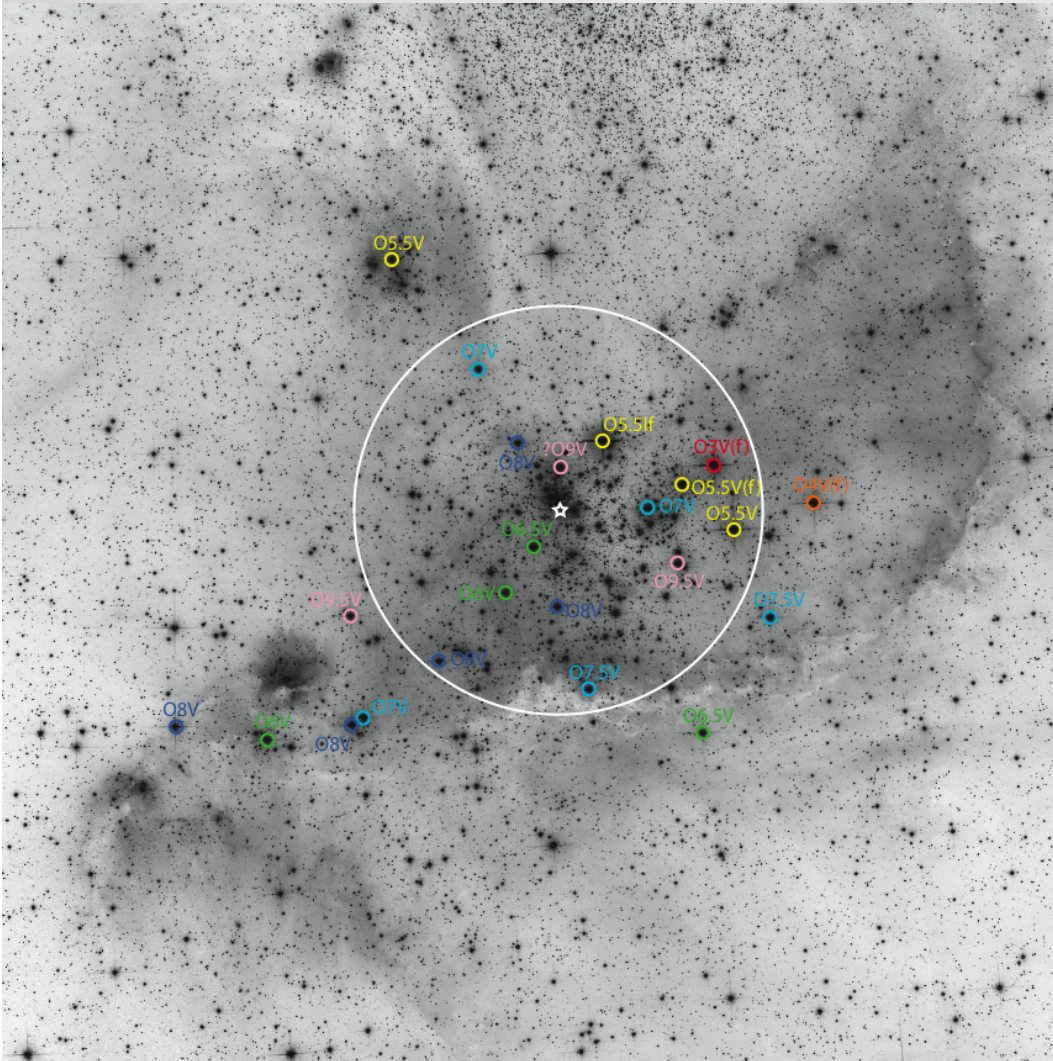
Young stellar population  
(NGC 346)

Pre-MS stars

# NGC 346



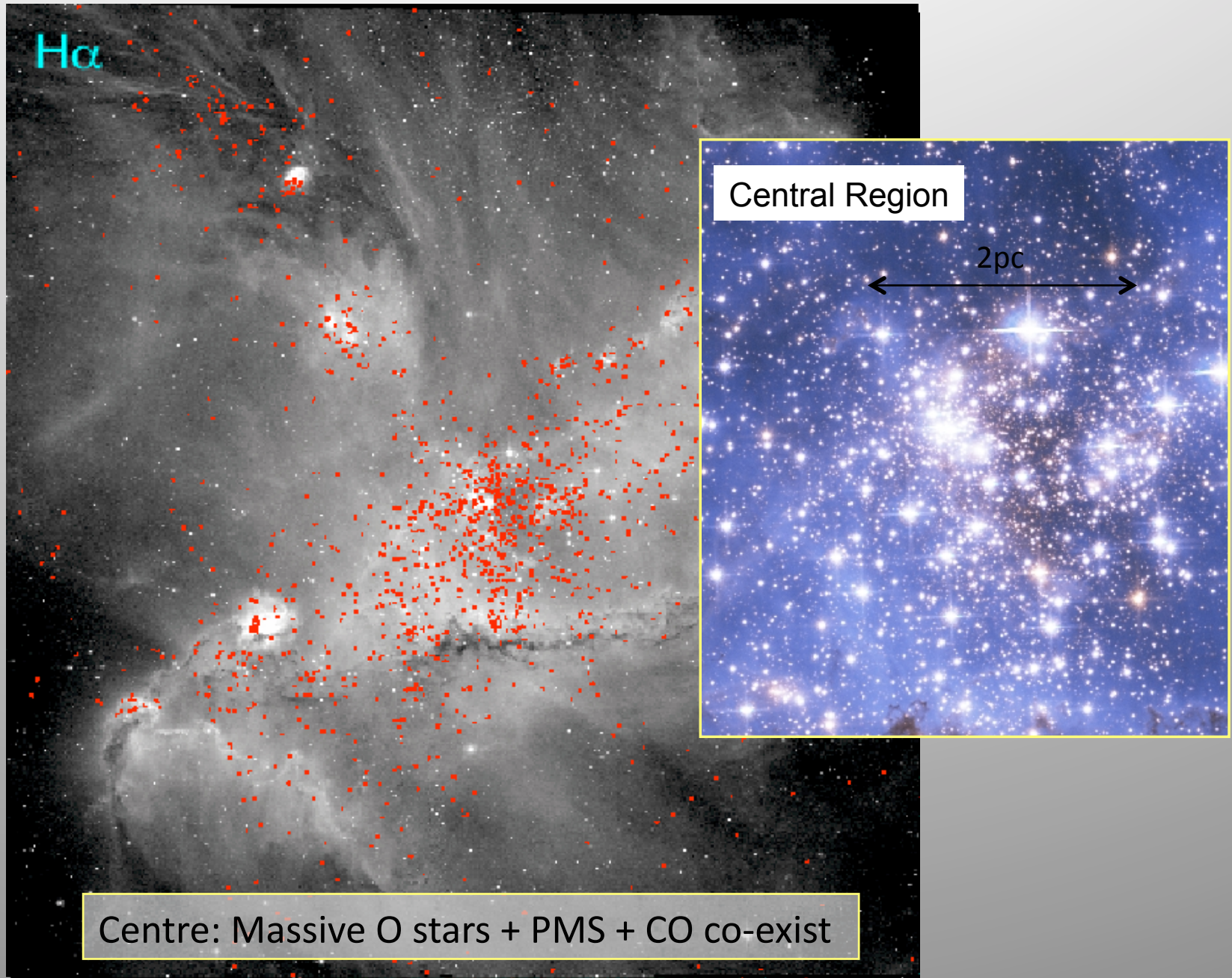
# O stars in NGC 346



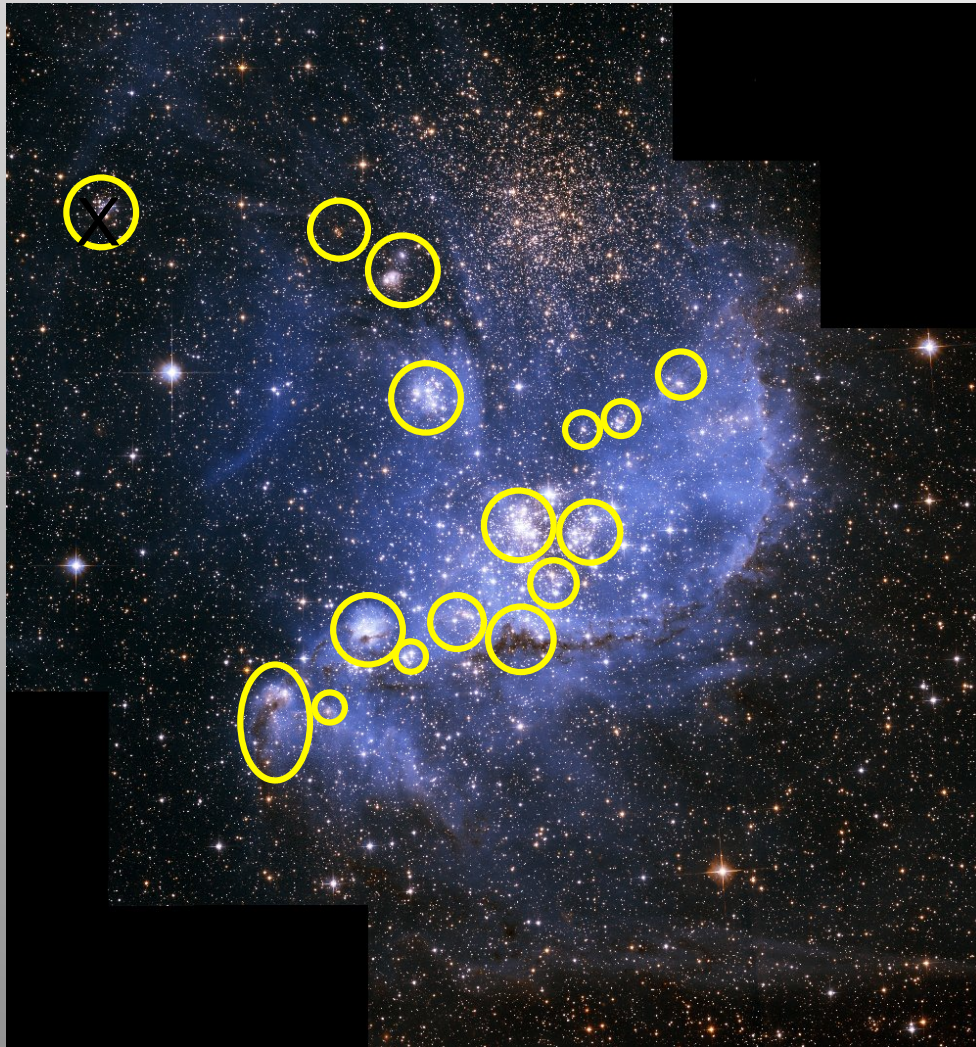
## IMF Analysis:

- Salpeter (0.8-60  $M_{\odot}$ )
- Mass segregation is present
- Half-mass radius = 9 pc
- Total cluster mass  
=  $4 \times 10^5 M_{\odot}$

## Pre-MS Spatial Distribution ( $0.6 - 3 M_{\odot}$ )



# Sub-Clusters



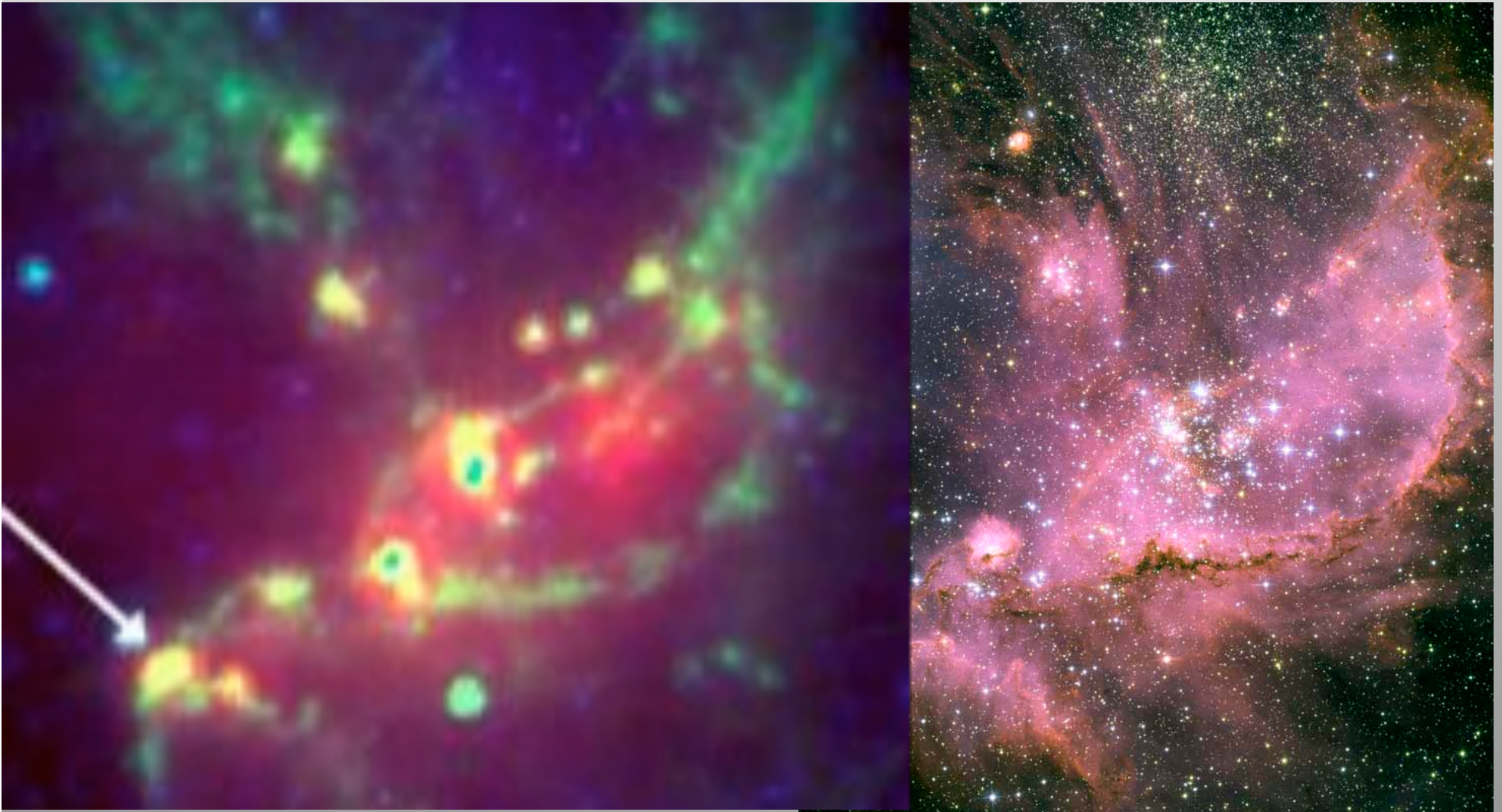
All 15 sub-clusters have an age of  $3 \pm 1$  Myr i.e. coeval

Sub-clusters embedded in nebulosity + coincide with clumps of molecular gas

Crossing time  $\sim 2$  Myr ( $c = 10$  km/s)  $\approx 1$  crossing time old

Formation is probably due to hierarchical fragmentation of a molecular cloud (e.g. Bonnell et al. 2003). Supported by clustering behaviour of PMS stars (Schmeja et al. 2009) and crossing time.

Spitzer: 111 YSOs: all sub-clusters contain YSOs – SF is still ongoing.  
YSOs strongly concentrated in central cluster – also most massive.

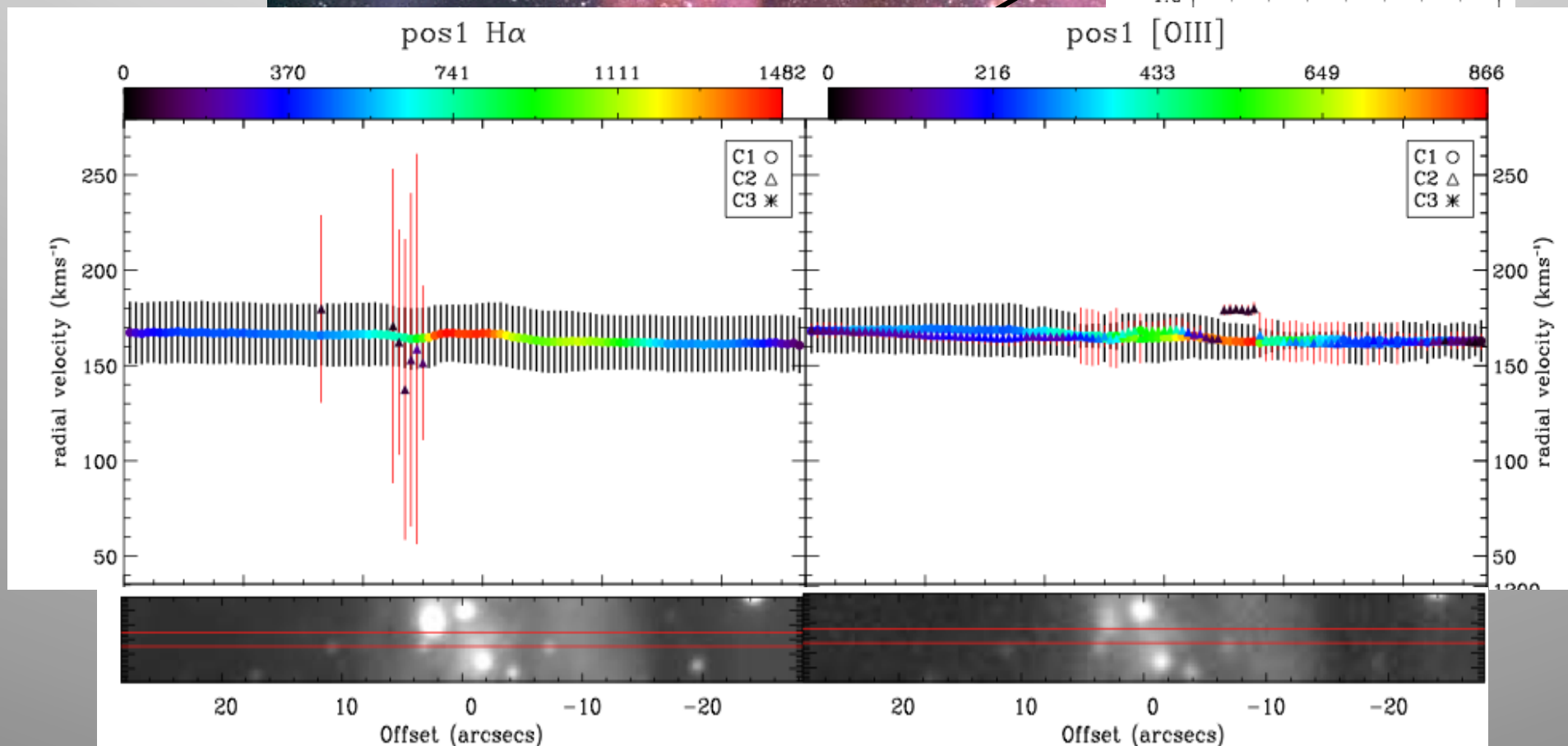
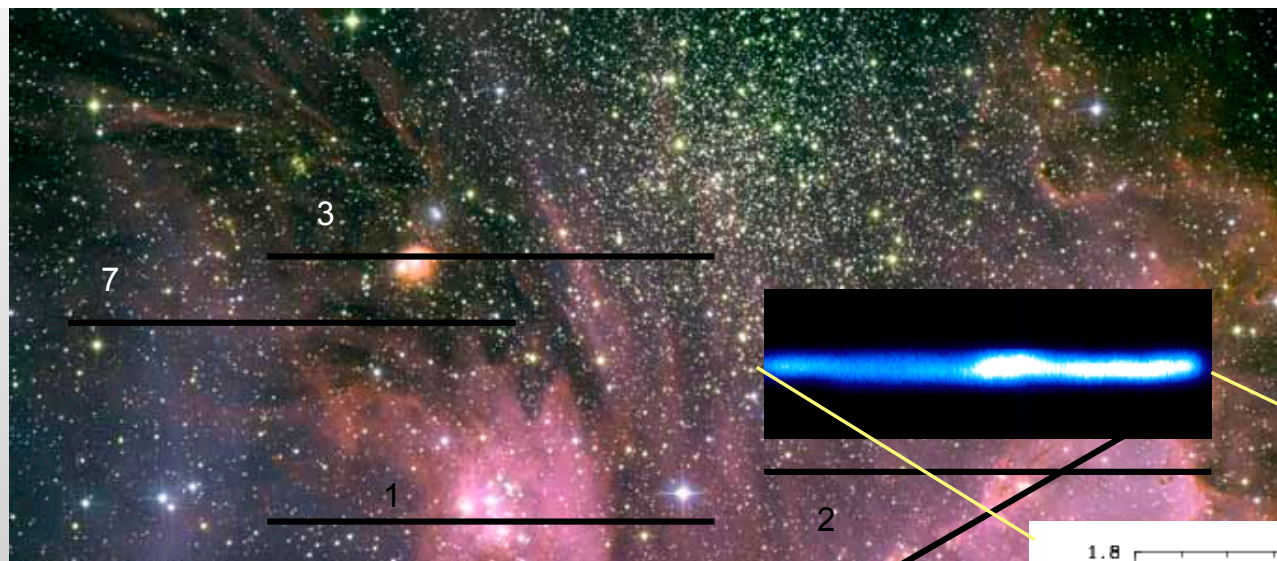


Simon et al. (2007)

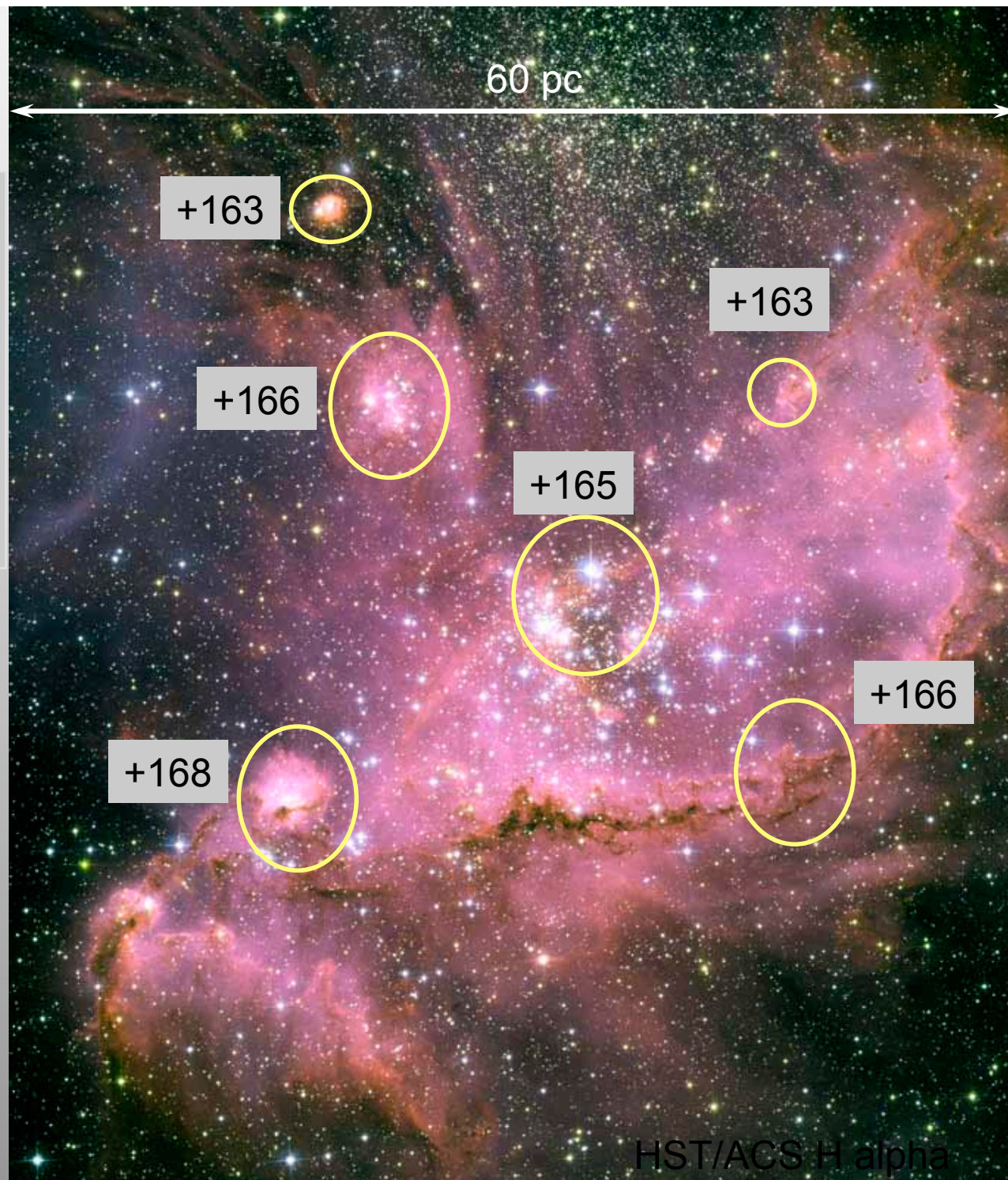
HST/ACS

# The Dynamics of N66

- based on observations obtained with the echelle spectrograph UCLES on the AAT
  - resolution = 6 km/s for H $\alpha$  and [O III]
- aim: map the gas motions over the nebula and study the stellar feedback and gas expulsion



Sub-clusters all have very similar velocities - not clear that they will coalesce to form one central cluster?



# Gas Dynamics

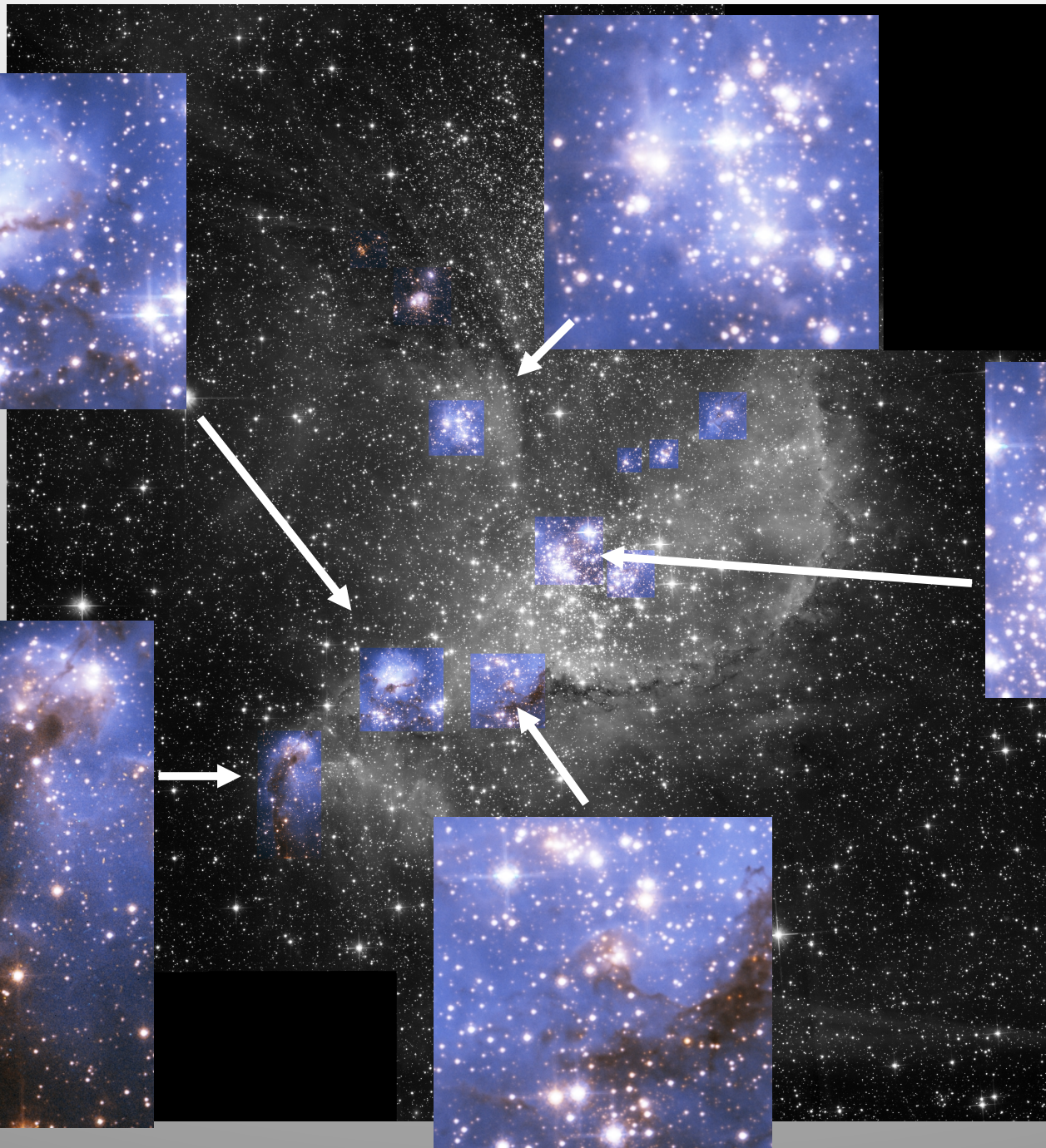
- No evidence for large scale ionized gas motions
- Gas is not being expelled by combined effects of stellar winds in central cluster – why?
- Has hot gas leaked out ? (cf. 30 Dor, Lopez et al.2010)
  - may be expected in turbulent, clumpy ISM
- Are stellar winds much less effective at SMC metallicity? YES  
 $L_{\text{rad}} \sim 10^3 - 10^5 L_{\text{wind}}$  for 5 NGC 346 O stars (Bouret et al. 2003)
  - Mass loss rates are >5 x lower than Galaxy
- Classical H II region expansion for N66 (radiation pressure may also play a role)
- Residual gas will not be removed until first supernova

# Conclusions

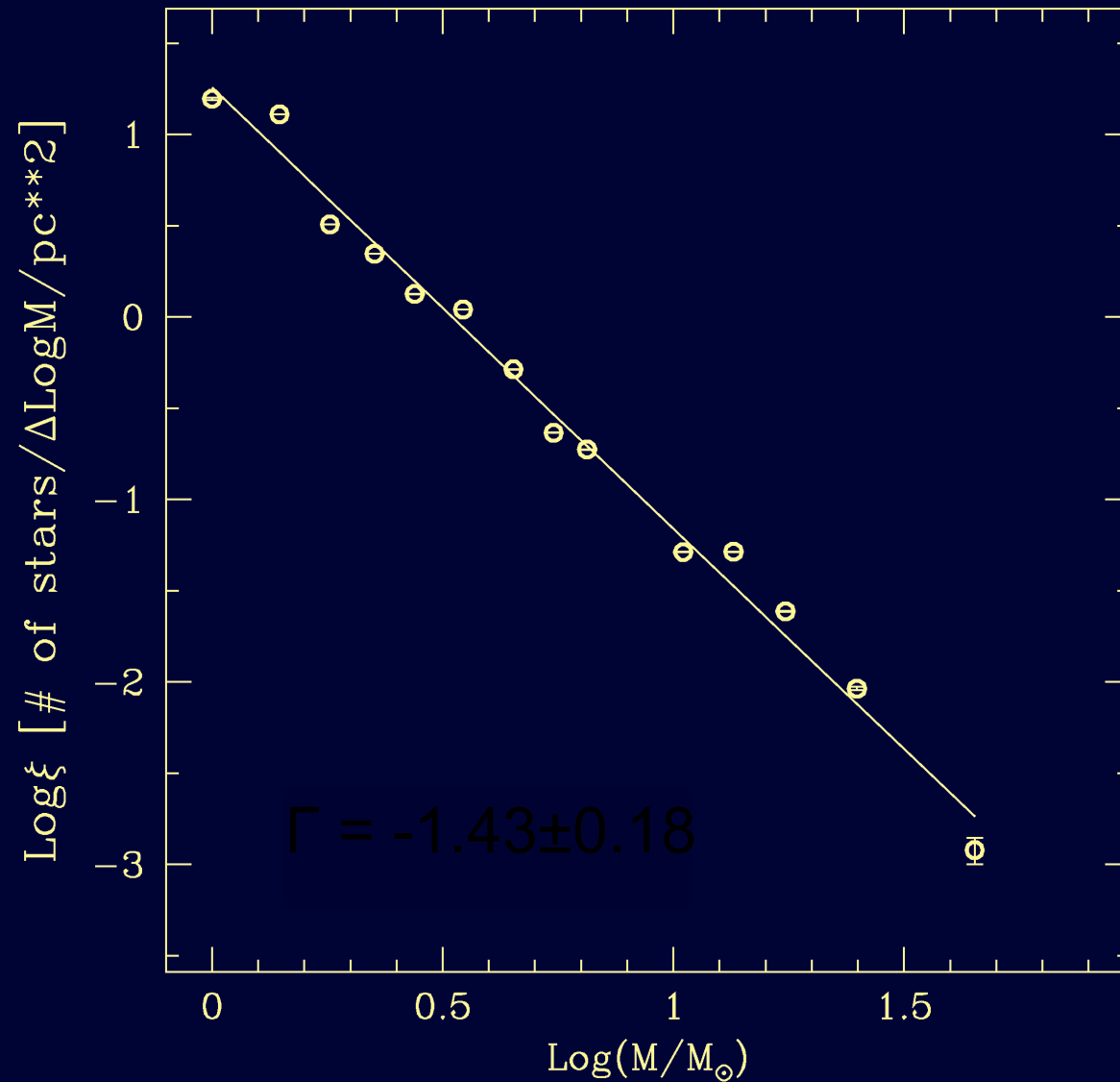
- The young SMC cluster NGC 346 contains a rich population of pre-main sequence stars and still has residual gas present
- The cluster shows significant spatial substructure - at least 15 coeval sub-clusters - strongly suggests formation due to hierarchical fragmentation of GMC
- NGC 346  $\approx$  1 crossing time old – hierarchical structure has not been erased yet
- Present day mass function is Salpeter and cluster is mass-segregated
- Ionized gas is quiescent - see no evidence for stellar wind interactions
- Residual gas not been expelled in a crossing time
- Future evolution of NGC 346 will be driven by H II region dynamics until first SNe occurs. Star formation is ongoing and has not yet been quenched.
- The relative velocities of the sub-clusters suggest they will not merge to form a single cluster – timescale is  $\sim 7$  Myr, well after the gas should be expelled by SNe.



Sub-clusters



# The Mass Function



The MF slope is consistent with Salpeter between 0.8 and 60  $M_{\odot}$ .

Total mass  
=  $4 \times 10^5 M_{\odot}$ .