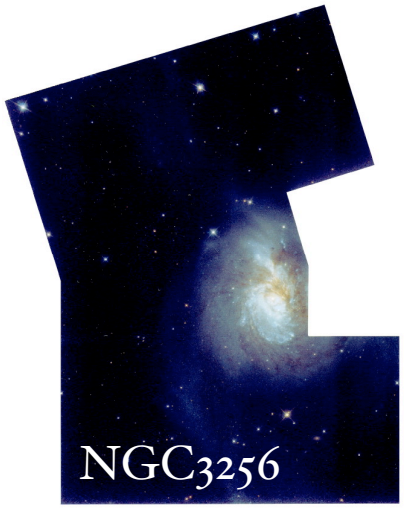
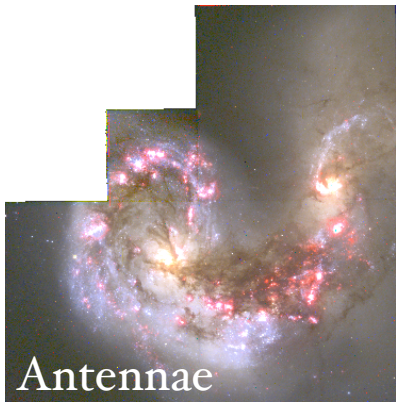
Resolved Extragalactic Star Clusters

Søren S. Larsen
Astronomical Institute, Utrecht University

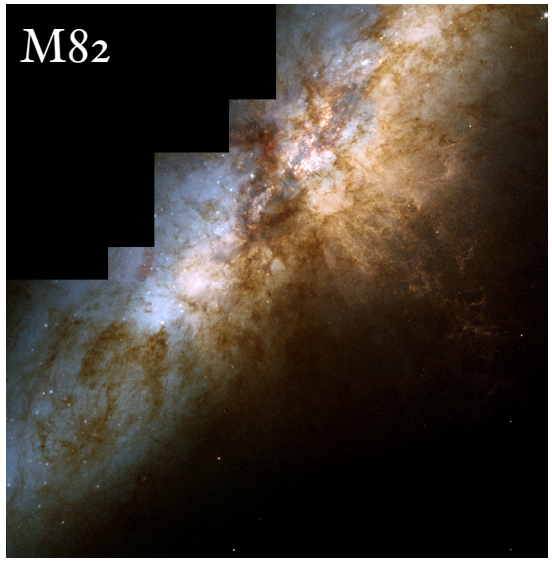
Young massive clusters - some hosts:

Mergers..

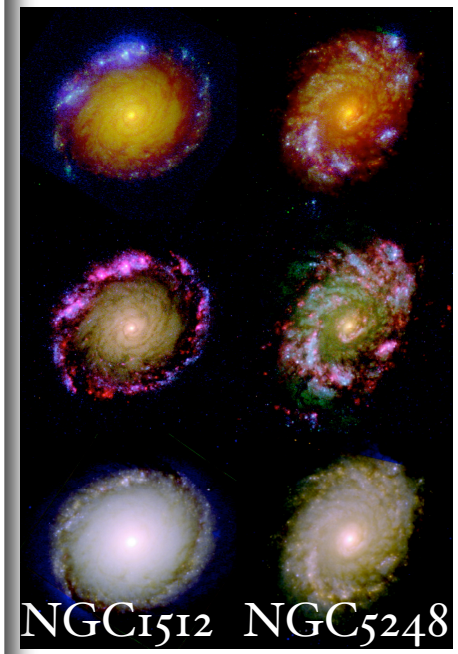




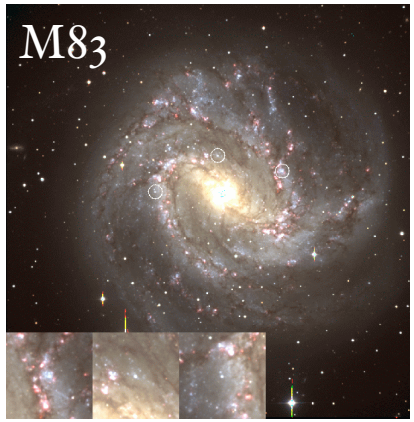
Interactions/starbursts

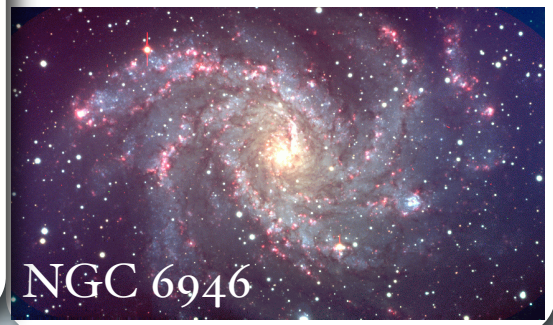


Starburst rings..

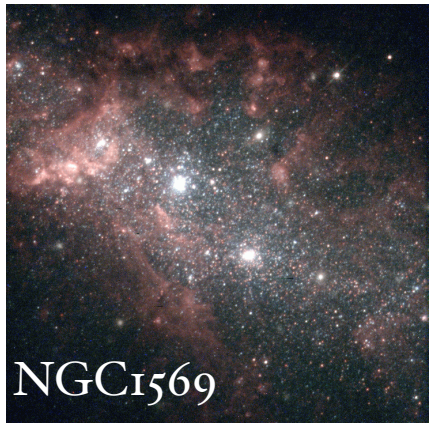


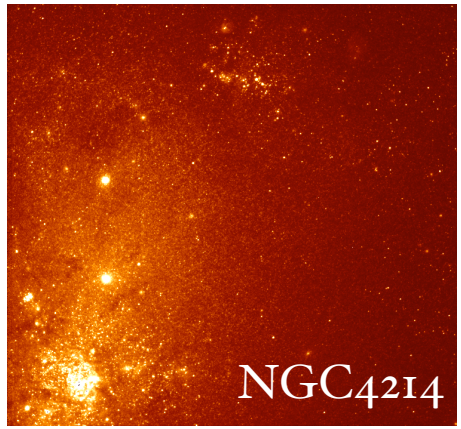
Spiral disks





Dwarfs





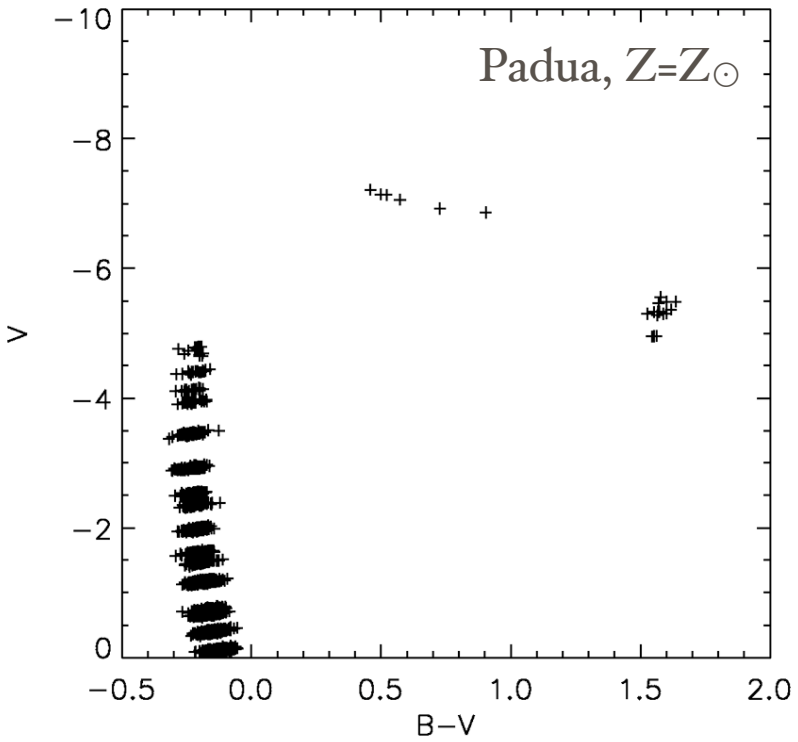
Reviews:
Whitmore 2003; Larsen 2004;
Whitmore 2007

HST and (Young) Extragalactic Star Clusters

- We now know that young (<1 Gyr), GC-like ($\gtrsim 10^5$ $M_\odot$, compact) star clusters are common in many different galaxies.
- Current issues:
  - Disruption time scales / mechanisms (e.g. mass dependency)
  - Mass / luminosity functions and their evolution over time
  - Formation efficiencies ("field stars" versus clusters)
  - Structural parameters (e.g. core/half-light/tidal radii)
- HST will continue to be a key resource for identifying and age-dating cluster populations (through multi-passband imaging)
- This presentation: Photometry of *individual stars* in young, massive extragalactic clusters is now within reach

Why go extragalactic?

- The most massive stars are rare and short-lived.
- Significant numbers of coeval samples only in young, massive (~10^5 $M_\odot$) clusters.
- Such clusters are themselves rare (only a few in Local Group)
- Need larger search volume!

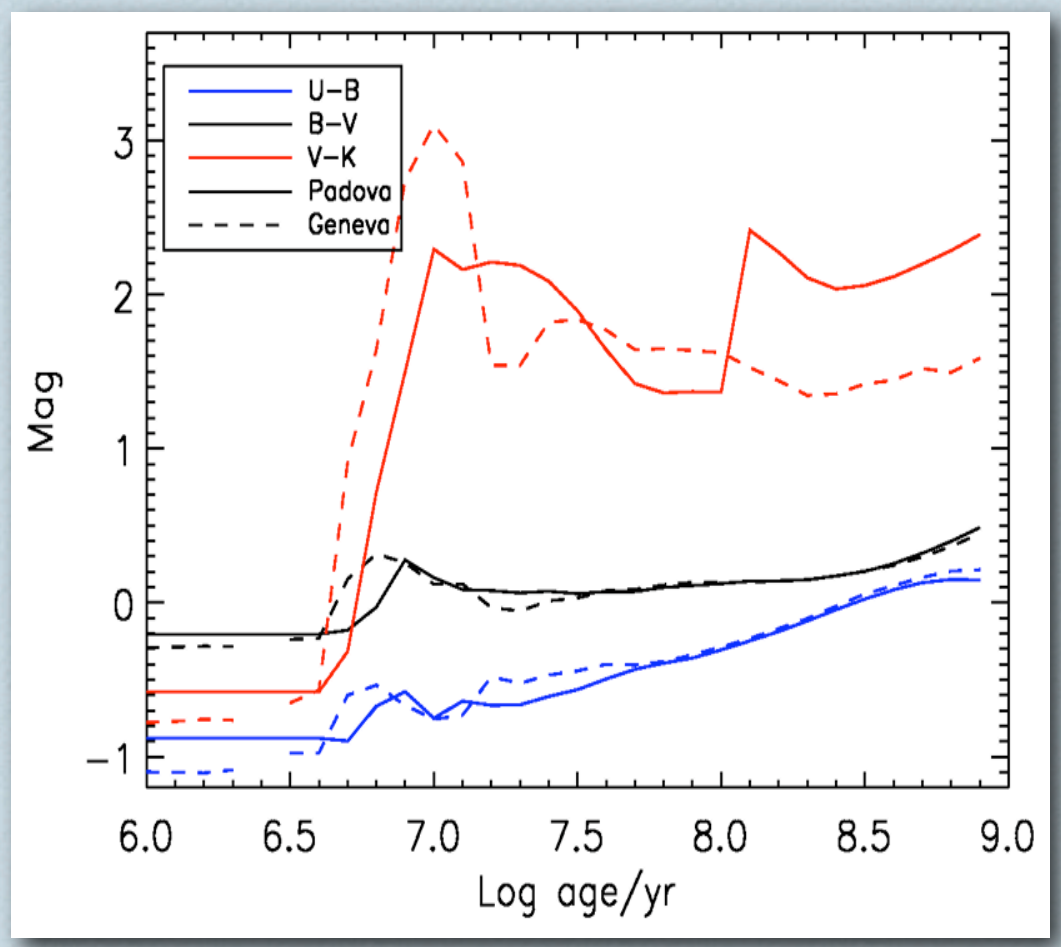


Simulated CMD:
- Log t = 7.2
- Mass = 10^5 $M_\odot$.

6 blue and 16 red supergiants

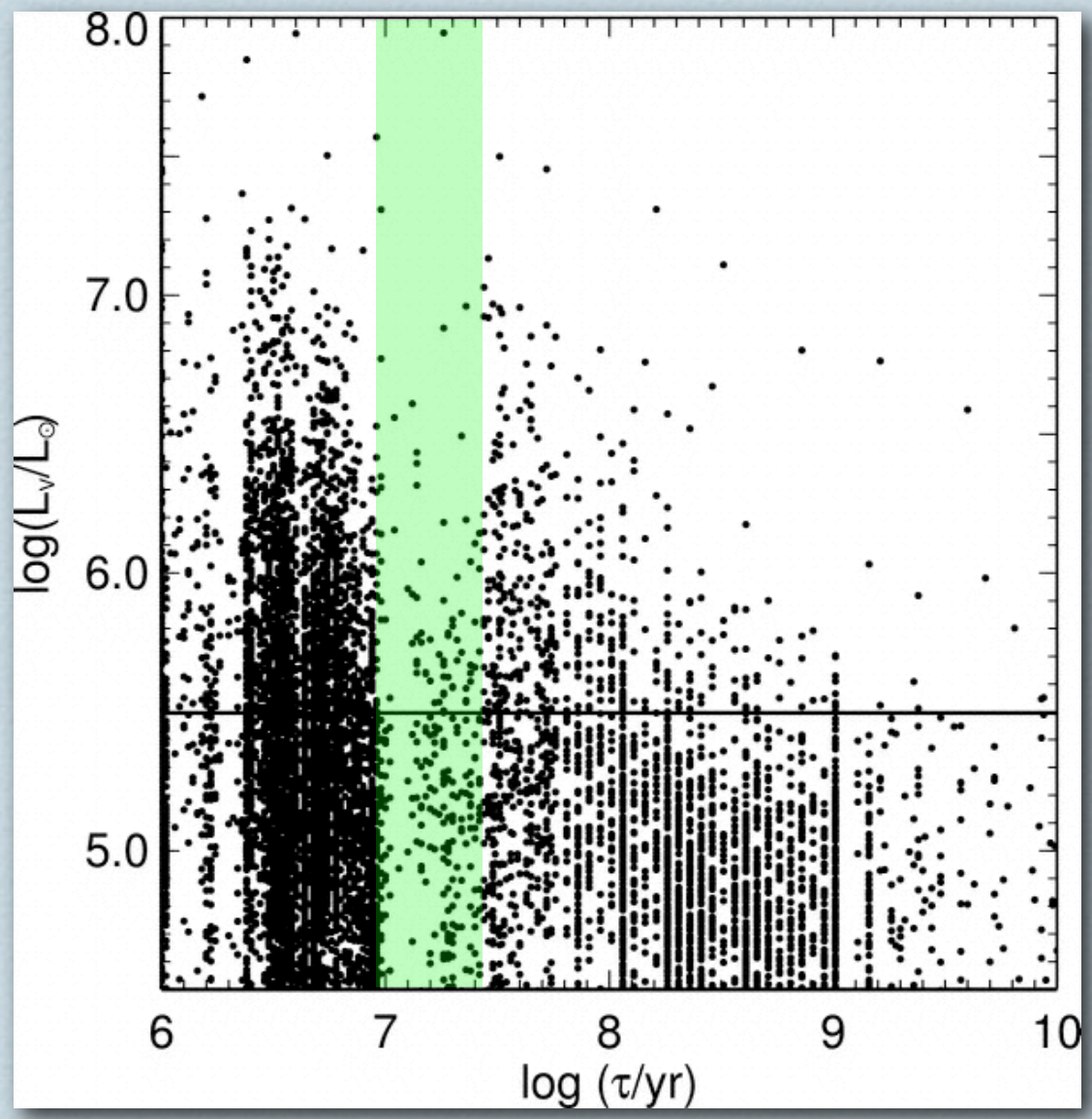
Uncertainties in SSPs

- Evolutionary tracks from different groups differ significantly for massive stars (e.g. treatment of mass loss, convection, rotation, etc.)
- Consequences for integrated properties predicted by SSP models



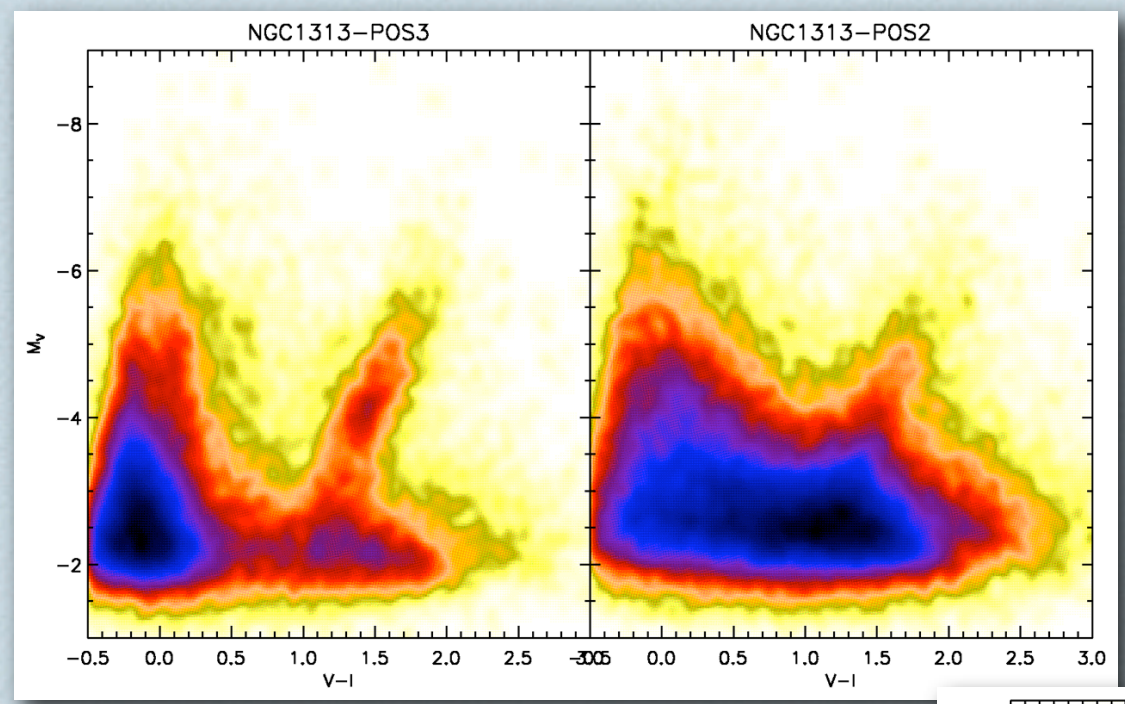
Consequences for cluster age-dating

Luminosity versus age for star clusters in the "Antennae"



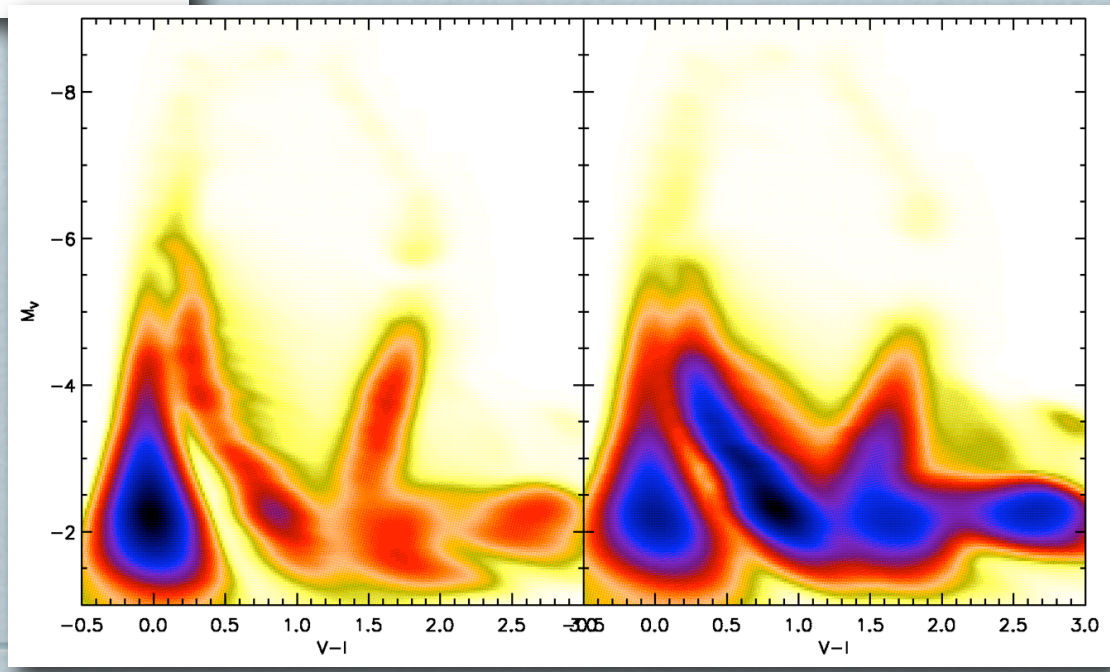
Whitmore, Chandar & Fall 2007

Reconstruction of CMDs

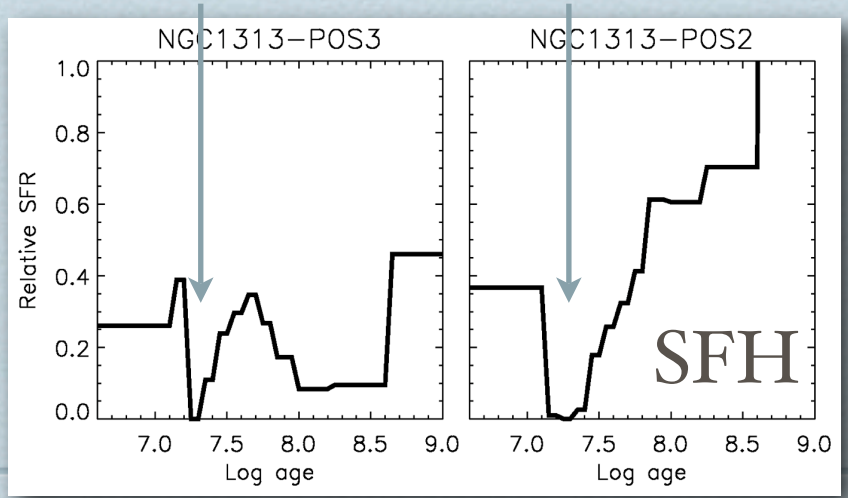


Observed CMDs
(NGC 1313, ACS/WFC)

Synthetic CMDs
(Padova isochr.)



RSG/BSG problems



YMCs in the MW

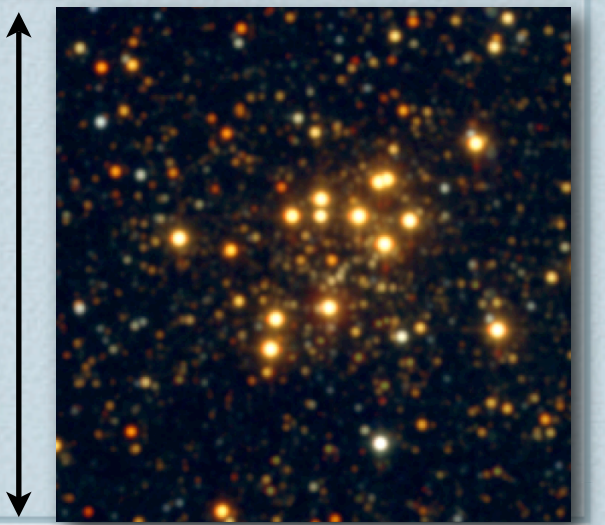
Westerlund 1:
Mass ~ 10^5 $M_\odot$
Age 3.5 - 5 Myr, Distance ~ 4 kpc, A_V~13 mag
(Westerlund 1961; Piatti et al. 1998; Clark et al. 2005; Kothes & Dougherty 2007)

The Super Star Cluster Westerlund 1
(2.2m MPG/ESO + WFI)

ESO PR Photo 09a/05 (22 March 2005) © European Southern Observatory

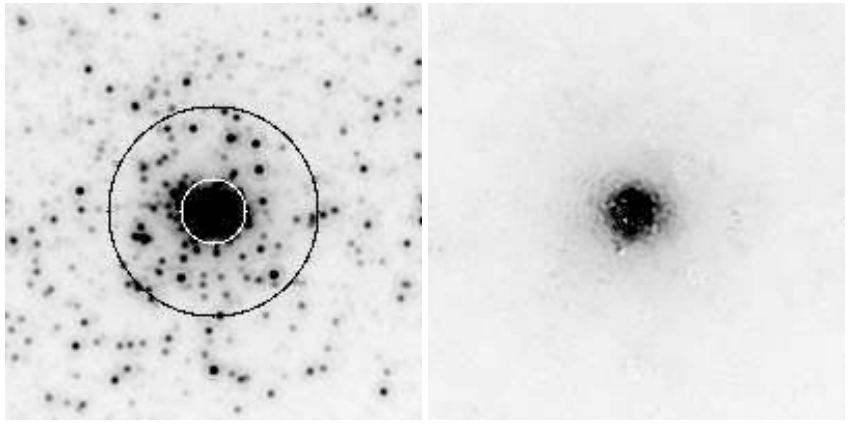
Cluster of 14 M supergiants:
Mass ~2×10^4 $M_\odot$ - 4×10^4 $M_\odot$
Age ~10 Myr, Distance ~ 5.8 kpc, A_V~25 mag
(Figer et al. 2006)

Rare and Hard to find!

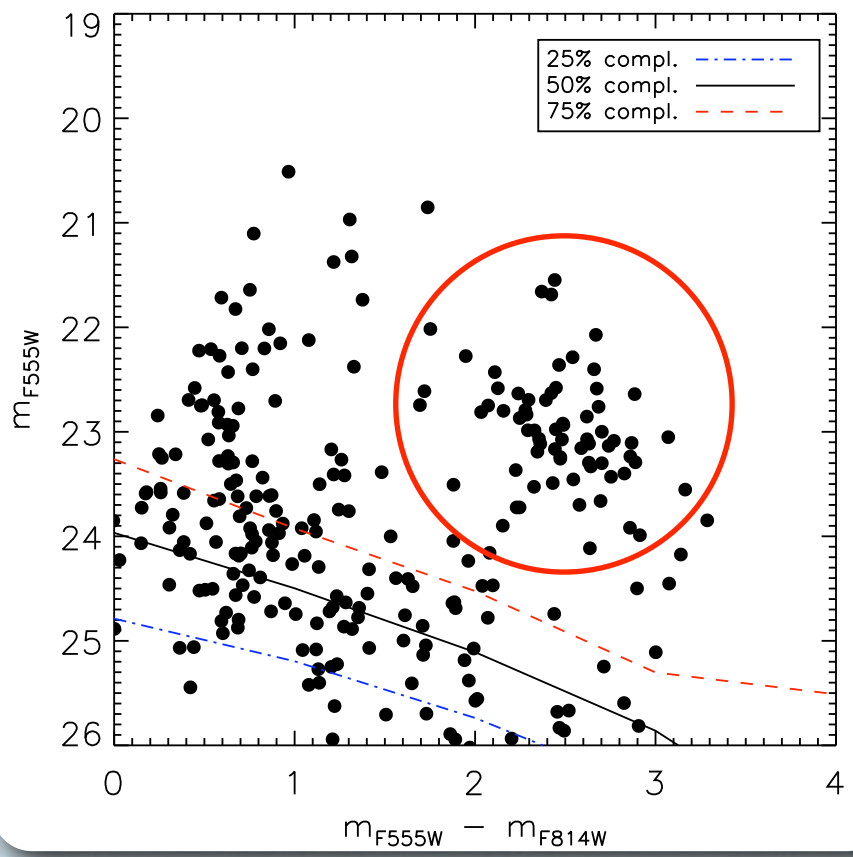


5' = 8.4 pc @ 5.8 kpc

NGC1569-B: Photometry of RSGs



HRC F814W image and residuals after ALLFRAME photometry

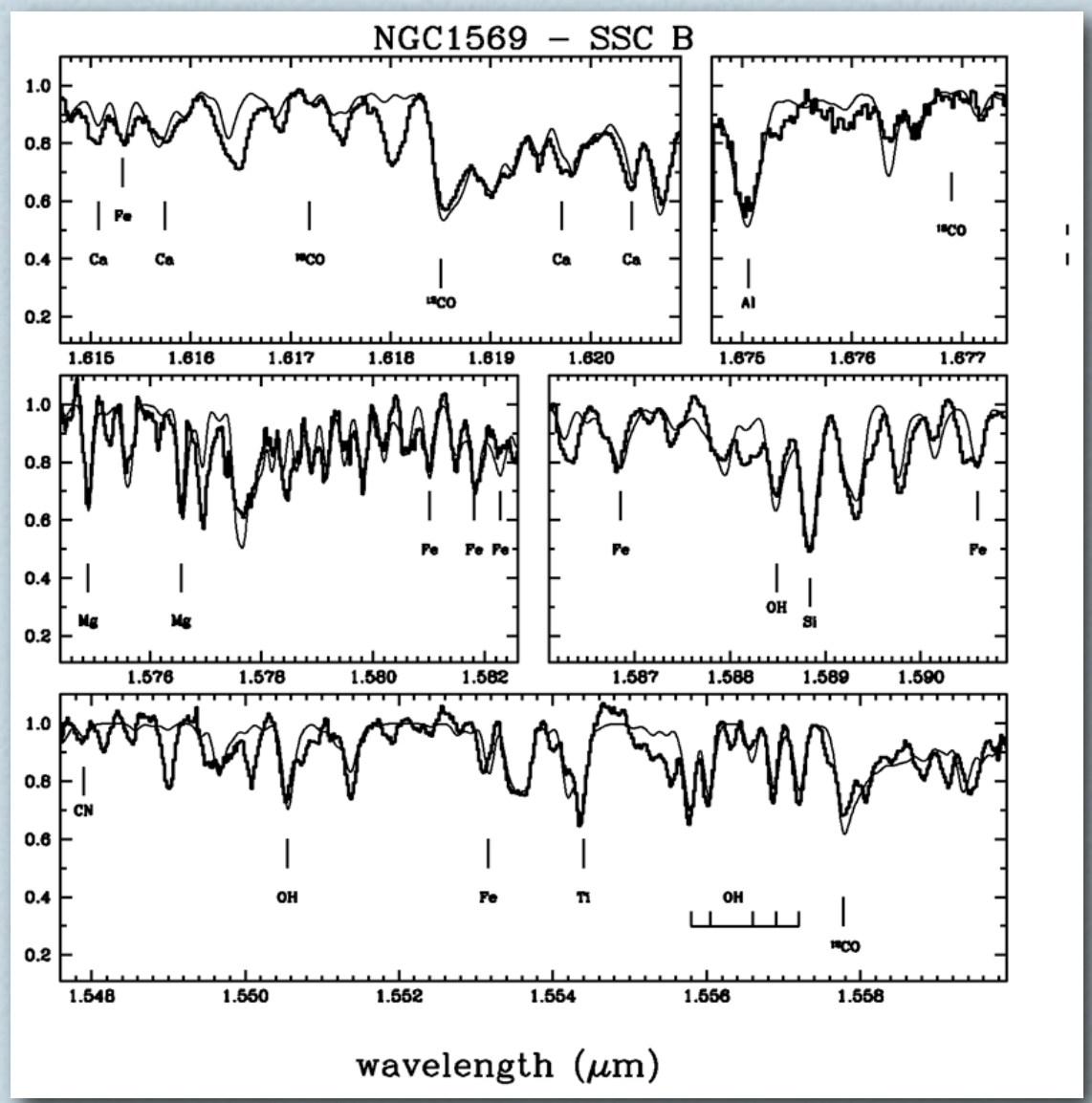


About 60 red supergiants detected outside 2 R_{hlr}! (largest number in Milky Way cluster = 26; Davies et al. 2007)

Larsen, Origlia et al. 2008

Data from GTO-9300 (P.I: H. Ford)

NGC1569-B: Near-IR spectroscopy



RSG properties

- From spectra:
  - T_{eff} = 3800+/-200 K
  - Log g = 0.0 +/- 0.5
- From CMD:
  - T_{eff} = 3850 K
  - Log g = 0.1

Abundances:

[Fe/H] = -0.63

[O/Fe] = 0.34

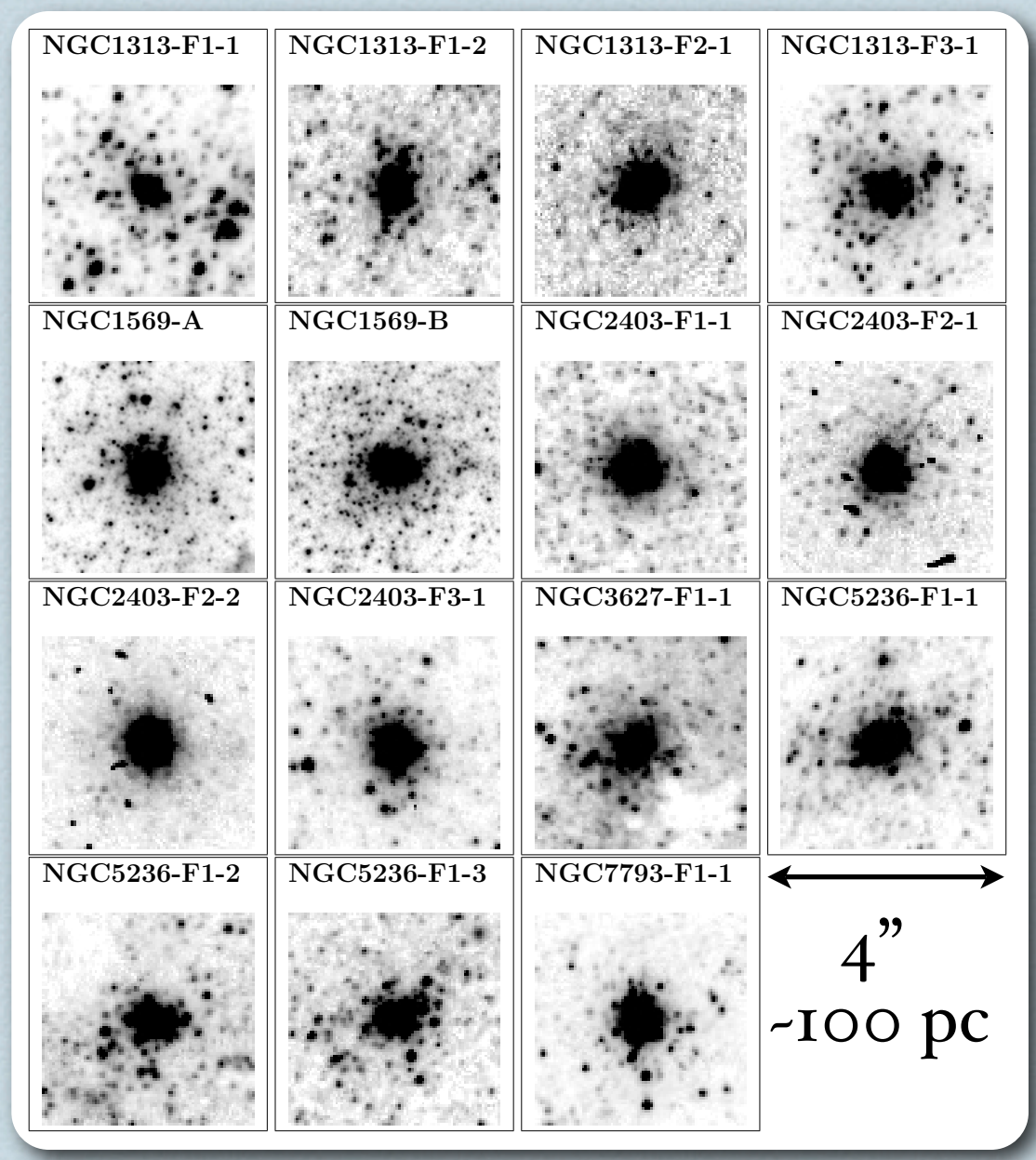
$^{12}C/^{13}C$ = 5

Keck/NIRSPEC H-band
Larsen, Origlia et al., 2008.

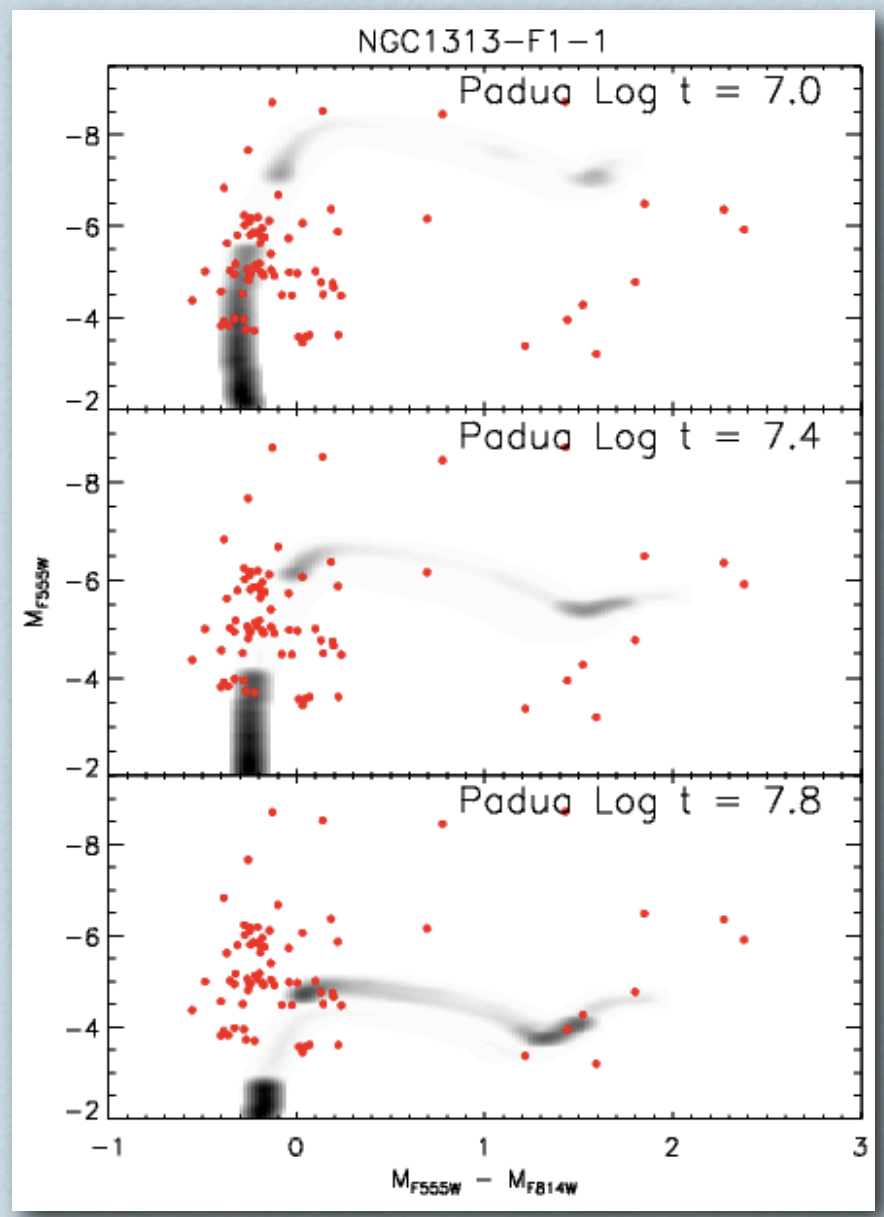
ACS/WFC images of YMCs

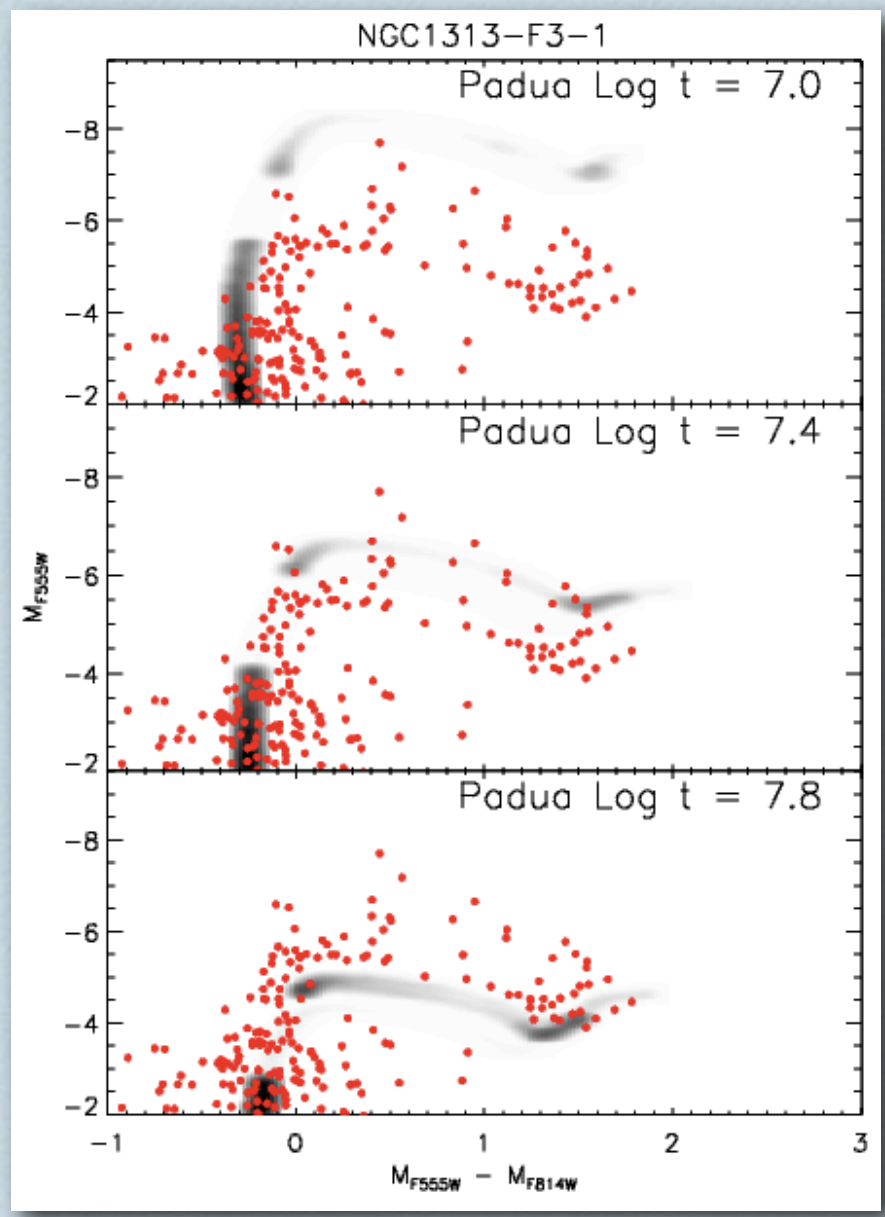
Several young (<10^8 yr), massive (>10^5 $M_\odot$) star clusters in nearby (~5 Mpc) galaxies already imaged by ACS/WFC.

Resolution (of outer parts) into individual stars evident.

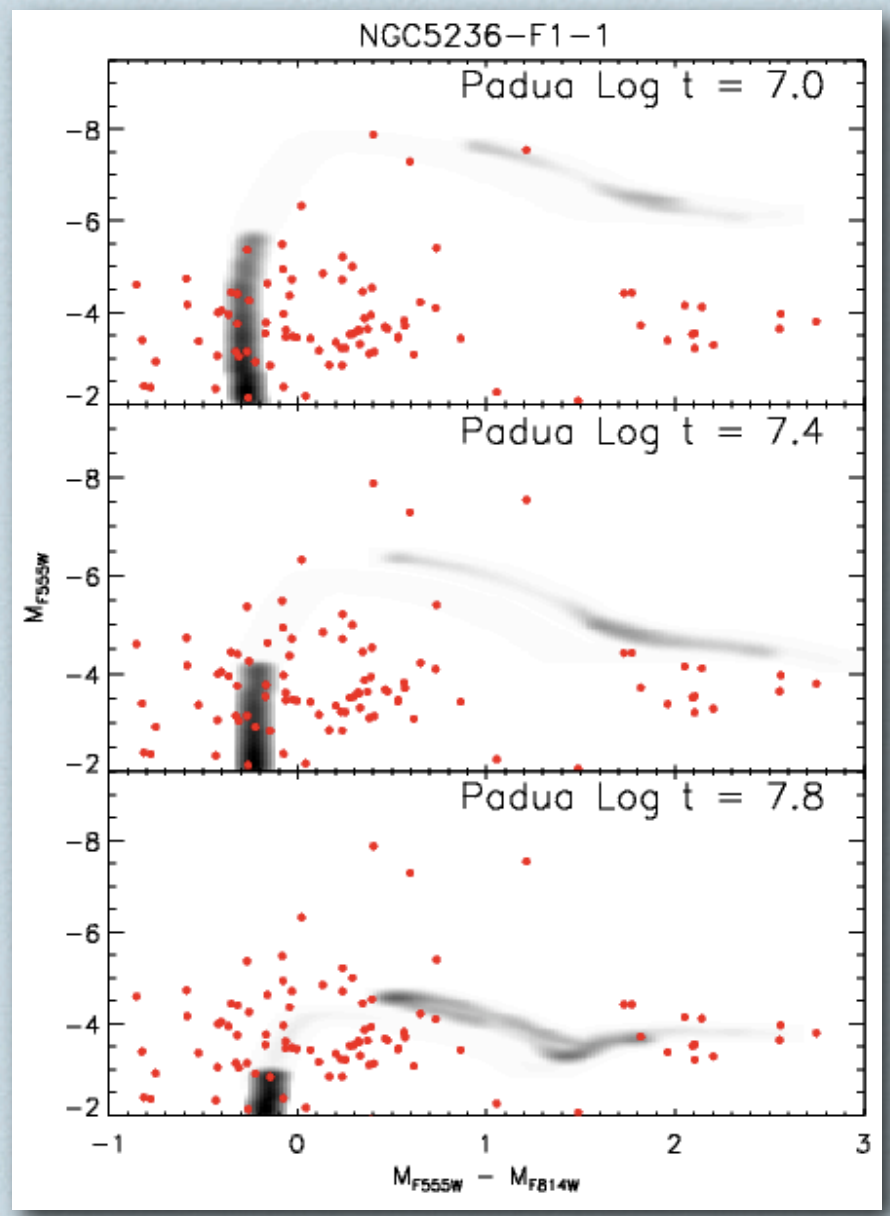


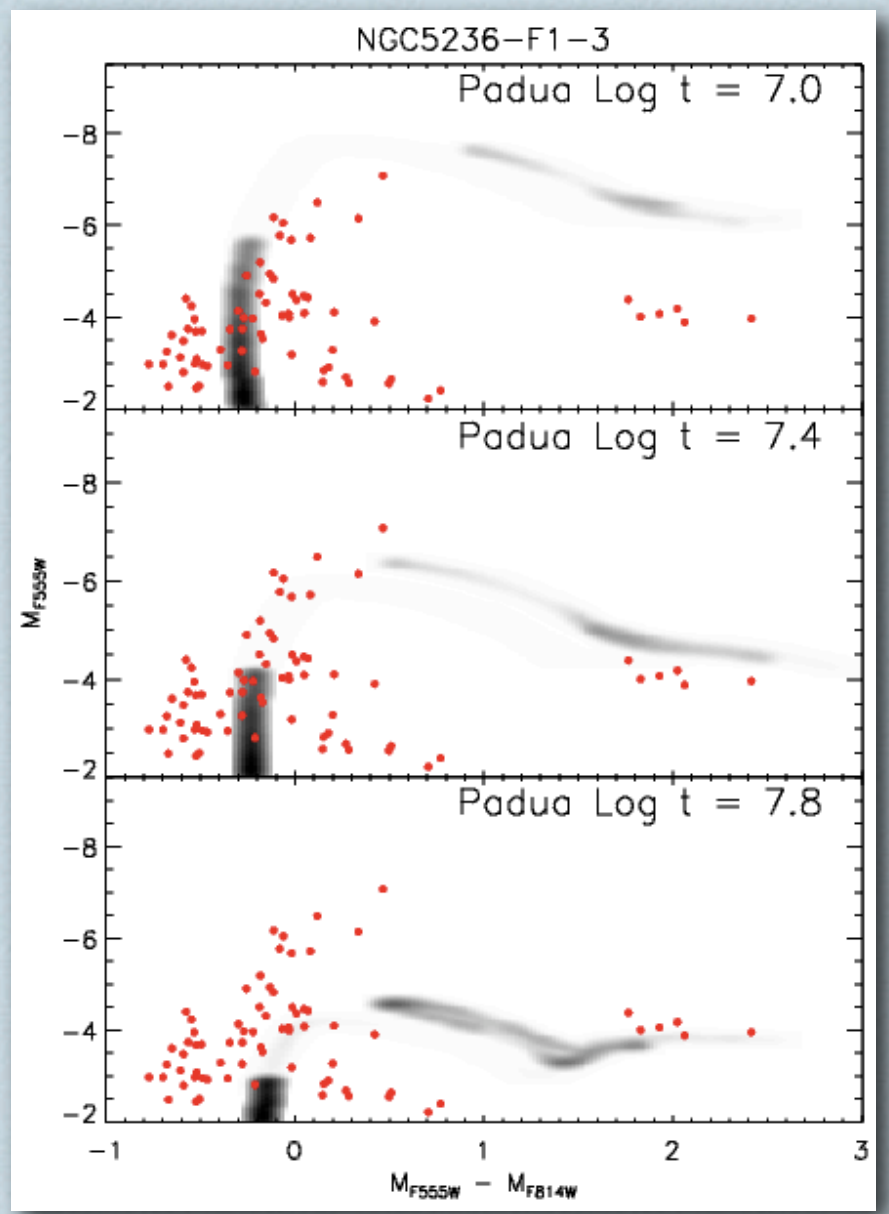
Observed and model CMDs



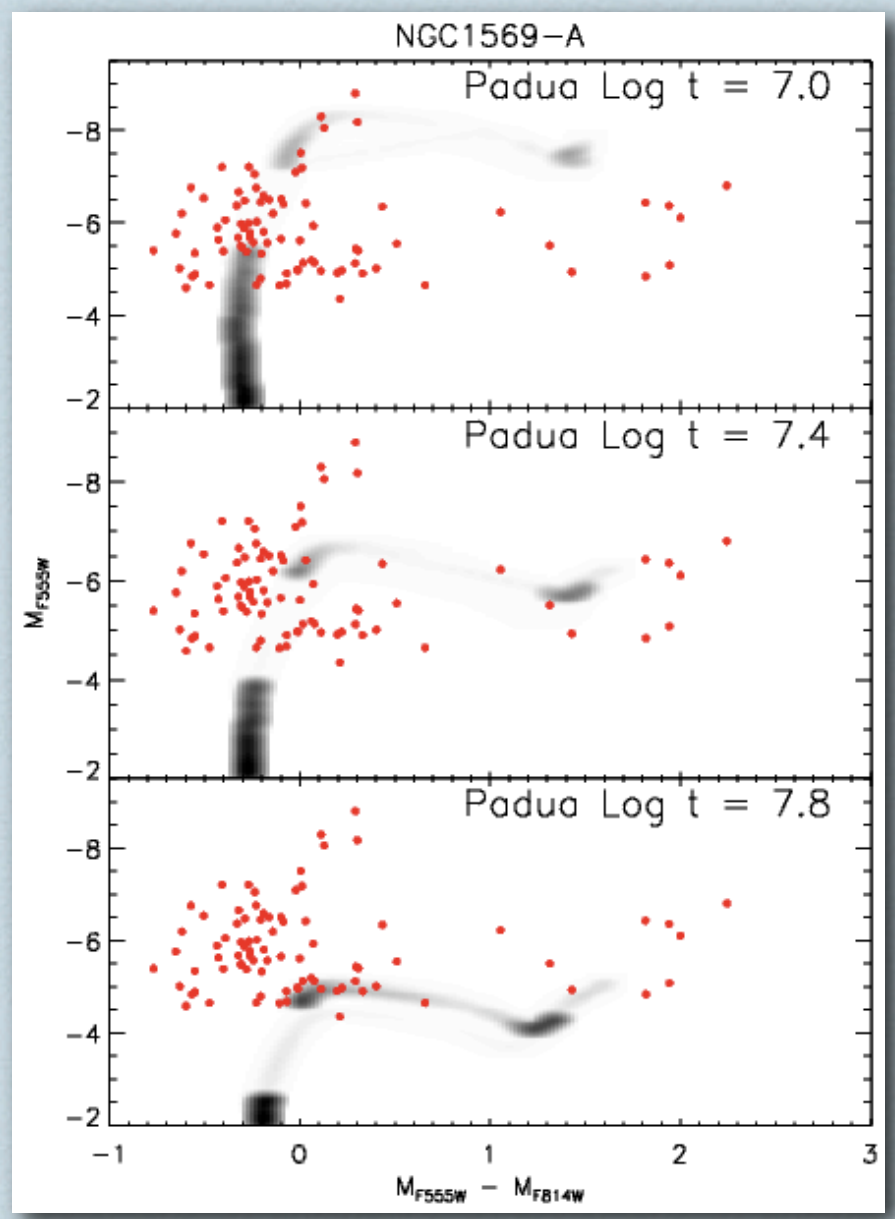


NGC 1313: Z ~ Z_{LMC} (Walsh & Roy 1997)

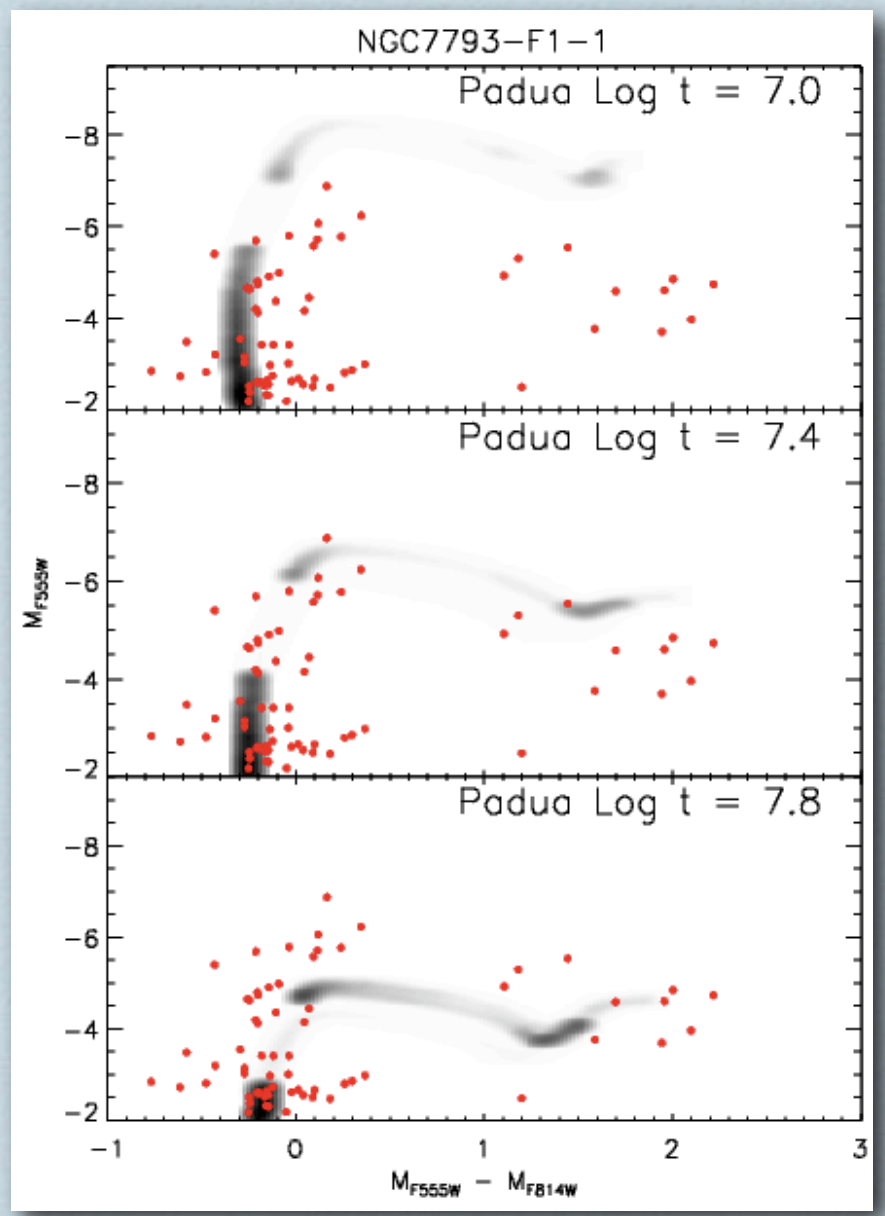




NGC 5236: Z ~ Z_{Sun} (Bresolin & Kennicutt 2002)



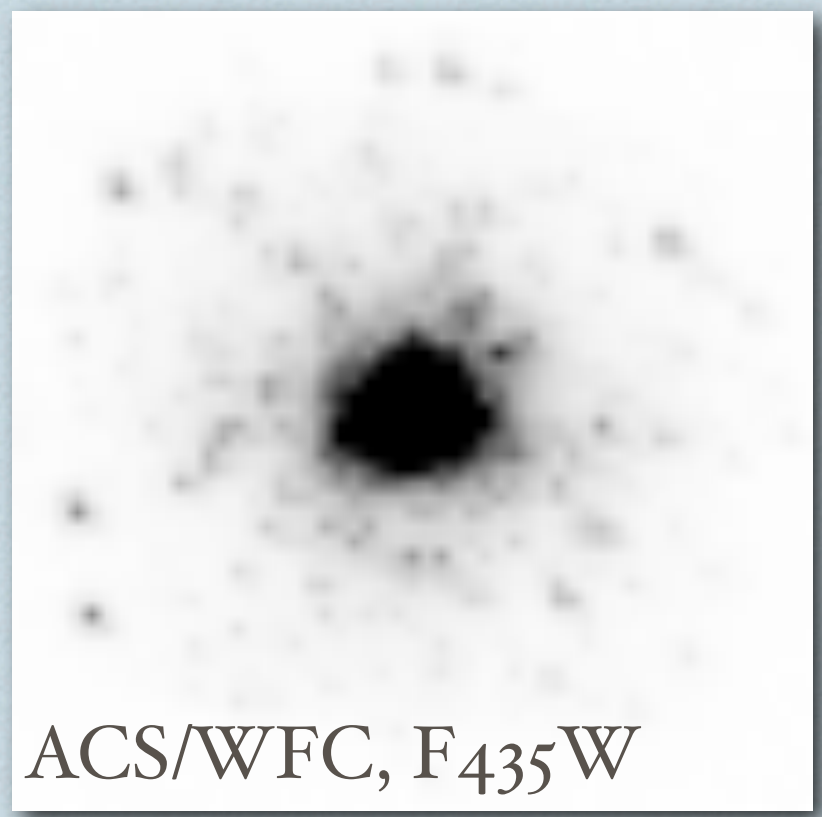
Z~Z_{SMC}
(Kobulnicky & Skillman 1997)



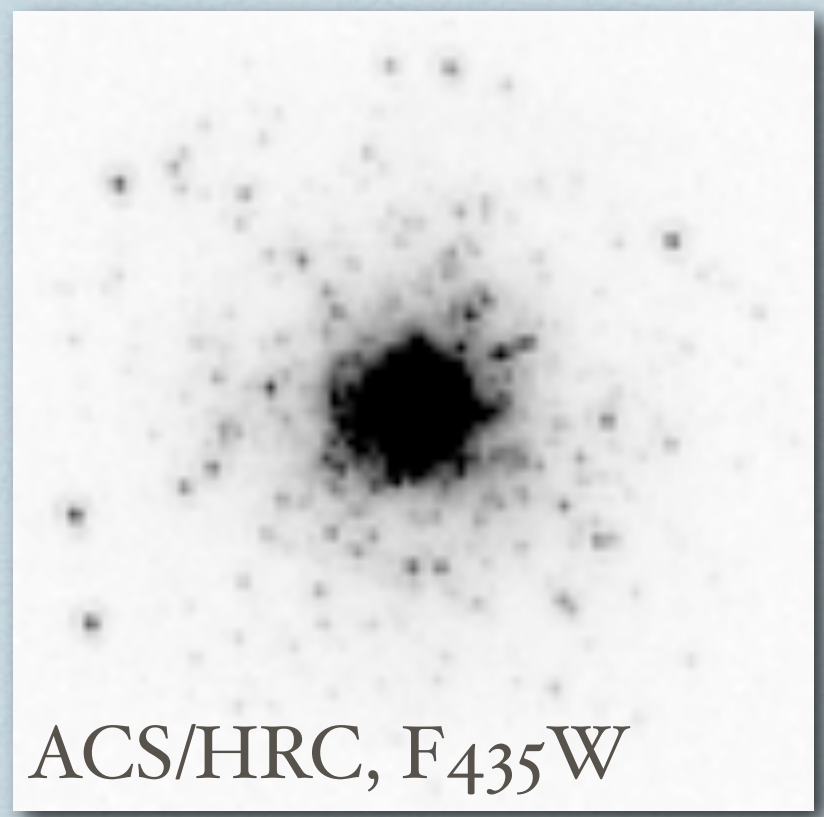
Z~Z_{LMC}
(Edmunds & Pagel 1984)

Simulated data

M = 10^5 $M_\odot$, Age = 30 Myr, D = 4 Mpc



ACS/WFC, F435W



ACS/HRC, F435W

Factor ~2 improvement in resolution - critical for crowded-field photometry!

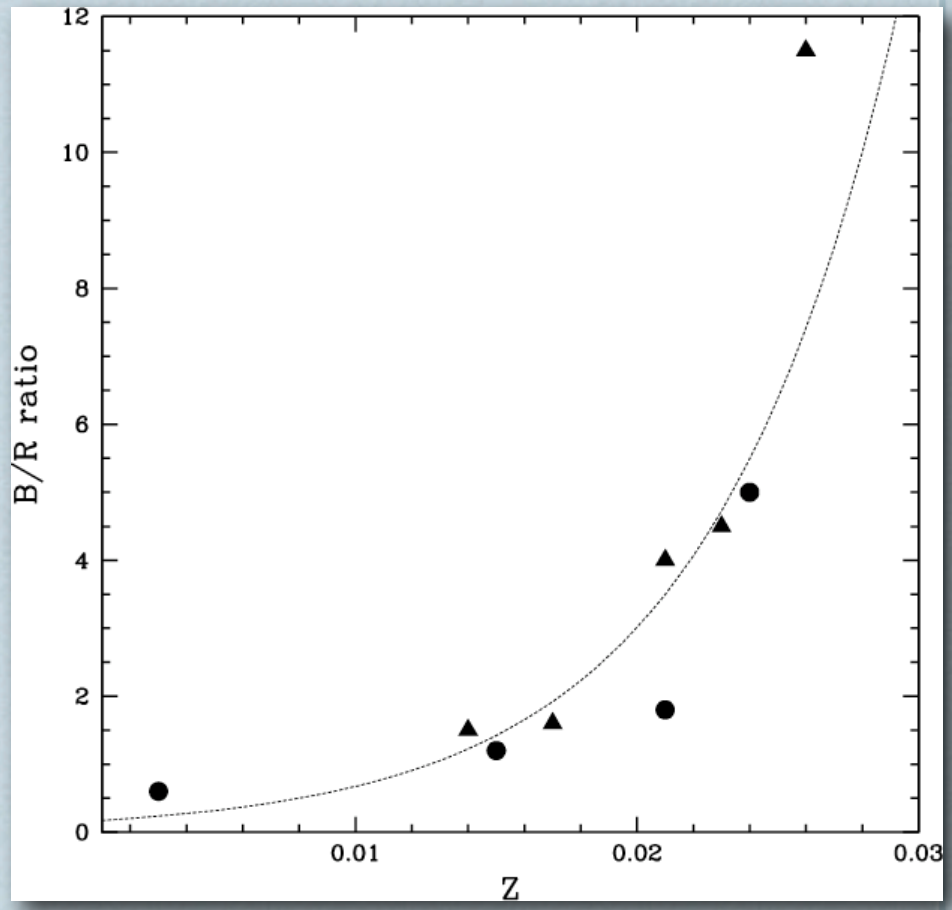
The blue to red supergiant ratio

Observed B/R ratio increases with Z. Contrary to model predictions.

- Mass loss?
- Convection?
- Rotation?

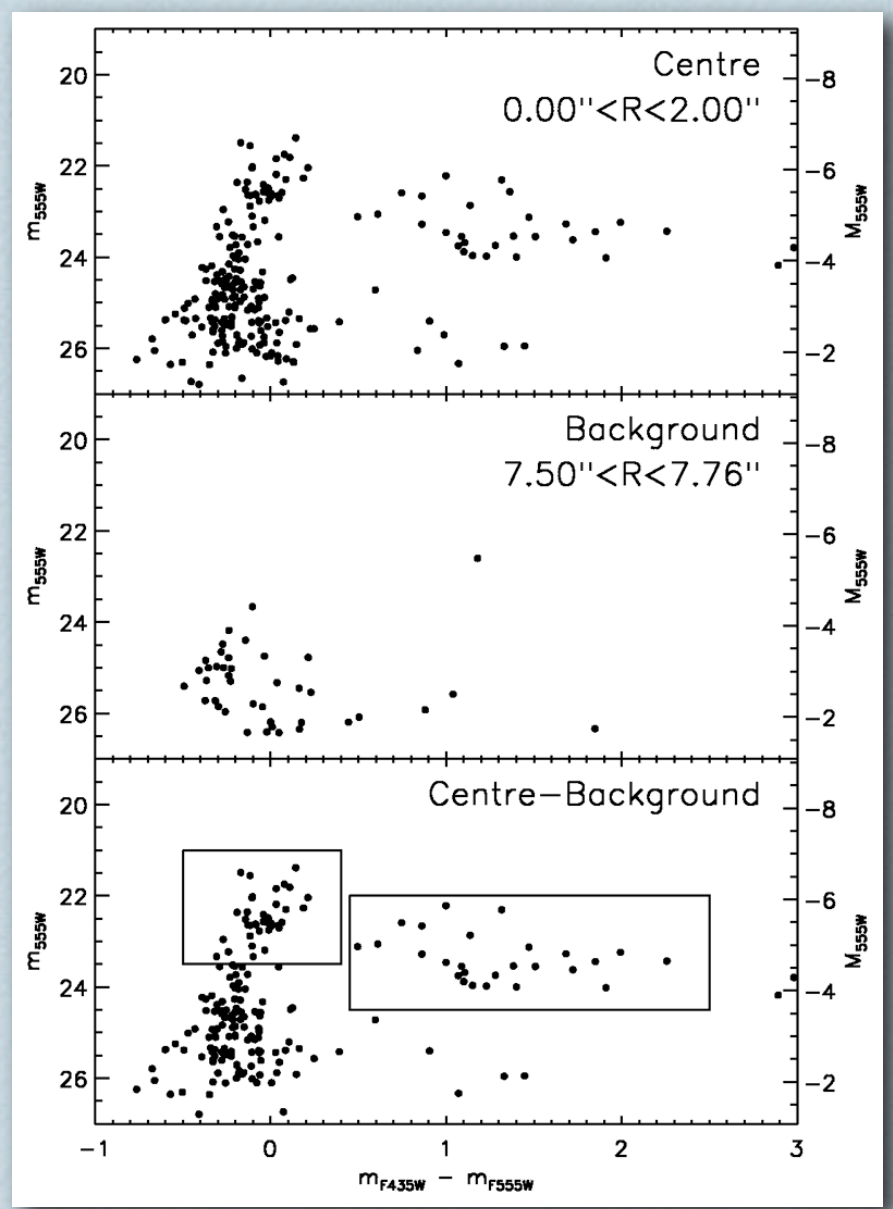
Does B/R ratio also depend on stellar mass? Expected from models, but current data insufficient to tell.

Field stars: confusion with main seq. stars; range of masses present.



Eggenberger et al. 2002

B/R ratio in NGC1313-F3-1



Observed B/R ratio = 1.4 +/- 0.4
(log t ~ 7.7, M_{TO}=7 $M_{\odot}$, Z~0.008)

Model predictions:
Padova - B/R = 0.73
Geneva - B/R = 0.8

YMCs: constrain properties (T_{eff}, log g) of RSGs and BSGs and the B/R ratio vs. age (mass) and Z.

Summary

- New and existing instruments on HST (ACS, WFC3) ideal for studying extragalactic star clusters.
- Need the maximum possible resolution to resolve individual stars.
- CMDs for several “young GCs” within reach!
- Combination of optical/UV colours will maximise resolution and provide stellar parameters for both hot and cool stars