Feedback efficiency in young stellar clusters in M83

Katherine Hollyhead, ARI

Nate Bastian, Angela Adamo, Esteban Silva-Villa, Jim Dale, Jenna Ryon and Zack Gazak

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Nearby galaxies provide extensive cluster populations to study their formation and evolution through photometry and spectroscopy e.g. M83

How long do clusters remain embedded in pre-natal gas?

Face on spiral galaxy at 4.5 Mpc – close enough to resolve individual clusters with HST

M83, from APOD

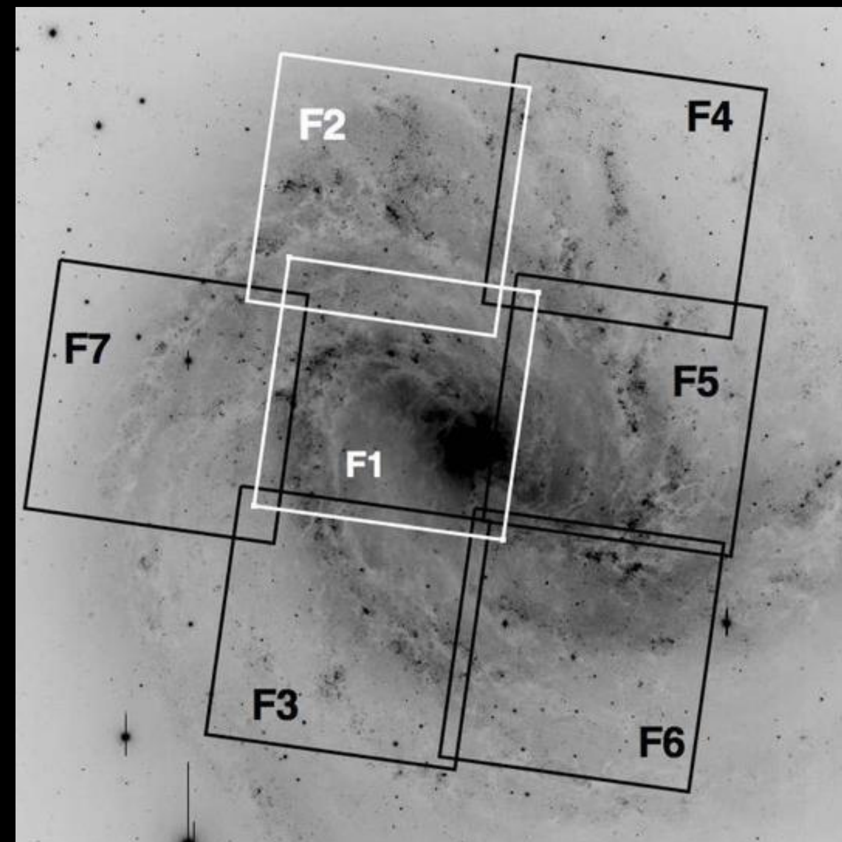
HST data available in U, B, V, Hα and I bands on Hubble Legacy Archive (HLA)

Already widely studied cluster population - e.g. Chandar et al, 2010, Whitmore et al, 2011, Bastian et al, 2012, Silva-Villa et al, 2013, Adamo et al, 2015

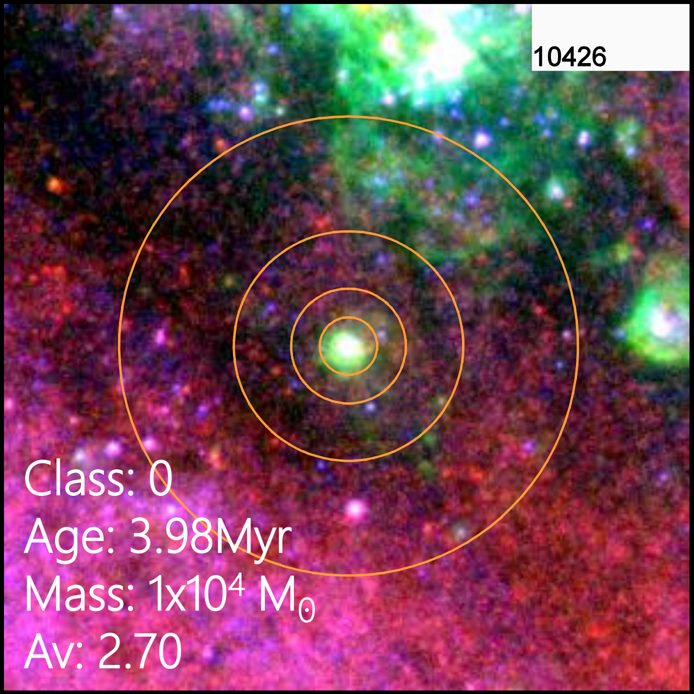
Optically selected cluster catalogue from Bastian et al, 2012 and Silva-Villa et al, 2014 with photometry in U, B, V, Hα and I bands and estimates of ages and masses (Adamo et al, 2010a, b)

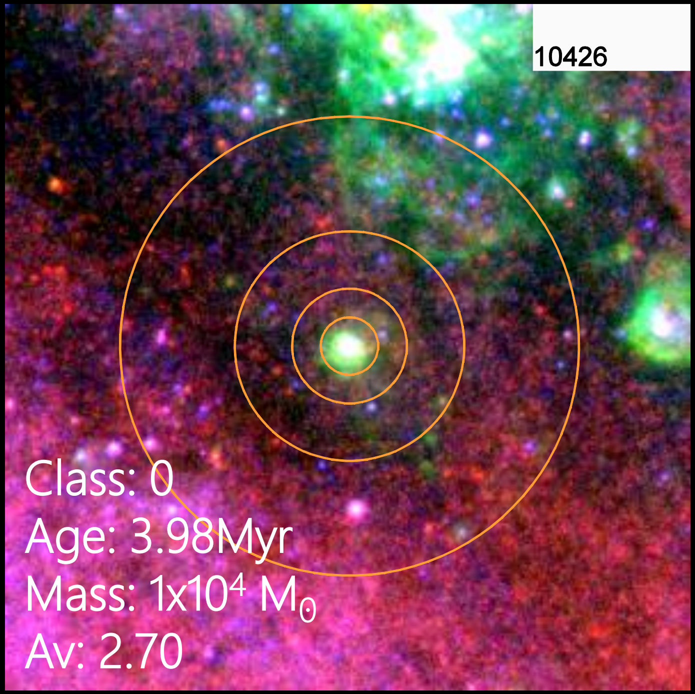
Youngest (<10 Myr), most massive (>5000 M) were visually inspected in B, Hα and V images to classify Hα morphology

92 clusters in the sample



Blair et al, 2014


10426
Class: 0
Age: 3.98Myr
Mass: 1x10^4 M$_0$
Av: 2.70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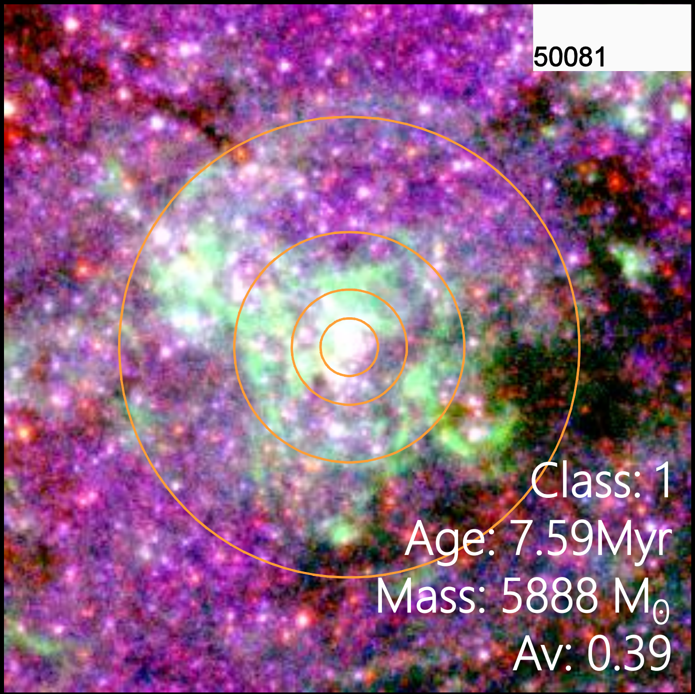
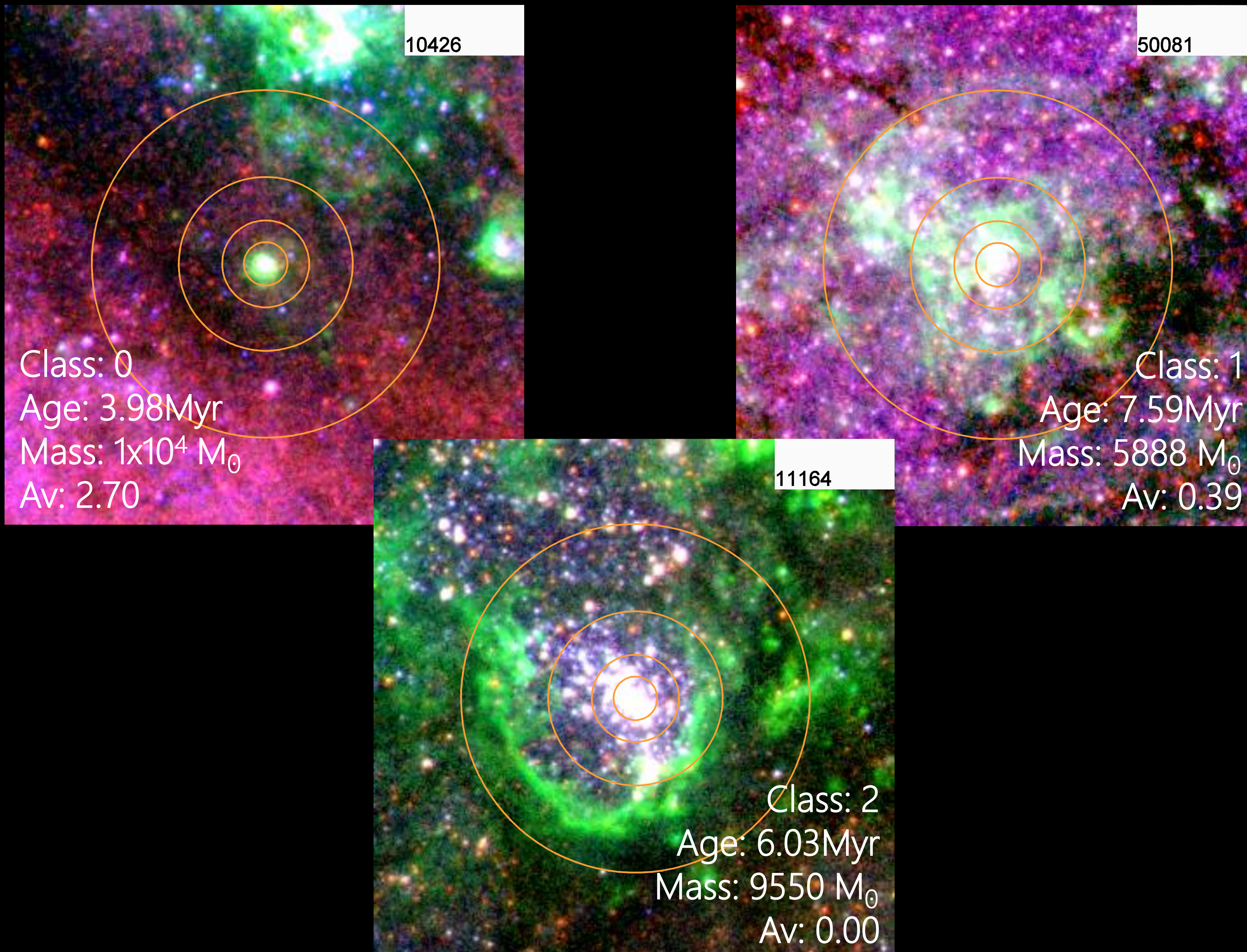

50081
Class: 1
Age: 7.59Myr
Mass: 5888 M$_\odot$
Av: 0.39


10426
Class: 0
Age: 3.98Myr
Mass: $1\text{x}10^4$ $M_\odot$
Av: 2.70
50081
Class: 1
Age: 7.59Myr
Mass: 5888 $M_\odot$
Av: 0.39
11164
Class: 2
Age: 6.03Myr
Mass: 9550 $M_\odot$
Av: 0.00

35 exposed, 16 partially embedded and 15 embedded clusters, other clusters removed (poor photometry etc)

Continuum subtracted Hα images confirm exposed/embedded classification

Colour-colour plot indicates clusters are gas free by 2-3 Myr

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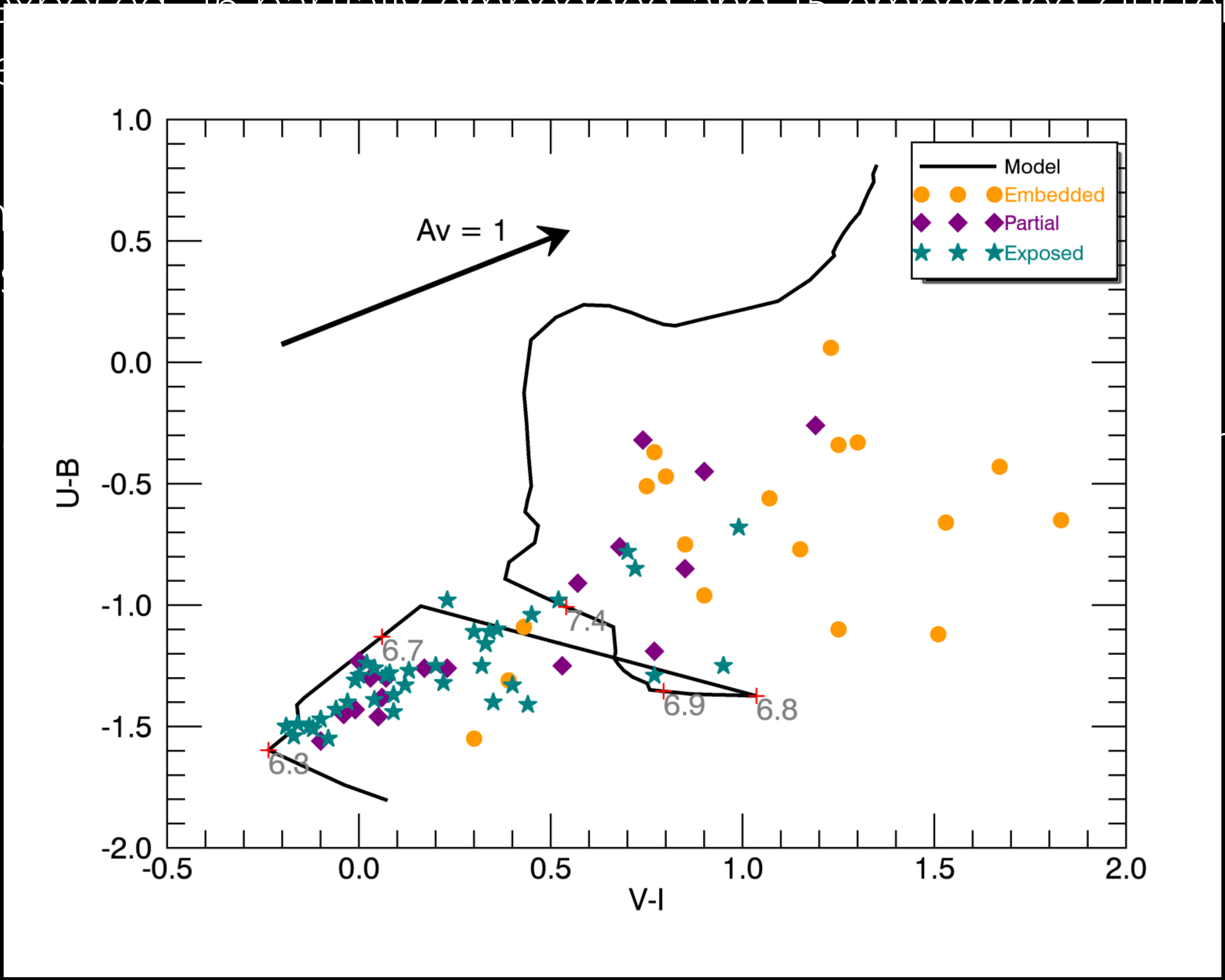
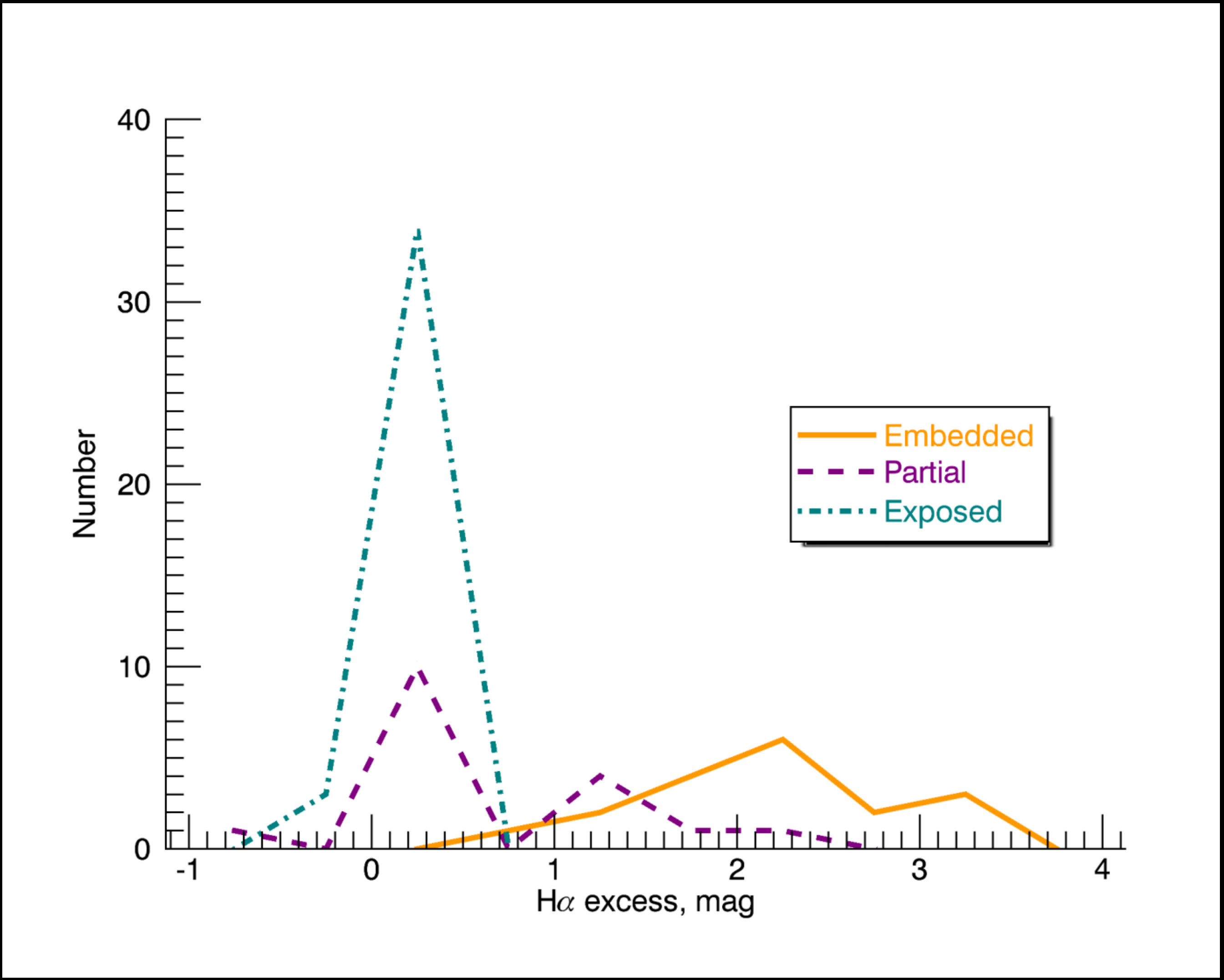


Model from Zackrisson et al, 2011

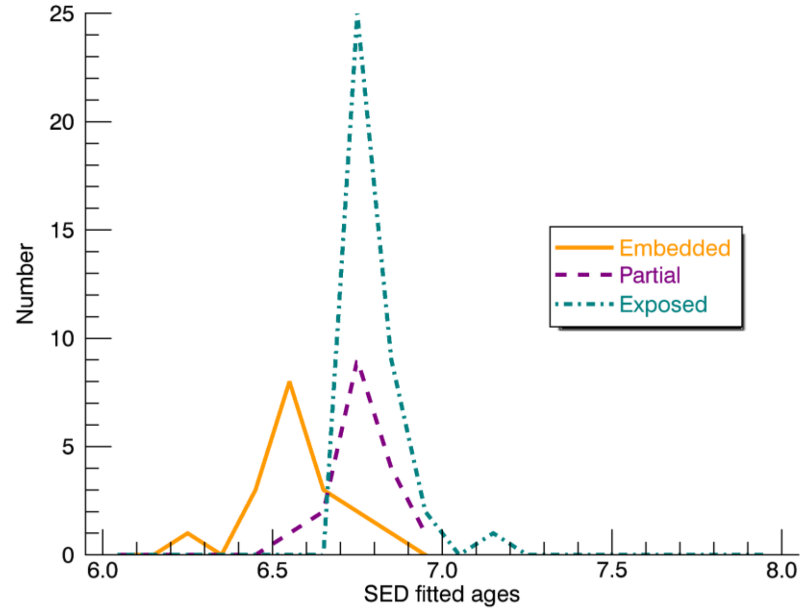
Hα can complicate SED age fitting of young clusters for newly exposed clusters with no Hα contribution – given older ages

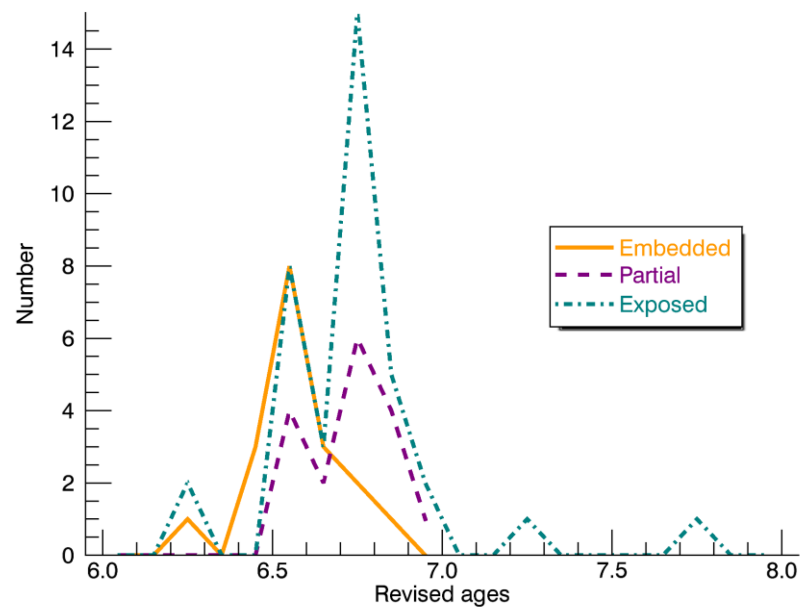


Some clusters free of gas are fitted better with only U, B, V and I

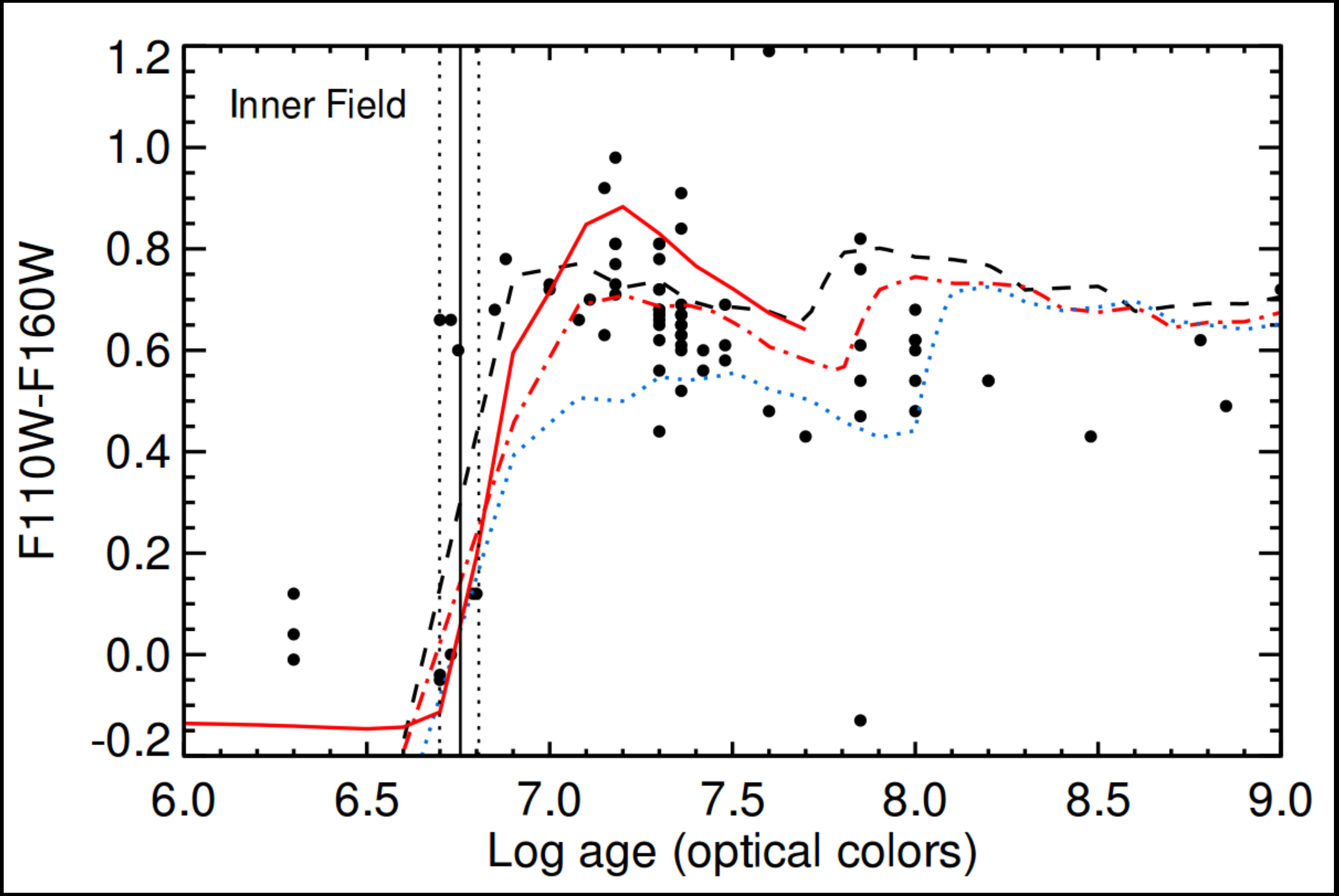
Combining colour-colour plot position, Av and level of Hα excess can choose most accurate fit

Age distribution indicates that gas removal is a very rapid process





Gazak et al, 2013 showed it was possible to constrain cluster ages using the presence of RSGs



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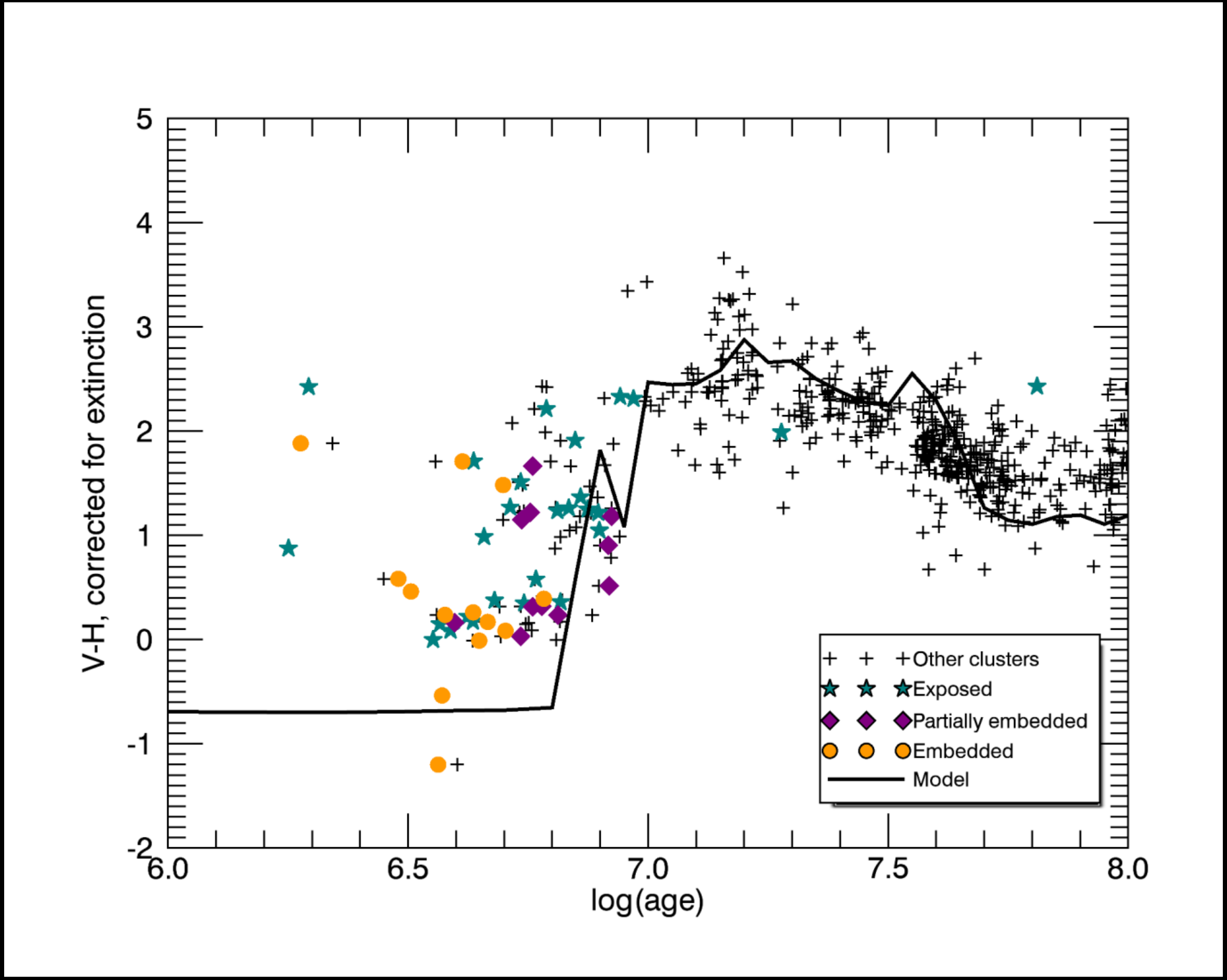

Hollyhead et al, 2015

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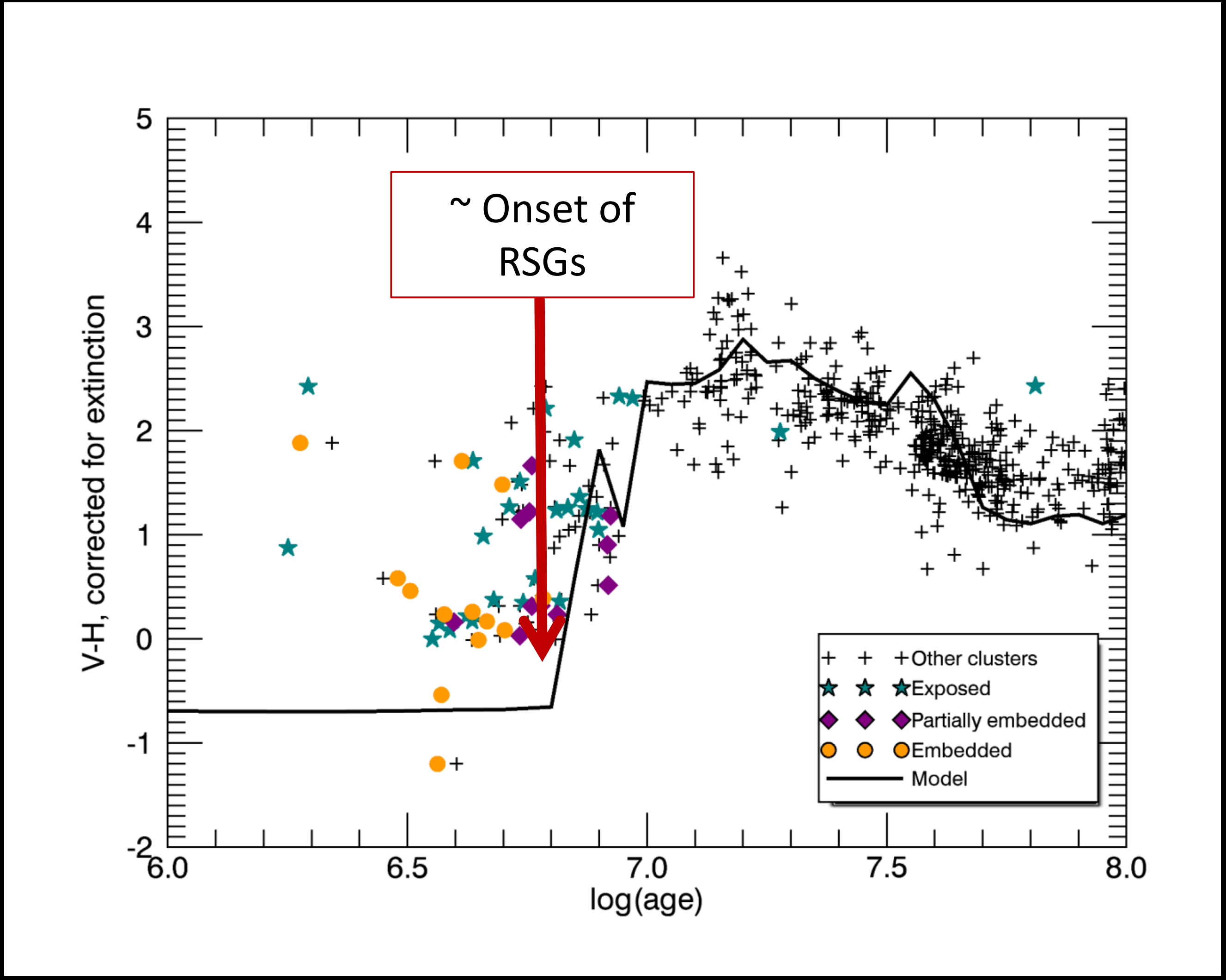
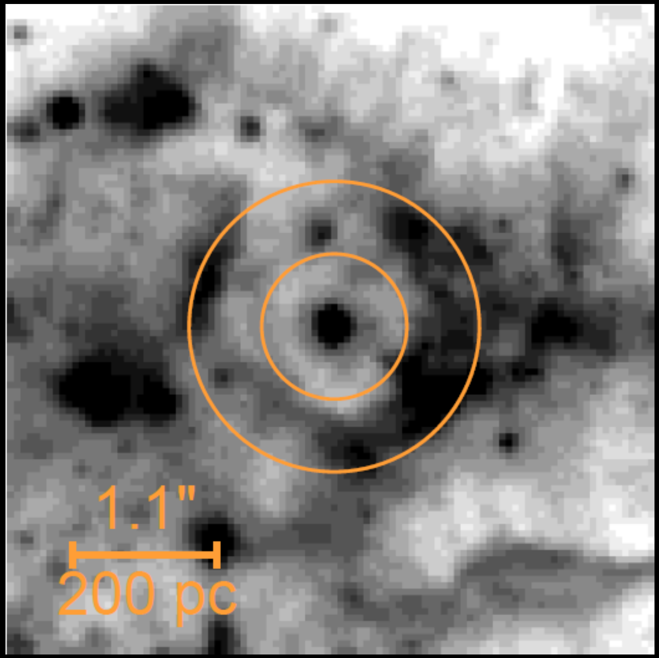


Hollyhead et al, 2015

Timescales for gas removal are consistent across all cluster mass regimes



Östlin et al, 2007
Bastian et al, 2014

Bastian et al, 2014 found clusters with masses > 10^6 $M_\odot$ that were exposed at ages < 6 Myr

Cluster 23 in ESO 338-IG04 – metal poor galaxy similar to GCs – with mass 5-20 x 10^6 $M_\odot$ and age ~6 Myr clearly exposed

Gas is moving out at ~ 40 km/s and size of bubble indicates first gas free ~ 2-3 Myr

Potential factors for rapid gas removal

Originally thought to be gas expulsion but gas exhaustion could play a larger part (remember Diederick Kruijssen's talk on Monday!)

High depletion of gas in star formation process could make it easier for surrounding gas to be driven away from the cluster producing the bubbles we see around exposed clusters – no extra feedback needs to be invoked

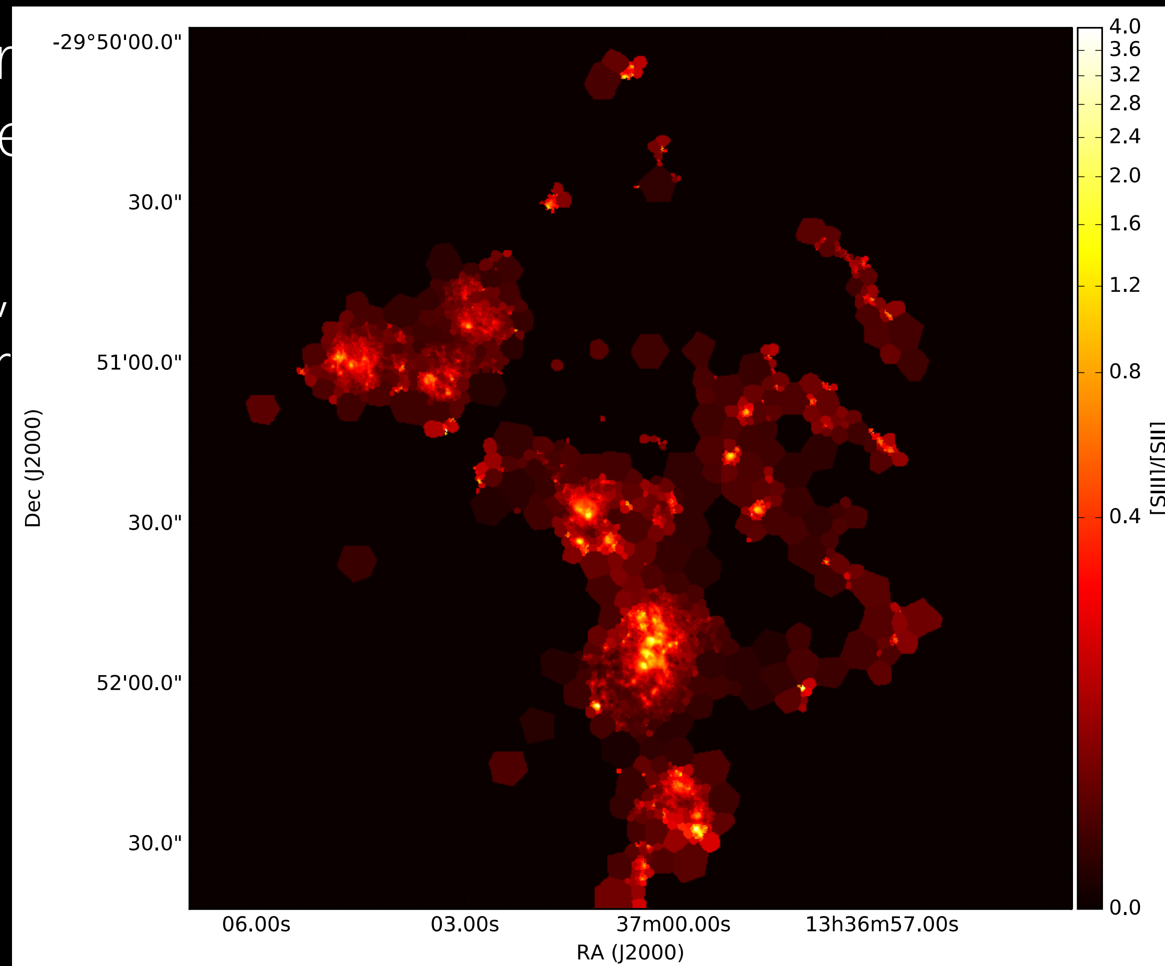
6 Wolf Rayet regions from Hadfield et al, 2005 overlap with clusters in our catalogue – could help remove nearby gas, or very high mass stars (> 100 $M_{\odot}$) with WR like features in the first few Myr (Smith et al, 2016)

Further work

Further study into the presence of WR stars in clusters in M 83 with MUSE data (PI Angela Adamo)

Survey by Hadfield et al, 2005 did not have full coverage of the galaxy – this data can provide further insight into the presence of WR stars in clusters

Further work

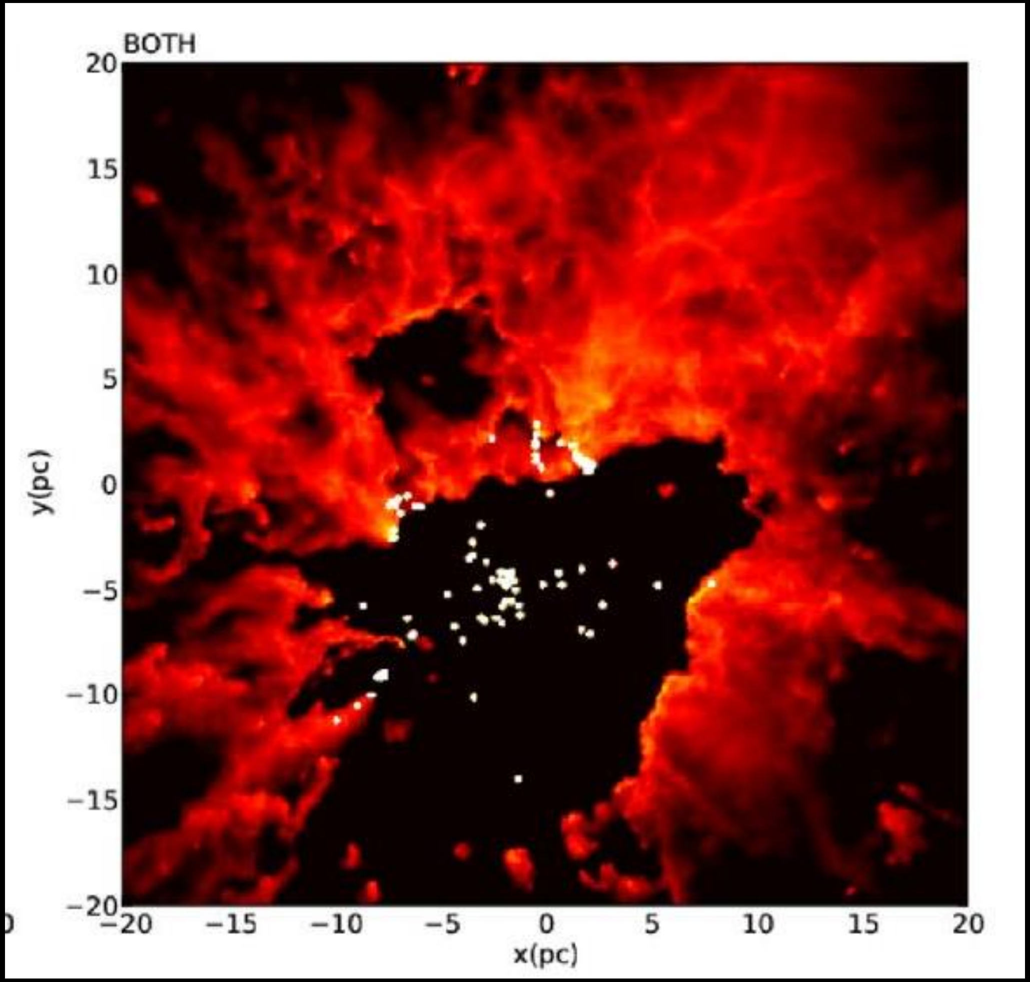


In conclusion

- Clusters begin to become gas free by 2-3 Myr
- Consistent time scales across all cluster masses
- Gas exhaustion plays a large role in the lack of gas seen in young clusters

Simulations by Dale et al, 2014 are in agreement with timescales of gas removal, with bubbles formed by 3 Myr for clusters of similar mass to our M83 sample

Simulations include ionisation and stellar winds from OB stars, though no radiation pressure



Dale et al, 2014