Spectrophotometric properties of cluster galaxies: galaxy evolution and cluster structure at z > 0.8

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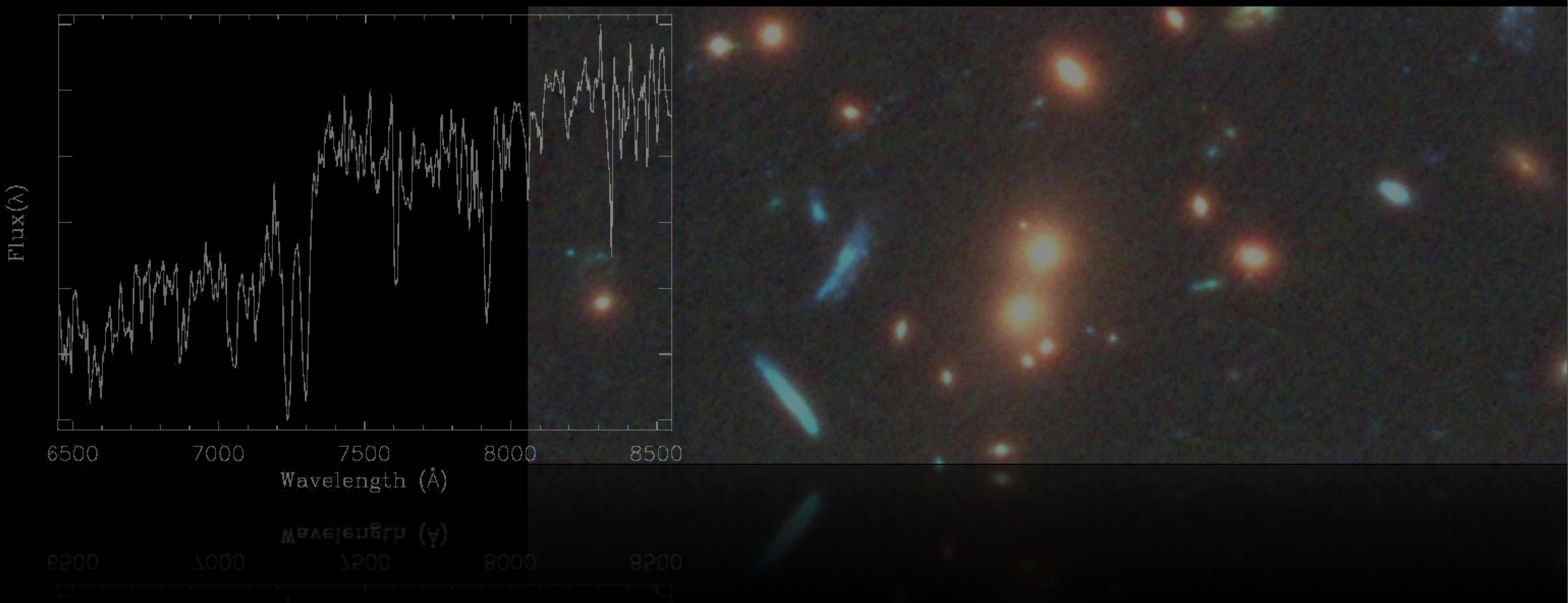

Collaborators

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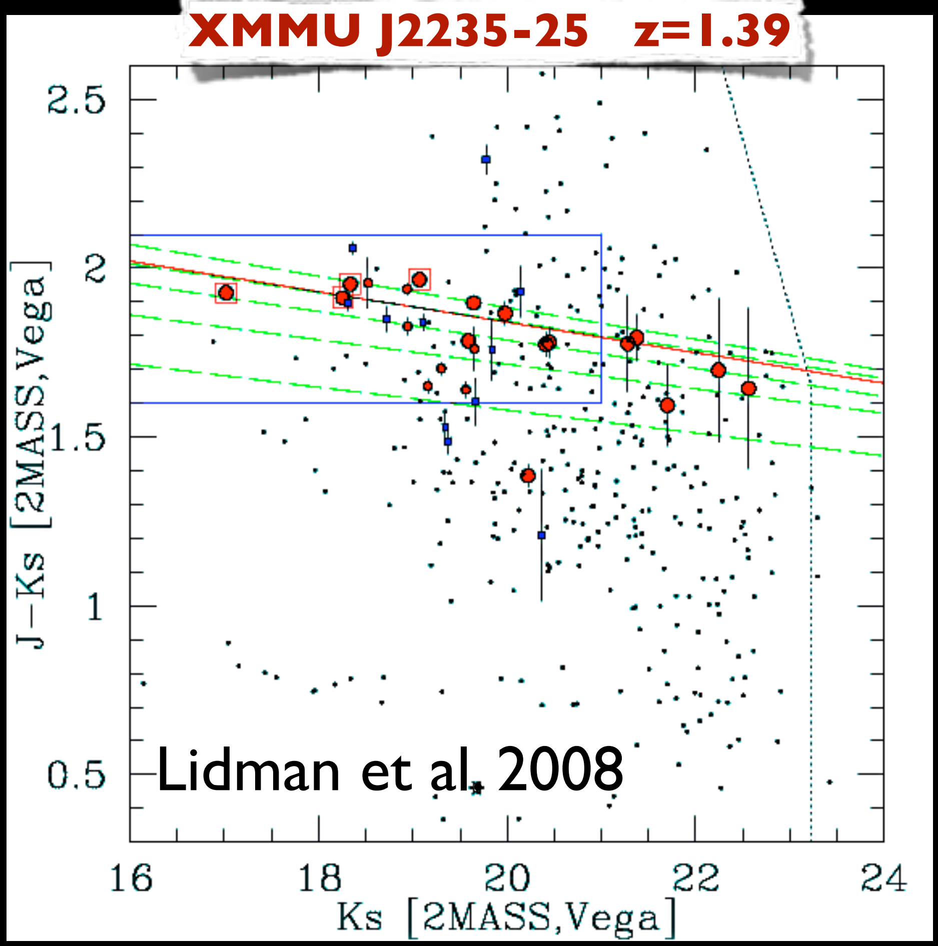
Gillian Wilson (UCR)
Adam Muzzin (Yale)



The Red-Sequence at z~1.4

(Lidman et al. 2008; Hilton et al. 2009)

First appearance of the Red-Sequence in protoclusters at $2 \lesssim z \lesssim 3$

(Kodama et al. 2007)

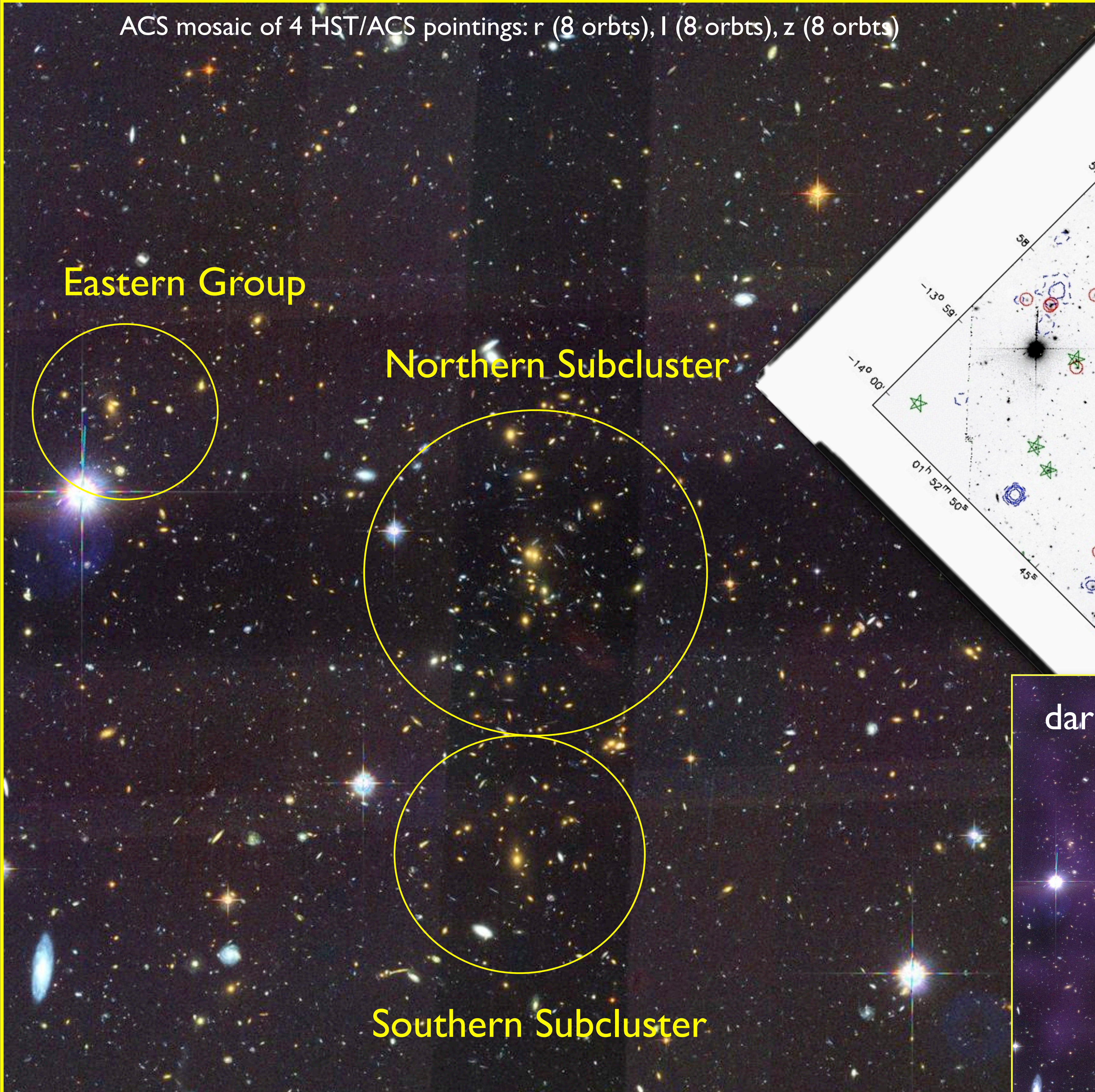
Massive galaxies at z~2

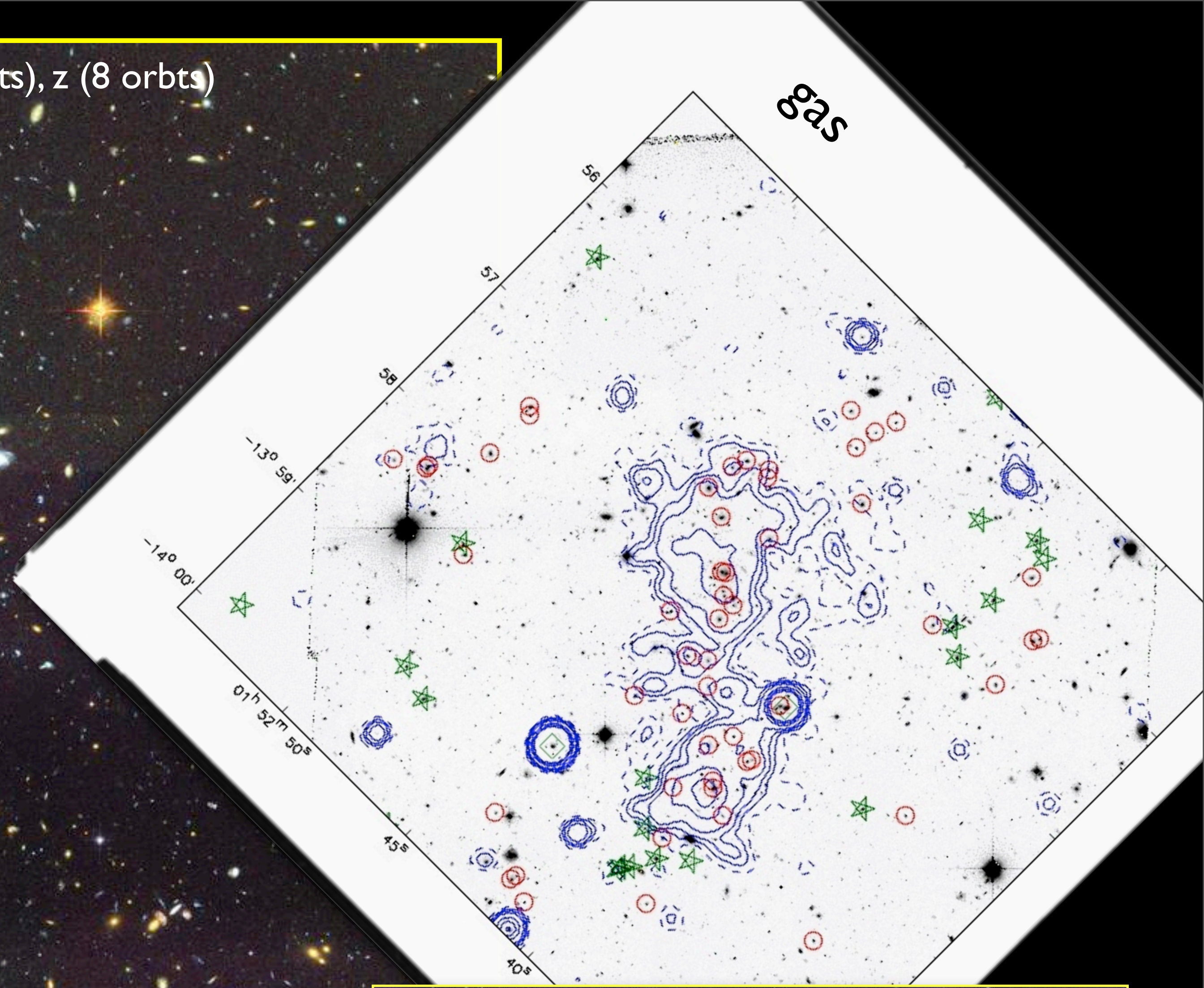
(Cimatti et al. 2004; Glazebrook et al. 2004)

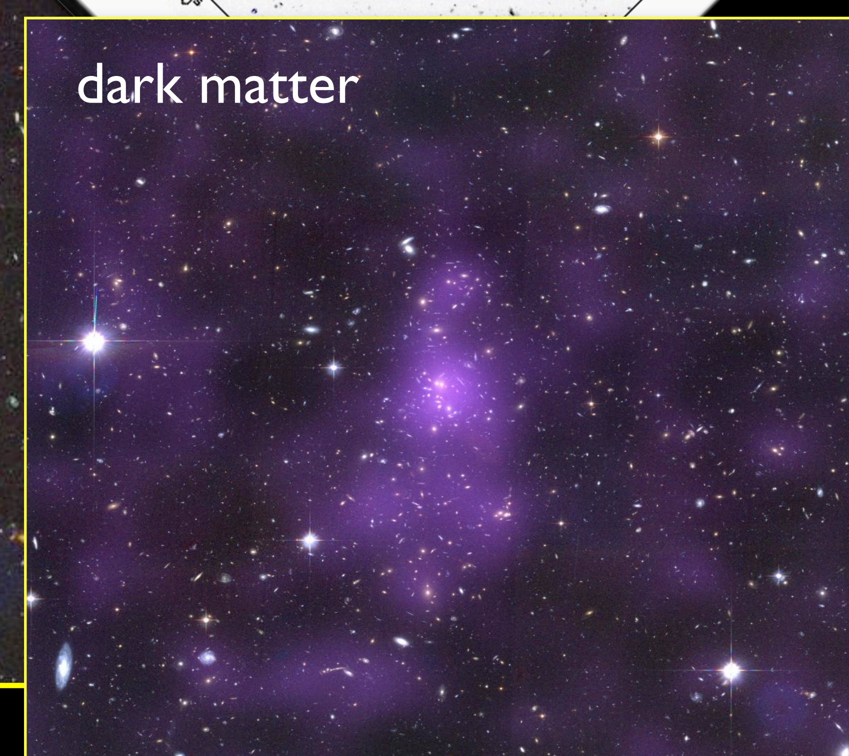
Motivation

- Tight Red-Sequence (RS) at $z \lesssim 1.5$
  ⇒ cluster early-type galaxies are already in place at ~4 Gyr after the Big-Bang
- How do luminous/massive early-type galaxies form at z>1.5?
- How do they suppress their star formation?
- What role does the environment play in their evolution and the formation of the RS?
- Answering the above questions requires a detailed analysis of the star formation history (SFH) of cluster galaxies at z>1
  - At z>1, galaxy transformations and evolution are expected to be more important
- A large sample of galaxy clusters at z>1 is needed to overcome cluster-to-cluster variations and statistical uncertainties

RXJ0152-13 z=0.84







Demarco et al. 2005; Girardi et al. 2005; Homeier et al. 2005; Jee et al. 2005; Tanaka et al. 2006

Multi-wavelength Data set

Cluster in ACS intermediate-redshift cluster sample (P.I.: H. Ford)

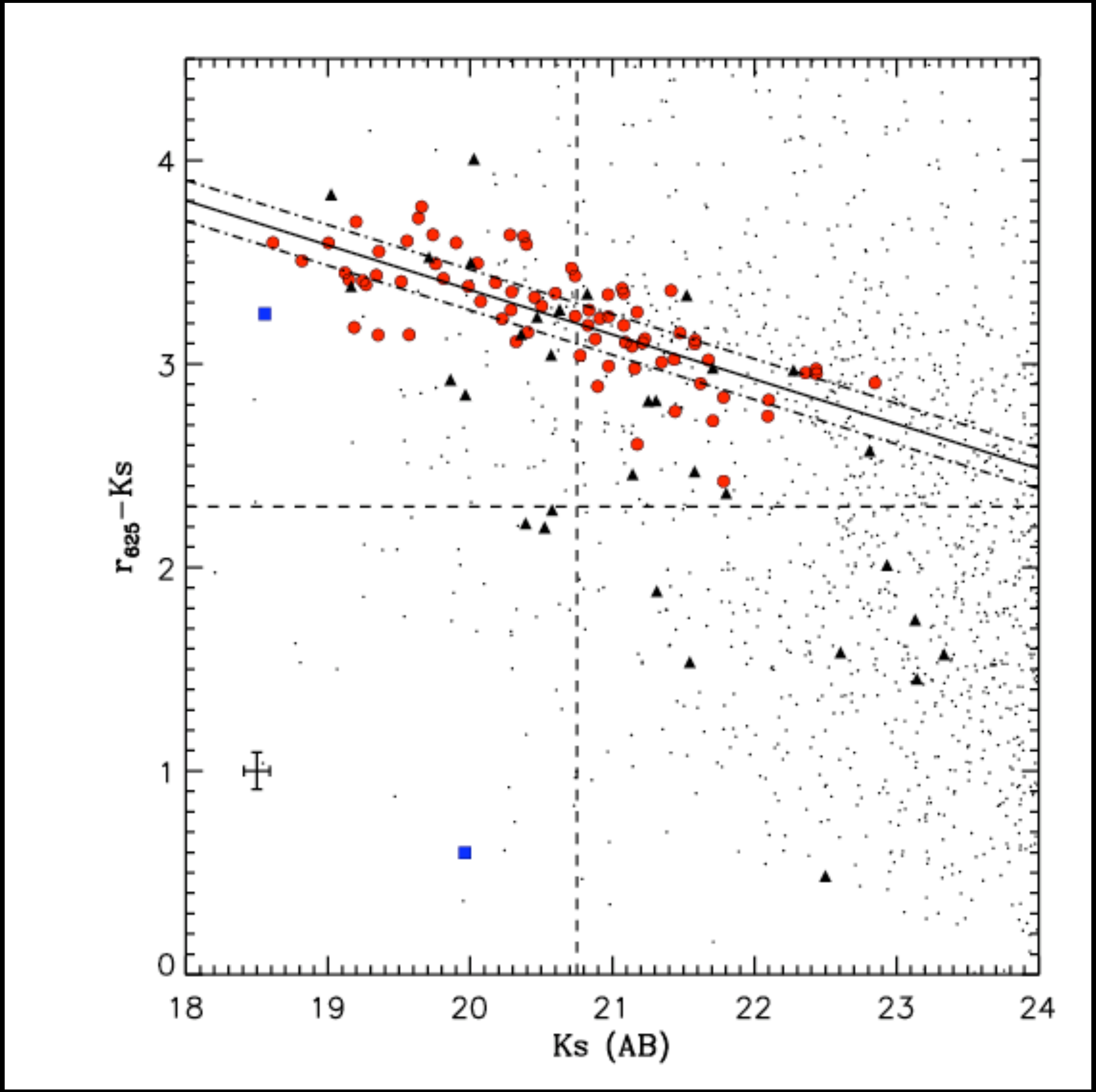
Cluster	Redshift	Imaging	Spectroscopy
RXJ0152-13	0.837 (102)	HST (i,r,z) | Chandra | VLT (V,R,I) | NTT (J,Ks) | Keck (B,V,R,I) | Spitzer | VLA	VLT/FORS

Current sample of spec confirmed members: 134
(32 new members: Demarco et al., in prep)

$\sigma_{v,134} \sim 1700$ km/s

RXJ0152-13: the cluster red-sequence

76 non [OII] members in Red-Sequence



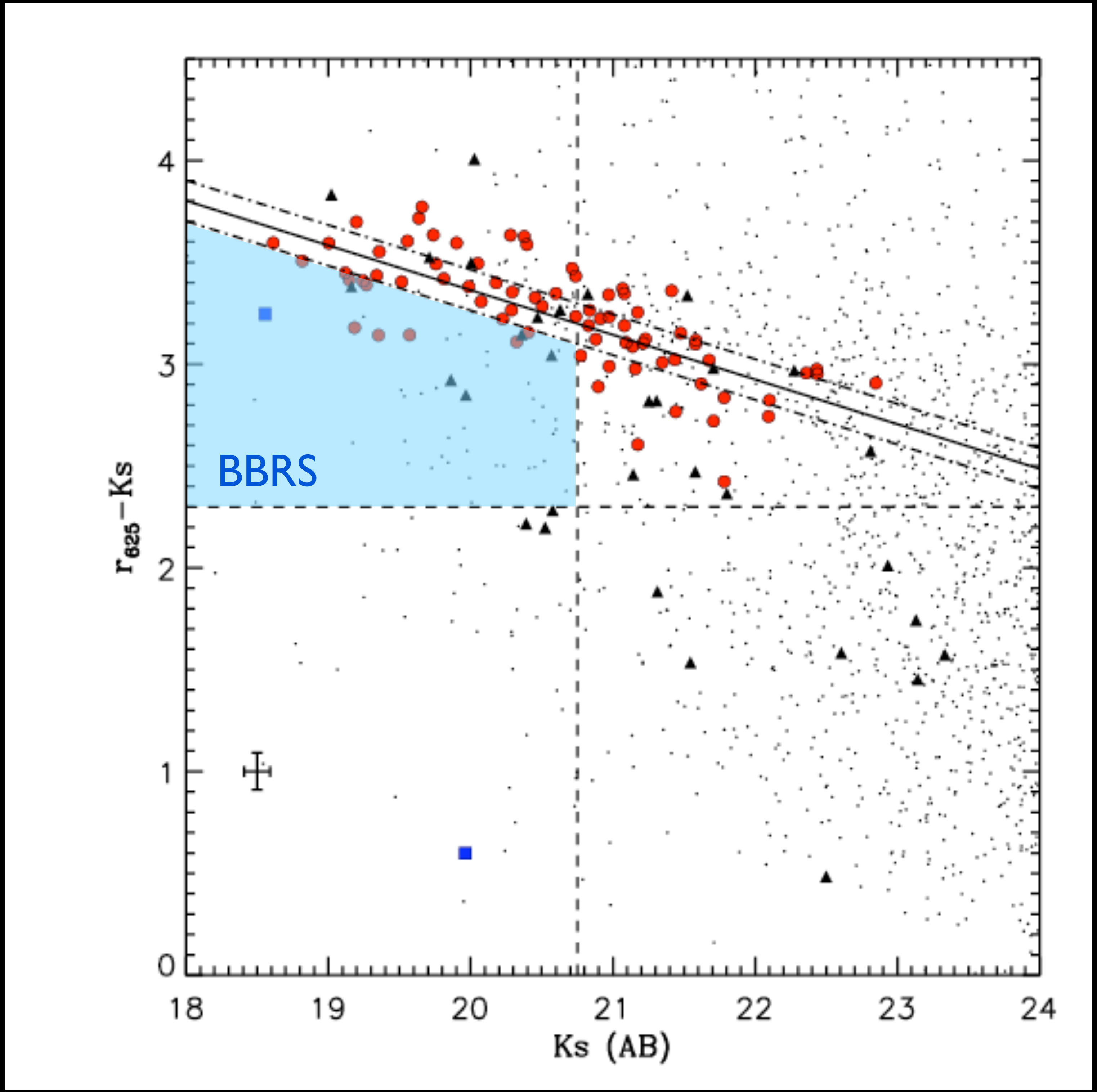
SofI + ACS photometry Demarco et al., in prep.

RXJ0152-13: the cluster red-sequence

- non [OII]
- [OII]
- AGN

76 non [OII] members in Red-Sequence

BBRS: Bright-Blue Red-Sequence (10)



SofI + ACS photometry

Demarco et al., in prep.

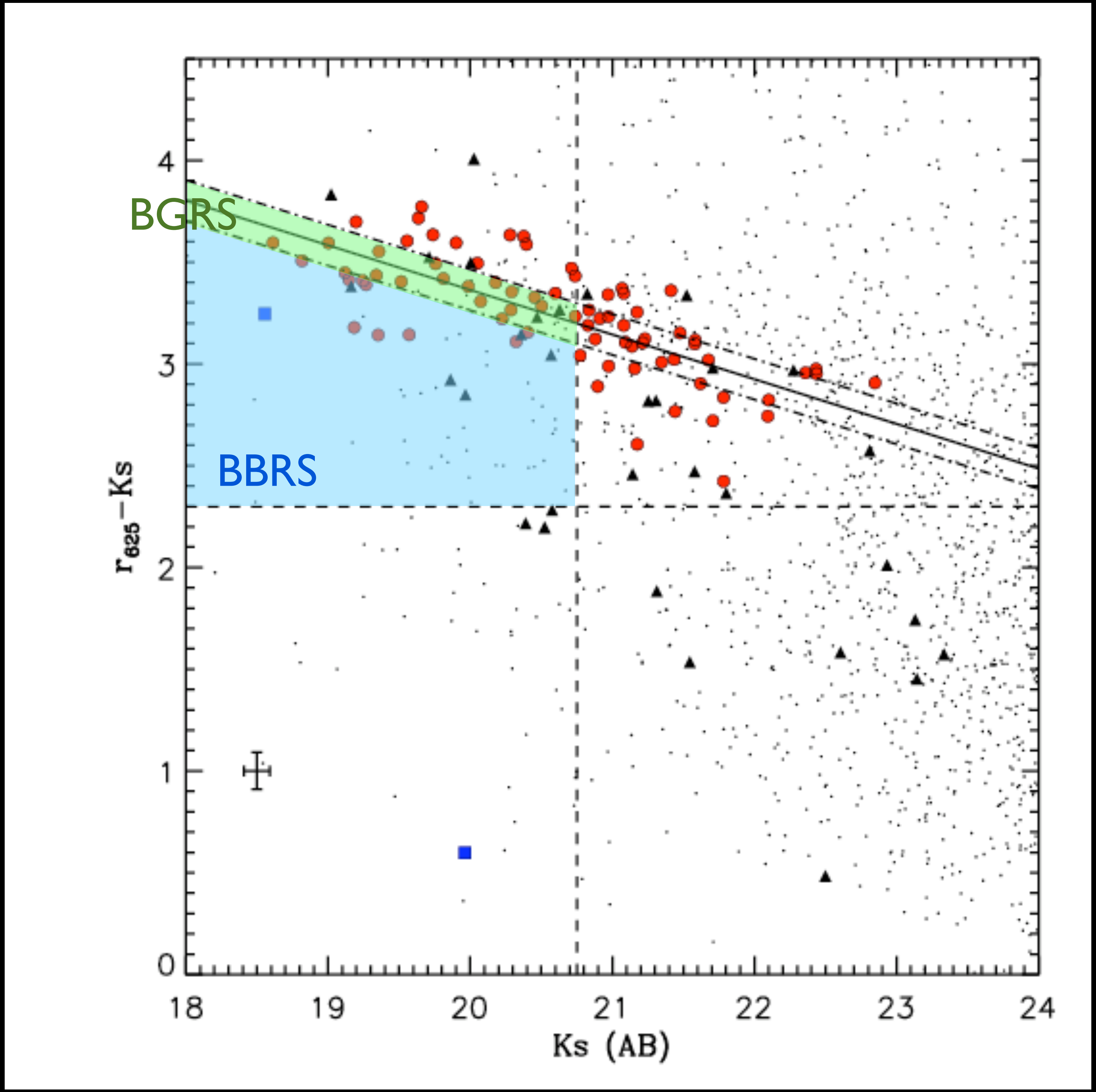
RXJ0152-13: the cluster red-sequence

- non [OII] (red circles)
- [OII] (triangles)
- AGN (blue squares)

76 non [OII] members in Red-Sequence

BBRS: Bright-Blue Red-Sequence (10)

BGRS: Bright-Green Red-Sequence (15)



SofI + ACS photometry

Demarco et al., in prep.

RXJ0152-13: the cluster red-sequence

non [OII]

[OII]

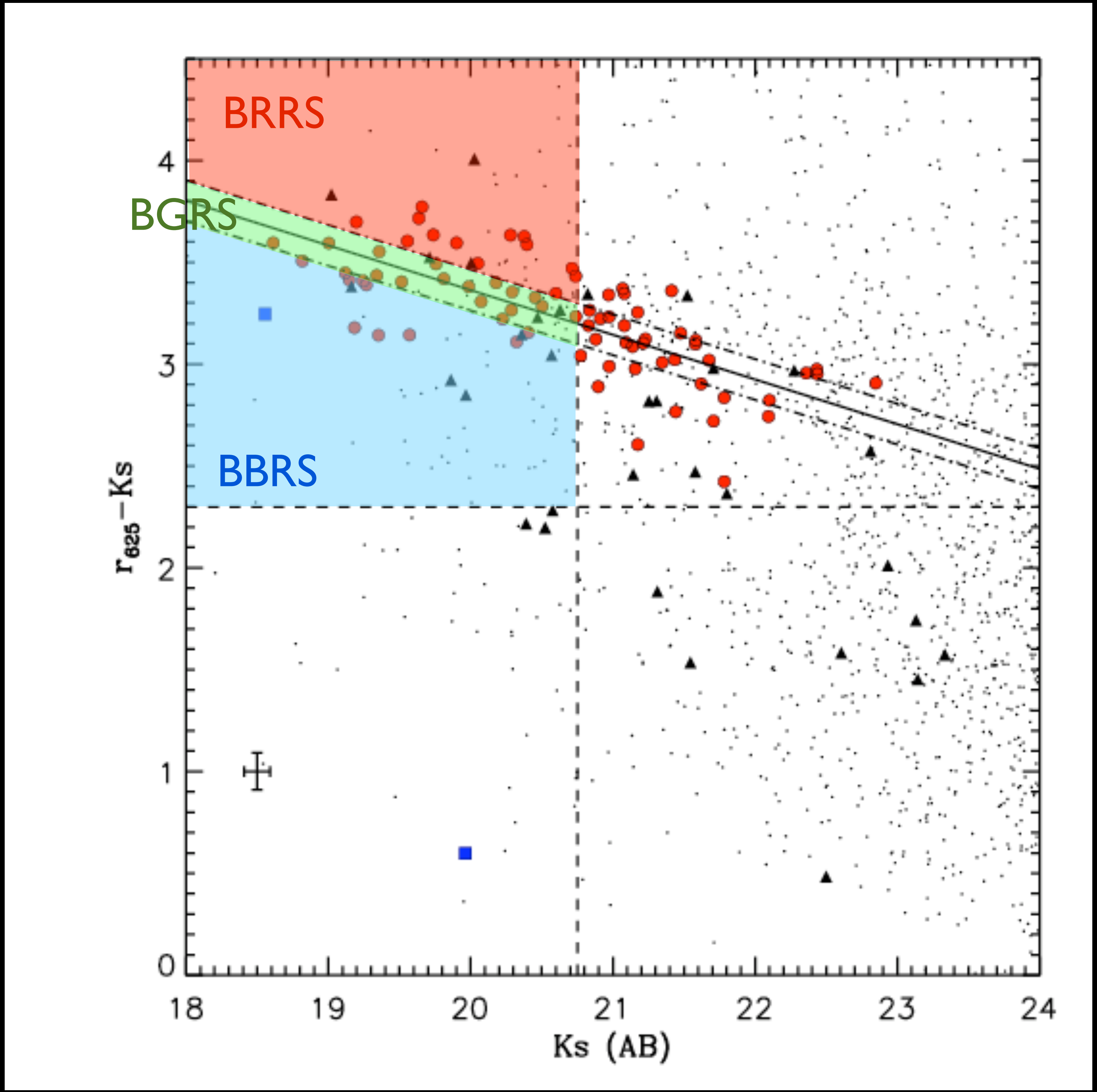
AGN

76 non [OII] members in Red-Sequence

BBRS: Bright-Blue Red-Sequence (10)

BGRS: Bright-Green Red-Sequence (15)

BRRS: Bright-Blue Red-Sequence (12)



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RXJ0152-13: the cluster red-sequence

● non [OII]
△ [OII]
■ AGN

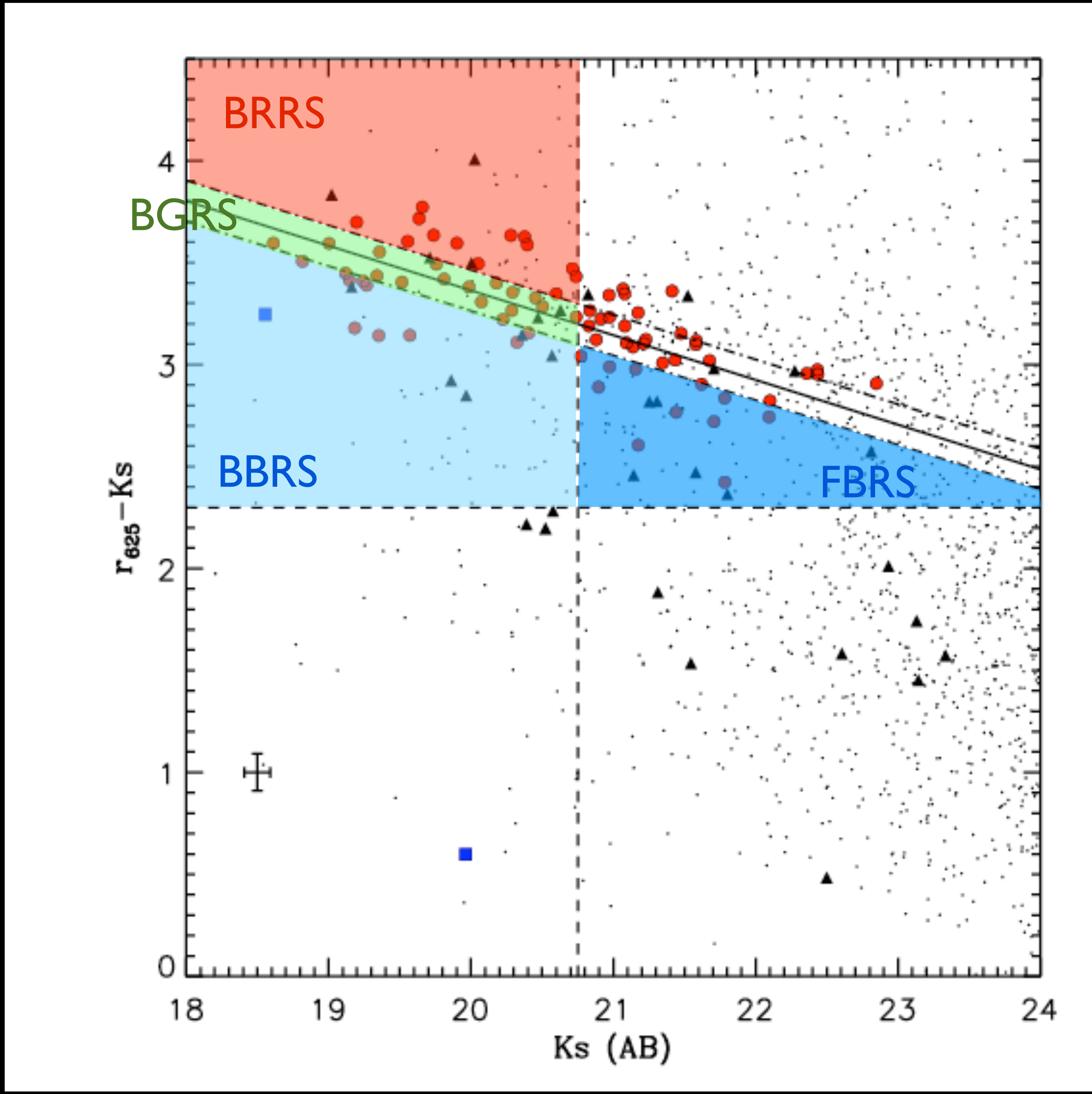
76 non [OII] members in Red-Sequence

BBRS: Bright-Blue Red-Sequence (10)

BGRS: Bright-Green Red-Sequence (15)

BRRS: Bright-Blue Red-Sequence (12)

FBRS: Faint-Blue Red-Sequence (9)



SofI + ACS photometry Demarco et al., in prep.

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- ● non [OII]
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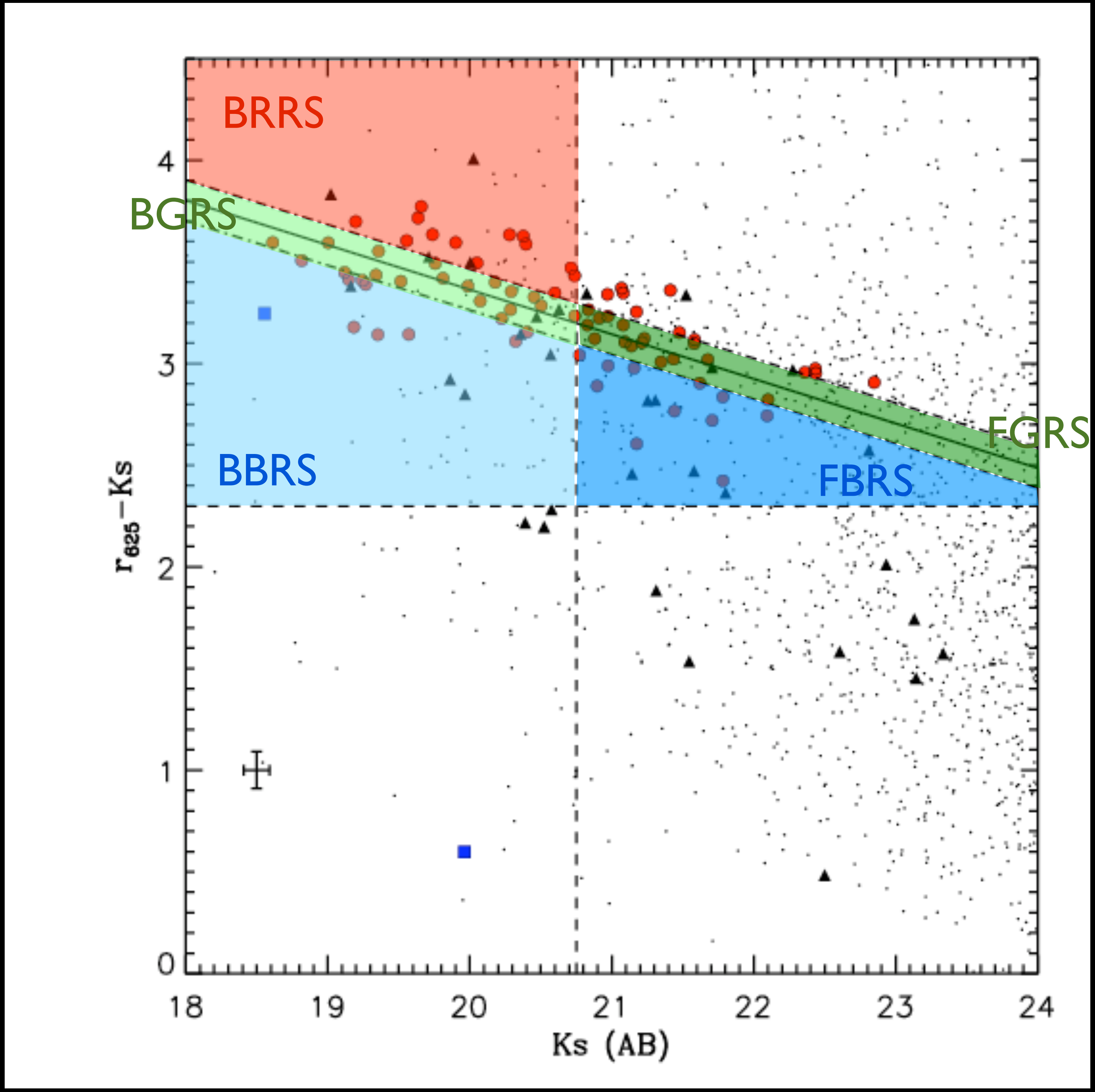

SofI + ACS photometry

Demarco et al., in prep.

RXJ0152-13: the cluster red-sequence

non [OII]

[OII]

AGN

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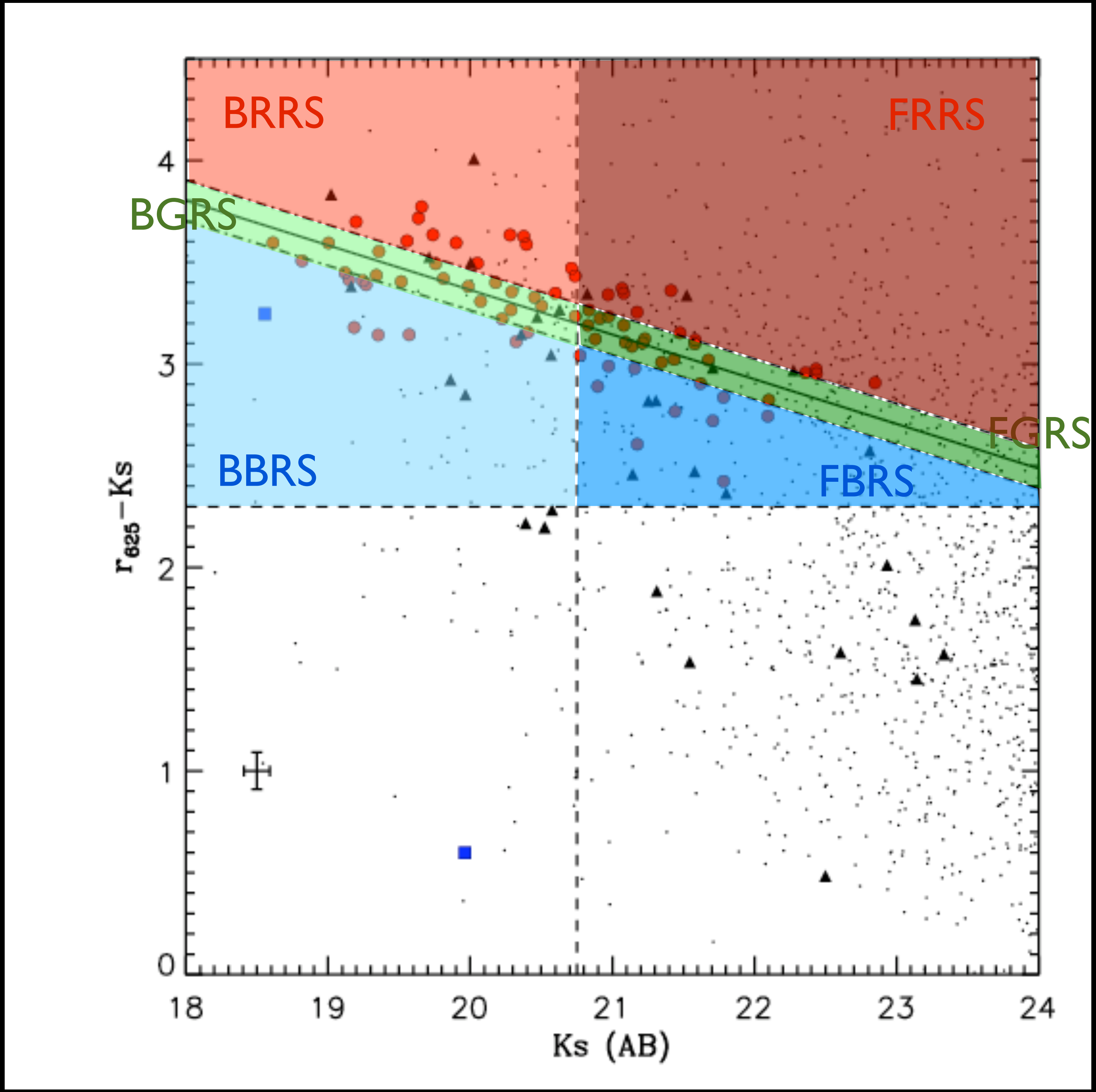
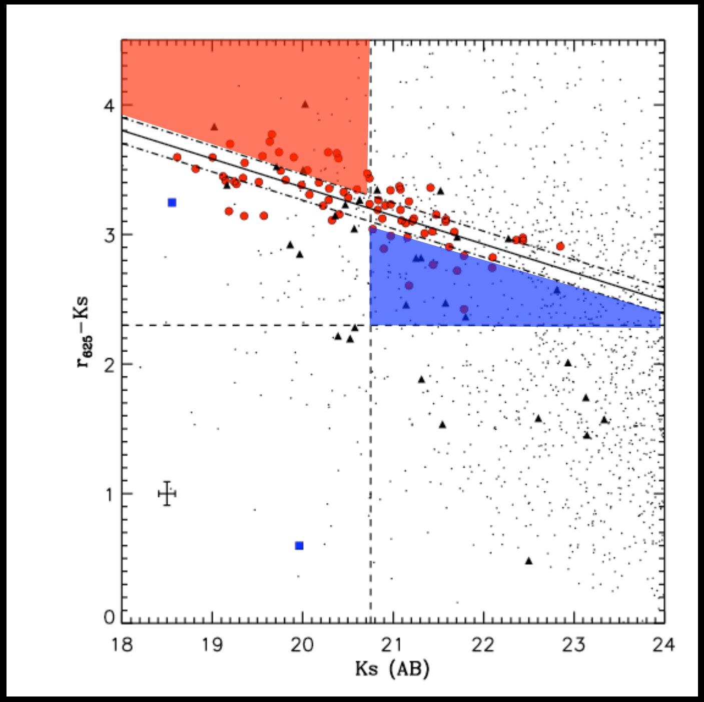
FRRS: Faint-Red Red-Sequence (10)

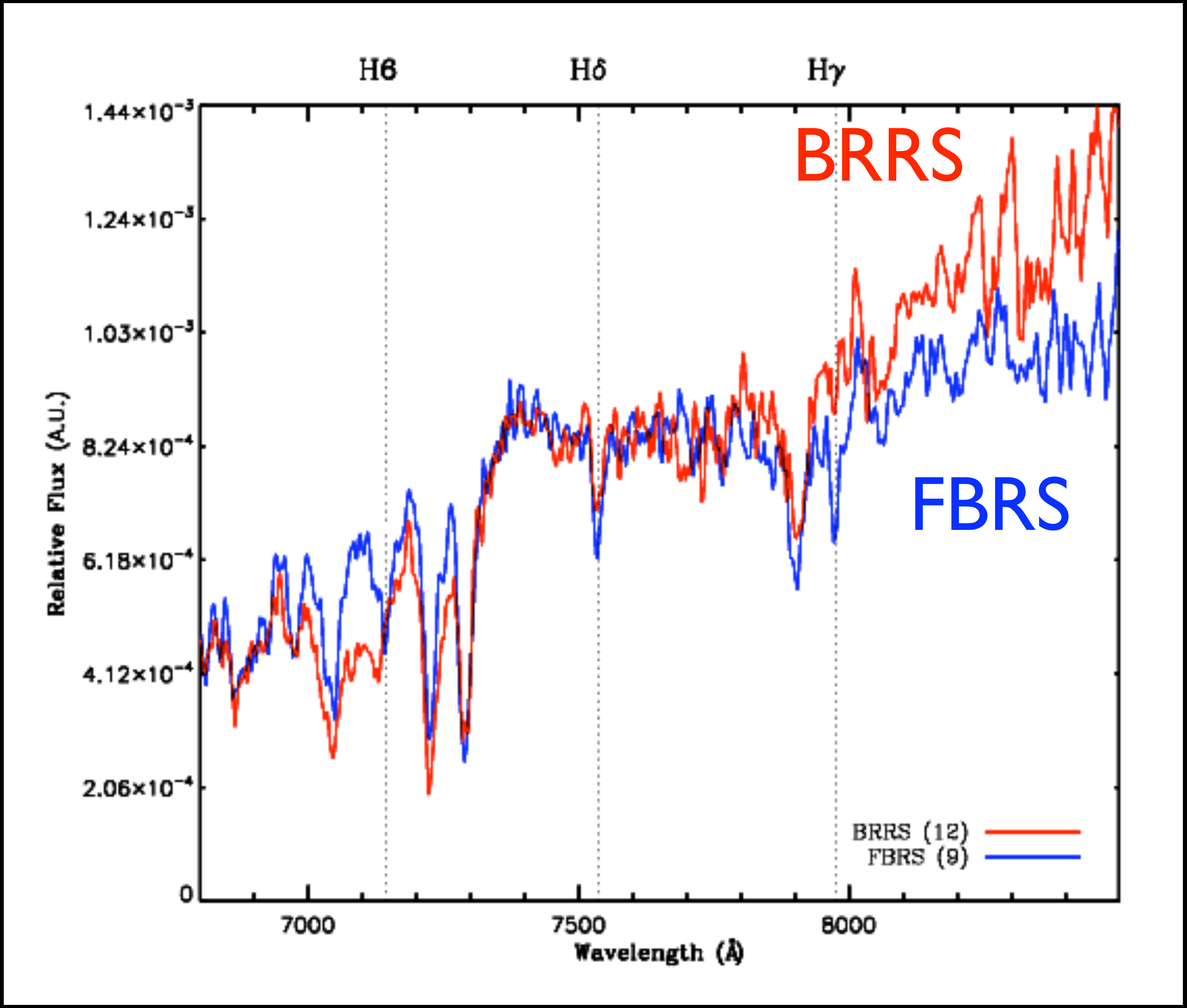


SofI + ACS photometry

Demarco et al., in prep.

RXJ0152-13: the extreme ends of its RS





More prominent Balmer features in FBRS galaxies compared to BRRS galaxies

RXJ0152-13: SFH in the RS

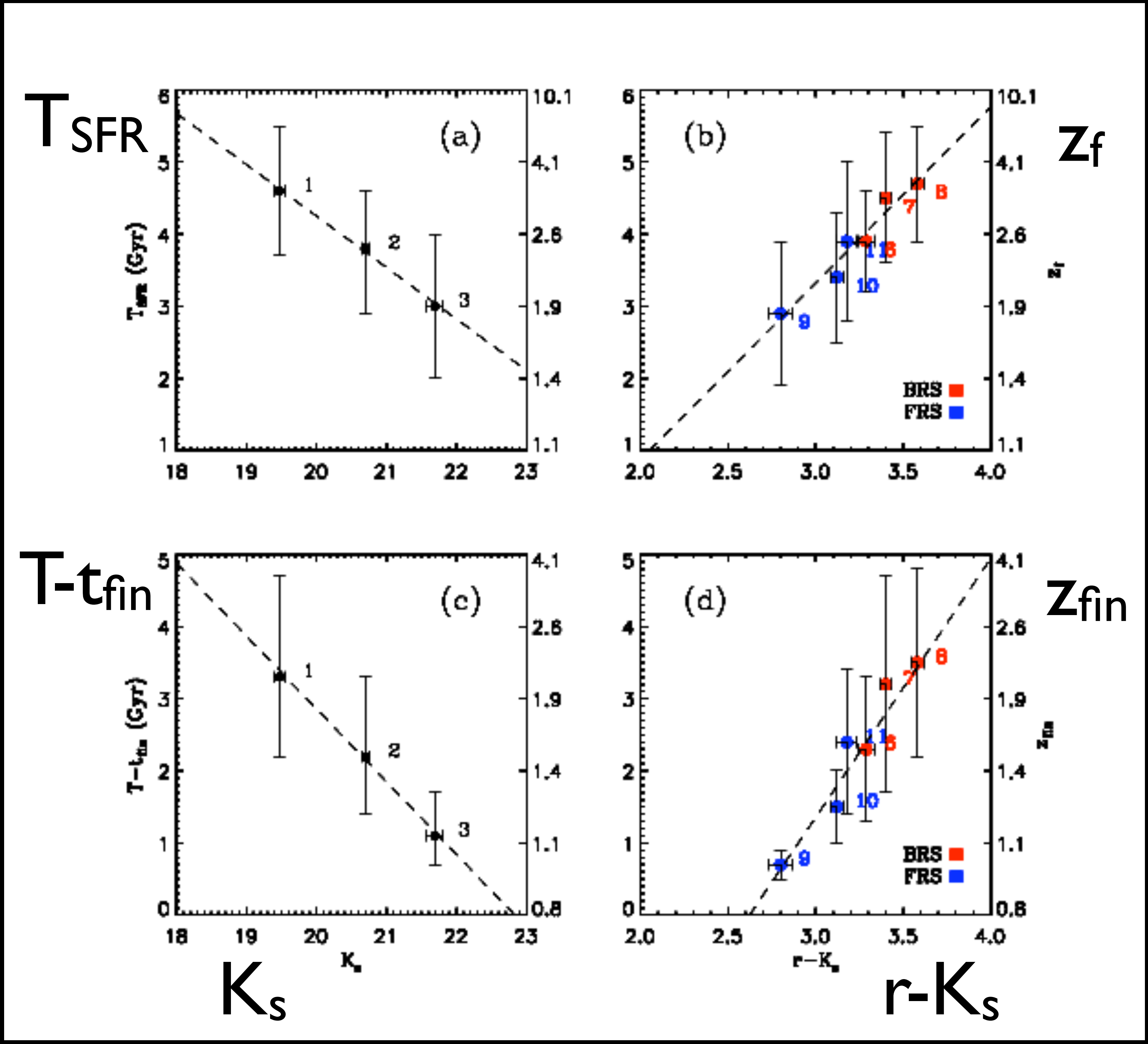
Spectrophotometric fitting

$$T_{SFR}(T,\tau) = \frac{\int_0^T (T-t)\psi(t,\tau)dt}{\int_0^T \psi(t,\tau)dt},$$

$$\psi(t,\tau) = \frac{1}{\tau^2}\ te^{\frac{-t}{\tau}}$$

$T\text{-}t_{fin}$: lookback time to last star-forming episode (Gobat et al. 2008)

FBRS galaxies have younger ages and more extended SFH than BRRS galaxies



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RXJ0152-13: SFH in the RS

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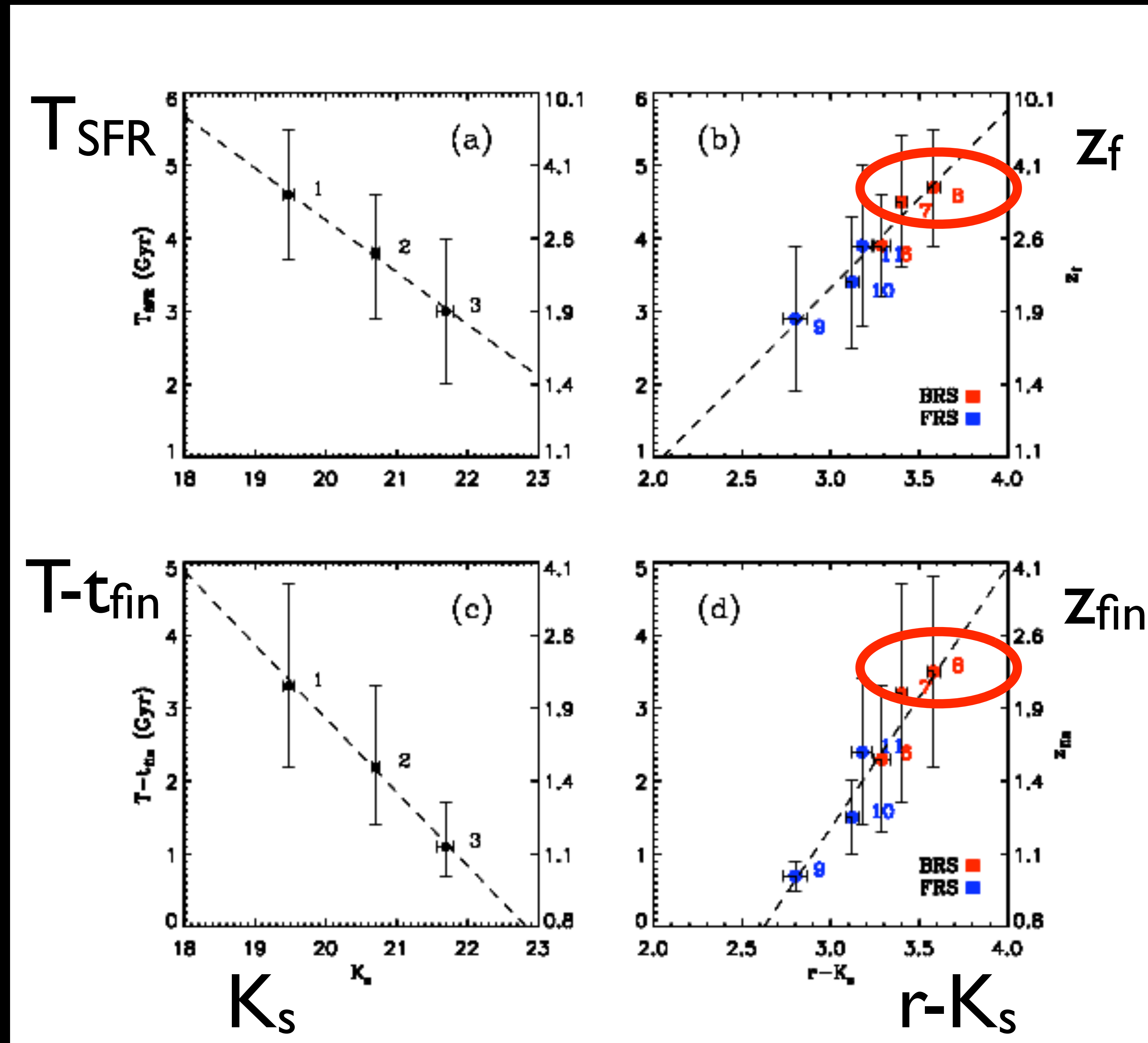

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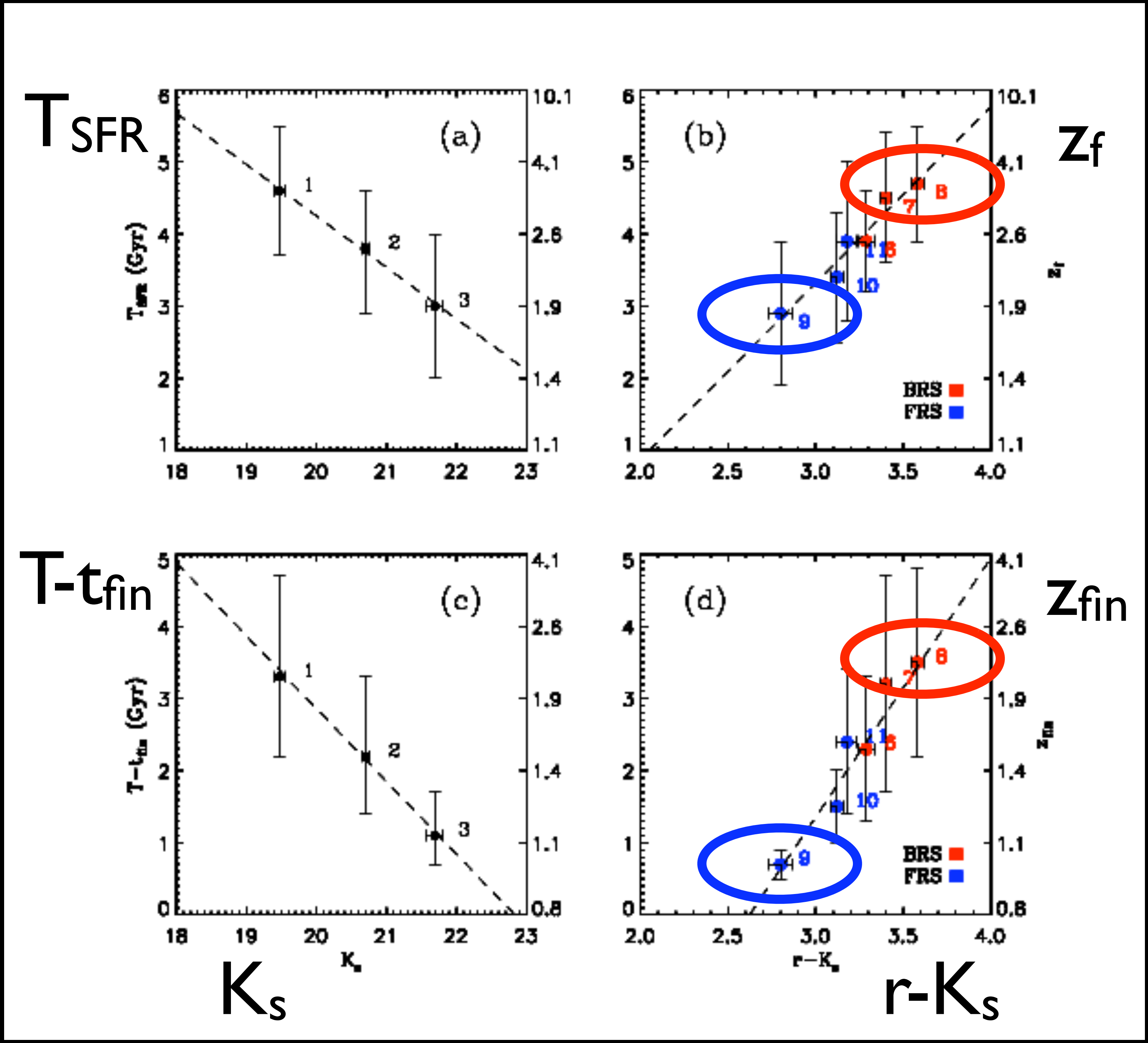


Demarco et al., in prep.

RXJ0152-13: local DM density (DMD)

□ BRRS

△ FBRS

———— $\Sigma_{DM}=20\ \sigma_{DM}$

- - - - - - - $\Sigma_{DM}=5\ \sigma_{DM}$

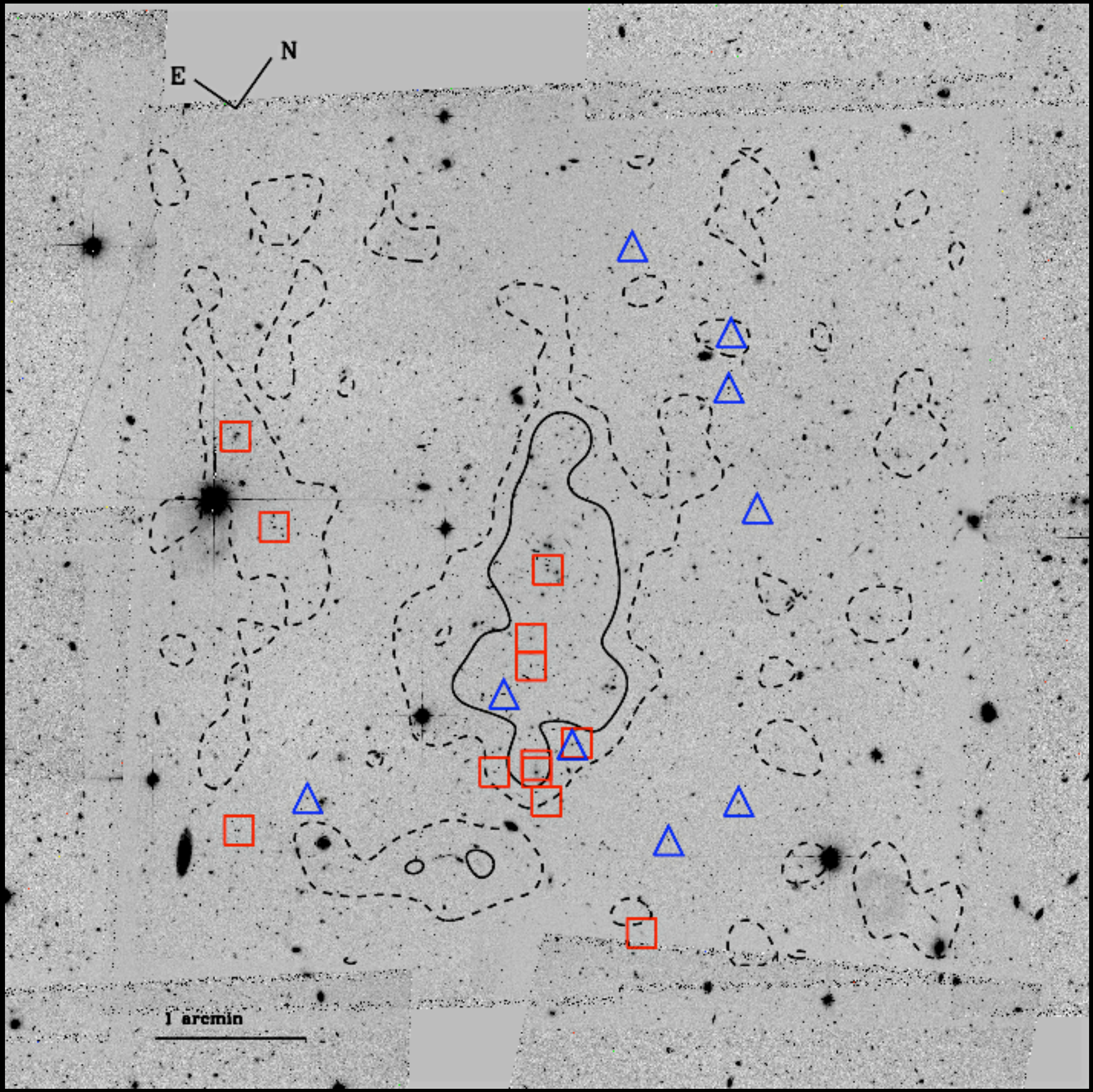
$\sigma_{DM} = 0.0057\ \Sigma c\ ;\ \Sigma c \sim 3650\ M_{\odot}\ pc^{-2}$

SFH determined by the environment

Massive galaxies in high and intermediate DMD regions

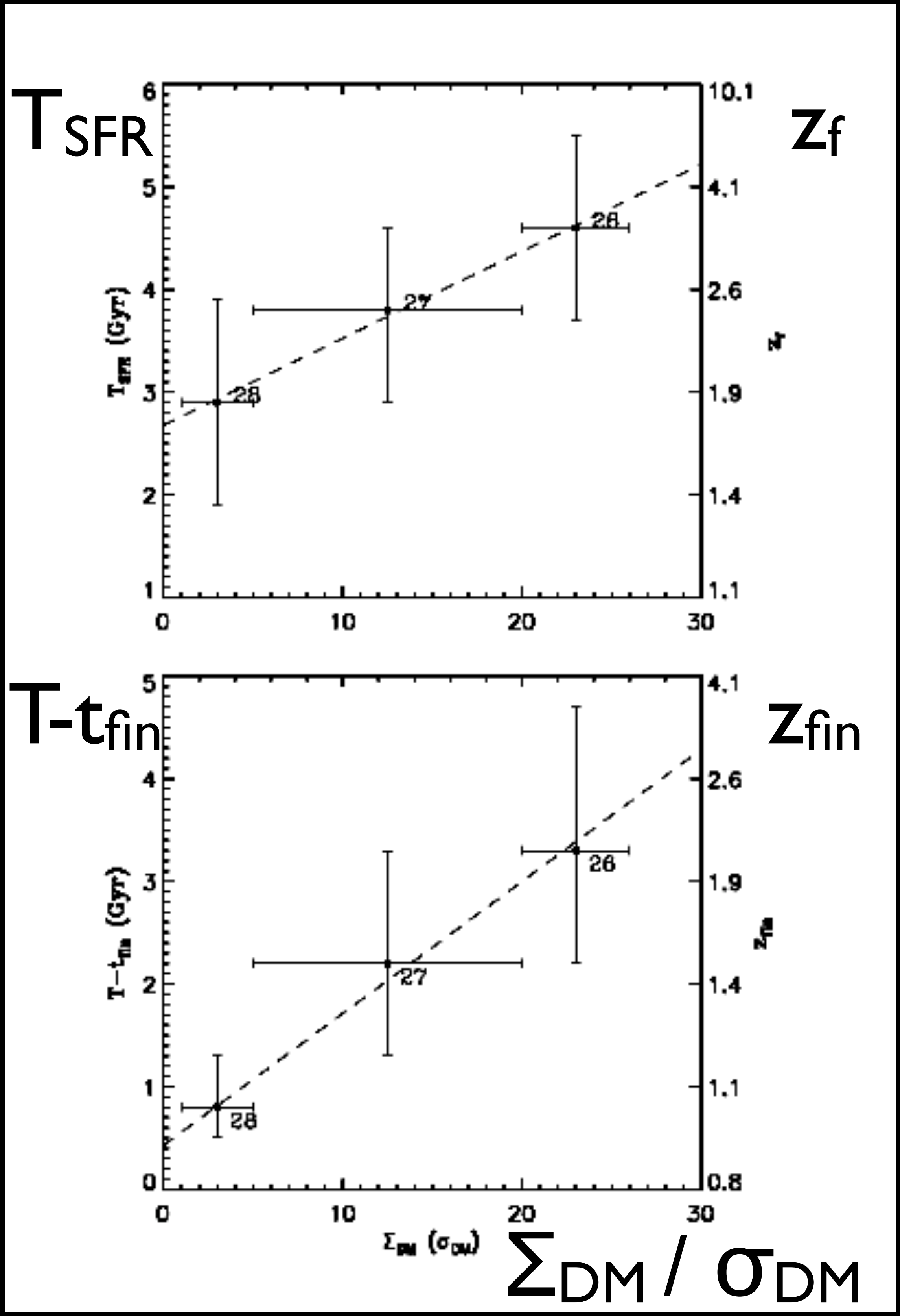
Nurture vs Nature

See Gobat's talk

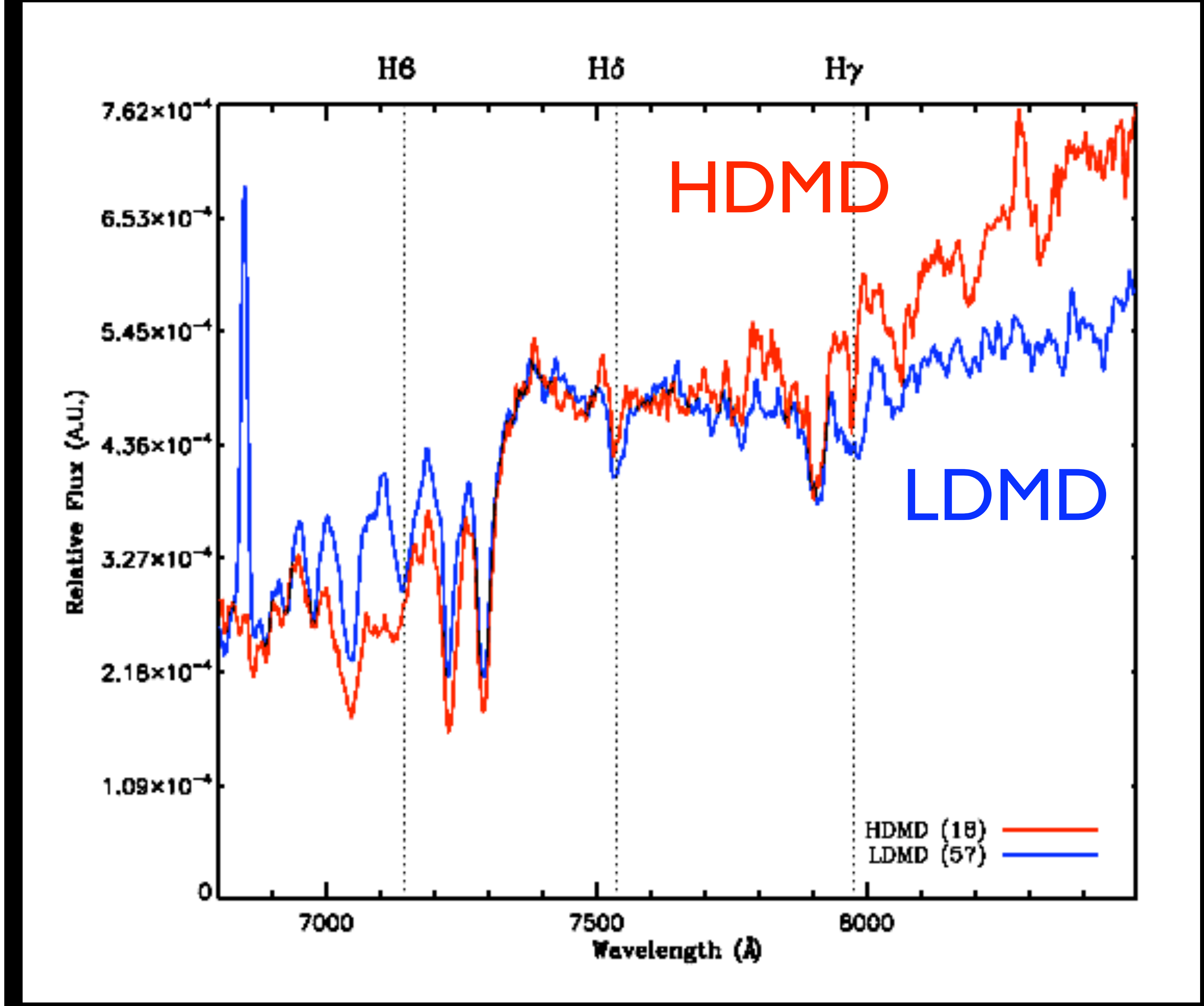


Jee et al. 2005; Blakeslee et al. 2006; Demarco et al., in prep.

RXJ0152-13: SFH as a function of local DM density



Younger ages and more extended SFH in cluster outskirts



Demarco et al., in prep.

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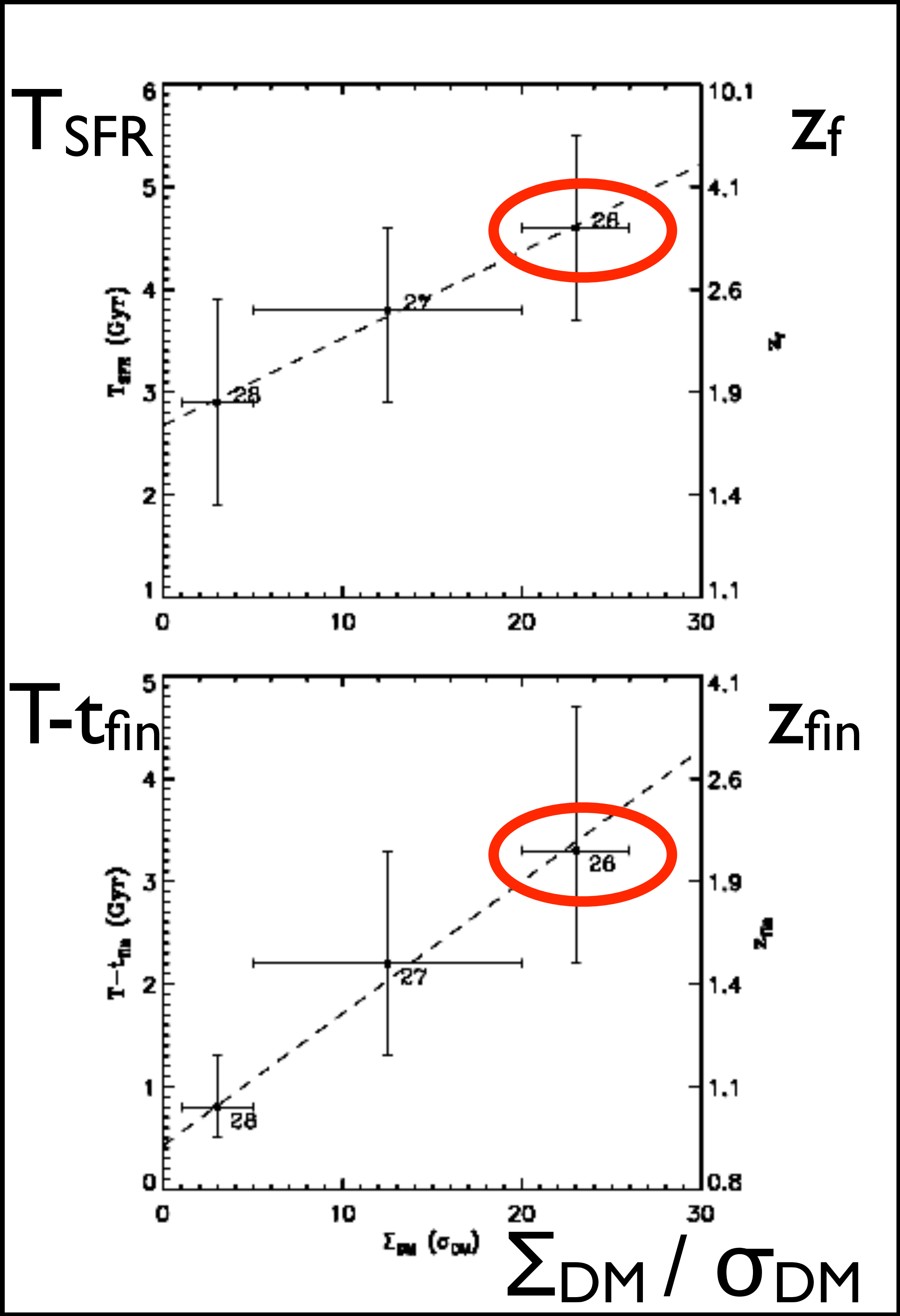

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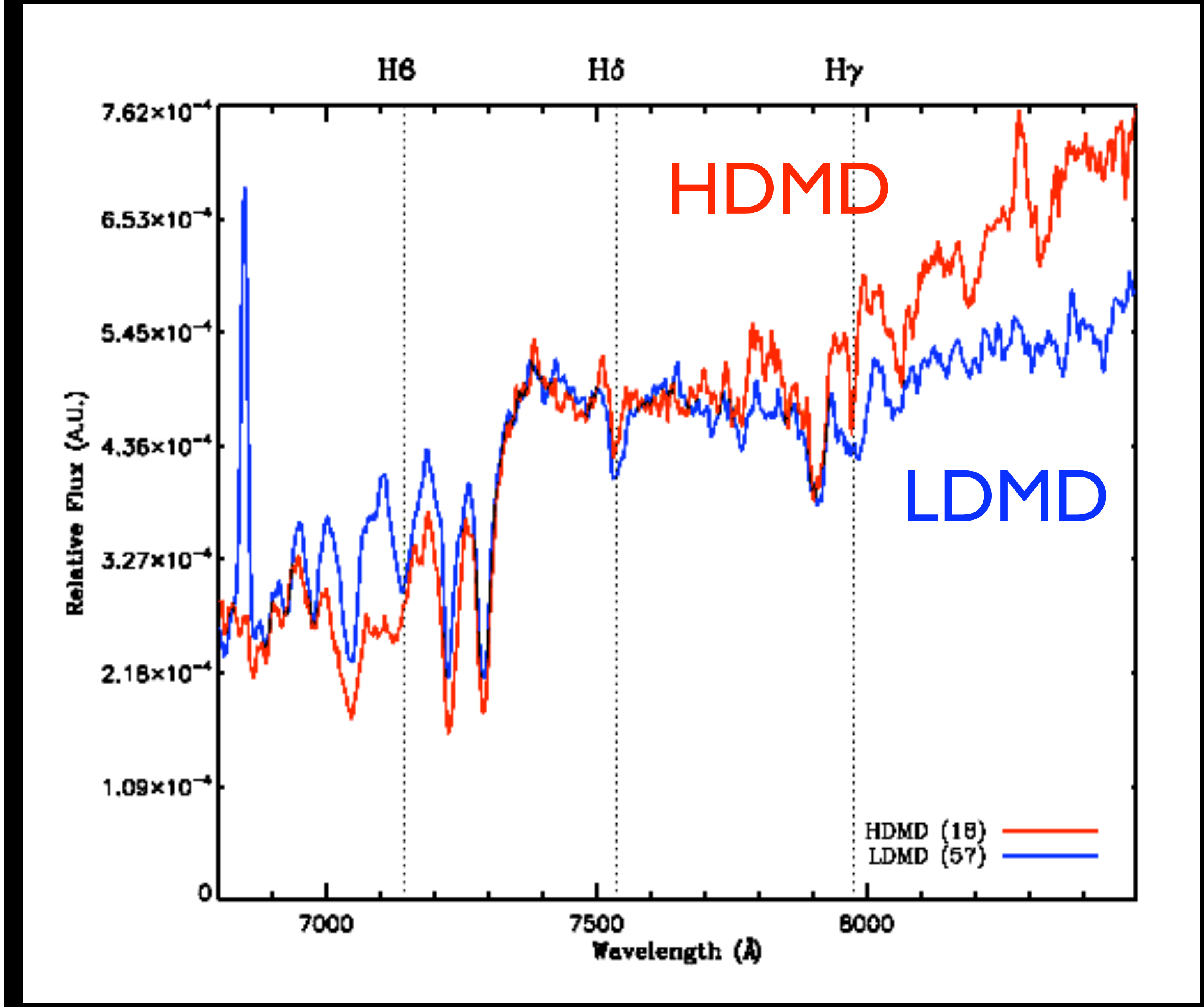
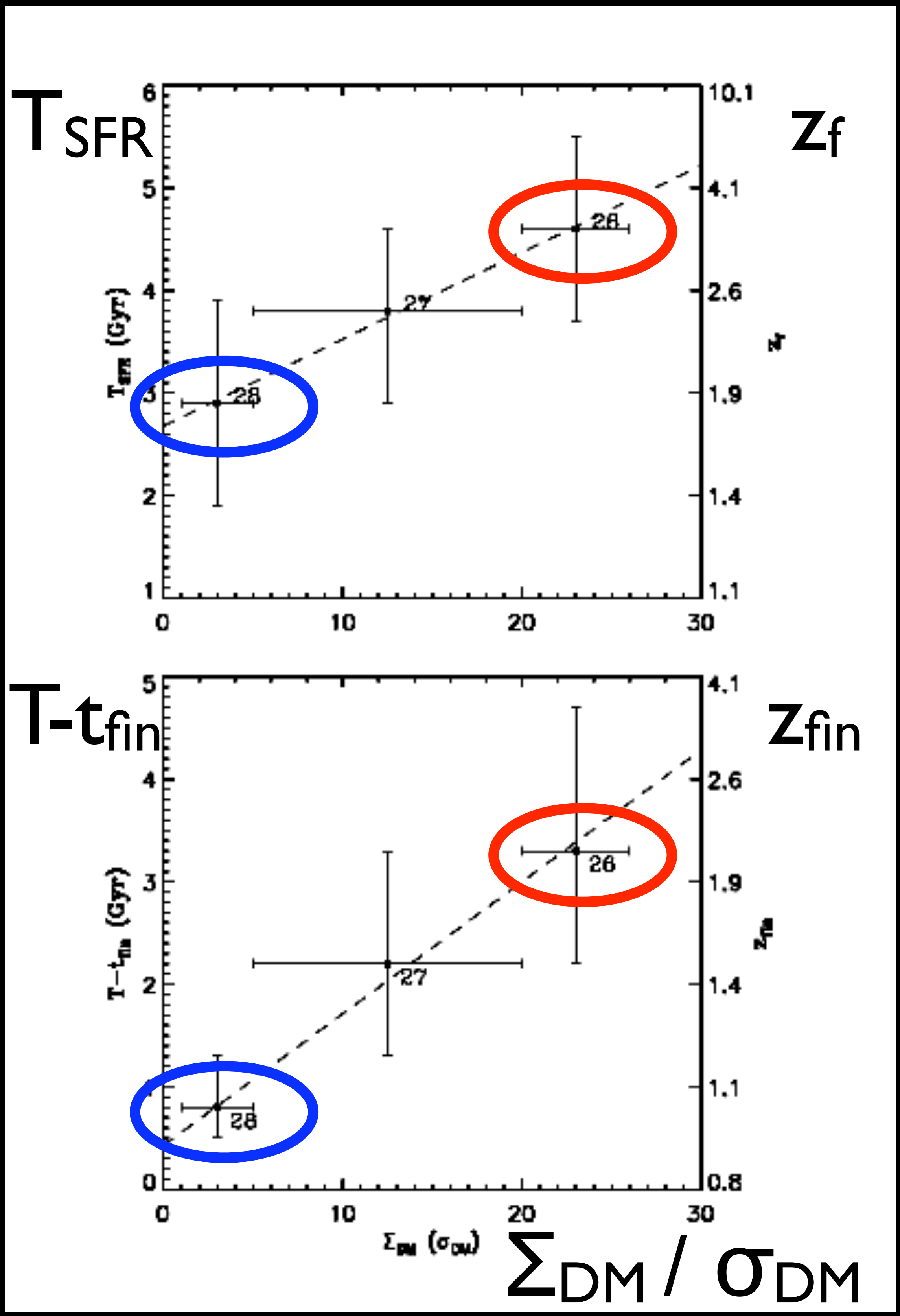


Demarco et al., in prep.

RXJ0152-13: SFH as a function of local DM density



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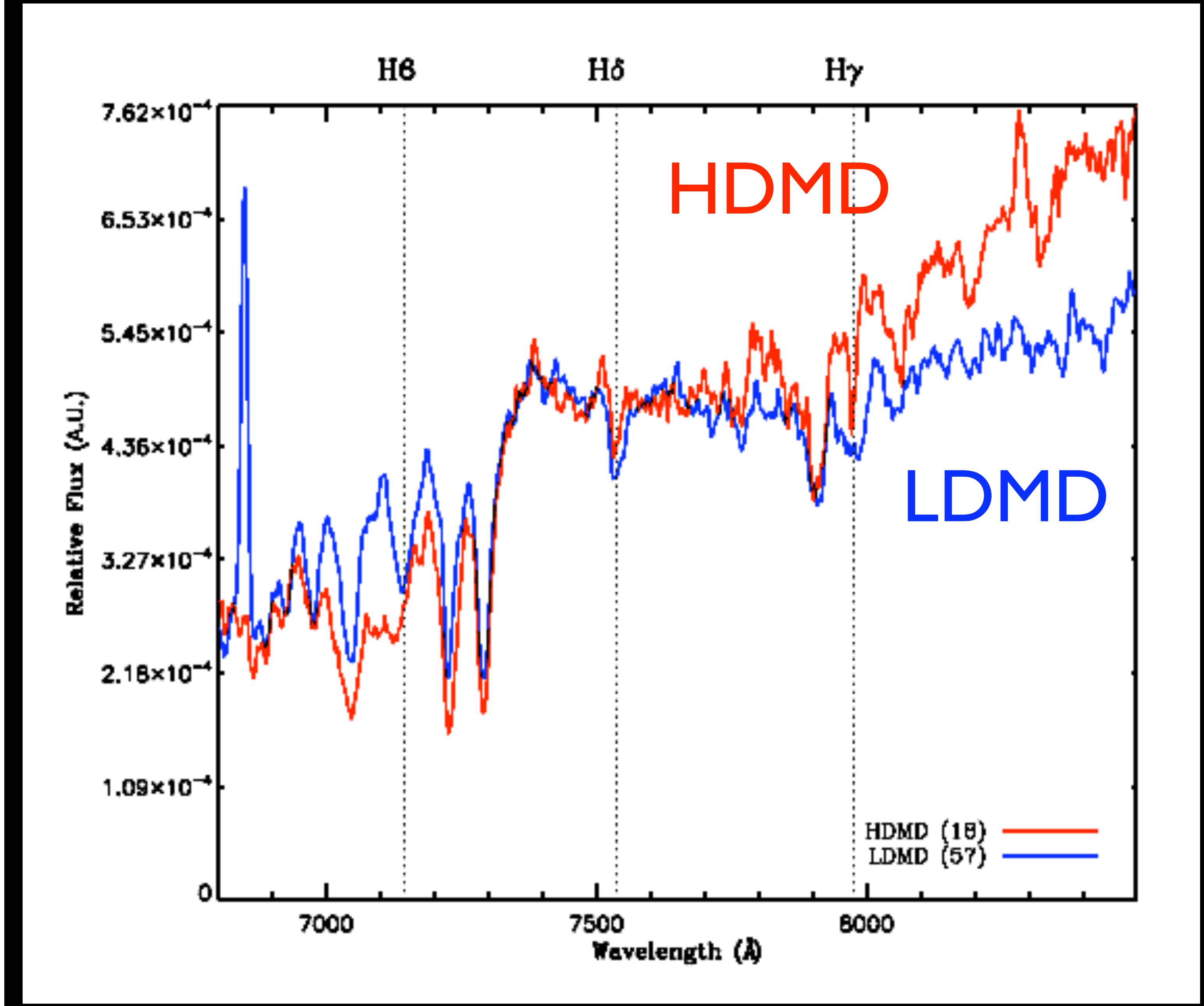


Demarco et al., in prep.

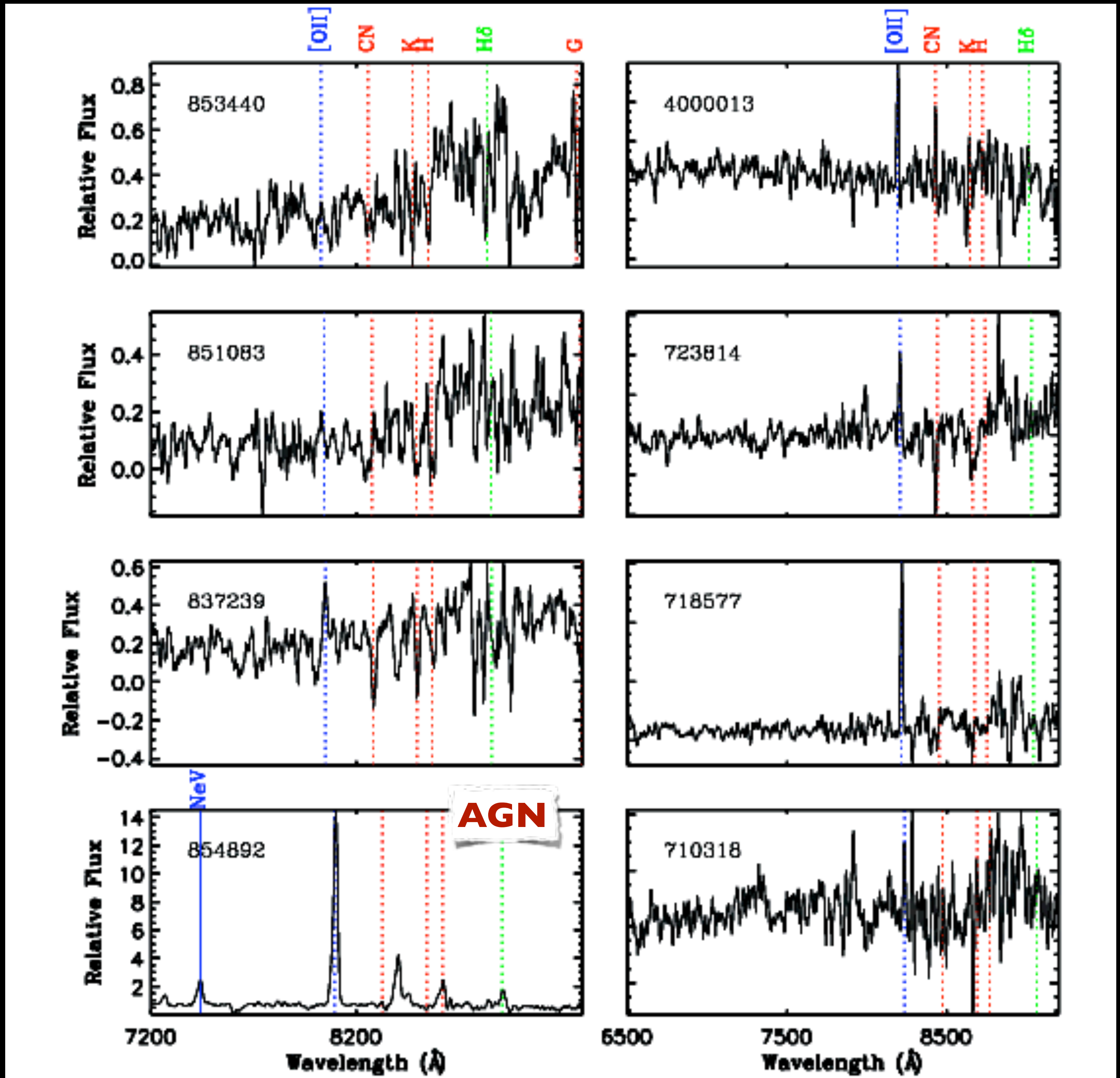
Two new SpARCS clusters confirmed at z>1

The SpARCS galaxy cluster survey: see Wilson's talk

SpARCS J1616+55: N_{tot}=10 ; N_{sec}=7

SpARCS J1610+55: N_{tot}=10 ; N_{sec}=7

Both clusters in the ELAIS-N1 field



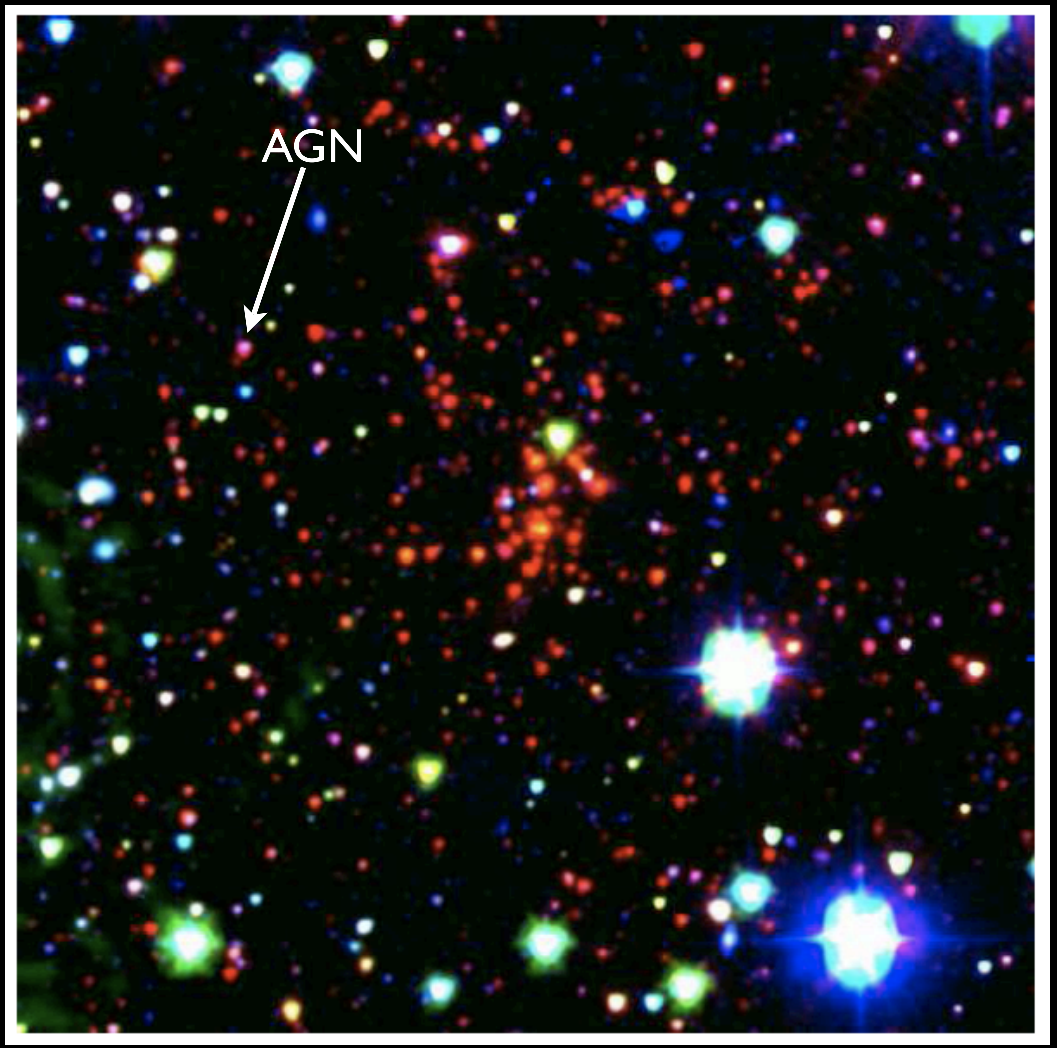
SpARCS J1616+55 z=1.161

SpARCS J1610+55 z=1.210

Demarco et al., ApJ, submitted.

SpARCS J1616+55

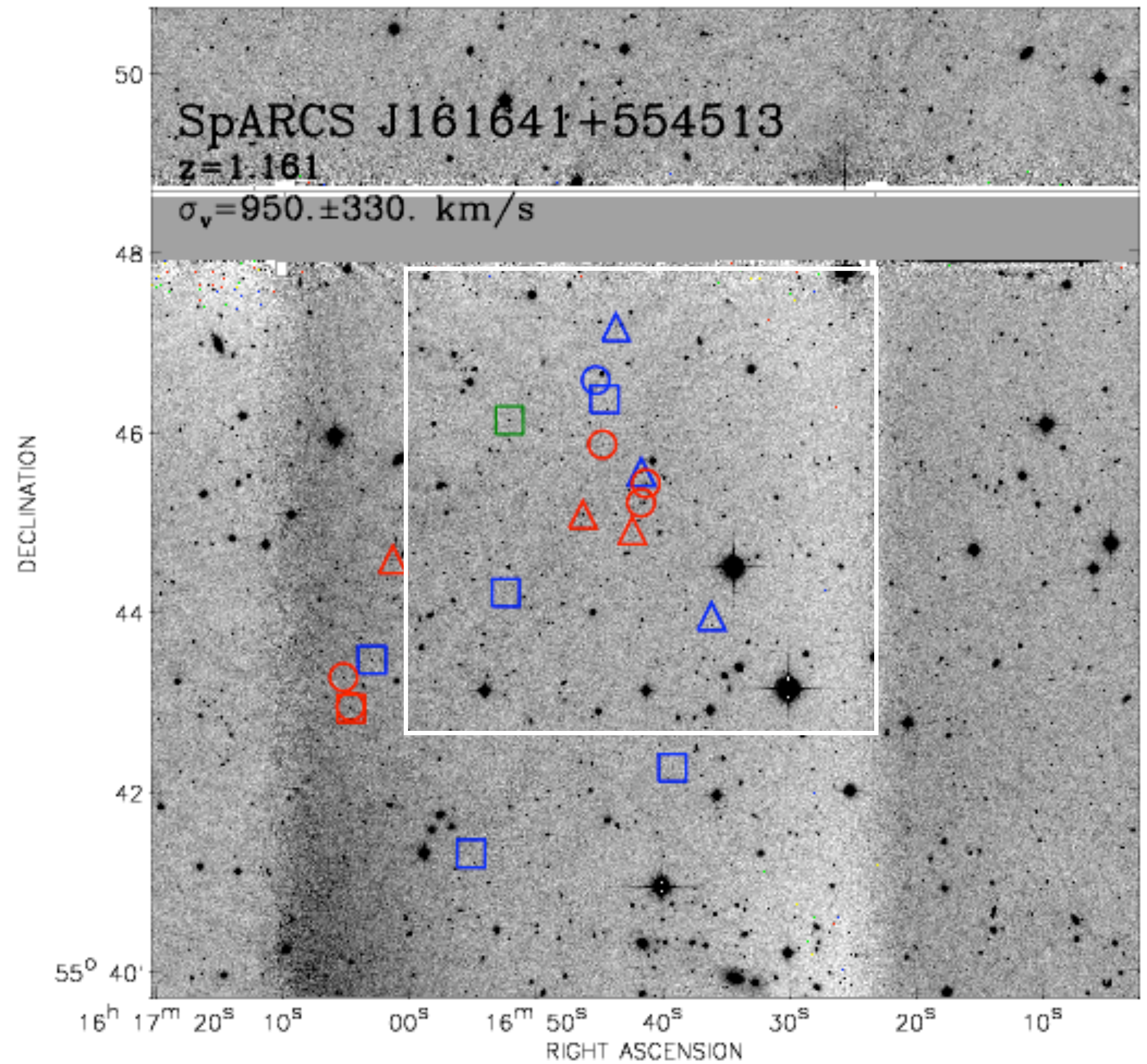
- Cluster (5 non [OII]+1 [OII])
- Field (1 non [OII]+5 [OII])
- AGN (1)



In GCLASS sample (see Muzzin's talk)

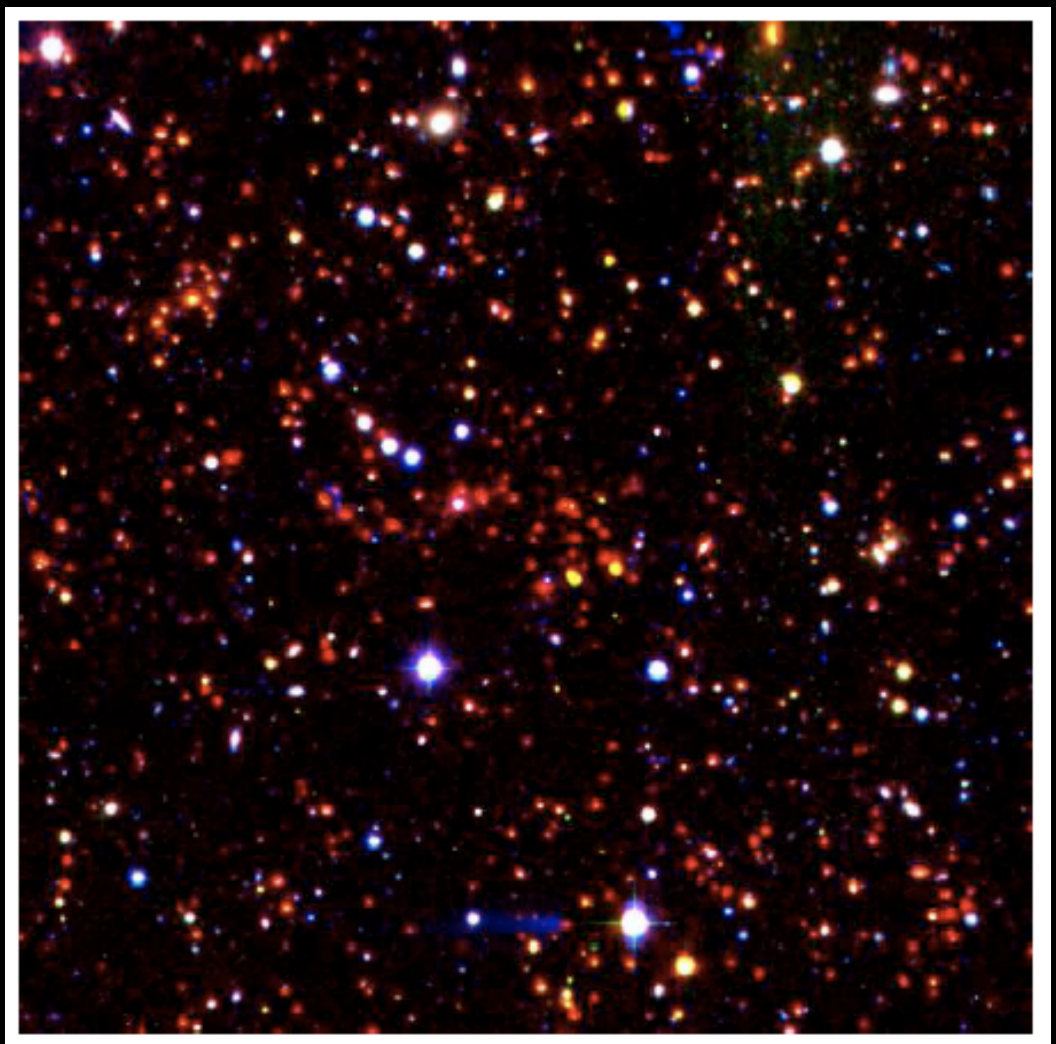
Demarco et al., ApJ, submitted.

z=1.161 σv~900 km/s



SpARCS J1610+55

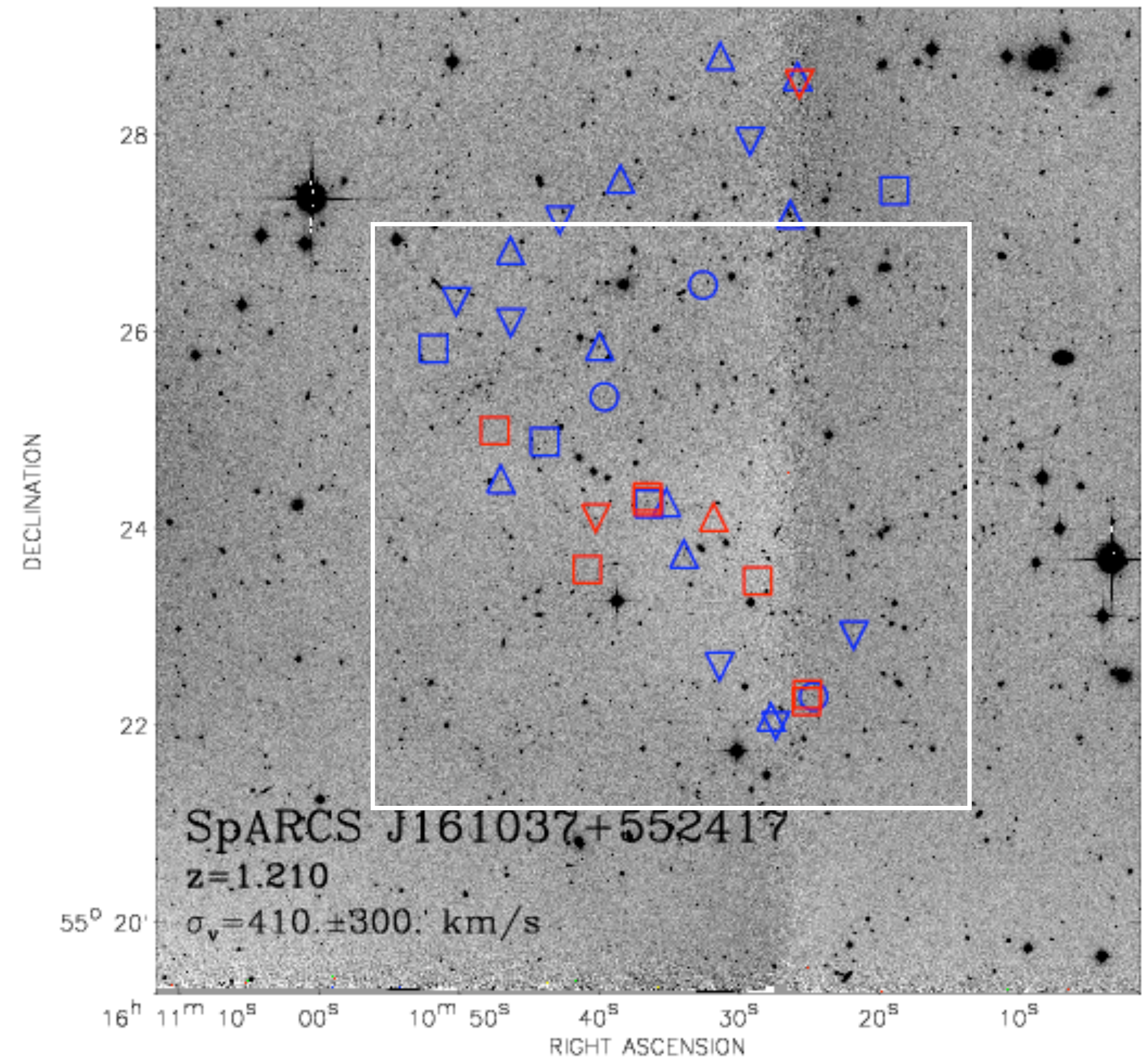
Cluster (0 non [OII]+7 [OII])
Field (3 non [OII]+4 [OII])



High fraction of [OII] members

Demarco et al., ApJ, submitted.

z=1.210 σv~400 km/s



Conclusions

- Non [OII] galaxies in the extreme ends of the RS have different SFHs: bright/massive and red galaxies have older ages and a shorter star formation time scale than faint and blue galaxies (downsizing)

- bright/massive and red galaxies in the RS are located in high density regions as opposed to faint and blue RS galaxies: environment should play a role in truncating and modulating the SFH of cluster galaxies

- Two new SpARCS galaxy clusters at $z>1$. The one at $z=1.16$ in GCLASS. The one at $z=1.2$ has a high fraction of [OII] members, a low velocity dispersion, and a filamentary structure: more data needed for a more robust analysis against selection biases and low-statistic uncertainties

- SpARCS clusters at $z>1$: paving the way for a better understanding of galaxy evolution, cluster structure and the formation of the RS