Early-type galaxy formation: understanding the role of the environment

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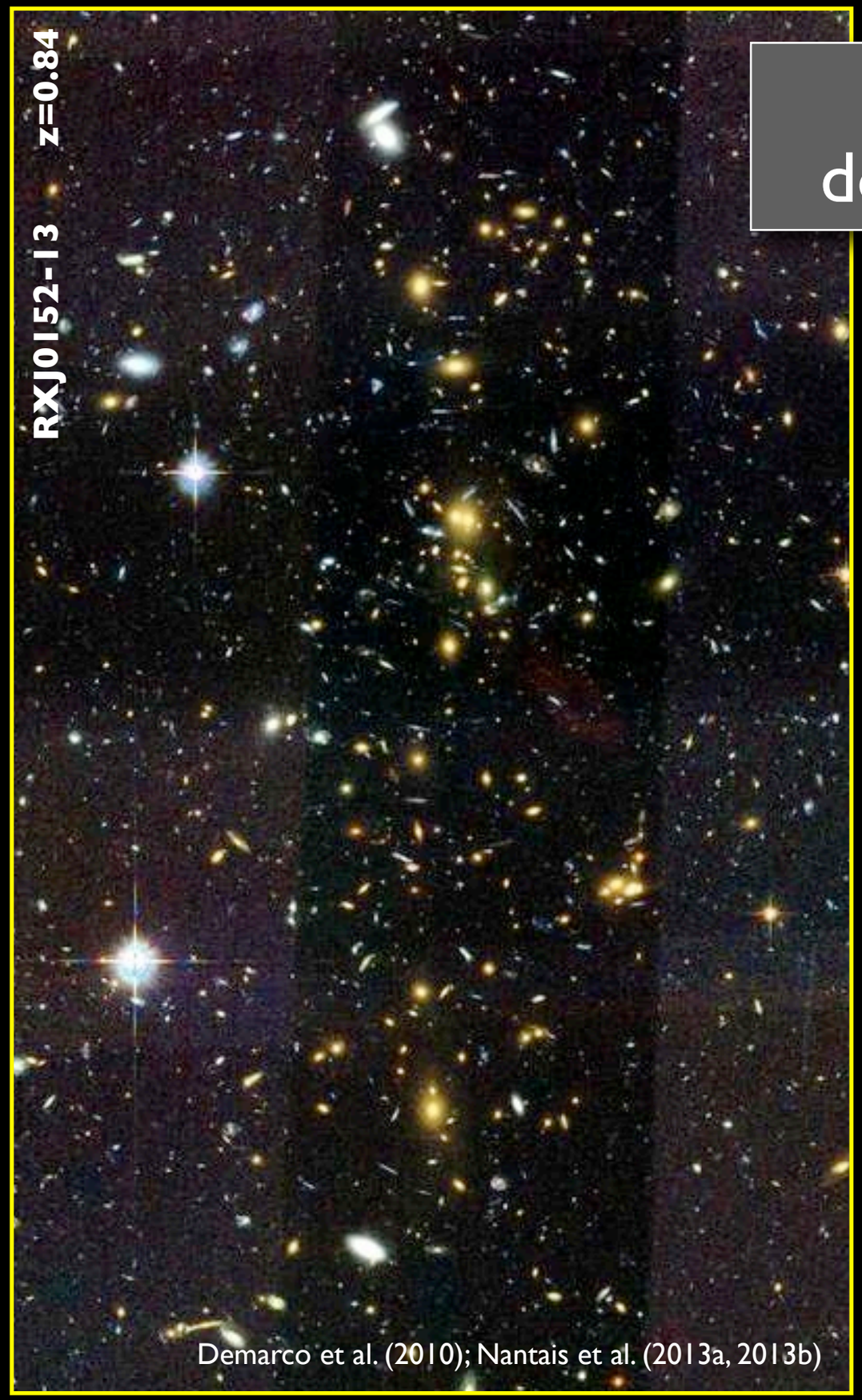
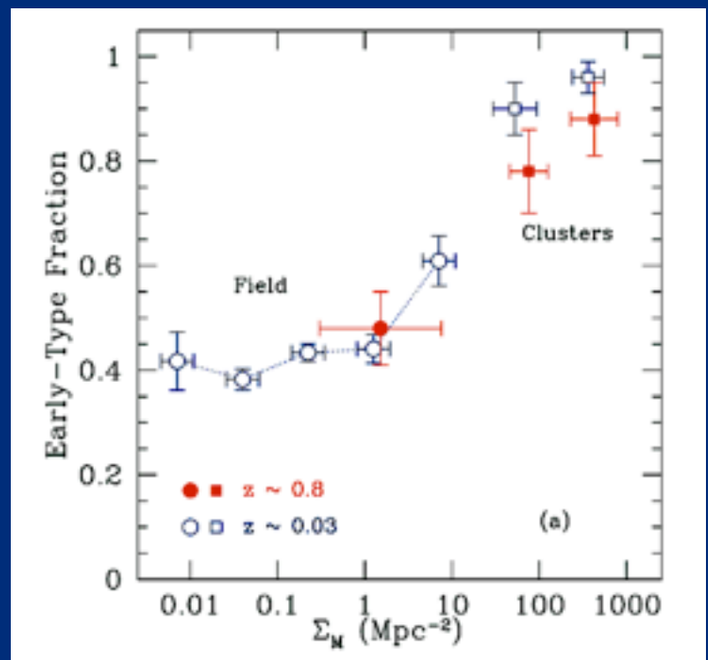
The cores of galaxy clusters are dominated by **early-type galaxies**

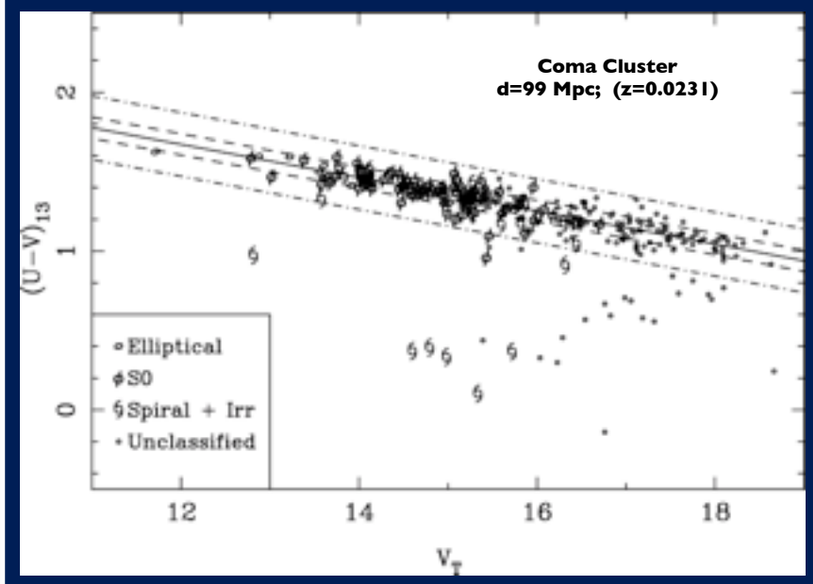


Demarco et al. (2010); Nantais et al. (2013a, 2013b)

The **Morphology-Density Relation**: densest regions are dominated by "read-and-dead" early-type galaxies

van der Wel et al. (2007)

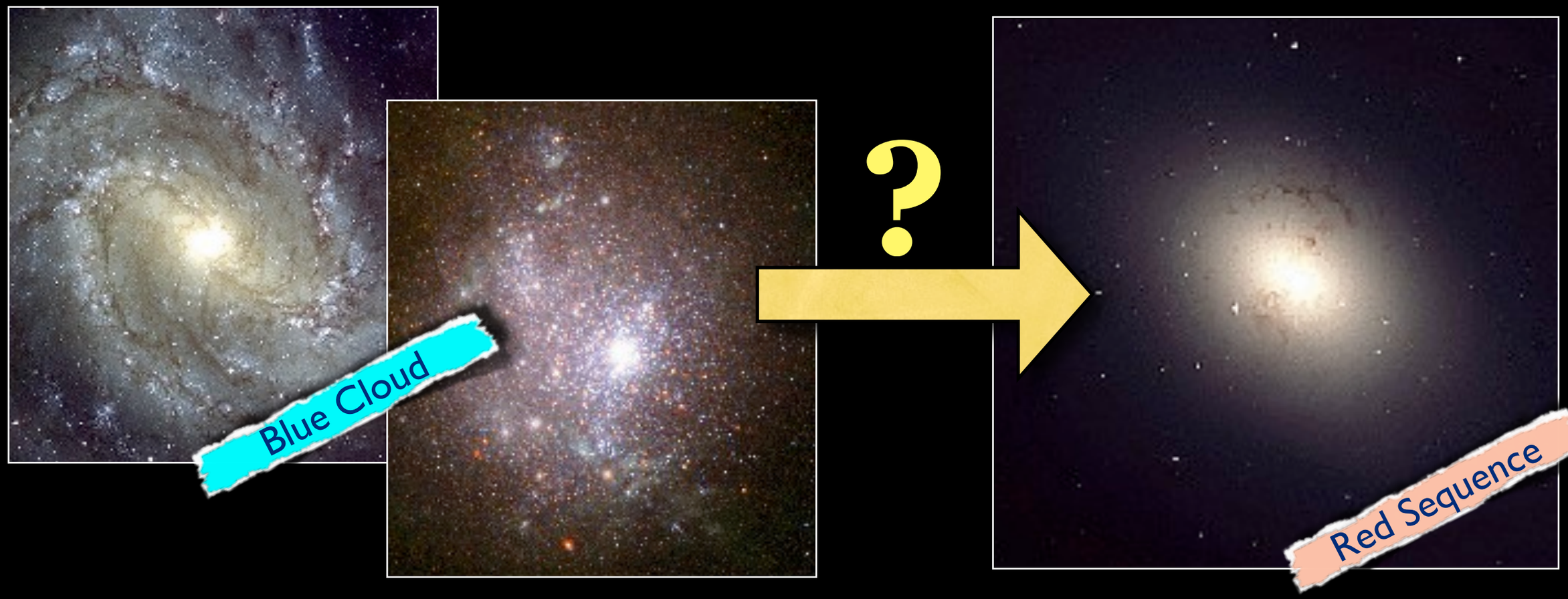




The **Red Sequence** of Early-Type Galaxies: "read-and-dead" galaxies form a tight distribution in color-magnitud space

Terlevich et al. (2001)

Star formation needs to be **quenched**



How? - Nurture vs Nature (?)

Nurture: environmental processes - local density; ram-pressure stripping; galaxy-galaxy interactions (e.g. harassment, mergers, low-speed encounters)
Nature: halo mass, initial conditions

Different processes, whatever their relative importance, should affect (or not) the kinematics, spatial distribution and content of the (molecular and ionized) gas component of galaxies.

Star-froming galaxies in intermediate density regions of clusters at high redshift:

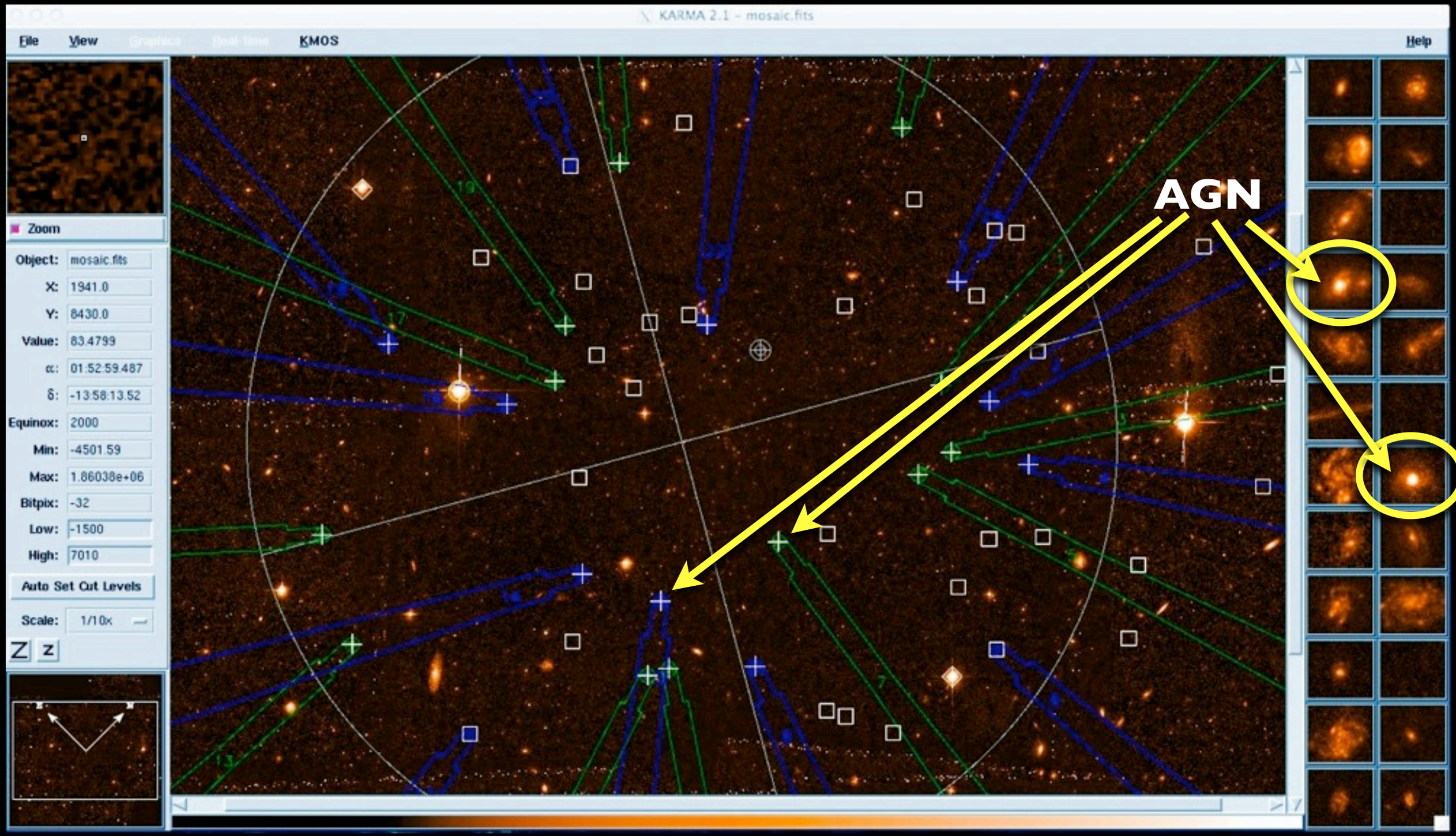
Hα emission down to a SFR_{lim}~$5M_{\odot}$ yr^{-1}

S/N=10 $Å^{-1}$, 10 / $\sqrt{3}$ / $\sqrt{4}$ = 2.9 $spaxel^{-1}$

KMOS sample of clusters of galaxies (44 h total):

NAME	REDSHIFT	SELECTION	PHOTOMETRY	SPECTROSCOPY	ESO Period
RX J0152-1357	0.84	X-Ray	ACS/WFC-3, Hawk-I/ISAAC, Spitzer, Chandra, VLA, Herschel	yes (FORS2)	92
XMM J1229+0151	0.98	X-Ray	ACS/WFC-3, Hawk-I/ISAAC	yes	93
RDCS J1252-2927	1.24	X-Ray	ACS/WFC-3 Hawk-I/ISAAC, Spitzer, Chandra	yes (FORS2)	93
XMM J2235.3-2557	1.39	X-Ray	ACS/WFC-3, Hawk-I/ISAAC	yes (FORS2)	93
XMM J2215-1738	1.45	X-Ray	ACS/WFC-3, Hawk-I/ISAAC	yes	92
CIG J0218-0510	1.62	IR	ACS/WFC-3, Hawk-I/ISAAC	yes	92

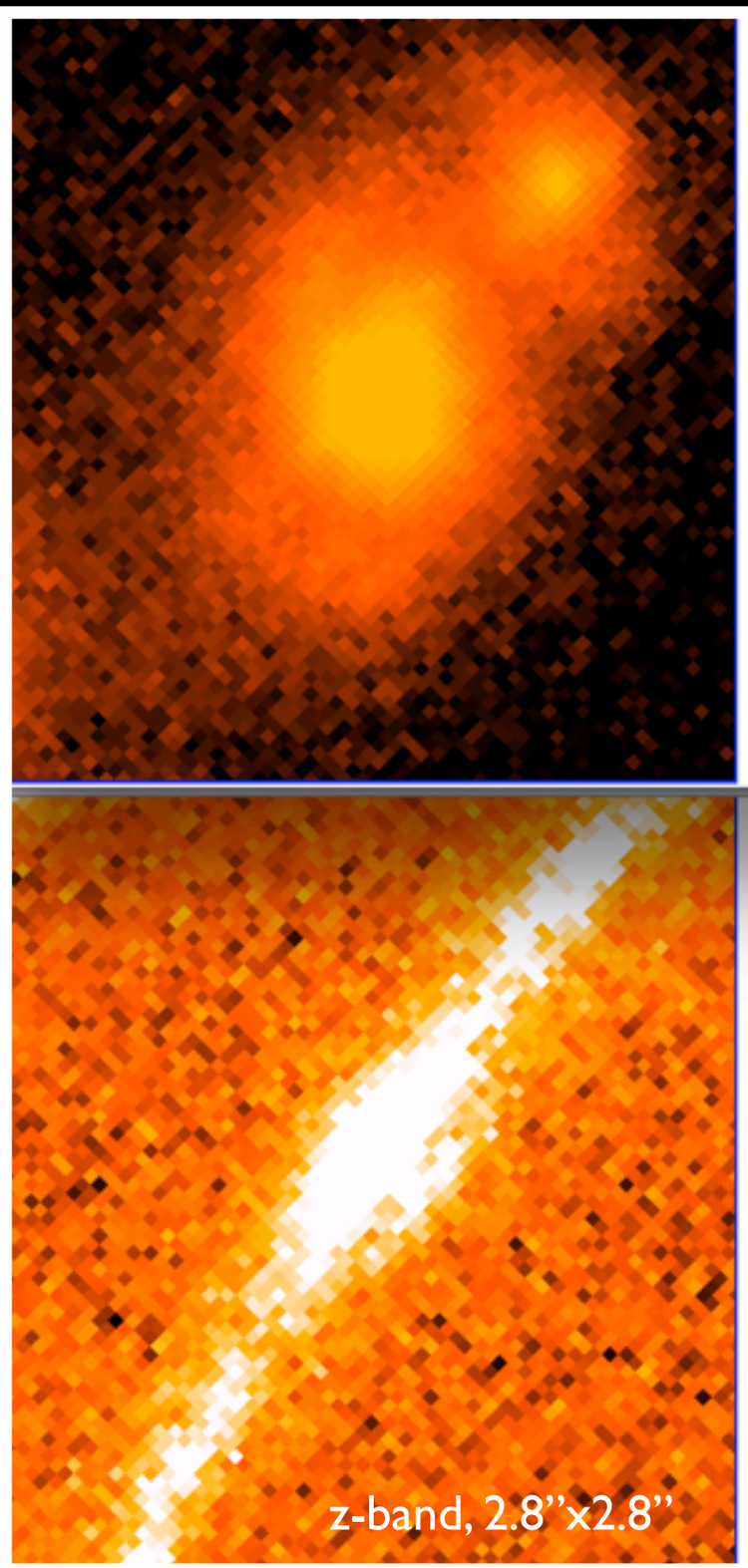
KMOS observations of RXJ0152-13 (z=0.84)



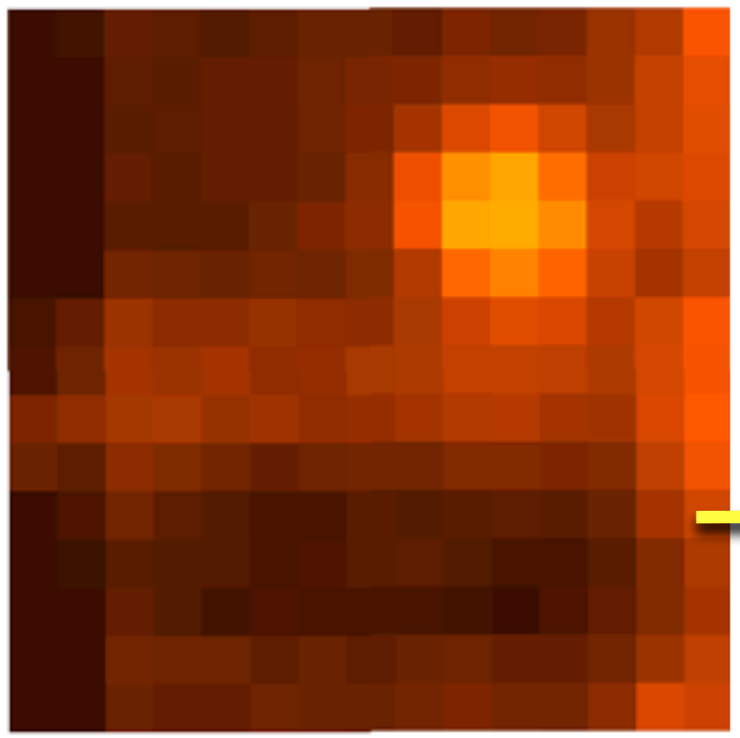
Hα within the YJ-band grating

So far: 1/6 OBs observed; 1.1 of 6.4 hrs (~17%)

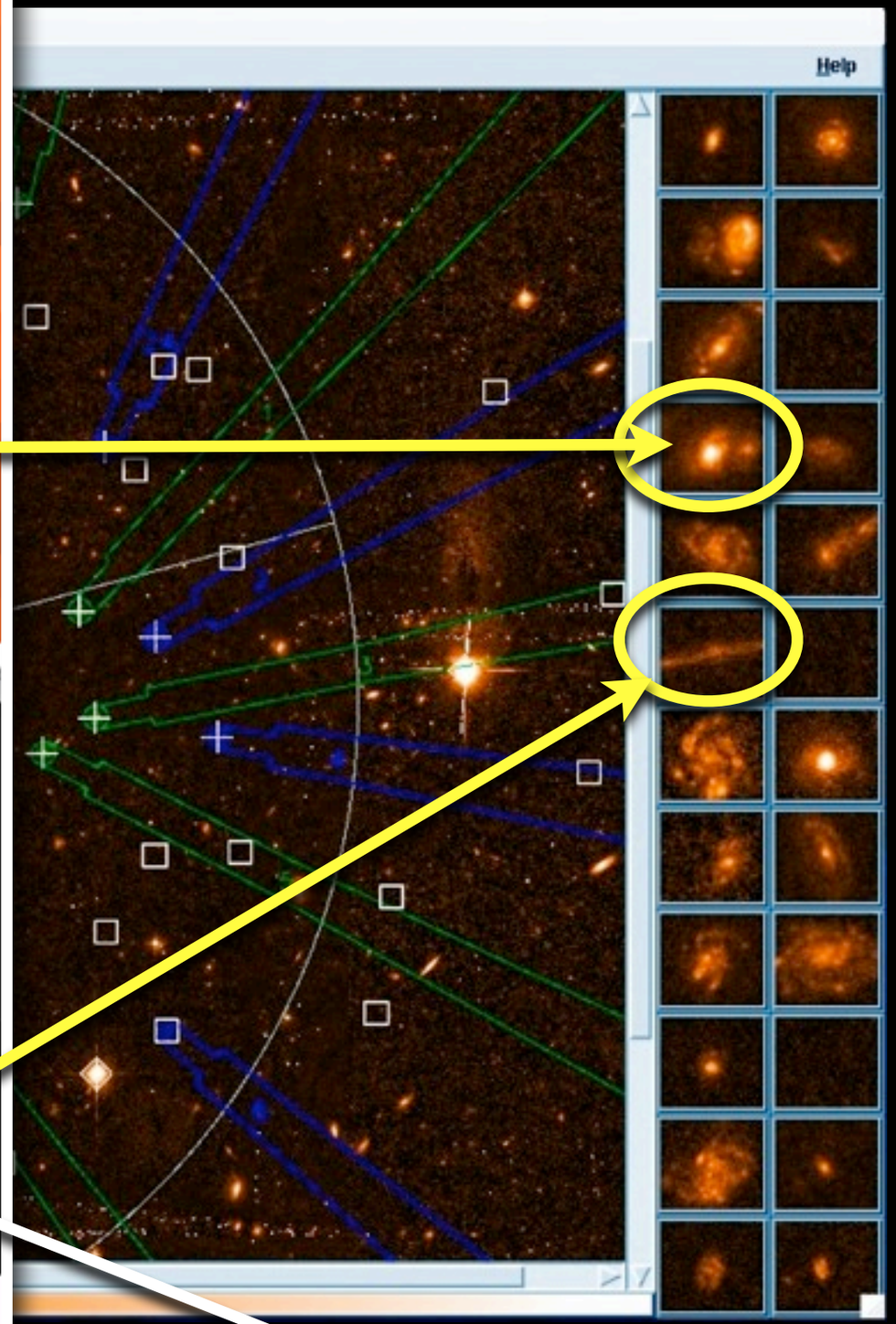
KMOS observations of RXJ0152-13 (z=0.84)



z-band, 2.8”x2.8”



KMOS Hα map (~0.7 hrs)



Data reduction with SPARK

Star formation evolution in galaxy clusters: a KMOS approach

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Abstract: One of the most characteristic features of galaxy clusters is the so-called "red sequence" (RS) that early-type galaxies form in a color-magnitude diagram. Since these galaxies are, in general, devoid of gas and dust, their red colors are mainly a consequence of their passive nature. The denser cluster core is dominated by these "red-and-dead" galaxies, some of them the most massive galaxies known. However, *the physical mechanisms responsible for quenching their star formation, thus originating the RS, are poorly understood.* Environmental effects should play a significant role in the formation of the RS by transforming t[illegible] observed galaxy properties from late- to early-type ones. Howe[illegible] details of how this actually happens are still unclear. In this [illegible] have initiated *a KMOS program aimed at studying* [illegible] *structure of star-forming cluster galaxies at 0.8<z<1.* formation period in the history of the universe [illegible] the physical mechanisms responsible fo[illegible] formation quenching, and the forma[illegible]

NAME	REDSHIFT	SF[illegible]	[illegible]RY	SPECTROSCOPY
RX J0152-1357	[illegible]	[illegible]	[illegible]pitzer	yes (FORS2)
XMM [illegible]	[illegible]	[illegible]	[illegible]	yes
[illegible]	[illegible]	[illegible]	[illegible]	yes (FORS2)
[illegible]	[illegible]	[illegible]	[illegible], Hawk-I/ISAAC	yes (FORS2)
[illegible]	[illegible]	[illegible]	ACS/WFC-3, Hawk-I/ISAAC	yes
[illegible]	[illegible]	IR	ACS/WFC-3, Hawk-I/ISAAC	yes

[illegible]ters in our KMOS program. All but one of them are X-ray selected. Extensive multi-[illegible]nd spectroscopic data are available, including VLT and HST imaging, as well as VLT [illegible] of 44 hours of KMOS time has been assigned to this program. Observations are in progress.

The scientific problem: [illegible] and that by z~1.4 is [illegible] faint end, becomin[illegible] Kodama et al. 2007, [illegible]ally happens is still uncle[illegible] galaxies formed directly as suc[illegible]lf-quenching mechanisms regulated [illegible]y-type galaxies get into the RS when locat[illegible]vironments in in-falling matter filaments (**nurture**, [illegible] history and at which local densities do the effects of [illegible]g and galaxy-galaxy interactions (e.g. harassment, mergers, [illegible]unters; Treu et al. 2003) become the dominant way in which gal[illegible]come passive and enter the RS in color-magnitude space? *All these p[illegible]sses, whatever their relative importance, should affect the kinematics, spatial distribution and content of the (molecular and ionized)*

[illegible]pproach and the cluster sample: the available observational evidence [illegible]hows that it is possible, when comparing with numerical models, to establish the most likely cause of any observed kinematical and structural anomaly in galaxies (Puech et al. 2009; Hammer et al. 2009). However, these systematic and comprehensive studies of the kinematics and detailed structure of baryons in cluster galaxies at high redshift (z>0.8) are still scarce. Here we aim at exploiting the capabilities of KMOS on the ESO VLT to map out the kinematical structure, spatial distribution and overall properties of the ionized gas components of galaxies for a sample of 6 galaxy clusters at 0.8<z<1.7 (see Table 1). In this way, we will search for the presence (or lack) of signatures of the different environmental (galaxy-ICM and galaxy-galaxy) interactions to better understand the physical mechanisms responsible for stellar quenching and the formation of the RS in clusters of galaxies. All but one of the clusters are part of the Hawk-I Cluster Survey (Huertas-Company & Lidman 2011).

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