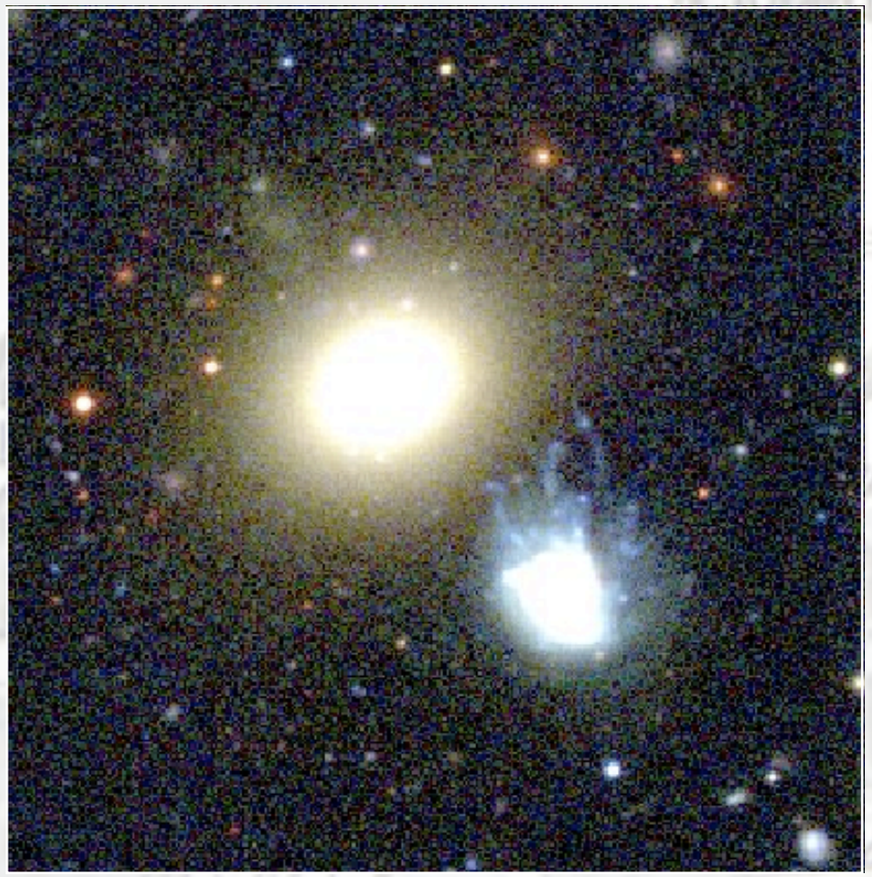
# The Coma 3-degree Survey
# Stripping and Quenching of Infalling Dwarfs


## Russell Smith

**Durham University**

~~1) Motivation~~ You all know it already!

2) UV tails & trails: Ongoing stripping of star-forming galaxies

3) Asorption-line spectroscopy: Recent quenching of outer dwarfs

4) Enviro-history of cluster members in models.


ESO Conference // Virgo, Fornax, Coma et al.: Stellar systems in high-density environments // Jun 2011

# The Coma 3-degree Survey

Associated with the HST/ACS Coma Treasury Survey (Carter et al. 2008), but much wider area, to beyond virial radius of cluster.

* **Data:**

* Comprehensive spectroscopy from MMT/Hectospec + SDSS:

  - “fast” redshift survey

  - “deep” stellar pops spectra

* Multiwavelength imaging including

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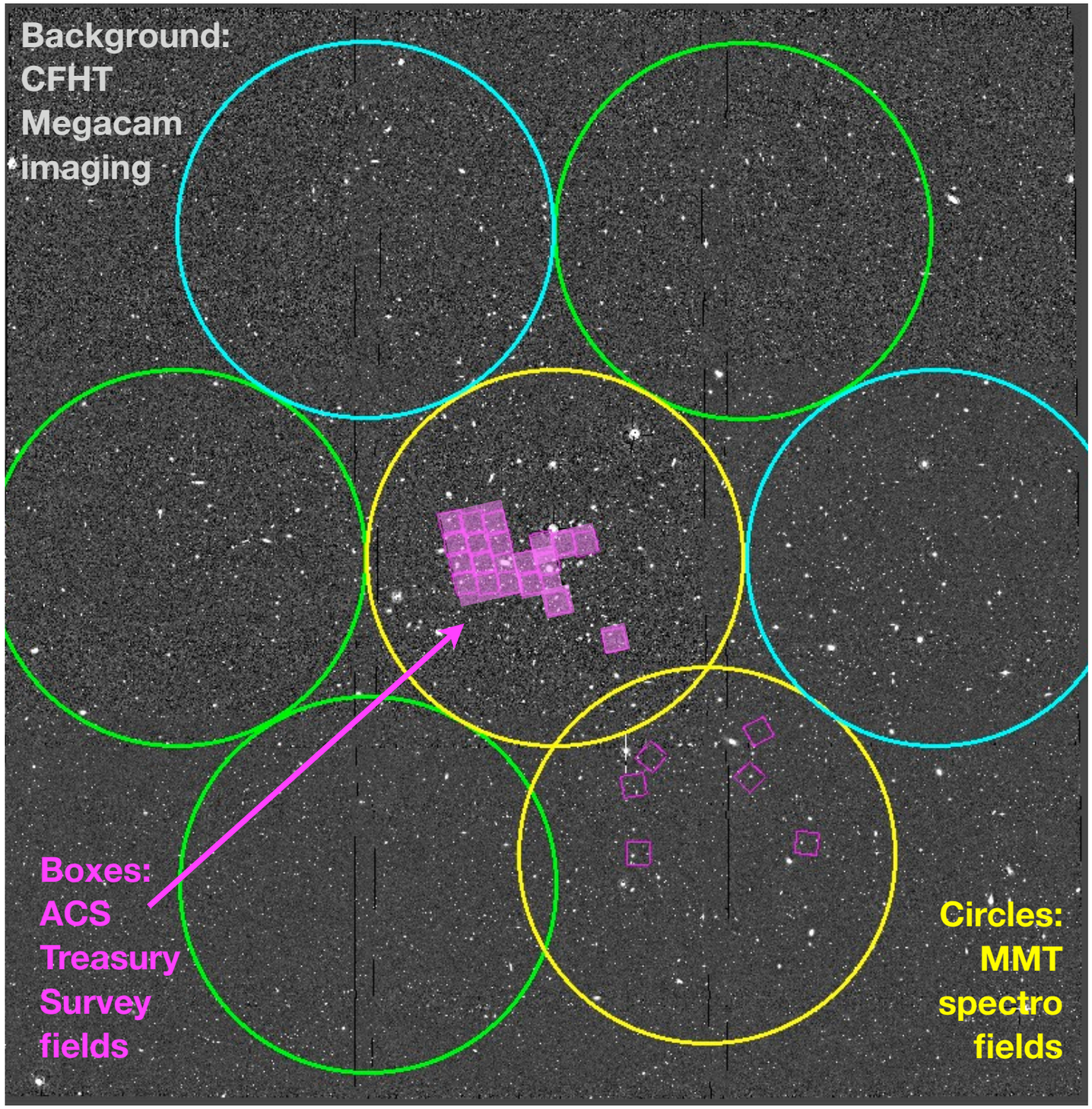


3 deg = 5 Mpc @ Coma

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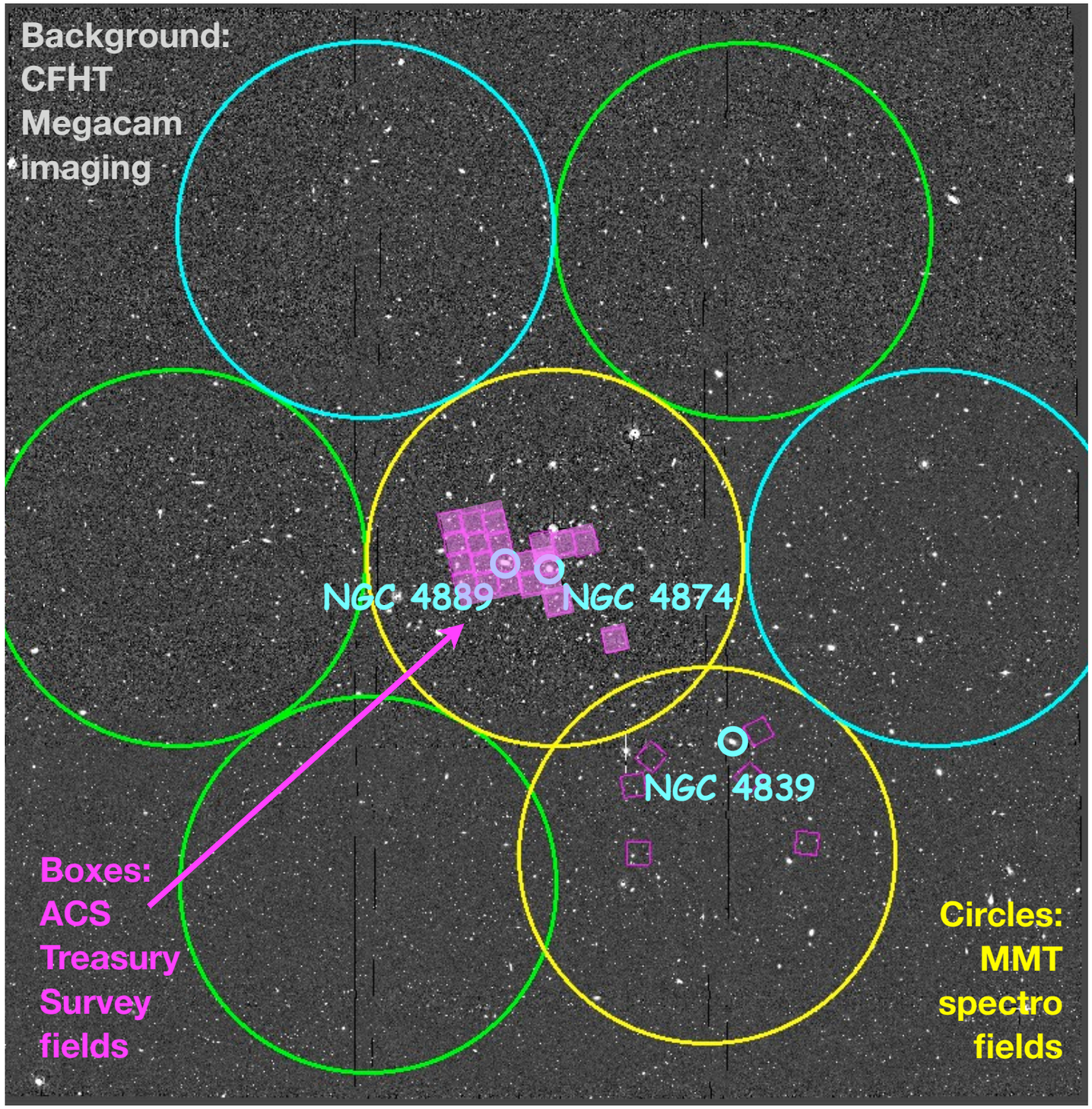


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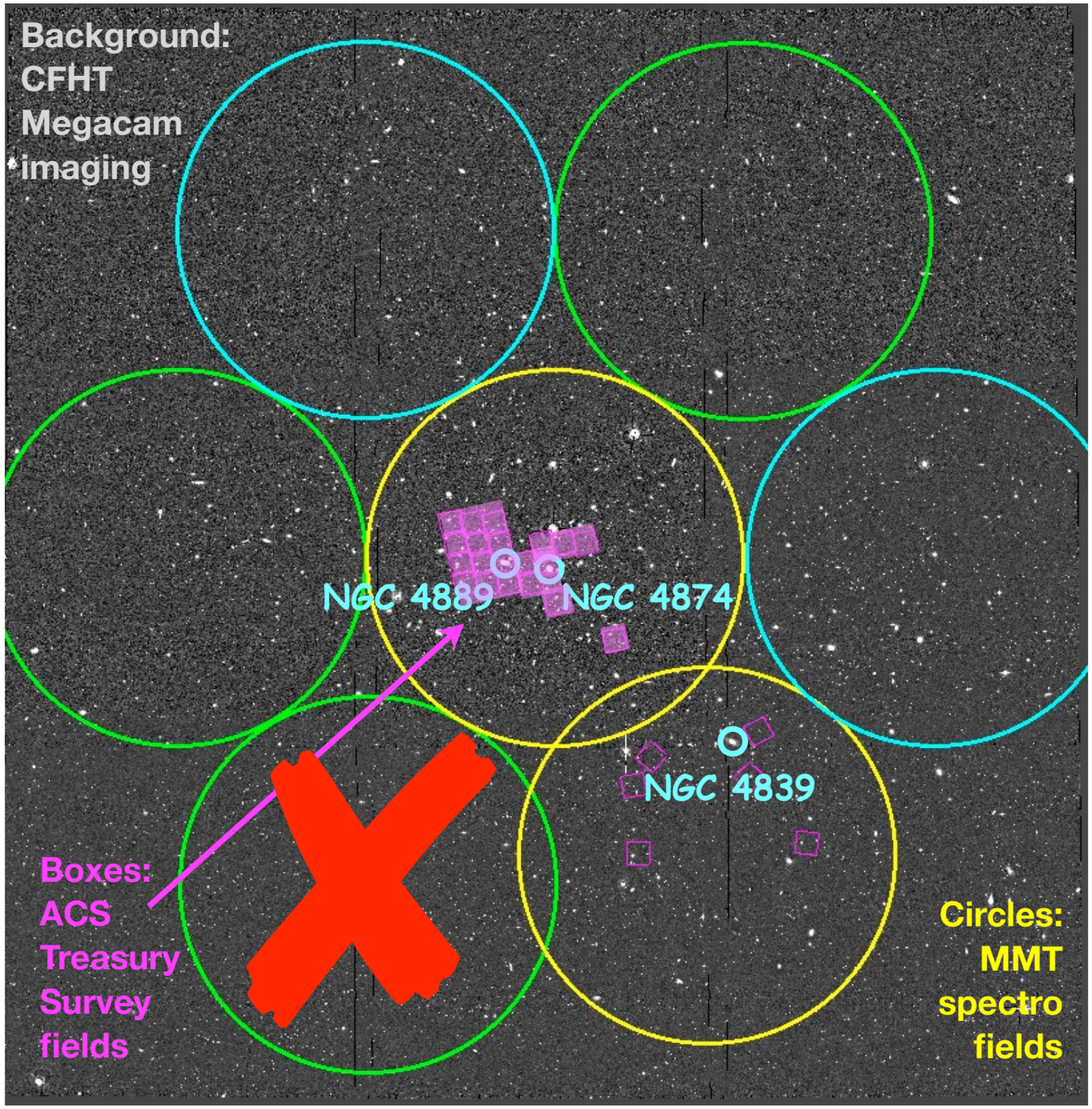


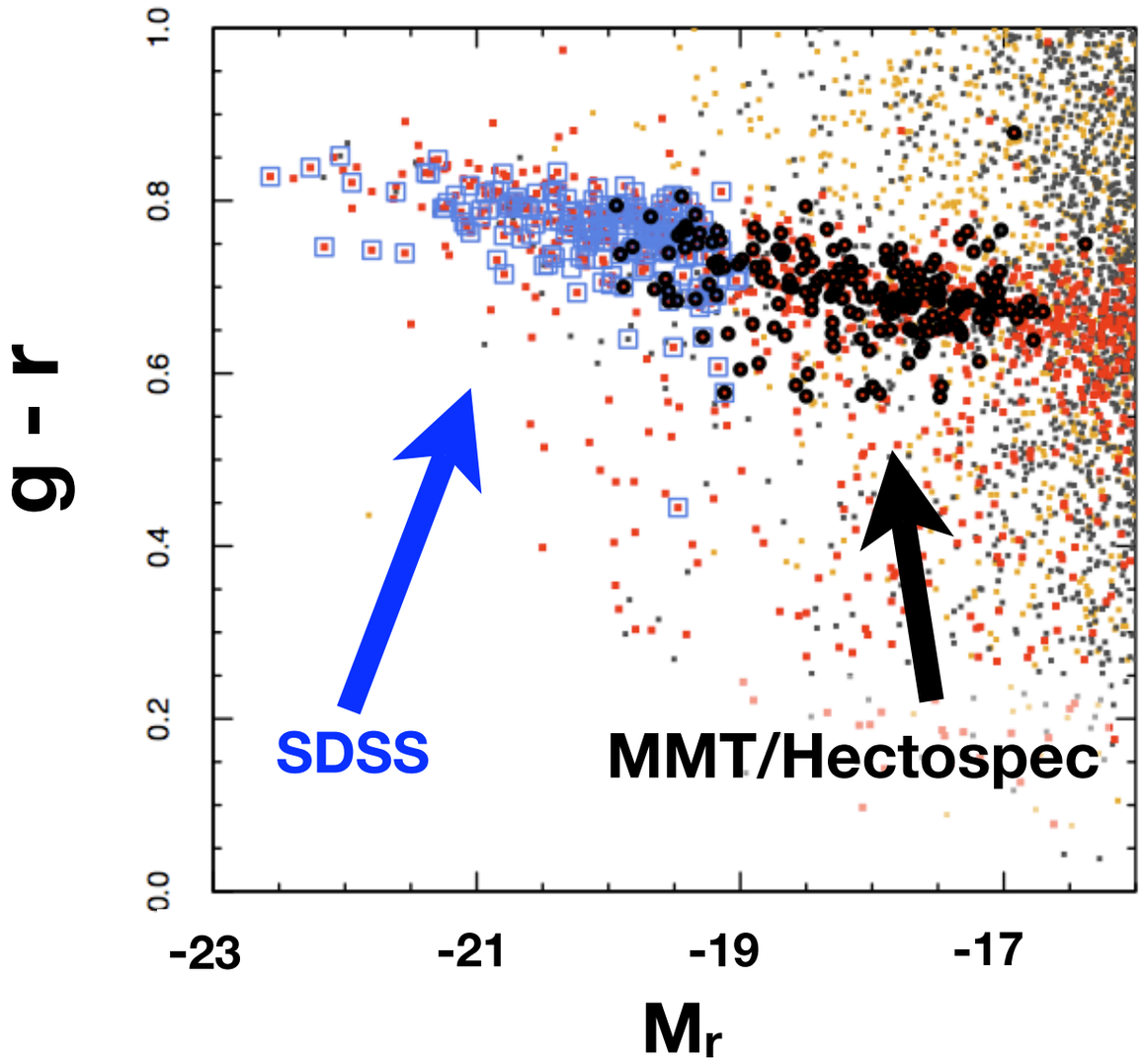

**3 deg = 5 Mpc @ Coma**

# MMT/Hectospec Spectrosopy

**Two programmes observed in parallel extending to 2.5 Mpc radius ~ $R_{vir}$**

**I.** A fast **redshift survey** of ~7,000 galaxies with r<20.5 to establish membership, measure LF, GSMF, etc. -> Marzke et al. (in prep).

**II.** Repeated observations to yield high-S/N spectra of "bright" dwarfs (r~17) for linestrengths -> stellar population information (RJS et al. 2009)




~160 "dwarf" galaxies (2-4 mag fainter than M*). Integration ~4-10 hours per galaxy, S/N ~ 50 per Angstrom.

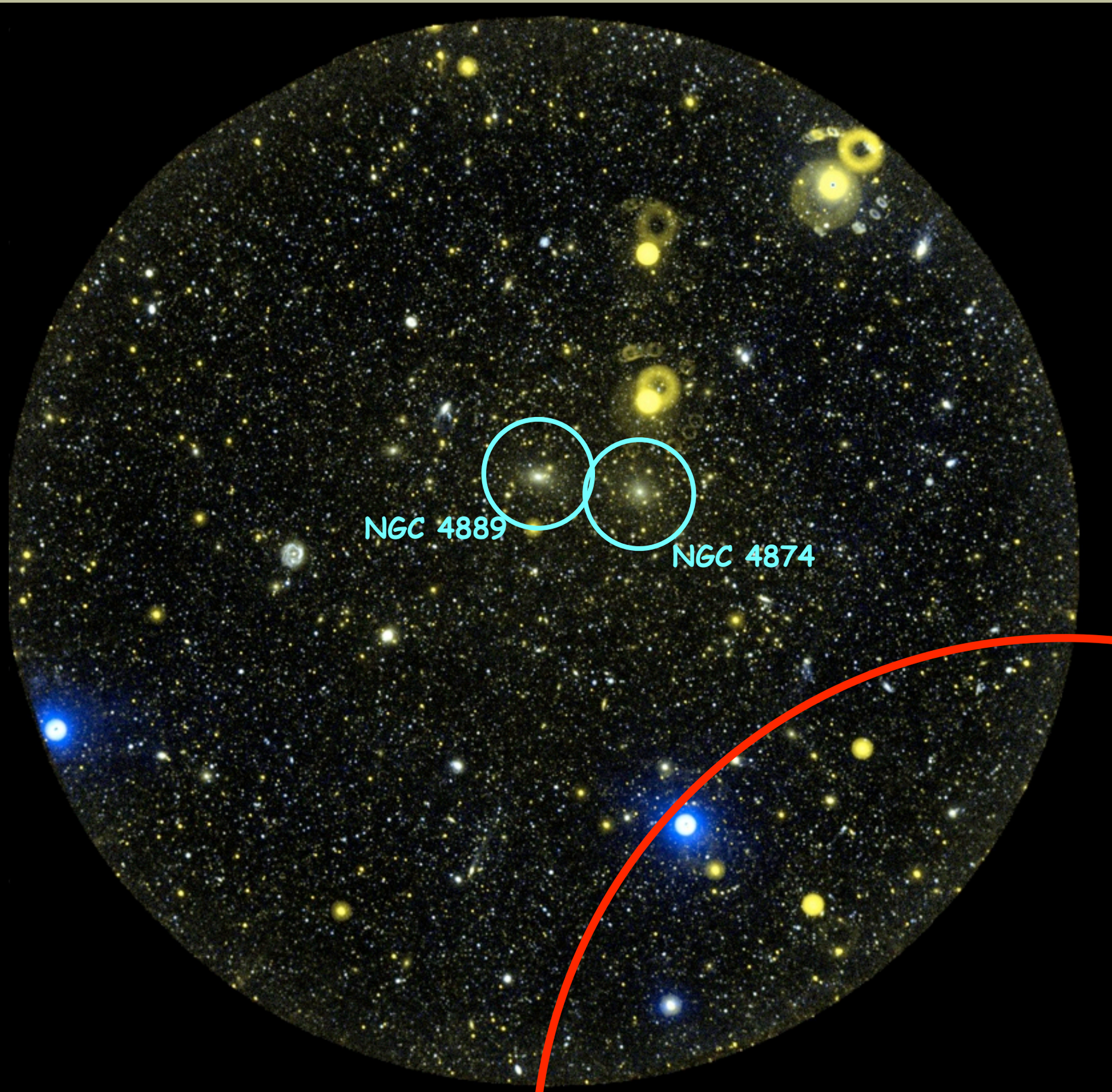
SDSS DR7 spectra re-analysed identically to ensure consistent treatment (Price et al. 2010).

Combined sample: ~430 galaxies.

# UV imaging

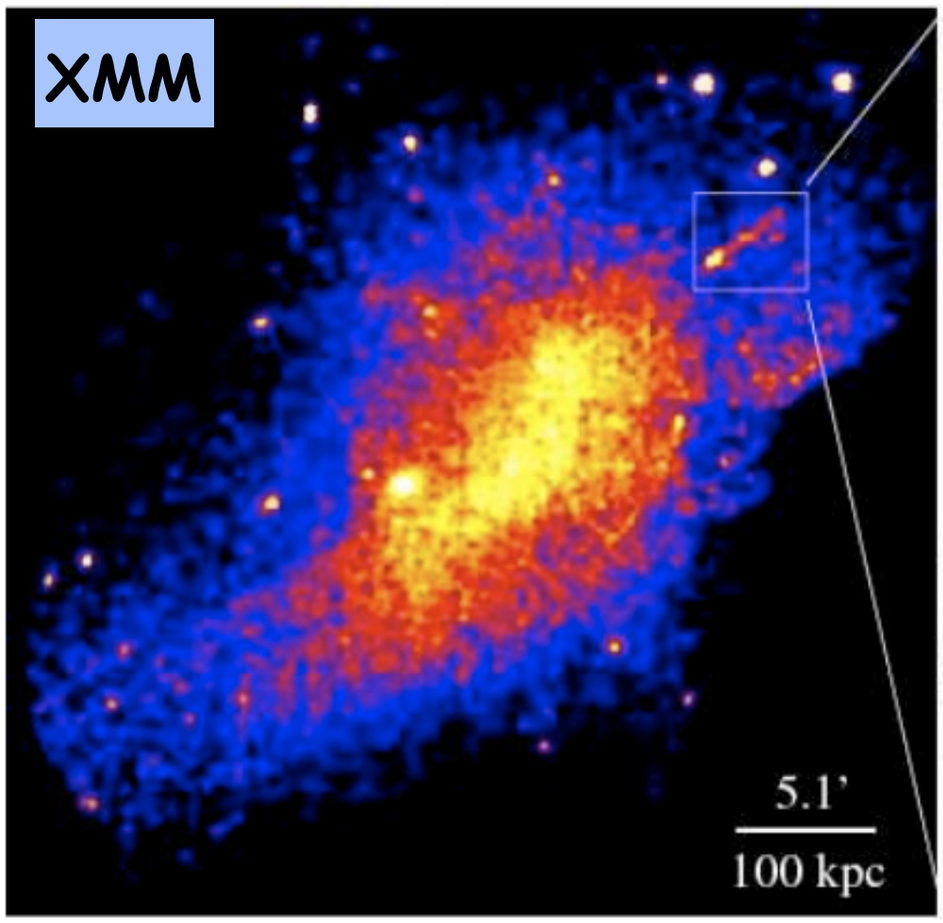
15 ksec GALEX Cycle 5 observation of Coma core.

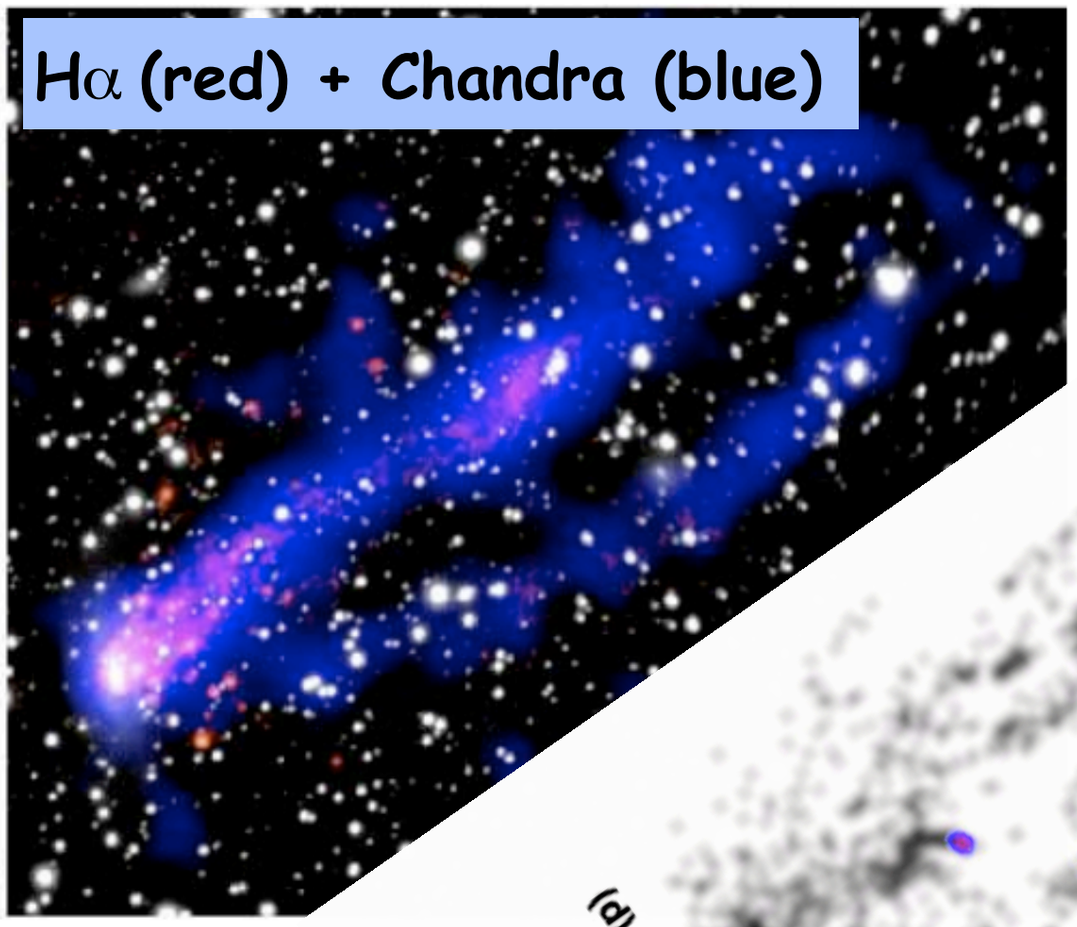
Combined with 20 ksec Cycle 2 observation of outskirts field to SW by Hammer et al. (2010 & LF paper submitted).



C3dS
Coma 3-degree Survey

# UV Tails & Trails: ongoing stripping



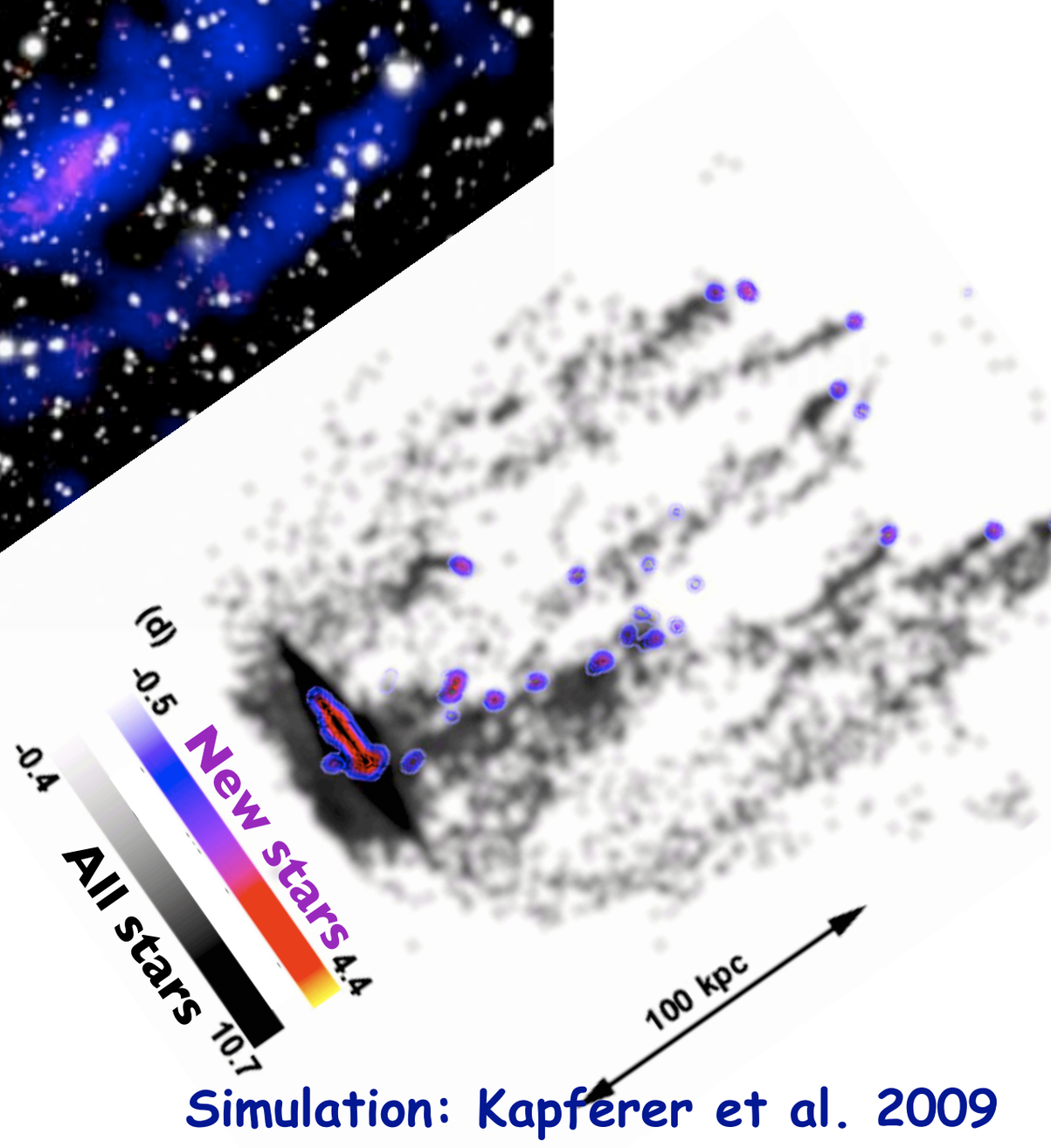




Abell 3627: Sun et al. (2007, 2009)

Small number of known “spectacular” stripping events in rich clusters.

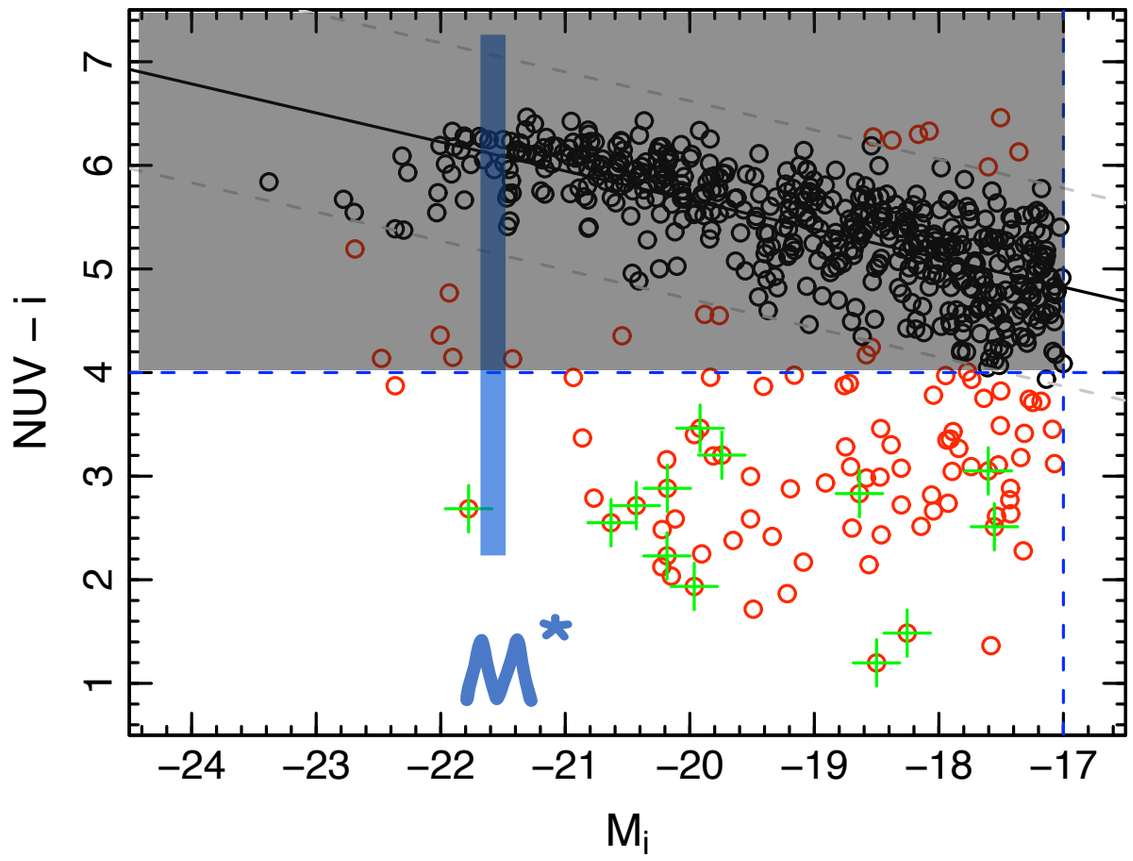
Removal of gas, leading to quenching of SF eventually....

... but temporarily perhaps enhance SF in tails of stripped material.




Simulation: Kapferer et al. 2009

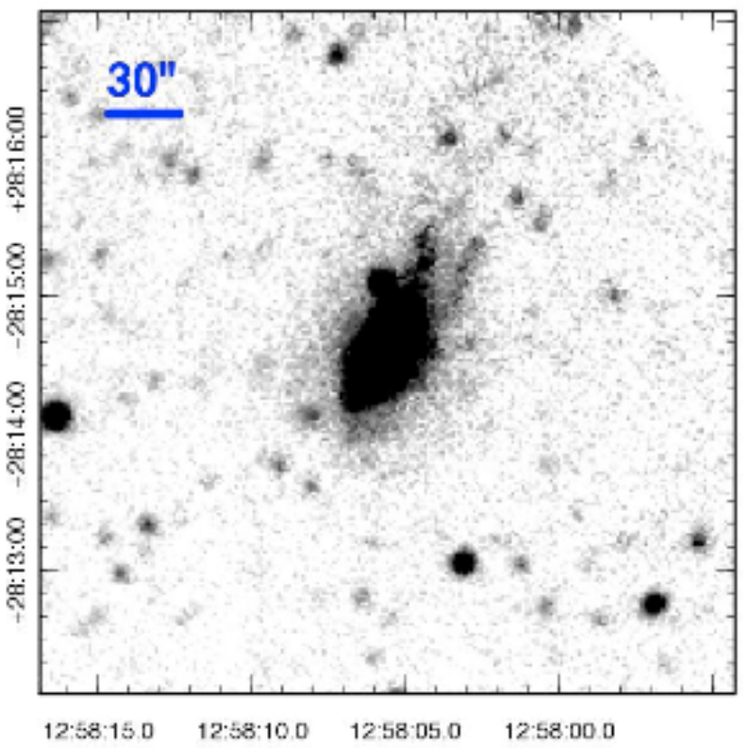
# Gas-Stripping Events (GSE)

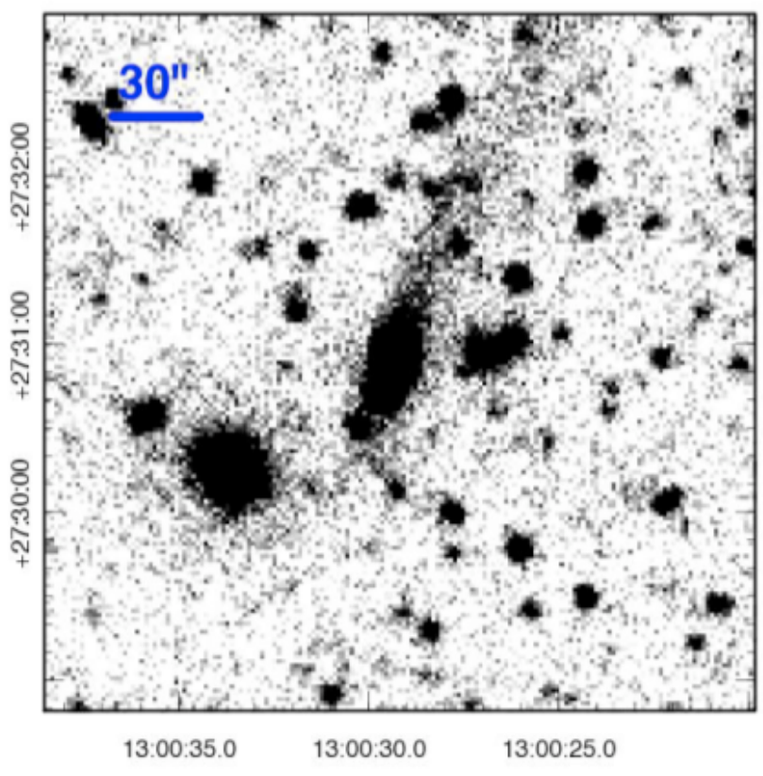


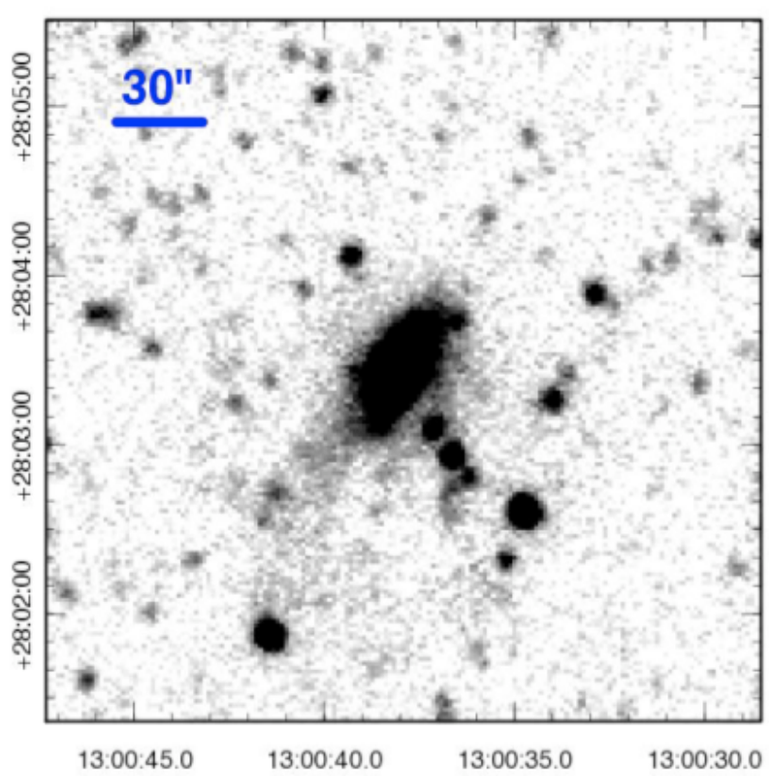

NUV - i colour-magnitude relation for **590 confirmed members** within two deep (>15ksec) Coma GALEX pointings, down to ~M*+4.5.

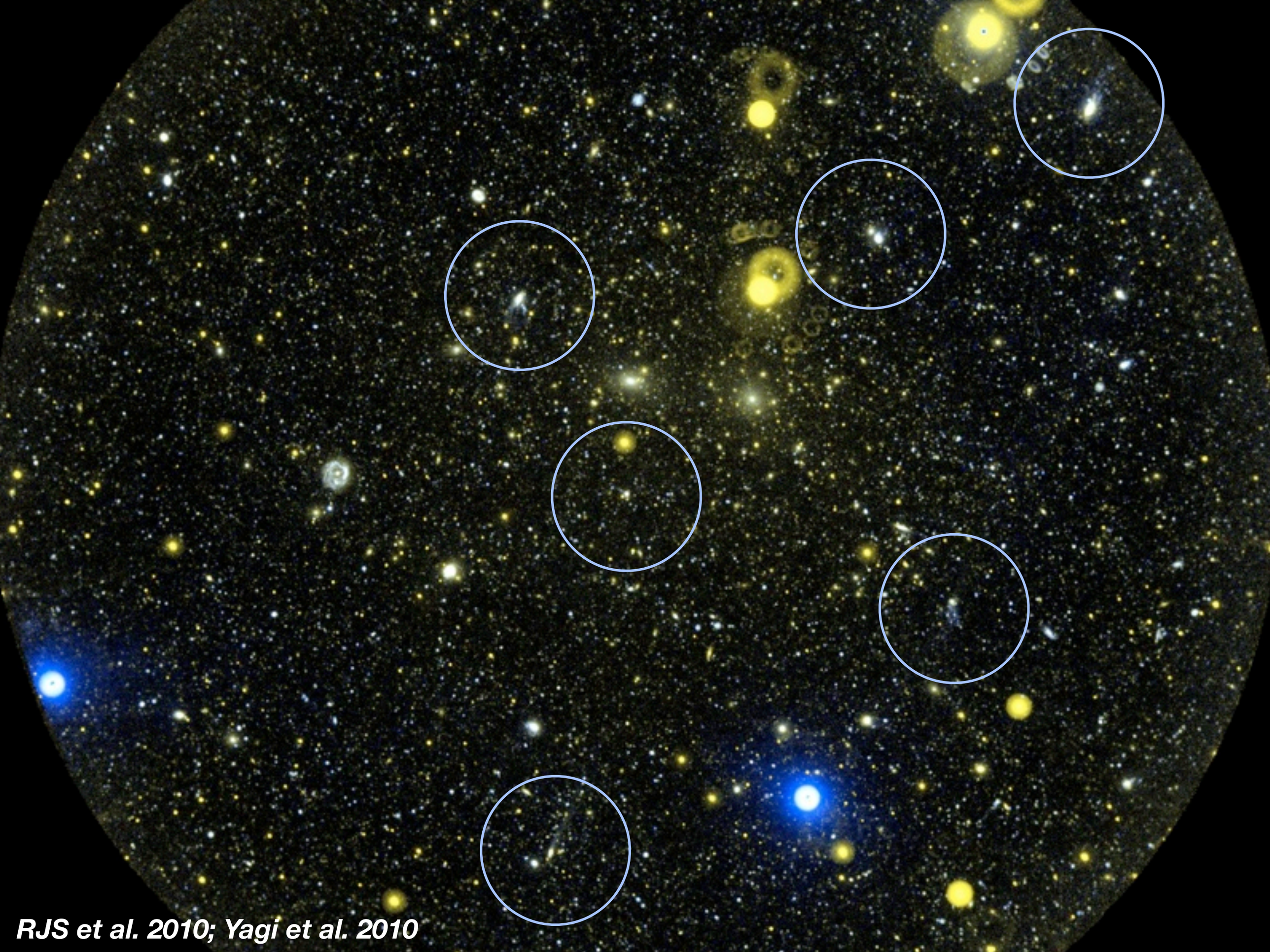
All 80 blue (NUV-i<4, $M_i$<-17) members examined for evidence of UV tails/trails: SF in stripped gas.

**Find 13 cases - not all "spectacular"!**

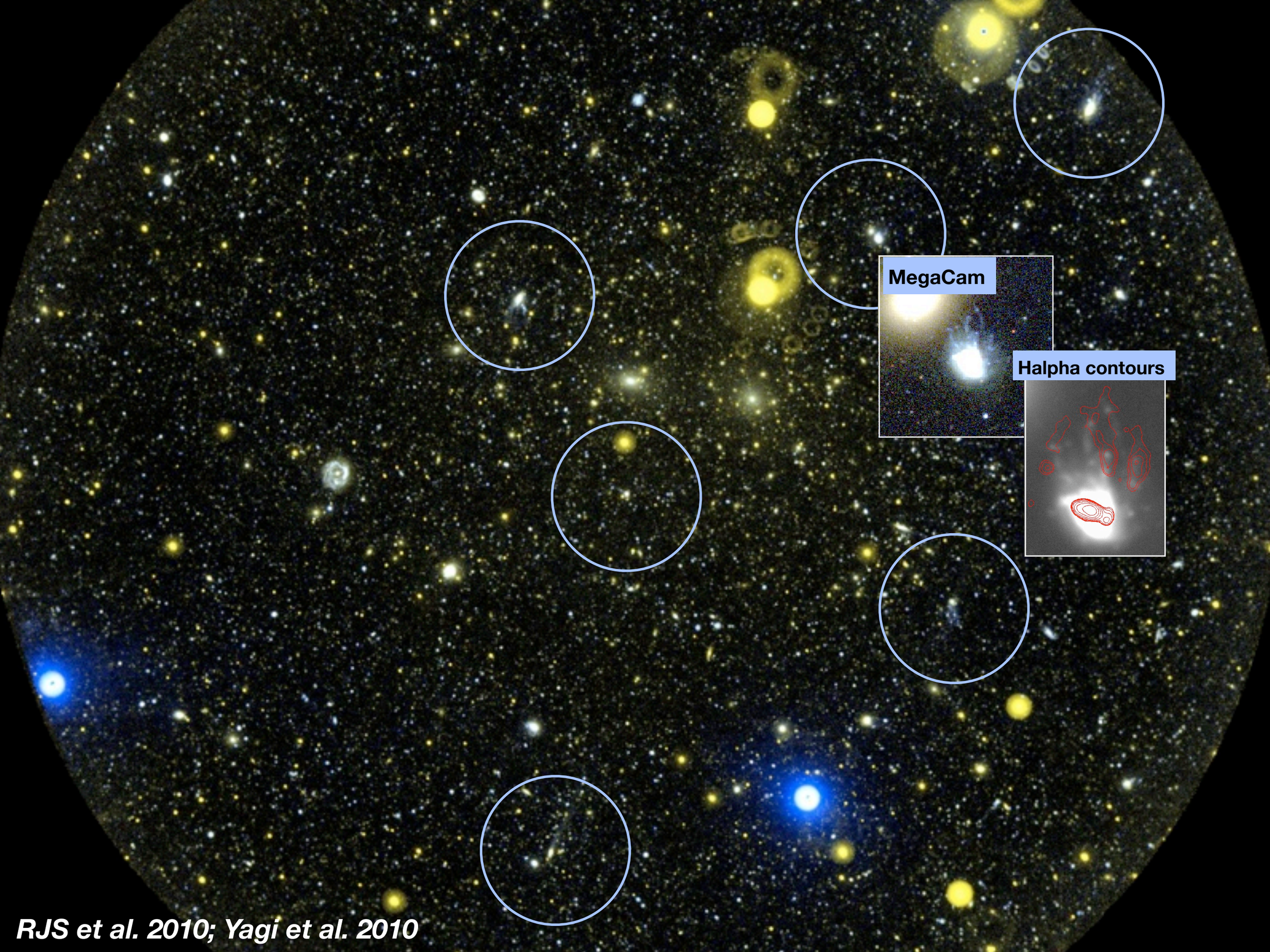




*RJS et al. 2010; Yagi et al. 2010*

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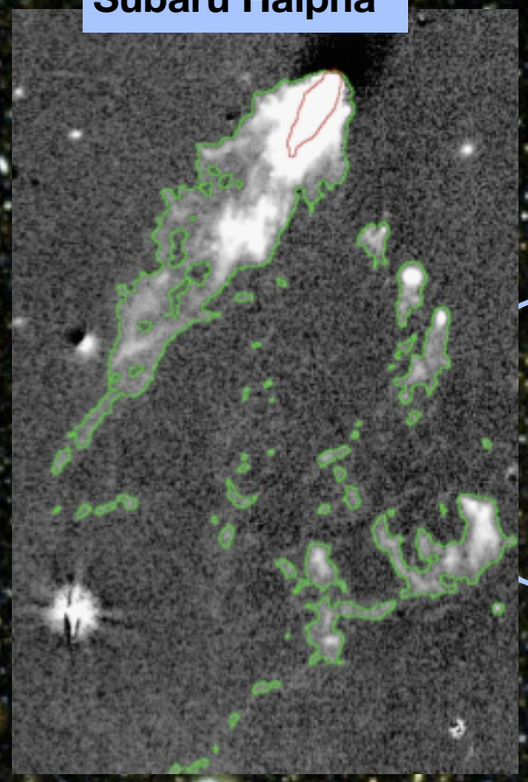
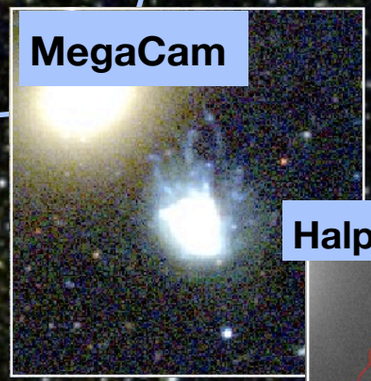
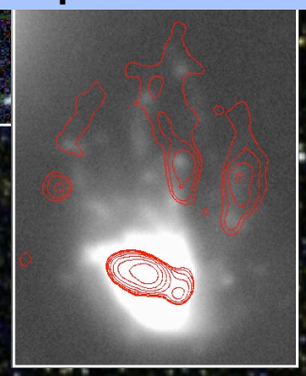
Subaru Halpha



MegaCam



Halpha contours



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HST/ACS

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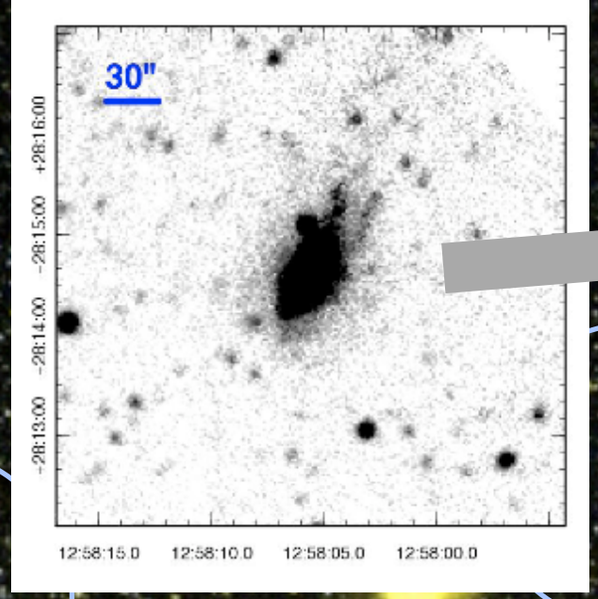
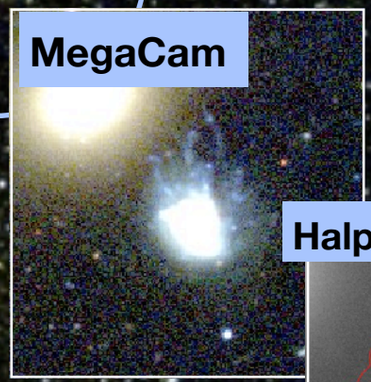



XMM


MegaCam



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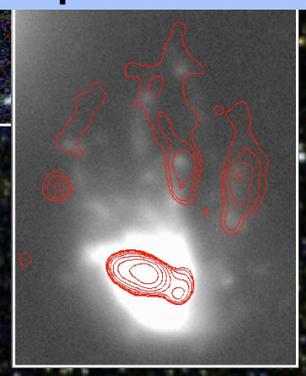
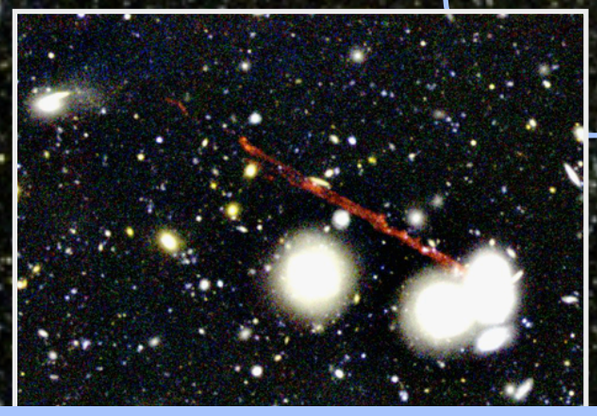
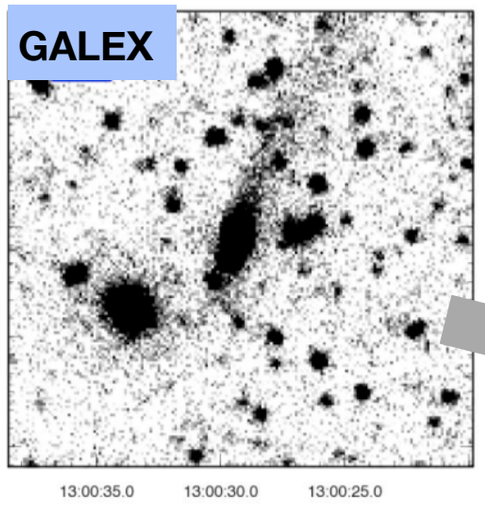
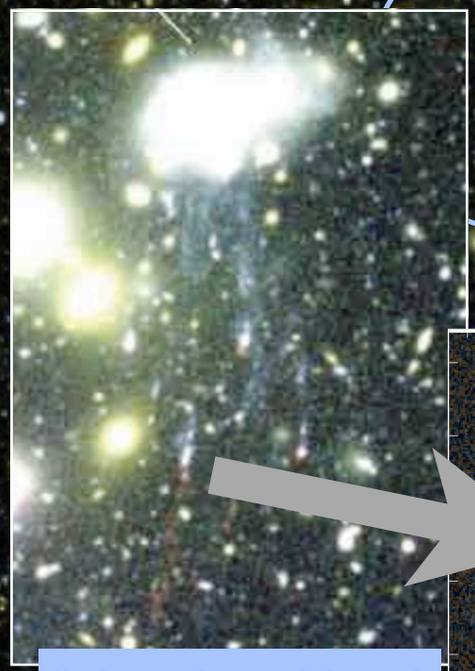




Subaru broad-band & Halpha (red)

GALEX



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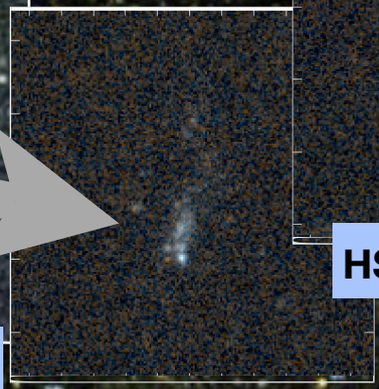

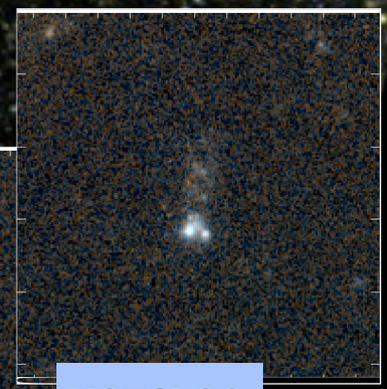

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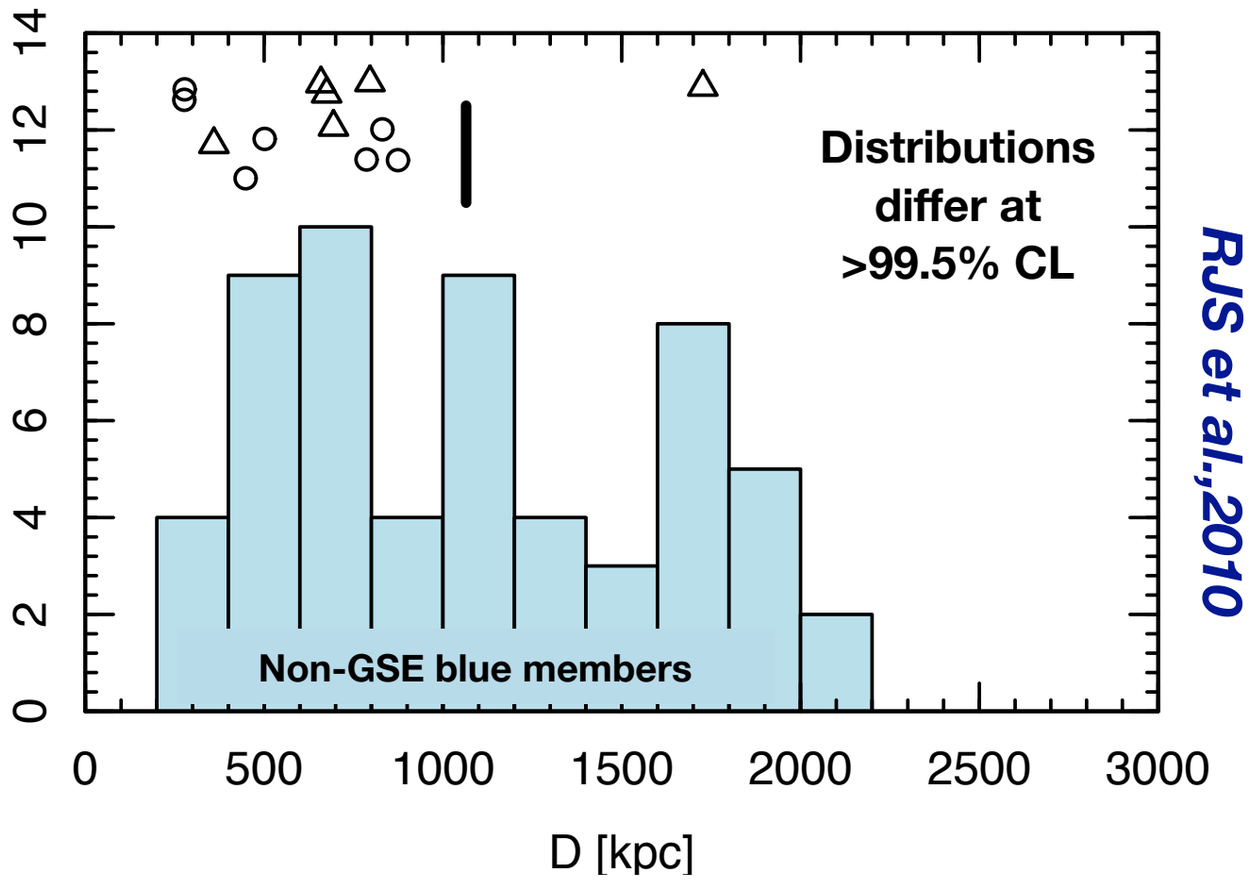
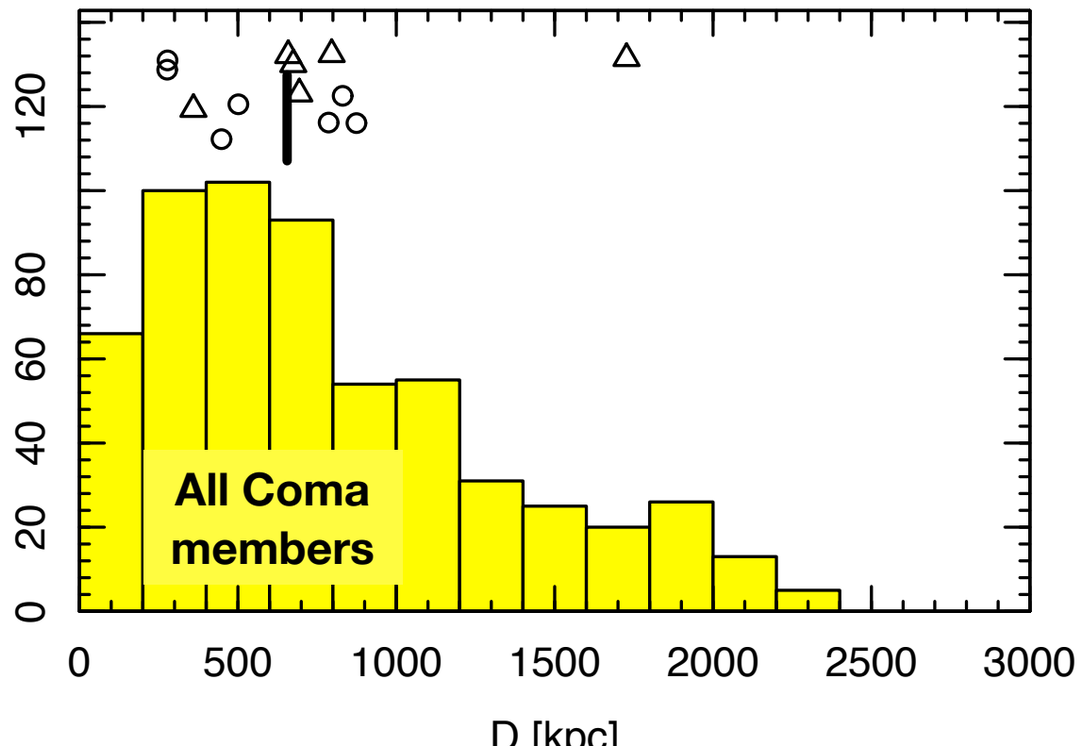
# Gas-Stripping Event (GSE) statistics

GSEs much more centrally concentrated than the non-GSE galaxies with similar colour.




GSE galaxies are distributed similarly to the *red* cluster members.



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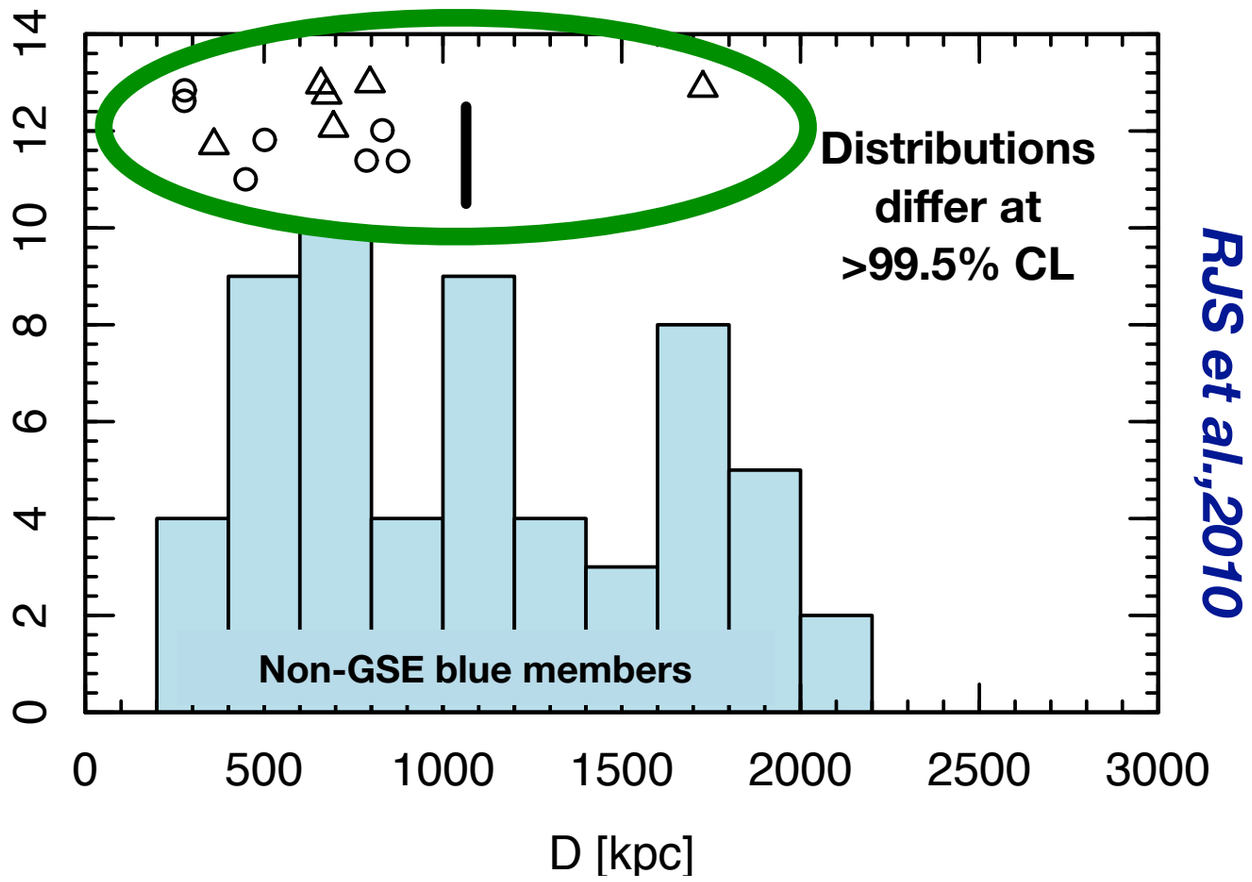


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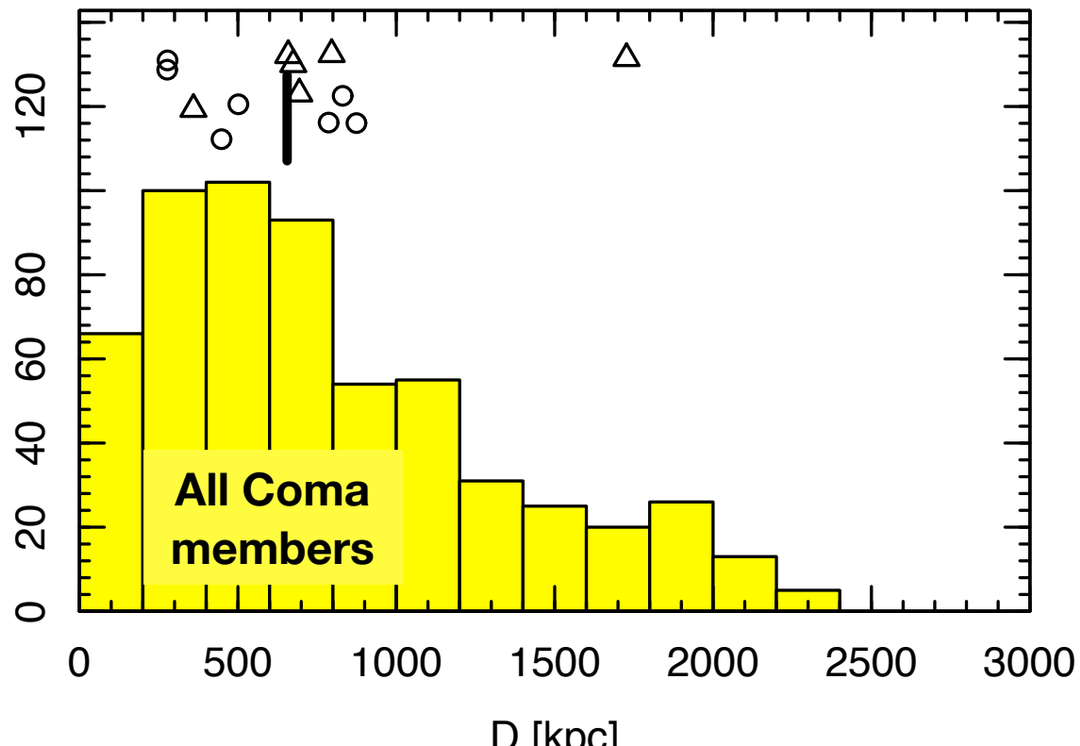

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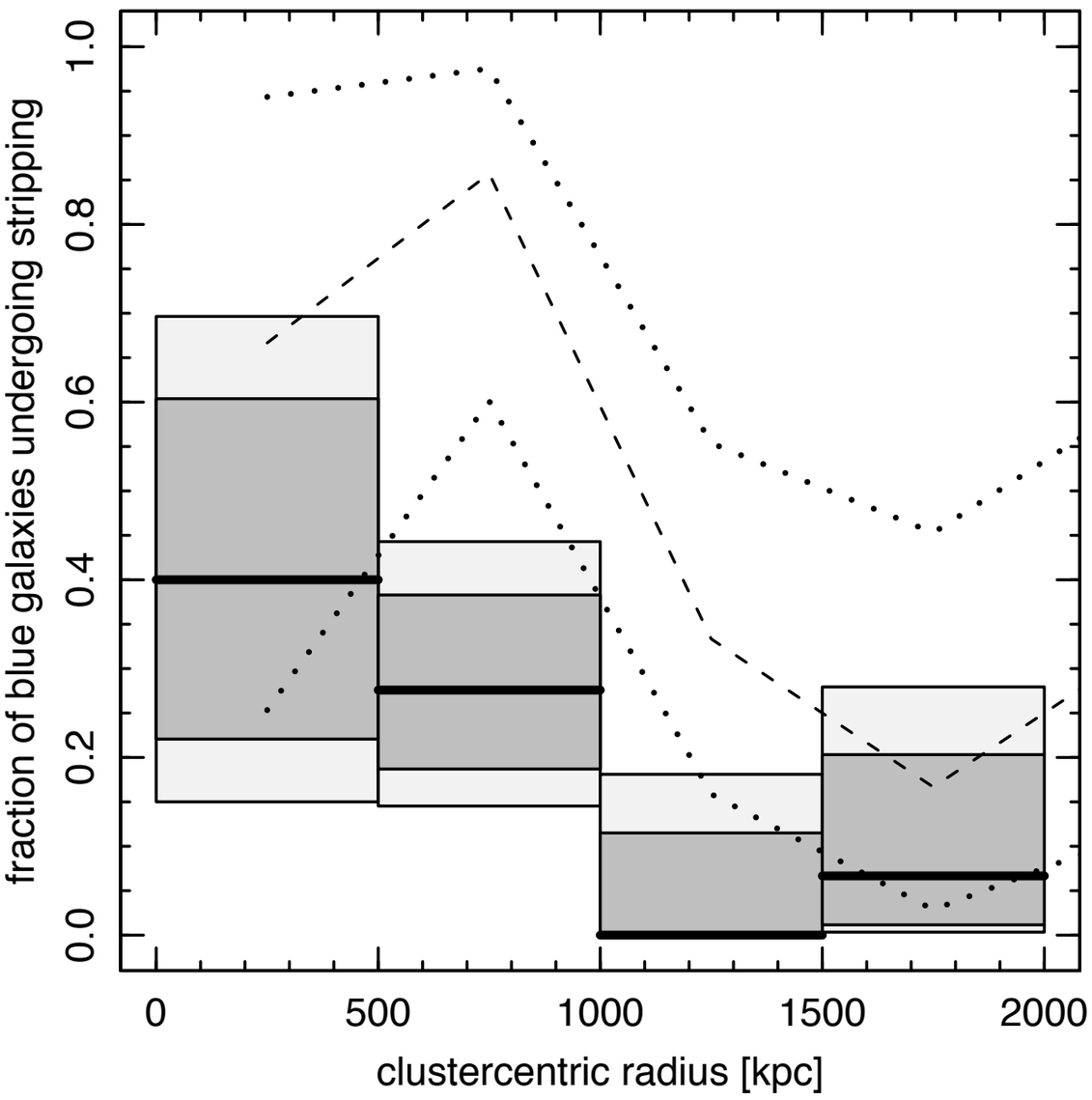
(Beyond 1 Mpc **~0%**)



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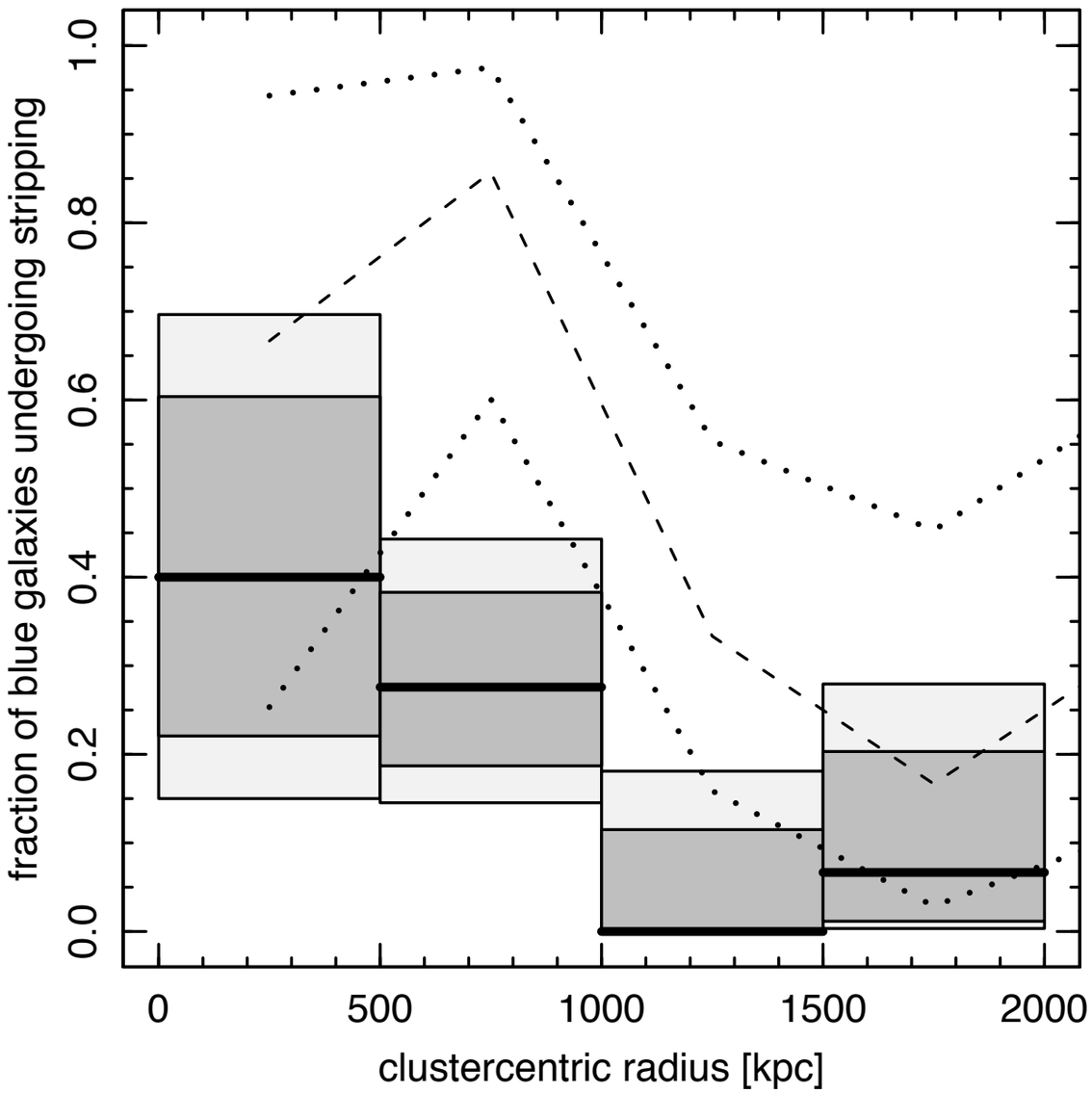


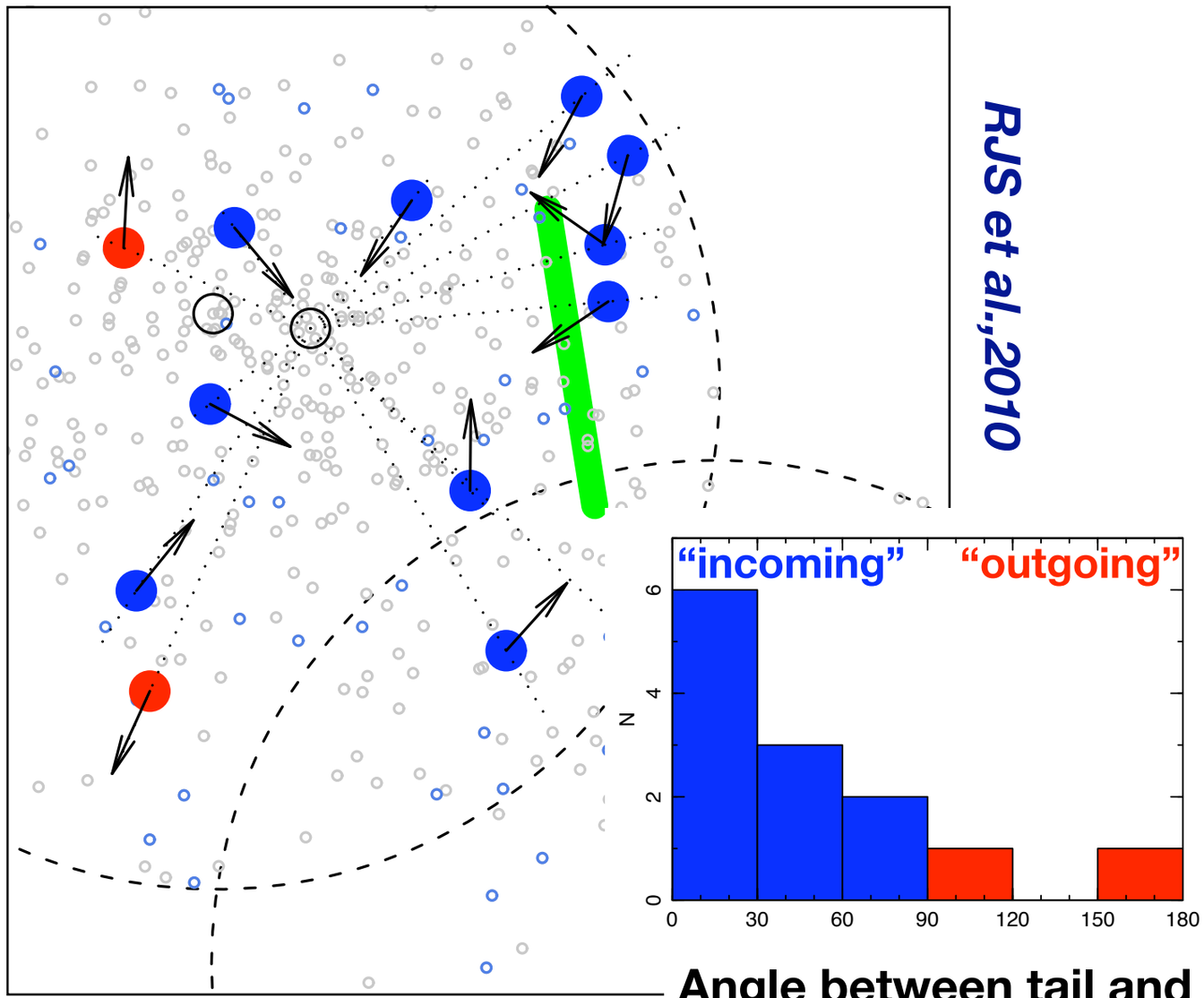

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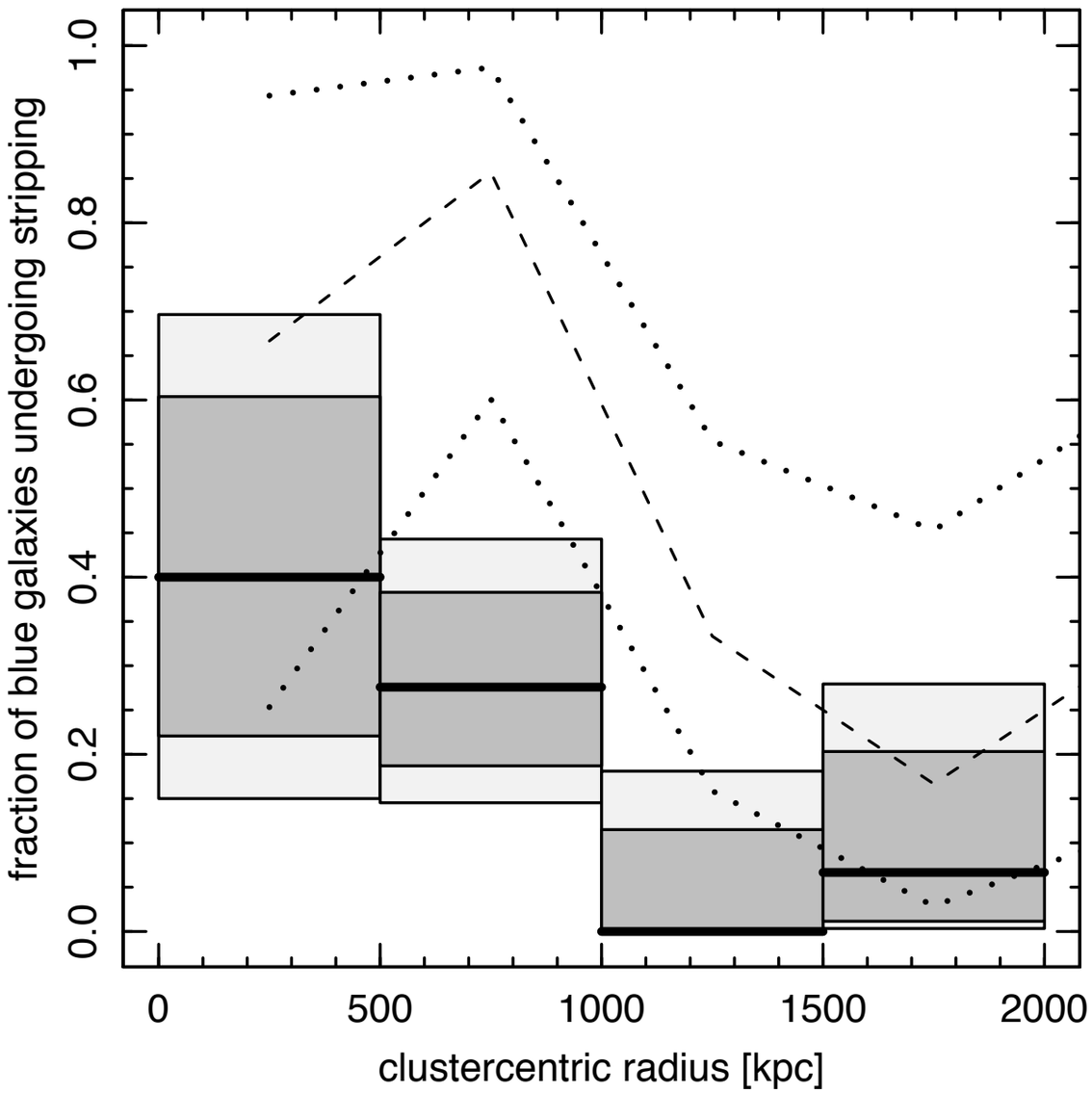
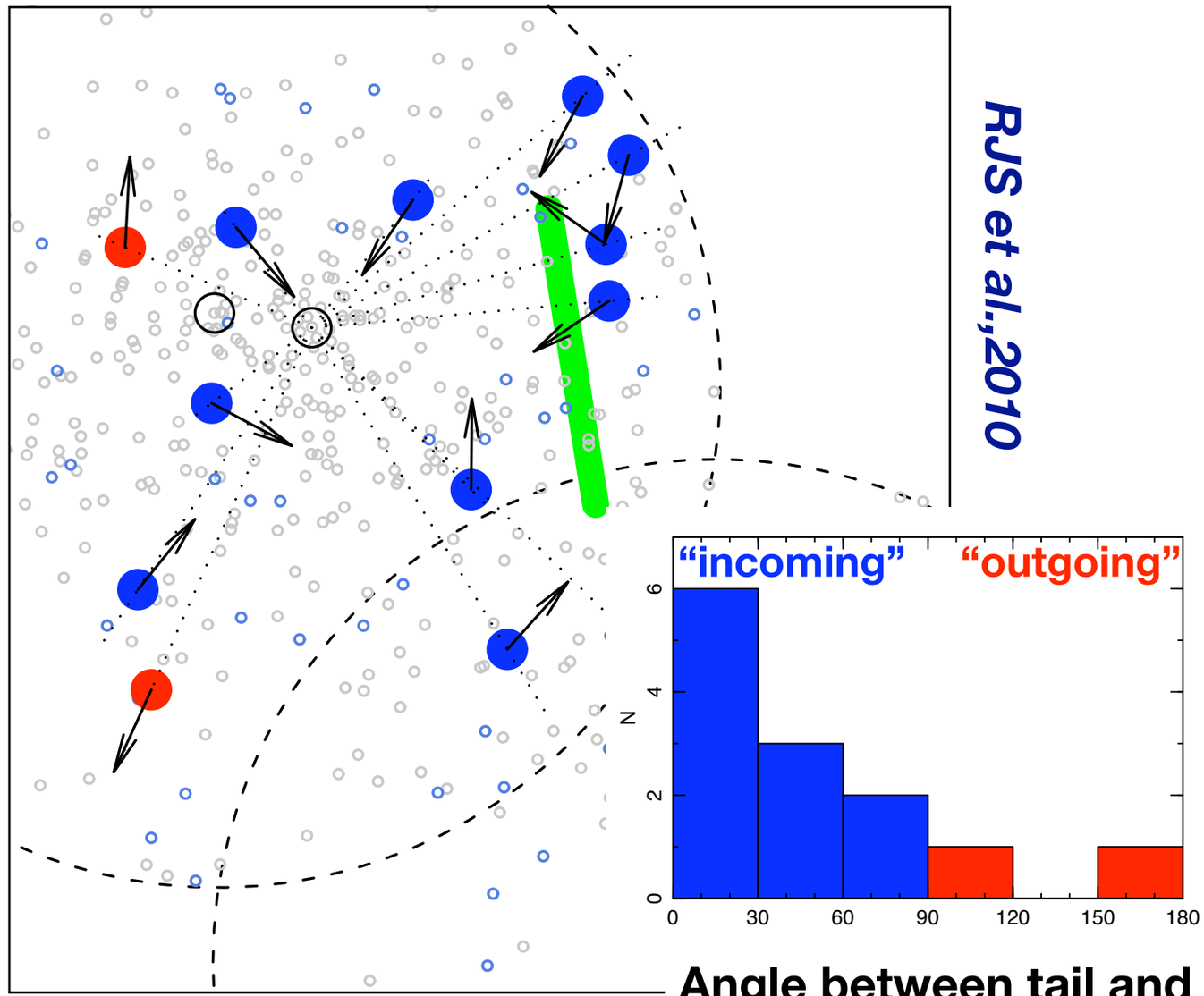



11 / 13 tails directed away from cluster centre, i.e. stripping on approach to cluster.

-> Stripping occurs on **first** passage through cluster centre, and is triggered at ~1Mpc radius.

# Enviro-history of model cluster members

We see trends with **projected** radius, well within the virial radius.

Is this expected?

Aren't clusters well-mixed at such radii?

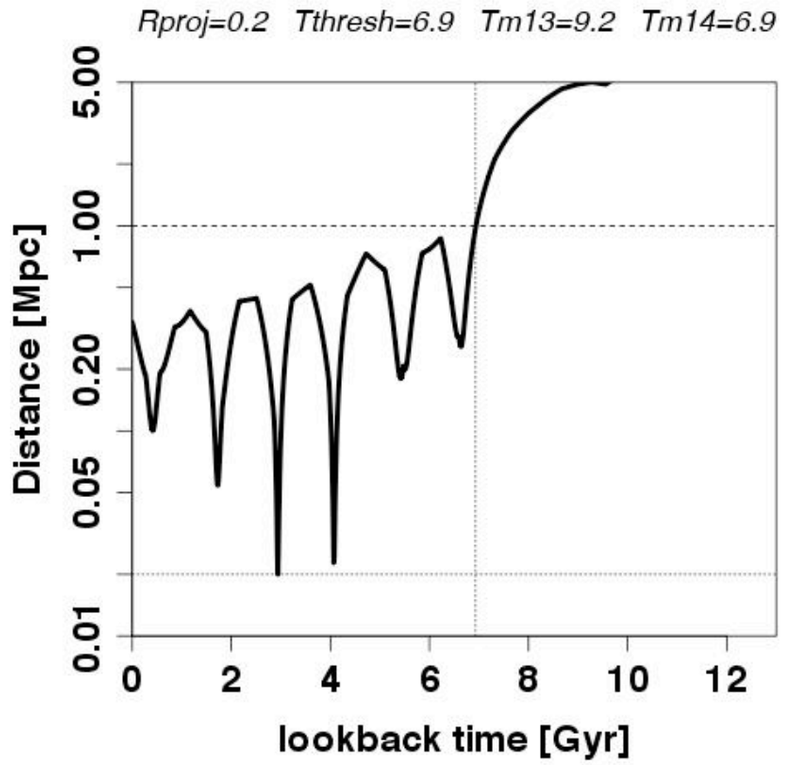
Shouldn't projection weaken the trends substantially?

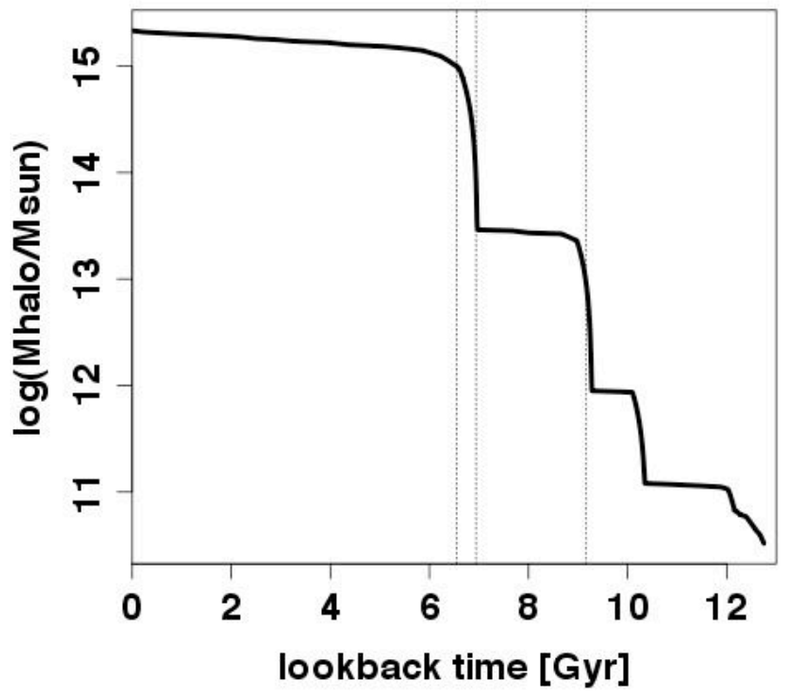
Address this with orbital history of ~10,000 $M_{stel}$ > $10^9$ $M_{sun}$ members of the four most massive clusters (~$10^{15}$ Msun) in Millenium Simulation.

**Ignore semi-analytic predicted SFH!**

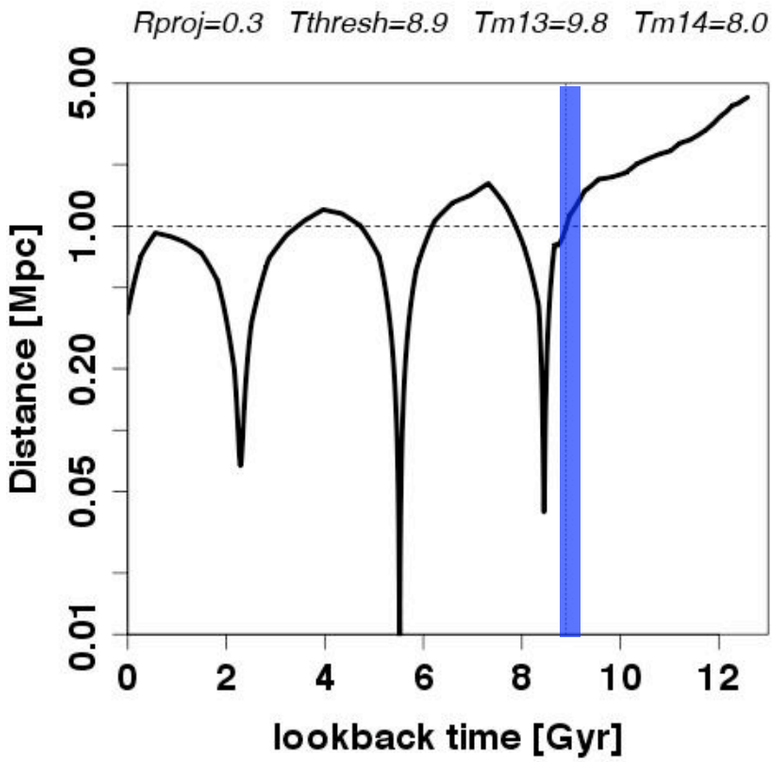
Track key "life events" of each simulated galaxy...

... and compare to projected location at z~0.

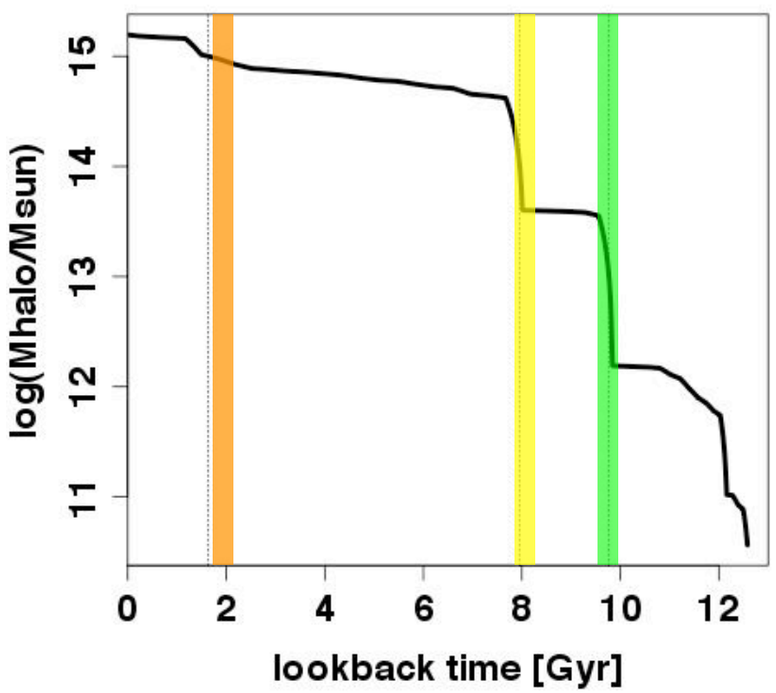


# Key events in life of a cluster galaxy?




Comes within 1Mpc of eventual halo-central galaxy




Becomes a member of a

$10^{13}$ $M_{sun}$ group,

$10^{14}$ $M_{sun}$ “Virgo”,

$10^{15}$ $M_{sun}$ “Coma”

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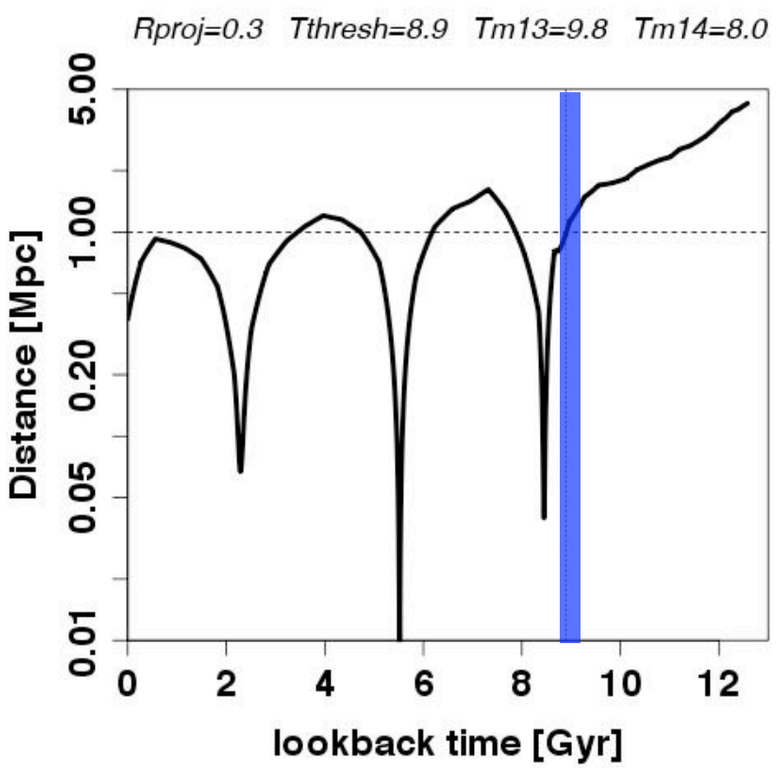


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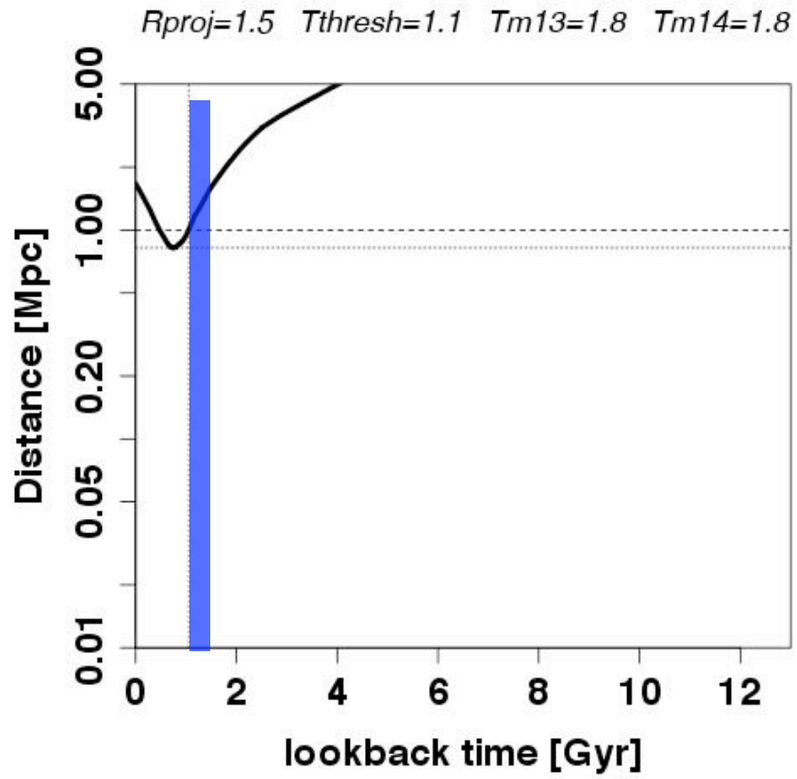


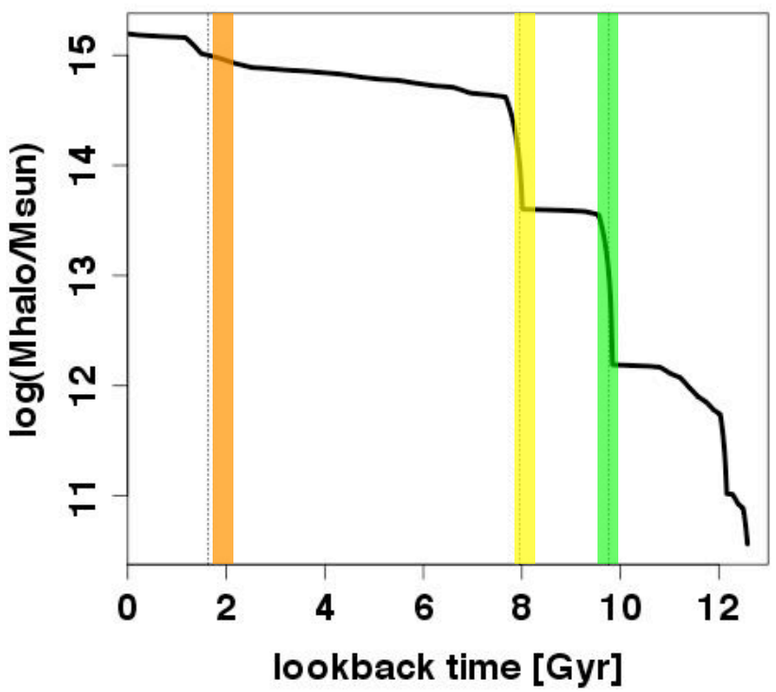


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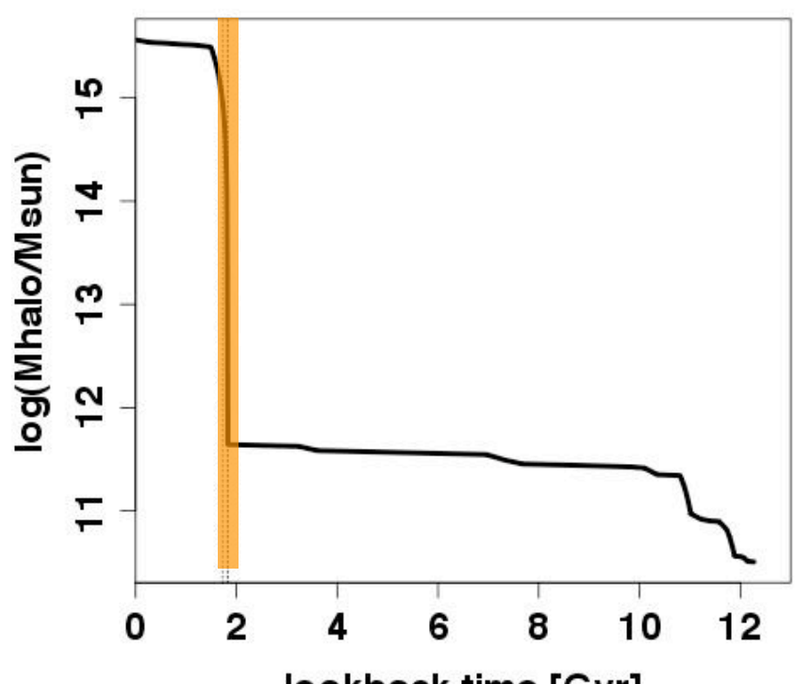
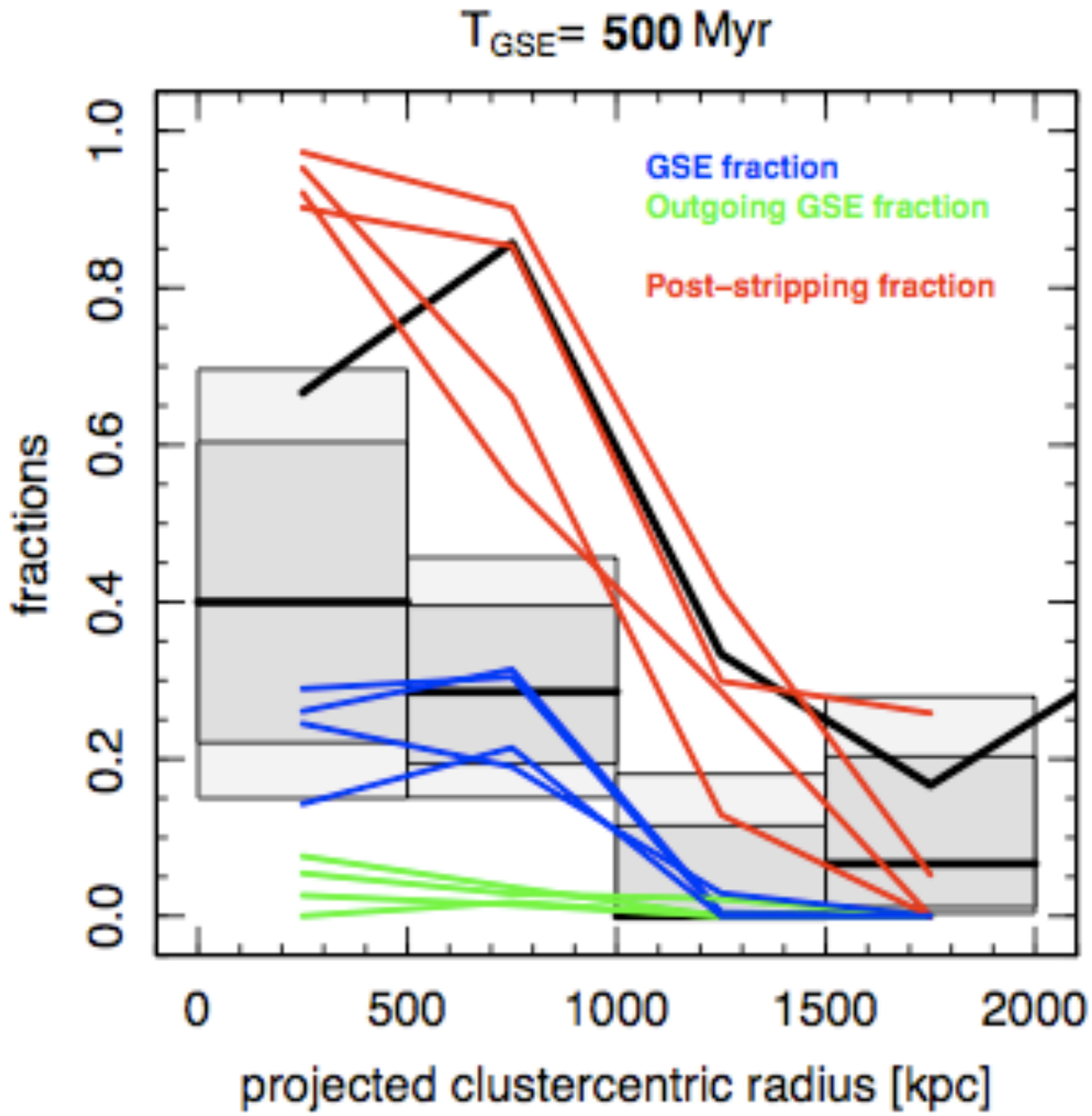


# Reproducing the ongoing-stripping fraction




***RJS et al. 2010***

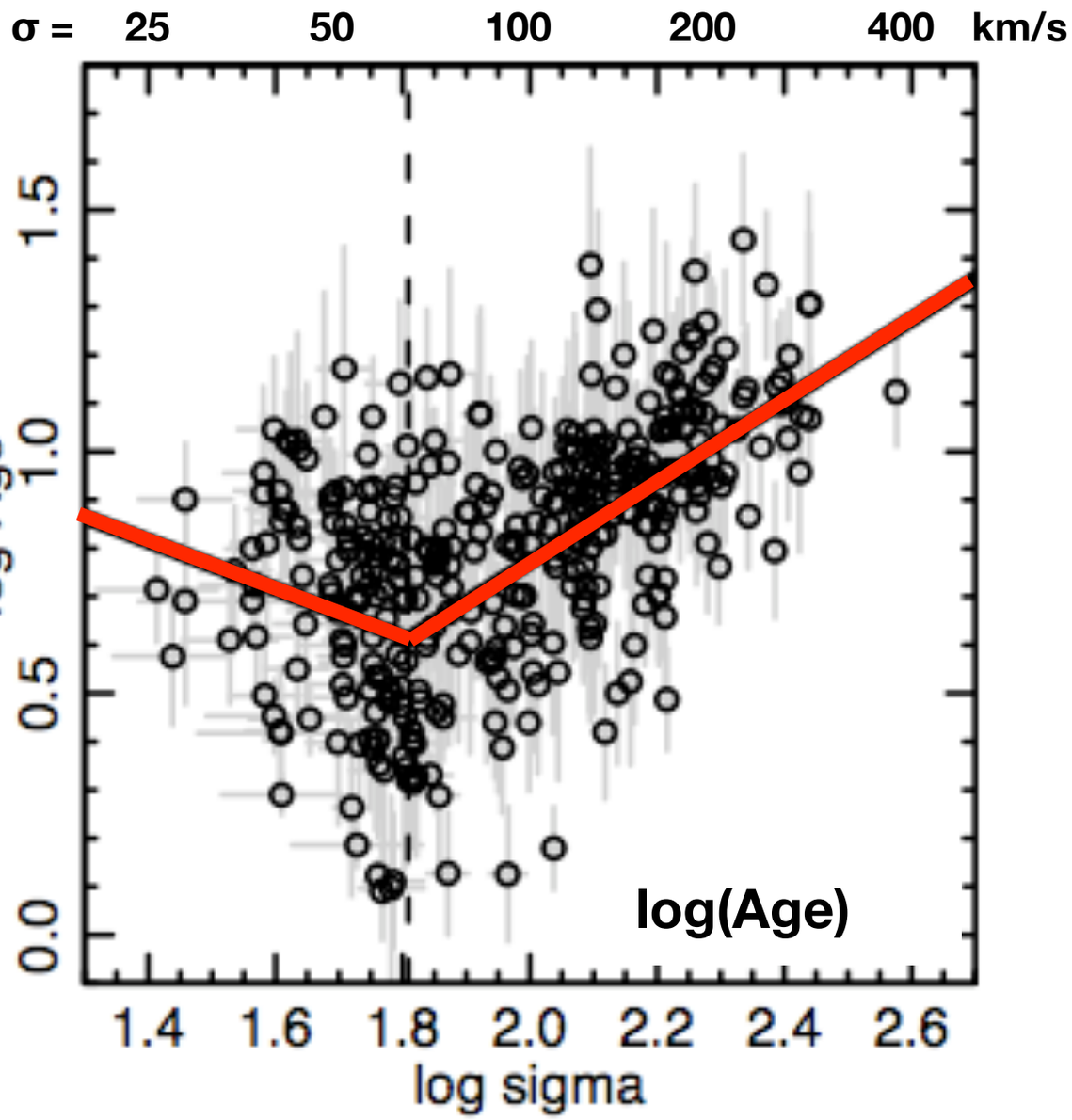
Can match fraction of GSEs, and low incidence of “outgoing” events, by assuming a dumb toy model where galaxies:

1) start to be stripped when they *first* come within 1Mpc,

2) remain visible for 500 Myr after this point

3) become “red” thereafter

# SDSS+Hectospec stellar populations




*RJS et al.,in prep*

SSP-equivalent ages from absorption line analyses.

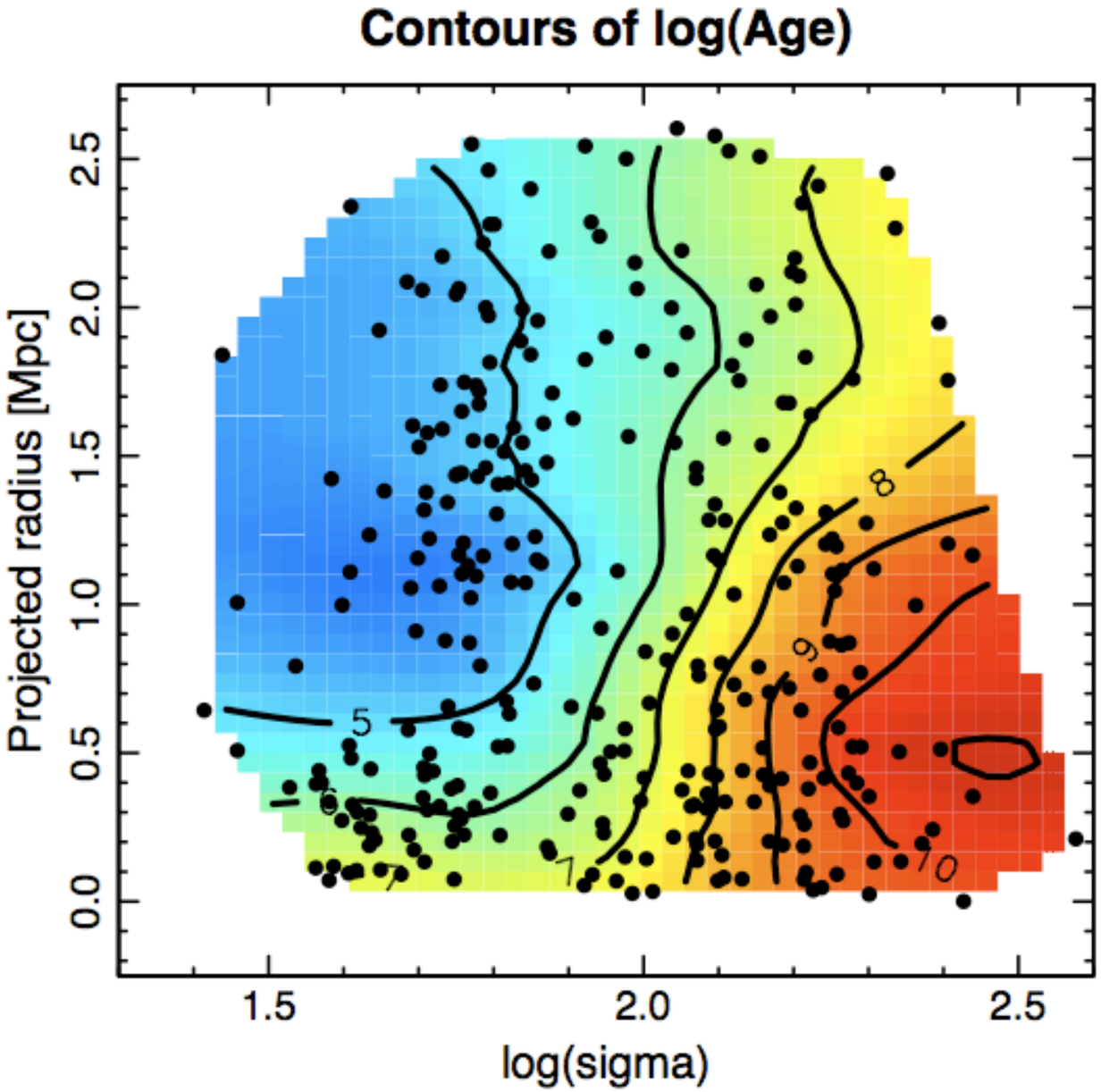
Low-σ galaxies are younger on average (Caldwell et al. 2003; Nelan, RJS et al. 2005; etc)

**What about environment?**

Earlier claims of steep environmental trends in Coma-SW dwarfs, e.g. Carter et al. (2002).

Contrasts with much weaker effect in giants e.g. NFPS (RJS et al. 2006)

# Age-radius-mass relations




*RJS et al.,in prep*

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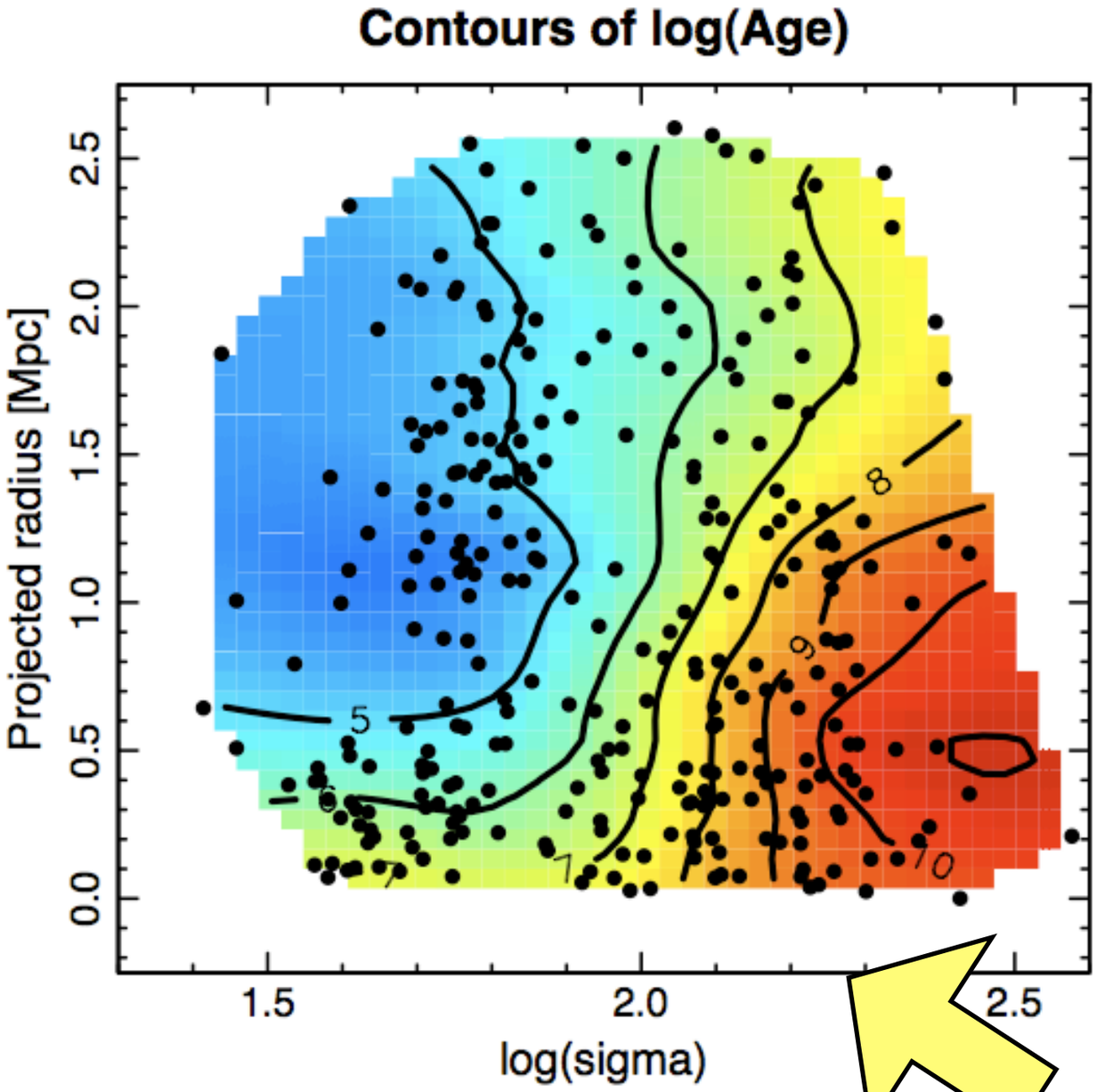


**Ages of giants depend mainly on “mass”**

*RJS et al.,in prep*

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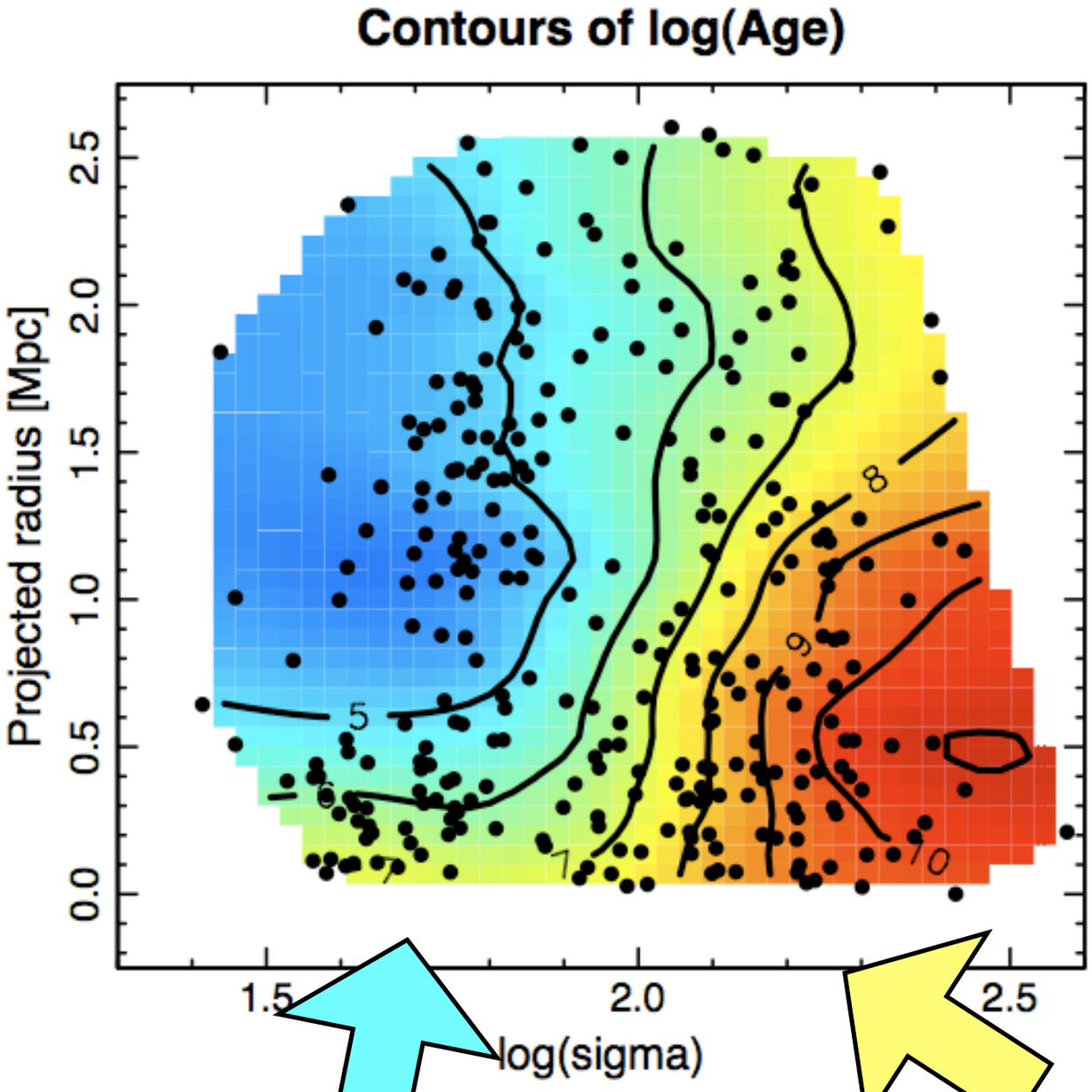


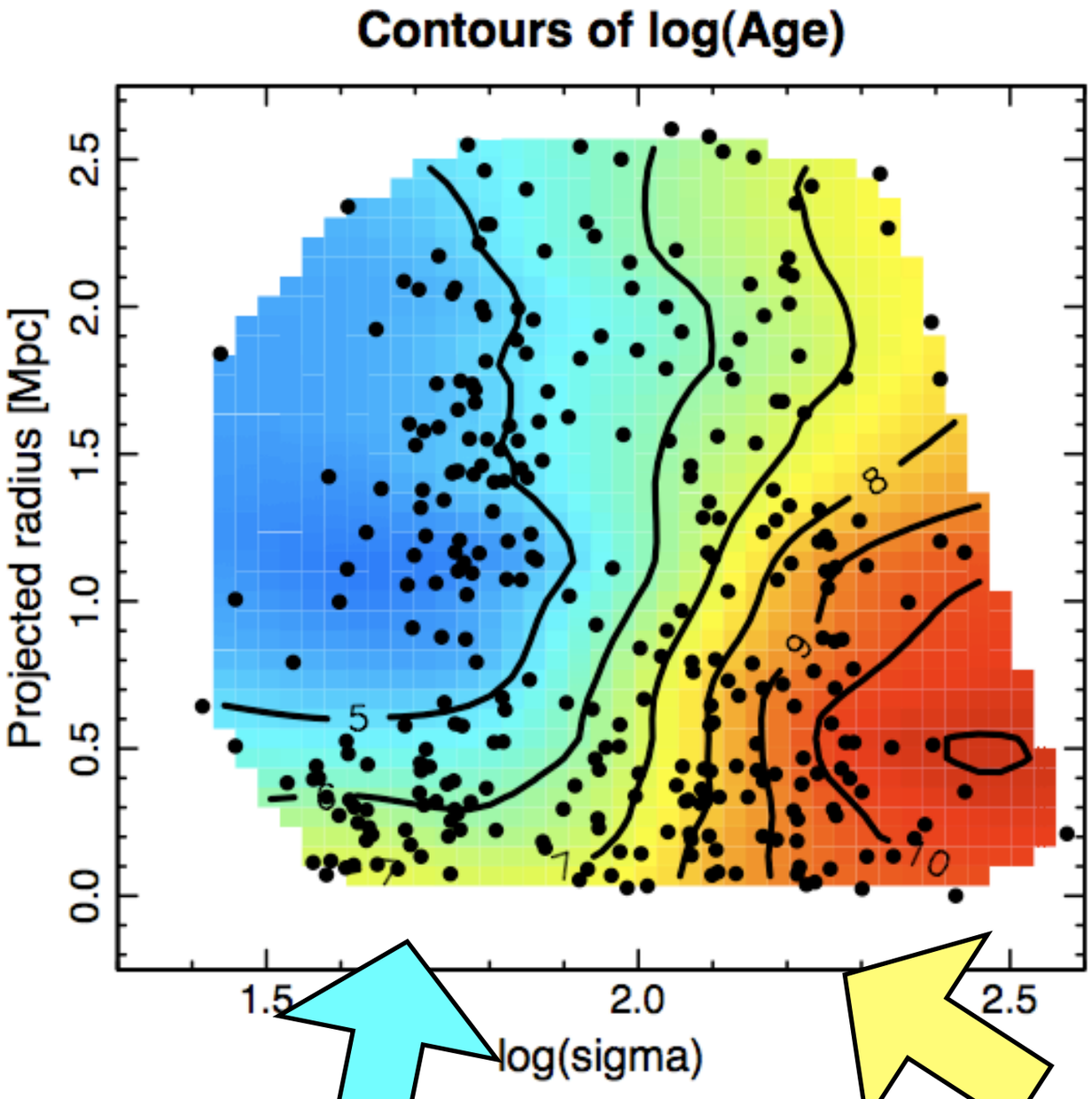

**Ages of dwarfs depend mainly on “environment”**

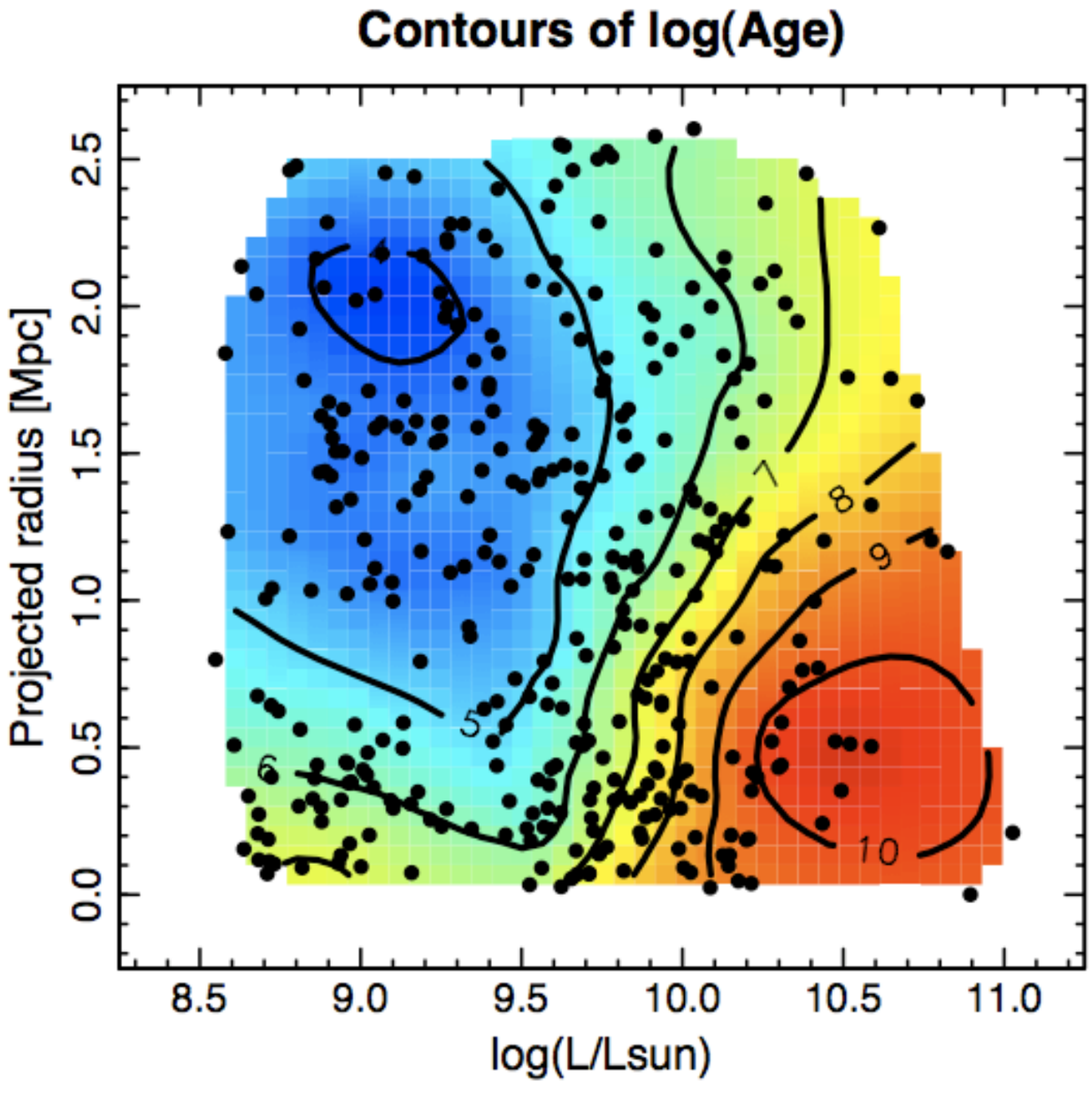
**Ages of giants depend mainly on “mass”**

*RJS et al.,in prep*

C3dS
Coma 3-degree Survey

# Age-radius-mass relations



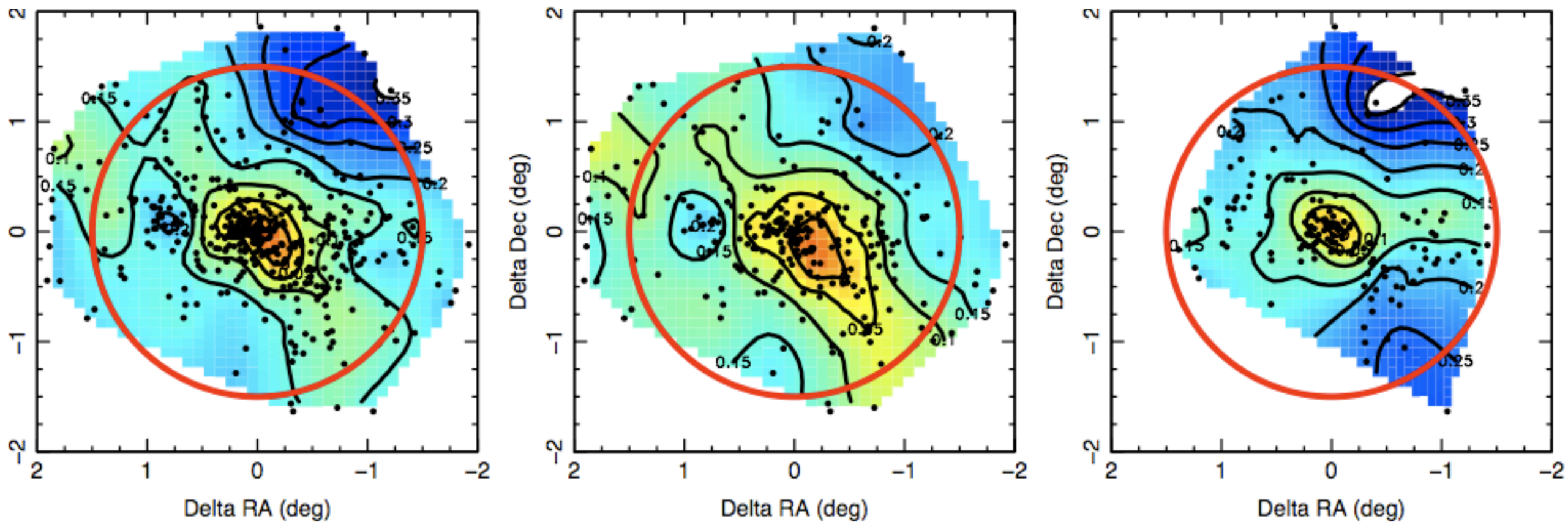

*RJS et al.,in prep*

**Ages of dwarfs depend mainly on “environment”**

**Ages of giants depend mainly on “mass”**

# Age-radius trend: universal, not localised

## Residuals from Age-Luminosity relation




*RJS et al.,in prep*

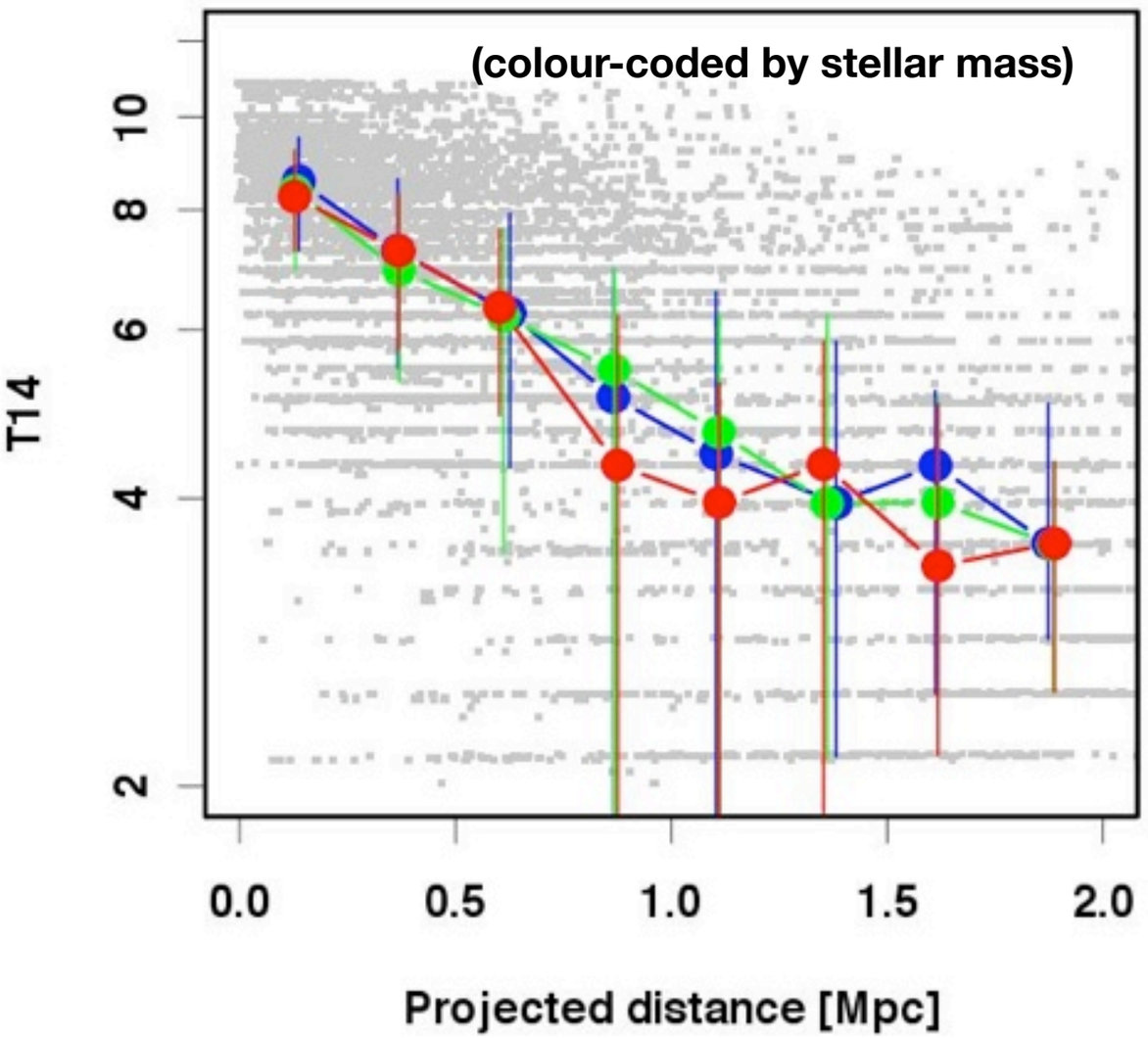
South-West of Coma is “special”: ongoing merger of NGC 4839 group.

BUT: outer galaxies are younger than those in core at all azimuths.

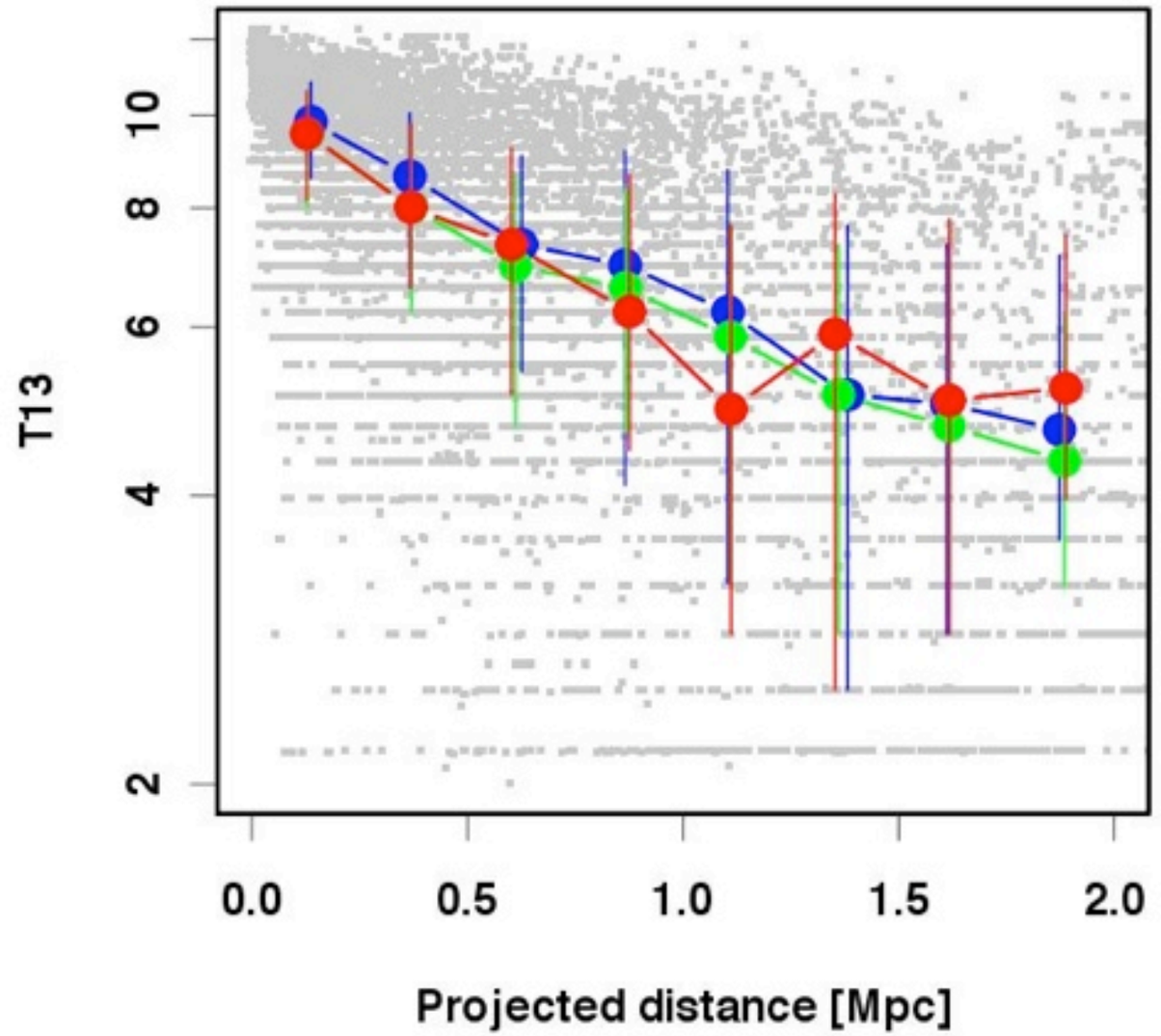
**It is the *central* region that is “unusual”, not the South-West!**

# Key events in life of a cluster galaxy?

## Time since incorporated into $10^{14}$ $M_{sun}$ halo




## Time since incorporated into $10^{13}$ $M_{sun}$ halo




Galaxies observed projected nearer cluster centre became members of clusters / groups earlier than those observed further out...

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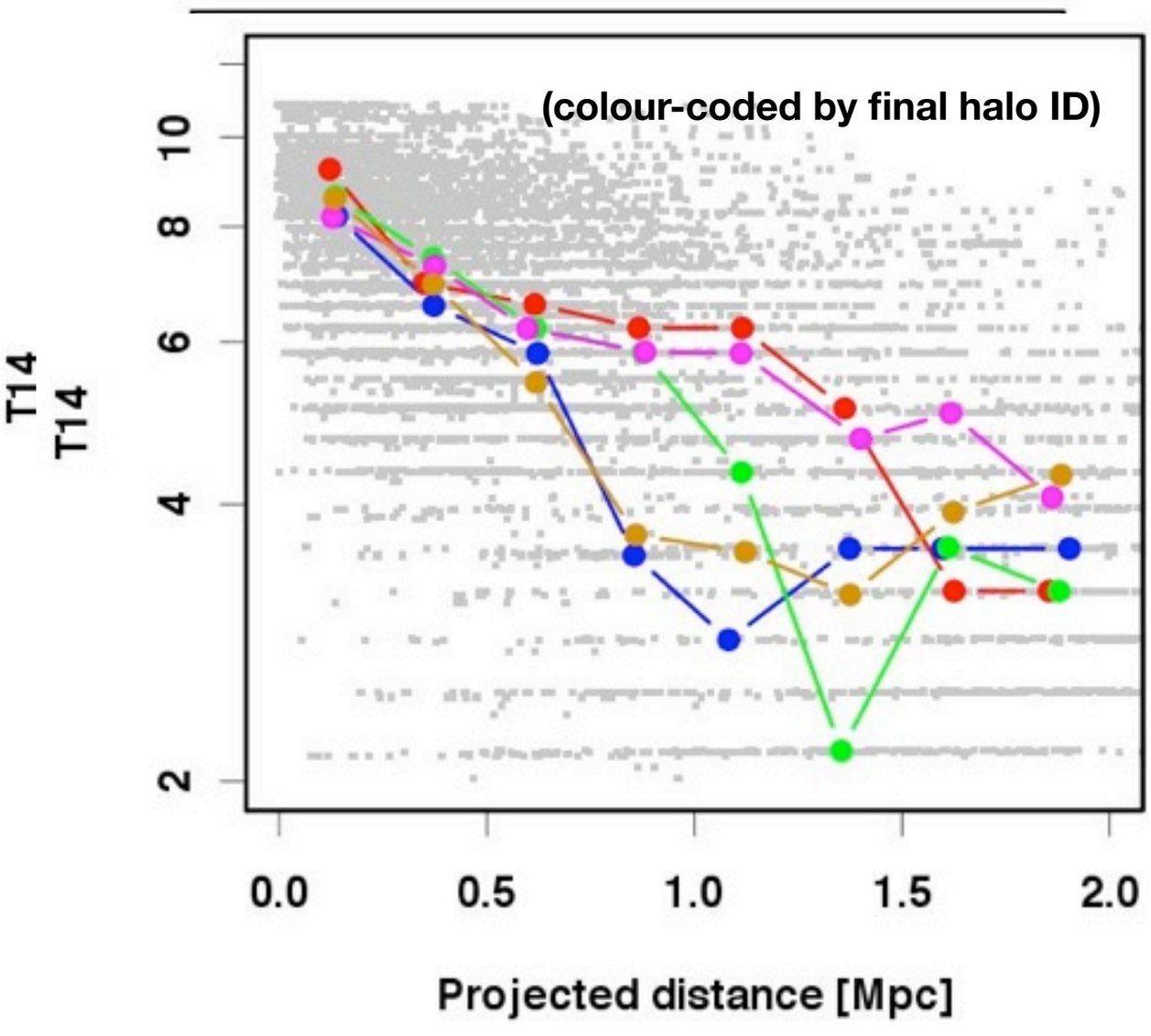


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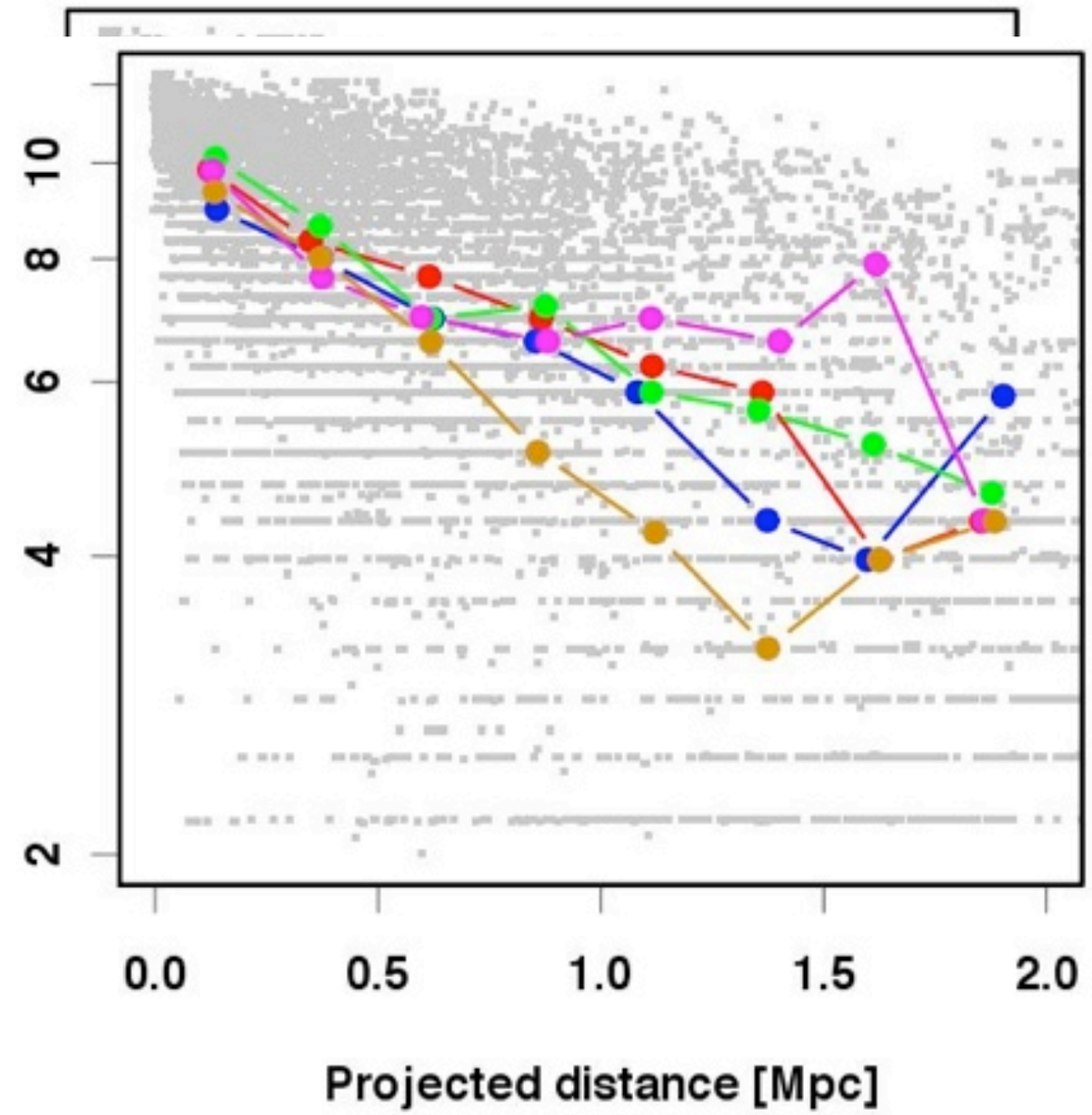
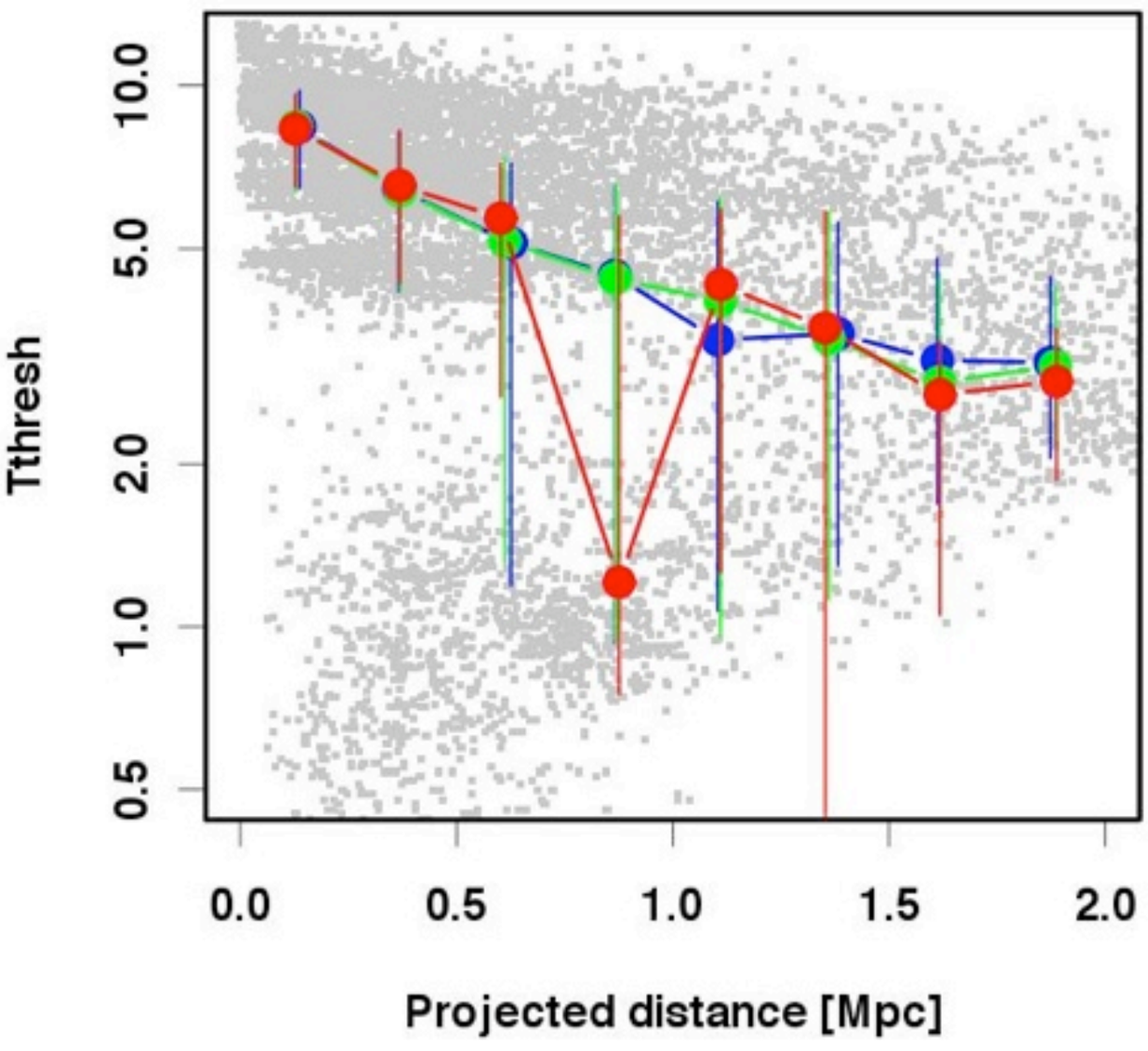



Galaxies observed projected nearer cluster centre became members of clusters / groups earlier than those observed further out...

# Key events in life of a cluster galaxy?

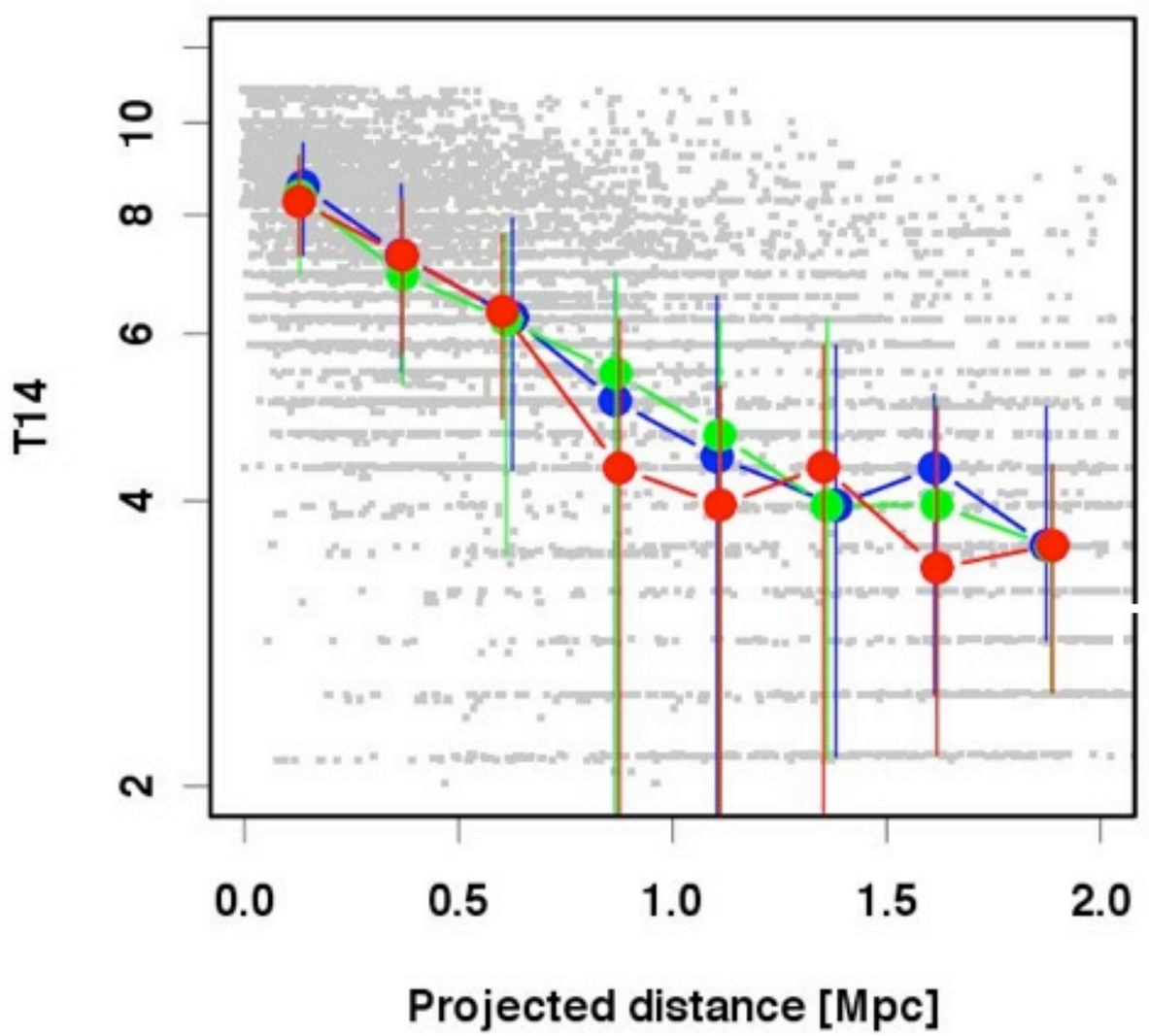
**Time since coming within 1Mpc of progenitor of eventual "BCG"**

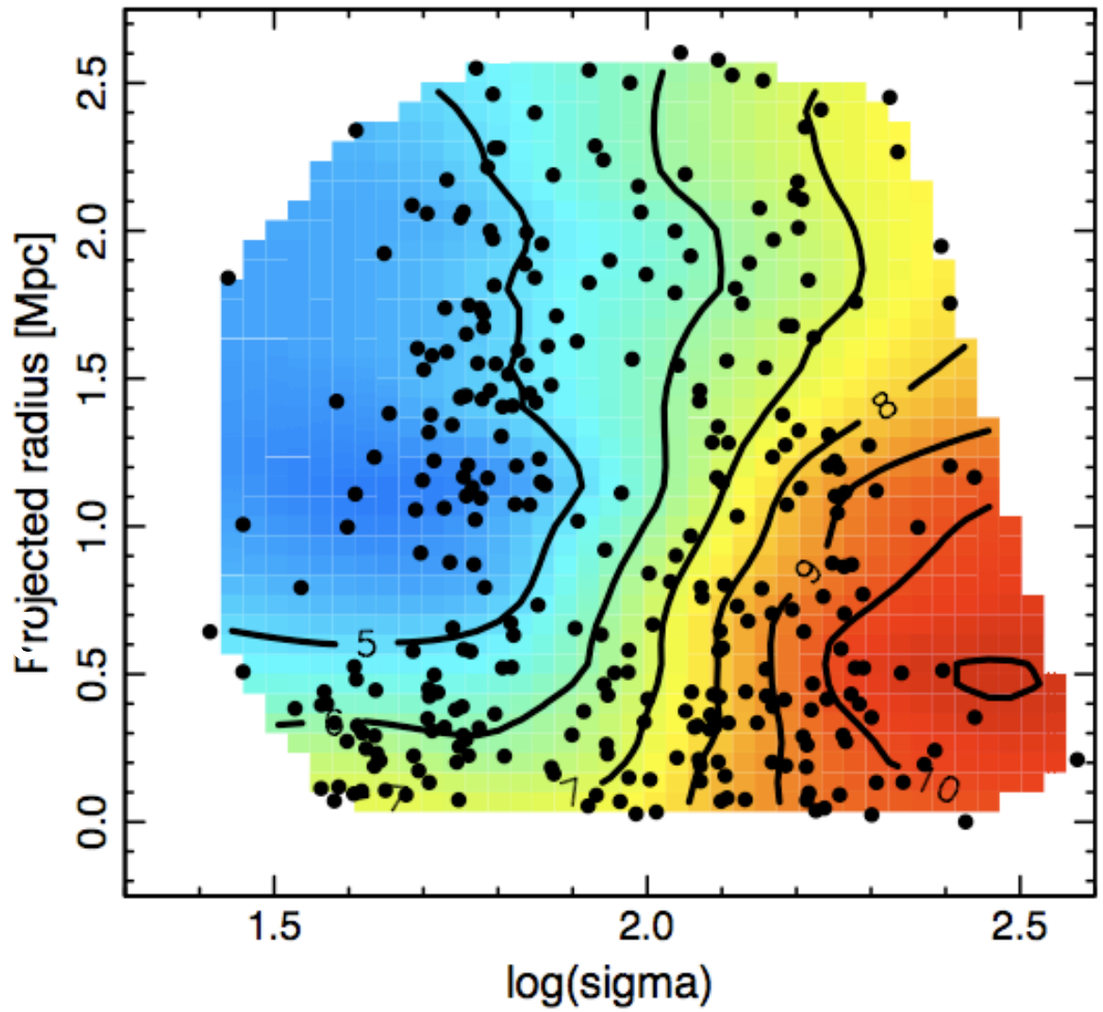



... and came within a given "threshold" radius earlier.

Simplistically, if SF "quenching" accompanies any of these events, we could predict age-radius trend...

# Quenching time vs radius



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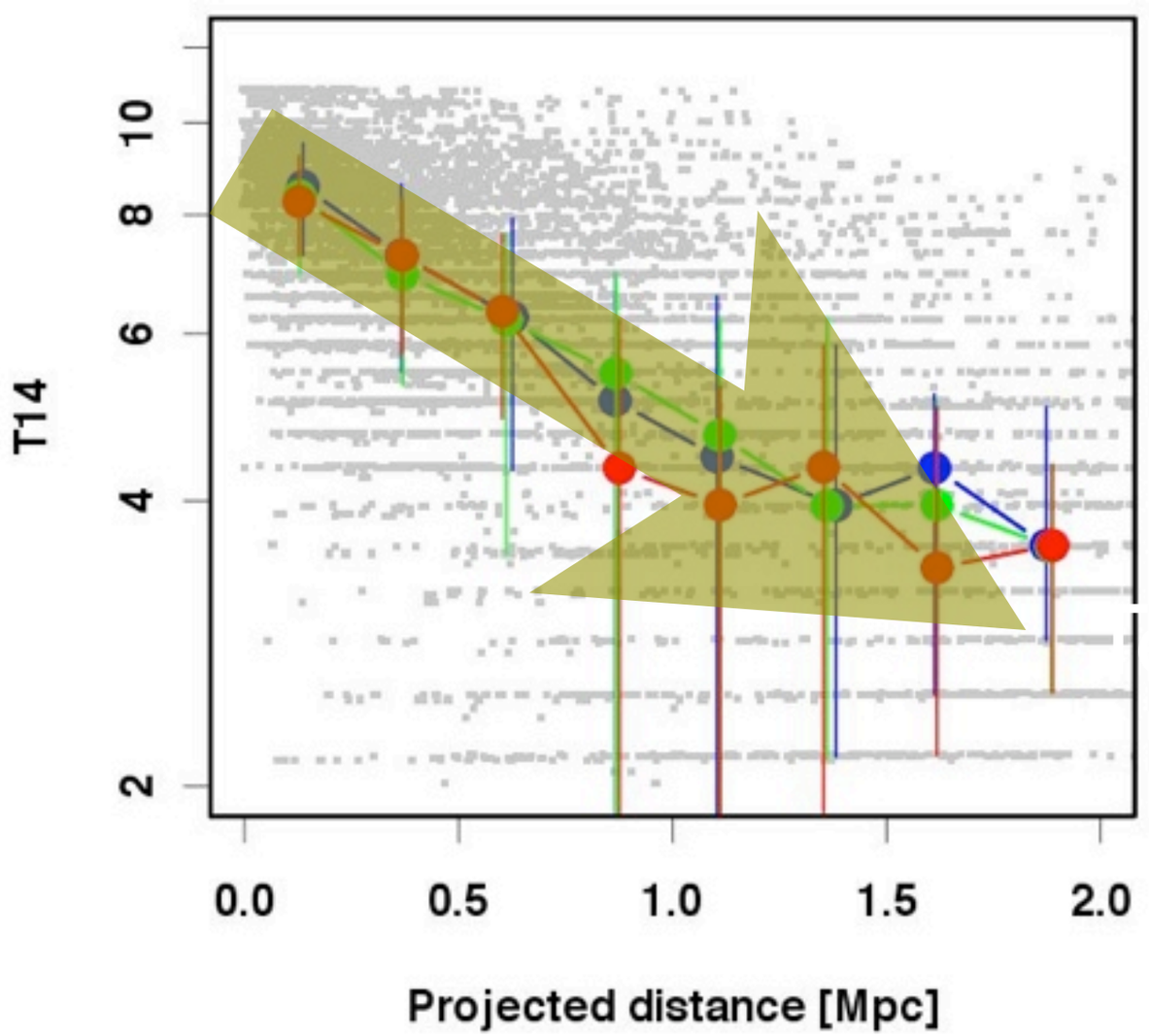


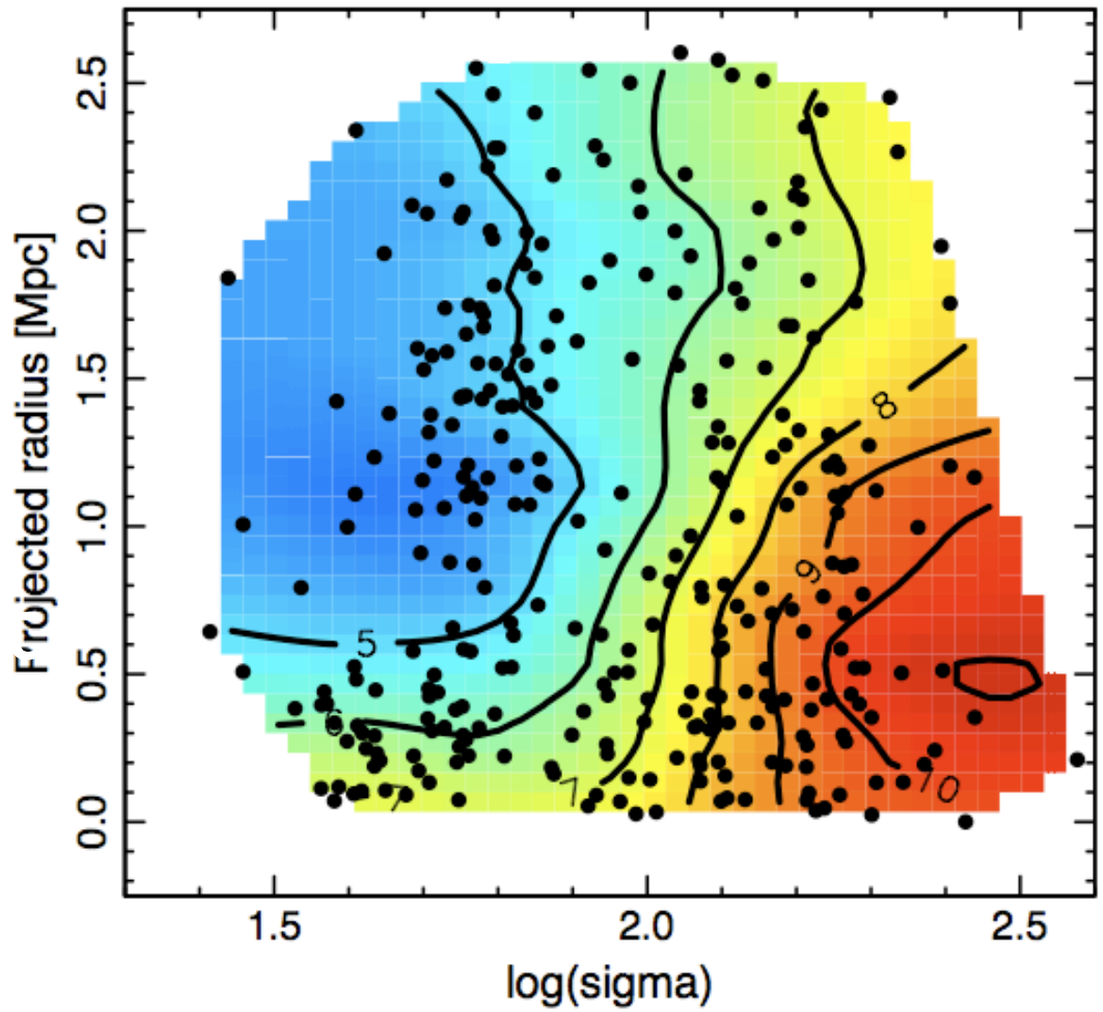

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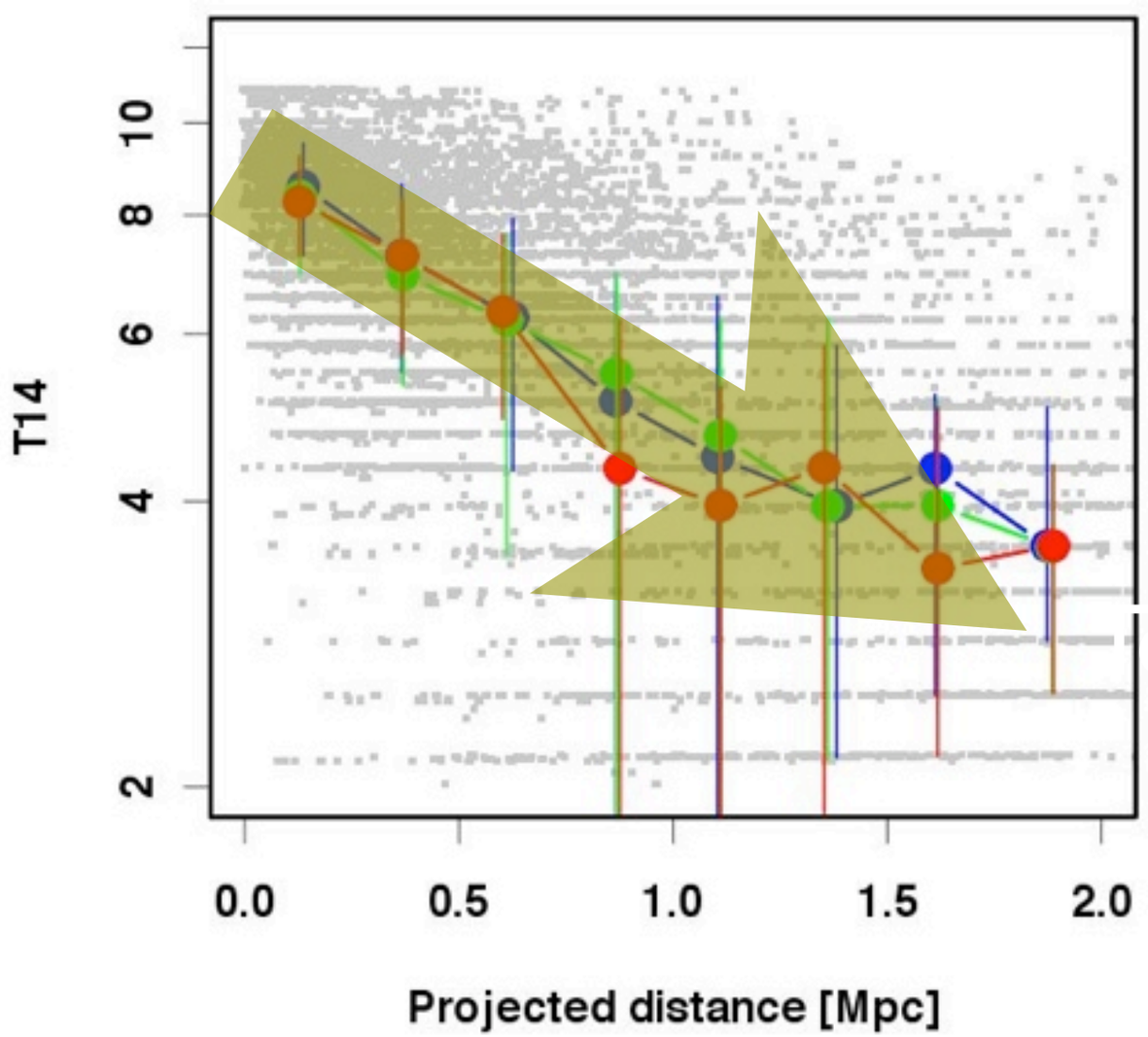


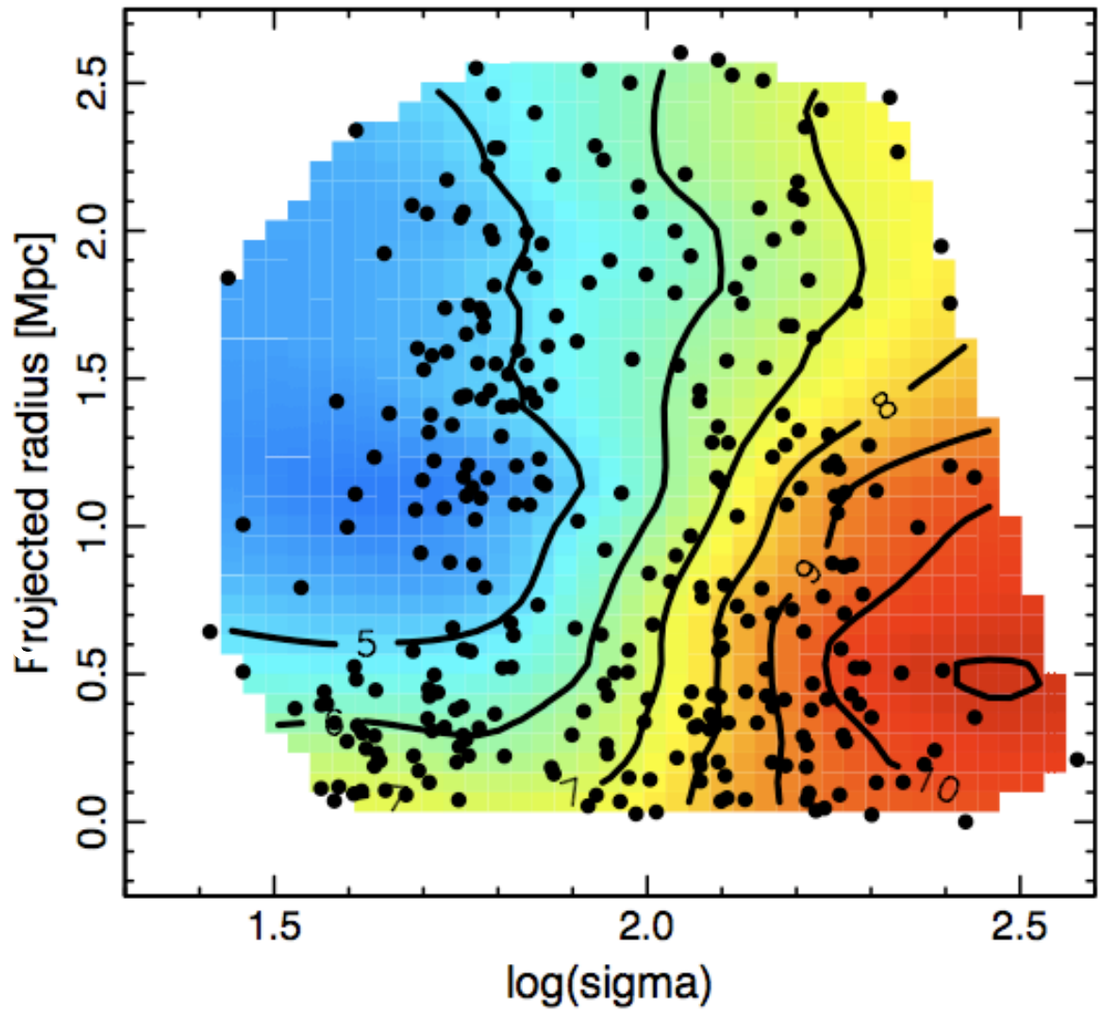


**Models: Δ log($T_{M14}$, $T_{M13}$, $T_{thresh}$) ≈ -0.2 $R_{proj}$ / Mpc**

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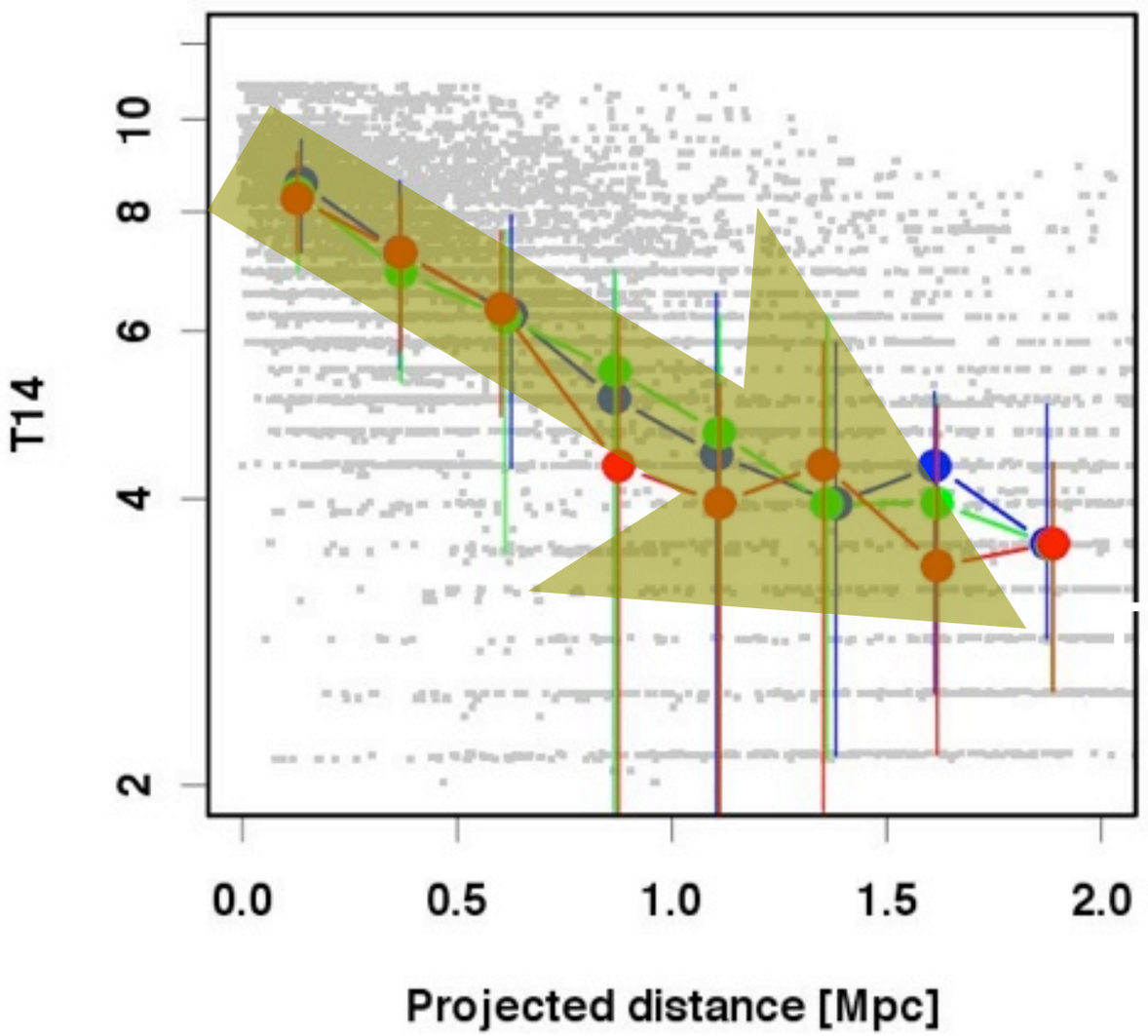


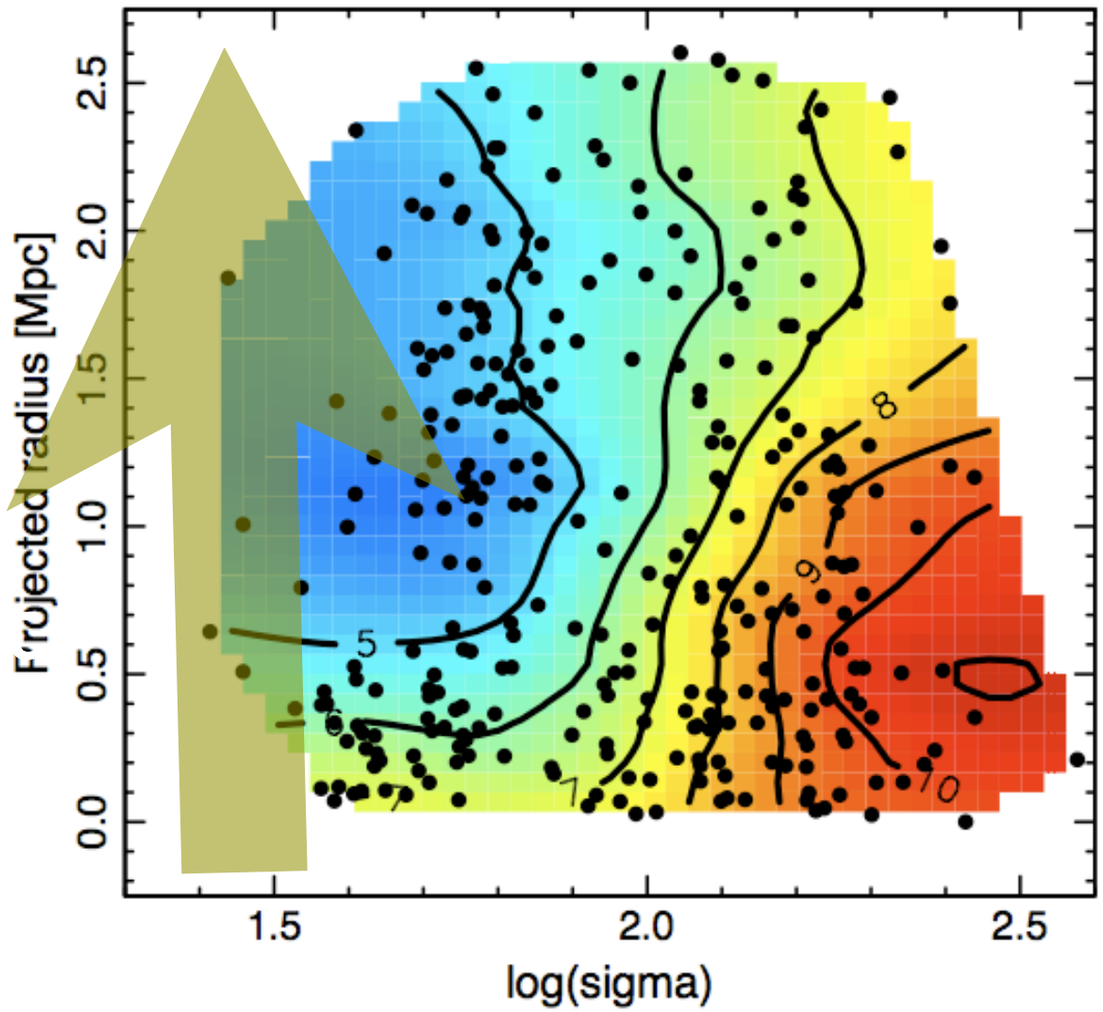


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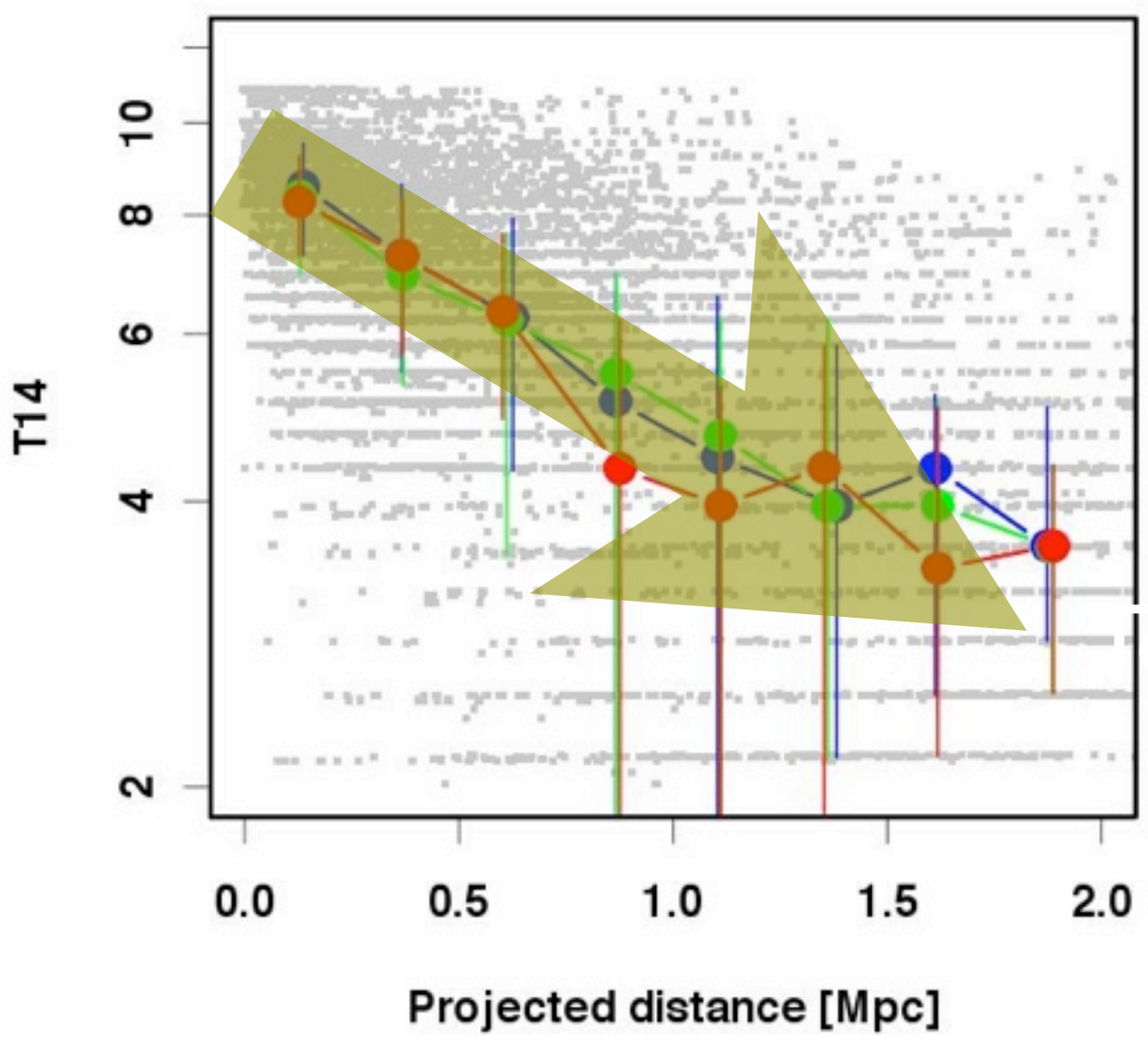


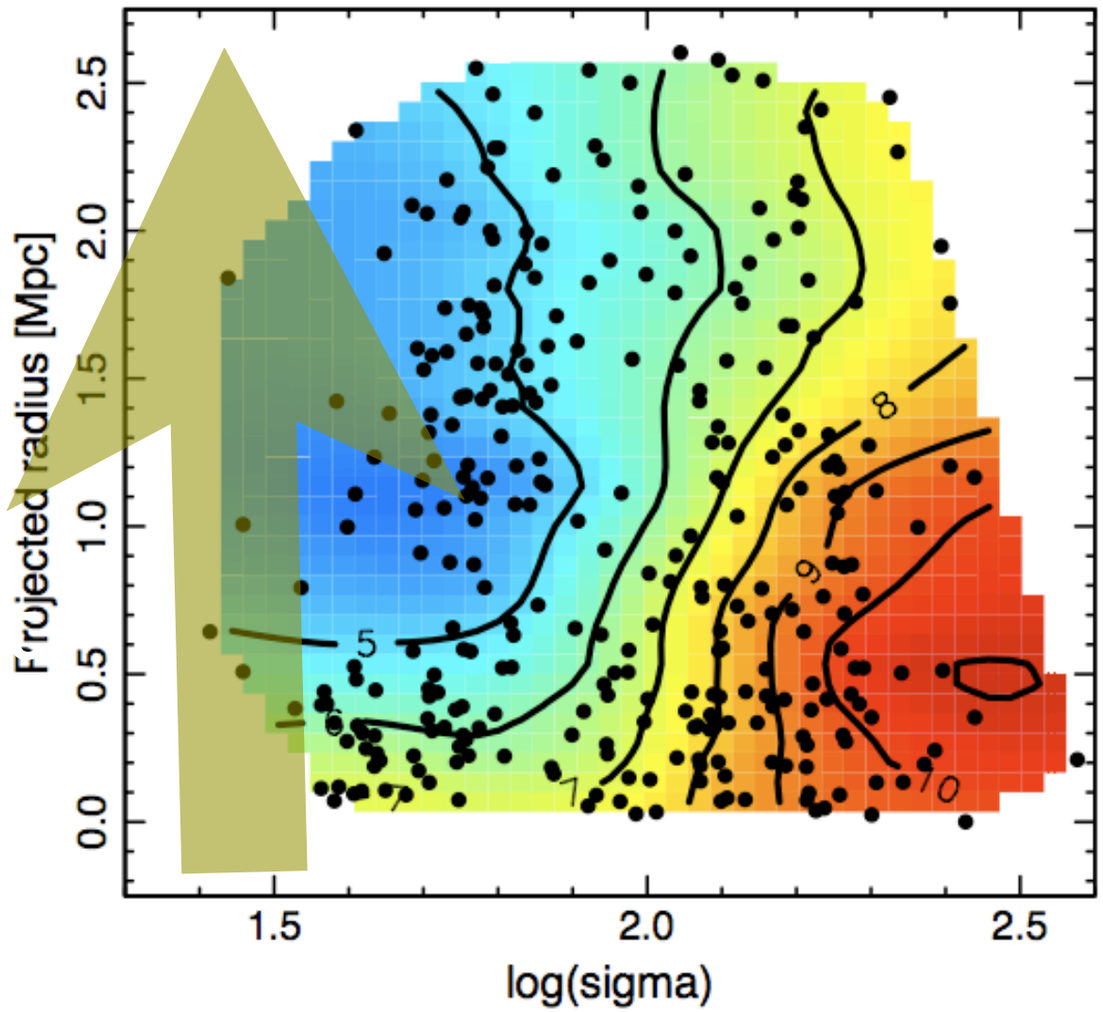


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**Data: Δ log($T_{SSP}$) ≈ -0.13±0.05 $R_{proj}$ / Mpc (dwarfs)**

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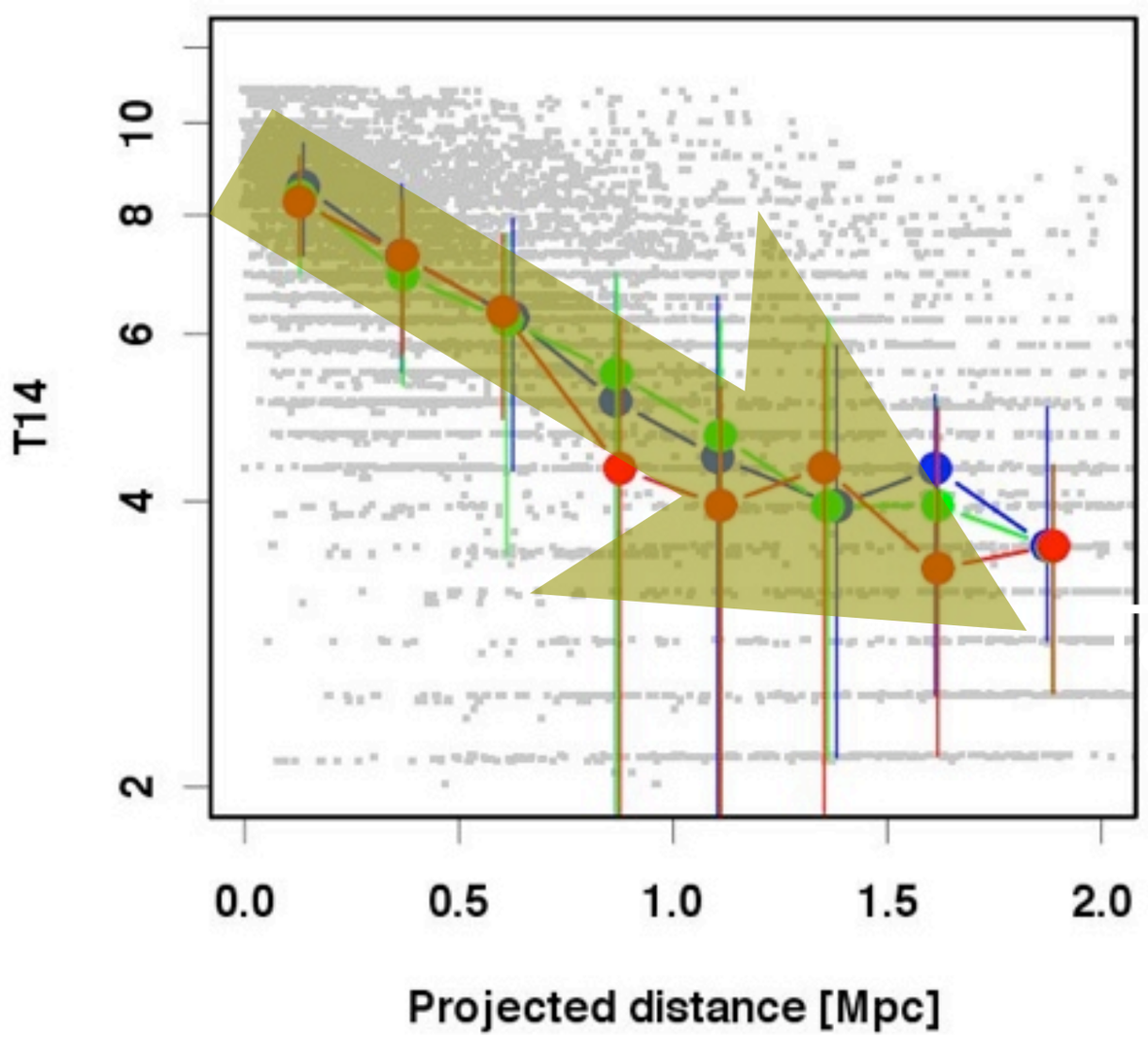


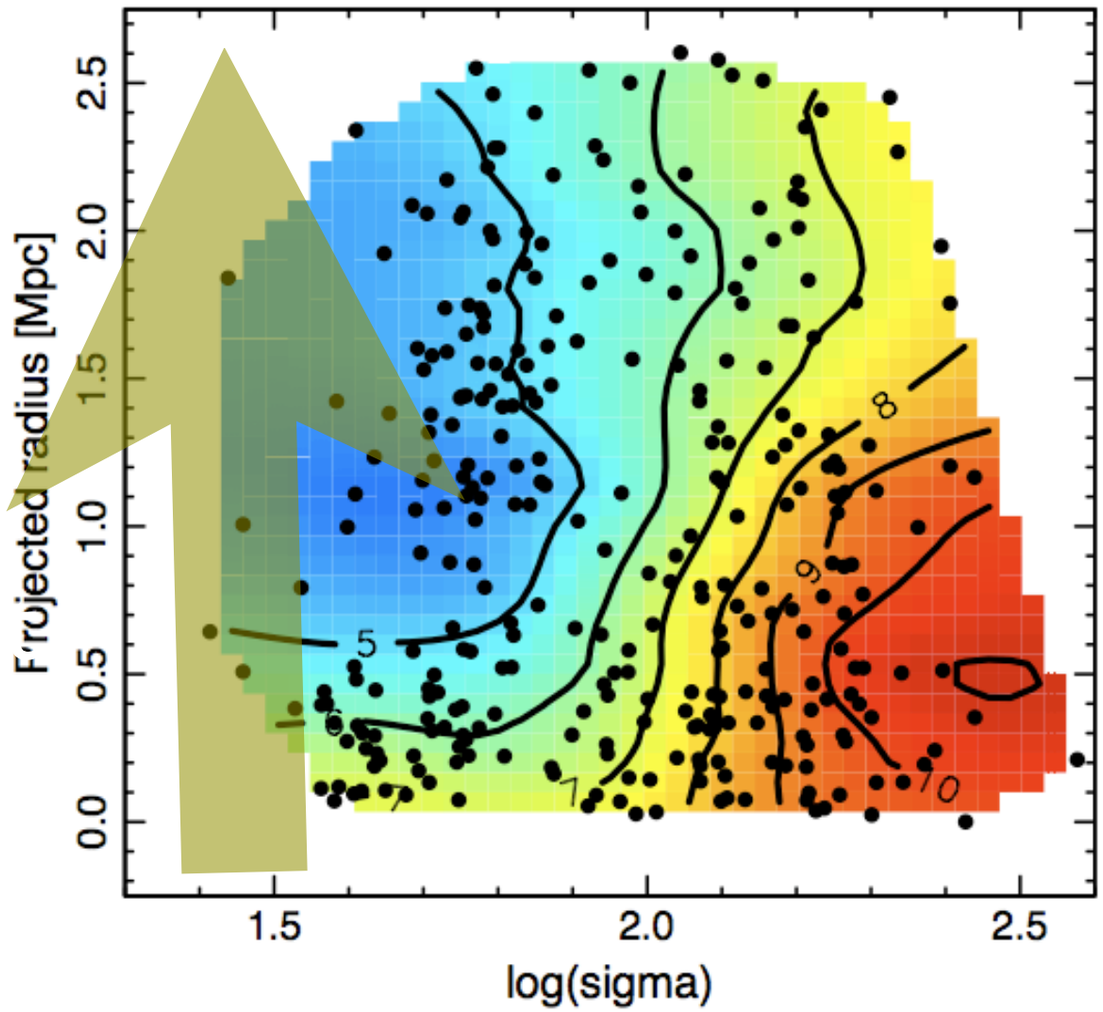


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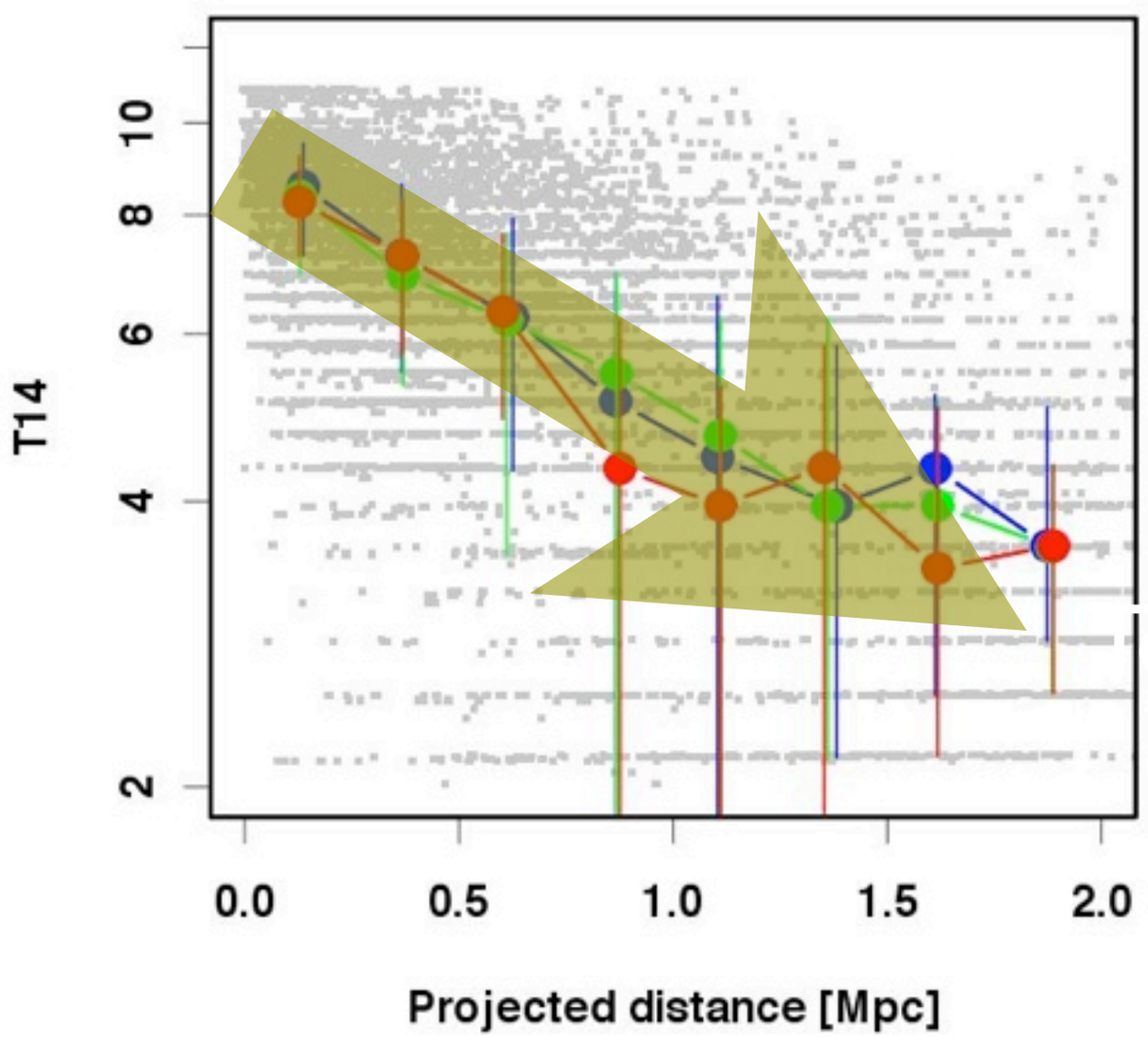


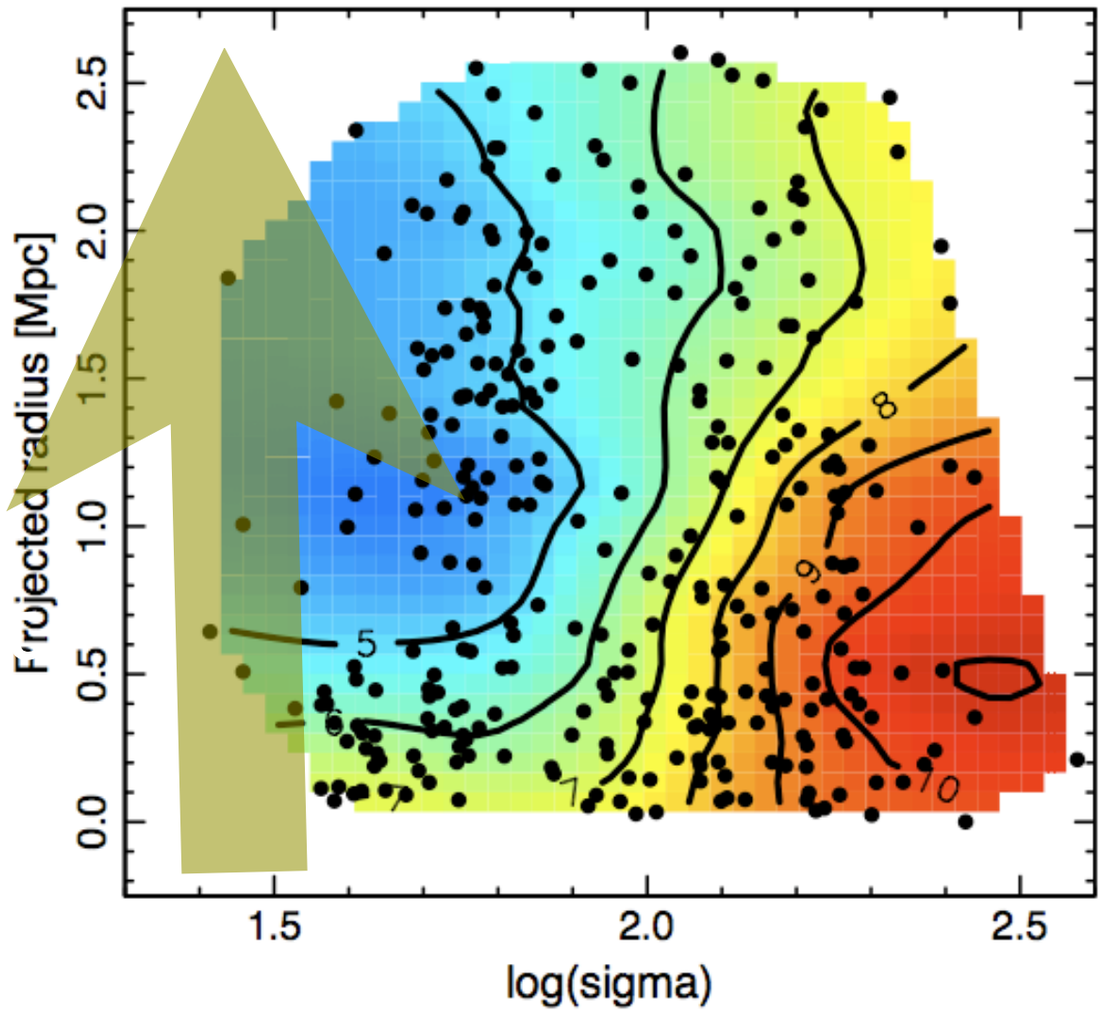


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Projected gradient of “key-event-times” is **sufficient to explain** observed age-radius trend (though need not **be** the sole explanation!)

# Summary

$$\log \frac{\text{Info(plot)}}{\text{Info(word)}} \sim 3$$

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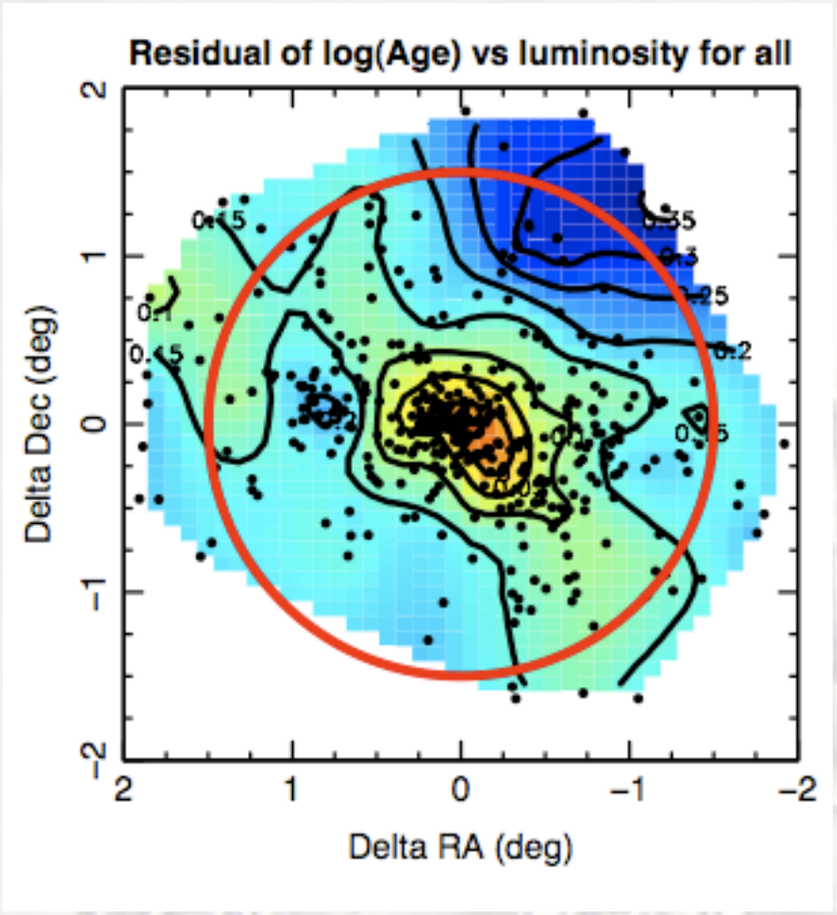


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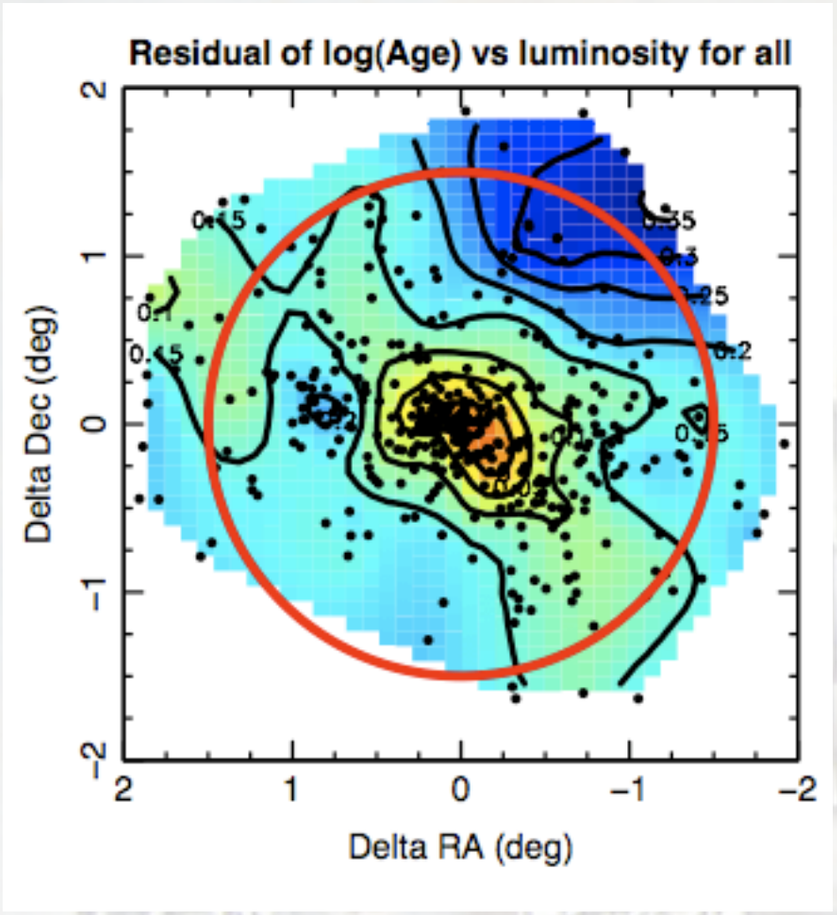


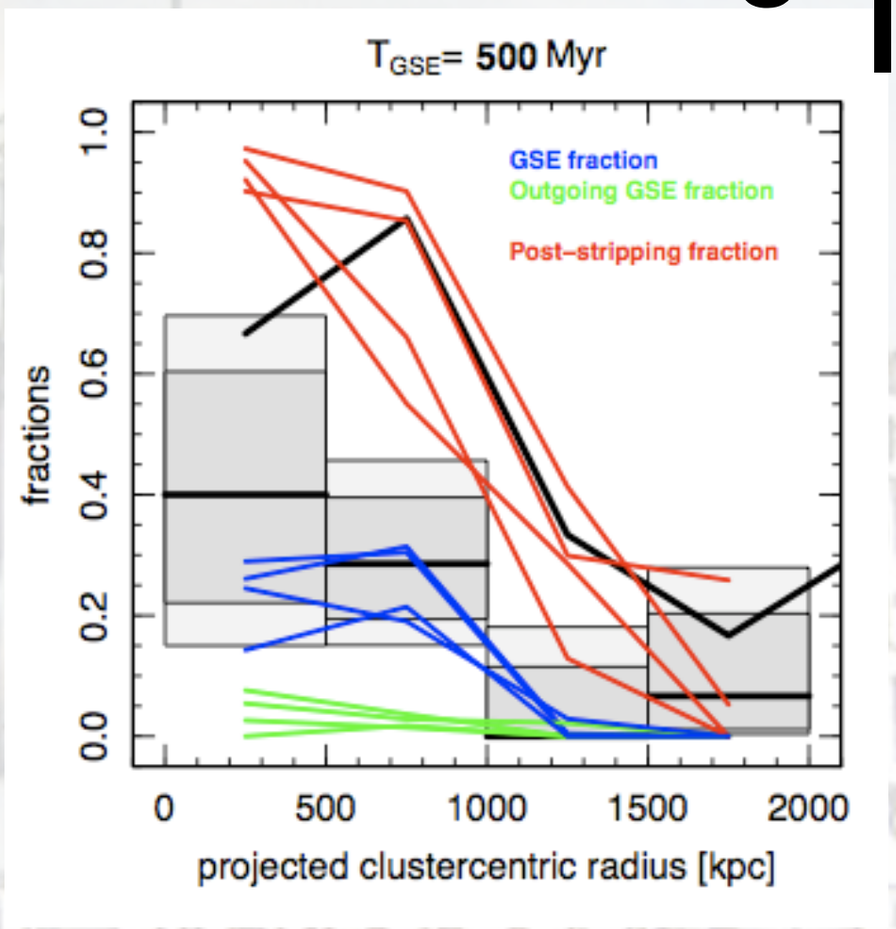

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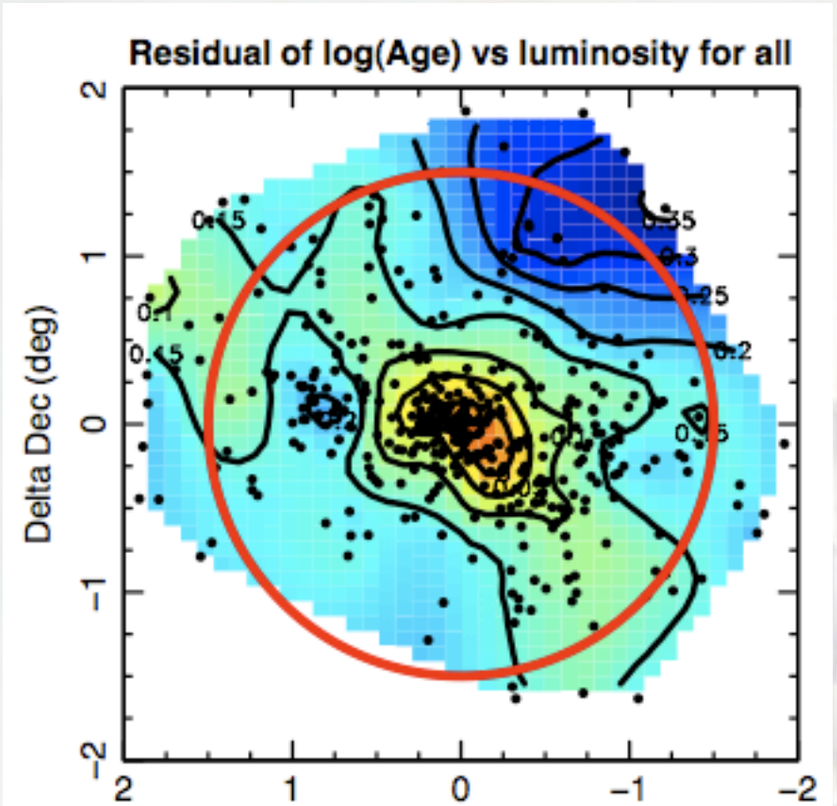


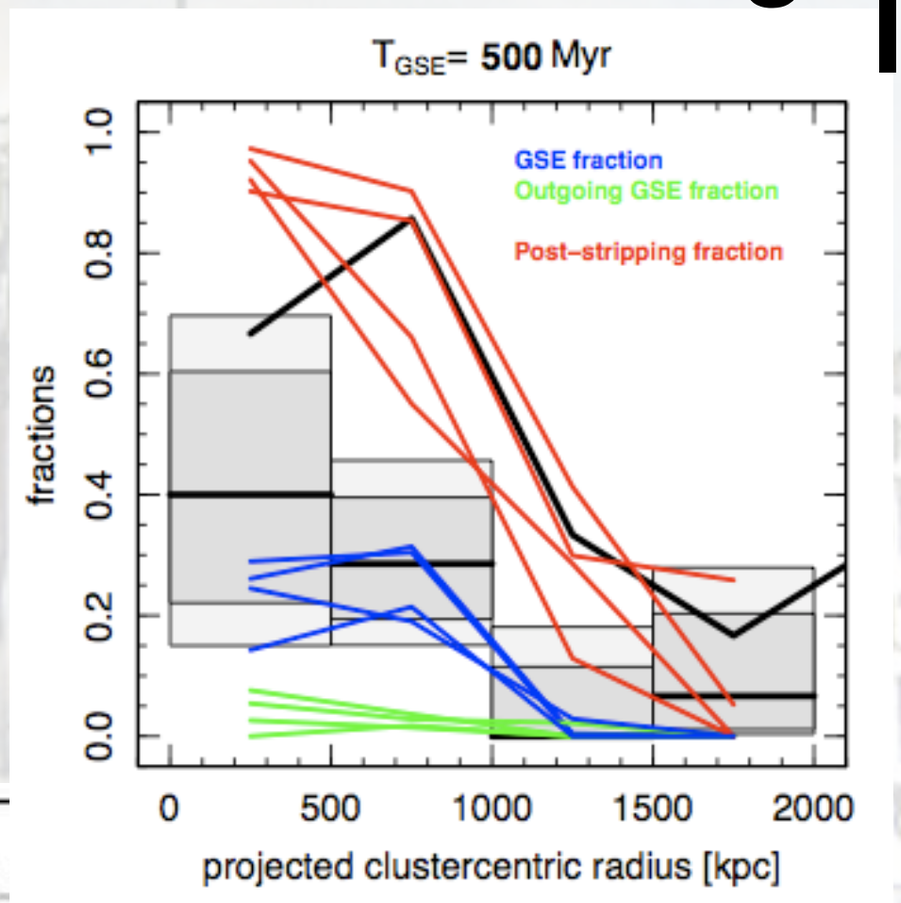


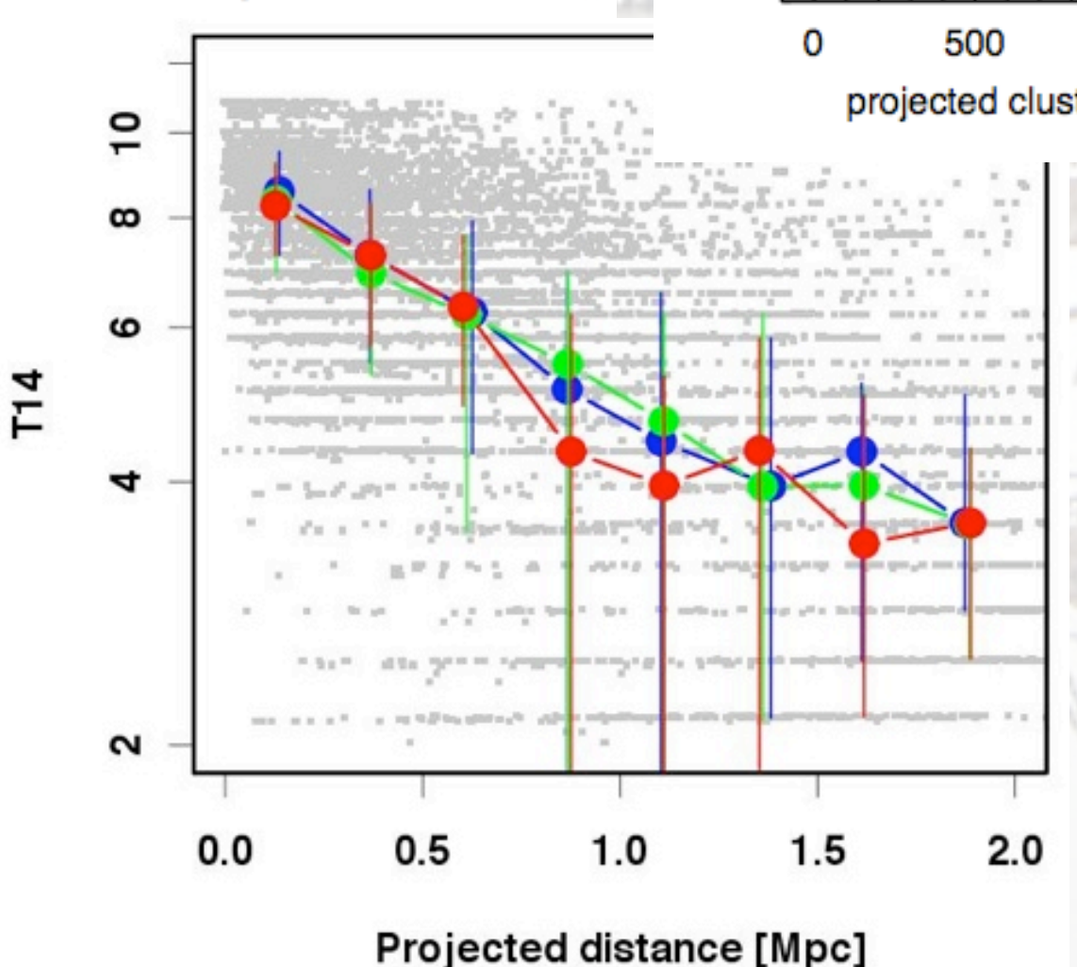

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