

# VESTIGE: A Virgo Environmental Survey Tracing Ionized Gas Emission



Matteo Fossati (MPE) on behalf of **Alessandro Boselli**

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# Why do we care about environment?

## Open questions

What do we know/learn about the detailed physics of various environmental mechanisms?

What number (or fraction) of galaxies become passive as a direct result of their surrounding environments?

What is the dominant quenching mechanism (in different environments)?

# VESTIGE

## A Virgo Environmental Survey Tracing Ionized Gas Emission

P.I. A. Boselli

Survey manager M. Fossati

50 allocated night with MegaCam  
(1°x1°) to cover the Virgo cluster  
within 1 virial radius ( $\sim 104^{\circ}2$ )

Integration time: 2 h in the H $\alpha$  filter  
( $\lambda = 6563 \text{ \AA}$ ,  $\Delta\lambda = 106 \text{ \AA}$ ;  $T = 93\%$ ),  
12 min in r (for the stellar  
continuum subtraction)

Sensitivity:

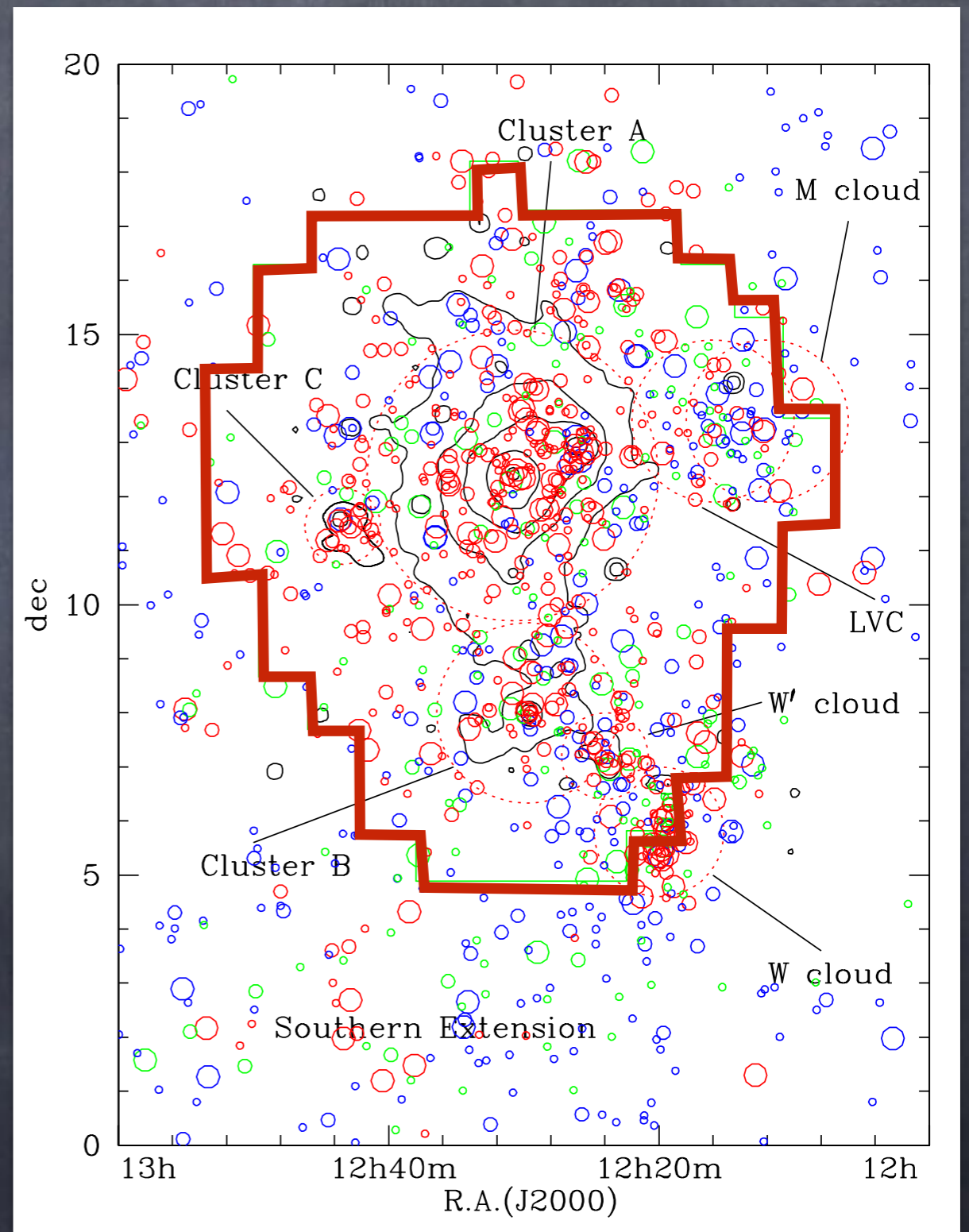
$f(\text{H}\alpha) \sim 4 \times 10^{-17} \text{ erg sec}^{-1} \text{ cm}^{-2} (5\sigma)$

for point sources

$\Sigma(\text{H}\alpha) \sim 2 \times 10^{-18} \text{ erg sec}^{-1} \text{ cm}^{-2}$

$\text{arcsec}^{-2} (1\sigma)$  for extended sources

at 3'' res



# VESTIGE

## A Virgo Environmental Survey Tracing Ionized Gas Emission

### Why Virgo?

The closest cluster of galaxies

Dist = 16.5 Mpc;

$M_{200} = 1.4-4.2 \times 10^{14} M_{\odot}$

High angular resolution (1 arcsec = 80 pc)

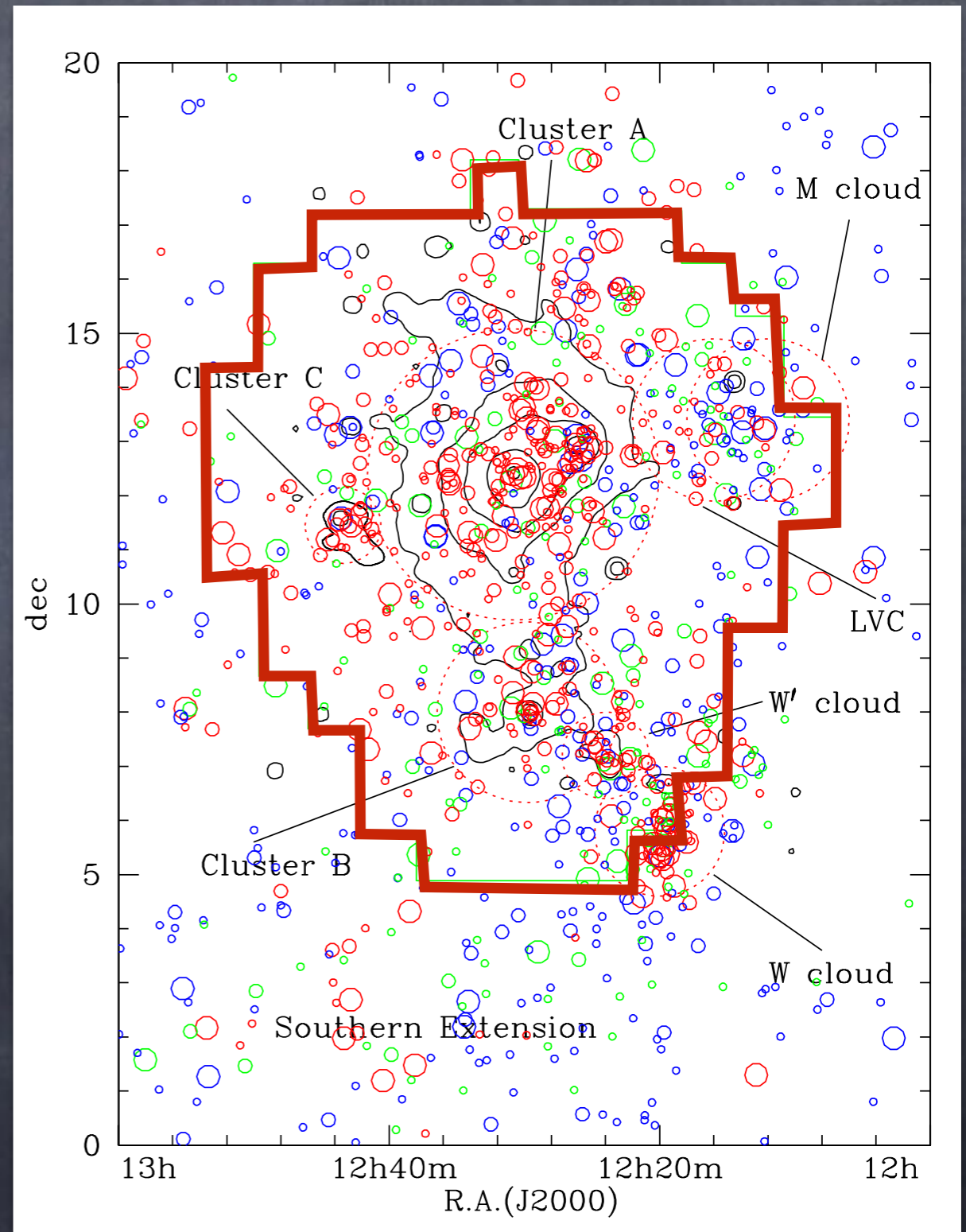
Access to the dwarfs ( $M_{\text{star}} \sim 10^{6-7} M_{\odot}$ )

Spiral rich cluster in formation

Multifrequency data available:

GUViCS (UV), NGVS (optical),

HeViCS (FIR), ALFALFA+VIVA (HI)



# VESTIGE

## A Virgo Environmental Survey Tracing Ionized Gas Emission

### 1) VIRGO SCIENCE

The effects of the environment on galaxy evolution (quenching)

The fate of the stripped gas in cluster galaxies

The star forming process in nearby galaxies

The ionised gas emission in early-type galaxies

The  $H\alpha$  luminosity function of galaxies

The  $H\alpha$  scaling relation in galaxies

The nature of dark galaxies

The dynamical structure of the Virgo cluster

The HII luminosity function of cluster galaxies

Planetary nebulae and the origin of the intracluster light

### 2) FOREGROUND SCIENCE

The diffuse ionised emission of the Milky Way

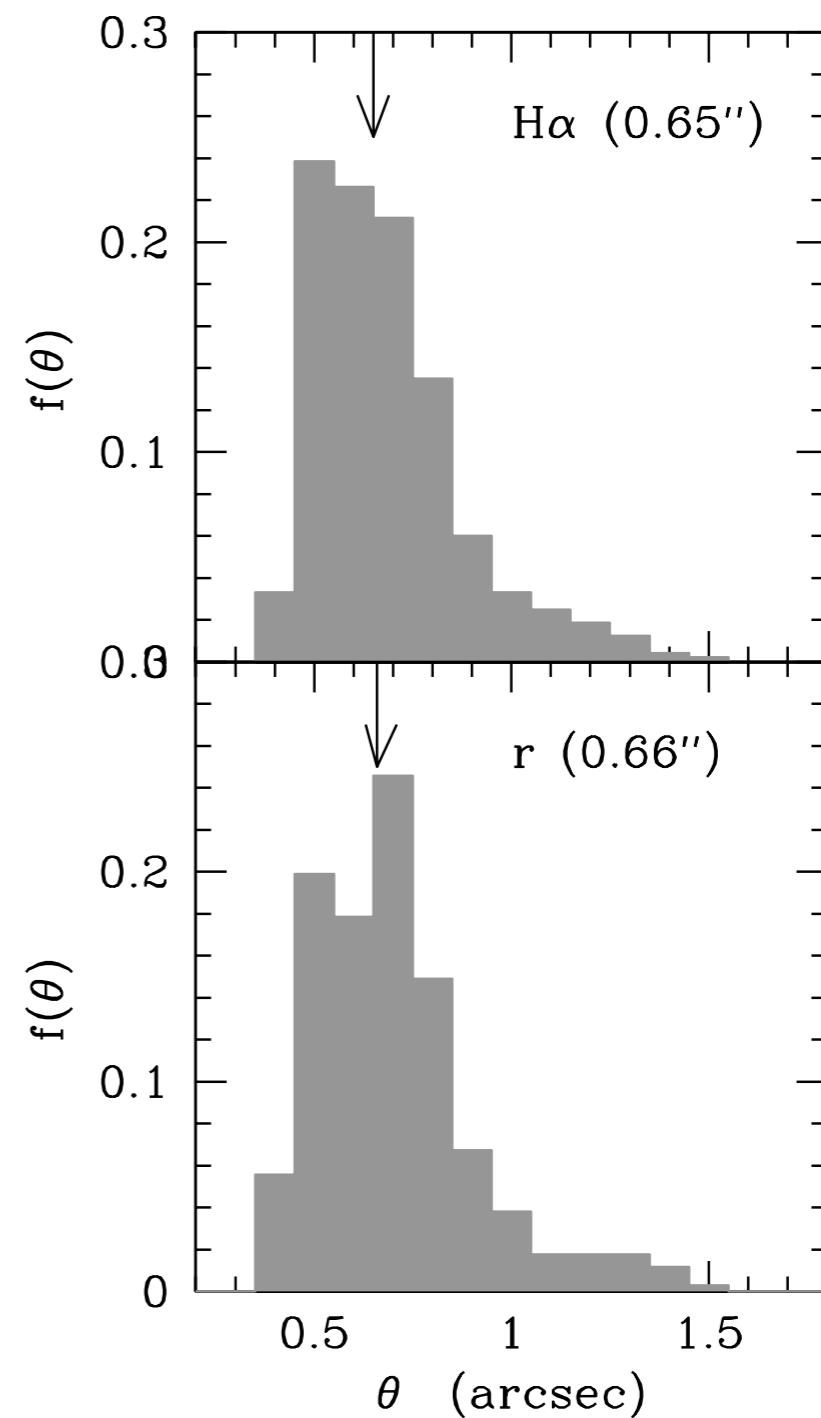
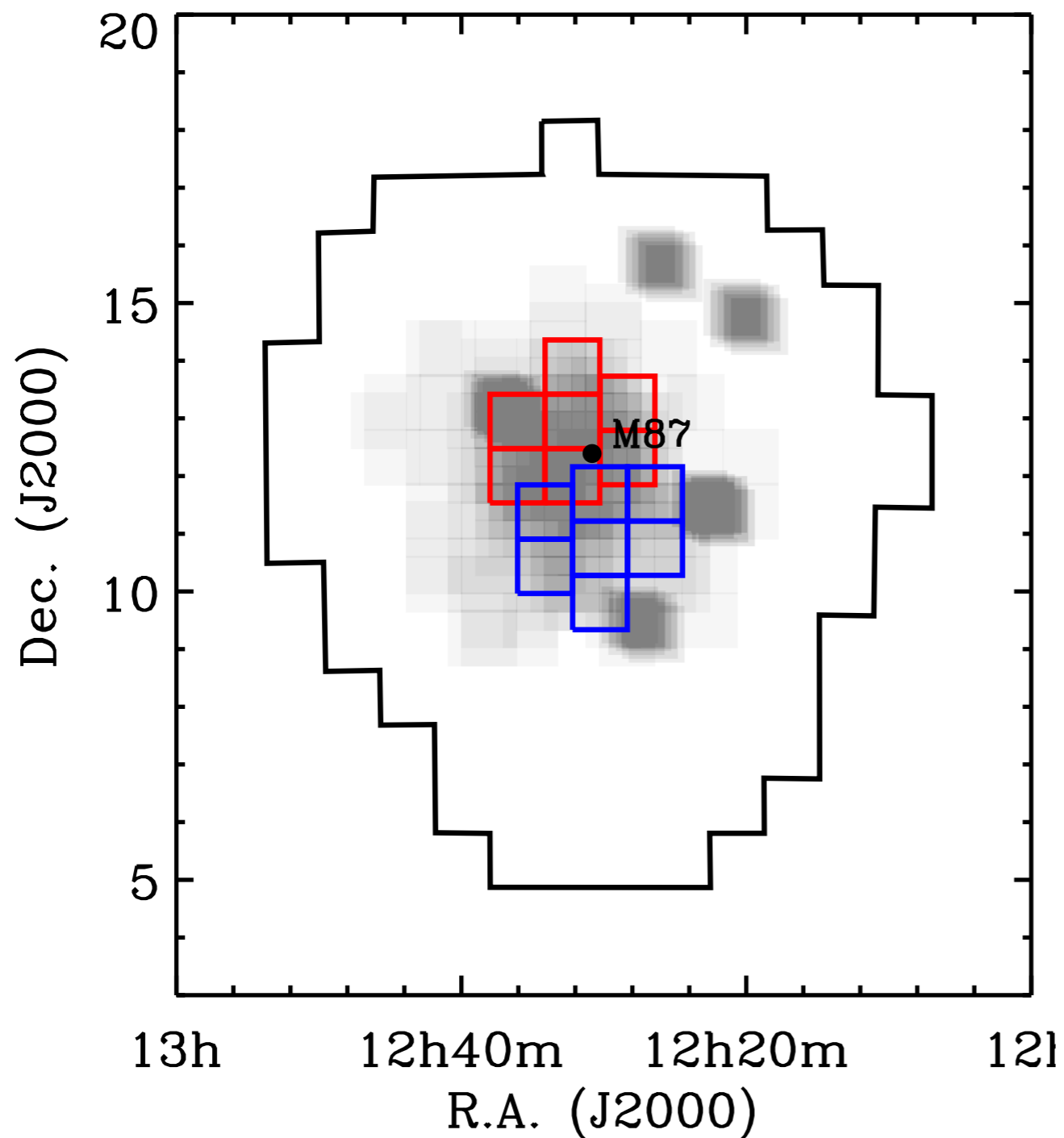
High velocity clouds, compact sources and Galactic fountains

### 3) BACKGROUND SCIENCE

High redshift emission line galaxies ( $Ly\alpha$  , [OII], [OIII])

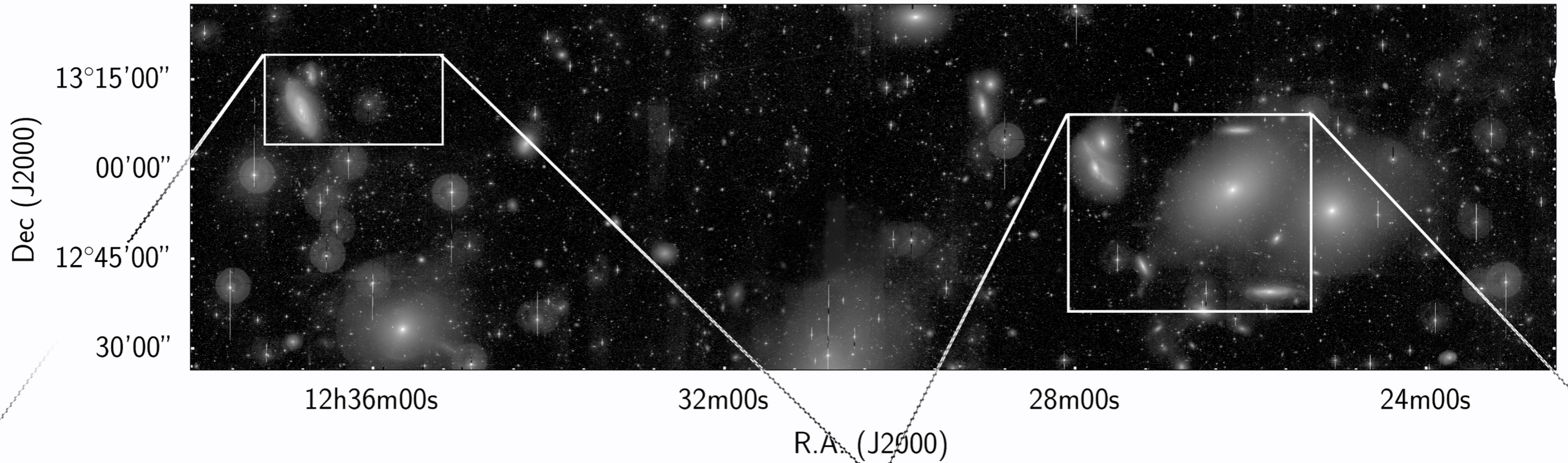
# VESTIGE

A Virgo Environmental Survey Tracing Ionized Gas Emission



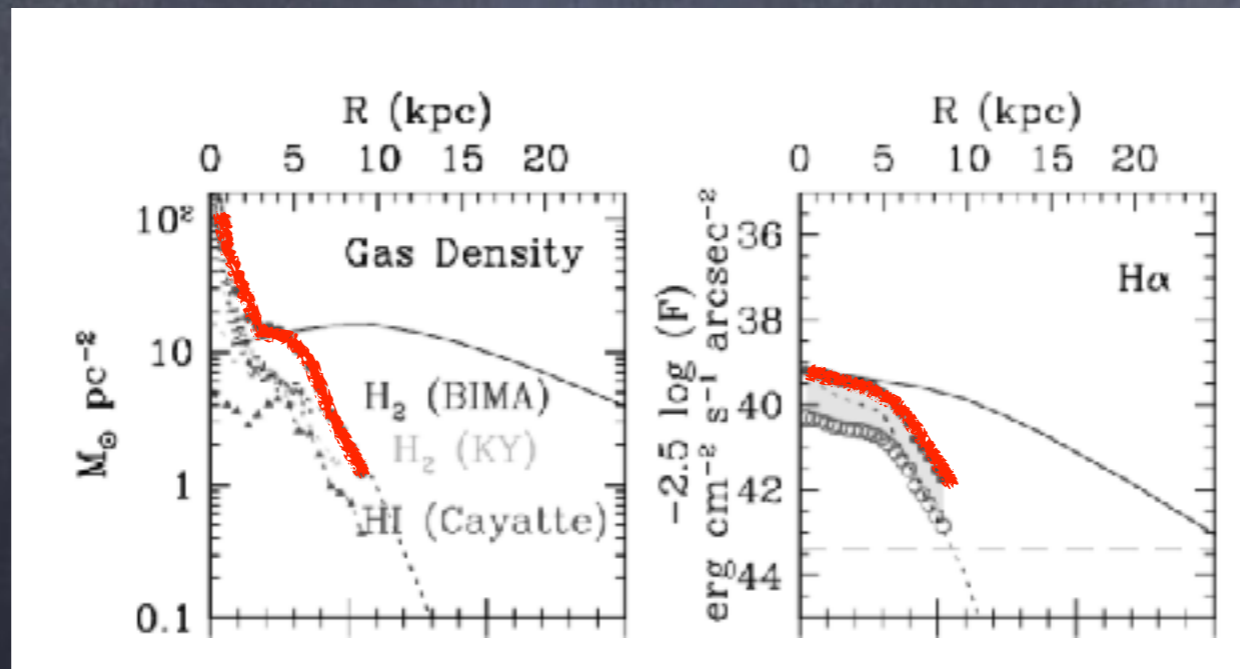
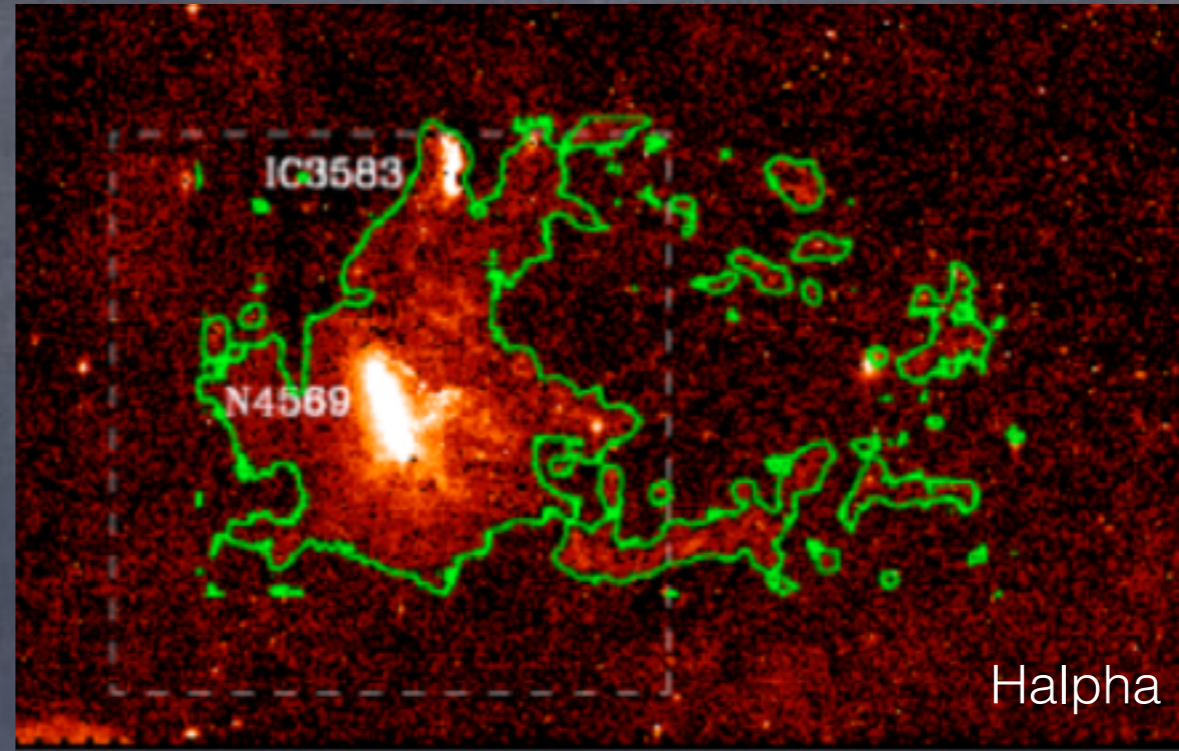
Status after 2017A (12 nights)

# A 4x1 deg strip in the cluster core



# VESTIGE-pilot NGC4569

RPS tail detection and truncation of radial profiles



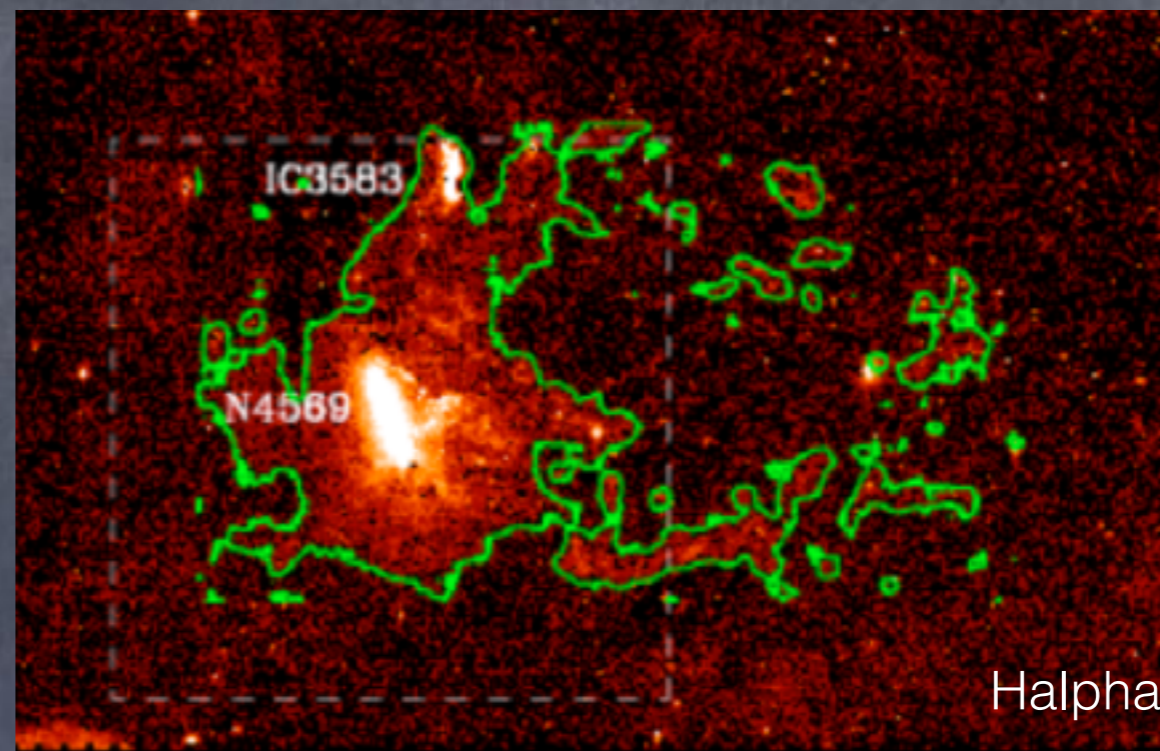
Disk truncation due to Ram pressure stripping

Boselli et al. 2006, 2016



# VESTIGE-pilot NGC4569

RPS tail detection and truncation of radial profiles

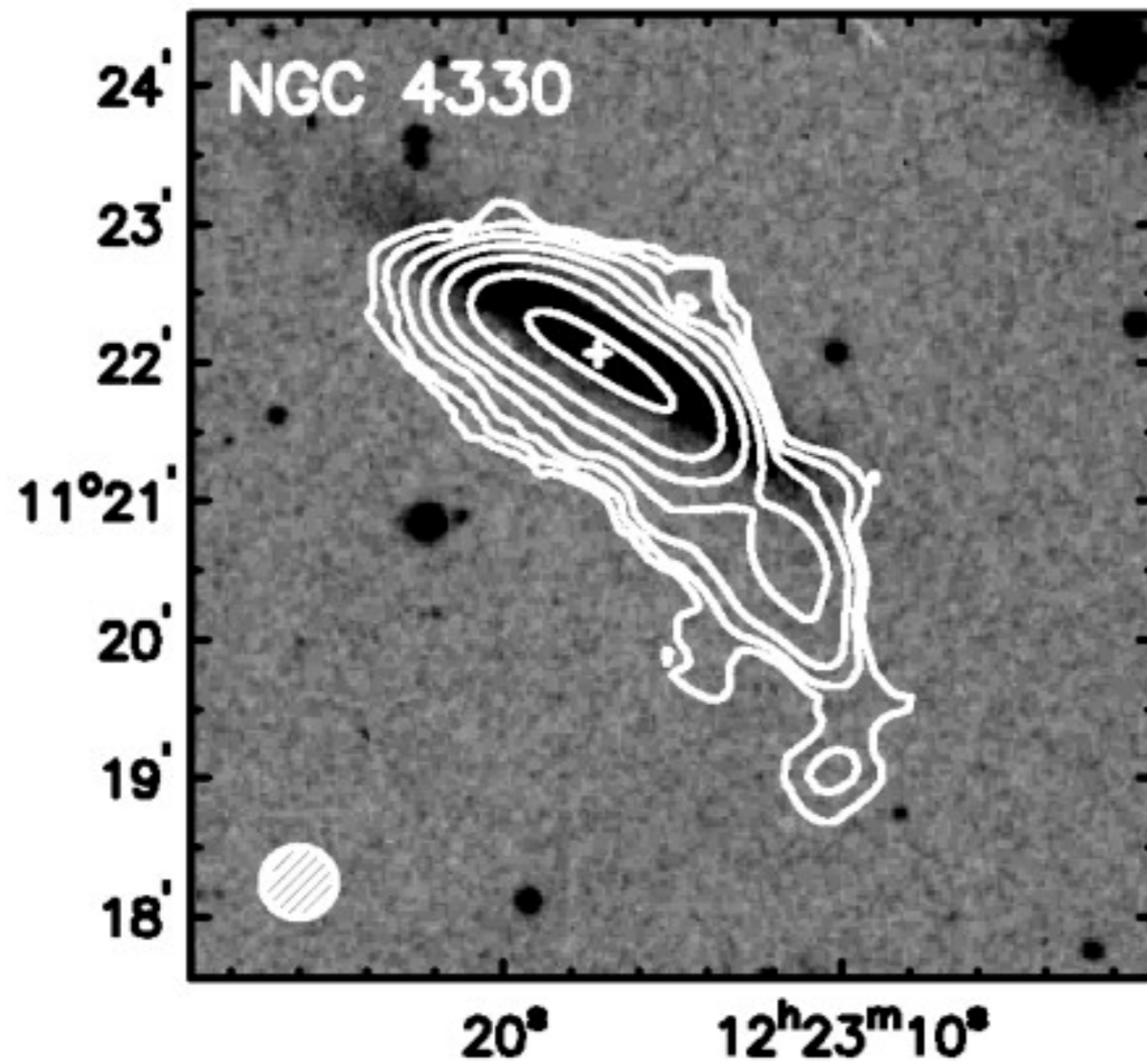


- The mass of the ionised gas in the tail is a large fraction of the stripped HI
- The ionization of the gas in the tail is supported by shocks and turbulence
- The mass of the gas expelled by the nuclear outflow is estimated to be 1-3% of the total stripped mass due to RPS

# VESTIGE-pilot NGC4330

Accurate reconstruction of the RPS quenching times

VIVA (HI)



Chung et al. 2007

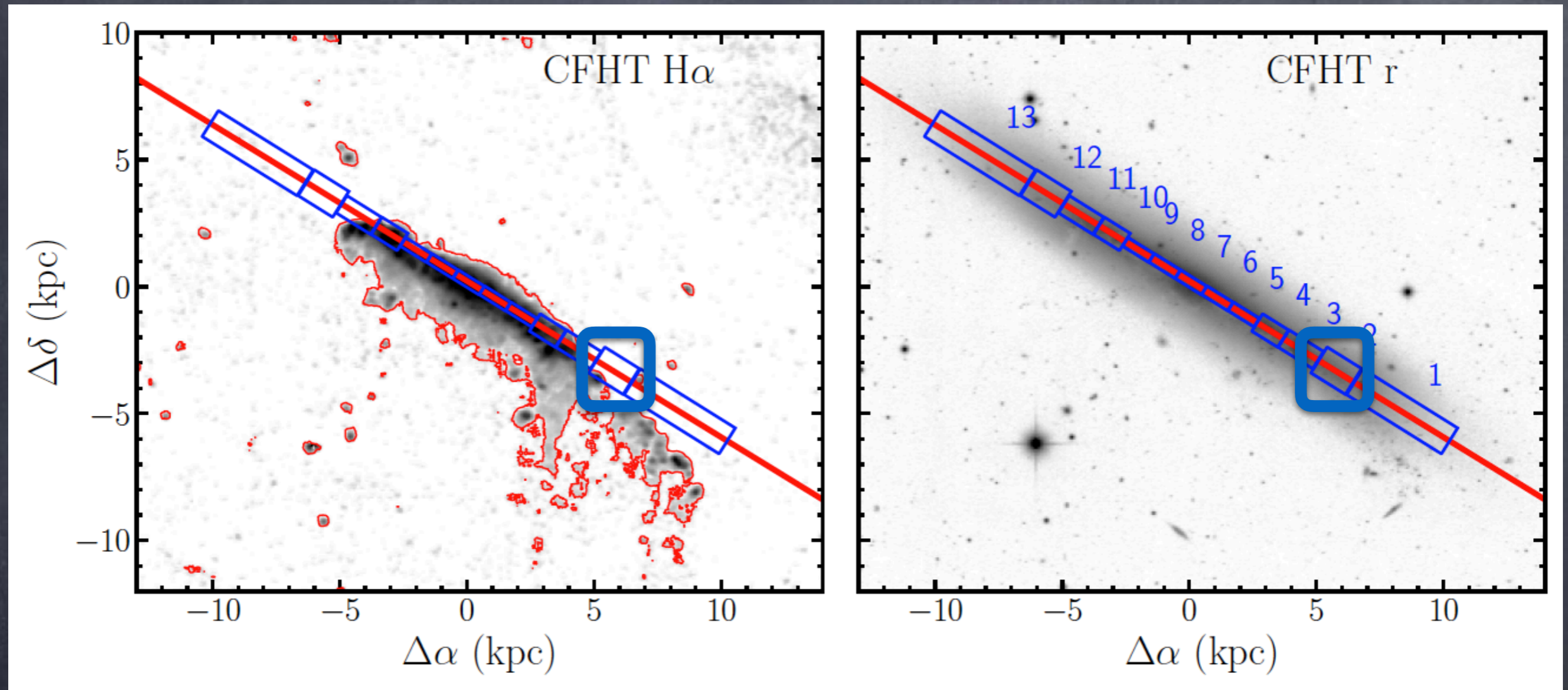
NGVS (optical)



Fossati et al. submitted

# VESTIGE-pilot NGC4330

Accurate reconstruction of the RPS quenching times



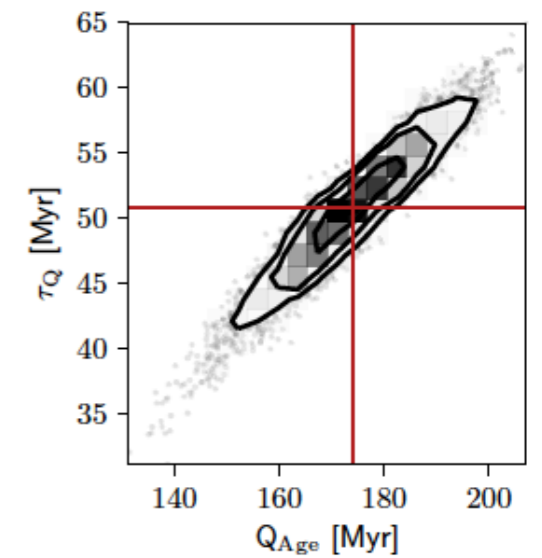
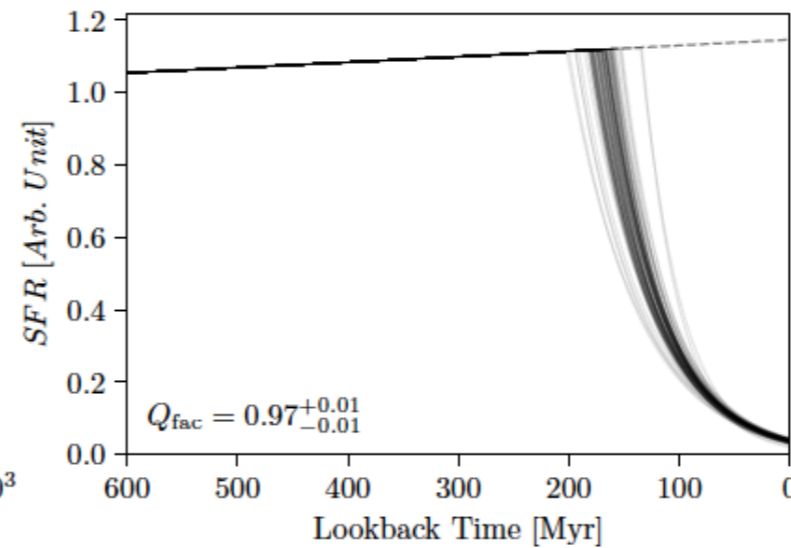
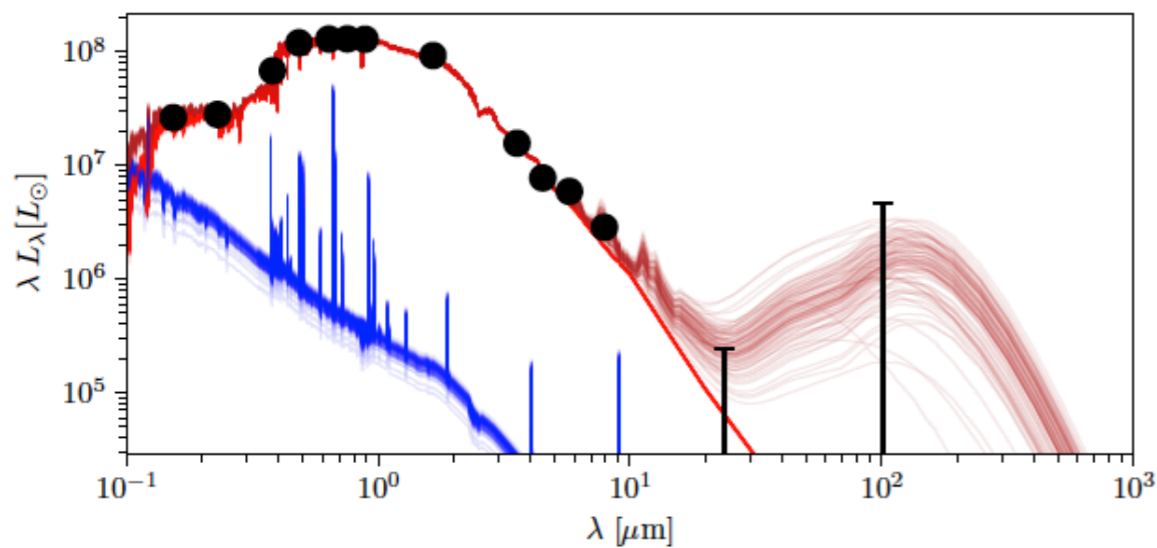
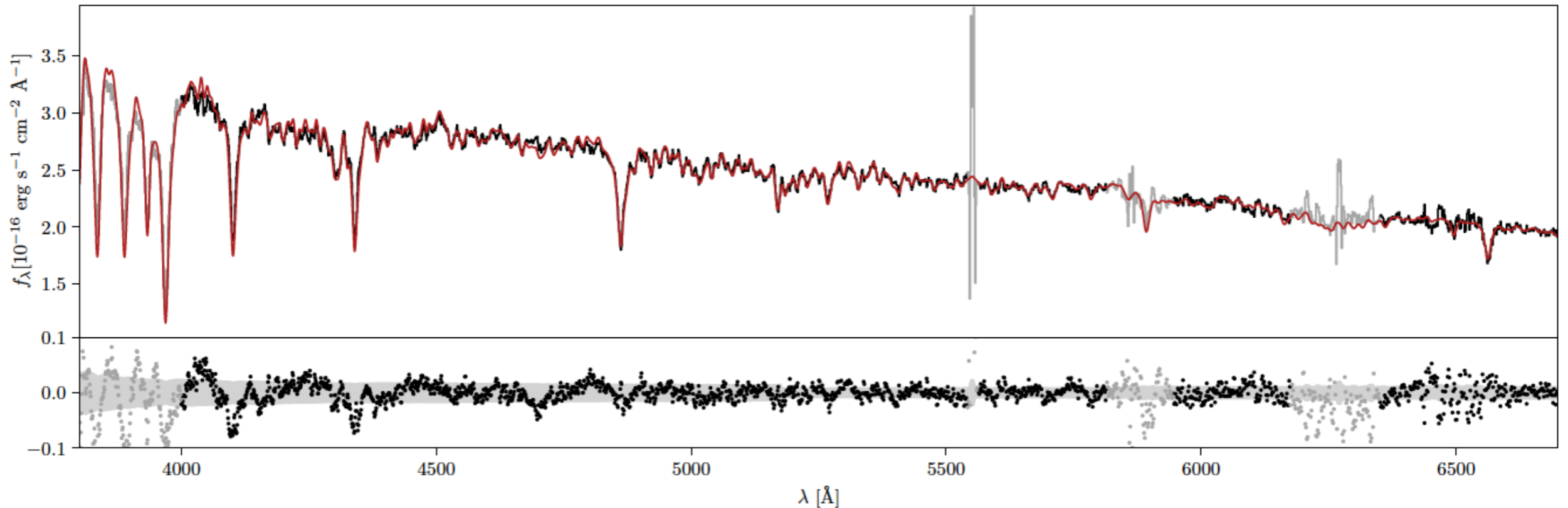
Jointly fit FORS2 spectroscopy (DDT) and 15 band photometry using MonteCarlo code (thanks to J.T.Mendel)

Radial SFH from Boissier & Prantzos (2000) models plus exponential truncation (2 free parameters: lookback time of the start of the quenching event and exponential timescale)

# VESTIGE-pilot NGC4330

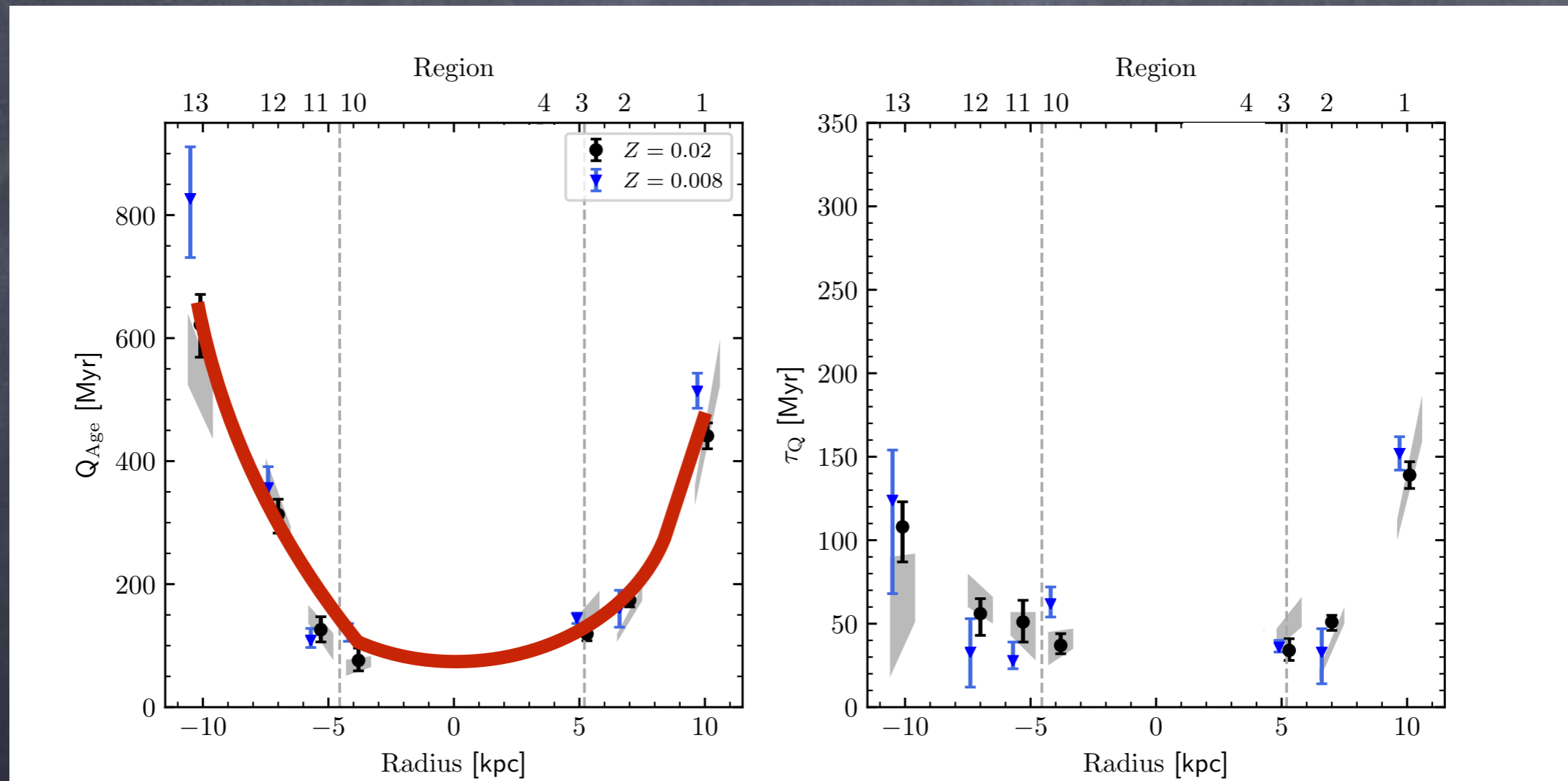
Accurate reconstruction of the RPS quenching times

Region 2



# VESTIGE-pilot NGC4330

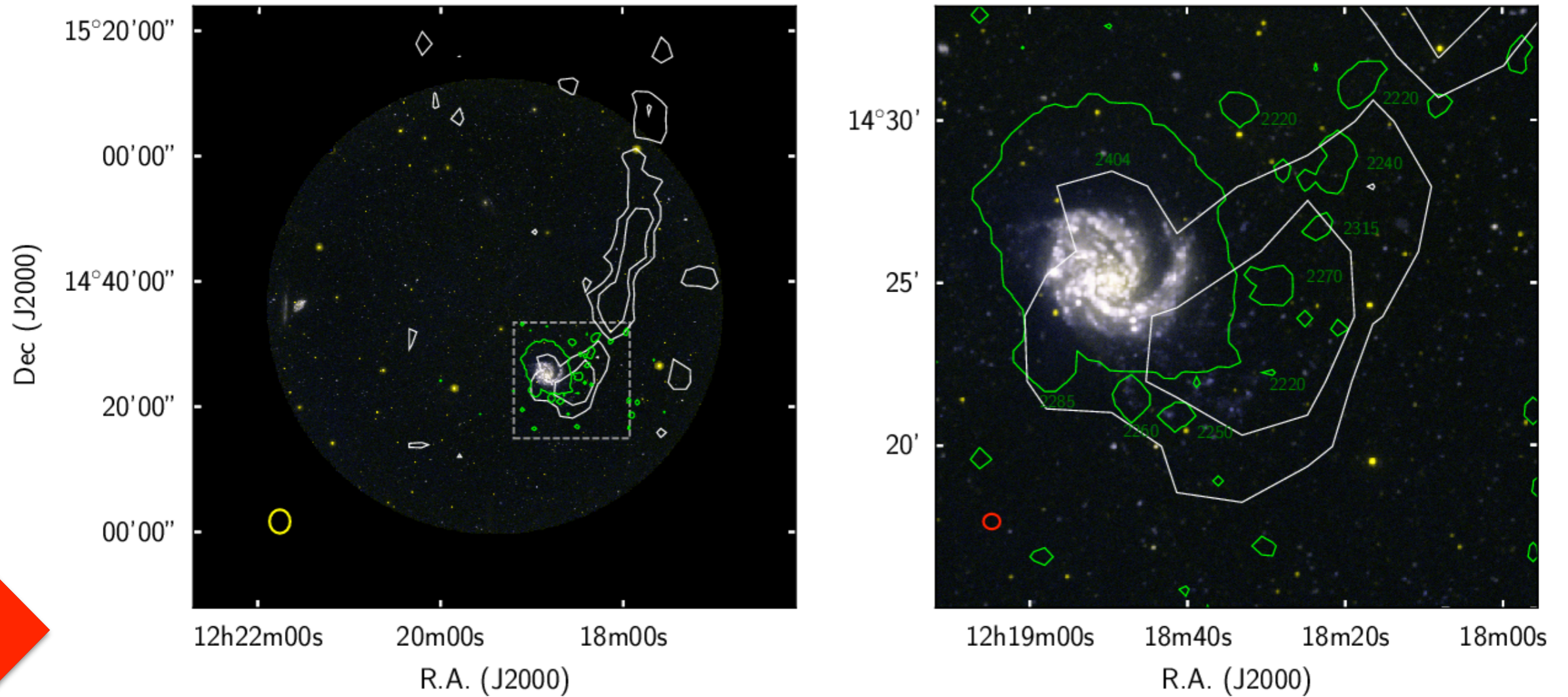
Accurate reconstruction of the RPS quenching times



- Outside-in quenching event, outskirts stripped first
- Short timescales, RPS event started 500 Myr ago, we estimate it will last another  $<1$  Gyr before the galaxy joins the red sequence of passive galaxies

# VESTIGE-pilot NGC4254

Star formation in the harrassed/stripped atomic gas tail

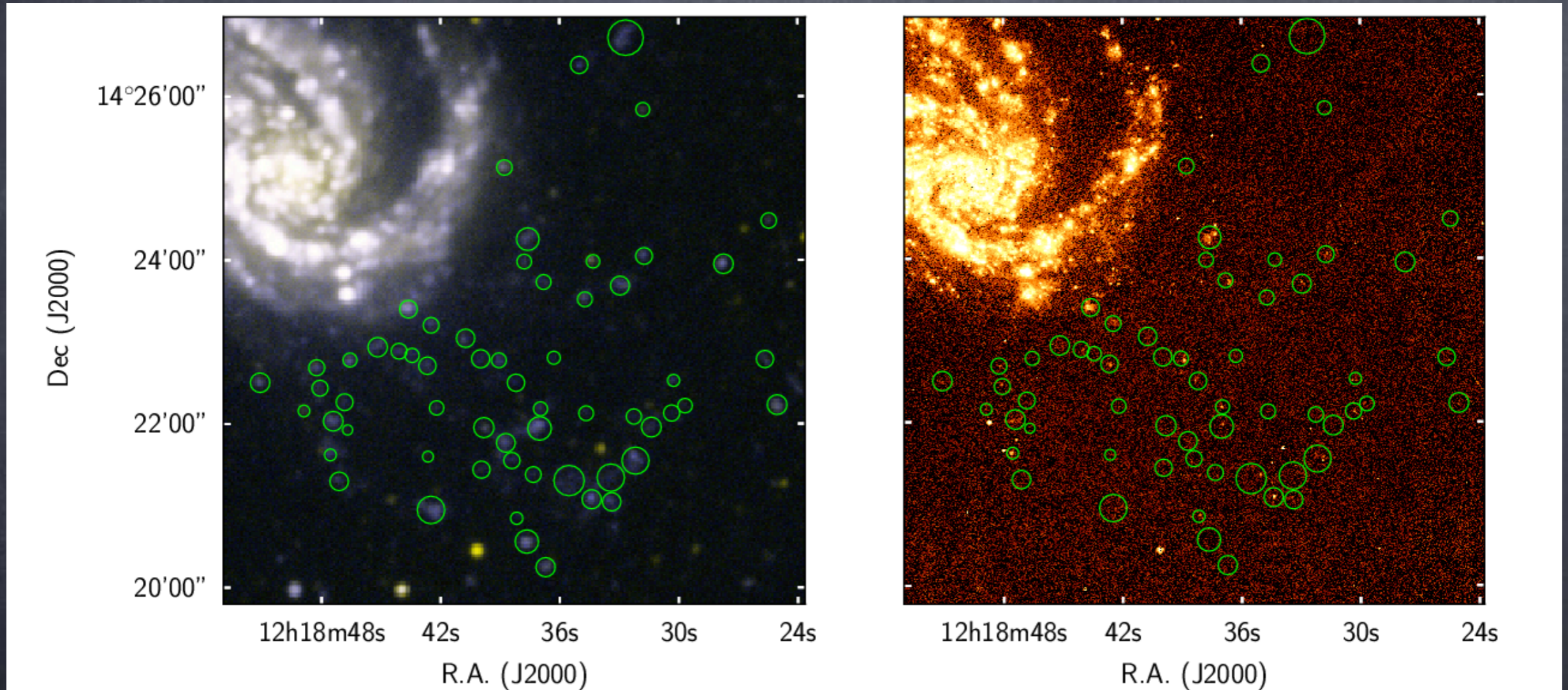


# VESTIGE-pilot NGC4254

Star formation in the harrassed/stripped atomic gas tail

GALEX FUV

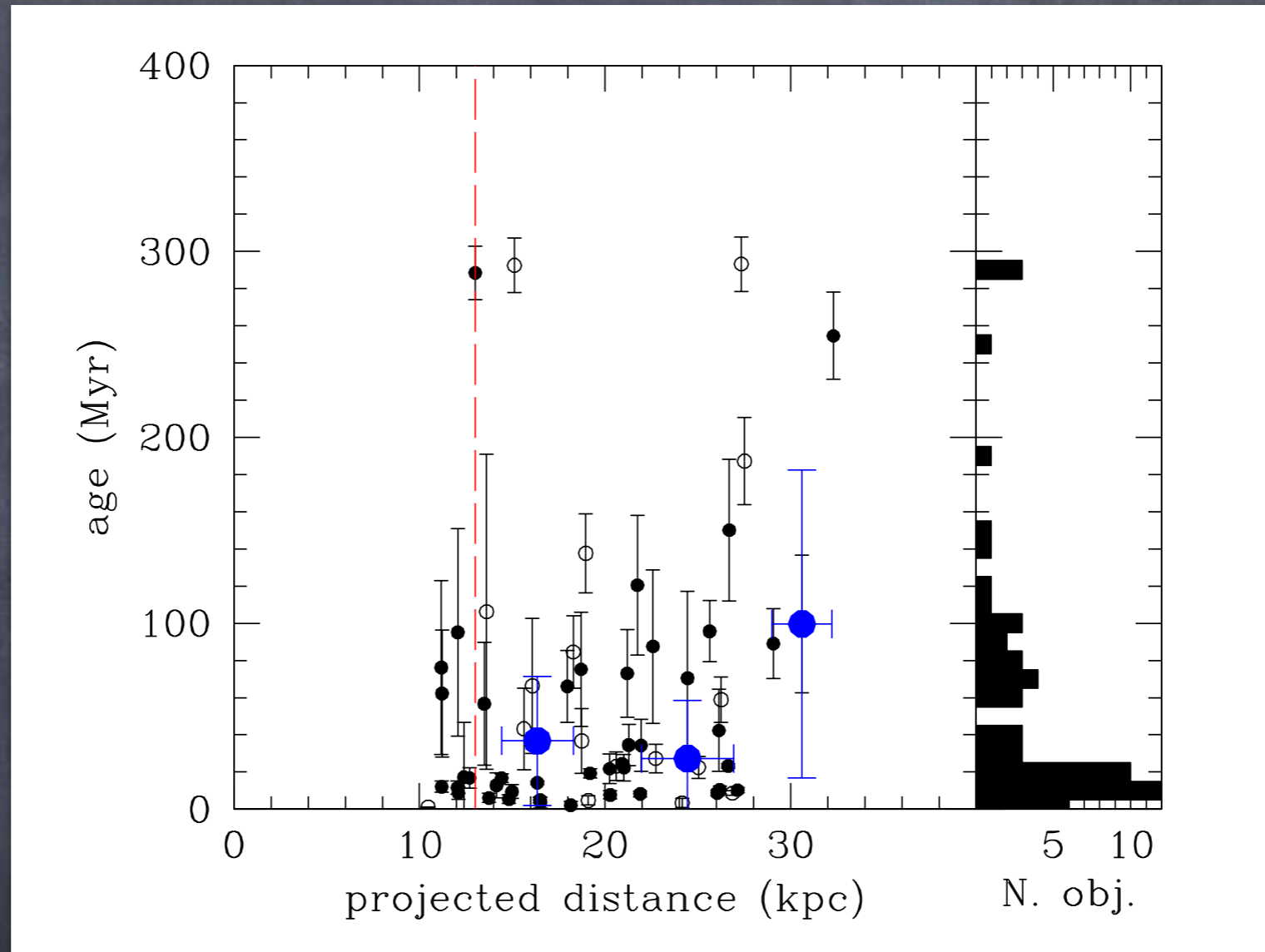
VESTIGE H $\alpha$



- 61 star forming regions outside the galaxy disk
- All identified and detected in FUV, only a few detected in H $\alpha$

# VESTIGE-pilot NGC4254

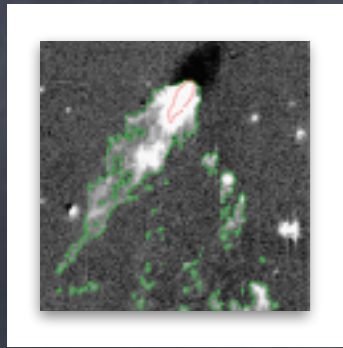
Star formation in the harrassed atomic gas tail



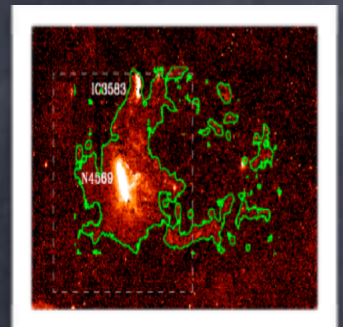
- Young ages, mild age gradient with distance



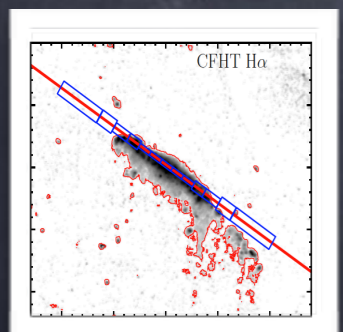
# Conclusions



Signatures of gas stripping phenomena are ubiquitous in local massive clusters (e.g. detection of ionised gas tails, truncated radial profiles, short quenching times).



VESTIGE is probing the Virgo cluster with unprecedented area and depth. Several tails already detected. RPS but also galaxy harassment



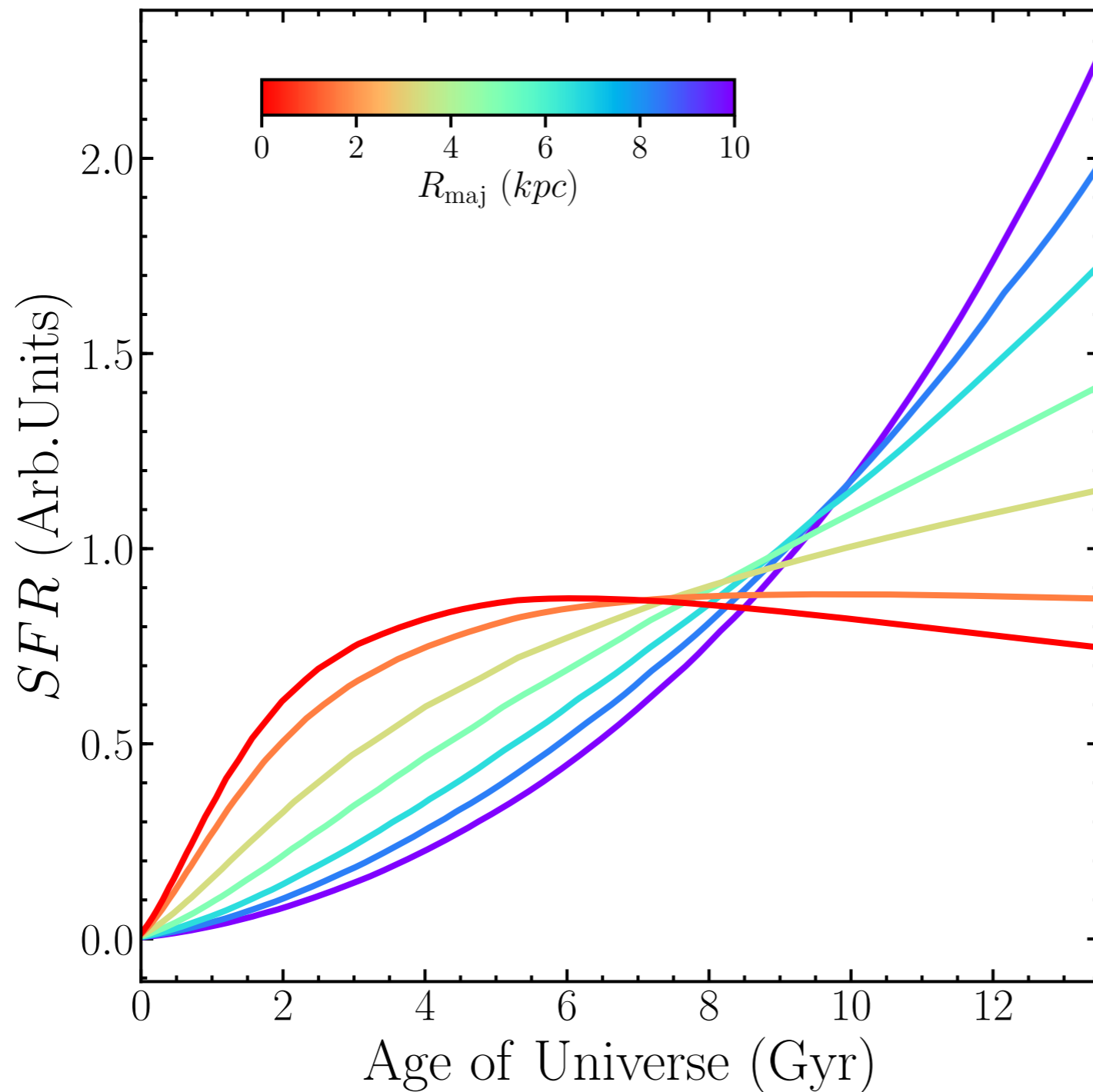
Monte Carlo methods coupled with state of the art models can robustly derive the age since the quenching event in case of RPS

Full statistical picture in the next two years with full VESTIGE survey and follow-up spectroscopic observations

Backup slides

# VESTIGE-pilot NGC4330

Accurate reconstruction of the RPS quenching times



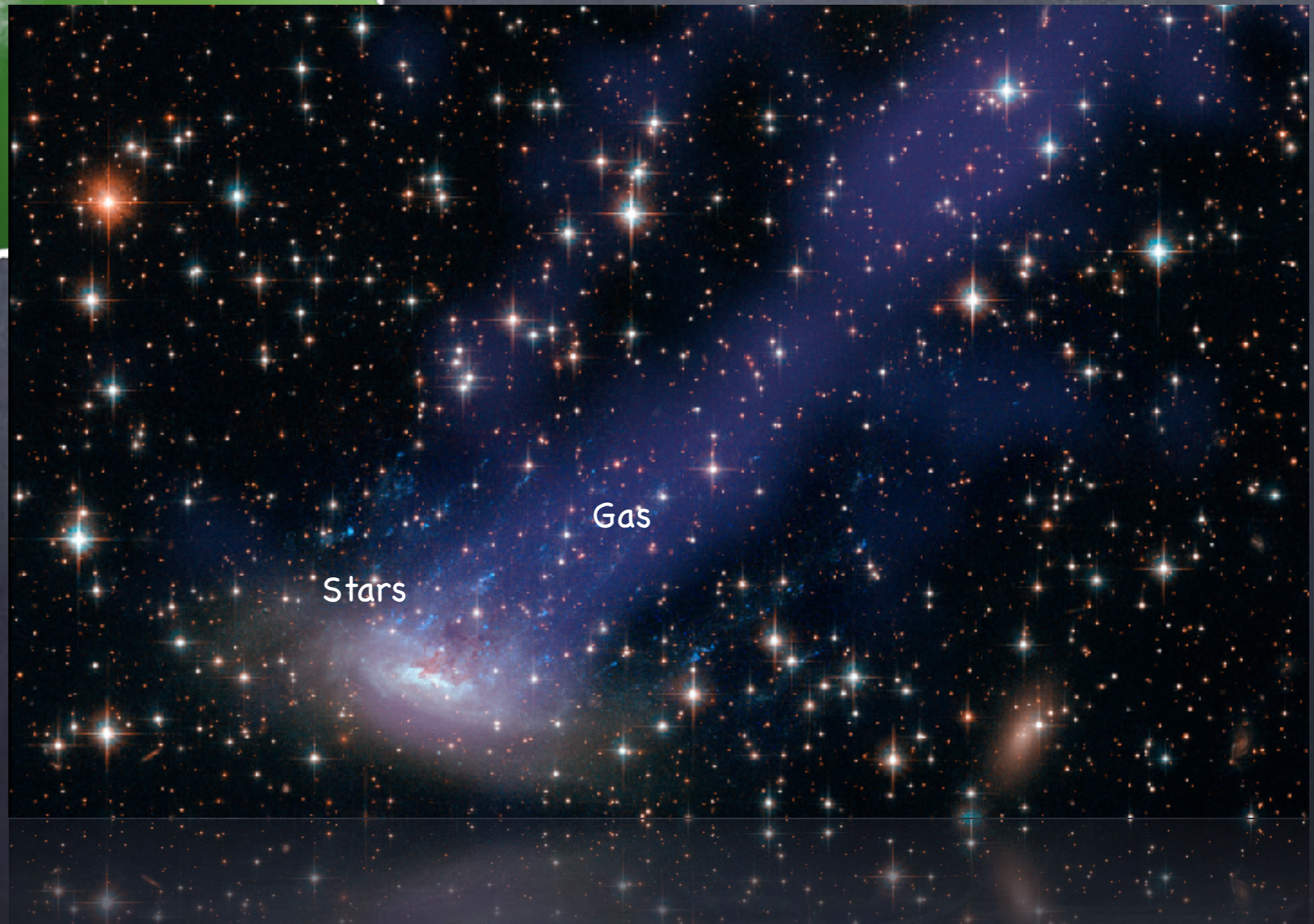
Models from  
Boissier & Prantzos 2000

$V_{\text{circ}} = 120 \text{ km/s}$   
 $\lambda = 0.05$

# What is ram-pressure stripping



- Two ingredients:
- 1) High velocity
  - 2) Dense environment



# What is ram-pressure stripping

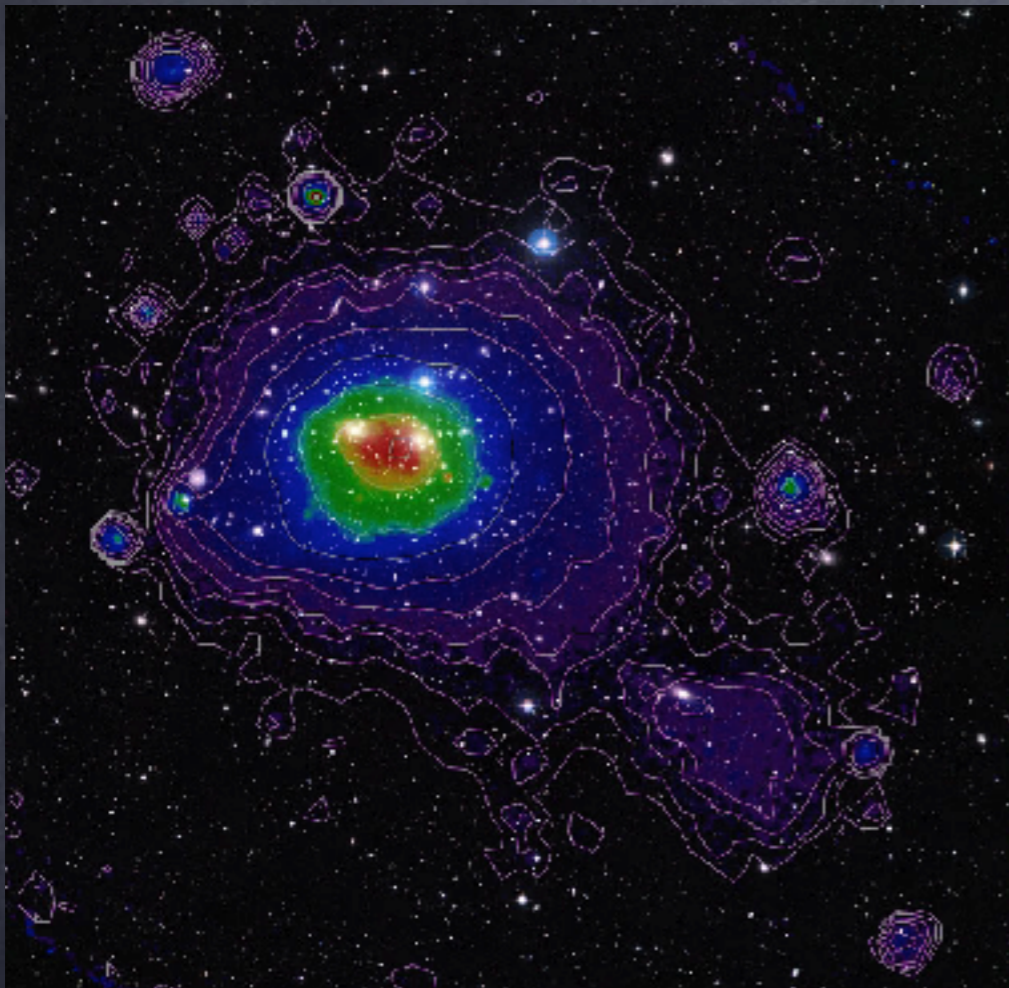
Galaxy clusters are the most massive structures in the Universe

- Hot and dense gas ( $10^7$ – $10^8$  K)
- High virial velocities (up to  $\sim 1000$  km/h)

The pressure exerted on a parcel of gas belonging to a galaxy is:

$$P = \rho * v^2$$

when it overcomes the gravitational force the gas is displaced.



Coma Cluster in X-Ray