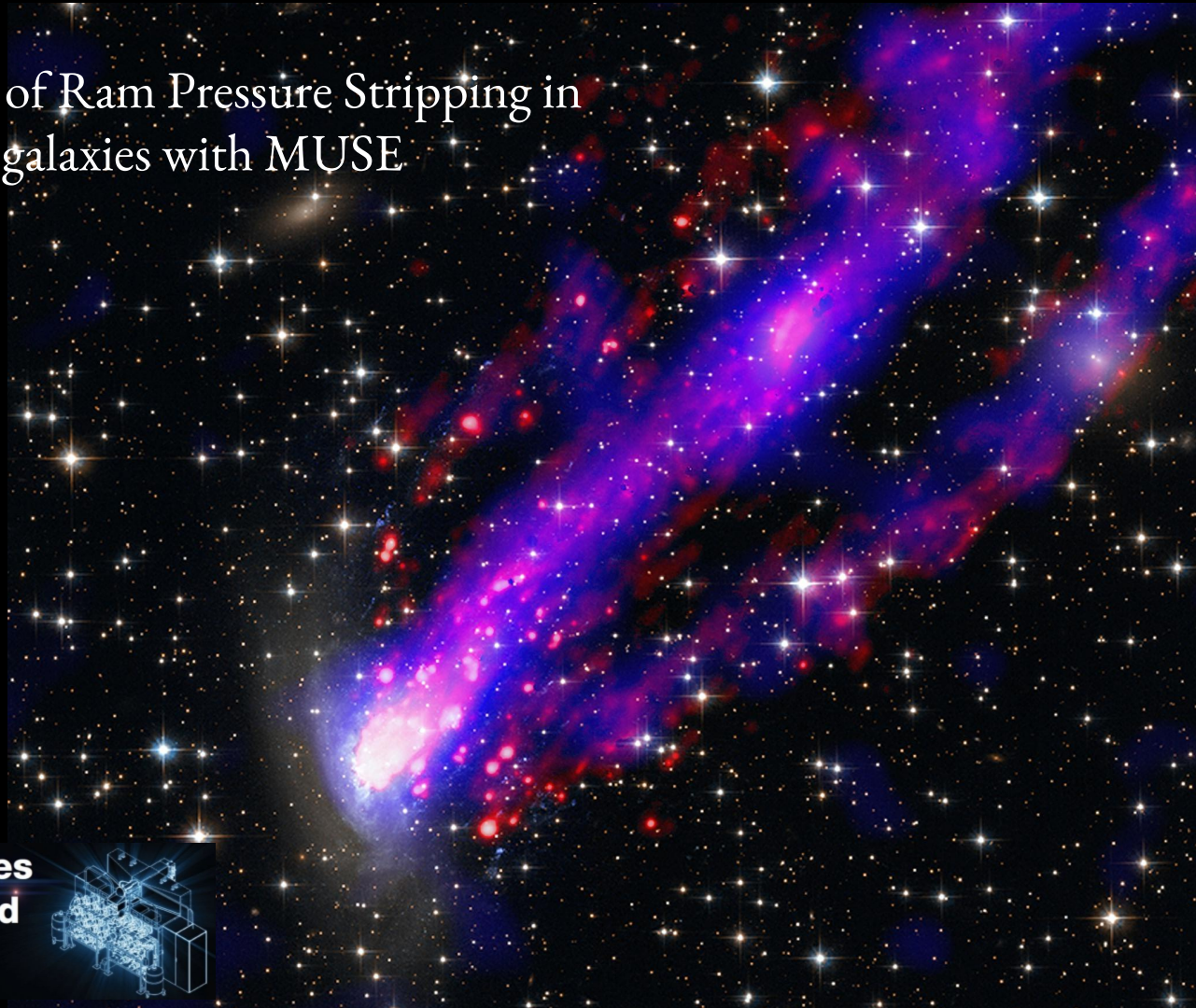


# Resolving the Physics of Ram Pressure Stripping in local cluster galaxies with MUSE

Matteo Fossati  
University of Milano-Bicocca

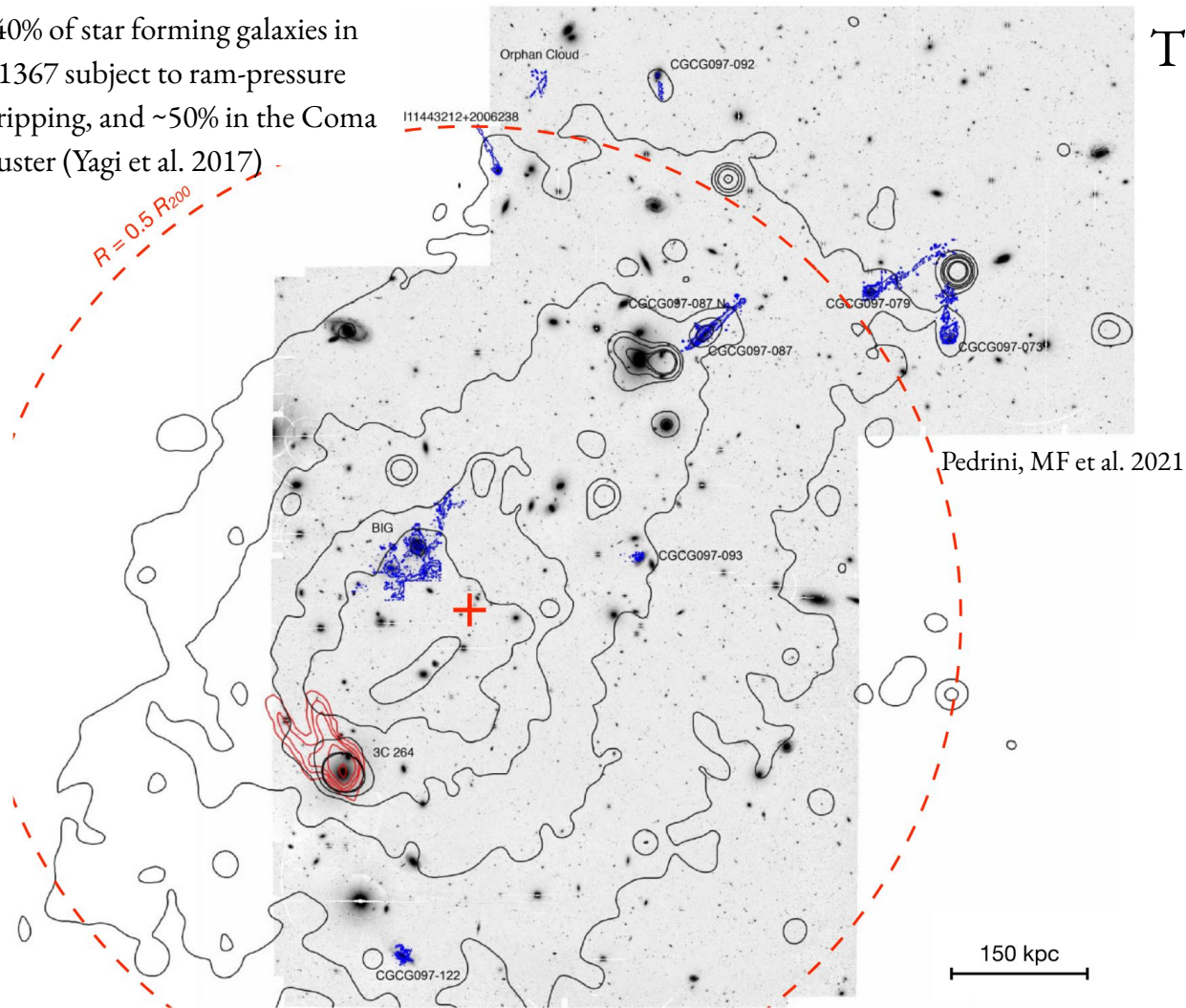


**A decade of discoveries  
with MUSE and beyond**

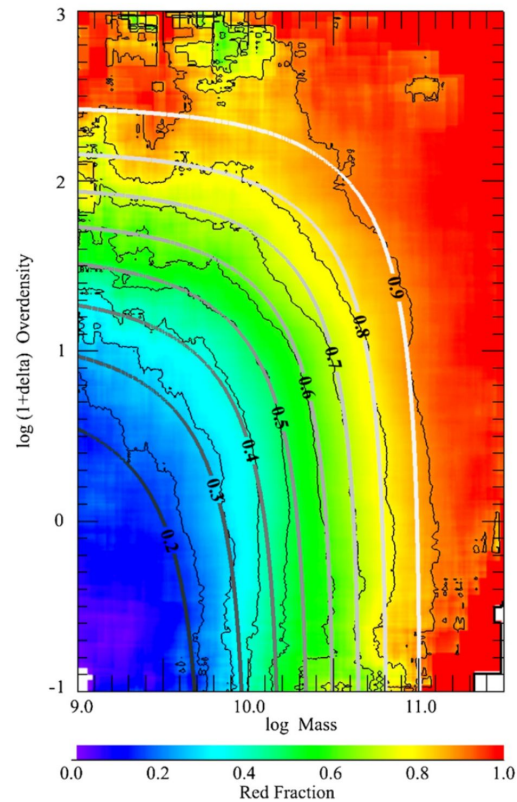
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~40% of star forming galaxies in A1367 subject to ram-pressure stripping, and ~50% in the Coma cluster (Yagi et al. 2017)



The environment shapes the properties of galaxies





# 10 years ago MUSE observed a galaxy far, far away...

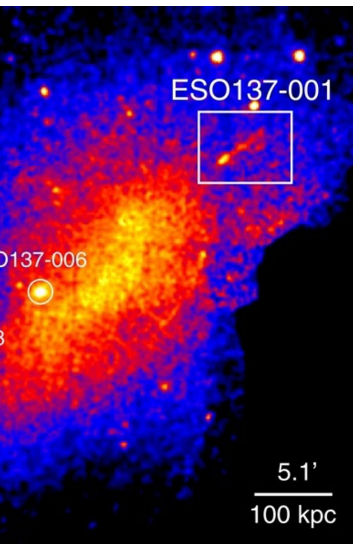


European  
Southern  
Observatory

eso1437 — Science Release

## MUSE Reveals True Story Behind Galactic Crash

10 November 2014

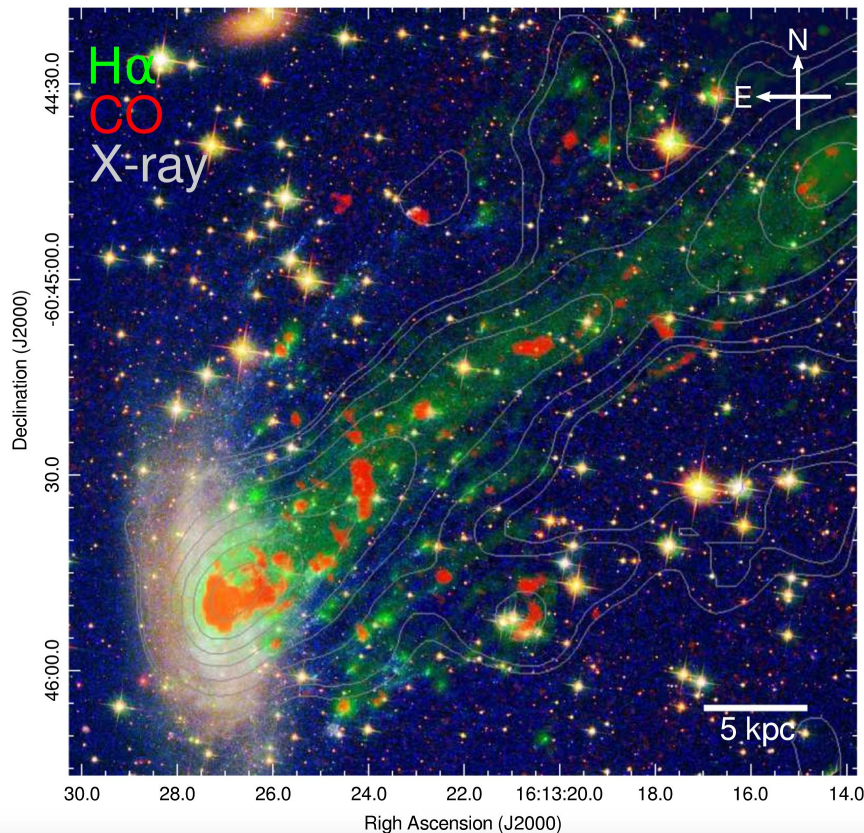


Norma Cluster  
(XMM Newton)



ESO137-001  
HST WFC3+ACS

Observations on June 21 2014

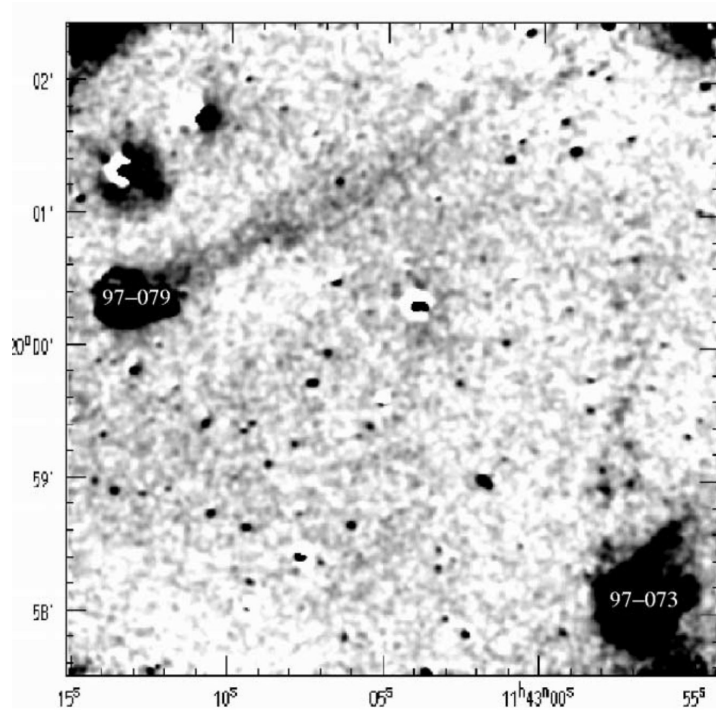


Sun et al. 2006, Fumagalli et al. 2014, MF et al. 2016, Jachym et al. 2019

# A new golden era for the study of environmental processes thanks to MUSE

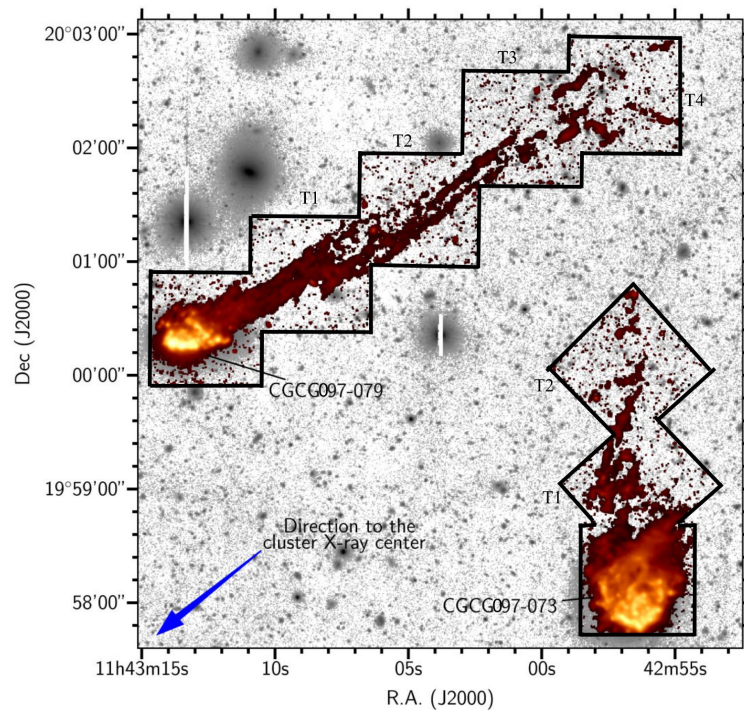
Ionized gas  
imaging

Pioneering Efforts before MUSE



6h NB imaging at 2.5m telescope, Gavazzi et al. 2001  
see also Subaru NB imaging by Yagi et al. 2017

With MUSE



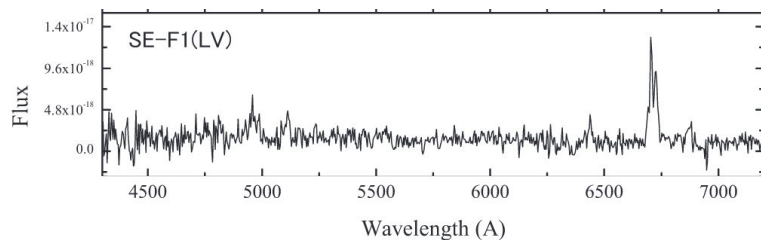
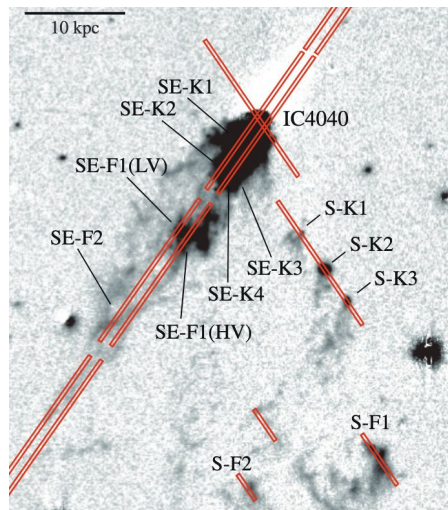
MUSE ~30 min per pointing, Pedrini, MF et al. 2021



# A new golden era for the study of environmental processes thanks to MUSE

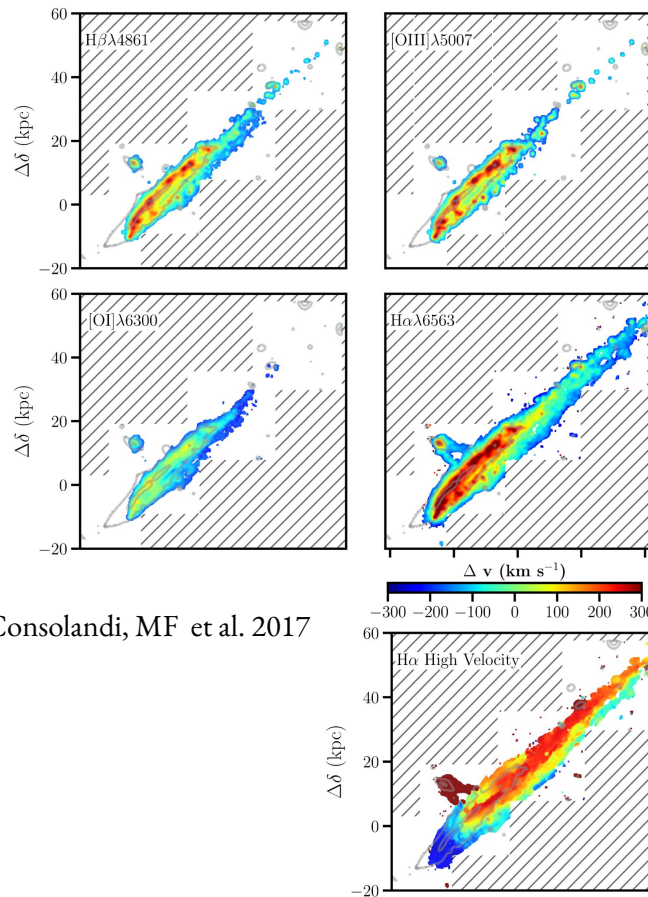
## Pioneering Efforts before MUSE

Spectroscopy



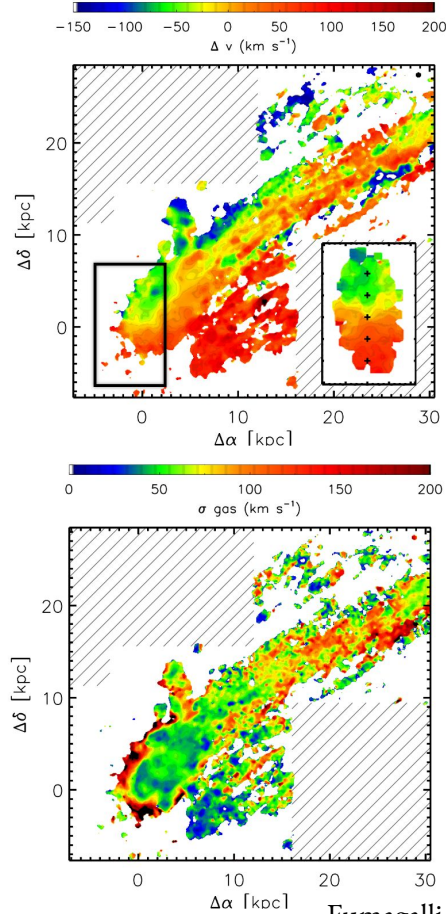
Yoshida et al. 2012

## With MUSE



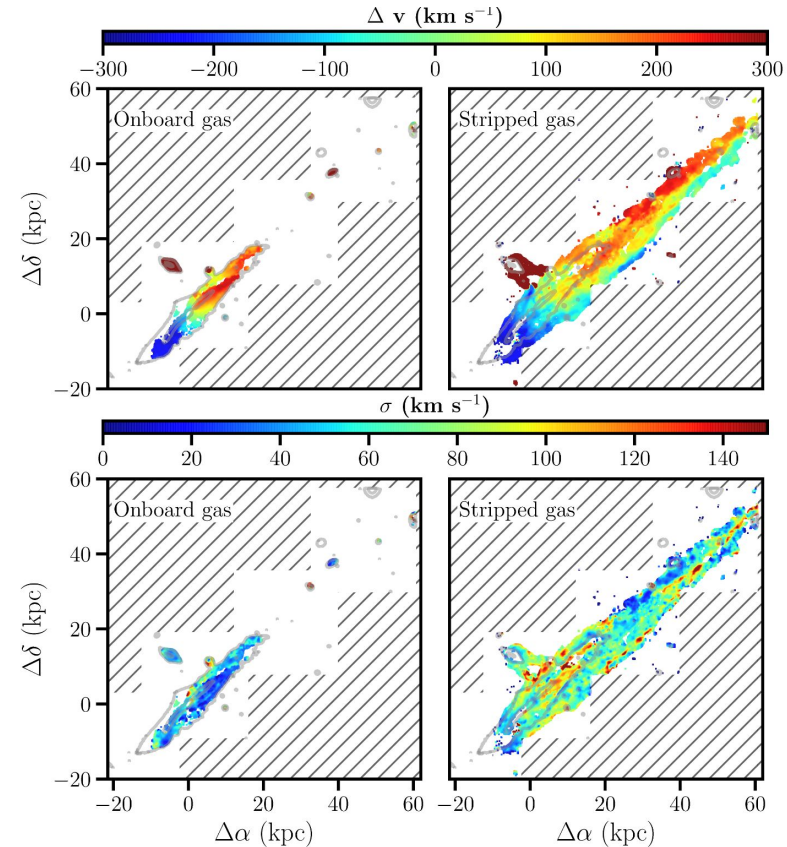
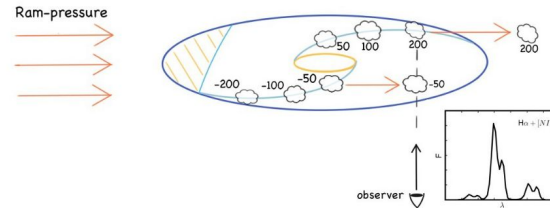
Consolandi, MF et al. 2017

# Kinematics of the stripping process



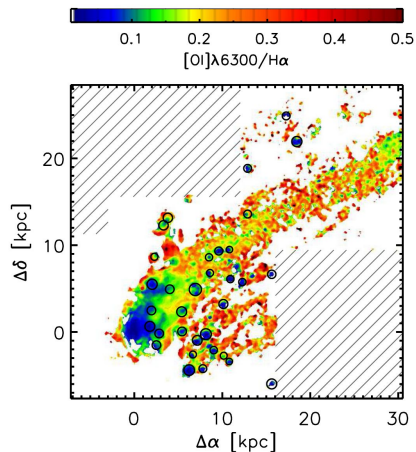
Ordered motion in the tail for low disk-wind angles. Onset of turbulence with increasing distance from the galaxy

Nearly edge-on RPS is less efficient, but a tail develops at high wind velocities. The budget of stripped vs disk gas is derived by multiple kinematic components

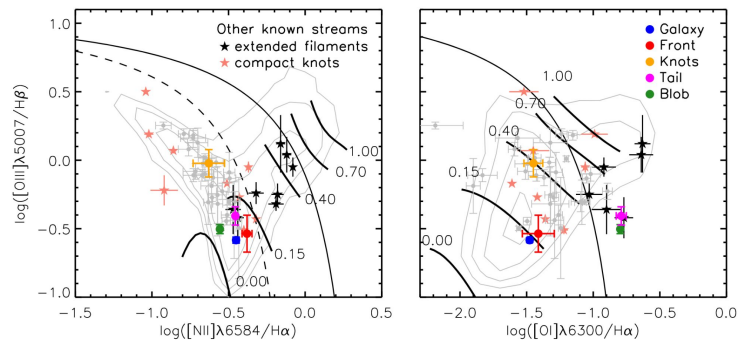


Consolandi, MF et al. 2017

# Gas Excitation during the stripping process

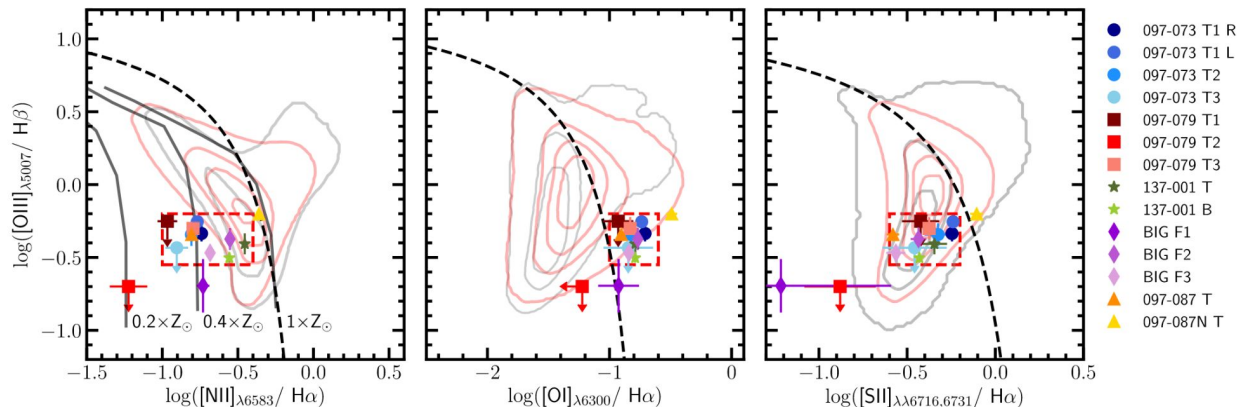


Fossati et al. 2016

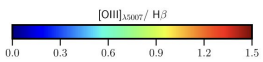


Unusual enhanced ratios of  $[\text{OI}]/\text{H}\alpha$  in the tail of ESO137-001, can be explained by moderately supersonic shocks.

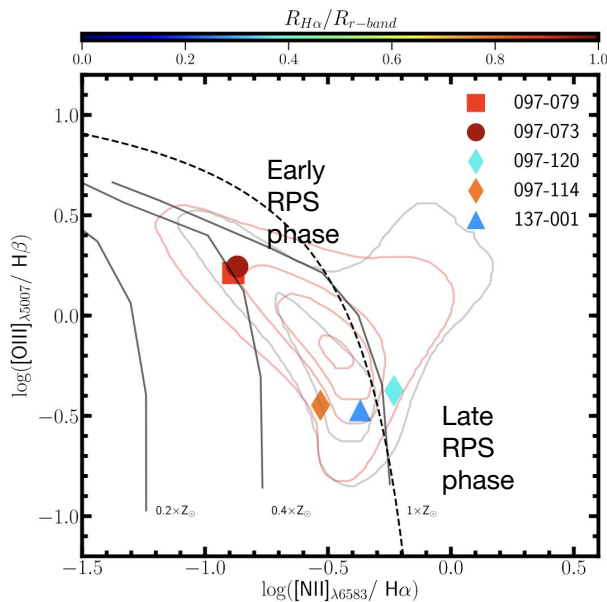
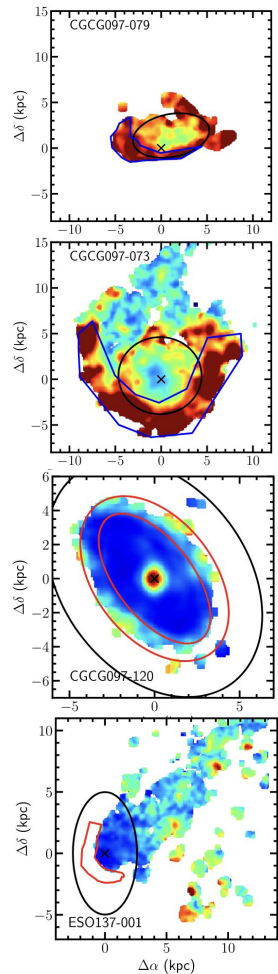
Enhanced  $[\text{OI}]/\text{H}\alpha$  ratios are unique signatures of RPS tails, they are not found in the nuclei of SDSS galaxies or outskirts of MANGA galaxies.



Pedrini, MF et al. 2021



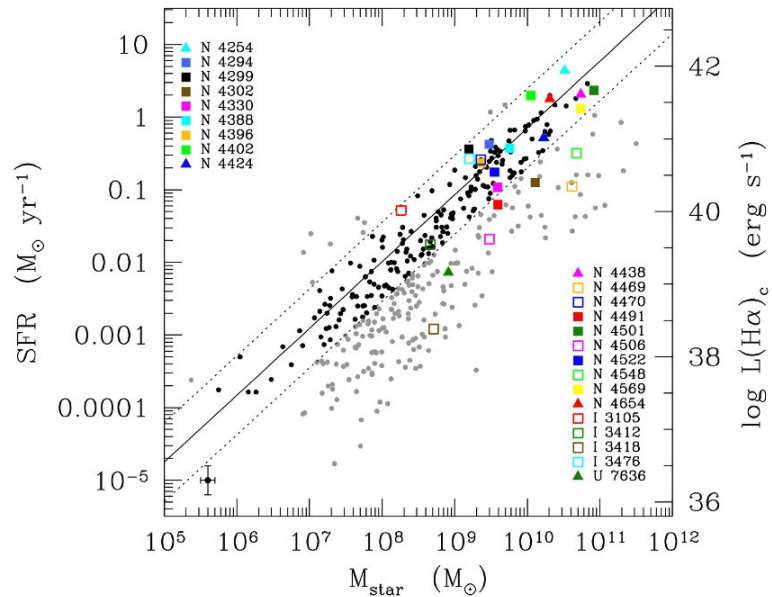
# Star Formation enhancement



Pedri, MF et al. 2021

More truncated disks (late RPS phase) show low ionization parameters and reduced SFR.

Only in early stripping phases SF is enhanced



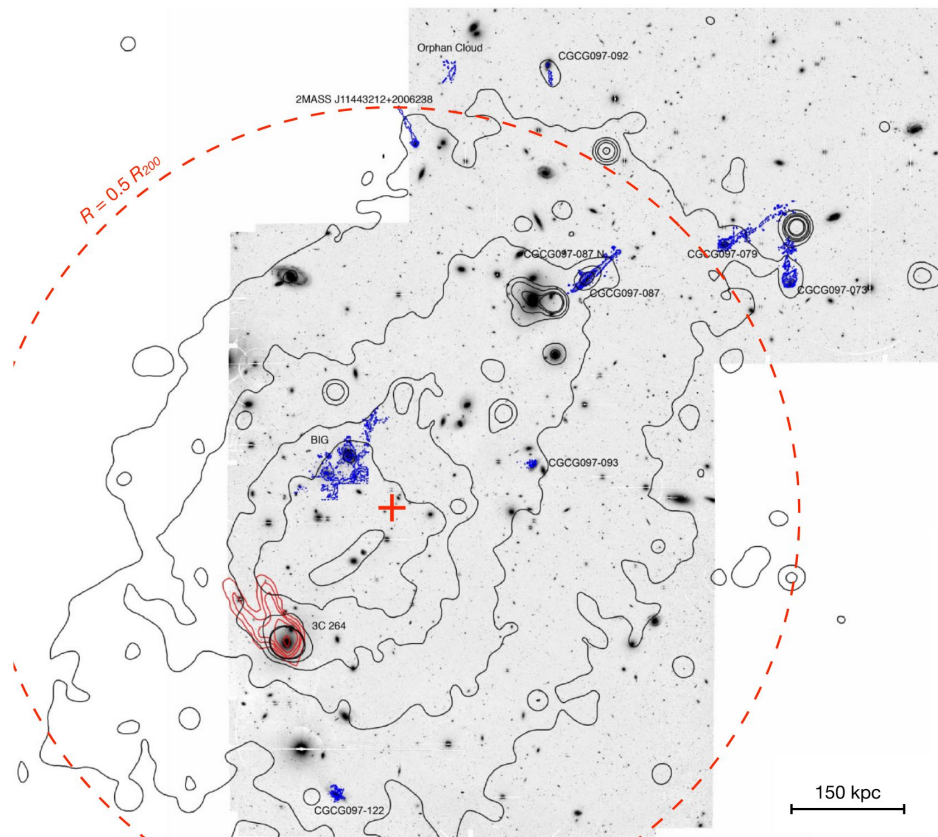
In a larger sample of galaxies in various stages of RPS, the SF enhancement is mild.

Boselli, MF et al. 2023



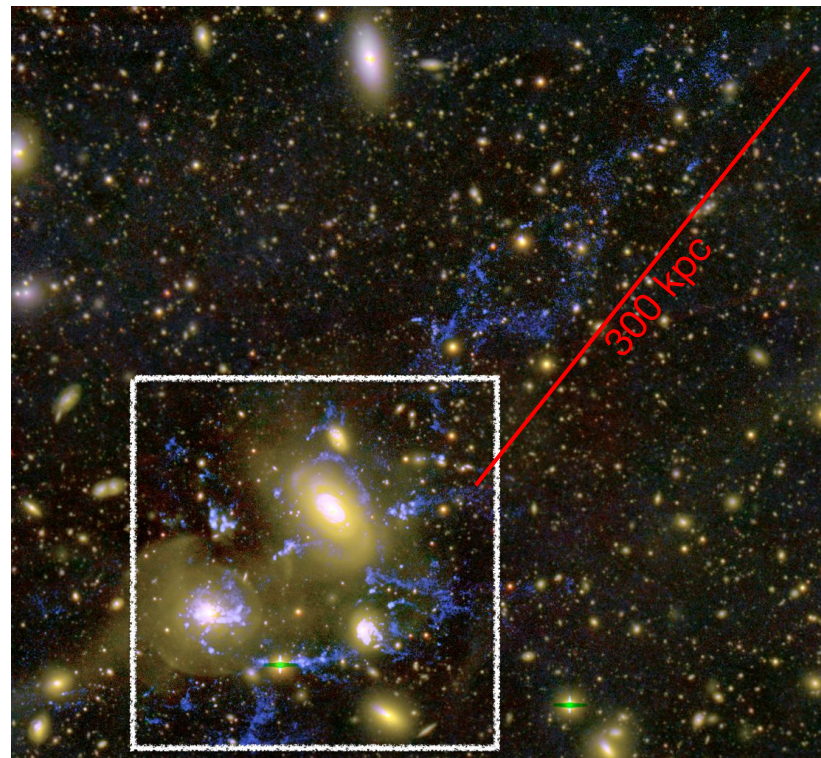
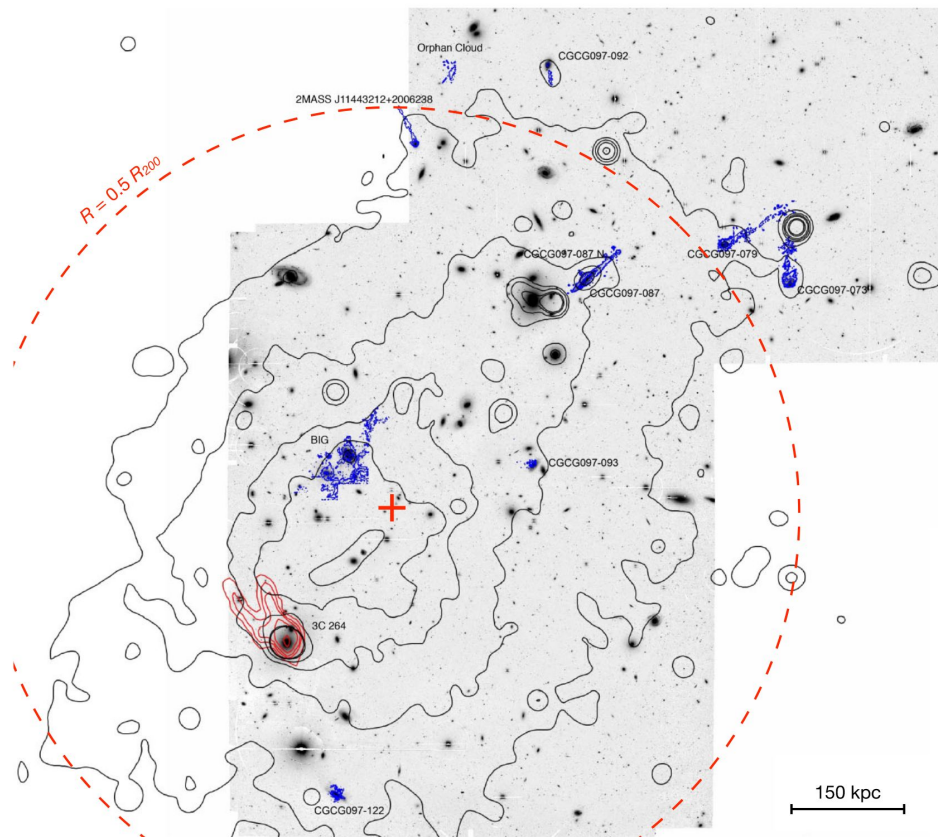
# MUSE goes BIG

BIG (Blue Infalling Group, Sakai et al. 2002, Cortese et al. 2006) is a group of galaxies falling into the A1367 cluster



# MUSE goes BIG

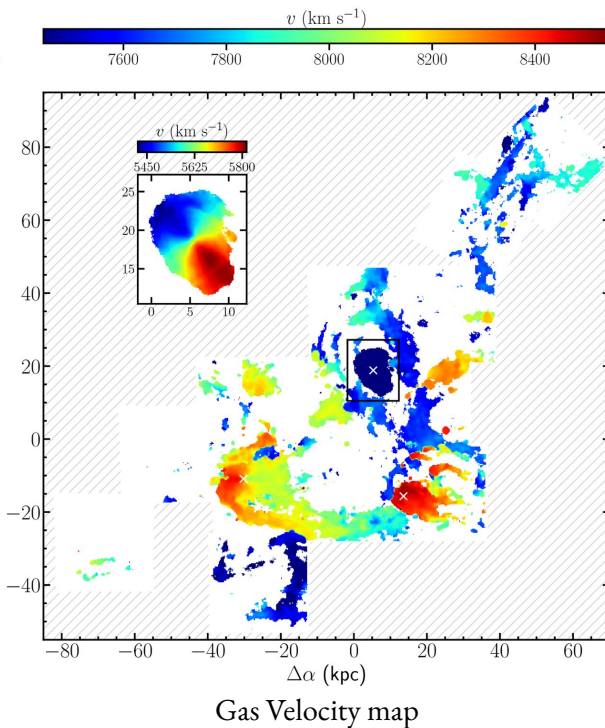
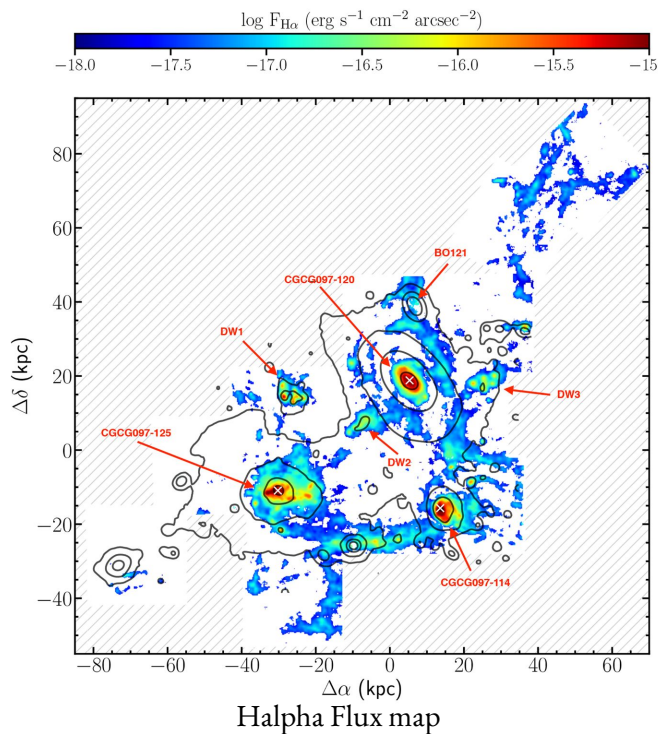
BIG (Blue Infalling Group, Sakai et al. 2002, Cortese et al. 2006) is a group of galaxies falling into the A1367 cluster



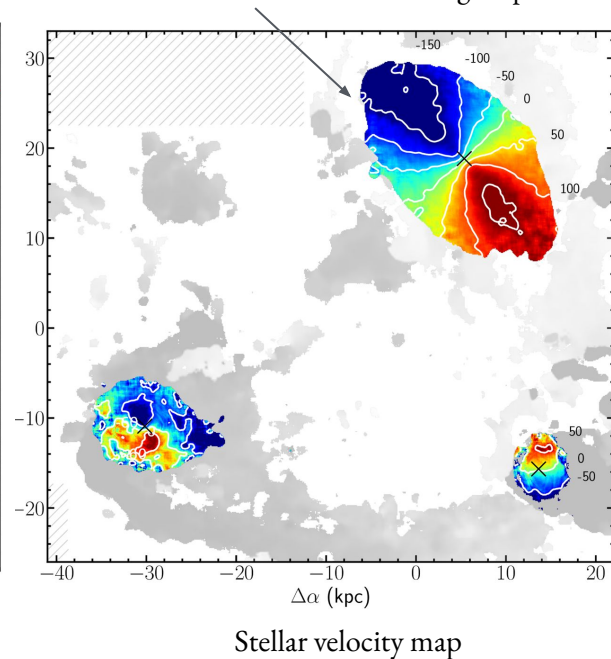


# MUSE goes BIG

MUSE revealed pre-processing in action in this group, including a post-merger remnant, stripped galaxies, newly formed tidal dwarfs, and turbulence along the filaments.

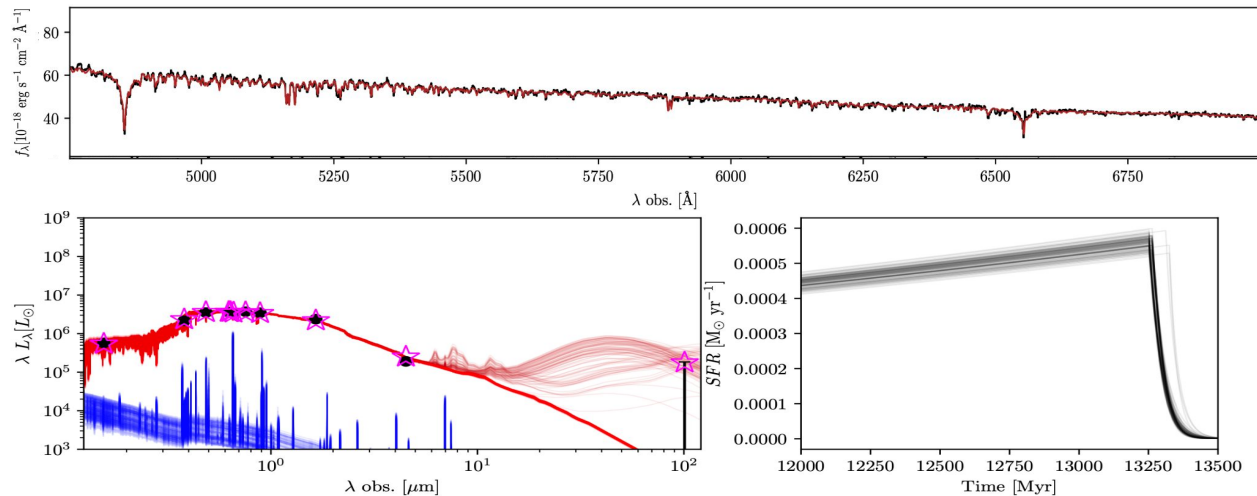
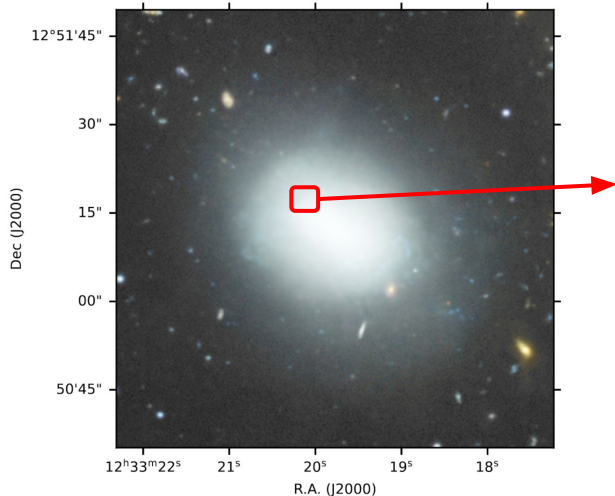


Unperturbed stellar disk, truncated gas disk, old RPS event not associated to the group





# Stellar population modelling

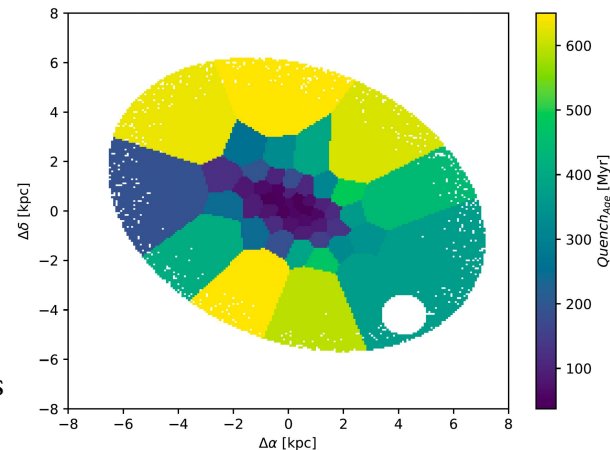


VCC1499 is a dwarf, blue, quiescent galaxy in the Virgo cluster (Fossati et al. in prep.)

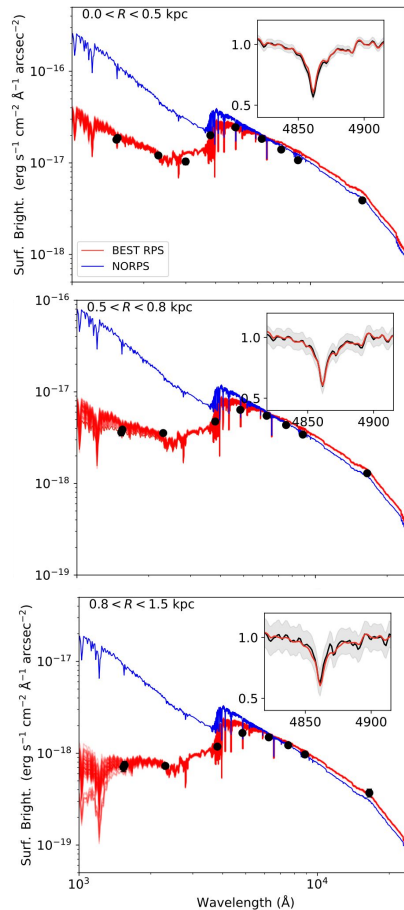
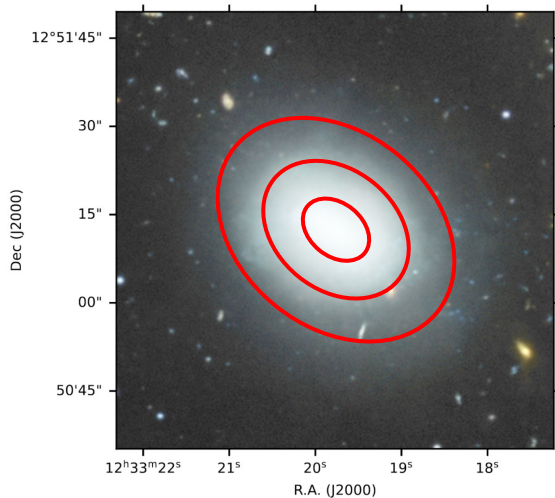
MUSE spectroscopy is key to constrain the quenching time.

Spatially resolved analysis shows outside-in quenching event.

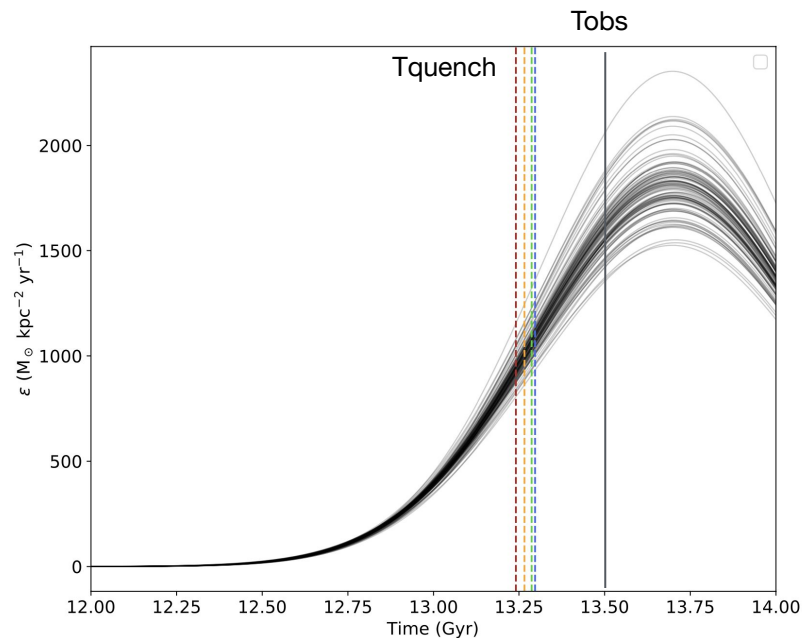
BlueMUSE will provide access to several additional Balmer lines + metallicity indicators



# Stellar population modelling



Combining photometry, MUSE spectroscopy and spatially resolved RPS models it is possible to constrain the RPS profile and the quenching history.  
Rapid quenching  $\sim 250$  Myr ago.



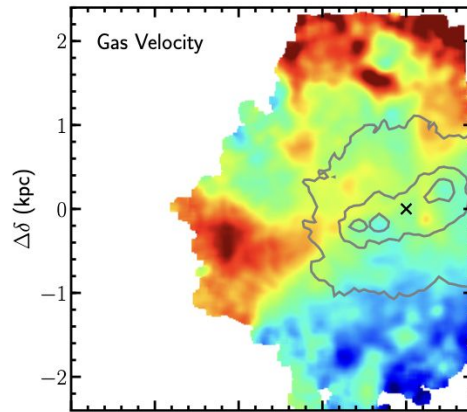
VCC1499 is a dwarf, blue, quiescent galaxy in the Virgo cluster (Fossati et al. in prep.)

# The legacy value of MUSE observations

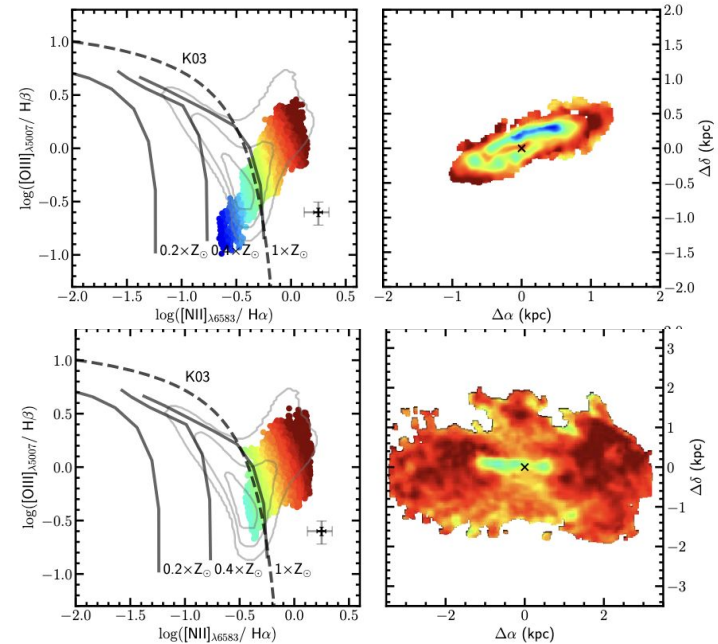
VESTIGE is an H $\alpha$  narrow-band blind survey of the Virgo cluster. Archival MUSE data has proven crucial in several VESTIGE publications. (Thanks for providing high-quality fully reduced data).



Multiple environmental processes at play: RPS in the merger remnant NGC 4424 (Boselli, MF et al. 2018)



Shock excited gas in the nuclear regions of seven S0 galaxies in the Virgo Cluster. RPS as an efficient formation channel for lenticulars in galaxy clusters. (Boselli, MF et al. 2022)



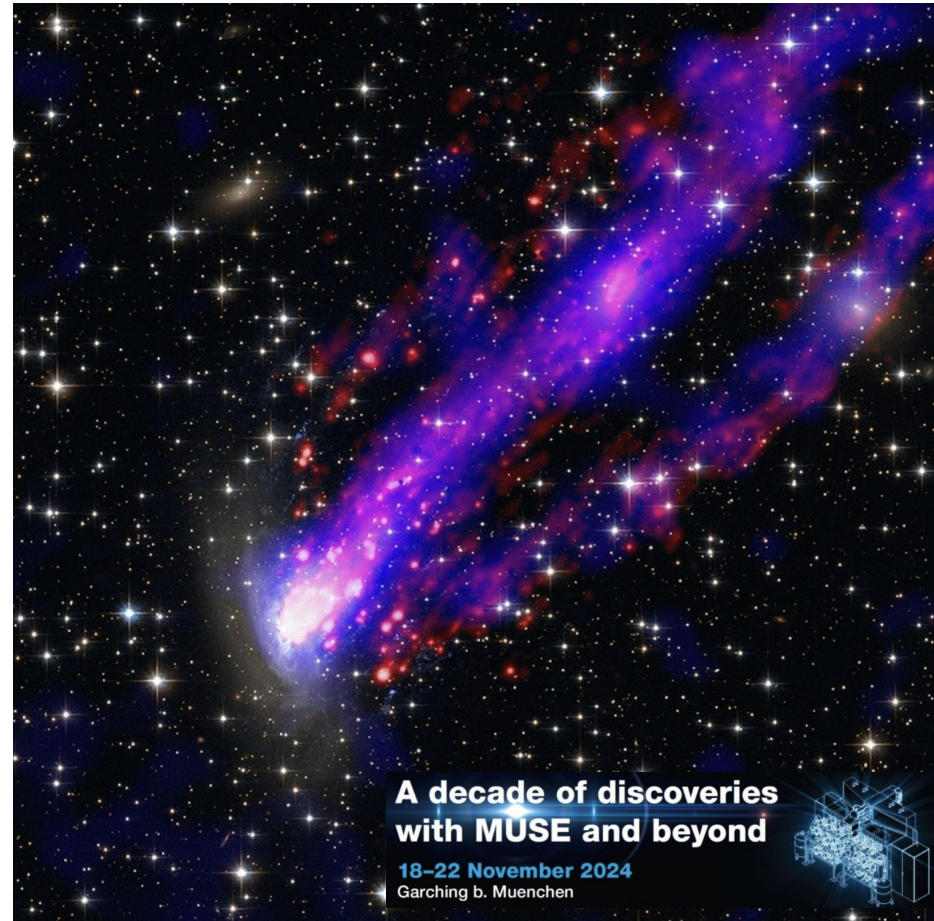


# 10 yrs of discoveries, and many more to come

MUSE brought the field of detailed studies of galaxy transformations in clusters to a new golden age.

With the revolutionary power of 2D spectroscopy in samples of cluster galaxies (see also B.Poggianti's talk) we uncovered the physics of stripping processes.

- Ordered motions dominate for few tens of Myr before turbulence takes over,
- Tail ionization is powered by collisions, thermal mixing with ICM, and to a lesser extent *in situ* star formation,
- Star formation can be temporarily enhanced, but RPS leads to quenching in  $<1$  Gyr (exact timescale depends on galaxy and cluster halo mass, infall velocity, disk-wind angle)
- RPS does not act alone, signatures of mergers and gravitational interactions in a fraction of the objects in our sample.



**A decade of discoveries  
with MUSE and beyond**

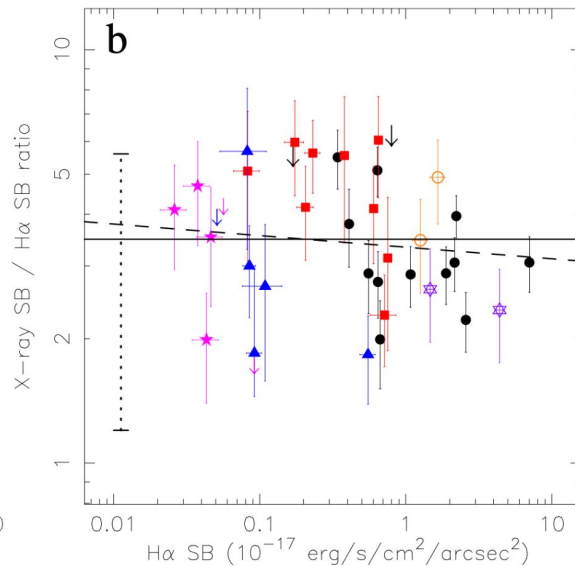
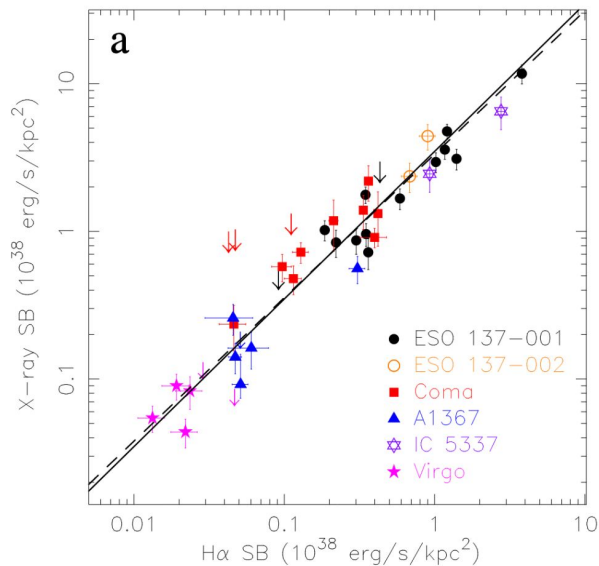
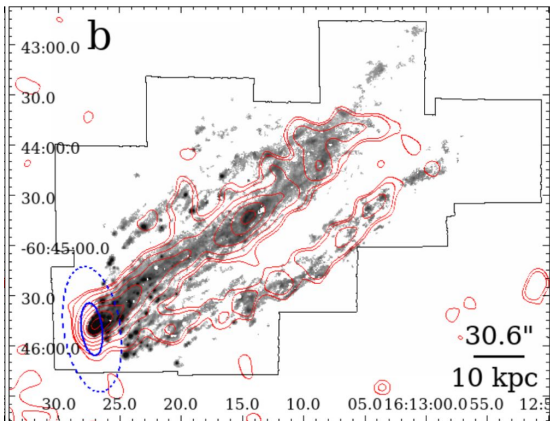
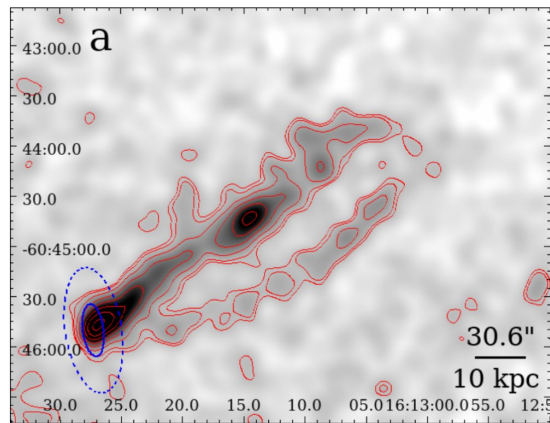
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## SUPPLEMENTARY SLIDES

# A nearly universal X-ray - H $\alpha$ correlation in RPS tails



Tails are multiphase. Mixing works on scales smaller than  $\sim 10$  kpc.  
Striking correlation across a factor of  $\sim 50$  in Mhalo.