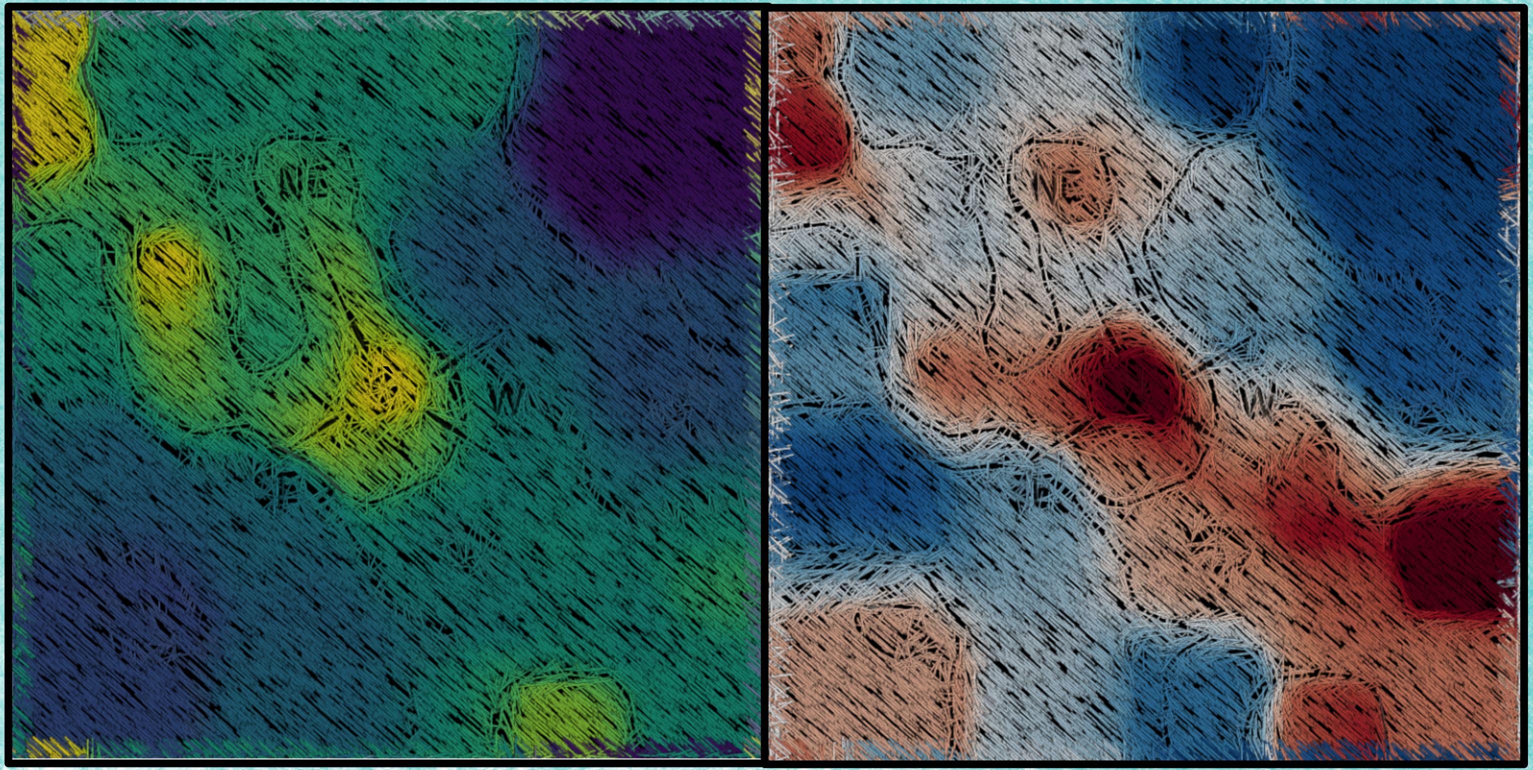
Star formation quenching
?in and/or around?
clusters of galaxies

Astronomical Institute
of the Czech Academy of Sciences

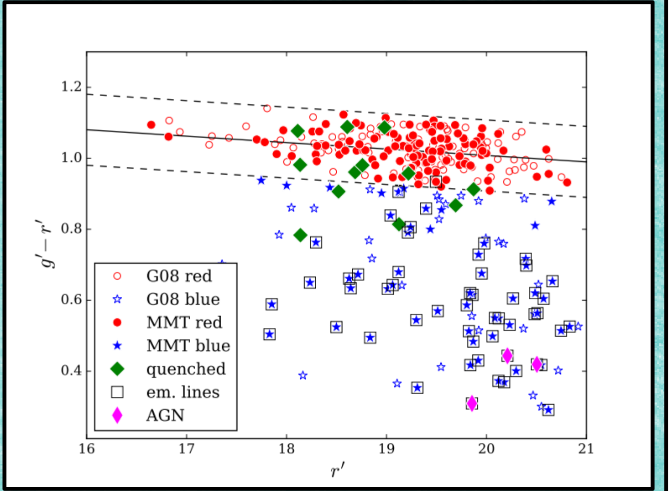
Boris Deshev



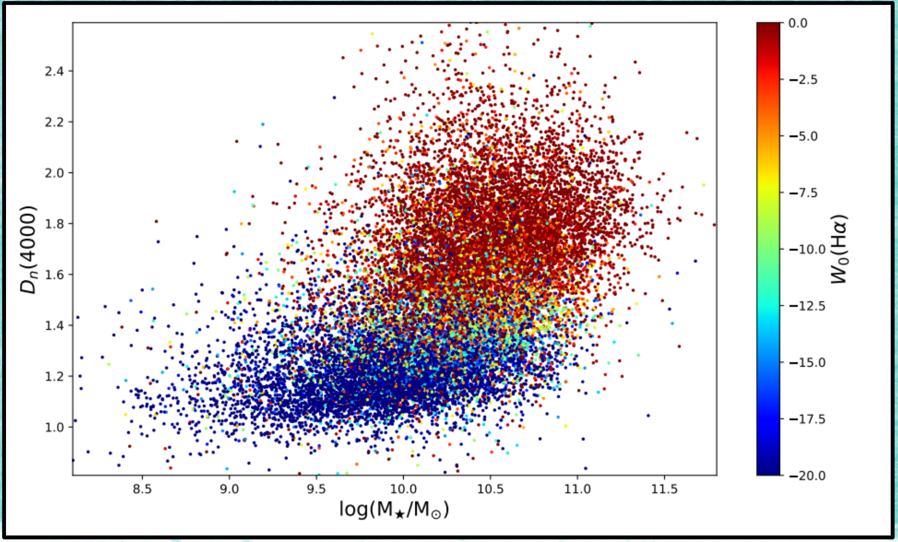
2.Oct.2023
Masaryk University
Brno

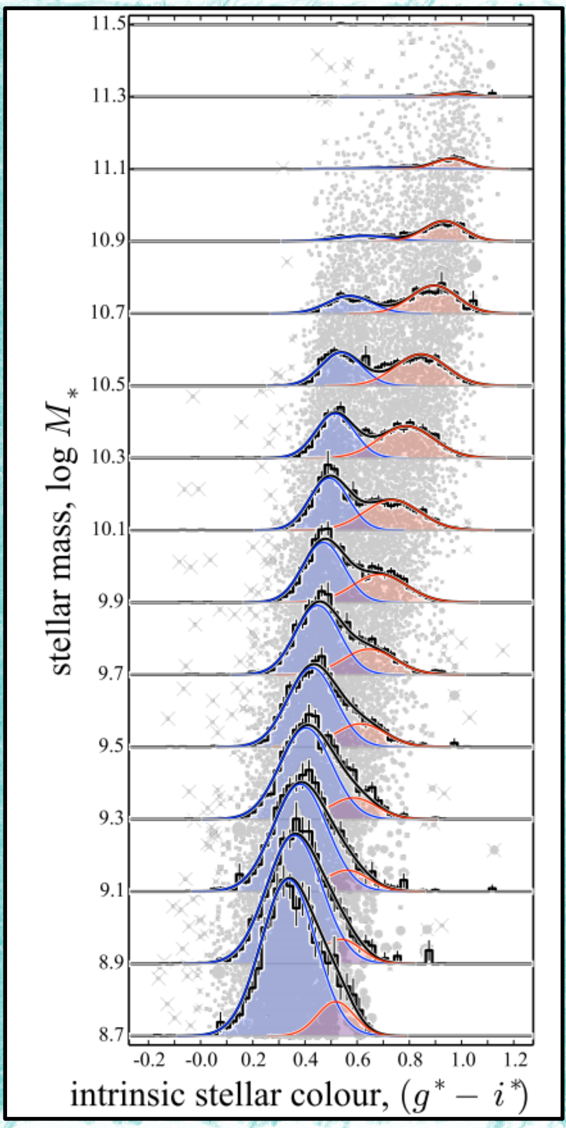
The red ones and the blue ones

Color – Magnitude diagram of Abell 520 members
Deshev et al. 2017



Stellar population age – stellar mass diagram
B. Deshev, Ph.D thesis
ACReS survey





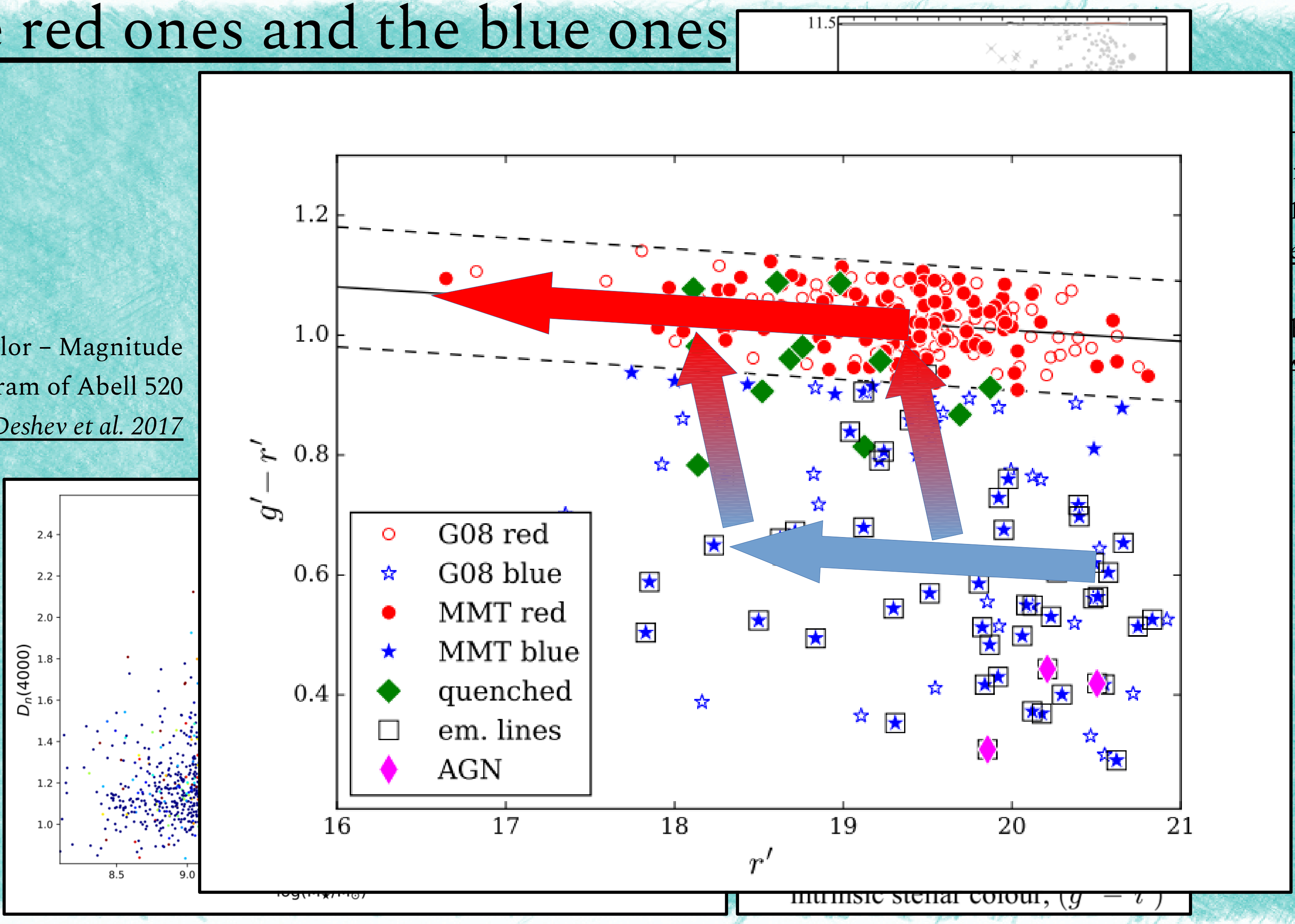
Color – stellar mass Diagram of galaxies at z<0.12
Taylor et al. 2014
Galaxy And Mass Assembly survey (GAMA)

The red ones and the blue ones

- stellar mass
m of galaxies
12
et al. 2014
And Mass
bly survey
A)

Color – Magnitude diagram of Abell 520 *Deshev et al. 2017*

Stellar population age – stellar mass diagram *B. Deshev, Ph.D thesis* ACReS survey



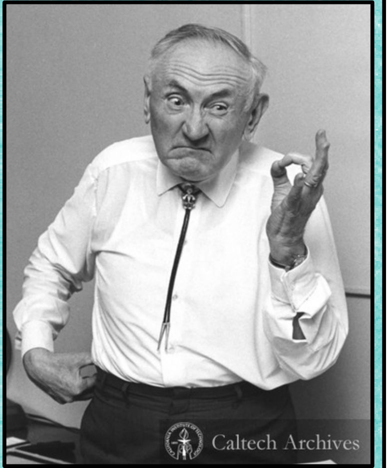
Environmental effects

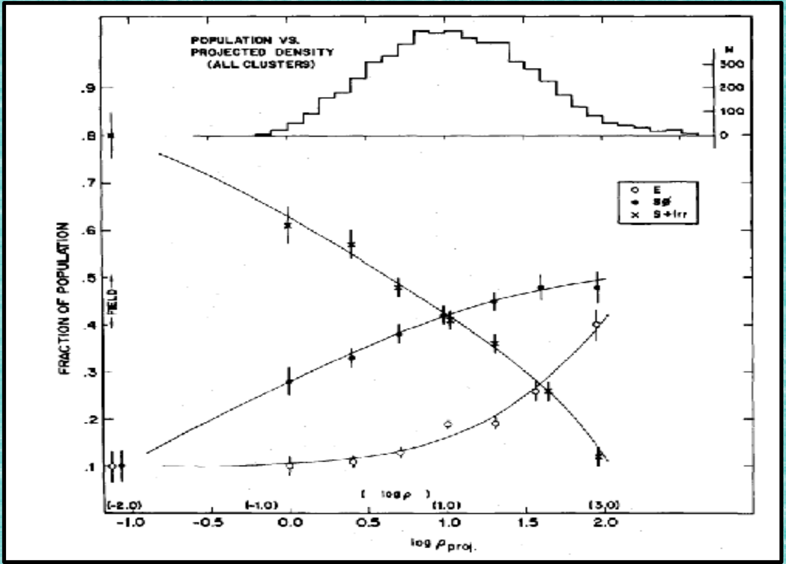
Dressler, 1980

Zwicky, 1938

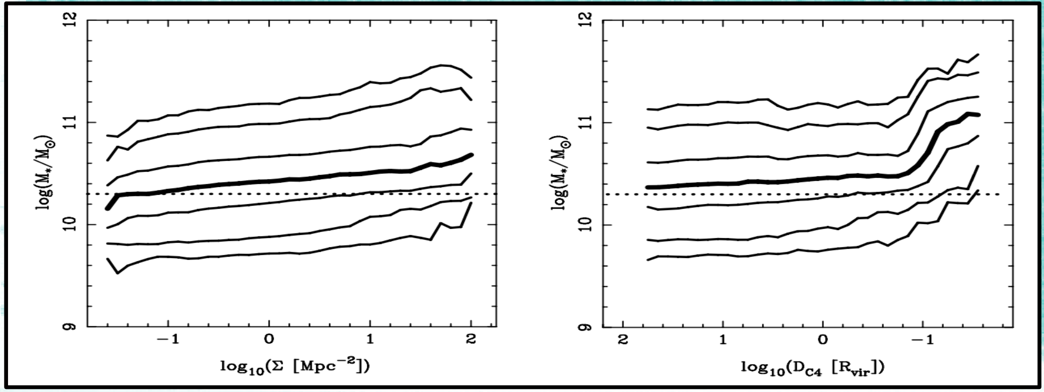
c) The process of clustering results in a segregation of nebular types inasmuch as the most massive nebulae exhibit the greatest tendency toward clustering.

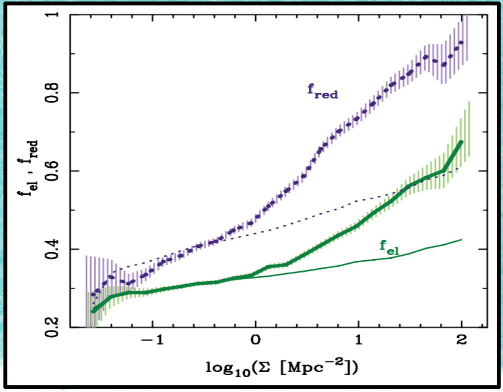
The fact that nebulae near the center of concentrated clusters are predominantly of the elliptic type, whereas spirals are relatively more numerous on the outskirts of clusters, is perhaps a first indication of the correctness of conclusion c. It will be necessary, however, to determine the masses of many nebulae before the assertion that the segregation of nebular types depends on their relative masses can be checked.[5]

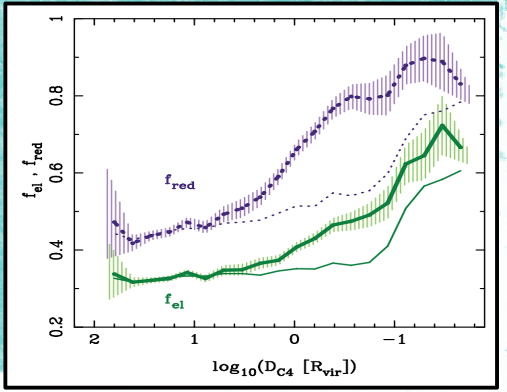




Bamford et al. 2009





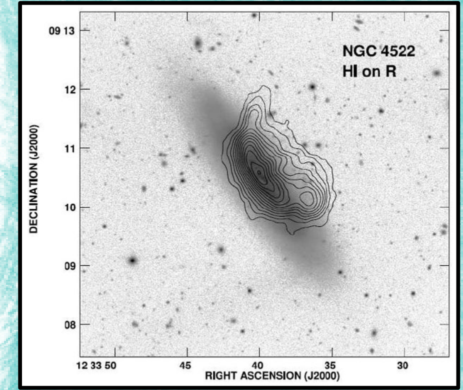


Environmental effects

Ram Pressure stripping

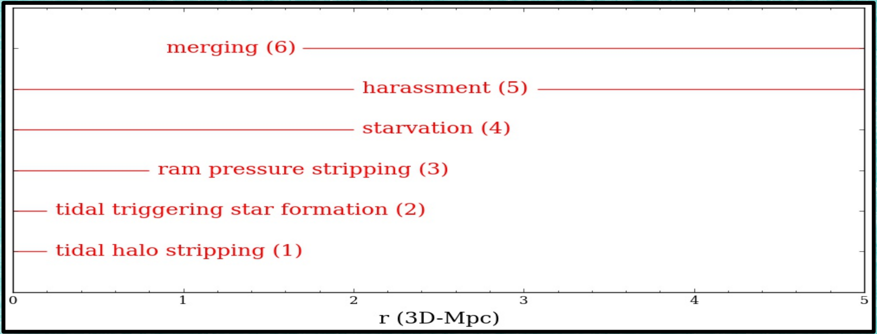
Gunn & Gott, 1972

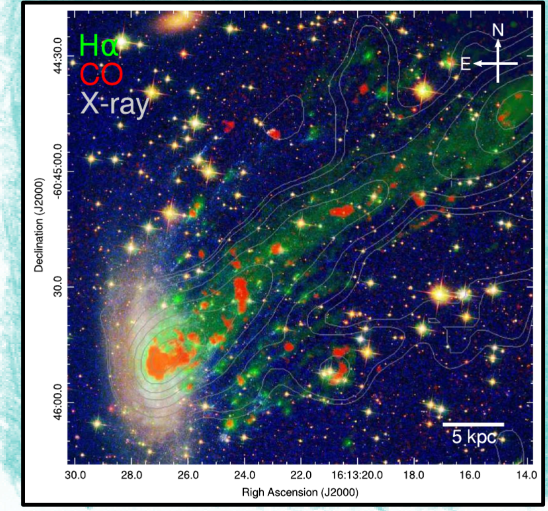
$$P_r = \rho_e v^2$$



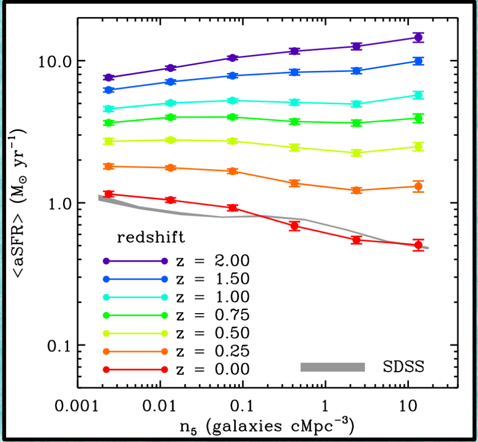
Kenny, van Gorkom and Vollmer, 2004

Treu et al. 2003

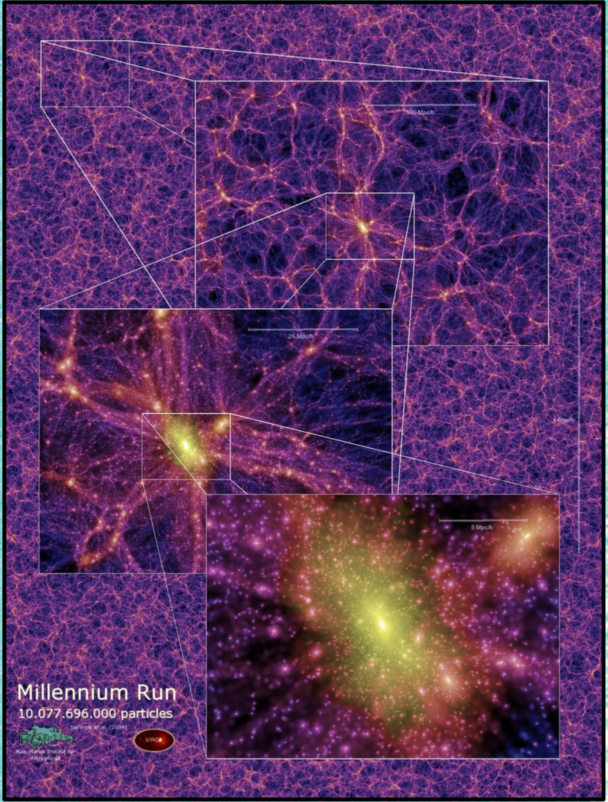




Jáchym et al. 2019



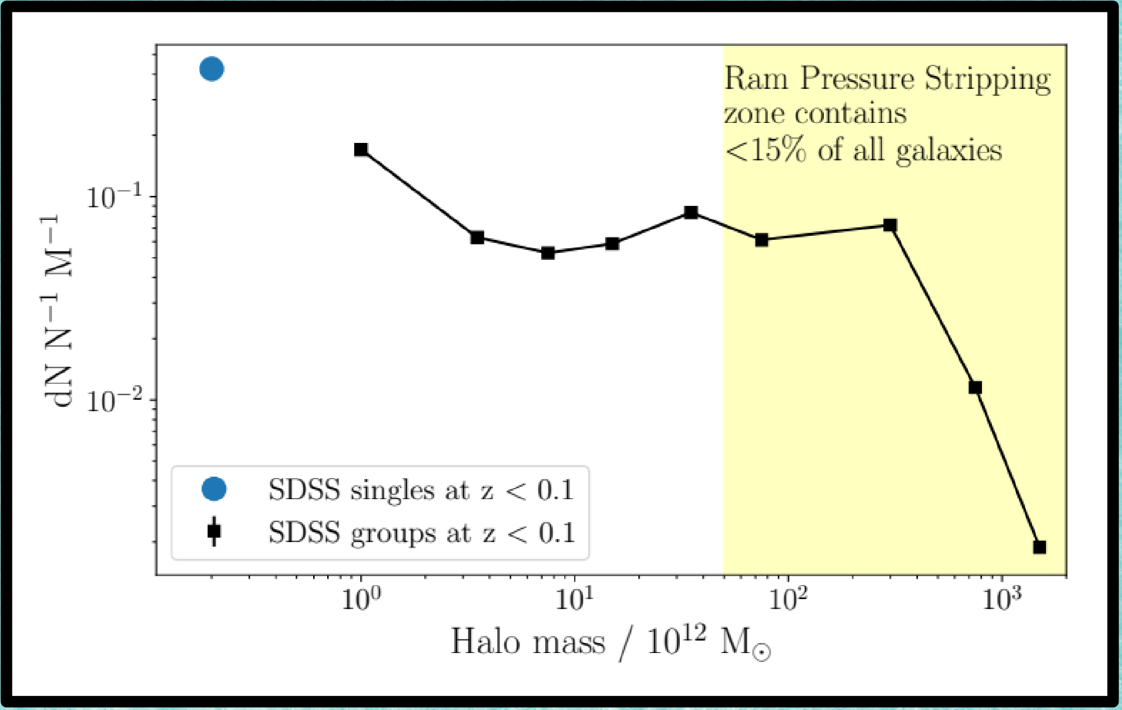
Hwang et al. 2019

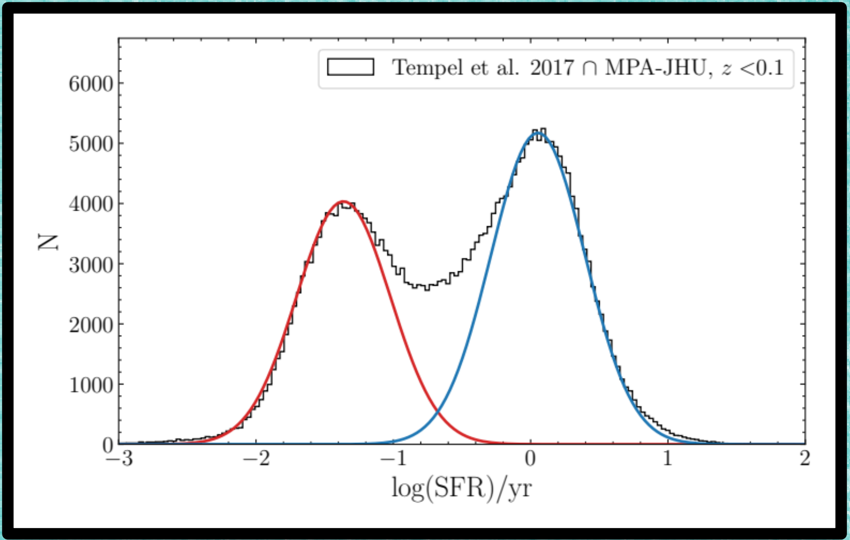


Springel et al. 2005

Ram Pressure stripping

Based on ~3x10^5 galaxies at z < 0.1
from SDSS, dr12
Tempel et al. 2017
catalog of groups and cluster in SDSS DR12

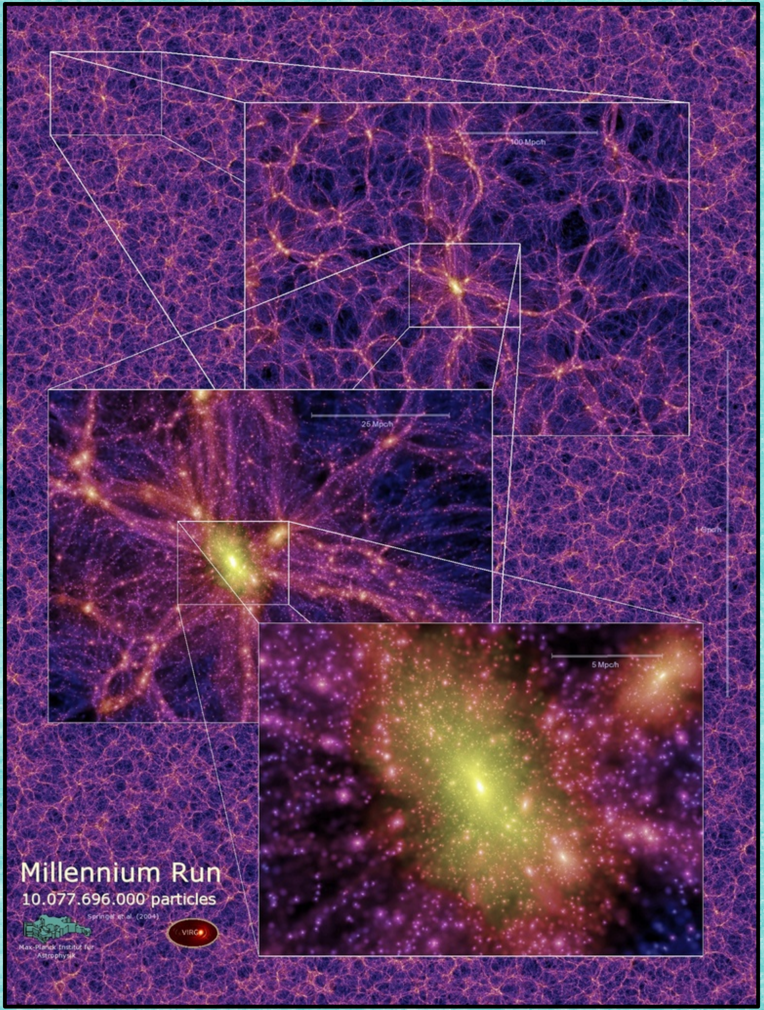




40% of galaxies at z < 0.1
show little or no
ongoing star formation
Deshev et al. in prep.

Evolution of environment

Springel et al. 2005



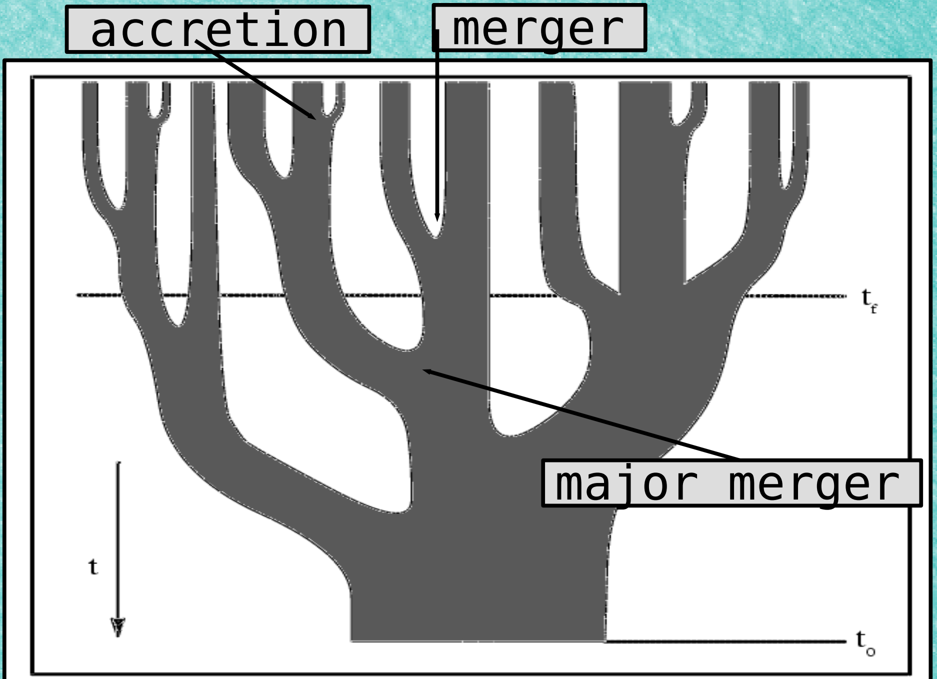


Figure 6. A schematic representation of a "merger tree" depicting the growth of a halo as the result of a series of mergers. Time increases from top to bottom in this figure and the widths of the branches of the tree represent the masses of the individual parent halos. Slicing through the tree horizontally gives the distribution of masses in the parent halos at a given time. The present time t_0 and the formation time t_f are marked by horizontal lines, where the formation time is defined as the time at which a parent halo containing in excess of half of the mass of the final halo was first created.

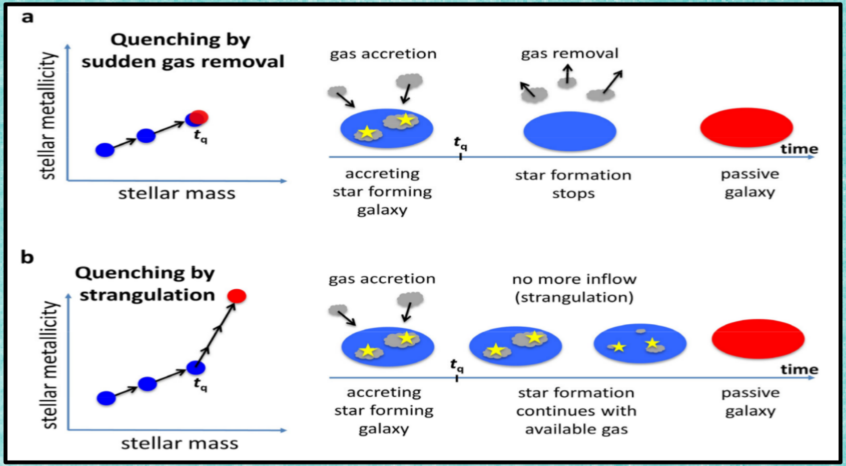
Lacey & Cole, 1993

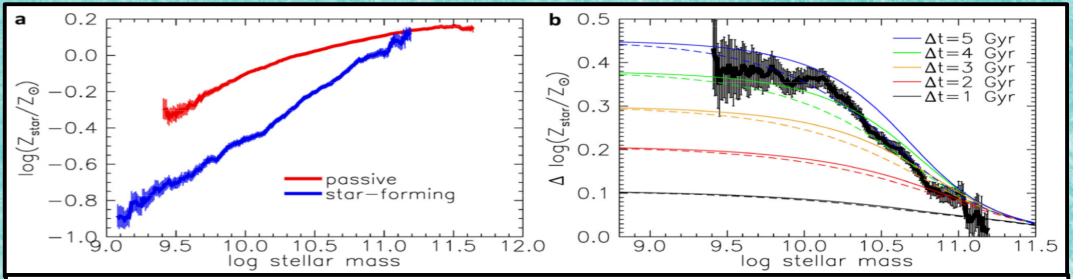
Strangulation or Ram pressure stripping

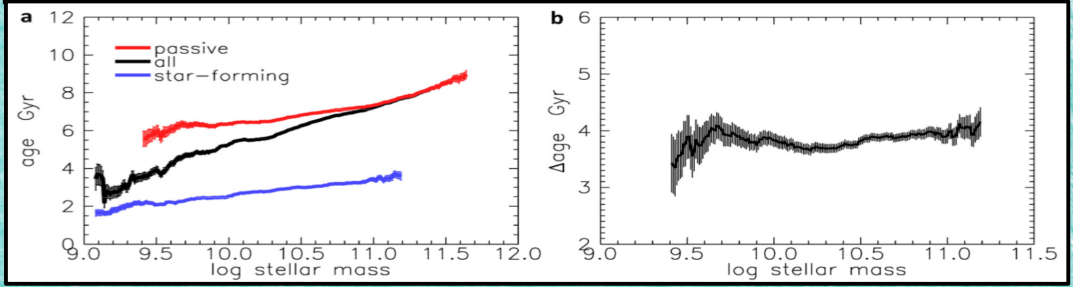
Strangulation or Starvation

Larson et al. 1980

Peng et al. 2015

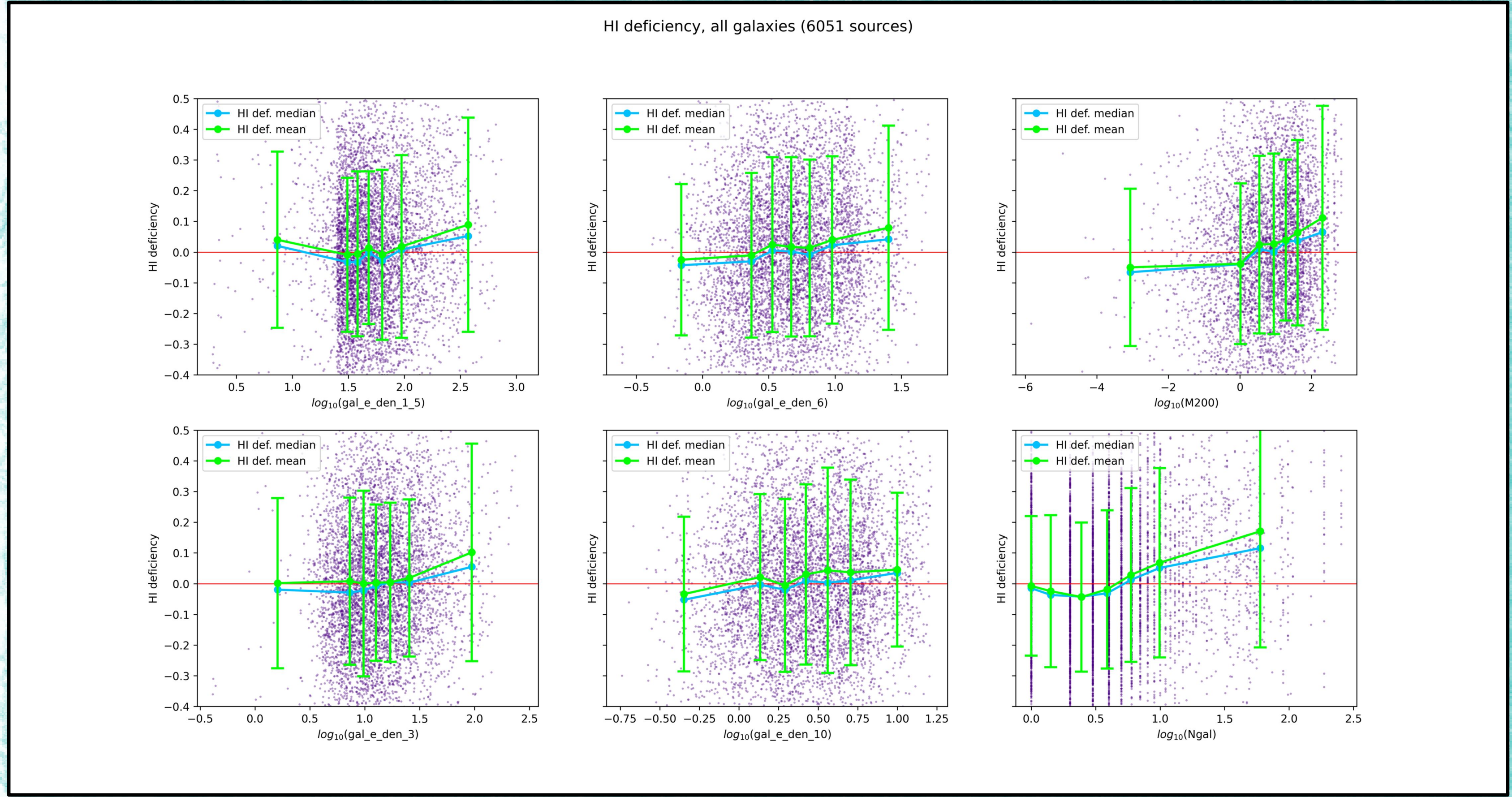






Environmental effects

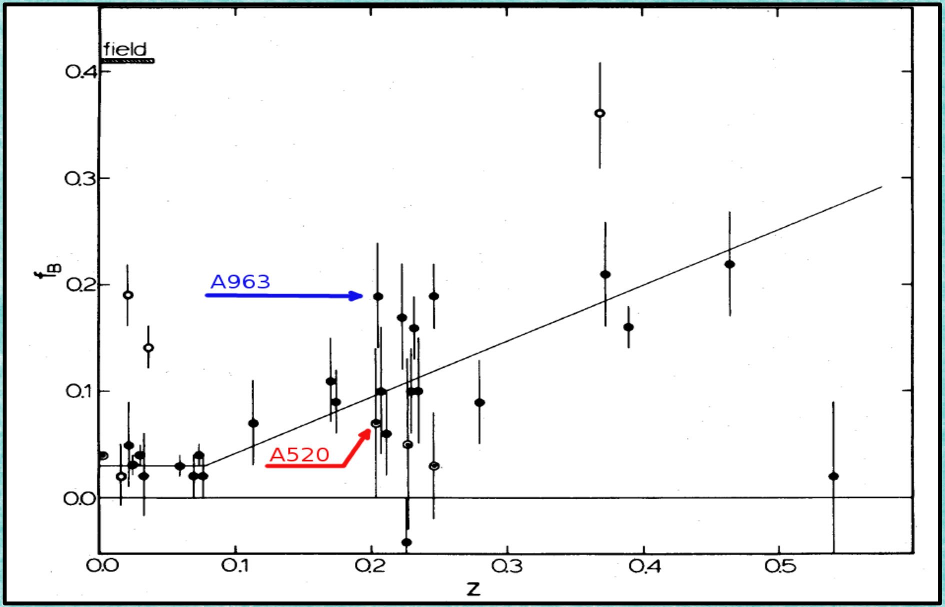
Work by Filip Janák, Univerzita Komenského v Bratislave, SK

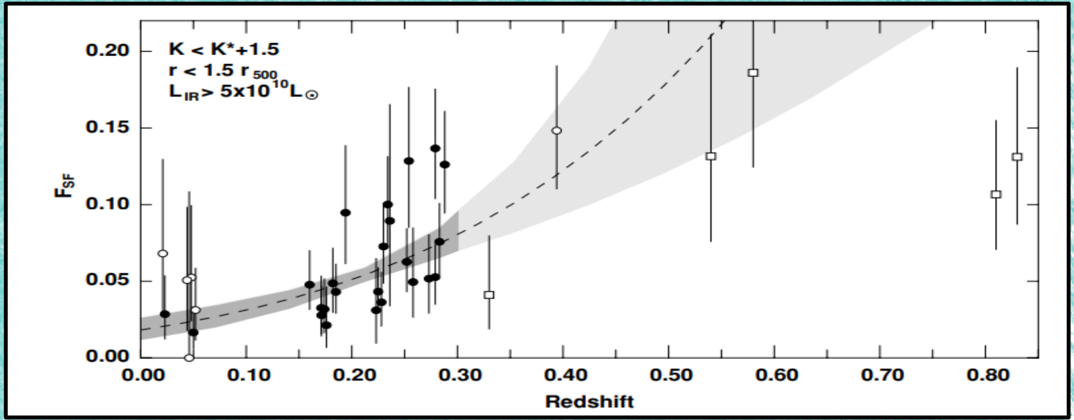


Using ML to predict HI mass of galaxies based on their optical properties

The Butcher-Oemler effect

Increasing with redshift fraction of star forming galaxies in clusters *Butcher & Oemler 1984*





Haines et al. 2009

Blue fraction (BO84)

A520 – 7%

A963 – 19%

SF fraction *(Deshev, Ph.D. thesis)*

A520 – 9%

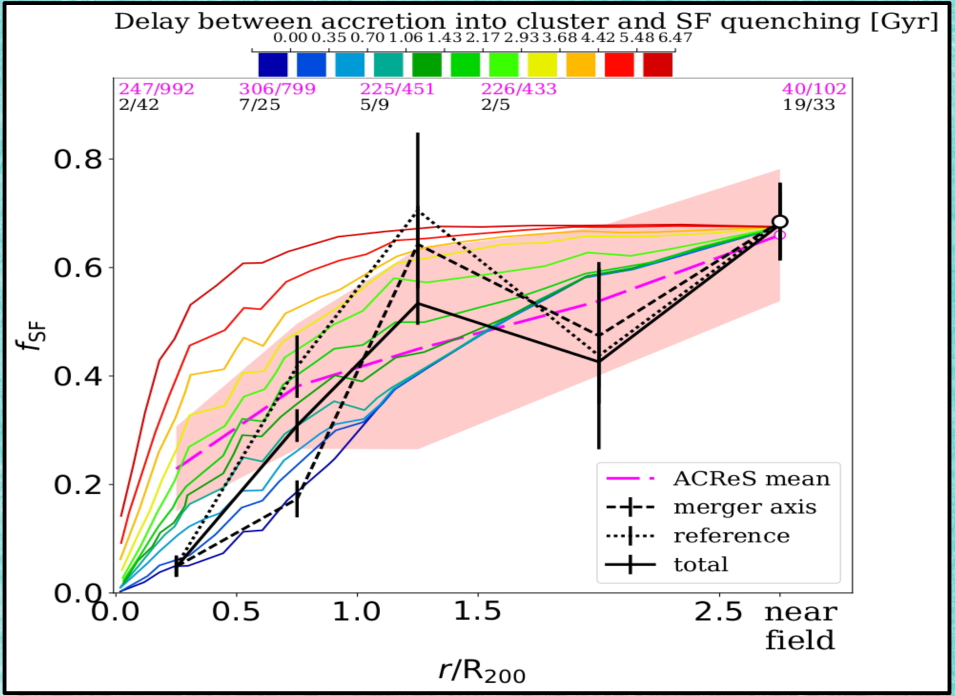
A963 – 27%

parameter	A963	A520
z	0.205$^{(a)}$	0.201$^{(a)}$
Richness class	3$^{(b)}$	3$^{(b)}$
R_{200}/Mpc	$2.68^{+0.37}_{-0.14}$ $^{(a)}$	$2.32^{+0.23}_{-0.22}$ $^{(a)}$
$M_{200}/10^{14}M_\odot$	$17.9^{+7.5}_{-2.4}$ $^{(a)}$	$11.6^{+3.7}_{-3.0}$ $^{(a)}$
σ_v/km s^{-1}	1199^{+112}_{-112} $^{(a)}$	1036^{+101}_{-97} $^{(a)}$
R^{WL}_{500}/Mpc	1.185$^{(c)}$	1.208$^{(c)}$
$M^{WL}_{vir}/10^{14}M_\odot$	$12.3^{+3.0}_{-3.0}$ $^{(c)}$	$15.3^{+3.0}_{-3.0}$ $^{(c)}$
$L_{X,bol,500}/10^{45}$erg s^{-1}	1.96±0.04$^{(d)}$	1.75±0.04$^{(d)}$
$T_{X,500}$/keV	6.2±0.2$^{(d)}$	7.8±0.4$^{(d)}$
Concentration	0.60$^{(e)}$	0.38$^{(e)}$
f_B	0.19±0.05$^{(e)}$	0.07±0.07$^{(e)}$
f_{SF}	0.27(0.41)±0.04$^{(f)}$	0.09(0.28)±0.04$^{(f)}$

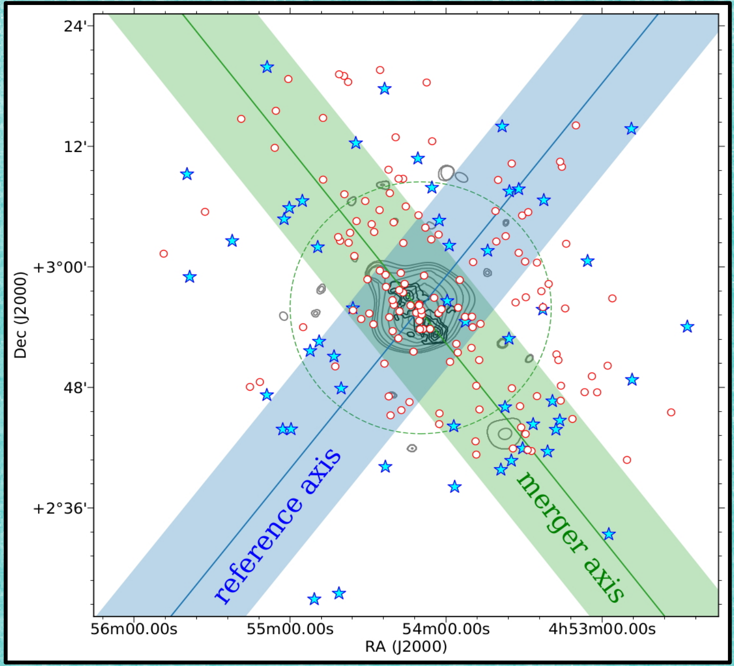
Abell 520

Evolutionary lines of different colour from *Haines et al. 2015*

Comparison sample of 10 non-merging clusters at 0.15<z<0.25

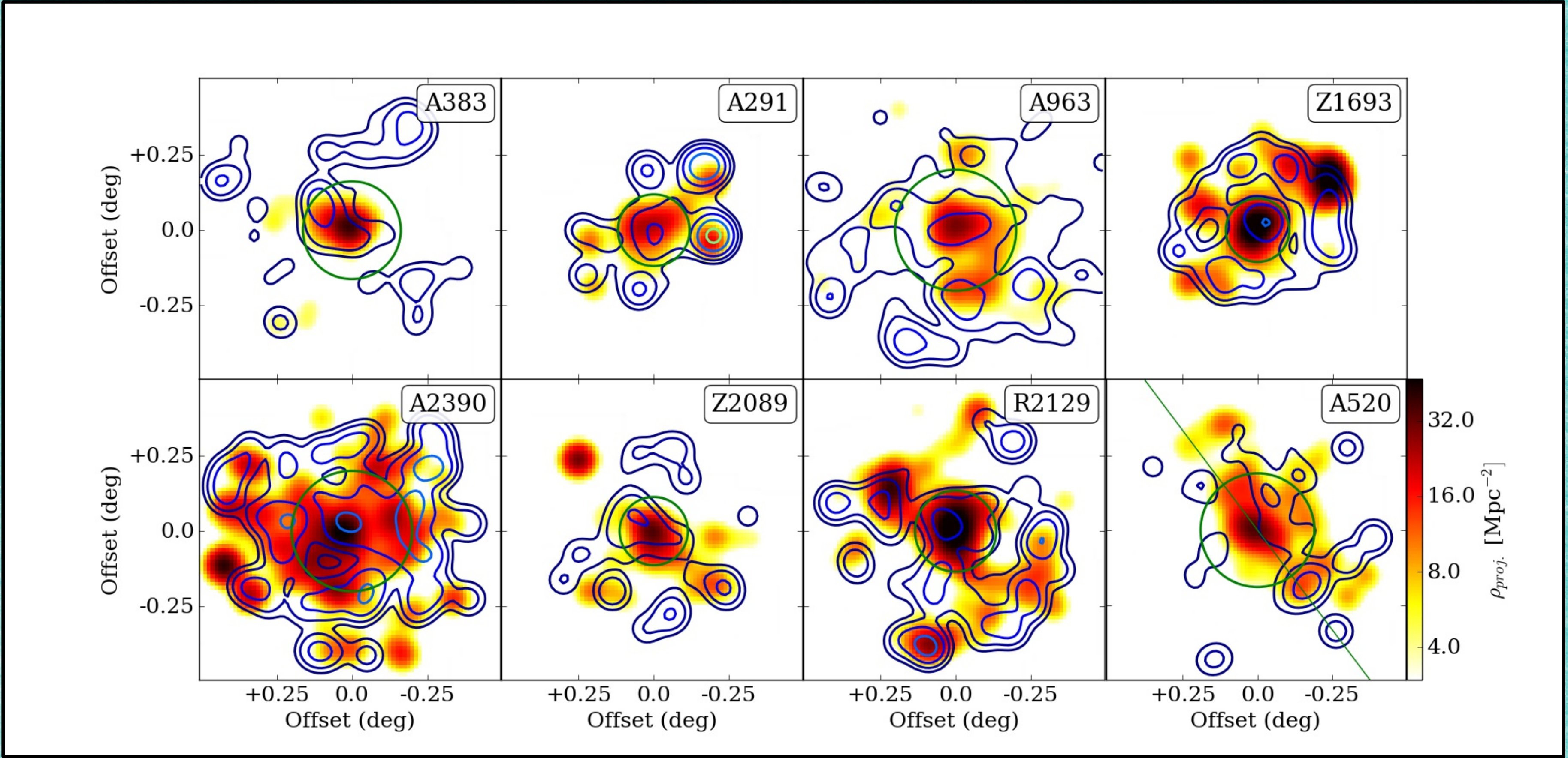


Deshev et al. 2017



Abell 520

Deshev et al. 2017



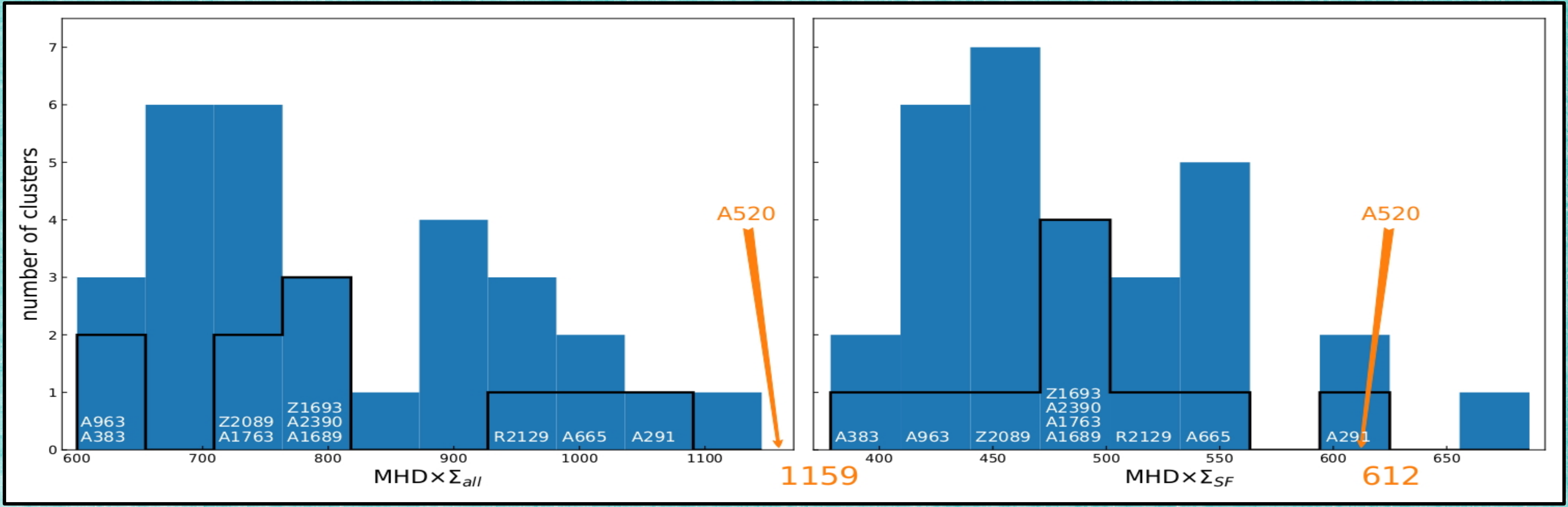
Abell 520

Modified Hausdorff Distance

Huttenlocher et al. 1993;

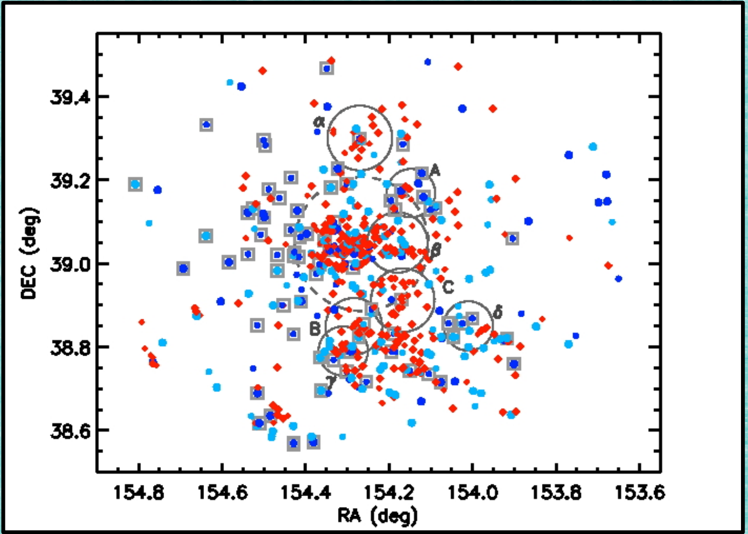
Dubuisson & Jain, 1994

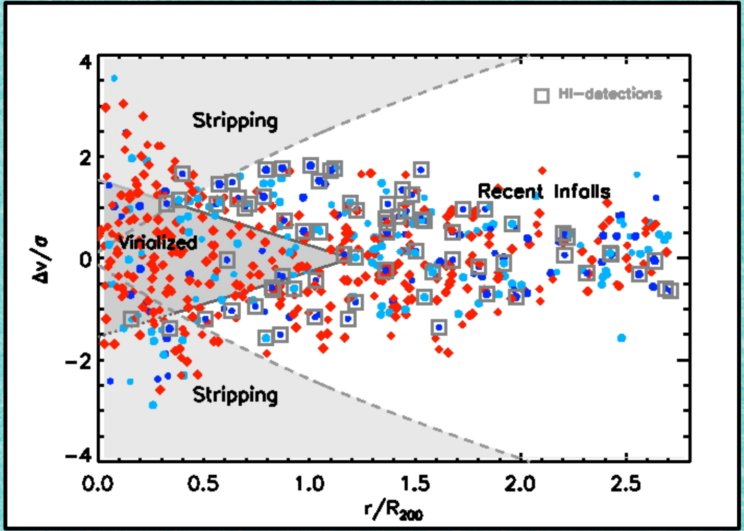
$$d(X,Y) = \frac{1}{N_X} \sum_{x_i \in X} min||x_i - y_i||$$



Deshev, Ph.D. thesis

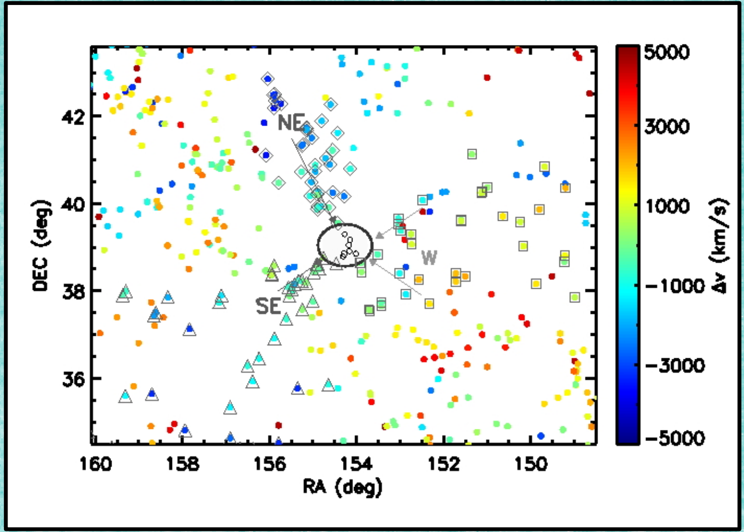
Abell 963

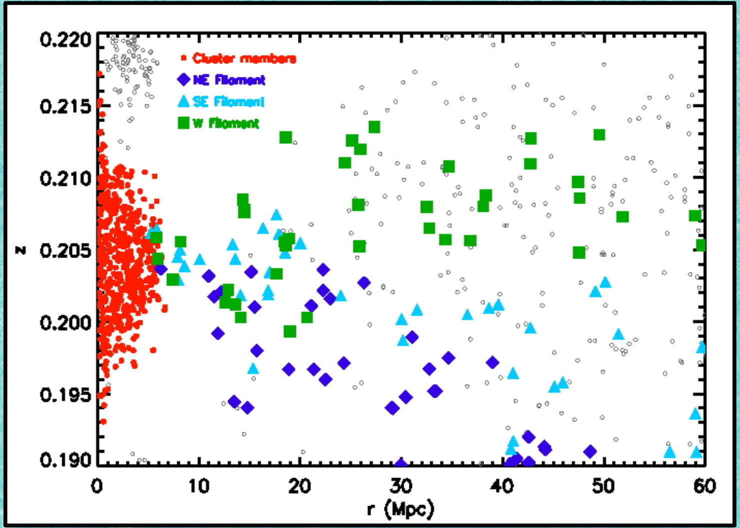




Projected phase space

Jaffe et al. 2016





BudHIes survey

Verheijen et al. 2007

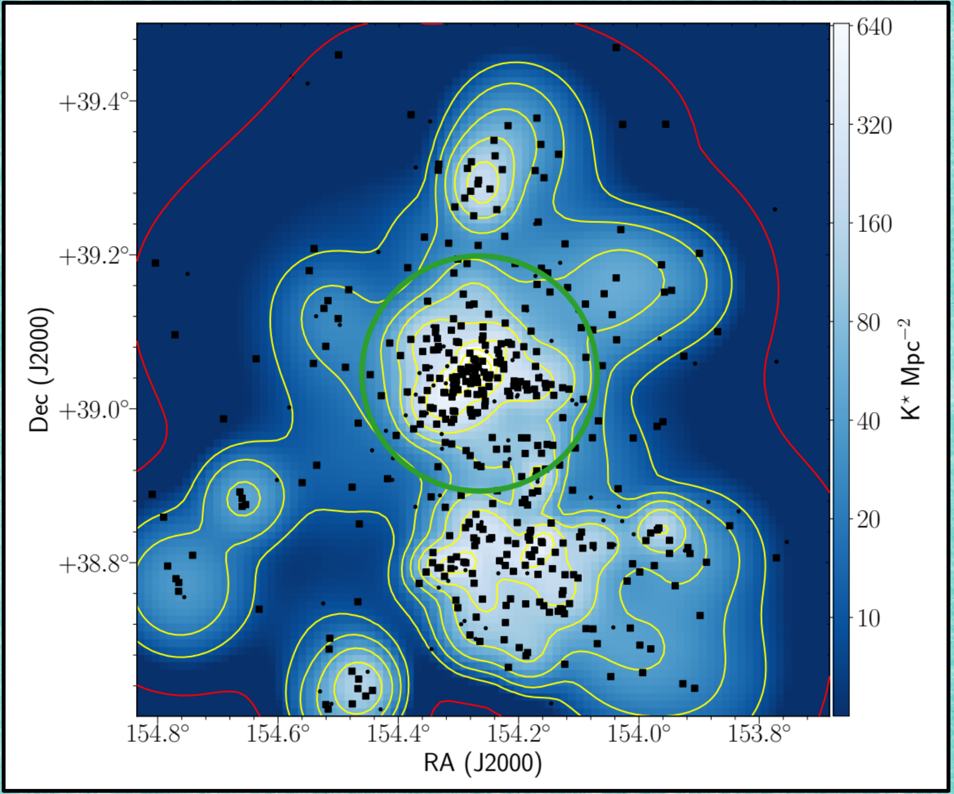
Deshev et al. 2009

Gogate et al. 2020

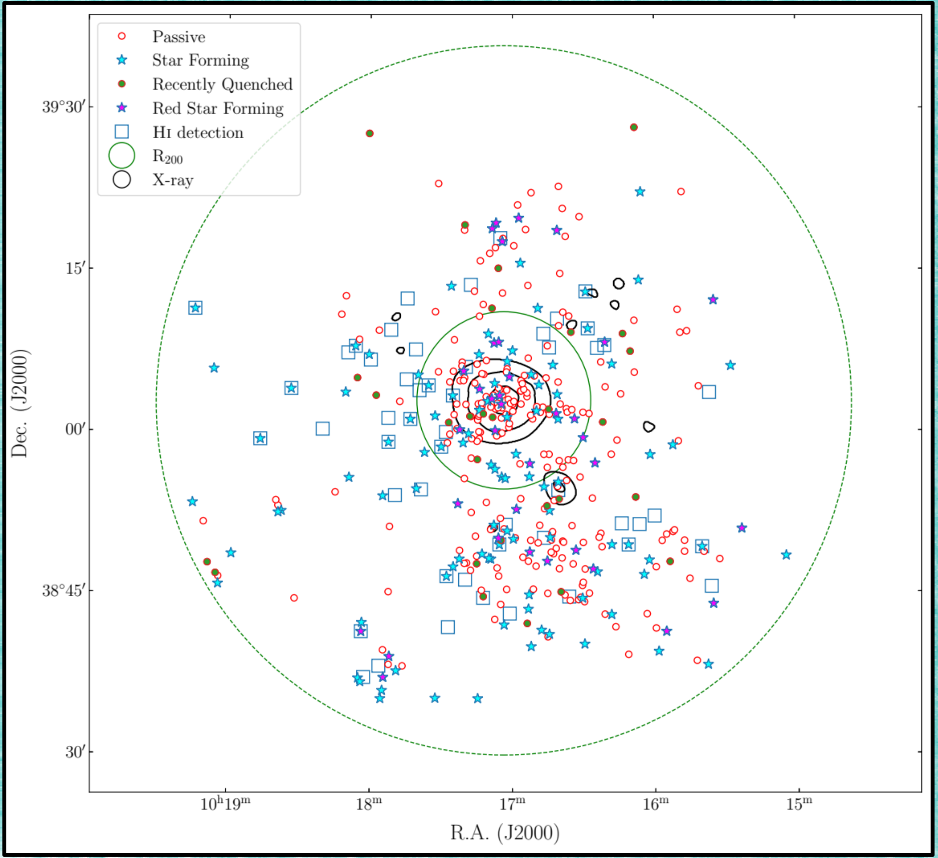
Abell 963

Deshev et al. 2020

K-band luminosity density from LoCuSS survey *Smith et al. 2010*

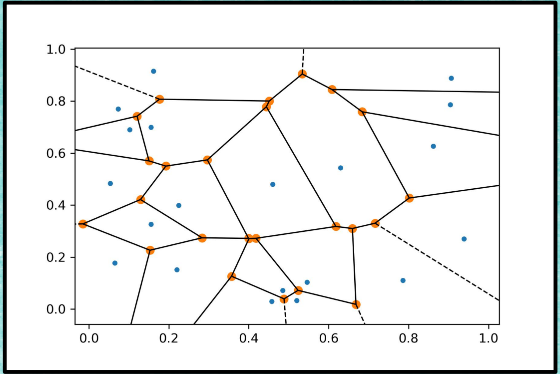


Optical spectroscopy with MMT from *Haines et al. 2013* and *Hwang et al. 2014* 386 galaxies with M*>10.0, no AGNs

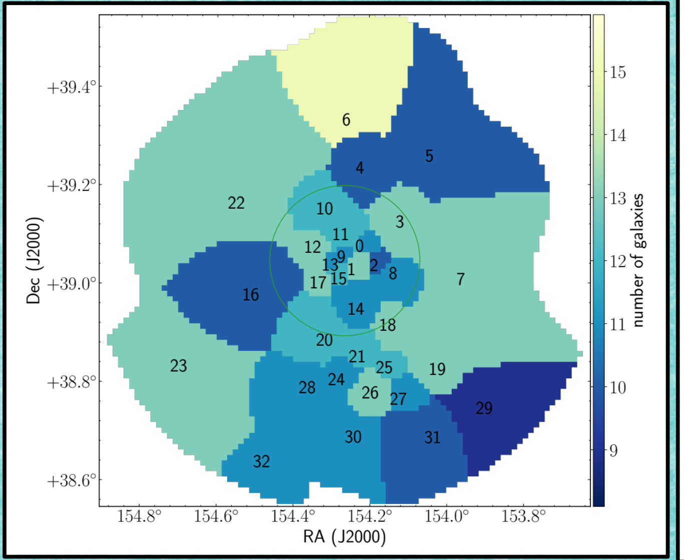


Abell 963

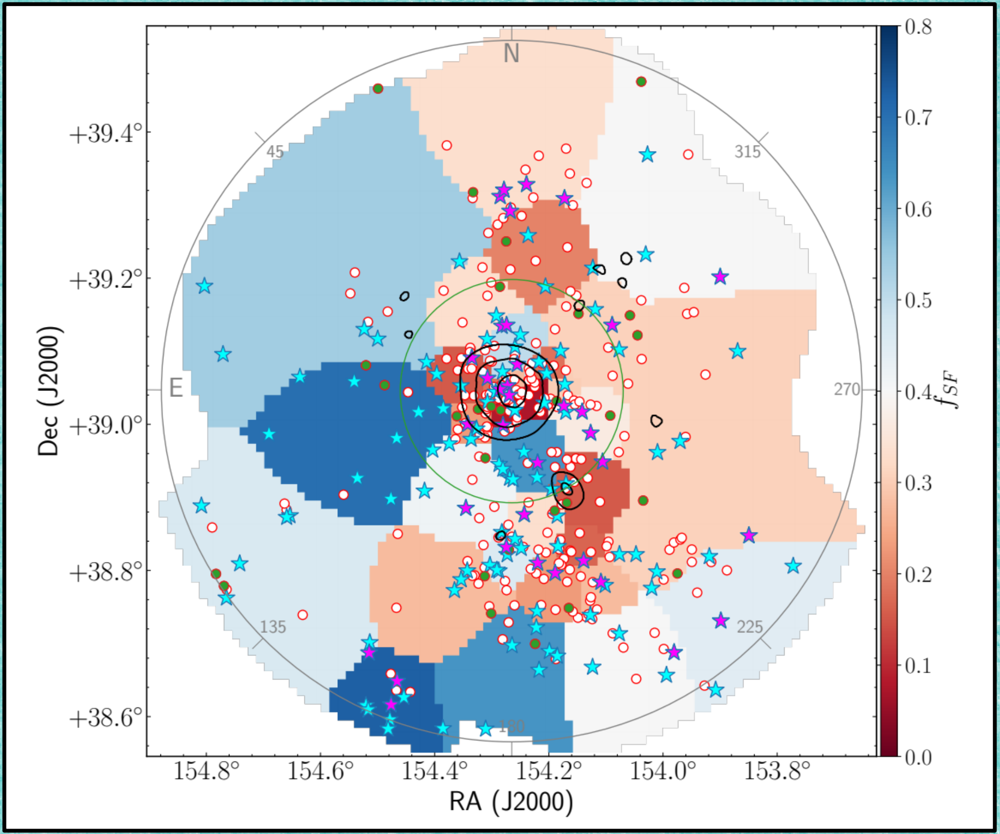
Voronoi tessellations and binning with *Vorbin* *Cappellari & Copin 2003*



Number of galaxies per Voronoi bin

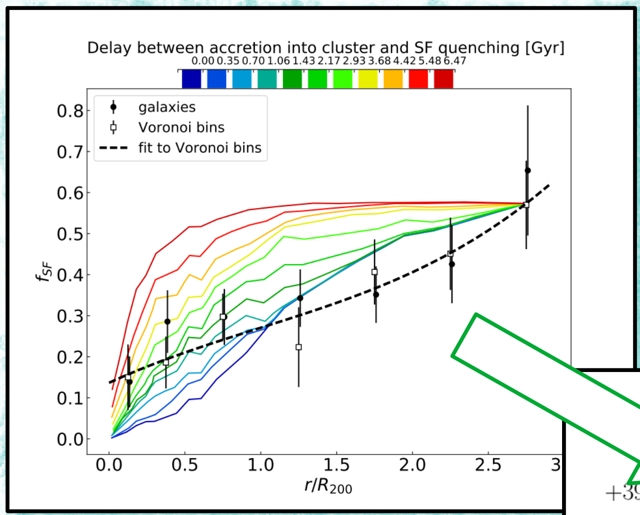


Fraction of star forming galaxies in Voronoi bins

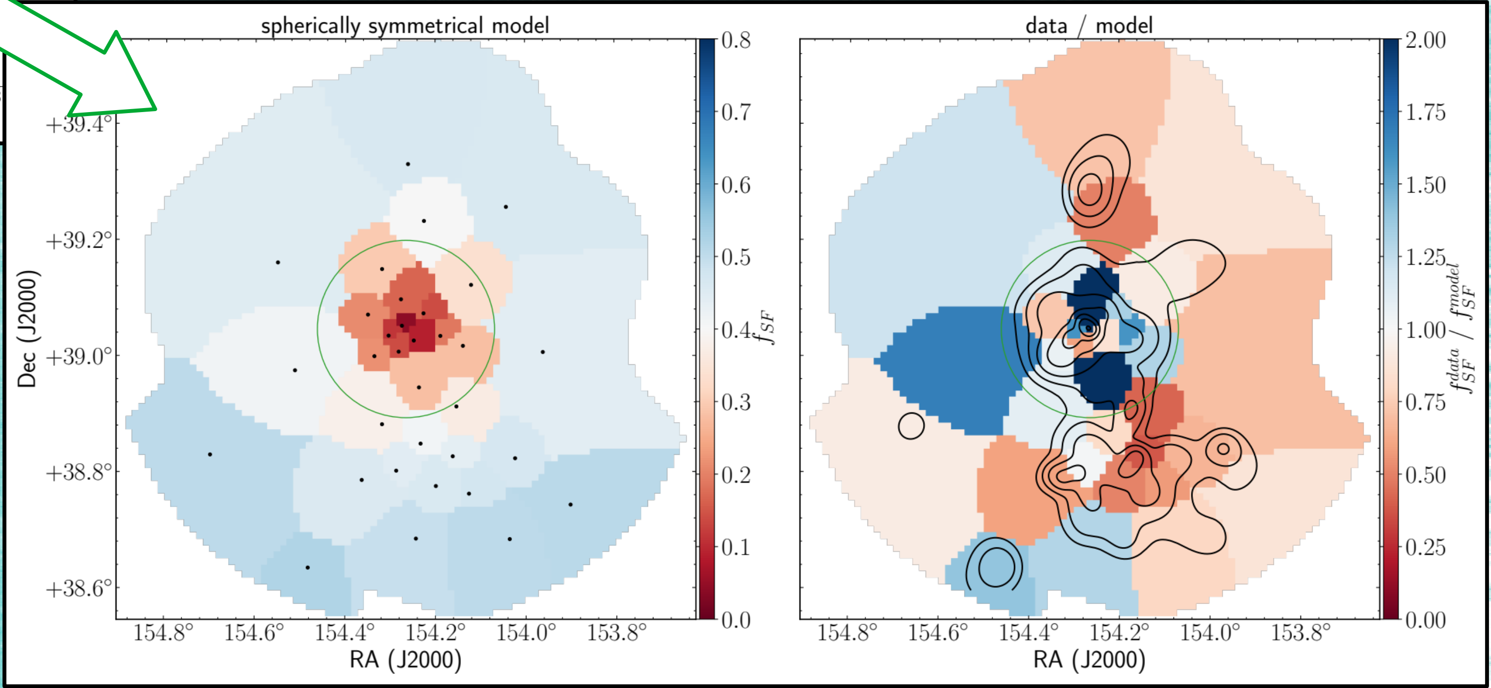


Deshev et al. 2020

Models for radial distribution of star forming fraction from *Haines et al. 2015*



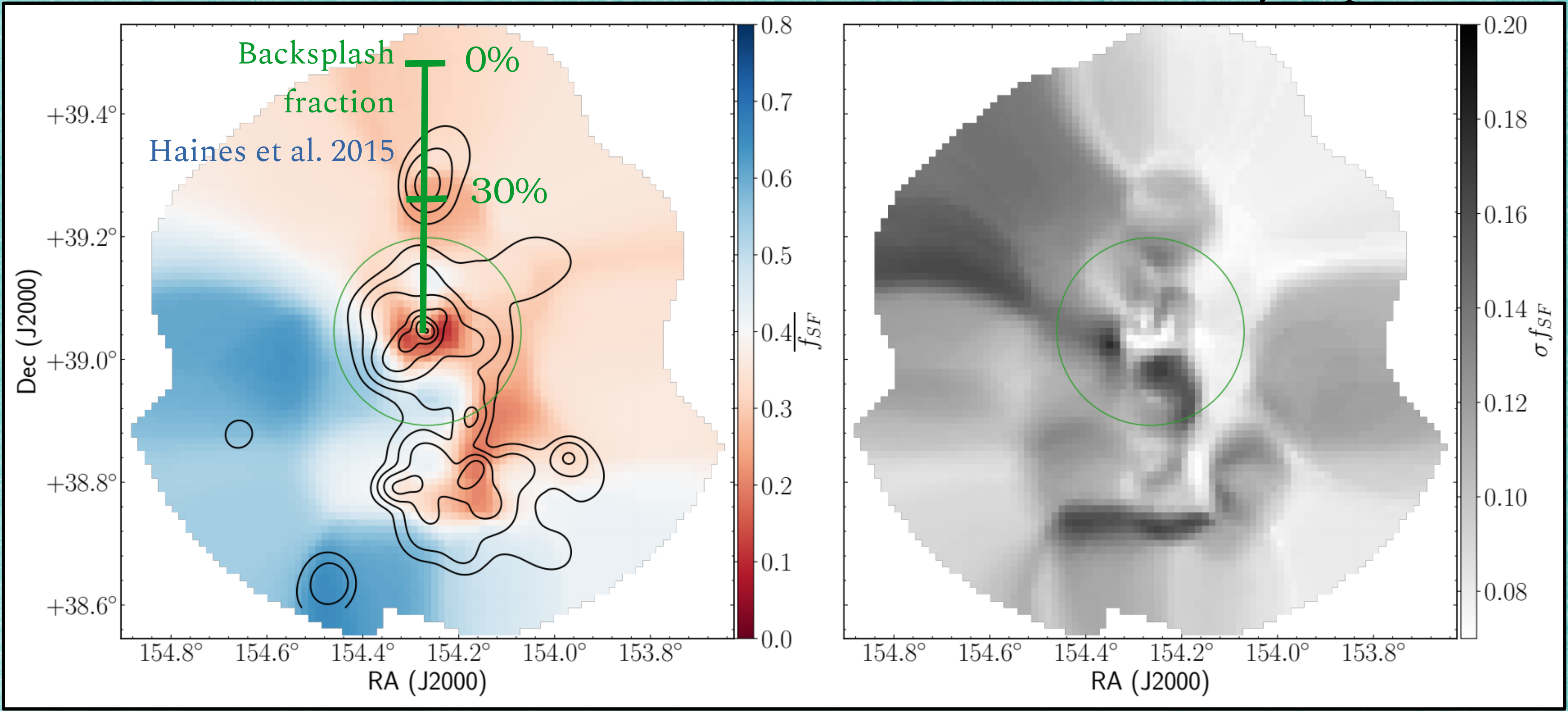
Deviations from the cluster-centric model for galaxy quenching



Deshev et al. 2020

Map of the local fraction of star forming galaxies

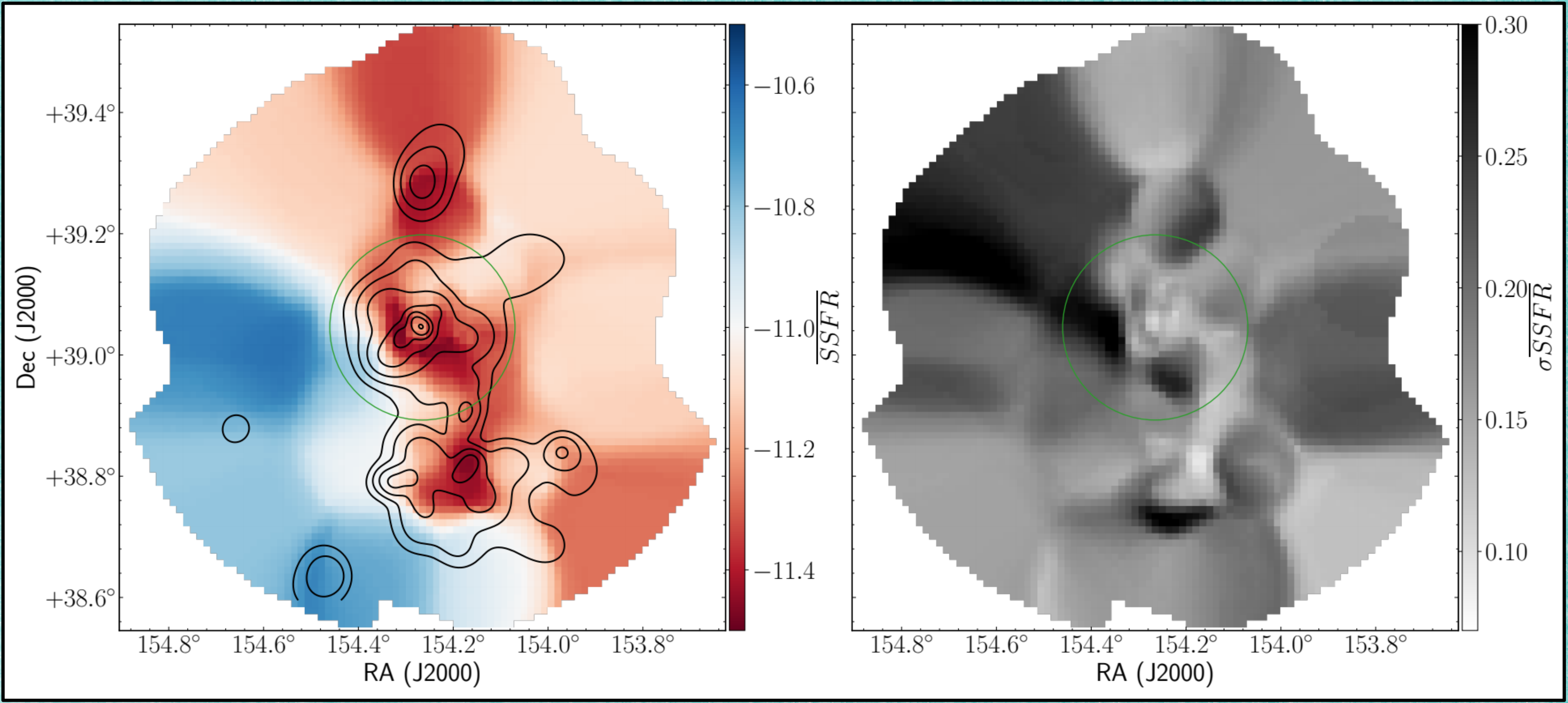
Uncertainty map



Deshev et al. 2020

Map of specific star formation rate

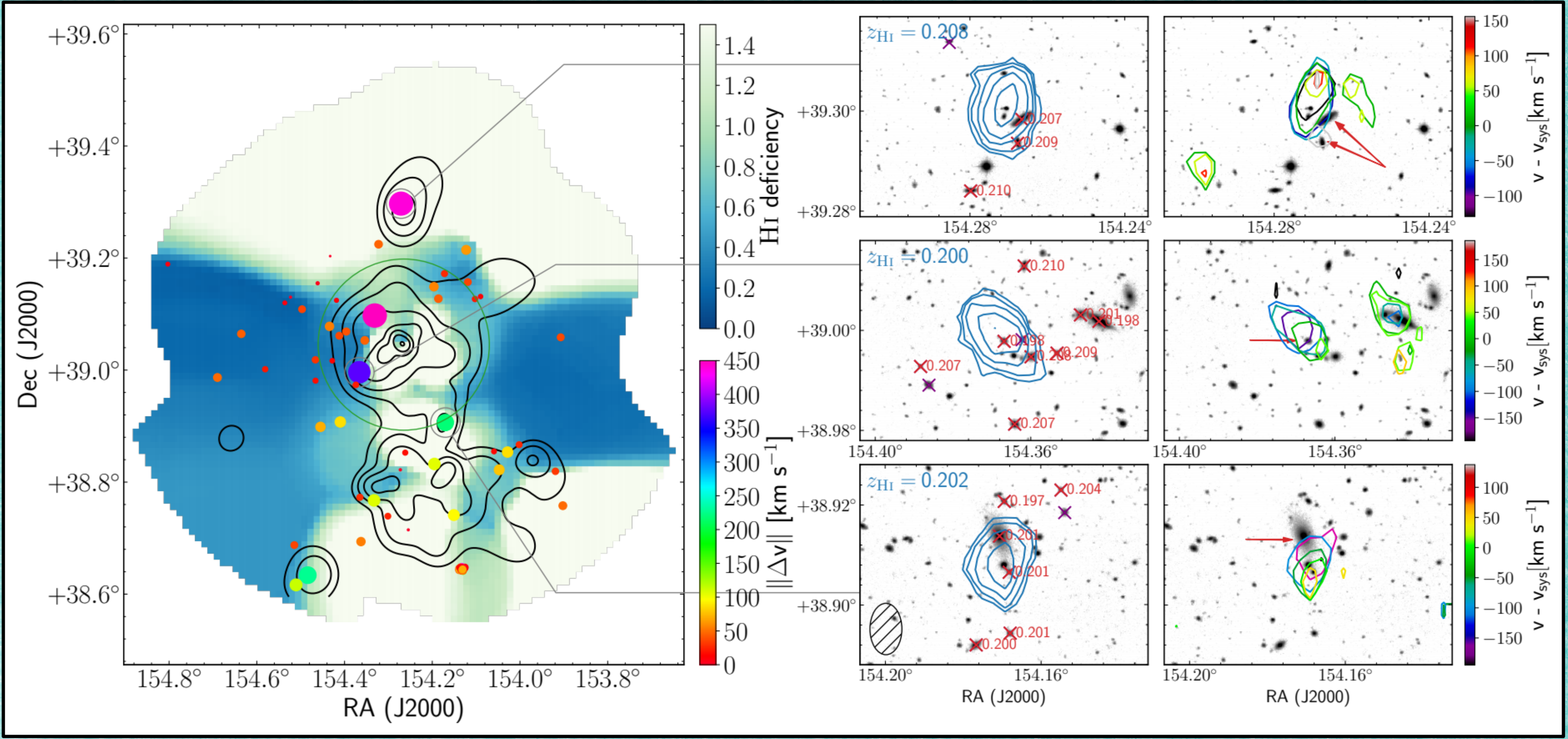
Uncertainty map



Deshev et al. 2020

Map of HI deficiency

Potential examples of ram pressure Stripping. First at z = 0.2



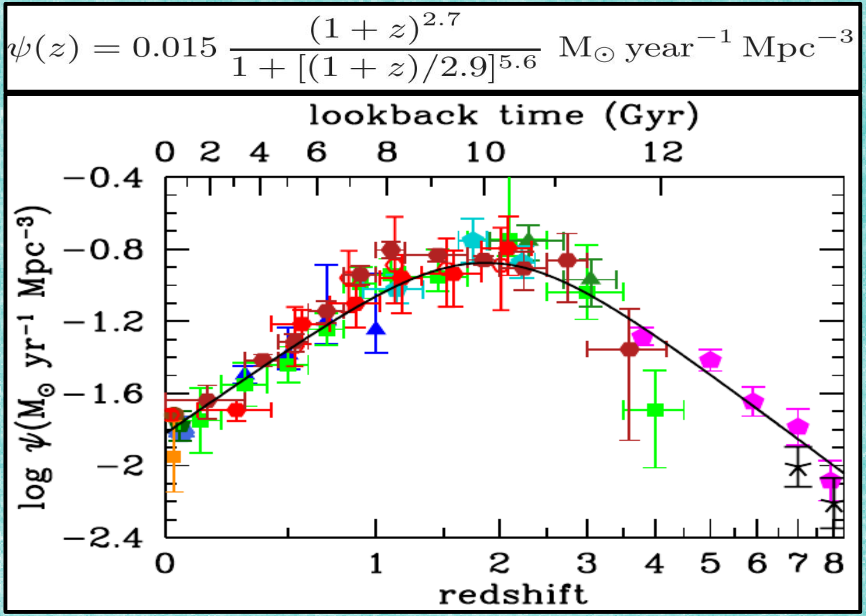
Deshev et al. 2020

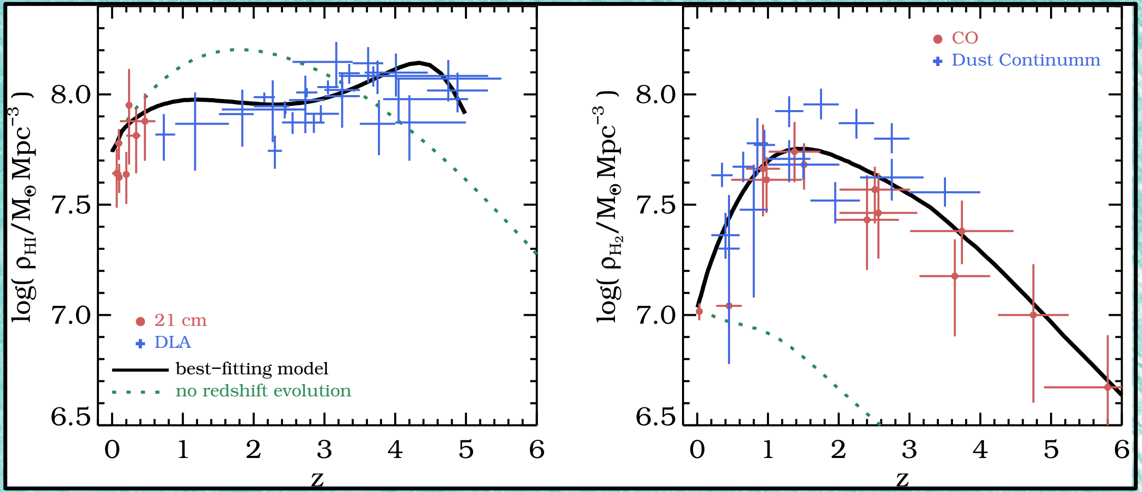
Conclusions:

- Accretion onto clusters is not isotropic
- Galaxies are likely pre-processed when infalling along LSS filaments
- Ram pressure stripping is important for a fraction of the newly accreted cluster galaxies
- Major cluster mergers do quench star formation
- The data have so much more to give

Cosmological galaxy evolution

Star formation rate
density evolution
Madau & Dickinson, 2014





Gao et al. 2023