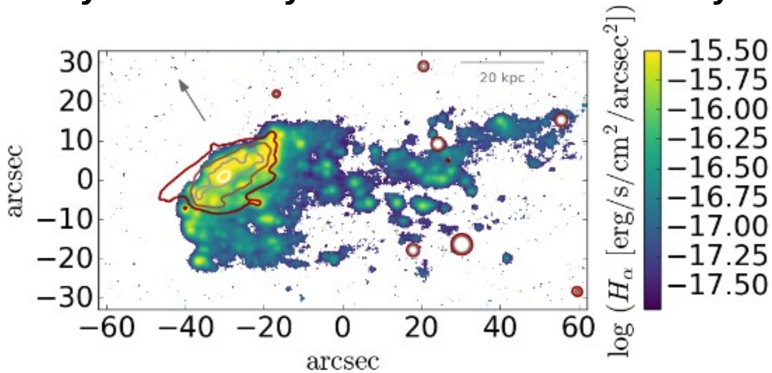
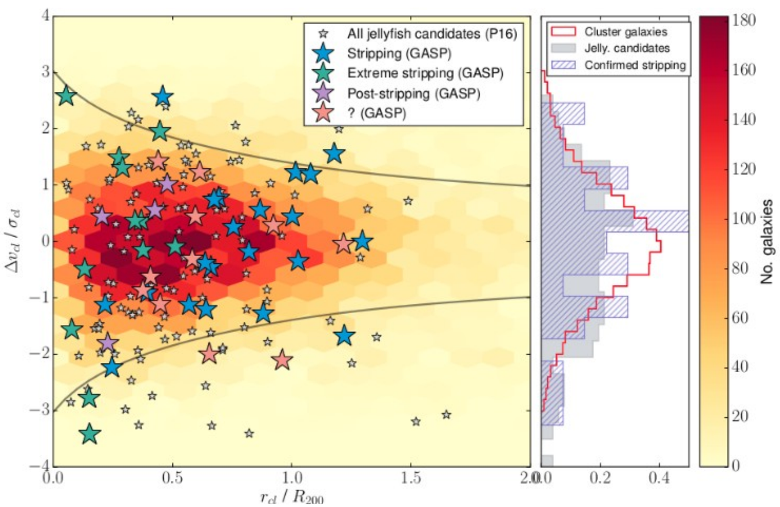
Towards a Better Understanding of Environmental Effects in Groups and Clusters using Phase-space

Jelly Fish Galaxy JO206 from GASP survey

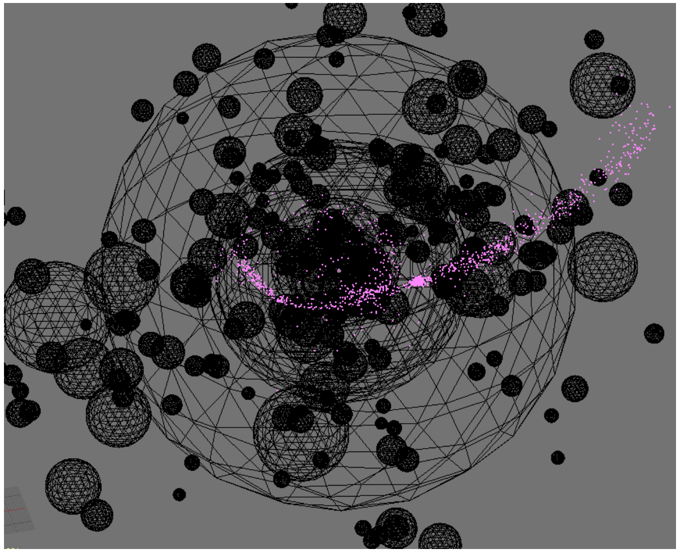


(Poggianti et al. 2017)

Jelly Fish Locations in Projected Phase-Space



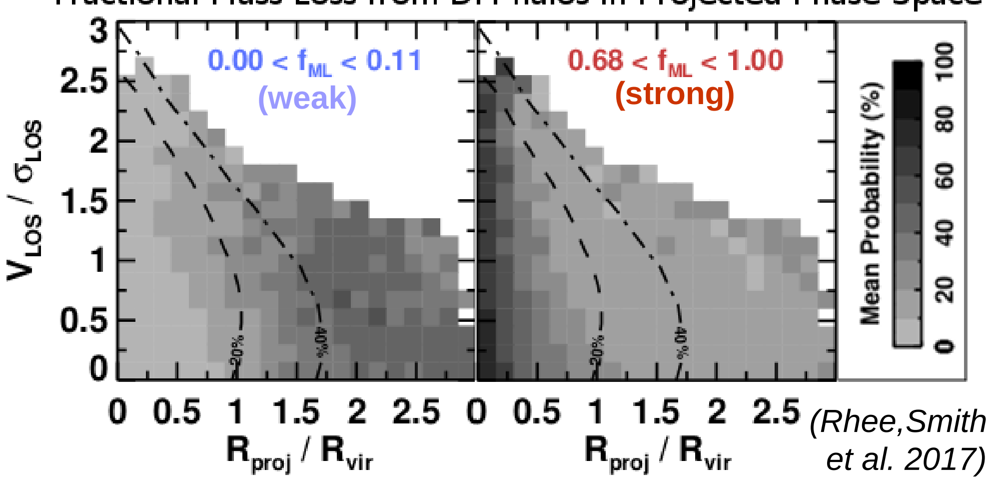
(Jaffe et al. 2017)



Tidal Mass loss of stars (pink) from galaxy in harassment simulation (bubbles are cluster & cluster-members

(From Smith et al. 2015)

Fractional Mass Loss from DM halos in Projected Phase-Space



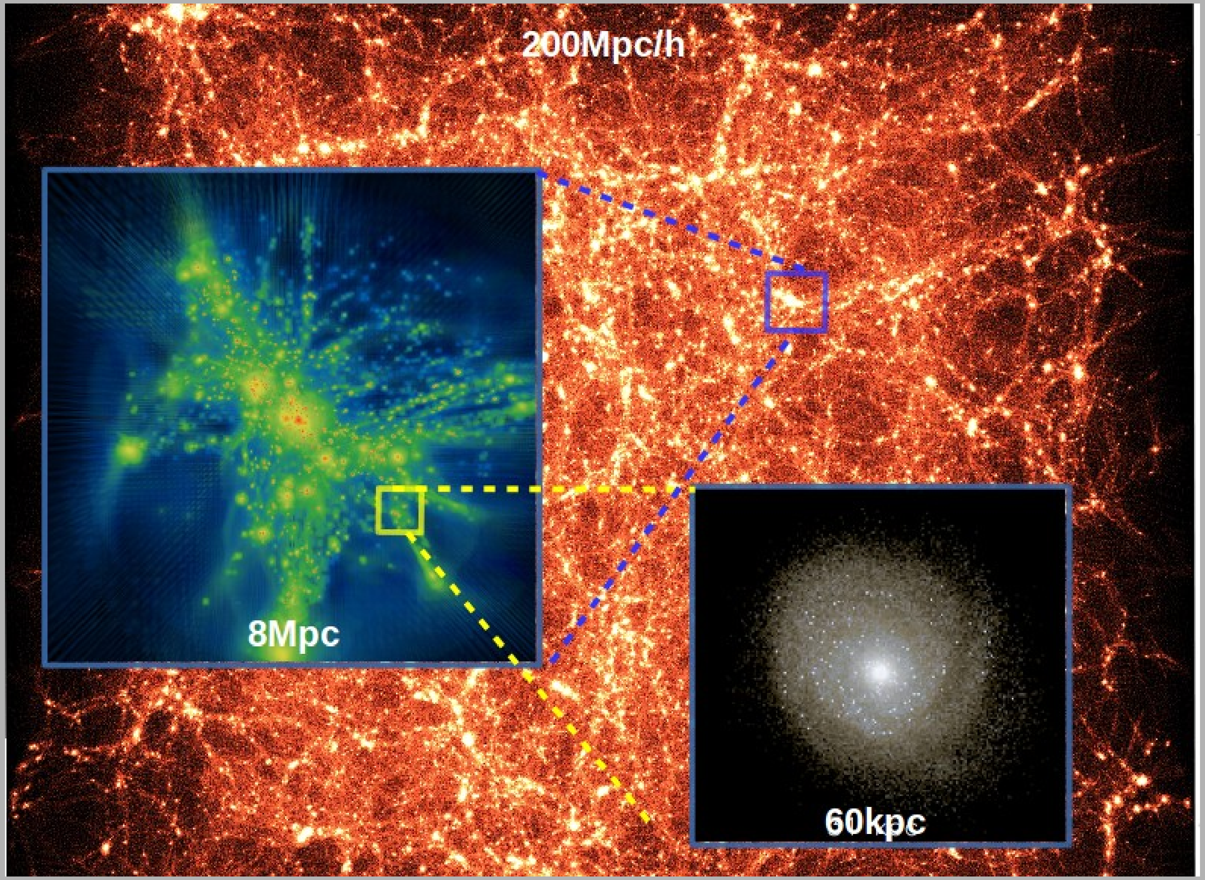
(Rhee,Smith et al. 2017)

Rory Smith

8th KIAS Workshop on Cosmology and Structure Formation, 2018

Simulation details: YZICS

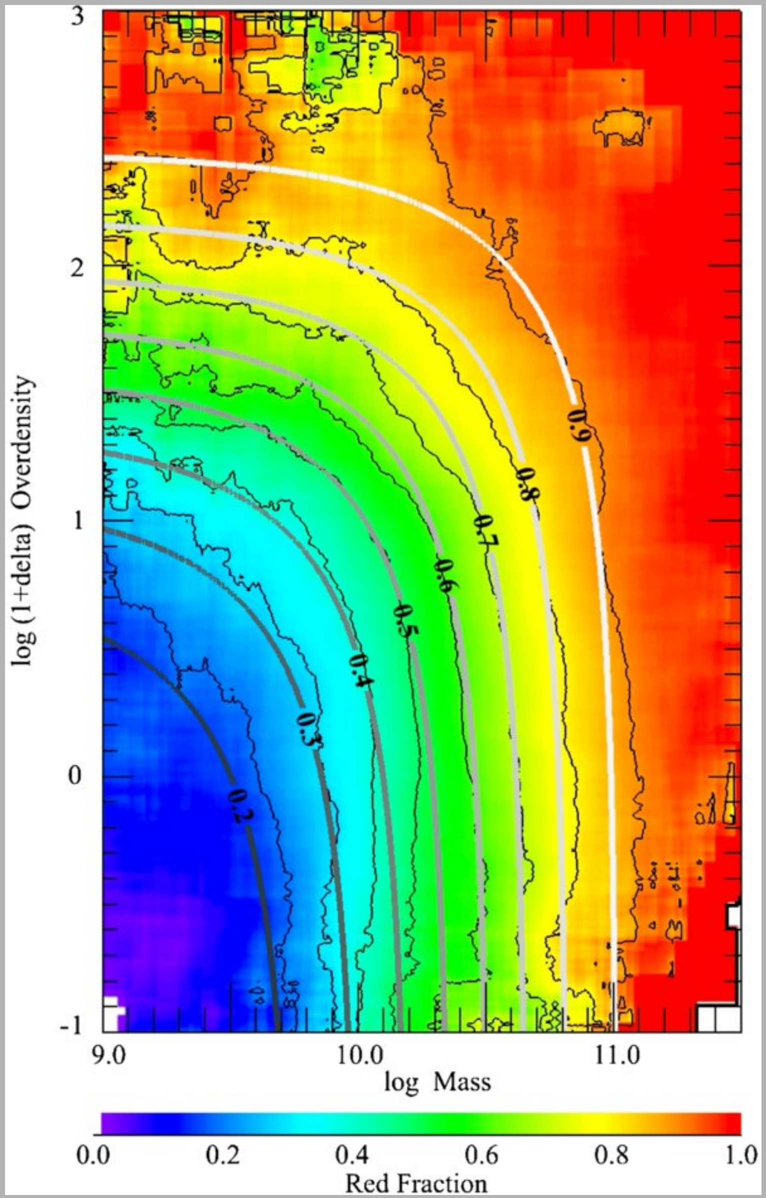
Hoseung Choi,
Yonsei University
PhD supervisor: Sukyoung Yi



Zoomed cosmological simulations of groups and cluster

- 15 systems in total
  (Mass range 5e13-1e15 M_{sol})
- Simulation resolution:
  → Spatial: 760 pc
  → Min halo mass: ~1e9 M_{sol}
- Good time resolution (70 Myr)
- Baryonic physics:
  Hydrodynamical gas, star formation, stellar feedback, BH formation, AGN feedback, etc

Galaxy properties function of mass and environment

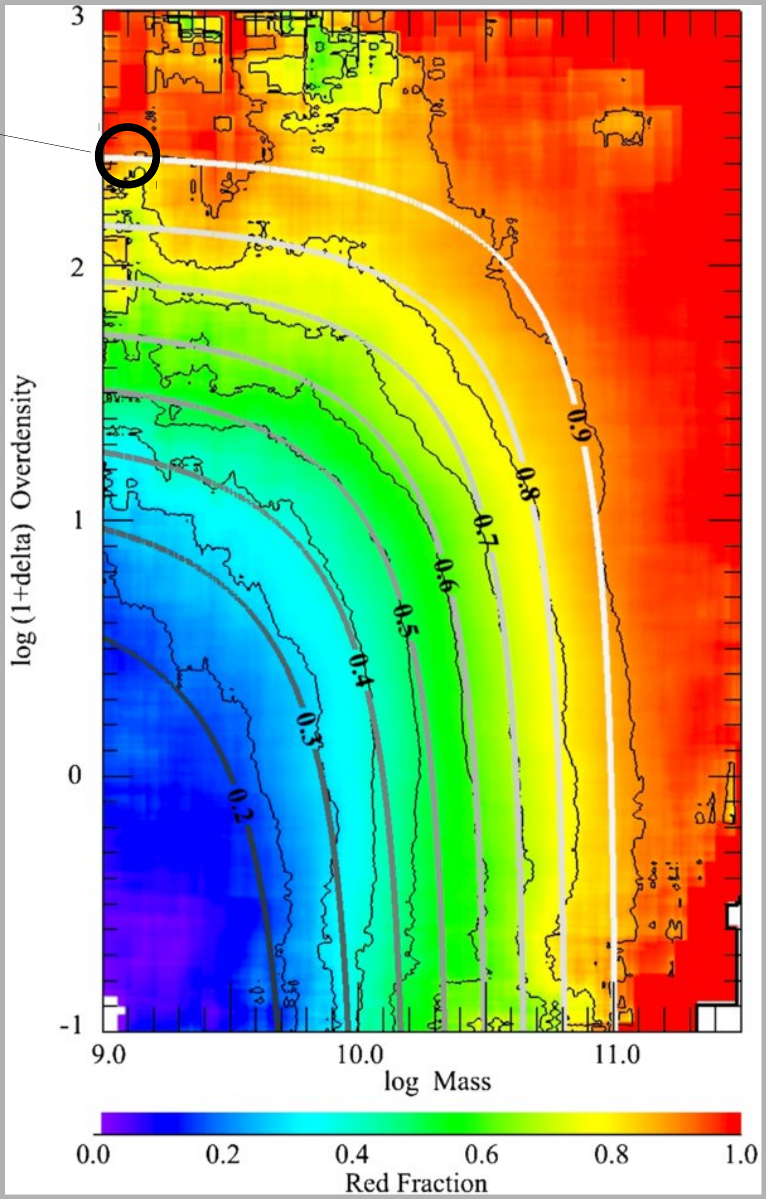


Peng et al. 2010

To see effects of **environment**, need to first control for **galaxy mass**

Galaxy properties function of mass and environment

e.g. Dwarfs in a cluster

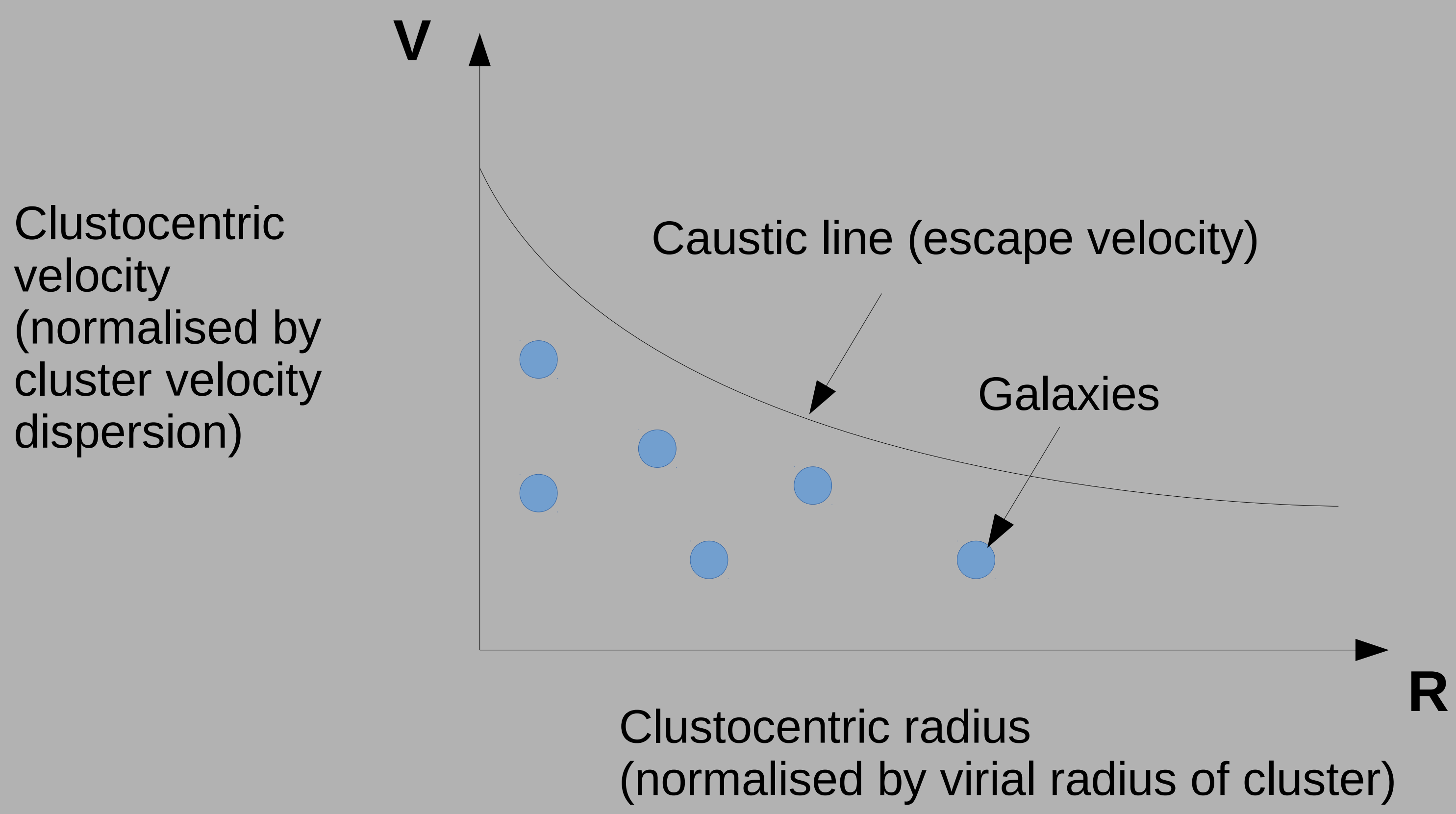


Peng et al. 2010

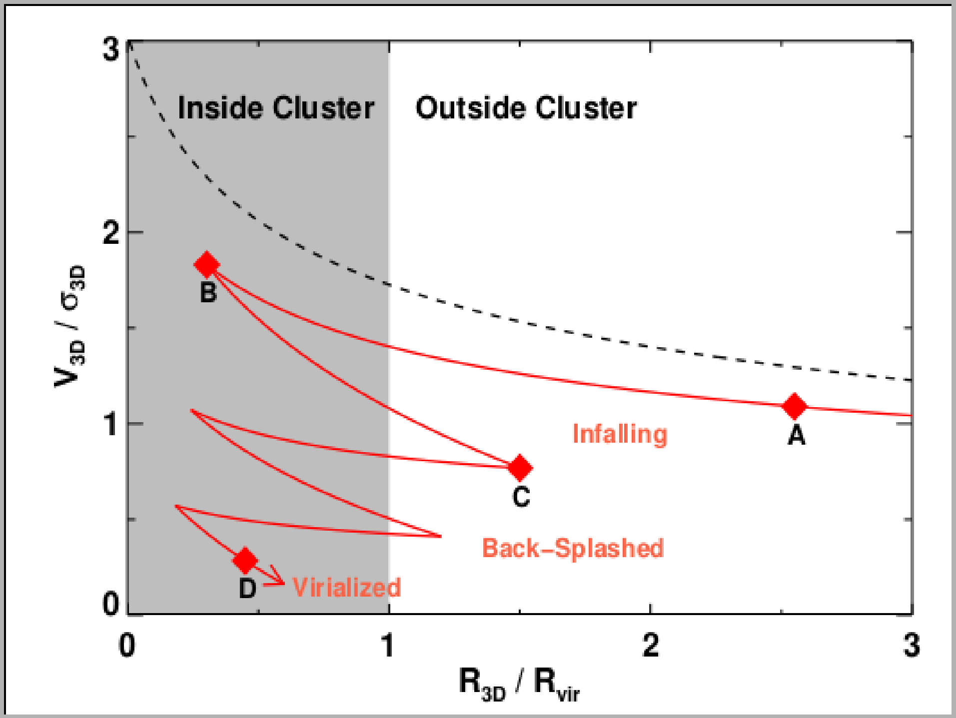
To see effects of **environment**, need to first control for **galaxy mass**

… but environmental effects don't act instantly → **Infall time** is another key parameter.

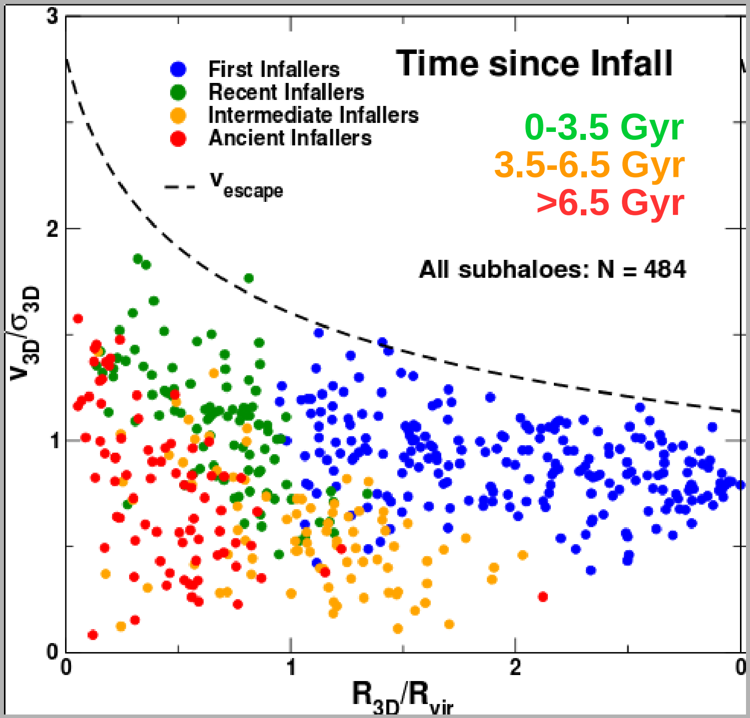
Phase-space:
What is a phase-space diagram?



Phase-space diagrams to determine infall times



Cartoon track of infalling galaxy in phase-space



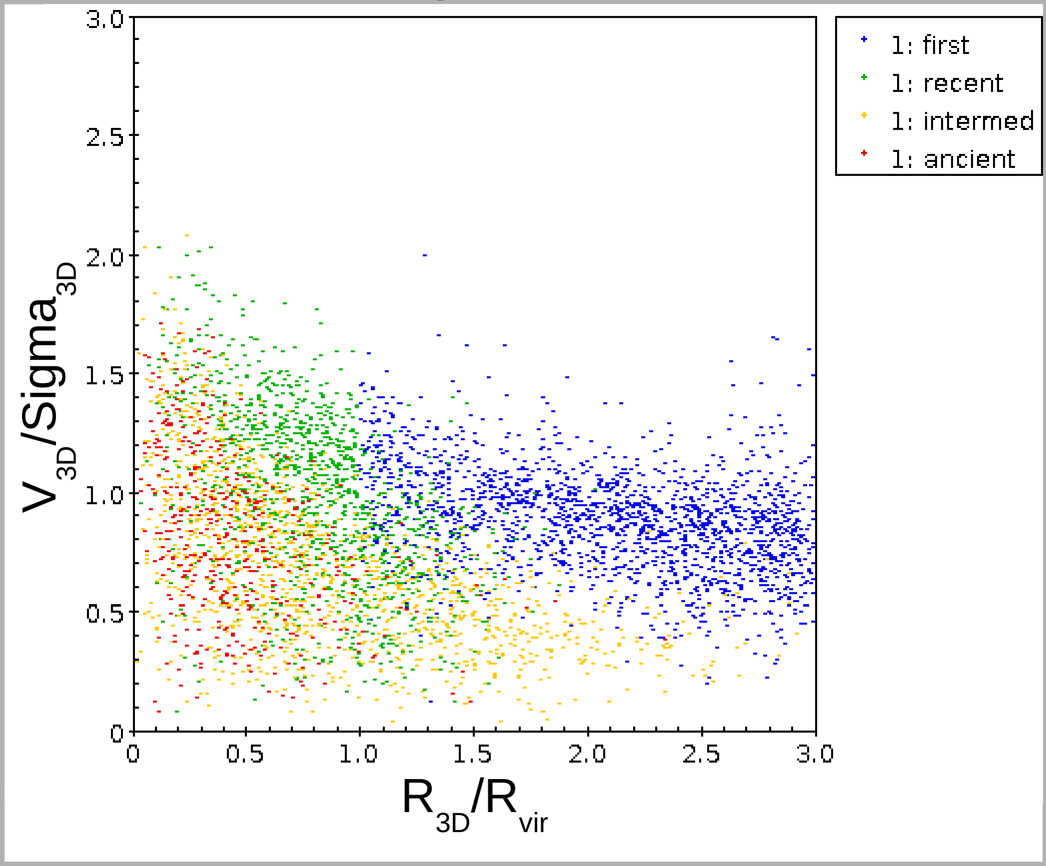
3D phase-space diagram of single cluster at z=0, with galaxies coloured by time since infall

Separate quite neatly….but these are 3D phase-space diagrams!

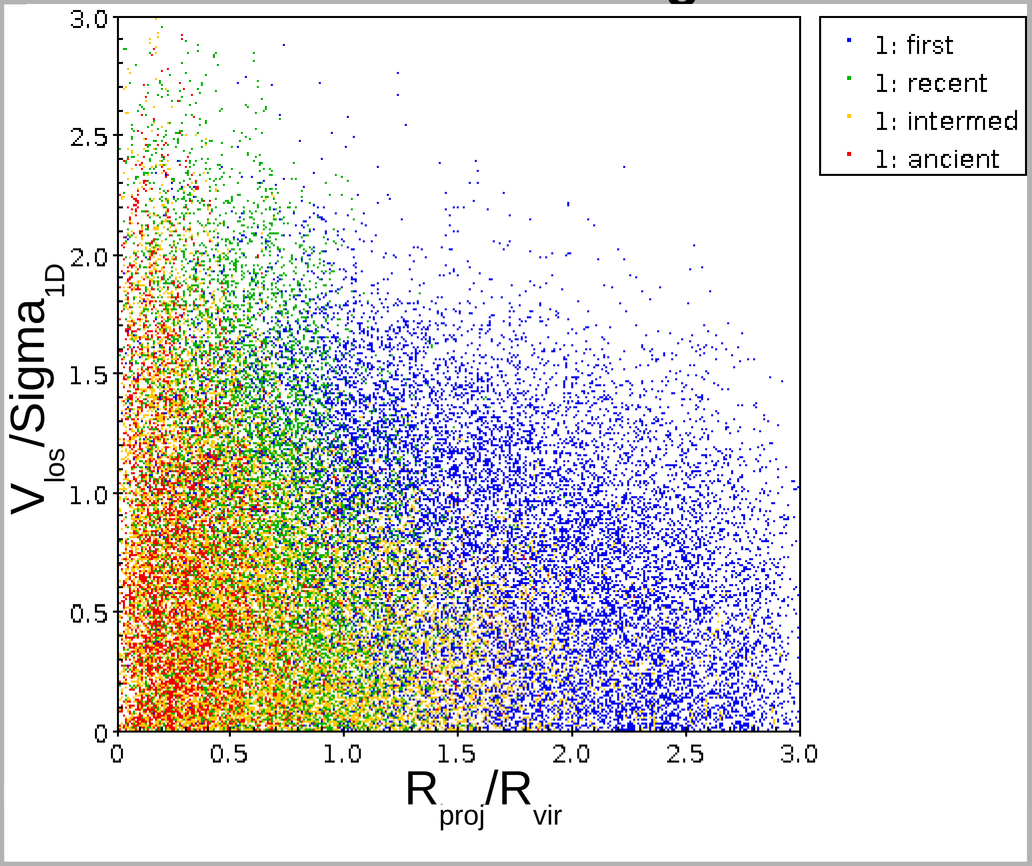
from Rhee, Smith et al. 2017

Projection effects

3D



10 random line-of-sights



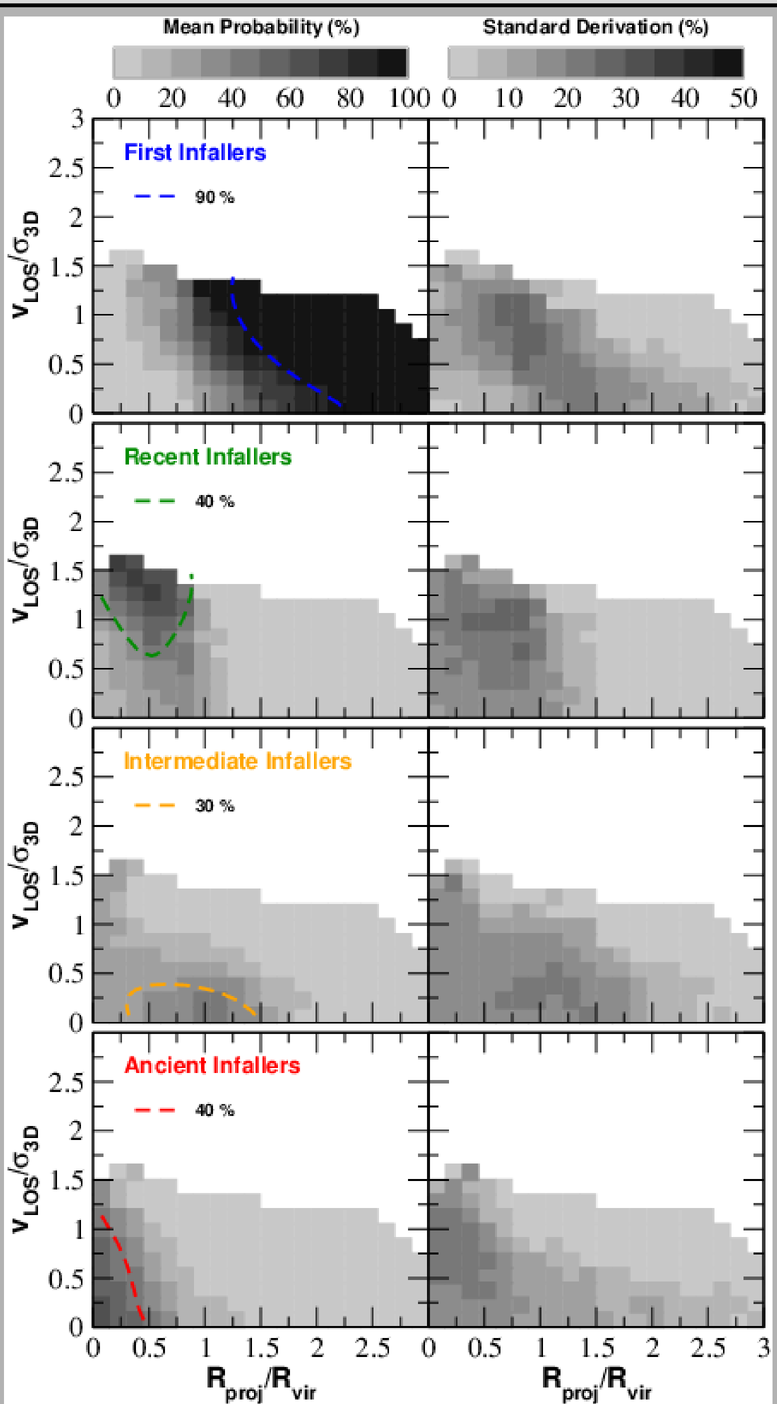
3D phase space diagram → 2D ‘projected’ phase space diagram

Probability of finding a particular infall time

Jinsu Rhee, Yonsei

Colour key of infall time

First infallers	Not yet
Recent infallers	0-3.6 Gyr
Intermediate	3.6-6.5 Gyr
Ancient infallers	>6.5 Gyr



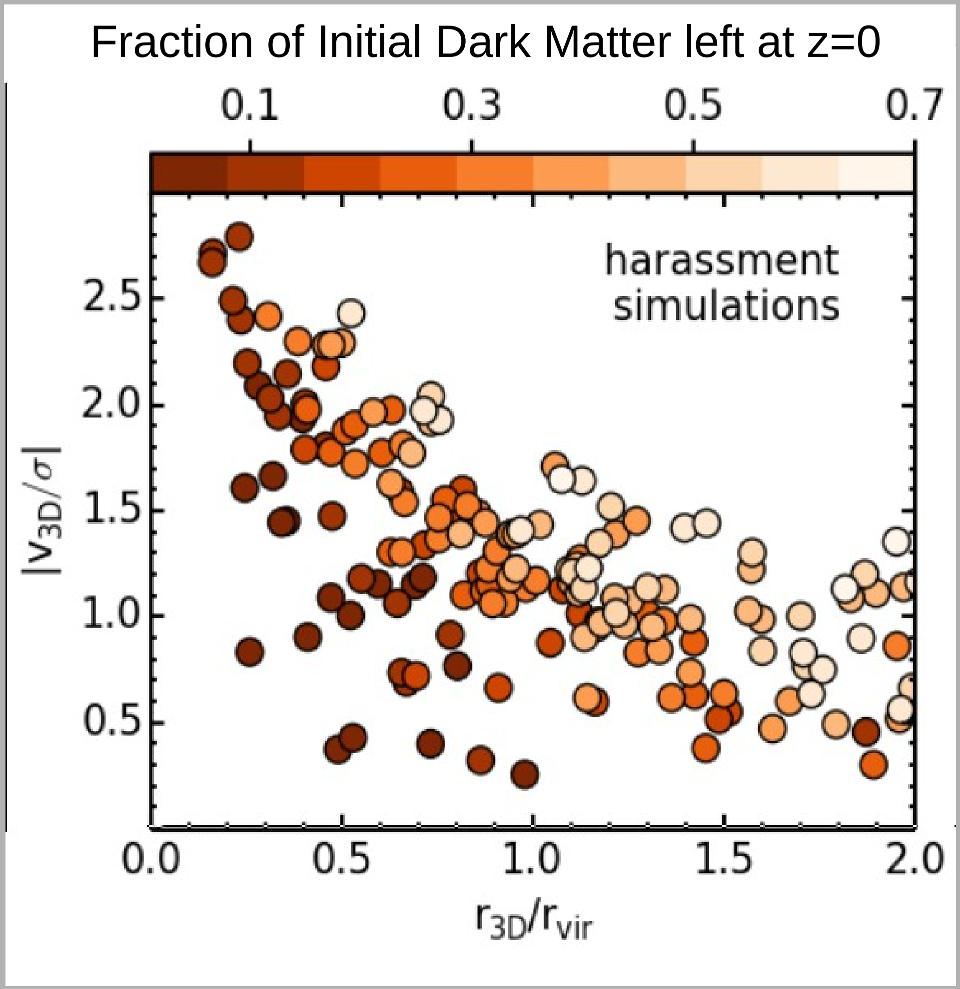
Gives a statistical result – so works best with many galaxies………. and even better with many clusters

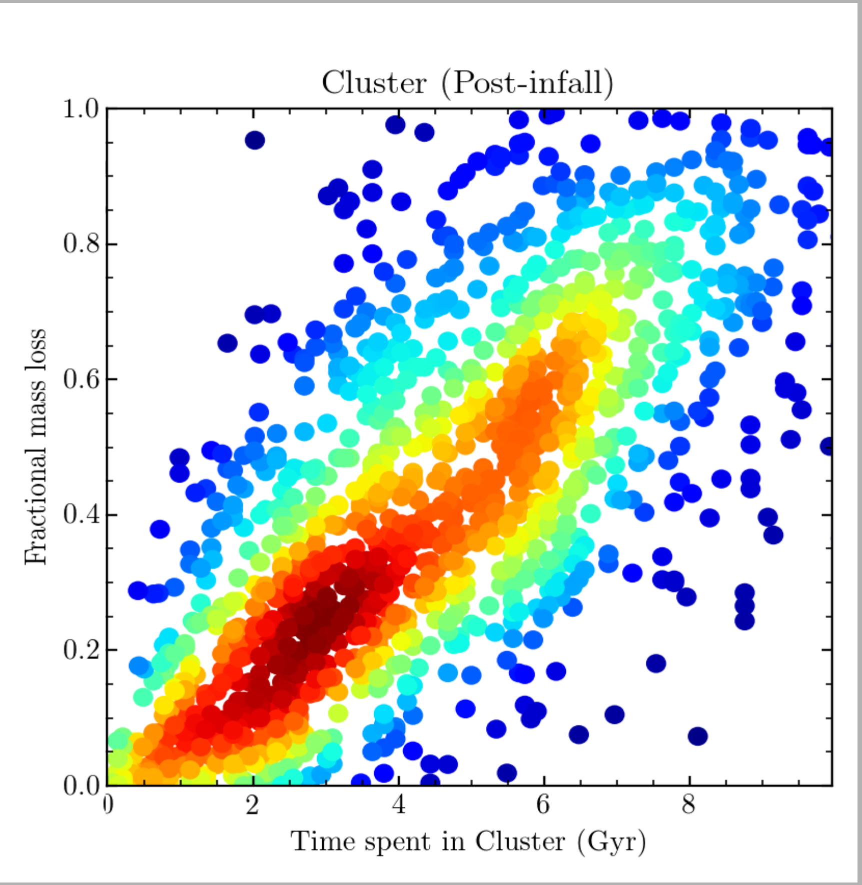
(Left column) ***Mean probability*** *of the given infall time*

(Right column) ***Standard deviation*** *(arising from cluster-cluster variations, line-of-sight, etc)*

Rhee, Smith et al. 2017

Tidal Mass loss in Phase-Space





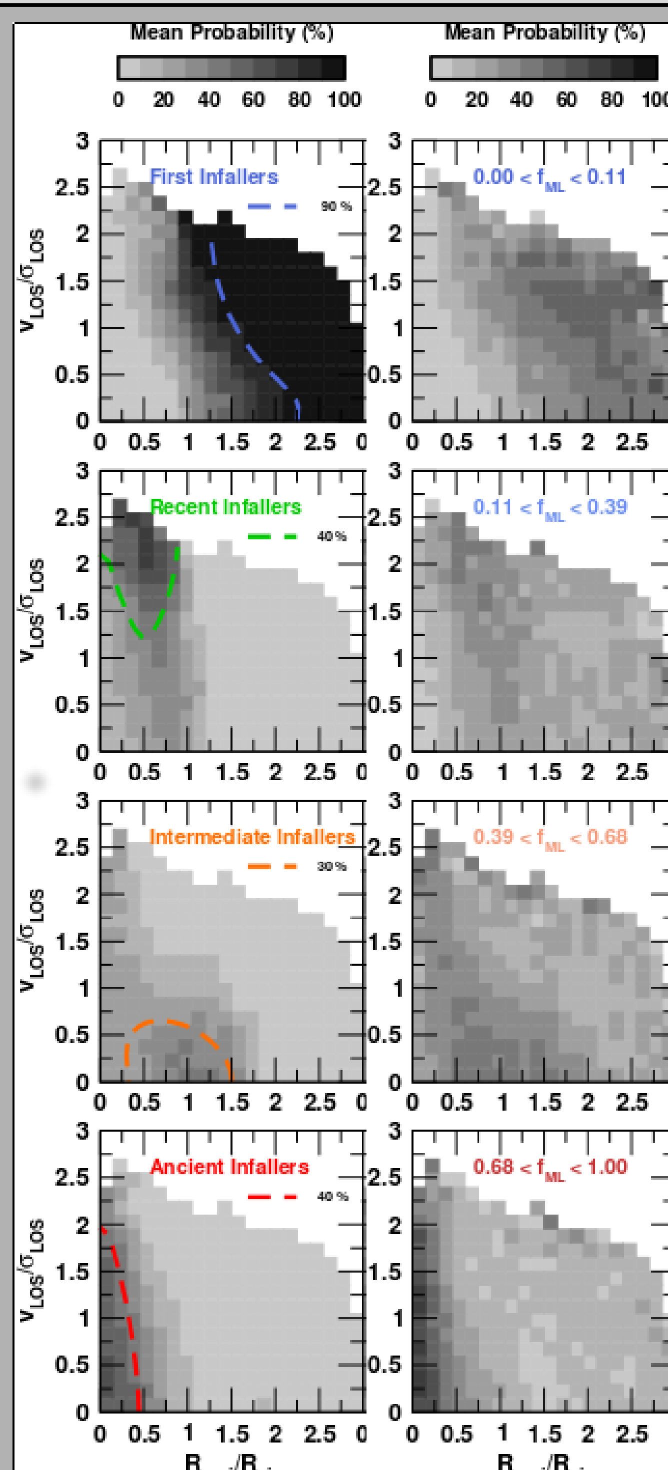
From Han, Smith et al. 2018

Smith et al 2015

Clear correlation between infall time and DM mass loss within the cluster

Infall time and Tidal Mass Loss linked in Projected Phase-Space:

(Left column)
Time since infall



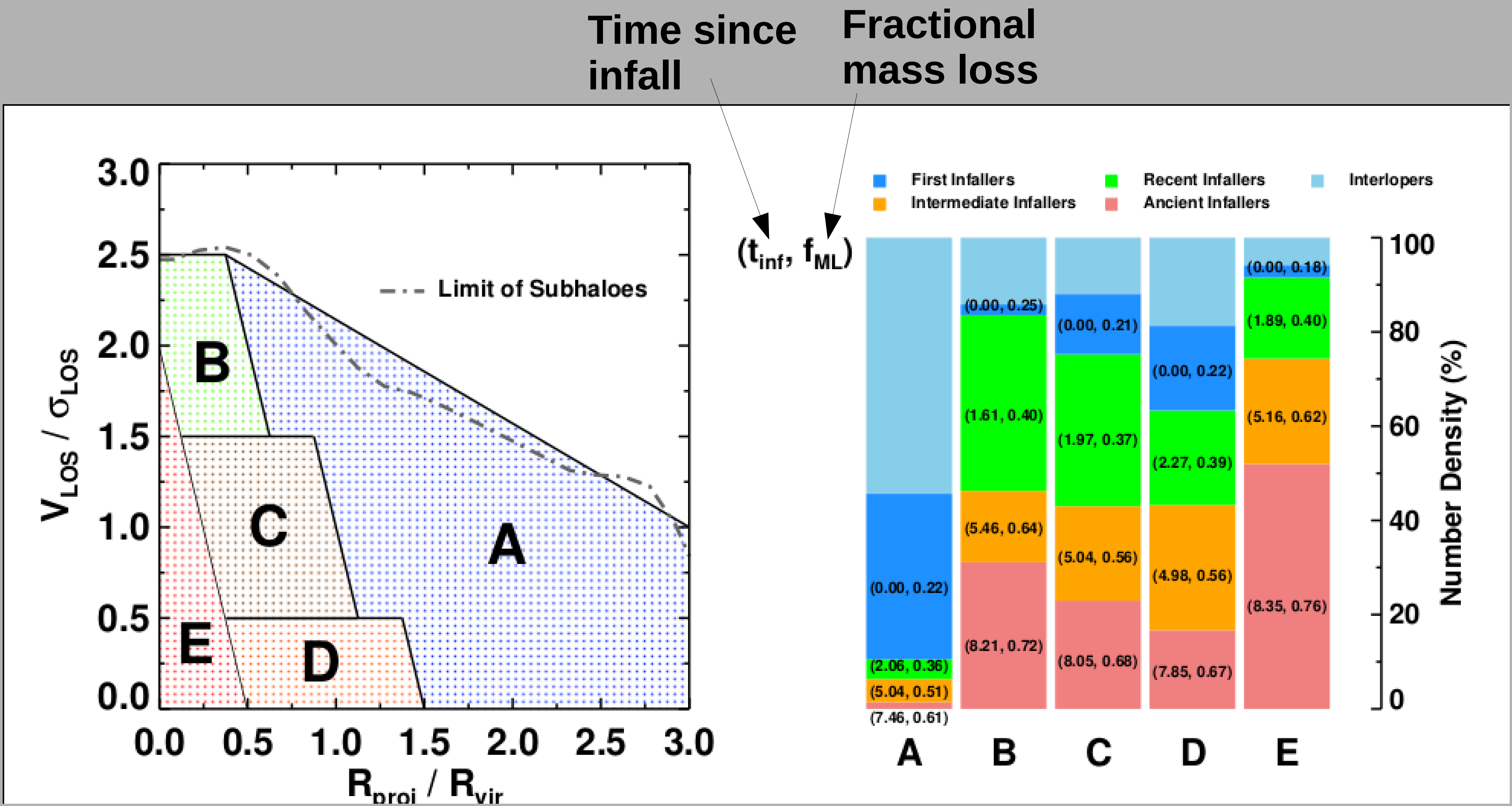
(Right column)
Fractional mass loss

N.b. Fractional mass loss = fraction of peak mass remaining at z=0

- Similarity between infall time and tidal mass loss diagrams
- Location in phase-space gives information on tidal mass loss

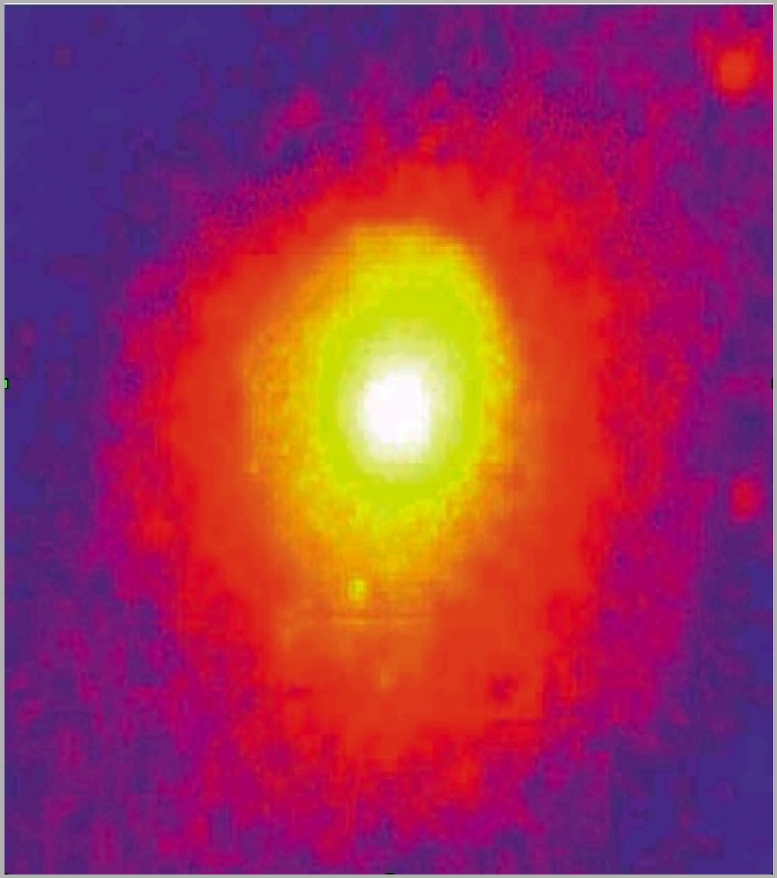
Rhee, Smith et al. 2017

Satellite Population by Phase-Space Region

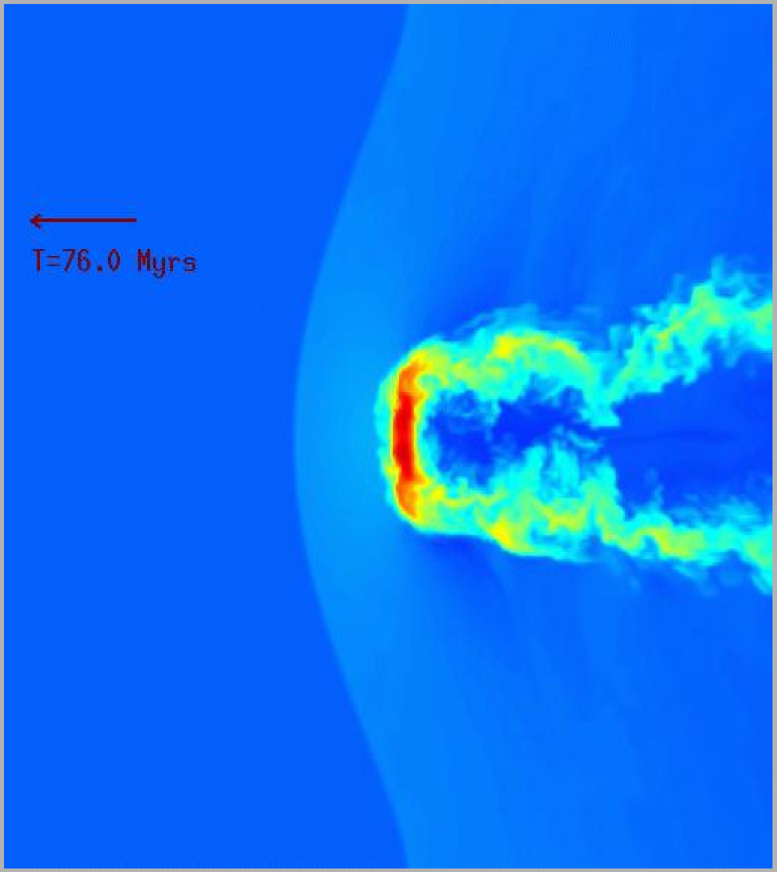


Breakdown of galaxy properties (infall time & halo mass-loss) in different regions in phase-space from Rhee, Smith et al. 2017

Ram Pressure Stripping



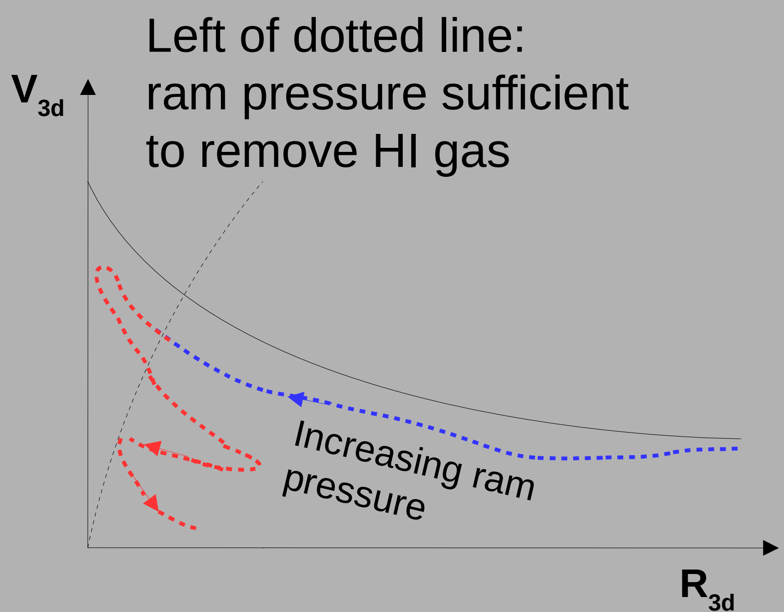
Virgo cluster in X-rays, ROSAT



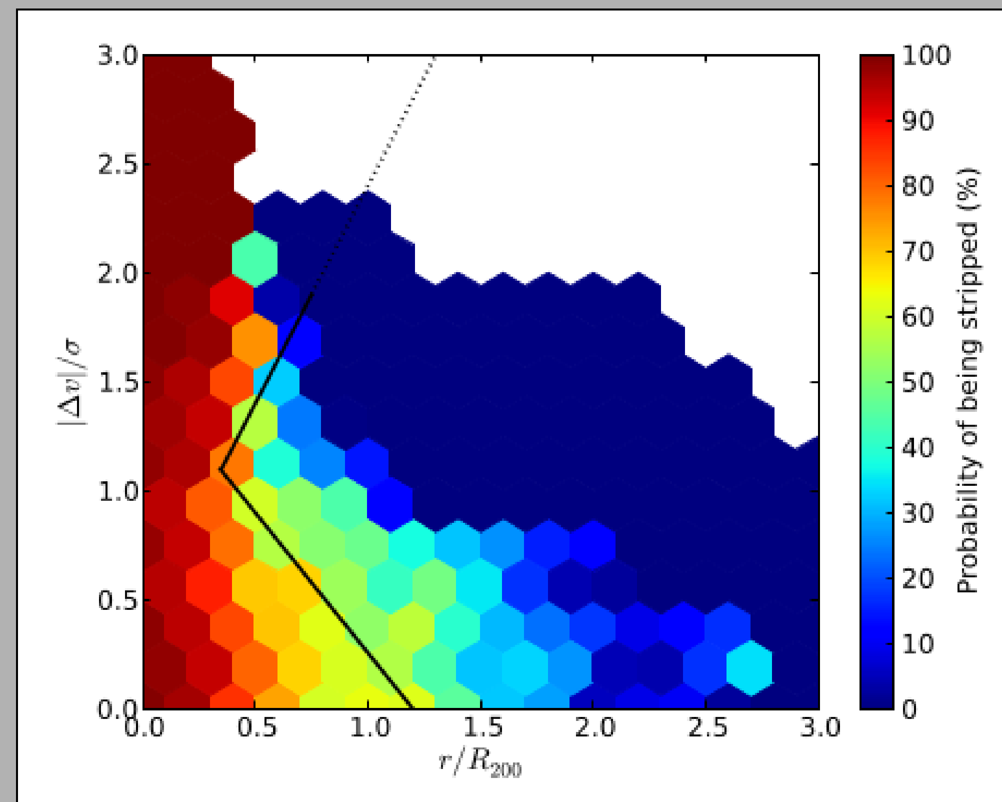
Ram pressure simulation, Quilis 2000

The motion of a galaxy through the intra-cluster medium causes a drag force on it's HI gas disk

Ram pressure stripped galaxies in phase-space
Semi-analytical approach

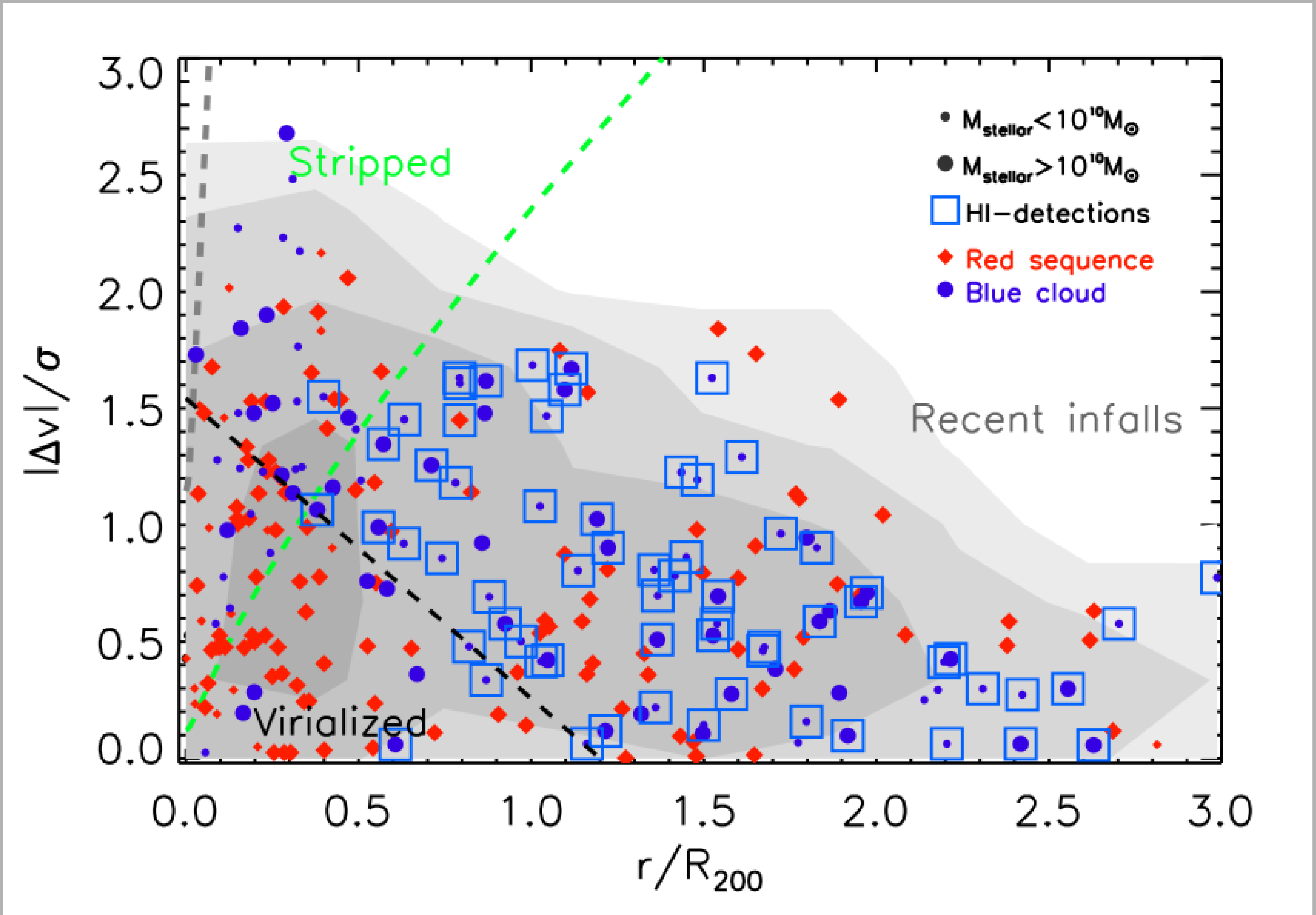


$$RP = \rho_{ICM}\, v_{gal}^{2}$$



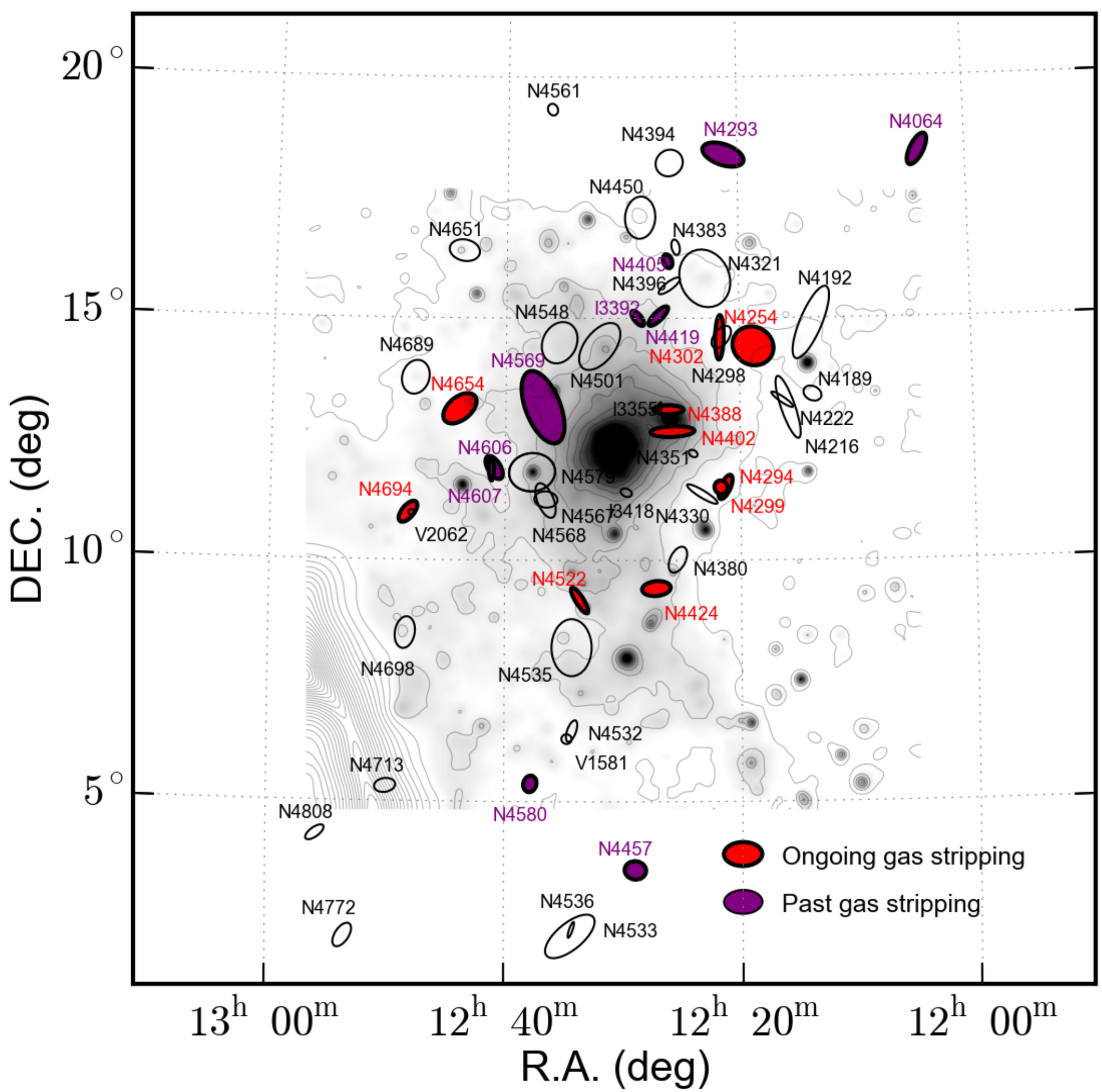
Probability of having been ram pressure stripped in projected phase-space (*Jaffe, Smith et al. 2015*)

Ram Pressure Stripping in Phase-Space
The Abell 963 Cluster



Jaffe, Smith et al. 2015

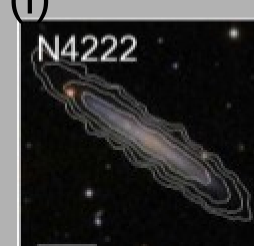
Application to the Virgo Cluster:



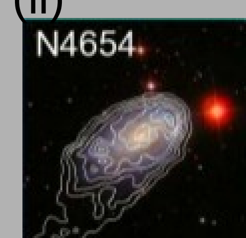
VIVA II; Yoon, Chung, Smith et al. 2017

- Collaboration with:
  Aeree Chung (left)
  & Hyein Yoon (right)
- VIVA survey:
  Deep VLA imaging of the HI gas disks of Virgo cluster spirals
- Galaxies categorised by Hyein based on HI morphology:
  (i) before ram pressure
  (ii) active ram pressure
  (iii) past ram pressure

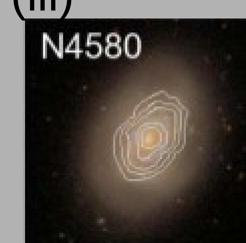
(i)



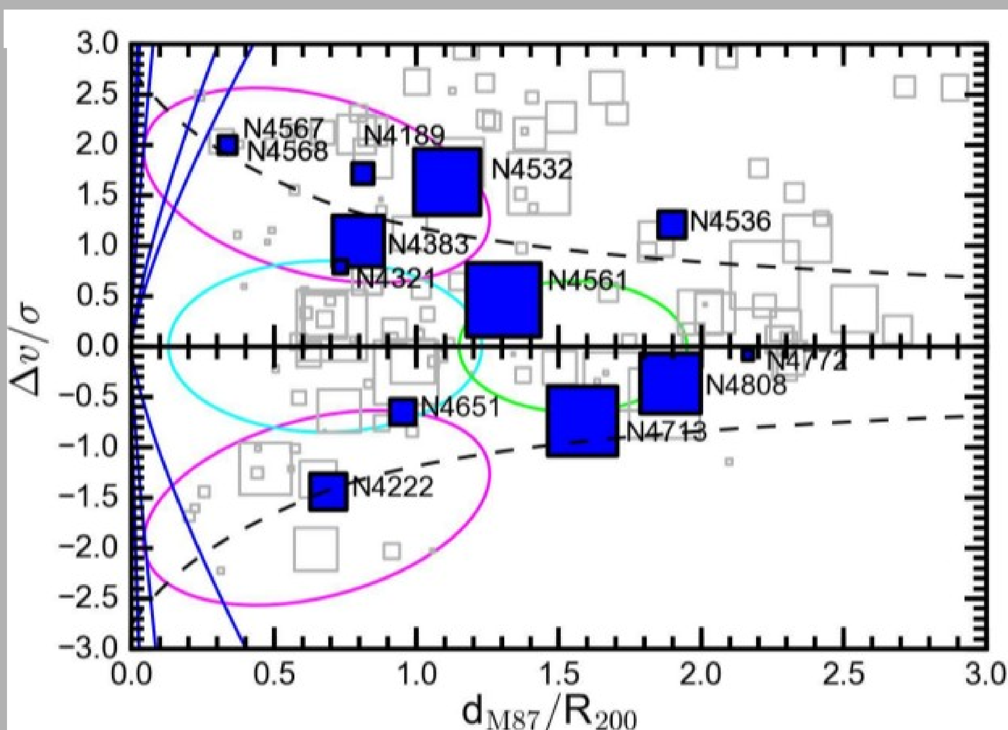
(ii)

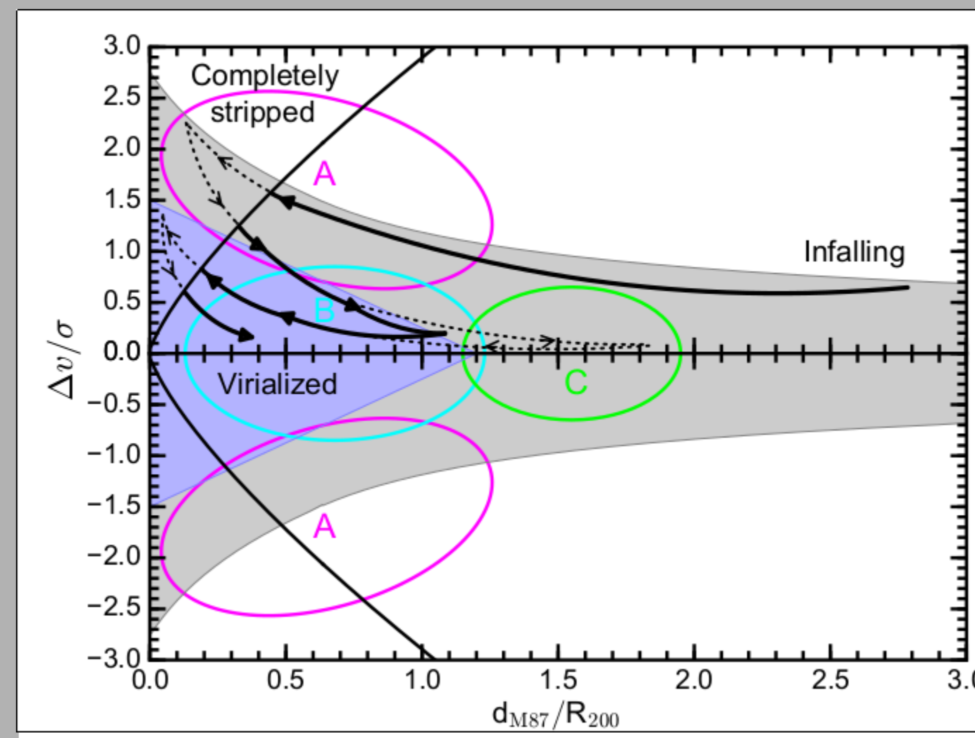


(iii)

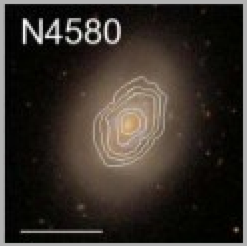


‘Before Ram pressure’ Sample
Extended gas rich disks in Phase-space

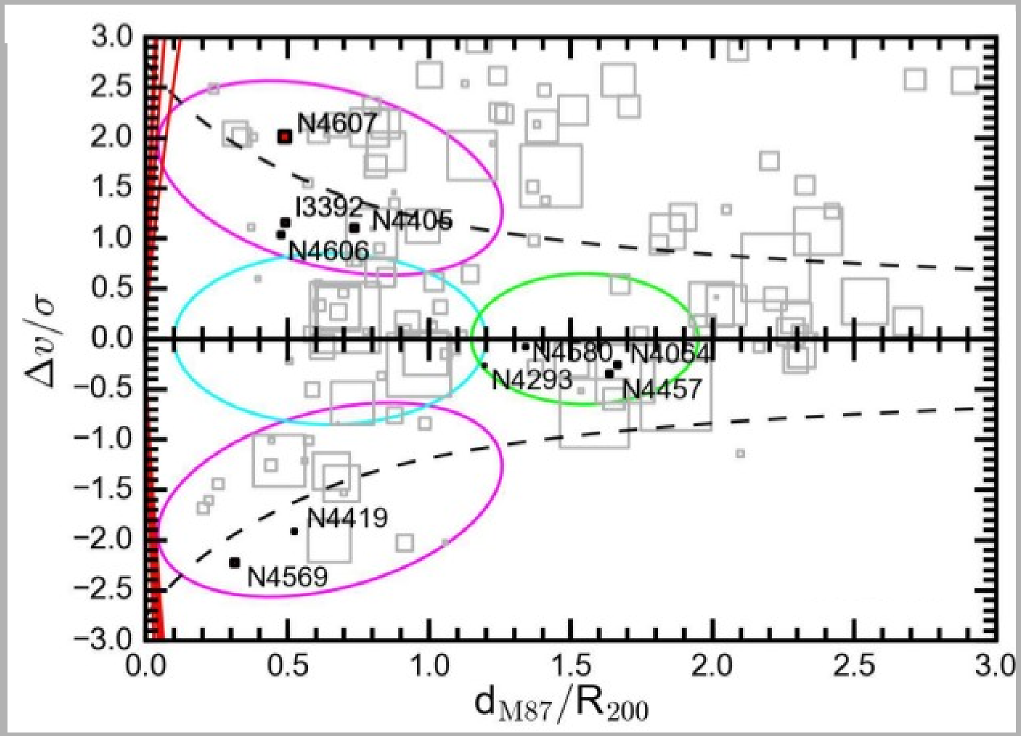


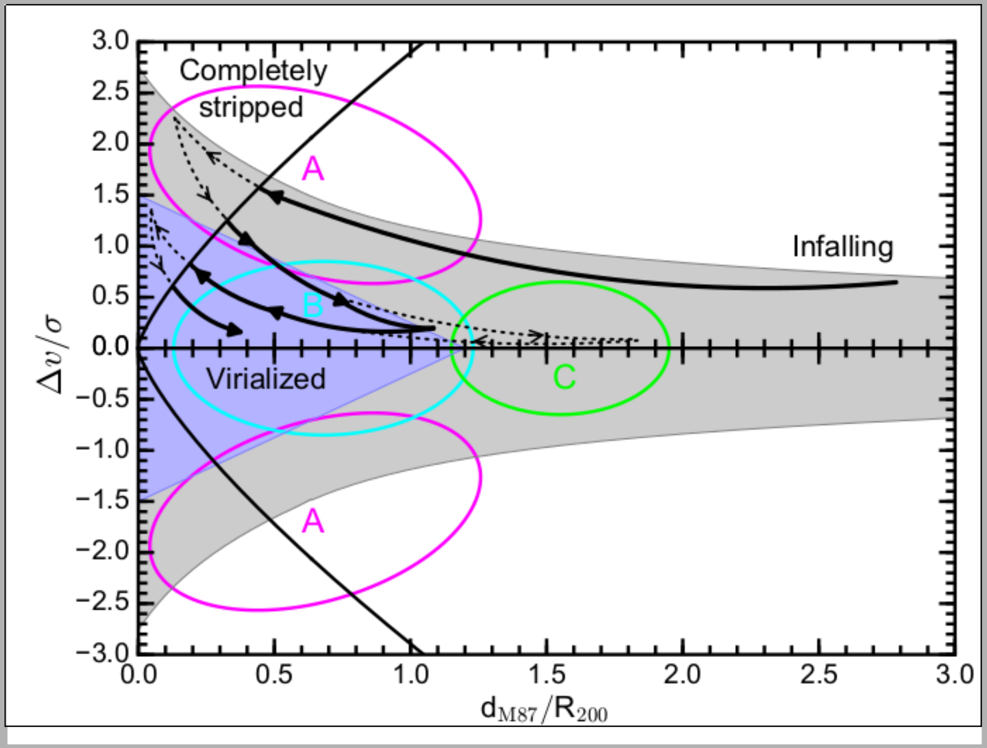


Yoon, Chung, Smith et al. 2017



‘After Ram Pressure’ in Phase-space: Heavily Truncated Gas Disks

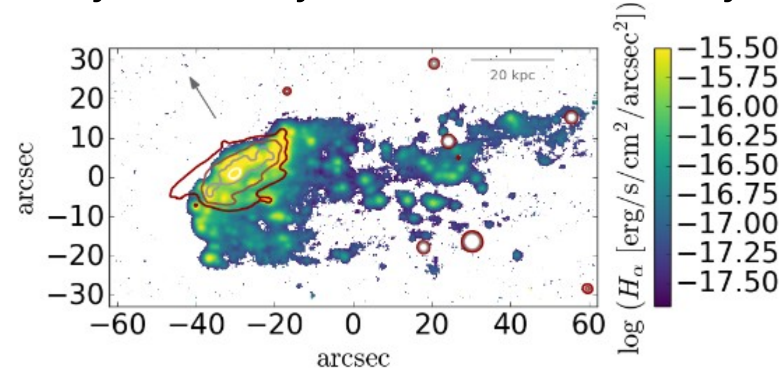




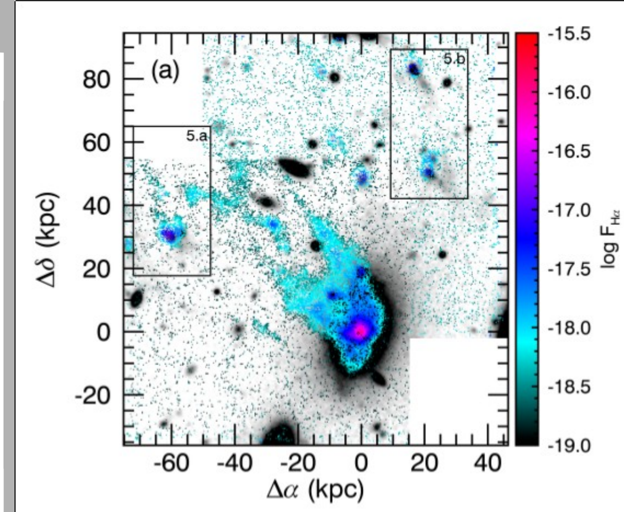
Yoon, Chung, Smith et al. 2017

Jellyfish galaxies in phase-space

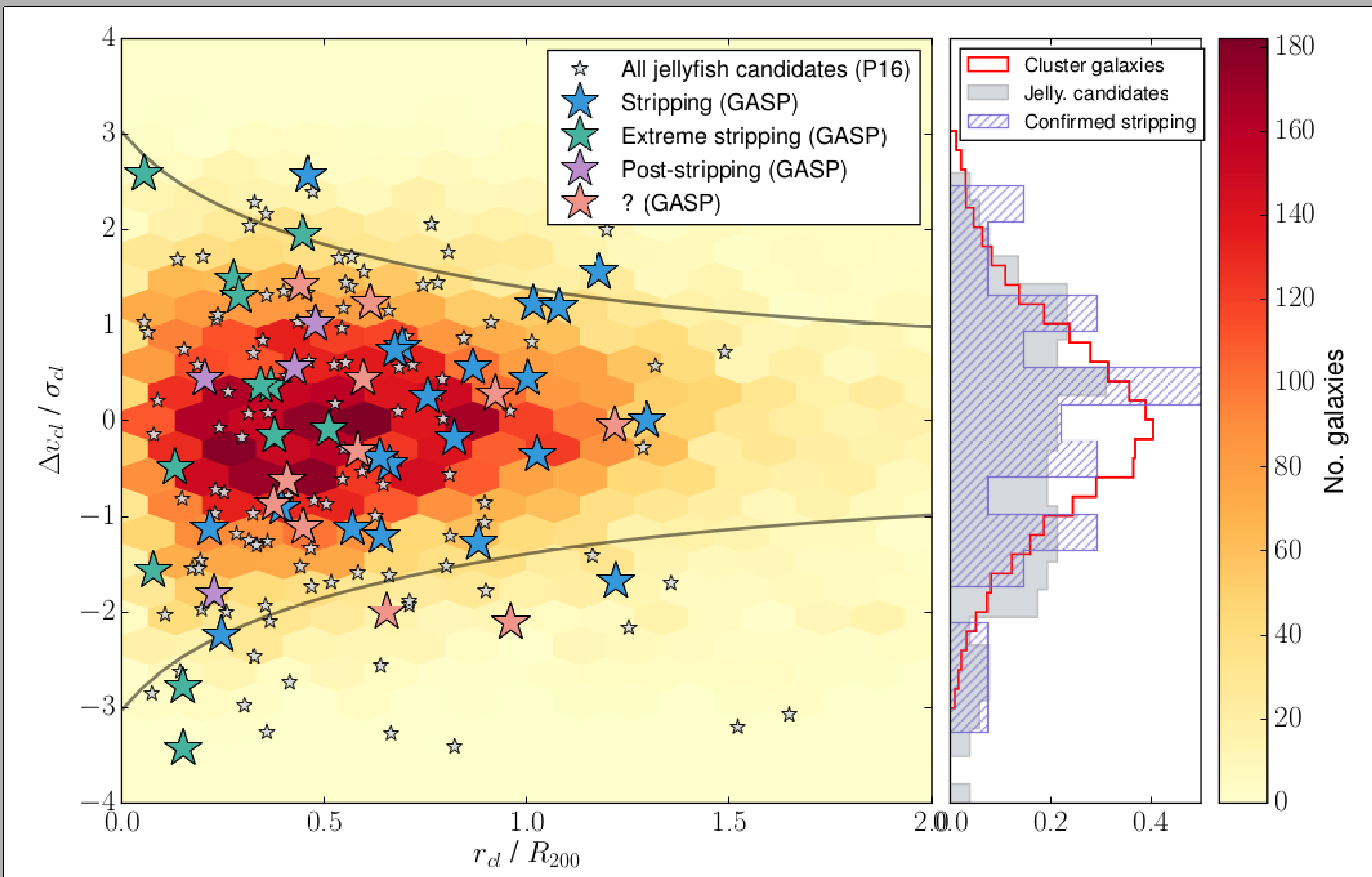
Jelly Fish Galaxy JO206 from GASP survey



(Poggianti et al. 2017)



Sheen, Smith et al. 2017



2D distribution of Jelly's differs from that of rest of galaxies -

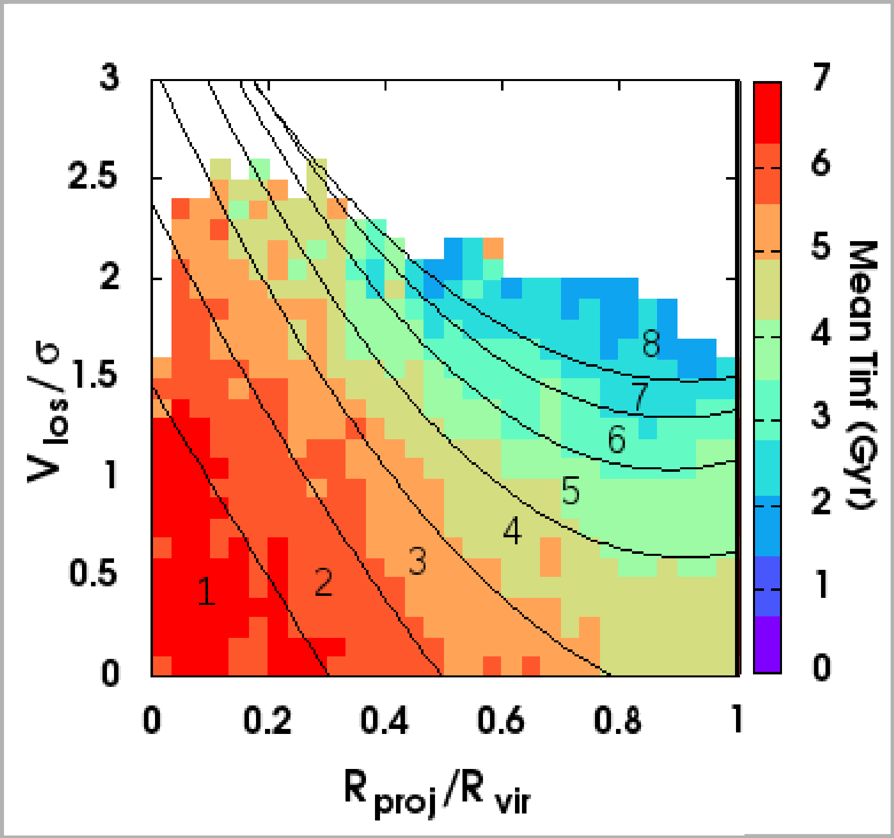
Jaffe et al. 2018

Mean properties in Phase-space zones from simulations:

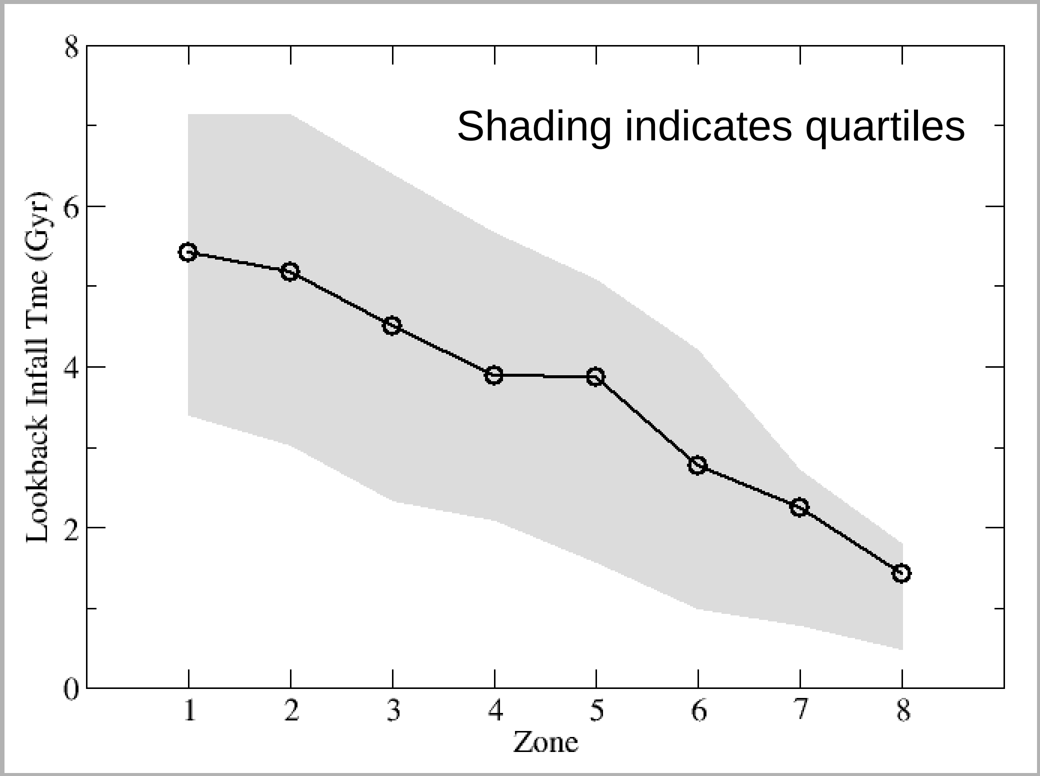
For application to large samples of clusters and groups

Anna Pasquali, Heidelberg

Mean infall time in phase-space:



Time since infall vs zone:



Pasquali, Smith et al. 2018 (submitted)

Mean properties in Phase-space zones from simulations:

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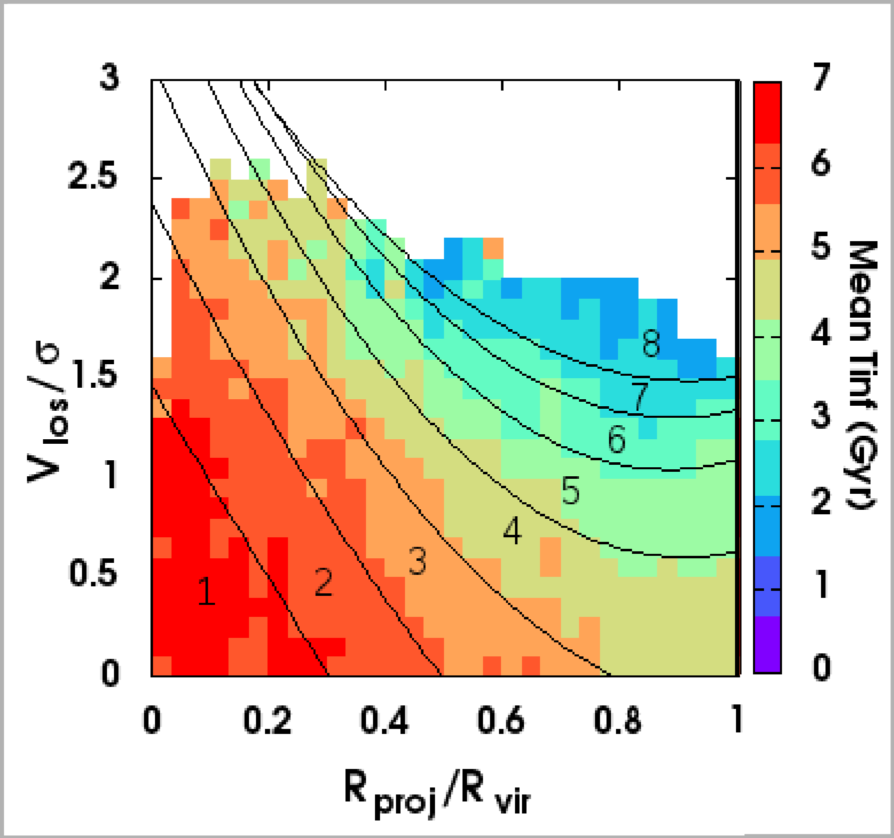
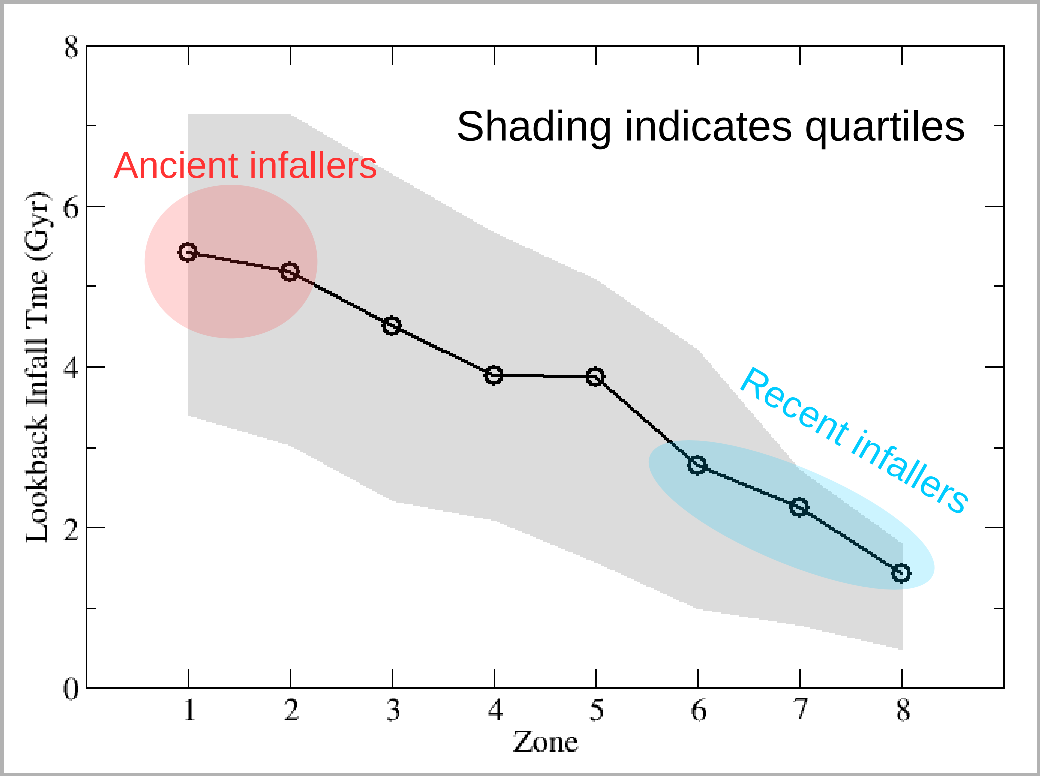
Mean infall time in phase-space:



Time since infall vs zone:



Pasquali, Smith et al. 2018 (submitted)

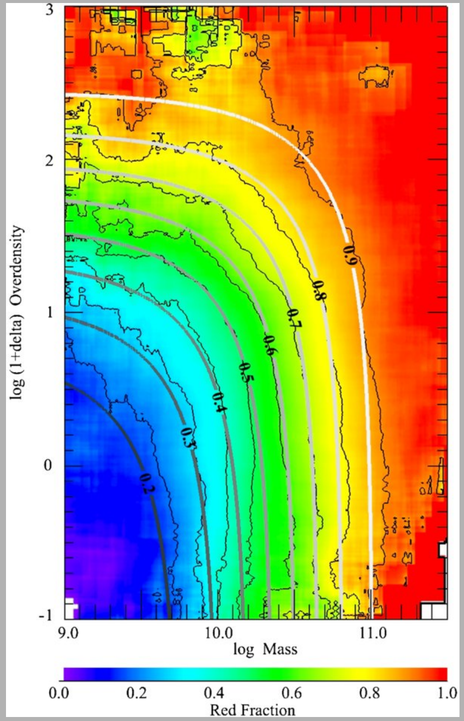
SDSS Galaxy properties across Phase-Space:

Anna Pasquali, Heidelberg

Applied to Wang et al. 2014 group catalogue:

- Host masses from giant galaxies to massive clusters: log(Mhost)=12 -15

- Satellites from dwarfs to giant galaxies: log(M*)=9-12.5



Peng et al. 2010

Galaxy properties from Gallazzi 2018 catologue:

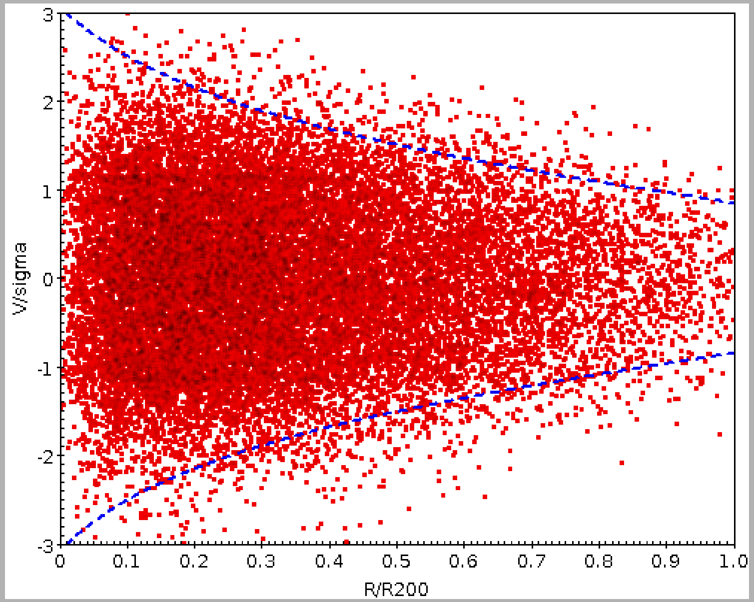
- PDFs derived from SDSS DR7 spectra

- Luminosity weighted age, Age_L

- Specific star formation rate, sSFR

- Stellar metallicity, Z/Zsol

- Alpha abundances, α/Fe



Total sample in Phase-Space (~30,000 galaxies)

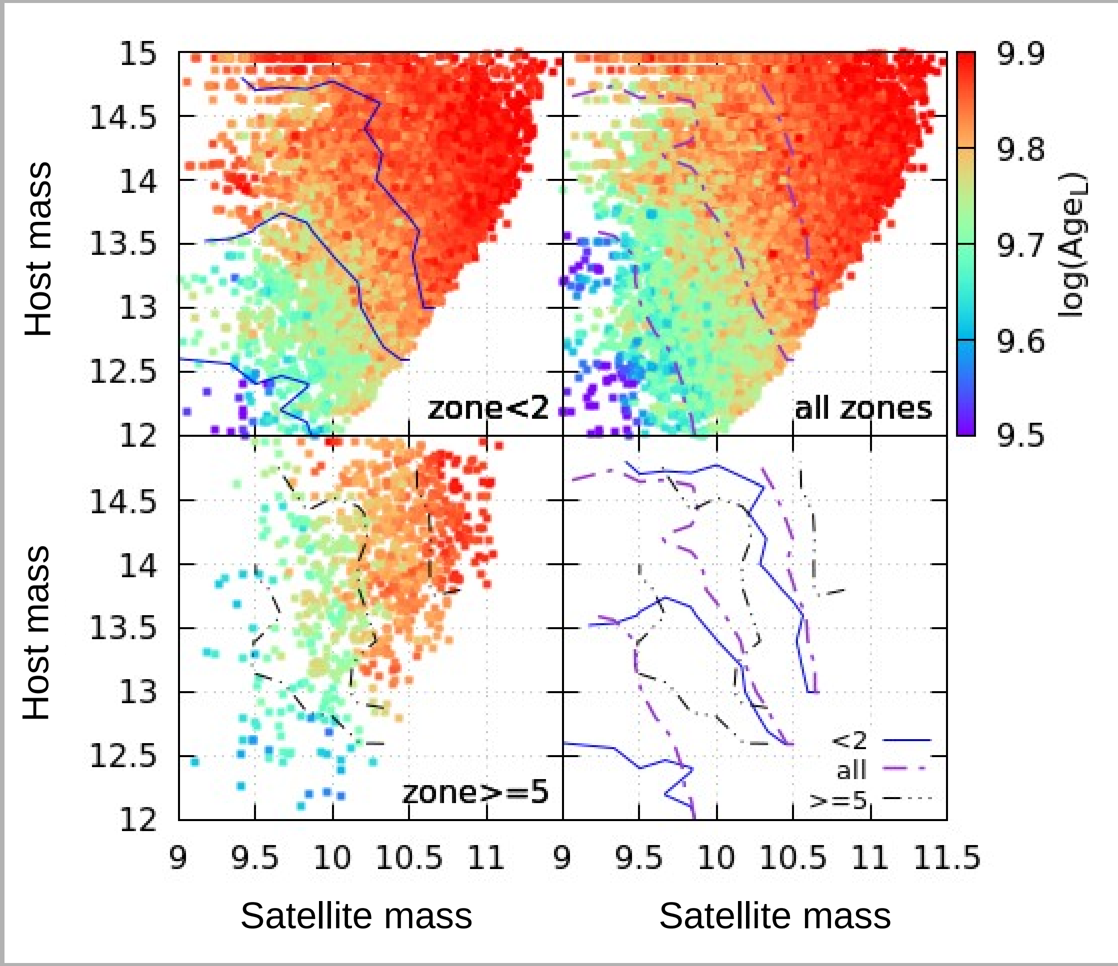
Mean properties in Phase-space zones:

Anna Pasquali, Heidelberg

Luminosity weighted age:

Ancient infallers

Recent infallers



Pasquali, Smith et al. 2018 (submitted)

Mean properties in Phase-space zones:

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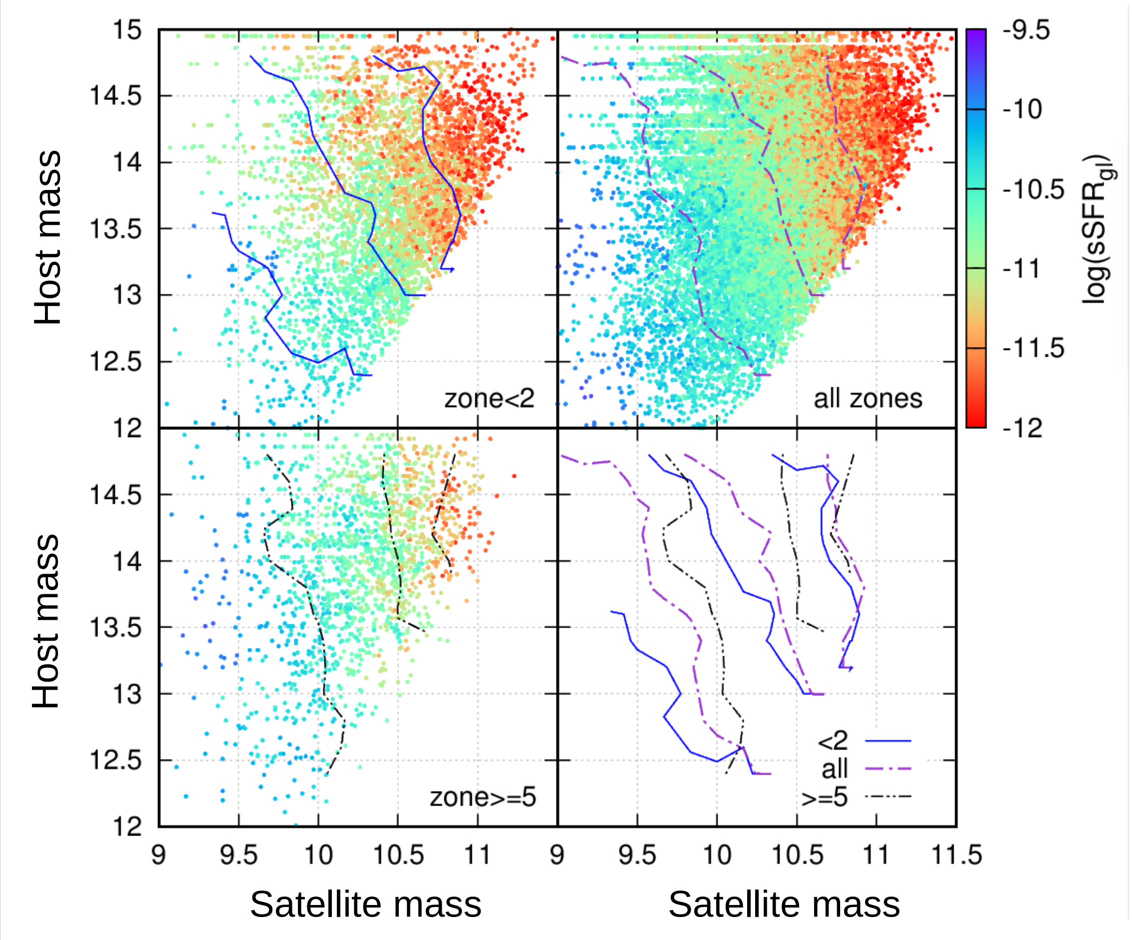
Specific Star Formation Rate (sSFR):

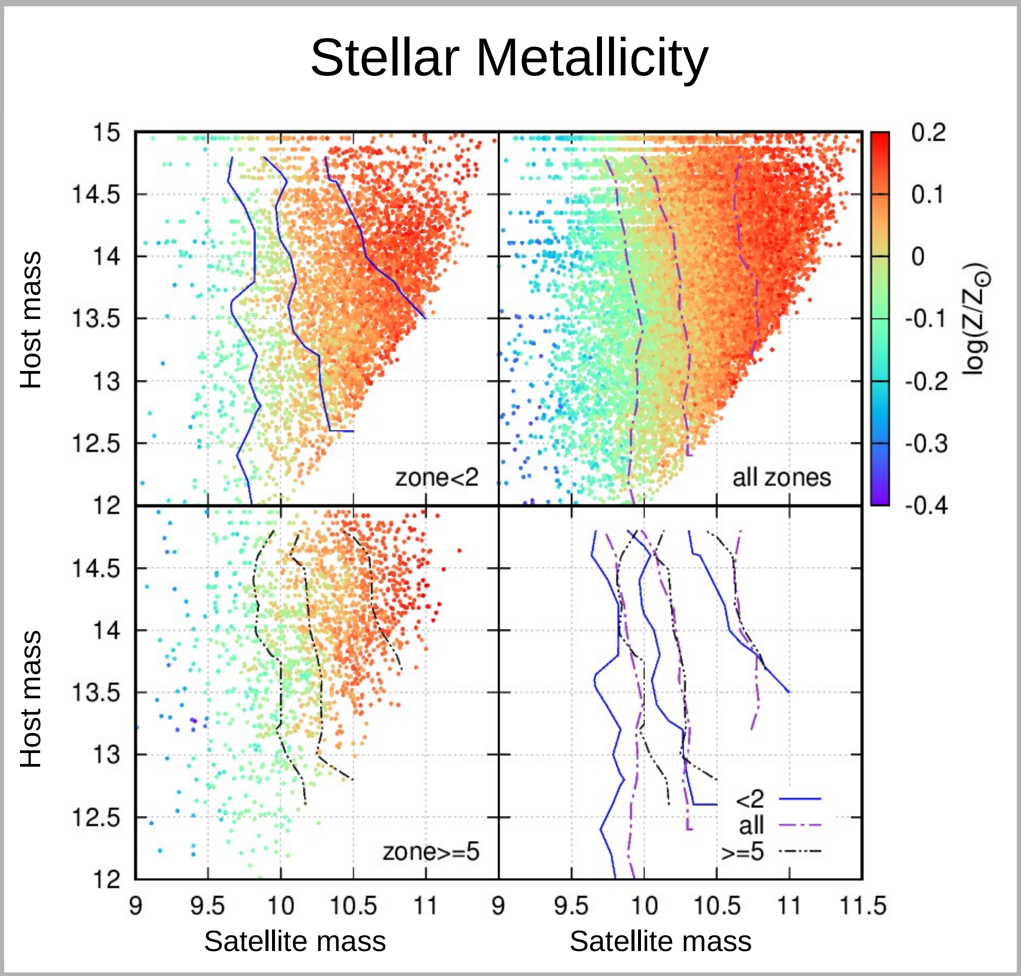
Ancient infallers

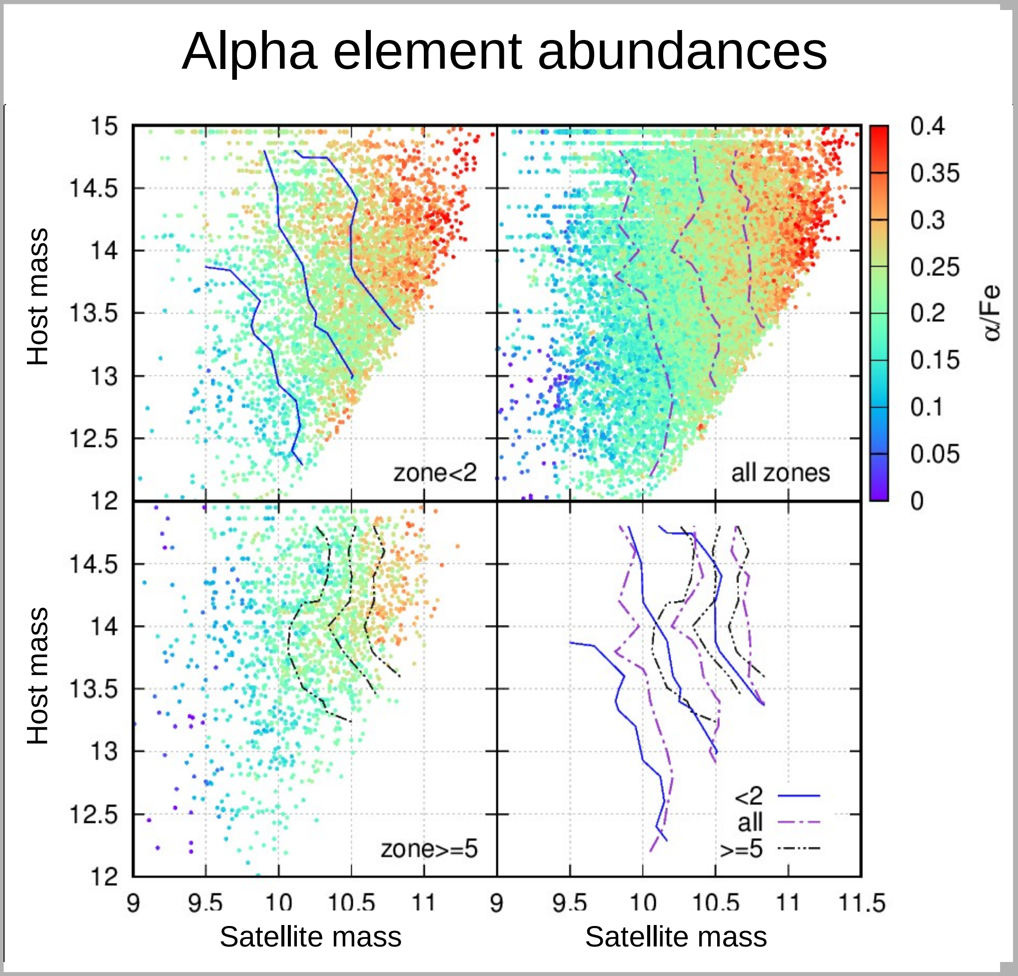
Recent infallers



Pasquali, Smith et al. 2018 (submitted)

Metallicities by infall time:

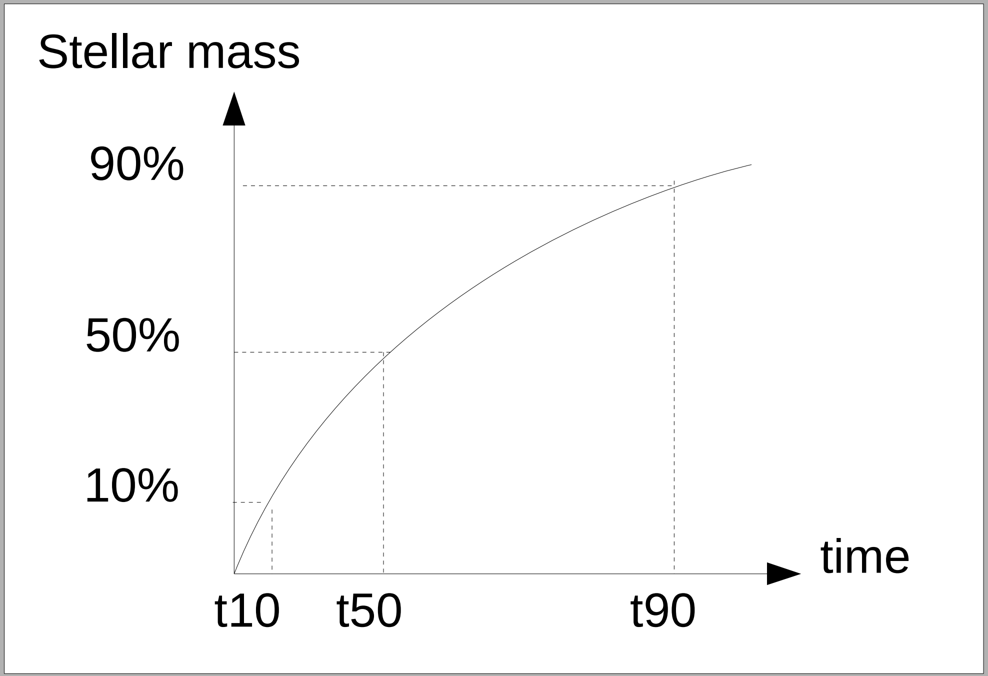




Pasquali, Smith et al. 2018 (submitted)

Camilla Pacifici
NASA Goddard

Stellar Mass growth History



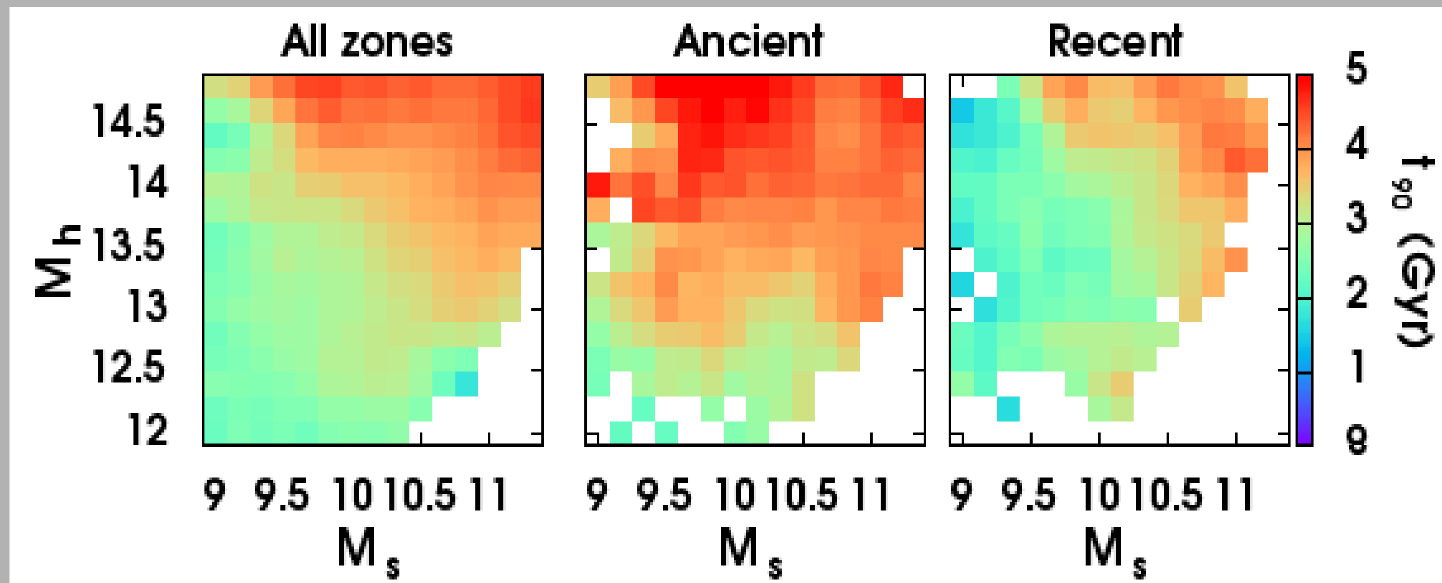
SED fitting for ~200,000 SDSS galaxies:

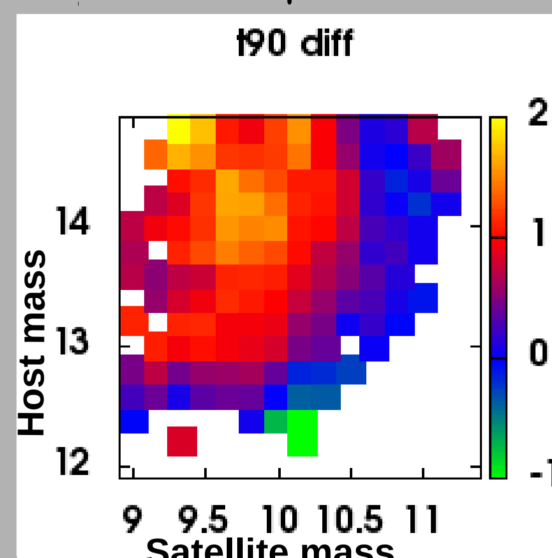
- SEDs combining NUV, optical, IR
- Constrain star formation history and stellar mass growth evolution
- Details in: Pacifici et al. 2016
- Mass growth history parameterised: → t10, t50, t90

(lookback times when 10, 50 and 90% of final stellar mass was assembled)

Camilla Pacifici
NASA Goddard

Stellar Mass growth History





Differences in satellite mass growth resulting from time spent in their host:

Summary

- **Location in phase-space provides information on infall-time, tidal mass loss & ram pressure stripping**

- **Best results are statistical: many clusters, many galaxies, many lines-of-sight**

- **First results from phase-space very promising**
  → results make sense
  → clear changes in galaxy properties when varying infall time distribution *(at fixed mass and environment)*

- **Extend approach to:**
  → Other galaxy properties (shapes, morphology, colour & density profile, LSB features, SFHs
  →Other samples: (higher redshift, groups, deep and/or high resolution imaging, IFU surveys (e.g. GASP, SAMI), etc