RAM PRESSURE TRIGGERS AGN IN GALAXY CLUSTERS

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AGN & STAR FORMATION

- Radiative-mode AGN occur due to fuelling of central supermassive black hole by gas
- Need to funnel gas to central regions to trigger AGN activity
- Both star formation and AGN activity need cold gas - fundamental link, same trigger?
  (e.g. Di Matteo, Springel & Hernquist 2005, Schawinski et al. 2007)

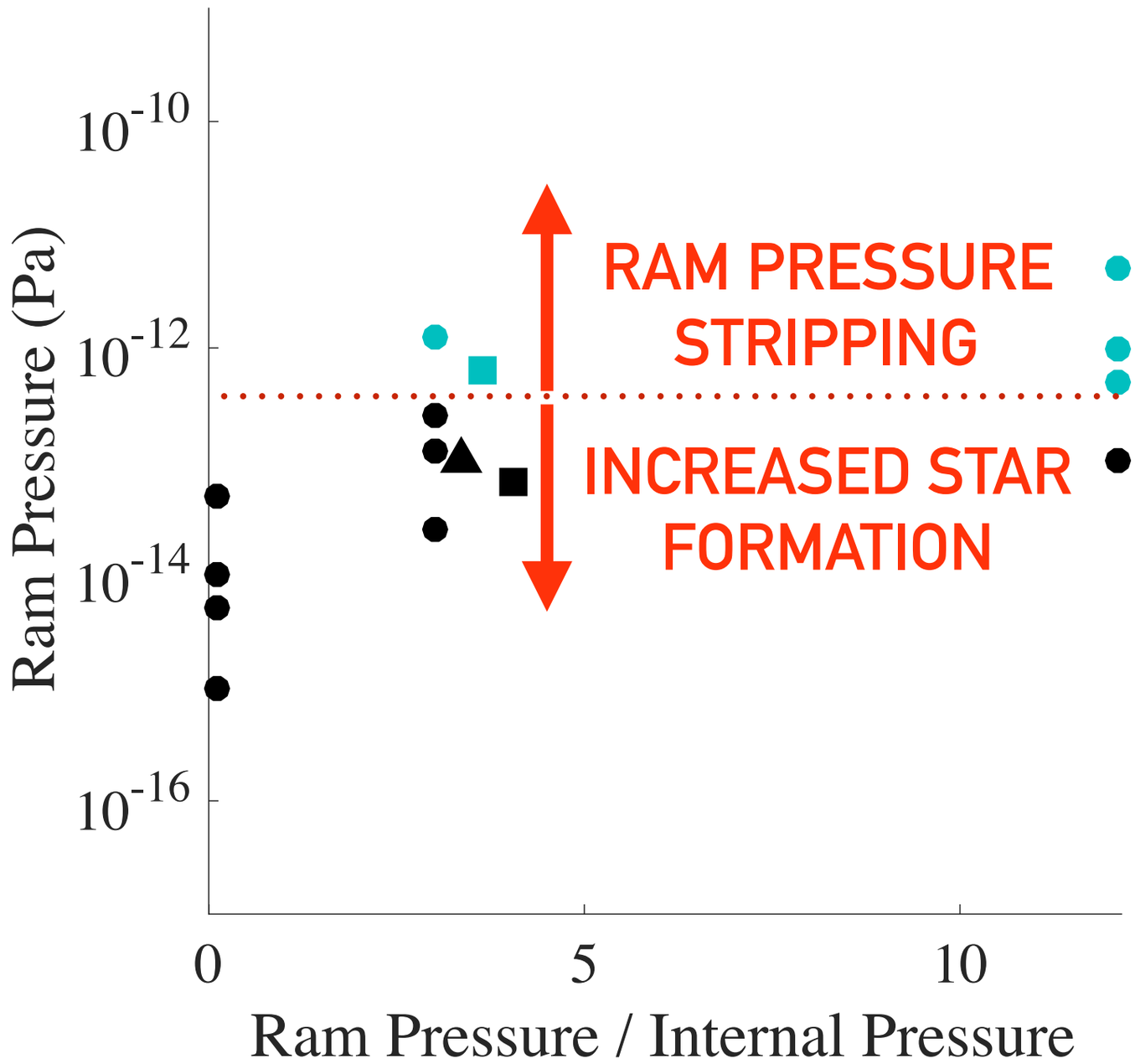
RAM PRESSURE

- Hydrodynamical simulations show ram pressure

$$P_{\mathrm{ram}} = \rho v^2$$

can increase star formation

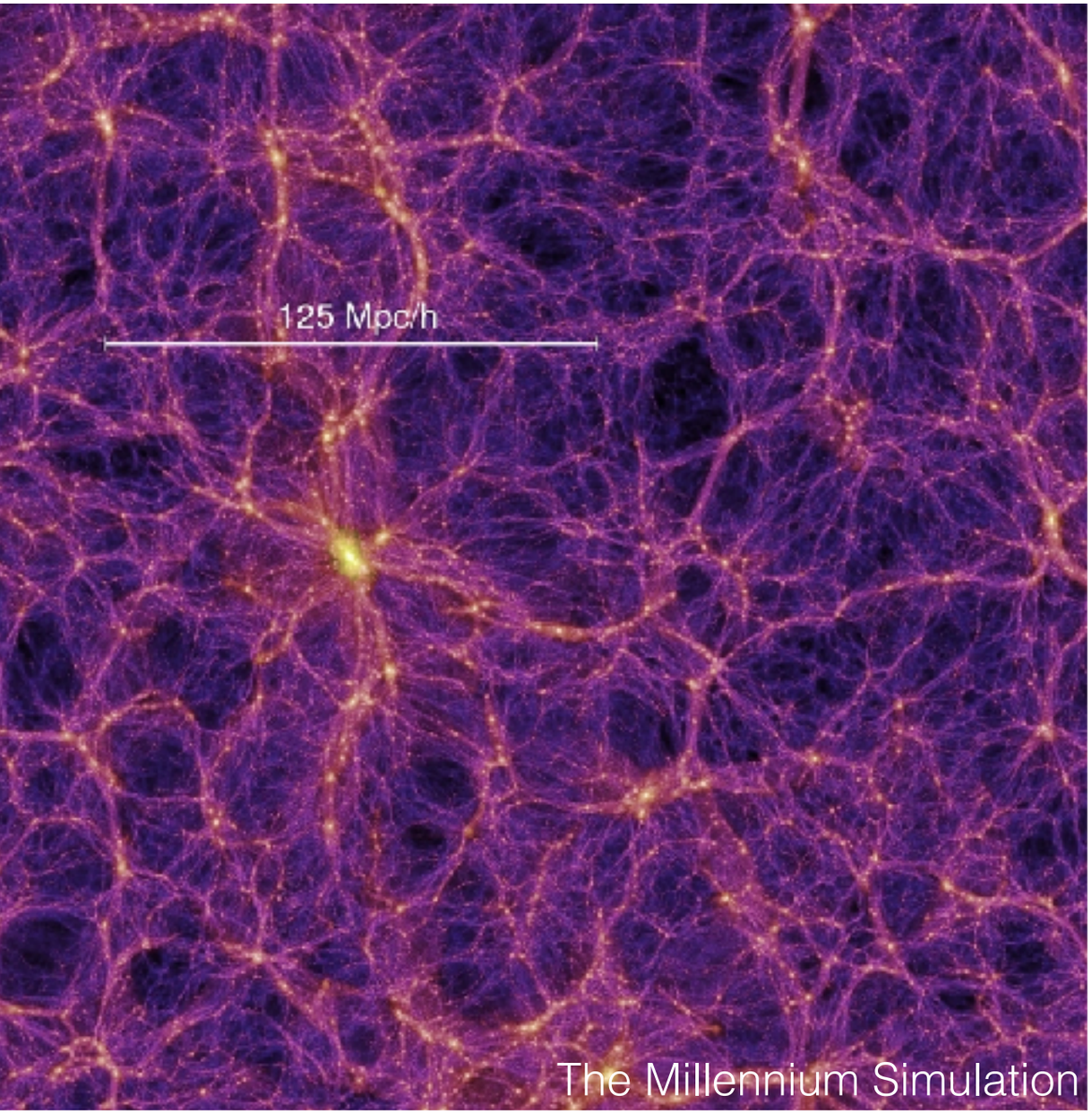
- Can trigger AGN too?
  - Cause angular momentum loss in gas clouds?
  - Trigger gravitational instabilities?



OUR WORK (Marshall et al. 2018)

- Took galaxies from semi-analytic model SAGE (Croton et al. 2016)
- Modelled the triggering of AGN in clusters based on ram pressure - see where in clusters these would be
- Compared to SDSS observations of z<0.09 clusters (Pimbblet et al. 2013)
- Find that ram pressure explains the observed locations of AGN in clusters well - a plausible AGN trigger!

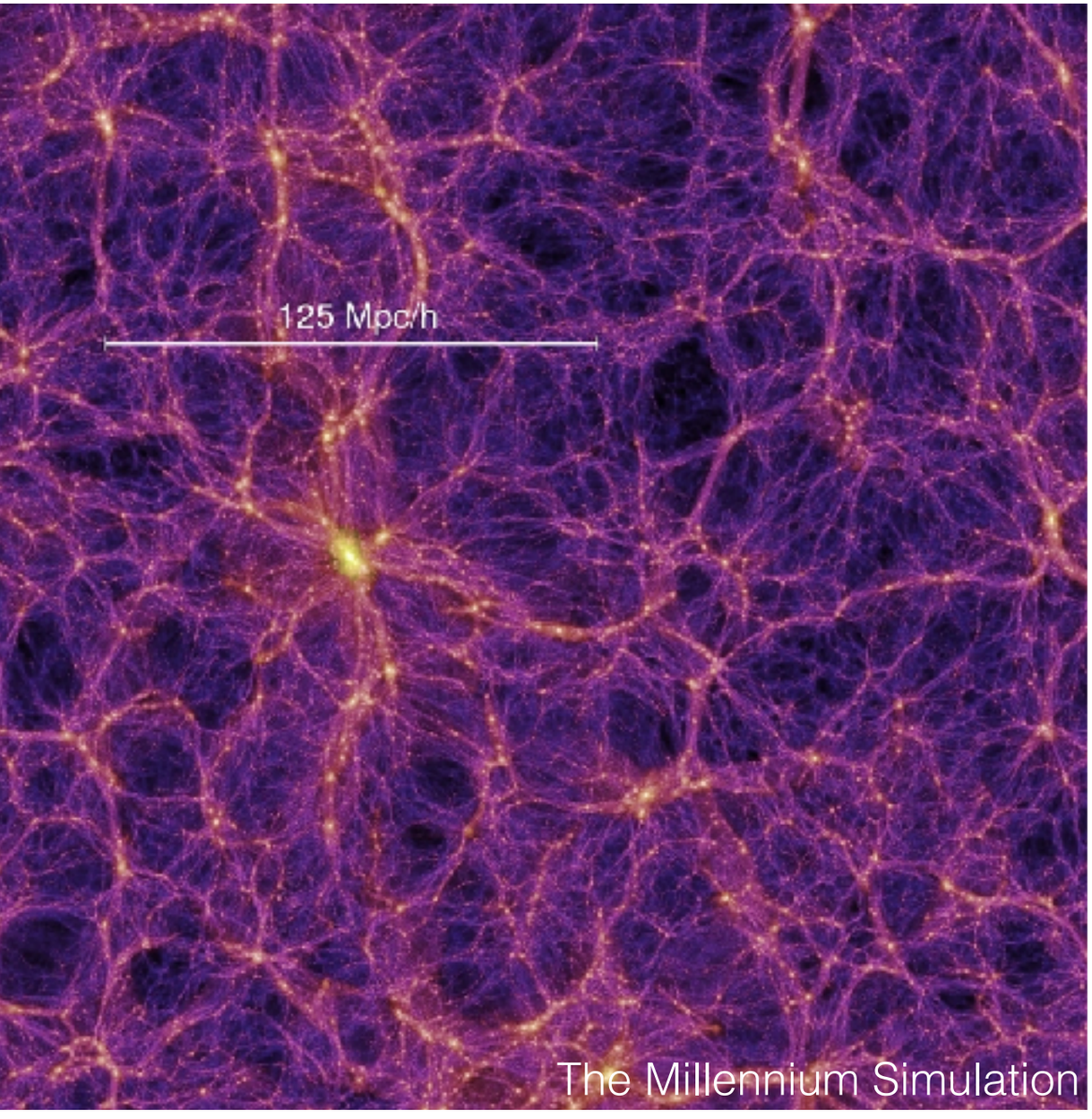
THE DATA: SIMULATIONS



The Millennium Simulation

- Use simulated galaxies from the Semi-Analytic Galaxy Evolution Model (SAGE; Croton et al. 2016)
  - Based on the Millennium Simulation (Springel et al. 2005)
  - Models baryonic physics to give estimates for galaxy properties
- Sample of galaxies matches the observational sample: choose ~34000 galaxies in ~1000 clusters at z = 0

THE DATA: SIMULATIONS



- Model ram pressure AGN triggering using simulated galaxies:
  - Approximate cluster density profile using Chandra observations (Fujita et al. 2006; Vikhlinin et al. 2006)
  - Known galaxy velocity & assumed ICM density profile → ram pressure
  - Internal disk pressure: assume pressure equilibrium with the surrounding ICM

TRIGGERING MODELS

- Trigger AGN when

$$P_{\rm low} < P_{\rm ram} < P_{\rm high}$$

and

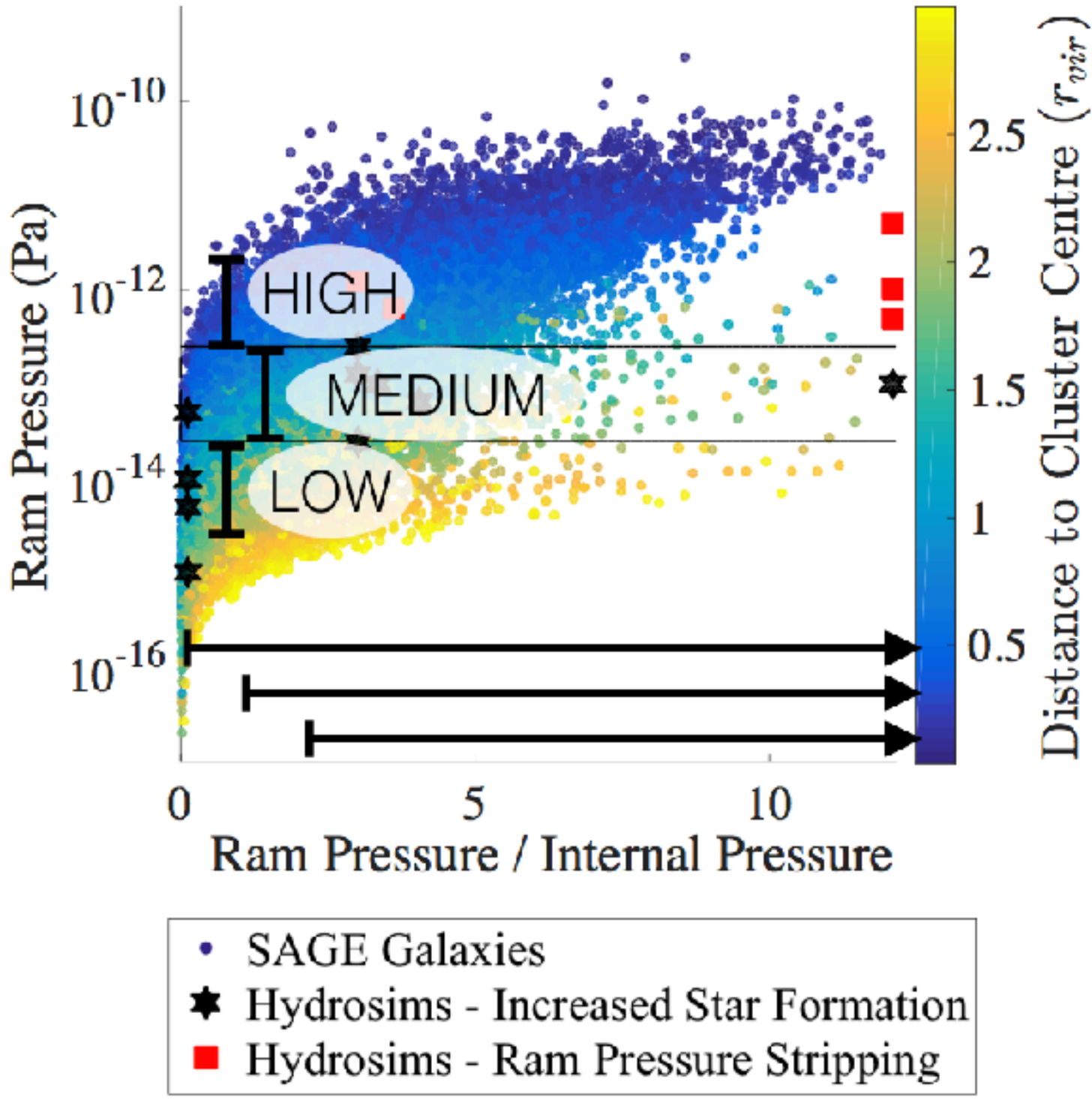
$$P_{\rm ram}/P_{\rm internal} > \text{threshold}$$

- 3 different ram pressure ranges:

P_{low} (Pa)	P_{high} (Pa)
2.5e-15	2.5e-14
2.5e-14	2.5e-13
2.5e-13	2.5e-12

- 3 different ratio thresholds:

$$\text{threshold} = 0, 1, 2$$



THE DATA: OBSERVATIONS

- Use Pimbblet et al. (2013) data of 6 clusters from the SDSS

$$4.3 \times 10^{14} < M_{vir} < 9.2 \times 10^{14} M_{\odot}$$

$$0.070 < z < 0.089$$

$$M_{*} > 10^{10.4} M_{\odot}$$

$$M_{r} < -19.96$$

$$r < 3 r_{vir}$$

THE DATA: OBSERVATIONS

- Classify AGN using emission-line diagnostics
- Also select galaxies with excessive star formation
- Exclude those that appear morphologically disturbed, pair galaxies and those in substructure
- Left with 18 AGN/star-formers

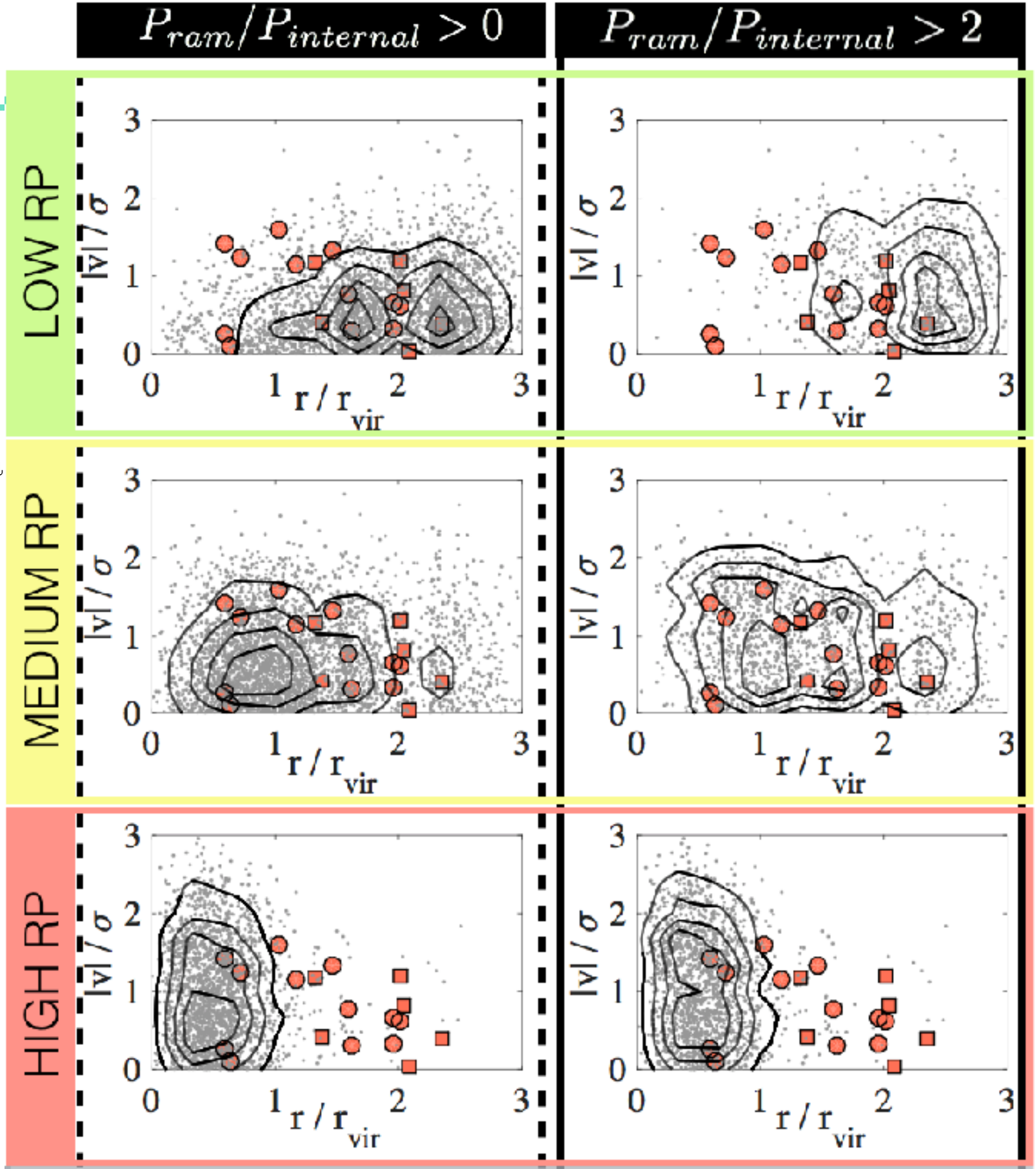
RESULTS

- Compare distribution in (projected) radius - velocity space

- Best fitting model:

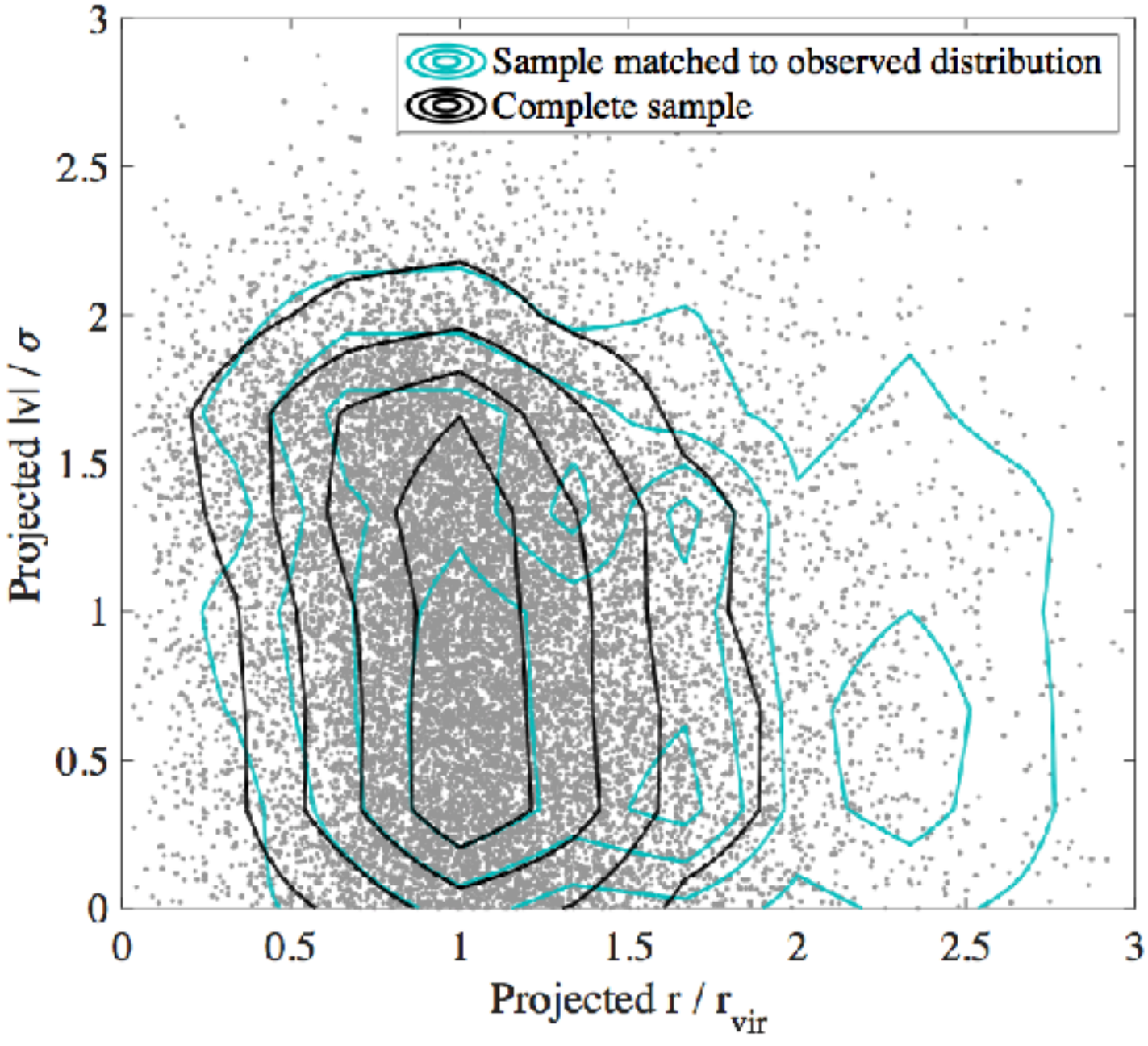
$$2.5 \times 10^{-14} < P_{\rm ram} < 2.5 \times 10^{-13} {\rm Pa}$$
$$P_{\rm ram}/P_{\rm internal} > 2$$

- Consistent with pressures that increase star formation



Simulated AGN
Contours of Number Density of Simulated AGN
Observed AGN
Observed Intense Star-Formers

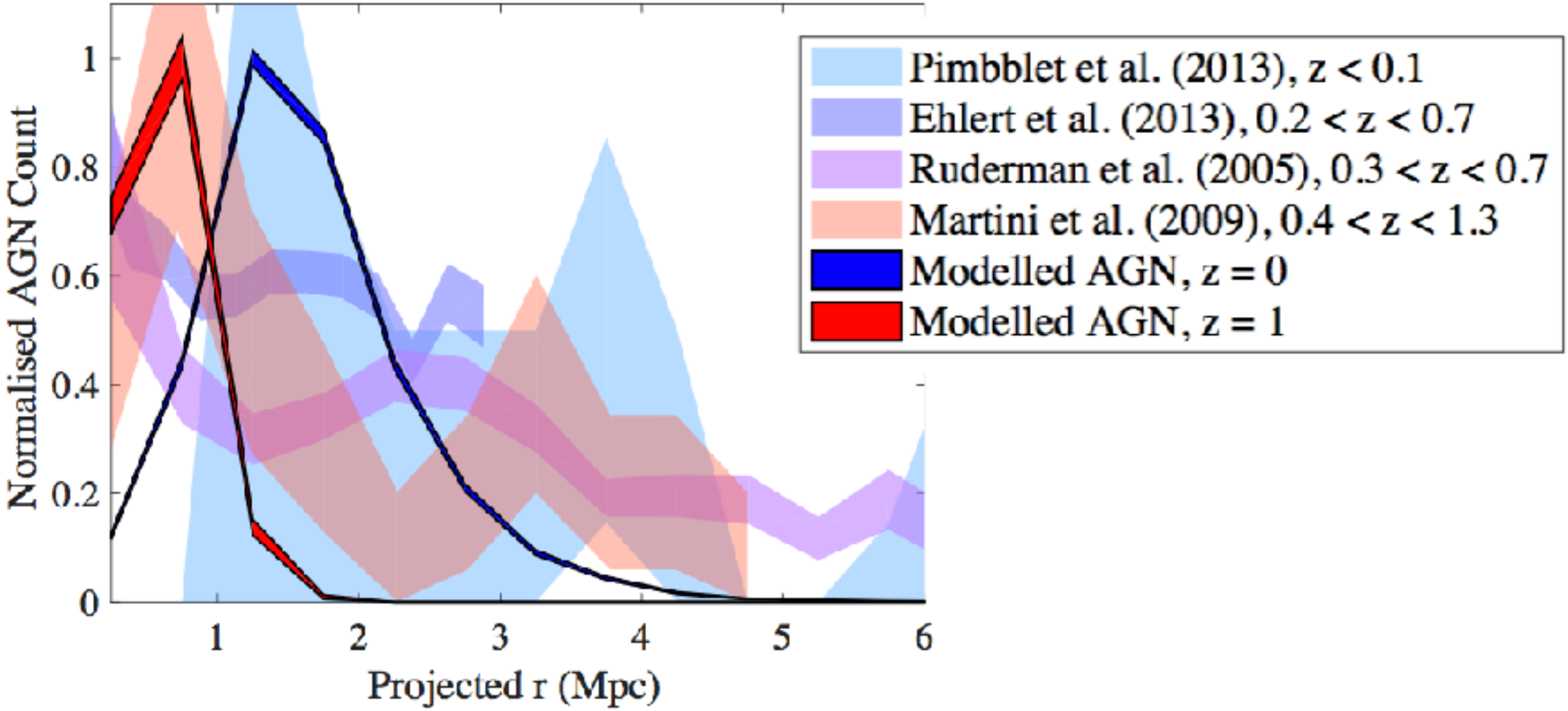
TRUE (UNMATCHED) DISTRIBUTION



- Simulated galaxies which matched the radial distribution of observations
- SAGE has many more galaxies at low radius
- Spectroscopy results in not all galaxies being observed
- The AGN distribution for SAGE galaxies that don't follow the observational distribution is peaked around 1 r_{vir}

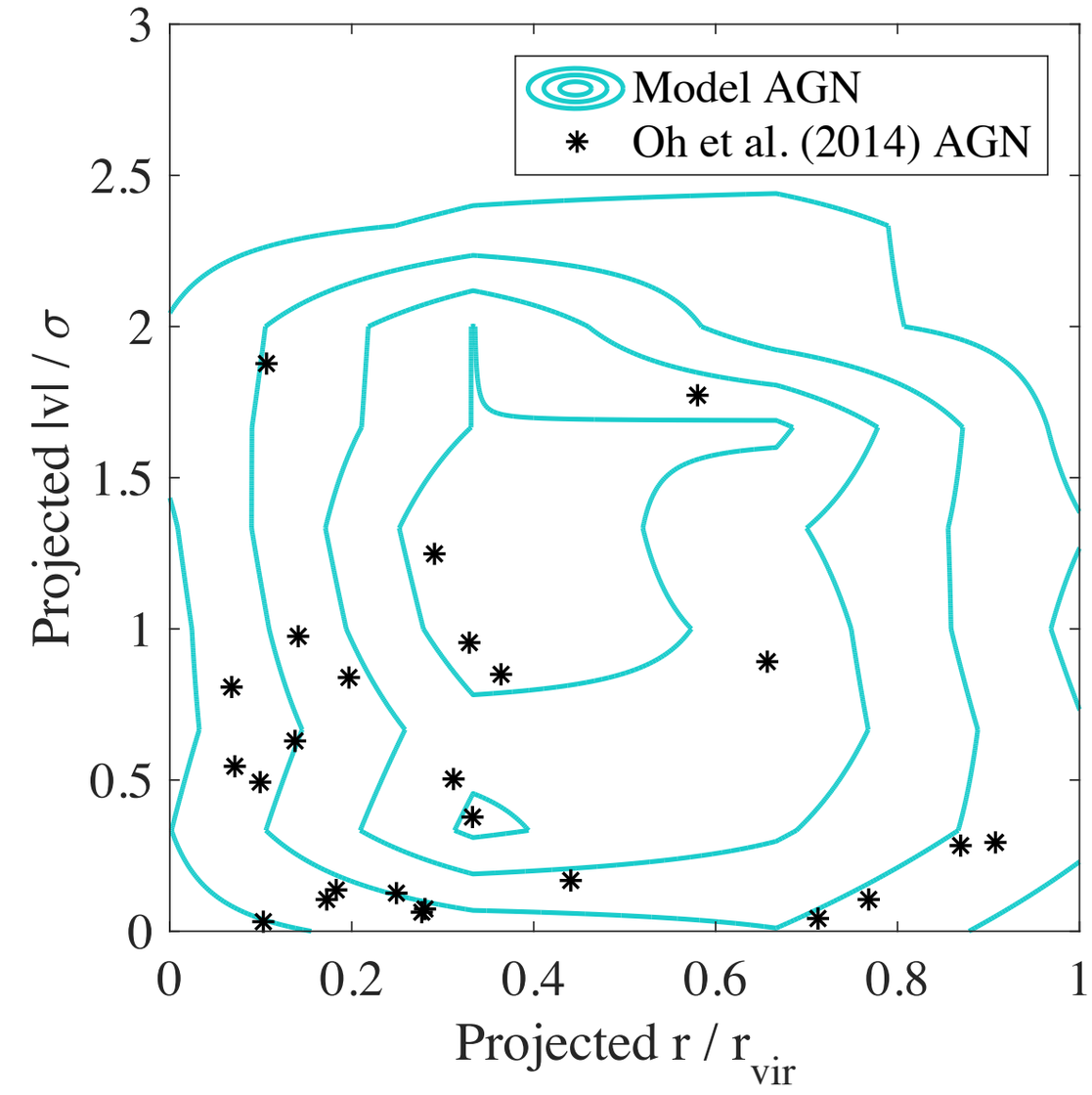
ADDITIONAL COMPARISONS/PREDICTIONS HIGH REDSHIFT CLUSTERS

- Extended model to predict distribution for z = 1 clusters
  - Shift of AGN to smaller physical radii at higher redshift (but larger fractions of the virial radius)
  - Reasonably consistent with higher redshift observations

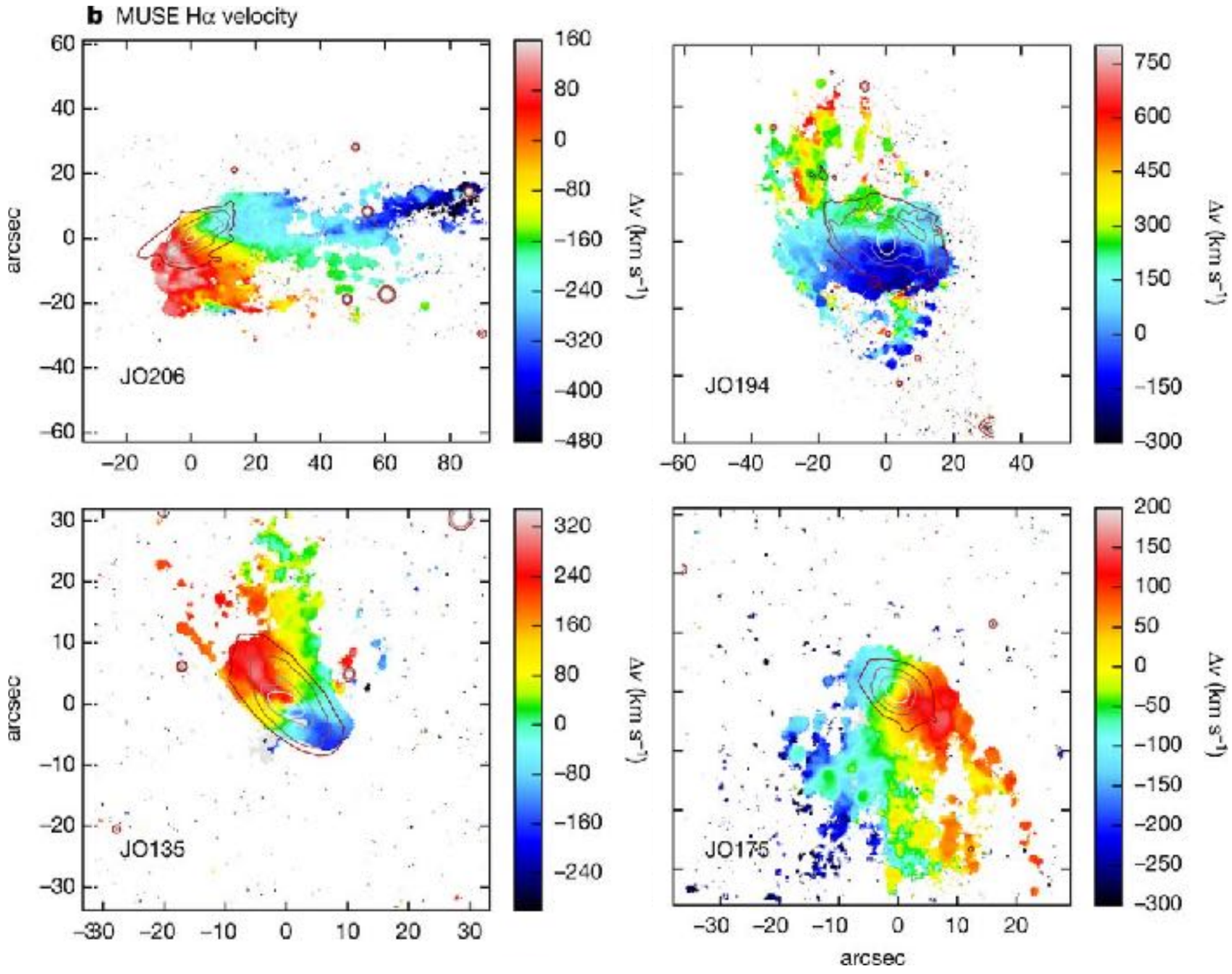


ADDITIONAL COMPARISONS/PREDICTIONS GALAXY GROUPS

- Reasonable agreement with Oh et al. (2014) X-ray AGN in galaxy groups, $12.7 < \log M_{\rm vir}/M_\odot < 14.5$, at $0.5 < z < 1.1$



RECENT OBSERVATIONS



Poggianti et al. 2017

- Six out of a sample of seven ‘jellyfish’ galaxies host an AGN

CONCLUSIONS

- Hydrodynamical simulations suggest that low ram pressures might lead to star formation → AGN activity?
- We test this using a semi-analytic model and comparing it to observations
- Locations of observed AGN in phase space can be explained by AGN triggering by intermediate ram pressures

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Madeline Marshall et al. (2018)