Galaxies in large-scale filaments in EAGLE simulation

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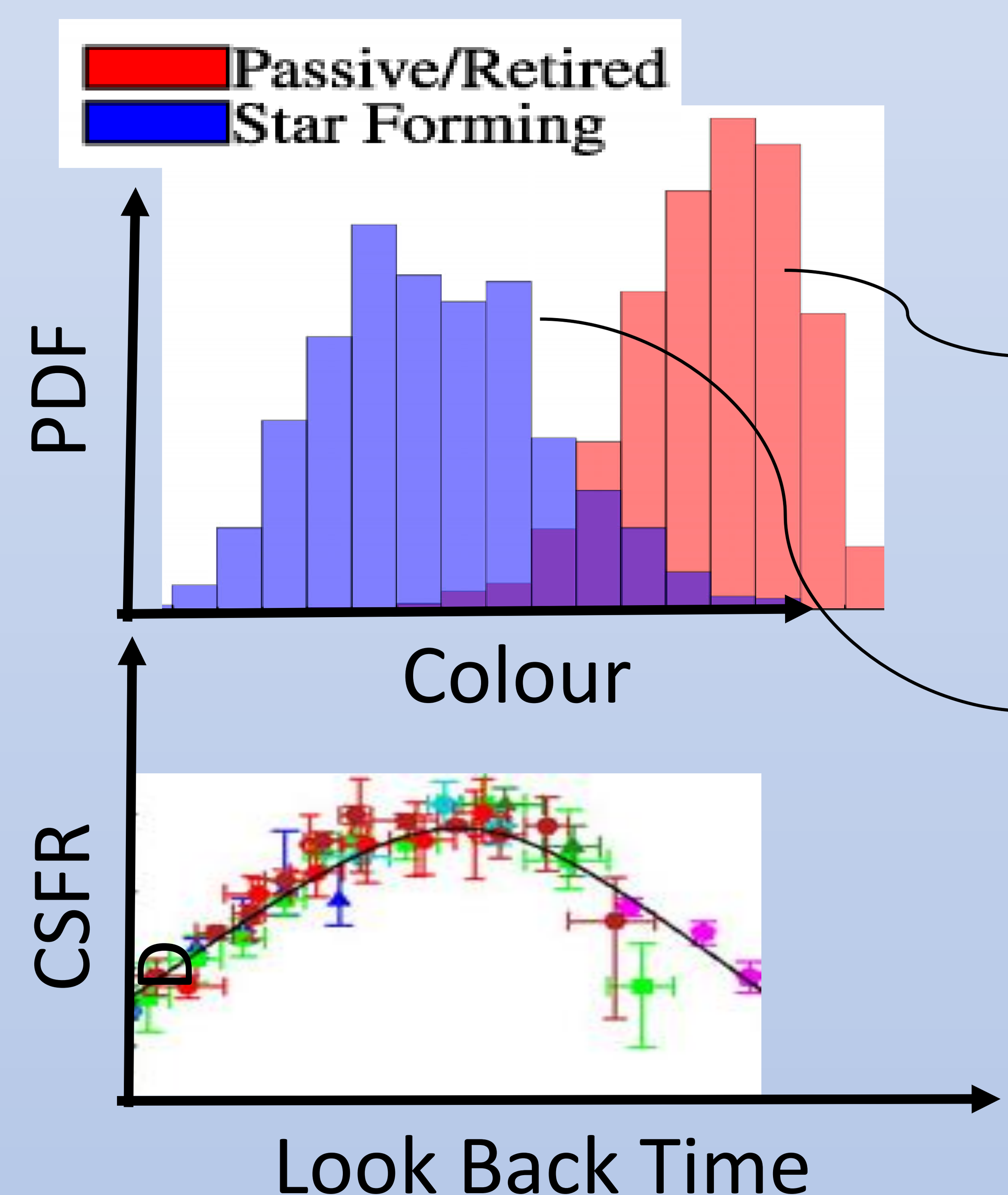
Background

- Galaxies can be broadly classified as actively star forming spiral galaxies (usually blue in colour) and passively star forming elliptical galaxies (usually red in colour).
- The density of rate of star formation in the Universe (CSFRD) decreased from its peak value 3.5 Gyr after the Big Bang.
- As gravity aggregates galaxies together, the number density of galaxies around a galaxy (quantified by environment) plays a crucial in role in his quenching of star formation rate.

Why filament environment?

- Galaxies in high density environment (cluster/group) form stars at less rate compared to low density environment (field).
- Observations: ½ of missing baryons in the Universe may reside as warm-hot intergalactic medium in large-scale filaments.
- Story of galaxy evolution is incomplete without knowing what happens in intermediate density environment (filament).

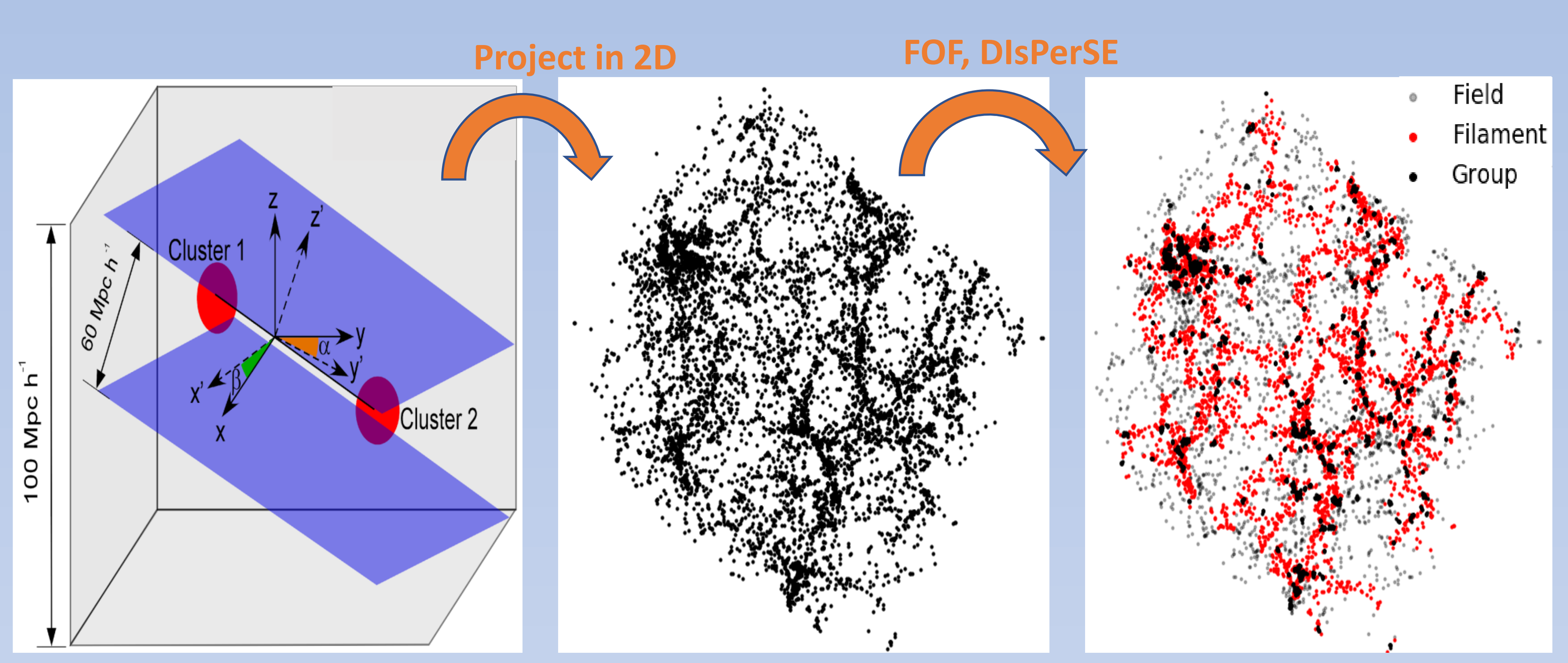


Credit: Penny et. al. 2015

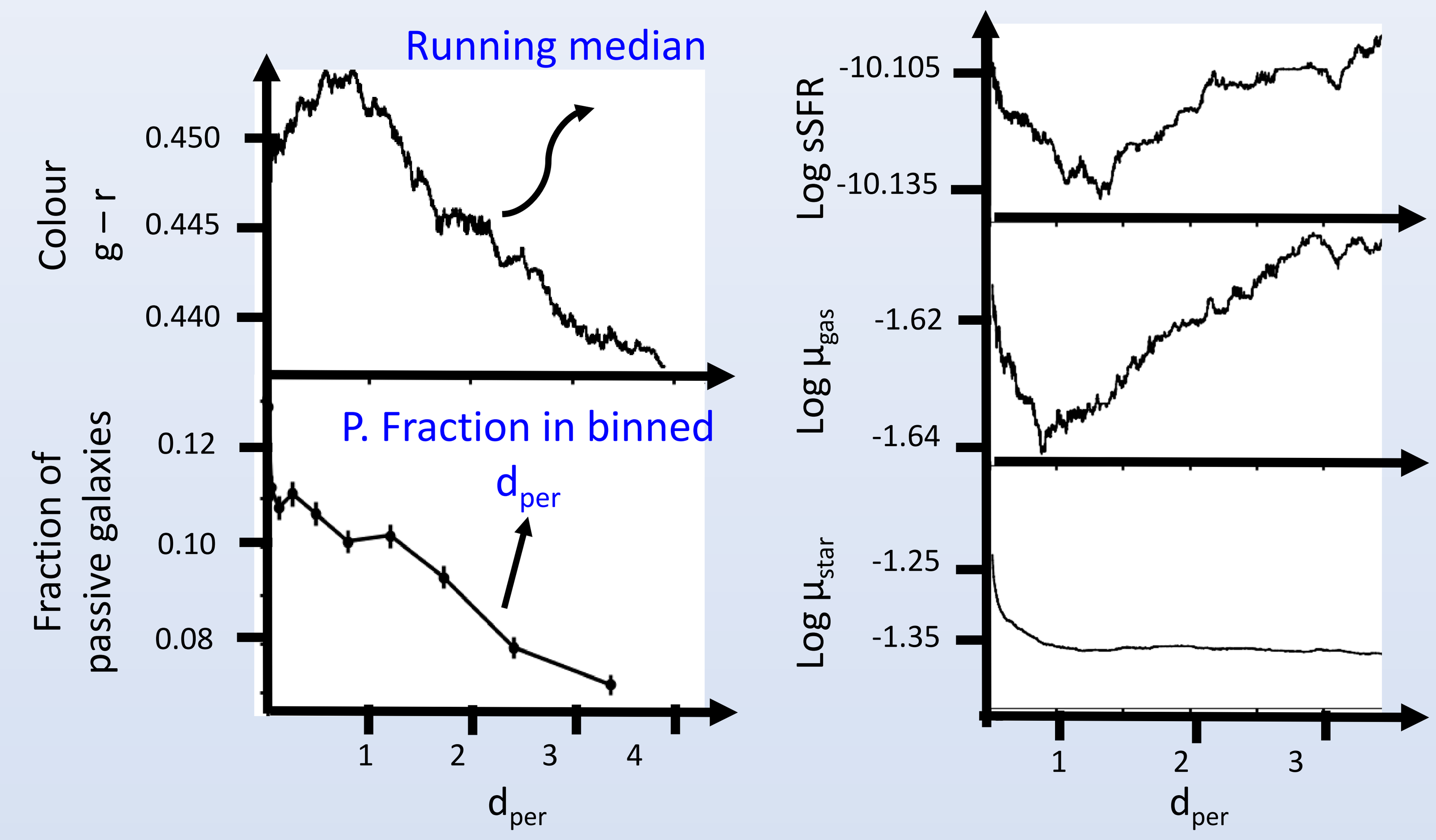
Credit: Madau P., Dickinson M., 2014

Mock Observations

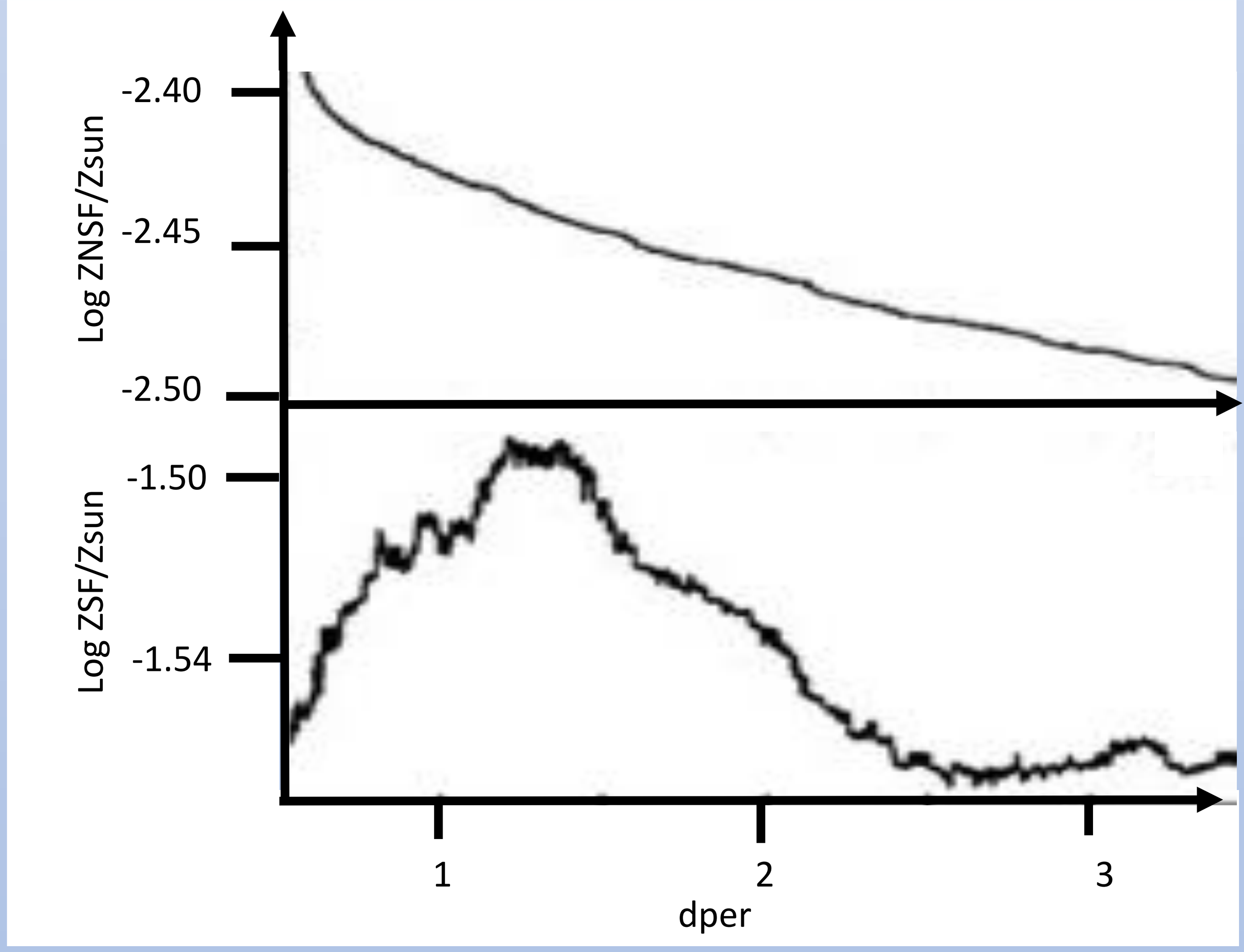
- Simulations provide all the information about the galaxies that form in them which helps in performing mock observations.
- We use Evolution and Assembly of GaLaxies in their Environment (EAGLE) simulation.
- We select two clusters with total mass (M) ≥ 10^{14} M_{sun} at a time and cut a slice of thickness 60 Mpc from the simulation box.
- Using Discrete Persistent Structures Extractor (DisPerSE) and friend-of-friend (FOF) algorithm we quantify the environment of a galaxy.
- For combinations of 9 clusters one gets 36 mock observations.
- We stack all the observations together and study the properties of galaxies as a function of perpendicular distance from the spine of the filaments (d_{per}).



Results



- The increase in colour saturates at ~1 Mpc from the spine of the filaments decrease in colour very close to the spine. Fraction of passive galaxies (with specific star formation rate (sSFR=SFR/M_{star}) < 0.01 Gyr^{-1}) increases with decreasing d_{per}
- sSFR and gas mass fraction (μ_{gas} = gas mass/total mass) decrease on approaching the spine of the filaments. Increase in stellar mass fraction (μ_{star} = stellar mass/total mass) on approaching.
- The star forming gas (Temperature ~10^4 K) metallicity (Z_{SF}) within $d_{per} \lesssim 2$ Mpc is elevated relative to gas further away.
- The non-star forming gas metallicity Z_{NSF}, on the other hand increases smoothly with decreasing d_{per} , indicating accretion of non-star-forming gas on the filament galaxies.



Conclusions

- Galaxies become redder and more passive closer to the central axis of the filaments. This trend is observed within a radius of 2 Mpc around the spine of the filament, thus providing an upper limit for the filaments' radius.
- The intrafilamentary gas condenses into the filament galaxies thus fuelling star formation in them.
- The trends in galaxy properties are a consequence of increased gravitational interactions between filament galaxies closer to the spine of the filament. This enhancement in the interaction rate is caused by an increased number density of galaxies closer to the centre of the filaments.

References

- Mahajan S., Singh A., Shobhana D., 2018, MNRAS, 478, 4336
- Singh A., Mahajan S., Bagla J. S., 2020, MNRAS, 497, 2265

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