Simulating Galaxy Clusters with Dust Formation and Evolution

ASTRO-TS
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Eda Gjergo

Second year PhD Student in Physics
(INAF scholarship)
Università di Trieste / Osservatorio Astronomico di Trieste

Primary Supervisor:	**Gian Luigi Granato**
Co-Supervisor:	Giuseppe Murante
Co-Supervisor:	Stefano Borgani

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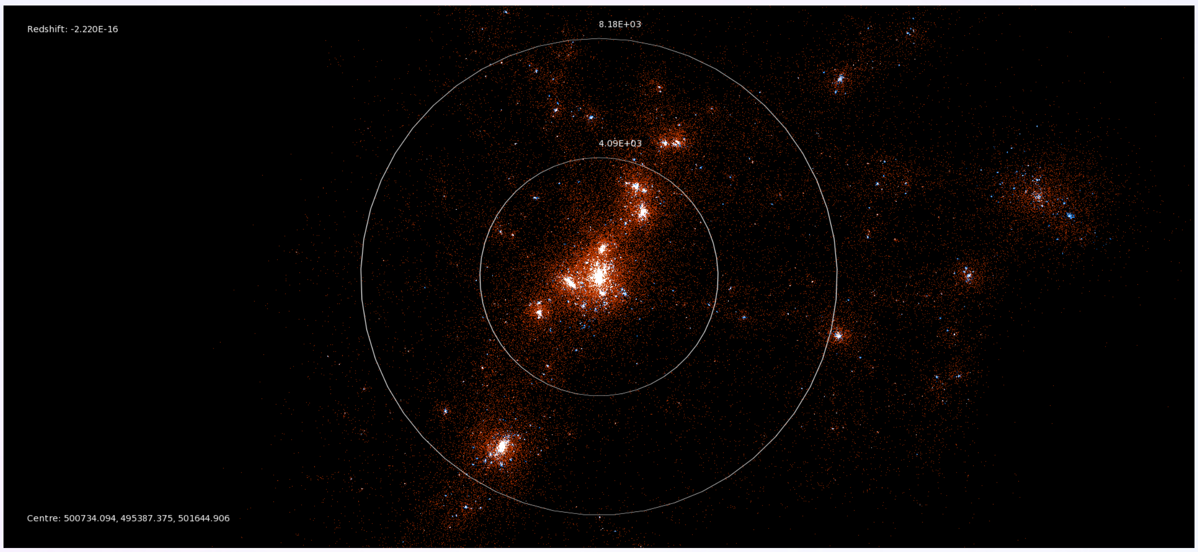
At the Observatory of Trieste:



- We run a private version of `GADGET-3` (Ragone-Figueroa+13) with:
  - Tree-PM + SPH.
  - AGN feedback.
  - Star formation and stellar feedback.
  - radiative cooling.
  - chemical evolution.

- 2 test regions extracted from DM-only simulation
- $M_{200} \simeq 3 \times 10^{14}\ M_{\odot}$.
- $M_{\rm gas} = 1.53 \times 10^{8}\ M_{\odot}$.
- $\sim 2 \times 10^{6}$ gas particles.

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What is dust, and why does it matter?

- Cosmic dust refers to small solid particles, with a range from a few molecules to $\leqslant 1\mu m$.

Figure: ©Hubble Space Telescope. Optical bands (left) Infrared bands (right).

- Most important dust property for us: it reprocesses light.
- Dust is opaque in the UV/optical, but transparent and emissive in the IR/sub-mm.

Dust effects on the Spectral Energy Distribution (SED)[1]

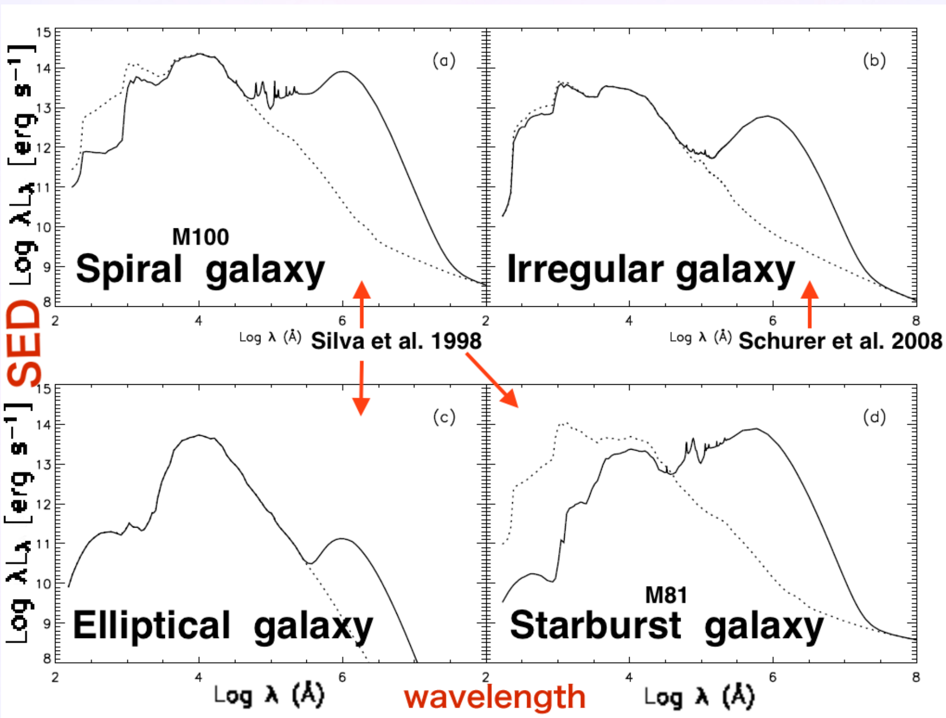


FIGURE: Graph which shows the effect of dust on the SED of local galaxies. Solid lines: SED after dust reprocessing. Dashed lines: the intrinsic SED.

[1]Schurer A., 2009, PhD Thesis

Mock images from post-processing tool GRASIL-3D

Simulating the effect of dust particles in galaxies (until now, in post-processing only, Granato+15)

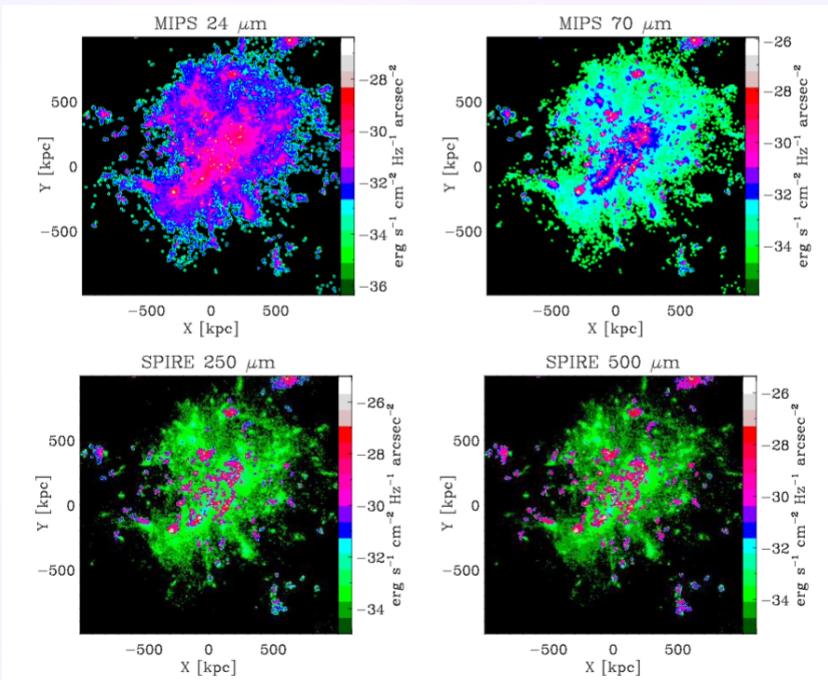


Figure: Examples of images of a cluster region at z=1 produced by GRASIL-3D in various NIR to sub-mm bands. The physical size of each panel is 2000 kpc, close to the Planck HFI beam at that redshift. No telescope effects (like point spread functions, pixel sizes,etc.) have been taken into account.

Map of the Dust Evolution Method

- Hirashita15 shows that by assuming 2 dust grain sizes only it is possible to reproduce results consistent with a continuous distribution model (i.e. Asano+13).
- We trace 2 dust species: carbonacous dust and silicates

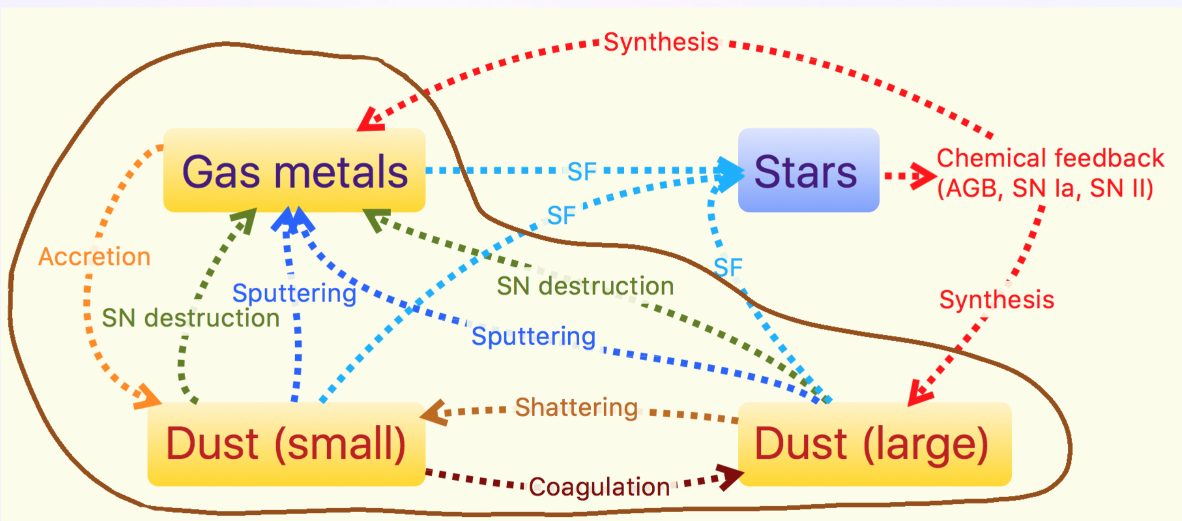
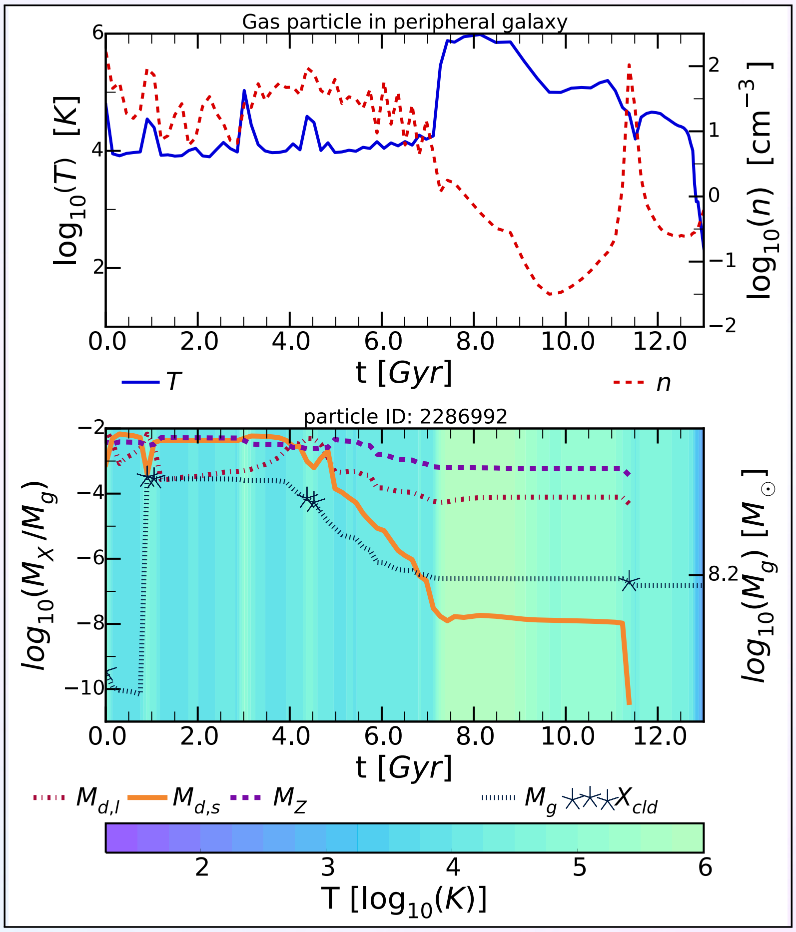


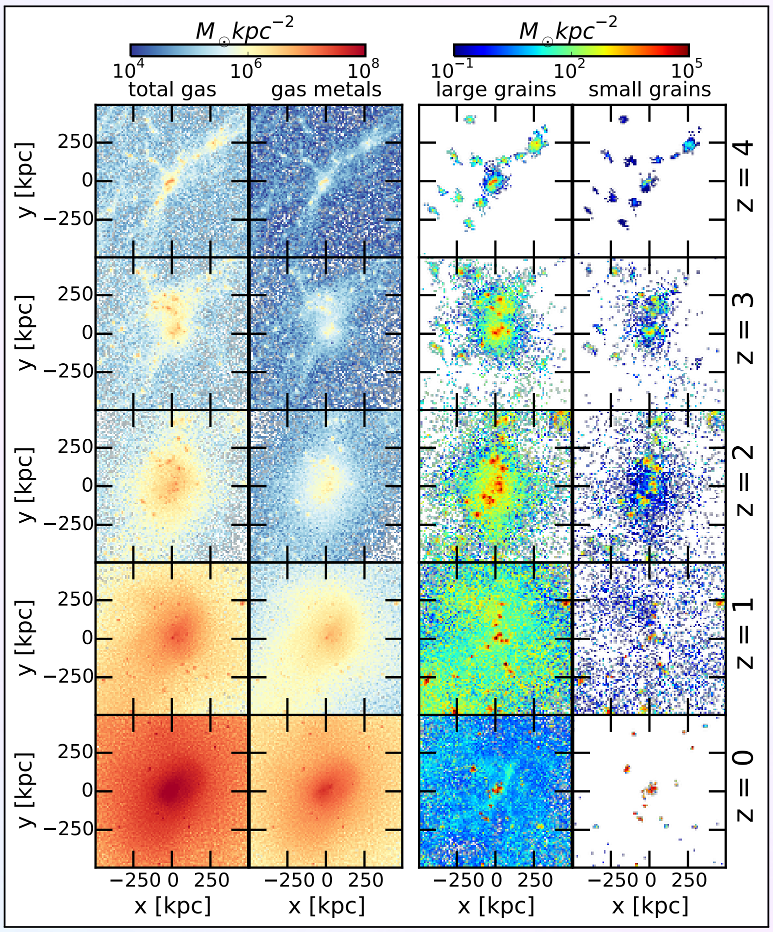
Figure: Brown line encloses gas metals and solid metals (dust) inside gas particles. Lines show the metal evolution processes. Blue box represents star particles. Arrows point to the direction of mass fluxes.

What happens within gas particles?



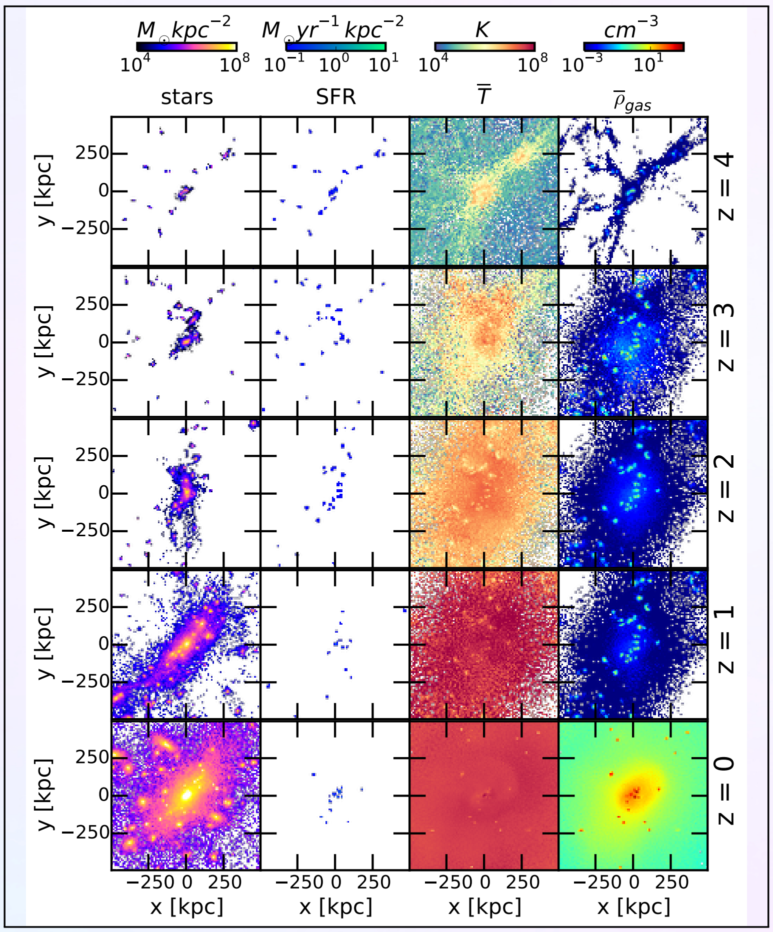
- Gas particle in quiet, isolated galaxy.
- Small grains increase rapidly via shattering whenever the particle's density is $> 1cm^{-3}$.
- Coagulation and accretion increase the large grains' mass at snapshots where the particle is multiphase.

Column density maps



- The spatial distribution of gas metals matches the total gas distribution.
- Dust evolutionary processes dominate the dust distribution, particularly after $z = 2$.
- Sputtering disrupts more efficiently small grains compared to large grains.
- Small grains survive in selected cold regions.

Column density maps



- Notice the high temperatures and densities at $z = 0$.
- The sites where dust survives are cold, dense gas pockets.
- These pockets are the sites of star formation.

Time evolution of masses

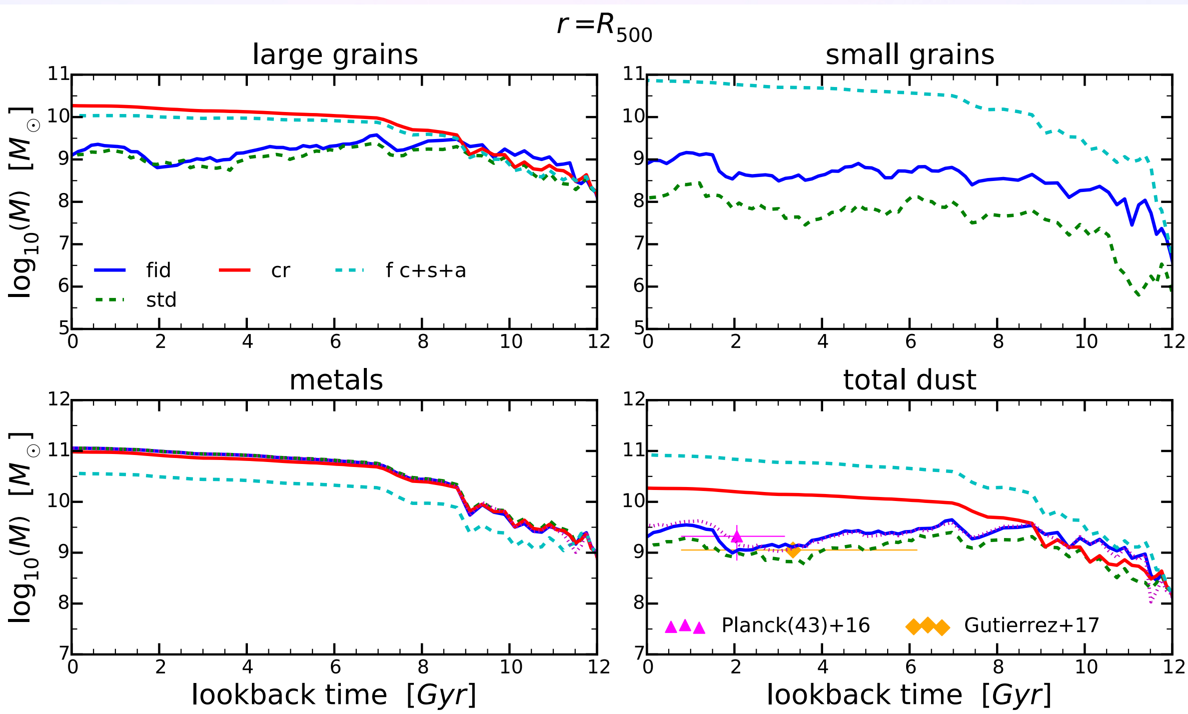


Figure: For 4 runs (fid: our fiducial parametrization. std: original parameters. cr: run with large grains creation only. f c+s+a: fiducial run with creation, shattering and accretion). Magenta triangle: total dust mass for $M_{tot}^{500} \leq 5.5 \times 10^{14} M_{\odot}$ from the Planck Collaboration. Orange diamond (Gutierrez+17): upper limit of the dust mass in clusters between $0.06 < z < 0.7$ observed in the 500μm channel at a 5 arcmin radius around clusters of $M_{tot}^{500} \sim 1.5 \times 10^{14} M_{\odot}$.

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Further Observational constraints

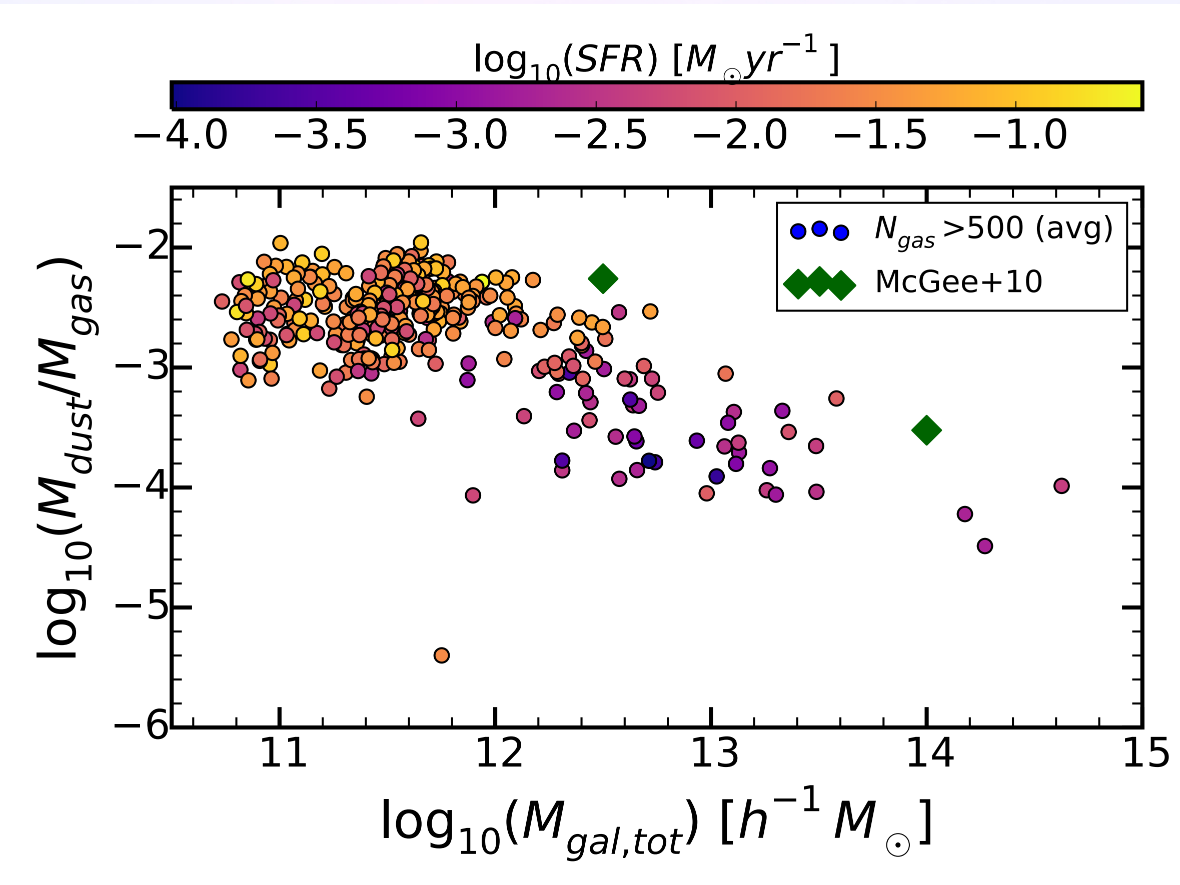

Figure: Dust-to-gas ratio vs masses of the massive substructures, color-coded by star formation rate. For a run on a massive region (D18)

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Summary and Future prospects

- I presented a dust evolution model embedded into our cosmological simulation code of clusters.
- Results are consistent with observations.

Future

- Feed the post-processing radiative transfer tool `Grasil-3D` (Dominguez-Tenreiro+14) with the new self-consistent dust abundances.
- Further test and costrain this model to observations.
- Extend dust method to `MUPPI` Milky-Way-like galaxy simulations.
- Gas cooling due to dust, H_2 catalysis on the grain's surface.

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