

Exercises 13

Statistical BH/AGN properties and AGN-host connection at $z=0$ in the $(500\text{Mpc})^3$ -run of the Magneticum simulation set

1. *BH properties*: Plot the distribution of BH accretion rates, AGN luminosities (down to 10^4 erg/s) and Eddington-ratios. Plot a 2D histogram of BH accretion rate versus BH mass (indicate different Eddington ratios as lines).
2. *Host-BH connection*:
 - Plot the BH-stellar mass relation (2D histogram and mean relation) and compare to the observed relation of McConnell & Ma.
 - Plot AGN luminosity vs SFR (2D histogram and mean relation) and compare to the observations of Rosario et al. 2012. Is there a relation?
3. *In which hosts are AGN preferentially residing?* Plot the fraction of luminous AGN ($L > 10^{45}$ erg/s) and of moderately luminous AGN ($10^{43} \text{ erg/s} < L < 10^{45}$ erg/s) as a function of galaxy stellar mass, SFR and sSFR.
4. *Are AGN hosts mostly star-forming, star-bursting or quiescent?* Plot the SFR-stellar mass plane (2D histogram), indicate the main sequence of SF galaxies, first color-code with the number of galaxies, and second/third color-code with the fraction of luminous/moderately luminous AGN.

Interpret your results, also with respect to recent observations. To what extent are BHs and their host galaxies co-evolving?

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Helpful instructions:

- You'll get a catalogue containing galaxies with masses above $1e10 M_{\odot}$, and corresponding BHs. The format is the following:
1. Mhalo 2. Mstellar 3. M_{BH} 4. BHAccRate 5. "dummy" 6. cent/sat-status 7. Number_BHs 8. SFR 9. "dummy"
Masses are in $M_{\odot}$, rates in $M_{\odot}/\text{yr}$, central BH=0 or satellite BH=1
If BH quantities have values of -99, it means that this galaxy does not contain a BH (normally not yet seeded).
- Bolometric AGN luminosities can be calculate from BH accretion rates, and Eddington accretion rates from M_{BH} (watch out with units!!)
- BH properties (first task) should be calculate for both only central BHs and all BHs, for all the remaining tasks only central BHs more massive than $1e6 M_{\odot}$ should be considered (so that they are not too affected by seeding)
- The main sequence of SF can indicated by fitting the SF galaxies in the simulations (compare to observed relation as well!)
- Note that simulation details you can find in today's lecture slides and in *Hirschmann+14*

- Reading suggestions:
- Some famous large-scale simulations:
 - Schaye et al. 2015: "The EAGLE project: simulating the evolution and assembly of galaxies and their environments"
 - Nelson et al. 2019: IllustrisTNG50
 - Dave et al 20??: Simba simulation
- Group B (Early Universe Simulations):
 - Di Matteo et al. 2017: "The origin of the most massive black holes at high-z: BlueTides and the next quasar frontier" (*Gerald*)
 - Rosdahl et al. 2018: "The SPHINX cosmological simulations of the first billion years: the impact of binary stars on reionization"
 - Kannan et al. 2022: The Thesan simulation