# The Impact of Active Black Holes on Simulated Dwarf Galaxies

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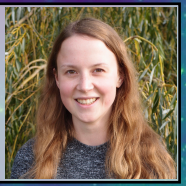
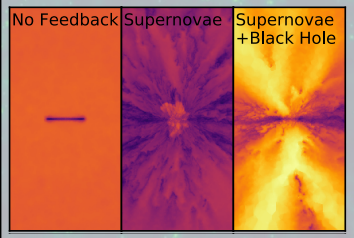


**Motivation:** Virtually all large galaxies, like the Milky Way, host black holes at their centres. Some of these black holes are 'active', i.e. they are growing by devouring gas, releasing massive amounts of energy as the gas spirals inwards. Recent observations have revealed that at least some small galaxies (so-called dwarf galaxies) host black holes, too. This discovery represents a *paradigm shift* as black holes had previously not been included in dwarf galaxy models. I have used both **isolated simulations of individual galaxies** as well as **cosmological simulations (encompassing 10 000s of galaxies)** to investigate the impact of active black holes on dwarf galaxies.

## (I) Isolated Simulations

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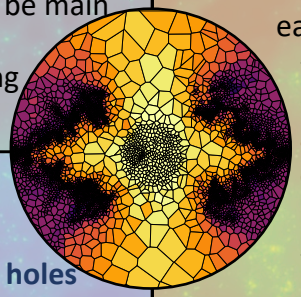
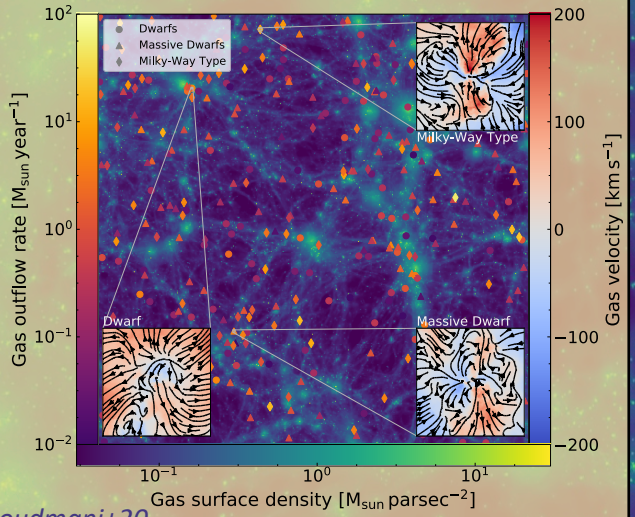
- High-resolution simulations with **moving-mesh code AREPO** *(Springel, 10)*
- Compare effects of **'feedback mechanisms'**: galactic processes preventing excessive star formation
- Previously **supernovae (explosions of massive stars)** assumed to be main feedback process in dwarfs
- **Active black holes heat up (and accelerate) outflows** emanating from galaxy disc, but no significant effect on star formation



## (II) Cosmological Simulations: Outflows

- Use **cosmological simulation suite FABLE** *(Henden+18)* to study dwarfs within realistic cosmological environment
- Gas density for whole simulation box: each tiny green dot is a galaxy
- Markers (colour-coded by outflow rates) show locations of **active black holes hosted by dwarfs, massive dwarfs or Milky-Way type galaxies**
- Zoomed insets show outflows

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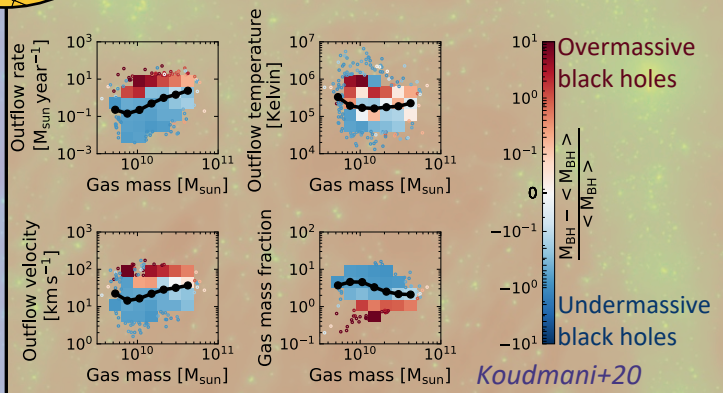


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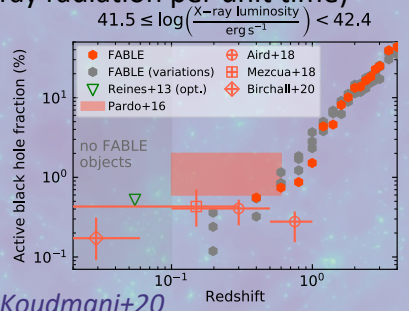
- Distribution of outflow properties for low-mass galaxies colour-coded by black hole mass offset
- **Overmassive black holes** (at fixed galaxy gas mass) drive **higher outflow rates, velocities and temperatures** as well as **reduced gas mass fractions**
- Overmassive black holes also **suppress star formation in dwarfs in early Universe** (not shown)

## (III) Cosmological Simulations: Mock X-ray Luminosities

- **Observations constrain fraction of dwarfs hosting active black holes** with a certain X-ray luminosity (amount of X-ray radiation per unit time)
- **At low redshift (local Universe), high-luminosity black holes in dwarfs are missing** from FABLE
→powerful supernovae* **suppressing black hole growth** & luminosities?
- Intermediate redshifts: good agreement
- **Prediction** for high-redshift (early Universe) X-ray missions (*Athena, LYNX*): huge increase in **active black hole fraction**

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*Supernovae set to high efficiencies as hitherto assumed to be main feedback process

## Conclusions:

- Overmassive black holes in simulated dwarfs drive hotter and faster outflows leading to a reduced gas reservoir and can suppress star formation in early Universe
- Lack of high-luminosity black holes at low redshifts highlights possibility that supernovae could be too strong in FABLE's dwarfs curtailing black hole growth & feedback
- **Next step:** Run simulations with more realistic supernova energetics to test whether this would increase black hole feedback and star formation suppression in dwarfs

**References:** Springel, 2010, MNRAS, 401, 791 • Henden+2018 , MNRAS, 479, 5385 • Koudmani+2019, MNRAS, 484, 2047 • Koudmani+2020, preprint (arXiv:2007.10342)