La bella e la bestia

Bella e la bestia

Brutto e’ bello

#MeToo
The beauty of science

Fake news?
Fake results?
Fake missions?
The beauty of black holes (and their host galaxies)

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Beauty for the physicist

Black holes are described by Kerr’s metric as an exact solution of Einstein’s equation.

The simplest objects: two parameters, mass and spin.
Beauty for the astrophysicist

Sgr A*

a black hole

the heart of a galaxy

stars

gas
Massive black holes in galaxies

Massive black holes should naturally grow along with galaxies through accretion and MBH-MBH mergers and influence the galaxy through feedback.
Galaxies and massive black holes

Supernova feedback energizes gas and suppress black hole accretion in low-mass galaxies (Dubois+14; Habouzit+17; Bower+17; Angles-Alcazar+17; Prieto+17; McAlpine+17,18)

Then, black holes catch up with their galaxies
Galaxies and massive black holes

Bentz, et al.

![Graph showing the relationship between $M_{BH}$ and $M_{stars}$]
Galaxies and massive black holes

The high-z sample covers a range compatible with z=0 observations, especially considering Eddington’s bias (Shields+06; Lauer+07; Volonteri&Stark09).
Galaxies and massive black holes

The high-z sample covers a range compatible with z=0 observations, especially considering Eddington’s bias (Shields+06;Lauer+07;Volonteri&Stark09)

\[ \log L_{\text{bol}} > 47 \]
\[ \log L_{\text{bol}} > 45 \]

\( z = 5-6 \) (faint)
\( z = 5-6 \) (bright)
Simulated galaxies and black holes happily evolve towards the observations.
Galaxies and massive black holes

Measuring the same quantities in simulations and observations

Simulated galaxies and black holes happily evolve towards the observations
Galaxies and massive black holes

Simulated galaxies and black holes happily evolve towards the observations.

$z=0$
$z=5-6$ (faint)
$z=5-6$ (bright)
$z>7$ (sim)
Feedback: radiation vs jets

Ramses: Grid-based hydro solver with mesh refinement (Teyssier 2002)

Turbulent, inhomogeneous interstellar medium (Wagner & Bicknell 2011)
- no cooling, gravity, star formation

Radiation: RAMSES-RT (Rosdahl et al. 2013, Rosdahl & Teyssier 2015)
- moment method to solve radiative transfer in RAMSES
- radiation pressure + diffusion of multi-scattering IR radiation
- reduced speed of light approximation
- AGN SED with 5 photon groups, IR $\rightarrow$ UV (Bieri+16)

Jet: - hydro source term, cylindrical base, orientation can be chosen
- steady density/momentum/energy flux
- $\rho_{\text{jet}} = 0.01 \rho_{\text{ambient}}$
- straight beam, self-collimated by internal shocks

Cielo, Bieri, MV+18
Feedback: radiation vs jets

A mass outflow rate of $\dot{M} < 10^4 M_\odot/\text{yr}$ in all cases except max46 and min46 – only in these two cases the gas distribution is affected.
A mass inflow rate of $\dot{M} = 0.01 \, M_\odot/\text{yr}$ corresponds to an AGN power of $P_{\text{AGN}} = \epsilon \dot{M} c^2 = 5.7 \times 10^{43} \text{ erg/s}$ for $\epsilon = 0.1$.
The journey of two black holes

Gravity

Dynamical Friction

\(~100 \text{ kpc} - 1 \text{ kpc} \) (galaxy mergers)

\(~100 \text{ Mpc} \) (cosmology)

Gas torques? Stellar scattering? Last pc problem

\(~1 \text{ millipc} \) (BH merger)

\(~1 \text{ kpc} - 1 \text{ pc} \) (binary formation)

Courtesy of Hugo Pfister