The Black Hole-Galaxy Connection in IllustrisTNG

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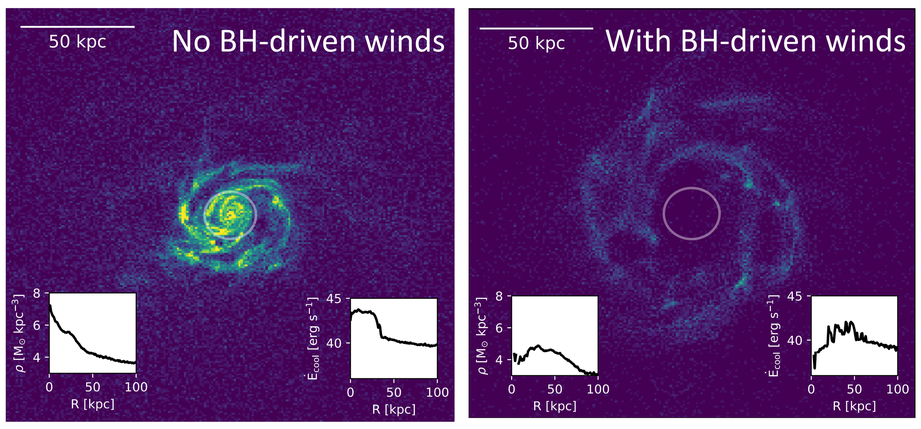
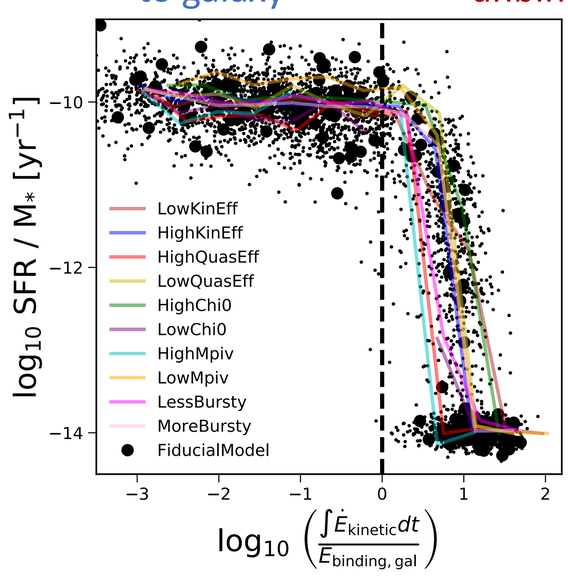
Many lines of evidence suggest that black hole (BH) feedback is the driver of quiescence in galaxies with stellar masses $\gtrsim 10^{10}$ $M_\odot$. We present results from the IllustrisTNG simulation that illuminate the link between BH mass, stellar mass, and star formation rate in the context of a model where quiescence is produced by BH feedback.

BH feedback causes quiescence in TNG



Kinetic winds in TNG shove gas out of the galaxy via randomly directed injections of momentum from the BH. This produces extended and disturbed disks, flattened radial gas density profiles, and lower halo gas cooling rates.

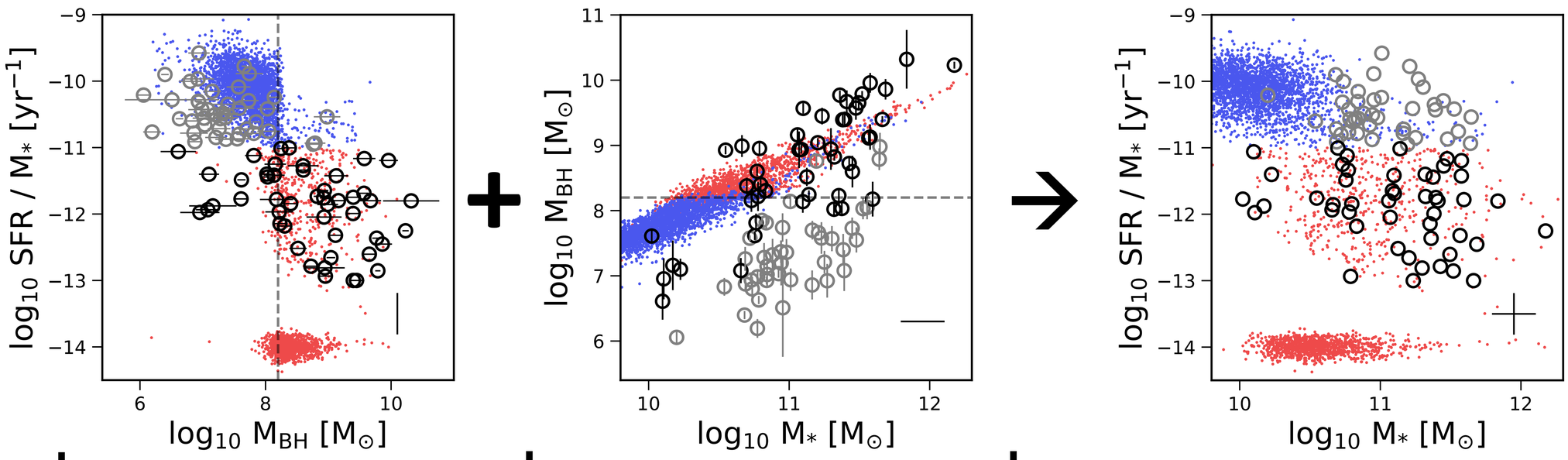
Gas is bound to galaxy ← → BH feedback unbinds gas



In TNG, *galaxies become quiescent when the cumulative amount of energy from BH-driven kinetic winds exceeds the gravitational binding energy of the galaxy*, $3GM(< 2r_e) / [5(2r_e)]$. This is true for all existing model variations that alter the parameters of the BH-driven wind physics in TNG.

TNG model variations that do not include BH-driven kinetic winds *do not* produce quiescence.

The BH-galaxy connection determines galaxy population statistics



TNG • SF • Q	BH mass reflects the cumulative energy from BH feedback. This causes quiescence above a BH mass threshold of $10^{8.1}$ $M_\odot$.	There exists a tight coupling between BH and stellar mass. Above the BH mass threshold, galaxies are quiescent.	BH mass is the property which determines quiescence. Therefore *the way BHs populate galaxies will determine the stellar mass distribution of star-forming and quiescent galaxies*.
Observations o SF o Q	Observations show a much more gradual decrease of star formation rate as a function of BH mass (**Terrazas+17**).	Quiescence correlates with BH mass in observations (**Terrazas+16**). The observed BH-stellar mass relation has substantial scatter.	A BH mass threshold of $10^{8.1}$ $M_\odot$ corresponds to stellar masses of $10^{10\text{-}10.5}$ $M_\odot$ in TNG. Above this stellar mass range the star forming main sequence ceases to exist, in disagreement with observations.

Conclusions

This study of IllustrisTNG illustrates the importance of linking BH mass, the determining property for quiescence at least in this model, with stellar mass. We note that TNG disagrees with observations in two important ways: (1) quiescence abruptly occurs at a BH mass of $10^{8.1}$ $M_\odot$ and (2) the BH-stellar mass relation is too tight. We show that if BH mass determines quiescence in the real universe then models must realistically link both quiescence to BH mass and BH mass to stellar mass in order to produce realistic distributions of star forming and quiescent galaxies as a function of stellar mass.