ARTICLE SUMMARY: GROWTH OF BLACK HOLES AND THEIR HOST GALAXIES

This week's article discusses the relationship between black holes and their host galaxies. The authors ran a series of simulations in which they pitted two identical galaxies against each other and examined the outcome. From the simulations we see galaxy mergers lead to inflows of nuclear[1] gas, which produces quasars that blow out all nearby gas and effectively render the galaxy and black hole red and dead. We also learn that the velocity dispersion[2] of the stars in a galaxy are related to the mass of the central black hole.

The simulation itself takes into account all of your usual factors that affect the time evolution of large-scale astrophysical simulations. The only difference here is what the particles are doing - colliding in galaxy form, and the authors model black holes and the luminosity fed back into them in detail. I'll concentrate on the findings of the simulation, and not the validity of its methods.

The main portion of the article discusses figure one in depth - illustrating the difference between the evolution of a collision of galaxies with and without supermassive black hole in their nucleus. Figure one shows snapshots of the evolution of colliding galaxies that are about the size of our Milky Way. The top galaxy contains a black hole, and the bottom galaxy does not. We see in the first column that the black hole mass has already grown significantly (top row). In the second column, we the gas in the black hole galaxies is relatively less dense and higher in temperature. In the third column, we see both systems in the quasar phase. The black holes on the top have merged and are growing extremely fast. In the last column, we see the quasar has expelled nearby gas and star formation stops. We can say the galaxy is "dead" - no more star formation is occurring in the top row. That means the galaxy's stars grow old, and red. In contrast, the bottom non-black hole galaxy still has some nuclear gas and star formation is still happening. Figure two explains the top row of figure one quantitatively. We see all of the characteristics I just described, and a little more - we can approximate the lifetime or phase of the quasar (phasar perhaps?) to be about 100 million years. The quasar phase is represented in the peaks of star formation and black hole accretion graphs. We see that the less massive the galaxy (small = low v_{virial} - see below) the longer the quasar phase - meaning we should observe more dim quasars, and we do.

The other part of this article discusses figure three - a graph of the mass of a the central black hole vs the velocity dispersion of stars in simulated and observed galaxies. The most obvious feature of the graph is the success of the simulation - it matches the observed

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[1]I think nuclear just refers to the nucleus of the galaxy - think active galactic nucleus

[2]velocity dispersion is just a measure of the spread of different velocities of stars relative to the mean velocity

data reasonably well upon first examination. (I do wonder how they chose these observed galaxies though - hopefully they didn't choose the ones that fit their data...). We see immediately from the graph that a high mass corresponds to a high velocity dispersion, a relation the authors hoped for. The inset of figure three shows $v_{vir} vs \sigma$, but we expected this relationship (again, see below). One more feature of note is the systematic differences the in $M - \sigma$ relationship of the galaxies that formed from collisions that contained a lot of gas - the more initial gas the higher the mass of the black hole. This is comforting - more food for the black hole means it will get bigger.

1. IMPORTANT EQUATIONS FOR BLACK HOLES

- Schwarzschid Radius $\Longrightarrow R_s = \frac{2GM_{object}}{c^2}$
  - note that $V_{BH} \propto \rho^{-3/2}$ so large black holes have small densities
- Feedback Energy rate $\Longrightarrow \dot{E} = fL = fn\dot{M}c^2$
  - f =fraction of luminosity fed back into the surrounding gas $\approx .05$
  - $L =$ accretion luminosity $= f\eta\dot{M}c^2$
  - $\eta =$ radiative efficiency $= .1$
  - $\dot{M} =$ mass accretion rate
- M-V-R relation from the Virial Theorem $\Longrightarrow M_{galaxy} = \frac{5R_{galaxy}\langle v^2\rangle}{3G}$