AIP, An der Sternwarte 16, D-14482 Potsdam, GERMANY, ph:(+049) 0331 7499517(work)

Khalatyan Arman

Abstract

In this thesis, we present numerical study of the influence of feedback owing to nuclear activity in galaxies onto the type and morphology of galaxies in cosmological context.
Over the past two decades, computer simulations of the gravitational growth of structure in the model, in which structure grows hierarchically, have greatly helped to understand the formation process and the properties of galactic dark matter halos, as well as their distribution and motion of matter in space. This part of the structure formation process is now well understood. However, cosmological simulations those try to include baryon physics and star formation processes in order to allow a direct comparison with the luminous properties of observed galaxies have encountered considerable difficulties.
The uncertainty in the implementating the complicated baryonic processes in simulations and the limited numerical resolution are main hurdles in modern numerical cosmology. Sub-grid methods may allow to overcome these problems, however in cosmology this approach is still in its infancies.
One generic problem of these studies has been that the formed elliptical galaxies in simulations are appearing to be bluer than observed ellipticals, i.e. they exhibit a too large a fraction of and younger (and thus bluer) stars.
Another problem is related to the formation the disk galaxies with observed gas content, luminosity and disk properties.
It is widely believed that this failure to account for the data is caused by an insufficient modelling of the physics of star formation and its associated feedback processes. The inclusion of supernovae feedback solves problems related to the so-called overcooling, thus preventing excessive star formation rates in simulated galaxies. However, the input energy of SN appears to be not sufficient to terminate the star formation process.
Another powerful energy source known in nature, which could terminate the star formation process, is nuclear activity. Active Galactic Nuclei are triggered by rapidly accretion of cool gas onto a central massive Black Hole.
All massive spheroids show evidence for a central black hole. The relation between the black hole mass and bulge mass suggests that the black hole contains ~0.2% of the bulge stellar mass. The gravitational binding energy released by matter accreted onto the black hole is ~10% of the rest mass energy.
A small fraction of this energy could be sufficient to affect the dynamics and the thermal state of the intergalactic medium dramatically.
The black hole grows through Bondi accretion and a fraction of the accretion power is distributed as thermal feedback into the surrounding gas. The gas expands or contracts until AGN heating and radiative cooling balance each other. The balance of heating and cooling is used to determine a quasi-equilibrium temperature at which the black hole accretes in self-regulated equilibrium with the surrounding intergalactic medium. This temperature grows with the black hole mass. The temperature increase is very steep around a critical black hole mass due to the shape of the cooling function.
The heating rate per unit mass of the gas depends on three parameters: the accretion efficiency with respect to the Bondi rate, α, the fraction of the accretion power converted into heat, β, and the mass M_{gas} on which the heat is distributed.
We have performed a set of non-cosmological hydrodynamic simulations of galaxy mergers to explore parameter space for the self-regulated black hole accretion model. The results of simulations show that the AGN are indeed capable to terminate efficiently the star formation processes. The spheroid which remains after disk galaxy collision is "redder" (contains more older stars) in color than simulations without AGN.
We have successfully predicted the AGN model parameters and with the simple analytical toy model, we can predict under what conditions the AGN will be in the quasar mode.

After the fixing the model parameters, we did the set of high resolution fully cosmological gas dynamical simulations - among the first simulations of this kind ever performed - to investigate the effects of AGN on the type (color of galaxy) and morphology (shape) of an elliptical galaxy.

These high-resolution cosmological simulations were performed on some of the largest supercomputers in Europe.

In the simulation without black hole, the galaxy ends up with a visual aspect ratio and radial density profile consistent with those of observed elliptical galaxies. The model galaxy also exhibits boxy isophotes.

However, in the absence of feedback owing to nuclear activity, it has a central blue light excess that is abnormal for a galaxy with these properties. In the case of simulations that incorporate feedback owing to a central black hole, star formation is quenched by AGN feedback, the galaxy is now clearly located on the red part of the color -- magnitude diagram, consistent with the appearance of observed elliptical galaxies.

Our simulations also follow the enrichment of the interstellar medium with heavy elements owing to supernovae. The simulations demonstrate that even moderate winds caused by nuclear activity can easily produce the required enrichment of the IGM at $z\sim3$ although in a realistic situation supernova wind are also likely to play a role. The field of studying the complex interaction between galaxy formation, AGN and the ISM is still in its infancy. However, the need of AGN feedback in galaxy formation appears as fundamental physical results independently of the many uncertainties concerning the outlining details of how it works.

We conclude that nuclear activity and the physics that give rise to this phenomenon are indispensible ingredients to an thorough understanding of the galaxy formation process.