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HIERARCHICAL CLUSTERING AND ACTIVE GALAXIES.

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The growth of Super Massive Black Holes and the parallel development of activity in galactic nuclei are implemented in an analytic code of hierarchical clustering. The evolution of the luminosity function of quasars and AGN will be computed with special attention paid to the connection between quasars and Seyfert galaxies. One of the major interests of the model is the parallel study of quasar formation and evolution and the History of Star Formation.

1 The Barcelona model

The model of Barcelona has been presented by E. Salvador-Solé in his oral contribution entitled "*Modeling the density-morphology relation and the galaxy/AGN connection*". A detailed description is also given in Manrique et al., 2000, in preparation. Here, only a brief introduction will be made, to outline the major differences between the abovementioned model and previous works.

The big novelty of the model is the use of a *modified* Press - Schechter formalism of the hierarchical dark matter halo (DMH) formation. The internal structure of the dark matter halos is modeled and a distinction is made between dark matter halo merging and accretion. Next to the dark matter evolution the baryonic matter evolution is also followed, through the mechanisms of radiative cooling, star formation and re-heating, where all component (hot and cold gas, and stars) are taken into account.

The evolution of galaxies of different types is followed, as well as their localization within groups and/or clusters. The evolution of the central galaxy depends on the properties of the host halo and of the surrounding satellite galaxies that it captures. This captures depend on the orbits of the galaxies, in other words on the potential well and the initial orbital conditions. The capture of such satellite galaxies, which can be very numerous but whose sizes are small in comparison to the central galaxy, only produces minor effects. On the contrary, in the case of a capture of a galaxy with a mass comparable to the central galaxy, the latter's disk (if it exists) can be destroyed, forming thus a new spheroid. This kind of capture is, therefore, crucial for the final configuration of the central galaxy and for the galactic halo gas, due to feedback mechanisms.

Generally speaking, a central galaxy is characterized by its total baryonic mass, the mass of its gaseous and stellar components and the respective metalicities, the star formation rate in the disk and the bulge, the surface density of the disk and the mass of the central black hole. The destiny of the black hole and the AGN activity are related to the history of the galaxy. This si what triggers the parallel study of "normal" galaxies and AGN.

2 Central Black Hole Evolution and Nourishing Mechanisms

After their formation black holes evolve nourished mainly by host galaxies interactions. Galactic bulges can collect material in three different ways: by cooling flows, by the direct infall of low momentum material from the galactic halo during a merger event between two galaxies of comparable sizes, and a mass transfer from the disk to the bulge through non-axisymmetric perturbations (e.g. spiral arms and bars).

2.1 Characteristic Timescales

A certain number of characteristic timescales are involved in the modeling of black holes and their connection to normal galaxies. Table 1 summarizes some of them, in increasing order. Not all of them appear in the present paper but all of them are used in the above described model. "AD" and "BLR" denote the accretion disk and broad line region, respectively.

Table 1: Characteristic timescales involved in the modeling of AGN

	duration	description
$t_{heat,AD}$	?	heating time of the material falling onto the AD
$t_{cross,AD}$	hours - months	time needed by photons to cross the AD
$t_{heat,BLR}$	$\sim$ 1 day	Compton heating time in the BLR
$t_{cross,BLR}$	$\sim$ days	crossing time of the inner BLR by photons
$t_{infall,BLR}$	$\sim$ a few years	gas infall onto the AD through BLR
$t_{infall,BH}$	$10^3 - 10^5$ years	gas infall from AD to BH
t_{Edd}	$\sim$ Myr	timescale for the growth of the BH through accretion
t_{dyn}	$1 - 100$ Myr	dynamical time of the host galaxy bulge
t_{acc}	$3t_{dyn}$	quasar "duty cycle"
$t_{cool,BLR}$	$\sim 0.1 - 10$ Gyr	Compton cooling time in the BLR
t_{quiet}	a few Gyr	quasar quiescence phase

2.2 Galaxy Mergers in the DMH Centers

When galaxies of comparable sizes merge, usually near the center of the dark matter halos, the disks that possibly exist are destroyed and a new spheroid is formed. Due to dynamical friction the two black holes (with masses M^1_{BH} and M^2_{BH}) of the involved galaxies will soon find their way towards the central region and coalesce. A fraction ϵ of the cool gas, M_{gaz}, of the spheroid will fall onto the galaxy center, nourishing the black hole, whose mass will now be:

$$M_{BH} = M^1_{BH} + M^2_{BH} + \epsilon(f_* M_* + M_{gaz}),$$

where f_* denotes the fraction of the stelar mass accreted, M_*, generally considered to be null.

The typical accretion and radiation time for a black hole is nowadays believed to be much shorter than the characteristic timescales of its host galaxy. However, it is this "short-term" evolution of the black hole that determines the light curve of an active galactic nucleus, and this why it should be modeled. In the case of a rapid growth of the bulge we suppose an exponential variation of the accretion rate, inspired by Dopita (1997), but asymmetrically bell-shaped:

$$\frac{dM_{BH}}{dt} \propto \frac{\Delta M_{BH}}{t_{acc}} \left[1 - exp\left(-\frac{t}{t_{dyn}}\right)\right] exp\left(-\frac{t}{t_{acc}}\right),$$

where $\Delta M_{BH} = \epsilon(f_* M_* + M_{gaz})$ and $t_{acc} = 3t_{dyn}$, as explained in table 1.

The difference between this and the Dopita curves is the use of two different timescales: t_{dyn} for the ascending part and t_{acc} for the descending part. This accretion rate, in units of t_{dyn}, is presented schematically in figure 1. The same equation applies in the case of a black hole nourished through the process of cooling flows.

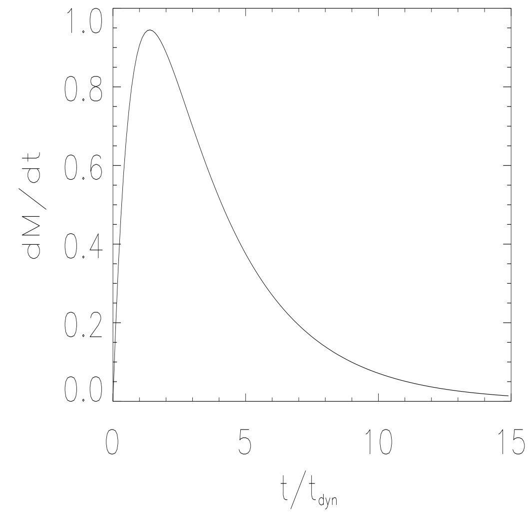

Figure 1: Accretion rate versus time (in units of t_{dyn})

2.3 Slow Fueling

In the case of a slow but continual growth of the galactic bulge as spiral arms and bars transfer angular moment towards the outer regions and mass towards the center of the galaxy, the mass of the (new) black hole will be given by:

$$M_{BH} = M_{BH}^0 + \tilde{\epsilon}(f_* M_*^{D\to B} + M_{gaz}^{D\to B}),$$

where $M_*^{D\to B}$ and $M_{gaz}^{D\to B}$ denote the stellar and gaseous mass, respectively, transfered from the disk to the bulge. In this case a constant accretion rate is adopted:

$$\frac{dM_{BH}}{dt} = \frac{\Delta M_{BH}}{t_{acc}},$$

where ΔM_{BH} is equal, this time, to $\tilde{\epsilon}(f_* M_*^{D\to B} + M_{gaz}^{D\to B})$.

3 AGN Light Curves

According to the present model, the bolometric luminosity of an AGN of a given type is determined by its accretion rate, dM_{BH}/dt, the initial mass of the central black hole, M_{BH}, and the time elapsed since the beginning of the accretion process. The luminosity sustains the inflow rate and vice versa, in such a way as to respect the Eddington regime, since only an under-Eddington luminosity gives a stationary solution, as described in Manrique et al. For a given accretion rate the light emitted from a region of radius R_{acc}, and which in fact is the accretion disk, varies with time as:

$$L_{BH}(t) = \epsilon_{Edd} L_{Edd} = \frac{L_{Edd}}{1 + \frac{L_{Edd} R_{acc}}{G M_{BH}}} \times \frac{dM_{BH}}{dt},$$

where L_{Edd} is the Eddington luminosity.

In the case of major mergers or cooling flows, this relation will give rise to a bell-shaped light curve with the same characteristic timescales as for the accretion rate, dM_{BH}/dt.

4 Conclusions and Perspectives

The model presented above will allow us to make predictions on several issues that relate quasars to normal galaxies and to the background cosmology. The problem of the existence of a BH within all galaxies and the time delay between the collapse of a dark matter halo and the formation of a black hole in its center will be studied first. The relations between the different types of AGN, their connection to normal galaxies, and the relations between the masses of the dark matter halos, the galactic disks and bulges, and the black holes can then be looked for. Issues like the role of AGN and obscured AGN in the reionization history of the Universe, the X-ray and UV backgrounds can be examined.

This model will give as an output a theoretical quasar luminosity function and its evolution with time. Its comparison with the observed luminosity function issued from recent or new large quasar samples (e.g. VIRMOS, 2dF, SDSS) will allow us to better adjust the values of our parameters and tests our assumptions.

References

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3. Salvador-Solé, 2000, "*Modeling the density-morphology relation and the galaxy/AGN connection*", this issue