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DYNAMICS OF BLACK HOLES PAIRS IN A HIERARCHICAL UNIVERSE: THE SMBHS DESCENDANTS OF $Z = 1$ BINARY MERGING GALAXIES

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RESUMEN

Seguimos la evolución de pares de agujeros negros supermasivos (AN) en las últimas etapas de su evolución, $r \sim$ pc. Empleamos un modelo semianálitico que considera un sistema binario de ANs con tres discos, la contribución a la masa del disco circumbinario debida a la acreción cósmica y la correspondiente deposición de momento angular en el sistema binario de ANs. Mientras el disco circumbinario quita momento angular al par, la transferencia de masa cósmica añade una fracción de su momento angular al momento angular orbital del par de agujeros negros, influyendo en su separación.

ABSTRACT

We follow the evolution of supermasive black hole (BH) pairs in the last stages of their evolution $r \sim$ pc. We have used a semianalytical model that includes a BHs binary system with triple disks, the mass added to the circumbinary disk due to cosmic accretion and the corresponding exchange of angular momentum between accretion, mass transfer and orbital motion. While the circumbinary disk removes angular momentum, the cosmological mass transfer adds some fraction of its angular momentum to the orbital angular momentum of the BH pair.

Key Words: accretion, accretion disks — binaries: general — black hole physics — galaxies: nuclei

1. INTRODUCTION

The current understanding of the cosmic large-scale structure origin is included in the ΛCDM scenario. According to this cosmological model the self-gravitating systems at galactic scales have been formed following a hierarchical process of mass accretion and mergers. Thus, it is posible to find a relationship between dark matter halos mass accretion/merging histories and the interactions between galaxies. Considering that all stellar spheroids have a black hole in their center, raises as a natural question whether the BHs follow the galaxies assembly history. The BH pairs in their path to coalesce may produce a wide range of signals according to the BH pair properties (separation between BH, masses, etc.), from gravitational waves at small separations ($\ll$1 pc) to multiple accreting BH spatially resolved ($\sim$ kpc), or a variable electromagnetic flux due to the orbital motion. If the coalescence process is not efficient or common there might be intermediate mass BH wandering within the galaxies. This signatures would open up entirely new scientific opportunities, to probe fundamental physics, astrophysics and cosmology. We present preliminary results of this PhD thesis project and comment on the expected results.

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2. PRELIMINARY RESULTS

2.1. *The tool*

We have studied the response of a gaseous disk to an external potential (Goldreich & Tremaine 1979) considering a system of a BH pair with triple disks: 2 accretion disks around each BH and a circumbinary disk (Hayasaki 2009) including cosmic mass accretion through a semianalytical tool.

The circumbinary disk removes angular momentum through resonant interaction while cosmic mass transfer adds momentum to the BH pair. Earlier studies have shown that the evolution of BHs pairs depend on how galaxies are populated with BHs (Volonteri 2010, and references therein), as a first approach we have seeded dark matter halos with BHs following the relation total mass-BH mass suggested by Ferrarese (2002)[2].

2.2. *The simulation*

The typical mass accretion history (see Figure 1) is an increasing function of time which shows the hierarchical structure formation. But not everything comes out from major mergers, there is a fraction of the accreted mass going to the center of the galaxy. We have taken this fraction from cosmological dark matter only N-body simulations of the evolution of

[2]However see Kormendy & Bender (2011).

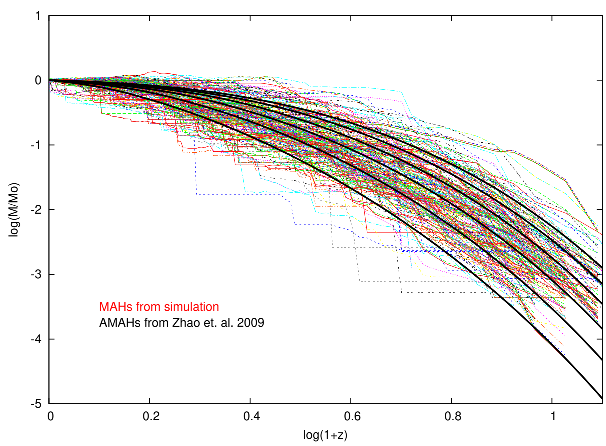

Fig. 1. Mass accretion histories from the simulation and average mass accretion histories from Zhao et al. (2009)

the local Universe to calculate its effect on the BH pair orbital angular momentum.

We have used mass accretion histories from a numerical simulation of 64 h^{-1} Mpc with 256^3 particles with mass $m_p = 1.63 \times 10^7\ M_\odot$, that reproduces the main features that characterise the local Universe (Gottlöber et al. 2010).

2.3. *The constrained sample*

We have selected dark matter halos corresponding to merging galaxies pairs as initial conditions for our model based on the galaxies selection criteria used by Bell et al. (2006). The sample consists of $\sim$150 pairs of halos with separations $\lesssim$30 kpc and masses $M_h \gtrsim 2,5 \times 10^{10}\ M_\odot$ at $z = 1$. We have followed the evolution of the pairs in the sample mentioned above, in particular the distance evolution between BHs in pairs at different epoch (see Figure 2).

3. SUMMARY & CONCLUSIONS

BH pairs and their signatures are valuable as probes to general relativity, probes of accretion disk properties, cosmological observations and gravitational waves sources counterparts.

Constrained simulations represent a powerful tool to understand the history of the best known part of the Universe. By using them it is possible to construct a constrained sample of posible merging galaxies corresponding to any epoch of the local Universe.

Depending on the efficiency of the angular momentum transport mechanisms we are able to get

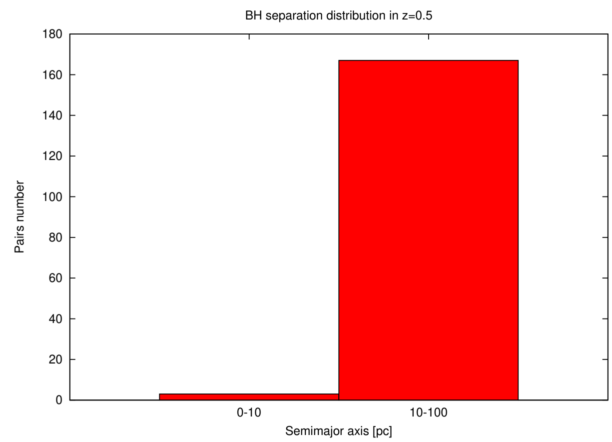

Fig. 2. Number of BH pairs with separations less than 10 pc or between 10–100 pc at $z = 1$. At this epoch few BHs mergers are expected.

the separations distribution of pairs in the local Universe. The current preliminary results suggest that disk-BH pair interaction is a mechanism by wich BH pairs can coalesce within a Hubble time and BH merger rate is small in the local Universe (see Figure 2).

Currently there is an important effort in the astronomical comunity to perform a census of the black hole pairs population at different stages. Once they are completed our study will be important to make data interpretation.

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