Dormant black holes tell a story about the evolution of active galactic nuclei

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**Abstract.** In our recent paper (Salucci et al. 1998) we have investigated the mass distribution function of massive dark objects in galaxies, exploiting the available optical and radio observations. Under the assumption that massive black holes power active galactic nuclei, we have compared the mass functions of massive dark objects and black holes responsible for the observed activity. We have found that a scenario with a single short burst per active galactic nucleus is in a good agreement with the available data. Here we summarize and discuss the main points of our study.

1. **Introduction**

How and why active galactic nuclei (AGN) form and evolve is still, in many respects, mysterious. From direct counts of AGN and from the intensity of the backgrounds at high energies we can infer that the activity in nuclei of galaxies was much higher in the past than in the present universe. If we accept the paradigm that nuclear activity in galaxies is sustained by accretion onto a massive black holes (BHs) (see Rees 1996 for a review), then the problem of the location and discovery of the remnants of such past activity immediately arises. Recently, the number of detections of massive dark objects (MDOs) in nuclei of inactive galaxies has increased rapidly (Magorrian et al. 1998; van der Marel 1997; Ford et al. 1997; for a review, see Kormendy and Richstone 1995), suggesting that we are finding out the fossil of the past nuclear activity. In the following we will assume that MDOs are BHs dormant after a shining past.
2. Mass function of massive dark objects

The mass of MDOs in galaxy centers can be evaluated by using very high resolution spectroscopy and photometry of nearby host galaxies. Magorrian et al. (1998) have successfully exploited the very high resolution of HST photometry together with high resolution spectroscopy from ground of 36 elliptical (E) and S0 galaxies to estimate their MDO masses. In spite of the large scatter on the data, they confirm the existence of a relationship between the mass of the hot galactic component $M_{\text{sph}}$ and the MDO/BH mass, $M_{\text{BH}}$, already suggested by Kormendy (1993), although they also claim the presence of a significant scatter. Following a different and more indirect approach, van der Marel (1998) has analyzed the HST photometry of a sample of 46 early type galaxies.

As a first step in the construction of MDOs mass function (MF) we (Salucci et al. 1998) have estimated the MF of the hot component of the normal galaxies, by exploiting the luminosity functions (LF), the average fraction of the total luminosity in the spheroidal component of galaxies of different morphologies and adopting mass-luminosity ratio: $M/L_V \approx 5.5 \times 10^{-2} h (L_V/L_\odot)$. The overall shape of the MF is relatively flat at $M < 10^{11} M_\odot$ and exhibits an exponential decline for $M > 10^{11} M_\odot$. At $M > 5 \times 10^{10} M_\odot$ the mass function is dominated by spheroids in E and S0 galaxies. The Sa/Sab galaxies exhibit an exponential decline of their MF for $M > 10^{10} M_\odot$ and Sbc/Scd galaxies for $M > 10^8 M_\odot$.

Next, we have used the distribution of the $M_{\text{MDO}}/M_{\text{sph}}$ ratio to infer the mass function of MDOs. The average value of $M_{\text{MDO}}/M_{\text{sph}}$ is still under debate and it ranges from $\sim 10^{-2}$ (Magorrian et al. 1998) to $\sim 2 \times 10^{-3}$ (Ho 1998). Due to observational difficulties, the results so far obtained are expected to give only hints on the true statistics. However, a large scatter of the ratio $x = M_{\text{MDO}}/M_{\text{sph}}$, at constant $M_{\text{sph}}$, has been found regardless of different assumptions and data analyses. Our MF is shown in Figure 1. The total mass density predicted by this distribution is $\rho_{\text{BH}} \approx 8.2 \times 10^{5} M_\odot/Mpc^3 (H_\odot/70)$, where $H_\odot$ is a Hubble constant. Most of the mass density is ascribed to BHs in E and S0 galaxies, and only a small fraction is in BHs resident in late spiral types.

A different approach to evaluation of MDO mass function relies on the hypothesis that radio emission from the nuclei of radio quiet galaxies is related to the mass of their MDOs. As a matter of fact, a strong trend between MDO mass and nuclear radio luminosities has been found by Franceschini et al. (1998). Moreover, similar correlation is expected in the case of tiny mass inflows, when advection dominated accretion flows (ADAF) occur (e.g. Mahadevan 1997) or in the case of self absorbed radio emission. Thus, the radio LF of the nuclear emission of low-power spheroidal galaxies can be used to probe the MDO mass function. We have used it as a consistency check for the MF derived from the optical spectroscopy and photometry (see Figure 1).

3. Mass function of relic black holes

Soltan (1982) showed that the AGN counts can provide a meaningful lower limit to the mass density deposited in the galaxy centres. In Salucci et al. (1998) we have showed that the mass function of relic BHs (AMF) can be obtained with
simple hypothesis by exploiting the information on the evolution of AGN and QSO LFs. The luminosity functions and cosmic evolutions are available now for optically (see e.g. Pei 1995) and soft X-ray selected objects (Hasinger, 1998). We have taken into account the contribution to the BH mass function coming from type 2 or obscured AGN, which are possibly responsible for a major portion of the intensity of the 2-50 keV X-ray background (HXRB). This hypothesis is strongly supported by optical identifications of serendipitous sources detected by BeppoSAX in the 5-14 keV band (Fiore et al. 1998). The existence of type 2 AGN is postulated by unified models of AGN (see Antonucci 1993 for a comprehensive review), which are strongly supported by many observational evidences (see e.g. Granato et al 1997). The resulting MF is shown in Figure 1.

4. Comparison

The comparison of the MF of the relic BHs to the MDO MF is used to cast light on the characteristics of the evolution of the nuclear activity in galaxies.

Nice agreement can be found between the mass functions derived from investigations on MDOs resident in local galaxies and the mass function of the BHs inferred from the past activity of AGN under very simple and sound hy-
hypotheses: i) the nuclear activity is a single short event; ii) the spectra of the AGN do not much depend on the redshift; iii) the mass-radiation conversion efficiency of accretion $\epsilon \simeq 0.1$; iv) the HXRB is produced by absorbed AGN in the context of the (weak) unified scheme; v) $\lambda = L/L_E$ is an increasing function of the luminosity. The last hypothesis is strongly supported by observational findings (see e.g. Padovani 1989). Recurrency or supply–limited accretion at low luminosities may explain this result.

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