A fundamental relation between Supermassive Black Holes and Dark Matter Haloes

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Contemporary galactic formation and evolution models all incorporate the role of a supermassive black hole (SBH). As a constraint they use known observational relations, such as the Tully-Fisher and $M_{BH} - \sigma$ relations. In the $M_{BH} - \sigma$ relation, the velocity dispersion is measured within a region which, though large compared to the black hole sphere of influence, is at least an order of magnitude smaller than the optical radius of the galaxy, and is likely dominated by luminous matter. Therefore, despite the obvious interest of its apparent universality and small intrinsic scatter, the $M_{BH} - \sigma$ relation is unable to tell us about the connection between SBHs and baryonic structures other than the bulge. In particular, the link to the dark matter (DM) component remains unaddressed. This is unfortunate, because it is not the mass of the bulge but the total gravitational mass or the mass of the DM halo which drives the formation of SBHs in most of the proposed theoretical models: according to these models, the fundamental relation is one between M_{BH} and M_{DM}. The $M_{BH} - \sigma$ relation is a by-product of such a relation, since in standard CDM scenarios the bulge mass is connected to the halo properties.

This missing link between SBHs and DM haloes was recently discovered by Ferrarese (2002) who found a strong observational relation between the asymptotic rotational velocity v_c (imparted to the disk) and the bulge mass (measured through the bulge stellar velocity dispersion σ). In combination with the known $M_{BH} - \sigma$ relation this leads to a connection between the SBH and DM halo (see Fig. 1). However, galaxies with v_c <150 km s^{-1} seem to deviate significantly from the relation defined by the more massive systems. On the contrary the Tully-Fisher relation (which reveals a connection between M_{DM} and the total baryonic mass of the galaxy) holds with negligible intrinsic scatter down to $v_c \sim 80$ km s^{-1}. The fact that the $v_c - \sigma$ (or $v_c - M_{BH}$) relation breaks down for the least massive galaxies must reflect a fundamental change in the way by which bulges (and hence SBHs) form as the mass of the DM halo decreases below a critical value. It might also be an indication that the less massive haloes are unable to form SBHs, as argued on theoretical grounds.

We present the results of an observational project which extends our previous investigations of the $v_c - \sigma$ relation in the region of $v_c \sim$150 km s^{-1}. This project involves deep spectroscopy of the hot stellar components of a sample of 29 galaxies with either the VLT or 3.5m Calar Alto telescope. Our galaxies are selected from the sample of Verheijen and Palunas & Williams with published HI or Hα rotation curves that extend beyond the optical radius. The results give new insight in SBHs and the formation of galaxies and their link.

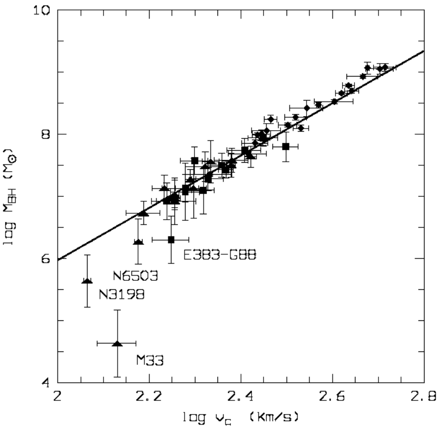

Fig. D 09. The $v_c - M_{BH}$ relation (1). Ferrarese's data (2002) are represented by triangles, Kronawitter's (2000) by circles and Baes et al. (2003)'s by squares.