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Upper limits on the mass of supermassive black holes from HST/STIS archival data

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Abstract. The growth of supermassive black holes (SMBHs) appears to be closely linked with the formation of spheroids. There is a pressing need to acquire better statistics on SMBH masses, since the existing samples are preferentially weighted toward early-type galaxies with very massive SMBHs. With this motivation we started a project aimed at measuring upper limits on the mass of the SMBHs that can be present in the center of all the nearby galaxies ($D < 100$ Mpc) for which STIS/G750M spectra are available in the HST archive. These upper limits will be derived by modeling the central emission-line widths ([N II] $\lambda\lambda 6548, 6583$, H$\alpha$ and [S II] $\lambda\lambda 6716, 6731$) observed over an aperture of $\sim 0\farcs1$ ($R < 50$ pc). Here we present our preliminary results for a subsample of 48 bulges.

Key words. Black hole physics – Galaxies: kinematics and dynamics – Galaxies: structure

1. Introduction

The census of supermassive black holes (SMBHs) is large enough to probe the links between mass of SMBHs and the global properties of the host galaxies. One of the most tightest relations connects the bulge velocity dispersion σ_c with the black hole mass $M_\bullet$ (see Ferrarese & Ford 2005,for a review). However, accurate measurements of SMBH masses are available for a few tens of galaxies and the addition of new determinations is highly desirable.

To this purpose we started a project aimed at measuring upper limits on $M_\bullet$ that can be present in the center of all the nearby galaxies ($D < 100$ Mpc) for which STIS/G750M spectra are available in the HST archive. We retrieved data for 182 galaxies spanning over all the morphological types. This will extend previous works by Sarzi et al. (2002) and Verdoes Kleijn et al. (2006). Here, we show the preliminary results for a subsample of 48 bulges with σ_c available in literature. We measured the upper limit on $M_\bullet$ for galaxies observed by HST/STIS as part of the Proposals 7354, 7361, 7403, 8228, 9068 and 9143.

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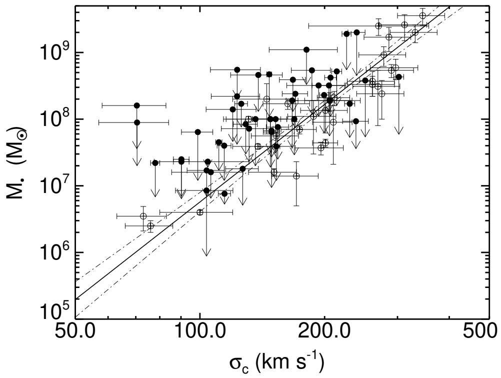

Fig. 1. Comparison between our $M_\bullet$ upper limits (filled circles) and the $M_\bullet - \sigma_c$ relation. The edges of the arrows correspond to upper limits obtained with $i = 33°$ and $i = 81°$, respectively. The open circles show the galaxies with accurate measurements of $M_\bullet$ (Ferrarese & Ford 2005).

2. Data reduction and analysis

The STIS/G750M spectra were obtained with either the 0.″2 × 52″ or 0.″1 × 52″slit crossing the galaxy nucleus along a random position angle. The observed spectral region includes the [N II] $\lambda\lambda$6548, 6583, Hα, [S II] $\lambda\lambda$6716, 6731 emission lines. Data reduction was performed with the STIS pipeline, which we implemented to clean cosmic rays and hot pixels. For each galaxy we obtained the nuclear spectrum by extracting a 0.″25-wide aperture centered on the continuum peak. The ionized-gas velocity dispersion was measured by fitting Gaussians with the same width and velocity to the narrow component of the [N II] and [S II] emission lines. The Hα line and broad components were fitted with additional Gaussians.

We assumed that the ionized gas resides in a thin disk and moves into circular orbits. The local circular velocity is dictated by the gravitational influence of the putative SMBH. In our model we neglected non-gravitational forces as well as the mass contribution of the stellar component. By taking into account for these effects, we would obtain tighter upper limits on $M_\bullet$. To derive the upper limits on $M_\bullet$ we first built the gaseous velocity field and projected it onto the sky plane according to the disk orientation. Then we observed it by simulating the actual setup of STIS as done by Sarzi et al. (2002). We have no information on the orientation of the gaseous disk within the central aperture. Therefore, to reproduce the observed line width and flux radial profile we adopted two different inclinations of the gaseous disk. We used a nearly face-on disk ($i = 33°$) with a larger $M_\bullet$ and a nearly edge-on disk ($i = 81°$) with a smaller $M_\bullet$. They correspond to 68% upper and lower confidence limits for the $M_\bullet$ for randomly orientated disks. Moreover, we assumed the slit to be placed along the disk major axis. Indeed, by extracting a squared aperture we minimized the effect of the unknown position angle. For each galaxy, we calculated the two upper limits on $M_\bullet$ that are shown in Figure 1.

3. Results

For some galaxies of the sample, either upper limits (Sarzi et al. 2002; Coccato et al. 2006) or accurate measurements of $M_\bullet$ (Ferrarese & Ford 2005) were available. They are consistent within errors with our measurements. Therefore, we are confident to obtain reliable estimates of the upper limit on $M_\bullet$ for all the remaining galaxies of our sample. This method will allow to increase the statistical significance of the relationships between $M_\bullet$ and galaxy properties. Adding new masses in both the upper and lower ends of $M_\bullet - \sigma_c$ will allow to identify peculiar objects worthy of further investigations. The resulting upper limits are close to the $M_\bullet - \sigma_c$ by Ferrarese & Ford (2005). At small σ_c most of $M_\bullet$ are above $M_\bullet - \sigma_c$. This can be explained in term of non-gravitational forces (Sarzi et al. 2002). At larger σ_c some of $M_\bullet$ fall below the $M_\bullet - \sigma_c$ relation. They could be the laggard SMBHs discussed by Vittorini et al. (2005).

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