Black holes in low-mass bulges and pseudobulges

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Abstract. Over the past decade we have learned that probably all ellipticals and bulges contain a central supermassive black hole (SMBH). The mass of the SMBH correlates both with the mass of the bulge component (about 0.15% of the bulge mass) and with the velocity dispersion σ of the bulge. We are investigating whether these relations remain valid or how they change when galaxies with pseudobulges, very low-mass bulges or bulgeless galaxies are considered. Studying SMBH relations for both classical bulges and pseudobulges can reveal the importance of different growing mechanisms (mergers vs. secular evolution) for the evolution of SMBHs. Low-mass classical bulges and bulgeless galaxies may harbour seed black holes in their earliest evolutionary stages, and studying them is of paramount importance for understanding the link between bulge evolution and black hole growth.

Keywords. galaxies: kinematics and dynamics, galaxies: bulges

1. Introduction

It is well established that all galaxies with a massive bulge component harbour a central supermassive black hole (SMBH). The mass of this SMBH $M_\bullet$ correlates with bulge properties such as the bulge mass and the velocity dispersion σ. Our knowledge of the behaviour of these correlations is mainly based on studies of massive ellipticals or early-type spiral galaxies with a massive classical bulge component, but is rather poor for other types of galaxies and bulges. Currently the low-σ end ($\sigma < 120$ km/s) is insufficiently constrained, with very few stellar or gas dynamical SMBH mass measurements. Even more unclear is the situation for galaxies that do not have a bulge at all. A few studies indicate that low-mass black holes may be present in bulgeless galaxies, but possible correlations with host galaxy properties are unclear.

If the growth of SMBHs is as tightly connected to the growth of the surrounding bulge as the $M_\bullet$-σ relation suggests, the question arises whether SMBHs in pseudobulges obey the same correlations as SMBHs in classical bulges. Pseudobulges are the result of secular evolution. They have disclike characteristics, are flattened, often show spiral structure or nuclear bars and are rotation dominated. Real systems can contain both a classical and a pseudobulge component at the same time. Two of the three SMBHs found in pseudobulges are actually located in such compound systems (NGC 2787 and NGC 3384). Based on only these two examples it is not possible to conclude whether their masses scale with classical bulges only, or also with pseudobulges (Erwin *et al.* 2007).

2. Observations and first results

The goal of our study is to measure black hole masses for a larger number of low-σ galaxies and to investigate if and how the $M_\bullet$-σ relation changes when only pseudobulges

Table 1. Galaxies observed with SINFONI and their distance D, velocity dispersion σ, sphere of influence d_{soi} and spatial resolution (FWHM)

Galaxy	D (Mpc)	σ (km/s)	d_{soi} ($''$)	resolution ($''$)	bulge type	AO mode
NGC 1398	18	200	0.34	0.19...0.32	pseudo	NGS
NGC 3368	10	128	0.22	0.15...0.25	pseudo	LGS
NGC 3627	10	115	0.19	0.15/0.088	pseudo	LGS
NGC 3489	12	105	0.12	0.08	class.	NGS
NGC 4486a	16	111	0.13	0.10	class.	NGS
NGC 5102	4	65	0.10	0.12/0.07	class.	NGS
NGC 1316	19	220	0.44	0.12/0.09	class.	NGS

are considered. In inactive galaxies, the evidence for the existence of black holes and their masses comes from gravitational effects on the dynamics of stars or gas inside the black hole's sphere of influence. Since the radius of the sphere of influence scales with $M_\bullet$, high resolution observations are needed to detect SMBHs in the low-mass regime. We therefore use the the integral-field spectrograph SINFONI (Eisenhauer *et al.* 2003, Bonnet *et al.* 2004), which can deliver diffraction-limited resolution thanks to the adaptive optics (AO) system, and is able to penetrate dust as it operates in the near-IR. We have observed seven galaxies in the K band so far, two with the recently commissioned laser guide star (LGS) PARSEC (Rabien *et al.* 2004), the rest in natural guide star (NGS) mode. Table 1 gives an overview of the observations and the achieved resolutions.

The stellar kinematics is extracted from the CO bandheads at > 2.29 μm using the maximum penalized likelihood method of Gebhardt *et al.* (2000) with a number of late-type stars observed with SINFONI as templates. The dynamical modelling is based on the Schwarzschild superposition code of Thomas *et al.* (2004). After obtaining the luminosity profile from high-resolution imaging, orbit libraries are constructed in a number of gravitational potentials, each of them calculated with a different black hole mass $M_\bullet$ and mass-to-light ratio Υ. The best-fitting parameters then follow from a χ^2-analysis.

The first result of our study is the detection of a SMBH in the low-luminosity elliptical galaxy NGC 4486a in the Virgo cluster. The bright star $\approx 2.5''$ away from the centre was used as a natural guide star for AO correction and offered a spatial resolution of $\approx 0.1''$. A black hole of mass $M_\bullet = 1.25^{+0.75}_{-0.79} \times 10^7 M_\odot$ (90% C.L.) was found (Nowak *et al.* 2007), in perfect agreement with the predictions of the $M_\bullet$-σ relation of Tremaine *et al.* (2002). The analysis of the remaining galaxies is under way. Particularly interesting is the pseudobulge galaxy NGC 3368, which shows a stellar σ drop and two infalling, counterrotating clouds of H_2 in the centre. Observations of more galaxies are planned to build a statistically significant sample of pseudobulges and low-mass bulges.

References

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