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Unravelling the mystery within dwarf elliptical galaxies

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Abstract. Black hole (BH) theories predict the existence of an "intermediate" mass BH at the centers of dwarf elliptical (dE) galaxies. These intermediate mass black holes (IMBHs) are believed to bridge the observational gap between stellar-mass BHs ($M_{\rm BH} \lesssim 10^3 {\rm M}_\odot$) and supermassive BHs ($M_{\rm BH} \gtrsim 10^6 {\rm M}_\odot$). Our project aims at finding tighter empirical constrains on the existence, location, and mass range of these hypothetical objects. For this purpose, we are conducting a deep IMBH search in a sample of ∼30 Local Volume dwarf galaxies. Using the Robert Stobie Spectograph (RSS) on the newly constructed Southern African Large Telescope (SALT), long-slit spectroscopic observations along the major-axis will be acquired for each galaxy to determine their kinematic and dynamical properties, particularly at their centers.

Keywords. galaxies: dwarf, kinematics and dynamics, formation, evolution

1. Introduction

Dwarf galaxies constitute the most common galaxy type in the Local Volume (D$\lesssim$10 Mpc) and in neighboring galaxy clusters. In particular, dwarf elliptical (dE) galaxies have been observed to thrive in rich cluster environments where they exhibit a truly gregarious nature. Locally, this behavior has been observed in the nearby Sculptor and Centaurus A groups (Jerjen, Binggeli & Freeman 2000). However, their faint luminosities ($M_V > -17\overset{\rm m}{.}0$) and low effective surface brightness ($\mu_V > 22\,{\rm mag\,arcsec^{-2}}$), make observing dE galaxies extremely challenging, even with 10m-class telescopes.

We plan to use the SALT telescope to determine the kinematics of nearby dwarf galaxies. This project will make use of the two prime features unique to SALT: namely, the high sensitivity in the ultraviolet and infrared, as well as its large field-of-view ($8' \times 8'$). Long-slit spectra along the semi-major axis of each dwarf galaxy will be obtained using the RSS spectrograph. The resulting kinematical information will be used in dynamical modelling of the galaxy, from which a wealth of information can be extracted. Our main goal is to detect IMBHs within the central regions of low luminous dEs in order to confirm their existence and constrain their masses. Making use of our radial rotation velocity and velocity dispersion measurements, the global dark matter content of dwarf galaxies will also be investigated, another crucial piece of the puzzle needed for cosmological studies.

2. Current status of the $M_{\rm BH}$-σ relation

Observations of early-type galaxies (i.e. ellipticals, lenticulars but also spiral bulges) have shown most of them to contain central supermassive BHs. Ferrarese & Merritt (2000) found a strong correlation between the central BH mass and the velocity dispersion σ of the host galaxy of the form:

$$\log\left(M_{\rm BH}/{\rm M}_\odot\right) = 4.80(\pm 0.54)\log\left(\sigma/\sigma_0\right) - 2.9(\pm 1.3), \qquad (2.1)$$

where σ_0 is a reference value usually taken to be $\sigma_0 = 200\,{\rm km\,s^{-1}}$. However, to explore the lower end of this relation (i.e. the "intermediate" mass range of $10^3{\rm M}_\odot \lesssim M_{\rm BH} \lesssim 10^6{\rm M}_\odot$), kinematical information is needed for galaxies with velocity dispersion of the order $20 \lesssim \sigma \lesssim 50\,{\rm km\,s^{-1}}$. Taking this and extrapolating the above relation to the intermediate BH mass regime, immediately implies that dE galaxies (owing to their relatively small velocity dispersions) are highly likely to host IMBHs.

Currently, there exist BH mass estimates for only one nucleated dE galaxy, NGC 205 (Valluri *et al.* 2000). These authors obtained high resolution spectra of the central region of NGC 205 using the Space Telescope Imaging Spectograph (STIS) on the Hubble Space Telescope (HST). The kinematical information resulted in a firm upper mass estimate of $2.2 \times 10^4{\rm M}_\odot$ for the central IMBH in NGC 205. Spectra of six Virgo dE galaxies were obtained by Geha *et al.* (2002) with the Echelle Spectograph and Imager (ESI) on the Keck II telescope. However, the resulting spatial resolution of the acquired spectra proved insufficient in determining reliable BH mass estimates.

3. Proposed observations

We will use the SALT/RSS instrument to obtain spectra of dwarf galaxies in the "nearby" Sculptor, Centaurus A and M83 groups. By choosing dwarf galaxies within the Local Volume (D $< 10\,$Mpc) and observing under excellent seeing conditions, we are guaranteed the spatial resolution needed in probing the radius of influence of the BH.

To fully exploit the UV sensitivity of the SALT detectors, spectra will be acquired in the blue spectral region where we are particularly interested in the well-defined calcium II H and K lines, prominent absorption features in the spectra of dE galaxies. These lines will be used in measuring the radial velocities and velocity dispersion along the major axis of the galaxy using the Gauss-Hermite line-profile fitting method as described in van der Marel & Franx (1993). The Ca II H and K lines will give us better precision in extracting the kinematics of target galaxies, compared to the weaker Ca II triplet lines, generally observed in the red part of the spectrum.

To ensure for the successful extraction of the kinematical information we need high S/N spectra for each dwarf galaxy. With the SALT telescope's large aperture, we expect to detect low surface brightness dwarf galaxies out to $\mu_V \sim 24\,{\rm mag\,arcsec^{-2}}$. The large light collecting area and field-of-view makes the SALT telescope ideal for investigating the IMBH hypothesis in faint, extended dwarf galaxies.

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