MUSE observations of the intermediate mass black hole ESO 243-49 HLX-1

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Abstract

The formation of intermediate mass black holes is still poorly understood. With the discovery of the best intermediate mass black hole candidate, HLX-1 in the galaxy ESO 243-49, we can finally test some of the theories. Thanks to data taken with the Multi Unit Spectrograph Explorer (MUSE) on the VLT, which provides high-precision spectra in the visible and near infra-red domain (4750-9350 Angstroms), we are investigating both the intermediate mass black hole and its environment. We present preliminary results on the mass of the supermassive black hole in ESO 243-49 and constraints obtained on merger events in the galaxy.

Introduction

Black holes can be classified by their mass : stellar mass black holes with masses below 100 $M_\odot$ come from the gravitational collapse of massive stars and supermassive black holes (SMBH) have a mass range of 10^6-10^9 $M_\odot$ and are located in the center of massive galaxies. Theoretically, intermediate mass black holes (10^2-10^5 $M_\odot$) are also proposed but the observational evidence for these objects is weak and their origin is still unclear. Even if the theory doesn't rule out a black hole with a mass which is between those 2 ranges, find one is difficult. Currently, the best candidat is HLX-1 in the galaxy ESO 243-49 (Farrell et al. 2009) which may originate from a past collision between ESO 243-49 and a dwarf galaxy (Webb et al. 2010). Determining the mass of the SMBH of ESO 243-49 and the mass of HLX-1 with the M-σ relation and the stellar population in the region of HLX-1 will help for future simulations of ESO 243-49 collision scenarios.

Method

The data were taken with the integral-field units of MUSE on the Very Large Telescope with a spectral resolution of 2.6 Å in the wavelength range 4750-9350Å. 12 observations of 500s were reduced and combined with the ESO software Reflex (Hook et al., 2008). To determine the velocity dispersion and the stellar population, we used the Penalized PiXel-Fitting method (Cappellari & Emsellem 2004) : creating a model galaxy spectrum by convolving a parametrized line-of-sight velocity distribution with stellar template spectra and fitting the model to the ESO 243-49 spectrum (Fig.1). We defined 2 regions (Fig.2) : the central bulge to determine the central velocity dispersion σ_c, corrected to an effective aperture $r_e/8$ with r_e the half-light radius and use the relation : $M_{BH}=1.32(\pm0.36)\times10^8 M_\odot(\sigma_c/200)^{4.72\pm0.36}$ (Ferrarese & Merritt 2000) and the half-light region to estimate the effective velocity dispersion σ_e and use the relation : $M_{BH}=1.2(\pm0.2)\times10^8 M_\odot(\sigma_e/200)^{3.75\pm0.3}$ (Gebhardt et al. 2000). The regions were elliptical (Fig. 1) and circular apertures are needed to apply the M-σ relation so we used radii equal to the semi-major and semi-minor axis of the ellipses. We used the MILES and the Indo-U.S. library for templates spectra.

Results

	ESO 243-49	
Radius	Semi-major axis	Semi-minor axis
Central velocity dispersion σ_c (km/s)	205.2±1.7 (1σ)	222.8±1.8 (1σ)
Effective velocity dispersion σ_e (km/s)	201.6±1.7 (1σ)	202.1±1.8 (1σ)
Black hole Mass M_{BH}	0.9-4.5×10^8 $M_\odot$	

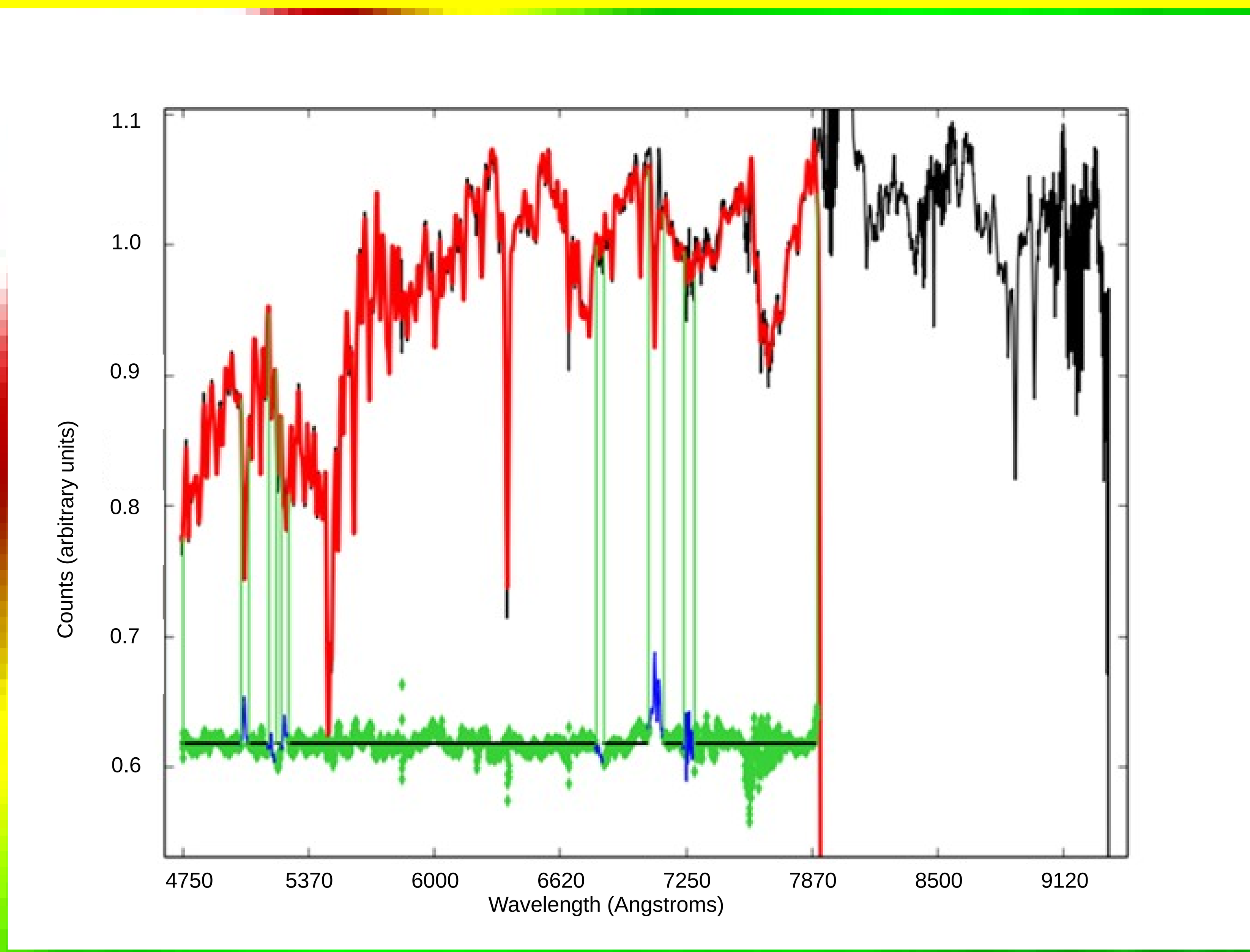

Fig. 1: ESO 243-49 spectrum (black) fitted by pPXF with the model galaxy spectrum (red) using MILES library. Residuals (green) and non-fitted gas emission lines (blue) are also fitted.

Discussions

We have made an estimate of the mass of the supermassive black hole in ESO 243-49 using the velocity dispersion : we estimate a mass of $0.9 - 4.5\times10^8$ $M_\odot$ (1σ). This estimate is similar to the estimate made using the black hole mass-host spheroid luminosity relation (Savorgnan et al., 2013) $0.3 - 3.7\times10^7$ $M_\odot$ (1σ) and the value from the black hole fundamental plane relationship (Koerding et al., 2006) of $0.5 - 55.0\times10^7$ $M_\odot$ (1σ). Given the short exposure time, we do not have a reliable (3σ) detection of HLX-1 and therefore can not use this method to make a good mass constraint of the IMBH. However, there is evidence for a young stellar population possibly associated with HLX-1, as proposed by Farrell et al. (2012). Further work continues to investigate the nature of HLX-1 and ESO 243-49, in particular looking for evidence of collisions. The constraints made during this work will be used in SPH simulations to understand the possible collision between HLX-1 and ESO 243-49.

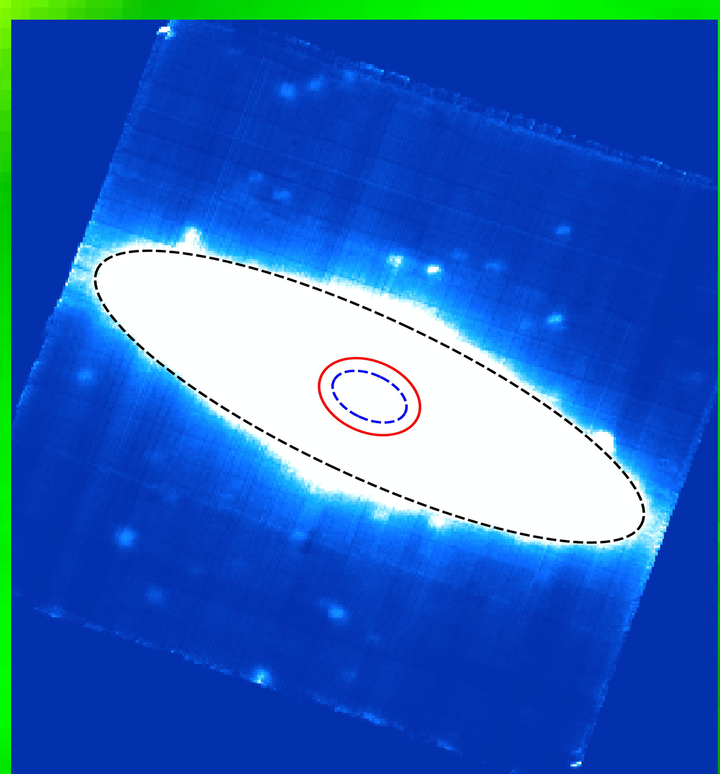

Fig.2 : Bulge region (blue dotted line), half-light region (red line), "total" luminosity region (black dotted line)

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