Scaling relations of IMBH and their host-galaxies

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Growing Black Holes: Accretion and Mergers – 19/May/2022

Nuclear (I)MBH: what was known by 2017/20



NGC104 Kiziltan17



Optical follow-up spectroscopy of IMBH/LWSMBH

- Optically selected AGN candidates (SDSS):
- IMBH: **305** galaxies (M_{BH}<200 000 M_{Sun})
 LWSMBH: **1623** galaxies (2*10⁵<M_{BH}<10⁶ M_{Sun})
- Of the **141** X-ray confirmed IMBHs/LWSMBHs:
- **44** galaxies observed by our team with MagE (Magellan)
- □ <u>15</u> with ESI (Keck). +<u>11</u> spectra were found in the Keck archive
- 9 with RSS (SALT). In total <u>76</u> unique objects.

The targets of our optical follow-up campaign

J0023-0109	J0044+0109	J0055-0020	J0108-0006	J0115+0108	J0127+0035
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2519k 5 kpc	378k	76k	791k 📃 🔤	590k	471k _
J0135+0024	J0228-0901	J0233-0748	J0240+0103	J0249-0815	J0804+0958
			and a star of		
155k	202k	514k	942k	242k	27k
J0914+0451	J0914+1156	J1106+2003	J1107+1347	J1115-0004	J1159-0106
				1	
103k	189k	173k	122k	115k	189k
J1213+1401	J1215+0147	J1227+0757	J1244+1105	J1303+1914	J1311+0039
				Sec. Sec. Con	
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				Contractor	
138k 5 kpc	1032k	43k	921k _	103k	54k
J1321-0309	J1342+0530	J1357+2231	J1405+0916	J1417+0724	J1434+0338
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		Constant of the			and the second second
220k	65k	101k	675k	116k	629k
J1448+1608	J1516+2058	J1526+0659	J1534+0408	J1558+2728	J1605+1748
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167k	962k	408k	112k 🔹 🔜	112k	116k 🛛 🖳
J1617-0019	J1624-0054	J2056+0010	J2202+1151	J2213+1242	J2229-0051
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<mark>ڪ2k</mark> 5 k <u>pc</u>	588k 🔍	861k	580k _	215k	180k
		J2305+0024	J2348-0912		

ESI





MagE

Virial mass estimate

The virial mass of a black hole, according to Reines, A. E., Greene, J. E., & Geha, M. 2013, ApJ, 775, 116

$$M_{BH} = 3.72 \times 10^{6} (FWHM_{H\alpha} / 10^{3} \text{ km/s})^{2.06} \times (L_{H\alpha} / 10^{42} \text{ erg/s})^{0.47} M_{sun}$$

The upper limit of the IMBH mass is taken as 200 000 $\rm M_{Sun}$ (+1 σ systematic uncertainty in the estimate of the virial mass of a black hole from BLR $\rm H_{alpha}$, equal 100 000 $\rm M_{Sun}$)

Challenge: estimate the virial mass of central black holes

• sample of confirmed candidates for IMBH / LWSMBH (76).

Data reduction and post-processing of MagE and ESI data

MagE: a low-res echelle at the 6.5m Magellan

ESI: a low-res echelle at the 10m Keck

 $\begin{aligned} & \mathsf{R}_{\mathsf{MagE}} = 6400 \; (\sigma_{\mathsf{inst}} = 20 \; \mathsf{km/s}) \\ & \mathsf{R}_{\mathsf{ESI}} = 8700 \; (\sigma_{\mathsf{inst}} = 15 \; \mathsf{km/s}), \\ & 0.3 < \lambda < 1.0 \; \mathsf{um} \end{aligned}$



Analysis of the spectra of host galaxies with IMBH and LWSMBH

6500

Three-component parametric 2d fit of the galactic center (NBURSTs):

5000

5500

Galaxy SDSS J110731.23+134712.8 M_{BH} = 3.74e+04 M_{Sun}



Wavelength, [Å



Also we find binary IMBH (MagE and ESI observations)



Subtraction of the stellar continuum



Top panel - original 2d spectrum. The lower panel is the spectrum with the subtracted stellar substrate (stellar population spectrum).

Non-parametric emission lines fitting

All other parameters are linearly fitted at each minimization function evaluation using an iterative procedure that includes the following two steps:

(i) the fluxes of all emission line components are determined by solving a linear problem with a non-negative constraint;

(ii) the shape of the NLR component is reconstructed in a nonparametric way by solving a linear



Non-parametric emission lines fitting in 2D

1107+13_0070_0072_0074_0076_24062018_spec_H_alpha+[NII]



1107+13_0070_0072_0074_0076_24062018_fit_H_alpha+[NII]



1107+13_0070_0072_0074_0076_24062018_resid_H_alpha+[NII]



1107+13_0070_0072_0074_0076_24062018_blr_H_alpha+[NII]



1107+13_0070_0072_0074_0076_24062018_nlr

The $M_{BH}\text{-}\sigma_{\text{bulge}}$ relation

- estimates of virial masses of 44+11+8 (MagE+ESI+SALT) galaxies were obtained. The masses were refined for the slit losses and seeing effects.
- is there a correlation between the mass of a black hole and the velocity dispersion of bulge stars?
- it is too early to draw a conclusion about the coevolution of the bulge and low-mass black holes based on this correlation alone



Summary

- We have observed dozens of host galaxies of confirmed IMBH and LWSMBH candidates. The data were reduced and fitted, and the velocity dispersion of galaxy bulges was obtained.
- We have developed a method for two-dimensional nonparametric analysis of the emission spectrum of the host galaxy (I)MBH to refine the mass of the central black hole.
- \Box We conclude that a population of IMBHs in AGN with $\rm M_{BH} < 10^5 \, M_{\odot}$ exists and this fact disfavors massive SMBH seeds
- □ IMBHs in the nearby Universe do not seem to co-evolve with their host galaxies: they grow by accretion, while their hosts grow secularly (even though the gas supplies may be connected)

Thank you