AGN powered by intermediate-mass black holes: the parent sample of optically selected candidates from 1 million SDSS spectra

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Growing Black Holes: Accretion & Mergers
Nepal Kathmandu, May 15-20 2022

Subsequent talks from our team about IMBHs at this conference

Thursday, May 19

12:00 - ***Victoria Toptun***: X-ray follow-up and archival data: IMBH confirmation

12:15 - ***Kirill Grishin***: Structural properties and environment of IMBH hosts

14:00 - ***Vladimir Goradzhanov***: Optical spectroscopic follow-up: MBH-sigma relation

14:15 - ***Mariia Demianenko***: Optical variability of IMBHs

Friday, May 20

11:05 - ***Igor Chilingarian***: How do SMBHs grow in the low-mass regime?

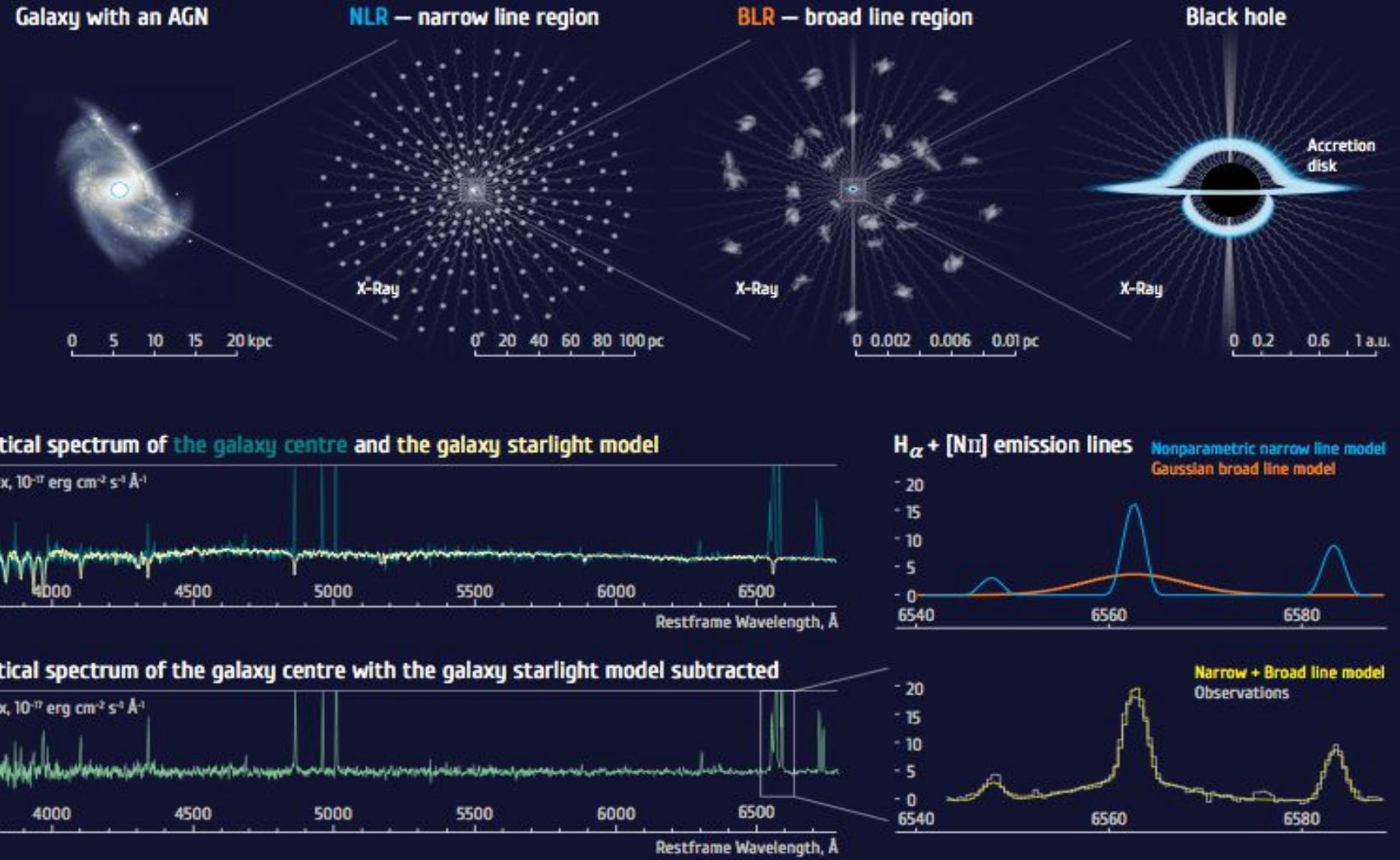
The formation of supermassive black holes in galaxy centers

What are the SMBHs seeds? One (or at the same time?) of three:

- super-Eddington accretion on stellar mass seeds (Pop-III star remnants)?
- direct collapse of massive gas clouds (10^5 M_{sun}) in the early Universe?
- merging of stellar mass seeds in clusters + subsequent accretion?
- merging IMBH?

Estimating the mass of a central black hole in an AGN is not an easy task. Especially, from single epoch observations.

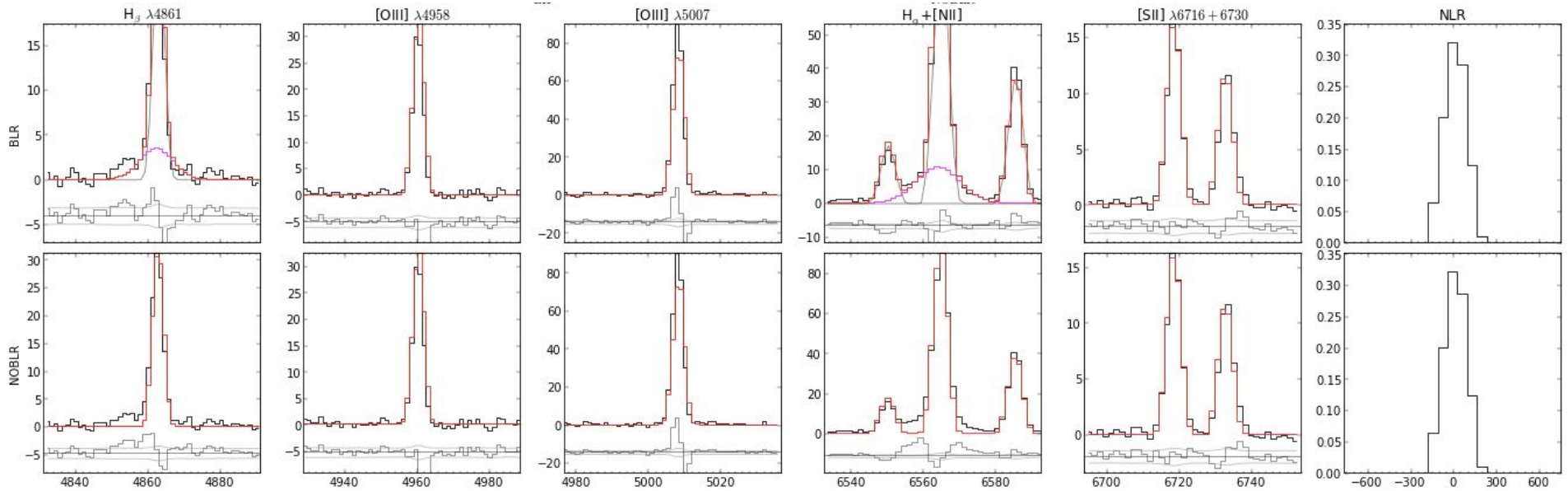
Chilingarian et al. 2018


Galaxy with an AGN
NLR — narrow line region
BLR — broad line region
Black hole
X-Ray
X-Ray
X-Ray
Accretion disk
0 5 10 15 20 kpc
0 20 40 60 80 100 pc
0 0.002 0.006 0.01 pc
0 0.2 0.6 1 a.u.
An optical spectrum of the galaxy centre and the galaxy starlight model
40, Flux, 10⁻¹⁷ erg cm⁻² s⁻¹ Å⁻¹
30
20
4000
4500
5000
5500
6000
6500
Restframe Wavelength, Å
An optical spectrum of the galaxy centre with the galaxy starlight model subtracted
20, Flux, 10⁻¹⁷ erg cm⁻² s⁻¹ Å⁻¹
10
-10
4000
4500
5000
5500
6000
6500
Restframe Wavelength, Å
Hα + [NII] emission lines
Nonparametric narrow line model
Gaussian broad line model
20
15
10
5
0
6540
6560
6580
Narrow + Broad line model
Observations
20
15
10
5
0
6540
6560
6580

An example of a non-parametric fit of an emission spectrum an AGN

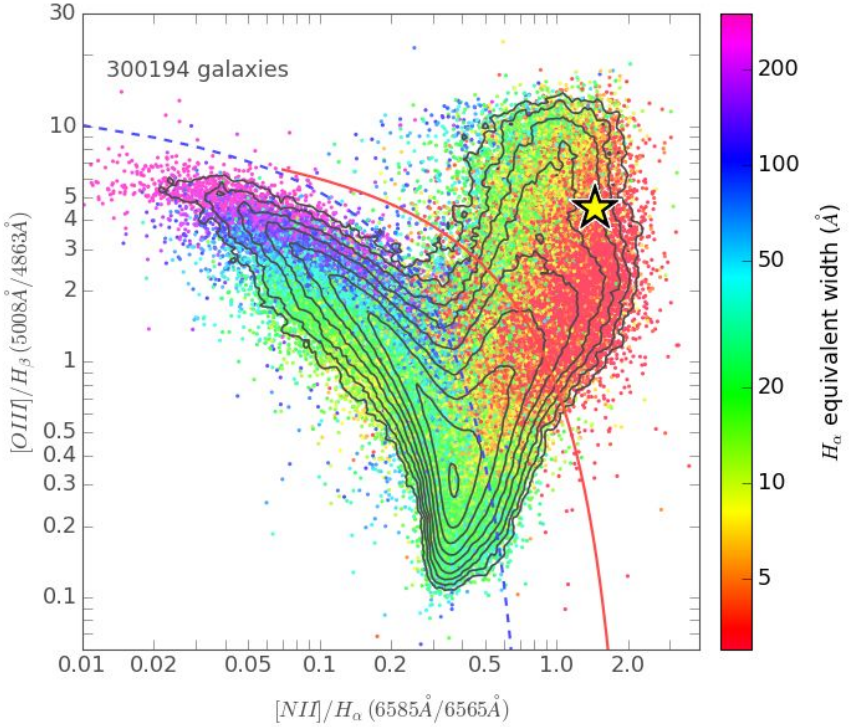
Allowed emission lines
broad (par) + narrow (non-par)
Hα/β/... 6563/4861

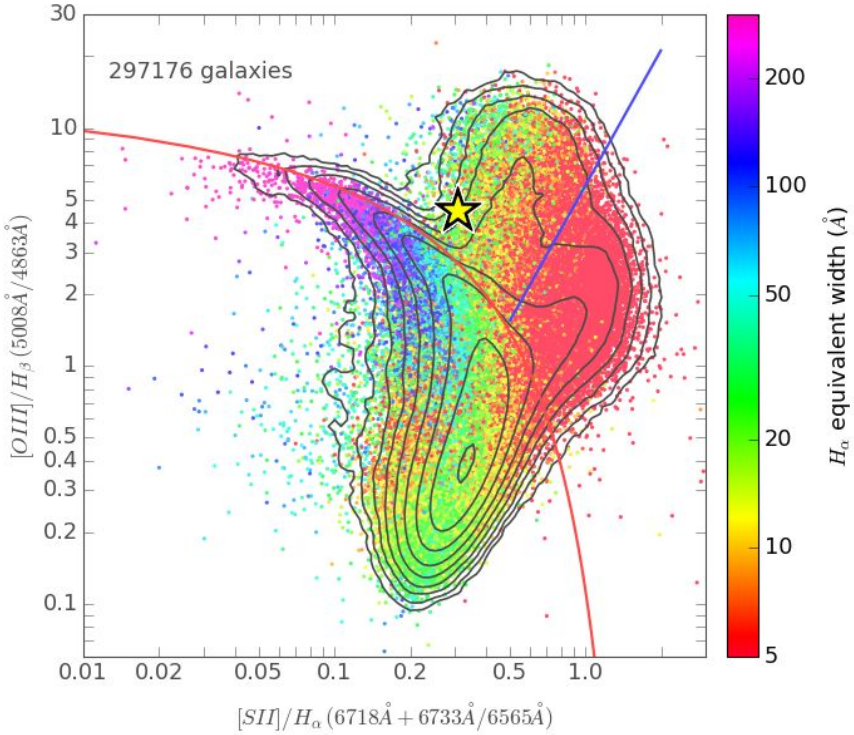
Forbidden emission lines: narrow (non-parametric)
[OIII] 4959/5007, [N II] λ6583, [N II] λ6548,
[S II] 6717/6731



Baldwin-Phillips-Terlevich (BPT) diagnostic [OIII]/[NII] and [OIII]/[SII]

to reject objects where the ionization was induced by star formation, because such objects often have broad Balmer lines originating from transient stellar events (core-collapse SNe) rather than from an AGN.





*charts for different objects

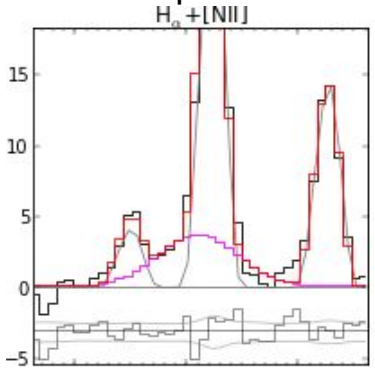
Reference Catalog of Spectral Energy Distributions

RCSED

https://rcsed2.voxastro.org/
http://rcsed.sai.msu.ru/

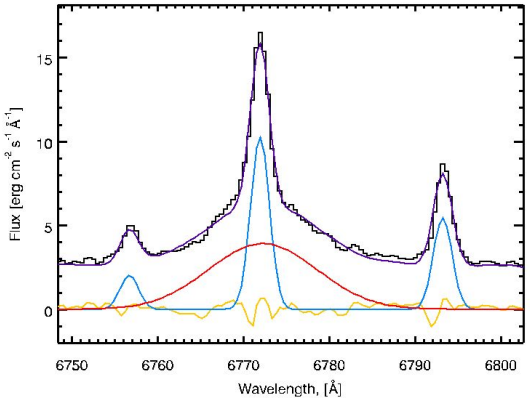
BLR+NLR fit of emission

sdss spectrum



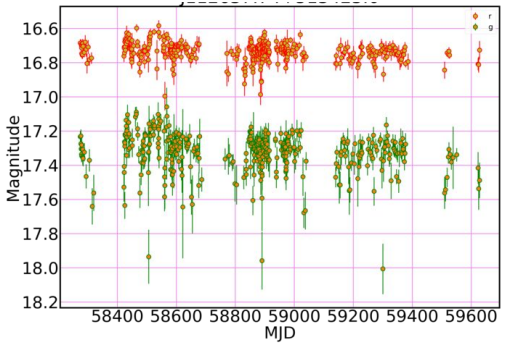
primary selection

get a high-resolution spectrum

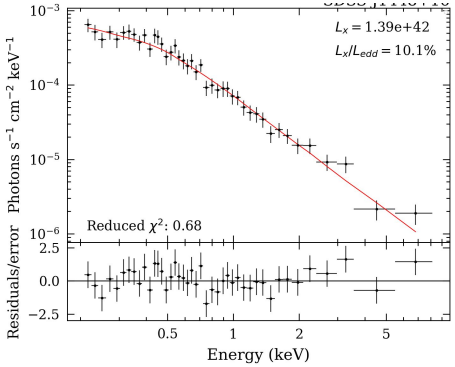


refine the BH mass

checking for optical variability



X-ray archives



Proof of the AGN nature

Selection of candidates: a set of criteria applied to the data

- telluric lines do not cover principal emission lines (Hα Hβ [OIII] [NII])

$$|(1+z)*5007.0-5577.0|<4\text{Å}$$

- Flux in BLR and NLR is accurate

$$(F-F_{err}*\sqrt{\chi^2})*\sqrt{\frac{\chi^2}{F+F_{err}*\sqrt{\chi^2}}}<0.5$$

- BLR is significantly broader than NLR

$$\sqrt{\frac{\sigma^2_{BLR}-\sigma^2_{NLR}}{\sigma^2_{NLR}}}>2.0$$

- Adding a BLR yields a statistically significant improvement of the fitting quality

$$\chi^2_{noBLR}-\chi^2_{withBLR}>20$$

- Ratio between M_{BH} and its uncertainty

$$M/M_{err}>3$$

- Verification with the BPT: AGN or transitional region

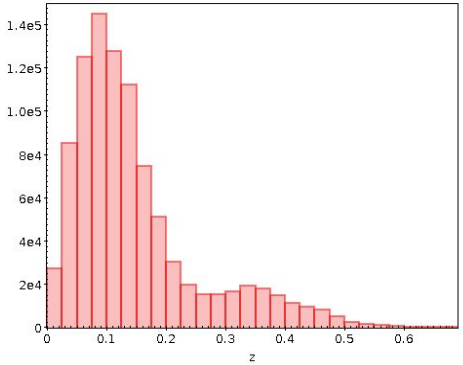
- Virial $M_{BH} < 200{,}000\ M_{sun}$

Initial data: fiber spectra from *Sloan Digital Sky Surveys*

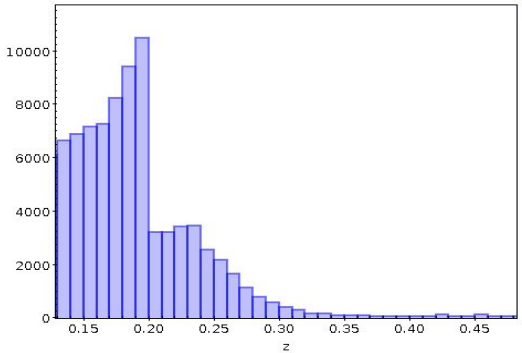
SDSS DR7 - 938,487

eBOSS SDSS DR15 - 154,764 (subset: 0 < z < 0.2 and 0.2<z<0.6 with spectrum SNR>15)

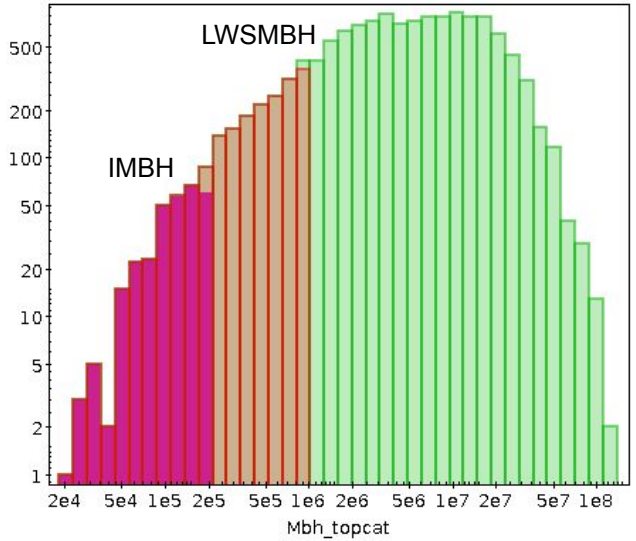
SDSS redshift distribution

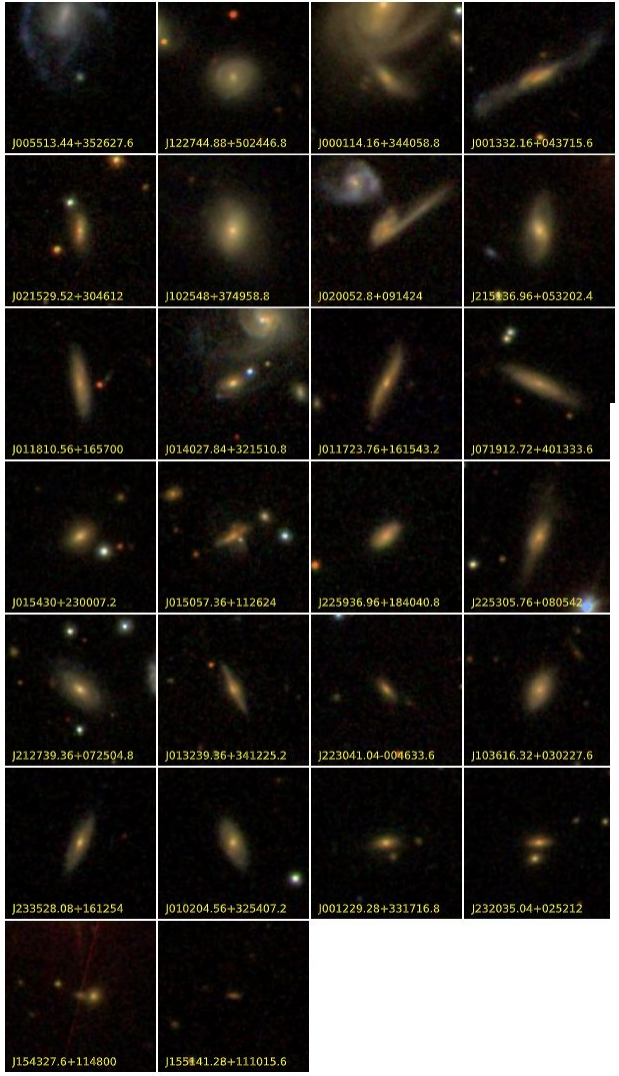


eBOSS redshift distribution

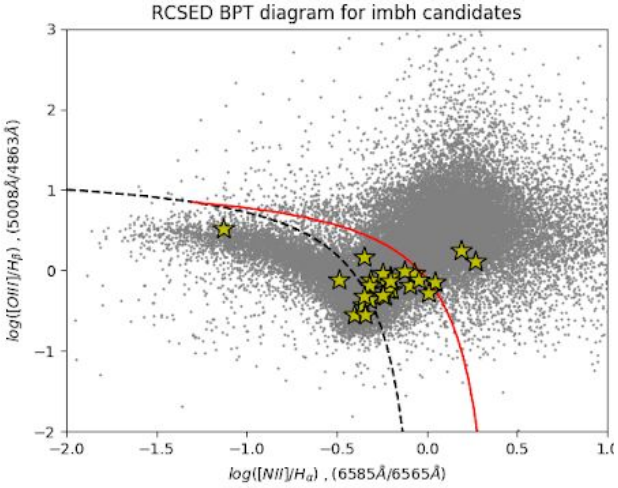


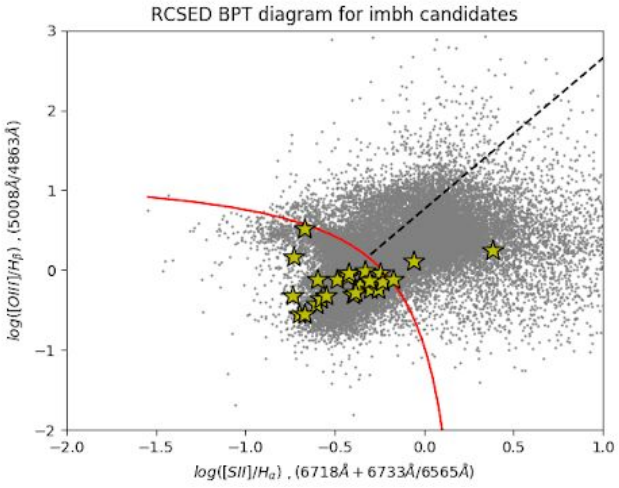
M_{BH} distribution



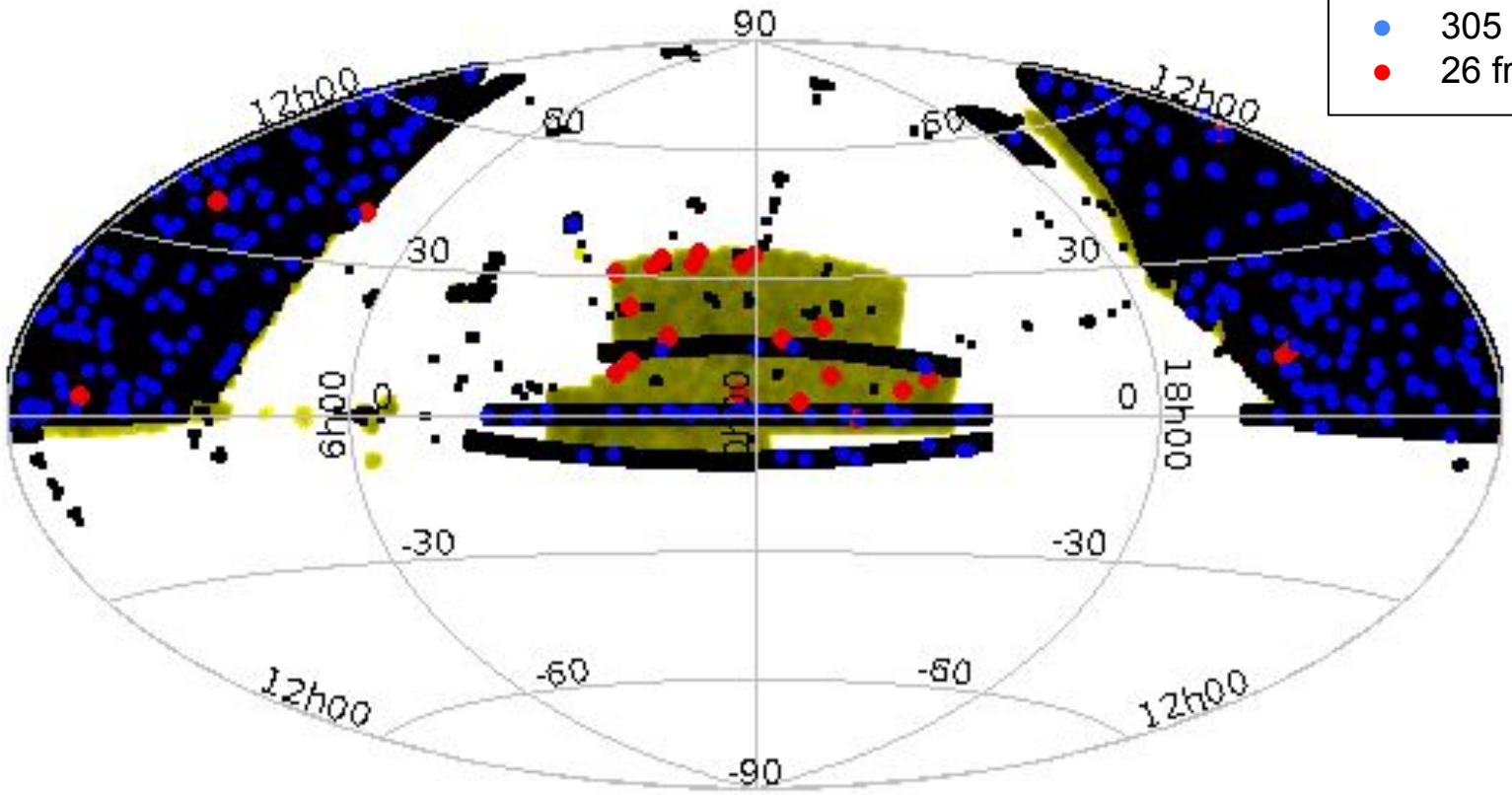


We found 26 new IMBH candidates (6 without BPT and 20 with BPT) from the SDSS DR15 eBOSS sample by processing 154,764 1d spectra at z<0.2 (all data is now in RCSEDv2)





Distribution of IMBHs in the sky (equatorial cord)



catalog area
- SDSS DR7
- eBOSS

IMBH
- 305 from SDSS
- 26 from eBOSS

The final sample

LWSMBH: "light-weight" SMBH

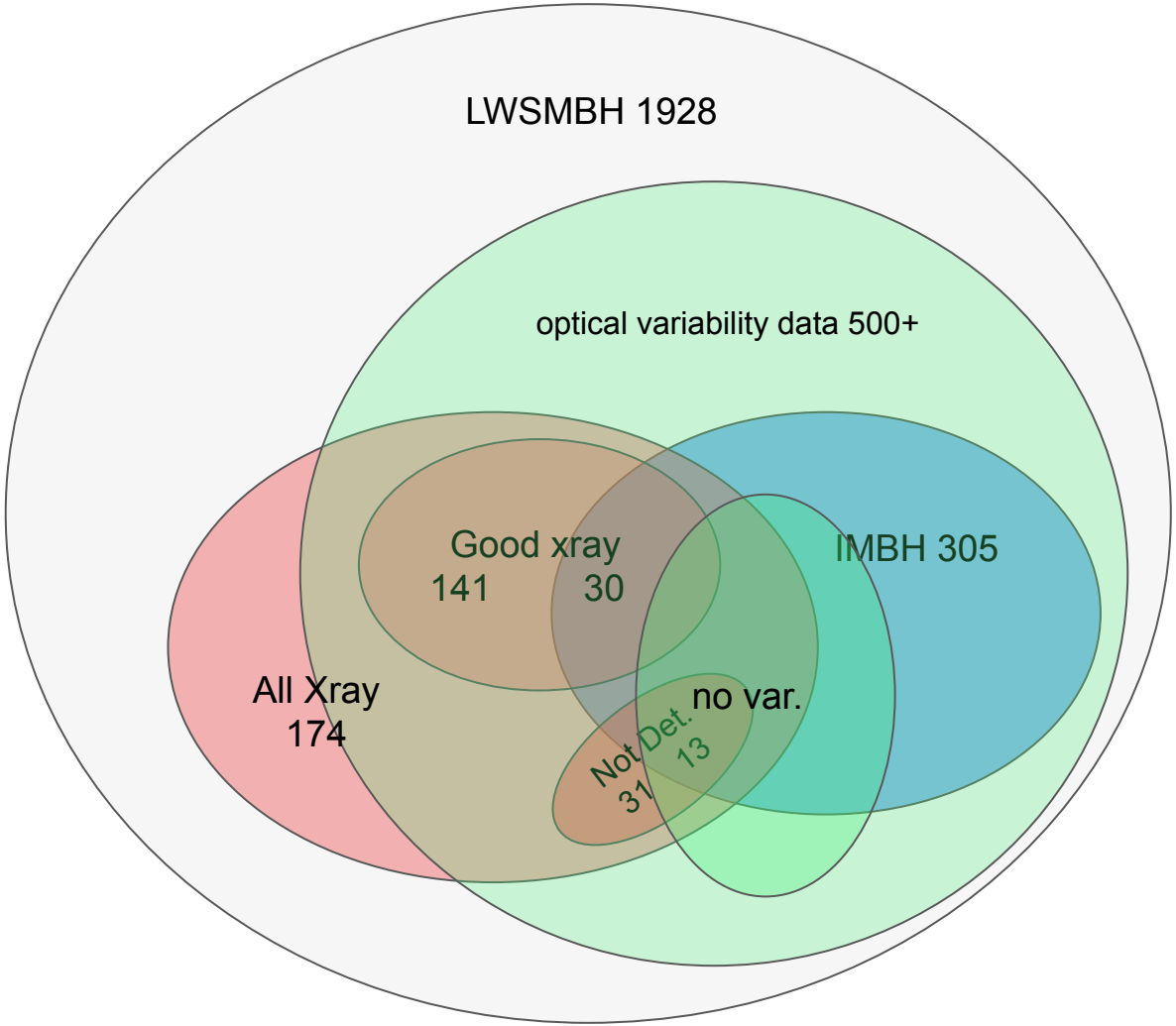
IMBH: intermediate-mass black hole

1928 galaxies in the sample

- 1623 LWSMBH ($M_{BH} < 10^6 M_{sun}$)
- 305 IMBH ($M_{BH} < 2*10^5 M_{sun}$)

Among this sample:

- X-ray data: 174 objects
- optical follow-up spectroscopy: 72 objects
- optical variability: 500+ targets



Thank you for your attention

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