Looking for the broad emission lines in AGN2 with deep NIR spectroscopy

and

the measure of the mass of Intermediate Mass BH

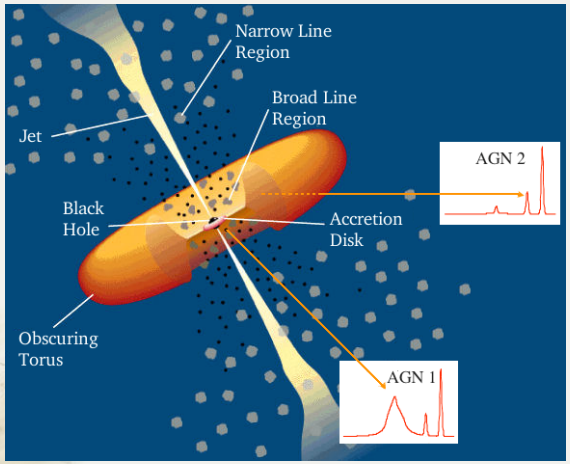
Francesca Onori
Federica Ricci

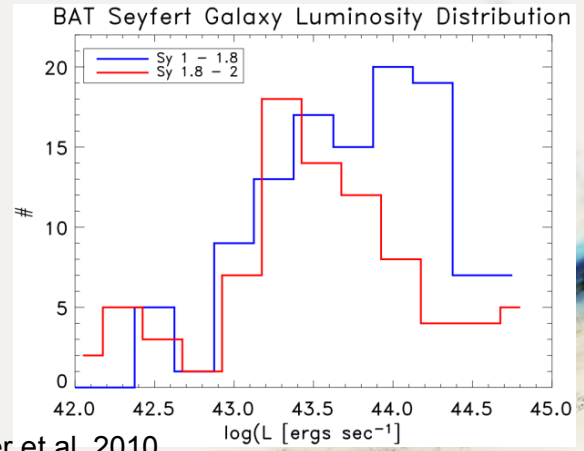
Dipartimento di Matematica e Fisica
Università degli studi "Roma Tre"

F. La Franca, M. Brusa, E. Sani, R. Maiolino, S. Bianchi, A. Bongiorno, F. Fiore, A. Marconi and C. Vignali

Active Galactic Nuclei – Unified Model

According to the Unified Model, AGN1 (with Broad and Narrow Emission Lines spectra) and AGN2 (only Narrow Emission Lines spectra) are the same objects seen at different viewing angles.



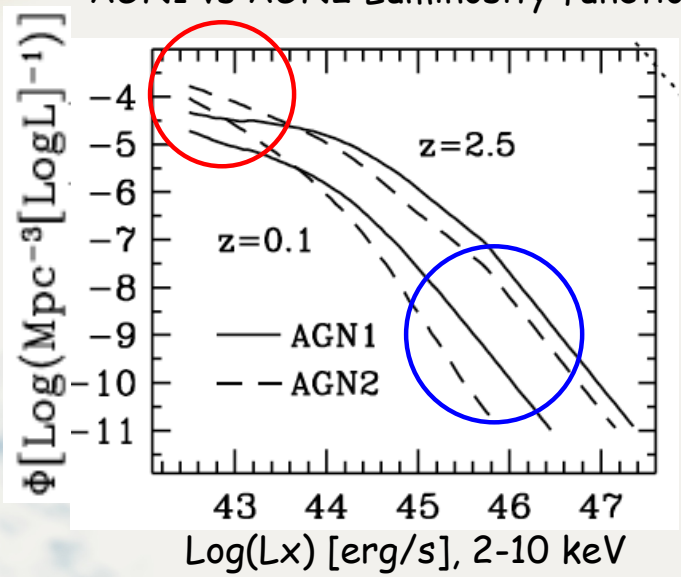


Tueller et al. 2010

However AGN1 and AGN2 show:

- different luminosity functions (Ueda+03, La Franca+05, Ueda+14)
- different host galaxies
- (probably) different accretion rates and BH masses

AGN1 vs AGN2 Luminosity function



La Franca et al. 2005

Virial methods of BH mass measurement

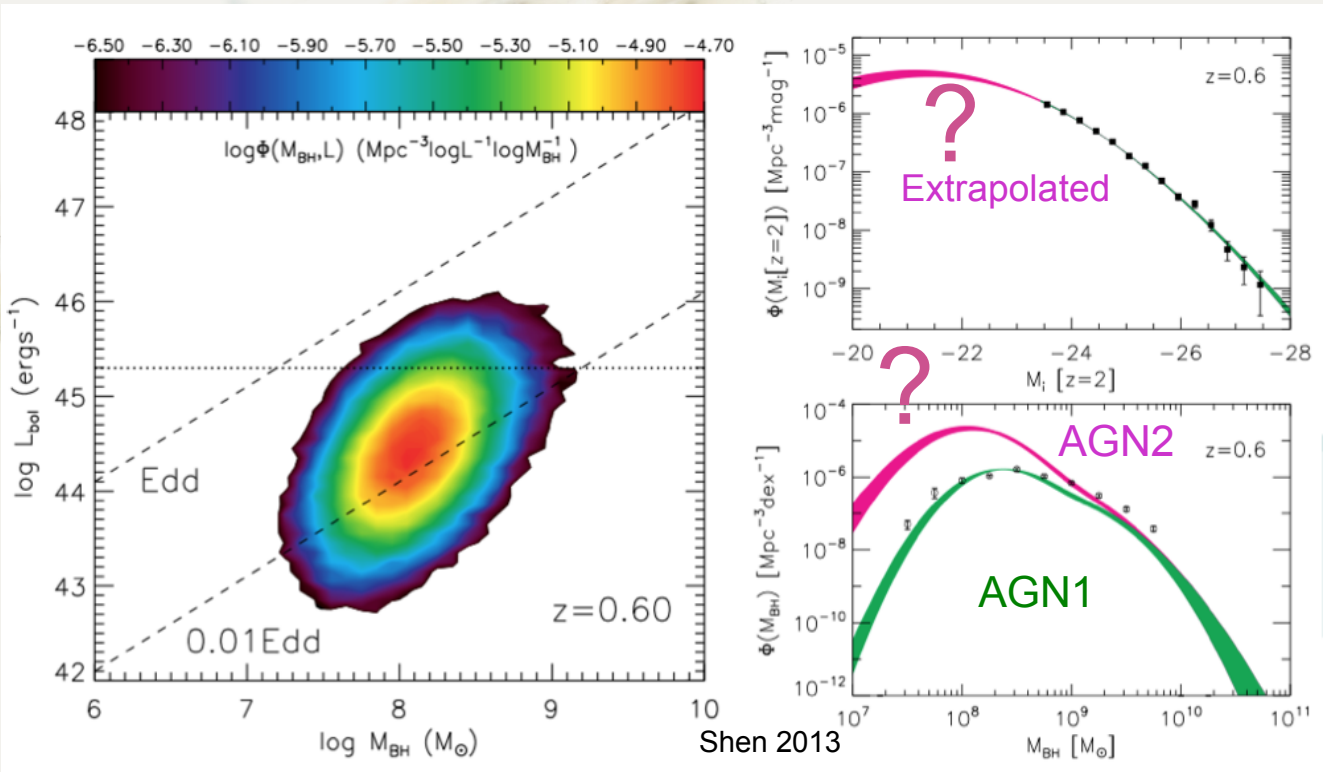
We are missing a complete picture of the BH mass function.

We are not able to measure the BH mass for the lower luminosity, lower mass, more obscured sources: namely, the AGN2 (which are missing W, the BLR width)

For AGN1 only!

$$\log\left(\frac{M_{\rm SE}}{M_\odot}\right) = a + b\log\left(\frac{L}{10^{44}\,{\rm erg\,s^{-1}}}\right) + c\log\left(\frac{W}{\rm km\,s^{-1}}\right)$$

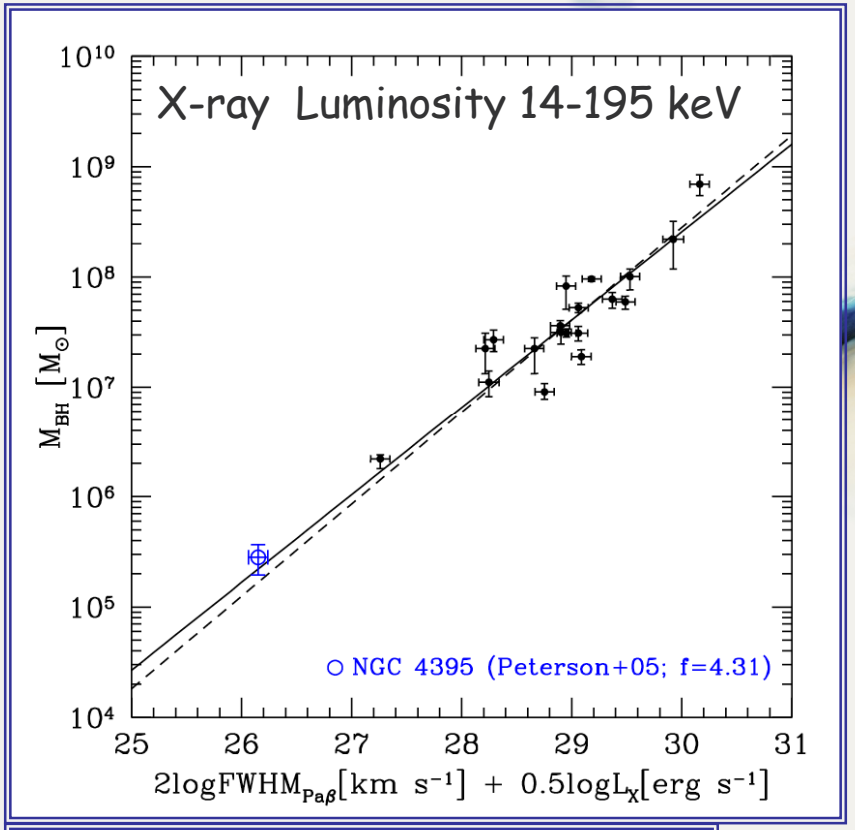
and those low luminosity AGN1/2 where huge galaxy contamination prevent a reliable measure of the luminosity L



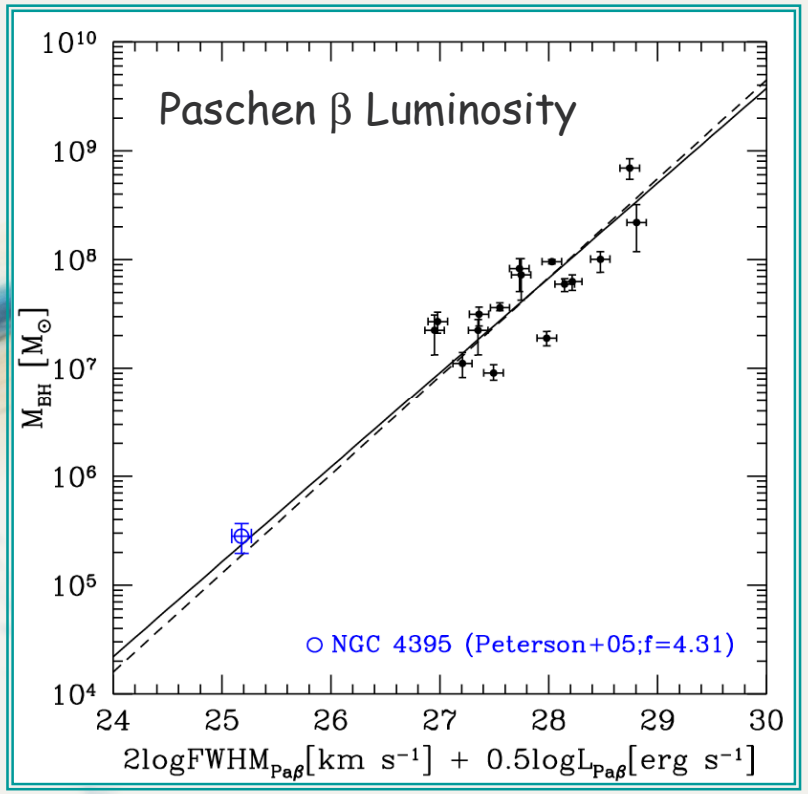
Shen 2013

A new NIR virial relation potentially able to work with Low luminosity AGN1 and AGN2

We have calibrated 2 new NIR virial relations based on the Paβ FWHM which use either the X-ray or the Paβ luminosities **less affected by reddening/absorption problems.**



$$\log\left(\frac{M_{BH}}{M_\odot}\right) = \log\left[\left(\frac{FWHM_{Pa\beta}}{10^4\ km\ s^{-1}}\right)^2\left(\frac{L_X}{10^{42}\ erg\ s^{-1}}\right)^{0.5}\right] +7.65(\pm0.02)\ \pm\ 0.24\,,$$



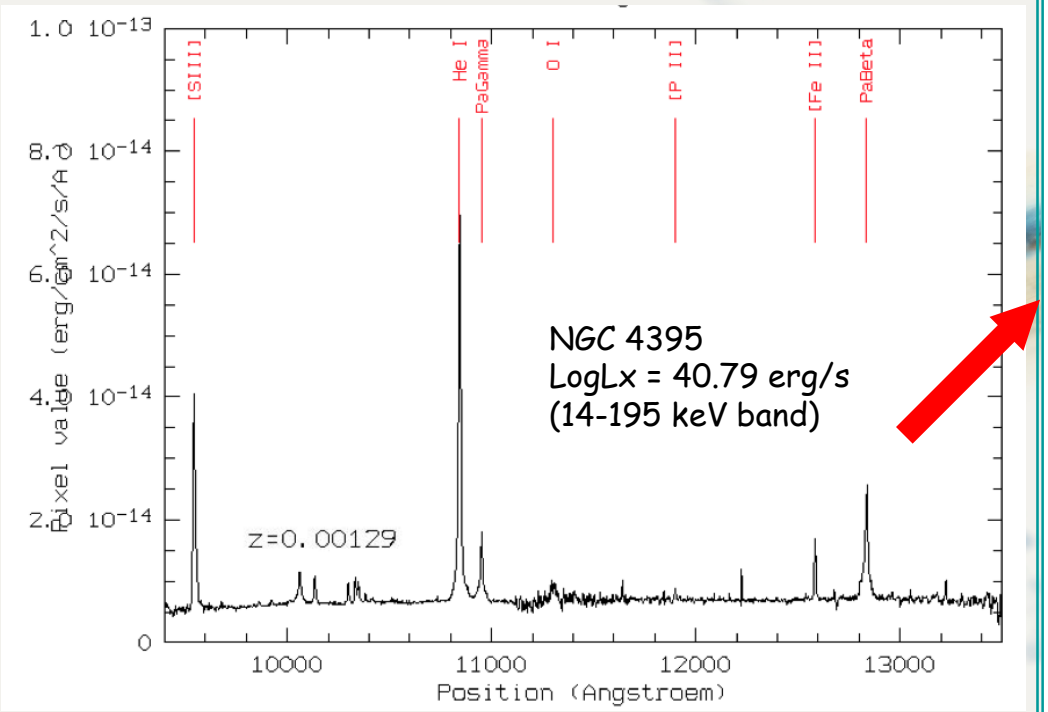
$$\log\left(\frac{M_{BH}}{M_\odot}\right) = \log\left[\left(\frac{FWHM_{Pa\beta}}{10^4\ km\ s^{-1}}\right)^2\left(\frac{L_{Pa\beta}}{10^{40}\ erg\ s^{-1}}\right)^{0.5}\right] +7.89(\pm0.03)\ \pm\ 0.27\,.$$

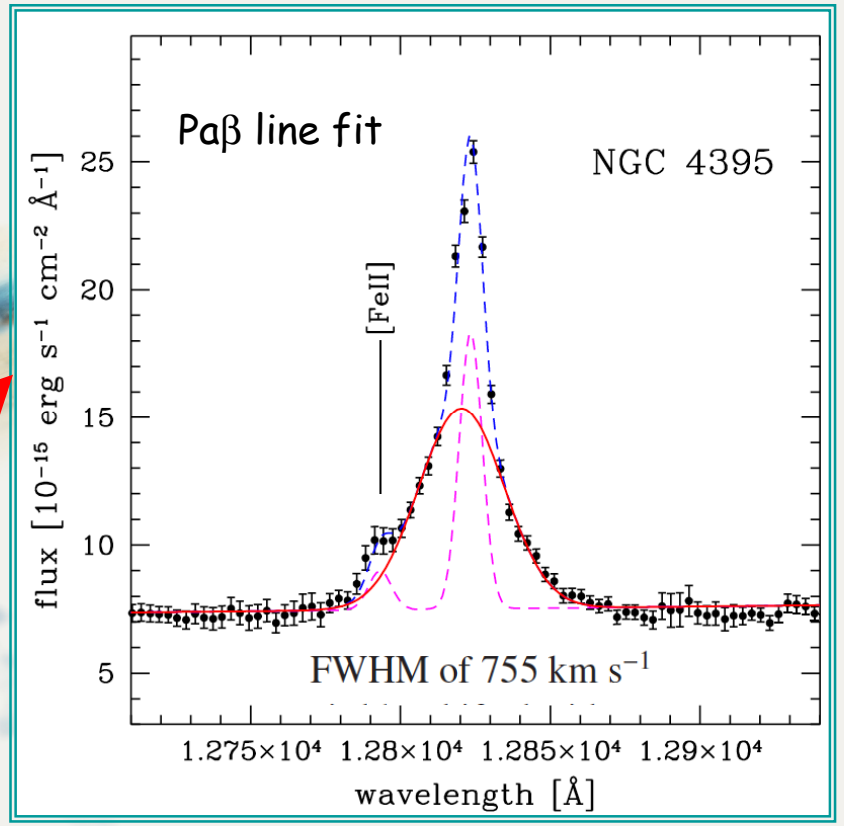
La Franca, Onori, Ricci et al. (submitted)

New measure of the mass of the IMBH NGC4395: one of the smallest SMBH!

According to Galaxy/AGN evolution models very few IMBH at z~0 expected

LUCI@LBT: zJspec, H+K200, 2.2 Å/px, slit:1", R=1360, 8x6 min





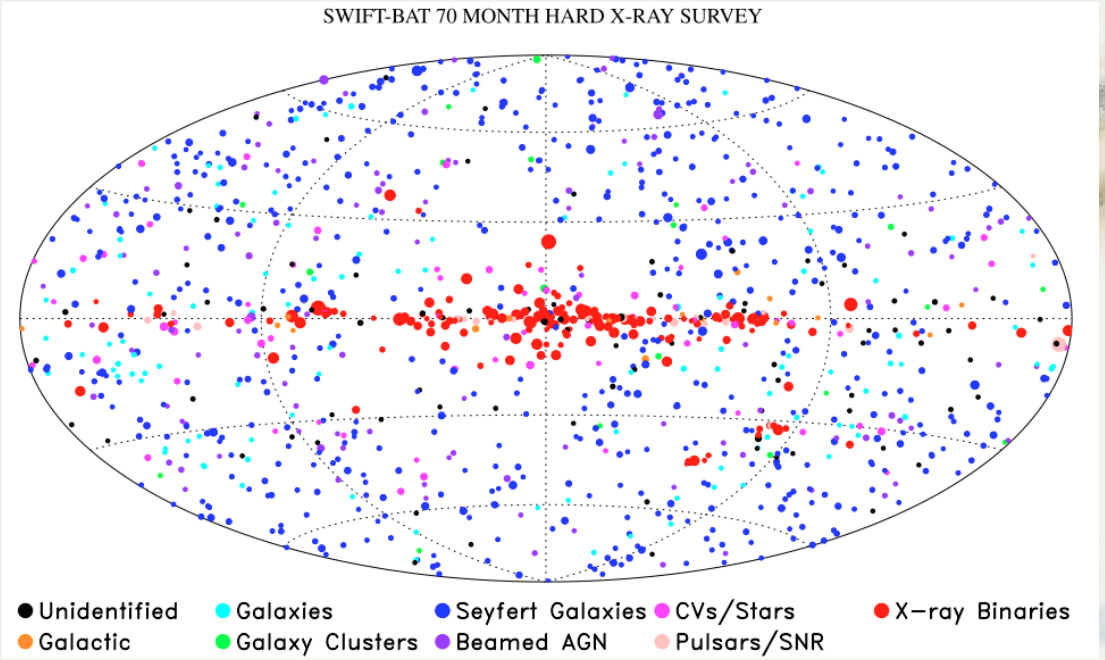
$$\log\left(\frac{M_{BH}}{M_\odot}\right) = \log\left[\left(\frac{FWHM_{Pa\beta}}{10^4\ km\ s^{-1}}\right)^2\left(\frac{L_X}{10^{42}\ erg\ s^{-1}}\right)^{0.5}\right] + 7.65(\pm 0.02) \pm 0.24,$$

$$M_{BH} = 1.7\ ^{+1.3}_{-0.7} \times 10^5 M_\odot$$

La Franca, Onori, Ricci et al. (submitted)

Project: measure BH masses of either low-luminosity AGN1 or AGN2 in the SWIFT/BAT 70-month sample using the new NIR virial relationships

Selected in the 14-195 keV band: no incompleteness in the Compton-thin AGN2 pop., no galaxy contamination in the X-ray luminosity measure



Baumgartner et al., 2012

1171 hard X-ray sources
>700 AGN
41 AGN2 z<0.1 observed

TABLE 4
COUNTERPART TYPES IN THE *Swift*-BAT 70 MONTH CATALOG

Class	Source Type	# in catalog
0	Unknown[a]	65
1	Galactic [b]	23
2	Galaxy[c]	111
3	Galaxy Cluster	19
4	Seyfert I (Sy1.0–1.5)	292
5	Seyfert II (Sy1.7–2.0)	261
6	Other AGN	23
7	Blazar / BL Lac	49
8	QSO[d]	86
9	Cataclysmic Variable star (CV)	55
10	Pulsar	20
11	Supernova Remnant (SNR)	6
12	Star	14
13	High Mass X-ray Binary (HMXB)	85
14	Low Mass X-ray Binary (LMXB)	84
15	Other X-ray Binary (XRB)	17
		—
	Total	1210

Observations and Instruments

ISAAC@VLT

23 observed with J and K, low and medium resolution, slit 0.8″

Mode	Array	Spectral Range	Pixel Scale (arcsec)	Resolution for 1 arcsec slit
SWS1-LR	Hawaii	0.98 – 2.5 μm	0.147	$\sim$ 500
SWS1-MR	Hawaii	0.98 – 2.5 μm	0.147	$\sim$ 3000

LUCIFER@LBT

10 AGN2 and low-L AGN1 observed with zJ and K, slit 1″

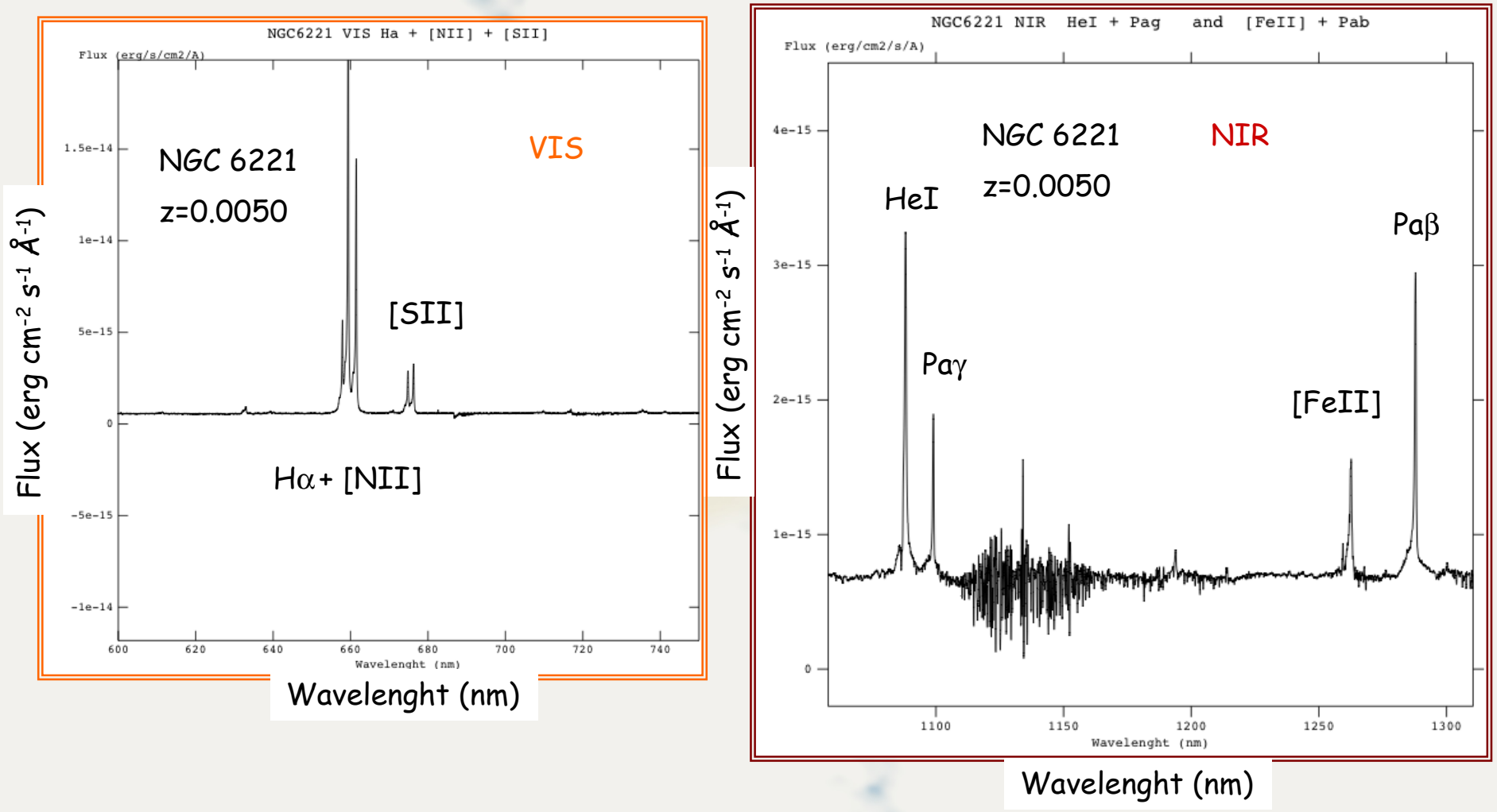
CAMERA	N 1.8	
scale	$0.25''/px$	
FOV	$4'\times 2.8'$	
SLIT	1 ″	
GRATING	FILTER	zJspec
	H+K	200 lines/mm
	λ_c	11750 Å
	IS	2.16 Å/px
	R	1360
	Δv	220 km/s
	FILTER	K
	zJHK	210 lines/mm
	λ_c	22000 Å
	IS	1.60 Å/px
	R	3437
	Δv	87 km/s

XShooter@VLT

11 AGN2, slit 0.9″

arm	slit width (") [2]	R=(λ/Δλ)	sampling (pix/FWHM)	arm	slit width (")	R=(λ/Δλ)	sampling (pix/FWHM)	arm	slit width (")	R=(λ/Δλ)	sampling (pix/FWHM)
UVB	0.5	9900	3.2	VIS	0.4	18200	2.9	NIR	0.4	10500	2.2
	0.8	6200	5.2		0.7	10600	4.9		0.6	7780	2.9
									0.6JH [4]	7760	
	1.0	4350	5.4		0.9	7450	7.1		0.9	5300	4.2

Xshooter: final spectra



NGC 6221: the broad component arises in the NIR

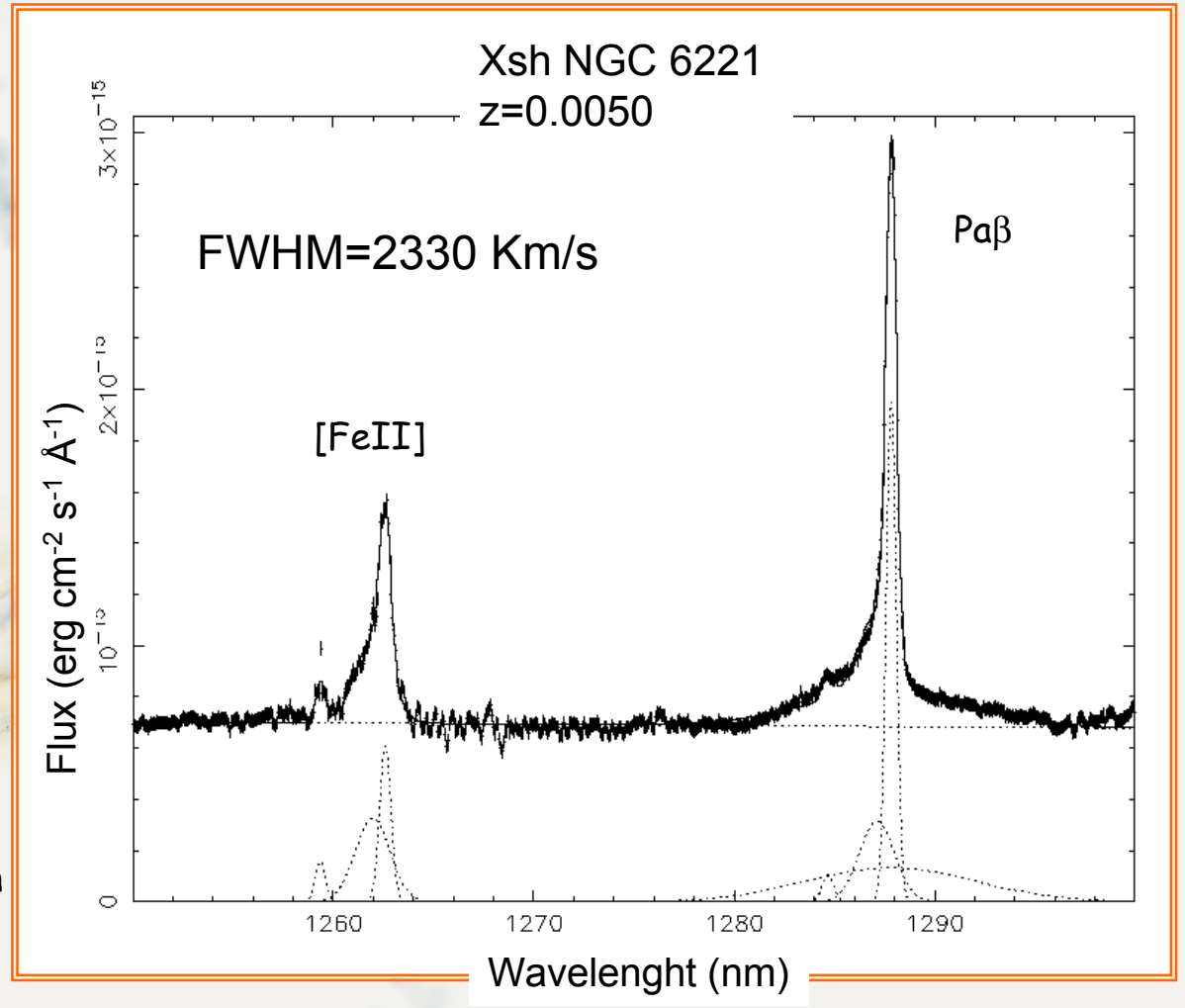
Xshooter: final spectra

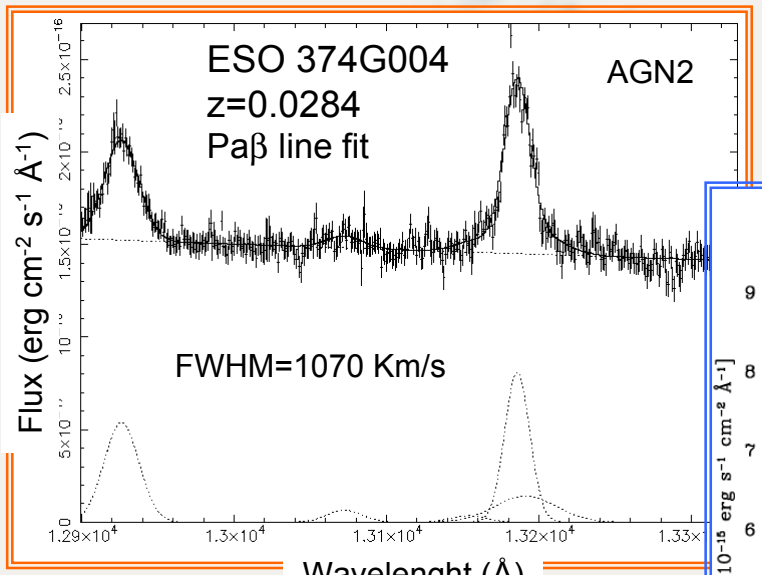
NGC 6221
Log(Lx)= 42.05 erg/s

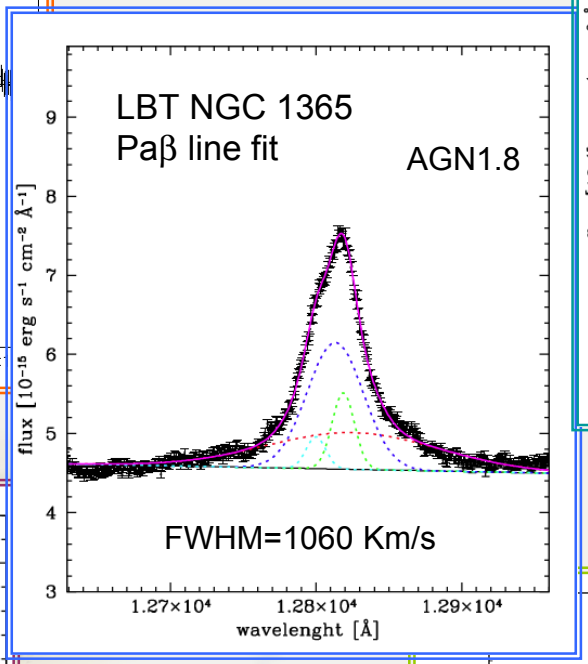
First AGN2 BH mass virial measure!

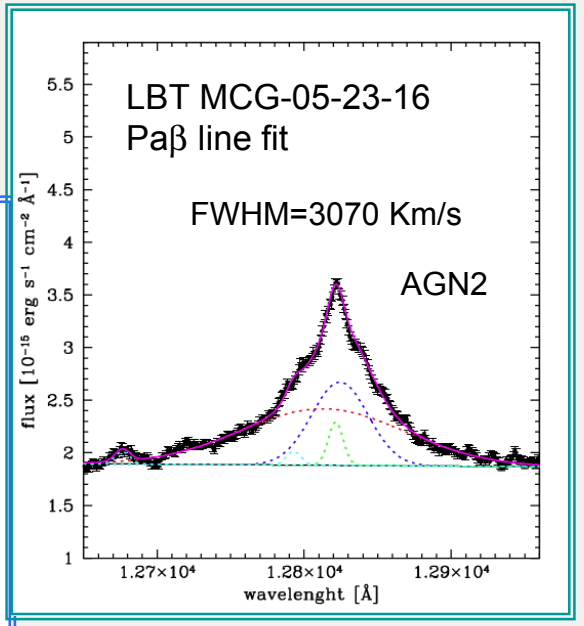
$Log(M_{BH})=(6.62\pm0.24)\ M_{sun}$

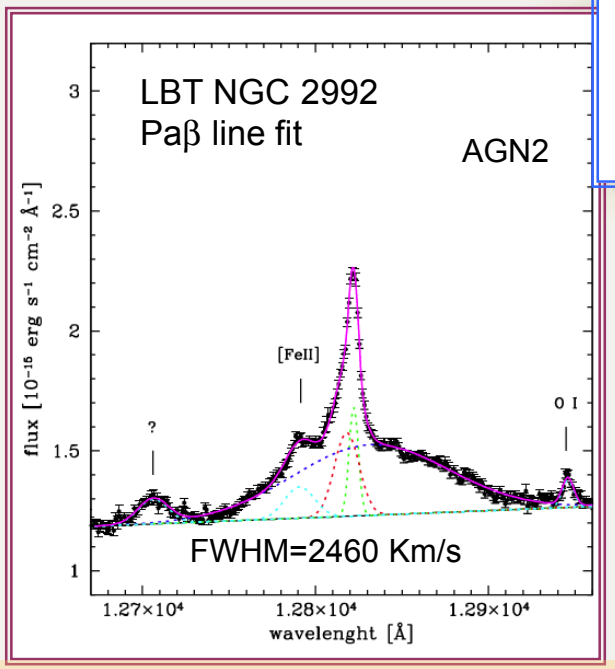
$\sim 4x10^6\ M_{sun}$

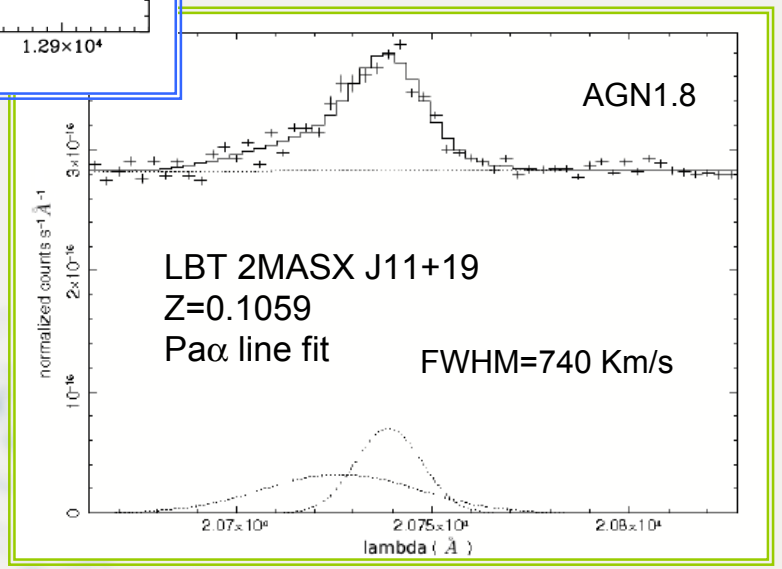



ESO 374G004
z=0.0284
Paβ line fit
AGN2
FWHM=1070 Km/s
Flux (erg cm-2 s-1 Å-1)
Wavelenght (Å)

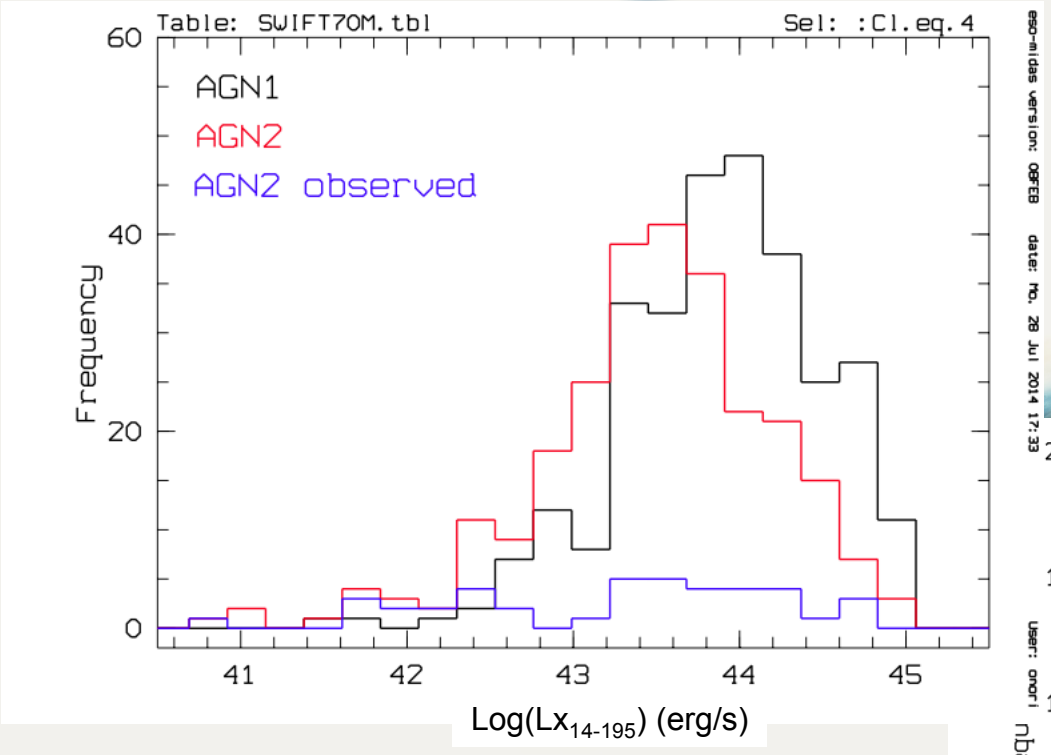

LBT NGC 1365
Paβ line fit
AGN1.8
FWHM=1060 Km/s
flux [10-15 erg s-1 cm-2 Å-1]
wavelenght [Å]


LBT MCG-05-23-16
Paβ line fit
FWHM=3070 Km/s
AGN2
flux [10-15 erg s-1 cm-2 Å-1]
wavelenght [Å]


LBT NGC 2992
Paβ line fit
AGN2
[FeII]
?
O I
FWHM=2460 Km/s
flux [10-15 erg s-1 cm-2 Å-1]
wavelenght [Å]

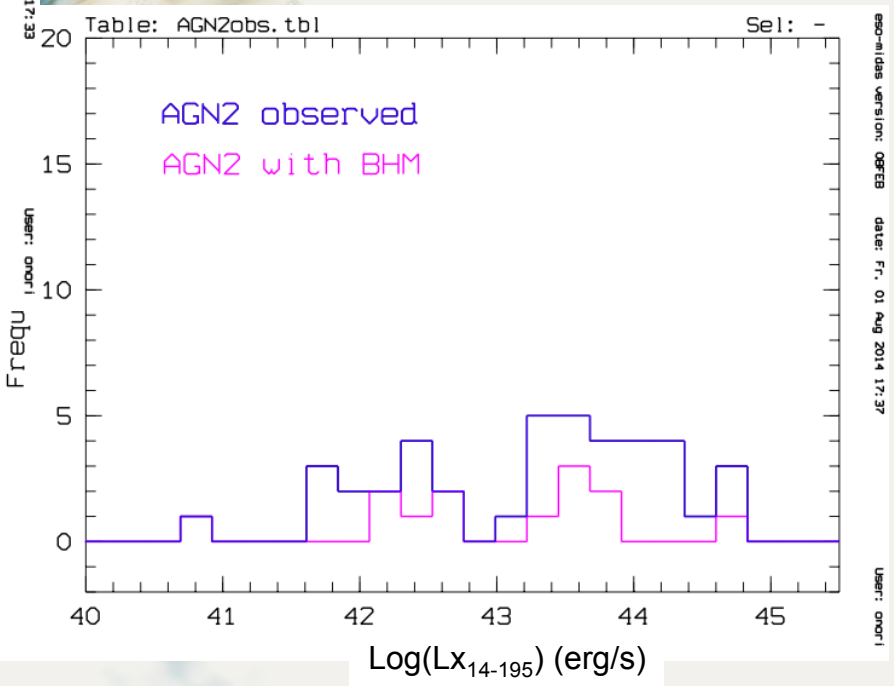

AGN1.8
LBT 2MASX J11+19
Z=0.1059
Paα line fit
FWHM=740 Km/s
normalized counts s-1 Å-1
lambda (Å)

RESULTS:
AGN2 BH masses - Distribution in SWIFT70M



41 AGN2 randomly selected from SWIFT70M

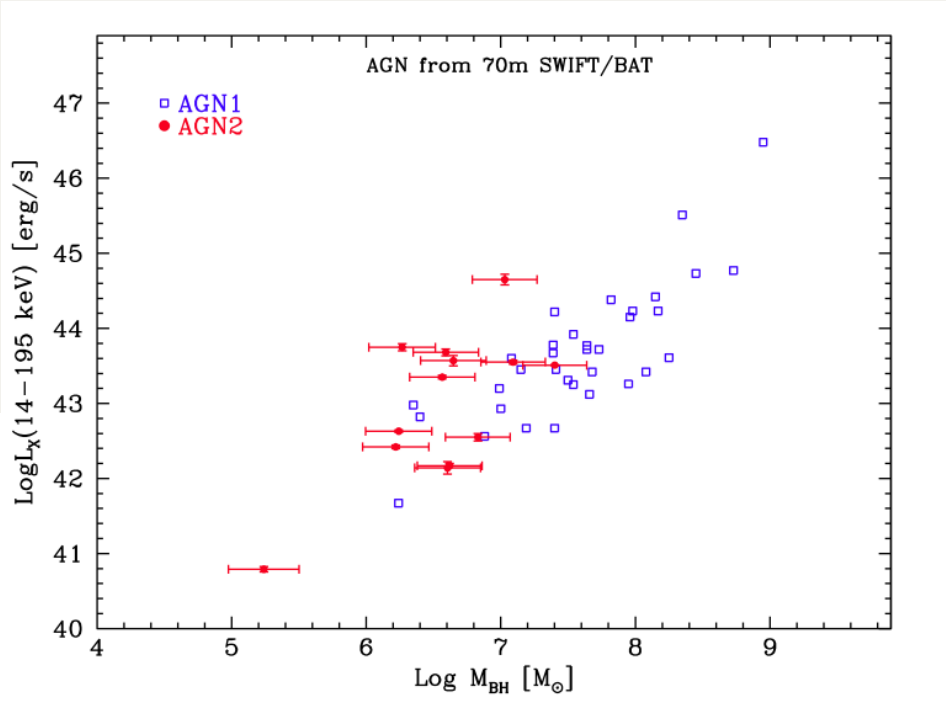
Broad emission line component (Pa β, Paα, HeI) found in 13 objects.

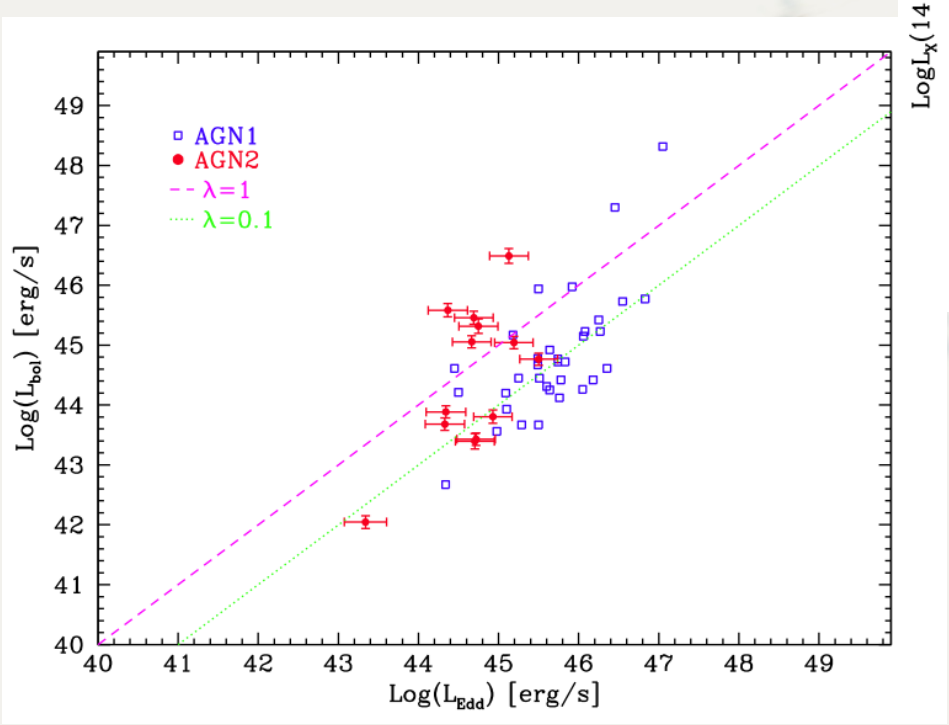


13 AGN2 BH mass directly measured using our new NIR relation.

Preliminary promising results

- AGN2 and low luminosity AGN1 have indeed lower BH Masses (<$10^7 M_{sun}$) than brighter AGN1
- some AGN2 (5) and low-luminisoty AGN1 (3) are super-Eddington





AGN2: <Log(M_{BH})>=6.6 M_{sun}

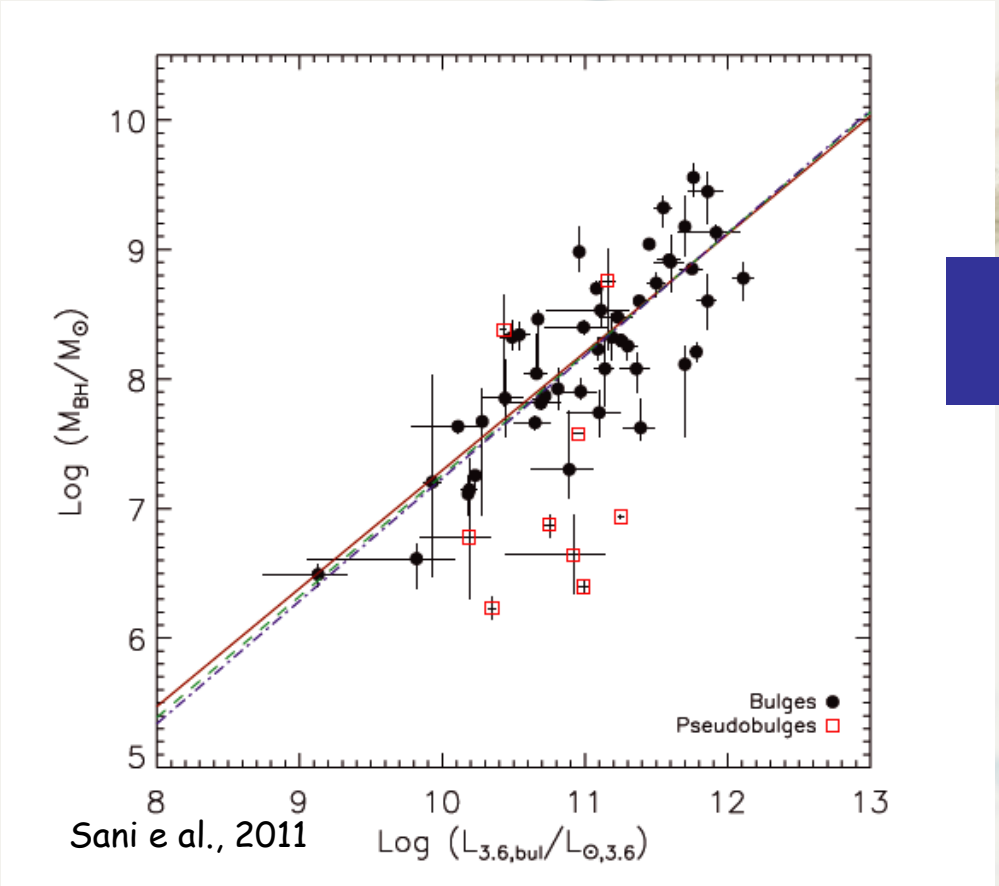
AGN1: <Log(M_{BH})>=7.6 M_{sun}

13 AGN2 BH mass directly measured using our new NIR relation.

Next step:

Where the BH mass has been measured very important scaling relations with the bulge properties have been found, suggesting a strong link between the AGN and the host galaxy evolution.

Are the M-L relationship valid for AGN2 as well?



Sani e al., 2011

Where are our AGNs in this relation?

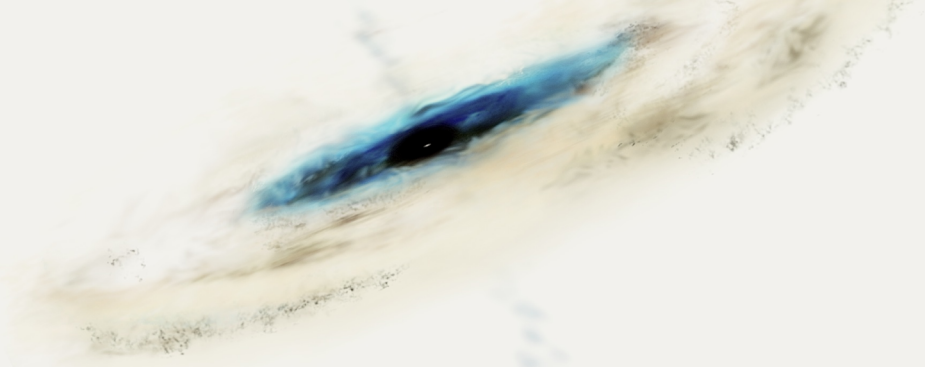
Conclusions

- We selected 41 AGN2 from SWIFT/BAT 70-month catalog.
- We observed in the NIR band using LUCIFER@LBT, Xshooter@VLT and ISAAC@VLT.
- We have calibrated 2 new NIR virial relations able to work also with AGN2 and derived a new BHM measure for NGC4395
- We found broad component of permitted NIR emission lines (Paα, Paβ and HeI) in 13 objects and measured their BH masses using our virial relations.

- AGN2 and low luminosity AGN1 have low BH Masses ($<10^7 M_{sun}$) and some are super-Eddington.

- **AGN2 should be properly taken into account to derive the SMBH MF**

Thanks !



RESULTS: 13 AGN2 BH masses

Measure of the BHM					
object name	z	cl	$\log L_X$ [erg/s]	$FWHM_{rest}$ [km/s]	$\log M_{BH}$ [$M_\odot$]
(1)	(2)	(3)	(4)	(5)	(6)
NGC4395	0.0013	1.9**	40.79	786	5.24±0.26
2MSXJ11+19	0.1059	1.8	44.65	741	7.03±0.24
MCG05-23	0.0085	2	43.51	1510	7.40±0.24
LEDA 093974	0.0239	2	43.68	909	6.60±0.24
NGC2992	0.0077	2	42.55	2463	6.83±0.24
NGC1365	0.0055	1.8	42.63	1062	6.24±0.25
NGC7465*	0.0066	2	42.14	2300	6.60±0.24
Mrk 1210	0.0135	2	43.35	1087	6.57±0.24
MCG-01-24-12	0.0196	2	43.55	1977	7.09±0.24
ESO 374G44	0.0284	2	43.57	1071	6.65±0.24
CGCG 420-15	0.0294	2	43.75	577	6.27±0.25
NGC6221	0.0050	2	42.05	2330	6.62±0.24
NGC7314	0.0048	1.9	42.42	1171	6.22±0.25

*FWHM from Almeida C.R. et al., 2009
**Sy1 from Peterson et al.,2005