Studying the outskirts of Reverberaion mapped AGNs

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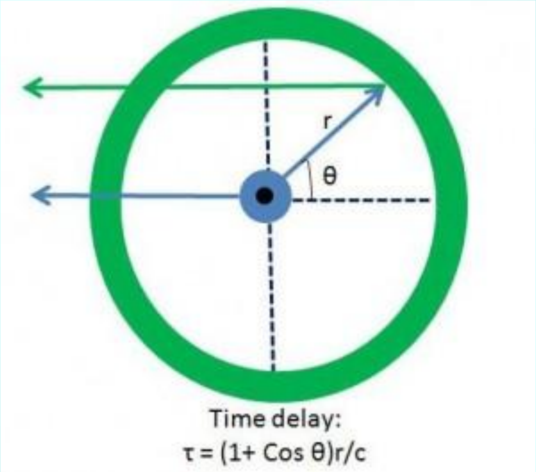
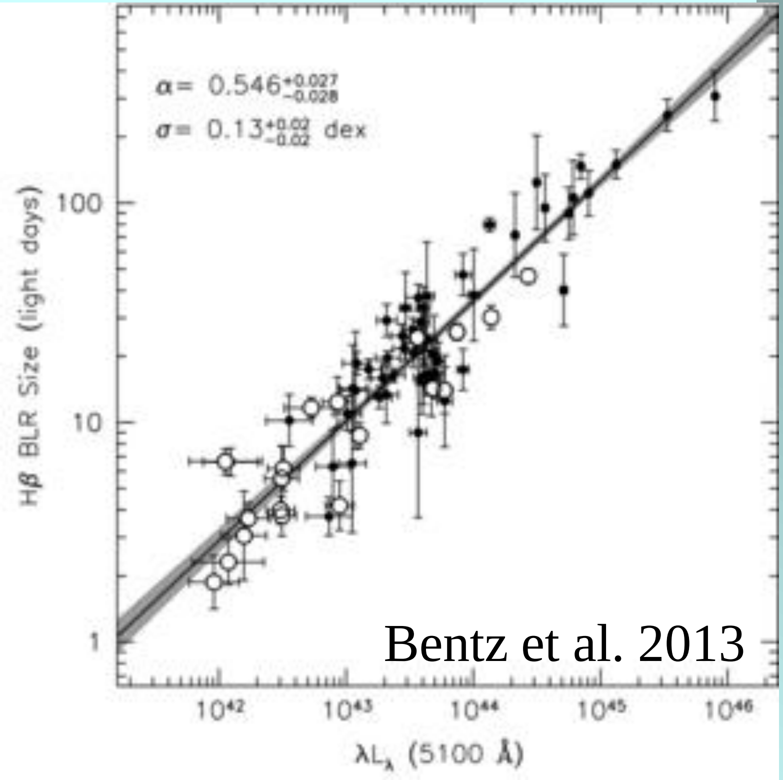
New Frontiers in Black hole Astrophysics

IAUS 324



BLR Size – Luminosity relation

Studies from the past three decades resulted by now with almost 100 AGNs with sufficient data to determine the BLR size through time lag of the lines relative to the continuum.



Bentz et al. 2013

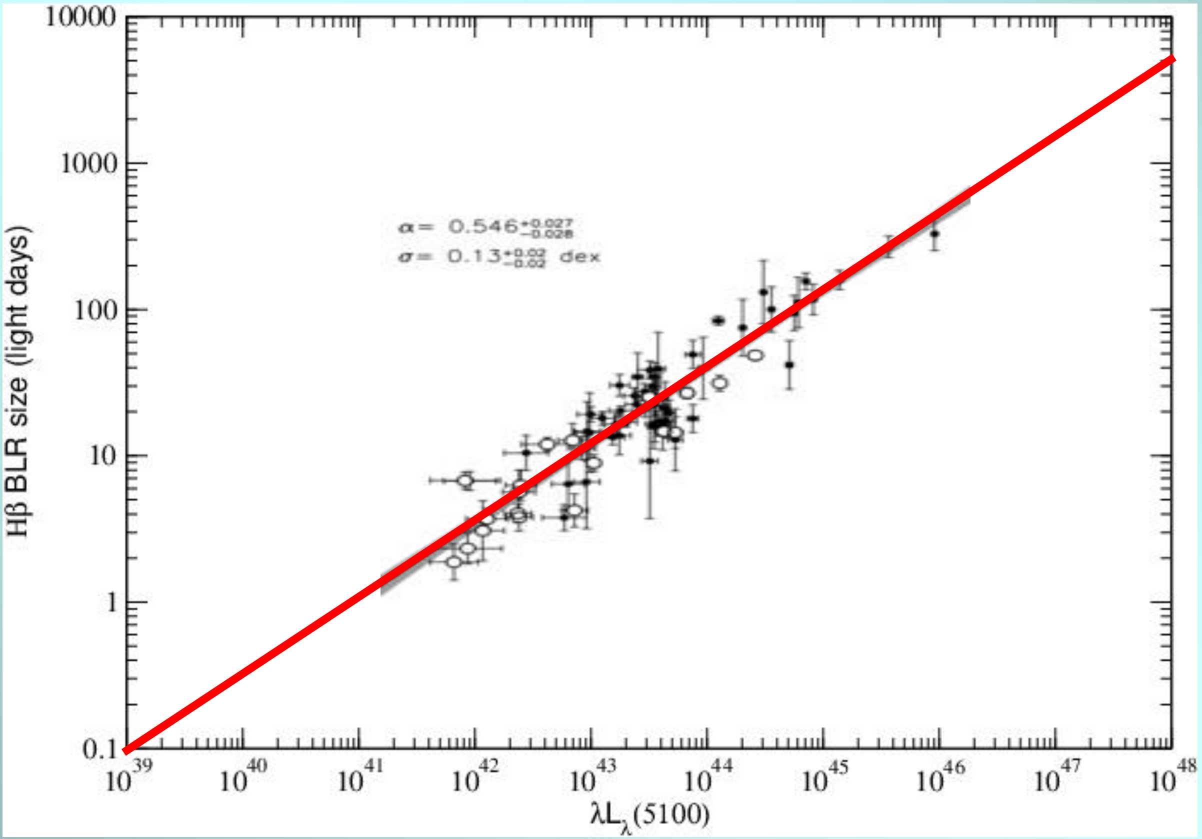
$$R_{BLR} \propto [\lambda L_{\lambda}(5100\ \text{Å})]^{(0.546\pm0.027)}$$

The R-L relation is broadly used to estimate the black hole mass of thousands of AGNs using the single epoch method.

This relation is also used for high-luminosity AGNs in order to study the cosmological evolution of AGNs (mass function, accretion history, etc.).

We can start now to study sub-groups within AGNs with reverberation mapping.

Broadening the luminosity range



Studies span four orders of magnitude.

There are 4 more orders of magnitude to be explored.

Extrapolation does not necessarily give the real situation.

We need to expand the luminosity range with reverberation mapping studies.

High-Luminosity High-Redshift AGNs

Difficulties:

• Reverberation mapping requires a lot of telescope resources.

• High-luminosity objects have much larger BLR and much longer variability timescales.

• Longer monitoring periods are needed – of order of a decade(s).

• TACs do not want to commit a telescope for such long periods.

• Light curves are smeared by relativistic time dilution.

• The continuum variations are smeared by the large BLR size – thus it is hard to detect the line variations.

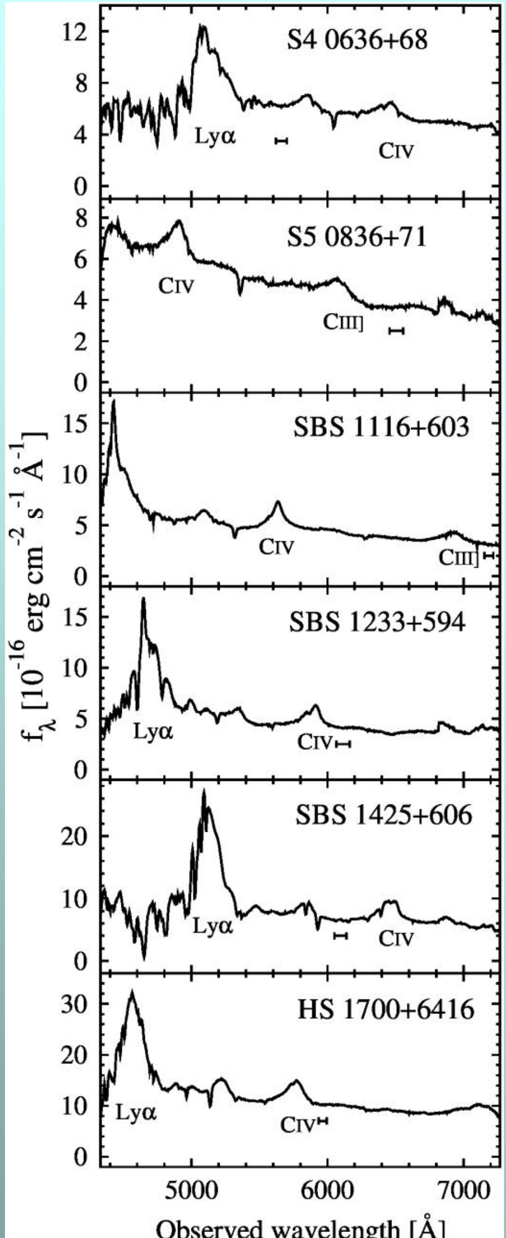
Only few attempts so far with not much success.

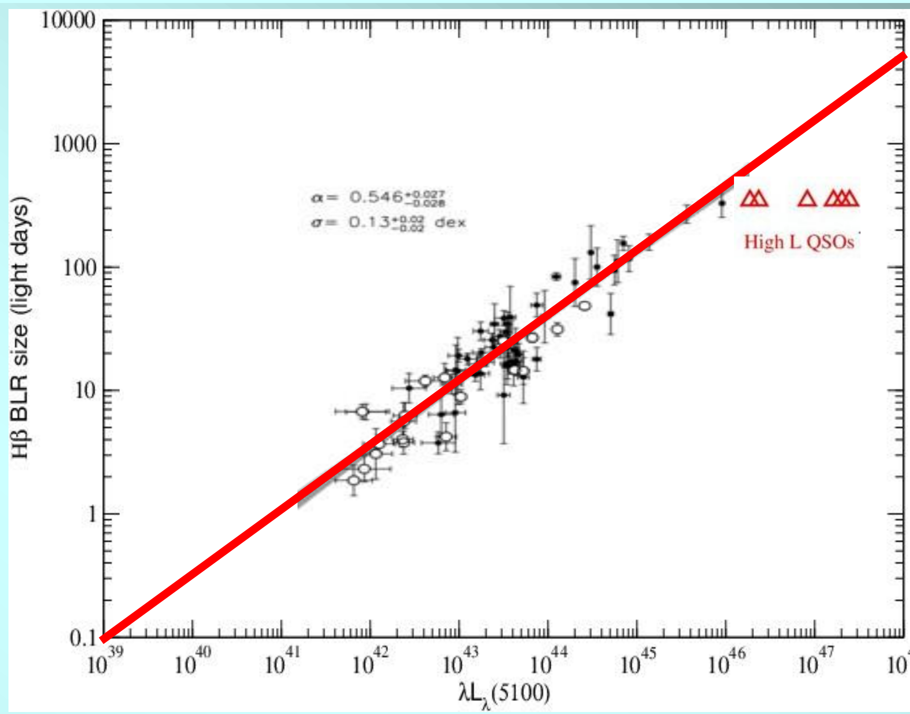
HET High-Luminosity Quasar monitoring

- S.K., N. Brandt, D. Schneider, H. Netzer, D. Maoz, O. Shemmer
- Photometric monitoring of 11 high-luminosity high-redshift quasars for the past two decades at the 1m Wise Observatory.
- 6 of which were spectroscopic monitored for 13 years at 9m Hobby-Eberly Telescope (HET).
- $2.1 < z < 3.2$
- $10^{46} < \lambda L_{\lambda}(5100\ \text{Å}) < 10^{47.5}$ erg/s
- Northern hemisphere objects. Uses 12 observing hours a year.
- Lines monitored are C IV and Lyα.

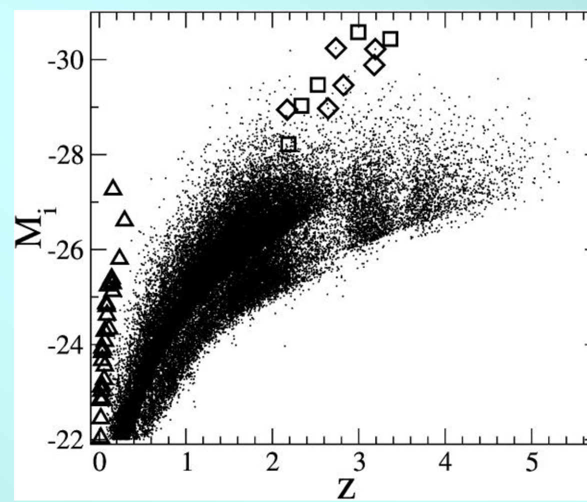
Some ***preliminary*** results from the first 5 years were published in Kaspi et al. (2007, ApJ, 659, 997)

Sample Spectra and Luminosity





The objects in our sample are among the most luminous quasars and lie within the primary epoch of black hole growth for luminous quasars.



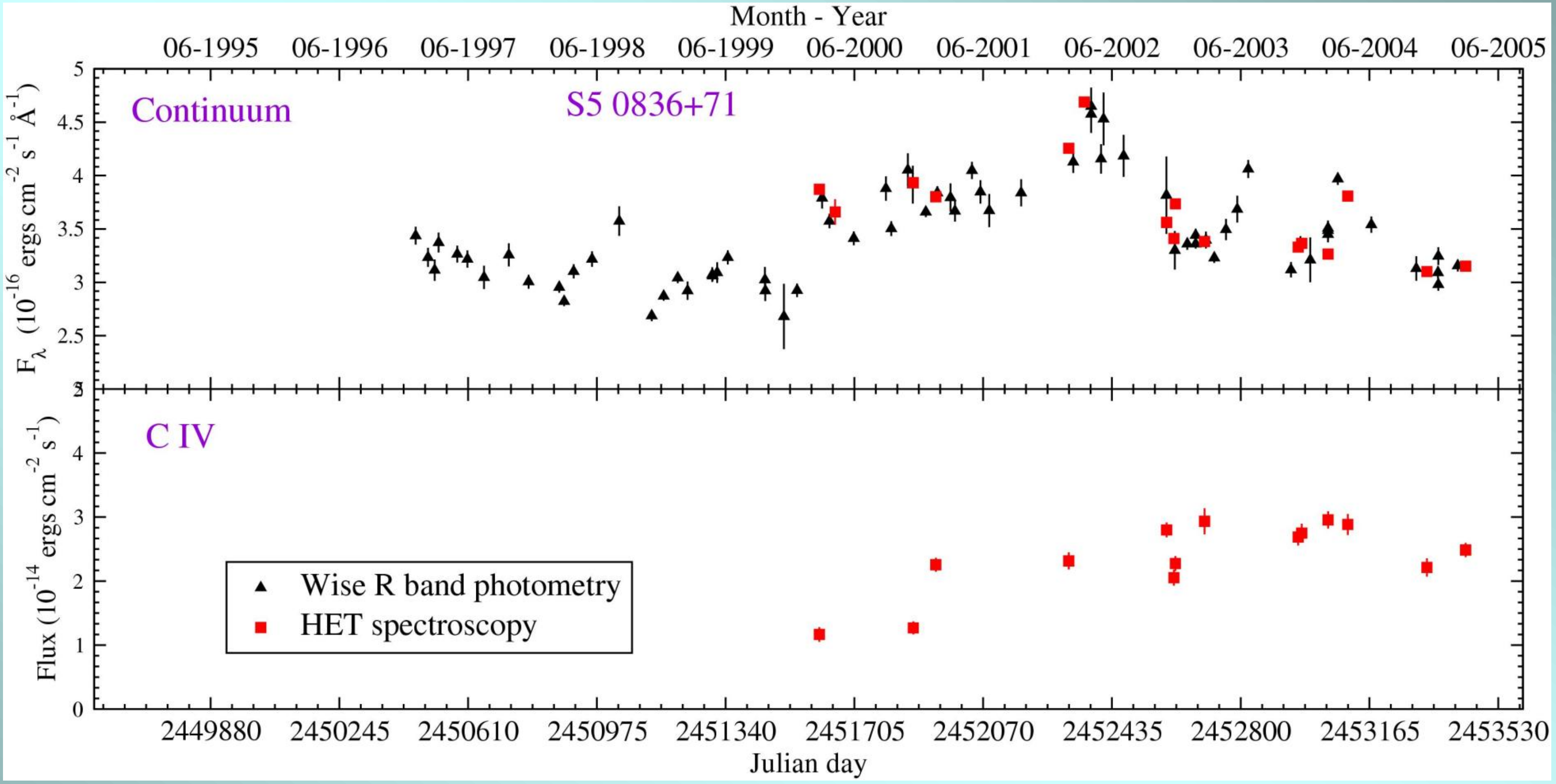
Preliminary results

Light curves spanning over 13 years and CCFs were shown here for the 3 objects and 2 emission lines for each object.

Results are preliminary broadly consistent with the Kaspi et al. (2007) results that are shown in the following, and were taken out from here due to propriety reasons.

Results will be published in Kaspi et al. (in preparation)

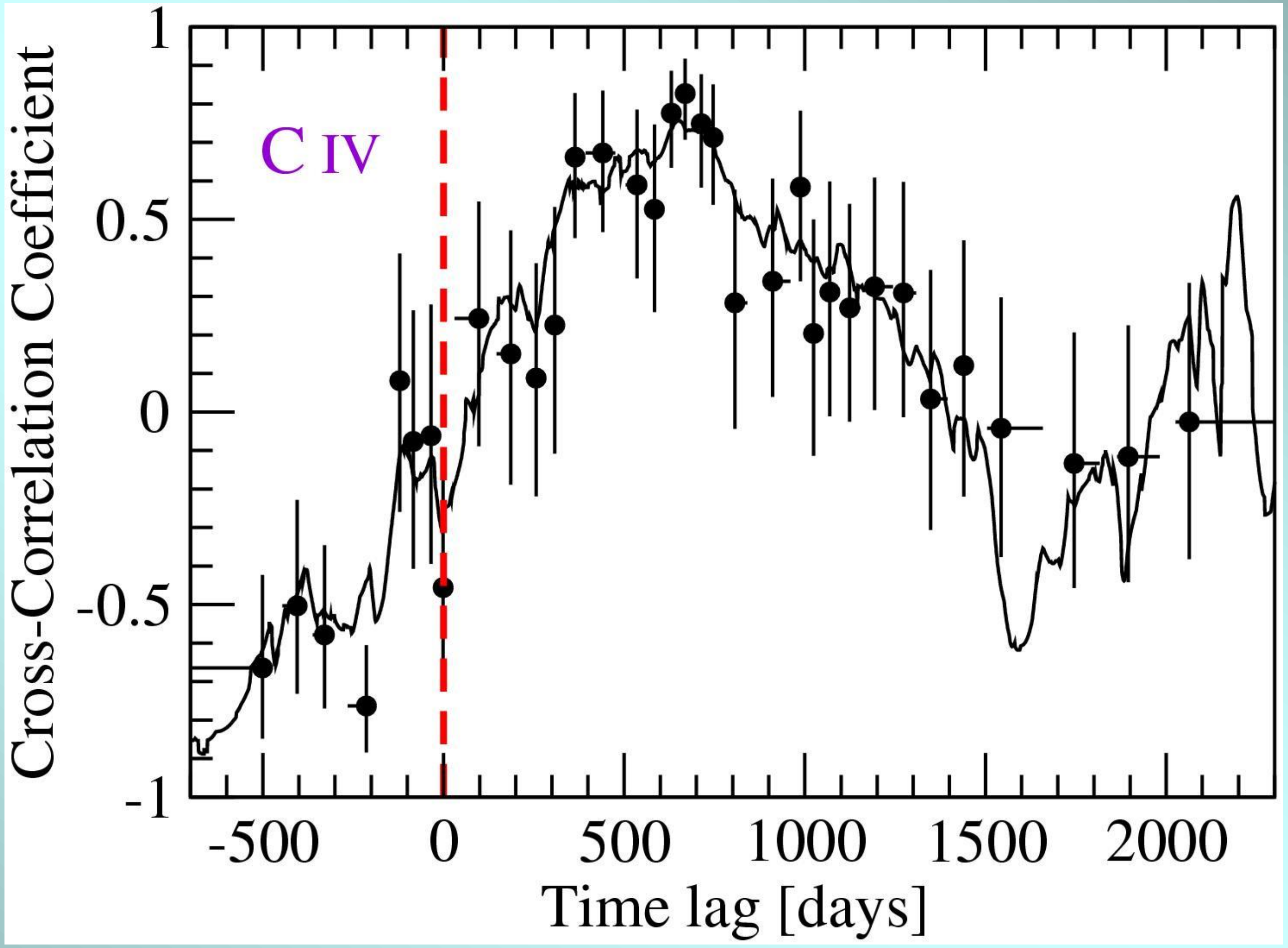
S5 0836+71



λL_λ(5100 Å) = 1.1×10^{46} erg/s   z = 2.172   ΔR=0.34   ΔB=0.44

Kaspi et al. (2007)

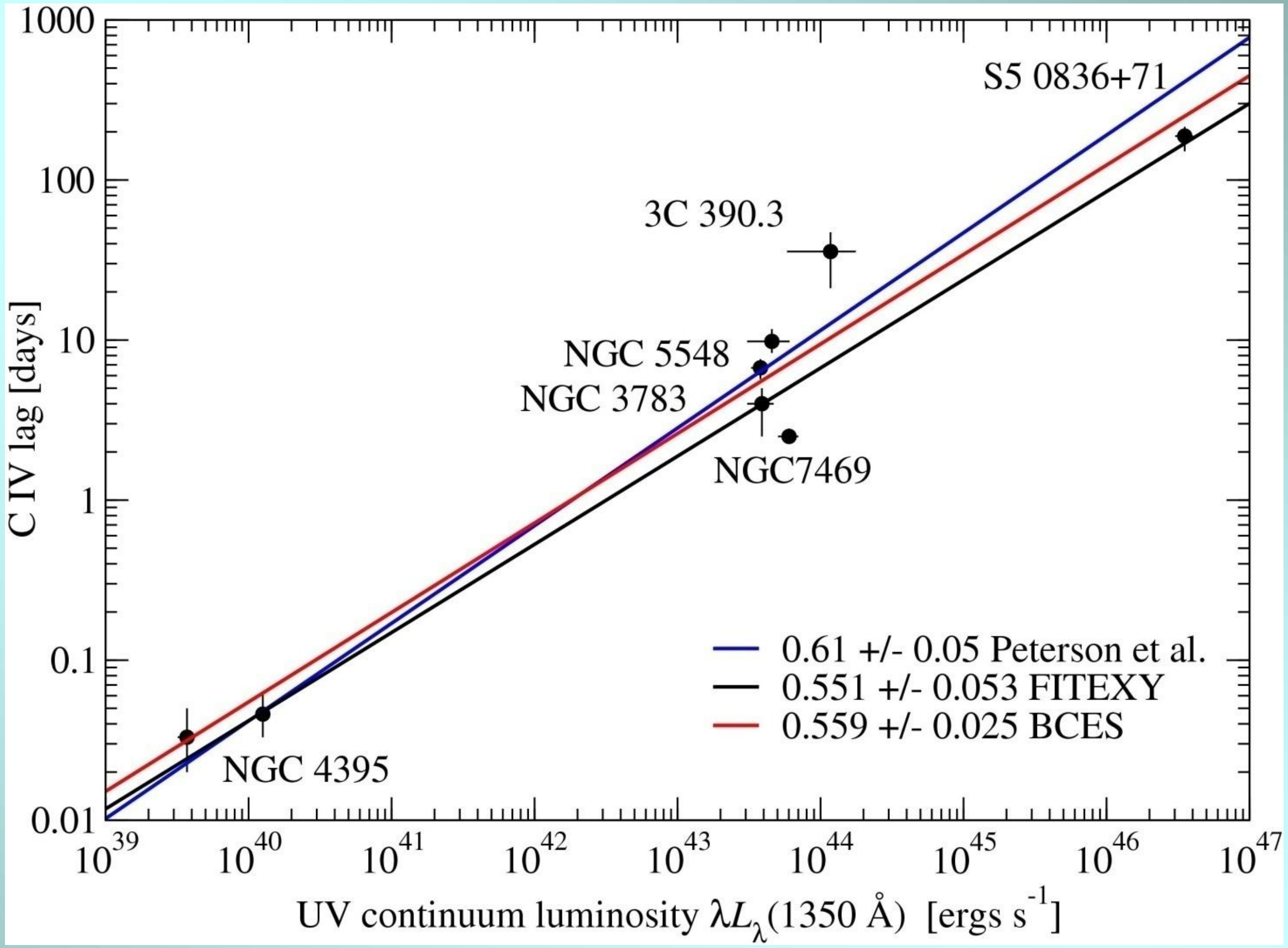
S5 0836+71: C IV – Continuum CCF



Rest frame time lag: 188^{+27}_{-37} days

Kaspi et al. (2007)

Broadening the Luminosity range – C IV



A preliminary result suggests a correlation between the C IV size and the luminosity

Kaspi et al. (2007)

SEAMBHs Reverberation Mapping

Jian-Min Wang, Pu Du, Chen Hu, Hagai Netzer, Shai Kaspi,
Jing-Min Bai, Yan-Rung Li, et al. (SEAMBH collaboration)

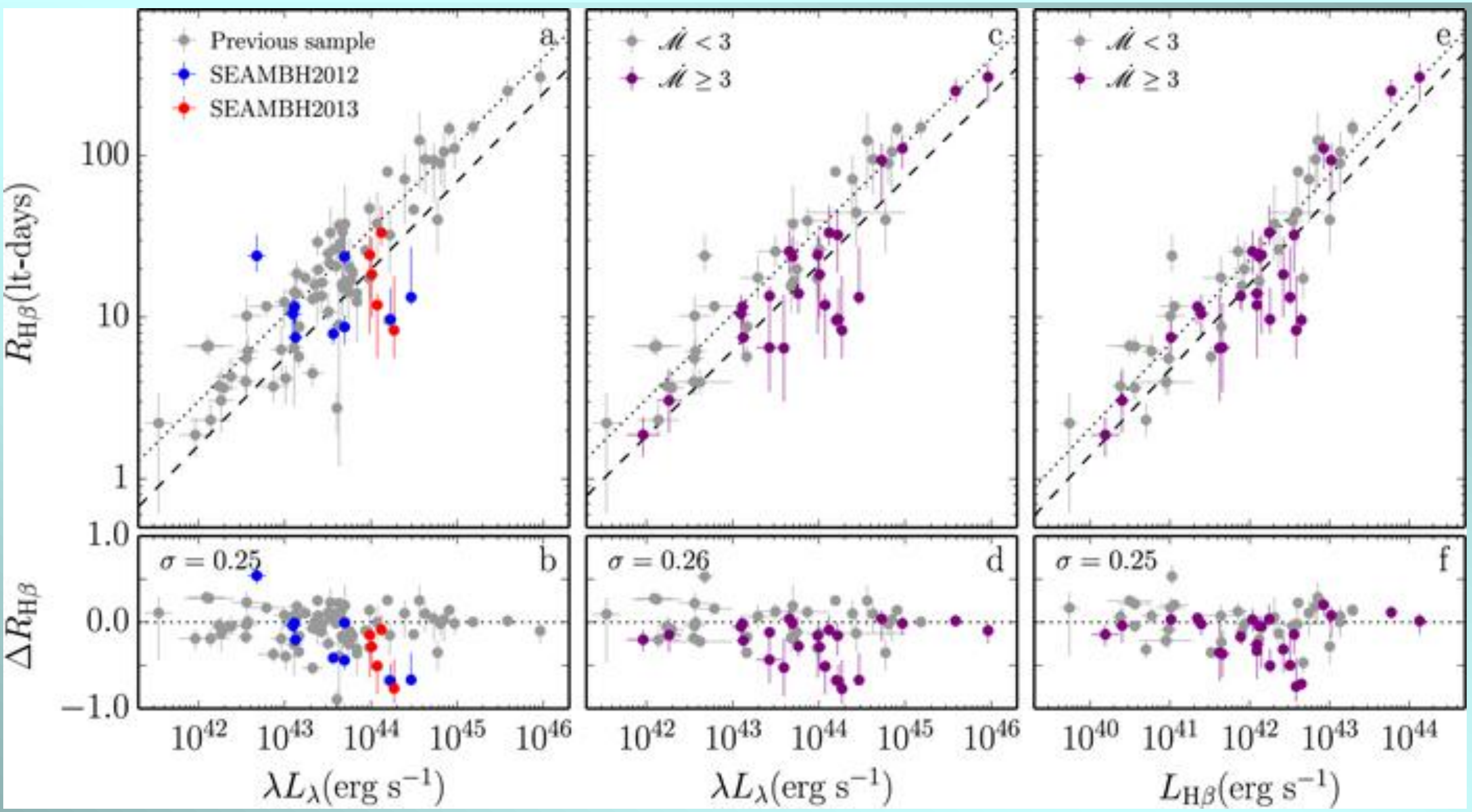
Supper Eddington Accreting Massive Black Holes (SEAMBHs)
Reverberation mapping project –

RM of objects with BH accreting at Supper Eddington rate.
Spectroscopic observation from Lijiang 2.5 m telescope.
Photometric observations from Wise 1m telescope.

10 Objects monitored during 2012 – for 9 a time lag was obtained
8 Objects monitored during 2013 – for 5 a time lag was obtained

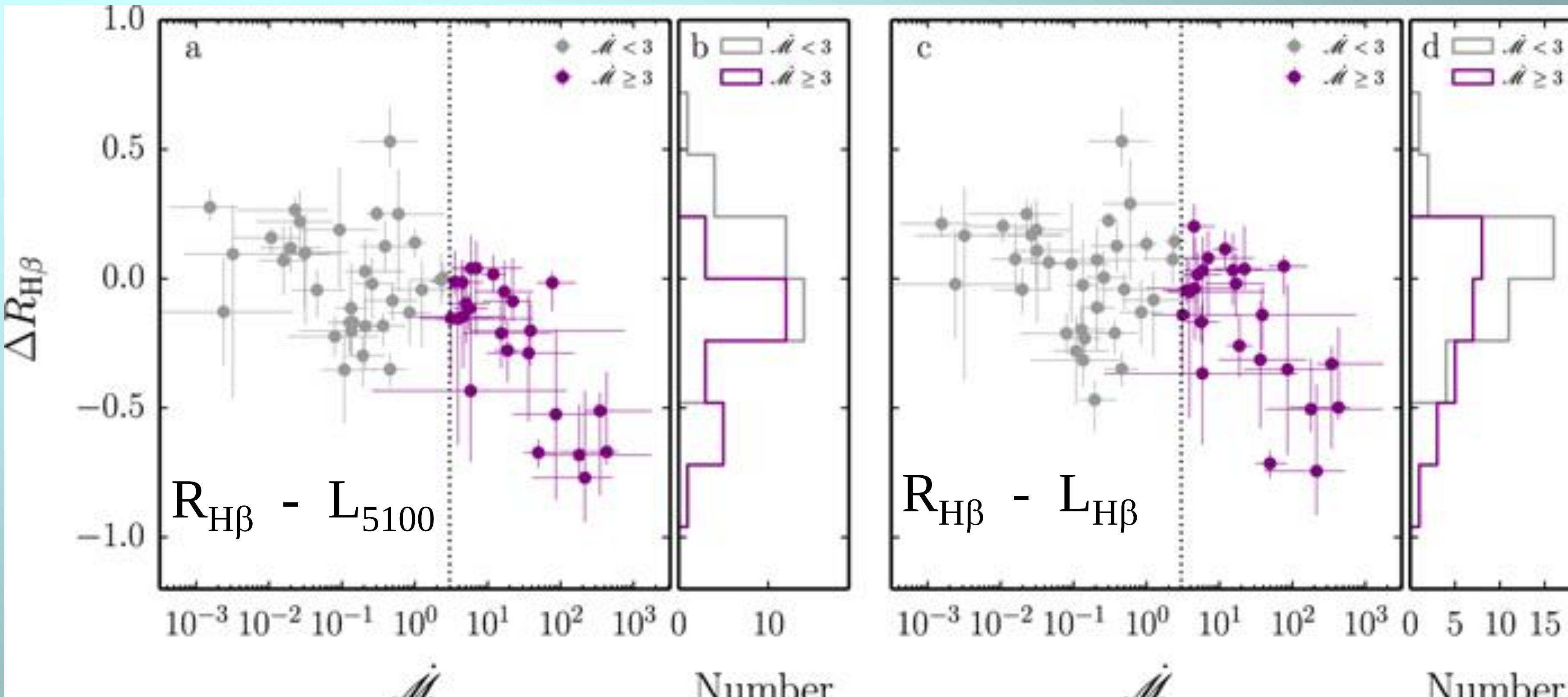
Wang et al. (2014), Hu et al. (2015), Du et al. (2014, 2015)

SEAMBH Reverberation Mapping



R-L relation of SEAMBH is below the relation of AGNs accreting at sub-Eddington rate ("normal" AGNs)

SEAMBH Reverberation Mapping



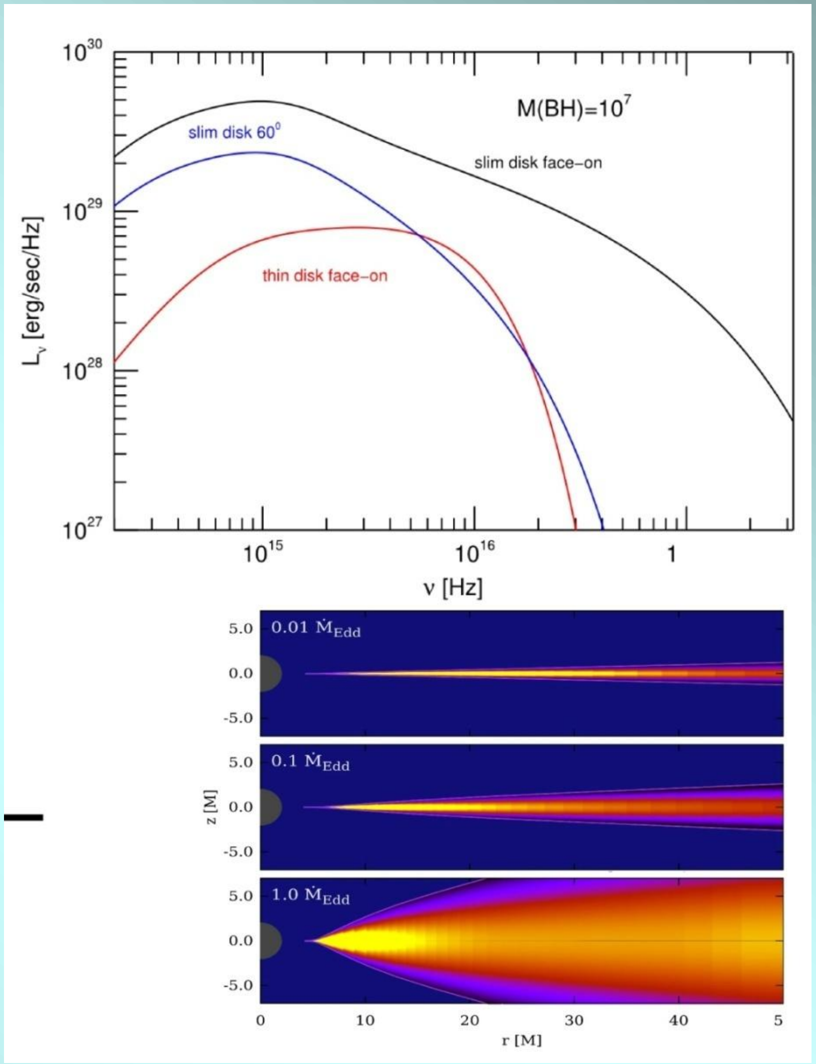
Beyond $\dot{\mathscr{M}} \sim 3$ the deviation of individual objects from the R-L relation, $|\Delta R_{H\beta}|$ increases with $\dot{\mathscr{M}}$, which implies that the Hβ time lags become shorter with increasing accretion rate relative to normal AGNs with the same luminosity.

Slim accretion disks around SMBHs

Are SEAMBH powered by a slim accretion disk while sub-Eddington accreting AGNs are powered by a thin accretion disk?

We used a RM sample of both types and fitted their SED with accretion disk models to look for the difference.

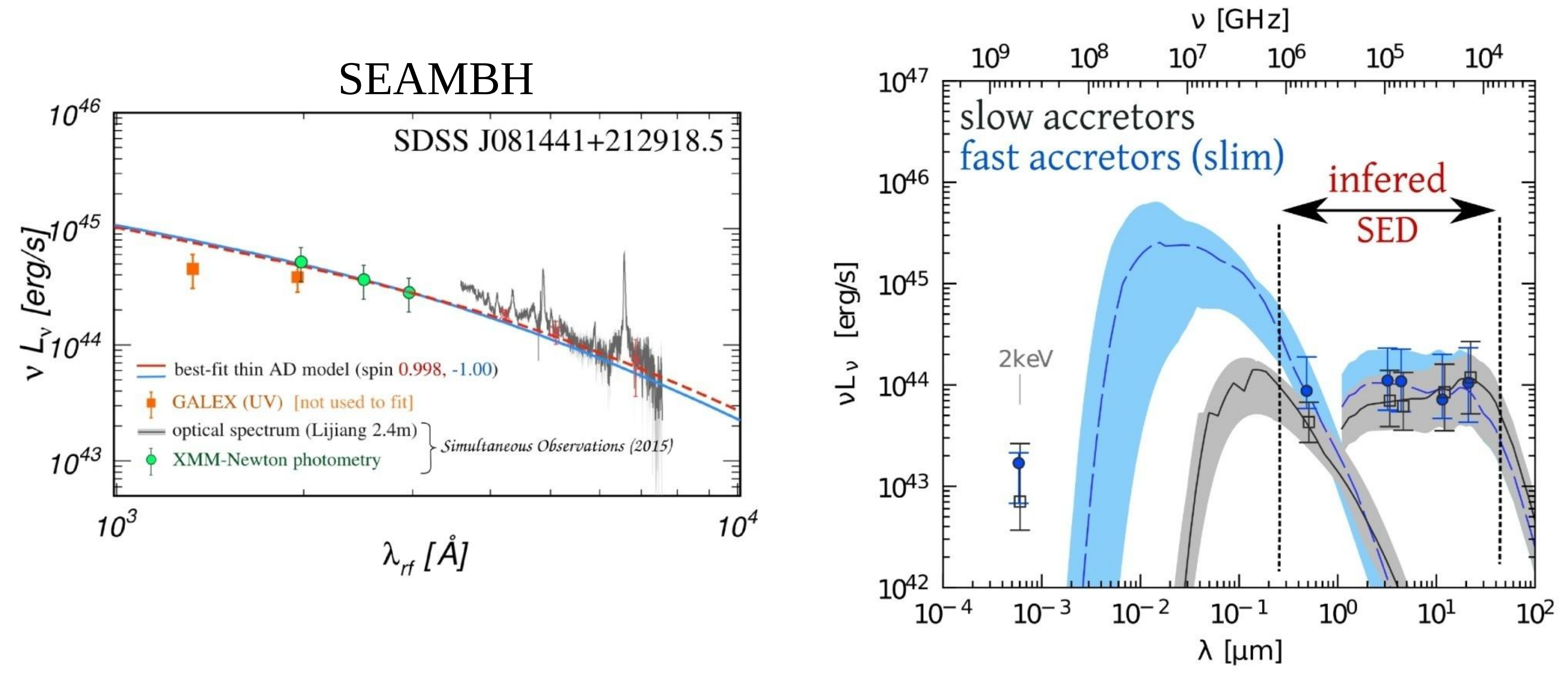
The fitting takes into account the measured BH mass, accretion rate, BH spin, and intrinsic reddening of the sources.



(From Sodowski 2011)

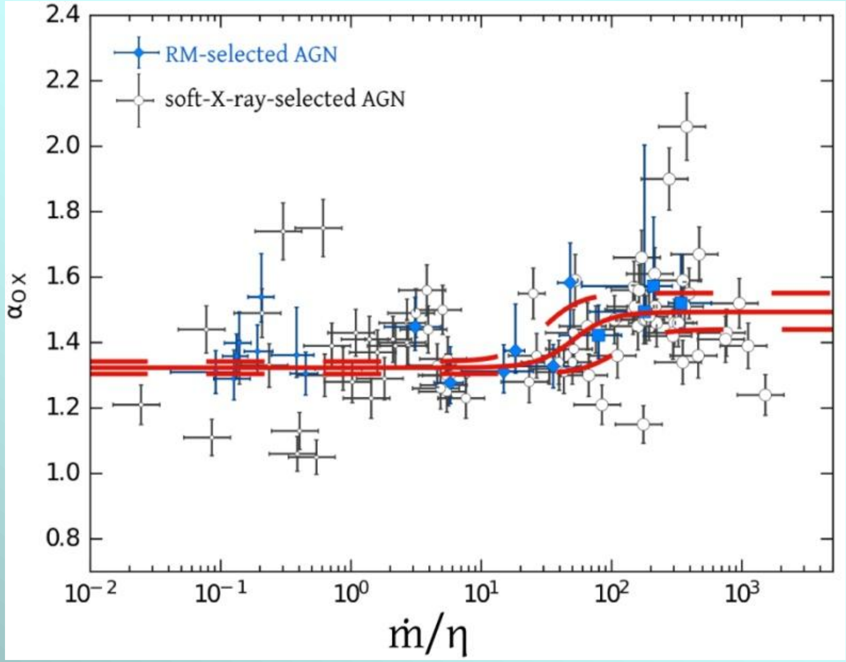
Castello-Mor N., Netzer H, Kaspi S. (2016)
Castello-Mor N., Kaspi S. , Netzer H, et al. (submitted)

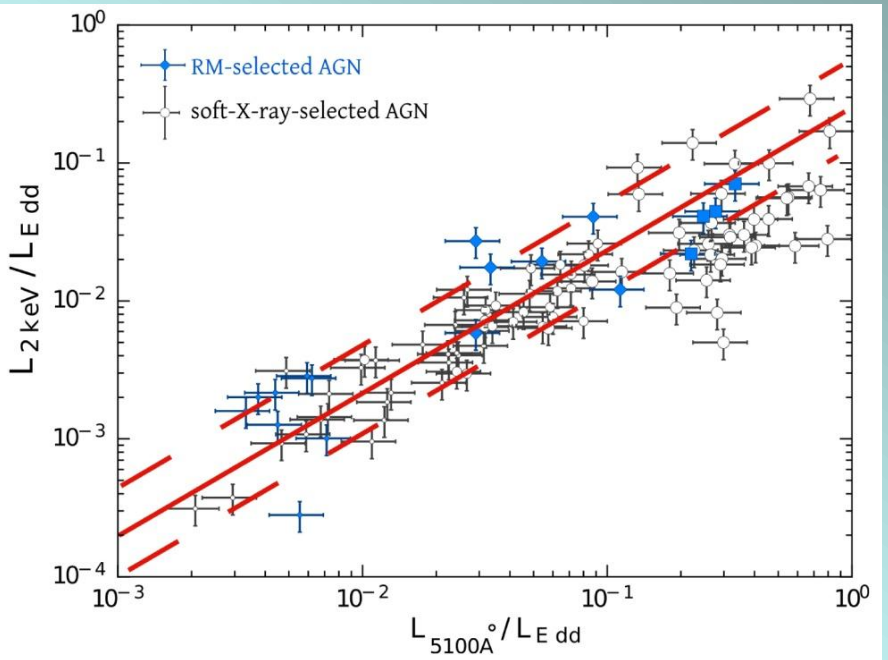
Can thin AD models explain the intrinsic optical /UV SED of any AGN?



This accretion disk models can be used to obtain satisfactory fits to the intrinsic 0.2-1 μm AGN SED. The median SED for slow and fast accretors (Sub-Eddington and Supper-Edington sources) show no statistical evidence for different optical/UV spectrum or torus emission.

What is the connection between the Eddington ratio and the X-ray emission?





The high Eddington ratio tail is at higher values of α_{OX} .
The transition is at $\dot{m}/\eta \sim 53$ and is likely related to the onset of slim disc accretion.

Higher L_{5100}/L_{Edd} represent larger comptonized emission. However, for $L_{5100}>0.2L_{Edd}$ the X-ray luminosity saturates at $L_{2keV}=0.03L_{Edd}$.
These are sources beyond the transition accretion rate.

Explaining the differences….

We found various indications for transition in X-ray and UV properties at very high Eddington ratio.

Additional physics, occurring in the nuclear regions of high $\dot{m}$ sources and responsible for making the slim disc SED consistent with that of thin discs, must be at work.

One option:
Powerful winds (as simulations suggests) can carry away a significant amount of the accreted energy from the innermost regions, decreasing its UV radiation (indicated by the similar torus emission) and perhaps quenching the disc corona.

Summary

• The number of AGNs with reverberation mapping measurements is starting to be high enough so that we can start looking at properties of sub-groups and their possible differences.

• Reverberation mapping of high-luminosity high-redshift quasars is difficult but first results show time lags of order of a few hundred days for 10^{47} erg/s objects, in accordance with R-L relations.

• Reverberation mapping of SEAMBHs show their BLR to be smaller than in sub-Eddington AGNs. Maybe connected with the different accretion disc.

• The optical/UV spectrum of SEAMBHs can be explain by a thin accretion disc with no need to invoke slim accretion disk due to the similarity of the two in this wavelength region.

• The transition in X-ray and UV properties at very high Eddington ratio requires additional physics to occur at the inner regions of these AGNs.

Thank You