Super-Eddington Accreting Massive Black Holes in Active Galactic Nuclei

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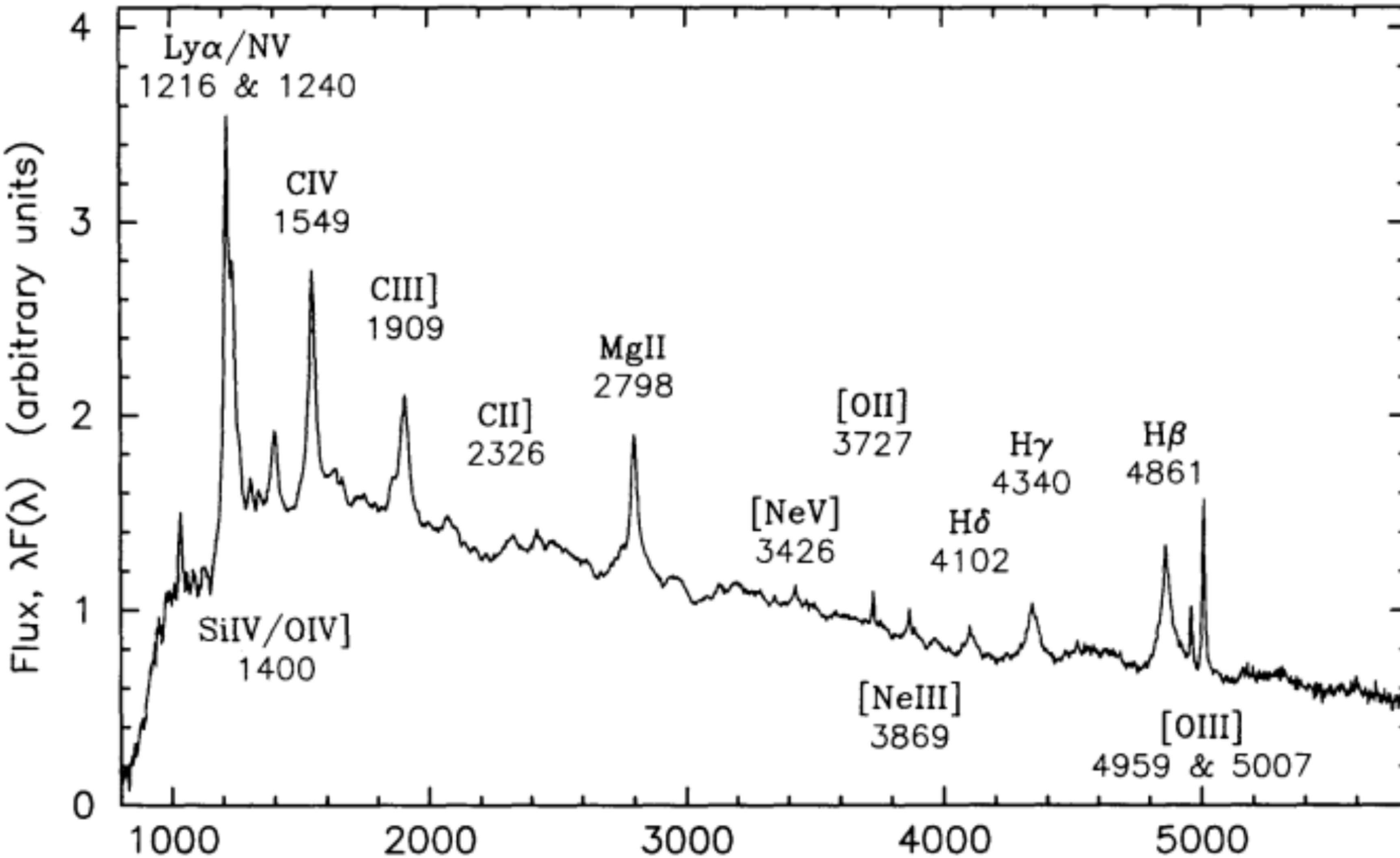
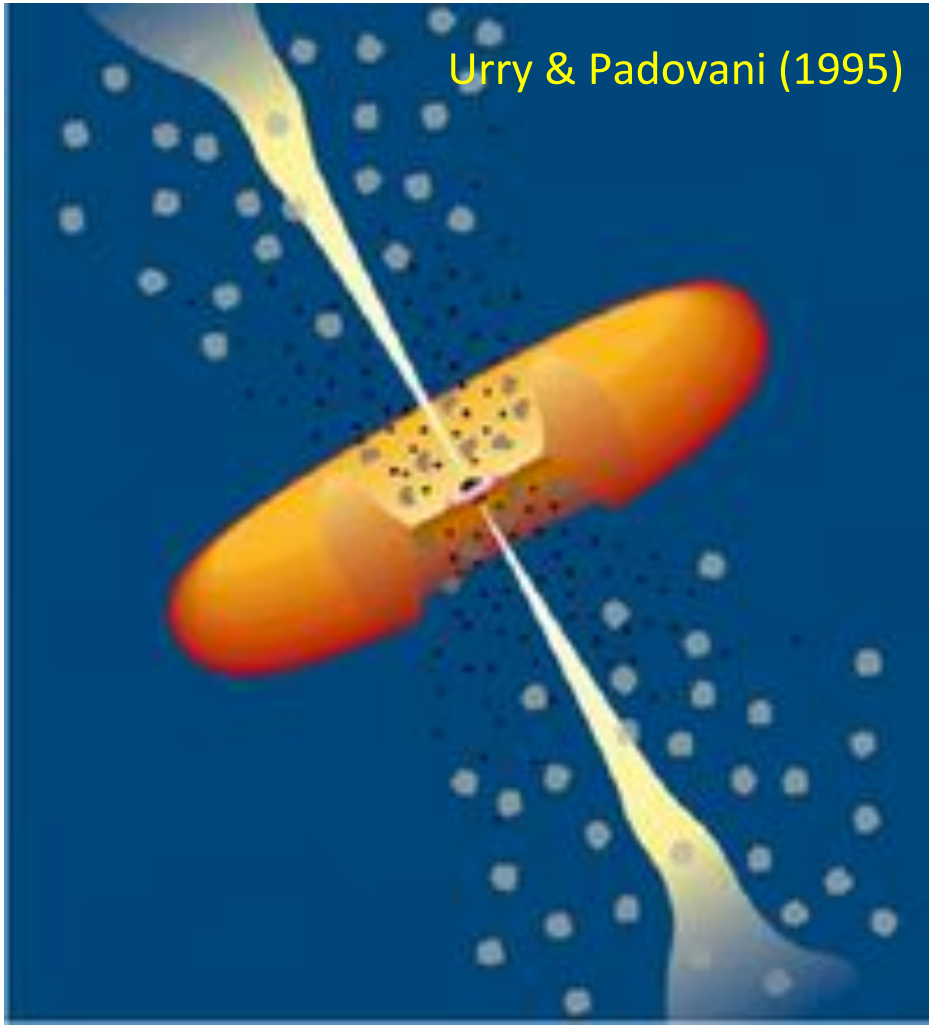
2017/08/22, Belgrade



Lyα/NV
1216 & 1240
CIV
1549
CIII]
1909
CII]
2326
MgII
2798
[OII]
3727
Hγ
4340
Hβ
4861
[NeV]
3426
Hδ
4102
SiIV/OIV]
1400
[NeIII]
3869
[OIII]
4959 & 5007
Flux, λF(λ) (arbitrary units)
0
1
2
3
4
1000
2000
3000
4000
5000



What we know:

1) BH mass?

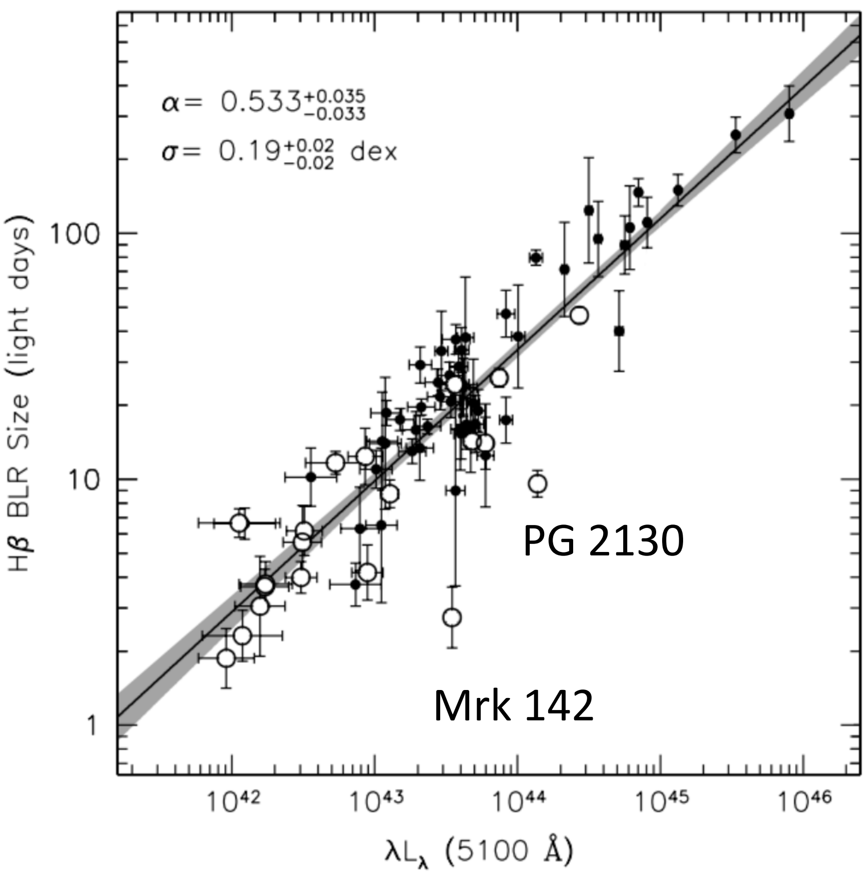
2) BH accretion rate?

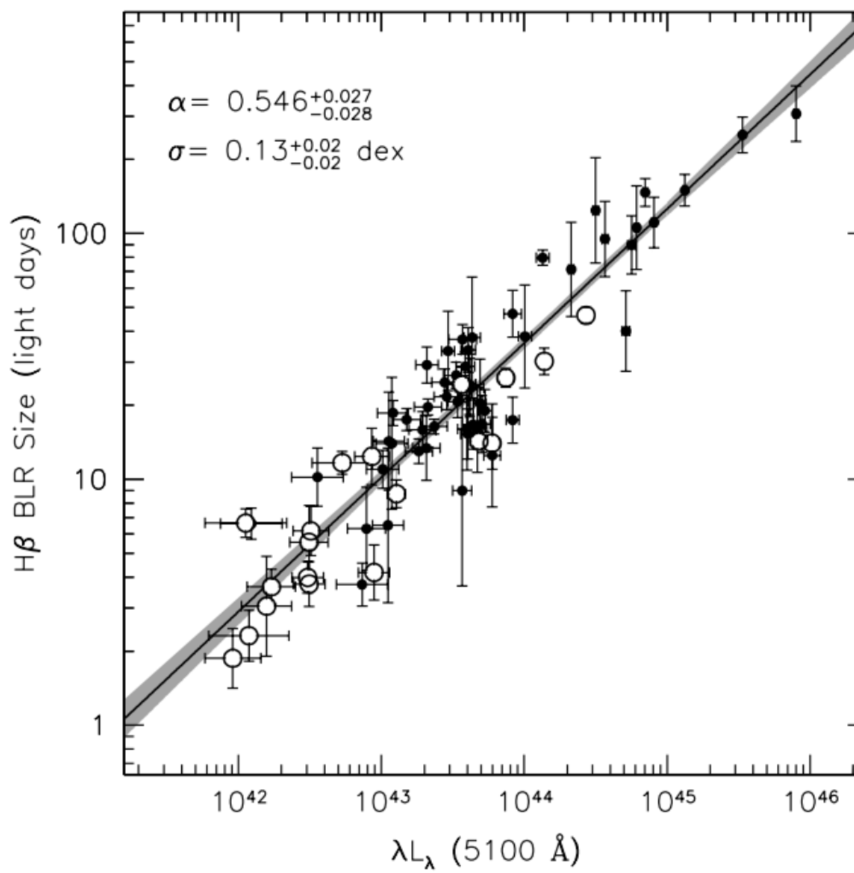
3) BH spins?

4) inclinations?

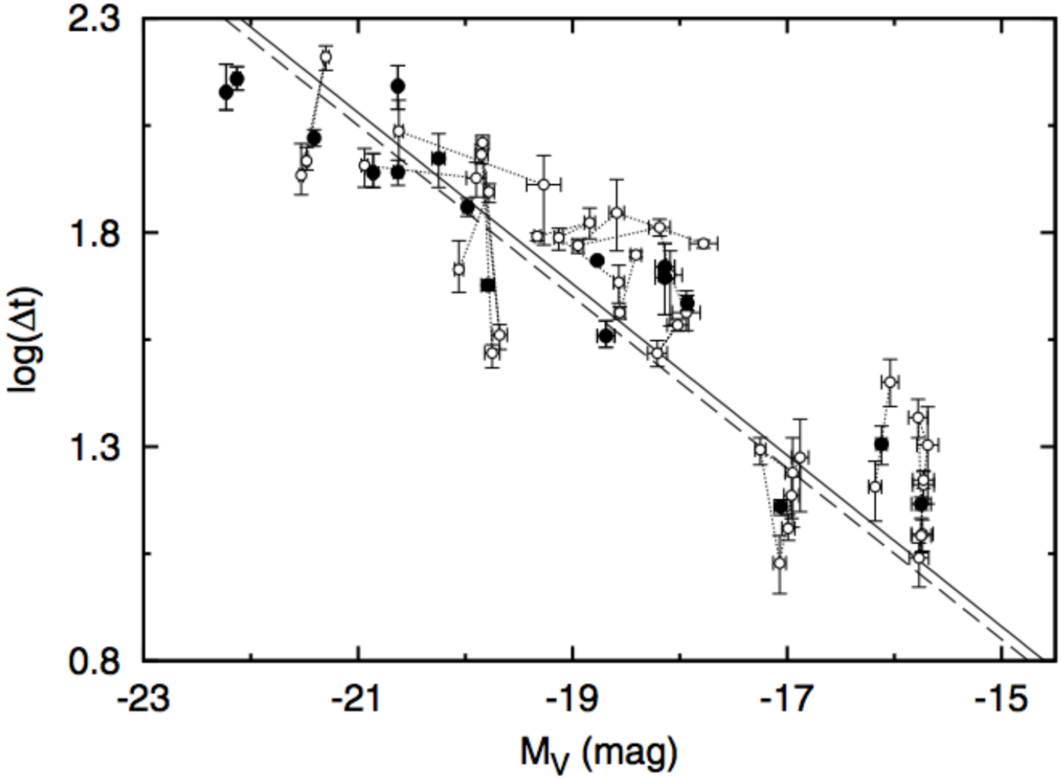
Two size-scaling relations

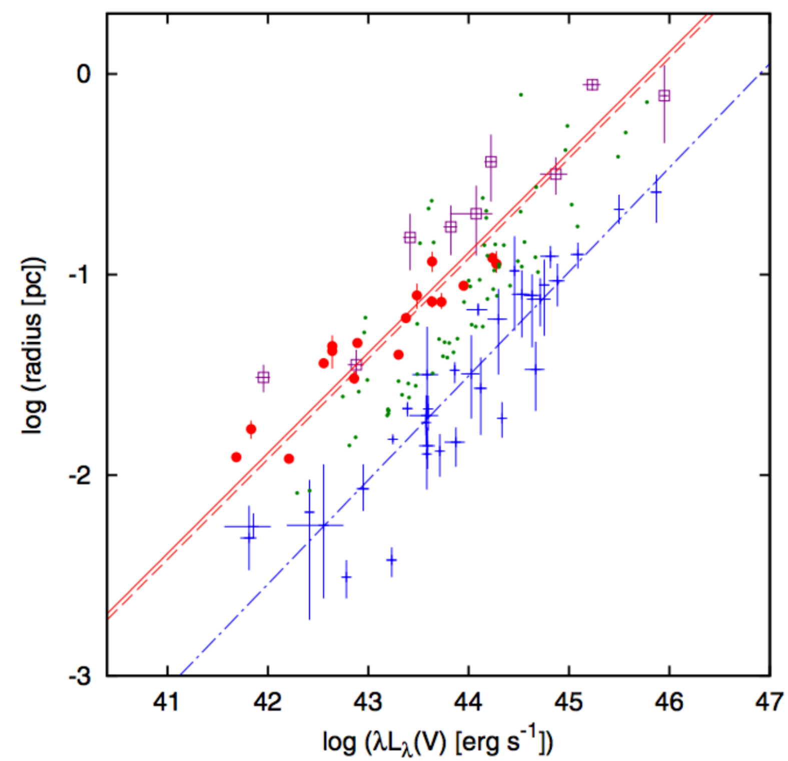
- R_{BLR}-L relation (Kaspi et al. 2000; Bentz et al. 2013)





Dusty Torus (Koshida et al. 2014)
(since 2000)



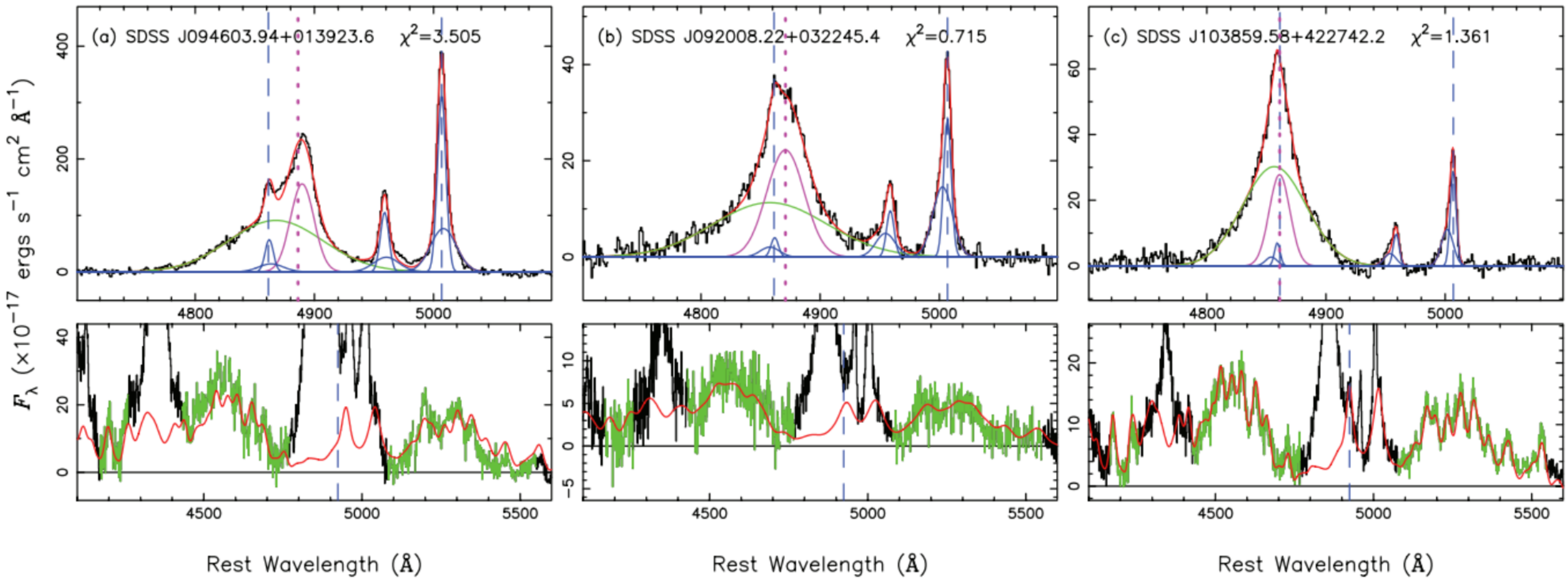


Is there a connection between the BLR and Torus?

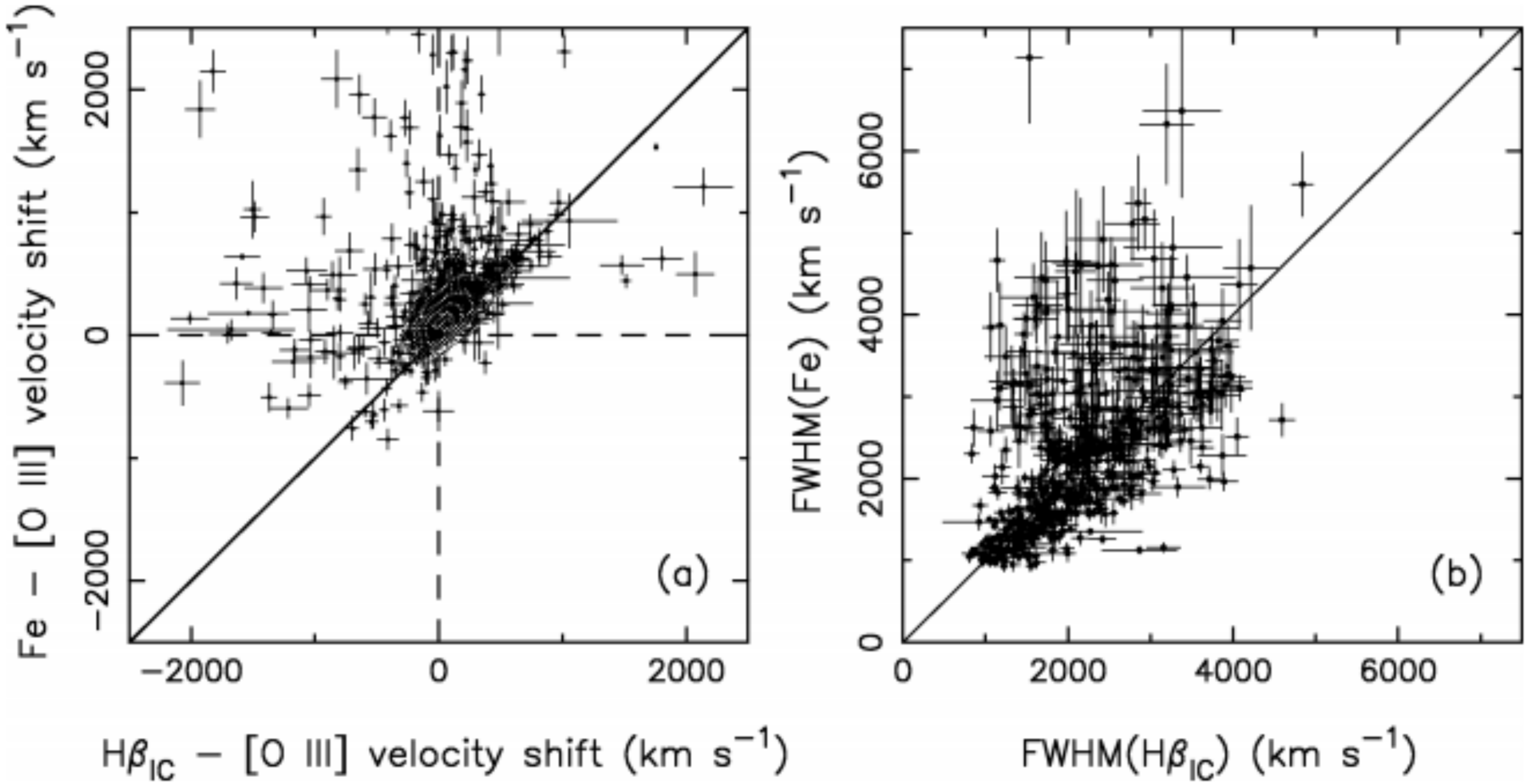
SDSS data implications

(Hu, Wang, Ho 2008a,b)

Basic physics: from torus to accretion disks



Redshifted intermediate line: infalling gas?



Fe II: redshifts? with intermediate Hβ?

Purposes of RM-Project

- AGN physics: BLR

  Origin? Structure? Radiation?

- Accretion physics: anisotropic radiation

  Super-Eddington accretion (2012)?

- BH fundamental parameters: mass and spin

  Virial mass? RM-mass?

- SMBH formation: ultrafast growth

  Black hole candles

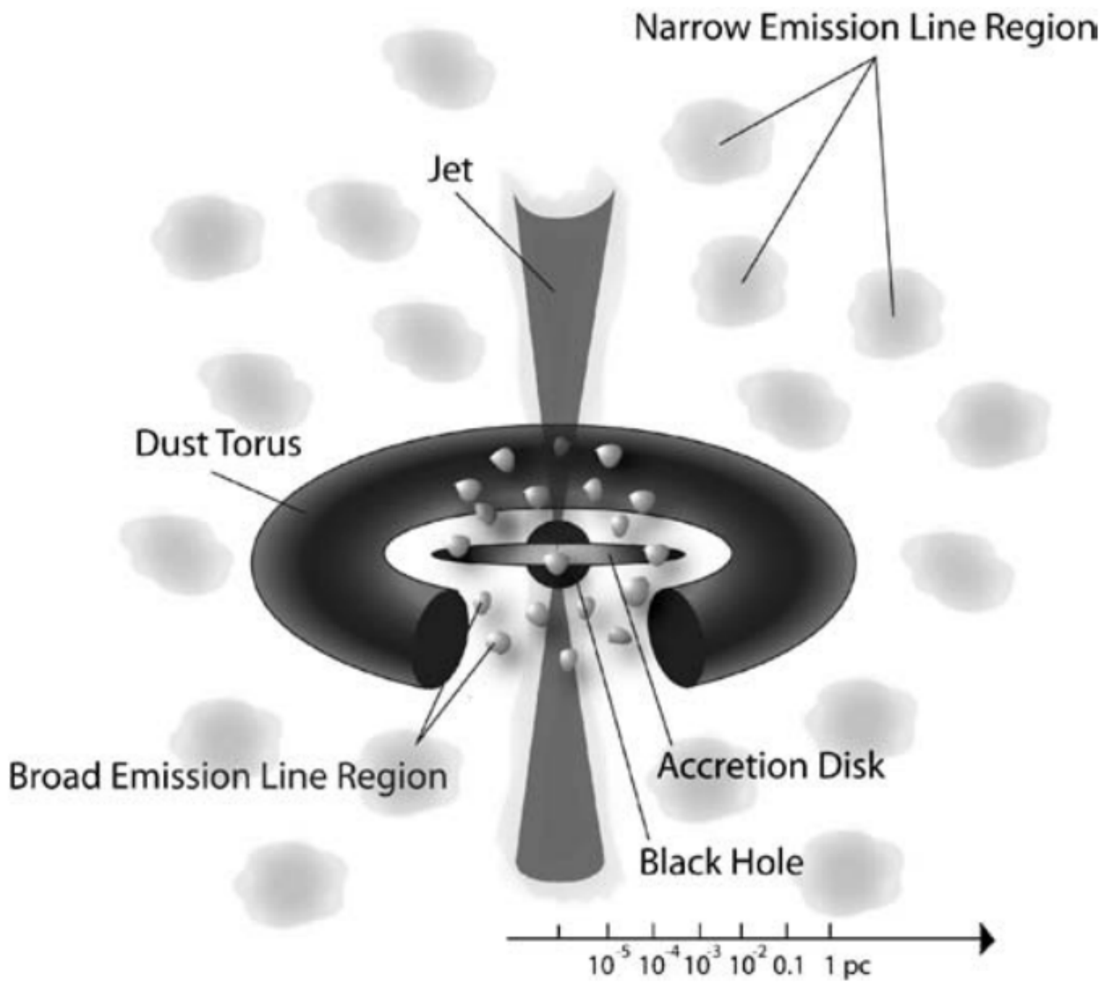
  Saturated luminosity? Scatters?

- Coevolution of BH and host
- For cosmology

The Lijiang 2.4m telescope: YFOSC since 2012

Yunnan Observatories, CAS

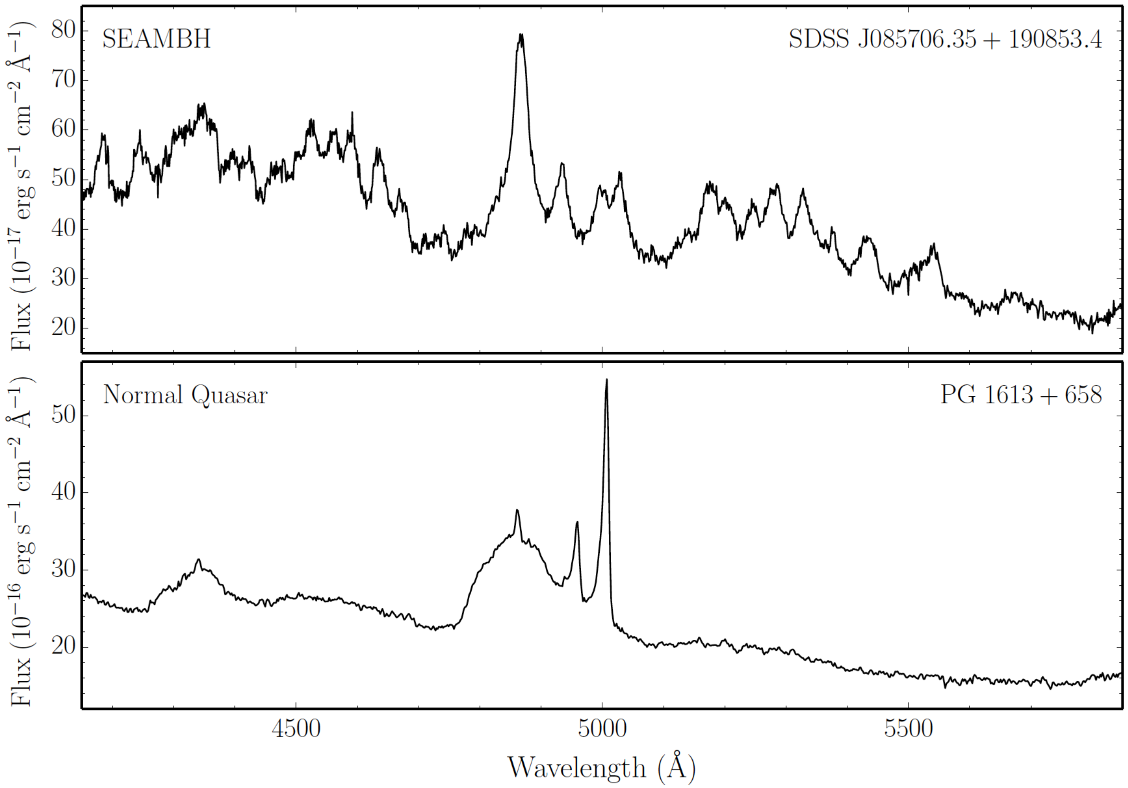
Reverberation mapping



Sample

- SEAMBH2012
- SEAMBH2013
- SEAMBH2014
- SEAMBH2015

total： 35 SEAMBHs



Methods and software

available for public

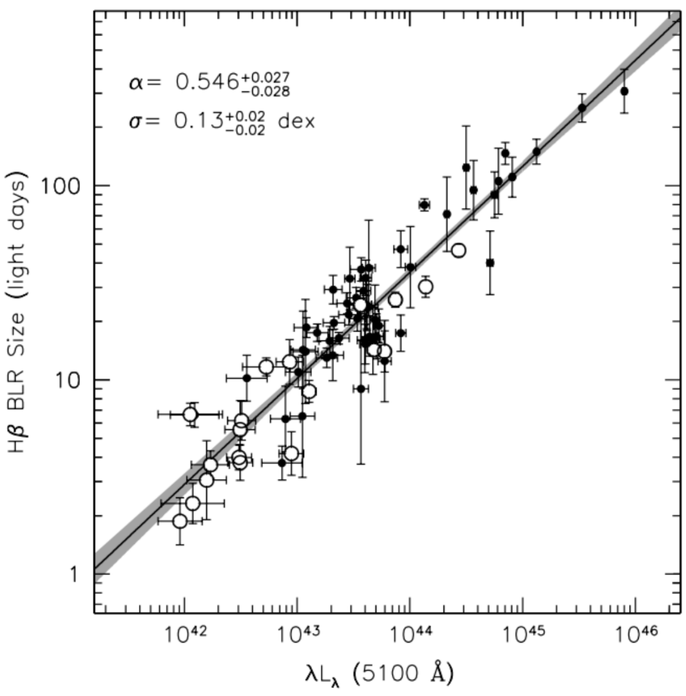
- Calibration method: fitting scheme
- Profile deconvolution: velocity-resolved map
- MICA: sub-structures of the BLR
- RM-mass: Markov Chain Monte-Carlo

  (MCMC technique)

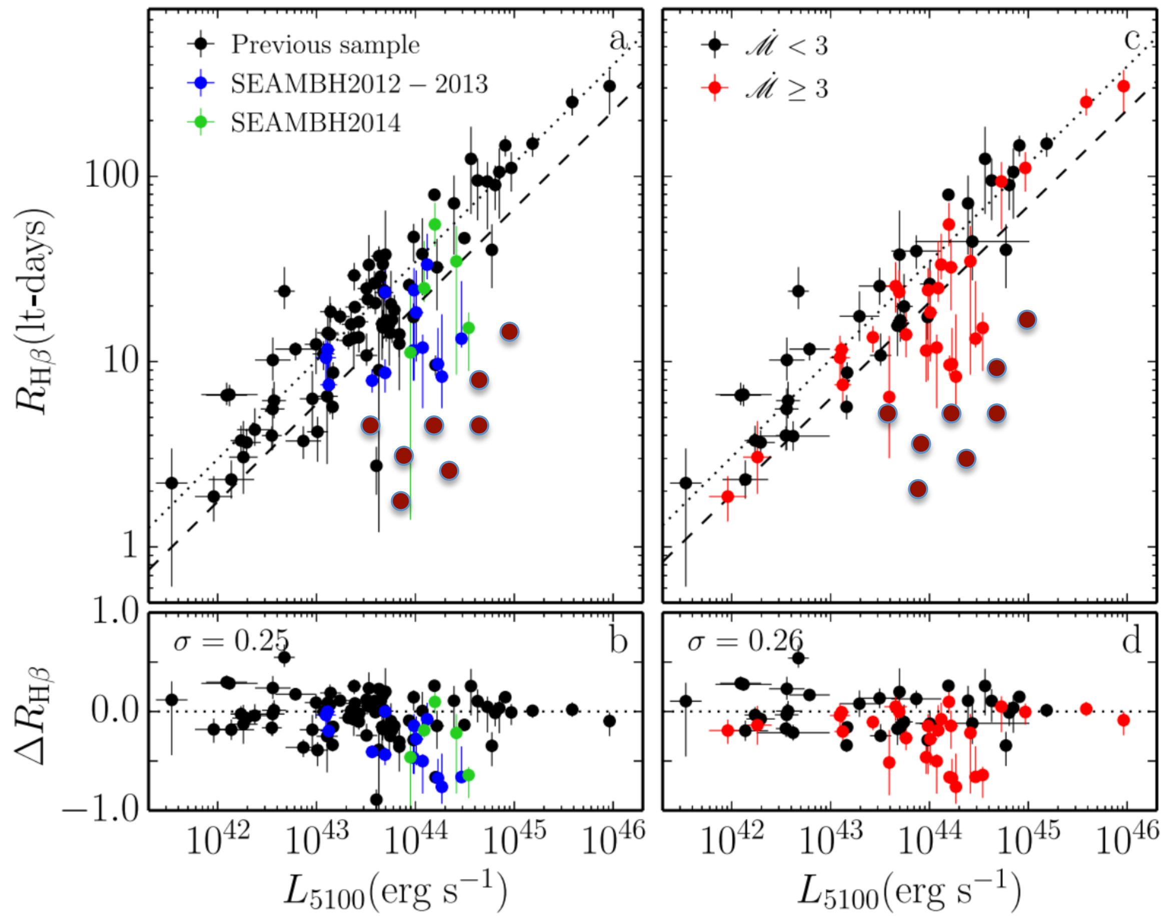
Current Results

SEAMBHs： *R*-*L* relation

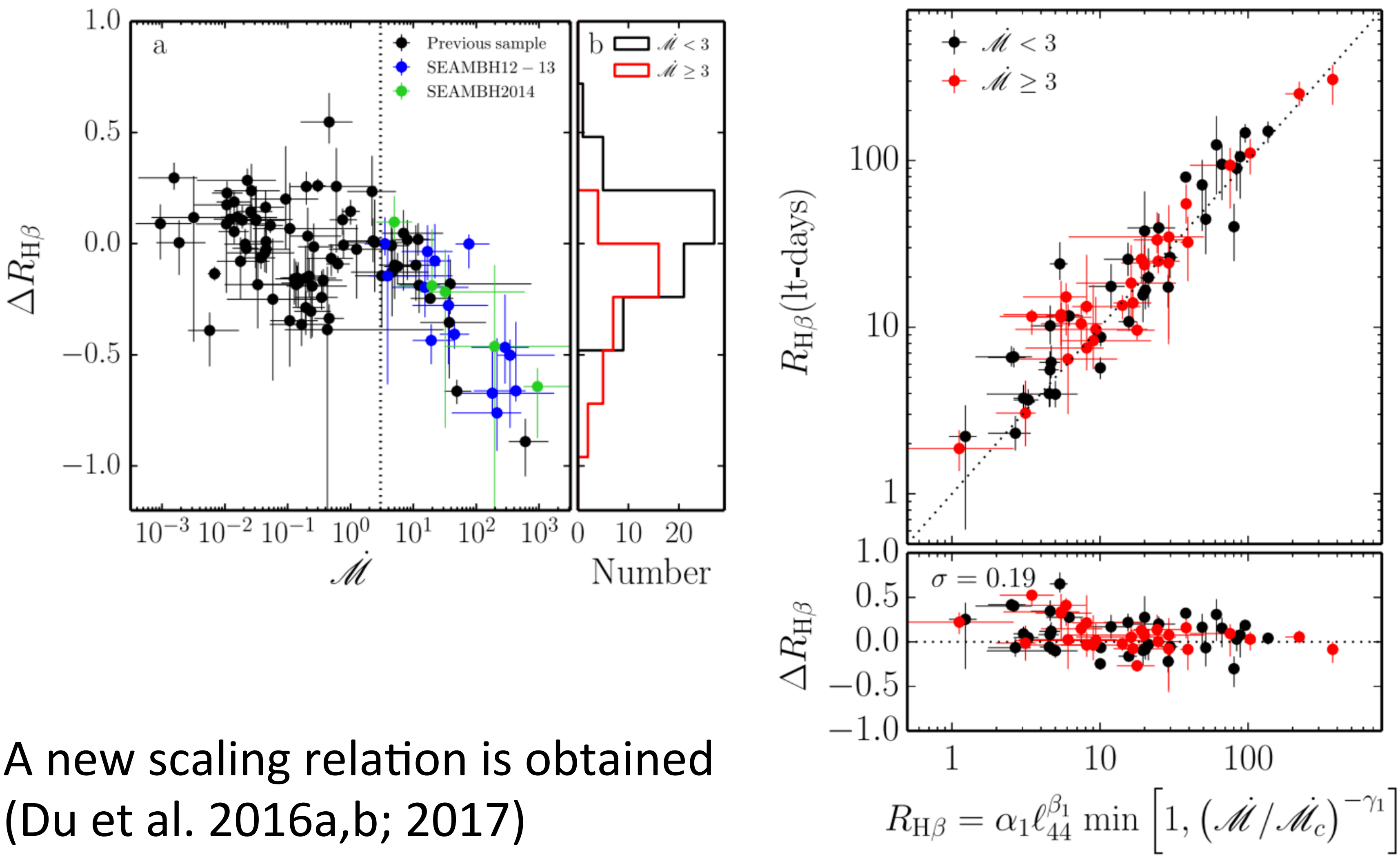
- Broken！ (Du et al. 2015; 2016a; 2017)



Kaspi et al. (2000)
Bentz et al. (2013)



New scaling relation: two-parameters



A new scaling relation is obtained (Du et al. 2016a,b; 2017)

Observed Hβ lags:

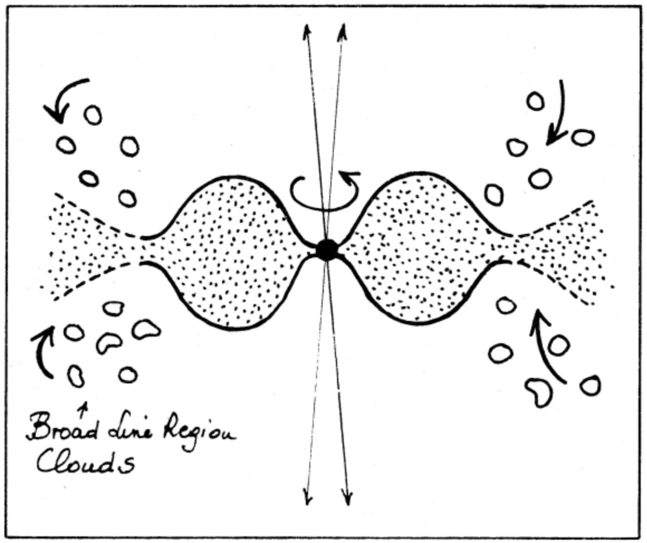
Physical meanings?

BLR: structure? R-L relation?

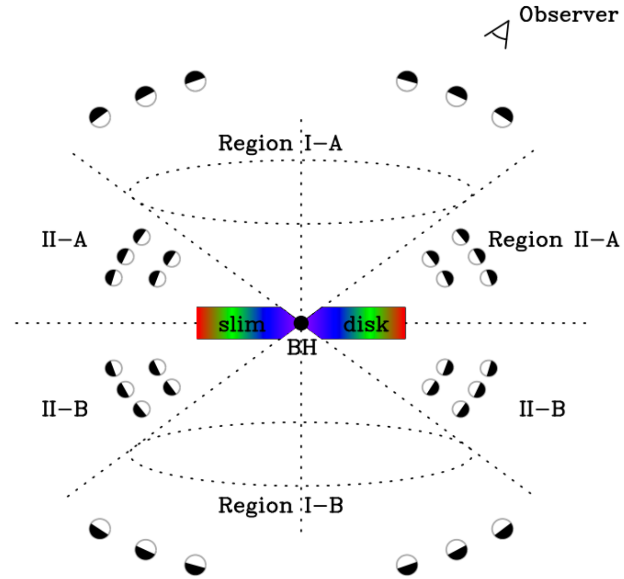
BH Virial-mass: accuracy?

are to be answered

High-$\dot{\mathscr{M}}$ disks: self-shadowing effects



Alloin (1990)



(Wang et al. 2014)

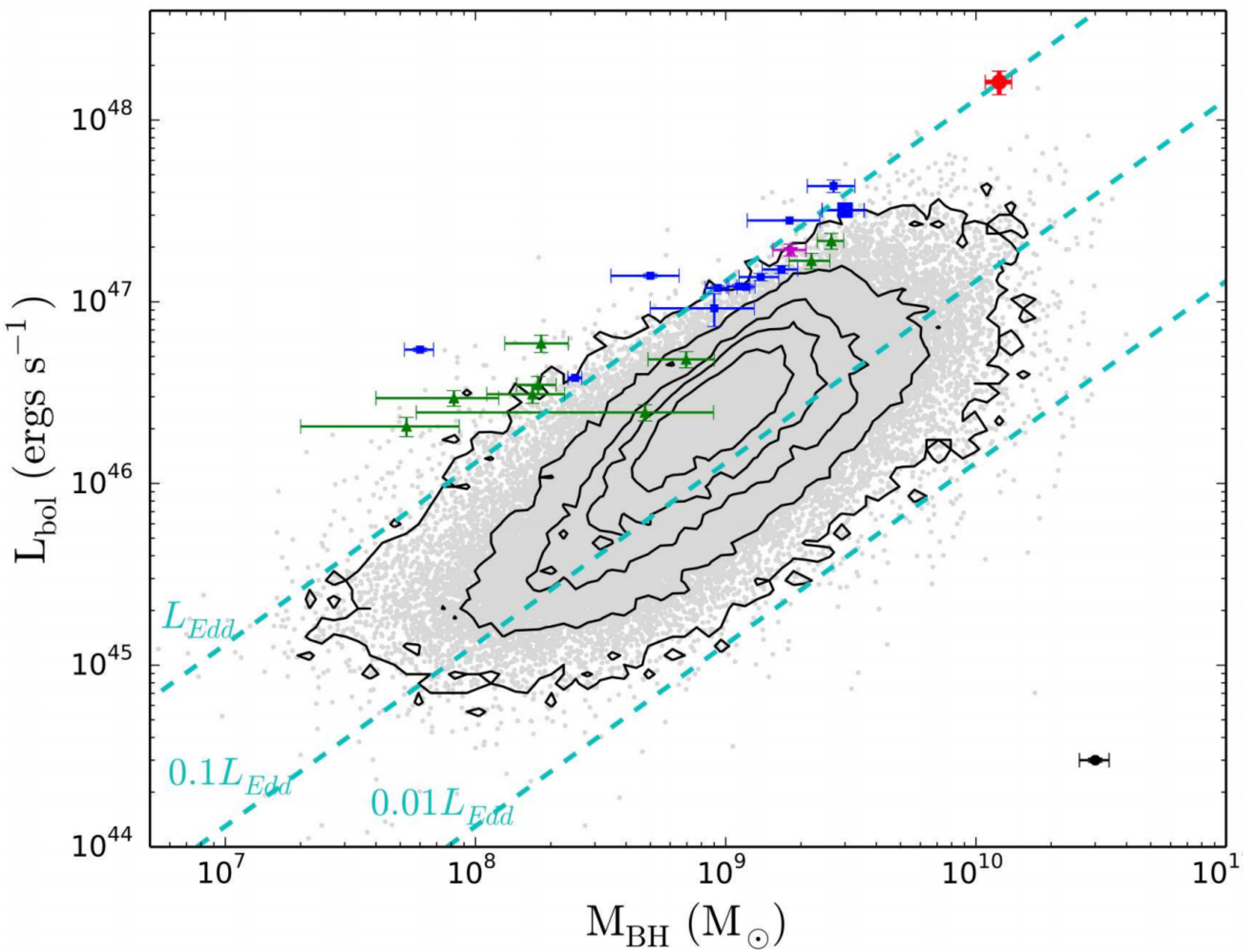
Shadowed BLR: shrinks and shorter lags

longer lags? (longer campaign to monitor)

Consequence: weak line quasars

SMBH formation: ultrafast growth

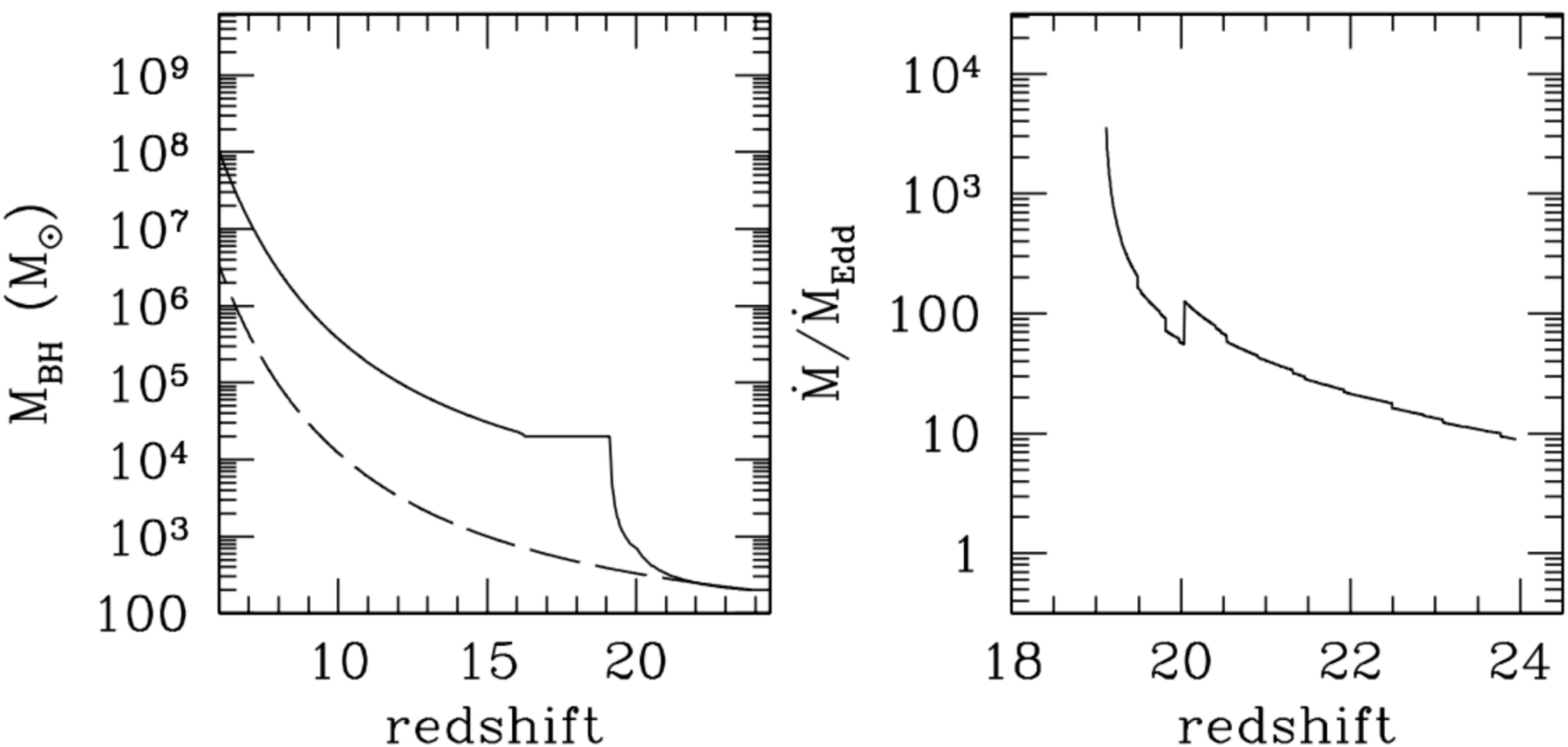
$$z > 6.0 : \qquad M_\bullet = 10^9 - 10^{10} M_\odot$$



L_{bol} (ergs s^{-1})
M_{BH} ($M_\odot$)
10^{44}
10^{45}
10^{46}
10^{47}
10^{48}
10^{7}
10^{8}
10^{9}
10^{10}
10^{11}
L_{Edd}
$0.1L_{Edd}$
$0.01L_{Edd}$

Ultrafast growth of BHs

(Volonteri & Rees 2005)



- SEAMBHs exist

Accretion rates: ~ 10^3Eddington rate

$$t_\bullet = \frac{\ln M_\bullet / M_\bullet^0}{\dot{\mathscr{M}}\,\delta_\bullet}\, t_{\rm Salp} = 0.69\,\dot{\mathscr{M}}_3^{-1}\delta_{-2}^{-1} M_{10,3}\,{\rm Gyr}$$

In local, we are witnessing:

$10^3 \rightarrow 10^{10} M_\odot$

fast growth of seed BH in high-z Universe.

Accretion physics?

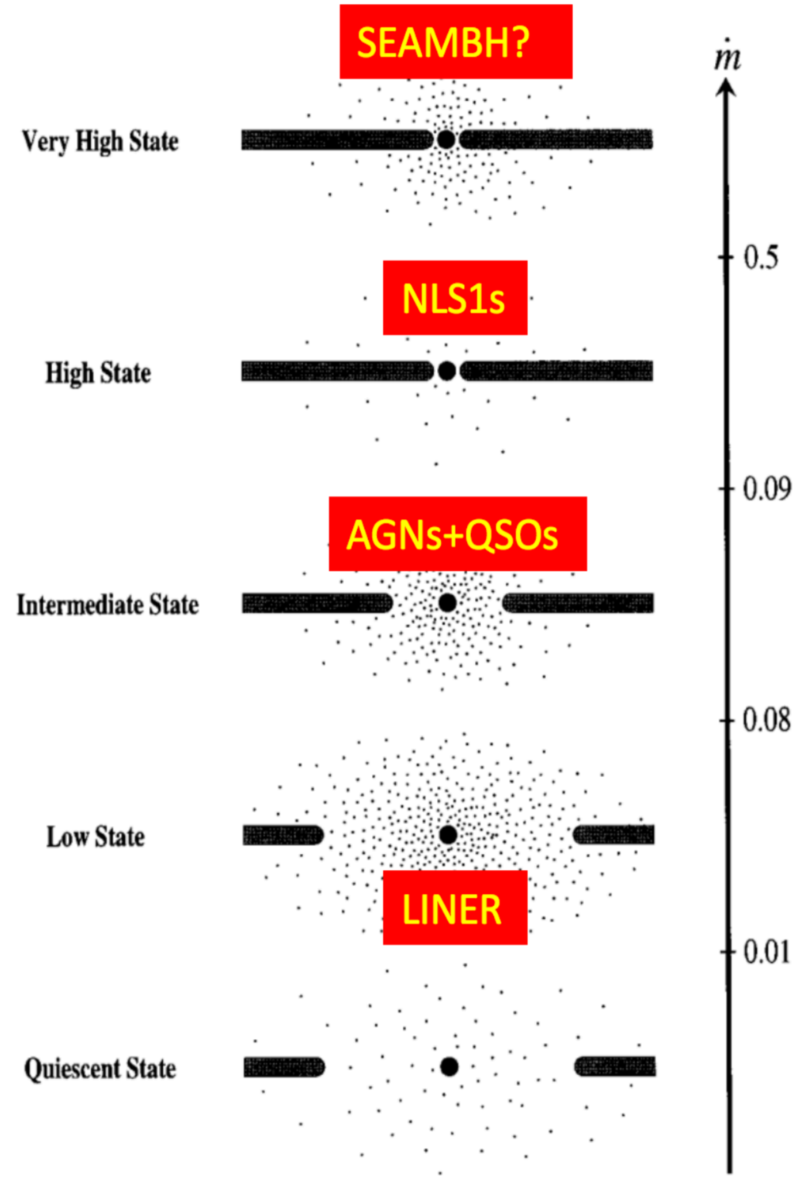
Accretion Physics

Low accretion disks (ADAF; ADIOs)

$$L_{\rm rad} \propto \dot{M}^2$$

Shakura-Sunyaev disks (intermediate rates)

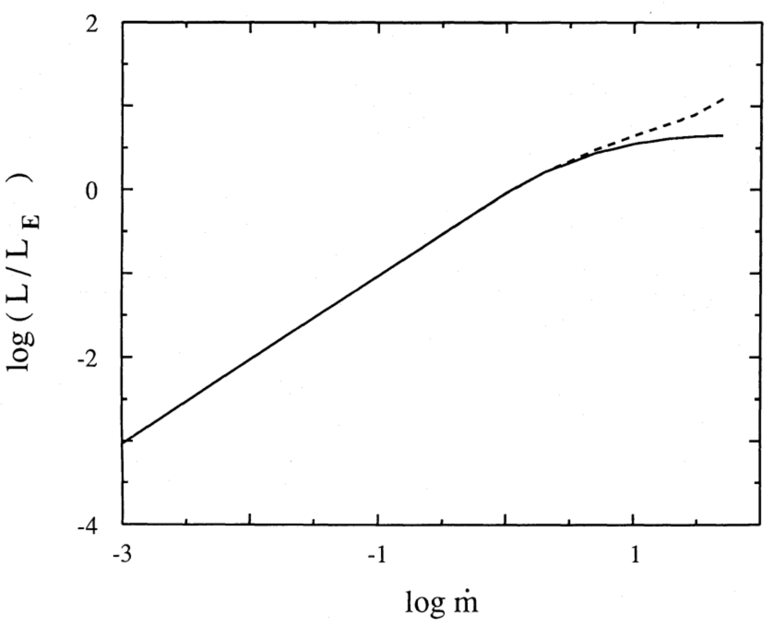
$$L_{\rm rad} \propto \dot{M}$$

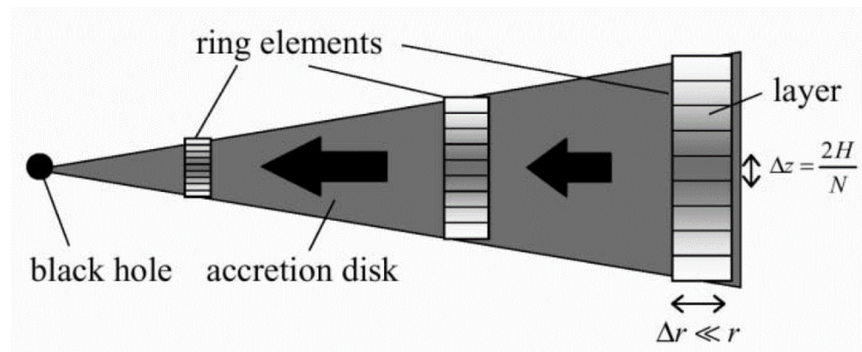


THE ASTROPHYSICAL JOURNAL, 332:646–658, 1988 September 15

SLIM ACCRETION DISKS

M. A. ABRAMOWICZ,[1,2] B. CZERNY,[1,3] J. P. LASOTA,[1,4] AND E. SZUSZKIEWICZ[1]
Received 1987 November 16; accepted 1988 February 29





$$L_\bullet = \ell_0(1 + \ln \dot{m}_\bullet)M_\bullet$$

- Transonic flow
- Sub-Keplerian rotation
- Photon trapping effects

Wang & Zhou (1999): self-similar solution
Mineshige+(2000)
Sadowski et al. (2013)

Photon bubble instability

(Begelman 2002)

THE ASTROPHYSICAL JOURNAL, 568:L97–L100, 2002 April 1

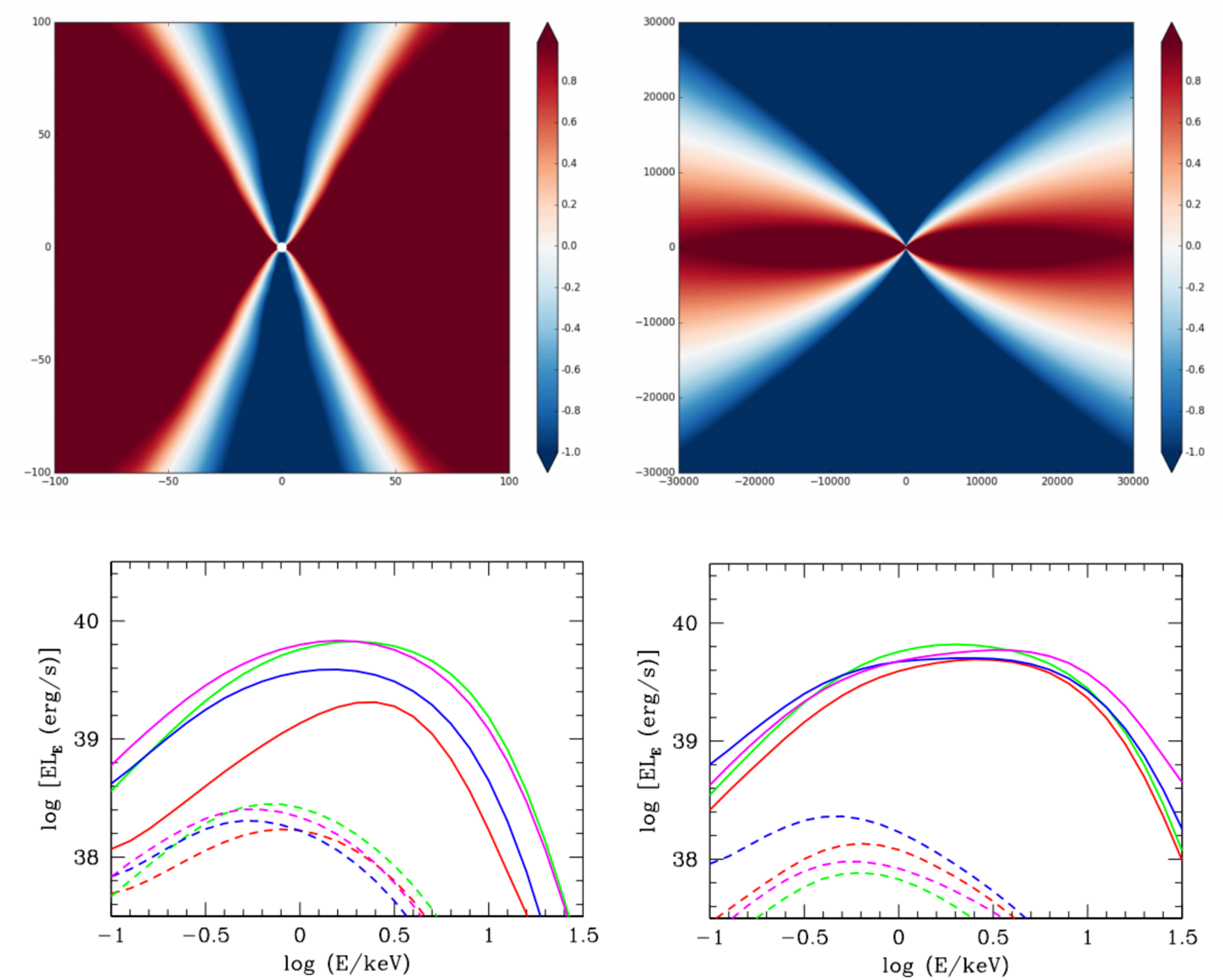
SUPER-EDDINGTON FLUXES FROM THIN ACCRETION DISKS?

MITCHELL C. BEGELMAN[1]

$$\frac{L_{\rm max}}{L_{\rm Edd}} > \epsilon \dot{m}_{\rm in,\,max} \sim 30 \xi_{-1}^{4/5} \alpha_{-2} \left(\frac{m}{10}\right)^{1/5} \frac{\epsilon}{0.1} \left(\frac{x_{\rm in}}{6}\right)^{1/2}$$

For $M_\bullet = 10^7 M_\odot$, $L/L_{\rm Edd} \approx 300$

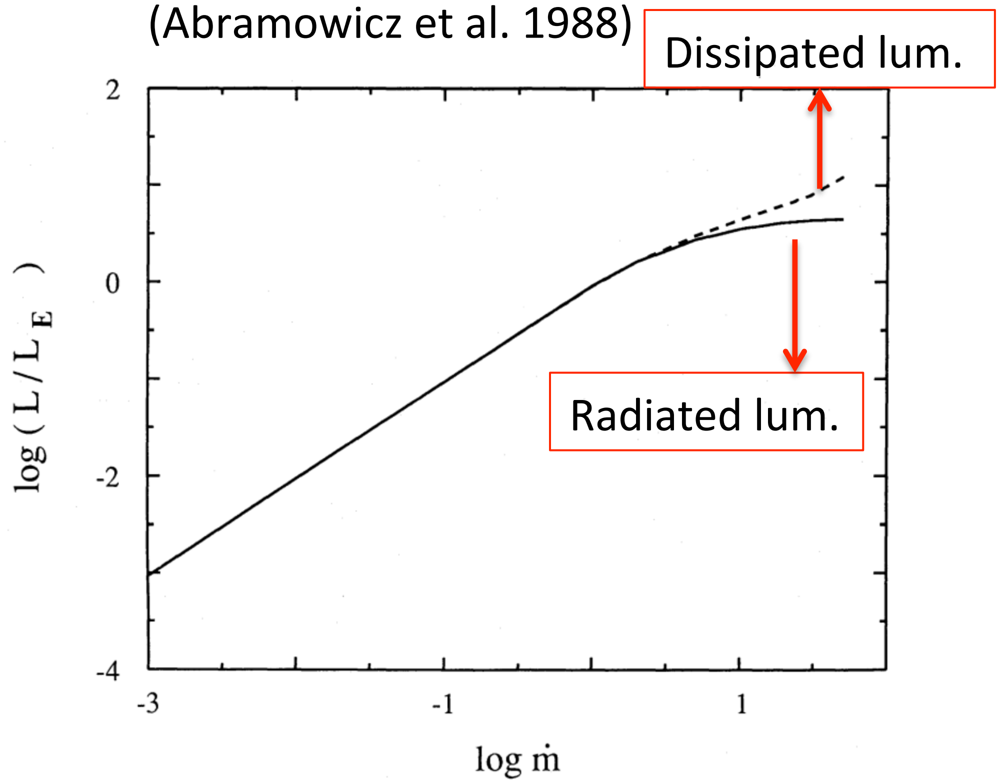
Narayan, Sadowski & Sori (2017)



Evidence for saturated luminosity

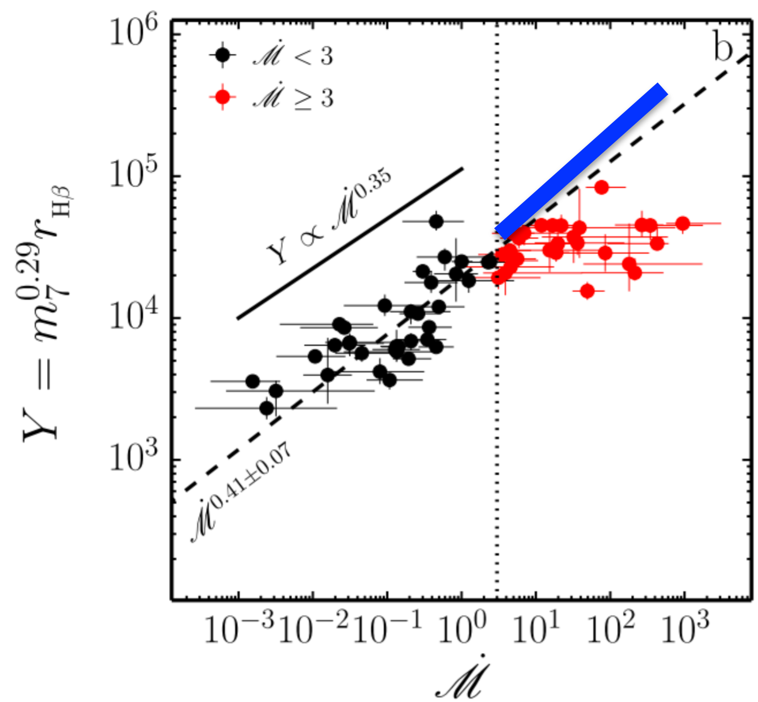
Slim accretion disks

(Abramowicz et al. 1988)



SEAMBH collaboration

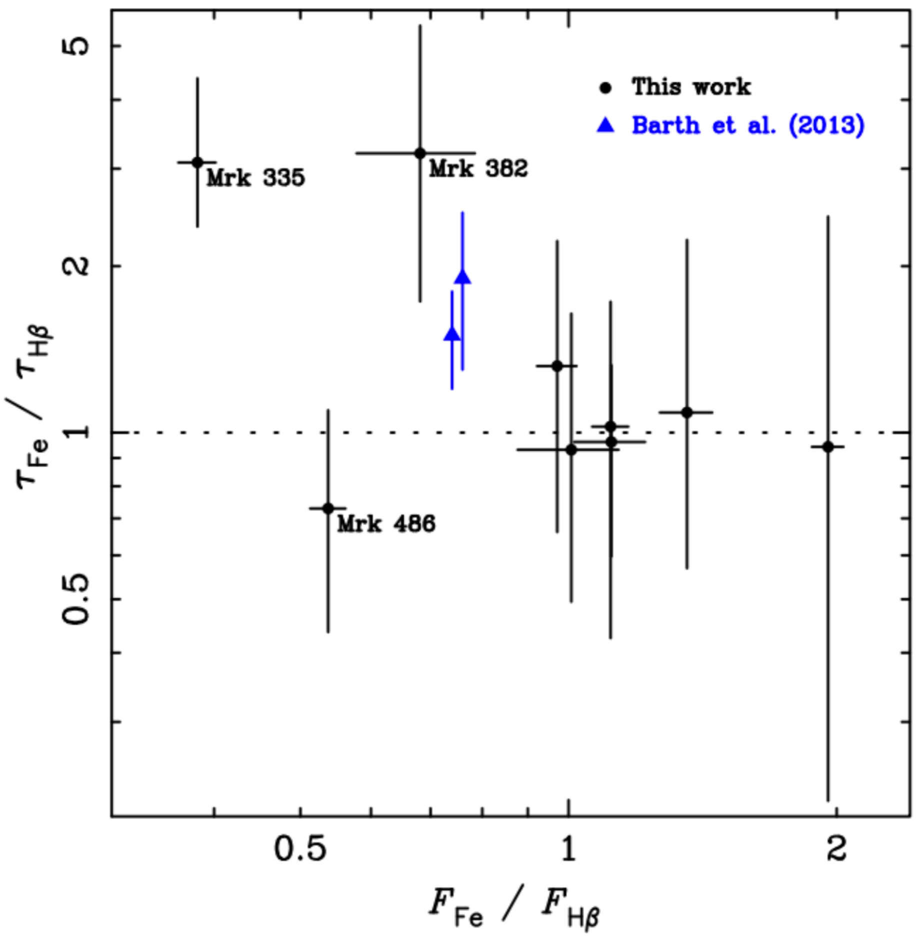
(Du et al. 2016a)

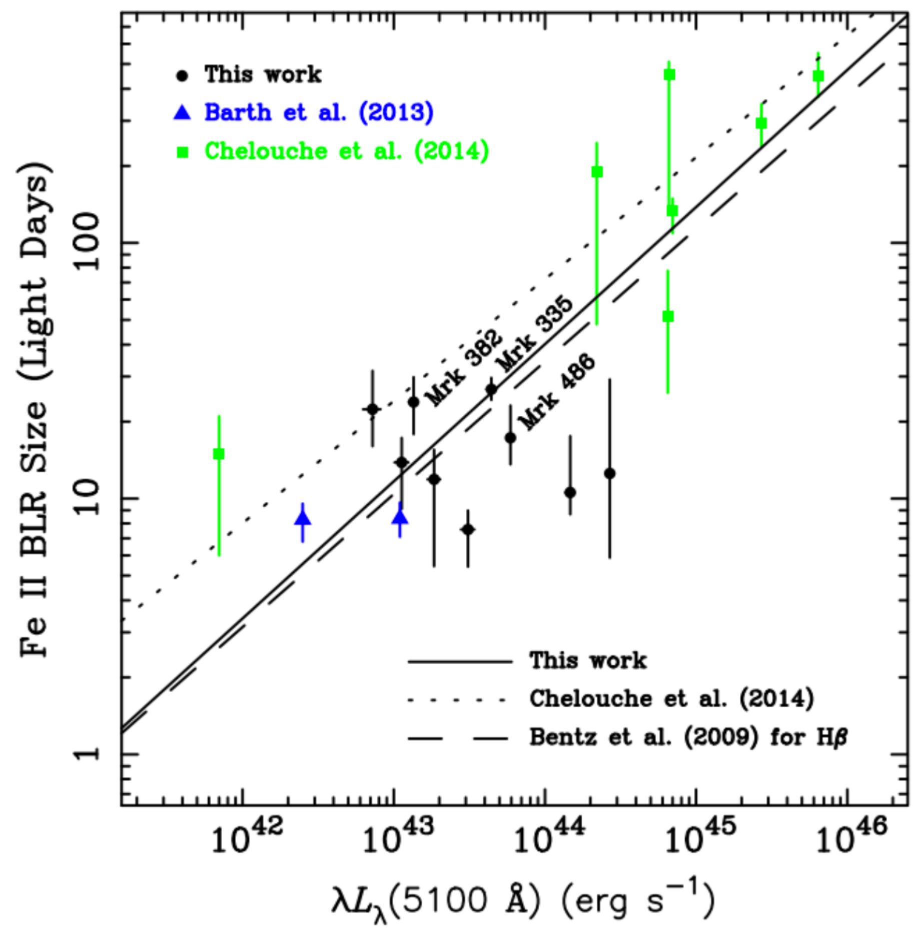


Photon trapping effects: $L_\bullet = \ell_0(1 + a \ln \dot{m}_{15}) M_\bullet$ (theory)

Saturated luminosity --> cosmological candles (Obs.)

Fe II-RM (Hu+2015)





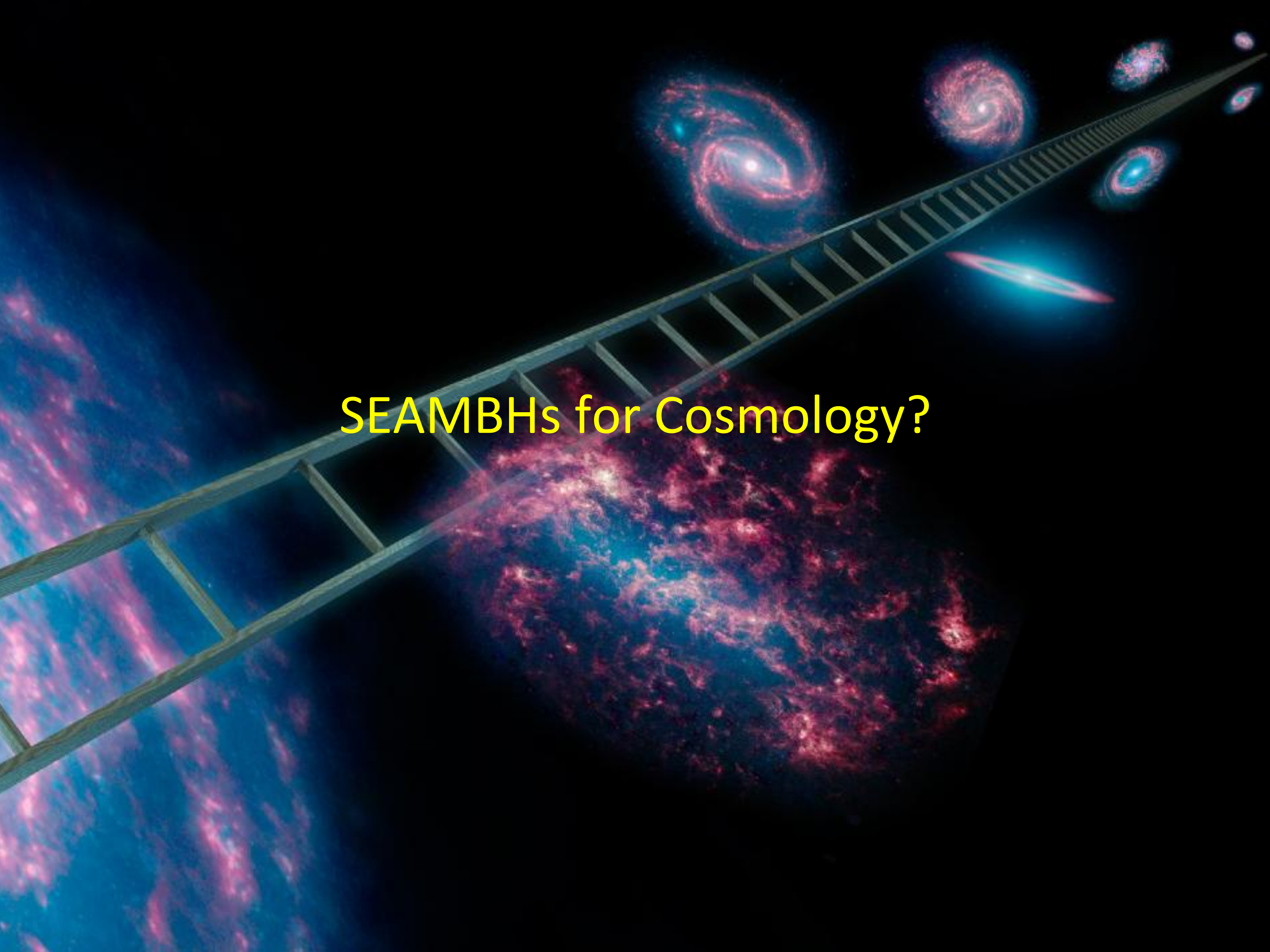
Super-Eddington Accretion Physics:

1) geometrically slim: lags shortened

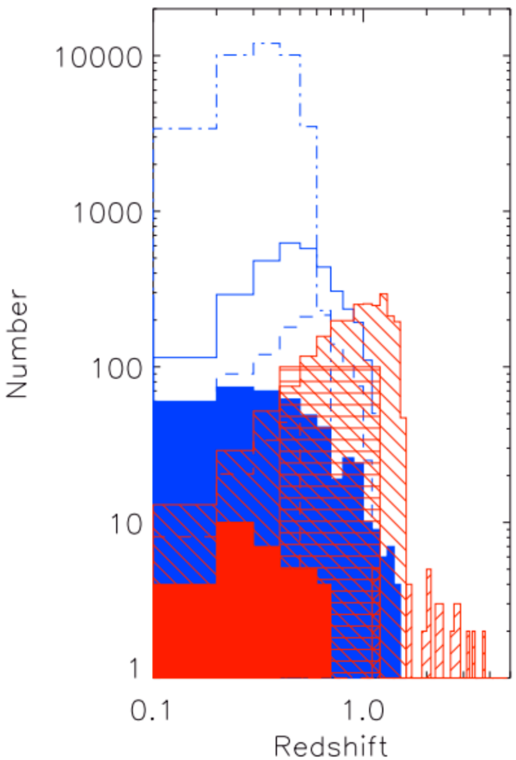
2) photon trapping: saturated luminosity

3) a new scaling relation established for BLR

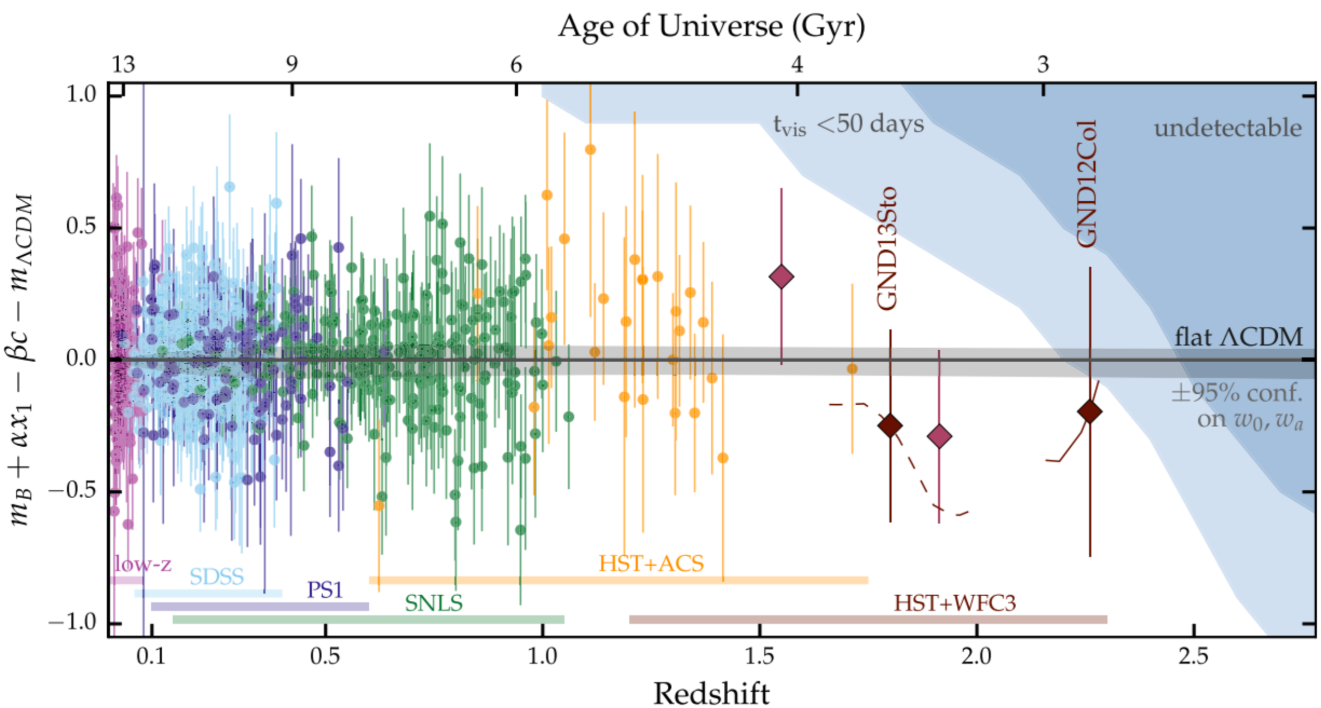
SEAMBHs for Cosmology?



SNIa for cosmology: z<1.5



Hook (2013)



Rodney, Riess et al. (2015)

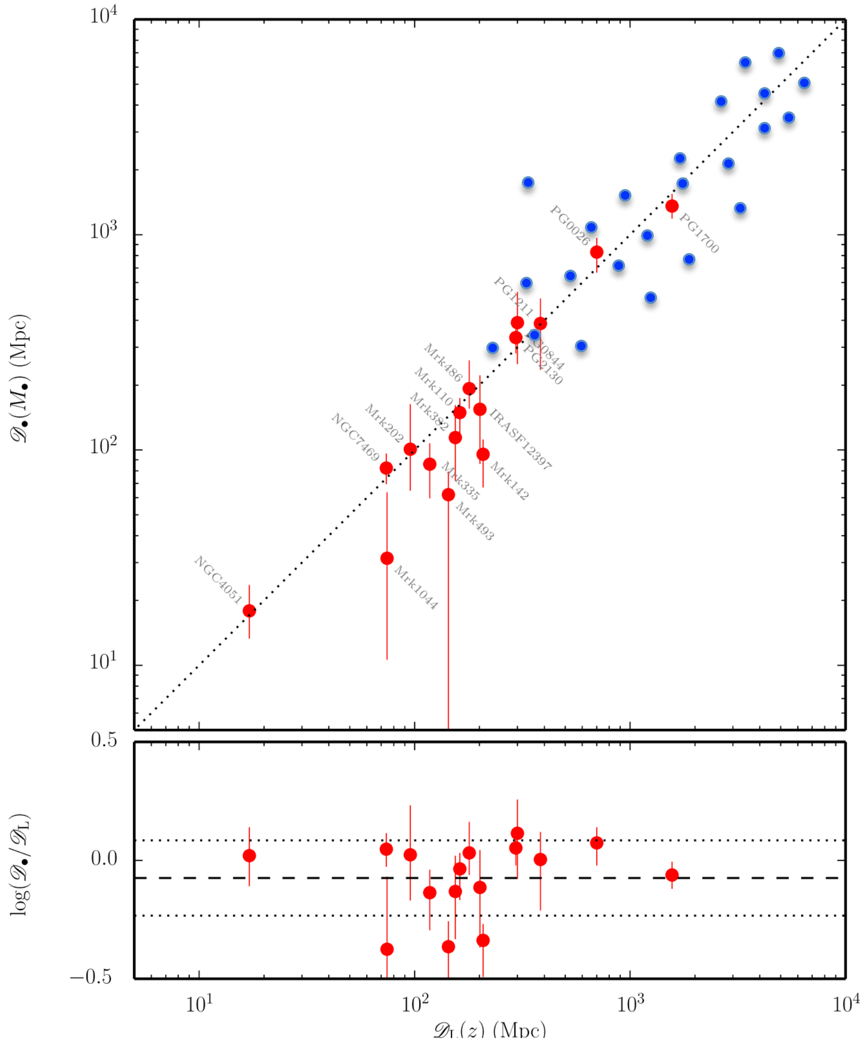
SEAMBH for cosmology

(Wang et al. 2013; 2014)

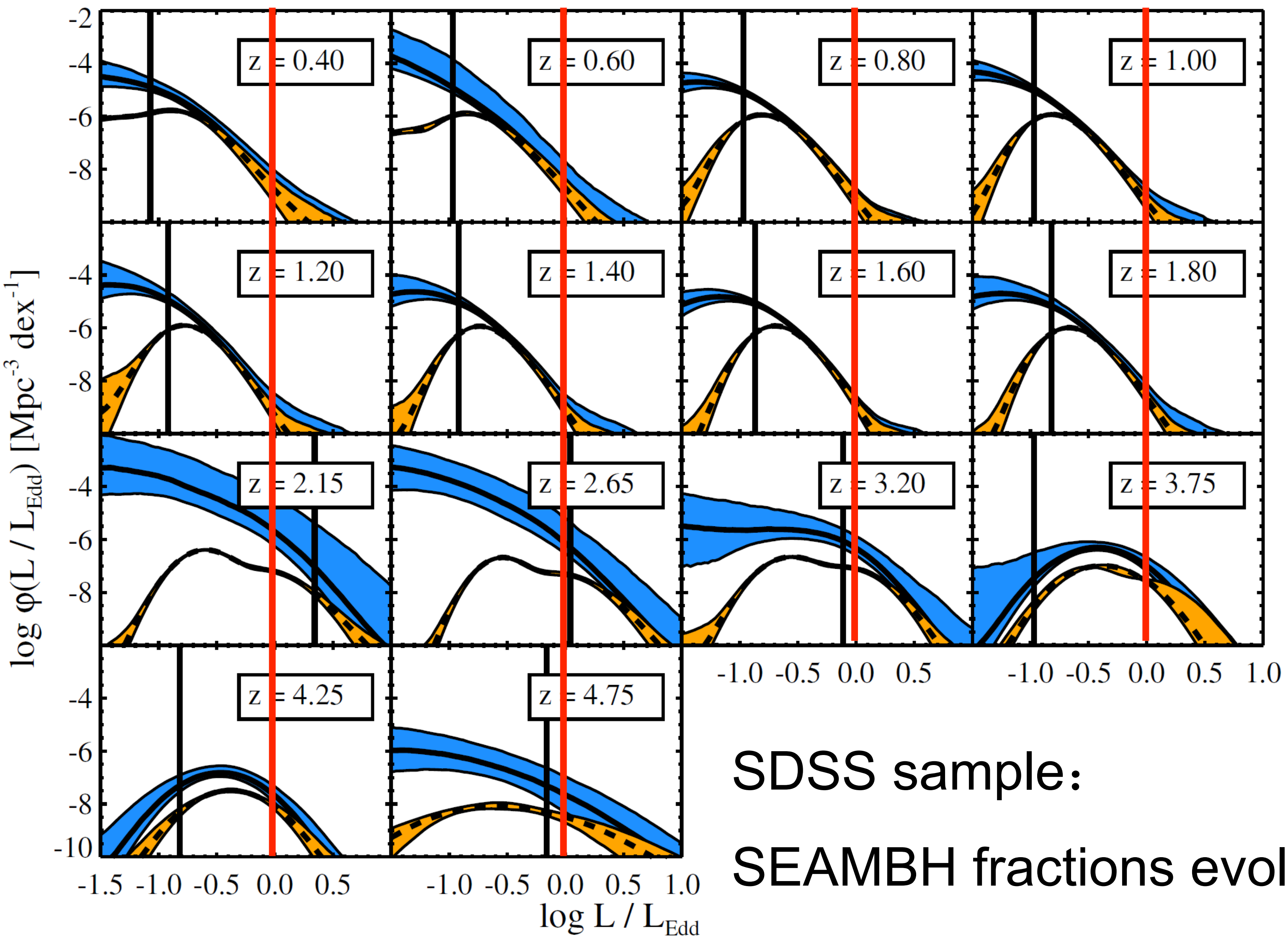
- Saturated luminosity: standard candles

$$L_{\bullet} = \ell_0(1 + a\ln\dot{m}_{15})M_{\bullet}$$

Intrinsic scatter: 0.15 dex



Eddington ratio function (Kelly & Shen 2013)

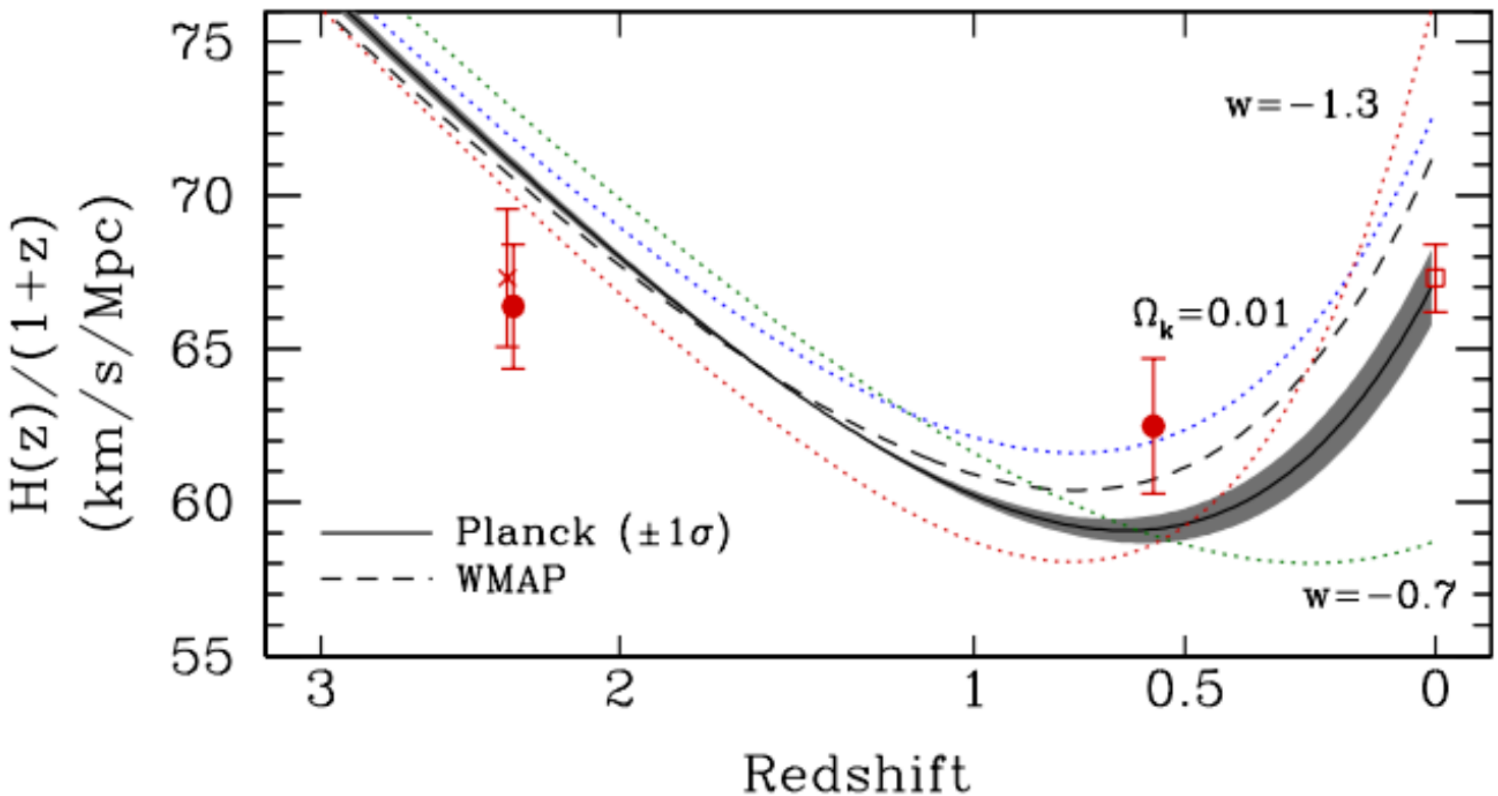


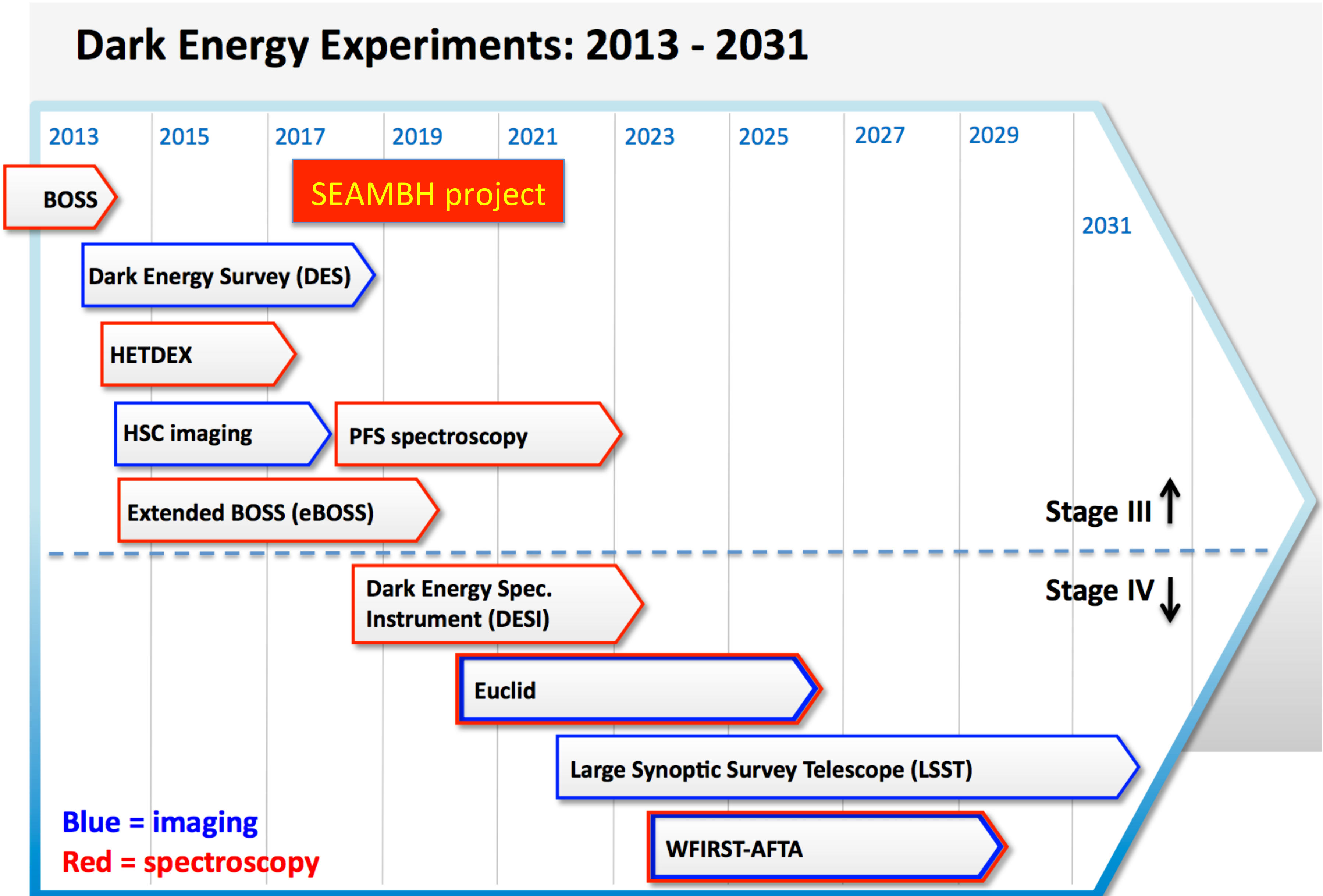
SDSS sample：

SEAMBH fractions evolve

Lyα Forest BAO measurement

(Aubourg et al. 2015)




Dark Energy Experiments: 2013 - 2031
2013
2015
2017
2019
2021
2023
2025
2027
2029
2031
BOSS
SEAMBH project
Dark Energy Survey (DES)
HETDEX
HSC imaging
PFS spectroscopy
Extended BOSS (eBOSS)
Stage III
Stage IV
Dark Energy Spec. Instrument (DESI)
Euclid
Large Synoptic Survey Telescope (LSST)
WFIRST-AFTA
Blue = imaging
Red = spectroscopy

Current observations

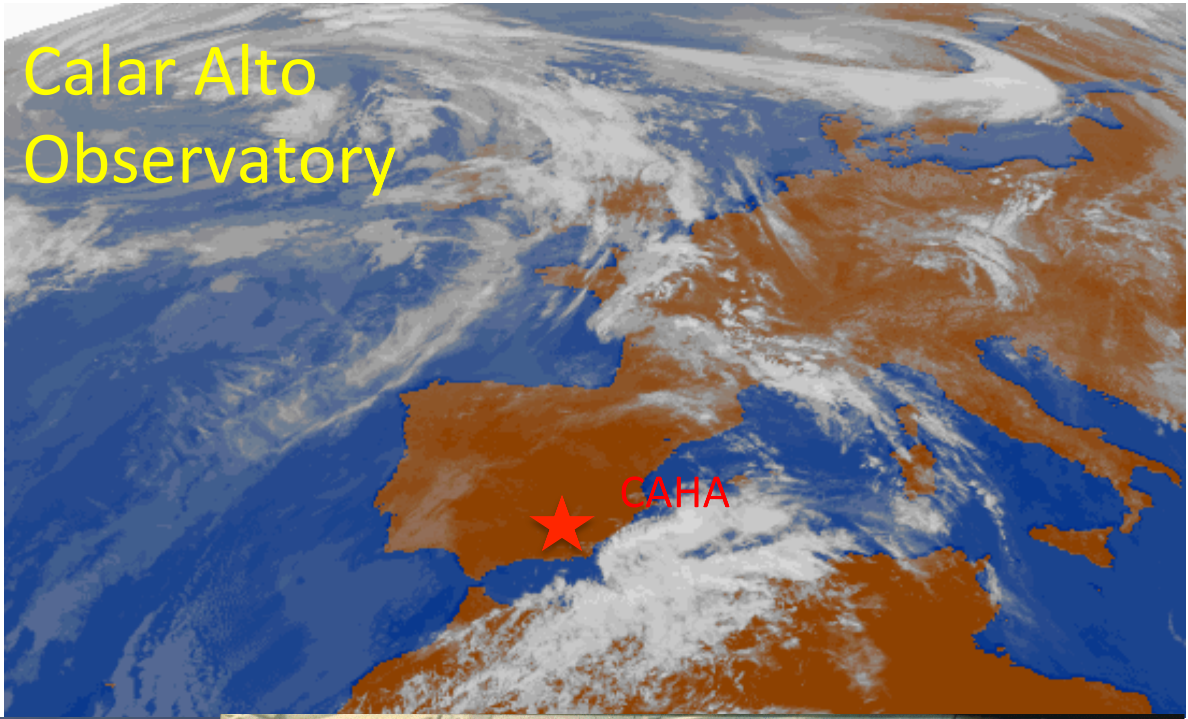
Wyoming U.: WIRO2.3m (2017-2021)

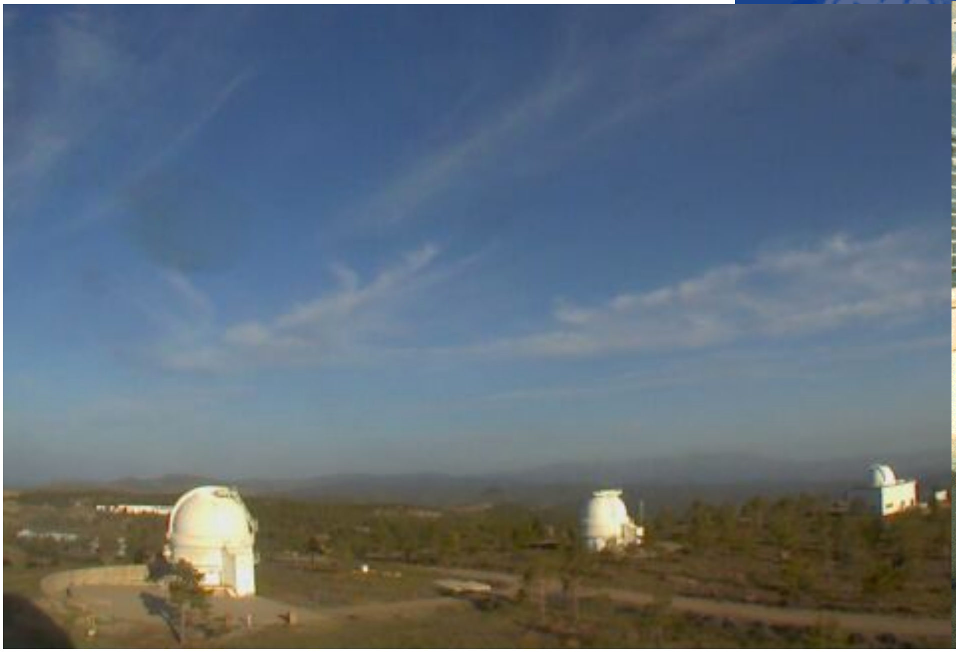
MAHA (Monitoring AGN with Hbeta Asymmetry)

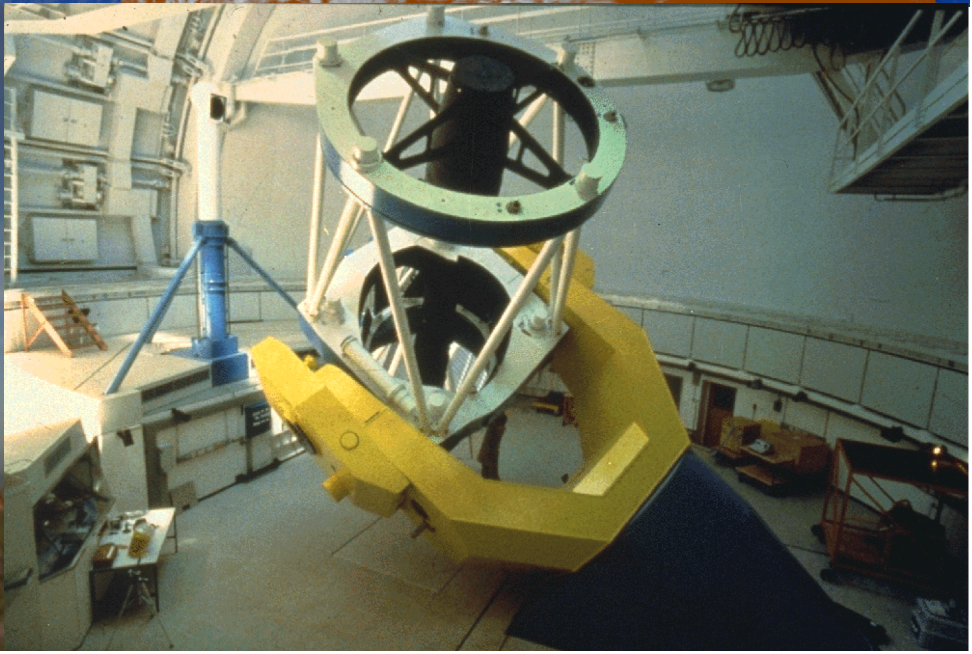
for BLR and SMBH binaries

Since 2017-2021

Focus: SEAMBHs







Lijiang2.4m: 1/3 for SEAMBHs

Summary

- SEAMBH:
  - — Hbeta lags are shortened by Mdot
  - — Saturated luminosity
  - — Fe II follows Hbeta
  - — for cosmology
- MAHA: looking for virialized components
- many things are forthcoming