Super-Eddington Accreting Massive Black Holes in Active Galactic Nuclei

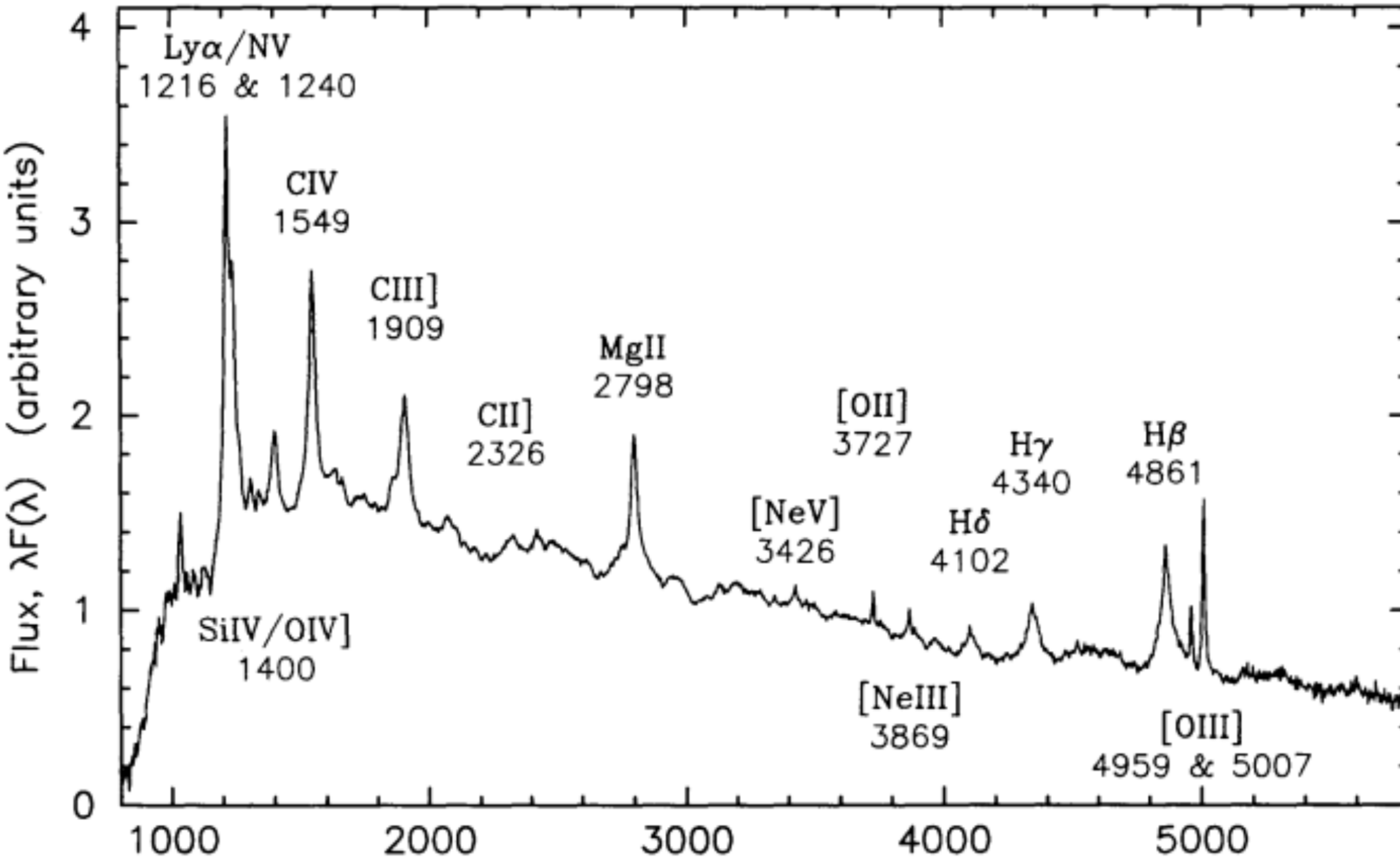
Jian-Min Wang

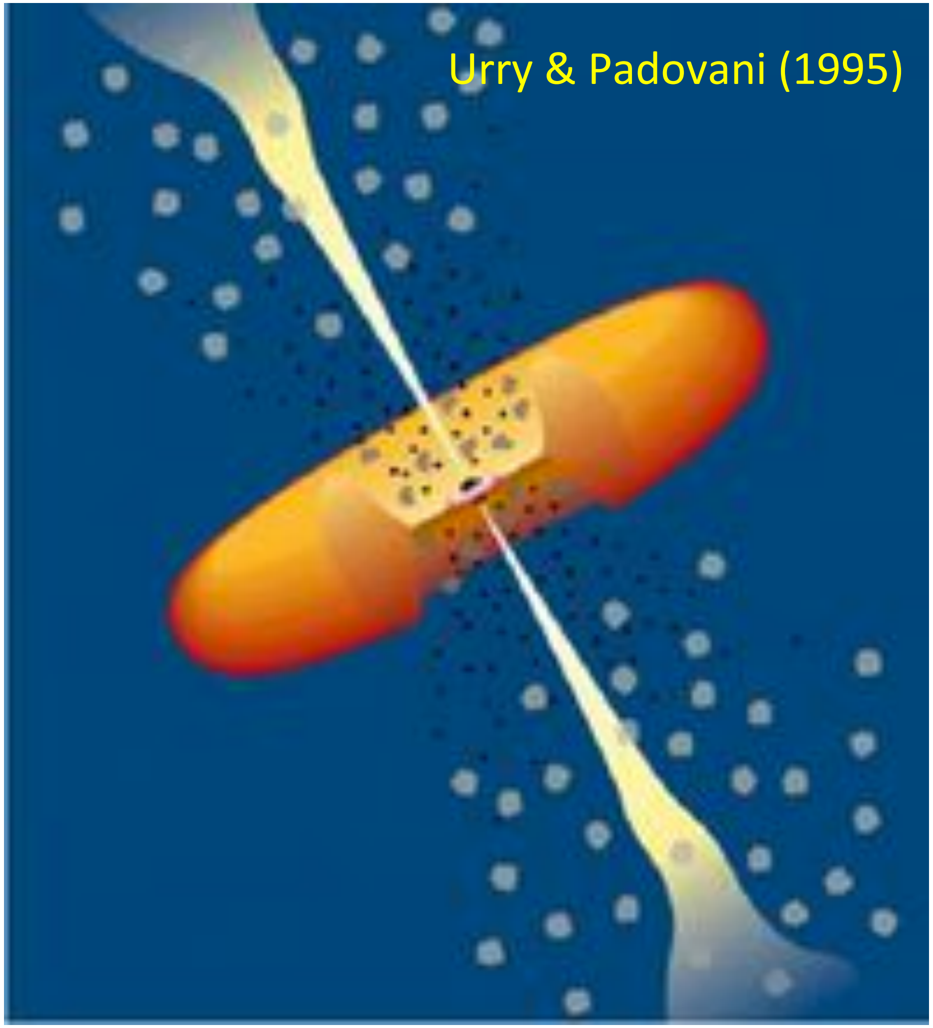
Institute of High Energy Physics,

National Astronomical Observatory of China

Chinese Academy of Sciences, Beijing 100049

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?

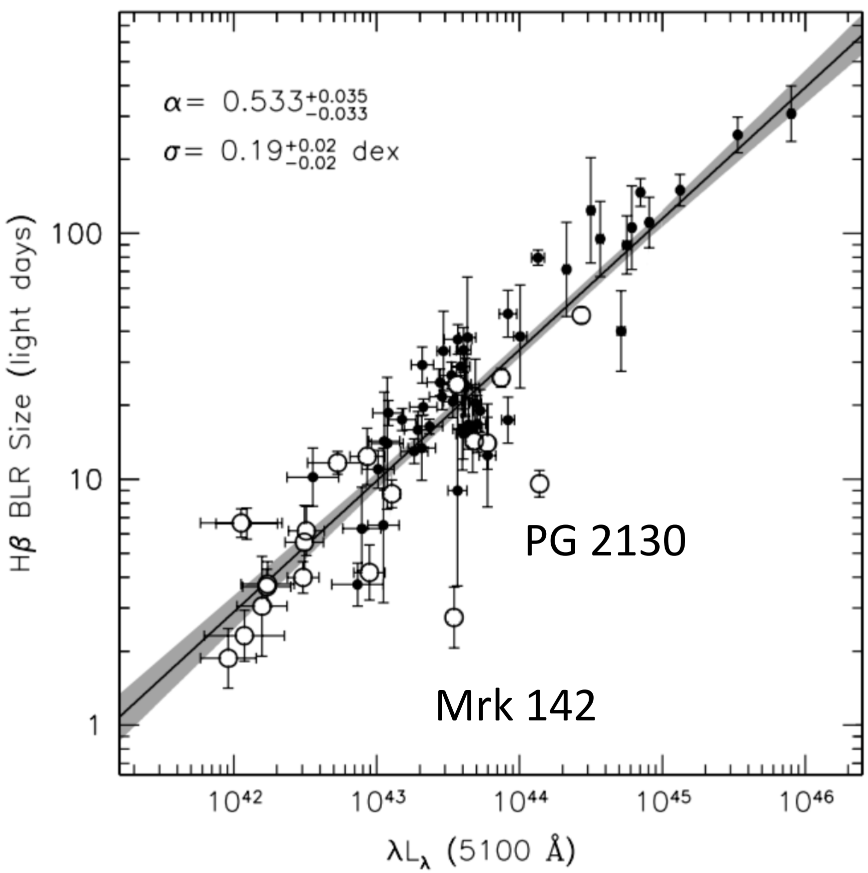
2) BH accretion rate?

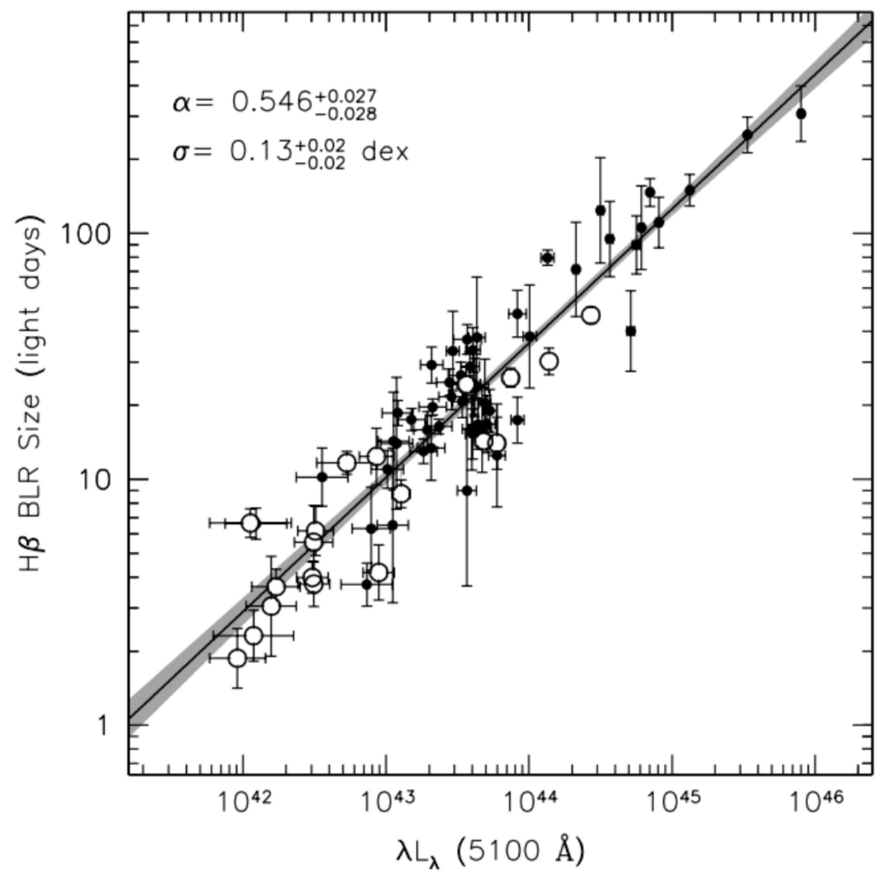
3) BH spins?

4) inclinations?

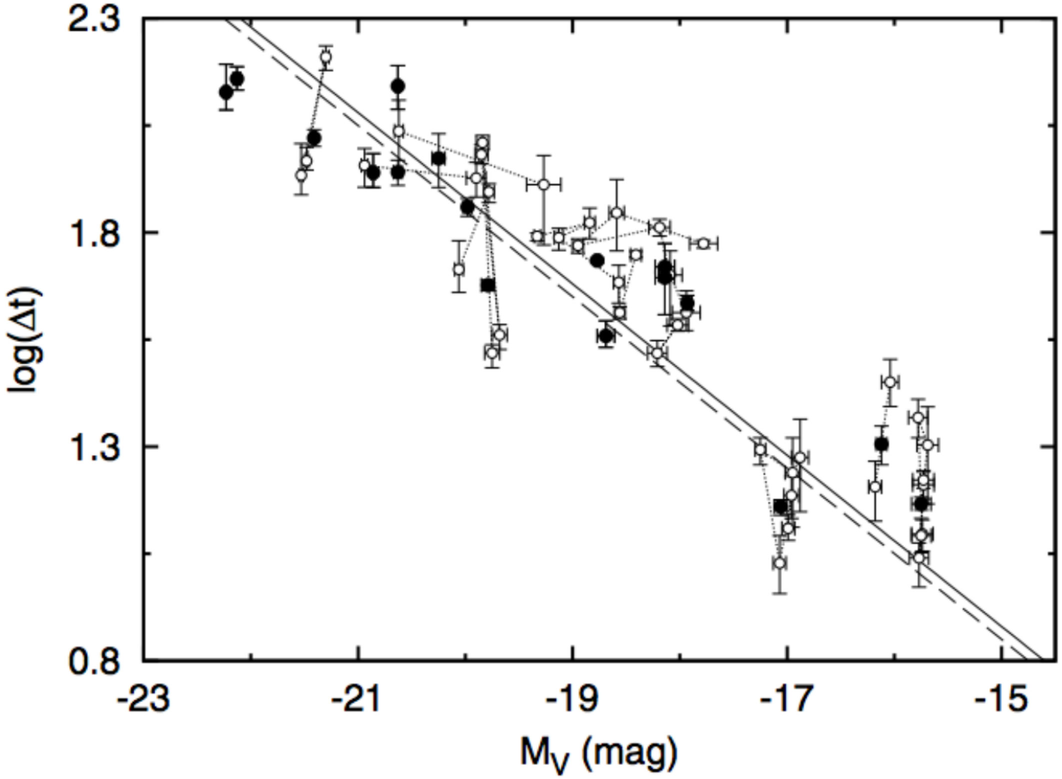
Two size-scaling relations

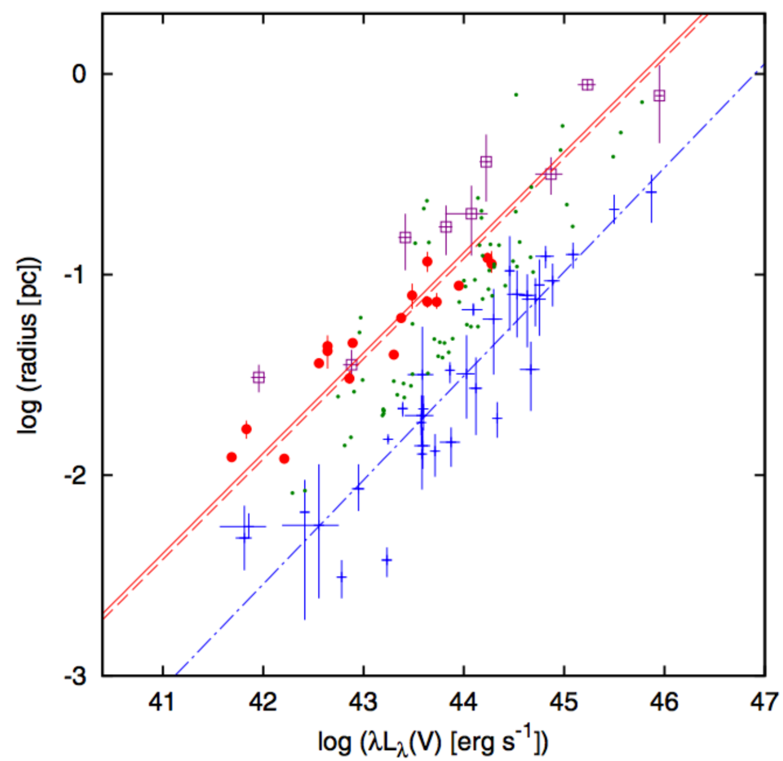
- R_{BLR}-L relation (Kaspi et al. 2000; Bentz et al. 2013)





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



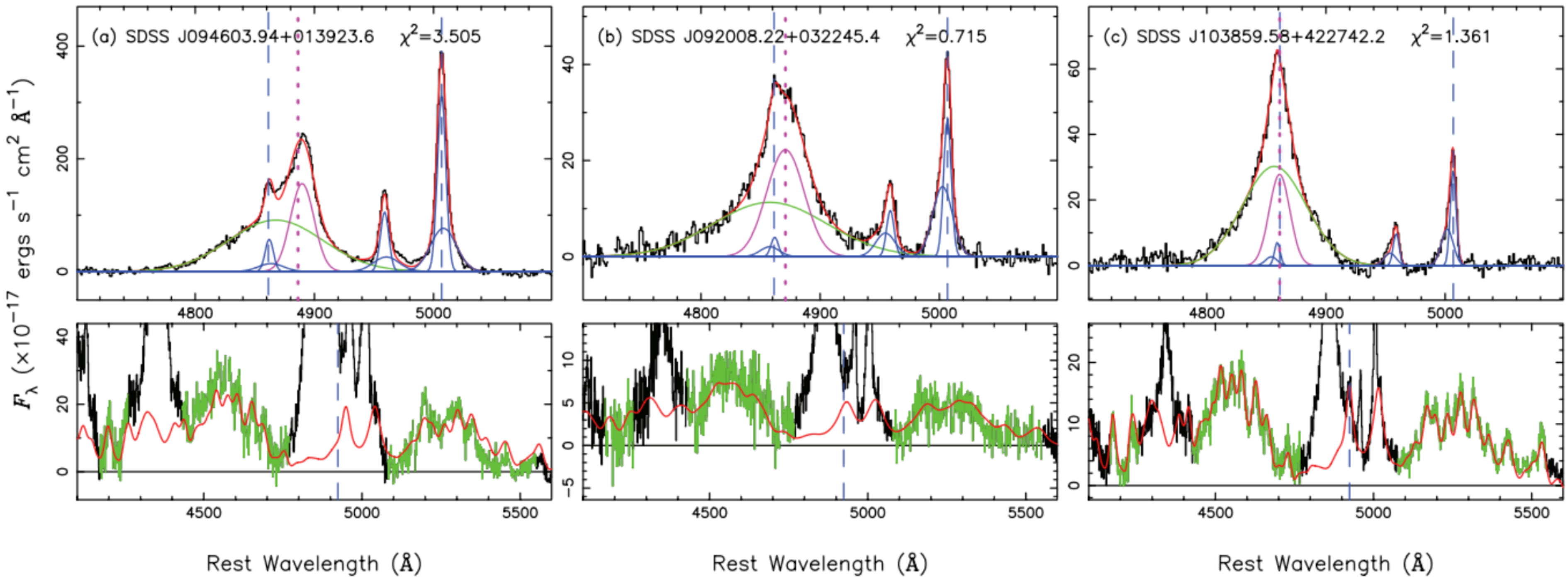


Is there a connection between the BLR and Torus?

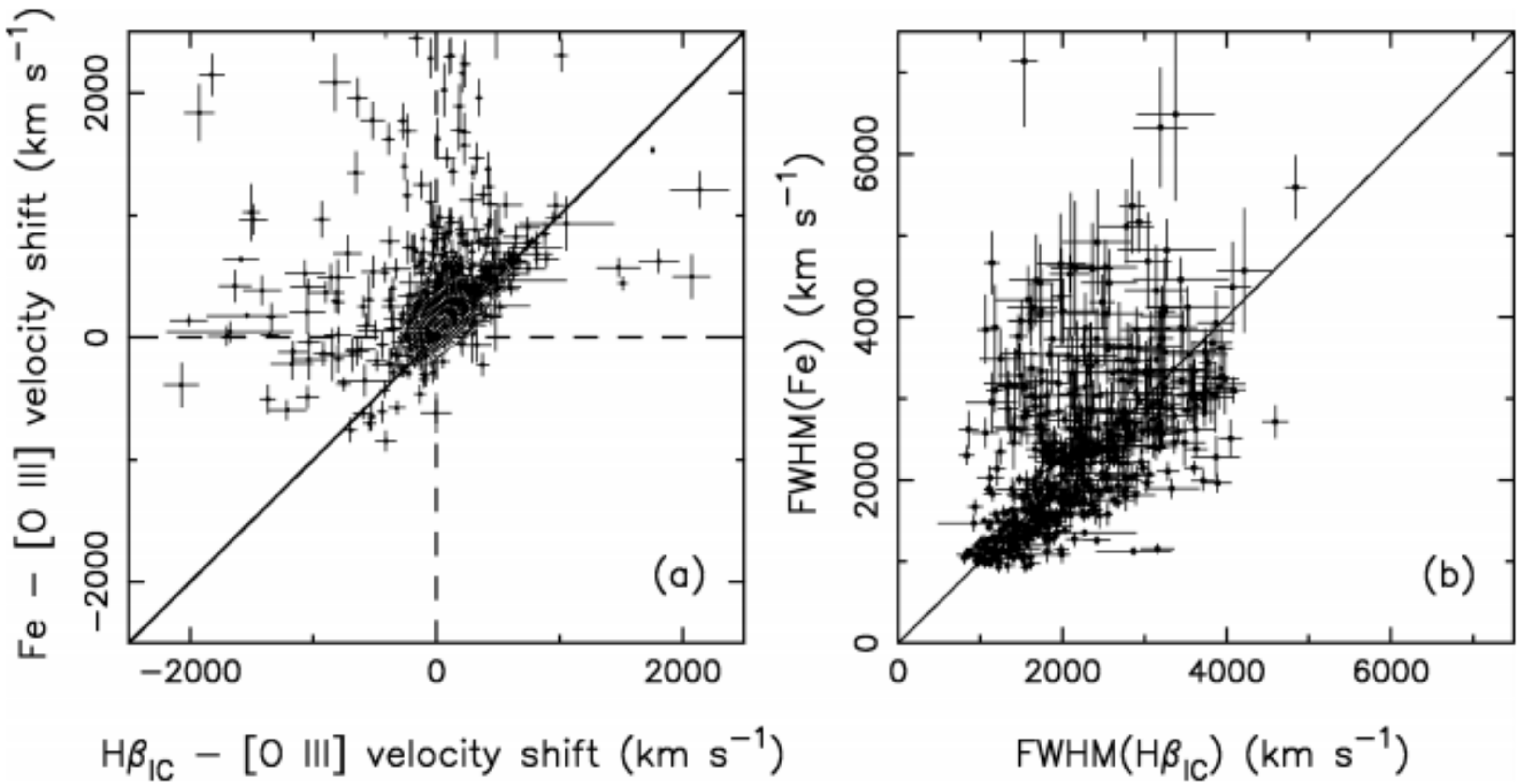
SDSS data implications

(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

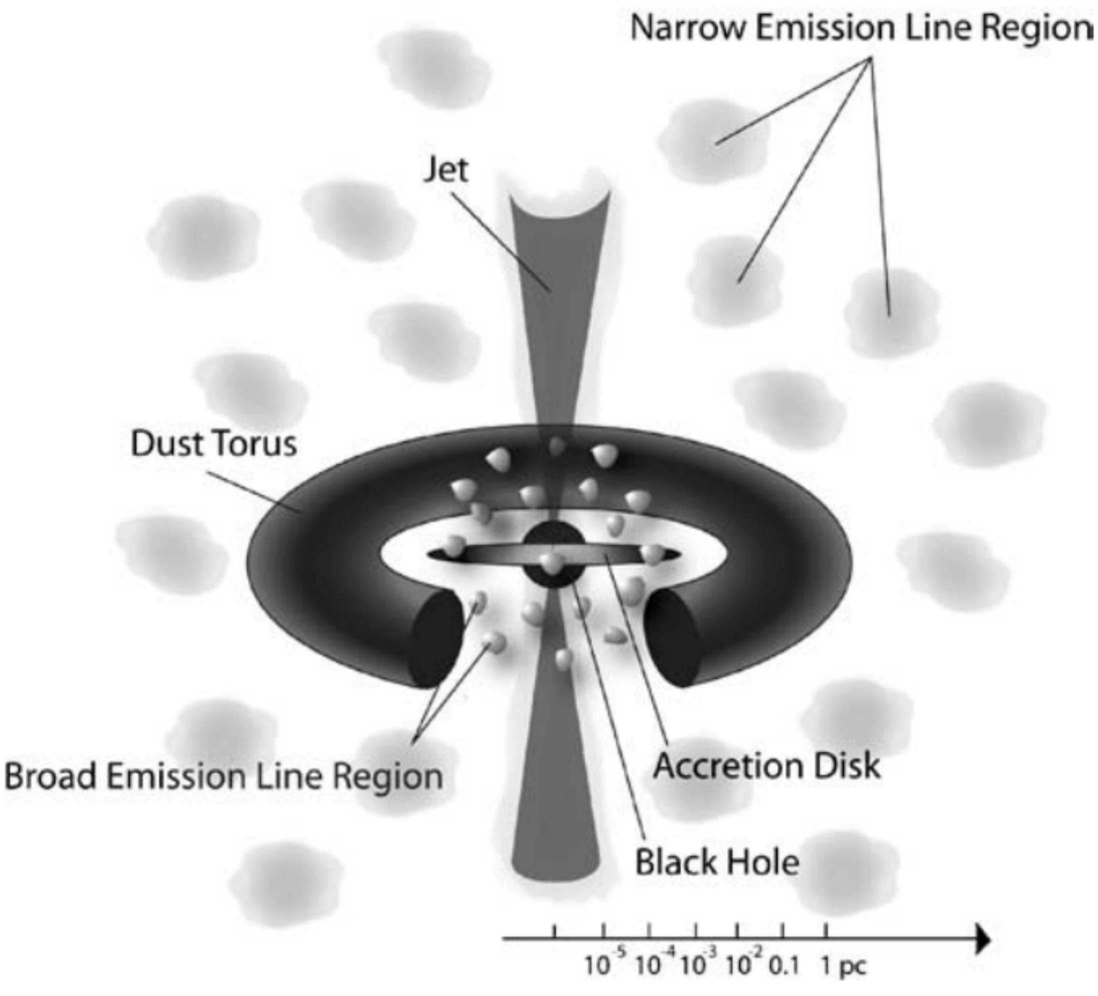
    Saturated luminosity? Scatters?

- Coevolution of BH and host
- For cosmology

The Lijiang 2.4m telescope: YFOSC since 2012

Yunnan Observatories, CAS

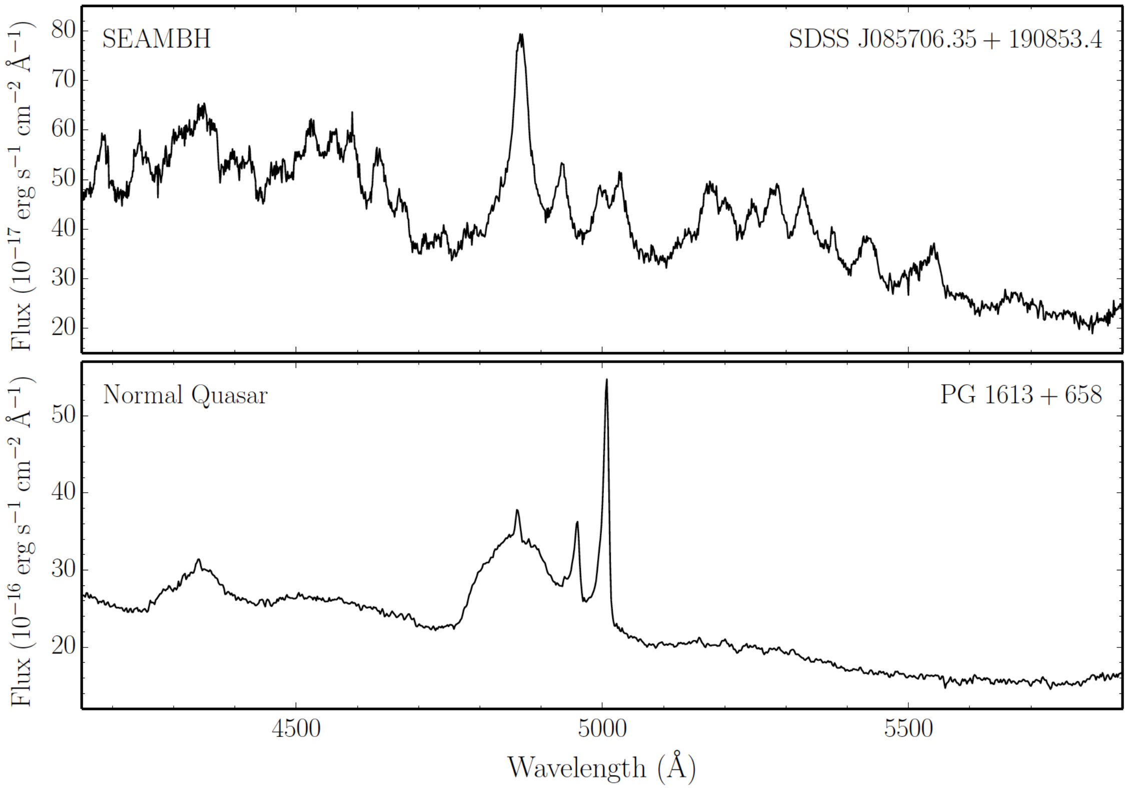
Reverberation mapping



Sample

- SEAMBH2012
- SEAMBH2013
- SEAMBH2014
- SEAMBH2015

total： 35 SEAMBHs



Methods and software

available for public

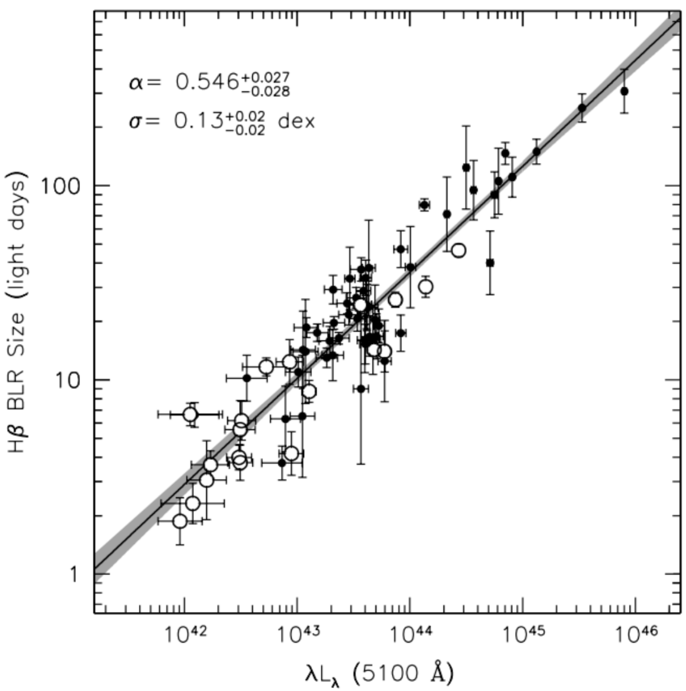
- Calibration method: fitting scheme
- Profile deconvolution: velocity-resolved map
- MICA: sub-structures of the BLR
- RM-mass: Markov Chain Monte-Carlo

  (MCMC technique)

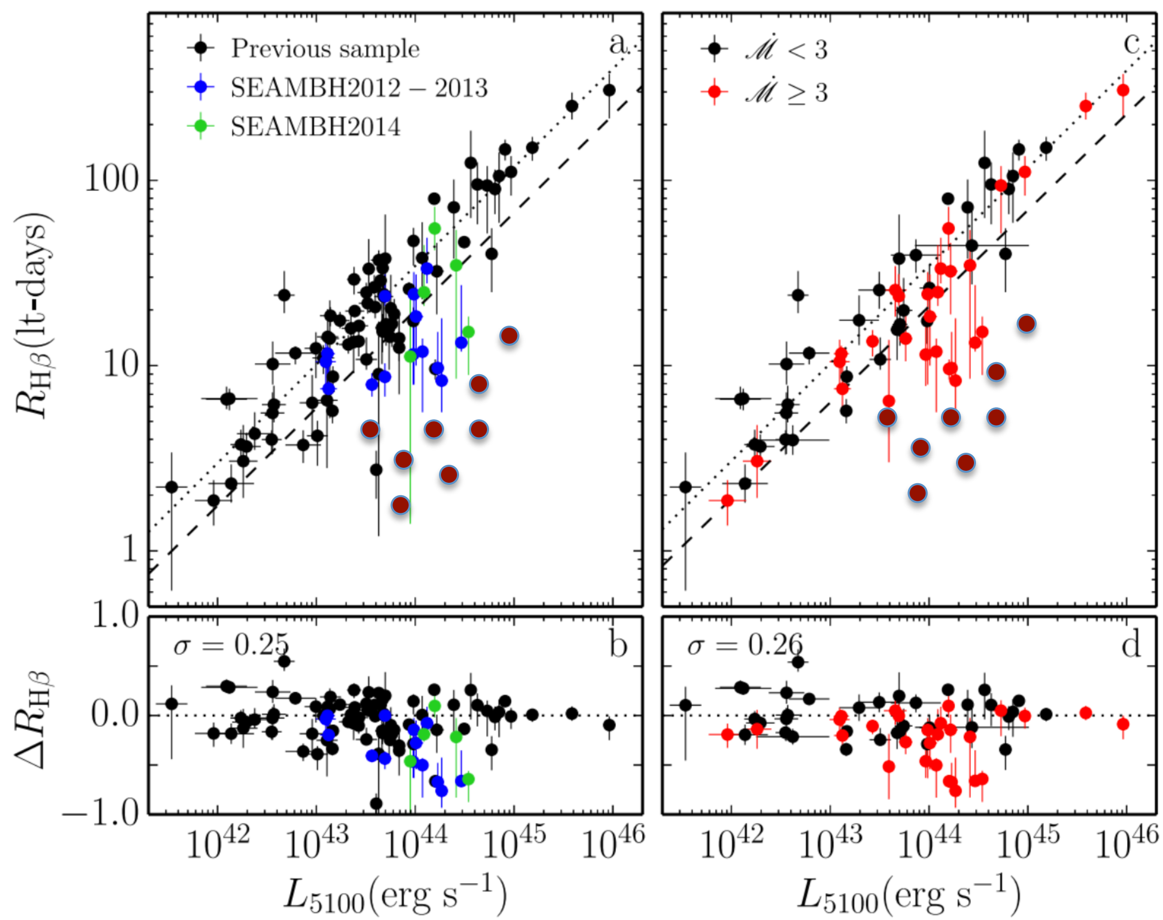
Current Results

SEAMBHs： *R*-*L* relation

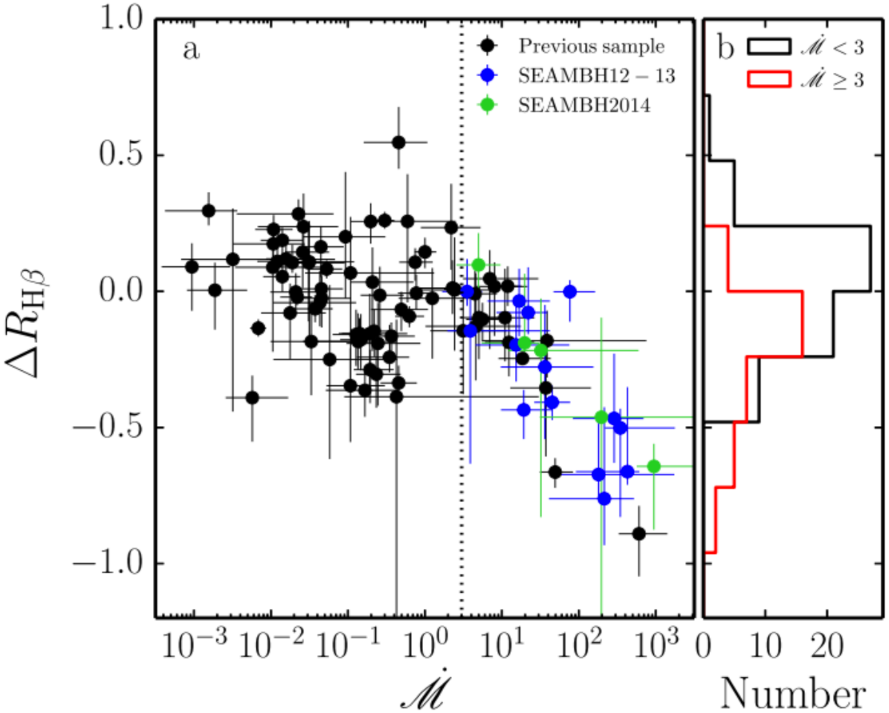
- Broken！ (Du et al. 2015; 2016a; 2017)

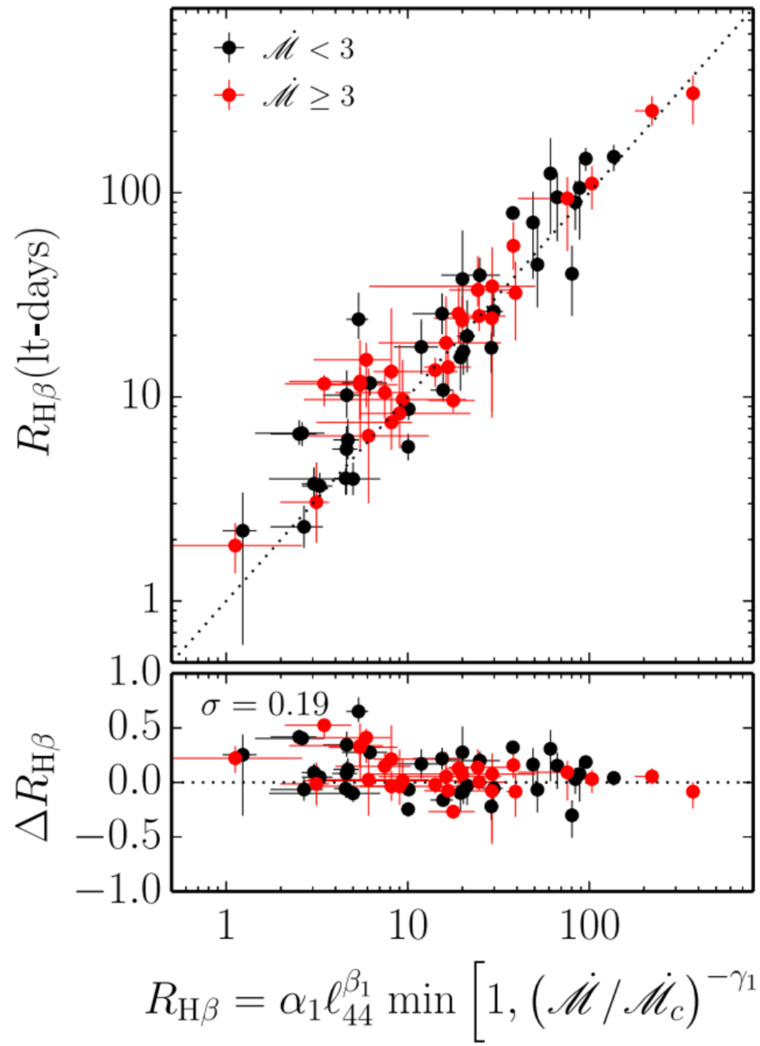


Kaspi et al. (2000)
Bentz et al. (2013)



New scaling relation: two-parameters





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

Observed Hβ lags:

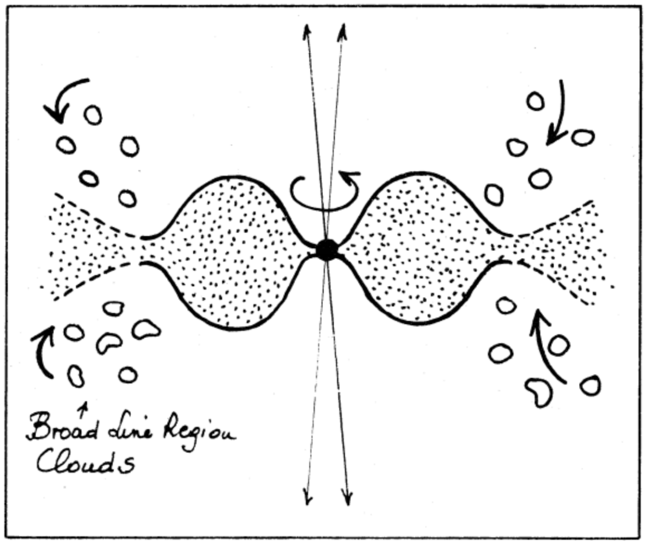
Physical meanings?

BLR: structure? R-L relation?

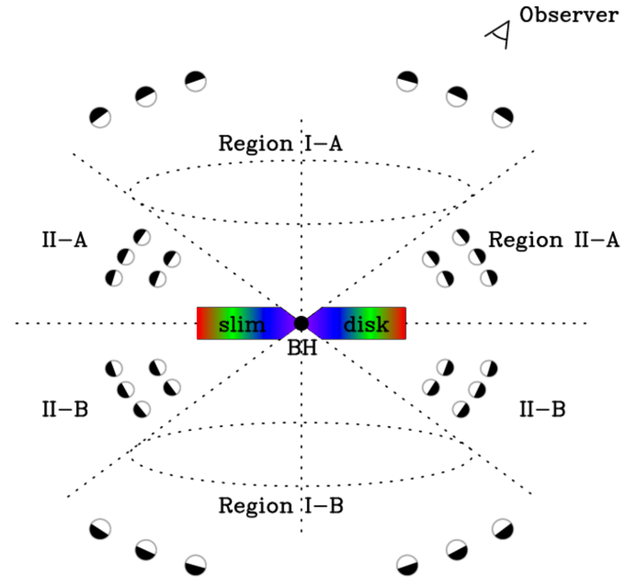
BH Virial-mass: accuracy?

are to be answered

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



Alloin (1990)



(Wang et al. 2014)

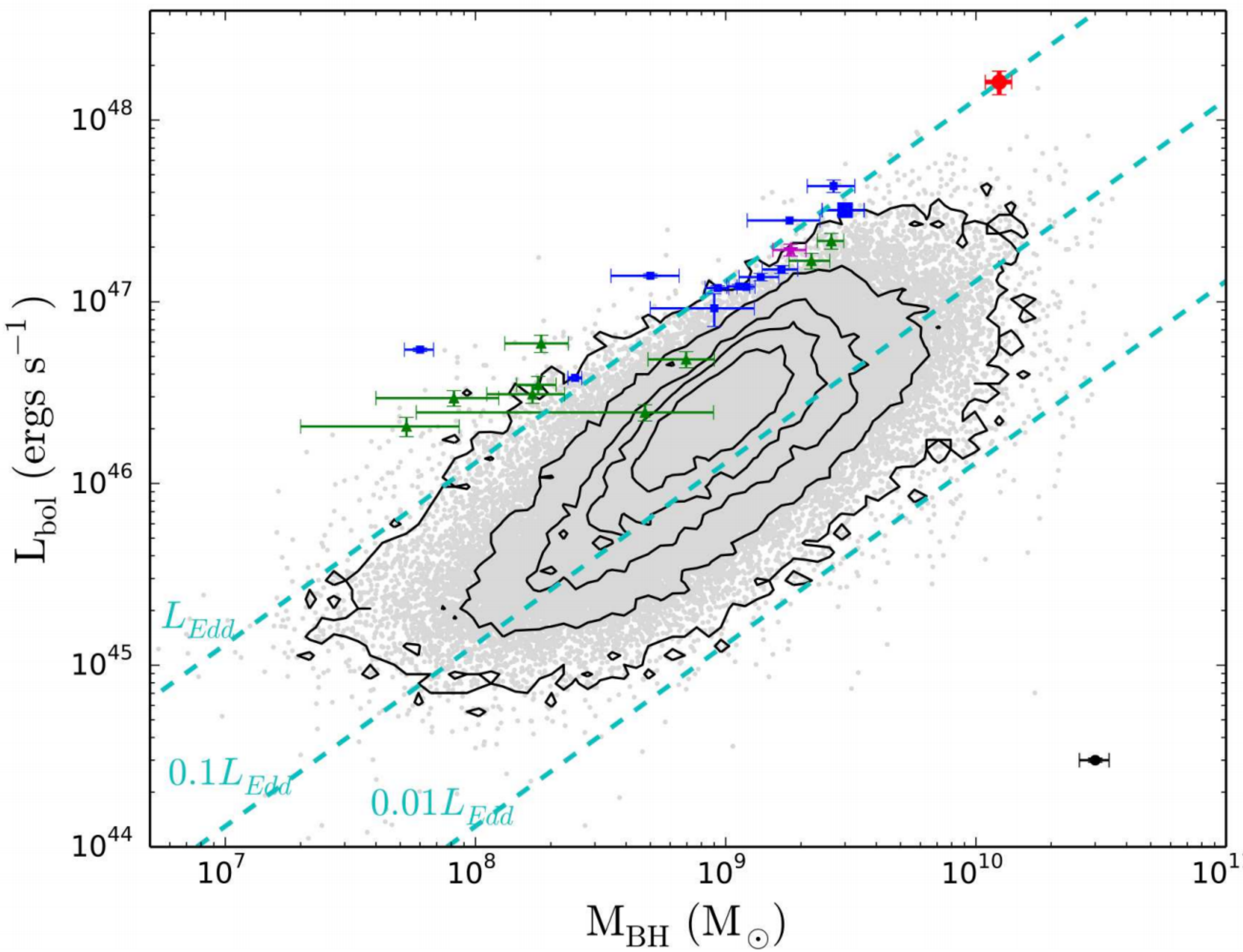
Shadowed BLR: shrinks and shorter lags

longer lags? (longer campaign to monitor)

Consequence: weak line quasars

SMBH formation: ultrafast growth

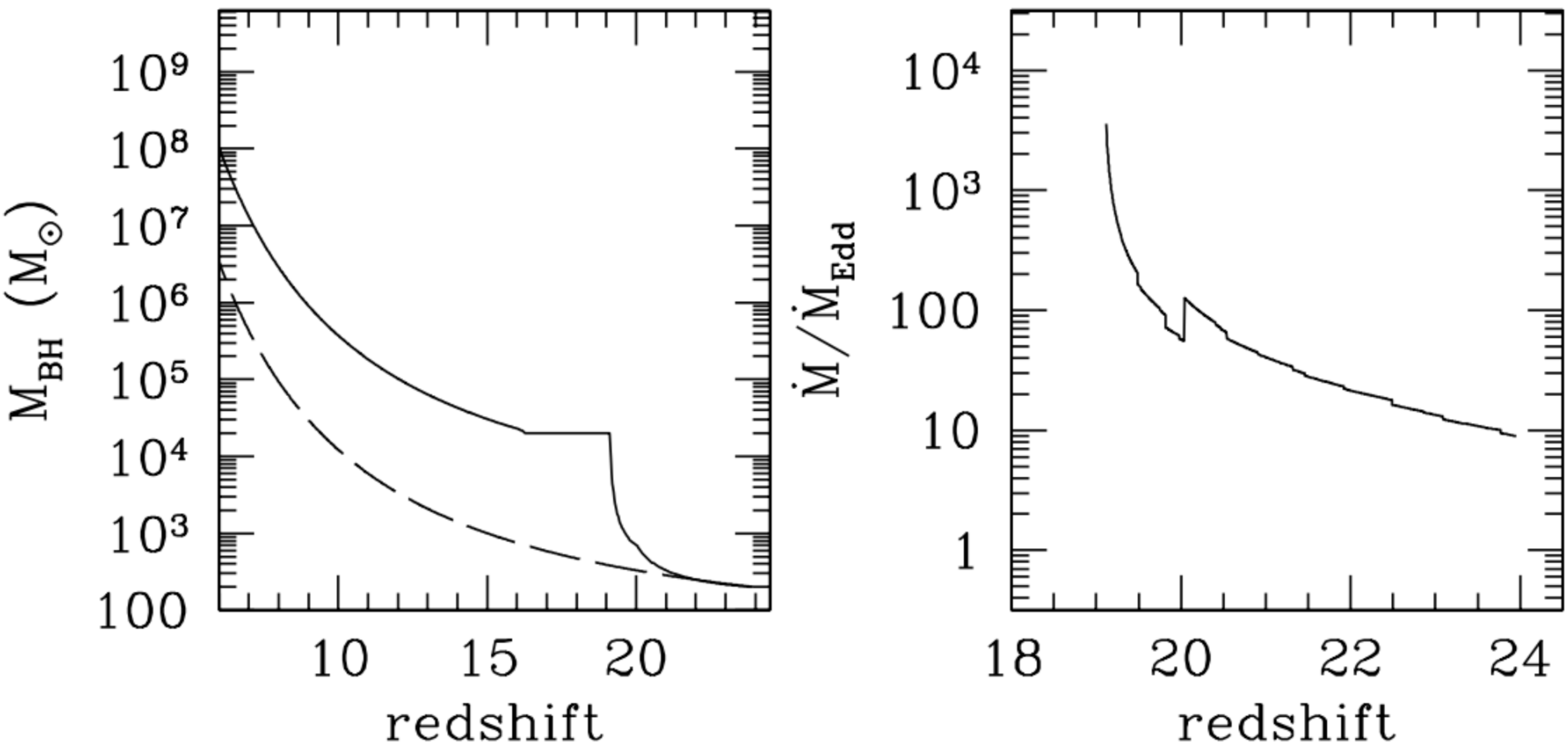
$$z > 6.0 : \qquad M_\bullet = 10^9 - 10^{10} M_\odot$$



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

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?

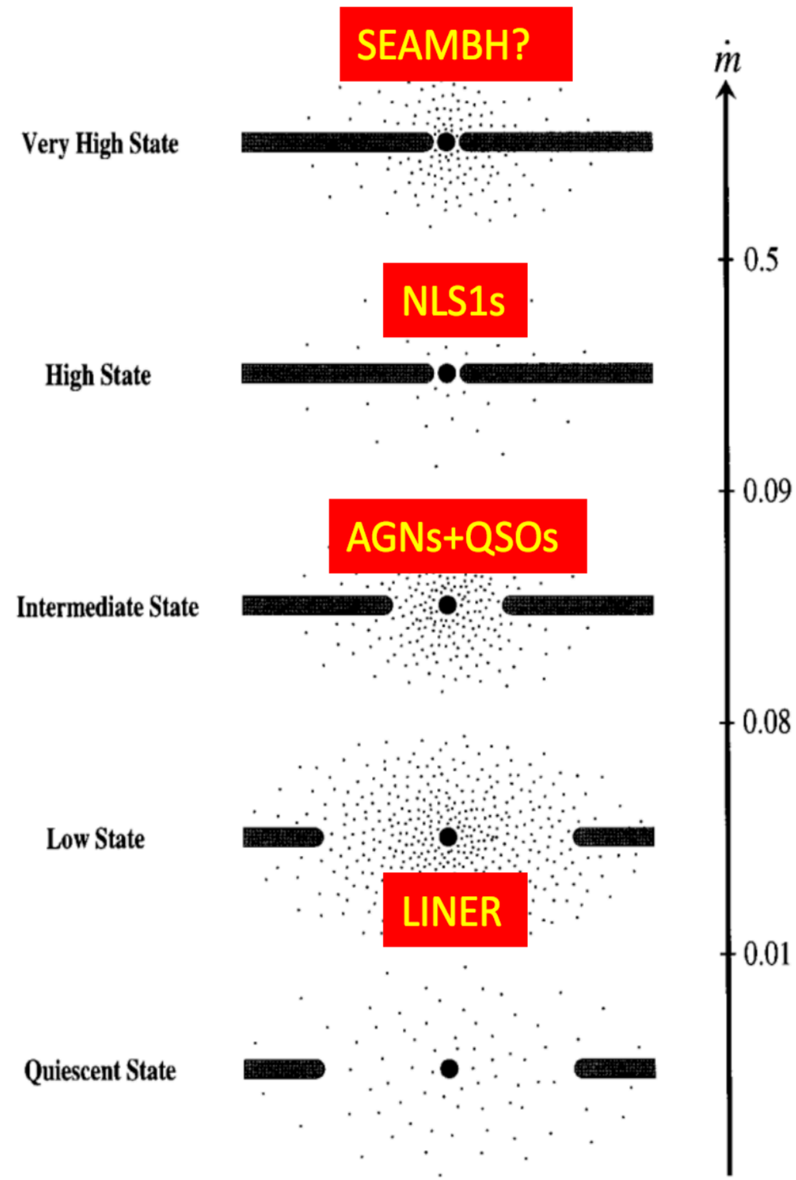
Accretion Physics

Low accretion disks
(ADAF; ADIOs)

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

Shakura-Sunyaev disks
(intermediate rates)

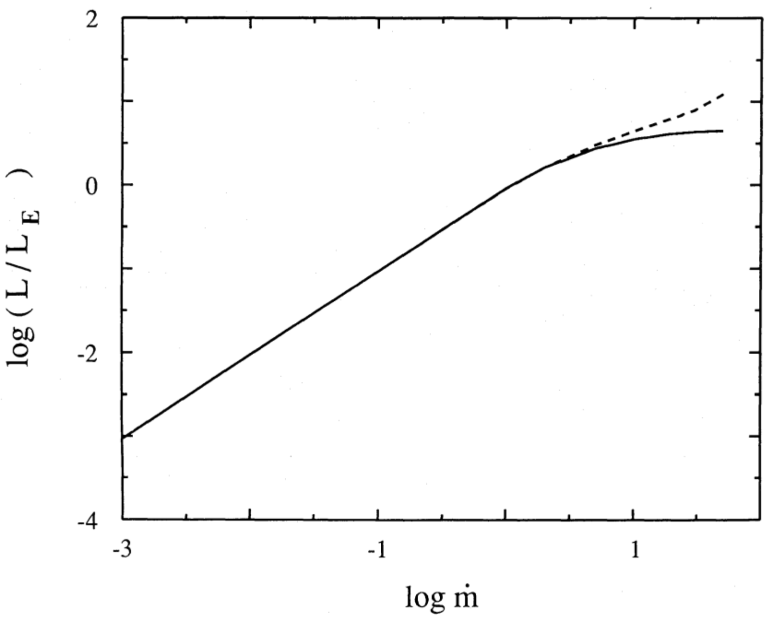
$$L_{\rm rad} \propto \dot{M}$$

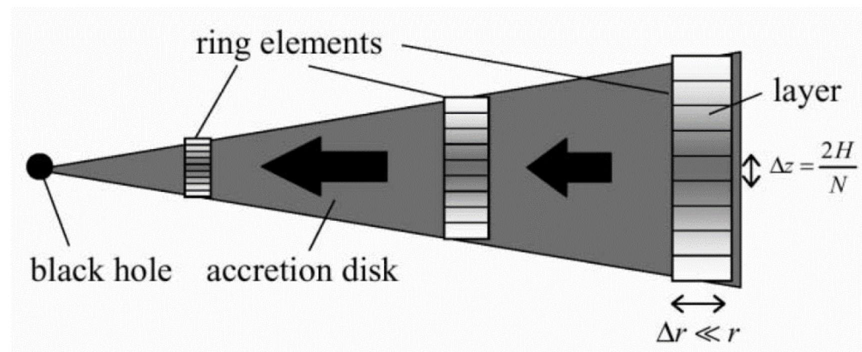


THE ASTROPHYSICAL JOURNAL, 332:646–658, 1988 September 15

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

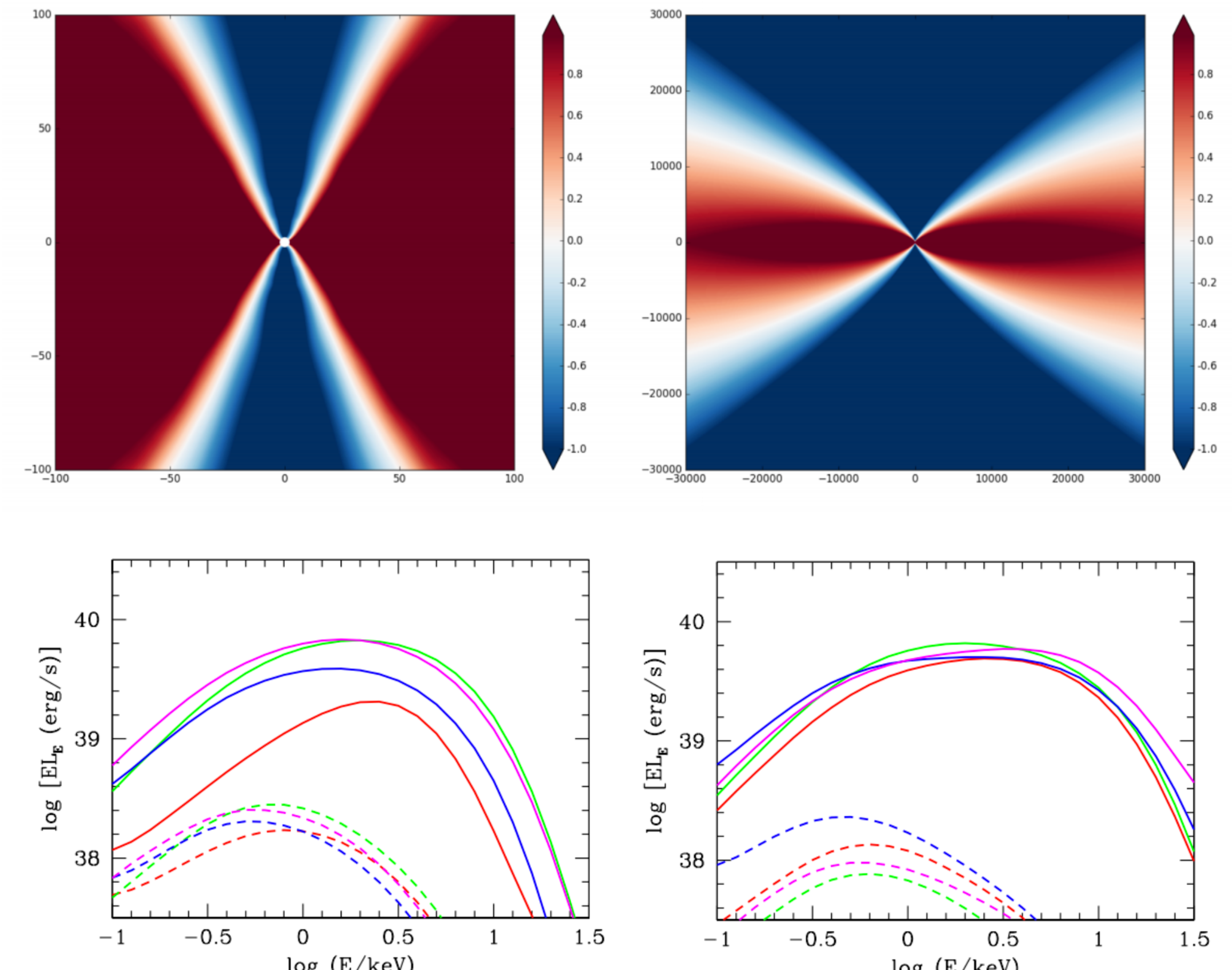
SUPER-EDDINGTON FLUXES FROM THIN ACCRETION DISKS?

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

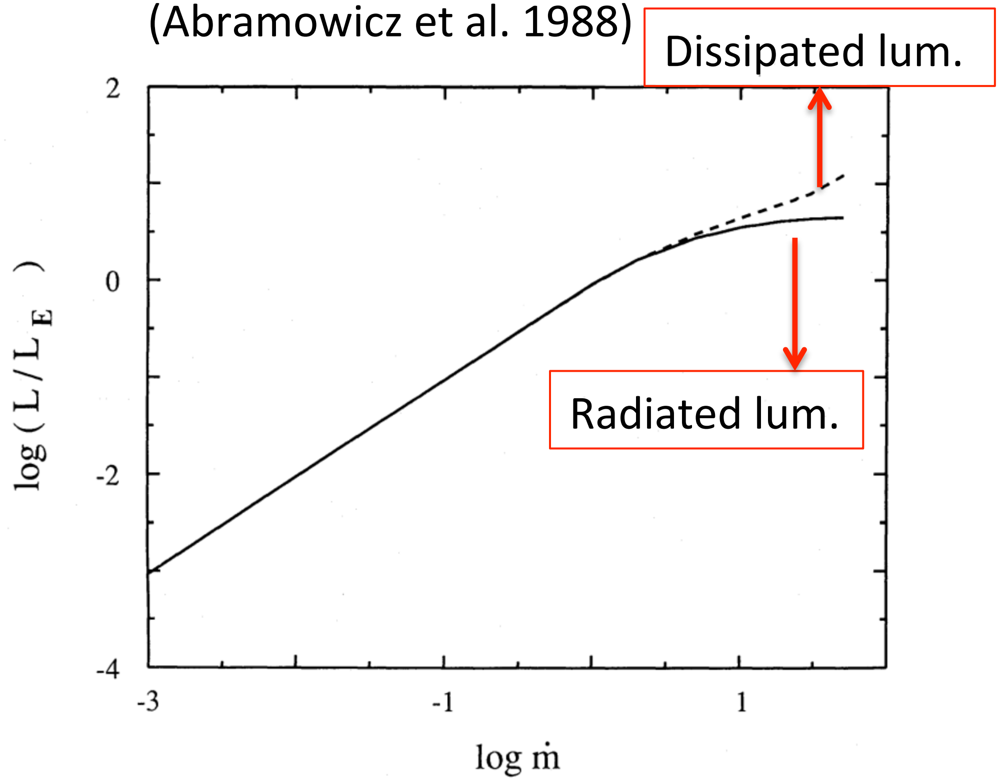
Narayan, Sadowski & Sori (2017)



Evidence for saturated luminosity

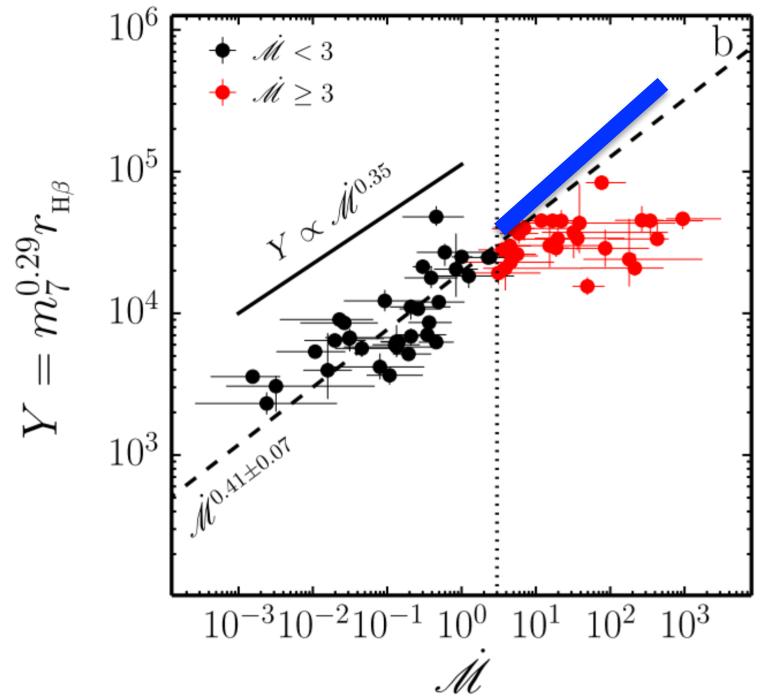
Slim accretion disks

(Abramowicz et al. 1988)



SEAMBH collaboration

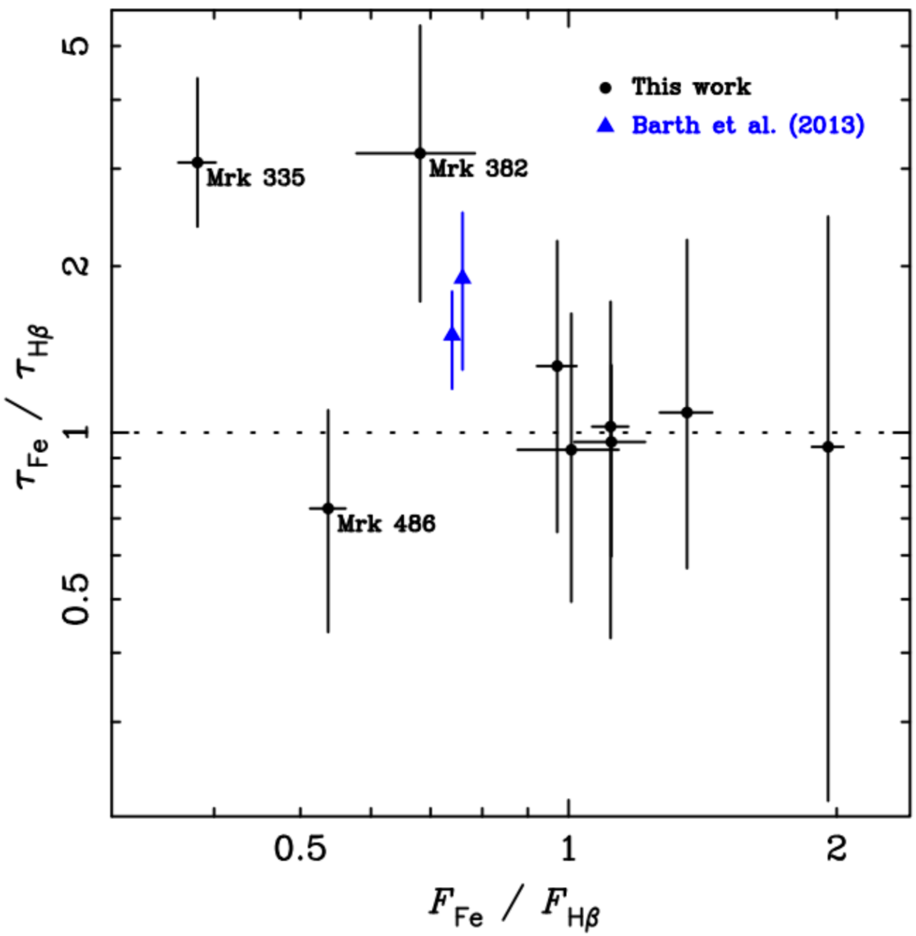
(Du et al. 2016a)

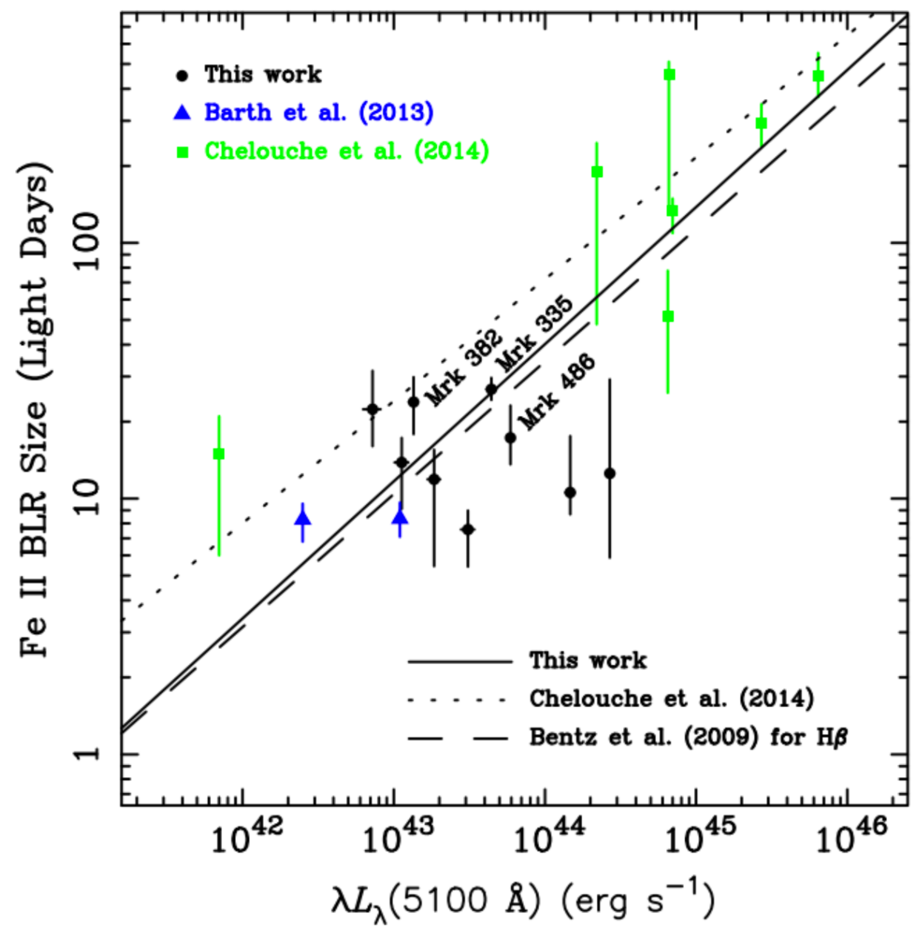


Photon trapping effects: $L_{\bullet} = \ell_0(1 + a\ln\dot{m}_{15})M_{\bullet}$ (theory)

Saturated luminosity --> cosmological candles (Obs.)

Fe II-RM (Hu+2015)





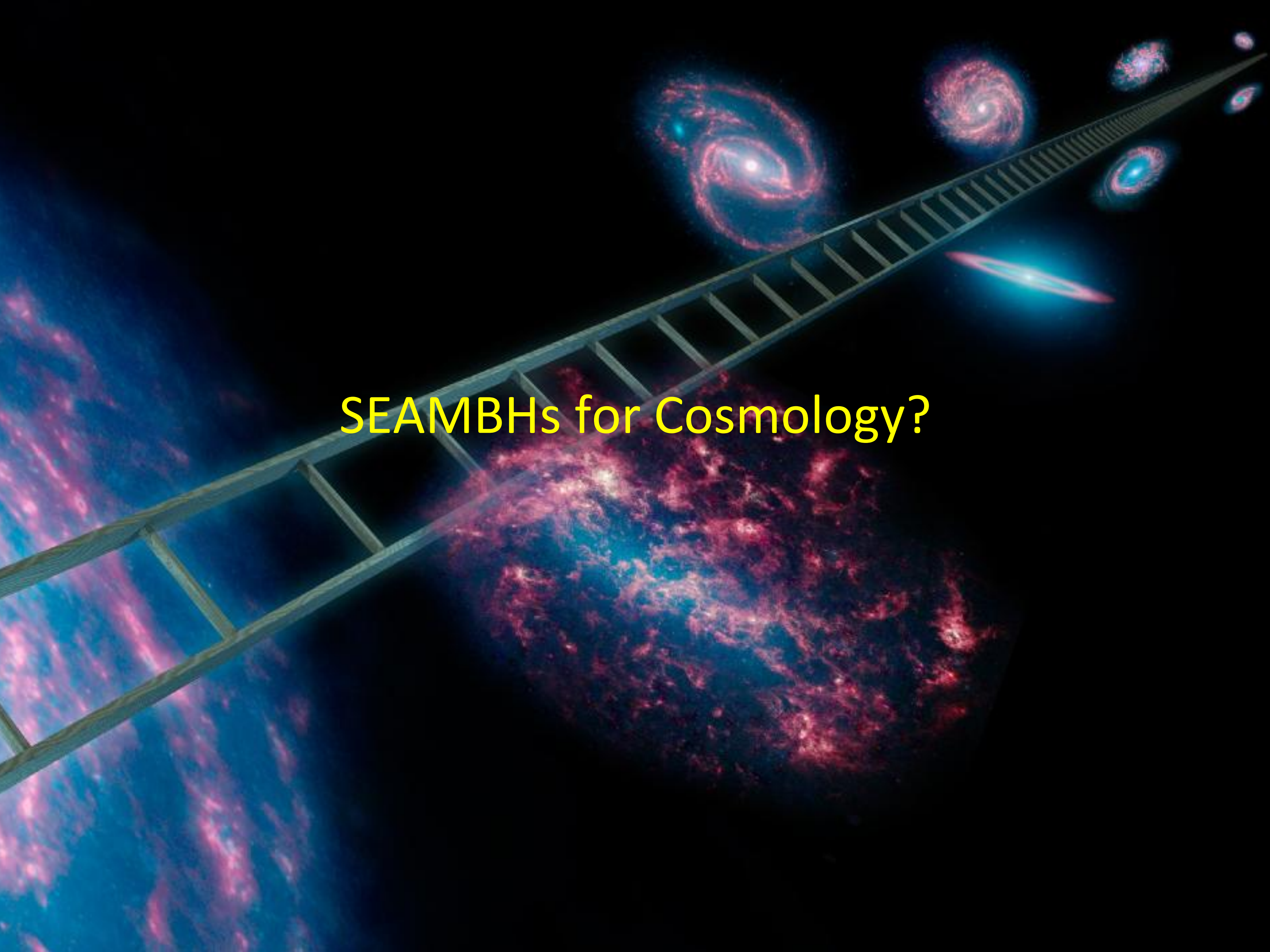
Super-Eddington Accretion Physics:

1) geometrically slim: lags shortened

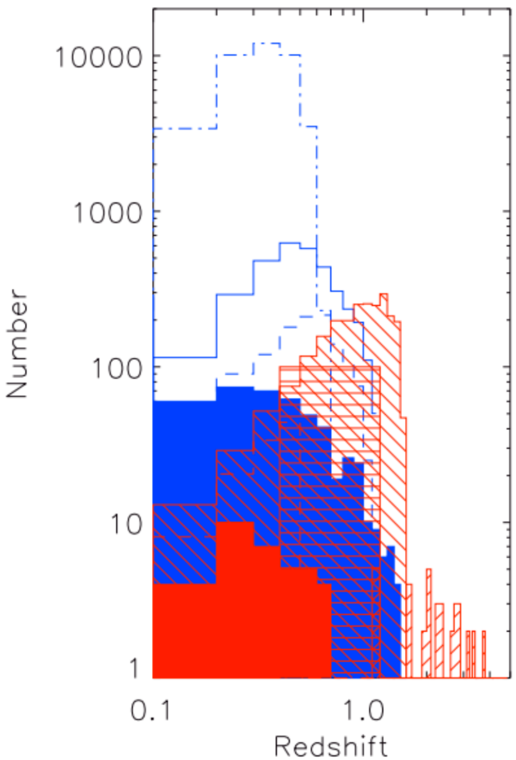
2) photon trapping: saturated luminosity

3) a new scaling relation established for BLR

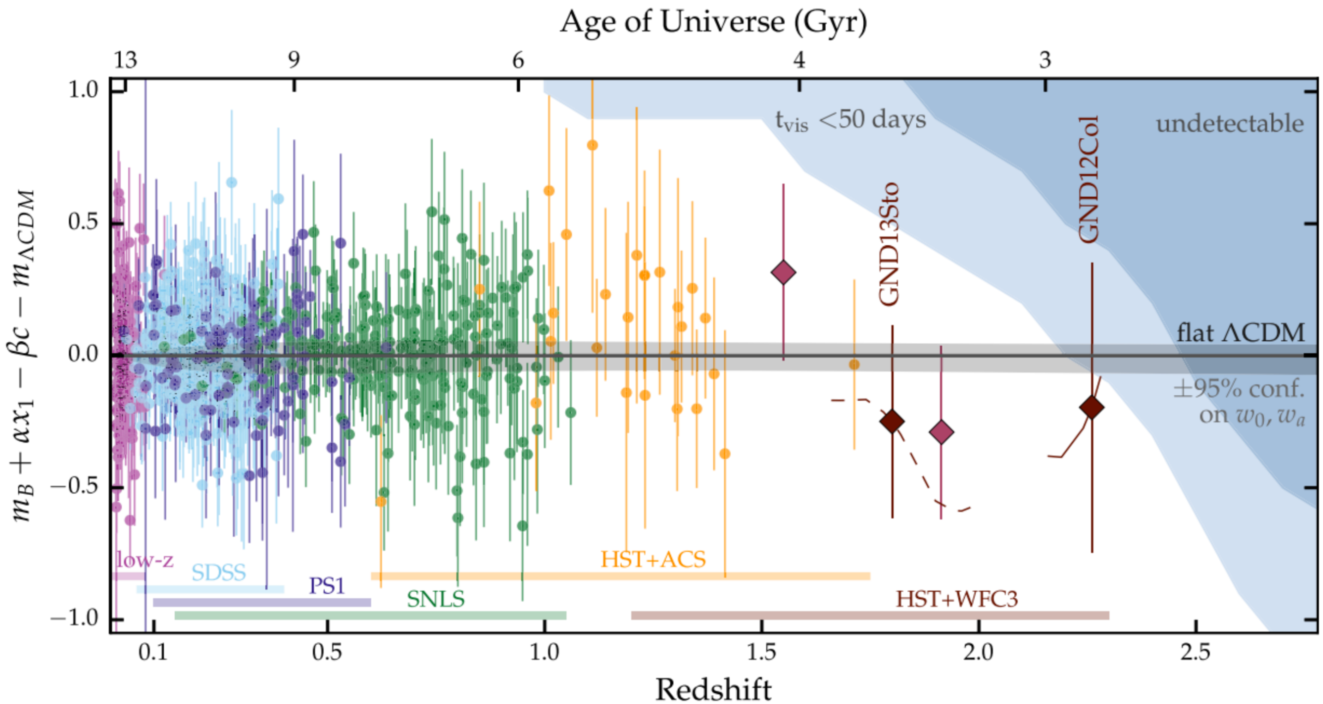
SEAMBHs for Cosmology?



SNIa for cosmology: z<1.5



Hook (2013)



Rodney, Riess et al. (2015)

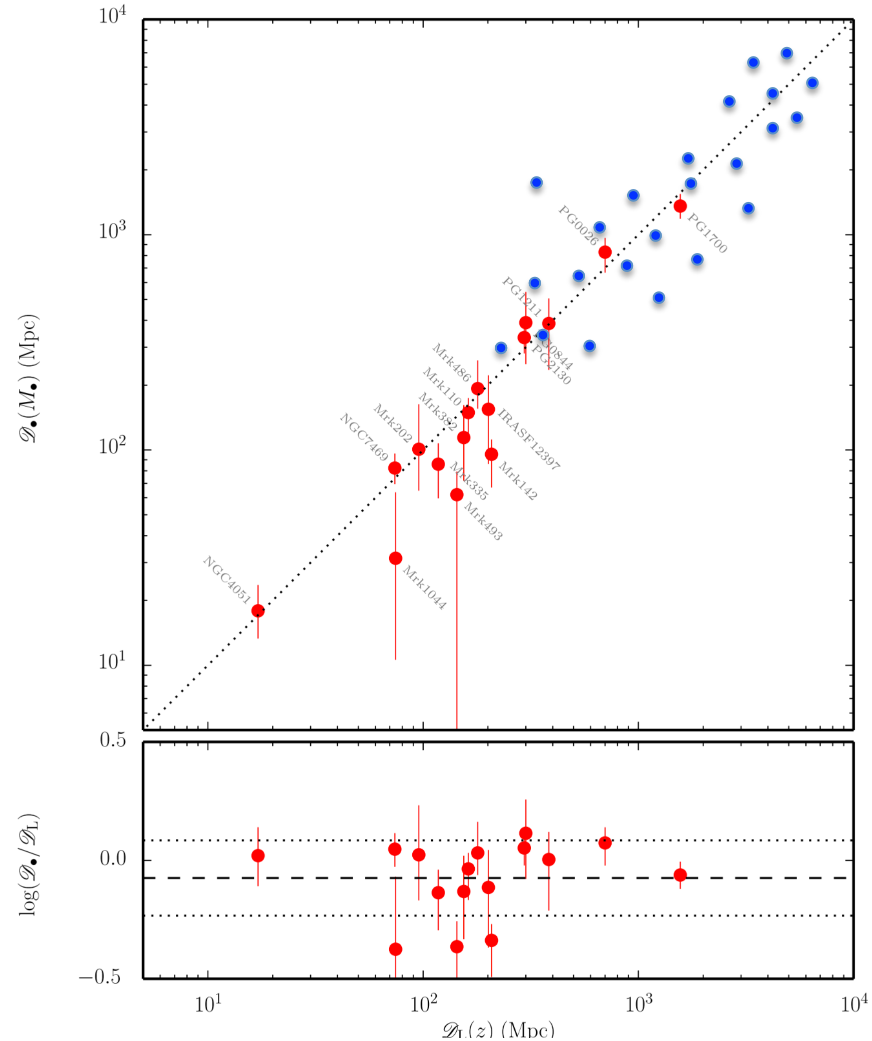
SEAMBH for cosmology

(Wang et al. 2013; 2014)

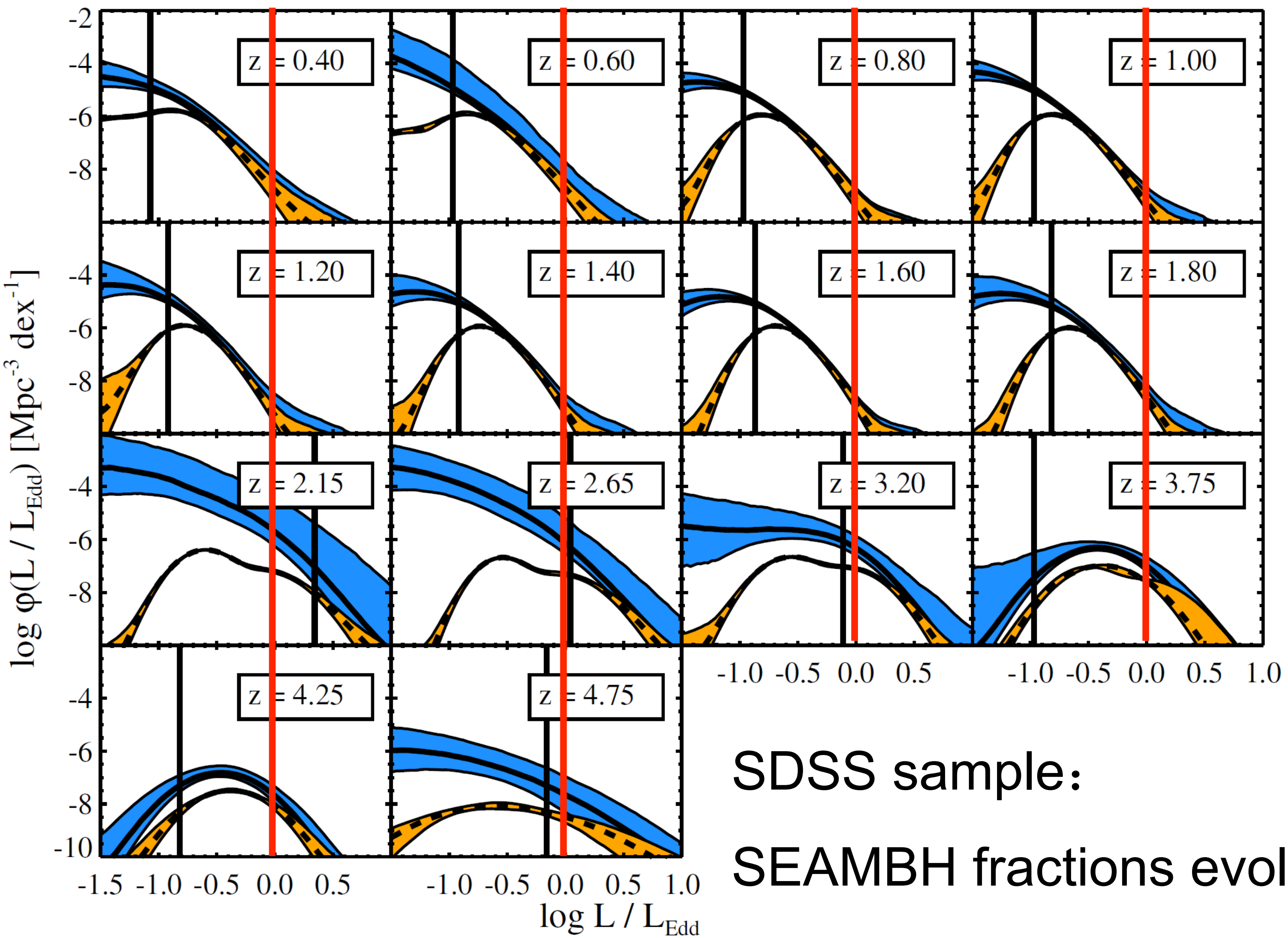
- Saturated luminosity: standard candles

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

Intrinsic scatter: 0.15 dex



Eddington ratio function (Kelly & Shen 2013)

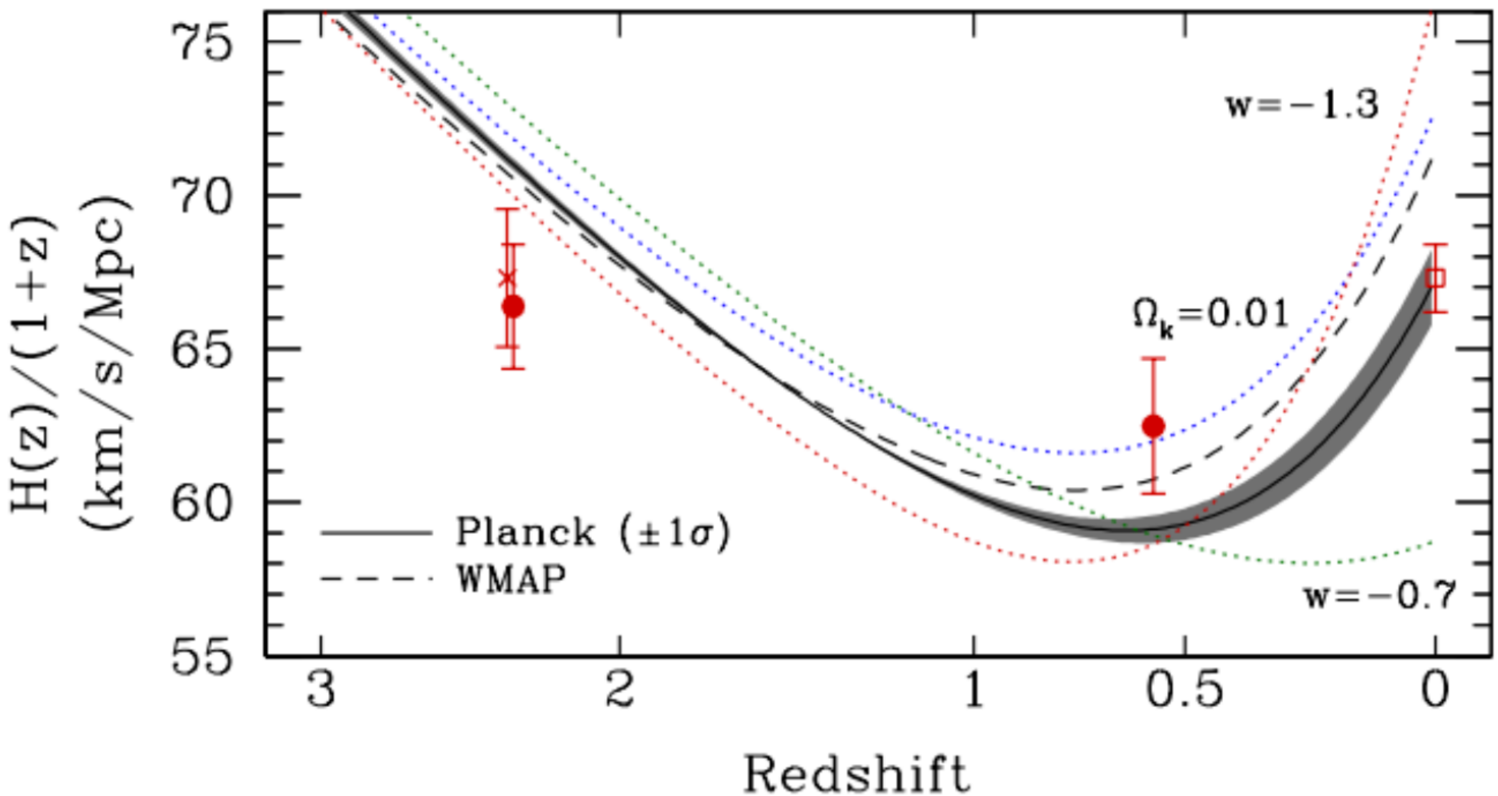


SDSS sample：

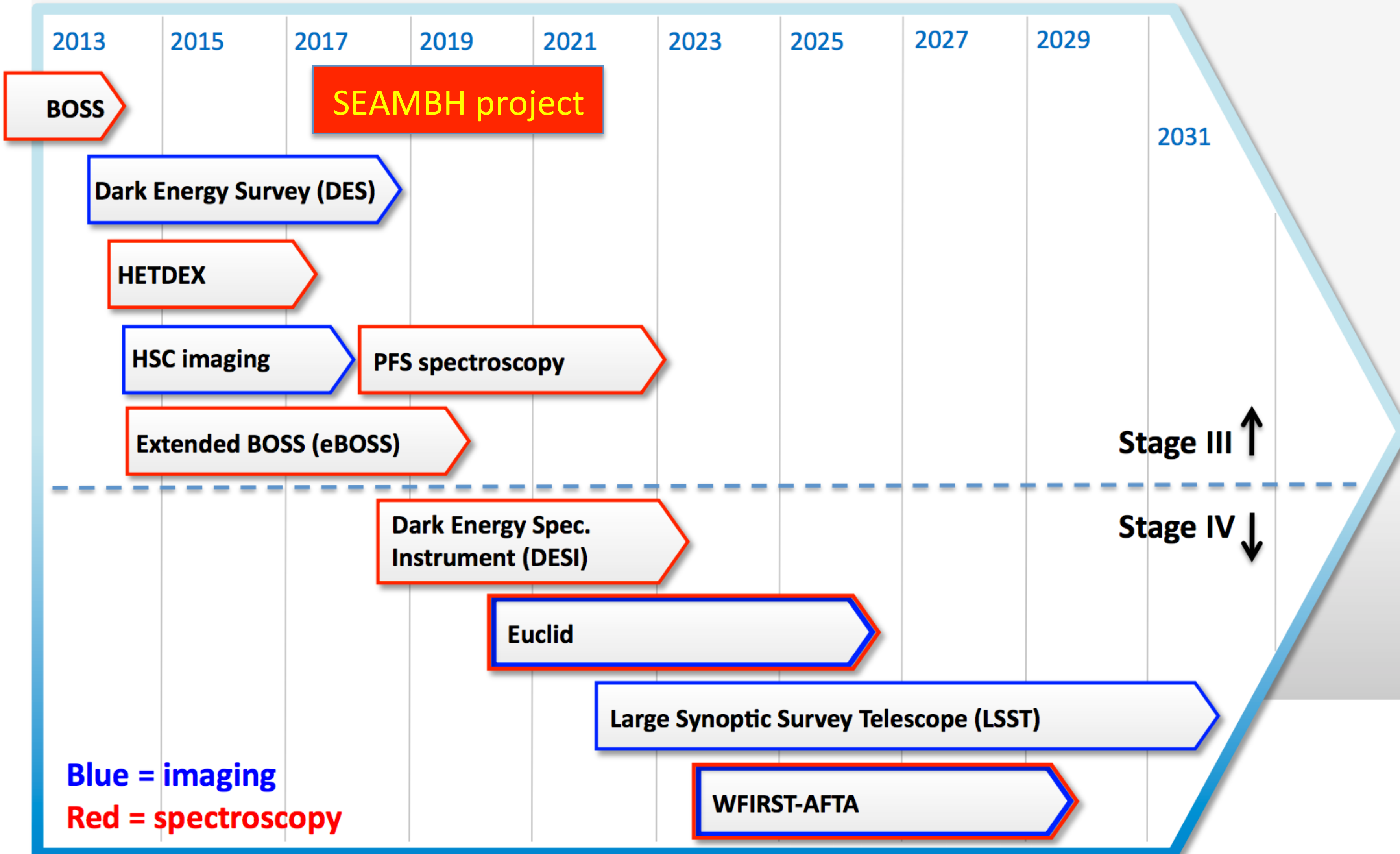
SEAMBH fractions evolve

Lyα Forest BAO measurement

(Aubourg et al. 2015)



Dark Energy Experiments: 2013 - 2031



Current observations

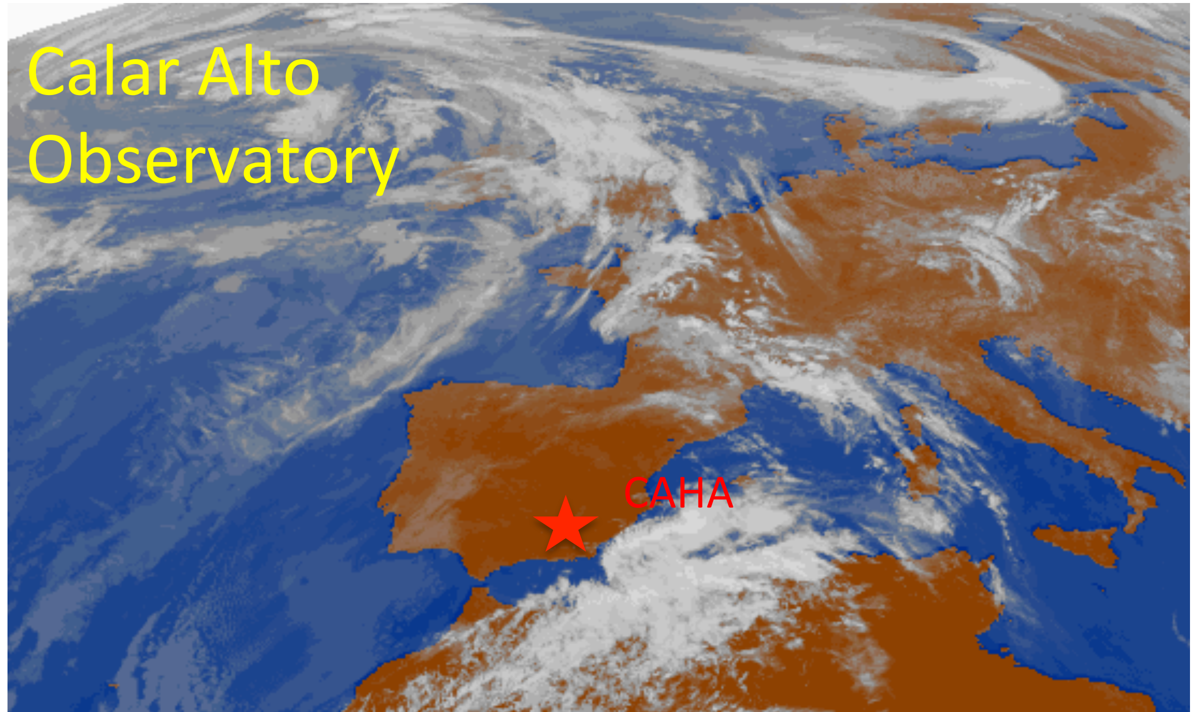
Wyoming U.: WIRO2.3m (2017-2021)

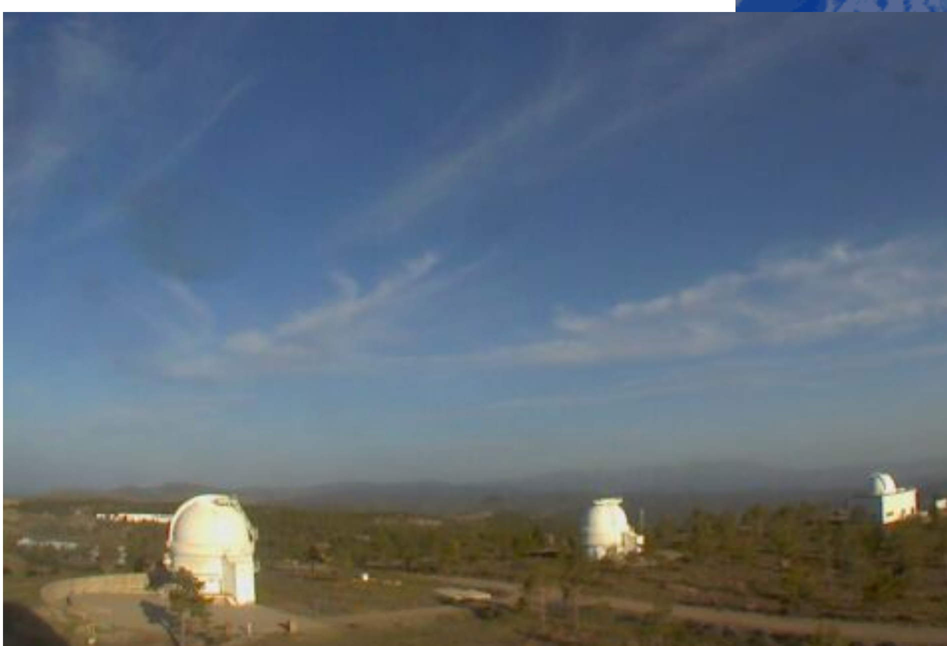
MAHA (Monitoring AGN with Hbeta Asymmetry)

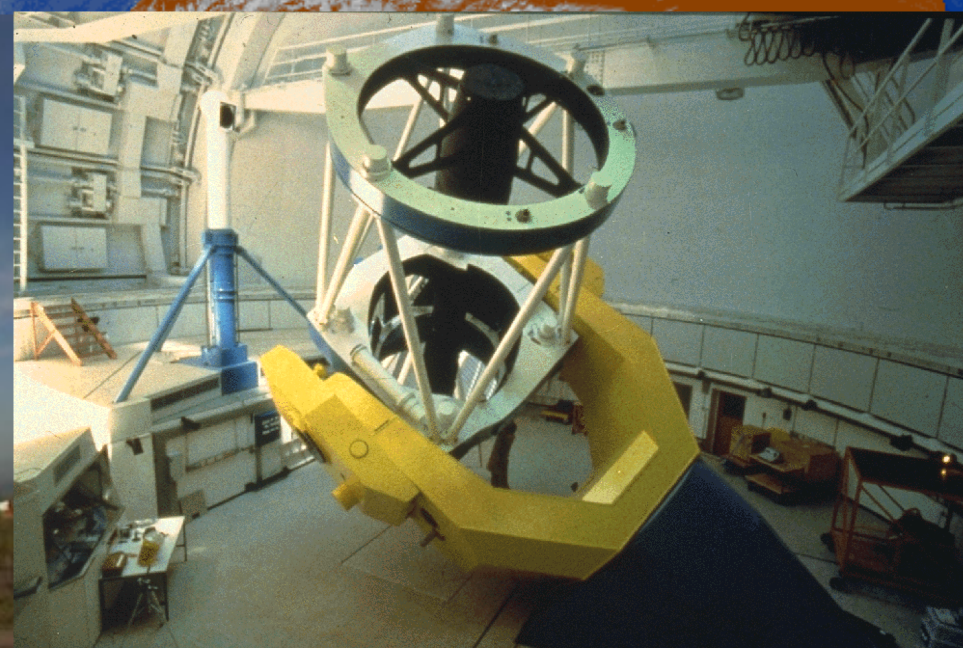
for BLR and SMBH binaries

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