SEAMBH Project: Overview

Super-Eddington Accreting Massive Black Holes

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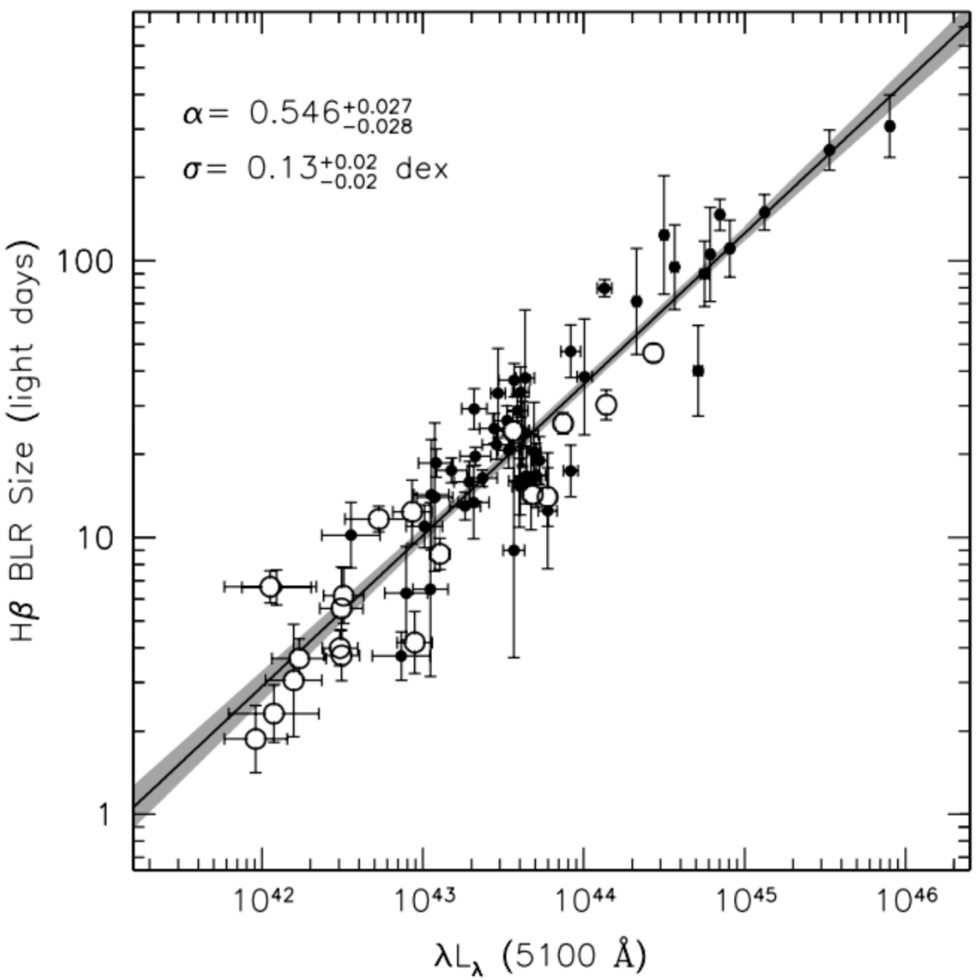
R-*L* relation

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



- BH mass
- Accretion rates?
- BH spins?
- Radiation pressure?

Outline

- Purpose of the project
- Major results
- Future 5-year Plan

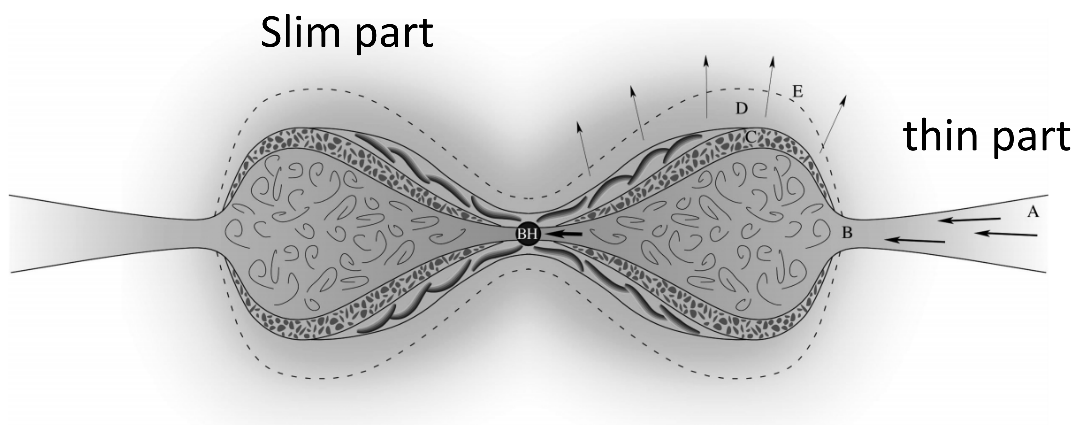
Target & Purpose

- $L/L_{\rm Edd} - \Gamma_{2-10{\rm keV}}$ correlation: $\Gamma_{2-10{\rm keV}}$
- Shakura-Sunyaev disk model

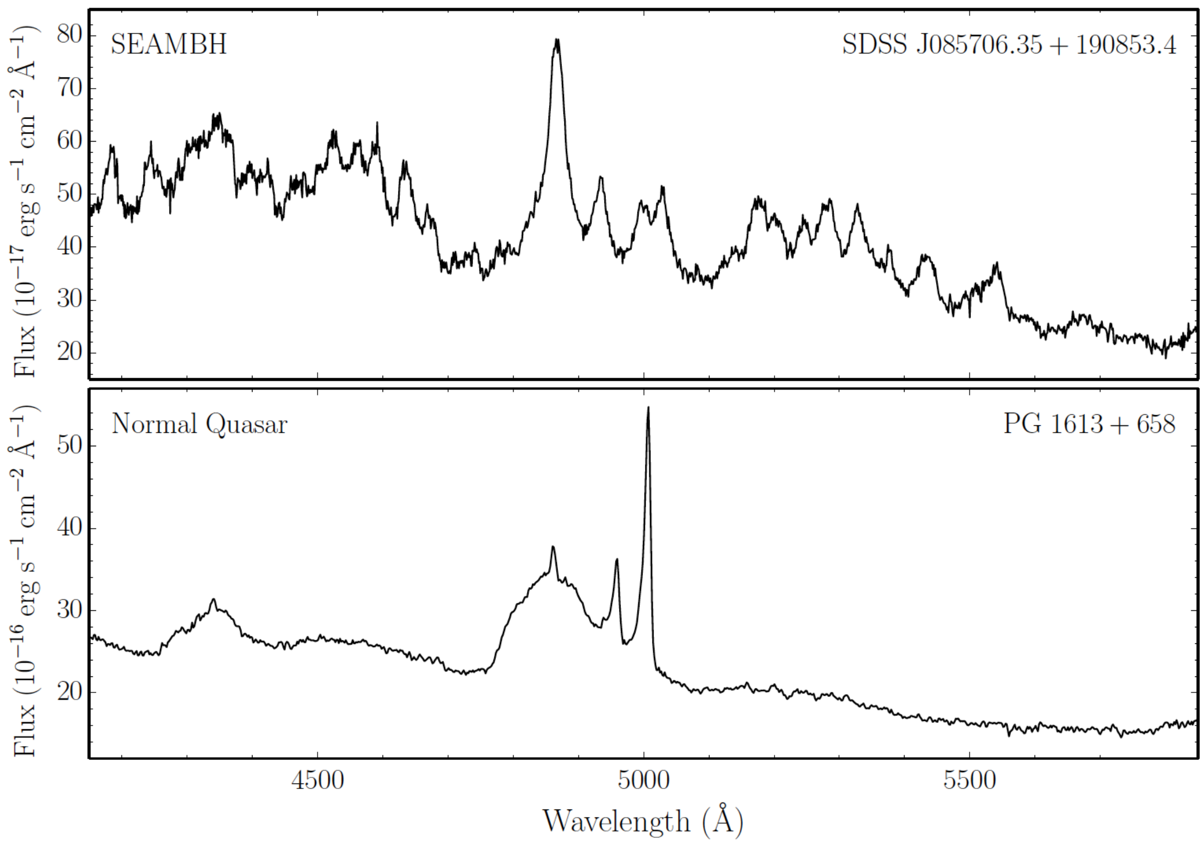
$$L_\nu = 1.58 \times 10^{28}\, \dot{m}_{\bullet,0.1}^{2/3} m_7^{2/3} \nu_{14}^{1/3} \cos i \int_{x_{\rm in}}^{\infty} \frac{x^{5/3}}{e^x - 1} dx \quad {\rm erg\ s^{-1}\, Hz^{-1}},$$

$$\dot{\mathscr{M}} = \dot{M}_\bullet / L_{\rm Edd}\, c^{-2}$$

$$\dot{\mathscr{M}} = 20.1 \left(\frac{\ell_{44}}{\cos i} \right)^{3/2} m_7^{-2}$$



SDSS quasars: targets< 17mag



- ~1/5 QSOs are SEAMBHs
- their densities increase with z

About 30 targets: 20 Lags (2012-2014)

- Accretion onto BH
- BLR physics
- Cosmology

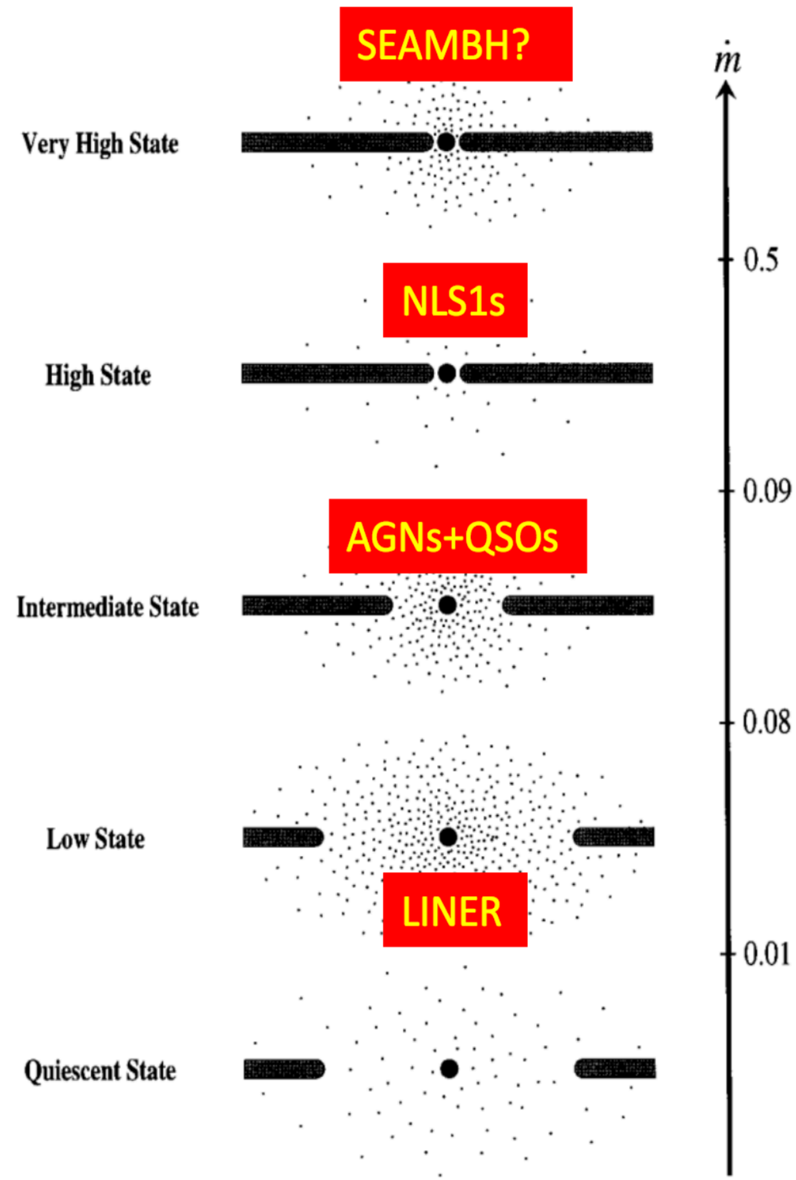
Accretion Physics

Low accretion disks
(ADAF; ADIOs)

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

Shakura-Sunyaev disks
(intermediate rates)

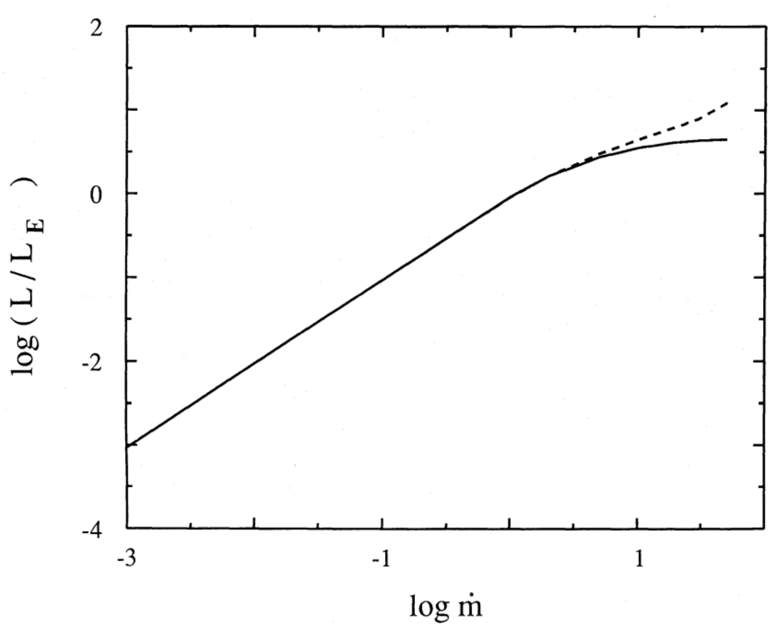
$$L_{\rm rad} \propto \dot{M}$$

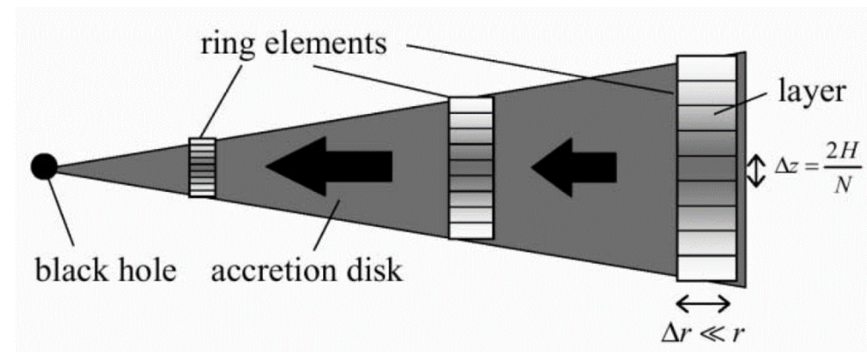


THE ASTROPHYSICAL JOURNAL, 332:646–658, 1988 September 15

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?

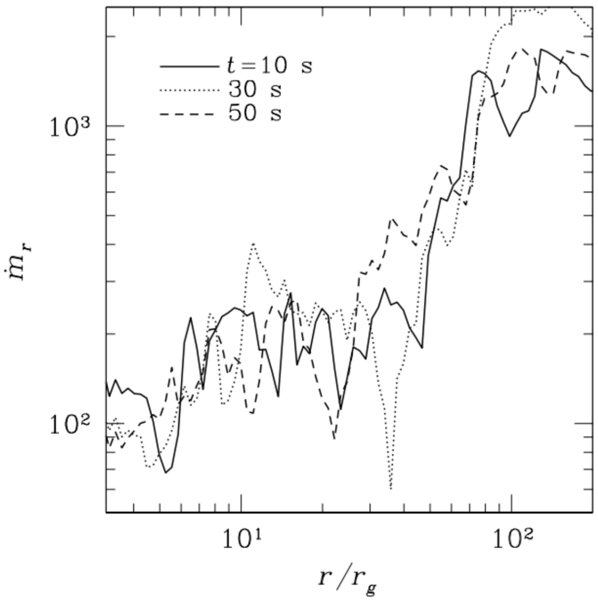
MITCHELL C. BEGELMAN[1]

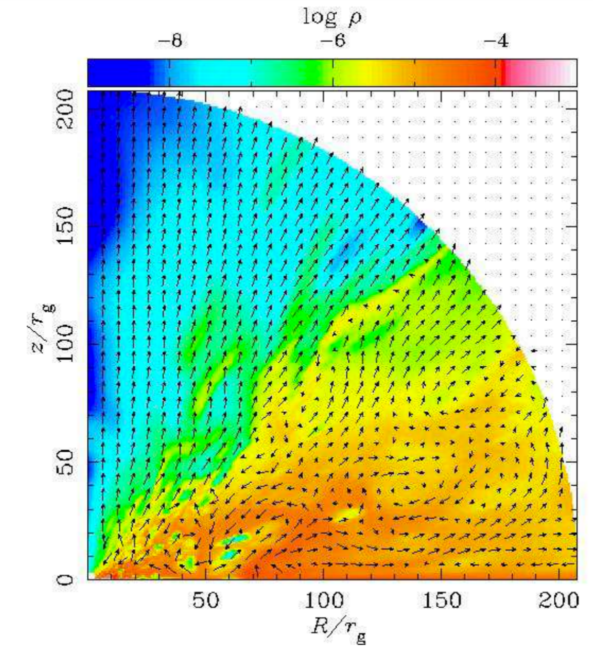
$$\frac{L_{\max}}{L_{\rm Edd}} > \epsilon \dot{m}_{\rm in,\,max} \sim 30 \xi_{-1}^{4/5} \alpha_{-2} \left(\frac{m}{10}\right)^{1/5} \frac{\epsilon}{0.1} \left(\frac{x_{\rm in}}{6}\right)^{1/2}$$

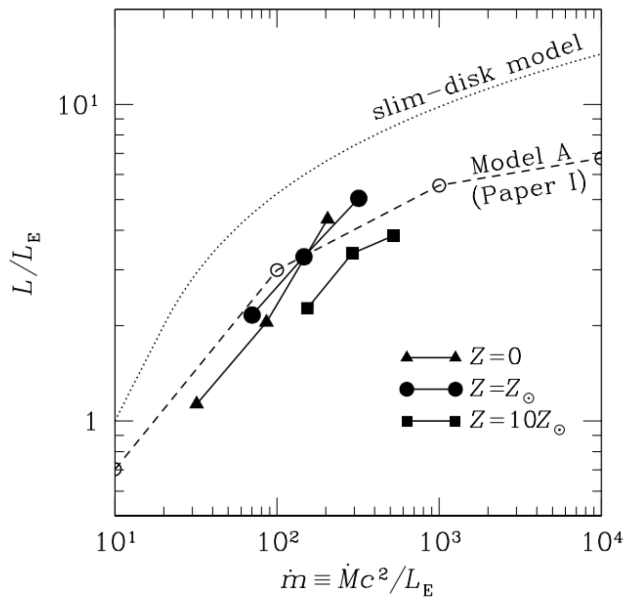
For $M_\bullet = 10^7 M_\odot$, $L/L_{\rm Edd} \approx 300$

Numerical simulations

- Kyoto Group (Ohsuga et al. 2005: 2D)







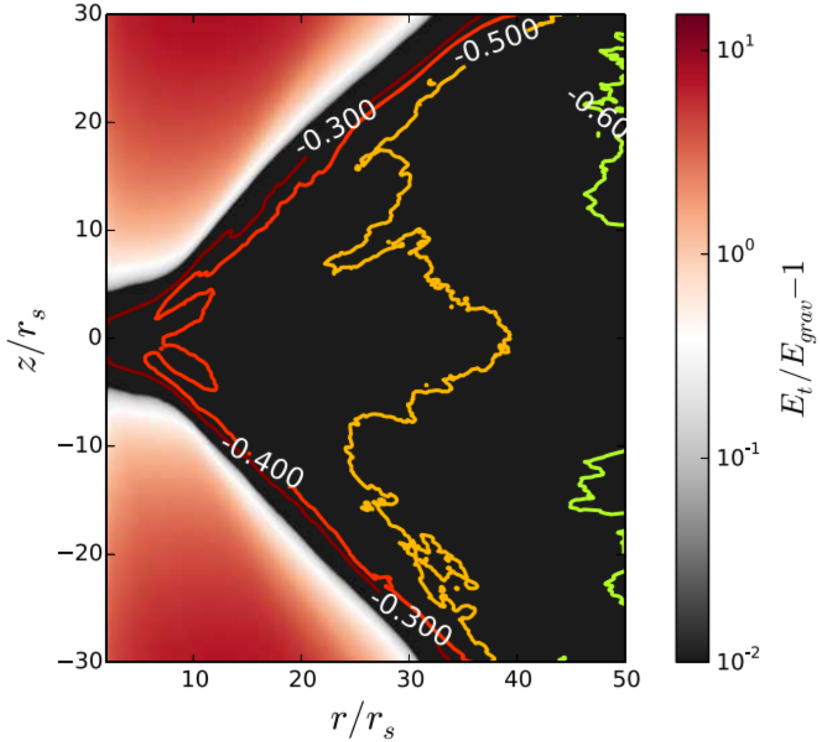
Outflows: >90% accretion rate

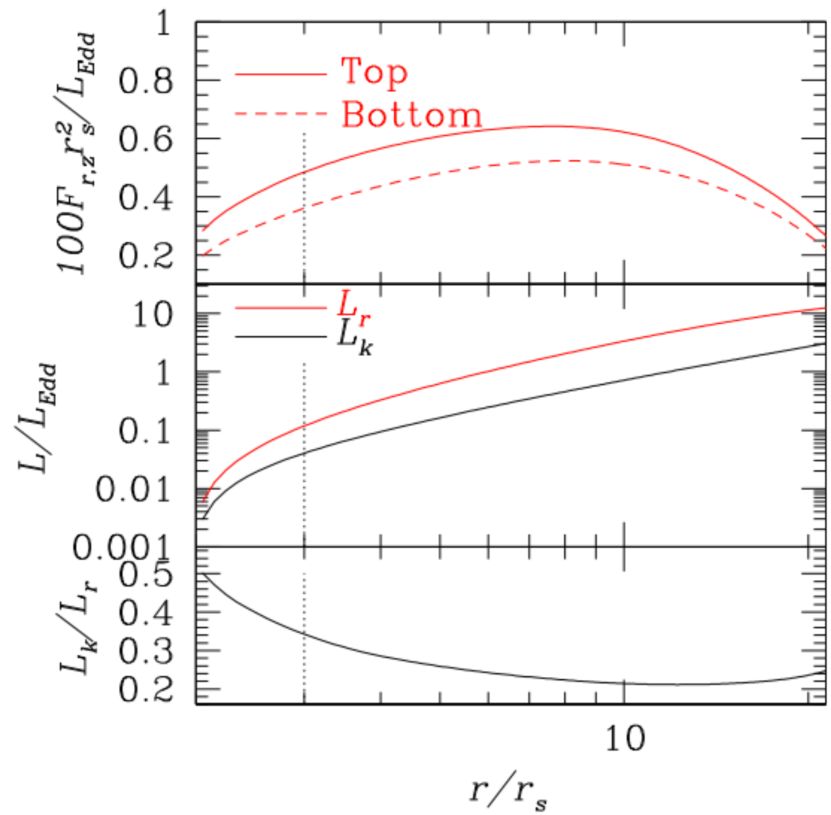
Geometry: slim H/R~1

Luminosity: a few $L_{\rm Edd}$

Princeton Group: 3D-MHD

(Jiang et al. 2014)





the outflow is about 29% of the net accretion rate.

Harvard Group: 3D GR

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MNRAS **453,** 3213–3221 (2015) doi:10.1093/mnras/stv1802

Powerful radiative jets in supercritical accretion discs around non-spinning black holes

Aleksander Sądowski[1★] and Ramesh Narayan[2]

ALL SEAMBH are radio-quiet!

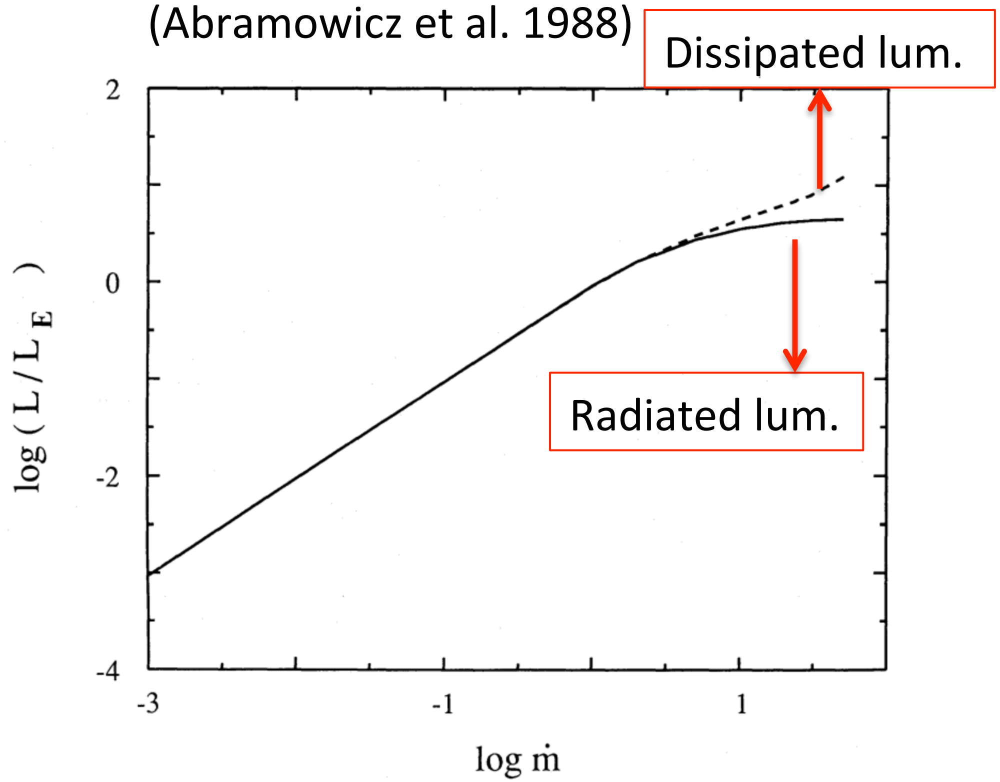
Different results

- Outflows: how strong?
- Saturated luminosity: radiative efficiency?
- Geometry?
- Jet formation?

Evidence for saturated luminosity

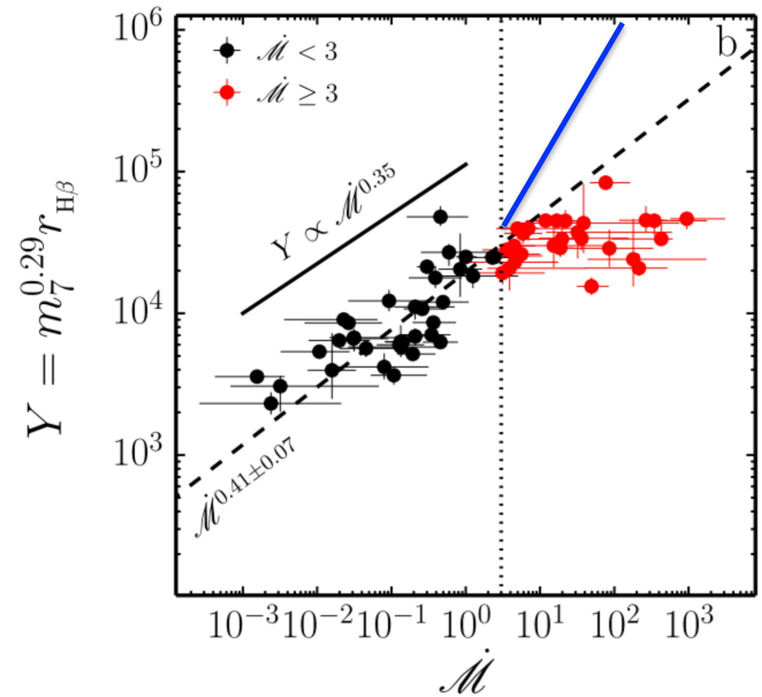
Slim accretion disks

(Abramowicz et al. 1988)



SEAMBH collaboration

(Du et al. 2016a)



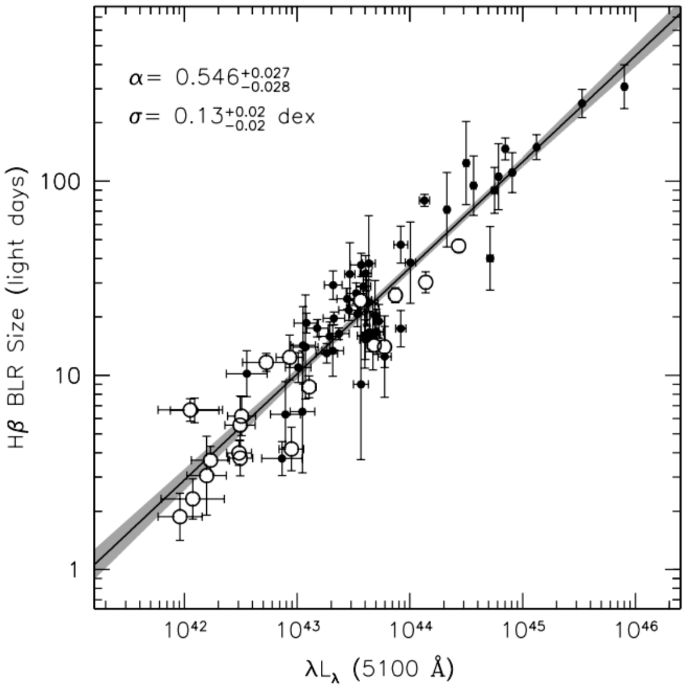
Photon trapping effects: $L_\bullet = \ell_0(1 + a\ln\dot{m}_{15})M_\bullet$ (theory)

Saturated luminosity --> cosmological candles (Obs.)

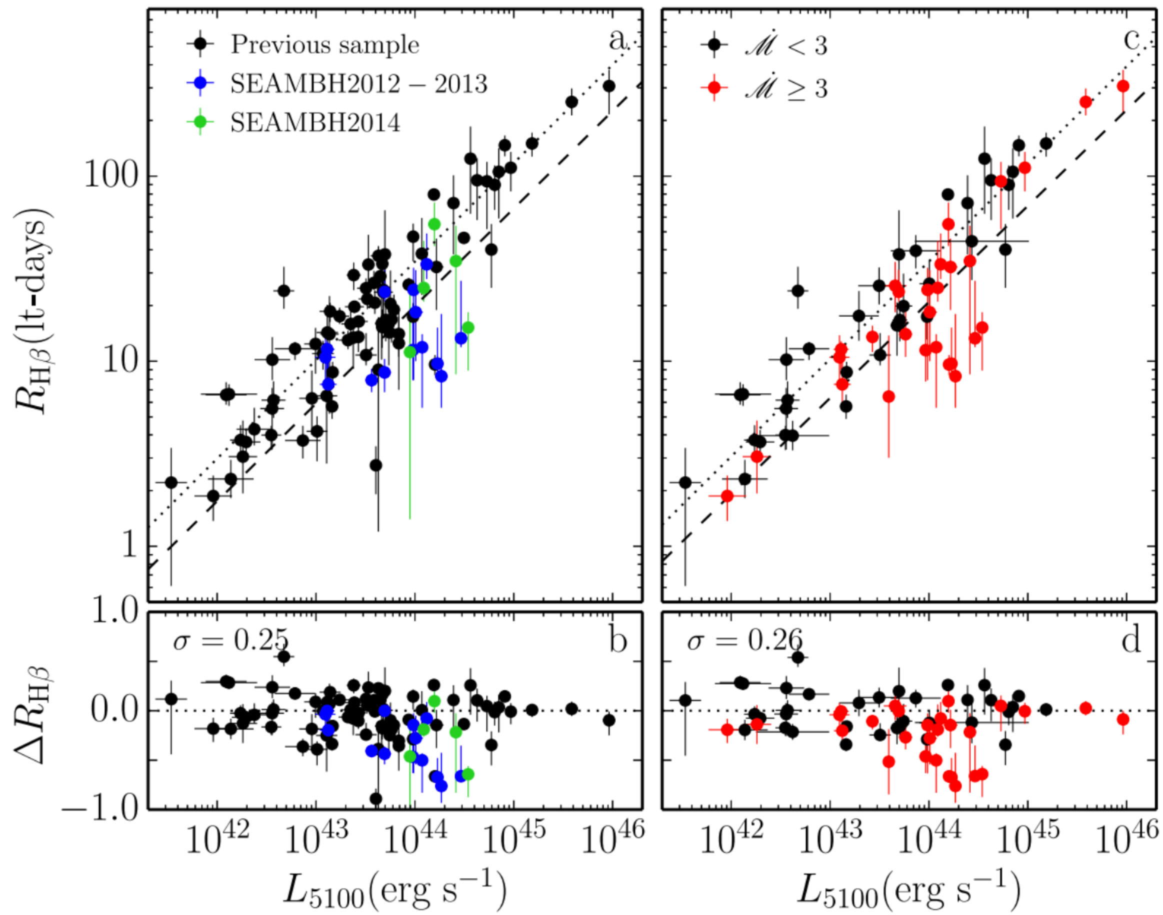
BLR Physics

SEAMBH on *R*-*L* Relation

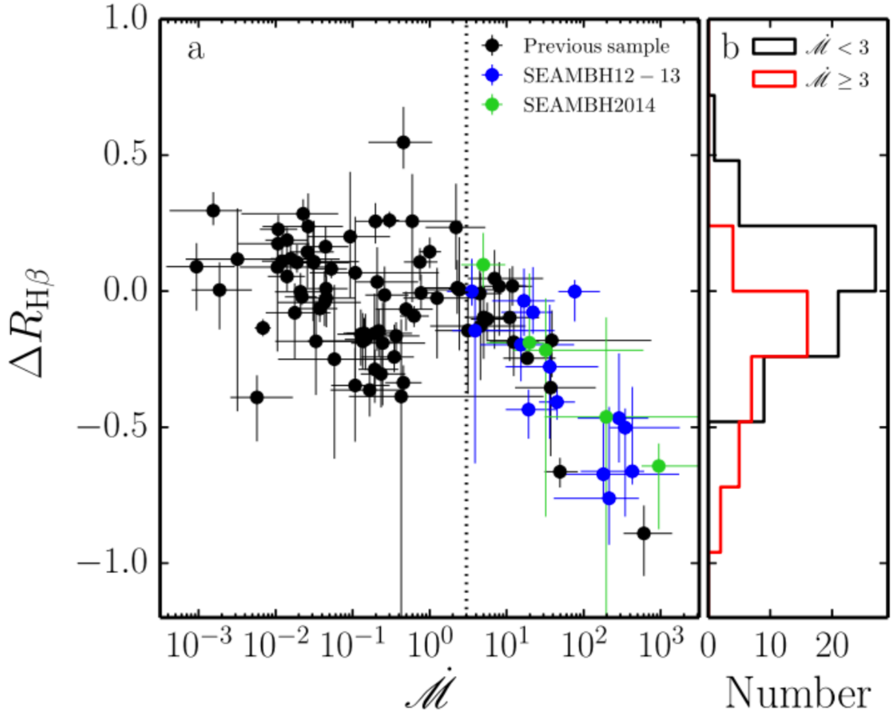
- The well-known *R*-*L* relation: broken? (Du et al. 2015; 2016a)

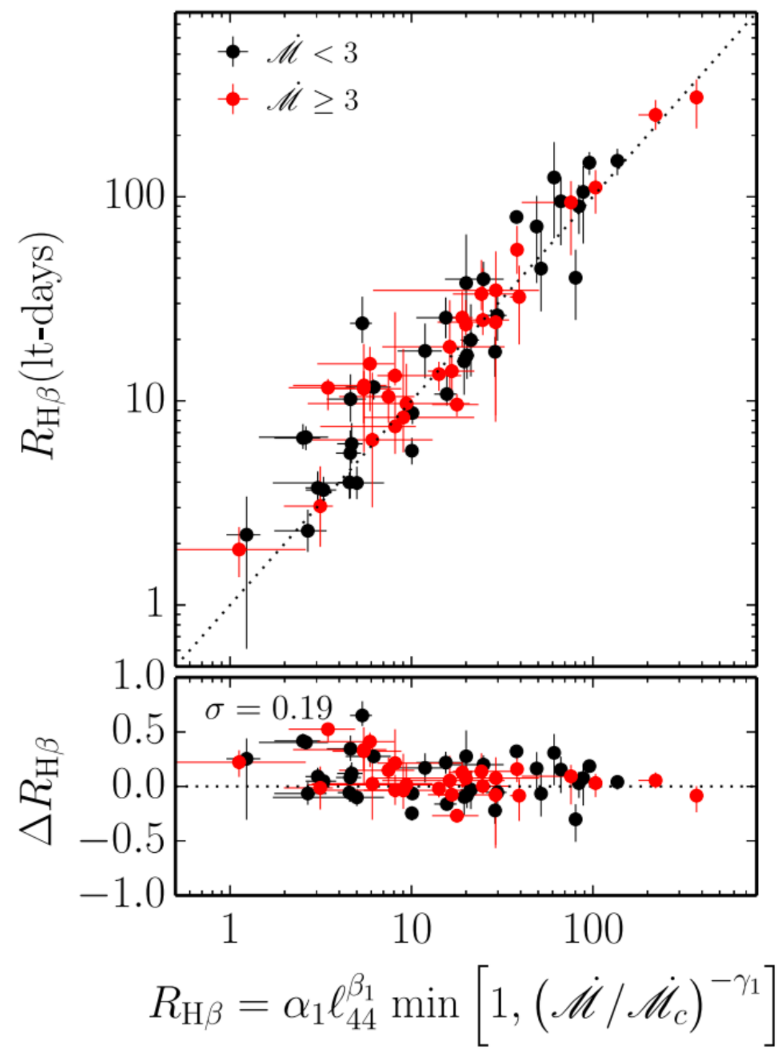


Kaspi et al. (2000)
Bentz et al. (2013)



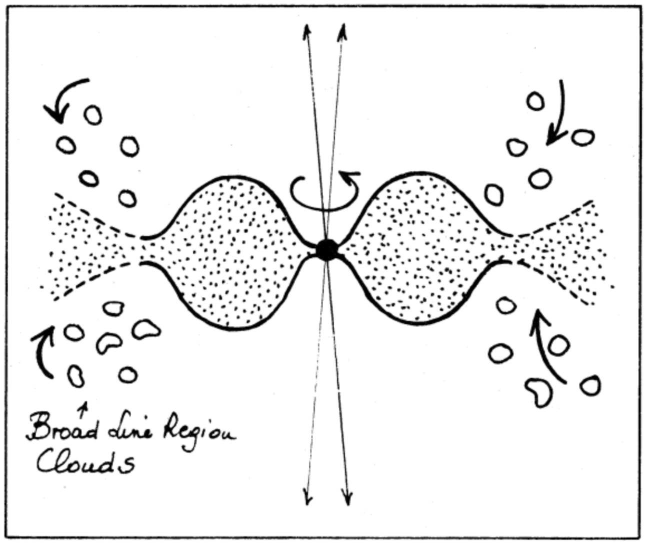
Hβ Lags: shortened



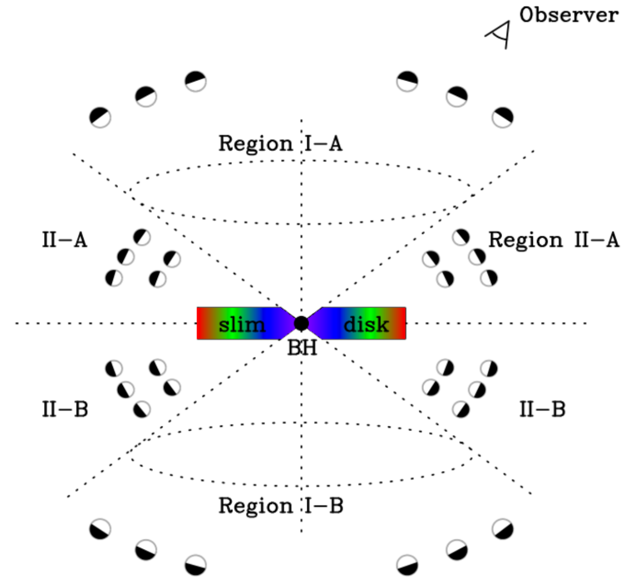


A new scaling relation is obtained (Du et al. 2016a,b)

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



Alloin (1990)



(Wang et al. 2014)

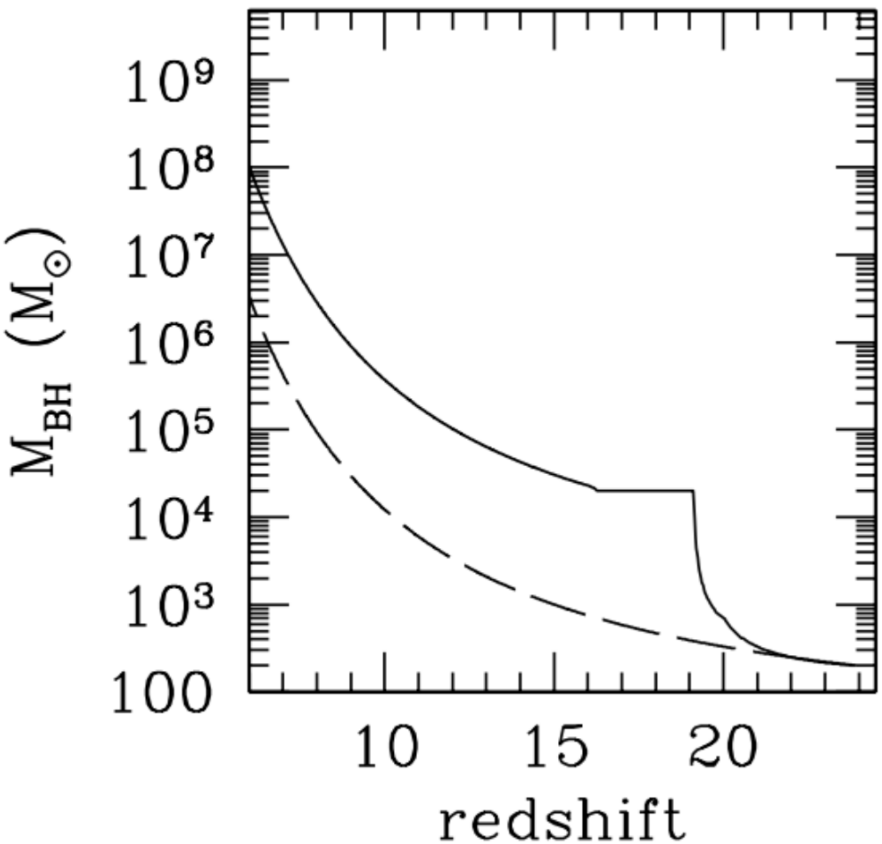
Shadowed BLR: shrinks and shorter lags

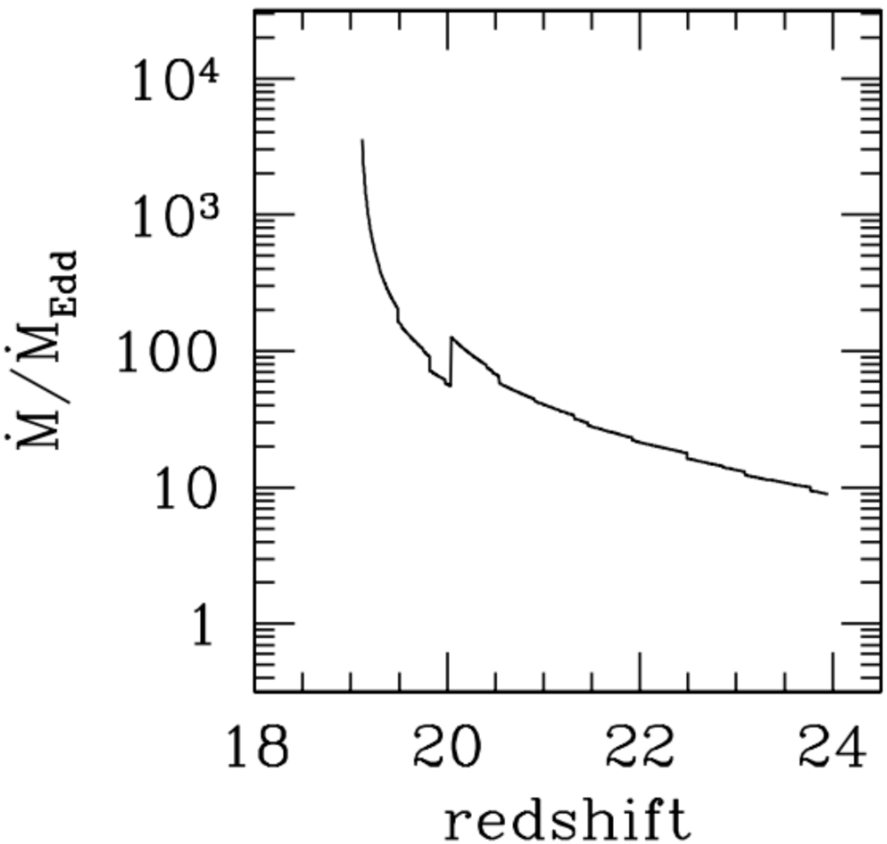
longer lags? (longer campaign to monitor)

Consequence: weak line quasars

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.

Super-Eddington Accretion Physics:

1) geometrically slim: lags shortened

2) photon trapping: saturated luminosity

3) a new scaling relation established for BLR

- SEAMBH observations and properties

  (P. Du’s talk)

- Fe II reverberation mapping: 9 objects+

  a better calibration method a fitting scheme for LC

  (in C. Hu’s talk)

- Markov Chain Monte-Carlo (MCMC): virial factor

  (in Yan-Rong Li’s talk)

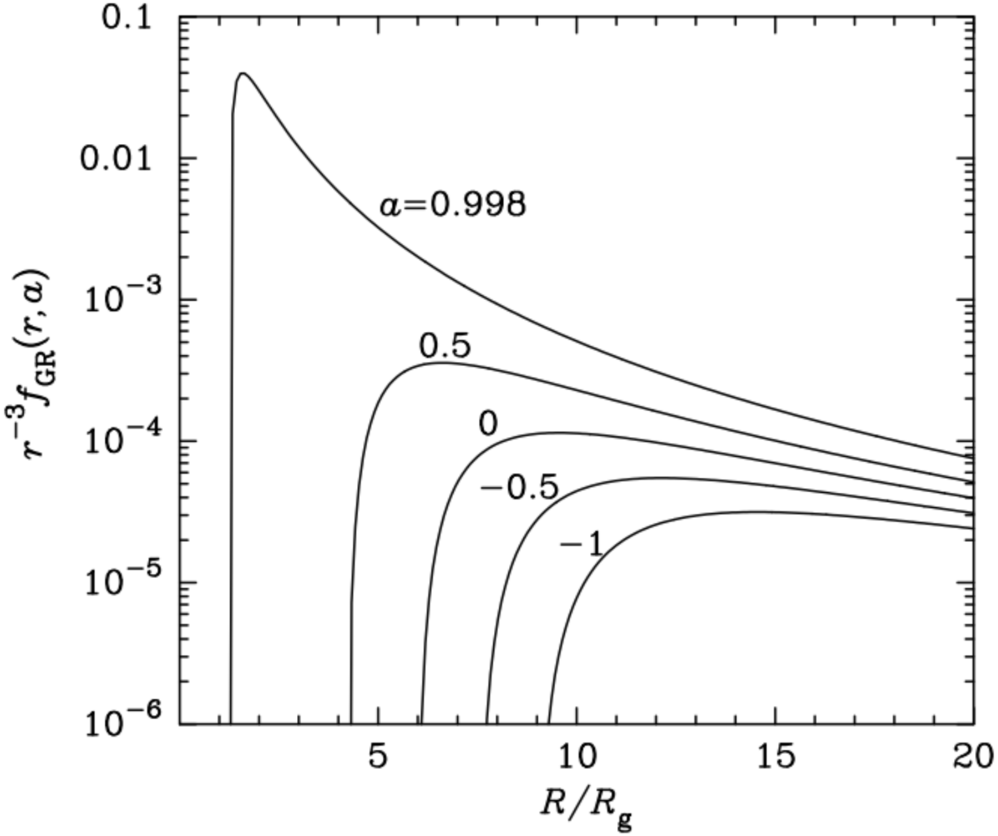
- Multiple Inhomogeneous Component Analysis (MICA)

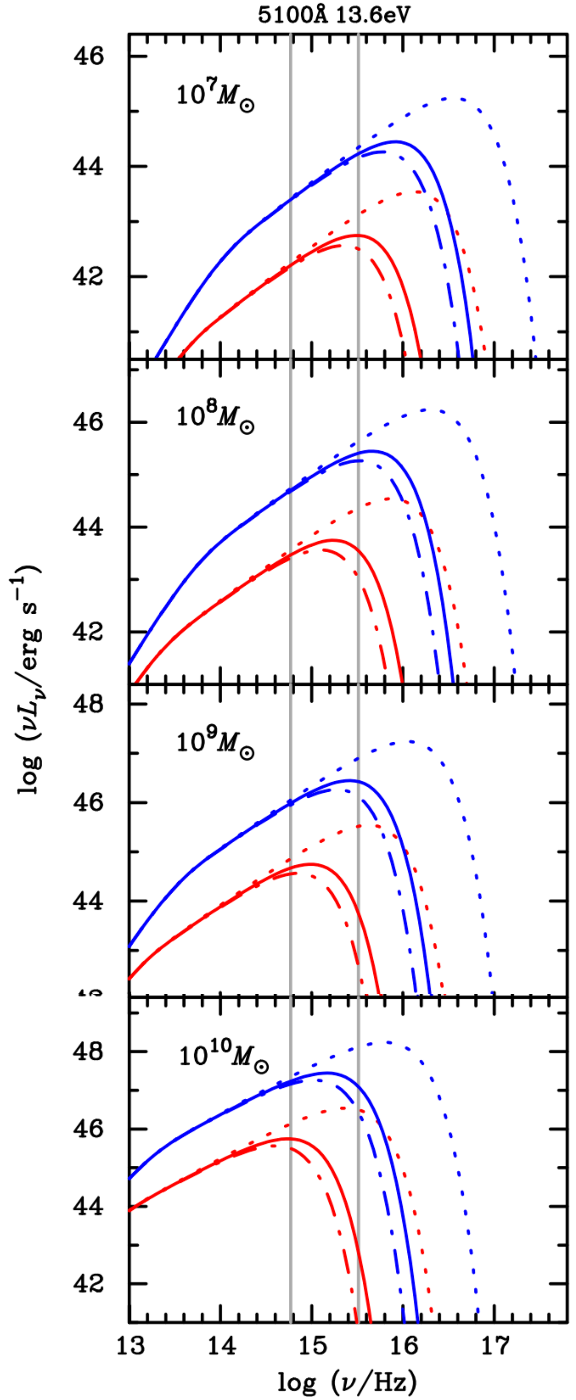
  supermassive black hole binaries?

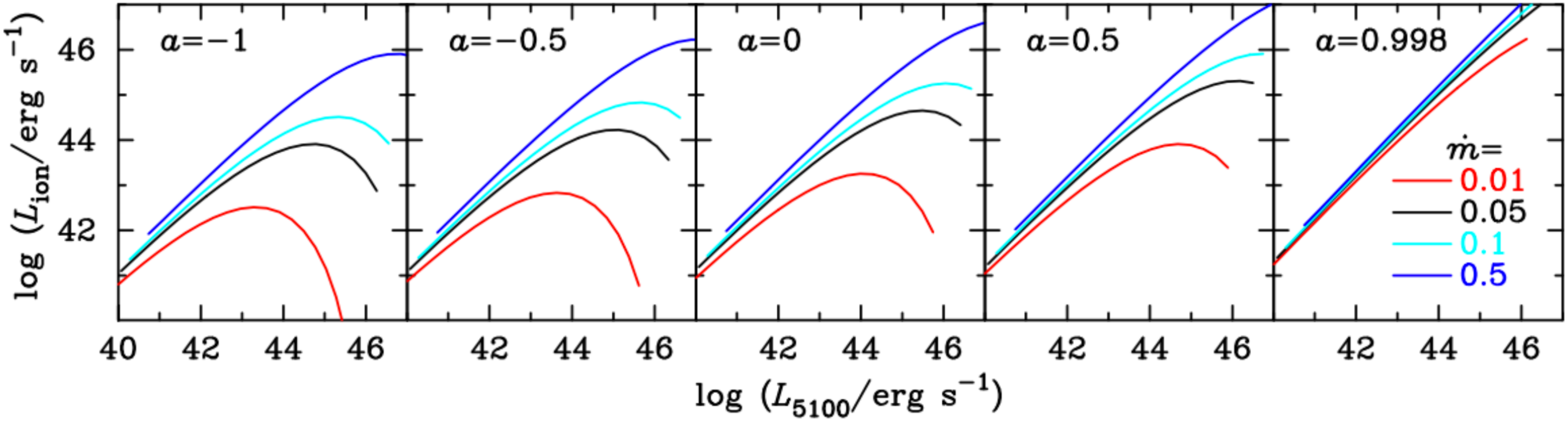
  (in Yan-Rong Li’s talk)

Black Hole Spin?

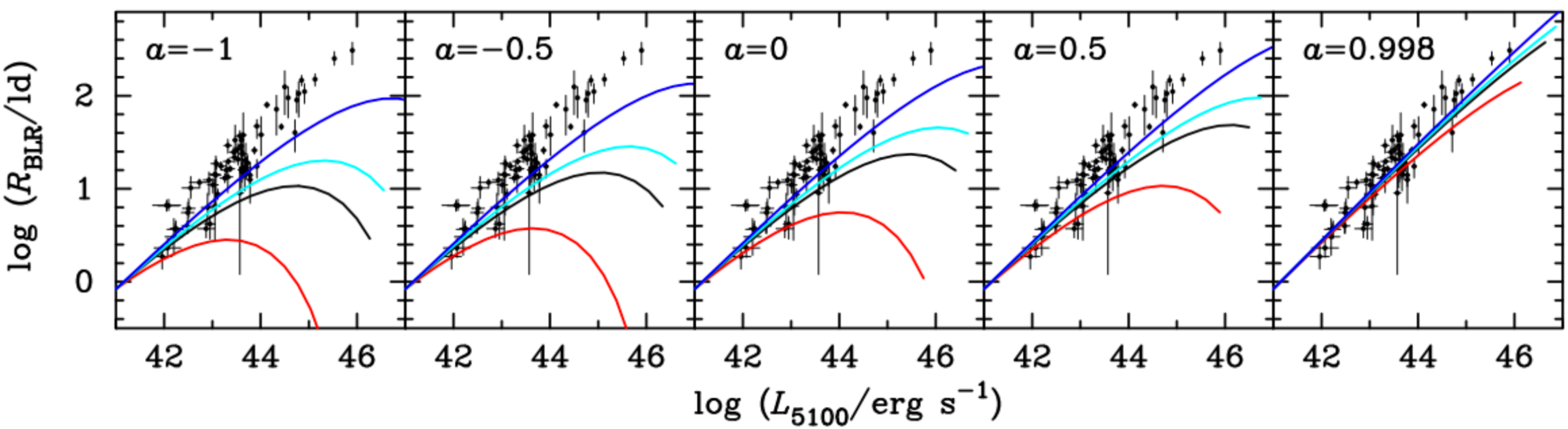
(Wang et al. 2014)



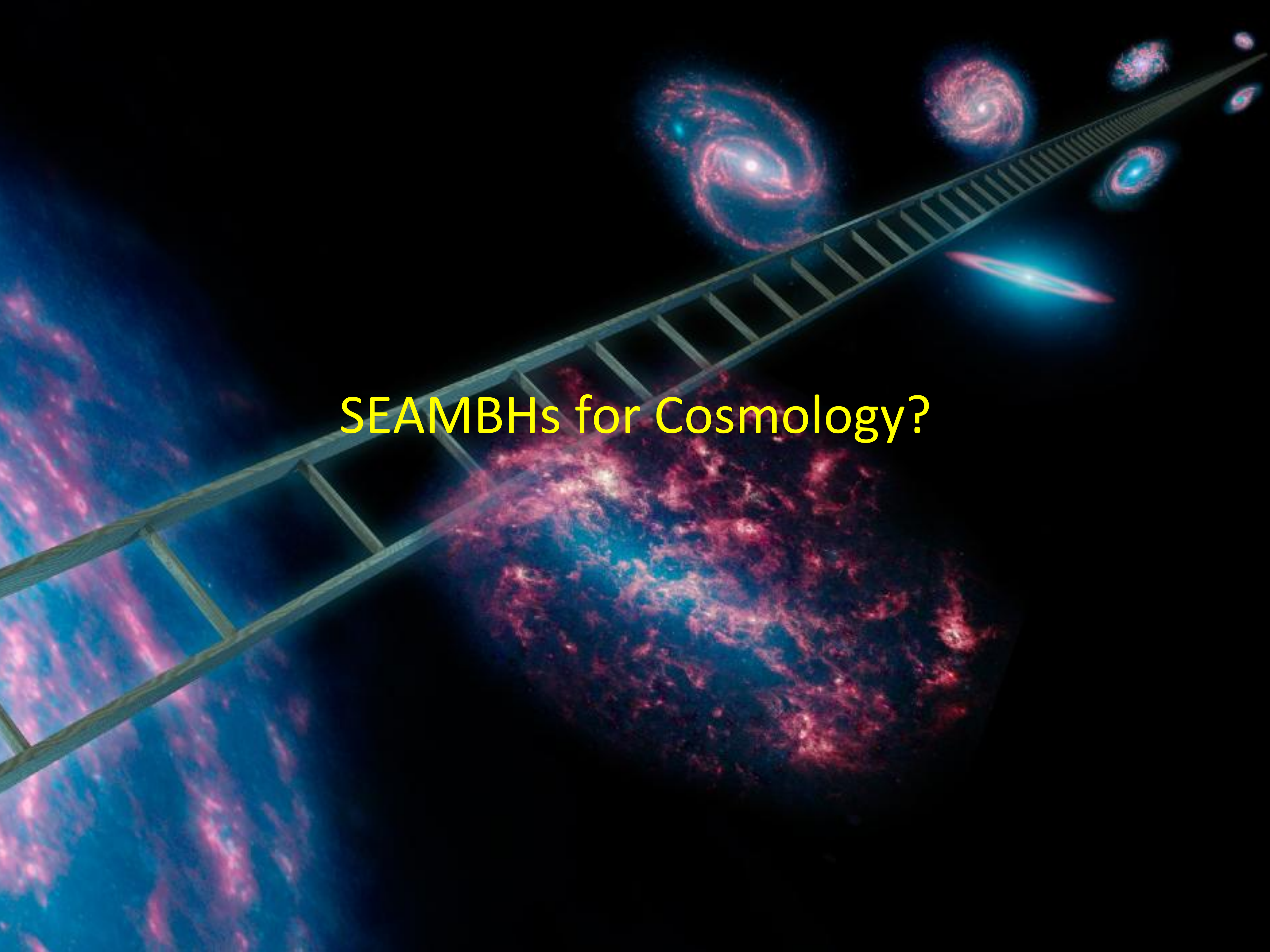




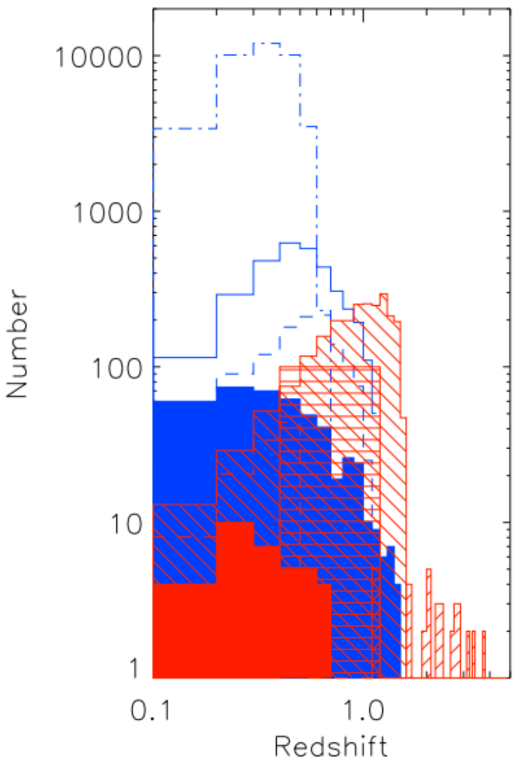
$$\Xi = \frac{L_{\rm ion}}{4\pi R_{\rm BLR}^2 cnkT}$$



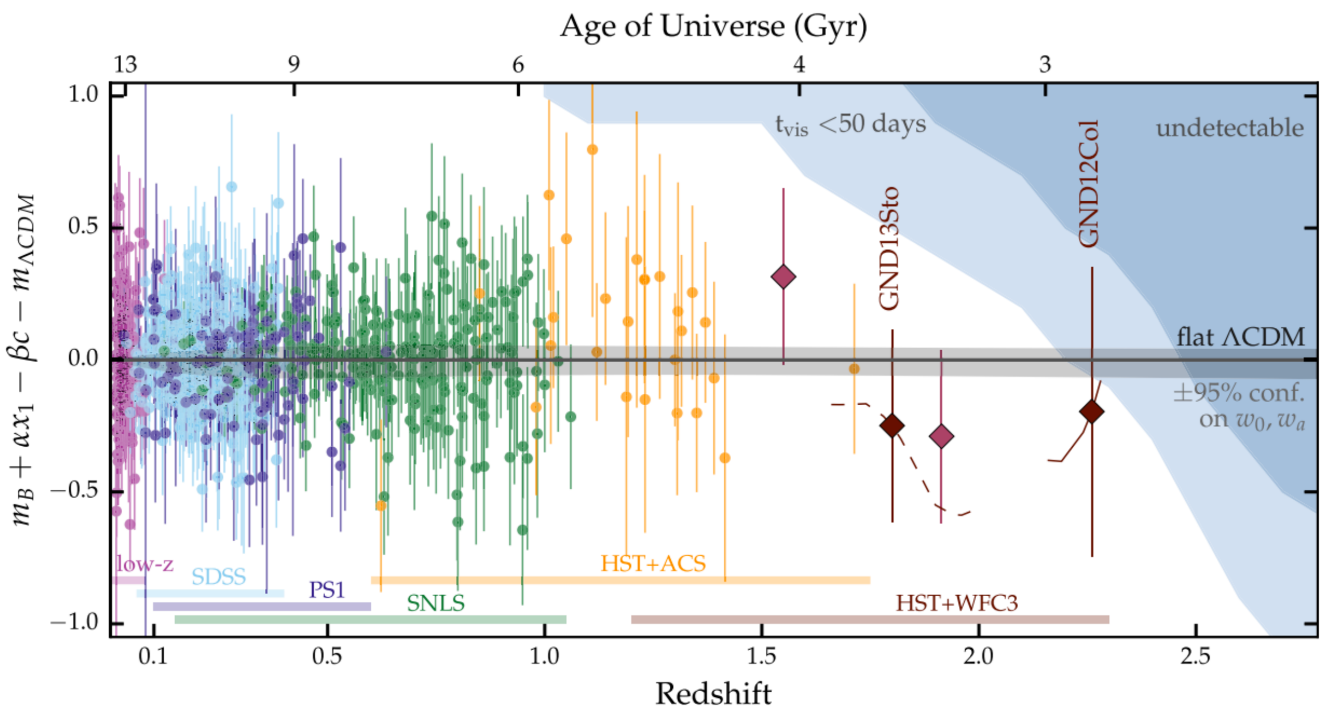
SEAMBHs for Cosmology?



SNIa for cosmology: z<1.5



Hook (2013)



Rodney, Riess et al. (2015)

SEAMBH for cosmology

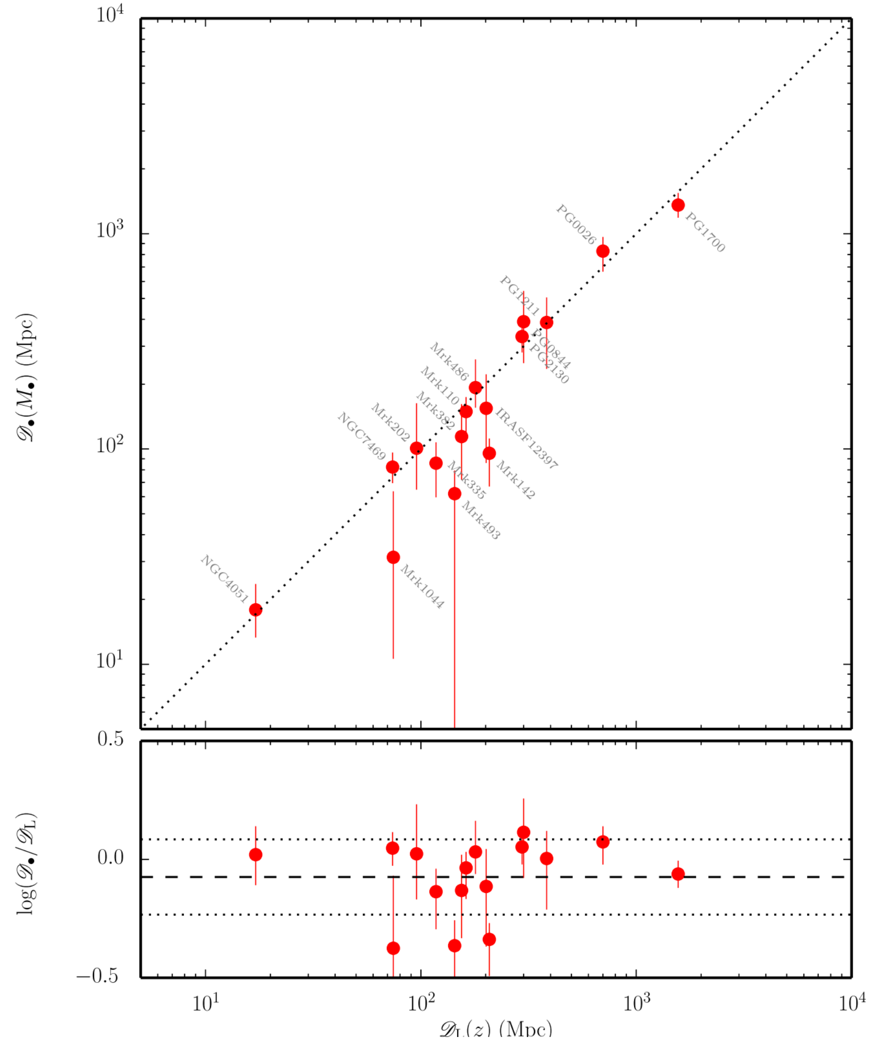
(Wang et al. 2013; 2014)

- Saturated luminosity:

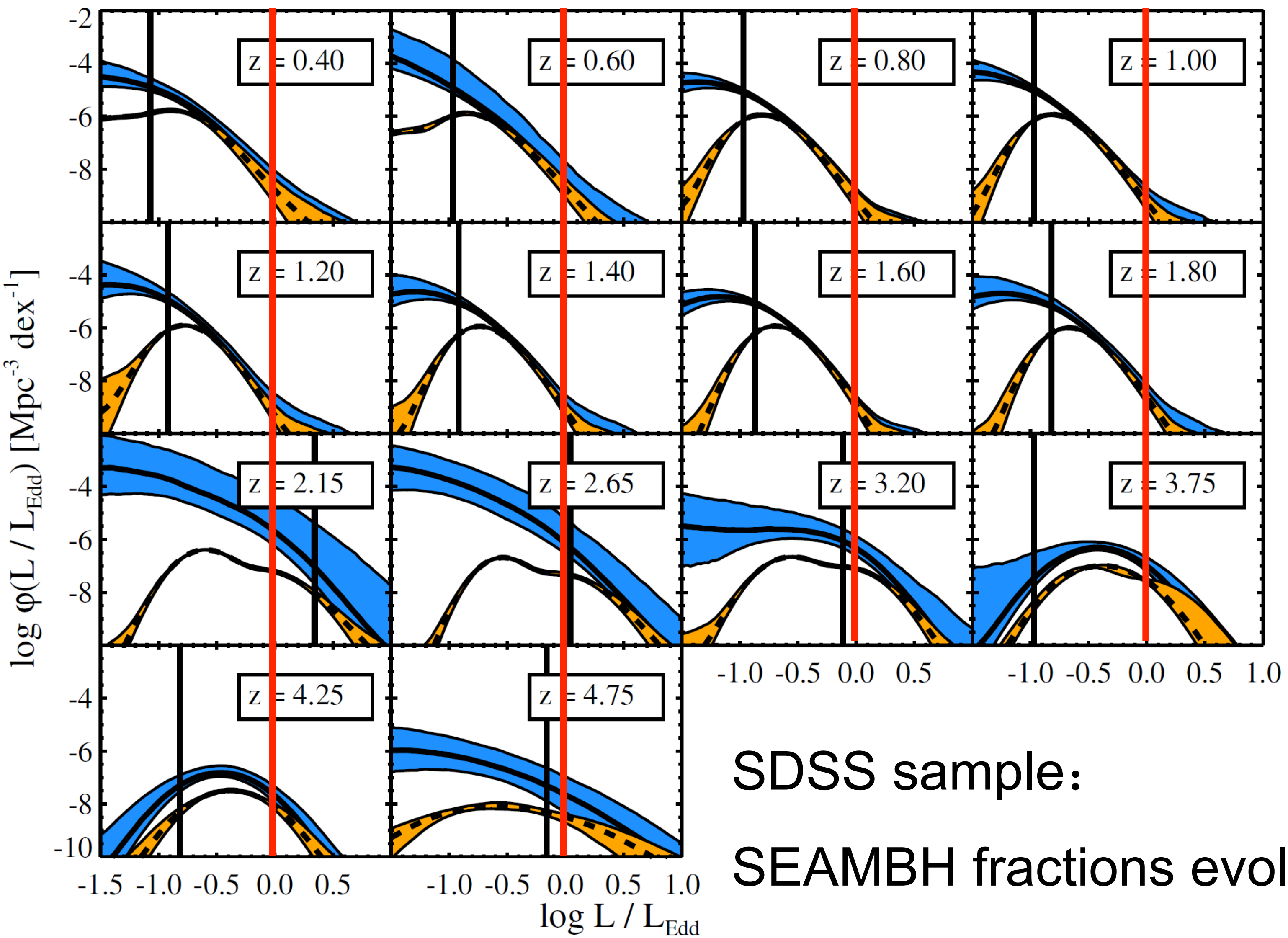
standard candles

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

Intrinsic scatter: 0.15 dex



Eddington ratio function (Kelly & Shen 2013)

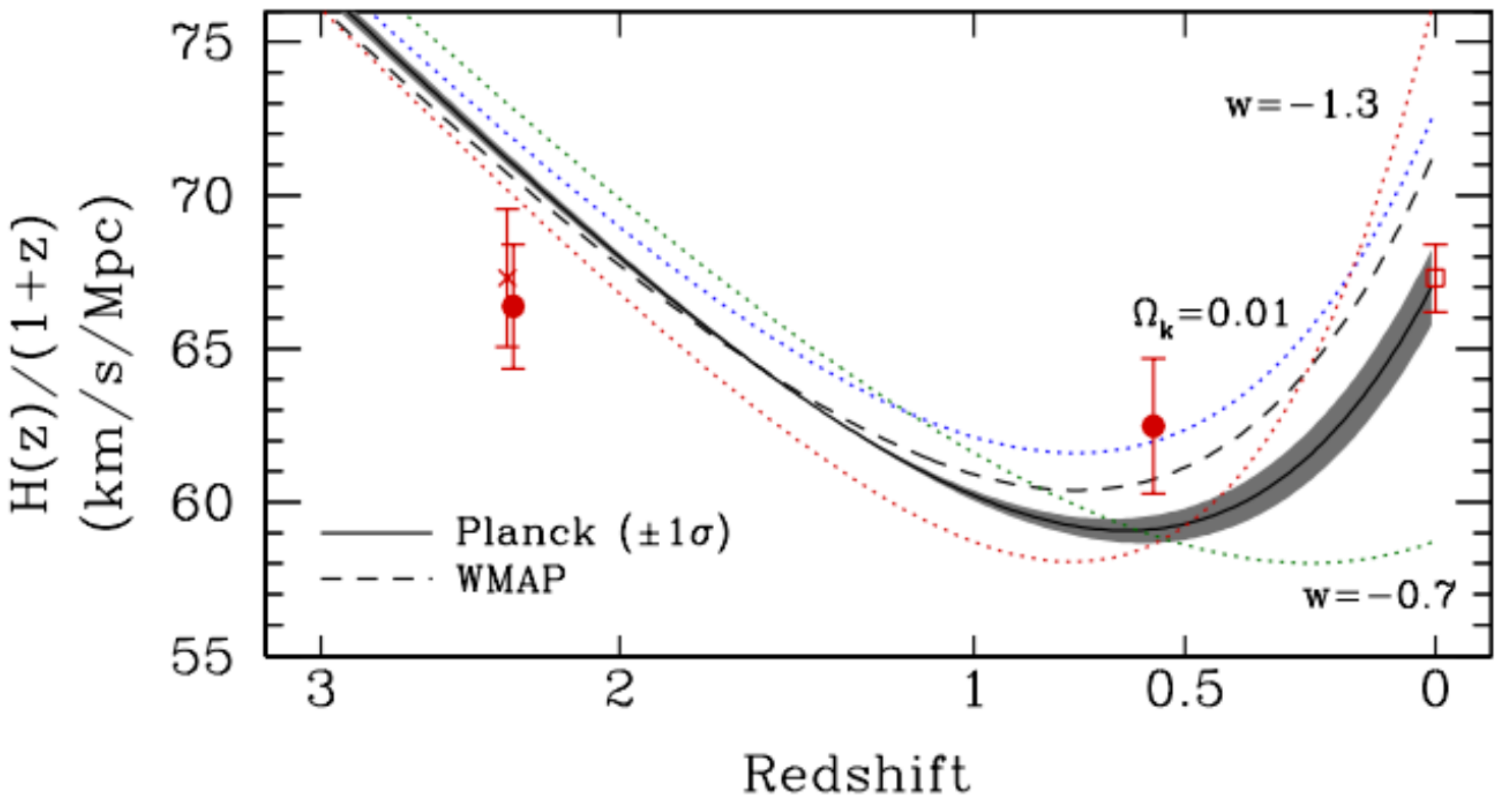


SDSS sample：

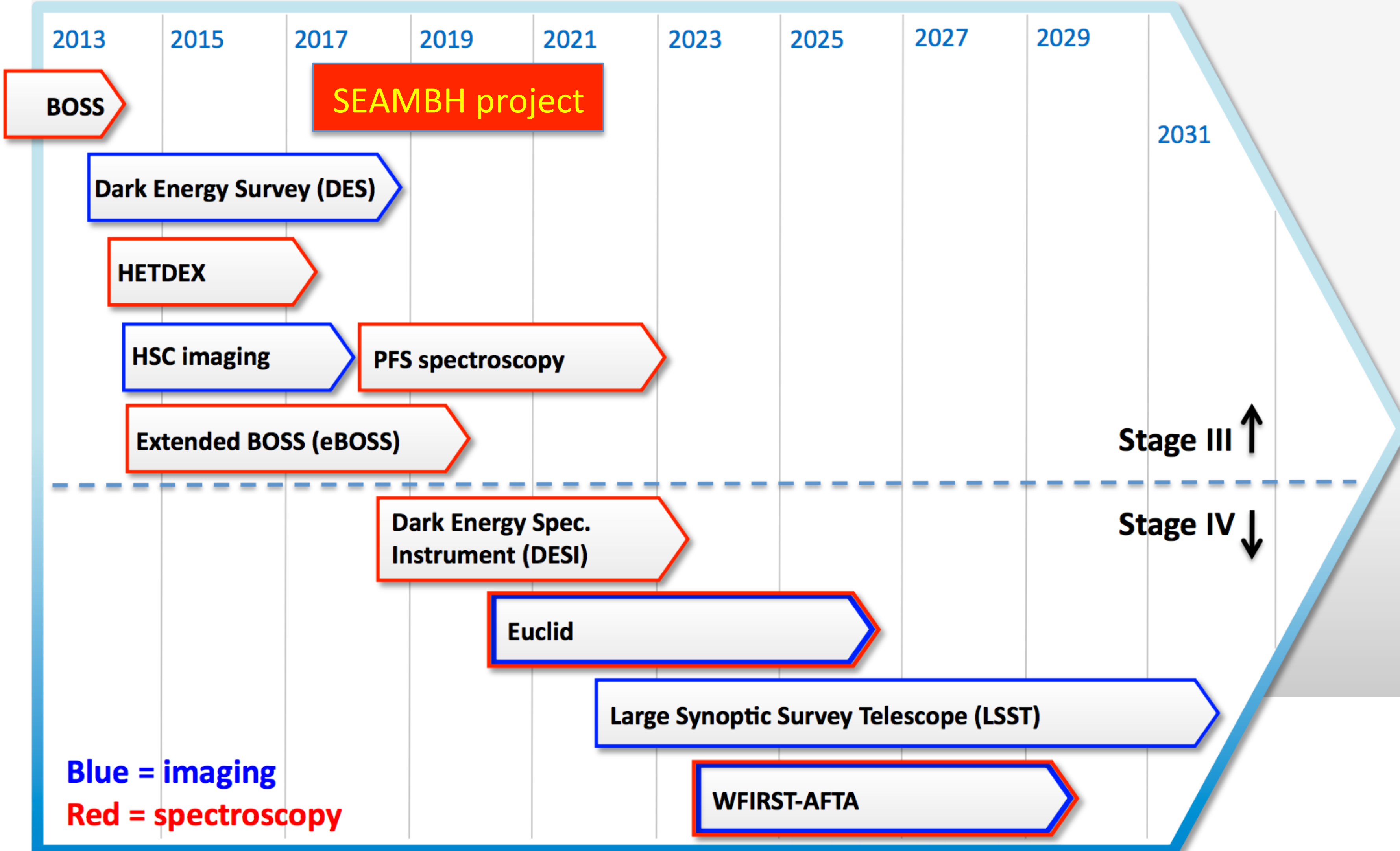
SEAMBH fractions evolve

Lyα Forest BAO measurement

(Aubourg et al. 2015)



Dark Energy Experiments: 2013 - 2031



Future 5-year Plans

- SEAMBH properties:
  - saturated luminosity

    scatters? black hole candles?
  - shortened lags

    physics behind: BLR+accretion
  - reverberation of multiwavelength continuum from

    radio, IR, optical to X-rays

    accretion physics

- Is *R*-*L* relation biased?

  an homogeneous Hβ sample with

Mass:	$M_\bullet = 10^6 - 10^{10} M_\odot$;
Luminosity:	$L_{5100} > 10^{45}$erg/s;
Accretion rate:	$\dot{M} = (10^{-3} \sim 10^3) L_{\rm Edd}/c^2$
spin:	$-1 \leq a \leq 0.998$

- A large campaign in China: 200AGNs

  8 Institutions: spectroscopic and photometric RM

  IHEP, YANO, PKU, NAOC, NJU, USTC, XAO, PMO

sMAGIC

(wanted)

spectroscopically Monitoring Active Galaxies International Campaign

call for collaborations in this workshop

a network of telescope for RM campaign