Seoul National University AGN Monitoring Project (SAMP)

Investigating the High-Luminosity End of Hβ Radius-Luminosity relation

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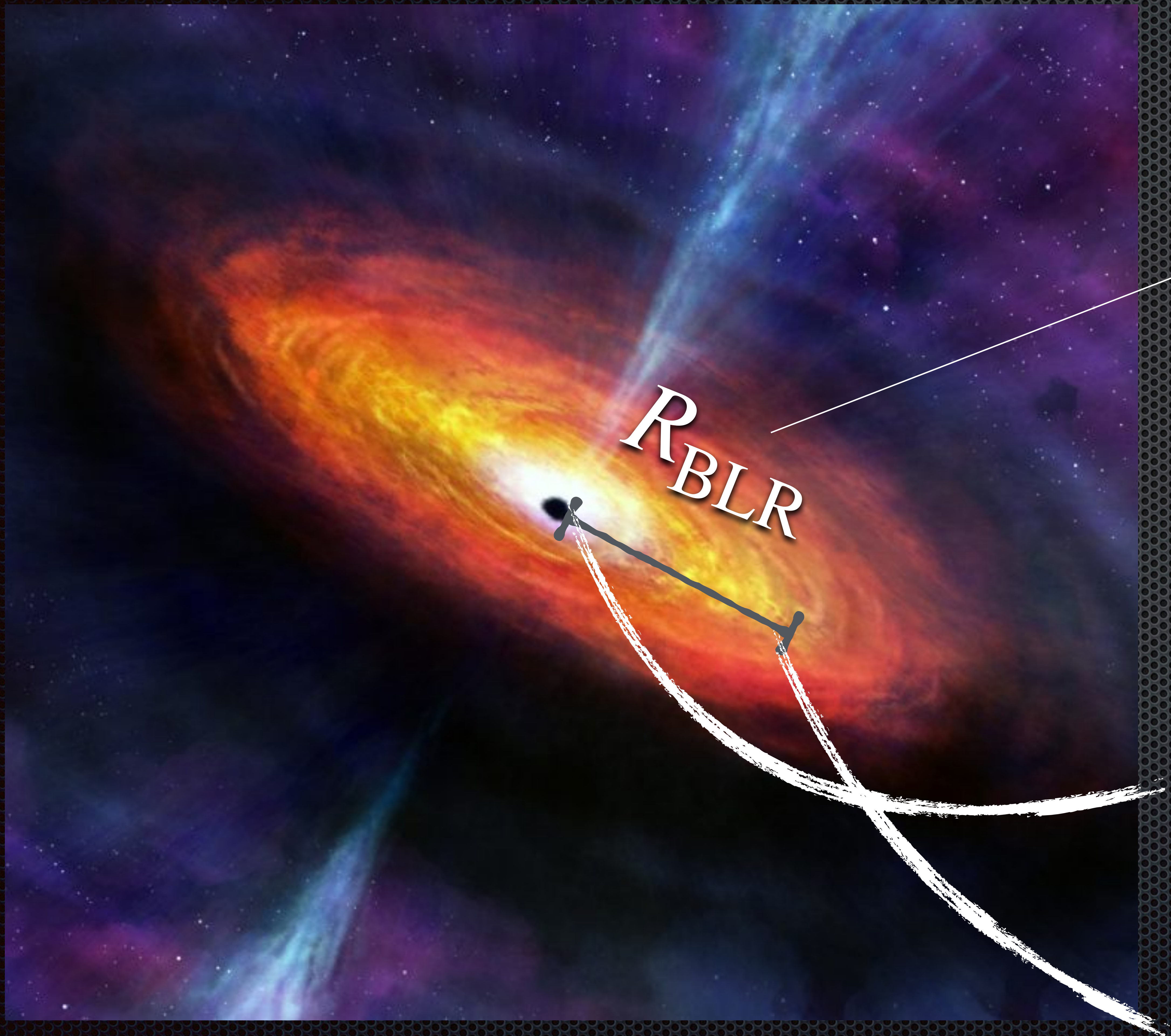
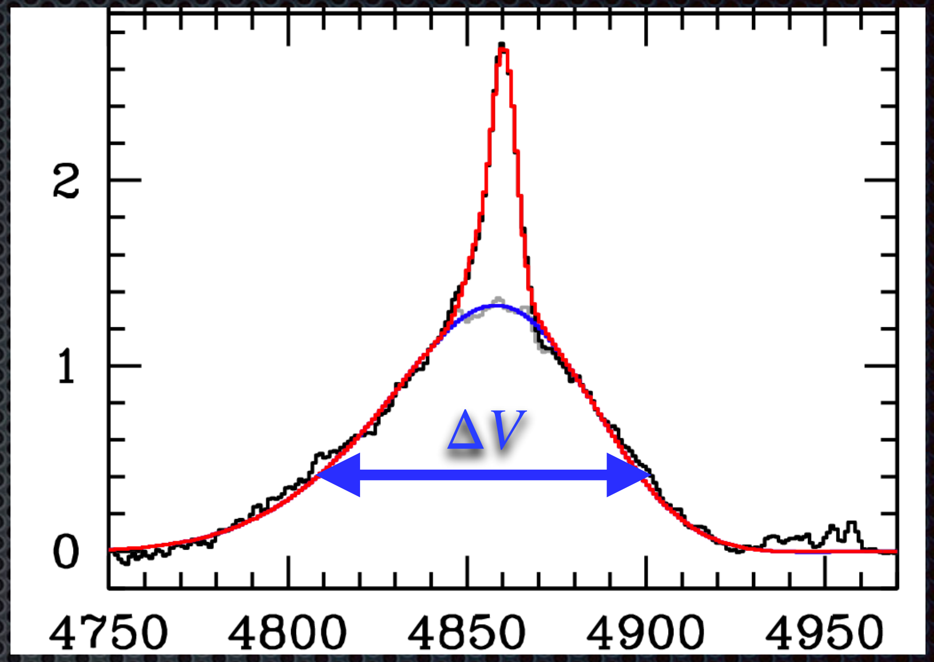
in collaboration with Jong-Hak Woo, and entire SAMP collaboration

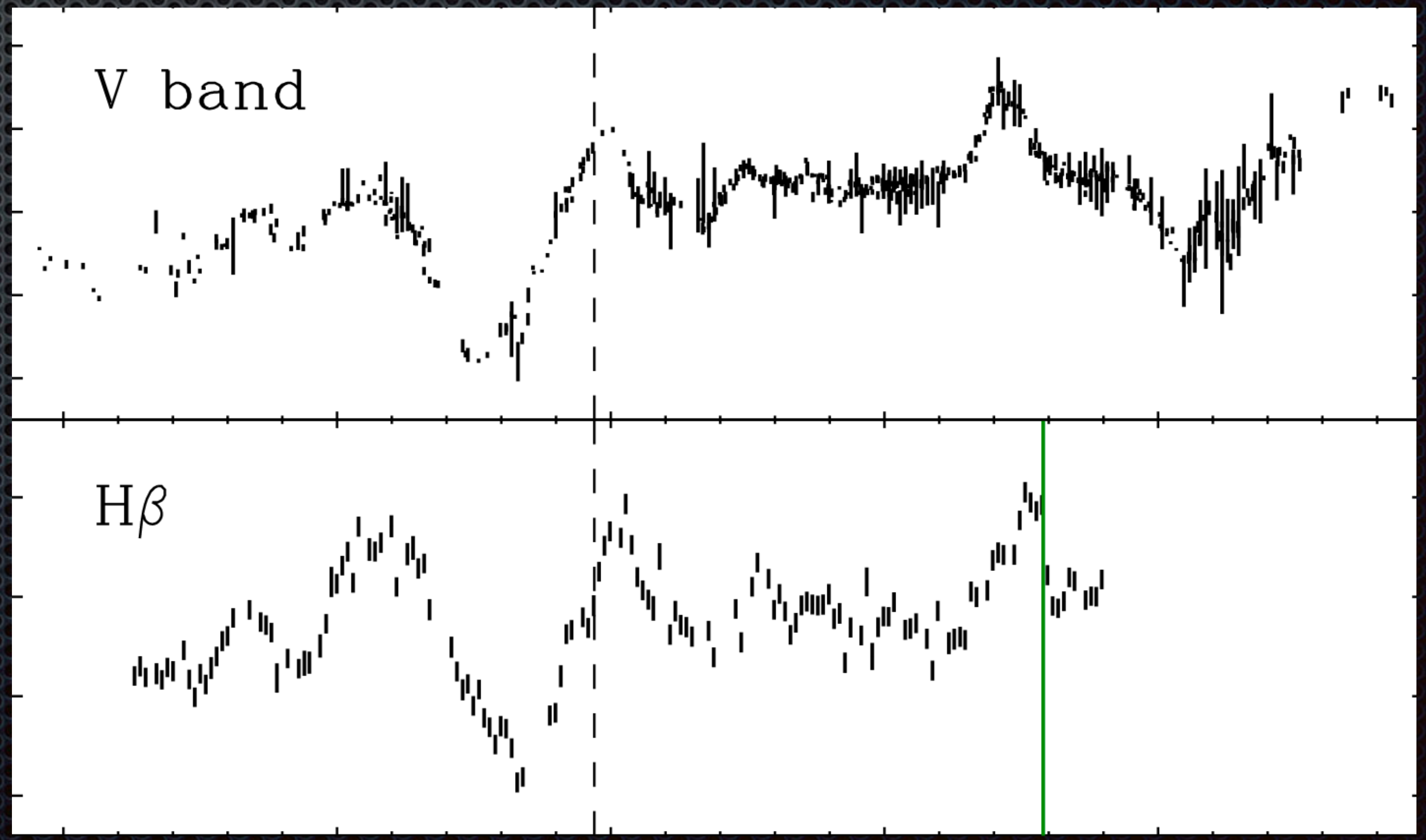
Measuring M_{BH}



Credit: Nahks Tr'Ehnl (Penn State University)

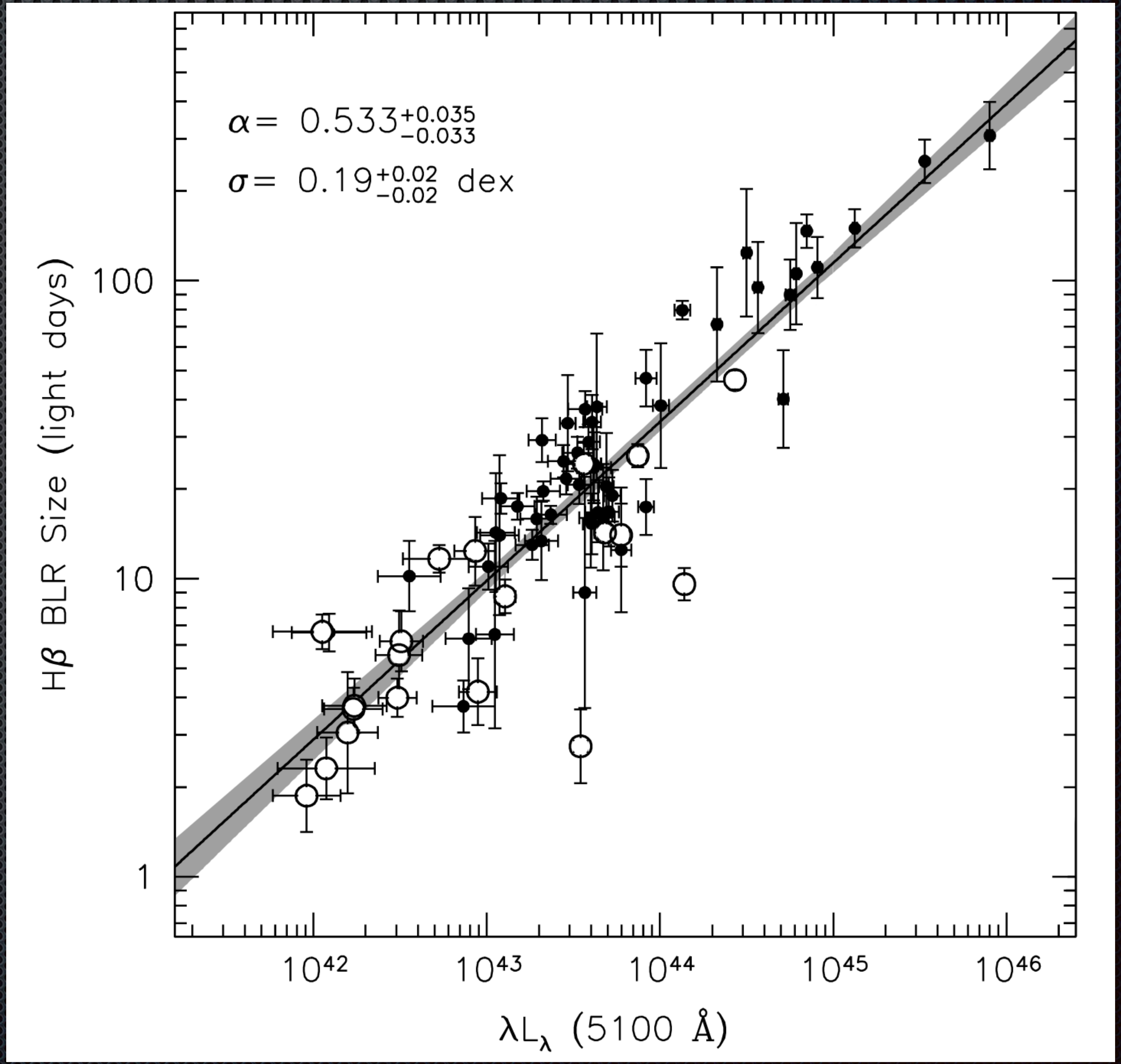


$$M_{BH} = \frac{f\, R_{BLR}\, \Delta V^2}{G}$$



Hβ Radius — Luminosity relation

- **Establishment.**
    - Kaspi et al. (2000); Bentz et al. (2009 , 2013)
- **Single-epoch BH mass.**
    - Greene & Ho (2005); Vestergaard & Peterson (2006); Shen et al. (2011); Liu et al. (2019); etc
- **Constrain cosmology:**
    - Watson et al. (2011); Martínez-Aldama et al. (2019); Khadka et al. (2021,2022), etc



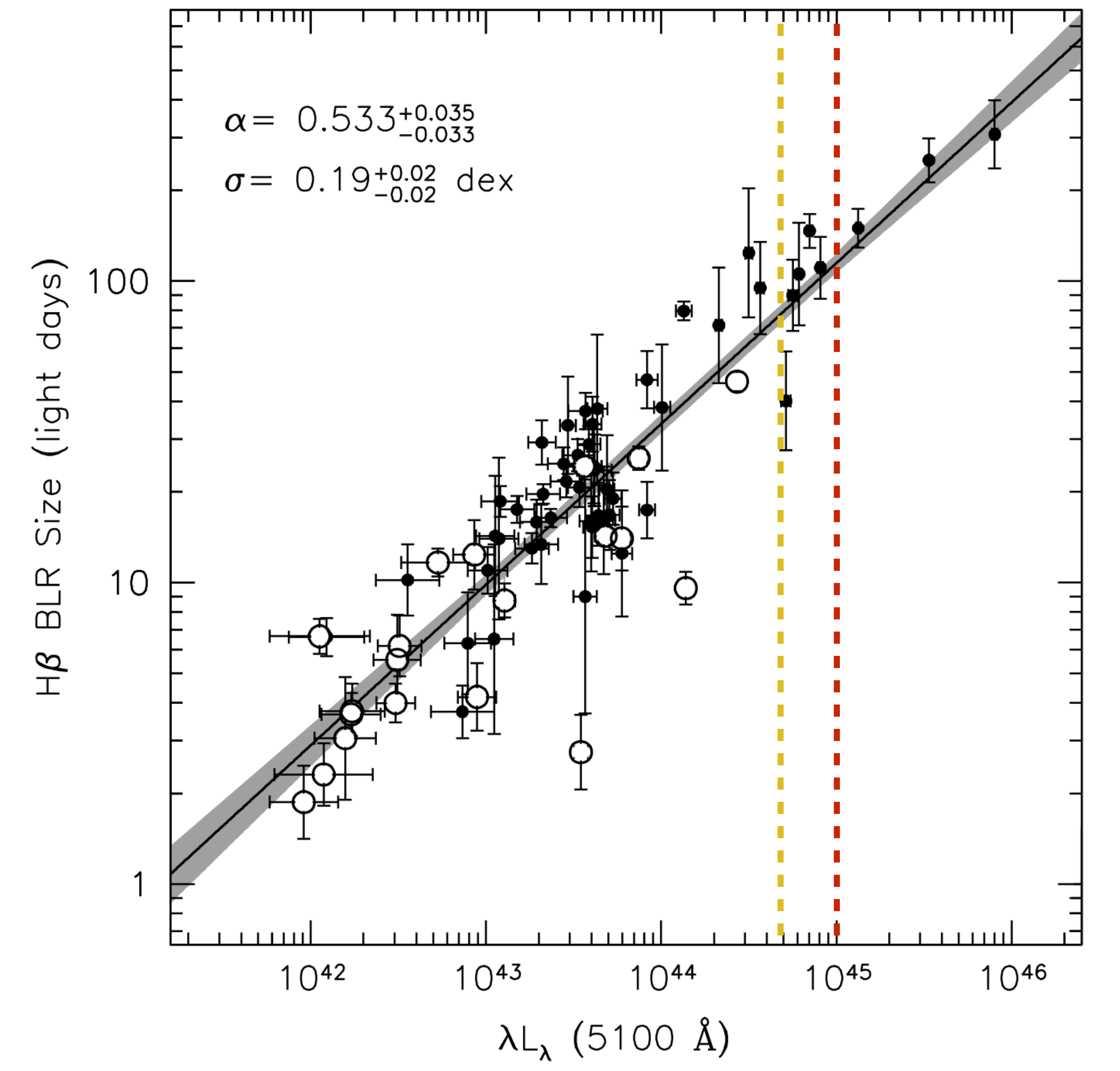
Bentz et al. (2013)

Hβ Radius — Luminosity relation

Sample is biased to low-to-moderate L_{5100} and low-z AGNs

Difficulty:

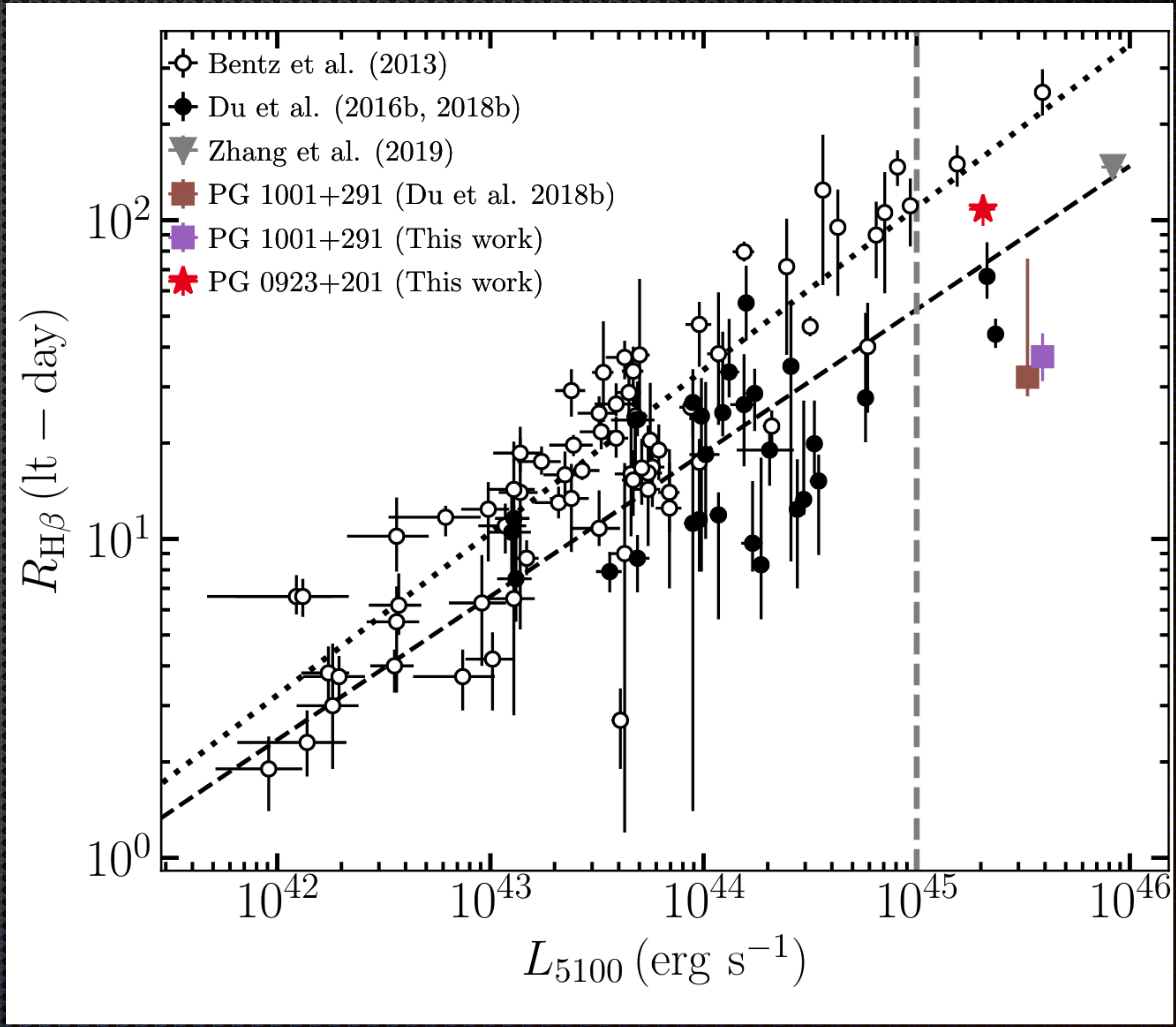
1. requiring large amount of observing resources and long baseline;
2. variability are typically not large



Bentz et al. (2013)

Complications

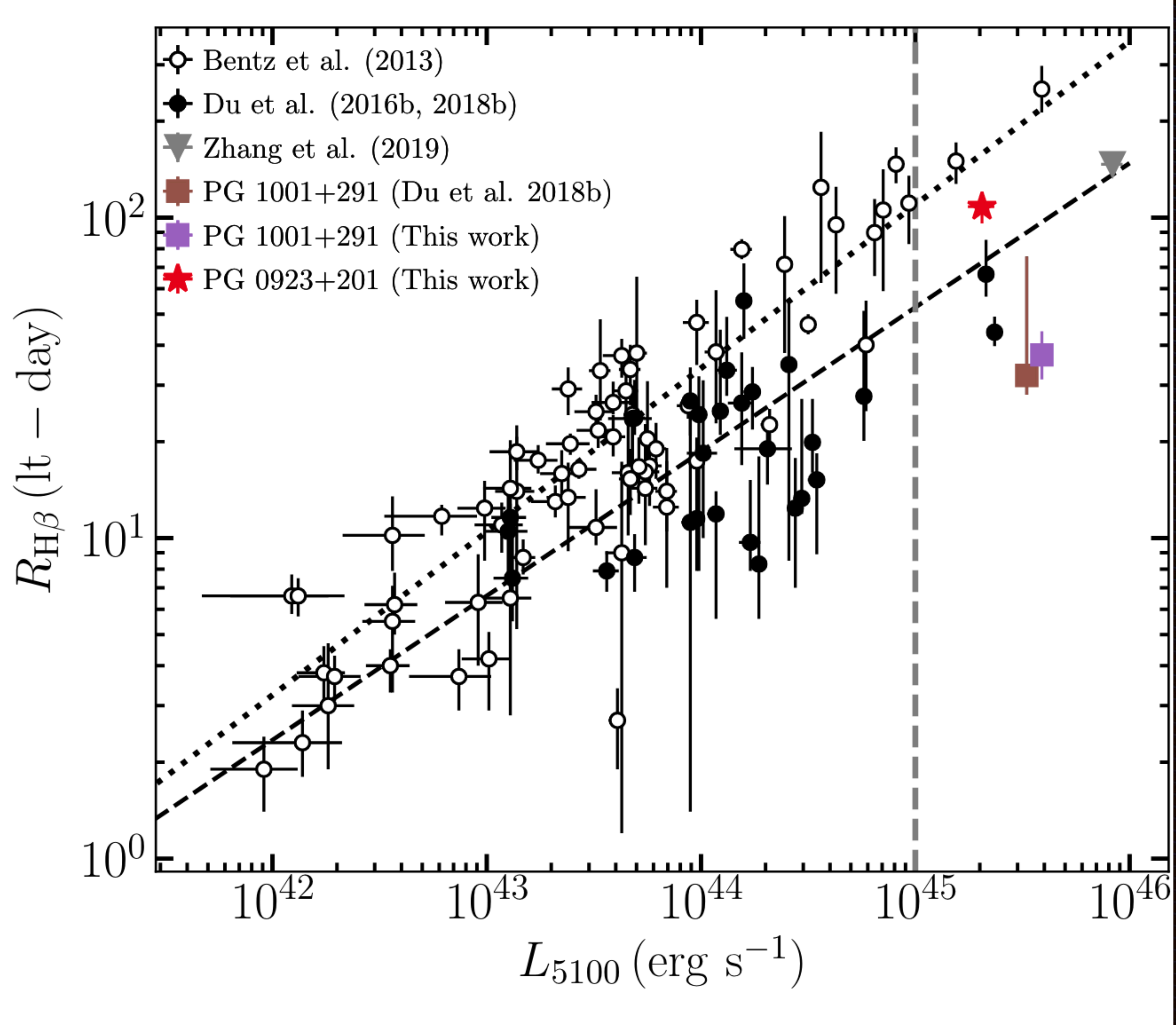
- Much more **scattered**, especially at high Luminosity end (~0.8 dex difference at >$10^{45.0}$ erg s^{-1})
- Systematic offset for super Eddington accreting BHs (e.g., Du et al. 2015, Du & Wang 2019)



Li et al. (2021)

Consequences

- **Bias** in the single-epoch BH mass estimation, especially at high Luminoisty (high-z)
- Weak constraints to cosmology (e.g., Khadka et al. 2022)

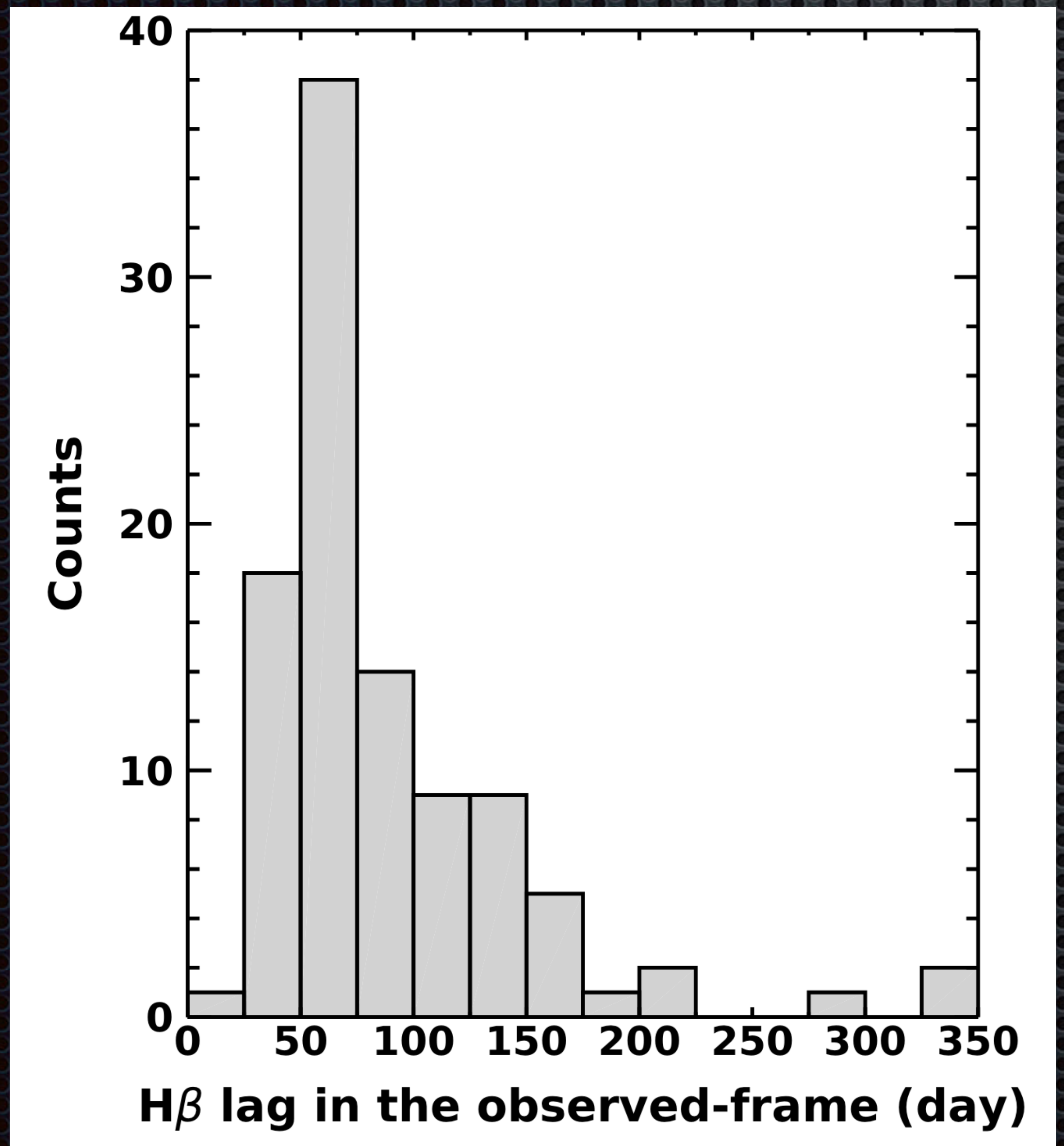


Li et al. (2021)

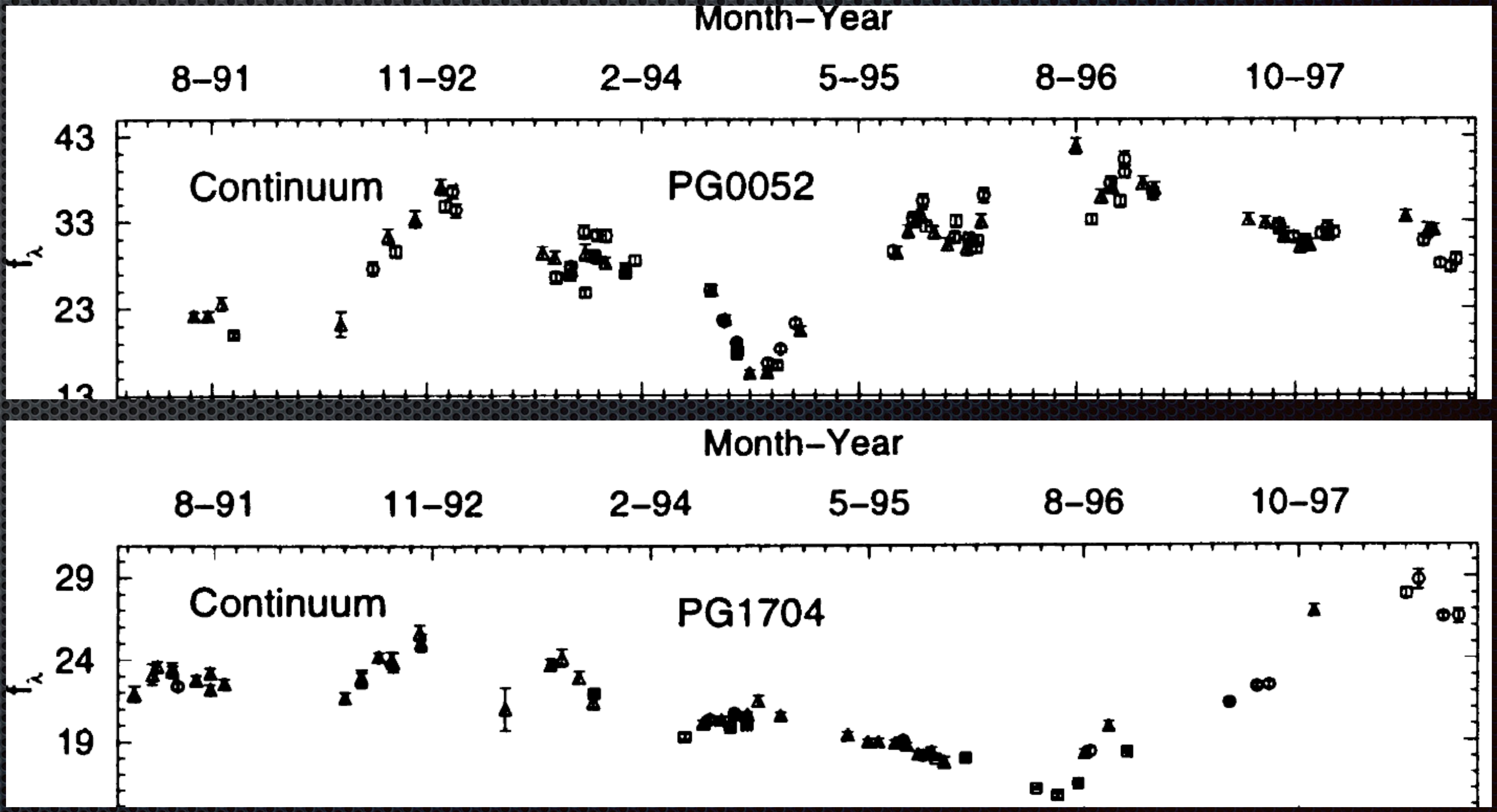
Seoul National University AGN Monitoring Project (SAMP)

Program design (Woo et al. 2019)

From 100 relatively high luminosity AGNs out to z~0.5



Woo et al. (2019)

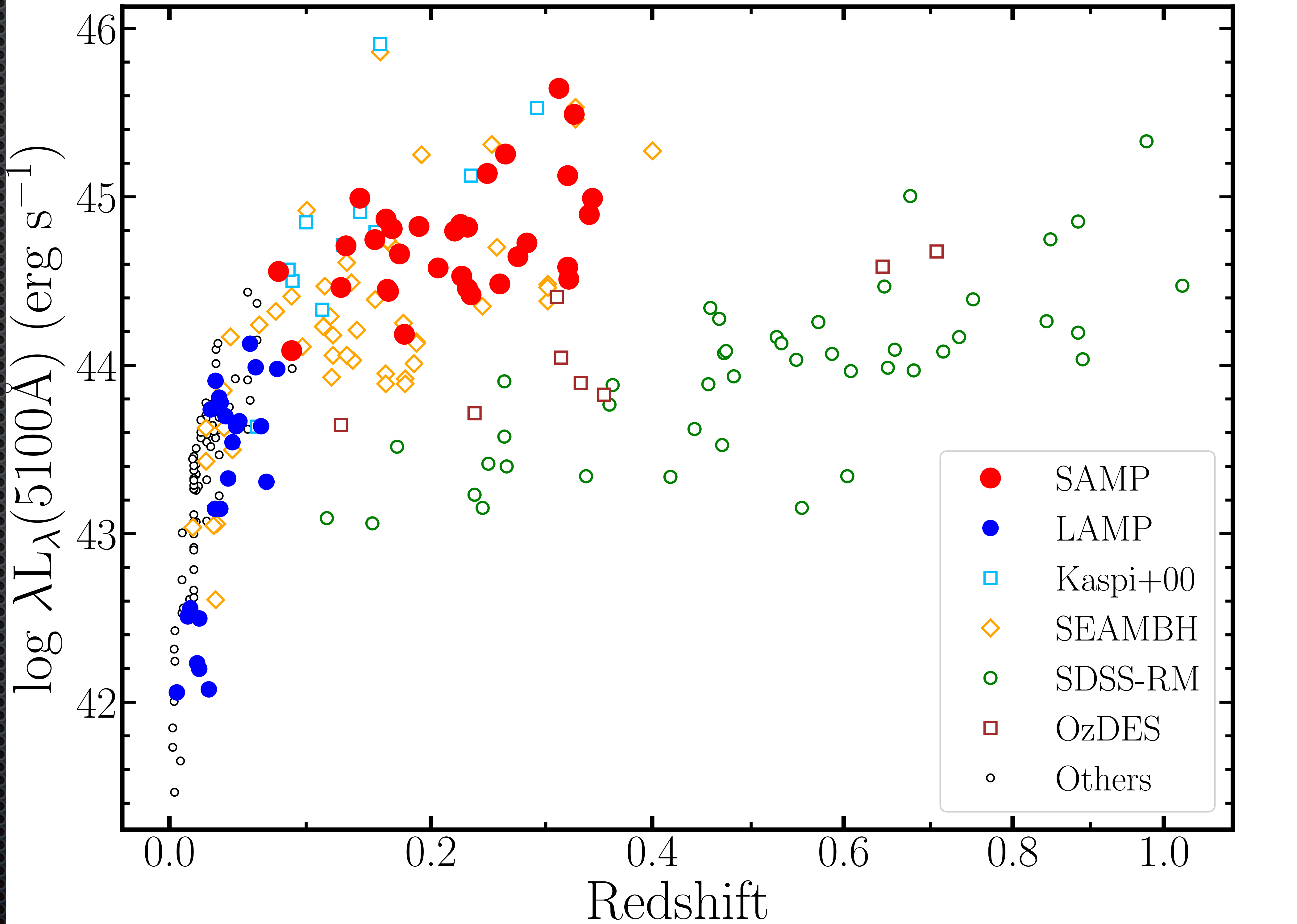


Kaspi et al. (2000)

SAMP final sample

We select 32 objects with large variability as final sample

- Luminosity range:
  - $L_{5100} = 10^{44.0\sim45.6}$ erg s^{-1}
- Redshift range:
  - 0.08 ~ 0.37
- Most have strong [O III]



SAMP observation

Statistics:

- Six-year baseline

- Photometry:
  - cadence: 3-5 days
  - Two bands (B, V) taken

- Spectroscopy:
  - cadence: 15-20 days
  - High SNR for sinigle-epoch spectrum

Photometry

MDM 1.3m

LOAO 1m

Lick 1m

LCOGT

DOAO

Spectroscopy

Lick Shane 3m

MDM Hiltner 2.4m

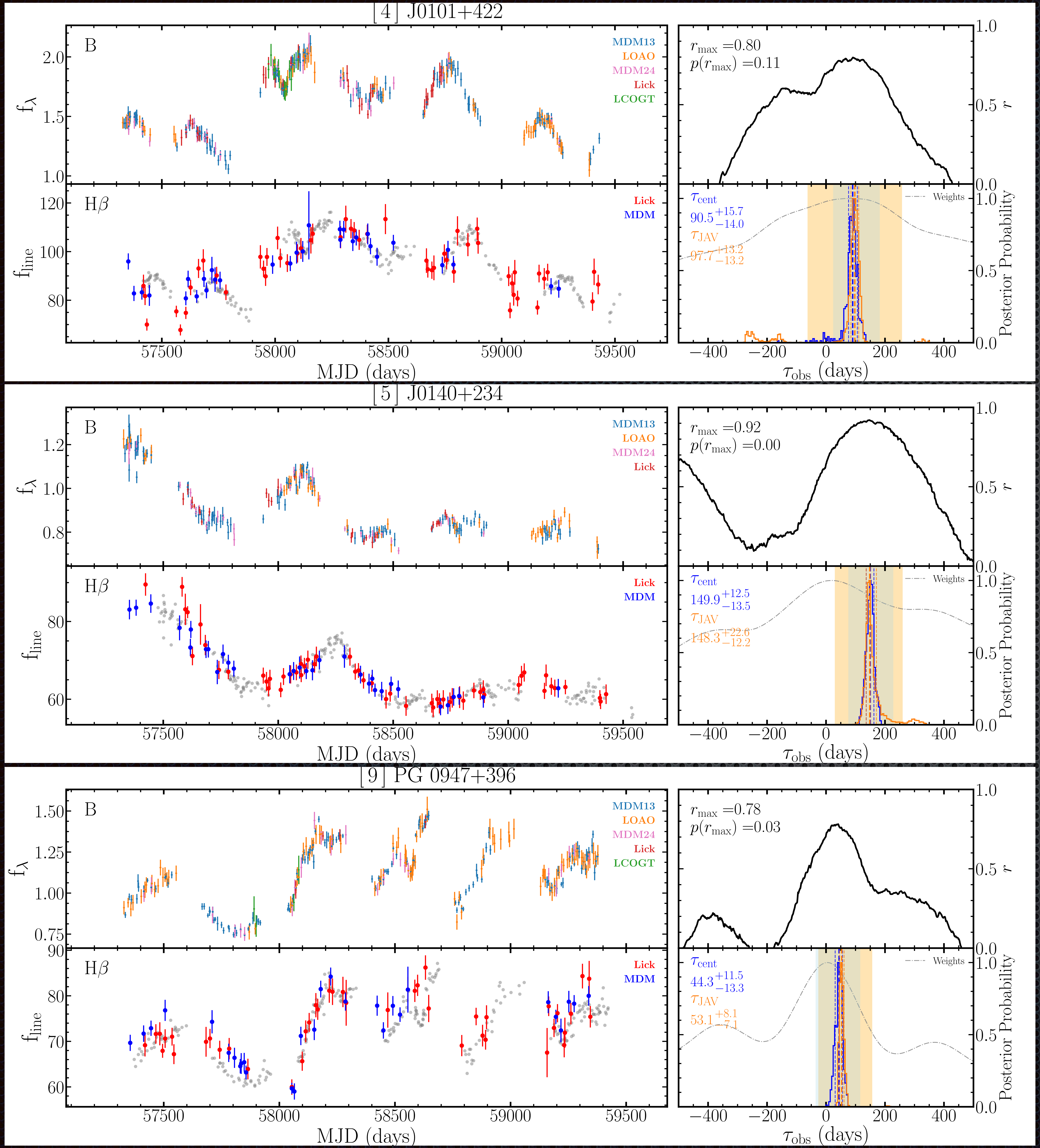
SAMP collaboration

Program PI: Jong-Hak Woo (SNU)

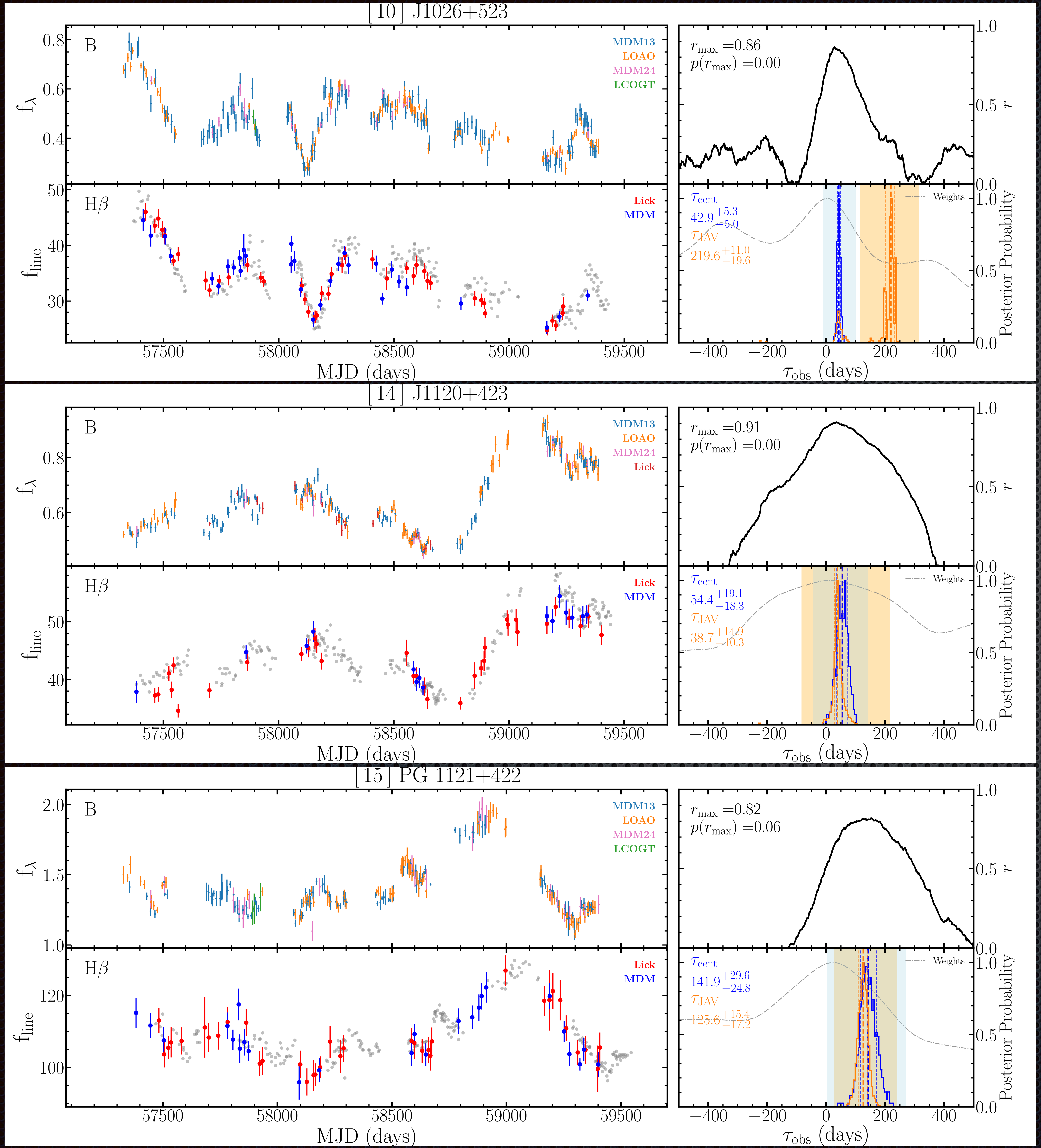
Main contribution (Co-PI):

- Tommaso Treu (UCLA)
- Elena Gallo (U-M)
- Aaron Barth (UCI)
- Vardha N. Bennert (Car Poly)

Other main contribution: Shu Wang, Donghoon Son, Suvendu Rakshit (ARIES), Hojin Cho, Edmund Hodges-Kluck (U-M), Vivian U (UCI), Jaejin Shin (KASI), Amit Kumar Mandal, Changseok Kim, Minjin Kim (KNU), Tae-Woo Kim, Hengxiao Guo (SHAO), and all participated observers



- Lag measured using **ICCF** and JAVELIN
- Select **r_{max} > 0.6 ; p-value < 0.2 ; f_{peak} > 0.6** objects as reliable sample
- **24** selected reliable objects



- Lag measured using **ICCF** and JAVELIN
- Select **r_{max} > 0.6 ; p-value < 0.2 ; f_{peak} > 0.6** objects as reliable sample
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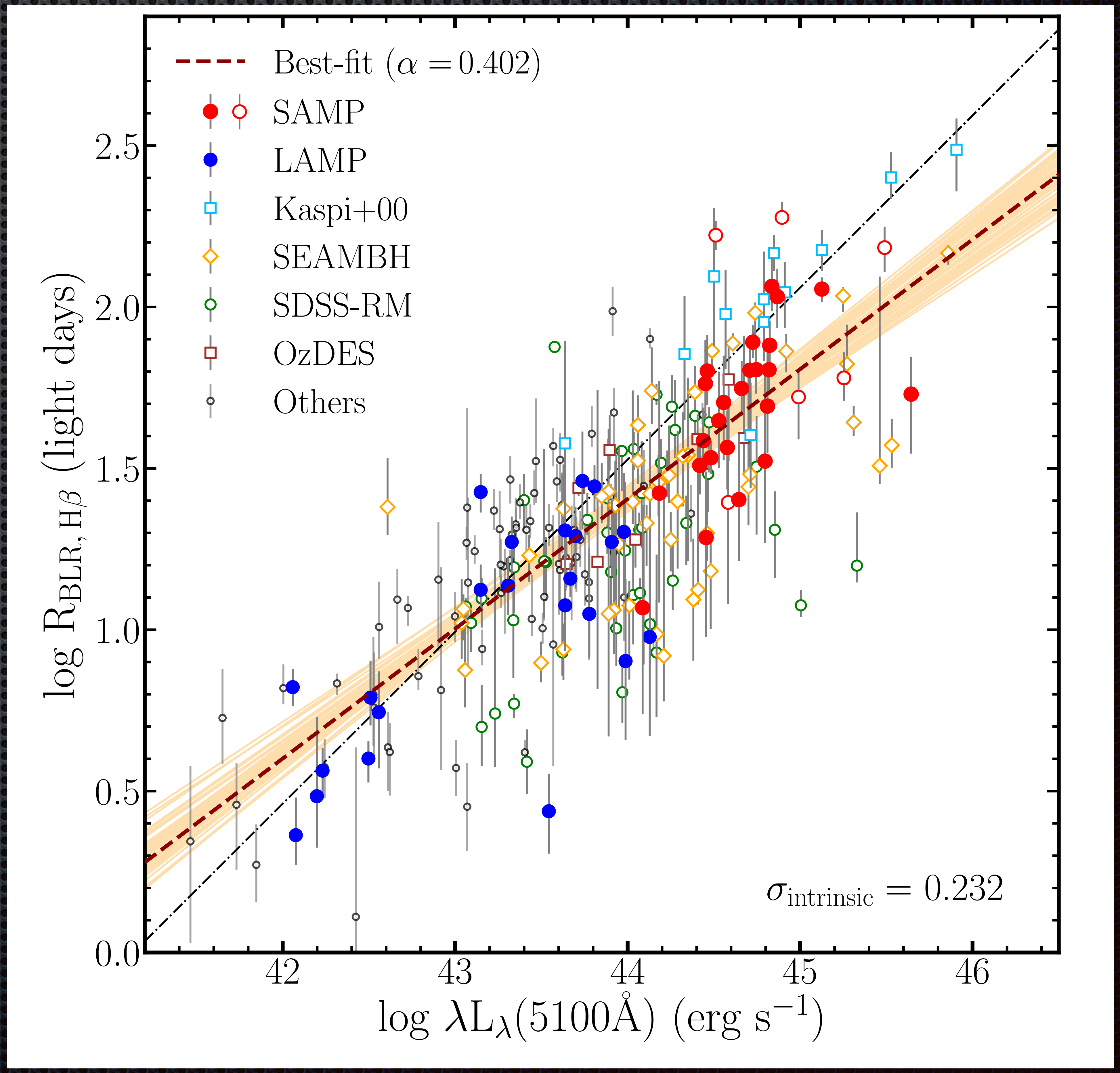
R—L relation from SAMP

1. SAMP high-luminosity AGNs are located ***beneath*** the expectation from Bentz et al. relation.

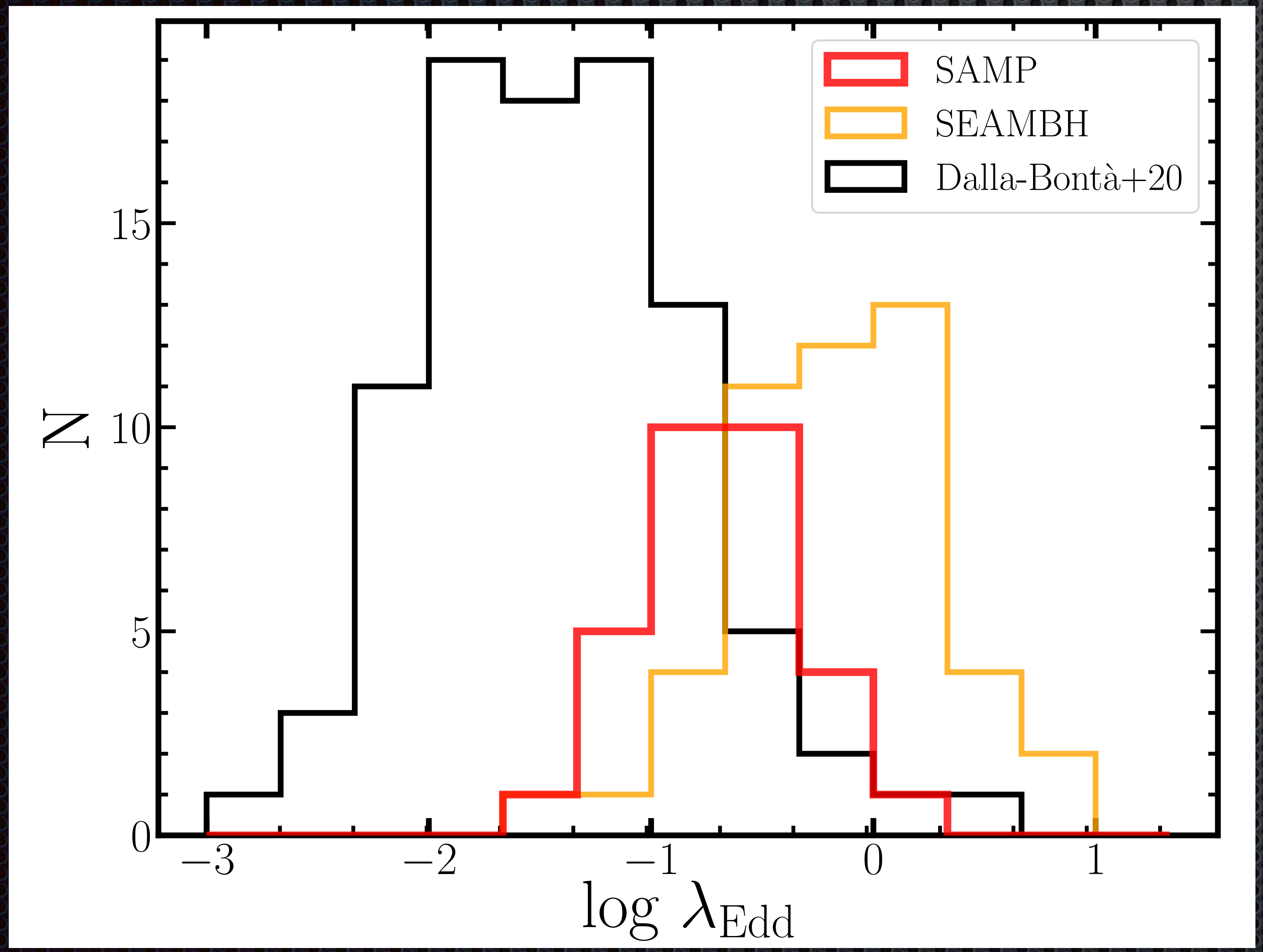
2. The best-fit **slope is around 0.4.**

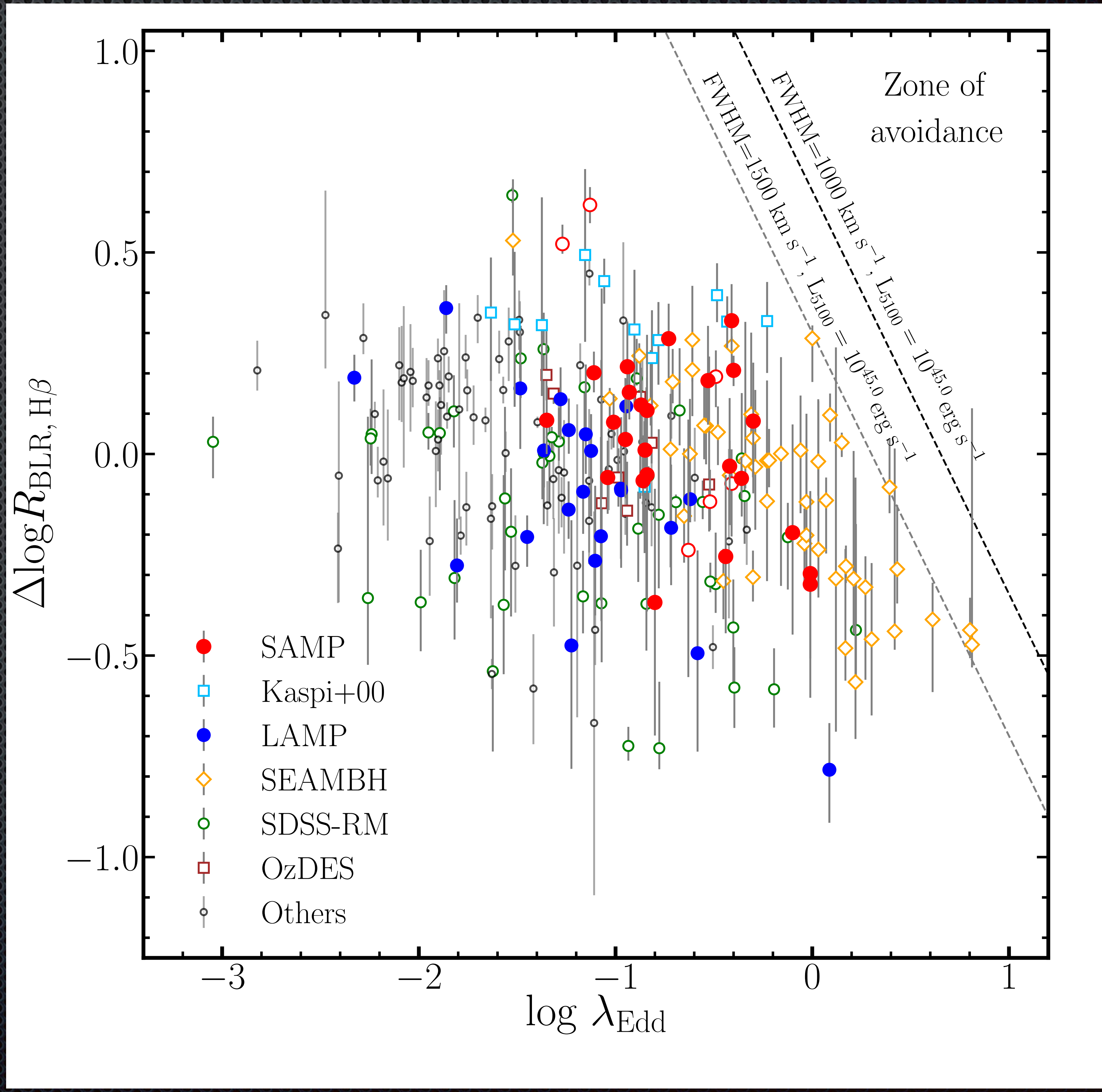


Woo et al. (2023), submitted

Deviation vs. Eddington ratio ($\lambda_{\rm Edd}$)

SAMP has moderate $\lambda_{\rm Edd}$

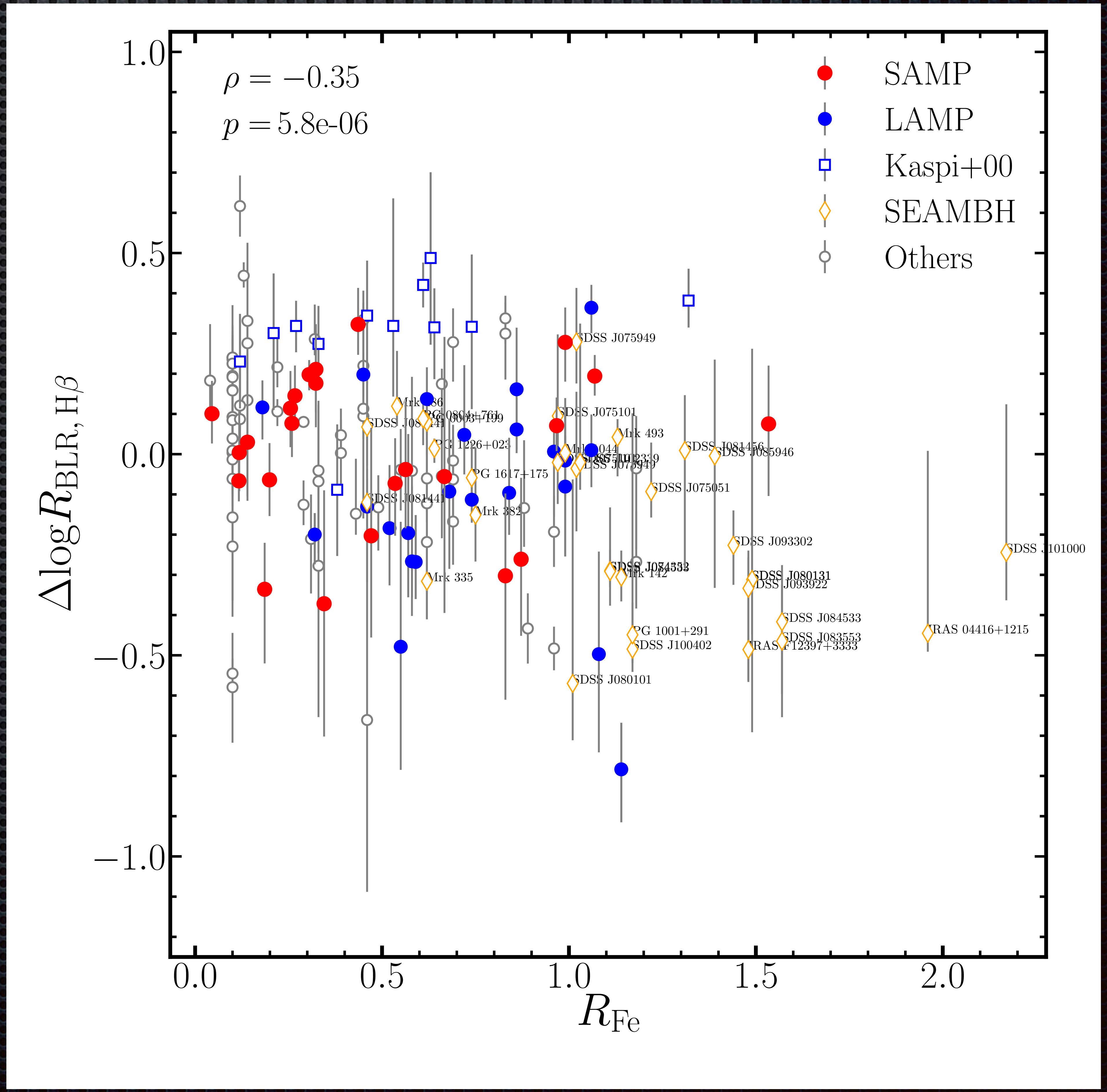




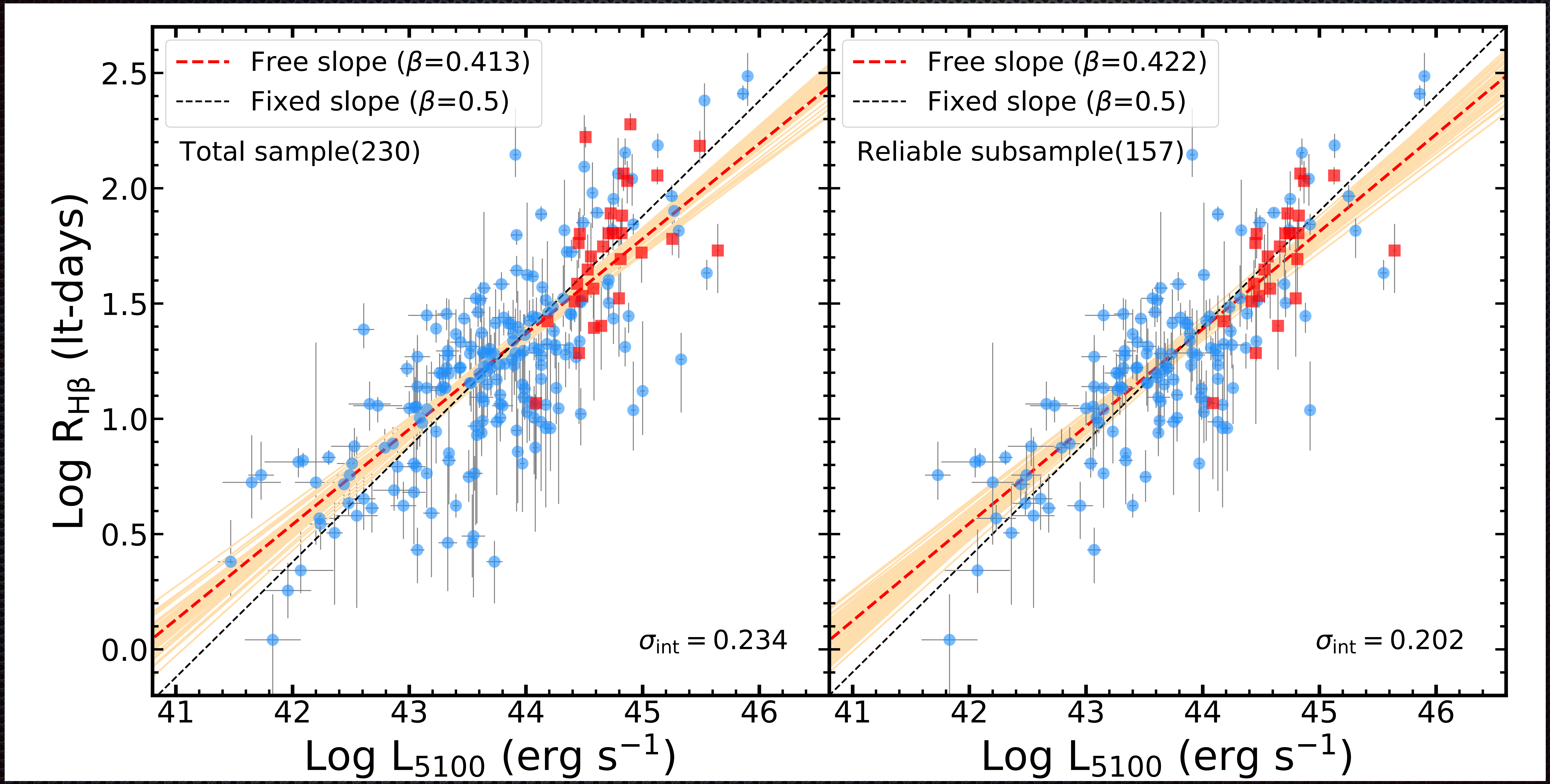
Woo et al. (2023), submitted

Deviation vs. R_{Fe}

1. There is no trend within SAMP
2. Combining with historical measurement, the **trend against R_{Fe} is present but not very strong**



Use uniform lag measurement

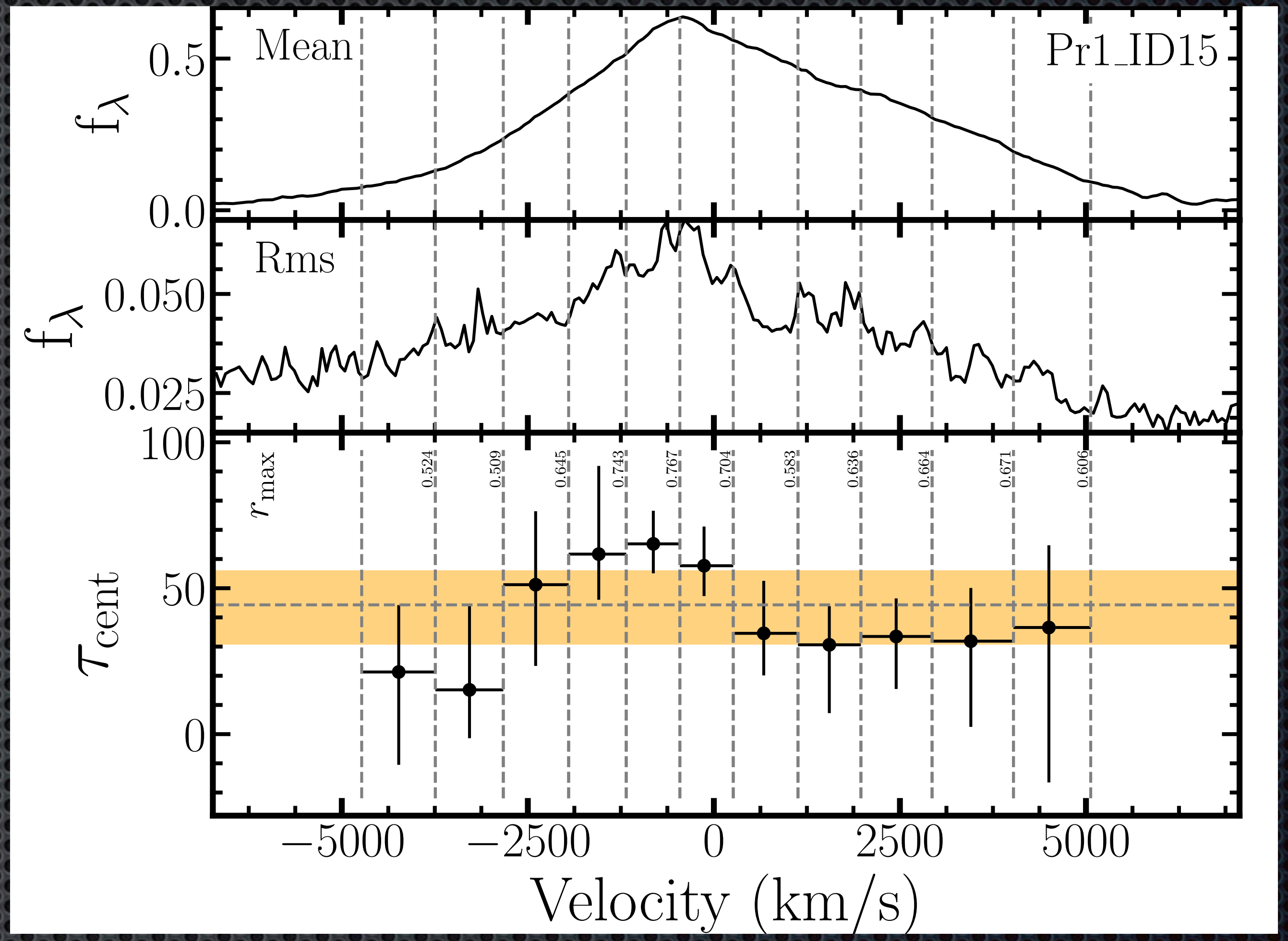


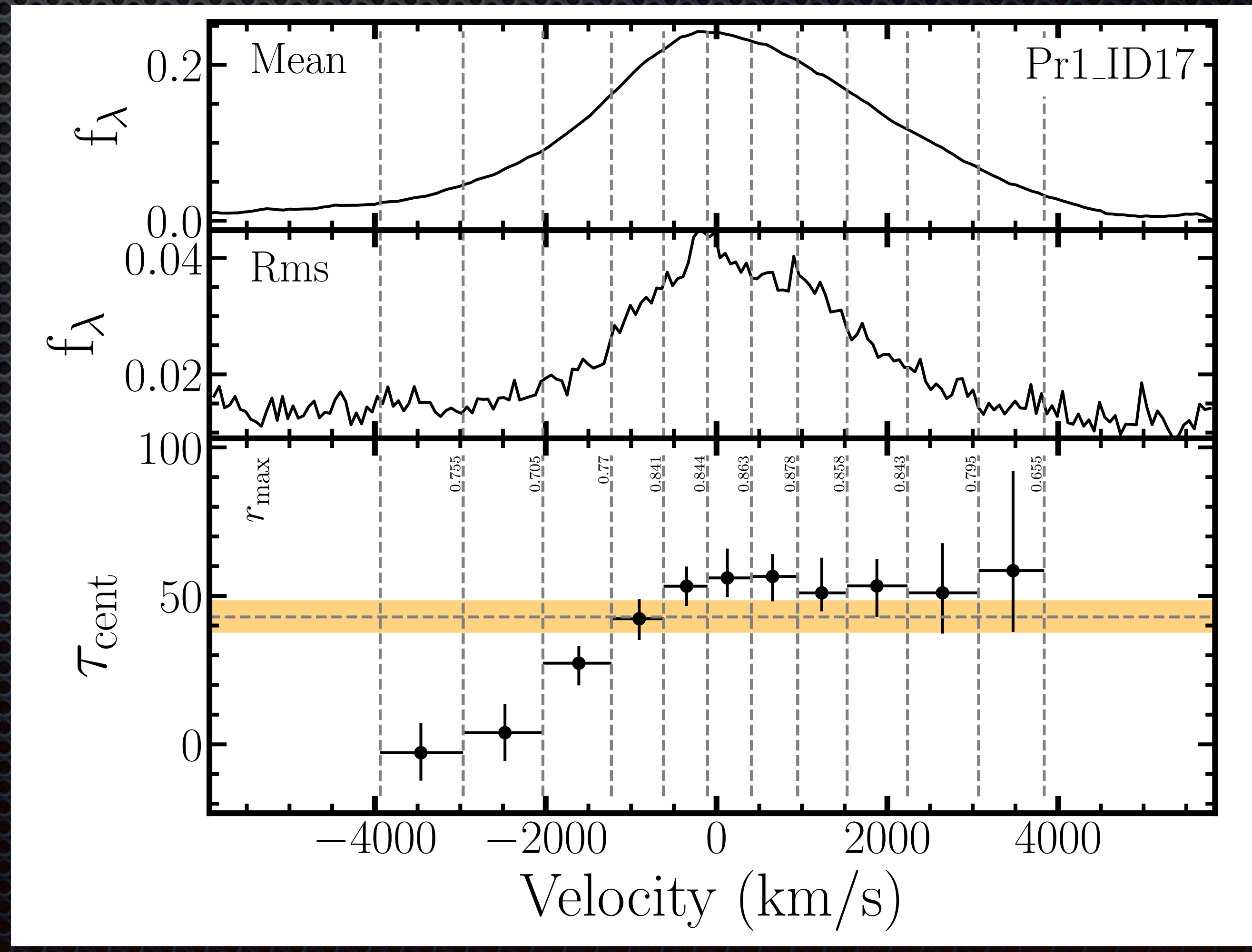
Wang et al. (2023), in preparation

What about BLR kinematics?

$$M_{\rm BH} = \frac{f\, R_{\rm BLR}\, \Delta V^2}{G}$$

- f factor is the main uncertainties in RM / SE BH mass
- Velocity Resolved RM

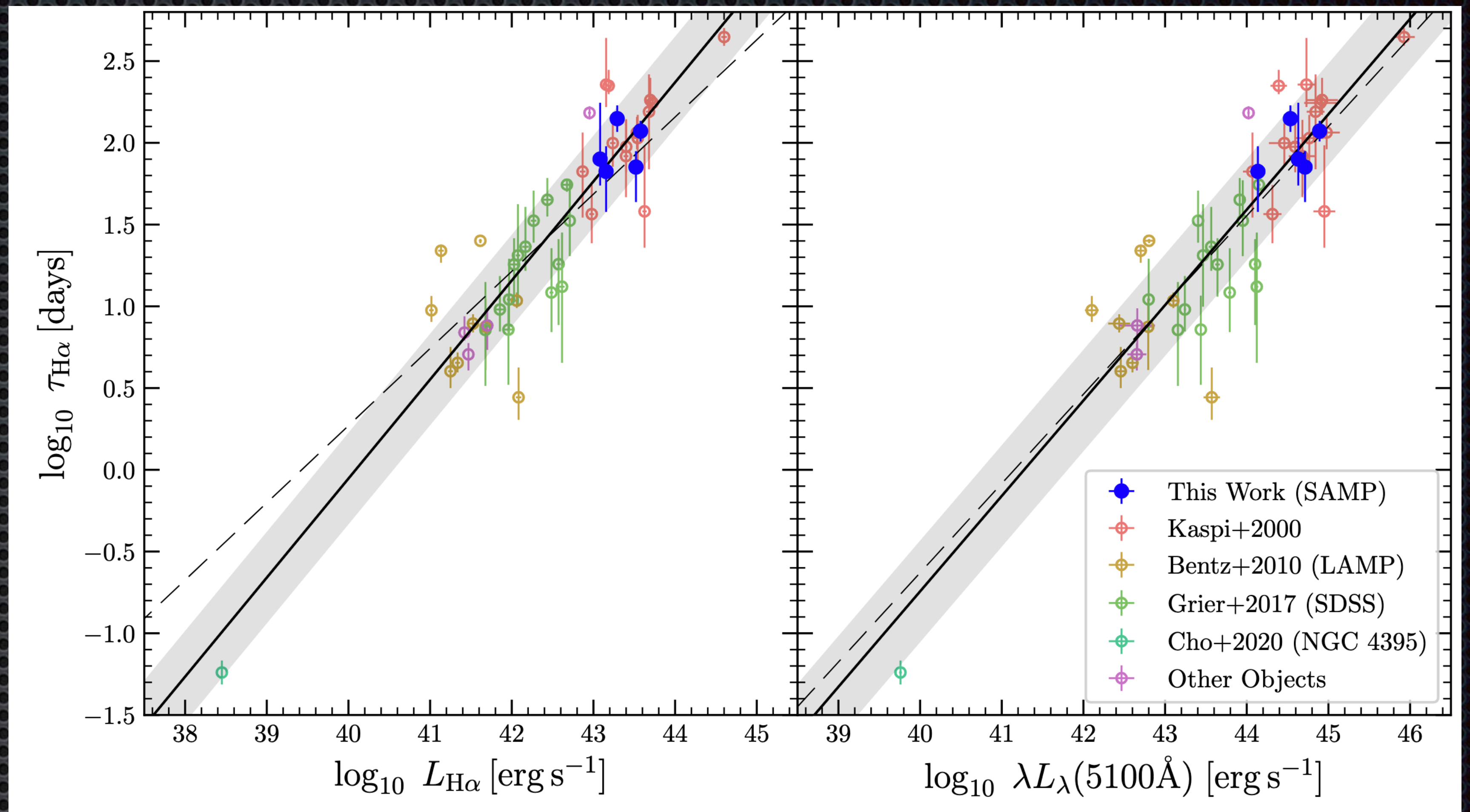




Other main results

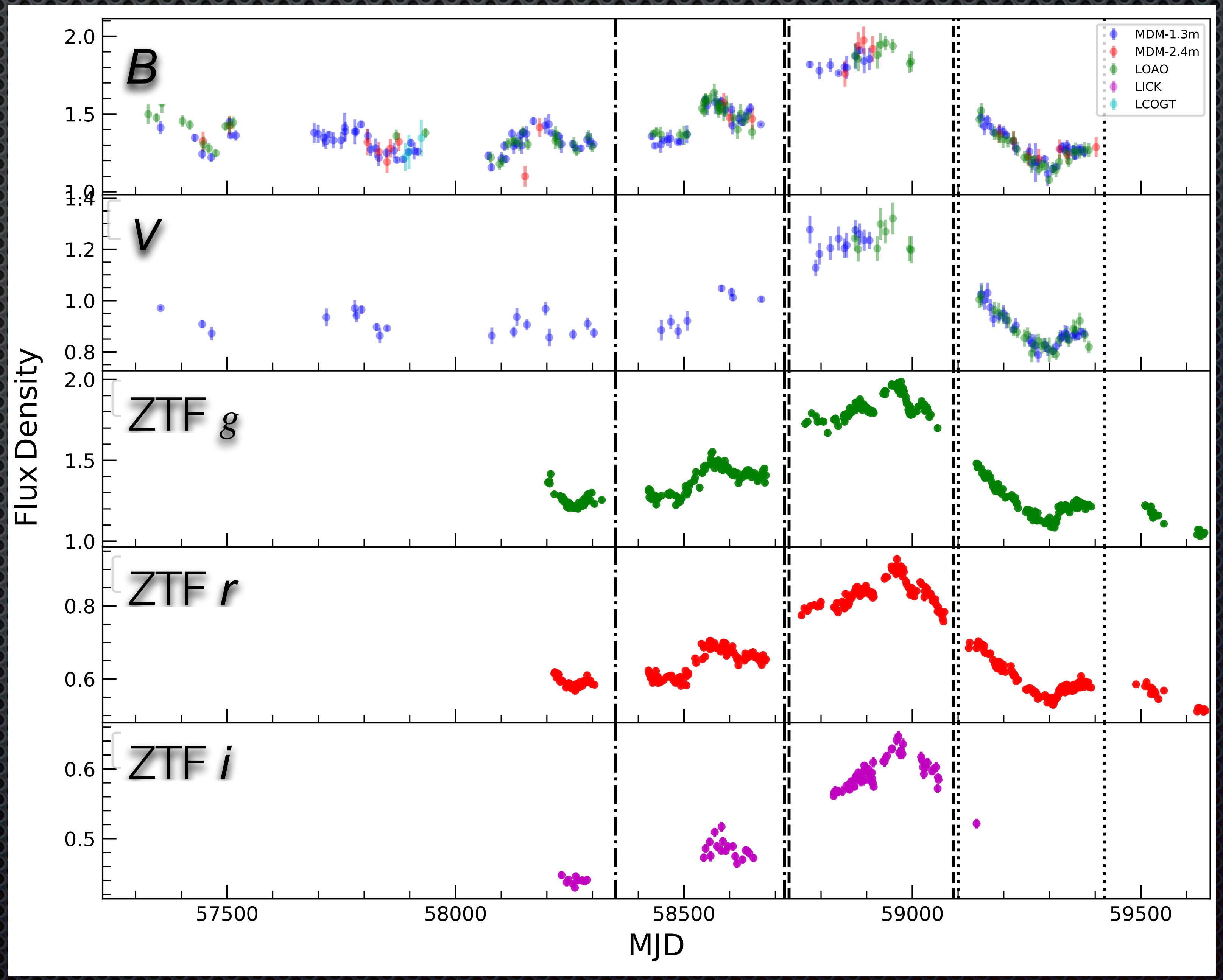
(1) $\mathbf{H}\alpha$ lags and R—L relation

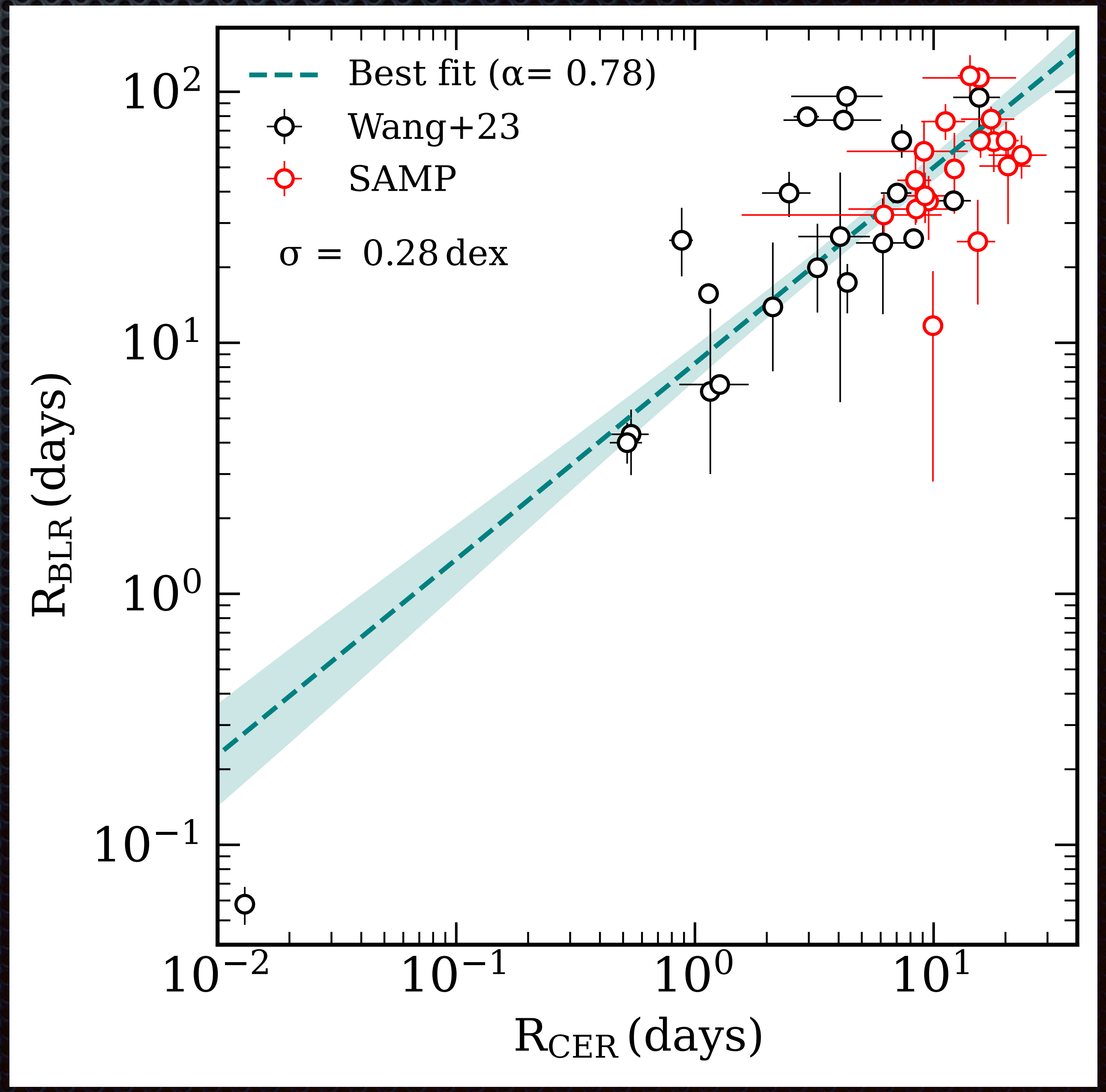
Cho et al. (2023), ApJ, accepted



(2) continuum RM

Mandal et al. (2023), in preparation





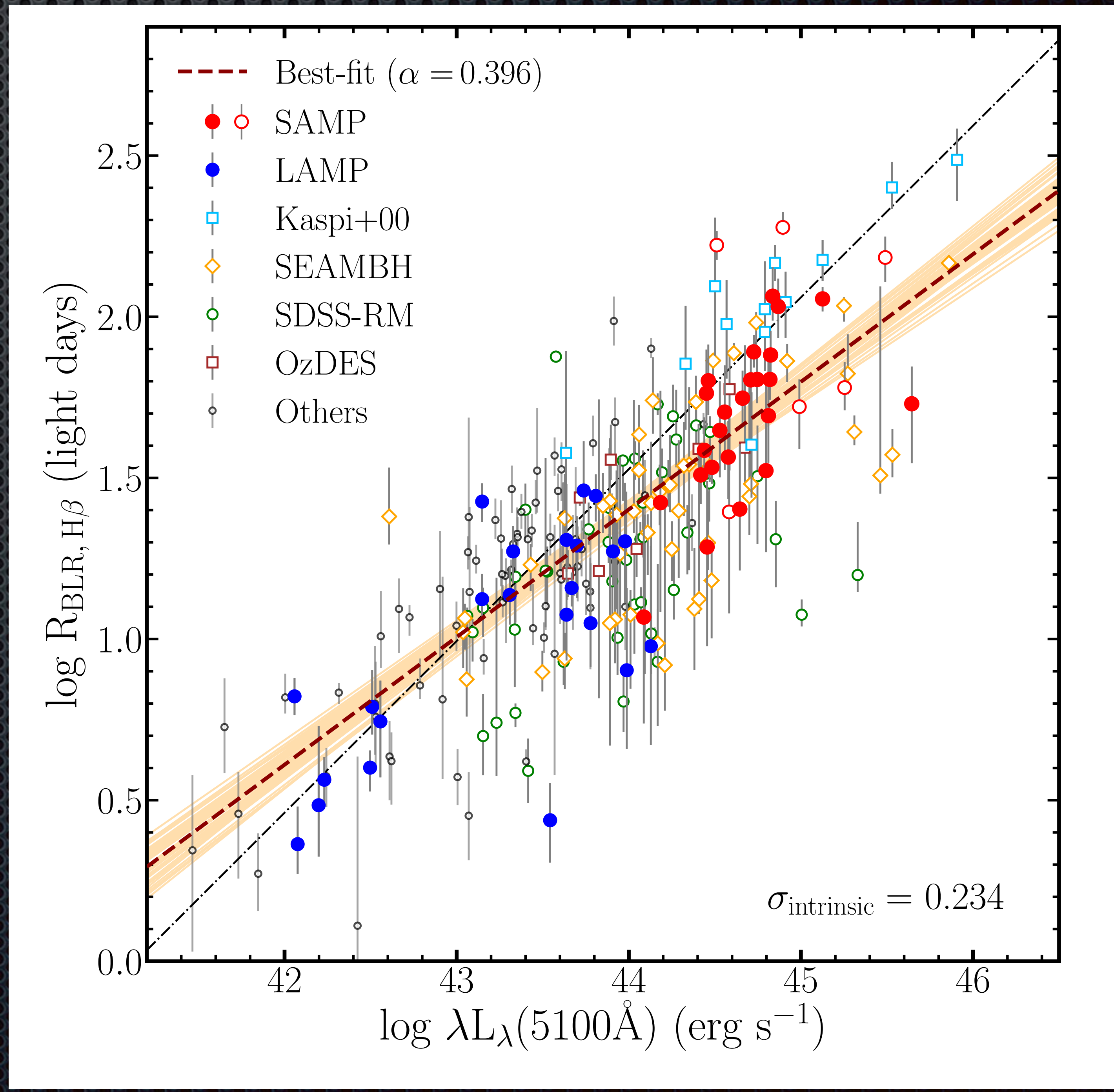
Summary

1. SAMP is a **6-year** dedicated RM program, aiming to constrain the high-luminosity end of R—L relation. (Woo et al. 2019)

2. We monitored **32 moderate to high-luminosity AGNs**, and successfully measured **24 reliable lags** (**Woo et al. 2023**)

3. These high-luminosity AGNs are located ***beneath*** the expectation from Bentz et al. relation. The best-fit **slope is around 0.4**. An uniform lag analysis is needed for understanding the relation between deviation and AGN parameters.

4. Velocity-resolved lags are measured for ~15 objects (Wang et al. 2023b, in prepration)



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