AGN Continuum Reverberation Mapping: Diffuse Continuum

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Outline

Background for Continuum Reverberation Mapping

Q: why the lag inferred disk size is larger than the SSD prediction?

Main Projects:

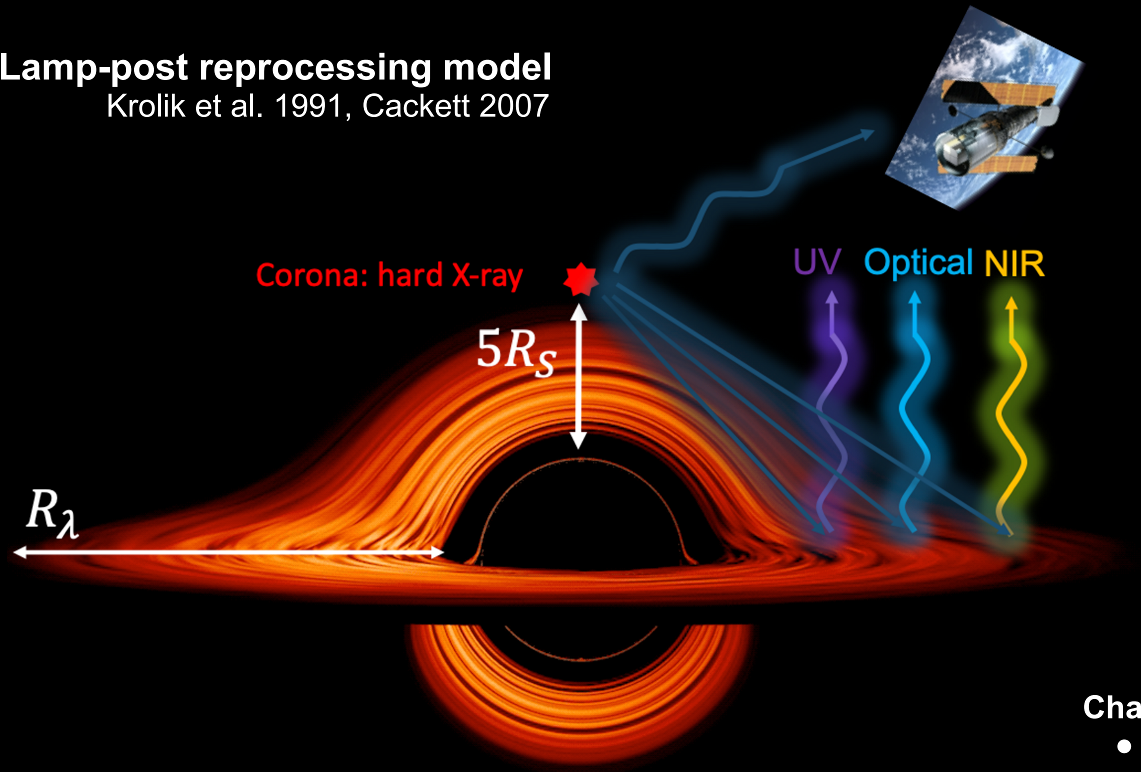
- Largest sample: AGN Continuum Reverberation Mapping Based on ZTF Light Curves
- IMBH: Optical Continuum Reverberation in the Dwarf Seyfert Nucleus of NGC 4395

Future prospects:

- Reverberation Mapping for Intermediate-Mass Black Holes

Continuum reverberation mapping

Lamp-post reprocessing model
Krolik et al. 1991, Cackett 2007



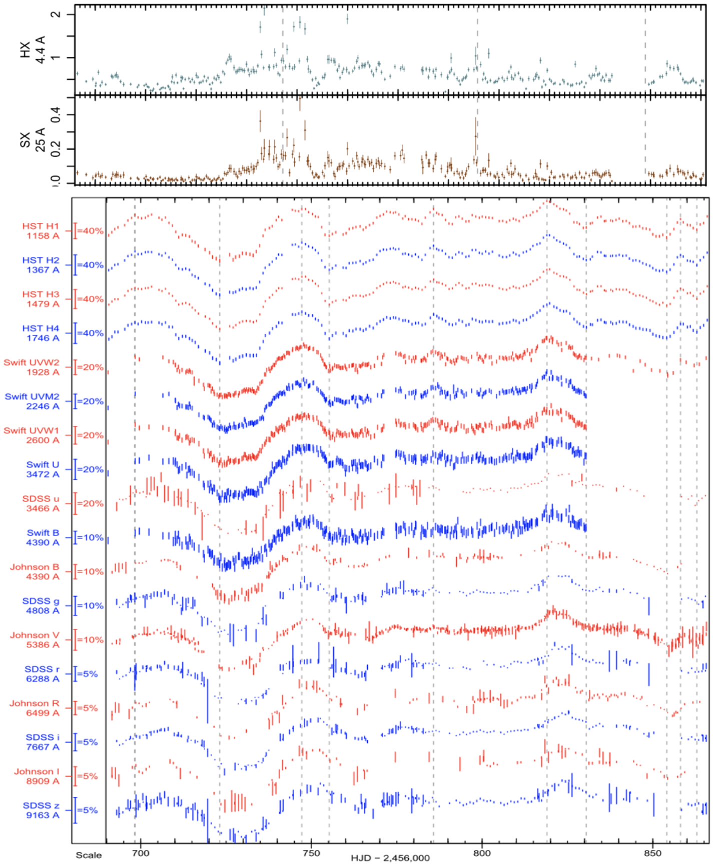
Credit: NASA's Goddard Space Flight Center/Jeremy Schnittman

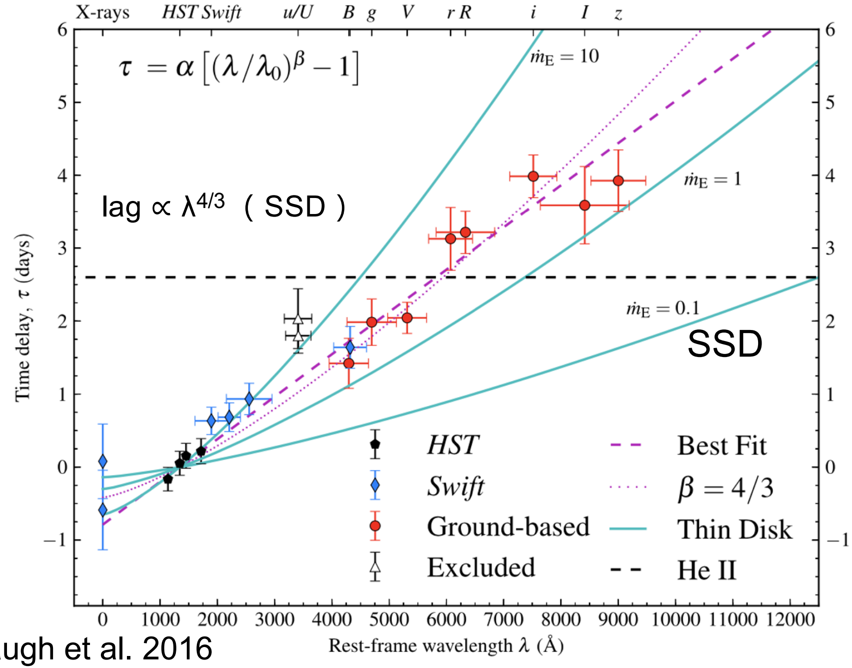
Challenges :

- **disk size**
- **negative lag**

See Zhenyi Cai's talk

Continuum RM for NGC 5548 (AGN STORM 1)





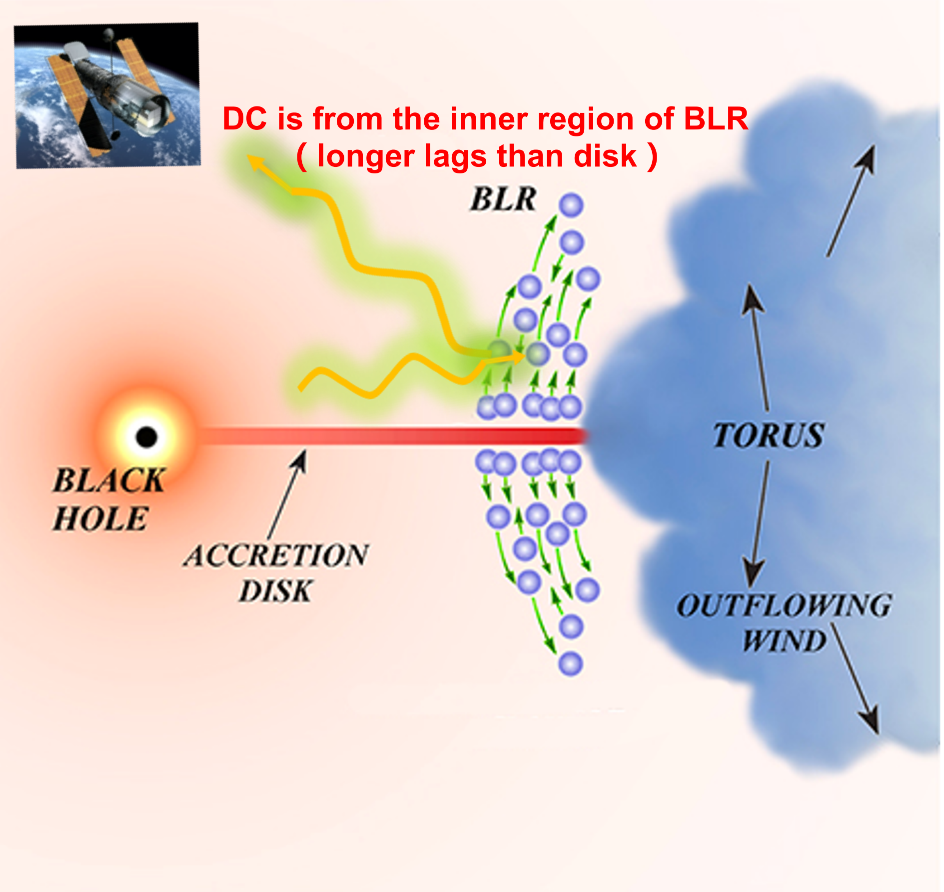
Fausnaugh et al. 2016

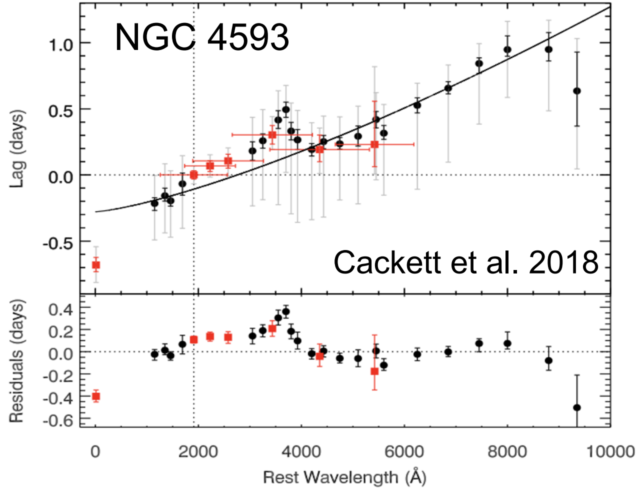
1) **Observed lags are larger than SSD prediction**

1) **U/u band lag excess**

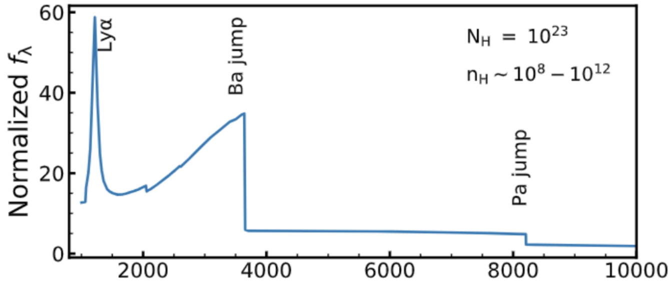
Diffisue Continuum

Diffuse continuum from BLR





Diffuse Continuum (DC) spectrum



DC = H, He free–bound+ free–free+ scattering

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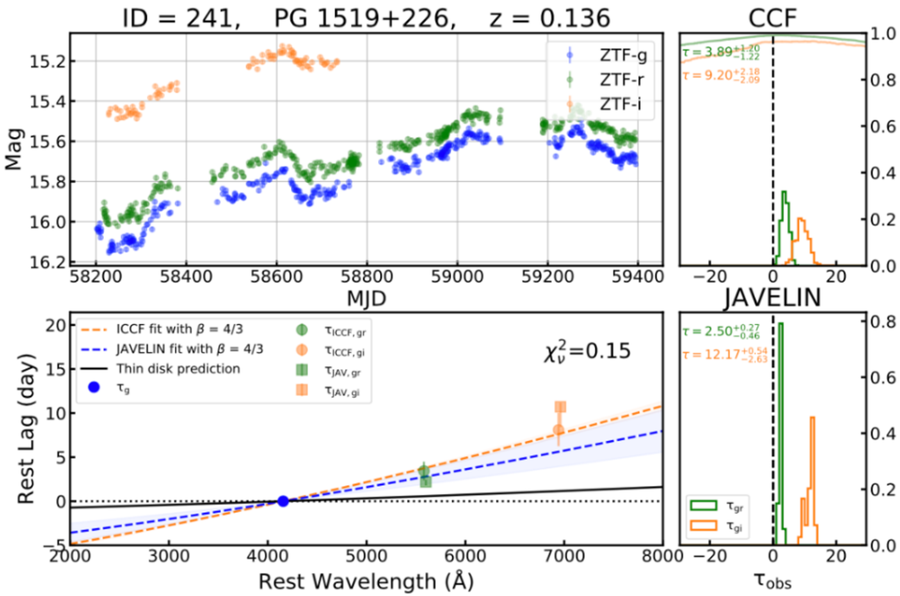
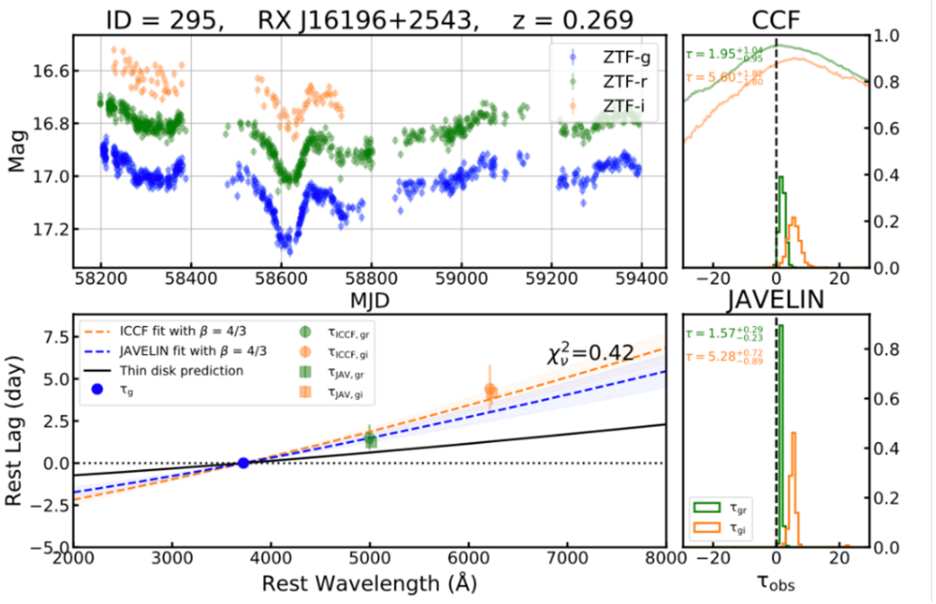
Continuum RM for Bright AGNs in ZTF Survey

- Sample：94 radio-quiet type 1 AGNs with z < 0.8 and BH mass
- Criteria: significant continuum lag (r_max, p-value, lag consistency, lag error)

Guo et al. 2022b

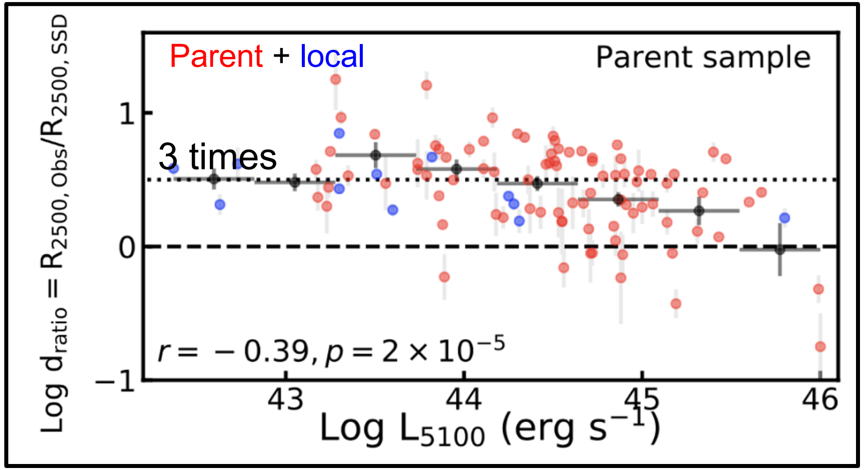


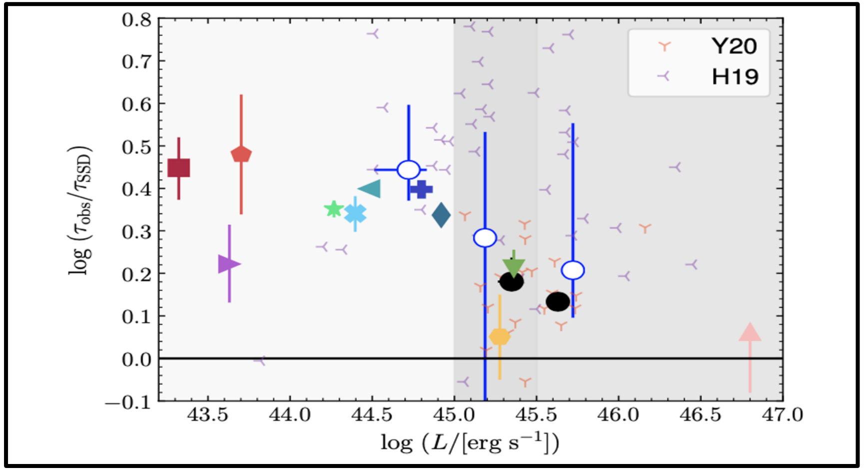


$$\tau = \frac{R_{\lambda_0}}{c}\left[\left(\frac{\lambda}{\lambda_0}\right)^{\beta} - 1\right],$$

$$R_{\lambda,\mathrm{SSD}} = \left(X\frac{k\lambda}{hc}\right)^{4/3}\left[\left(\frac{GM_{\mathrm{BH}}}{8\pi\sigma}\right)\left(\frac{L_{\mathrm{E}}}{\eta c^2}\right)(3+\kappa)\dot{m}\right]^{1/3}$$

Baldwin effect for diffuse continuum (DC)?





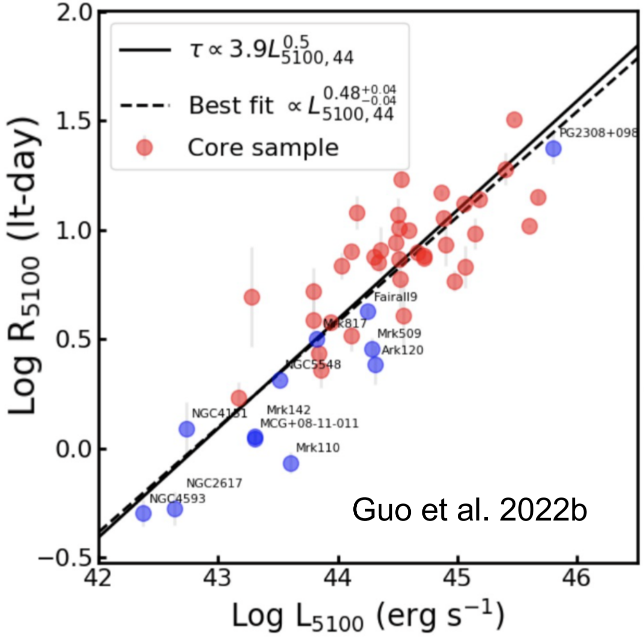
Li, Sun et al. 2021

also see Guo W.J. et al. 2022

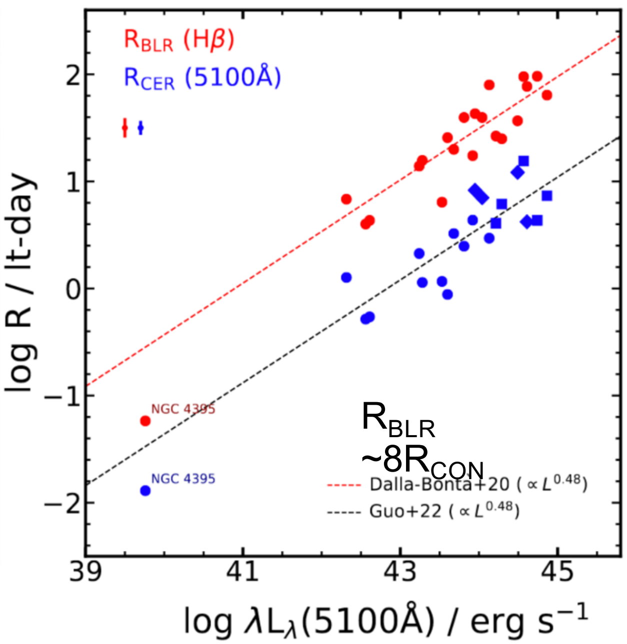
- **Confirm the unexpected large disk size**
- **DC contribution to the observed optical continuum decreases with increasing luminosity**

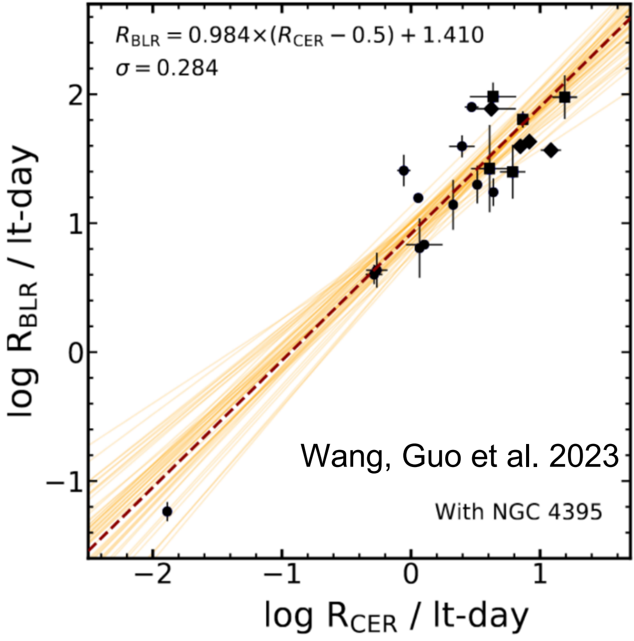
R-L relation of diffuse continuum

R-L relation



Estimate reverberation BH mass via CRM





Evidence to support the major contribution of DC (also see Netzer 2021)

1) easy for a large AGN sample, e.g., LSST
2) lags are very short, possible for high-z quasar

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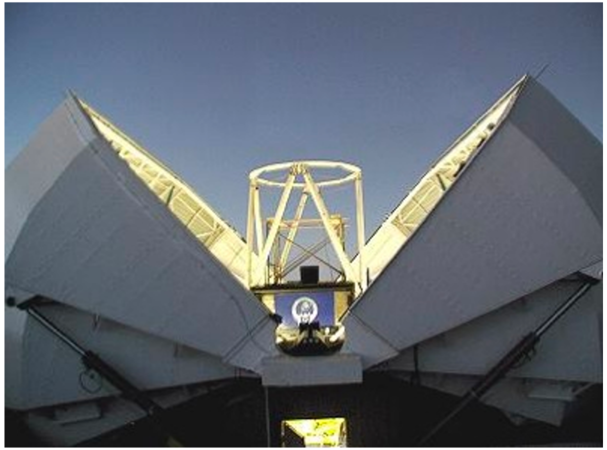
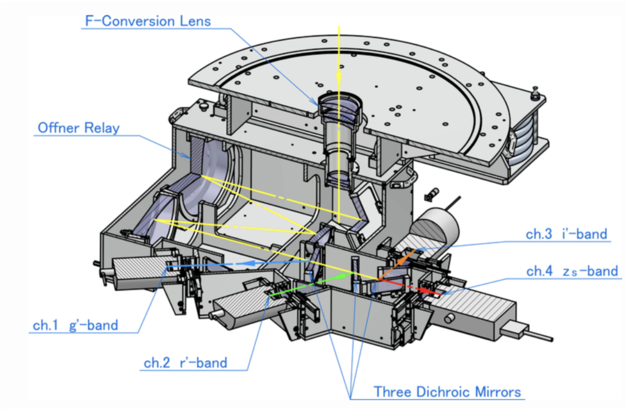
NGC 4395

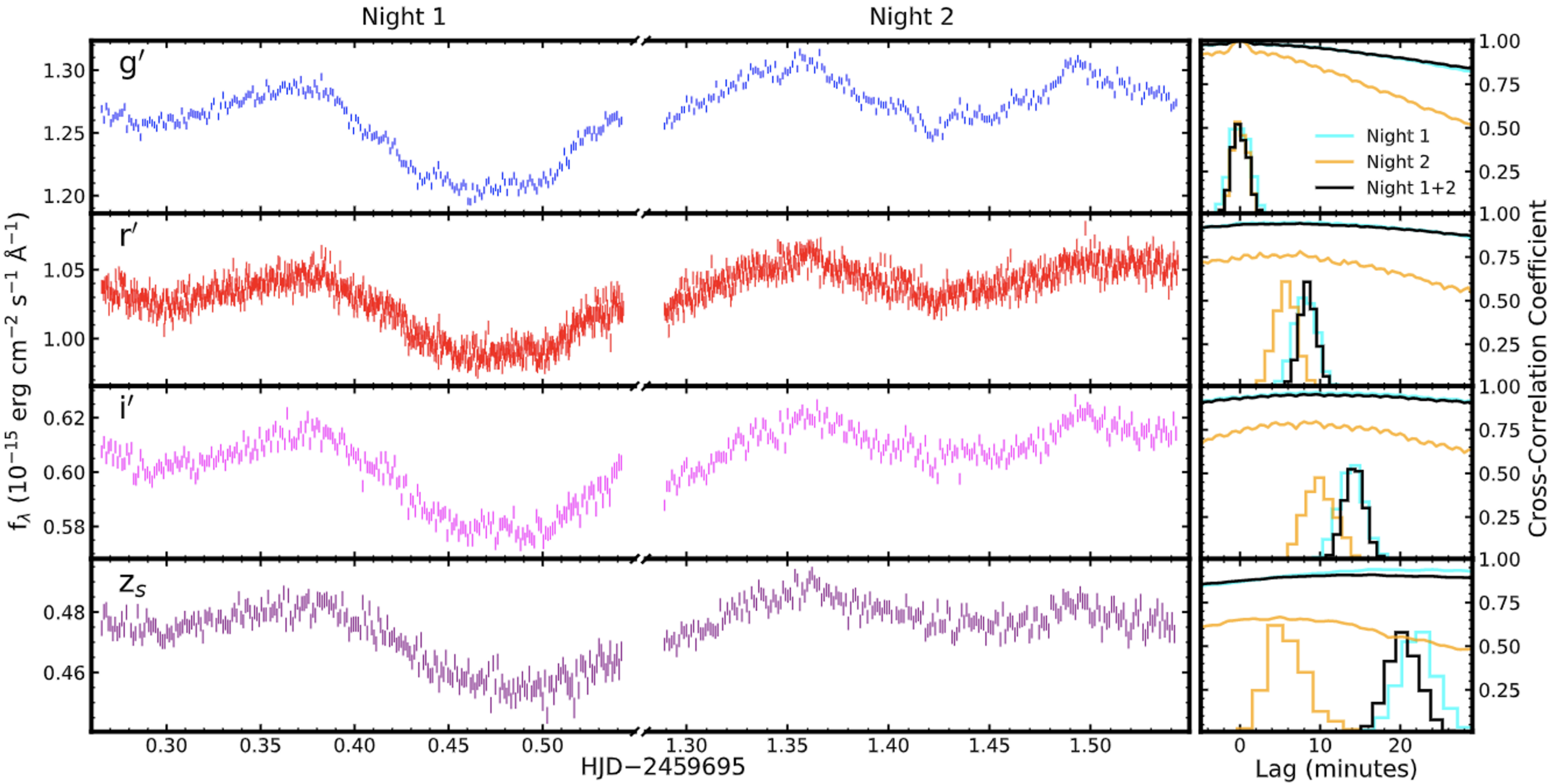
Haleakala Observatory, on Maui, Hawaii





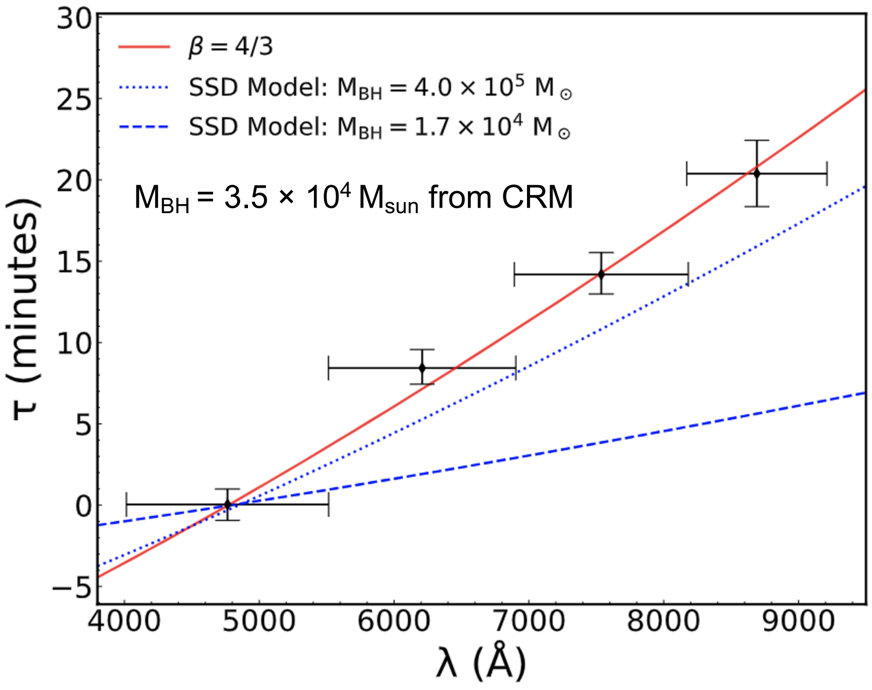
LCOGT
MuSCAT3 (four-channel imager) on 2m FTN telescope

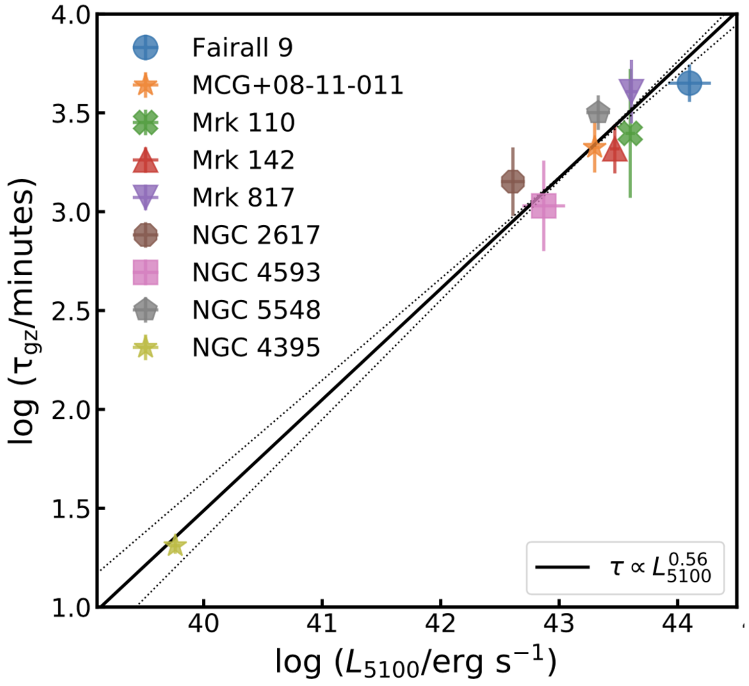
Continuum light curves of NGC 4395



Montano, Guo, Barth et al. 2022 (also see Mchardy et al. 2023)

Wavelength-lag & R- L relation





Continuum emtting size is larger than SSD prediction

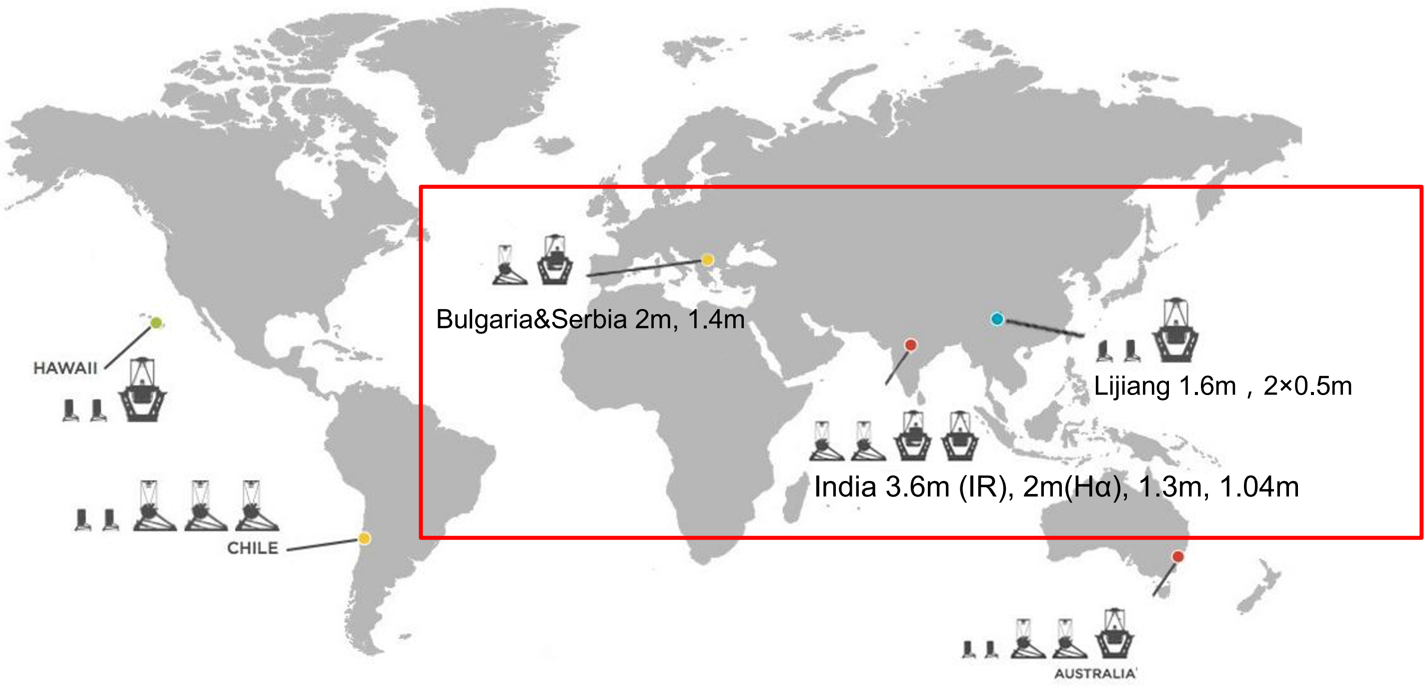
Slope is consistent with 0.5

DC is dominated in the observed continuum lags in IMBHs

Montano, Guo et al. 2022

CRM& BLR RM for NGC 4395 this April (2 nights)

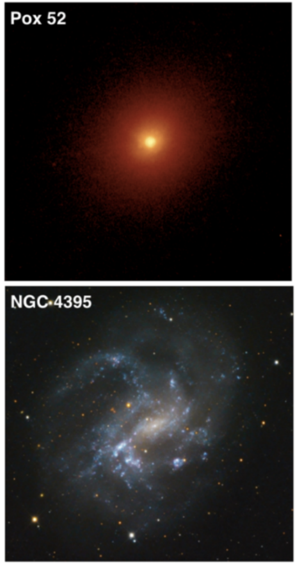
Mini AGN STORM

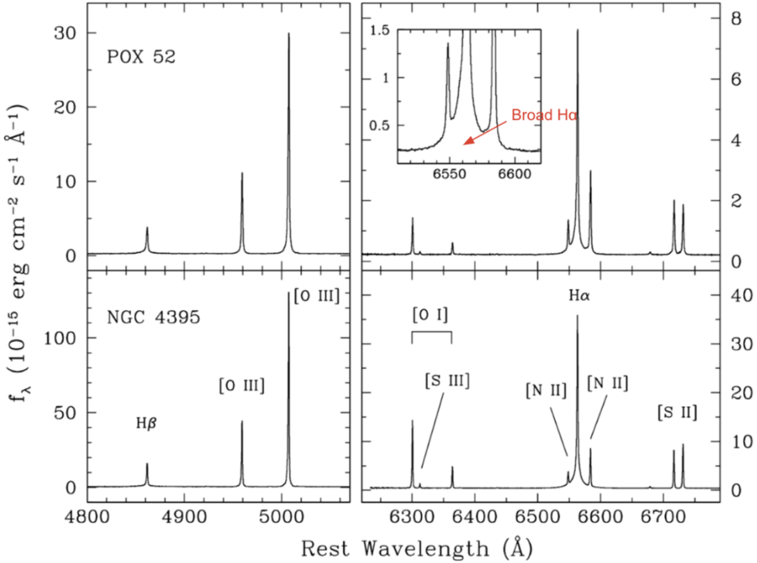


Swift & AstroSat (NUV, FUV), Chandra (X-ray)

Other IMBH candidates

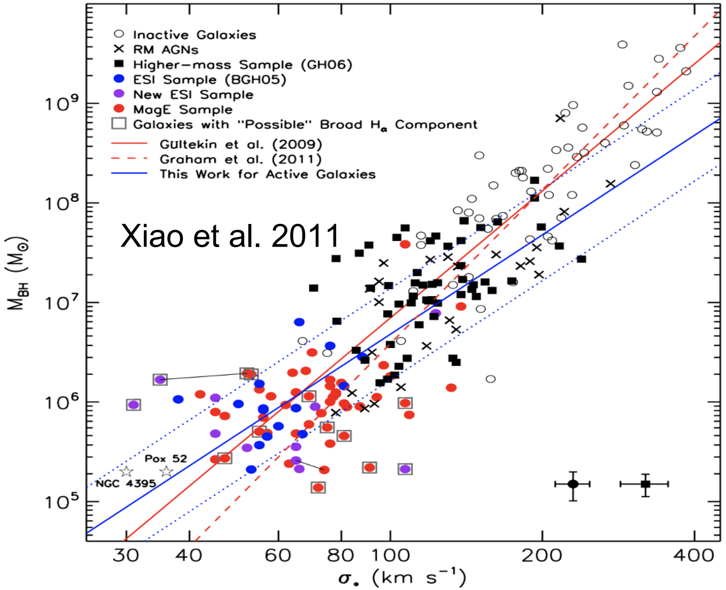
POX 52





MuSCAT4 on 2m FTS / Siding Spring Obs. (This November)

Other candidates



Greene+07,Dong+12,Liu+18,Chilingarian+18

IMBH-photoRM Project

IMBH-photoRM project (BLR RM & CRM)

Goals:

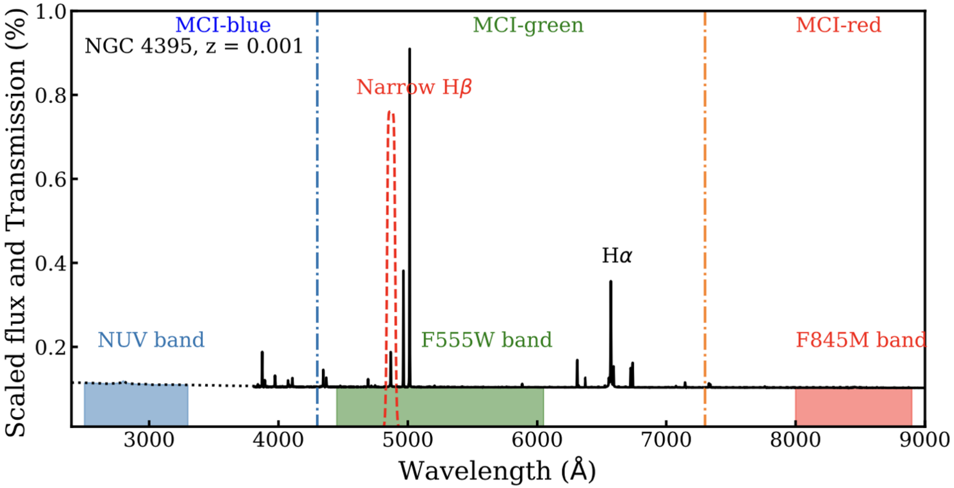
- Probe the continuum and BLR lag for 10-20 IMBHs
- Obtain the (semi) reverberation BH mass
- Measure the accretion disk size
- Extend the R-L relation (DC, Hβ, and Hα) to low mass regime

Telescope: ground-based and space telescope (XMM-Newton, Chandra, CSST/MCI)

Unique merits:

- Short lags and short monitoring baseline
- Accessable for small telescopes (1-2 m)
- Micro-variability detection with MCI (high resolution, less host contamination)

Chinese Survey Space Telescope/Multi-Channel Imager (CSST/MCI)



Take-away messages

- **DC must have contributions (10%-50+%, Guo22a) to the observed continuum lags**
- **CRM will be a good method to estimate the reverberation BH mass in LSST era**
- **Stay tuned for our IMBH-photoRM results (welcome to join us)**

Contact information:
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Thanks for your attention！