DARK ENERGY SURVEY

OzDES

Mapping the Growth of Supermassive Black Holes with DECam

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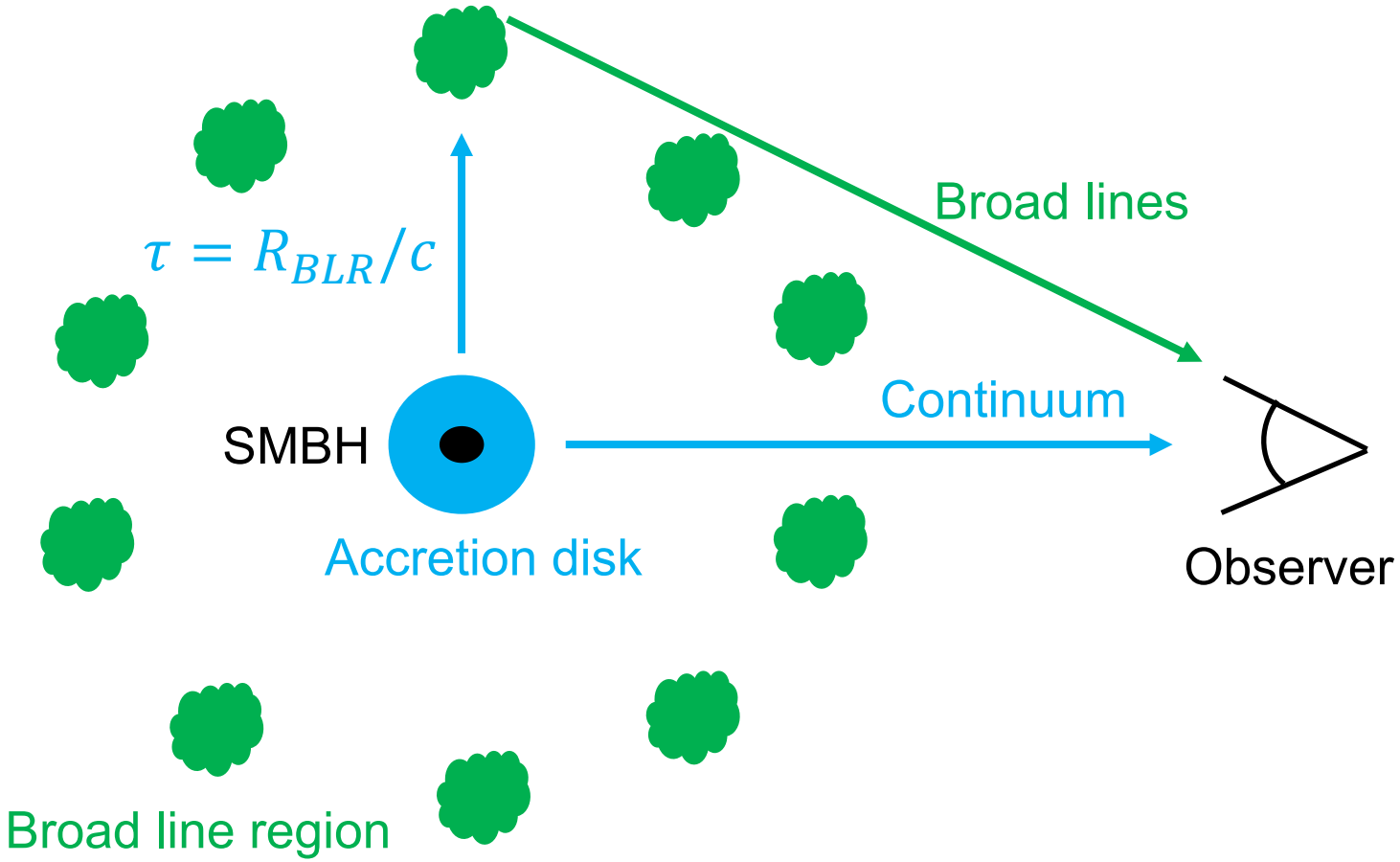
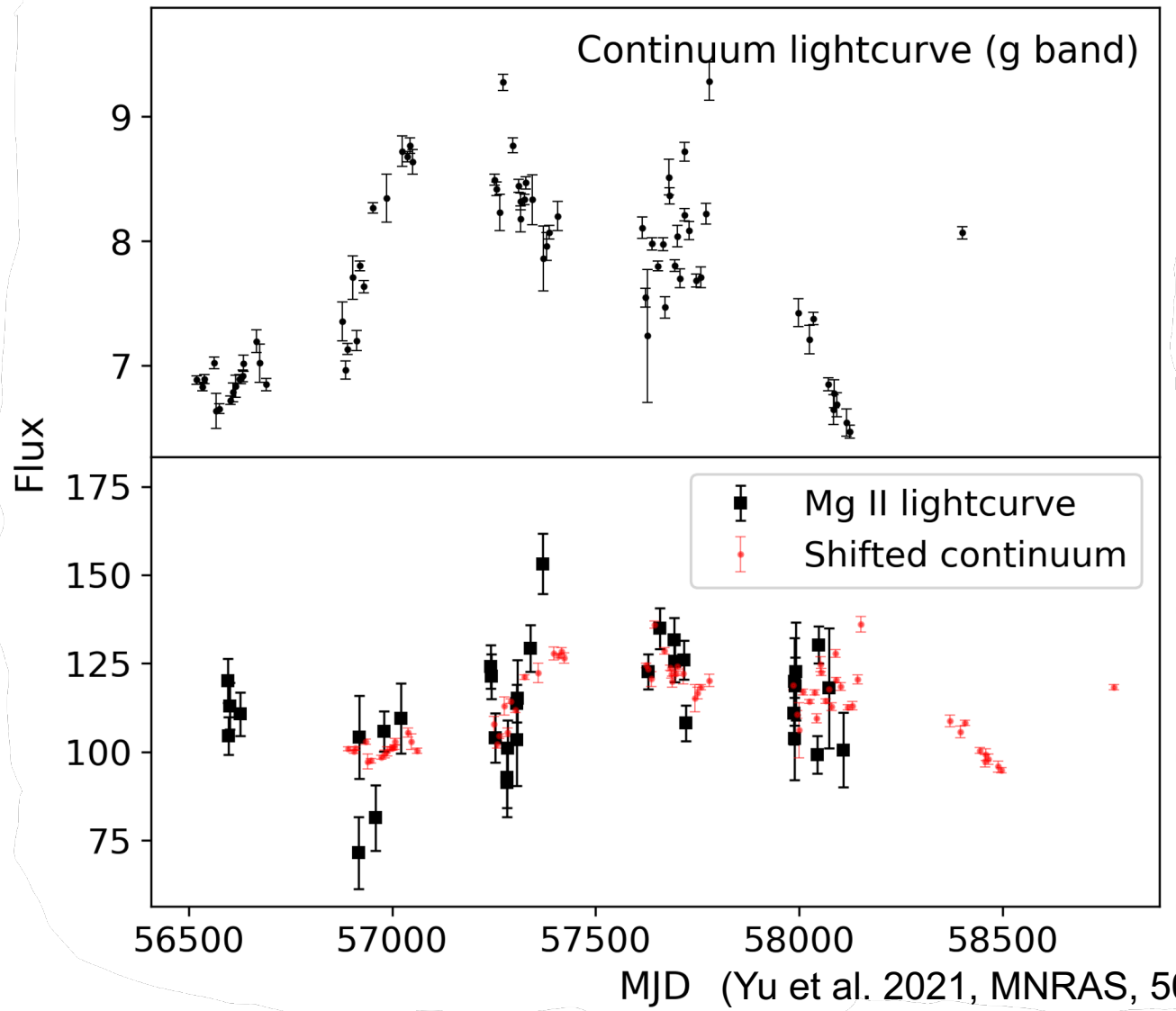
Mass of Supermassive Black Holes

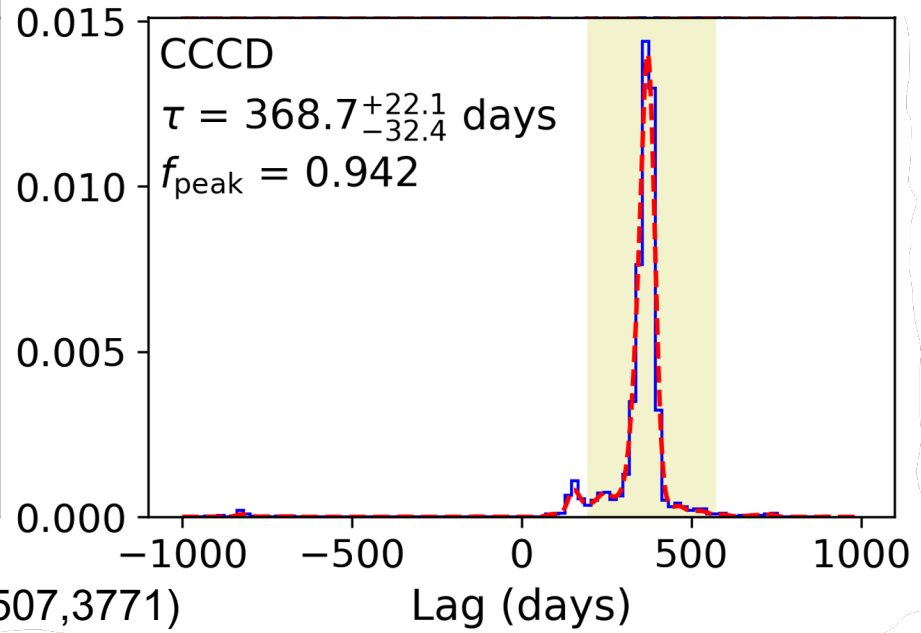


- BH mass: a critical parameter for SMBH studies
- Reverberation mapping: most accurate method to measure the BH mass in AGNs beyond the local universe
- AGN broad line variability echoes the continuum variability
- Time lag τ → BLR size R_{BLR}
- BH mass: $M_{\rm BH} = \dfrac{f c \langle \tau \rangle \Delta v^2}{G}$

RM Lag measurements

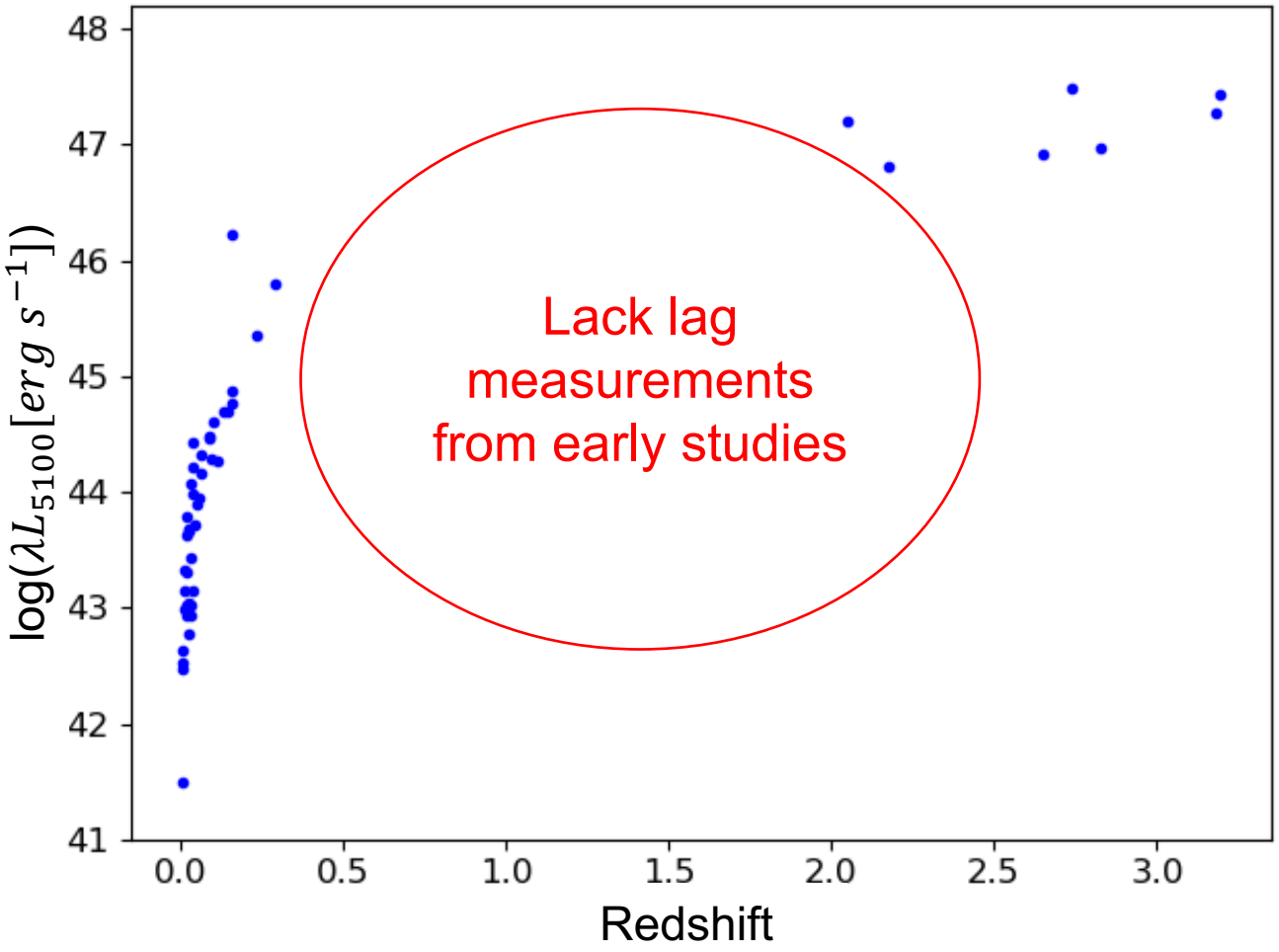


- Time lag from lightcurves: observationally expensive
- R–L relation: allows single-epoch BH mass estimates



(Yu et al. 2021, MNRAS, 507,3771)

“Industrial scale” RM: motivations



(Early measurements: Peterson et al. 2004 , Kaspi et al. 2007, Bentz et al. 2009, Denney et al. 2010, Barth et al. 2011a,b, Grier et al. 2012, Trevese et al. 2014)

- Early RM results: limited sample size and parameter-space coverage

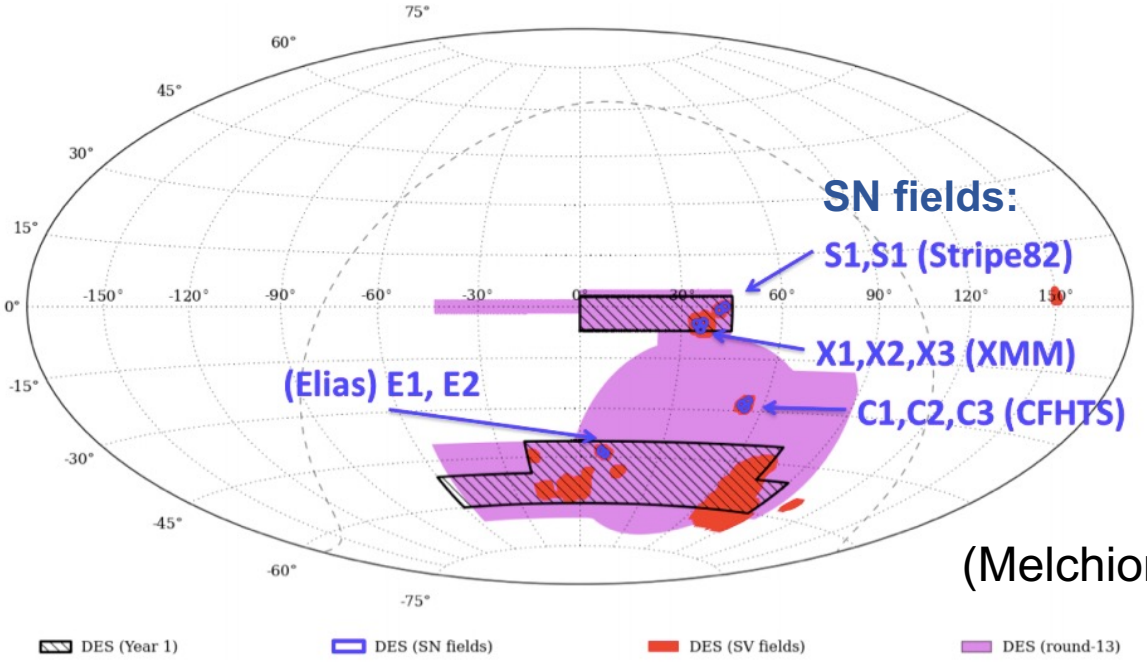
  → Poorly constrained R – L relation for Mg II and C IV (critical for high redshifts)

- “Industrial scale” RM: large and homogeneous sample, long monitoring baseline

  (e.g., SDSS RM project, OzDES RM project)

OzDES RM project

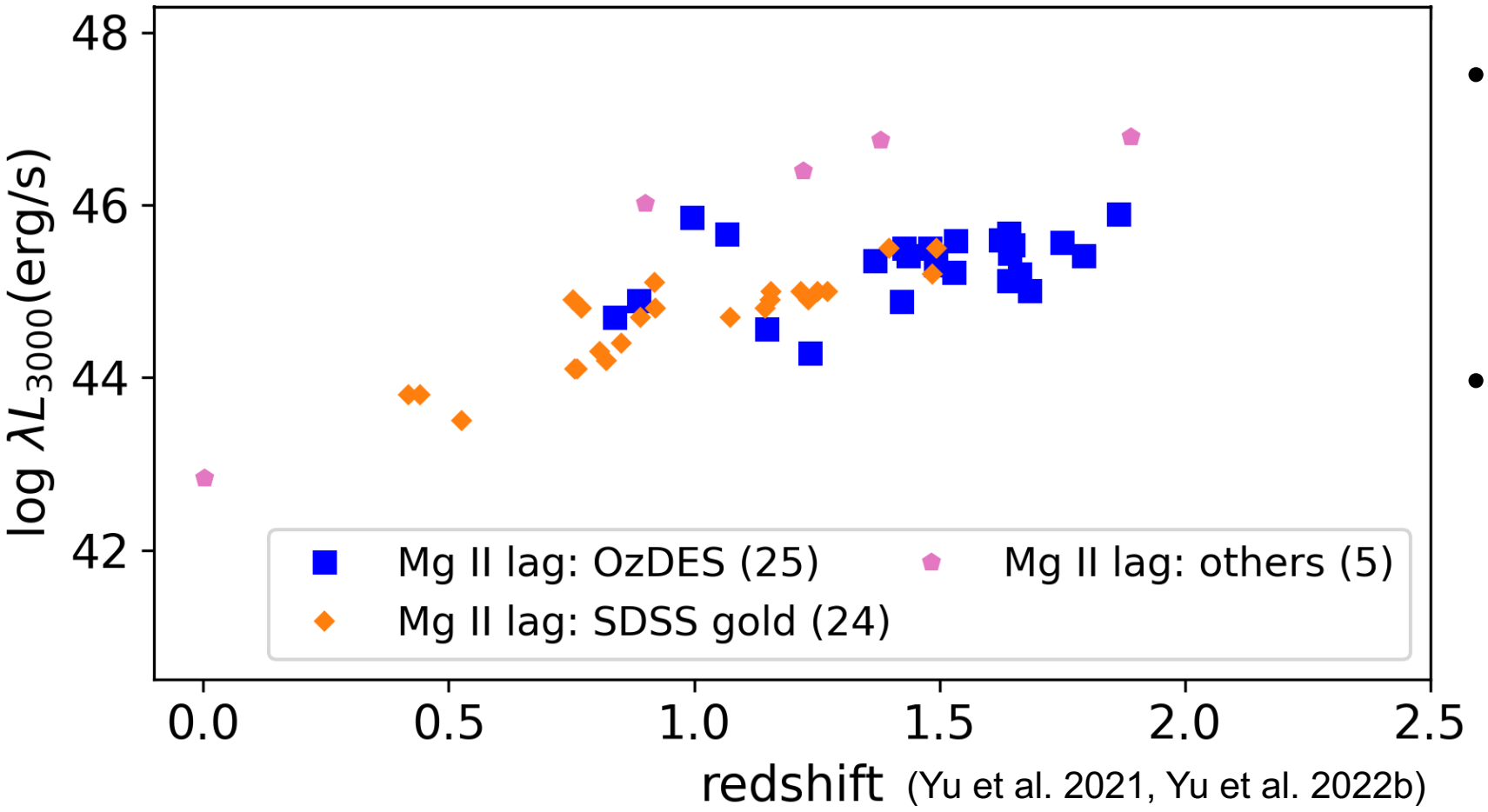
- DECam enables one of the leading “industrial scale” RM campaigns
- 6-year monitoring of 735 quasars in the DES SN fields
- DES photometry: ~ weekly cadence (~ 120 epochs)
- OzDES spectroscopy: ~ monthly cadence (~ 40 epochs)



(Melchior 2014)

- DES: 6 years, ~ 5000 deg^2
- DES SN fields: insensitively monitored with weekly cadence
- OzDES: spectroscopic survey in DES SN fields

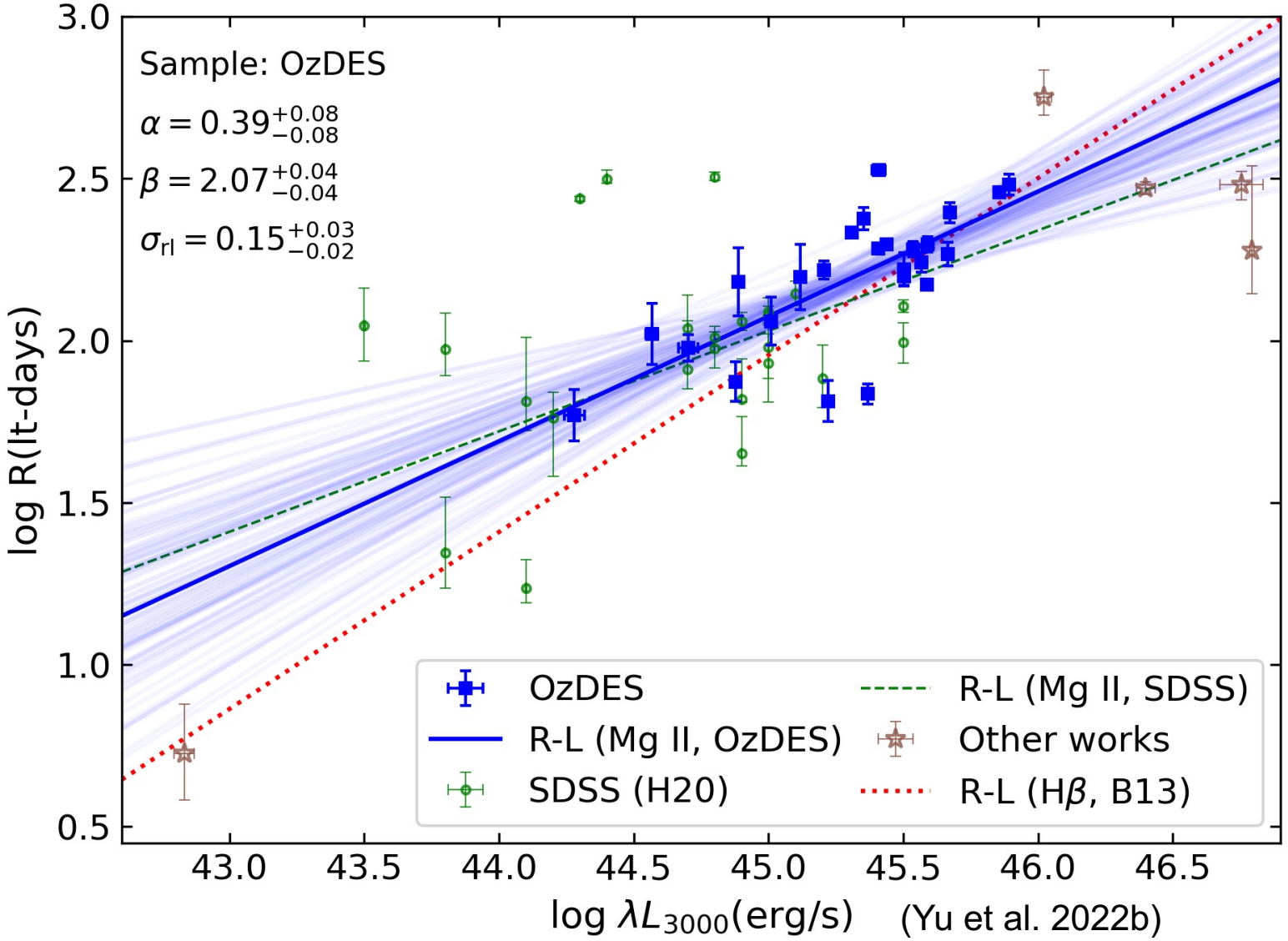
Mg II RM: Lag measurements



(Yu et al. 2021, Yu et al. 2022b)

- 25 lag measurements: significantly increase the number of Mg II lags
- Extending toward higher redshifts and luminosities

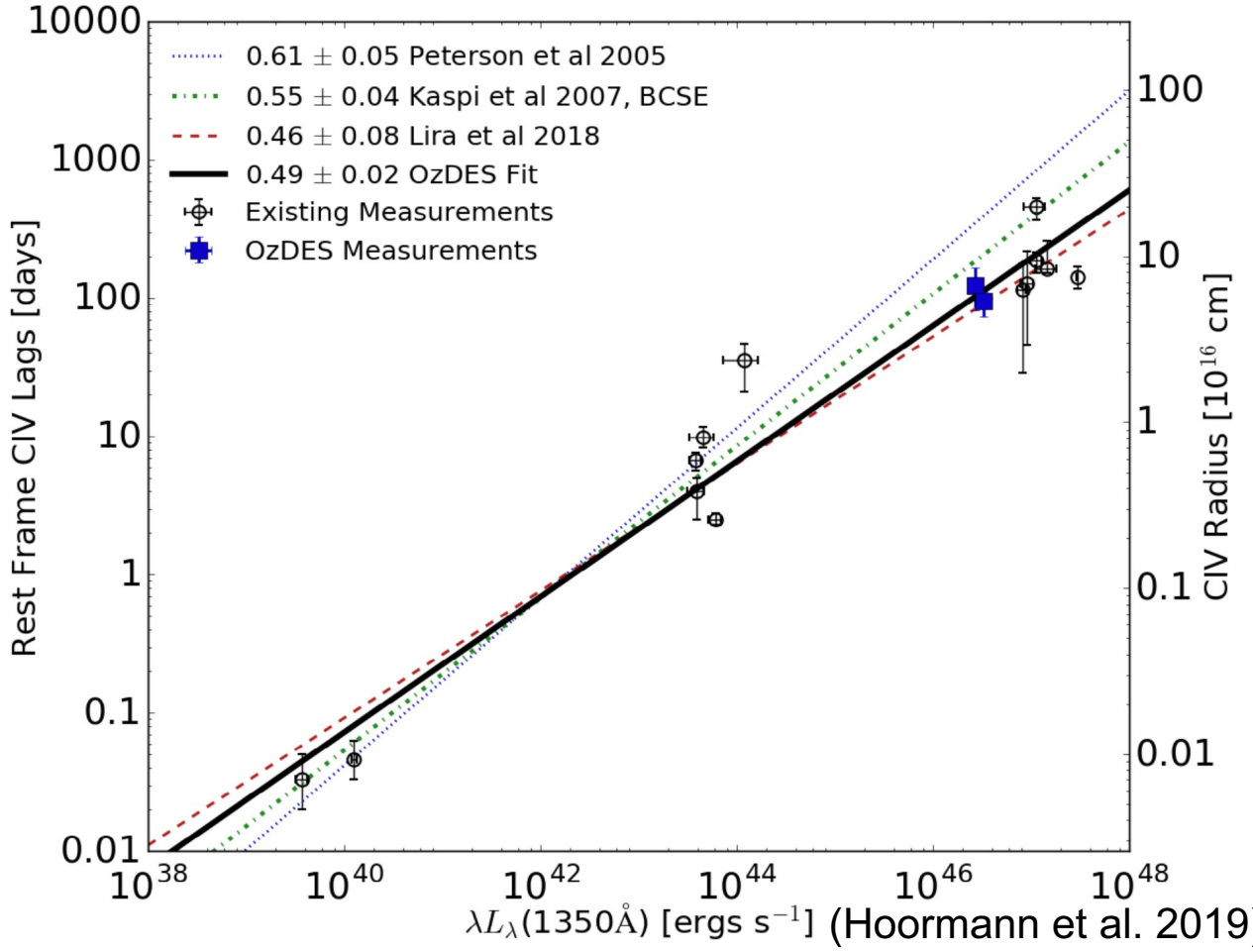
Mg II RM: R - L relation



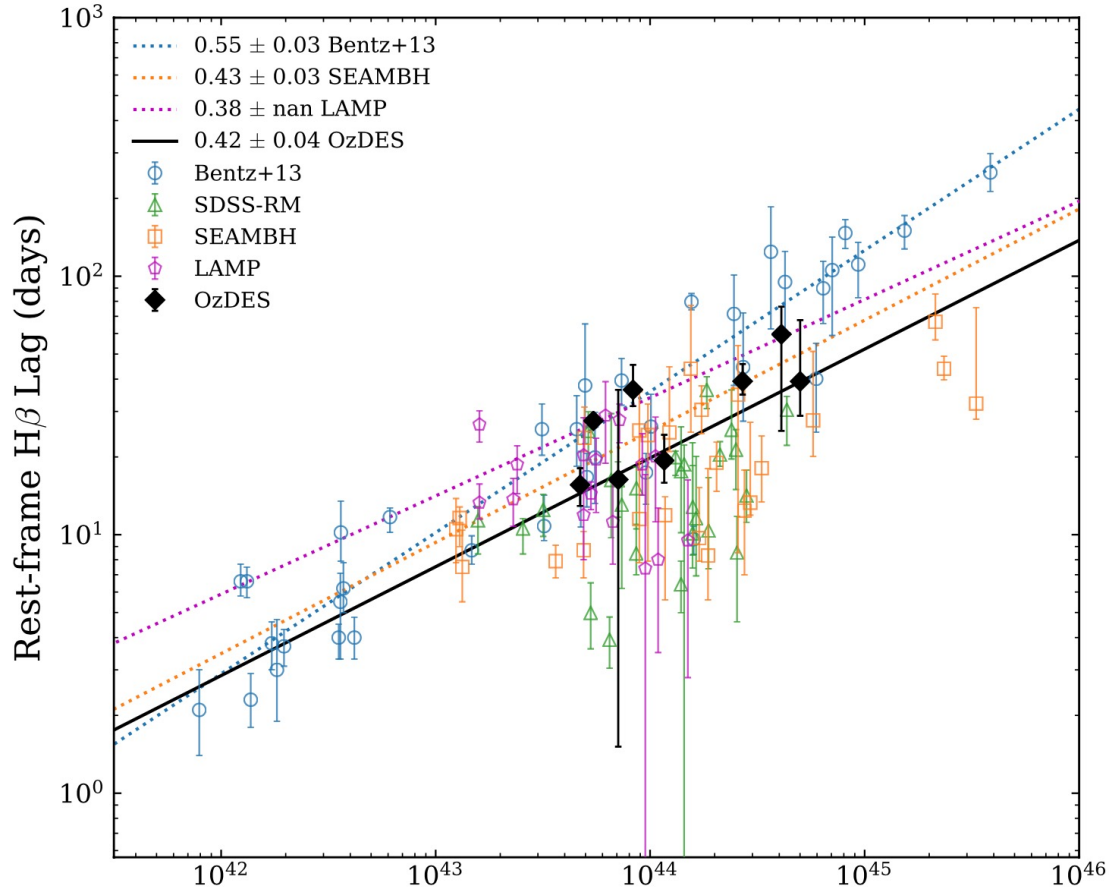
- Broadly consistent with the Mg II R-L relation from Homayouni et al. 2020, while shallower than the Hβ R-L relations
- The intrinsic scatter (~ 0.15 dex) is much smaller than Homayouni et al. 2020 (~ 0.3 dex)
- Enables better single-epoch mass at cosmic noon

Hβ and C IV RM

- C IV lags for 2 quasars at z = 1.9 and z = 2.6
- Hβ lags for 8 quasars



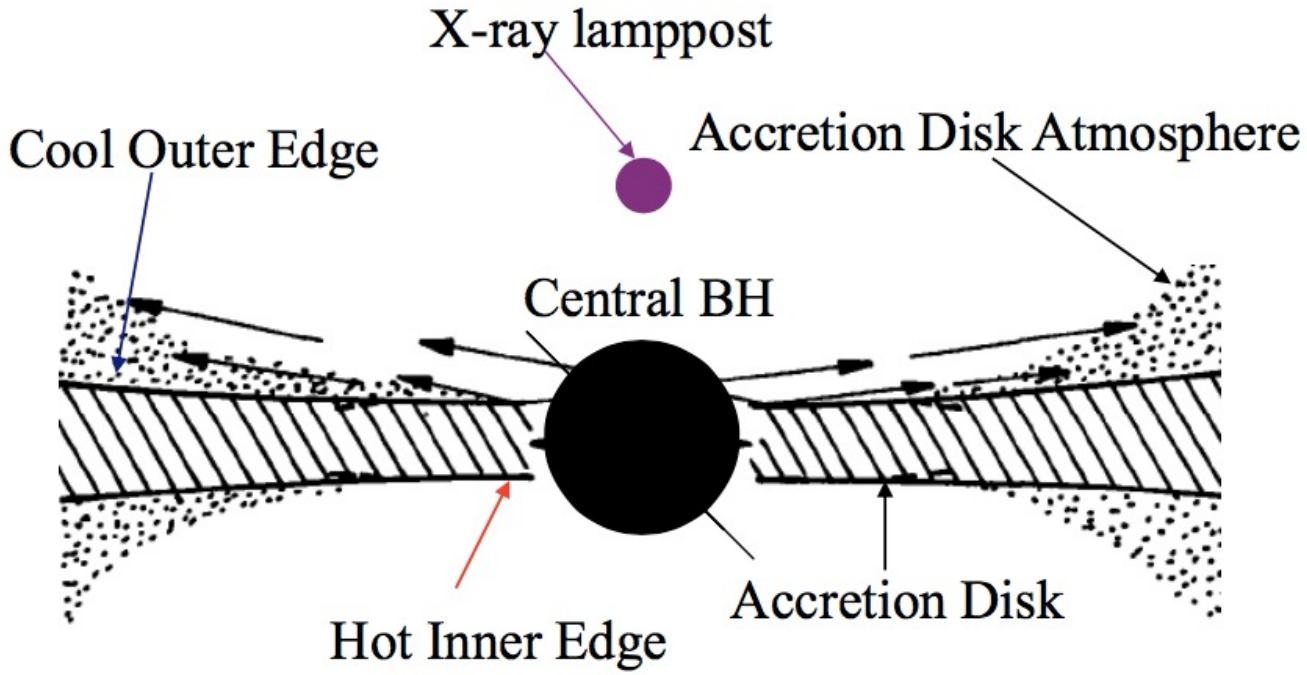
(Hoormann et al. 2019)



(Malik et al. in prep.)

Continuum RM

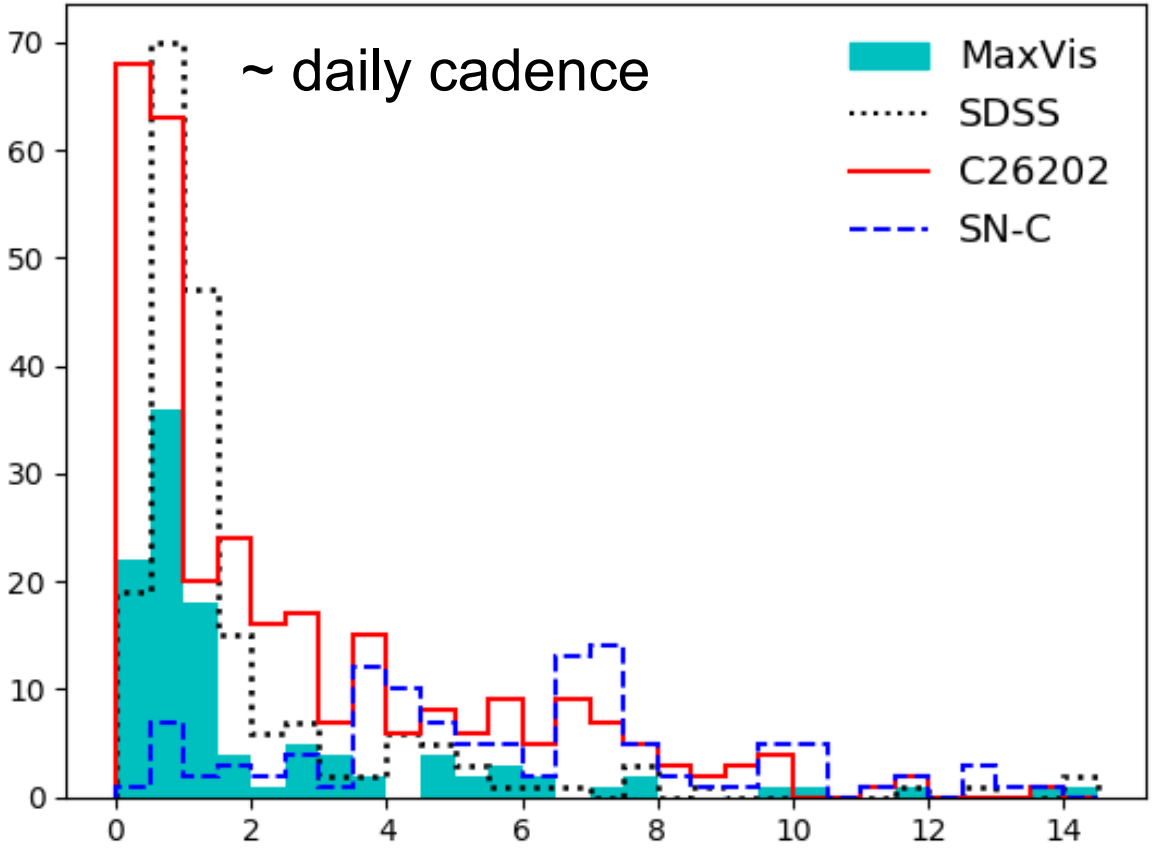
- Temperature gradient of the disk: $T \propto R^{-1/\beta}$
- AGN continuum: multi-temperature black-body
- Continuum lag: light travel time within the disk

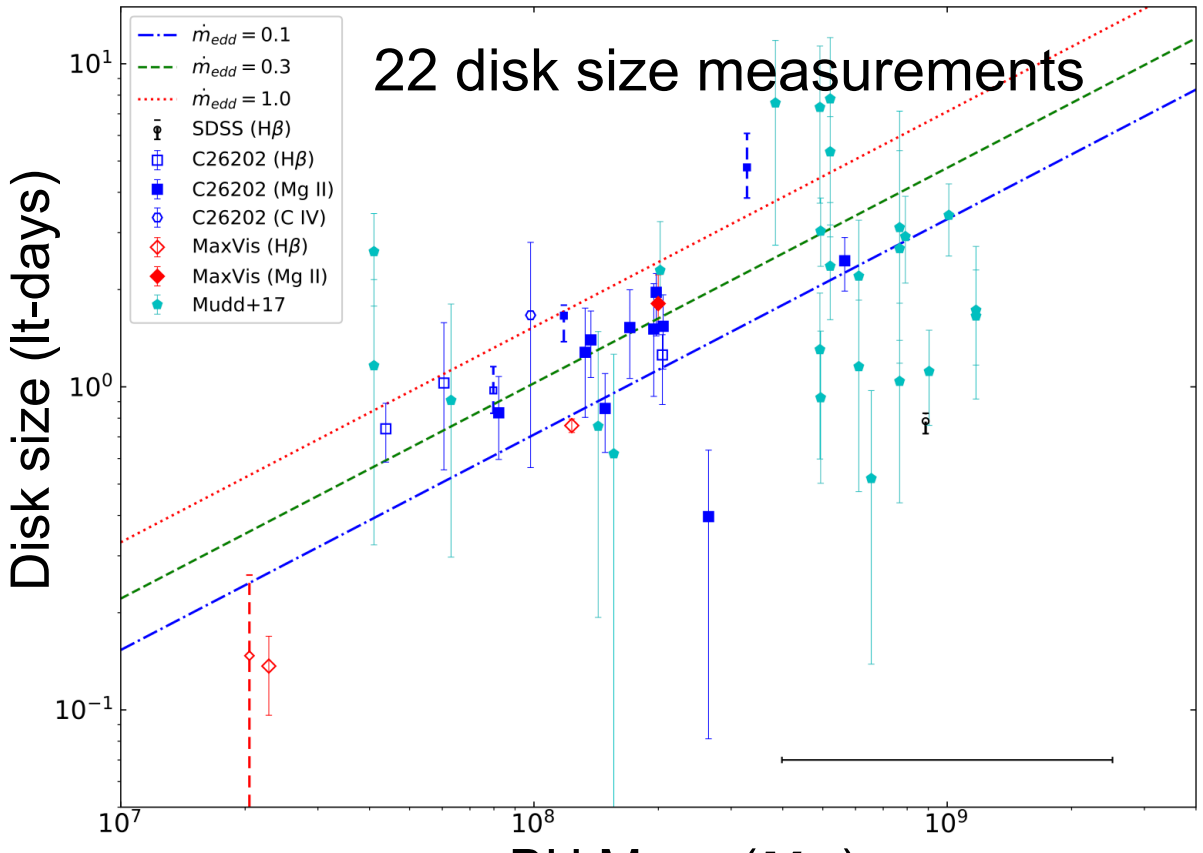


Shakura and Sunyaev, 1973

Continuum RM with DES

- Photometry from DES standard star fields with ~ daily cadence
- 22 disk size measurements, in general agreement with the standard thin disk model

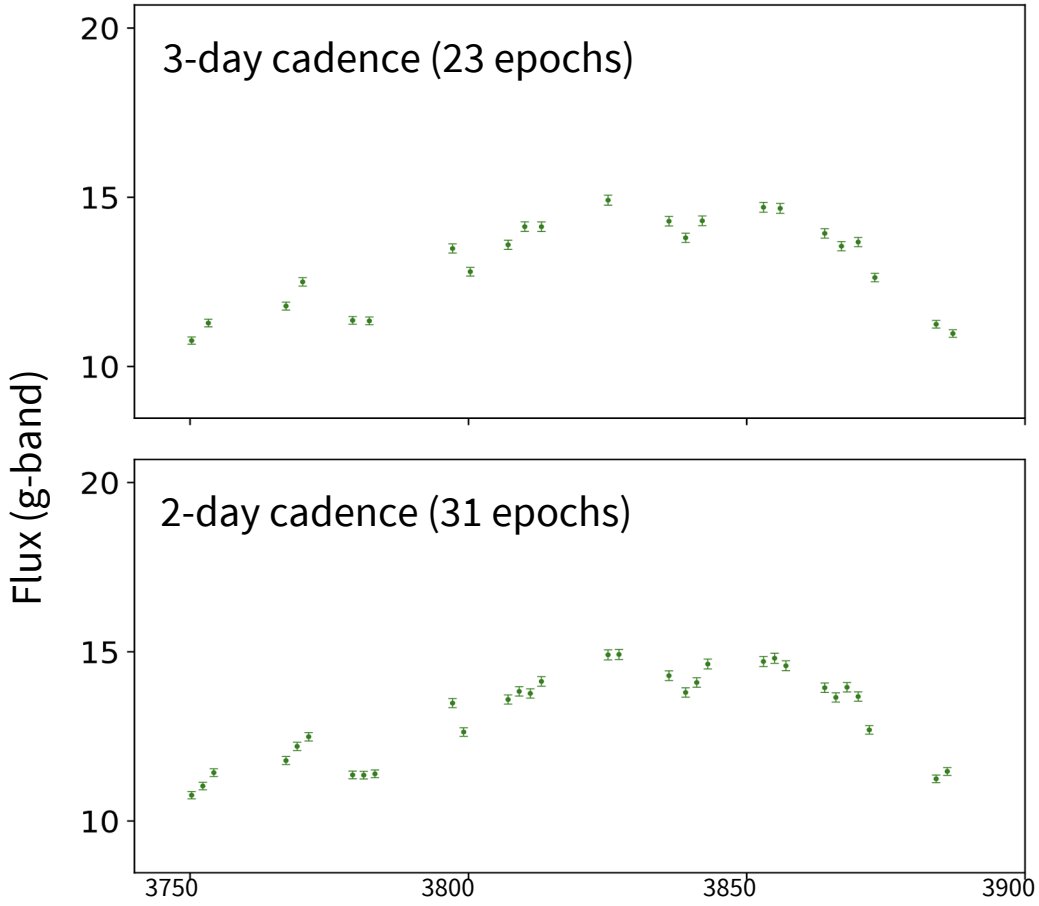


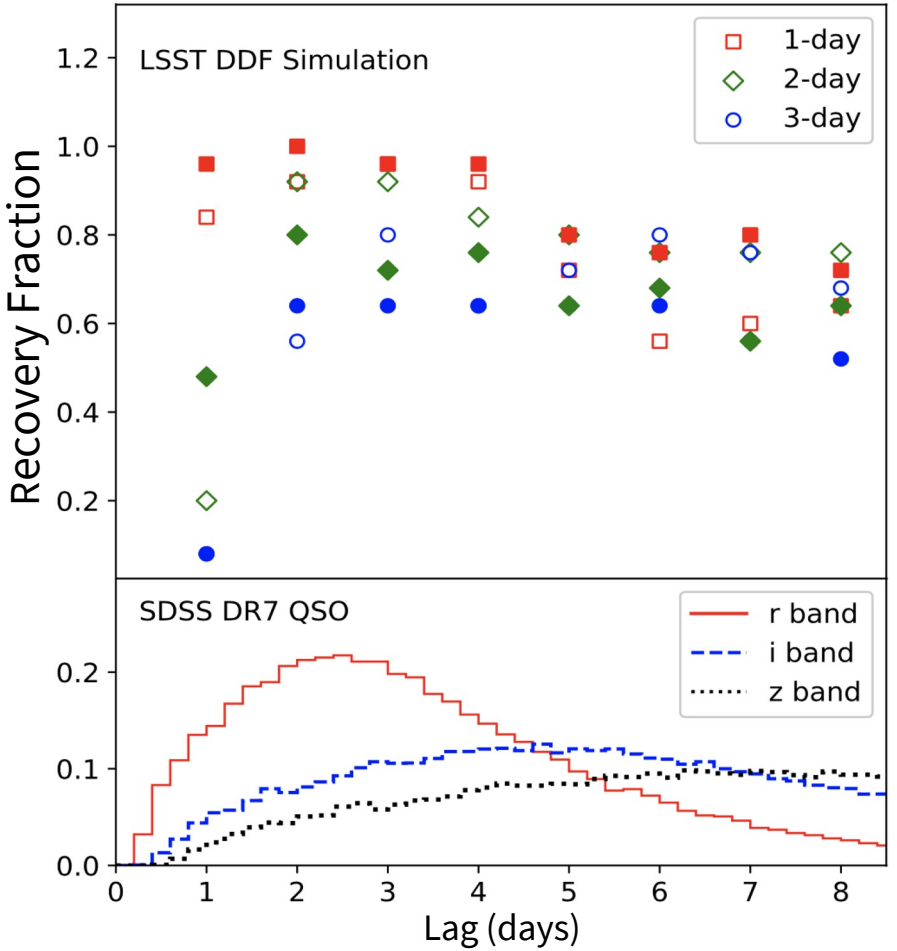


(Yu et al. 2020a, ApJS, 246, 16)

Continuum RM in LSST DDFs: effect of cadence

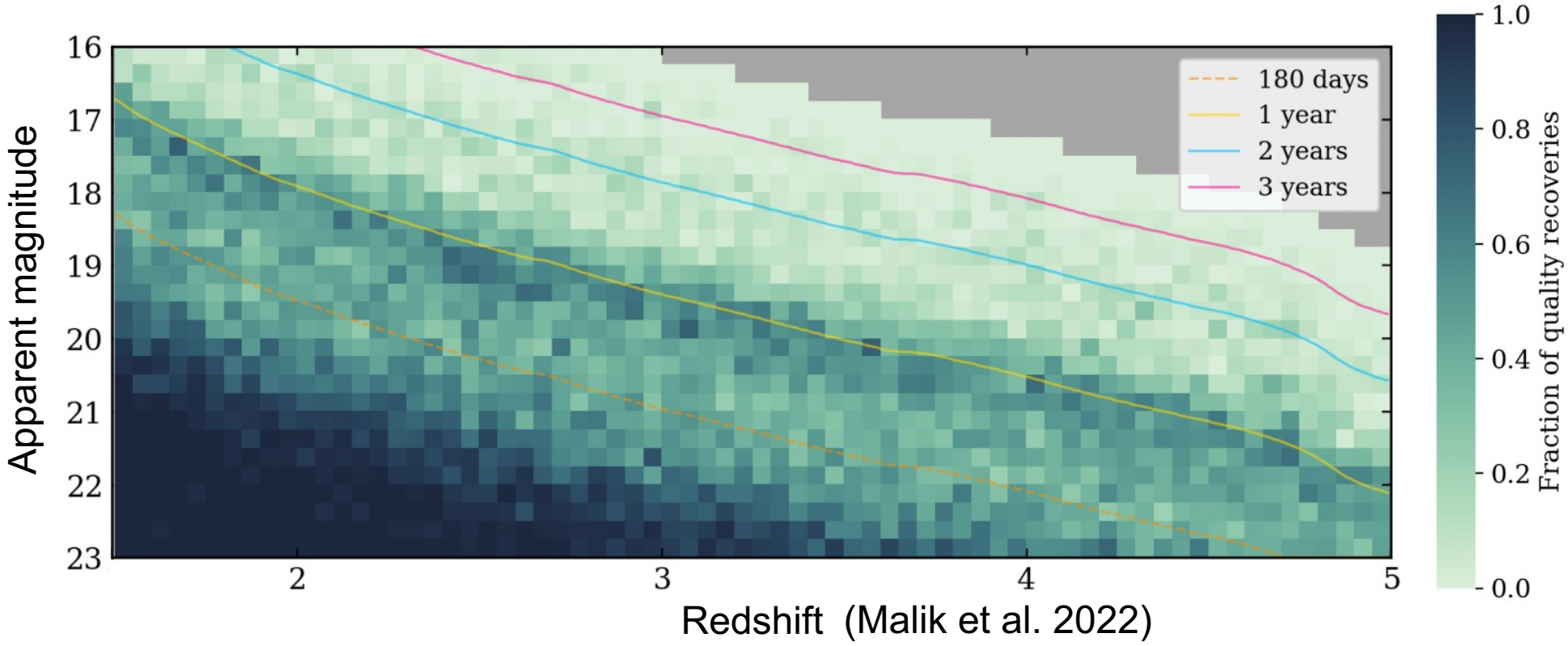
- LSST can produce an order of magnitude more disk size measurements
- Simulations: significant increase in the yield from 3-day cadence to 2/1-day





Toward Future RM Campaigns

- Future surveys: LSST, Black Hole Mapper (SDSS-V), TiDES (4MOST), …
- Simulations for survey design: Long season length is important for lag measurement



(Malik et al. 2022)

Summary

- OzDES RM project: one of the leading “industrial scale” RM project - 735 quasars, 6-year monitoring, ~ weekly photometry and ~ monthly spectroscopy

- One of the largest samples of the Mg II lags and black hole mass:

  25 Mg II lags with higher redshift and luminosity
- Best constraints of the Mg II R - L relation to date

- Accretion disk sizes for 22 new objects. Most measurements are consistent with the standard thin disk model

- Simulations for future RM campaigns: higher cadence and long season length are important