SDSS-RM: A Multi-Object Quasar Reverberation Mapping Project

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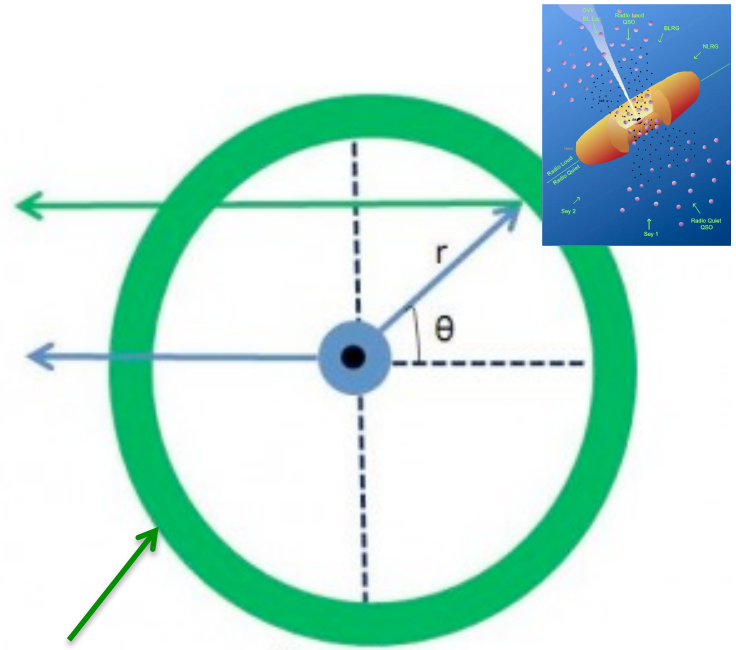
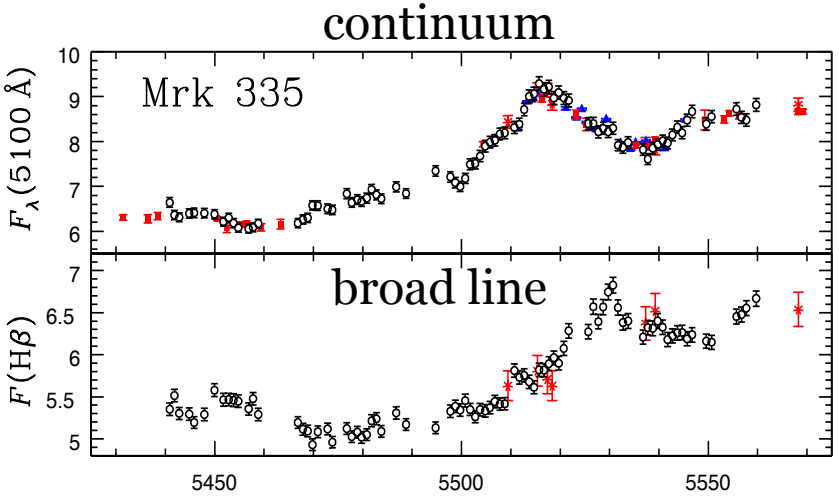
AGN Reverberation Mapping

- Measuring the broad line lags → RM BH mass
- Calibrations for Single-epoch BH mass





$$M_{\rm BH} = f\left(\frac{\Delta V^2 R}{G}\right)$$

Primary (direct) method to measure BH mass in AGN/quasars or at z>0.3.

Limitations of the current RM AGN sample

~50 AGN with RM lag measurements

- almost exclusively at z<0.3
- Most are Hbeta lags with some CIV lags and few/no MgII lags
- Sample heterogeneous, and does not uniformly sample the AGN parameter space (luminosity, emission line properties)

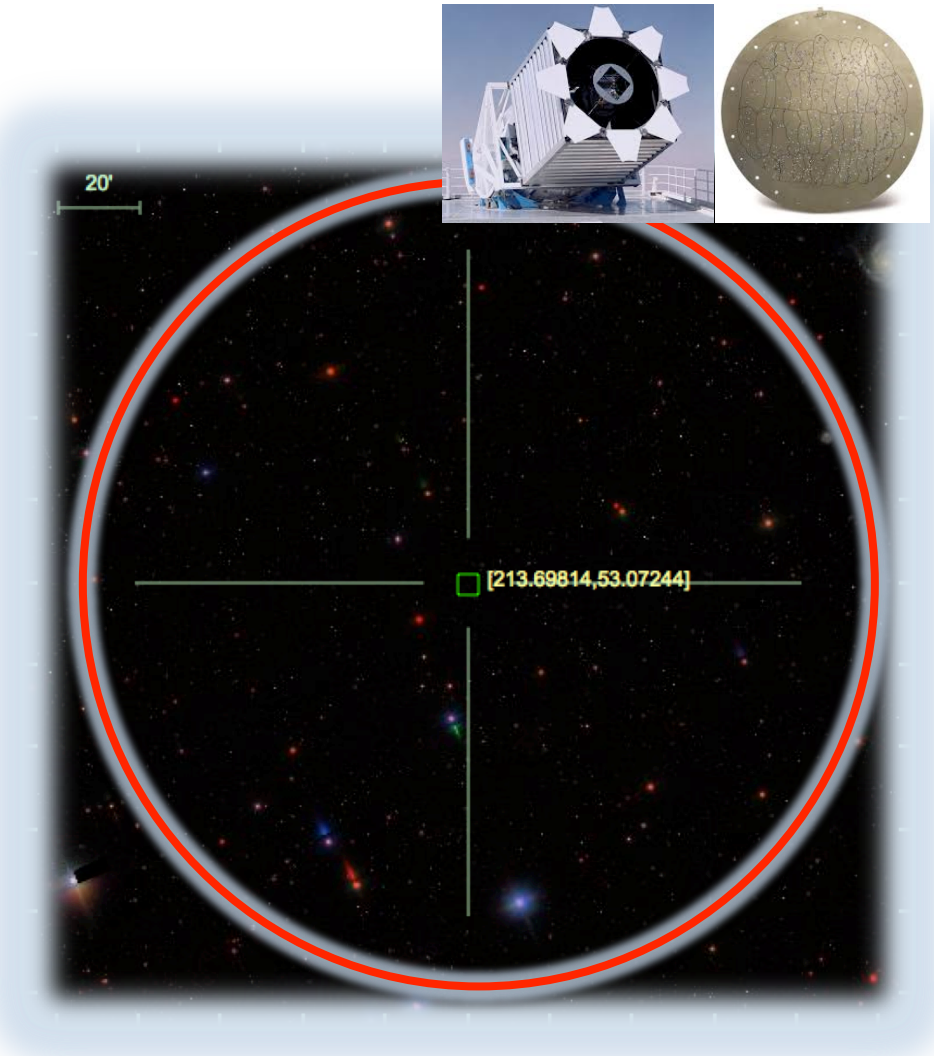
→ **Two decades of effort !!**

The limitations of the current RM sample severely impact the reliability of the single-epoch BH mass estimators at high-redshift.

Need to substantially improve the RM sample, in a more efficient way.

SDSS-RM in a nutshell

- Motivation: expanding the RM AGN sample in both size and luminosity-redshift range
- Simultaneous monitoring a uniform sample of 849 quasars at $0.1<z<4.5$ in a single 7 deg^2 field with the SDSS-BOSS spectrograph; 32 epochs completed in 2014A; continue through 2017 with reduced cadence
- Dense photometric light curves (~2-4 day cadence) since 2010 (PanSTARRS 1 + SDSS-RM imaging)



SDSS-RM Project: http://www.sdssrm.org

Science from SDSS-RM

Primary Science

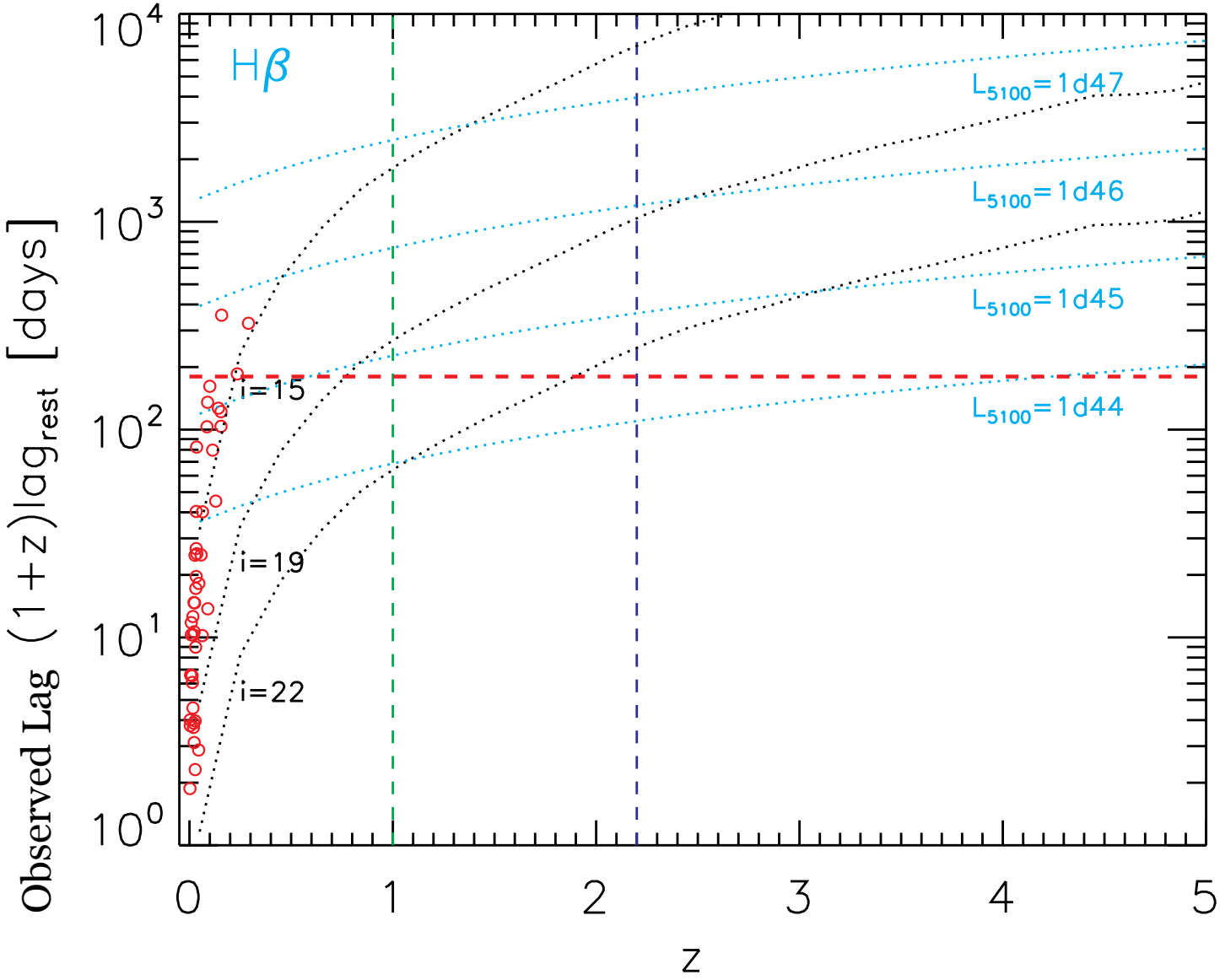
- BLR RM lags and BH masses at z>0.3
- Structure and kinematics of the BLR
- The R-L relations for different lines
- Better calibrations of SE BH mass estimators

Ancillary Science

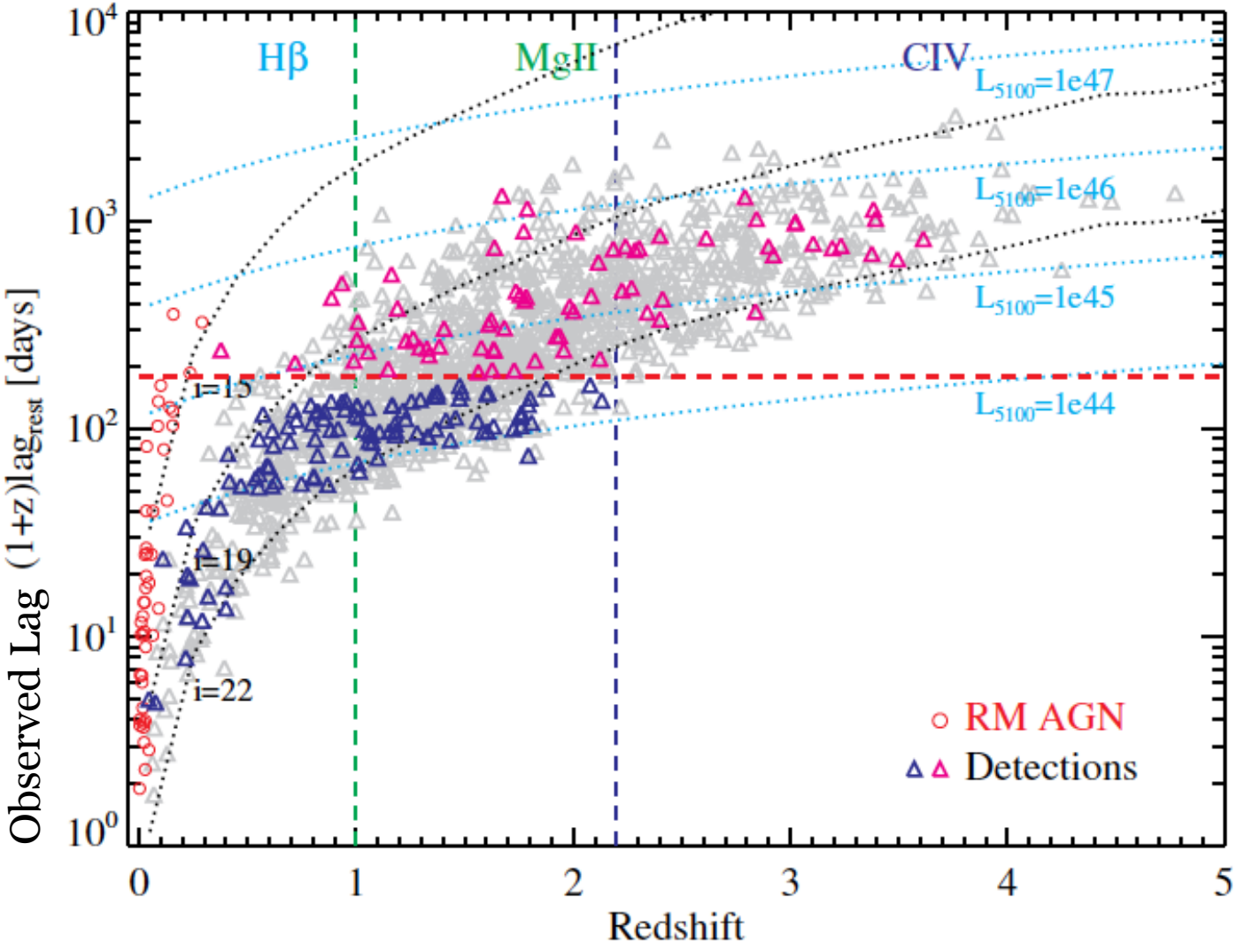
- Photometric and spectral quasar variability
- Quasar/host decomposition of coadded spectra and imaging
- BALQSO trough variability
- Quasar narrow metal absorption lines

Pathfinder RM program for the big-data era!

SDSS-RM: Promises and Challenges



SDSS-RM: Promises and Challenges



6-month

Expected lag detections from SDSS-RM

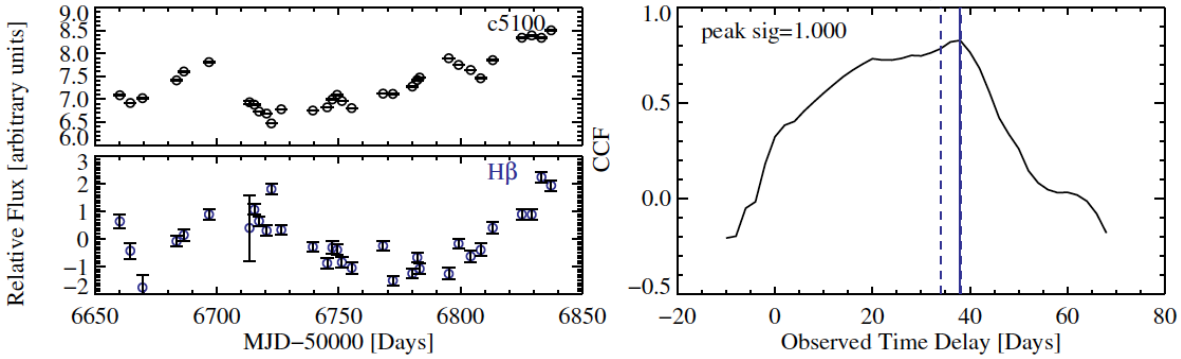
Shen et al. (2015a)

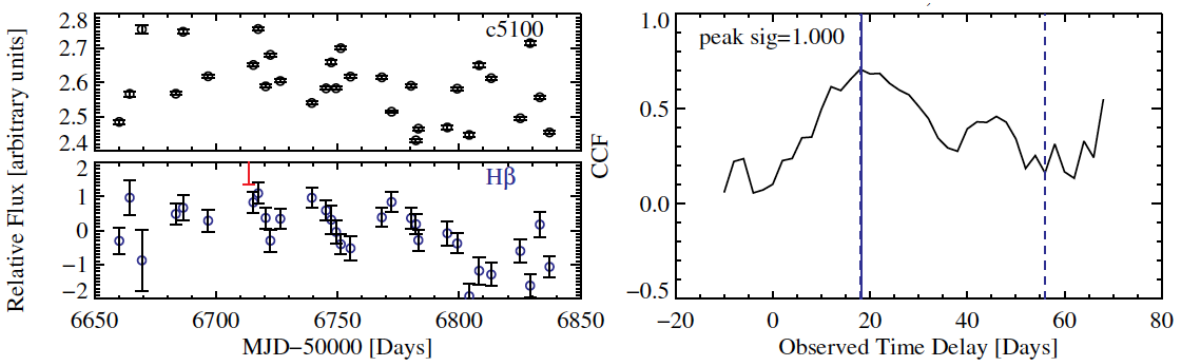
Some early science papers:

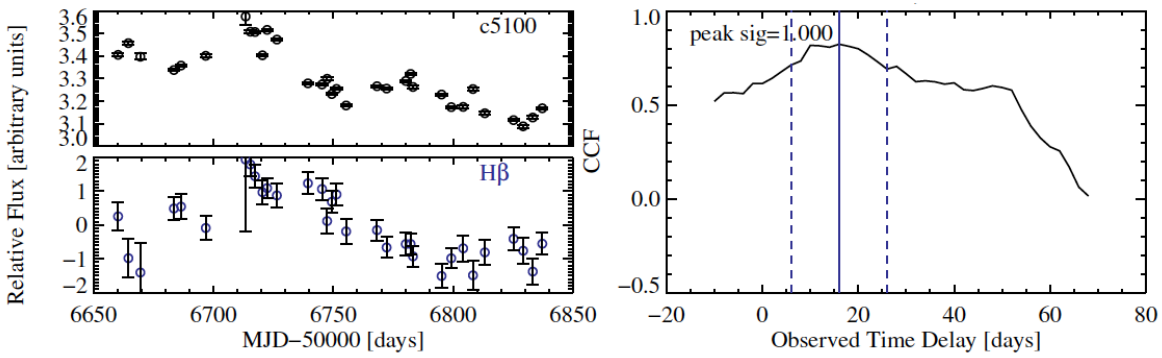
- **First RM broad-line lag detections at z>0.3**: Shen et al. 2015b
- **Discovery of a M-sigma relation at z~0.6**: Shen et al. 2015c
- Structure functions of broad-line variability: Sun et al. 2015
- Rapid trough variability in a broad absorption line quasar: Grier et al. 2015
- Stellar populations of quasar hosts from coadded SDSS-RM spectra: Matsuoka et al. 2015

Early science results: first lag detections at z>~0.3

Based on 6-month spectroscopy only

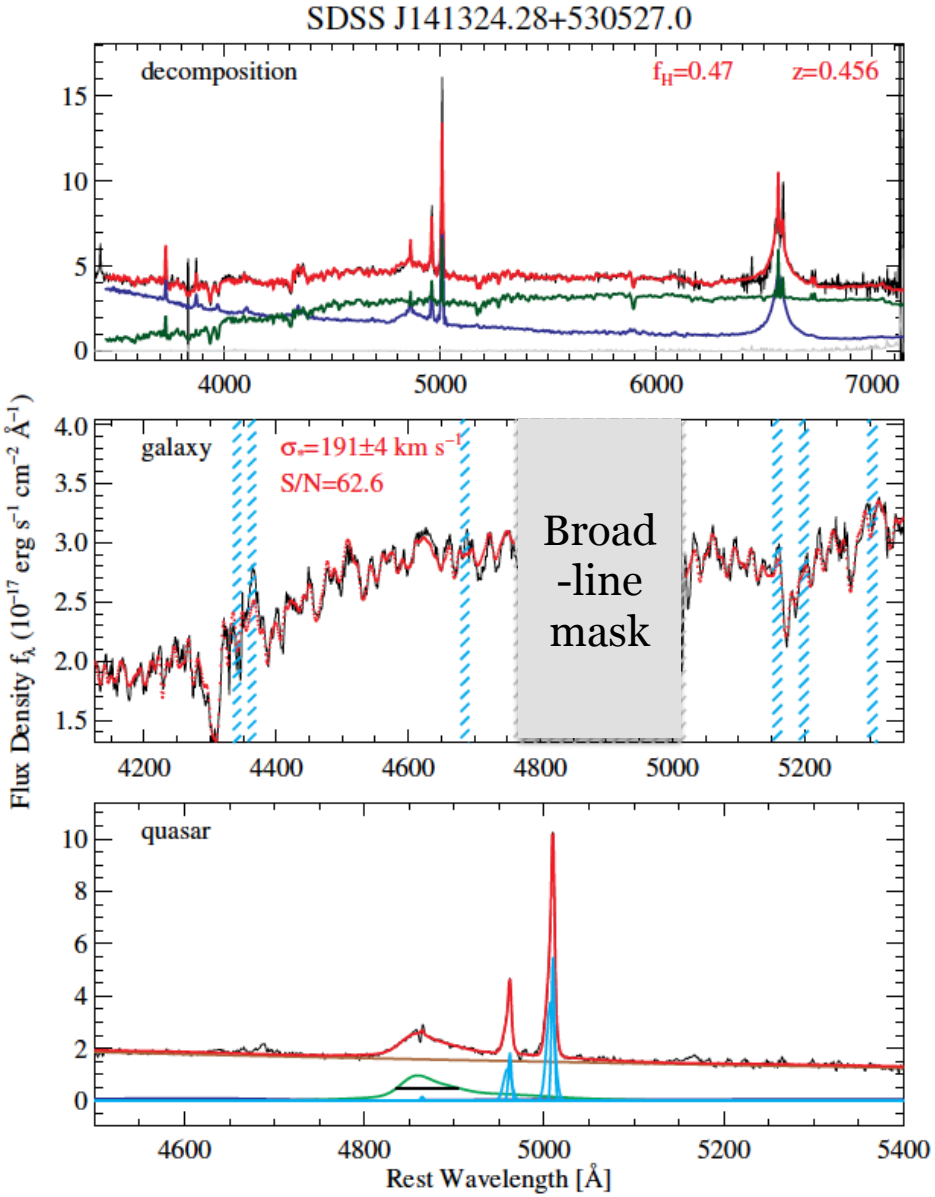






Shen et al. (2015b, in prep)

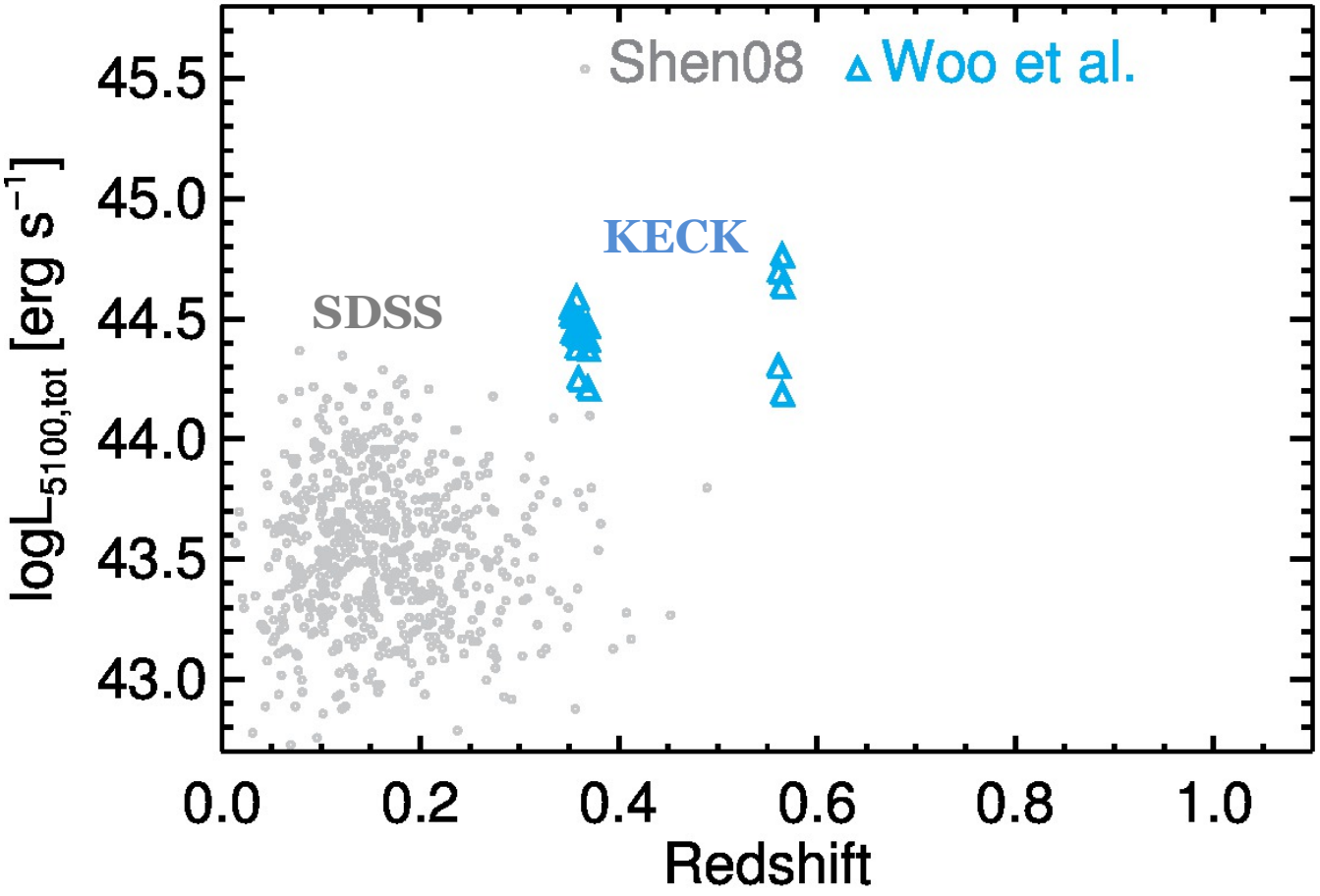
Early science results: stellar velocity dispersion (sigma) in high-z quasar hosts



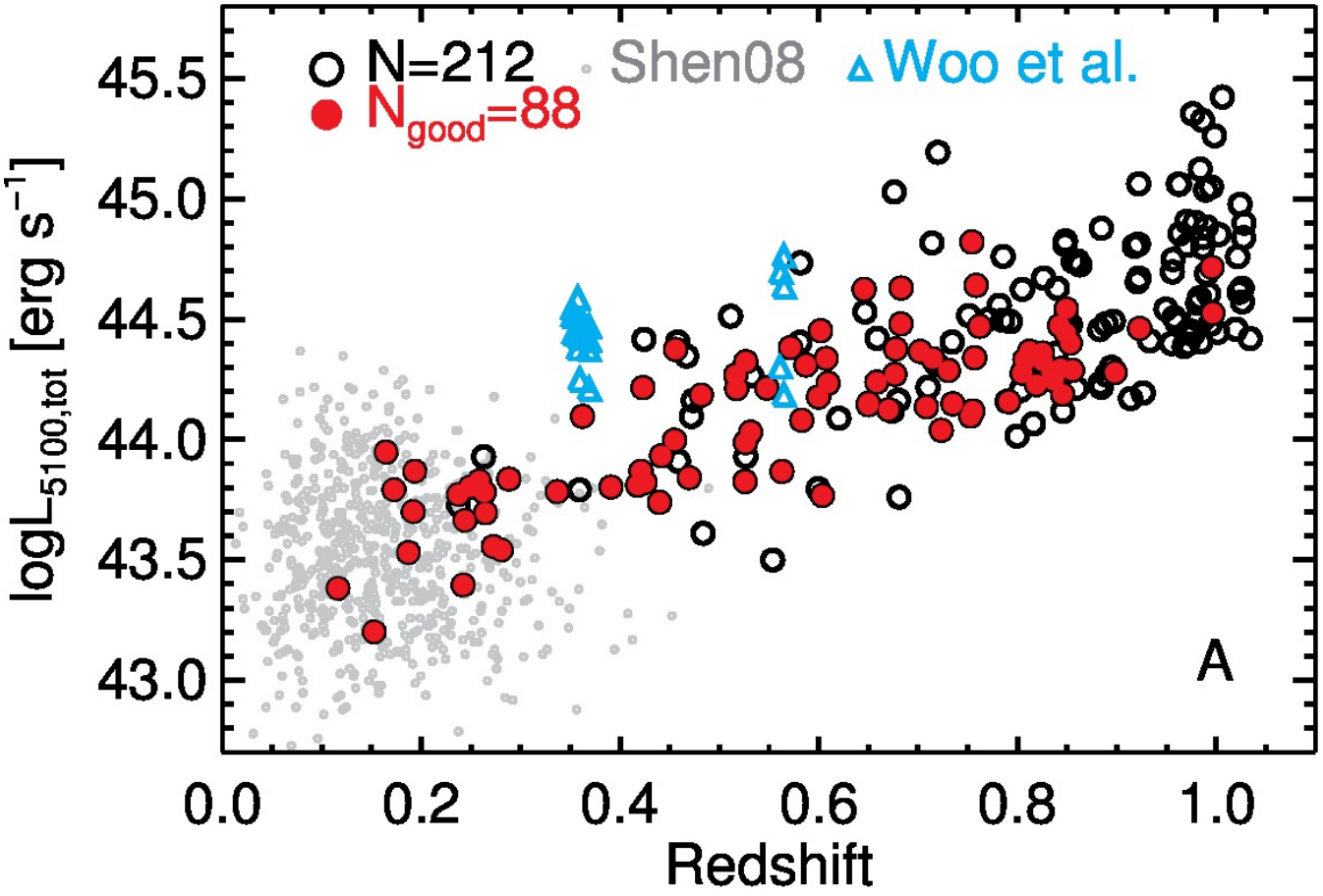
Coadded spectra from 32 epochs: ~ 6-8 hrs on 6-8m telescopes – hundreds of them!

Shen et al. (2015c, submitted)

Previous quasar samples with sigma measurements



Improvement over previous samples

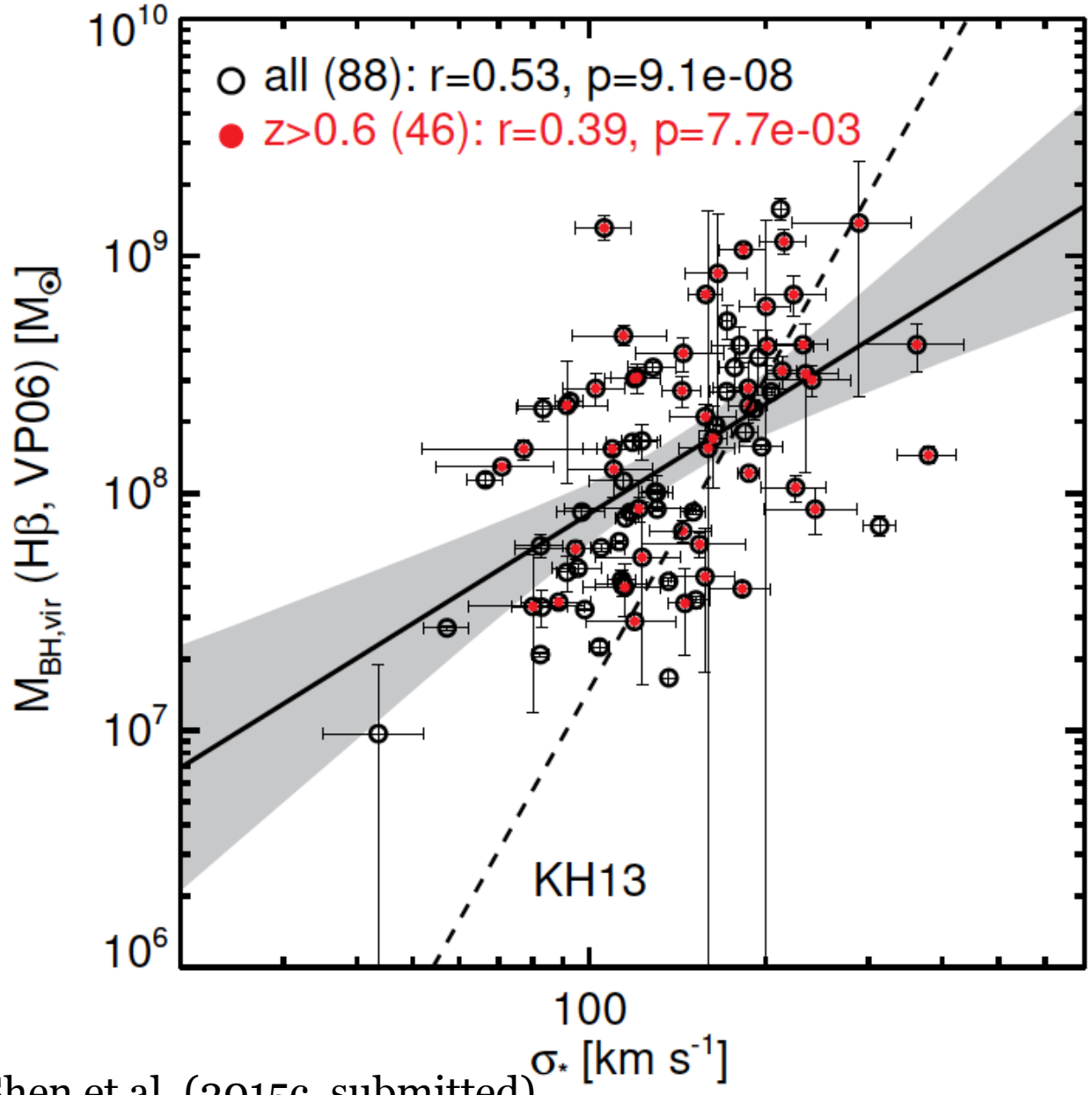


88 quasars at 0.1<z<1 (<z>=0.6) with sigma measurements.

46 are at z>0.6, where no sigma has been measured in quasars before

Shen et al. (2015c, submitted)

A M-sigma relation at z~0.6



First robust detection at z>0.3

The much shallower slope is consistent with selection biases; no evidence for evolution in the M-sigma relation to z~1

Shen et al. (2015c, submitted)

Summary

- SDSS-RM:
  - more efficient RM with MOS surveys
  - expanding the redshift-luminosity range of the RM AGN sample
  - new insights on AGN physics and galaxy-BH co-evolution
- Future opportunities
  - large-scale MOS-RM programs (ozDES, 4most, MSE, etc)
  - synergy with other programs (e.g., transient follow-up, deep galaxy spectroscopy, etc.)