Large Area Optical Spectroscopic Surveys: Science with 4MOST

Expanding the 4MOST AGN Science case

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1. The 4MOST virial black hole data base

2. AGN outflows and time-domain studies

3. Fe II multiplet line emission

4. AGN composites

1. Reverberation Mapping as the virial mass calibrator

- reverberation mapping (RM) has proven to be a viable technique to measure the BLR size **R** and the widths of the emission lines **FWHM** which gives the mass **M** of the black hole

- RM measurements are calibrators for deriving BH masses

$$M = \frac{FWHM^2 \cdot R}{G}$$

- an important results of RM studies is the discovery of a tight R-L relation

- measuring L and FWHM gives M

- pairs of lines and luminosities:

$$\begin{array}{lcl} H\alpha, H\beta & \cup & L_{5100} \\ MgII & \cup & L_{3000} \\ CIV & \cup & L_{1350} \end{array}$$

$$M = \frac{FWHM^2 \cdot L(R)}{G}$$

Creating the 4MOST RM calibration database

- black hole masses are calibrated for a sample of only 40 AGNs based on Hβ, Hα lines

- other mass estimators are unrepresentative for high L and high z AGN (e.g. Richards[2011])

- **a RM calibration database for z > 0.4 is required**, i.e.
  we request multiple (one) field visits, e.g. similar to LMC,SMC multiple field visits (dPM, O.S.)
  .AND. ATLAS survey T. Shanks

- RM templates can be created with e.g. CIV 1549, CIII] 1908, Mg II 2798 lines with 4MOST

- after calibrating AGN BH masses with rest-frame UV lines, reliable virial BH mass estimators will become available for z > 0.4

4MOST will create calibrated virial black hole estimators up to large redshifts

we expect no negative impact on the DRS science cases from 4FS simulations

Black Hole Mass Estimators Uncertainties

$$M_m = 3.37 \cdot \left(\frac{L_{3000}}{10^{44}\, erg\, s^{-1}}\right)^{0.47} \cdot \left(\frac{FWHM_{\ MgII}}{km\, s^{-1}}\right)^{2} M_{sun}$$

$$M_K = 2.04 \cdot \left(\frac{L_{3000}}{10^{44}\, erg\, s^{-1}}\right)^{0.88} \cdot \left(\frac{FWHM_{\ MgII}}{km\, s^{-1}}\right)^{2} M_{sun}$$

$$M_{Sa} = 10^{7.7} \left(\frac{L_{5100}}{10^{44}\, erg\, s^{-1}}\right)^{0.50} \cdot \left(\frac{FWHM_{\ MgII}}{3000\, km\, s^{-1}}\right)^{2} M_{sun}$$

$$M_{G\beta} = 3.6 \cdot 10^{6} \left(\frac{L_{H\beta}}{10^{42}\, erg\, s^{-1}}\right)^{0.56} \cdot \left(\frac{FWHM_{\ H\beta}}{1000\, km\, s^{-1}}\right)^{2} M_{sun}$$

$$M_{V\beta} = 10^{6.67} \left(\frac{L_{H\beta}}{10^{42}\, erg\, s^{-1}}\right)^{0.63} \cdot \left(\frac{FWHM_{\ H\beta}}{1000\, km\, s^{-1}}\right)^{2} M_{sun}$$

$$M_{Sh} = 10^{7.7} \left(\frac{L_{5100}}{10^{44}\, erg\, s^{-1}}\right)^{0.50} \cdot \left(\frac{FWHM_{\ H\beta}}{3000\, km\, s^{-1}}\right)^{2} M_{sun}$$

$$M_{G51} = 4.4 \cdot 10^{6} \left(\frac{L_{5100}}{10^{44}\, erg\, s^{-1}}\right)^{0.64} \cdot \left(\frac{FWHM_{\ H\beta}}{1000\, km\, s^{-1}}\right)^{2} M_{sun}$$

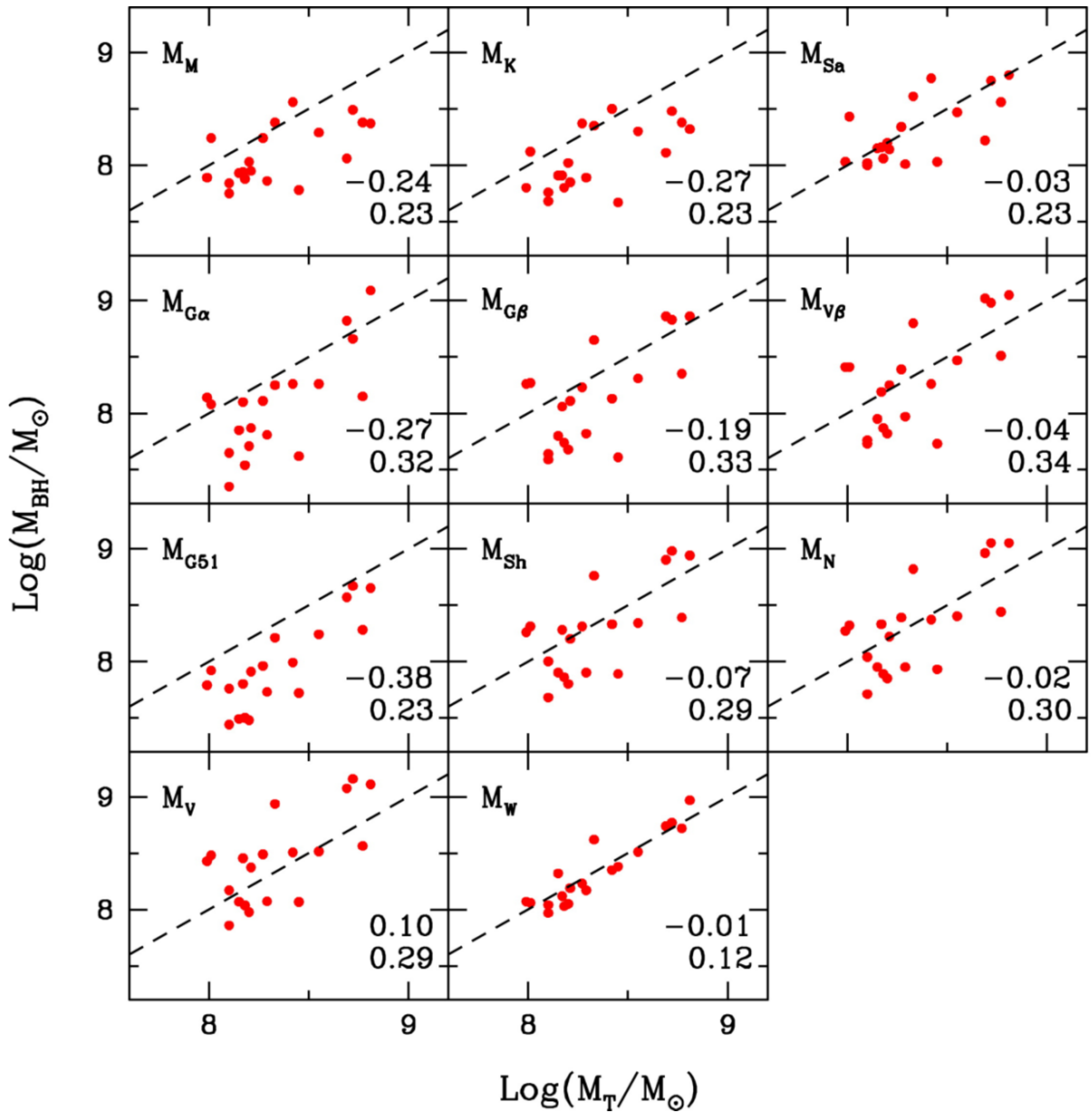
$$M_{V} = 10^{6.9} \left(\frac{L_{5100}}{10^{46}\, erg\, s^{-1}}\right)^{0.50} \cdot \left(\frac{FWHM_{\ H\beta}}{1000\, km\, s^{-1}}\right)^{2} M_{sun}$$

$$M_{N} = 1.05 \cdot 10^{8} \left(\frac{L_{5100}}{10^{46}\, erg\, s^{-1}}\right)^{0.50} \cdot \left(\frac{FWHM_{\ H\beta}}{1000\, km\, s^{-1}}\right)^{2} M_{sun}$$

$$M_{G\alpha} = 2.0 \cdot 10^{6} \left(\frac{L_{H\alpha}}{10^{42}\, erg\, s^{-1}}\right)^{0.55} \cdot \left(\frac{FWHM_{\ H\alpha}}{1000\, km\, s^{-1}}\right)^{2.06} M_{sun}$$

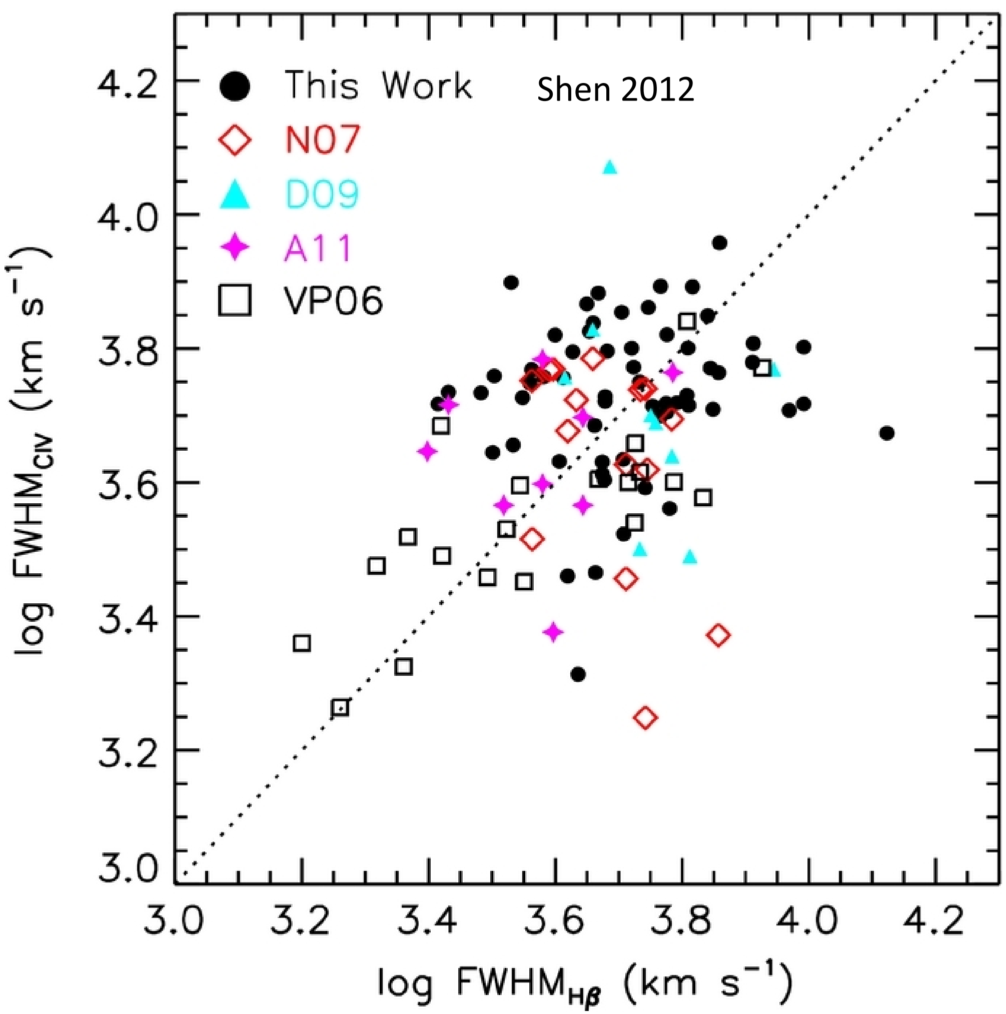
$$M_{W} = 2.15 \cdot 10^{8} \left(\frac{L_{5100}}{10^{44}\, erg\, s^{-1}}\right)^{0.52} \cdot \left(\frac{\sigma_{\ H\beta}}{3000\, km\, s^{-1}}\right)^{2} M_{sun}$$

$$M_{T} = 10^{8.58} \left(\frac{L_{5100}}{10^{44}\, erg\, s^{-1}}\right)^{0.52} \cdot \left(\frac{\sigma_{\ H\beta}}{3000\, km\, s^{-1}}\right)^{2} M_{sun}$$



The average difference $\log M_{BH} - log M_T$ and rms scatter in

Line Width Correlations



comparision between Hβ and C IV FWHM

only for the low redshift and low-luminosity sample VP06 there is a significant correlation

C IV is poorly correlated with Hβ, suggesting different BLRs for both lines

Reberveration Mapping calibration required to obtain precise virial BH masses

The 4MOST virial black hole mass data base

- it will be of great interest to derive calibrated virial masses from different lines with 4MOST

- combining AGN black hole masses with eROSITA spectra and MW data then subsequently yields

  - Eddington ratios
  - the amount of Comptonization
  - the solid angle of the reflector
  - the Compton y parameters

this further allows to investigate in great detail the role of feedback in a cosmological context

4MOST will create a large and precise AGN mass data base

2. AGN outflows and time-domain studies

- intrinsic absorption lines in quasar spectra are often produced by outflowing winds launched from the accretion disc

- the absorption lines appear in AGN spectra as absorption lines (intrinsic narrow, mini-BAL, BALs)

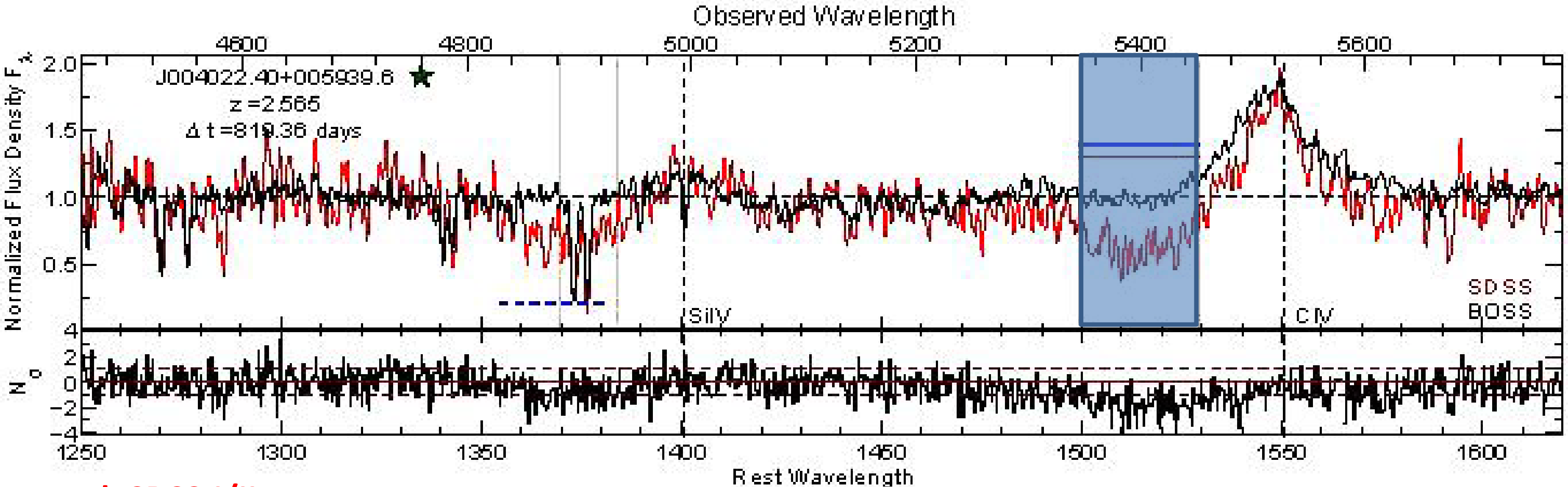
- absorption lines are of importance for two main reasons
  - disc accretion require significant mass ejection from expulsion of angular momentum
  - winds produce feedback into galaxies, regulating star formation and further accretion

- absorption line **disappearance** provides information on the
  - disc-wind rotation and
  - changes in the shielding gas

absorption line variability studies with 4MOST opens a new window to map AGN outflows as a function of time, redshift and luminosity

SDSS-I/II/III spectra of quasars with disappearing BAL troughs

- SDSS-I/II and SDSS-III observations revealed for the first time disappreared and disappearing C IV BAL



red: SDSS-I/II
black: SDSS-3 (BOSS)

BALs are shown as shaded areas
solid blue: disappeared BAL trough

- as the observation span about 3 years with 2 per cent disappeared and 3 per cent disappearing troughs this suggests that BAL absorbers spend about a century along our line of sight

- frequency of absorption line variability and timescales might be different in dependence of z and L

Extending absorption line variability studies with 4MOST

- 4 MOST will provide absorption line measurements for about 1 million AGNs, extending BAL studies in luminous quasars

- this includes intrinsic narrow absorption lines, mini-BALs and BALs over a large L and z range

- expect two epochs of 4MOST spectra per target plus multi-epoch AGN samples we might expect multiple field visits from the LMC,SMC proposal (e.g. dPM O.S.)

- this gives absorption line variability and timescale measurements as a function of z and L

4MOST will allow discovering possible origins of the AGN disc-wind rotation, changes in shielding gas and outflowing wind parameters and kinematics

3. Fe II multiplet line emission measurements – high resolution science

- the presence of Fe II emission indicates densities of the emtting regions larger than $n > 10^9$ cm^{-3}, such densities are only present in the accretion disc or the BLR clouds (Baschek 1963, Wampler 1987)

- the Fe II spectrum shows more than 1000 lines

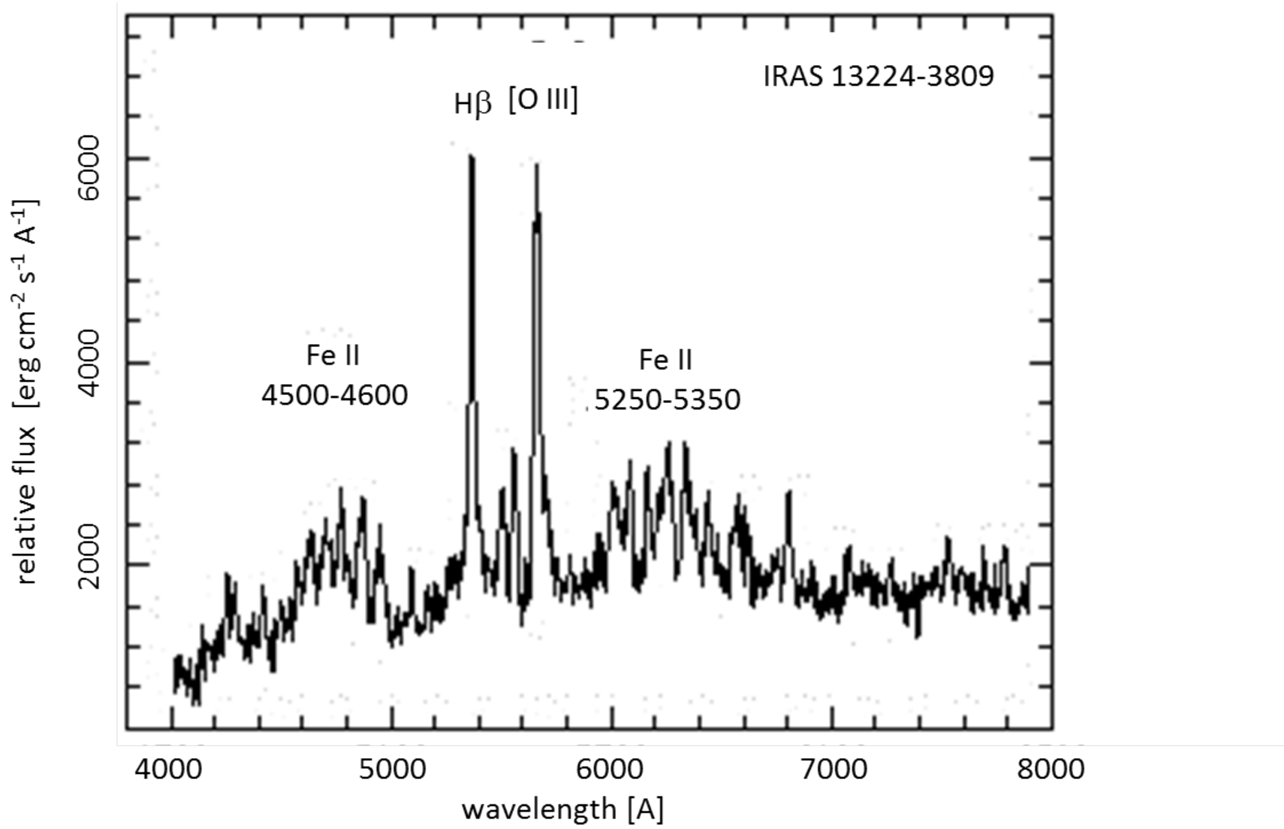
- X-ray photons are required to ionize such dense region from Fe I to Fe II

- T < 40000 K

- the intensity of the Fe II emission reaches that of the strongest line, the Ly α line

the intensity of Fe II can presently not be explained with photoionisation models

Fe II multiplet measurements with 4MOST

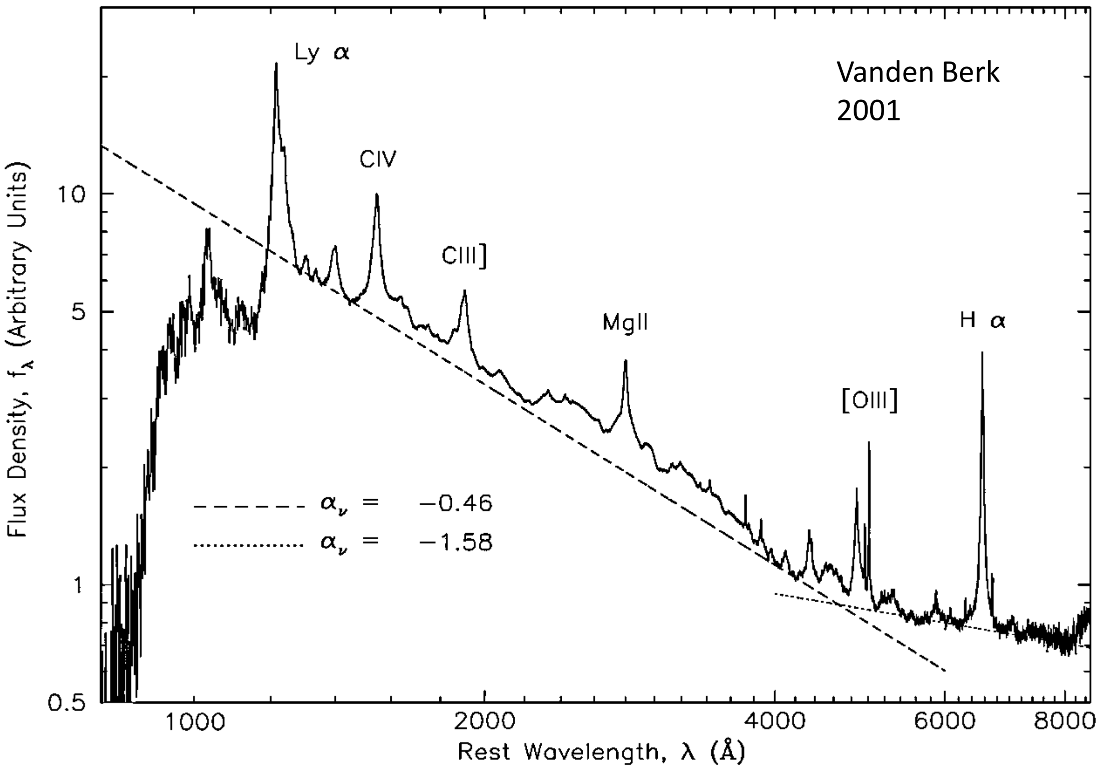


- systematic analysis of the Fe II blended multiplet emission lines from the UV to the Optical

- creating a large data base of very precise Fe II multiplet parameters, e.g. the EW, line strength, line shifts

eROSITA X-ray spectra and 4MOST Fe II templates in z and L shells will address the Fe II problem

4. Quasar composite spectra



- composite quasar spectra using a homogeneous data set of over 2200 spectra from SDSS
- z = (0.044, 4.789) , R=1800

4MOST allows to create a large data base of X-ray selected rest-frame UV and optical EW values and possible relations to redshift and mass extending QSO composite spectra produced by SDSS and 2df

4MOST will build upon present AGN research and will add new multi-epoch time-domain science

the AGN DRS science cases described my A. Merloni can be expanded by

calibrated black hole mass estimators

time-dependent absorption line variability studies

understanding the Fe II multiplet emission

AGN composite spectra and multi-epoch comparisons