Photometric Reverberation Mapping of AGNs at $0.1 < z < 0.8$

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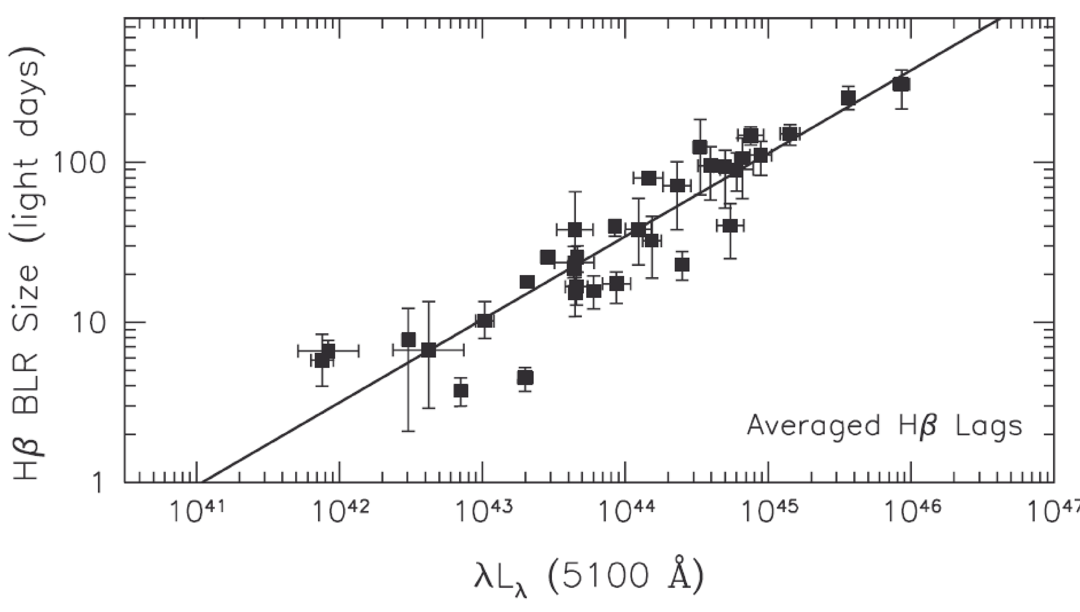
1. Introduction

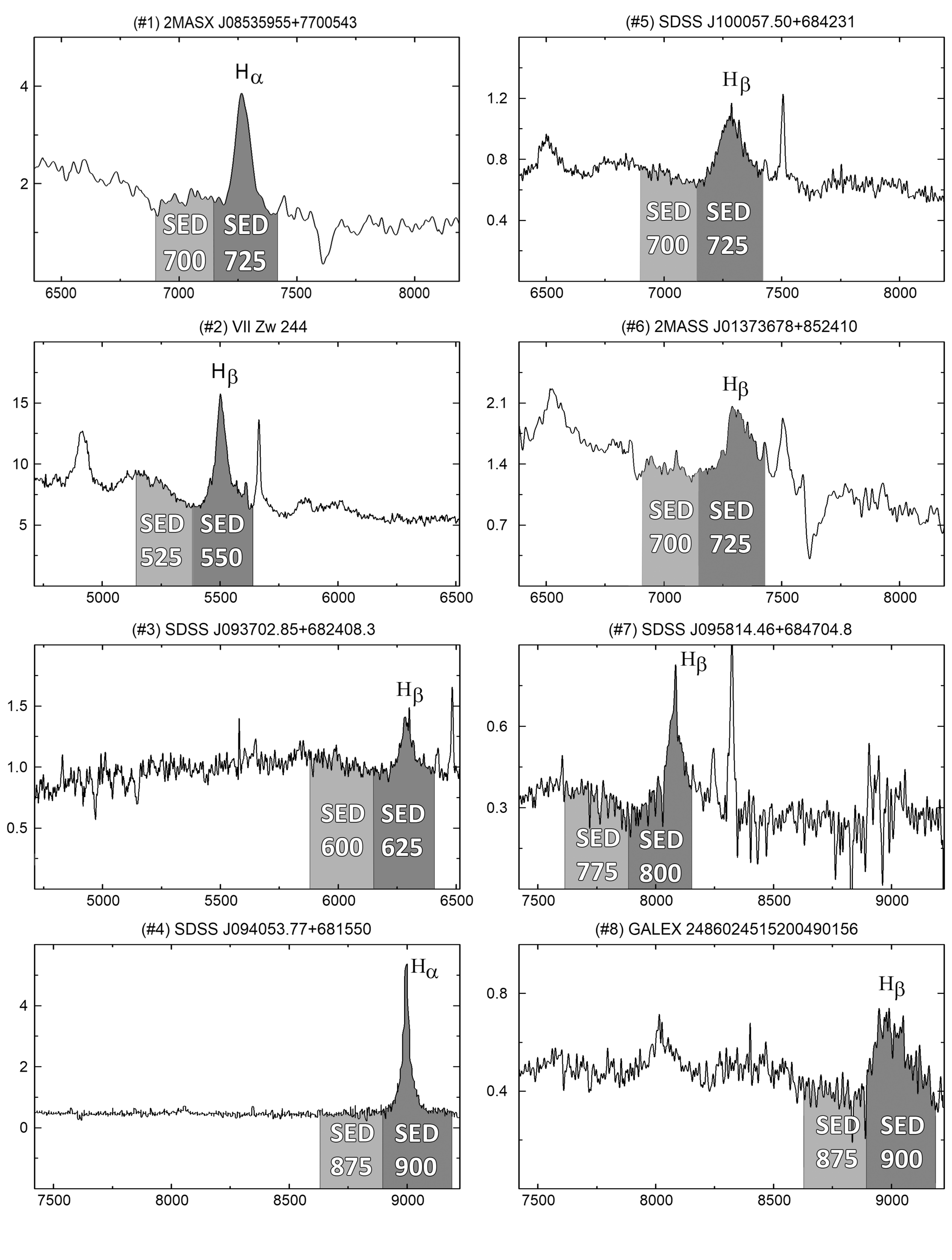
It is assumed there is a SMBH surrounded with an accretion disk (AD) in the centre of AGNs. A hot AD generates a variable UV/optical continuum re-emitted in broad lines in the photoionization regions – BLR. Reverberation mapping [1,2] relies on the measurement of the time delay τ between the signal in continuum and lines: $R_{BLR} \equiv c\tau$. In [3] the relation between BLR size and luminosity at 5100Å is suggested:



The main goal is to expand this dependence up to $z \sim 0.8$.

2. Observations

The observations were carried out on the 1-m Zeiss telescope (SAO) using the **MaNGaL**[a] and **MMPP**[b] instruments in the photometric mode. The 250Å-band SED filters covering 5000 – 9000Å were used. For each object, 2 filters were chosen: one corresponding to the broad H_β (or H_α) line and another corresponding to the continuum near.



Our sample consists of 8 nonsetting AGN type 1 at redshifts from 0.11 to 0.85. Started in February 2018, the monthly observations have given up to 27 measurements for every object from the sample.

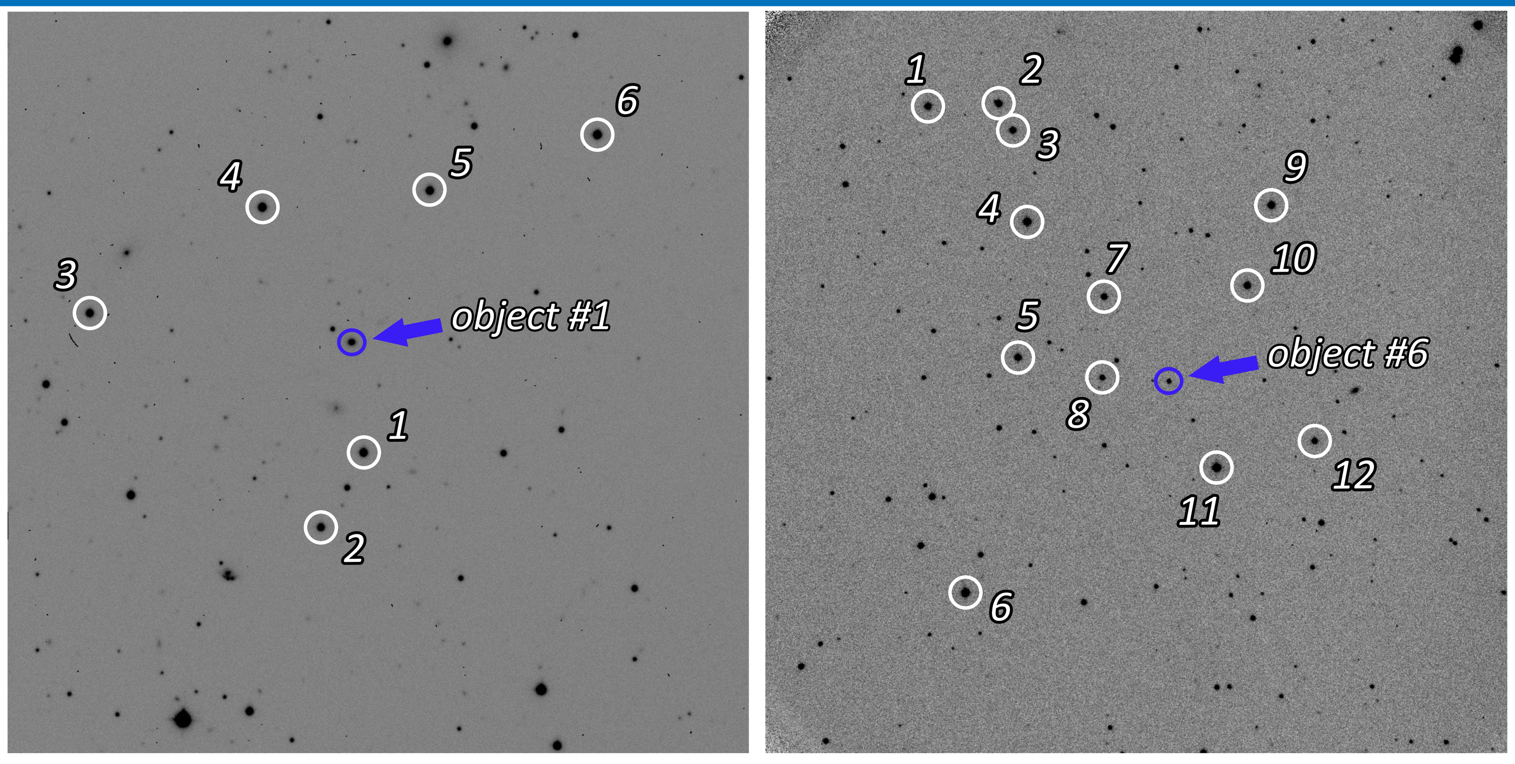
To minimize the atmospheric variations and to define the local standards the photometric standard stars are observed quasi-simultaneously. The average accuracy of photometry is 0.03 mag.

[a]Mapper of Narrow Galaxies Lines; Moiseev & Perepelitsyn
[b]Multi-Mode Photometer-Polarimeter

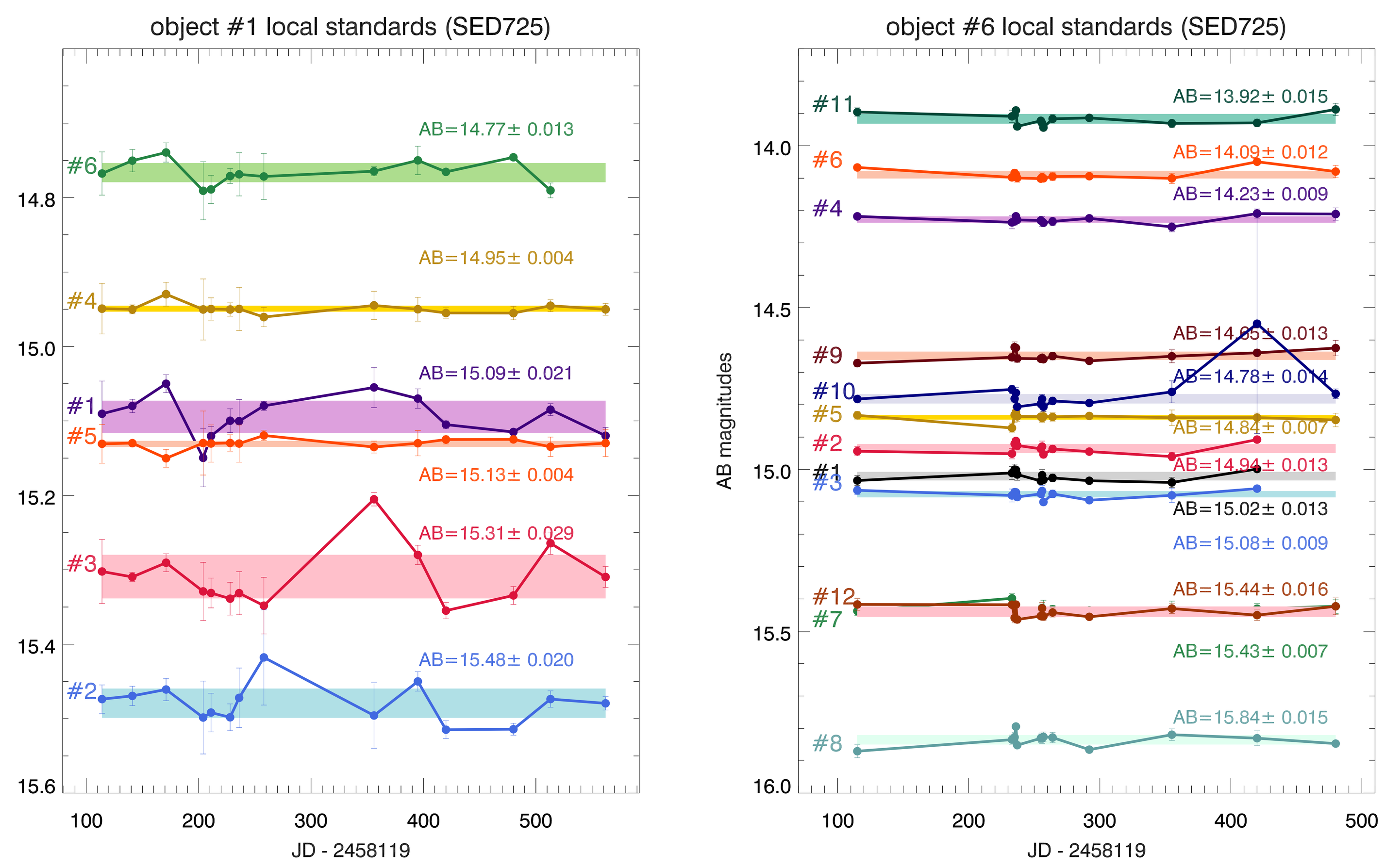
3. Sample of Objects

#	Name	RA (J2000) Dec	Mag	z	Type	SED filters
1	2MASX J08535955+7700543	$08^h53^m59^s.4$ $+77°00'55''$	V:17.0	0.106	Sy1	[725 + 700]
2	VII Zw 244	$08^h44^m45^s.3$ $+76°53'09''$	V:15.7	0.131	Sy1	[550 + 525]
3	SDSS J093702.85+682408.3	$09^h37^m02^s.9$ $+68°24'08''$	V:18.0	0.294	Sy1,QSO	[650 + 625]
4	SDSS J094053.77+681550.3	$09^h40^m53^s.8$ $+68°15'50''$	V:19.4	0.371	QSO	[900 + 875]
5	SDSS J100057.50+684231.0	$10^h00^m57^s.5$ $+68°42'31''$	V:19.0	0.499	QSO	[725 + 700]
6	2MASS J01373678+8524106	$01^h37^m36^s.7$ $+85°24'11''$	V:16.6	0.499	Sy1	[725 + 700]
7	SDSS J095814.46+684704.8	$09^h58^m14^s.4$ $+68°47'05''$	V:19.7	0.662	QSO	[800 + 775]
8	GALEX 2486024515200490156	$10^h01^m51^s.6$ $+69°35'27''$	V:19.6	0.847	QSO	[900 + 875]

4. Results

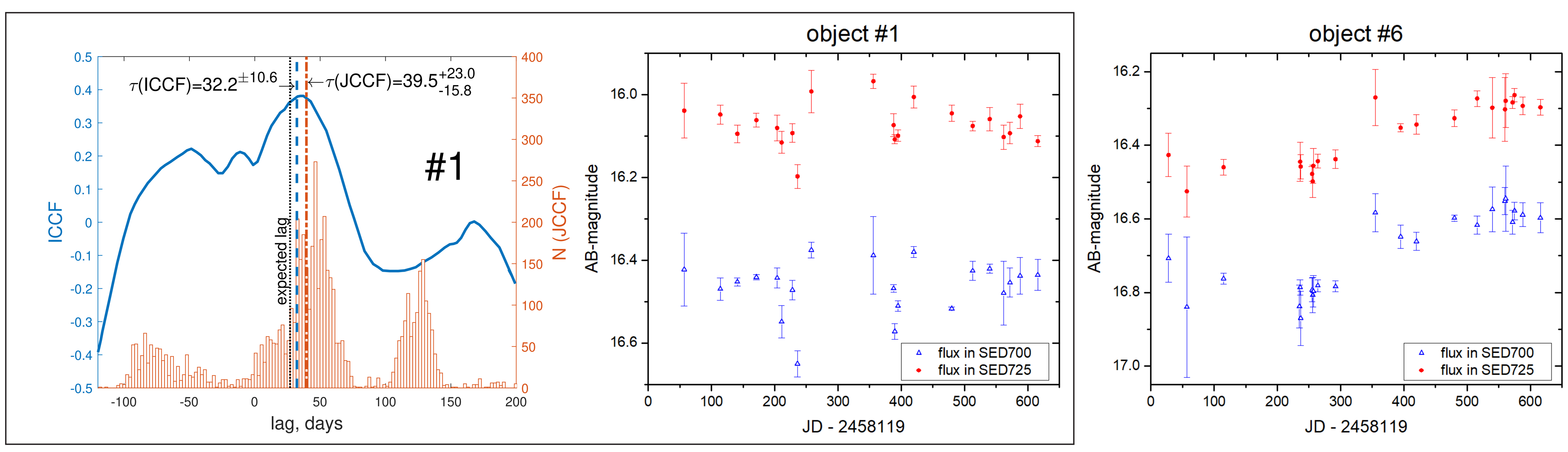


The local standards for each sample object are selected. On the right, we show the image of field #6 (2MASS J01373678+8524106) obtained in the SED725 filter (FoV – $8.'7 \times 8.'7$) with marked local standards. On the right are the local standards curves for the objects #1 and #6. To examine the variability of the stars in the fields gained fluxes were normalized to the most frequently observed and the most stable star flux. The fluxes are given in AB-magnitudes. On the light curves, the 3σ confidence area are also plotted.



The obtained light curves for the objects #1 and #6 show that the objects are highly variable with clearly seen long-term trend and short-term changes. The broad line flux is plotted with red dots and the continuum flux by blue ones.

The solid curve in Figure "ICCF and JCCF" below denotes the interpolated cross-correlation function (ICCF). Fitting the Gaussian to the most powerful ICCF peak gives us an estimate of the time delay $\tau(ICCF) = 32.2^{\pm 10.6}$ days. Note that to obtain a contrast peak, it is also necessary to subtract the contribution of the continuum to the total flux in the emission line.



The figure also shows the JCCF method as a histogram obtained using `JAVELIN` [4] (Just Another Vehicle for Estimating Lags in Nuclei) code implemented in the `python` programming language. As a result, we got the value $\tau(JCCF) = 39.5^{+23.0}_{-15.8}$ days. The estimate itself corresponds to the median value of the most powerful peak, located in the range from -20 to 80 days in the figure. Corresponding delay time estimates marked by dashed ($\tau(ICCF)$) and dash-dotted ($\tau(JCCF)$) vertical lines. The dotted line shows the expected value of τ from calibrations.

References

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5. Conclusions

1. For each of the sample objects up to 27 epochs are gained in two medium-band SED filters corresponding to the broad $H_{\alpha(\beta)}$ line and continuum near.
2. The unvariable stars — the local standard stars — are defined using the photometric standards for each object from the sample. The differential photometry by local standards in frame solves the atmospheric variations that provides the 0.03 mag photometric accuracy.
3. Preliminary cross-correlation results of object 2MASX J08535955+7700543 (#1) reverberation mapping are shown above. Applying the classical cross-correlation function and `JAVELIN` gave estimates of the delay time $\tau(ICCF) = 32.2^{\pm 10.6}$ days and $\tau(JCCF) = 39.5^{+23.0}_{-15.8}$ days that are consistent with each other and within the accuracy of the existing calibration dependencies.