A search for rapid optical variability in low-mass Seyfert galaxies: NGC 4395

E. Semkov[1], R. Bachev[1], A. Strigachev[1], S. Peneva[1], A. C. Gupta[2]

[1] Institute of Astronomy, Bulgarian Academy of Sciences, Bulgaria
[2] Aryabhatta Research Intitute of Observational Sciences, Nainital, India

Introduction

Brightness variability is an intrinsic feature of all accreting objects, from interacting binaries with a compact component (cataclysmic variables, dwarf novae, Galactic black holes, etc.) to supermassive accreting systems (quasars, Seyfert nuclei). The cause of the variability is not yet fully understood, but should somehow be related to some instability processes associated with the accretion itself. Therefore studying variability might help to better understand accretion, which appears to be one of the most important processes for energy generation and all-scale structure building in the Universe. Time scales of accretion-driven optical variability are very different and perhaps depend on many unknowns, but as a first approximation they appear to scale with the mass of the compact object. Thus stellar-mass compact accretors may vary significantly within minutes or seconds, while a 10^9 $M_\odot$ (radio-quiet) quasar typically needs weeks or months for such a brightness change. The gap between them is partially filled by the IMBH (intermediate mass black holes, ~10^3 $M_\odot$), whose observational appearance is mostly in the X-ray bands, and LLAGN (low-luminosity/mass active galactic nuclei, ~$10^{5\text{-}6}$ $M_\odot$), which can successfully be studied in optical bands as well. We selected a sample of such low-mass AGN to probe the characteristics (time scales, amplitudes, color dependences, etc.) of their short-term optical variability. All objects are radio-quiet, e.g. no relativistic jet contribution is present to alter the characteristics of the accretion-attributed variability.

NGC 4395 is a nearby (z = 0.001) Sd-type active galaxy with broad optical emission lines and a point-like hard X-ray source. It is often referred to as the nearest and the least luminous Seyfert 1 type AGN. Its central black hole mass and Eddington ratio, measured trough the reverberation-mapping technique, are found to be M_{BH}~4.10^5 $M_\odot$ and L/L_{Edd}~0.001 (Peterson et al. 2005). The X-rays continuum of this object shows very rapid variations on seconds-to-minutes time scale (Leighly 1999; Vaughan et al. 2005). On the other hand, rapid (intranight) optical variations have been previously reported by Lira et al. (1999) and Desroches et al. (2006) who, during a low activity state, also found a lag of optical bands behind the UV (~25 min) and X-rays (~45 min), consistent with the idea of a hard radiation reprocessing within the accretion disk into softer wavelengths. Similarly, for this object variations are found in the optical and near IR bands by Minezaki et al. (2006) and Skelton et al. (2005).

Observations and reductions

We monitored NGC 4395 for 2-5 hours each observing night for several nights during the period March – April, 2011. The object was observed with the 2-m RCC and 50/70 Schmidt telescopes of NAO Rozhen, and the 60-cm telescope of Belogradchik observatory. All telescopes are equipped with CCD detectors and standard UBVRI filter sets. To improve the signal-to-noise ratio, the smaller 60-cm telescope observed without filter on some occasions. All frames were properly corrected for bias/dark current and flat field. Photometry was performed with an aperture radius of 4 and 6 arcsec, which is typically 2 times the seeing. Variable atmospheric conditions (seeing, transparency), combined with a rich stellar field and underlying host galaxy make aperture photometry quite difficult and the results should be interpreted with care (e.g. Fig. 5).

***Table 1**. Log of observations and measured VRI magnitudes of NGC 4395*

JD 2455…	V	err	R	err	I	err	Telescope
646.42	16.30	0.03	16.02	0.03	15.98	0.04	AOB60
647.34	16.22	0.04	15.90	0.04	15.92	0.05	AOB60
648.34	16.17	0.05	15.93	0.03	15.87	0.04	AOB60
652.36	16.34	0.05	16.06	0.04	15.99	0.05	AOB60
656.34	16.10	0.04	15.92	0.06	15.92	0.08	R50/70
659.33	16.22	0.02	15.93	0.02			R2m
661.33	16.10	0.02	15.89	0.02			R2m
681.41	16.33	0.04	16.15	0.03			R2m

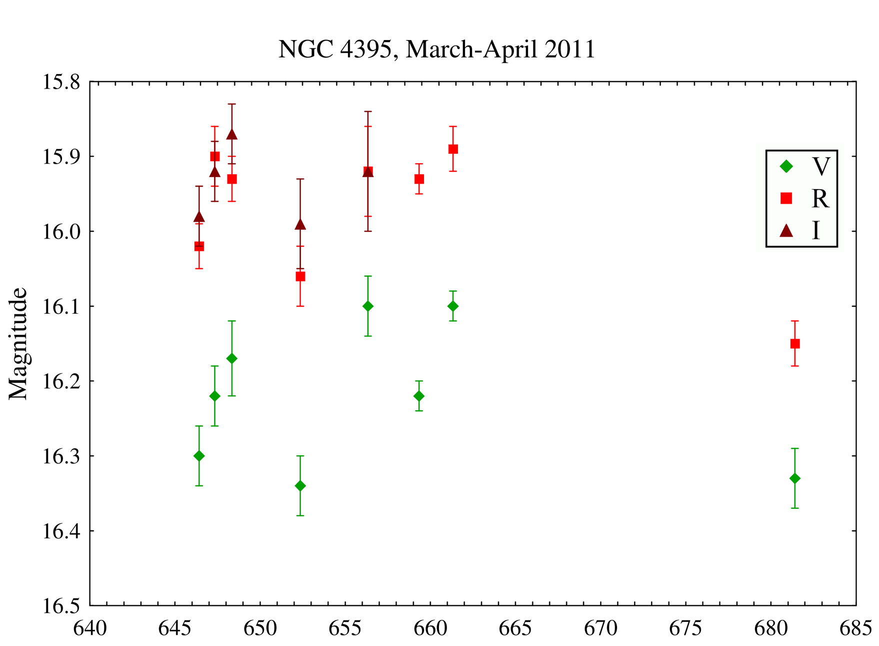

***Fig. 2.** Short-term variability of NGC 4395 during the observational period*

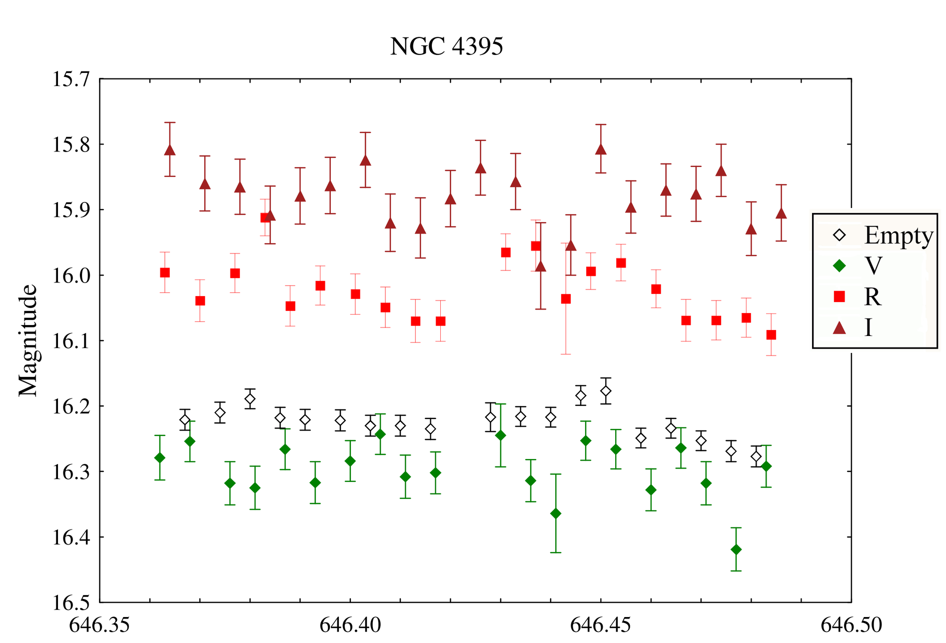

***Fig. 3.** Intra-night variability in 3 colors as well as in unfiltered light during the night of 25.03.2011. 60 cm telescope of Belogradchik Observatory*

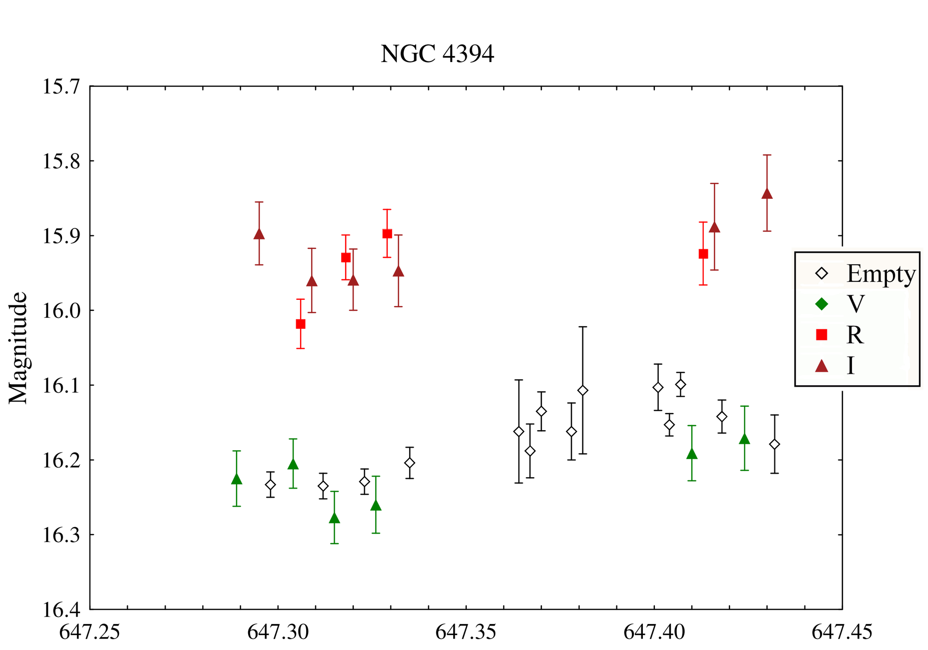

***Fig. 4.** The same as in Fig. 3 for the night of 26.03.2011*

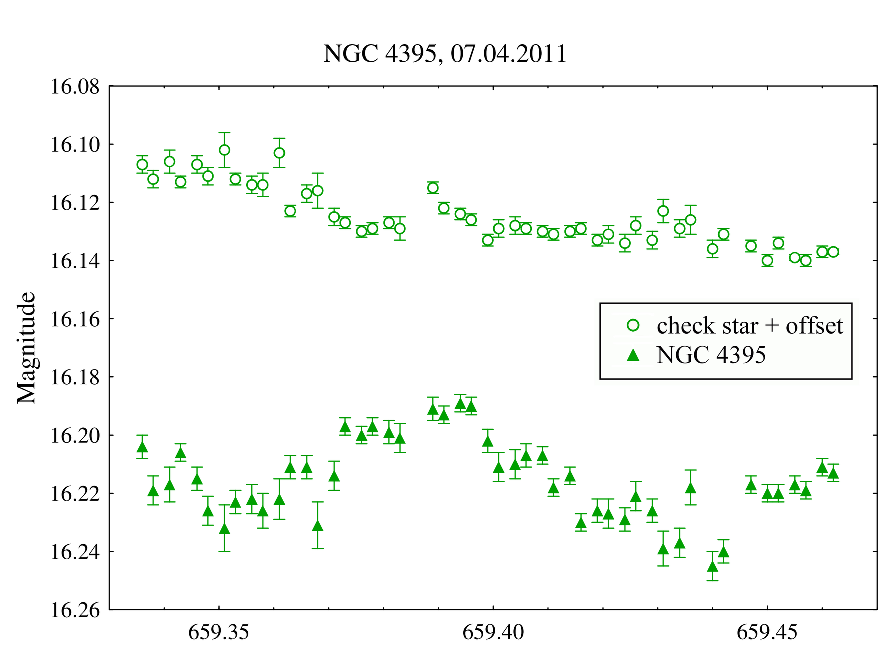

***Fig. 5.** V-band variability of NGC 4395 and a check star. 2m RCC telescope of NAO Rozhen*

***Fig. 1.** A color image of NGC 4395 obtained with the 2-m RCC telescope of NAO Rozhen (VersArray CCD camera + B, V and R filters)*

Results

Table 1 gives the log of the observations and measured magnitudes. All magnitudes are measured with 6 arcsec aperture radius, with respect to a check star with no other color corrections. Background is subtracted from an annulus just outside the diaphragm. No host galaxy contribution is removed. In order to facilitate future monitoring, we calibrated secondary standard stars in the field of NGC 4395. For that purpose we observed in a photometric night calibrated standards in the field of M67 (Chevalier & Ilovaisky, 1991). The errors are mostly due to the calibration. As this result is based on single-night observations, it should be considered preliminary. The short-term variations (VRI bands) of NGC 4395 on a day-to-day scale are shown in Fig. 2. Despite the mostly unstable weather conditions, we see good indications of variability amplitudes of 0.2 - 0.3 mag for the period of monitoring. The object appears to be on average ~0.4 mag brighter than it was the last time it was observed by us (May 04, 2006) and should perhaps be considered in a high state. Unfortunately, the lack of systematic photometric data prevents drawing a firm conclusion about its brightness state. Fig. 3 - 5 show examples of intra-night variations. In spite of the previous reports, no significant variations, exceeding the errors, are seen there as well as during the other nights of monitoring.

Discussion and conclusions

During seven nights and a total of ~16 hours of monitoring with two telescopes, NGC 4395 showed some variability on a day scale but no significant intra-night variations. The later, if present at all, can be described as slow, small-amplitude wobbles or trends. This result is in a stark contrast with the X-ray variability picture; however is not surprising, considering the probably different regions producing these two wavebands. While the X-rays are produced very near the center or in compact regions in the corona above the accretion disk (hot spots), the optical emission arises in a much geometrically larger region in the accretion disk. Obviously, only a small fraction of the optical emission is due to X-ray reprocessing; otherwise even light-travel effects (smearing) cannot prevent optical variations of up to a magnitude to be observed on an hour timescale (taken into account the time lags, mentioned in Sect. 1). On the other hand, the X-ray monitoring was performed a few years ago, during perhaps a lower brightness state. There is no way to know if the X-ray variations are of such violent nature during the time of our observations.

Acknowledgements. This research was partially supported by the grants BIn 13-09, DO 02-85 and DO 02-362 of the National Science Fund of the Ministry of Education, Youth and Science, Bulgaria.

References:

Chevalier C., Ilovaisky S. A., 1991, A&AS, 90, 225
Desroches L. B., et al., 2006, ApJ 650, 88
Leighly K. M., 1999, ApJS 125, 297
Lira P., et al., 1999, MNRAS, 305, 109
Minezaki T., et al., 2006, ApJ 643, 5
Peterson B. M. et al., 2005, ApJ 632, 799
Skelton J. E. et al., 2005, MNRAS, 358, 781
Vaughan S. et al., 2005, MNRAS 356, 524