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INTERNATIONAL CHANGING LOOK AGN MONITORING PROJECT: FIRST RESULTS

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The Changing Look AGNs (CL AGNs) are objects that undergo dramatic variability of the emission line profiles and classification type of which can move from one spectral class to another within a very short time interval (from days to years). We started the project ([1] of spectral and photometric multiwavelength (from IR to X-ray) monitoring which includes the selected set of the CL AGNs. At start we were going to use several telescopes:2-m (ShAO), 2.5-m, 1.25-m, 0.6-m, 0.5-m (SAI), MASTER global net, and *Swift* (UVOT and XRT) observatories. Then additionally, we used spectral data obtained at the WIRO, SAAO and photometry obtained at the WISE, and some other observatories. The main goal of the project is to investigate the possibilities for the repeating CL events. Investigation of such type of objects can be very informative for understanding the nature of these fast strong variations as well as the physics of the AGNs. We present the first results of our research for several CL AGNs which were mostly published already. We discovered some new CL events in several objects and discussed common properties of the CL AGNs.

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1. INTRODUCTION

Active Galactic Nuclei (AGNs) are galaxies with incredibly bright cores which concentrate and radiate more energy than most galaxies. It is believed that at

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their centers are super-massive black holes (SMBHs) that are feeding off surrounding stars, dust and gas. The AGNs have different spectral types (see details in [2]) which can be connected with different orientation to the line of site and existence of dust toruses around the SMBHs (AGN unification schemes [3]). One of the biggest challenge to the simple AGN unification schemes is existence of Changing-look (CL) AGNs. Changing-look AGNs are objects which undergo dramatic variability of their emission line profiles and classification type. They can move from one spectral class to another within very short time intervals (from weeks to years). One of the first know CL – NGC 4151 was discovered by us at 1984 [4], and after that till present time more than 100 CL AGNs have been discovered.

At 2016 we have begun spectral observations of the NGC2617 (a known CL [5]) with 2-m telescope (ShAO) and proposed the project of spectral and photometric multiwavelength (IR to X-ray) monitoring of such objects. The project includes the selected set of AGNs known already as the CL AGNs [1]. The investigation of recurrent CL events is the main goal of the CL monitoring project. First results of the project for several CLs are already published at [1,6–26]. The project includes collaboration with scientists from 11 countries.

2. OBSERVATIONAL DATA AND RESULTS

We are using the 2.5-m telescope of the CMO SAI and 1.25-m telescope of the Crimean SAI observatory (DAS) for IR $JHKL$ photometry and optical spectrophotometery, 2.3-m telescope WIRO, 2-m Zeiss (ShAO), 1.9-m telescope (SAAO) and small telesopes 0.6-m (CMO), Zeiss-600, AZT-5 (DAS) for $UBVRI$ photometry (and some others). We obtain historical light curves for known and newly discovered objects using the MASTER observations. We apply for X-ray and UV observations of some CL AGNs with the $Swift$.

2.1. NGC 2617

Intensive multi-wavelength observations of NGC 2617 were triggered by the discovery [5] of a CL event in 2013. At 2016 we started our research of the object to trace potential recurrent state changes and published our results of long-term monitoring in [1,6–13,25,26]. We proposed (using the MASTER photometry) [10] that the type change had probably occurred before 2013 – between 2010 October and 2012 February. We found significant variability at all wavelengths and in the intensities and profiles of the broad Balmer lines. We firstly noted presence of the the emission peak at the red wing of Hβ [10]. Reverberation mapping was carried out for 8 observing seasons during 2021-2024. We obtained time delays of

~ 4 d for the response of the Hβ line to optical continuum variations. The X-ray variations correlate well with the UV and optical, with a few days lag for longer wavelengths. The K band lagged the B band by ~ 15 d during the last 3 seasons, which is significantly shorter than the delays reported previously by the 2016 and 2017–2019 campaigns. Near-IR variability arises from two different emission regions: the outer part of the accretion disc and a more distant dust component. The HK-band variability is governed primarily by dust. The Hβ/Hα ratio variations (for broad components only) correlate with the X-ray and UV fluxes. The spectral type changed from type 1.2 (2016) to type 1.9 (January 2024) and then was a more rapid change to type 1.5 occurred in February 2024. We interpret these changes as a combination of two factors: changes in the accretion rate as a dominant cause but also the sublimation or recovery of dust along the line of sight

2.2. NGC 1566

NGC 1566 is a galaxy with a very well-studied variable active nucleus in the South Hemisphere. It is a nearest AGN and CL AGN. It is one of the first discovered CLs (see details and references in [15]). Our results of the NGC 1566 investigations published in [14,16,19,21,22]. We presented optical, UV and X-ray light curves of the nearby changing look of the NGC 1566 obtained with the Neil Gehrels *Swift* Observatory and the MASTER Global Robotic Network over the period 2007- 2020. We also report on our optical spectroscopy (started soon after the brightening was discovered in July 2018) at the South African Astronomical Observatory with the 1.9-m telescope on the night 2018 August 2–3. A substantial increase in X-ray flux (by 1.5 orders of magnitude), as well as outburst in UV and optical bands were observed at 2018. After the maximum was reached at the beginning of 2018 July the fluxes in all bands decreased with some fluctuations. The amplitude of the flux variability is strongest in the X-ray band and decreases with increasing wavelength. Low-resolution spectra reveal a dramatic strengthening of the broad emission as well as high-ionization [FeX] λ6374 lines. These lines were not detected so strongly in the past published spectra. The change in the type of the optical spectrum was accompanied by a significant change in the X-ray spectrum. All these facts confirm NGC 1566 to be a changing look Seyfert galaxy [15]. In the next publications [19, 21, 22] we concentrated on the remarkable post-maximum behaviour of the object after July 2018 when all bands decreased with some fluctuations. We observed three significant re-brightenings in the post-maximum period during 17 Nov. 2018 – 10 Jan. 2019, 29 Apr. – 19 Jun. 2019 and 27 Jul.– 6 Aug. 2019. An X-ray flux minimum occurred in Mar. 2019. The UV minimum occurred about 3 months later. It was accompanied by a decrease of the Luv/Lx ratio. New post-maximum spectra covering (31 Nov. 2018–23 Sep. 2019) show dramatic changes compared to 2 Aug. 2018, with fading of the broad lines and [FeX] λ6374 until Mar. 2019. These lines became somewhat brighter in Aug.-Sep. 2019. Effectively, two CL states were observed for this object: changing to type 1.2 and then returning to the low state as a type 1.8 Sy. We suggest that the changes are due mostly to fluctuations in the energy generation. The estimated Eddington ratios are about 0.00055 for minimum in 2014 and 0.02.8 for maximum in 2018.

2.3. NGC 3516

NGC 3516 is not only the first object with detection of spectral variability for Seyfert galaxies but also the first example of a CL AGN (see details and references in [20]). Our results for the object are published in [18–20]. We present the results of photometric and spectroscopic monitoring campaigns of the NGC3516 carried out in 2016 to 2020 covering the wavelength range from the X-ray to the optical. The facilities included the telescopes of the CMO SAI MSU, the 2.3-m WIRO telescope, 2.0-m telescope ShAO and the XRT and UVOT of $Swift$ and some others. We found that NGC 3516 brightened to a high state and could be classified as Sy1.5 during the spring 2016, late spring of 2020, and had a deep minimum in 2017–2018. We fixed several transitions of the spectral type and confirm that the object is CL AGNs as it was discovered in [27]. We have measured time delays in the responses of the Balmer and He II 4686 lines to continuum variations. In the case of the best-characterized broad Hβ line, the delay to continuum variability is about 17 days in the blue wing and is clearly shorter, 9 days, in the red, which is suggestive of inflow. As the broad lines strengthened, the blue side came to dominate the Balmer lines, resulting in very asymmetric profiles with blueshifted peaks during this high state. During the outburst the X-ray flux reached its maximum on 1 April 2020 and it was the highest value ever observed for NGC 3516 by the $Swift$ observatory. The X-ray hard photon index became softer, 1.8 in the maximum on 21 Apr 2020 compared to the mean 0.7 during earlier epochs before 2020. We have found that the UV and optical variations correlated well (with a small time delay of 1 – 2 days) with the X-ray until the beginning of April 2020, but later, until the end of Jun. 2020, these variations were not correlated. We suggest that this fact may be a consequence of partial obscuration by Compton-thick clouds crossing the line of sight.

3. DISCUSSION AND CONCLUSIONS

From our results we can conclude that the variability across several wavebands in CL AGNs (spanning from X-rays to the UV/Optical) is driven by variable illumination of the accretion disc (AD) by soft X-rays. We have to determine the most significant common features of such variability. That can help us to find the most likely explanations for the CL phenomenon (see e.g. discussion and references in [21, 22]). There are several different possibilities that have been considered: variable obscuration, AD flares, tidal disruption events (TDEs), and supernova event. The TDE and supernova explanations can be rejected given the differences between expected and observed time scales for such events, as well as their spectral properties and evolution. An alternative theory proposes the tidal stripping of stars [28, 29], which could lead to more frequent and recurrent events [30] if these stars have bound orbits similar to some known objects near the SMBH in the Milky Way. However, the mechanism has not been investigated in sufficient details yet. At present we are far from understanding the CL phenomenon, and many questions remain still.

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