THE REMARKABLE POST-MAXIMUM BEHAVIOR OF THE CHANGING LOOK SEYFERT GALAXY NGC 2617

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.Optical and near-infrared photometry, optical spectroscopy, and soft X-ray and UV monitoring of the changing-look active galactic nucleus NGC 2617 show that it continues to have the appearance of a type-1 Seyfert galaxy. An optical light curve for 2010–2016 indicates that the change of type probably occurred between 2010 October and 2012 February and was not related to the brightening in 2013. In 2016, NGC 2617 brightened again to a level of activity close to that in 2013 April. We find variations in all pass bands and in both the intensities and profiles of the broad Balmer lines. A new displaced emission peak has appeared in Hβ. X-ray variations are well correlated with UV–optical variability and possibly lead by 2–3 d. The K band lags the J band by about 21.5 $\pm$ 2.5 d and lags the combined B + J filters by 25 d. J lags B by about 3 d. This could be because J-band variability arises from the outer part of the accretion disc, while K-band variability comes from thermal re-emission by dust. We propose that spectral-type changes are a result of increasing central luminosity causing sublimation of the innermost dust in the hollow bi-conical outflow. We briefly discuss various other possible reasons that might explain the dramatic changes in NGC 2617.

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1. INTRODUCTION

In the unified model, two main types of AGN, broad-line (or type I) and narrow-line (type II) are postulated to be the same sort of object, whose appearance depends on the viewer's line of sight. The two types are so-named because of the characteristic emission lines in their spectra – type I AGN have very broad emission lines and a higher level of continuum emission, while type II AGN lack the broad-line signatures and instead feature very narrow emission lines and weaker continua. The idea behind the unification scheme is that the central black hole is surrounded by an "obscuring torus" of gas and dust. Thus, if the broad emission lines are produced in a region close to the central black hole, while the narrow-line features are created at a more distant radius outside the torus, it is possible for the broad lines to be hidden, depending on the angle at which the AGN is seen. The best evidence for this scenario comes from spectropolarimetry observations of some type II AGN in which broad emission lines are seen in polarized light, as would happen if the broad-line region truly were hidden, and the light were being reflected off the torus and into the viewer's line of sight.

For decades, astronomers wondered why we see internal regions in some active galactic nuclei, but not in others. The most popular explanation is a different viewing angle: if the AGN is located flat relative to the observer from the Earth, then a hot gas falling in a spiral into its black hole can be considered, and if it is tilted to the line of sight, only slow moving gas clouds will be visible light year distance or more from the black hole. However, there are AGNS that do not fit into these representations: they can either open the inner region of the nucleus or hide it, in other words, changing look their type.

Active galactic nuclei (AGNs) can be classified on the basis of their optical spectra into 'type-1' AGNs (Sy1), showing prominent broad Balmer lines, and 'type-2' AGNs (Sy2), lacking obvious broad Balmer lines. Designations such as 'Seyfert 1.8' are used for intermediate cases [1]. Rare cases of so-called 'changing-look' AGNs (CL AGNs) – AGNs that show extreme changes of spectral type – pro-vide important tests of theories of the Sy1/Sy2 dichotomy. The first detailed investigations of changes from type 2 to type 1 and back to type 2 were for Mrk 6 [2] and for NGC 4151 [3–5]. Recent reviews by Shappee et al. [6] and Koay et al. [7] give lists of objects and references.

CL AGNs such as NGC 2617 are rare. There are currently only some tens of cases known. However, the small number of known CL AGNs is comparable to the number of AGNs that have had many years of spectral monitoring. It is therefore reasonable to suspect that perhaps each strongly variable AGN could be found to be a CL AGN if observed long enough. This assumption is supported by recent results of Runco et al. [8] that about 38 per cent of 102 Seyferts changed the type, and about 3 per cent of the objects have disappearing Hβ on time-scales of 3–9 yr. Also, MacLeod et al. [9] estimate that >15 per cent of strongly variable luminous quasars exhibit a changing-look behaviour on rest-frame time-scales of 3000–4000 d.

2. OBSERVATIONS

We commenced the spectroscopic and photometric monitoring of NGC 2617 in 2016 January to see if it still appeared to be a type-1 AGN three years after the intensive 2013 monitoring campaign of Shappee et al. [6]. Our observations included IR (JHK) and optical (BVRcIc) photometry and spectroscopy. Additionally, we have used unfiltered optical monitoring by the MASTER robotic network from 2010 to 2016. We found that the nucleus of NGC 2617 remains in a high state and can still be classified as a type-1 AGN [10]. The optical photometry and IR photometry show that the activity of NGC 2617 is continuing and that it underwent another series of outbursts in 2016 April–June. These outbursts are comparable, in level, to those when NGC 2617 was observed by Shappee et al. [6] in 2013 May [11,12]. We subsequently applied for soft X-ray and UV observations with the Swift/XRT. These began on 2016 May 17 and continued till 2016 June 23.

3. OPTICAL SPECTROSCOPY

We obtained optical spectra covering 4100–7000 Åwith the 2 × 2 prism spectrograph and a 4K CCD (spectral resolution 3–7 Å) on the 2-m Zeiss telescope of the Shamakhy Astrophysical Observatory (ShAO) on the four nights of 2016 February 3 and 4, March 4 and April 9. Examples of mean spectra of the Hβ region for three of the nights can be seen in Fig.1 together with a spectrum from Shappee et al. [6]. It can be seen from all our 2016 spectra that NGC 2617 can be classified without any doubt as a type-1 AGN.

In our spectra, one can see a displaced emission component in the red wing of Hβ at a relative velocity of +2500 km s^{-1}, which was not apparent in spectra obtained in 2013. We could not verify that this new component is also present in the Hα profile because of the inferior resolution of the prism spectrograph at long wavelengths. The emission component cannot be identified confidently in the profile of H_γ as there is strong [O III] λ4363 emission.

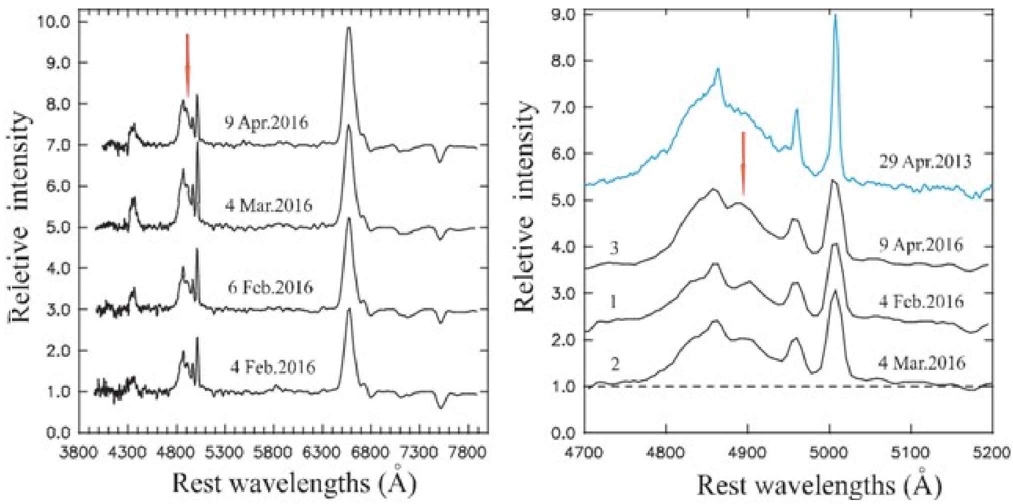

Fig. 1. Top panel: our mean spectra for four dates normalized to the continuum and offset for clarity. Bottom panel: comparison between the Shappee et al. [6] Apache Point Observatory 2013 April 25 spectrum of the Hβ region of NGC 2617 and our spectra from 2016 February 4 (1), March 4 (2) and April 9 (3). Spectra have been normalized to the continuum level, and then relative calibration has been performed by assuming a constant flux in [O III] λ5007 and λ4959. Spectra are offset for clarity. The arrows show the locations of the displaced emission peak in the red wing of Hβ.

4. OPTICAL BVRCIC OBSERVATIONS

We obtained optical BVRcIc CCD data with the AZT-5 (a Maksutov 50-cm meniscus telescope equipped with an Apogee Alta U8300 CCD camera) at the MSU Crimean Observatory and with the Zeiss-600 using a 4K CCD at ShAO on 17 nights in 2016 March–May. The data were calibrated using SDSS stars within 1.5 arcmin of NGC 2617 and transformed into the Johnson–Cousins magnitude system in the same manner as Shappee et al. [6]. We measured the background within an annulus of radii 35–45 arcsec.

The BVRI light curves are shown in Fig.2. The magnitudes are for an aperture of 5 arcsec radius. NGC 2617 can be seen to have brightened by about 0.3 mag in B during March and then decreased by 0.1 mag in the middle of April. At the end of April, it began to brighten again and reached a maximum of 14.6 in B on May 19. One more maximum of the similar magnitude was reached near June 15. The amplitude of variations in V was about half the amplitude in B. Variations in Rc and Ic were synchronized with B-band variations but still with smaller amplitudes.

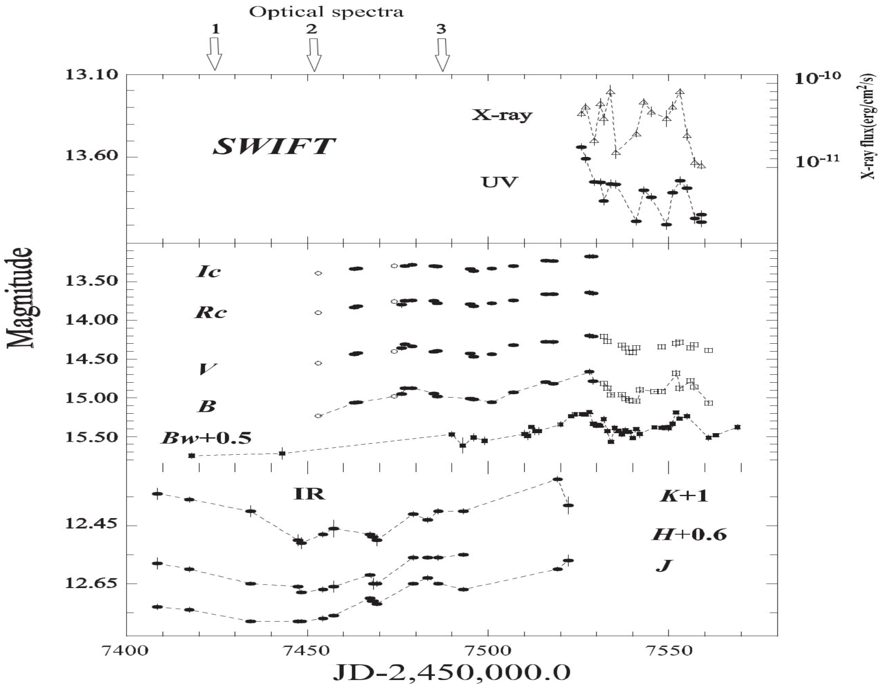

Fig. 2. Near-IR (bottom panel), optical (middle panel) and UV–X-ray (top panel) photometric observations of NGC 2617 over the 5-month period from 2016 January 30 to June 29. The solid circles in the middle panel are BVRcIc data obtained with AZT-5, while the open circles are observations with the Zeiss-600. Open boxes are filtered BV data obtained by the MASTER network, and solid squares (Bw) are from unfiltered MASTER data reduced to the B system. In the top panel, the solid circles are the combined Swift UV photometry reduced to the UVW1 system, whilst the X-ray flux is shown by the open triangles. Error bars are shown, but they are generally smaller than the plotting symbols. The dates of the optical spectra are indicated.

5. RESULTS

We determined the lag time in the K band (2.2 μm) relative to the optical variability in NGC 2617 in 2016 was about 25 days, which coincides with the estimate of the radius at which dust should be sublimated. For NGC2617, lags between variability at different wavelengths are defined. These results partially confirmed the previously obtained results, which are partly new and original; in particular the determination of the lag time of flow variations in the filter K, the relative optical variability is the first reliable result for this object.

We firstly discovered the presence of a variable emission component in the H_β line profile in the Seyfert galaxy NGC 2617 and noted that similar features are characteristic of other galaxies that changed their spectral type.

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