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Discovery of new changing look in NGC 1566

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Abstract. We present continuation of the multi-wavelength (from X-ray to optical) monitoring of the nearby changing look (CL) active galactic nucleus in the galaxy NGC 1566 performed with the *Neil Gehrels Swift Observatory*,the MASTER Global Robotic Network over the period 2007–2019. We also present continuation of optical spectroscopy using the South African Astronomical Observatory 1.9-m telescope between Aug. 2018 and Mar. 2019. We investigate remarkable re-brightenings in of the light curve following the decline from the bright phase observed at Dec. 2018 and at the end of May 2019. For the last optical spectra (31 Nov. 2018–28 Mar. 2019) we see dramatic changes compared to 2 Aug. 2018, accompanied by the fading of broad emission lines and high-ionization [FeX]6374Å line. Effectively, one more CL was observed for this object: changing from Sy1.2 to the low state as Sy 1.8–Sy1.9 type. Some possible explanations of the observed CL are discussed.

Keywords. AGN, Spectra, photometry, X-ray, variability, NGC 1566

1. Introduction

The NGC 1566 was discovered at 1826 by James Dunlop and has long history of investigations (see e.g. references at da Silva *et al.* (2017); Oknyansky *et al.* (2019); Parker *et al.* (2019)). The broad nuclear emission lines characteristic of the Seyfert phenomenon in this object were discovered in 1956 by de Vaucouleurs & de Vaucouleurs (1961); de Vaucouleurs (1973) and confirmed in 1962 by Shobbrook (1966). The NGC 1566 nucleus was later classified as type 1. It is one of the brightest ($V \approx 10^m.0$ but $V_{AGN} \approx 13^m.0$ in 5 arcsec radius aperture) and nearest galaxies with AGN in the South Hemisphere. This object is also nearest Changing Look (CL) AGN (Oknyansky *et al.* (2019)). The nucleus of NGC 1566 has a low brightness relative to the host galaxy ($V \approx 13^m.0$) and CL events there were probably discovered just because it is so close. The Changing Look active galactic nuclei (CL AGNs) are objects which undergo dramatic variability of the emission line profiles and classification type, which can change from type 1 (showing both broad and narrow lines) to type 1.9 (where the broad lines almost disappear) or vice versa within a short time interval (typically a few months). The dramatical spectral variations in NGC 1566 had been reported firstly by Pastoriza & Gerola (1970) after comparison of the spectrum obtained in 1969 with some of the earliest spectroscopic investigations, in 1956 (de Vaucouleurs & de Vaucouleurs (1961)), in 1962 (Shobbrook (1966)) where broad Hβ line was much more intensive. That was done soon after discovery of variability of AGNs in continuum (Fitch *et al.* (1967)) and variability of emission lines was not too unexpectable. The object had several dramatic changes of its spectrum during the past tens of years (da Silva *et al.* (2017)) but was not identified as a CL AGN until the 2018 event Oknyansky *et al.* (2018, 2019)) since this designation only came into common use in the past decade.

NGC 1566 is a galaxy with a very well-studied variable active nucleus, but most intensive multiwave photometic observations were done during past year after discovery of a new reawakening (Kuin *et al.* (2018); Ferrigno *et al.* (2018); Grupe *et al.* (2018a); Parker *et al.* (2019); Cutri (2018)) and new CL phase (see Oknyansky *et al.* (2018, 2019) and references there). A substantial increase of X-ray flux by 1.5 orders of magnitude was observed following the brightening in the UV and optical bands during the last year. After a maximum was reached at the beginning of July 2018 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.

2. Observational data and results

We summarize a study of optical, UV and X-ray light curves of the nearby changing look active galactic nucleus in the galaxy NGC 1566 obtained with the Neil Gehrels Swift Observatory and the MASTER Global Robotic Network over the period 2007–2019. The light curves for 2007-2018 are presented by (Oknyansky *et al.* (2019)) and those for the years 2018–2019 are shown in Fig. 1. It can be seen there that all variations in the optical, UV and X-ray are well correlated. We also report on optical spectroscopy using the South African Astronomical Observatory 1.9-m telescope between Aug 2018 (Oknyansky *et al.* (2018, 2019)) and Mar 2019. A substantial increase in X-ray flux by 1.5 orders of magnitude was observed following the brightening in the UV and optical bands during the first half of 2018 (Ducci *et al.* (2018); Kuin *et al.* (2018); Ferrigno *et al.* (2018); Grupe *et al.* (2018a); Oknyansky *et al.* (2018, 2019); Parker *et al.* (2019)). The amplitude of the flux variability is strongest in the X-ray band and decreases with increasing wavelength. After a maximum was reached at the beginning of July 2018, the fluxes in all bands decreased with some fluctuations. The most remarkable re-brightening in the light curve following the decline from the bright phase was observed at MJD range 58440-58494 (Event 1) and 58603-58654 (Event 2). Event 1 and Event 2 are indicated in Fig. 1 (see also Grupe *et al.* (2018b) and Grupe *et al.* (2019)). The amplitudes of the re-brightening in UV and optical bands are significantly higher for Event 1 than for Event 2. That is different from the X-ray variations for which fluxes in the maxima were about the same. This difference is well seen at Fig. 1. If we take into account the host galaxy contamination in the aperture used then the relative decreases from the maximum in July 2018 to minimum in June 2019 in the different UV/Opt bands were about the same ($\sim$9 times).

Low-resolution spectra (2 Aug 2018) (see Fig. 2) reveal a dramatic strengthening of the broad emission as well as high-ionization [FeX]6374Å lines. These lines were not detected so strongly in the past published spectra. The change in the type of the optical spectrum (Oknyansky *et al.* (2018, 2019)) was accompanied by a significant change in the X-ray spectrum. For the last spectra (30 Nov 2018–28 Mar 2019) we see dramatic changes compared to Aug 2018, accompanied by the fading of the broad emission lines. Effectively, two changing look were observed by us for this object during the past year.

3. Conclusion

NGC 1566 is one of the typical examples of a CL AGN, since it demonstrates dramatical variability of broad emission lines, UV continuum, high ionisation lines like [FeVII] and [FeX], and also recurrent brightening and dimming events. NGC 1566 is one of the

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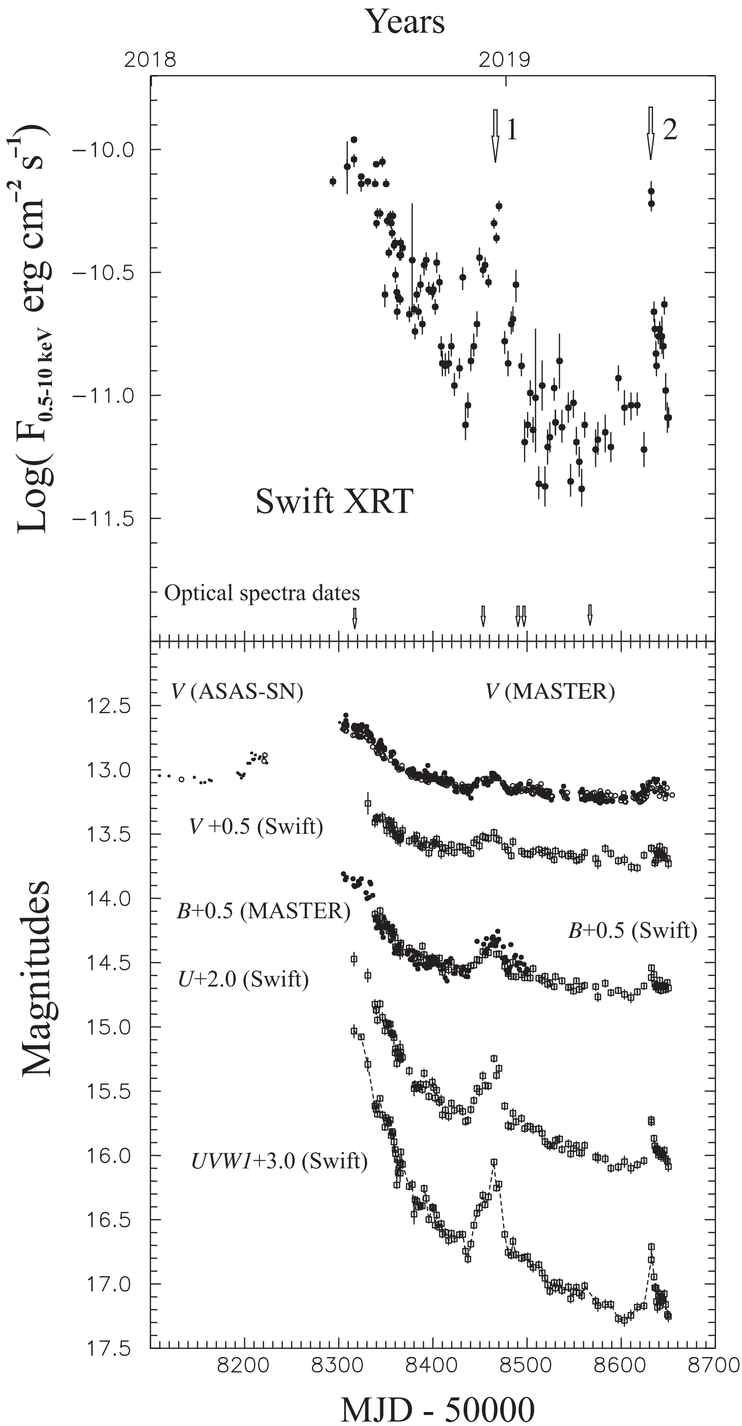

Figure 1. Multi-wavelength observations of NGC 1566 shown for 2018-2019 only. *Top Panel:* The *Swift*/XRT 0.5–10 keV X-ray flux (in erg cm^{-2} s^{-1}) – (filled circles). The big arrows show locations of the Event 1 and the Event 2 (see in the text).*Bottom Panel:* The large open circles are MASTER unfiltered optical photometry of NGC 1566 reduced to the V system while the points are V ASAS-SN (nightly means) reduced to the *Swift* V system. The filed circles are MASTER BV photometry. The open boxes are $UVW1$ and UBV data obtained by *Swift*.

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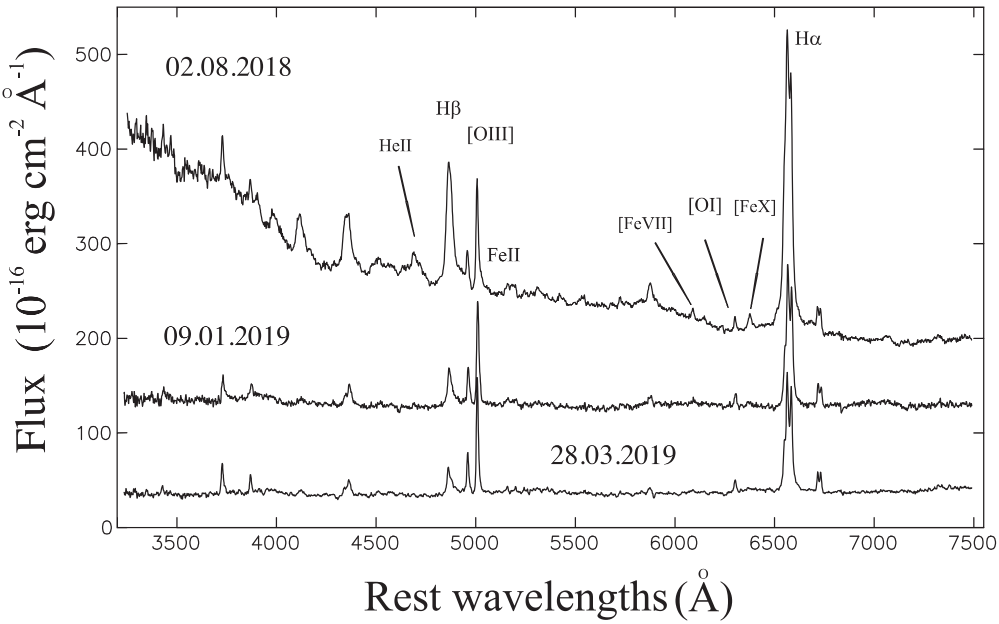

Figure 2. The isolated nuclear (low resolution) nonstellar spectra in NGC 1566 obtained by subtraction of the host galaxy spectrum from the original spectrum. (See details in the text). The spectra for 2 Aug 2018 and 9 Jan 2019 are shifted up $10^{-14} erg\ cm^{-2} A^{-1}$ for good seeing

clearest illustrations of Seyfert spectra ranging from type 1.2 to type 1.9 AGNs at different epochs. The object is nearest AGN and CL AGN and so it offers one of the best opportunities for studying this phenomenon. The light curves from X-ray to optical bands presented here show very good correlations over a long time interval. This result is mostly in agreement with a scenario where the variability across several wavebands (spanning X-rays–UV/Optical) is driven by variable illumination of the accretion disc by soft X-rays (see the same conclusions for another CL object, NGC2617 Shappee *et al.* (2014) and Oknyansky *et al.* (2017)) . We have shown, using spectroscopy (1.9 m SAAO) and multi-wavelength photometry (MASTER, *Swift* Ultraviolet/Optical and XRT Telescopes), that NGC 1566 recently experienced a dramatic outburst in all wavelengths, including a considerable strengthening of broad permitted and high ionisation [FeX]6374Å lines, as well as substantial changes in the shape of the optical and X-ray continua Oknyansky *et al.* (2019). After a maximum was reached at the beginning of July 2018, the fluxes in all bands dramatically decreased with some fluctuations. The strength of the broad permitted, high ionisation [FeX]6374Å lines and UV continuum dramatically decreased (end of March 2019) and the object can then be classified as Sy1.8–Sy1.9. So we witnessed a second CL in NGC1566.

Despite the successes of the simple orientation-based AGN unification scheme, there are significant problems that cannot be explained solely by different orientations. A major challenge to the simple model is the existence of CL AGNs. Orientation obviously cannot change on the time-scale of the observed type changes, and hence some other explanation is needed. What must happen to make such a dramatic changes possible? An alternative explanation is that transitions from type 1 to type Sy2 AGNs or vice versa are connected with some dramatic variability of the ionizing radiation, such as temporarily switching on or switching off their engine Lyutyj *et al.* (1984); Penston & Perez (1984); Runnoe *et al.* (2016); Katebi *et al.* (2019). More references on the possible explanations for the CL phenomenon can be found in discussions by MacLeod *et al.* (2019).

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