CHANGING LOOKS OF THE NUCLEUS OF SEYFERT GALAXY NGC 1566 IN COMPARISON WITH OTHER CL AGNS

The post-maximum behaviour of the changing-look Seyfert galaxy NGC 1566

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Swift X-Ray Telescope · PSU · LU · OAB

ABSTRACT

- We present results of the long-term multi-wavelength study of optical, UV and X-ray variability of the nearby changing-look (CL) Seyfert NGC 1566 observed with the *Swift* observatory and the MASTER Global Robotic Network (2007-2019) as well as spectral observations with South African Astronomical Observatory 1.9-m telescope started soon after the brightening was discovered in July 2018.
- We started spectral observations with South African Astronomical Observatory 1.9-m telescope soon after the brightening was discovered in July 2018 and present here the data for the interval between Aug. 2018 to Sep. 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 [Fe X] 6374 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.**
- Variability properties of NGC1566 are compared with our results for other CL AGNs: NGC4151, NGC2617, NGC3516, and Mrk6 (published or firstly presented).

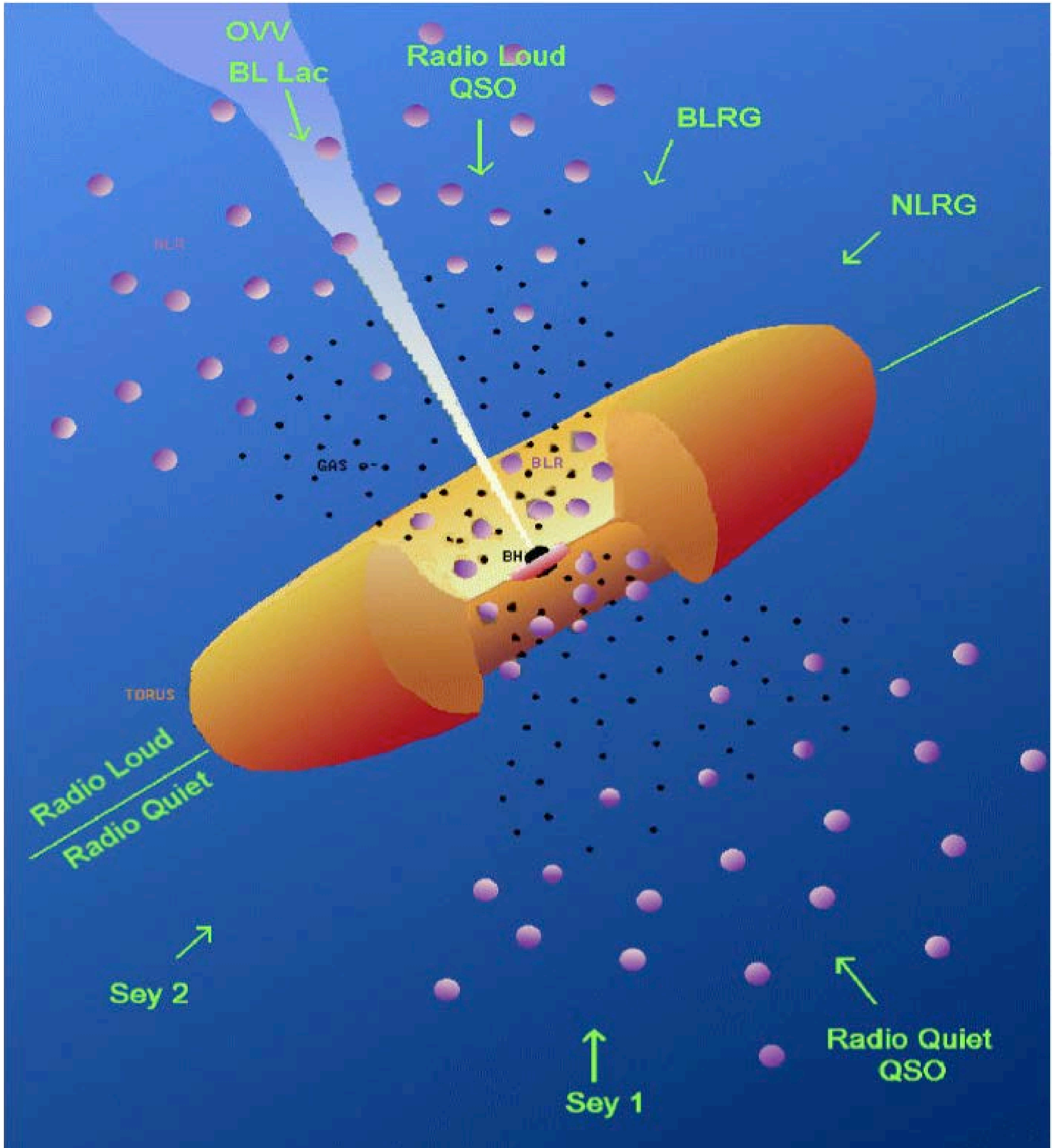
The Changing Look AGNs Monitoring Project

- Changing-look” AGNs (CL 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).
- We have begun a project of spectral and photometric multiwavelength (IR to X-ray) monitoring which include the selected set of AGNs known already as the CL AGNs
- We are using the 2.5-m telescope of CMO SAI for IR *JHK UBVRI* photometry and spectrophotometery, 2.3-m telescope WIRO, 2-m Zeiss (ShAO) and small telesopes 0.6-m (CMO), Zeiss-600, AZT-5 (Crimean SAI observatory) for *UBVRI* photometry (and some others).
- We are also going to search for new CL AGNs using data from the MASTER project and we can obtain historical light curves for known and newly discovered objects using the MASTER observations.
- We are planning to apply for X-ray and UV observations of some CL AGNs with the *Swift*.

Publications

- **V.M. Lyutyi, V.L. Oknyanskii, K.K. Chuvaev , " NGC 4151 - a Seyfert 2 in a deep photometric minimum", Soviet Astronomy Letters , 10, N12, 335-336, 1984.**
- **V.L Oknyansky, C.M. Gaskell, N.A. Huseynov , V.M. Lipunov et al. "The curtain remains open: NGC 2617 continues in a high state", MNRAS, 467, N2, 1496-1504, 2017.**
- **V.L Oknyansky, H. Winkler, S.S. Tsygankov, V.M. Lipunov et al., "New changing look case in NGC 1566", MNRAS, 483, N1, 558-564, 2019.**
- **D. Ilic, V.L. Oknyansky, S.S. Tsygankov, A.A.Belinaski, A.A. et al., "A flare in the optical spotted in the changing-look Seyfert NGC 3516", A&A, 638, A13-1-A13-7, 2020.**
- V.L. Oknyansky, S.S. Tsygankov, V.M. Lipunov et.al., "Discovery of new changing look in NGC 1566", Proceedings of the International Astronomical Union, **S356**, 127-131, 2021.
- **V.L. Oknyansky, H. Winkler, S.S. Tsygankov, V.M. Lipunov et.al., "The post-maximum behaviour of the changing-look Seyfert galaxy NGC 1566", MNRAS, 498, N1, 718-727, 2020.**
- V.L. Oknyansky., Kh. M. Mikhailov, N.A.Huseynov, "Changing Looks of the Nucleus of Seyfert Galaxy NGC 3516 during 2016–2020", Astronomy Reports, **64**, N12, 979-984, 2020.
- **V.L. Oknyansky, M.Brotherton, S.S.Tsygankov, A.B. Dodin et al., "Multi-Wavelength Monitoring and Reverberation Mapping of a Changing Look Event in the Seyfert Galaxy NGC 3516", MNRAS, 505, N1, 1029-1047, 2021.**

A common cartoon of a thermal AGN:



One of the biggest challenge to simple AGN unification schemes:
existence of "Changing-look" (CL) AGNs.

NGC4151 – is one of the first discovered CL AGNs
Lyuty,Oknyansky,Chuvaev (1984)
Penston&Perez (1984)

(After Urry & Padovani 1995; see Keel 1980; Krolik&Begelman 1988; Antonucci 1993)

NGC 4151: a Seyfert 2 in a deep photometric minimum

V. M. Lyutyĭ, V. L. Oknyanskiĭ, and K. K. Chuvaev

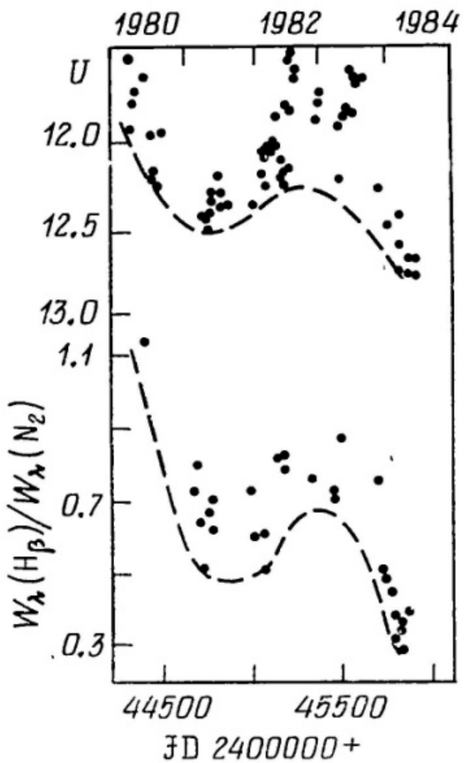
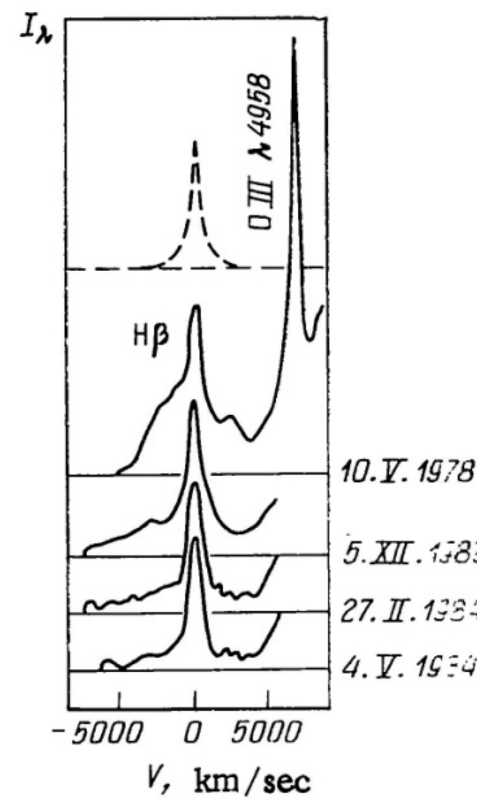
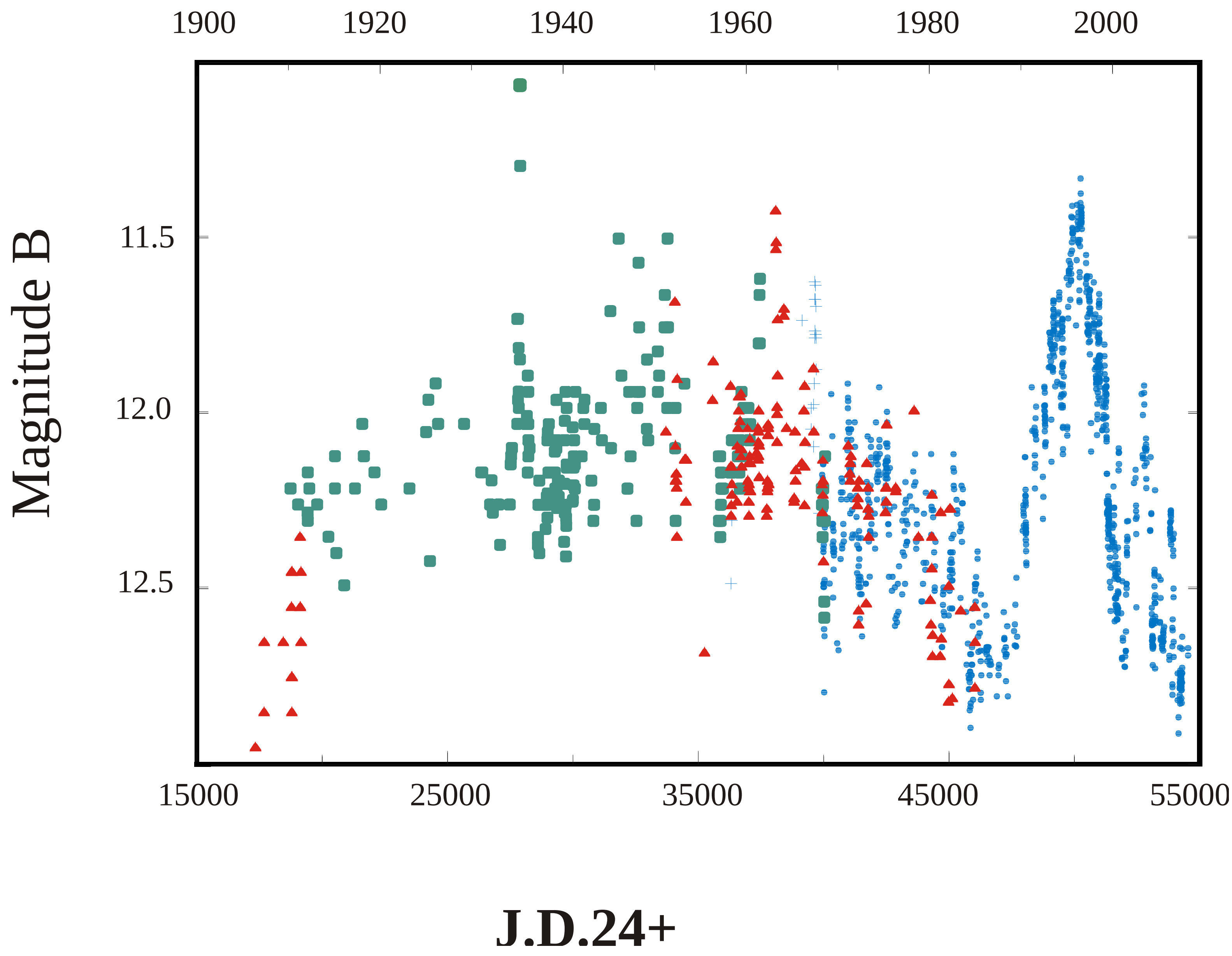


FIG. 1. Comparative variations in the optical continuum (U magnitude) of the NGC 4151 nucleus and the ratio $W_\lambda(H\beta)/W_\lambda(N_2)$. The lower envelopes outline the slow fluctuations.

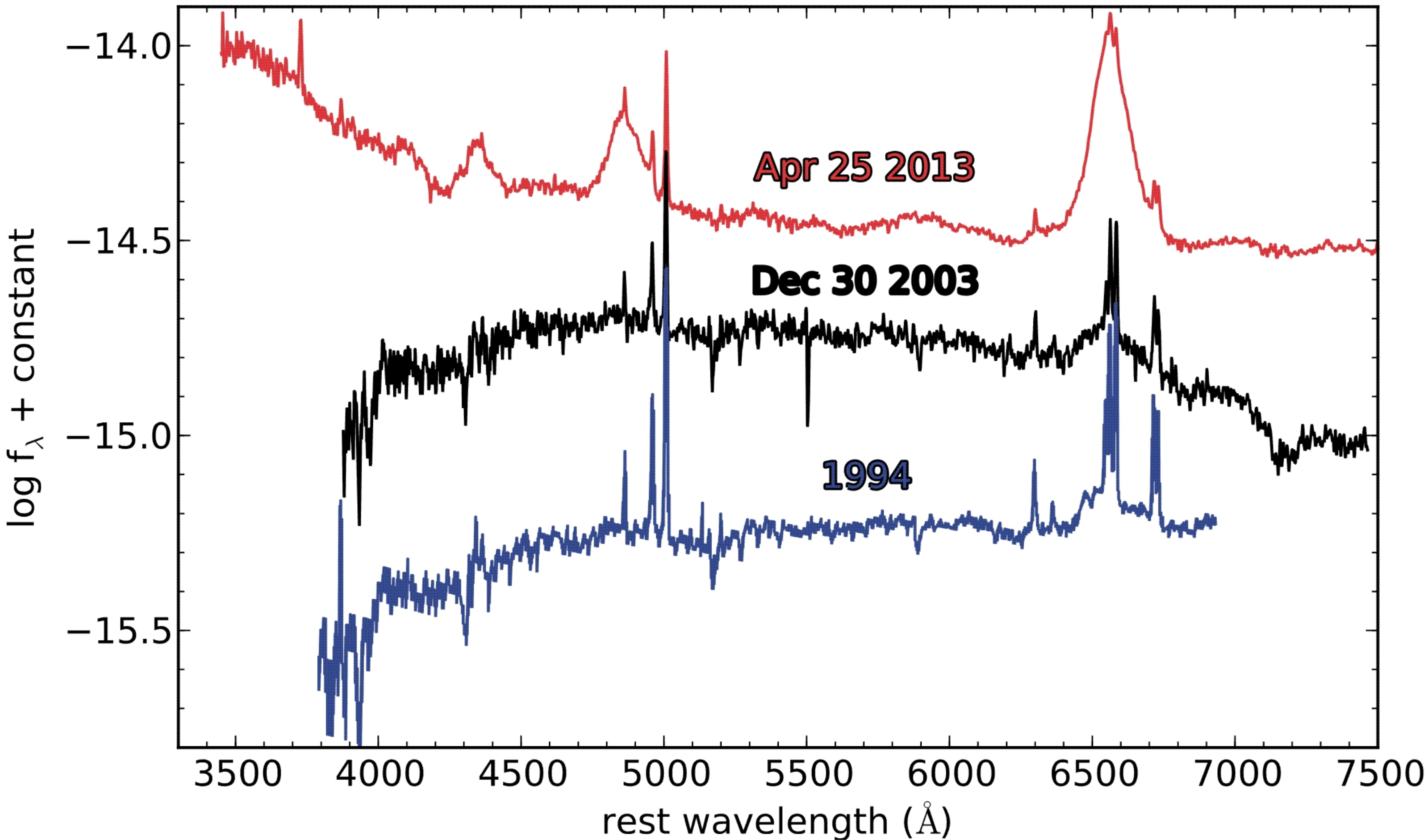




- Oknyanskij et al. (1977, 2007, 2013)

NGC4151

NGC 2617 “The man behind the curtain… ” Shappee et al (2014)



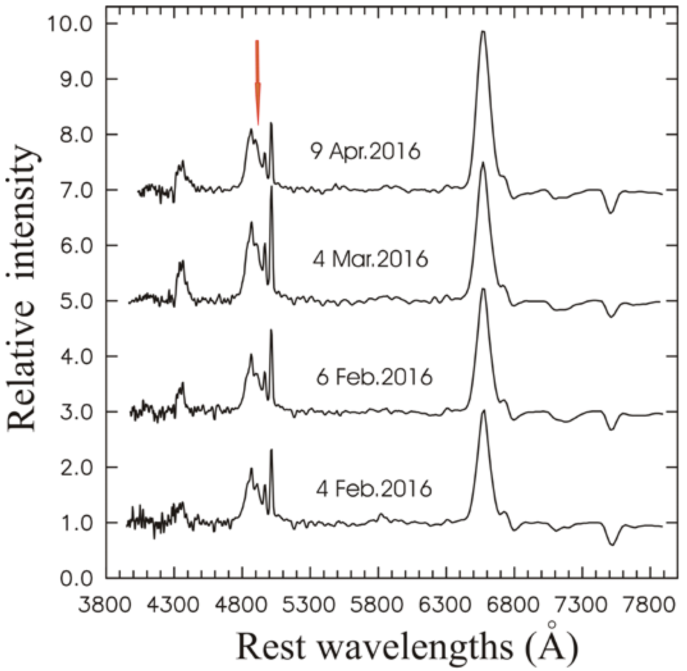
2013

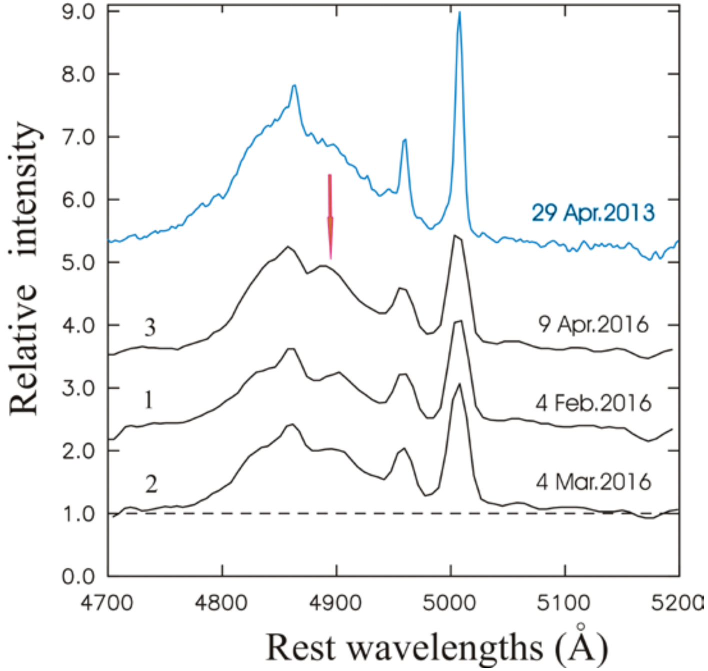
2016

NGC2617

Oknyansky et al.,2017 (MNRAS)

“ The curtain remains open:… ”





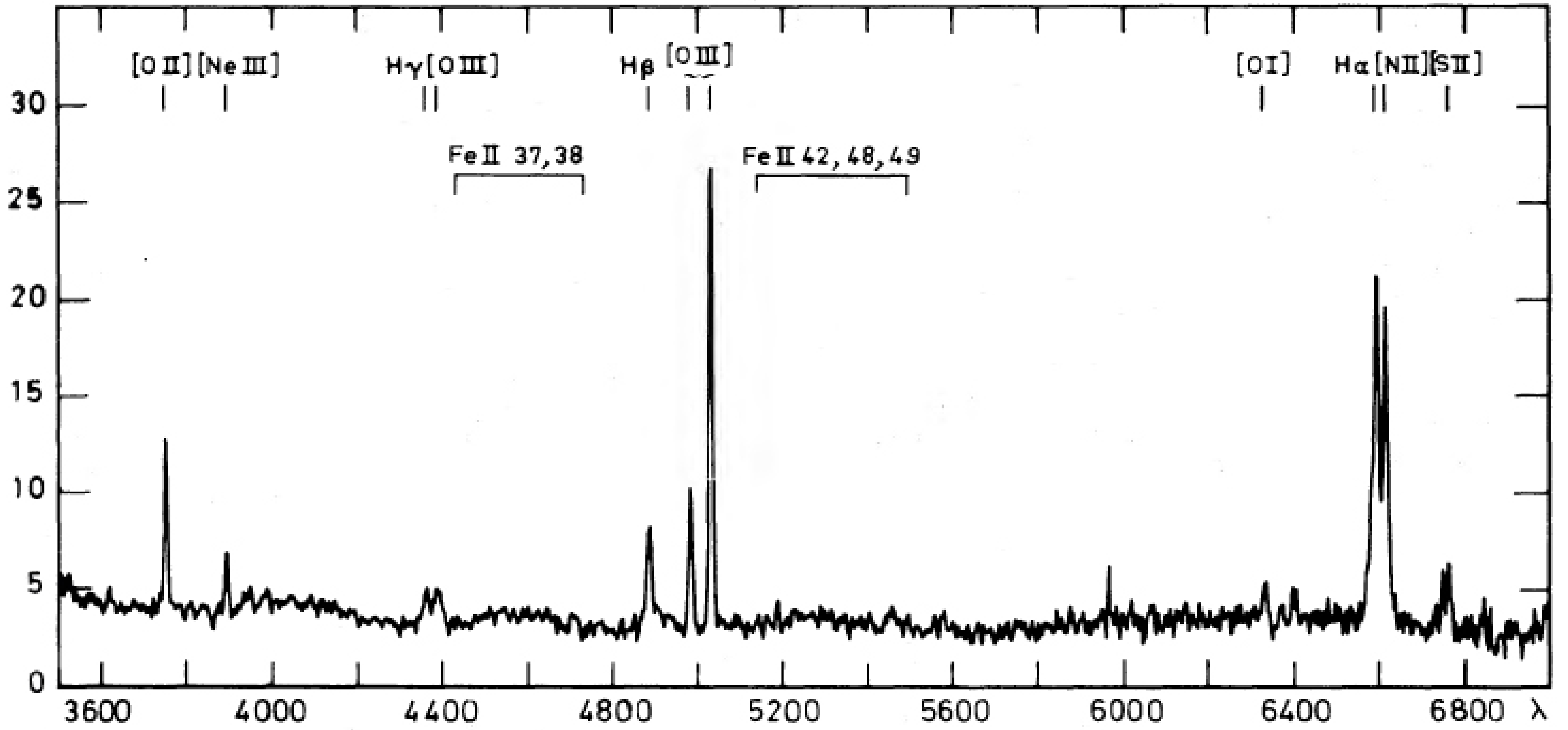
NGC1566,   ESA/Hubble & NASA

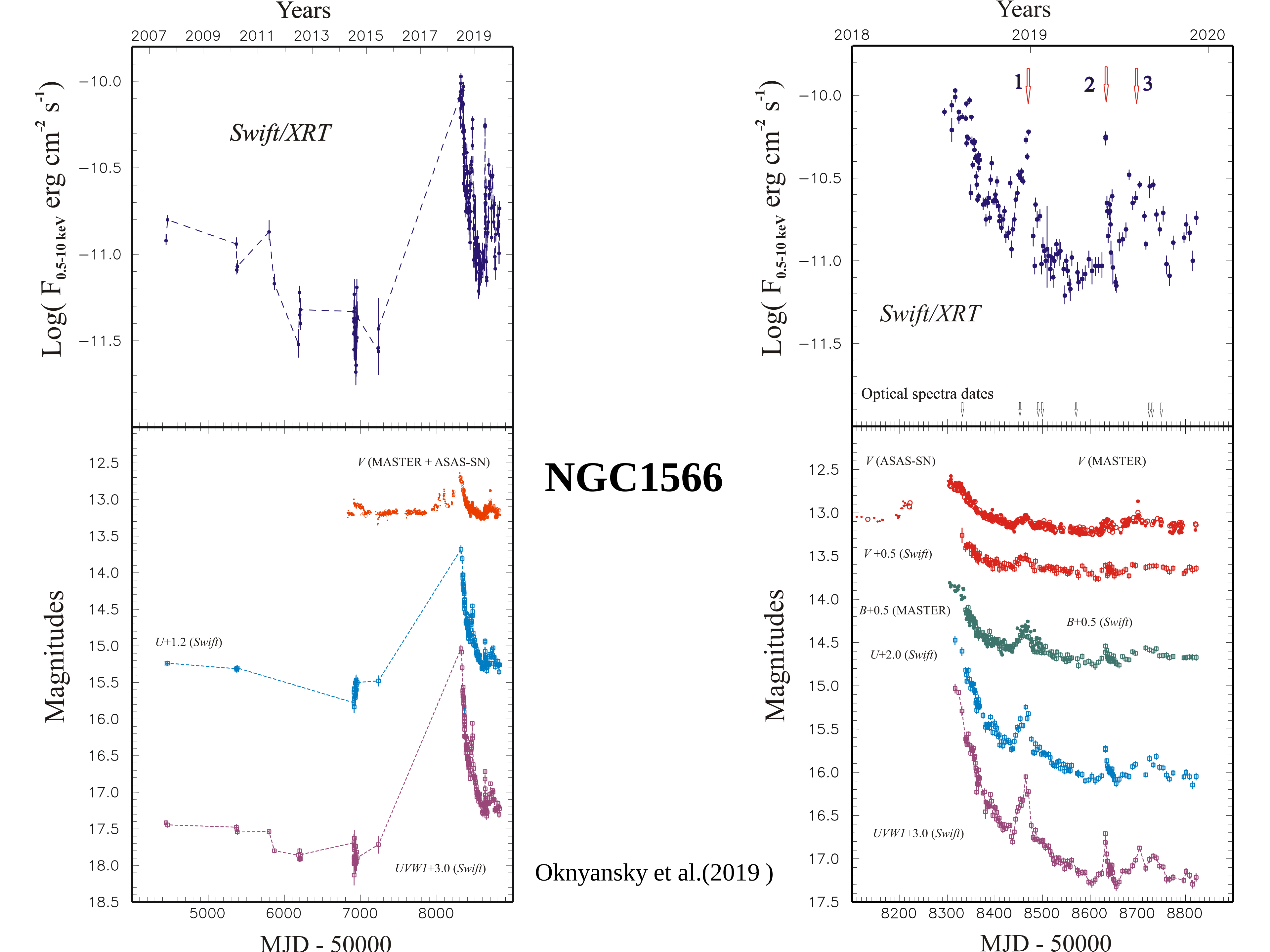
NGC1566

- NGC 1566 is a galaxy with a very well-studied variable active nucleus (V ≈ 10 , V(AGN) ≈13, D ≈ 7.2 Mpc).
- The most significant recorded past out-bursts were observed in 1962 and 1988 (da Silva et al. 2017).
- First RM Baribaud et al. (1992), Oknyansky&Horn (2001).
- On 12-19 June 2018 data from the INTEGRAL showed that NGC 1566 was in outburst in hard X-rays (Ducci et al. 2018)
- Follow-up observations with the Swift observatory (Kuin et al. 2018; Ferrigno et al. 2018; Grupe et al. 2018, 2019; Oknyansky et al. 2019, 2020).
- Brighten 1.0 mag at 3.4 microns and 1.4 magnitudes at 4.6 microns January 2017 - July 2018 (Cutri et al. 2018)
- Discovery of CL cases Oknyansky et al. (2018, 2019, 2020).

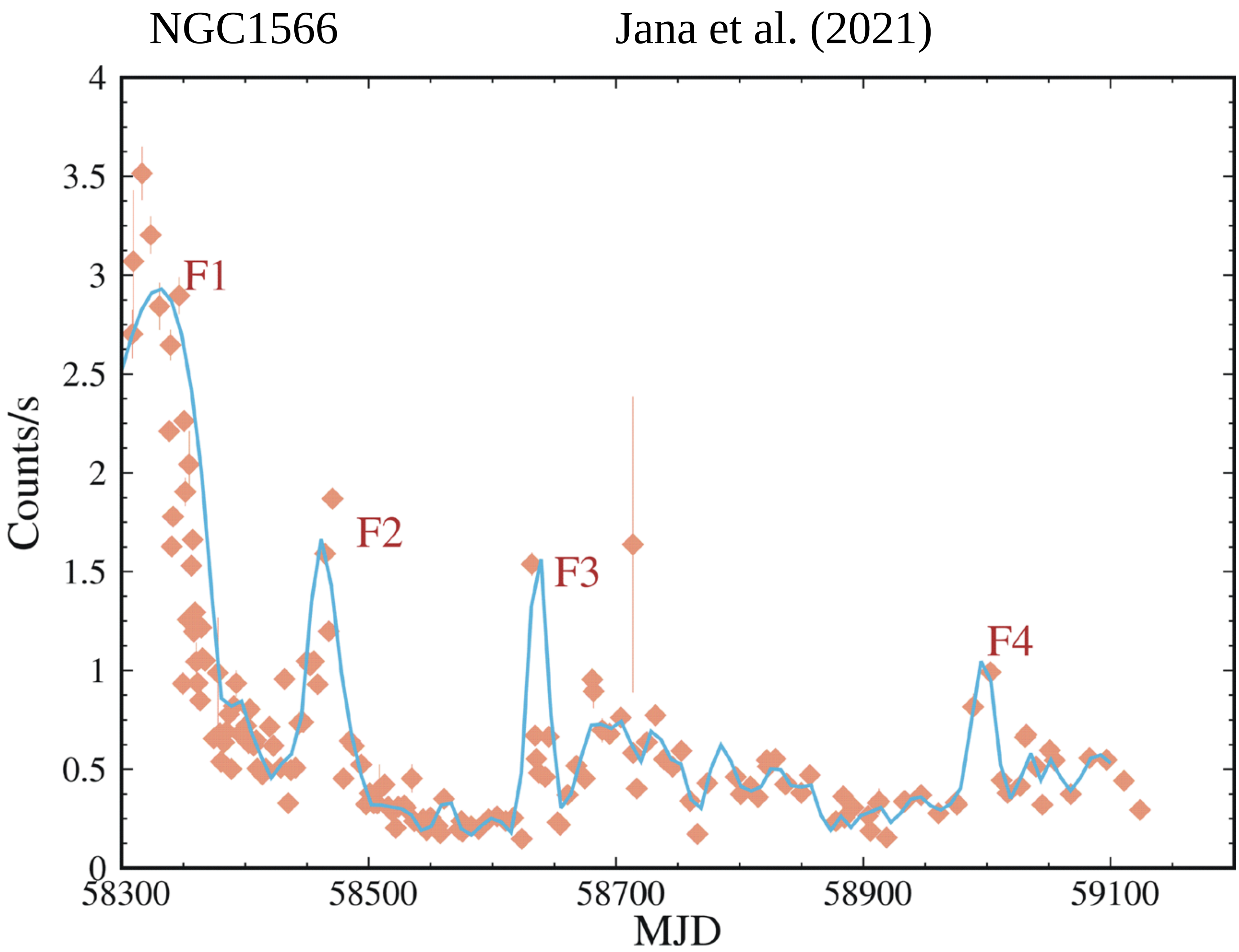
Alloin et.al. (1985),
Jan. 1981

NGC1566



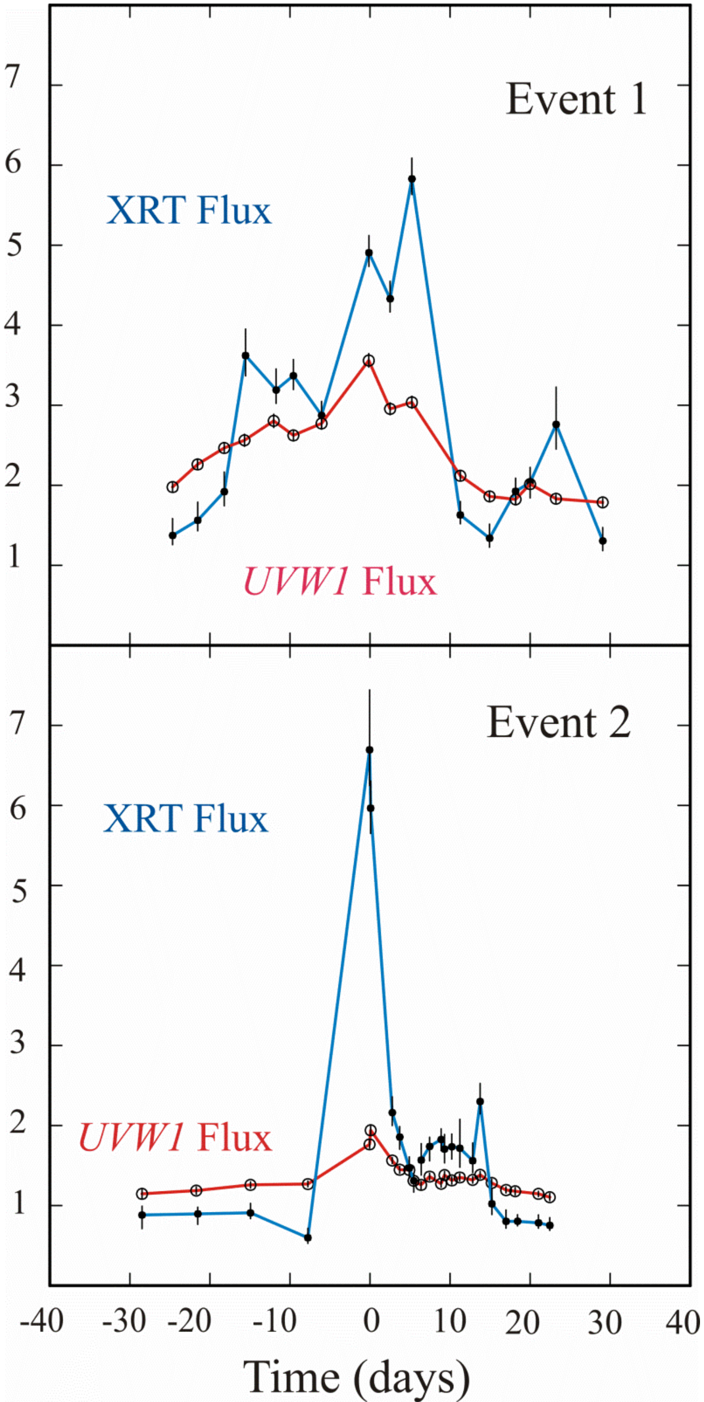


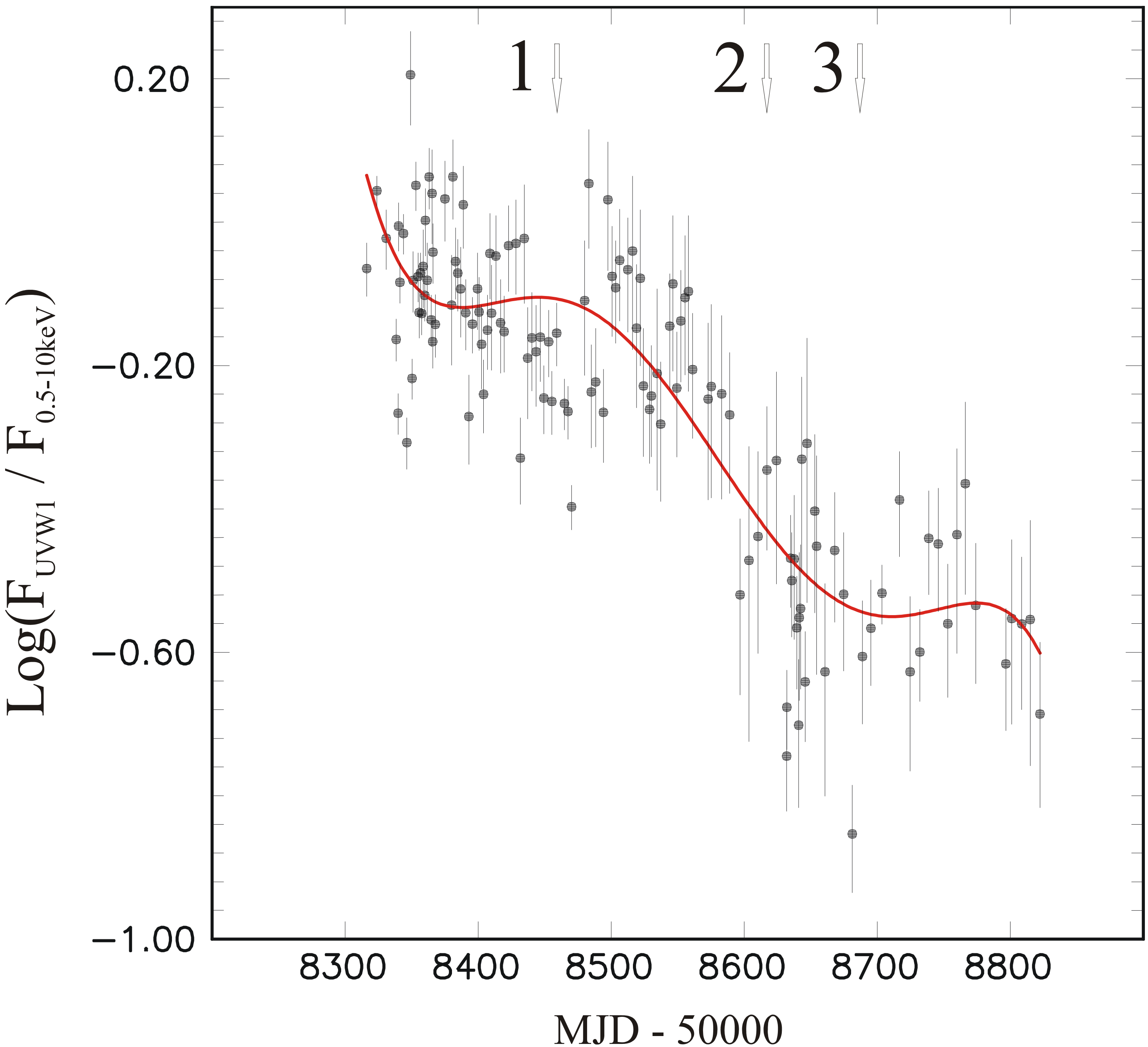
NGC1566
Oknyansky et al.(2019)
Years
2007
2009
2011
2013
2015
2017
2019
Swift/XRT
Log(F0.5-10 keV erg cm-2 s-1)
−10.0
−10.5
−11.0
−11.5
V (MASTER + ASAS-SN)
U+1.2 (Swift)
UVW1+3.0 (Swift)
Magnitudes
MJD - 50000
5000
6000
7000
8000
Years
2018
2019
2020
1
2
3
Optical spectra dates
V (ASAS-SN)
V (MASTER)
V +0.5 (Swift)
B+0.5 (MASTER)
B+0.5 (Swift)
U+2.0 (Swift)
UVW1+3.0 (Swift)
8200
8300
8400
8500
8600
8700
8800



NGC1566
Jana et al. (2021)
Counts/s
MJD
F1
F2
F3
F4
0
0.5
1
1.5
2
2.5
3
3.5
4
58300
58500
58700
58900
59100

SWIFT
NGC1566



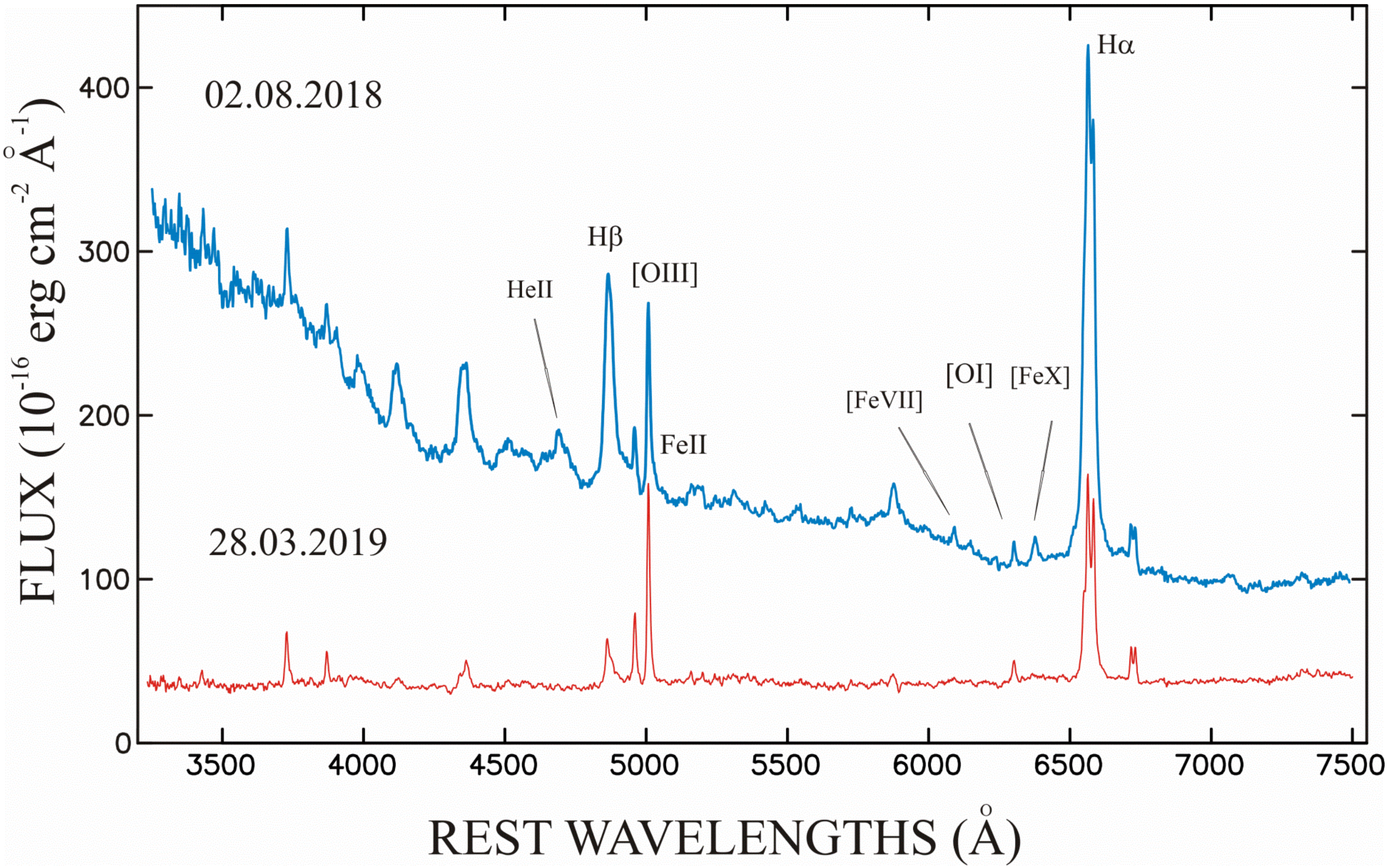


1
2
3
0.20
−0.20
−0.60
−1.00
8300
8400
8500
8600
8700
8800
Log(F_UVW1 / F_0.5-10keV)
MJD - 50000

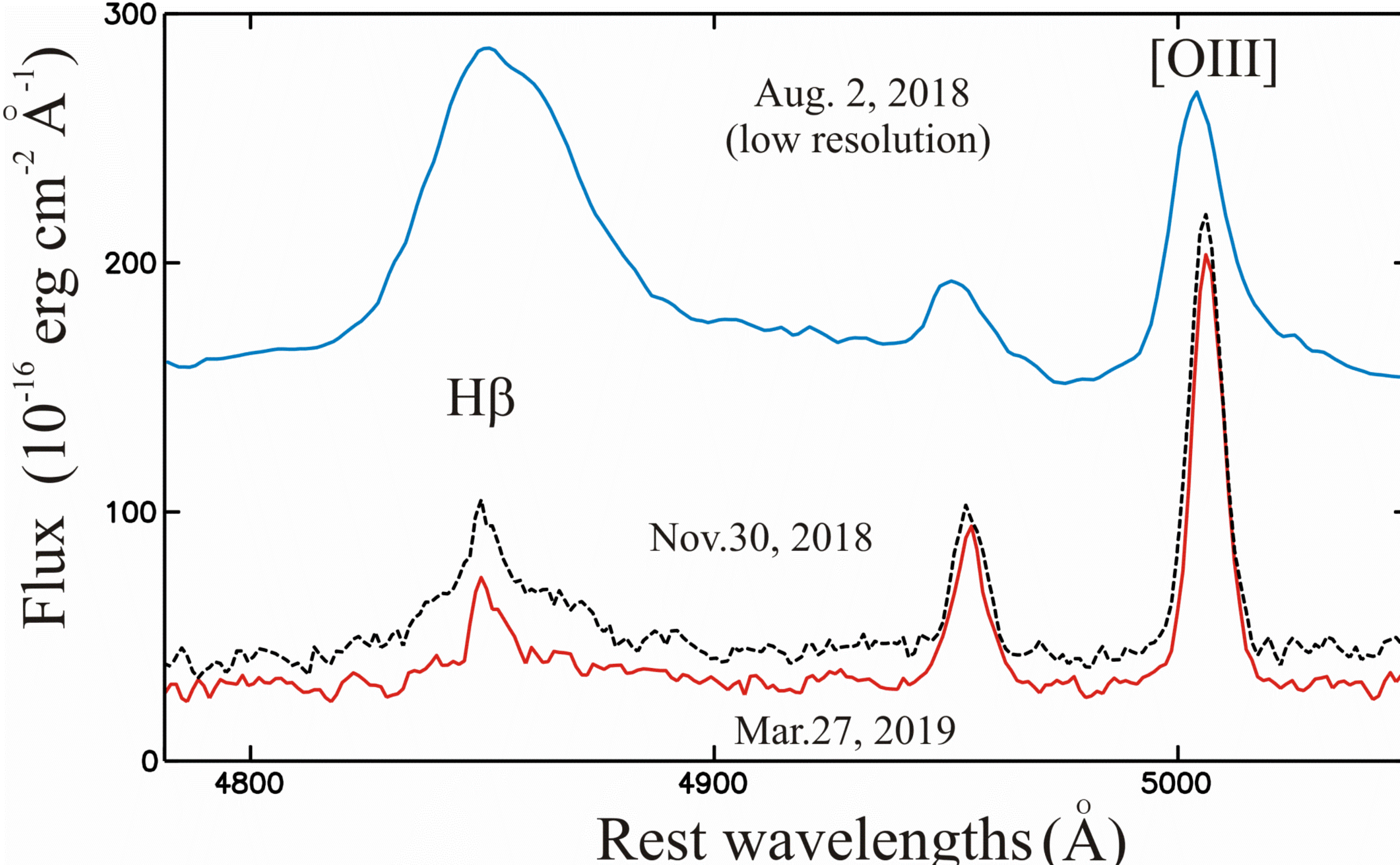
Light curves. Published results (Oknyansky et al. 2019, 2020, MNRAS)

- 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 ***Swift*** Observatory and the MASTER Global Robotic Network over the period 2007-2019.
- 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 year. After a maximum was reached at the beginning of July 2018, the fluxes in all bands decreased with some fluctuations. The fix 3 rebrughtenings.
- The amplitude of the flux variability is strongest in the X-ray band and decreases with increasing wavelength.
- We have found a strong decrease of the UV/X-ray ratio after Mar. 2019 and a rise of X-ray flux.
- If take into account the host galaxy contamination in the used aperture then partial decreases from the maximum in July 2018 to minimum in June 2019 in the different UV/Opt bands became about the same (~ 9 times).
- The obscuration scenario along can be rejected since we didn't find any signature of variable absorption from the X-ray and UV/Opt data.

NGC1566 Oknyansky et al. (2019)



NGC1566 Oknyansky et al. (2019)



Paper I results on spectral variability (Oknyansky et al. 2019, MNRAS)

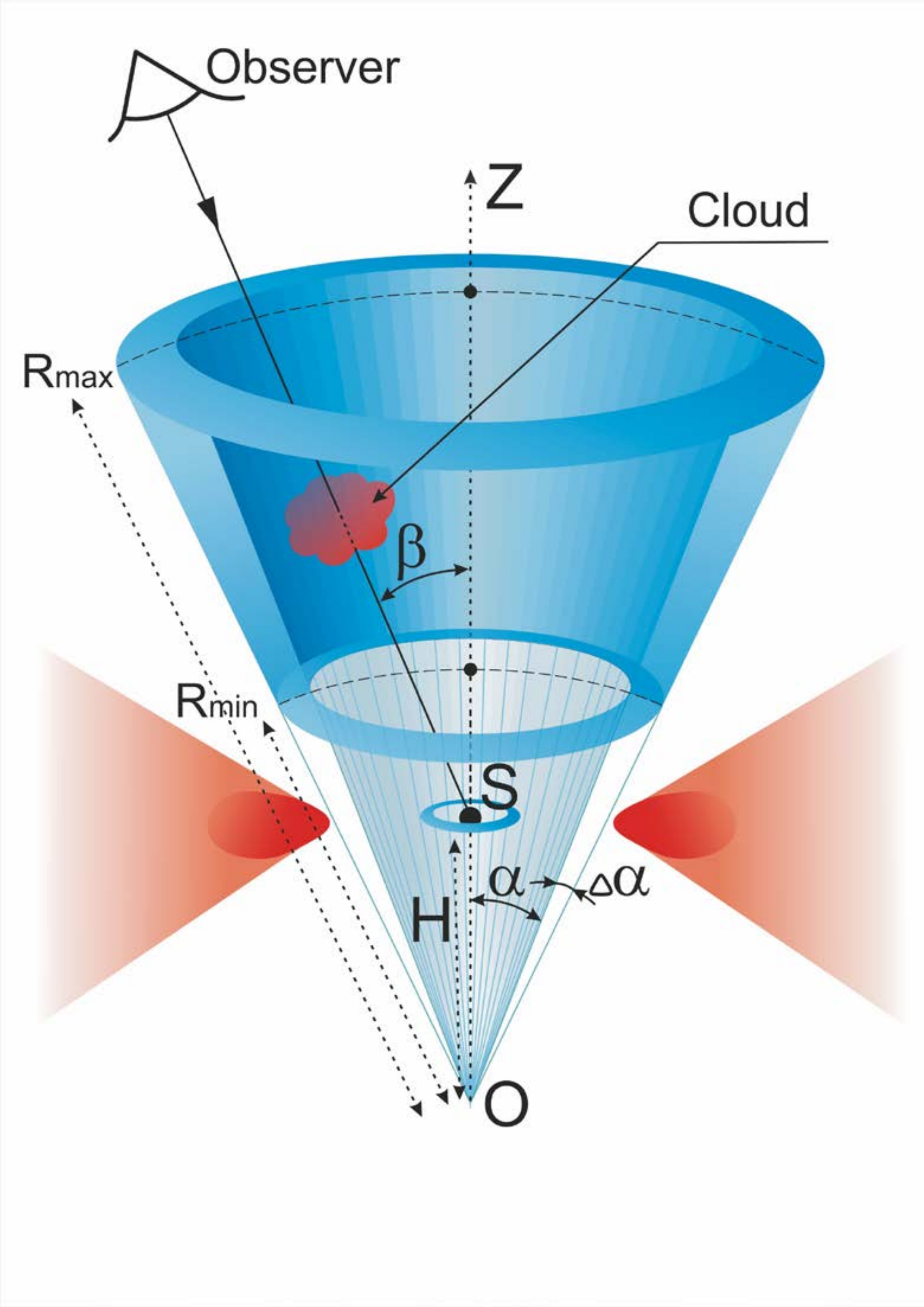
- Hβ is quite a lot brighter than [OIII]5007A. The total Hβ to [OIII]5007A line ratio is about 4.2 0.4, corresponding to a Sy1.2 classification according to the criteria proposed by Winkler (1992).
- The Hα to Hβ ratio for the Gaussian broad components is 2.7 0.3 . The obscuration of the broad line region is negligible.
- The HeII4686A emission feature is bright and broad.
- The [FeX]6374A coronal emission line is stronger than [OI]6300A, something that has not been seen before in NGC 1566. (The variability of coronal lines has also been detected in a number of CL AGNs: NGC 4151, NGC 5548, NGC 7469, 3C 390.3 and others (Oknyanskij & Chuvaev 1982; Oknyanskii et al. 1991; Veilleux 1988; Landt et al. 2015a,b; Parker et al. 2016)
- A strong UV continuum is clearly seen in our spectrum, and was far more prominent than what is visible in spectra collected during earlier low states.
- FeII emission is evidently much stronger now than in recent years.

We suspect that such strong outbursts in NGC1566 may be recurrent events with the timescale about several tens of years.

Paper II spectral results

(Oknyansky et al. 2020, MNRAS)

- Hβ is significantly lower than [OIII]5007A. The total Hβ to [OIII]5007A line ratio is about 0.50 0.05 (Mar. 2019), corresponding to a Sy1.8-Sy1.9 classification according to the criteria proposed by Winkler (1992).
- The Hα to Hβ ratio is 6.08 0.3. If take into account [NII] lines then the ratio is big still ~4.9. The obscuration of the broad line region? Different location of Hβ and Hα region? See Ilic et al. (2012) for another explanations.
- The HeII4686A emission feature is about not seen.
- The [FeX]6374A coronal emission line is about not seen. So we see strong drop down of the line during half-year after the maximum
- The UV Balmer continuum is not seen in our spectrum, and it is strongly different with the past spectra at Aug 2. 2018 and it is the same is it visible in spectra collected during earlier low states.
- FeII emission is evidently much lower now than in the summer 2018 spectrum.
- Our most recent spectra of Aug.- Sep. 2019 show lines again fractionally stronger than in Mar. 2019.
- **Effectively, two changing look (CL) cases were observed for this object: changing to Sy1.2 type and then returning to the low state as Sy 1.8 - Sy 1.9.**



The proposed model

Oknyansky&Gaskell (2015)

Variations of the accretion rate as well as sublimation and/or recovering of dust on the line of sight (following the strong luminosity variations) can explain CL events

[Thanks to graphic designer
Natalia Sinugina]

Common properties of CL AGNs

- **1. CLs are recurrent events.**
- **2. After the strong outbursts, as a rule some re-brightenings are happen.**
- **3. UV/X-ray drop down at post main maximum time.**
- **4. UV delayed to X-ray on few days.**
- **5. UV and X-ray variations are correlated but some uncorrelated events are typical.**
- **6. During the strong outbursts the dust sublimates. The dust can be recovered if the object moves to a low state at least on few years. That can explain variations in the IR time delay and CLs. (see Oknyansky et al.,2017).**
- **7. Hα/Hβ (~5-10) is higher in low states.**
- **8. The time delays grow along Hγ, Hβ, Hα**
- **9. The double-peaked broad Balmer lines in high state and symmetrical ones in low state.**
- **10. Variable coronal line, which are more broad than other forbidden lines and are blueshifted.**
- **11. Appearance of strong Balmer continuum during the high states is typical for CL AGNs.**
- **12. CL AGNs have low accretion rate << 1% Edd in minimuma and few % in maximuma.**

Post Script

- Tidal disruption events occur when a star passes too close to a massive black hole and it is totally ripped apart by tidal forces. It may also happen that the star is not close enough to the black hole to be totally disrupted and a less dramatic event might happen. If the stellar orbit is bound and highly eccentric, just like some stars in the centre of our own Galaxy, repeated flares should occur. (Campana et al., 2015, Ivanov and Chernyakova, 2006).

*Thanks to **Pavel Ivanov** and **Martin Gaskell** for useful discussions, thanks to the **Swift, SAAO, CMO** and **MASTER** teams for organizing the observations.*

Thanks to you for attention