————————————————————

CN2024A-44

Extragalactic panel
Elena Shablovinskaya | elena.shablovinskaia@mail.udp.cl
UDP
astronomer

Search for optical intraday variability in RQ AGN IC 4329A

Abstract

The origin of the compact variable mm emission observed in radio-quiet (RQ) AGN is still a subject of debate. Alongside other mechanisms, the possibility is considered that radio emission is generated in a low-power small-scale jet, a scaled-down version of the extended relativistic jets observed in radio-loud sources. If so, it can be assumed that similar to a powerful jet, processes in the plasma in a tiny jet may lead to rapid optical intraday variability (IDV). Within this proposal, we plan to conduct continuous minute-cadence photometric observations of the nearby RQ AGN IC 4329A. Recent mm observations have revealed a bright compact core, but the lack of correlation with X-rays and the presence of rapid radio variability suggest possible jet activity. Intranight monitoring offers a unique opportunity to uncover rapid variability, shedding light on the role of a small-scale jet in mm emission.

Observing Blocks

Instrument/Telescope	Req. time	Min. time	1^{st} Option	2^{nd} Option
CCD Camera/Speculoos	3 nights	1 nights	April Any	April Any

CoIs

Name	Institution	e-mail	Observer?
Claudio Ricci	UDP	claudio.ricci@mail.udp.cl	False

Status of the project

- Past nights: 0
- Future nights: 3
- Long term: False
- Large program: False

- Thesis: False

List of Targets

ID	RA	DEC	Mag
IC 4329A	13:49:19.3	-30:18:34.2	V=13.66

SCIENTIFIC AIM AND RATIONALE

The subpc-scale central region of active galactic nuclei (AGN), where energy is produced via the accretion of matter onto supermassive black holes (SMBH), is in general spatially unresolved with modern instruments. Thus, the study of the physical, geometrical and dynamical parameters of the plasma close to the SMBH provided by the multi-wavelength observations of temporal variability of the AGN flux is particularly important.

It is known that in the optical range, AGN emission varies on the scale of decades (including violent changes, as in changing-look AGN, Ricci & Trakhtenbrot 2022, arXiv:2211.05132), as well as on the scale of several weeks and days when the variation is primarily associated with emission from the accretion disk and the broad line region. However, some AGN reveal also significant variability in optics within a night, on the time scale of hour(s). Such intraday variability (IDV) at a level of a few 0.01 mag has been discovered in many blazars, i.e. AGN where the jet is oriented toward the observer (see data compilation in Gupta 2018, Galaxies, 6, 1). Furthermore, it is often correlated with rapid rotations of the polarization vector (e.g. Shablovinskaya & Afanasiev 2019, MNRAS, 482, 4). This not only indicates the small linear size of the region (around light hours), where electrons responsible for synchrotron radiation move along the magnetic field lines but also suggests processes that violently change the physical properties of the plasma, such as magnetic reconnection (e.g. Zhang et al. 2022, ApJ, 924, 90) or shock propagation in a turbulent environment (e.g. Böttcher 2021, Physics, 3, 4).

In cases where the jet is not oriented towards the observer, we observe it as a bright extended radio structure, and the AGN itself is classified as radio-loud (RL). RL AGN make up only a small percentage ($\sim$10%) of the population. Most AGN are classified as radio-quiet (RQ), but this does not mean the complete absence of radio emission in their spectra. Although the radio intensity in RQ AGN is several orders of magnitude weaker than in RL AGN, radio structures with different complicated morphologies are detected in RQ AGN. Moreover, radio emission tends to correlate with X-rays as $L_R/L_X = 10^{-5}$ (Laor & Behar 2008, MNRAS, 390, 847). The origin of this radio emission in the absence of a powerful relativistic jet is still a subject of debate. In the recent review by Panessa et al. (2019, Nature Astronomy, 3, 387), four mechanisms are considered to be the most favourable, including the low-power small-scale jet. Recently, structures similar to this have been found in radio observations of RQ AGN, such as in I Zw 1 (Yang et al. 2023, arXiv:2305.12525) and a sample of narrow-line Seyfert 1 galaxies (Singha et al. 2023, arXiv:2309.16926).

In this proposal, we aim to test the hypothesis of the origin of radio emission in RQ AGN by a scaled-down jet using the search for optical IDV. To achieve this, we plan to conduct several nights of continuous photometric observations with a cadence of $\sim$ a minute of the nearby and bright RQ AGN IC 4329A. This source is observed as an unobscured AGN with bright and variable X-ray intensity, originating from the accretion disk corona. Recent high-resolution ALMA observations have revealed the presence of a bright compact core in the mm ($\sim$100 GHz) range (Inoue & Doi 2018, PASJ, 66, 6). While the nature of the unresolved mm core remains unclear, it is ubiquitously detected in many AGN, and mm flux tightly correlates with the X-ray emission, indicating a strong connection between the regions where this radiation is generated (Ricci et al. 2023, ApJL, 952, 2). However, simultaneous X-ray/mm monitoring of IC 4329A has revealed a lack of correlation in variability between the two ranges on timescales of several days, and violent mm flares when the flux increased by about 3 times do not appear in the X-ray light curve (in preparation). This suggests that the variability of radio emission in this AGN may be caused by jet activity. Unfortunately, the available data from photometric surveys and monitoring campaigns have a lower cadence (a day or more), where the contribution of other variable structures, such as the accretion disk, is significant. Intranight monitoring provides a unique opportunity to search for rapid variability, which will be a crucial argument in favour of or against a small-scale jet as the compact mm emission source.

TECHNICAL DESCRIPTION

We propose to observe the object IC 4329A ($z = 0.016$, RA=$13^h49^m19^s.3$, Dec=-30°18′34″.2), a nearby extended ($\sim 1' \times 20''$) active galaxy with an integrated brightness of $V = 13.66$ mag. For the purpose of searching for optical IDV, we suggest conducting continuous photometric observations over 3 nights (with a minimum required time of 1 night) with a cadence of approximately 1-2 minutes. The observations are planned to be carried out using a broadband g-sdss filter. We expect brightness variability at the level of 0.01 mag, which is why the required accuracy should be no less than 0.001 mag, easily achievable through differential photometry even with small telescopes. Given the brightness of the object, on larger telescopes, to avoid CCD saturation, the exposure time for such a task should be very short, less than the frame readout time, making observations inefficient. A 1-meter-class telescope is the most suitable choice for this task.

Among all telescopes smaller than 2 meters, the Speculoos telescopes are the most suitable for the proposed observations. The telescope is equipped with a set of broadband filters, and the QE of the system is $\geqslant 60\%$ in photometric mode. Importantly, the system provides an image scale of $0.3''$/pix, so even in the case of the best seeing conditions at SSO ($0.7''$), the observed PSF satisfies the Kotelnikov-Nyquist theorem, and no systematic error will be introduced into the observations. The field of view of the system is $\sim 6'$, allowing the selection of 5-6 stars comparable in brightness to the target in the FoV for differential photometry.

Since the goal of the observations is to search for relative changes in the brightness, absolute photometric calibration throughout the night is not critical. The use of differential photometry with reference stars in the field makes observations possible even under poor transparency and in cirruses. Because each night requires obtaining the longest continuous series of observations possible, the best visibility of the object occurs between April 1st and May 1st, except for the period from April 19th to April 27th, when the separation between the object and the Moon is $<50°$. The standard set of calibrations (bias, dark and flat-fields) is required.

CURRENT STATUS OF THE PROJECT

The proposal for observation time on this topic is being submitted for the first time. The PI and co-I of the proposal are part of the Chilean community, ensuring its 100% involvement. Both the PI and co-I have a track record of experience in studying the multiwavelength variability of AGN. Below is a list of key recent publications related to the theme of this proposal.

- Kawamuro T., **Ricci C.**, Mushotzky R. F. et al.; "BASS XXXIV: A Catalog of the Nuclear Mm-wave Continuum Emission Properties of AGNs Constrained on Scales $\lesssim$ 100–200 pc", arXiv:2309.02776, 10.48550/arXiv.2309.02776 (2023)

- **Ricci C.**, Chang C.-S., Kawamuro T. et al.; "A Tight Correlation between Millimeter and X-Ray Emission in Accreting Massive Black Holes from <100 mas Resolution ALMA Observations", ApJL, 952, 2, id.L28, 10.3847/2041-8213/acda27 (2023)

- **Shablovinskaya E.**, Malygin E., Oparin D.; "Chromatic optical polarization of BL Lac: while faint and bright", MNRAS, 519, 3, 3798-3810, 10.1093/mnras/stac3775 (2023)

- Afanasiev V. L., **Shablovinskaya E.**, Uklein R., Malygin E.; "Stokes-Polarimeter for 1-m Telescope", Astr. Bul., vol. 76, 1, pp.102-108, 10.1134/S1990341321010028 (2021)

- **Shablovinskaya E. S.**, Afanasiev V. L.; "The intraday variations of the polarization vector direction in radio source S5 0716+714", MNRAS, vol. 482, 4, pp.4322-4328 10.1093/mnras/sty2943 (2019)