SF2A 2023
M. N'Diaye, A. Siebert, N. Lagarde, O. Venot, K. Baillié, M. Béthermin, E. Lagadec, J. Malzac, J. Richard (eds)

OPTICAL AND X-RAY VARIABILITY IN THE ACTIVE CGCG 077-102 NED02 GALAXY

K. Parra Ramos[2,1], C. Adami[2], J. T. Harry[3], M. Ulmer[3], G. B. Lima Neto[1] and P. Amram[2]

Abstract. Supermassive black holes are known to play an essential role during the evolution of their galaxy host due to the close connection between their properties, which makes the study of the active galactic nuclei (AGN) activity essential to understand the processes behind the galaxy formation and evolution. In this work, we used the spectrograph MISTRAL to obtain optical spectra of the galaxy pair CGCG 077-102 localized within the Abell 2063 cluster. We used Chandra and XMM-Newton archival data to derive its X-ray spectral shape and variability, and the Zwicky Transient Facility time-domain survey to obtain light curves in g and r-bands. We classified the galaxy CGCG 077-102 NED02 as a Seyfert, and we confirmed the passive state of its companion. We found that CGCG 077-102 NED02 light curve (g-band) shows a significant variability and is well described by a damped random walk model, with the best-fitted damping timescale parameter $\tau_{\rm DRW} = 30^{+28}_{-12}$ days, which points toward a moderately massive black hole of $\sim 10^6$ $M_\odot$. In the X-ray counterpart, we found that the $0.5 - 10$ keV flux varied between observations by factors up to ~ 2, which is likely non-random. In the future, we will characterize the spectral variability of CGCG 077-102 NED02 and search for quasi-periodic oscillations in the X-ray flux to obtain a deeper insight into the processes related to the AGN activity.

Keywords: galaxy pair, active galactic nuclei, x-ray, optical, variability, supermassive black hole

1 Introduction

Several works have shown that nuclear activity is related to galaxy interactions, where a high fraction of active galactic nuclei (AGNs) are observed in close pair of galaxies (e.g., Ellison et al. 2011). However, a fraction of AGNs can be missed in the optical selection due to the high obscuration resulting from the merging process, which makes it difficult to understand the role of mergers in nuclear activity (Pfeifle et al. 2019; Guainazzi et al. 2021). Moreover, the variability is an important characteristic observed in all wavelength ranges of the electromagnetic emission of AGNs, as it can be related to physical processes that occur in their accretion disk and jets that still need to be better understood. In this context, our attention was brought to the galaxy pair CGCG 077-102 (members: CGCG 077-102 NED01 and CGCG 077-102 NED02, NED01 and NED02 hereafter) because we discovered a variable X-ray source in the nucleus of one galaxy of the pair, which was never reported in the literature as an AGN before.

2 Optical Spectroscopy of the CGCG 077-102 Pair

We mapped the galaxy pair at the *Observatoire de Haute Provence* in order to investigate its spectral characteristics with the instruments MISTRAL and GHASP. We classified the galaxy NED02 as a Seyfert, and we confirmed the passive state of its companion NED01 with the spectrograph MISTRAL. Based on the GHASP observations, we estimated a lower black hole mass limit of $M_{BH} > 1.2 \times 10^5$ $M_\odot$ for NED02.

[1] Instituto de Astronomia, Geoféisica e Ciências Atmosféricas, Universidade de São Paulo, São Paulo, Brazil
[2] Aix-Marseille Université, CNRS, CNES, Laboratoire d'Astrophysique de Marseille, Marseille, France
[3] Department of Physics and Astronomy, CIERA, Northwestern University, Evanston, IL 60208-3112, USA

© Société Française d'Astronomie et d'Astrophysique (SF2A) 2023

3 Optical Variability

We used the public Zwicky Transient Facility data to investigate the optical variability of NED02 in g and r filters. After applying a noise correction to the data, we did not detect short-term variability on time scales from weeks to months in any filter. However, we found that NED02 has aperiodic stochastic variability in long timescales in the g-band that can be well described by the Damped Random Walk (DRW) model (Fig. 1). From the best-fitted DRW model, we found a characteristic damping timescale of $\tau_{\rm DRW} = 30^{+28}_{-12}$ days, and using the $\tau_{\rm DRW} - M_{BH}$ relation (Burke et al. 2021), we found $M_{BH} = 10^{6.65^{+0.72}_{-0.55}}$ M$_\odot$.

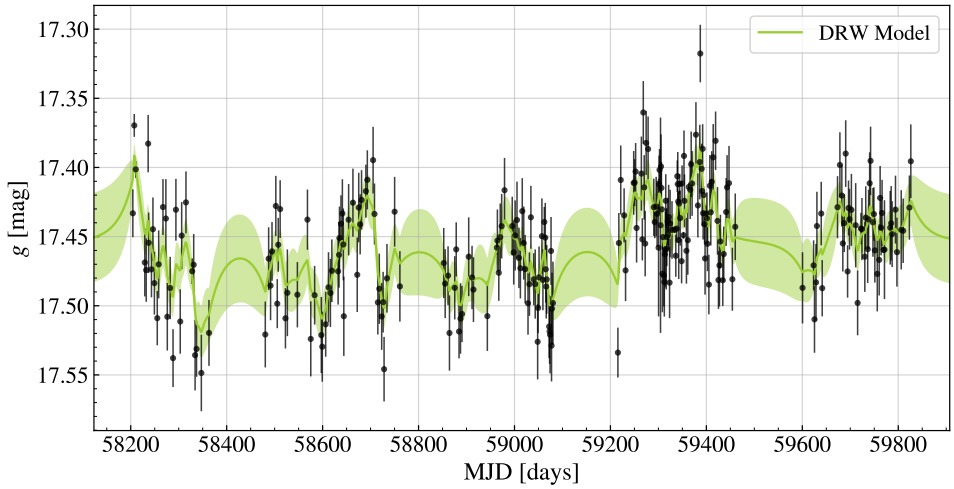

Fig. 1. The detrended light curve of NED02 in g-band (black dots). The best-fitted DRW model with a 1σ of uncertainty (shaded area) is shown in green.

4 X-Ray Analysis

We used Chandra and XMM-Newton archival data, and we did not find evidence of multiple X-ray sources or an extended component within NED02. However, we detected a significant non-random variation in the $0.5-10$ keV X-ray flux inter-observations between $\sim$ 4 days for short-term variations up to $\sim$ 700 days for long-term variations.

5 Conclusions

Our results show that NED02 is a Seyfert hosting a black hole moderately massive of 10^6 M$_\odot$. Moreover, NED02 shows surprising signs of variability in the optical as well as likely non-random variations in X-rays. In the future, we expect to obtain follow-up X-ray data to investigate its possible non-random variability and understand its correlations with the optical one. Also, our findings encourage us to characterize the spectral variability of NED02 with follow-up MISTRAL data. A complete and detailed version of this work can be found in Adami et al. (2023).

K.P.R. acknowledges financial support of the *Coordenação de Aperfeiçoamento de Pessoal de Néivel Superior* (CAPES), Grant No. 88887.694541/2022 – 00

References

Adami, C., Parra Ramos, K., Harry, J. T., et al. 2023, arXiv e-prints, arXiv:2307.10772
Burke, C. J., Shen, Y., Blaes, O., et al. 2021, Science, 373, 789
Ellison, S. L., Patton, D. R., Mendel, J. T., & Scudder, J. M. 2011, MNRAS, 418, 2043
Guainazzi, M., De Rosa, A., Bianchi, S., et al. 2021, MNRAS, 504, 393
Pfeifle, R. W., Satyapal, S., Secrest, N. J., et al. 2019, ApJ, 875, 117