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VARIABLE EMISSION LINES FROM CGCG 077-102 NED02, AN AGN EMBEDDED IN A DEEP GRAVITATIONAL WELL OF A RICH CLUSTER OF GALAXIES

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Abstract. We present preliminary results about the variability of the central AGN in CGCG 077-102.

Keywords: AGN, variability, CGCG 077-102 NED02

1 Introduction

The AGN CGCG 077-102 NED02 (hereafter NED02) was discovered in X-rays by a search for tidal disruption events in clusters of galaxies. NED02 is part of a rare pair (with companion NED01) of AGN-Normal galaxy systems deep in the gravitational potential of a rich cluster of galaxies (Adami et al. 2023). Here we report on a 2-year campaign carried out using the MISTRAL Instrument at the OHP (Schmitt et al. 2024). The X-ray emission is variable on time-scales as short as one day. In the optical, however, over 30-60 days of monitoring, no variability was detected in the optical continuum and broad band observations were needed to detect the ∼0.3 mag (r,g band) variations. Unlike Adami et al. (2023), we found no statistically significant variability in the lines with optical continuum monitoring. The analysis we carried out did, however, provide new insights to the environment around the central SMBH as well as another estimate of its mass.

2 Science background and technical analysis

The visual appearance of NED02 is that we are observing it as if it is ∼face-on, and is consistent with the lack of variable absorption lines when compared to Fig. 13 from Misawa et al. (2004). The spectrum appears similar to that of the classical type I Seyfert NGC 4151 (Fig. 1). Thus, it would appear at the superficial level that the accretion disk around the SMBH in NED02 has not been significantly affected by ram-pressure stripping.

Spectral modeling was done with the Python tool "BADASS," which robustly handles the spectral continuum, simultaneous fitting of any number of narrow and broad line components, as well as Monte Carlo estimates of parameter uncertainties (`https://github.com/remingtonsexton/BADASS3`). Fig. 2 is an example BADASS fit for one of our spectral datasets of NED02. The spectral emission lines of interest to us are the SII doublet (denoted SIIa and SIIb), and the Hα line lying between the NII doublet (denoted NIIa and NIIb). In the BADASS fits, the velocity offset vs rest frame energy and the line dispersions were set to be equal among the two lines in each doublet. For the NII lines, the NIIb amplitude was fixed as 3.049 times the NIIa amplitude (Dojčinović et al. 2023). Both the broad and narrow lines were modeled as Voigt profiles (except one spectral data set, which was better modeled with Gaussian lines). Galactic extinction was set at 0.078 (see `http://bit.ly/43R80uw` in SDSS r band), and a cosmology of $H_0 = 69.6$ km/s/Mpc and $\Omega_m = 0.286$ was used. Fit values and 95% confidence intervals were taken for the line equivalent widths (EWs) and fluxes. The larger of the asymmetric error bars was taken for error propagation calculations. Total is 13 nights of (usable) data, spanning a period of 146 days. 3 nights of data were omitted due to excessive noise or calibration issues. Continuum flux values at the NII complex and SII doublet were derived with the Python package PHEW (`https://github.com/CoolStarsCU/PHEW`). The ratio of the NED02/NED01 continuum were used to weight the EW values. Since the observations were not evenly spaced, we linearly interpolated data points to the EW and continuum sequences, to achieve a uniform 1 day spacing & standardize cross-correlation lag to be in days.

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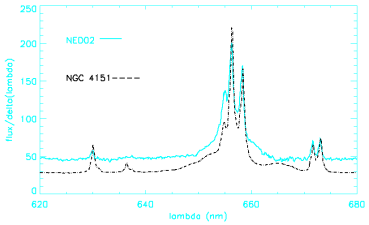
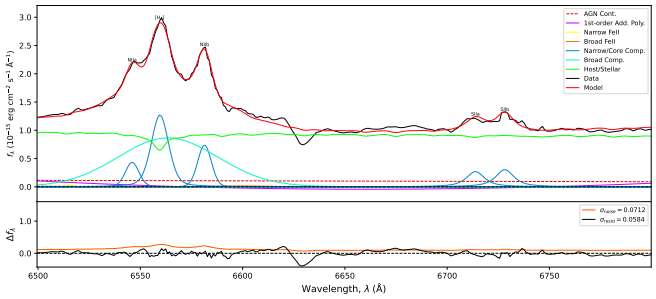


Fig. 1. Left: Spectra of NED02 (MISTRAL) and NGC4151.

Fig. 2. Bottom: Typical spectral modeling of the MISTRAL spectra.



3 Results and conclusions

Monitoring of the lines led to inconclusive results due to a lack of strong variability, see Fig. 3. We have, however, derived some properties of the SMBH environment, which we had not investigated prior. For example, we used the SII forbidden line ratios to estimate the electron density, with an n_e of about 400-600 cm^{-3}, which is in the range for AGNs found, for example, by Kakkad et al. (2018). From our BADASS fits of the Hα broad line, we used the derived FHWM and line luminosity, in tandem with empirical relations in the literature, e.g. Dalla Bontà et al. (2025), to estimate the SMBH mass. Our new estimate of the mass is about 2E8 $M_\odot$, which, from the relatively low X-ray luminosity, implies the central engine is emitting at well below the Eddington limit. In summary, NED02 has the properties of a typical AGN. How NED02, while deep in the cluster gravitational well, can still have significant enough accretion to appear as an AGN is still an open challenge.

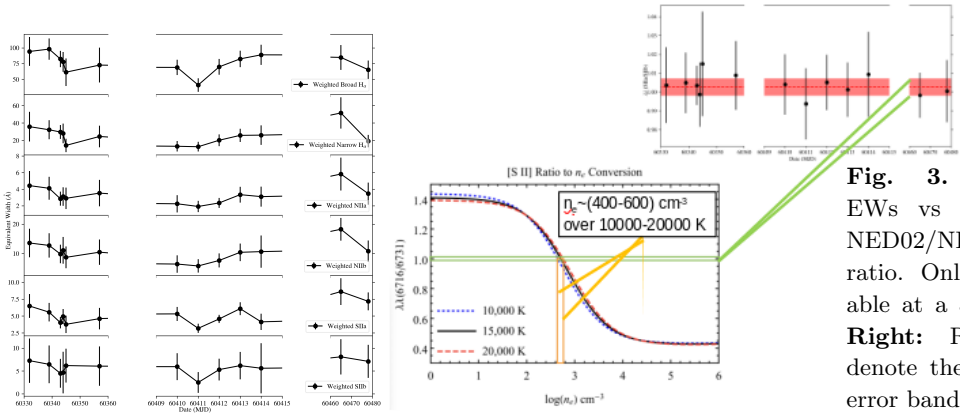


Fig. 3. Left: Optical line EWs vs time, weighted by the NED02/NED01 continuum flux ratio. Only the narrow Hα is variable at a 5% confidence threshold. **Right:** Red line & shaded area denote the weighted mean and 1σ error band in the SIIa/SIIb ratio

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