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Probing outskirts of accretion disks through O I λ11297 broad emission line of active galactic nuclei

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We report the first detection of a double-peak broad emission line in the near-infrared region (NIR) associated with the O I λ11297 emission in the Seyfert 1 galaxy III Zw 002. Simultaneously, we detected double-peak emission in the Paα line. We reproduce the observed profile due to a disk inclined by 18°, with a maximum emission radius of 52.43 lt-day. This work marks a significant step in understanding the accretion disk outskirts in active galactic nuclei (AGNs).

The phenomenon of double-peaked broad emission lines (DPBELs) has been extensively studied in optical spectra. They are most commonly detected using optical spectroscopy in the Balmer lines and interpreted as evidence for the presence of an accretion disk. Previous studies have highlighted persistent features in the Hβ line of III Zw 002 (Mrk 1501 or PG 0007+106), with evidence of both blue and red asymmetries in the line profile. Grier et al. (2017) revealed a persistent redward feature in the Hβ line, consistent with a disk model, while Popović et al. (2003) observed both blue and red asymmetries, suggesting a disk model combined with a Gaussian component. Despite the extensive variability observed across various wavelengths, the near-infrared (NIR) region has remained largely unexplored for III Zw 002.

The NIR spectrum of III Zw 002 was captured on July 28, 2021, using the GNIRS spectrograph at the Gemini North telescope. The setup covered a 0.8–2.5 μm spectral range with a resolution of 1700. The observations consisted of eight 150s exposures. The telluric star A0V HIP186 was observed at an airmass of 1.052. The analysis confirmed the double-peaked nature of III Zw 002 and revealed double-peaked profiles in Paα and OIλ11287 lines. The data reduction process is detailed in Dias dos Santos et al. (2023). The NIR spectroscopy allowed us to simultaneously detect double-peaked profiles in different lines emitted by the BLR of III Zw 002 and set important constraints on the size and geometry of the accretion disk of such AGN.

The double peak profiles were fitted using a disk-based model (Chen & Halpern, 1989), with an additional Gaussian component referred to as non-disk clouds, representing the classical broad line region (BLR). We derive the disk inclination, a key parameter for estimating the virial factor (f, see e.g., Panda et al. (2019)). Utilizing measured inclinations and various values of gas distribution (κ) representative of the disk geometry, we obtain virial factors consistent with those of other AGNs, supporting the reliability of our method.

Furthermore, the fit analysis indicated that the disk is geometrically more extended in O I (up to 18.86 ld-day) than in Paα (16.77 ld-day), meaning that the lines originate from slightly different maximum emissivity radii. This result corroborates several works that have demonstrated through kinematic and photoionization models that the O I line originates in the outer portion of the BLR (Martínez-Aldama et al., 2015). The interpretation of our findings points out that both emission lines originate in a BLR distribution of clouds dominated by a planar geometry, with orbits well described by those of a Keplerian disk. The result provides a comprehensive understanding of the BLR dynamics in III Zw 002 and sheds light on the underlying mechanisms driving its peculiar emission line profiles.

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