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Doctoral Thesis: **Morphology of Circumnuclear Accreting Gas in Active Galactic Nuclei**

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Thesis Supervisor: dr hab. Alex G. Markowitz

Referee's report:

The Thesis deals with the analysis of obscuration in active galactic nuclei (AGN), which is very common for many systems, especially for highly inclined AGN when the line-of-sight penetrates a larger amount of obscuring material concentrated in clumps in a torus-like structure along the equatorial plane. After the Introduction, the first part of the Thesis contains a comprehensive analysis of applicability and limitations of the state-of-art torus models to current X-ray data. For this purpose, the student simulated a large set of data using the response functions of current X-ray instruments on-board the XMM-Newton and NuSTAR satellites and applied a novel Bayesian Nested Sampling method for global fitting, testing which parameter values are confidentially recovered and under which conditions the fits can lead to wrong results. This work has already been published in the Monthly Notices of the Royal Astronomical Society. It contains a thorough analysis, warning of possible caveats when using single-epoch data and analysis guidelines for the community, emphasising that synthetic-data simulations should be beneficial along with the data analysis.

In the next Chapter, the student performed a multi-wavelength analysis of a unique changing-look AGN LEDA 1154204 using multiple optical and X-ray data. Given the wealth of available data and complexity of the analysis, this work led to an extended paper that was submitted to the Astronomy & Astrophysics journal. The student has performed a comprehensive timing and spectral analysis of both optical and X-ray data. The studied AGN was classified as Type-1.9 since it exhibited broad H-alpha (Ha) line profile but missing H-beta (Hb) broad component. During a flare in 2020, the Hb broad component clearly appeared in the optical spectra and diminished in a few months again as the flux dropped, returning to the similar state as before the flare. The broad optical lines are fitted by a combination of a Gaussian line and a relativistic diskline profile in the Schwarzschild metric. It is concluded that both lines are needed to fit the data, as the measured line does not have a characteristic double-peaked profile as the diskline. The Gaussian line is, however, broader than the diskline, which questions its physical origin. Moreover, the Gaussian component is found to be redshifted and proposed to be explained by an outflow, but outflows are usually characterized by blueshifted components and this would also not explain the broadening of the line. Given the fine structures visible on the line peak in Fig. 6, it seems that there are still some not properly modelled narrow features, rising a question how well the continuum and narrow components are subtracted and how trustable the fitting results with the diskline and Gaussian models are.

The last chapter contains a methodology setup and first results for detecting the obscuration events in the all-sky survey using the eROSITA mission. The eROSITA catalogue is specific to have the capability to detect plenty of events, from which the most interesting could be targeted by deep more sensitive follow-up observations, which is mentioned as the future plan of the research and this work is very useful for the community, as it gives a recipe how to use shallow X-ray surveys to detect AGN changing-obscuration events.

The Thesis is clearly written and structured. The introduction clearly summarises the basics of AGN physics and structure, describing the individual AGN components and the AGN unification scenario. There are only a few points that could be included: black hole mergers as possible scenarios for the supermassive black hole growth, reverberation mapping for our knowledge of location of the broad line region, recent observation of NGC 3147 with Hubble showing a very broad Ha line and thus questioning its 'true' type-2 nature, FR classification affected by the environment rather than the jet power, quasi-periodic eruptions as examples of the AGN extreme variability. The student should also correct some inconsistencies in cross-links (e.g. equation 4.1 is reffered to as 4.2, Fig. 4.8 as 4.5, etc.), a few minor typos (the the), complete list of references and list of abbreviations: e.g. XRB as X-ray Background (which is also rather confusing with typical use of this abbreviation for X-ray binaries), CLAGN and COAGN are confused in the List of Abbreviations, some abbreviations are made in the text multiple times (AGN, COAGN), some are not further used (MAD). The unit in gravitation constant should have m^2, not to -2. In plots of spectra in Paper II, there should be photons in y-axis units. But these are only minor things that should be corrected for the final version of the PhD Thesis. The scientific content of the Thesis is very valuable, proving the quality of the work done by the student.

Summing up, I consider the doctoral thesis of Tathagata Saha to be a valuable contribution and to meet the criteria prescribed by the law for a doctoral dissertation. Therefore, I request that this dissertation be admitted to a public defense.

Possible questions to the PhD defense:

In the Chapter 2, the presented simulations are done for different flux levels and for 100ks exposure time with XMM and 50ks NuSTAR. What kind of detectors are needed for a significant improvement in the fit reliability and are some of the currently proposed future telescopes equipped with the new generation of X-ray instruments that would be significantly more capable than the current ones in constraining the exact geometry and physical parameters of the obscuring medium?

In Chapter 3 in Sect. 6, it is mentioned that the AGNSED model does not provide good results for the higher black-hole mass. Also, the Edd. ratio ~ 0.03 for lower mass is more consistent with the accretion rate that is typical for changing-look phenomena. Would these suggest the lower mass measurement to be more likely? And why the mass measurements from both FWHM(Ha) and FWHM(Hb) provide inaccurate estimates?

Still in Chapter 3, the proposed main interpretation of the changing-look event in this source is due to an instability in the disc, but the X-ray spectra do not change only their normalization (as shown in Fig.2). Is that expected from an accretion disc instability model?

In Prague, on 12th of January 2024

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