Obserwatorium Astronomiczne
Uniwersytetu Warszawskiego

Al. Ujazdowskie 4, 00 478 Warszawa
tel: (22) 55-30-507, fax: (22) 629-49-67
www.astrouw.edu.pl

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Prof. dr hab. Szymon Kozłowski
Obserwatorium Astronomiczne
Uniwersytetu Warszawskiego
Al. Ujazdowskie 4
00-478 Warszawa
e-mail: simkoz@astrouw.edu.pl

Review of the doctoral dissertation by Saikruba Krishnan entitled „Time-Domain and Spectroscopic Studies of Active Galactic Nuclei"

The doctoral thesis prepared by Saikruba Krishnan is a dissertation that I evaluate positively. This work is evidence of high analytical expertise, ability to conduct scientific research, ability to analyze data, and construct conclusions that lead to further improvements in the presented methods. It also constitutes an original solution to a scientific problem (the first scientific chapter), and demonstrates the candidate's general knowledge in the AGN variability studies. Moreover, the topics undertaken are current and significant for our understanding of the still not well-understood engines of Active Galactic Nuclei (AGN).

The doctoral dissertation submitted to me for review addresses two scientific topics that are presented in a form of two main chapters. The first one is related to the detection, non-detection, and false positive detection of both periodic and quasi-periodic oscillations in the power spectra of AGN. The second topic addresses a high amplitude X-ray variable AGN observed in a range of wavelengths. I review the content of those two chapters below.

In the first scientific chapter, by simulation means, the PhD student presents studies on the detection of periodic/quasi-periodic signals using two statistical methods, that include Auto-Correlation Function (ACF) and Phase Dispersion Minimization (PDM). The simulated light curves are meant to resemble the real data in terms of cadence, where at the beginning one day sampling and 250 day data lengths are chosen, and later the cadence changes during various trials to resemble that of real data (ie. 10-years-long unevenly sampled data, that include seasonal gaps). There is no photometric noise added to the data, which obviously might change the final conclusions of these analyses, that in turn would be a function of the signal-to-noise ratio. Nevertheless, I find this chapter valuable and interesting.

There are numerous simulation setups, each consisting of 1000 light curves, that differ by the choice of the power spectrum that is used for simulations. These simulations include pure Lorentzian PSD to investigate QPO identification, the correlated noise described by a power-law PSD with slopes spanning 0.4-3.0, including the red-noise (PSD slope 2.0), and the mixture model containing a combination of the power-law and Lorentzian PSDs. A broken power-law PSD with a number of slopes at both low and high frequencies was also tested. The PhD student, using the ACF method, tests how often pure correlated noise leads to variability being interpreted as QPOs. The main finding is that if the considered timescales are shorter than one third of the data span, the false-positive rate decreases significantly (below 0.3%). The false positive rate increases with the increasingly steeper PSDs. Another performed test was to understand false negatives, meaning the lack of detection of a QPO, when it was included as the input in the simulation.

Similar analyses to those mentioned above were performed with the Phase Dispersion Minimization (PDM) method. One of the key findings is that the minimum dispersion for the red noise-like processes may not mean QPO identification. The Ph.D. student analyzed the PDM minima for the combined QPO and correlated noise setup. The chapter is concisely summarized by elaboration on e.g. published false-positive period/QPO detections and general issues with the ACF and PDM methods.

This chapter was published as an article in the Monthly Notices of the Royal Astronomical Society in 2021, with the Ph.D. student as the first and leading author. Krishnan S. et al. 2021, MNRAS, 508, 3975 - and was cited 4 times (according to NASA ADS).

In the second scientific chapter, the Ph.D. student analyzes and attempts to interpret an X-ray light curve for an AGN that exhibits high flux variations in several observation epochs. This source has been also observed in a follow-up mode in a wide range of frequencies spanning the X-ray-UV-optical bands, with spectroscopy (VLT FORS2/SALT), but also optical (ATLAS) and mid-IR (WISE) archival data were obtained.

The chapter first describes the three relevant X-ray missions – eRosita, XMM-Newton, and NICER, data reductions, but also contains the presentation of the optical, IR, and spectroscopic data. The X-ray data analyses start by fitting the power-law model to the X-ray continuum (to all three missions). Subsequently, more spectral components are added (double power-law model) and the Gaussian Kα fit is performed (with a non-detection). The Ph.D. student models a SED in a broader range of wavelengths by the inclusion of the optical ATLAS data, where the near-peak SED and off-the-peak SED are fitted separately. The fitting is done with the AGNSED model (where the flux changes are attributed to changes in the accretion rate and truncation of the accretion disk), the model that includes disk emission, warm Comptonizing, and inner hot Comptonizing regions. To describe the broad-band X-ray continuum in the high and low flux states, the Thcomp model with double Comptonization is also used. For several optical FORS2 and SALT spectra, the line and continuum fitting is performed. The chapter is summarized by a review of all possible sources of such variability and their properties: variability timescales, disk instability models, TDEs.

In addition to the two main scientific chapters, the thesis consist of two more key chapters: a comprehensive Introduction and Conclusions. I find both chapters to be well written with a plentiful of references (over 360). The thesis has a standard format; after the title page, it contains Declaration of Authorship, abstract, short acknowledgements, list of contents, list of figures, list of tables, four chapters mentioned above, scientific acknowledgements, and references. The thesis is

121 pages long and contains over 360 references. One of the scientific chapters was already published in the Monthly Notices of the Royal Astronomical Society in 2021, with the PhD student as the first and leading author.

One minor comment:

Throughout the text, the PhD student was using phrase the “red noise” to all types of PSD power-law slopes, which was rather confusing to me. Red noise means a single PSD slope of 2. I suggest using phrase “correlated noise” instead.

Summing up, I consider the doctoral thesis of Saikruba Krishnan to be a valuable contribution to science 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.

Prof. dr hab. Szymon Kozłowski