

External Examiner Report on Doctoral Dissertation for PhD Degree

In this evaluation report, I give my assessment of the PhD thesis by Mr. Swayamtrupta Panda, titled "Physical Conditions in the Broad-line Regions of Active Galaxies".

Overall academic merit of the dissertation

The thesis presents original research results in the area of astrophysical aspects of various phenomena around black holes. It presents methods and tools to investigate the physical conditions of gaseous matter surrounding the central supermassive black holes in the center of each galaxy. The focus of the thesis is on theoretical calculations using an open code, CLOUDY, for radiative transfer of gas illuminated by the intense radiation from the vicinity the black holes. Especially, ionic transitions related to relatively low ionization energy (< 20 eV), Low-Ionization emission Lines, are used as the probe to investigate the physics around the black holes.

Through a series of computations, the candidate has derived various constraints on, e.g., the metal content in the gas and the size of gaseous clouds. Derived size of gaseous clouds will be an important information in order to further investigate the origin of the gaseous clouds.

Swayamtrupta Panda authored and co-authored a large number of publications, including a single-authored paper published this year. Some of those articles already made impact in the literature with a sufficient number of citations to them, even within a short period of time.

Given that the photoionization processes of the clouds and radiation from those clouds are fairly well understood by this dissertation, the wavelength dependence of the emission lines (line profile) and its time variation would further enable one to figure out the structure and the motion of gaseous matter surrounding the black holes.

Structure and composition

The thesis is written well, and its scientific merits are undoubtedly of superb quality. The structure of the dissertation is coherent and flows logically from chapter to chapter, from one publication to another.

The brief review parts in Chapters 1 and 9 (Appendix) are fairly broad and sufficient. Chapter 1 constitutes the Introduction and explains the topic of research, the methodology used and the research questions in detail. The basic physics of the open code used for the calculations throughout this thesis, CLOUDY, is described and explained properly in Section 1.5. In other words, the candidate has used this code not as a black box. It would have been nice to include a more profound discussion upon what would happen when other photoionization codes are used.

Chapters 2–7 contain several, first-authored articles published in the peer-reviewed journals. Through intensive CLOUDY calculations, he studied the Fe II emission lines (caused by the transitions of iron ions) comprehensively.

Special attention is devoted to the extreme UV to Soft X-ray emission of the illuminating radiation (Chapter 3) and the orientation effect [the geometry of the plane of the accreting gas (the accretion disk) relative to the distant observer] (Chapters 4, 5 and 7). Because of the latter effect, the gaseous matter illuminated by the disk "sees" a different shape of the radiation compared to the distant observer. Additionally, it is discussed that a certain sub-group of the

active massive black holes can be used as the cosmological distance indicators. In Chapter 6, he also exploited another emission lines, Ca II other than the conventional Fe II. As the results of those investigations, he has derived various constraints on the the metal and dust contents, the turbulent motion in the clouds, and the distance between the clouds and the central illumination source surrounding the central black hole.

The successful publication of these results exhibits fullness of his PhD studies in the year from 2016 to 2021.

Recommendation

To summarise, my conclusion is that the PhD thesis of Mr. Swayamtrupta Panda presents original research results of immense importance. Namely, he is ready to contribute much to this field of black hole physics as a post-doctor researcher from now on. With this understanding, I thus recommend that the candidate is awarded the doctoral degree.

Furthermore, I would like to emphasise that the work presented in this thesis is outstanding, and I would like to ask the Scientific Council of Center for Theoretical Physics to recognise the high importance of the results for further studies.

Sincerely yours,



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