Report on thesis

submitted to the Faculty of Mathematics and Physics
Charles University

☐ assessment of the supervisor ☒ assessment of the opponent

☐ bachelor thesis ☒ diploma thesis

Author: Bc. Jakub Podgorný

Title: Polarisation of X-ray emission from accretion discs in active galactic nuclei

Study program and field: Physics, Astronomy and Astrophysics

Year of submission: 2020

Name and titles of supervisor/opponent: Dr. Frédéric Marin

Workplace: Astronomical Observatory of Strasbourg

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Professional level of work:

☒ excellent ☐ very good ☐ average ☐ below average ☐ unsatisfactory

Factual errors:

☐ almost none ☒ a reasonable number given the range ☐ less substantial numerous ☐ serious

Results:

☒ original ☐ original and adopted ☐ non-trivial ☐ quoted from literature ☐ transcribed

Scope of work:

☒ large ☐ standard ☐ sufficient ☐ insufficient

Graphic, language and formal level:

☐ excellent ☒ very good ☐ average ☐ below average ☐ unsatisfactory

(English must be improved, but at master-level it is sufficient)

Typos:

☐ almost none ☒ a reasonable number given the scope and topic ☐ numerous

Overall level of work:

☐ excellent ☒ very good ☐ average ☐ below average ☐ unsatisfactory

Assessment, comments and remarks of the supervisor/opponent:

This manuscript is the result of months of hard work from a student who clearly have understood deeply his subject. The emergence of reprocessed emission from accretion disks (in X-ray binaries or Active Galactic Nuclei, AGNs) is far from easy to understand since it requires numerous fields of expertise and mathematical approaches, including non trivial general relativistic effects. The community is yet to agree on the most likely scenario for the emission and features of X-rays in AGNs and this only concerns spectroscopy/photometry. This master thesis includes another important aspect of light: its polarization state. This is much less studied than the spectroscopic part because it is physically more complex to understand and to measure it. Nevertheless, the student took different radiative transfer codes, including mine, and used them to agregate data and models for a bright comparisons of the outcomes. This helped to spot potential weaknesses in all the codes and lead to long and fruitful discussions. Such work mustcoincider be done and it is not easy for a master student. The discussion of the results, both qualitatively and quantitatively, indicate that he has understood the simulations and the physics. This is very good and the manuscript is a mirror of this work. In addition, the use of the IXPEOBSSIM tool to predict the futue measurements of AGN X-ray polarization by IXPE helps to put in context his work. This is very much needed since it will be a very important spatial mission that should be launched in 2021 (probably in the fall). This, actually, would be very much in line with a PhD thesis and this student is clearly the best student to accomplish such work.

The global quality of this work is very great and is only slightly hampered by a level of English that should be improved. I did not find a major mistake throughout the manuscript but I found many small corrections to be done, mainly by being more specific or more exhaustive. I have listed below several remarks that should be corrected in the text before any final submission. Otherwise, I am impressed by the quality of this work and I most certainly recommend him for a Master degree with honors.

Remarks (in order of appearance in the manuscript):

- SIR George Gabriel Stokes
- Polarigenesis: a few high energy mecanisms for polarization creation are missing
- “approximately 1.84e5 photons are required to hold the [1% MDP]”: it would have been nice to have a real flux from an AGN or microquasar to have a precise idea of the required amount of time needed to reach this MDP, then compare it to X-ray spectroscopy and optical polarization measurements
- “… stars, including the sun, due to the Zeeman and/or Hanle effect...” stars are also polarized simply because they are not perfectly spherical
- “It has been only a recent trend to experimentally probe polarisation at X and γ wavelengths” it was a big trend in the 70’s with rockets, balloons and satellites (Ariel V and Intercosmos), but the development of non-rotable X-ray optics and the poor sensitivity of Bragg crystals to measure X-ray polarization killed the field for 40 years.
- on page 12, a few more sentences could have been written to explain what are the BLR and NLR (high vs low density gas, keplerian vs radial motion, composition etc …) since they are extremely important to classify AGNs
- p13: radiohydrodynamical ?
- “Detailed studies of these correlations support the partial origin of soft excess in the disc accretion” there is a lot of tension about the soft excess in AGNs, in particular because its properties does not vary with the disk size/mass.
- “All the computations of interaction of light and matter in this region are more complicated due to the fact that multiple-scattering must be taken into account”, plus it takes a lot of time to compute, so most of the codes/models usually neglect scattering.
- Modern research in spectral and polarimetric properties of AGNs → CLOUDY code should have been mentioned too.

- p28, STOKES, “regarding the horizontal stratification of disc”, I think “vertical structure” was meant, although STOKES can create both a vertical and a radial structure at the same time.
- “Since the discovery of cosmic X-rays in 1962”, since the MEASUREMENT. X-rays from sapce were already expected from theories.
- “The main reason was a rather faint nature of polarisation signal from the expected sources and difficulties in constructing high-sensitivity detectors on the basis of Thomson scattering and Bragg diffraction.” It was a bit more complex, see Marin (2018), “The Growth of Interest in Astronomical X-Ray Polarimetry”.
- “Me and my supervisor”, my supervisor and I
- “unlike the STOKES polarisation results, which are rather unique.” they are completely unique
- “Both normalization attempts are nearly perfect (with relative difference <10%) at the Compton hump feature” this difference should be examined by the student. Where does it come from ?
- “Regarding the STOKES results presented, it cannot be yet excluded that the soft excess has not dominant origin in thermal processes as a natural continuation of the big blue bump.” this is a good reasonning. Many experts do not agree with the disc origin of the soft-excess.
- The amount of photons simulated per model should have been given, together with the averaged amount of time needed to complete such simulations.
- “It was also important to implement cyclic loading of the newly created nine FITS tables and prepare the routine for all available Stokes parameters in the reflection tables” why do you need cyclic loading ?
- “the blurred Fe Kα line in the total spectrum serves as a powerful feature for fitting of inclination, spin and disc’s ionization in the AGNs or X-ray binaries spectra” this is still debated since several other mecanisms could produce this skewed iron line feature without invoking general relativistic effects
- Comparing polarization results between the Chandrasekhar formula and STOKES, multiple scattering appears extremely important. It would have been nice to show a plot of the number of scattering (averaged) per energy bin for STOKES. It is an outpout of the model that is available quickly and easily.
- why no type-2 IXPEOBSSIM simulations have been done ? They are not very brght but they surely have much larger polarization degrees (see NGC 1068 and/or the Circinus Galaxy)
- eXTP is mentioned in addition to IXPE, but what about the hard X-ray polarimetric missions/concepts ?

Possible questions during the defence and topics for discussion:

- what are the other X-ray polarimetric missions in preparation ?
- is it important (in the future) to measure the Compton hump polarization and why ?
- how much scattering is happening per energy bin in STOKES spectra (relevant with respect to Chandrasekhar approach) ?
- because of the line forest below 1 keV, is it worth to observe the X-ray poalrization of AGNs in the very soft band ?
- do we know anything about the soft excess polarization (certainly not in X-rays but maybe in far-ultraviolet ?)
- how much the X-ray results from the simulations (at infinity) will be changed when other AGN components (mainly the BLR, the torus and the winds, not even mentionning the jets) are taken into account ?

Work

☒ I recommend

☐ I do not recommend

to be recognized as a diploma/bachelor thesis.

I suggest a grade:

☐ excellent ☒ very good ☐ good ☐ failed

Place, date and signature of the supervisor/opponent:

Strasbourg, June 5th, 2020