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Warsaw, 20 September 2021

Referee report for the PhD Thesis of mgr Karthik Balasubramaniam

The PhD Thesis of mgr Karthik Balasubramaniam titled “**Fluorescent Iron Lines in Various Types of Radio-Loud Active Galactic Nuclei**” prepared under the supervision of prof. Łukasz Stawarz aims to address the issue of observed properties of the Kalpha line and the insight we can gain for these sources. The author selected three representative sources with different properties (a bright quasar with a large scale structure, much fainter LINER type source, and finally faint, one of the youngest radio sources).

Correspondingly, the Thesis consists of 4 major sections: the Introduction and the three sections devoted to each of the three sources. The three publications have co-authors but mgr Balasubramaniam is the leading author in two of these papers, and he contributed significantly to the third one (actually, Paper I). The text finishes with a separate section containing the conclusions and final remarks.

Introduction

The first section is very nice, well balanced, and offers a very good introduction to the complexity of AGN, with key references also from the past. Nice that the author stresses the role of the accretion rate in unification scheme; originally only the importance of the viewing angle has been recognized.

The basic physics behind the Kalpha line formation is introduced. In Sect. 1.2 we have a good introduction to still much disputed aspect of the geometry of the inner X-ray producing region which Kalpha studies attempt to address. Finally, the author discusses the satellites used for collecting X-ray spectra. It is nice that also future missions are included.

Results contained in the Thesis

In paper I the author shows the analysis of the high quality X-ray spectrum of broad-line quasar 4C +74.26 with giant large-scale radio morphology. To interpret the spectrum, the author used the best currently available model for X-ray reflection RELXILL but also allowed for an ionized absorber. There are most recent modifications to RELXILL (relxillCp and relxillpCp) replacing the exponential decay of the power law with proper shape at high energies (this is not important for the Thesis) and introducing relativistic effects in the light propagation from the lamp to the observer. However, I do not think this is a big problem since the geometrical setup (a point-like source) is an approximation anyway and I do not think that the main conclusion - the absence of the cold disk close to the central black hole - is affected by this simplification.

The result: location of the inner cold disk radius at a few tens of gravitational radii is a nice observational confirmation of rather general belief that strong jets need strong support from the ion torus surrounding the central black hole and the collimating large scale magnetic fields.

Paper II addresses the issue of the K α emission in a LINER galaxy which additionally shows traces of the intermittent activity in the radio morphology. There mgr Balasubramaniam detects the thermal emission from the nuclear plasma, and an iron emission coming from strongly ionized plasma. He argues that this line emission is associated with the Broad Line Region in the source.

The discussion of this last point could have been a bit more careful. There are estimates of the black hole mass in this source (e.g. $\log M/M_{\text{sun}} = 8.47$, Kozieł-Wierzbowska et al. 2012). With the adopted distance to the BLR as in Thesis (5.7×10^{-3} pc) we would expect quite broad lines in the BLR, while in the optical spectra we clearly see the presence of the Intermediate Line Region (ILB), with considerably narrower lines (Kozieł-Wierzbowska et al. 2012). Thus the material with the hydrogen column derived from X-ray data must be selectively shielding only the inner BLR, not the outer ILR, which is geometrically possible but not discussed. Or, alternatively, there is no BLR coexisting with the hot plasma anyway, which is not ruled out in the paper, in my opinion. This leaves the question of the presence of the hidden BLR in LINERS still unsolved.

In Paper III the author addresses the issue of the possible insight into the nuclear activity from K α line studies in the case of very freshly activated elliptical galaxy., with the kinematic age of the jet only of order of 60 years. The authors revealed the presence of both the hot thermal gas in the source as well as the cold material reprocessing part of the X-ray emission. The measurement is consistent with the X-ray Baldwin effect seen in general in the AGN studies with XMM, Chandra and Suzaku over the years. The physical nature of this trend is unclear although the suggestion of slowly decreasing torus extension with the rise of the luminosity, as suggested by Ricci et al. (2013) seems reasonable. As discussed in the Thesis, the source is actually heavily absorbed (which is clear from the measurement of EW, but also from looking at Fig. 4.7 and the X-ray slope), with partial covering by Compton-thick clumps, so the measured column density of the cold absorber does not represent the actual amount of absorption in the source. This is why the agreement with the Compton-thick sources analyzed by Boorman et al. (2018) is so good. I am not sure why the authors consider the agreement as surprising while concluding themselves about dominant role of Compton-thick partial covering in their source.

Summarizing: the results obtained by Mgr Karthik Balasubramaniam are important for our understanding of the processes taking place in the plasma surrounding the central supermassive black hole in radio-loud active galaxies. Object selection is interesting - three sources represent extreme cases of AGN activity. The data analysis is performed very carefully. The discussions based on each of the sources are justified, and the final summary shows that indeed K α line is a very useful probe of the thermal state and location of the emitting plasma. In the brighter source the existence of the standard disk at radii about a few tens of gravitational radii is confirmed, with the transition to the hot flow at smaller radii. In the two dimmer objects the K α line traces the properties of the hotter plasma and the clumpy outer region. In the concluding remarks I missed the aspect of the viewing angle as one of the important parameters shaping the observed K α line.

Minor comments:

In the text, American version of 'disk' (in opposite to UK disc) is fine, but the author could notice that the automatic system changed also 'discussed' into diskussed'. As for black hole - galaxy connection (Section 1.1.1), Magorrian et al. (1998) were certainly the first to notice the black hole-bulge relation.

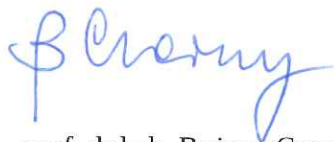
The statement about the disk solution stability in Sect. 1.1.2 is not quite correct but this is a complex issue, not fully solved, and not too relevant for the Thesis. Specifically, solutions are easily described as stable/unstable as in Chen et al. (1995) locally, at a given radius, but the positions of the stability/instability zones depend on the radius, so the issue of global stability is far more complex.

In Section 1.1.3 the author argues that BLR clouds are bound although recently BLR as well as dusty torus are frequently modeled as a combination of wind/failed wind, so a fraction of clouds may actually be escaping from the gravitational field.

In Paper II the author gives the ID of the observational run with *Chandra* but does not mention the name of the PI.

Conclusion

In summary, I consider the doctoral thesis of mgr Karthik Balasubramaniam to be a valuable contribution to AGN research 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.



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