Point processes as a mathematical tool to describe black-hole accretion disc stochastic variability

(PhD thesis)

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The PhD thesis written by Tomáš Pecháček deals with one of the most important topics of recent relativistic astrophysics, namely the modelling of complex optical phenomena observed in Galactic and extragalactic black hole systems. These phenomena are, according to standard approaches, related to radiation of accretion discs orbiting the black holes. Their complex spectral profile is usually attributed to radiation of hot spots appearing on the disc surface due to some stochastic processes that is influenced by a variety of relativistic effects appearing due to the strong gravitational field of the black hole (gravitational and Doppler frequency shift, Doppler beaming, gravitational focusing).

The present thesis is concentrated on modelling of the complex stochastic processes under simplified model of the relativistic phenomena. In fact, the relativistic phenomena are studied in an analytical manner and the so called Beloborodov approximation is used in deriving the above mentioned optical phenomena and the time delay effects are also treated in the approximation allowing for application of analytical formulae. However, the thesis is concentrated on treating the stochastic phenomena related to creation and development of hot spot ensembles in the scope of the recent approaches to stochastic methods that could be applied to the radiating discs with hot spots. The basical ideas of the stochastic methods and approaches are introduced in full generality and then the special stochastic methods applicable to the accretion discs optical phenomena are discussed – namely the random walk and Markow chain models are presented. The relations among the hot spots are treated in the framework of cluster processes – Chinese and Hawkes processes, the pulse avalanche model and generalized Chinese process.

These models are used in order to create simulated spectral profiles generated by accretion disc hot spots orbiting the black hole. The thesis brings interesting new results showing the principal ability of the cluster avalanche models to generate results that could be qualitatively well related to the observed spectral profiles including their breaking points, even if the relativistic effects are treated only in the Beloborodov approximation in the Schwarzschild black hole fields, neglecting thus all the rotational effects of Kerr black holes expected in realistic astrophysical situations, and even allowing only the disc regions (and inclination angles) excluding presence of photon trajectories with turning points of the radial motion. I have the following comments and questions.

1. The author should explain that even for inclination angles $\theta_0 \sim 70°$ and radiation emitted at the marginally stable orbit ($r_{ms} \sim 6M$) used in the thesis, the photon trajectories have no turning point and the Beloborodov approximation can be used.
2. Are the avalanche model conditional probabilities (Eqs. (1.10) (1.11), p. 5) correctly writen?
3. The author uses PSD (Power spectral density), I would like to recall that usually PDS (Power density spectrum) is used in the literature.
4. What is the quantity to which the relative errors are related (p. 17, §1).
5. There should be only one sentence around Eq. (2.52) at p. 21.

6. Time differences in (2.50) and around should be defined consistently. What is λ in definition of b (p. 22).
7. Eq. (3.14) (p. 32) has to be corrected.
8. Which relativistic effects could be similar to the internal properties of the signal (p. 53, § above 3.3.3)?
9. What kind of geometric units do not scale inversely with mass (p. 67)?
10. What kind of effects beside the relativistic ones create the differences between the figures 3.14 and 3.7 (p. 69).
11. The author discussed the relation of the characteristic time given by the orbital (Keplerian) motion in connection to the internal avalanche timescales (p. 79). But the timescale related to the radial inward drift probably could also be relevant.
12. There is a number of misprints and other faults (doubled words, etc.).

All of the comments and questions do not invalidate the high level of the presented thesis which brings new insights into the very complex and interesting area of the stochastic processes in accretion discs around black holes. The results were published in relevant impacted journals (3 papers) and in conference proceedings. The present thesis clearly demonstrates ability of its author to make research of very high quality. Therefore, I recommend him to obtain the PhD degree.

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