

LETTERS TO THE EDITORS

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Exotic aspects of black holes: an astronaut near the horizon

(on the methodological note by A A Grib and Yu V Pavlov
"Is it possible to see the infinite future of the Universe when falling into a black hole?")

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Abstract. We comment on the methodological note by A A Grib and Yu V Pavlov [*Phys. Usp.* 52 257 (2009)] to show that its authors are incorrect in understanding a passage that they quote from A M Cherepashchuk's book *Black holes in the Universe* (Fryazino: Vek-2, 2005, p. 7) and which supposes an astronaut to be at rest in the vicinity of the horizon (not to fall freely into a black hole). With this error corrected, Grib and Pavlov's note is quite useful methodologically.

I read with the interesting methodological note by A A Grib and Yu V Pavlov "Is it possible to see the infinite future of the Universe when falling into a black hole?" [1], where some aspects of the space–time structure of a black hole are explained on a rigorous mathematical level. So far, several thousand black hole candidates have been discovered, and recent observations of processes near event horizons of some supermassive black holes are consistent with the predictions of general relativity. This fact, as was once justly noted by V L Ginzburg, strengthens our belief that black holes actually exist. It is therefore important to understand the black hole structure (similarly to our understanding of the stellar structure), and to adequately reflect it in the popular science literature. Grib and Pavlov provide such a contribution. It complements the relevant books and papers by Novikov and Frolov (see, e.g., [2, 3]).

I would like to make a couple of remarks on [1] in order to explain some misunderstandings.

In the Introduction [1, p. 280], the authors quote (quite precisely) some text from my popular science book *Black Holes in the Universe* [4, p. 7]; "If the situation is reversed and we analyze it from the point of view of the astronaut lingering near the horizon then the rate of events in the external Universe is extremely accelerated...." I stress that here I am speaking about a spacecraft that is not freely falling into a black hole (which is the main point in [1]) but which is steadily lingering in the immediate vicinity of the event horizon (for example, using a hypothetical superpowerful braking engine).

Further in the text, the authors of [1] criticize the quoted citation by emphasizing that in this case, the term "the infinite future" is used inappropriately. However, if the astronaut falls radially into a supermassive black hole and, after switching on the superpowerful engine, stops and lingers immediately near the event horizon (at a distance comparable to the size of the spacecraft, i.e., $\sim 10^{-10}$ of the horizon radius), the difference in the rate of time for the astronaut and in the external Universe becomes so large that the astronaut would be able to see the 'practically' infinite future of our Universe. Of course, direct observations of the external Universe would be hampered by several known facts: a strong radiation background captured by the black hole inside the photon sphere, effects due to the gravitational lensing of light from the remote Universe in the strong gravitational field of the black hole, and a strong blueshift of photons incoming from the external Universe; finally, the very notion of the astronaut in our case is conventional, because he must survive the huge influence of gravitational forces near the event horizon.

In only briefly mentioning black hole physics (my book [4] is mainly devoted to a discussion of the most recent observational facts on black holes), I had no opportunity to describe all these reasons in detail. In my opinion, it was sufficient only to mention the principal possibility of observing the very distant future of the Universe. In a more detailed description published in the book (also quoted by the authors of [1]) "Astronomy. XXI century" [5], I discussed one of these reasons: "...of course, the energy of photons detected by the astronaut from the external Universe will shift to the high-energy part of the spectrum and he will need special devices to make observations...." Possibly, I should have described all the reasons that make observations difficult and also mentioned that if direct observations are impossible, then the astronaut, after having lingered above the event horizon, should have turned on the acceleration engines to return to the external Universe in order to directly see the very distant future. However, it is hardly useful to give such details in a book mainly devoted to the observational appearance of black holes. In concluding, the citation from my book [4] quoted in [1] and its criticism are irrelevant to the interesting problem of falling into a black hole as considered by the authors. It is hard to agree with this criticism.

One more remark. The authors of [1] stress (p. 282) that because the singularity is in the future with respect to the event horizon, it is impossible to see the black hole singularity before the moment of catastrophic death. But in [4, p. 9, 10], writing that by moving in time under the event horizon the astronaut would see the singularity, I did not specify the exact moment when this occurs. Clearly, the astronaut will see the singularity at the moment of his death, and hence the singularity is not shown in Fig. 2 in my book [4] giving the conventional picture of what the astronaut falling under the

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event horizon will see. It is important that in contrast to an external observer (outside the horizon), the astronaut can in principle reach the singularity. Here I agree with the opinion of the authors of [1] that in the popular science literature, one should rigorously use the terminology. Apparently, instead of the verb 'to see' I should have used the verb 'to reach.'

Generally, I consider Grib and Pavlov's note [1] as a methodologically useful, elucidating some of the peculiarities of such extreme objects as black holes.

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