Comment on "Straight lightning as a signature of macroscopic dark matter"

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(Received 21 May 2021; accepted 9 March 2022; published 11 April 2022)

In the discussed paper [N. Starkman, H. Winch, J. S. Sidhu, and G. Starkman, Straight lightning as a signature of macroscopic dark matter, Phys. Rev. D **103**, 063024 (2021)], the authors have made several assumptions and statements concerning the initiation and propagation of lightning flashes induced by macroscopic dark matter passing through the atmosphere. The authors suggest that the path of dark matter can be identified by looking for lightning with straight channels, although such channels have not been previously reported. Even though we agree with the suggestion of the authors that macroscopic dark matter could, in theory, give rise to straight lightning channels, there are several statements in the paper that are not sufficiently clear and which could lead to misinterpretation. Our comments on the paper are the following.

DOI: 10.1103/PhysRevD.105.088301

1. In the discussed paper [1], the authors assumed that, once a plasma channel resulting from macroscopic dark matter is created at an appropriate location, a lightning leader may be "locked in" to the plasma channel and propagate downward along it to the ground. The authors have not provided a clear explanation as to the physical interpretation of the locked-in mechanism, even though they assumed that there is a discharge channel connecting the macro channel and the charge center in the cloud (Sec. III D of the discussed paper [1]). Here, we will provide physical scenarios describing how this connection can take place. Let us consider two cases.

a. *The speed of the macro is faster than the speed of propagation of electrical discharges in virgin air.*—As the macro passes through the cloud, there is a chance that the macro channel could intercept an already existing electrical discharge inside the cloud, but this event is highly improbable. A more probable scenario would be the following. Since the macro channel is highly conducting, it will be polarized when exposed to an electric field [2,3]. As the macro channel passes through the cloud and when it is in the vicinity of a charge center, the channel will be polarized and charge of opposite polarity to that of the charge center will be induced on the region of the macro channel which is in the vicinity of the charge center. If the background electric field is large enough, the induced charge could, in turn, be high enough to generate an electrical discharge in the form of a streamer-initiated leader [4,5] traveling from the macro channel into the charge center. In this case, the macro channel will be physically connected to the charge center. This connection could further enhance electrical breakdowns inside the charge center. Different forms of electrical discharges that drive other lightning processes, such as dart leaders, continuing currents, and M components, along such leaders could also take place when the macro channel is connected to the charge center, and all these discharges could generate ionization waves along the macro channel feeding the charge accumulated on it. However, since the macro channel is moving faster than the electrical discharges propagating in virgin air (such as stepped leaders), this charging process will not be able to generate electrical discharges that propagate outward from the tip of the macro channel, keeping the channel straight and without branches. The electrical activity taking place along the macro channel would keep its conductivity high and prevent the channel from decaying prematurely. Of course, the situation would be somewhat similar to that described above even if the macro channel intercepted an already existing electrical activity inside the cloud.

As the macro channel propagates through the cloud, electrical breakdown could first take place to the main upper positive charge center, and, as the macro channel continues its downward journey, it could give rise to an electrical discharge also toward the midlevel negative charge center. In this case, the two main charge centers will be connected through the macro channel, which could trigger a cloud discharge, namely, electrical discharges propagating between the two charge centers assisted by the macro channel. However, since the macro still continues to propagate downward, electrical discharges from either the

positive charge center or the negative charge center or from both could feed the macro channel depositing charge along it. The polarity of the charge on the macro channel when it reaches the ground will be determined by the amount of charge in the charge centers and the intensity of the electrical activity taking place inside individual charge centers.

b. *The speed of the macro is slower than the speed of propagation of electrical discharges in virgin air.*—For example, electrical discharges in virgin air first take place in the form of streamer discharges. The speed of these streamers could be in the range of 10^6 m/s [6], and, if the speed of the macroscopic dark matter particle is lower than that of the streamers, then these streamers will move ahead of the plasma channel generating leader-type discharges from the tip of the macro channel. As the macro passes close to the charge centers of the cloud, such electrical discharges could propagate outward in the form of stepped leaders from the tip of the macro channel toward charge centers when a sufficient amount of charge is accumulated at the tip due to the polarization of the macro channel in the electric field created by the charge centers. Such discharges could create a connection between the macro channel and the charge centers in the cloud. Since the macro is propagating slower than these electrical discharges, the latter propagate ahead of the tip of the macro channel. However, the path of these electrical discharges will be determined by the background electric field and may not coincide with the subsequent path of the macro channel. Thus, some parts of the discharge channel could remain straight while the rest become tortuous. Possibly, it could lead to a straight channel with tortuous branches. Since the stepped leader is moving faster than the macro, the former will reach the ground first.

Interestingly, the propagation of a discharge ahead of the tip of a macro channel is similar to that taking place during rocket-and-wire triggered lightning flashes in which, as the wire extends upward from the ground, charges accumulate along the wire due to the background electric field [7]. When the charge at the tip of the wire becomes sufficiently large, an upward stepped leader will initiate due to ionization processes taking place at and near the tip. The breaking out of a leaderlike discharge from the tip of the downward-moving macro channel could take place exactly in the same manner.

2. The authors claim that there would not be sufficient time for the upward connecting leaders to be initiated from ground toward the downcoming plasma channel. However, experimental data [8] suggest the existence of upward connecting leaders with dart leaders traveling toward the ground at speeds exceeding 10^6–10^7 m/s. This clearly shows that discharge channels moving toward the ground even with rather high speeds can initiate upward connecting leaders. This indicates that the charged plasma channel moving downward with a speed of 2.5×10^5 m/s as considered in the paper [1] will provide ample time for the generation of an upward connecting leader. It is worth noting that a recent study shows that a macro channel could be polarized even in the fair-weather electric field and give rise to lightning-like discharges but with less intense electrical activity [9].

The authors express their gratitude to the anonymous reviewer, who helped us to considerably improve the manuscript.

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