Stimulated axion decay in superradiant clouds around primordial black holes

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Rotating black holes suffer from the well-known superradiant instability when spinning too fast, and release their excess rotational energy by producing particles in their vicinity.

In this work, we have shown that primordial black holes, born from the gravitational collapse of very overdense regions in the early Universe, can produce dense clouds of axions around them through the superradiant instability. Although these primordial black holes are born with small spin, black hole mergers can lead to highly spinning black holes that suffer from such instabilities. Axions are hypothetical particles predicted in the Peccei-Quinn theory to explain the puzzling smallness of the neutron's electric dipole moment. As a bonus, they are ideal candidates to account for the mysterious dark matter in the Universe. The axion clouds produced around spinning primordial black holes can be so dense that the stimulated decay of the axions into photons can generate a laser-like effect, producing some of the brightest electromagnetic blasts in the cosmos.

For the preferred value of the (yet unknown) axion mass, for which they can account for all of the dark matter in the Universe, such explosions occur at radiofrequencies around 1 GHz, triggered by the superradiant instability of small primordial black holes with around the Earth's mass.

These intense lasers last only for a few milliseconds, since the strong electric field produced within the axion cloud quickly shuts down the process. But in this short period the axion-black hole clouds can shine brighter than a thousand million suns. All these properties are, in fact, in tantalizing agreement with those of the several "fast radio bursts" that have been observed in the past decade.

Our scenario thus offers a common explanation to both dark matter and fast radio bursts, based on new elementary particles that could be detected in the laboratory within the next few years. Dark matter may not be so "dark" after all.