Physicist solves century old problem of radiation reaction

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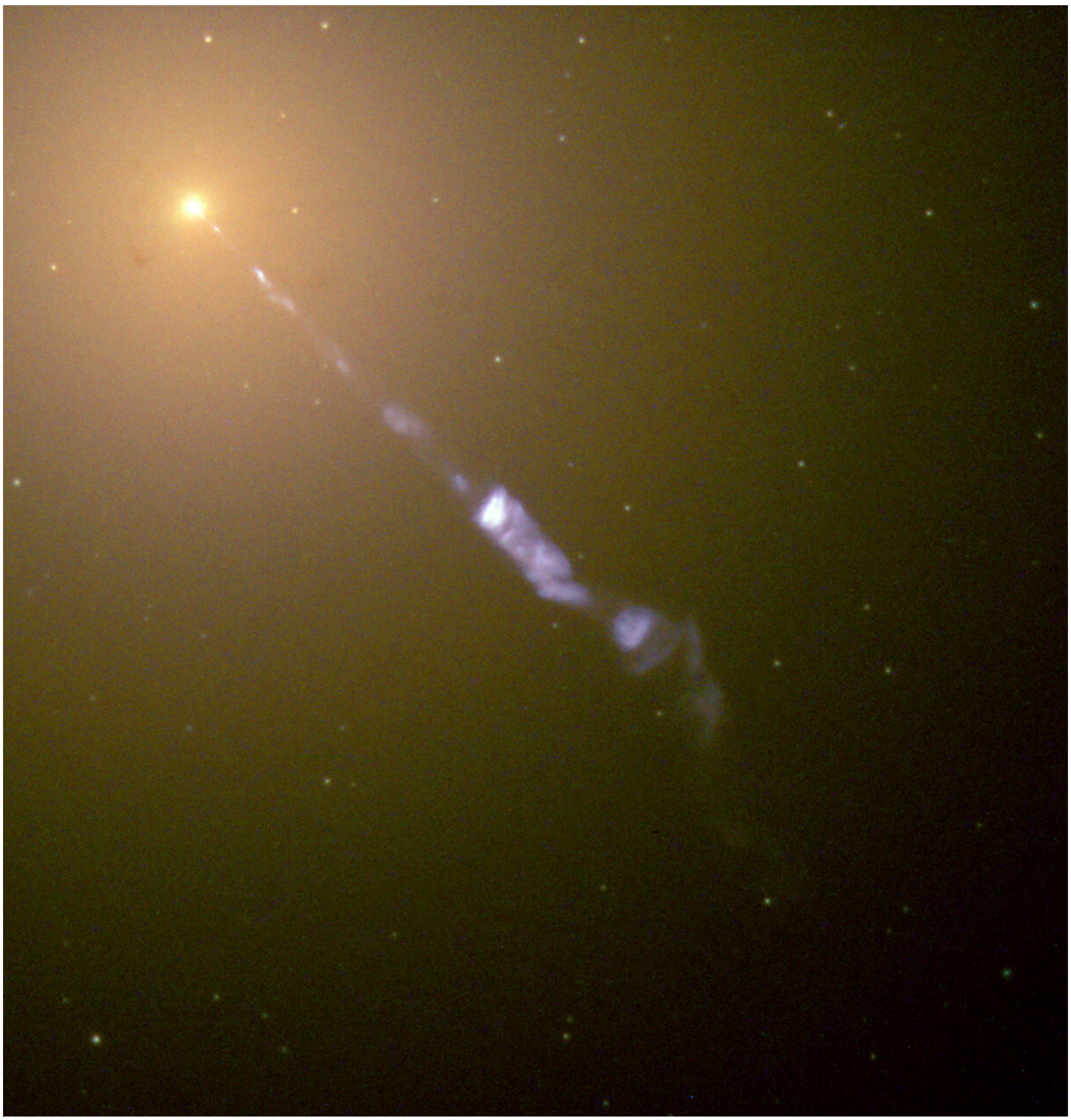

Black Hole-Powered Jet of Electrons and Sub-Atomic Particles Streaming From Centre of Galaxy M87; the blue light is Synchrotron radiation which should produce radiation reaction. Credit: NASA and The Hubble Heritage Team (STScI/AURA)

A Lancaster physicist has proposed a radical solution to the question of how a charged particle, such as an electron, responded to its own electromagnetic field.

This question has challenged physicists for over 100 years but mathematical physicist Dr. Jonathan Gratus has suggested an alternative approach—published in the *Journal of Physics A: Mathematical and Theoretical* with controversial implications.

It is well established that if a point charge accelerates it produces electromagnetic radiation. This radiation has both energy and momentum, which must come from somewhere. It is usually assumed that they come from the energy and momentum of the charged particle, damping the motion.

The history of attempts to calculate this radiation reaction (also known as radiation damping) date back to Lorentz in 1892. Major contributions were then made by many well known physicists including Plank, Abraham, von Laue, Born, Schott, Pauli, Dirac and Landau. Active research continues to this day with many articles published every year.

The challenge is that according to Maxwell's equations, the electric field at the actual point where the point particle is, is infinite. Hence the force on that point particle should also be infinite.

Various methods have been used to renormalise away this infinity. This leads to the well established Lorentz-Abraham-Dirac equation.

Unfortunately, this equation has well known pathological solutions. For example, a particle obeying this equation may accelerate forever with no external force or accelerate before any force is applied. There is also the quantum version of radiation damping. Ironically, this is one of the few phenomena where the quantum version occurs at lower energies than the classical one.

Physicists are actively searching for this effect. This requires `colliding' very high energy electrons and powerful laser beams, a challenge as the biggest particle accelerators are not situated near the most powerful lasers. However, firing lasers into plasmas will produce high energy electron, which can then interact with the laser beam. This only requires a powerful laser. Current results show that quantum radiation reaction does exist.

The alternative approach is to consider many charged particles, where each particle responds to the fields of all the other charged particles, but not itself. This approach was hitherto dismissed, since it was assumed that this would not conserve energy and momentum.

However, Dr. Gratus shows that this assumption is false, with the energy and momentum of one particle's radiation coming from the external fields used to accelerate it.

He says that "the controversial implications of this result is that there need not be classical radiation reaction at all. We may therefore consider the discovery of quantum radiation reaction as similar to the discovery of Pluto, which was found following predictions based on discrepancies in the motion of Neptune. Corrected calculations showed there were no discrepancies. Similarly radiation reaction was predicted, found and then shown not to be needed."

More information: Jonathan Gratus, Maxwell–Lorentz without self-interactions: conservation of energy and momentum, *Journal of Physics A: Mathematical and Theoretical* (2022). DOI: 10.1088/1751-8121/ac48ee

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