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Giant elves: Lightning-generated electromagnetic pulses in giant planets.

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We currently have direct optical observations of atmospheric electricity in the two giant gaseous planets of our Solar System [1-5] as well as radio signatures that are possibly generated by lightning from the two icy planets Uranus and Neptune [6,7].

On Earth, the electrical activity of the troposphere is associated with secondary electrical phenomena called Transient Luminous Events (TLEs) that occur in the mesosphere and lower ionosphere. This led some researchers to ask if similar processes may also exist in other planets, focusing first on the quasi-static coupling mechanism [8], which on Earth is responsible for halos and sprites and then including also the induction field, which is negligible in our planet but dominant in Saturn [9].

However, one can show that, according to the best available estimation for lightning parameters, in giant planets such as Saturn and Jupiter the effect of the electromagnetic pulse (EMP) dominates the effect that a lightning discharge has on the lower ionosphere above it.

Using a Finite-Differences, Time-Domain (FDTD) solver for the EMP we found [10] that electrically active storms may create a localized but long-lasting layer of enhanced ionization of up to 10^3 cm^{-3} free electrons below the ionosphere, thus extending the ionosphere downward. We also estimate that the electromagnetic pulse transports 10^7 J to 10^{10} J toward the ionosphere. There emissions of light of up to 10^8 J would create a transient luminous event analogous to a terrestrial elve. Although these emissions are about 10 times fainter than the emissions coming from the lightning itself, it may be possible to target them for detection by filtering the appropiate wavelengths.

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