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Modeling the top-side ionospheric electric field variations induced by a cosmic Gamma-ray-burst

Massimo Materassi*(1), Mirko Piersanti(2), Giulia D'Angelo(2), Emanuele Papini(3)
(1) Istituto dei Sistemi Complessi del Consiglio Nazionale delle Ricerche ISC-CNR, Firenze (Italy), e-mail: massimo.materassi@cnr.it
(2) Department of Physical and Chemical Sciences, University of L'Aquila, 67100 L'Aquila (Italy), e-mail: mirko.piersanti@univaq.it; giulia.dangelo@inaf.it.
(3) INAF-Istituto di Astrofisica e Planetologia Spaziali, Rome (Italy); e-mail: emanuele.papini@inaf.it

The Earth's atmosphere, the ionization stability of which plays a fundamental role for the evolution and endurance of life, is exposed to the effect of cosmic explosions producing high energy Gamma-ray-bursts (GRBs). During cosmic GRBs (and solar flares too), the intense high energy photon flux can abnormally ionize the lower ionosphere by producing a large increase of free electron density. As a consequence, the electron density grows giving rise to a variation of the ionospheric conductivity. In doing so, a GRB might deplete stratospheric ozone on a global scale, hence causing potentially serious threats to the biosphere.

During the last decades, an average of more than one GRB per day were recorded. Nevertheless, measurable effects on the ionosphere were rarely observed, in any case, on its bottom-side (from about 60 km up to about 350 km of altitude). Last year, [1] reported evidence of an intense top-side ionospheric perturbation (at about 500 km), induced by a significant sudden ionospheric disturbance directly correlated with the October 9, 2022 Gamma-ray-burst (GRB221009A). The authors of [1] explained the direct causality between the GRB and the strong perturbation observed in the top-side ionospheric electric field, developing a first simple phenomenological model which is able to correctly reproduce the long time scale dynamics of the ionospheric electric field.

The mathematical model in [1] is rather preliminary, neglecting not only possible transport terms in the ionization equation and in the related electric field equation, but also assuming time-independent electron-chemical collision frequency and recombination rate. Here we present a new model for the top-side ionospheric electric field variation, as induced by a GRB, using a more realistic approach for the evaluation of the ionospheric conductivity, in which the sudden arrival of high energy photons leads to an explicit time dependence both in electron collisions and recombination.

An attempt to take into account the transport terms and 3-dimensional nature of the phenomenon is also done.

Reference

1. Piersanti, M., Ubertini, P., Battiston, R. et al. "Evidence of an upper ionospheric electric field perturbation correlated with a gamma ray burst." *Nature Communications* **14**, 7013 (2023). https://doi.org/10.1038/s41467-023-42551-5.