Project title: Rapid Solar Variability and the Effect on Earth's Ionosphere

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Helpful existing knowledge:	Some fundamental astrophysics knowledge, preferably solar physics. Coding skills in python, IDL, or Matlab

Project Description:

BACKGROUND: During a solar flare, the Sun suddenly releases bursts of radiation that disturb the Earth's ionosphere. These disturbances change the behaviour of charged particles in ionospheric layers, causing absorption or distortion of radio signals used by the communication and navigation systems that modern society relies on every day. This interdisciplinary research aims to find out which types of solar flares affect the ionosphere the most, how the ionosphere reacts and recovers, and ultimately how we can better predict these space weather effects.

The influence of solar flares on the Earth's upper atmosphere has been studied for decades using both theoretical and experimental approaches. However, many key questions remain unresolved regarding how different flare characteristics shape the magnitude and structure of the ionospheric response, and current forecasting capability remains limited. Traditionally, simulations of ionospheric disturbances have used synthetic flare spectra generated by the Flare Irradiance Spectral Model (FISM). Recent studies, however, have demonstrated that FISM systematically underestimates the fluxes of several geoeffective emissions at various flare phases. As a result, the predicted enhancements in ionospheric ionisation fail to reproduce experimentally observed behaviour. Furthermore, the geoeffectiveness of individual solar spectral lines has so far been assessed only from a theoretical standpoint. Consequently, the relative contributions of different spectral emissions to ionisation in the various ionospheric layers are not clear yet.

PROJECT DESCRIPTION: The three main objectives of the research project are:

- To determine which characteristics of solar flares (such as magnitude, location on the solar disk/centre-to-limb-variability, impulsivity, etc.) ultimately define the form and dynamics of the resulting geoeffective spectral emission.
- To construct an empirical model of the ionospheric total electron content response to solar flares with a given spectral profile.
- To experimentally determine the absorption altitudes for different geoeffective spectral ranges using synchronised solar irradiance data and GNSS measurements along partially illuminated paths.

This project aims to address these gaps by combining advanced methods with multi-year spectral observations from state-of-the-art solar observatories alongside global measurements from the Global Navigation Satellite System. This integrated approach

will enable the first empirical characterisation of the true flare spectrum and the physical processes governing its most influential emissions. The project will also improve understanding of
charged-particle redistribution across ionospheric layers in response to flares and, ultimately, will deliver a robust, empirically calibrated tool capable of predicting ionospheric responses to flares with arbitrary spectral profiles.

Useful references:

Bekker, S. Z., Milligan, R. O., and Ryakhovsky, I. A., “Response of Ionospheric Total Electron Content to the Impulsive and Late Phases of X Class Solar Flares With Various Center to Limb Locations”, Journal of Geophysical Research (Space Physics), vol. 130, no. 10, Art. no. e2025JA034281, Wiley, 2025. doi:10.1029/2025JA034281.

O'Hare, A. N., Bekker, S., Greatorex, H. J., and Milligan, R. O., “Investigating a Characteristic Time Lag in the Ionospheric F-Region's Response to Solar Flares”, Atmosphere, vol. 16, no. 8, Art. no. 937, 2025. doi:10.3390/atmos16080937.

O'Hare, A. N., Bekker, S., Hayes, L. A., and Milligan, R. O., “Quasi-Periodic Pulsations in Ionospheric TEC Synchronized With Solar Flare EUV Emission”, Journal of Geophysical Research (Space Physics), vol. 130, no. 4, Art. no. e2024JA033493, Wiley, 2025. doi:10.1029/2024JA033493.

Bekker, S., Milligan, R. O., and Ryakhovsky, I. A., “The Influence of Different Phases of a Solar Flare on Changes in the Total Electron Content in the Earth's Ionosphere”, The Astrophysical Journal, vol. 971, no. 2, Art. no. 188, IOP, 2024. doi:10.3847/1538-4357/ad631d.