An Analysis on the Possibility of Establishing a Critical Threshold Energy Level for the Solar Flares Regarding the Interactions of the Emitted Hard X-Ray Beams and the Ionosphere

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Abstract

This paper presents an analysis of the interactions of the hard x-rays emitted through the high-energy solar flares, often seen in the X and Y class, within the ionosphere which is located in the thermosphere. Hence, the paper concentrates on whether it's possible to specify a critical threshold energy level for the hard x-ray emissions from a solar flare that cause the x-ray beam to reach the Earth's crust and its inhabitants, assuming that the intensity of the hard x-ray beam is kept as a constant. This should serve as a critical point in determining the harmful effects of the solar flares in the atmosphere and furthermore on Earth as a whole. The methodology that has been followed is the application of a well-known scientific effect to the problem, the photoelectric effect, and the evaluation of the implications of its conclusions. It is then seen that as the intensity of the X-ray beam is kept as a constant, the energy of the incoming x-ray beam does not affect the process of atmospheric absorption, since energy is quantized by the photons and that the decreasing wavelength does not contribute to the number of electrons liberated in the ionospheric D region.

Keywords

Solar flare - Ionosphere - X rays - Solar activity - Emission - Absorption - Energy - Photoelectric effect

Introduction

This research paper is focused on the examination of the mutual correlation between the hard x-rays emitted through the X and Y class high energy solar flares with the ionosphere that is an integral part of the thermosphere. The question we as a team specified our research into is “Can there be a critical energy threshold for the hard X-rays emitted through the solar flares in which the Earth’s atmosphere cannot process it and if so, what would it be?” Our hypothesis was that the threshold could be found through the calculation and understanding of the Photoelectric effect that is naturally occurring by the interactions between the hard X-rays and the competence of the Earth’s atmosphere and surface.

For reference data, we researched the November 4, 2003 Giant Solar flare, it was the most major one currently recorded by scientists. In essence, solar flares are incidents that have immense effects on both the natural specimens of our planet and the infrastructure of telecommunication technology. After thoroughly examining the example of the November 4, 2003 Giant Solar flare, we started to research a joint threshold that can define the amount of radiation the Earth’s atmosphere could absorb. Solar flares emit many kinds of waves ranging from Gamma to X-Rays; however, for the ease of comprehension and drawing the limits of our paper, we narrowed our research down to the examination of the amount of X-Rays solar flares emit only. [2]

To better understand how X-rays interact with the structure of the Earth’s atmosphere, we firstly gathered information on the Earth’s atmospheric layers, namely the thermosphere and its integral part the ionosphere. These two layers’ main function is to absorb any rays that enter the atmosphere with their abundance of Oxygen and Nitrogen gasses in their compositions. Essentially, the thermosphere is the layer of the atmosphere which lies just above the mesosphere. Within this layer of the atmosphere, UV light induces photoionization of molecules, resulting in the formation of ions. The formation of the ions further translates into the subsequent formation of the ionosphere. The ionosphere is a dense layer of electrons and ionized atoms and molecules that extends from 48 kilometers above the surface to 965 kilometers, intersecting with the previously mentioned layers mesosphere and thermosphere. This mobile zone expands and contracts in response to solar circumstances, and it is subdivided into three regions: D, E, and F, depending on the wavelength of solar light absorbed. Throughout the paper, the reader will come across the D region the most, mainly because this is the region where hard X-Ray beams interact with the atmospheric composition and are absorbed. Since the ionosphere is composed of charged particles, it is extremely sensitive to changes in magnetic and electric conditions in space. These circumstances, along with other phenomena like bursts of charged particles, are referred to as space weather and are frequently associated with solar activity. The ionosphere is an essential connection in the Sun-Earth interaction chain, since through the ionosphere radio communications can be possible. [9]

The paper consists of two sections: Limitations of the Photoelectric Absorption and The Effect of Quantized Energy on the Amount of Emitted Electrons.

Discussion

Limitations of the Photoelectric Absorption

The photoelectric effect is the starting point of quantum mechanics in its modern form, and the idea of quantized energy. Hence, understanding the limitations of the photoelectric effect and the absorption of a photon by a material is crucial in evaluating the interactions between the x-rays and the molecules in the D region of the ionosphere. X-rays, and their carriers, photons are by no means affected by the magnetosphere of the Earth, since they are not electrically charged. Thus, the only significant interaction between the incoming X-rays and the atmosphere occurs in the D region of the ionosphere which is located at the thermosphere of the atmosphere. The incoming X-rays often collide with the atoms, and their electrons, located in the D region which is highly famous with the high density of electrons it includes. Hence, as the X-rays collide with N_2 and O_2 atoms, the energy coming from the X-rays are absorbed by the atom, and as a result, an electron is set free with a specific amount of kinetic energy. This is known as the photoelectric effect, and hence is important in evaluating the hypothesis since the increasing energy of the incoming photons does not specifically cause an increase in the emission of the electrons of a molecule after a certain frequency threshold. However, it should be noted that the intensity of the incoming X-rays are to be taken into account as a constant, since the increase in the intensity of the X-rays is linearly correlated with the amount of electrons emitted. [8]

The Effect of Quantized Energy on the Amount of Emitted Electrons

The calculation of the energy of an emitted electron via the photoelectric effect is made by the equation:

$$K = hf - \Phi$$

In which "K" is the maximum kinetic energy that the electron can possess after being set free from the atom of the material, "h" is the Planck constant, "f" is the frequency of the incoming radiation, and "Φ" is the work function, which denotes the required energy needed to tear off an electron from the specified atom. Work function is a function of the material, and is higher in nonmetals compared to metals. Recalling the approved postulations of the photoelectric effect, one can easily see that the quantized energy carried by single photons can be only used in the tearing off of one electron, and that after a threshold frequency, which is also a function of the specified material, the value of the frequency, and thus, the wavelength of the specified radiation does not matter regarding the amount of electrons emitted from a set of material. The excess energy after subtracting the work function from the incoming photon energy only affects the kinetic energy of the emitted electrons, and hence does not have any significant effect on the amount of liberated electrons.

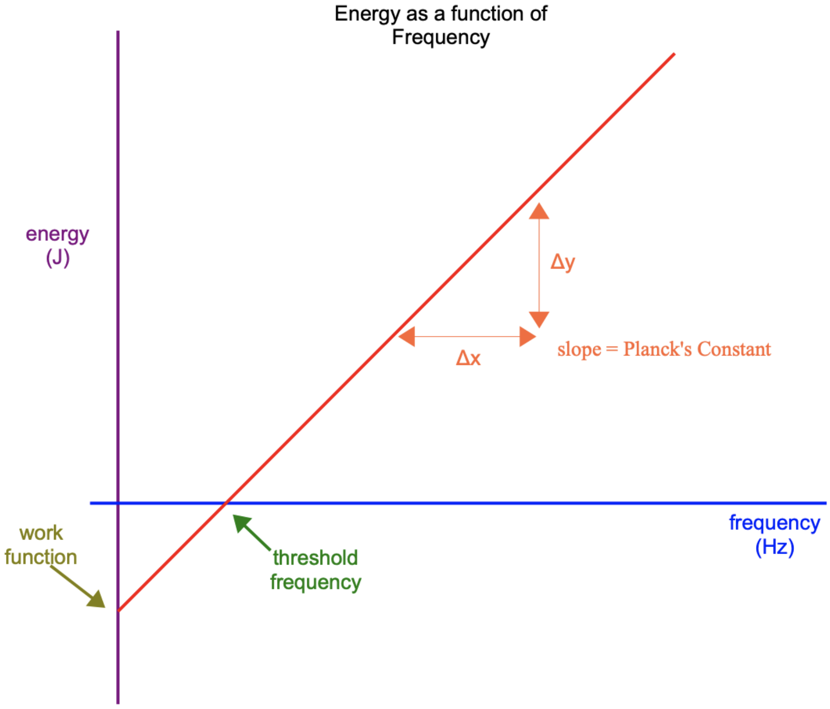

Figure 1, From [1], Energy as a function of Frequency

This is indeed crucial in our understanding of the hypothesis and the x-ray interactions with the ionosphere. In the hypothesis we established, we consider the energy of an incoming beam, and we are trying to determine whether it is possible for the incoming x-rays to reach the Earth's crust and its inhabitants after a critical threshold energy level. However, our hypothesis does not specifically account for the intensity of the incoming beam, since it is also a major observational problem that is yet to be resolved by the scientific community. The minor interactions of the X-ray beams with the outermost parts of the atmosphere cause the diffraction and scattering of beams before entering the ionosphere, and therefore prevents us from setting a specific conclusion regarding a critical threshold energy value for a solar flare that could be then seen as a danger threshold for the life on Earth . Briefly, the intensity of the incoming X-ray beams cannot be specified and vary significantly from their predicted source values. At this point, it is needless to say that the hard x-rays that this research concentrates on have wavelengths high above the threshold frequency needed to enable photoelectric effect on the N and O molecules of the atmosphere.

Conclusion

The research we have conducted over the course of the last two months allowed us to examine the interaction between the X-rays emitted through the solar flare activities and respected layers of the atmosphere of the Earth, namely the thermosphere and the ionosphere, especially the ionospheric D region. In the end we have reached the conclusion that it is highly unlikely to determine a critical threshold energy for the solar flares that enable the hard X-ray beams emitted from them to reach to the Earth's crust, due to the complex diffraction and scattering patterns of the X-ray beams and the fact that as the intensity of the beam is kept as constant, the amount of energy a beam possesses do not affect the amount of electrons ionized. Hence, it should be noted that further specifications and enhancements could be made by rigorous mathematical analyses.

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