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P6_11 Shields Up! The Physics of Star Wars

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Abstract

This paper seeks to establish the feasibility of creating a plasma-based shield to deflect laser-based weapons as seen in the *Star Wars* universe. We find that a field strength of $< 5T$ is sufficient to deflect the visible lasers seen in the *Star Wars* films and television shows. Therefore it is possible to create magnetic fields strong enough to replicate these effects using current terrestrial technology. This also has the consequence that visible light could not be used to observe outside of the shield with, and thus the pilots would need to use an Ultra-Violet camera instead.

Introduction

In the *Star Wars* universe, recently in the news because of the upcoming release of *Star Wars Episode VII.* [1], the starships have a shield defence system that is capable of deflecting laser-based weapons. In this paper we will explore the feasibility of such a shield, assuming that they are produced by containing a plasma in a magnetic field. We will calculate the plasma frequency required to protect the spacecraft and hence the strength of a field required to contain such a plasma.

Calculations

In order to deflect an electromagnetic wave of a given frequency, the plasma frequency, ω_{pe}, must be equal or greater than the frequency of this incident beam. This is given by

$$\omega_{pe} = \sqrt{\frac{n_e e^2}{m_e \epsilon_0}}, \tag{1}$$

where n_e is the number density of the electrons, (we assume the ion motion and density is insignificant when compared to the electron motion due to the much larger mass of protons), e is the elementary charge, m_e is the mass of an electron and ϵ_0 is the electric constant. The plasma will exert a pressure, P_p, which is given by ideal gas law

$$P_P = nk_BT = 2n_ek_BT, \tag{2}$$

where k_B is the Boltzmann constant and T is the temperature (in Kelvin). We assume here the total number density n is the sum of the ion and electron number densities, $n_e + n_i = 2n_e$ given $n_e = n_i$ as the plasma is quasi-neutral. From the equation of motion for a non-moving plasma [2], we know that the magnetic field exerts a pressure, P_B, which is given by

$$P_B = \frac{B^2}{2\mu_0}, \tag{3}$$

where B is the magnetic field strength and μ_0 is the magnetic constant. In order for the magnetic field to contain the plasma around the ship, $P_P = P_B$. In this paper we will assume the ship is in an area of space with negligible external plasma and magnetic fields. By equating Eq. (2) and Eq. (3) we are able to calculate the magnetic field strength required;

$$B = \sqrt{4\mu_0 k_B T \frac{\omega_{pe}^2 m_e \epsilon_0}{e^2}}. \tag{4}$$

Terrestrial plasmas can exist at a T as low as $1000K$ [3], we then use this temperature to calculate the magnetic field required to deflect incident radiation at a range of frequencies. This is summarized in Fig. 1.

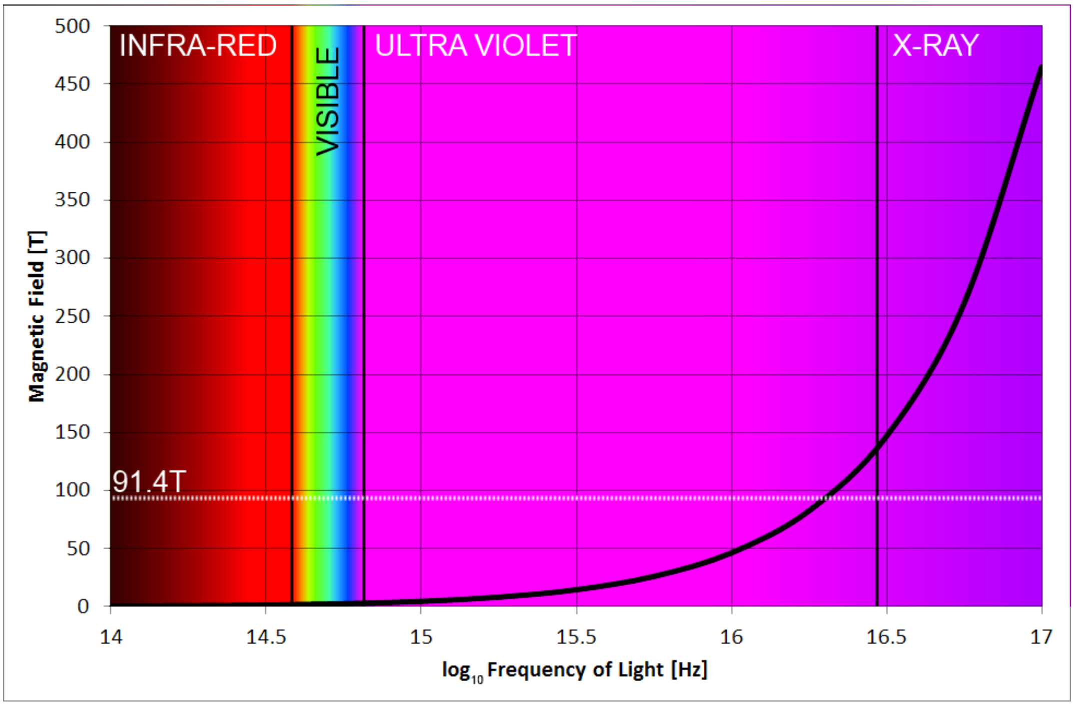

Fig. 1: Magnetic field required to deflect incident radiation as a function of frequency.

Conclusion

The largest field strength produced terrestrially is 91.4T [4] and it is therefore assumed that any race suitably technologically advanced to explore space in such a manner would also be capable of producing this field strength in space. This field strength corresponds to a plasma capable of reflecting light well into the Ultra-Violet.

Therefore we can conclude that it is possible to use a plasma-based shield against laser-based weaponry. A field strength of $< 5T$ would be required to deflect the visible lasers seen in the *Star Wars* films and television shows. Fields of this strength have been shown to have no adverse effects on mammalian subjects, even with prolonged exposure [5]. The properties of this plasma-based shield also works to the detriment of the pilots, as they will be prevented from using the same frequencies they are deflecting to observe with. In the *Star Wars* universe, where the visible lasers seen are red and green, the pilots would then only be able to observe outside of the shield using an Ultra-Violet camera, otherwise their view would be dominated by blue light.

References

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