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P3_1 Black Hole Formation within Starkiller Base

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Abstract

In the film "Star Wars: The Force Awakens", Starkiller Base pulls an entire star into its fuel chamber to power a laser weapon system. By estimating the dimensions of the fuel chamber, we find that the maximum mass a fuelling star can have before it collapses into a black hole is approximately 7.5 $M_{\odot}$, however, the additional gravitational force produced would make the planet uninhabitable.

Introduction

In the "Star Wars" films, Starkiller Base is a dwarf planet converted to a mobile weapons platform by the First Order which siphons entire stars into a fuel chamber located in the core of the planet. These stars are used to power a laser weapon which is capable of destroying solar systems, similar to the Death Star from previous films.

The planet, however, only has a radius of 330 km [1], with the fuel chamber radius only about 1/15th of this size, as shown in Figure 1 [2]. The addition of stellar masses of fuel to the core of the planet would substantially increase the gravitational force felt at the surface. Equally, if the mass was great enough, the Schwarzschild radius could be approached, potentially forming a black hole within the core of the planet.

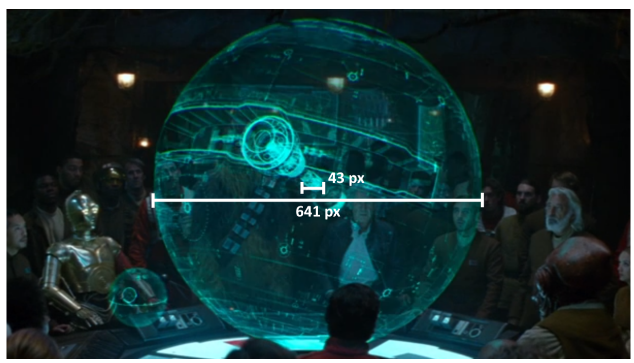

Figure 1: Screenshot from "Star Wars Episode VII: The Force Awakens" showing the size of the fuel chamber in comparison to the rest of the planet.

Theory

The Schwarzschild radius, r_s, is the minimum radius a body of mass M can have before collapsing into a black hole, and is given by

$$r_s = \frac{2GM}{c^2}, \tag{1}$$

where the constants c and G represent the speed of light in a vacuum and the gravitational constant respectively [3]. If we assume the laws of physics in the Star Wars universe are the same as in our own, we can take c to be 2.998×10^8 ms^{-1} and G as 6.674×10^{-11} Nm^2kg^{-2} . This equation can be rearranged to give an expression for the maximum mass, $M_{\max}$, a body of radius r can have without collapsing into a black hole:

$$M_{\max} = \frac{rc^2}{2G}. \tag{2}$$

So, if a star must be contained within a fuel chamber with a radius 1/15th that of Starkiller Base (330 km), by substituting a Schwarzchild radius of 22 km into Eq. (2), we can determine the maximum mass of a star which could be contained within such a chamber. Taking c and G to be the same as in our universe, we estimate $M_{\max}$ to be approximately 1.5×10^{31} kg or 7.5 solar masses ($M_{\odot}$).

However, even if the star did not collapse into a black hole, the additional mass within the core would significantly increase the gravitational force present on the planet. The acceleration due to gravity on the surface of a planet is given by

$$g = \frac{GM_p}{r^2}, \tag{3}$$

where M_p is the mass of the planet, g is the acceleration due to gravity and r is the distance from the centre of the planet.

Starkiller base has a radius of only 330 km, lower than that of many moons. It can be therefore assumed that the planet's mass is negligible when compared to solar masses, thus we take the value of M_p to be equal to the mass of the star captured in the fuel chamber.

Using Eq. (3), we find that if Starkiller Base contained a 7.5 $M_{\odot}$ star and had a radius of 330 km, this would give a value for g of 9.2×10^9 ms^{-2}.

Discussion

The maximum mass of a star that could be used as a fuel is 7.5 $M_{\odot}$. A star with this mass would be considered a hot B-type star [4] (assuming it is on the main sequence), which have masses ranging from 2.5 $M_{\odot}$ to 12 $M_{\odot}$. Therefore, all stars apart from all O-type and some B-type stars could be successfully contained. These star types make up less than 0.2% [5] of all main sequence stars in our own galaxy. If we assume the Star Wars universe follows a star distribution similar to that of our universe, the overwhelming majority of stars present in the universe would be suitable for use as fuel in Starkiller Base.

The increased gravitational force that would be felt as a result of containing the star would pose more significant problems. On Earth, g is equal to 9.8 ms^{-2}. A person standing on Starkiller Base would feel a force roughly a billion times greater than this if a 7.5 $M_{\odot}$ star is contained within the planet. This would likely be enough to cause the planet to implode. Even if the planet maintained structural integrity, the incredible force would cause a person to be crushed under their own weight, making the planet unsuitable for a base of human operations. The planet is many orders of magnitude lower in mass than even the smallest stars, thus without some form of protection from this extreme gravitational field the planet would be of little use to humans.

Conclusion

Starkiller base could contain any star with a mass below 7.5 $M_{\odot}$ without creating a deadly black hole in the core of the planet. However, the increase in planetary mass caused by this fuel would greatly increase the gravitational force at the surface of the planet to levels that would be unsuitable for humans, and the planet would likely be destroyed without some form of structural support.

References

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