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P2_2 Black Holes in Magic: The Gathering

D. J. Mott, C. Murgatroyd, J. P. Stinton, C. J. Kinsman

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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Abstract

In this paper, we investigate one possible method by which a character in the card game "Magic: The Gathering" could summon a creature, by rotating a pre-existing stellar black hole to form a ring singularity with radius 1 m. Such a singularity could hypothetically act in a similar way to a traversable wormhole [1]. We find that spinning up a $5M_\odot$ black hole would require an energy of 2.025×10^{39} J, and assuming a single turn in the game corresponds to a day in real life, we place the lower bound on the size of a "Land" card at 4.25×10^{27} acres.

The Game

In the trading card game, Magic: The Gathering, players compete to defeat their opponents by summoning powerful creatures and casting spells. In order to do these things, the players must play "Land" cards, which generate a magical energy called "Mana". Each basic Land card can generate one Mana per turn, and with few exceptions, summoning a creature requires at least one Mana [2].

Premise

We consider that the mechanism by which the game's creatures are transported onto the battlefield is similar to using a wormhole. In particular, a Kerr black hole (rotating, uncharged) would have a ring singularity [3] which could hypothetically act in a way similar to a traversable wormhole [1]. We presume that the characters in the game already have access to a static, uncharged black hole of mass $5M_\odot$ ($M_\odot$ being the solar mass, 1.988×10^{30} kg [4]), and that they are capable of inducing a rotation in the black hole given enough energy. For the purposes of this paper, we consider it sufficient that the ring singularity have a radius of $a = 1$ m, so the creature traversing the "wormhole" can pass through the ring without contacting the singularity[1].

Spinning up a Black Hole

For a ring singularity with radius a, the angular momentum, J, is given by [5]:

$$J = aMc \tag{1}$$

where M is the total mass of the black hole, including its rotational energy. The energy needed to spin a black hole can be found using Einstein's mass-energy equivalence, $E = mc^2$, substituting m for the mass difference between a static and a rotating black hole:

$$E_{rot} = c^2(M - M_I). \tag{2}$$

In Eq. 2, M_I refers to the black hole's irreducible mass, or its mass before being spun up

[1] In reality, we do not know where or when a creature would find themselves after passing through a ring singularity. We assume the characters in the game have some control over this.

(in our case, $M_I = 5M_\odot$).

The Christodoulou-Ruffini mass formula relates a rotating black hole's mass to its irreducible mass [6]:

$$2M_I^2 = M^2 + \sqrt{M^4 - \frac{J^2c^2}{G^2}} \quad (3)$$

By substituting in Eq. 1 and rearranging, we found the total mass M as a function of M_I and a:

$$M = \sqrt{\frac{4M_I^4}{4M_I^2 - \frac{a^2c^4}{G^2}}} \quad (4)$$

Given that $c = 3.00\times10^8$ ms^{-1} and $G = 6.67\times 10^{-11}$ m^{3}kg^{-1}s^{-2} , $a = 1$ m, and $M_I = 5M_\odot$, we substituted Eq. 4 into Eq. 2 and solved for the rotational energy E_{rot}, which was found to be 2.03×10^{39} J[2].

Obtaining Energy from Land

The energy E_{rot} must be contained within the Mana generated by a single Land card. Since a Land can generate 1 Mana every turn, the Land must replenish this energy during the turn. We assume a single turn of the game is 1 day, and that the energy is replenished by flux from the sun.

If the game world has a similar sun to Earth, the solar constant can be taken as $G_{SC} = 1.361$ kWm^{-2} [7]. It is a simple calculation to find the area A of Land needed to capture E_{rot} in $t = 1$ day (86400 s):

$$A = \frac{E_{rot}}{G_{SC}t} \quad (5)$$

The area A of a single Land was found to be 1.73×10^{31} m^2, which is equivalent to 4.28×10^{27} acres. This is greater in area than the entire surface of the Earth ($A_{Earth} = 5.1\times10^{14}$ m^2 [8]) by 17 orders of magnitude.

[2] The term M_I^4 in Eq. 4 is large enough that a handheld calculator may not be able to process the calculation.

Conclusion

We conclude that the energy E_{rot} required to spin up a static black hole, such that its ring singularity has a radius $a = 1$ m, is 2.03×10^{39} J. If a Land card were to provide this energy once per day, being replenished only by a solar flux with solar constant $G_{SC} = 1.361$ kW/m^2, the Land must have an area of 4.28×10^{27} acres.

Summary

Based on the large energies and Land areas calculated, characters in Magic: The Gathering are unlikely to use Kerr black holes to summon creatures (unless they have access to some other source of energy that we have not considered).

References

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