## P4_2 Tunguska Event - Antimatter Meteor?

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**Abstract**

A colossal explosion occurred over central Siberia in 1908. This is known as the Tunguska event. One of the more unlikely theories that exists is that an antimatter meteor is responsible. In this paper, we investigate the mass of antimatter needed in order to yield the estimated energy released during this event for conventional and relativistic meteors. We find that a mass of 0.4-0.9 $kg$ is needed for a conventional meteor and we have produced a plot of rest mass against velocity for a relativistic meteor.

### Introduction

In 1908, a fireball was seen in the skies of central Siberia which has created a lot of speculation and mystery about how it happened. This is known as the Tunguska event, which resulted in the flattening of 60,000,000 trees over 2,000 $km^2$ [1]. One of the more unlikely theories about the cause of this event is that it occurred due to an antimatter meteor [2]. In this paper, we investigate the mass requirement needed for the antimatter meteor if it was the cause of this fireball. We will assume all the energy released from this meteor will be converted into the energy of the explosion.

### Theory

One of Albert Einstein's most well known equations is of energy-mass equivalence:

$$E = mc^2, \qquad (1)$$

where $E$ is the energy released if all of an object's mass $m$ is converted into energy. We will assume the meteor's mass is small, as matter-antimatter annihilation will produce consider-

ably more energy than a standard meteor explosion. In addition to this, the meteor would have kinetic energy, though the contribution is only significant when objects travel at relativistic velocities. Therefore, the mass requirement $m$ by rearranging Equation (1) for a conventional meteor would be:

$$m = \frac{E}{c^2}. \qquad (2)$$

However, if we consider a small blob of antimatter moving at a relativistic velocity $v_r$, then the total relativistic energy $E_r$ can be determined by using:

$$E_r^2 = p^2 c^2 + m_0^2 c^4, \qquad (3)$$

where $p$ is the relativistic momentum given by $p = \gamma m_0 v_r$, $m_0$ is the rest mass of the antimatter blob and $\gamma$ is the relativistic parameter defined below [3]:

$$\gamma = \frac{1}{\sqrt{1 - \frac{v_r^2}{c^2}}}. \qquad (4)$$

**Rest Mass of Antimatter Blob Against Relativistic Velocity**
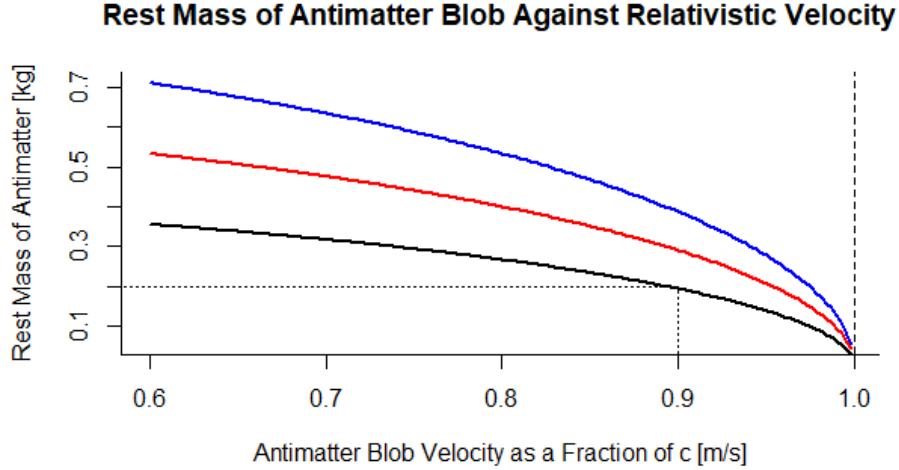
Figure 1: A graph demonstrating the rest mass $m_0$ of an antimatter blob against its relativistic velocity $v_r$. The black, red and blue curves relate to the total relativistic energy $E_r$ being 40 $PJ$, 60 $PJ$ and 80 $PJ$ respectively.

The relativistic mass requirement $m_0$ can be rearranged from Equation (3) such that:

$$m_0 = \sqrt{\frac{E_r^2}{\gamma^2 v_r^2 c^2 + c^4}}. \qquad (5)$$

**Results**

The range of values for the energy released during the Tunguska event is from 10-20 megatons of TNT [1] (between 40-80 $PJ$ by converting the units). Therefore, $E$ and $E_r$ will be in this range. Using this, we estimate the amount of antimatter needed to be between 0.4-0.9 $kg$ for a conventional meteor, by using Equation (2).

However, for a small blob of antimatter moving at a relativistic velocity, a much smaller amount of mass is required to produce the amount of energy needed as long as the velocity is high. Figure (1) demonstrates this point. Our analytical and numerical solutions indicate that if $E_r = 40$ $PJ$ and $v_r = 0.9$ $c$, the required rest mass $m_0$ will need to be 0.2 $kg$, indicated in Figure (1). This has been calculated by using Equations (4) and (5).

**Conclusion**

To summarize, we have determined the amount of mass needed for a conventional and relativistic meteor made out of antimatter. We have a range of masses of 0.4-0.9 $kg$ for a conventional meteor. For a relativistic meteor, we have produced Figure (1) that provides the rest mass requirement of the meteor, depending on its relativistic velocity. In reality, energy will be lost, so the real mass needs to be higher than that calculated, as the determined mass is a minimum amount.

It is uncertain how this antimatter could have come into existence to trigger this event, as the universe is matter dominated. Therefore, we conclude the antimatter meteor theory to be unlikely.

**References**

[1] https://www.sciencedaily.com/terms/tunguska_event.htm [Accessed 8 October 2019]

[2] P. J. Wyatt, Nature **181**, 1194 (1958).

[3] https://landgreen.github.io/physics/notes/relativity/special/index.html [Accessed 3 November 2019]