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A1 8 Armageddon: The Christmas Special!

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Abstract
Santa (Bruce Willis) has lost control of his reindeer, they're going to crash! Using the information gathered over the last four papers about Armageddon (1998), we investigate the physical consequences of the impact. Approximating Santa and his sleigh as an asteroid, we found that the transient crater diameter would be 32.18 km, with a final size of 50.83 km. Additionally, with the knowledge of the crater being complex, we found the central peak (hereafter named 'Santa Mountain') to have a height of 2.73 km. In another scenario, we calculated the velocity that Santa would have to travel at to knock the asteroid off of a collision course in a similar manner to the DART mission, and find it would take a speed of 4.42×10^{11} m/s to save Christmas.

Introduction

On his journey around the world delivering presents to all the kids on the 'nice' list, Santa lost control of his reindeer and is on a collision course with the ground at supersonic speeds! Over the course of our previous four papers about the film Armageddon, we have investigated many different aspects of asteroid collisions and crater formation. Using this information - as well as some new concepts - we investigate the scenario of what would happen during an impact event with Santa's sleigh. Finally, returning to Armageddon one last time: what would happen if Santa bravely decided to stop the Armageddon asteroid in a similar fashion to the DART mission.

Calculations

1. Crashing Home for Christmas - Using the method discussed in [1], we used the Melosh Scaling law to find the diameter of the transient (initial) crater (D_{tc}):

$$D_{tc} = 1.161 \left(\frac{\rho_p}{\rho_t}\right)^{\frac{1}{3}} L^{0.78} v_i^{0.44} g^{-0.22} sin^{\frac{1}{3}}(\theta) \quad (1)$$

Here we used value of projectile density ($\rho_p = 0.5$ g/cm^3 [2]) found from strong pine wood, as the majority of the composition of this object is the sleigh and the toys carried in his bag that we assumed to be mostly wooden. Target density (ρ_t) = 5.51 g/cm^3, $g = 9.81$ m/s^2, and $\theta = 45°$ [1]. L is the diameter of the body, found via:

$$L = 2 \sqrt[3]{\frac{3m_{Santa}}{4\pi\rho_p}}, \quad (2)$$

which is derived from spherical volume, $V = \frac{4}{3}\pi\left(\frac{D}{2}\right)^3$, and $m = \rho V$. From previous PST papers we can find that $m_{Santa} = 7.15 \times 10^8$ kg and $v_i = 1.56 \times 10^6$ m/s [3]. This gives $D_{tc} = 32.18$ km.

Since this diameter is larger than the simple-to-complex transition (D_{sc}) for a crater on Earth (which is ≈ 3.2 km) [4], it is safe to assume that the final crater (D_{cc}) would have a complex morphology. The diameter of this crater is therefore:

$$D_{cc} = 1.17 \left(\frac{D_{tc}^{1.13}}{D_{sc}^{0.13}} \right) = 50.83 \text{ km} \tag{3}$$

The depth of this crater can also be found; on average a complex crater has a depth:diameter ratio between 1:20 and 1:10 [4]. For this specific crater, the depth values are between 2.54 km and 5.08 km.

Since the crater is complex in nature a central uplift of materials is formed - a process observed in most, if not all, complex craters in the Solar System. This feature is formed in a similar process as dropping an object into liquid, wherein it collapses back into itself and pushes the material in the centre upwards.

$$h = 0.06D^{1.1} \approx 2.73 \text{ km [5]} \tag{4}$$

Thus, upon collision Santa and his sleigh of presents would cause the formation of a 2.73 km high peak which we have named 'Santa Mountain'. The recognised definition of a mountain is any landform taller than 600 m [6], meaning the described collision has indeed created a new mountain. In Christmas-themed units, the peak is roughly 2275 reindeer tall (as the average male reindeer stands 1.2 m at the shoulder [7]).

2. Saving Christmas - Here we revisit the original Armageddon asteroid, however with NASA failing to stop its approach, it is down to Santa to save Christmas! Using Santa's sleigh as a kinetic impactor, we attempt to divert the asteroid via momentum exchange. With the scenario found previously [8], we can find the momentum of the asteroid as the product of $m_{Arm} = 1.39 \times 10^{21}$ kg and $\Delta v = 2.274$ cm/s. Therefore, for the required speed of Santa to divert the asteroid:

$$v_{Santa} = \left(\frac{m_{Arm} \Delta v}{m_{Santa}} \right) \approx 4.42 \times 10^{11} \text{ m/s} \tag{5}$$

This is approximately 1500× the speed of light, and thus impossible in reality - sadly dooming Christmas!

Conclusion

In this paper we determined physical properties of the crater formed if Santa's sleigh were to impact with Earth, with a final crater of diameter 50.83 km, depth $2.54 - 5.08$ km, and a central peak large enough to be classified as a mountain, at 2.73 km. We also determined that in order to prevent an impact with Earth, Santa would have to collide with the Armageddon asteroid at a speed almost 1500× the speed of light. Therefore, Christmas magic may be the only option to save Earth - a potential route more scientifically sound than the method suggested in Armageddon!

Disclaimer: No Santas or reindeer were harmed in the making of this PST paper.

References

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