Astronerds overanalyze ‘Don’t look up’

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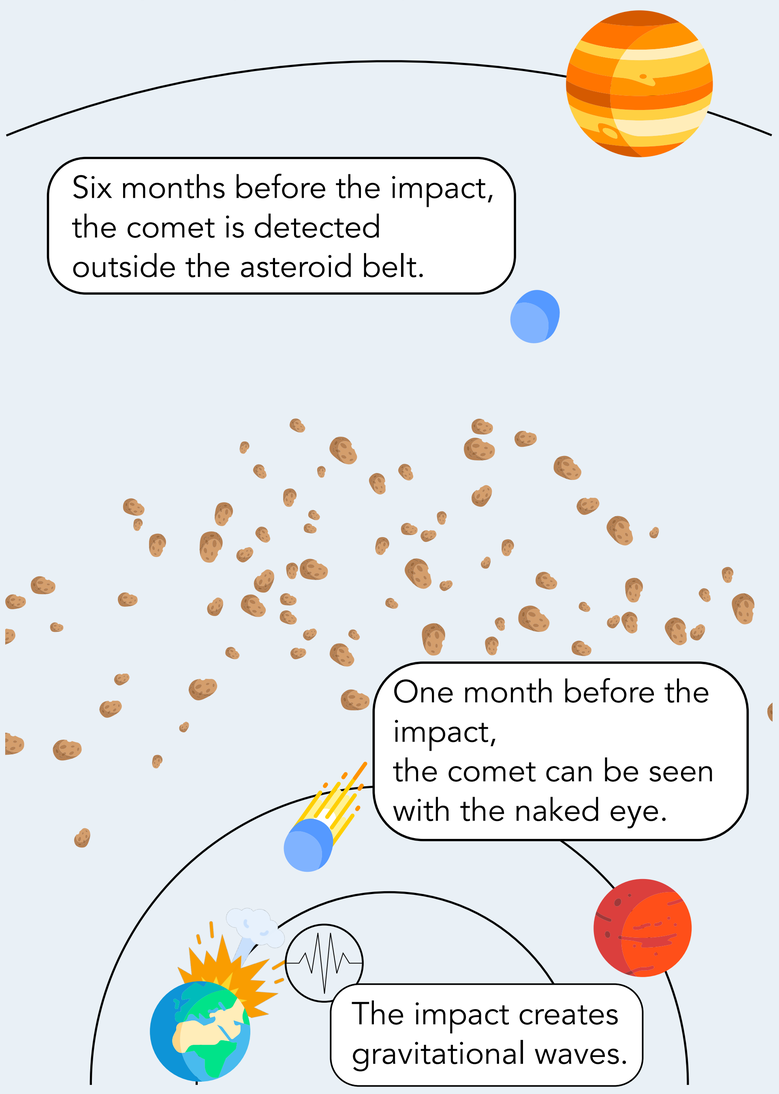
1. Introduction

The promise of a tragicomedy and a thrilling cast has enticed millions of Netflix subscribers to watch "Don’t Look up". Despite plenty of comic relief did the political (not so subtle) subtext sometimes feel too real. But how realistic is the actual premise of the movie, of a 9 km sized comet hitting earth and destroying almost all life on it? We have analyzed in detail the reasonableness of the comets origin, composition, trajectory, discovery and impact on earth.



2. Composition

In the movie, they state the worth of the rare earth metals contained in the comet as $W_{total} = 32 \times 10^{12}\,\$$. Using the properties of rare earth metal with the highest solar abundance Scandium[a] and the market price of its oxide (Sc_2O_3) of $w_{SO} = 991.14\,\$\,\mathrm{kg}^{-1}$[2], we can calculate the mass of Scandium in the comet as $M_{Sc} = 2.0993 \times 10^{10}\,\mathrm{kg}$. We can then calculate the minimum mass of the hydrogen in the cloud from which this comet condensed as $M_H = 3.2274 \times 10^{17}\,\mathrm{kg}$ where we used the molar masses $M_{m,Sc} = 45 \times 10^{-3}\,\mathrm{kg\,mol}^{-1}$ and $M_{m,H} = 10^{-3}\,\mathrm{kg\,mol}^{-1}$ and the solar photosphere abundance of Scandium $A_{Sc} = 3.16$. With this, we can calculate the total mass of all the heavy elements as $M_{tot} = 4.4825 \times 10^{15}\,\mathrm{kg}$ (using $Z = 0.72$ and $X = 0.01$) and the resulting mean density of the comet as $\bar{\rho} = 1.1743 \times 10^{4}\,\mathrm{kg\,m}^{-3}$. Compared to the density of comets of $0.6 \times 10^{3}\,\mathrm{kg\,m}^{-3}$, this value is too large.

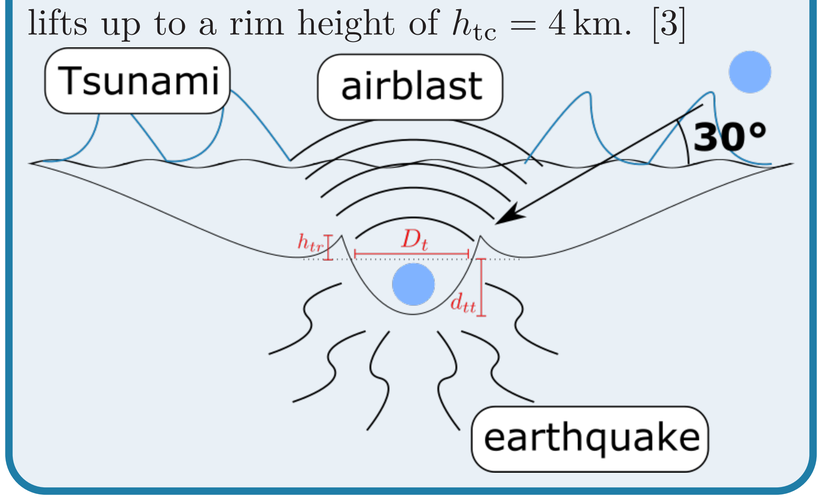
[a] nearly an order of magnitude higher than the rest[1]

3.Dynamical origin

Using the craters on the Moon as a proxy for the impact frequency on Earth, such a comet/asteroid impact would be very rare - roughly once every 10^8 yr. Six months before impact, the object would be between $1-2$ AU from Earth for an asteroid (75% of impacts) or about 3 AU from Earth for a comet (25% of impacts). The impact velocities range from $20\,\mathrm{km\,s}^{-1}$ for an asteroid to up to $\sim 50\,\mathrm{km\,s}^{-1}$ for a long-period comet.

5. Impact and Crater

In the movie it is visible that the comet hits off the coast of Chile. The atmosphere and water layer have a negligible effect on its velocity. Estimating the impact angle to be 30°, the diameter of the transient crater is $D_{\mathrm{tc}} = 55.98\,\mathrm{km}$ and the depth measured from the pre-impact surface is $d_{\mathrm{tc}} = 19.79\,\mathrm{km}$. The ground around the crater lifts up to a rim height of $h_{\mathrm{tc}} = 4\,\mathrm{km}$. [3]



6. Gravitational Waves

The rapid deceleration of the comet during the impact creates gravitational waves with strain of the order $\sim 10^{-27}$. LIGO, with a maximal sensitivity to a strain of $\sim 10^{-23}$, would not be able to detect that.

4. Visibility in the sky

In the movie, they saw the comet of 9 km diameter when it was six months away from reaching Earth, which we computed to be at 2.894 AU distance from us, therefore, inside the asteroid belt. We find that the apparent flux of the comet at Earth is $\sim$ 13 photons $\mathrm{m}^{-2}\mathrm{s}^{-1}$, hich is more than the visibility of the night sky ~ 10 photons $\mathrm{m}^{-2}\mathrm{s}^{-1}$, hence, observable by our telescopes. Moreover, the comet is visible to the naked eyes when it is 0.001 AU away from us, which translates to being about one hour away before the impact. However, if we also consider the coma, typically 1000 times bigger than the core, the comet will be seen by us at 0.62 AU distance and arrive in around 4 weeks. This seems like a correct detail in the movie.

7. Environmental Effects

The comet creates a tsunami, an airblast and an earthquake. The main characters spend their last hours in Michigan $\sim 9000\,\mathrm{km}$ away from the impact.

Tsunami: If we neglect the effect the decreasing depth of the ocean towards land, we can calculate the height of the wave at the coast of Chile to be 223.95 m.

Earthquake: The earthquake caused by the impact is of magnitude 10.11 at the epicentre and of effective magnitude 3.96 in Michigan, which corresponds approximately to what is shown in the movie. It will take 30 min for the strongest seismic waves to arrive.

Airblast: The peak overpressure in Michigan is 25.5 psi with wind velocities up to $262\,\mathrm{m/s}$, which would kill everyone instantly. This airblast would arrive 155 min after impact. The peak overpressure on the opposite point from the impact would still be 5.23 psi, so that most buildings collapse, everybody is injured and some people are killed.[3, 4]

8. Conclusions

The movie gets most of the physics correct with details differing.

1. The discrepancy in density can have multiple explanations (unexpected enrichment of the comet with rare earth metals, much higher prices of REM in the setting of the movie) but we believe that the Businessman just lied about the worth of the comet to get his mission approved.

2. The time delay between earthquake and airblast is shown to be seconds, but it would actually be $\sim$ 2.5 hours. This can be excused for dramatics of the movie.

9. References

[1] Katharina Lodders. Solar elemental abundances, 2019.

[2] SMM. Scandium oxide today | Rare Earth | SMM - China Metal Market. https://www.metal.com/Rare-Earth-Oxides/202104090003.

[3] Gareth S. Collins, H. Jay Melosh, and Robert A. Marcus. Earth impact effects program: A web-based computer program for calculating the regional environmental consequences of a meteoroid impact on earth. *Meteoritics & Planetary Science*, 40(6):817–840, 2005.

[4] R. Karl Zipf, Ph. D, and Kenneth L. Cashdollar. Effects of blast pressure on structures and the human body, 2006.

Some icons were taken from flaticon.com.

10. Acknowledgment

We would like to thank ICS for the existence of the pool room where exciting ideas emerge.

11. Supplementary material