Dr. Giulio Mazzolo
Website: giuliomazzolo.com

I have written this long feature article as part of the final assignment of the online and media writing module offered by the University of the West of England (UWE Bristol, UK). The module was taught across 10 weeks of online content between April and July 2022. The targeted audience are readers with an interest in astronomy, who may have an academic background in science and who want to keep up with the latest discoveries and understand astronomical science. To write the story, I have contacted the following experts, who kindly provided the original quotes in the article: i) Josep Trigo-Rodríguez, principal investigator of the Meteorites, Minor Bodies and Planetary Sciences Research Group at the Institute of Space Sciences in Barcelona, Spain, and ii) Clemens Rumpf, senior Guidance Navigation and Control engineer at Astranis in California, USA, and author of a study on population vulnerability models for asteroid impacts.

Asteroids striking the Earth: how likely is that?

Life on Earth has already experienced mass extinction due to a massive asteroid falling onto our planet. But how large must an asteroid be for this to happen again, and is it likely to occur in our lifetime?

Due to their limited investments on space observations, dinosaurs were caught off guard when a large asteroid struck the Earth, wiping them out together with three fourths of all life species around.

Sixty-six million years later, humans are trying not to repeat the mistake. With a diverse set of observatories, satellites and space missions, they are scanning the heavens for threatening asteroids or so-called near-Earth objects (NEO) on a collision course with our home planet, tracking thousands of bodies across the Solar System.

An immense amount of data, which is helping scientists address the question: how likely is it that an asteroid will hit the Earth, and what would be the consequences of such an event?

Who is who?

Prior to looking at risk estimations, a quick clarification on asteroids, meteoroids, meteors and meteorites, terms often but incorrectly used interchangeably.

Both asteroids and meteoroids are rocky objects in outer space. However, asteroids can be up to hundreds of kilometres in diameter — with some of the biggest populating the asteroid belt, a region between the orbits of Mars and Jupiter — while meteoroids are not larger than approximately one metre.

A meteor is instead the luminous trace left in the sky by an object heated up while falling through the Earth’s atmosphere — a phenomenon better known as a shooting star. Finally, an object that is not entirely vaporised by the friction with the atmosphere and reaches the ground is a meteorite.

Having made this clarification, we can now focus on how often hazardous objects may strike the Earth.

When size matters

Every day, more than 100 tons of grains of matter bombard the Earth, while objects that are a few metres large hit our planet once per year on average. These bodies pose no threat, as they burn in the upper layers of the atmosphere. On the contrary, objects which are a few tens of metres in size would start having significant consequences.

One famous example is the Tunguska event, the largest impact on Earth in recorded history. On the morning of June 30, 1908, a meteoroid about 50 metres in size crossed the Siberian sky at a speed of about 27 km/s, disintegrating due to the friction with the atmosphere at an altitude of 5 to 10 kilometres. The explosion released an estimated amount of energy of 12 megatons — approximately 800 times the atomic bomb dropped on Hiroshima. The area was sparsely populated, so only a couple of people are believed to have perished. However, the explosion released enough energy to flatten an estimated 80 million trees over a distance of 15 to 30 kilometres.

Bodies larger than the Tunguska meteoroid would not burn entirely in the atmosphere and reach the ground instead. This would be the case of objects of about 100 metres in size, which could strike the Earth approximately every 2,000 years. Such bodies would obliterate vast regions and lead to massive casualties, but would not cause mass extinction.

For mass extinction to happen, a much bigger object would be needed. For reference, the asteroid that put an end to the era of the dinosaurs is believed to have been 12 kilometres in size. However, the minimum size required is debated.

"*It also depends on the energy delivered, which in turns depends on the incoming velocity and nature of the object,*" says Josep Trigo-Rodríguez, principal investigator of the Meteorites, Minor Bodies and Planetary Sciences Research Group at the Institute of Space Sciences in Barcelona, Spain, and author of the book Asteroid Impact Risk. "I*f we consider an asteroid which is 10 kilometres in diameter, then the timescale for an impact is a few tens of millions of years.*"

A timescale much longer than that of human civilization, considering that modern humans arose in Africa around 200 to 300 thousand years ago.

But asteroids are not the only objects in the Solar System which could end up on a collision course with the Earth. One example are comets, which however would probably have different kinds of consequences on our planet, due to their distinct internal composition from asteroids.

As Trigo-Rodríguez explains, "*most asteroids are chondritic, made by silicates, sulphides and metals, and some are metallic and far harder. The more solid they are, the higher their ability not to break in the atmosphere and excavate craters. On the other hand, comets are highly porous and fragile. They probably tend to produce airbursts, authentic chemical bombs injecting massive amounts of oxygen, sulfur, phosphorus and sodium in the biosphere.*"

Say an asteroid will hit us…so what?

But going back to asteroids, what exactly would be the environmental consequences of the impact of a large one on the Earth?

"*We generally distinguish between immediate and long-term effects,*" says Clemens Rumpf, senior Guidance Navigation and Control engineer at Astranis in California, USA. "*Immediate effects include overpressure shock, storm-like winds, heat radiation, and in the event of a ground impact also cratering, ejecta blanketing, earthquakes, and tsunamis. Long term effects include, but are certainly not limited to, the deposition of dust in the atmosphere, associated climate change and decreases in yields from agriculture. The longer-term effects tend to only become relevant for larger impactors of the 100-metre size class.*"

Given the scale of such environmental effects, it is crucial to translate them into population loss, to adequately prepare for a potential threat.

"*There are multiple steps in order to estimate human casualties,*" explains Rumpf. "*First, the severity of each impact effect needs to be quantified. Here, we relied on nuclear weapons test data to relate energy release levels to some of the effect severities, for example heat radiation or overpressure shock. In other cases, for example tsunamis, sophisticated computer simulations predict the severity of the effect.*"

"*The second step is to then relate the effect severity to human vulnerability. In other words, we estimate how harmful a given effect with a certain severity is for a human,*" continues Rumpf, who investigated this topic in the study *Population vulnerability models for asteroid impact risk assessment* published in *Meteoritics & Planetary Science* in 2017.

To this aim, Rumpf and colleagues looked for established literature data on how this type of effect has affected humans in the past. "*For example, for tsunamis, we looked at tsunami and flooding data, or, for heat radiation, we looked at burn victim data. Finally, we can model the extent of each impact effect around the impact location. From global population maps, we can determine how many people live in an affected area. Together with the vulnerability and severity numbers calculated earlier, the total casualty numbers can be estimated. Given the nature and complexity of the problem, many of these steps represent averages with a significant uncertainty bound around them.*"

A cosmic dart

But of course, in case of an asteroid heading towards the Earth, we do not want to face tremendous casualties and worldwide catastrophes, but rather eliminate the risk before it is too late.

Scientists are evaluating some projects to do so, mainly aimed at modifying the asteroid's trajectory. Examples include the detonation of nuclear explosions in the object's proximity, or focusing solar radiation or laser light onto the asteroid to vaporise material on its surface and create a "thrust" able to push it.

One other strategy to knock the asteroid off course is to crash a space probe into it. To test the feasibility of such an idea, on November 23 last year NASA launched the DART (Double Asteroid Redirection Test) mission.

The target object is a system of two asteroids located roughly 11 million kilometres away — for comparison, the minimum distance between the Earth and Mars is approximately 55 million kilometres. The two asteroids are Didymos (Greek for "twin"), 780 metres in diameter, and Dimorphos, 160 metres long and orbiting Didymos as a sort of moon. The system is not on a collision course with the Earth and has been chosen for practical advantages only.

The space probe will crash on Dimorphos between September 26 and October 1, 2022, changing the object's velocity by less than 1 mm/s. A tiny amount, which however will reduce by roughly 10 minutes Dimorphos' orbital period around Didymos (currently almost 12 hours long).

While we wait for DART to reach its target, there is one thing we should keep in mind, though.

Asteroids are not just a potential threat to our species, but also an invaluable source of information on the origin and evolution of the Solar System, and thus of how we came to be.

And if we think that amino acids (the building blocks of proteins and hence life) have been found on asteroids — such as on Ryugu, an asteroid visited by the Japanese spacecraft Hayabusa2 between 2018 and 2019 — and could have arrived on Earth via primordial impacts, we may be able to look at asteroids not only as carriers of death, but also as donors of life.