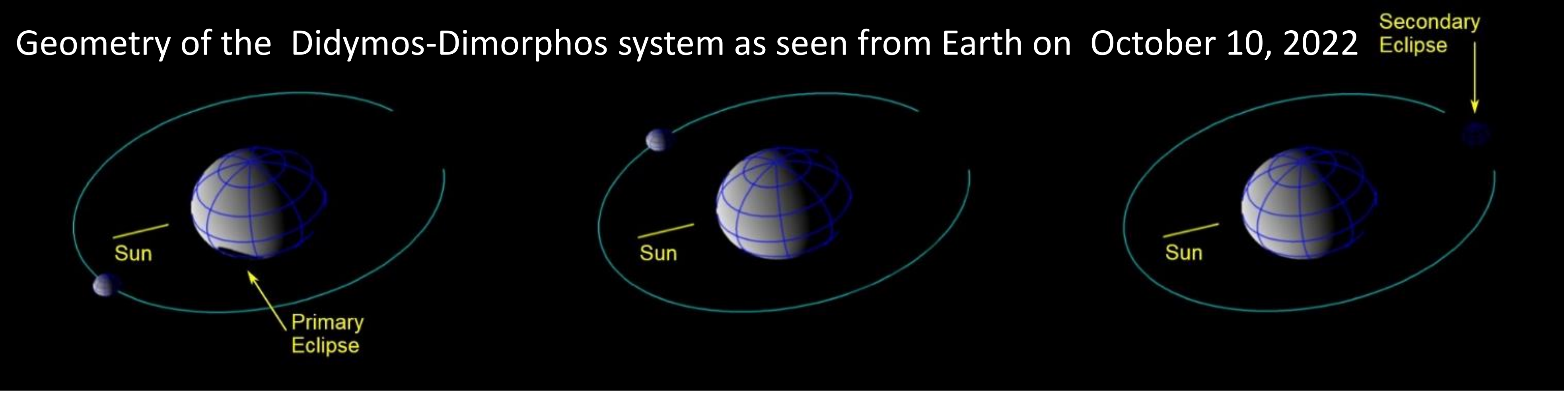
Humanities first experiment to re-direct an asteroid that could collide with Earth

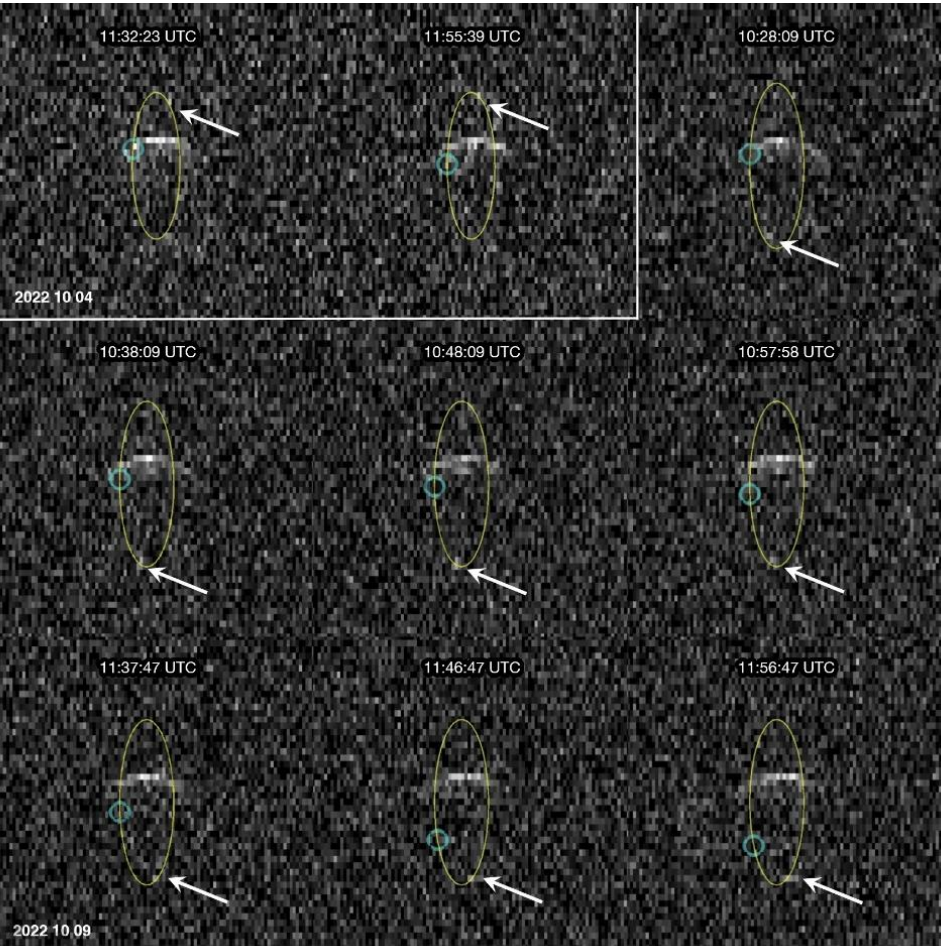
In September 2022, the NASA Double Asteroid Redirection Test satellite (DART) successfully impacted the 150 meter large moon Dimorphos orbiting the 760 m diameter Near Earth Object (NEO) Didymos. Our team participated in determining the effect of the collision with extensive observations from the Danish 1.54m telescope in Chile before and after the collision. The result and analysis of the observations were published in Nature (www.nature.com/articles/s41586-023-05805-2) on April 20, 2023. Interviews include: sciencenews.dk/en/satellite-nudged-an-asteroid-slightly-but-enough-to-save-earth and https://soundcloud.com/science_stories/dart-aendrede-asteroides-retning-i-rummet
The Didymos-system was 11 million km from Earth at the time of the impact. It was not on collision course with Earth, but the experiment was the first test of how humanity can re-direct cosmic objects that in the future could otherwise hit Earth.

Collision with a NEO of km size (such as the Didymos asteroid itself) could be the end of humanity, and a NEO the size of its moon Dimorphos could cause regional damage of a scale never experienced before in human history. Even a 50m NEO could destroy areas of thousands of square km. If the DART satellite had impacted the big Didymos asteroid itself, the effect on its orbit would have been too small to be detectable. The clever choice to hit its small moon Dimorphos instead, is that we could measure the effect of the collision with high accuracy. Before the impact, we had measured the orbital period of Dimorphos around Didymos to 11t55min17.3sec with a precision of half a second. The analysis of the observations from after the impact, that are now published in Nature, showed that the period had decreased with 33 minutes due to the collision.

This number is very encouraging for humanity's possibility to redirect NEOs in the future, whenever it becomes necessary. If the impact had been fully inelastic, such as the collision of a car into a wall, the decrease in the orbital period would have been only 7 minutes. The rest was because the satellite drilled its way through the top layers of the asteroid and heated the layers below such that hot steam and dust was propelled back out through the "drilling tunnel" and acted as a natural rocket motor, breaking the speed of Dimorphos almost 5 times more than the push from DART itself could have done.

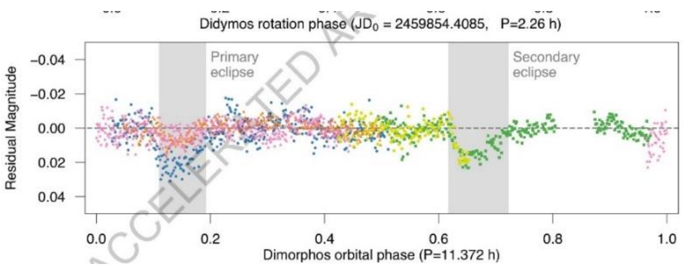


Left: the eclipse geometry.
Each time Dimorphos goes in front or behind Didymos, we saw a small dip in the intensity of the light from the system. The time between the dips, made it possible to determine Dimorphos' orbital period before and after the impact with high accuracy.



Our work is part of a larger team work, including several telescopes worldwide, which secured high confidence in the methods and analyses.

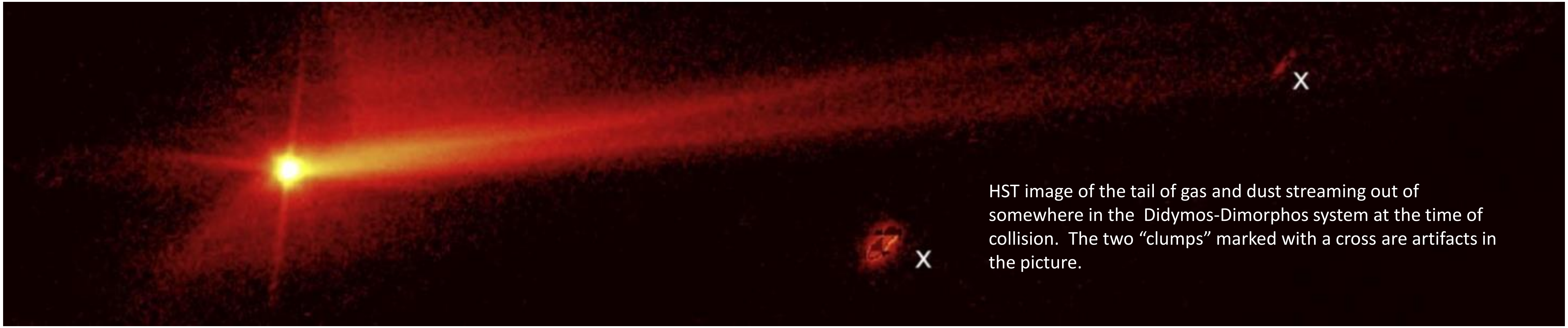
Left: Radar beams reflected on October 4 and 9, 2022 show Dimorphous' post-impact position in its orbit, while the green circles indicating its position predicted from pre-impact orbital data. The radar beams were emitted from the 70m Goldstone radio telescope with a power of 430,000 W and the radar echoes were captured by the 100m Greenbank telescope. No other images, not even the Hubble images, were able to resolve Didymos and Dimorphos from one another.



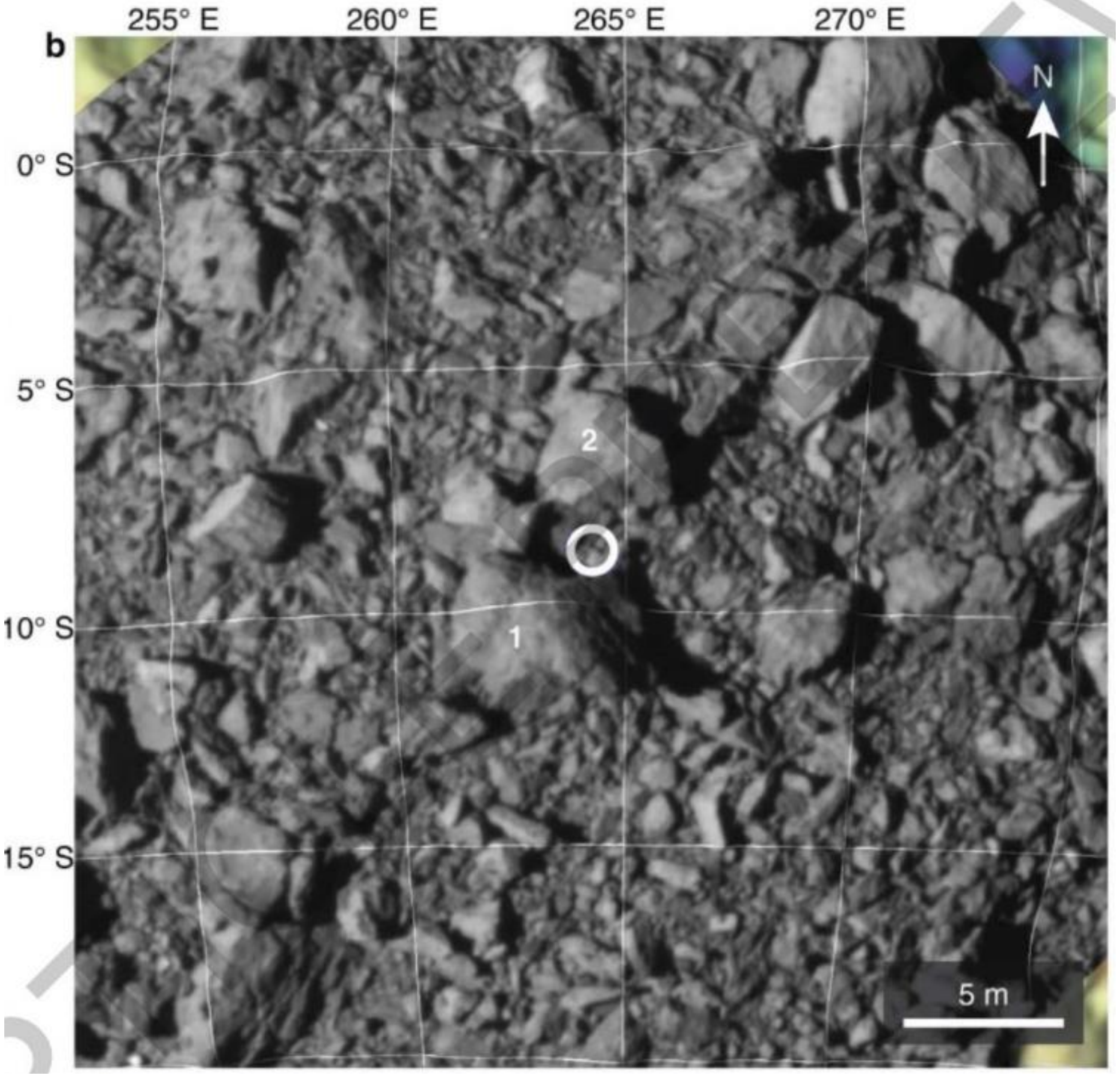
Above: The eclipse light curve phase folded to Dimorphos' new orbital period of 11t 22min 19s, as observed on Oct.22, 2022.

The Didymos-system is a double asteroid. Didymos itself is 780 meters in diameter, but it is orbited by another asteroid, Dimorphos, which is 150m in diameter. The Hubble Space Telescope (HST) detected the cloud of gas and dust shown in the image below, streaming out from the Didymos system at the time of the collision. This proved that DART had collided with one of the two asteroids. But neither HST or any optical telescope on Earth could see where exactly in the system the cloud came from, and could not measure how much re-direction the collision had caused. That required longer and much more detailed observations. Our team participated in these observations from the Danish 1.54m telescope in Chile. Combined we used a whole arsenal of optical telescopes, plus two of the worlds largest radio telescopes, to determine the effect of the collision. The results will contribute to make it possibly in the future to redirect dangerous asteroids and comets on collision course with the Earth. One conclusion is that an impact similar to the DART impact would be able to move an asteroid of the same type as Dimorphos away from collision, if there were time enough to prepare the mission several years before a predicted collision with Earth (such that the redirection only needs to be tiny).

This is only the beginning of a large number of experiments and observations needed to secure humanity against the enormous catastrophes that would follow from a cosmic collision with a NEO. There is a tremendous number of NEOs smaller than Dimorphos crossing Earth’s orbit each year, and even asteroids with only a fraction of Dimorphos‘ mass could course humanity unbelievable damage and problems, in particular if they hit densely populated areas.



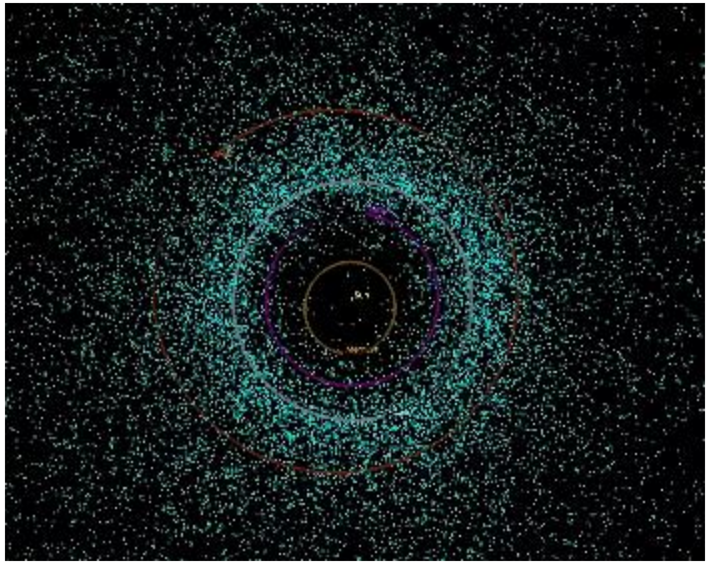
HST image of the tail of gas and dust streaming out of somewhere in the Didymos-Dimorphos system at the time of collision. The two “clumps” marked with a cross are artifacts in the picture.

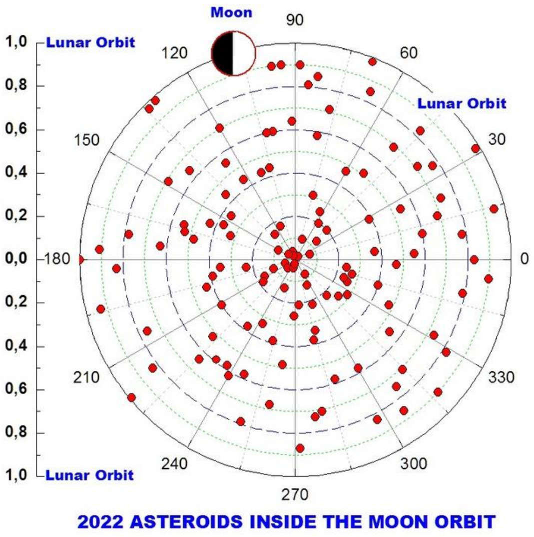


Images of the area of Dimorphos where the collision took place, taken by DART's on-board camera during the final approach, showing the rubble like surface in different scales. **Above:** most of the ellipsoid leading end of Dimorphos where DART's onboard camera guided the satellite to hit. A mountain range in the shadow area of Dimorphos is seen to the right in the picture. **Right:** the last full frame image taken 2 seconds before impact . Pixel size is 5.5 cm, the point of impact is shown with a circle in the middle of the picture, and the two boulders on each side of the impact place are ca 6.5 m. long.

A video of the impact can be found at
https://www.youtube.com/watch?v=SbMNEhIv-eQ&ab_channel=SciNews

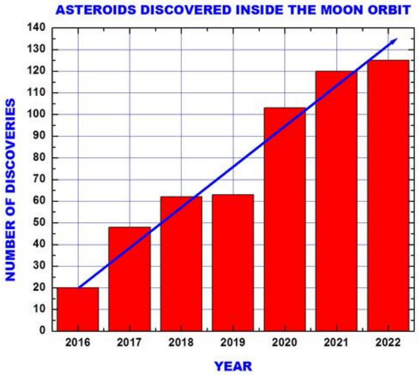
How likely is it to collide with a Near Earth Object? -- and how dangerous is it?





Left: the 125 known asteroids that during 2022 passed Earth within the Moon's orbit. Red dots mark their position at closest approach.

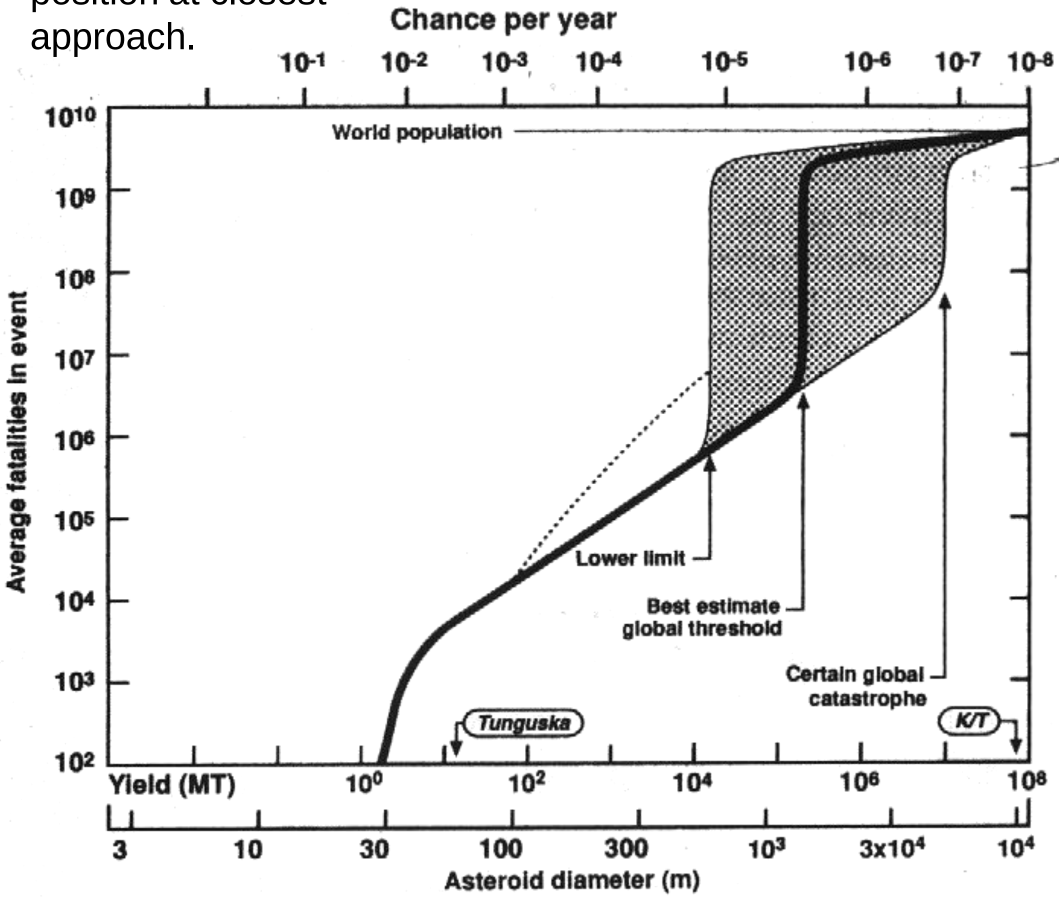
Right: number of asteroids discovered year-by-year to have passed Earth within the Moon's orbit.



Above: blue dots show all the asteroids known to come close to the Earth's orbit (NEAs) and their positions on January 2018. More than 20,000 of them are larger than Dimorphos and almost 1000 are larger than 1km. Circles show the orbits of Mercury, Venus, Earth and Mars.

www.youtube.com/watch?v=vfvo-Ujb_qk&ab_channel=NASAJetPropulsionLaboratory shows how the known number of NEOs have changed from 1999 to 2018, together with an animation of how they move and how close they came to collision with Earth.

Right: One estimate of how many people would die (y-axis) in case of a collision with an asteroid ranging in diameter between 3 meters and 10 km (lower x-axis) and a corresponding estimate of the likelihood of such a collision (upper x-axis). Remark that the estimate that a collision of a NEA of 1km in diameter statistically would take place every 1 million years and could result in final the end of the existence of humanity on Earth.



Left: The Hiroshima bomb was intentionally exploded in the height of 600 m to maximize the effect of the resulting blast wawe of 0.02MT (mega-tons TNT). This explosive power corresponds to the collision with a 1m asteroid.

Below right: USA 's military estimated that 12 km^2 of Hiroshima was destroyed due to the nuclear bomb. Japanese officials determined that 69% of Hiroshima's buildings were grounded and another 6–7% damaged.

Left: Maybe it looked like this in central Siberia near the river of Tunguska on the morning of June 30 1908, when a comet only 50 m in diameter entered Earth's atmosphere with a velocity of 65,000 km/h and exploded in 8 km's height with a power 1000 times the Hiroshima bomb. The blast wave destroied 2000 km^2 and 8 million trees, and blew people in the ocean 600 km away

The Tunguska impactor exploded heigh in the atmosphere because it came at a very shallow angle and was made of ice. If it had been more dense ("stone-like") it would have exploded lower in the atmosphere and caused more damage. An asteroid of Dimorphos' size could explode as the Tunguska, but could also make thousands of times more damage, dependening on its collision velocity, composition and entrance angle in the atmosphere -- and depending on where on Earth it hit.