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SATELLITE MEGACONSTELLATIONS AND THEIR IMPACT ON ASTRONOMY

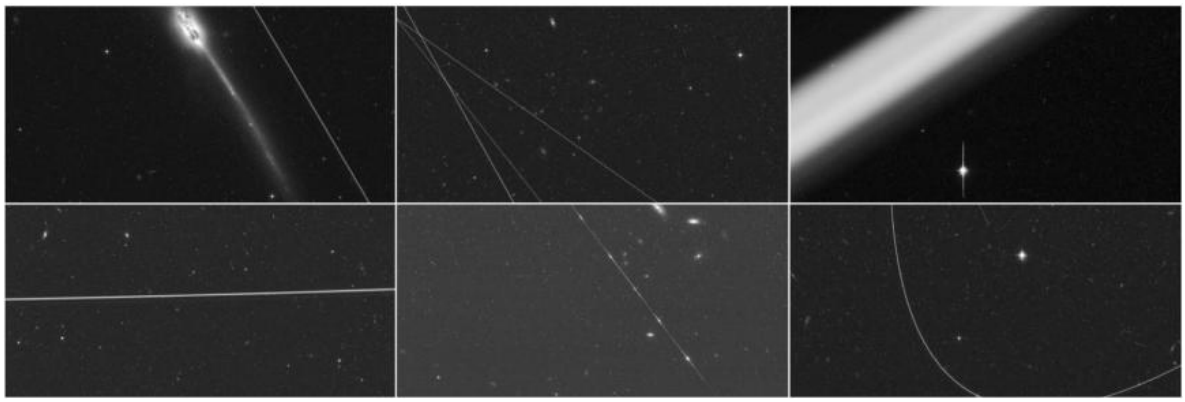
Do you remember that at the beginning of 2023, a comet, C/2022 E3 (ZTF), passed by Earth, one that had not come close to Earth since the Middle Ages? At the beginning of the year, I found myself ready every evening at sunset to observe this comet with my binoculars. No matter how hard I tried to observe it, I could not because of my position on Earth from my home in Guatemala. So, on February 1st of that year, I decided to go to Puerto San José, a beach in my country free from light pollution, so that I could finally observe the comet. It was already sunset; I was at the perfect latitude, with my binoculars calibrated and ready to observe the comet during the 3 minutes in which it would be visible from Guatemala... Binoculars on and... a line of thousands of bright white dots passed across my field of view. I could not see the comet because of these objects. You may wonder: What were those bright dots? The 49 Starlink satellites that were launched into orbit in 2022.

Technology continues to develop, although sometimes it creates points of conflict, as is the case with satellite megaconstellations, which provide benefits for global internet connectivity but affect astronomical observatories, the development of research in the different branches of Astronomy, the detection of celestial bodies approaching Earth, and contribute to light pollution of the night skies (Duffy, 2022). Starlink, constitutes one of the most visible examples of this problem. Satellite megaconstellations therefore represent a challenge for Astronomy.

The different investigations, observations, and analyses carried out by the multiple branches of Astronomy are affected by satellite megaconstellations. This is because they obstruct the field and range of view of ground-based observatories and even those located in Earth's orbit, such as the Hubble Space Telescope, which has produced multiple images with white lines that compromise observations. What are these white lines? They are trails produced by satellites crossing the telescope's field of view during an observation. A study published in

December 2025 in the journal Nature (Borlaff et al., 2025) indicated that as more satellite constellations are deployed, more images received from different observatories are affected; and although it is true that these trails can be removed with the help of editing tools, astrophysicist Jonathan McDowell mentions that this tool sometimes simply does not work because it can compromise the scientific information contained in the image. Calculations have been made to determine the probability that a Starlink satellite will appear in an observatory's field of view by 2030: for an orbiting observatory, there is a 33% probability, while for a ground-based observatory, there is a 41% probability. Another thing that must be taken into account is that these satellites do not have an established orbital flight path, but rather their algorithm is modified suddenly and without apparent order in order to fulfill their purpose: to provide internet coverage to a vast region of Earth. Therefore, an astronomer cannot calculate when a Starlink satellite will not pass through their field of view (McFall-Johnsen, 2023; Odenwald, 2022).

Figure 1. *Examples of satellite trails identified in the Hubble Space Telescope images.*



Source: Kruk et al., 2023.

Satellites produce greater visual and light pollution for the observation of celestial bodies. The first generations of Starlink demonstrated this problem, as they are covered with a material that reflects sunlight, giving them considerably high brightness (visible to the human eye), thus contributing to increased light pollution in the skies. Although Elon Musk has changed the material covering the satellites and modified their design to reduce this brightness, the second and third generations of Starlink continue to bring this problem to the table. A person does not need to be at the La Silla Observatory in Chile to notice the problem;

simply going outside to observe the stars at night is enough to see that the night sky is brighter, less clear, and has several bright white dots moving at high speeds. This is a real problem if we take into account that the number of satellites in Earth's orbit continues to grow rapidly and that there are proposals to deploy hundreds of thousands of satellites over the coming decades. If nearly one-third of the world's population already cannot observe the Milky Way in the night sky because of current light pollution... what will no longer be observable in the sky in the future? (Odenwald, 2022; Loeffler, 2023; Davis, 2016).

Throughout Earth's existence, multiple cataclysms have occurred that have nearly extinguished life on Earth. Before *Homo sapiens* dominated the Earth, the dominant beings on this planet were dinosaurs; they became extinct, presumably, because of the impact of a comet. What prevents the same thing from happening to humans? Human intelligence and mastery over nature. Astronomical observations involve, beyond the discovery and location of stars, planets, black holes, and other celestial bodies, monitoring planetary atmospheres, calculating the orbits of celestial bodies and rockets for space exploration, and, most importantly, detecting meteorites, meteors, and even comets heading toward Earth. As mentioned before, satellite megaconstellations obstruct the field of view of multiple observatories used for astronomical research and monitoring, and therefore they can also make it more difficult to detect and characterize some near-Earth objects. This prevents humans from being able to deflect these potential collisions in time. The fact that celestial bodies on a collision course with Earth may be prevented from being detected and deflected due to a lack of adequate visibility is only the first disadvantage of satellite constellations in space-related matters.

Now, although it is true that comets considered deadly are 10 or more kilometers in diameter and are easy to detect, then there is nothing to worry about, right? Well, we should worry about smaller meteors and meteorites, such as the one that formed “Meteor Crater” in Arizona, United States. This was a meteorite 1.3 km in diameter, and its impact resulted in the immense crater that is now a tourist attraction. Or what about the 20 m diameter Chelyabinsk meteorite that injured many people, damaged power transmission towers, buildings, and roads, caused avalanches, etc., with its shock wave as it entered Earth's

atmosphere over a city in Russia in 2013? Regardless of the size of the meteorite, if it falls near human civilization, it is a high-risk phenomenon (Harris et al., 2015; Artemieva and Shuvalov, 2016).

Satellite megaconstellations represent one of the new challenges resulting from the expansion of human activity into space. Although they bring global connectivity benefits, such as Starlink, they also entail a large number of risks and consequences that create chaos in science and humanity and threaten to alter our view and interpretation of the Universe from Earth. Action must be taken now to regulate these types of projects, which could be carried out without creating total discord with science before it is too late and more companies and countries, such as China, join in, intending to deploy their own global internet satellites to compete with Starlink and OneWeb (McCready, 2026). If we add to the 50 000 satellites that are presumed to be in orbit by 2027 those currently under development, what will become of Astronomy, the branch of science that places human beings in space and time and gives them their sense of meaning? What will the night sky look like in a couple of years? How much of our night sky will remain observable, and how much of the scientific information we obtain from the Universe will be preserved?

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