New ESO study evaluates impact of satellite constellations on astronomical observations

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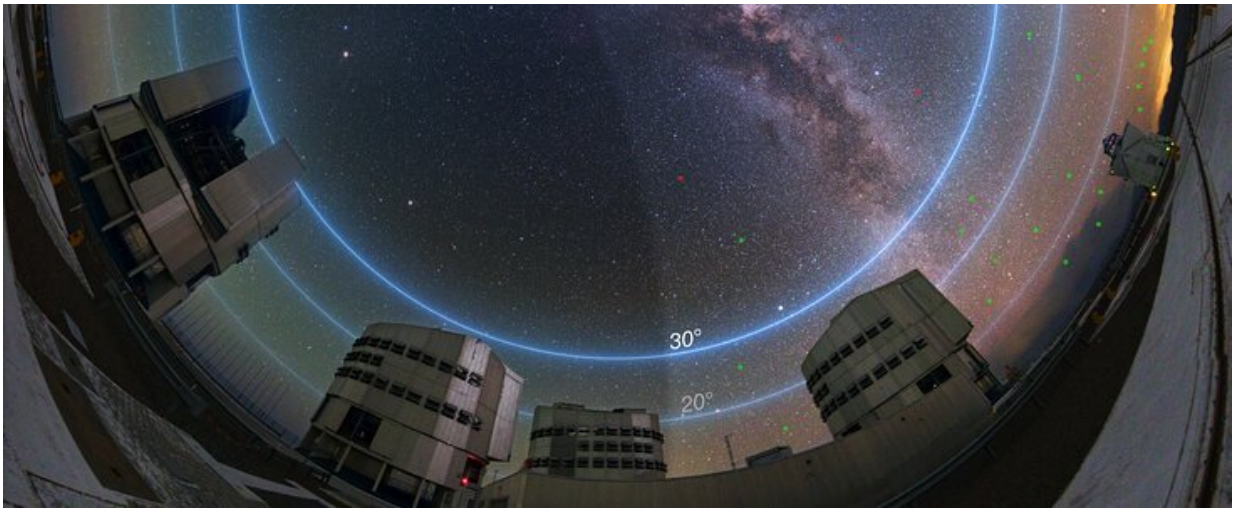

Areas of the sky most affected by satellite constellations. Credit: ESO

Astronomers have recently raised concerns about the impact of satellite mega-constellations on scientific research. To better understand the effect these constellations could have on astronomical observations, ESO commissioned a scientific study of their impact, focusing on observations with ESO telescopes in the visible and infrared but also considering other observatories. The study, which considers a total of 18 representative satellite constellations under development by SpaceX, Amazon, OneWeb and others, together amounting to over 26 thousand satellites, has now been accepted for publication in *Astronomy &*

Astrophysics.

The study finds that large telescopes like ESO's Very Large Telescope (VLT) and ESO's upcoming Extremely Large Telescope (ELT) will be "moderately affected" by the constellations under development. The effect is more pronounced for long exposures (of about 1000 s), up to 3% of which could be ruined during twilight, the time between dawn and sunrise and between sunset and dusk. Shorter exposures would be less impacted, with fewer than 0.5% of observations of this type affected. Observations conducted at other times during the night would also be less affected, as the satellites would be in the shadow of the Earth and therefore not illuminated. Depending on the science case, the impacts could be lessened by making changes to the operating schedules of ESO telescopes, though these changes come at a cost. On the industry side, an effective step to mitigate impacts would be to darken the satellites.

The study also finds that the greatest impact could be on wide-field surveys, in particular those done with large telescopes. For example, up to 30% to 50% of exposures with the US National Science Foundation's Vera C. Rubin Observatory (not an ESO facility) would be "severely affected," depending on the time of year, the time of night, and the simplifying assumptions of the study. Mitigation techniques that could be applied on ESO telescopes would not work for this observatory although other strategies are being actively explored. Further studies are required to fully understand the scientific implications of this loss of observational data and complexities in their analysis. Wide-field survey telescopes like the Rubin Observatory can scan large parts of the sky quickly, making them crucial to spot short-lived phenomena like supernovae or potentially dangerous asteroids. Because of their unique capability to generate very large data sets and to find observation targets for many other observatories, astronomy communities and funding agencies in Europe and elsewhere have ranked wide-field survey telescopes as a top priority for future developments in astronomy.

Professional and amateur astronomers alike have also raised concerns about how satellite mega-constellations could impact the pristine views of the night sky. The study shows that about 1600 satellites from the constellations will be above the horizon of an observatory at mid-latitude, most of which will be low in the sky—within 30 degrees of the horizon. Above this—the part of the sky where most astronomical observations take place—there will be about 250 constellation satellites at any given time. While they are all illuminated by the Sun at sunset and sunrise, more and more get into the shadow of the Earth toward the middle of the night. The ESO study assumes a brightness for all of these satellites. With this assumption, up to about 100 satellites could be bright enough to be visible with the naked eye during twilight hours, about 10 of which would be higher than 30 degrees of elevation. All these numbers plummet as the night gets darker and the satellites fall into the shadow of the Earth. Overall, these new satellite constellations would about double the number of satellites visible in the night sky to the naked eye above 30 degrees.

This annotated image shows the night sky at ESO's Paranal Observatory around twilight, about 90 minutes before sunrise. The blue lines mark degrees of elevation above the horizon. A new ESO study looking into the impact of satellite constellations on astronomical observations shows that up to about 100 satellites could be bright enough to be visible with the naked eye during twilight hours (magnitude 5-6 or brighter). The vast majority of these, their locations marked with small green circles in the image, would be low in the sky, below about 30 degrees elevation, and/or would be rather faint. Only a few satellites, their locations marked in red, would be above 30 degrees of the horizon -- the

part of the sky where most astronomical observations take place -- and be relatively bright (magnitude of about 3-4). For comparison, Polaris, the North Star, has a magnitude of 2, which is 2.5 times brighter than an object of magnitude 3. The number of visible satellites plummets towards the middle of the night when more satellites fall into the shadow of the Earth, represented by the dark area on the left of the image. Satellites within the Earth's shadow are invisible. Credit: ESO/Y. Beletsky/L. Calçada

These numbers do not include the trains of satellites visible immediately after launch. Whilst spectacular and bright, they are short lived and visible only briefly after sunset or before sunrise, and—at any given time—only from a very limited area on Earth.

The ESO study uses simplifications and assumptions to obtain conservative estimates of the effects, which may be smaller in reality than calculated in the paper. More sophisticated modelling will be necessary to more precisely quantify the actual impacts. While the focus is on ESO telescopes, the results apply to similar non-ESO telescopes that also operate in the visible and infrared, with similar instrumentation and science cases.

Satellite constellations will also have an impact on radio, millimetre and submillimetre observatories, including the Atacama Large Millimeter/submillimeter Array (ALMA) and the Atacama Pathfinder Experiment (APEX). This impact will be considered in further studies.

ESO, together with other observatories, the International Astronomical Union (IAU), the American Astronomical Society (AAS), the UK Royal Astronomical Society (RAS), and other societies, is taking measures to raise the awareness of this issue in global fora such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) and the European Committee on Radio Astronomy Frequencies (CRAF). This is

being done while exploring with the space companies practical solutions that can safeguard the large-scale investments made in cutting-edge ground-based astronomy facilities. ESO supports the development of regulatory frameworks that will ultimately ensure the harmonious coexistence of highly promising technological advancements in low Earth orbit with the conditions that enable humankind to continue its observation and understanding of the Universe.

More information: O. R. Hainaut et al, Impact of satellite constellations on astronomical observations with ESO telescopes in the visible and infrared domains, *Astronomy & Astrophysics* (2020). DOI: 10.1051/0004-6361/202037501

Provided by ESO