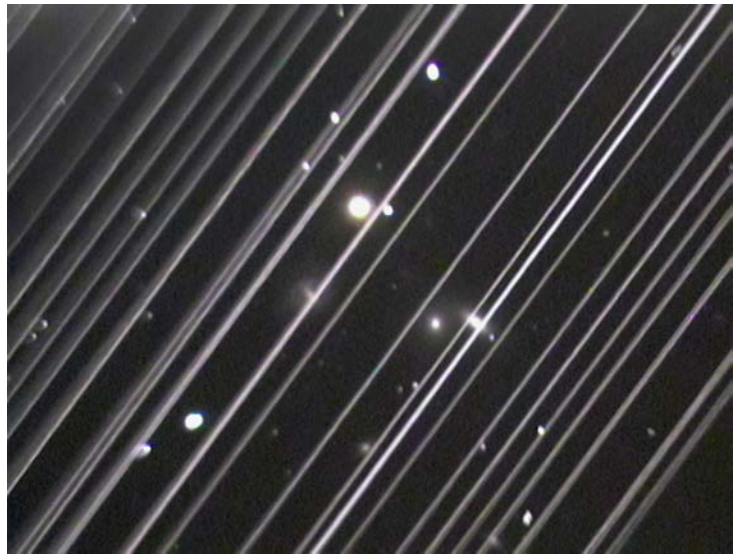


The impact of mega- constellations of communication satellites on Astronomy

PIERO BENVENUTI

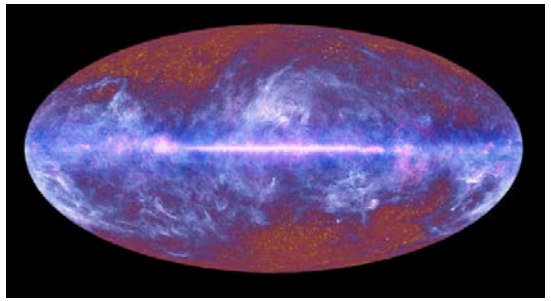
INTERNATIONAL ASTRONOMICAL UNION

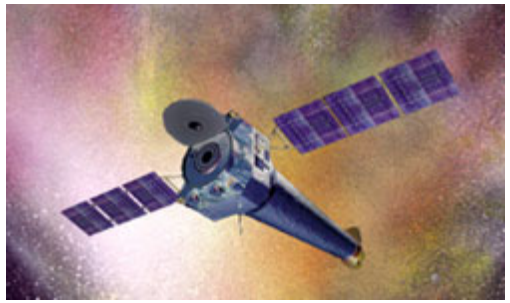
The International Astronomical Union

- Over 13,000 professional astronomers from about 80 Countries.
- Founded in 1919.
- Main mission: promote and safeguard the science of astronomy in all its aspects through international cooperation.
- An authoritative voice, not directly linked to any specific national or multinational facility or project.
- In collaboration with UN OOSA and the Spanish Government will hold a Conference on the protection of the dark and (radio)quiet sky, hosted by the Istituto de Astrofísica de Canarias in October 2020.

The progress of astronomical knowledge

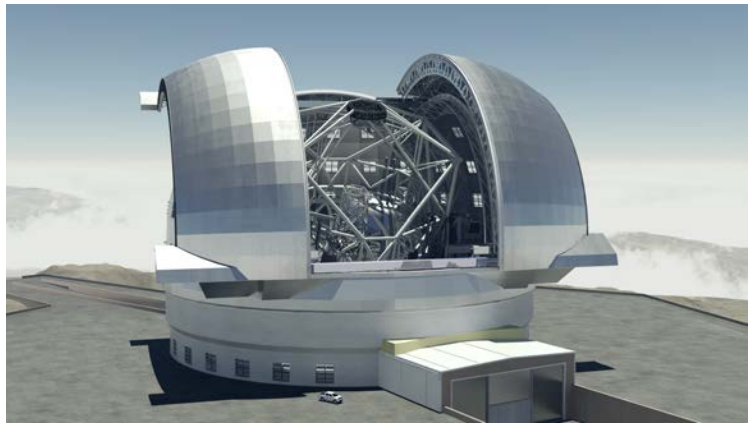
- Astronomy, the most ancient science, is very much indebted to space technology for its tremendous progress in knowledge in the past 50 years.
- Space-born instruments opened the access to the observation of the entire electromagnetic spectrum emitted by celestial bodies and phenomena.
- The new window has been instrumental to build a comprehensive model of the cosmos, but also to consolidate basic science, from high energy plasma to General Relativity.





Space and ground telescopes are complementary

- Large collective areas (mirrors), wide fields detectors and suites of interchangeable instrumentation cannot easily board a satellite.
- Ground optical and radio facilities remain an essential commodity for the progress of the science of astronomy
- However, the space-ground alliance for astronomy is now threatened by the mega-constellations of satellites… why?



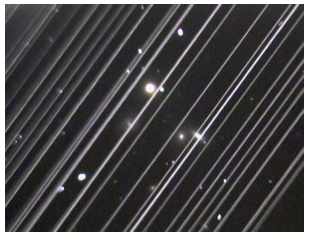
Commotion vs scientific assessment

- IAU Commission B7 ("Protection of Existing and Potential Observatory Sites") and the Working Group "Dark and Quiet Sky Protection" were invested by the IAU Executive Committee to assess the situation and to start discussions with the companies that are responsible for the launch and operation of the mega-constellations in order to study measures to mitigate their impact on astronomical observation as well as on the pristine night sky appearance.
- Commission B7 asked 7 skilled astronomers from various organizations (Rubin Observatory, U. Michigan, CAHA, ESO and ESA) to perform simulation on the number and brightness of the satellites once the known mega-constellation will be fully deployed.
- The results are preliminary, but they agree on some basic facts

Basic facts

- While there is a large uncertainty in the future number of satellites, simulations were conducted based on a large sample of ~26,000 satellites from 18 constellations, with publicly available data on their parameters.
- With this sample, the number of satellites above the horizon visible at any given time would be between 1300 - 2500, depending on the latitude.
- Of these, about 260 satellites would be above an elevation of 30° on the horizon (where most astronomical observations are performed).
- When the sun is at 18° of elevation below the horizon (i.e. when the night is dark, after or before astronomical twilight), the number of illuminated satellites above the horizon would be about 1000, (~160 with an elevation higher than 30°).
- These numbers decrease toward the middle of the night, when the Sun is lower below the horizon and more satellites are in the Earth's shadow.

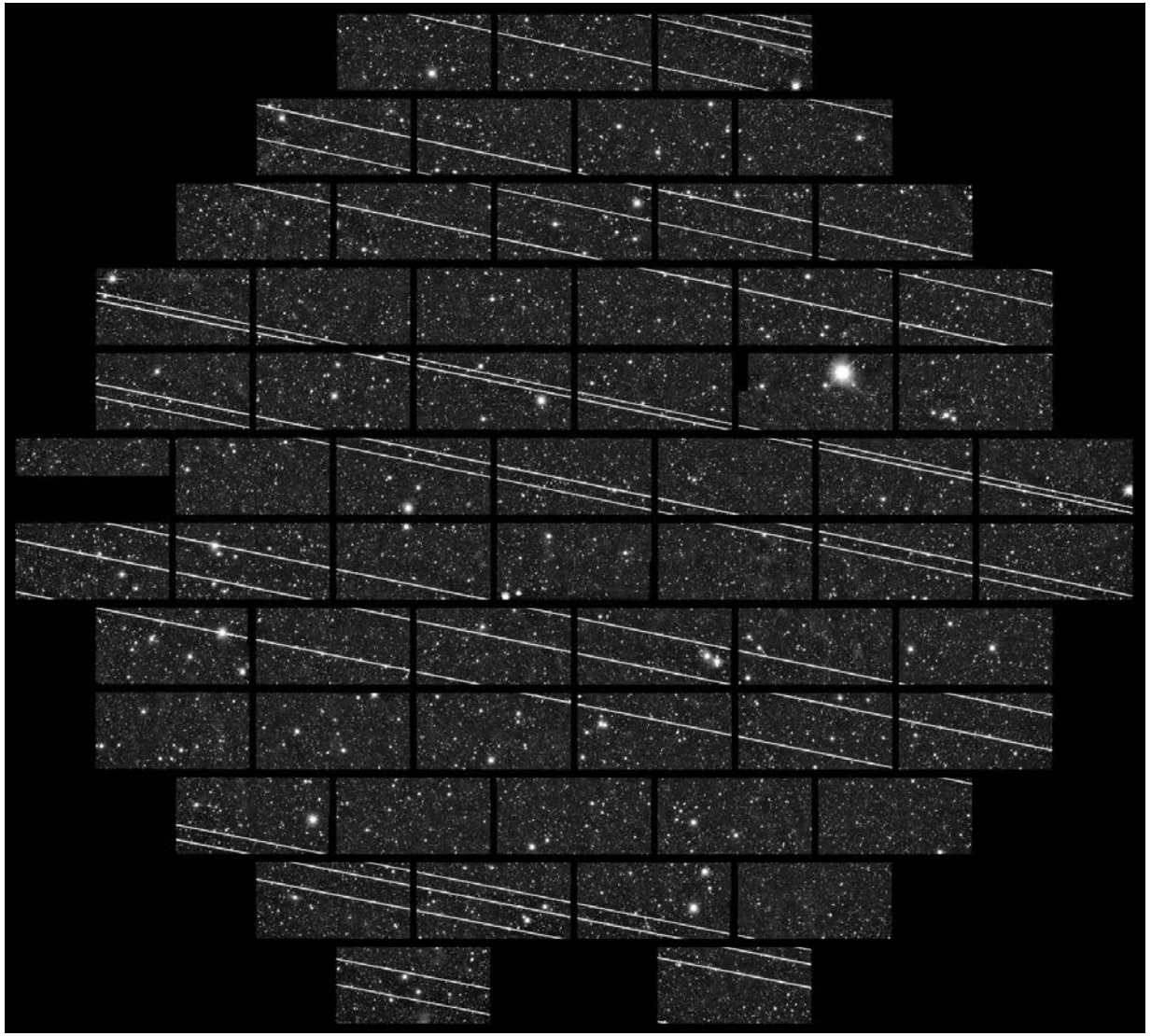
How many satellites will one see?

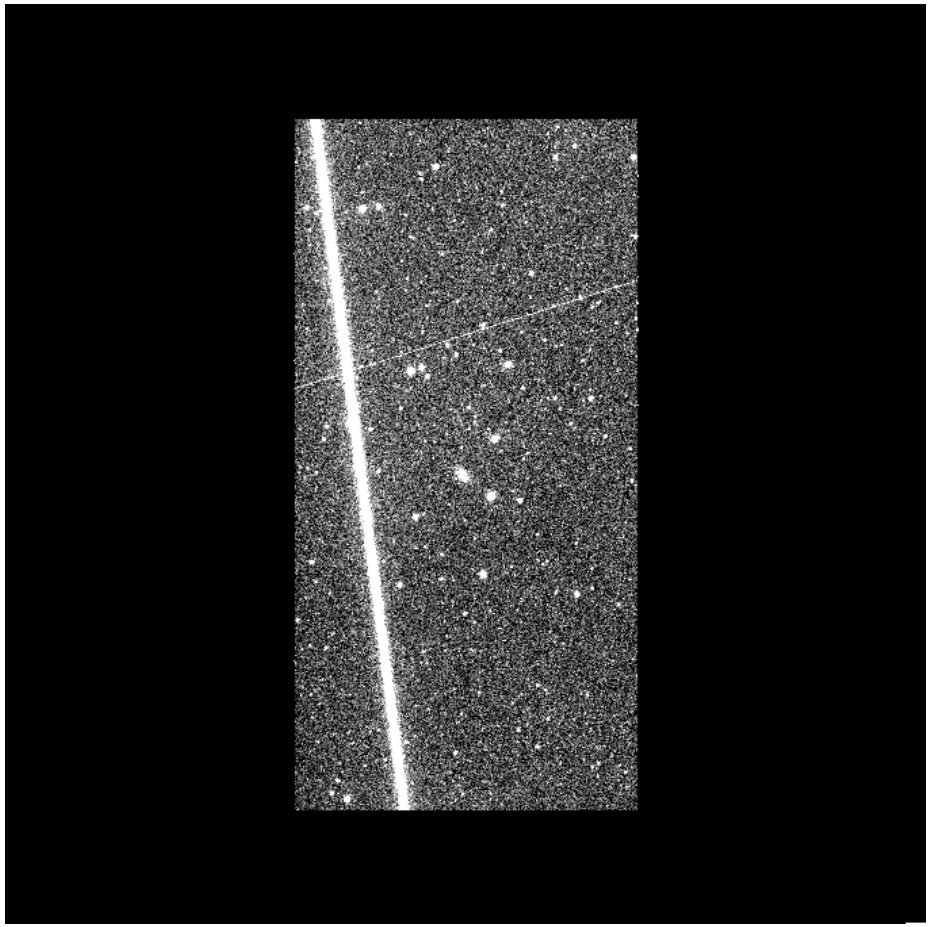


- At the moment it is difficult to predict how many of the above illuminated satellites will be visible to the naked eye, because of uncertainties on their actual reflectivity (experiments are being made to reduce it by adopting different coatings).
- The appearance of the pristine night sky, particularly when observed from dark sites, will be anyway altered, because the new satellites are predicted to be brighter of 99% of the existing orbiting manmade objects. The interference with the uncontaminated vision of the night sky will be particularly important in the regions of the sky close to the horizon and less evident at high elevation.
- The spectacular appearance of visible trains of satellites ("string of pearls"), often used as representative of the mega-constellations' impact, is significant during the launch and orbit raising phase because they are considerably brighter than when at their operational altitude and orientation. The global effect depends on how long the satellites are in this phase and on the frequency of launches.

The serious impact on astronomy

- Apart from their naked eye visibility, it is estimated that the trails of the new satellites will be bright enough to saturate the modern detectors, particularly when used with large telescopes.
- Scientific astronomical observations will be therefore **severely affected**. In principle, in the cases of medium-narrow field imaging and spectroscopic observations, the interference can be mitigated by accurate prediction of the trails and interrupting the exposure during their passage. However, the large number of trails creates significant and complicated overheads to the scheduling and operation of astronomical observations.
- In the cases of modern fast wide field surveys, like the ones by the Vera C. Rubin Telescope (a.k.a LSST), the impact is far more serious because it is currently predicted that **30-40% of the images will be badly damaged**.





IAU conclusions

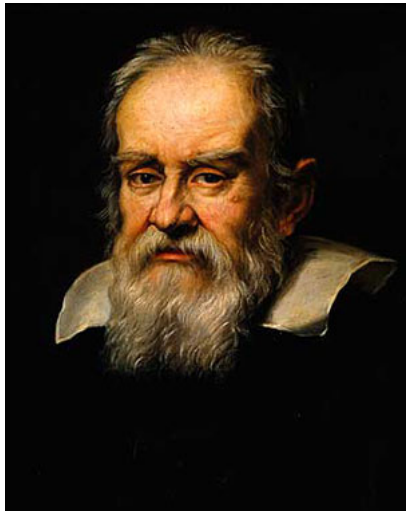
- The IAU considers that the above consequences are creating a worrying negative impact on the progress of ground astronomy, diverting human and financial resources from pure research to studying and implementing mitigating measures.
- While the effect in the radio and submillimetre wavelength ranges is still under investigation, it is clear that the impact in the optical domain is particularly serious, because it substantially decreases the efficiency of large facilities for which important public funds have been invested.
- The IAU, in close collaboration with the American Astronomical Society AAS, will continue and initiate discussions with the private companies that are planning to launch and operate any constellation that may interfere with astronomical observations, both professional and amateur ones, in order to mitigate their negative effects.

An appeal to UN OOSA

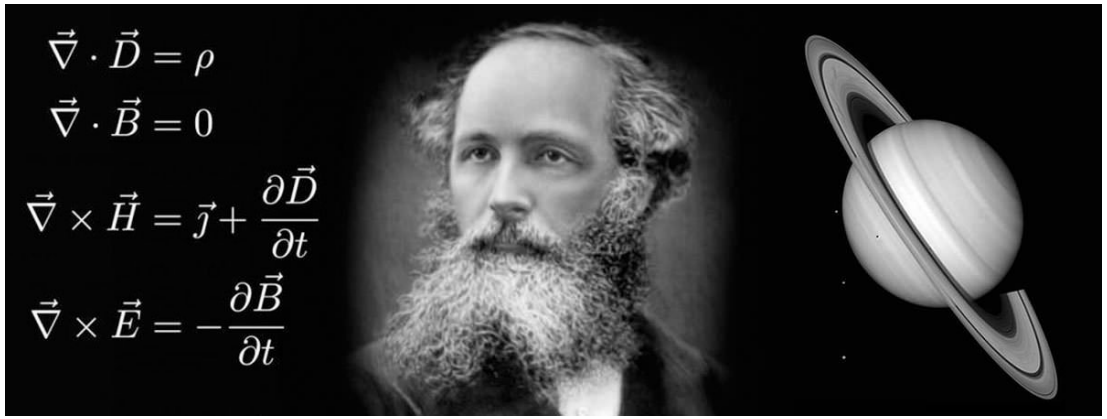
- The IAU notes that currently there are no internationally agreed rules or guidelines on the brightness of orbiting manmade objects.
- While until now this was not considered a priority topic, it is now becoming increasingly relevant.
- Therefore the IAU strongly suggest that UN OOSA consider the possibility of including the above topic in the agenda of the most adequate of its Working Groups.
- In addition, the specific theme of the mega-satellites will be included in the Programme of the IAU/UNOOSA/IAC Conference "Dark and Quiet Skies for Science and Society", which will be held in Santa Cruz de Canarias from 5-8 October 2020 (https://www.iau.org/news/announcements/detail/ann20003/).

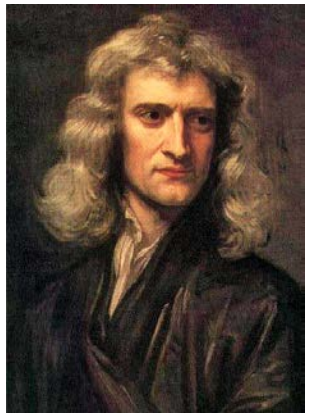
Progress must go on! However, what about lessons learned ???

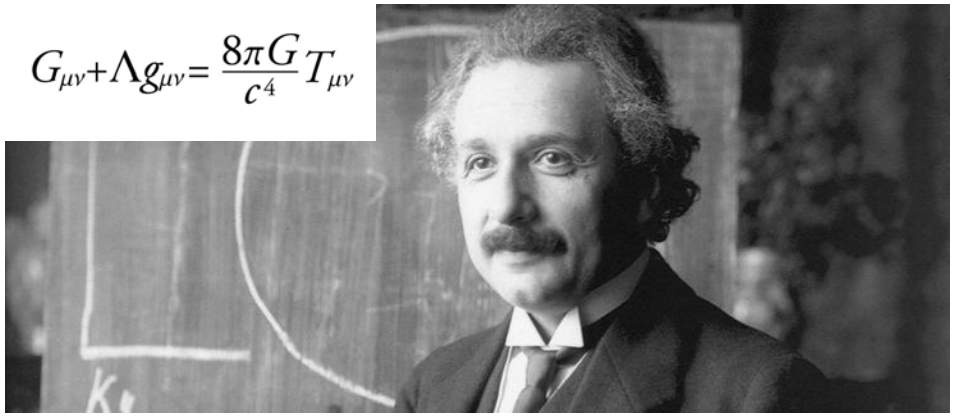
No Science, no technological progress!



- The IAU wishes to stress that technological progress is only made possible by a parallel advance in scientific knowledge.
- Space users should be continuously reminded that their satellites would not fly nor properly communicate without the essential contributions that astronomy and physics have made to celestial mechanics, orbital dynamics and relativity.
- **It is in everybody's interest to preserve and support the progress of pure science.**







Docta ignorantia (learned ignorance)

- Space astronomy taught us how little we know…