News & views

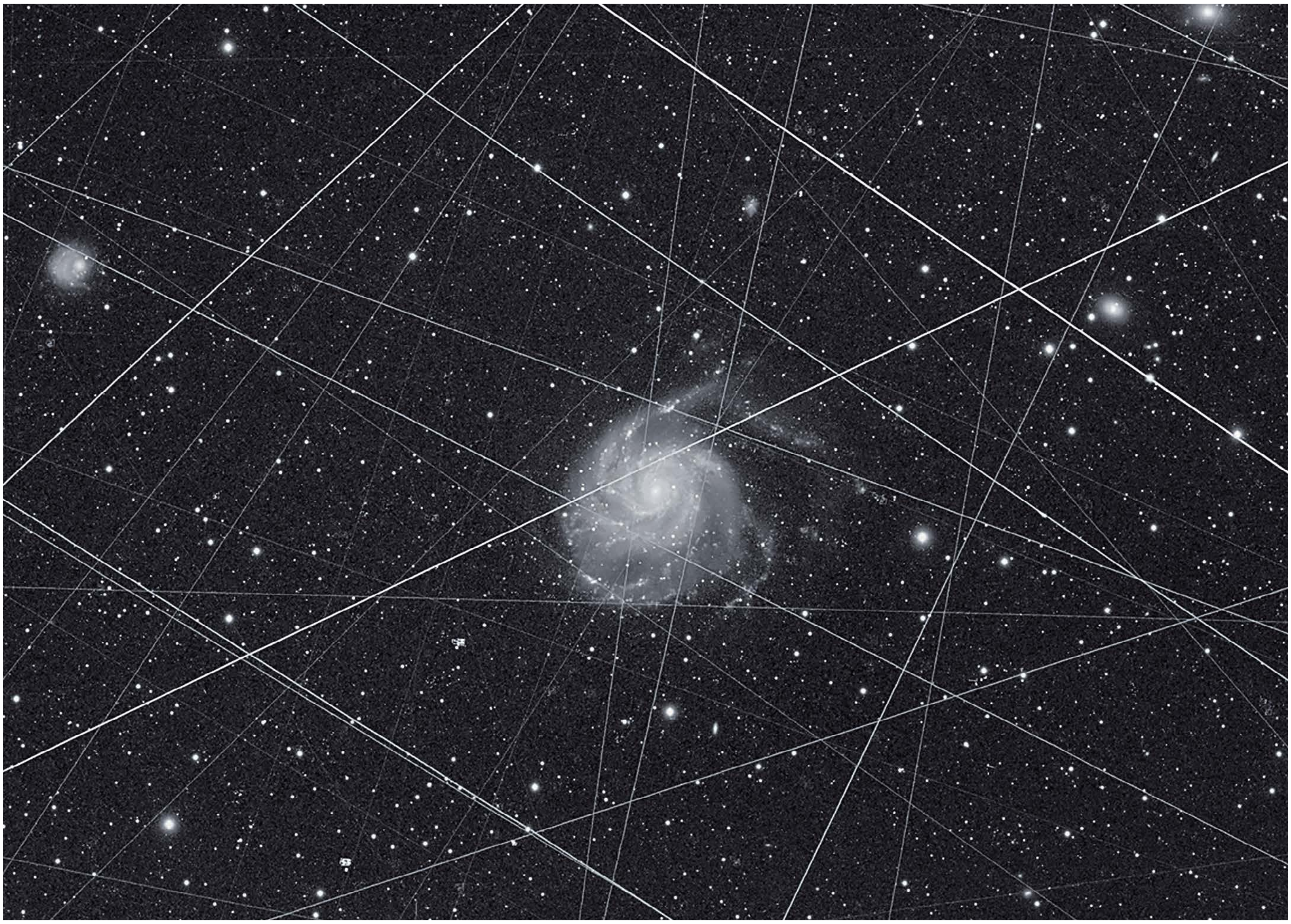

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Figure 1 | Satellite trails across the night sky are creating problems for astrophotography.

Astronomy

Bright satellites are disrupting astronomy

Samantha Lawler

A team of amateur and professional astronomers has determined that a satellite one-third of the size of a tennis court is one of the brightest objects in the sky — with dire consequences for ground-based astronomy. **See p.938**

The night sky is changing, with batches of human-made, moving 'stars' being added every week. Urban light pollution has masked this change from many people[1] — but not from astronomers and stargazers, who are painfully aware of the increasing number of bright satellites in the sky. These objects can be seen around the world, regardless of which country operates them, because they remain sunlit long after the sky has grown dark. On page 938, Nandakumar *et al.*[2] report that one of the newest satellites, BlueWalker 3, outshines all but a handful of the brightest visible stars. It exemplifies how, without stronger regulation, satellites could substantially change the view of the night sky worldwide (Fig. 1), and severely jeopardize future use of Earth's orbit for science, communication and space exploration.

The number of satellites in orbit is growing rapidly: between 2017 and 2022, companies filed applications requesting that more than one million satellites be granted access to the radiofrequency spectrum, which allows the satellites to communicate with stations on Earth[3]. The BlueWalker 3 satellite, which has been in orbit since September 2022, was launched by a relatively small operator, telecommunications firm AST SpaceMobile, which plans to operate around 90 large satellites in total.

Because of this growing threat to the night sky, many astronomers have spent a great deal of time speaking to emerging satellite 'megaconstellation' operators, such as SpaceX, OneWeb and Amazon Kuiper — urging them to consider using fewer satellites or engineering fainter satellites, even though such changes would not increase the companies' profit margins (see go.nature.com/3fzu1qz). Some of these interactions have resulted in the publication of recommended guidelines (see go.nature.com/3u4afhc and go.nature.com/47mwxkk).

SpaceX's Starlink megaconstellation currently dominates orbit, and comprises the majority of the satellites that are visible to the naked eye from sites unencumbered by urban light pollution. In the past four years, SpaceX has launched around 5,400 new satellites (7% of these have already deorbited; see go.nature.com/3sapv8n). Currently, the company owns and operates 57% of the 8,859 total active satellites in orbit (see go.nature.com/3qymhwc). After urgent requests from astronomers worldwide, SpaceX tested several strategies for reducing the brightness of its satellites. Despite being larger than the original models, the latest Starlinks are indeed fainter[4]. But Nandakumar and colleagues' study highlights flaws in this system of good-faith discussions between astronomers and satellite operators: anyone can launch satellites of any brightness at any time, and no operator is obliged to launch fainter satellites.

The huge increase in commercial satellites — even the faint ones — is making all areas of observational astronomy research increasingly difficult: astronomers require more telescope time for the same scientific return because a portion of data will be lost to satellites 'photobombing' telescopes every night. For example, in 2024, the Vera C. Rubin Observatory in Chile will start systematically imaging the entire visible sky every three nights, using the largest digital camera ever built. In a future sky with 40,000 satellites, at least 10% of all its images are predicted to include at least one satellite, hamstringing all future scientific output from this facility, which is funded largely by US taxpayers, before it even begins operations[5].

Satellites have already added noise to radio astronomy observations[6] and even to images from the Hubble Space Telescope[7]. Most governments require corporations to pay fines to those affected by a firm's pollution. Perhaps it's time to require these for-profit satellite companies to pay compensation for the negative impact they are having on taxpayer-funded astronomy research. Even the task of measuring the brightness of satellites in orbit has been left to several groups of astronomers[8–10]. Nandakumar *et al.* tracked BlueWalker 3 meticulously as it orbited over observatories in Chile, the United States, Mexico, New Zealand, the Netherlands and Morocco. But these observations took away time from astrophysical research — and from other pursuits, in the case of the amateur astronomers involved in the study.

The authors also tracked an object called a launch vehicle adapter — a small satellite that helped BlueWalker 3 to successfully reach its operating orbit. They measured this satellite as it jettisoned from the larger satellite and orbited independently, noting that its orbit was not publicly reported for four days after the two objects parted ways. This lag is a potential problem for researchers attempting to mitigate the effects of satellites on astronomy by calculating their trajectories and pointing telescopes elsewhere in the sky. Clearly, such a strategy requires that orbit information to be complete and up-to-date.

AST SpaceMobile has stated that it is taking steps to address the concerns of astronomers for future launches, including plans to share detailed orbit data with astronomers. This is a positive development. However, as a prototype for the company's satellite constellation, BlueWalker 3 is more than 100 times brighter than a typical Starlink satellite[2,4]. So, unless the company enacts changes that substantially reduce the brightness of future satellites, reporting alone will not help naked-eye stargazers. And major software and hardware upgrades will still be required to enable telescopes worldwide to avoid imaging the satellites.

> **"A portion of data will be lost to satellites 'photobombing' telescopes every night."**

But the question of whether other satellite operators were aware of the jettisoned satellite once again highlights the problem of space junk and the increasingly crowded orbital space around Earth, pointing to the need for more robust regulation here too. A single unreported satellite doesn't pose a substantial risk of a collision, but that risk quickly multiplies if it becomes standard to report satellites days after they enter orbit, especially as the total number of launches escalates. This is particularly crucial for Starlink satellites, because they orbit in such a dense orbital shell that they already manoeuvre frequently to avoid collisions. Starlink's collision-avoidance manoeuvres increased exponentially from June 2022 to May 2023 (see go.nature.com/3ugnobh), and if each manoeuvre is not executed perfectly, the consequences could be devastating.

Any collisions in orbit will release many pieces of debris travelling at several kilometres per second, which can cause further collisions, and could lead to a runaway collisional cascade referred to as the Kessler syndrome[11]. This is the worst-case scenario: the onset of full Kessler syndrome would prevent the use of communication, weather, science and astronautical satellites in low Earth orbit for decades. And it is unclear whether a spacecraft could even be launched successfully through the debris shell to enable travel to other planets. Humans would effectively be trapped on Earth by space junk, with multiple tonnes of vaporized metal being added to the upper atmosphere every day through re-entry[12].

I often wonder what kind of night sky my children will inherit. Will the stars be hidden behind a crawling grid of bright satellites, or a hazardous snow globe of post-Kessler debris? Or will government regulators set strong safety and light-pollution rules before the night sky is all but lost? The future sky will be chosen in the coming years by the actions of private satellite companies and the government agencies that should be regulating them. And astronomers such as Nandakumar and colleagues will still be here, carefully looking up and documenting the results.

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