Simulating the impact of satellites on astronomical observations

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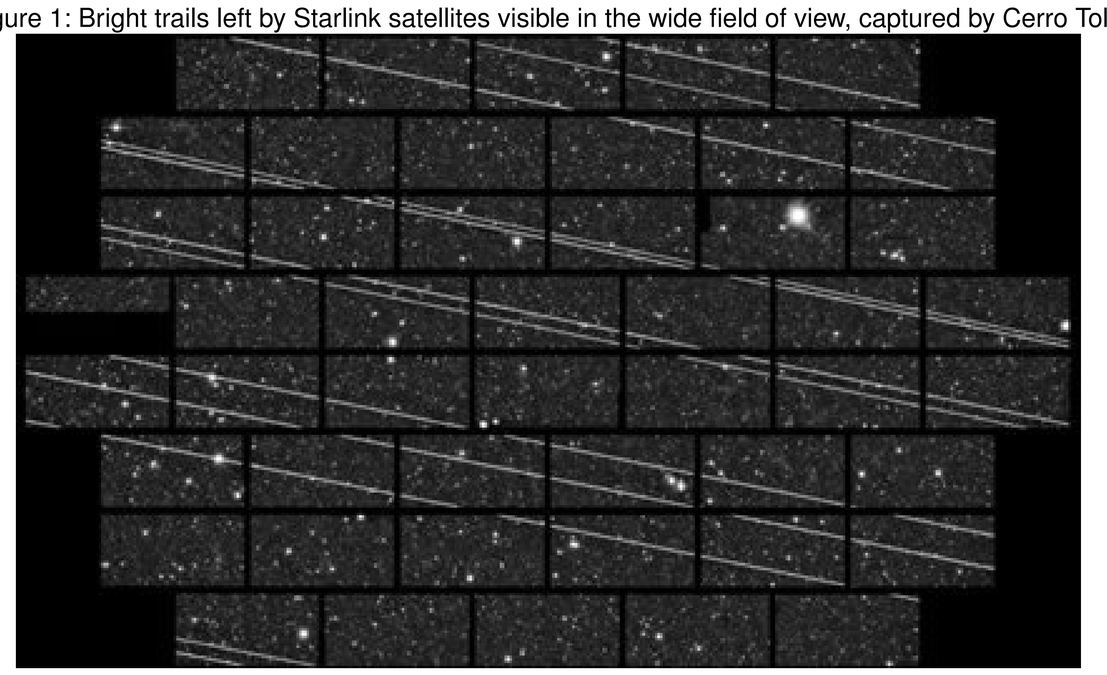
ABSTRACT

For millennia, human eyes were the only instrument for studying space. This changed in 1609 when Galileo Galilei created the first telescope and expanded our knowledge of the sky, opening new horizons for Astronomy. Today, new telescopes, such as Vera Rubin, GMT, and James Webb, promise to revolutionize studies by greatly increasing the available data. However, technological advances have also caused a growing number of satellites in Earth's orbit that interfere with astronomical observations by leaving trails as they pass in front of telescope lenses. Studies show that if launches continue, stars will be completely obscured within a few years. This work explores solutions to preserve the clear sky and continue astronomical discoveries. Our main result is the development of a technique called STAR-CLEAN that has the potential to completely mitigate interference in scientific observations.

1. INTRODUCTION

- Our eyes were the only instruments for study space;
- 1609: Galileo revolutionized astronomy;
- New telescopes will bring great scientific advances;
- Analyzing large amounts of data will be a major challenge;
- Satellites create new obstacles for observation.

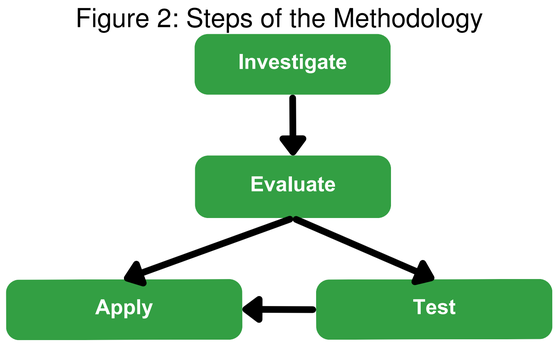
Figure 1: Bright trails left by Starlink satellites visible in the wide field of view, captured by Cerro Tolo.



Source: University of Illinois Grainger College of Engineering (2022).

2. METHODOLOGY

Figure 2: Steps of the Methodology



Source: The Authors (2025).

1. Possible solutions to the problem were investigated;
2. The pros and cons of each approach were evaluated;
3. The most suitable solution for our reality has been identified to deepen its study.

3. RESULTS

The possible solutions are shown in Table 1 and are explained afterward.

Table 1: Possible solutions

Solutions	Description
1	Prevent satellite launches
2	Divert telescope lenses
3	Software to minimize damage
4	Trail removal by snapshots

Source: The Authors (2025).

Solution 1: Prohibiting new launches or removing existing satellites is unfeasible due to the impact on essential services and the high financial cost of this solution.

Solution 2: Moving telescopes to satellite-free areas is financially unfeasible and extremely complex, with the difficulty increasing as more satellites enter orbit (Vance & Mense, 2013).

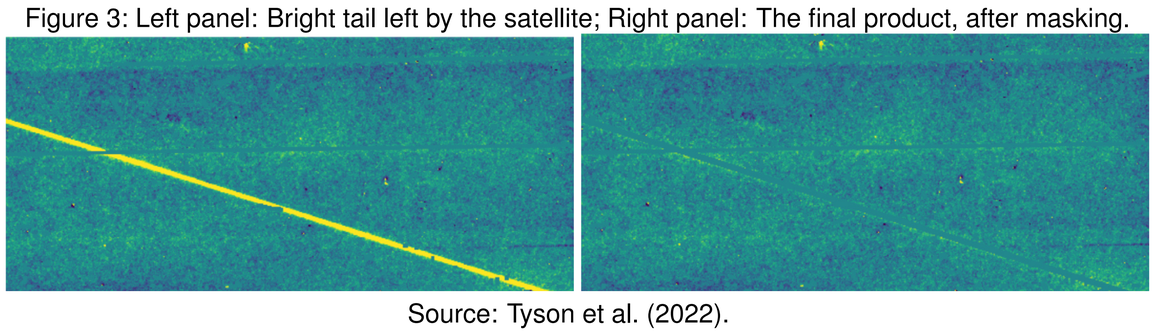
Solution 3: (Fig. 3): A viable solution, both economically and in terms of ease of application, but with the limitation that all information beneath the trail is lost (Hainaut & Williams, 2020; Tyson et al., 2020; Walker et al., 2020).

Solution 4: (STAR-Clean): The best solution, as it removes nearly all of the satellite trail and ensures data integrity and full visibility during observations, although it cannot be applied to all types of telescopes.

The STAR-Clean method is described in three stages:

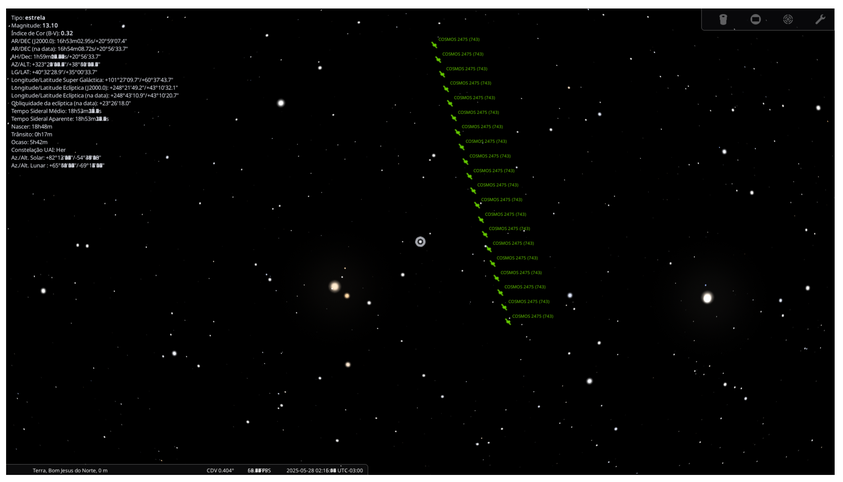
1. Creation of the Contaminated Image with Satellite Trail;
2. Identification and Removal of the Trail;
3. Merging for Star Recovery.

Figure 3: Left panel: Bright tail left by the satellite; Right panel: The final product, after masking.



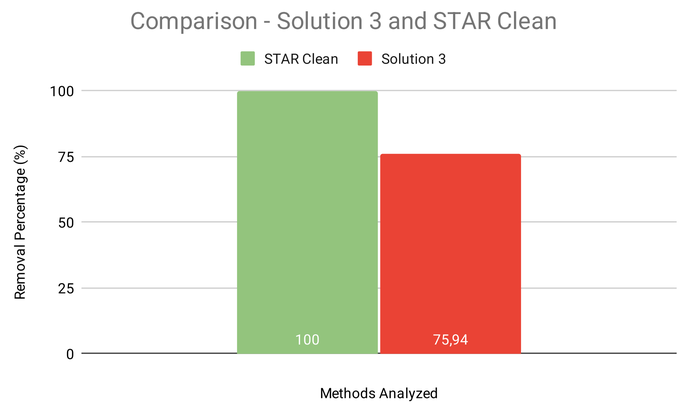
Source: Tyson et al. (2022).

Figure 4: Top panel: Complete trail from Satellites. Bottom panel: Exported image from STAR-Clean algorithm.



Source: Top panel: Screenshot of Stellarium (Zotti & Wolf, 2023); Bottom panel: STAR-Clean (2025).

Figure 5: Comparative Graphic between Solutions 3 and 4.



Source: The Authors (2025).

4. CONCLUSION

Although satellite interference remains an unfeasible limitation, it should continue to be regarded as a long-term goal. Currently, **Solution 3** is the most widely applied approach due to its practicality and ease of implementation. However, new techniques should be continuously tested to enhance data recovery and reduce observational losses.

With the development of **Solution 4** (STAR-Clean) and its ability to remove nearly all satellite streaks, this method shows strong potential to become the most adopted in the near future, particularly for telescopes where continuous image tracking allows for its effective application. Such advancements are essential to ensure the continuity of astronomical observations, the integrity of scientific data, and the long-term protection of the night sky for future discoveries.

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