The Impact of Satellite Constellations on Solar System Science with LSST

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ABSTRACT: With an estimated 400,000 satellites being launched into Low and Medium Earth Orbit (LEO, MEO) over the next years, astronomical surveys like LSST may suffer data loss. This project aims to assess the loss of Solar System Object (SSO) discoveries for the Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) as a result of bright satellite trails from LEO satellite constellations such as Starlink and OneWeb. Our simulations show that during a month of the LSST survey, about 0.1% of observations are directly obliterated due to trails of ~30,000 Starlink V2 satellite, even if providers follow recommendations to limit brightness to below 7th mag. As at least 6 observations of the same object are required for discovery, the predicted discovery loss rate is about 6% for the planned 400,000 satellites per month or about 0.15% per 10k satellites per month.

INTRODUCTION

This project aims to quantify the data loss for Rubin Observatory's Legacy Survey of Space and Time (LSST) from artificial satellite constellations, namely SpaceX's Starlink V1 & V2, and OneWeb. With an estimate of over 400,000 satellites to be launched in the near future, as estimated by the IAU Centre for the Protection of Dark and Quiet Sky From Satellite Constellation Interference (IAU CPS), their bright trails can lead to loss in pixel data and systematic errors in LSST camera sensors. This preliminary estimation is done with the assumption of no mitigation effects implemented as mentioned in Tyson et al. (2020), like satellite-avoidance scheduling schemes or application of black diffuse applique on originally white satellite surfaces. One such mitigation strategy is investigated by Hu et al. (2022), which aims to adjust Rubin Observatory's scheduler algorithm to avoid satellites and their trails, discovering that adding dodging weights to the satellite avoidance algorithm can effectively reduce the amount of satellite trails by a factor of 2 as well as improve pixel loss, with a trade-off of 10% decrease in LSST observing time. Increasing night sky brightness leads to increasing exposure time required to achieve the desired signal to noise ratio (S/N), which in turn requires higher cost. A measure of this phenomenon of was demonstrated by Barentine et al. (2023).

We simulate Starlink V2 like constellation by propagating TLEs and checking each satellite against each field of the LSST. Making use of simulated detections for Solar System Objects following the Pan-STARRS Synthetic Solar System Model (S3M, Grav et al. 2011) we check if any observation lies within a 3 arcsecond distance from the satellite's trail. Earth shadowing is accounted for. As each SSO requires a minimum of 6 observations be discoverable, the loss of even one observation could lead to LSST missing to report the object.

RESULTS

Observations coinciding with satellite trails are demonstrated in Figure 1.

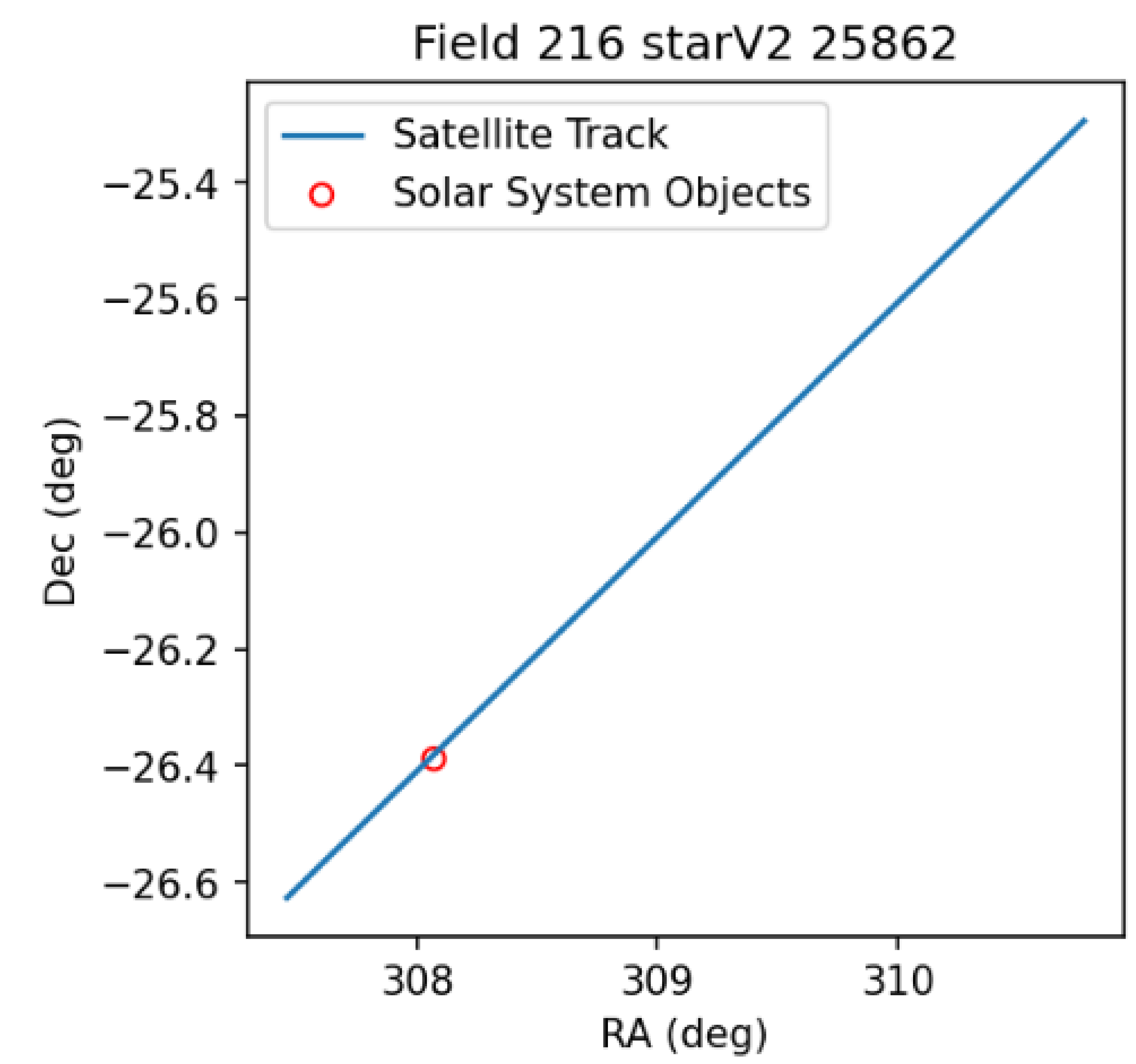

Figure 1: An example of a Solar System Object as observed by LSST coinciding with a simulated Starlink satellite track.

For Starlink V2 i.e 29,988 satellites propagated against the first 20,000 LSST fields, which corresponds to about 29 days, we discover that a total of 836 observations are affected, i.e about 0.1% of all observations. Transforming and projecting these affected observations in the topocentric frame of LSST is depicted in Figure 2.

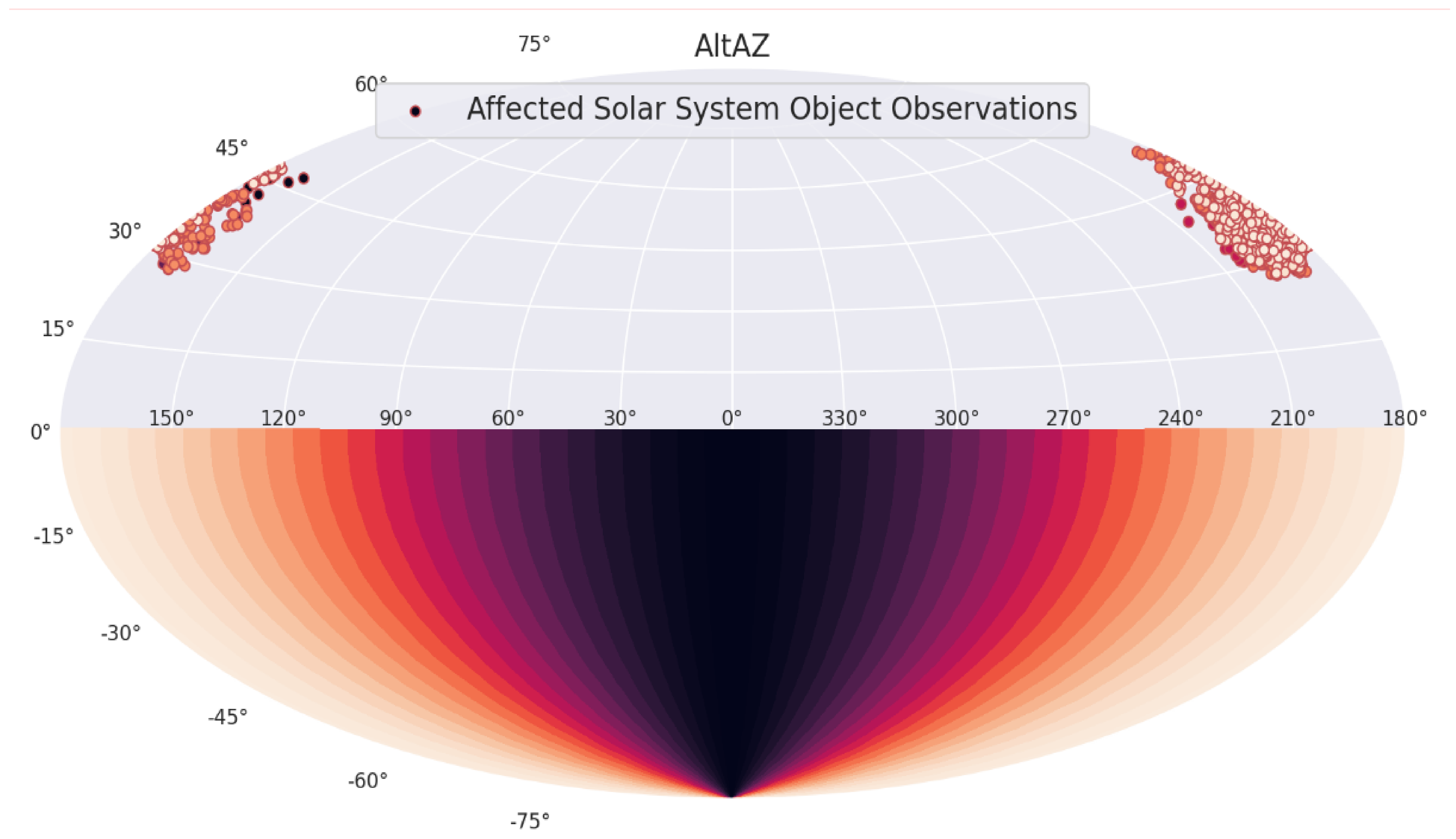

Figure 2: Affected LSST observations in the topocentric frame. Twilight detections of Solar System Objects are most strongly affected.

Affected observations plotted in ICRF are shown in Figure 3.

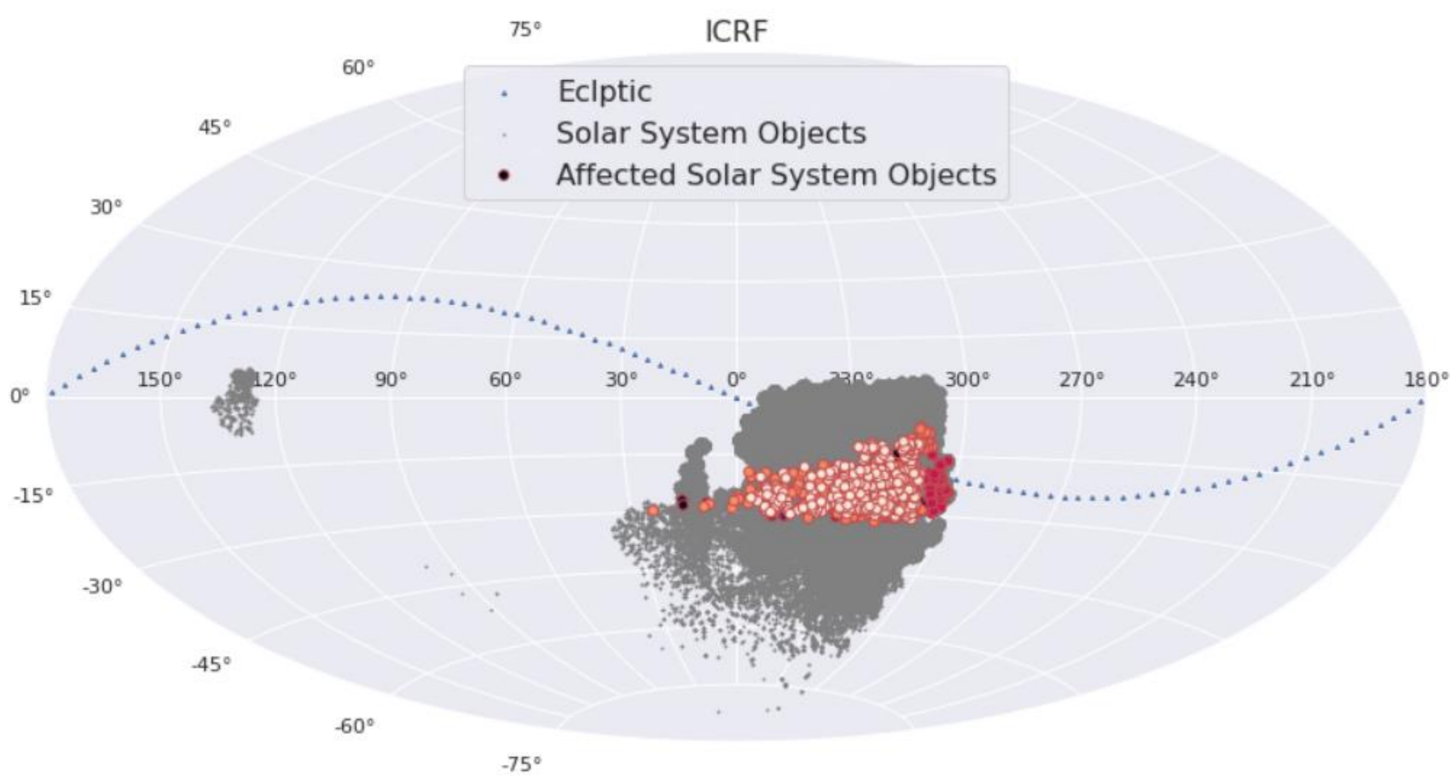

Figure 3: Affected LSST observations shown in ICRF.

FUTURE SCOPE

While these preliminary results check against the first 20,000 simulated LSST observations, the project is being extended to run across the entirety of the LSST duration and create a census of all affected observations and missed objects. This analysis will be repeated for the entirety of the Starlink constellation as well as the OneWeb constellation. It is estimated by IAU CPS that over the next ten years the number of satellites in LEO may reach up to over 400,000; hence we will also analyze a worst-case scenario by simulating 400,000 satellites and measure its impact on SSO data loss with LSST.
The results of these simulations aim to inform mitigation strategies and provide an assessment of which populations are most affected. This is important for future SSO models and debiasing schemes. The fidelity of this model can also be improved by better modeling the satellite brightness and its effects on the trail width for LSST.

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