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Plasma Signatures of Space Objects Observed by the Arase Satellite

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The Intelligence Advanced Research Projects Activity (IARPA) Space Debris Identification and Tracking (SINTRA) program aims to develop a next-generation capability to detect, track, and characterize small space debris (<10 cm). Although small space debris can cause mission-ending damage, only objects larger than 10 cm can be reliably and persistently tracked with current capabilities. Our role in the SINTRA program is to investigate the feasibility of a novel methodology wherein objects are detected and characterized from the perturbations they produce in the plasma of Earth's space environment. The initial focus is on plasma waves excited by a "generator" object in low earth orbit and seen by in situ measurements from a nearby "detector" satellite. A handful of such observations from the Swarm-E/CASSIOPE satellite have been published [1]. However, it is not yet clear in general what conditions allow these plasma waves to be generated and how frequently they could be detected. We are analyzing a large amount of data from JAXA's Arase satellite to form a more complete picture. As a first step towards the eventual goal of detecting and characterizing untracked small space debris, we are associating observed plasma signatures with currently tracked space objects. For a number of months in 2018, we have identified conjunctions between Arase and every object in the Space-Track database and are analyzing the corresponding measurements from Arase's electric and magnetic field probes.

To facilitate this analysis, we have automated the data processing procedure to find conjunctions and store the corresponding Arase observations. Given its primary scientific mission of studying the radiation belts, Arase is in a highly elliptical orbit. Each time Arase passes through perigee (every ~9 hours), it spends about 15 minutes at altitudes below 1000 km in the plasma of the ionosphere, during which time tens of conjunctions <300 km occur with Space-Track objects. For each perigee pass, we store information on the conjunction geometry, ancillary variables (Earth's magnetic field from IGRF and electron density from IRI), and Arase observations. The Arase observations used are the level 2 onboard frequency analyzer (OFA) measurements of electric (10 Hz to 20 kHz) and magnetic (1 Hz to 20 kHz) field spectra, the level 3 OFA wave property data, and the plasma density derived from the high frequency analyzer (HFA) measurements.

In this presentation, we will show several case studies of plasma waves associated with close conjunctions as well as the statistical results of aggregating hundreds of perigee passes in 2018. The case studies show that the plasma waves occur during conjunctions with a variety of objects (large satellites, CubeSats, and small pieces of debris, for example) and exhibit a variety of characteristics consistent with different wave types. The statistical results give a more complete picture of the relationship between conjunction distance and enhancement in the electric and/or magnetic field spectrum. The statistical results are further categorized by the generator radar cross-section (a proxy for object size), generator motion relative to Earth's magnetic field, and more. Finally, we will give our current assessment of what characteristics (range, size, etc.) of unknown objects could be gleaned from these types of observations and how they might feed into an orbital debris tracking system.

References

[1] P. A. Bernhardt, L. Scott, A. Howarth, and G. J. Morales, "Observations of plasma waves generated by charged space objects," Physics of Plasmas, vol. 30, no. 9, p. 092106, Sep. 2023, doi: 10.1063/5.0155454.