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Orbital Resonances and Averaging in the Motion of Satellites

Abstract. Many physical systems can be modeled as having an underlying dynamical skeleton that organizes and governs how all the possible behaviors are related. The global properties of multidimensional, nearly integrable Hamiltonian systems are determined by the relative location and size of the predominant resonances. The dynamical model governing satellite motion (assuming non-commensurate orbital frequencies) is referred to in the astrophysical and celestial dynamics communities as the quadrupolar, secular, hierarchical restricted four-body problem with an oblate primary. In the non-autonomous case, this model degenerates to either the classical Kozai-Lidov mechanism or the critical inclination resonances. In the time-dependent model, brought about in this case by the Moon's perturbed motion, secular resonances involving the frequencies of perturbed motions become woven throughout the inclination, eccentricity, and semi-major axis space in an exceedingly complicated web-like structure, emanating from the classical critical inclinations. In this talk, I will review this 2.5 degree-of-freedom Hamiltonian system from both a Gauss averaging and Laplace-Lagrange secular theory perspective.

It is the structure of the satellite and the nature of its orbit that determine which perturbations are significant and which are negligible. In this sense, every distinct problem conditions its particular scheme of computation, and many refinements, sometimes reducing the always elaborate calculations in a marked degree, depend on a careful examination of the dynamical situation. I will show the breakdown of our basic dynamical model in the presence of resonances of a non-secular origin and close encounters with the Moon.

Bio. Aaron J. Rosengren is an Assistant Professor in the College of Engineering at the University of Arizona and Affiliate Member of the Interdisciplinary Program in Applied Mathematics, specializing in astrodynamics-based space situational awareness. In his first year at UA, he received the "Junior Faculty Award for Excellence at the Student Interface" in recognition of his teaching efforts. Prior to joining UA and the SSA-Arizona Initiative in 2017, he spent one year at the Aristotle University of Thessaloniki in Greece working in the Department of Physics, as part of the European Union H2020 Project ReDSHIFT. He has also served as a member of the EU Asteroid and Space Debris Network, Stardust, working for two years at the Institute of Applied Physics Nello Carrara of the Italian National Research Council. He held visiting researcher positions at both the University of Rome Tor Vergata in Italy and the Belgrade Astronomical Observatory in Serbia. His research interests include space situational awareness, orbital debris, celestial mechanics, and planetary science. He twice received the "COSPAR Outstanding Paper Award For Young Scientists" and his recent manuscript co-authored with J. Daquin and colleagues was nominated by Springer-Nature as one of the "180 groundbreaking articles that could help change the world."