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Titan and Saturn Atmospheric Occultation Experiments using Analytical Ray-Tracing

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The Cassini S/C, which terminated its mission on September 15th 2017, led to many scientific discoveries during its crossing through the Jovian system and its tour of the Saturn system. For instance, let us mention the geological discoveries of the Enceladus' water plumes, Titan's hydrocarbon lakes or the torus of gas on the Jovian orbit of Europa. Additionally, let us mention that the last close approach orbits during Cassini's grand finale have revealed the tremendous complexity of Saturn's gravity field which exhibits a time-variable component. The Juno mission is currently probing the Jovian system since July 2016 and has already revealed many novelties, too. One of them is the North-South asymmetry of Jupiter's gravitational field but also the large-scale structure of Jupiter's atmospheric jet streams which would extend thousands of kilometers deep. All these examples spotlight the outstanding complexity represented by an accurate modeling of the internal structure of the two gas giants. In this context, radio occultation experiments are crucial tools to constrain the planets' interior models. Indeed, by determining density, pressure, and temperature profiles in the high atmosphere, atmospheric occultation experiments provide also initial conditions of internal structures' models. However, because of the procedures which are usually employed, it is challenging to associate errors to these initial conditions, yet they determine the uncertainty in the evolution of the models.

In this context, we discuss the benefit of a new formalism based on a full reformulation of the fundamental equations of optics for processing atmospheric occultations data. This recently proposed new approach provides a very comprehensive description of the light path as well as the light time while crossing a planetary atmosphere. In addition, it determines directly the errors since it provides analytical relations between the observables and the physical parameters. We use this new formalism to process Cassini's Doppler data acquired during occultations by Titan's spherical atmosphere and by Saturn's oblate atmosphere. The validity of the proposed approach is assessed by comparing the results with previous studies available in the literature.