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An analytic orbit model of Saturn's F ring strands

N. Albers and M. Sremčević
LASP, University of Colorado at Boulder, 392 UCB, Boulder, Colorado 80309-0392, USA (Nicole.Albers@lasp.colorado.edu / Fax: +1-303-492-6946)

Abstract

One aspect of Saturn's F ring's dynamic appearance are the F ring strands. Winding around the ring's wiggly core as a kinematic spiral [3], these rather tenuous filaments most likely originate from a violent collision [2]. The encounters may in principle occur between larger objects within the F ring, or between a distinct and possibly external object and the F ring core. The impact event will surely leave a characteristic dynamical trace in the appearance and distribution of the strand's orbital elements. Our goal is to develop an orbital model of the F ring strands, and using more than hundred of Cassini UVIS occultations to determine the model orbital parameters. These orbital parameters will then be used to constrain the impact origin of the strands. In this paper we present the analytical orbital model of F ring strands and initial data comparison.

Strand's orbit model

The F ring core is surprisingly well-described with a freely-precessing inclined ellipse [1]. Deviations from this simple ellipse are on the order of 10-20km and most likely due to the two shepherds: Prometheus and Pandora. This result suggests that strand particles are likewise well-described with a simple set of nearly constant elliptic orbital elements. Individual particles, however, must have different elliptic elements, since otherwise no spiral pattern would appear. Thus we envision the strand orbit model as a continuous distribution of elliptic elements. In practice we assume that the strand's semimajor axis is the only free variable. Then, all other parameters, such as orbital frequencies (mean motion $n = d\lambda/dt$, apsidal precession $\dot{\varpi}$ and nodal precession $\dot{\Omega}$), shape parameters (eccentricity e, inclination i), and angular elements (mean longitude λ, longitude of pericenter ϖ and longitude of ascending node Ω) are solely functions of semimajor axis a, or in practice low order polynomials of a. The orbital frequencies are calculated from standard theories (e.g. [4]). Eccentricity is, for instance, $e(a) = e_0 + e_1 a + e_2 a^2$. The mean longitude λ, longitude of pericenter ϖ and longitude of ascending node Ω are modeled as $X(t, a) = X_0 + \dot{X}(a)(t - t_x)$, where X stands for any of $(\lambda, \varpi, \Omega)$. The epochs of the angles are kept independent $(t_\lambda \neq t_\varpi \neq t_\Omega)$, thus allowing for greater complexity. We note that t_λ can be interpreted as the strand creation time as this denotes the only instance in time at which all particles share the same longitude. Then t_ϖ denotes apsidal alignment, which is not necessarily equivalent to t_λ. Our strand orbital model is described with less than dozen parameters (e.g. e_0, e_1, e_2, λ_0, t_λ, ...) which will be constrained from occultations.

Figure 1 shows an example of a potential F ring strand as seen by different idealistic observations. These observations can be described as: *System Snapshot* (upper panel), *Panorama* (middle panel), and *Particle-Tracking* observations (bottom panel). In particular: A *System Snapshot* is an instantaneous image of the entire F ring. Unfortunately, this is not obtainable. A *Panorama* is the observation mode currently used by the Cassini ISS Team and presented in [3]. In this case the camera is staring at a constant inertial longitude while the F ring moves through the field of view due to its orbital motion. In the case of a *Particle-Tracking* observation the camera is following the ring's orbital motion and illustrates individual Keplerian ellipses.

As shown in Fig. 1 our model reproduces the typically observed kinematic spiral of the F ring strands. Interestingly, it is rather difficult *not* to obtain a spiral pattern in the *Panorama* observing mode.

We will discuss various scenarios and the possibility of distinguishing between these using occultation observations.

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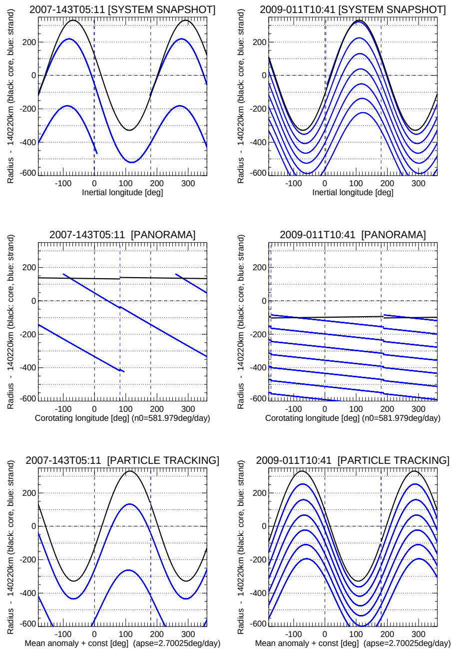

Figure 1: Evolution of a given strand. The images reveal the multiple faces of strands shortly after its creation (left panels) and two years later (right panels), each for one of the three ideal observation techniques described in the main text. F ring core and inner strand are marked in black and blue, respectively.

References

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