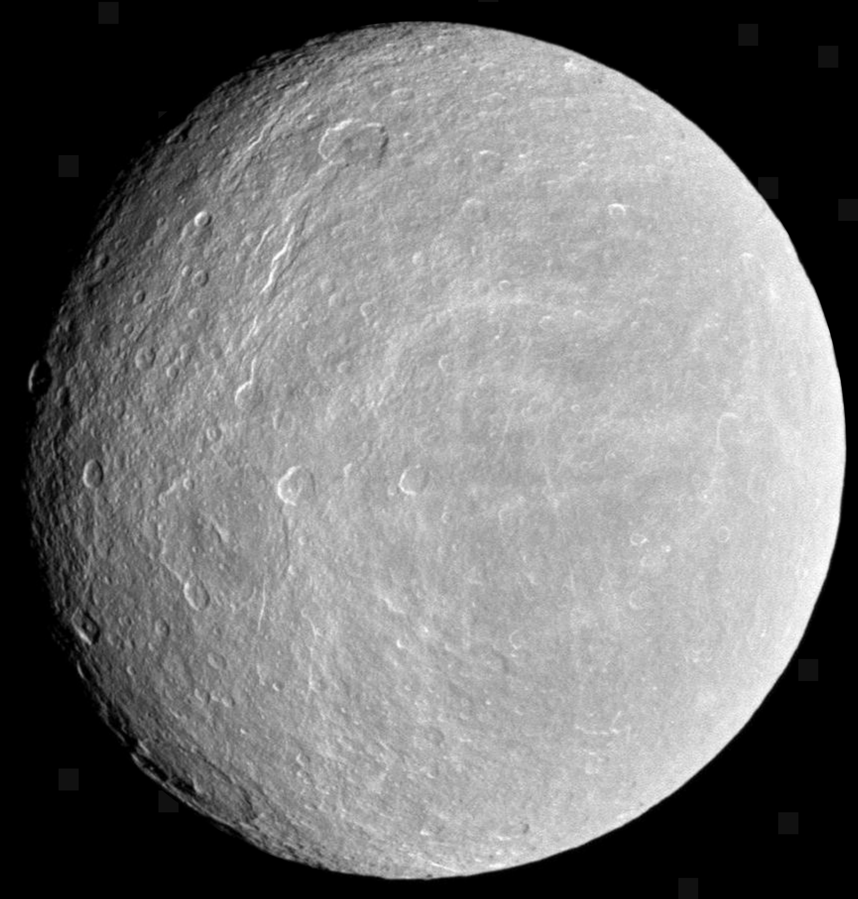

# Energetic ion observations on Rhea


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## Abstract

Cassini flew by Saturn's moon Rhea four times between 2005 and today. During two of these flybys MIMI/LEMMS energetic particle detector onboard Cassini detected significant reduction of energetic ion fluxes (20 keV - 300 keV) in vicinity of Rhea, which is probably caused by plasma absorption by the moon. The profile of the flux dropout shows differences in the different energy channels of LEMMS, primarily due to finite gyroradius effects. Other factors that contribute to the shape of the depletion profile are the properties of the background magnetospheric magnetic and electric fields, the structure of Rhea's interaction region, the ion composition and the response function of the different LEMMS channels.

Using the test-particle approach and taking into account all these factors, we model the motion the energetic particles in the Saturnian magnetosphere and simulate the observed depletion profile for R3 Rhea flyby.


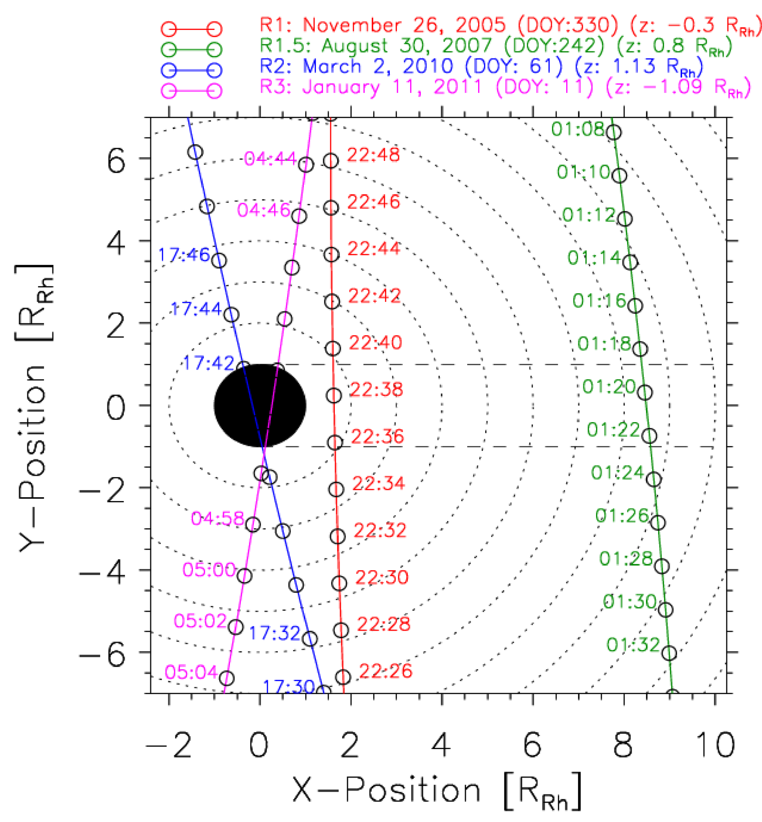


*Fig.1 Equatorial (xy) projection of the four Rhea flybys to date. (1)*

## Theoretical aspects

Motion of the charged particle in the planetary magnetic field is conditioned by combination of the cyclotron motion of the particle, bounce motion between mirror points and drift motion of the guiding center. Consequently, there are three main approaches how to model the motion of the charged particles, each of them is appropriate for different scientific goals:

(a) Full particle trajectory (b) Guiding-center approximation (c) Bounce-average approximation

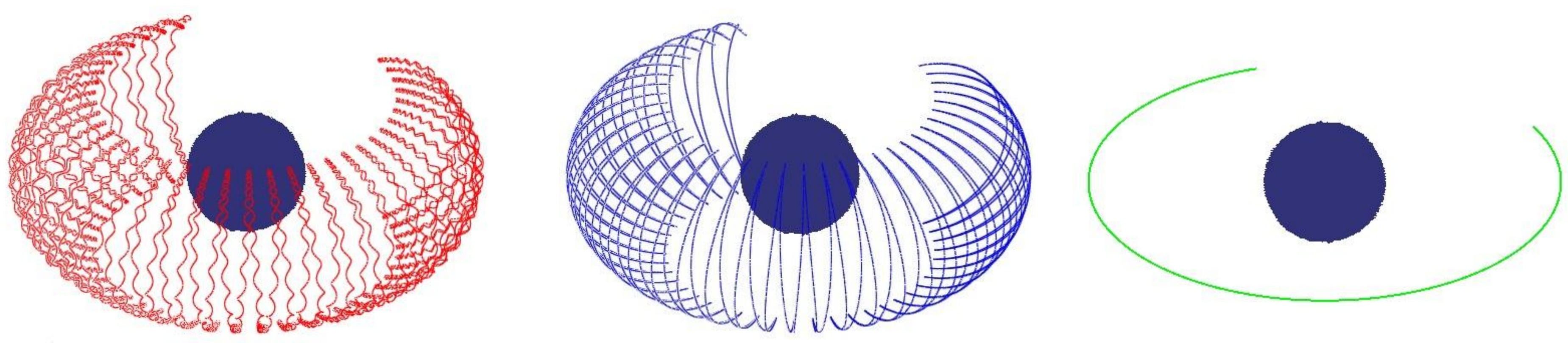

*Fig.2 Different methods of charged particle tracing.*

In addition particle drift motion depends on the characteristics of the planetary magnetosphere and might be influenced in the first place by:

1. Co-rotational and convectional electric field
2. Gradient and curvature drift

$$V_d = \underbrace{\frac{((\vec{R}\times\vec{\Omega})\times\vec{B})\times\vec{B}}{B^2} + \frac{\vec{E}\times\vec{B}}{B^2}}_{1} + \underbrace{\frac{W_\perp \vec{B}\times\nabla B}{qB^3} + \frac{2W_{//}\hat{r}_c\times\vec{B}}{qR_cB^2}}_{2} \qquad (1)$$

## Co-rotation electric field

In case of Saturnian magnetosphere, co-rotation electric filed plays most significant role for the motion of energetic ions.

$$\vec{E}_{corot} = -C_s\cdot\left(\vec{v}_{corot}\times\vec{B}_{dip}\right) \qquad (2)$$

where $\vec{v}_{corot} = \vec{\Omega}\times\vec{r}$ (3)

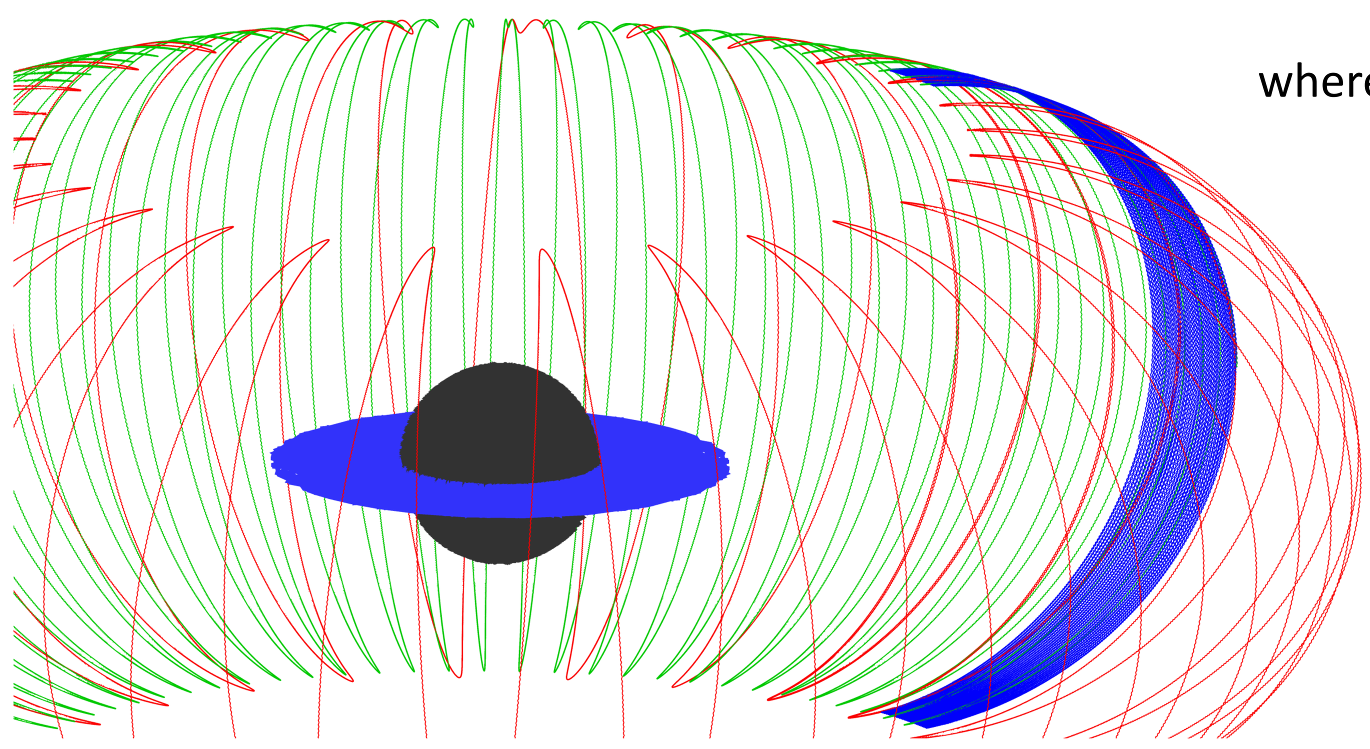

*Fig.3 Trajectories of an energetic ion (27 keV) in the magnetosphere of Saturn assuming dipole magnetic filed without electric field (blue line) and including the co-rotation electric field, with $C_s = 0.3$ (green line) and $C_s = 1$ (red line).*

## Observations by CASSINI

The figure below represents the differential intensities of the energetic ions detected by MIMI/LEMMS instrument during four Rhea flybys.

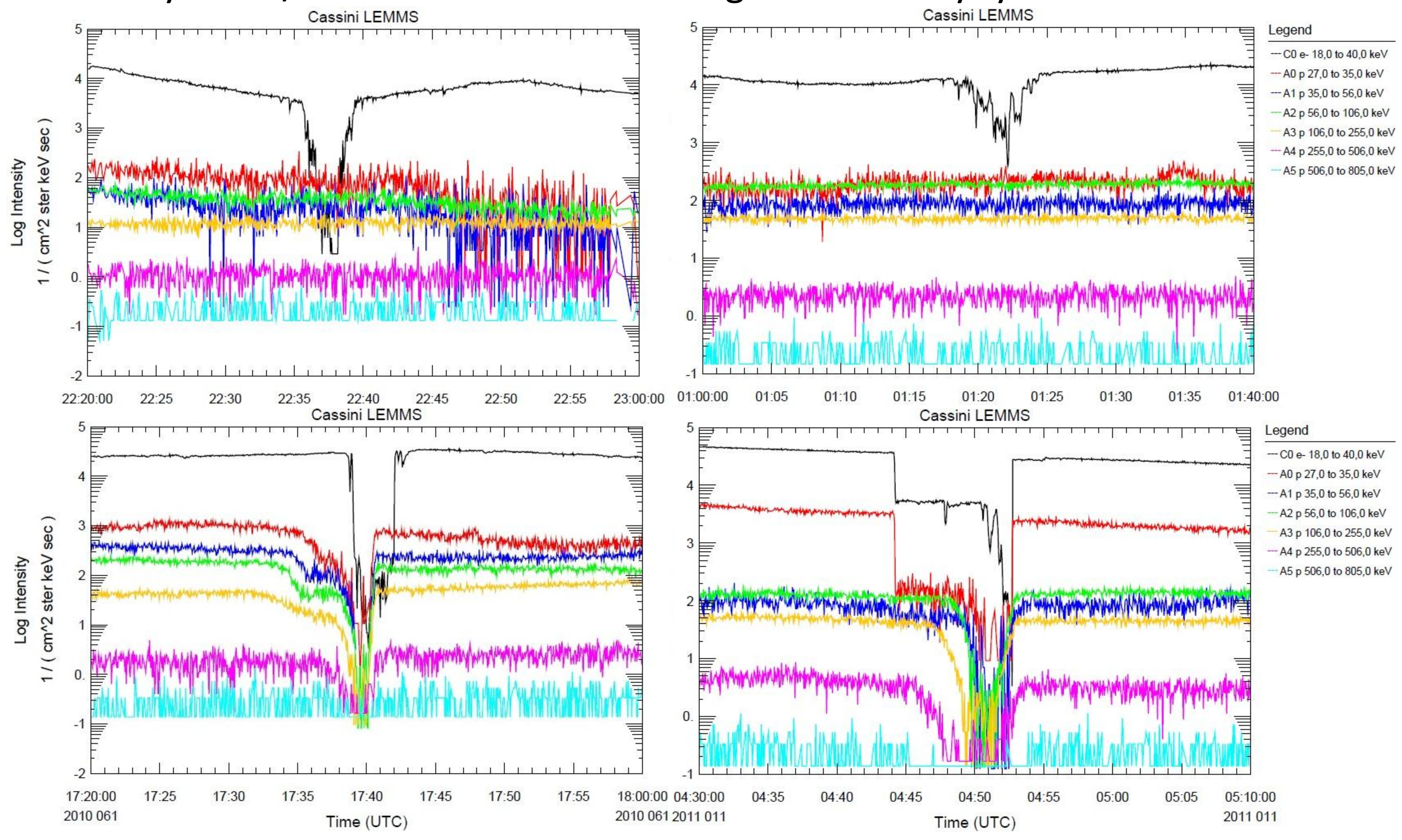


*Fig.4 Cassini LEMMS channels rate for the Rhea Flybys: R1, R1b, R2, R3 (from the top left corner). (2)*

### Simulation of the Rhea fly-by R3

We perform the backward-tracing of the energetic ions, using the full particle trajectory method, considering the dipole model of the Saturnian magnetic field and including the co-rotation electric field, in order to model the possible trajectories of the energetic ions in vicinity of Rhea and simulate the observed depletion in ions flux intensity for R3 Rhea flyby.
Here we consider the particles of energies, appropriate to the LEMMS channels A0, A1, A2, A3 and A4, which are distributed isotropically and omnidirectionally.

(5a) (5b) (5c)

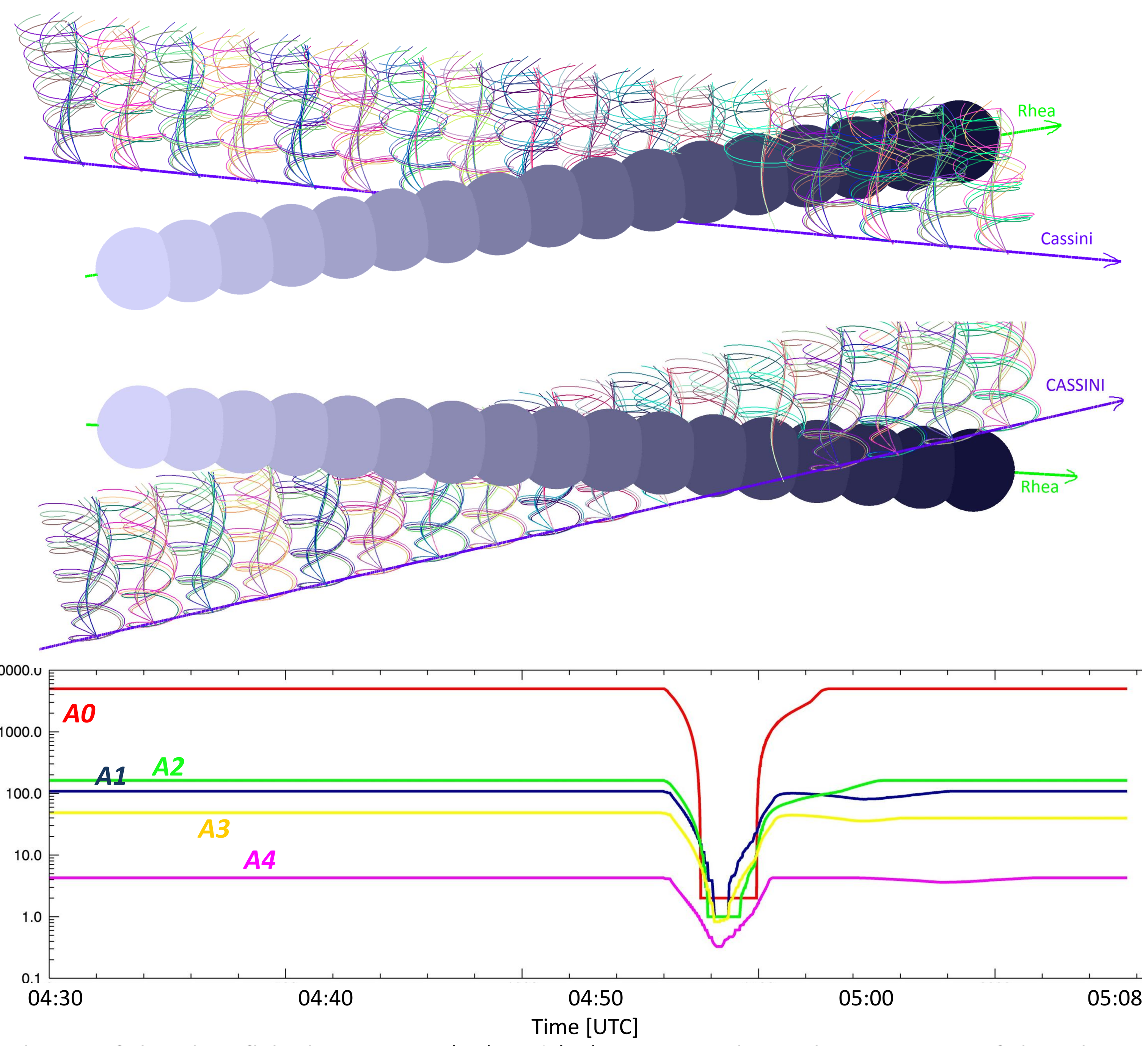


*Fig.5 Simulation of the Rhea flyby by CASSINI. (5a) and (5c) represent the evolution in time of the relative position of Rhea and CASSINI. (5c) represent the simulation of the differential intensity which might be measured by MIMI/LEMMS detector at this time.*

## Discussion of the results and future steps

We developed the working model for calculation of the charged particle trajectories in the planetary magnetosphere and applied it to Saturn for simulation of the Rhea flyby.
The next step will be inclusion of the pointing for MIMI/LEMMS and exploration whether non-dipolar effects and field time variations are important in shaping the ion profile, and we will also examine if LEMMS responds primarily to protons (as assumed until today) or to heavier ions.

## *References*


*(1) E. Roussos et al. Energetic electron observations of Rhea's magnetospheric interaction. Icarus. 2012*
*(2) MIDL - online data analysis tool of MIMI data*



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