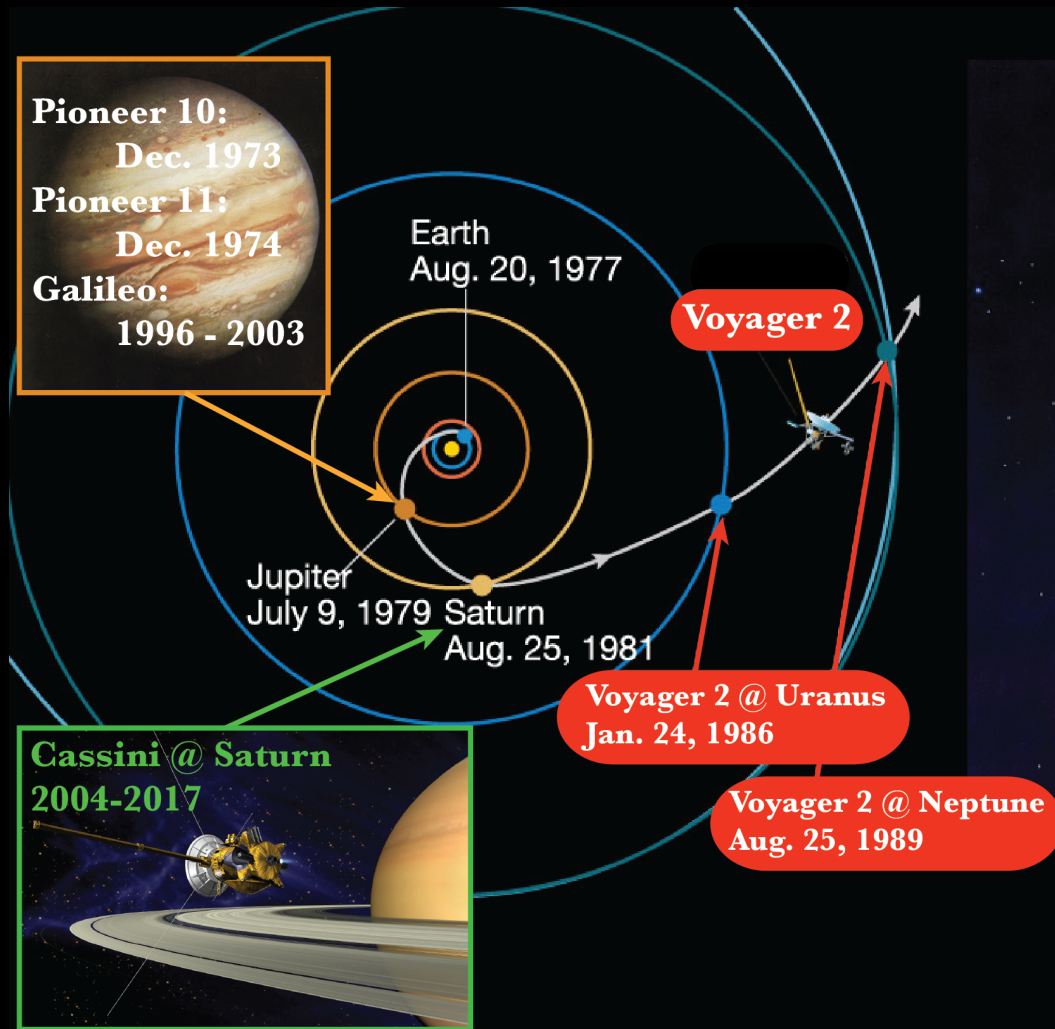# A new outlook at Uranus' and Neptune's 10 keV - 5 MeV energy electron distributions from data analyses and physics-based models

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- Discuss the role of different mechanisms within the magnetospheres of Uranus and Neptune.

- Data analysis and interpretation of Voyager 2's in-situ data are guided by a theoretical modeling of the energetic electron populations.

- We compare our preliminary results at Ice Giants with our current understanding of processes at play at Saturn.

MODELING APPROACH AND DATA SETS

We model the energy and spatial distributions of electrons in the different magnetospheres with the help of a diffusion theory particle transport code that solves the governing three-dimensional Fokker-Planck equation:
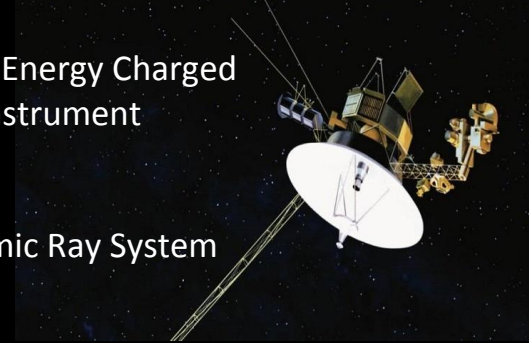
$$\frac{\partial f(J_1, J_2, J_3, t)}{\partial t} = (S) + (L) + \frac{1}{G}\frac{\partial}{\partial L}\left[GD_{LL}\frac{\partial f(M, J, L, t)}{\partial L}\right]_{M,J}$$
$$- \frac{1}{G'}\sum_{i=1,2}\frac{\partial}{\partial Q_i}\left[G'\left(\frac{dQ_i}{dt}\right)f(E, y, L, t)\right]$$
$$+ \frac{1}{G'}\sum_{i,j=1,2}\frac{\partial}{\partial Q_i}\left[G'D_{ij}\frac{\partial f(E, y, L, t)}{\partial Q_j}\right] \quad (1)$$
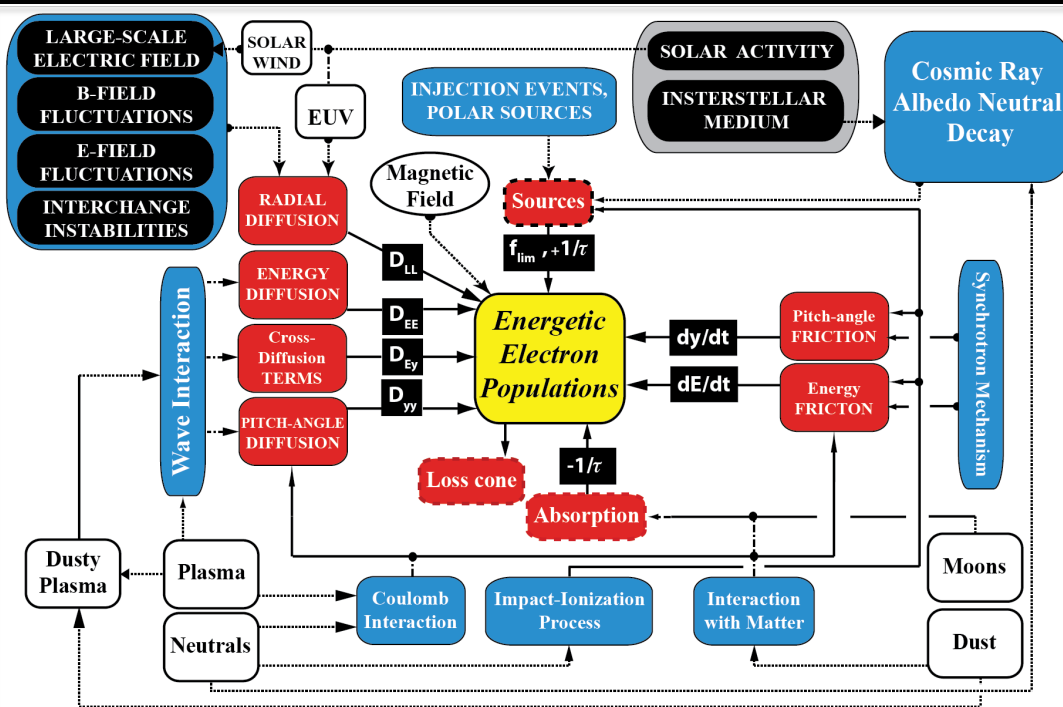
Theoretical approach for our three-dimensional modeling of electron populations at outer planets.

VOYAGER 2 DATA SETS FOR OUR STUDY:

- from magnetometer (MAG)

- from Low Energy Charged Particle instrument (LECP)

- from Cosmic Ray System (CRS)
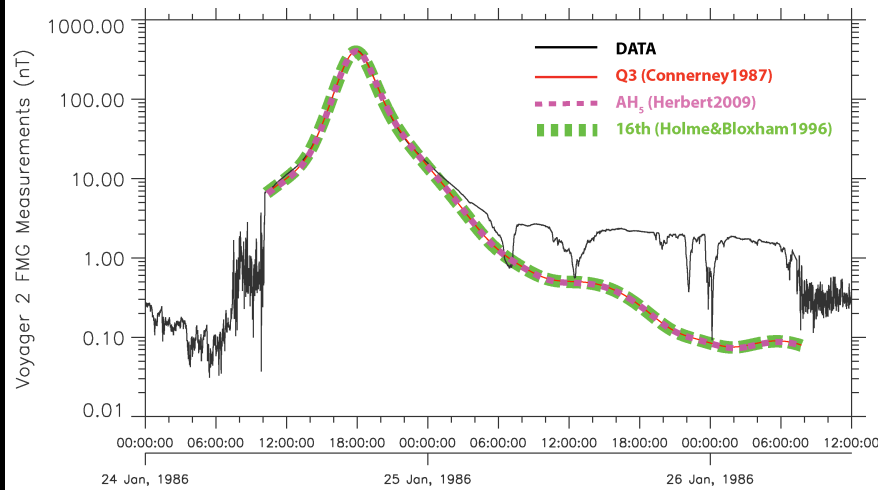
- from Plasma Wave Subsystem (PWS)

CASSINI DATA SETS FOR OUR STUDY:

- from magnetometer (MAG)

- from Electron Spectrometer (CAPS/ELS)

- from Low-Energy Magnetospheric Measurements System (MIMI/LEMMS)

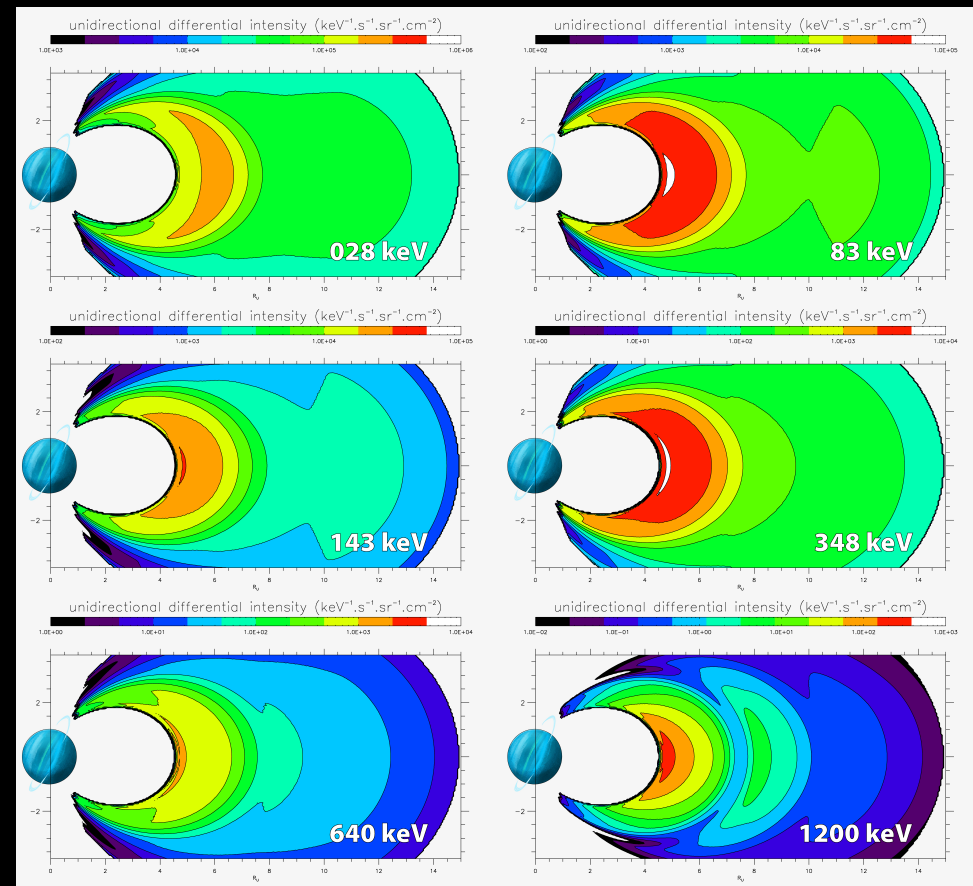- from Radio & Plasma Wave Science instrument (RPWS)
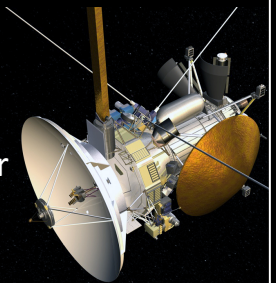
Left-hand panel: Magnitude of magnetic field (48-s averages) and comparisons with magnetic field models. The Q3 model is used in the present work.
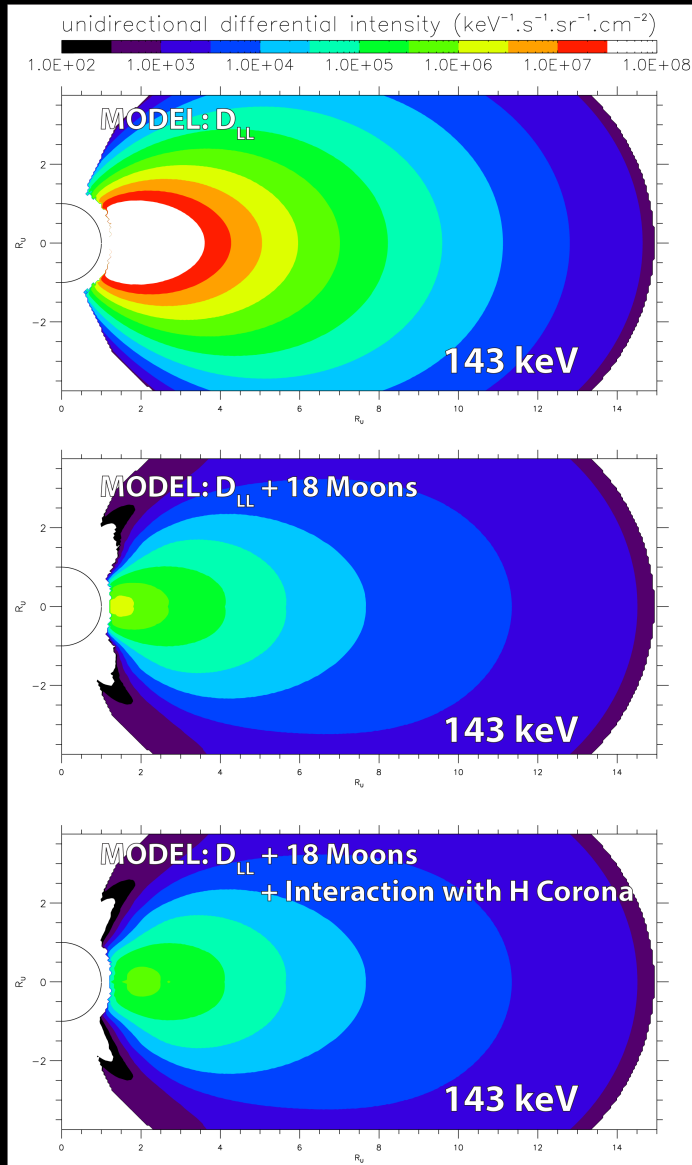

after *Santos-Costa, "Reappraising the Distributions of Energetic Electrons at Jupiter, Saturn and Uranus from Data Analyses and Physics-based Models", Earth and Space Science Open Archive, doi: 10.1002/essoar. 10505829.1, 2021*

Right set of panels: Meridian profiles of the Uranian energetic electron population inferred from in-situ data (after Mauk et al., 1987; Selesnick and Stone, 1991; Garrett et al., 2015). Note that there is an absence of data inside ~4.2 R_U that prevents to empirically model the charged particle environment close to the planet.

Left set of panels: Simulated meridian profiles of the Uranian energetic electron population when model accounts only for radial diffusion (top), radial diffusion and sweeping effect by 18 moons (middle), and all previous processes + interaction with H corona (bottom).

Bottom right panels: Comparisons between data and simulations along Voyager 2's trajectory for different LECP energy channels. Three sets of model results are discussed for each energy:

1. Radial diffusion D_{LL}
2. D_{LL} + sweeping effect by 18 moons
3. D_{LL} + sweeping effect by 18 moons + interaction with H corona
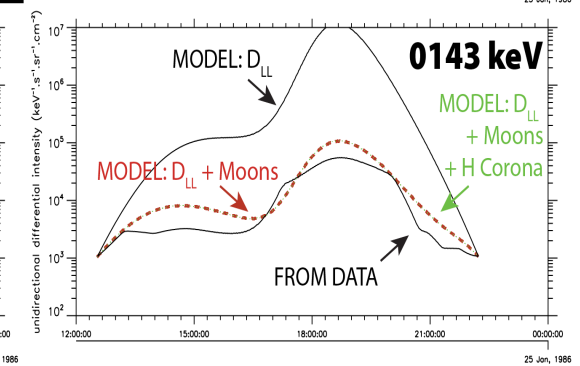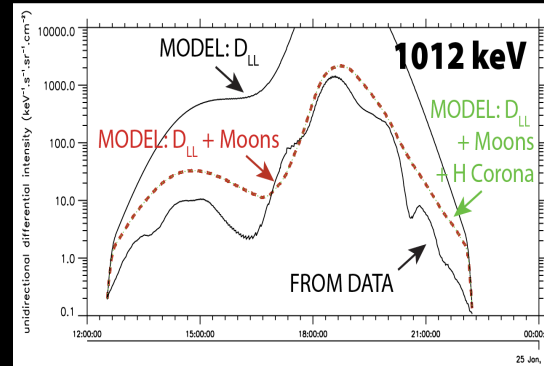
INVESTIGATING NEPTUNE'S ENERGETIC ELECTRON POPULATIONS (1/1)

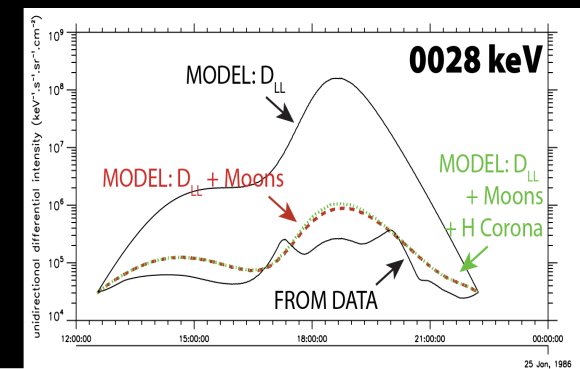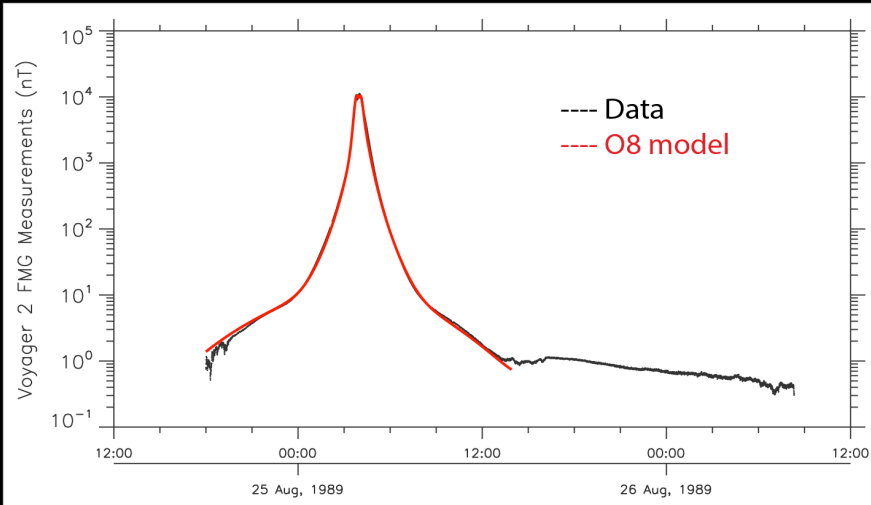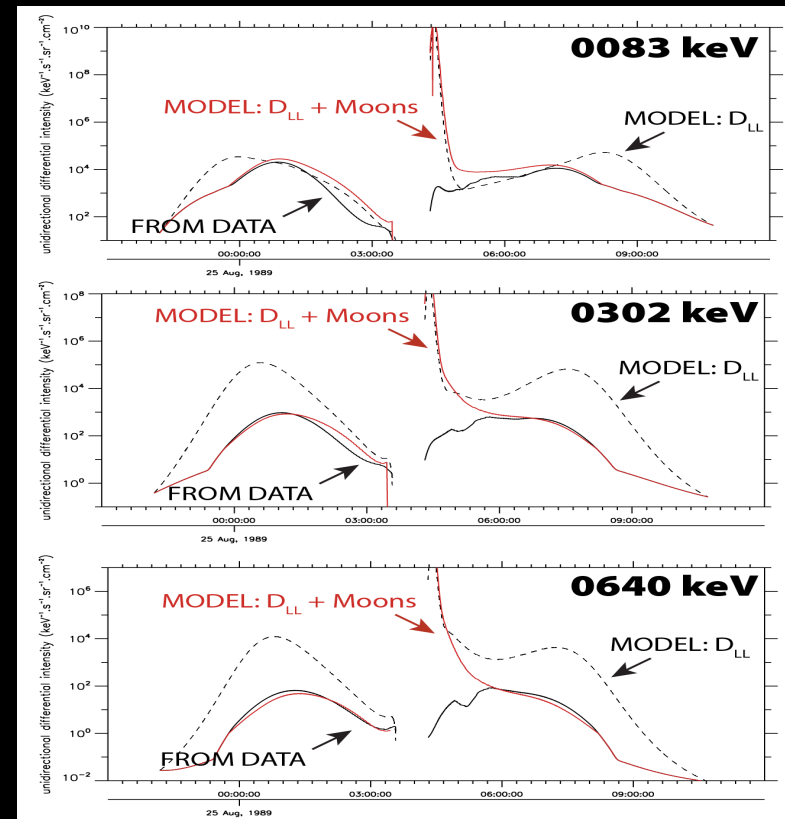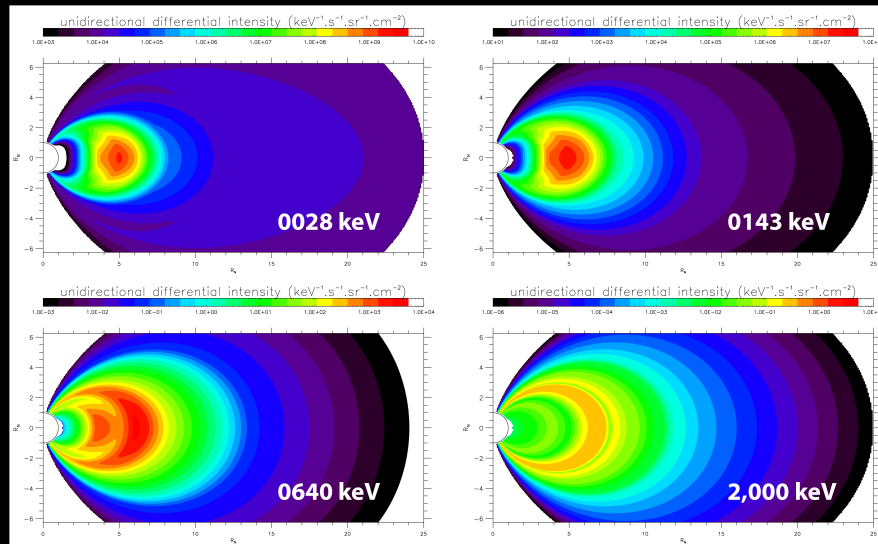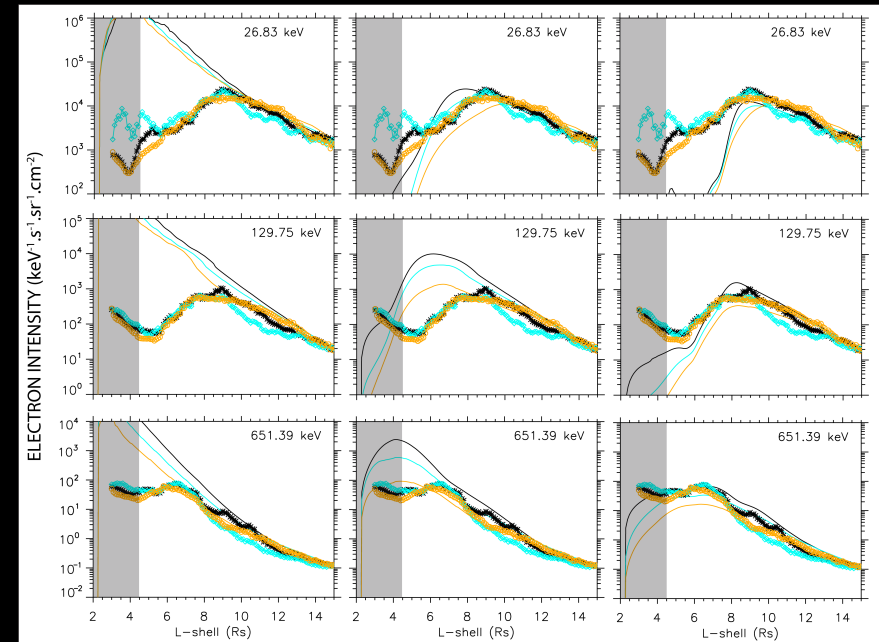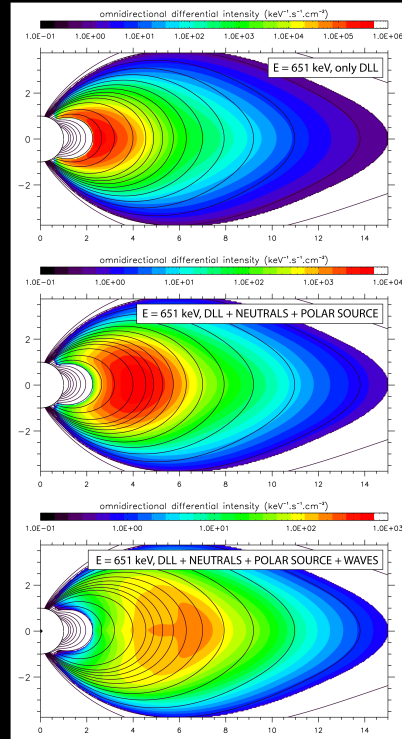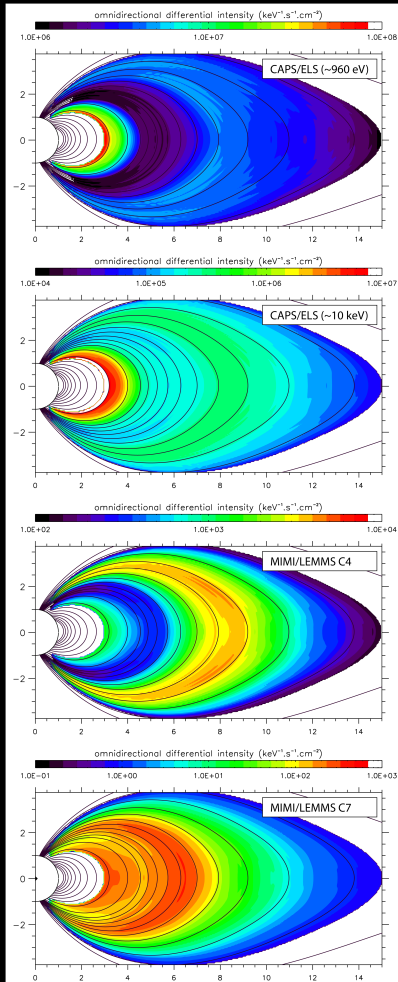**Left-hand panel:** Magnitude of magnetic field (48-s averages) and comparison with magnetic field model. The O8 model is used in the present work (Connerney et al., 1991). **Lower left panels:** Meridian profiles of Neptune's energetic electron population inferred from in-situ data (after Mauk et al., 1991; Stone et al., 1989; Garrett & Evans, 2017). **Below panels:** Samples of simulation results demonstrating the coupled role of radial transport and moon sweeping effect.

Left set of panels: Samples of mission-averaged data for different energy channels of CAPS/ELS and MIMI/LEMMS instruments. **Middle set of panels:** Samples of simulations results with different processes taken into account. **Right set of panels:** Samples of comparisons between MIMI/LEMMS data and models when simulations included only radial transport (left-hand panels), combined radial diffusion with interaction with neutrals and a polar source (middle panels), and accounted for all previous mechanisms + wave interaction (right-hand panels). Symbols are used to display the data. Black color is used to display radial profiles for 80^0, cyan for 40^0, and orange for 20^0 pitch-angle.

after *Santos-Costa, "Reappraising the Distributions of Energetic Electrons at Jupiter, Saturn and Uranus from Data Analyses and Physics-based Models", Earth and Space Science Open Archive, doi: 10.1002/essoar.10505829.1, 2021*