Preliminary results from a new model of the Io torus, fed by the two *Juno* fly-bys of Io

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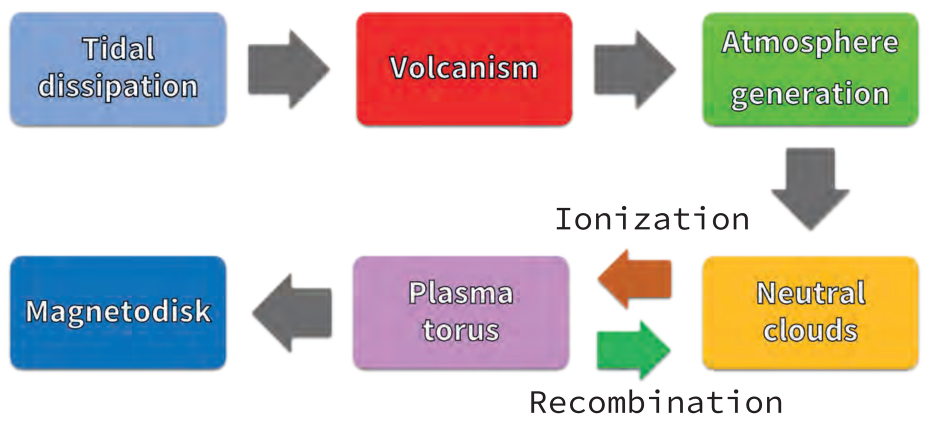
WHAT IS THE IO TORUS?

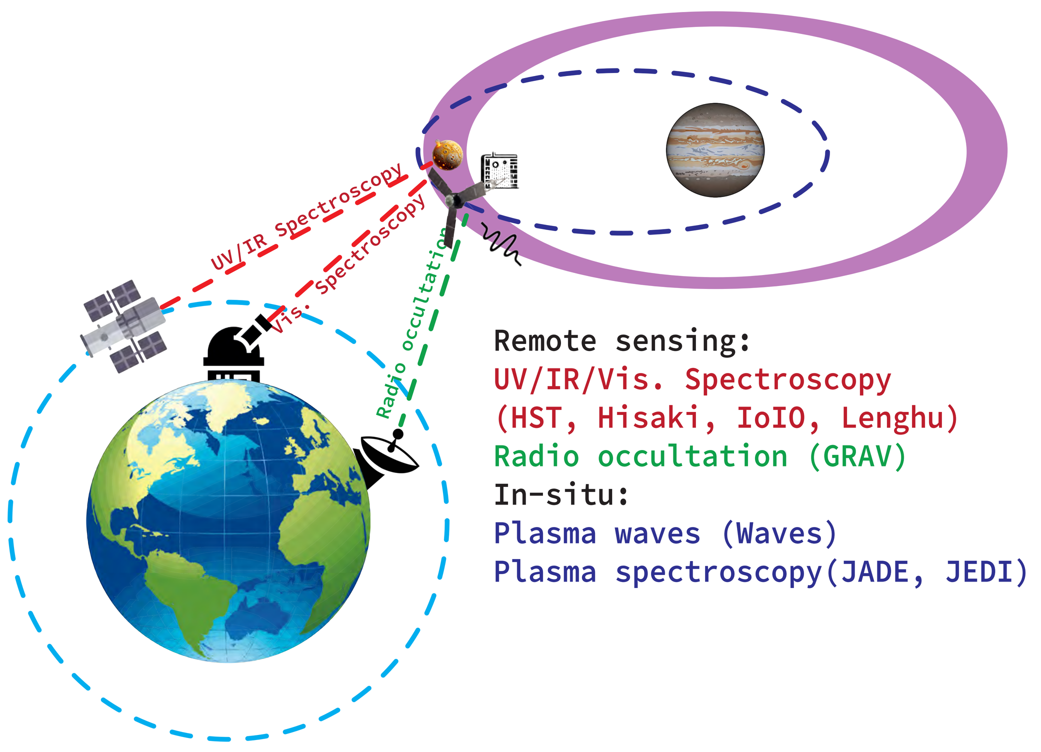
- Zone where ions, electrons, neutrals meet.
- Io has a dense SO2 atmosphere.
- The neutrals sputtered from Io's exosphere and the plasma particles corotating with the magnetic field interact.
- Neutrals are ionised by electrons and ions; ions recombine into neutrals, in a two-way interaction.



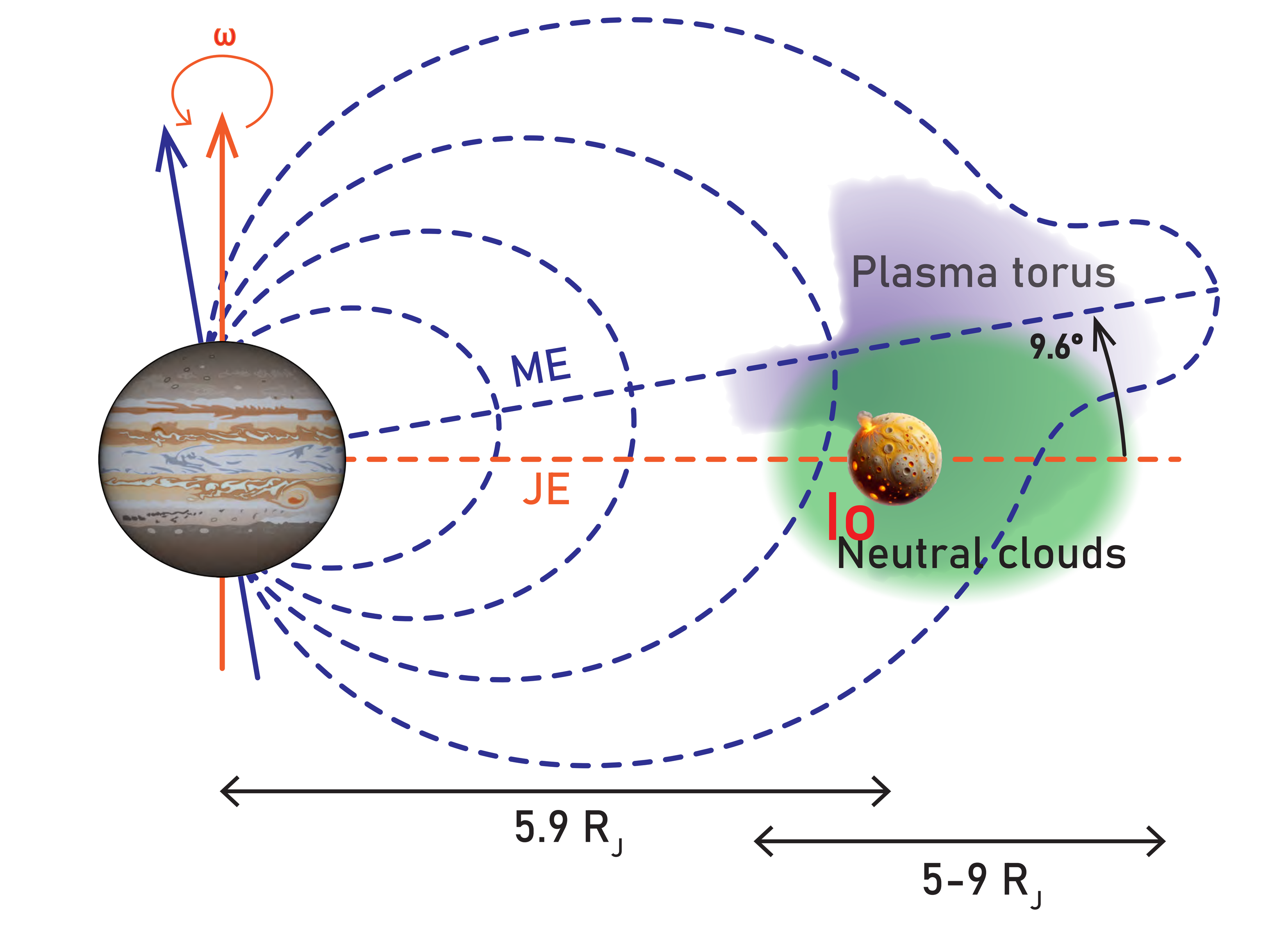
PAST OBSERVATIONS

- Several missions crossed the plasma torus in the past: *Pioneer 10 & 11*, *Voyager 1*, *Ulysses*, *Galileo*.
- Other missions explored the torus from a distance: *Cassini*, *Hisaki*.

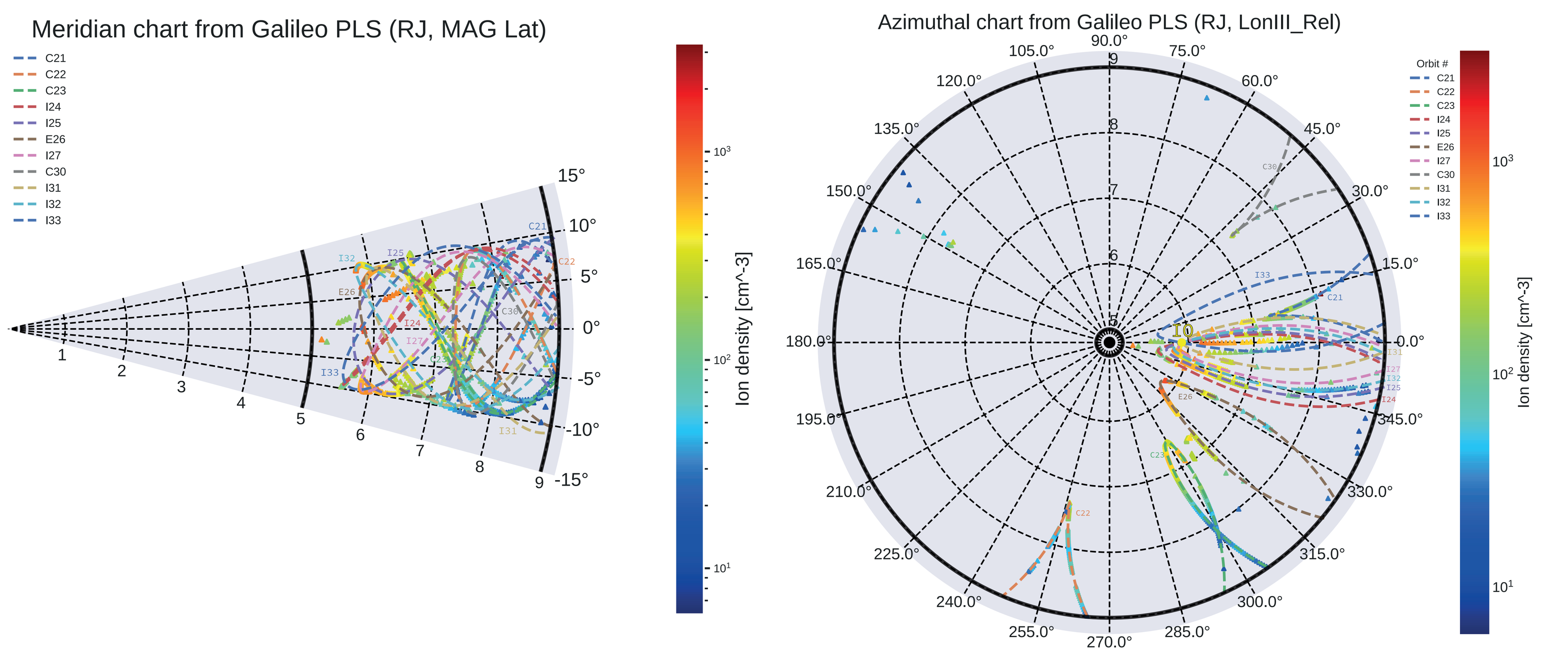
FROM *JUNO* TO THE NEXT



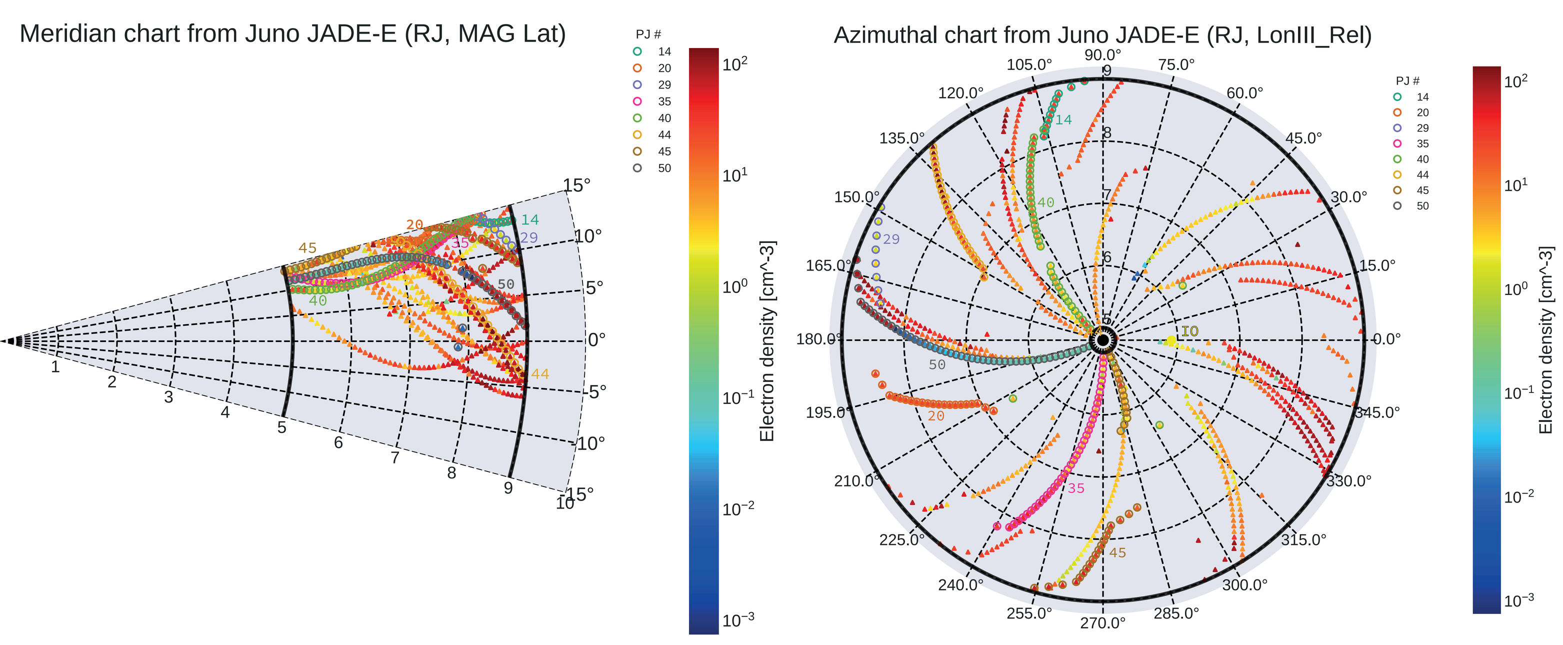
- After roaming in the Jovian system, Juno will fly by Io on December 30, 2023, and February 3, 2024.
- This will feed our model with new information from several instruments: JADE, JEDI, Waves, GRAV.
- The wealth of past data and incoming observations will constrain the model parameters.
- The remote sensing data from HST, Hisaki, JWST and ground-based telescopes will be assimilated into the model.



PRESENT RESULTS



The abundances of charged particles from *Galileo* and *Juno* missions can provide a globally rich coverage of the Io plasma torus.



IMPACT

- For the first time, a model will merge all these observations into one framework: plasma spectrometry, radio science, UV/IR/Visible spectroscopy, both in-situ and from remote.
- This will better model the properties of the torus, for future missions: *JUICE* and *Europa Clipper*.

REFERENCES

LinkedIn

For more information regarding the foundation of our work, scan with your phone the QR code here on the right.

Bibliography

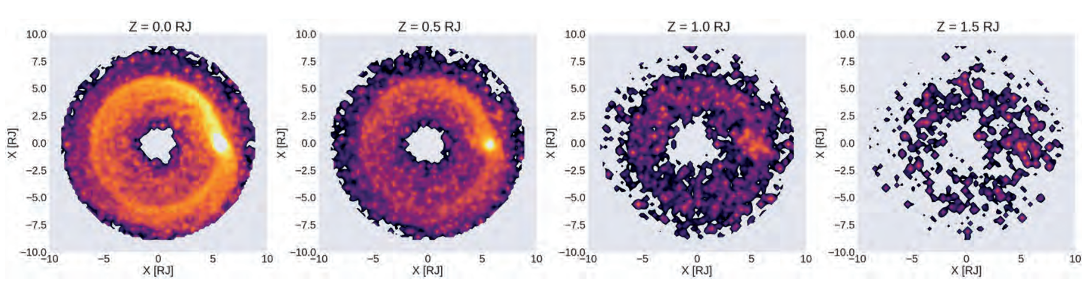
OUSTANDING QUESTIONS

- What are the coupling mechanisms in terms of chemistry and dynamics?
- What is the relationship between volcanism on Io and magnetospheric transport?

OUR APPROACH

We are going to develop a model of the coupling between the neutral and plasma tori, aiming at assimilating different observations.

NEUTRAL TORUS

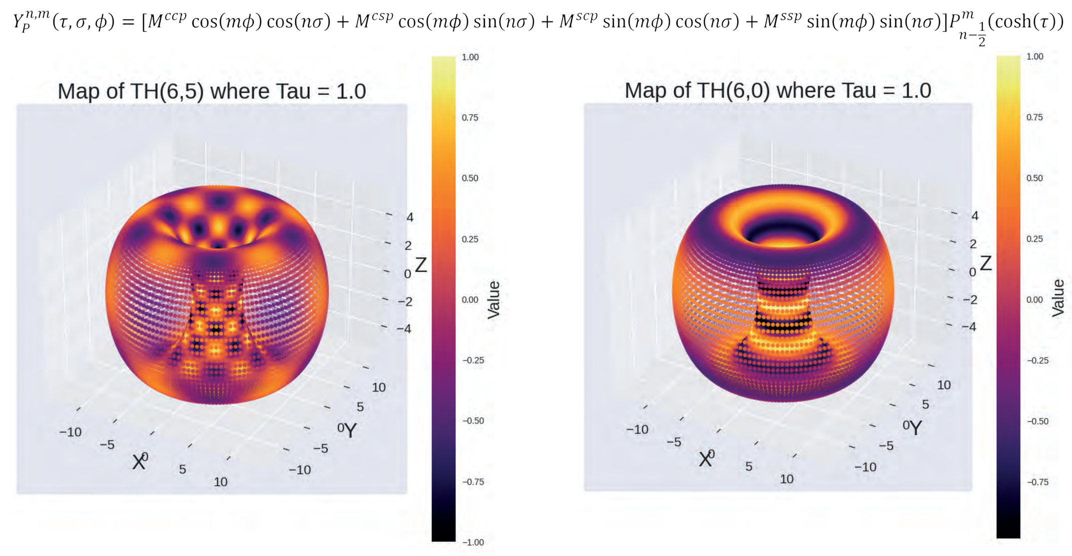


- Simulated 2D distributions of neutrals in the torus were provided us on some Z-aligned planes.
- In order to interpolate these results, we have built a toroidal harmonics expansion tool.
- The harmonic coefficients will be fitted upon the known density points.

$$x = \frac{a\sinh(\tau)\cos(\phi)}{\cosh(\tau)-\cos(\sigma)} \Bigg| y = \frac{a\sinh(\tau)\sin(\phi)}{\cosh(\tau)-\cos(\sigma)} \Bigg| z = \frac{a\sin(\sigma)}{\cosh(\tau)-\cos(\sigma)}$$

$$f(\tau,\sigma,\phi) = \sqrt{\cosh(\tau)-\cos(\sigma)}\sum_{n=0}^{N}\sum_{m=0}^{n}\left[Y_P^{n,m}(\tau,\sigma,\phi) + Y_Q^{n,m}(\tau,\sigma,\phi)\right]$$

$$Y_P^{n,m}(\tau,\sigma,\phi) = \left[M^{ccp}\cos(m\phi)\cos(n\sigma) + M^{csp}\cos(m\phi)\sin(n\sigma) + M^{scp}\sin(m\phi)\cos(n\sigma) + M^{ssp}\sin(m\phi)\sin(n\sigma)\right]P^m_{n-\frac{1}{2}}(\cosh(\tau))$$



PLASMA MODELING

- The model will assume already-known first guess densities on the equator.
- Neutral species will act as source terms in the plasma equilibrium equation, with input densities coming from the neutral model.
- Plasma densities will be mapped along the field lines by using the theory of field line equilibrium:

$$\frac{\partial P_{||}}{\partial s} - \left(P_{||} - P_{\perp}\right)\frac{1}{B}\frac{\partial B}{\partial s} - m_i n_i \frac{\partial}{\partial s}\left[\frac{1}{2}\Omega^2 R^2(s)\right] + n_i \frac{\partial}{\partial s}\left[G\frac{M_J m_i}{r}\right] + n_i Z_i q \frac{\partial \Phi}{\partial s} = 0$$