An Alfvénic source for suprathermal electrons in the Io torus

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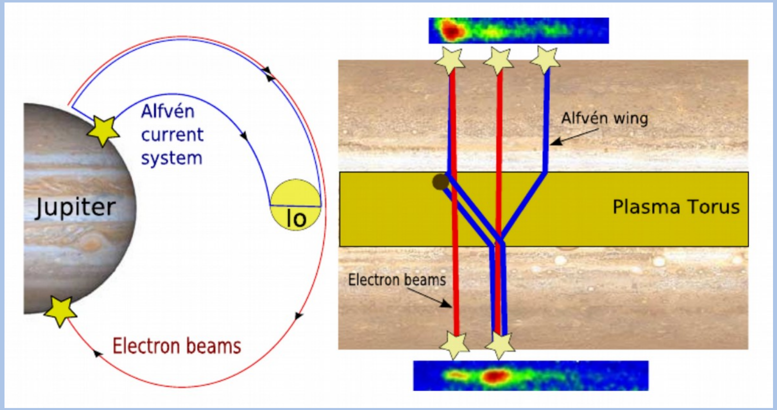
Sources of Alfvén energy

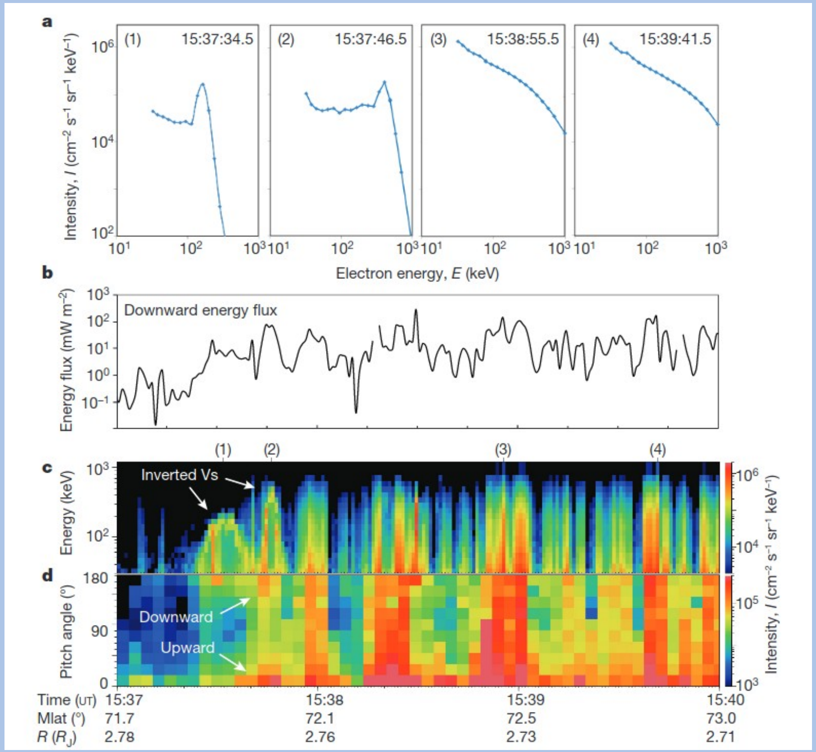
- The motion of Io through its torus generates Alfvénic perturbations.



[*Bonfond* et al, *GRL* 2008]

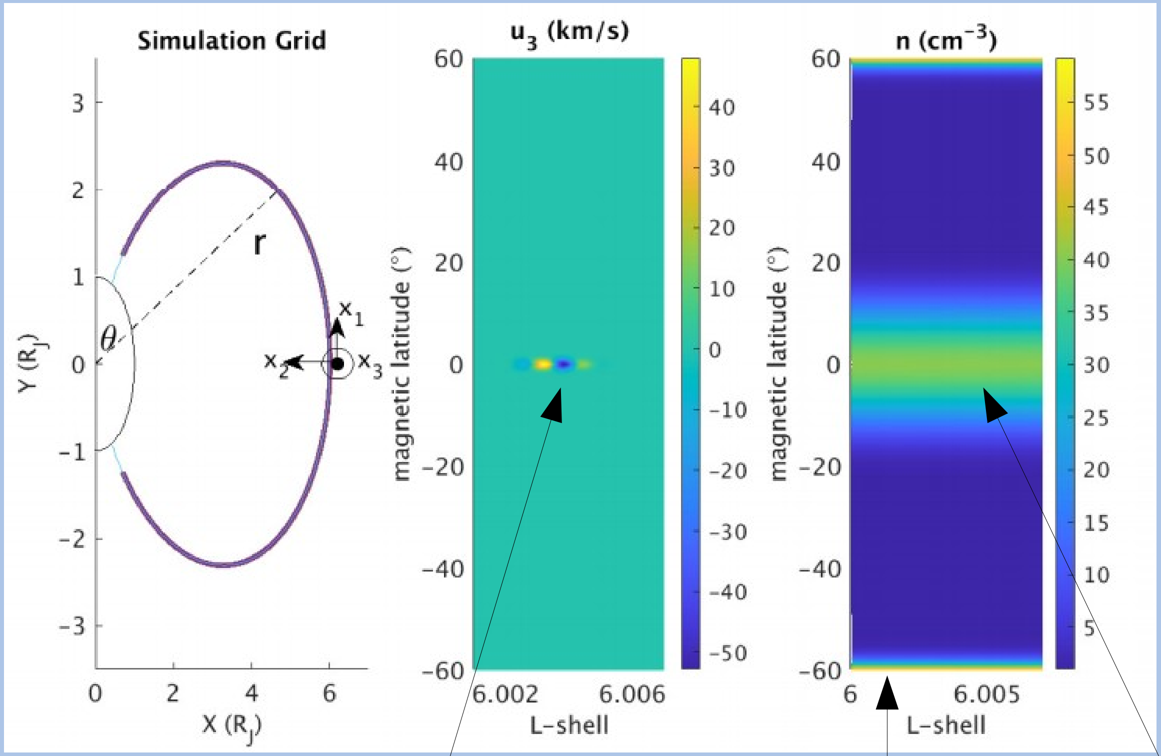
- In addition, radial transport may be a mechanism to facilitate the radial interchange of flux tubes (*Gold*, 1959), akin to a Rayleigh-Taylor (RT) instability.
- Hybrid simulations of the RT instability illustrate parallel propagating Alfvén waves (*Stauffer et al*., 2019).

Juno observations illustrate substantial broadband electron energization (e.g. *Mauk* et al., 2017, *Allegrini* et al., 2017), associated with dispersive scale Alfvén waves (DAWs).



[*Mauk* et al, *Nature* 2017]

Gyrofluid Kinetic Electron (GKE) model



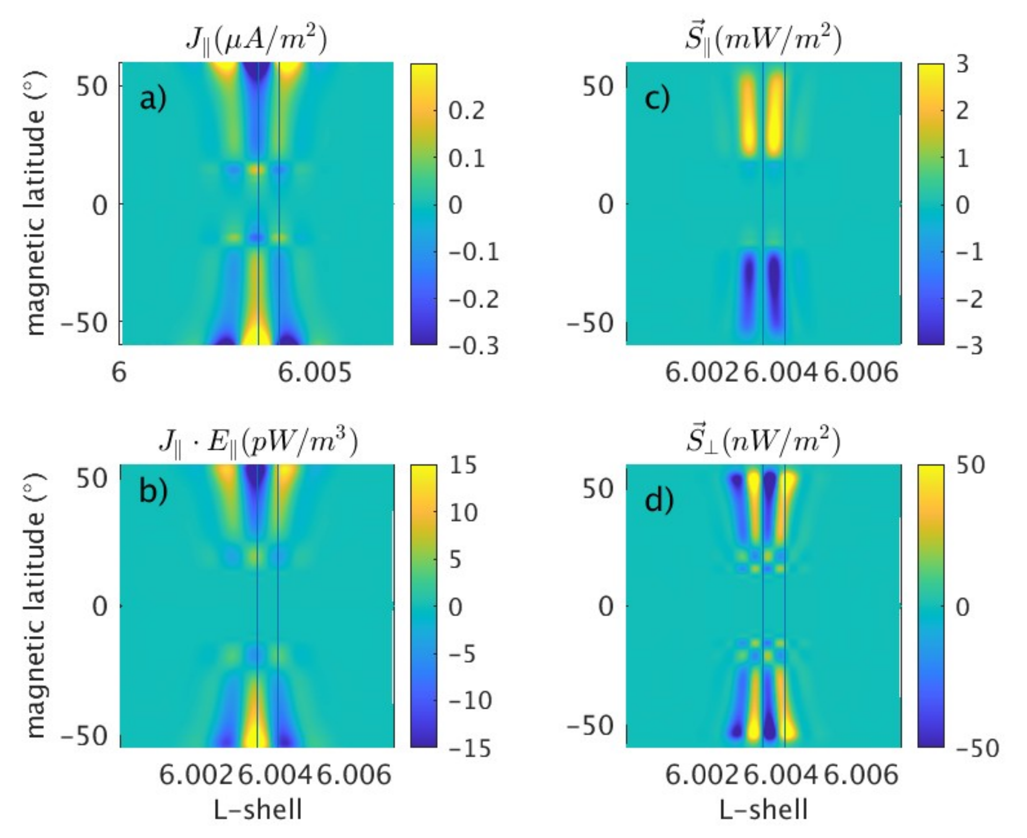
Initial velocity perturbation

Ionospheric ramp

Torus enhancement

- We study electron acceleration due to dispersive Alfvén waves using the GKE model (Damiano et al., 2015, 2019).
- The model uses a gyrofluid treatment for the ions based on the kinetic fluid theory of Cheng and Johnson, 1999.
- A drift-kinetic treatment is used for the parallel electron dynamics (including a mirror force term).

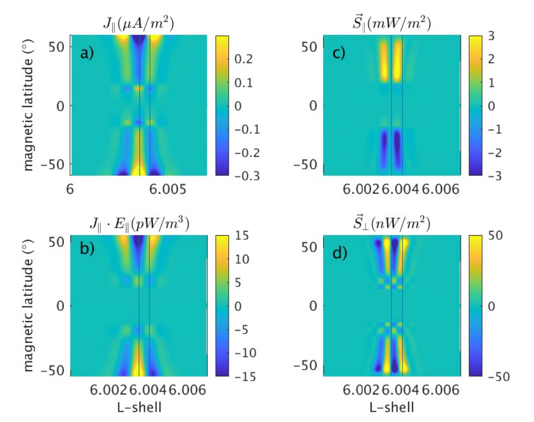
Snapshot of wave propagation

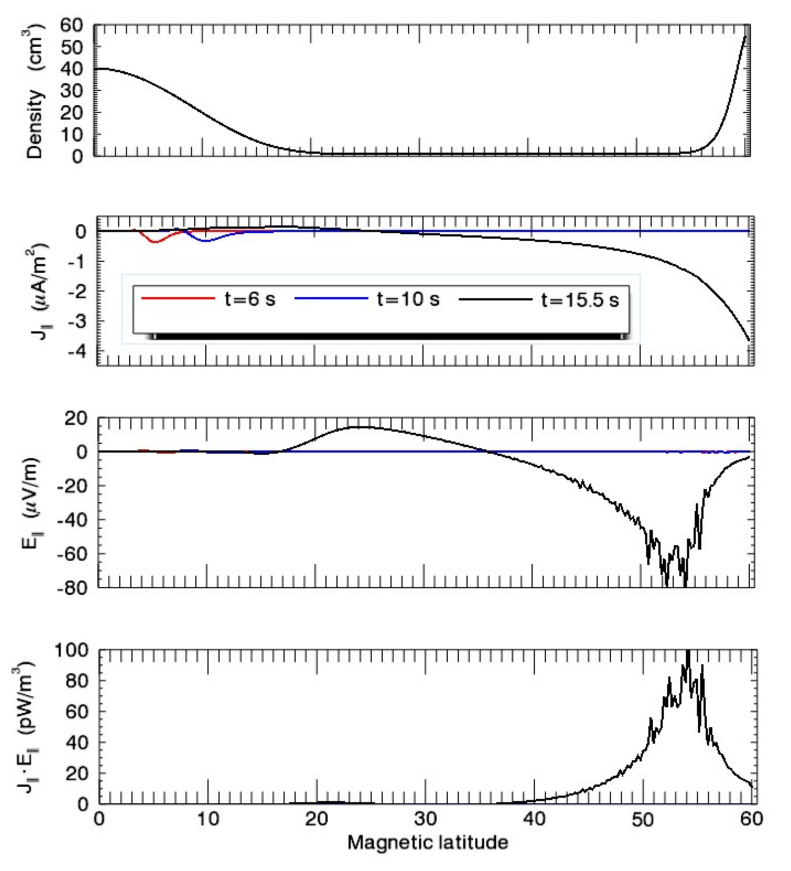


- Vertical lines identify opposing current regimes.
- Left line – upwards at ionosphere.
- Right line – downwards at ionosphere.
- Parallel current peaks at B-field nulls.
- Perpendicular Poynting flux ($S_{\perp}$) feeds wave energy to facilitate electron energization (panel d).
- Vertical lines are current regimes.
- Low-latitude cells from torus boundary reflection.
- Flux tube narrows to electron inertial scales (λ_e ~ km) at high latitude.

$$E_{||} = \mu_o \lambda_e^2 \frac{\partial j_{||}}{\partial t}$$

Propagation properties along central field line

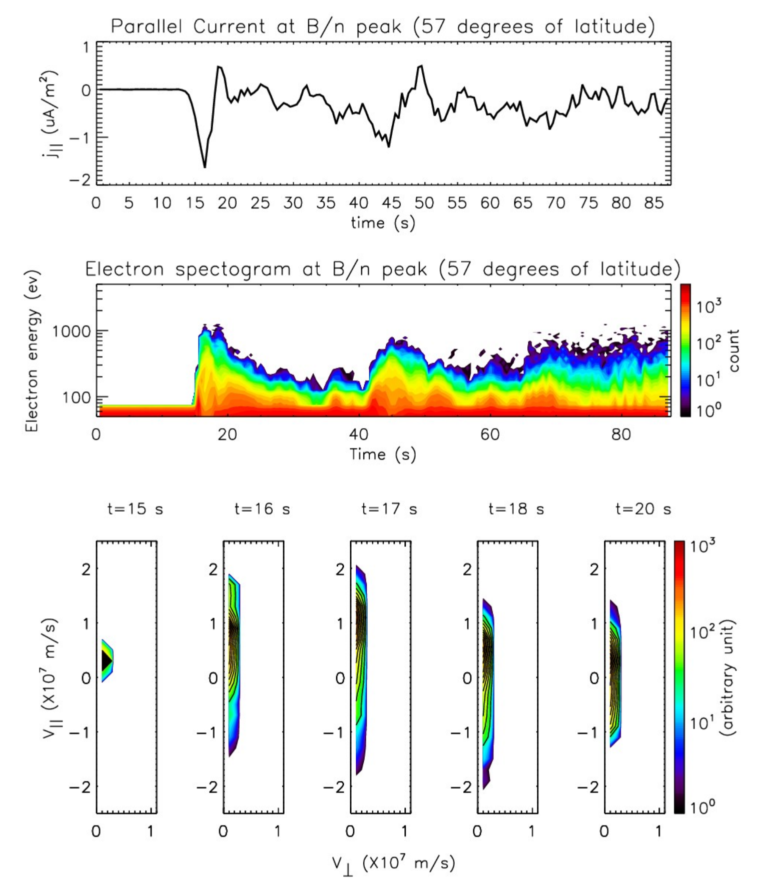




- The figure to the right shows magnitudes along the central field line.
- $J_{||}$ peaks at high latitude due to magnetic field convergence.
- $E_{||}$ proportional to $J_{||}$ until B/n peak (56°).
- $E_{||}$ decreases beyond B/n peak due to increased availability of electrons.
- $J_{||} \cdot E_{||} > 0$ represents wave energy sink.

Temporal evolution at high-latitude

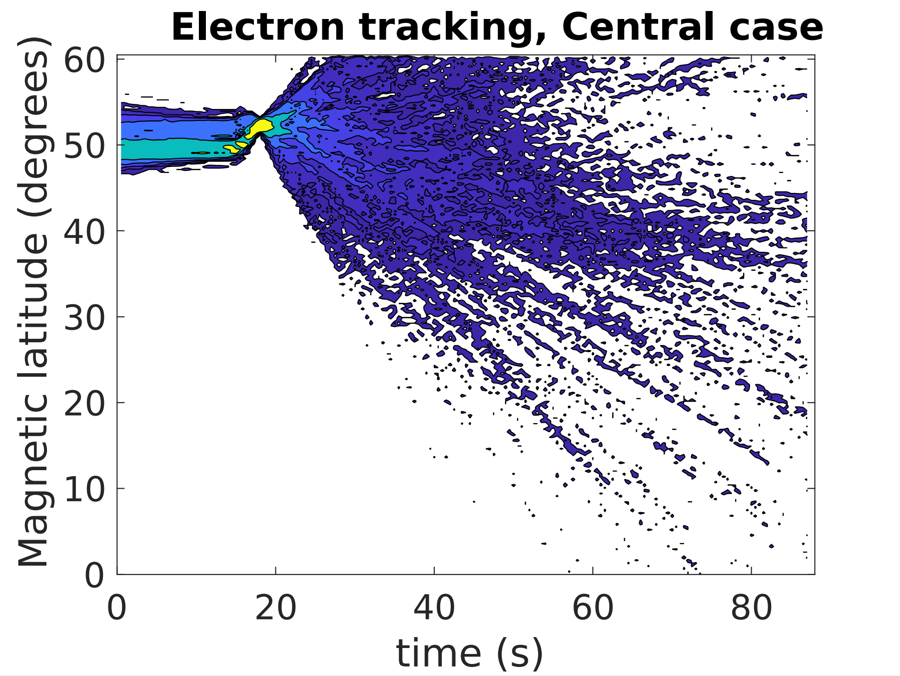
- Current at peak of B/n ratio shows successive wave passages (initial at 18 s, second at 48 s).
- The passage of the wave induces highly energized broadband electron distributions (qualitatively consistent with Juno observations).
- Distributions are highly elongated along the parallel direction.
- Parallel current is carried by the bulk drifting of the distributions.
- Heating persists post-passage of the wave.

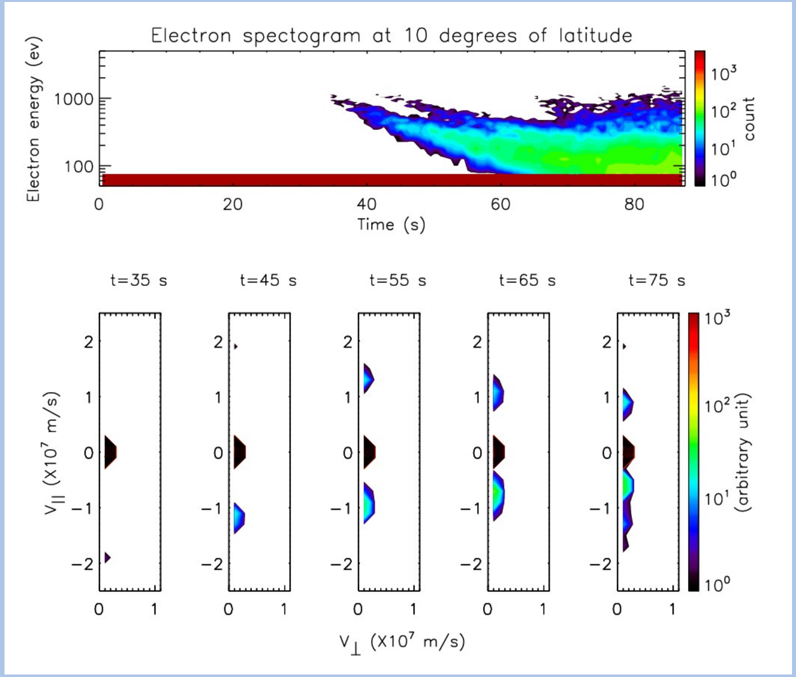


Temporal evolution of energized electrons

- Latitudinal evolution of electrons energized at B/n peak.

- Spectrogram at 10 degrees shows energy dispersion.



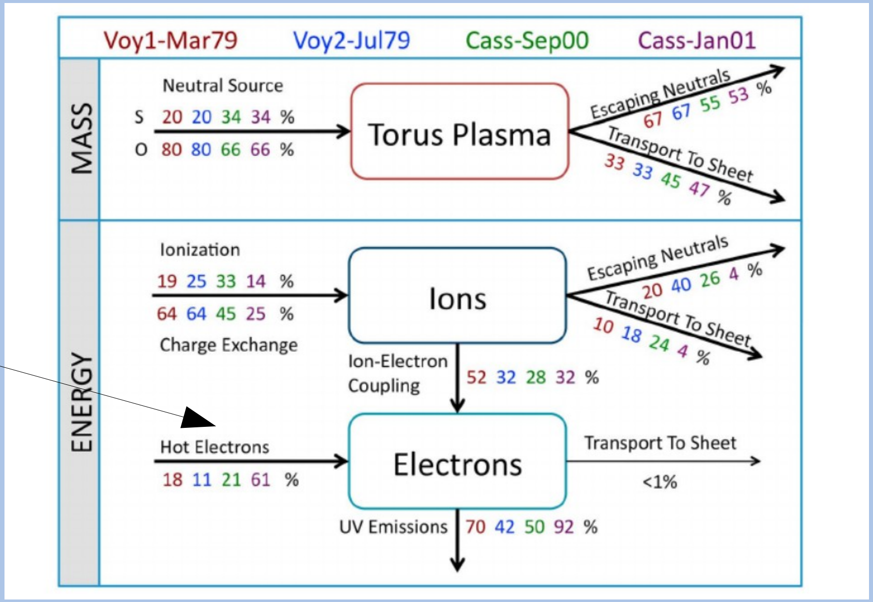


- Corresponding distribution functions are suggestive of trans-hemispheric beams (*Bonfond* et al., 2008).

Summary

- We use a GKE model to produce broadband energization of high-latitude electrons up to ~ 1 keV associated with dispersive Alfvén wave activity.
- Electron heating persists post-energization which may be source of suprathermal electrons.
- Bi-directional energized electrons are suggestive of trans-hemispheric beams at lower latitudes (*Bonfond* et al., 2008).

Energized electrons may provide the energy source for torus dynamics (*Coffin et al.,* 2020*)*



Bagenal and Delamere, 2011