Solar wind interaction at Jupiter

\( v \) constant \( \Rightarrow v \sim 400 \text{ km s}^{-1} \)

\( nvr^2 = \text{constant} \Rightarrow n \sim 0.2 \text{ cm}^{-3} \)

\( B_{\text{mag}} r^2 = \text{constant} \Rightarrow B_{\text{mag}} \sim 0.2 \text{ nT} \)

\( B_x \sim 0.2 B_y \)

Jovian dipole moment the opposite direction as Earth

\( \Rightarrow \) Northward IMF leads to increased dynamics

Northward IMF: MP \( \sim 63 R_J \)

Southward IMF: MP \( \sim 92 R_J \)
The Jovian magnetosphere is the largest object inside the solar system.
Tail can reach past the orbit of Saturn - 5 AU or over 1000 $R_J$ away
Processes controlling Jovian magnetosphere

Jupiter magnetic field strength -
“surface” equatorial field = 700,000 nT

Jupiter corotation rate - 9.6 hours

Internal plasma source - 1 ton s⁻¹ lost from Io
Corotation

Moons travel into their own wake
Io’s orbital velocity = 17 km s$^{-1}$
Plasma flow velocity = 74 km s$^{-1}$
Magnetotail

Corotation (in addition to other processes) leads to significant dawn - dusk asymmetry

Bi-directional streaming plasma observed by Ulysses ⇒ closed fieldlines
Reconnection - Dungy model
Reconnection - Vasyliunas model

Physics of the Jovian magnetosphere
Pulsating X-ray spot
- 45 minute period

Relativistic electrons with
40 minute intensity variations
on the dusk side, high latitude

Quasi-periodic explosive
magnetic merging process
During quiet solar activity times, Jupiter a stronger radio source than the Sun
Closure of cororation currents in the auroral zone?
Multiple Footprint Aurora

Alfvén wing

$\nabla \rho$

Torus
\( M_A = 0.3 \)
\( \beta = 0.04 \)
\( M_s > 1 \) but fast Mach number < 1
Io has equatorial aurora
Plasma Density and Flow

Io’s ionosphere is strongly advections dominated

Plasma slowed in Io’s ionosphere, redirected around moon, an then reaccelerated in the wake (by ~ 6R_J).

Ionosphere has smaller density and smaller scale height on upstream side maximum density seen in the flanks ~ 10x enhancement in wake ~ 5x

How is mass supplied to torus? How is it heated/accelerated?
About 2/3 of ioegenic material lost through charge exchange
Neutral Cloud

- Cold torus: Ne $\approx 1000$ cm$^{-3}$, S$^+$, Ti, Te $\approx 1$ eV
- Neutral cloud: SO$_2$, SO, O, S, Na
- Warm torus: 90% of plasma, Ne $\approx 2000$ cm$^{-3}$, O$^+$, S$^{++}$, Ti $\approx 100$ eV, Te $\approx 5$ eV

Diagram showing the interaction of the neutral cloud with Io and the magnetic field.
Jet: Electric fields associated with Jupiter’s magnetospheric interaction with Io rip ions out of Io’s collisionally thick atmosphere.
Stream: Leads Io’s orbit and undulates above and below the centrifugal equator. Stream formed by NaX⁺.
Banana: Low energy neutral cloud generated by sputtering
Closer to Jupiter than Io, at ~ 5.6 $R_J$

**Ribbon** - tracer for position of max density

At the same radial distance as Io
Ribbon

Jupiter  Cold torus  Ribbon  Io  Warm torus

$T_i, n_e, n_i$ decrease
$n_e, n_i$ increase at center to cold torus

$T_i$ decrease
$n_e$ increase

$T_i$ peak

$n_e, n_i$
Decrease
$T_i, T_e$?

S$^+_{\text{emissions}}$