

MAGNETÓSFERAS

MATERIAL COMPLEMENTARIO DEL CURSO DE PLANETOLOGIA 2014

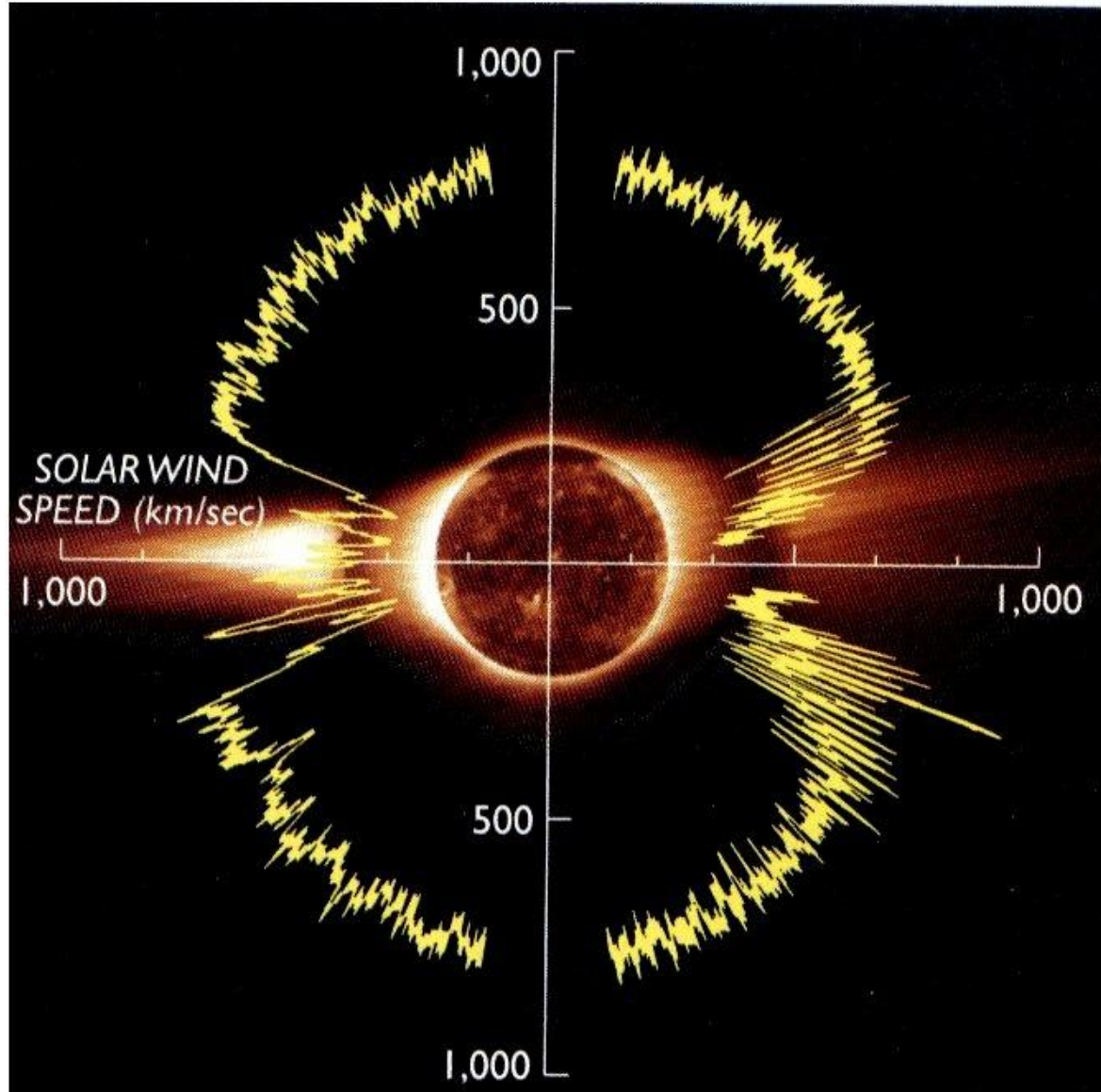
<http://www.astronomia.edu.uy/depto/planetologia/planet.html>

Tabaré Gallardo

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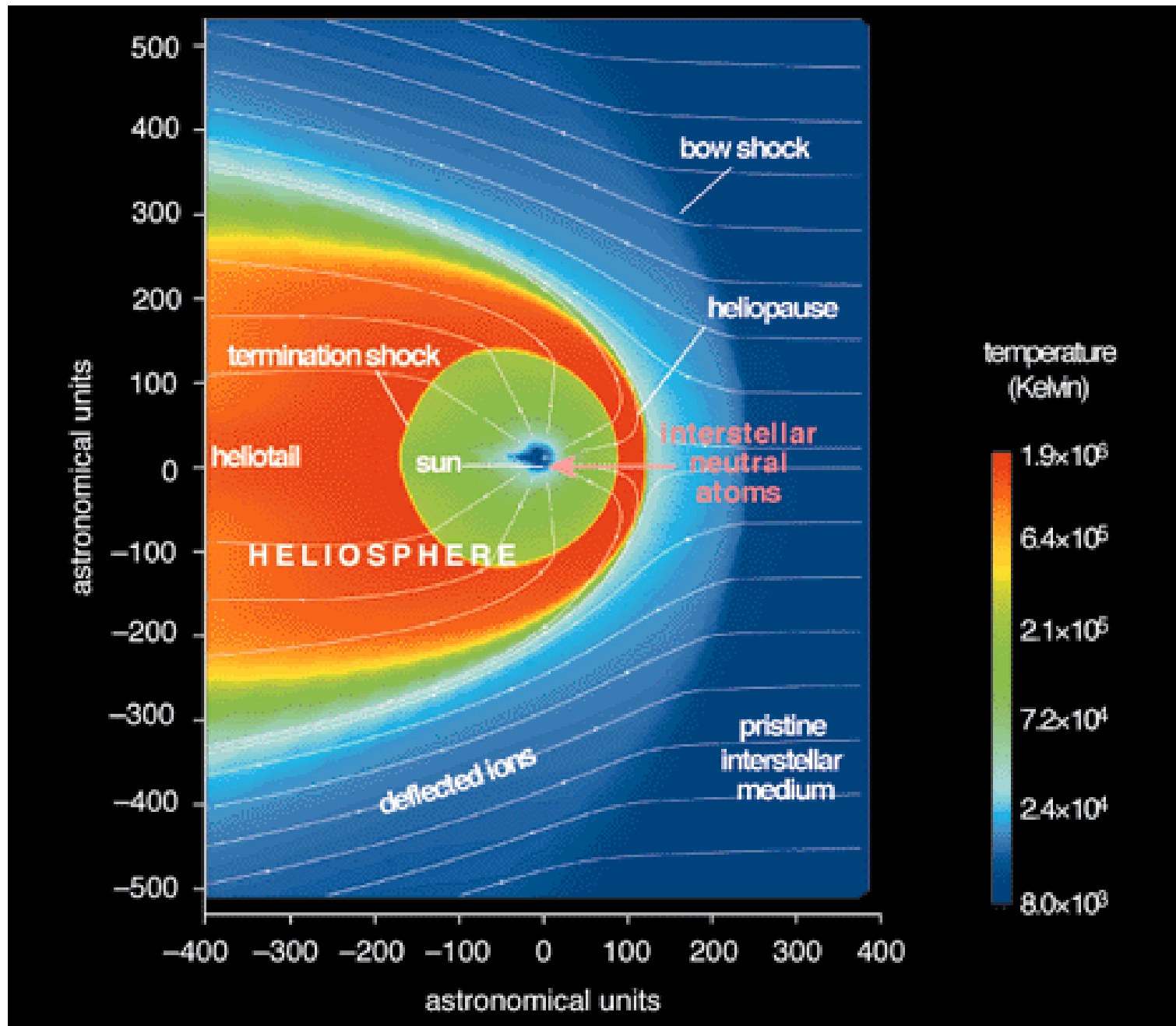
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Viento Solar



VIENTO SOLAR: flujo de plasma (p y e) originado en la corona debido a la diferencia de presión entre ésta y el medio interplanetario. El VS genera el campo magnético interplanetario. A 1 ua del Sol tiene densidad de 5 partículas por cc y viaja a 100-1000 km/s.

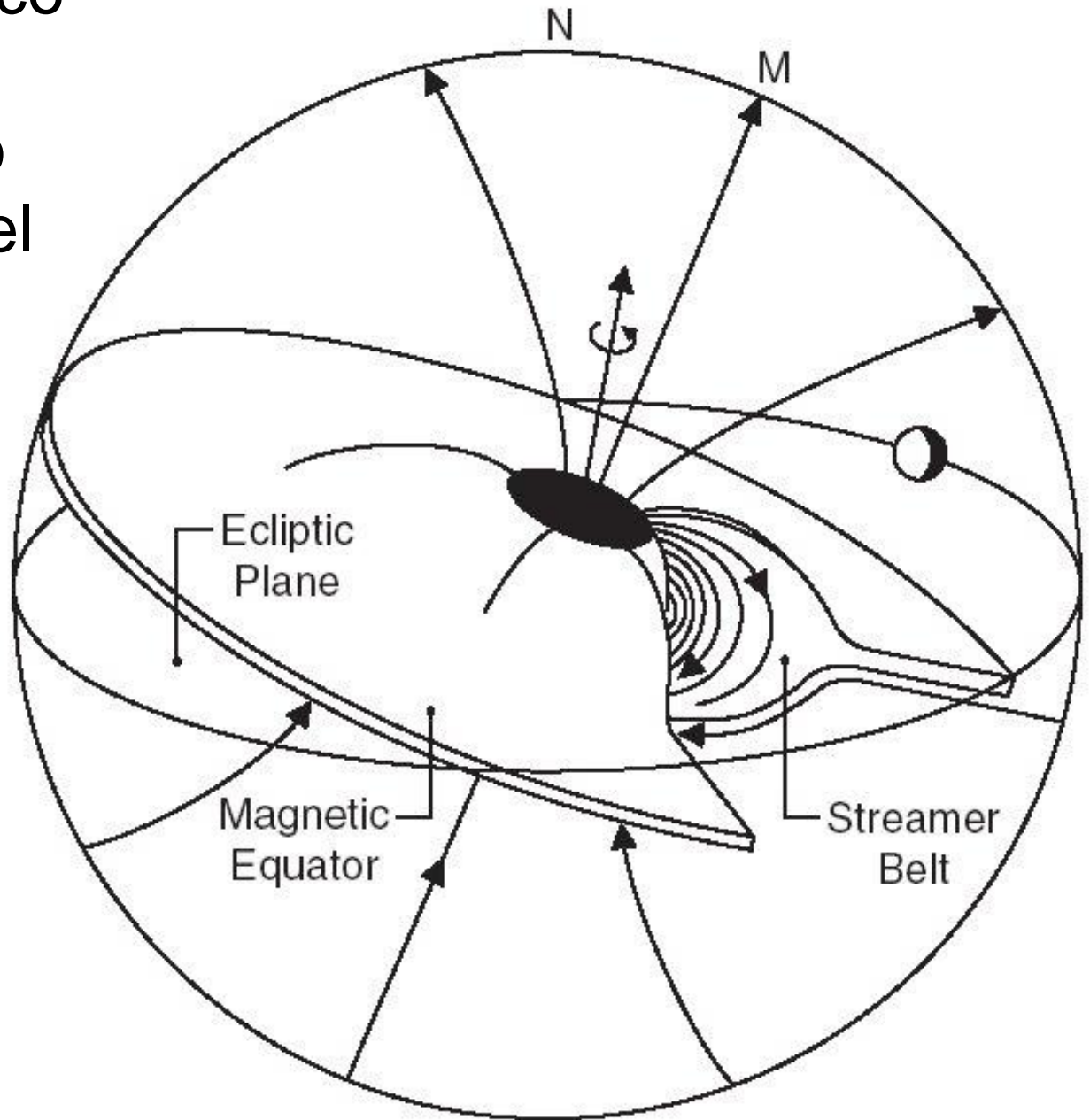
HELIOFERA

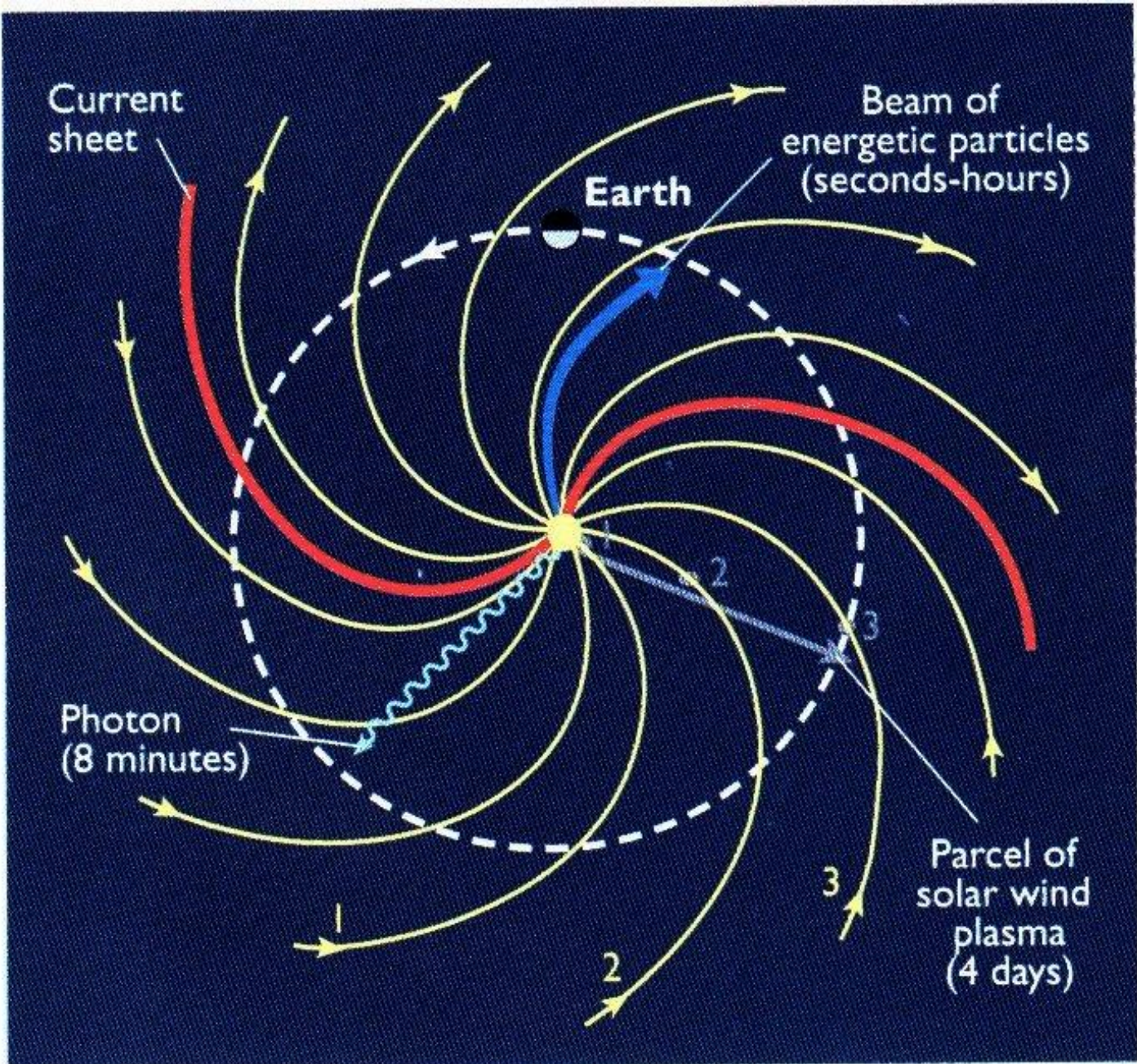


Bow Shock Around LL Orionis



Campo magnético
solar e
interplanetario
(embebido en el
viento solar)





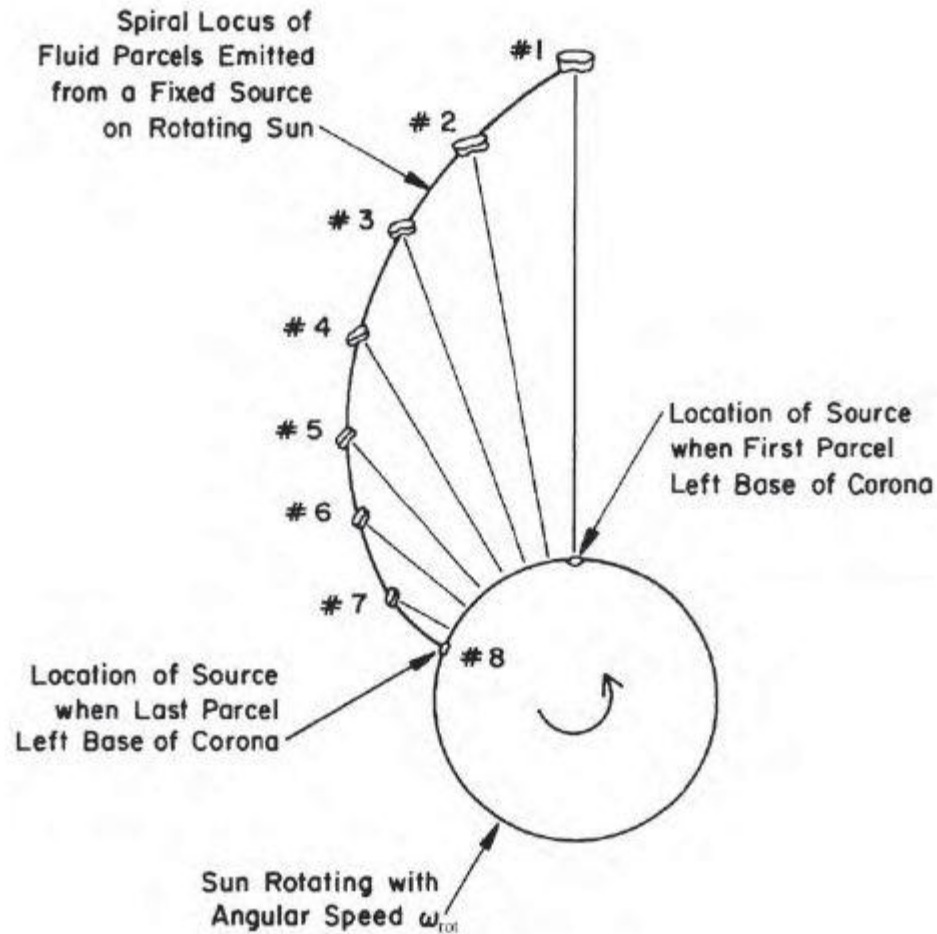


Figure 7.10 Archimedean (or Parker) spiral of solar wind particles streaming away from the Sun. (Hundhausen 1995)

(b)

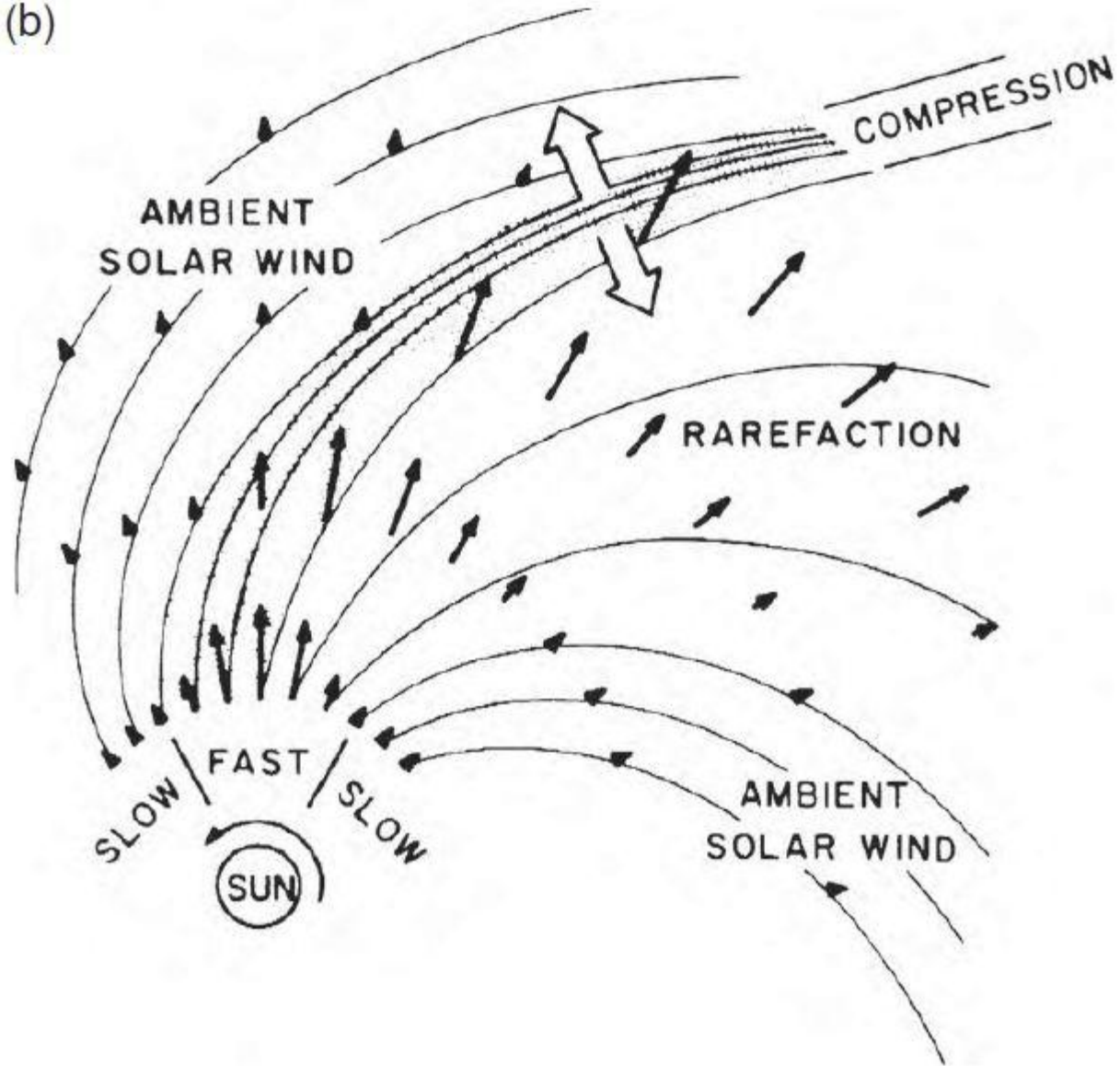
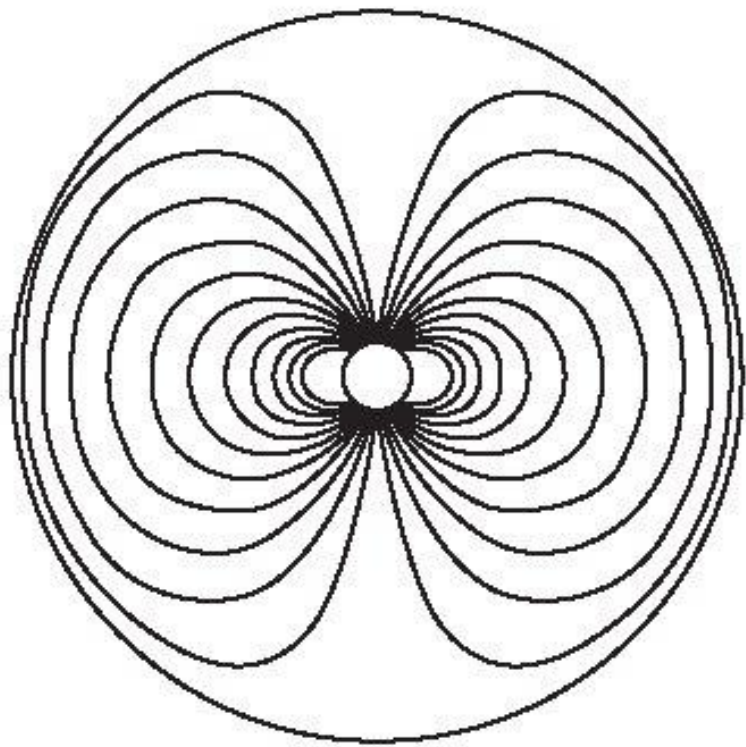


Table E.17 Solar Wind Properties at 1 AU^a

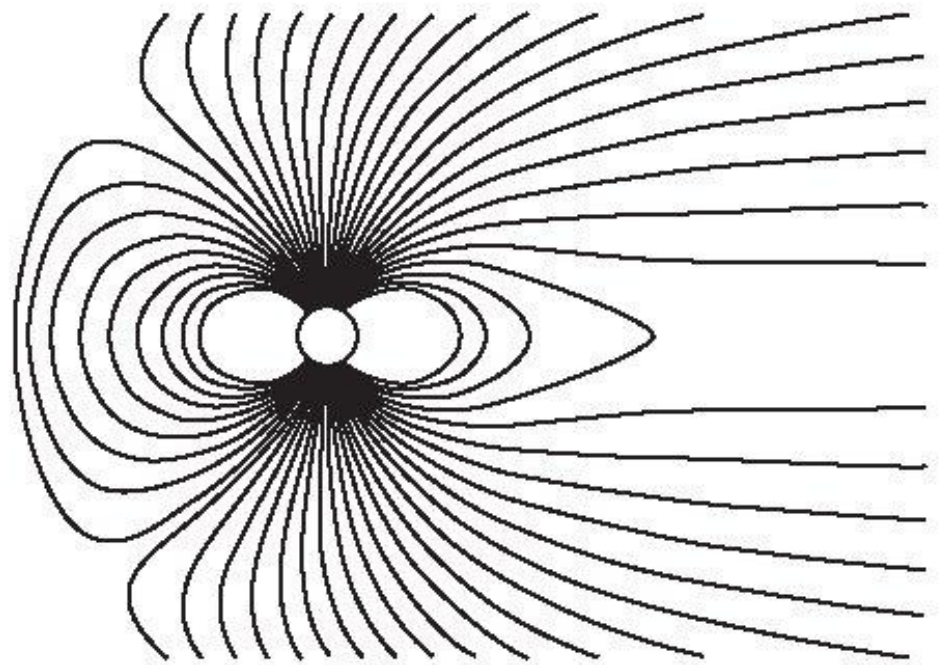
	Most Probable Value	5–95% Range
Density (protons cm ⁻³)	5	3–20
Velocity (km s ⁻¹)	375	320–710
Magnetic field (γ)	5.1	2.2–9.9
Electron temp. (10 ⁵ K)	1.2	0.9–2
Proton temp. (10 ⁵ K)	0.5	0.1–3
Sound speed (km s ⁻¹)	59	41–91
Alfvén speed (km s ⁻¹)	50	30–100

^a After Gosling (2007).

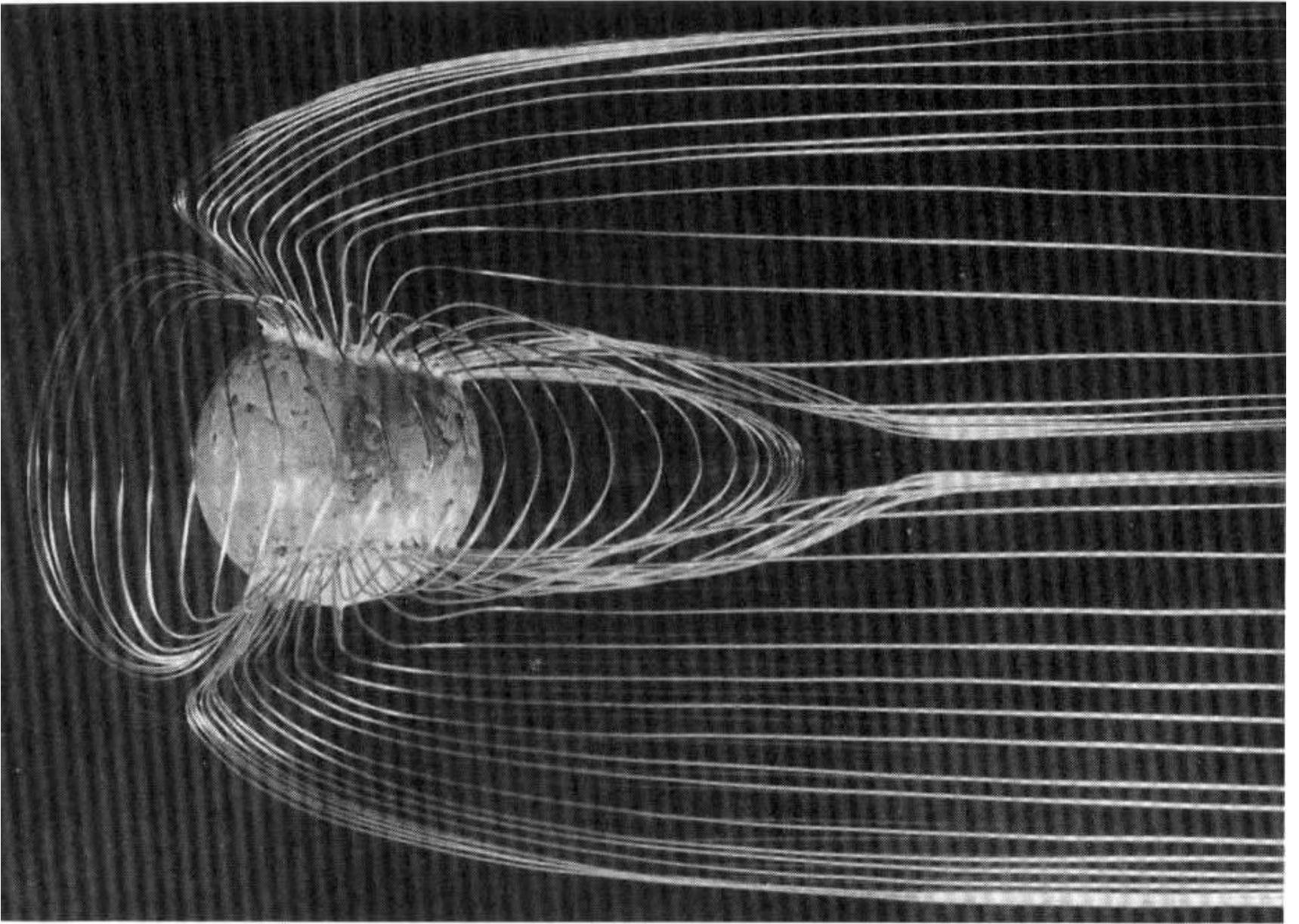
SPUTTERING: efecto de las colisiones del plasma con la superficie o atmósfera



Spherical Magnetopause

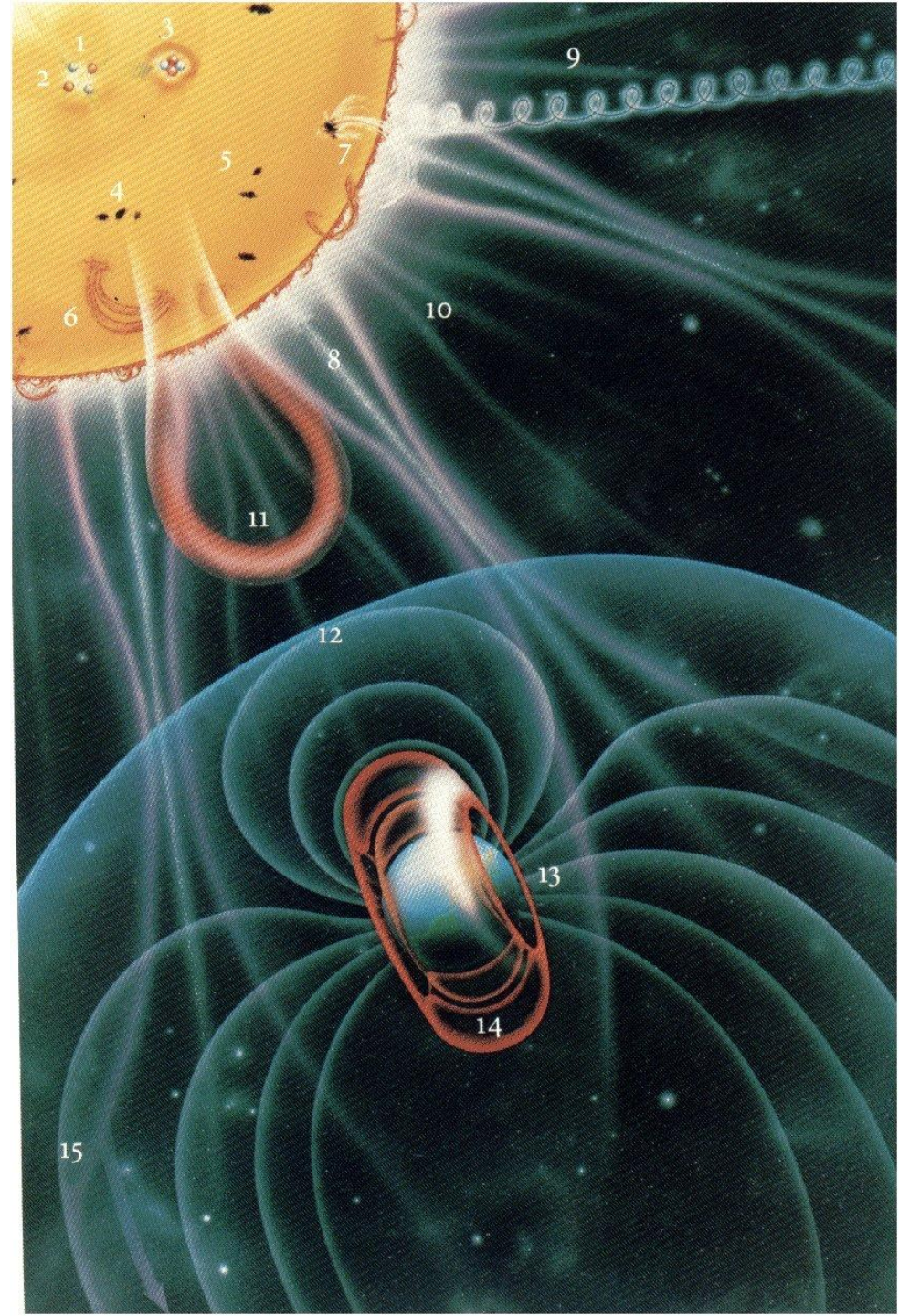


Empirical Magnetosphere



Efecto en la magnetósfera y cinturones de Van Allen

RAYOS CÓSMICOS:
intensidad inversa a la
actividad solar



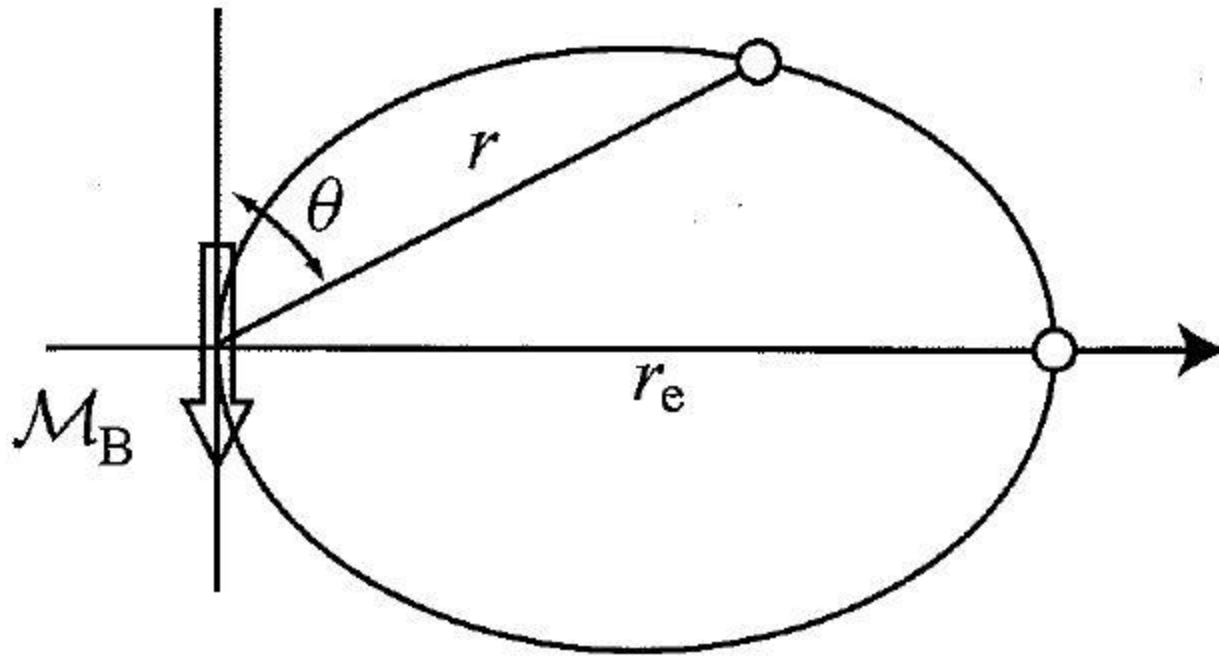


Figure 7.11 Sketch of a field line in a dipole magnetic field.
 (Adapted from Roederer 1970)

$$B_r = -\frac{2\mathcal{M}_B}{r^3} \cos \theta,$$

$$B_\theta = \frac{\mathcal{M}_B}{r^3} \sin \theta,$$

$$B_\phi = 0,$$

INTENSIDAD SUPERFICIAL: momento de dipolo magnético dividido R^3

Table E.18 Characteristics of Planetary Magnetic Fields^a

	Mercury	Earth	Jupiter	Saturn	Uranus	Neptune
Magnetic moment (\mathcal{M}_\oplus)	2.4×10^{-4}	1 ^b	20 000	600	50	25
Surface B at dipole equator (nT)	190	3.1×10^4	4.28×10^5	2.2×10^4	2.3×10^4	1.4×10^4
Maximum/minimum ^c	2	2.8	4.5	4.6	12	9
Dipole tilt ^d	$<0.8^\circ$	10.8°	9.6°	0.0°	59°	47°
Dipole offset (R_p)	0.16	0.08	0.12	~ 0.04	0.3	0.55
Magnetopause distance ^e (R_p)	1.45	10	42	19	25	24

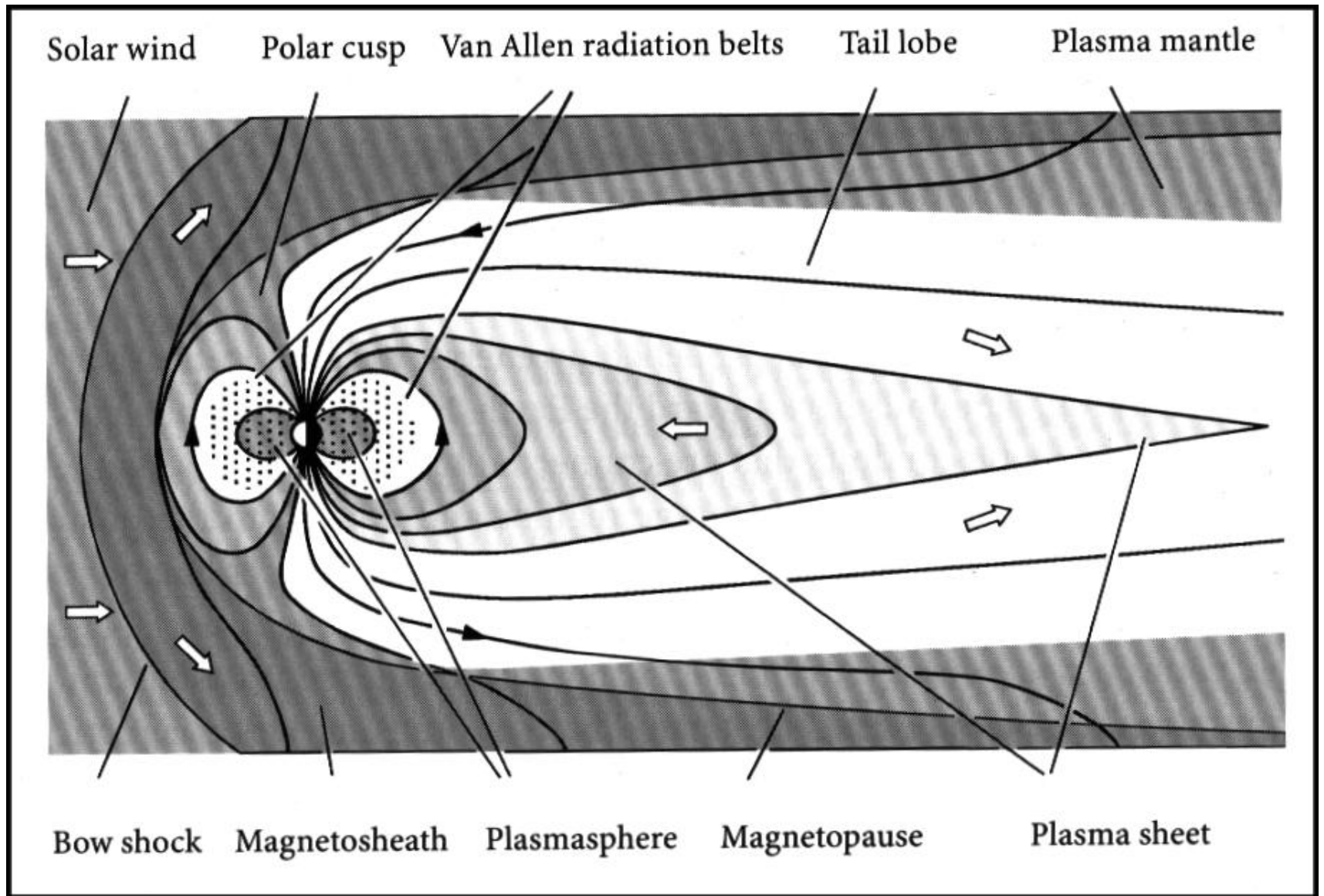
^a After Kivelson and Bagenal (2007), with updates for Mercury based on *MESSENGER* data.

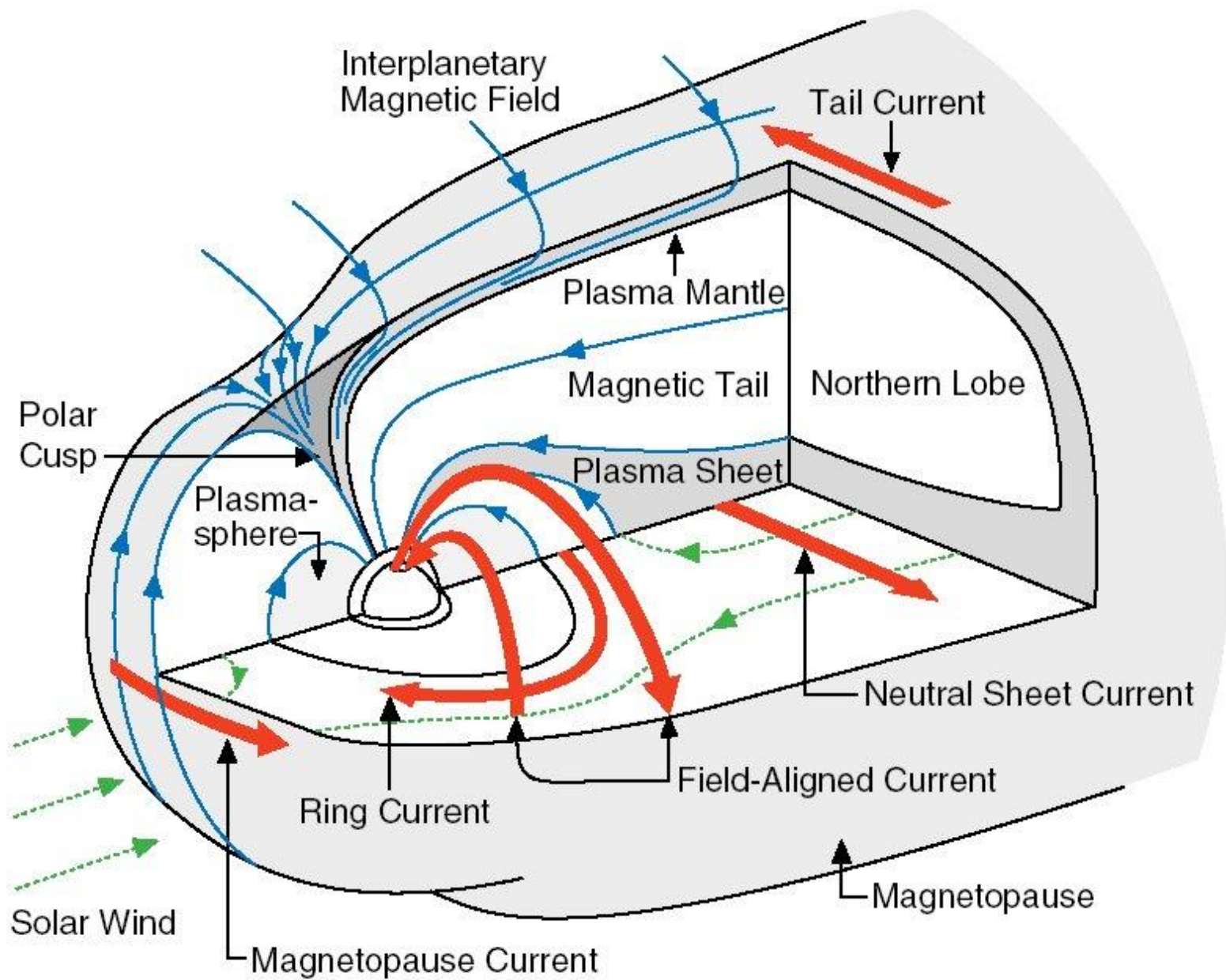
^b $\mathcal{M}_\oplus = 7.906 \times 10^{22} \text{ N m T}^{-1}$.

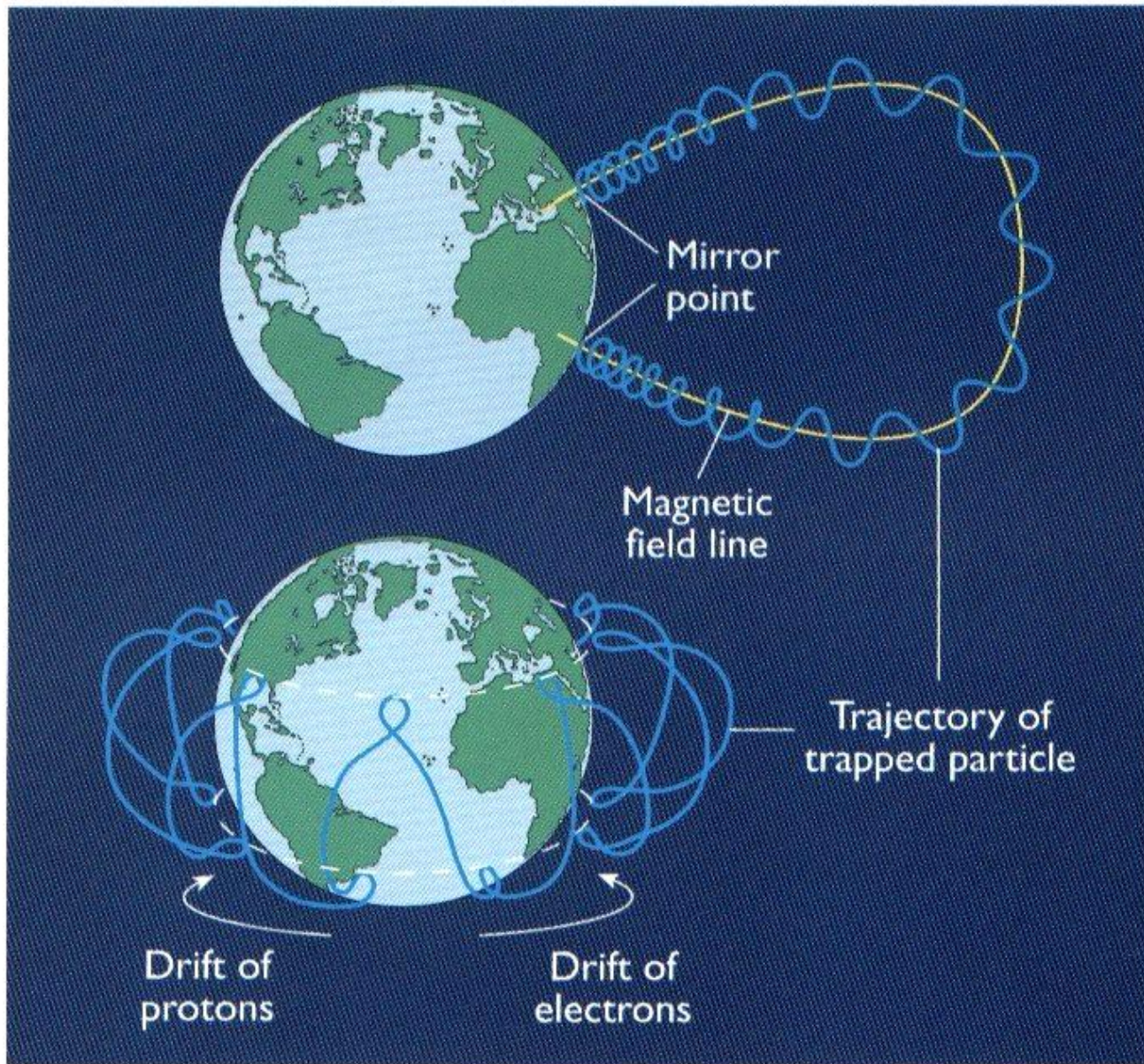
^c Ratio of maximum to minimum surface magnetic field strength (equal to 2 for a centered dipole field).

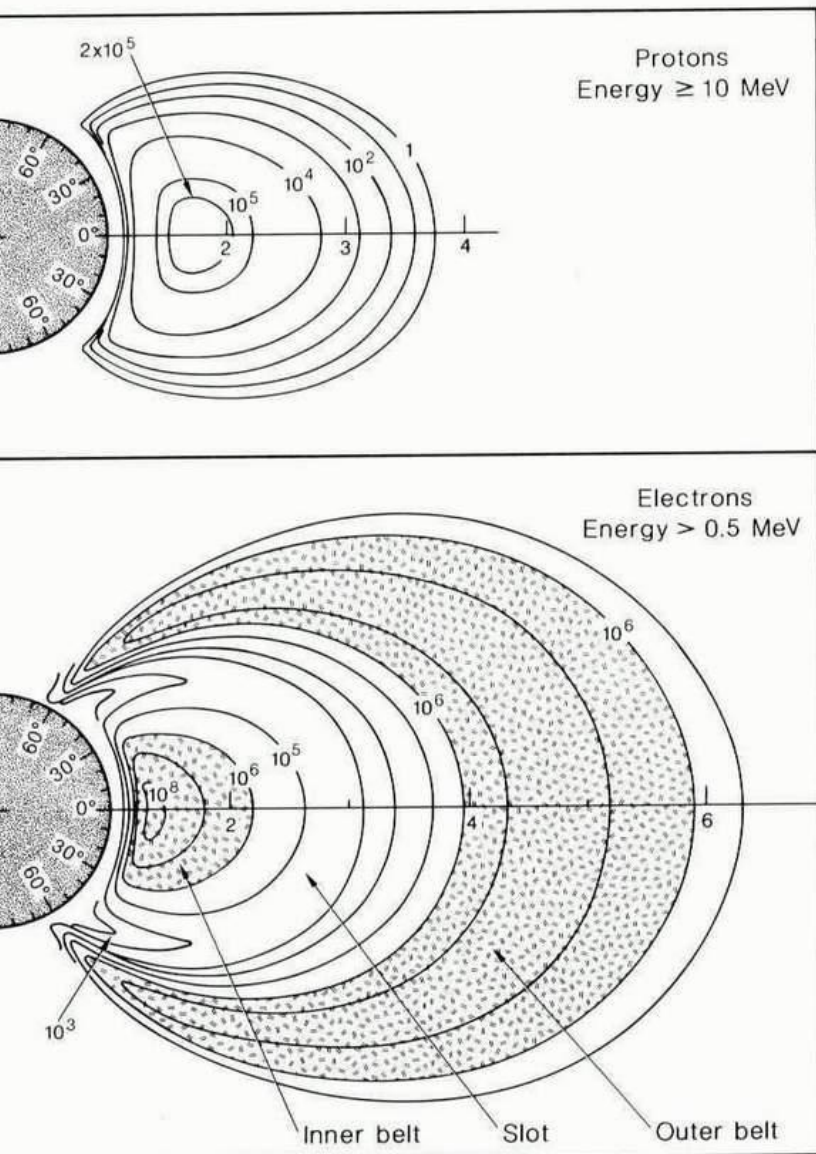
^d Angle between the magnetic and rotation axis.

^e Typical standoff distance of the magnetopause at the nose of the magnetosphere, in planetary radii.









VAN ALLEN: cinturones de partículas cargadas atrapadas. El movimiento del plasma puede ser controlado por el campo magnético, rotación planetaria y viento solar.

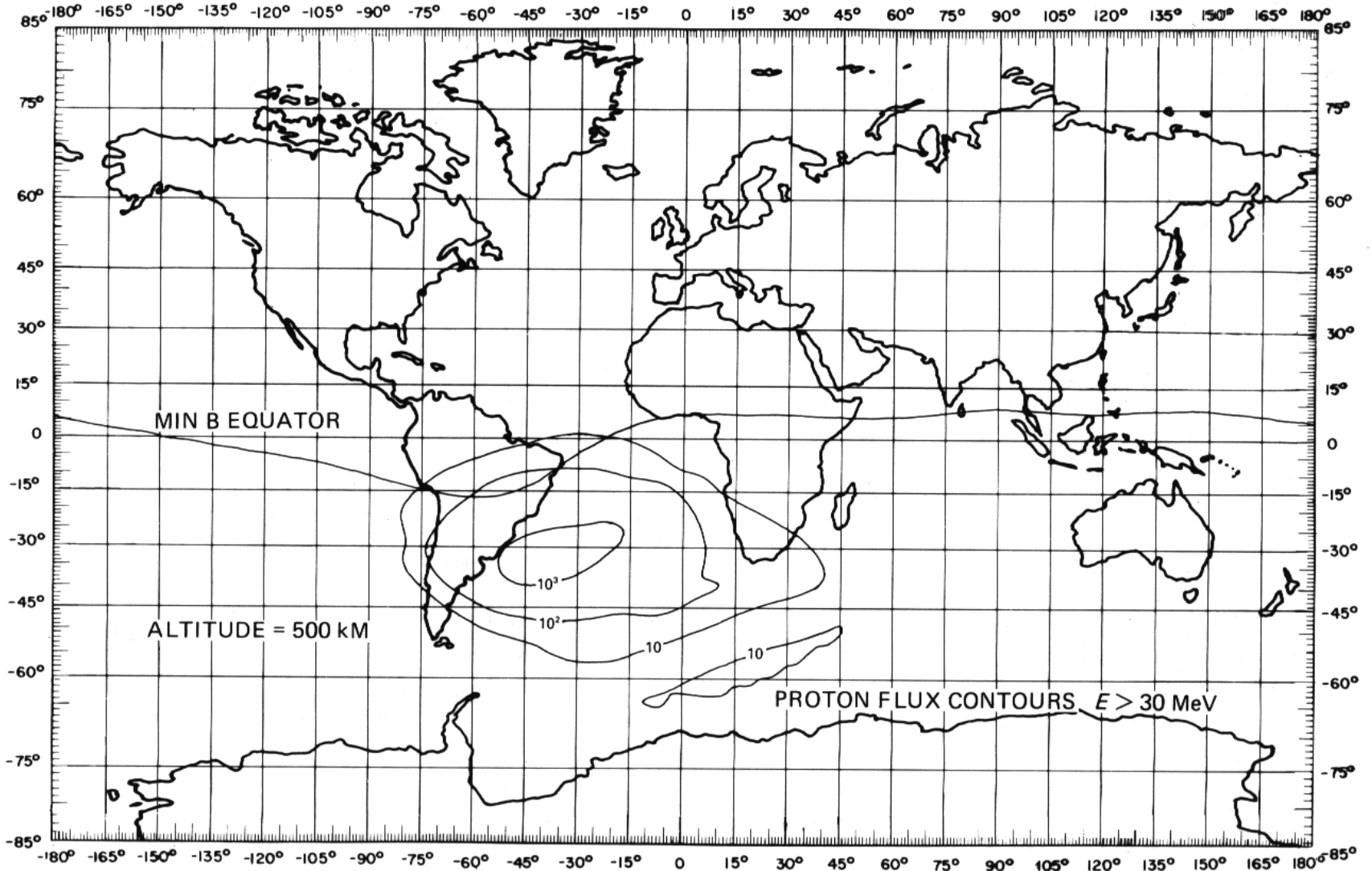
$$B_{\text{total}} = B_{\text{propio}} + B_{\text{inducido}}$$

FIG. 1.20. Earth's radiation belts. The top panel shows the contours of the omnidirectional flux (particles per square centimeter per second) of protons with energies greater than 10 MeV. The bottom panel shows the contours of the omnidirectional flux of electrons with energies greater than 0.5 MeV.

tends into the solar wind becomes ionized and adds
 low, further decelerating it.
 own of the magnetized flow around the planet leads to
 magnetic-field lines over the obstacle and the formation

Trapped radiation (cont.)

Omni-directional flux in protons $\text{cm}^{-2} \text{s}^{-1}$. (Adapted from Stassinopoulos, E. G., *World Maps of Constant B, L, and Flux Contours*, NASA SP-3054, 1970.)



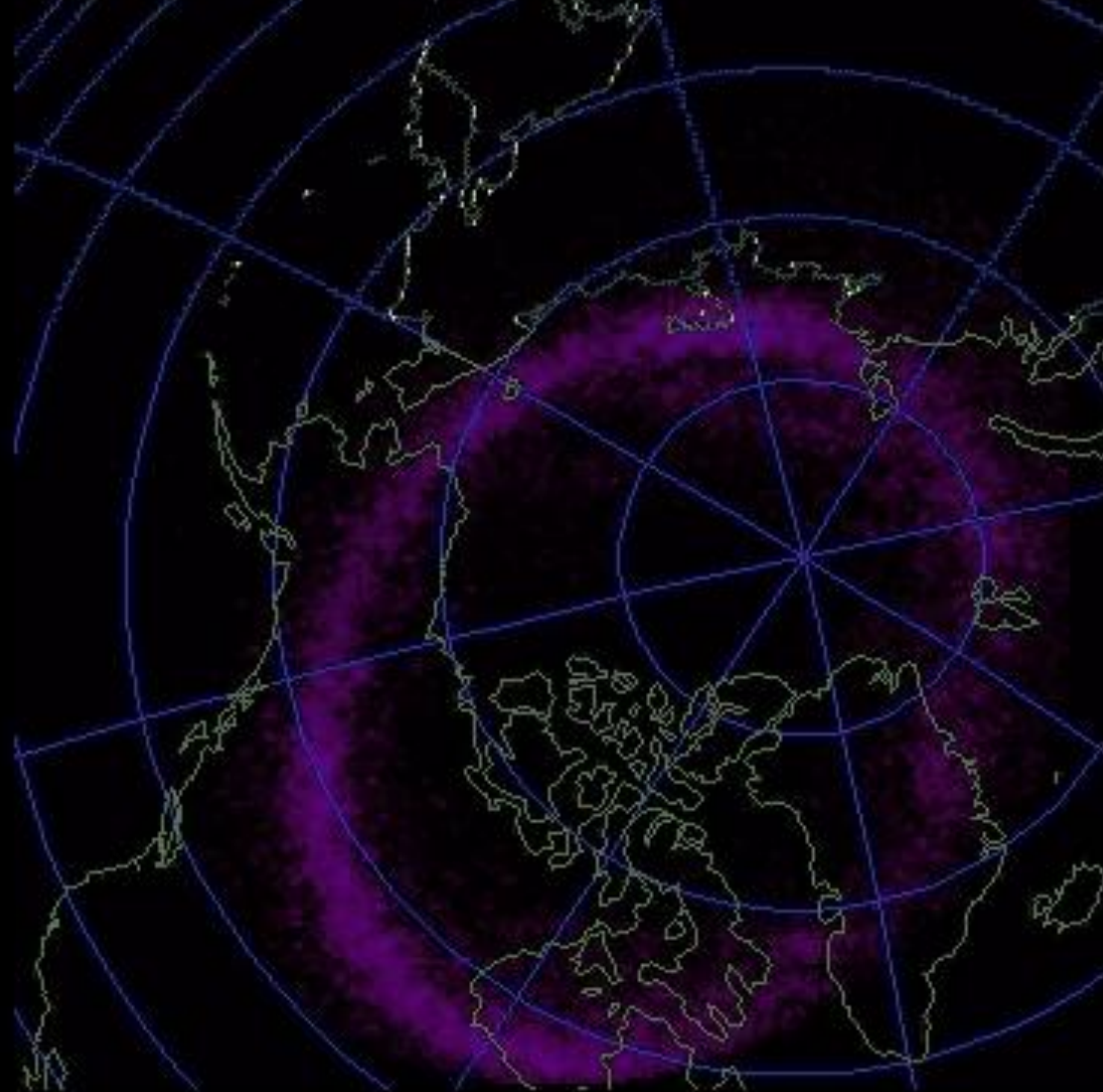


(JAN CURTIS)

970111

LBHL

1003 UT



MAGNETÓSFERAS:

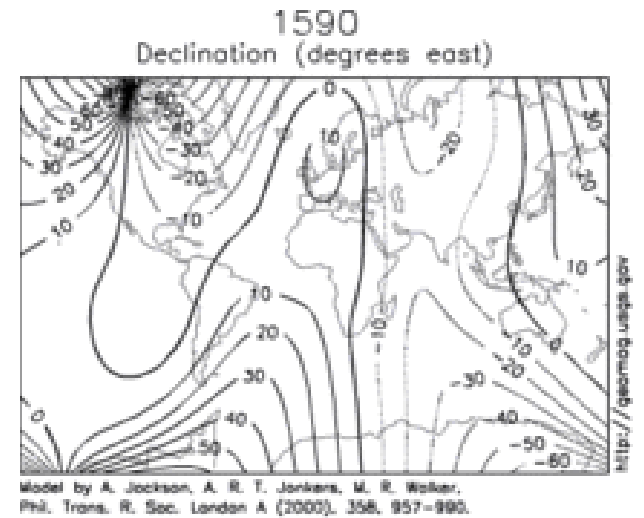
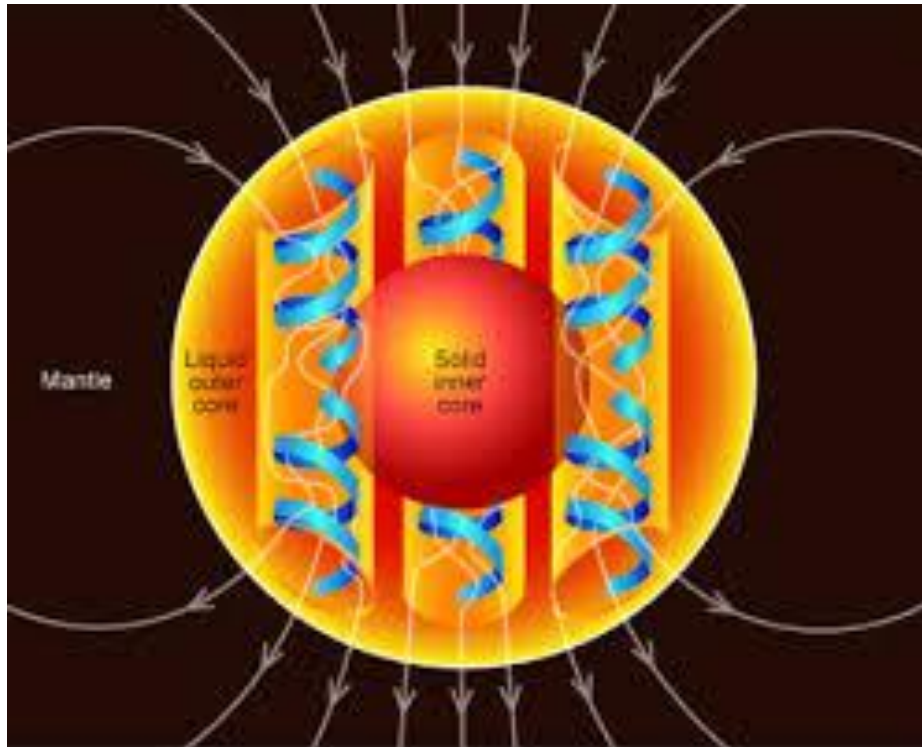
Estructuras magnéticas de entre 10 y 100 radios planetarios que interactúan con el VS.

Son sustentadas por los campos magnéticos que a su vez se generan por: dínamo (Tierra, JSUN, Mercurio), interacción VS-ionósfera (Venus, Marte, cometas) o por magnetismo remanente (Marte, Luna, asteroides).

Pueden emitir fotones en UV y visible (por átomos) o en radio (electrones acelerados).

Forma: depende de la intensidad del campo, del flujo de VS y de los movimientos de las partículas cargadas.

TEORÍA DÍNAMO: fluído conductor en movimiento que induce campo magnético

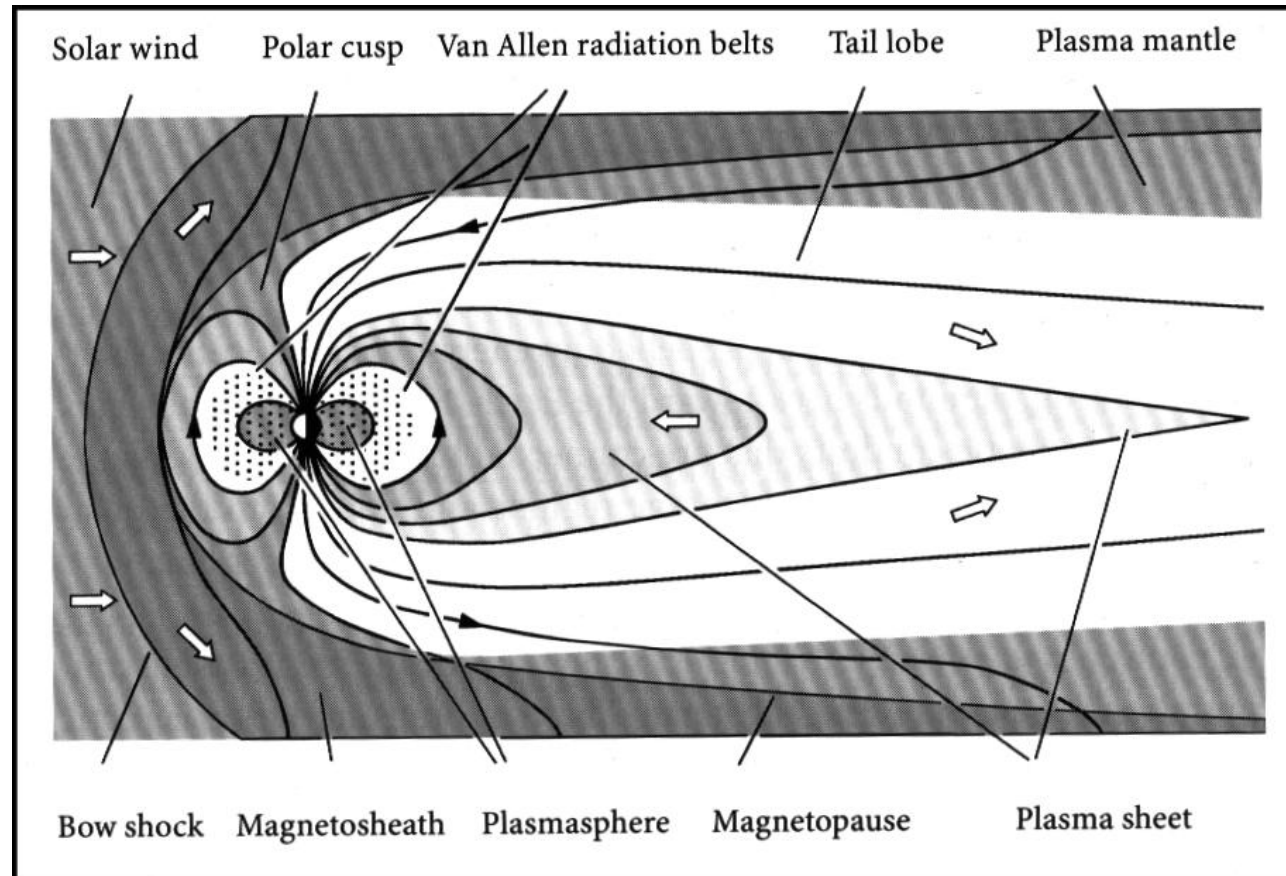


TEMPERATURA DE CURIE: por encima de ella se pierde la memoria magnética

MAGNETÓSFERA:
cavidad en Viento Solar
producida por campo
magnético del planeta.

**BOW SHOCK (ESCUDO DE
CHOQUE):** escudo por donde se
desvia el viento solar

MAGNETOPAUSA:
límite entre
magnetósfera y
campo magnético
interplanetario



MAGNETOCOLA: extensión de la magnetósfera en la dirección anti-Sol. Llega hasta 1000 radios terrestres.

RECONEXIÓN: líneas de campo de dirección contraria que se aniquilan convirtiendo energía magnética en térmica y cinética del plasma. En la magnetósfera terrestre estos eventos generan tormentas magnéticas.

EVENTO DE DESCONEXIÓN: observado en la cola de los cometas al pasar de un hemisferio magnético a otro.

EMISIÓN SINCROTRÓN (RADIO): emisión generada por electrones acelerados a altas velocidades por los campos magnéticos planetarios.

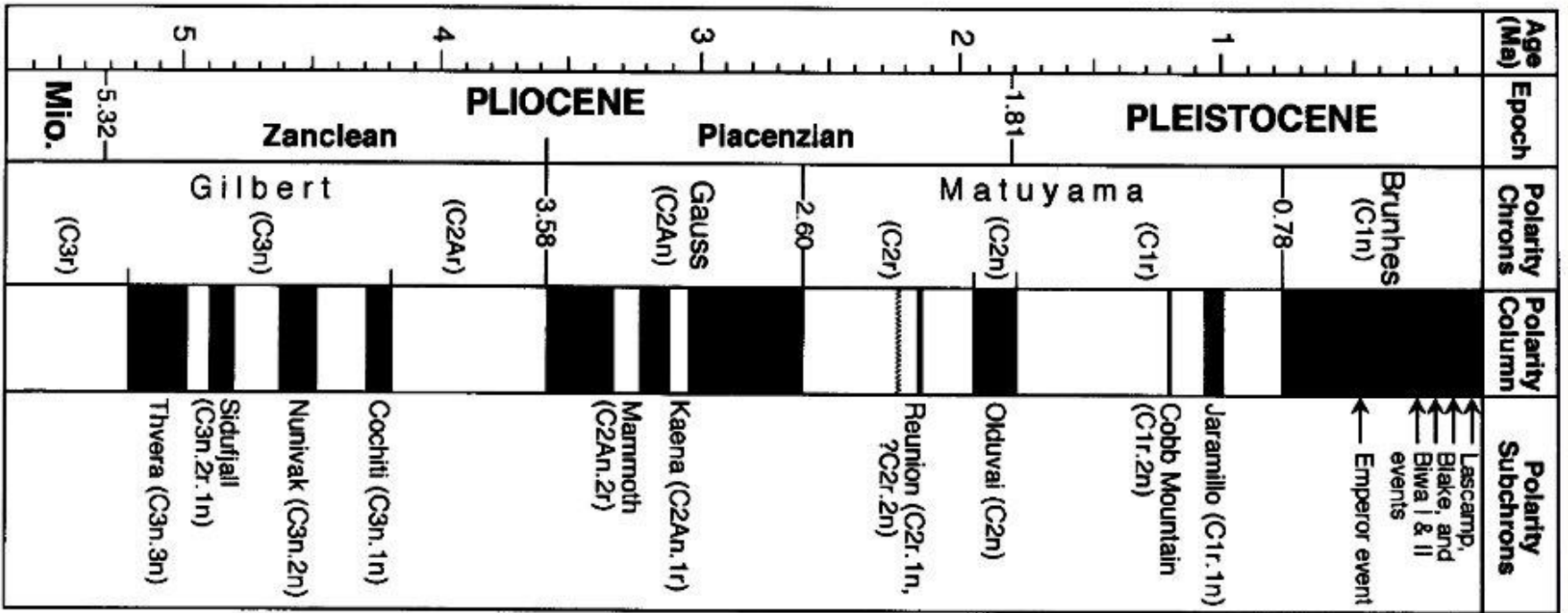
CLIMA ESPACIAL:

Efecto de la variable actividad solar en planetas, magnetósferas, atmósferas, cuerpos menores, satélites naturales y artificiales

TRES AGENTES:

- RADIACIÓN SOLAR (fotoionización)
- VIENTO SOLAR (ionización, auroras)
- CAMPO MAGNÉTICO INTERPLANETARIO (eventos de desconexión, corrientes inducidas)

Inversiones magnéticas terrestres recientes



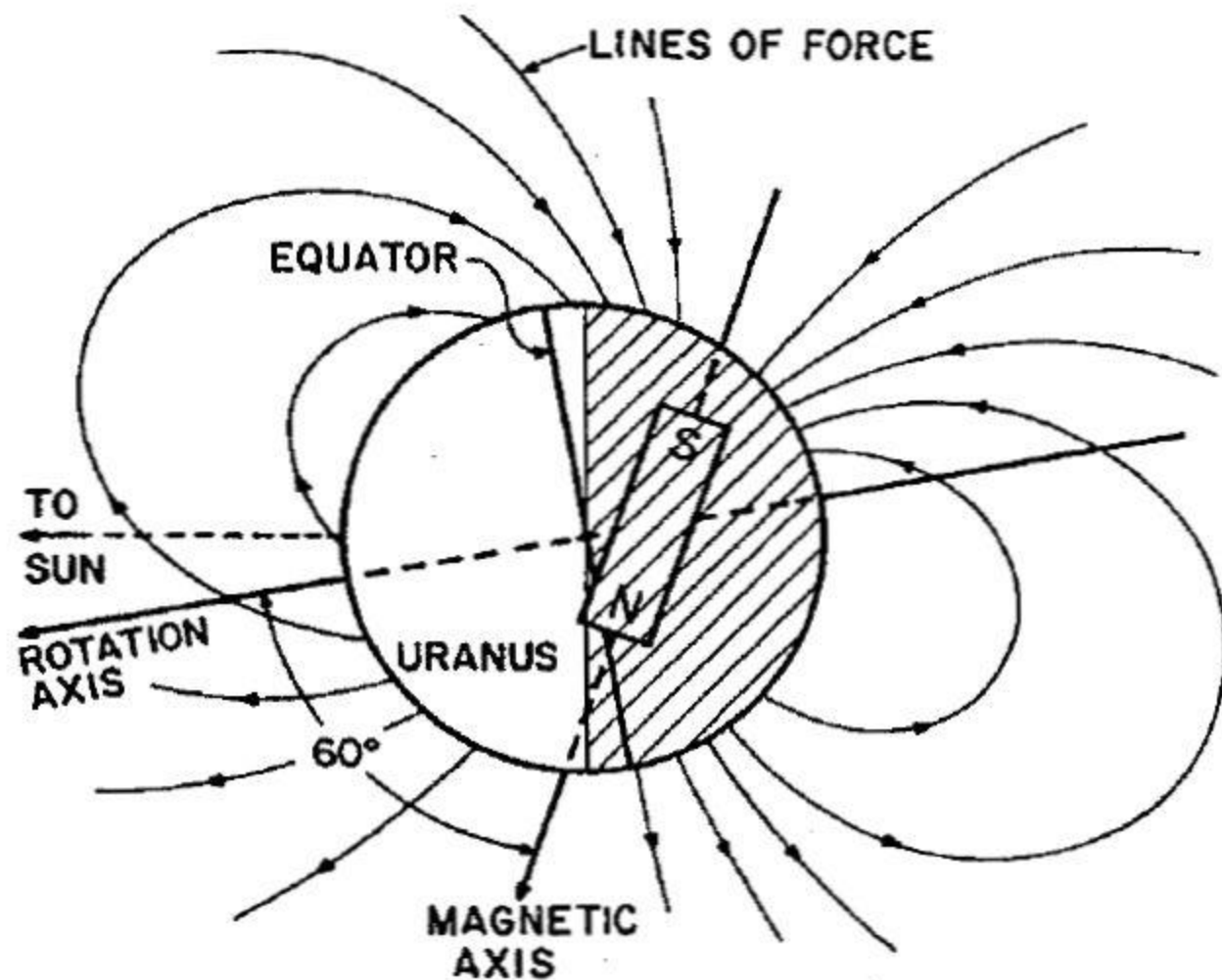


Figure 7.43 A sketch of Uranus's offset dipole magnetic field. (Ness *et al.* 1991)

Table 7.3 Plasma characteristics of planetary magnetospheres.

	Mercury	Earth	Jupiter	Saturn	Uranus	Neptune
Maximum density (cm^{-3})	1	1000–4000	>3000	~100	3	2
Composition	H^+	O^+ , H^+ , N^+ , He^+ , He^{++}	O^{n+} , S^{n+} , SO_2^+ , Cl^+	O^+ , H_2O^+ , H^+	H^+	N^+ , H^+
Dominant source	solar wind	ionosphere solar wind	Io	rings, Enceladus, Tethys, Dione	atmosphere	Triton
Production rate (ions s^{-1})	?	2×10^{26}	$>10^{28}$	10^{26}	10^{25}	10^{25}
Ion lifetime	minutes	days, ^a hours ^b	10–100 days	1 month–years	1–30 days	1 day
Plasma motion controlled by:	solar wind	rotation ^a solar wind ^b	rotation	rotation	solar wind + rotation	rotation (+ solar wind?)

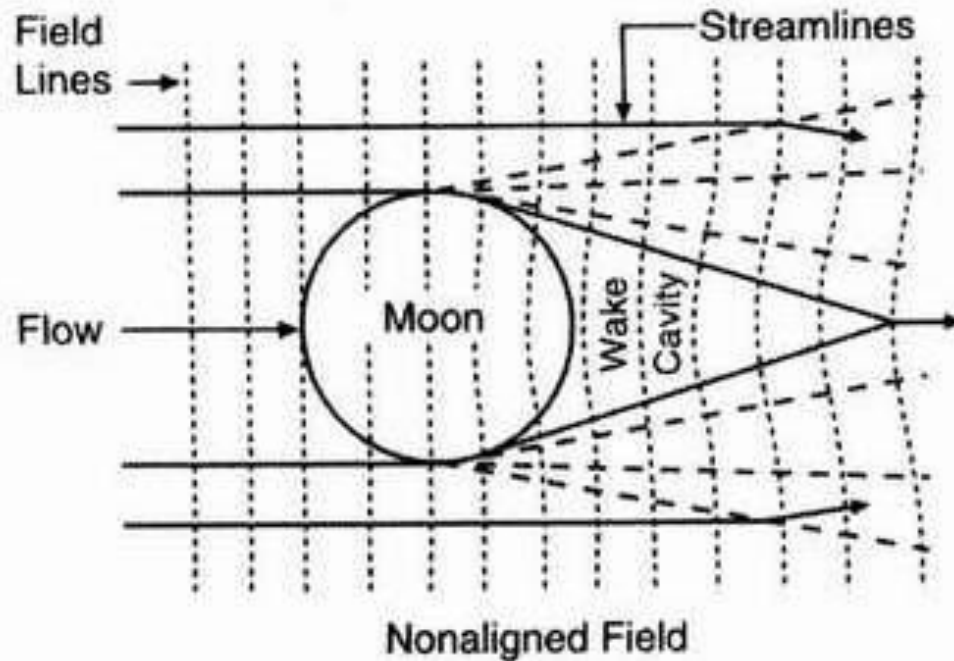
After Kivelson and Bagenal (2007).

^a Inside plasmasphere.

^b Outside plasmasphere.

Efecto en planeta sin atmosfera ni campo magnetico

(a)



(b)

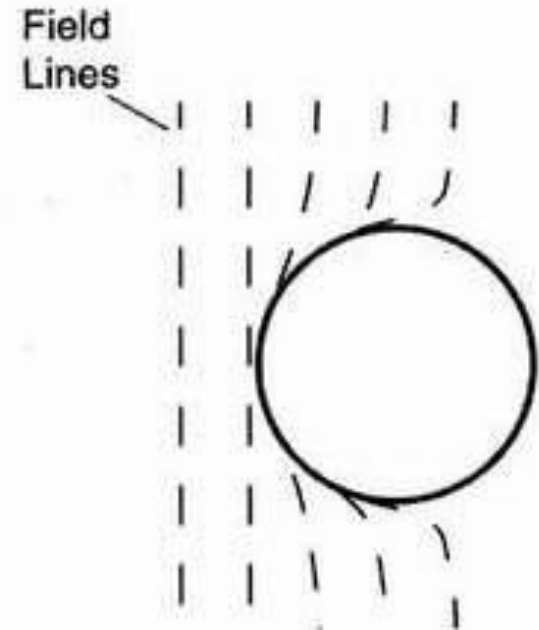
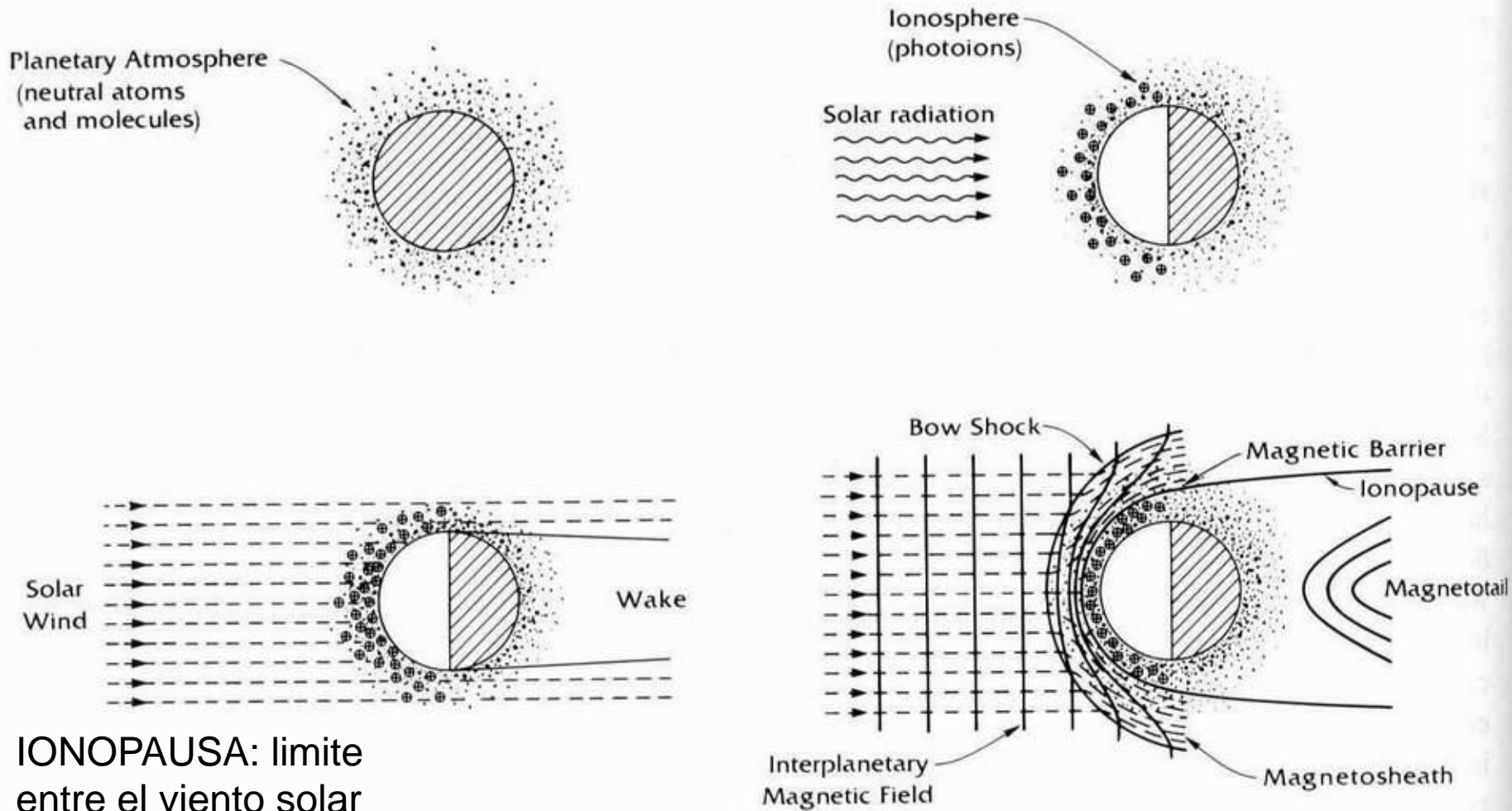


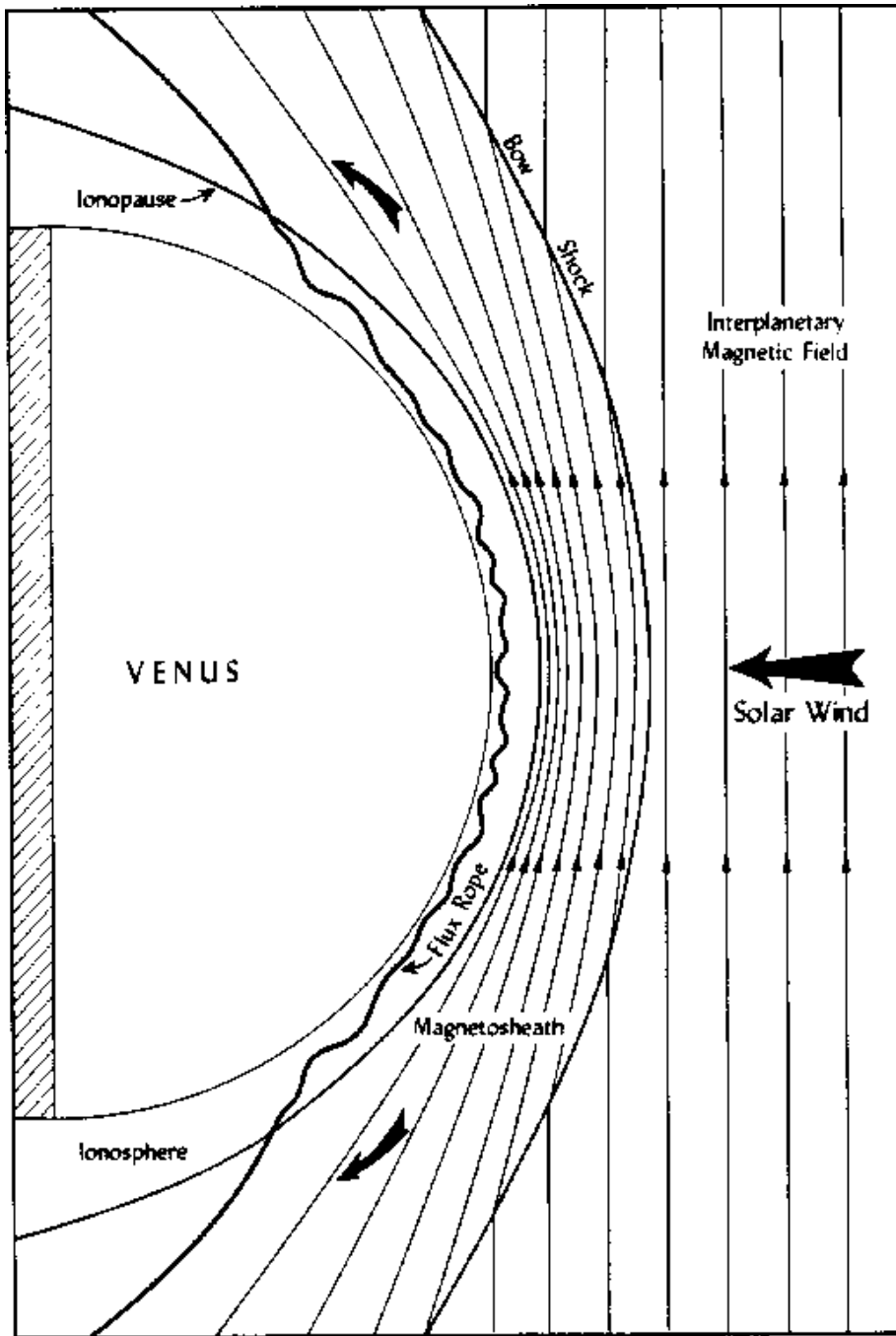
FIGURE 7.8 Interaction of the solar wind with various types of planetary bodies that do not possess internal magnetic fields. (a) A nonconducting body, (b) a conducting body, and (c) a body with an ionosphere. (Adapted from Luhmann 1995)

Planeta con atmosfera y sin campo

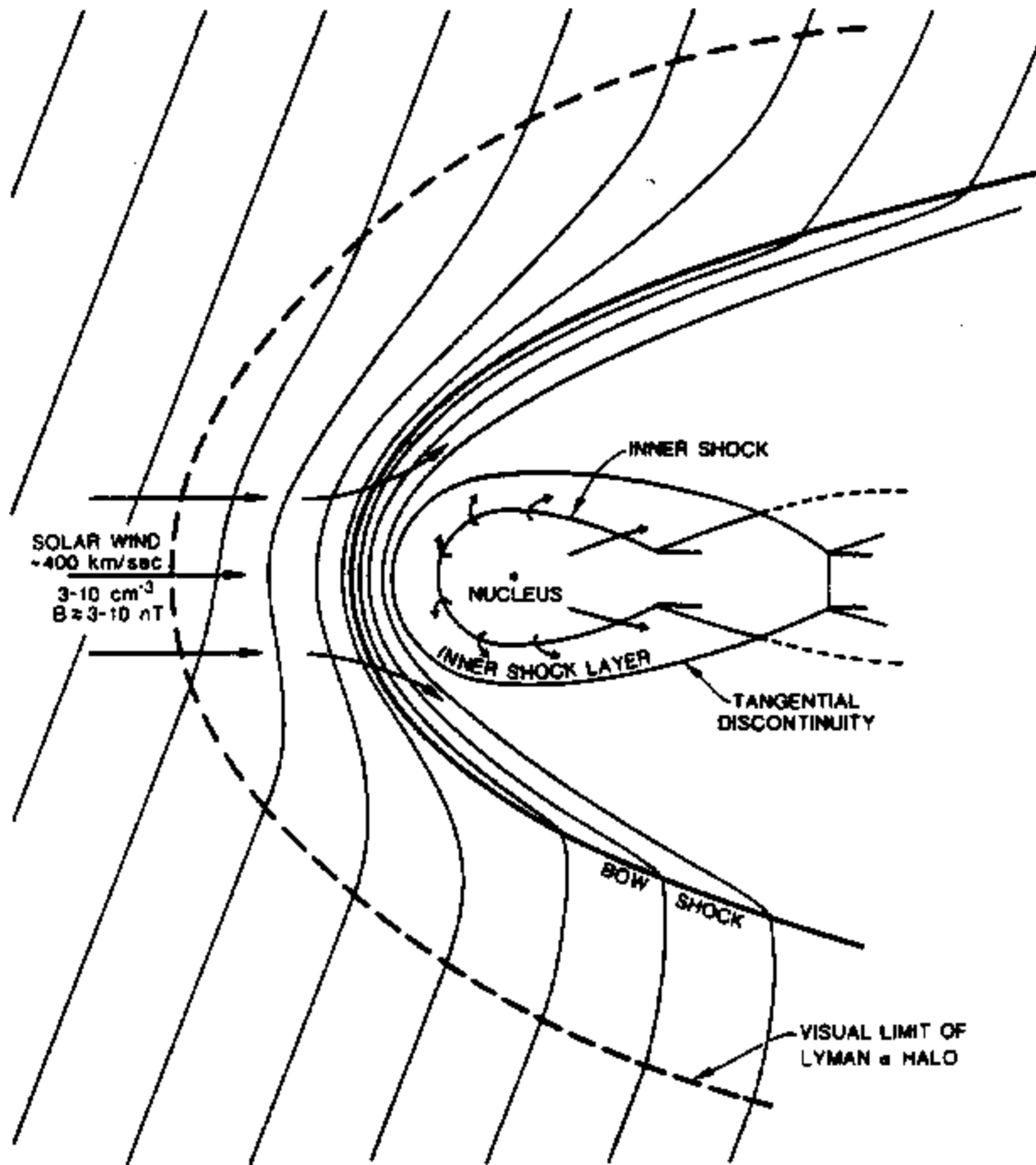


IONOPAUSA: limite entre el viento solar y la ionosfera para planetas sin atmosfera

FIG. 8.5. Illustration of the steps that lead to the formation of an ionospheric planetary obstacle in a flowing plasma like the solar wind. Ionization by solar radiation, for example, is followed by diversion of the external plasma flow only if that flow is magnetized.



Venus y Marte
no poseen
campo
magnetico



Cometa

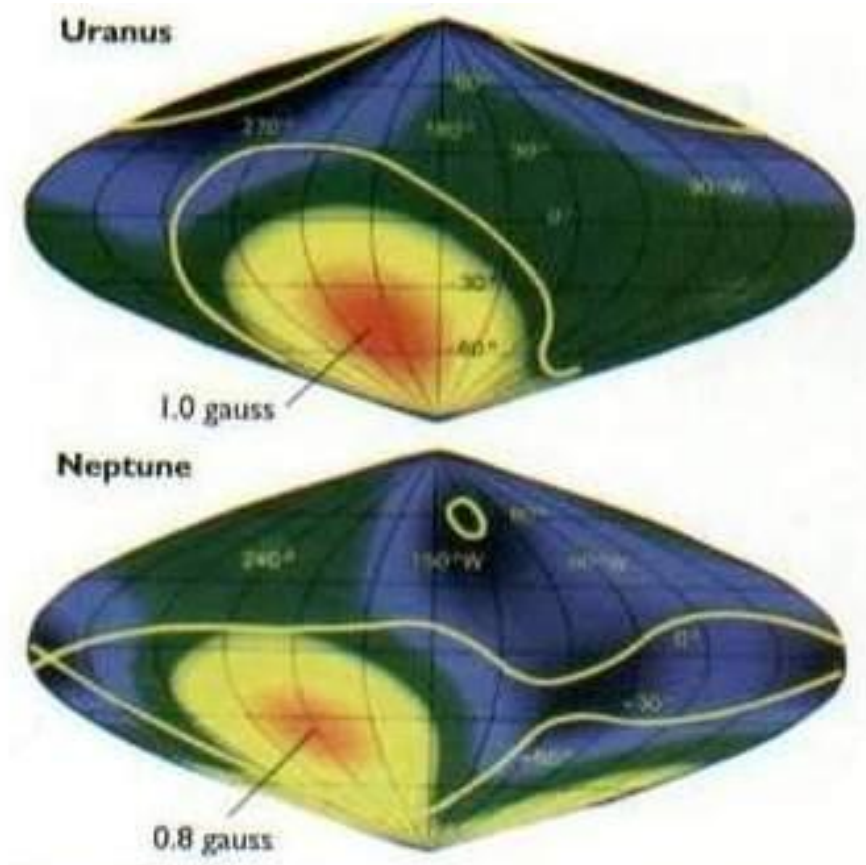
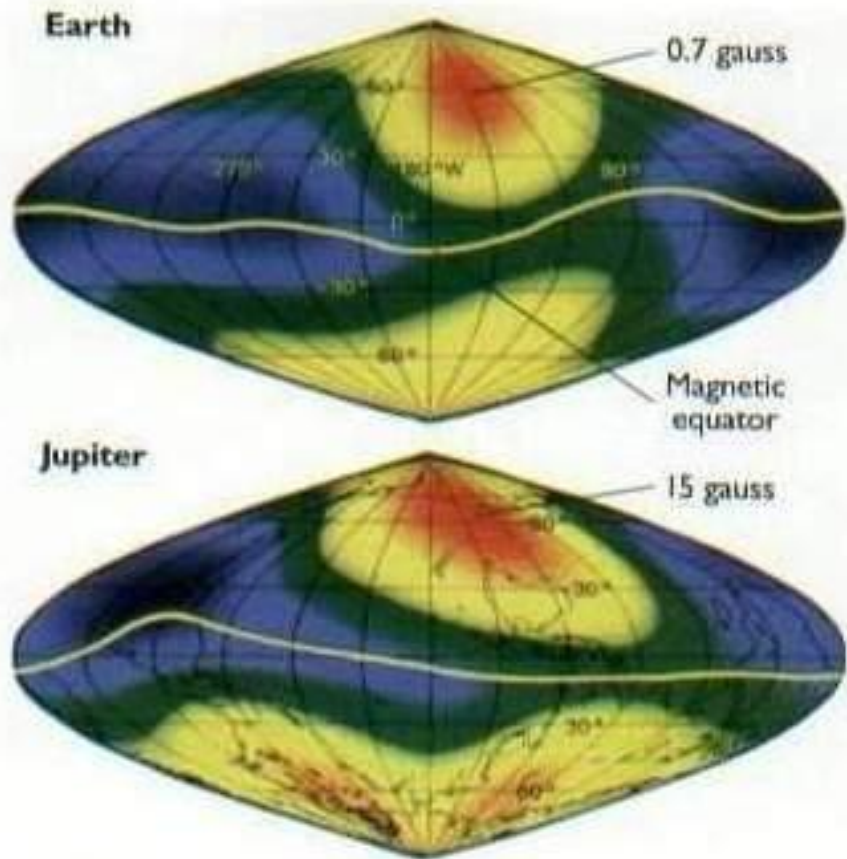
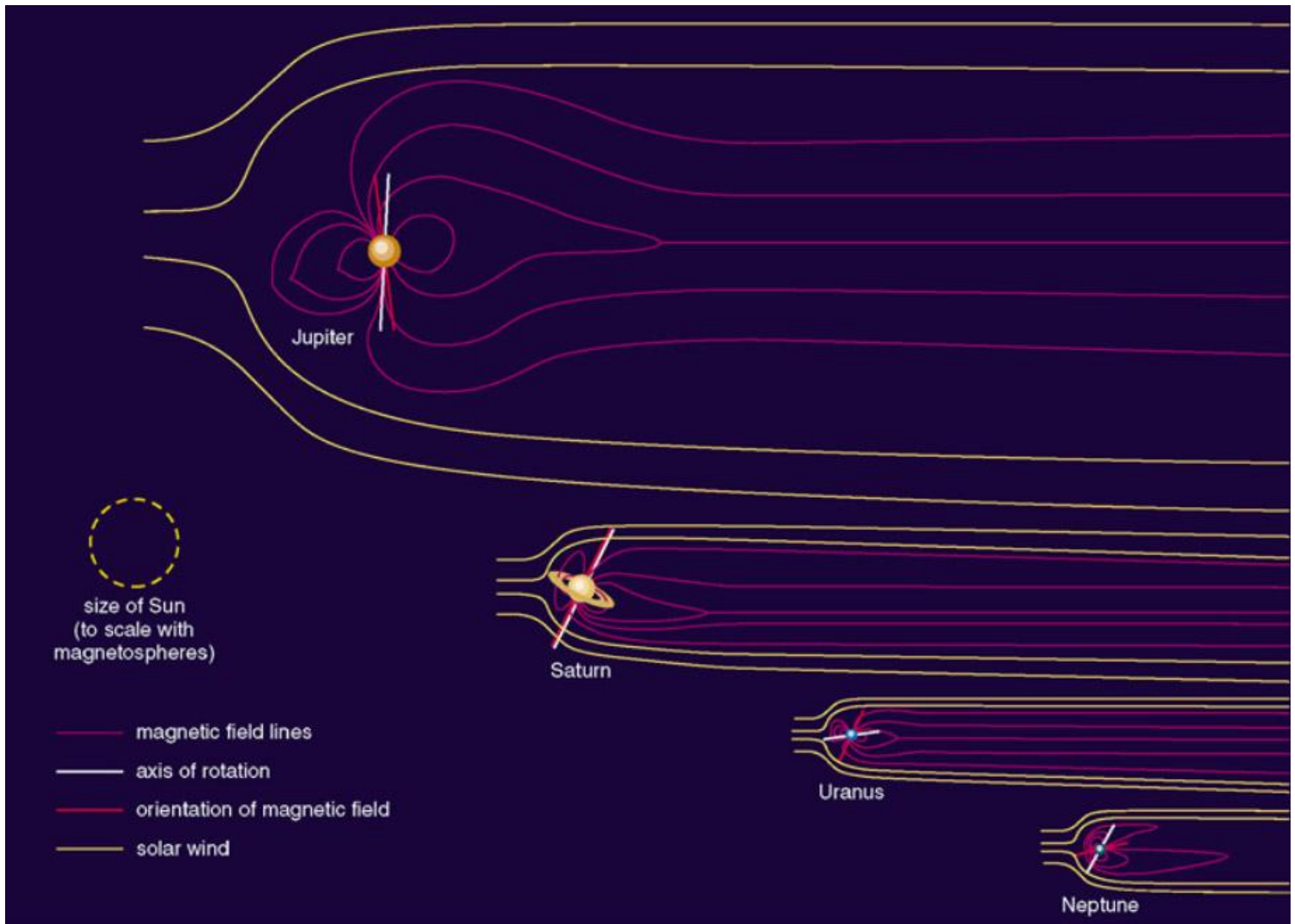
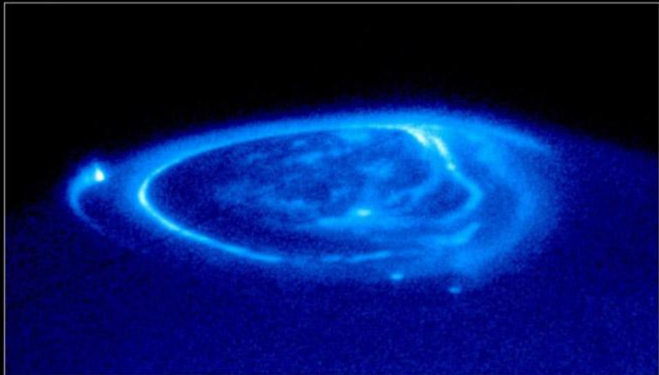
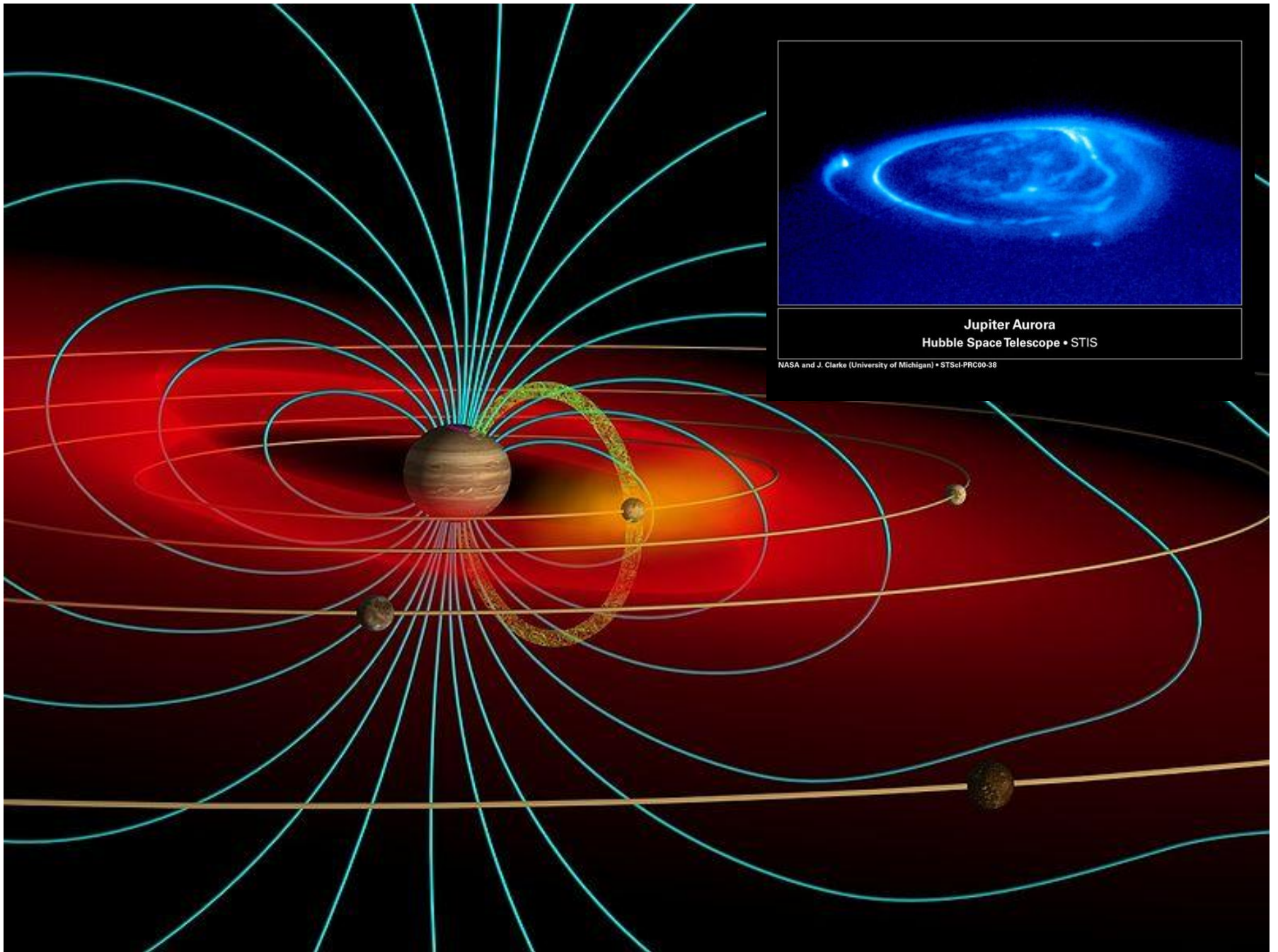


Figure 4. The magnetic fields on the surface of Earth, Jupiter, Uranus, and Neptune exhibit a wide range of strengths. Note especially how the dipole fields of Uranus and Neptune, which are markedly offset from the planets' centers, create distinctly asymmetric surface fields.





Jupiter Aurora
Hubble Space Telescope • STIS

NASA and J. Clarke (University of Michigan) • STScI-PRC00-38

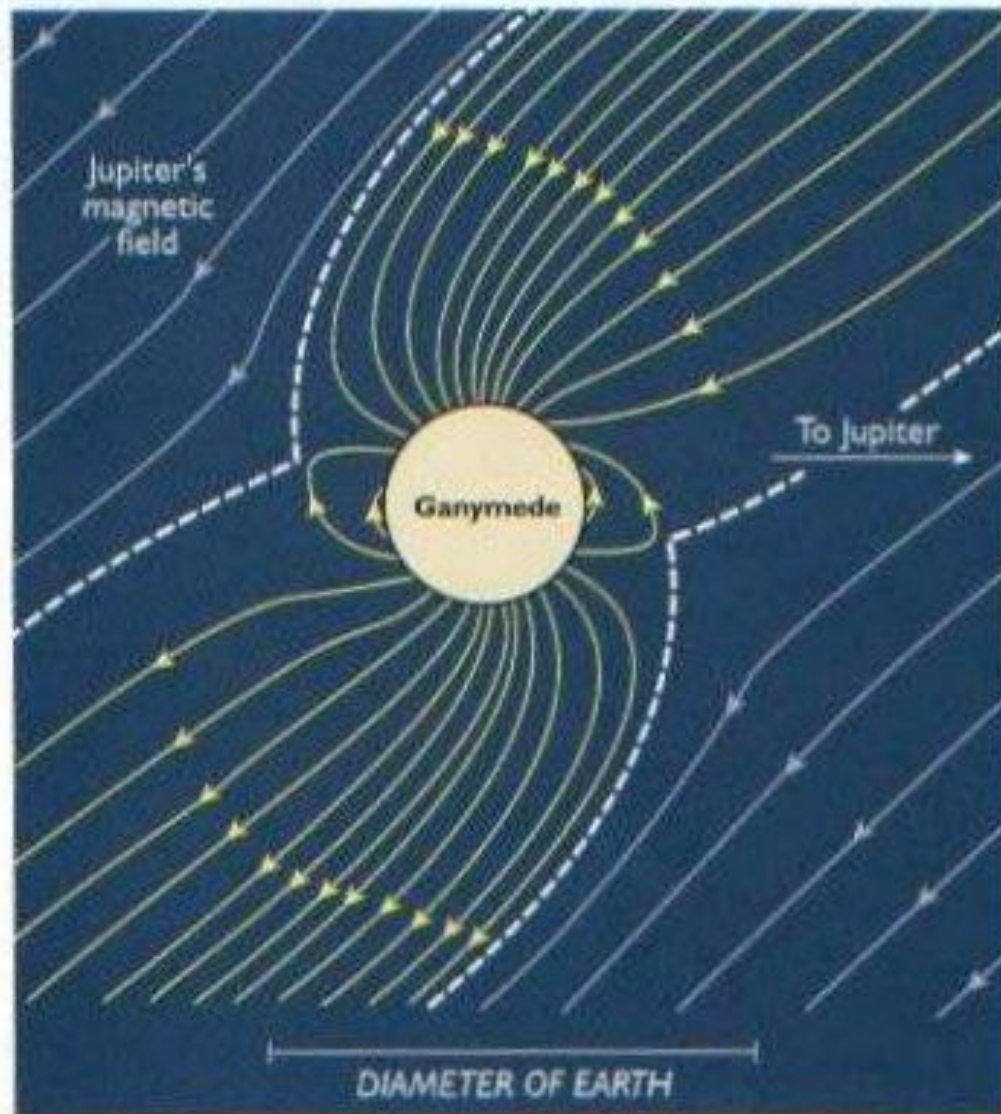
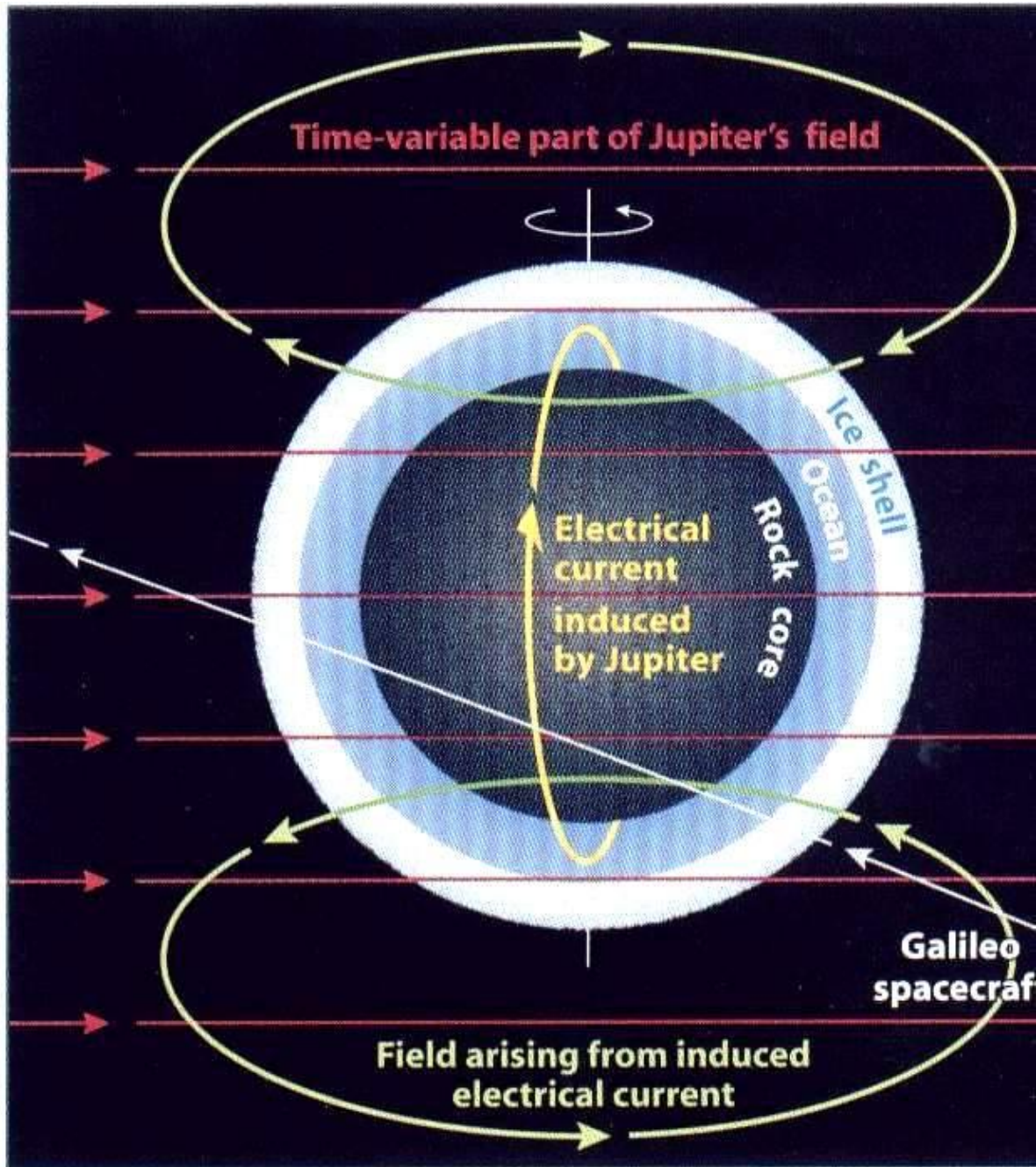


Figure 20. The magnetosphere of Ganymede is shown for conditions at the time of Galileo's first two flybys in 1996, from a perspective in front of the moon along its orbit. Gray lines represent the magnetic field of Jupiter, and yellow lines those attached to Ganymede.



BIBLIOGRAFIA

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