Plasma environment of Europa

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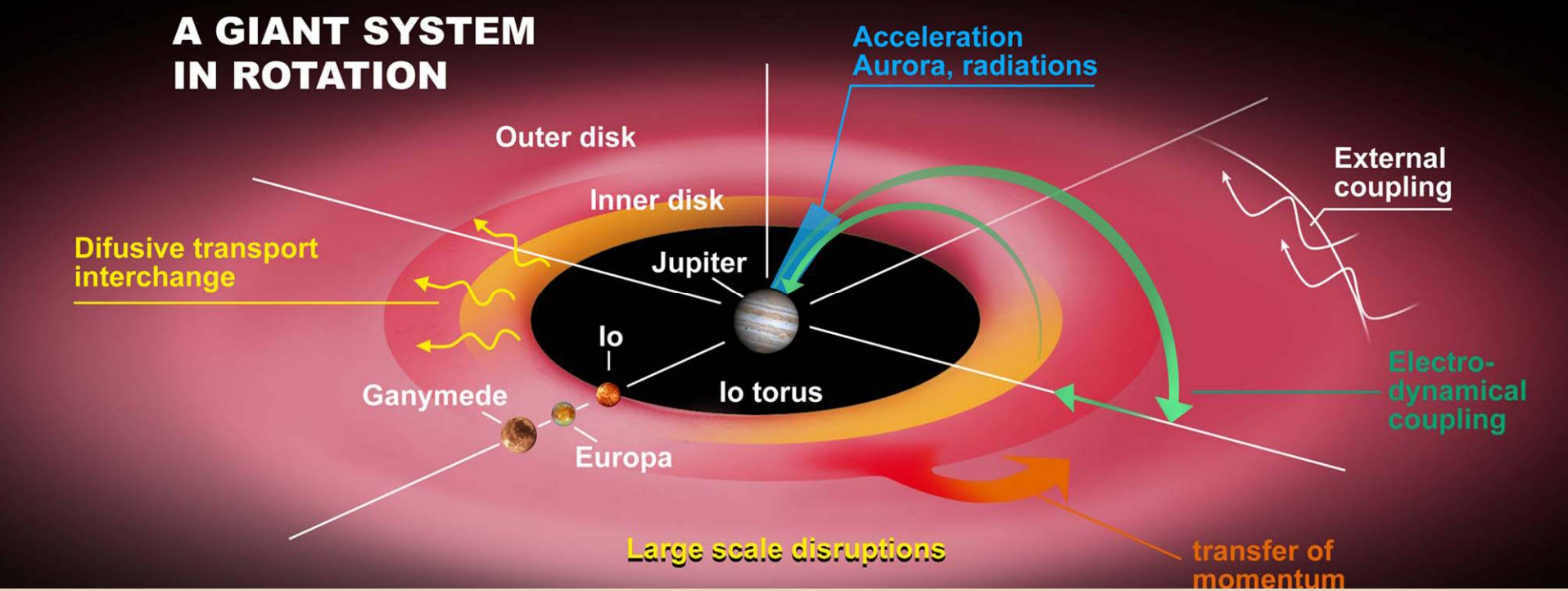
a review of plasma conditions and effects near Europa
of interest to prime tasks of a landing mission

Acknowledgements to used publications:
K.Khurana et al, Russell et al, Frank et al., Paranicas et al., Kivelson et al.,
Johnson et al., Krupp et al., etc



Jupiter specifics

weak solar wind: ★ internal effects dominate

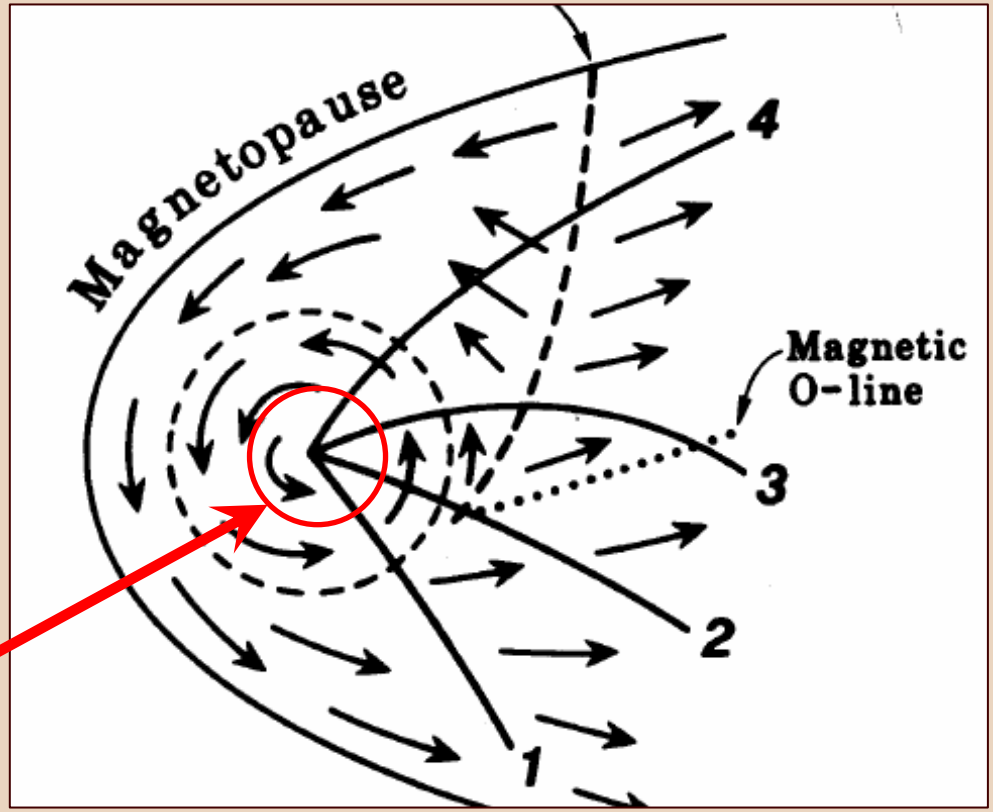
strong magnetic field & fast rotation: ★ powerful energizing environment

Io outflow: ★ strong outflow of cold heavy ions

rotating magnetosphere

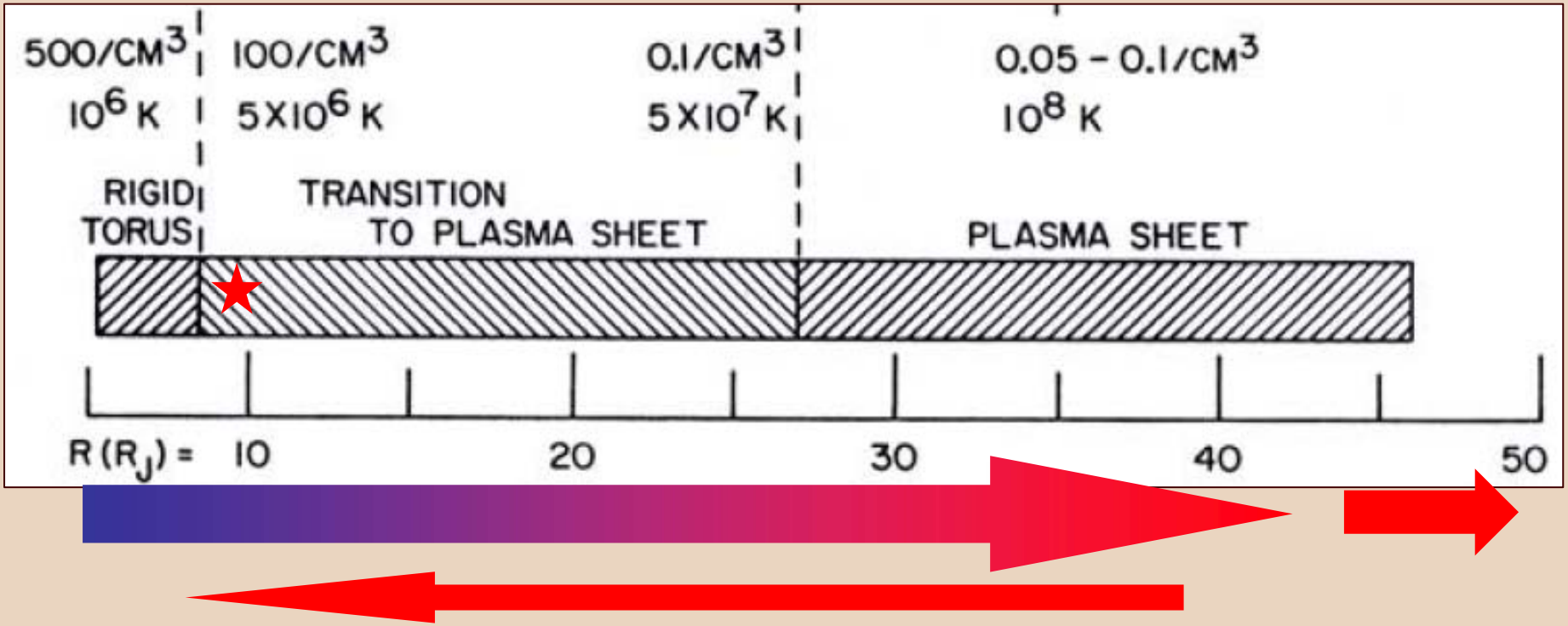
electric potential of rotation at **Jupiter** is **400 MV**, solar wind “only” **1 MV**

at **Earth** both are ~ **100 kV**



Europa location

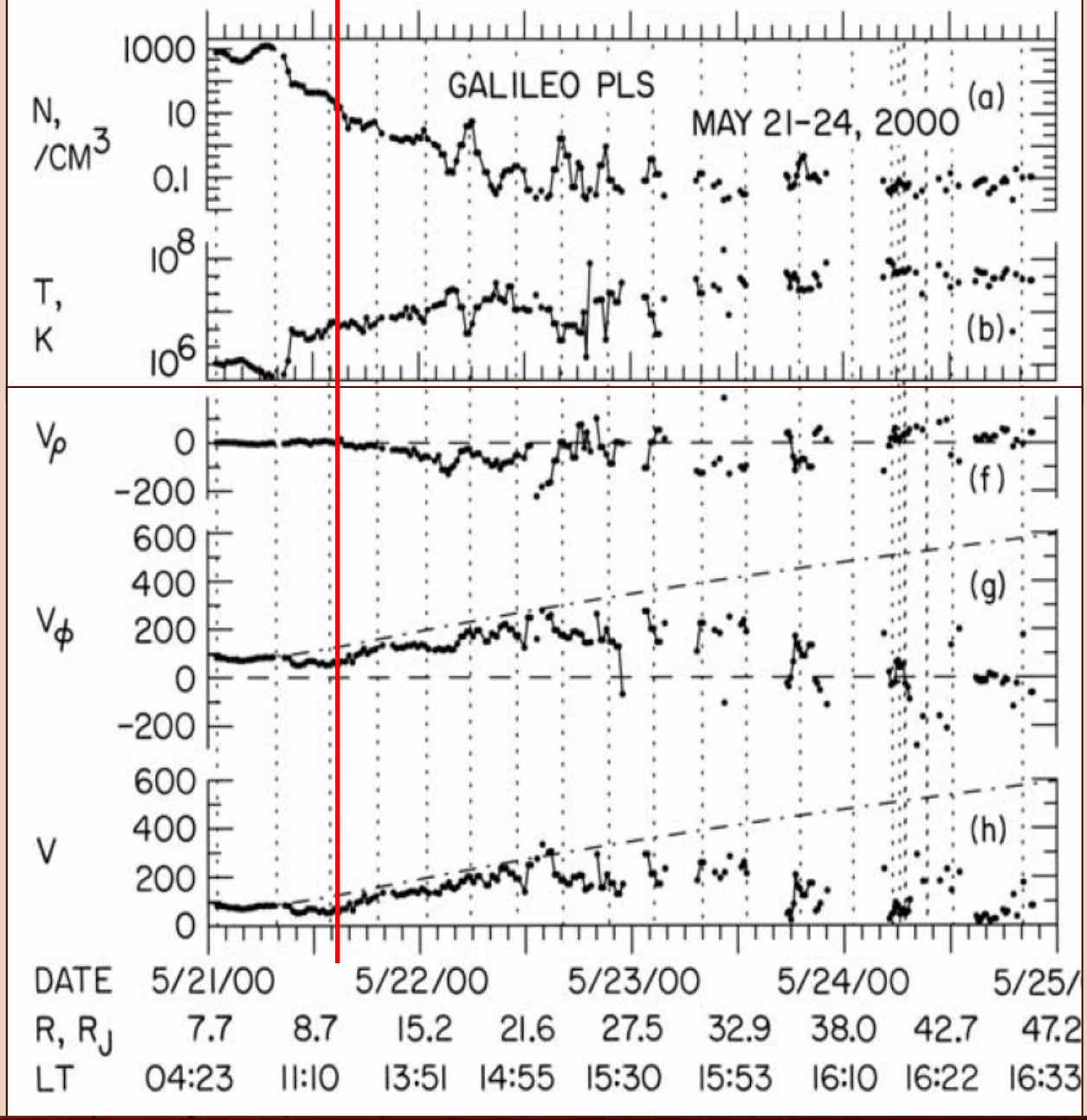
particle populations



magnetic flux tubes with **cold plasma (100 eV)** diffuse out and heated
most of plasma is lost

flux tubes with **hot rarefied plasma 10's of keV** return back to Jupiter

Outer radiation belts ~ 1-100 MeV are accelerated tails of hot plasma
balance of hot and cold populations powers instabilities


GALILEO PLS
MAY 21-24, 2000
N, /CM3
1000
10
0.1
(a)
T, K
10^8
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(b)
Vρ
0
-200
(f)
Vφ
600
400
200
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-200
(g)
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(h)
DATE 5/21/00 5/22/00 5/23/00 5/24/00 5/25/
R, RJ 7.7 8.7 15.2 21.6 27.5 32.9 38.0 42.7 47.2
LT 04:23 11:10 13:51 14:55 15:30 15:53 16:10 16:22 16:33

variability

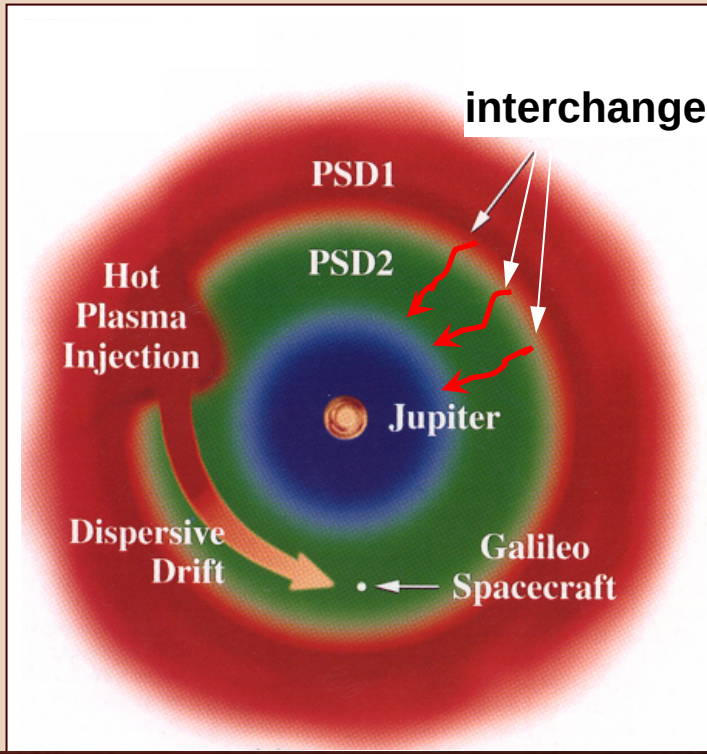
cold plasma diffuse outside + up and down motion relative to Europa orbit

bursty iward radial transport of hot plasma: three time scales

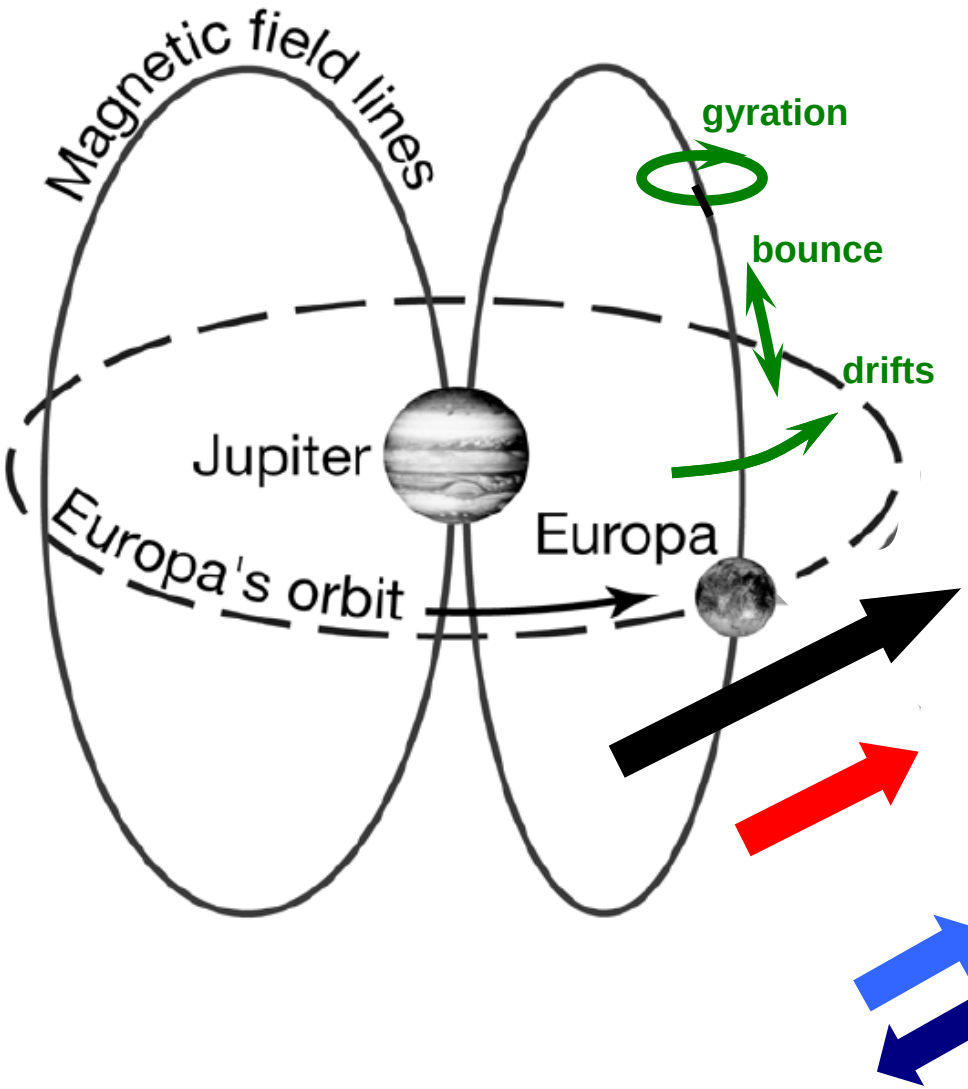
- interchange: relatively empty flux tubes penetrate inside
  minutes, 100 km/s
- injections: drifting hot plasma regions
  hours
- substorms: global unloading, a bunch of injections
  days

cold plasma: 10-200 cm^{-3} pressure 2-10 nPa

energetic plasma (> 20 keV): pressure ?-10 nPa



particle motion



Europa orbital motion 14 km/s

corotation velocity 117 km/s

Europa is standing in plasma flow ~100 km/s

electric field drift ~ 40 mV/m

energetic plasma has gradient drifts

ions drift in direction of corotation
Europa moves ~5000 km per bounce

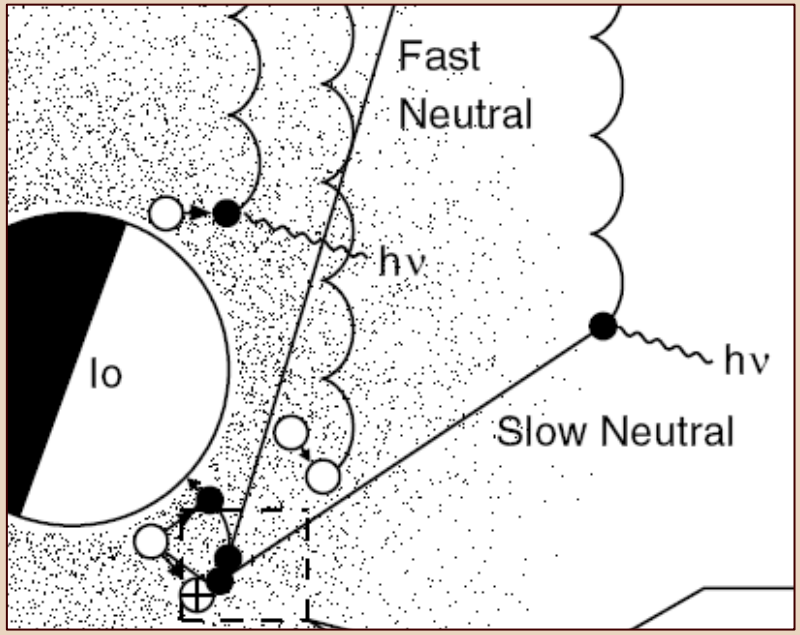
electrons drift against corotation
< 20 MeV can not overcome corotation
> 20 MeV faster than corotation
Europa moves ~300 km per bounce

plasma effects-1

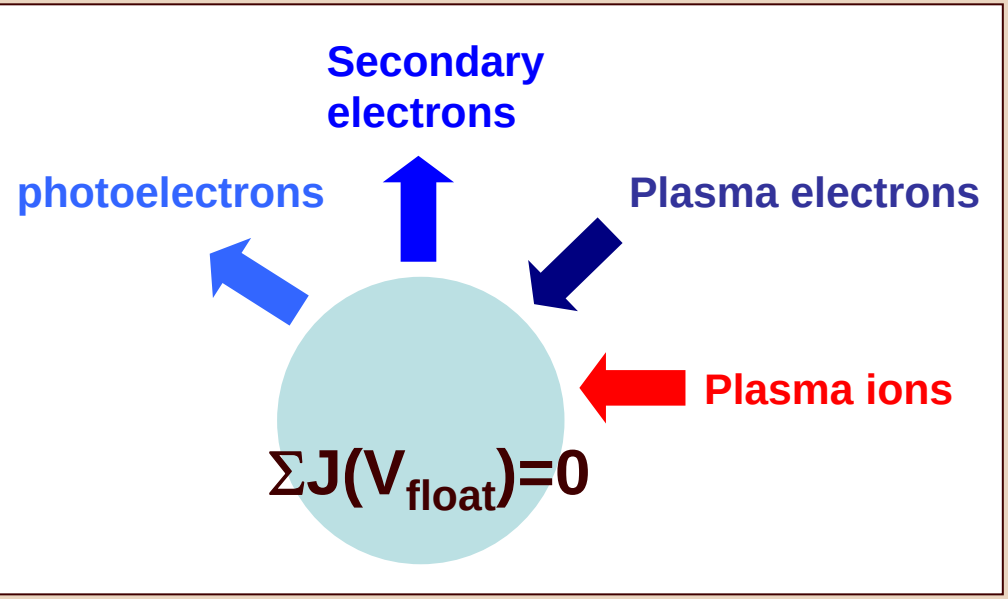
- **high abundance of heavy ions: sulfur:** Schwefelaufnahmevermögen

- **fast pick-up of fresh ions by corotation:**
  ions acquire velocity ~ 100 km/s and run away

analysis of neutrals by ionization might be a problem (Phobos-type experiment)



plasma effects-2



- **surface charging**

objects in plasma acquire floating potential so that total current is zero

floating potential is of the order of temperature of dominating flux

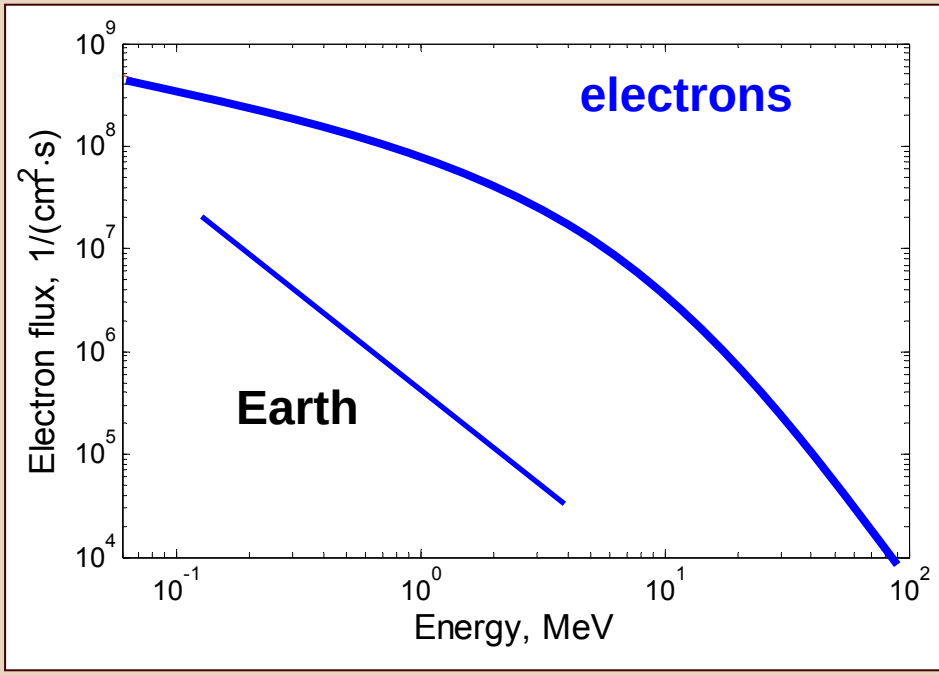
in solar wind (Phobos, asteroids) photoelectrons dominate **V ~ +1-5 V**

at Europa photocurrent is weak, if cold electrons dominate **V ~ -100 V**
if hot electrons (>keV) **V ~ - some keV**

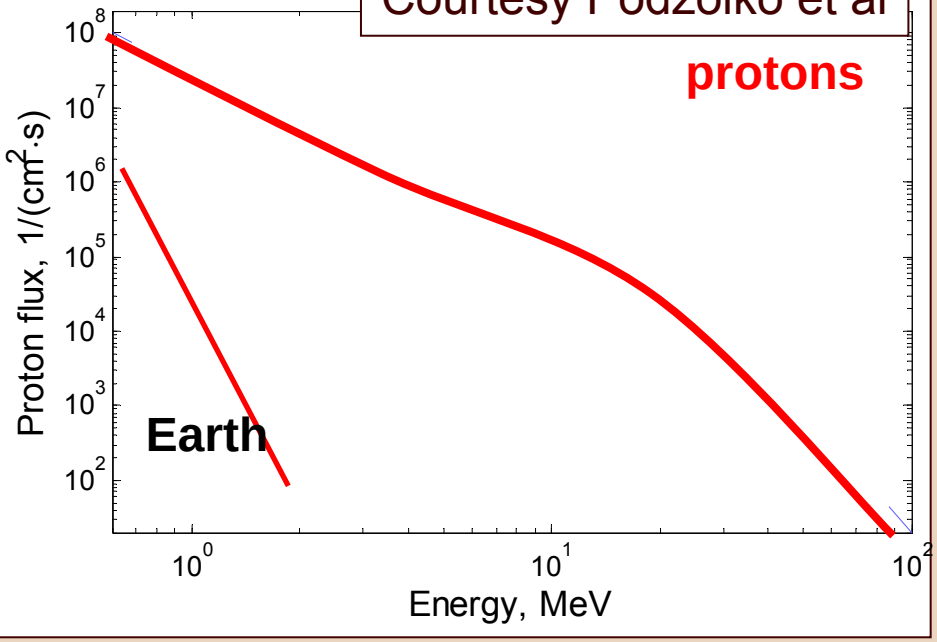
spacecraft are equipotential (by conducting layer)

but ice, regolith, moving elements may be differentially charged

energetic plasmas



Courtesy Podzolko et al



total **dose** amounts to **megarad** - a killing quantity for a near-Earth satellites

Galileo survived 650 krad (estimate), 3 times above nominal,
thanks to a very conservative design

for various instruments and conditions doses might be substantially different

dose is “global climate”, while “regional climate” and “weather” are also important

plasma effects-3

dose **behind 1 cm** of Al is dominated be electrons: **1 Mrad** for 2 months

dose with **no shielding** is dominated by ions: **0.2 Grad** for 2 months

ions penetrate to sub-mm depths
important for open sensitive elements (like CCD's)
► total dose
► single event upsets

electrons pass ~0.5 cm of unit density per MeV
important for electronics
► total dose
► internal charging

bremsstrahlung gamma rays from electrons (>10 MeV) can pass 10's of cm

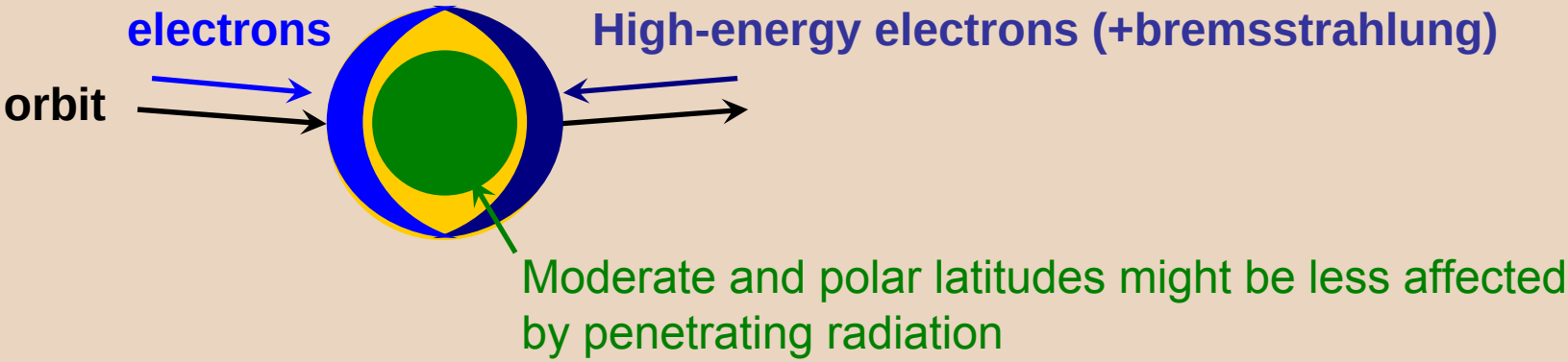
plasma effects-4

- **radiation affects the spacecraft as well as … Europa surface**

tomorrow's talk by Patterson et al.

1 rad = 100 erg/g ~ 10^{-10} eV/nuclon *** mega/gigarads * millions of years**

what organics can survive ? How deep to dig ?
detailed calculations + surface formation +differential rotation



conclusions

Jupiter has powerful magnetosphere

- ✓ a lot of heavy ions
- ✓ fast acceleration of new ions
- ✓ surface charging
- ✓ radiation effects on spacecraft
- ✓ radiation effects on surface