L'ambiente spaziale

1. **(Pre-lancio)**
2. **Lancio**
    - **Vibrazioni**
    - **Accelerazioni**
    - **Shocks**
    - **Termica**
    - **Pressione**
3. **Post-lancio**

Vibrazioni

- Rumore Acustico
- Vibrazione dai motori
  - Densità spettrale di potenza

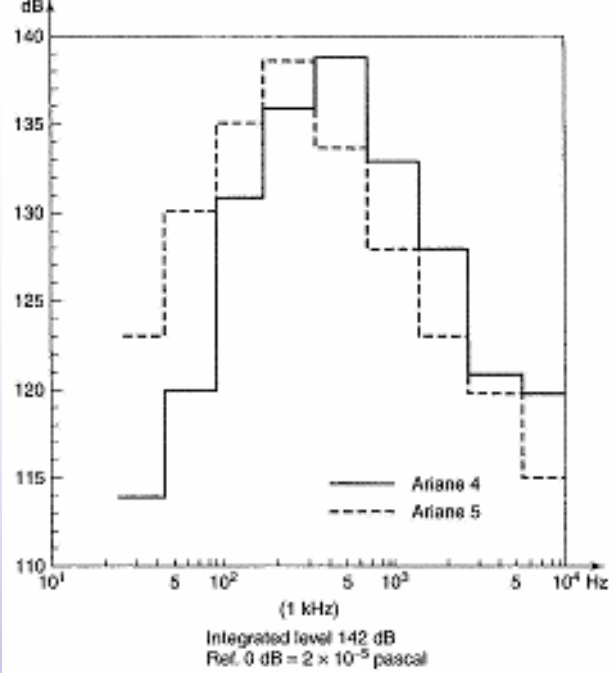


Figure 2.1 Ariane noise spectrum under SPELDA fairing, Ariane 4 [2] and SPELTRA, Ariane 5 [3]

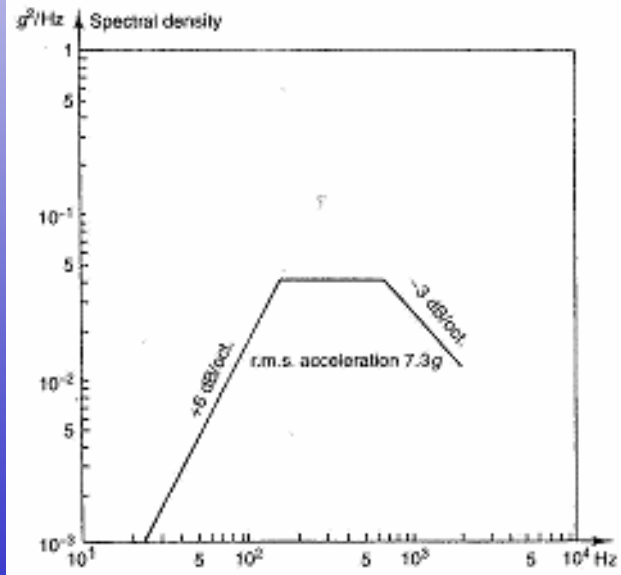
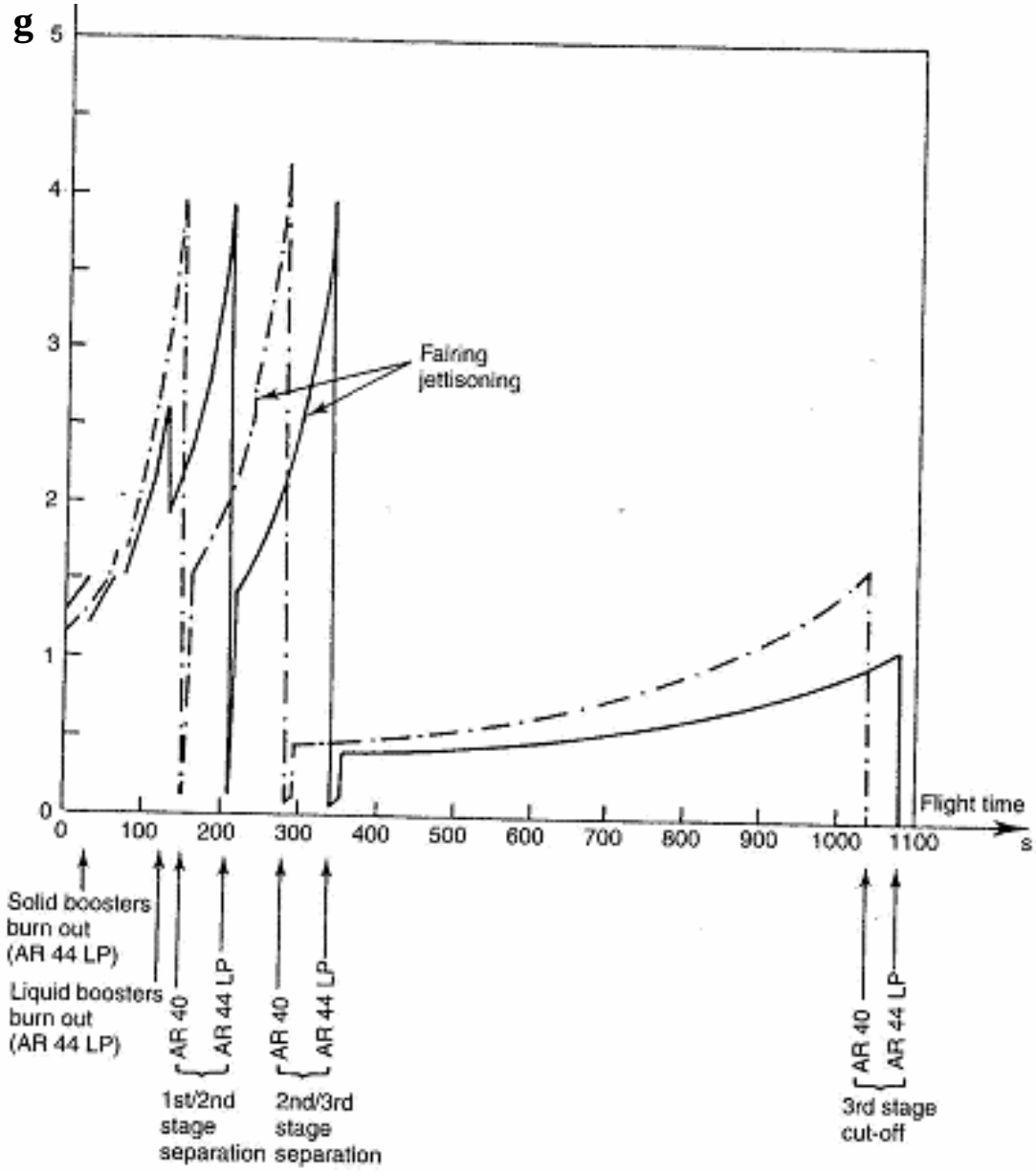


Figure 2.2 Ariane 4 random vibration spectrum (Reproduced by permission of Arianespace [2])

Accelerazioni statiche



ure 2.3 Ariane static acceleration profile (Reproduced by permission of Arianes-e [2])

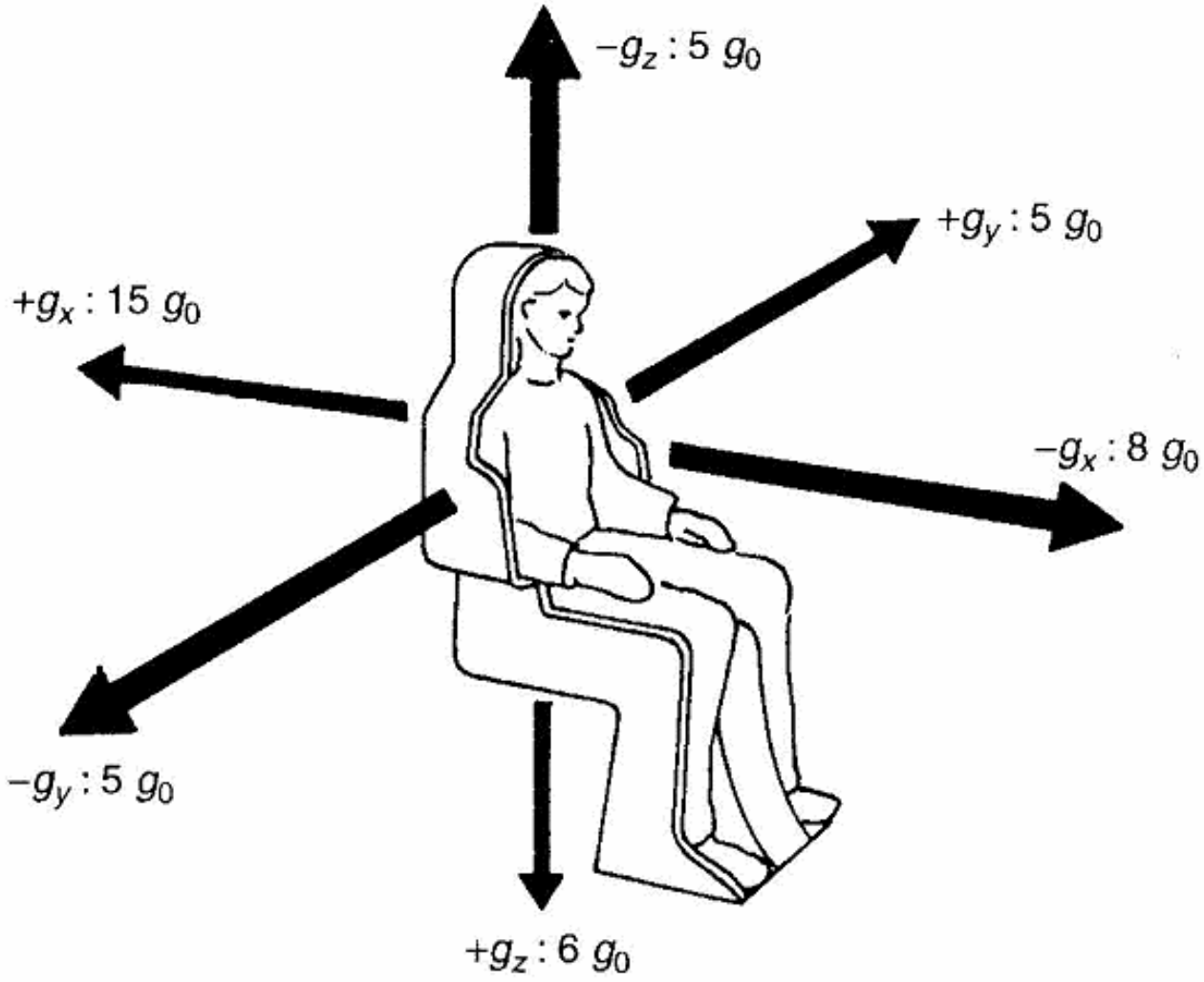


Figure 2.4 Typical tolerance to sustained linear acceleration as a function of direction of acceleration

Shocks

Bulloni esplosivi

Attenuazione sulle strutture meccaniche

Termica

Riscaldamento per attrito su atmosfera

Disaccoppiamento termico con payloads

Riduzione di pressione

Ventilazione della ‘cargo bay’

L'ambiente in orbita

Il sole

- Massa 2.10^{30} kg
- Raggio 7.10^{8} m
- Potenza $3.9\ 10^{26}$ W
- Emissione con picco a 460 nm
- T superficie 5800 K
- Spettro di corpo nero

- Vento solare (pressione di radiazione!!!!)

  450 km/sec

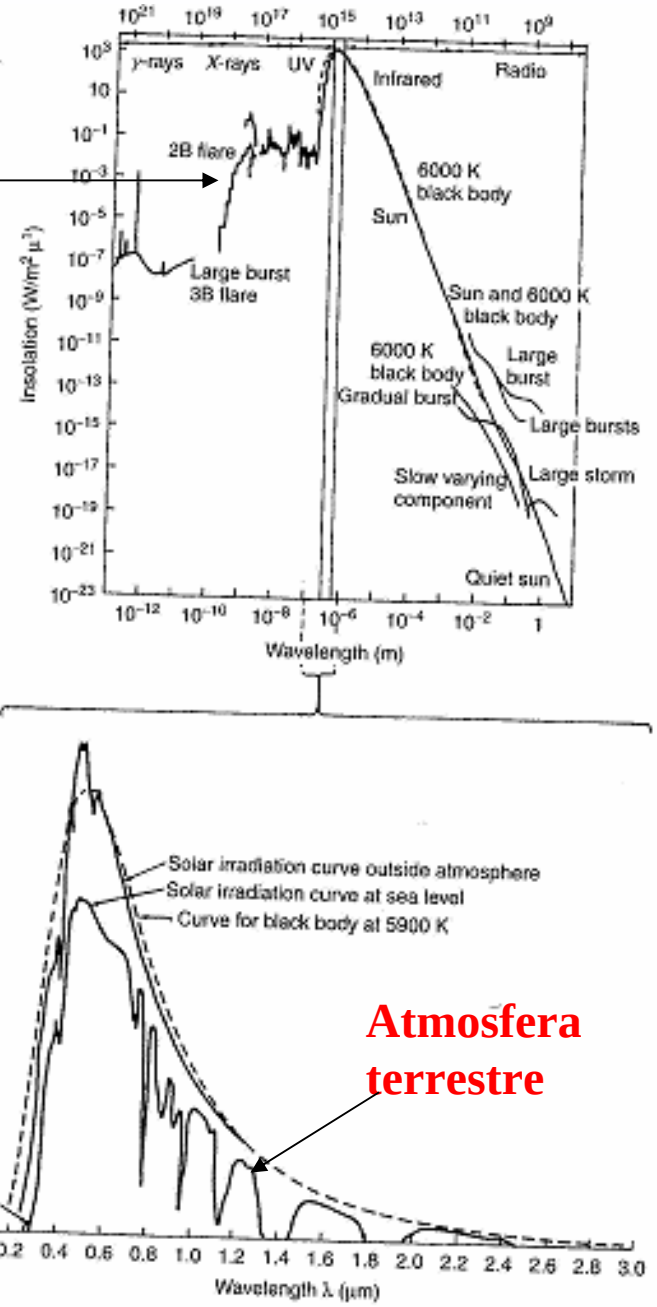
A terra → 9 p/cm^3

  100000 K

- Grossa variabilità con il tempo (macchie, flares etc.)

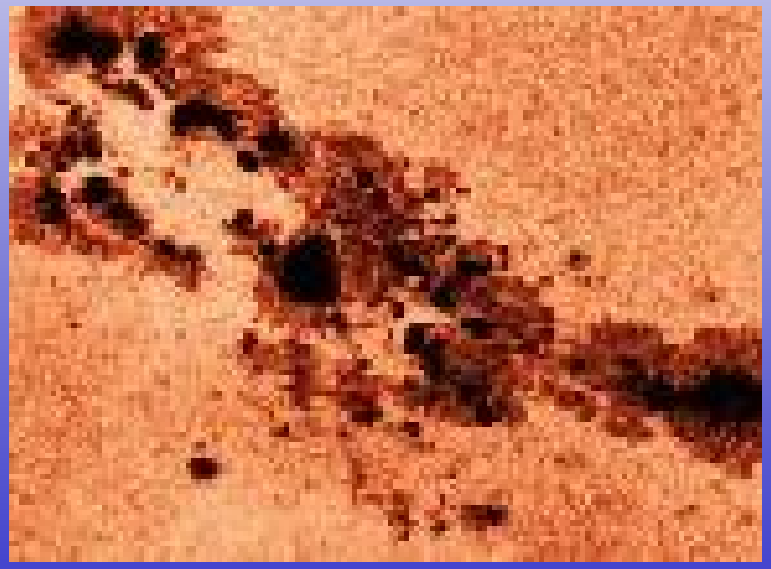
Atmosfera del sole

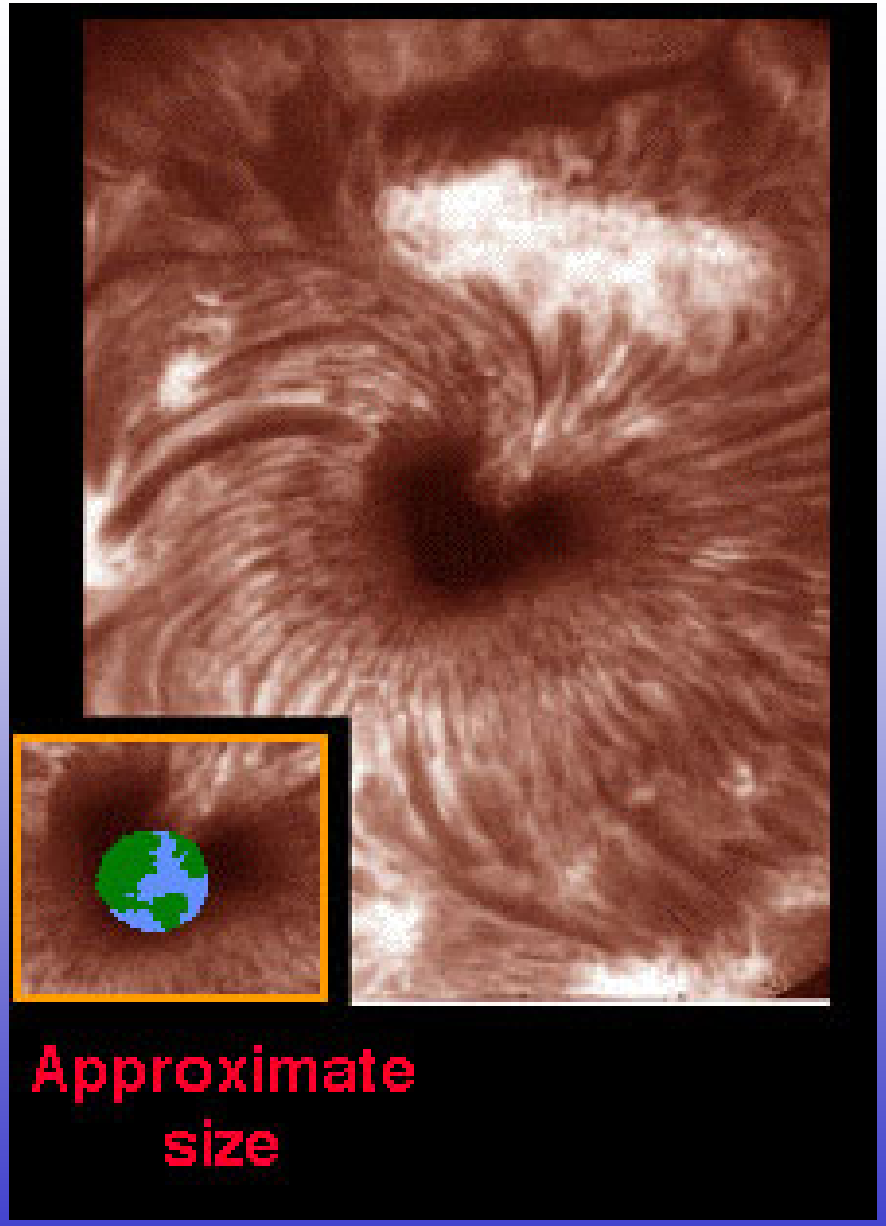
Cromosfera: 10000 K (UV)
Corona: 10^6 K (X)

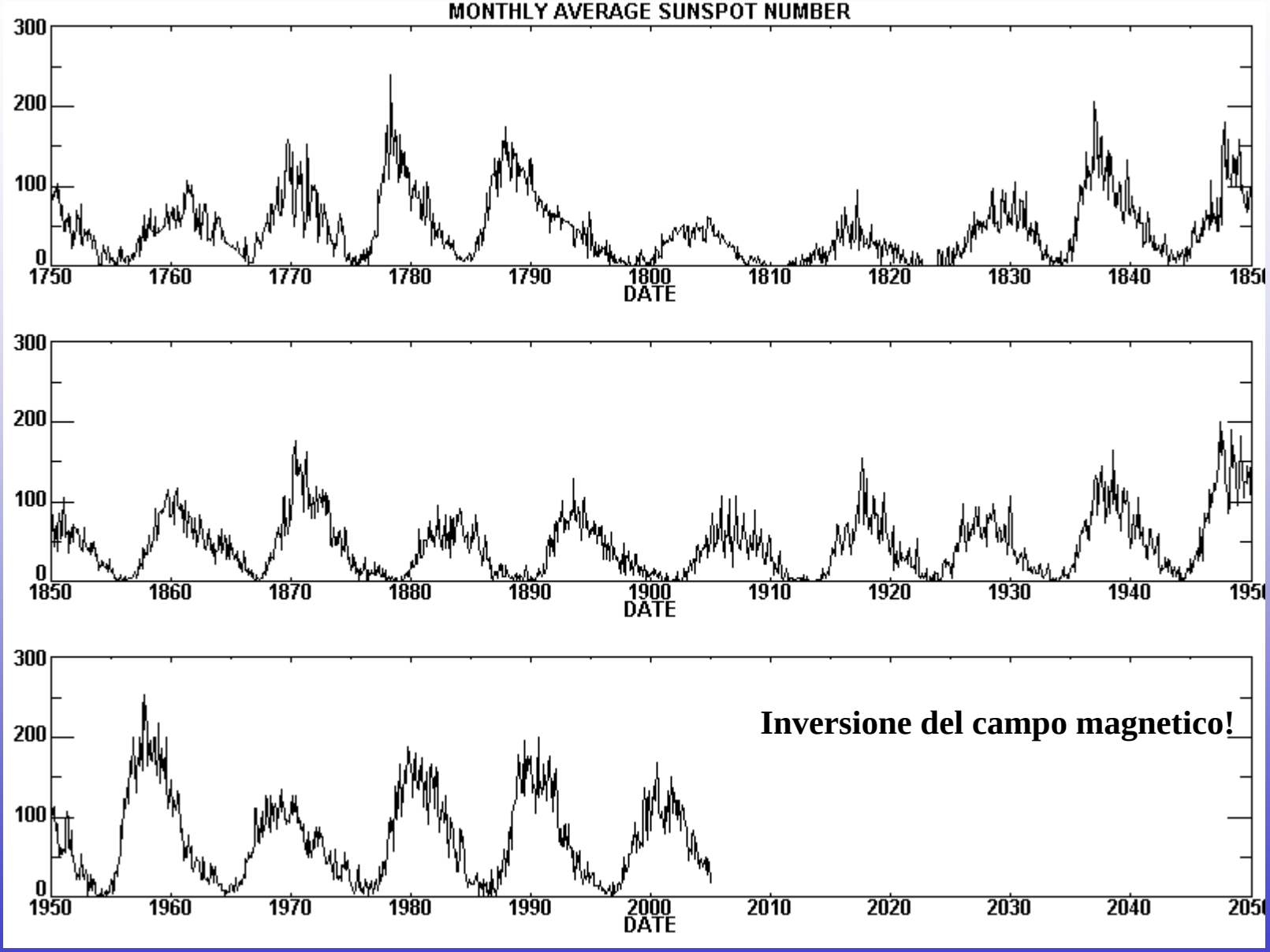


Atmosfera terrestre

ıre 2.7 Solar spectrum (Reproduced by permission from Hynek, J. A. (1951) *Astro-sics*, McGraw-Hill)

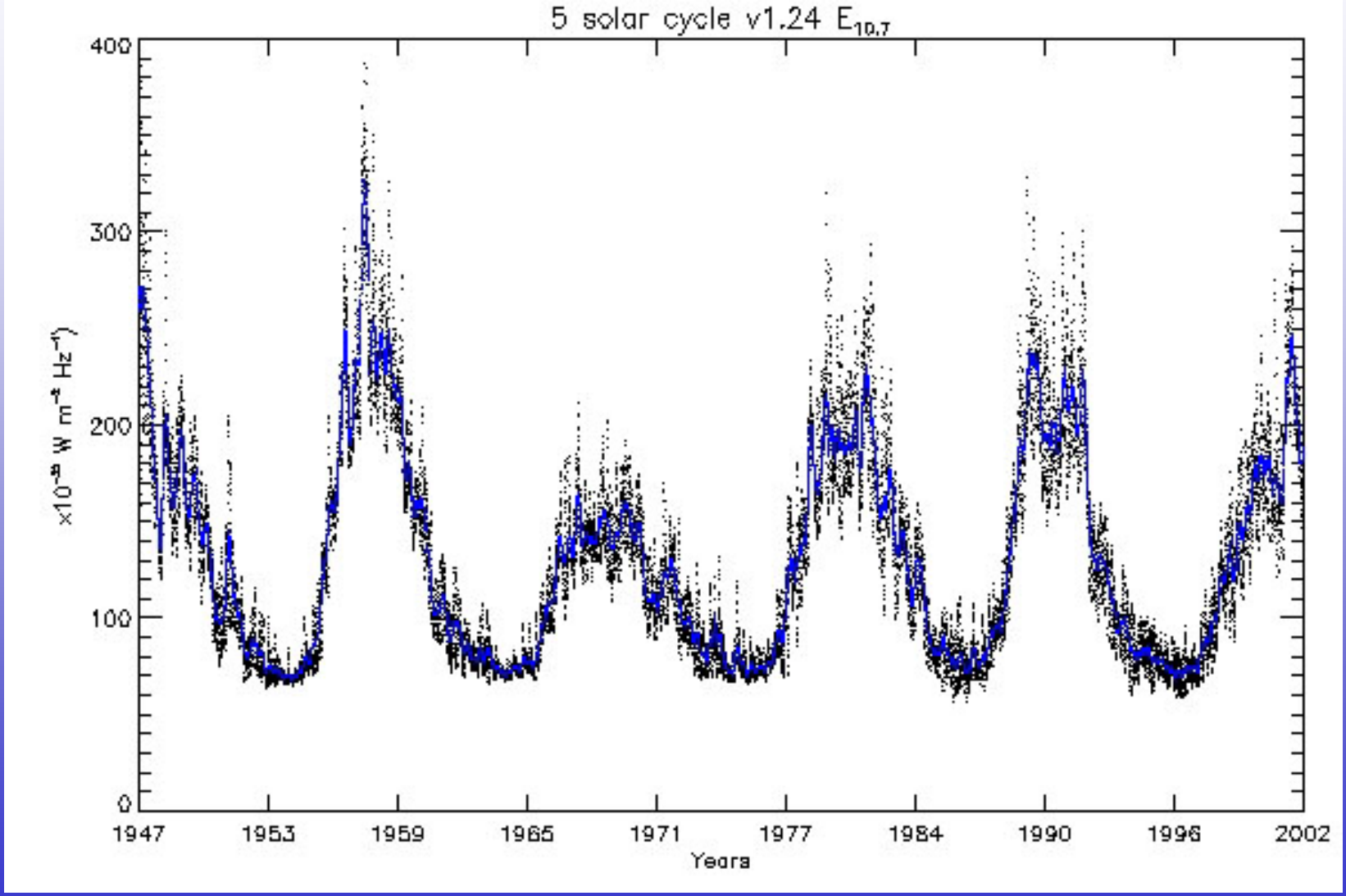



Approximate
size


MONTHLY AVERAGE SUNSPOT NUMBER
300
200
100
0
1750
1760
1770
1780
1790
1800
1810
1820
1830
1840
DATE
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
DATE
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
DATE
Inversione del campo magnetico!

Indice F10.7

Flusso medio giornaliero a λ=10.7 cm
(10^{-22} W/m^2 . Hz)



Raggi cosmici carichi

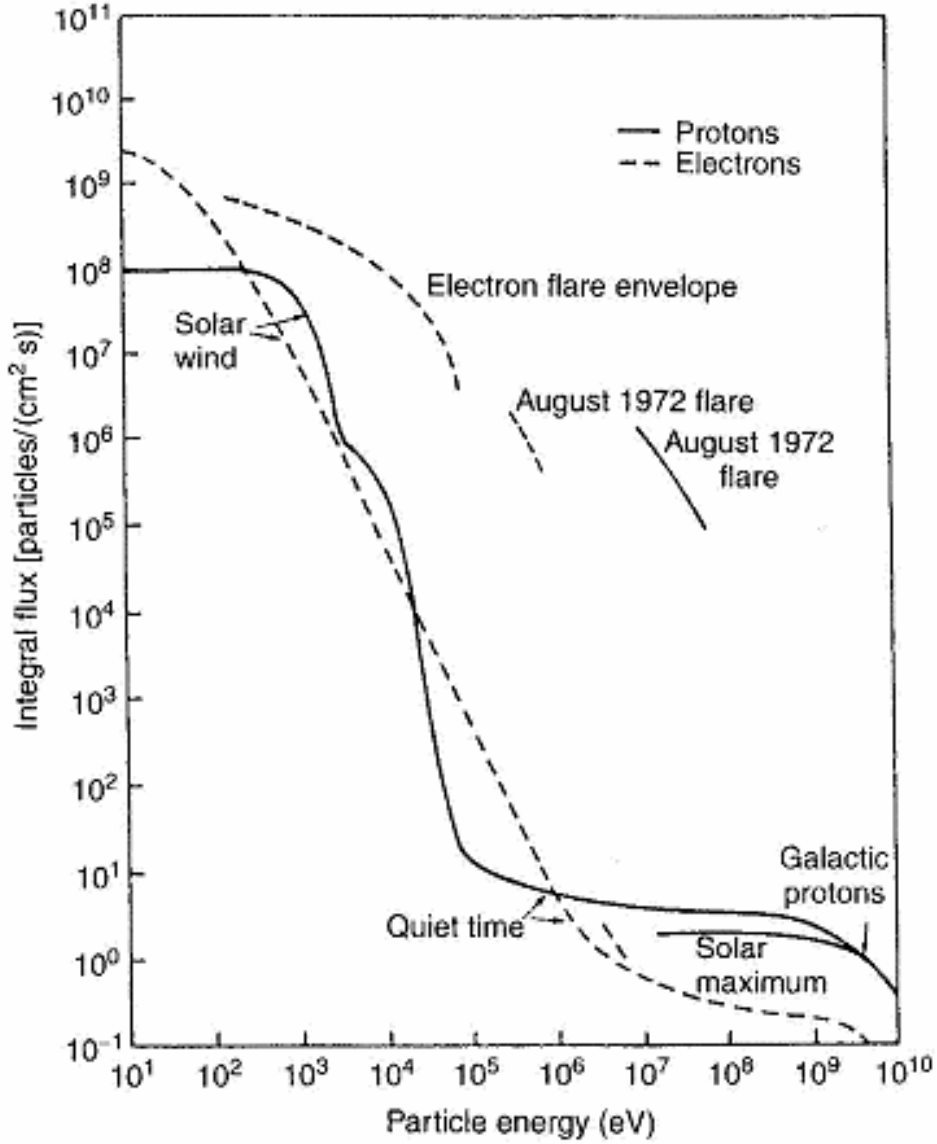
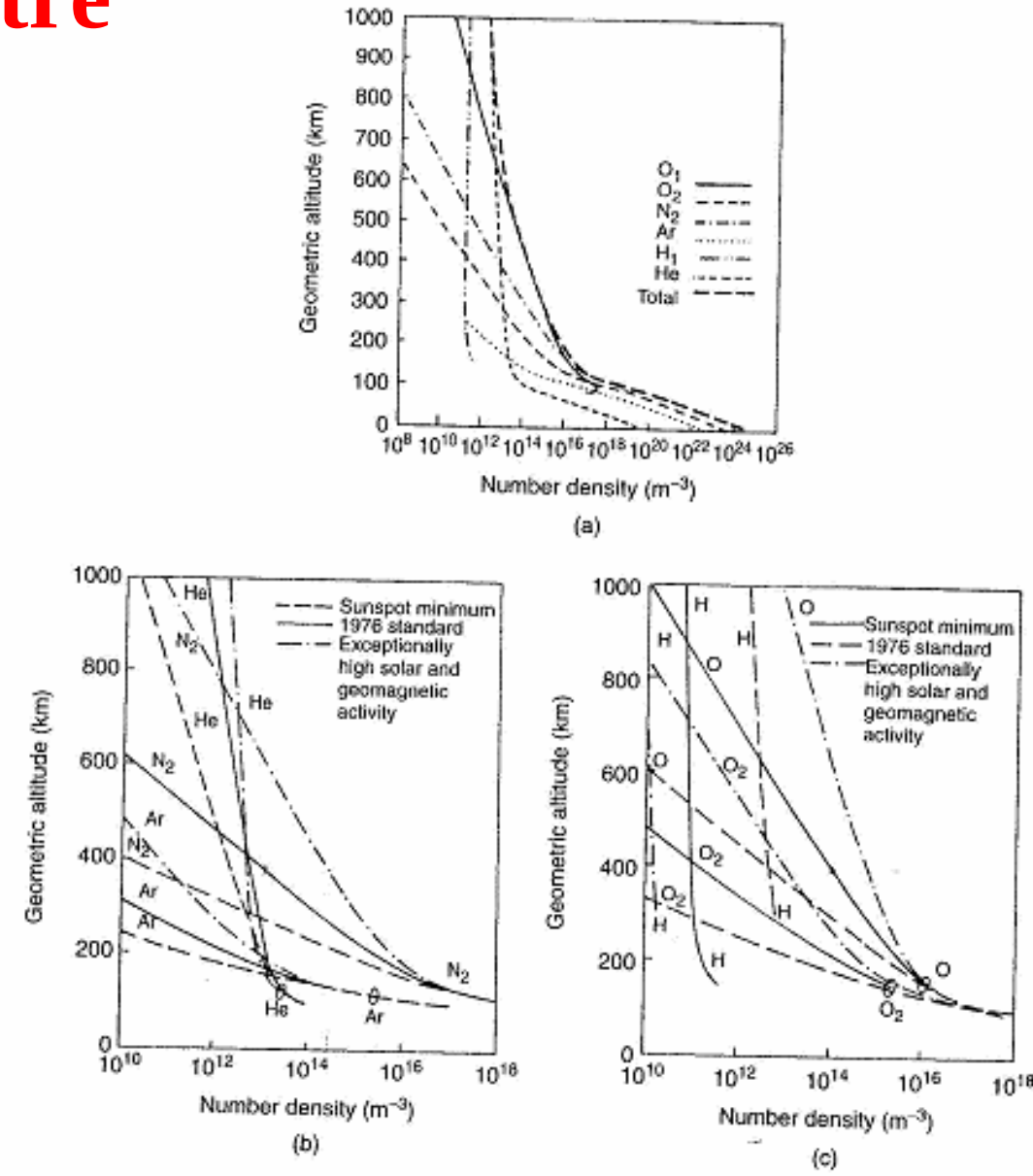


Figure 2.9 Electron and proton spectra (From *Solar Cell Array Design Handbook* by H. S. Rauschenback, Copyright © 1980 by Van Nostrand Reinhold. All rights reserved)

L’atmosfera terrestre

Dipendenza dall’attività solare



igure 2.10 Species concentration (a) in US standard atmosphere and (b, c) under extreme conditions

Temperatura esosferica

$\rho=\rho_0 \exp(-k/T)$

Effetto dell'attività solare sul drag atmosferico!

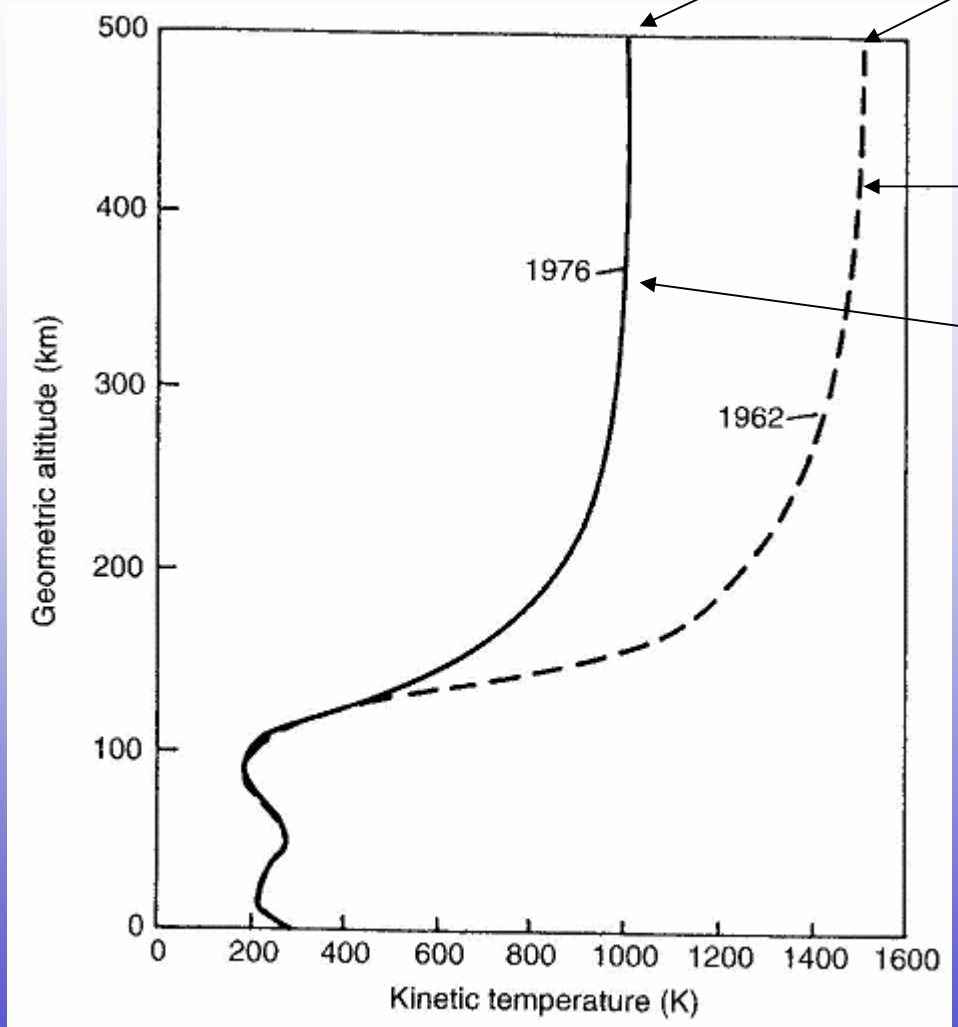


Figure 2.11 Temperature profile of atmosphere

Solar maximum

Solar minimum

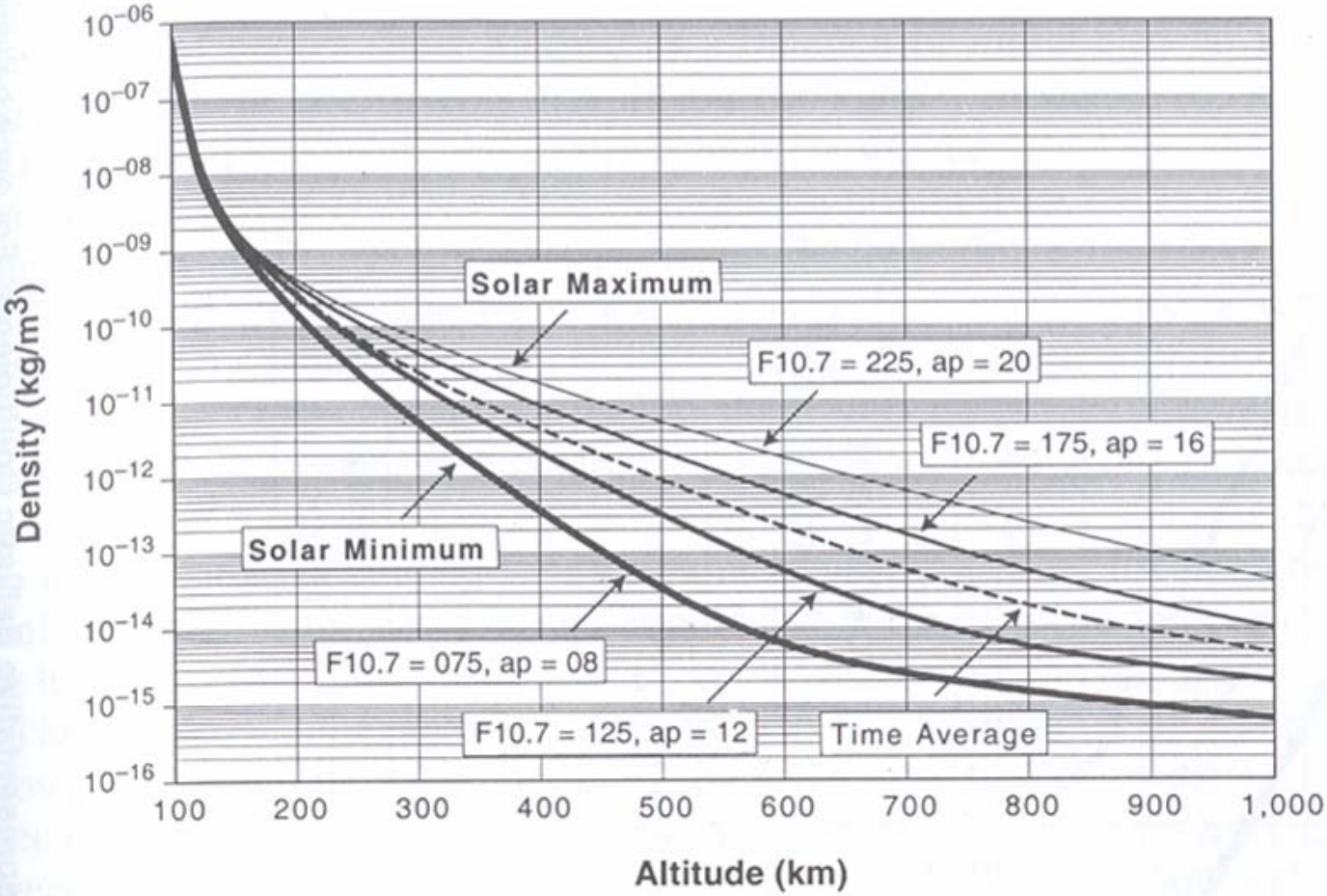


Fig. 8-2. Density vs. Altitude for Various F10.7 Values. Note that the curves have the same shape as the altitude maintenance curves in Fig. 7-8.

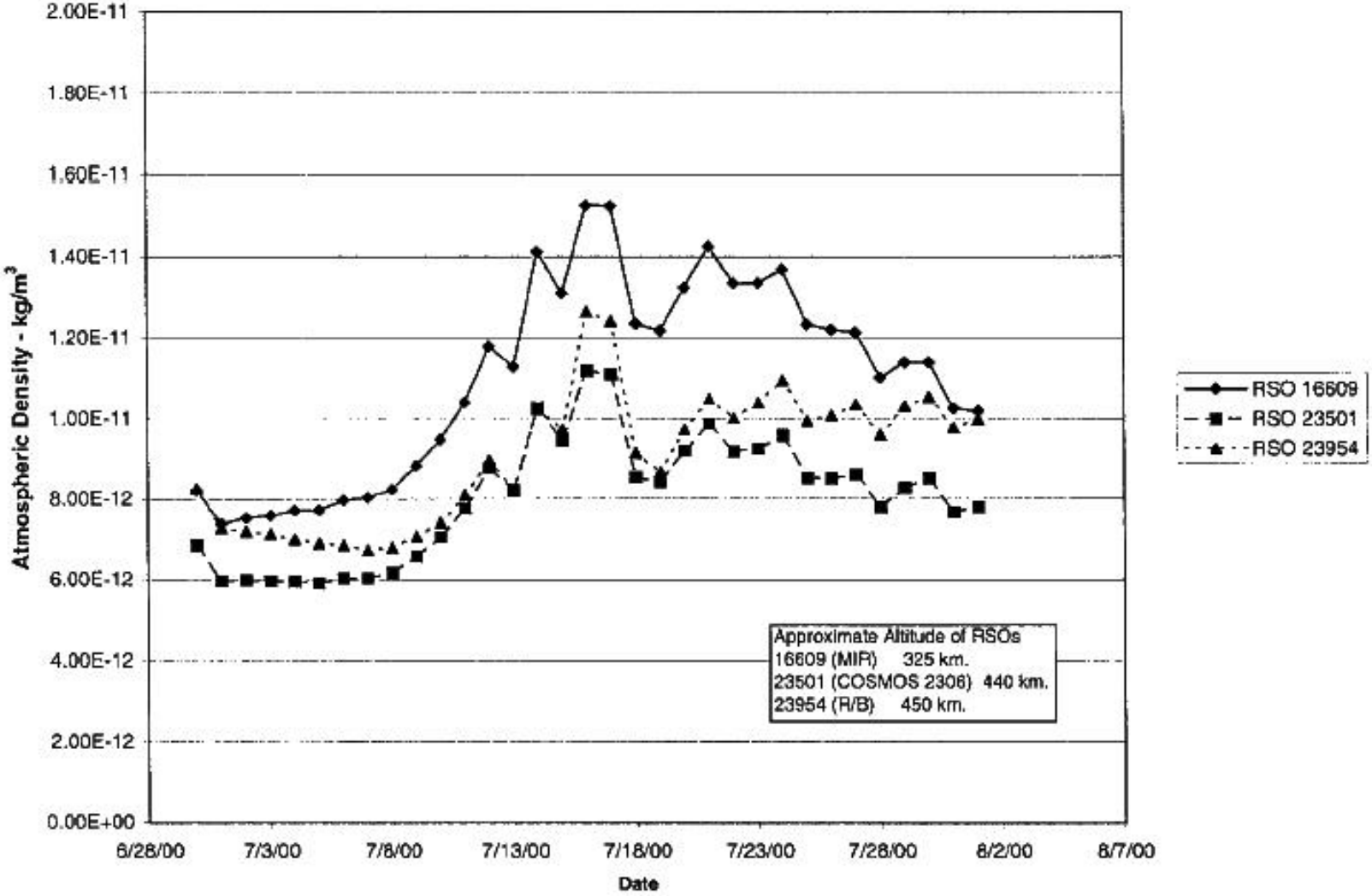


Figure 5. MSISE-90 density July 2000 – selected RSOs.

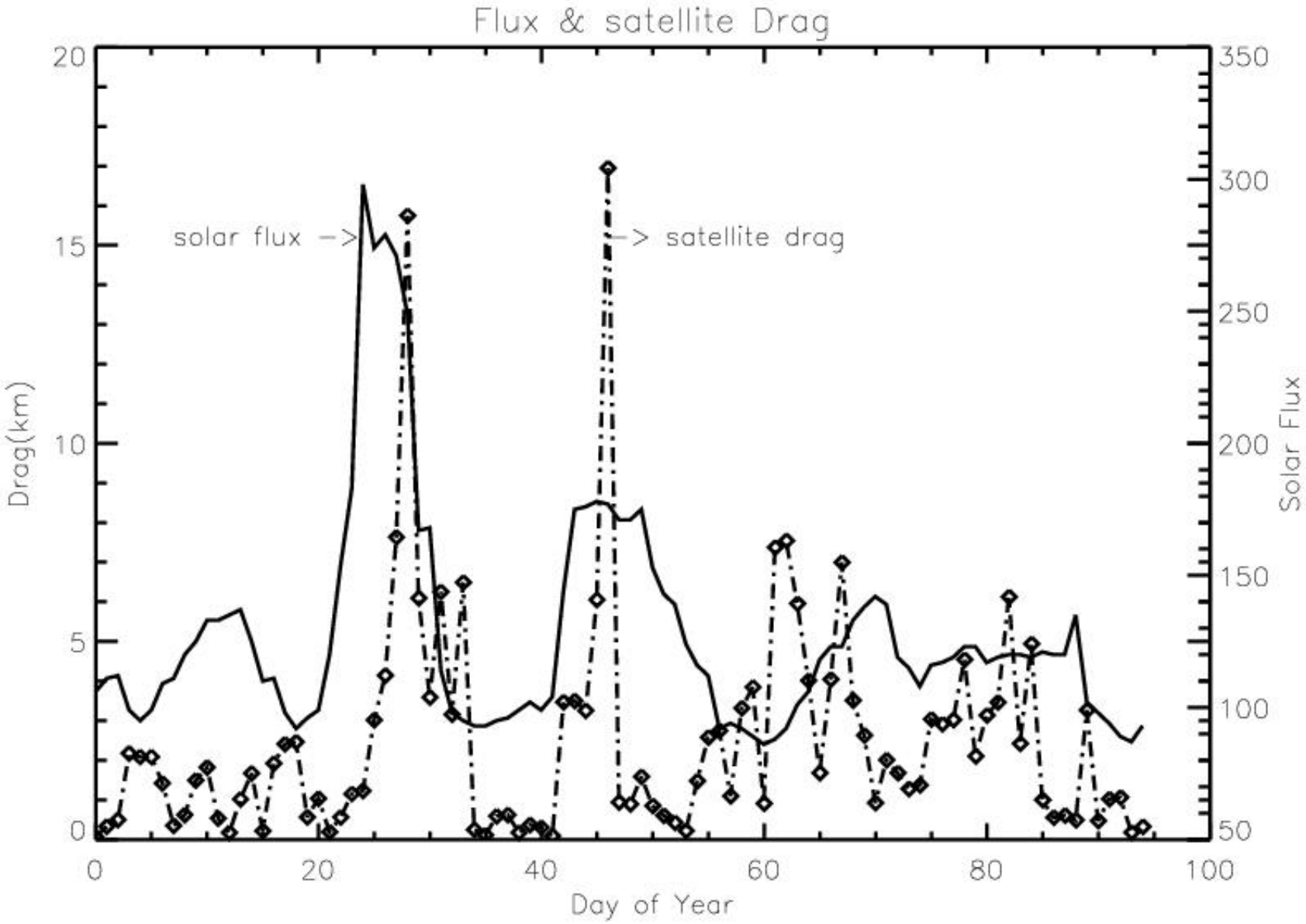

Flux & satellite Drag
solar flux ->
-> satellite drag
Drag(km)
Solar Flux
Day of Year
0
5
10
15
20
50
100
150
200
250
300
350
0
20
40
60
80
100

Table 2.3 Mean free path λ_0 as a function of altitude

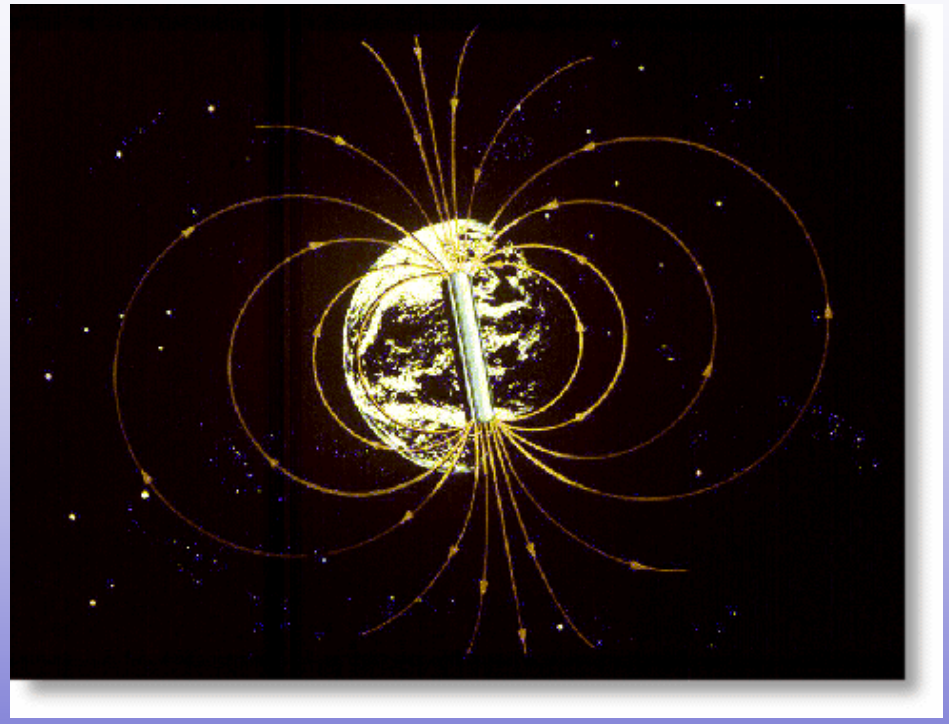
Altitude (km)	λ_0 (m)	Altitude (km)	λ_0 (m)
100	0.142	300	2.6×10^3
120	3.31	400	16×10^3
140	18	500	77×10^3
160	53	600	280×10^3
180	120	700	730×10^3
200	240	800	1400×10^3

Lo scambio termico dominante è per radiazione!

Il campo magnetico terrestre

Correnti che circolano nel *core* della terra

- 11° tilt from rotation axis
- Inverted dipole
- **Offset** from centre of Earth
- Dipole moment $8*10^{15}$ Tm^3 ($30.4\ \mu T\ R^3_{Earth}$)
- **Multipole** terms
- **Time dependent** terms
- Interaction with solar wind



$$B(R,\lambda)=(1+\sin^2\lambda)^{1/2}\ B_0/R^3$$

B_0=0.3 gauss

λ=latitudine magnetica

R in unità di raggi terrestri

Correnti dovute al plasma solare

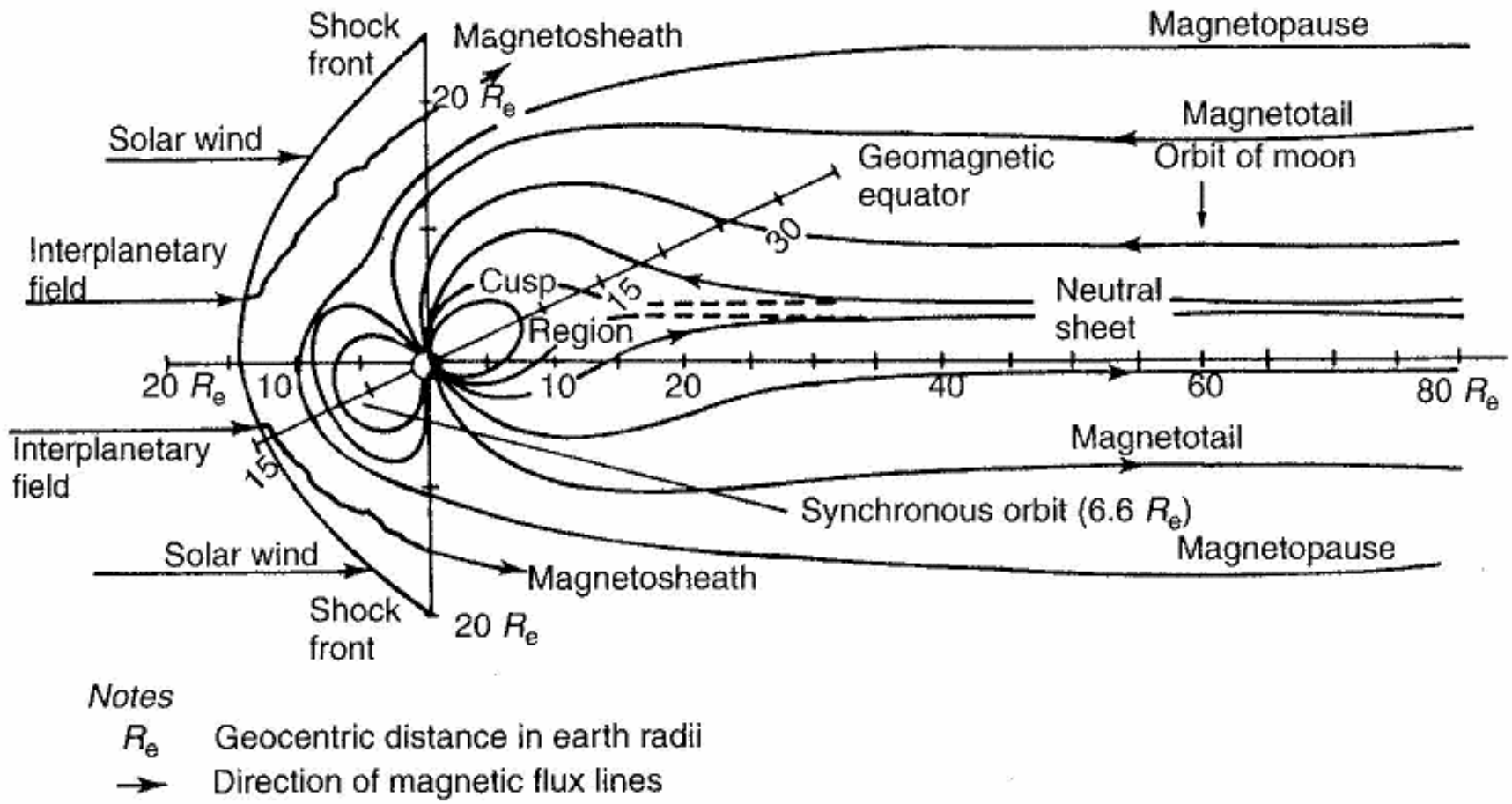


Figure 2.12 The Earth's magnetosphere (Reproduced by permission of Kluwer Academic Publishers)

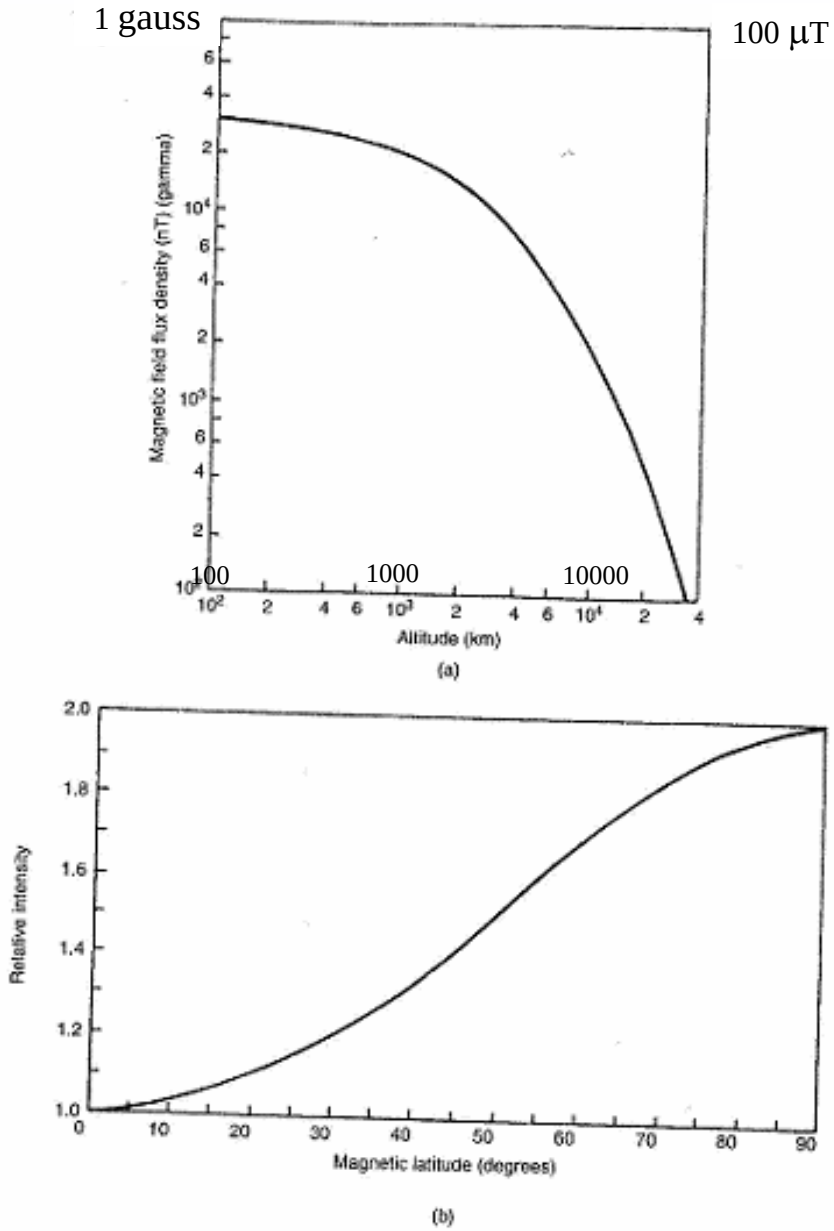
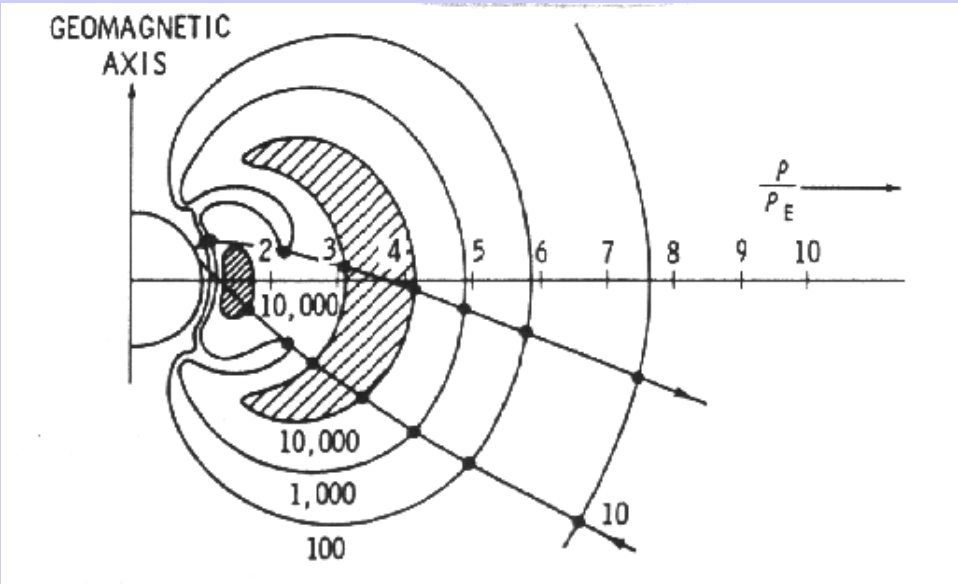


Figure 2.13 (a) Earth's magnetic field intensity at the magnetic equator as a function of altitude (Adapted from Reference [12]) and (b) relative intensity of the Earth's magnetic field as a function of magnetic latitude (Reproduced by permission of Kluwer Academic Publishers)

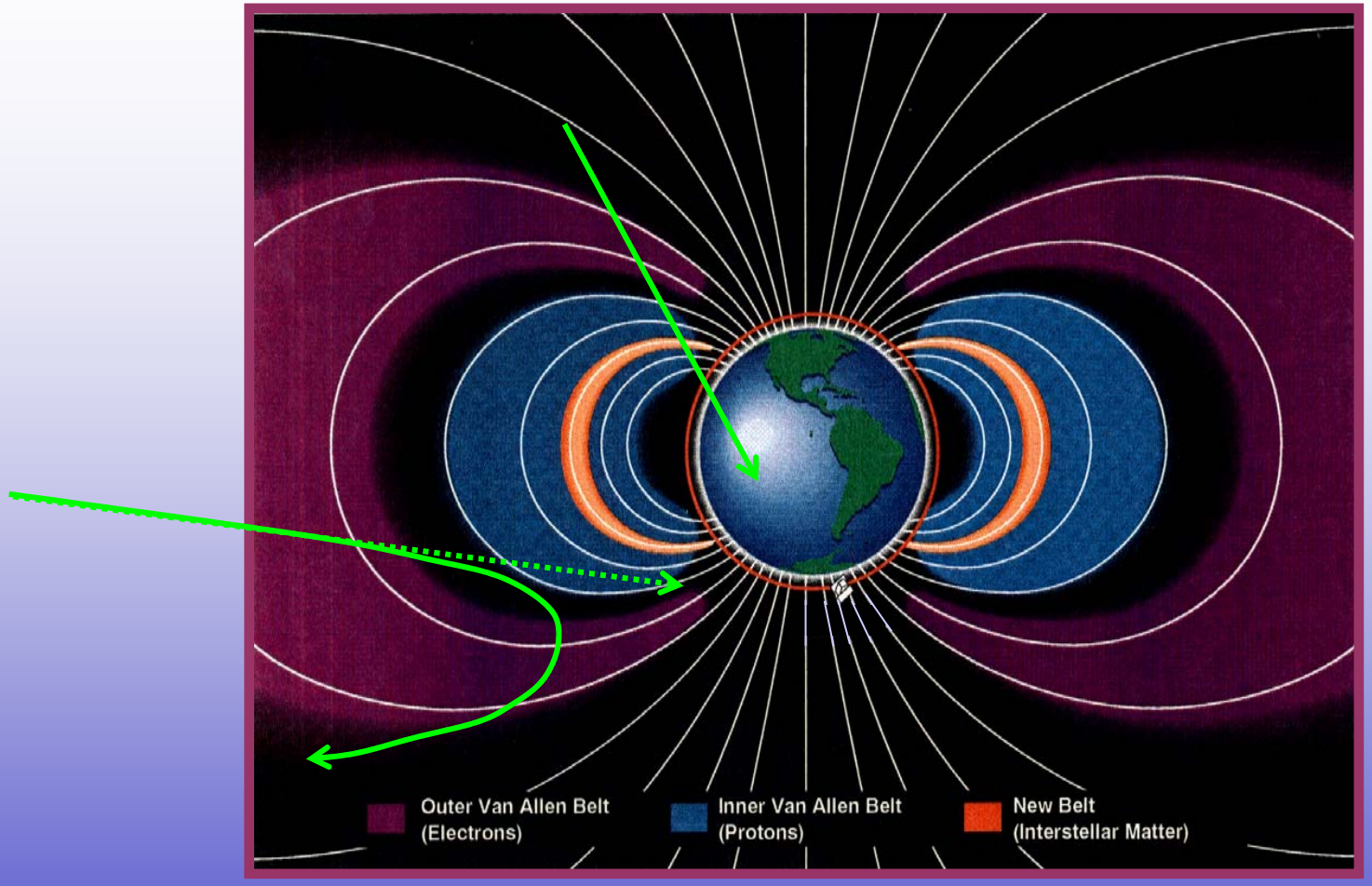
Le fasce di radiazione (o di Van Allen)

- Si tratta di zone in cui le particelle sono intrappolate dal campo magnetico terrestre.
- Il flusso di particelle è di ordini di grandezza superiore rispetto all'esterno
- Furono scoperte con un Geiger a bordo del satellite Explorer 1 dal gruppo di Van Allen nel 1958
- Elettroni e protoni sono costretti a spiraleggiare lungo le linee di forza del campo geomagnetico Possono costiuire un pericolo per i satelliti che vi si trovano all'interno



Primo schema fatto da Van Allen sulla struttura delle fasce di radiazione terrestri: quella più interna è relativa a protoni; mentre quella esterna è costituita principalmente da elettroni.

Trapped particles in Van Allen Belts



Low energy cosmic rays fluxes (< 1GeV) depend from the geomagnetic locations

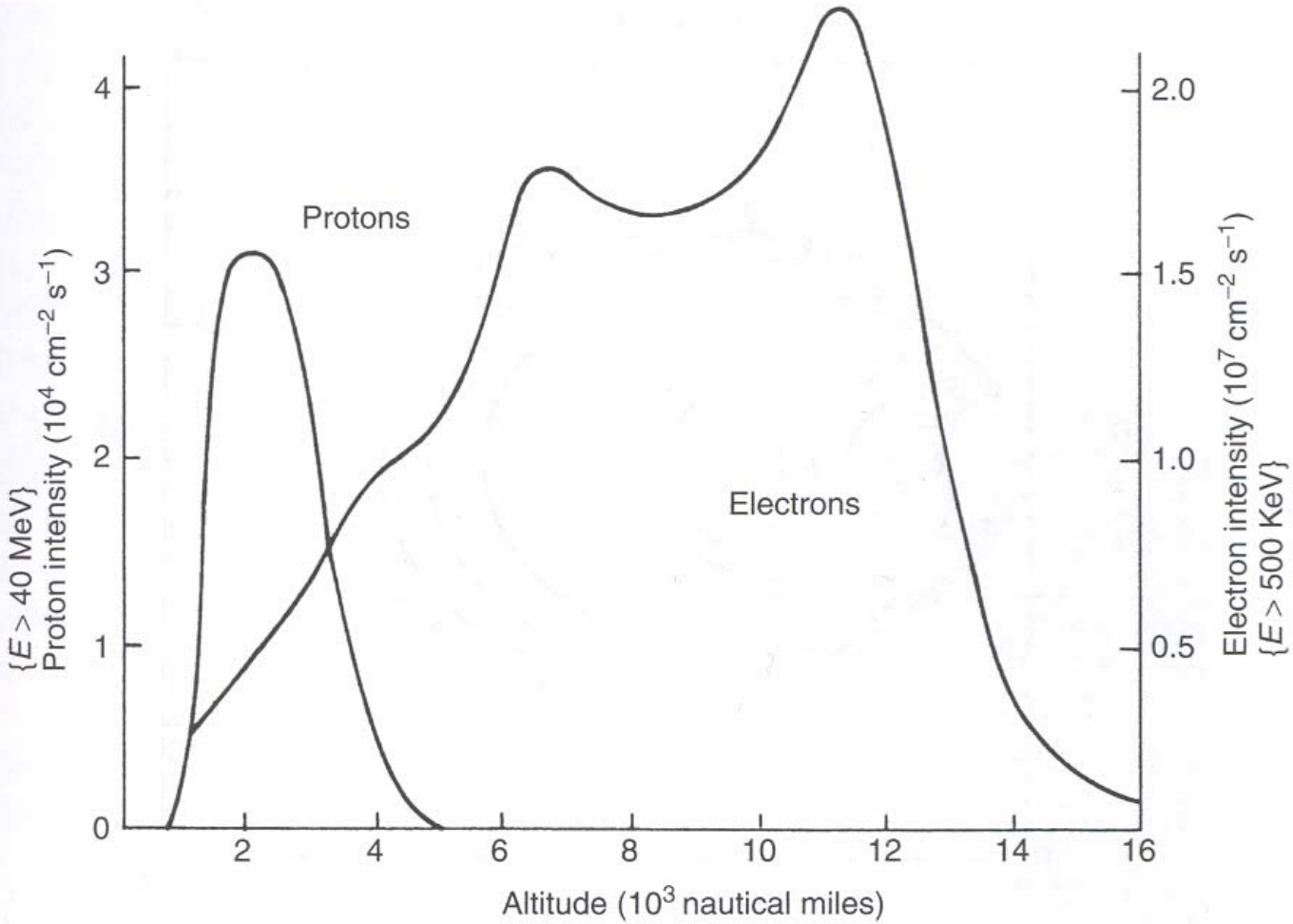
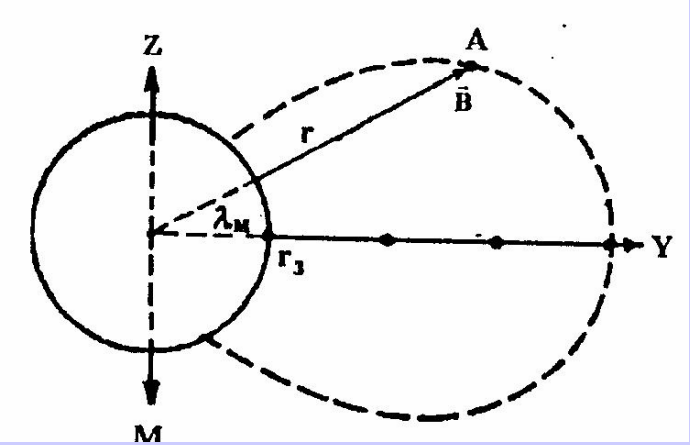


Figure 2.14 Van Allen radiation belts (idealized)

Moto delle particelle intrappolate nel campo geomagnetico

$$r = L \cos^2 \lambda_M$$

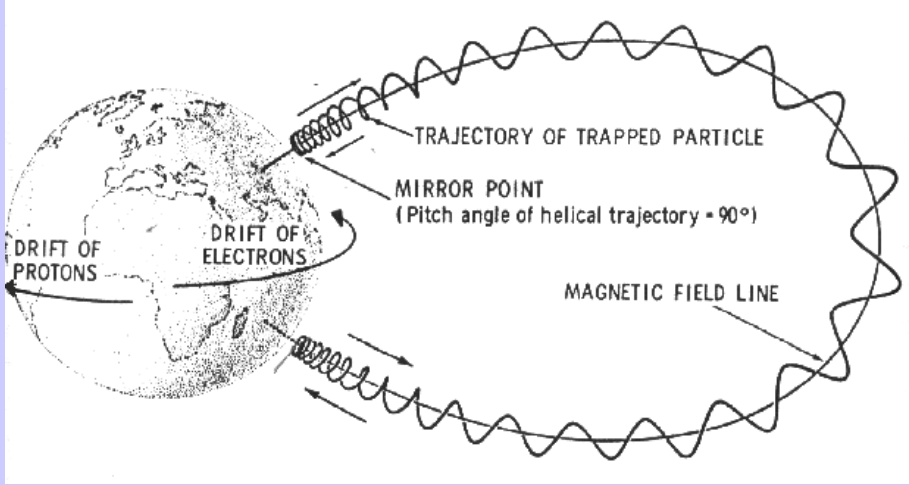


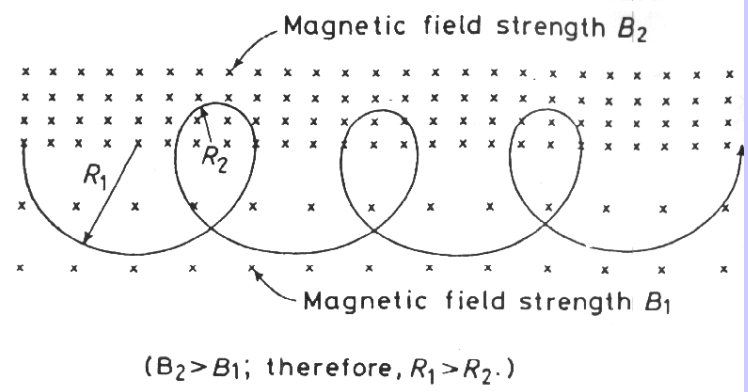
- Possono essere scomposte in tre componenti

1. Una rotazione circolare intorno alla linea di forza

2. Uno spostamento lungo la linea di forza del centro della rotazione del punto 1.

3. Uno spostamento (drift) in longitudine verso W (+) o E (-), dovuto alla disuniformità del campo magnetico (drift gradiente curvatura)





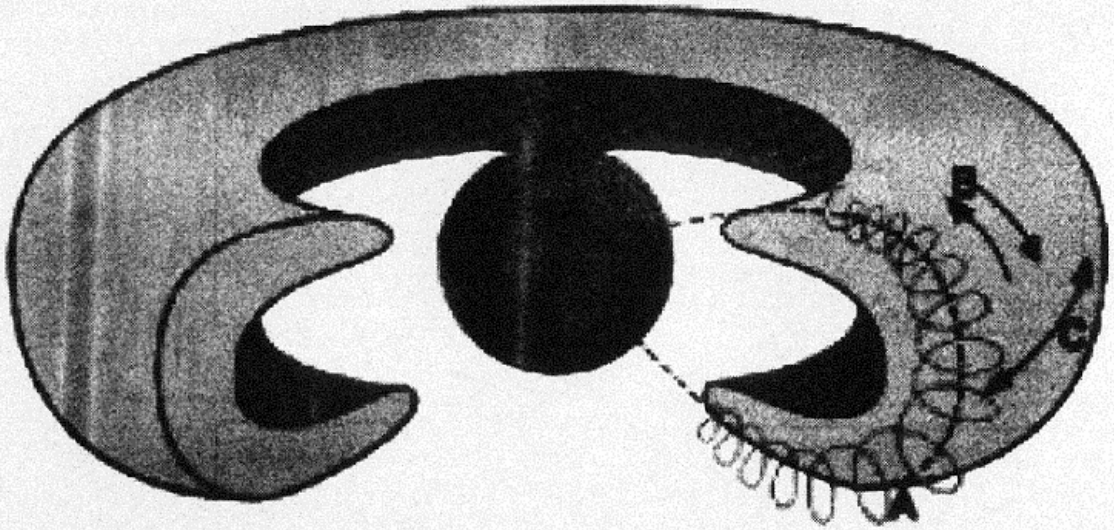


Fig. 8. Motion of charged particles in the geomagnetic belts. A) gyration B) bouncing C) drift.

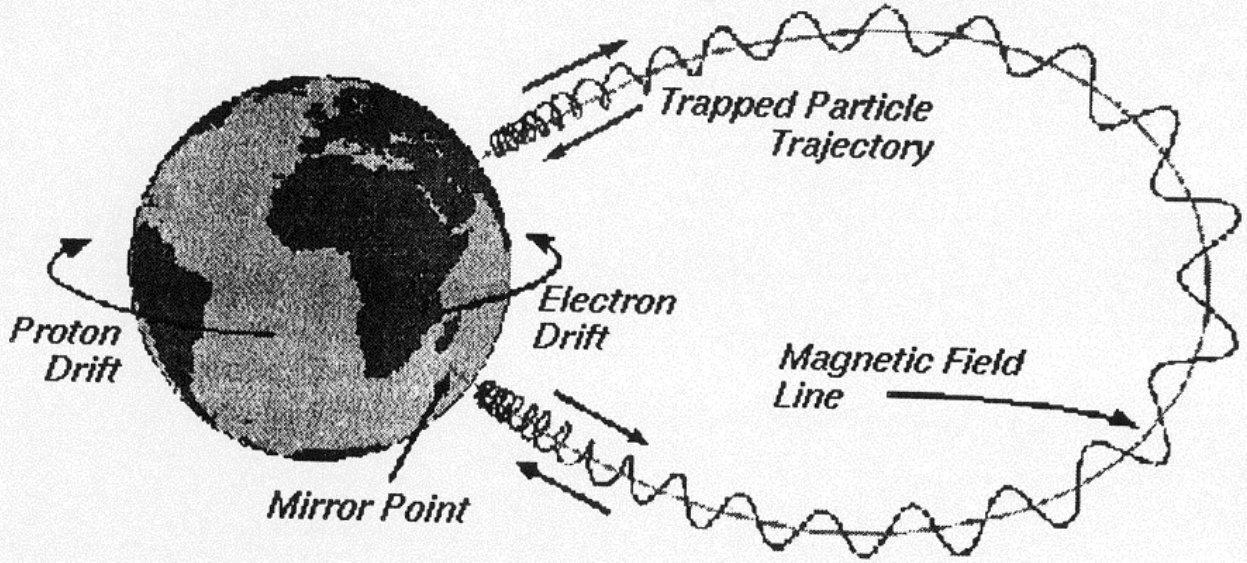
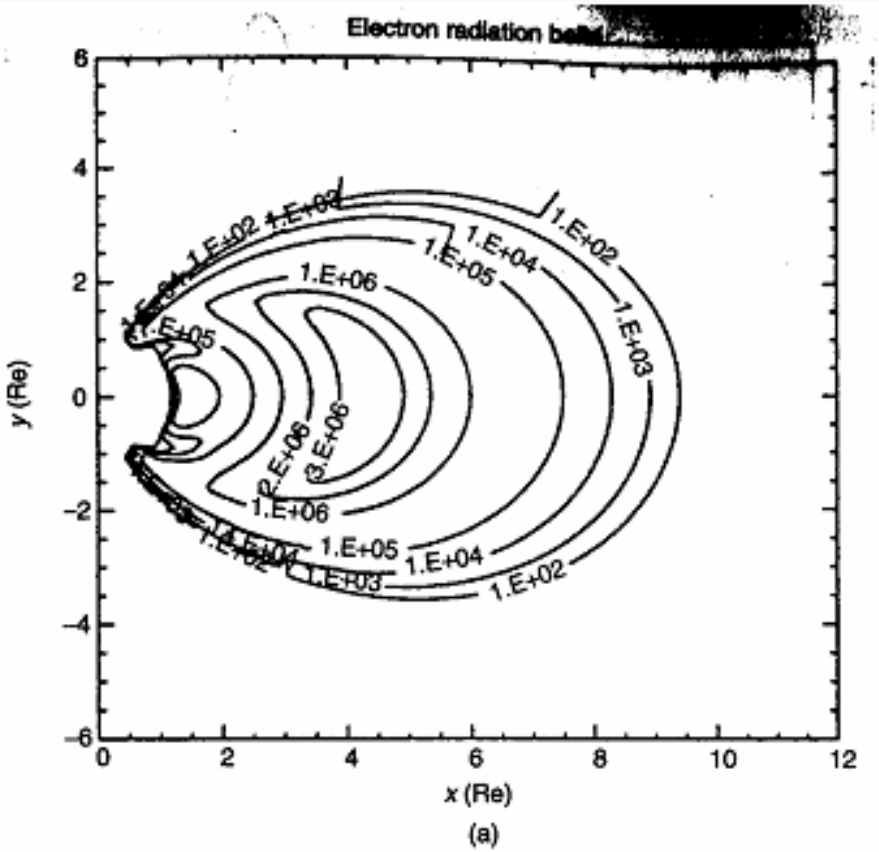


Fig. 1. Illustration of the motion of trapped particles in the Earth's magnetic field



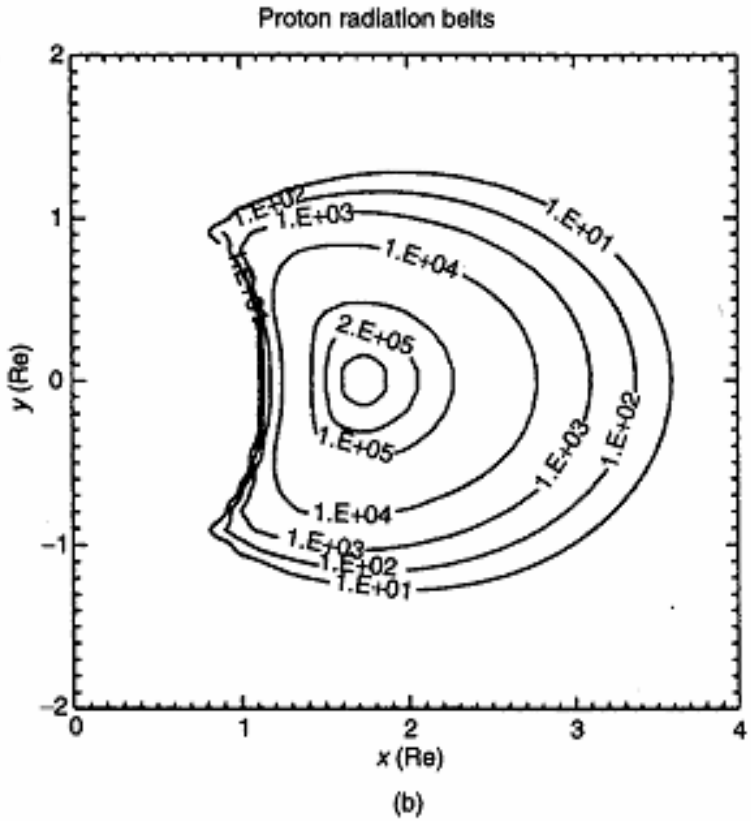
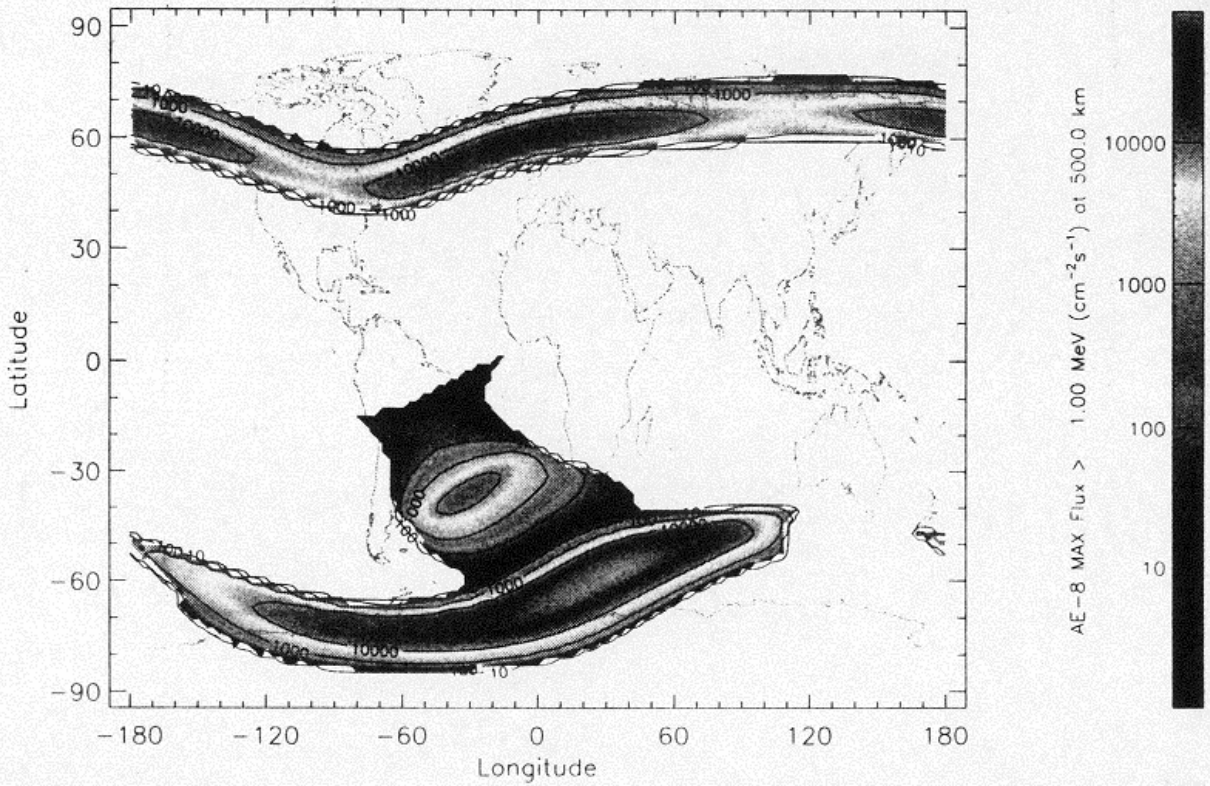
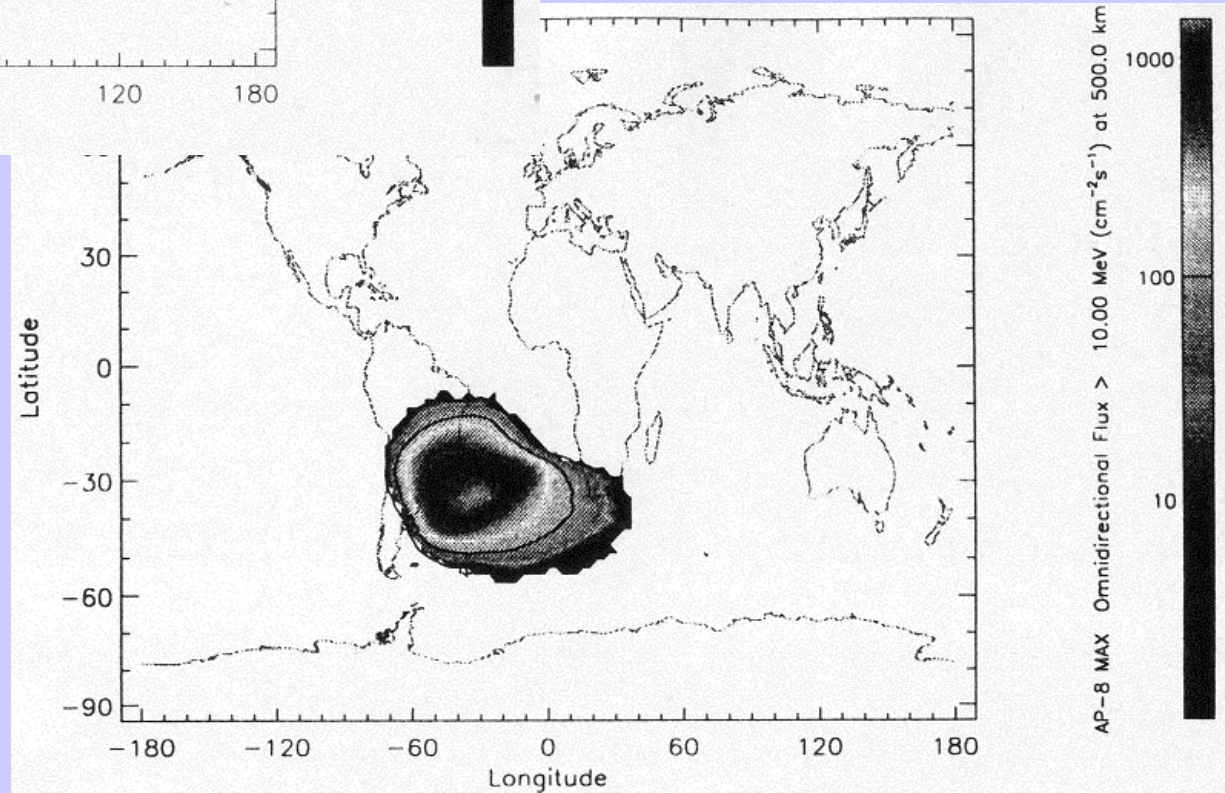


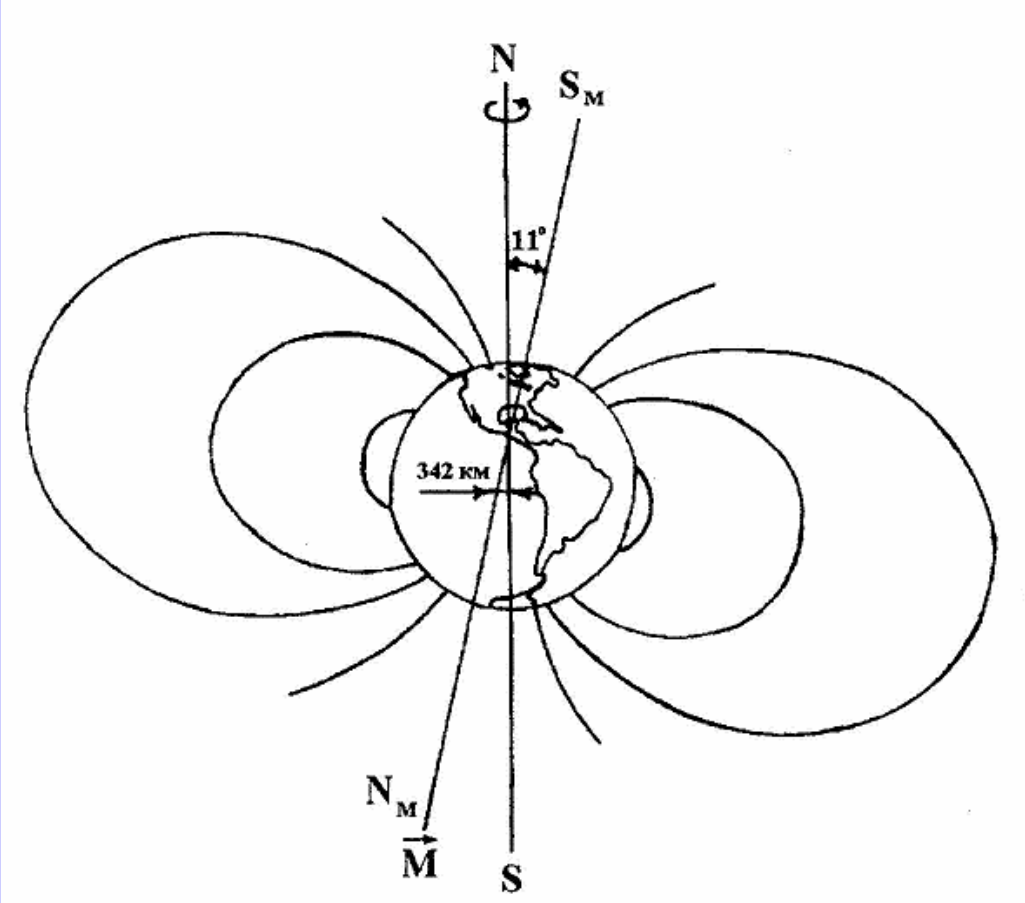
Figure 2.15 Radiation belt model particle fluxes. Contour plots in 'dipole space' in a plane containing the geo-dipole axis (y): (a) electron fluxes at greater than 1 MeV and (b) proton fluxes at greater than 10 MeV. (Axes are calibrated in Earth radii, Re) [13]. (Reproduced by permission of the International Astronautical Federation)



elettroni, E>1MeV
a 500 km di altezza

Protoni, E>10MeV
a 500 km di altezza





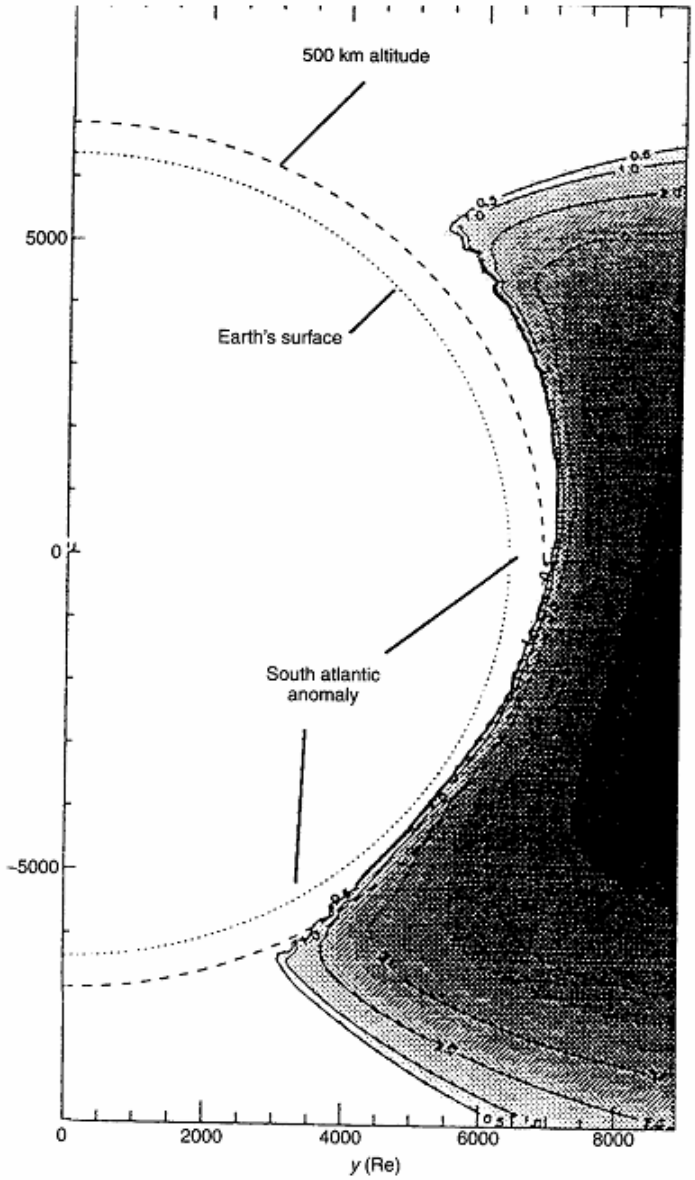
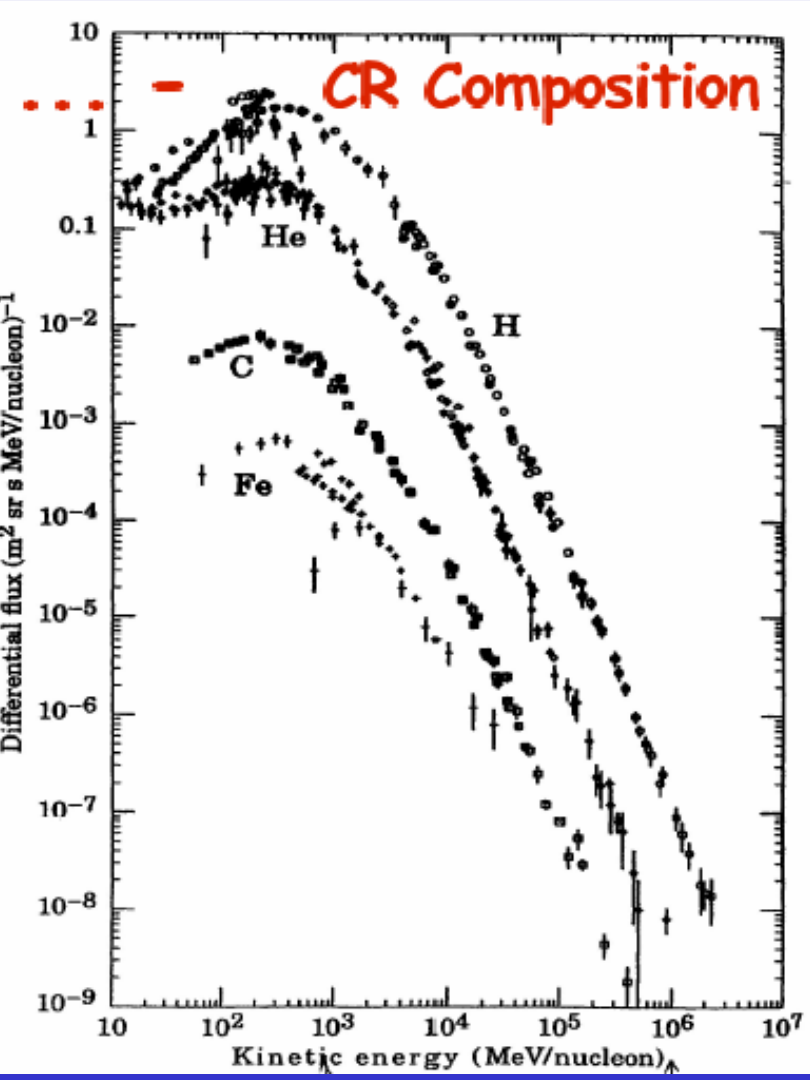


Figure 2.16 Proton radiation belt at low altitude, derived from AP8 model. Flux contours at longitude 325°. Tilt and offset brings contours below the 500 km altitude line. This is the South Atlantic anomaly [13]. (Reproduced by permission of the International Astronautical Federation)

SAA dovuta a offset e tilt dell'asse geomagnetico rispetto all'asse di rotazione

Attenzione agli effetti delle particelle intrappolate!!! (e di quelle emesse nei solar flares)

Enorme aumento di flusso rispetto al normale ambiente spaziale



RC galattici

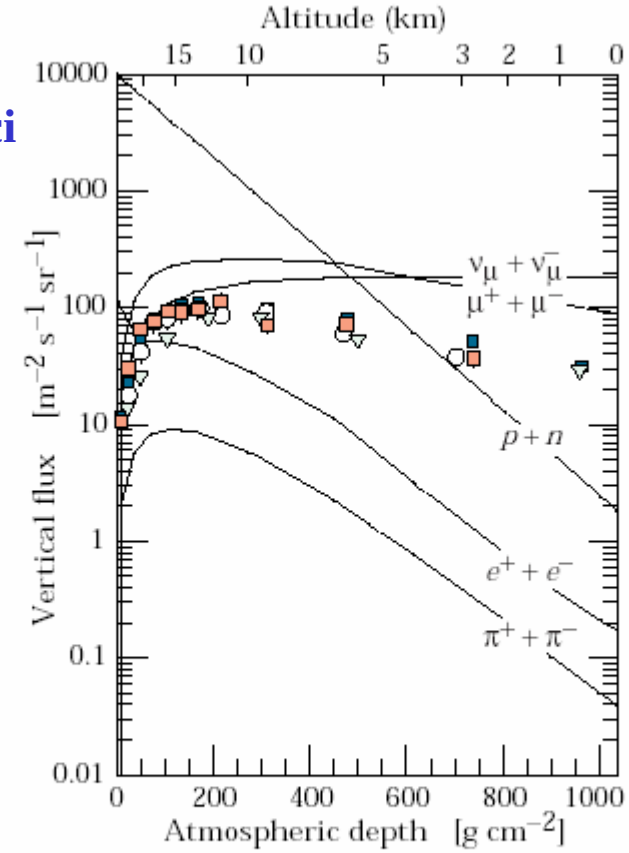


Figure 24.3: Vertical fluxes of cosmic rays in the atmosphere with $E > 1$ GeV estimated from the nucleon flux of Eq. (24.2). The points show measurements of negative muons with $E_\mu > 1$ GeV [4,19,20,21].

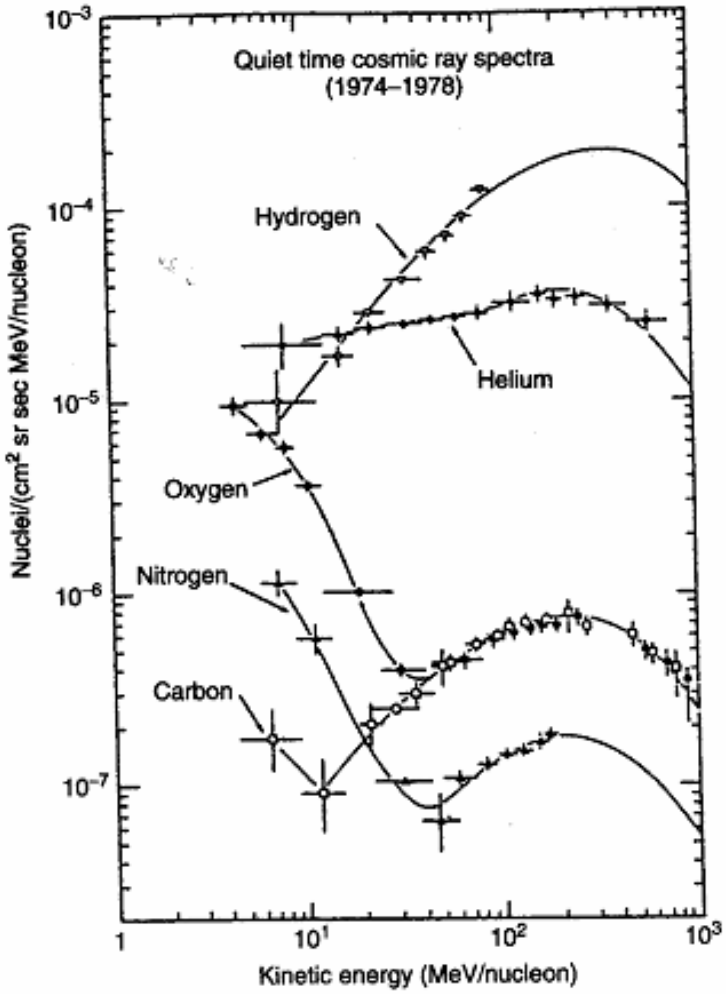


Figure 2.18 Quiet-time energy spectra for the elements H, He, C, N and O. Measured at 1 AU over the solar minimum period from 1974 to 1978 [16]. Note the 'anomalous' enhancements in the low-energy spectra of He, N and O. The data are from Caltech and Chicago experiments on IMP-7 and IMP-8 [16]. (Reproduced by permission of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California)

Potenziali effetti sull'elettronica delle particelle ionizzanti:

1. **Dose totale**
2. **SEE (SEU, SEL)**
3. **Danneggiamento dei pannelli solari**
4. **Caricamento dei dielettrici**

Soluzioni:

- **Schermi**
- **Circuiti di protezione**
- **Selezione dei componenti**
- **Ridondanze**

29.1. Definitions

The International Commission on Radiation Units and Measurements (ICRU) recommends the use of SI units. Therefore we list SI units first, followed by cgs (or other common) units in parentheses, where they differ.

- **Unit of activity** = becquerel (curie):

  1 Bq = 1 disintegration s^{-1} [$= 1/(3.7 \times 10^{10})$ Ci]

- **Unit of absorbed dose** = gray (rad):

  1 Gy = 1 joule kg^{-1} ($= 10^4$ erg g^{-1} = 100 rad)

  $= 6.24 \times 10^{12}$ MeV kg^{-1} deposited energy

- **Unit of exposure**, the quantity of x- or γ- radiation at a point in space integrated over time, in terms of charge of either sign produced by showering electrons in a small volume of air about the point:

  = 1 coul kg^{-1} of air (roentgen; 1 $R = 2.58 \times 10^{-4}$ coul kg^{-1})

  = 1 esu cm^{-3}(= 87.8 erg released energy per g of air)

Implicit in the definition is the assumption that the small test volume is embedded in a sufficiently large uniformly irradiated volume that the number of secondary electrons entering the volume equals the number leaving. This unit is somewhat historical, but appears on many measuring instruments.

- **Unit of equivalent dose** (for biological damage) = sievert [= 100 rem (**r**oentgen **e**quivalent for **m**an)]: Equivalent dose in Sv = absorbed dose in grays $\times$ w_R, where w_R (radiation weighting factor, formerly the quality factor Q) expresses long-term risk (primarily cancer and leukemia) from low-level chronic exposure. It depends upon the type of radiation and other factors, as follows [2]:

Table 29.1: Radiation weighting factors.

Radiation	w_R
X- and γ-rays, all energies	1
Electrons and muons, all energies	1
Neutrons < 10 keV	5
10–100 keV	10
> 100 keV to 2 MeV	20
2–20 MeV	10
> 20 MeV	5
Protons (other than recoils) > 2 MeV	5
Alphas, fission fragments, & heavy nuclei	20

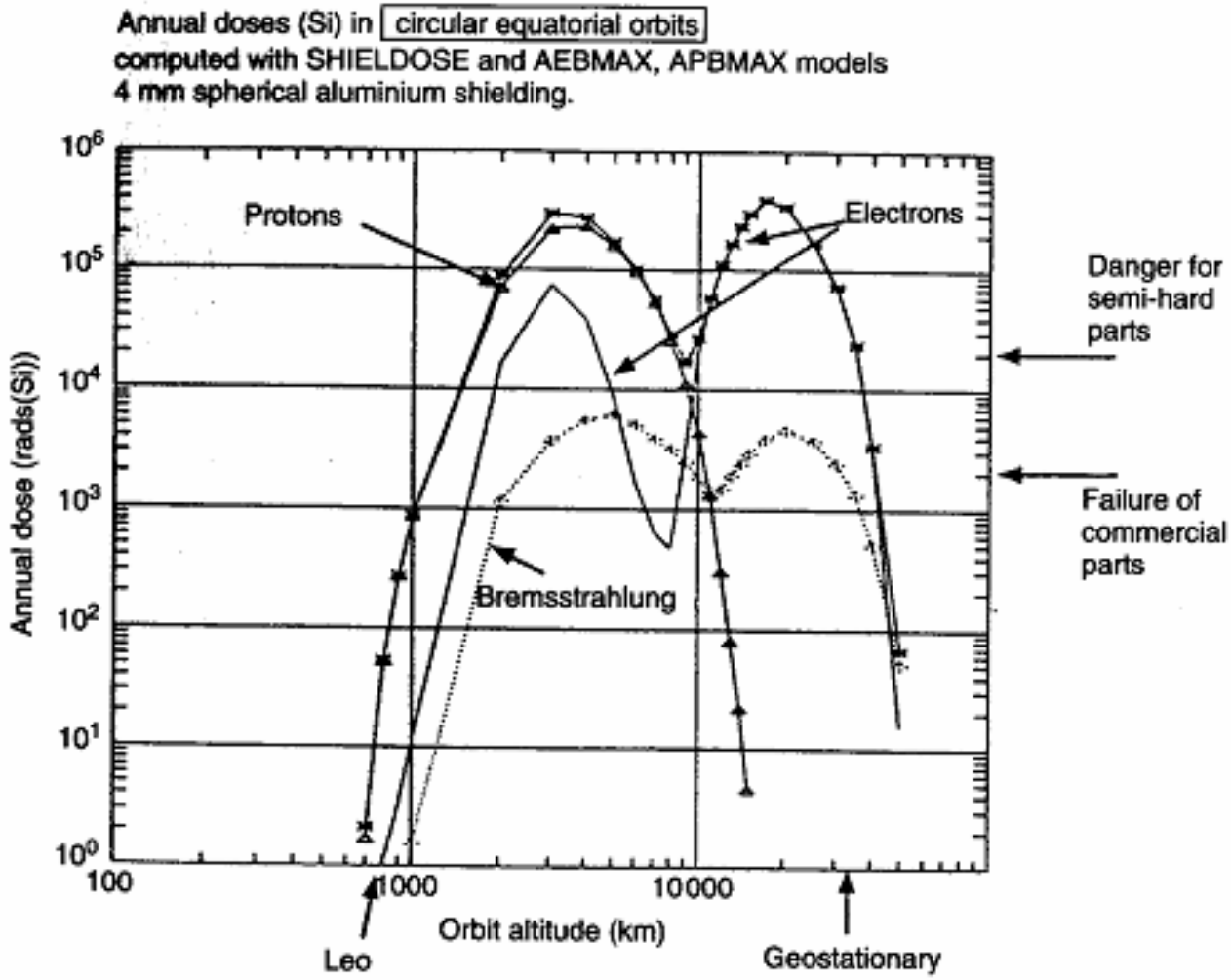


Figure 2.17 Variation of computed annual dose on circular orbits as a function of altitude. Computed with AE8 and AP8 models and SHIELDOSE [13]. (Reproduced by permission of the International Astronautical Federation)

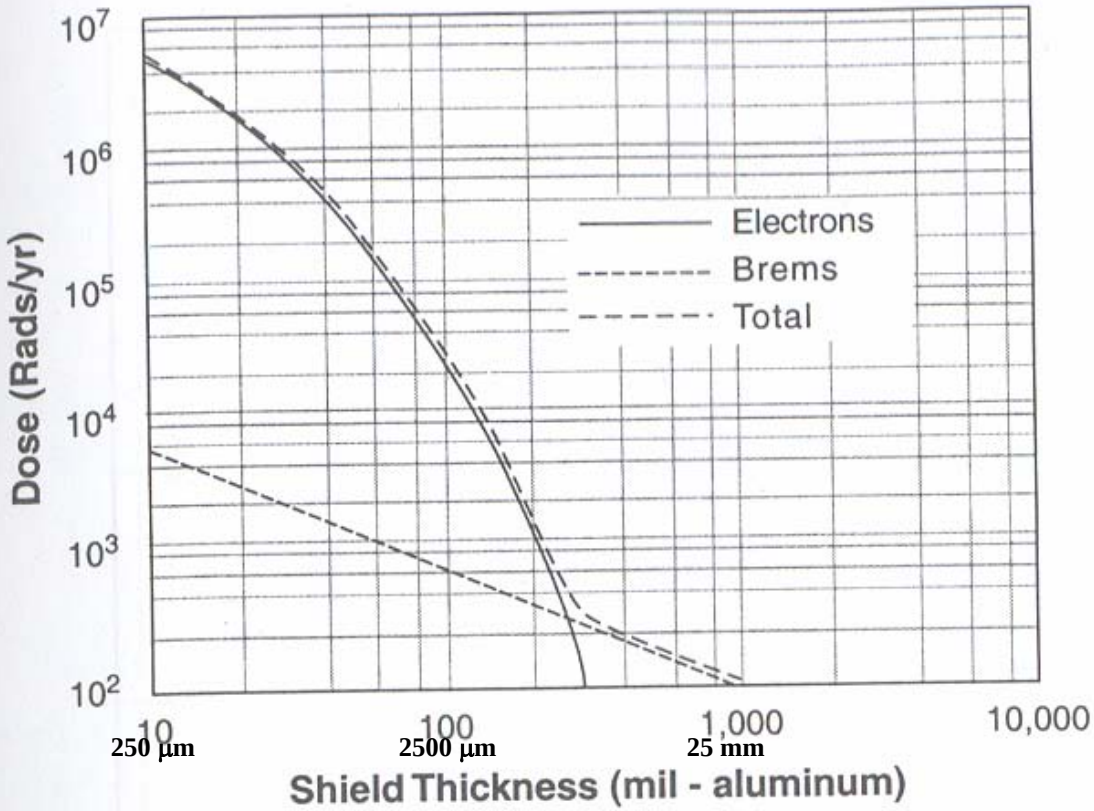


Fig. 8-10. Radiation Dose Rate in Geosynchronous Equatorial Orbit for Various Shield Thicknesses.

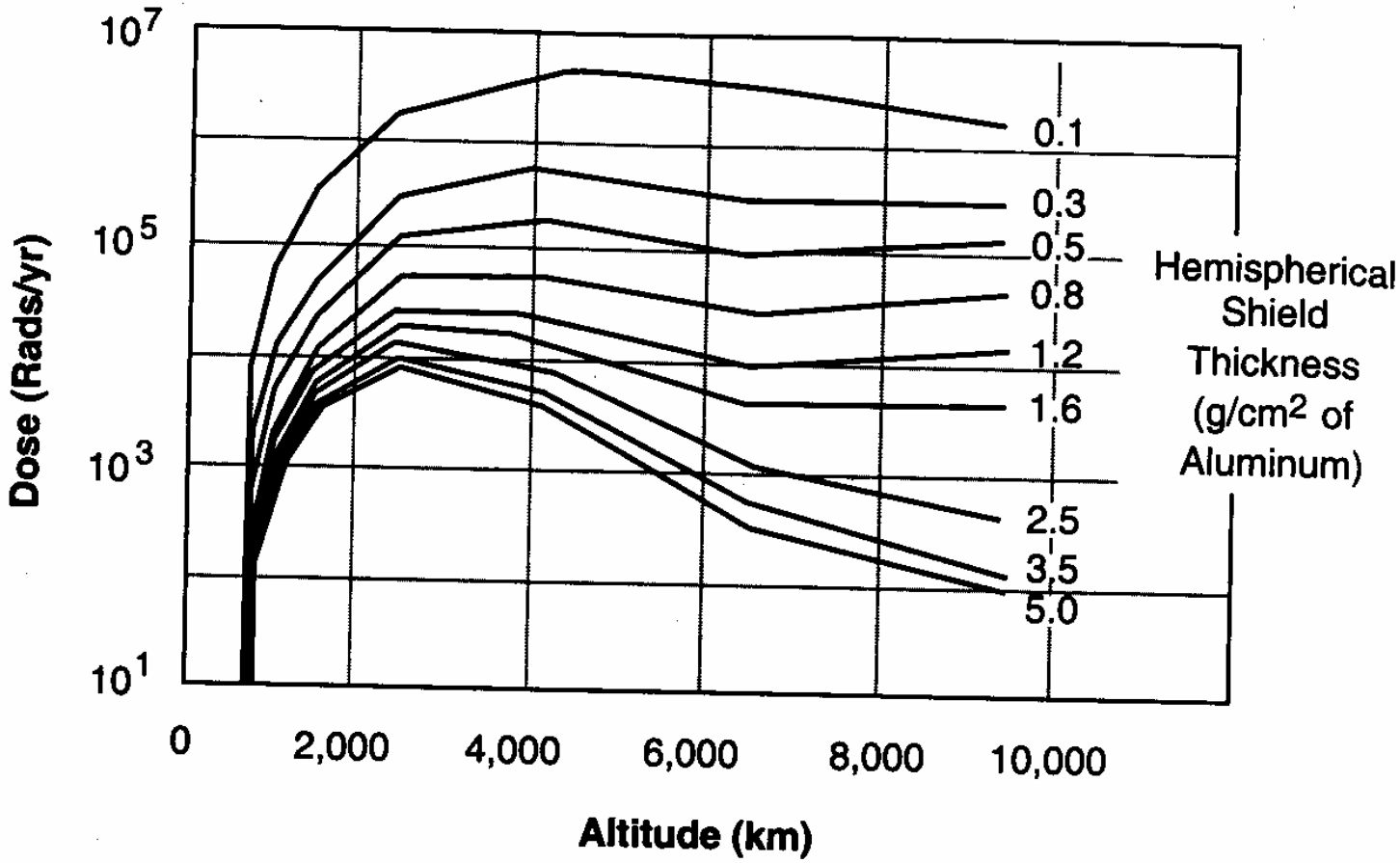


Fig. 8-9. Radiation Dose Rates as a Function of Altitude for Low-Altitude Polar Orbits. Dose rates are shown for several shielding depths.

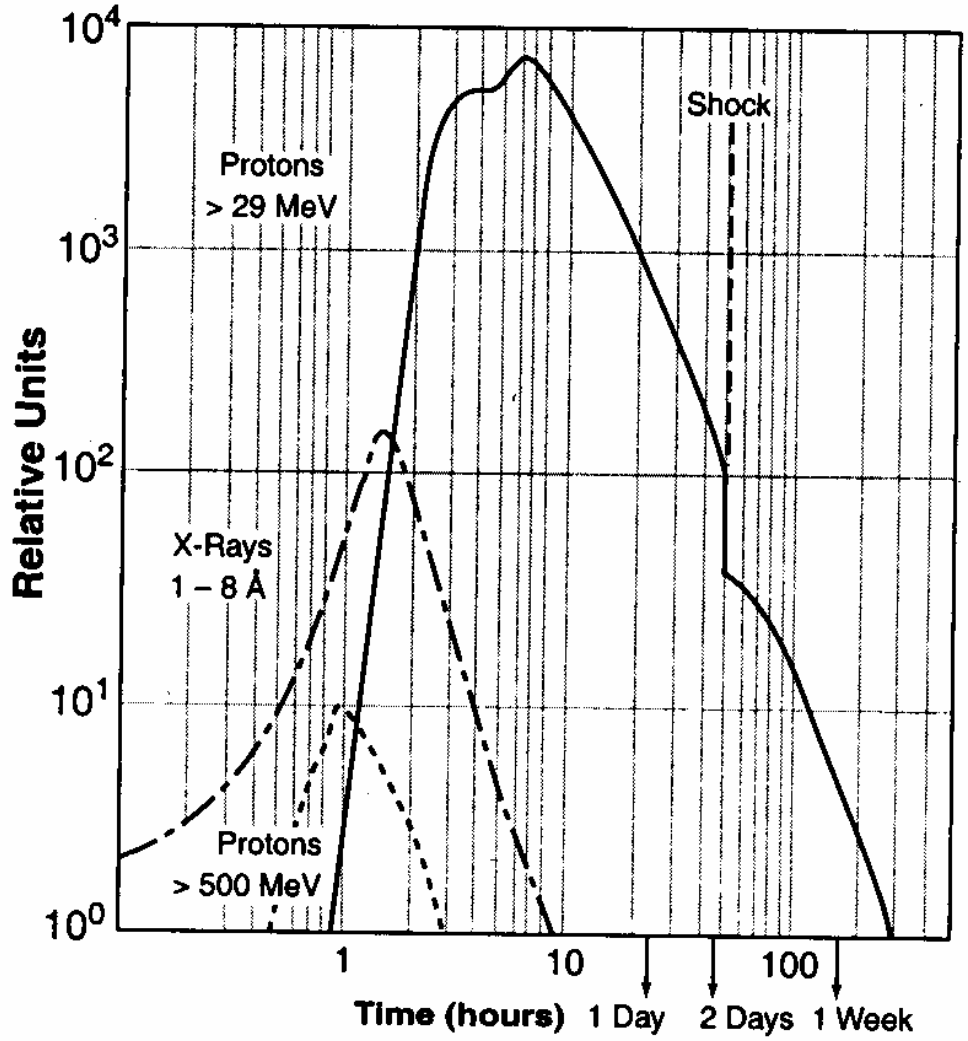


Fig. 8-11. Typical Time Evolution of a Solar Particle Event Observed on Earth.

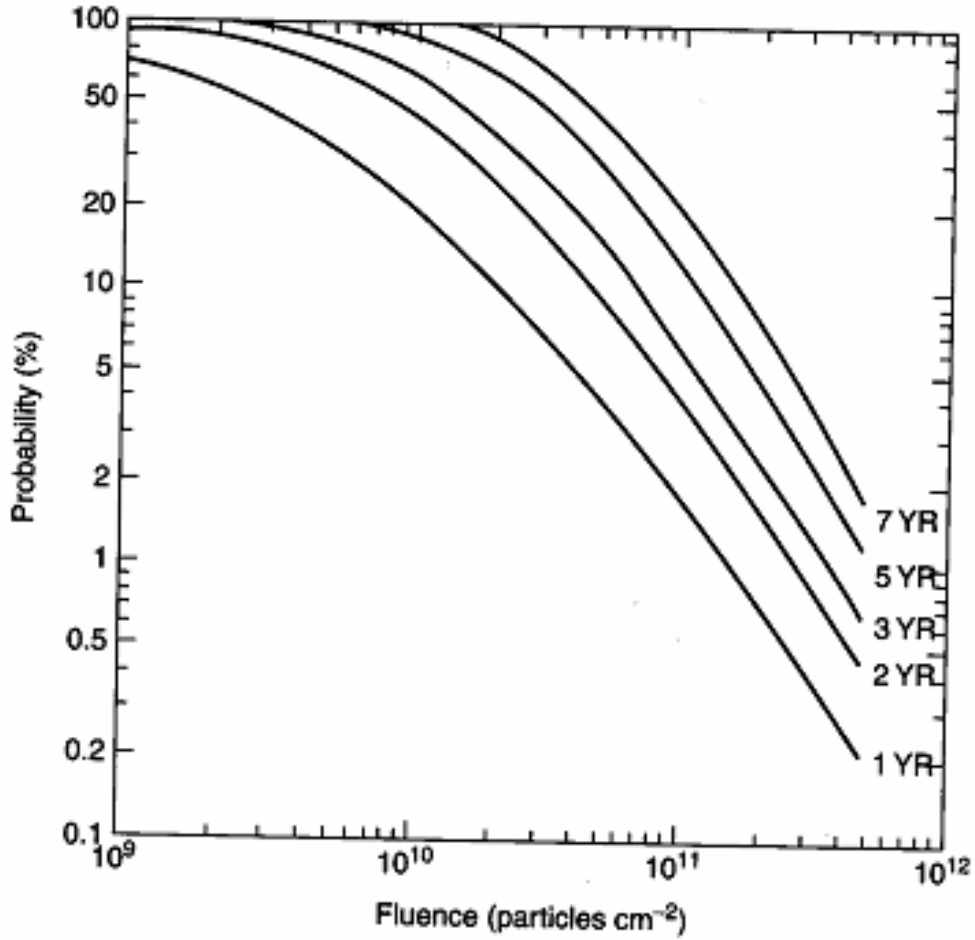


Figure 2.19 Probability of exceeding given levels of fluence energy >10 MeV *versus* active years of solar cycle. (Reproduced by permission of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California)

Table 2.9 Radiation dose in space-laboratory-type orbit (free space)

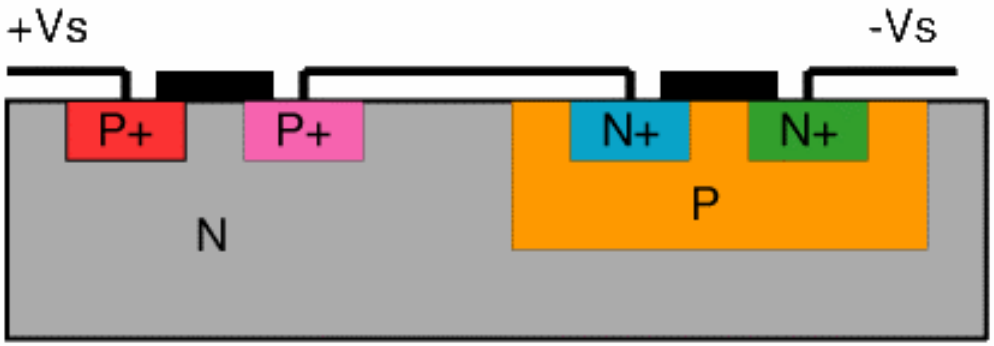
Source	Dose rate
Galactic radiation	0.01–0.05 rad/day =.0001-0.005 Gy/h
	(~0.3 rem/day)=.003 Sv/day
Radiation belts	protons: 1–10 rad/h =.01-0.1 Gy/h
	[behind 1 cm Al]
	electrons: 10^2–10^3 rad/h =1-10 Gy/h
	[at surface of S/C]
	(~1–30 rem/h) =.01-.3 Sv/day
Solar flares	12–350 rad/event = 0.12-3.5 Gy/event
	(~10 500 rem) =100 Sv/event = 0.1-5 Sv/day

Note: Mean dose on earth 250–300 millirem/year =2.5-3 mSv/yr

Single Event Latchup

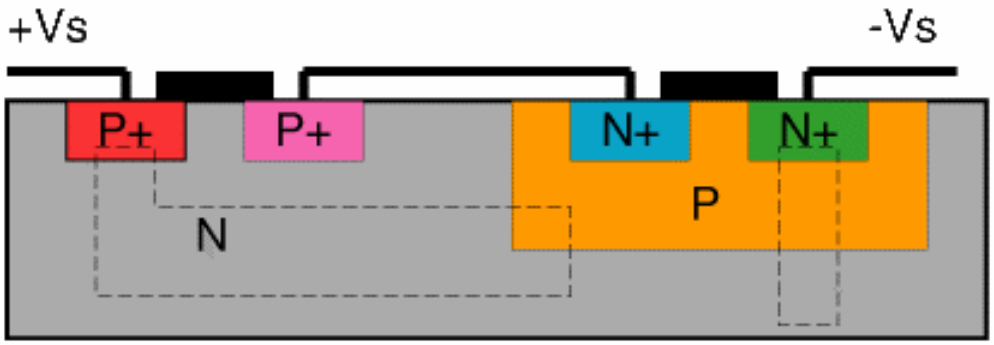
How Latchup Occurs

Circuits are manually made in silicon by combining adjacent p-type and n-type regions (i.e., over-seeded, or "doped," with appropriate impurities) into transistors. Paths other than those chosen to form the desired transistor can sometimes result in so-called parasitic transistors, which, under normal conditions, cannot be activated. Latchup occurs when a spurious current spike, such as that produced by a heavy cosmic ray, activates one of a pair of these parasitic transistors, which combine into a circuit with large positive feedback. The result is that the circuit turns fully on and causes a short across the device until the latter burns up or the power to it is cycled. This condition, when caused by a charged particle, is called Single Event Latchup.



CMOS Gate

Desired Circuit



Parasitic Transistors

Equivalent Circuit

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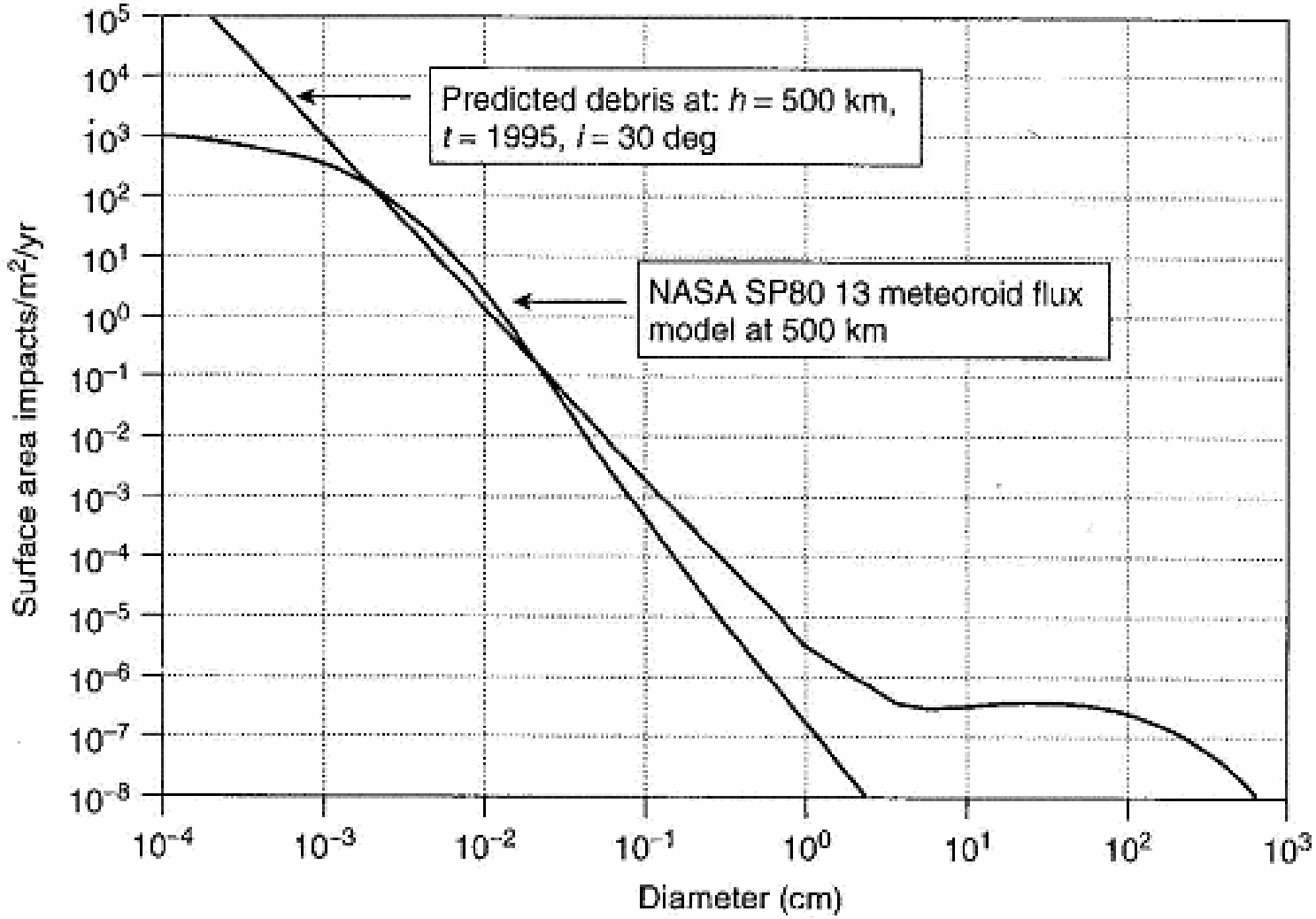

Figure 2.21 Comparison of the fluxes of predicted orbital debris and meteoroids (Reproduced by permission of NASA)