Space Radiation

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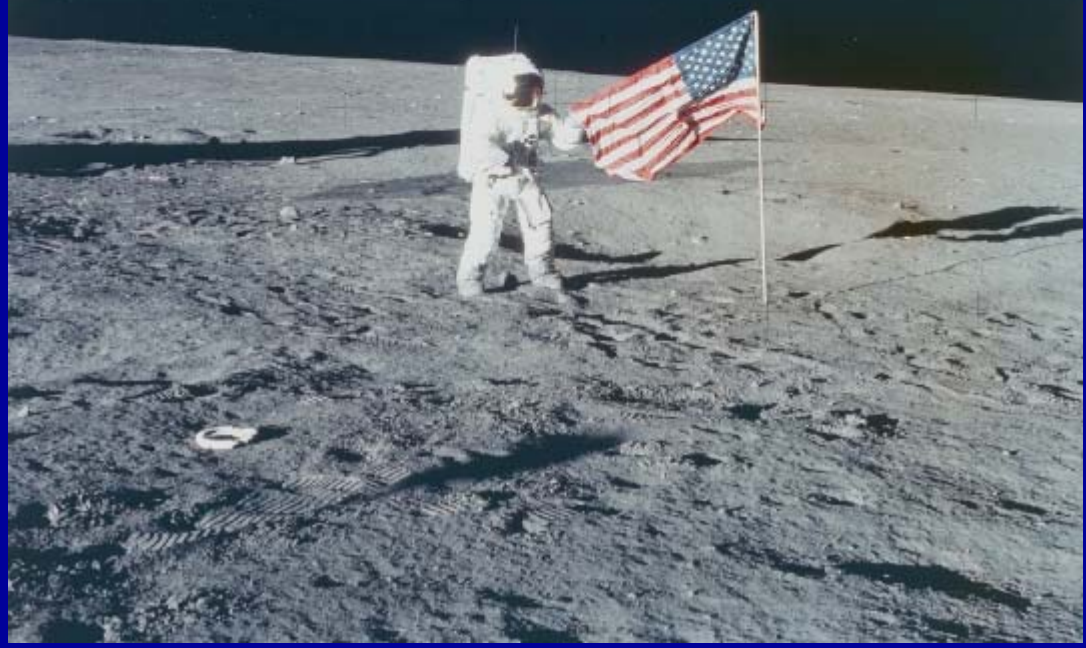
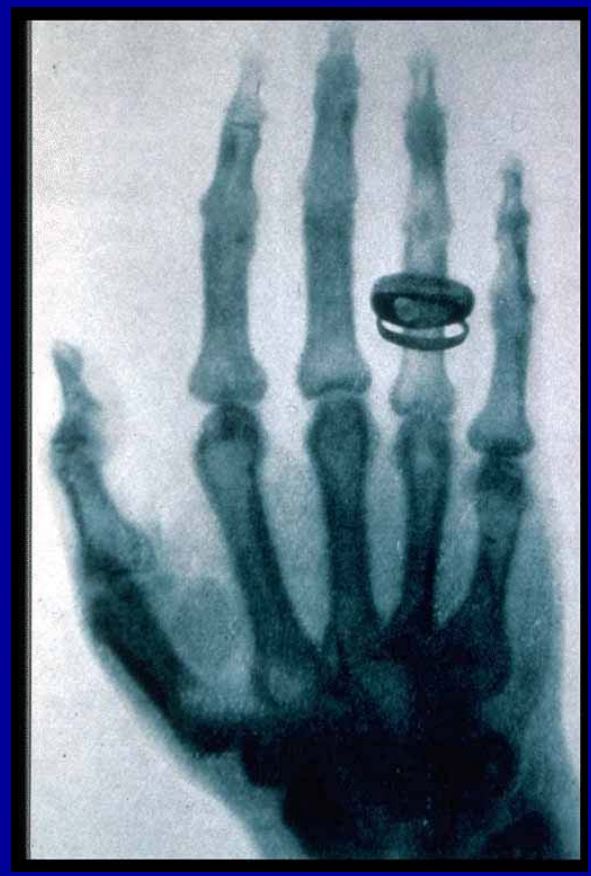


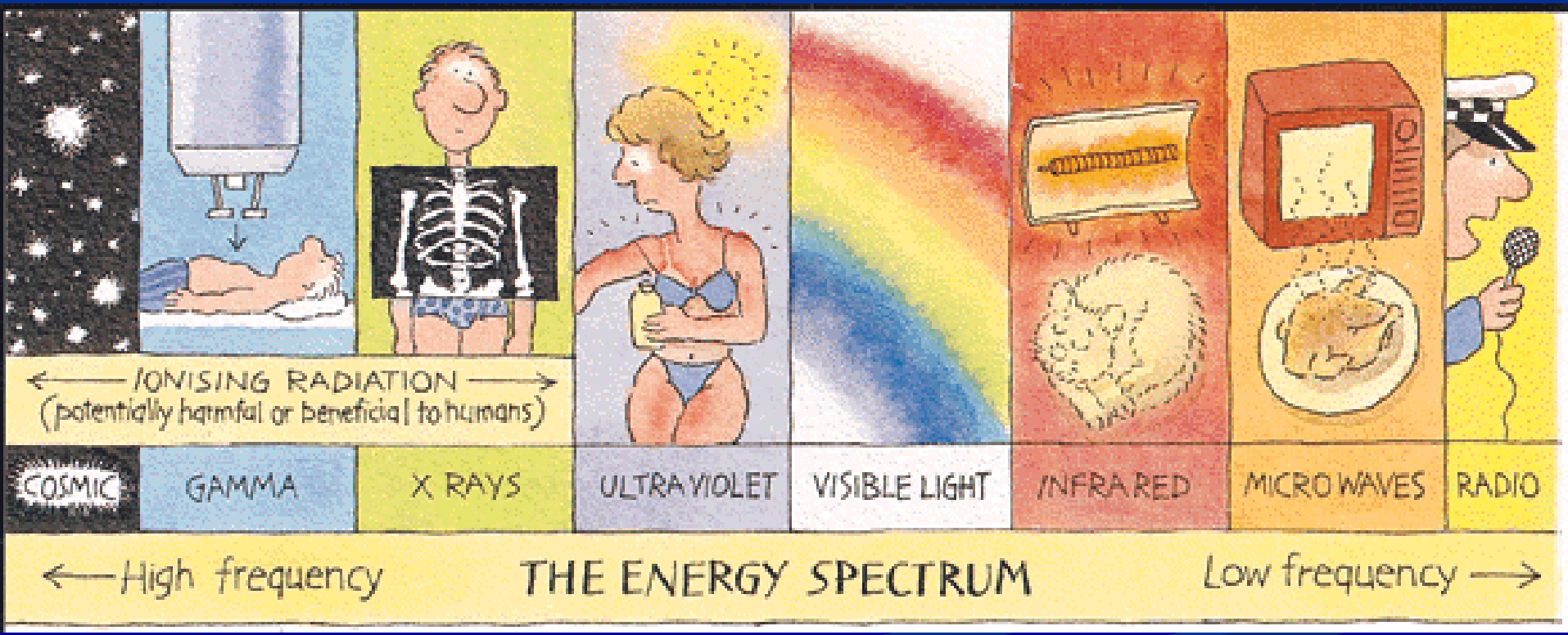
Discovery of X-rays
Wilhelm Roentgen (1845-1923)



Radiation 101

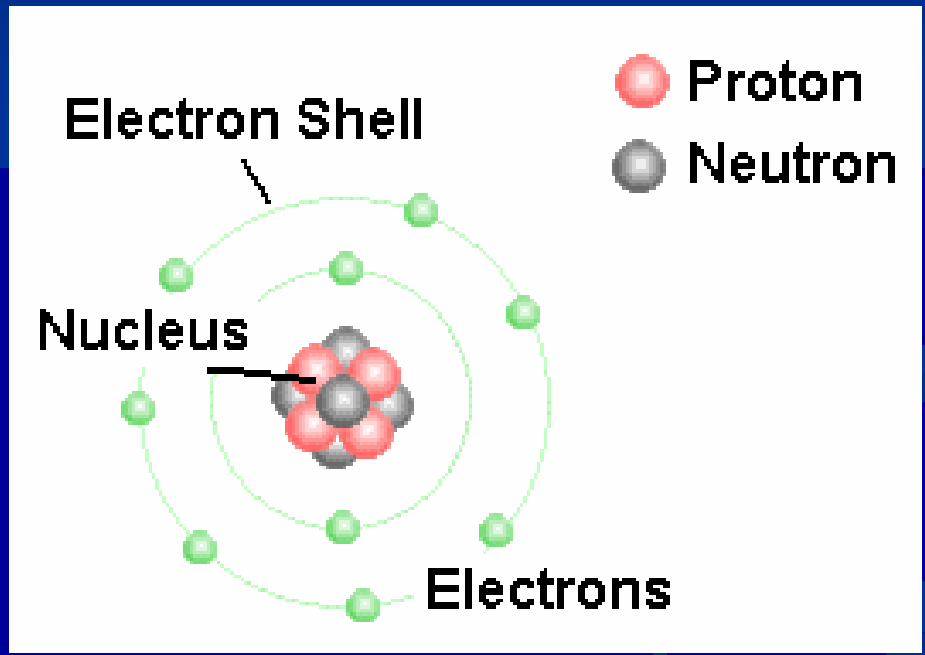
- Non ionizing radiation – Microwaves, UV, laser and etc.
- Ionizing radiation – X-rays, alpha, beta and gamma radiation
- Energetic particles – Charged particles and neutrons

Radiation 101 (continue)

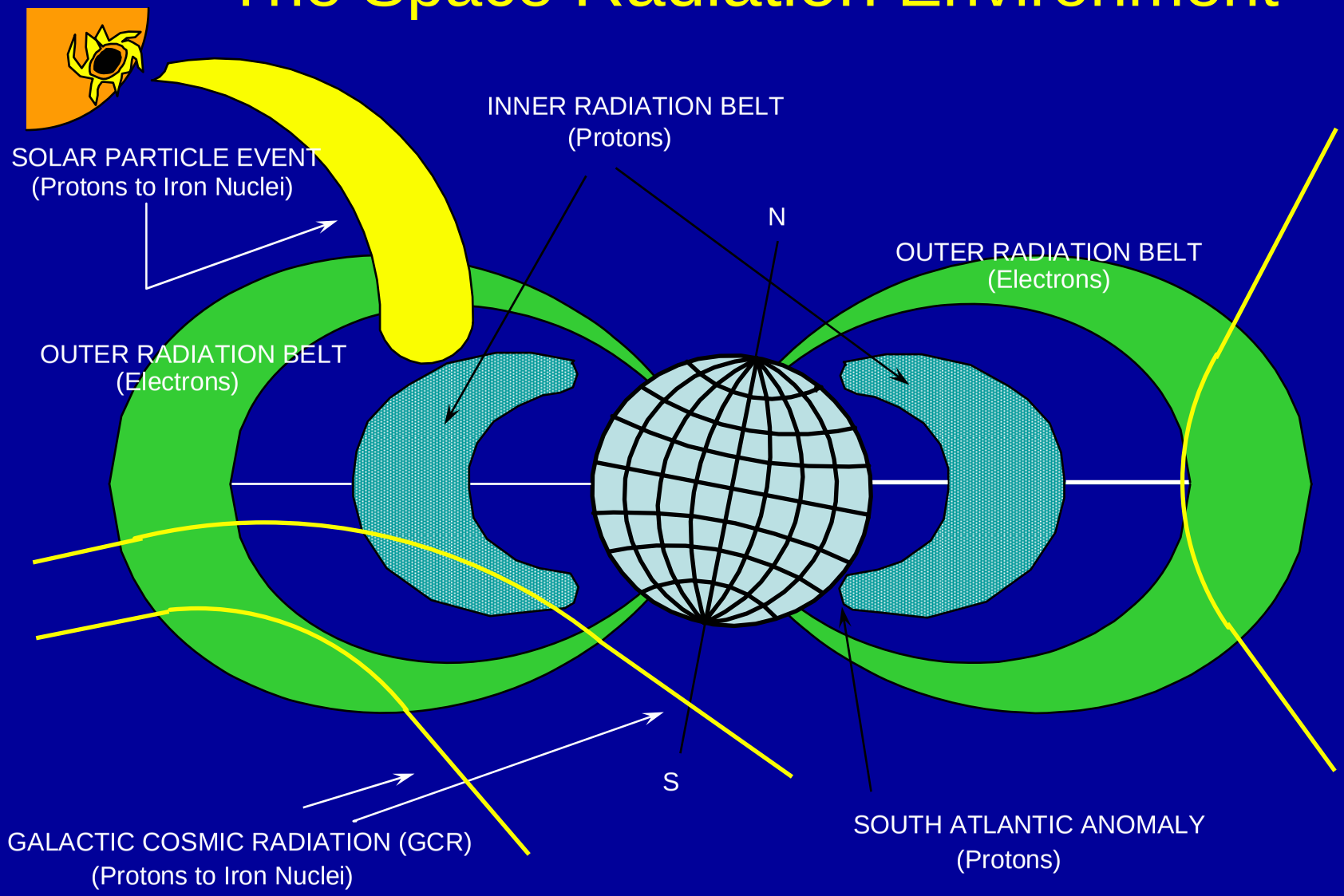


Radiation 101 (continue)

- Space radiation is composed of energetic charged particles (atoms with all of the electrons striped)
- Astronauts are exposed to secondary neutrons as well

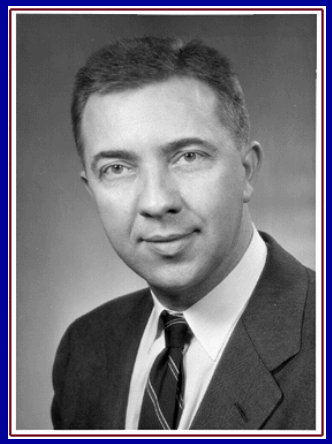


The Space Radiation Environment

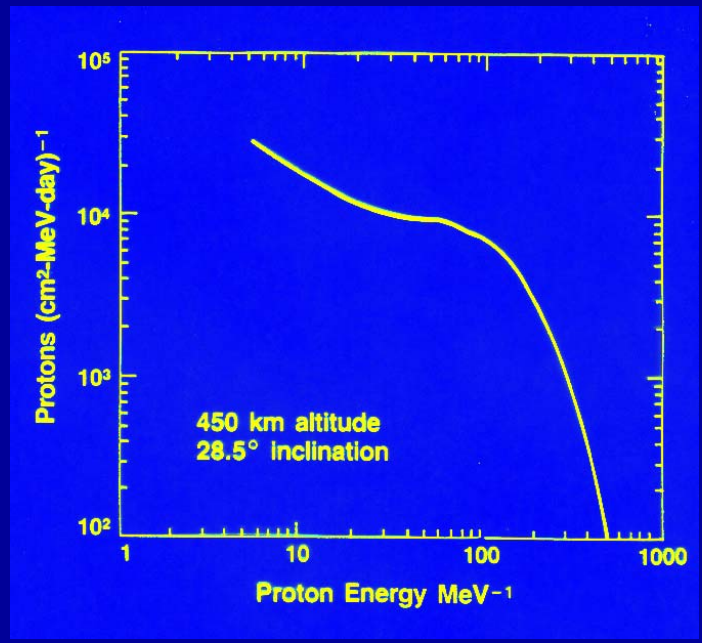


Representation of the major sources of ionizing radiation of importance to manned missions in low-Earth orbit. Note the spatial distribution of the trapped radiation belts.

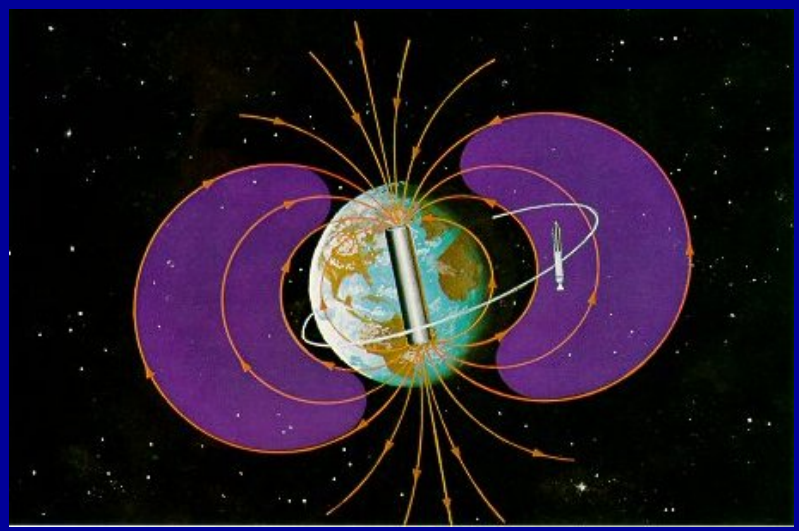
Van Allen Belt (Trapped radiation)



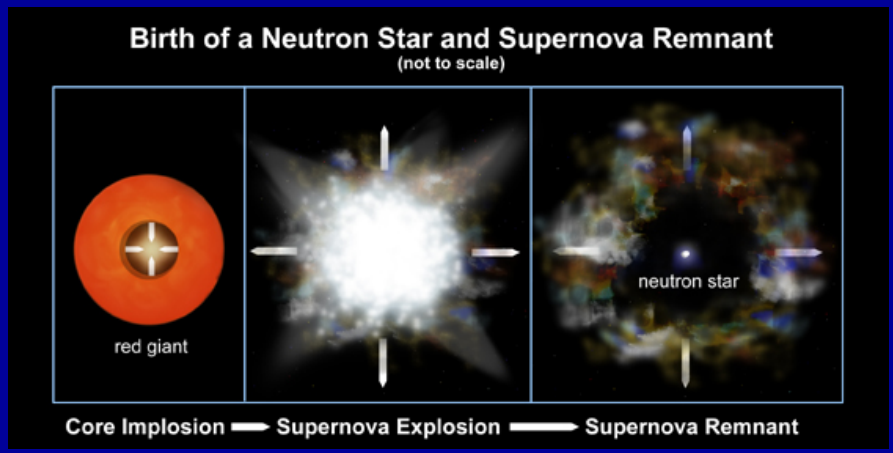
James Van Allen (1914 -)

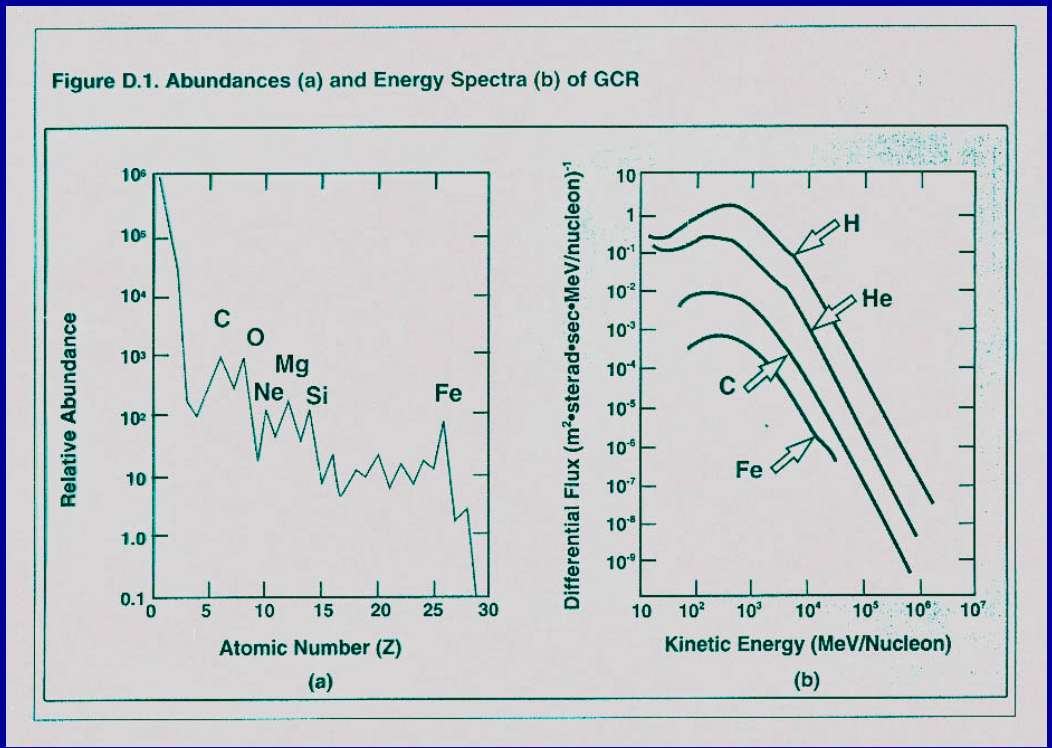


Energy spectrum of trapped protons

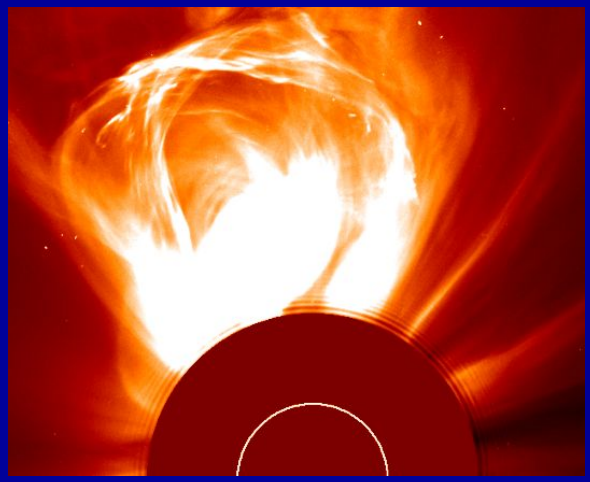


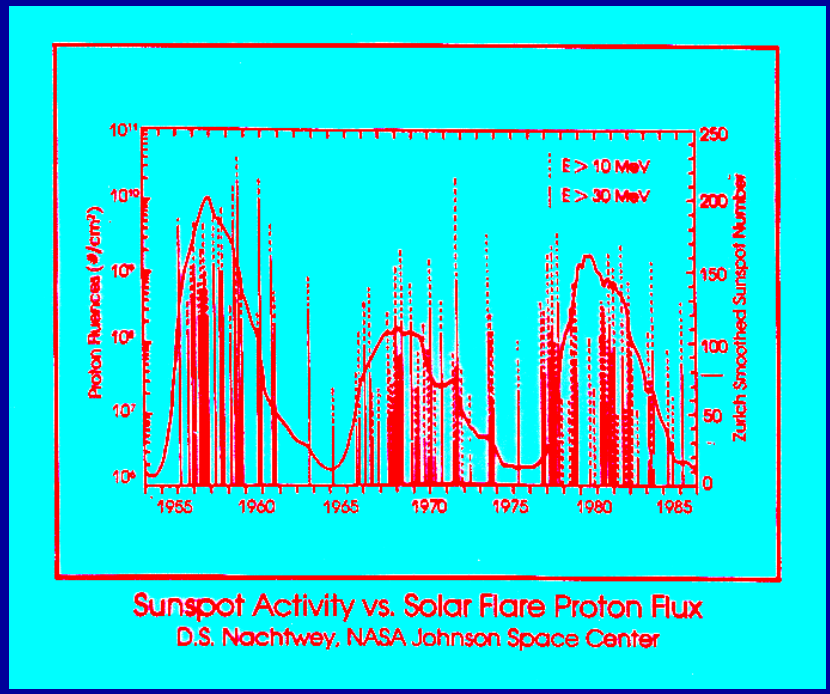
Origin of cosmic rays

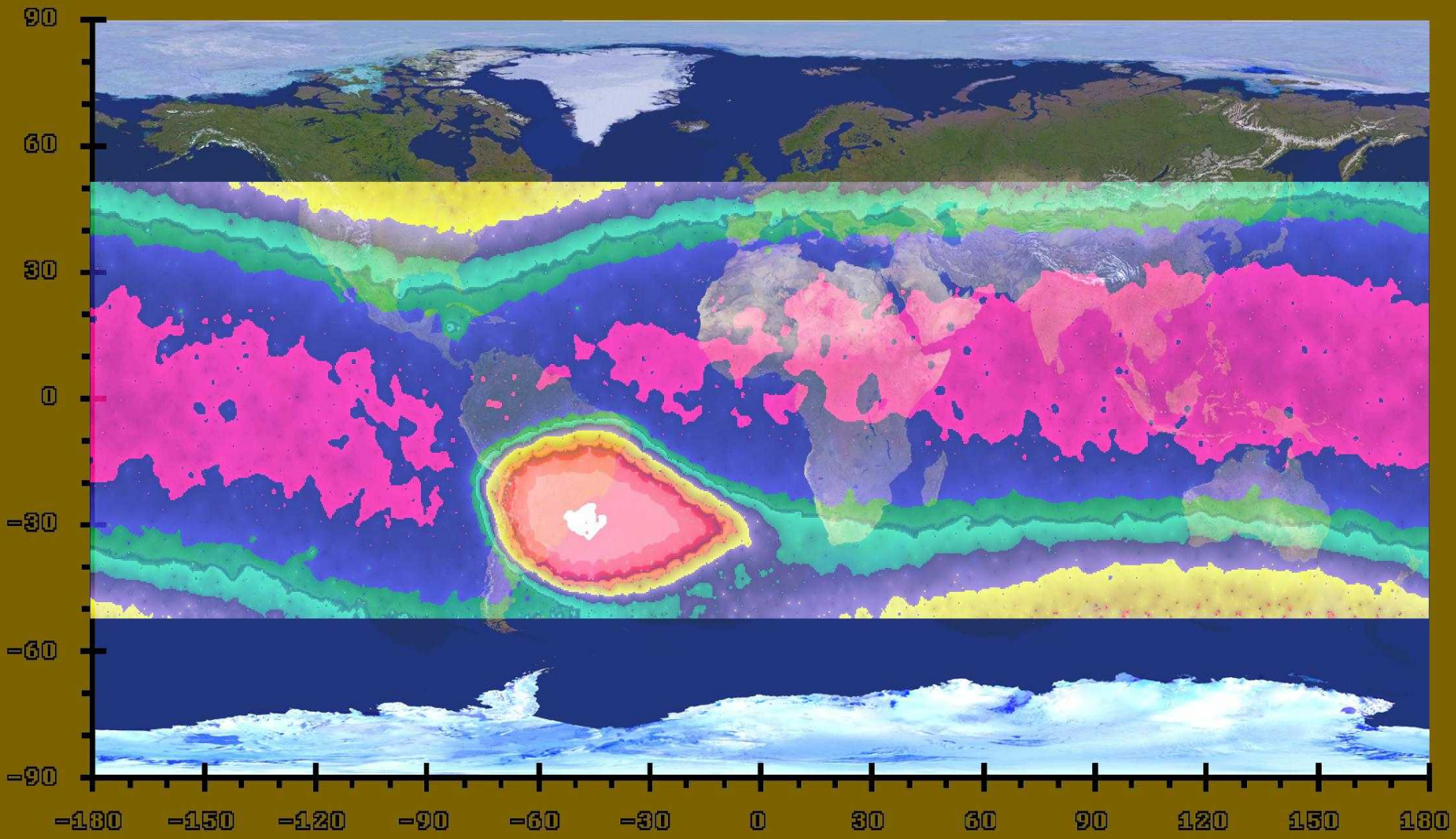




Solar particle event (Aurora)







Inclination = 51.6 deg.
Altitude ~ 385 km.
November 2, 1997 -
November 4, 1997

NASA-MIR 6 - Radiation Dosage
TEPC- PRIRODA

0 nGy/min 6500

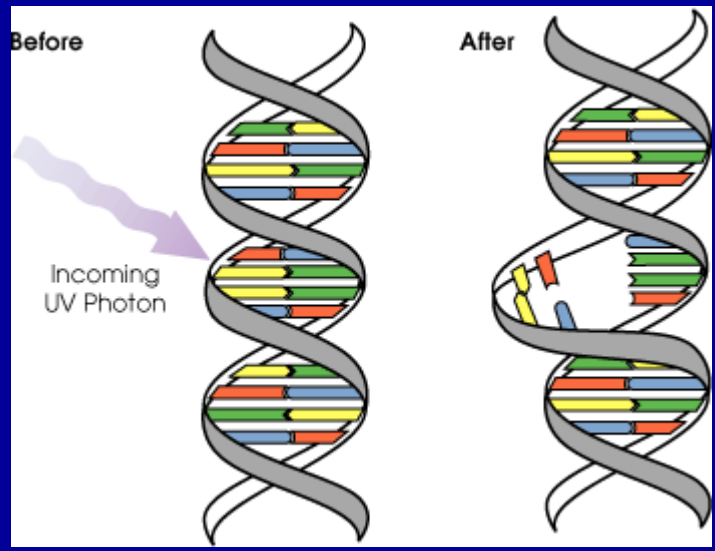
Neutrons

Summary of space radiation environment

- Major sources: Trapped protons, GCR, solar particle events
- Radiation type: Protons and heavy ions (high-LET)
- Energy of interest: 100 MeV/u ~10000 MeV/u
- Secondary neutrons
- Small amount of other types of radiation
- Ultraviolet radiation

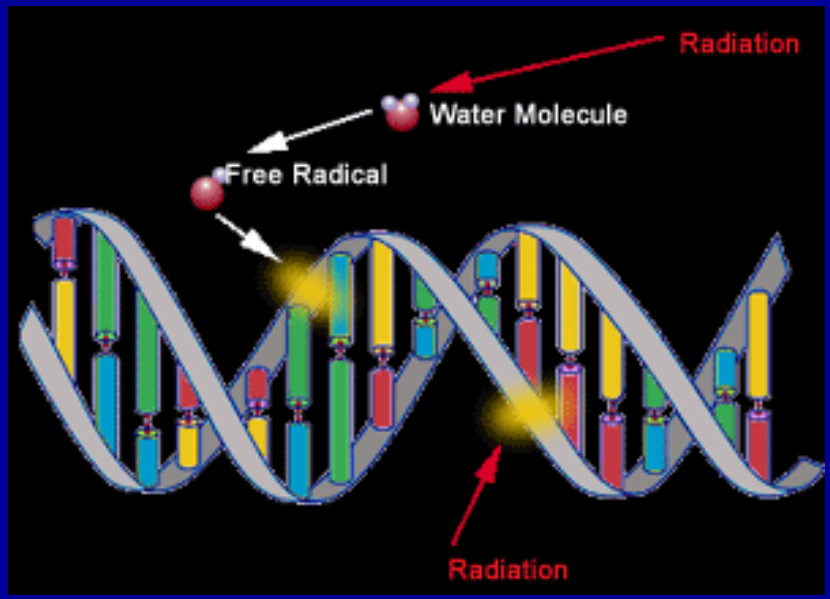
Ultraviolet radiation

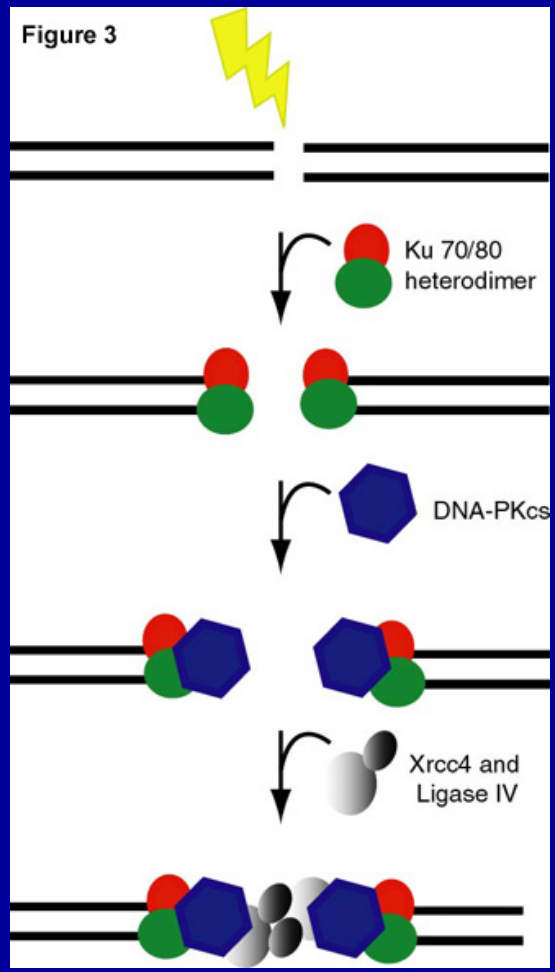
- Skin cancer and damages to the eye
- Most of the spacecraft windows are coated with UV blockers
- EVA visors are coated with UV blockers
- EVA suit has a layer of material to block UV



Ultraviolet (UV) photons harm the DNA molecules of living organisms in different ways. In one common damage event, adjacent bases bond with each other, instead of across the “ladder.” This makes a bulge, and the distorted DNA molecule does not function properly.

DNA damage from ionizing radiation
DNA strand breaks





Space Radiation Exposure

Mission	Altitude (nm)	Inc. (deg)	Duration (days)	Dose (cSv)
Gemini (Average)	245	30	4 h -14 d	0.05
Apollo (Average)			6-12 d	1.22
Skylab (Average)	206	50	28-84 d	7.2
STS-94	160	28.5	15.7	0.27
STS-95	310	28.5	8.9	2.1
Shuttle-Mir	190	51.6	3-5 mo.	10.1

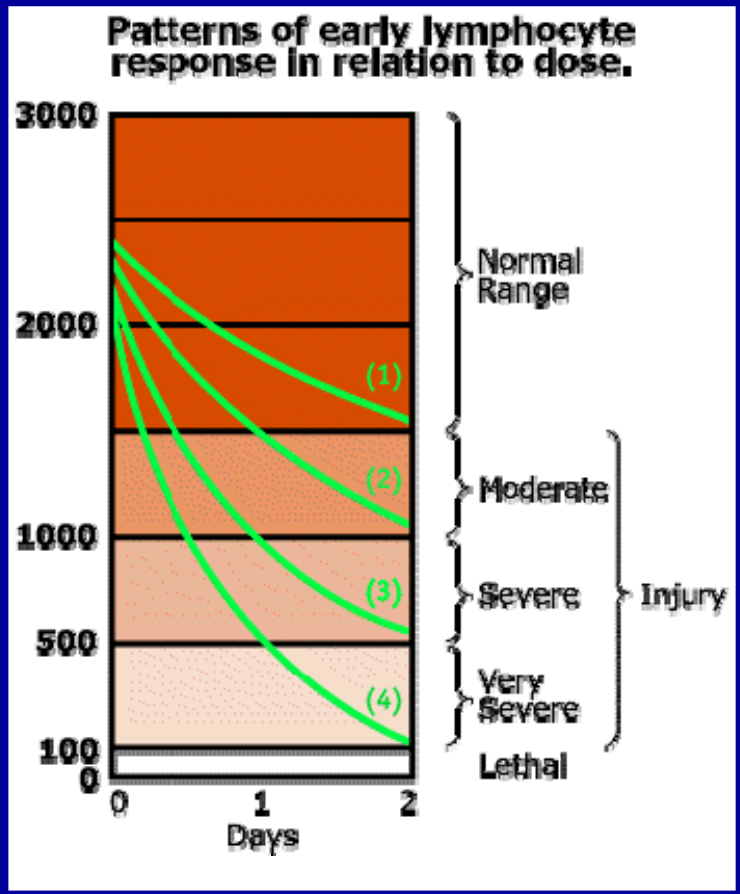
(0.005 cSv)

Radiation in our daily life (cSv)

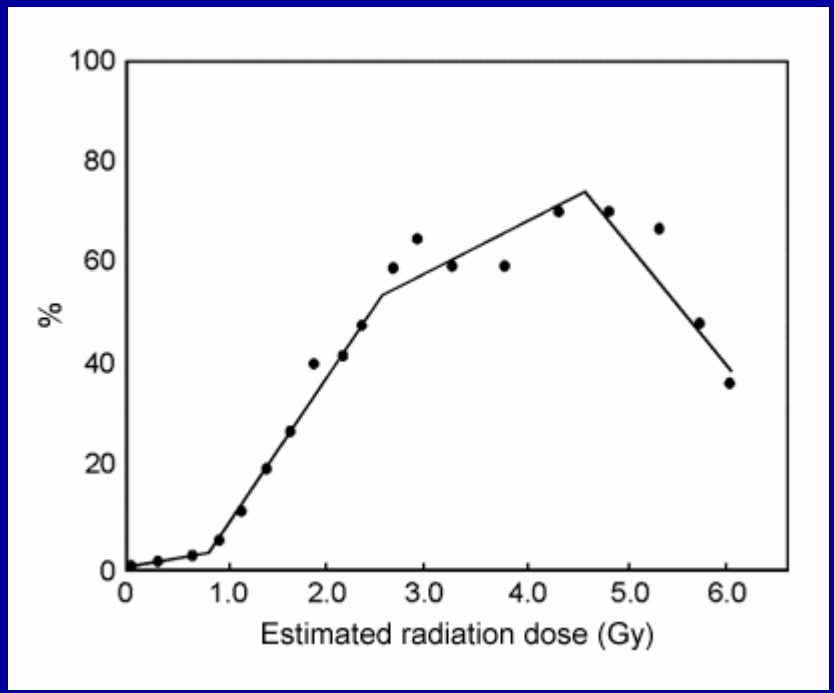
•Chest X-ray	0.002
•Lumbar spine X-rays	0.13
•Barium enema	0.7
•CT abdomen	0.8
•Living in Houston for one year	0.09
•Living in Denver for one year	0.3

Acute radiation syndrome

- Vomiting
- Diarrhea
- Reduction in the number of blood cells
- Bleeding
- Hair loss
- Temporary sterility in males
- Lens opacity
- Others

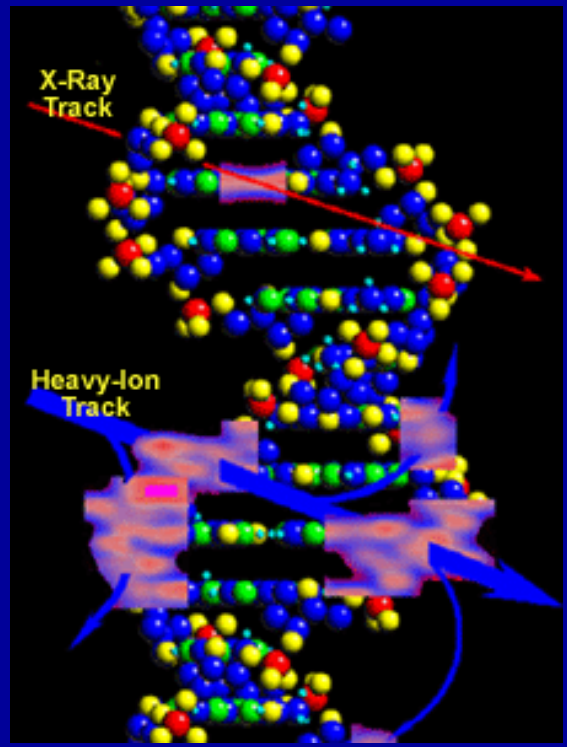


Acute radiation syndrome (continue)



Space Radiation Health Project

- What are the risks from exposure to space radiation?
- How to reduce the risks?



Identified Space Radiation Risks

• **Carcinogenesis --** Increased cancer morbidity or mortality risk in astronauts may be caused by occupational radiation exposure

• **Acute and late CNS risks --** Acute and late radiation damage to the central nervous system (CNS) may lead to changes in motor function and behavior, or neurological disorders.

• **Chronic and degenerative tissue risks --** Radiation exposure may result in degenerative tissue diseases (non-cancer or non-CNS) such as cardiac, circulatory, or digestive diseases, as well as cataracts.

•**Acute radiation risks --** Acute radiation syndromes may occur due to occupational radiation exposure.

Space Radiation Protection

- ALARA (As Low As Reasonably Achievable) principle
- Radiation exposure limits

Organ Specific Exposure Limits for Astronauts			
Exposure Interval	**Blood Forming Organs**	**Eye**	**Skin**
30 Days	25 cSv	100 cSv	150 cSv
Annual	50 cSv	200 cSv	300 cSv
Career	150 - 400 cSv [200 + 7.5(age - 30) for men] 100 - 300 cSv [200 + 7.5(age - 38) for women]	400 cSv	600 cSv

The dose limit for terrestrial radiation workers is 5 cSv per year

Space radiation monitoring

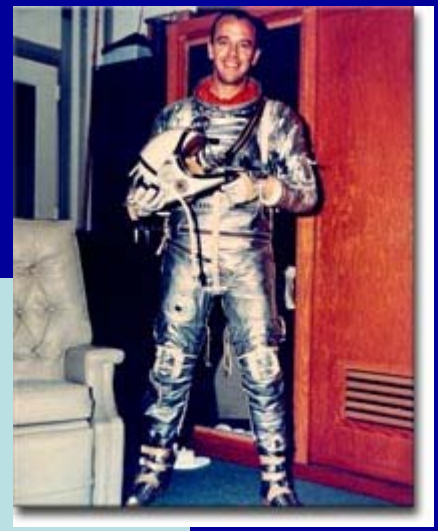
- Absorbed dose
- Dose equivalent (LET)
- Charged particle type and energy
- Neutron

Figure 14. Charged particle directional spectrometer (CPDS).

Figure 13. Tissue equivalent proportional counter (TEPC).

What are the evident biological effects of space radiation in astronauts?

Mortality



	Astronauts (N=312)
Spacecraft Accidents	14
Other Accidents	12
Cancer	5
CVD/CHD	3
Other/Unknown	1
TOTAL	35

Numbers provided by Mary Wear

Light Flashes

Budinger, Lyman and Tobias,

NATURE VOL. 239 SEPTEMBER 22 1972

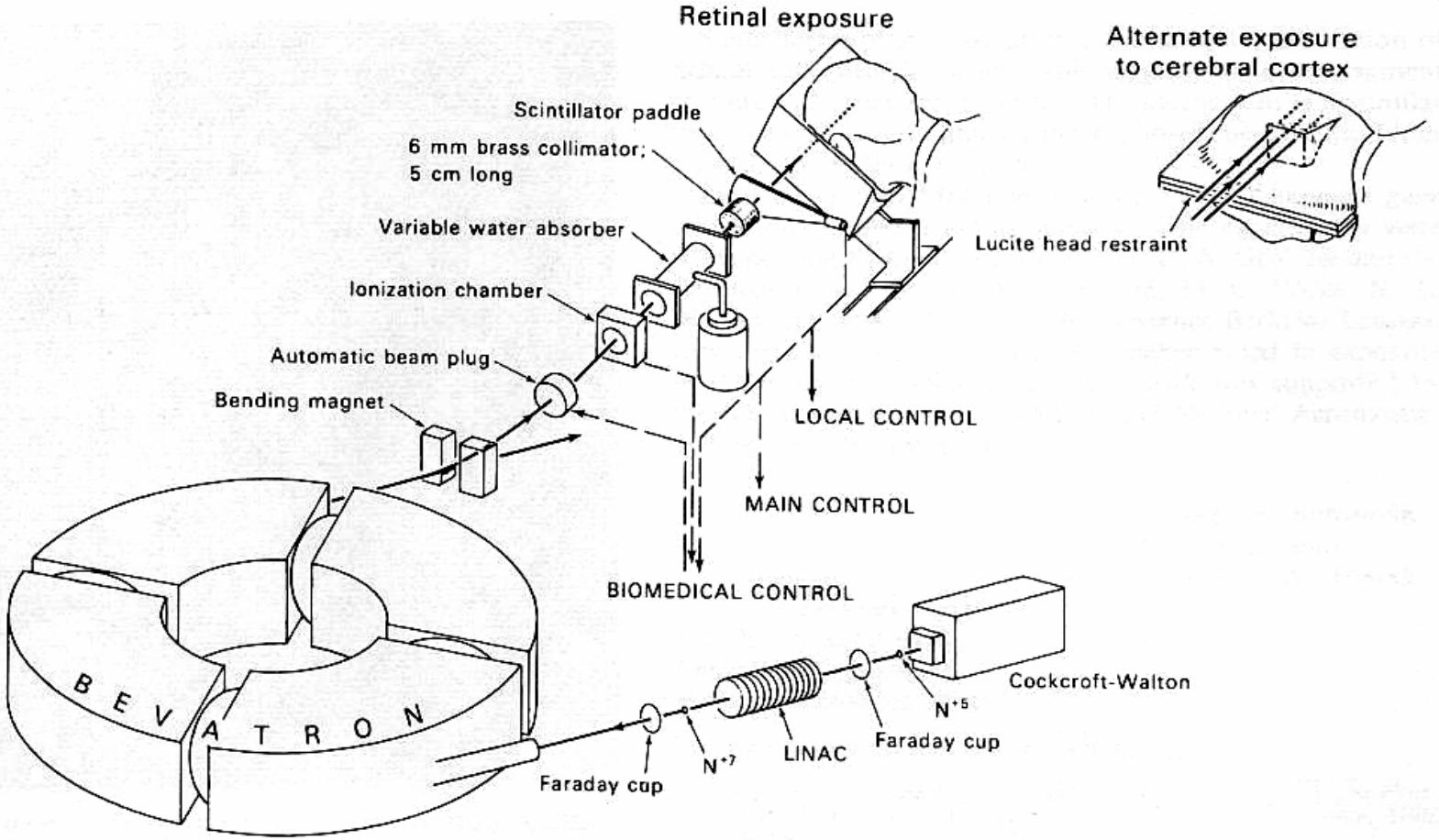


Fig. 1 Human eye and brain exposure—experimental configuration. Nitrogen ions, after final stripping, are injected into the Bevatron, accelerated to 266 MeV/nucleon, and stopped in known parts of the eye and brain.

Cataract

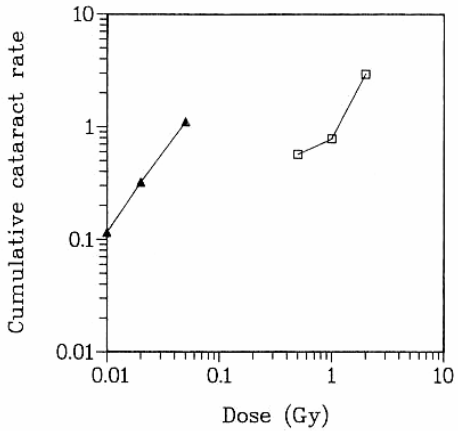
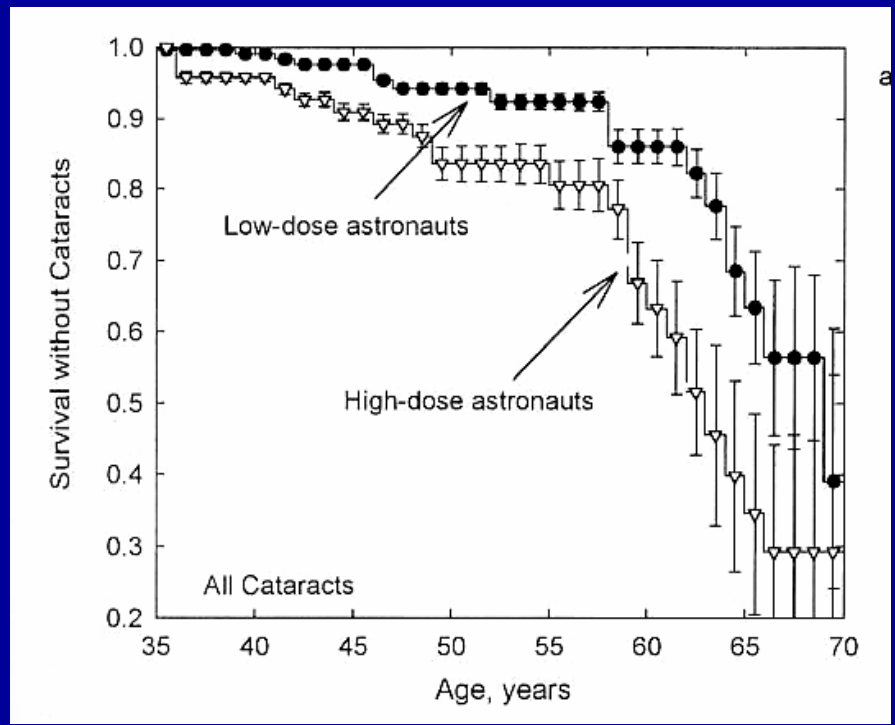


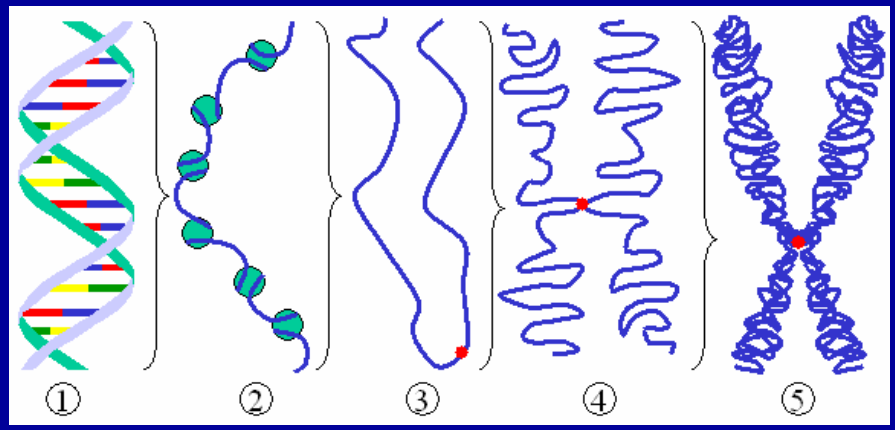
FIG. 2. Cumulative cataract rates (see text) for cataracts of grade 2 at 67 weeks postirradiation. □, X rays; ▲, iron ions. The lines joining the points are to guide the eye only.

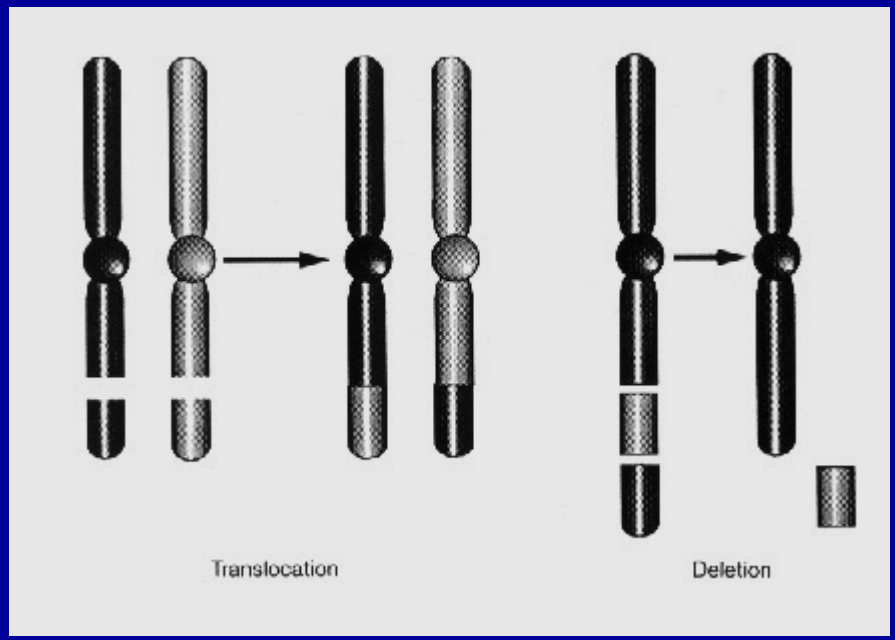
Brenner et al. Rad. Res. 1993



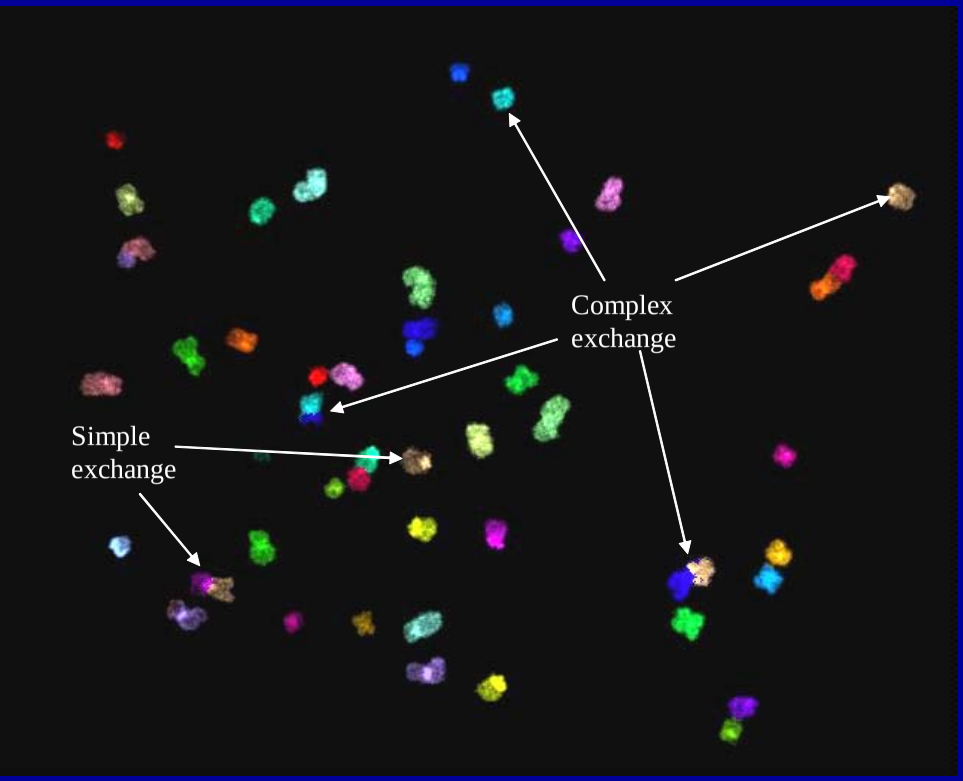
Cucinotta et al. 2001

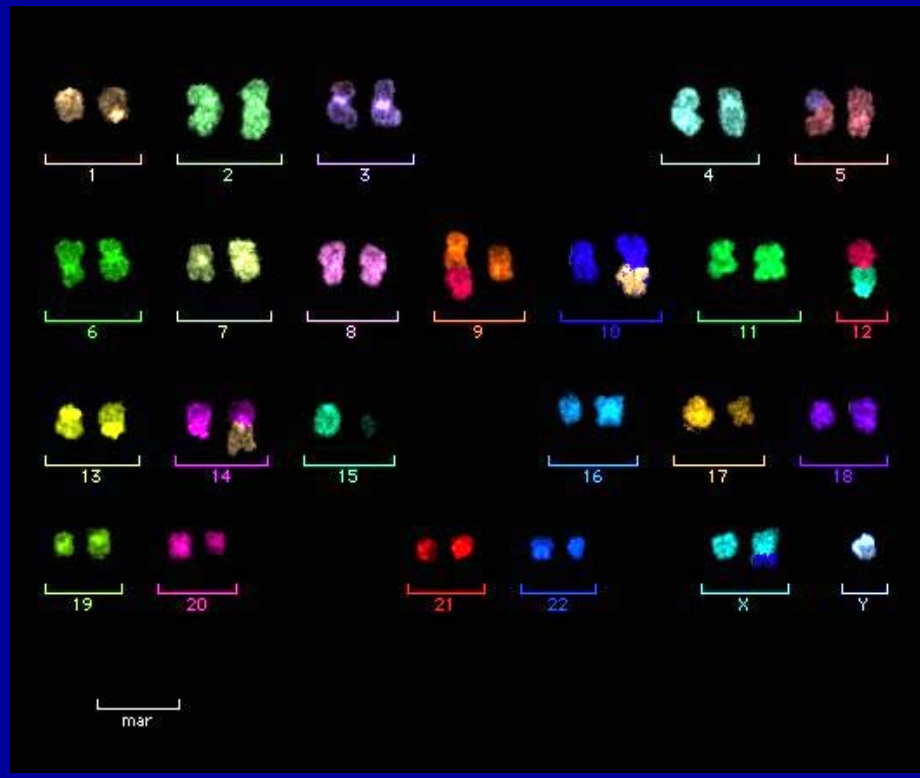
Chromosome aberrations observed in astronauts' lymphocytes





mFISH Analysis





Conclusions

- Astronauts receive the highest occupational radiation exposure

- Effective protections are needed to ensure the safety of astronauts on long duration space missions