Ioni pesanti: dalla terapia del cancro al viaggio su Marte

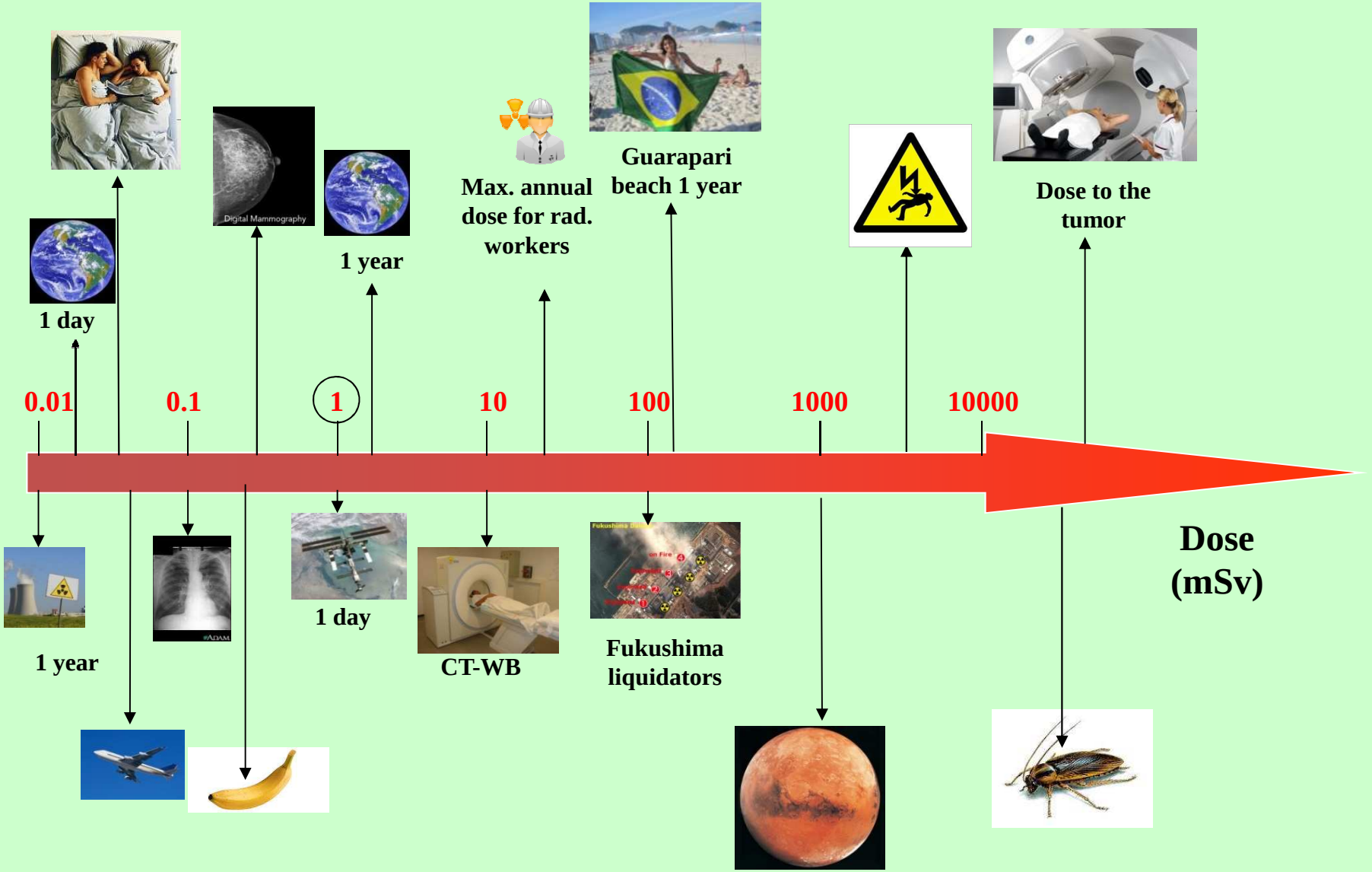
Marco Durante, TIFPA

www.tifpa.infn.it


Therapeutic benefit (cancer therapy, noncancer targets…)
Health risk (cancer, CVD, CNS…)

Radiation effects depends on the DOSE

Dose is an energy per unit mass and is measured in Sievert = Joule/kg



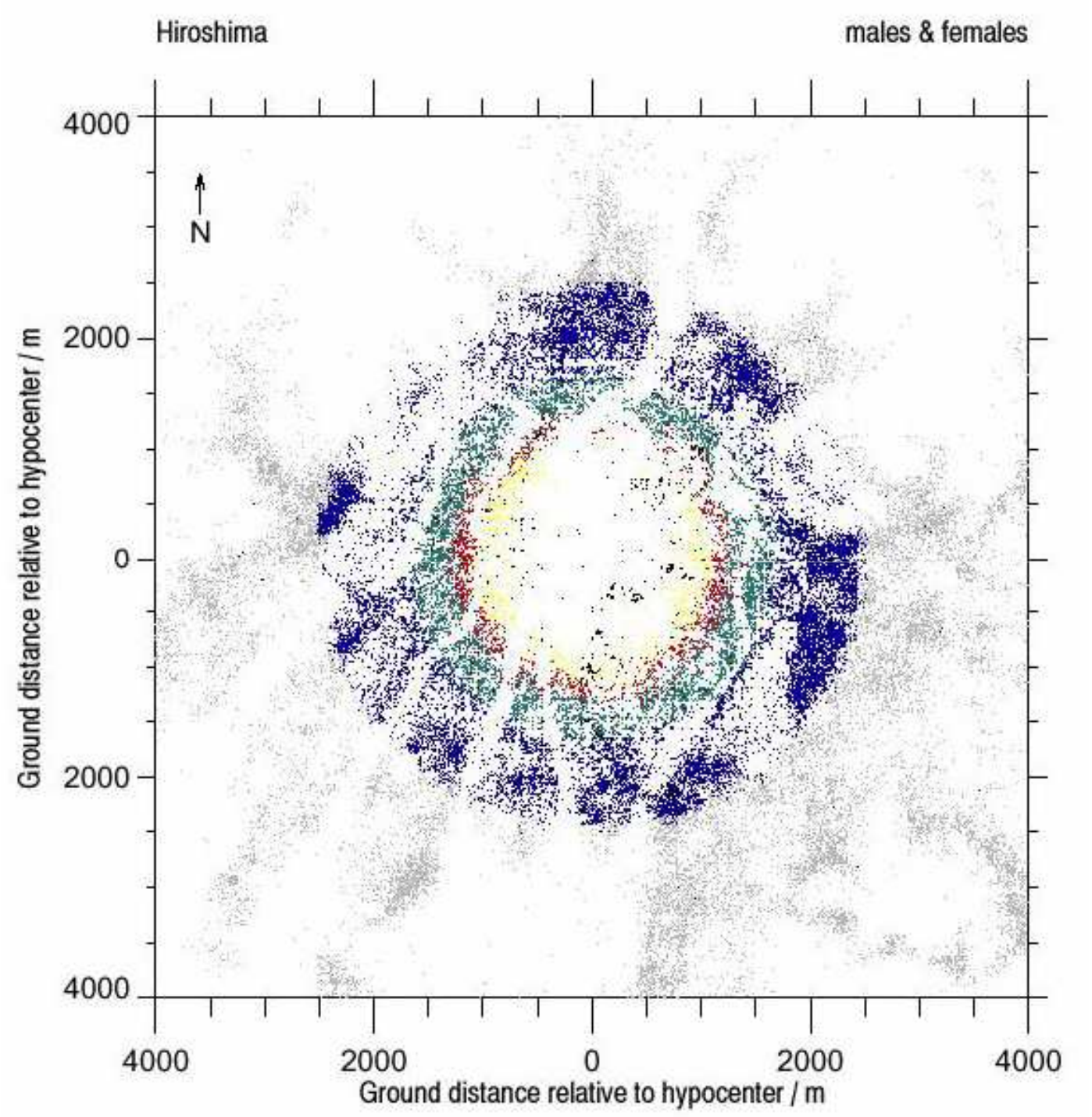
A-bomb : blast wave, thermal radiation nuclear radiation

Stochastic effects:
A-bomb survivors

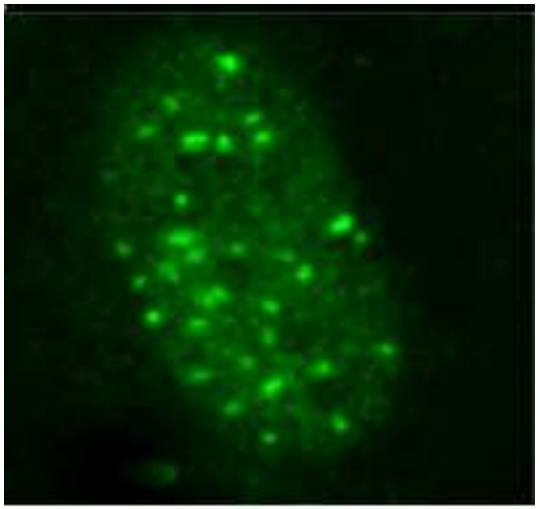
- 86,661 survivors followed (Life Span Study)
- 58% of this population died between 1950 (RERF foundation) and 2003 (last analysis in report 14, published in March 2012)
- 10,929 solid cancer deaths observed
- Approximately 644 (6%) attributed to radiation
- Approximately 1% of noncancer deaths are radiation-induced

Source: LSS report 14, RERF, March 2012

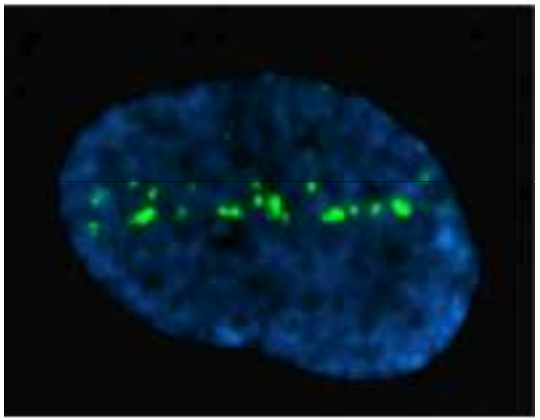
Radiation doses in Hiroshima survivors



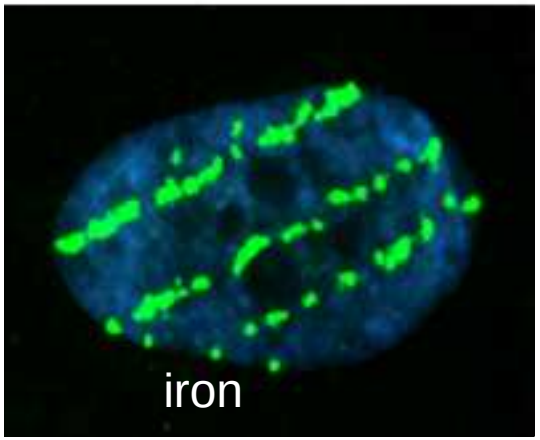
Charged particles



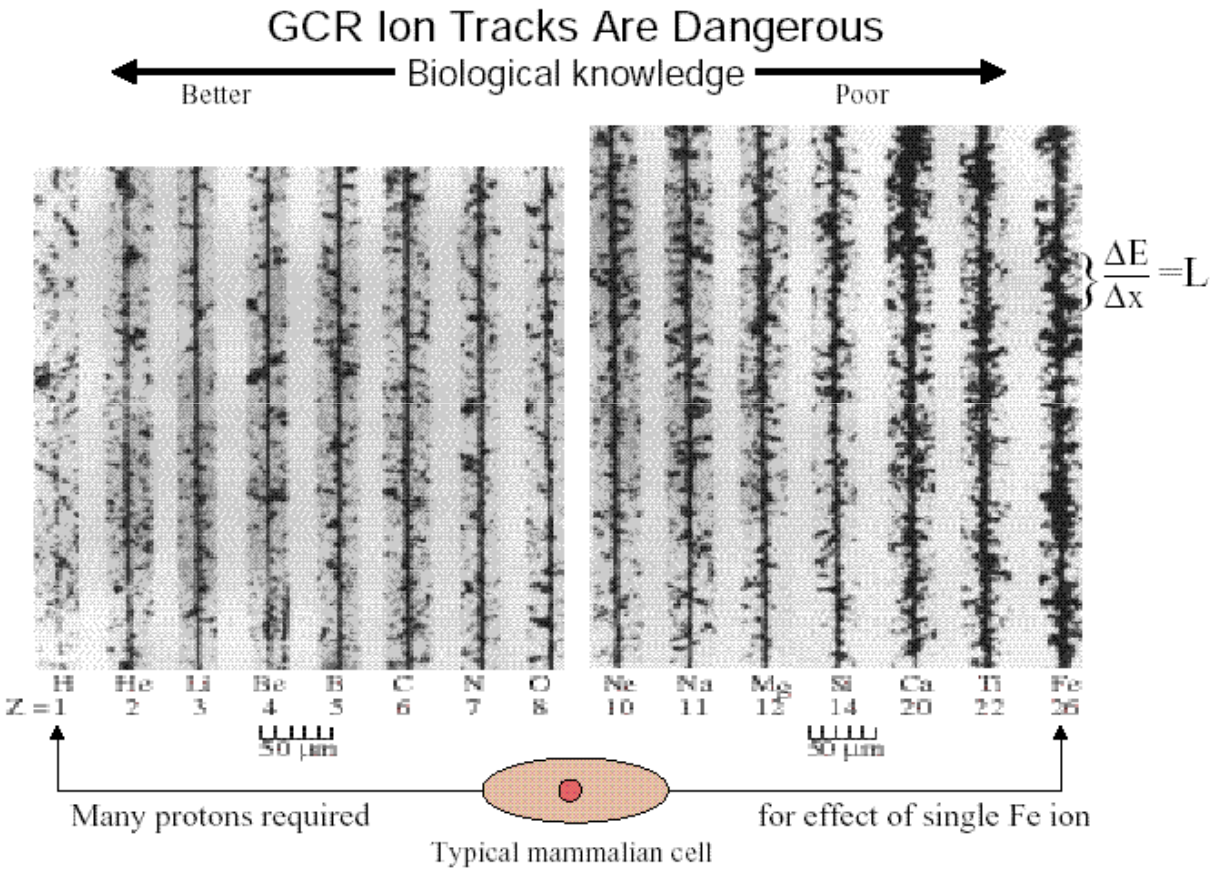
γ-rays



silicon



iron



Cucinotta and Durante, *Lancet Oncol.* 2006

An Analogy for Structured Energy Deposition and its Consequences

Low LET radiation produces isotropic damage to organized targets.

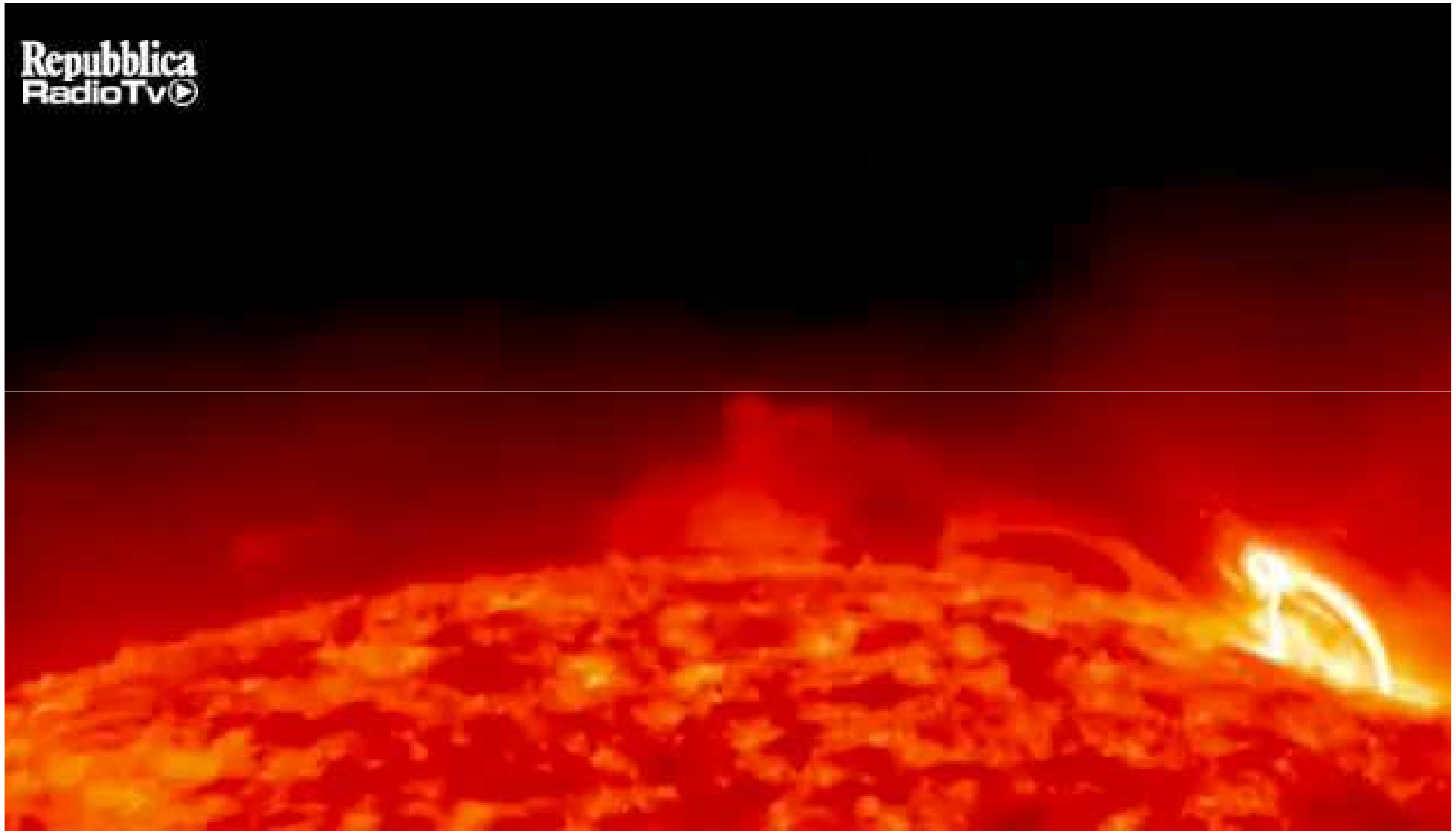
High LET radiation produces correlated damage to organized targets.

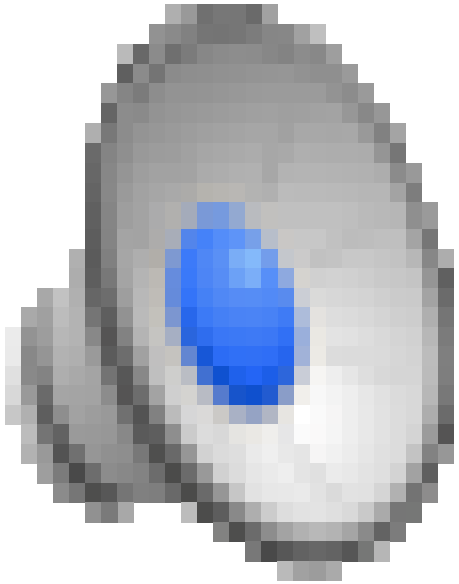
LET: Linear Energy Trar

Why are we interested in energetic heavy ions?

Heavy ion radiation is not present naturally on Earth

Valentine’s Solar flare 14.2.2011





Trento Institute for
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and Applications

The New York Times

Space & Cosmos

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINION

ENVIRONMENT | SPACE & COSMOS

Data Point to Radiation Risk for Travelers to Mars

Dose rate=1.8 mSv/day

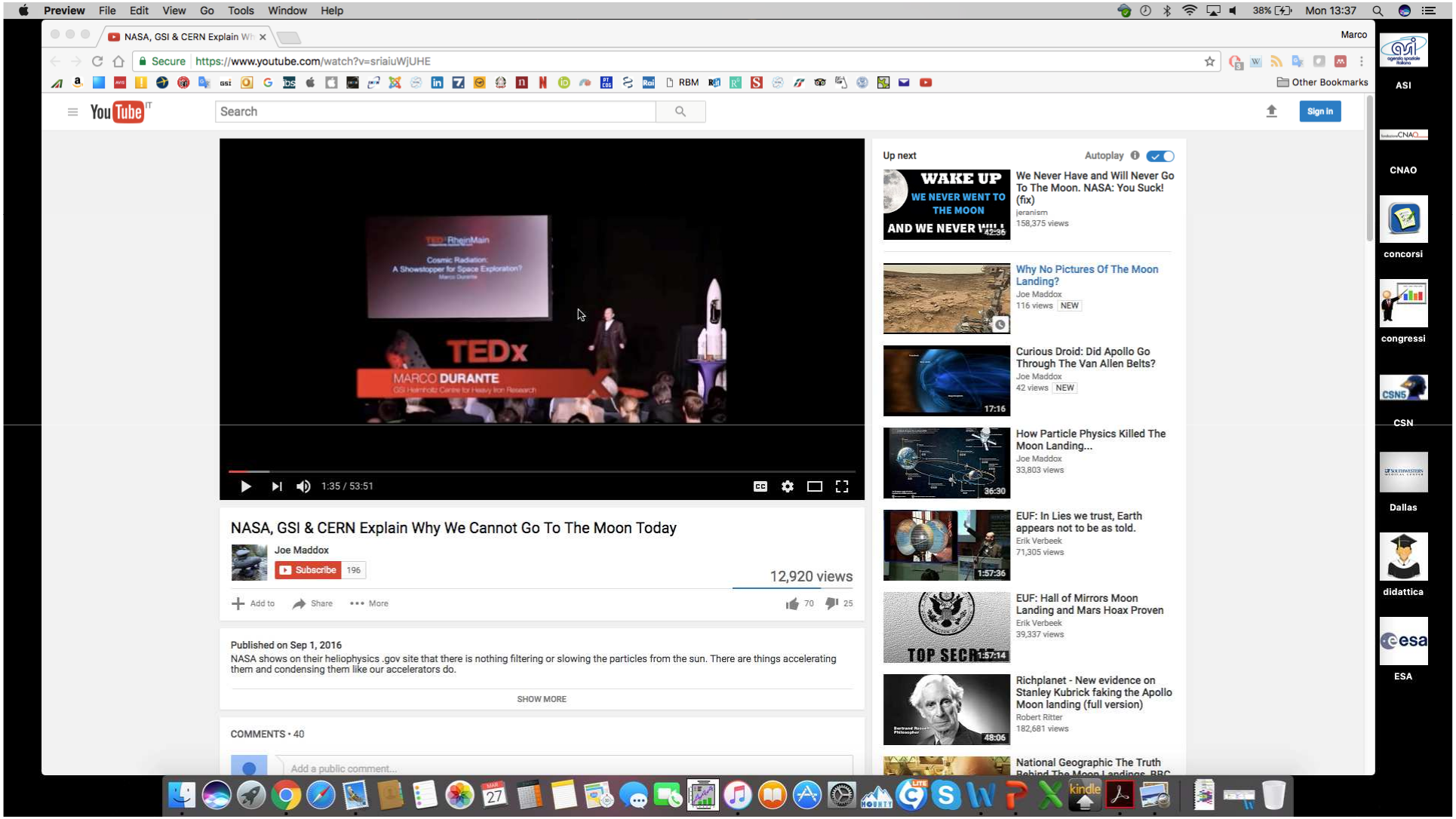
Total dose=1.8x501≈1 Sv

Health in Deep Space

1. Protection from space radiation (particularly very high energy heavy ions)
2. Psychosocial and behavioural problems
3. Physiological changes caused by microgravity

Modified by Mike Lockwood

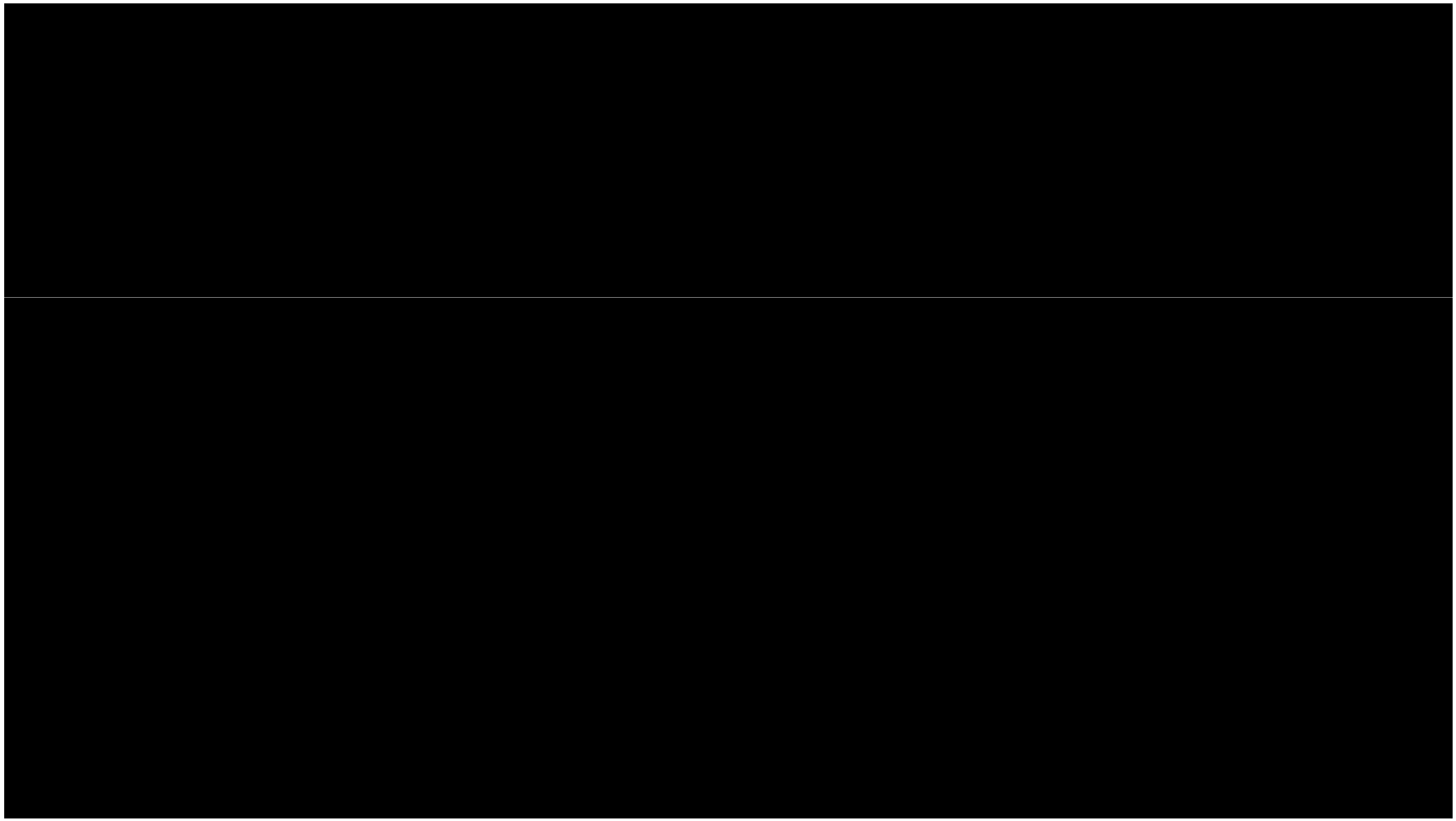
Disclaimer



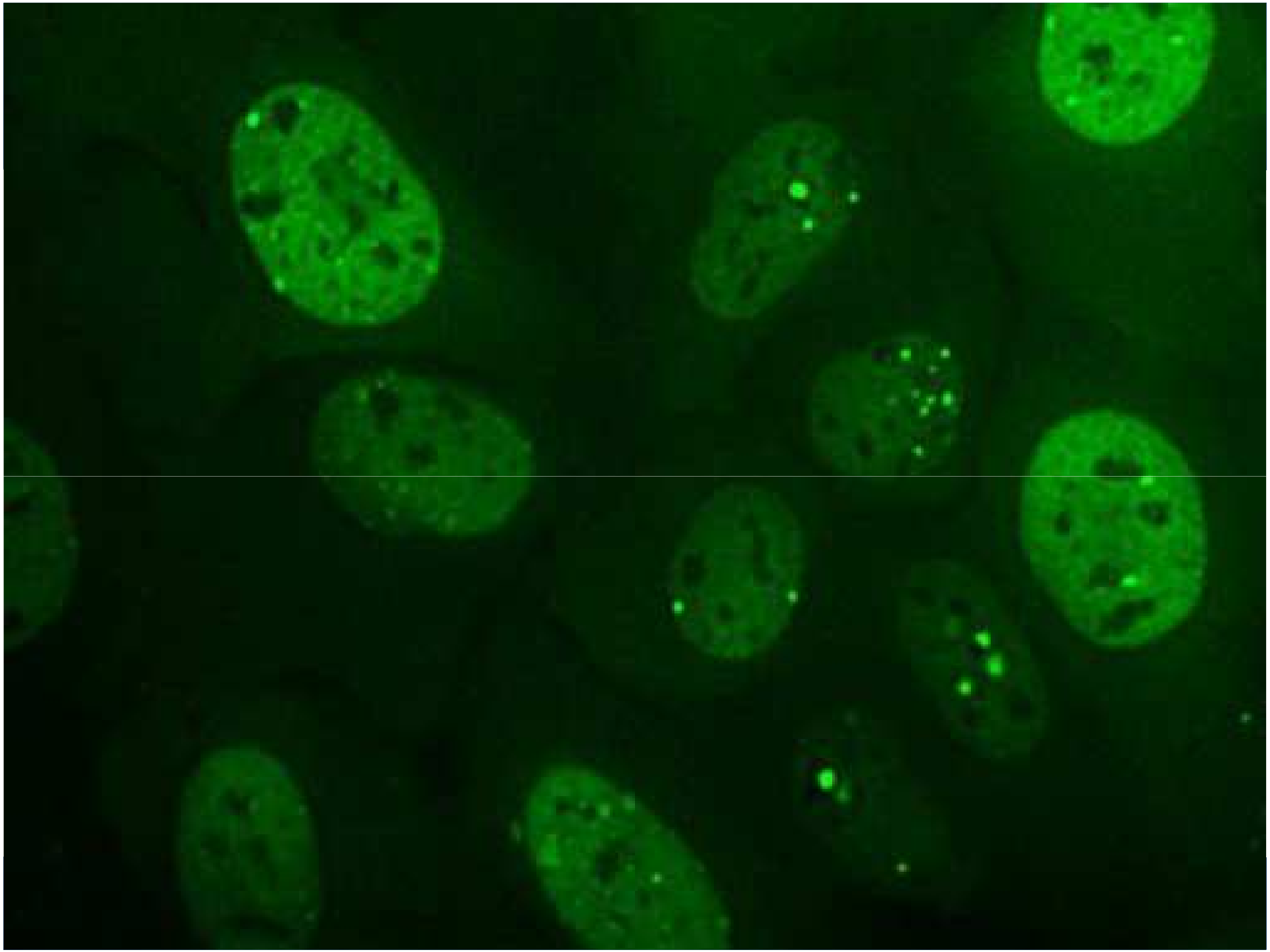
I do believe that humans landed on the Moon!

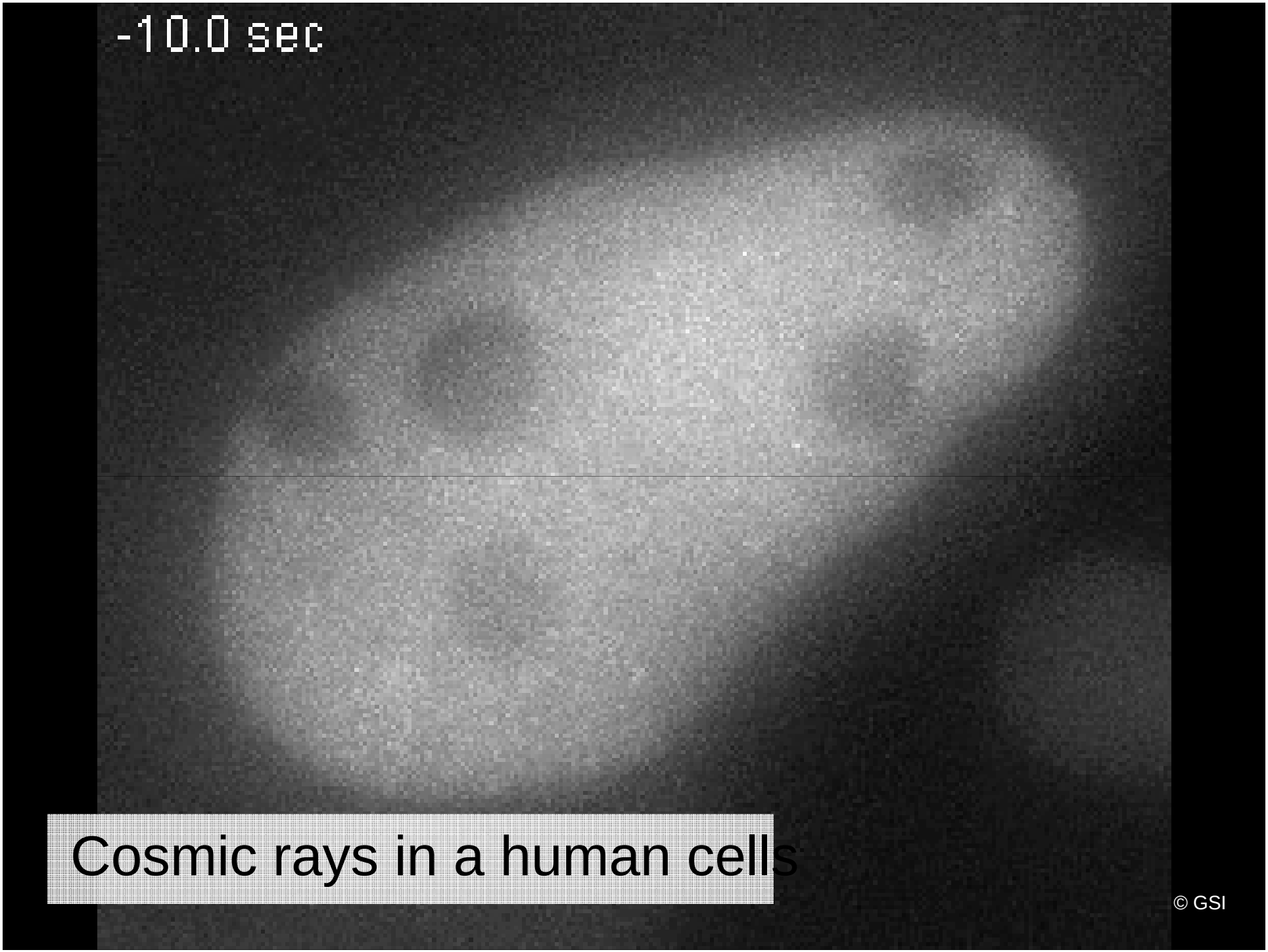
Biological effects of heavy ions

No human epidemiological data

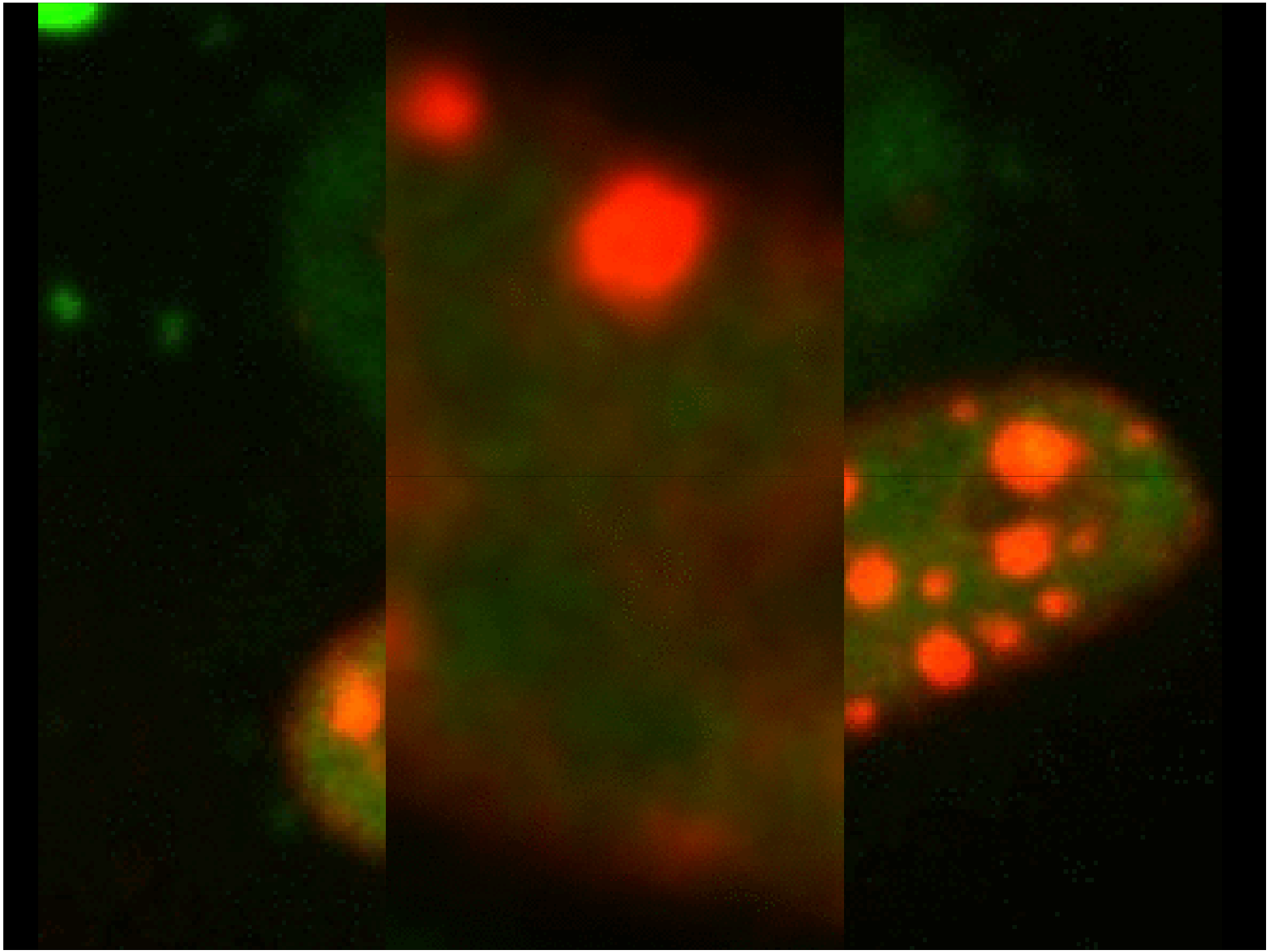



An accelerator can simulate cosmic rays on Earth
© A. Zschau, GSI

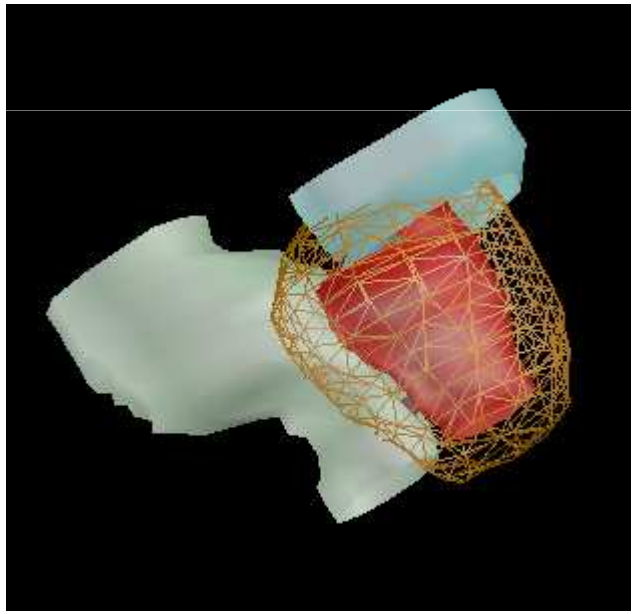


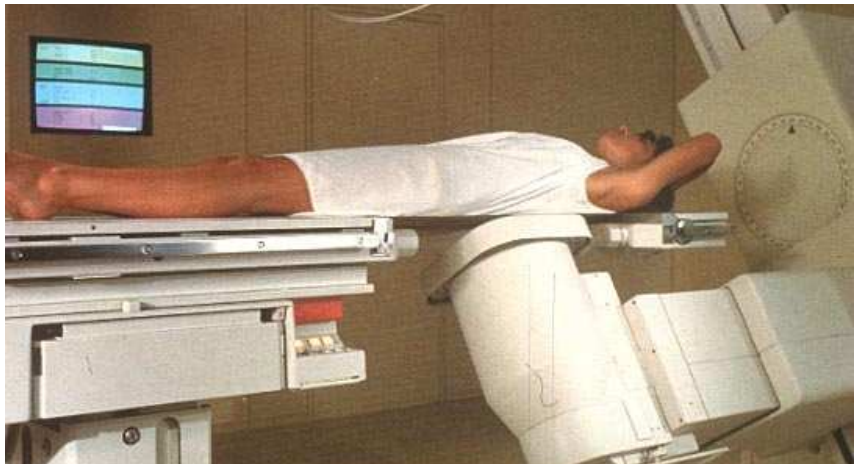


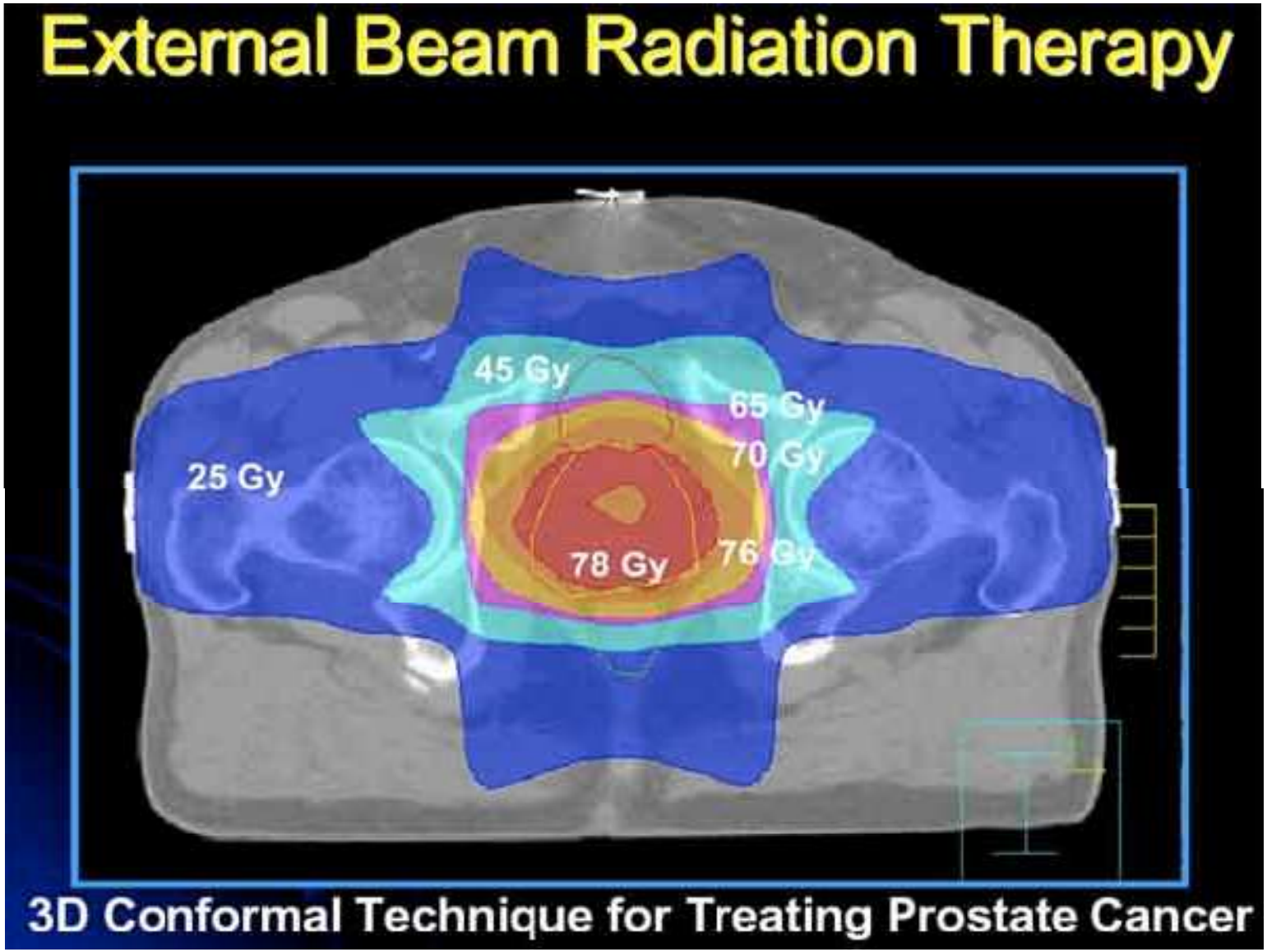
Cosmic rays in a human cells



The good side of radiation: radiotherapy





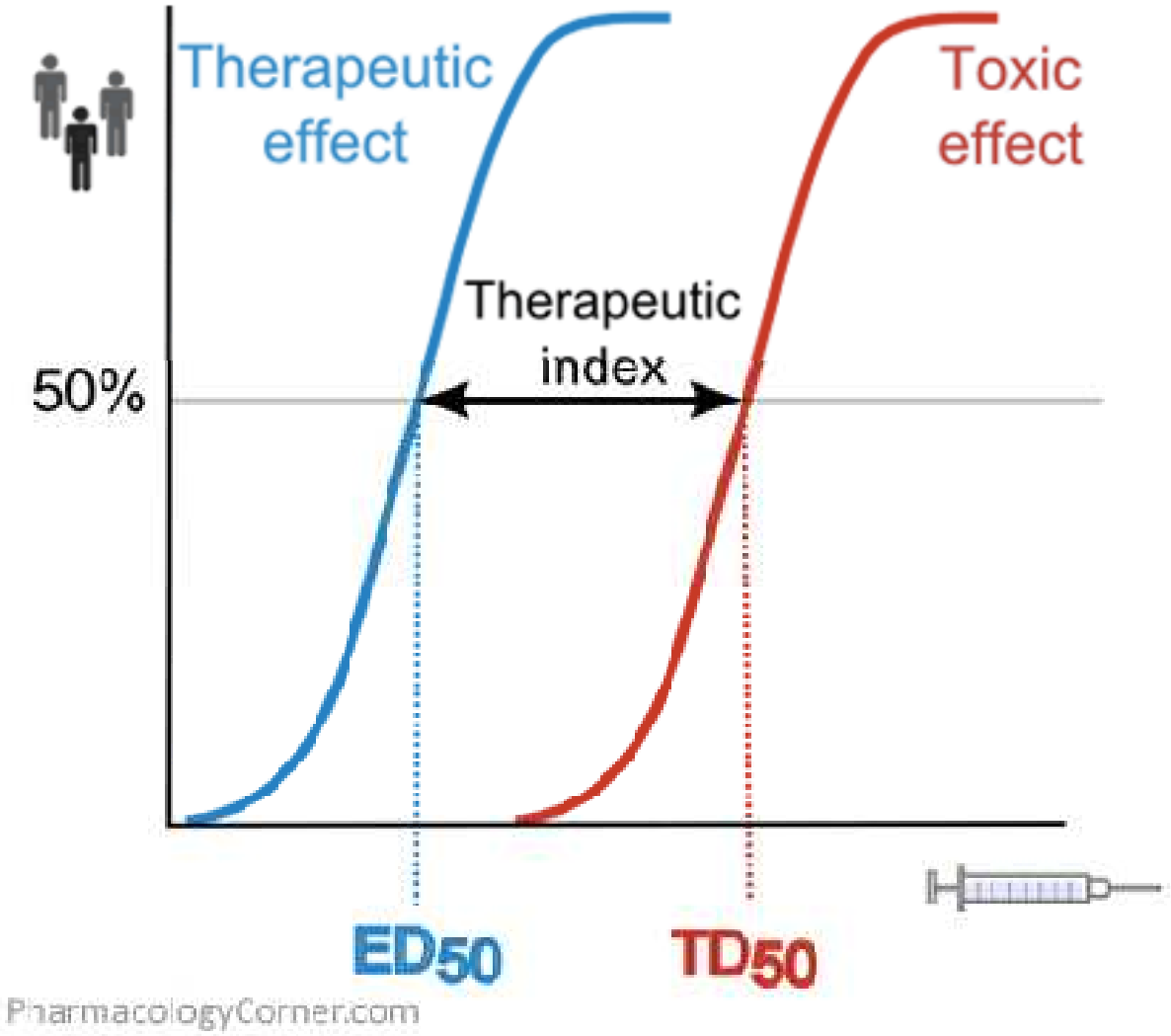


Treatment planning

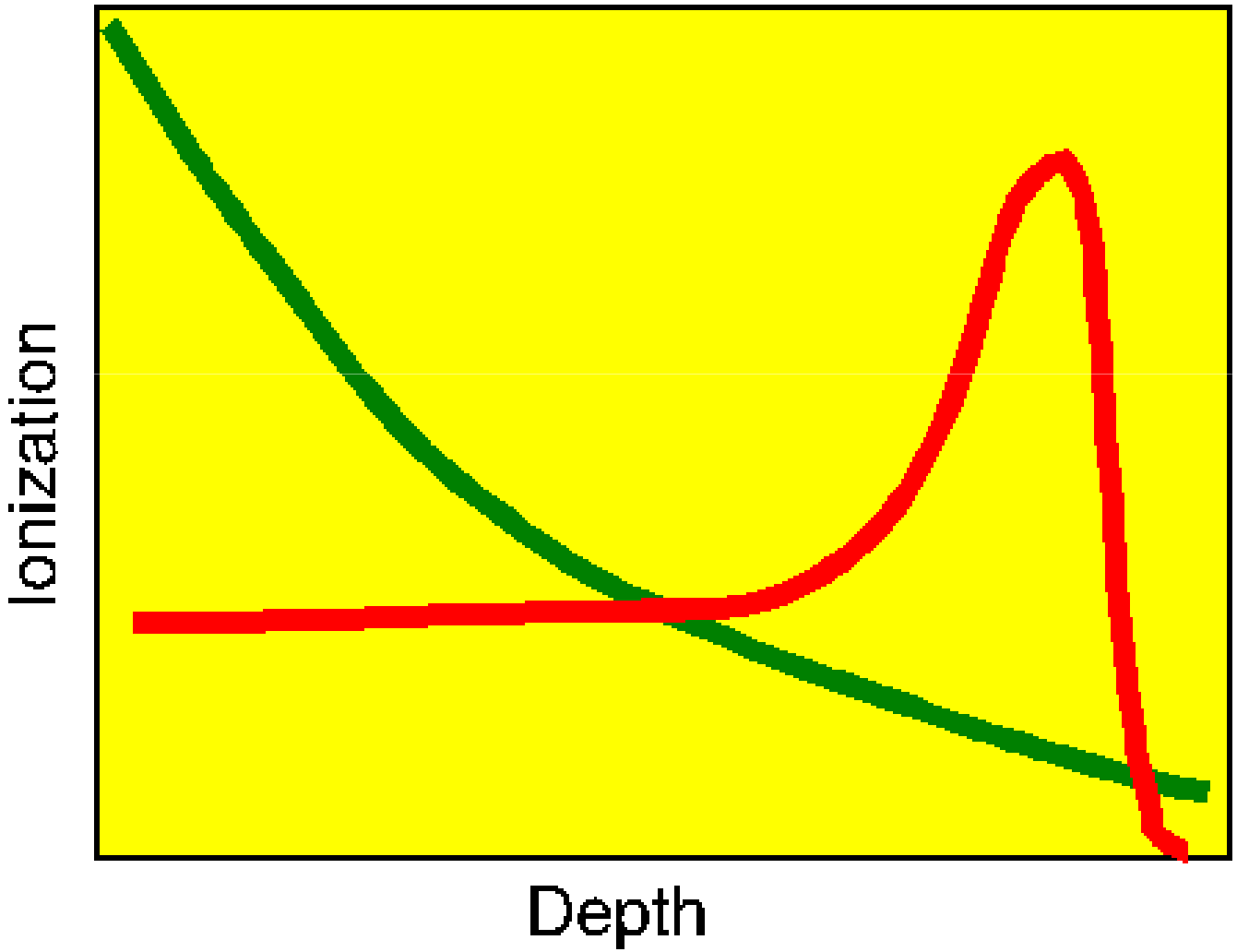
Generally, the total dose to the tumor is about 60 Gy, given in daily fractions of 2 Gy to spare the normal tissue

X-rays produced by LINACS (6-15 MV) are normally used

Therapeutic window

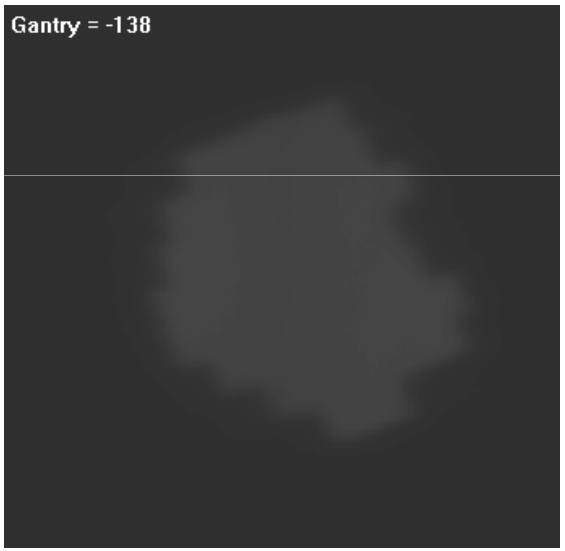


Charged particles for therapy

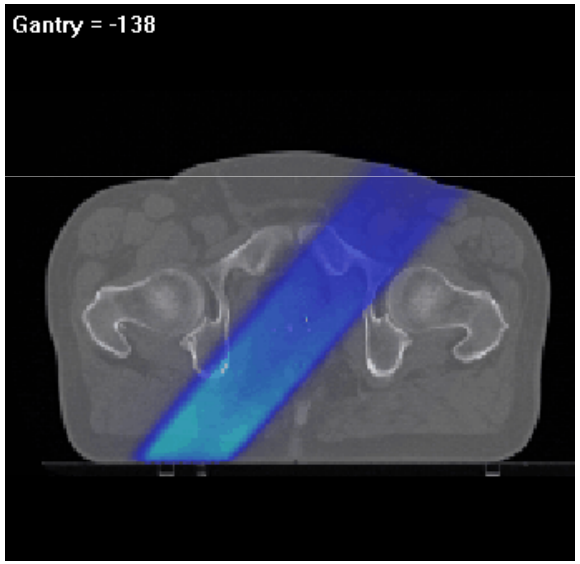


X-ray dose decrease with depth
We have to cross-fire on the tumor from many angles

Single field



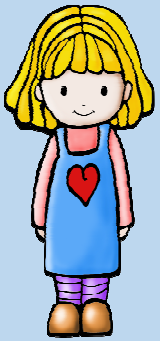
Dose per field



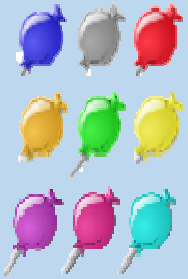
Total dose

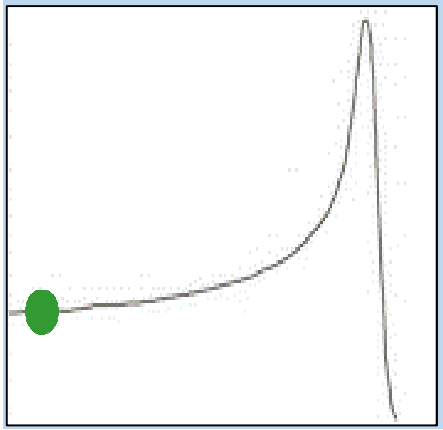
Excellent target conformity
Large normal tissue volume irradiated

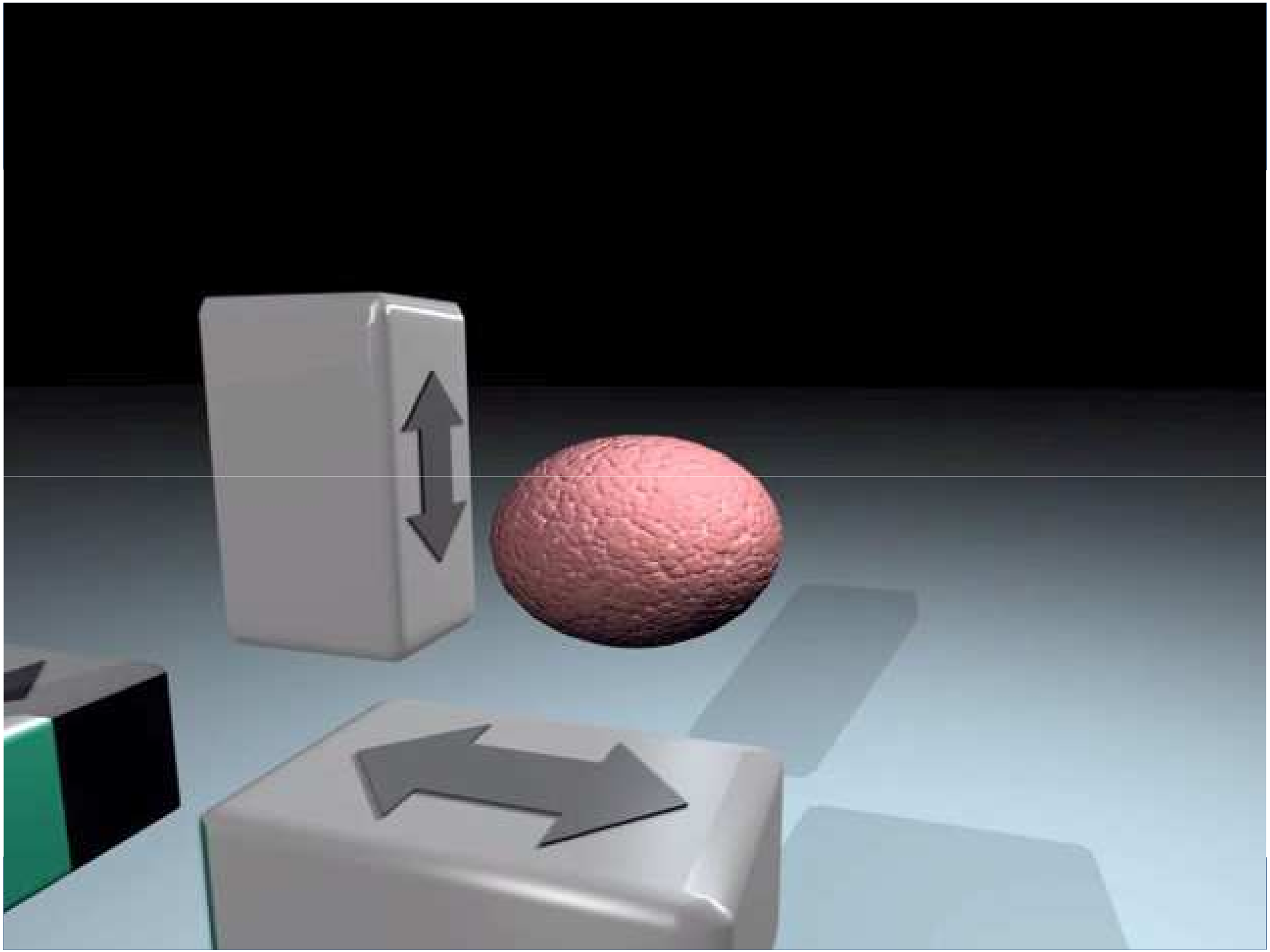
Courtesy B. Mijnheer



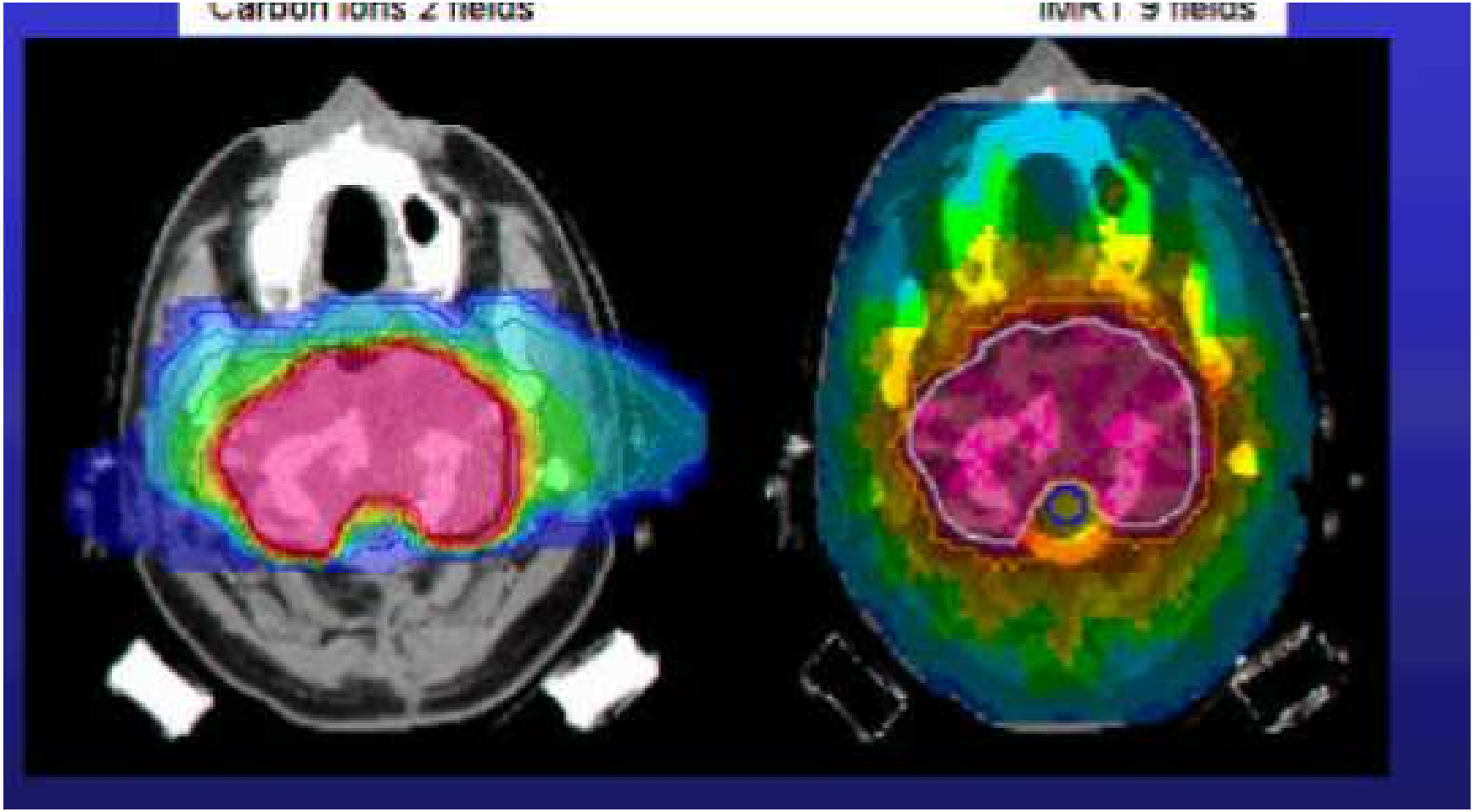

Come in We're
OPEN







C-ions vs. X-ray therapy



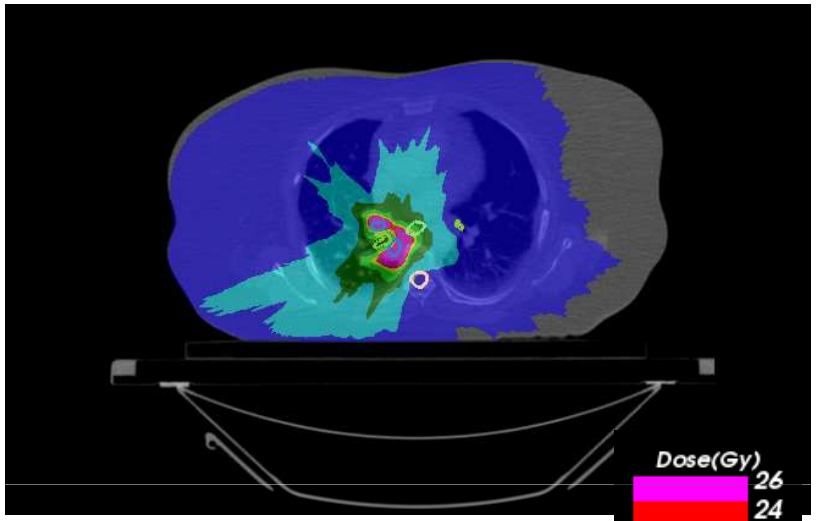
Champalimaud Foundation

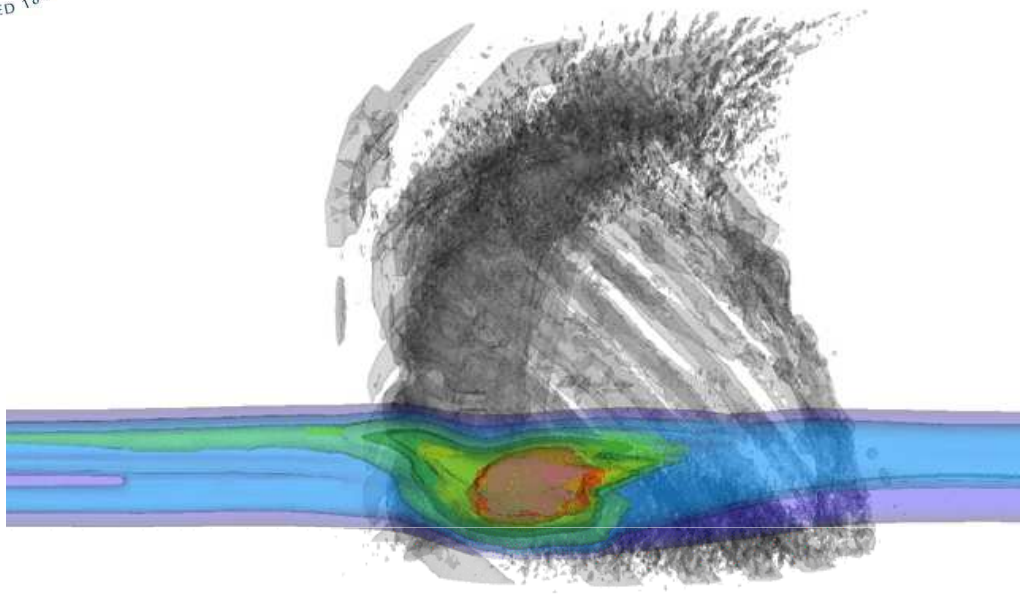
MEMORIAL SLOAN-KETTERING CANCER CENTER · ESTABLISHED 1884 ·

Lung tumors: SBRT vs. C-ions

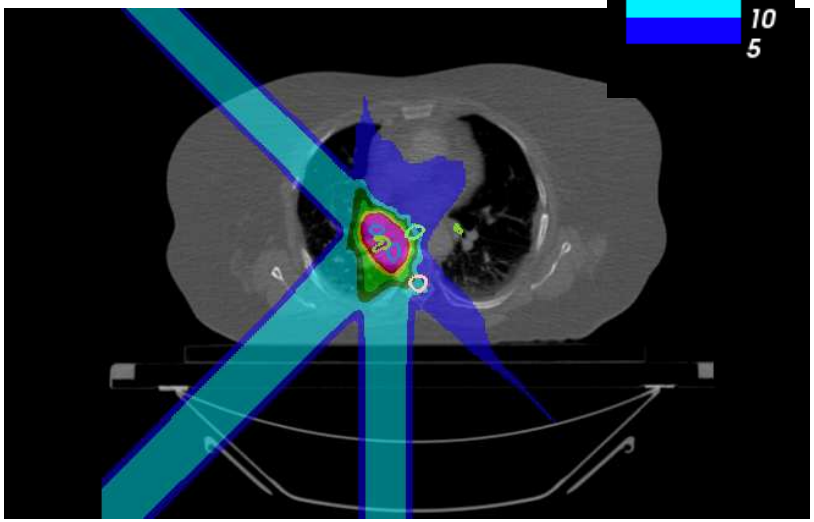
Single fraction, 25 Gy

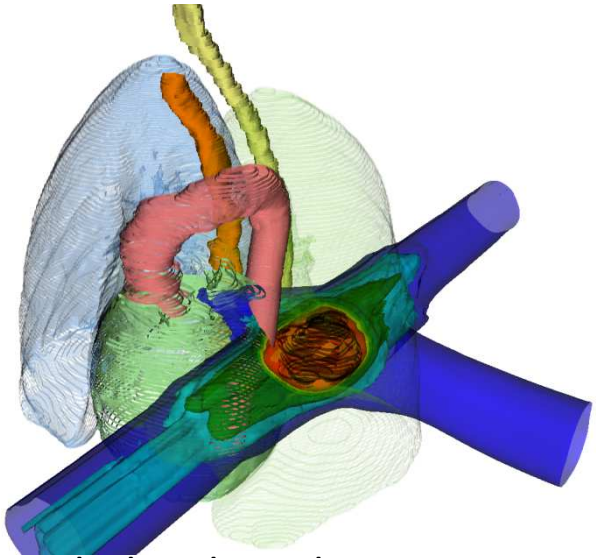
X-rays





C-ions

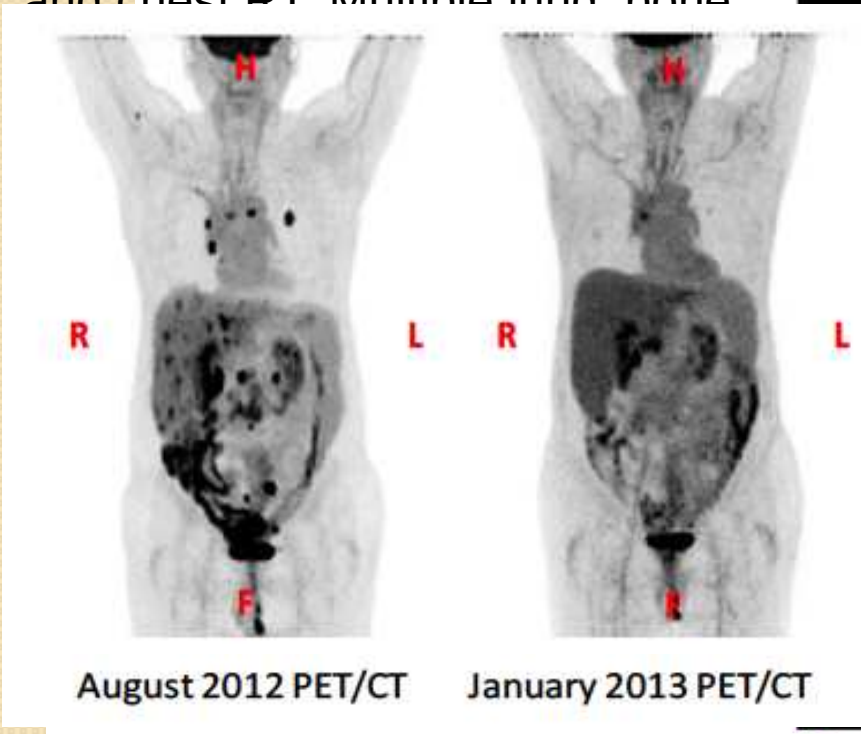




Kristjan Anderle, Ph.D. thesis, TU Darmstadt, 2014

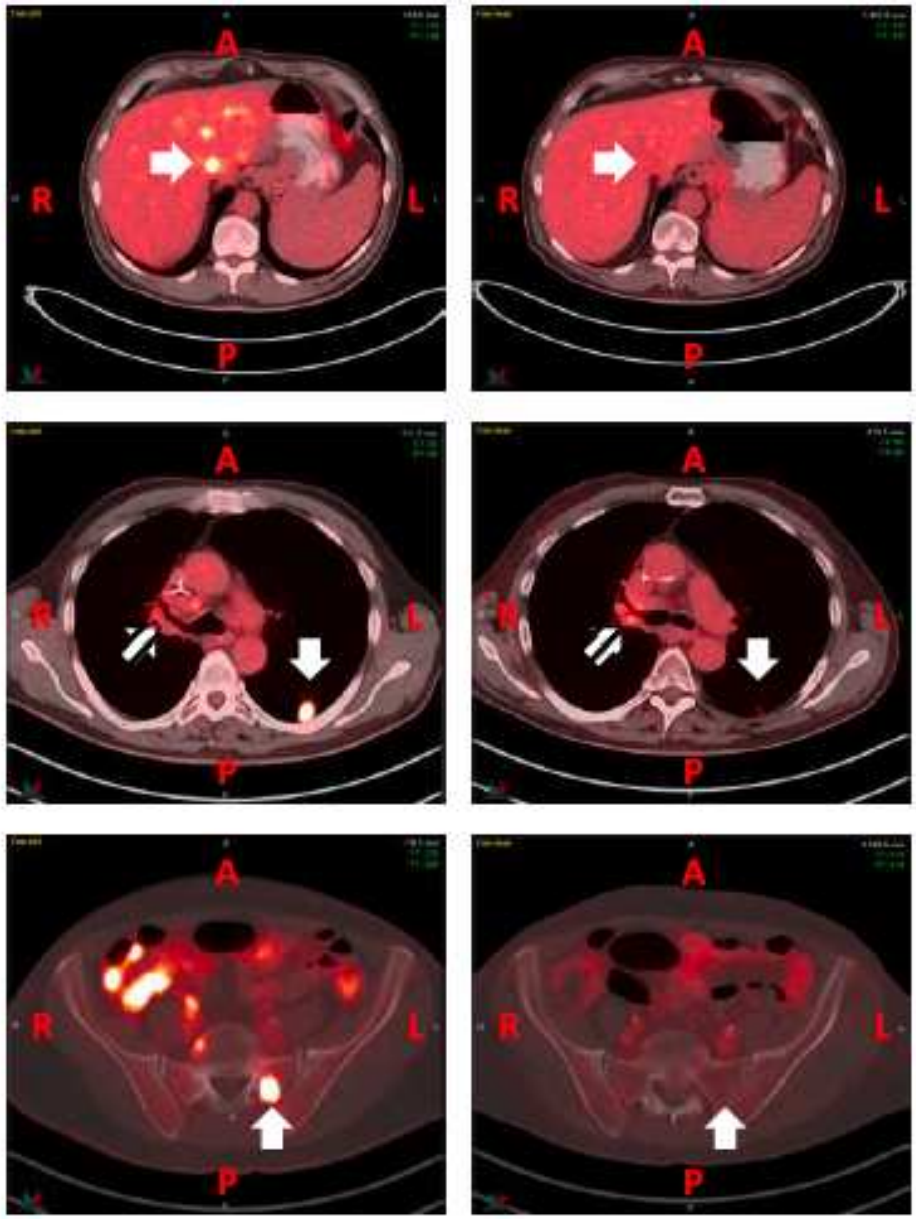
Combined radiotherapy and immunotherapy in the clinics: lung cancer trial

NSCLC progressing after 3 lines of
and chest RT: Multiple lung, bone

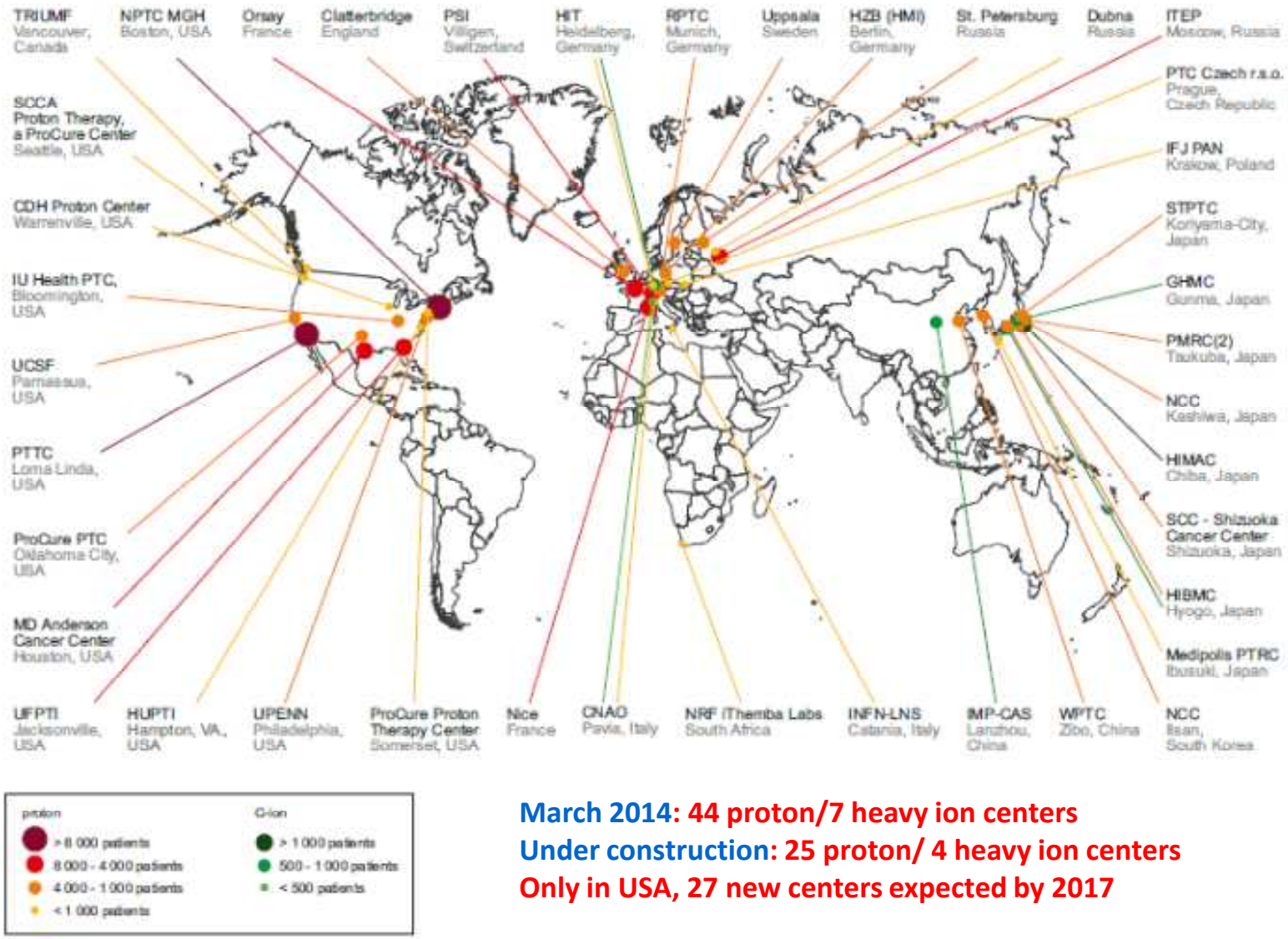


August 2012 PET/CT January 2013 PET/CT

RT to one liver met 6 Gy X 5 (TD 30 GY)
Ipilimumab, 3 mg/Kg, after first RT q3 weeks, X 4 c

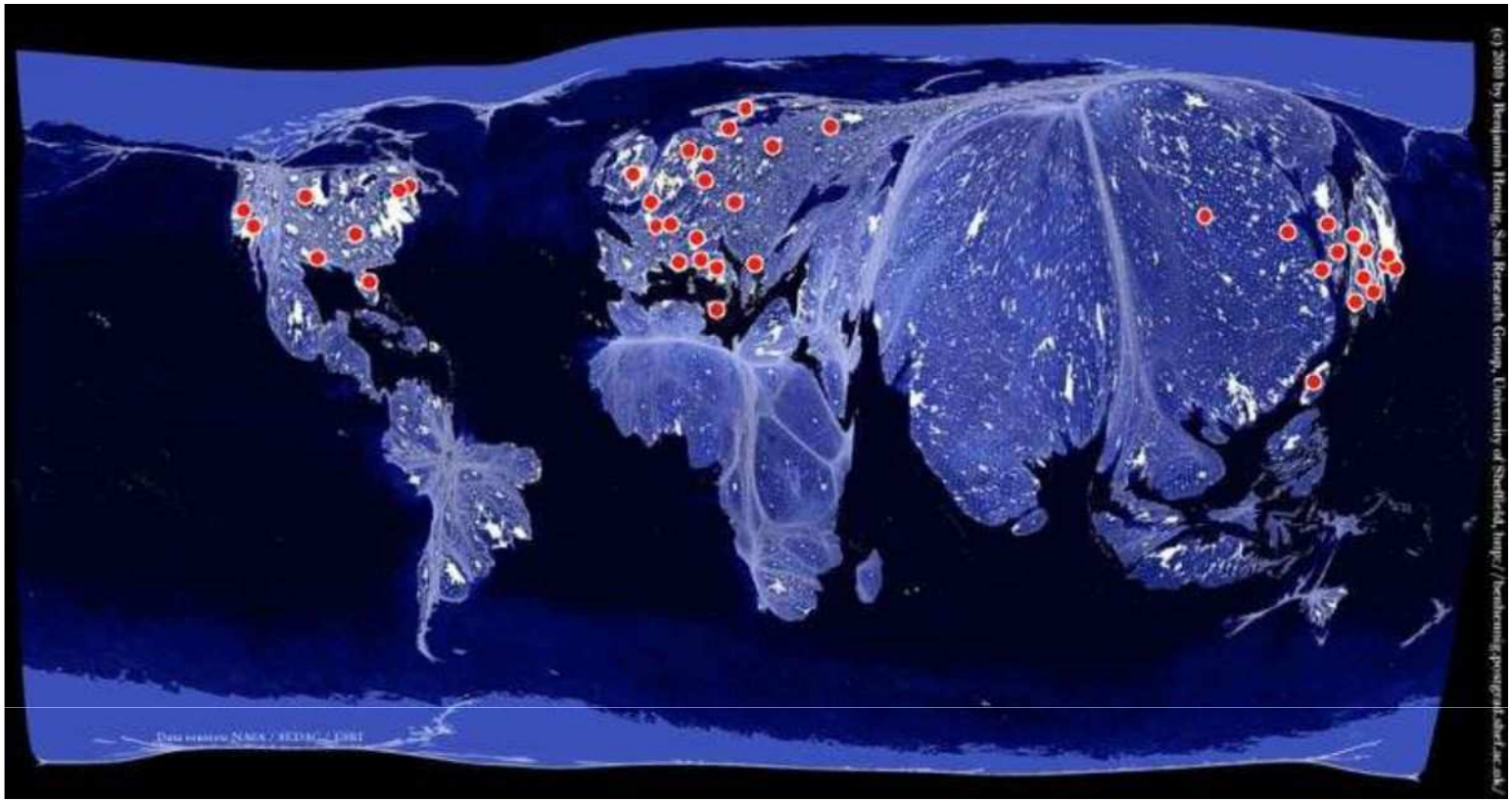


August 2012 PET/CT January 2013 PET/CT

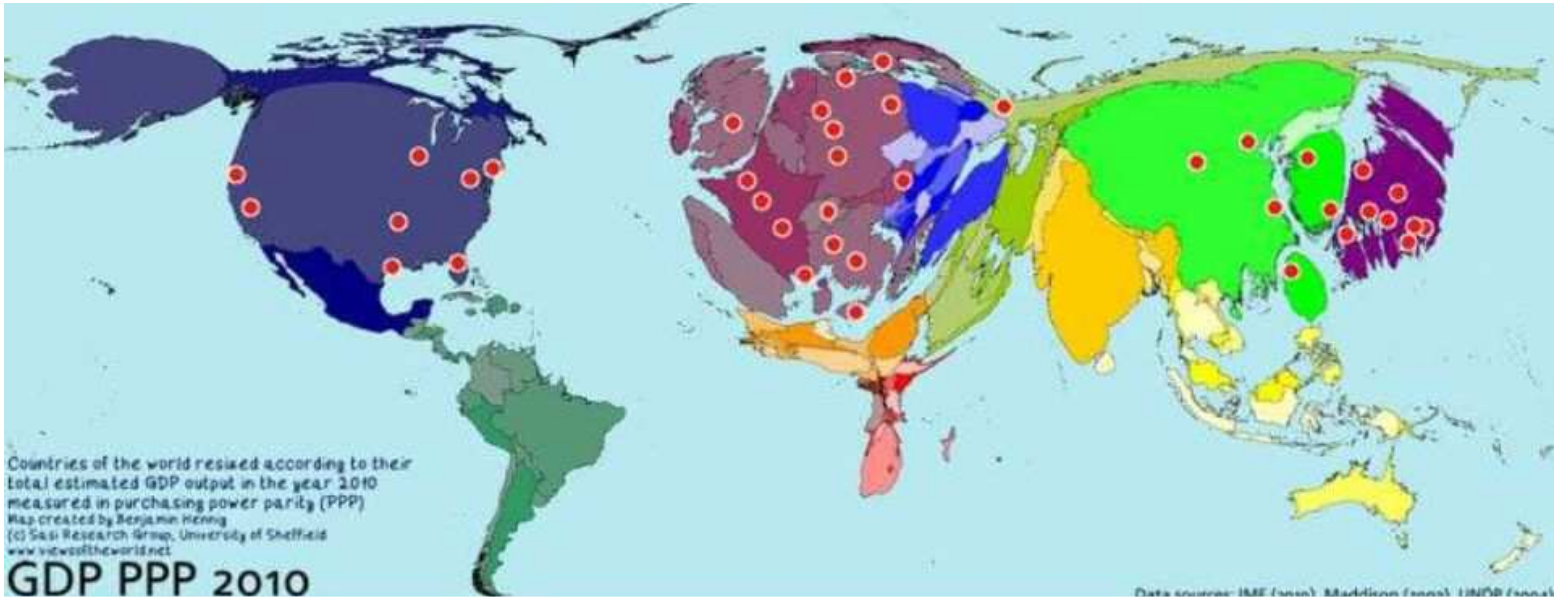


March 2014: 44 proton/7 heavy ion centers
Under construction: 25 proton/ 4 heavy ion centers
Only in USA, 27 new centers expected by 2017

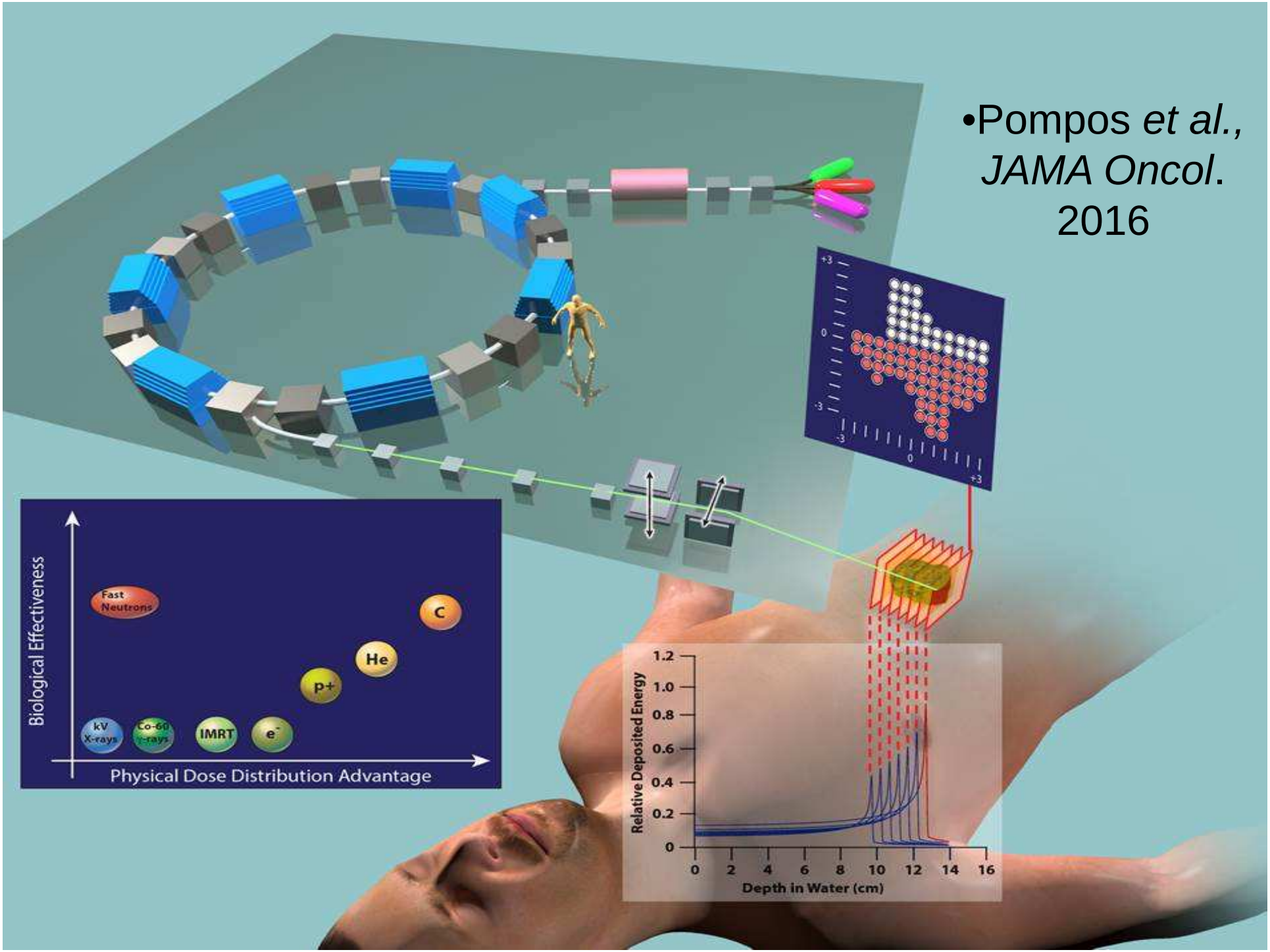
NuPECC report „Nuclear Physics in Medicine“, 2014
Available online www.nupecc.org



Population – scaled



GPD-scaled

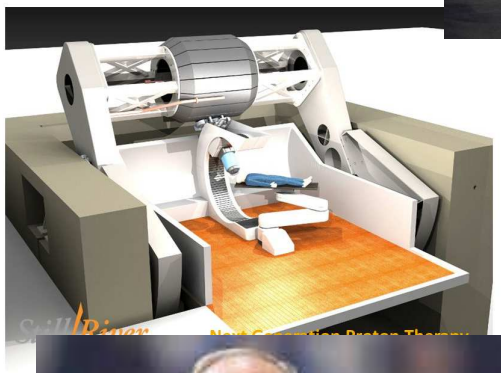


•Pompos *et al.*, *JAMA Oncol*. 2016

200

Heavy ions (protons + carbon ions)

2

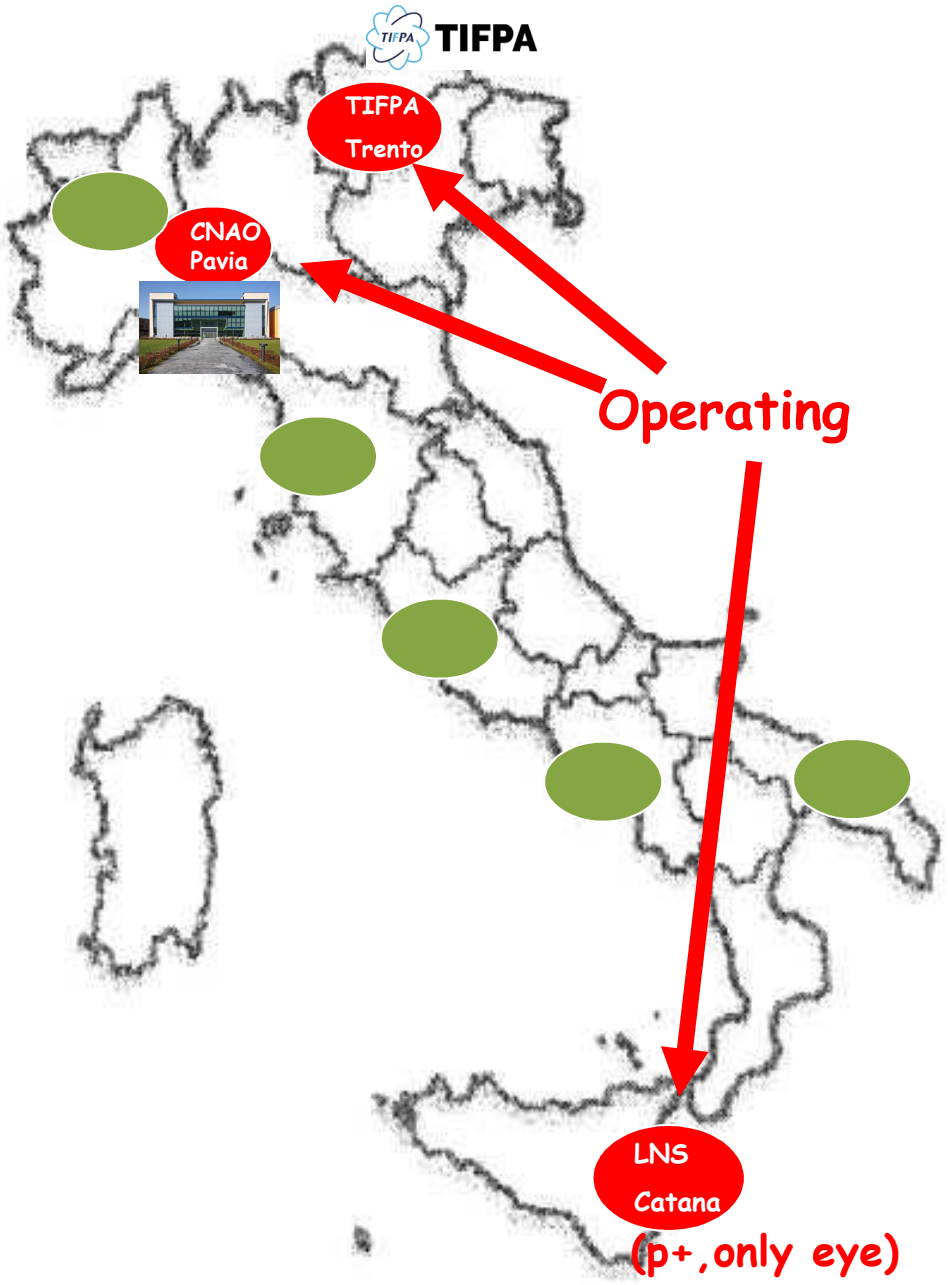


oton single-room

ITALIAN NETWORK FOR HADRONTHERAPY

EXISTING CENTRES

INTEREST FOR PROTONS



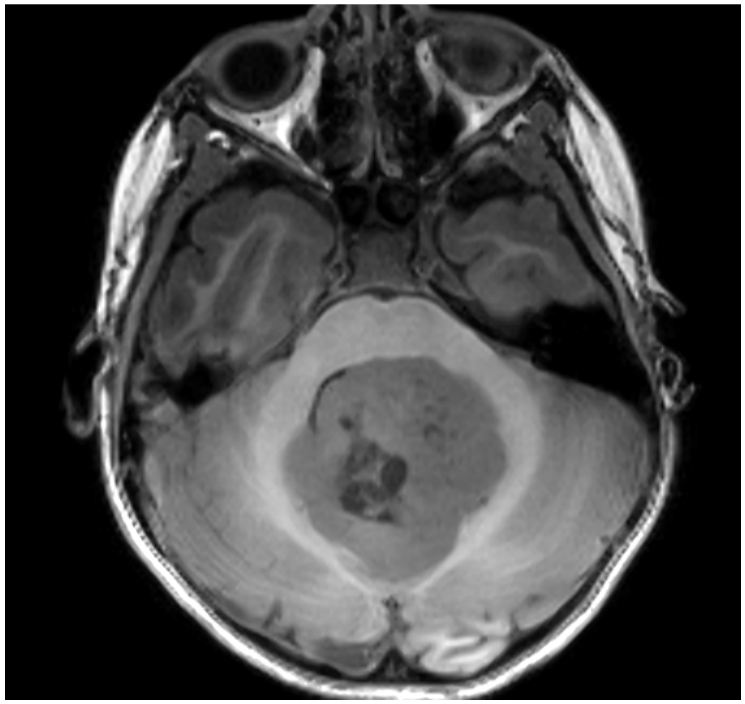
LEA adroterapia – Settembre 2016

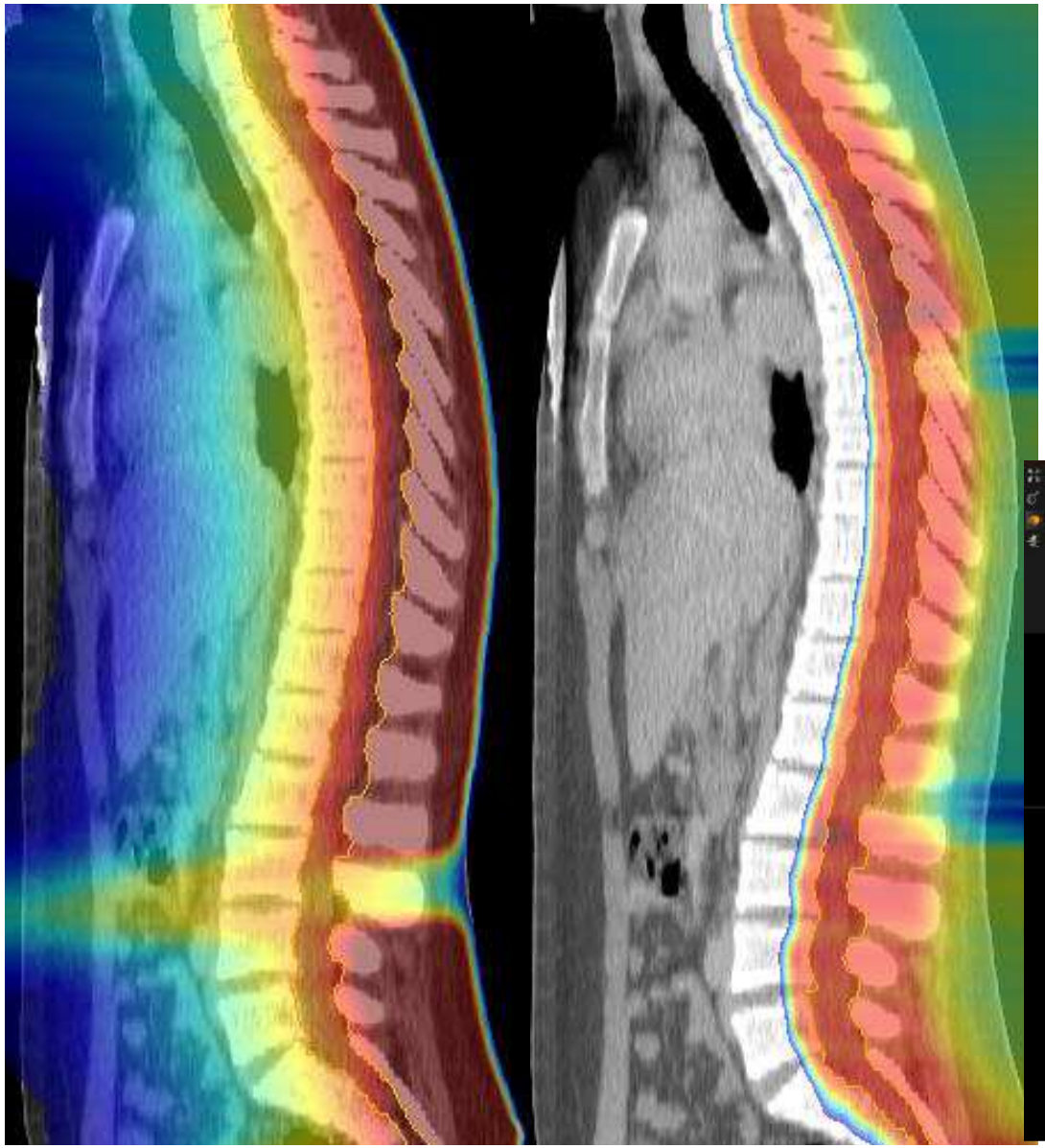
- Cordomi e condrosarcomi della base del cranio e del rachide;
- Tumori del tronco encefalico (esclusi i tumori intrinseci diffusi del ponte) e del midollo spinale;
- Sarcomi del distretto cervico--cefalico, paraspinali, retroperitoneali e pelvici;
- Sarcomi delle estremità ad istologia radioresistente (osteosarcoma, condrosarcoma);
- Meningiomi intracranici in sedi critiche (stretta adiacenza alle vie ottiche e al tronco encefalico);
- Tumori orbitari e periorbitari (es. seni paranasali) incluso il Melanoma oculare;
- Carcinoma adenoideo---cistico delle ghiandole salivari;
- Tumori solidi pediatrici;
- Tumori in pazienti affetti da sindromi genetiche e malattie del collageno associate ad un'aumentata radiosensibilità;
- Recidive che richiedono il ritrattamento in un'area già precedentemente sottoposta a radioterapia;

Tumori pediatrici

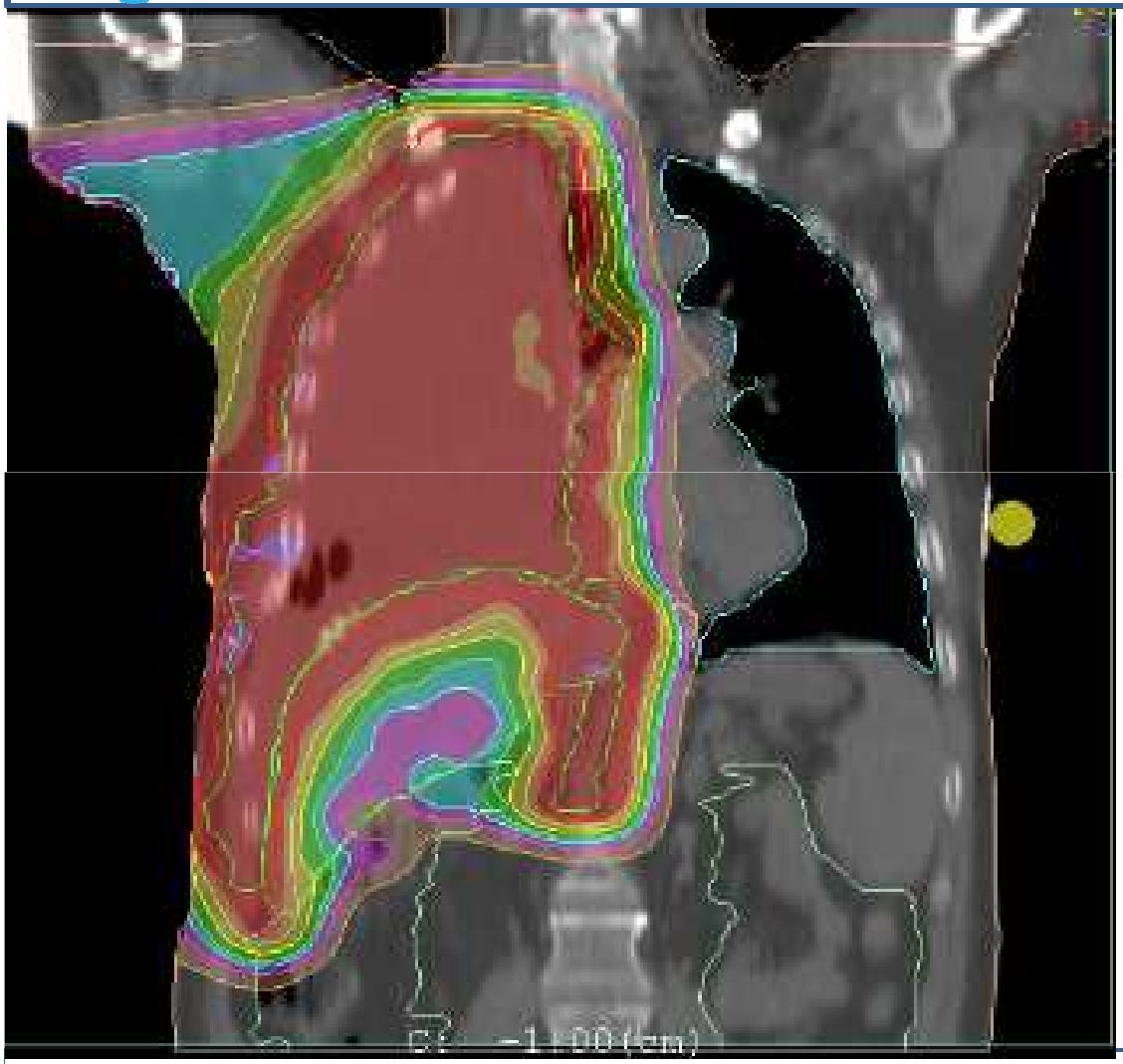
Pianificazione **In trattamento** **Ultimo giorno** **6 m post- P**

MEDULLOBLASTOMA PEDIATRICO





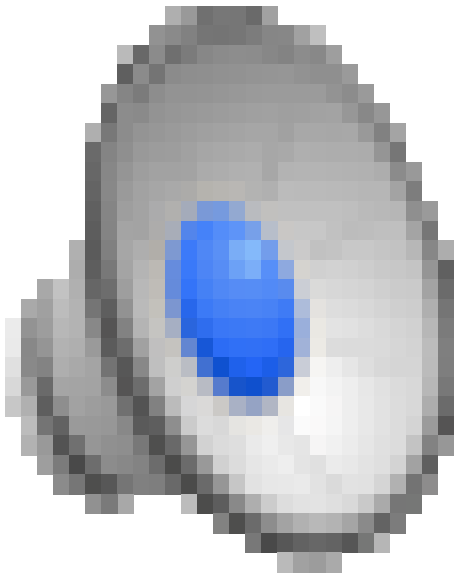
Trento Institute for
Fundamental Physics
and Applications



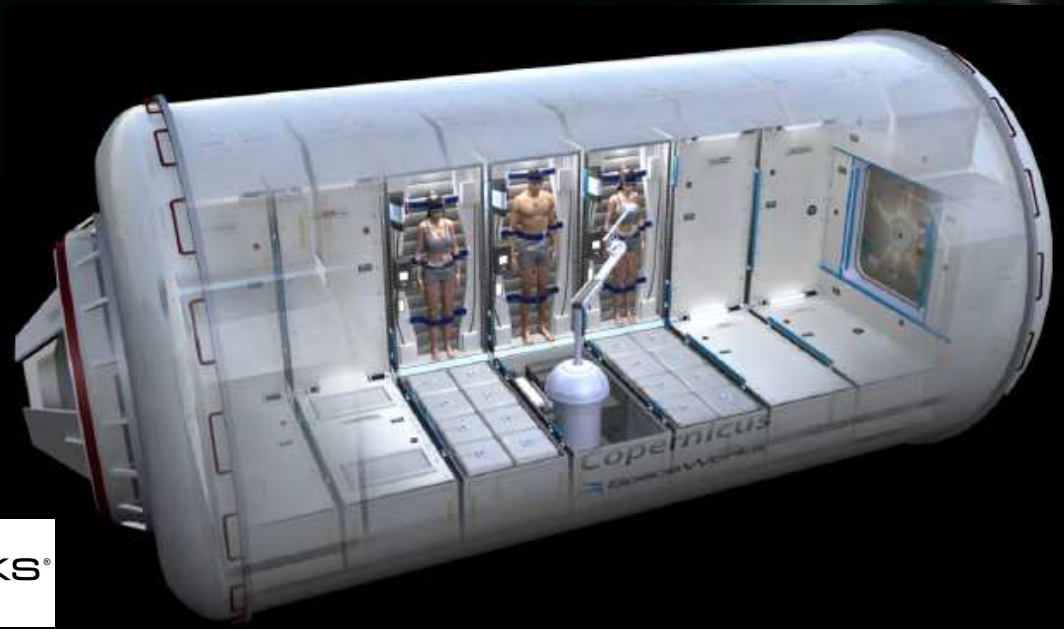
Treatment plan with protons: pleural mesothelioma

Courtesy of Marco Schwarz, TIFPA, Trento, Italy

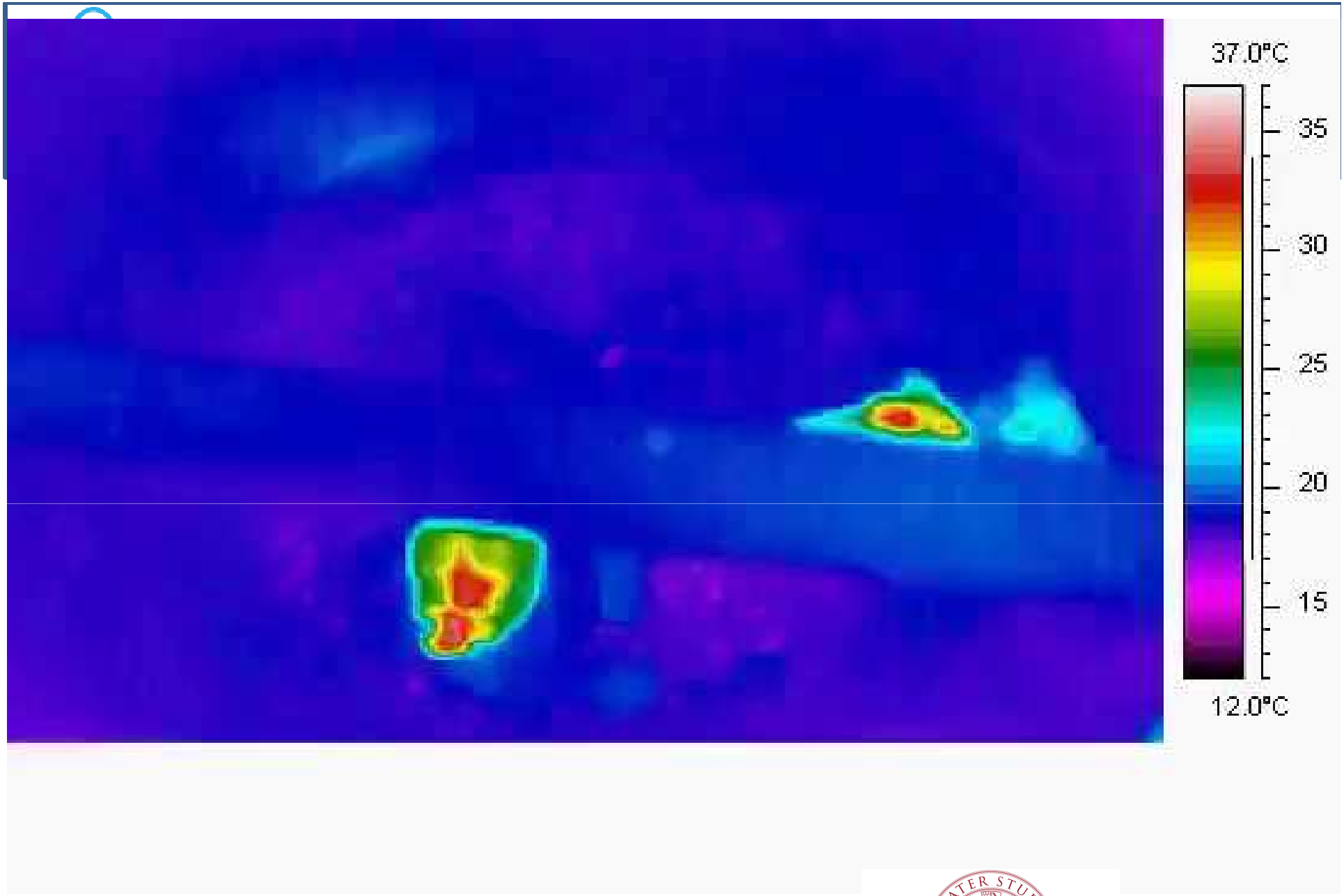
Range uncertainty: protons stop, but where?



Hibernation: space and therapy

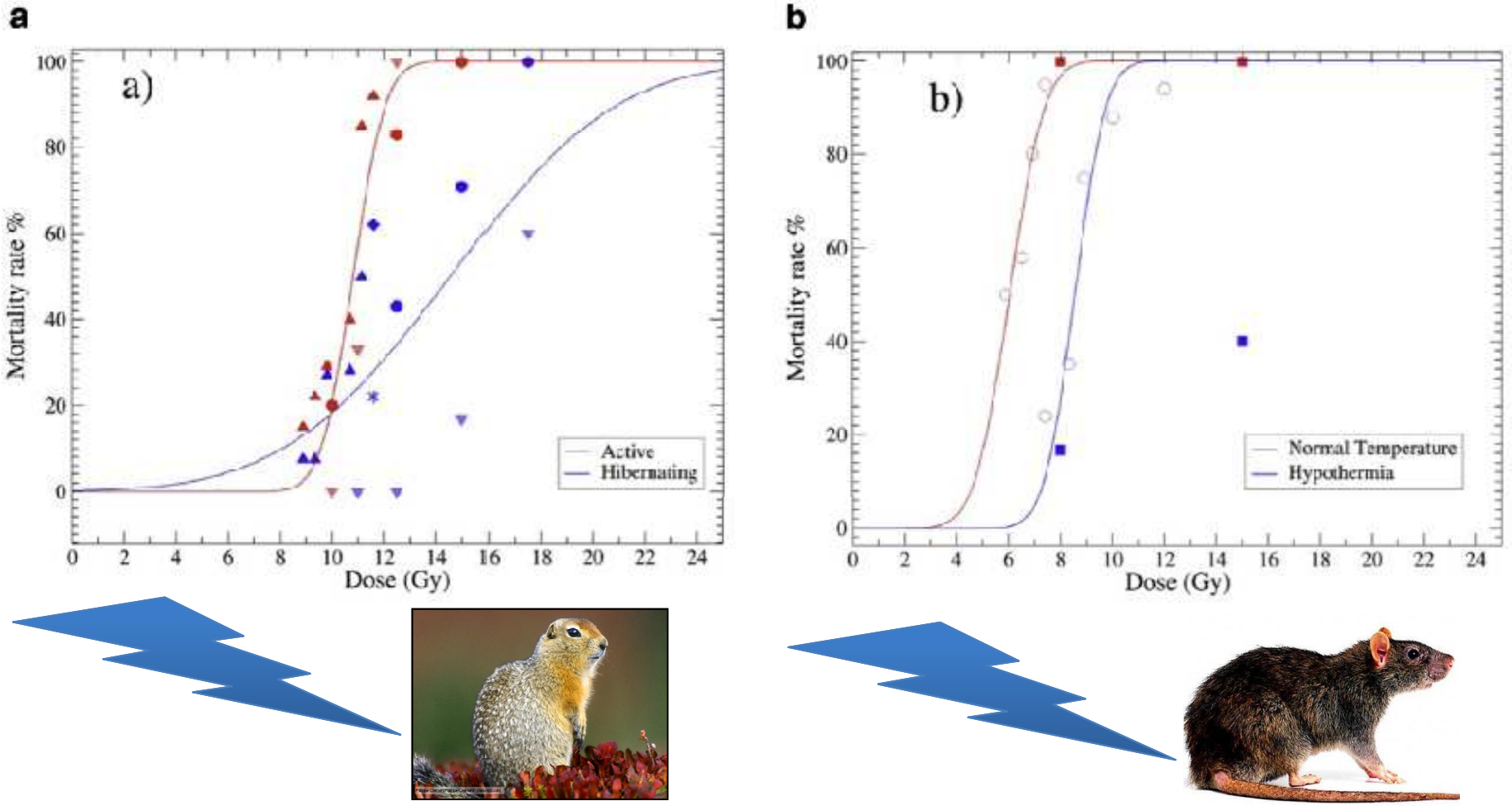


SpaceWorks®



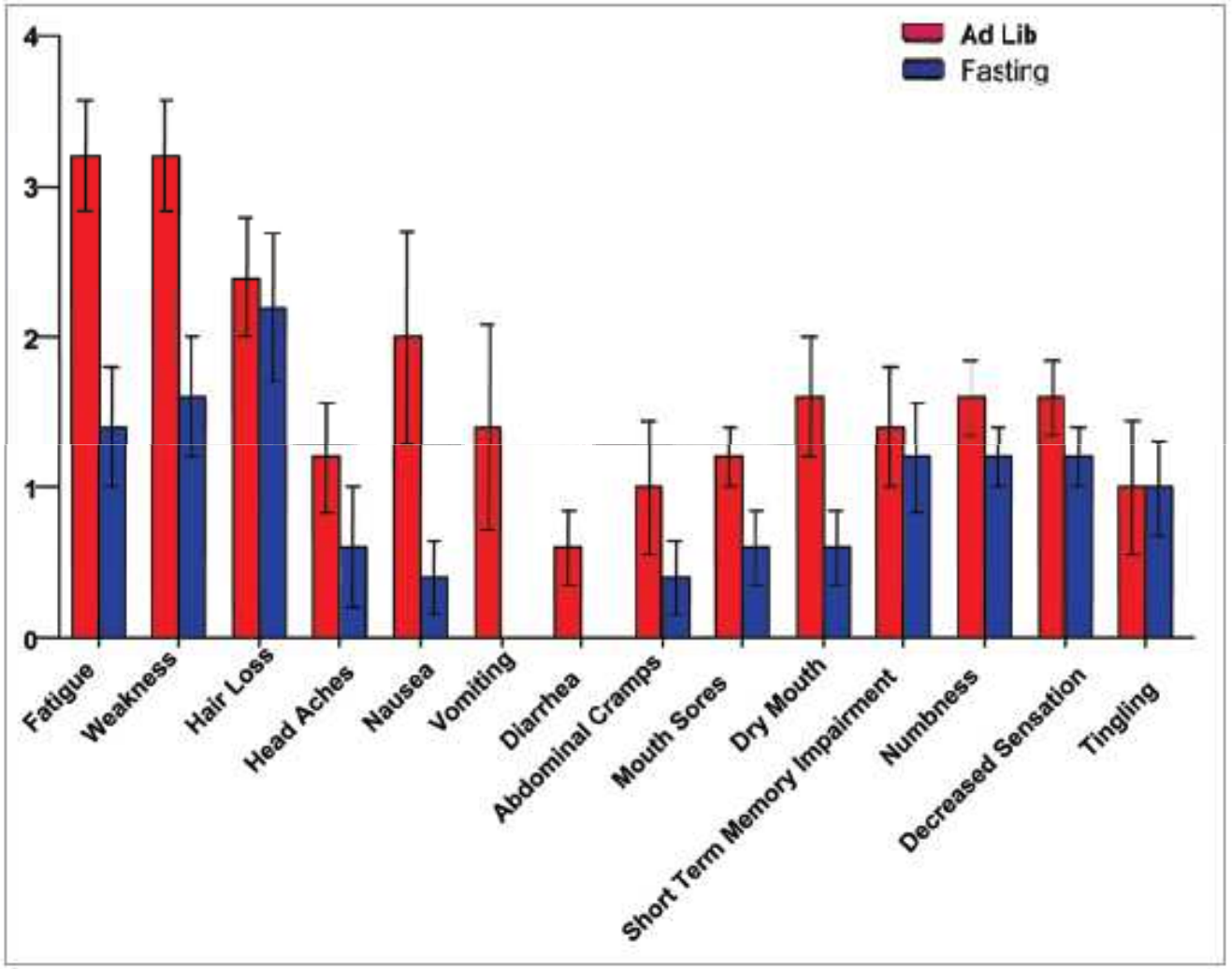
Courtesy of Prof. Matteo Cerri, University of Bologna

Cerri *et al., Life Sci. Space Res*. 2016



Animal	Normal conditions		Hibernation/hypothermia		Protective factor
	γ	LD50 (Gy)	γ	LD50 (Gy)	
Squirrels	4.4 ± 1.2	10.82 ± 0.17	1.1 ± 0.4	14.6 ± 1.1	1.35 ± 0.07
Rats	2.3 ± 0.5	6.03 ± 0.13	3.6 ± 2.7	8.6 ± 0.4	1.42 ± 0.10

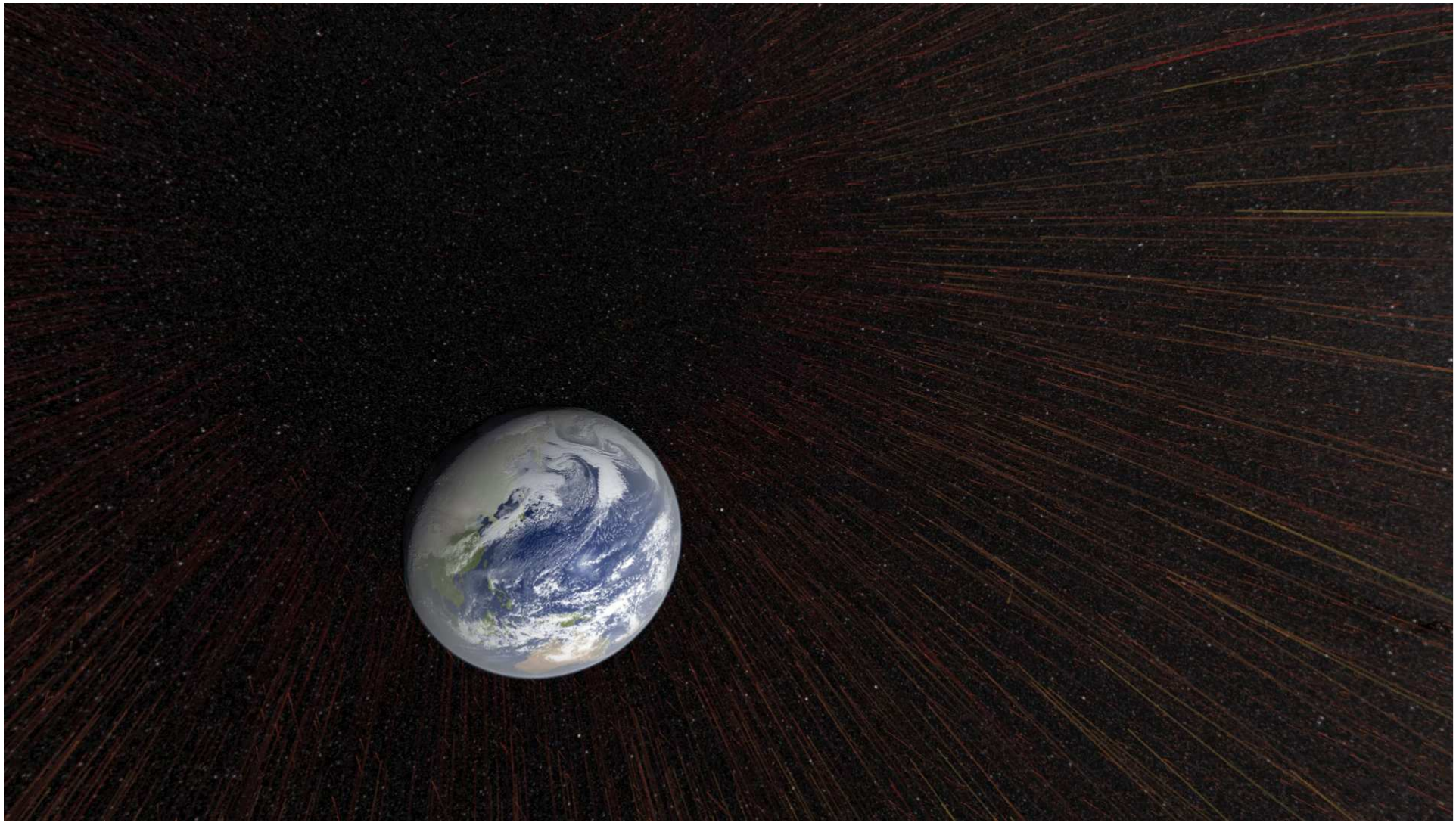
Hibernation in therapy?



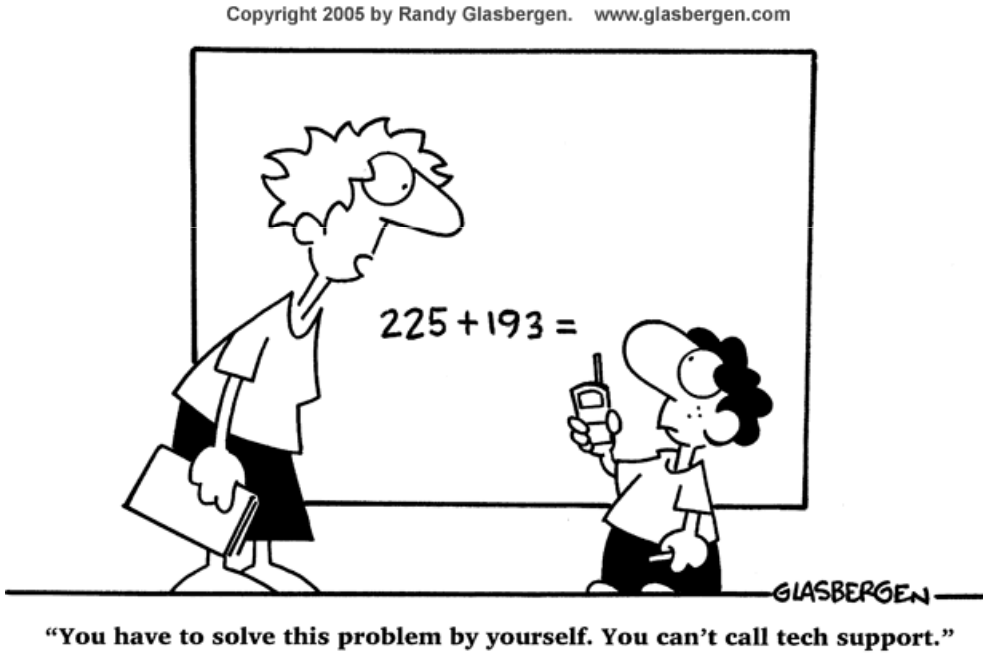
Lee *et al., Sci. Transl. Med.* 2012

Active shielding: magnets for protection

Photo: Theo Schacht, CC-by-sa 3.0/de



Thank you for attention!



"You have to solve this problem by yourself. You can't call tech support."