Deep Underground Long Term Evolution Experiments, a key to understand the impact of low doses on living organisms

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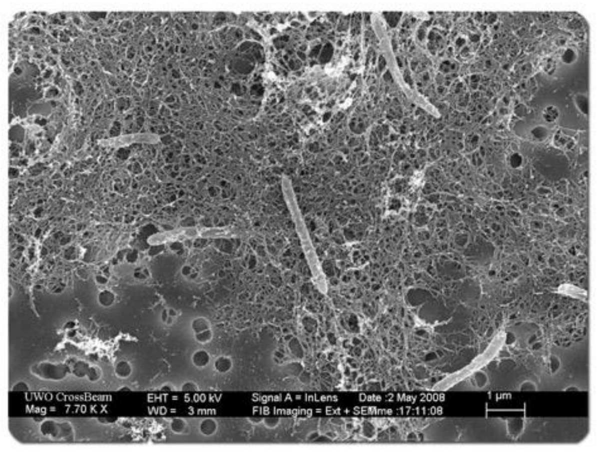
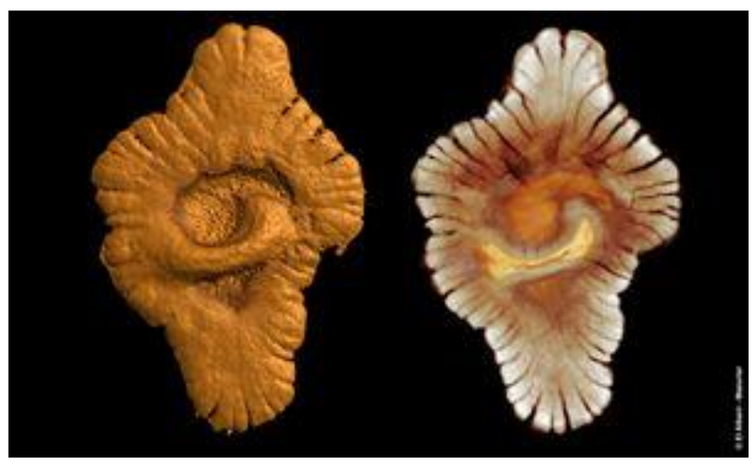
Is radioactivity a friend or a foe of life ?

- Too much radiation is obviously a foe
- There are also clear indications that natural radioactivity is a friend of life on earth
- And there are open questions on its impact on the emergence of life on earth



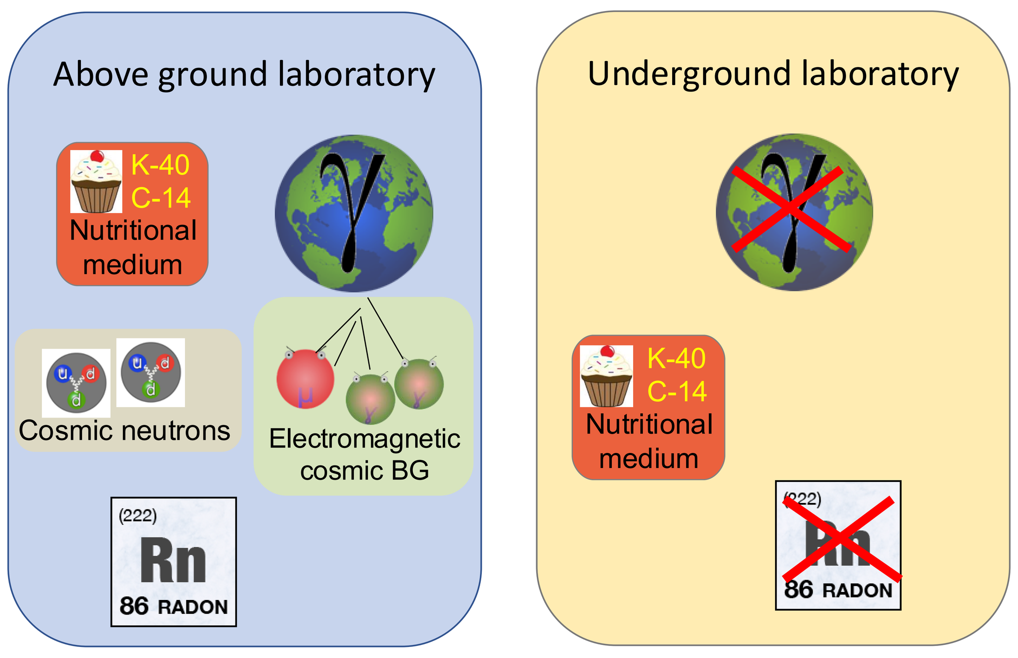
A single-species ecosystem discovered deep within Earth in a South-African gold mine feeds upon water radiolysis from natural radioactivity (Chivian et al, Science 2008)



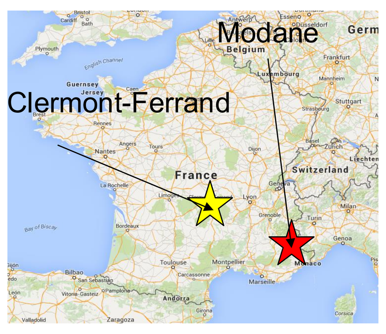
Large colonial organisms with coordinated growth grew up 2.1 Gyr ago a few kilometers from the site of the only known natural nuclear reactors in Gabon (El Albani et al, Nature 2010)

Deep Underground Laboratories are unique places to study the impact of low doses of radiation

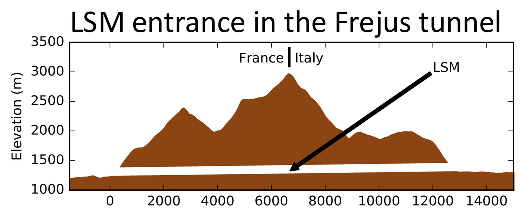
- Only places where background radioactivity can be almost completely suppressed
- 25 years of biological experiments in Deep Underground Laboratories yield surprising results



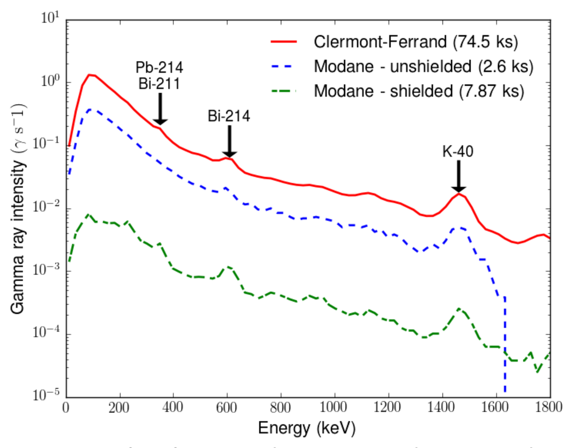
Scientific experiments in underground laboratories are protected from cosmic rays (muons, neutrons, gammas, …). Led shielding and air deradonization provide an additional cut of telluric radiation. The only remaining background comes from the radioelements in the nutritive medium.



LSM entrance in the Frejus tunnel



Located in the middle of Frejus tunnel at the border between France and Italy, Modane Underground Laboratory is protected from cosmic rays by almost 2000 meters of rocks. Led shielding provides additional suppression of radiative background.

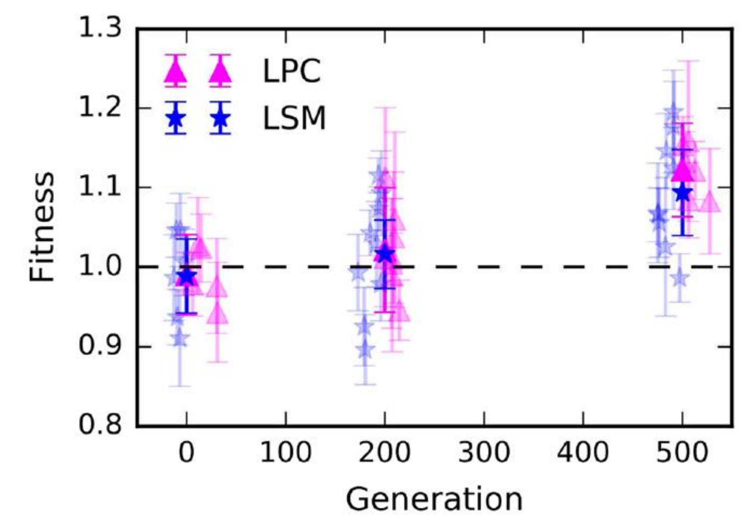


Gamma background measured at Modane Underground Laboratory in a led castle is 2 orders of magnitude lower than in Clermont-Ferrand.

Source	Method	LPCA Clermont (nGy hr^{-1})	LSM (nGy hr^{-1})	LSM (shielded) (nGy hr^{-1})
γ background	Dosimeter (simulations support this value)	150	20	<1
Cosmic rays (charged)	UNSCEAR	31	<<1	<<1
Cosmic rays (neutrons)	Simulation	4.4	<<1	<<1
^{40}K (γ)	Simulation	0.13	0.13	0.13
^{40}K (β)	Simulation	26	26	26
^{14}C (β)	Simulation	<<1	<<1	<<1
	Total	212	46	26

This table summarizes the main contributions to the radioactive background at LPCA and LSM during the first Long Term Evolution experiment. The comparison between the two laboratories shows how ^{40}K in the nutritive medium accounted for more than 99% of the total radiative background at LSM.

The first Long Term Evolution Experiment in Ultralow radioactivity shows no significant impact



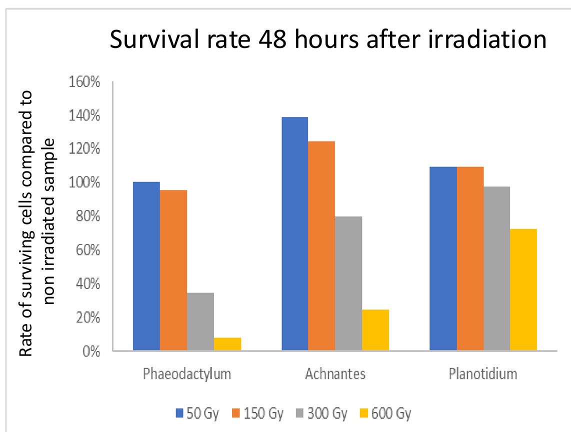
All bacterial strains cultivated both at LPCA and LSM do display an increase of their fitness after 500 generations in excellent agreement with literature. No significant difference is observed for the strains cultivated in ultralow radioactivity.

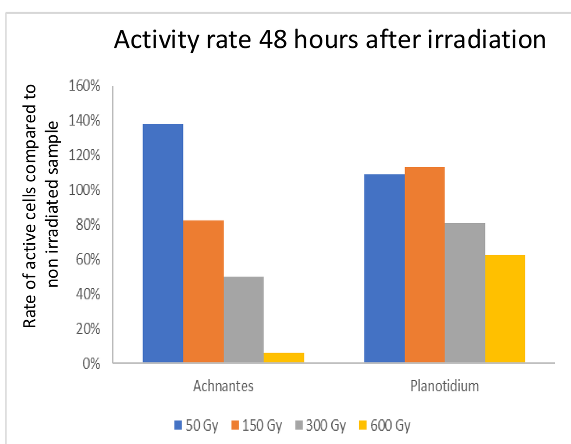
Next steps

RAMURe : Adaptive Response of Microalgae and cyanobacteria to Ultralow Radioactivity at Modane Underground Laboratory

Radioactive mineral springs are natural ecosystems where dose rate can reach more than 100 microGrays/h.

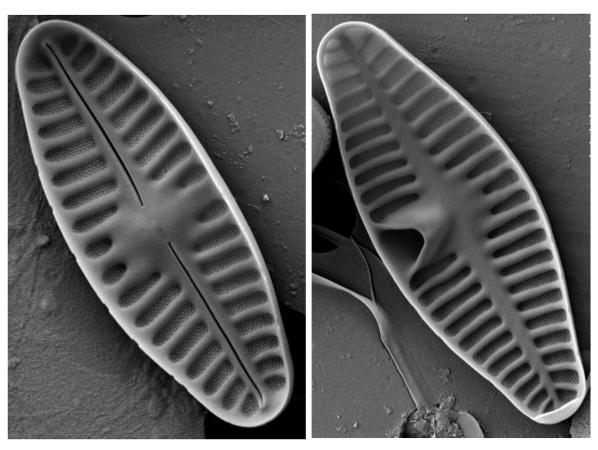
Goal : cultivate at LSM microorganisms coming from naturally radioactive environments





Diatoms coming from mineral springs are more resistant to radiation than lake (***Achnantes***) and marine (***Phaeodactylum***) diatoms

Method: compare the physiological response to irradiation of three diatom species, including one isolated from a radioactive mineral spring, after they have been cultivated in ultralow radioactivity



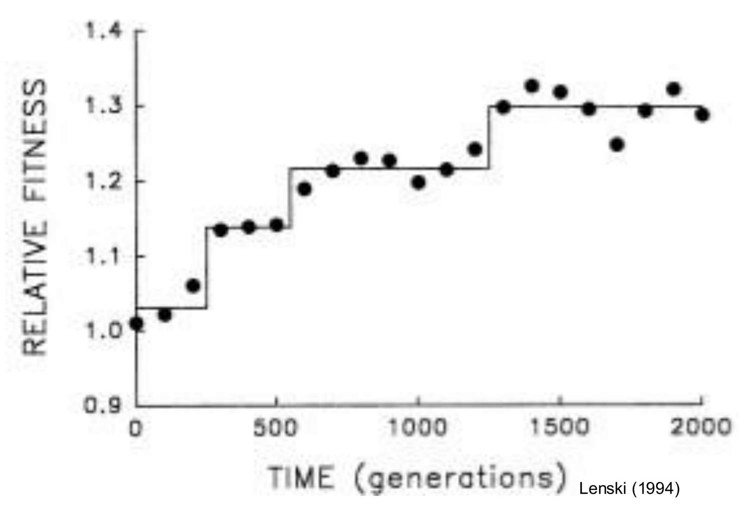
Some diatom species (Planotidium) isolated in Auvergne radioactive mineral springs display teratogenous forms (left)

New Long Term Evolution Experiments using nutritive media either enriched or depleted in ^{40}K

Main goal: document a radiation-induced deviation from the evolutionary path documented in the litterature

Mean: compare the fitness trajectories over 1000+ generations of bacterial strains that originate from the same ancestor and are cultivated in exactly the same environment but are exposed to growing radioactivity

Method: deplete or increase ^{40}K isotopic fraction in the nutritive medium



The evolutionary path of an *E. coli* strain has been documented over 60.000 generations by Lenski and collaborators since 1988.

Potassium has three naturally occurring isotopes: ^{39}K (93.258%) and ^{41}K (6.730%) are stable, while ^{40}K (0.012%) is radioactive, with a half-life of 1.25 billion years.

Sharing is encouraged

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