CZENDA – the Czech Experimental Novel Dosimetry Assembly aboard the BION-M2 Russian satellite

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CZECH TECHNICAL UNIVERSITY IN PRAGUE

ЦСКБ-Прогресс • ИМБП РАН

БИОН

НАУЧНЫЙ ПРОЕКТ "БИОН-М" №1

CZENDA

BASA

Photon Systems Instruments

UNIVERSITAS MASARYKIANA BRUNENSIS

CSO

CZECH SPACE OFFICE

JOINT INSTITUTE FOR NUCLEAR RESEARCH

1956 · 2016

INSTITUTE OF SPACE SCIENCE

ISS

ROMANIA

MEPhI

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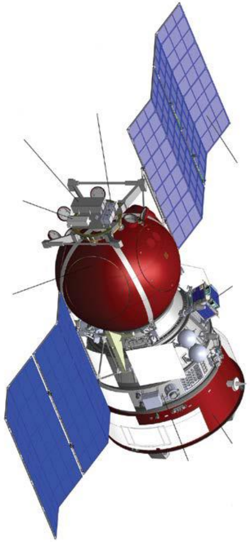
Orbit parameters for recoverable biological satellites

Parameter	Bion-M1	Foton-M4	Bion-M2
Flight dates	April 19 – May 19, 2013	July 19 – September 1, 2014	In 2021
Flight duration, days	30	45	30
Orbit inclination, º	64.8	64.5	51.6 or 64.8
Apogee, km	583	565	~1000
Perigee, km	563	260	~800
Orientation stabilization	Yes	Yes	Yes
Passive detectors (inside and outside)	Yes	Yes	Yes
Active detectors inside	Yes	Yes	Yes
Active detectors outside	No	No	Yes



Launching mass ~7 t, Recoverable capsule mass ~ 2 t

BION M2

Purposes of space experiment Bioradiation-2

1. Study of biologically significant characteristics of space ionizing radiation and effects of its impact on biological objects in open space and inside the satellite.

2. Research and testing of new methods and means of space dosimetry for their subsequent use in advanced space missions.

Tasks of space experiment Bioradiation-2:

conducting dosimetric support of biological experiments inside and outside of the satellite;

working out means and methods of radiation environment control caused by all radiation sources in Bion-M # 2 orbit, taking into account contribution to the dose of space radiation secondary neutrons;

verification of the space radiation transport methods in spacecraft shielding;

conducting radio-biological experiments with biological objects, which do not require special systems to maintain their vital functions.

Bioradiation-2

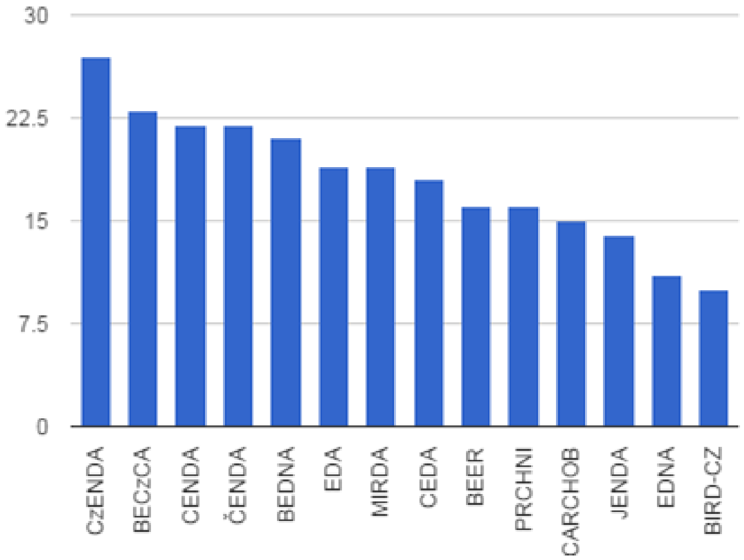
Name of scientific instrument	Location
Packages of passive detectors (PD-1, PD-2, PD-3, PD-4, PD-5, Brados)	Outside recoverable capsule in instrument pans (with lids)
SPD-M - boxes with passive detectors (TLD, SSTD) and biological objects (seeds)	Inside recoverable capsule (boxes SPD) and in 32 places on the inner surface of the recoverable capsule (Dosesphere packages of passive detectors)
RD3-B3 (silicon dosimeter)	Inside and outside recoverable capsule (in instrument pan)
Tritel-B (LET spectrometer of charged particles)	Inside recoverable capsule
Bubble-detectors (neutron dosimeters)	Inside recoverable capsule
CZENDA (???)	Inside recoverable capsule

Why CZENDA?

CZENDA = CZech Experimental Novel Dosimetry Assembly

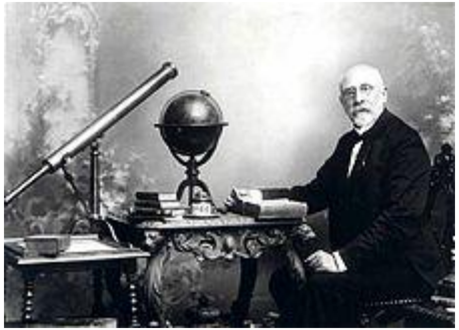
ЧЭНДА = Чешская Экспериментальная Научная Дозиметрическая Аппаратура

ČENDA = Česká Experimentální Nová Dozimetrická Aparatura



Čenda = Čeněk = Vincenc

Vincenc Strouhal (1850-1922)
- Czech experimental physicist
- one of founders of the Physics department at Charles University



Named after Strouhal:

- Strouhal number describing oscillating flow mechanisms
- Minor planet 7391 Strouhal
- Project CZENDA

Experimental devices in CZENDA

Type	Component	Institute	Mass [kg]	Dimensions [cm^3]	Power [W]	Memory [MB / day]
Active detectors	CANDY	NPI	0.4	23x16x3	1	10
	Timepix - radiation monitor	IEAP	0.3	8x5x2	2	300
	Timepix - particle microtracker	IEAP	0.3	8x5x3	3	600
Passive detectors	Track etched detectors	NPI, MEFI	0.1		-	-
	Nuclear emulsion	JINR, ISS	0.3	10x10x4	-	-
	Thermoluminescent detectors	NPI	0.2		-	-
Biological samples	Plasmids	NPI	0.005	1x1x0.1	-	-
	Lichens, Algae	MU, PSI	0.2	2.5x10x15	-	-
Other devices	Computer	NPI	0.45	10x12x4	19	1
	Support devices	NPI	0.8	-	-	-

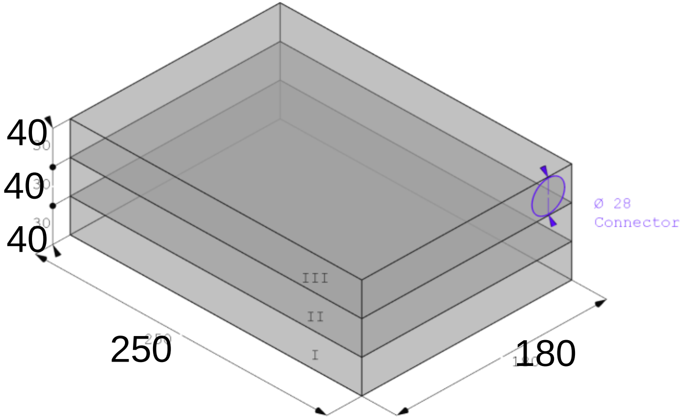
CZENDA’s basic parameters

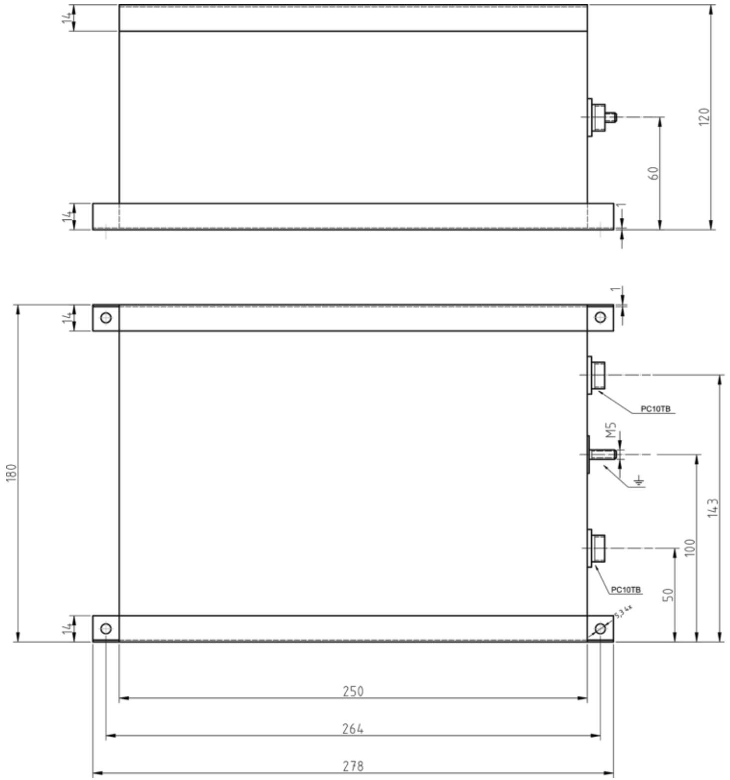
Mass: 3 kg

Dimensions: 250 x 180 x 120 mm^3

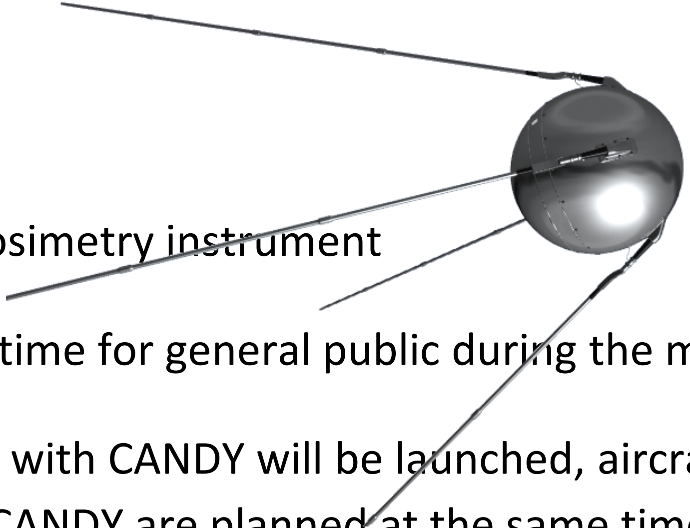
Source of DC, voltage 12V - 38V

Power Consumption 25W

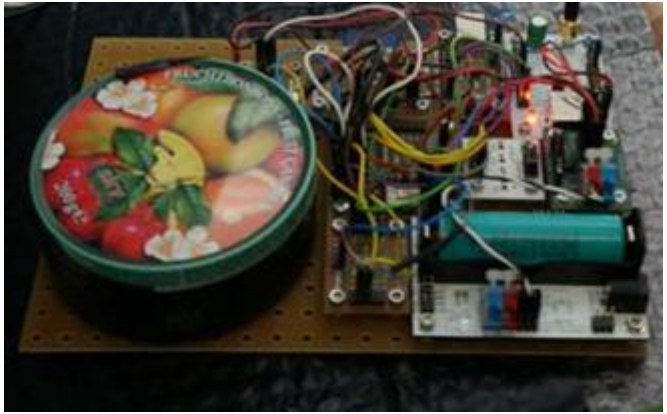




CANDY



- Implementation of the novel dosimetry instrument
- Proposal: data available at real time for general public during the mission
- Stratospheric balloon equipped with CANDY will be launched, aircraft and high-mountain measurements with CANDY are planned at the same time



http://www.mlab.cz/Modules/Sensors/PCRD02A/DOC/PCRD02A.cs.pdf

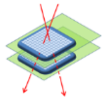
CZENDA-Timepix experiments on BION-M2

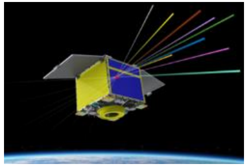
Instrumentation + proposed experiments: 3x

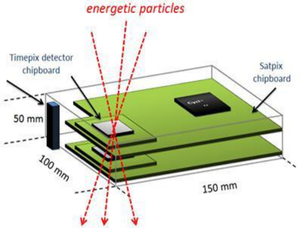
www.cern.ch/medipix

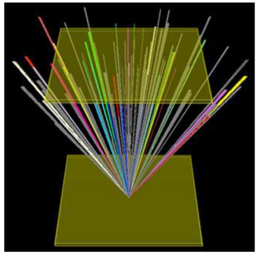
Characterization, quantum imaging dosimetry, monitoring and directional tracking of space radiation

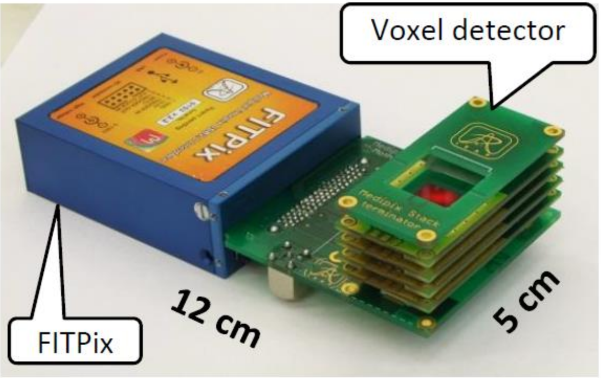
- RETURN MODULE (INSIDE THE PRESSURIZED CABIN)
  - **A: Miniaturized radiation monitor** for online quantum-imaging dosimetry of the mixed radiation field in the spacecraft environment. Wide-dynamic range, high-resolution: dose rate, dE/dx, LET spectra.
  - **B: Particle micro-tracker** for directional mapping of energetic charged particles inside the spacecraft module. Enhanced with wide field-of-view and high angular resolution including option to embed (biological) sample (see Fig.1 – illustration drawing) for precise tracking of high-LET particles across sample.











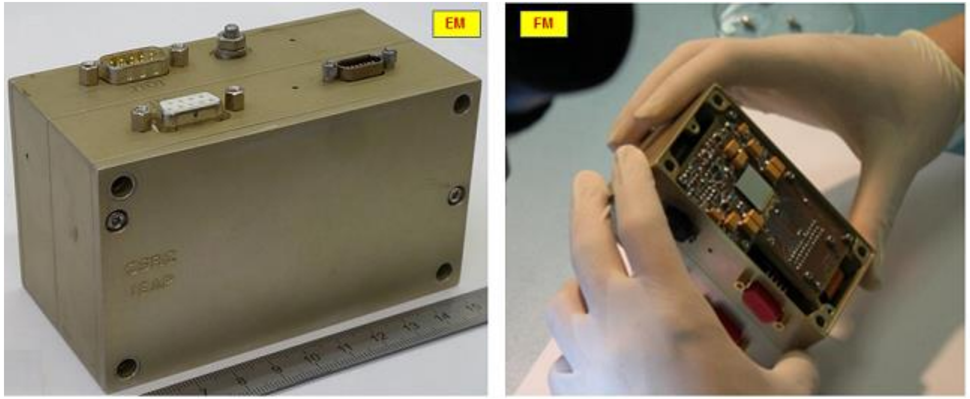
ideal joint projects with dosimetry/space radiology/astrobiology teams

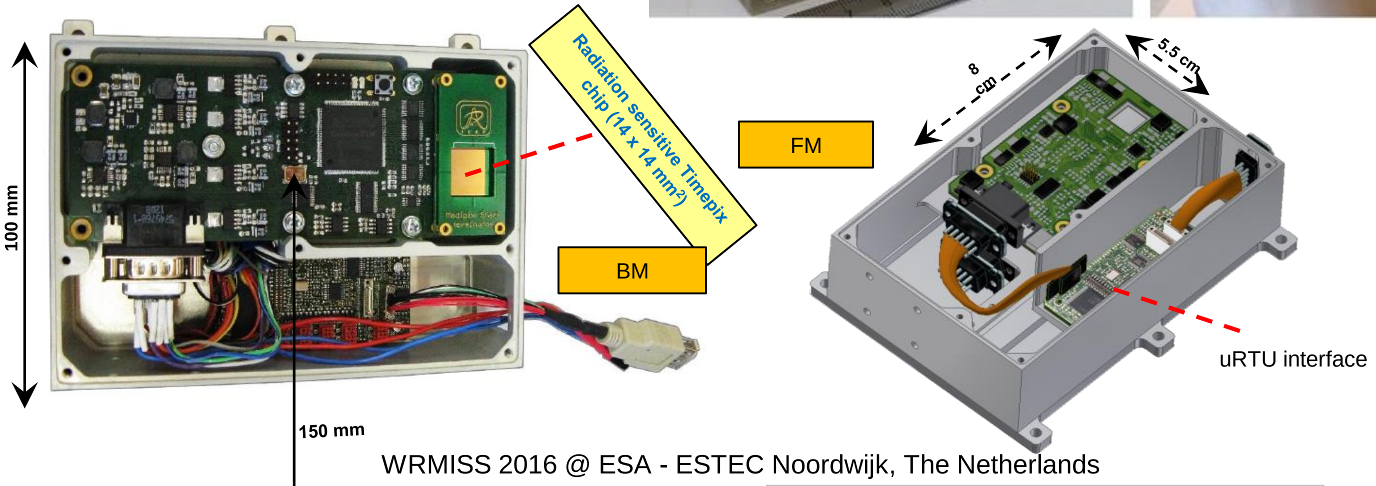
CZENDA-Timepix experiments on BION-M2

TPX experiment C: Outer deployment open space payload

"Heritage" is from project "SATRAM spacecraft payload on board ESA Proba-V satellite in LEO orbit since 2013"

- ORBITER SPACECRAT (DEPLOYMENT ON CAPSULE OUTER SURFACE)
  - **C: Outer deployment open space radiation monitoring payload** spectral and directional characterization of space radiation in wide-dynamic range along the satellite orbit.

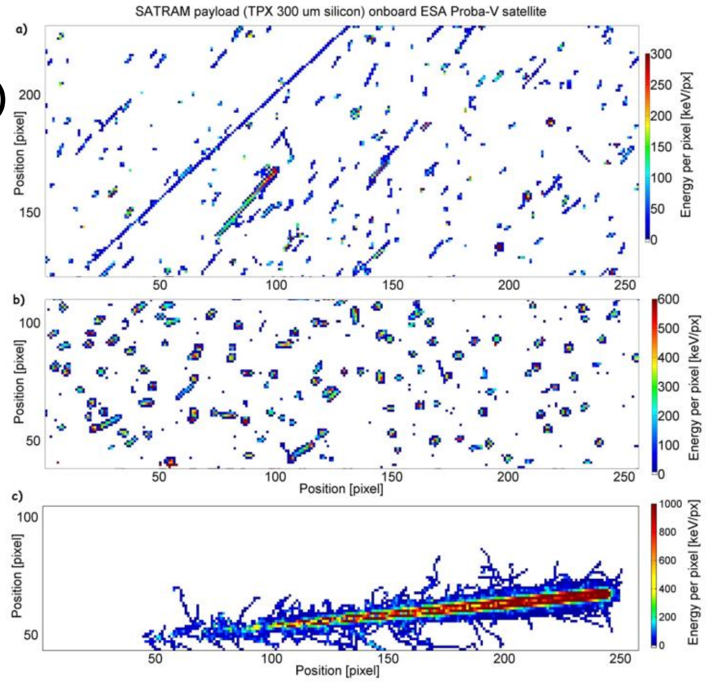




CZENDA-Timepix experiments on BION-M2

Instrumentation + proposed experiments

- TASKS/PHYSICS/DATA PRODUCTS
  - **Quantum-imaging dosimetry of space radiation, particle-type resolving power (dose rate, equiv DR, energy loss, LET-spectra)**
  - **Composition and spectral characterization (dE/dx) of mixed radiation field**
  - **Visualization of the radiation field**
  - **Directional mapping of energetic charged particles (compact micro-tracker)**

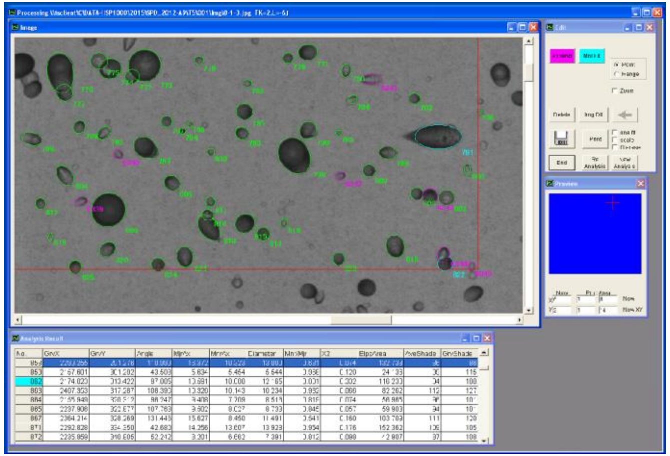


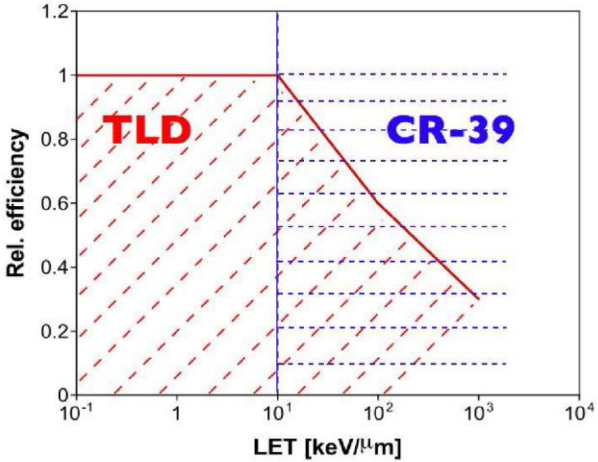
- CPU + DATA ACQUISITION + MEMORY + DATA TRANSFER
  - **Built-in (in payload) CPU/processor + data memory [RASPIX]**
  - **Spacecraft/capsule central computer + memory [ISS-TPX]**
  - **Downlink data transfer / Telemetry [SATRAM]**

- POWER
  - **From spacecraft/capsule system [SATRAM]**
  - **Built-in in payload [RASPIX]**

PNTDs, TLDs

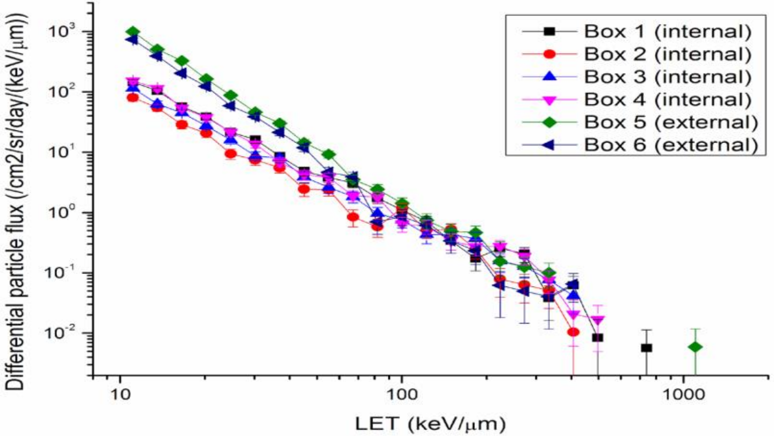
- Accurate assessment of dosimetric quantities (absorbed dose, equivalent dose, the spectra of linear energy transfer - LET) using advanced and well tested passive dosimetry methods throughout the flight.
- Intercomparison and verification of radiation detection techniques and technologies in the conditions of spaceflight.
- Support of the radiobiological experiments

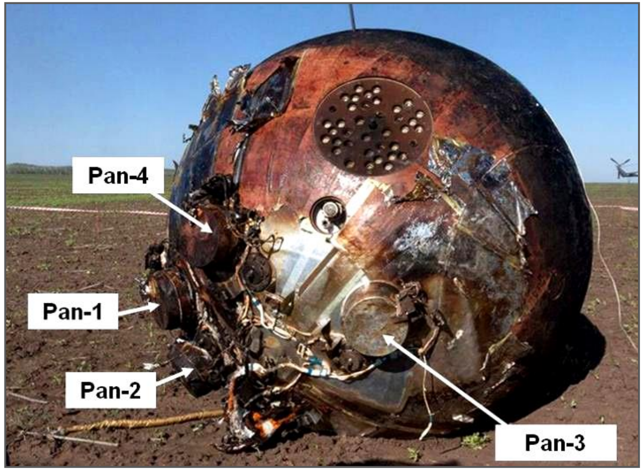


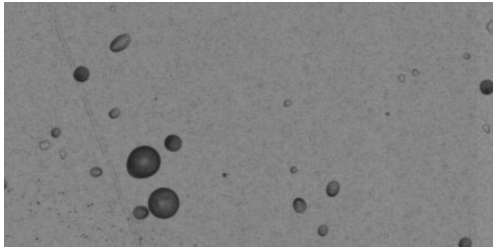


PNTDs, TLDs

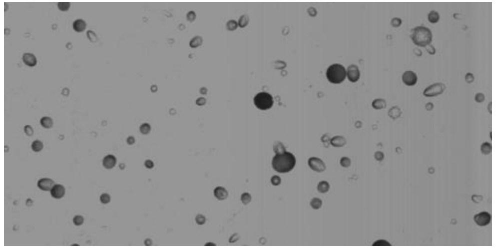
- Our experience from the last experiments at BION M1







internal



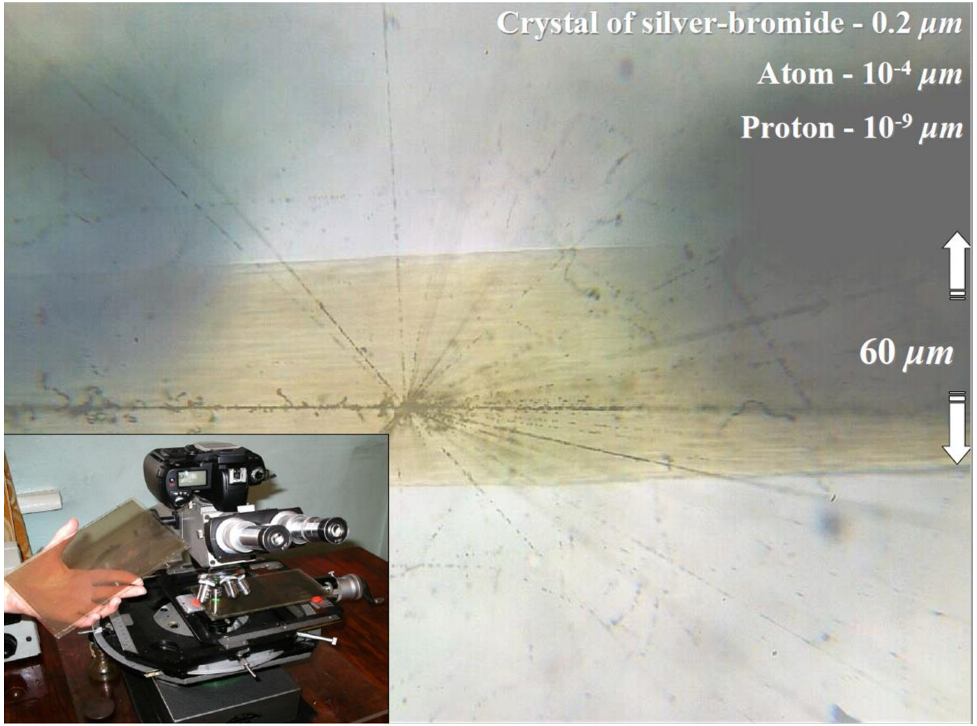
external

Nuclear emulsions

- Nice traditional method

Nuclear emulsions

- Nice traditional method
- Voxel detector, highest spatial resolution
- Identification of high-LET nuclei of GCR fluxes using a stack of nuclear emulsions (NE)
- Investigation of the possibility of detection of hypothetical dark matter particles by detecting recoil from the NE material.



Plasmid model system

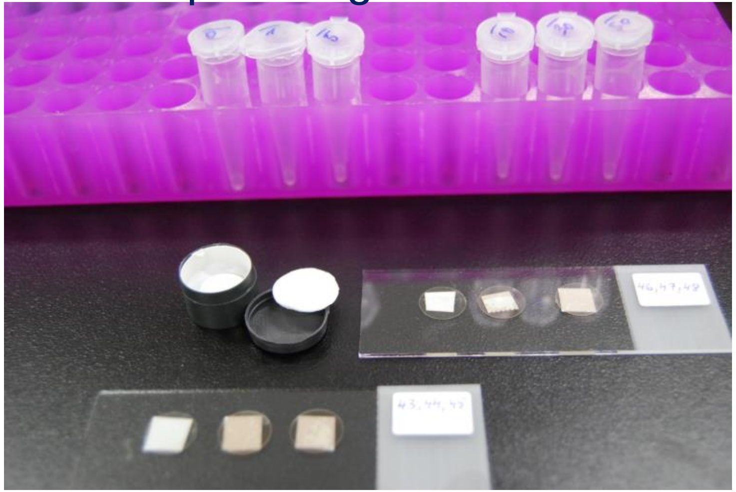
Biological consequences of radiation: (cellular) DNA as a target → its damage (strand breaks, base damage) correlate with dose and biological dose

Plasmid model: small, light, circular DNA molecule, stable, easy to handle (compare to cellular or animals models)

Samples

Direct effects: dry plasmid (possibly directly on track etch detectors or glass or Timepix) – small drops of almost no weight or sizes

Indirect effects: plasmid in water solution with buffers mimicking cell environment, possibly in Eppendorf tubes ... up to 10 g

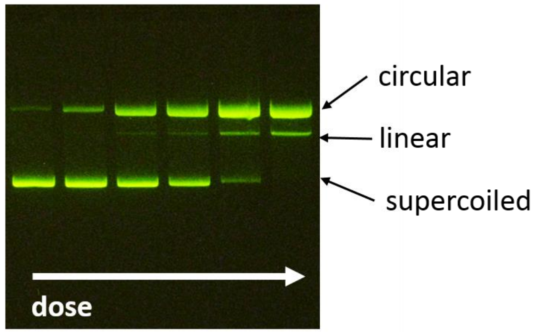


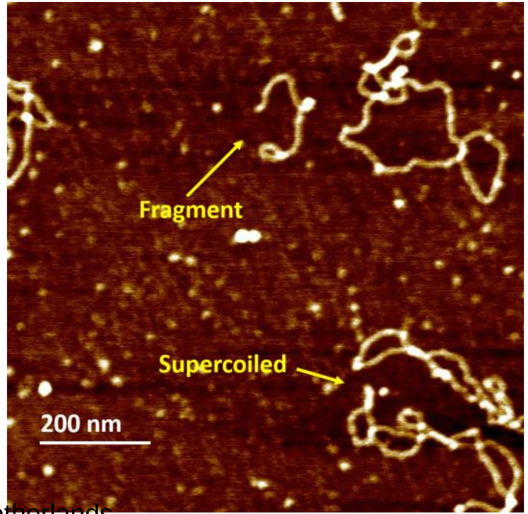
Method

Agarose gel electrophoresis: detection of strand breaks

Repair enzymes: detection of base damages

Possibly atomic force microscopy: detection of DNA fragments





Lichens and algae

Motivation:

Due to the best ability to survive in hard conditions lichens and algae might be the first plants sent to potentially habitable space bases / planets.

Aim:

to use lichens and algae as bio-indicators and to test how they withstand the radiation conditions in orbit within the space complex via real-time fluorescence measurements.

Lichens in space experiments overiew of State-of-Art

Lichens are considered models capable to survive in space thanks to their adaptations

Several species has been tested so far

Among them, *Xanthoria elegans* most frequently (18 months in space, Brandt et al. 2015)

Overwiev on what has been done in ‘ lichens in space ‘ so far

Lab preflight tests mimicking orbital/space conditions (physiology, viability, anatomy)

Expositions to space conditions on board or outside a spacecraft

Postflight lab test focusing negative effects on photosynthesis and physiology markers

in lichens exposed **in dry state**

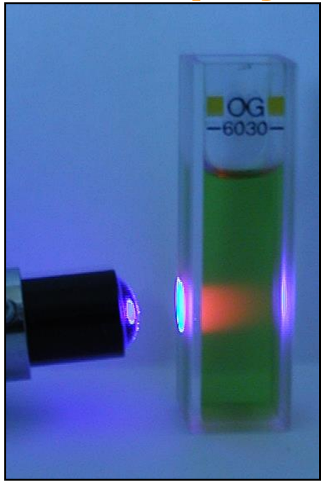
Our plans in lichen/alga exposition

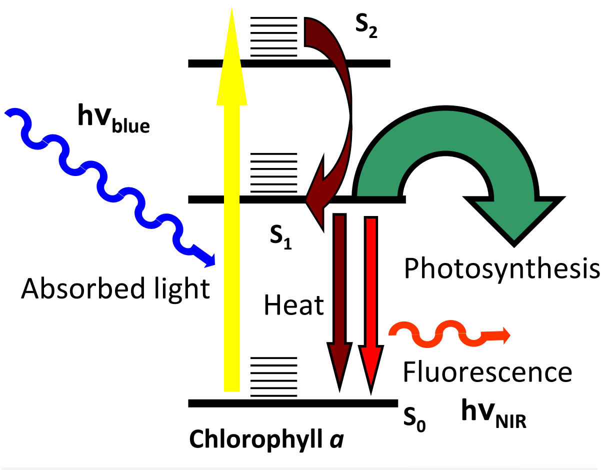
Detailed screening of lichens in preflight experiments

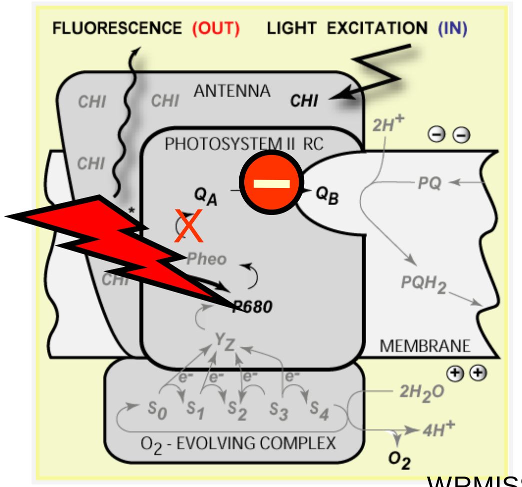
During a spaceflight, lichen/alga will be exposed to orbital radiation conditions in wet, i.e. active state

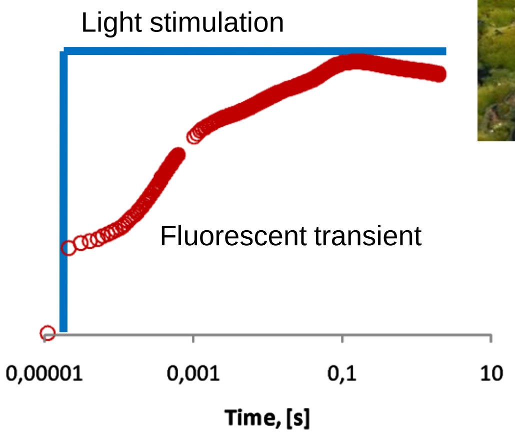
Several chlorophyll fluorescence techniques will be applied, e.g. fast chlorophyll fluorescence transient (OJIP) and 15 photosynthetic parameters recorded during flight repeatedly

Chlorophyll fluorescence and photosynthesis









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Summary - Experiments within CZENDA

1. novel dosimetry with the CANDY detector
2. Online quantum-imaging dosimetry of the mixed radiation field in the immediate spacecraft environment focused on wide-dynamic range and high-resolution of: dose rate, dE/dx, LET spectra.
3. Compact particle micro-tracker for directional mapping of energetic charged particles inside the spacecraft module. Enhanced with wide field-of-view and high angular resolution including option to embed (biological) sample for precise tracking of high-LET particles across sample.
4. Accurate assessment of dosimetric quantities (absorbed dose, equivalent dose, the spectra of linear energy transfer - LET) using advanced and well tested passive dosimetry methods throughout the flight.
5. Identification of high-LET nuclei of GCR fluxes using nuclear emulsions (NE); Investigation of the possibility of detection of hypothetical dark matter particles by detecting recoil from the NE material.
6. Intercomparison and verification of radiation detection techniques
7. Study of the biological effects of cosmic radiation on subcellular structure of DNA via exposure of dry plasmids.
8. To use lichens and algae such as bio-indicators and to test how they withstand the radiation conditions in orbit within the space complex via realtime fluorescence measurements.

BION M2
Preliminary schedule

- 2016 – Design project presentation
- 2017 - Documentation development
- 2018 - Qualification model manufacturing and testing
- 2019-2020 - Flight model manufacturing and testing
- 2021 – Flight testing

CZENDA
Future work

- Funding
- Proper exact design of the device
- Calibrations of CANDY in heavy ion sources (HIMAC, Protvino C-12, …)
- On-ground radiation exposures of lichens and algae

Thank you for your attention!