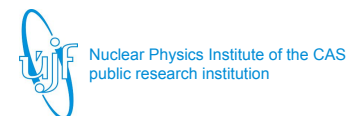


General Notes about CRREAT and Radiation Dosimetry Measurements onboard Aircraft

Ondrej Ploc and the team CRREAT

**Nuclear Physics Institute of the CAS,
Department of Radiation Dosimetry, Prague, Czech Republic**

EURADOS Webinar on CRREAT, March 10th, 2022



Scientific Team CRREAT



EUROPEAN UNION
European Structural and Investing Funds
Operational Programme Research,
Development and Education



MINISTRY OF EDUCATION,
YOUTH AND SPORTS



INSTITUTE OF ATMOSPHERIC PHYSICS
CAS



Nuclear Physics Institute of the CAS
public research institution

Project details

Funded period: Dec 2016 - Oct 2022 ?

Research domains:

1. **Dosimetry of ionizing radiation in atmosphere**
2. Physics of storm clouds and upper- atmosphere phenomena
3. Characteristics of the electromagnetic field in the atmosphere



Scientific Advisory Committee: Armenia, France, Germany, Japan, Russia, USA

Objectives

Observe relations between the atmospheric phenomena and ionizing radiation

- **Finding suitable methods for detection and dosimetry of thunderstorm radiation**
- Clarification of the causes of lightning discharge initiation

Clarify the phenomena causing variations of secondary cosmic particles (SCP)

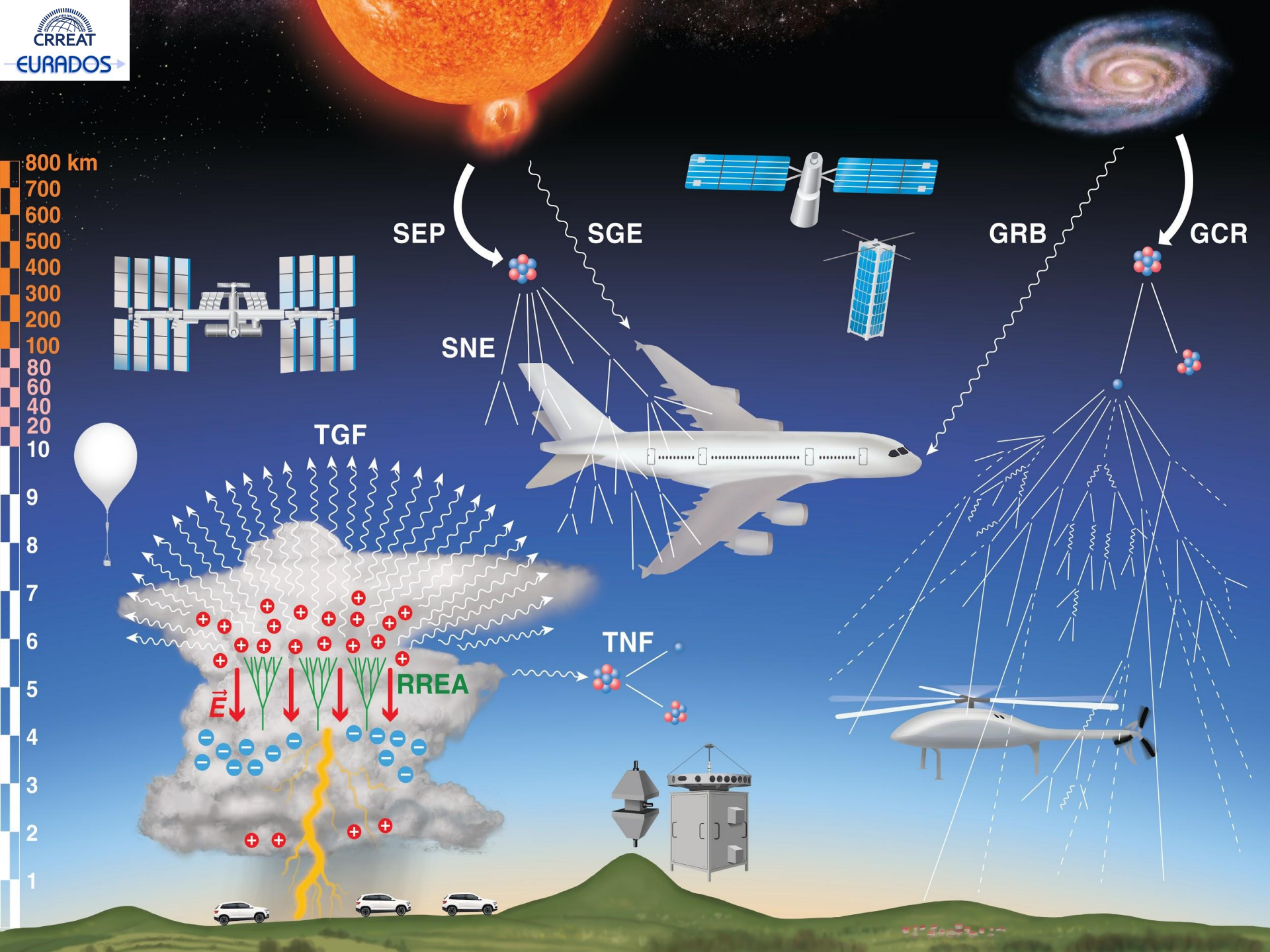
- Influence of the atmospheric state on the SCP detection (water in atmosphere, ...)
- Understanding of quasi-periodic and fluctuating phenomena in CR detection



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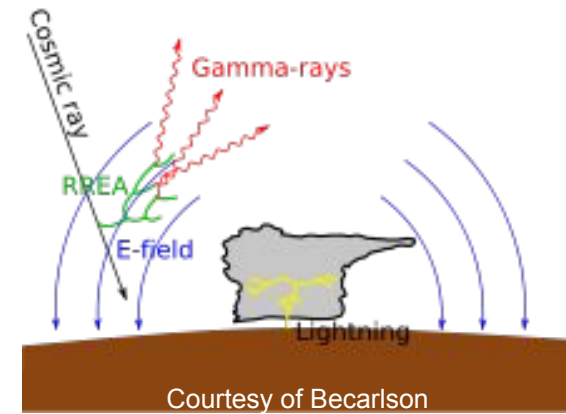


Thunderstorm radiation

Short vs long bursts

Terrestrial gamma-ray flashes (TGFs)

- Intense (sub-) millisecond flash of gamma radiation
- bremsstrahlung from RREA
- few 10^{17} gammas with energies of several MeV or higher
- Discovered in 1994 by BATSE satellite



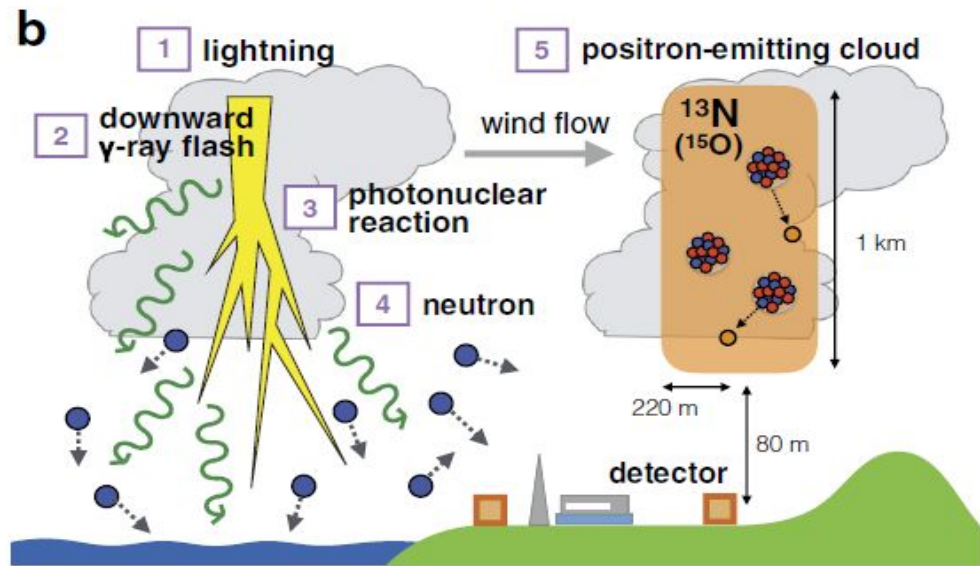
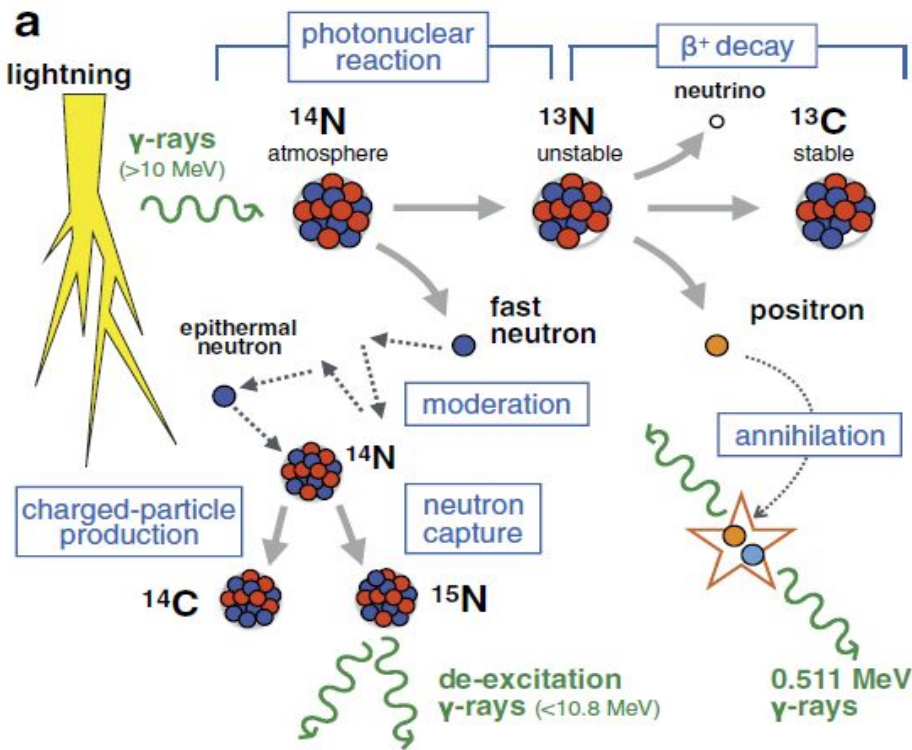
Thunderstorm Ground Enhancements (TGEs)

- prolonged rise of gamma ray intensity
- minute-scale duration
- preceded a negative field variation (lightning discharges el. field)
- On-ground measurements (high-mountain observatories, newly also low-altitude observatories in Czechia)
- Different from radon washouts

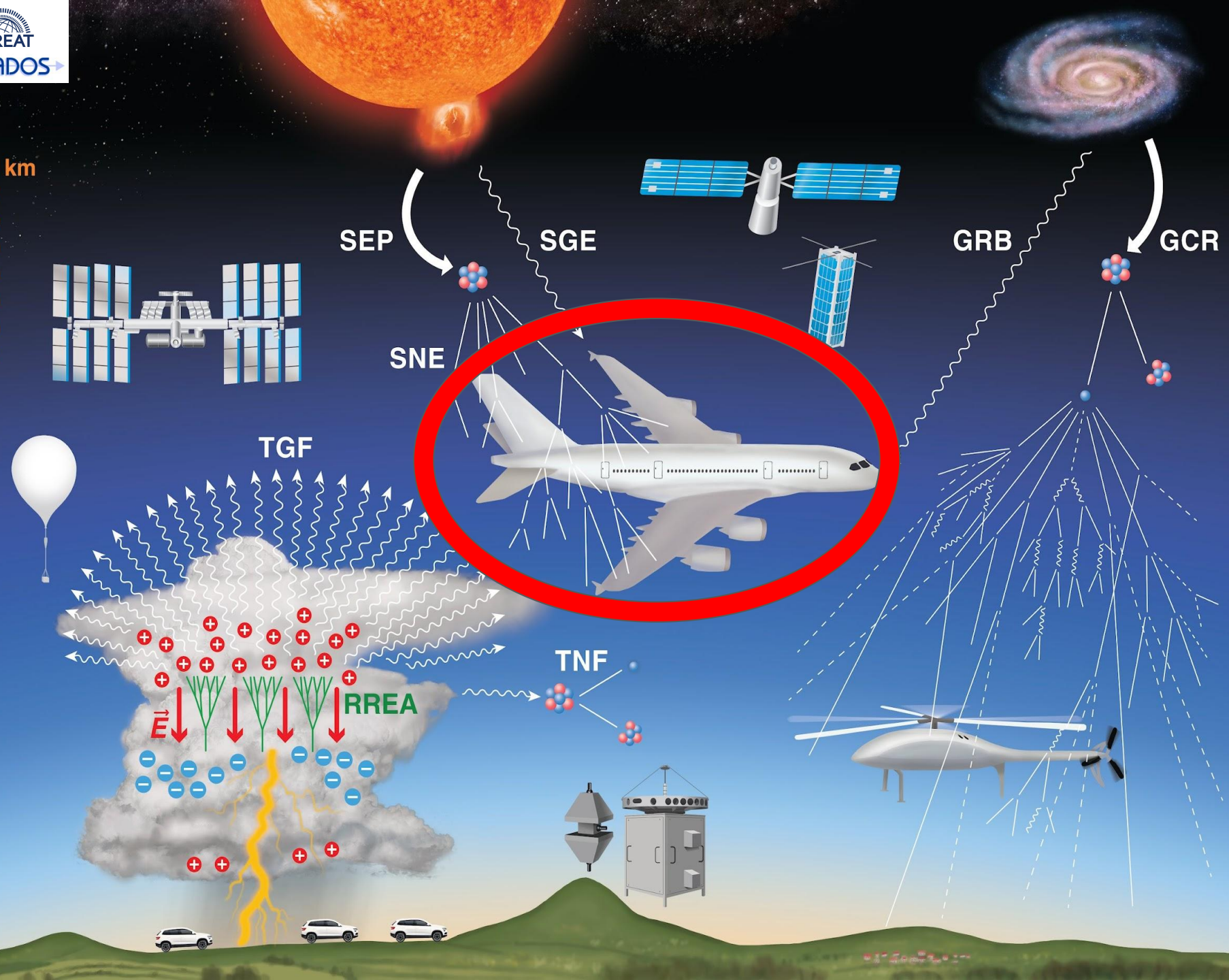
Thunderstorm radiation

Thunderous nuclear reactions

Enoto, T. et al. Nature 551, 481–484 (2017).



Photonuclear reactions triggered by lightning discharge.

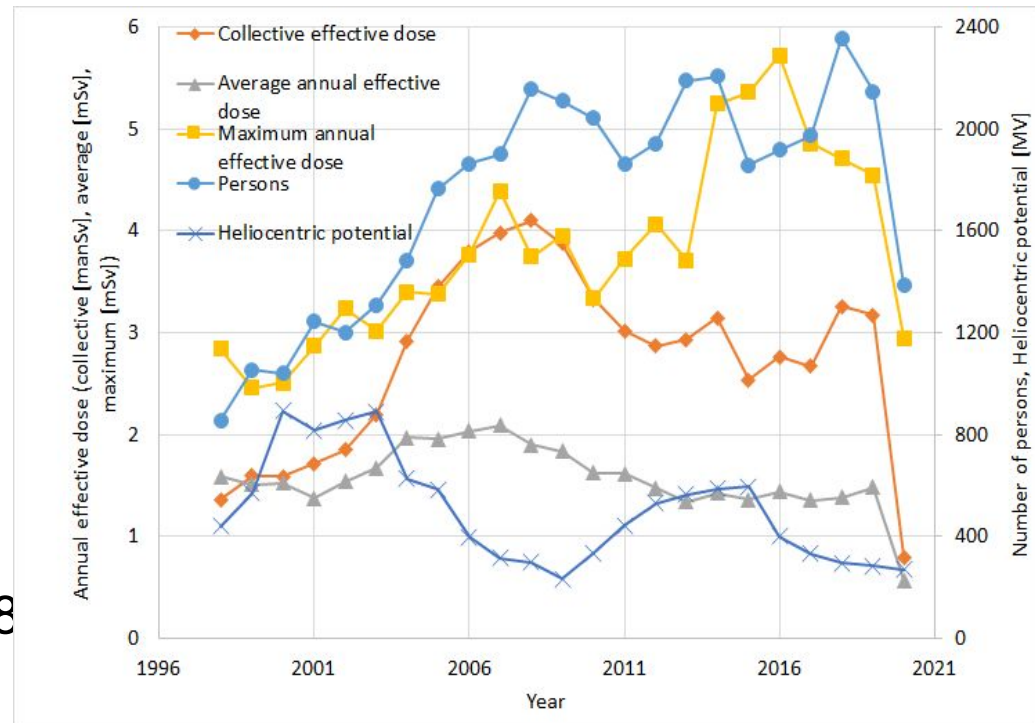


Motivation

Only GCR is taken into account for routine aircraft crew dosimetry, max E \approx 6 mSv/year in Czechia

SPE: occasionally >1 mSv/hour (Matthia et al.: J. Geophys. Res. 114, 2009)

TGF: 30-100 mSv/event (Bramlitt & Shonka: Health Phys. 108 76–86; 2015)

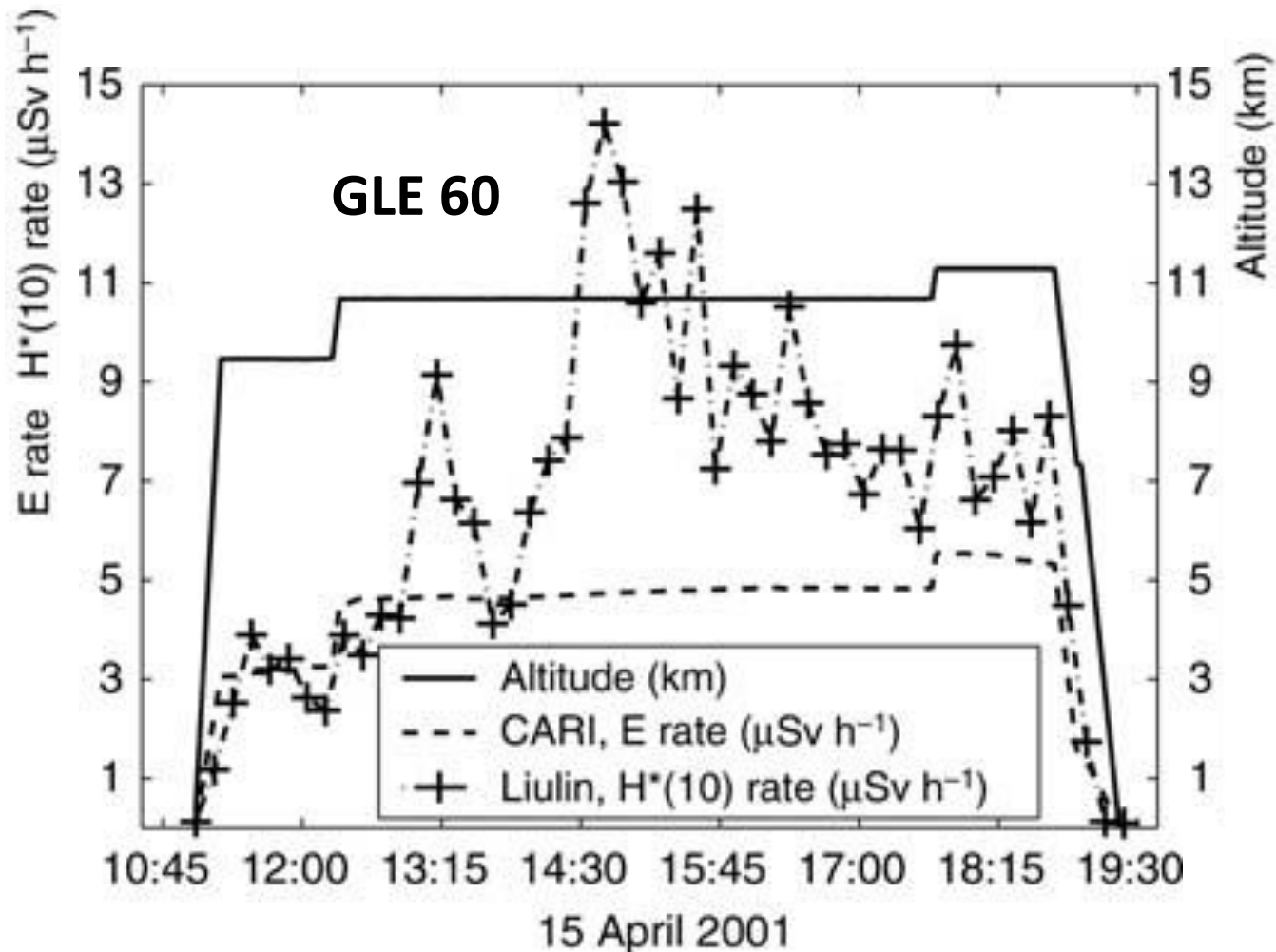


Commercial aircraft is hit by about one lightning strike per year on average.

- ⇒ 100 passengers per day are close to lightning / thunderstorm (not TGF)
- ⇒ If 1 TGF per 2600 lightning = every **10 to 30 days** an aircraft might be near TGF and potentially exposed

Radiation protection of aircraft crew and passengers

Effect of solar energetic particles



Spurny, F. and Dachev, T. Measurements during an Intense Solar Flare, GLE 60. Radiat. Prot. Dosim. 95, 273–275 (2001).

Dose Evaluation Method

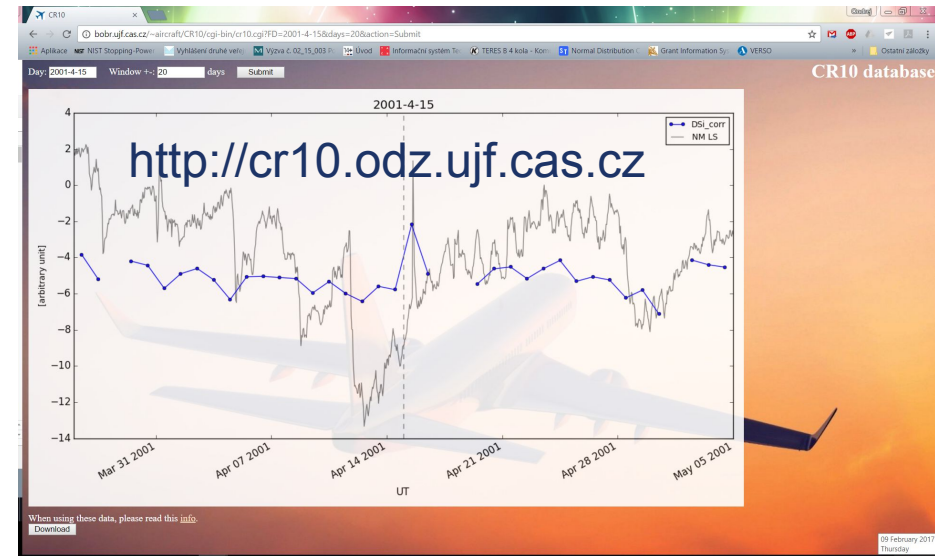
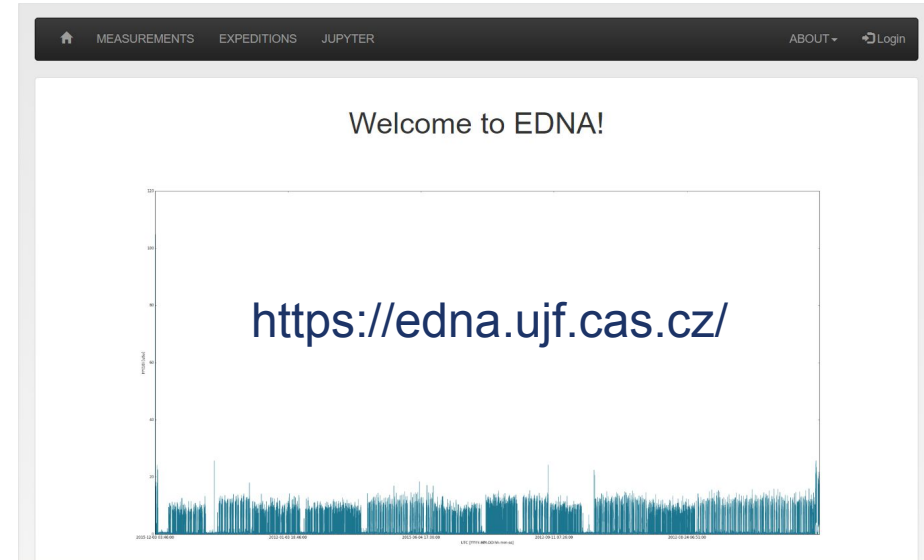
- 1. Proper dosimetry of Cosmic radiation**
 - Calibrations (CERF, HIMAC, NPI accelerators, N generators, radionuclides)
 - Onboard aircraft (long-term monitoring, intercomparison flight campaigns)
- 2. Selection of a suitable detector of the thunderstorm radiation**
 - Gamma spectrometer, effective for high-energies, short response, small dimensions and weight for UAV
 - Muon detector for detection of CR showers
- 3. Radiation tests in artificial lightning conditions**
 - at spark generators: high-voltage (BUT), High-current (FEE CTU)
- 4. Radiation measurements using balloons and UAVs (I. Ambrožová)**
 - stratospheric balloons FIK1-7, Helicopter Velos, gyrocopter Thunderfly
- 5. On-ground detection of the thunderstorm radiation phenomena**
 - SEVAN, gamma spectrometers, neutron detectors, MonRas etc.
on observatories (J. Šlegl) and cars (M. Kákona)
- 6. Radiation dosimetry onboard aircraft**
 - Besides CRs dosimetry also of TGF, TNF, TGE and other phenomena
 - Lightning detection, aircraft localization

Long-term monitoring onboard aircraft

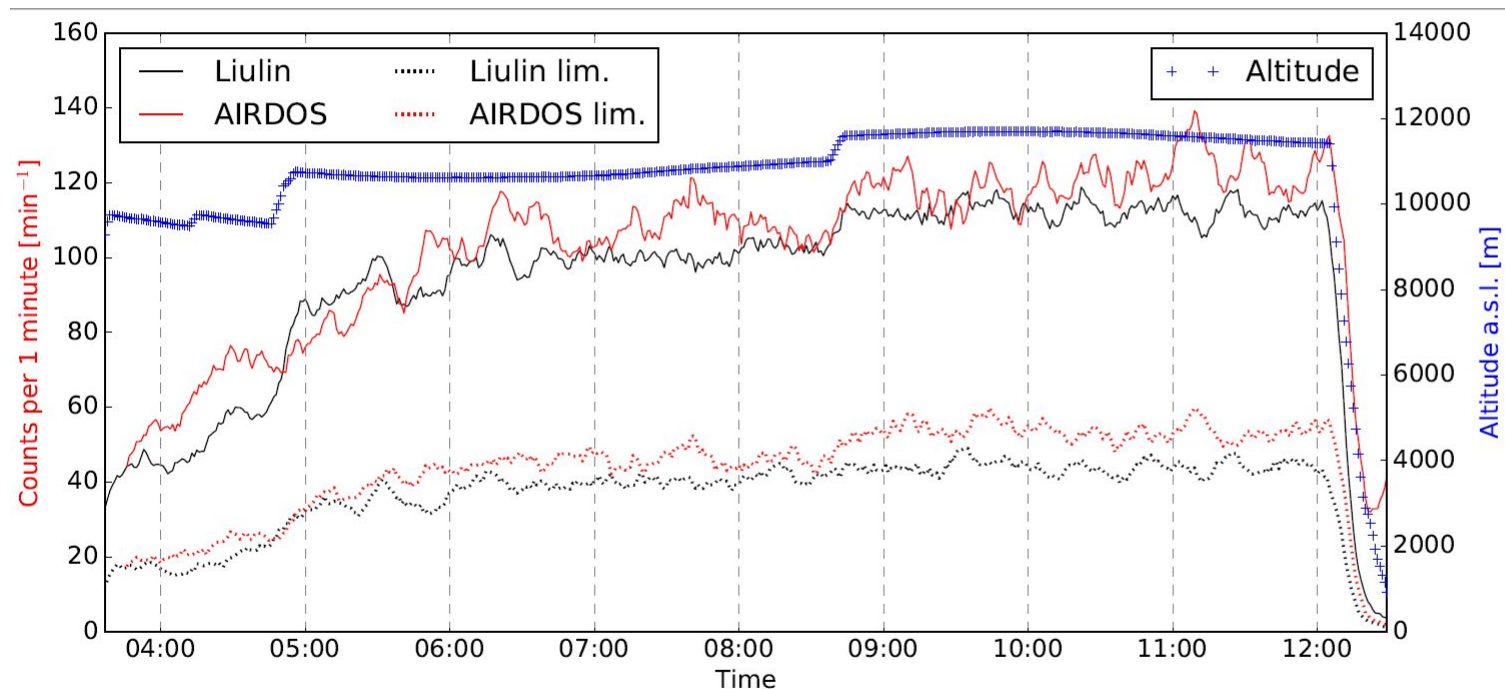
- Since 2001
- In collaboration with the Czech Airlines, SmartWings, ABS Jets
 - Si diodes for cosmic radiation
 - Liulin
 - Airdos



- PiTED
 - plastic scintillator
- Airdos-C
 - scintillation crystal + SiPM
- Stripe detectors
 - 4 layers in coincidence



Comparison of Liulin and Airdos



Onboard Airbus A350-900 Jan. 21 2018 during the AY74 flight from Tokyo to Helsinki (NRT-HEL)

Kakona M., Stepan V., et al. Comparative Measurements of Mixed Radiation Fields Using Liulin and AIRDOS Dosimeters, proceedings of the BPU conference, 2018

Long-term monitoring onboard aircraft

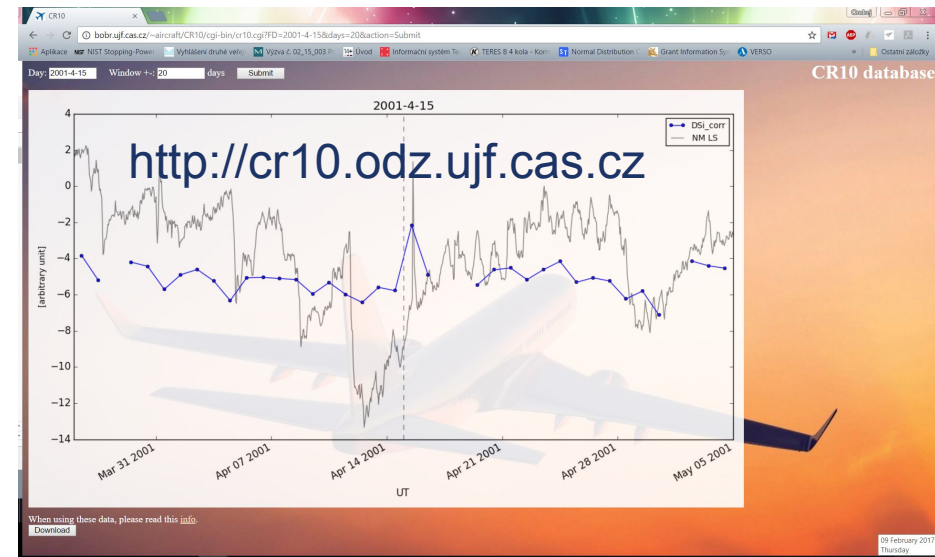
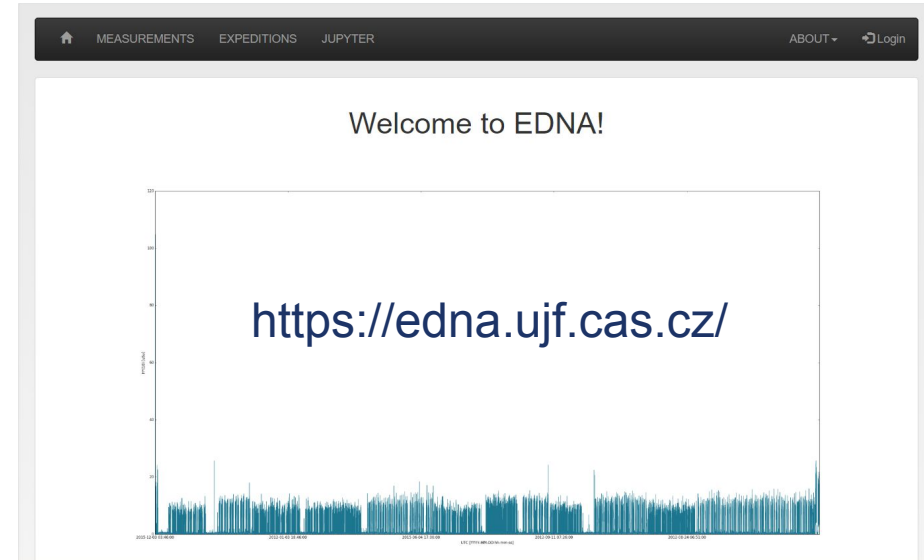
- Since 2001
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- PiTED

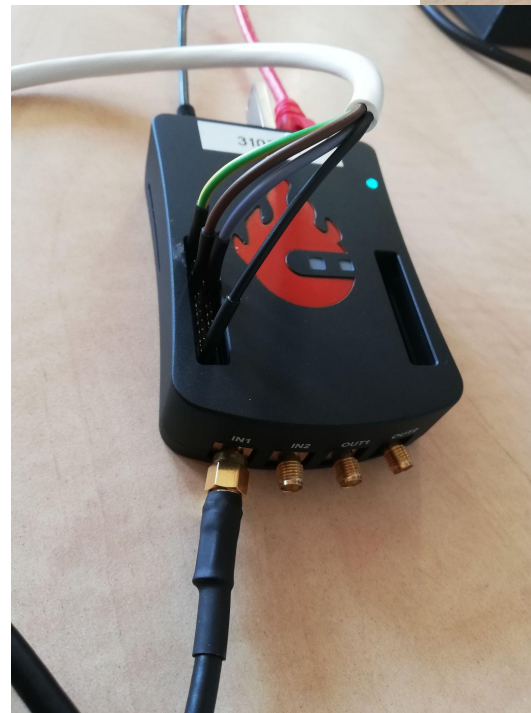
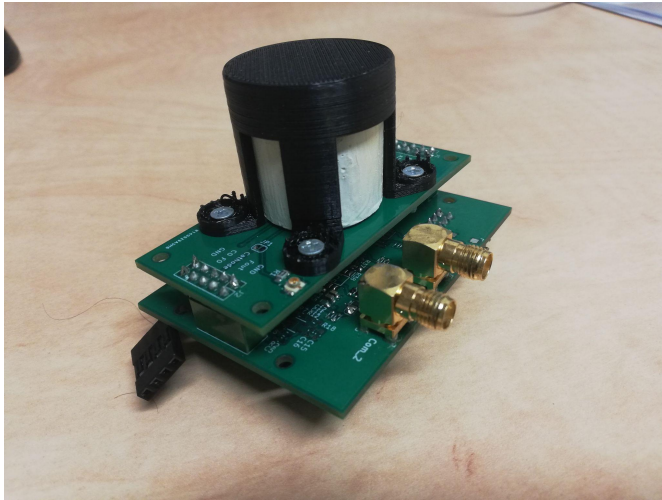
- Resulted in two on-line databases

<https://github.com/ODZ-UJF-AV-CR/AIRDOS02>



Current work - PiTED

- Development of a new type of dosimeter, based on plastic scintillator
- Plastic scintillator supports pulse shape discrimination - discrimination of neutrons and low LET component
- Focuses on measurements of neutrons



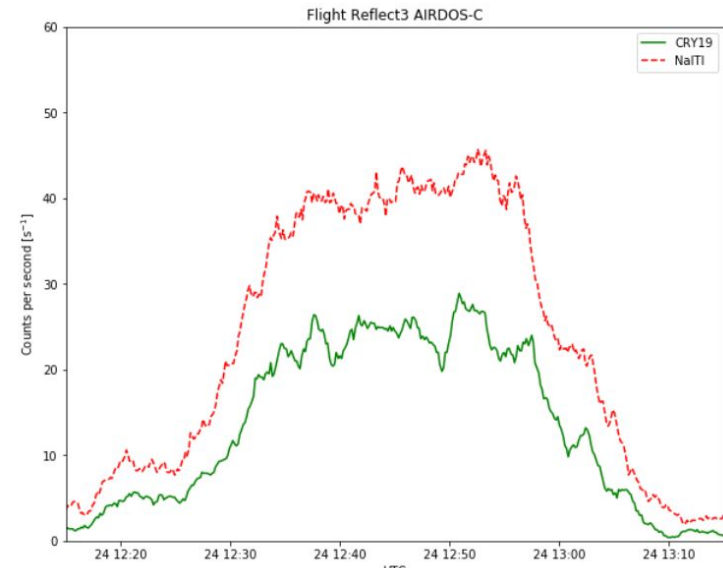
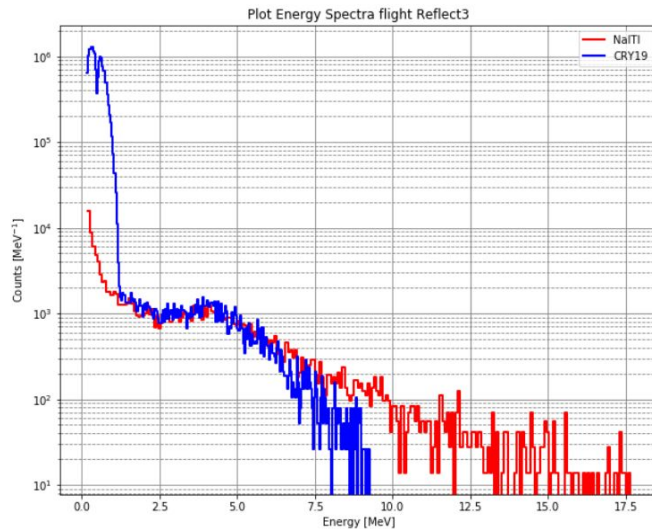
Suitable detector of thunderstorm radiation

Passive: TLDs, film dosimeters, ... long-term flight campaign will be in 2022

Active: [AIRDOSC01](#)



FWHM (keV), Energy resolution (%)				
Isotope	NaI(Tl)		CRY19	
Cs-137	139.00 keV	20.9%	121.35 keV	18.3%
Mn-54	196.51 keV	23.5%	132.61 keV	15.9%
Zn-65	243.95 keV	21.9%	101.06 keV	9.1%



REFLECT

REsearch FLight of EURADOS and CRREAT

- > 2h flight 29 Nov 2017, 1 flight level
- ABS Jets a.s., b. jet Embraer Legacy
- 10 countries, 12 institutes
- > 250 kg of instruments

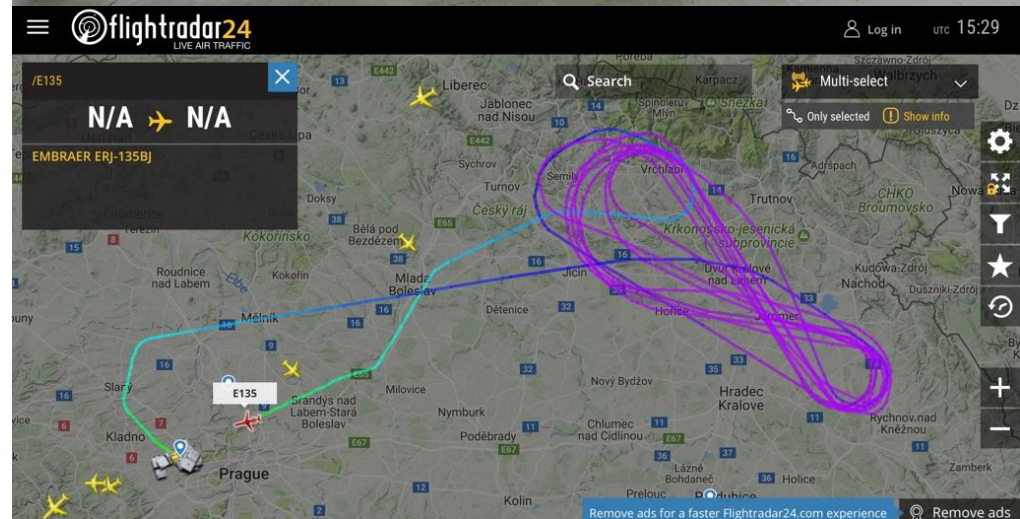
Main aims:

- Intercomparison
- validation of codes
- test of novel dosimetry methods

Ambrožová, Iva, et al. *Rad Meas* 137 (2020): 106433.

REFLECT 2, 3

- The same route, different detectors
- Shorter flight duration
- Dec 2020, Feb 2021



pREFLECT

= REFLECT with passive detectors

Action of Task 4:

Intercomparison of passive detectors onboard aircraft

- various passive detectors (TLD, OSL, RPL, D-shuttle, CR-39....) inside Al box (17 x 23 x 5.5 cm) together with Airdos + Liulin (as reference)
- several months onboard aircraft
- postponed until situation with air traffic becomes better
- onboard aircraft of Smart Wings from March 15th

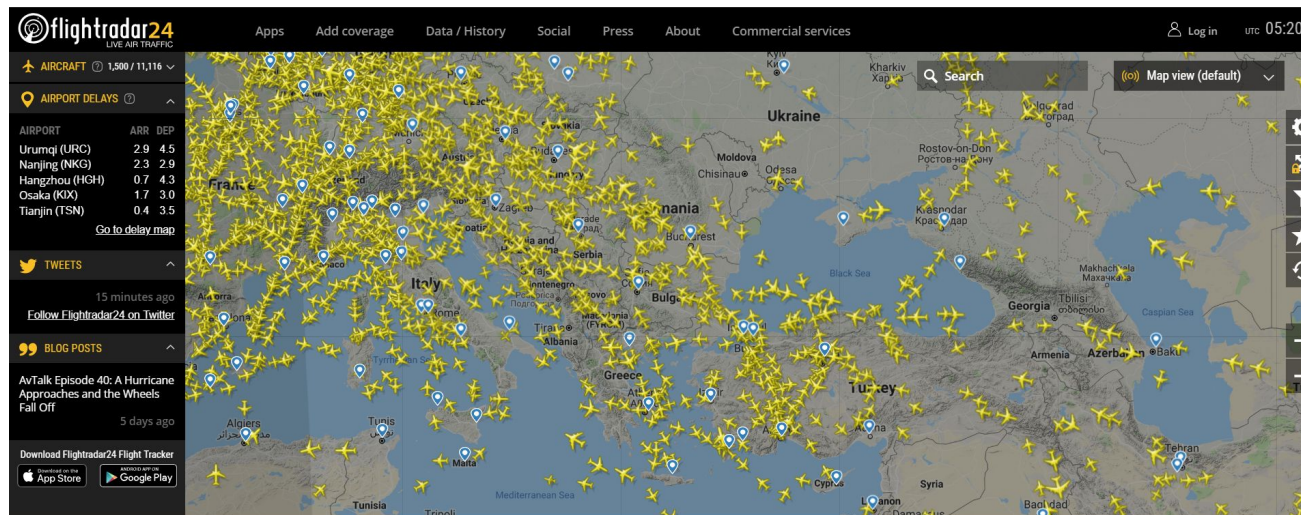


Radiation dosimetry onboard aircraft during thunderstorms

as many as possible radiation detectors (also gamma) installed onboard aircraft (by now: Czech Airlines, Smart Wings, ABS Jets, Air Stream Jets)

Evaluation of the flight path

- GPS onboard
- Data from the company
- **ADS-B receiver and access to the database FlightRadar24**



Conclusions

Radiation phenomena in thunderstorms can pose serious radiation risk to aircrew and passengers

Project **CRREAT** focuses to prove it by radiation measurements at different altitude levels

Method for evaluation of dose equivalent caused from thunderstorm radiation onboard aircraft was proposed, first steps were made.

Flight campaigns open for scientific community

Future: equip as many aircraft as possible with dosimeters sensitive also to high-energy gamma





Thank you for your attention!