Three years of Mini-EUSO telescope on board the International Space Station

M. Casolino
The JEM-EUSO collaboration

7-10-2022

The EUSO program

1. **EUSO-TA:** ***Ground detector installed in 2013 at Telescope Array site: currently operational***

2. **EUSO-BALLOONS:**
   - ***2014, Timmins, Canada***
   - ***2017 NASA Ultra long duration flight. EUSO-SPB***

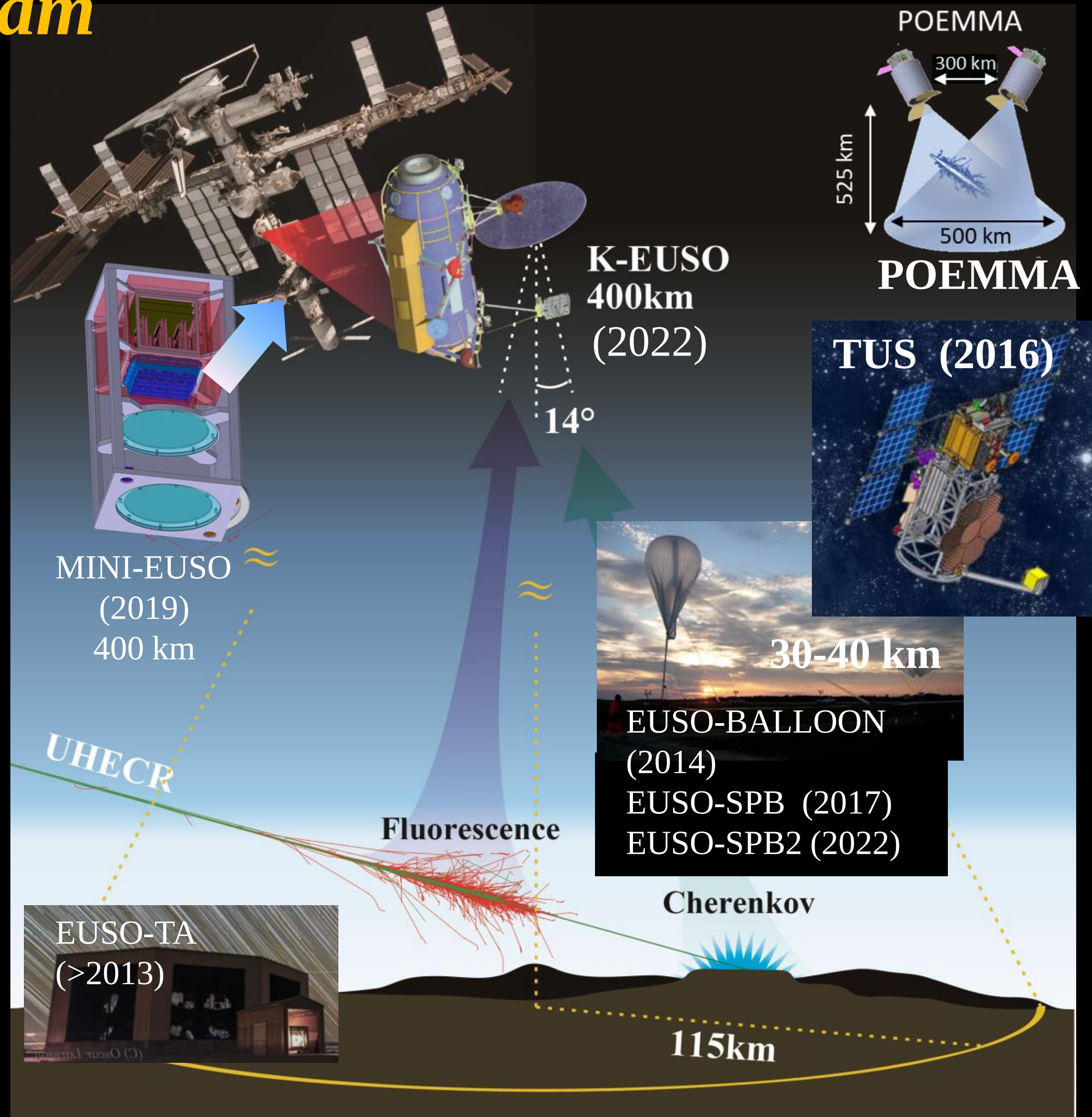
3. **TUS (2016):** free-flyer on Lomonosov Russian Satellite

4. **MINI-EUSO (2019):** ***Detector from International Space Station (ISS): 40 kg total.***

5. ***SPB-2 (NASA) (2023)***

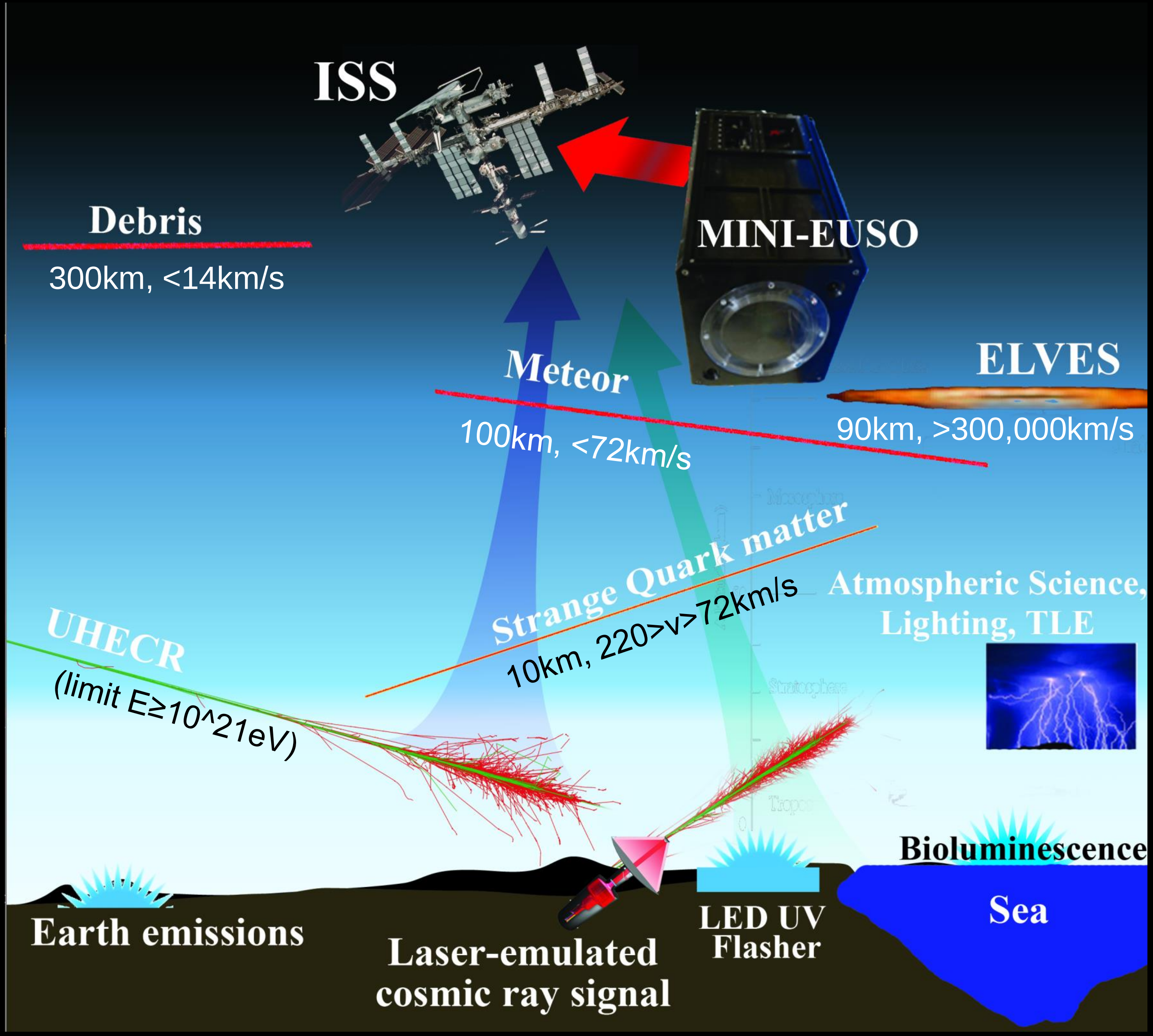
6. **K-EUSO (2025+):** ***ISS Phase A, Russian Space Agency***

7. **POEMMA (2025+):** ***NASA twin free-Flyer***



JEM-EUSO collaboration   16 Countries, 93 Institutes, 351 people

Science Objectives



Mini-EUSO/UV-Atmosfera

JEM-EUSO collaboration 16 Countries, 93 Institutes, 351 people

40kg, 60 W, 62*37*37 cm3

Ultraviolet, with Fresnel lenses

Near Infrared camera

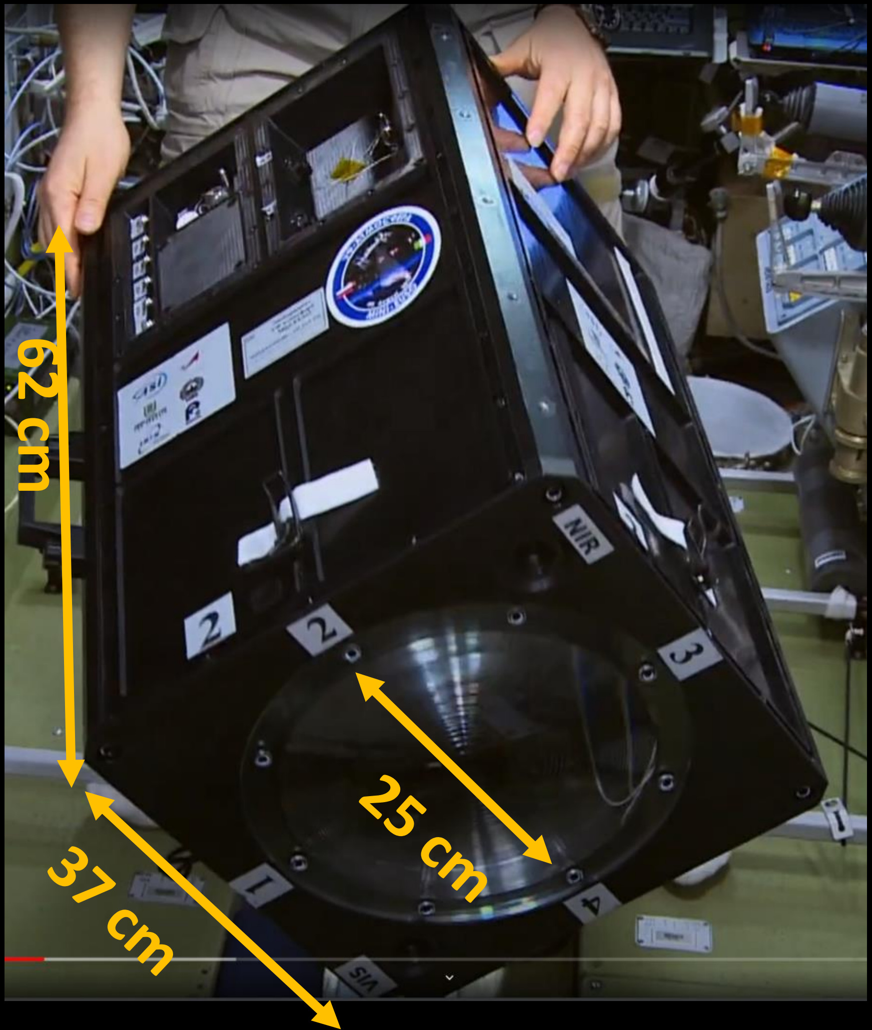
Visible camera

SiPM

2304 pixel

Same light/pixel of K-EUSO design

HVPS switch and dynamic range extension



Mini-EUSO: A high resolution detector for the study of terrestrial and cosmic UV emission from the International Space Station. ASR 62(10):2954{2965, Nov 2018.

Capel, F., et al. Mini-EUSO data acquisition and control software. JATIS, 5(4), OCT 2019. ISSN 2329-4124. doi:10.1117/1.JATIS.5.4.044009.

The integration and testing of the Mini-EUSO multi-level trigger system, ASR62 Issue: 10 Pages: 2966-2976 , 2018

Focal Surface

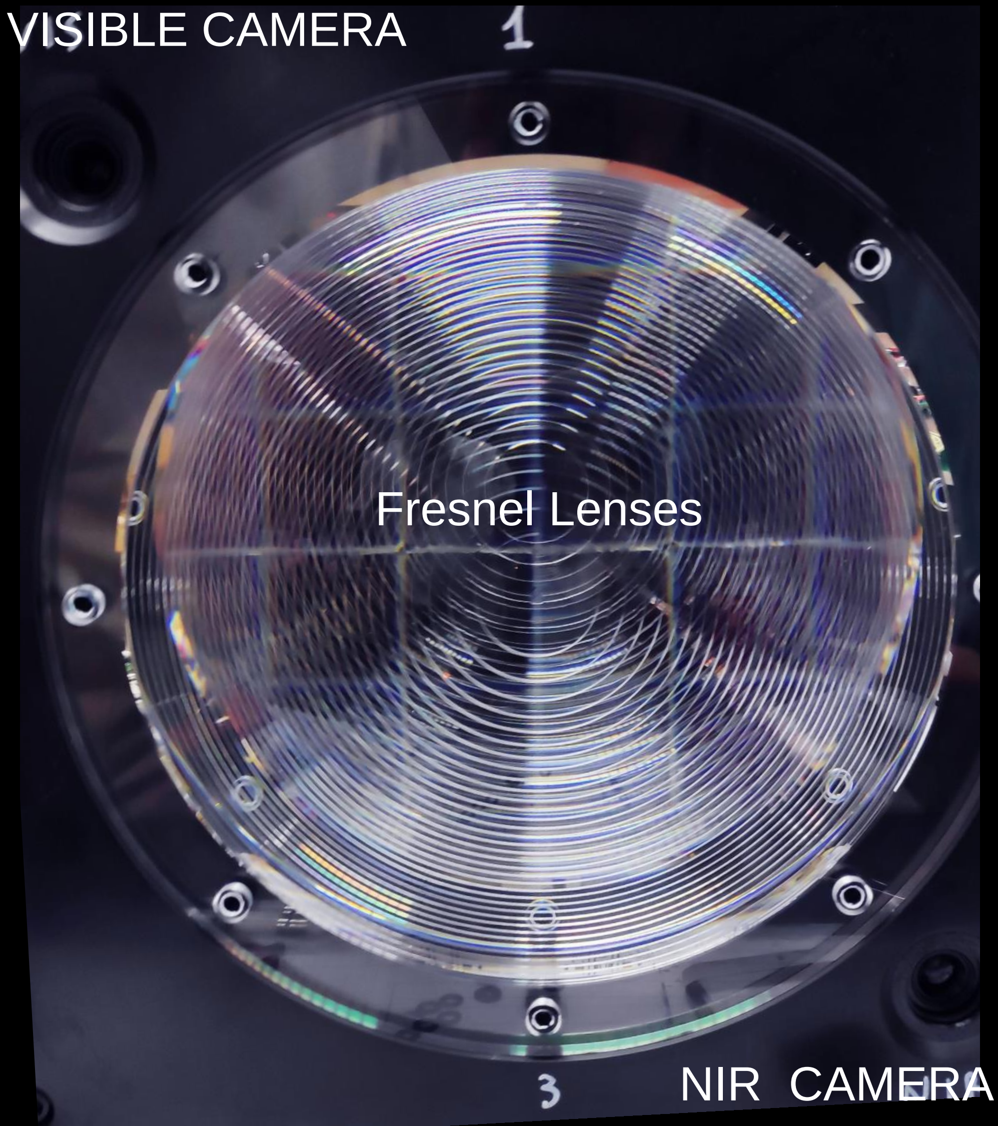
Silicon Photomultipliers
C14047-3050EA08
8*8 pixel Imaging system

C13365 single pixel

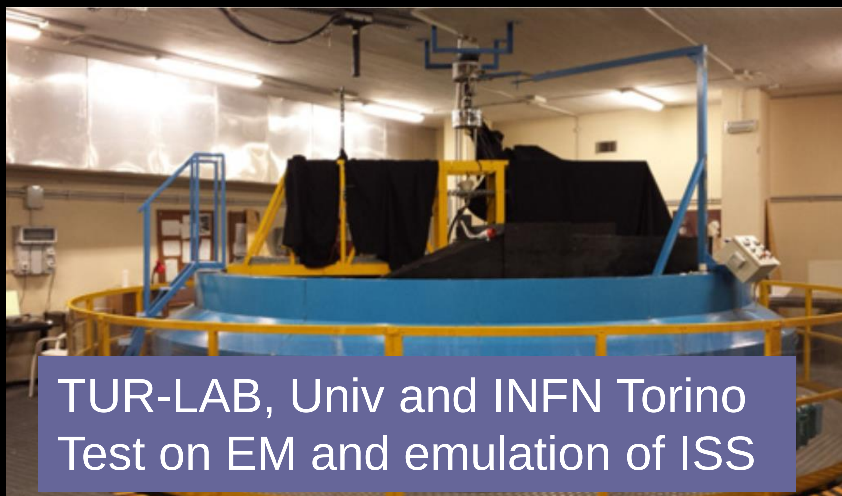
Light sensors
Hamamatsu
S1226-5BQ log
190-1000nm

ML8511 linear
280-400 nm

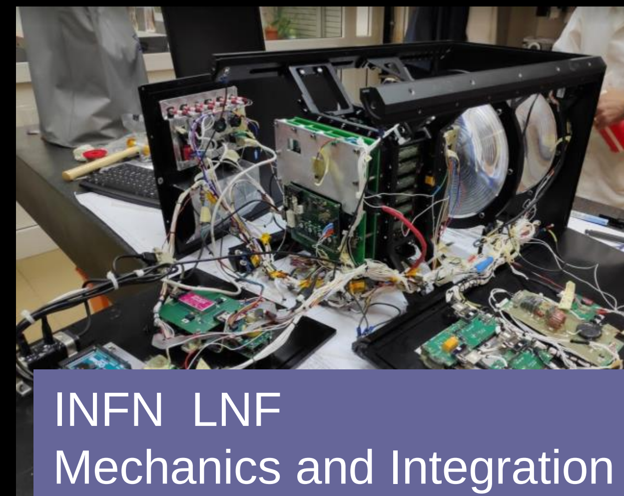
Fresnel Lenses



Test and Integration of EM and FM 2017-2019



TUR-LAB, Univ and INFN Torino
Test on EM and emulation of ISS



INFN LNF
Mechanics and Integration

INFN Tor Vergata
Qualification and Acceptance procedures

INFN Tor Vergata
Sky tests

Roll-out of Soyuz MS-14, 19/8/2019

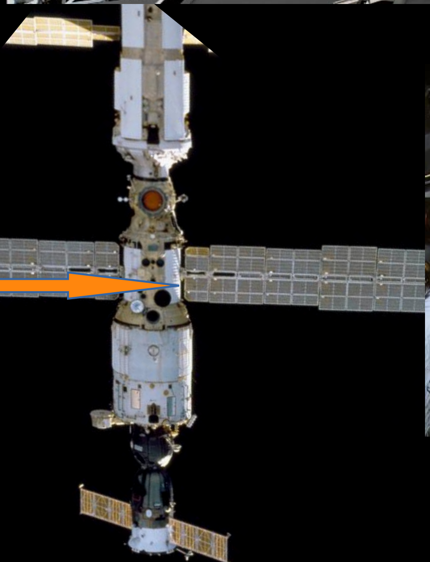
Launch, 22/8/2019

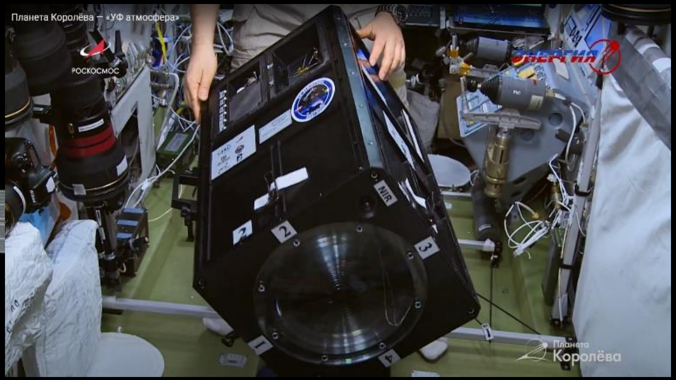
First docking, 24/8/2019 unsuccessful

Relocation of MS-13 from Zvezda to Poisk

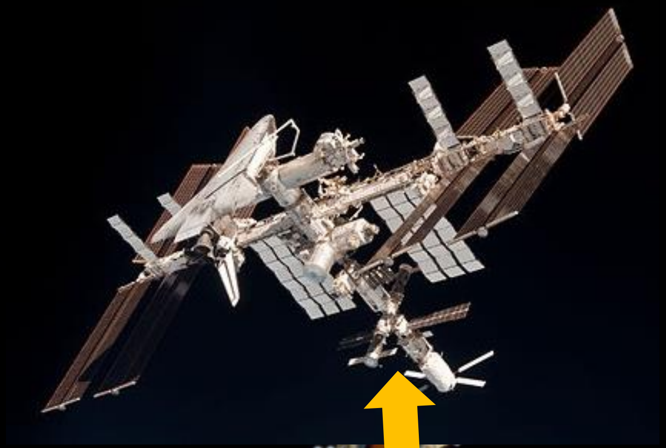
Second docking, 27/8/2019 successful

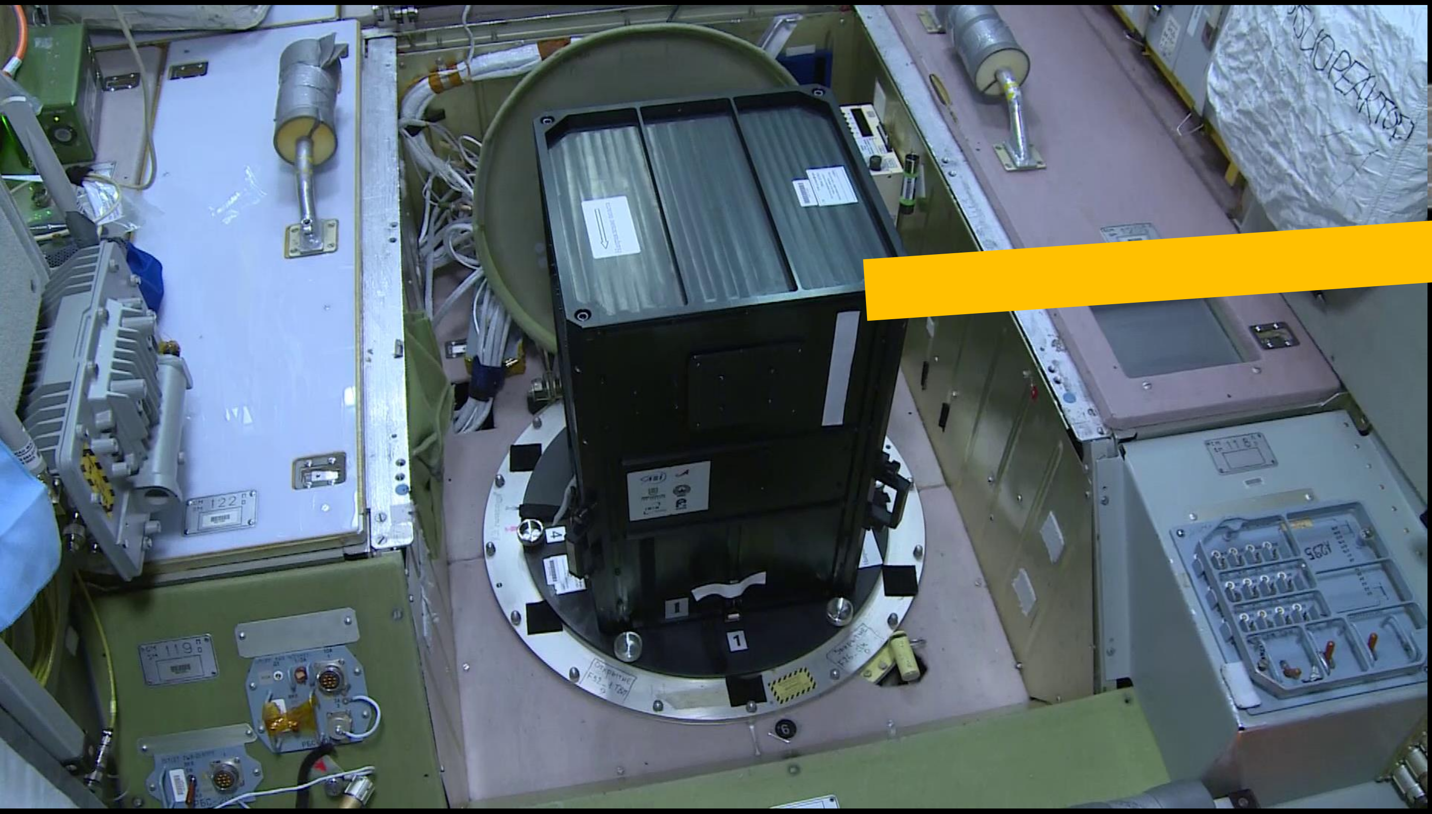
Installation - Uv transparent window Zvezda module, 07/10/2019

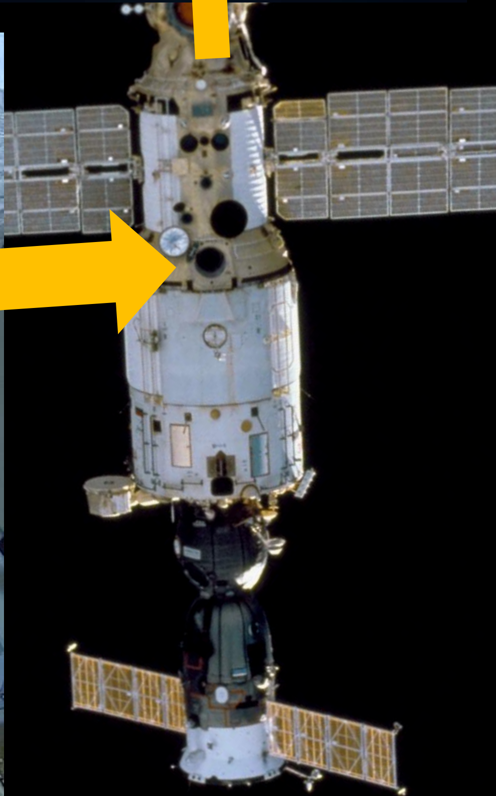




Uv transparent window, Zvezda module, International Space Station





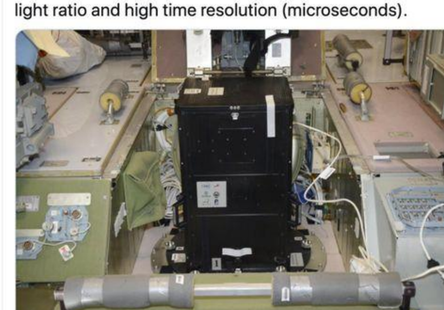


Sergei Kud-Svertchkov

Ivan Vagner
@ivan_mks63

Using the wide-angle UV emission detector, we conducted an #experiment 'UV Atmosphere'. It is aimed to get the atmosphere nocturnal glowing in the close UV wavelength.

This new experiment has its advantages: detector high light ratio and high time resolution (microseconds).

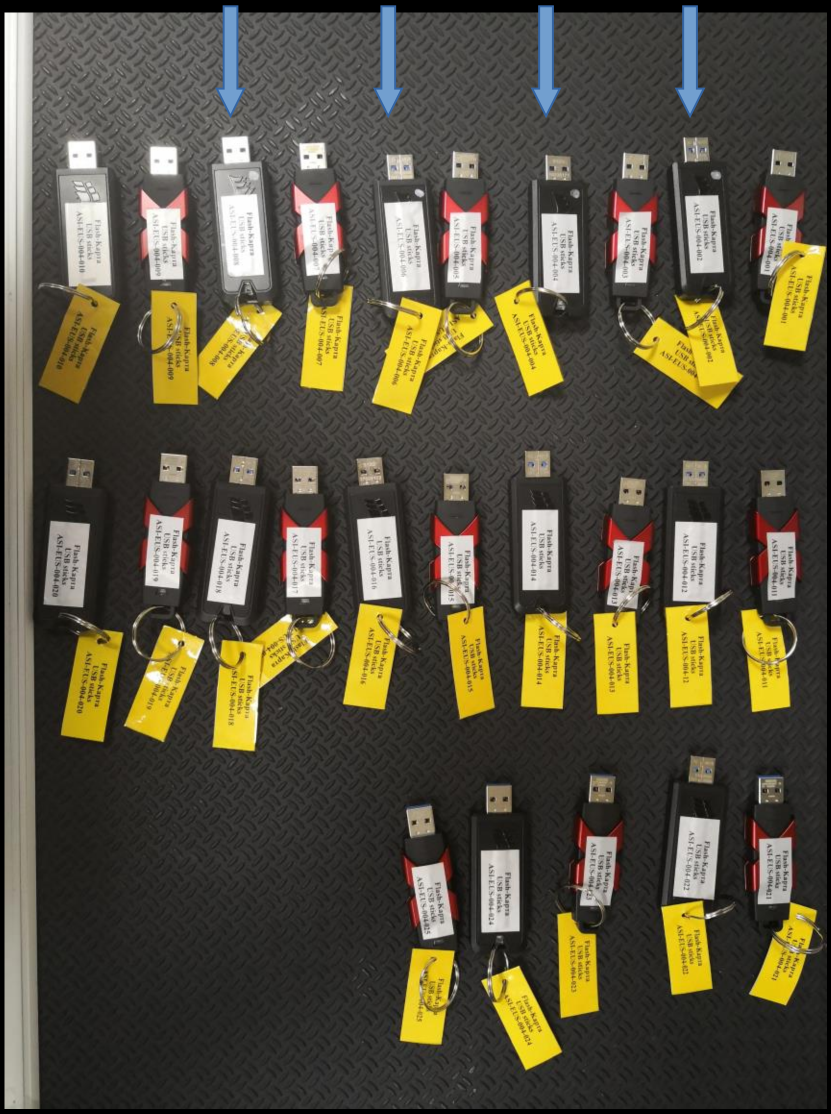


6:21 PM · Jun 29, 2020 · Twitter Web App


novitskiy_iss • Segui
novitskiy_iss Приветствую, друзья! Сегодня вместе с Тома Песке подсчитали, что мой общий налет равен 365 суткам. То есть ровно год в космосе за два полных полета и почти месяц третьего. Быстро время летит))
Наша вахта продолжается и мы продолжаем работать! А как проводите вы эти длинные майские выходные, у кого какие планы?
///
Piace a cesar_ventura06 e altri 2.967
Aggiungi un commento


novitskiy_iss • Segui
novitskiy_iss Знакомьтесь, это — широкоугольный детектор ультрафиолетового излучения ночной атмосферы. Этот телескоп предназначен для исследования кратковременных вспышек в земной атмосфере.
Целью эксперимента с одноименным названием #УФатмосфера является получение карты свечения ночной атмосферы в полосе длин волн ближнего ультрафиолета (300-400 нм) в пределах широт, доступных для наблюдения с орбиты полета Международной космической станции.
Piace a pilot.alexander e altri 2.397
Aggiungi un commento...
Pubblica

Pouch 004 refurbishment



CORSAIR 3.1 – new model

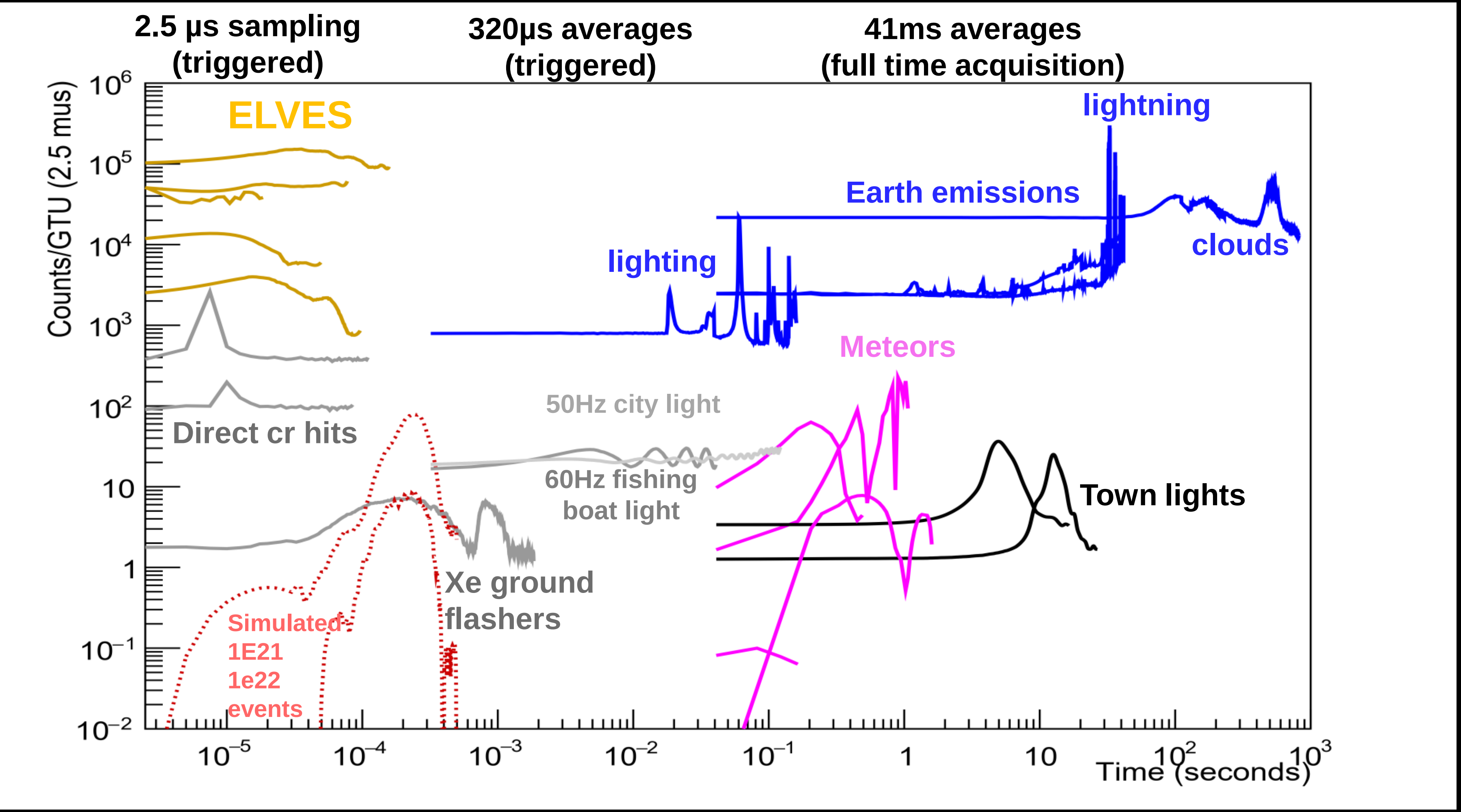
CORSAIR 3.0 – old model
Continuous CPU reset
No longer used

KINGSTON 3.0
Currently used – slow

Pouch 004 - v2 - will be completely equipped with CORSAIR 3.1 pens

From L. Marcelli

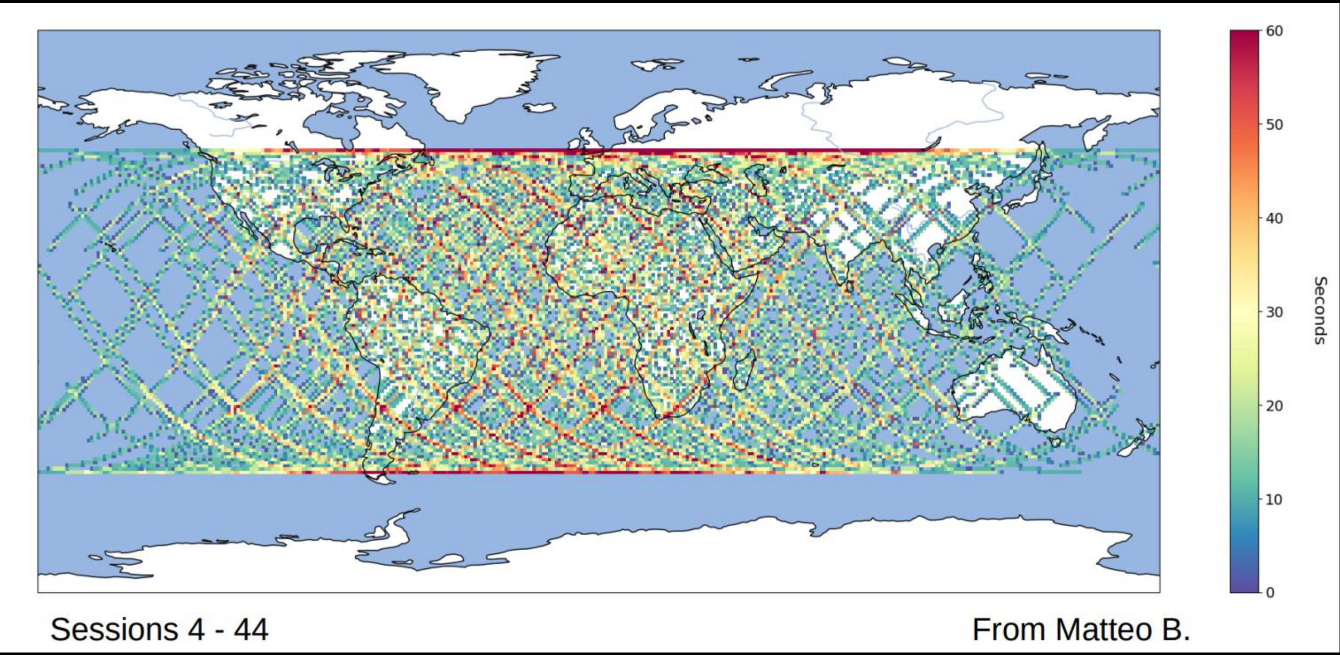
Time profile of various events



Earth Coverage

Now 61 sessions
Other 9 planned
by end 2022 other
10 by March 2023

120+ hours of
crew time



Clouds and sea emission

2019_12_05 18:30 UTC

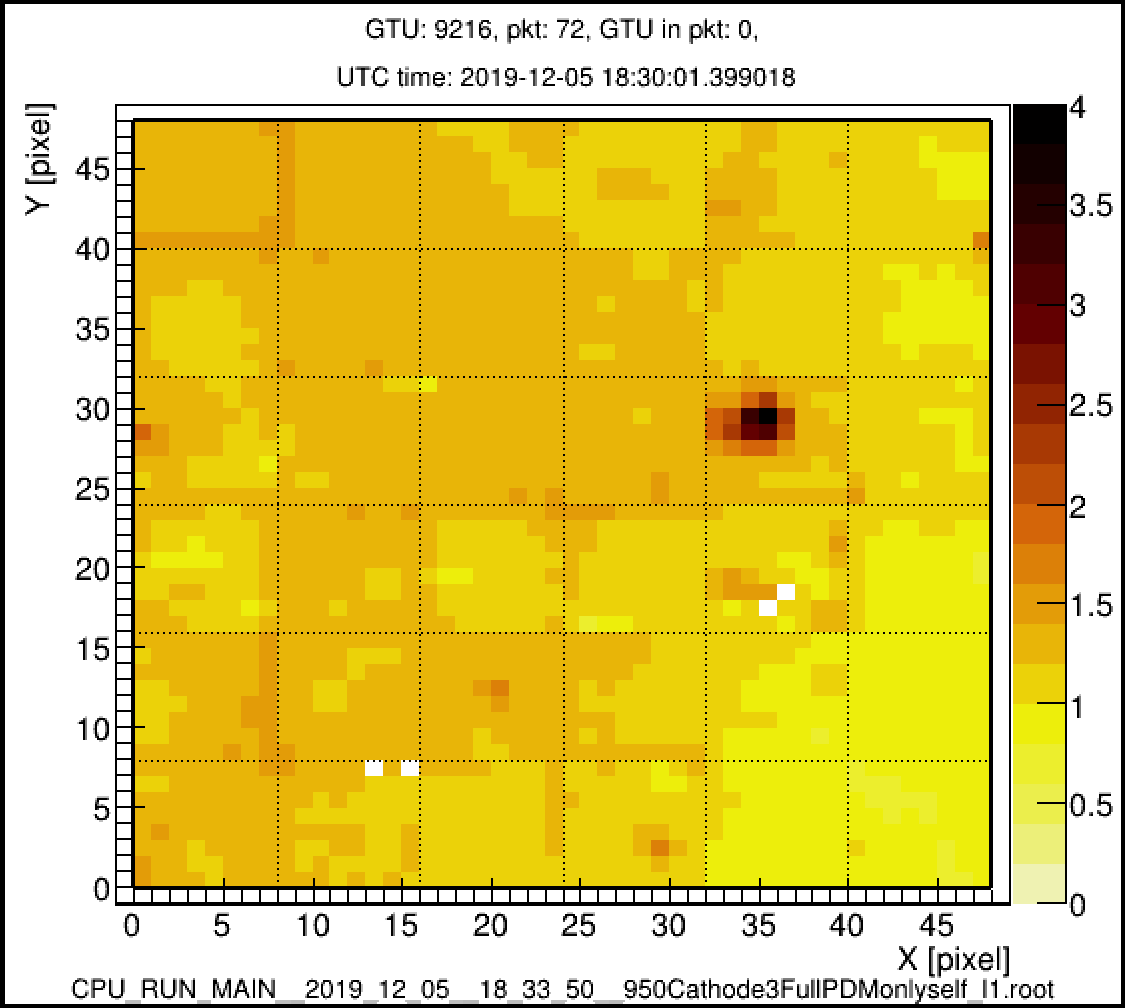
Counts/pixel/GTU

Indian Ocean

Pixel size 6.1km

ISS speed 7km/s

Yaw of 4 degrees

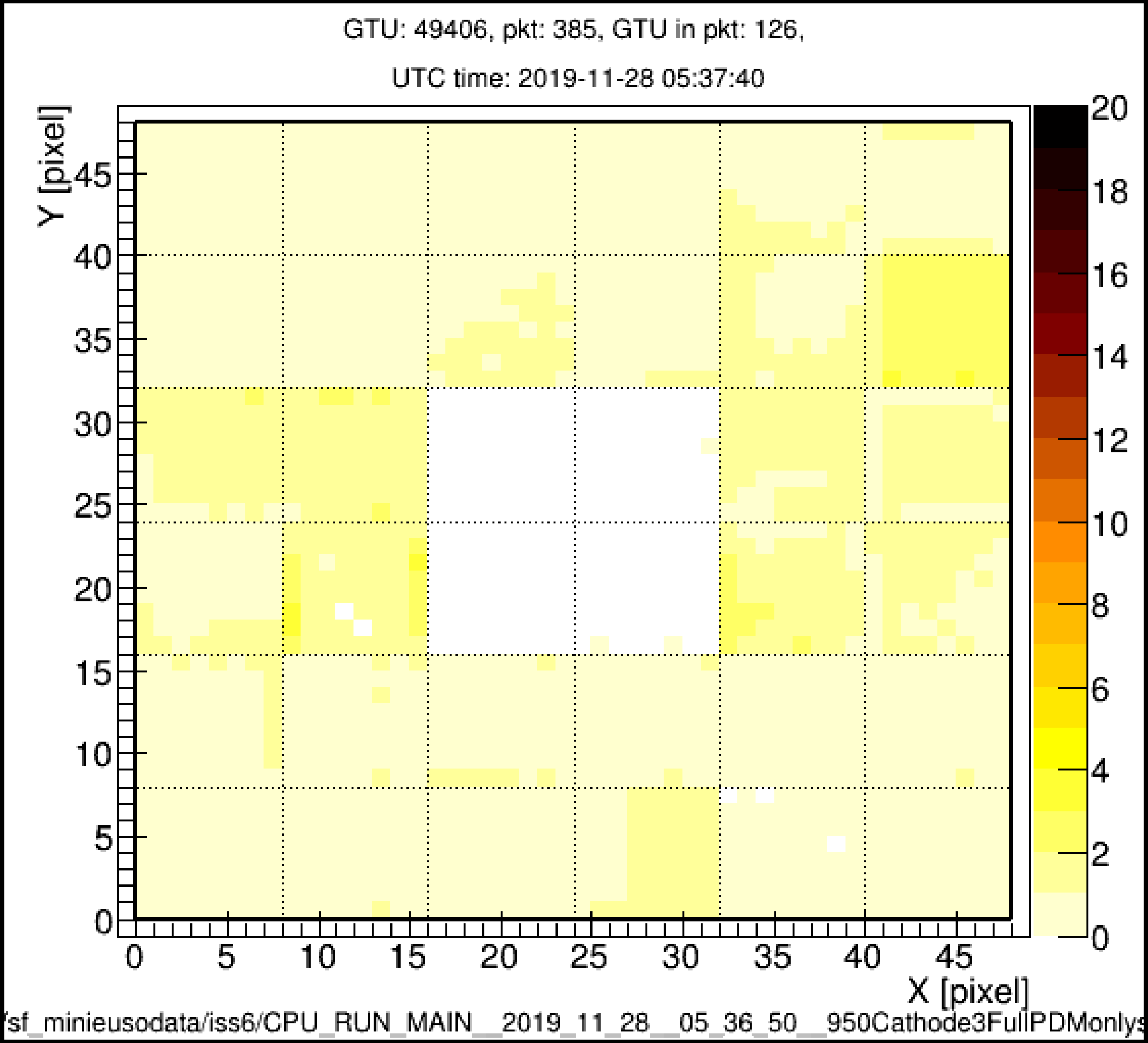


1 frame = signal integrated in 40.96 ms

~14 min video (1 frame every 128 frames) ~5s

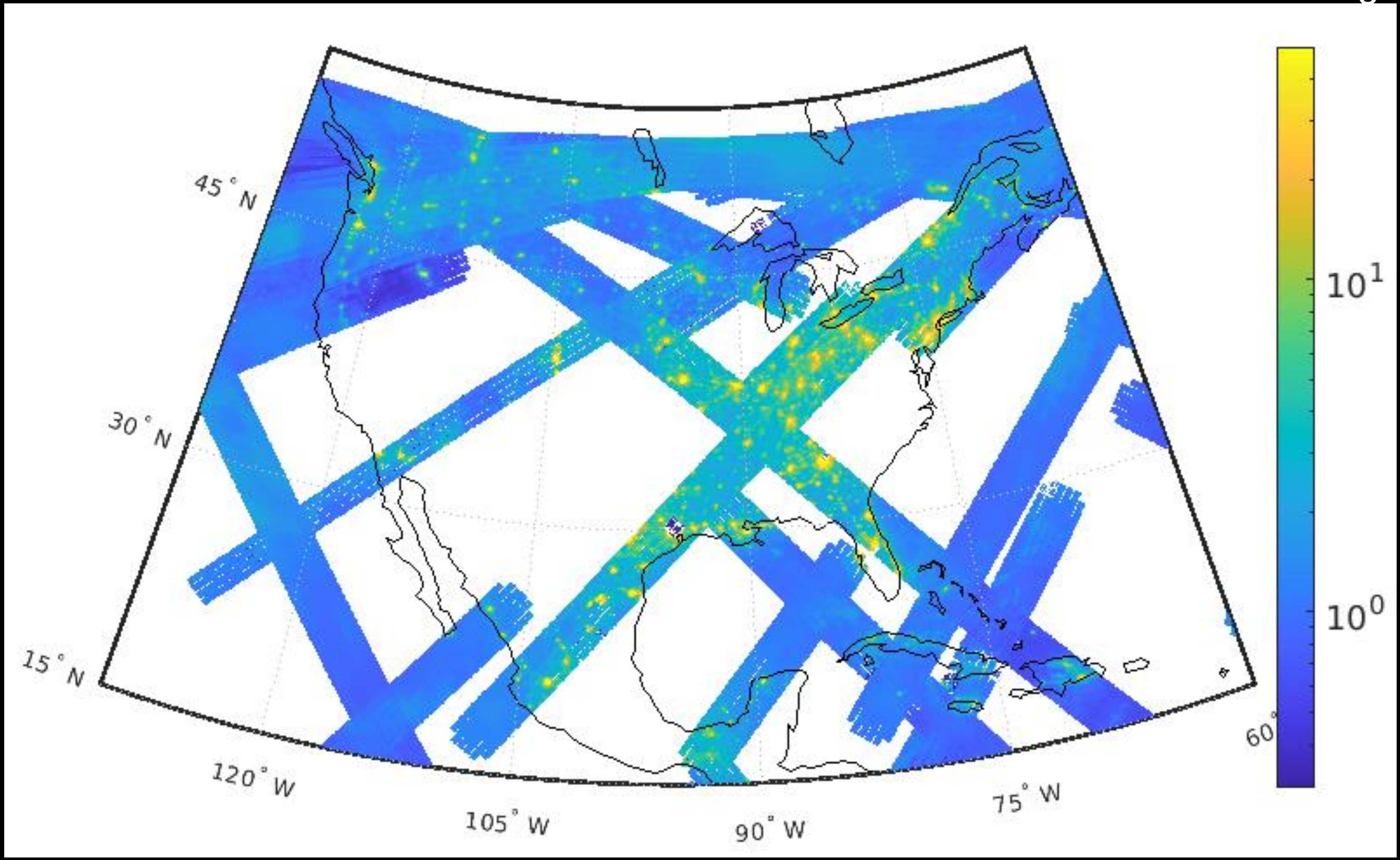
Lightning and protection of focal surface

40 ms



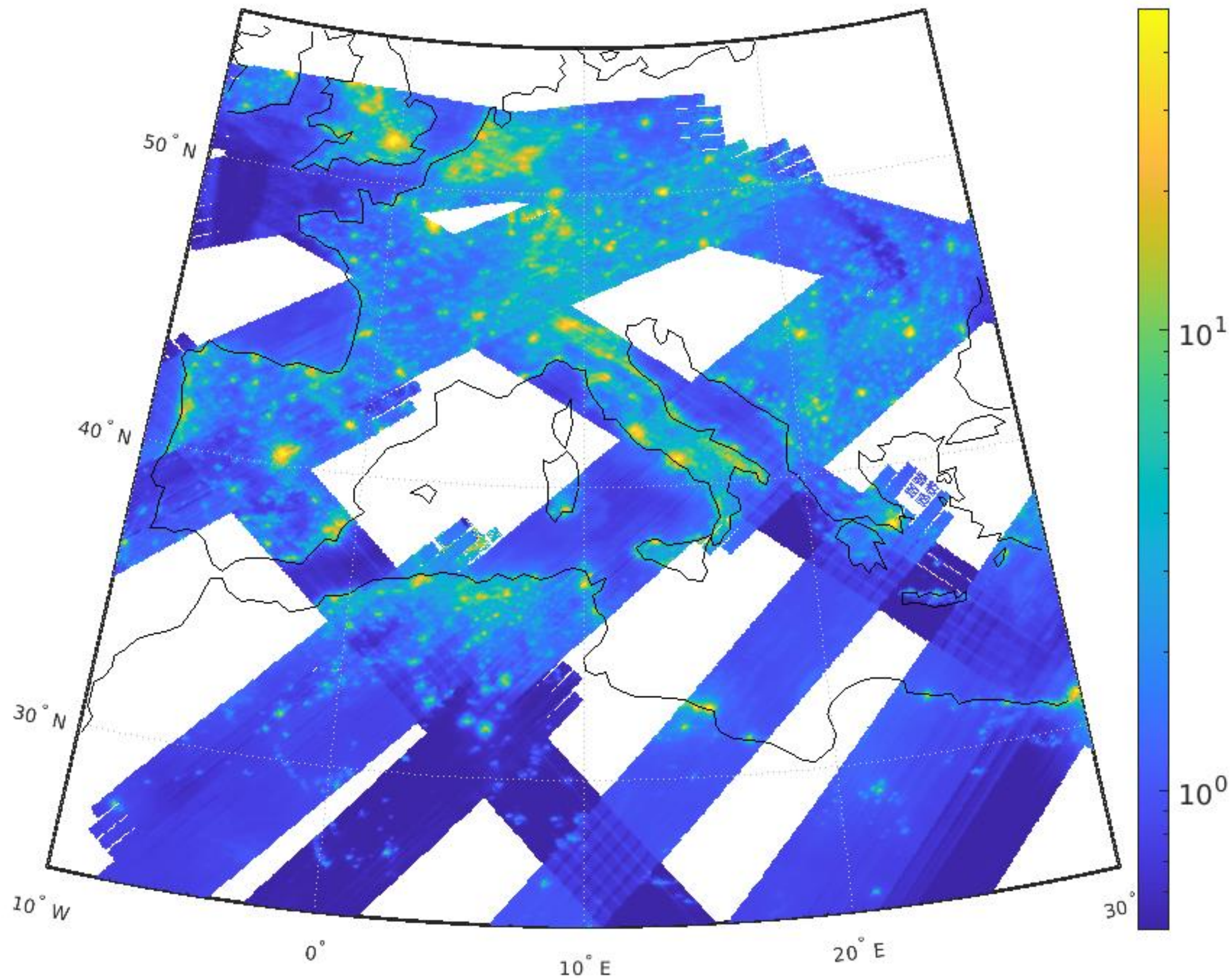
Northern America

K. Bolgrem

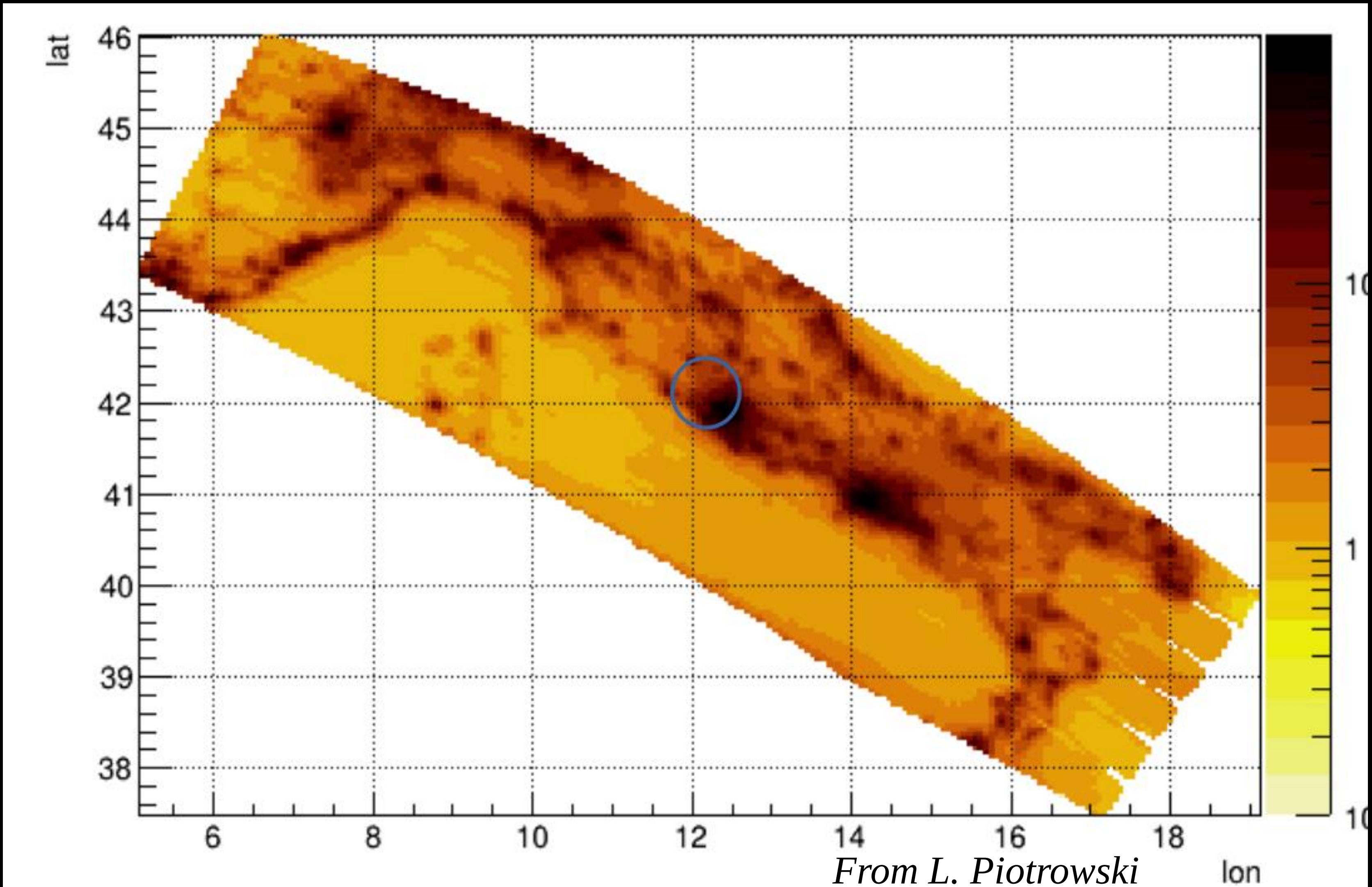


E1.3-0092-22 K. Bolgrem *Spatial and temporal variations of UV emissions observed by the Mini-EUSO detector*

Europe



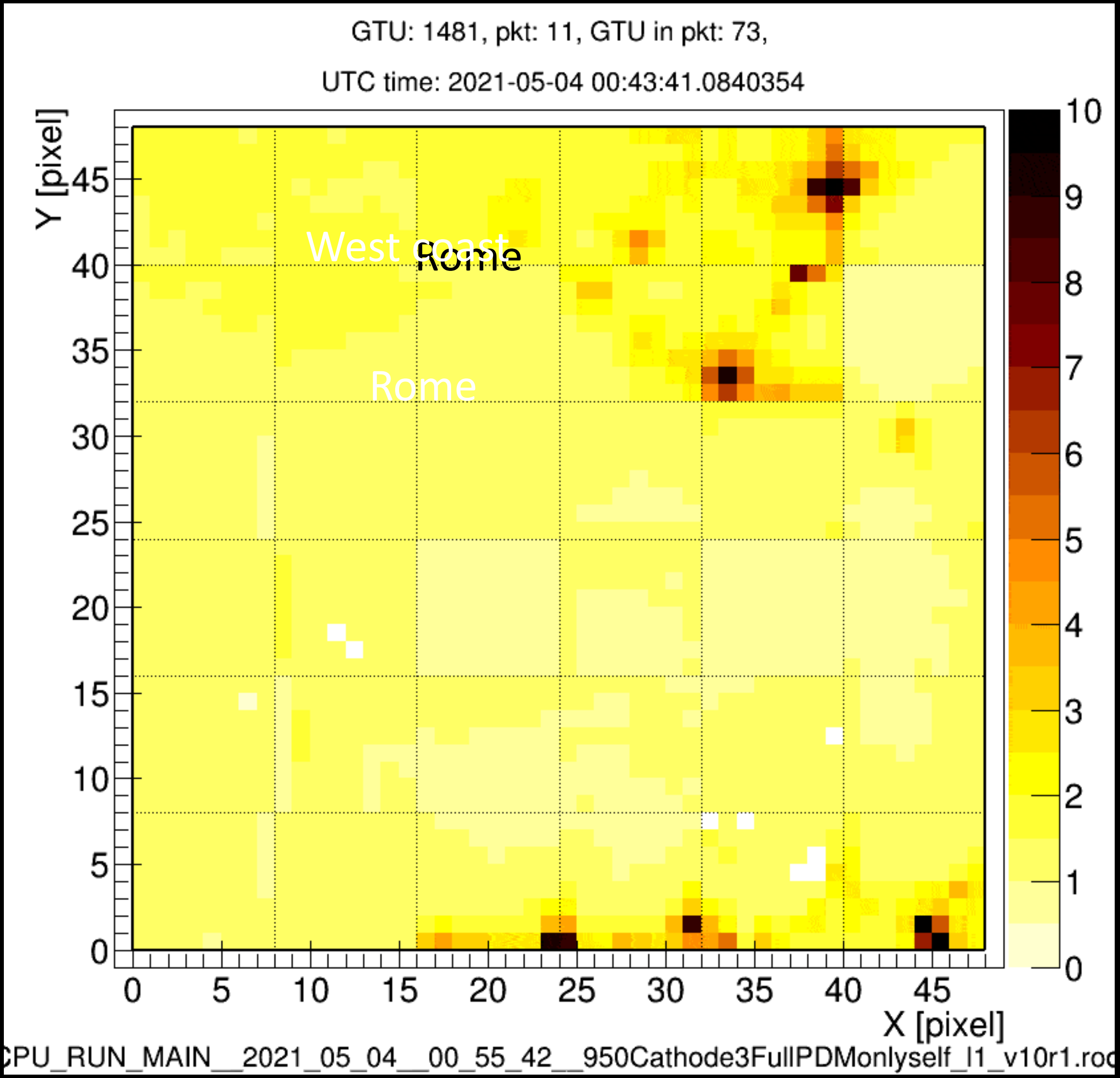
Italy, 15-9-2019



From L. Piotrowski

1count about 1E20 ph/km2 s sr

Shower simulation and end-to-end calibration with ground UV laser and UV flasher



see Hiroko's poster *An end-to-end in-flight calibration of the Mini-EUSO detector*

Cyclonic activity (no moon)

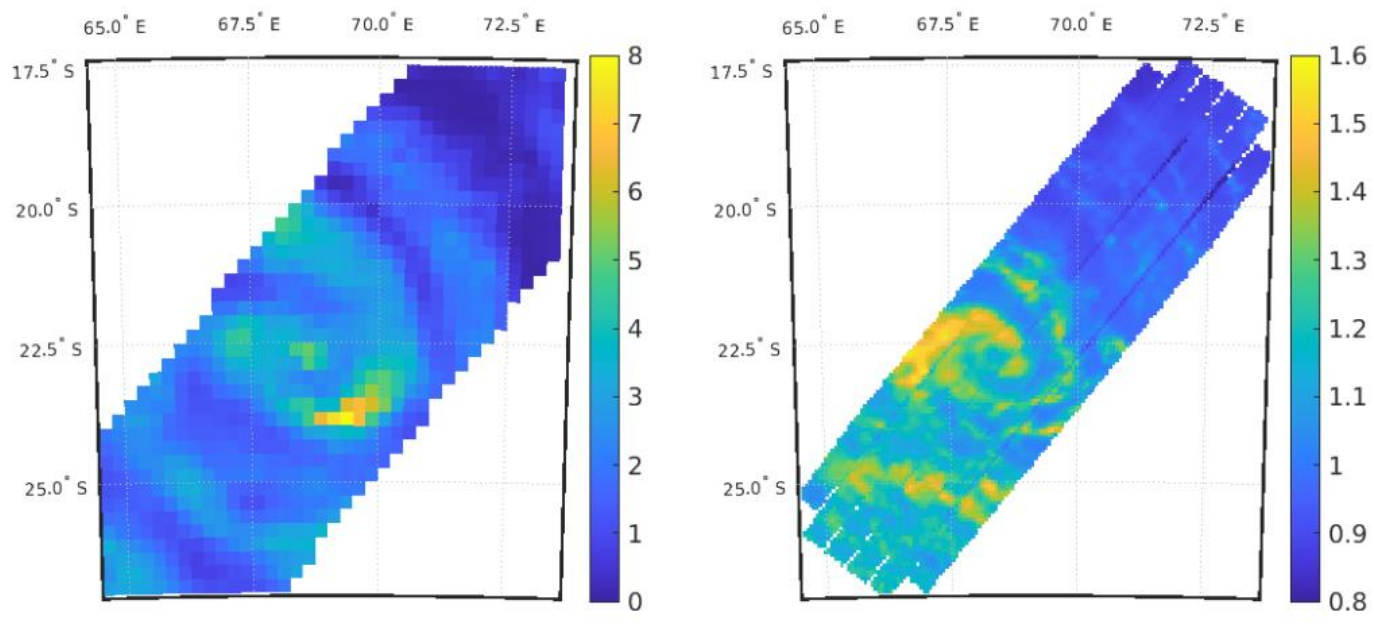
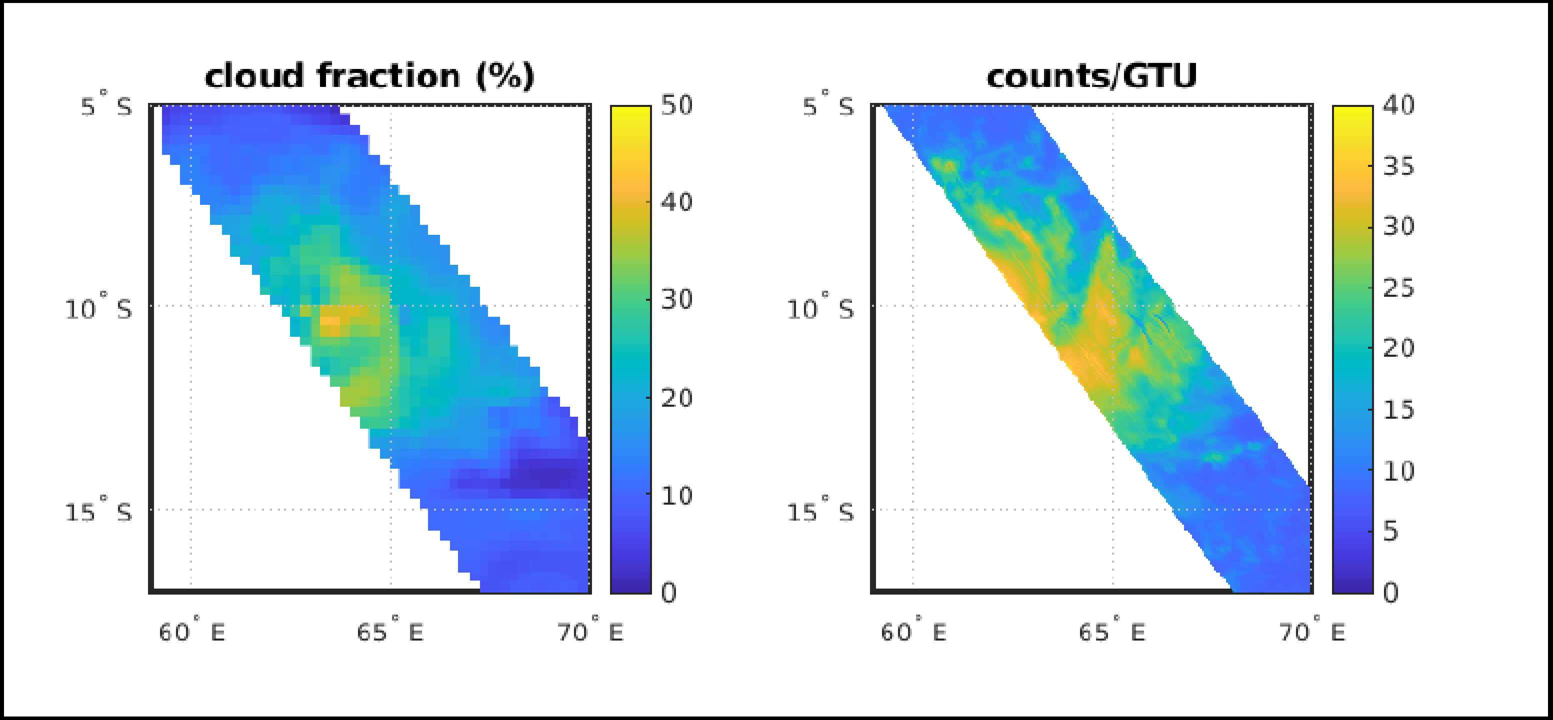


Figure 17. Modelled cloud fraction (%), 0.25° × 0.25° resolution (left) and Mini-EUSO UV counts in 0.05° × 0.05° map cells (right). Acquisition on 21-02-2020 22.00 UTC, ≃ 1000 km East of Mauritius island. In this case the Moon was below the horizon (−27.6°), therefore the cloud brightness is about 1.6 counts.

Moon elevation -27.6 degs

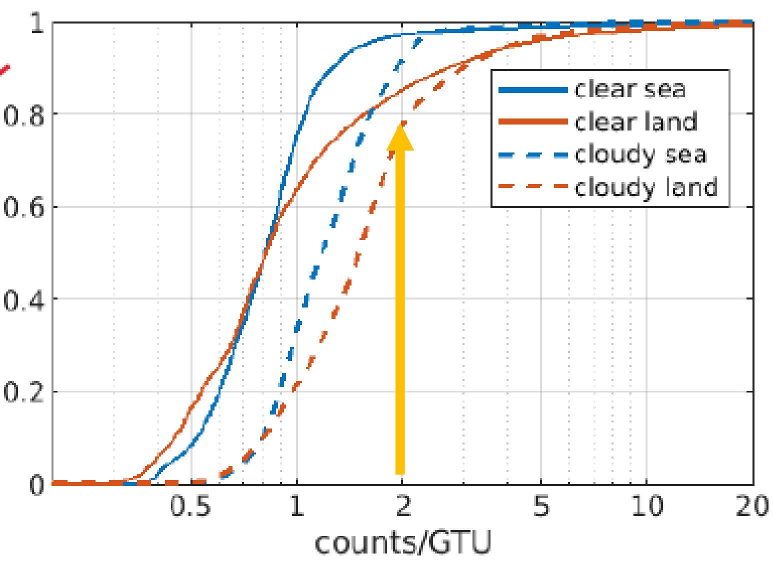
Cyclonic activity (moon)

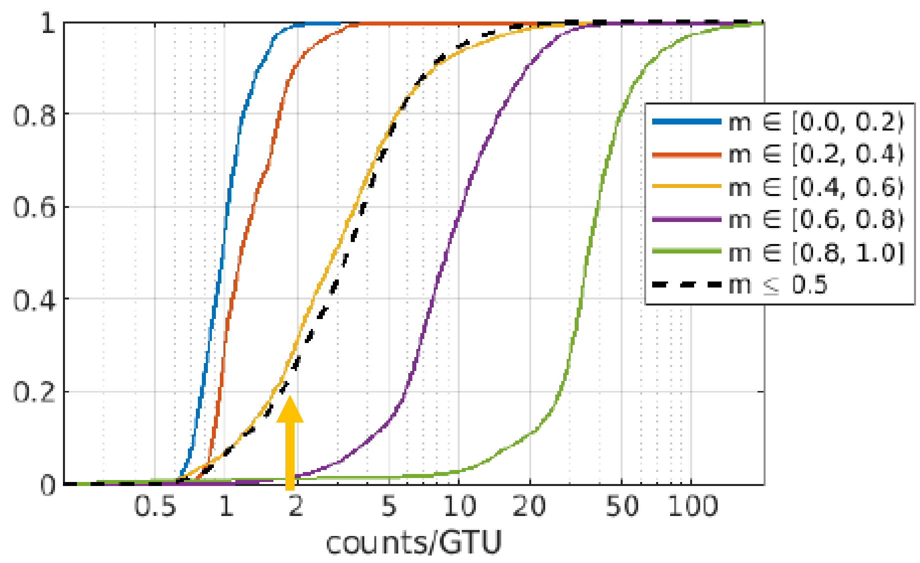
Model　　　　　　　　　　Data



Moon phase 0.64 Moon elevation 33.9 degs

Background distribution

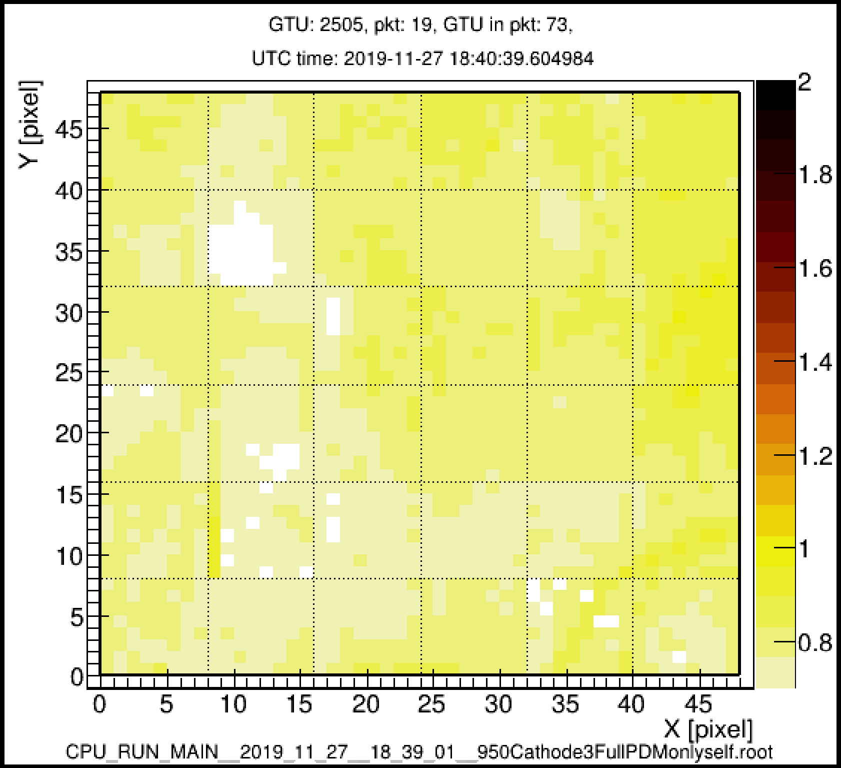


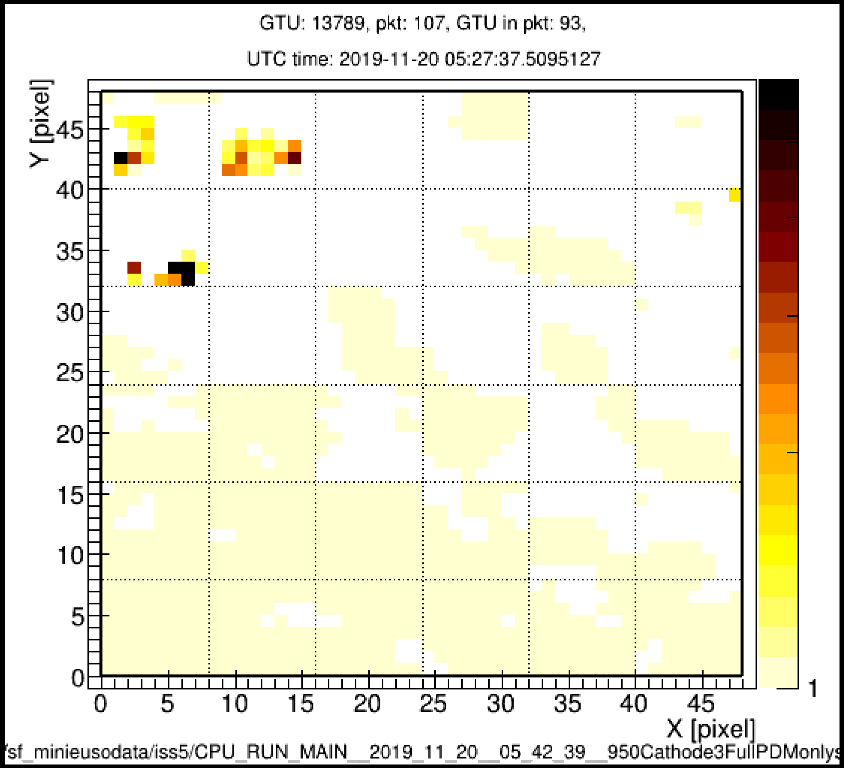


Clear conditions

Moon Phase

Meteors, Interstellar meteors and Search for Strange quark matter





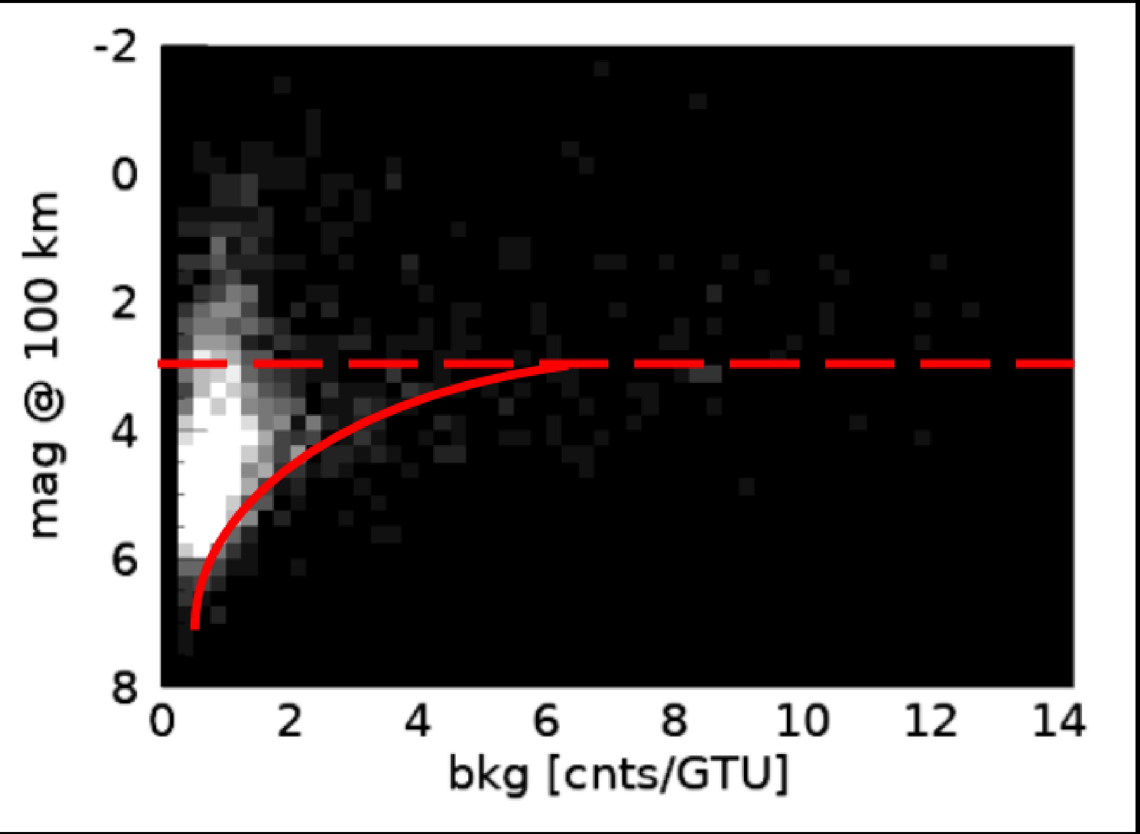
Meteor studies in the framework of the JEM-EUSO program. PLANETARY AND SPACE SCIENCE, 143(SI):245{255, SEP 1 2017.

JEM-EUSO: Meteor and nuclearite observations. Experimental Astronomy, 40:253{279, November 2015.

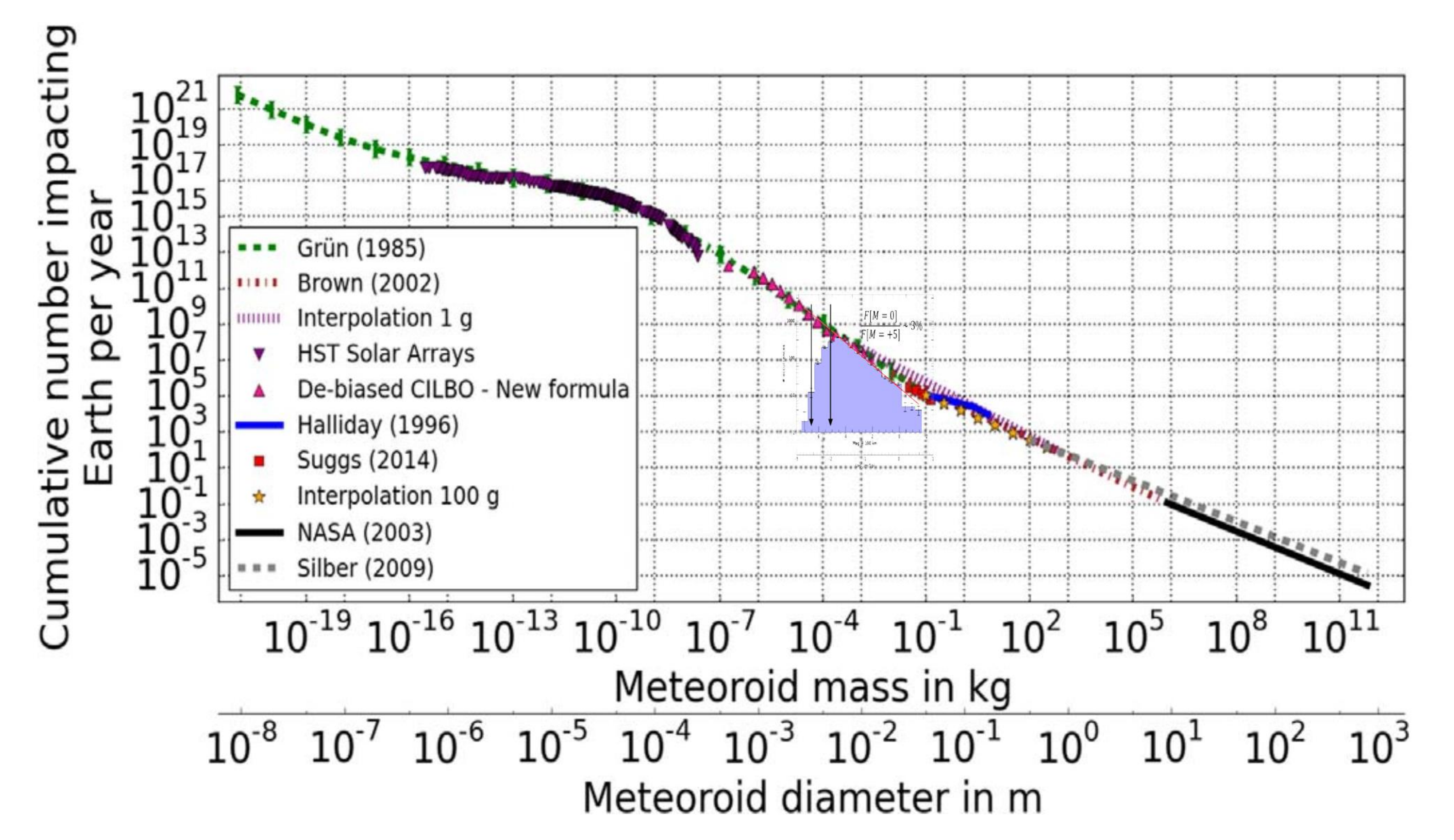
Background - Efficiency

Limiting magnitude
+ 6.5m (mass ~3 mg)

- Not completely efficient below +5m (mass ~10 mg)



Solar system meteors

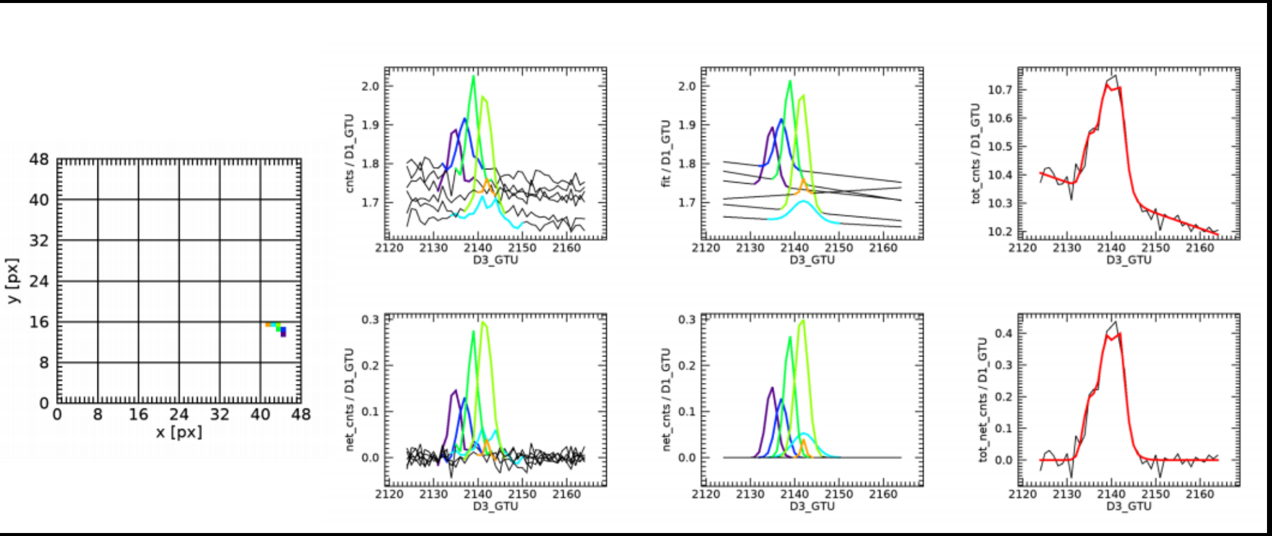


Magnitude and velocity of meteors

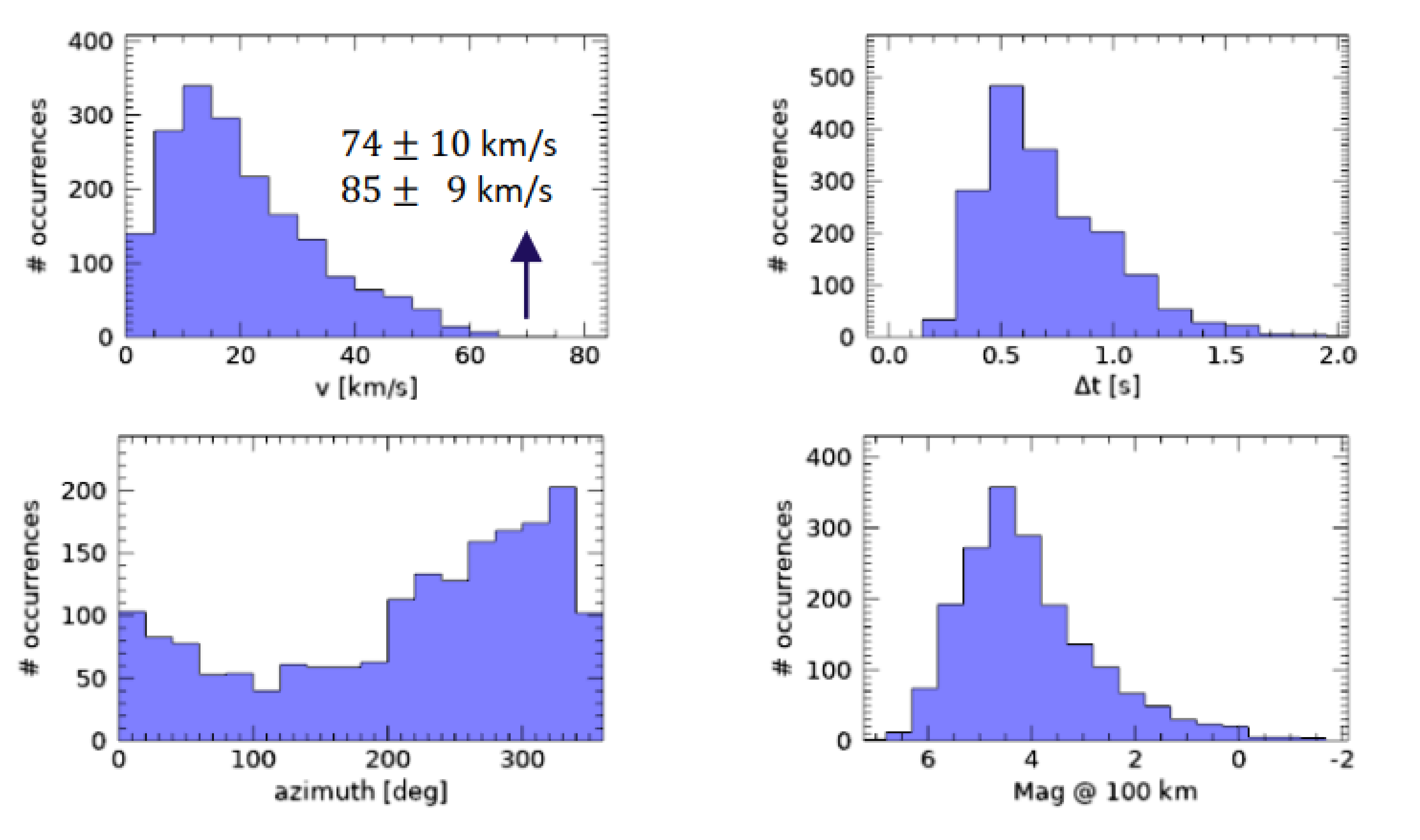
10000 meteors
detected so far

Magnitude down to +6.5

2D velocity projection
(lower estimation)



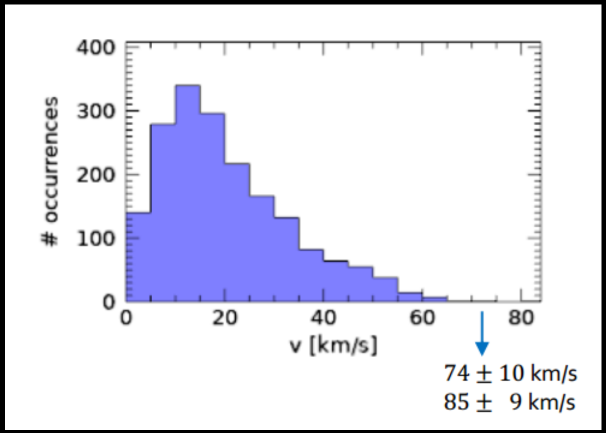
From M. Bertaina, D. Barghini, H. Miyamoto L. Piotrowski

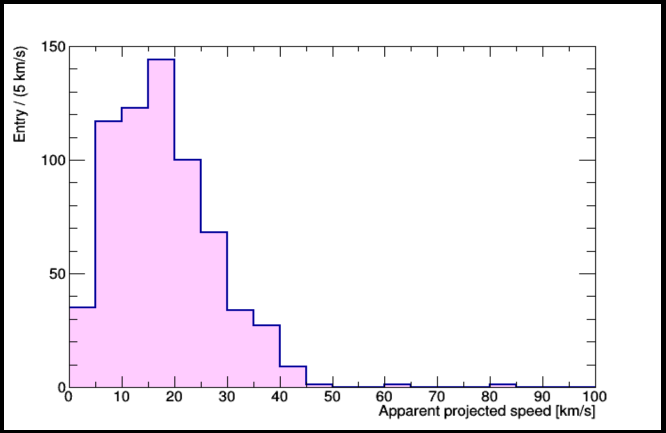


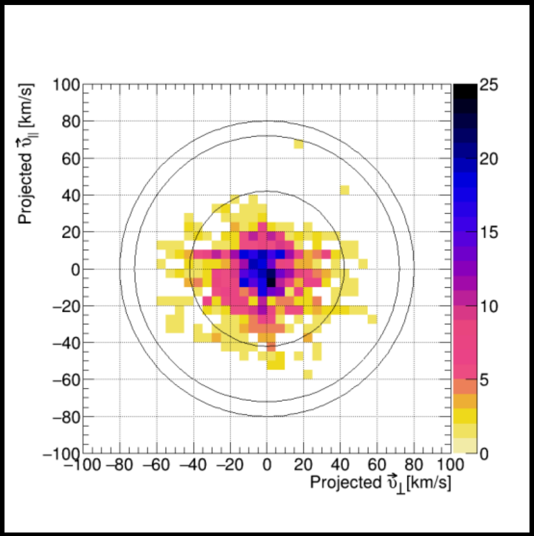
74 ± 10 km/s
85 ± 9 km/s
occurrences
v [km/s]
Δt [s]
azimuth [deg]
Mag @ 100 km

Meteors and candidate for Interstellar meteors

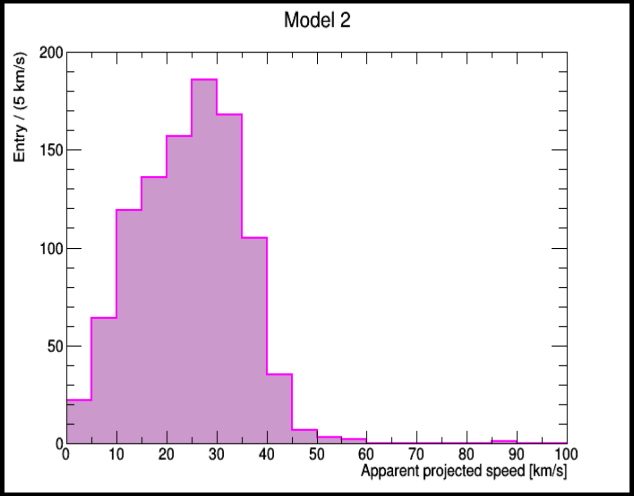
Earth centered coordinates

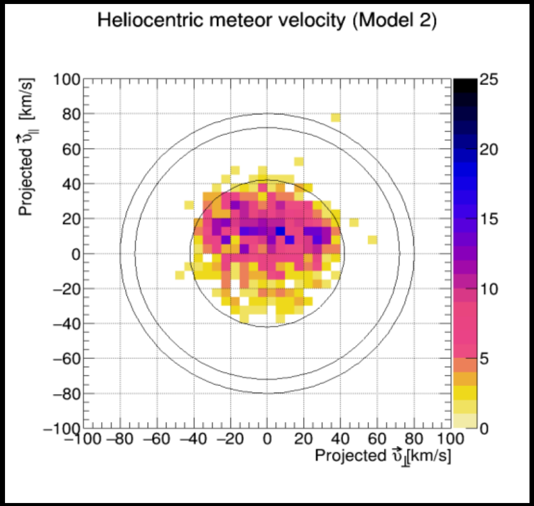






Sun centered coordinates





From Kenji Shinozaki

Interstellar meteoroid flux and u.l.

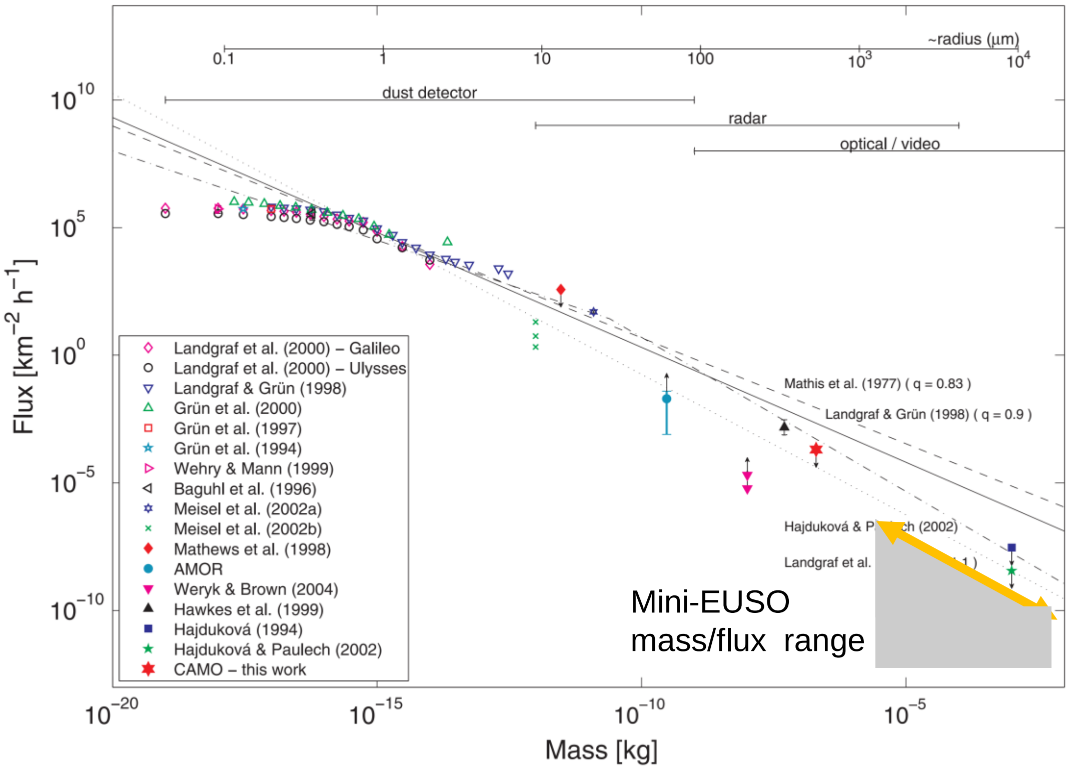
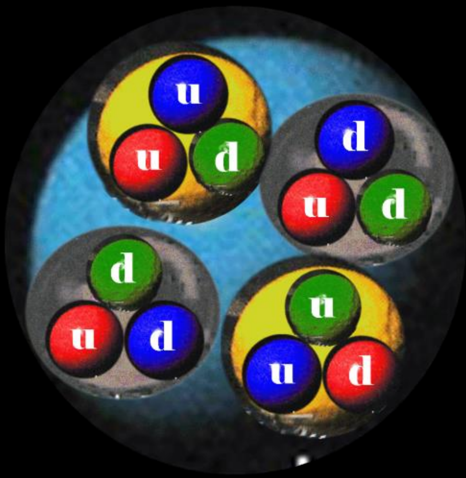


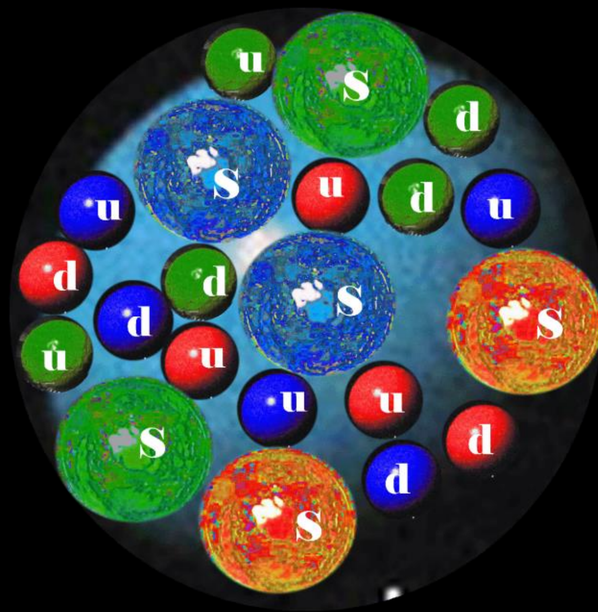
Figure 1. Interstellar meteoroid flux estimates from various studies. The large star represents our result. Arrows indicate upper and lower limits. The data points from Meisel et al. (2002b) are for Geminga supernova particles assuming different models and fits. The AMOR data include the results from Baggaley et al. (1993), as well as the interpretation of those data from Taylor et al. (1996) and Baggaley (2000). The points from Weryk & Brown (2004) are for $v_h > 2\sigma$ and $v_h > 3\sigma$, respectively, above the hyperbolic limit. The ranges at the top of the figure give the approximate sensitivity for different detectors. For comparison, the lines with different styles represent the mass distribution from several models and power-law fits. The slope from Mathis et al. (1977) is identical with the collisional cascade model (Dohnanyi 1969; Tanaka et al. 1996; Wyatt et al. 2007).

(A color version of this figure is available in the online journal.)

Strange Quark matter



Z=2 A=4 (He)
Z/A=0.5



Z=2 A=7
Z/A=0.286

u,d,s quark matter might be stable

Not limited in A

A=100, 1000….

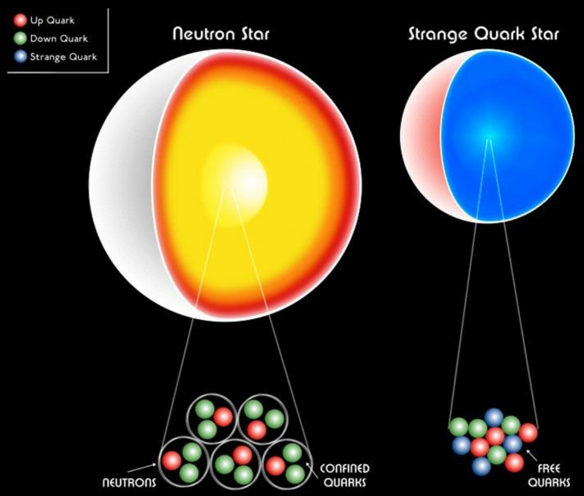
Z is almost zero due to cancellation of quark charge

Could account for Dark Matter

Also candidate of UHECR

No Exotic Physics needed

Strange quark matter, strangelets etc…



Quark stars?

Core of neutron stars?

Models with a strong phase transition: two-families of compact stars

Stars made of hadrons co-exist with stars made of strange quark matter

A. Drago, A. Lavagno, G.Pagliara, PRD 89 (2014)143014

G. Wiktorowicz, A.Drago, G. Pagliara, S. Popov; Astrophys. J. 846 (2017) 163

Cosmological origin?

Fragments could be present in the galaxy,

Burdin et al., Non-collider searches for stable massive particles, Physics Reports 582, 2015

N. Bucciantini, A. Drago, G. Pagliara, S. Traversi and A. Bauswein, 1908.02501.

SQM observations in the atmosphere

SQM brightness $\sim v^3$

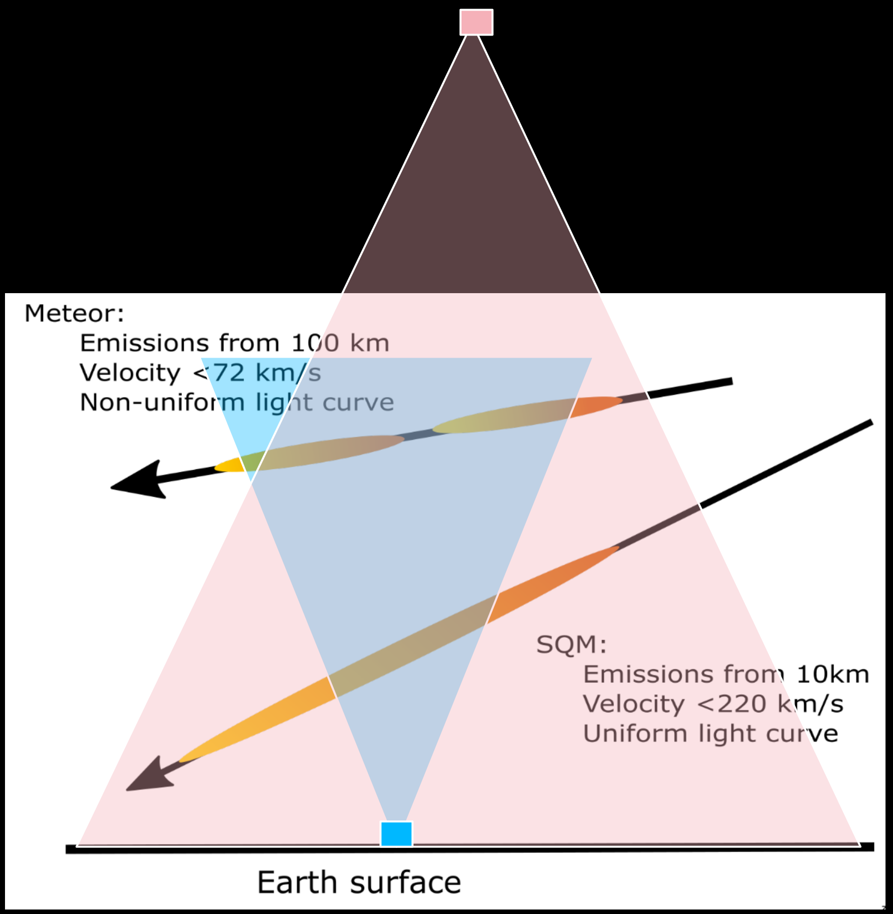
Signal deposited in pixel $\sim \frac{1}{t} = \frac{1}{v}$

Detection efficiency $\sim v^2$

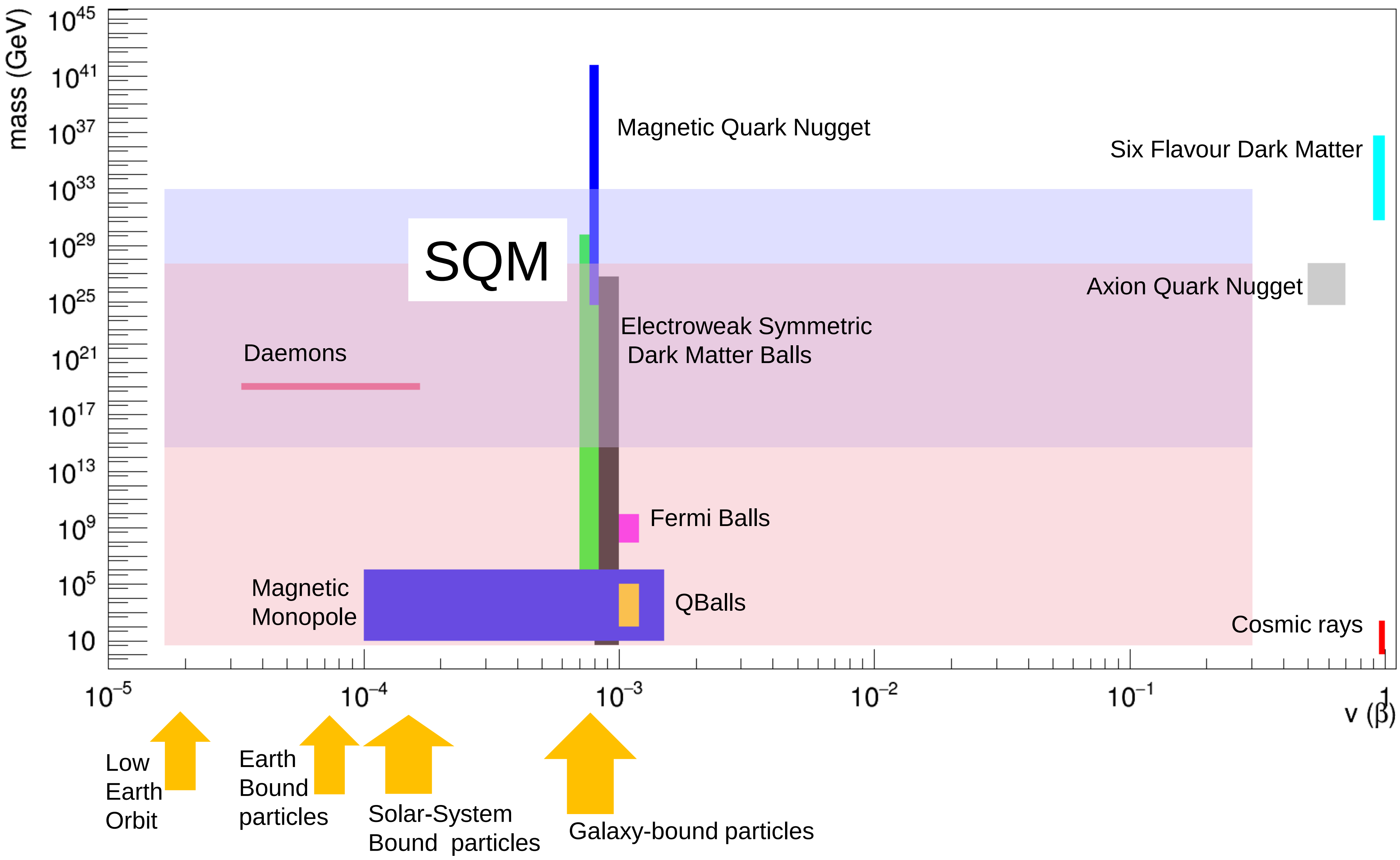
De Rújula, A., Glashow, S., Nuclearites—a novel form of cosmic radiation, Nature 312, 734–737 (1984).

Witten, Cosmic separation of phases. Phys. Rev. D ***30****, 272, 1984*

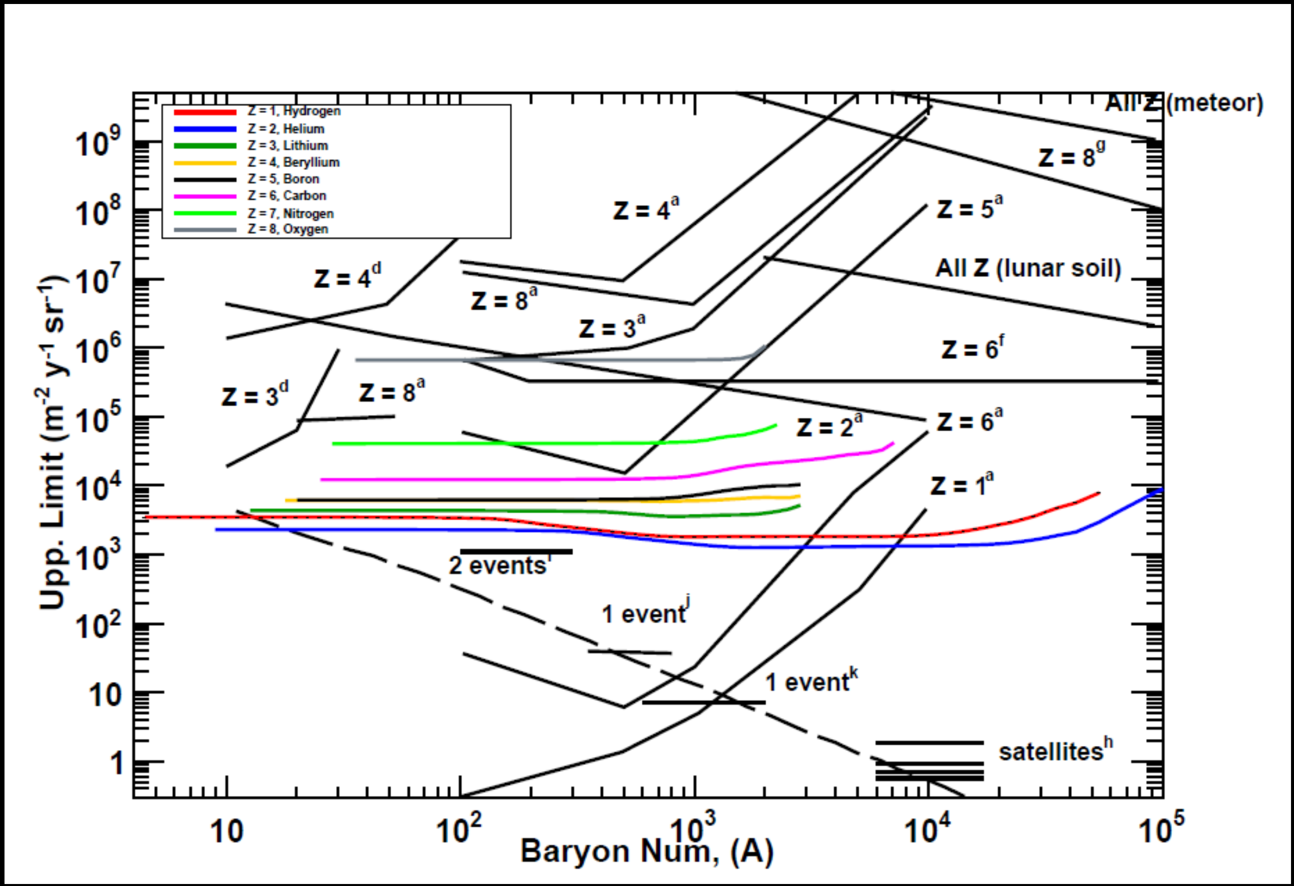
S. B. Shaulov et al, Strange Quark Matter and the Astrophysical Nature of Anomalous Effects in 1–100 PeV Cosmic Rays, JETP Letters, 2022, 116, No. 1, 1–10.

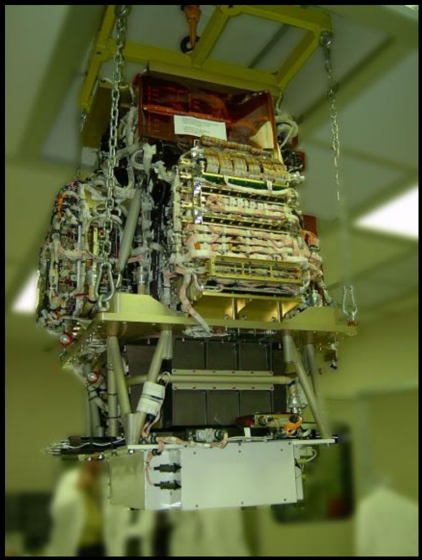


Zoology of SQM-like particles



SQM Upper limits in Pamela





predicted:

Phys. Rev. D **71**, 014026 (2005)

relic searches:

a) Phys. Rev. D **41**, 2074 (1990)
b) PRL **92**, 022501 (2004)
d) PRL **43**, 429 (1979)
e) Phys. Rev. D **30**, 1986 (1984)
f) Nuclear Phys. B **206**, 333 (1982)

heavy ion bombarding experiments:

c) PRL **81**, 2416 (1998)

g) satellite-based searches:

ARIEL-6 APJ **314**, 739 (1987)
HEAO-3 APJ **346**, 997 (1989)
Skylab APJ **220**, 719 (1978)
TREK Nature **396**, 50 (1998)

PAMELA, Z=1

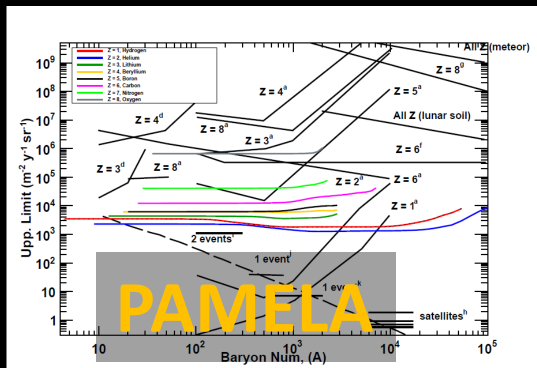
PAMELA, Z=2

Strangelet-like events detected by:

i) HECRO-81 PRL **65**, 2094 (1990)
j) ET Nuovo Cimento A Serie **106**, 843 (1993)
k) Phys. Rev. D **18**, 1382 (1978)

New Upper Limit on Strange Quark Matter Abundance in Cosmic Rays with the PAMELA Space Experiment PRL **115**, 111101 –

SQM observations in the atmosphere



SQM brightness $\sim v^3$

Signal deposited in pixel $\sim \frac{1}{t} = \frac{1}{v}$

Detection efficiency $\sim v^2$

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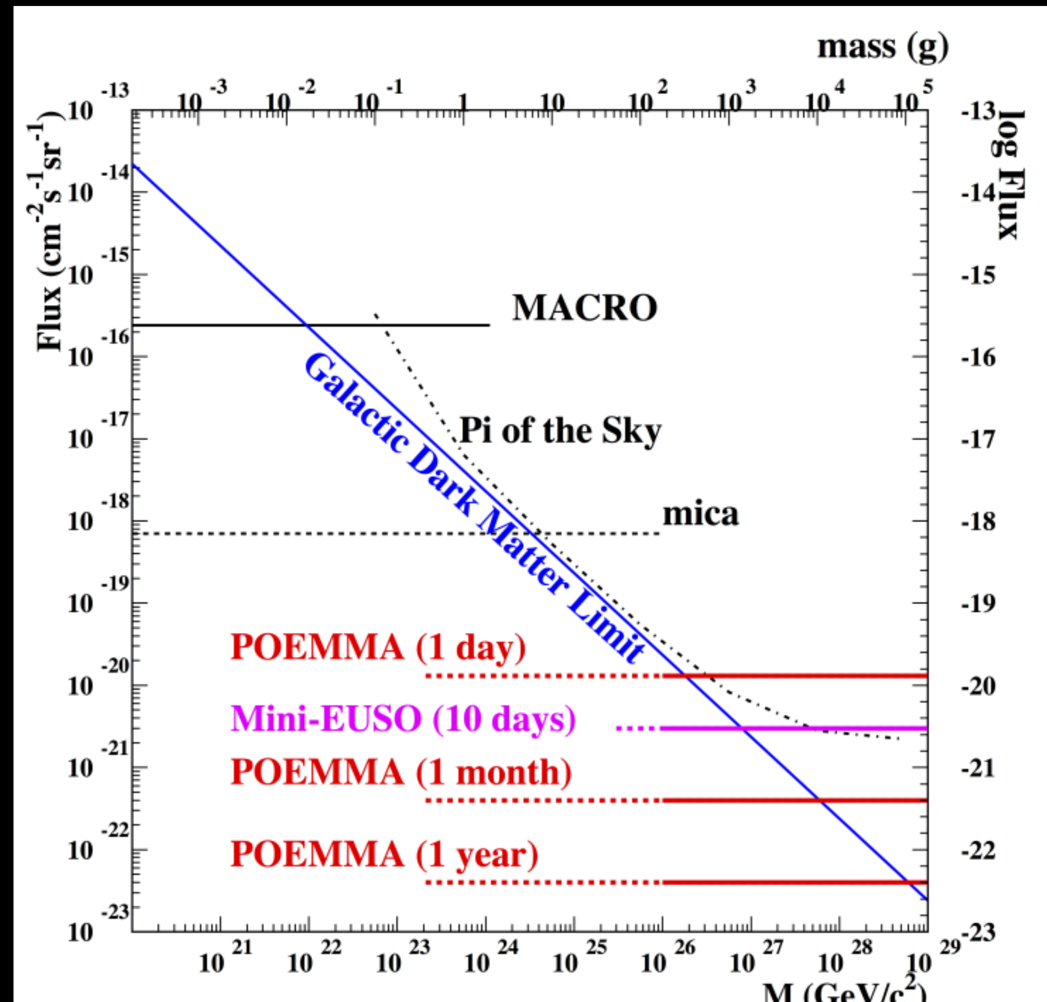
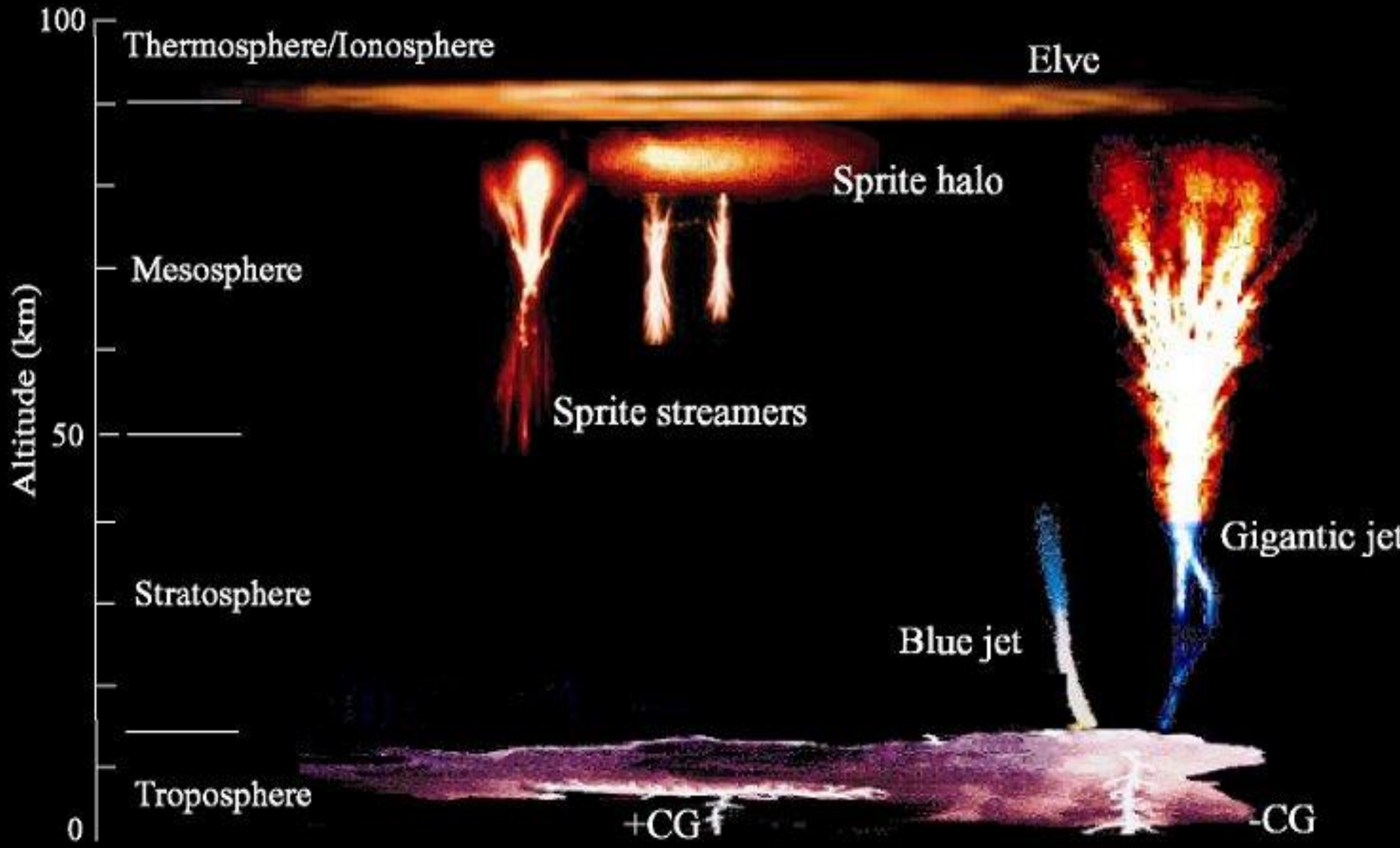


Meteor studies in the framework of the JEM-EUSO program. PLANETARY AND SPACE SCIENCE, 143(SI):245{255, SEP 1 2017.

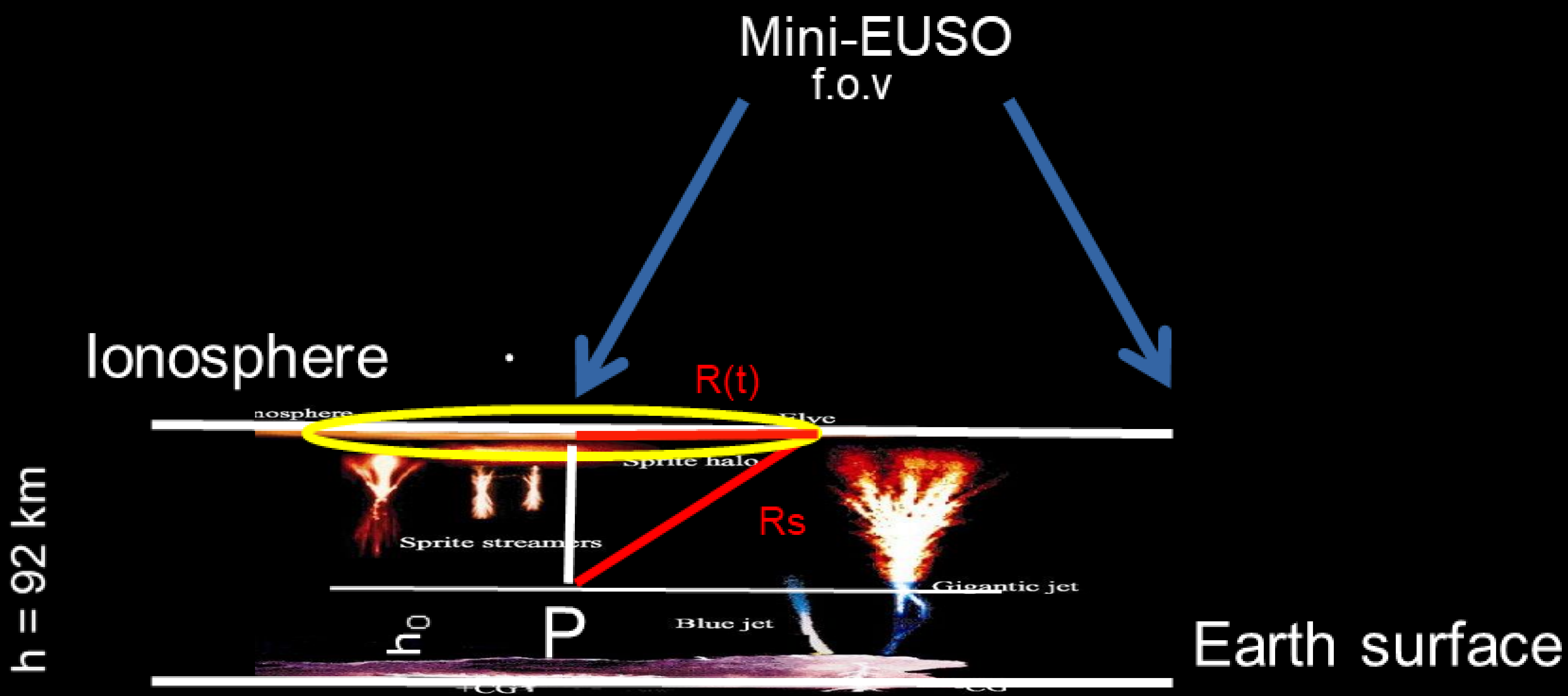
JEM-EUSO: Meteor and nuclearite observations. Experimental Astronomy, 40:253{279, November 2015.

ELVES

(transient luminous events)



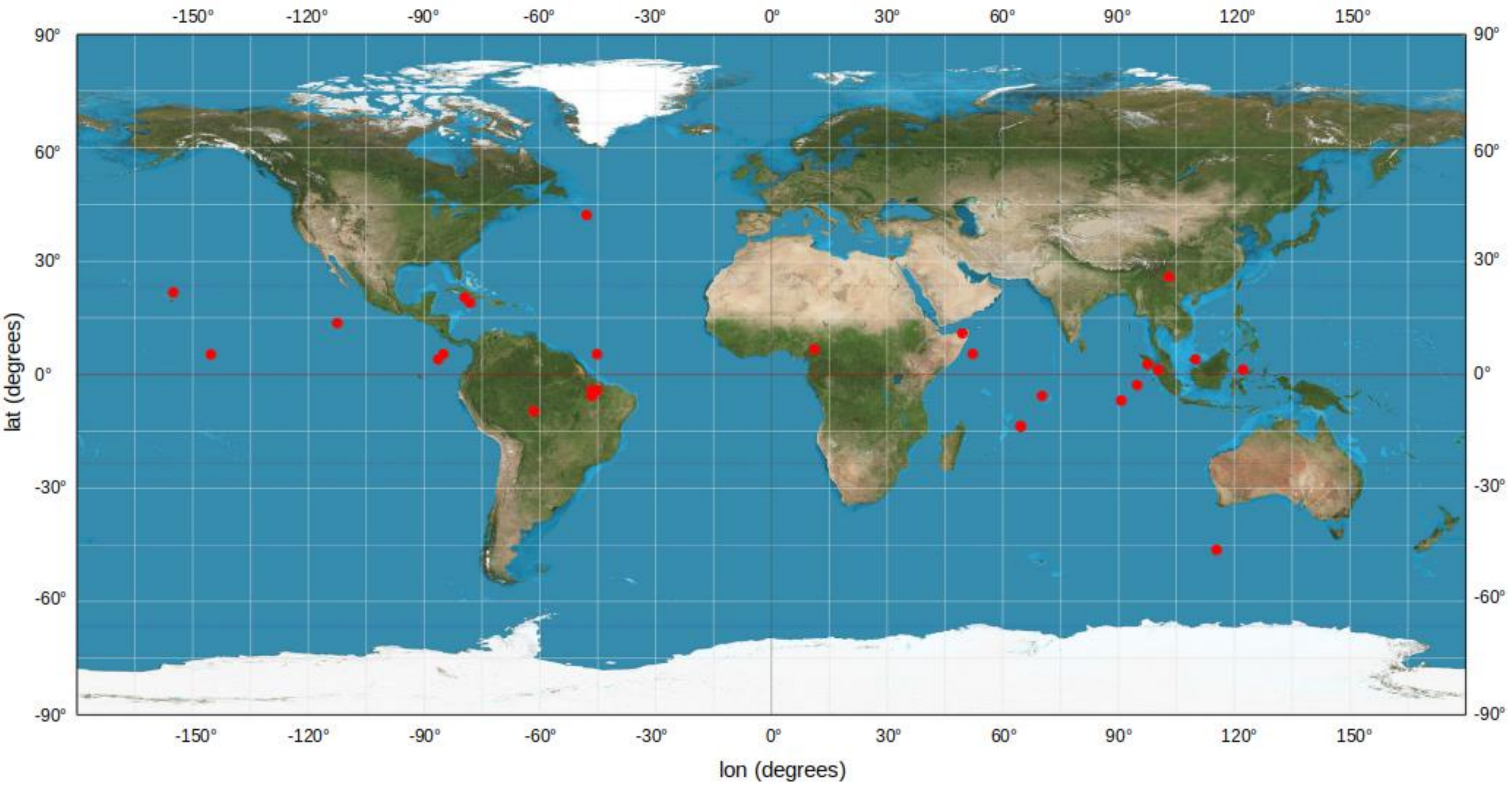
Radius vs time



P = lightning position at t=0
h = ionospheric altitude
h_o = lightning altitude (30 km)
R_s = sperical e.m wave radius
R(t) = observed elve radius

$R(t)= \sqrt{(c^2t^2-(h-h_0)^2)}$

26 main events ELVES (1st year)



ELVES (transient luminous events)

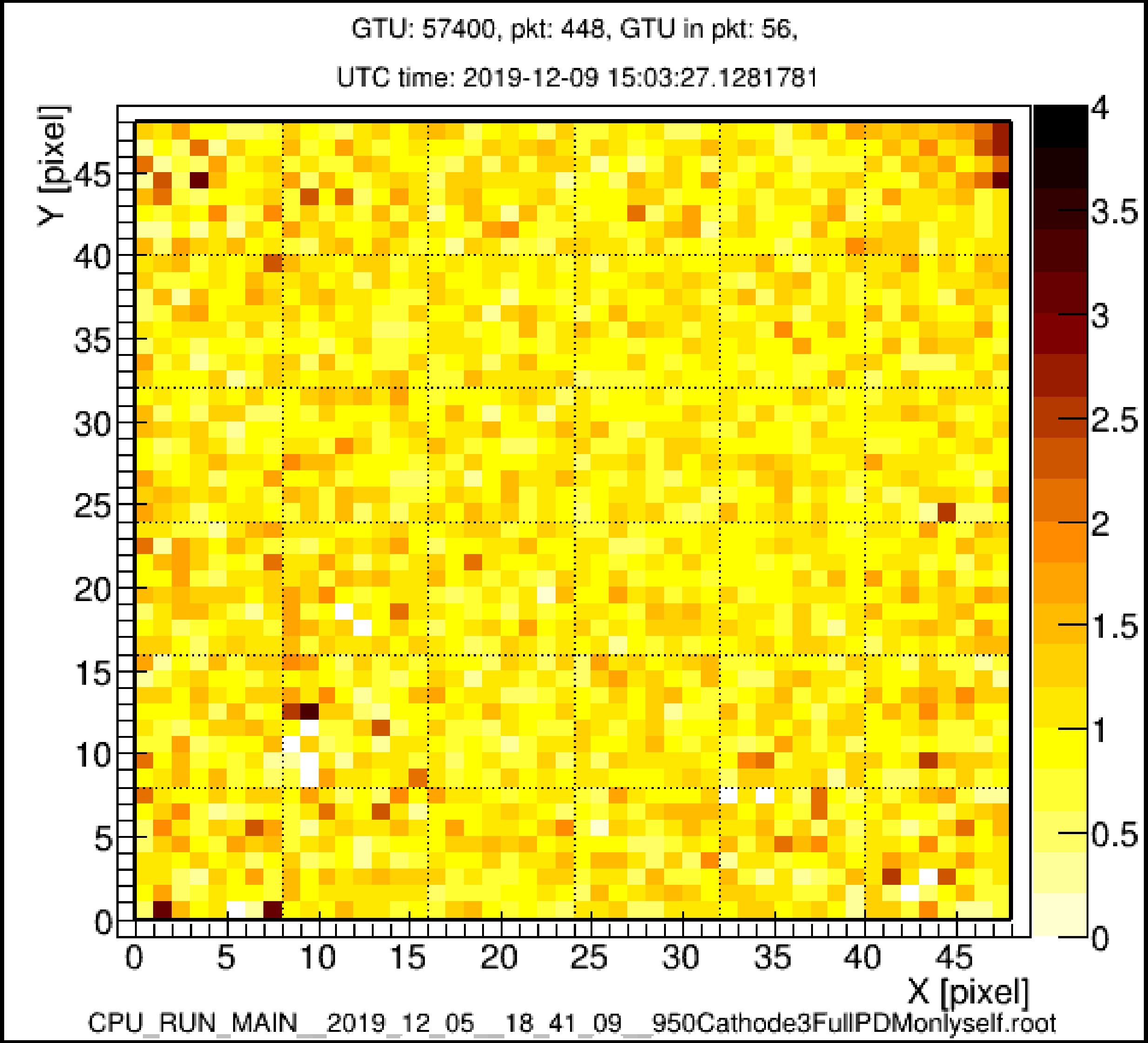
2.5μs sampling speed

Superluminal rings
100km+ radius

Upper atmospheric lighting releases e.m. wave which heats the ionosphere
Transient Gamma Flash relationship

About 400mus
Overall duration

See also Roberta's poster on Auger new results



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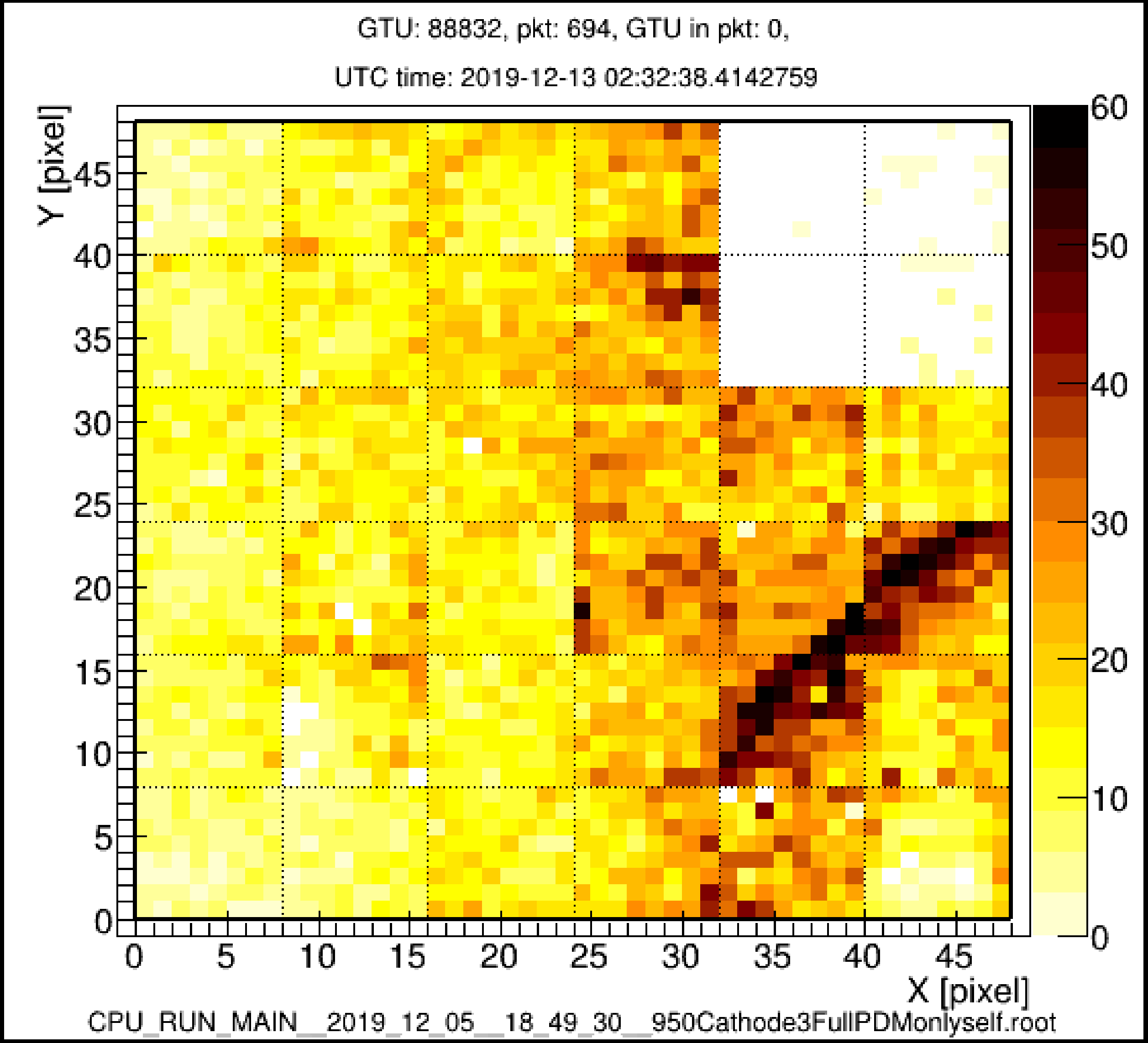
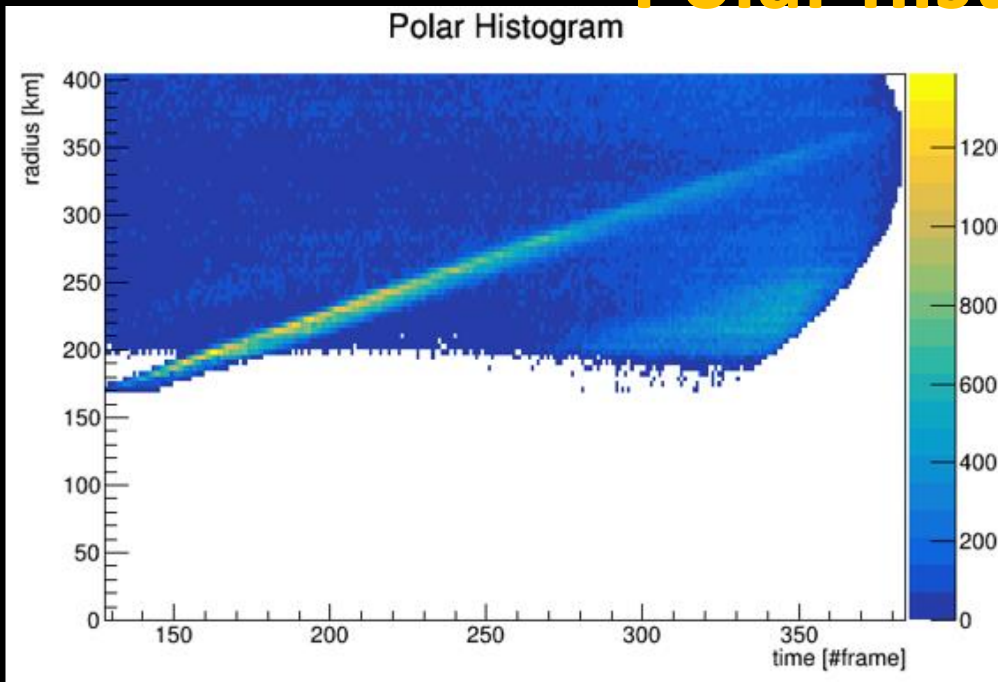
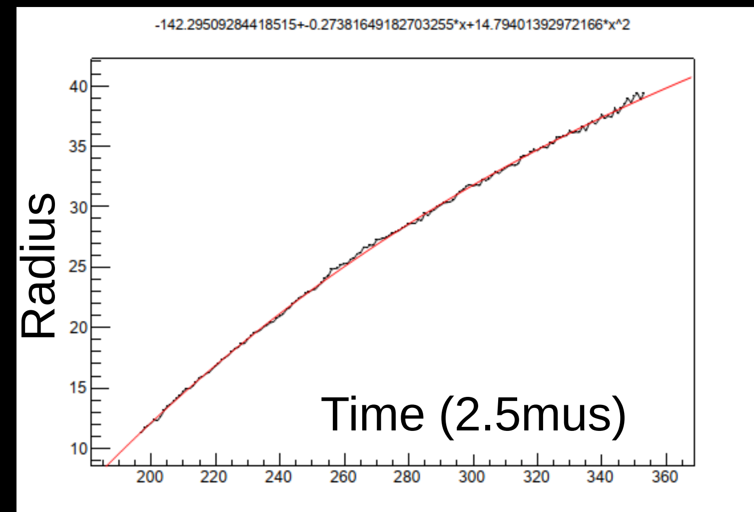
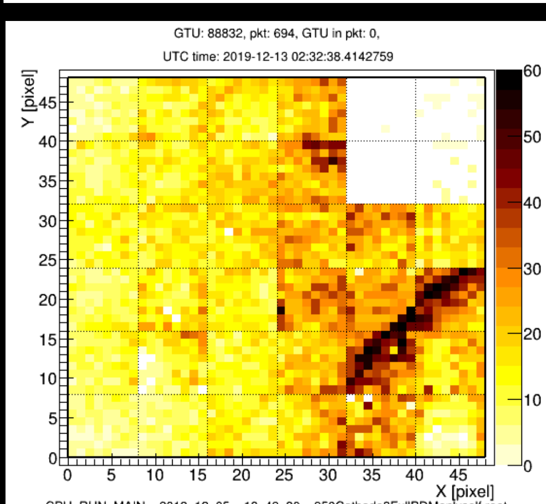


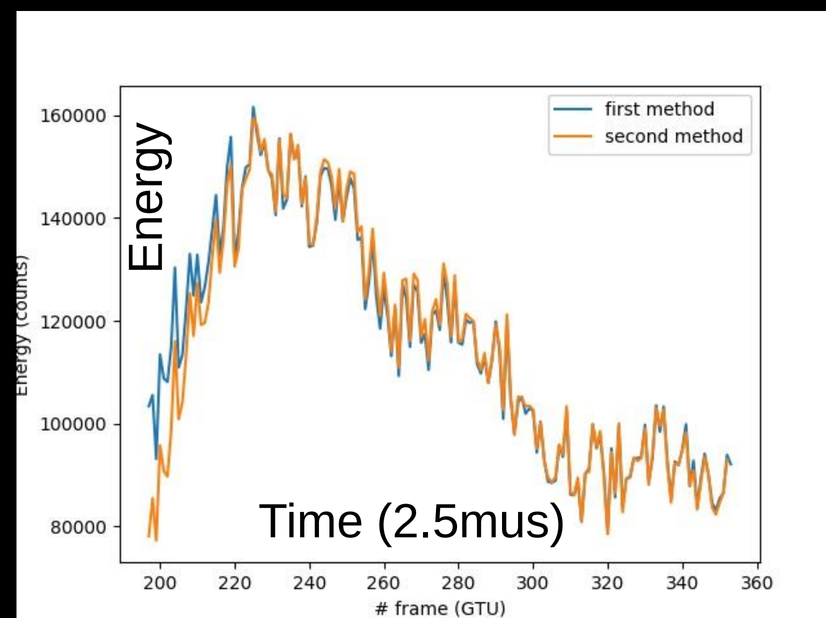
ELVE: 2019-12-05_n1
Polar histogram



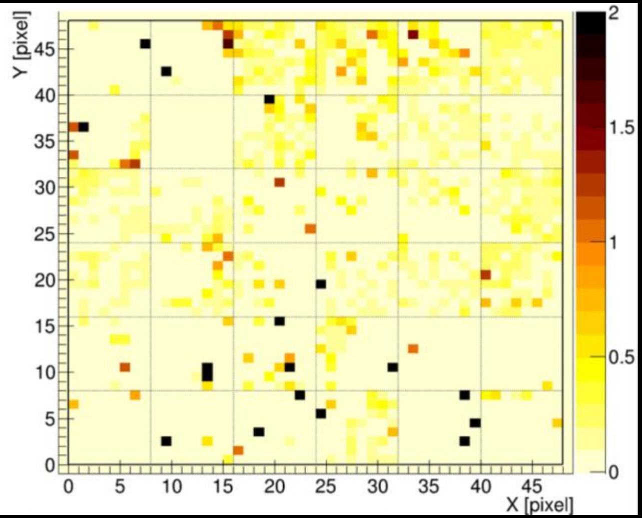


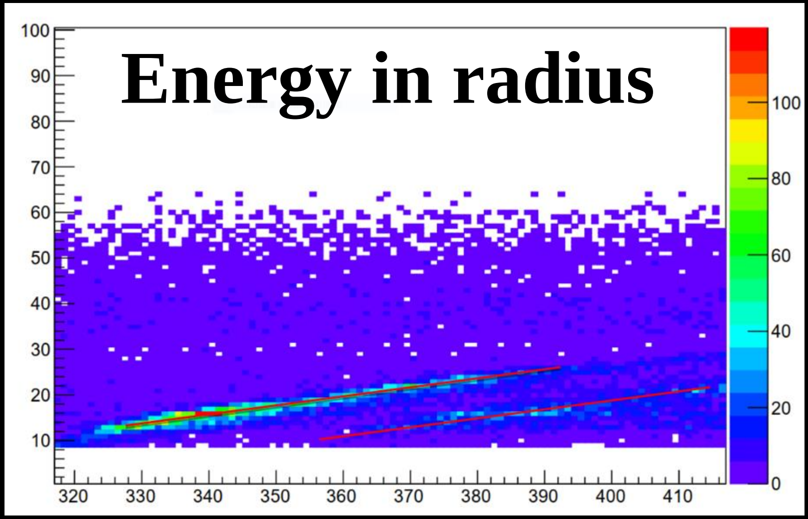


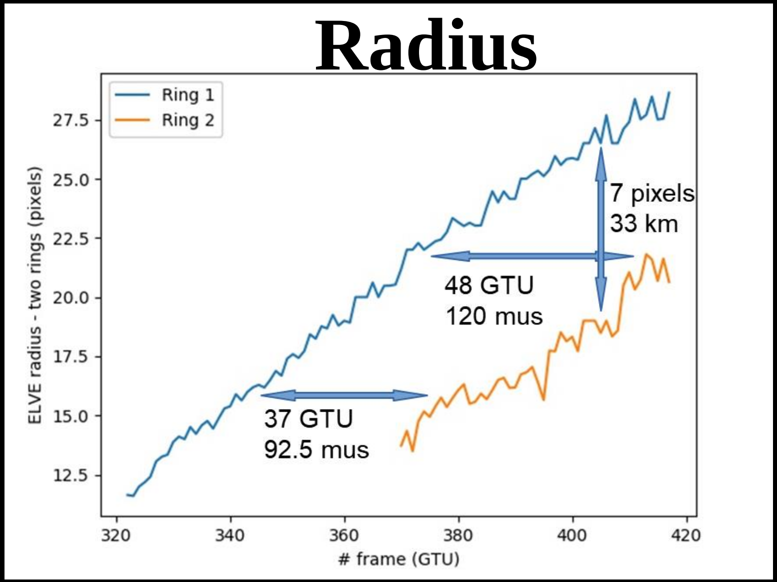
From L. Marcelli

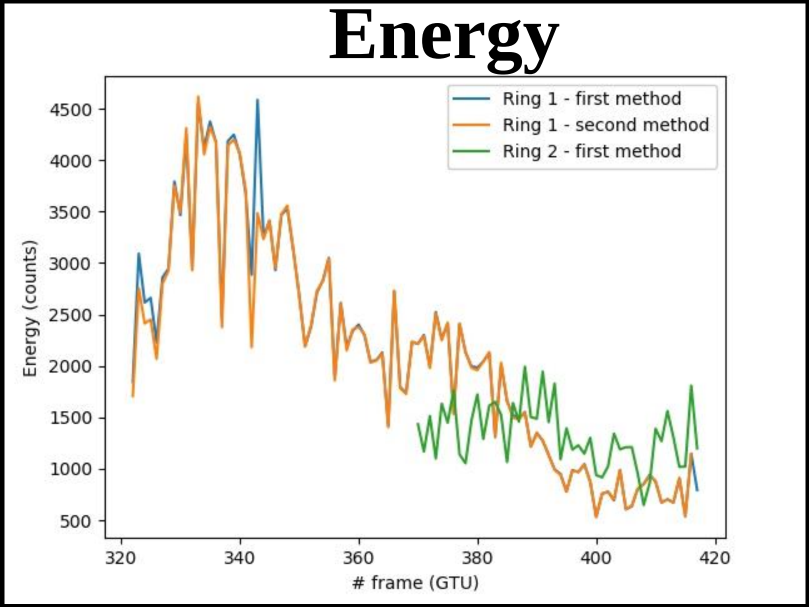


Double ringed ELVE

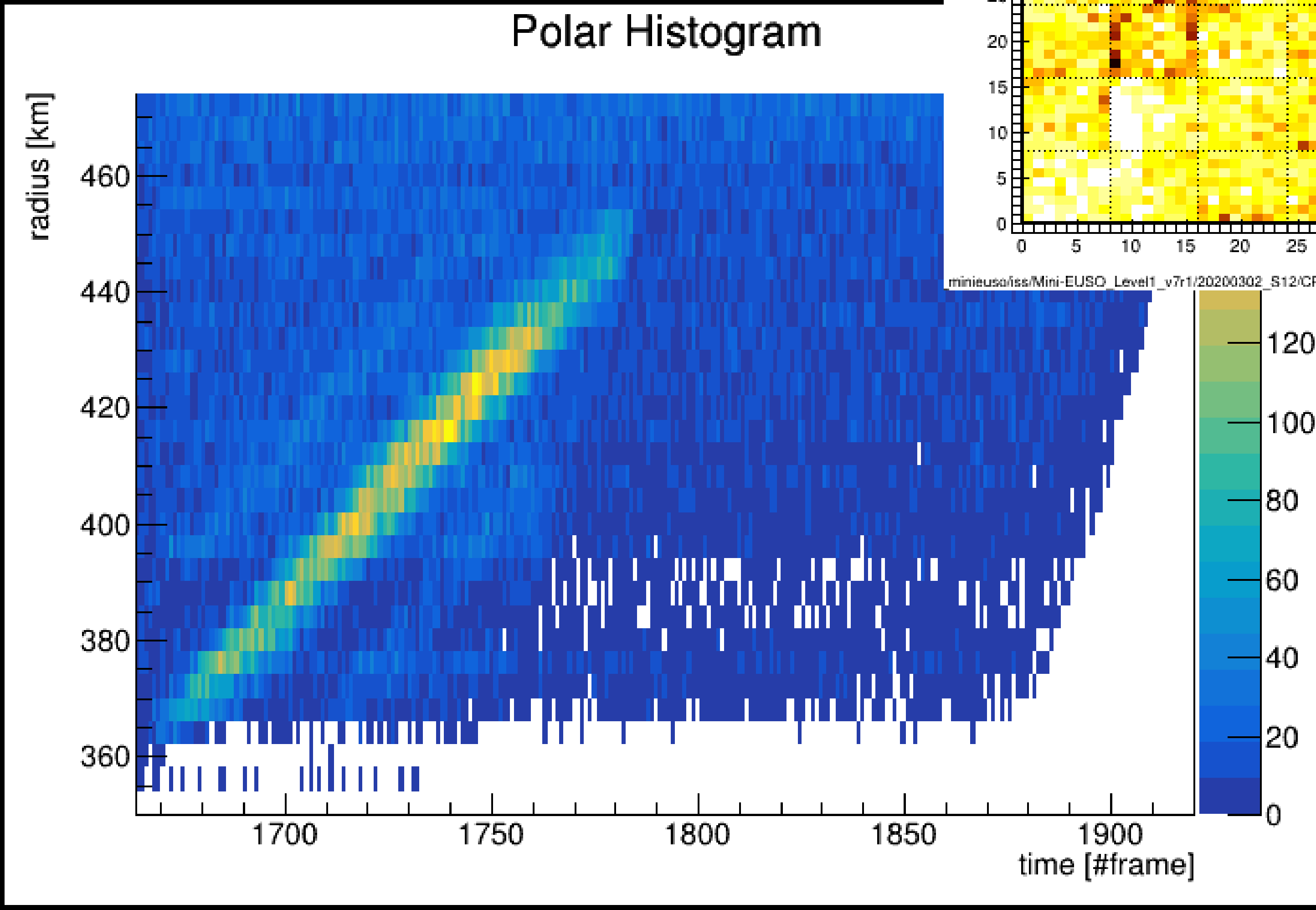


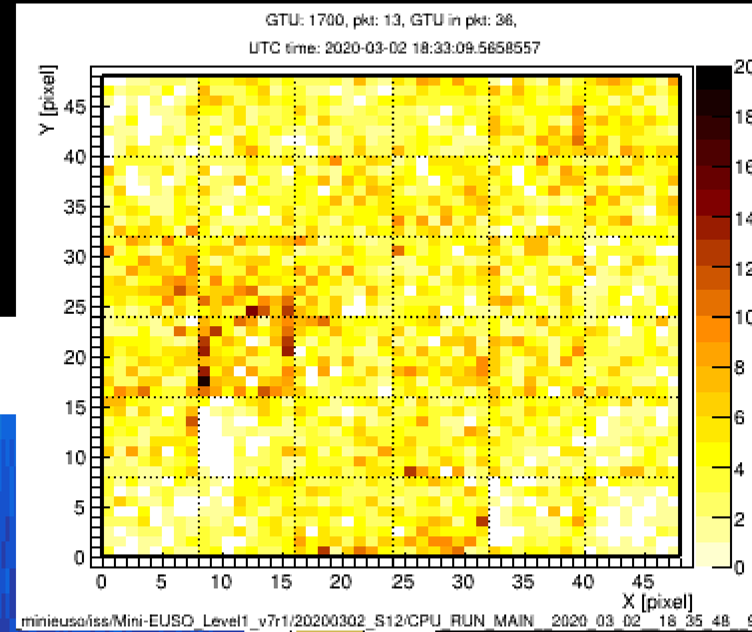




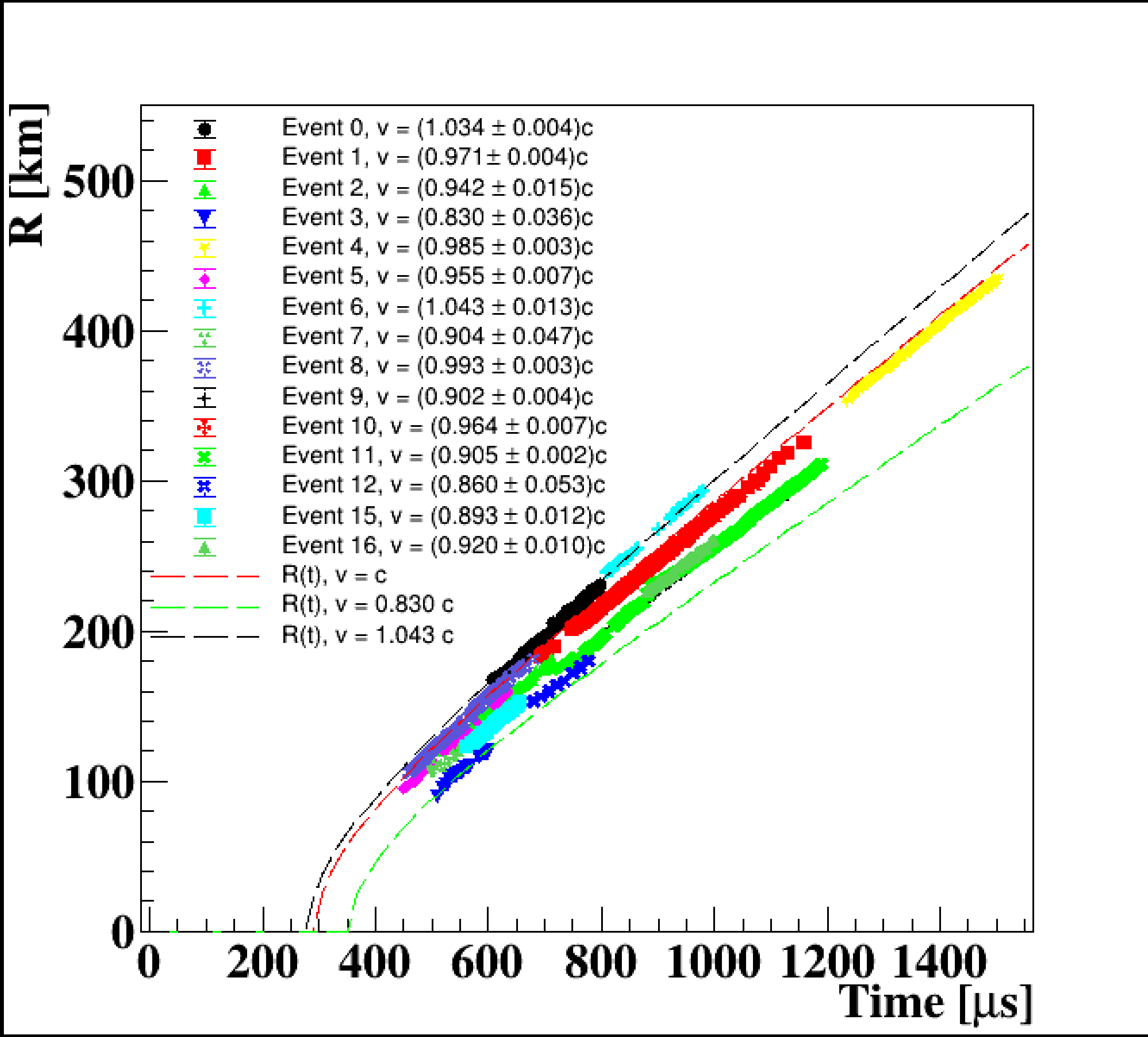


Three ringed ELVE

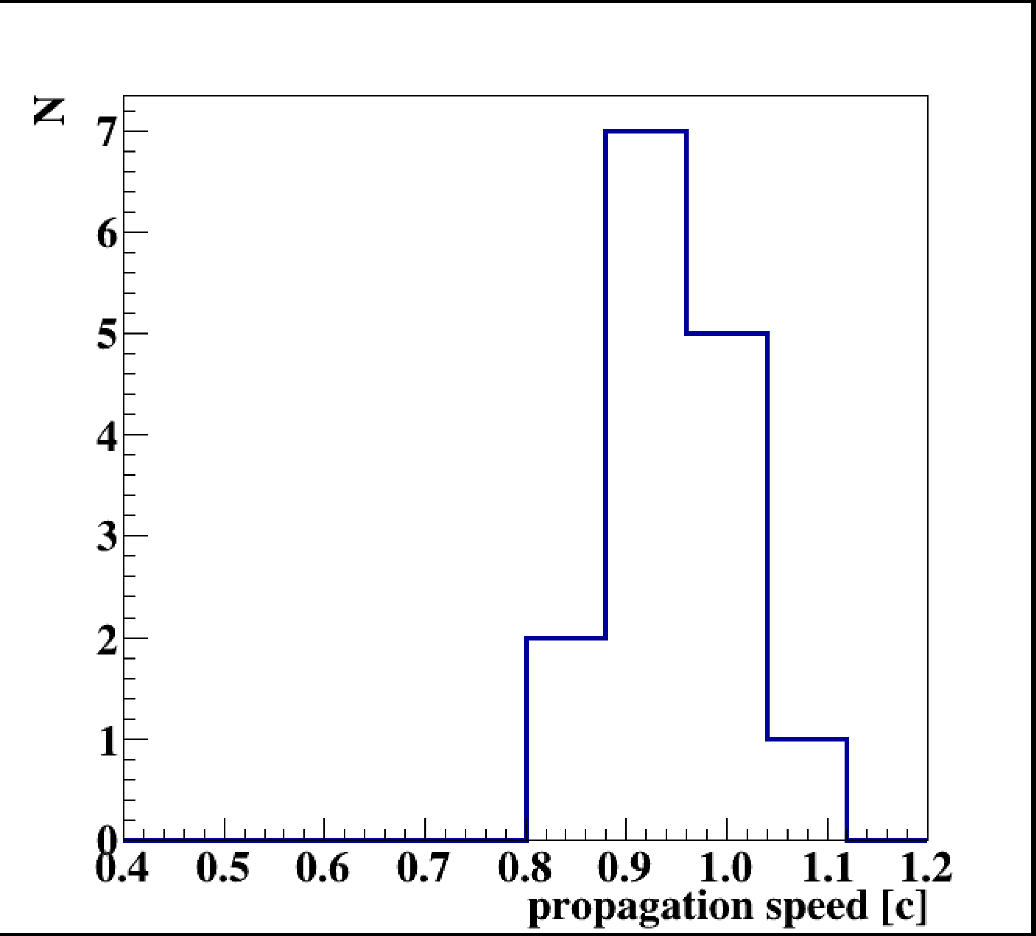




All ELVES combined



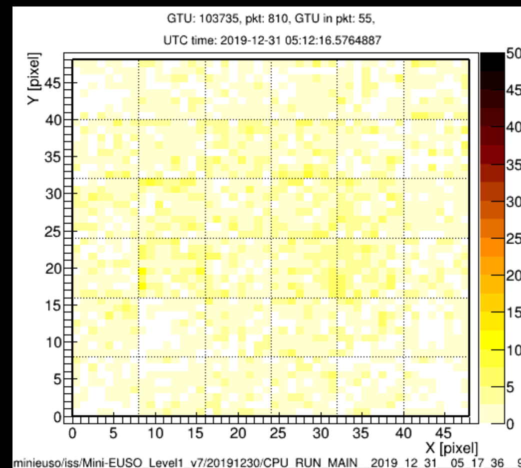
Velocity of ELVES

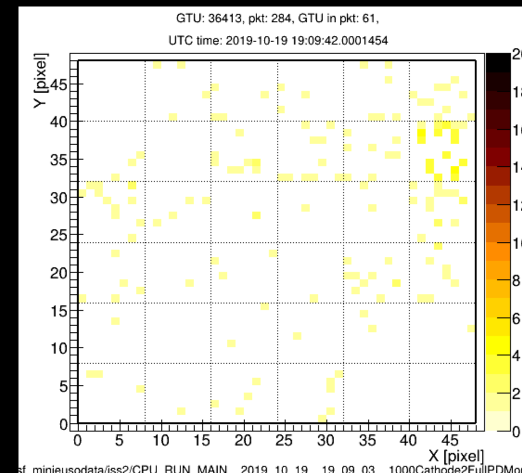


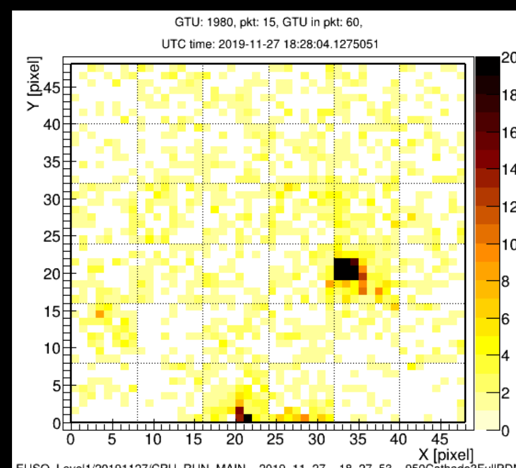
Direct hits on Focal Surface

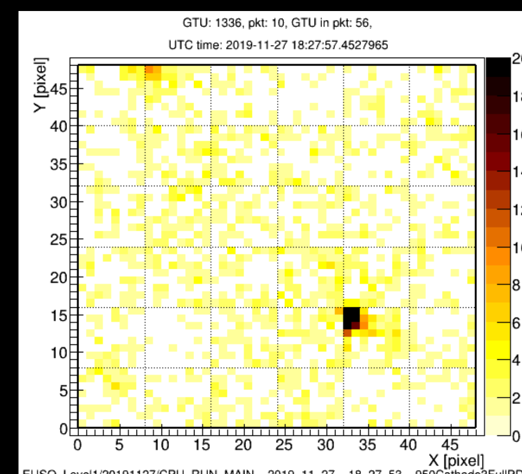
3, 2.5μs frames

Direct particle hitting FS



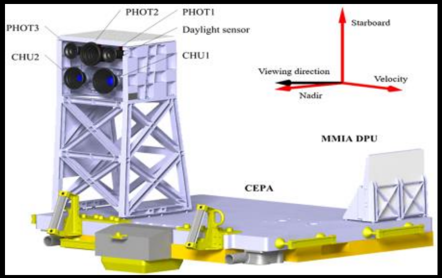






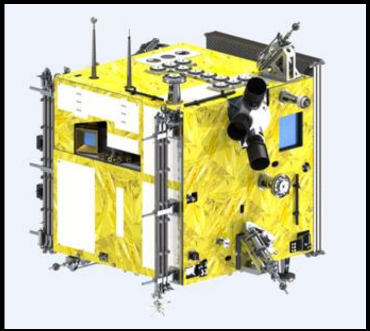
Joint observations with other detectors on the ISS

ASIM:
UV transients and ELVES



ALTEA-LIDAL («our»)
Correlation with radiation environment
of cosmic rays 100 Mev – GeV and
Transient Luminous Events

CSES-Limadou («our»)
(different orbit) + CSES-02 in development



Conclusions

Mini-EUSO on ISS for three years (TODAY!)

It proves that it is possible – with larger detectors – to perform UHECR observation from space, with measurements according to simulations

First two pouches are back from space.
Third expected in 2023 / launch of fourth


Godspeed, JEM-EUSO Program!
岩澤 駿
SHUN IWASAWA