Celebrazione per i 70 Anni dell'INFN - 35 anni di fisica delle astroparticelle nello spazio della Sezione Roma Tor Vergata

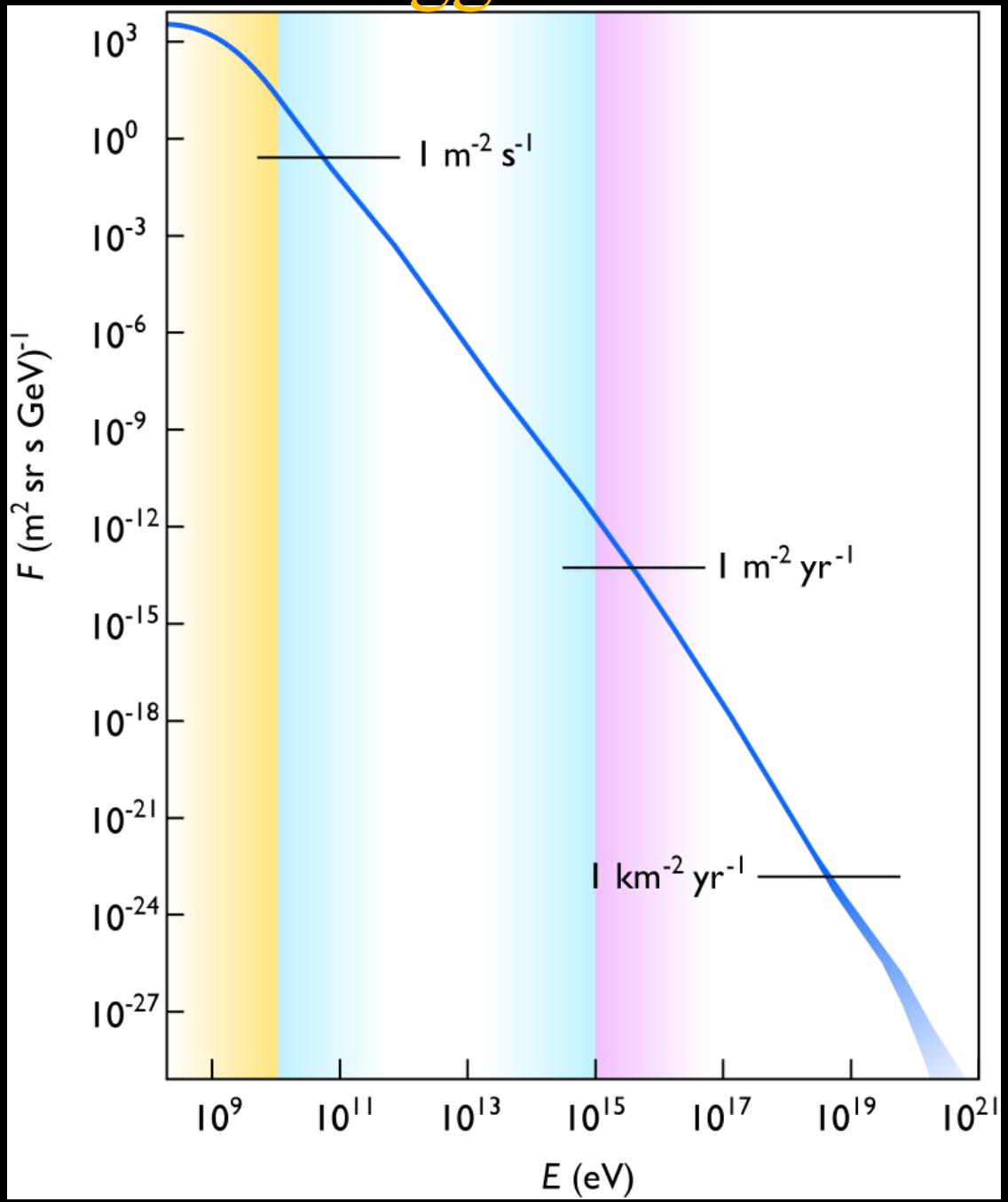
Raggi cosmici di altissima energia e dosimetria a bordo delle Stazioni Spaziali Internazionale e MIR

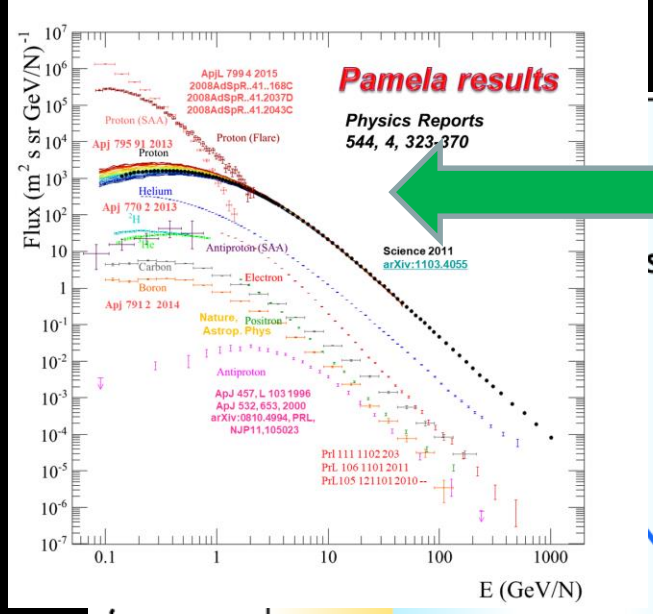
M. Casolino (INFN Sezione Roma Tor Vergata)

M. Casolino
L. Marcelli

11-05-2022

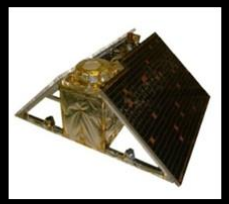
Spettro dei Raggi cosmici carichi



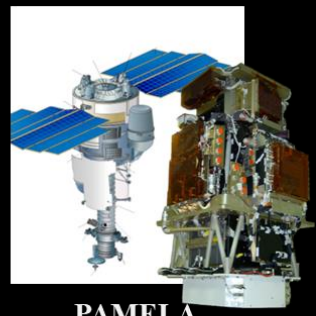


Satellite

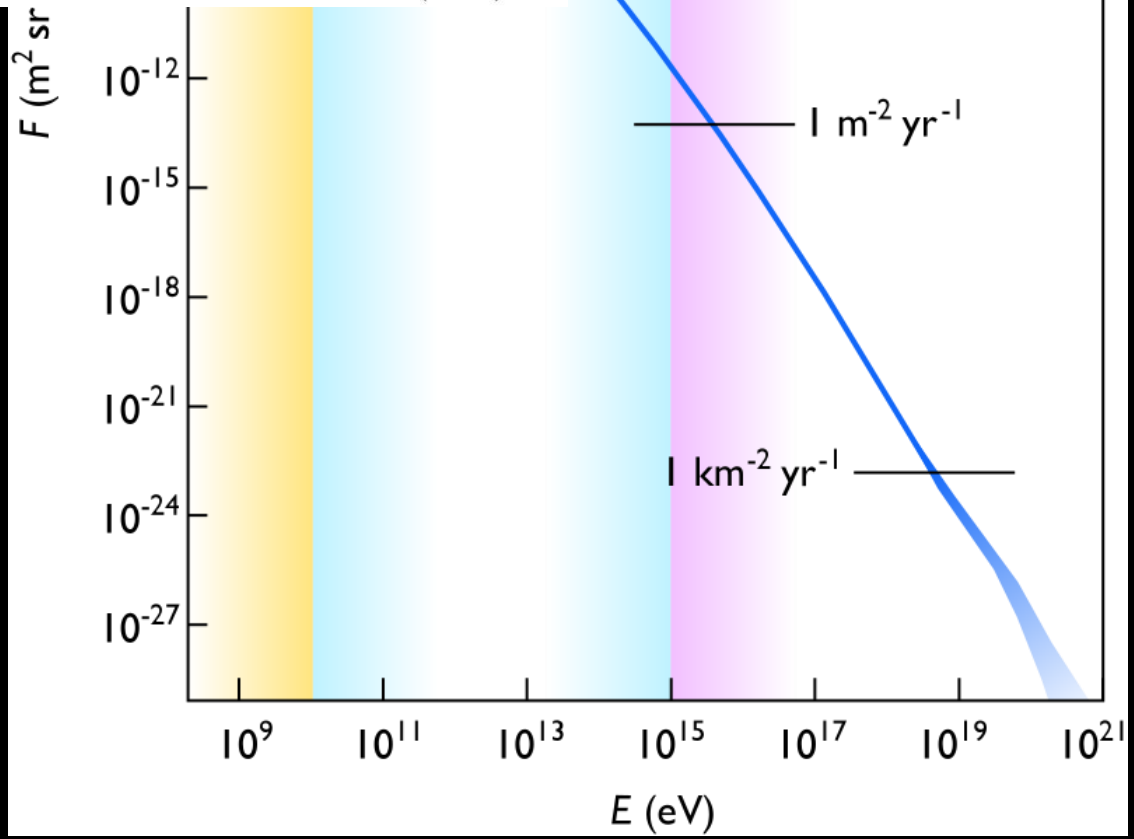
NINA-1
(1998-2000)

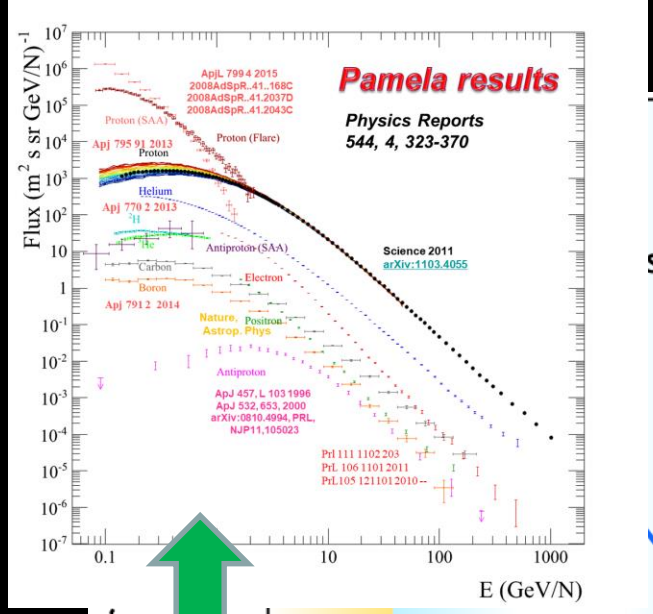


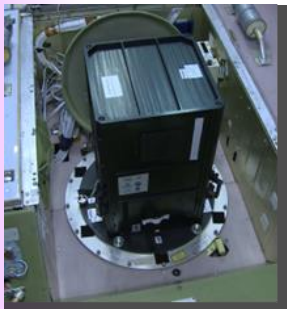
NINA-2 Satellite
(2000-2002)



PAMELA
(500 kg, 2006-2016)







MINI-EUSO EUSO-Balloon
SPB1 SPB2

F (m^2 sr

1 km^{-2} yr^{-1}

10^{15} 10^{17} 10^{19} 10^{21} (eV)

Mir Space Station

SilEye 1 (1995-1997)

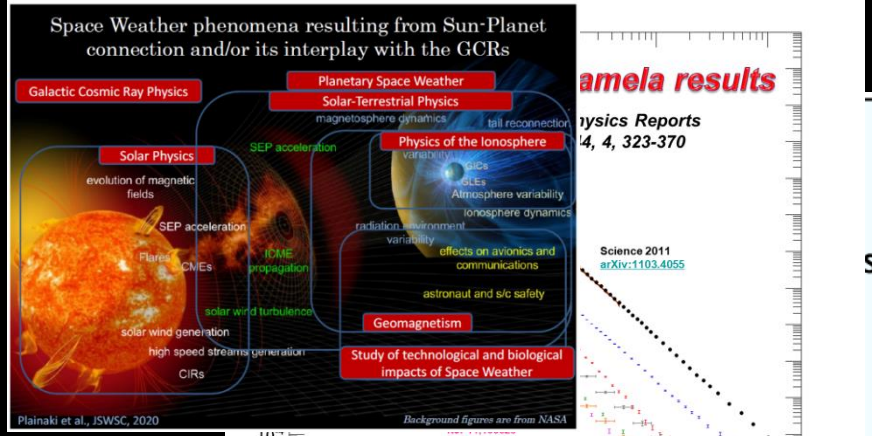
SilEye 2 (1998-2000)

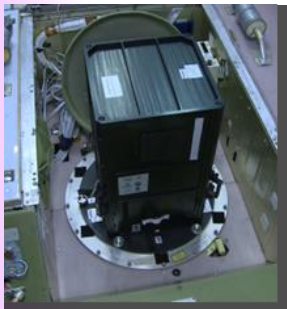
International Space Station

Alteino (2002-2010)

Lazio(2005-2006)

Altea (2006-2016)
Altea-Lidal (2020-)





MINI-EUSO EUSO-Balloon
SPB1 SPB2

F (m² sr

km⁻² yr⁻¹

(eV)

Mir Space Station

SilEye 1 (1995-1997)

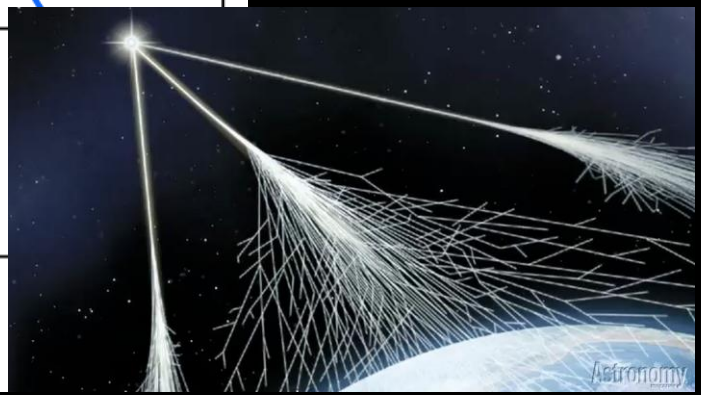
SilEye 2 (1998-2000)

International Space Station

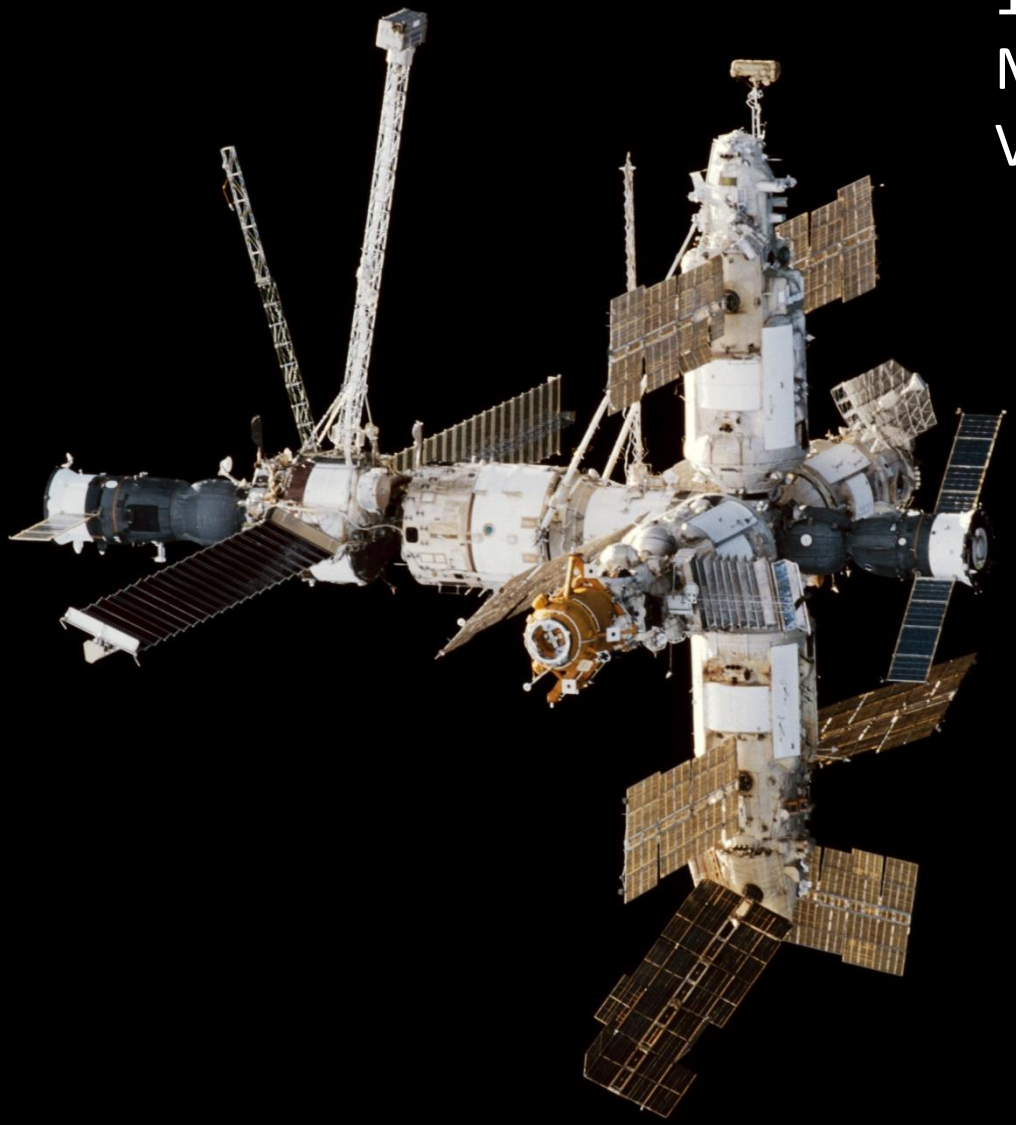
Alteino (2002-2010)

Lazio(2005-2006)

Altea (2006-2016)
Altea-Lidal (2020-)



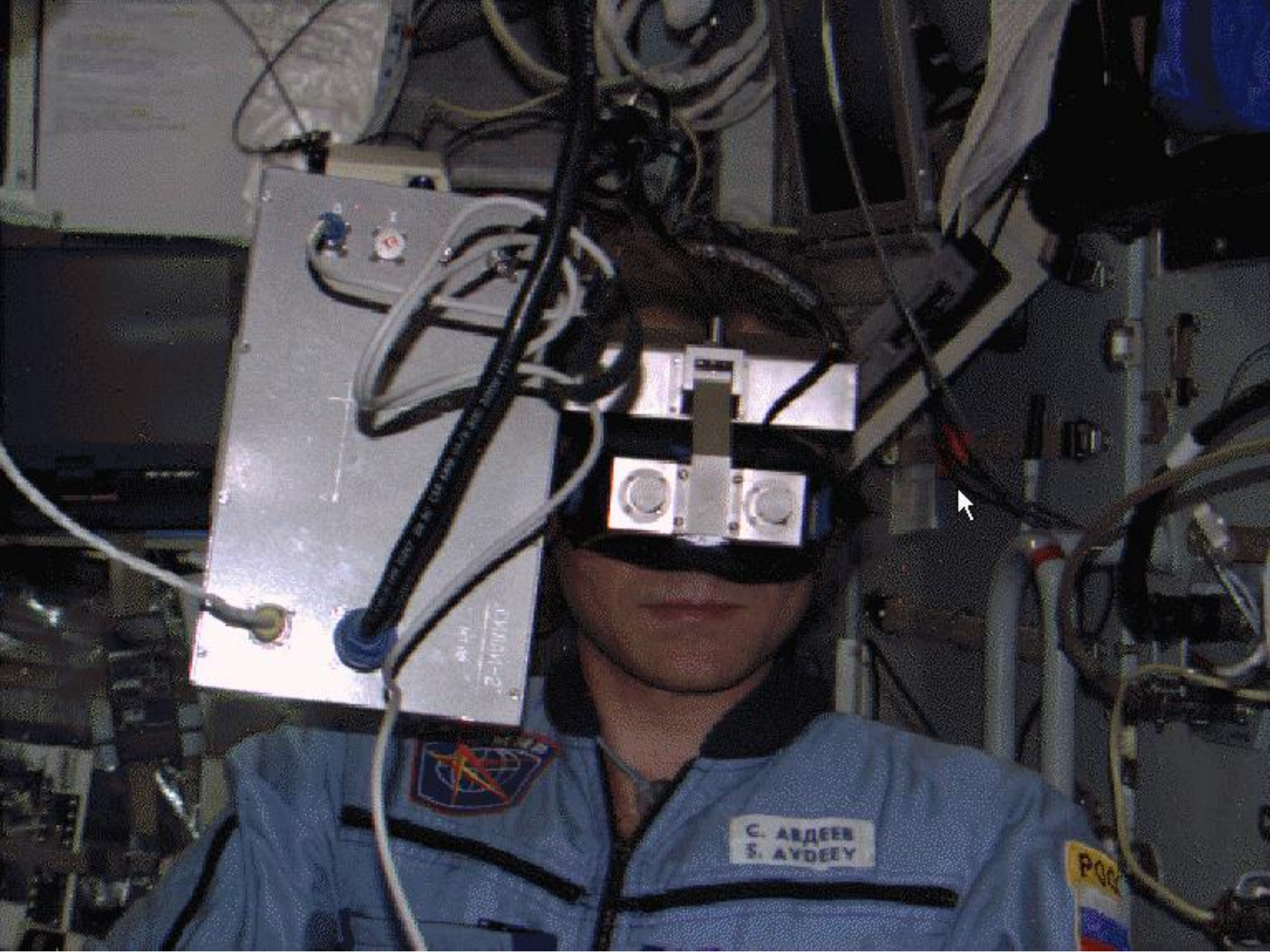
Mir Space Station



1986 – 2001
Mass - 129,7 T
Volume - 350 m^3

Cosmonaut Sergej Avdeev wearing the SilEye-1 helmet and detector on board Space Station MIR (1995)

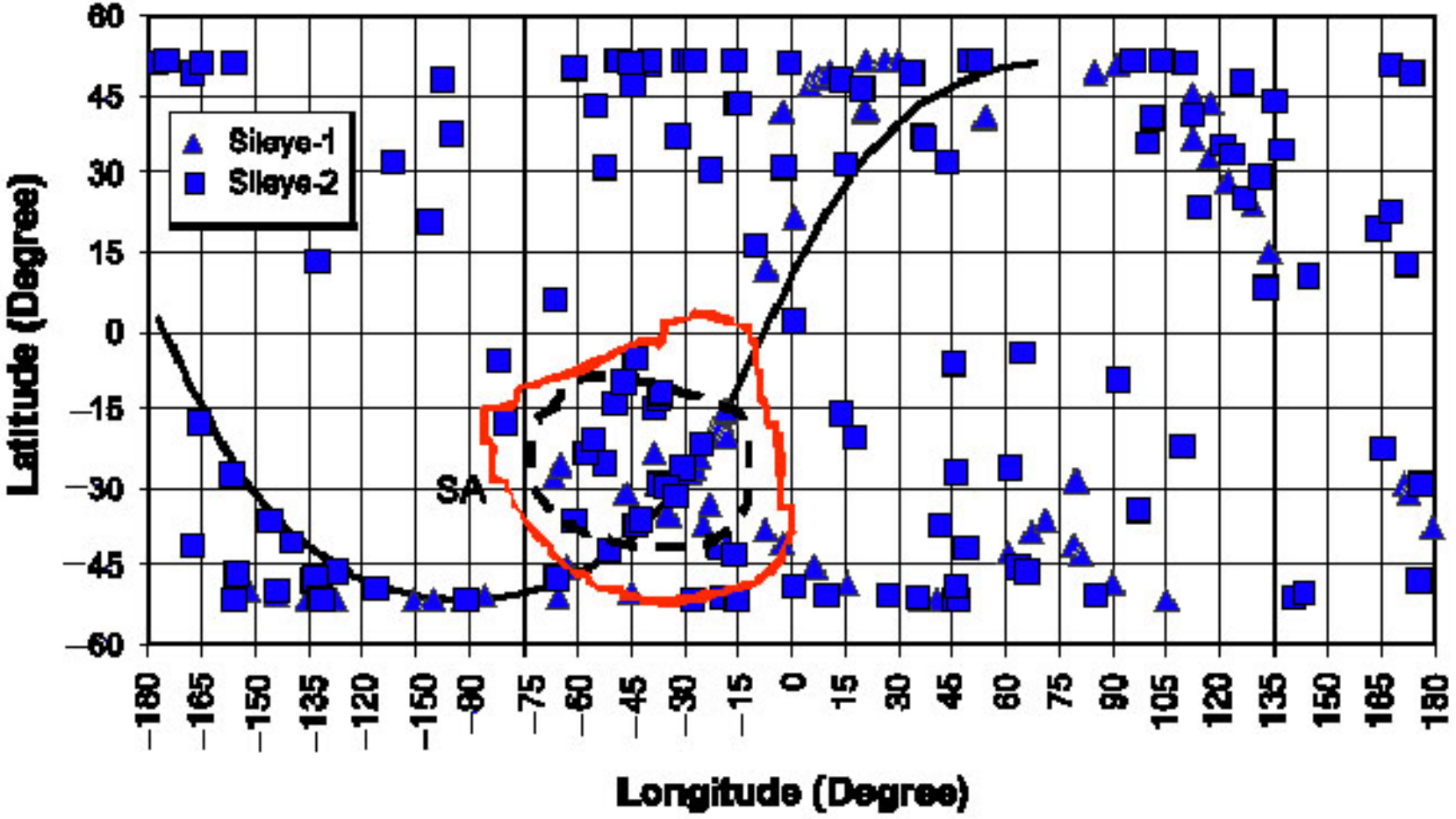
SilEye-2 (1997-2000)


С. АВДЕЕВ
S. AVDEEV

SilEye-2 cosmic ray data

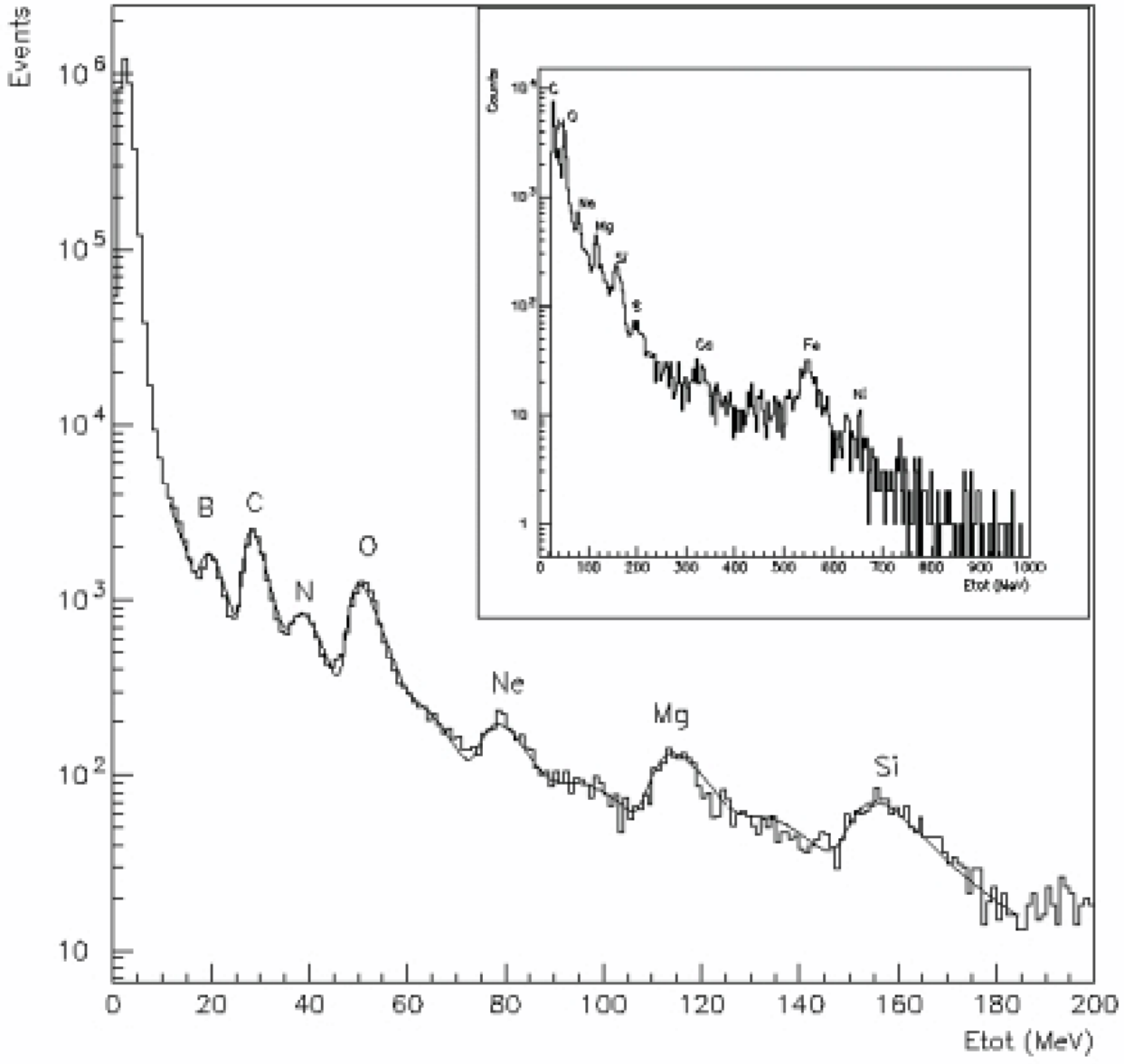
- Turned on in August 1998
- Systematic observations: October 1998
- Data set end: June 2000 - 93 acquisition sessions
- of which 24 devoted to Light Flash observation
- 1068 hours of observation
- 10^7 triggers
- 8 Solar Particle Events (SPE) observed

Sileye-1 & -2 on MIR: Two causes of Light Flashes



Casolino et al, Nature, 422, 680 (2003)

Nuclear Identification Capabilities



***Journal of Physics G: Nuclear and Particle Determining the characteristics of cosmic-radiation nuclei in the Sileye experiment on board the Mir orbital station. Instruments And Experimental Techniques**, 44(5):623{625, **SEP-OCT 2001**. ISSN 0020-4412. doi: 10.1023/A:1012389322155*

***The Sileye Altcriss experiment on board the International Space Station. Nuclear Instruments and Methods in Physics Research A**, 572:235{236, **March 2007**. doi:10.1016/j.nima.2006.10.311.*

***Detector response and calibration of the cosmic-ray detector of the Sileye-3/Alteino experiment. Advances in Space Research**, 37:1691{1696, **2006**. doi:10.1016/j.asr.2005.03.136.*

*[184] Casolino, M., et al. **Relative nuclear abundances inside ISS with Sileye-3/Alteino experiment. Advances in Space Research**, 37:1685{1690, **2006**. doi:10.1016/j.asr.2006.02.050.*

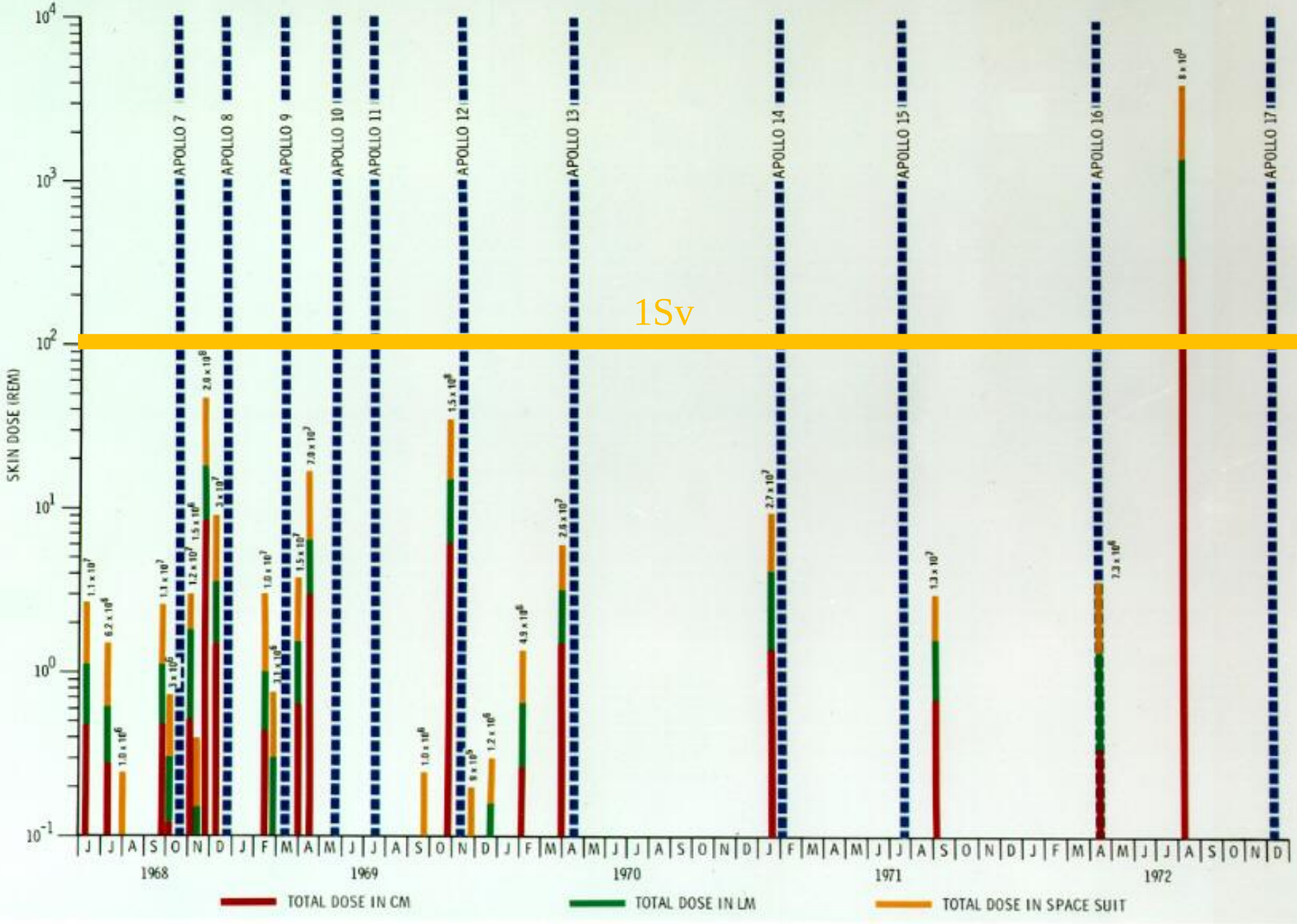
Study of the radiation environment on MIR space station with SILEYE-2 experiment. Advances in Space Research, 31:135{140, 2003. doi:10.1016/S0273-1177(02)00880-3.

In-flight performance of SilEye-2 experiment and cosmic ray abundances inside the Mir space station. Journal of Physics G Nuclear Physics, 27:2051{2064, October 2001. doi:10.1088/0954-3899/27/10/307.

Study of Cosmic Rays and Light Flashes on Board Space Station MIR: The Sileye Experiment. Advances

NASA-S-73-3131

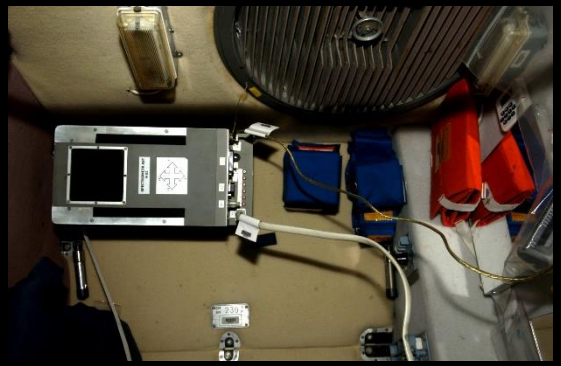
PARTICLE EVENT OCCURRENCE VERSUS CALCULATED EVENT DOSE

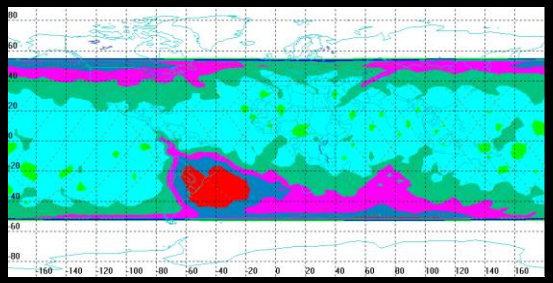


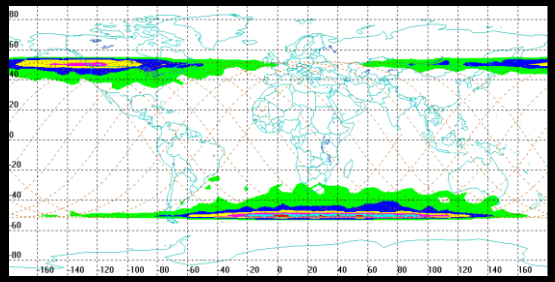
International Space Station

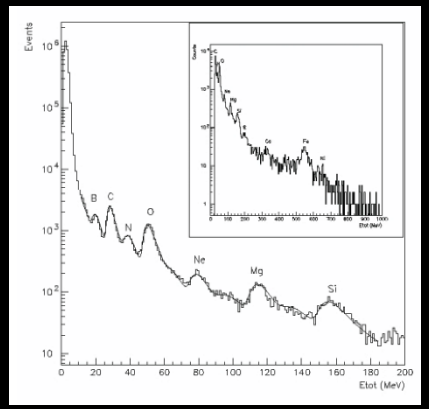
1998 –
Mass - 445 T
Volume - 916 m^3

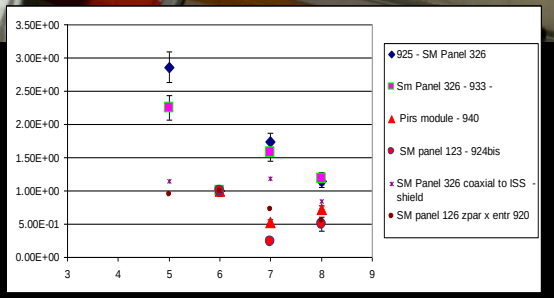
Sileye-3 Flight Model integration, Tor Vergata University. December 2001








Events
B
C
N
O
Ne
Mg
Si
Etot (MeV)

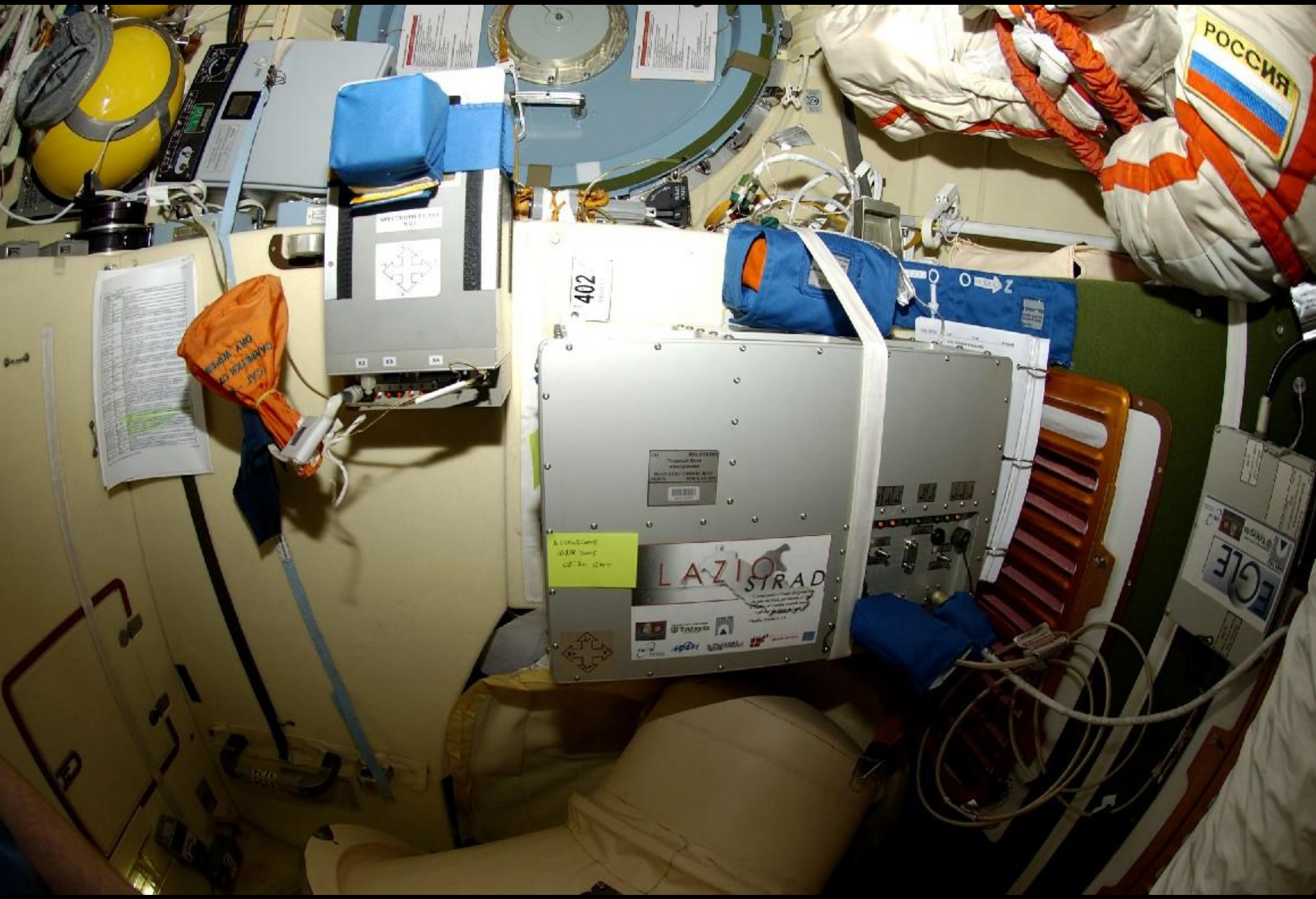

3.50E+00
3.00E+00
2.50E+00
2.00E+00
1.50E+00
1.00E+00
5.00E-01
0.00E+00
3
4
5
6
7
8
9
925 - SM Panel 326
Sm Panel 326 - 933 -
Pirs module - 940
SM panel 123 - 924bis
SM Panel 326 coaxial to ISS - shield
SM panel 126 zpar x entr 920

Christer Fuglesang, STS-116 Dec, 2006

Lazio – Sirad & Pamela, 2004

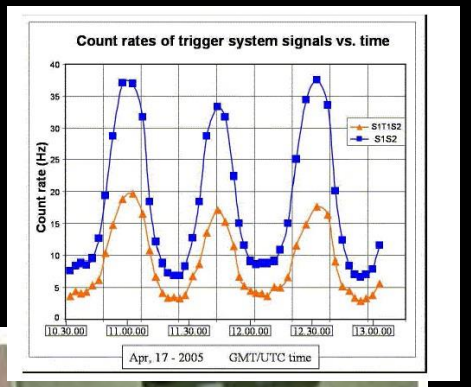

To ISS
To Soyuz
Sileye-3 & Lazio detectors inside PIRS module of ISS

LAZIO and Sileye-3Alteino detectors on ISS (2005)

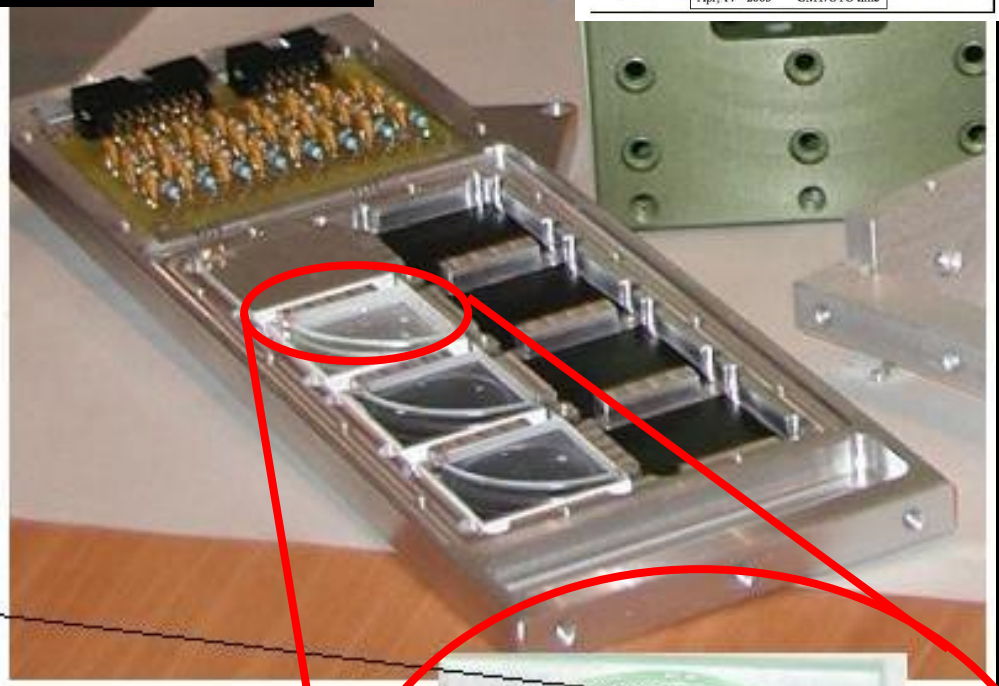


Lazio-Silicon Photomultipliers:

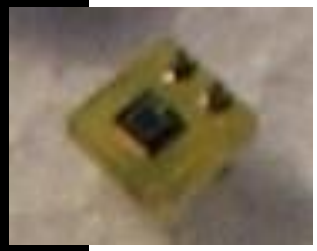
16 detectors with plastic tiles placed in two layers of the detector (original Dolgoshein-Mephi SiPM)



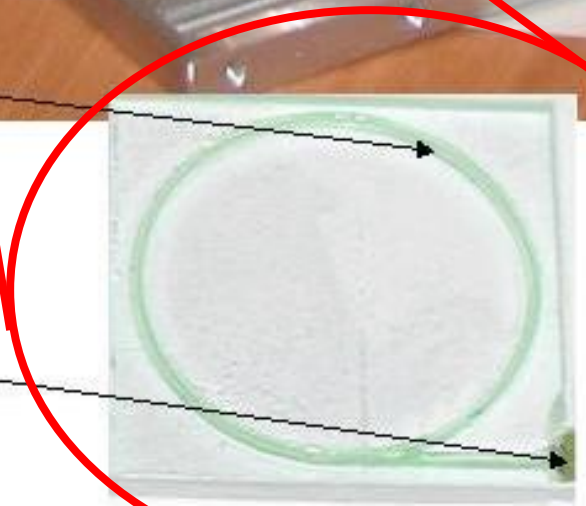
Tile:
Plastic scintillator
3x3x0.5 cm^3



Shifter



SiPM



LANFOS

(Large Area Non-destructive Food Sampler)

食品の非破壊放射能検査を可能とする
低コスト検出器の開発

Development of a low cost radiation detector for non-destructive assessment of food contamination

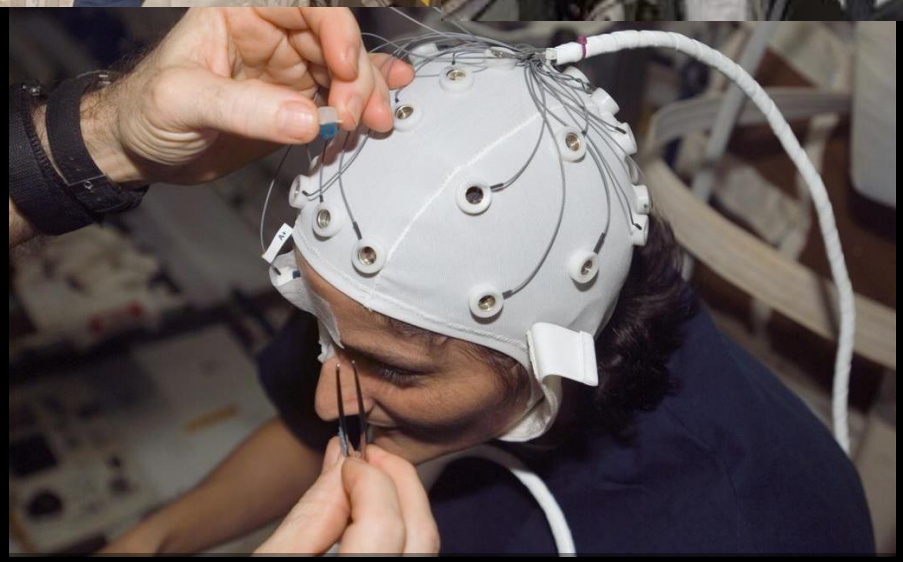
JST funding - 2012-2014

Minamisoma, Fukushima Region
2014-11-01

Patent JP,2014-039414 for
"realization of a radiation detector to measure cesium in food"

SiPM development for space-borne and ground detectors: From Lazio-Sirad and Mini-EUSO to Lanfos.
Nuclear Instruments and Methods in Physics Research A, 986:164649, January 2021. doi:10.1016/j.nima.2020.164649.
The simulation of the lanfos-h food radiation contamination detector using geant4 package. Computer Physics Communications, 187(0):49 { 54, 2015. ISSN 0010-4655. doi:http://dx.doi.org/10.1016/j.cpc.2014.10.010.
Lanfos: 4, a 4π detector for the assessment of radiation in food. B, Power and Energy Division Nuclear Power Research Group B, NE13002, sep 2013.

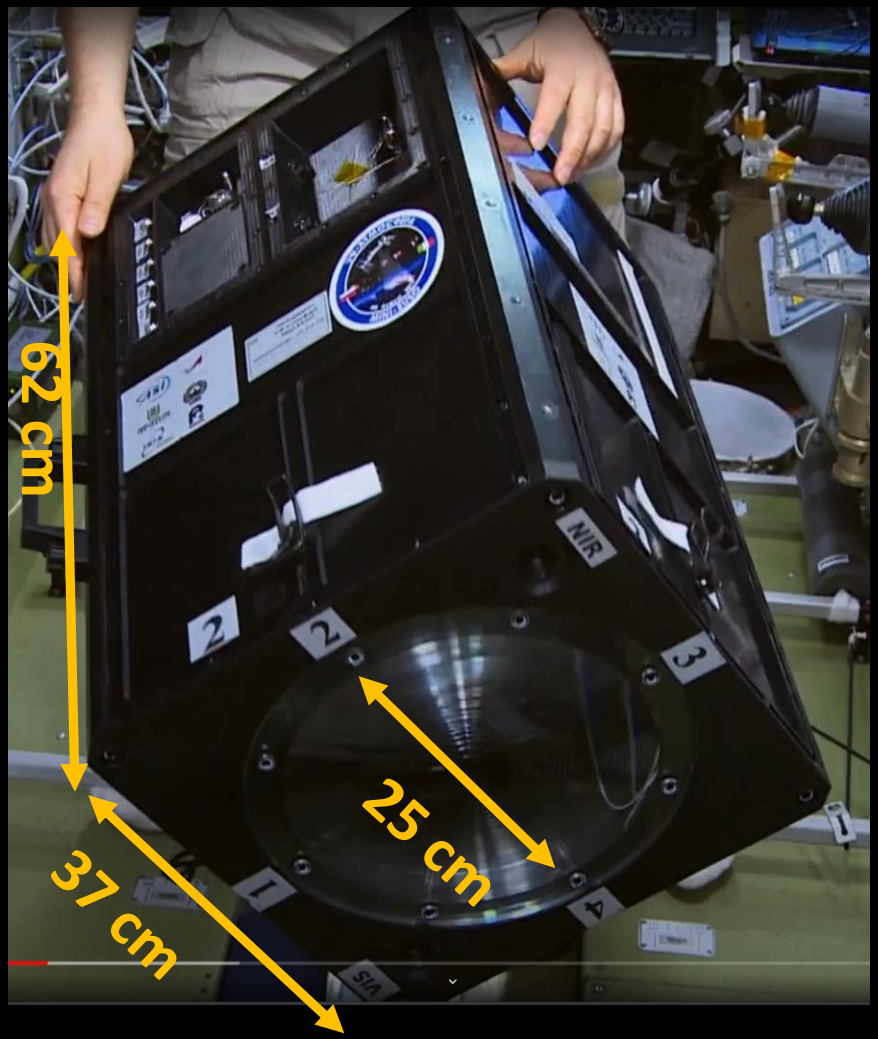
ALTEA 2006-2012 + Lidal 2019-



Sunita Williams, Mike Lopez-Alegria, P. Nespoli

Mini-EUSO/UV-Atmosfera

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

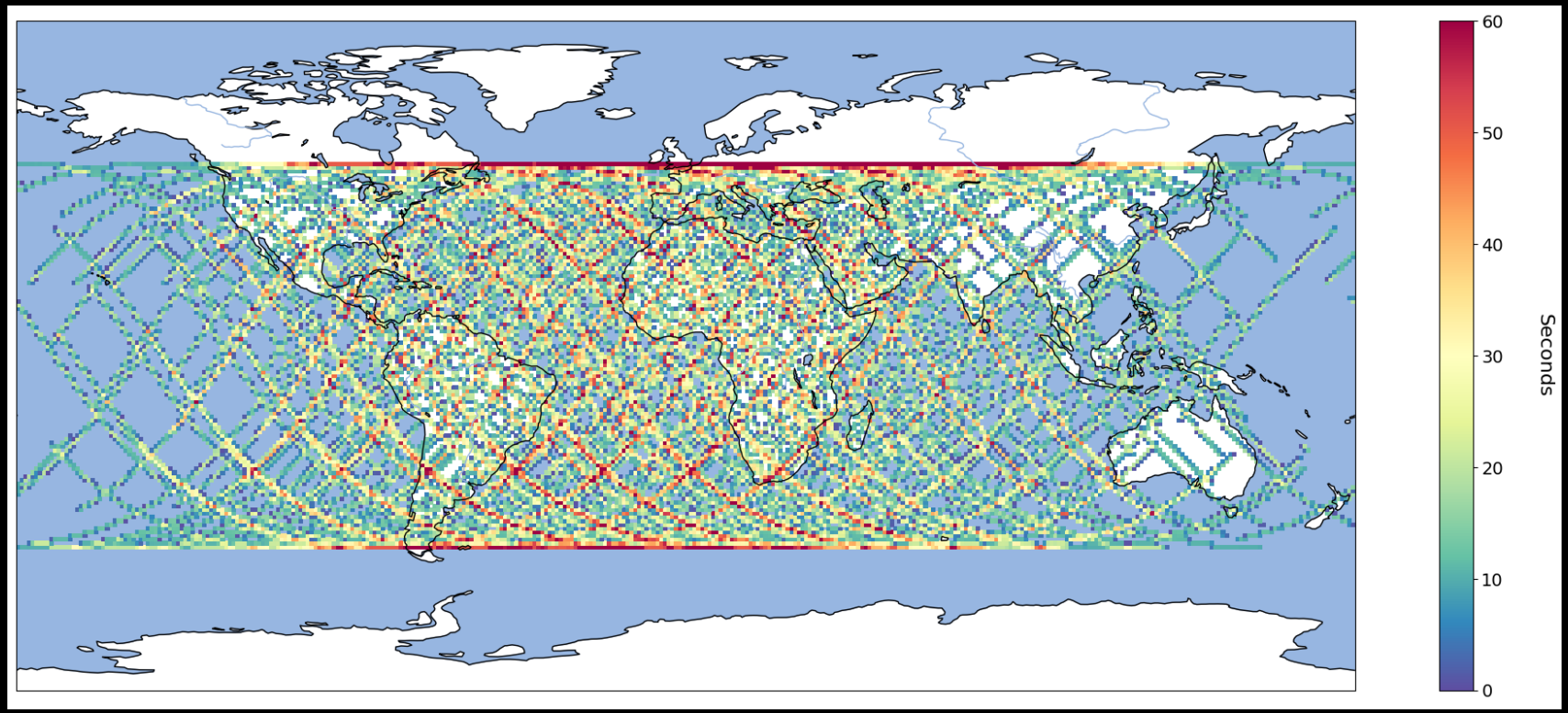


Mini-EUSO: A high resolution detector for the study of terrestrial and cosmic UV emission from the International Space Station. ASR 62(10):2954{2965, Nov 2018.

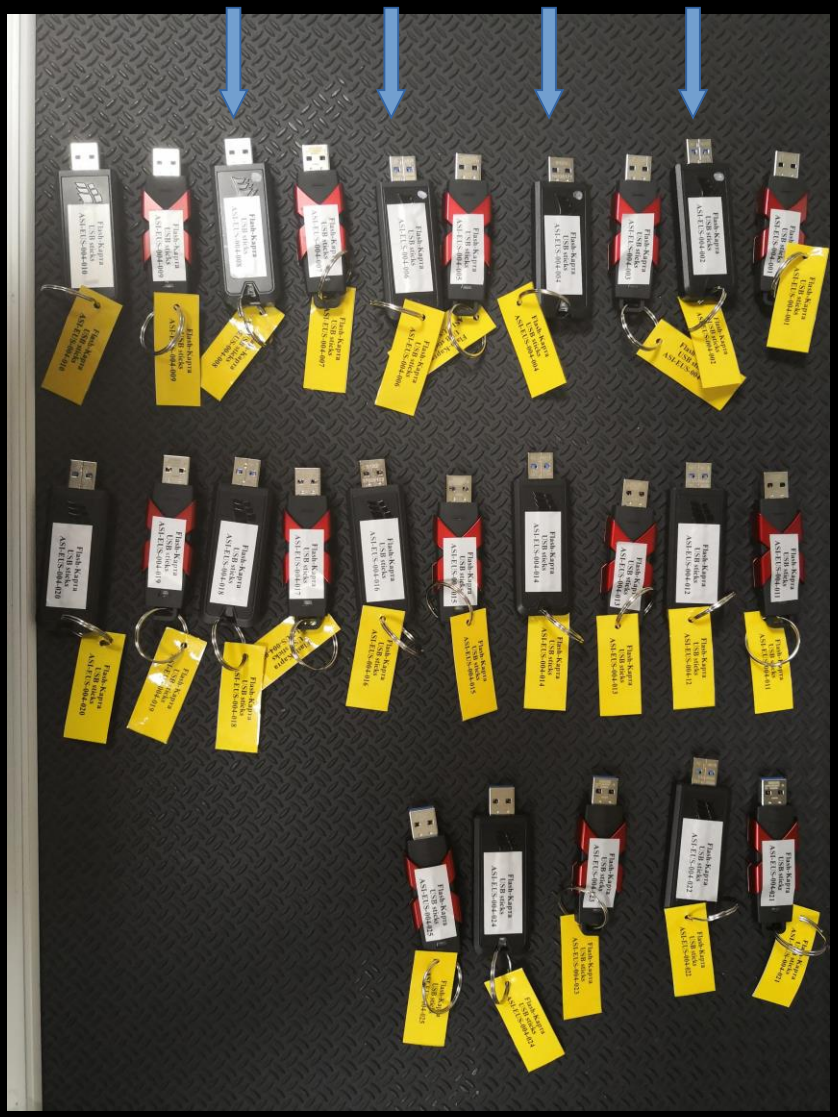
Capel, F., et al. Mini-EUSO data acquisition and control software. JATIS, 5(4), OCT 2019. ISSN 2329-4124. doi:10.1117/1.JATIS.5.4.044009.

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

Mini-EUSO
Earth Mapping



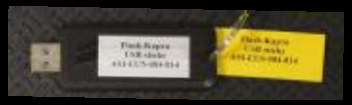
Bandwidth vs throughput



GOOD PENS:

CORSAIR 3.1 – new model

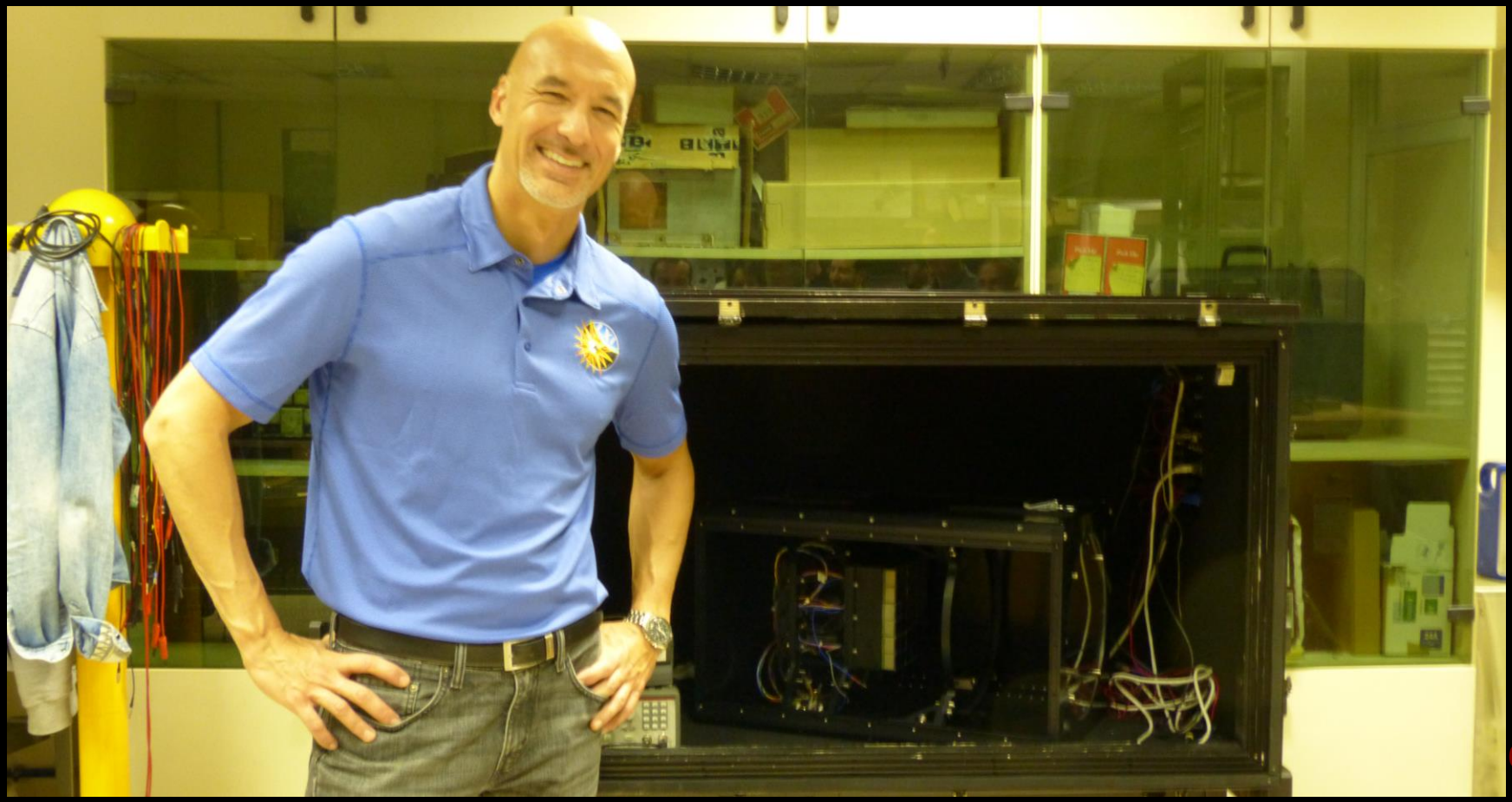
BAD PENS:



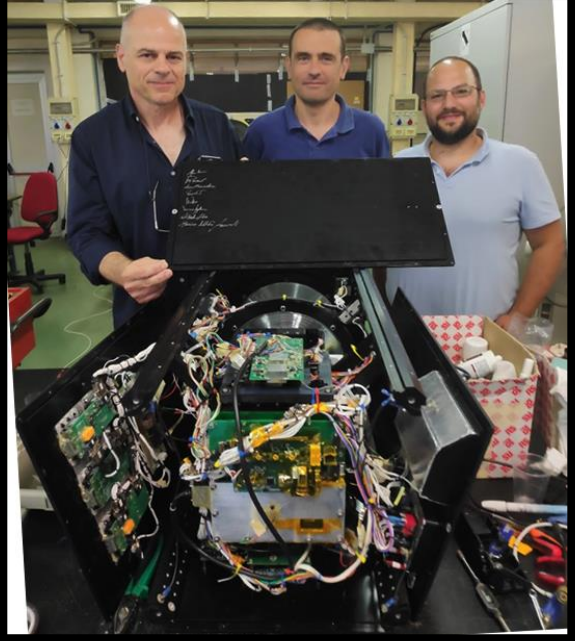
CORSAIR 3.0

KINGSTON 3.0

Clean Rooms

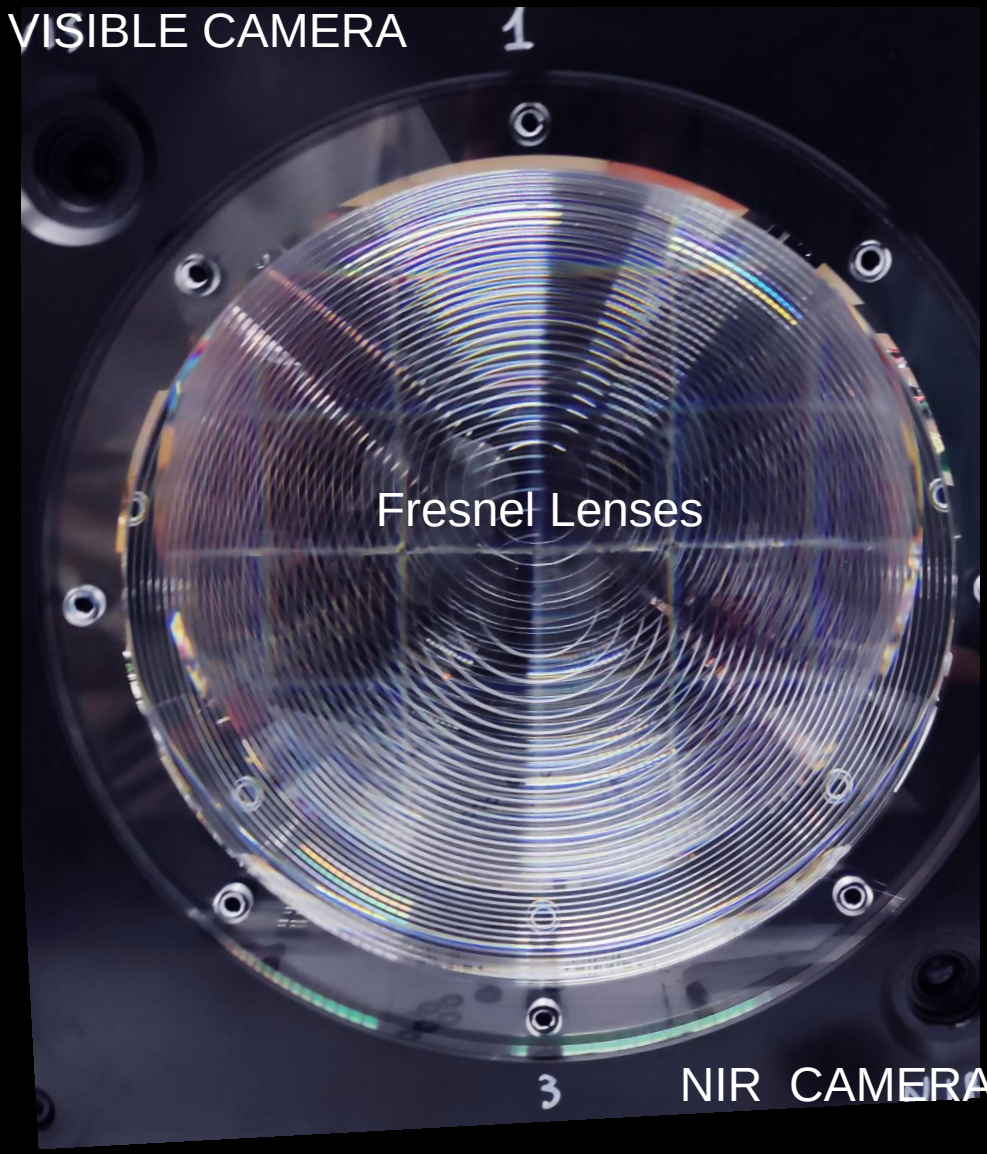


LNF Mechanics Shop



Clean Room Labs, Tov

Fresnel Lenses



Acceptance tests in Baikonur and integration with Soyuz MS-14

Building 254, assembly of Soyuz/Progress

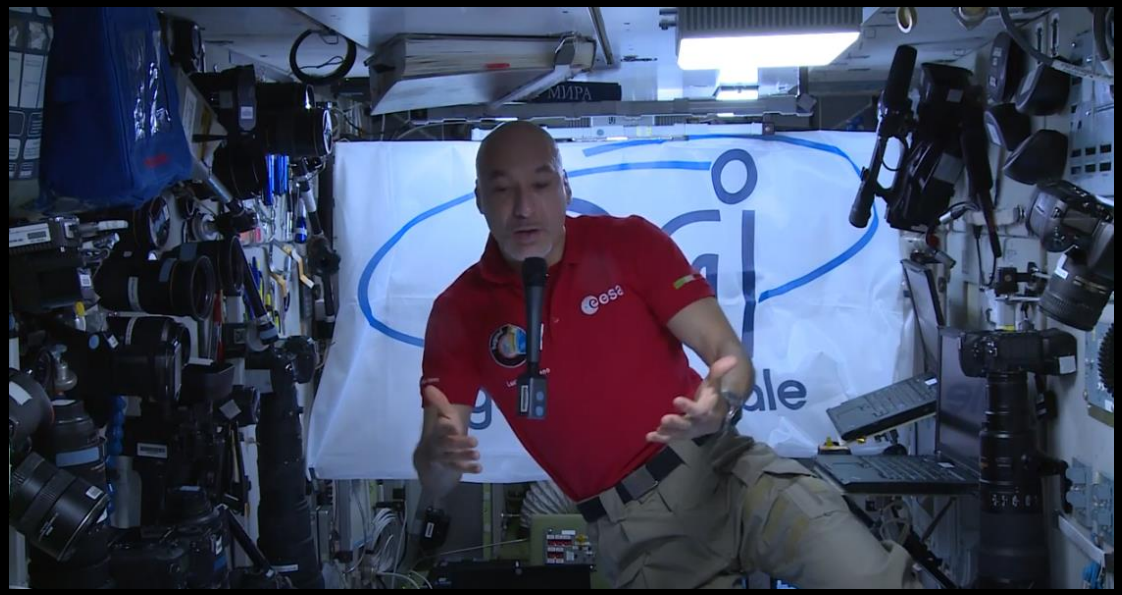
Roll-out of Soyuz MS-14, 19/8/2019

Launch, 2/8/2019

First docking, 24/8/2019 unsuccessful

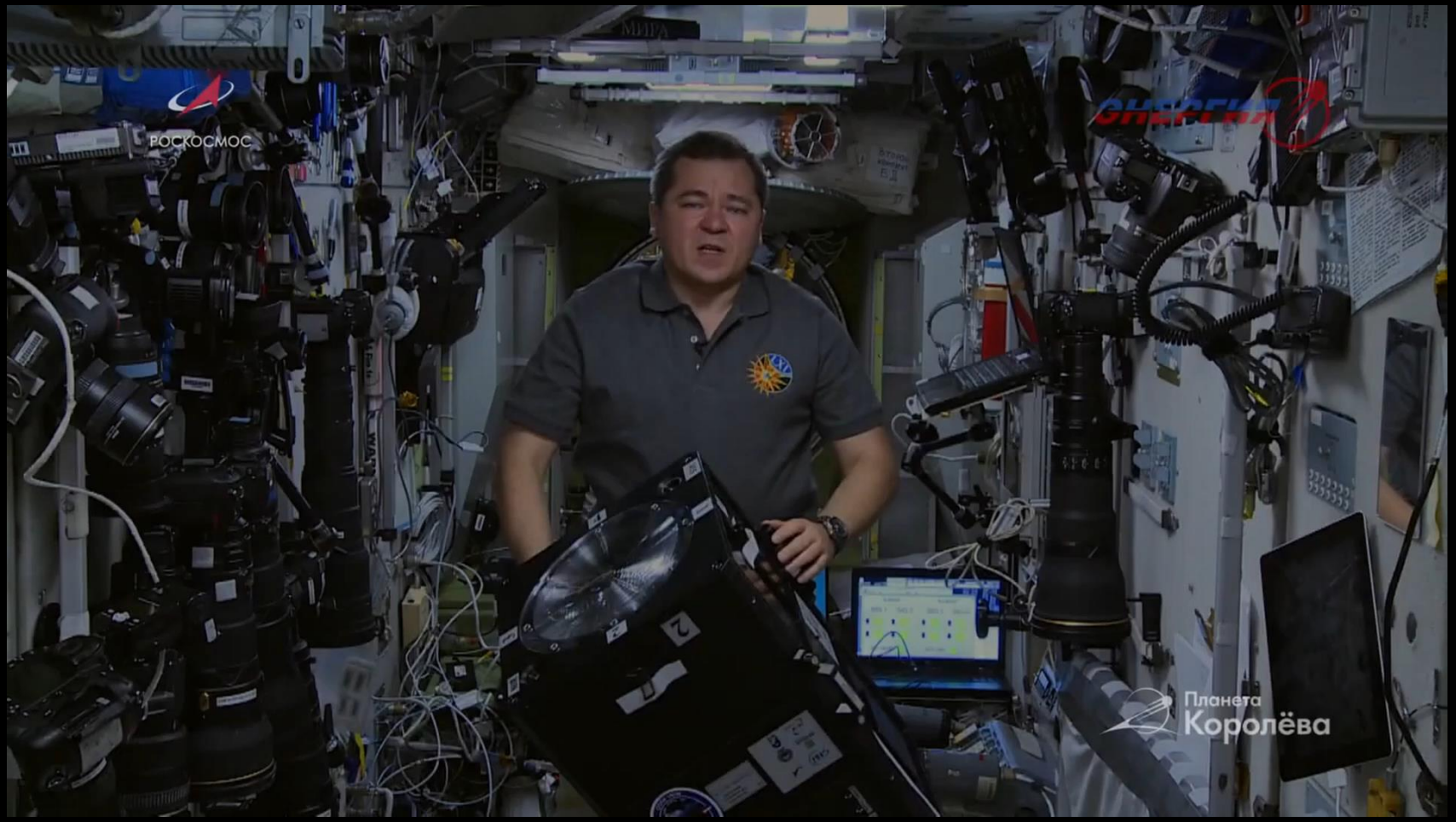
Relocation of MS-13 from Zvezda to Poisk

Second docking, 27/8/2019 successful



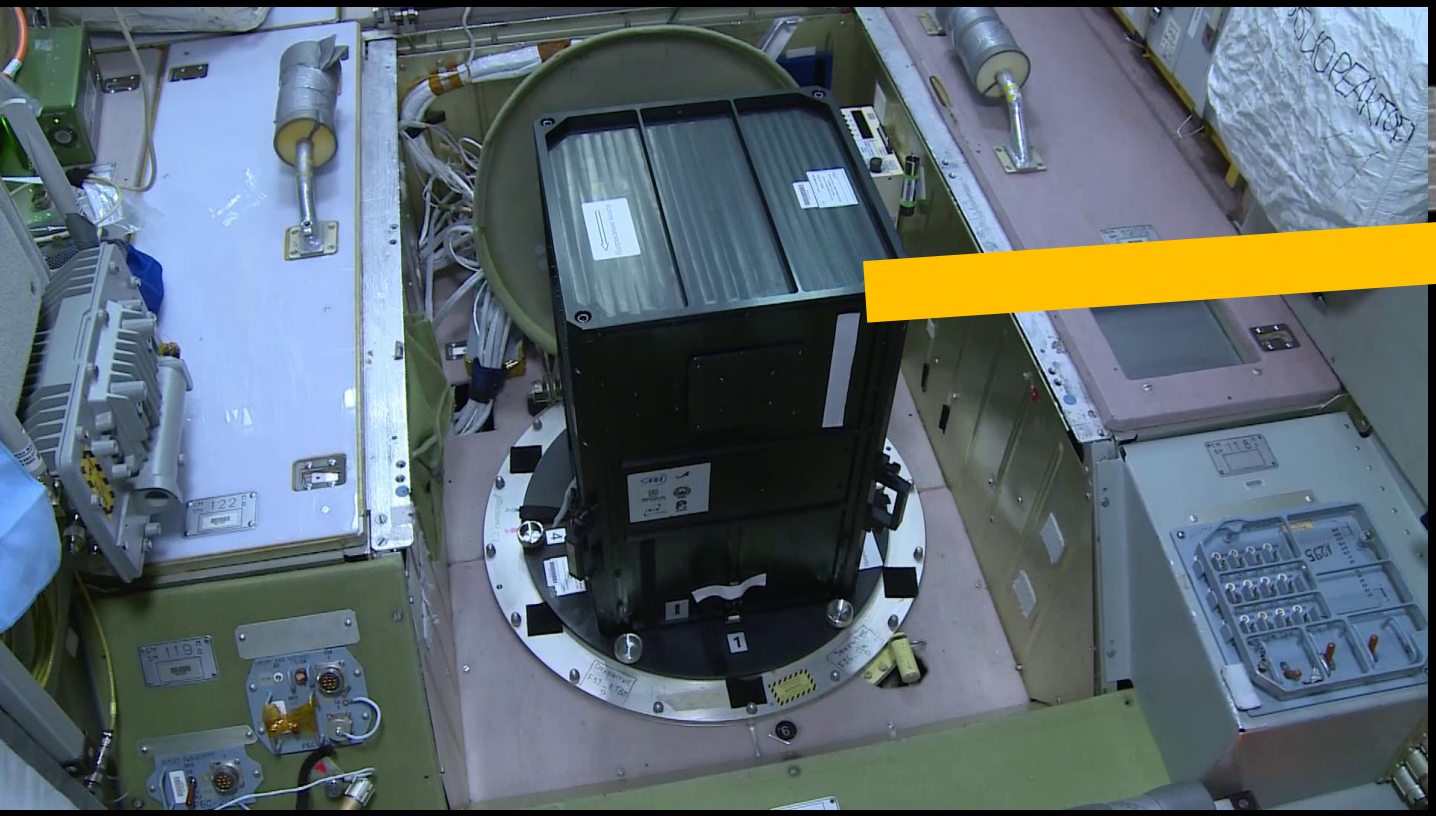
https://www.youtube.com/watch?v=wh21-hhOUQU&t=29s

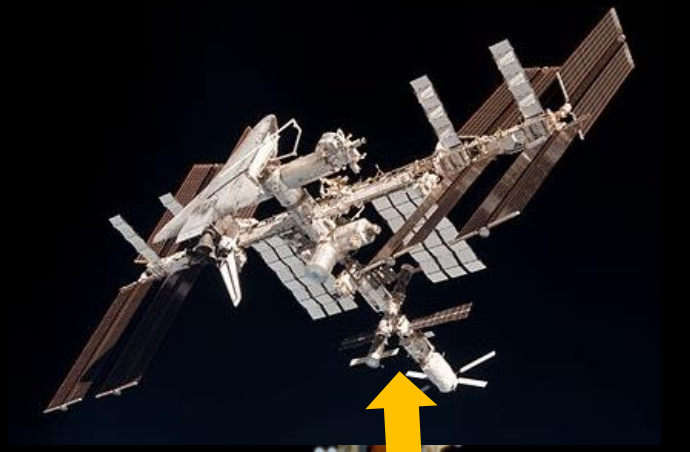
youtube.com/watch?v=lXedBGVHc4o

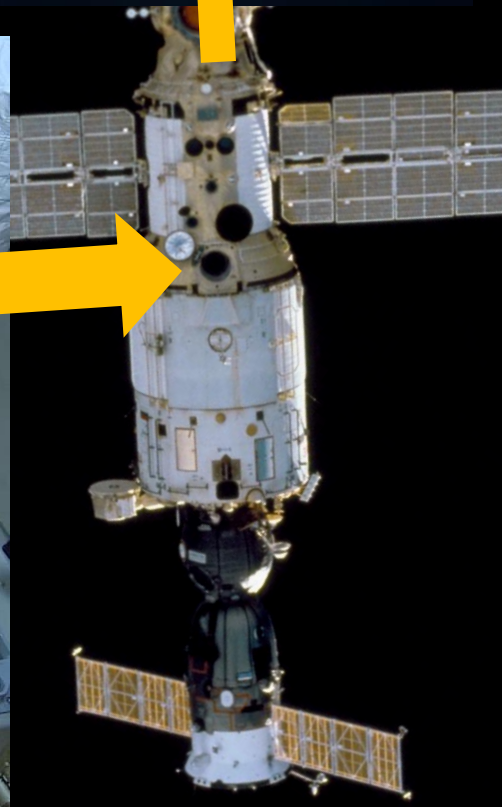


youtube.com/watch?v=lXedBGVHc4o

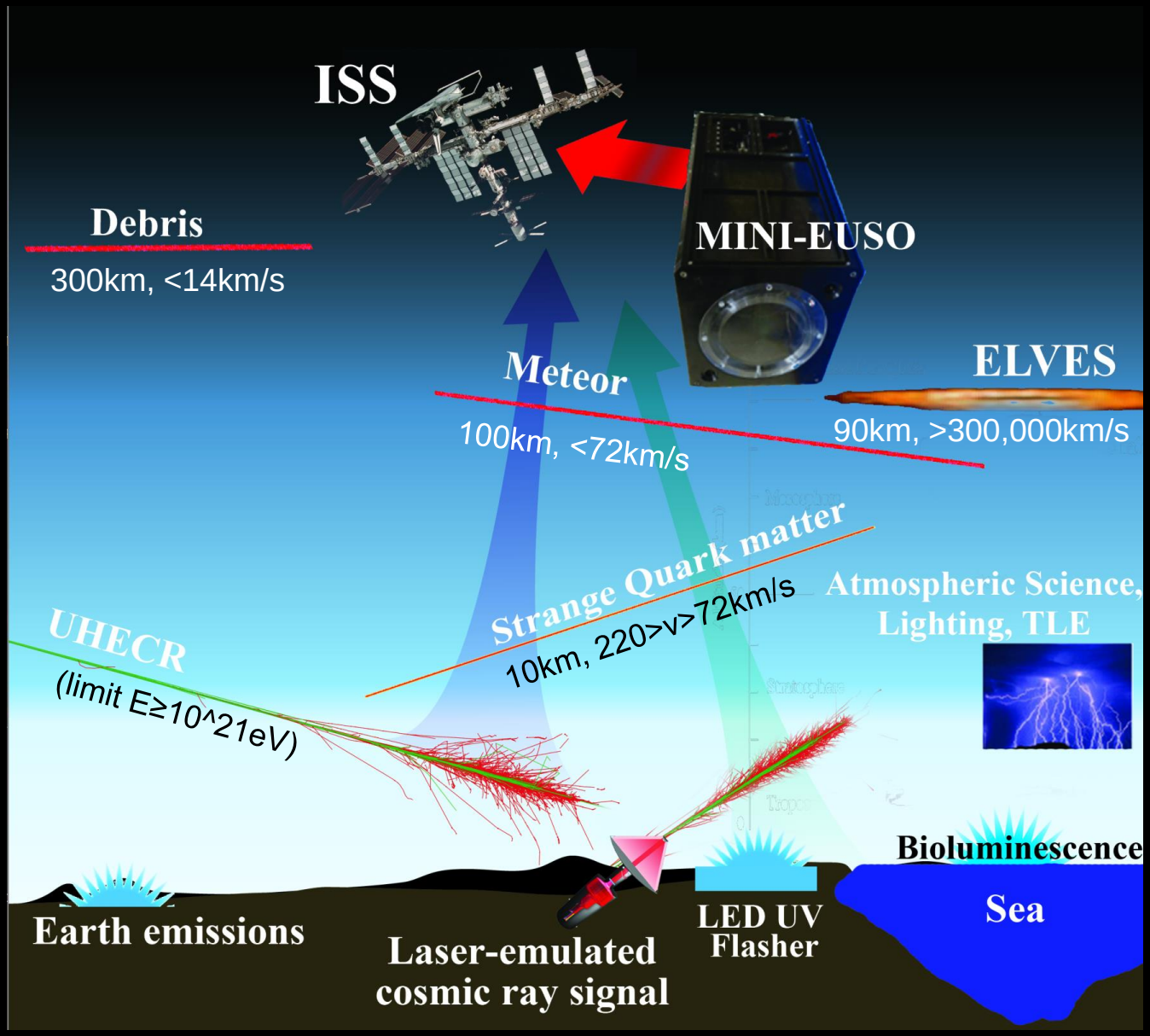
Uv transparent window, Zvezda module, International Space Station



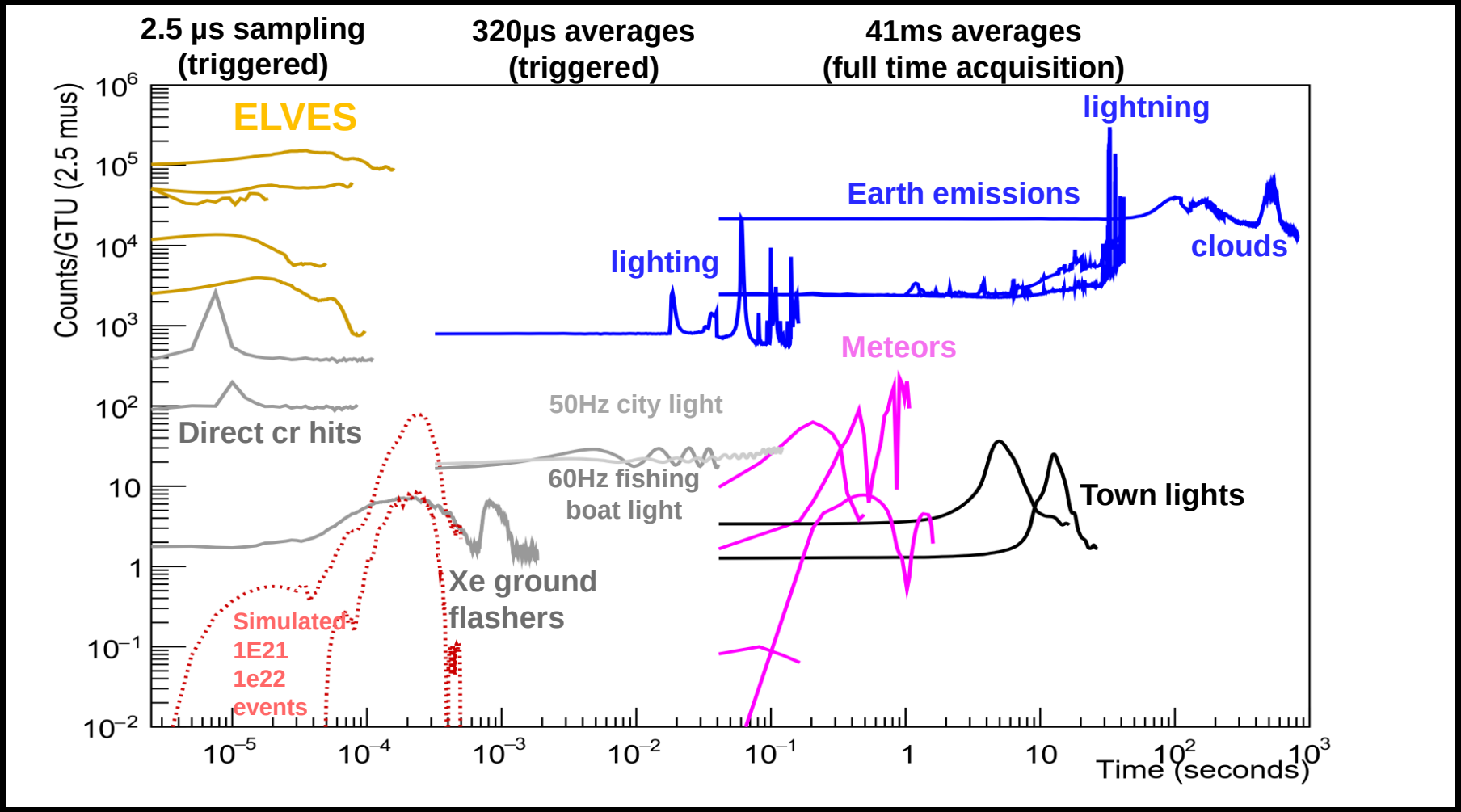




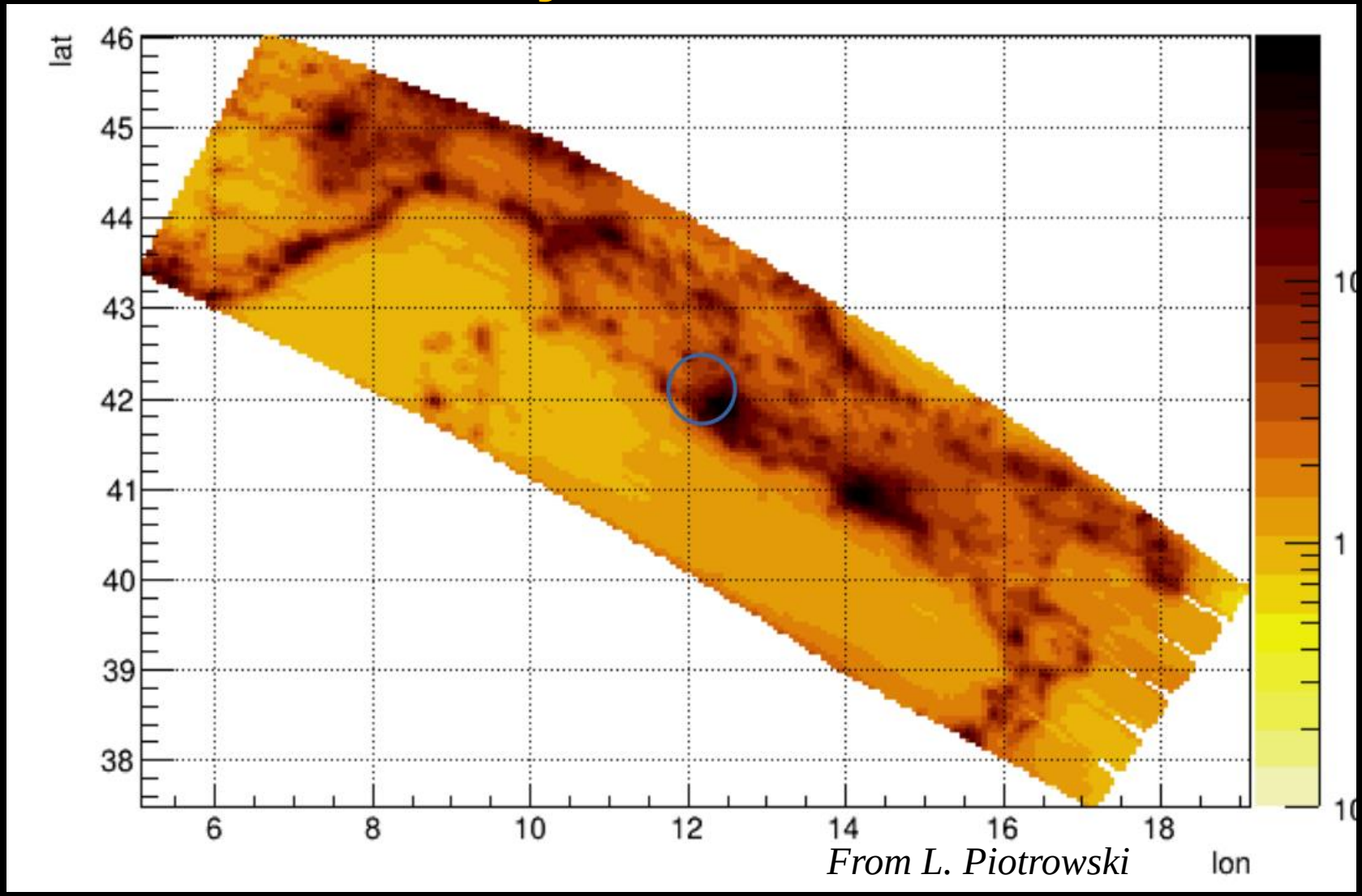
Science Objectives



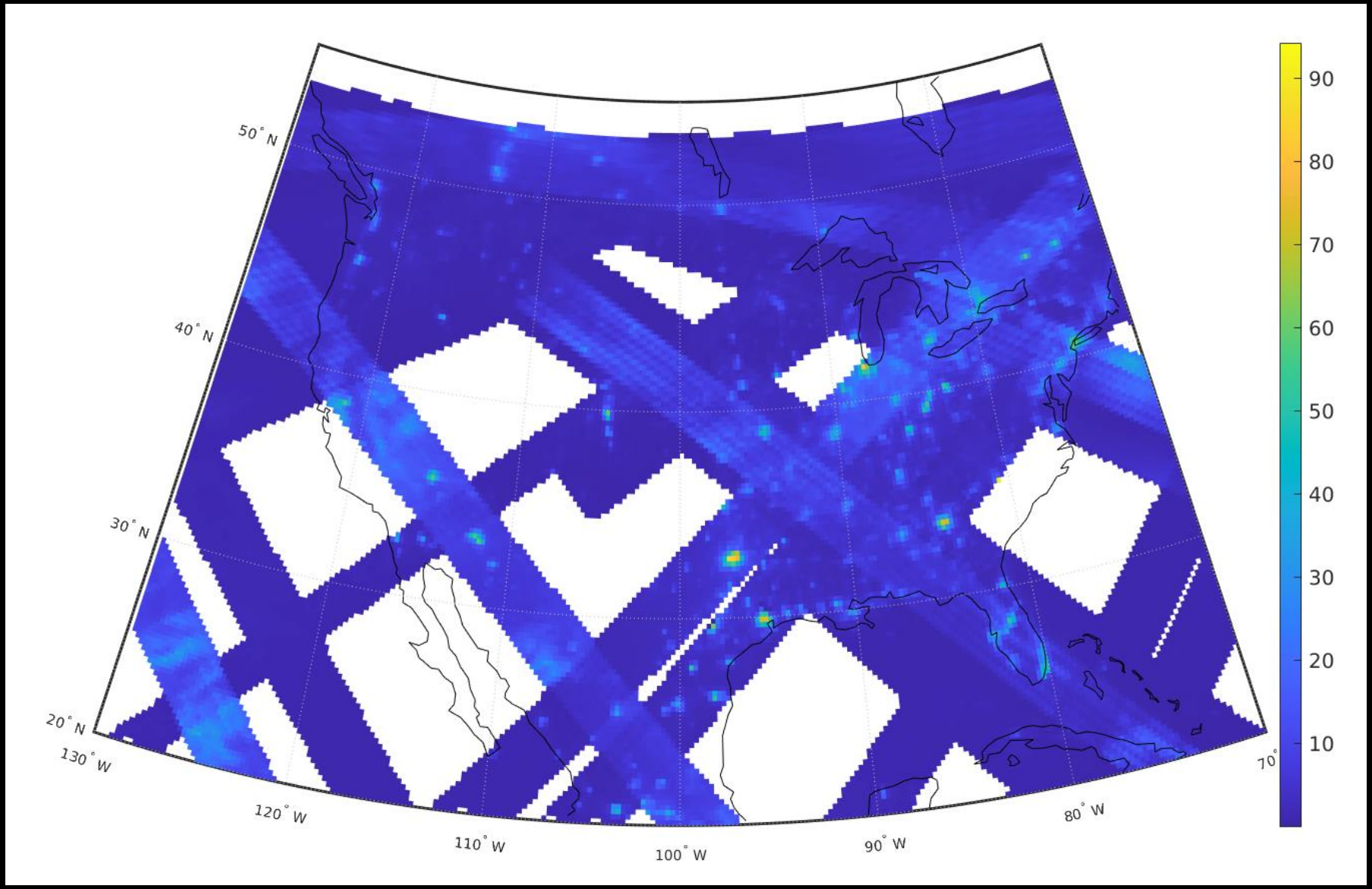
Time profile of various events



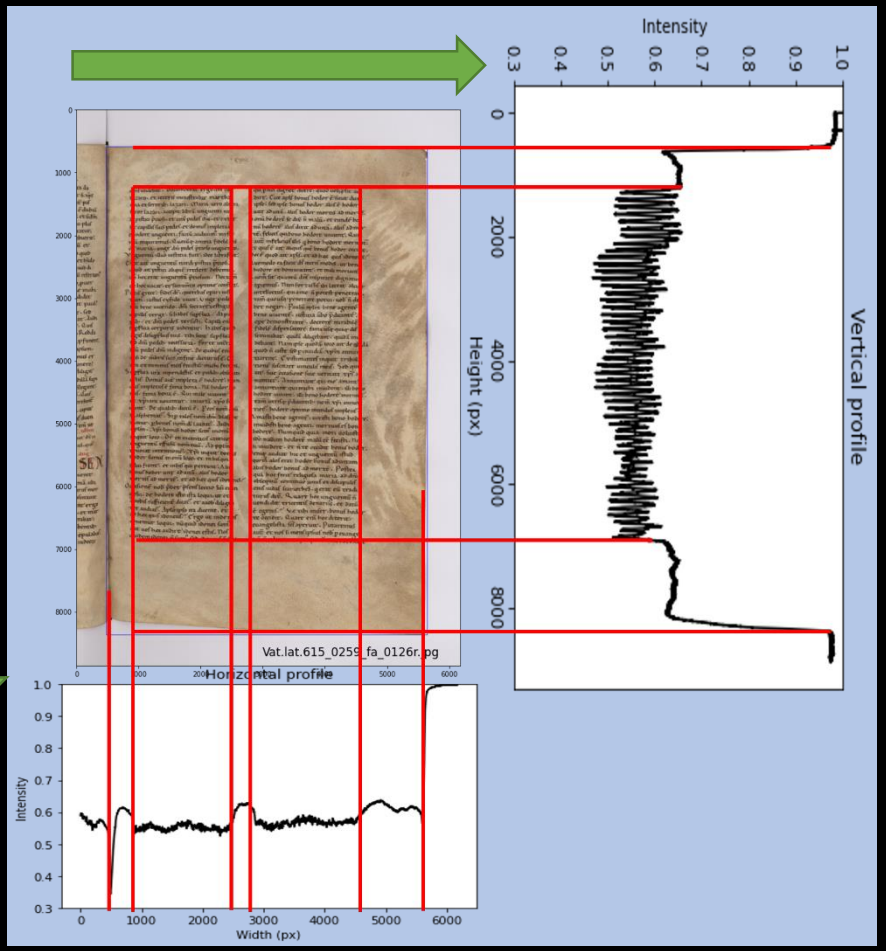
Italy, 15-9-2019

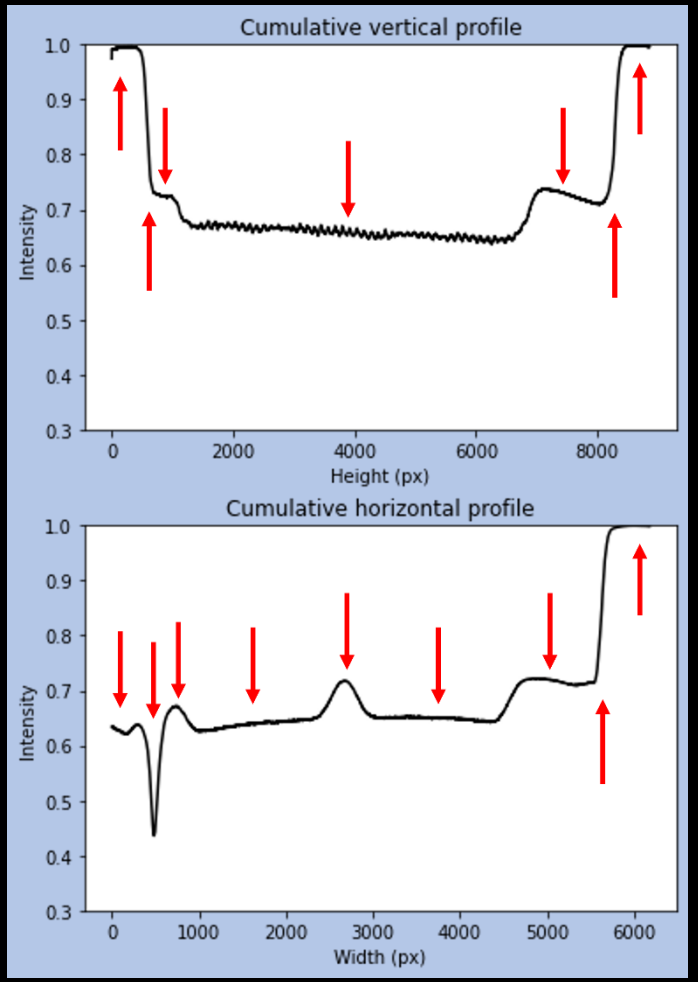


Northern America



Feature extraction in ancient manuscripts of the Vatican Apostolic Library



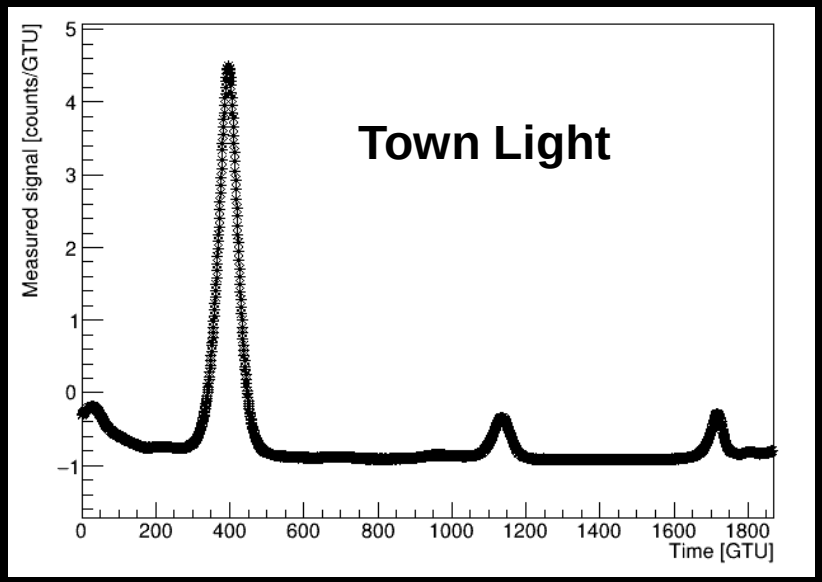


Massimiliano Foffi, G. Giuffrida

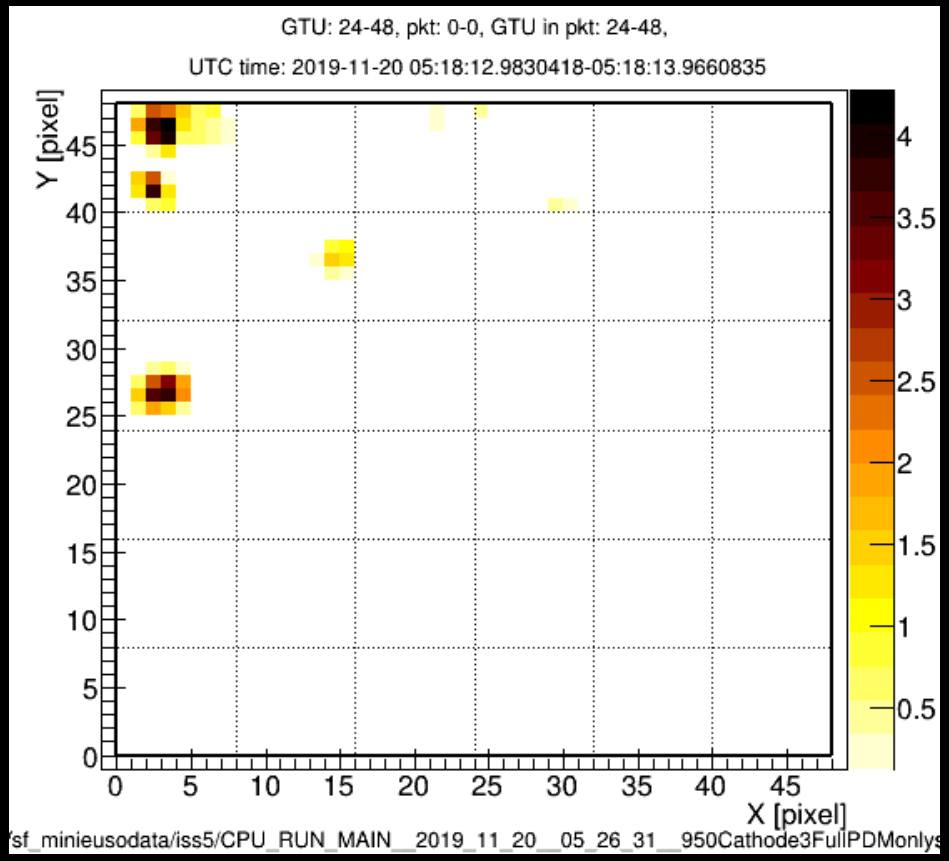
Ground emissions
(between Vancouver and Calgary)

41ms continuous sampling

Pixel size 6.1km
ISS speed 7km/s
Yaw of 4 degrees



41ms samples

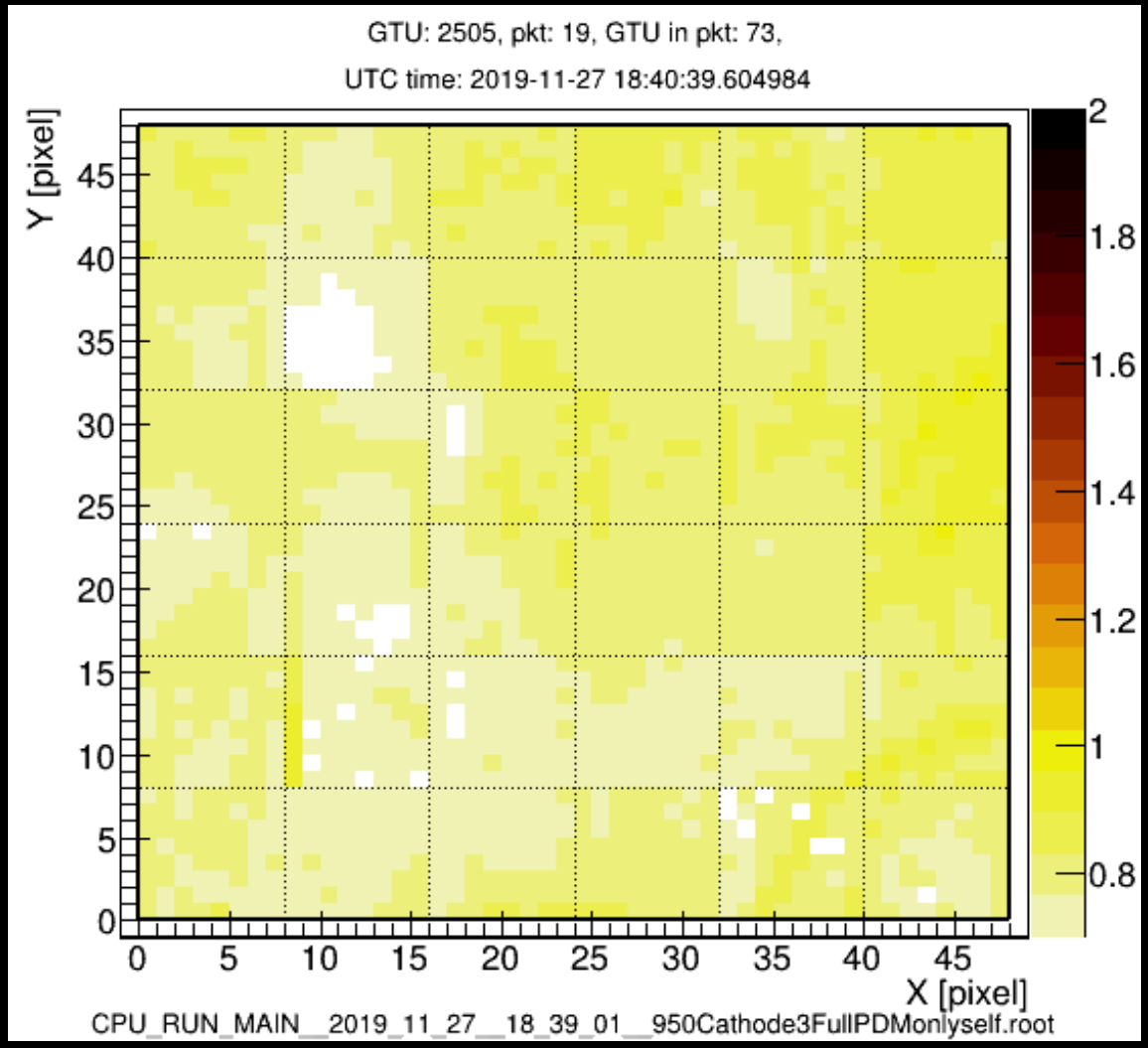


1s 25D3 frames average

Meteor observations with Mini-EUSO

1200 meteors detected so far

Maximum speed 72 km/s

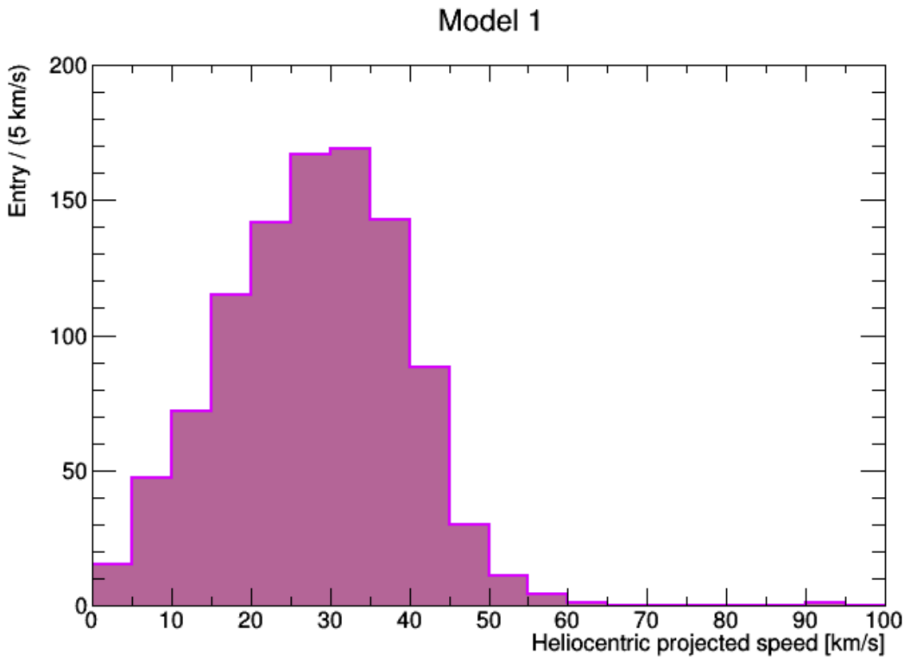


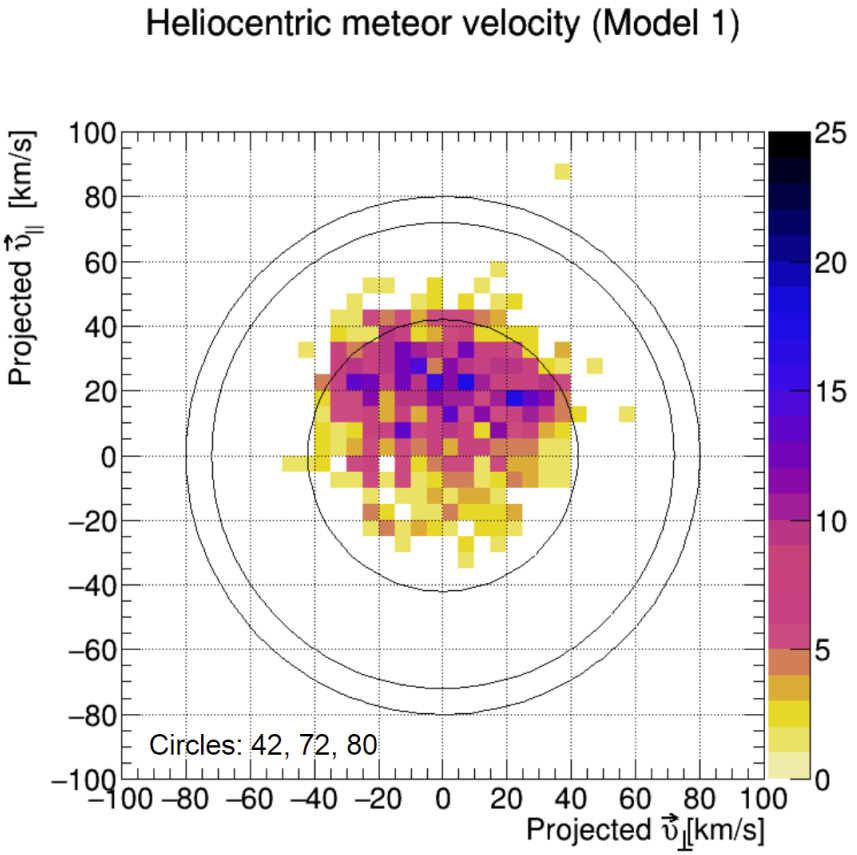
Meteor studies in the framework of the JEM-EUSO program. PLANETARY AND SPACE SCIENCE, 143(SI):245{255, SEP 1 2017.

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

Interstellar Meteor Candidate

Projected heliocentric (apprenent + Model 1)





From Shinozaki

Interstellar meteoroid flux

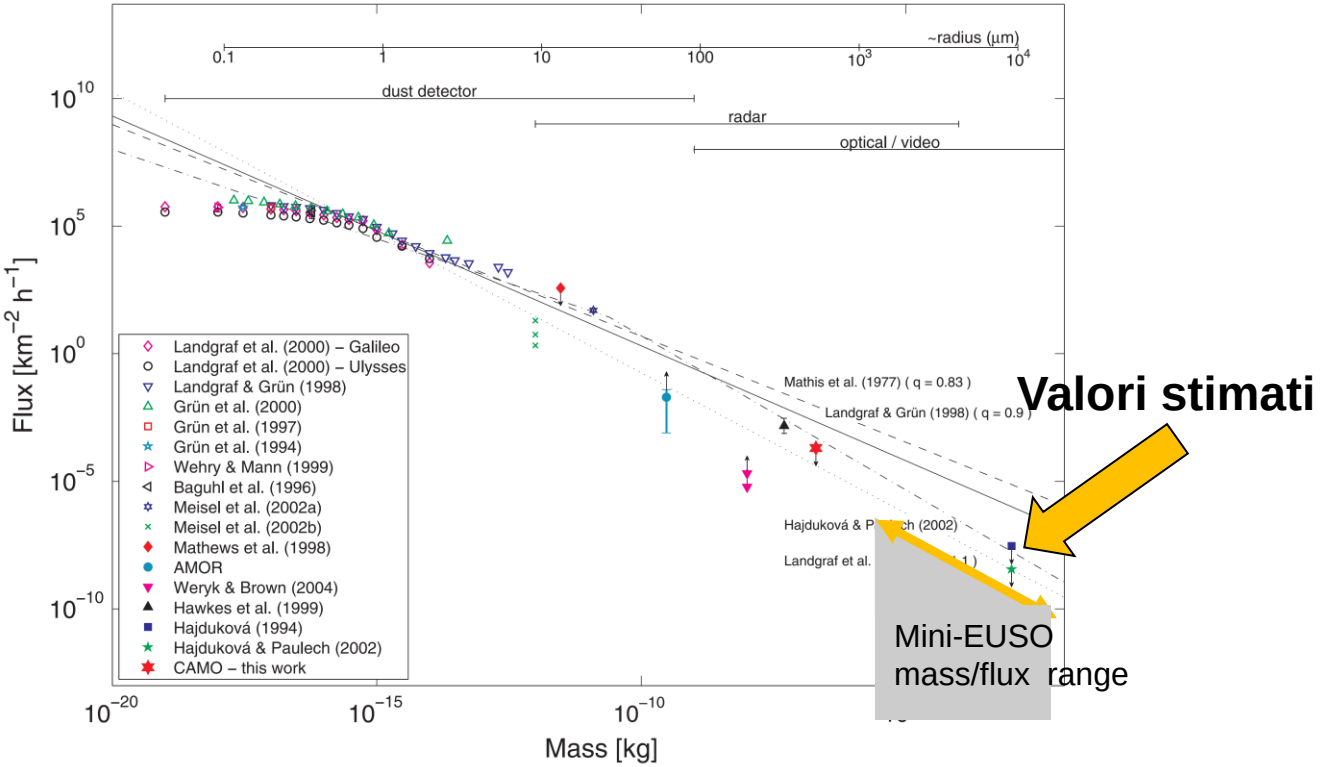
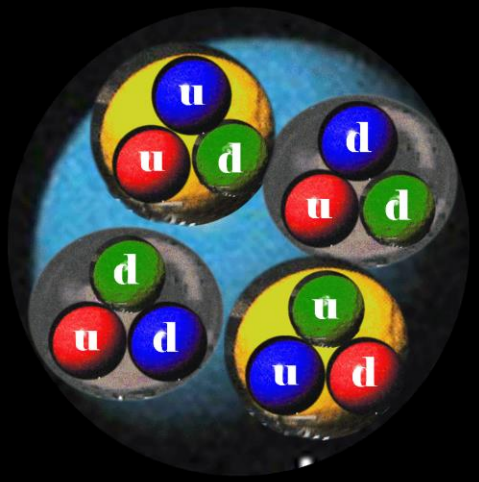


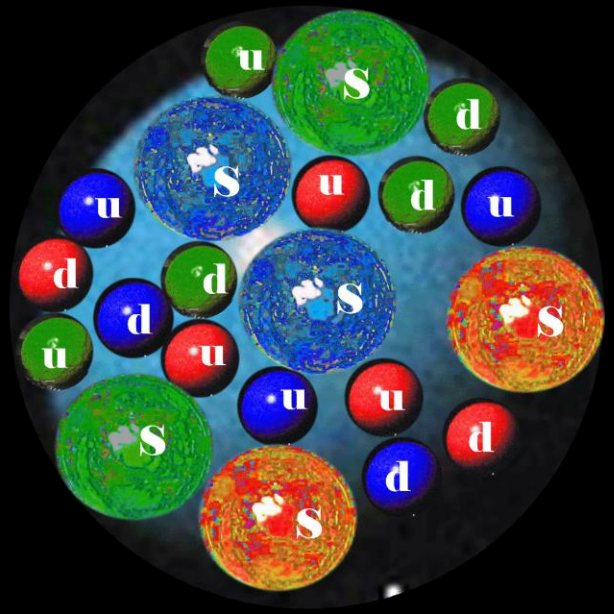
Figure 1. Interstellar meteoroid flux estimates from various studies. The large star represents our result. Arrows indicate upper and lower limits. The data points from Meisel et al. (2002b) are for Geminga supernova particles assuming different models and fits. The AMOR data include the results from 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….

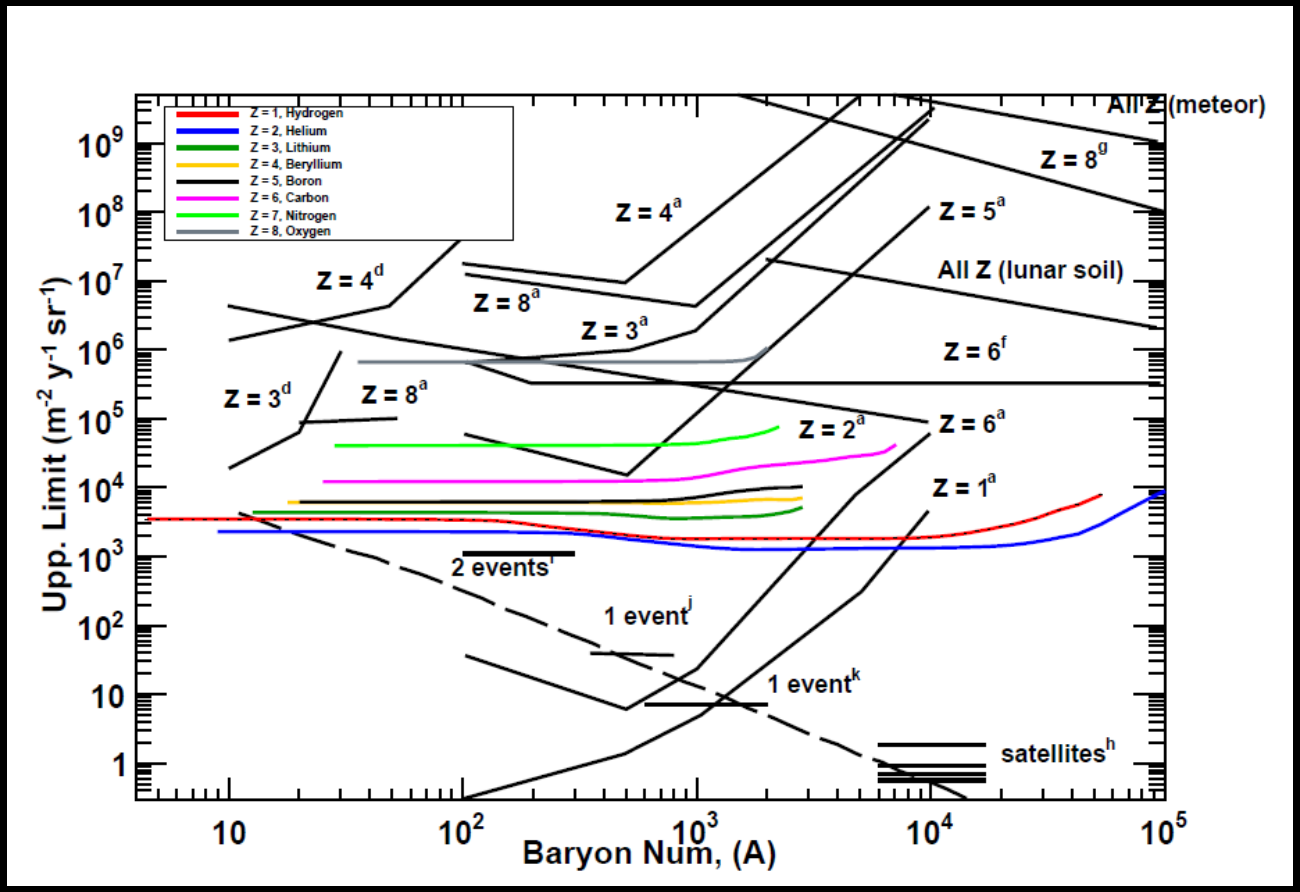
Z is almost zero due to cancellation of quark charge

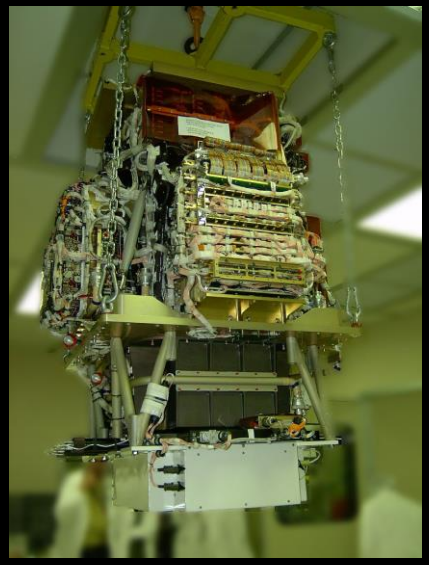
Could account for Dark Matter

Also candidate of UHECR

No Exotic Physics needed

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)

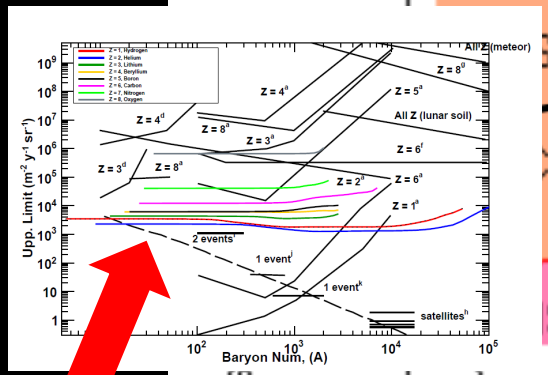
PAMELA, Z=1

PAMELA, Z=2

Strangelet-like events detected by:

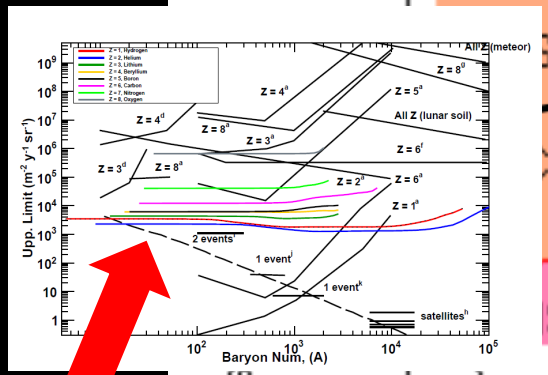
i) HECRO-81 PRL **65**, 2094 (1990)
j) ET Nuovo Cimento A Serie **106**, 843 (1993)
k) Phys. Rev. D **18**, 1382 (1978)

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



PAMELA

W.B. Banerdt et al. / Nuclear Physics B (Proc. Suppl.) 166 (2007) 203–208



PAMELA

Mini-EUSO

W.B. Banerdt et al. / Nuclear Physics B (Proc. Suppl.) 166 (2007) 203–208

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

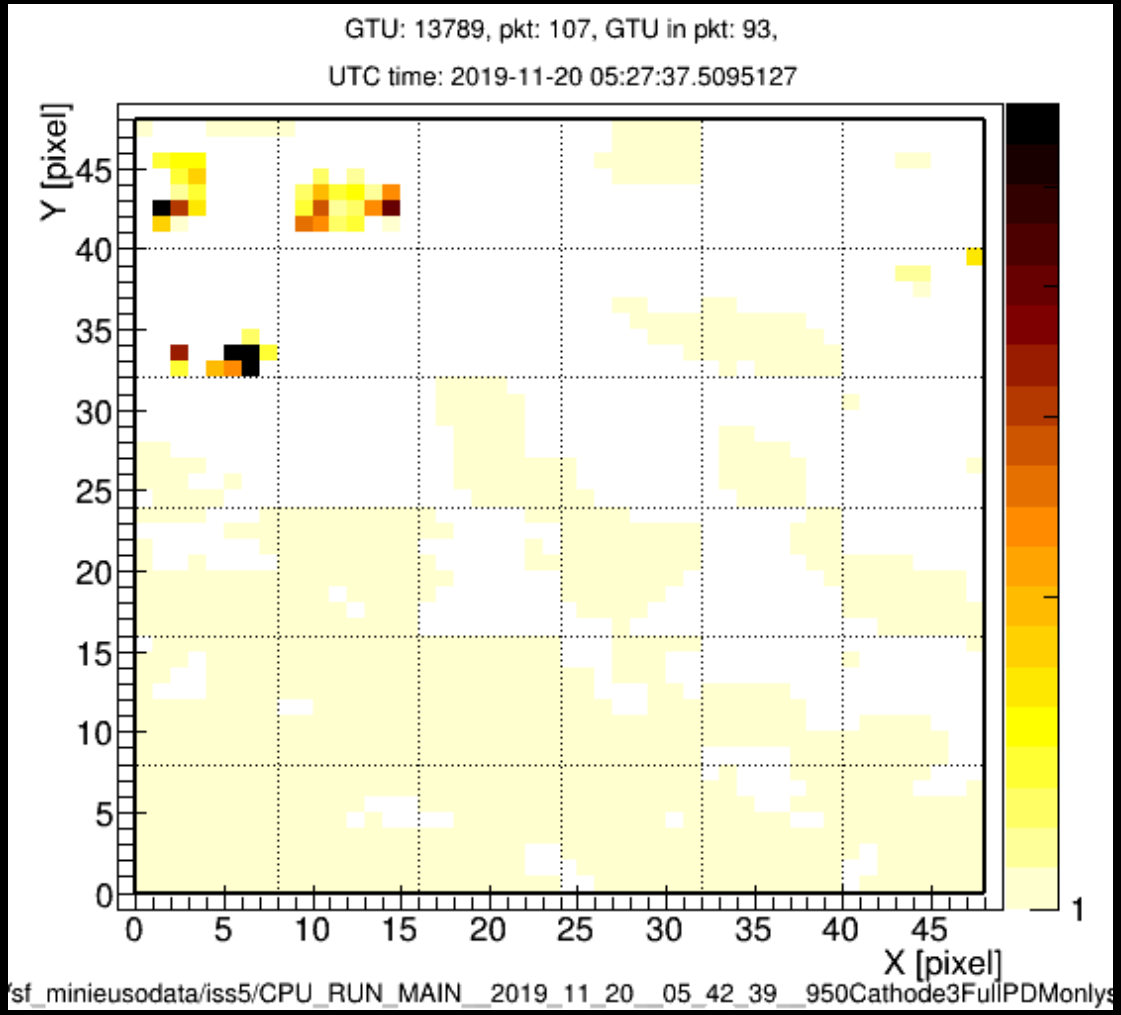
JEM-EUSO: Meteor and nuclearite observations. Experimental Astronomy, 40:253{279, November 2015.

Search for Strange quark matter

10000 meteors detected so far

Maximum speed 72 km/s
Interstellar meteors:
220km/s>V>72 km/s
Relevance for solar system formation, Kuiper belt.

SQM: 220km/s>V>72km/s
Long continuous track

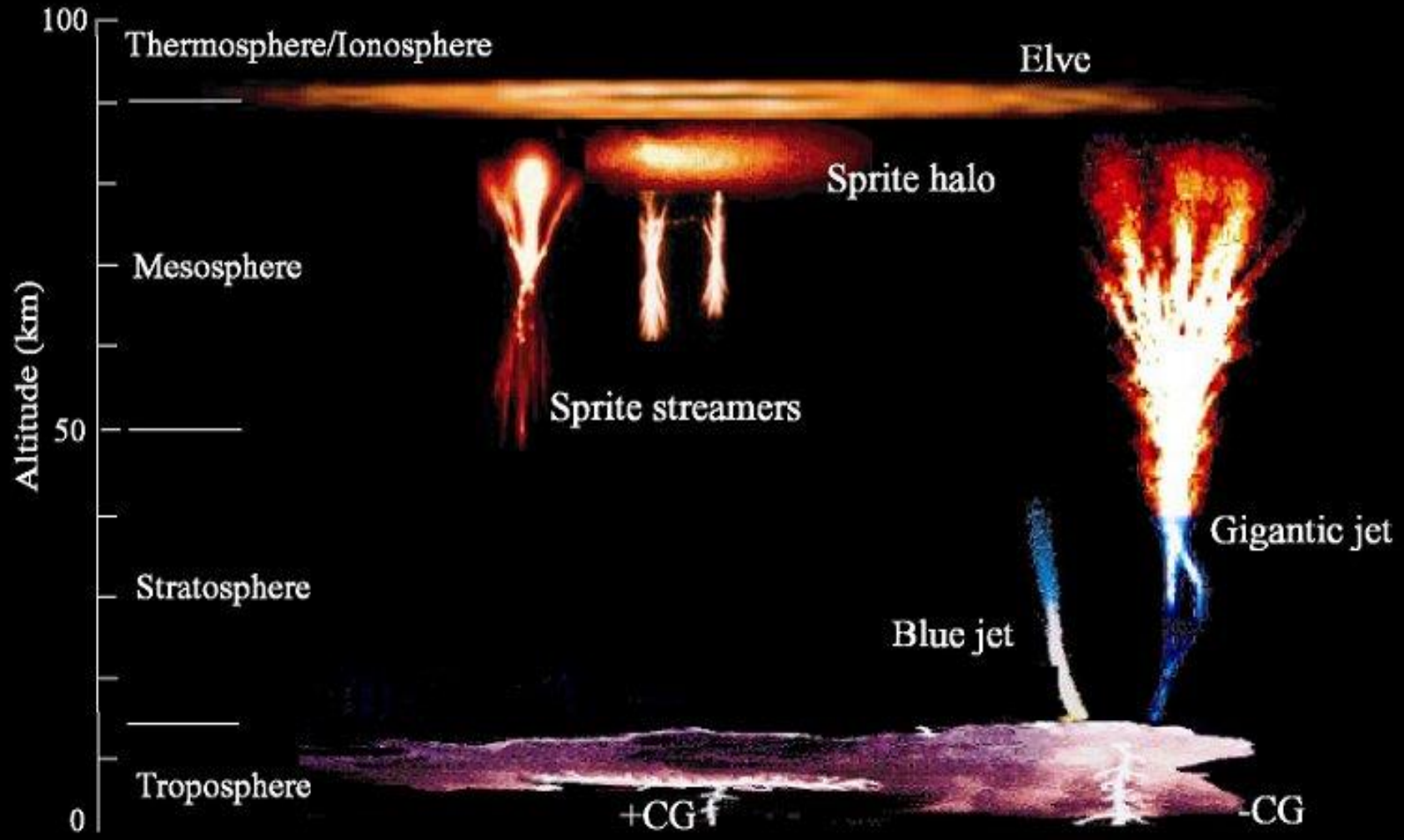


Meteor studies in the framework of the JEM-EUSO program. PLANETARY AND SPACE SCIENCE, 143(SI):245{255, SEP 1 2017.

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

ELVES

(transient luminous events)



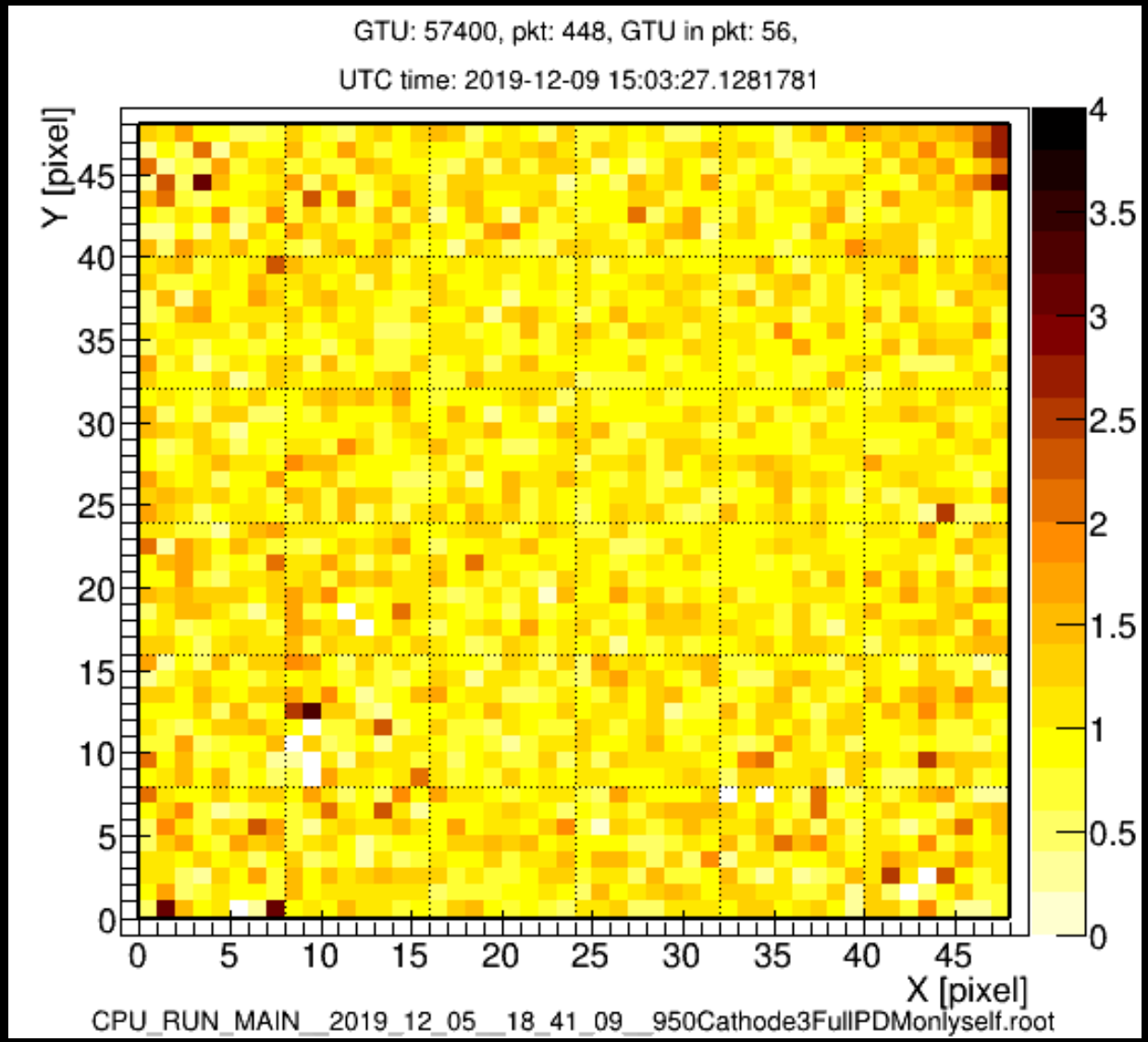
ELVES (transient luminous events)

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



ELVES (transient luminous events)

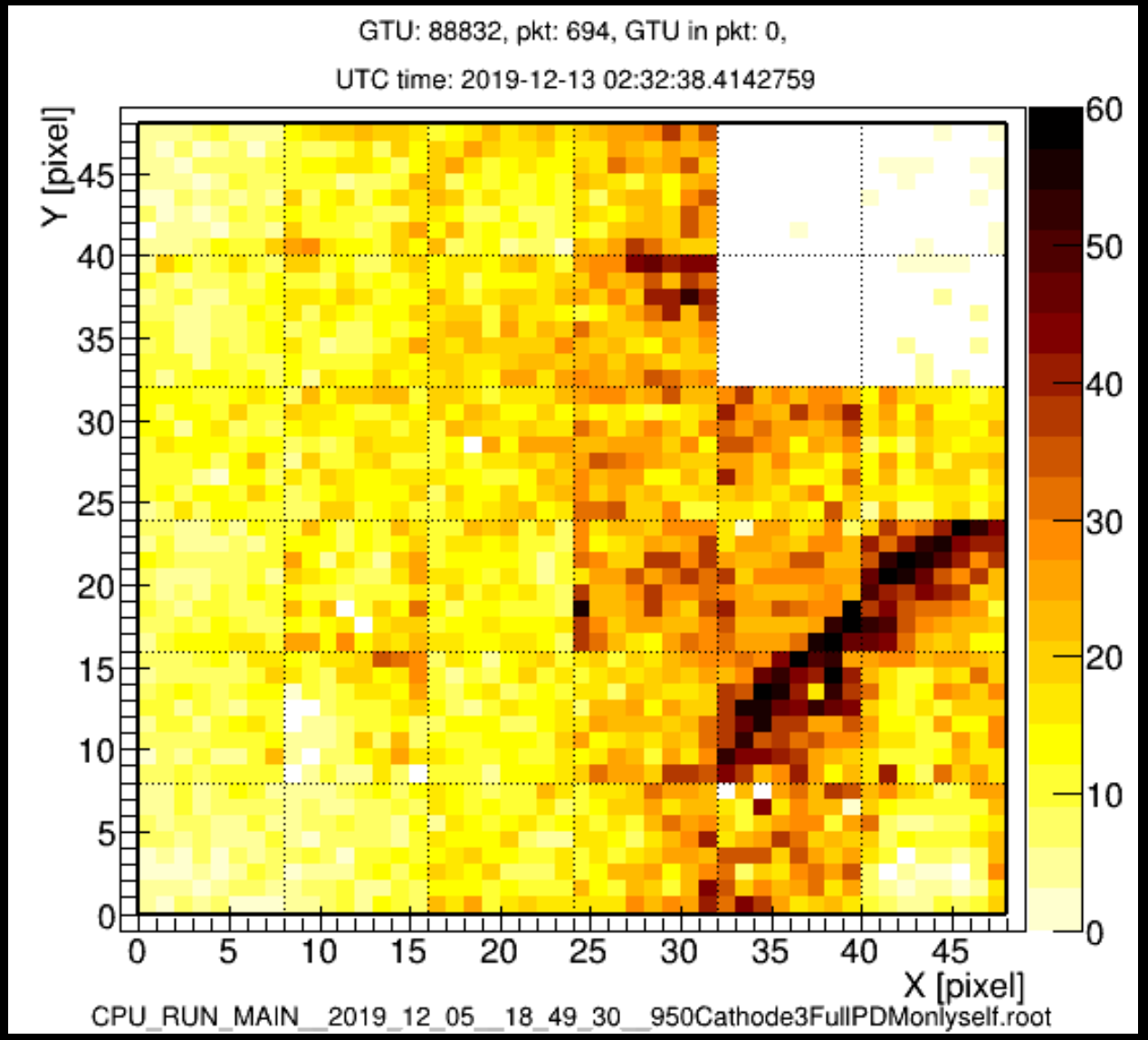
971. Observation of Transient Luminous Events with the Mini-EUSO telescope on board the ISS
laura marcelli (INFN, National Instit...

Superluminal rings
100km+ radius

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

About 400mus
Overall duration

2.5µs sampling speed



Selected publications

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

Demonstration designs for the remediation of space debris from the International Space Station, Acta Astronautica, doi:10.1016/j.actaastro.2015.03.004, Volume 112, July–August 2015, Pages 102-113

Secondary cameras onboard the Mini-EUSO experiment: Control software and calibration. Advances in Space Research, 64(5):1188{1198, Sep 2019.

**Accelerating strangelets via Penrose process in non-bps fuzz-balls. Nuclear Physics B, 954:115010, 2020.
ISSN 0550-3213. doi:https://doi.org/10.1016/j.nuclphysb.2020.115010.**

**Observation of ultra high energy cosmic rays from space: Status and perspectives.
PTEP, (12), DEC 2017. ISSN 2050-3911. doi:10.1093/ptep/ptx169.**

Capel, F., et al. Mini-EUSO data acquisition and control software. JOURNAL OF ASTRONOMICAL TELESCOPES INSTRUMENTS AND SYSTEMS, 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, ADVANCES IN SPACE RESEARCH Volume: 62 Issue: 10 Pages: 2966-2976 , 2018

**Meteor studies in the framework of the JEM-EUSO program. PLANETARY AND SPACE SCIENCE, 143(SI):245{255, SEP 1 2017. ISSN 0032-0633. doi:10.1016/j.pss.2016.12.001.
Abdellaoui, G., Abe, S., Adams, J. H., et al. 2018, Astroparticle Physics, 102, 98, doi: 10.1016/j.astropartphys.2018.05.007**

—. 2019, Astroparticle Physics, 111, 54, doi: 10.1016/j.astropartphys.2018.10.008

Adams, J., Ahmad, S., Albert, J.-N., et al. 2013, Astroparticle Physics, 44, 76, doi: https://doi.org/10.1016/j.astropartphys.2013.01.008

Adams, J. H., Ahmad, S., Albert, J. N., et al. 2015, Experimental Astronomy, 40, 281, doi: 10.1007/s10686-015-9467-9

Adams, J. H., Ahmad, S., Allard, D., et al. 2022, Space Science Reviews, 218, 3, doi: 10.1007/s11214-022-00870-x

Adams, Jr., J. H., Anchordoqui, L. A., Apple, J. A., et al. 2017, arXiv e-prints. https://arxiv.org/abs/1703.04513

Bacholle, S., Barrillon, P., Battisti, M., et al. 2021, The Astrophysical Journal Supplement Series, 253, 36, doi: 10.3847/1538-4365/abd93

Belov, A., Bertaina, M., Capel, F., et al. 2018, Advances in Space Research, 62, 2966, doi: https://doi.org/10.1016/j.asr.2017.10.044

Bisconti, F., Miyamoto, H., Barghini, D., et al. 2022, Experimental Astronomy, 53, 1, doi: 10.1007/s10686-021-09805-w

**Capel, F., Belov, A., Cambi`e, G., et al. 2019, Journal of Astronomical Telescopes, Instruments, and Systems, 5, 1, doi: 10.1117/1.JATIS.5.4.044009
Aerotecnica Missili & Spazio, 99(2):93{101, Jun 2020. ISSN 2524-6968. doi:10.1007/s42496-020-00047-1.**

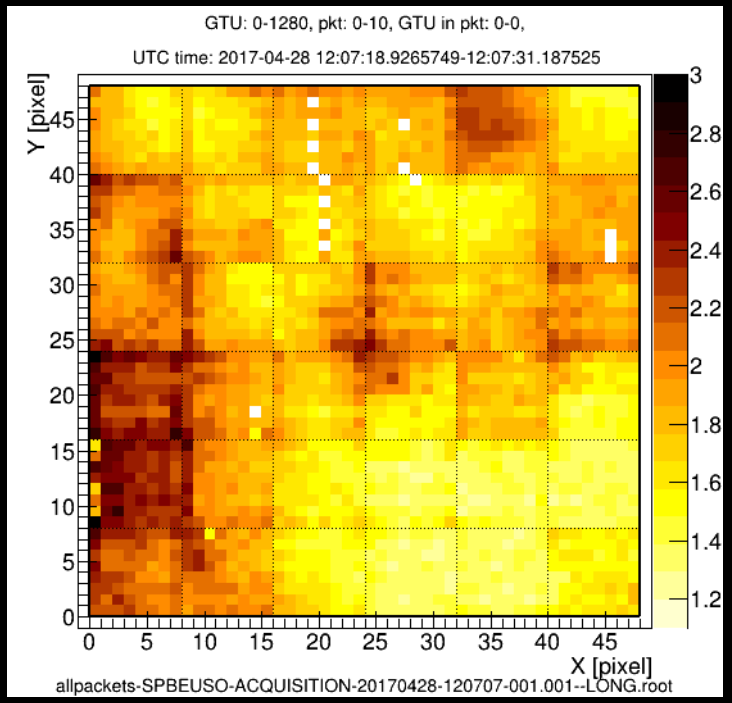
EUSO-SPB, April 2017
Wanaka, New Zealand

NASA Mission. 2nd Payload built by JEM-EUSO collaboration
New lenses, Focal Surface,
Improved Electronics

ICRC presentation

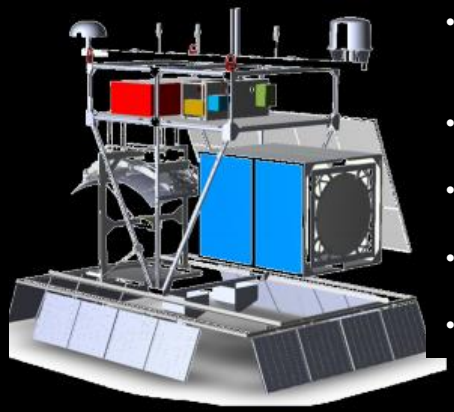
[306] [CRI306] EUSO-SPB Mission and Science
[1261] [CRI054] Calibrating and Testing EUSO-SPB in Flight using a Laser and LEDs on an Aircraft
[1273] [CRI201] The EUSO-SPB instrument
[1274] [CRI061] The trigger logic of EUSO-SPB and its performance
[1280] [CRI041] Preflight calibration and testing of EUSO-SPB in the lab and the desert
[1294] [CRI088] Expected number of Extensive Air Showers observable by EUSO-SPB
[1336] [CRI030] The Data Processor System of EUSO-SPB
1337] [CRI074] UCIRC: Infrared Cloud monitor for EUSO-SPB

EUSO-SPB1 flight

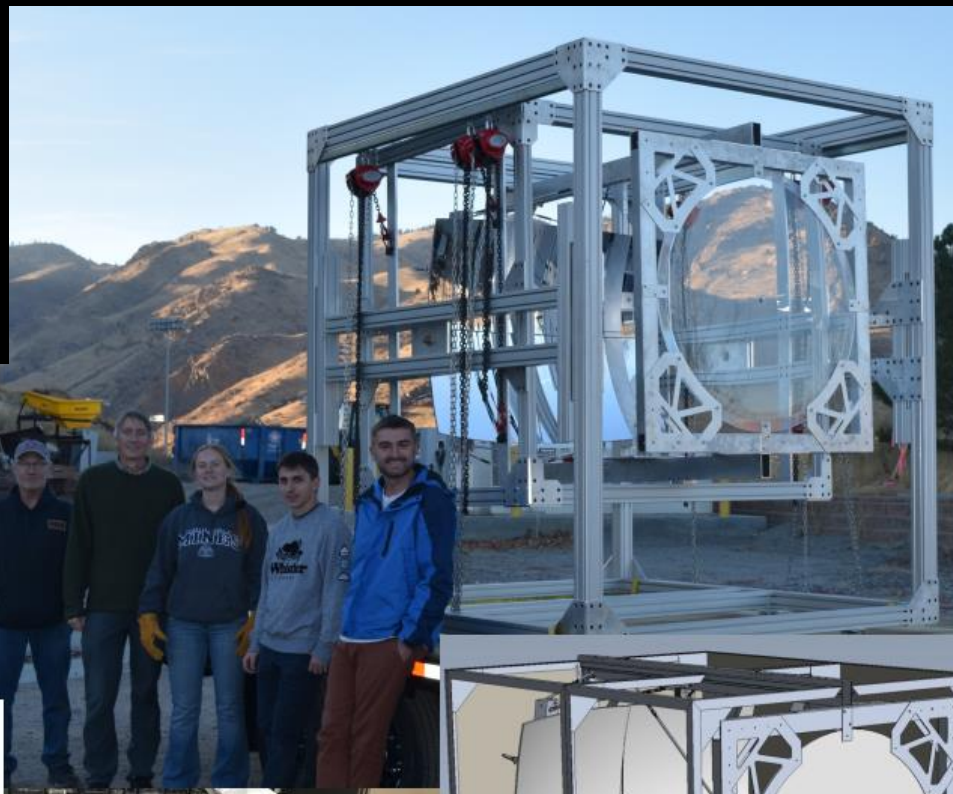


Launch April 25th 2017
(4/24 23:50 UTC)

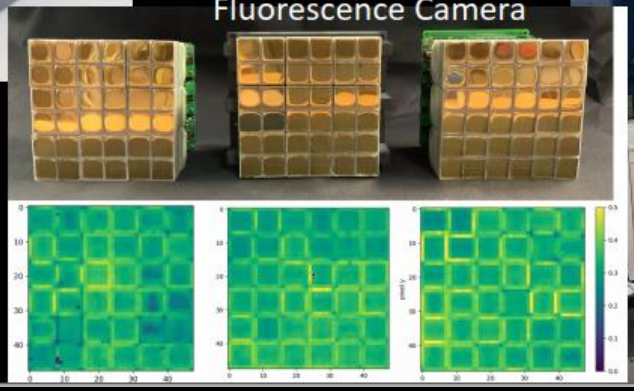
EUSO-SPB2

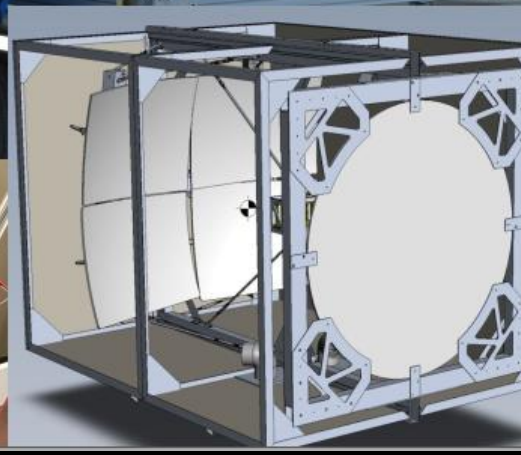


- UHECUHECR air-showers, Cherenkov light from stratosphere. $10^{16} < E < 10^{17}$ eV
- Discrimination of p, nuclei, photons looking at Cherenkov profile
- R air-showers, Cherenkov light from stratosphere. $10^{16} < E < 10^{17}$ eV
- Discrimination of p, nuclei, photons looking at Cherenkov profile
- Mission in 2023



Cherenkov Camera






Godspeed, JEM-EUSO Program!
岩澤 駿
SHUN IWASAWA