The Mini-EUSO telescope onboard the International Space Station: launch and first observations.

M. Casolino,

(INFN, Sezione Roma Tor Vergata)

JEM-EUSO collaboration

INFN - LNF
4-6-2020

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

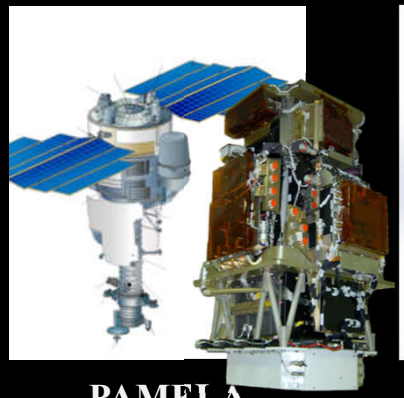
INFN Istituto Nazionale di Fisica Nucleare

Previous, current and planned balloon and space missions

Satellite

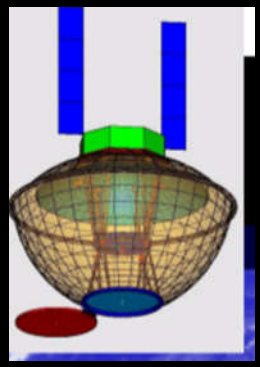
NINA-1
(1998-2000)

NINA-2 Satellite
(2000-2002)



PAMELA
(500 kg, 2006-2016)

K-EUSO
(500 kg, 2022)



POEMMA
(2025)

Mir Space Station

SilEye 1
(1995-1997)

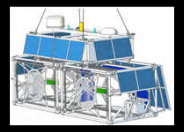
SilEye 2
(1998-2000)

Balloons

CAPRICE 94,98,
MASS, TS93

EUSO-BALLOON (2014)

EUSO-SPB (2017)



SPB2 (2022)

International Space Station

Alteino (2002-2010)

Lazio(2005-2006)

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

Mini-EUSO
(2019-)

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***

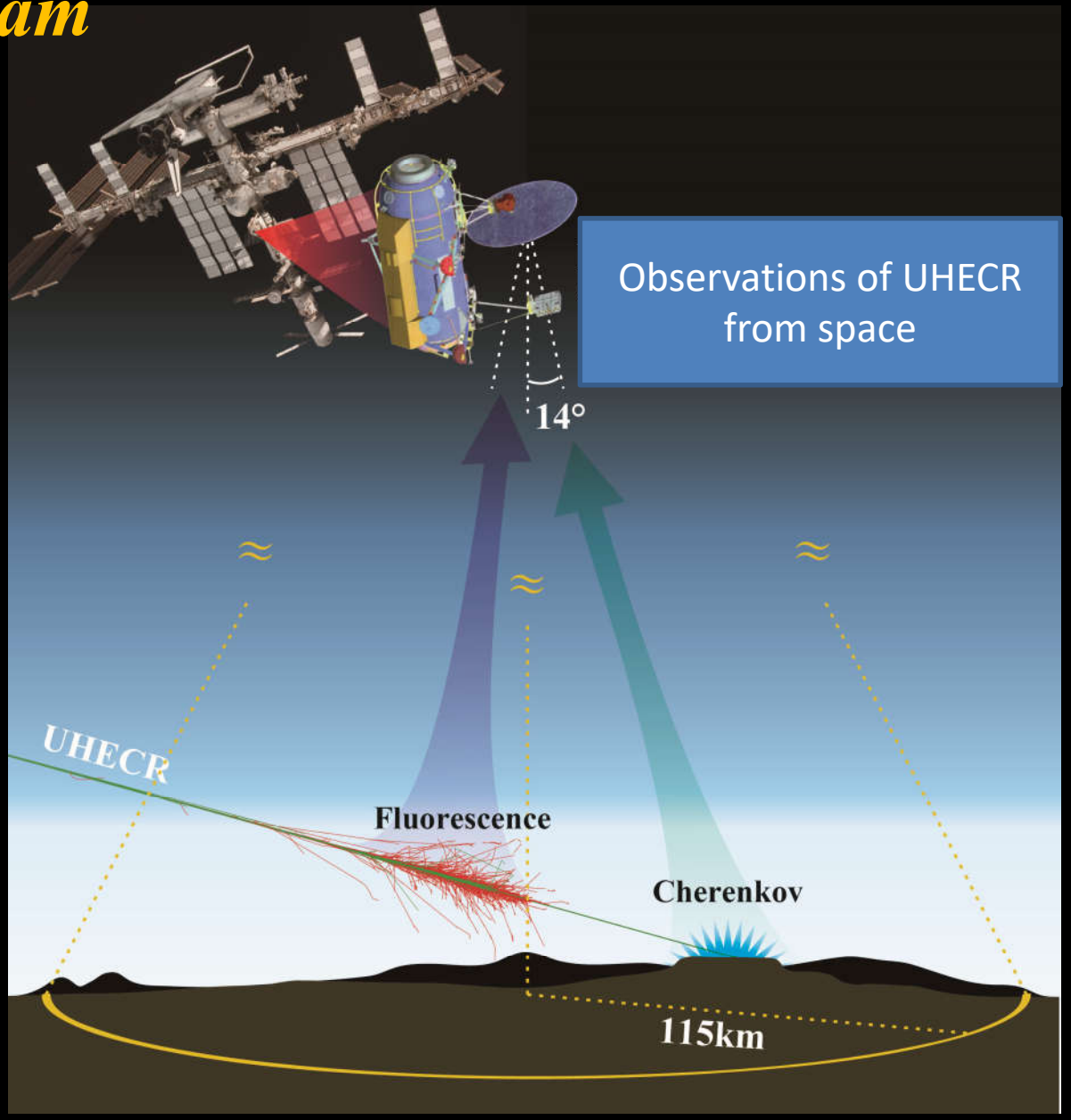
3. TUS (2016): free-flyer on Lomonosov Russian Satellite

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

5. *SPB-2 (NASA) (2022)*

6. K-EUSO (2023): ***ISS Phase A, Russian Space Agency***

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



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

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***

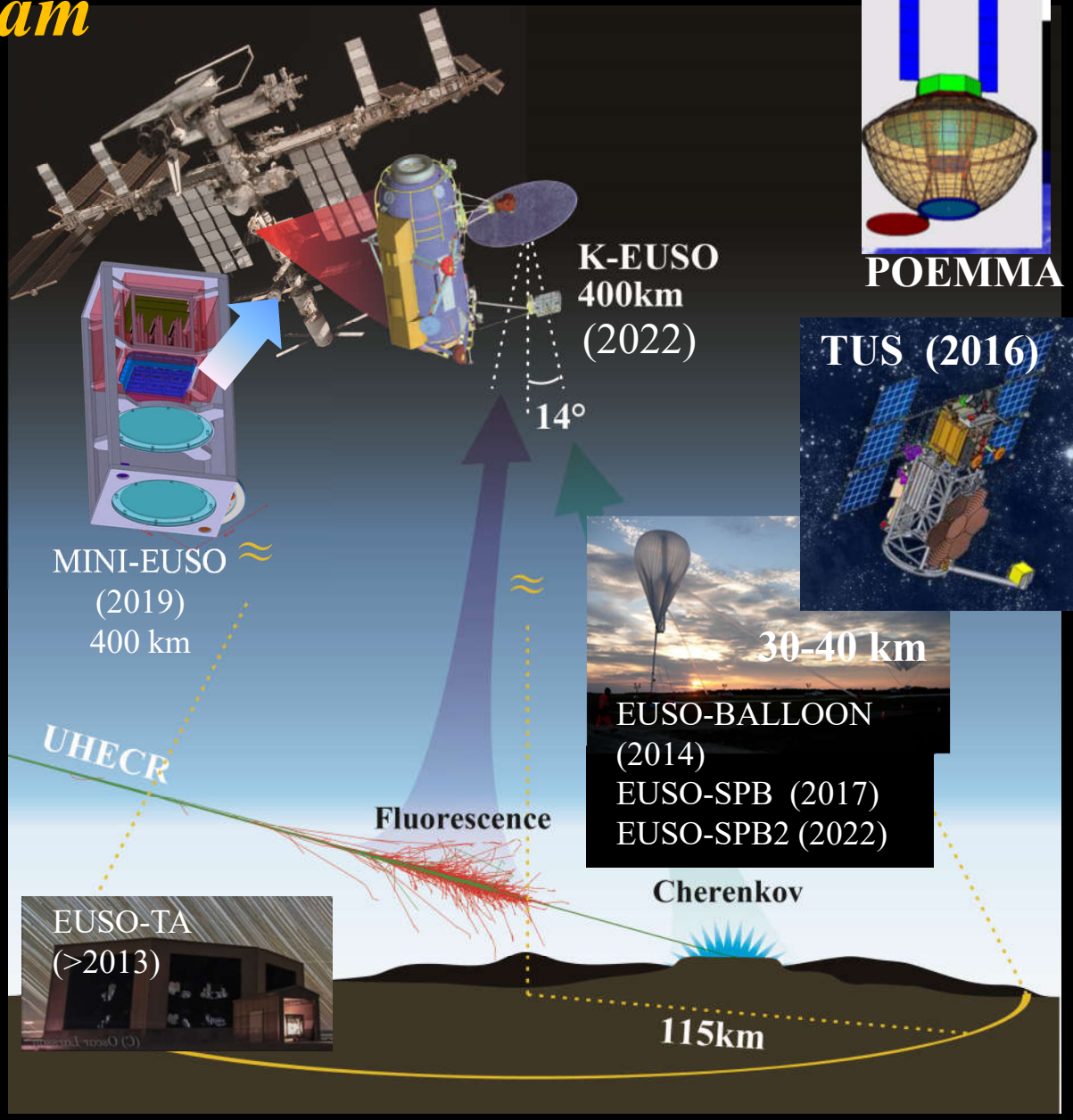
3. **TUS (2016):** free-flyer on Lomonosov Russian Satellite

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

5. ***SPB-2 (NASA) (2022)***

6. **K-EUSO (2023):** ***ISS Phase A, Russian Space Agency***

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



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

Mini-EUSO/UV-Atmosfera

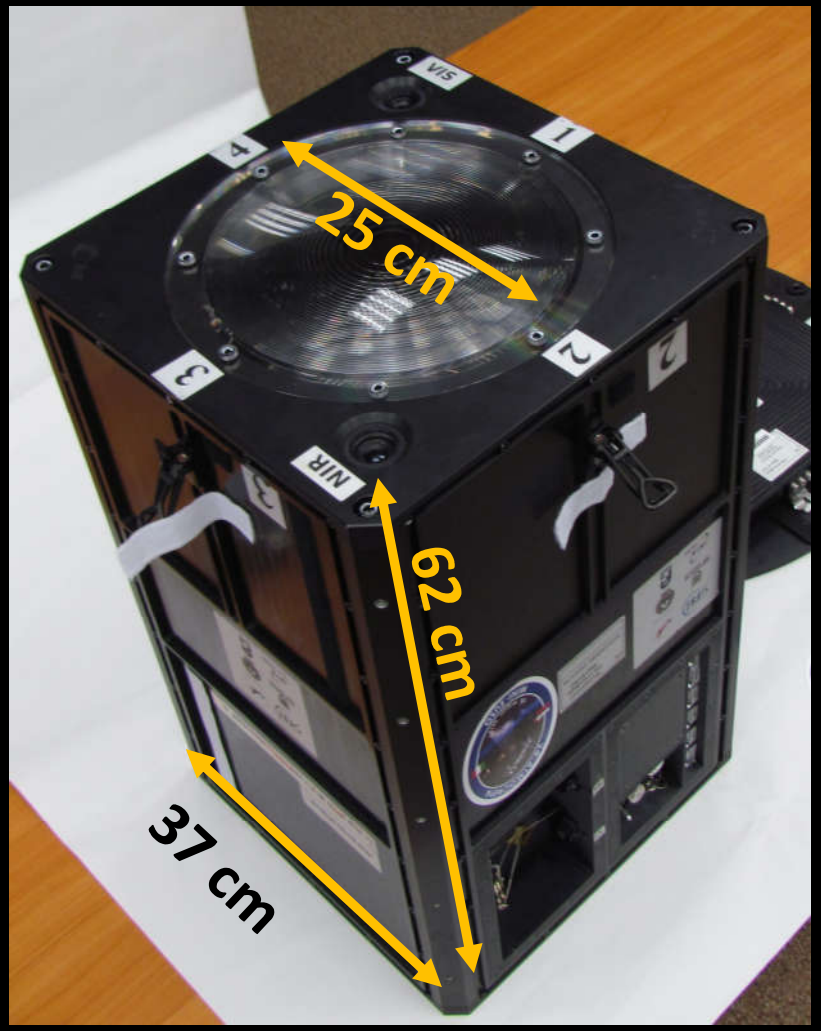
JEM-EUSO collaboration 16 Countries, 93 Institutes, 351 people

- Joint ASI-Roscosmos agreement
- Launched as part of the mission *«Beyond»* of L. Parmitano on the ISS
- Operated by Russian cosmonauts
- Design, realization, integration in Italy

- Joint project with Russia
  - Crew time
  - Upload/dowload mass
  - Telemetry for data and commands

- HW developed by JEM-EUSO collaboration, lenses, f/e electronics. Focal surface …
- Two models (flight and engineer) and two ground models in three years

→ **1/100th of future UHECR detectors from space *(same light/pixel)***



MINI-EUSO / UV-Atmosfera

Multiwavelength Imaging New Instrument for the Extreme Universe Space Observatory

40kg

60 W

62*37*37 cm3

Ultraviolet, with Fresnel lenses

Near Infrared camera

Visible camera

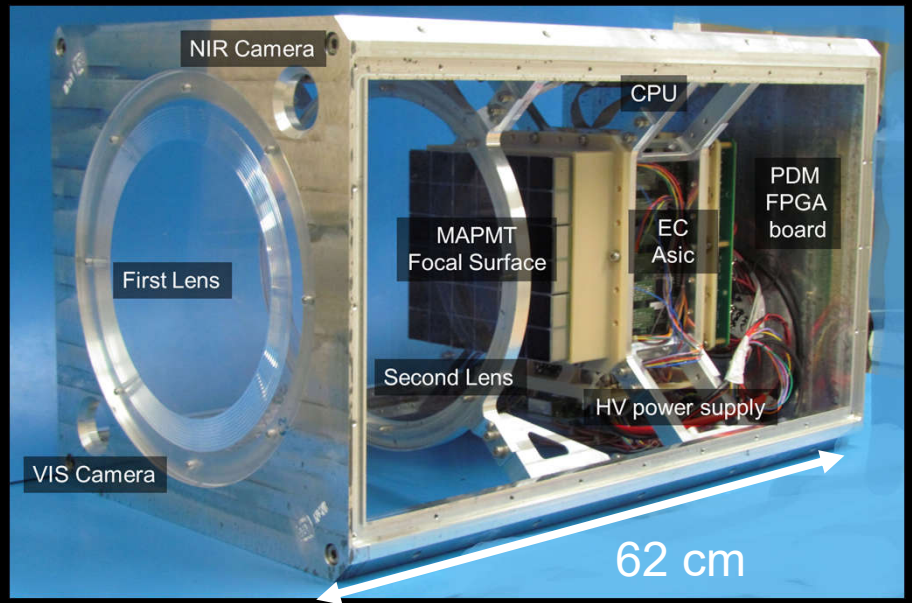
SiPM

2304 pixel

Same light/pixel of K-EUSO design

HVPS switch and dynamic range extension

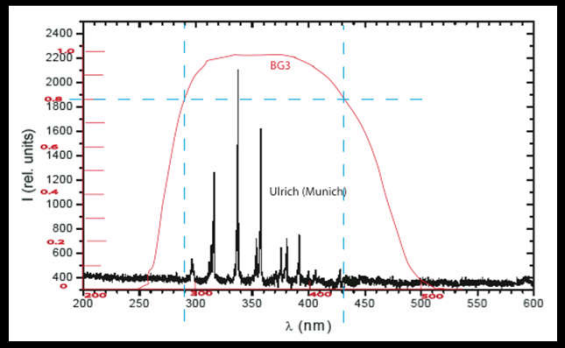
Flight Model
Baikonur tests
August 2019

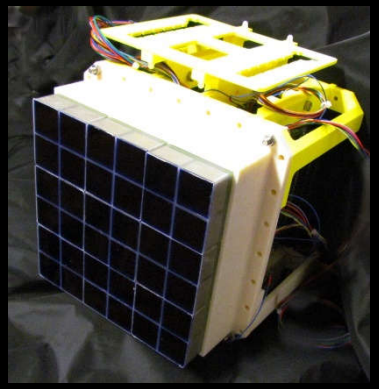


Engineering Model
Open structure with main detector items
September 2018

Mini-EUSO main sensors

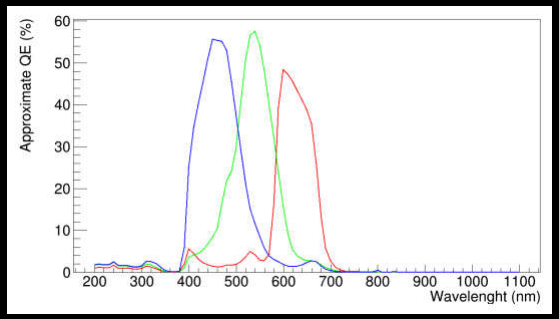
UV main camera
48*48 pixels
40 deg 243km 5km/pix
2.5mus and above

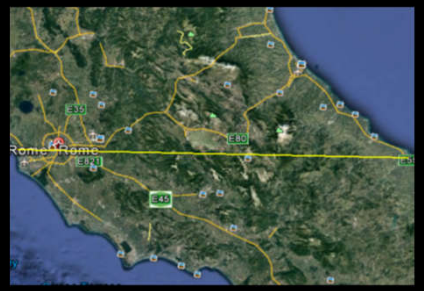




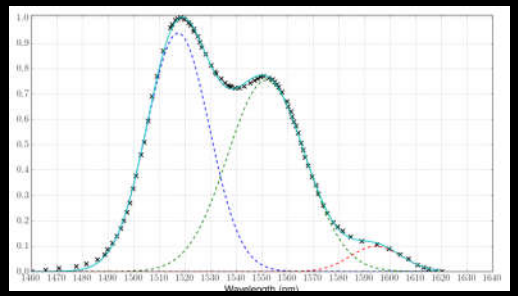
East-West Italy

RGB camera
1280*960 pixels
33.2*24.8 degrees
231*174 km 180 m/pixel
1s





NIR camera
(BW with phosphor coating)
1280*960 pixels
33.2*24.8 degrees
231*174 km 180 m/pixel
4s



Focal Surface

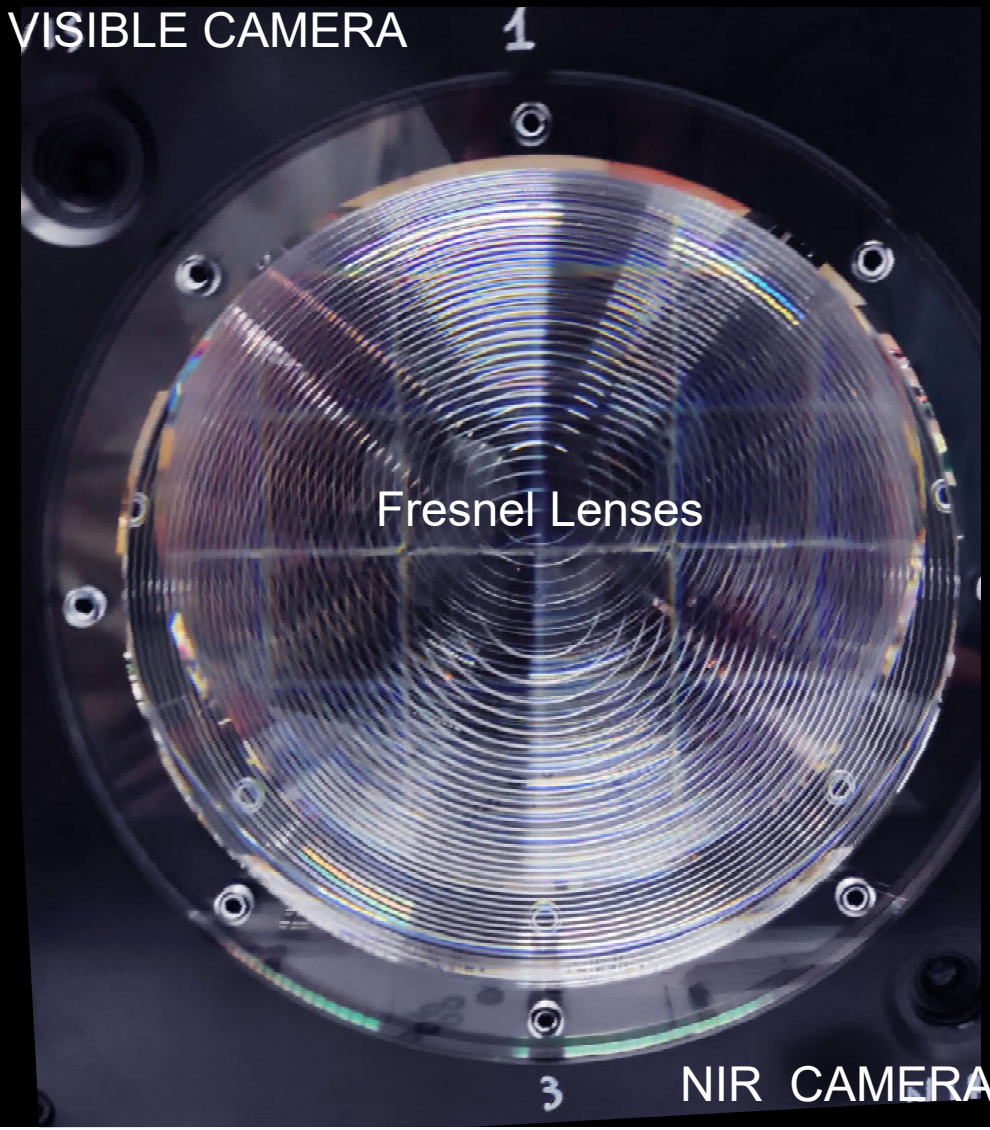
Silicon Photomultipliers
C14047-3050EA08
8*8 pixel Imaging system

C13365 single pixel

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

ML8511 linear
280-400 nm

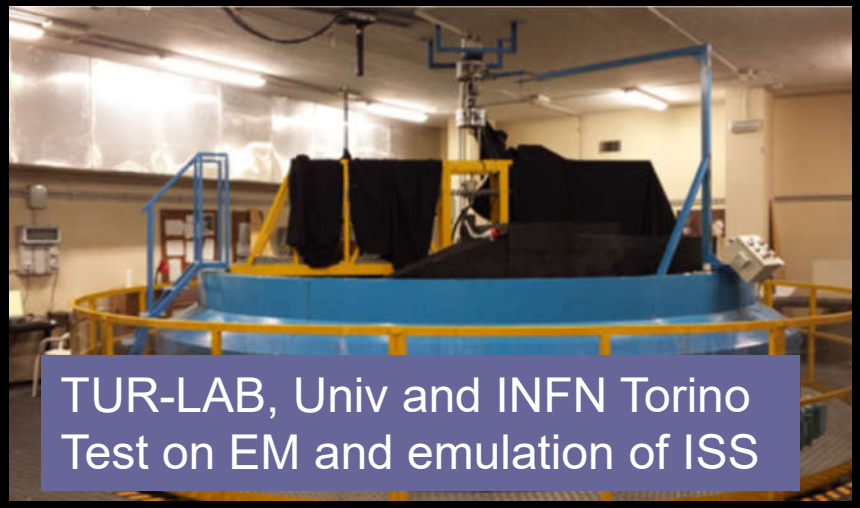
Fresnel Lenses



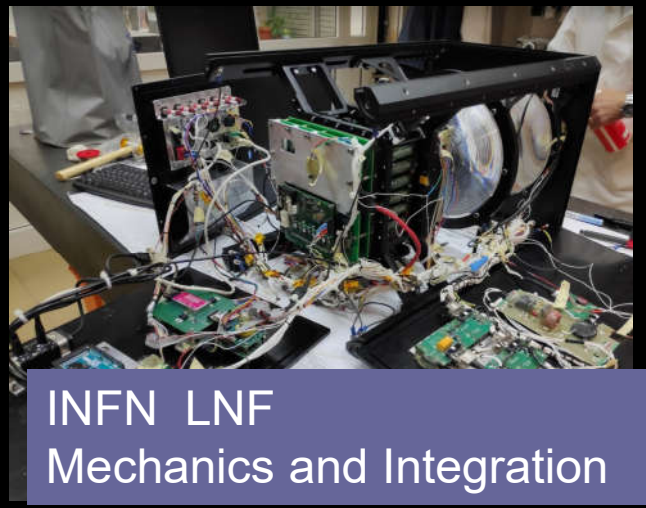
P. Nespoli con lente di Fresnel FM

Realizzate al Riken (Giappone)
5ns rms sulla superficie

Test and Integration of EM and FM 2017-2019



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

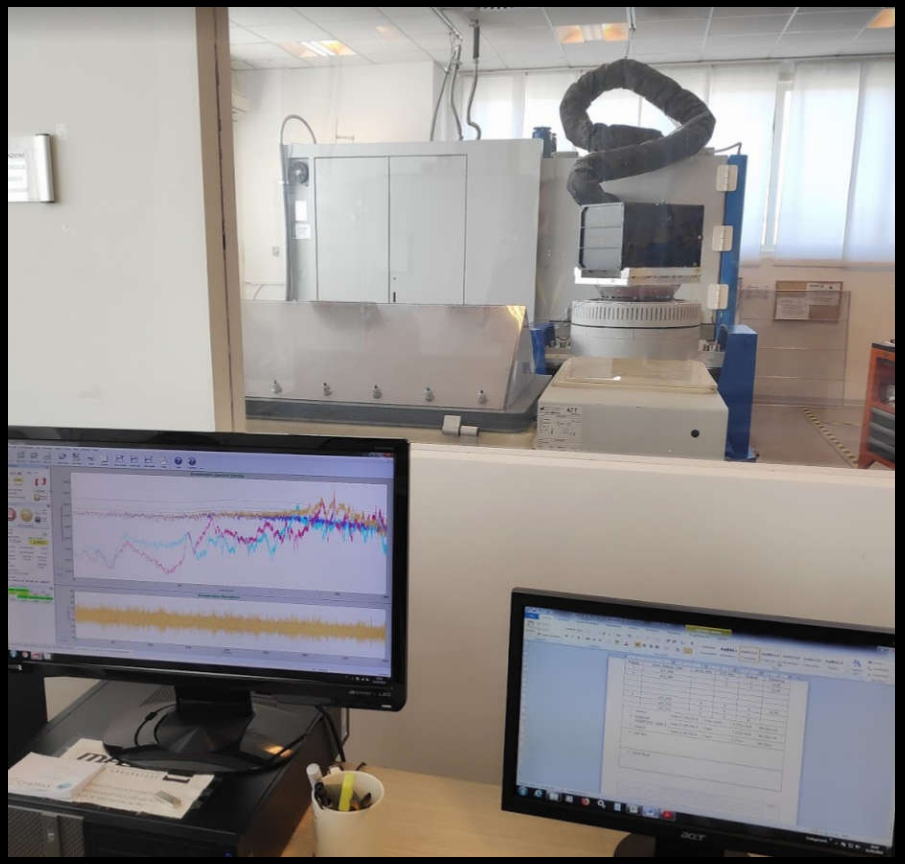


INFN LNF
Mechanics and Integration

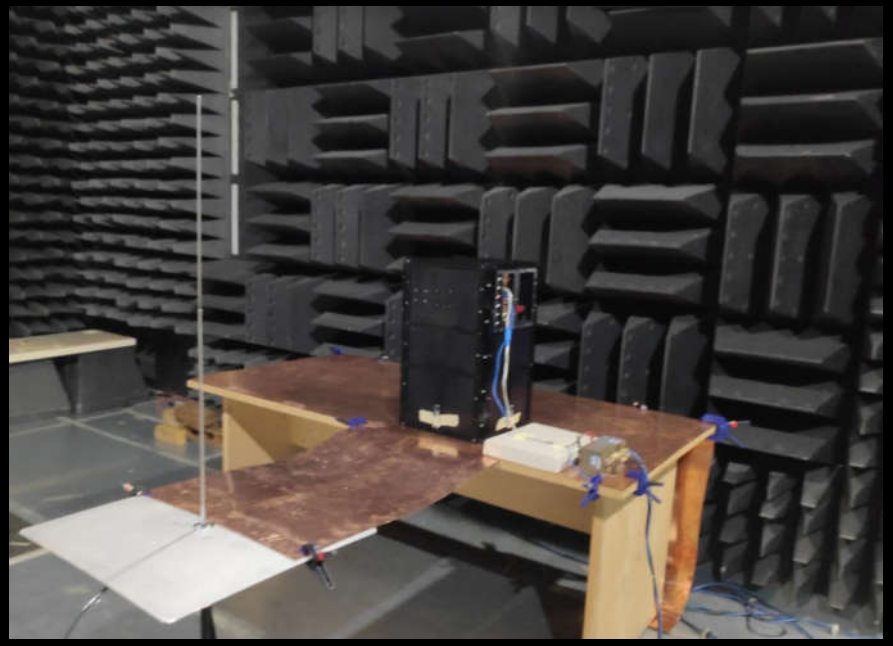
INFN Tor Vergata
Qualification and Acceptance procedures

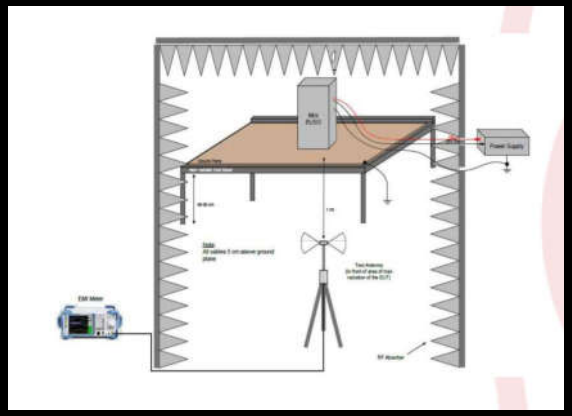
INFN Tor Vergata
Sky tests

Vibration tests in Torrita di Siena (MATE) 31/5/2019



Electromagnetic Compatibility tests on Engineering Model (EM) 14/1/2019





Acceptance tests in Baikonur and integration with Soyuz MS-14

Building 254, assembly of Soyuz/Progress

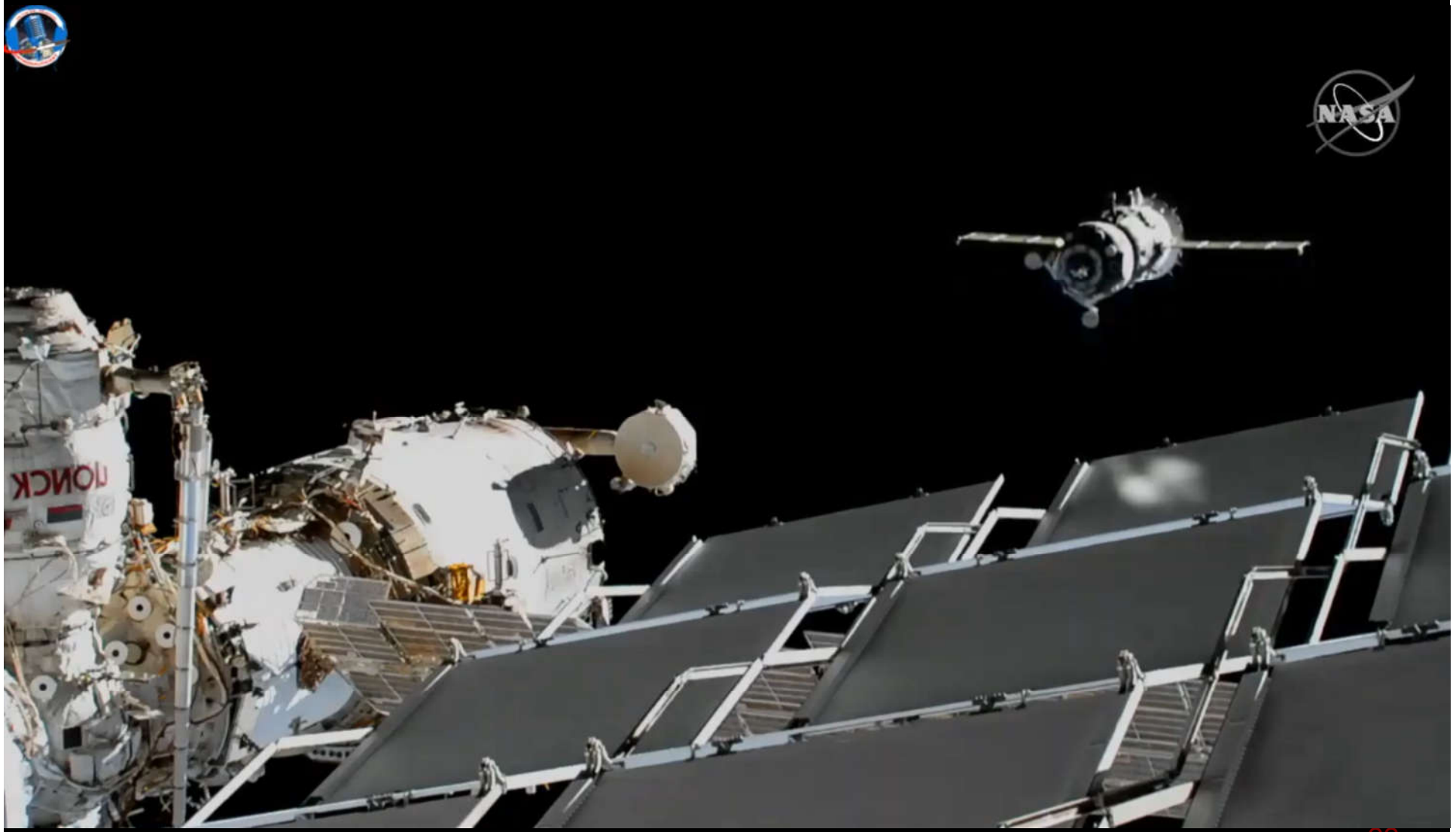
Roll-out of Soyuz MS-14, 19/8/2019

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

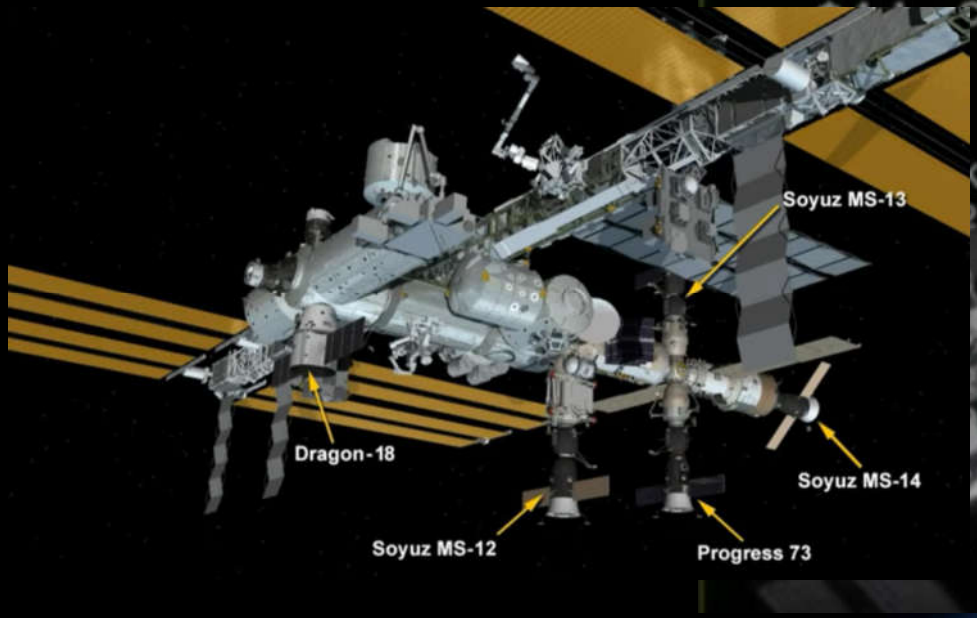
22/8/2019 Launch, Site 31, Baikonur Cosmodrome

First docking, 24/8/2019 unsuccessful

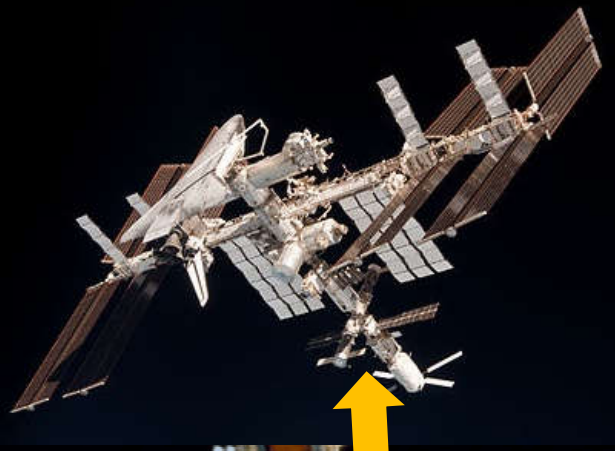
Relocation of MS-13 from Zvezda to Poisk

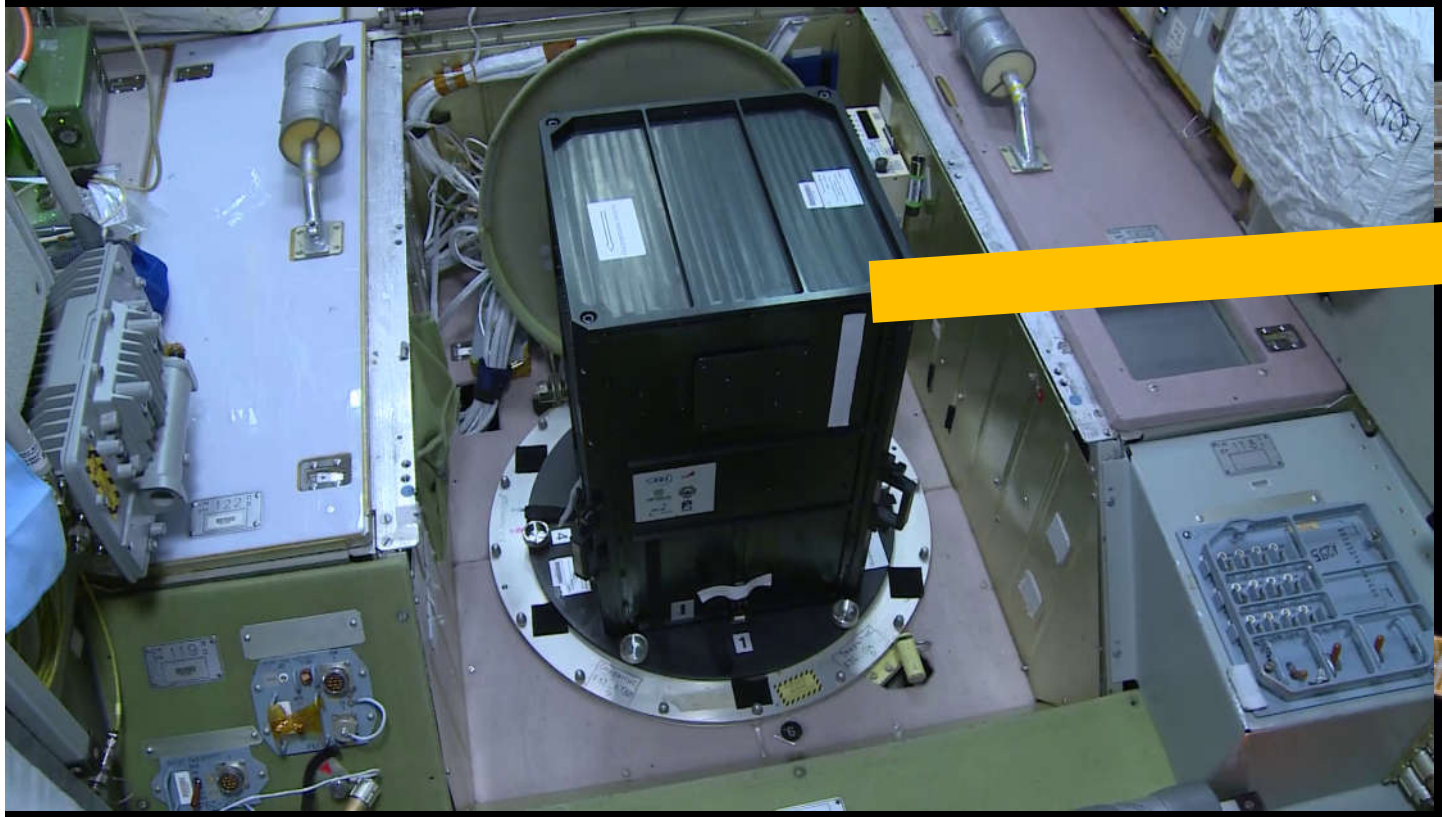


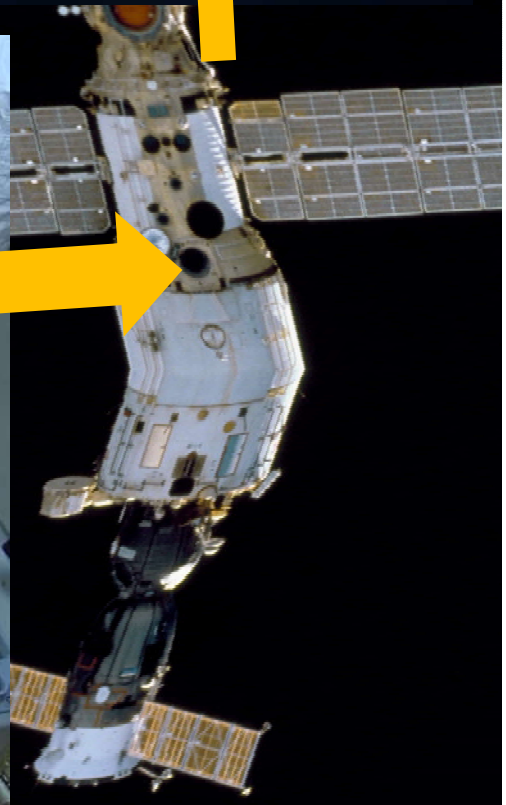
Second docking, 27/8/2019 successful



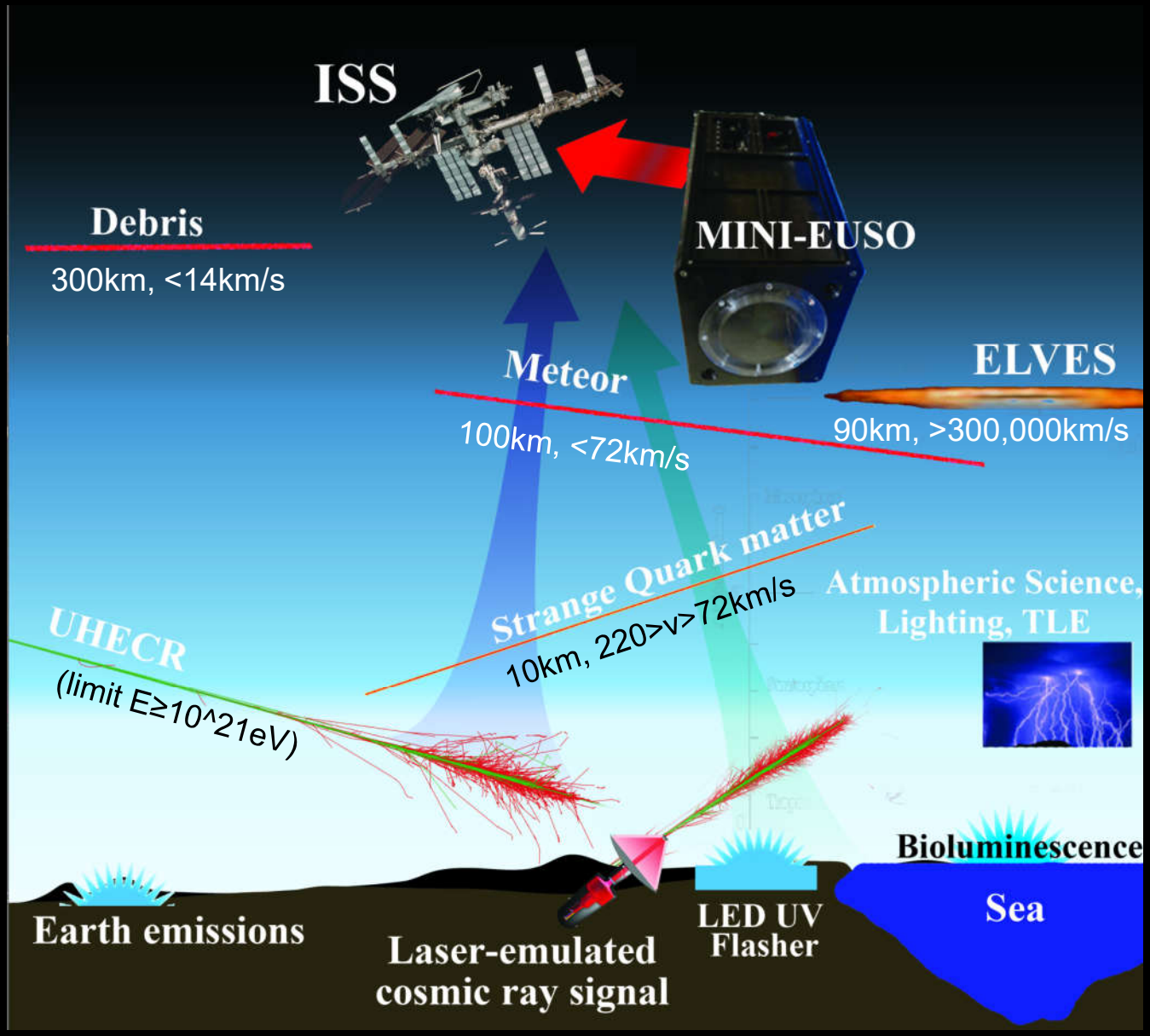
Uv transparent window, Zvezda module, International Space Station



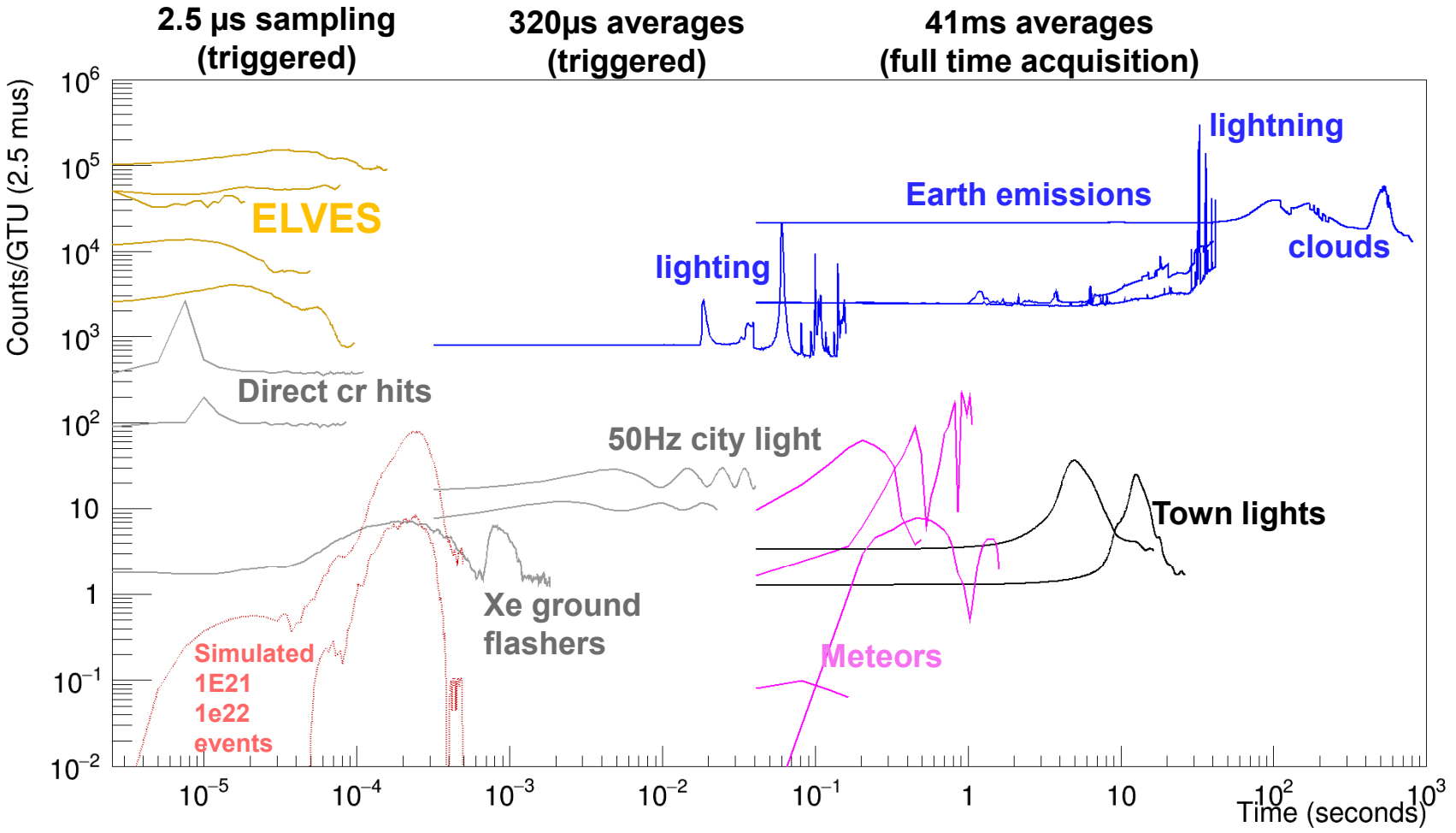




Science Objectives



Time profile of various events
(selected from 10% of data)



Mini-EUSO data from ISS 2019-2020 except simulated events
+imaging capabilities

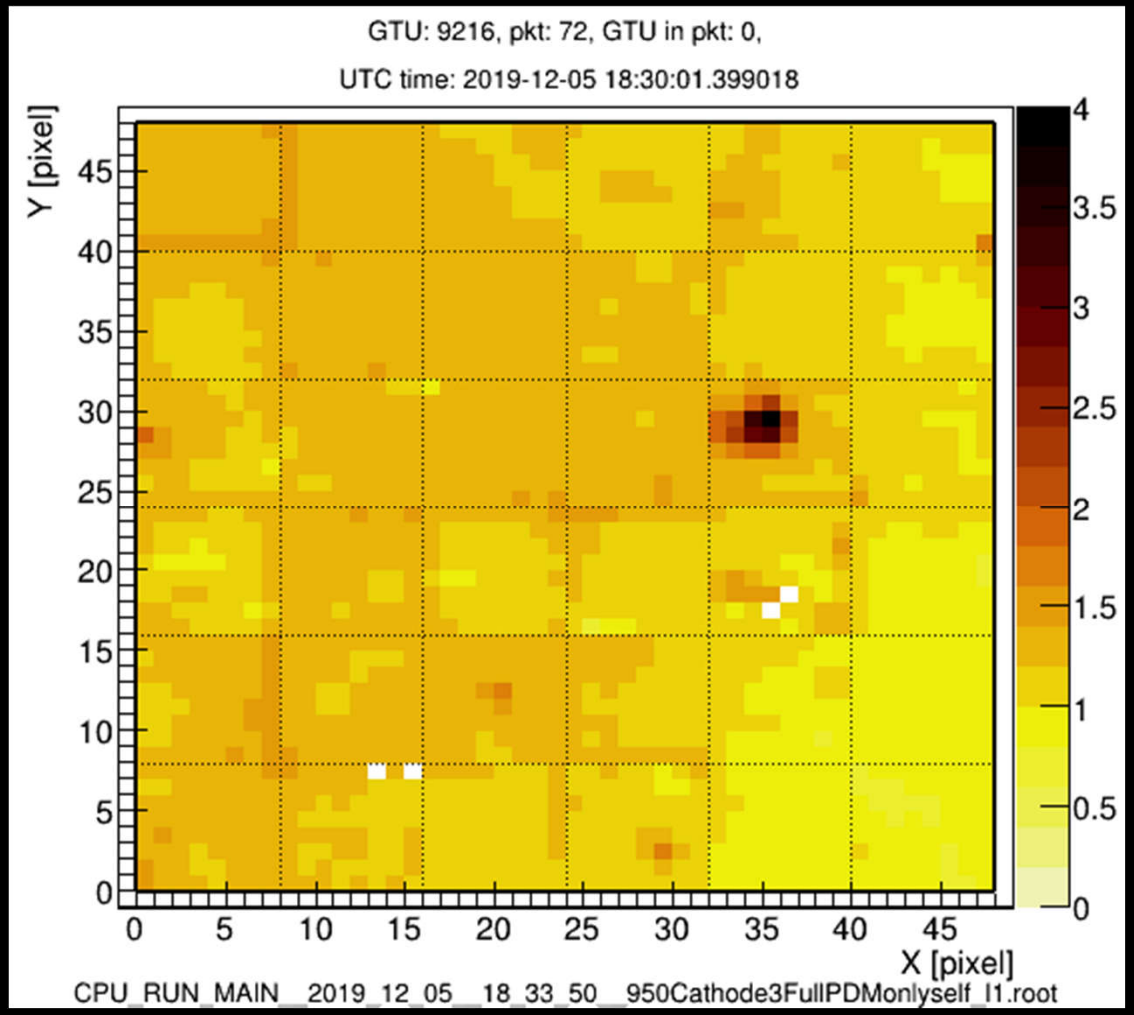
Clouds and sea emission

2019_12_05 18:30 UTC

Counts/pixel/GTU

Indian Ocean

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

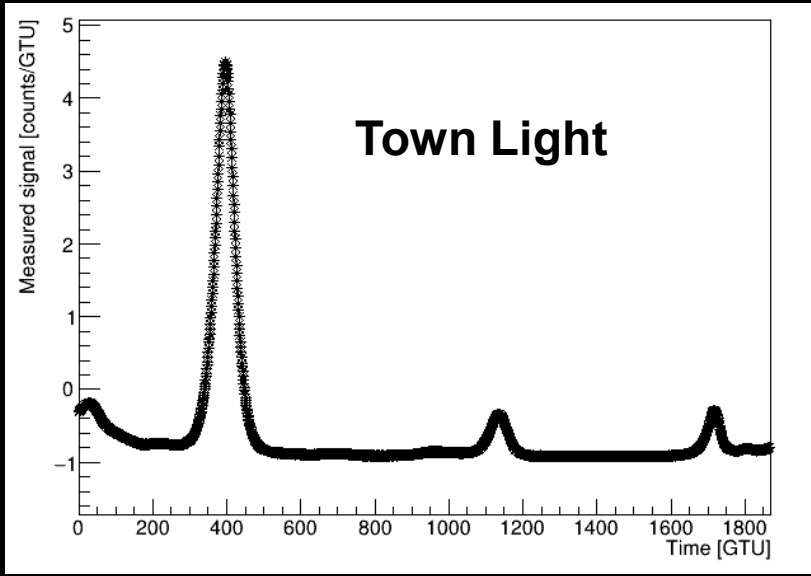


1 frame = signal integrated in 40.96 ms
~14 min video (1 frame every 128 frames) ~5s

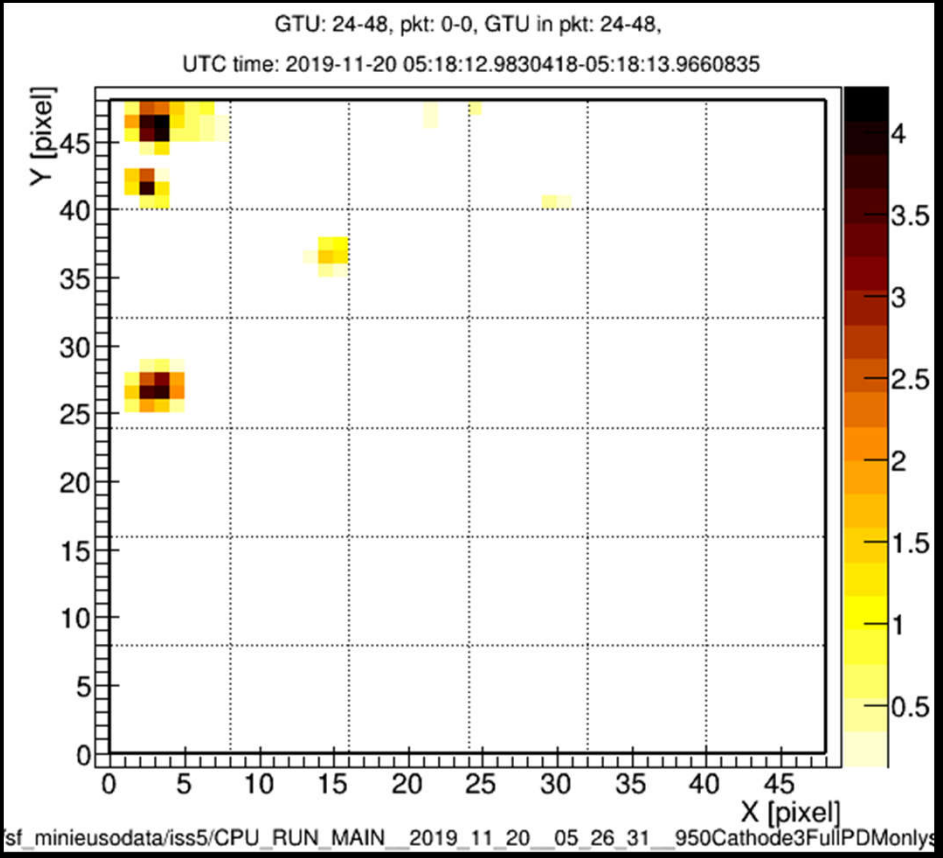
Ground emissions
(between Vancouver and Calgary)

41ms continuous sampling

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



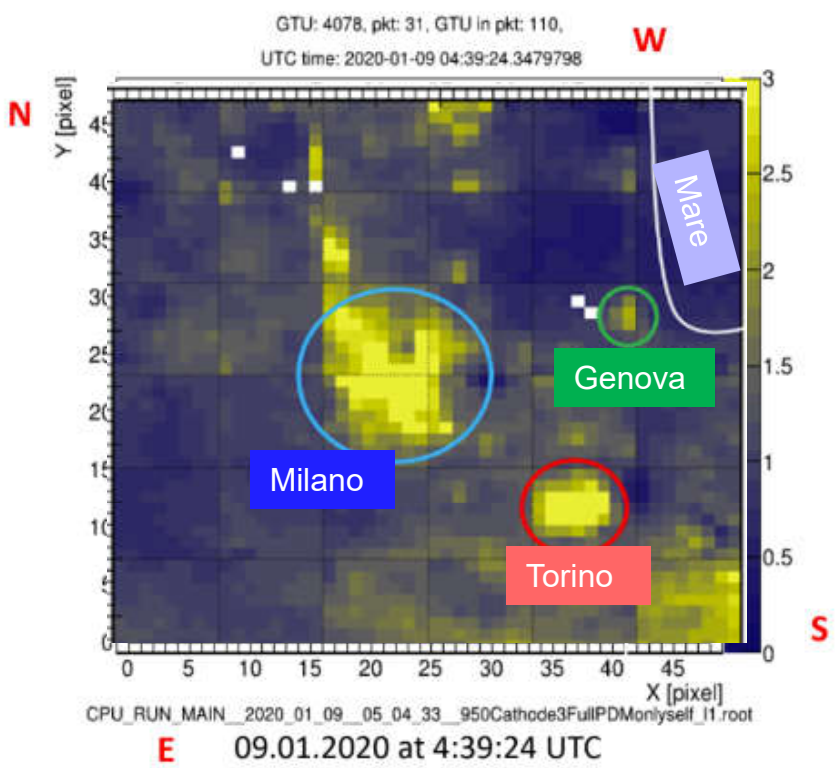
41ms samples

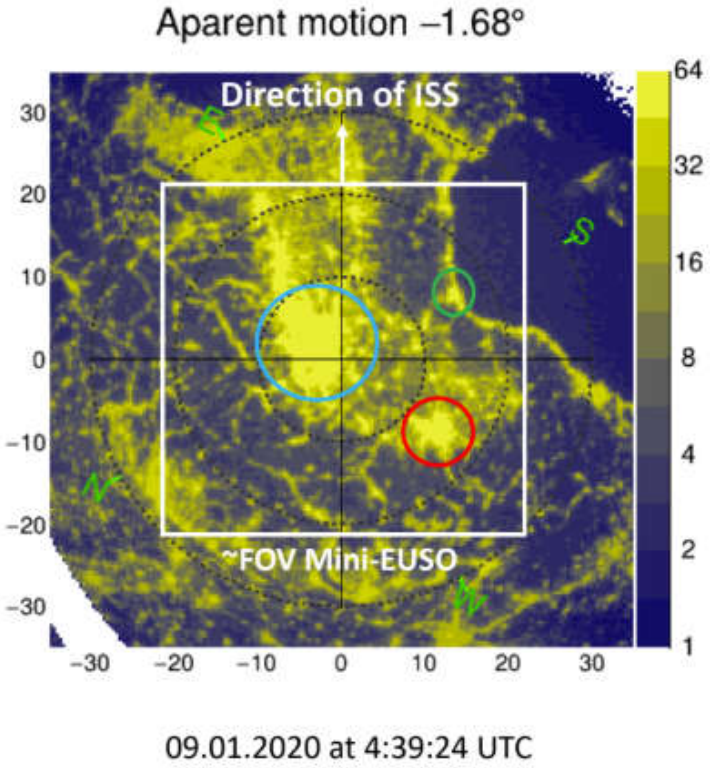


1s 25D3 frames average

Northern Italy

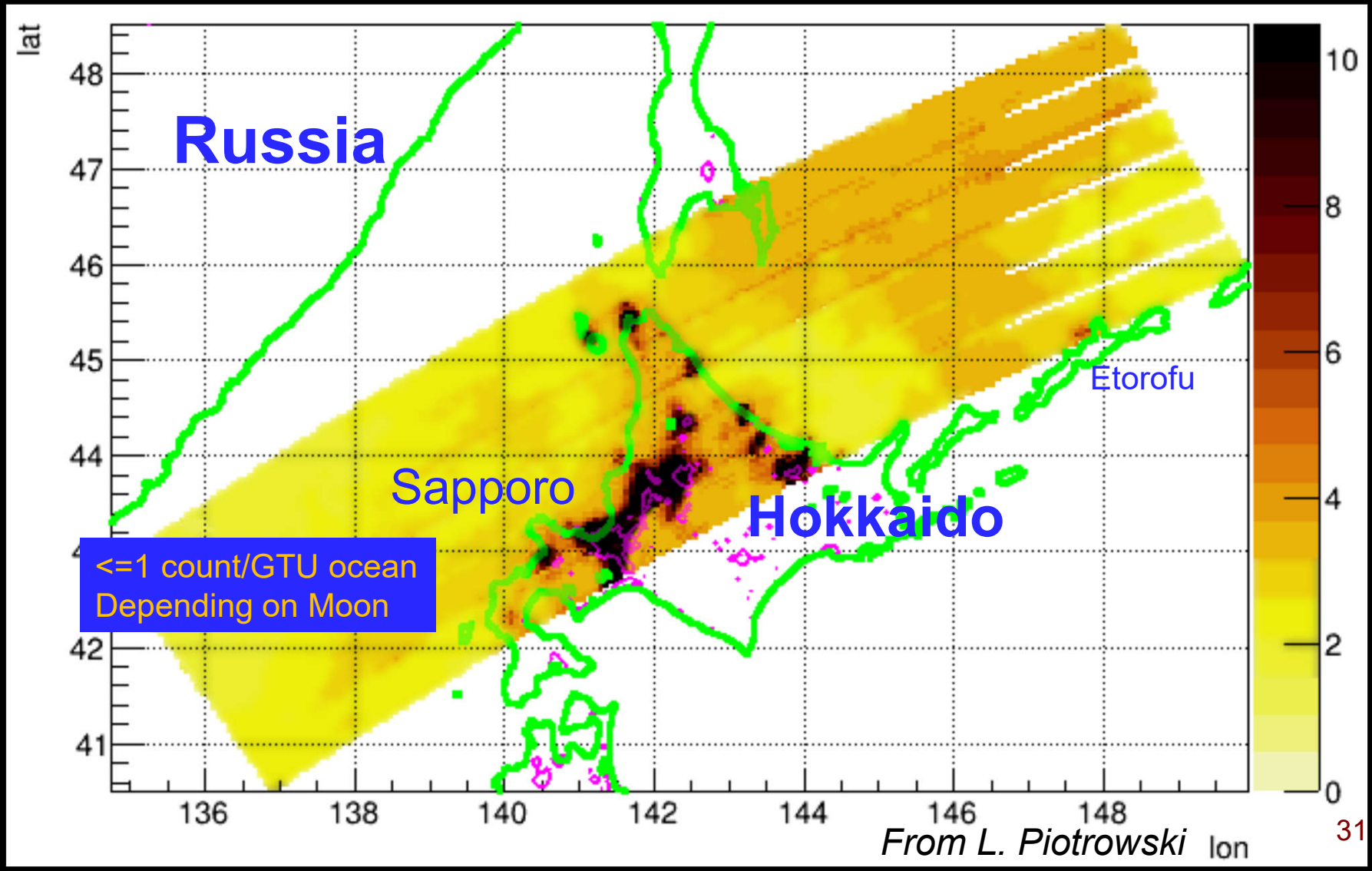
Mini-EUSO data (UV) Visible light ground maps



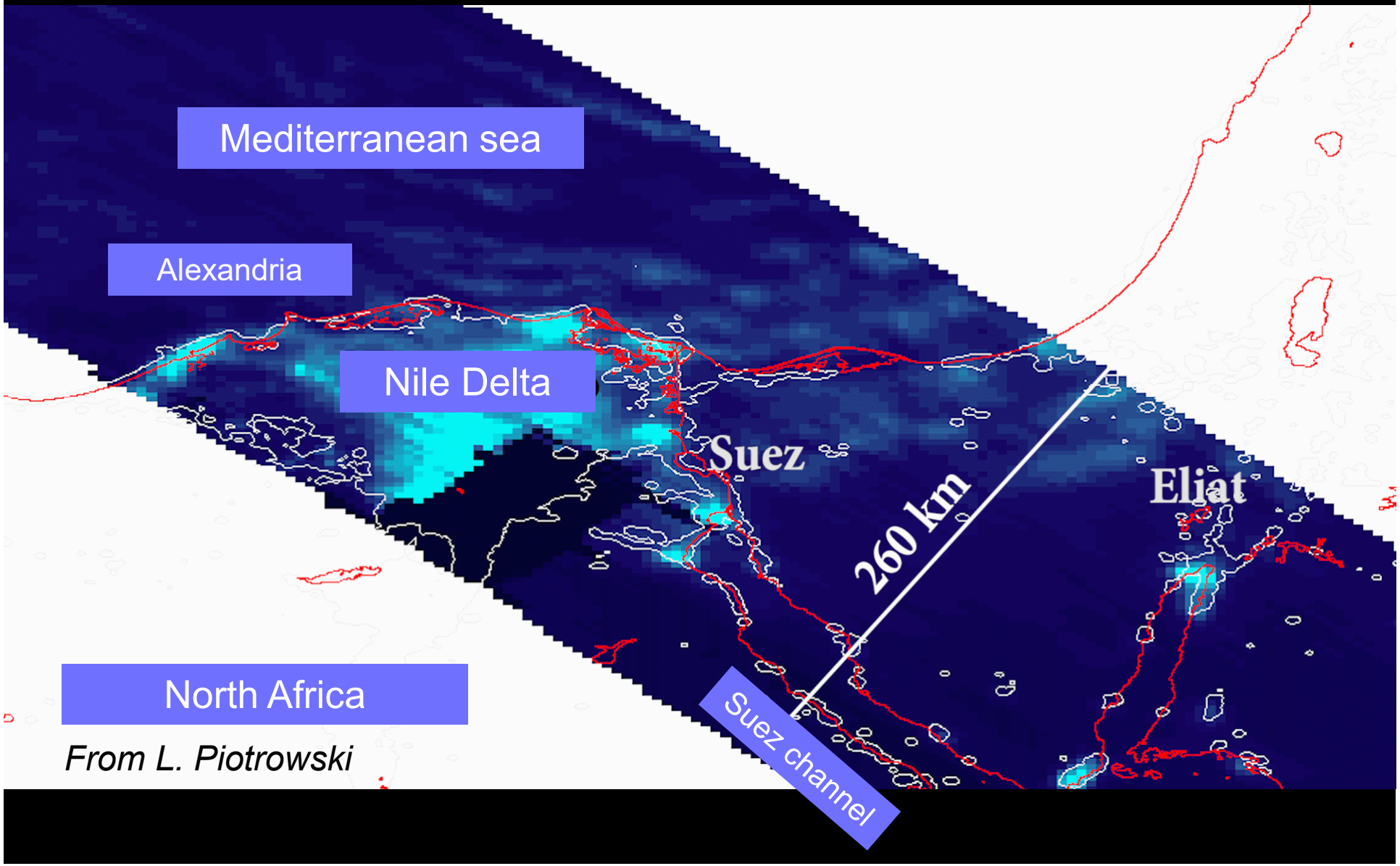


From F. Bisconti, K. Shinozaki

UV maps: Northern Japan



Egypt and Suez Channel



From L. Piotrowski

Visible camera data

3-seconds frames

Correlation with UV

Meteors, cloud, town

Ageing from radiation

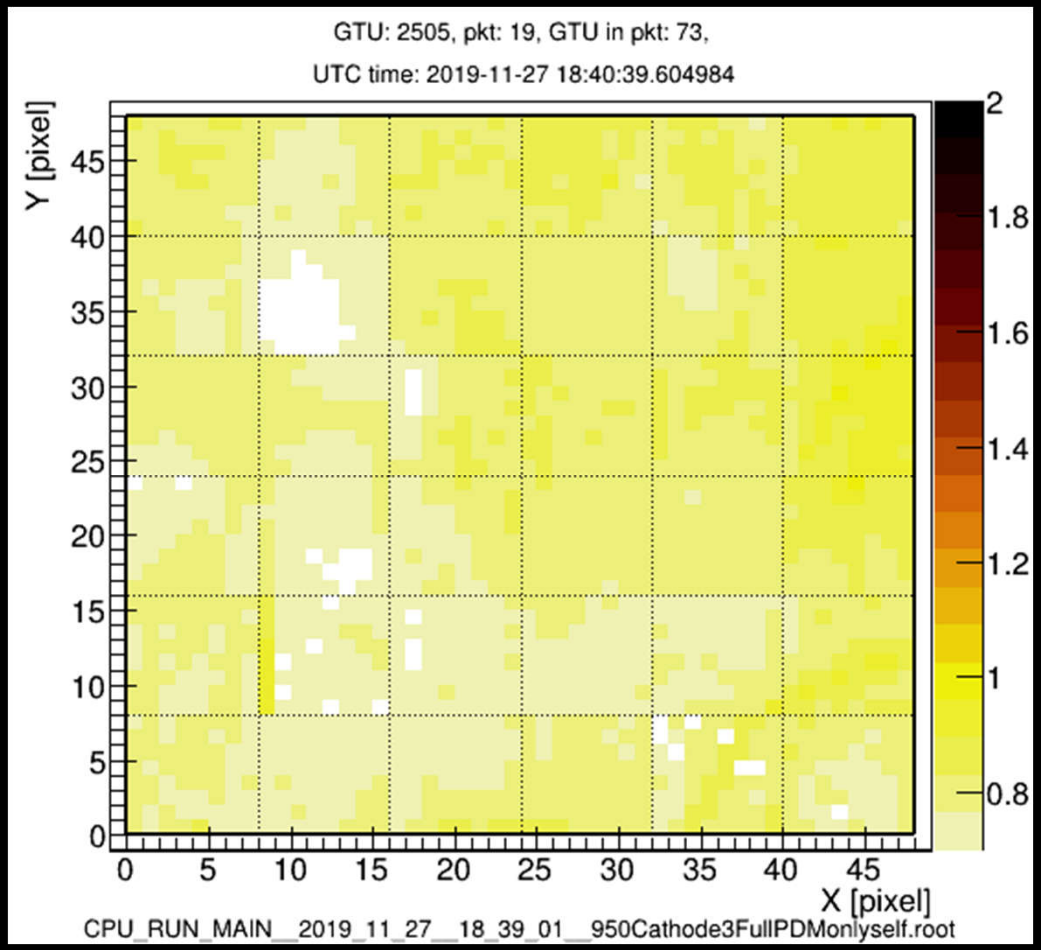
Single cosmic ray hits

Interstellar Meteors and Search for Strange quark matter

- 200 meteors detected so far
- Near Earth Objects, complementary to ground arrays (joint observations)

- Est. 2000 in data cards

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



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

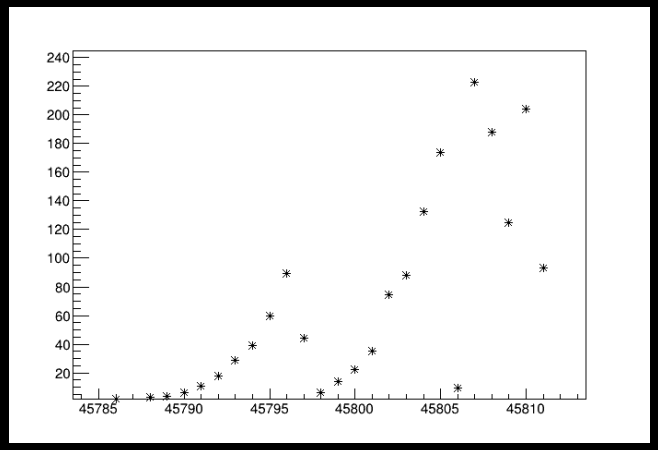
JEM-EUSO: Meteor and nuclearite observations. Experimental Astronomy, 40:253{279, November 2015.

Interstellar Meteors and Search for Strange quark matter

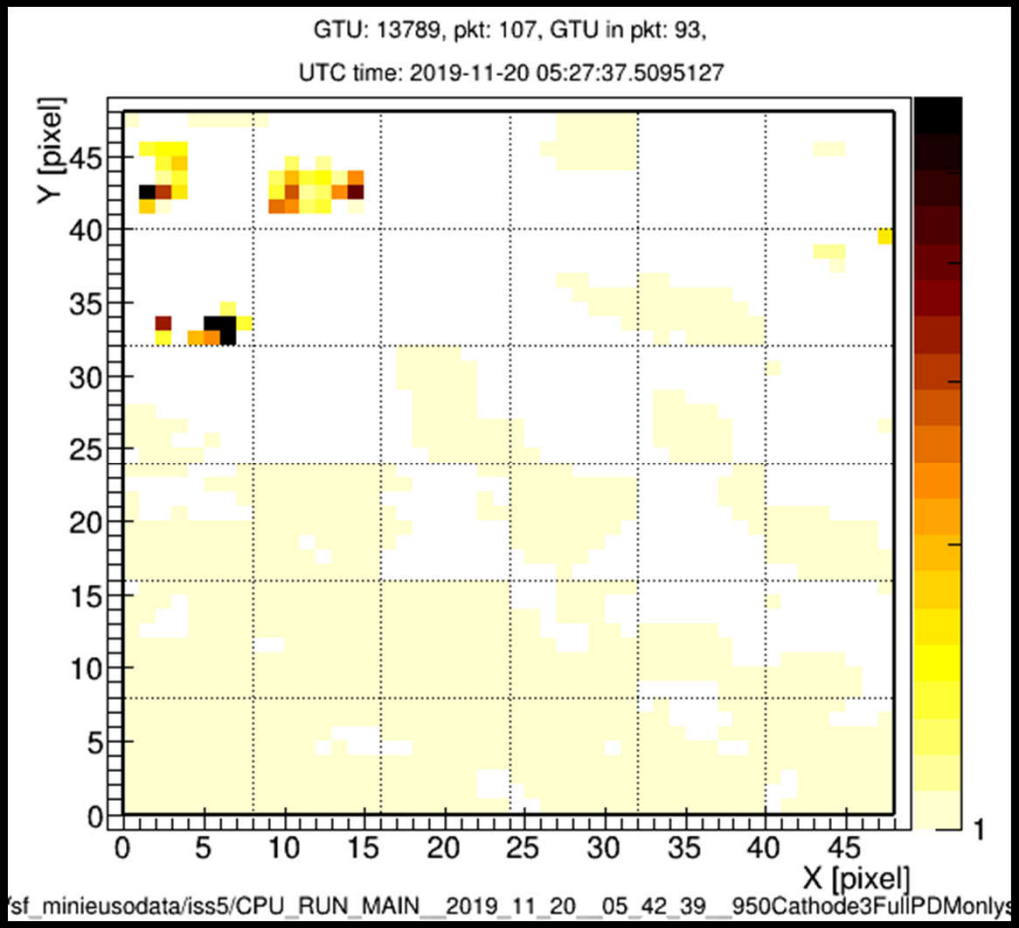
- 200 meteors detected so far
- Near Earth Objects, complementary to ground arrays (joint observations)

- Est. 2000 in data cards

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



Light curve



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.

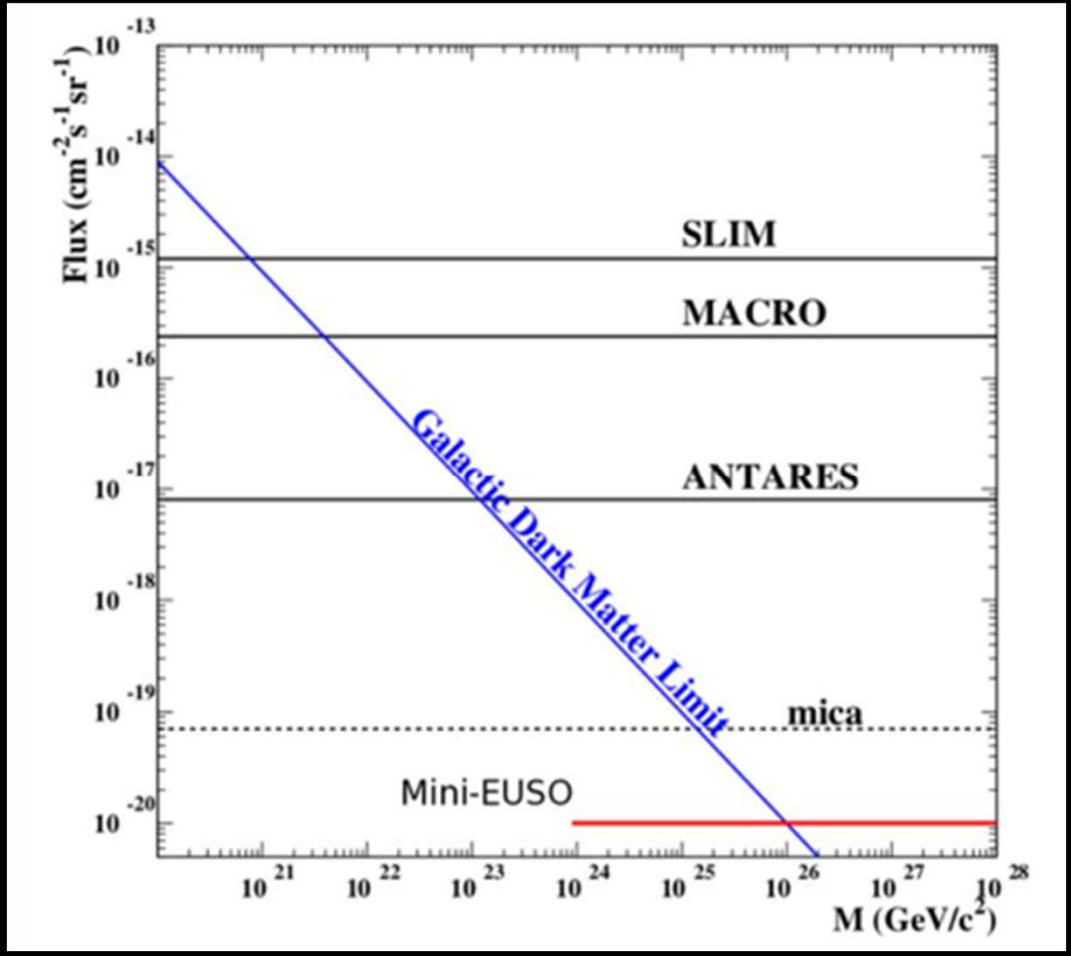
Interstellar Meteors and Search for Strange quark matter

- 200 meteors detected so far
- Near Earth Objects, complementary to ground arrays (joint observations)

- Est. 2000 in data cards

- 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.

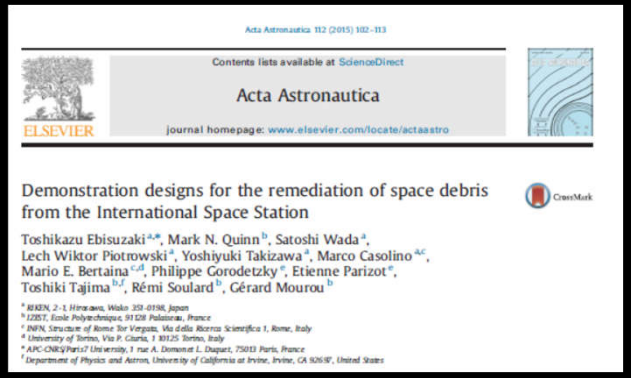
Mini-EUSO & Space Debris remediation

Search for known objects in f.o.v of minieuso

(in termination line between dark and light)

Norad and other catalogues

Look for unknown debris (includes meteors for this purpose)



Acta Astronautica 112 (2015) 102–113

Contents lists available at ScienceDirect

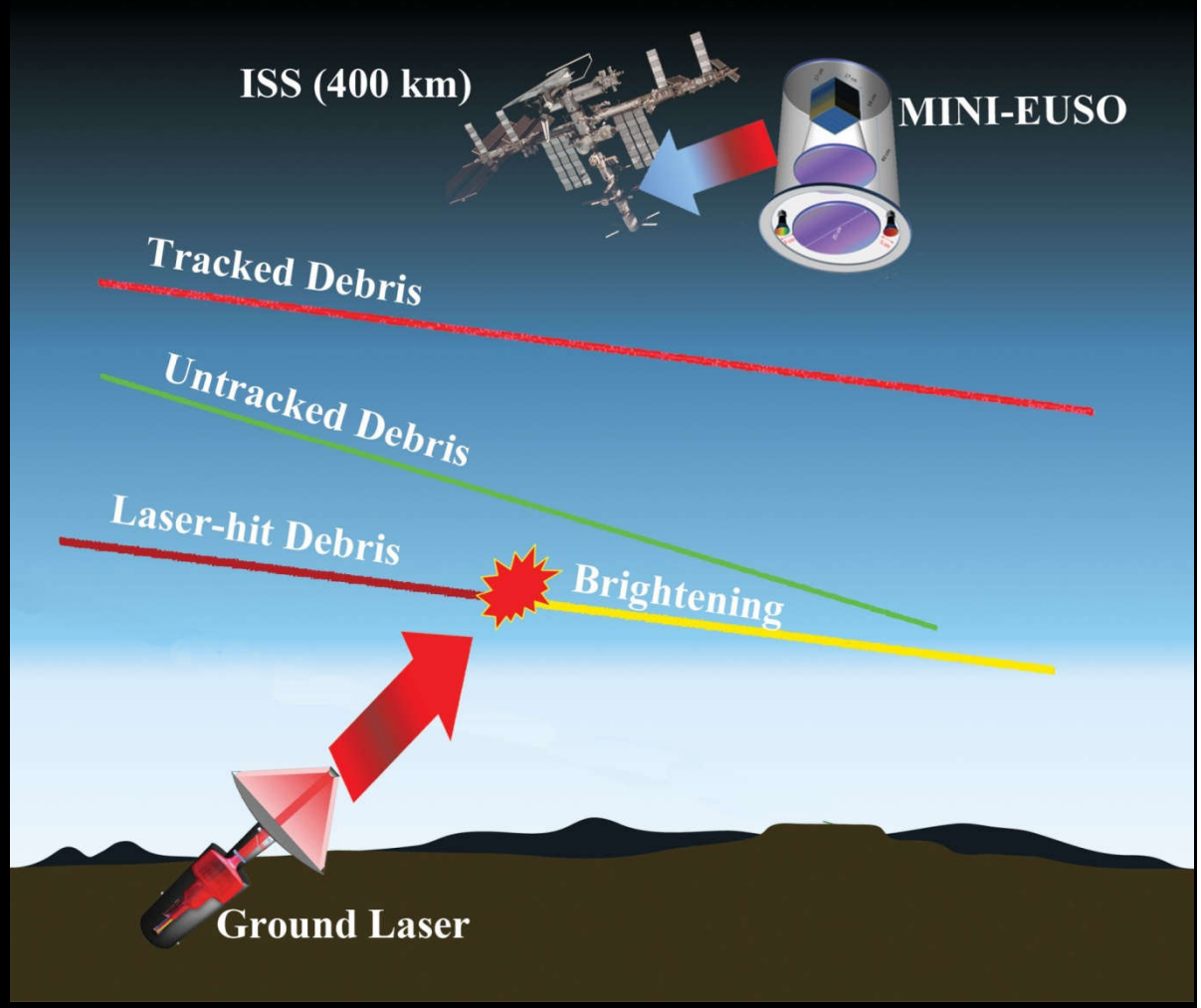
Acta Astronautica

journal homepage: www.elsevier.com/locate/actaastro

Demonstration designs for the remediation of space debris from the International Space Station

Toshikazu Ebisuzaki[a,*], Mark N. Quinn[b], Satoshi Wada[a], Lech Wiktor Piotrowski[a], Yoshiyuki Takizawa[a], Marco Casolino[a,c], Mario E. Bertaina[c,d], Philippe Gorodetzky[e], Etienne Parizot[e], Toshiki Tajima[b,f], Rémi Soulard[b], Gérard Mourou[b]

[a] RIKEN, 2-1, Hirosawa, Wako 351-0198, Japan
[b] IZEST, Ecole Polytechnique, 91128 Palaiseau, France
[c] INFN, Structure of Rome Tor Vergata, Via della Ricerca Scientifica 1, Rome, Italy
[d] University of Torino, Via P. Giuria, 1 10125 Torino, Italy
[e] APC-CNRS/Paris7 University, 1 rue A. Domonet L. Duquet, 75013 Paris, France
[f] Department of Physics and Astron, University of California at Irvine, Irvine, CA 92697, United States

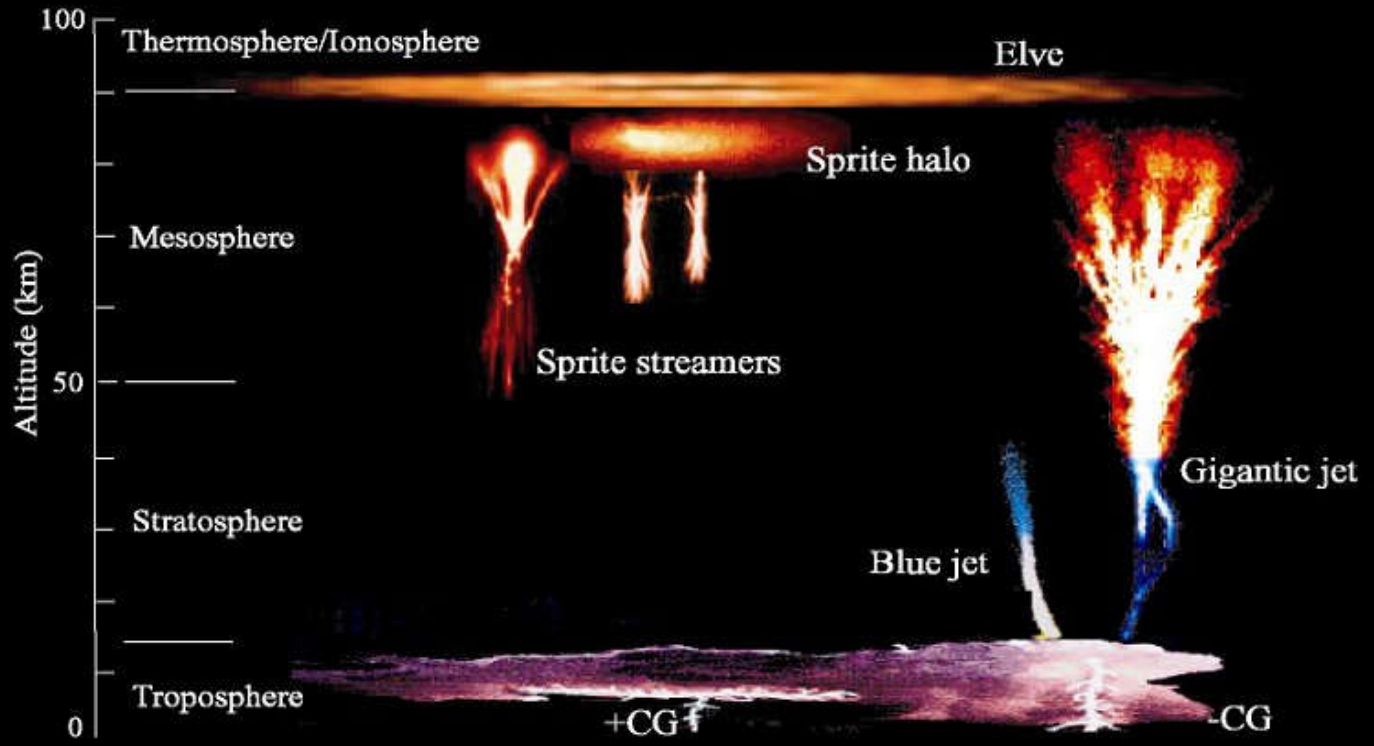


ELVES
(Transient luminous events)

Superluminal rings 100km+ radius

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

About 400μs overall duration

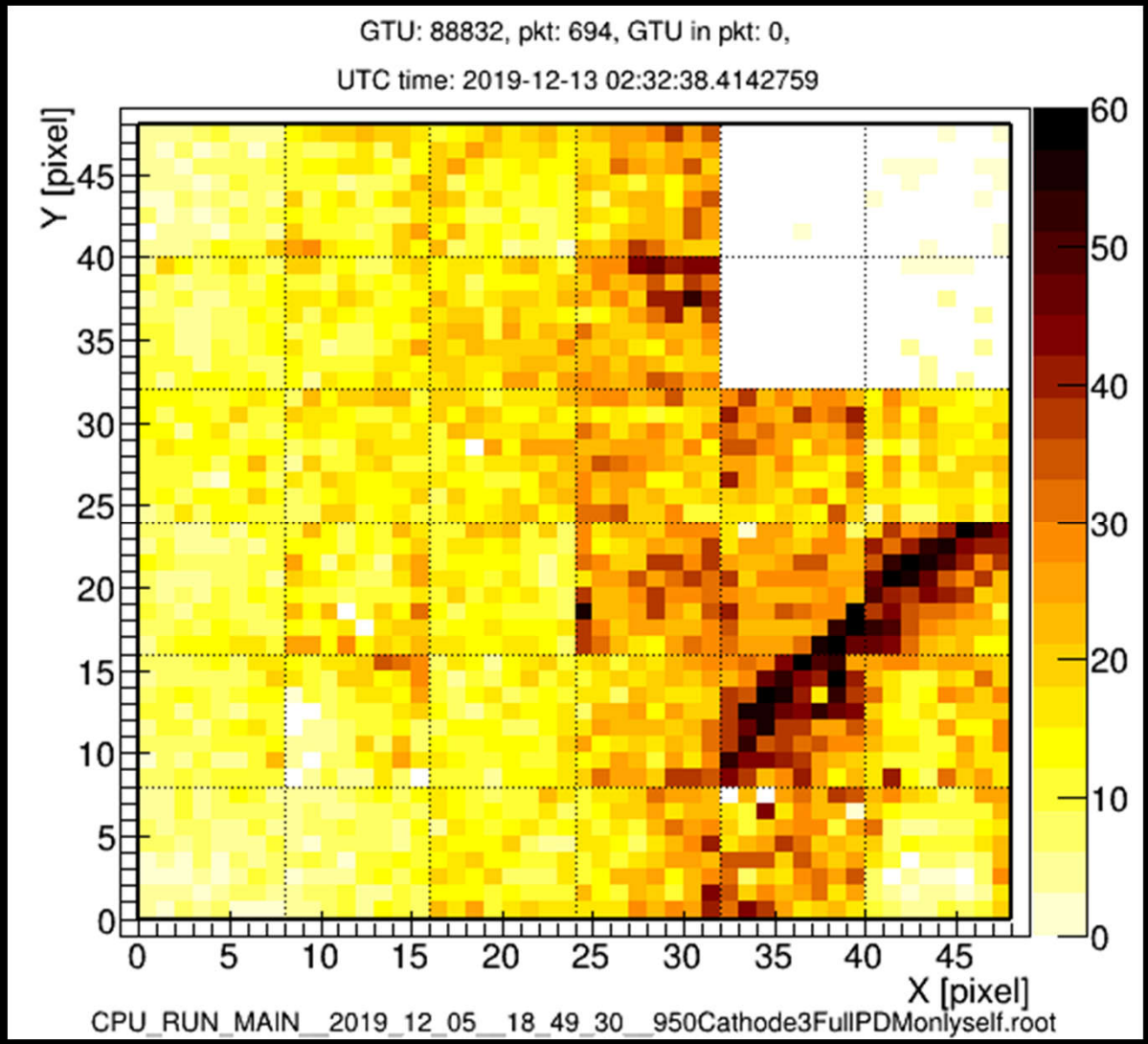


ELVES (transient luminous events)

Superluminal rings
100km+ radius

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

About 400mus
Overall duration



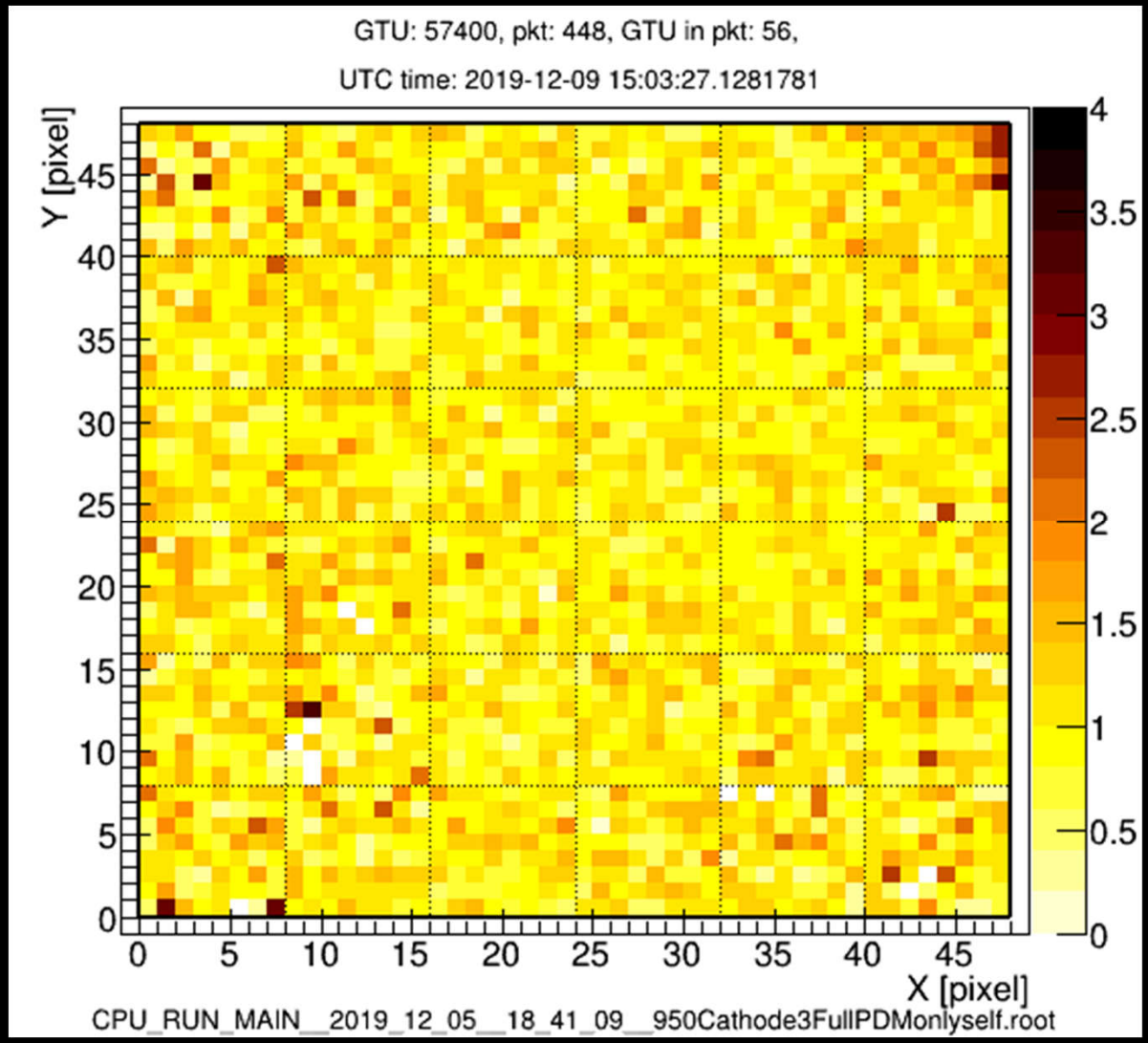
2.5μs
frames

ELVES (transient luminous events)

Superluminal rings
100km+ radius

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

About 400mus
Overall duration



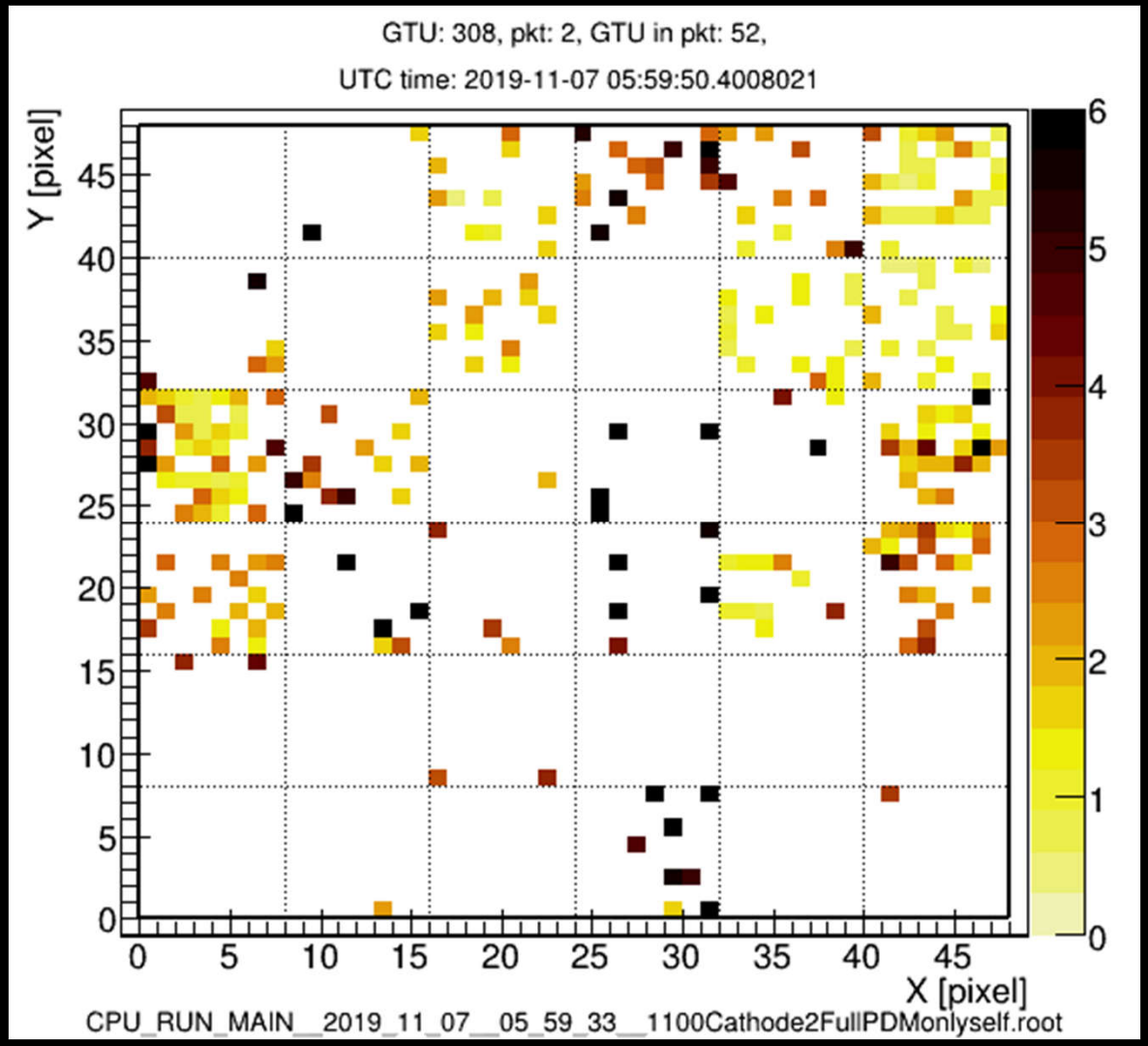
2.5µs frames

ELVES (transient luminous events)

Superluminal rings
100km+ radius

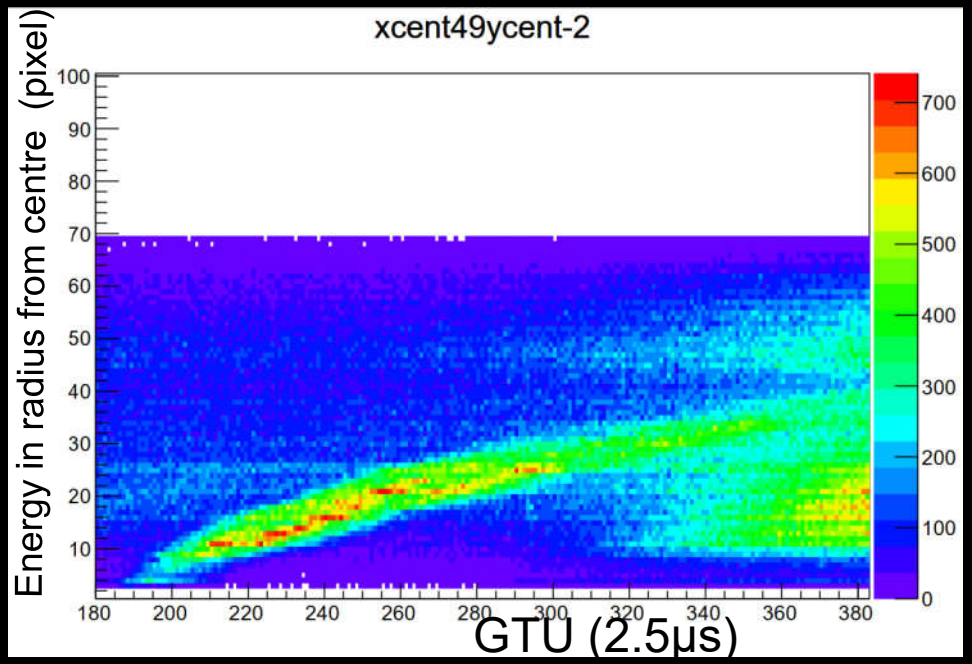
Upper atmospheric lighting releases e.m. wave which heats the ionosphere
Transient Gamma Flash relationship

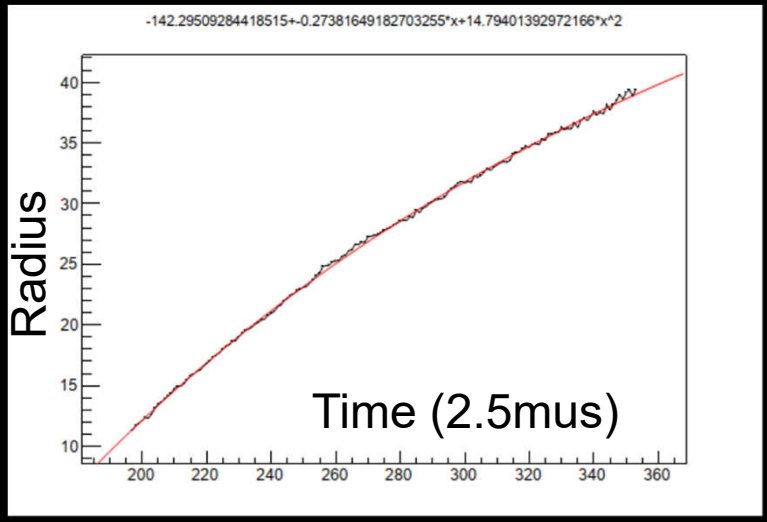
About 400mus
Overall duration



2.5µs frames

ELVE: 2019-12-05_n1
Polar histogram





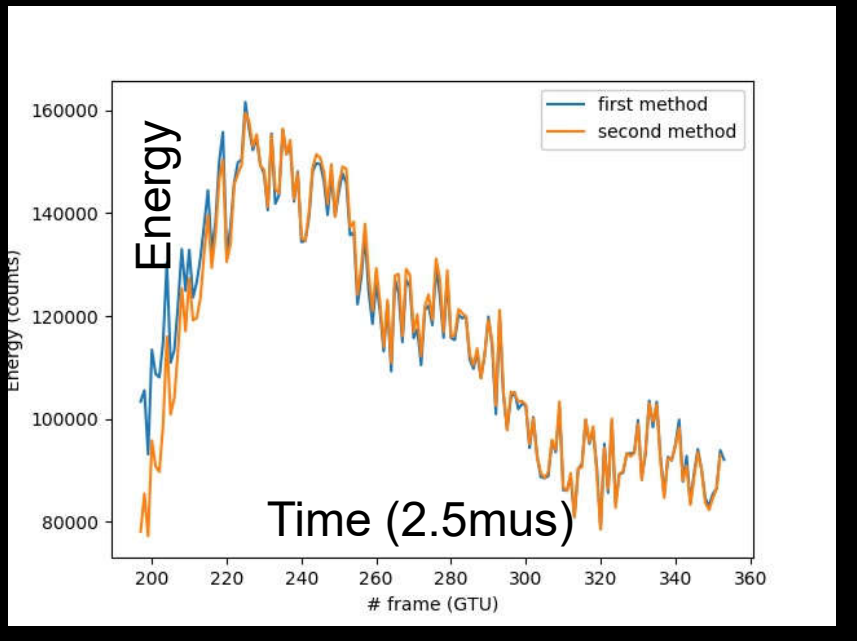
From L. Marcelli

Speed ≈ 0.18 pix/GTU ≈ 338 400 km/s

Pixel size:

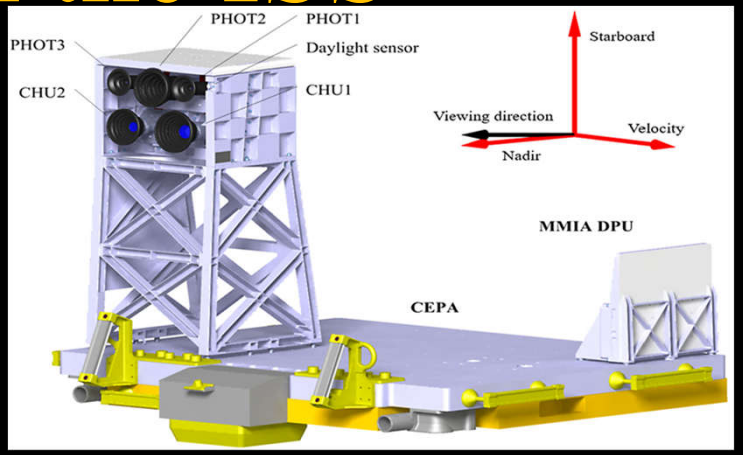
6.1 km on ground

4.7 km at 100 km



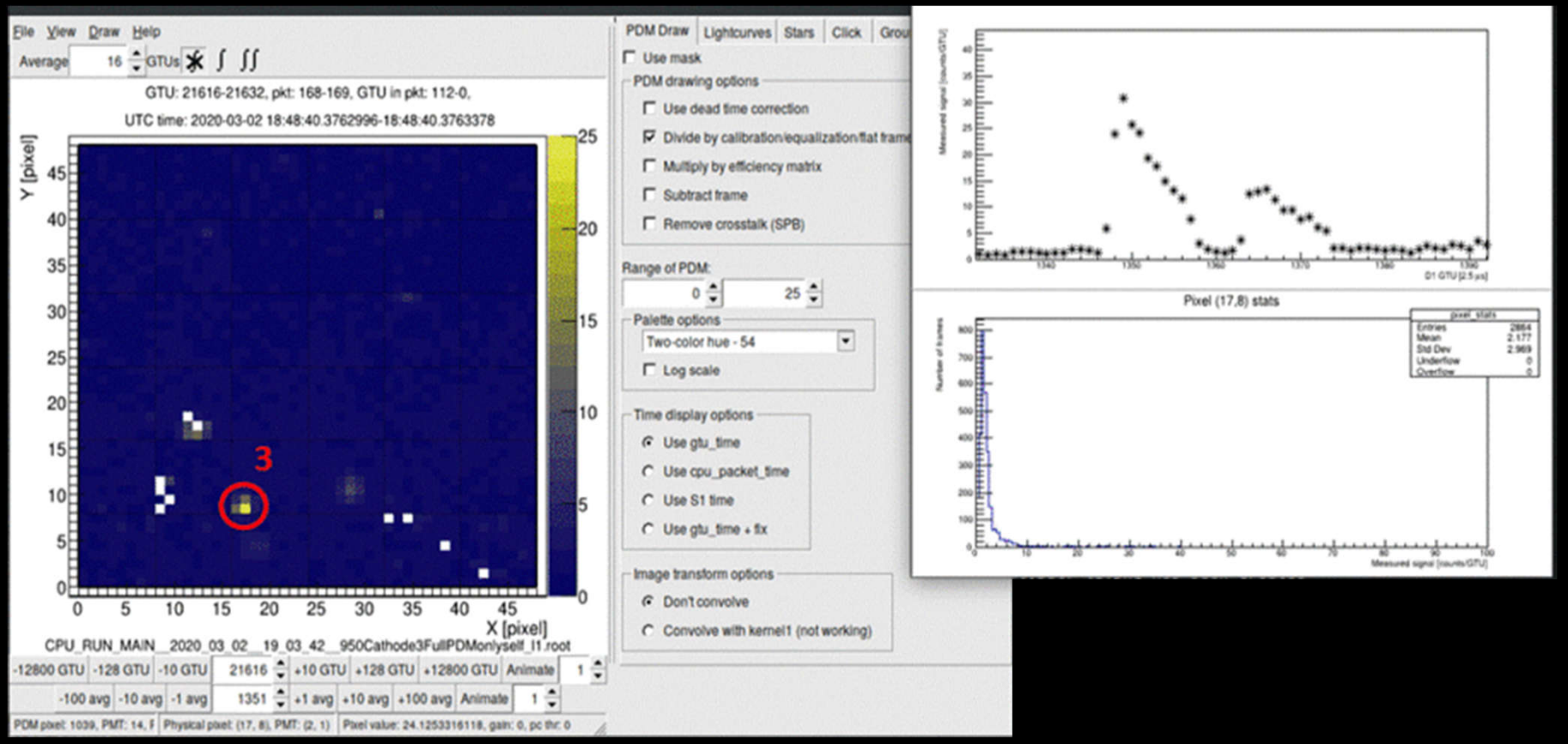
Joint observations with other detectors on the ISS

ASIM:
UV transients and ELVES



ALTEA-LIDAL
Correlation with radiation environment of cosmic rays 100 Mev – GeV and Transient Luminous Events

Ground flasher (triggered acquisition)

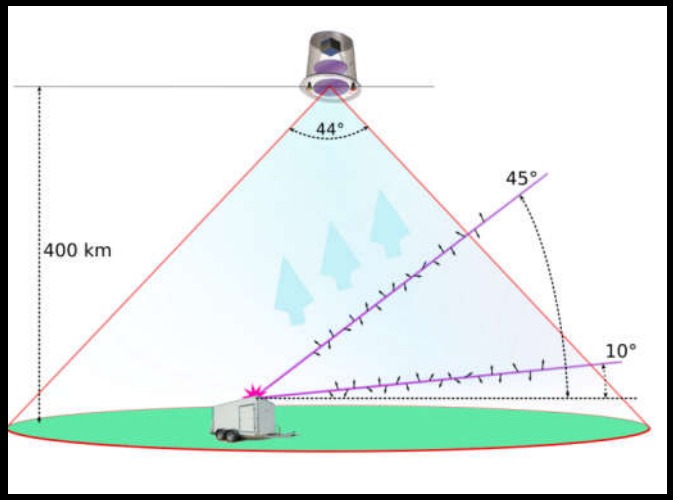


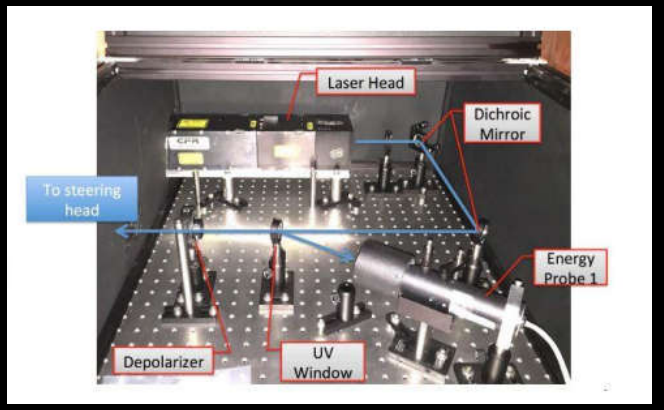
2.5 microsecond GTU, duration 20-100 GTU repeated – shifted - after >second

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

- 2kW pulsed UV LED array
- Calibration from ground
- Shoot when in field of view
- Pulsed and coded shots

- First system developed in Japan. Other systems in Europe and USA.





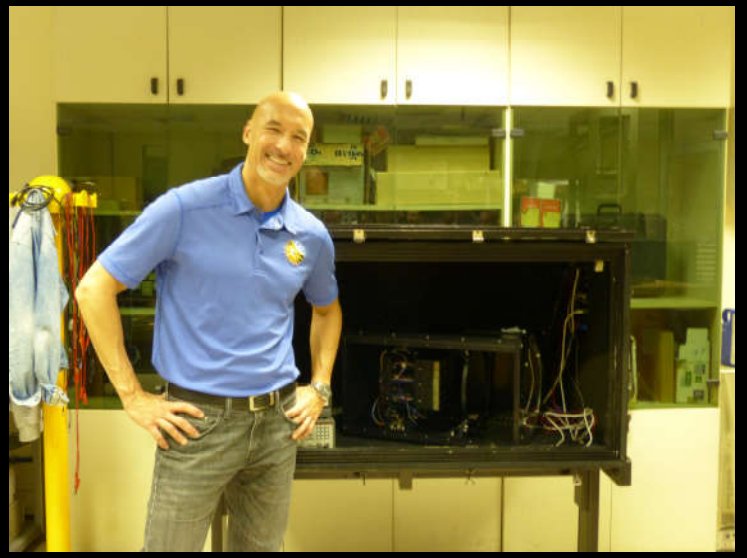
- Portable laser in Colorado
- Calibrated UV light source:
- pulsed 355 nm frequency tripled YAG laser
- Energy: 200 muJ to 90 mJ
- 360° azimuth, 90° zenith direction

From V. Kungel, L. Wienkle

Conclusions

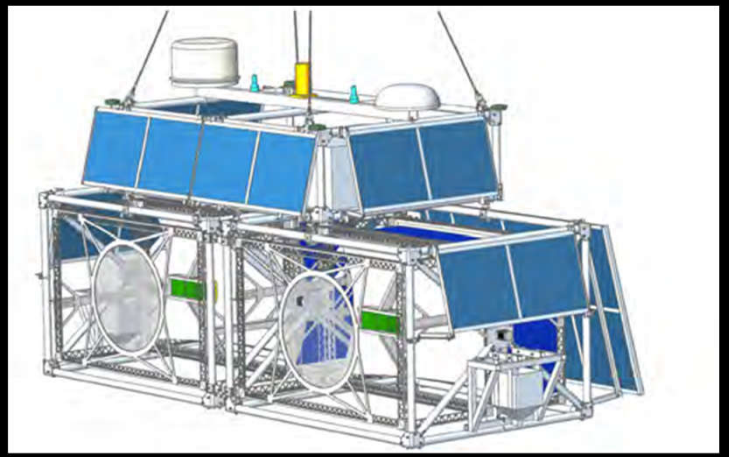
Mini-EUSO is working correctly on ISS

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



10% of data received by telemetry
Rest received in April with pouche

- Operations for at least three years
- Locate on other less busy windows
- Provide input to SPB2 flight



http://jem-euso.roma2.infn.it/

Selected (Mini-EUSO) 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.

In preparation:

The Mini-EUSO instrument
Observation of ELVES
Observation of Meteors

Missione Beyond – aspetti di outreach

L. Parmitano in visita
a Tor Vergata con FM Mini-EUSO

Video di Outreach da ISS
https://www.youtube.com/watch?v=QincAp4V-SM&t=1s

Video di outreach su Corriere della Sera

https://video.corriere.it/cronaca/mini-euso-luca-parmitano-protagonista-web-serie-beyond/2582bd90-aa06-11e9-a88c-fde1fa123548

Menzionato nel collegamento con Presid. Mattarella
https://www.youtube.com/watch?v=NMTTSB6BVaw

Missione Beyond – aspetti di outreach

INFN Press releases
http://home.infn.it/it/comunicazione/news/3671-mini-euso-parte-verso-la-stazione-spaziale-internazionale
http://home.infn.it/it/comunicazione/news/3921-prime-osservazioni-dell-esperimento-spaziale-mini-euso-attivato-dall-astronauta-esa-luca-parmitano

ASI PR https://www.globalscience.it/13793/vita-nello-spazio/mini-euso-in-viaggio-verso-la-iss/
Rai TV http://www.rainews.it/dl/rainews/media/Partita-la-Soyuz-a-bordo-il-robot-Fedor-e-il-telescopio-italiano-Mini-EUSO-166136a7-b76a-4826-bb3a-1146f0d5b8c1.html#foto-1
Aska news agency
https://www.askanews.it/video/2019/08/27/spazio-il-telescopio-italiano-minieuso-%c3%a8-sulla-iss-a-cosa-serve-20190827_video_12295136/
https://www.youtube.com/watch?v=ds02AzrpjkY
Videos https://video.virgilio.it/guarda-video/spazio-il-telescopio-italiano-minieuso-e-sulla-iss-a-cosa-serve_bc6077781276001
https://stream24.ilsole24ore.com/video/tecnologia/spazio-telescopio-italiano-minieuso-e-iss-cosa-serve/ACpFrSg
http://247.libero.it/focus/48293671/3/italia-nello-spazio-partita-la-soyuz-con-telescopio-mini-euso/
Various https://orbiter.it/cms/tag/telescopio-mini-euso/
http://www.italiannetwork.it/news.aspx?id=58976
https://notizie.tiscali.it/scienza/articoli/spazio-telescopio-italiano-minieuso-a-sulla-iss-cosa-serve-00001/
https://www.informazione.it/n/8BFE339C-59CE-414F-B4CA-FF62A575CFFF/Un-po-d-Italia-sulla-Soyuz-domani-lancio-telescopio-Mini-EUSO
https://lenotizie.org/tecnologia/partita-la-soyuz-bordo-il-robot-fedor-il-telescopio-italiano-mini-euso-84284868
https://www.zazoom.it/2019-08-22/lanciato-il-telescopio-mini-euso-osservera-la-terra-dal-modulo-russo-zvezda-della-stazione-spaziale/5752068/
https://sciencecue.it/esperimento-mini-euso-parmitano/18040/
https://www.globalscience.it/17103/luca-parmitano-racconta-mini-euso/
https://www.askanews.it/scienza-e-innovazione/2020/02/04/spazio-primi-dati-dal-telescopio-mini-euso-attivato-da-parmitano-pn_20200204_00076/
https://corrieredellumbria.corr.it/video/tv-news/1438055/spazio-luca-parmitano-racconta-l-esperimento-italiano-mini-euso.html

–APECC https://www.appec.org/news/mini-euso-now-in-space
IN2P3 website:
https://in2p3.cnrs.fr/fr/cnrsinfo/ultra-sensible-aux-uv-mini-euso-va-jeter-depuis-lespace-un-regard-inedit-sur-la-terre
– APC website:
- https://www.apc.univ-paris7.fr/APC_CS/fr/mini-eusoen-route-pour-liss
- https://www.apc.univ-paris7.fr/APC_CS/fr/arrimage-reussi-sur-liss-pour-mini-euso
– Physics department website at the University of Paris:
https://physique.univ-paris-diderot.fr/actualites/avec-mini-euso-lufr-de-physique-prend-pied-dans-la-station-spatiale-internationale

popular science media:
- https://www.techno-science.net/forum/viewtopic.php?t=46006
- https://www.bovary.gr/items/21096/i-empeiria-tis-l-oreal-taxideyei-sto-diastima
- https://news.cision.com/pt/l-oreal-portugal/r/l-oreal-leva-o-seu-conhecimento-em-inovacao-a-estacao-espacial-internacional,c637025147770000000