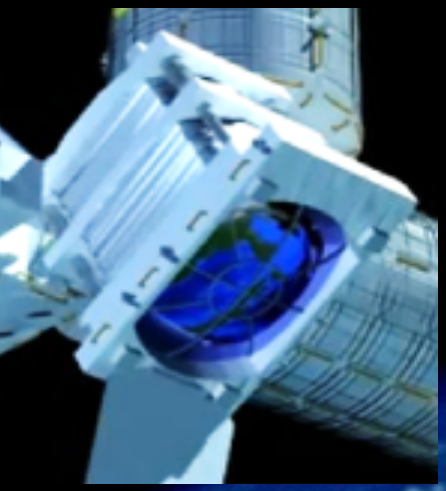


Extreme Universe Space Observatory

Mini-EUSO e attività correlate all'osservazione di meteore e Space Debris in associazione con PRISMA

M. Bertaina, R. Bonino, F. Fenu, G. Suino (Univ. Torino)

PRISMA day Firenze 16 Maggio 2017

Activities and possibles synergy with PRISMA network

Development, simulations and data taking with Mini-EUSO from 2018. Analysis of meteor events detected in coincidence with PRISMA network. Stereo-vision from ground and space in different bands. Mini-EUSO is focused on the 300-400 nm window (near UV). Detection of space debris?
Mini-EUSO is funded by ASI, INFN, MAECI. It involves different Univ., INAF and INFN institutes (Bari, Catania, Frascati, Napoli, Palermo, Roma Tor Vergata e Roma Uninettuno, Torino).
In France, APC - Univ. Paris Diderot (Paris), LAL (Orsay), IRAP (Toulouse) involved in Mini-EUSO development: it would be nice to have synergy with FRIPON network.

Proof of principle for the detection of space debris in the 1 - 10 cm size using detectors developed in the frame of astro-particle experiments. This project is currently funded by Univ. Torino and Compagnia di San Paolo. R. Bonino (Univ. Torino) is the project investigator (30 month project, started May 1st 2017).
We are now evaluating performance of Mini-EUSO and other telescopes developed in the framework of the JEM-EUSO program by means of dedicated simulations. From next year we plan to use a small telescope to take data together with the PRISMA cameras at INAF-OATo and OAdVA (informal talks with A. Carbognani, A. Cellino, D. Gardiol). 1 PRISMA camera is going to be acquired soon within this project.

In both activities we collaborate with Thales Alenia Space - Torino (R. Destefanis and L. Grassi).

The JEM-EUSO program

Ultra-High Energy cosmic rays from space

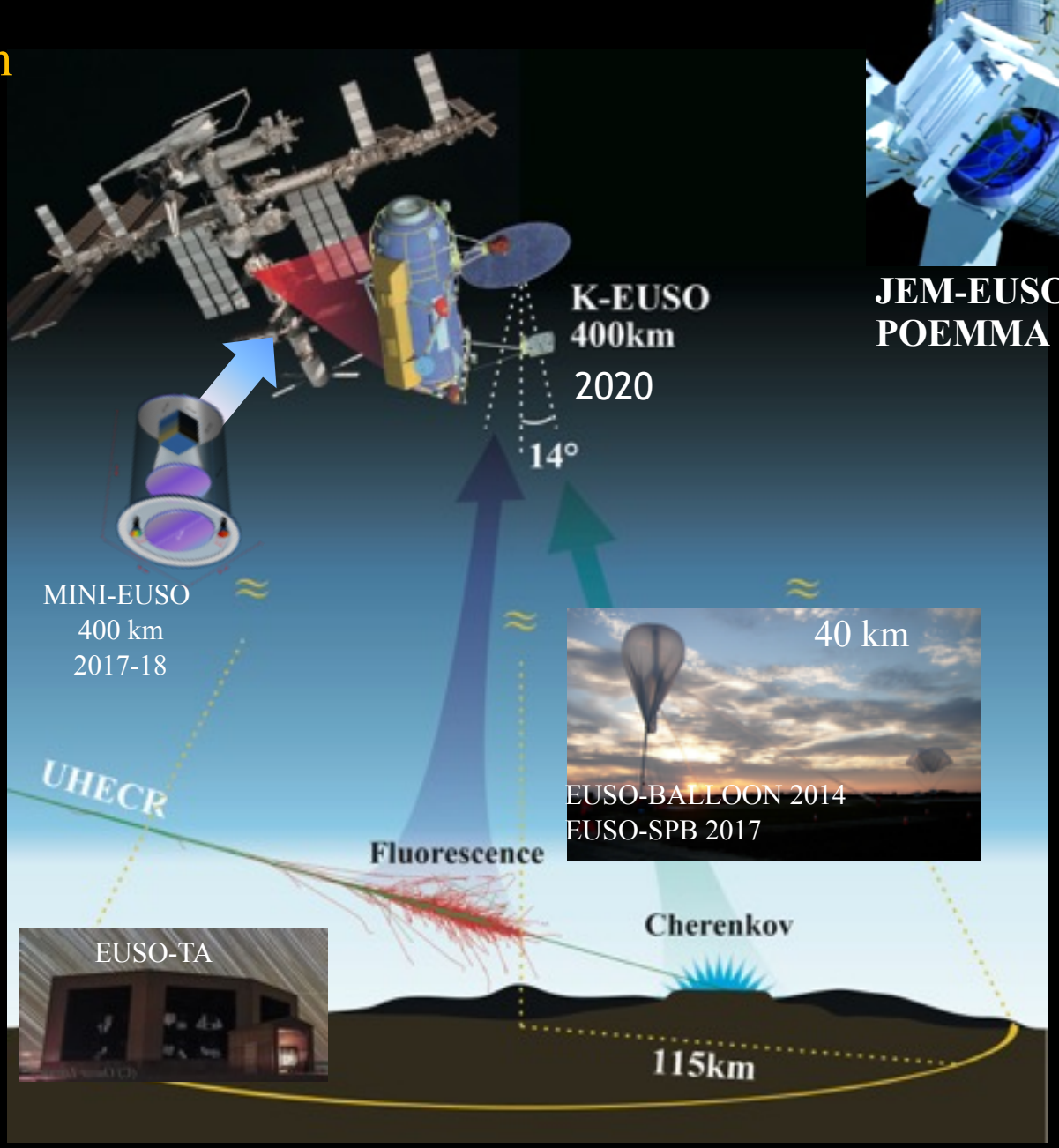
1. **EUSO-TA:** *Ground detector installed in 2013 at Telescope Array site: currently operational*

2. **EUSO-BALLOONS**: *1st balloon flight from Timmins, CA (French Space Agency) Aug 2014; NASA Ultra long duration flight: Apr-May 2017*

3. **MINI-EUSO (2017-18):** *Precursor from International Space Station (ISS: 30kg 2017). Approved by Italian and Russian Space agencies*

4. **K-EUSO (2020):** *ISS Approved by Russian Space Agency*

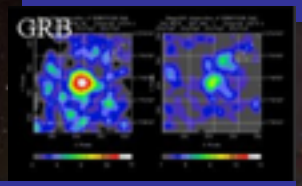
5. **JEM-EUSO-like detector (>2025): POEMMA - US free satellite (?)**

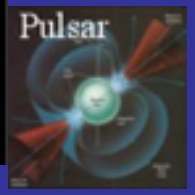


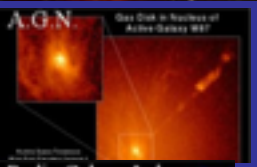
JEM-EUSO/ POEMMA

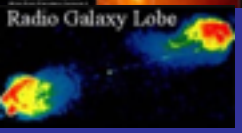
JEM-EUSO collaboration 16 Countries, 93 Institutes, 351 people

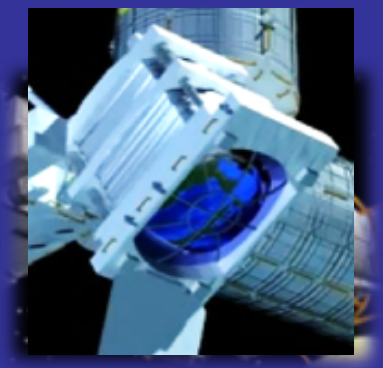
JEM-EUSO is an Astronomical Earth Observatory from Space

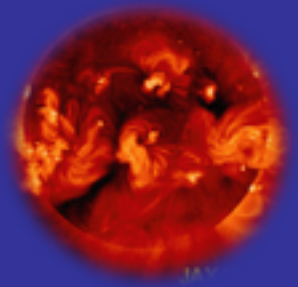












EECR s

Dust and Meteors, Space Debris, Nuclearites

Charged Particles

traviolet photons

UV, X, γ, ν
p, n, e

$X, \gamma, \upsilon, p, e$

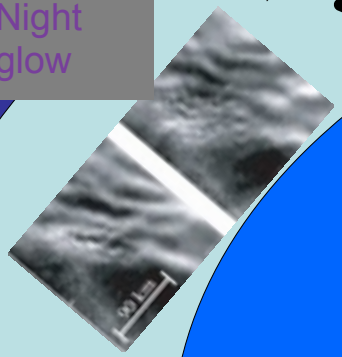
Air shower

Air shower

Atmosphere

Solar wind

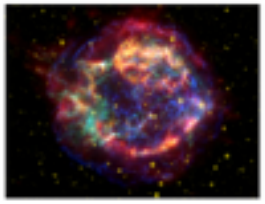
Night glow



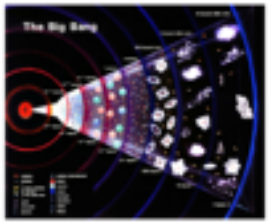
The Earth

Plasma Discahrge

EHE Neutrinos

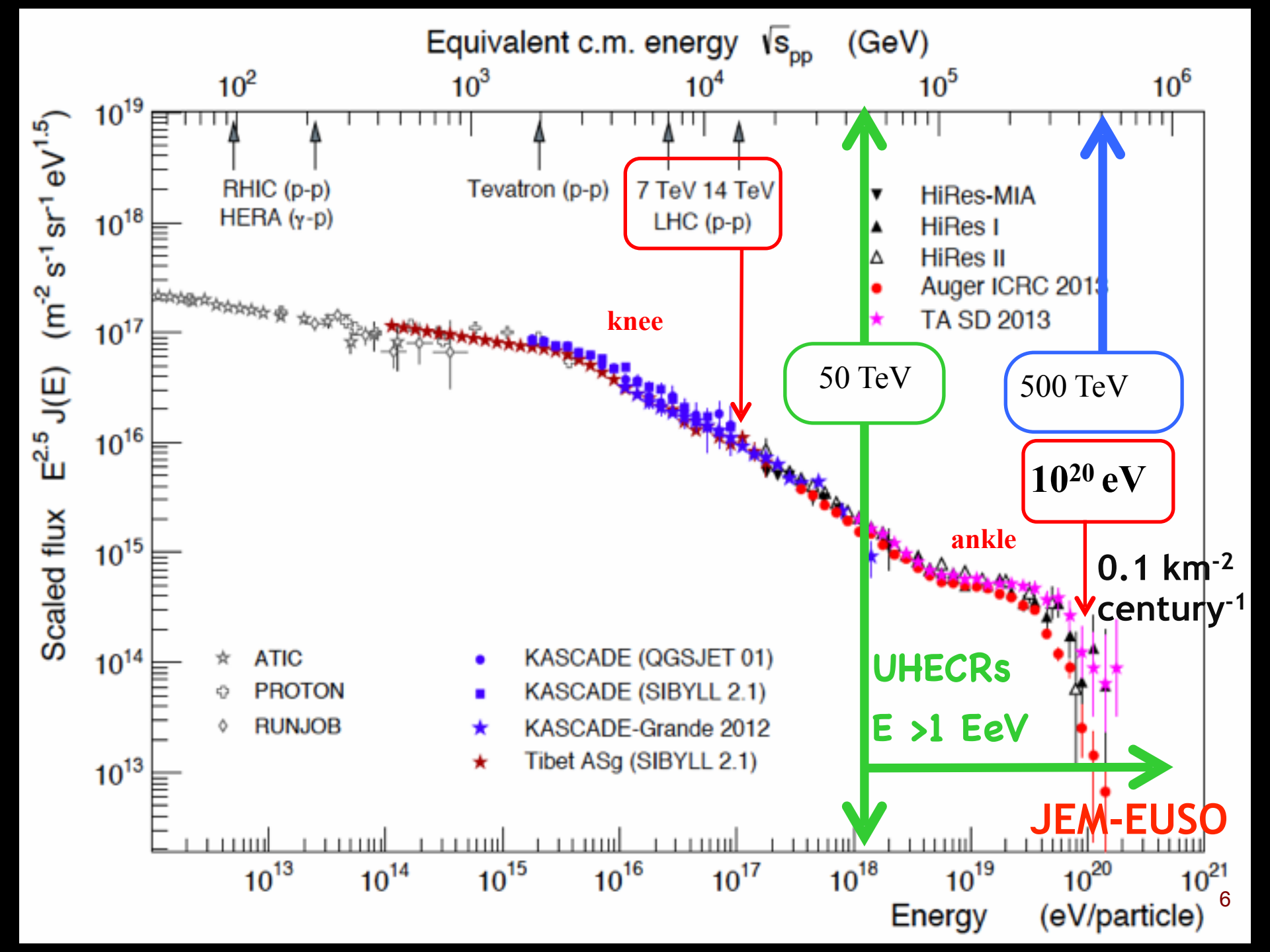


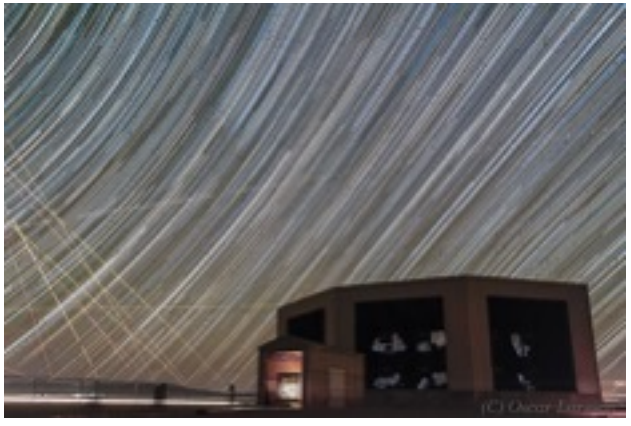
JEM-EUSO Science

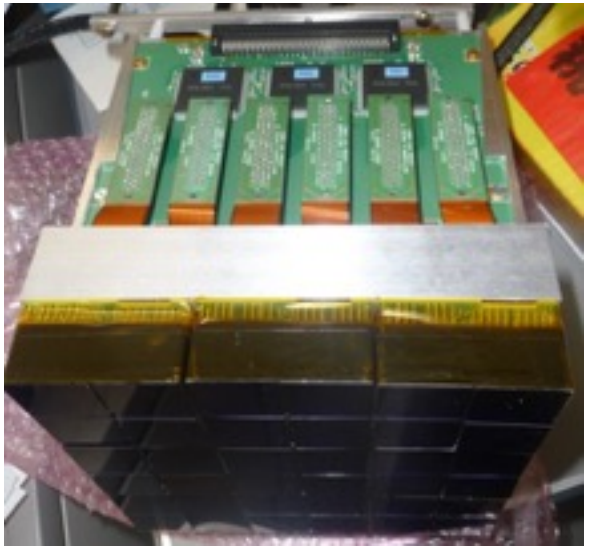


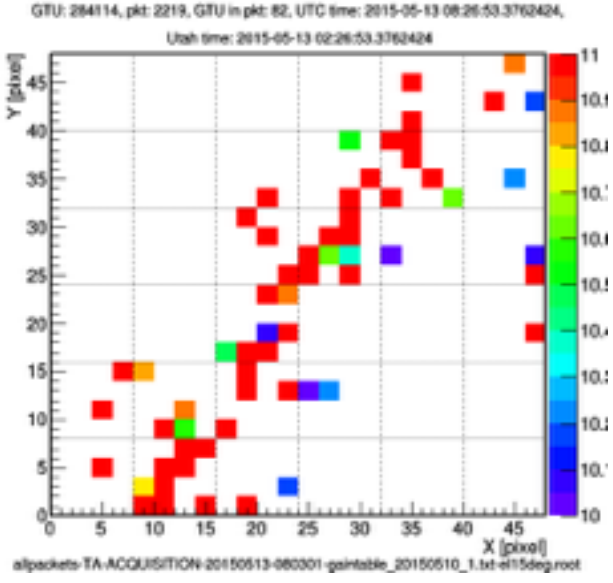
- **Astrophysics, Cosmology and Fundamental Science:**
  - Main Science Objectives:
    - *identification of UHE sources*
    - *measurement of the energy spectra of individual sources*
    - *measurement of the trans-GZK spectrum*
  - Exploratory objectives:
    - *discovery of UHE Gamma-rays*
    - *discovery of UHE neutrinos*
    - *study of the galactic and local extragalactic magnetic field*
    - *"Top-Down" scenario*
    - *Super Heavy Dark Matter, Nuclearites*

- **Atmospheric Science**
  - *Nightglow*
  - *the transient luminous events (TLE)*
  - ***meteors and meteoroids***
  - ***detection and tracking of space debris***


Equivalent c.m. energy √s_pp (GeV)
10^2
10^3
10^4
10^5
10^6
RHIC (p-p)
HERA (γ-p)
Tevatron (p-p)
7 TeV 14 TeV
LHC (p-p)
knee
ankle
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 201
TA SD 2013
50 TeV
500 TeV
10^20 eV
0.1 km^-2 century^-1
UHECRs
E >1 EeV
JEM-EUSO
ATIC
PROTON
RUNJOB
KASCADE (QGSJET 01)
KASCADE (SIBYLL 2.1)
KASCADE-Grande 2012
Tibet ASg (SIBYLL 2.1)
Scaled flux E^2.5 J(E) (m^-2 s^-1 sr^-1 eV^1.5)
10^19
10^18
10^17
10^16
10^15
10^14
10^13
10^13
10^14
10^15
10^16
10^17
10^18
10^19
10^20
10^21
Energy (eV/particle)



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Utah time: 2015-05-13 02:26:53.3762424
Y [pixel]
X [pixel]
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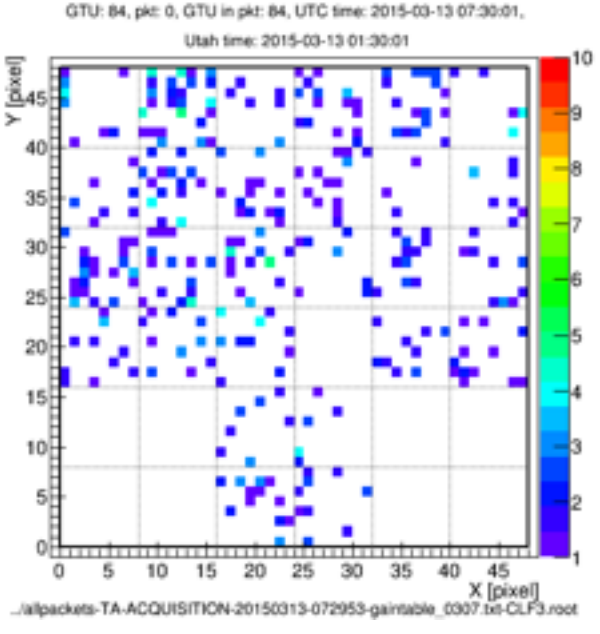
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Utah time: 2015-03-13 01:30:01
Y [pixel]
X [pixel]
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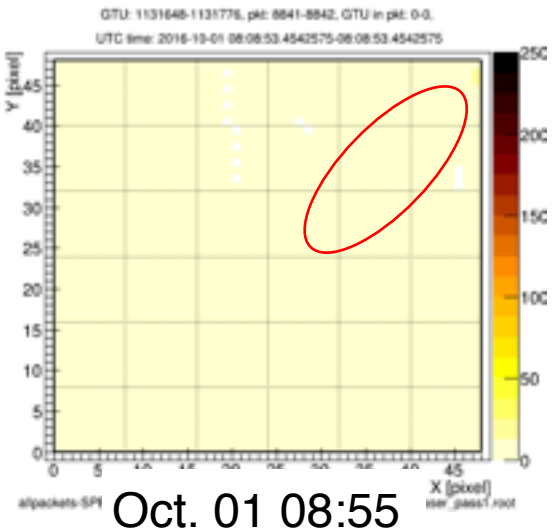
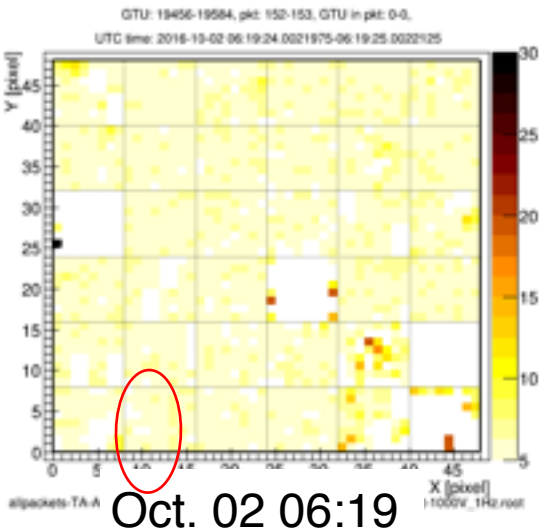
EUSO-TA

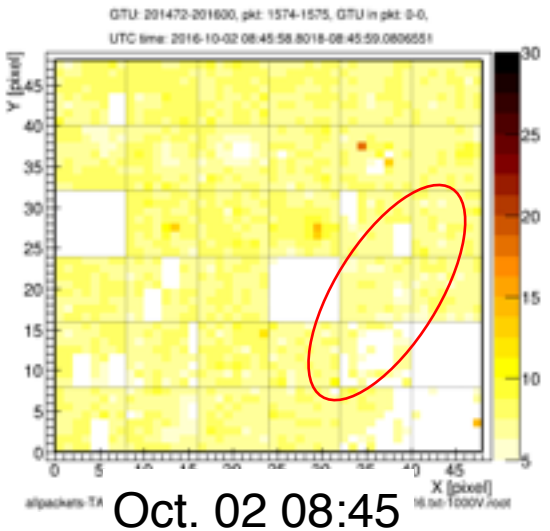
Meteors in October 2016



Oct. 01 08:55
(EUSO-SPB)

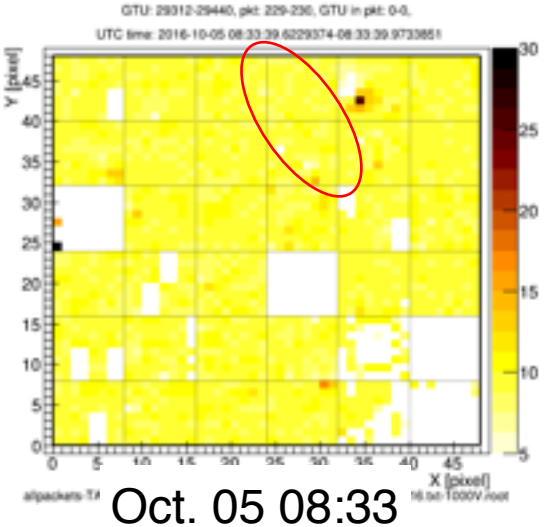


Oct. 02 06:19
(1 Hz)

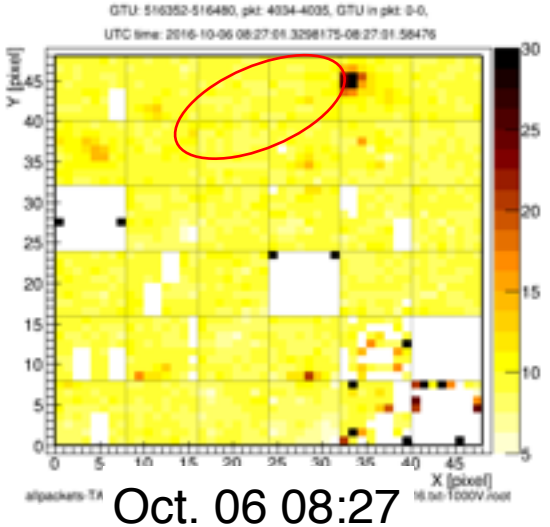


Oct. 02 08:45

Oct. 01 08:55
Oct. 02 06:19
Oct. 02 08:45
Oct. 05 08:33
Oct. 06 08:27



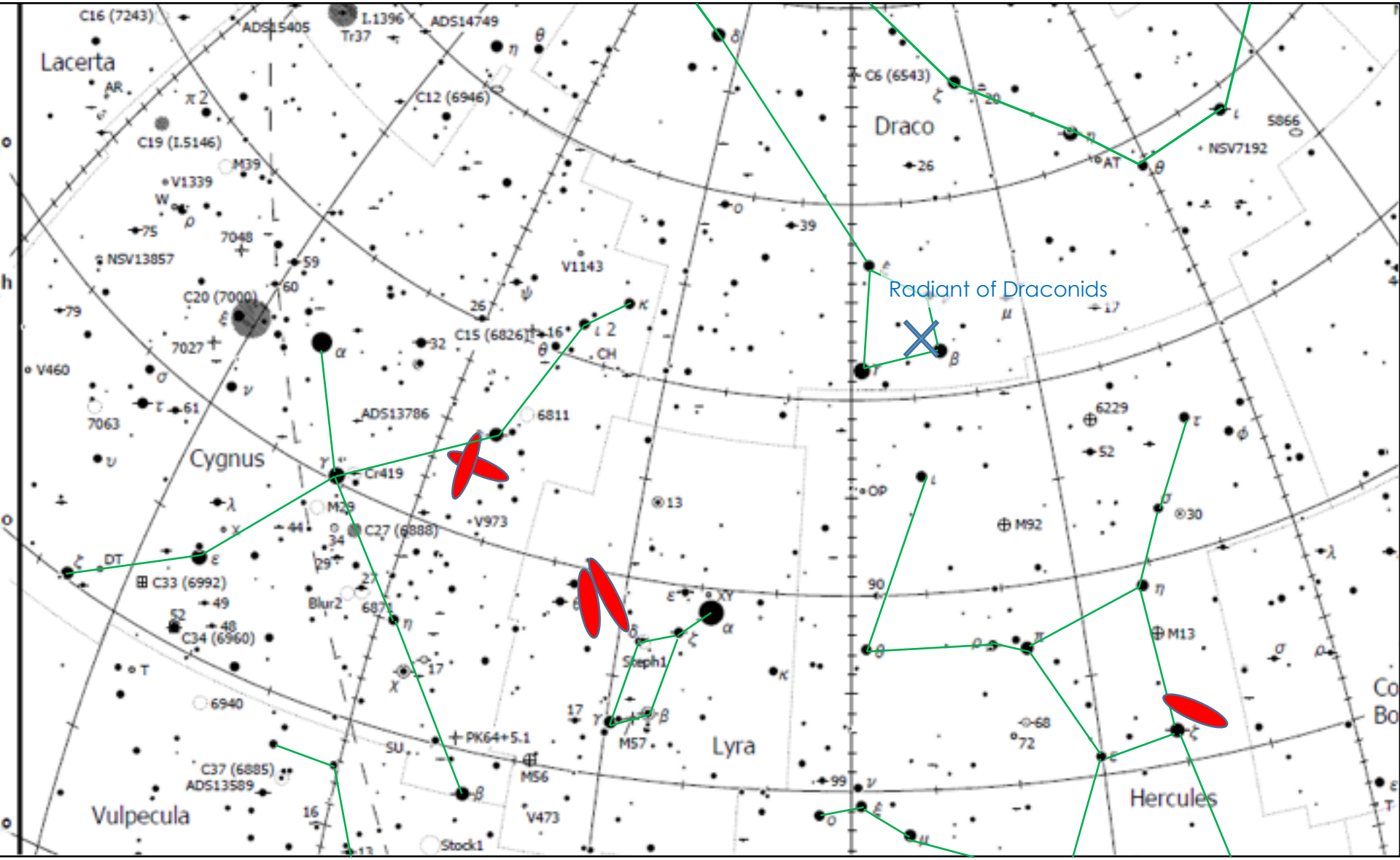
Oct. 05 08:33



Oct. 06 08:27

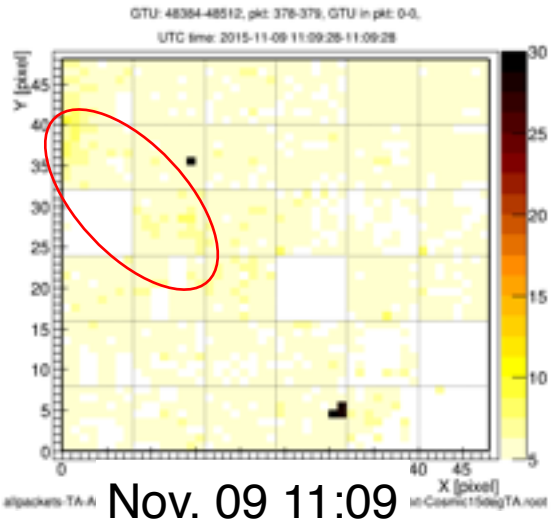
Y. Kawasaki (RIKEN)

Meteors in October 2016

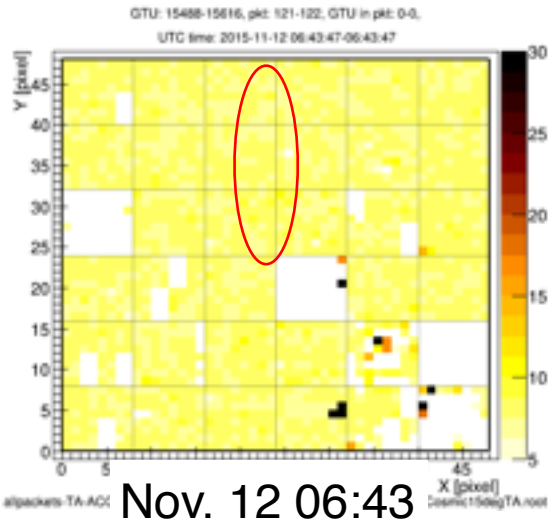


EUSO-TA

Meteors in November 2015

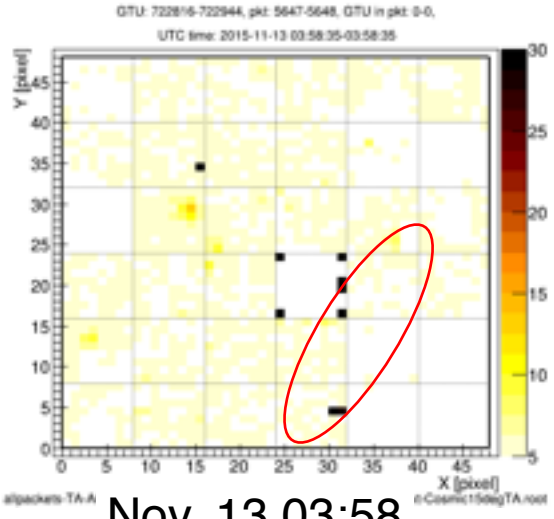


Nov. 09 11:09

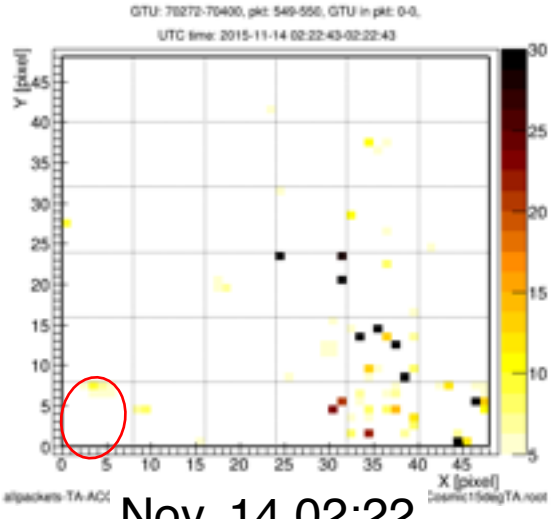


Nov. 12 06:43

Nov. 09 11:09
Nov. 12 06:43
Nov. 13 03:58
Nov. 14 02:22



Nov. 13 03:58

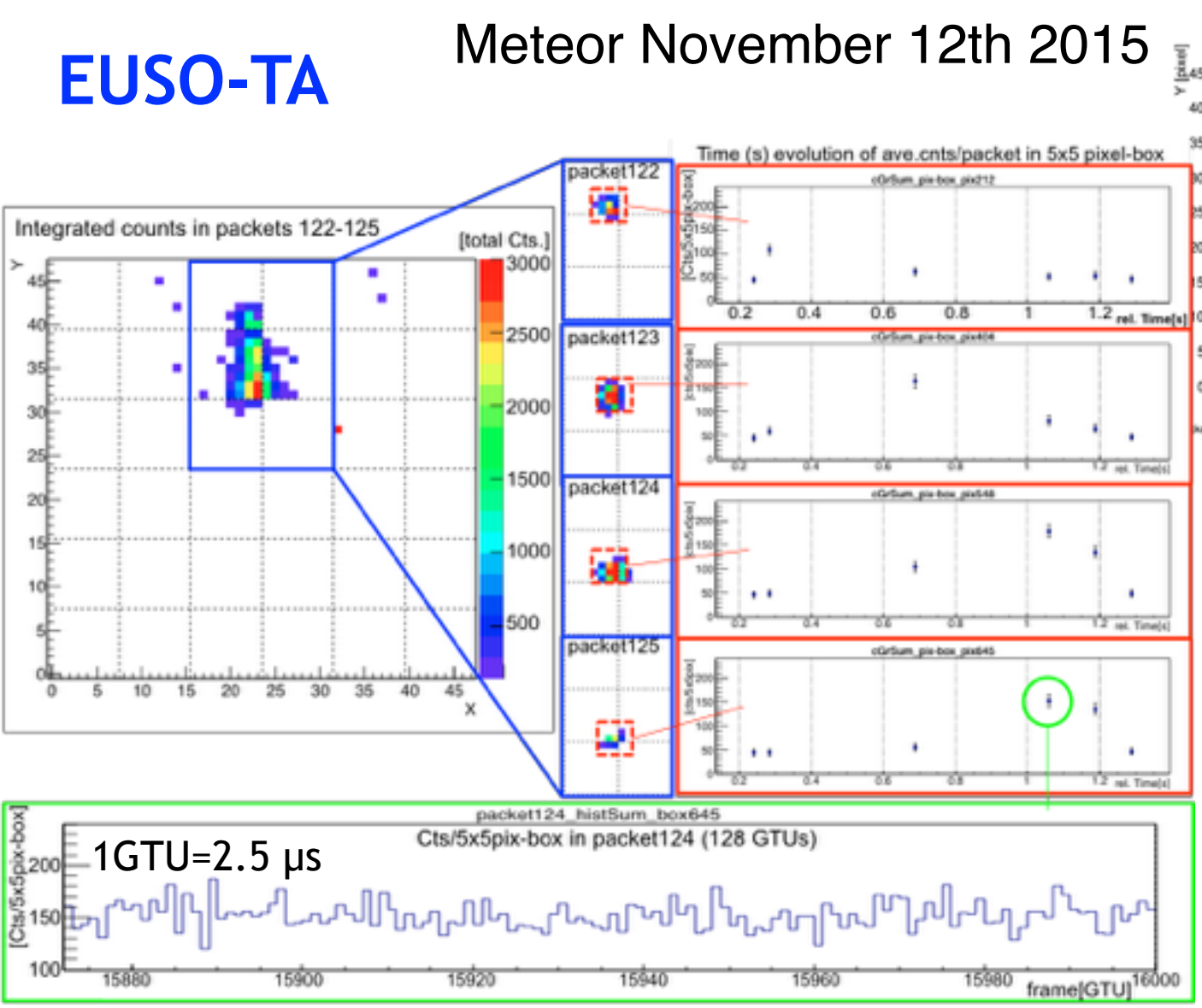


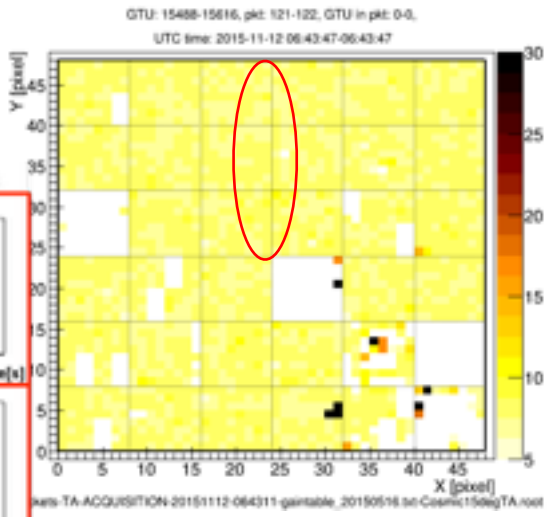
Nov. 14 02:22

Y. Kawasaki (RIKEN)

EUSO-TA

Meteor November 12th 2015

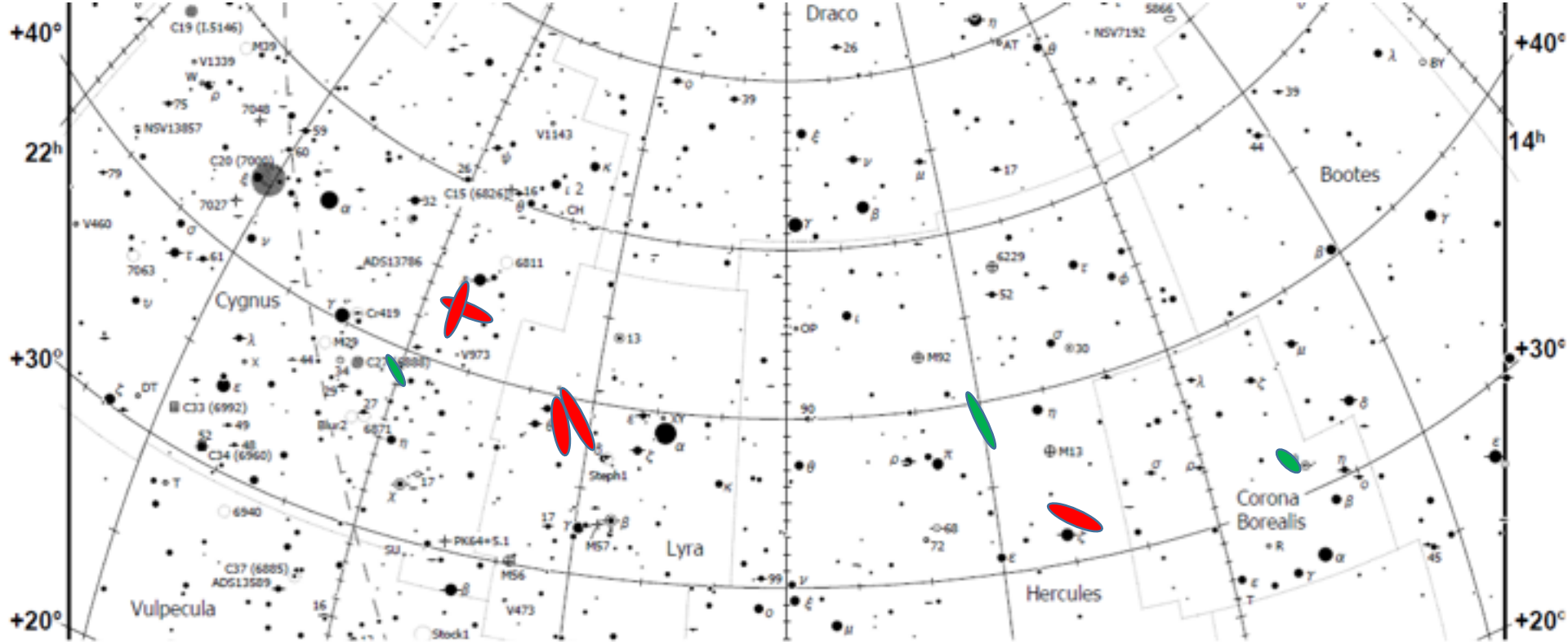




1 packet = 128 GTUs
= 320 μs

The morphology of the event shows a fast initial brightening of about 0.9 mag, followed by a slightly slower decline of about 1.7 mag.
Taking into account all the uncertainties, including those related to the conversion of the star magnitudes, given in B colour, we can conclude that this meteor reached a **magnitude ~ 2.5**.

Meteors in November 2015 (Green)



Nov. 12 06:43

Nov. 13 03:58

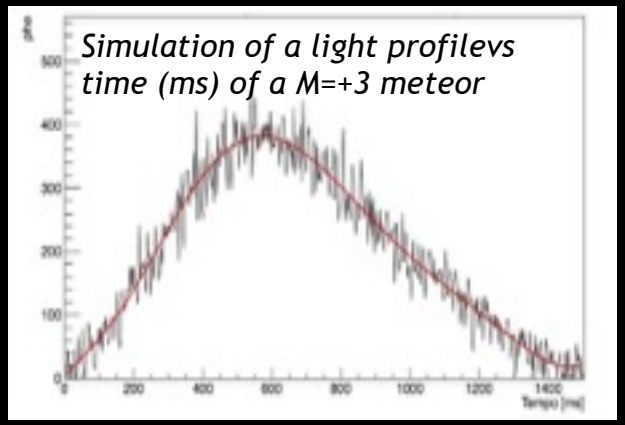
Nov. 14 02:22

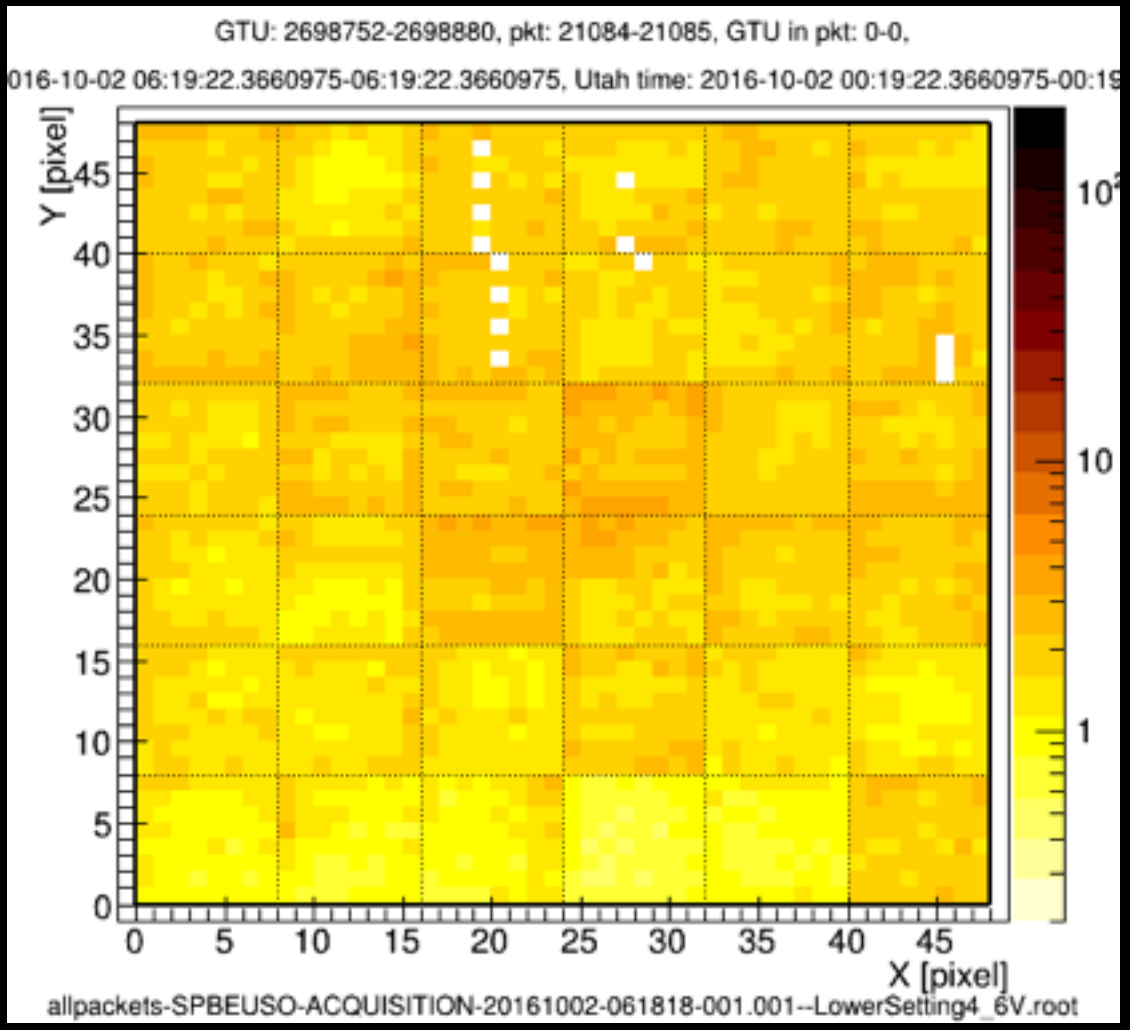
Meteors and Strange quark matter

meteor detected by EUSO-SPB detector at EUSO-TA site

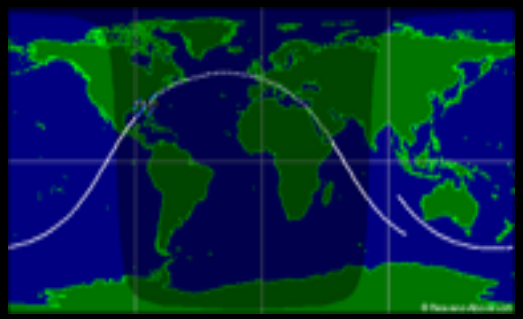
Meteors: Seconds, Solar system speed

Strange Quark matter (very dense): longer signal, interstellar origin and speed





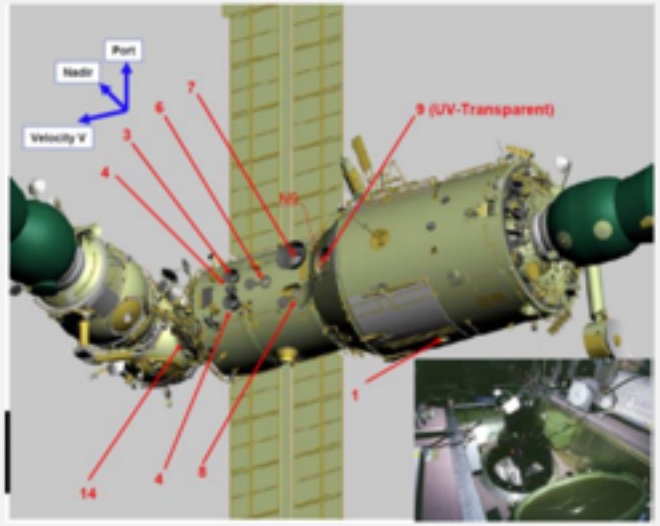
The ISS ORBIT



Inclination: 51.6°
Height: ~400km

MINI-EUSO/UV-ATMOSPHERE
Joint Italo-Russian experiment from ISS

MANPOWER IN THE MINI-EUSO PROJECT



UV atmosphere is a wide field of view telescope to be installed on board the Russian Segment of the ISS (UV transparent window of Service module)

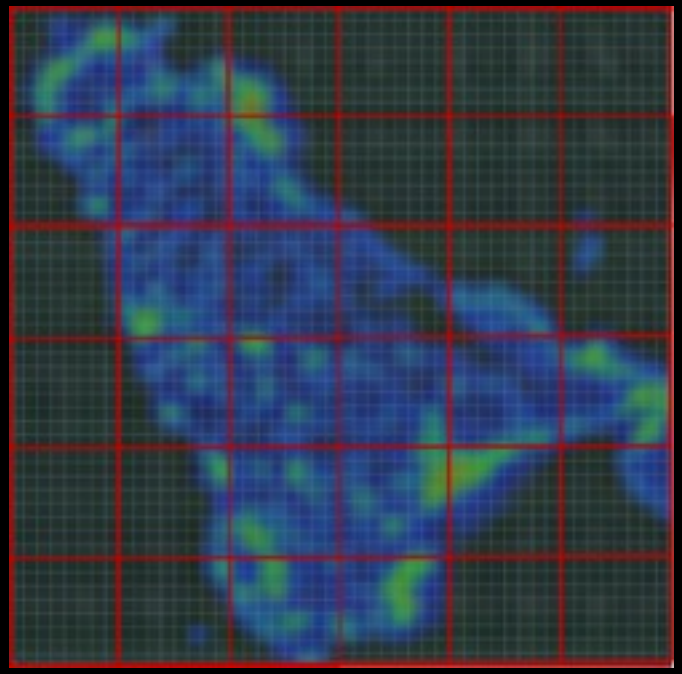
The experiment can be conducted during 2017:

53/54 expedition to the ISS by Italian astronaut P. Nespoli

54/55 expedition by Sergey Ryazansky

MINI-EUSO *Scientific objectives*

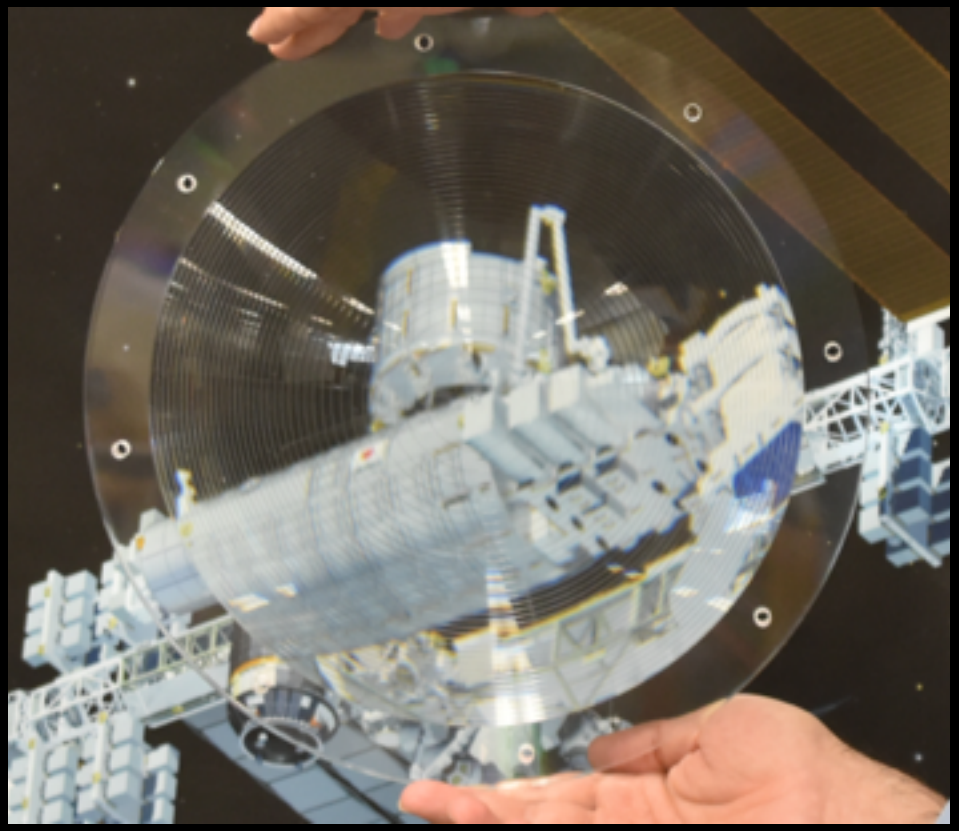
- UV emissions (300-400 nm) from night-Earth
- *Map of the Earth in UV*
- *Study of atmospheric phenomena*
  - *TLE in the ms range*
  - *lightning*
- Bioluminescence of Animal and vegetal organisms, white sea, plankton
- **Meteors**
- Strange quark matter
- **Debris detection and tracking**
- Trigger on laser events (E~10^{21} eV)
- Tsunami & wave watcher



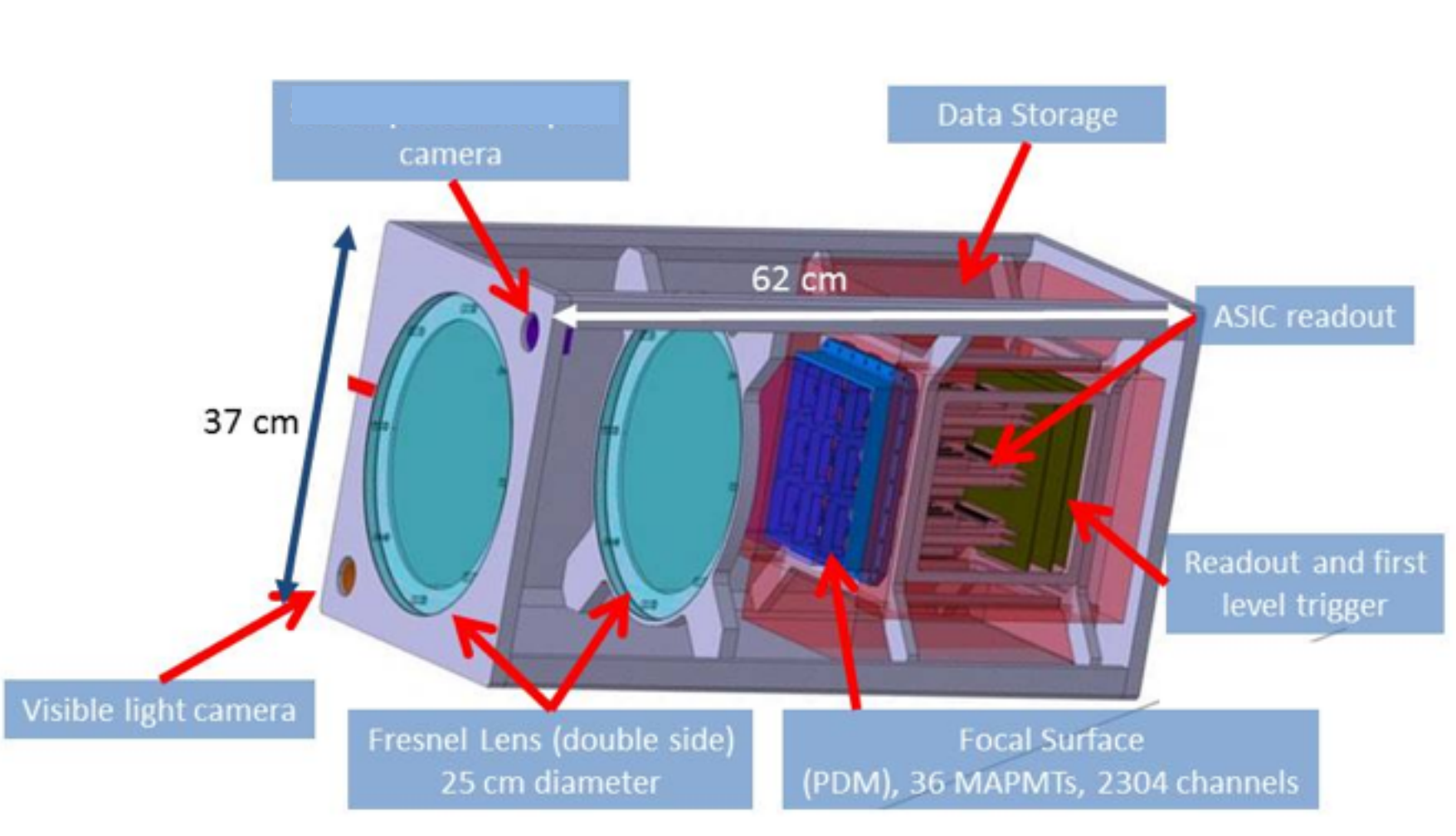
Full FoV = ± 20 deg
2304 pixels:
space resolution: 0.8 deg (5 km)
time resolution: 2.5 μs

MINI-EUSO
Technologial objectives

- *First use of Fresnel lenses in space*
- *Optimization of characteristics and performances of EUSO*
- *Raise the technological readiness level of the Hardware*
- *Ttest new HW in space*



MINI-EUSO


camera
Data Storage
62 cm
ASIC readout
37 cm
Readout and first level trigger
Visible light camera
Fresnel Lens (double side) 25 cm diameter
Focal Surface (PDM), 36 MAPMTs, 2304 channels


MINI-EUSO
Multiwavelength Imaging New Instrument
Extreme Universe Space Observatory
MINI-EUSO
Multiwavelength Imaging New Instrument
Extreme Universe Space Observatory
MINI-EUSO
Multiwavelength Imaging New Instrument
Extreme Universe Space Observatory

MINI-EUSO
Data Acquisition (DAQ) Chain

Sensor (photodetector)

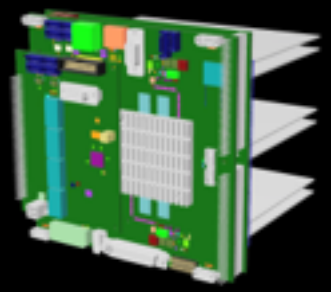
PMT
- Hamamatsu 64-ch MAPMT
- BG3 filter

EC-Unit
- 4 PMTs (256-ch) readout cables
- HV board
- potting

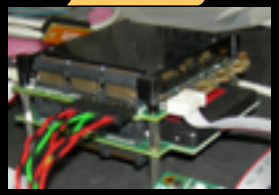
Front-end (FE) electronics

EC-ASIC
- 6 x ASICs
- readout
- counter

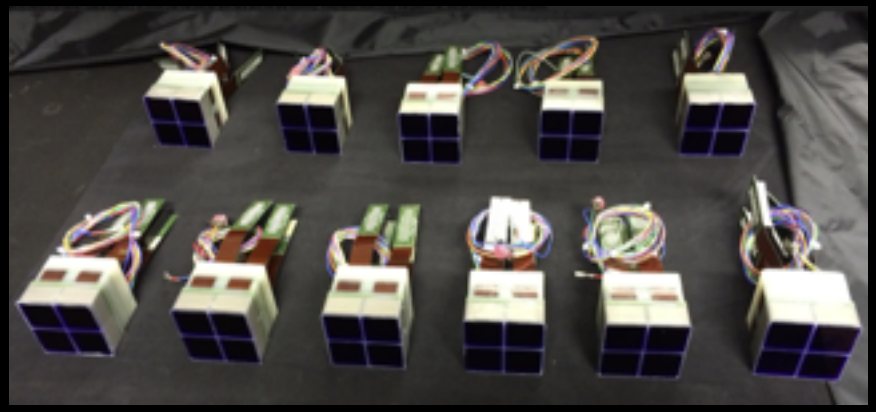
PDM-DP (MSU)
- Slow control
- Level 1 (L1, track) trigger

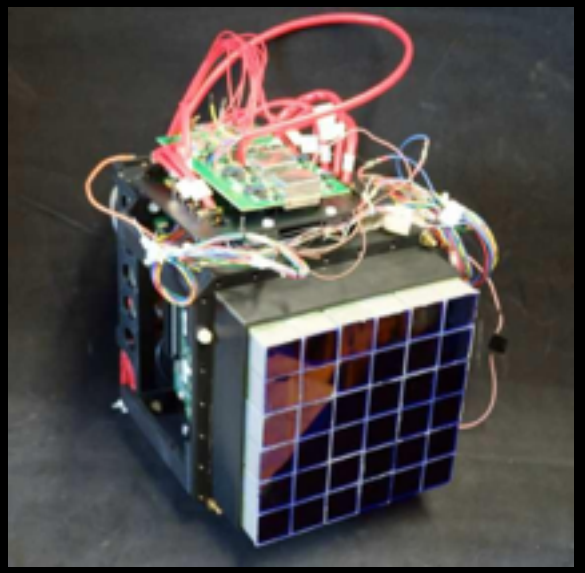


Data Processing (DP)
- Run control, config. FE electronics
- Console & GUI, remote access, etc.
- Data processing
- managing Mass Memory for data storage

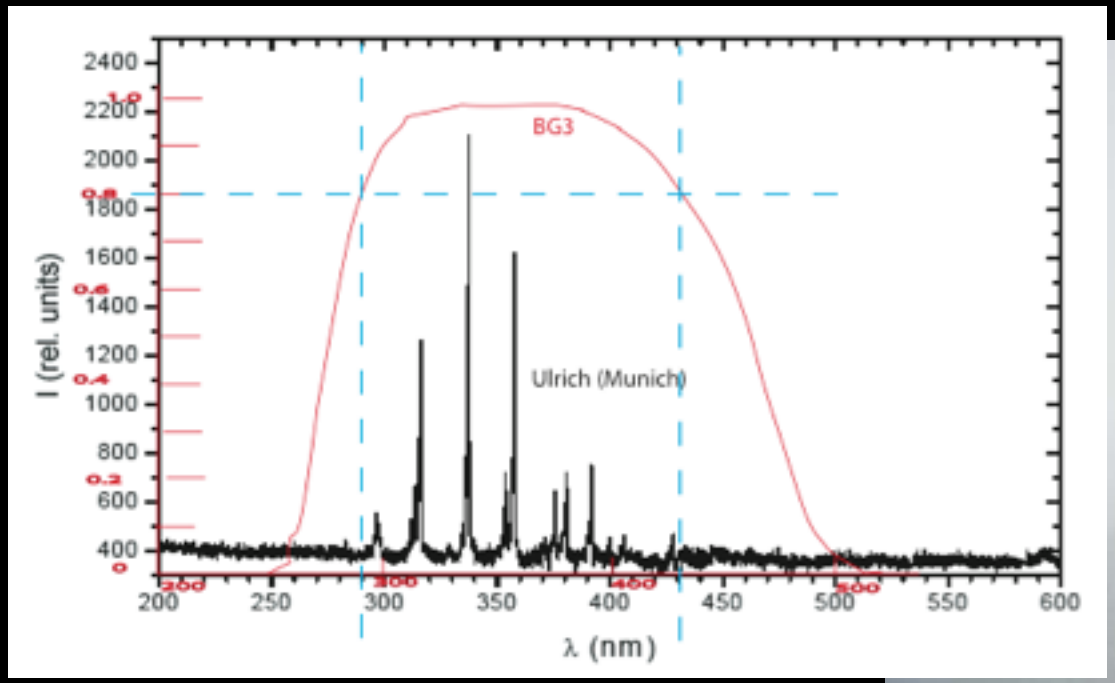


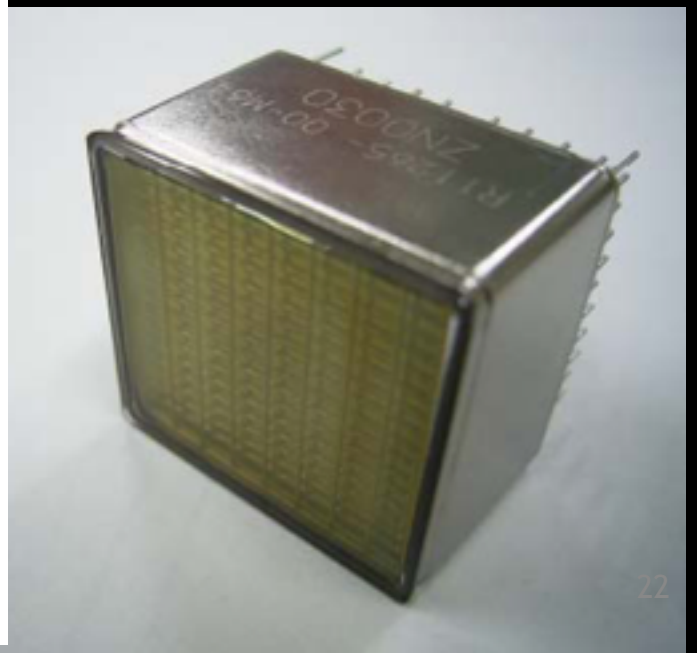
FM focal surface and electronics



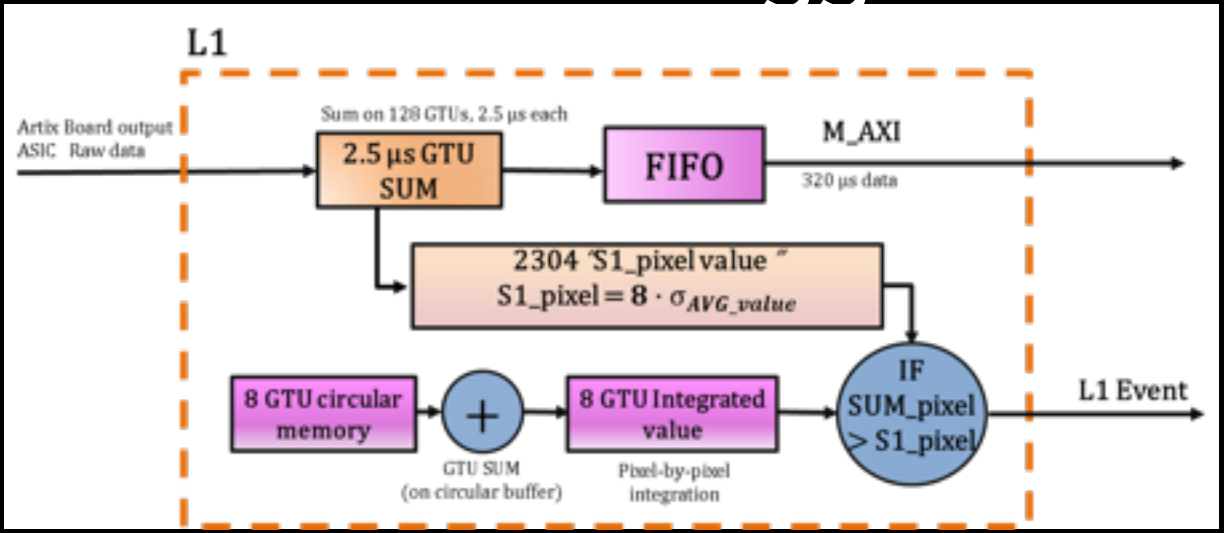


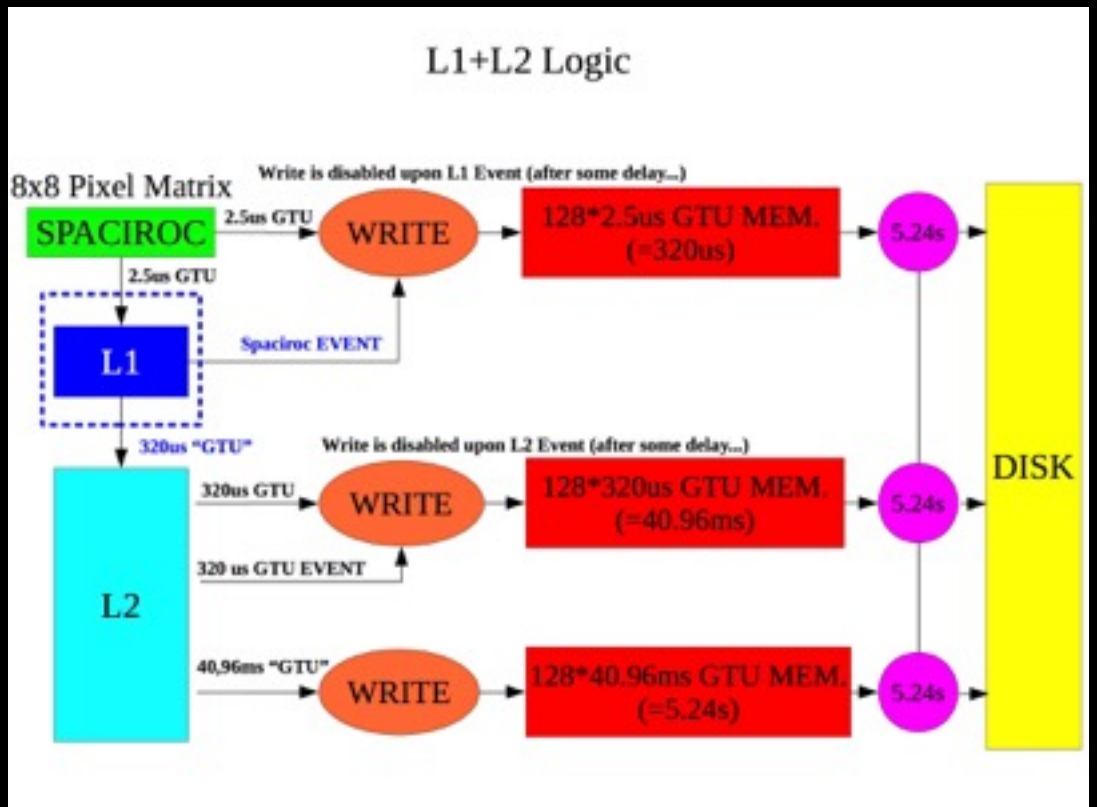
Hamamatsu
Ultra Bialkali high efficiency
MAPMT M64
64 channels in 8*8 grid
Arranged in 6*6 in PDM structure





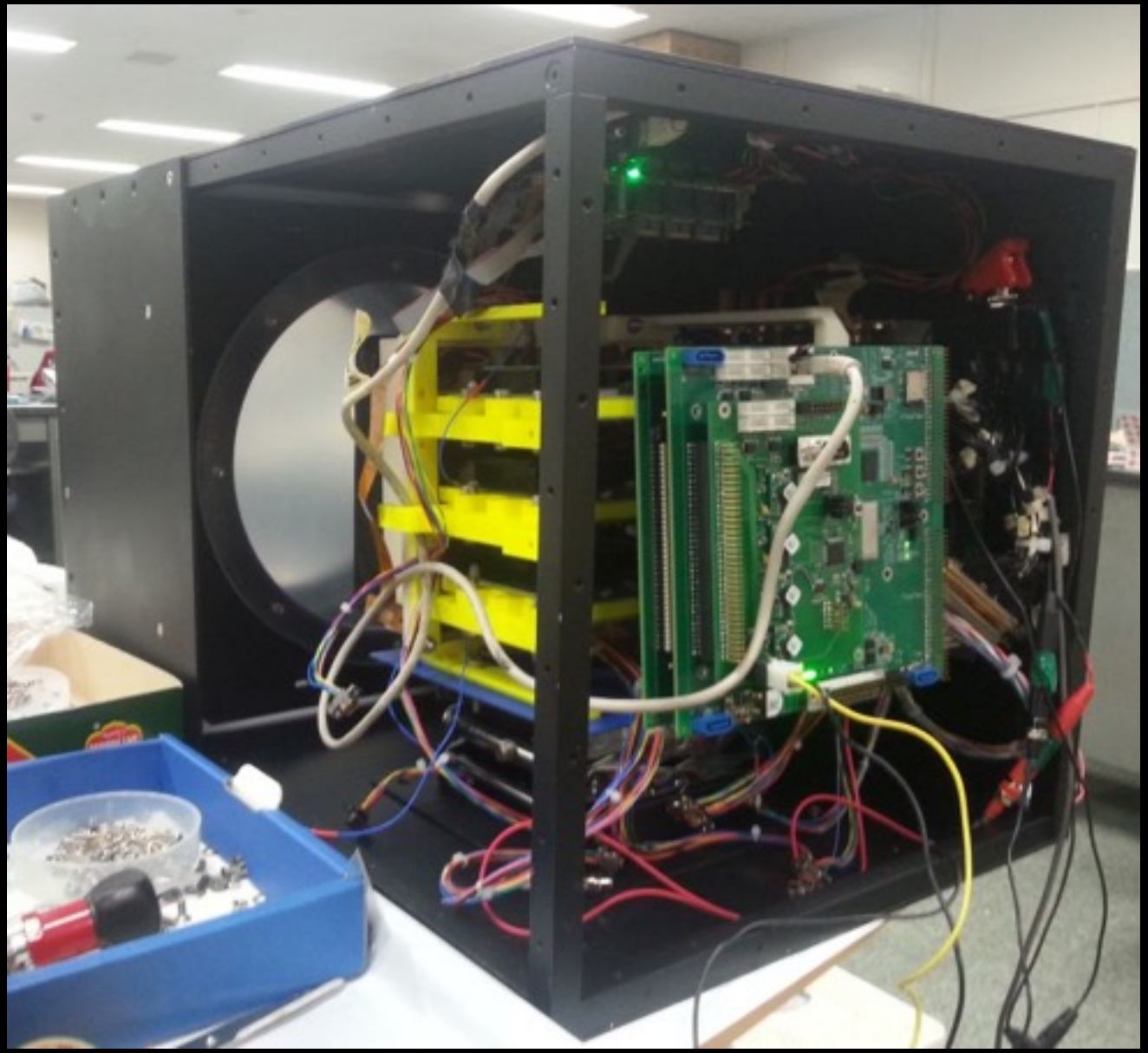
WP5 Trigger





- Triggered data @ 2.5 µs scale for CR-like events
- Triggered data @ 320 µs scale for TLEs-like events
- Full movie with ~40 ms time resolution for meteor, space-debris and strange quark matter research.

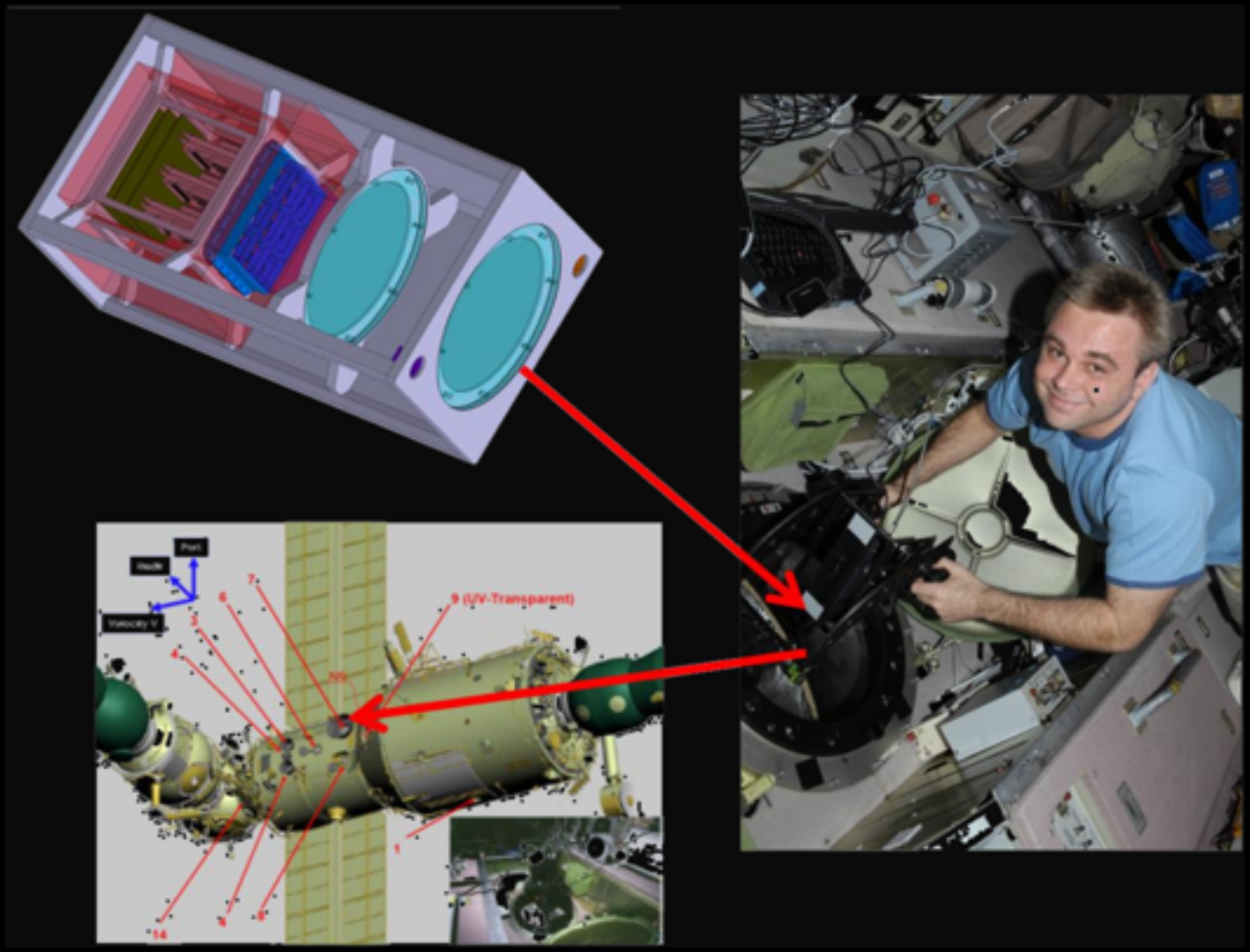
Engineering model of Mini-EUSO @ RIKEN (Jan. 2017)
(lens not included - just PMMA)



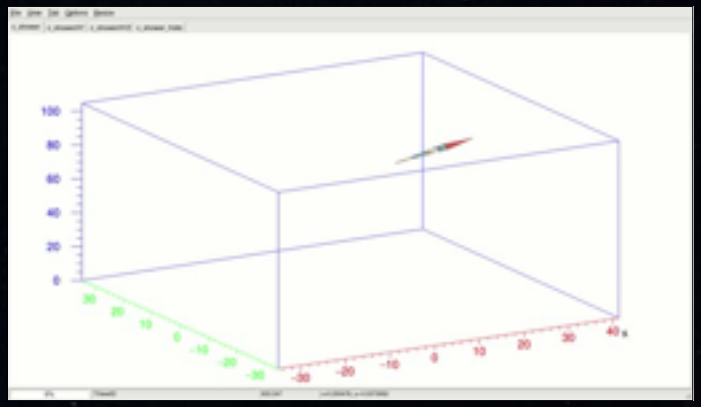
Detector Operations

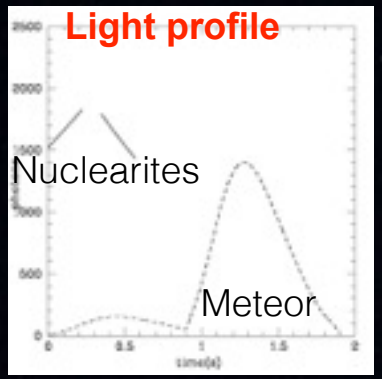
- Night observations
- About 40% orbit
- Nadir observations
- Off if ISS changes attitude
- Exchange of data disk

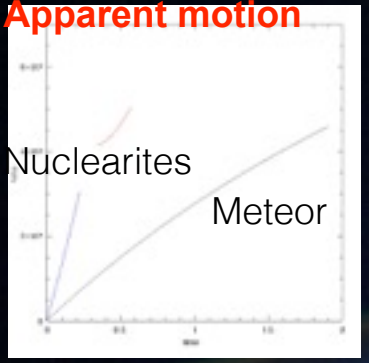
Uv Transparent window



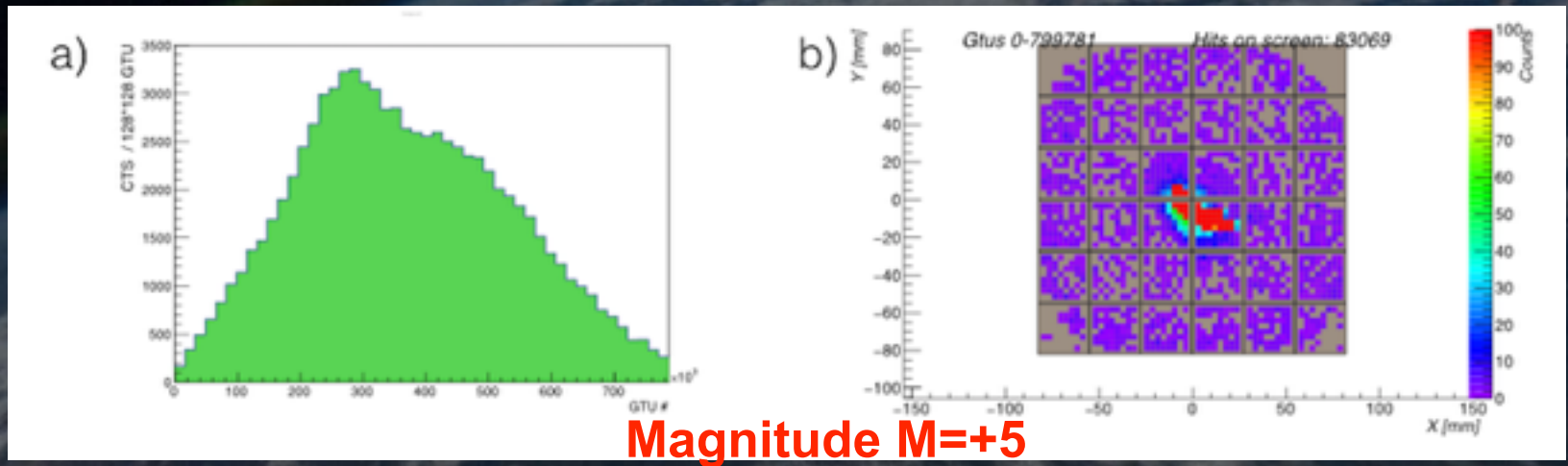
Mini-EUSO sensitivity to meteors (till M=+5)







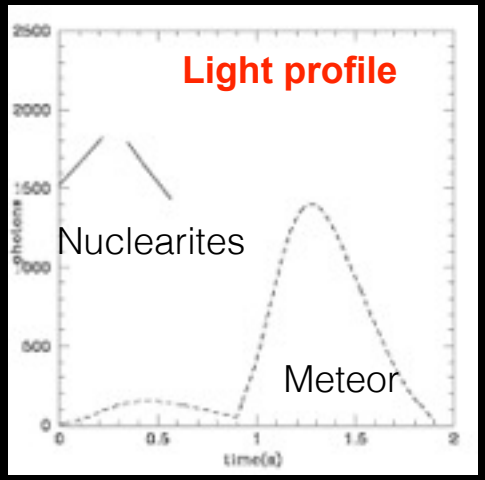
Expected rate: ~2/minute with M<+5

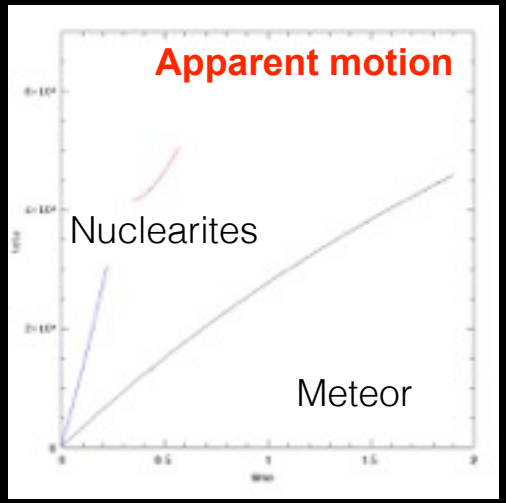


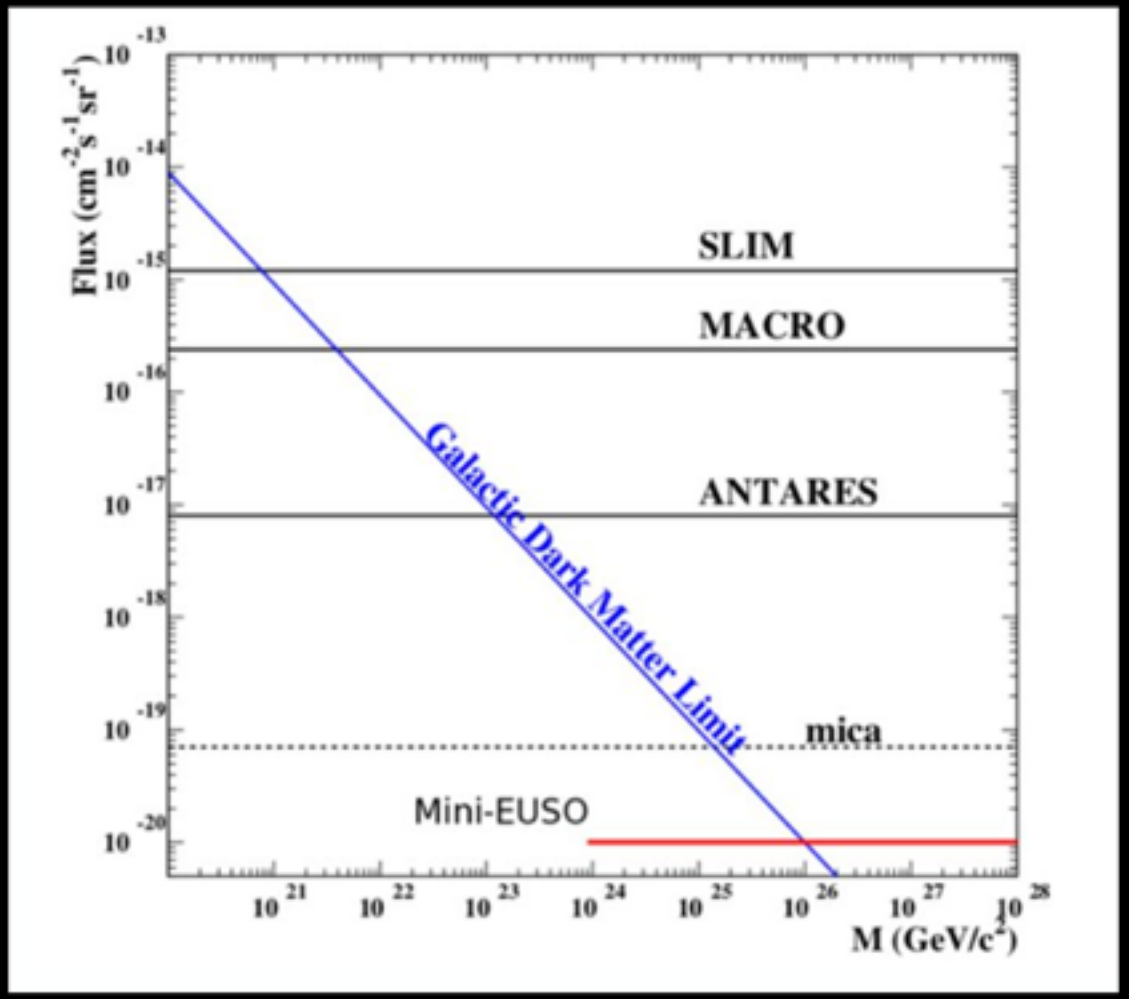
Magnitude M=+5

Meteor of the Perseids observed from ISS (Aug. 2011)

Search for Strange Quark matter

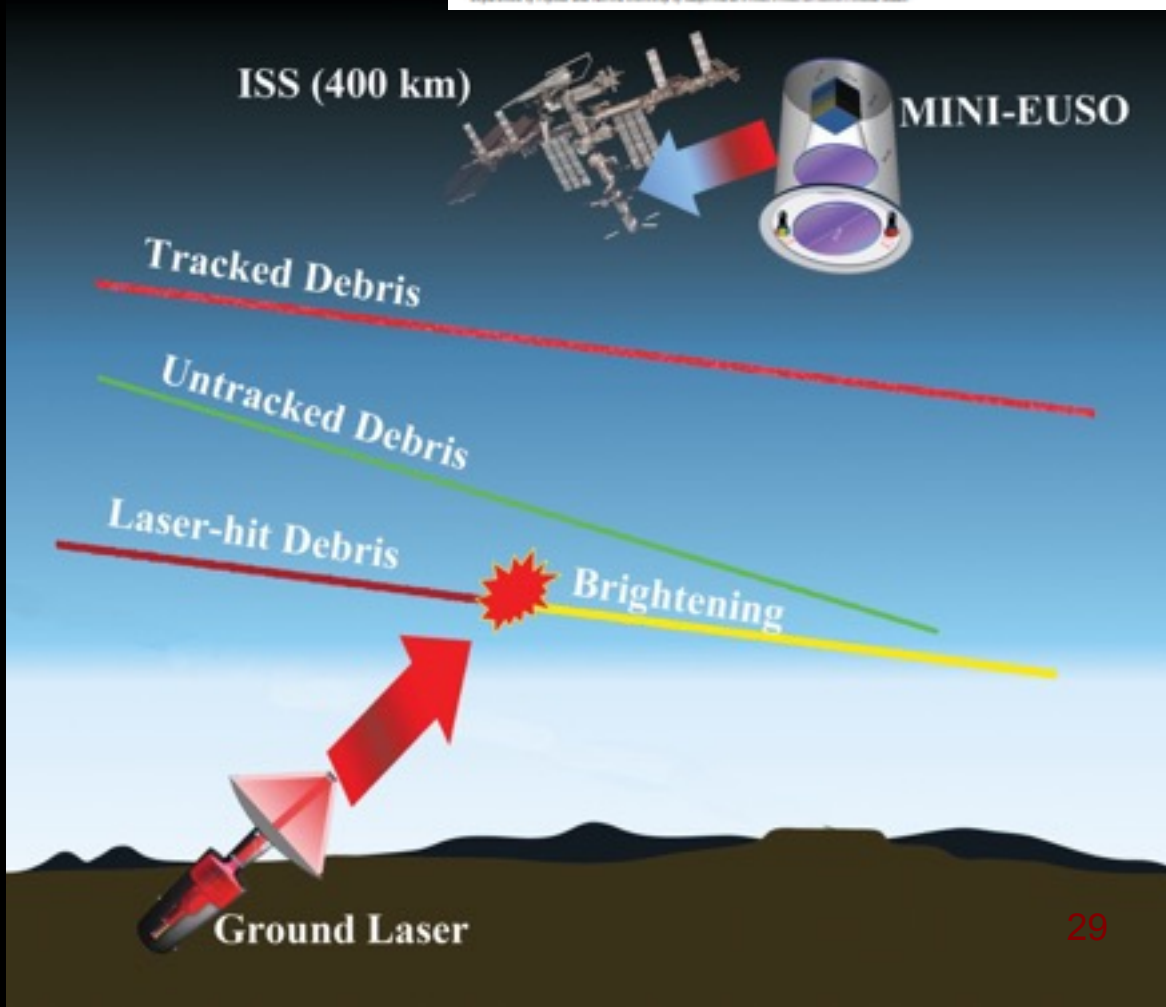




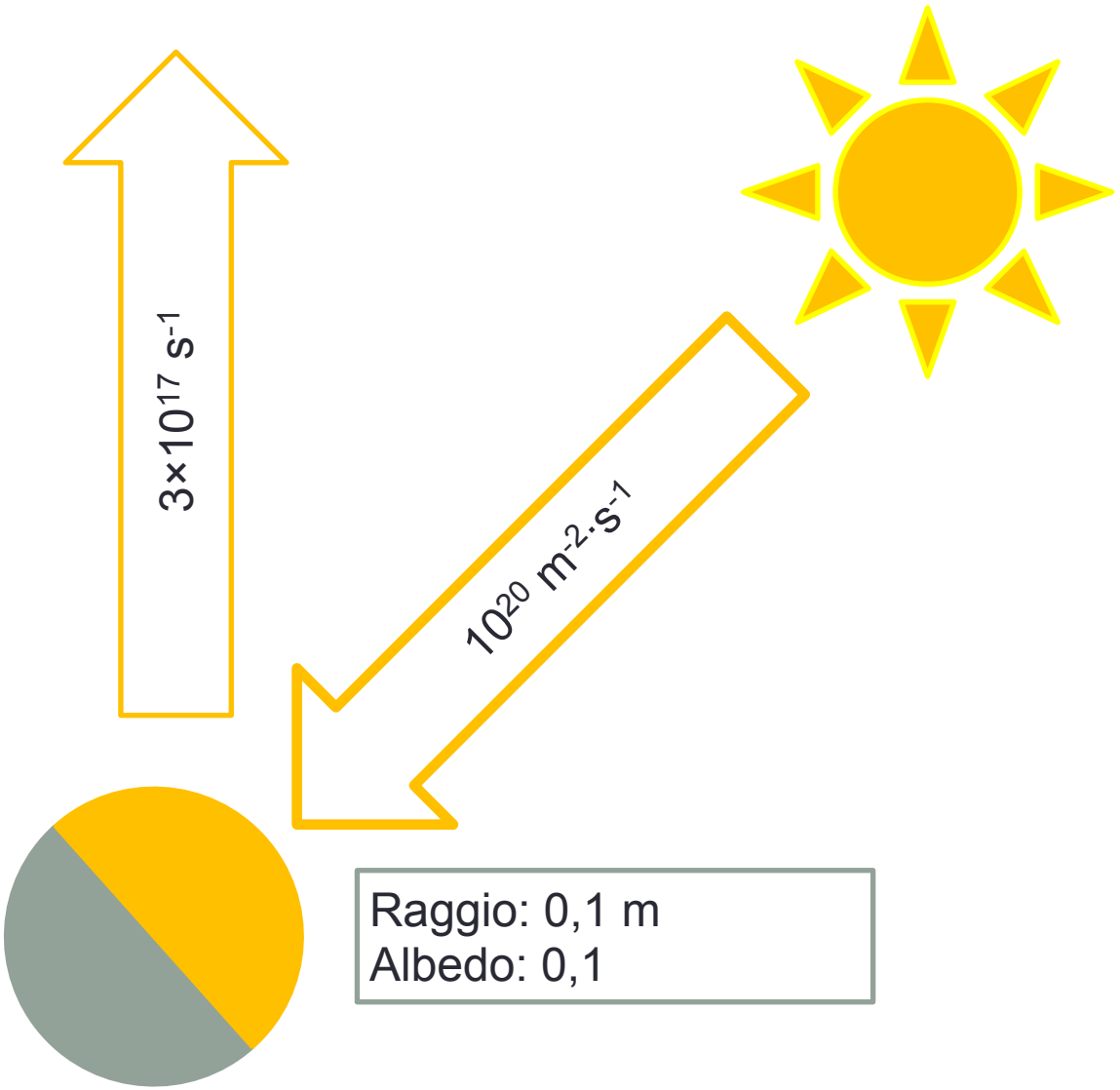


Mini-EUSO & Debris

- Norad data of known debris in f.o.v of minieuso (a few – termination line between dark and light)
- Look for unknown debris (includes meteors for this purpose)

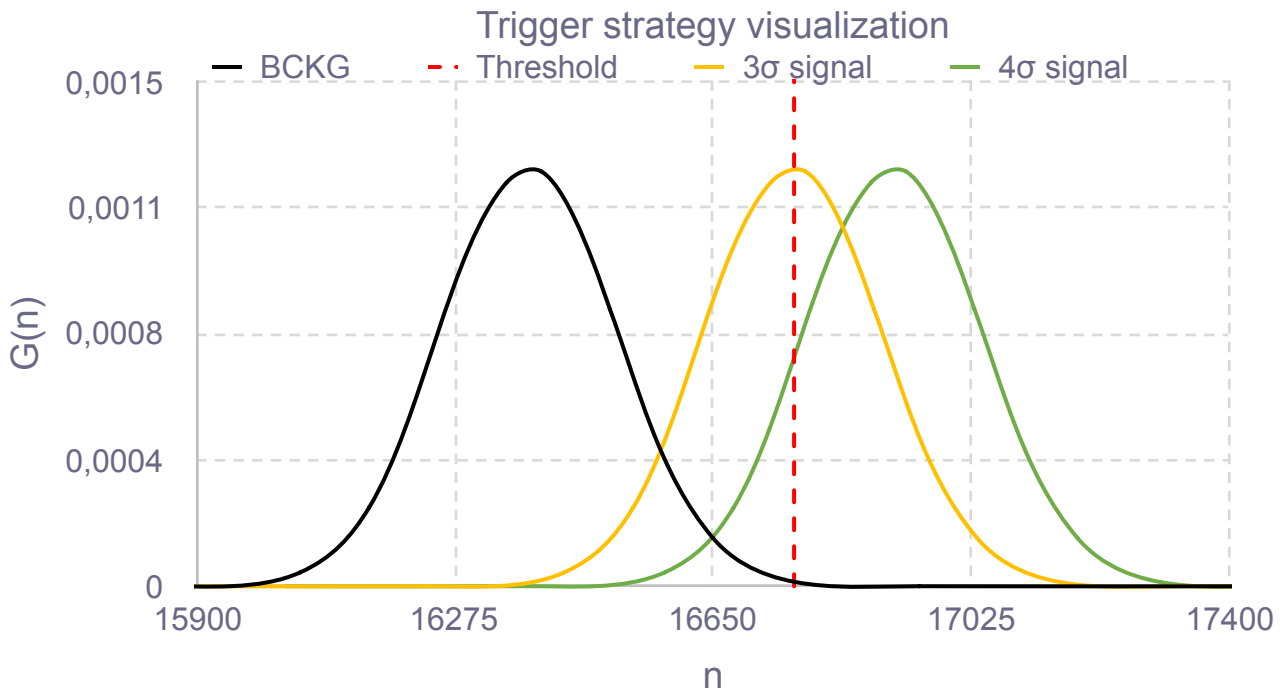


300 – 400 nm photon flux



Detection Strategy

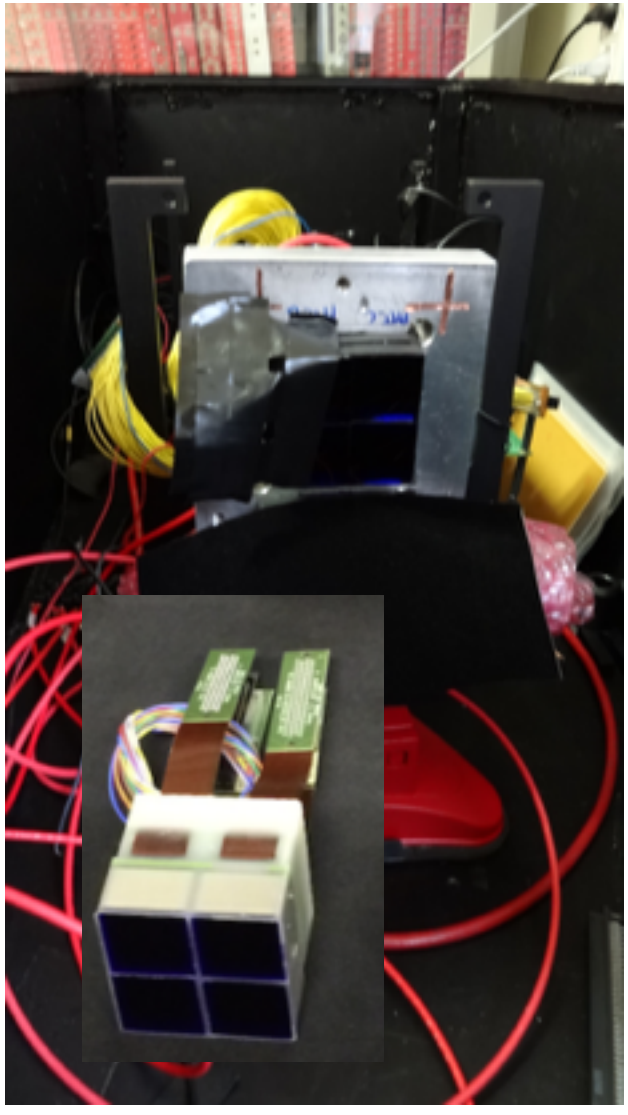
- Expected background level on oceans: 16768 counts/pix/41ms
- Threshold on offline analysis set at 4σ above background
- By requiring 2 blocks of 5 frames with signal above 4σ allows:
- - detect >90% of real events
- - rate of fake events < 1 fake/year.

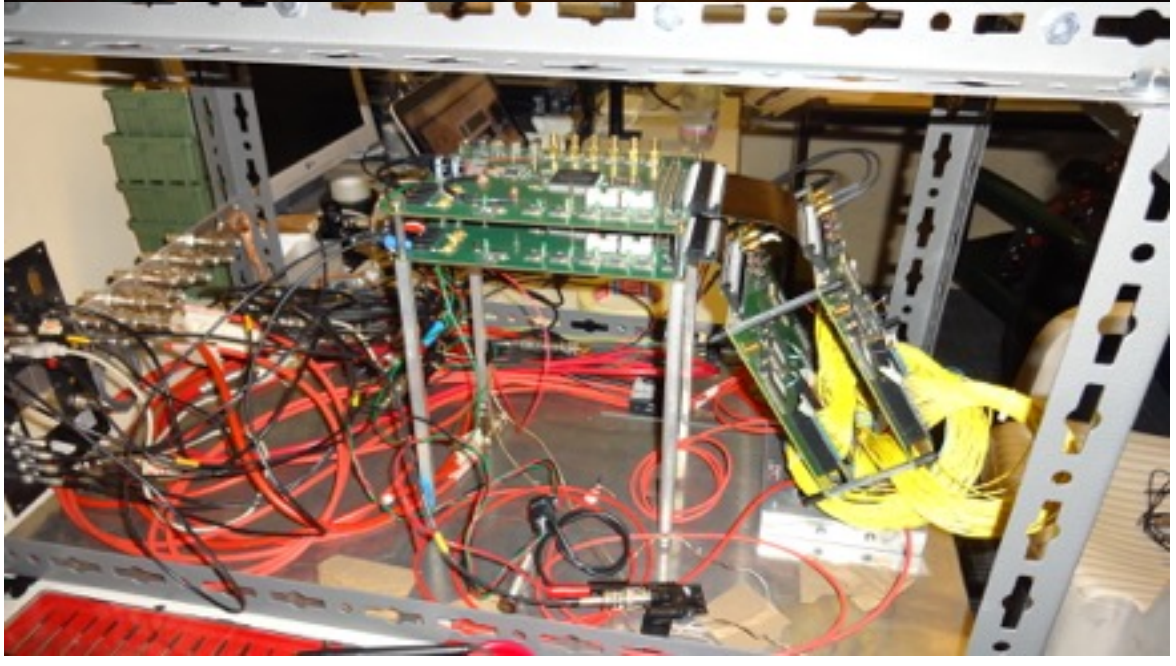


Plan for the future in collaboration with PRISMA network:

- Bring a prototype to INAF-OATo and OAdVA to test our technology with PRISMA camera to understand the performance of our UV detector. Very useful in view of Mini-EUSO imaging from space. It would be great to have a mode in PRISMA cameras sensitive to space debris…
- Simulate response of our prototype detector using the same ESAF software currently employed to study the performance of Mini-EUSO in order to understand the real performance for debris detection (meteor can look like debris at a first approximation).
- We plan to buy soon 1 PRISMA camera to add to the network as contribution of Univ. Torino to the PRISMA network.

EC configuration





Setup

!!!Photo(s) of inside the frame with the latest configuration needed!!!

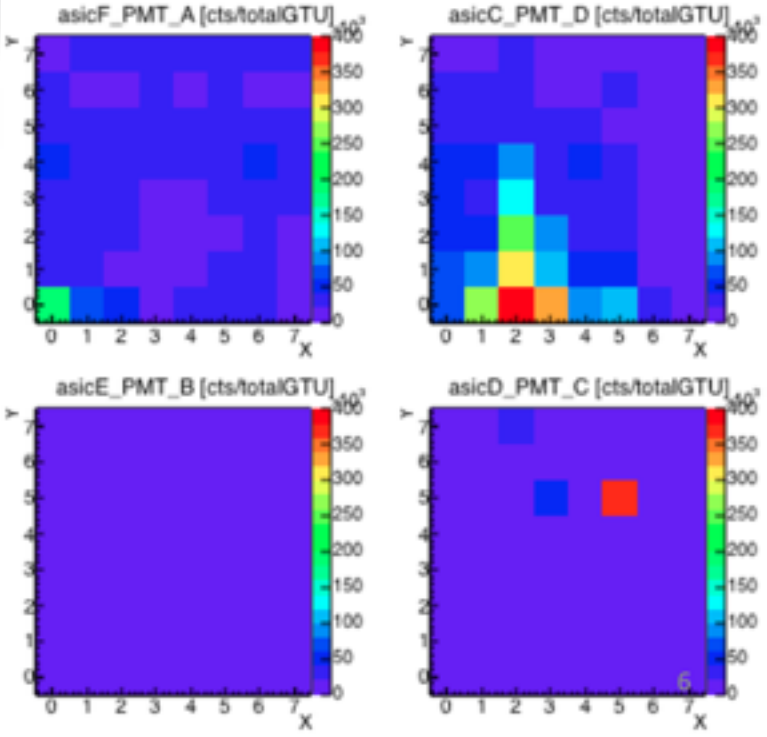
Lens: KPX118, 1 inch Plano-Convex Lens, 500mm EFL, FoV 0.33 deg/pix

Imaging Mole Antonelliana

(Cinema Tower, landmark of Turin)

- Distance: ~2km
- Pixel FoV: ~0.33deg = ~11.5m?
- total FoV: (11.5x16)^2 = 184^2 m²

Initialized by relative efficiencies (at DAC200)
Max 400k (full range)



Univ. of Torino at the core of the first attempt to have a FRIPON-like network in Italy in 2015…

Ministero dell'Istruzione dell'Università e della Ricerca

Dipartimento per la formazione superiore e per la Ricerca

Direzione Generale per il Coordinamento, la promozione e la valorizzazione della Ricerca

PRIN: PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE – Bando 2015

Prot. 2015WEBPXC

PART A

1 - Research Project Title

Italian Network for Meteors and Atmospheric Studies (INMAS)

Total cost of the project: ~700 kEuro.
Not funded, despite quite good score: 13/15

8 - List of the Research Units

nº	Associated Investigator	Category	University/Research Institution	E-mail address
1.	BERTAINA Mario Edoardo	Professore Associato (L. 240/10)	Università degli Studi di TORINO	bertaina@to.infn.it (adesione completata il 13/01/2016)
2.	LAZZARIN Monica	Ricercatore confermato	Università degli Studi di PADOVA	monica.lazzarin@unipd.it (adesione completata il 05/01/2016)
3.	FIORETTI Annamaria	Primo ricercatore	Consiglio Nazionale delle Ricerche	anna.fioretti@igg.cnr.it (adesione completata il 04/01/2016)
4.	CONTI Livio	Ricercatore confermato	Università Telematica Internazionale UNINETTUNO	livio.conti@uninettunouniversity.net (adesione completata il 14/01/2016)
5.	BARDI Ugo	Professore Associato confermato	Università degli Studi di FIRENZE	ugo.bardi@unifi.it (adesione completata il 08/01/2016)
6.	CELLINO Alberto	Primo ricercatore	Istituto Nazionale di Astrofisica	cellino@oato.inaf.it (adesione completata il 15/01/2016)

9 - Research project abstract

The aim of the INMAS project is to develop the Italian participation in a network of European observing facilities whose primary targets are bright meteors (the so-called bolides and fireballs) and the recovery of meteorites. A new network has been very recently established in France (FRIPON project), to fill the gap in the ground-based coverage of European sky, which affects primarily the western and southern regions of the continent. We propose to do the same in Italy to work in strict collaboration with France, the goal being to develop the most important international network for fireball detection and meteorite recovery. The big advantage with respect to similar projects started in the past in middle Europe is that of using a new generation of detectors that are ideal for the purposes of the project. The optical and the electronic design of the detectors, as well as the hardware and software needs for data treatment and the network connection have been specifically developed and made uniform for all the participating nodes of the FRIPON network. We want to follow the same approach in the organization of INMAS. The proposed grid and the adopted hardware are of great interest for the studies of interplanetary bodies and the dynamical and physical evolution of the population of small bodies of our Solar System and for the studies of collected meteorites. Those eventually recovered will be classified and investigated from the petrologic, genetic and evolutionary points of view, analyzed for their spectral characteristics and compared with known asteroids. The possibility to measure the radioactivity of samples shortly after the fall using gamma-ray spectrometers will allow us to reveal the presence of short-lived cosmogenic radioisotopes. The imprint of solar activity in meteorites will be also revealed by the measurement of radioisotopes of suitable half-life. Moreover, a network of ground-based detectors of bright meteors is an ideal complement of the planned MINI-EUSO project of meteor monitoring from the International Space Station. We will develop a strategy for a common data treatment between MINI-EUSO and INMAS. The project will also benefit from the existence in Italy of a Network of infrasound arrays. While the infrasound array monitoring can contribute to INMAS by extending monitoring during cloudy conditions, INMAS will provide valuable information for validating infrasound array observations. INMAS is also very suitable for the purposes of atmospheric studies. This includes the statistics of cloud coverage and lightning frequencies as well as the comparison of the optical depth measured using satellites and INMAS cameras. In addition, the measured cloud cover allows validating the simulations of cloud cover retrieved by numerical meteorological models. The project merges complementary expertise from scientists belonging to several Universities in Firenze, Napoli, Padova, Roma, Torino and research Institutions (CNR, INAF, INFN, INGV).

Shall we try again next time?

THANK YOU