

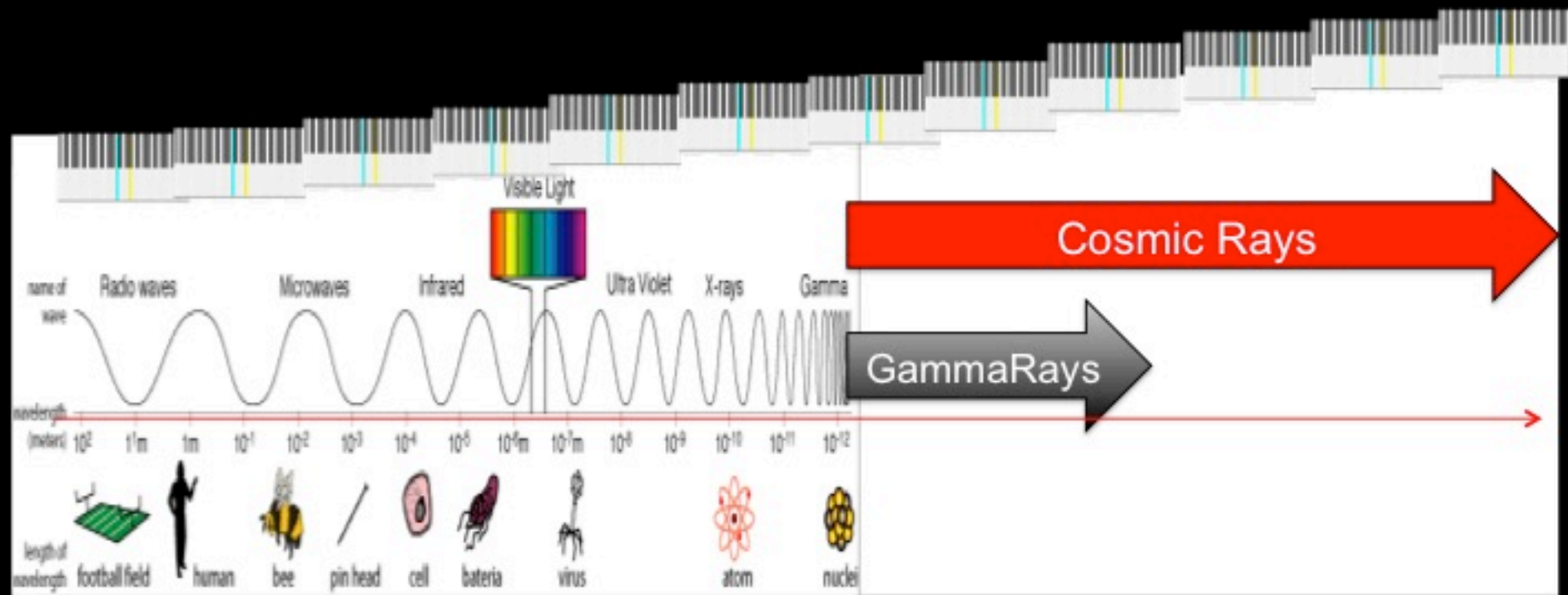
**EUSO**  
**Extreme Universe**  
**Space Observatory**  
**Update**

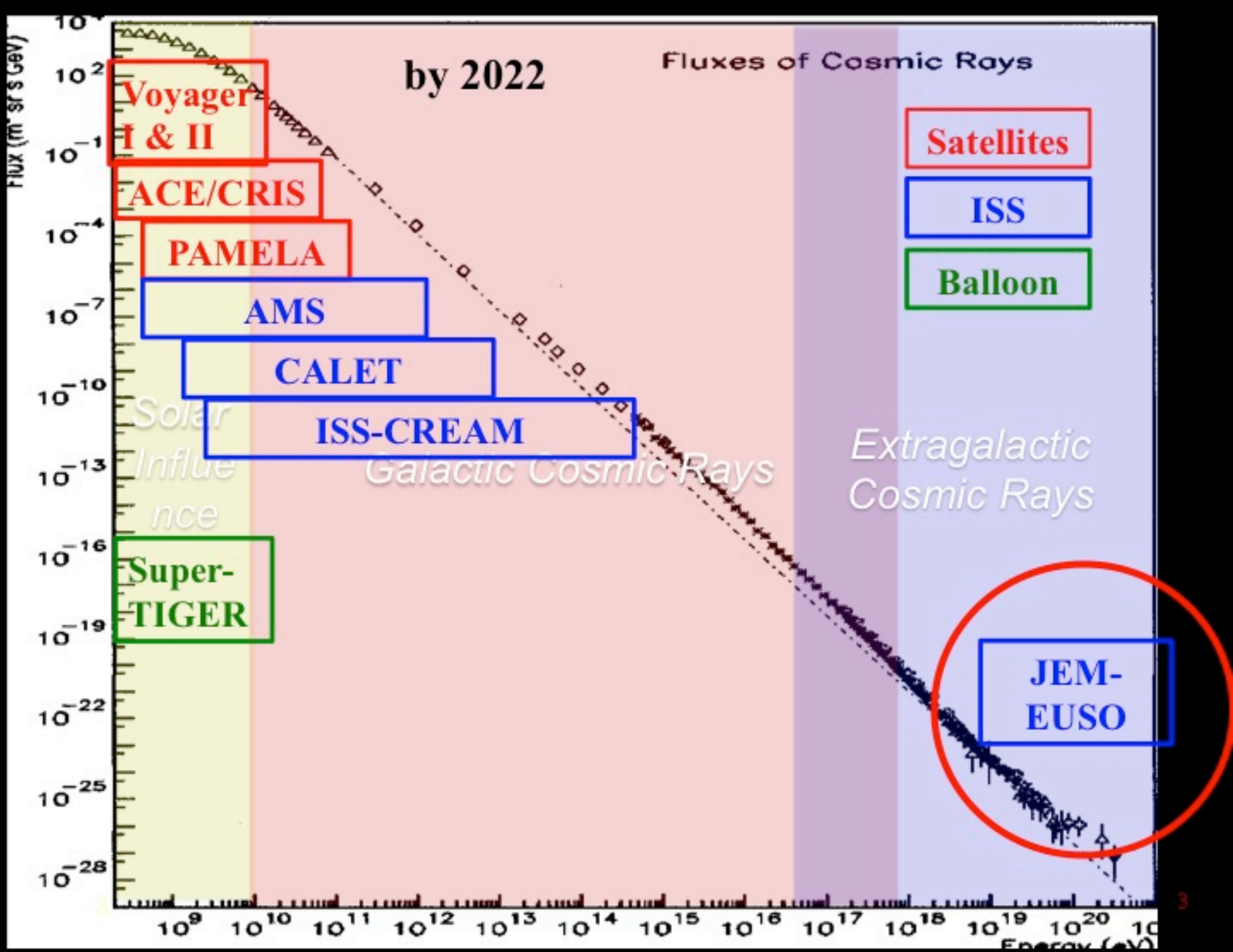
*Angela V. Olinto*

**The University of Chicago**

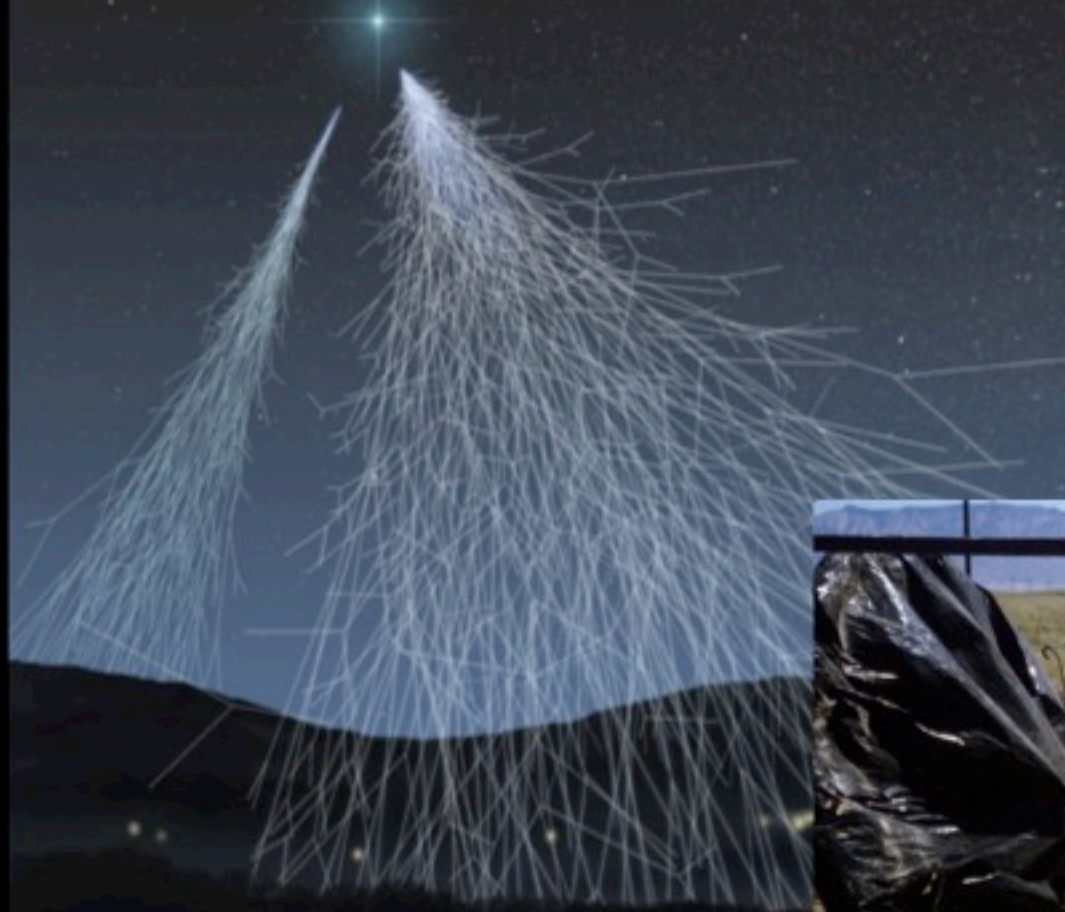
# Energy range of Radiation

**total 28+** orders of magnitude  
from  $10^{-8}$  eV to 0.3 ZeV (CR: from  $10^8$  to  $10^{20}$  eV)



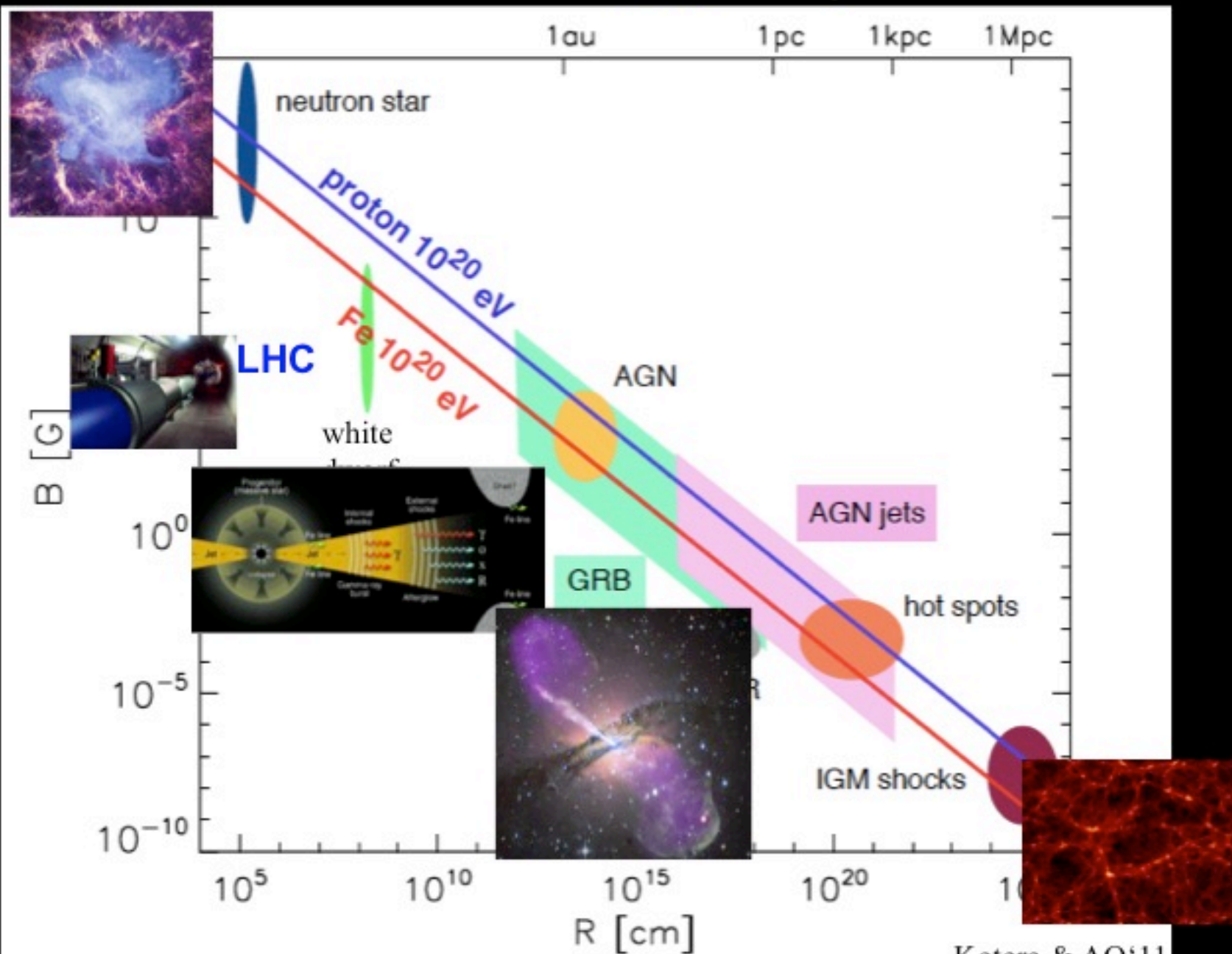


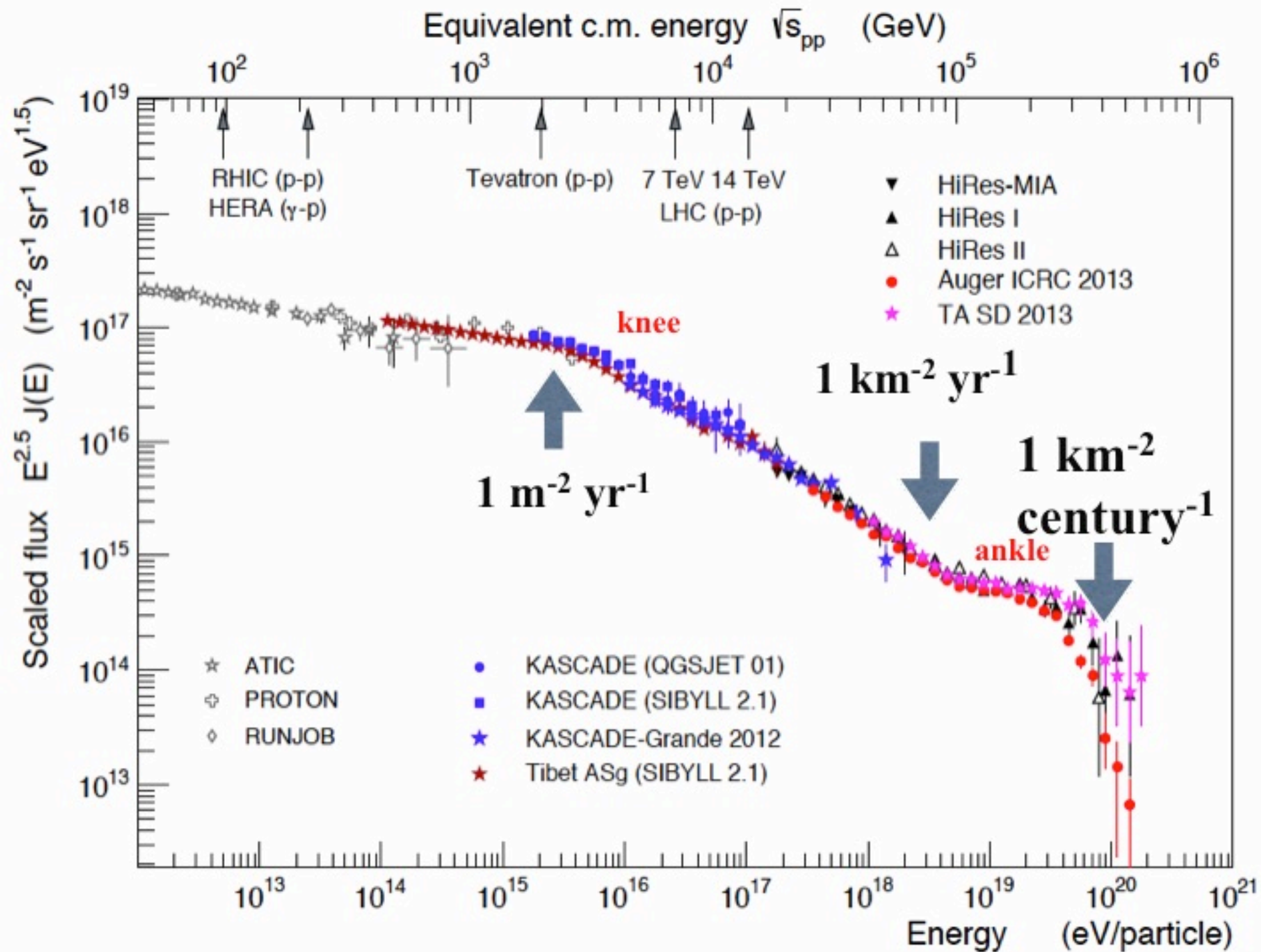
# Ultra High Energy Cosmic Rays



1962 John Linsley  
 $10^{20}$  eV event

# Hillas Plot: $E_{\max}$ required





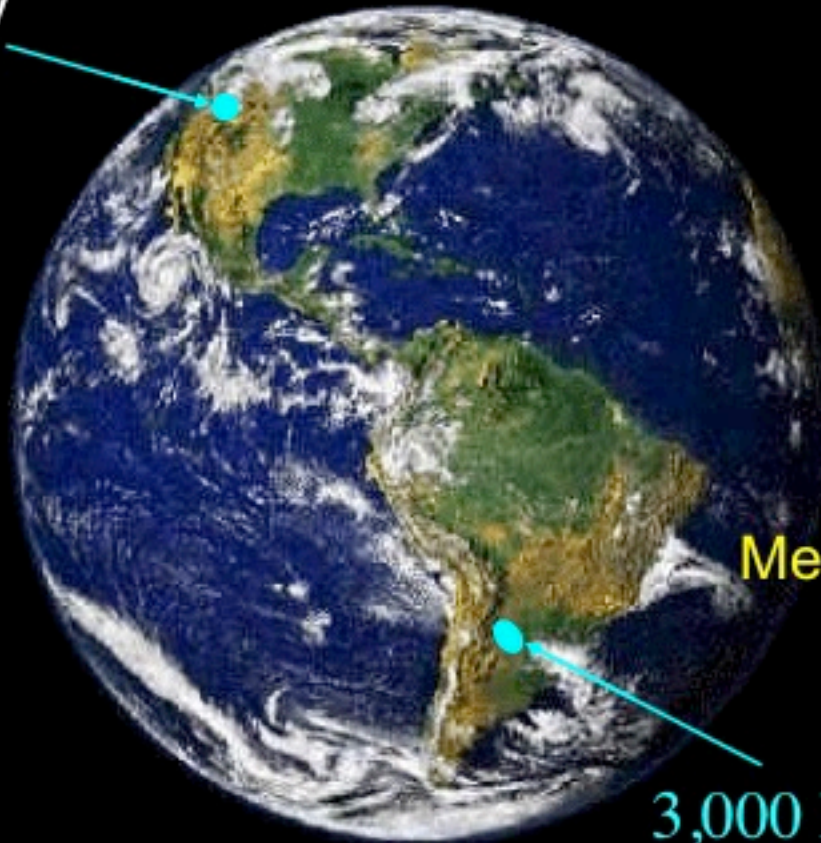
# Current Observatories of Ultrahigh Energy Cosmic Rays

Telescope Array

Utah, USA

(5 country  
collaboration)

700 km<sup>2</sup> array  
3 fluorescence  
telescopes



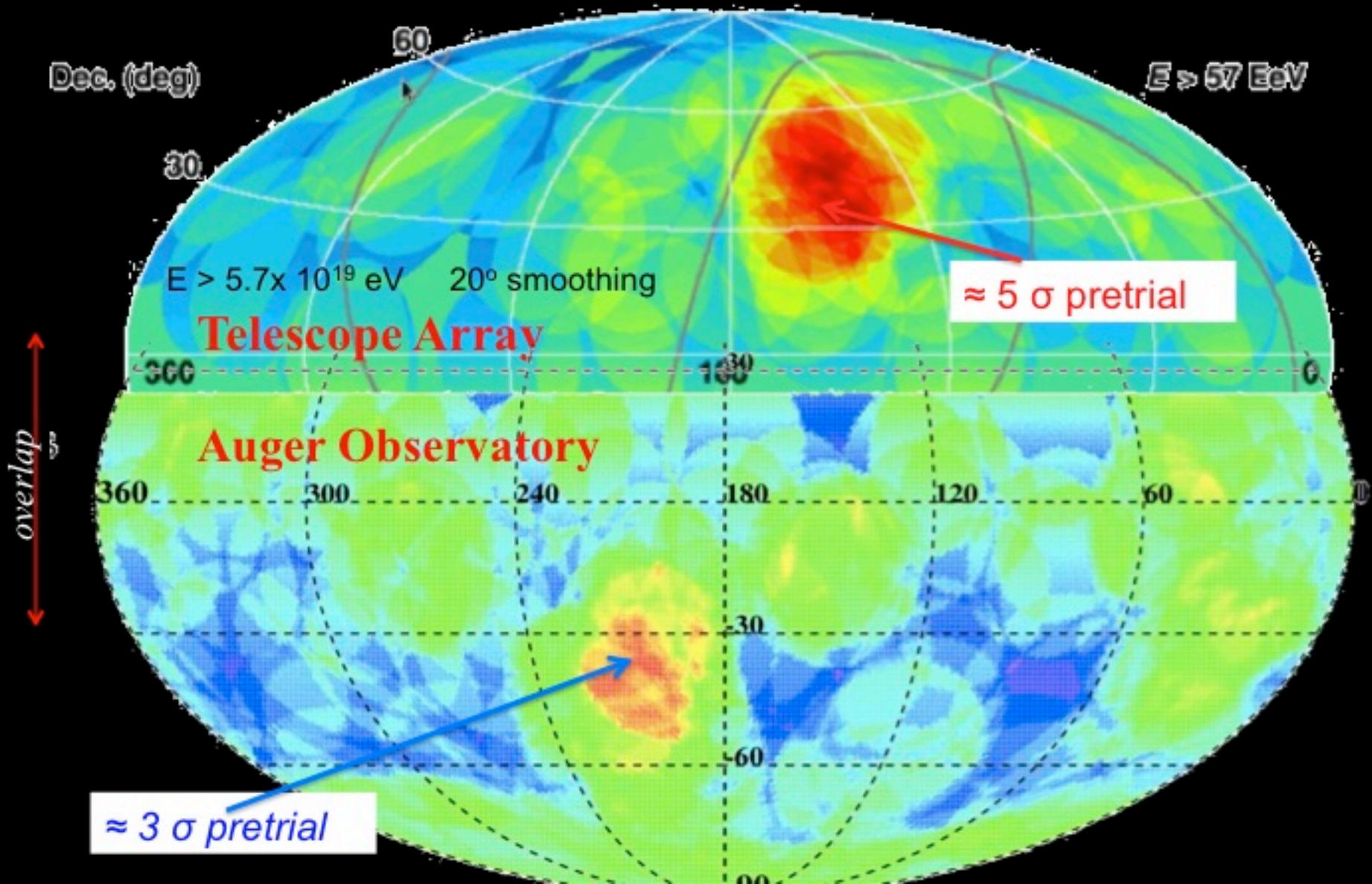
Pierre Auger  
Observatory

Mendoza, Argentina  
(19 country  
collaboration)

3,000 km<sup>2</sup> array  
4 fluorescence telescopes

# Anisotropy Hints > 60 EeV

## Statistically limited





# Fluorescence from SPACE



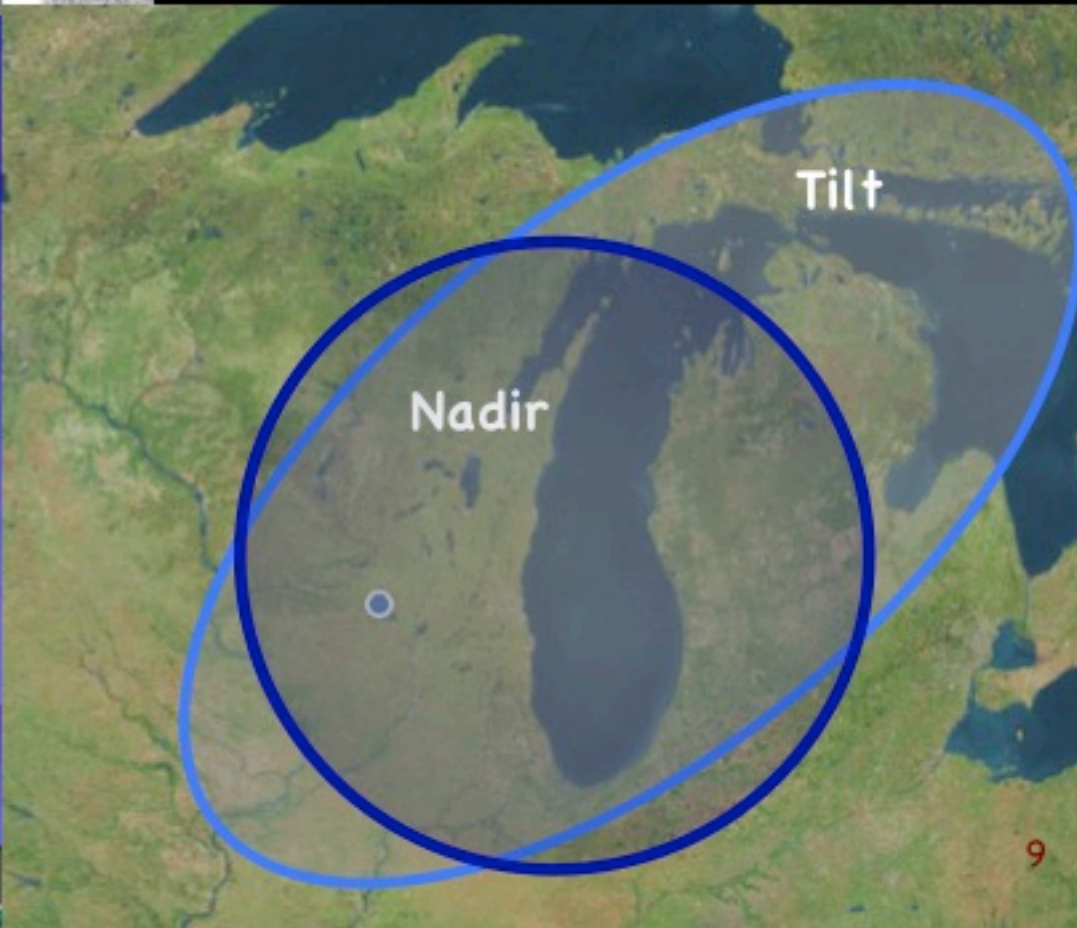
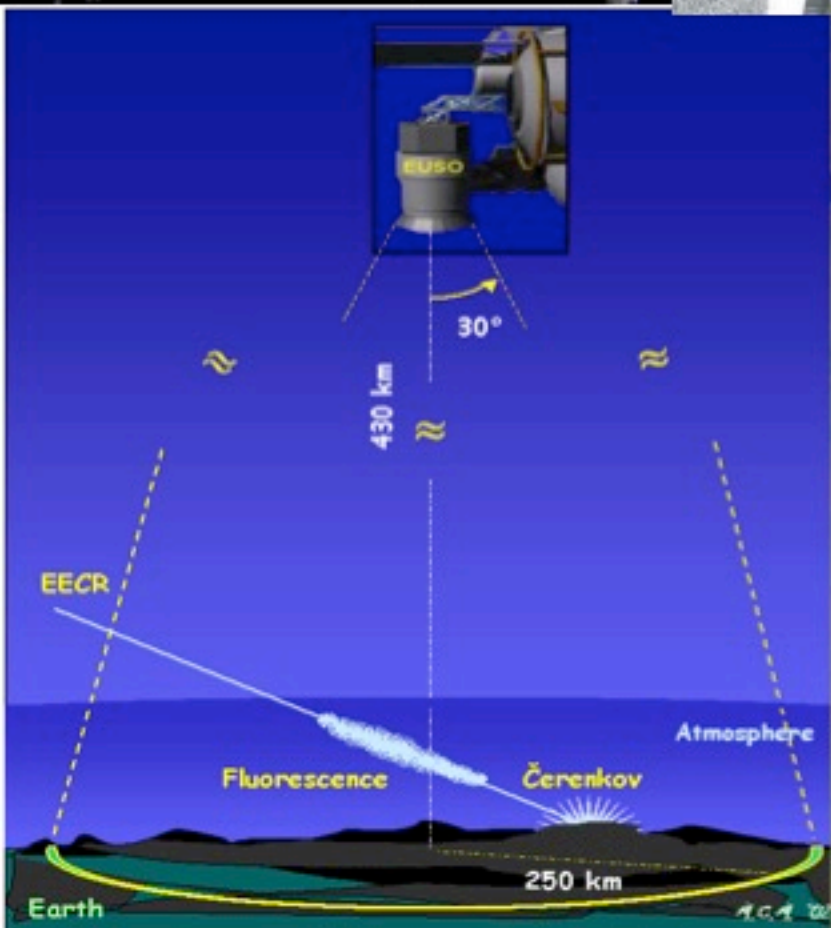
Nadir



John Linsley  
(1925-2002)



Tilt





# JEM-EUSO



Extreme Universe Space Observatory (EUSO)  
in the Japanese Experiment Module (JEM)  
of the International Space Station (ISS)

Japan, USA, Korea, Mexico, Russia, Algeria  
Europe: Bulgaria, France, Germany, Italy,  
Poland, Slovakia, Spain, Switzerland, Sweden

















16 Countries, 300 researchers

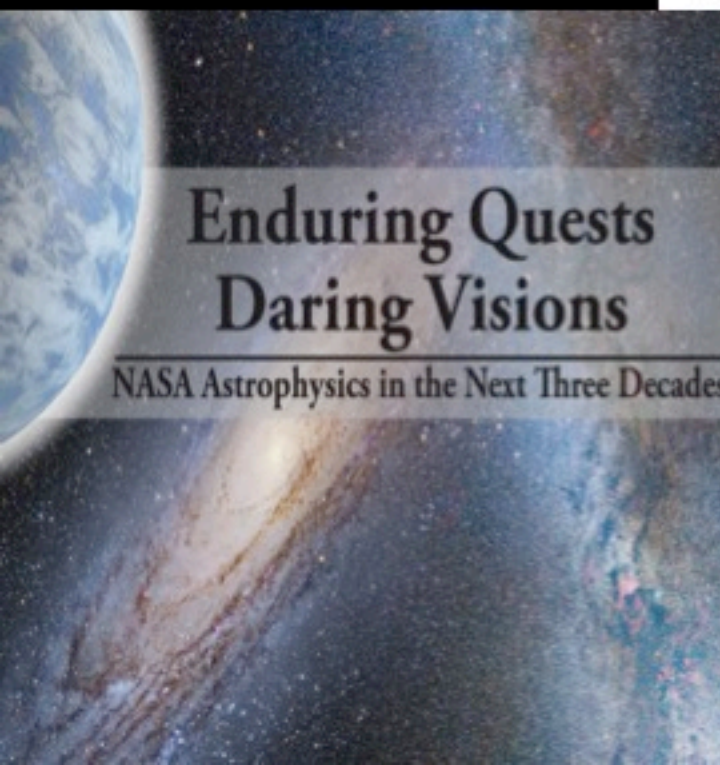
Leading institution: RIKEN



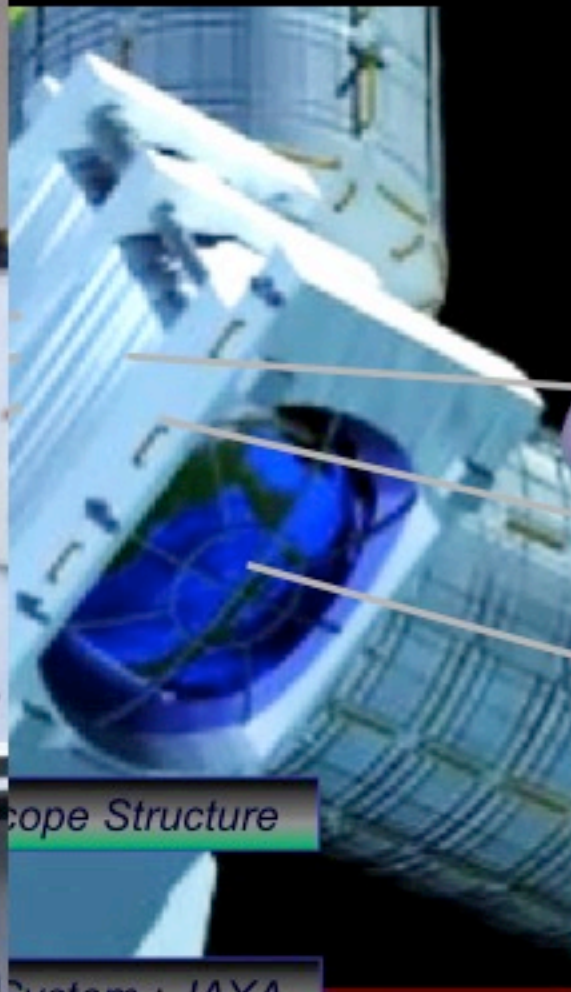
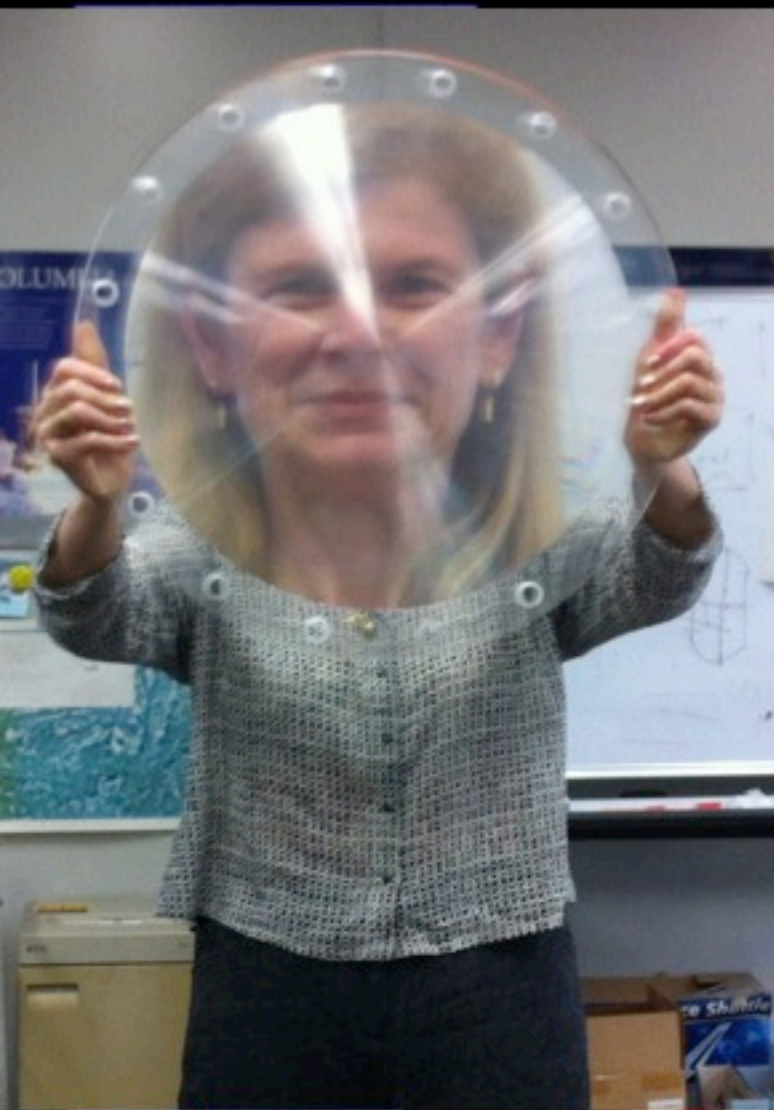
PI: Piergiorgio Picozza

# NASA Astrophysics Roadmap 2014

	Near-Term	Formative	Visionary
Gravitational Waves		 Gravitational Wave Surveyor	 Gravitational Wave Mapper
Cosmic rays	 JEM-EUSO		
Radio			 Cosmic Dawn Mapper
Microwaves		 CMB Polarization Surveyor	
Infrared	 JWST	 Far IR Surveyor	
Optical	 WFIRST-AFTA	 Euclid	 LUVOIR Surveyor
Ultraviolet	 TESS	 Gaia	 ExoEarth Mapper
X-rays	 NICER	 Astro-H	 Imaging X-ray Telescope



# Payload

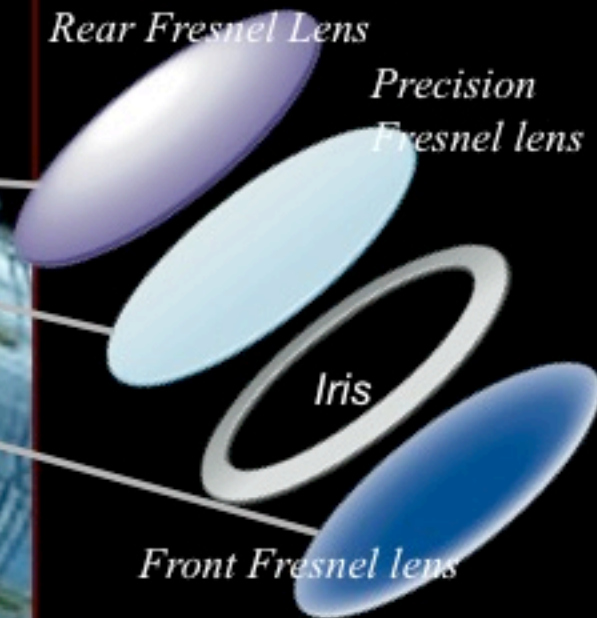


Optics



Rear Fresnel Lens

Precision  
Fresnel lens



Front Fresnel lens

On-board Calibration



Ground Based Calibration



Ground Support Equipment



Telescope Structure

System : JAXA

Atmospheric Monitoring



Simulation : Worldwide



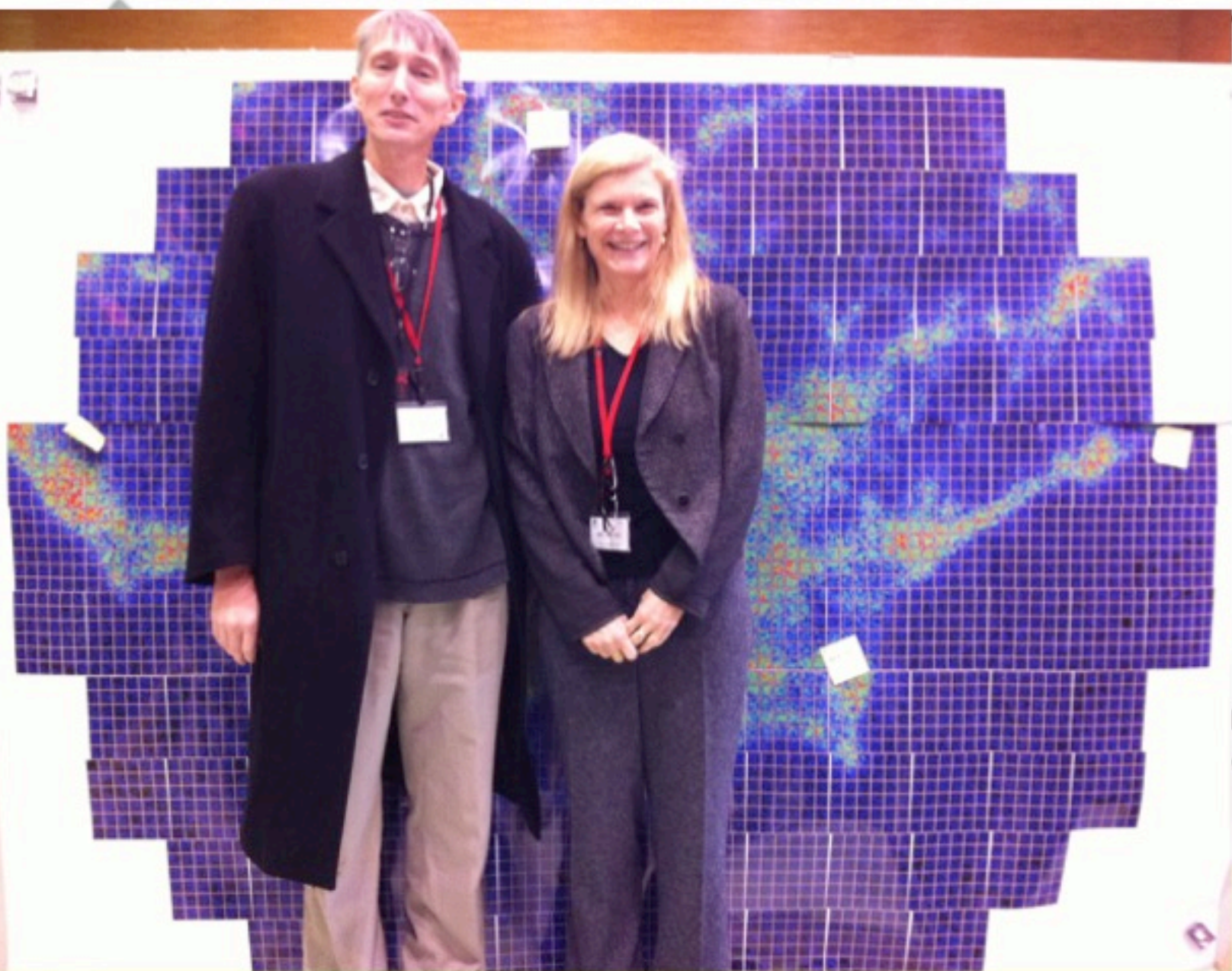
# Science Instrument



tics

# Focal Surface Detector

493  
MAP  
(8x8 pi



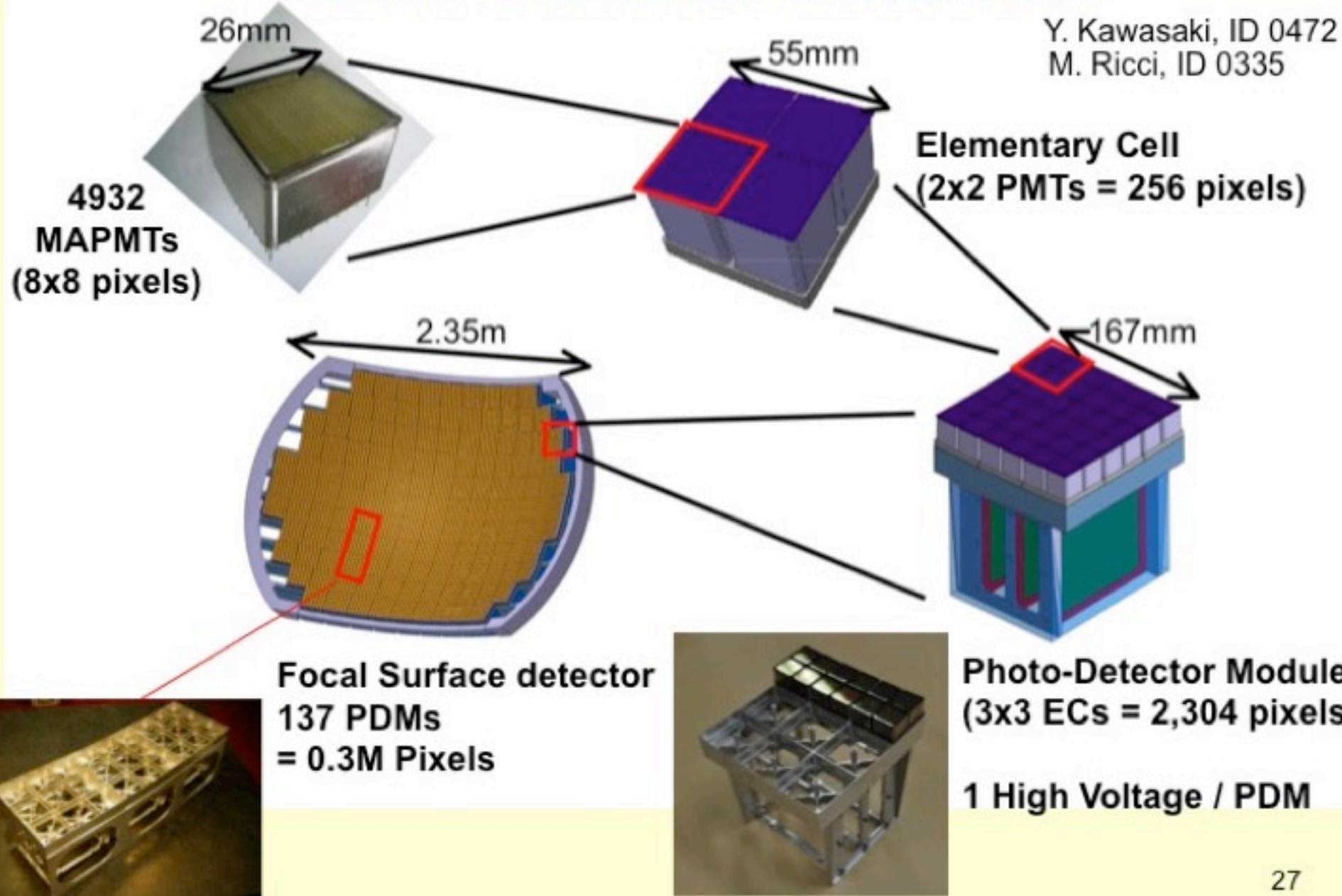
2

le  
ls

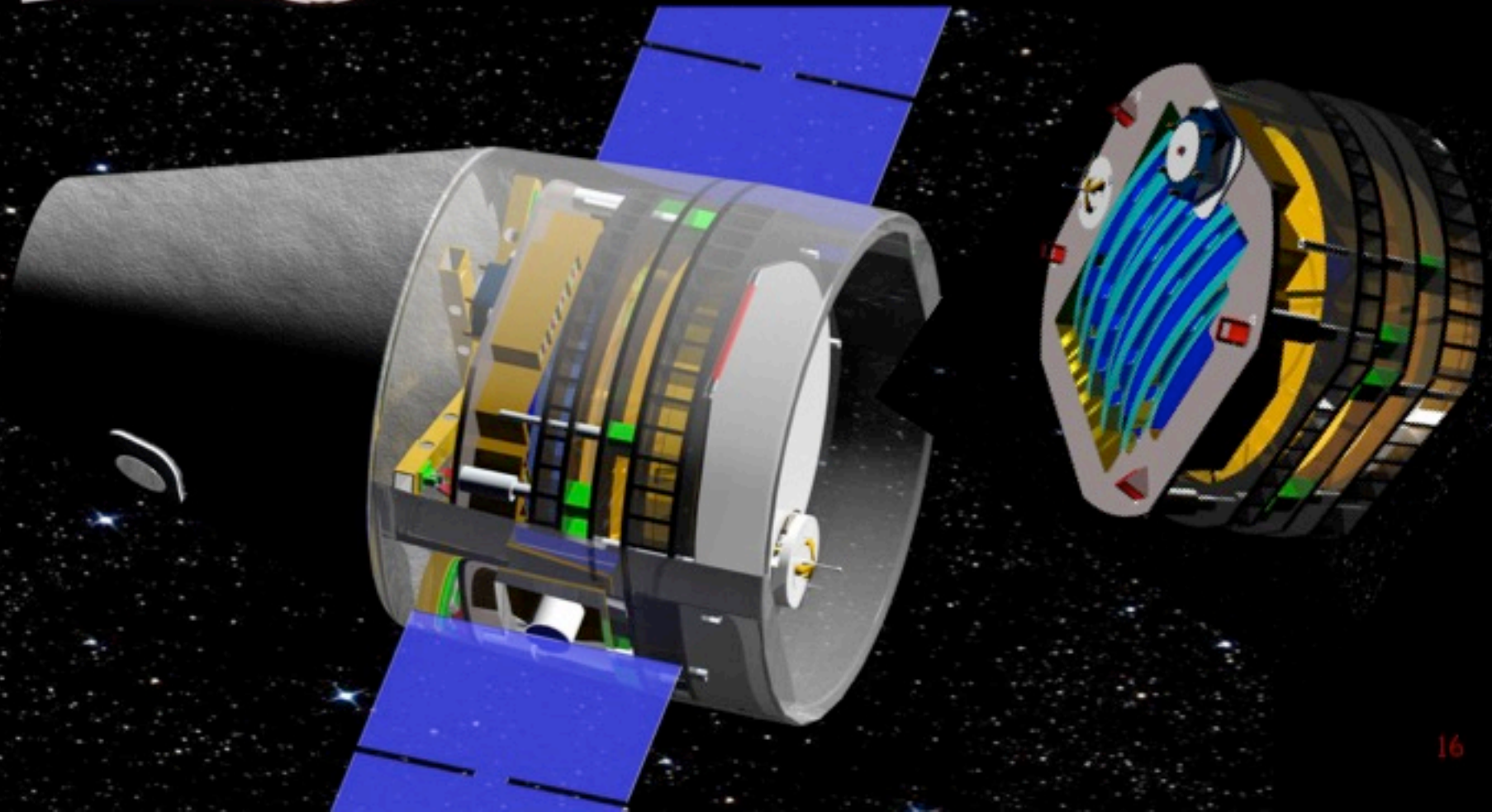
R

# Focal Surface Detector

Y. Kawasaki, ID 0472  
M. Ricci, ID 0335



SPACEX





# Full Sky Coverage with nearly uniform exposure

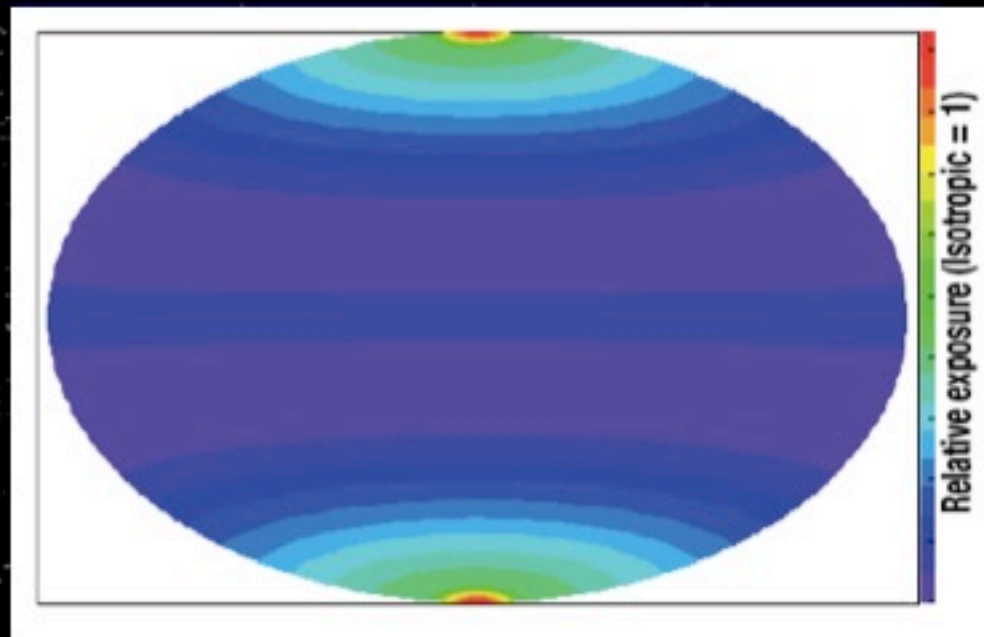


<http://www.nlsac.com> (LSA)

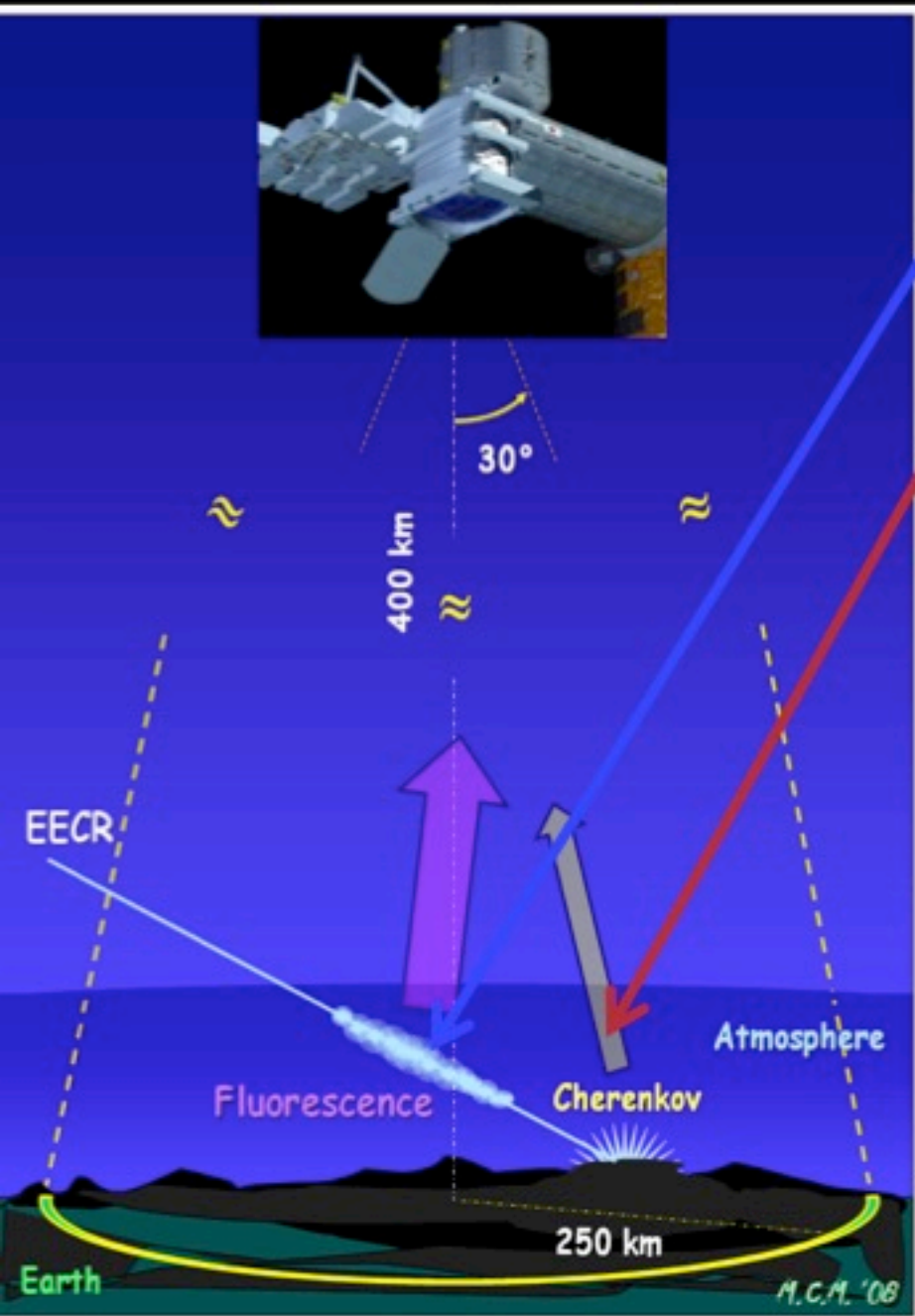
Inclination:  $51.6^\circ$

Height:  $\sim 400\text{km}$

## The ISS ORBIT

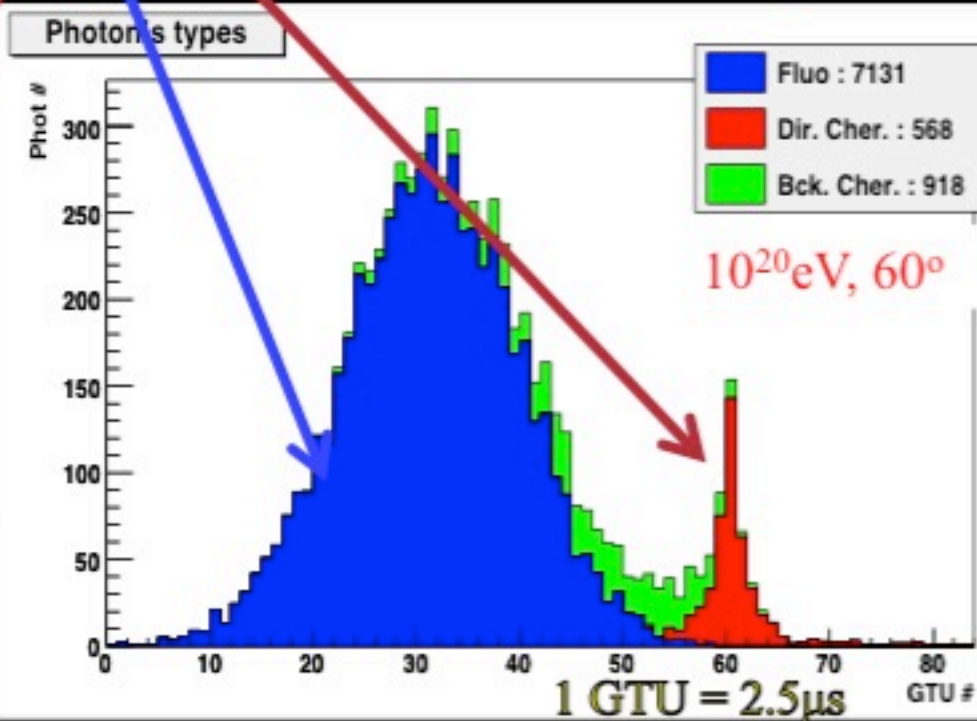


# Fluorescence from SPACE

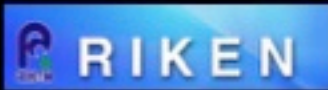


Fast Signal: 50 -150  $\mu$ s

- a) Fluorescence
- b) Scattered Cherenkov
- c) Direct (reflected Cherenkov)



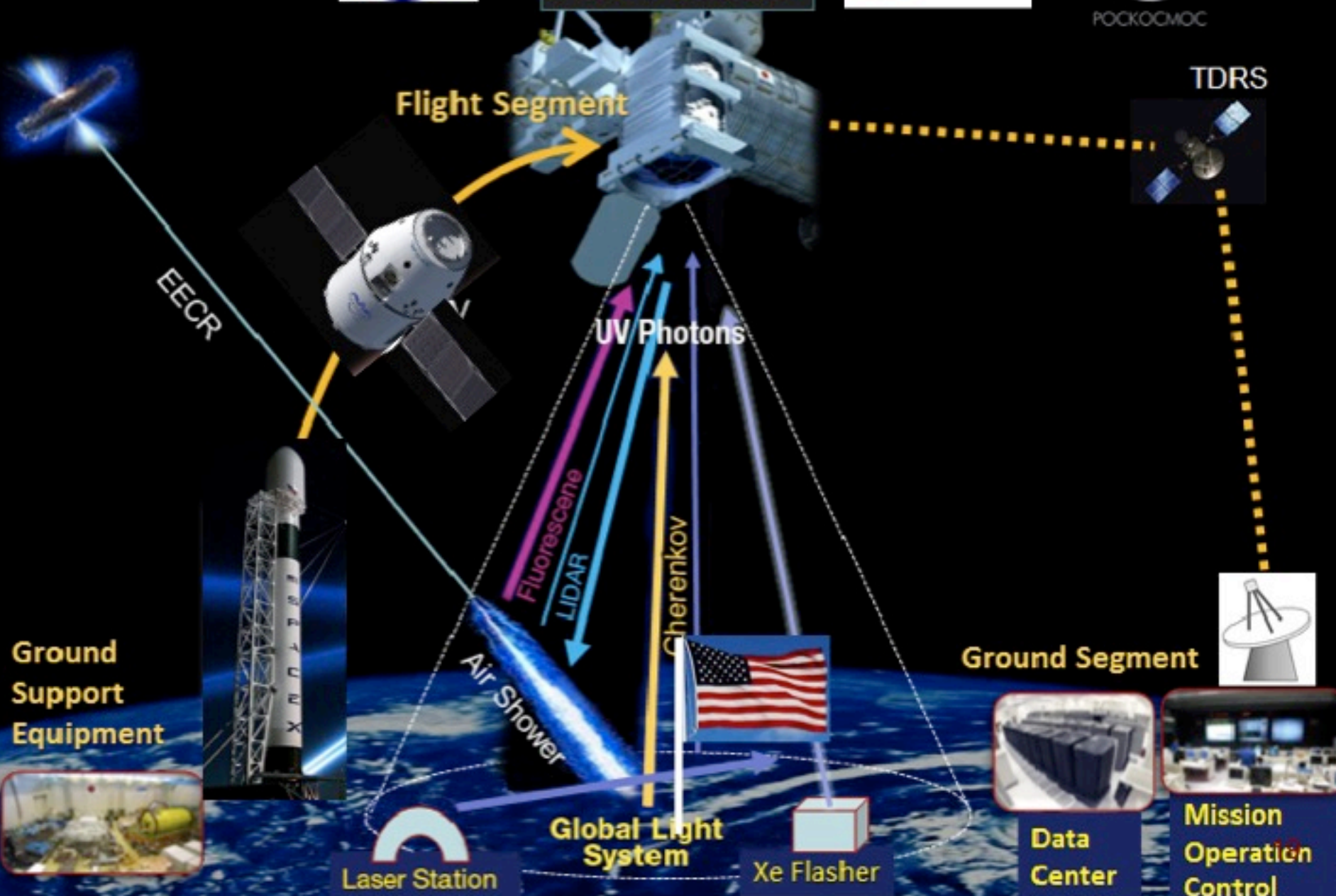
Background: 500 /m<sup>2</sup> sr ns



**JEM-EUSO**



POCKOONOC



# JEM EUSO GLS Some Candidate Locations



Location	Latitude	Elevation	Location	Latitude	Elevation
Jungfrauoch (Switzerland)	47°N	3.9 km	Chacaltaya (Bolivia)	16° S	5.3 km
Mt. Washington (NH, USA)	44° N	1.9 km	La Reunion (Madagascar)	21° S	1.0 km
Alma-Ata (Kazakhstan)	44° N	3.0 km	Cerro Tololo (Chile)	30° S	2.2 km
Climax (CO, USA)	39° N	3.5 km	Sutherland (South Africa)	32° S	1.8 m
Frisco Peak (UT, USA)	39° N	2.9 km	Pierre Auger (Argentina)	35° S	1.4 km
Mt Norikura (Japan)	30° N	4.3 km	South Island (New Zealand)	43° S	1.0 km
Mauna Kea (HI, USA)	20° N	>3.0 km			
HAWC Site (Mexico)	19° N	3.4 km			

# The EUSO program

1. TA-EUSO: Ground detector at Telescope Array site: 2013



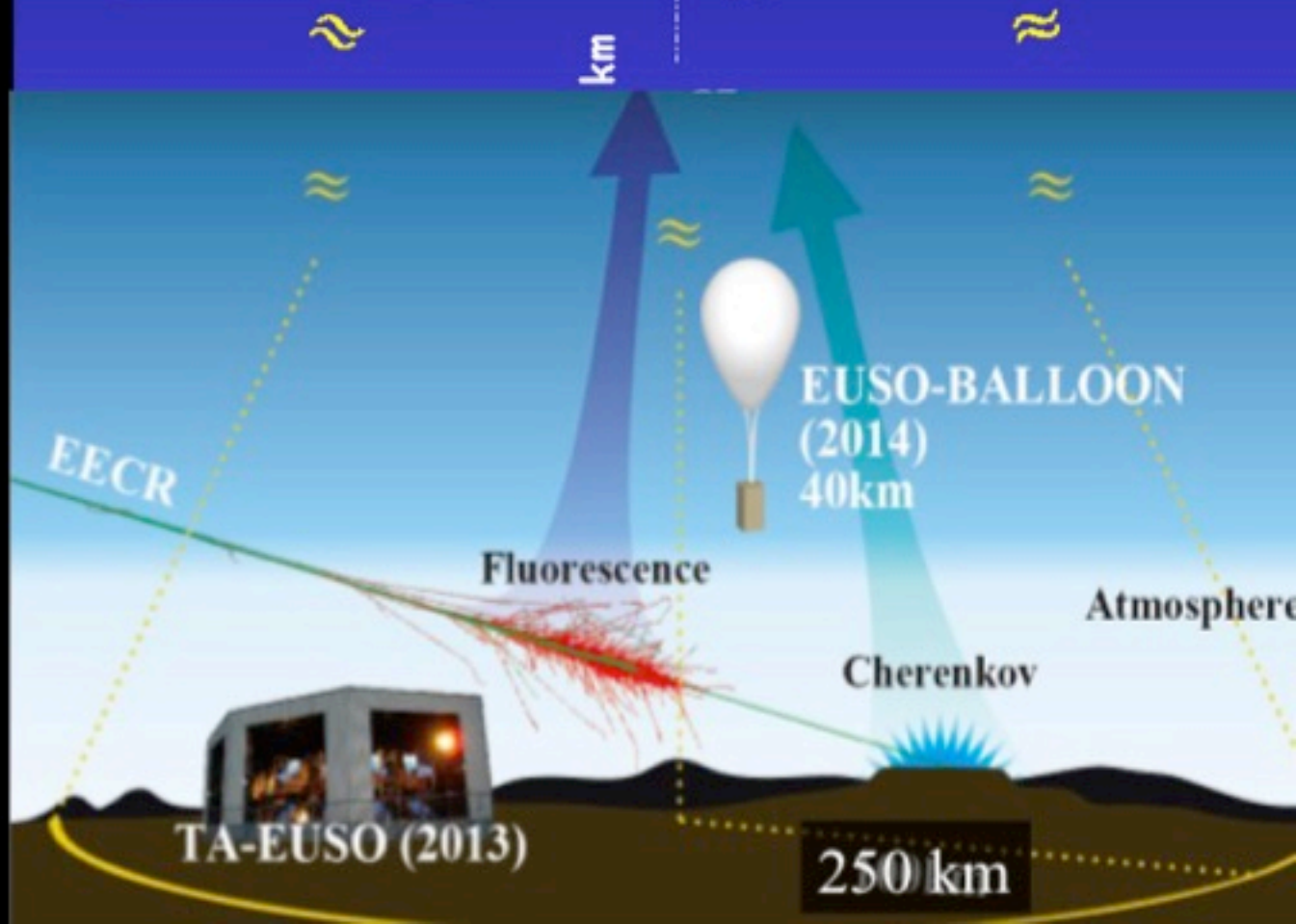
2. EUSO-BALLOON:  
1st flight from Timmins, Canada, August 2014

3. EUSO-SPB  
from Wanaka, NZ(2016-17)

4. Mini-EUSO in the ISS  
(2018)

4. KLYPVE →  
K-EUSO (2020)

5. JEM-EUSO  
(U.S.; >2020+)

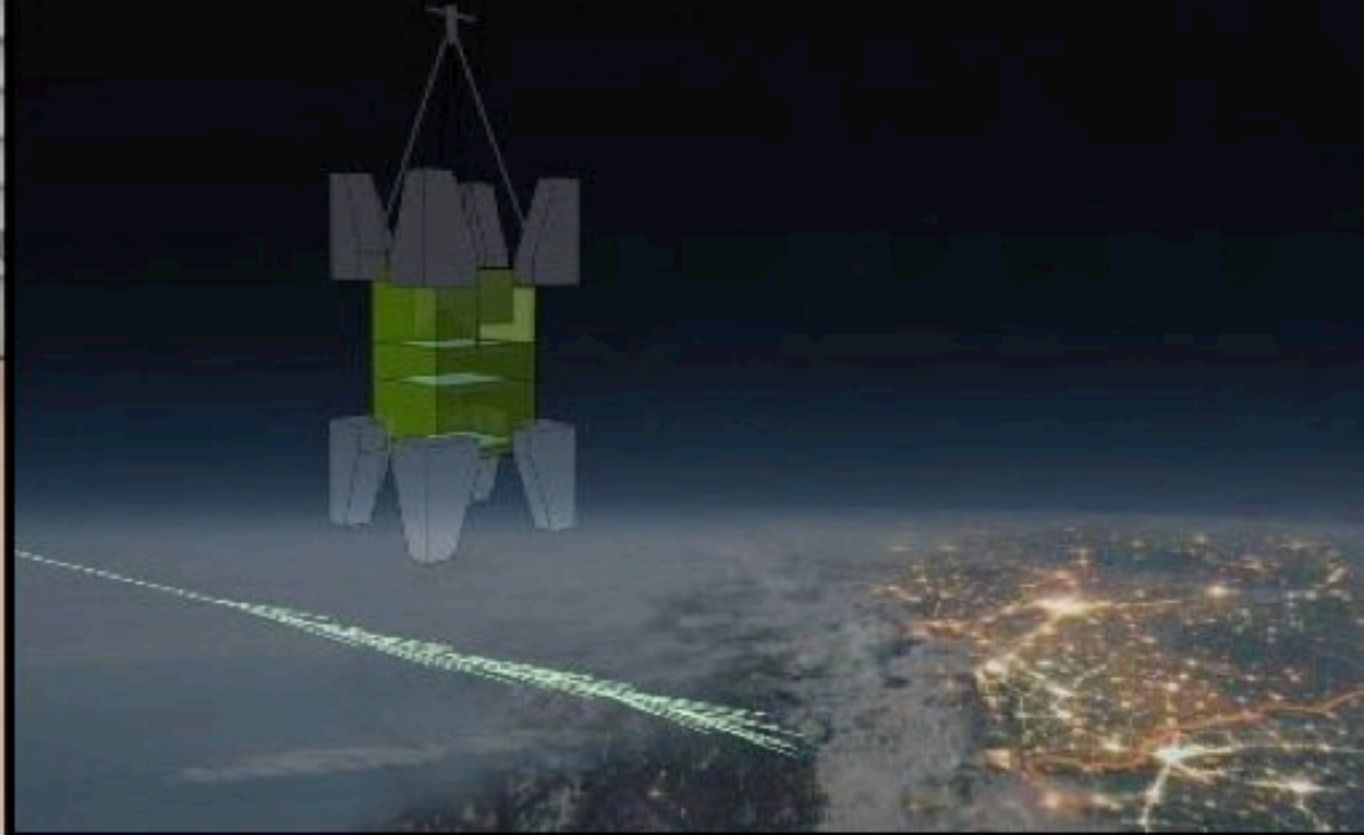


# EUSO – Balloon

**1st flight from Timmins, Canada (CNES)  
August 24-25, 2014**

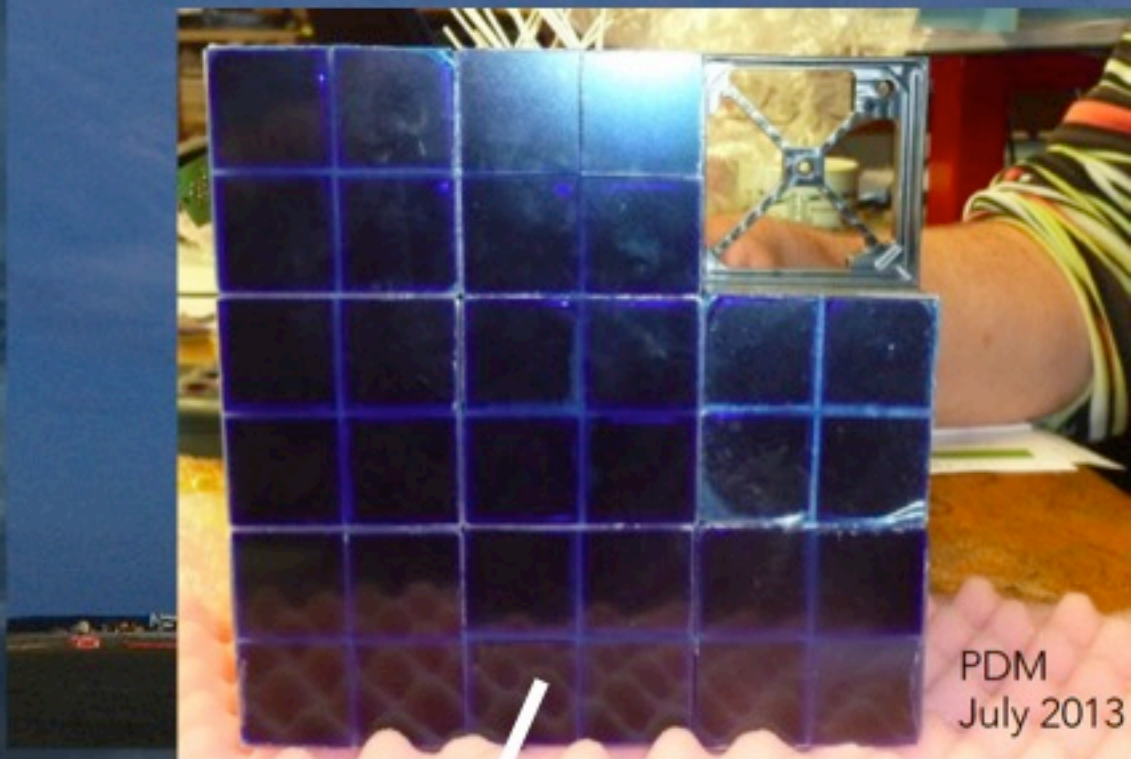


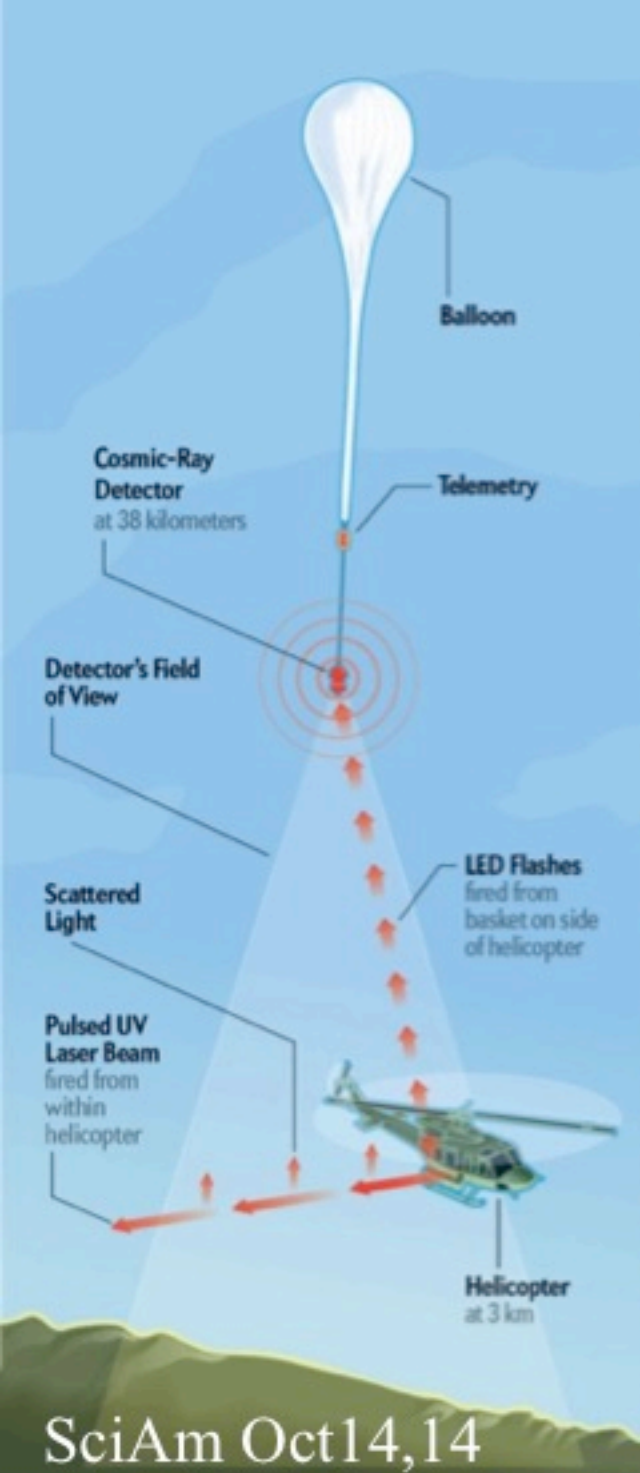
a pathfinder mission for JEM-EUSO  
E U S O - B A L L O O N



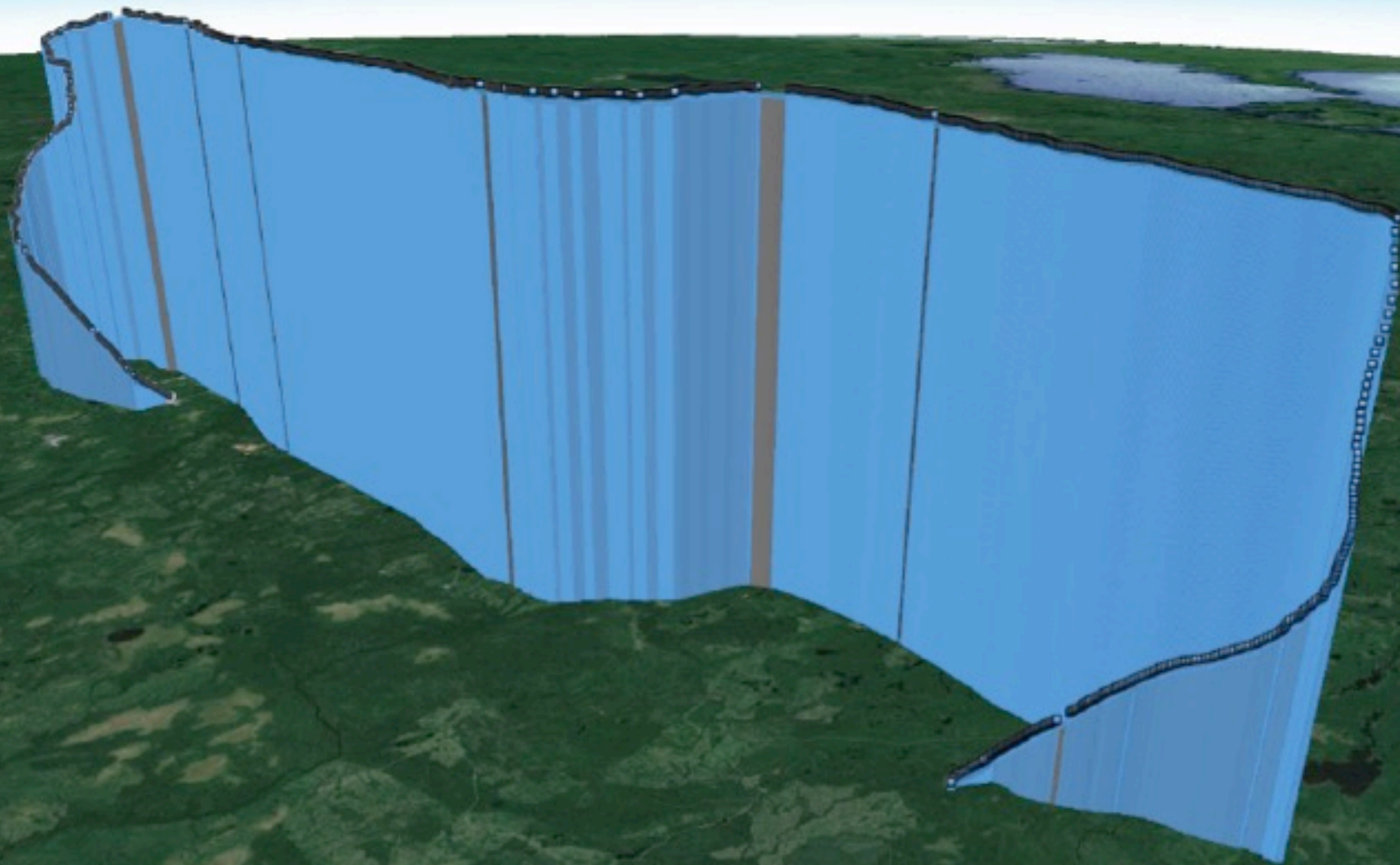
# EUSO Balloon:

1<sup>st</sup> flight and first light on 24-25.8.2014









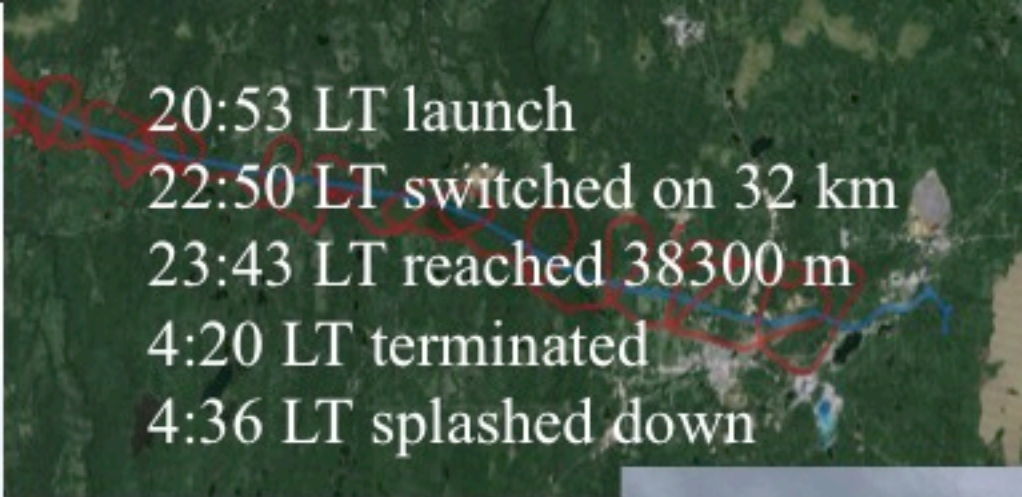
Data S/O: NOAA, U.S. Navy, NGA, GEBCO  
Image Landsat  
© 2014 Cnes/Spot Image  
Image NOAA

Google earth

Imagery Date: 4/10/2013 48°23'04.07" N 82°04'46.63" W elev 314 m eye alt 54.06 km



20:53 LT launch  
22:50 LT switched on 32 km  
23:43 LT reached 38300 m  
4:20 LT terminated  
4:36 LT splashed down



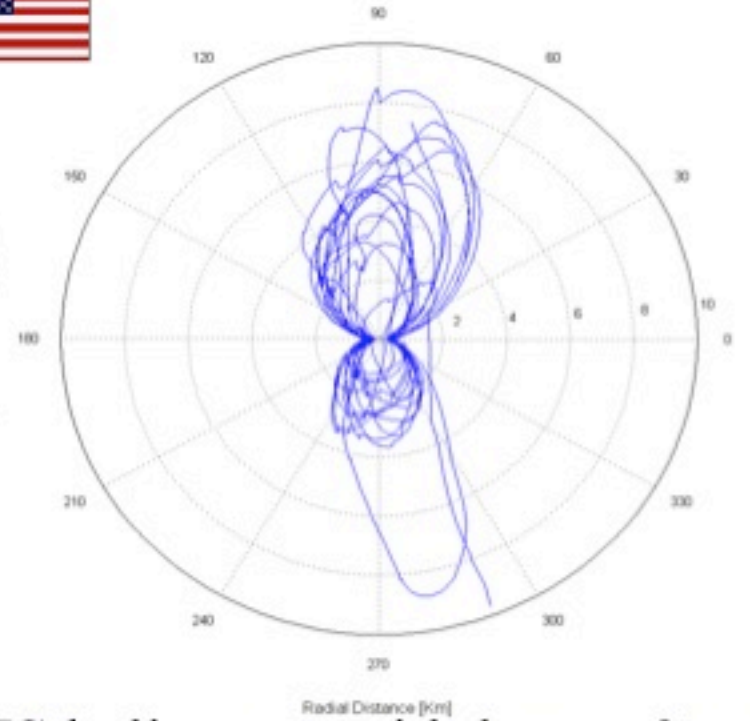
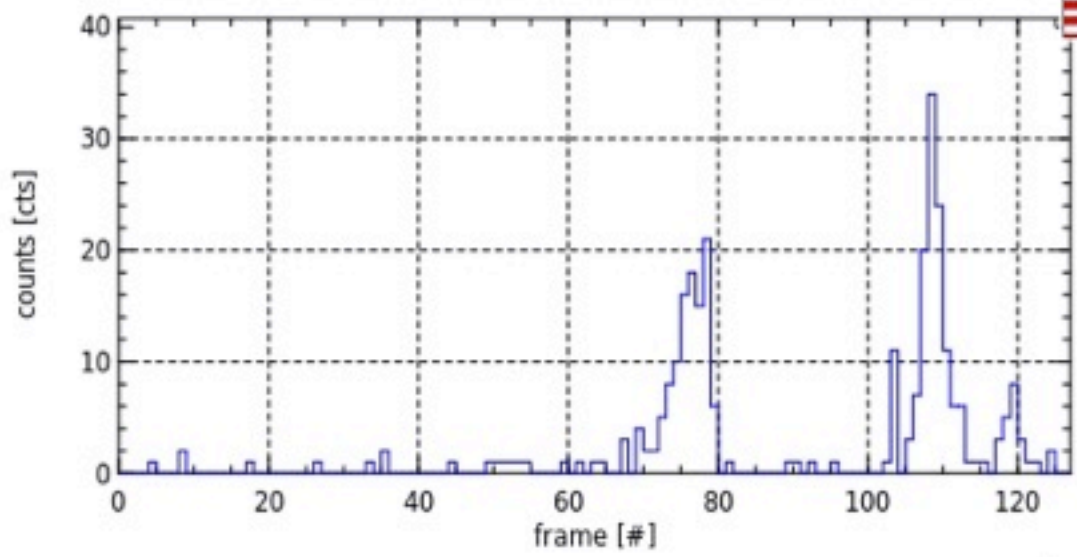
*the instrument booth floating above the waterline*

*"Lake Euso" - the site of cusoballoon's splashdown;*

Pixel Counts Evolution



Relative Position of Helicopter from Balloon  
win 10 Km



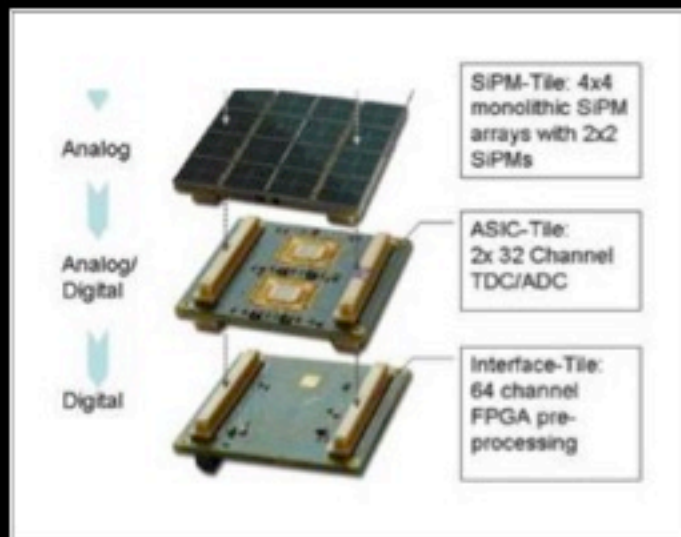
US helicopter with lasers & Xe flashers tracked the balloon > 5hrs of data  
Observed flashes, Laser shots

Low energy CRs with Geiger counter + IR camera cloud cover

# EUSO-SPB

Ultra Long Duration flight  
Super Pressure Balloon  
First observations of UHECRs  
from space  
Test SiPM focal surface

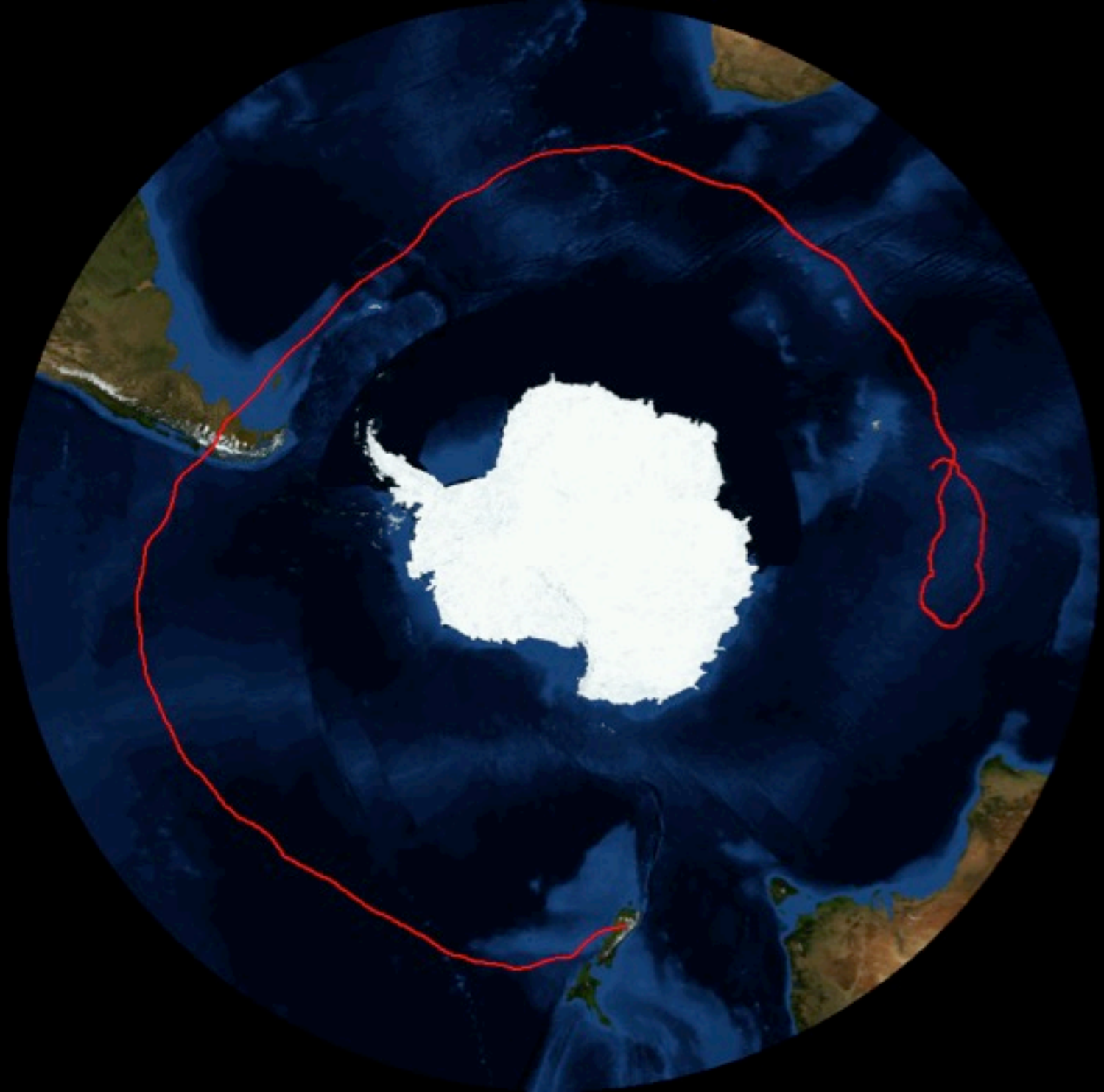
~ 10 -30 days



Launch site:  
Wanaka, NZ

Landing site:  
South America





# How many UHECRs > 60 EeV?

Auger + TA ~30 events/yr

**JEM-EUSO**

**~200 events > 60 EeV/yr**



Earth - surface ~  $5 \cdot 10^8 \text{ km}^2$

**~ $3.4 \cdot 10^6$  events/yr**

# How many UHECRs > 60 EeV?

Auger + TA ~30 events/yr

**JEM-EUSO**

~200 events > 60 EeV/yr

**40.0.m to go!**

Earth surface ~  $5 \cdot 10^8 \text{ km}^2$

~ $3.4 \cdot 10^6$  events/yr





**Extreme Energy Frontier  
Mysteries to be  
Resolved from Space!**

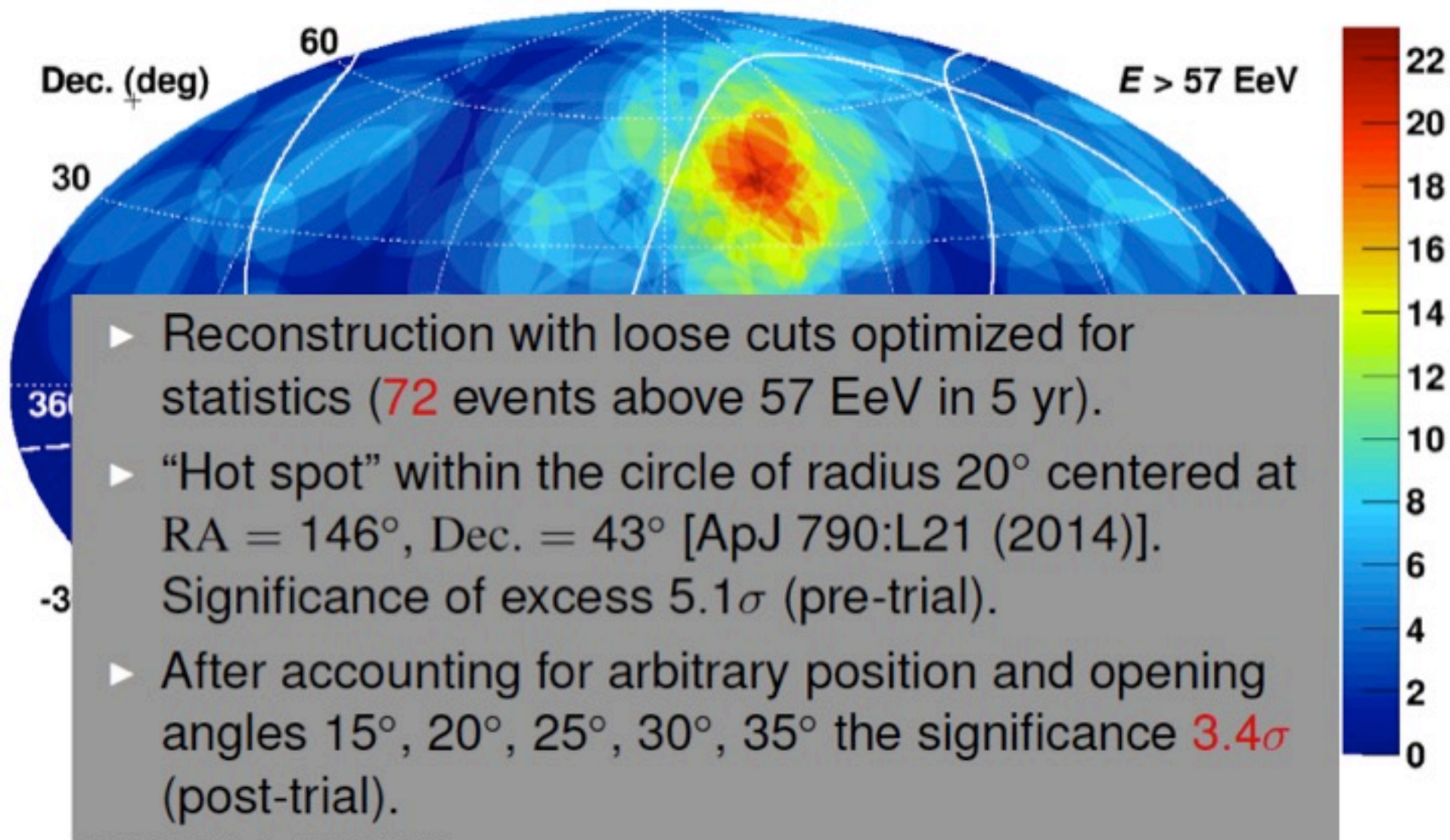
**Thanks!**



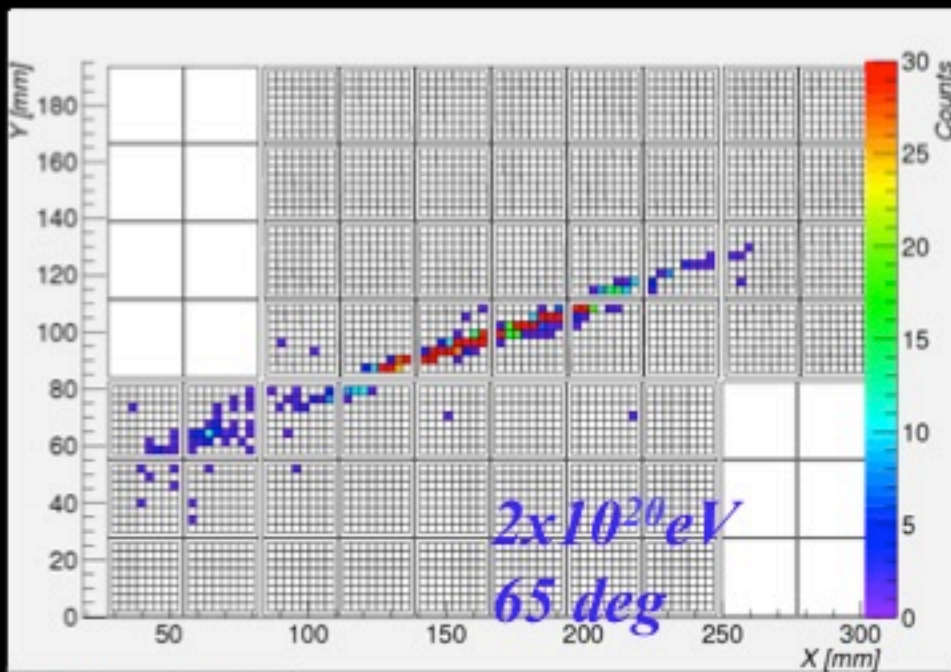


# Anisotropy Hints > 60 EeV

## Oversampling with 20°-radius circle

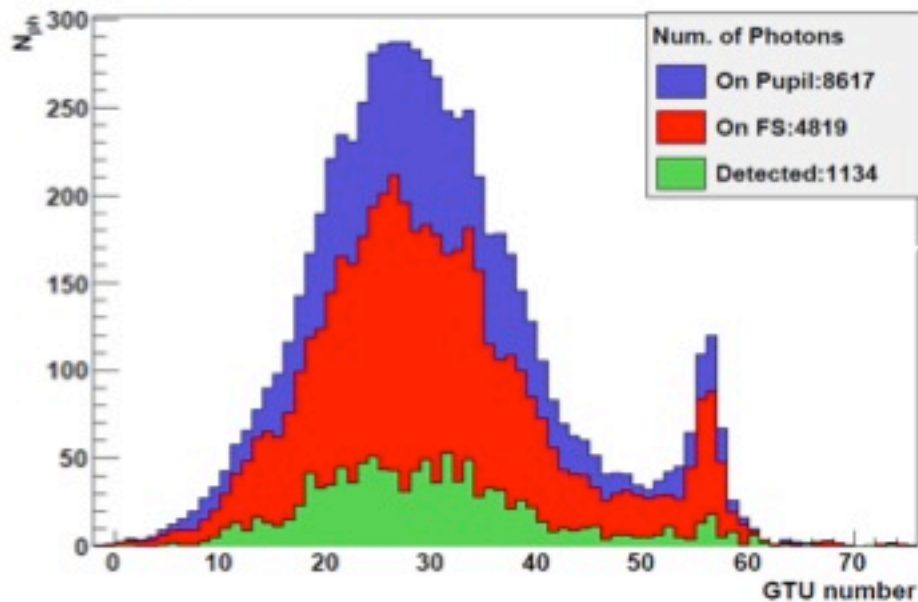


# Shower Simulation



Simulated air shower image on the focal surface detector.

Photons vs GTU



Detected photoelectrons are recorded every Gate Time Unit (GTU) of  $2.5 \mu\text{s}$  continuously.