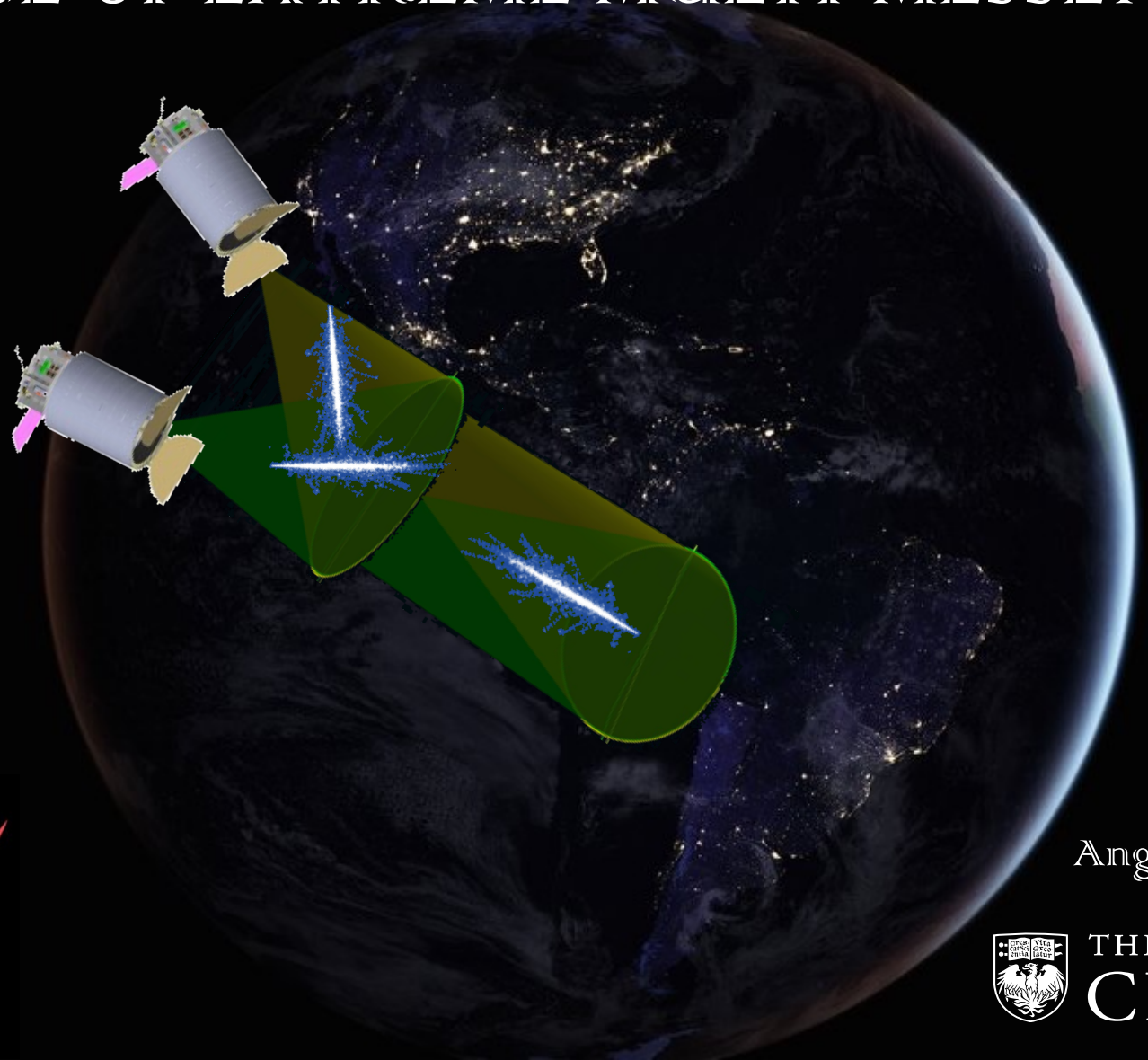
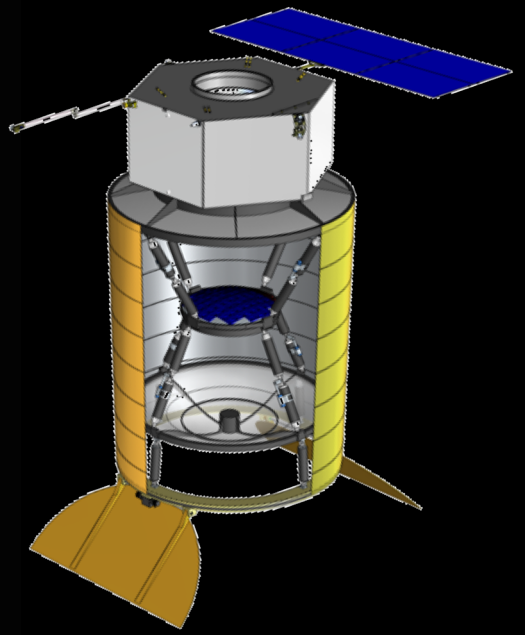
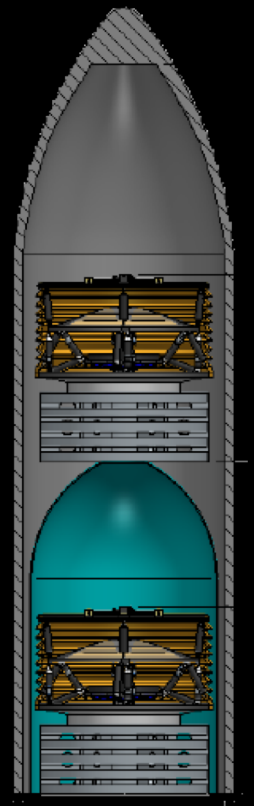
The Roadmap to the POEMMA mission

PROBE OF EXTREME MULTI-MESSENGER ASTROPHYSICS







Angela V. Olinto

THE UNIVERSITY OF CHICAGO

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NASA/GSFC

University of Maryland, Baltimore Co.

POEMMA Collaboration

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JAPAN: RIKEN: M. Casolino,, Y. Takizawa

MEXICO: **UNAM:** G. Medina Tanco

NORWAY: NTNU: F. Oikonomou

POLAND: **University of Warsaw:** L. W. Piotrowski; **NCNR, Lodz:** K. Shinozaki

RUSSIA: MSU: P. Klimov, M. Zotov

SLOVAKIA: **IEP, Slovak Academy of Science:** S. Mackovjak

SWITZERLAND: **University of Geneva:** A. Neronov

76 scientists from 38 institutions and 13 countries

OWL, JEM-EUSO, Auger, TA, Veritas, CTA, Fermi, Theory

POEMMA & EUSO APS Talks

Saturday, April 17, 2021

D10.00001 : Overview of the POEMMA Observatory, Angela V. Olinto, et al.

D10.00002 : Overview of the EUSO-SPB2 mission, Johannes Eser, et al.

D10.00003 : The EUSO-SPB2 Cherenkov Telescope, Performance of Camera, Eliza Gazda, et al.

D10.00004: Status of the EUSO-SPB2 Fluorescence Detector, George Filippatos

D10.00009: EUSO-SPB2 Telescope Optics and Testing, Viktoria Kungel

D21.00005: The EUSO-SPB2 mission, Lawrence Wiencke

D21.00006 : The Roadmap to the POEMMA Mission, Angela V. Olinto, et al.

Sunday, April 18, 2021

K10.00001: nuSpaceSim: A Comprehensive Simulation Package …Neutrinos for Space-based Experiment, John Krizmanic

K10.00002: NuPyProp - A Pythonic Monte Carlo Neutrino tau-lepton Simulation Package, Sameer Patel

Monday, April 19, 2021

Q10.00009 : Model independent probes of macroscopic dark matter with EUSOSPB2, Thomas Paul, et al.

S10.00005 : Prospects for EUSO-SPB2 detection of transient astrophysical sources of neutrinos, Mary Hall Reno, et al.

S10.00007 : Targets of Opportunity with POEMMA, Tonia Venters, et al.

Tuesday, April 20, 2021

X10.00005 : Sensitivities of UHE neutrino experiments to DM direct annihilation and decay to neutrinos, Claire Guepin, et al.

Astroparticle Physics Questions:

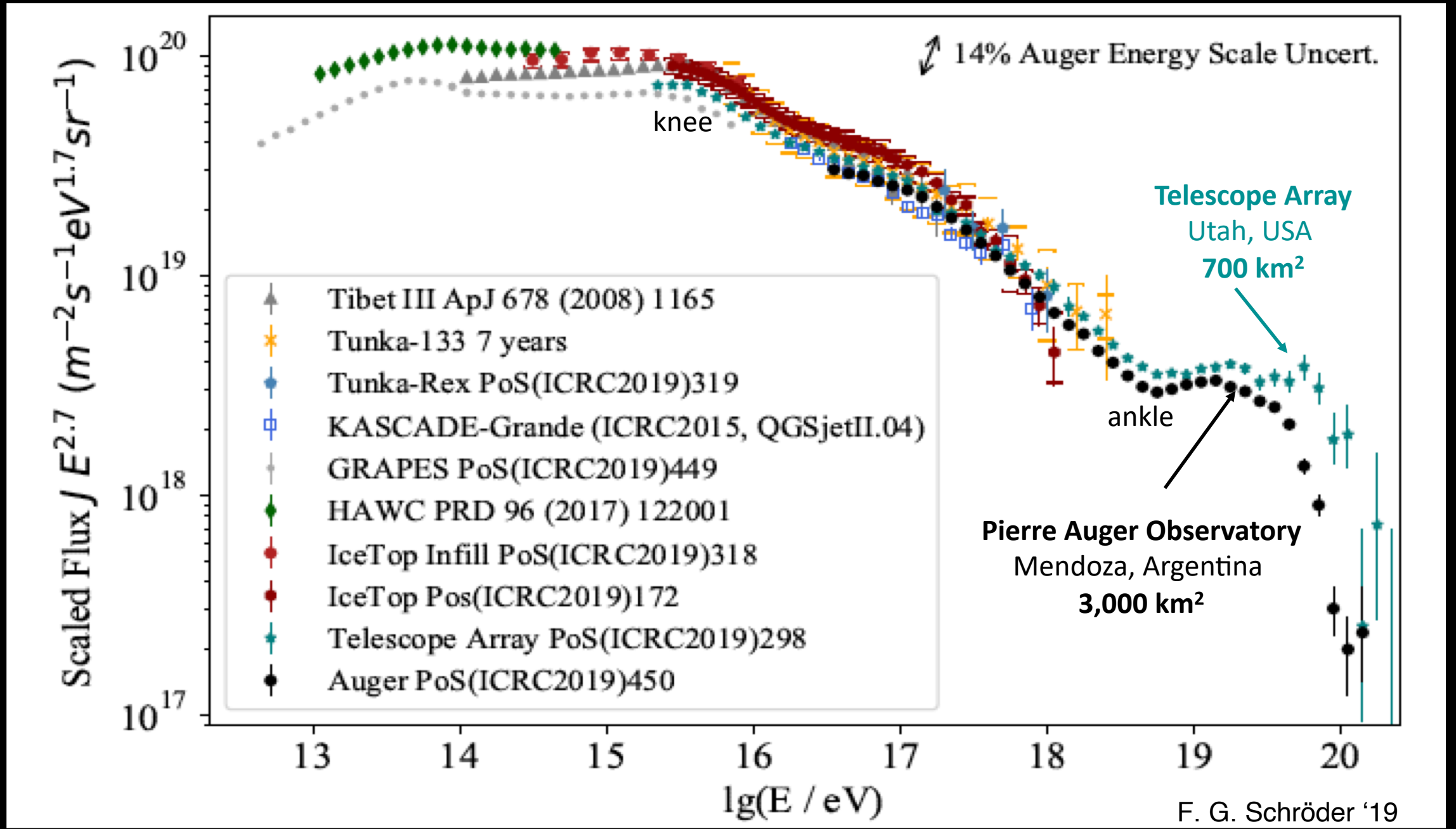
What are the sources of the **Ultra-High Energy Cosmic Rays** (UHECRs)?

Measure Spectrum, Composition, Anisotropies $E>10^{19}$ eV = 10 EeV

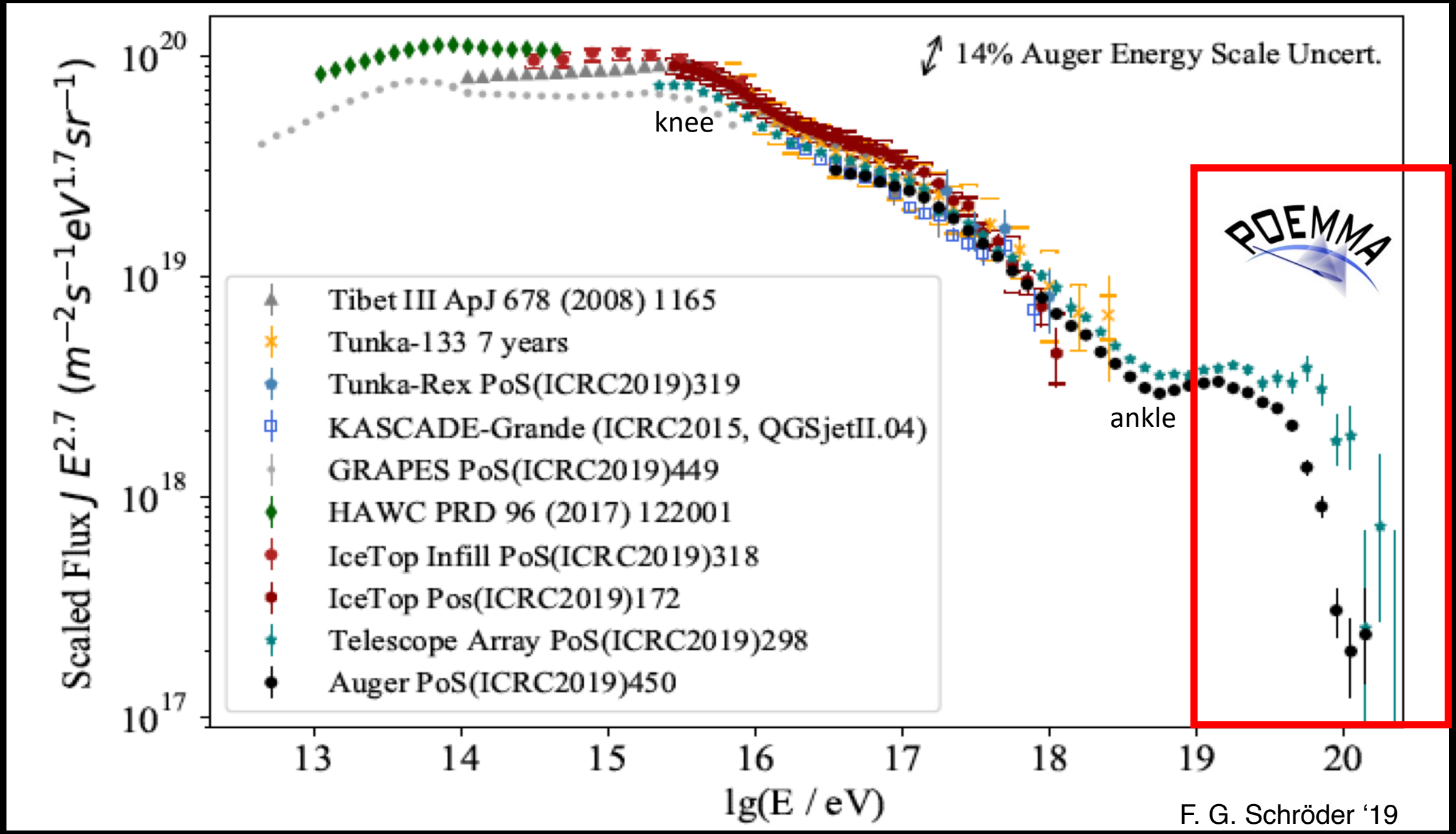
What are the sources of **Astrophysical Neutrinos**?

Multi-Messenger coincidence gamma-ray, gravitational waves, and neutrinos with $E>10^{16}$ eV = 10 PeV

What is the physics and astrophysics at energies >> "ground-based" accelerators? Are there New Interactions or Dark Matter signatures (e.g., Secret Neutrino Interactions, Extra-Dimensions, Supermassive Dark Matter, Macroscopic Dark Matter)?

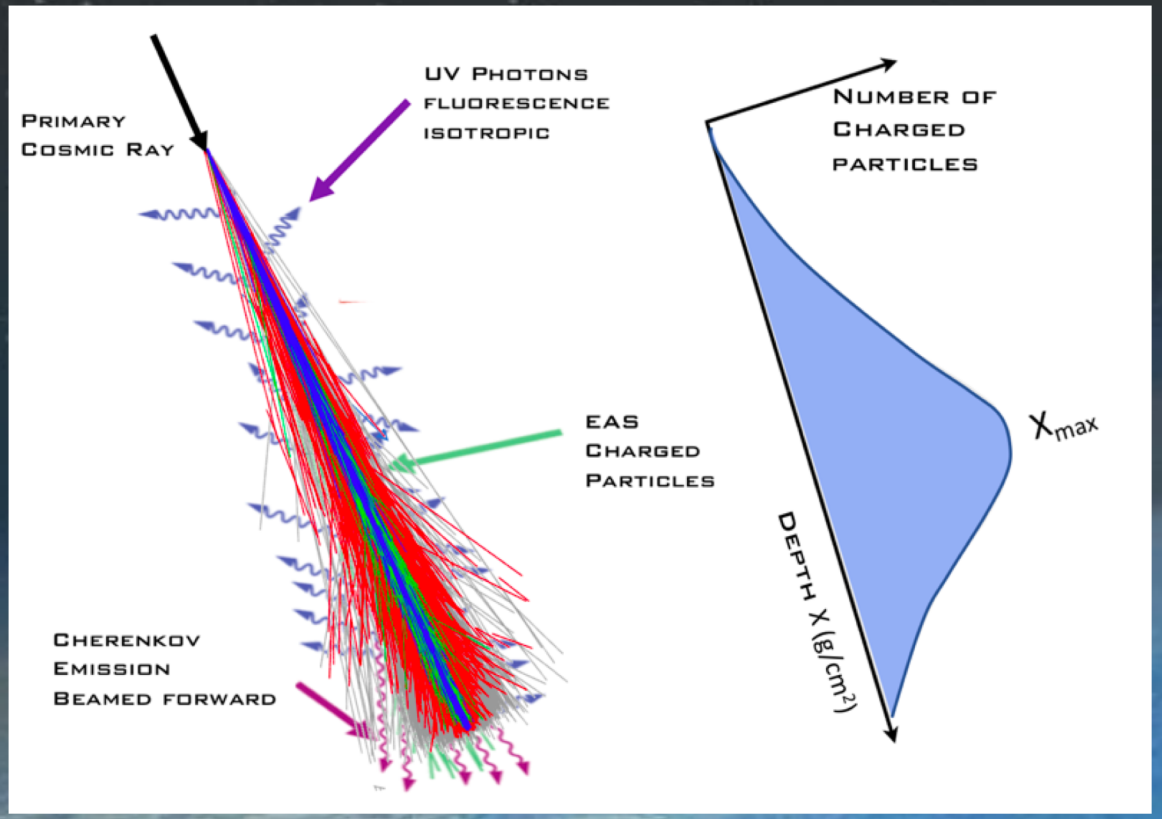


F. G. Schröder '19

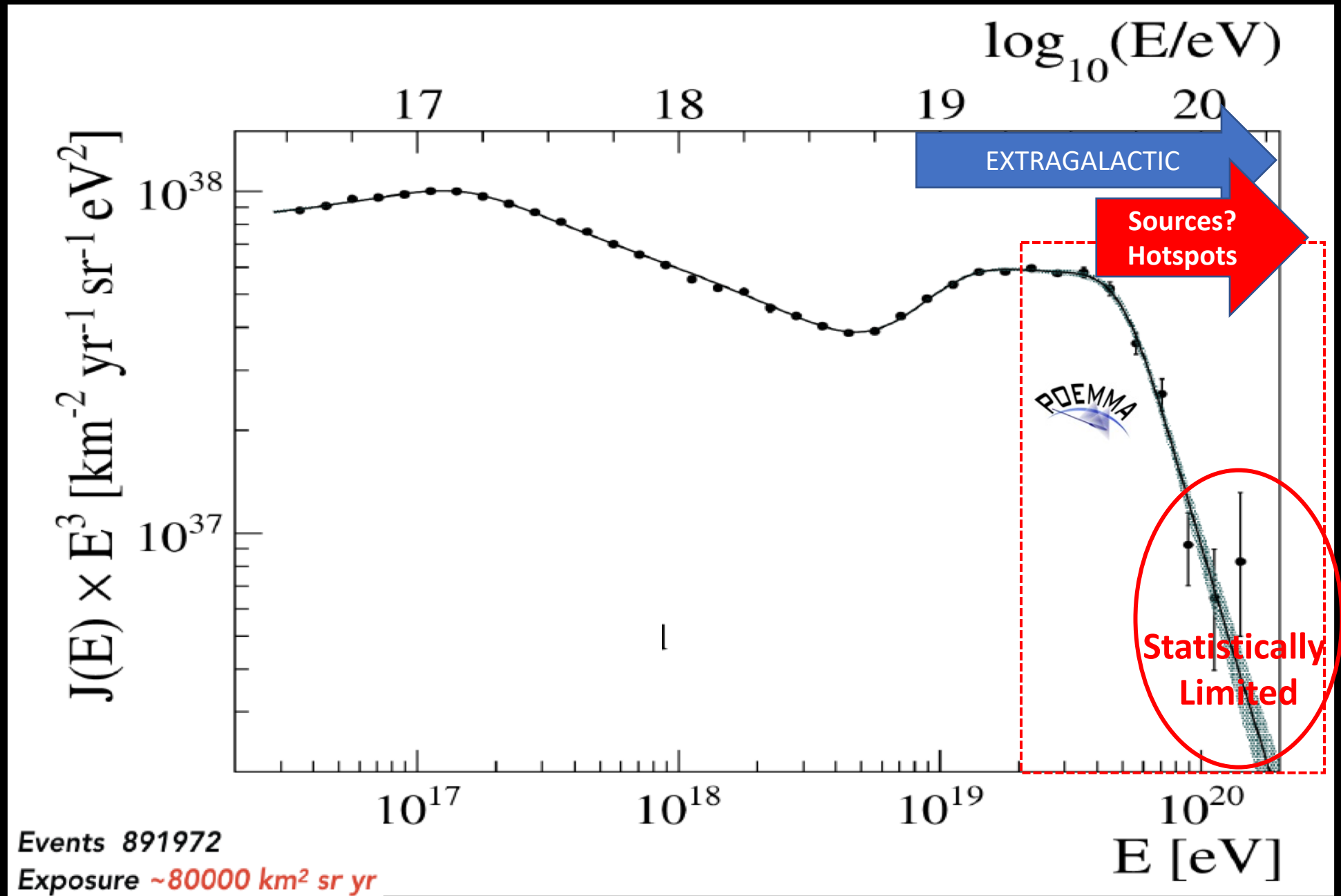


F. G. Schröder '19

Extensive Air Showers

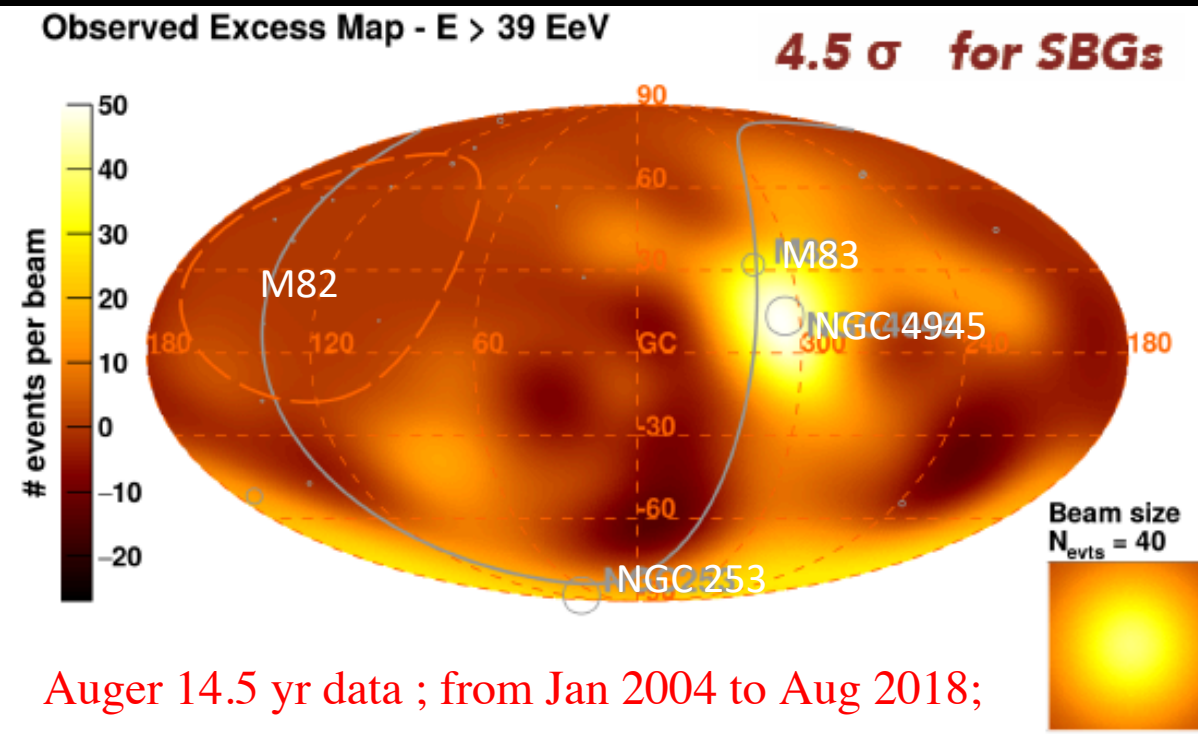


Auger Spectrum ICRC 2019

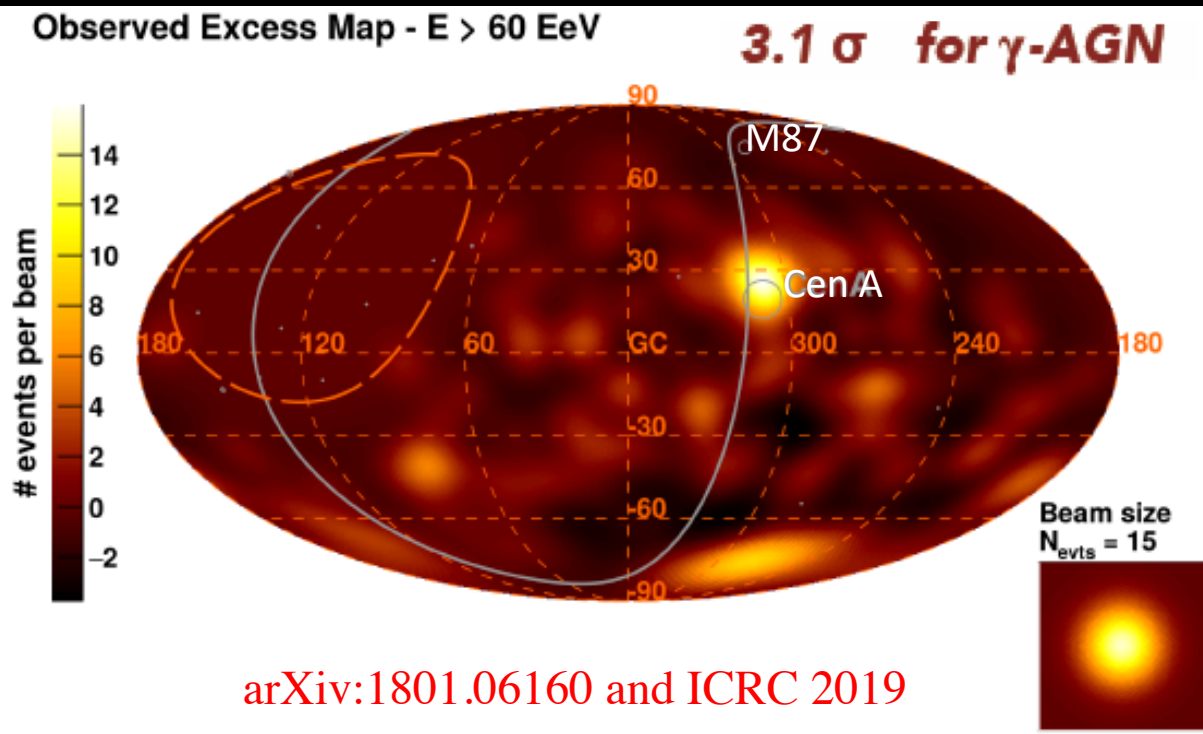


Auger (and TA) Anisotropy Hints > 40 EeV

Starbursts Galaxies (SBGs) or Active Galactic Nuclei (AGN)?



Auger 14.5 yr data ; from Jan 2004 to Aug 2018;



arXiv:1801.06160 and ICRC 2019


M82 – SBG

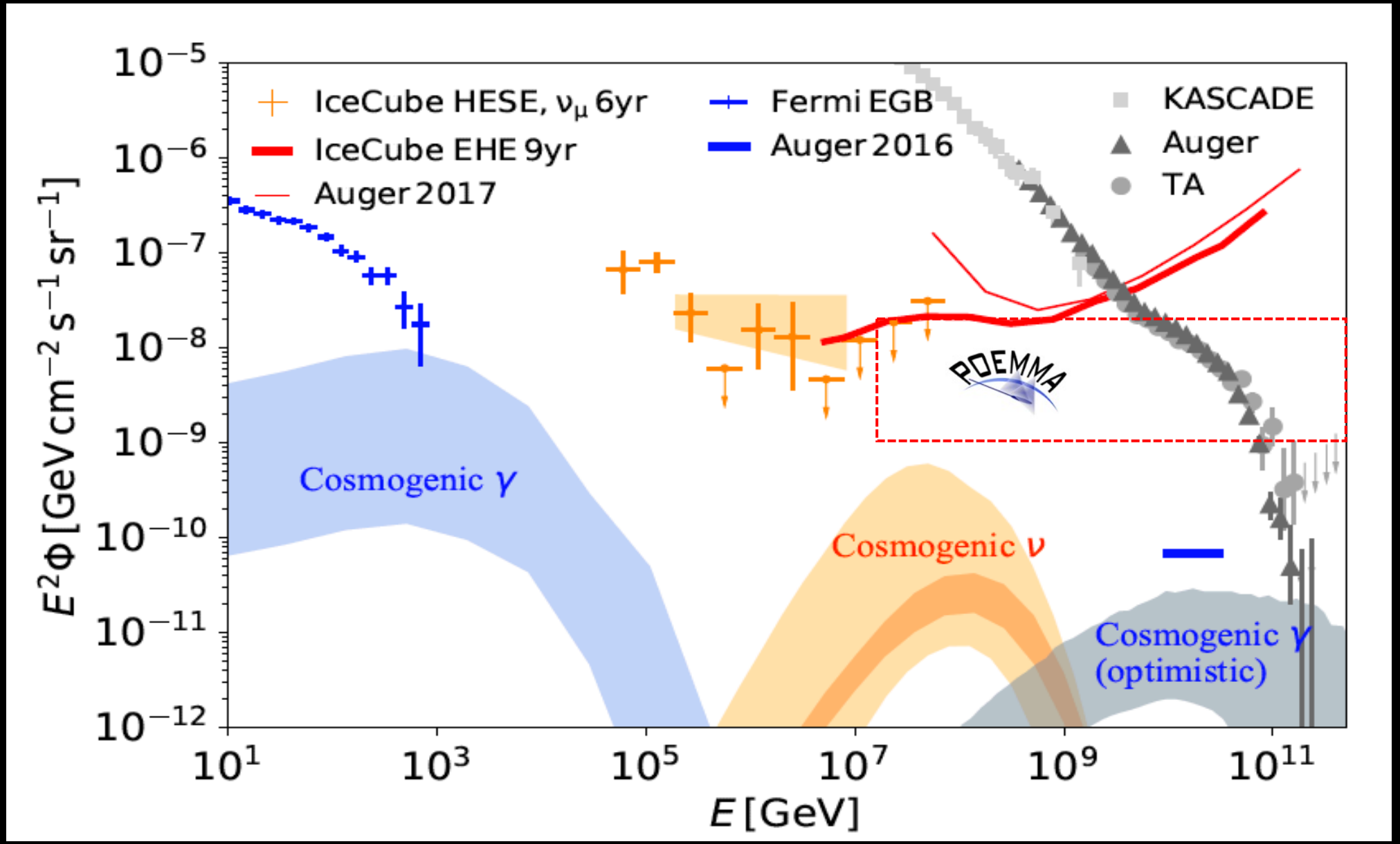

NGC 253 – SBG


M83 – SBG


M87- AGN

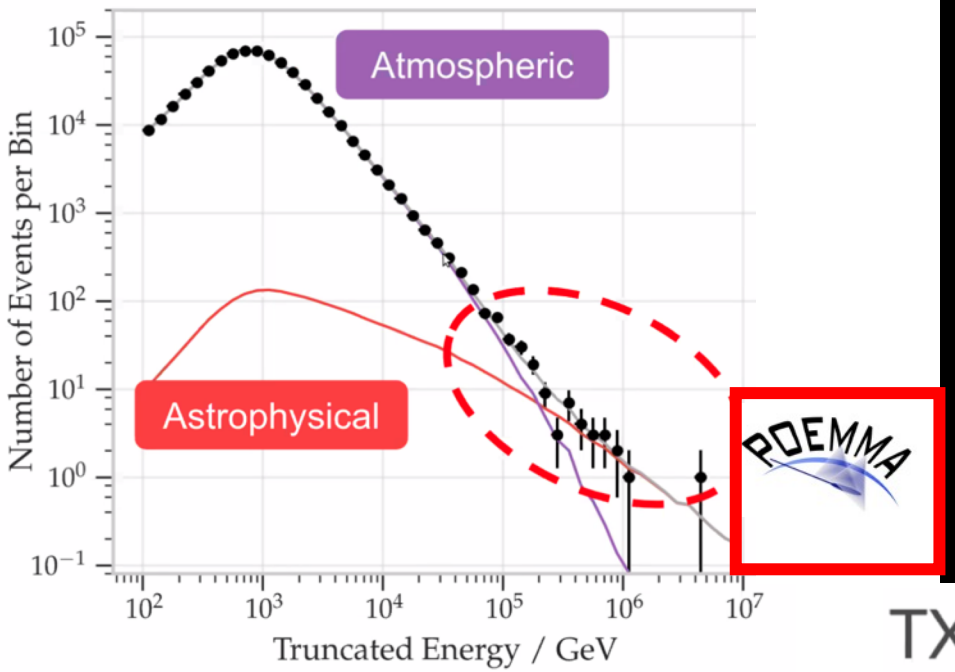

Centaurus A –AGN

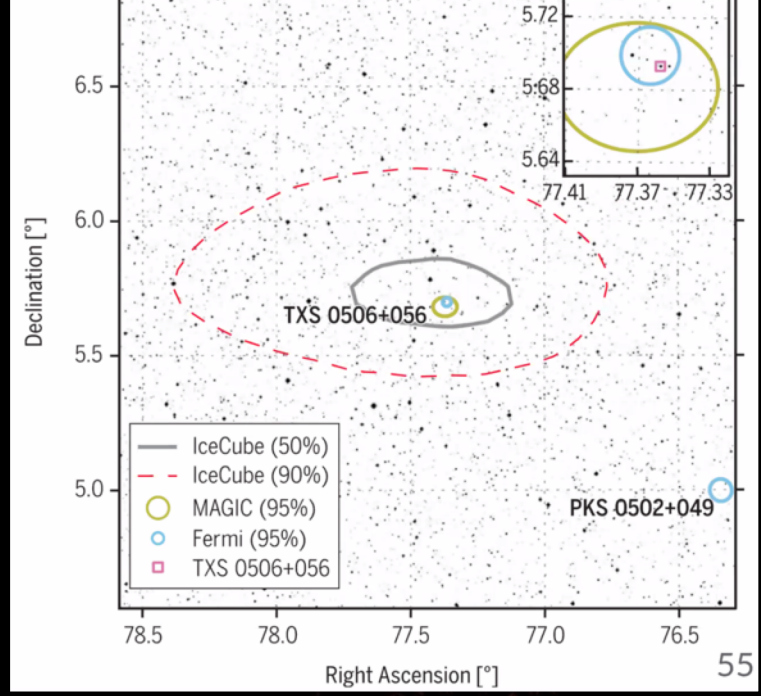
Cosmogenic & Astrophysical Messengers

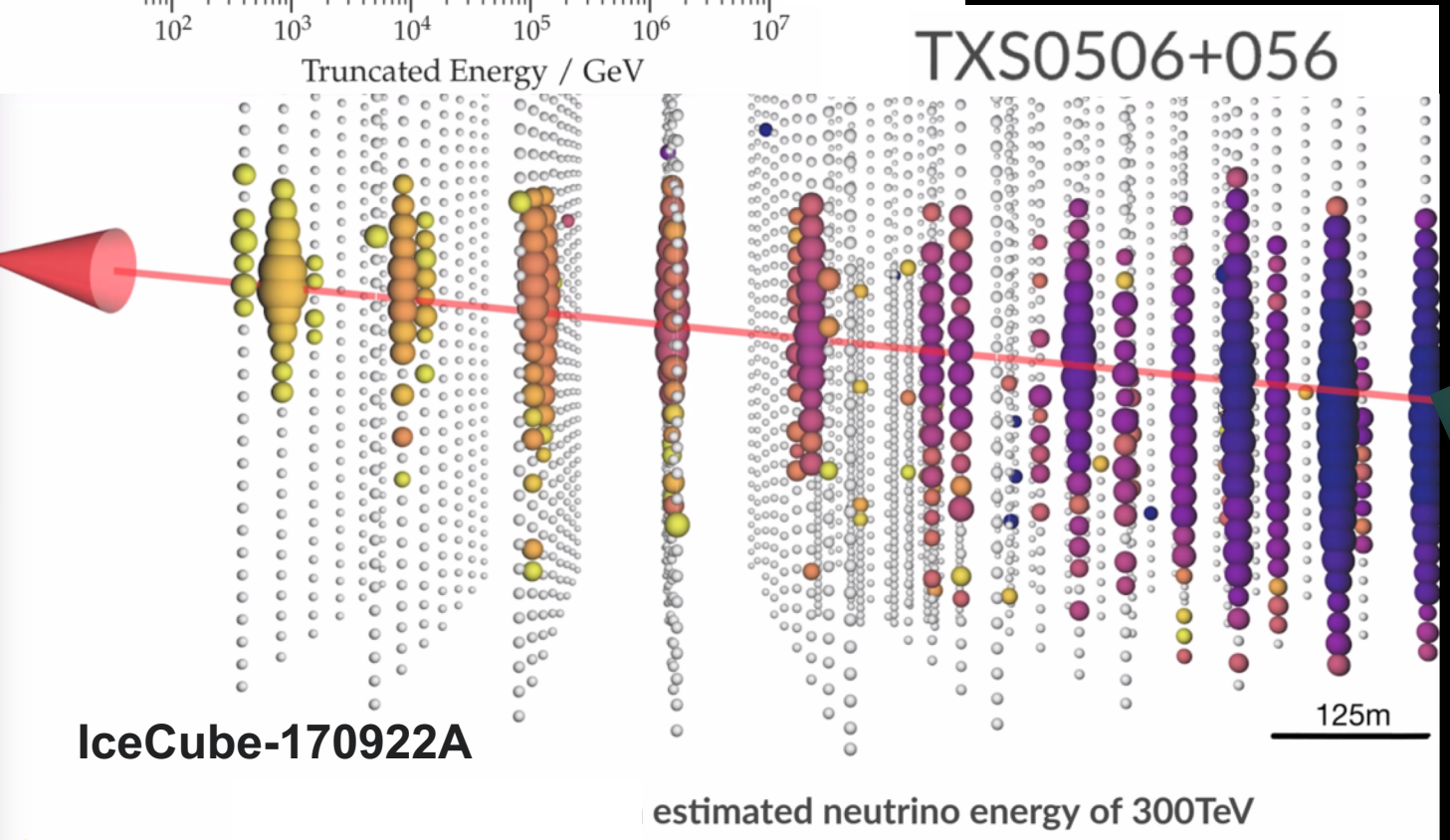


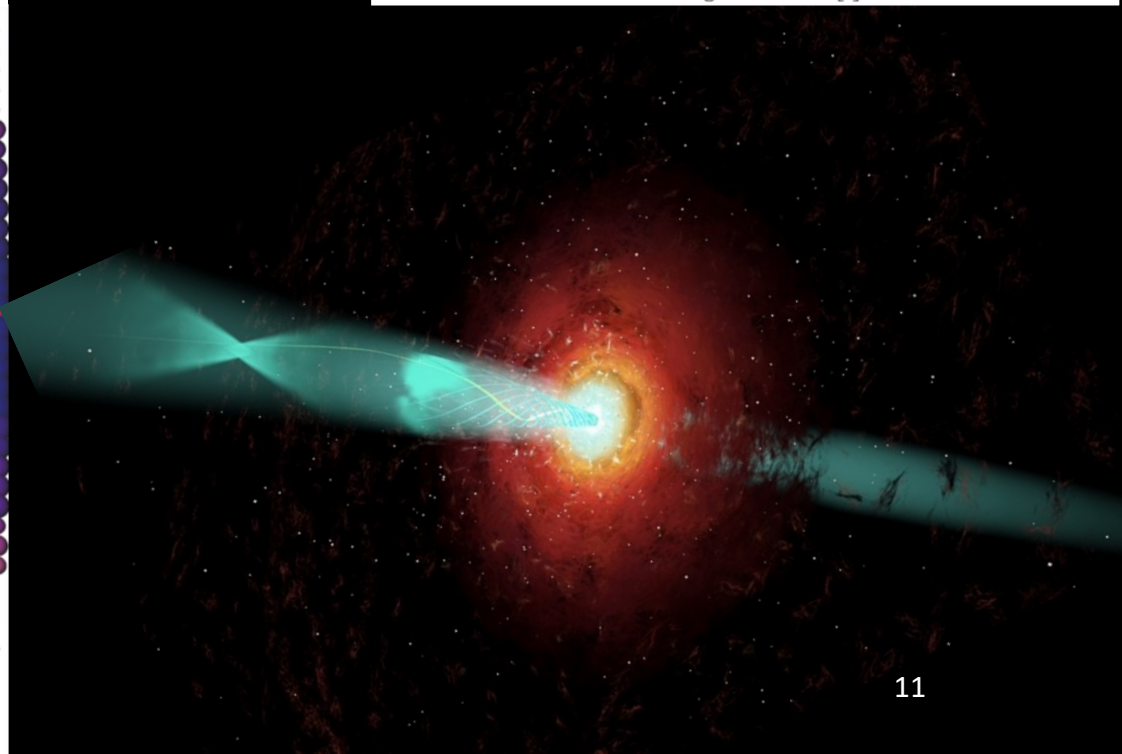
Batista et al, arXiv:1903.06714.pdf

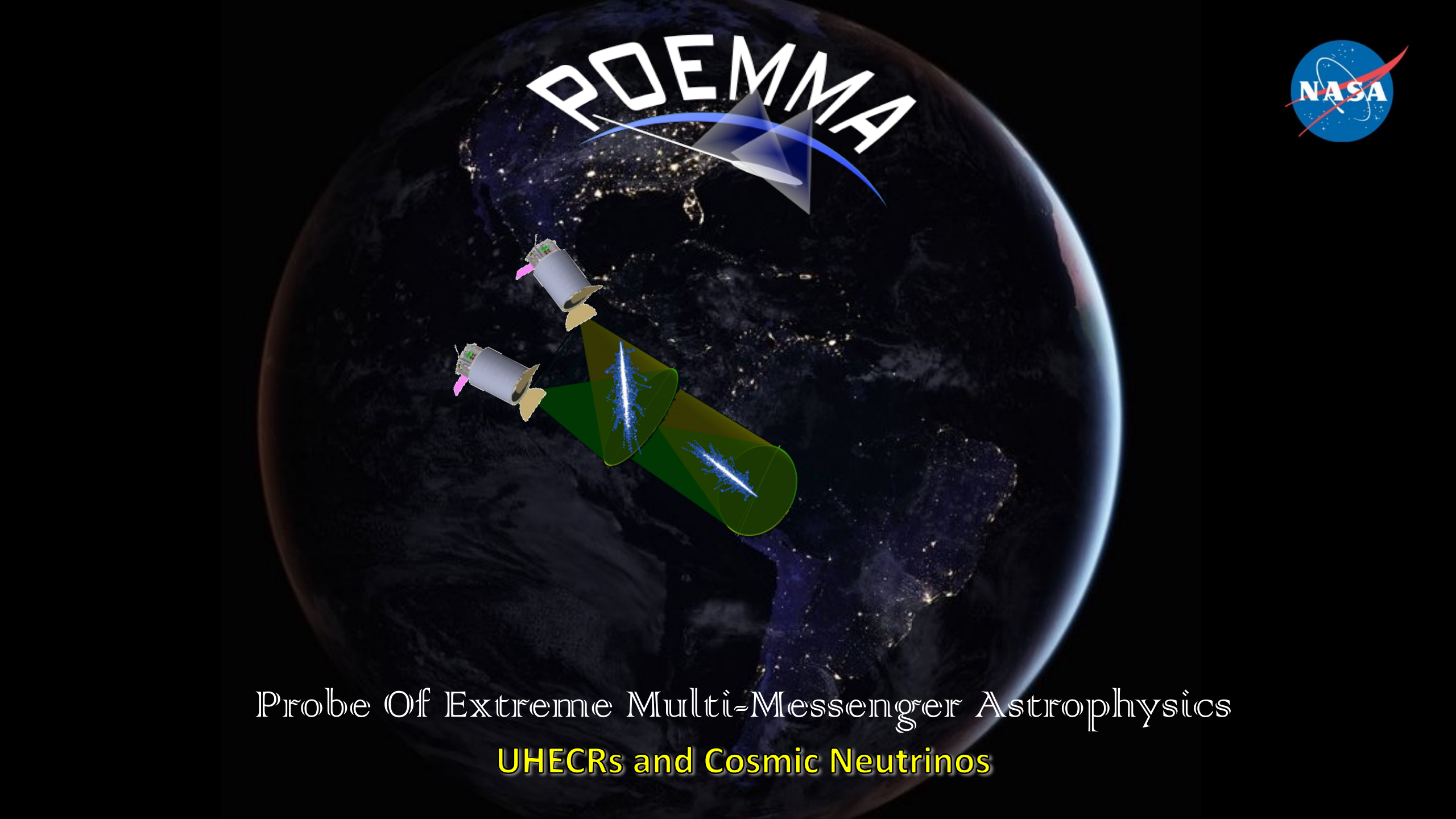
Astrophysical Neutrinos





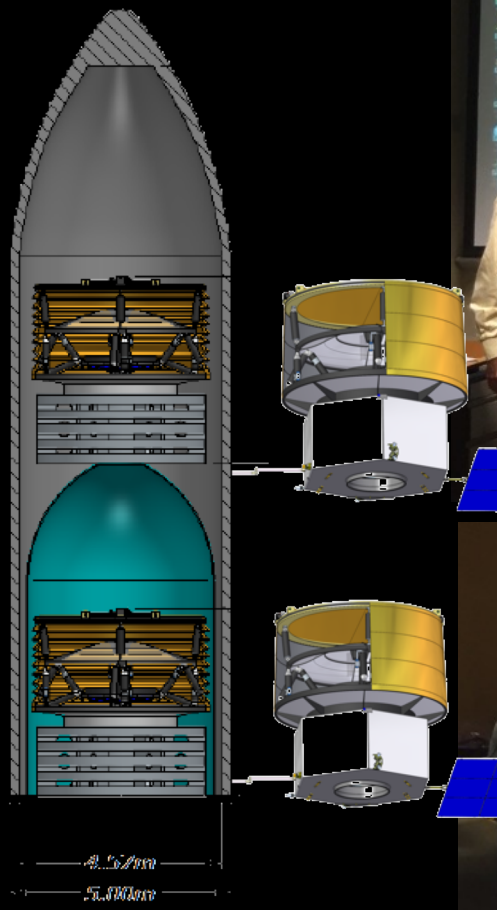


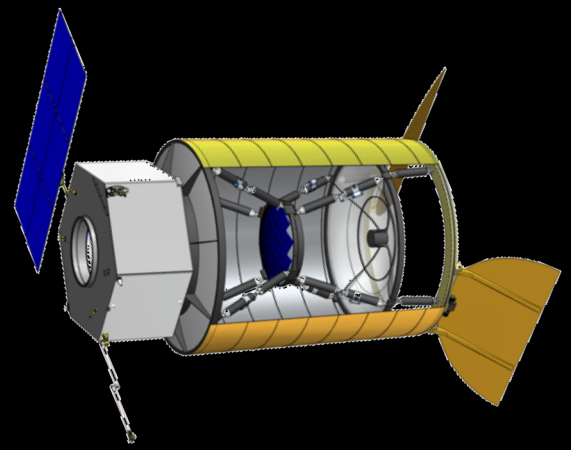


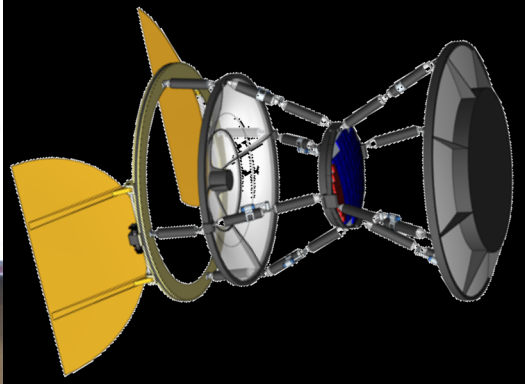

POEMMA
NASA
Probe Of Extreme Multi-Messenger Astrophysics
UHECRs and Cosmic Neutrinos

POEMMA at NASA-GSFC

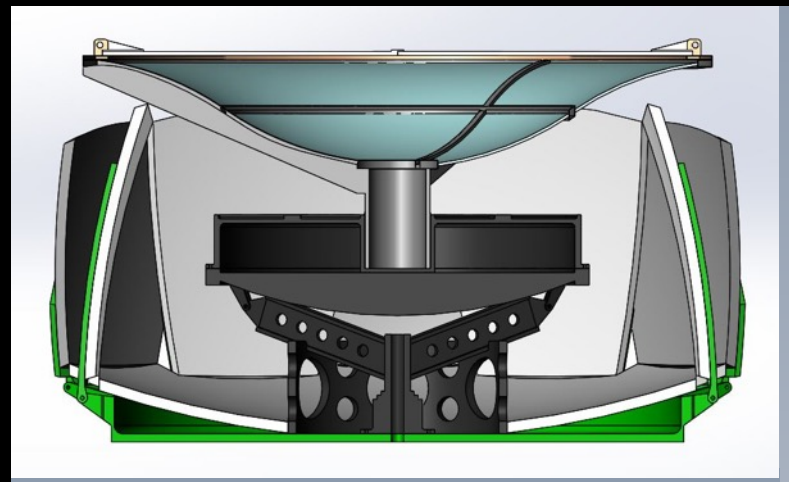
Instrument Design Lab: Jul 31-Aug 4, 2017
Mission Design Lab: Oct 30-Nov 3, 2017

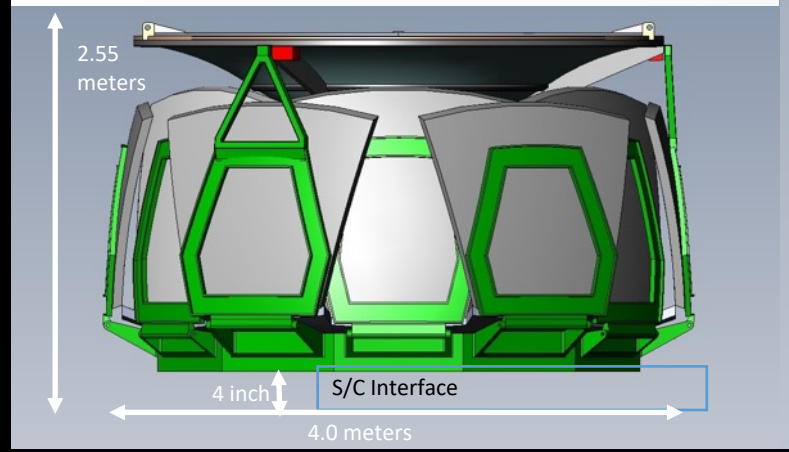


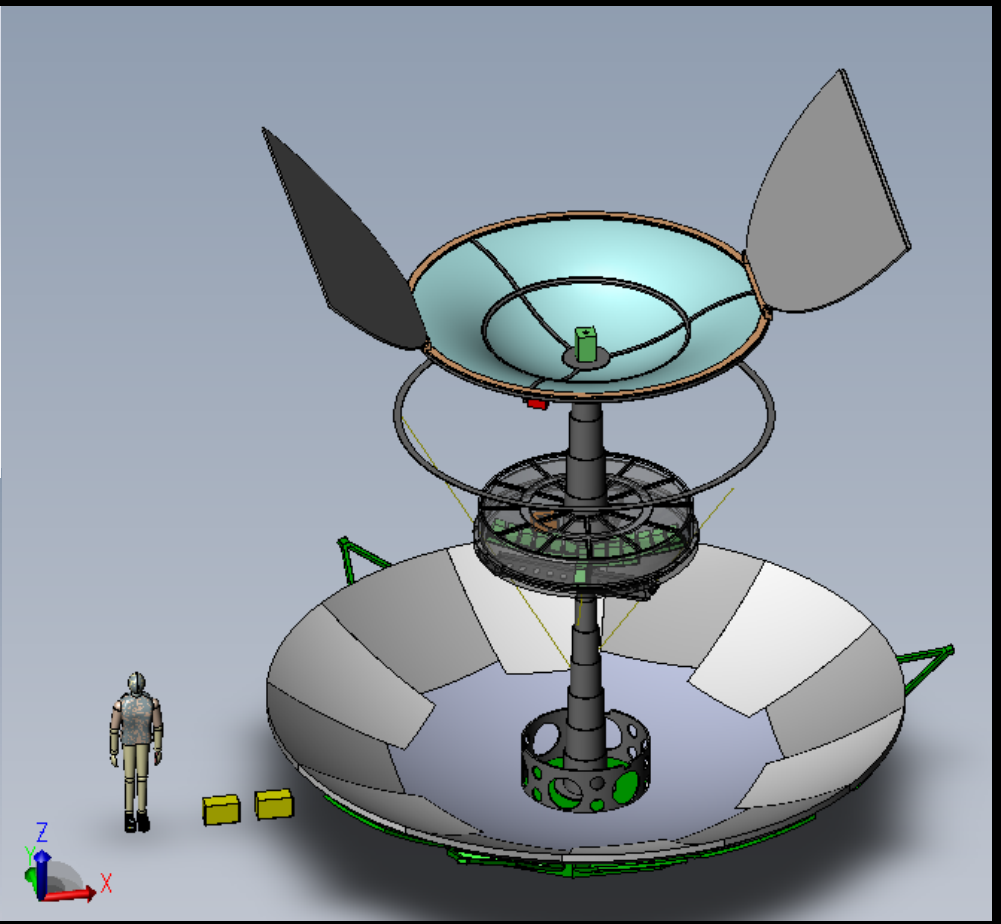




Pre-IDL Design







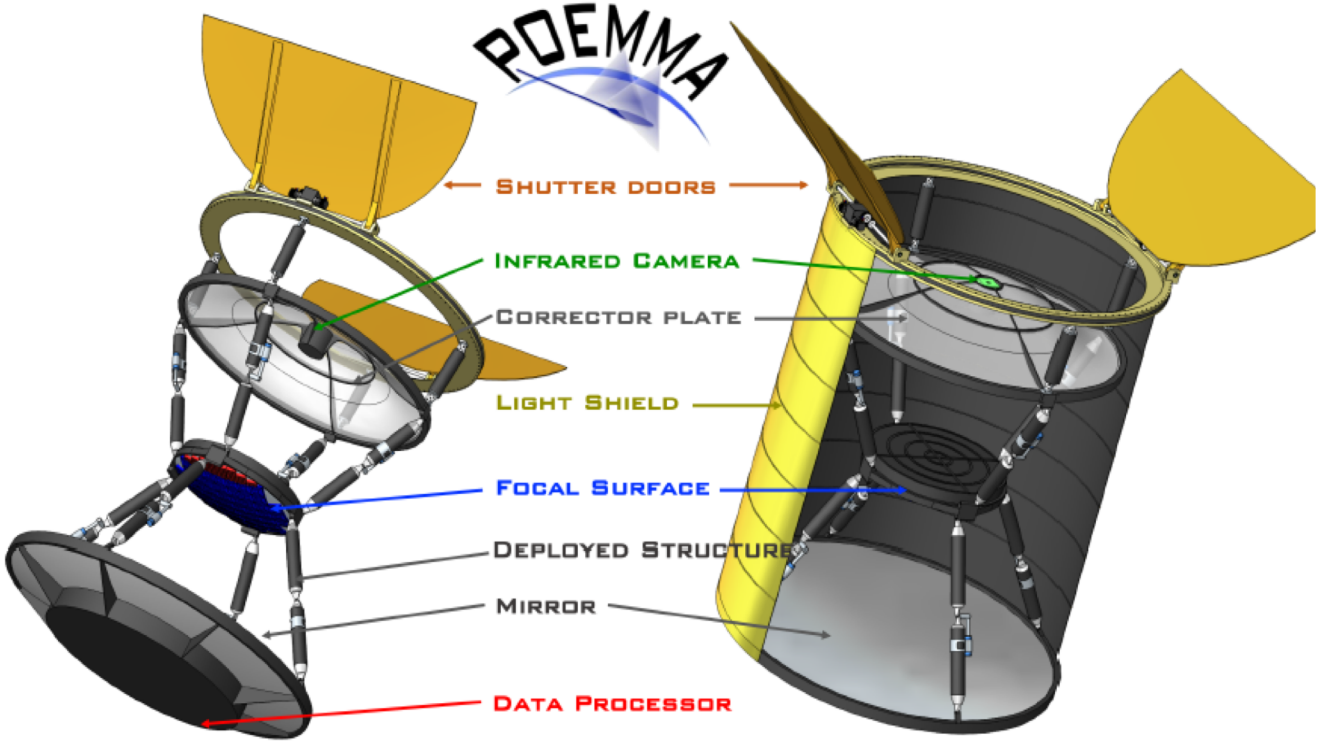
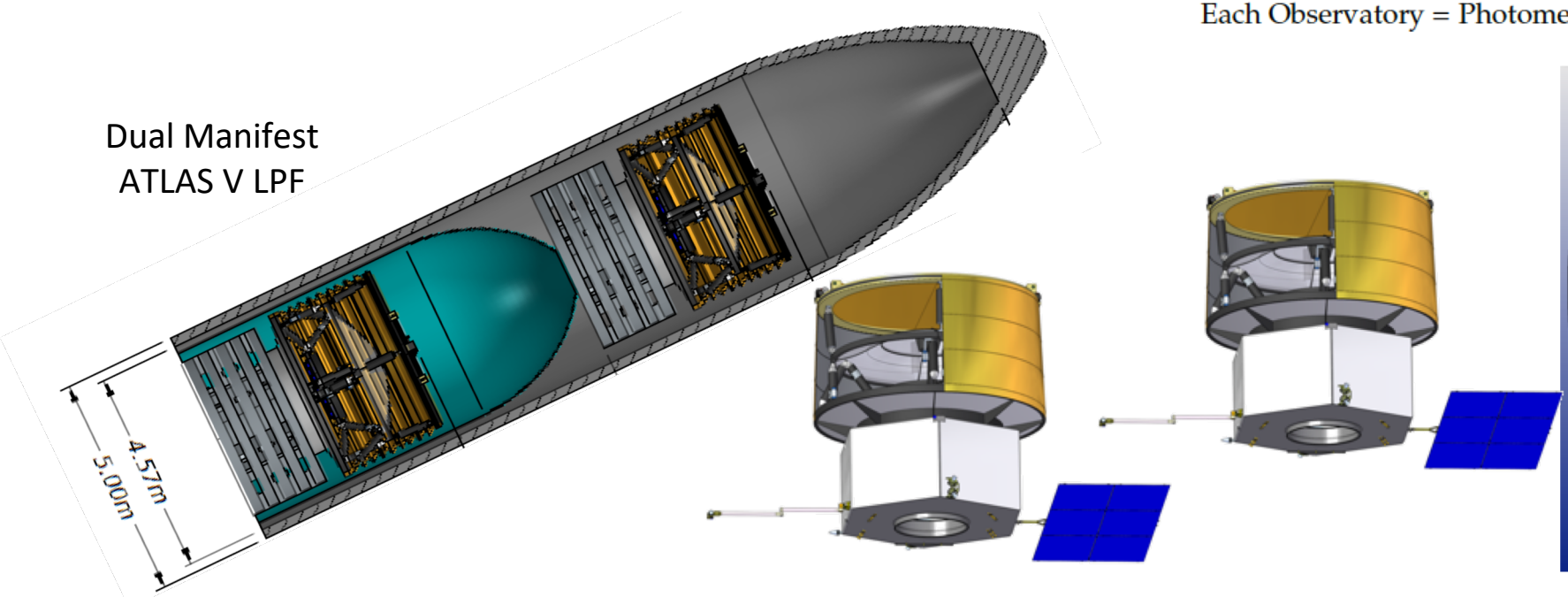


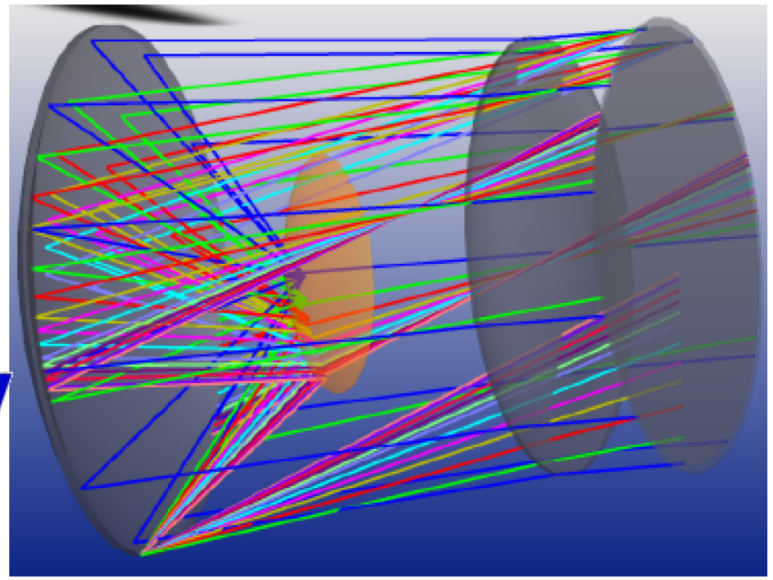
TABLE I: POEMMA Specifications:

Photometer	Components		Spacecraft	
Optics	Schmidt	45° full FoV	Slew rate	90° in 8 min
	Primary Mirror	4 m diam.	Pointing Res.	0.1°
	Corrector Lens	3.3 m diam.	Pointing Know.	0.01°
	Focal Surface	1.6 m diam.	Clock synch.	10 nsec
	Pixel Size	3×3 mm^2	Data Storage	7 days
	Pixel FoV	0.084°	Communication	S-band
PFC	MAPMT (1μs)	126,720 pixels	Wet Mass	3,450 kg
PCC	SiPM (20 ns)	15,360 pixels	Total Power	880 W
Photometer	(One)		Mission	(2 Observatories)
	Mass	1,550 kg	Lifetime	3 year (5 year goal)
	Power	590 W	Orbit	525 km, 28.5° Inc
	Data	< 1 GB/day	Orbit Period	95 min
			Observatory Sep.	~25 - 1000+ km

Each Observatory = Photometer + Spacecraft; POEMMA Mission = 2 Observatories

Dual Manifest
ATLAS V LPF

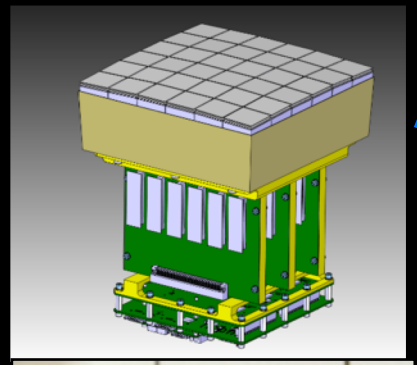


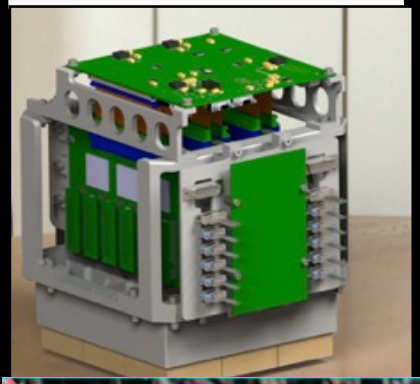


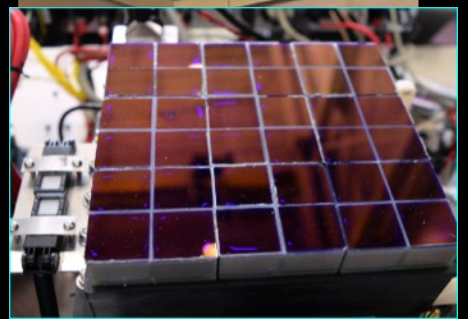
POEMMA

Hybrid Focal Surface

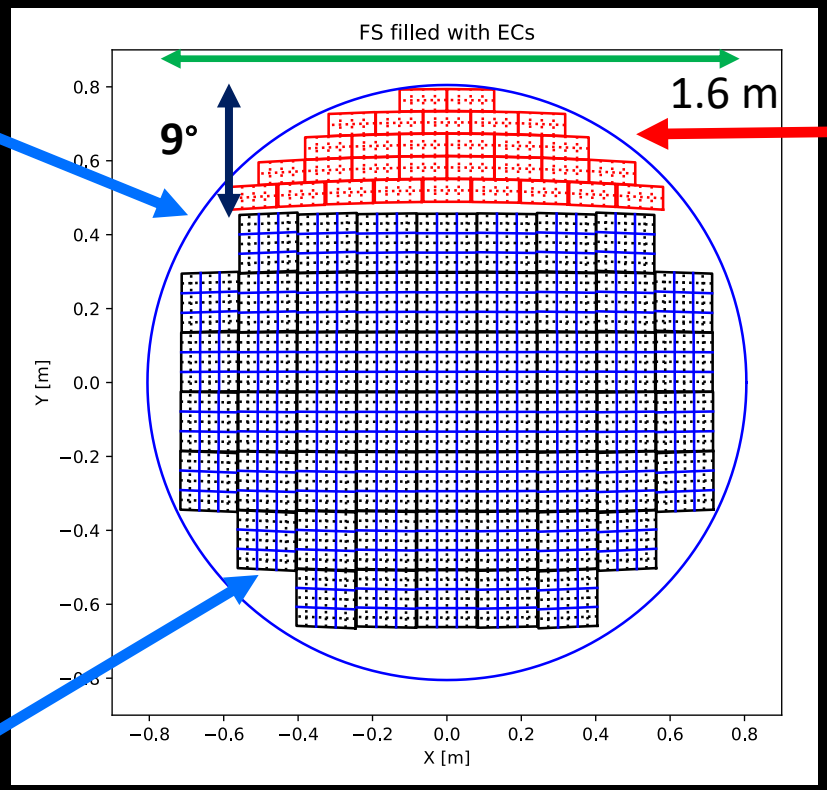
UV Fluorescence
MAPMTs with BG3 filter:
1 usec sampling





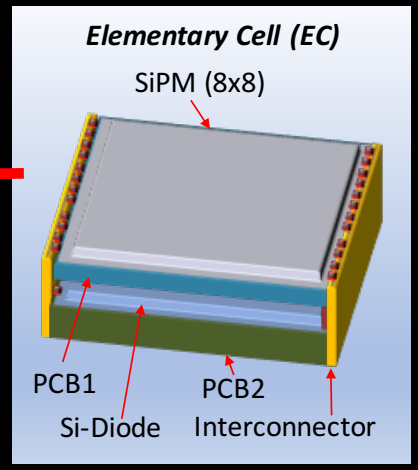


EUSO-SPB2
3 PDMs

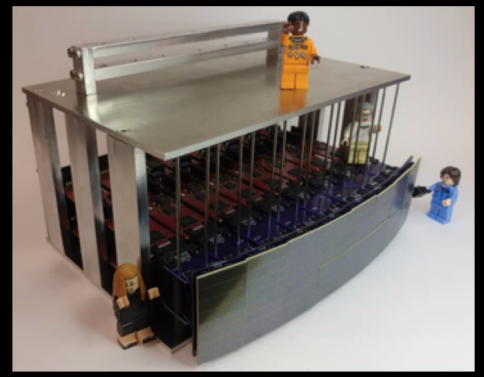


55 Photo Detector Modules (PDMs)
TOTAL 126,720 pixels
(1 PDM = 36 MAPMTs = 2,304 pixels)

Cherenkov Detection
SiPMs:
20 nsec sampling



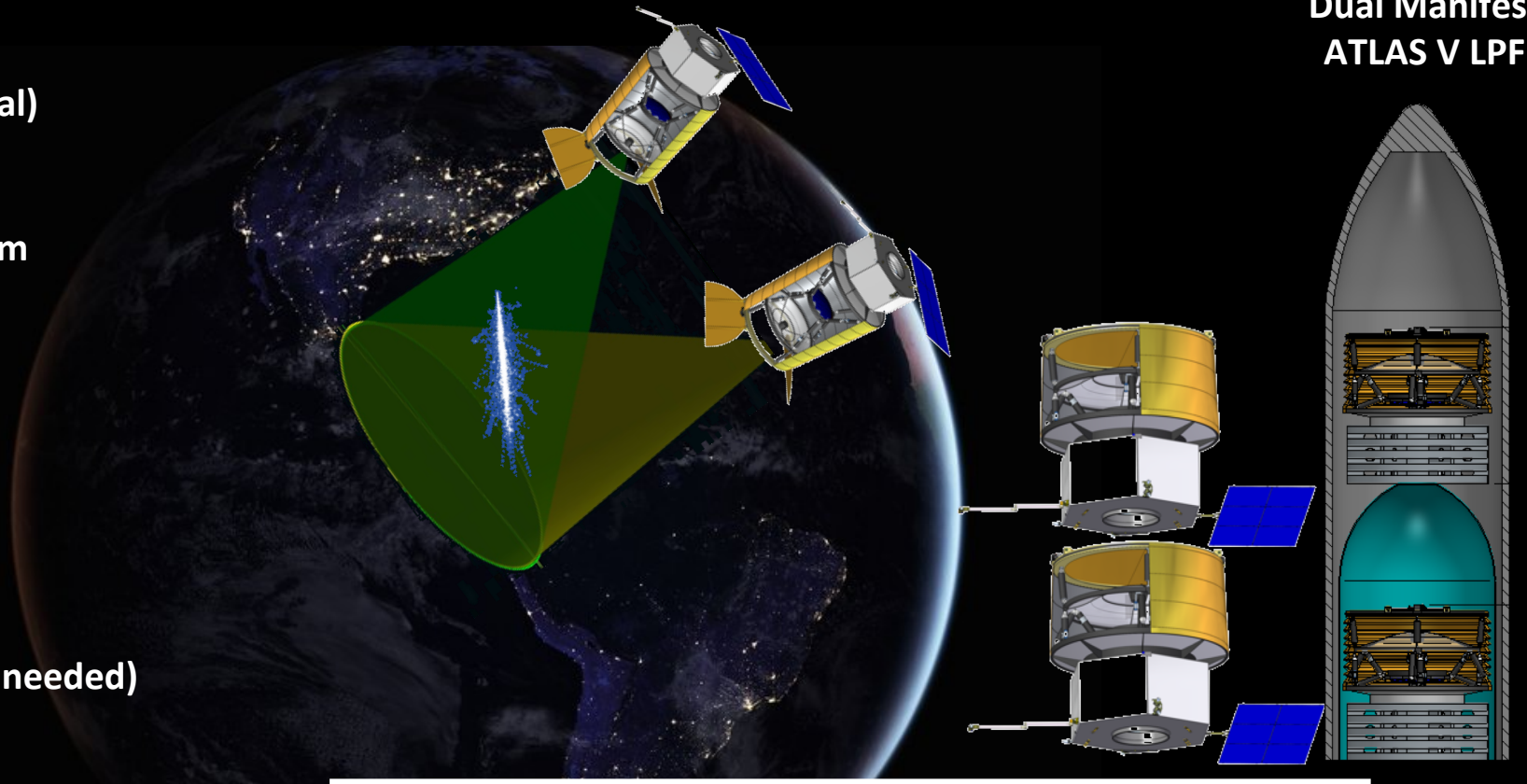
30 SiPM focal surface units
Total 15,360 pixels
512 pixels per FSU (64x4x2)



EUSO-SPB2
Cherenkov
Camera

POEMMA Mission

Mission Lifetime:	3 years (5 year goal)
Orbits:	525 km, 28.5° Inc
Orbit Period:	95 min
Satellite Separation:	~25 km – 1000+ km
Satellite Position:	1 m (knowledge)
Pointing Resolution:	0.1°
Pointing Knowledge:	0.01°
Slew Rate:	8 min for 90 °
Satellite Wet Mass:	3860 kg
Power:	2030 W
Data:	1 GB/day
Data Storage:	7 days
Communication:	S-band (X-band if needed)
Clock synch (timing):	10 nsec

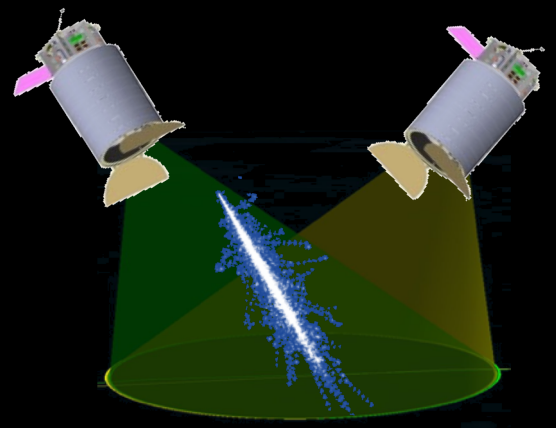


Dual Manifest
ATLAS V LPF

Operations:

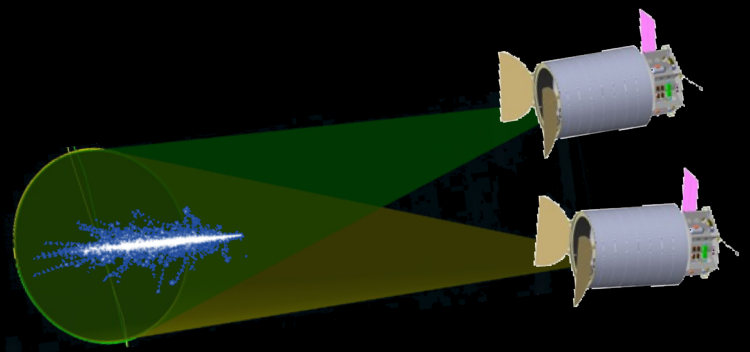
- Each satellite collects data autonomously
- Coincidences analyzed on the ground
- View the Earth at near-moonless nights, charge in day and telemeter data to ground
- ToO Mode: dedicated com uplink to re-orient satellites

Observation Modes	Telescope Separation	Pointing	Science Goals (section)
POEMMA-Stereo (mode-2)	~300 km	down close to Nadir; overlapping atmospheric volumes	**UHECR fluorescence** (2.2, 2.3) precision stereo reconstruction UHECR lower energies 10s EeVs
POEMMA-Limb (mode-3)	~25 km	towards the Limb; azimuth follows ToO target overlapping volume at Limb	**Neutrino Cherenkov** (2.4, 2.5, 2.6) **ToO-stereo**
		towards the Limb; overlapping volume nearby non-overlapping at Limb	**UHECR fluorescence** (2.2, 2.3) stereo reconstruction 10s EeV monocular for 100s EeVs
	~300 km	fast slew towards the Limb from POEMMA-Stereo mode azimuth follows ToO target	**Neutrino Cherenkov** (2.4, 2.5, 2.6) **ToO-dual**



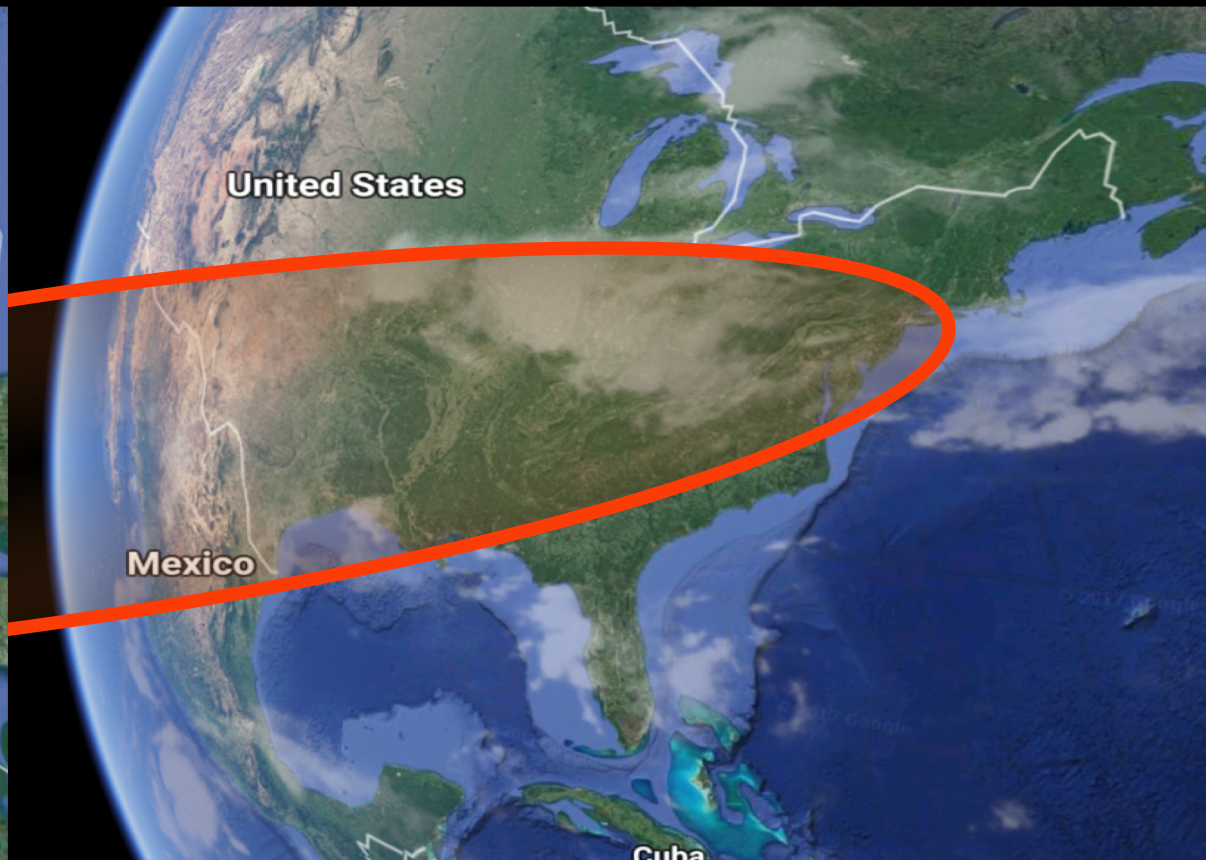
POEMMA

Observing Modes

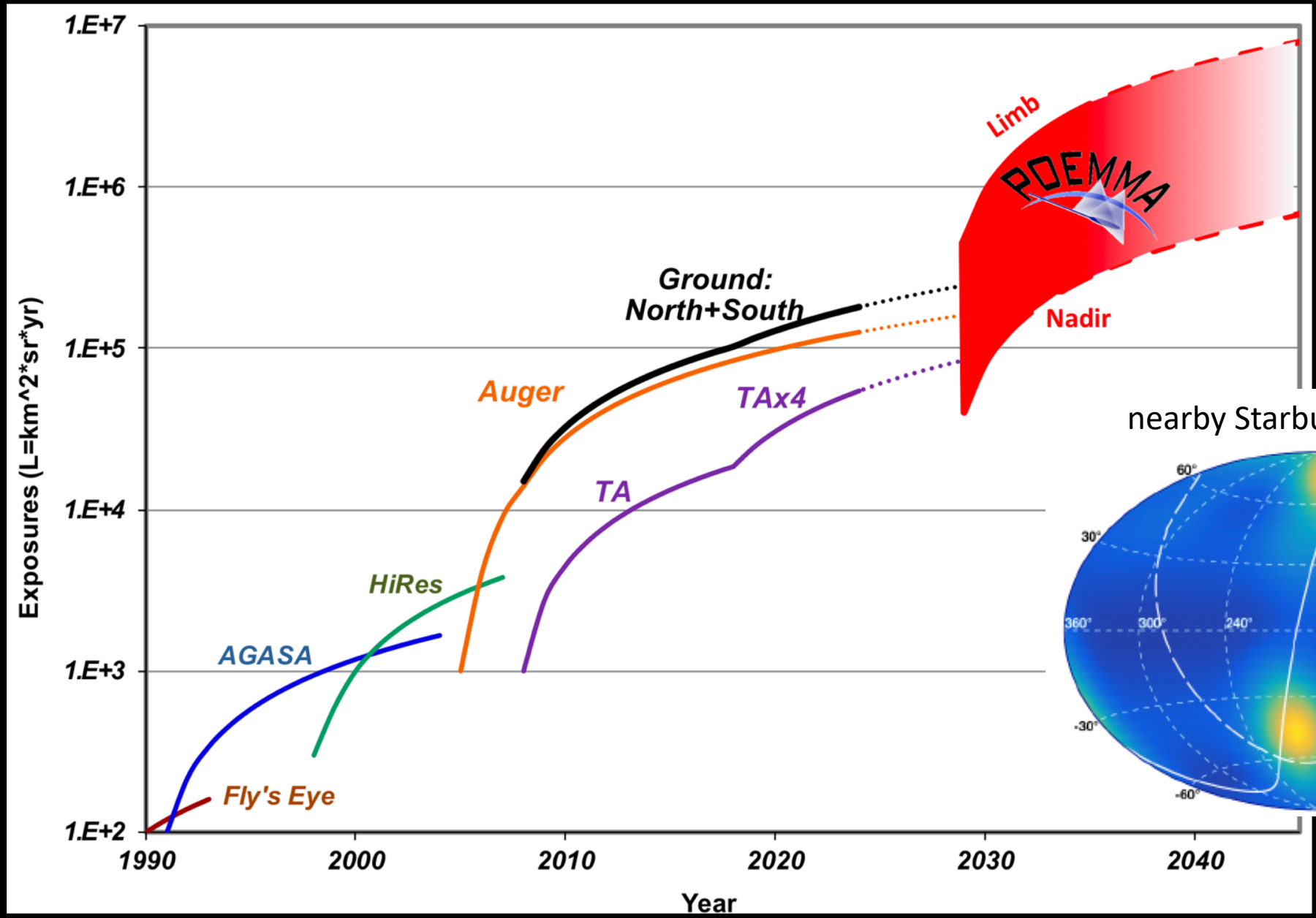


Nadir for UHECR: Radius 200-400 km

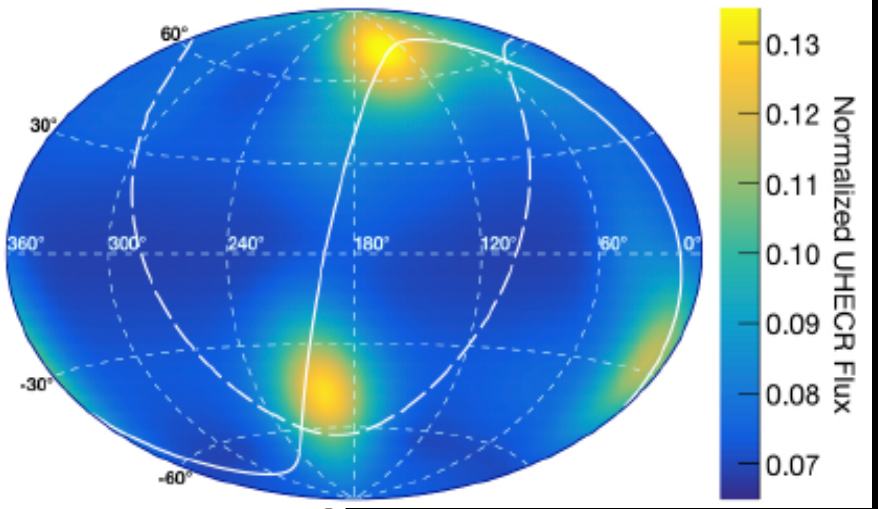
Limb for Neutrinos & UHECRs: Radius 3 10^3 km



POEMMA UHECR Exposure



nearby Starburst Galaxies Fermi-LAT



POEMMA: Neutrinos

Monday, April 19, 2021
S10.00007 : Targets of Opportunity with POEMMA, Tonia Venters, et al.

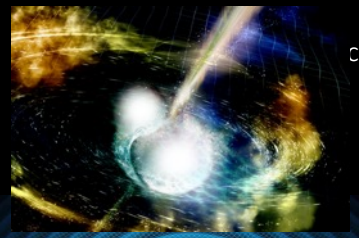
POEMMA designed to observe neutrinos with E > 20 PeV through Cherenkov signal of tau decays.

High-Energy Astrophysical Events generates neutrinos (ν_e,ν_μ) and 3 neutrino flavors reach Earth (Oscillations). Tau neutrinos generate tau leptons on their way out of the Earth's surface which decay producing up-going showers, detected by POEMMA

POEMMA: Neutrino Target of Opportunity

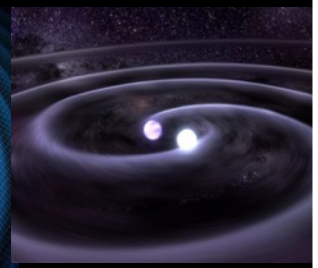
arXiv:1906.07209

Venters et al 2019 **Transient Events - 10s neutrinos/event from 10s of Mpc**



Artist's rep NS-NS merger.
Credit: NSF/LIGO/SSU/A. Simonnet.

Artist's rep WD-WD merger
Credit: Ars Technica

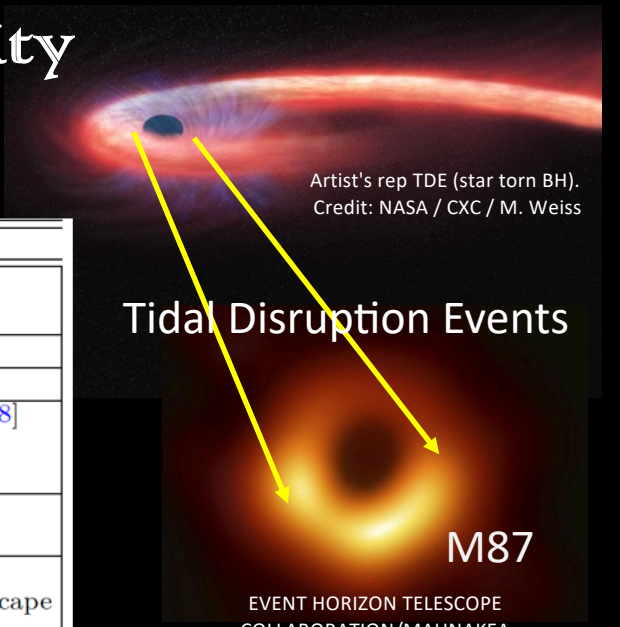


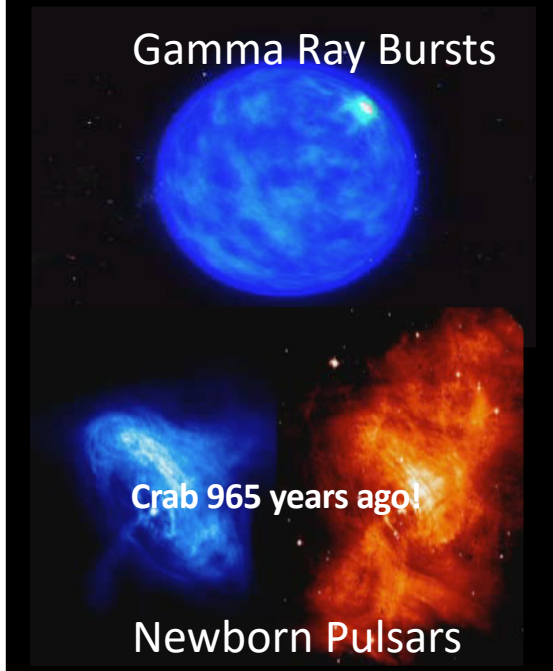
Artist's rep BH-BH merger.
Credit: NASA / JPL/
Swinburne Astron.Prods

Long Bursts				
Source Class	No. of ν's at GC	No. of ν's at 3 Mpc	Largest Distance for 1.0 ν per event	Model Reference
TDEs	1.1×10^5	0.8	3 Mpc	Dai and Fang [17] average
TDEs	5.6×10^5	3.9	6 Mpc	Dai and Fang [17] bright
TDEs	**2.2×10^8**	**1.4×10^3**	**115 Mpc**	**Lunardini and Winter [18] $M_{SMBH} = 5 \times 10^6 M_\odot$ Lumi Scaling Model**
TDEs	*6.3×10^7*	*396*	*62 Mpc*	*Lunardini and Winter [18] Base Scenario*
Blazar Flares	NA*	NA*	43 Mpc	RFGBW [19] – FSRQ proton-dominated advective escape model
lGRB Reverse Shock (ISM)	9.9×10^4	0.7	2 Mpc	Murase [15]
lGRB Reverse Shock (wind)	2.0×10^7	144	37 Mpc	Murase [15]
BH-BH merger	**2.3×10^7**	**160**	**39 Mpc**	**Kotera and Silk [20] (rescaled) Low Fluence**
BH-BH merger	**2.4×10^8**	**1.7×10^3**	**119 Mpc**	**Kotera and Silk [20] (rescaled) High Fluence**
NS-NS merger	**3.6×10^6**	**24.8**	**13 Mpc**	**Fang and Metzger [21]**
WD-WD merger	20.0	0	33 kpc	XMMD [22]
Newly-born Crab-like pulsars (p)	1.6×10^2	1.1×10^{-3}	98 kpc	Fang [23]
Newly-born magnetars (p)	2.1×10^4	0.1	1 Mpc	Fang [23]
Newly-born magnetars (Fe)	4.1×10^4	0.3	2 Mpc	Fang [23]

Short Bursts				
Source Class	No. of ν's at GC	No. of ν's at 3 Mpc	Largest Distance for 1.0 ν per event	Model Reference
sGRB Extended Emission (moderate)	9.0×10^7	6.5×10^2	81 Mpc	KMMK [16]

(*) Not applicable due to a lack of known blazars within 100 Mpc.

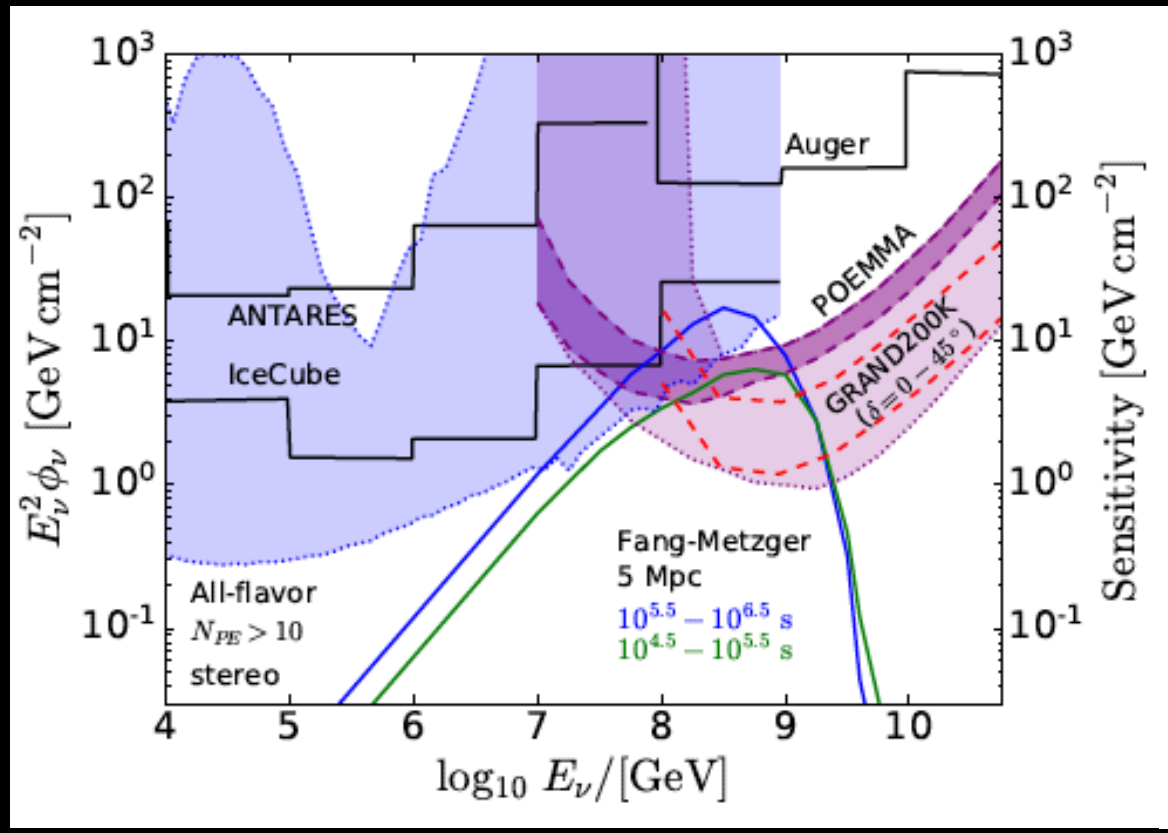




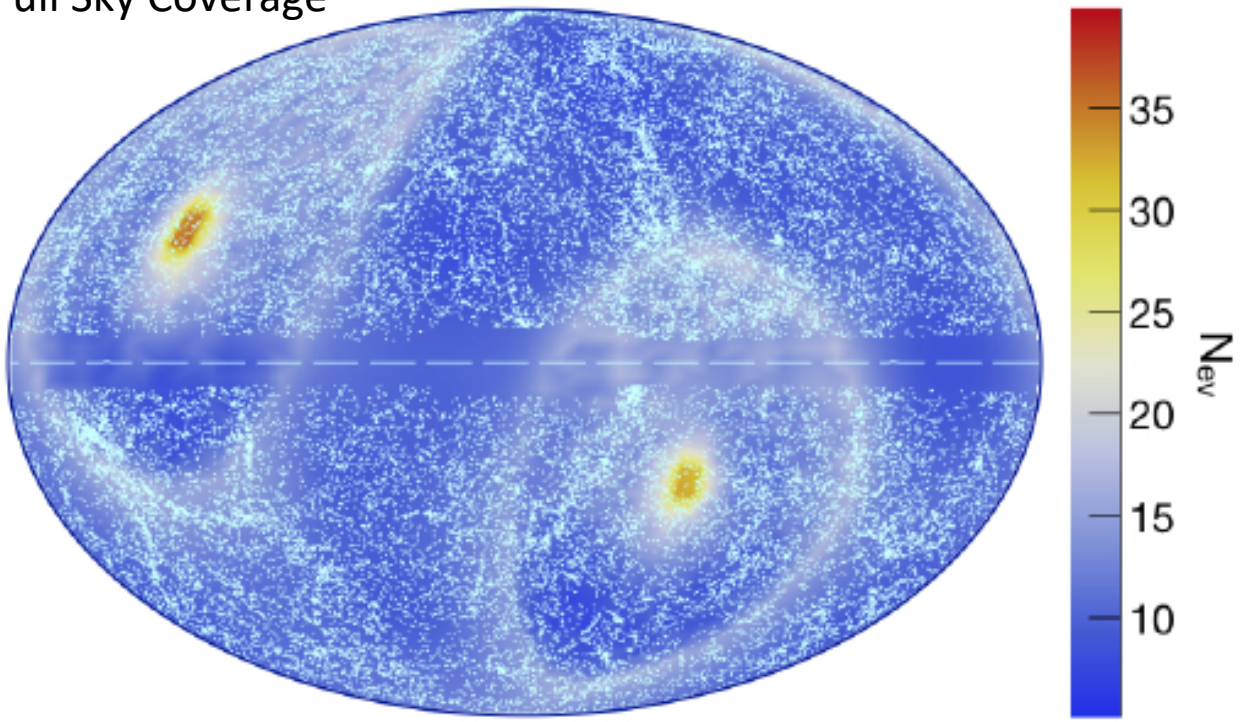
Credits: X-ray: NASA/CXC/ASU/J.Hester et al.;
Optical: NASA/HST/ASU/J.Hester et al.

Transient Neutrino Point Source Sensitivity

Long Bursts



Full Sky Coverage

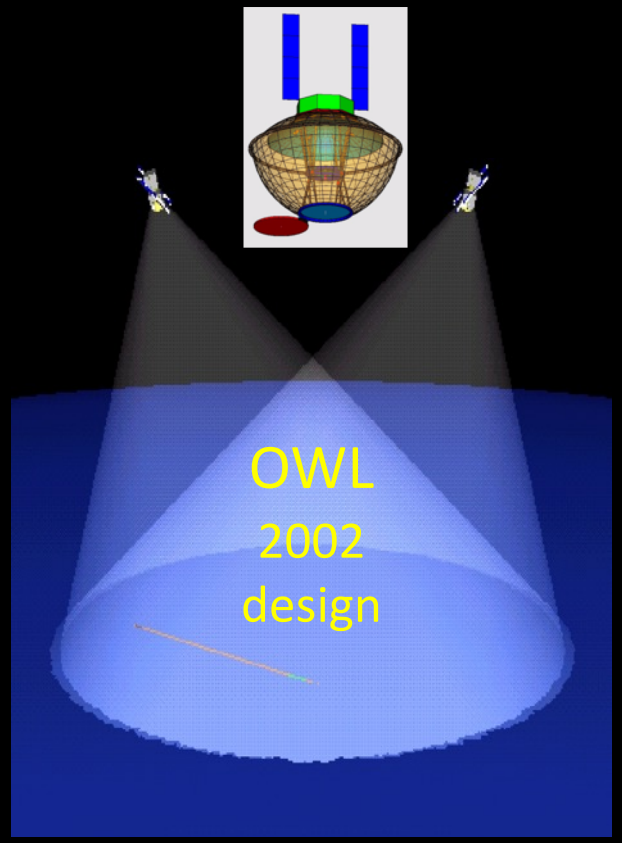


Fang & Metzger, arXiv:1707.04263

Venters et al. arXiv:1906.07209 and AVO et al. arXiv:2012.0794

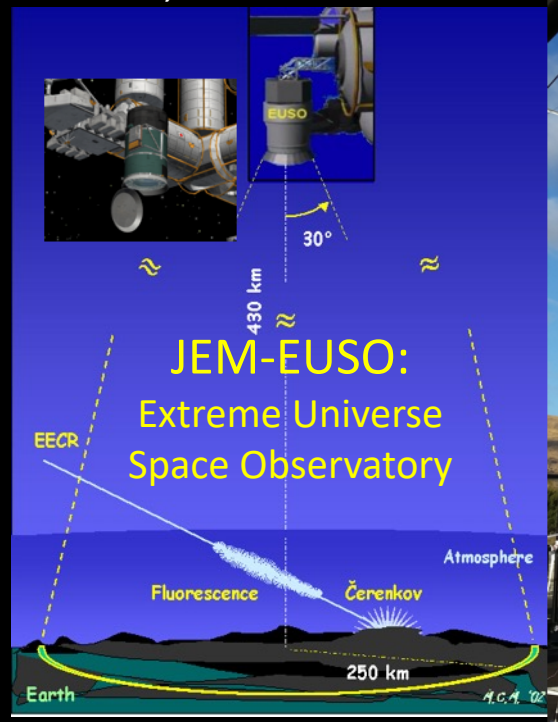
POEMMA Predecessors

Based on OWL 2002 study, JEM-EUSO, EUSO balloon & SPB experience, and CHANT proposal



rbiting
ide-angle
ight-collectors

TUS, KLYPVE-EUSO

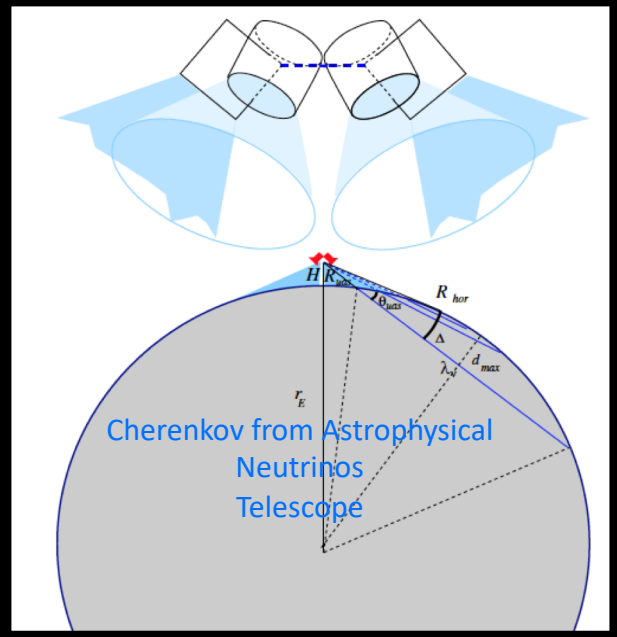


EUSO-Balloon
EUSO@TA
Mini-EUSO

EUSO-SPB1

EUSO-SPB2

CHANT



JEM-EUSO program

Joint Experiment Missions
Extreme Universe Space Observatory

EUSO-TA (2013-)

EUSO-Balloon (2014)

EUSO-SPB1 (2017)

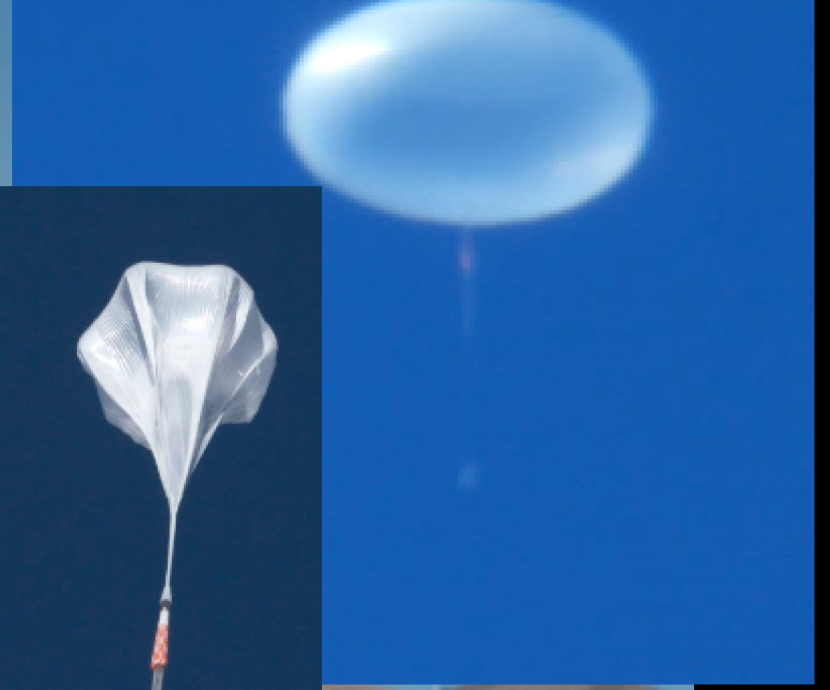
Mini-EUSO (2019)

EUSO-SPB2 (2023)

K-EUSO (2024+)

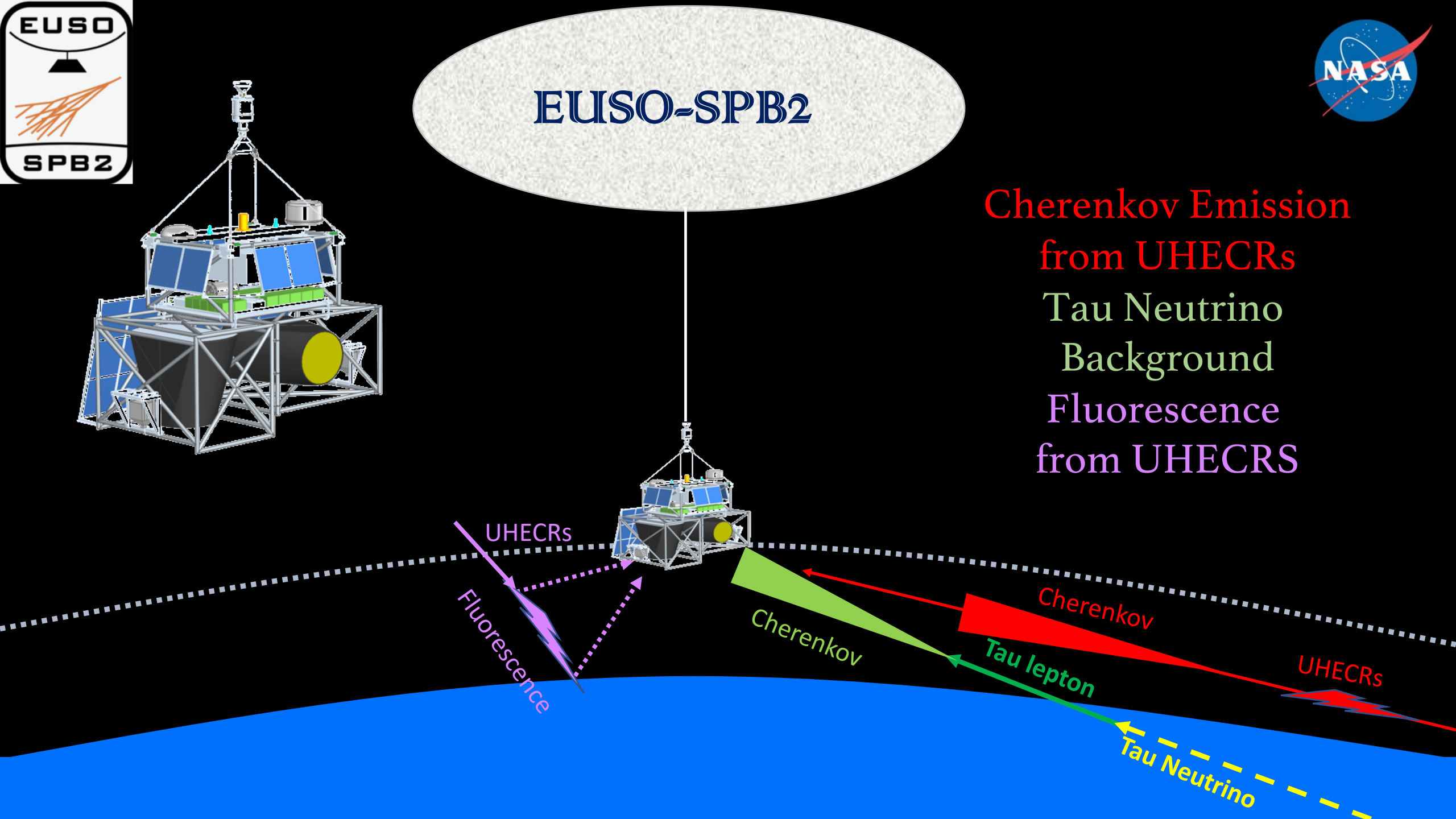
POEMMA (2028+)

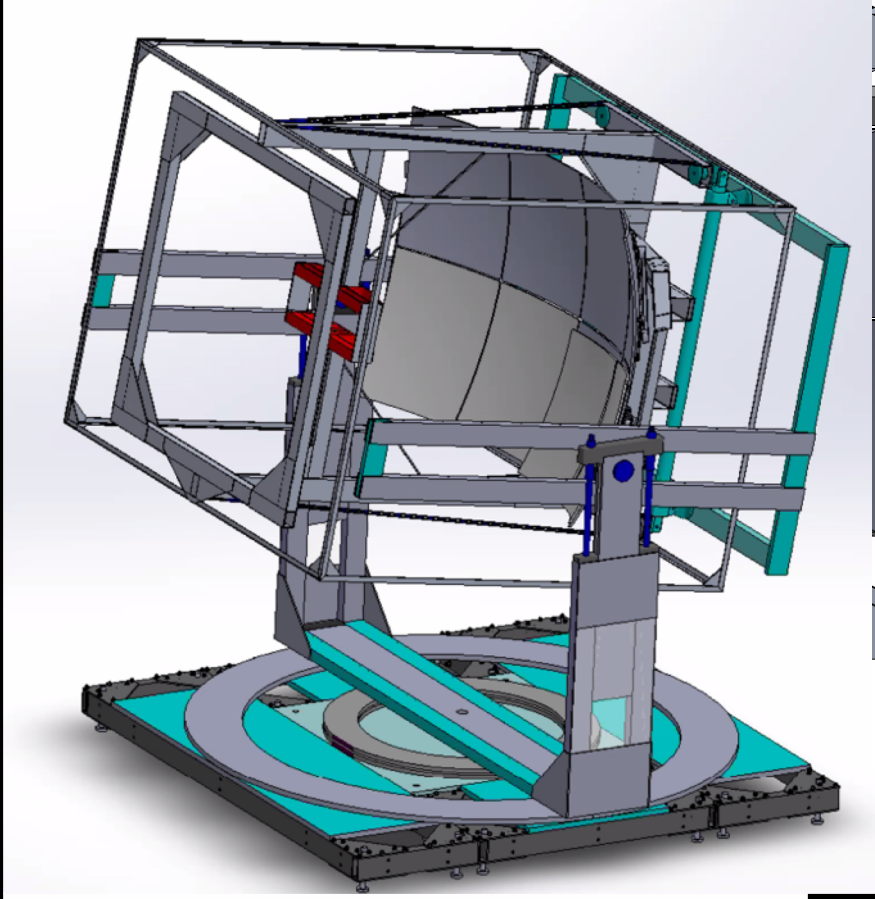
EUSO-SPB Extreme Universe Space Observatory on a Super Pressure Balloon



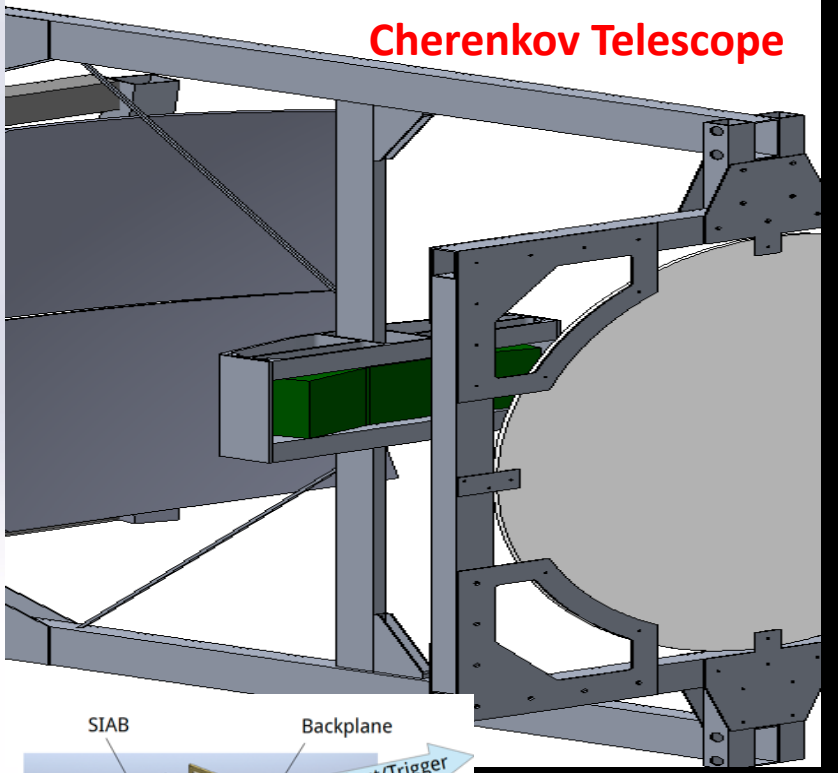
EUSO-SPB
launch,
April 24,
2017
23:51 UTC


Планета Королёва — «УФ атмосфера»
РОСКОСМОС
ЭНЕРГИЯ
МИРА
Планета Королёва

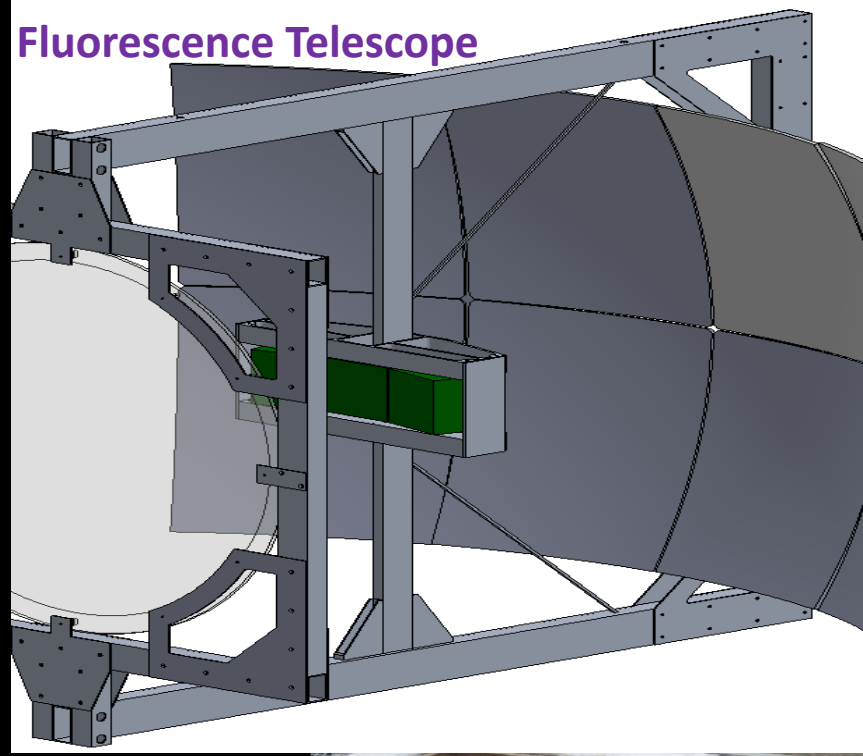

EUSO
SPB2
EUSO-SPB2
NASA
Cherenkov Emission
from UHECRs
Tau Neutrino
Background
Fluorescence
from UHECRS
UHECRs
Fluorescence
Cherenkov
Cherenkov
Tau lepton
UHECRs
Tau Neutrino

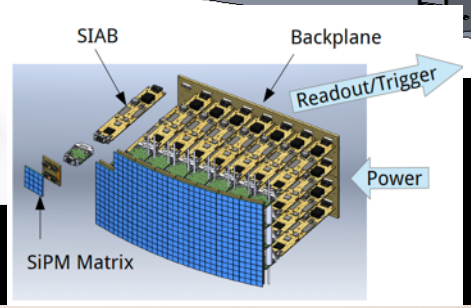


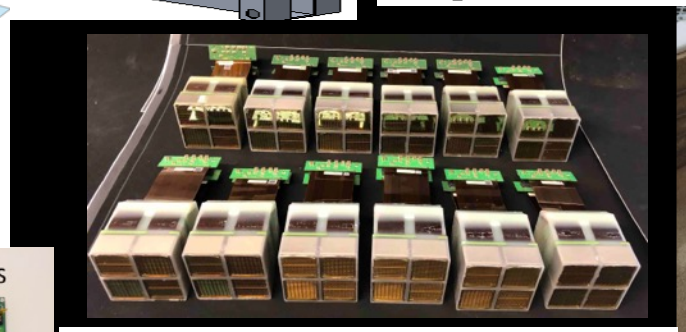
Cherenkov Telescope

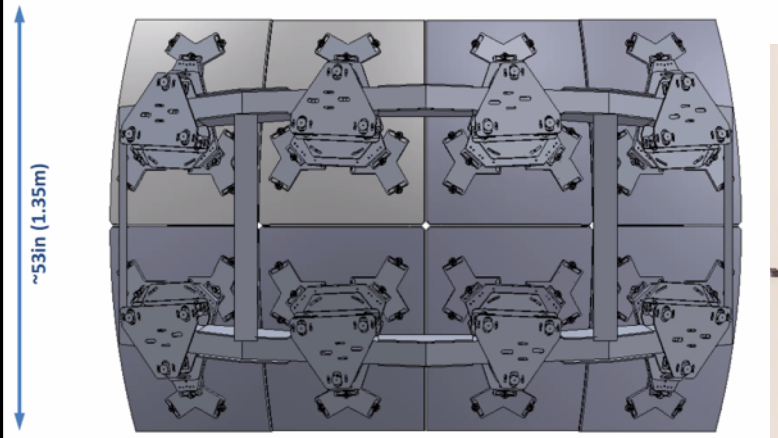


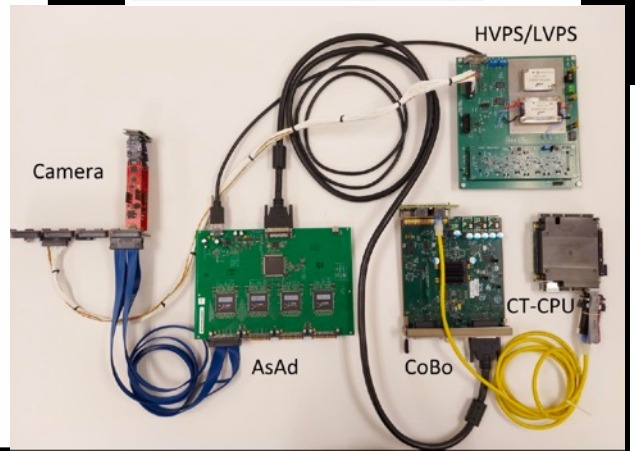
Fluorescence Telescope



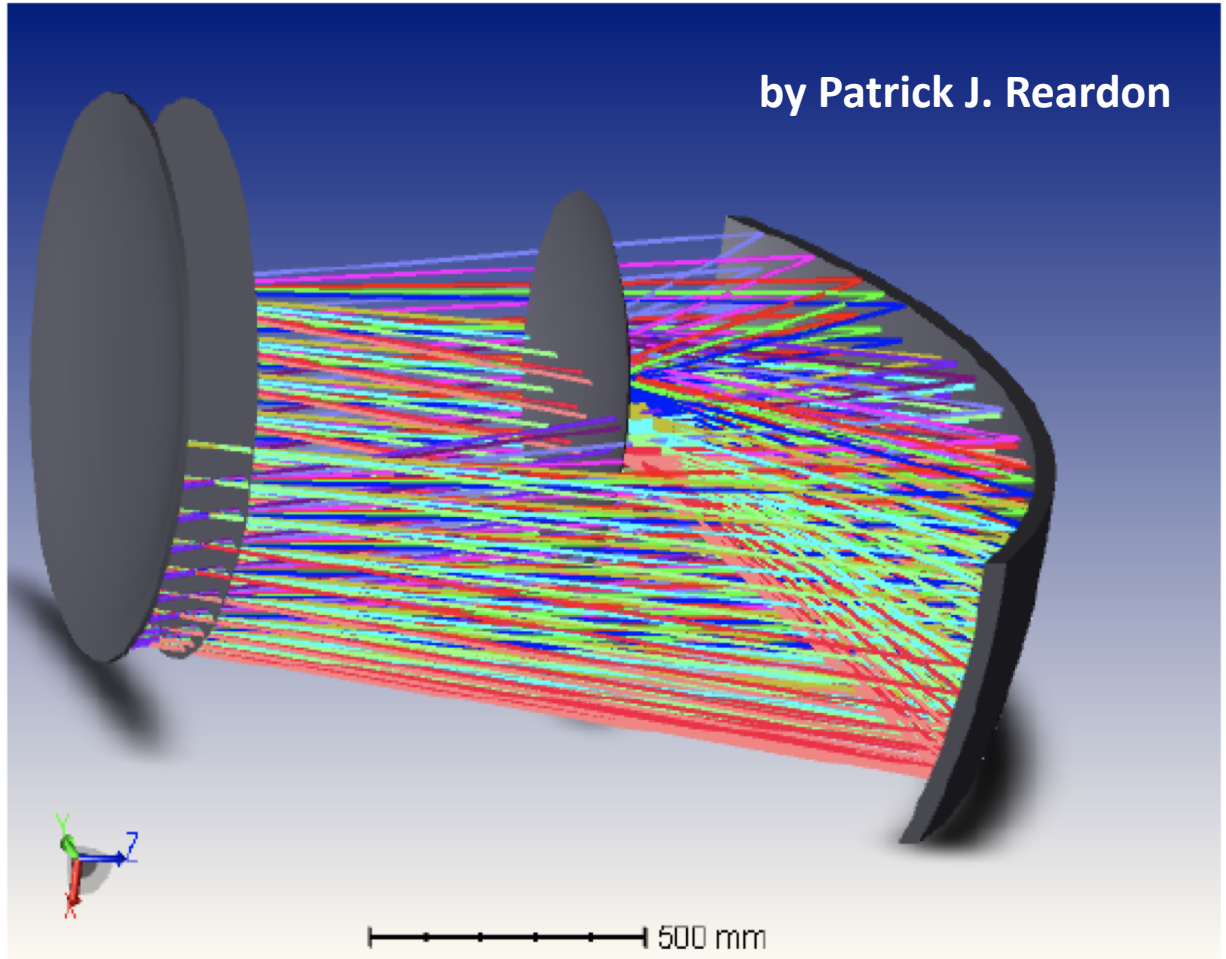








Bifocal Design



Cherenkov Telescopes

FoV 5◦ X 45◦ bi-focal mirror

FoV 5◦ X 45◦ normal mirror

Focal Surface

7cm x 70cm

Fluorescence Telescope

FoV 15◦ X 45◦ normal mirror

Corrector Plate: $1m^2$

Image resolution: ~ few mm

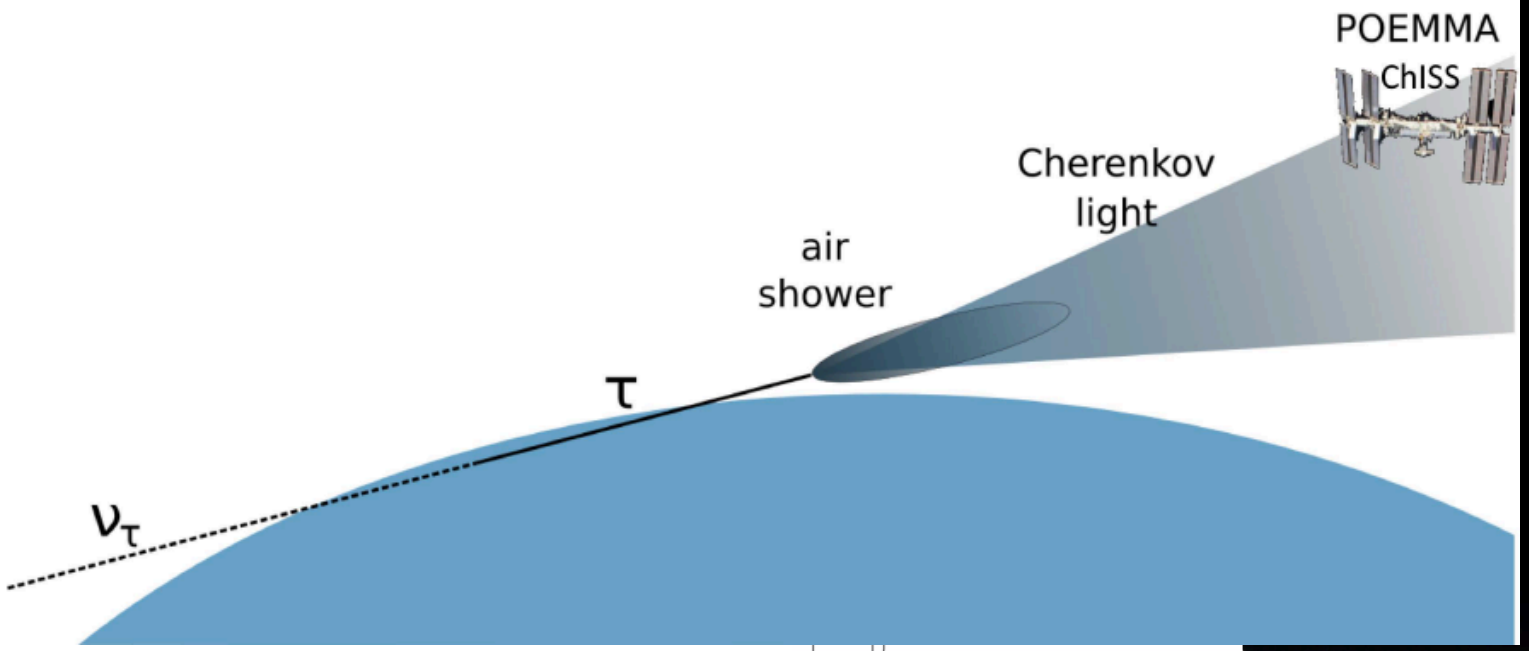
Pixel size: ~3mm square

Challenges/Opportunities:

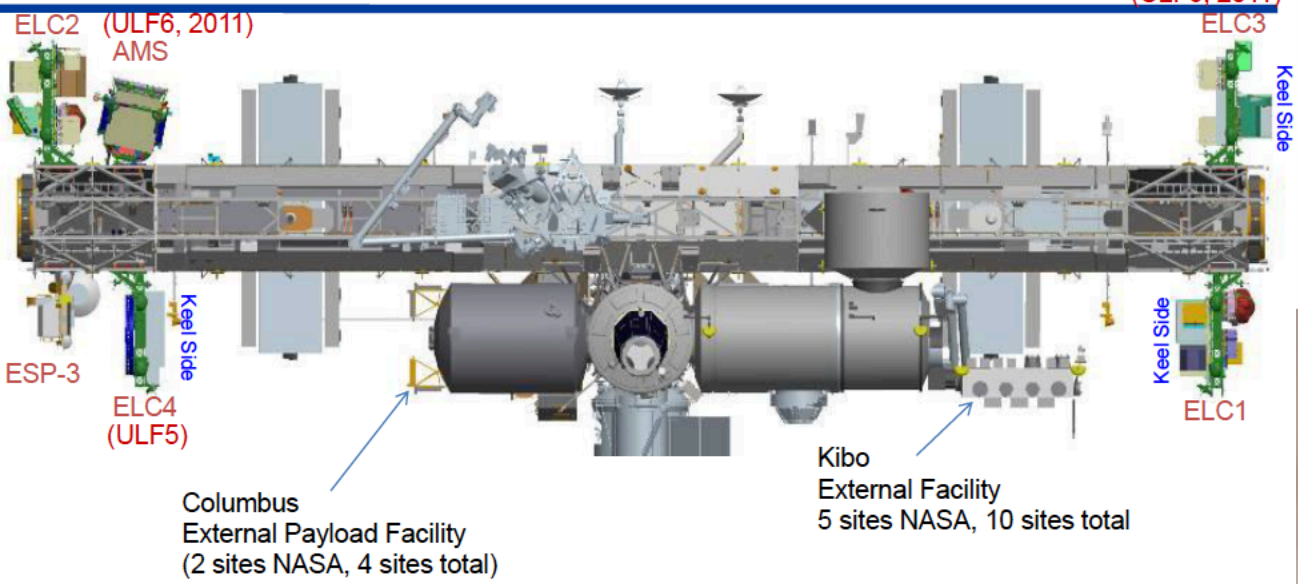
Space qualified SiPMs, ultra-fast ASICs, corrector lens development, bifocal mirror

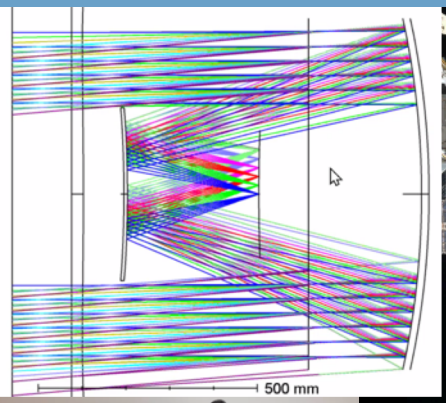
SPB stability

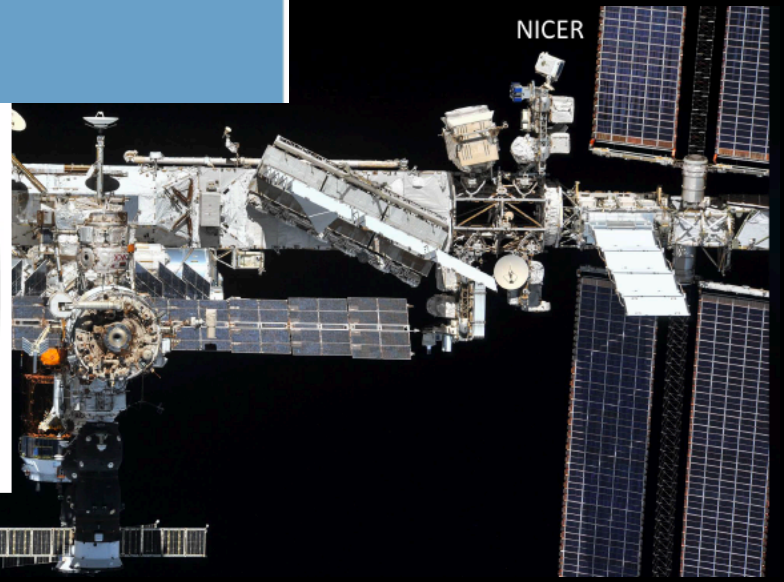
POEMMA-ChISS: POEMMA Cherenkov on the ISS



International Space Station (ISS) External Research Facilities







EUSO-SPB2 Cherenkov Camera

Astroparticle Physics Questions:

What are the sources of the **Ultra-High Energy Cosmic Rays** (UHECRs)?

Measure Spectrum, Composition, Anisotropies $E>10^{19}$ eV = 10 EeV

What are the sources of **Astrophysical Neutrinos**?

Multi-Messenger coincidence gamma-ray, gravitational waves, and neutrinos with
$E>10^{16}$ eV = 10 PeV

What is the physics and astrophysics at energies >> "ground-based" accelerators? Are there New Interactions or Dark Matter signatures (e.g., Secret Neutrino Interactions, Extra-Dimensions, Supermassive Dark Matter, Macroscopic Dark Matter)?

POEMMA

UHECR and Neutrino Observations

Earth's Atmosphere = Particle Observatory to discover the Origin of the Highest Energy Cosmic Rays ($E>10^{19}$ eV) and High Energy Neutrino Emission ($E>10^{16}$ eV) from Astrophysical Events and Study New Astro/Physics