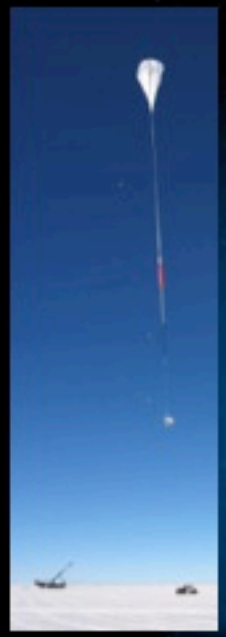
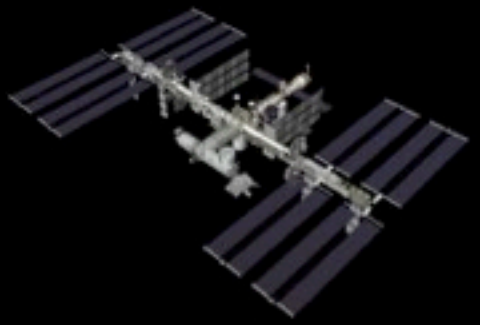
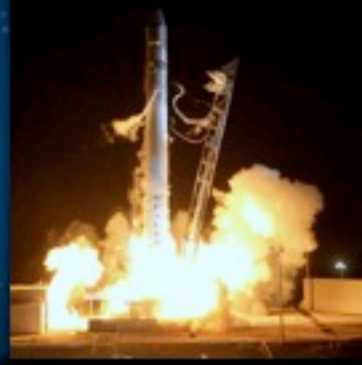
Unveiling the Origin of Cosmic Rays







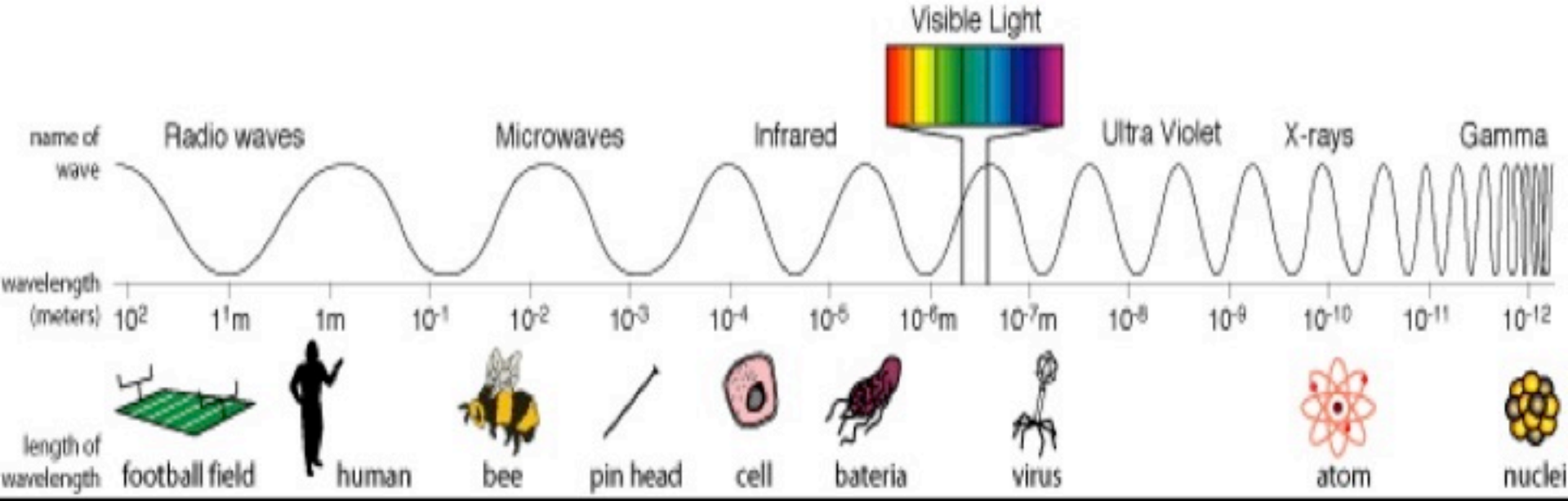
Angela V. Olinto
University of Chicago

APS meeting 4/14/15

Cosmic Ray Science

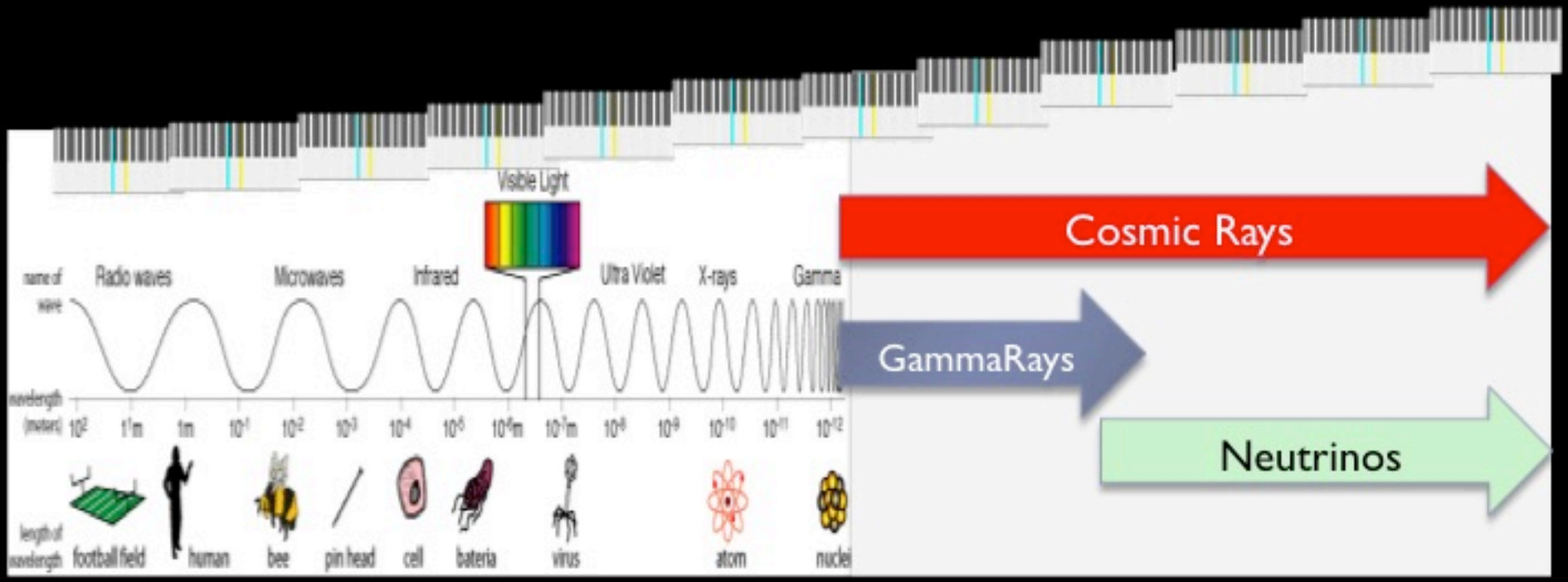
- Cosmic Sessions at APS april 2015
  - **Session Y9: Invited Session: New Results on Cosmic Rays** (Apr 14 2015 1:30PM, Key 5): DM indirect, HAWC, TA
  - Session S14 Missions and Instruments II (Cosmic Rays and Neutrinos)
  - Session K14 High Energy Cosmic Rays
  - Session M14 General Cosmic Rays
  - Session C14 Low Energy Cosmic Rays
  - Session H9 Invited Session: Astrophysical and Cosmological Neutrinos

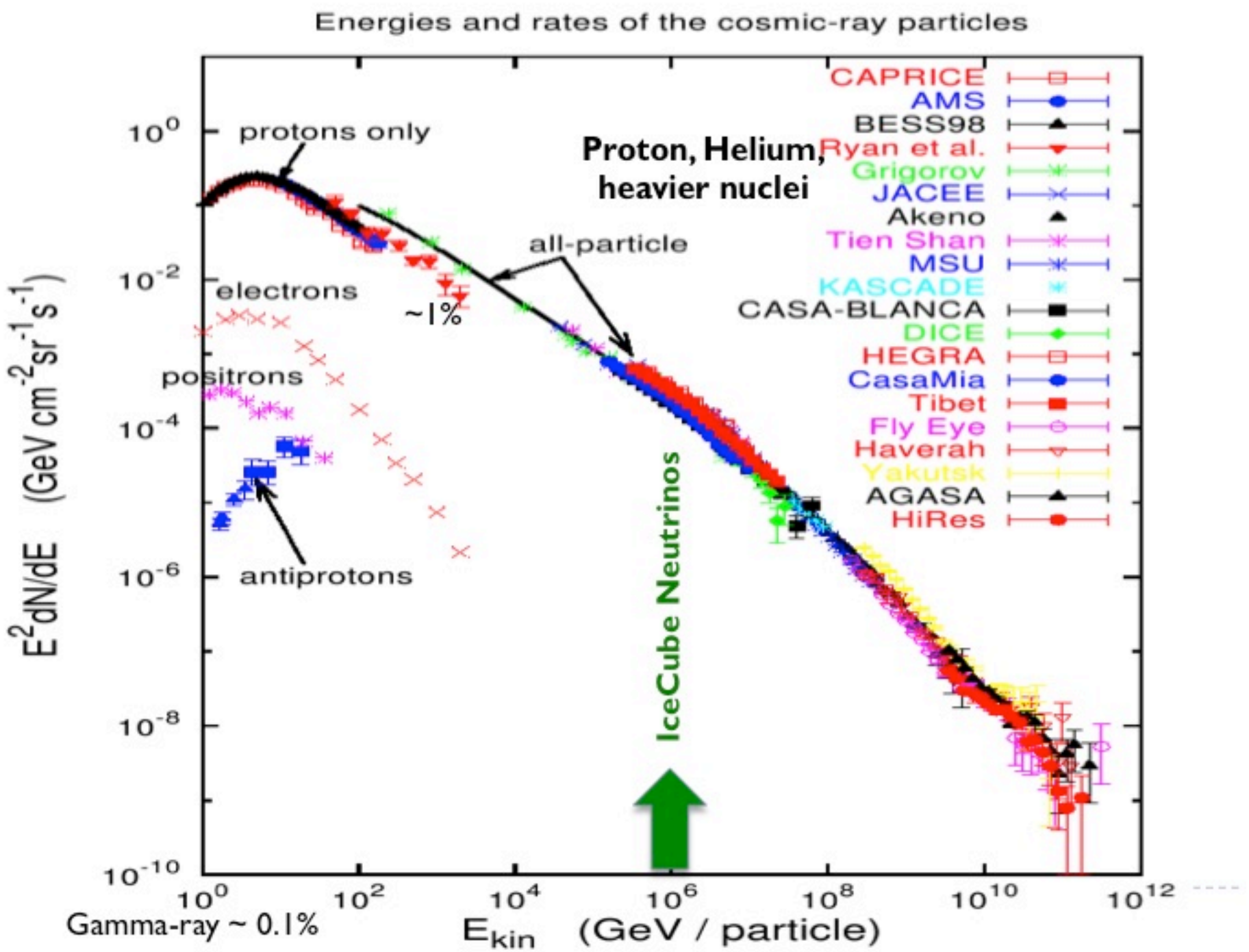
Photon "energy range"

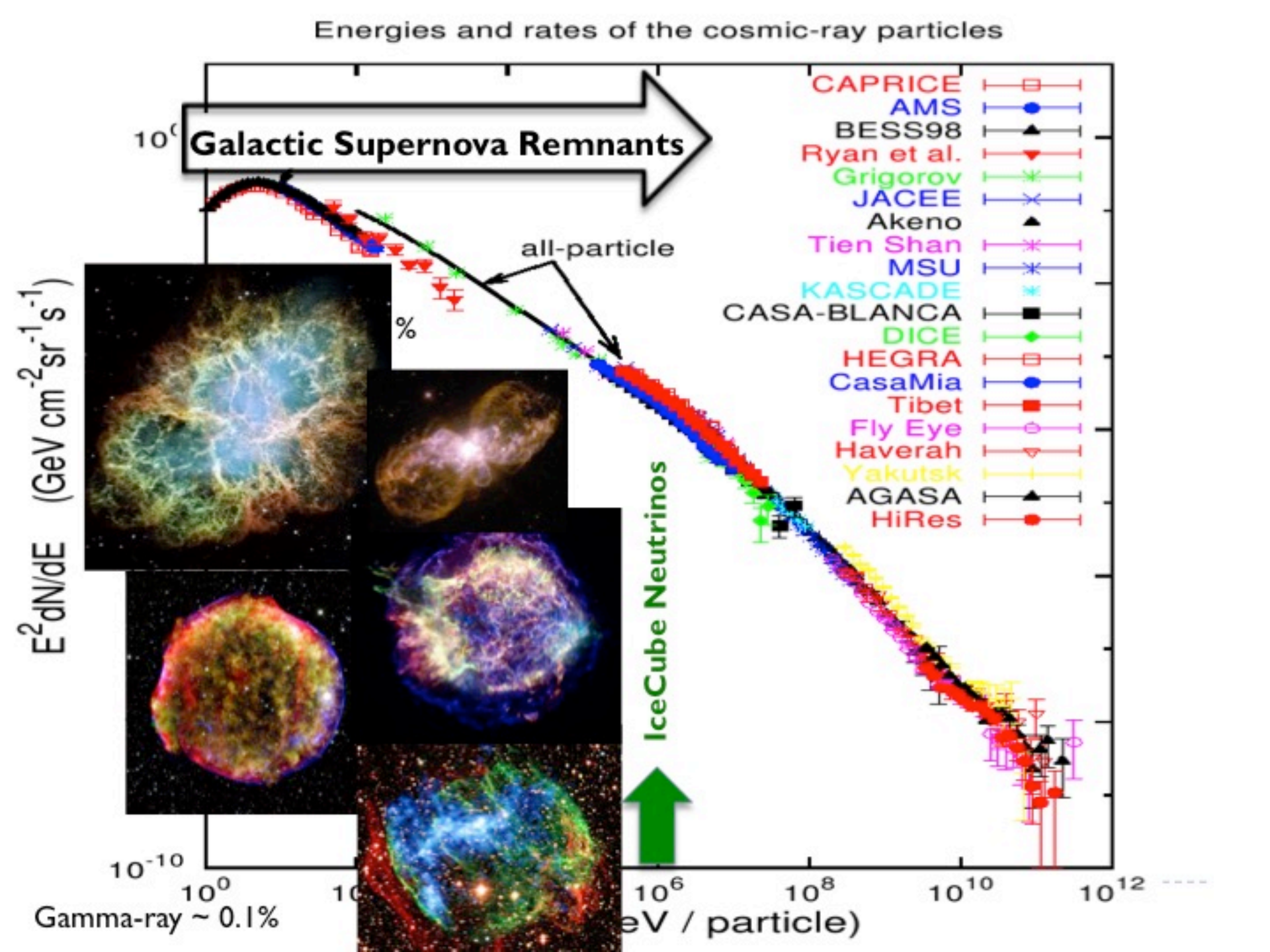


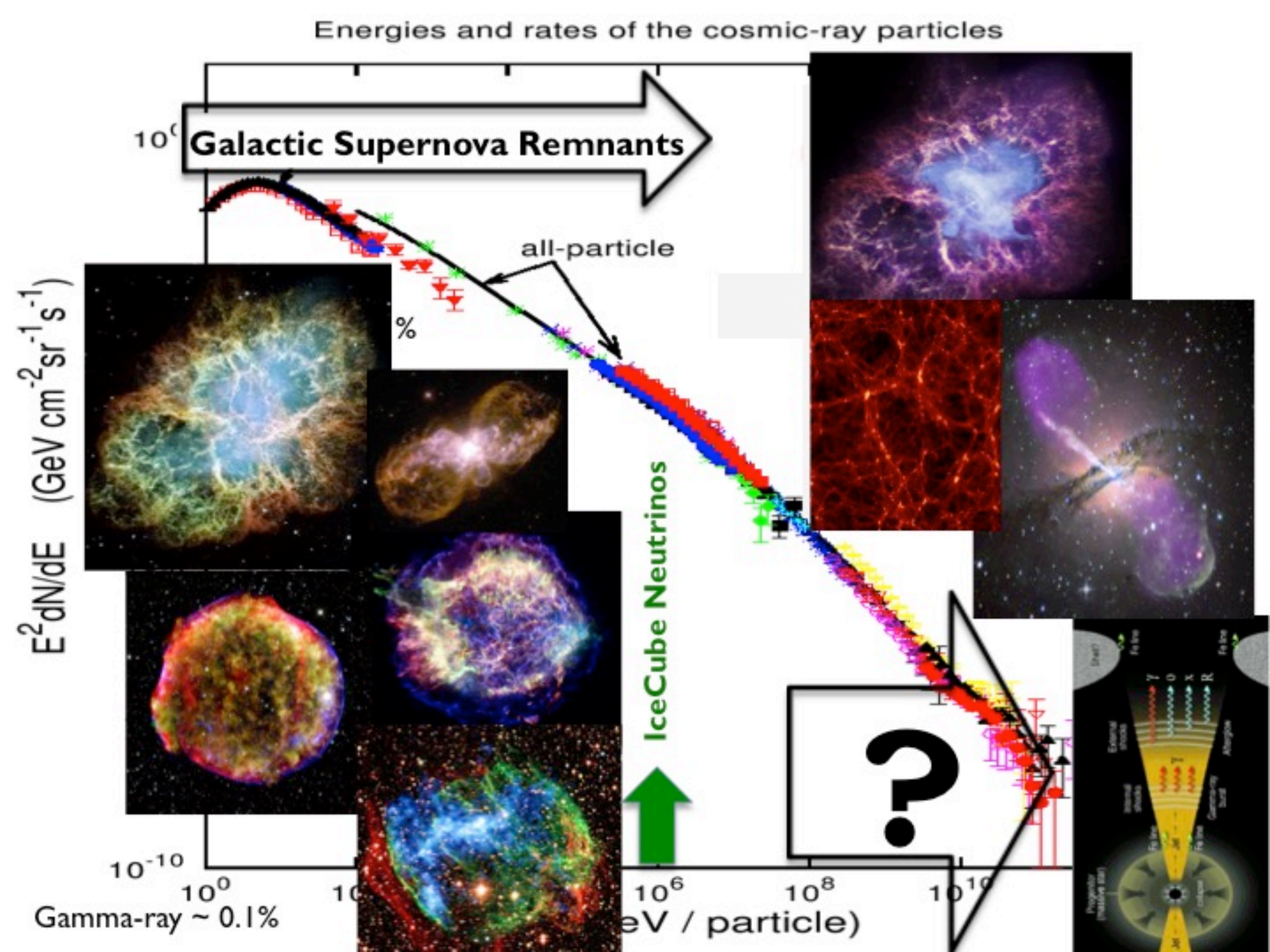
Multi-messengers of the Cosmic **Extreme Environments**

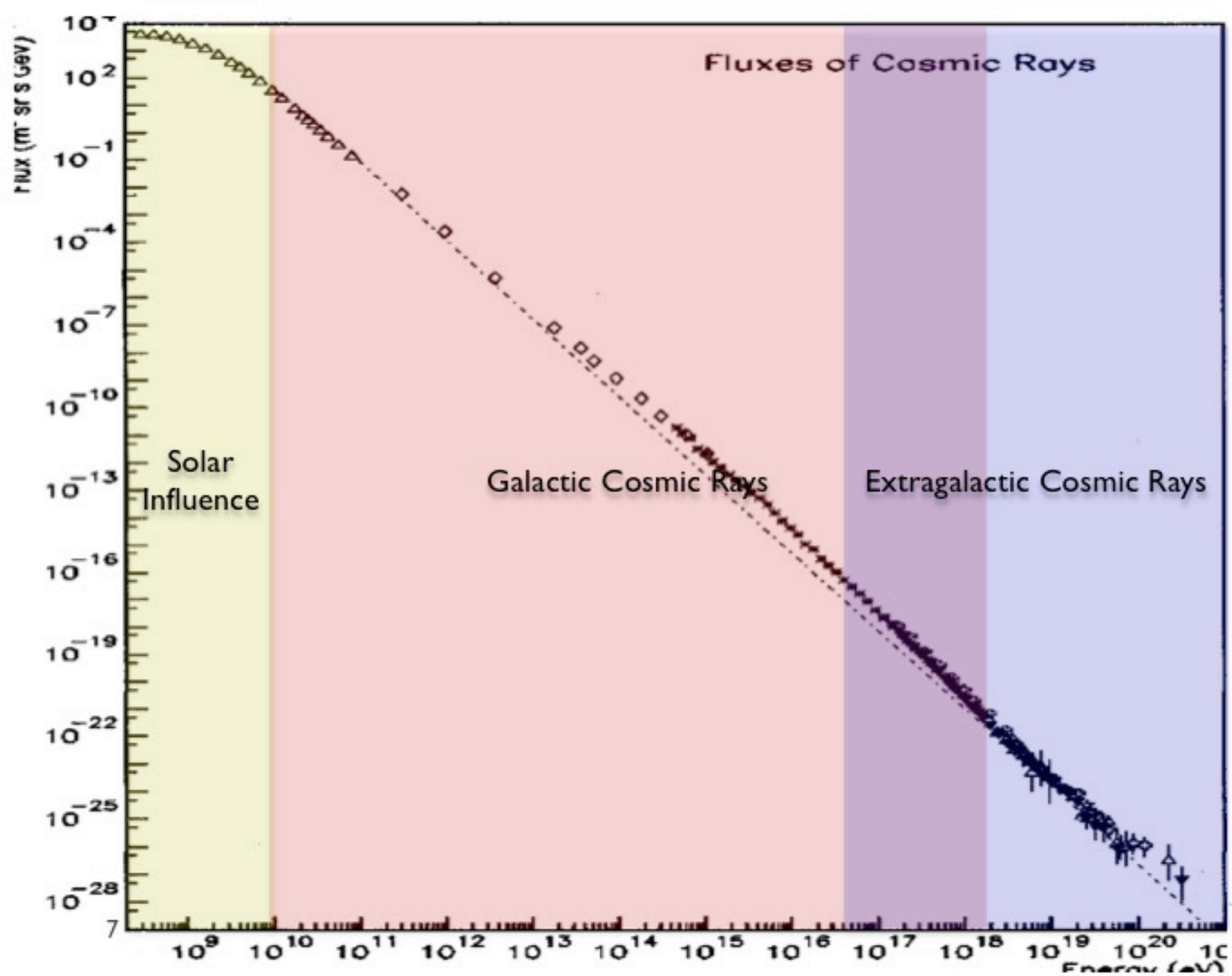
~ doubles the energy range

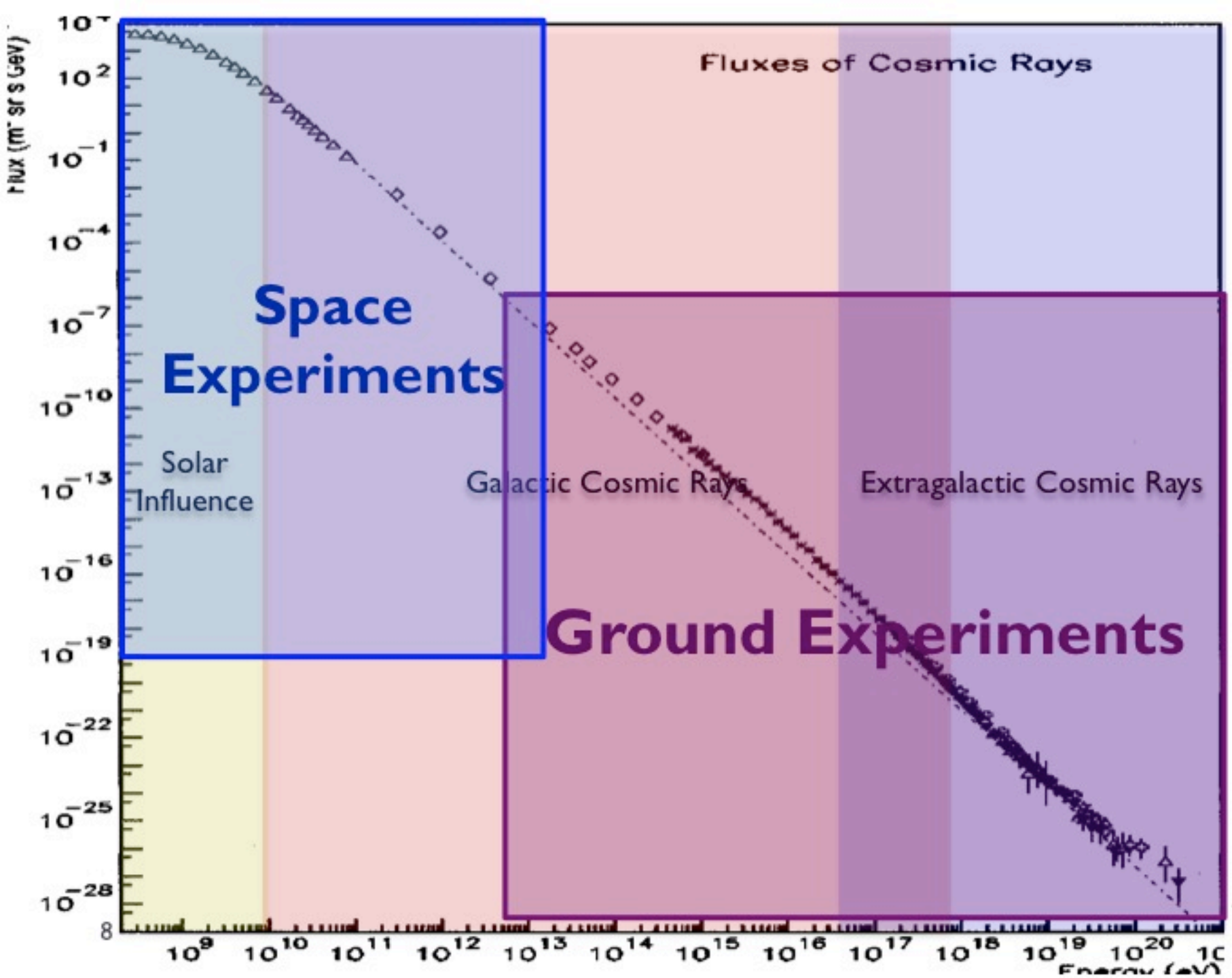


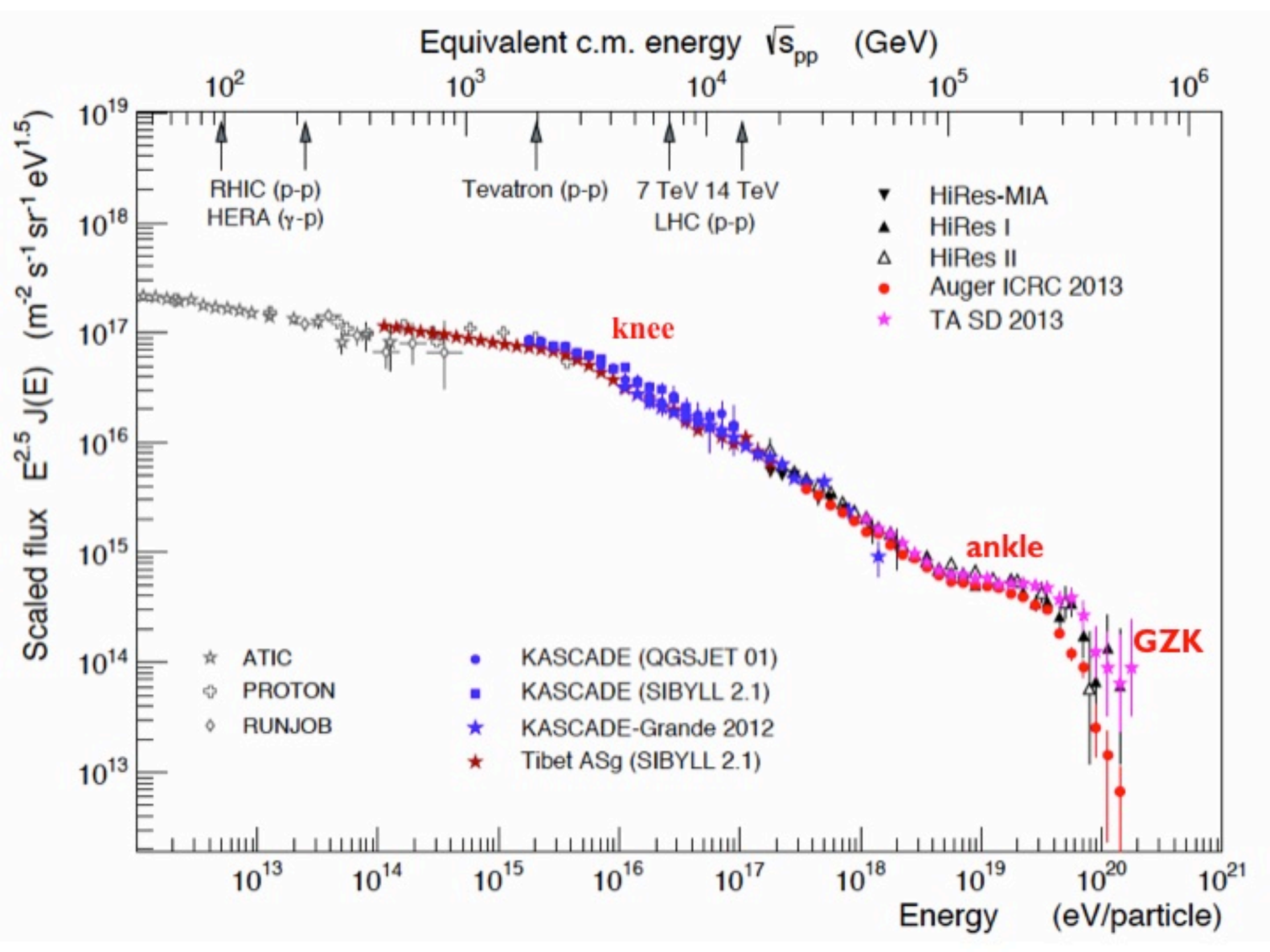

Energies and rates of the cosmic-ray particles
protons only
electrons
positrons
antiprotons
all-particle
~1%
Proton, Helium,
heavier nuclei
IceCube Neutrinos
CAPRICE
AMS
BESS98
Ryan et al.
Grigorov
JACEE
Akeno
Tien Shan
MSU
KASCADE
CASA-BLANCA
DICE
HEGRA
CasaMia
Tibet
Fly Eye
Haverah
Yakutsk
AGASA
HiRes
$E^2 dN/dE$ (GeV cm^{-2}sr^{-1}s^{-1})
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^0
10^2
10^4
10^6
10^8
10^{10}
10^{12}
Gamma-ray ~ 0.1%
E_{kin} (GeV / particle)

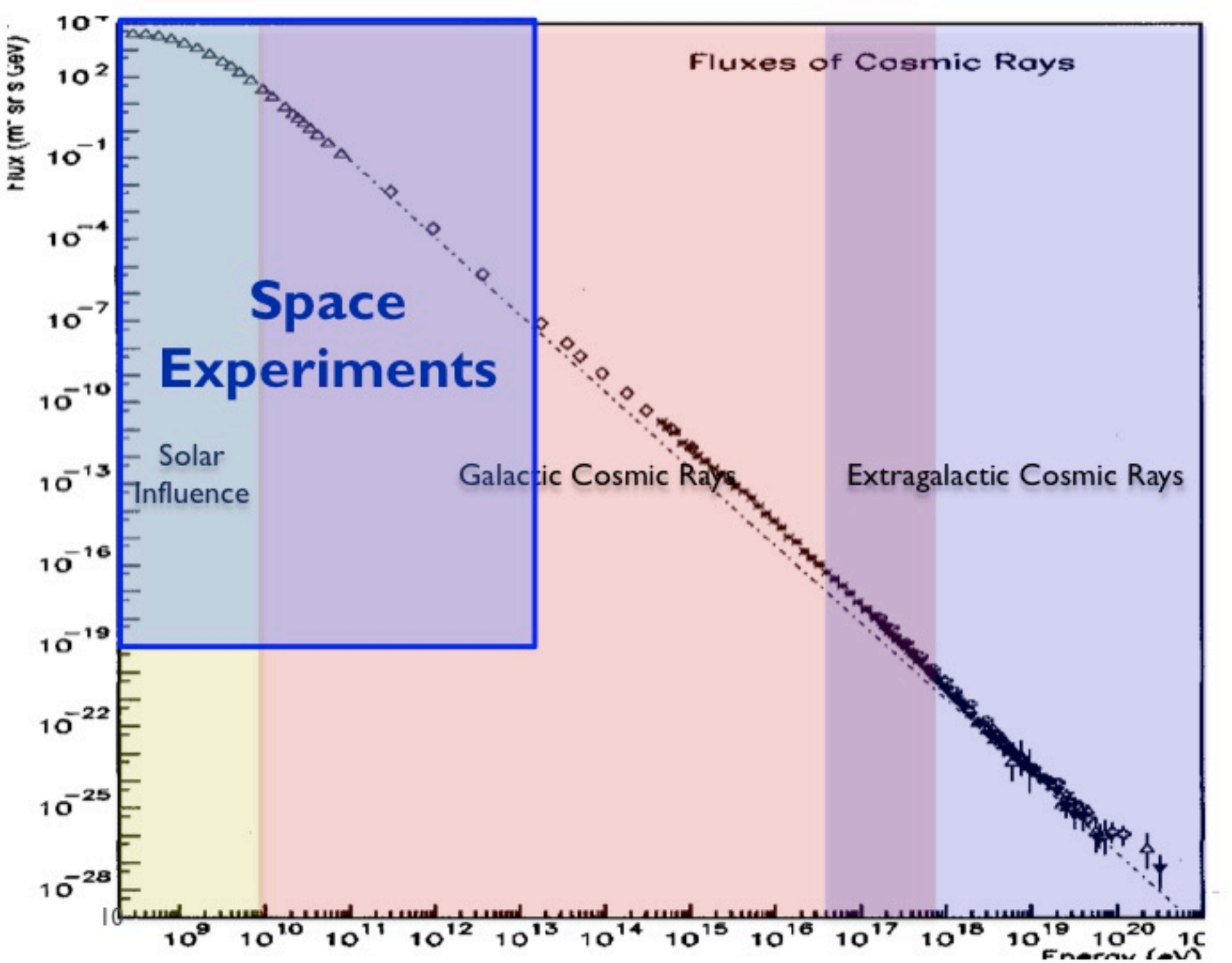

Energies and rates of the cosmic-ray particles
Galactic Supernova Remnants
all-particle
%
CAPRICE
AMS
BESS98
Ryan et al.
Grigorov
JACEE
Akeno
Tien Shan
MSU
KASCADE
CASA-BLANCA
DICE
HEGRA
CasaMia
Tibet
Fly Eye
Haverah
Yakutsk
AGASA
HiRes
IceCube Neutrinos
E²dN/dE (GeV cm⁻² sr⁻¹ s⁻¹)
10⁻¹⁰
10⁰
10⁶
10⁸
10¹⁰
10¹²
eV / particle)
Gamma-ray ~ 0.1%


Energies and rates of the cosmic-ray particles
Galactic Supernova Remnants
all-particle
%
IceCube Neutrinos
?
$E^2 dN/dE$ (GeV cm^{-2}sr^{-1}s^{-1})
10^{-10}
10^{0}
10^{6}
10^{8}
eV / particle)
Gamma-ray ~ 0.1%


Fluxes of Cosmic Rays
Solar Influence
Galactic Cosmic Rays
Extragalactic Cosmic Rays

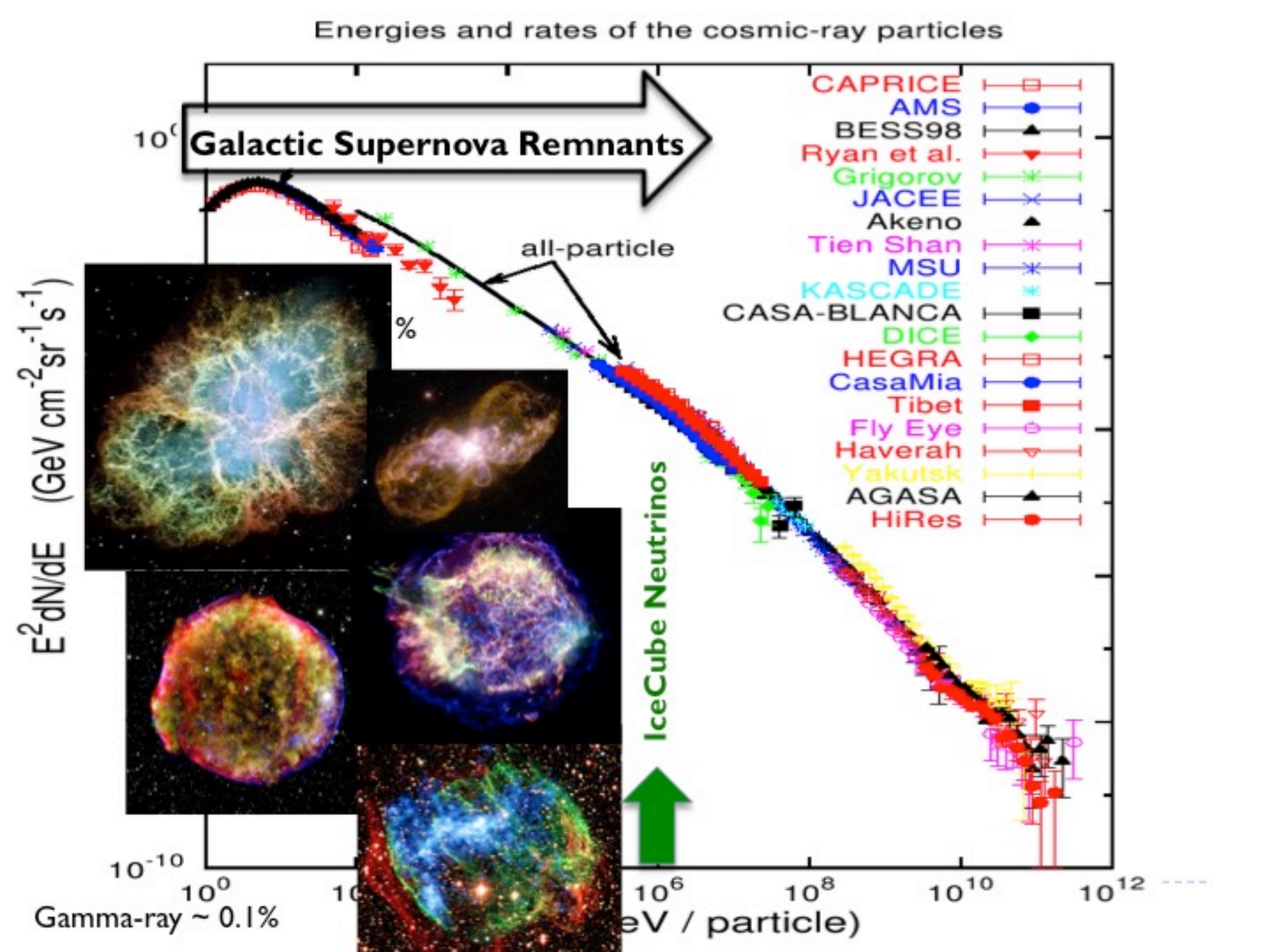

Fluxes of Cosmic Rays
Space Experiments
Solar Influence
Galactic Cosmic Rays
Extragalactic Cosmic Rays
Ground Experiments


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)
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 2013
TA SD 2013
knee
ankle
GZK
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)


Fluxes of Cosmic Rays
Space Experiments
Solar Influence
Galactic Cosmic Rays
Extragalactic Cosmic Rays
Flux (m² sr s GeV)
Energy (eV)

Open Questions in CR Science

- Origin of Galactic Cosmic Rays (GCR):
  - What are the accelerators?
  - What are they accelerating?
  - How do they propagate in the Galaxy?
  - Where is the Transition between Galactic & ExtraGalactic CRs?


Energies and rates of the cosmic-ray particles
Galactic Supernova Remnants
all-particle
%
CAPRICE
AMS
BESS98
Ryan et al.
Grigorov
JACEE
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DICE
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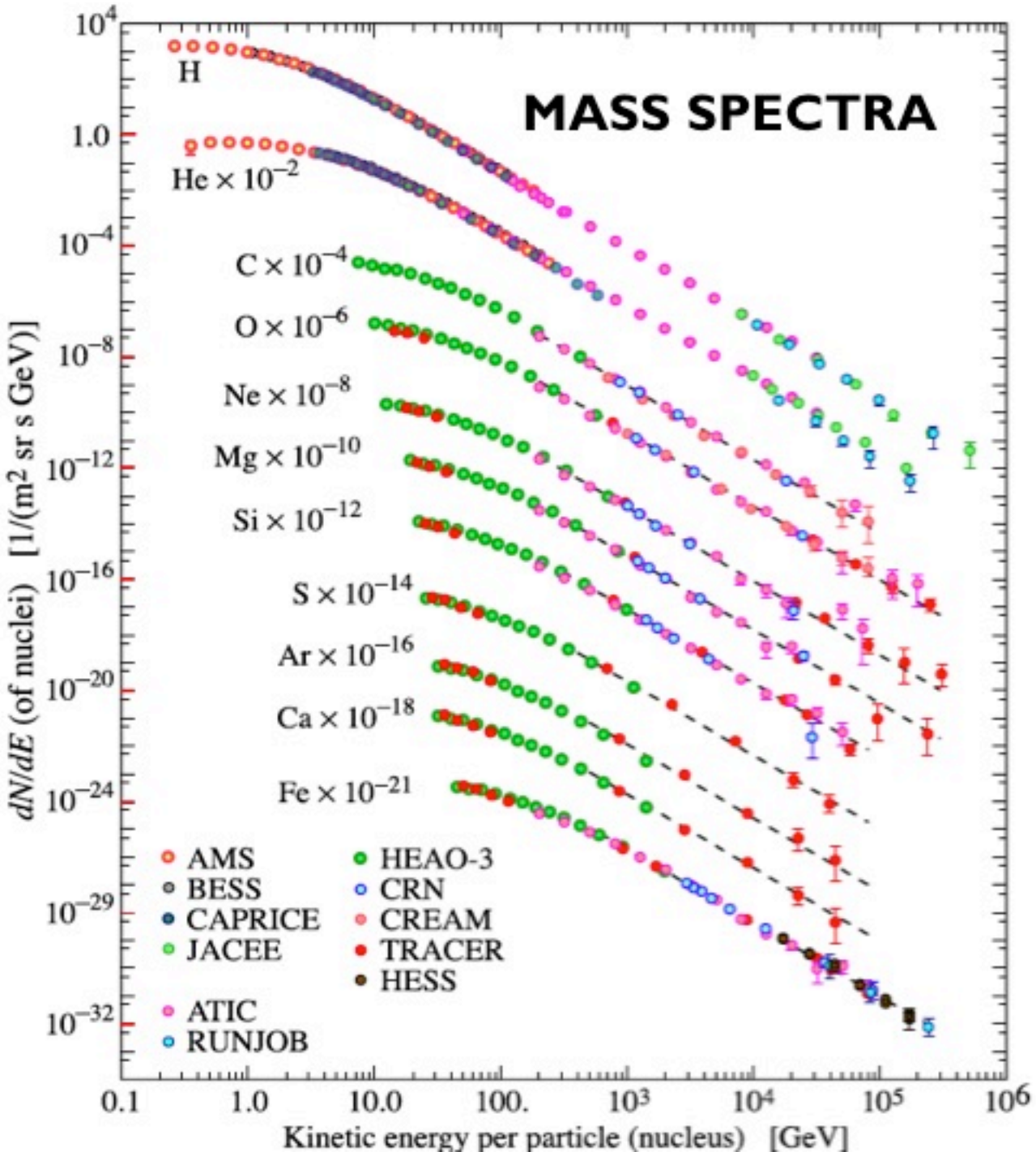
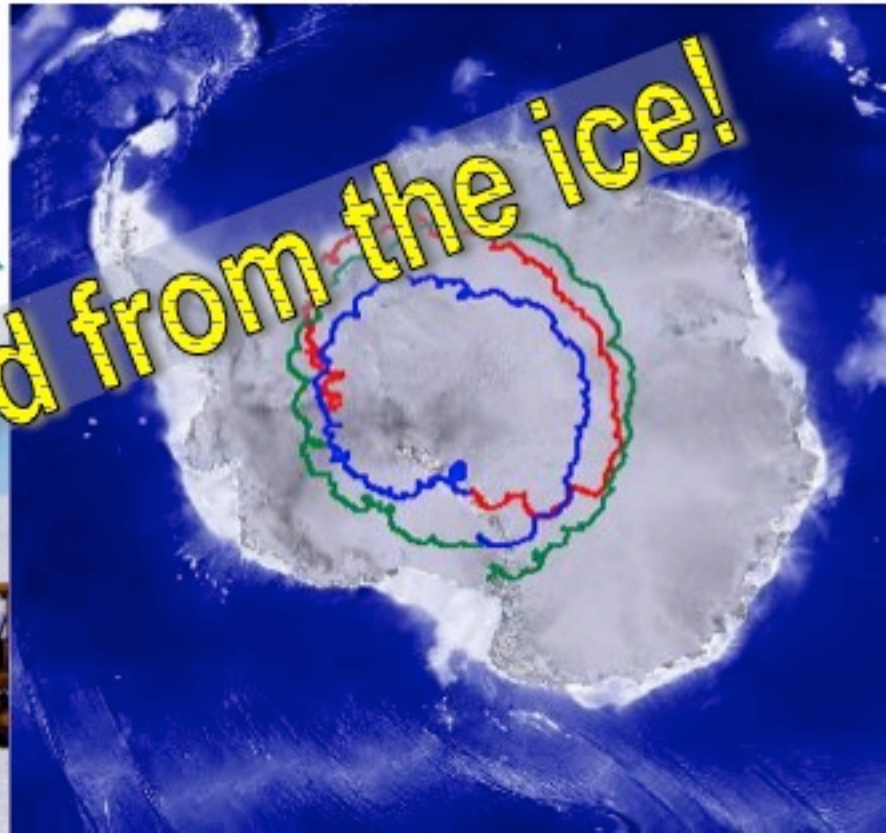
HiRes
IceCube Neutrinos
E²dN/dE (GeV cm⁻² sr⁻¹ s⁻¹)
10⁻¹⁰
10⁰
10⁶
10⁸
10¹⁰
10¹²
eV / particle)
Gamma-ray ~ 0.1%


MASS SPECTRA
H
He × 10^−2
C × 10^−4
O × 10^−6
Ne × 10^−8
Mg × 10^−10
Si × 10^−12
S × 10^−14
Ar × 10^−16
Ca × 10^−18
Fe × 10^−21
AMS
BESS
CAPRICE
JACEE
ATIC
RUNJOB
HEAO-3
CRN
CREAM
TRACER
HESS
dN/dE (of nuclei) [1/(m² sr s GeV)]
Kinetic energy per particle (nucleus) [GeV]
10^4
1.0
10^−4
10^−8
10^−12
10^−16
10^−20
10^−24
10^−29
10^−32
0.1
1.0
10.0
100.
10^3
10^4
10^5
10^6

Cosmic Rays Highlights

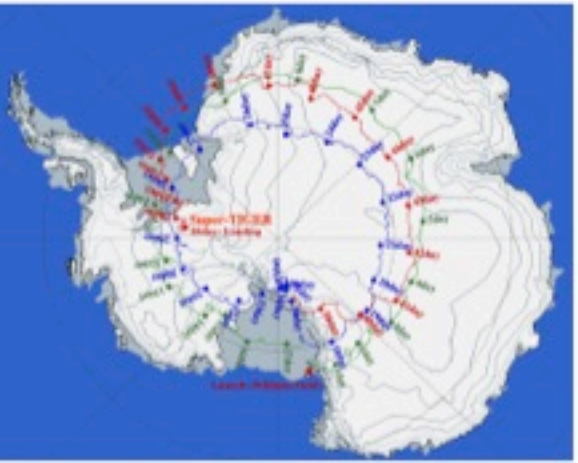
- Super-TIGER (Trans-Iron Galactic Element Recorder) breaks flight duration record: 55 days at 127,000 feet
  - Increase on **UltraHeavy Nuclei** data by 1 o.o.m. to study composition and origin of Galactic Cosmic Rays

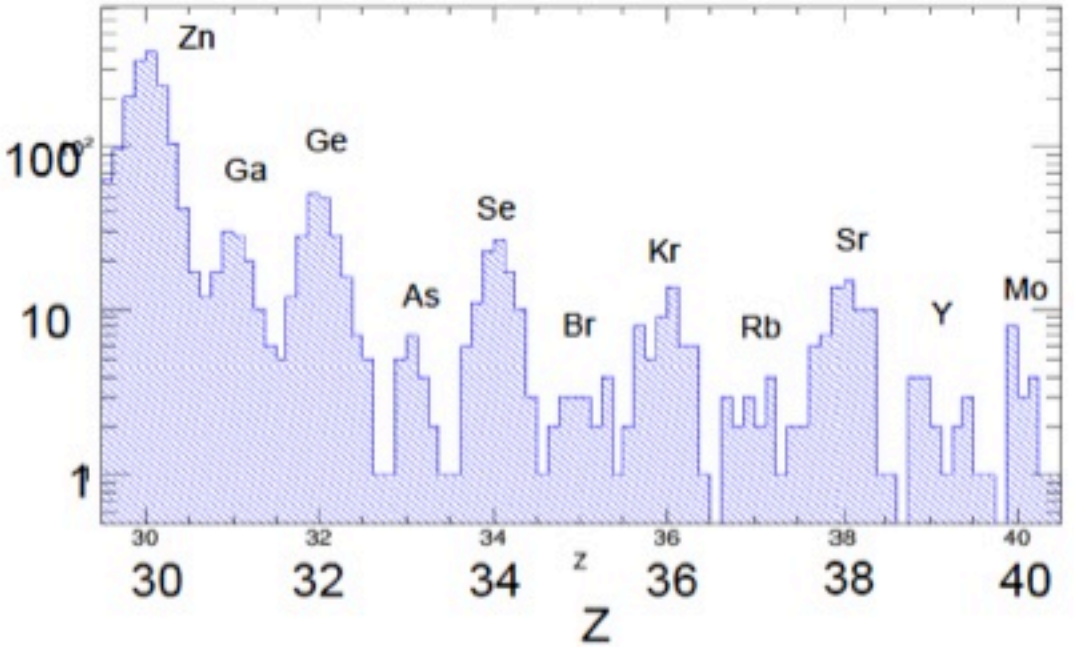


Important Recent Measurements of Ultra-Heavy Galactic Cosmic Rays

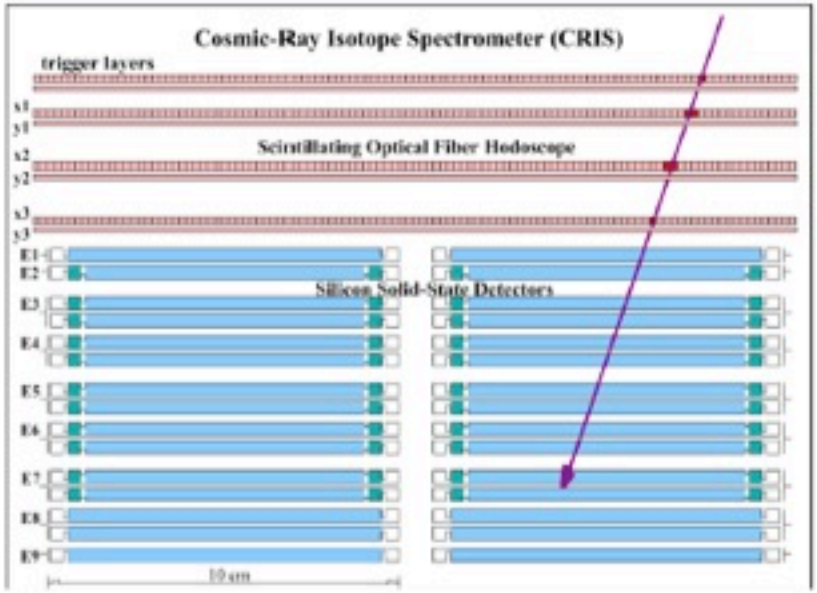
Bob Binns
CosmicSIG

- SuperTIGER
  - Uses dE/dx vs. Cherenkov & Cherenkov-Cherenkov technique to identify elements
- 55-day flight over Antarctica
- For the first time we have measured the abundances of all individual elements in the Z=30-40 range
- Confirms TIGER and ACE data showing that a cosmic-ray source that is a mix of massive star material with old ISM material greatly improves ordering of refractory and volatile elements and points to an OB association origin of GCRs.

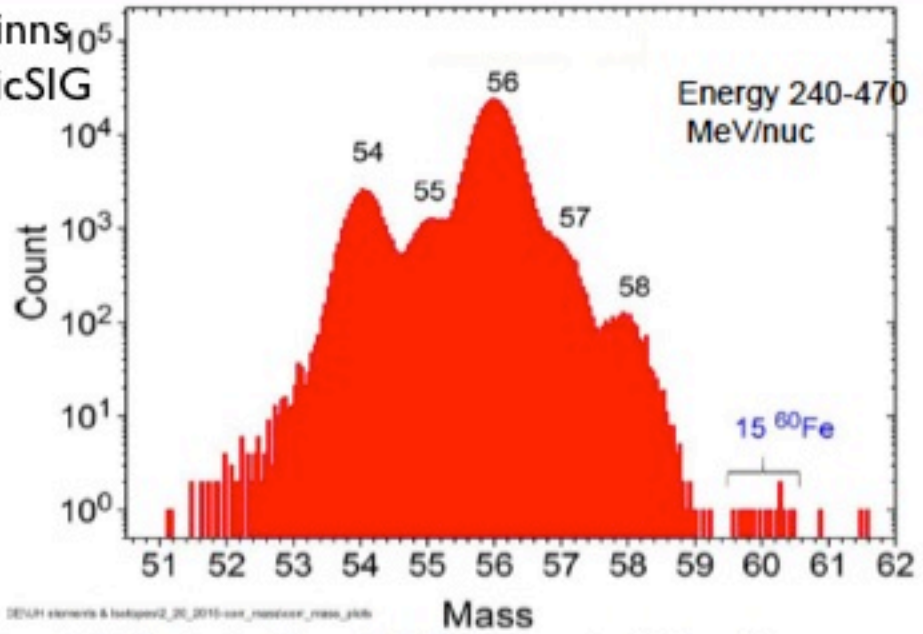




The Cosmic Ray Isotope Spectrometer (CRIS) on the Advanced Composition Explorer (ACE)



Bob Binns
CosmicSIG



- Measured $^{60}Fe/^{56}Fe$ ratio in GCRs. Ratio=(4.4 ± 1.6) x 10^{-5} (reported for the first time at this APS conference).
- ^{60}Fe is radioactive, decaying by beta decay with a half-life of 2.6 Myr.
- Based on this we estimate the maximum time between nucleosynthesis and acceleration to be ~2.5 Myr.
- OB associations appear to be the natural astrophysical setting for this to occur.
- Strong evidence of recent, nearby SNe

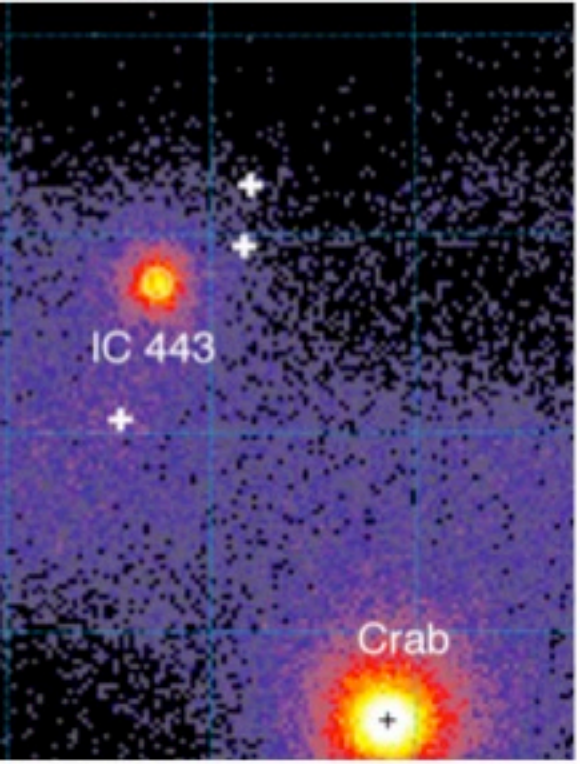
Open Questions in CR Science

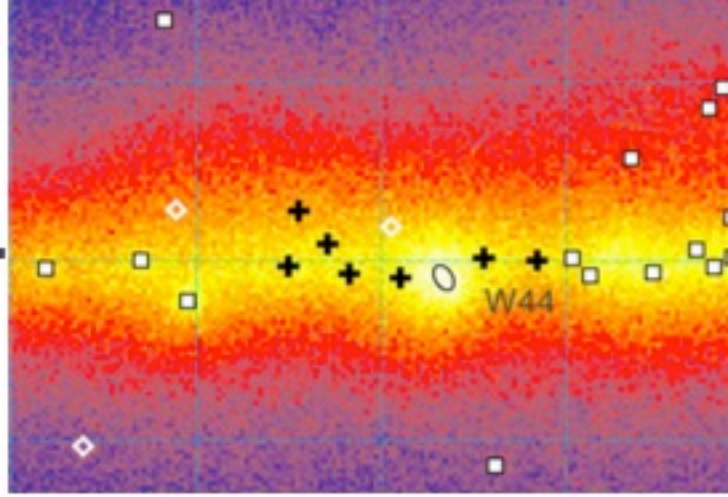
- Origin of Galactic Cosmic Rays (GCR):
  - **What are the accelerators? (**CosmicSIG + GammaSIG)
  - What are they accelerating?
  - How do they propagate in the Galaxy?
  - Where is the Transition between Galactic & ExtraGalactic CRs?

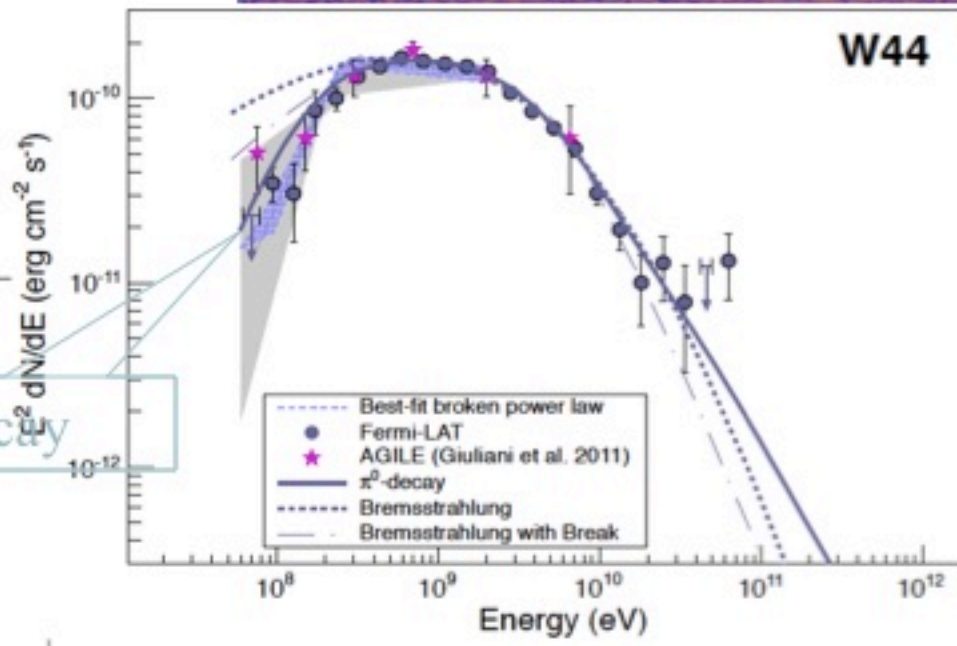
π^0 decay!

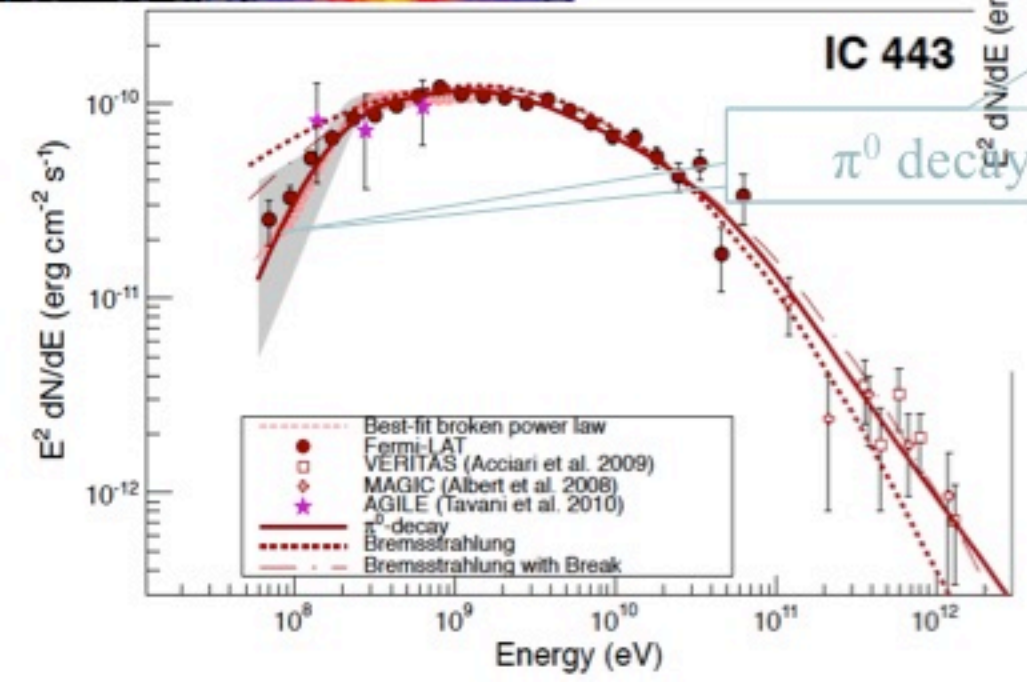
IC 443 & W44

Fermi & AGILE

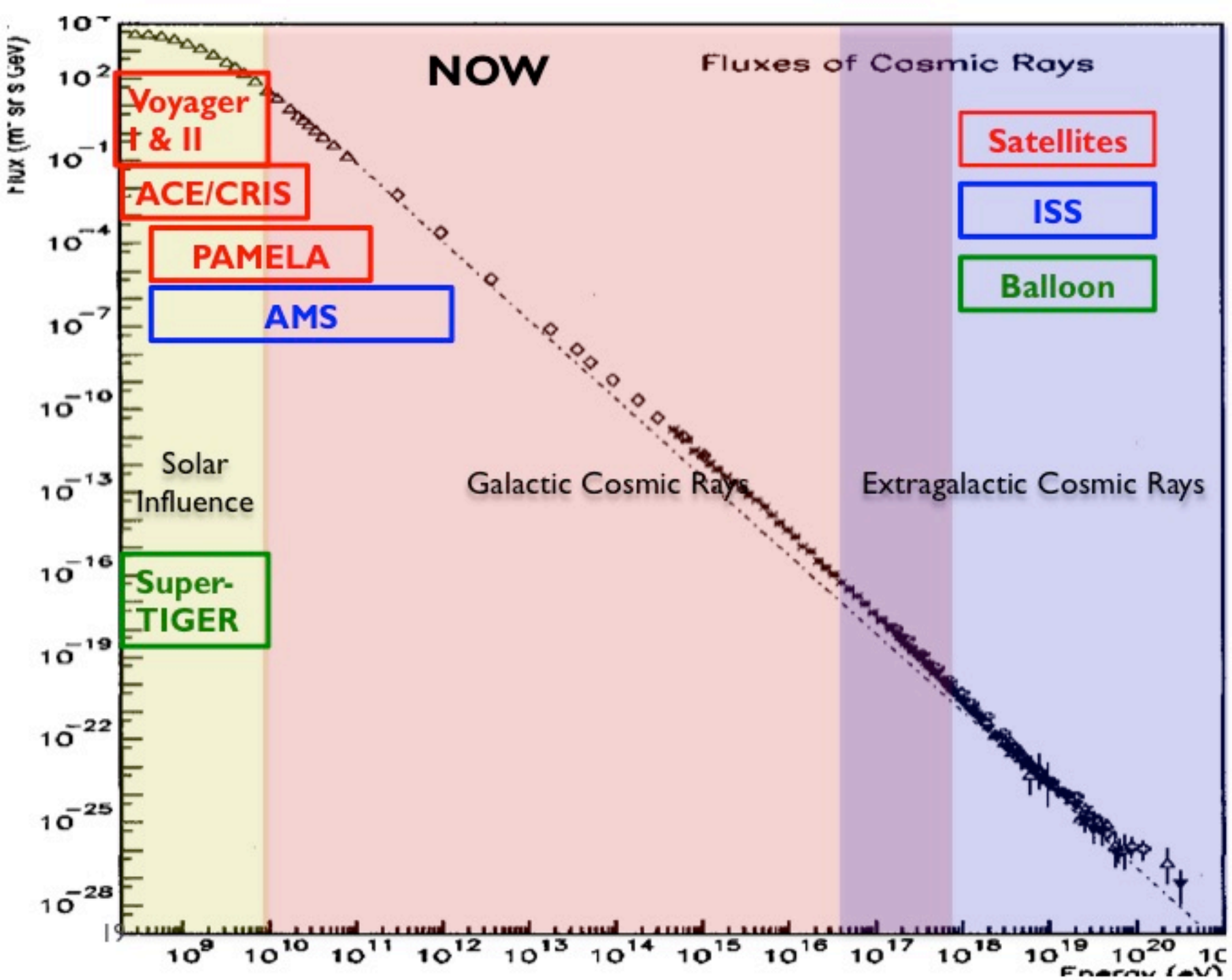








Ackermann et al (Fermi Collab) '13
arXiv:1302.3307

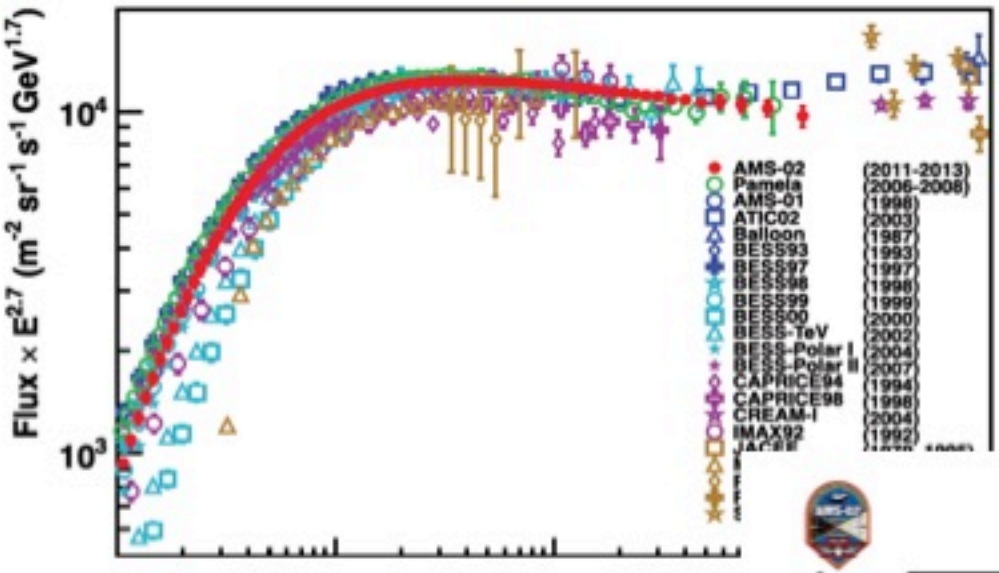

NOW
Fluxes of Cosmic Rays
Voyager I & II
ACE/CRIS
PAMELA
AMS
Satellites
ISS
Balloon
Solar Influence
Galactic Cosmic Rays
Extragalactic Cosmic Rays
Super-TIGER
Flux (m² sr s GeV)
Energy (eV)

Cosmic Rays Recent Highlights

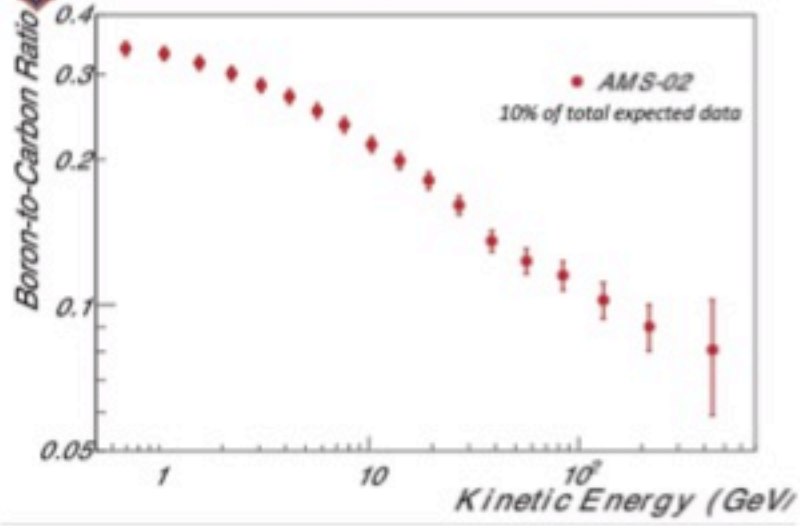
- AMS-02 (Alpha Magnetic Spectrometer) on the ISS

AMS-02

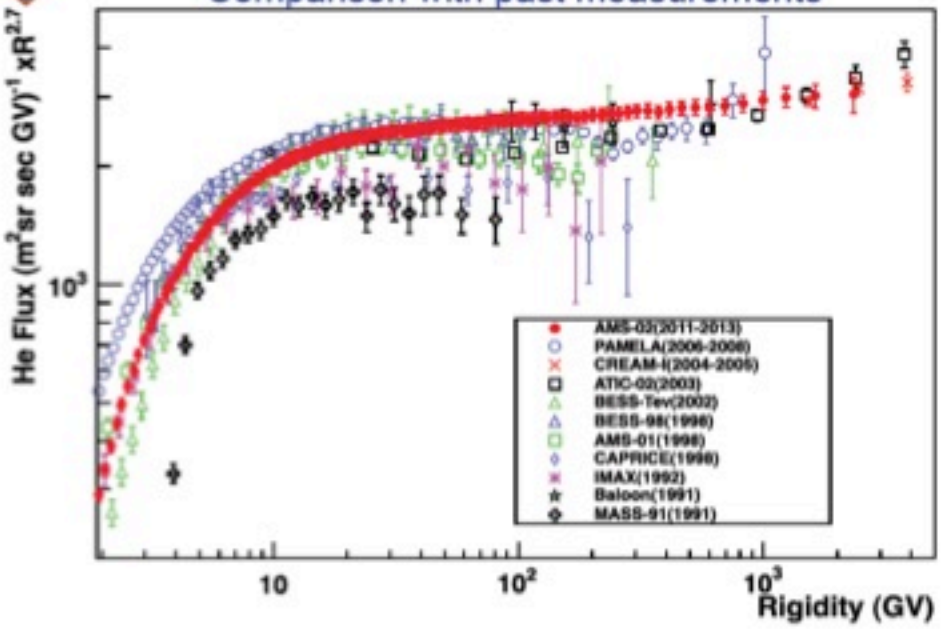
Proton flux
Comparison with past measurements

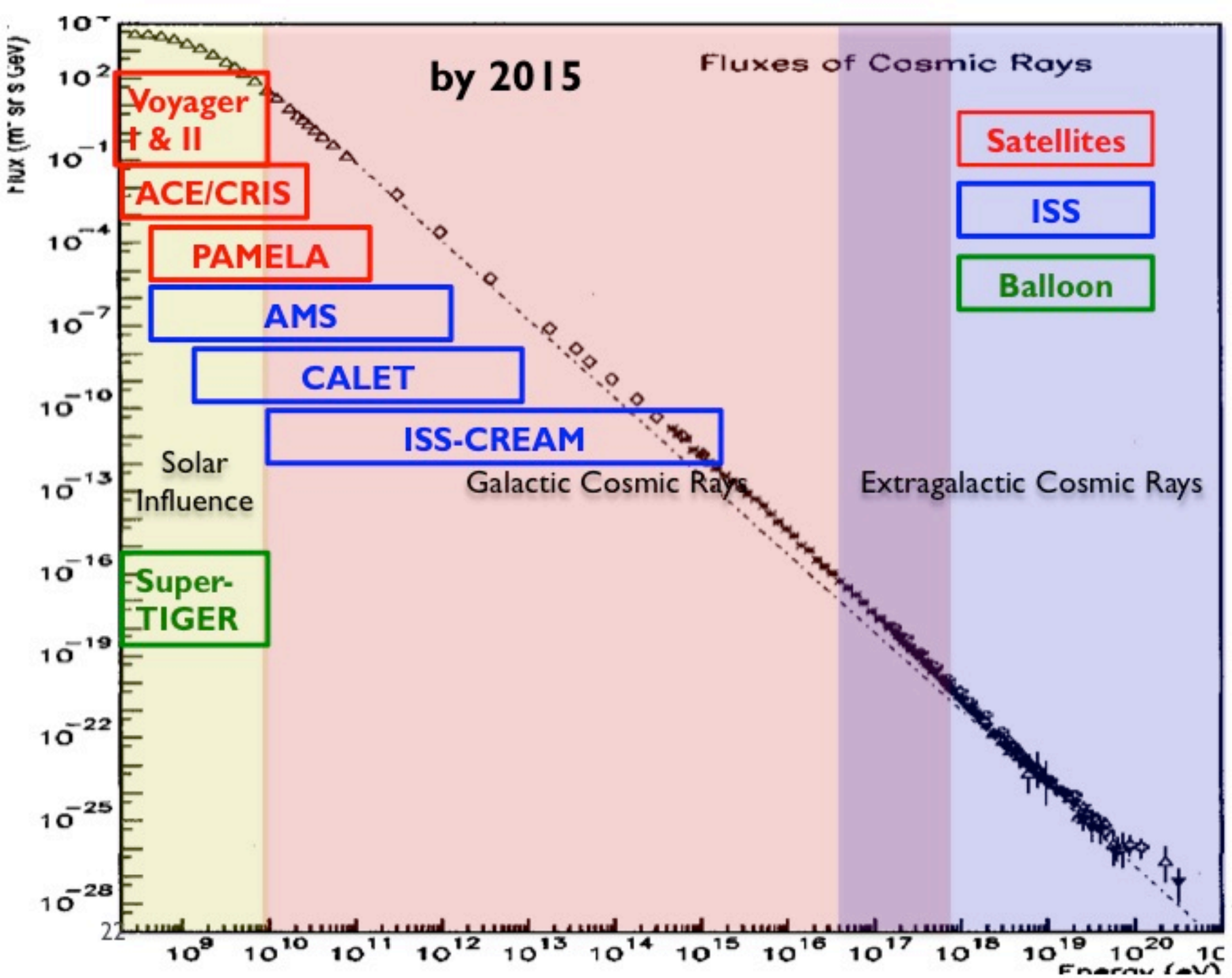


Boron-to-Carbon ratio

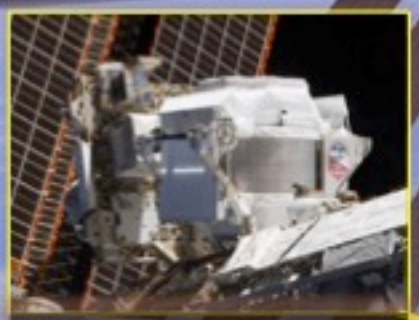


Helium flux
Comparison with past measurements

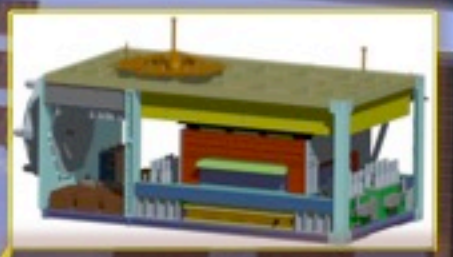



by 2015
Fluxes of Cosmic Rays
Voyager I & II
ACE/CRIS
PAMELA
AMS
CALET
ISS-CREAM
Super-TIGER
Satellites
ISS
Balloon
Solar Influence
Galactic Cosmic Rays
Extragalactic Cosmic Rays
Flux (m² sr s GeV)
Energy (eV)

"Cosmic Ray Observatory on the ISS"

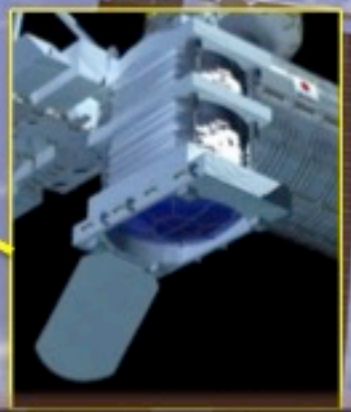


AMS Launch
May 16, 2011



ISS-CREAM
Sp-X Launch
2015-16

CALET on JEM
HTV Launch 2015

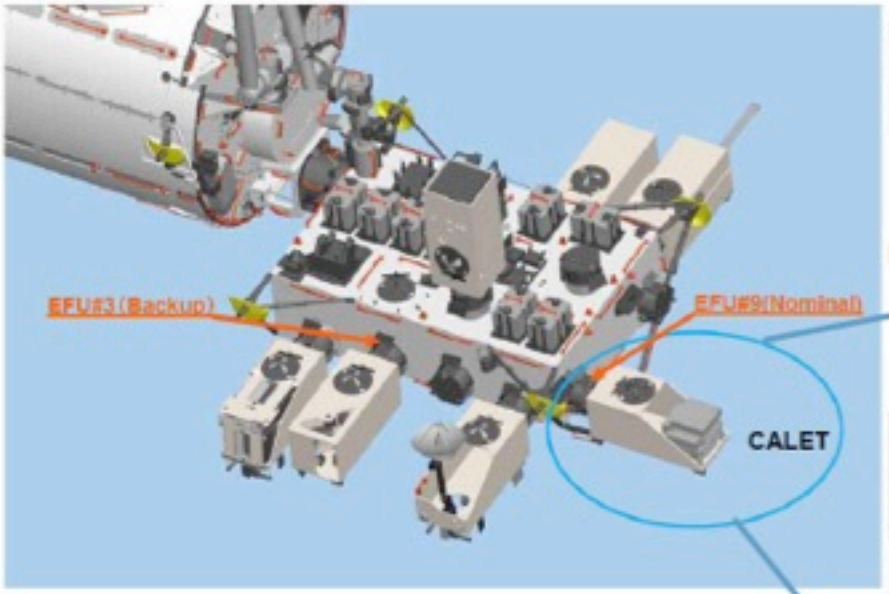


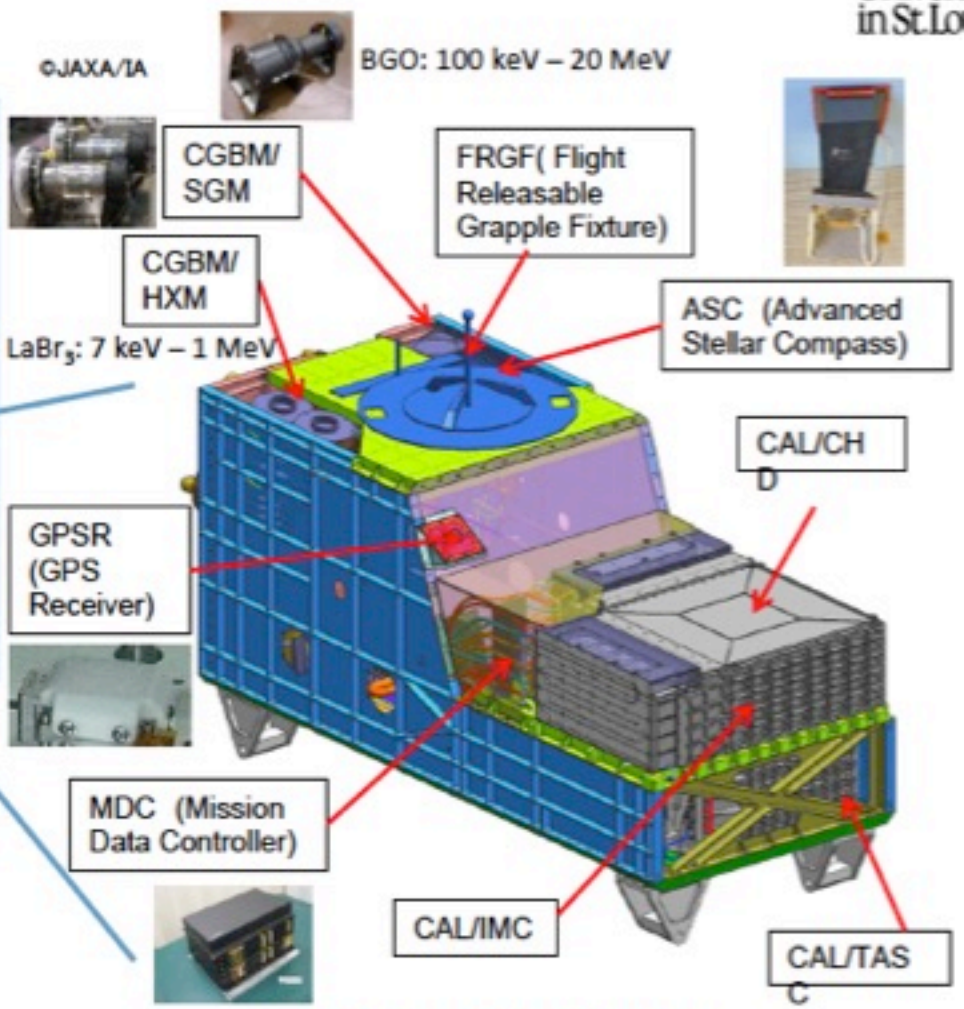
JEM-EUSO
2020 prop

CALET Payload Overview

Brian Flint Rauch

Washington University in St. Louis





- Launch carrier: HTV-5
- Launch target date: summer 2015
- Mission period: More than 2 years
  - (5 years target)
- Data rate:
  - Medium data rate: 300 kbps
  - Low data rate: 20 kbps

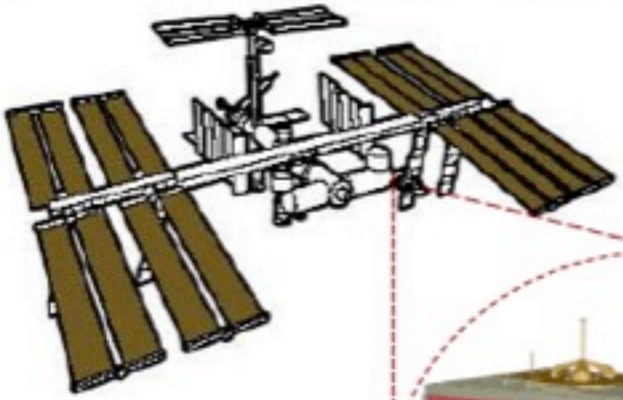
- Mass: 650 kg (Max)
- Standard Payload Size
- Power: 650 W (Max)

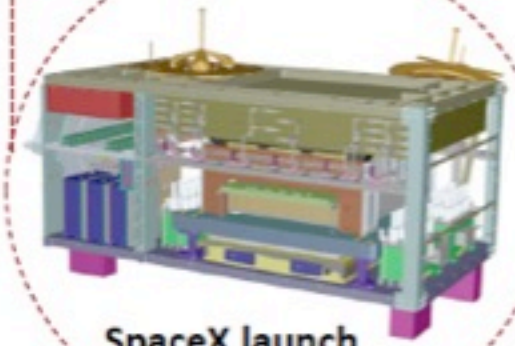
ISS-CREAM (CREAM for the ISS)

Cosmic Ray Energetics And Mass

PI: Eun-Suk Seo, University of Maryland

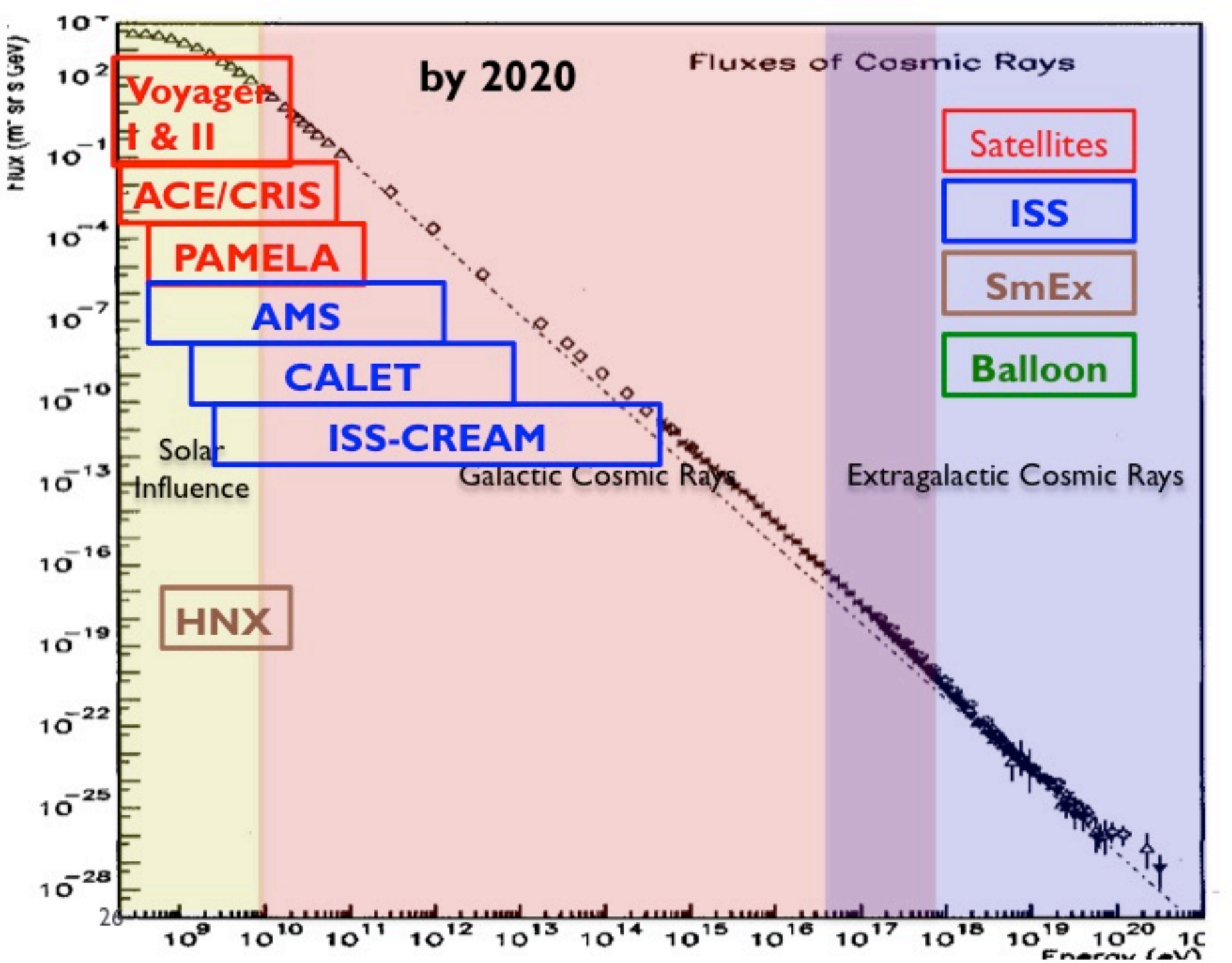
- The balloon-borne CREAM was flown 6 times over Antarctica with ~161 days of total flight time, the longest exposure to date for a single balloon project.
- ROSES 2010 proposal: Building on the success of the balloon flights, the payload is being transformed for accommodation on the ISS (NASA's share of JEM-EF).
- CREAM measures the energy spectra from 10^{12} to $>10^{15}$ eV over the elemental range from protons to iron.
- It extends the energy reach of direct measurements of cosmic rays to the **highest energy possible** to probe their origin, acceleration and propagation.





SpaceX launch

Increase the exposure by an order of magnitude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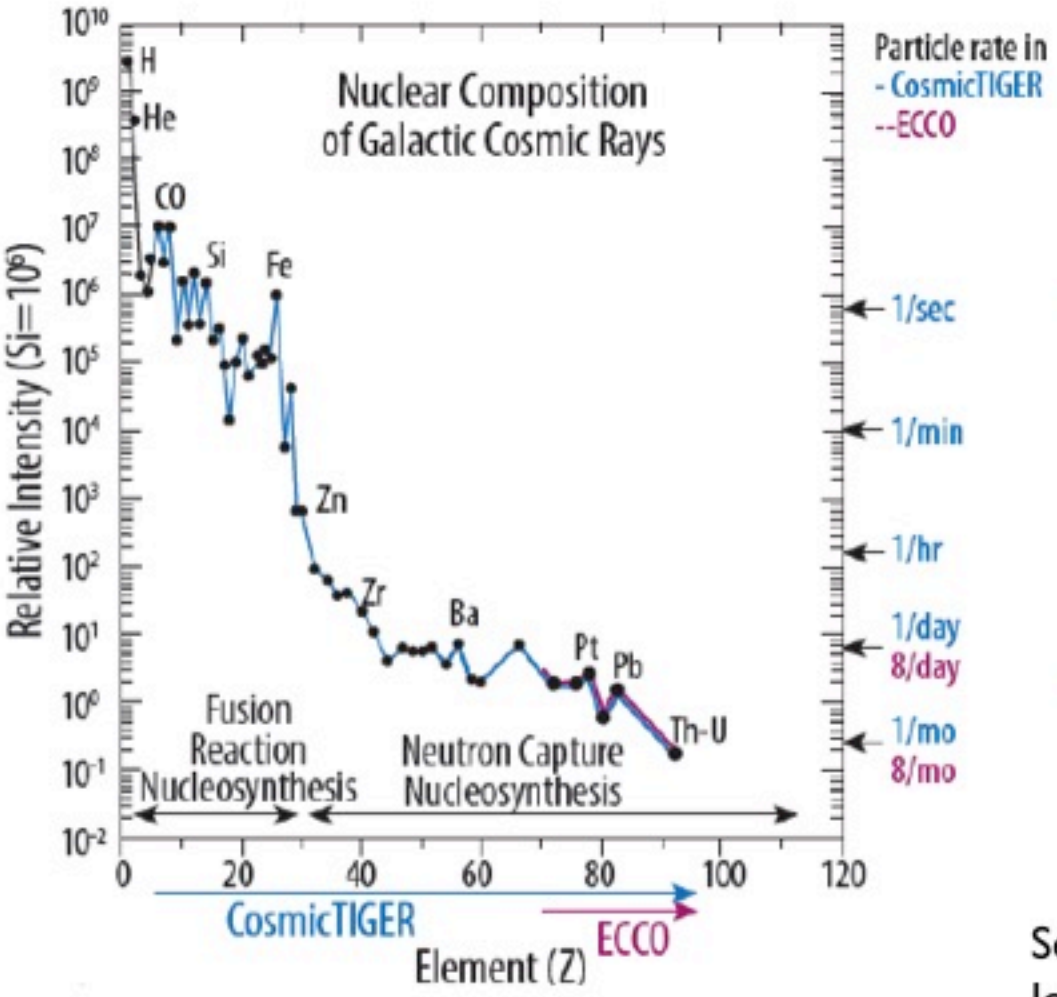
HNX
Satellites
ISS
SmEx
Balloon
Solar Influence
Galactic Cosmic Rays
Extragalactic Cosmic Rays

HNX Science Design

Bob Binns
CosmicSIG

- **HNX Explores to the end of the periodic table**
  - Elements in the upper 2/3rds are extremely rare



- **Requires a very large instrument with long exposure in space!**
- *HNX uses complementary active (CosmicTIGER) and passive (ECCO) detectors to give the required ~ 40 m²sr geometric factor*
- ECCO uses BP-1 (barium phosphate) glass detectors
  - Trek experiment on Mir used BP-1 to record the only cosmic-ray actinides (4 nuclei) reported
  - Require return to Earth for processing → SpaceX DragonLab
- CosmicTIGER electronic instrument is based on TIGER and SuperTIGER balloon instruments and HEAO and Solar Probe Plus space instruments

Session S14 Missions and Instruments II
John Mitchell

Open Questions in CR Science

- Origin of Galactic Cosmic Rays (GCR):
  - What are the accelerators?
  - What are they accelerating?
  - How do they propagate in the Galaxy?
  - Where is the Transition between Galactic & ExtraGalactic CRs?
- **Origin of ExtraGalactic Cosmic Rays (XGCR):**
  - What are the accelerators?
  - What are they accelerating?
  - How do they propagate to Earth?
  - At what Energy COSMIC RAY ASTRONOMY begins?
- How do Cosmic Rays Affect the Earth, the Solar System, the ISM, the Galaxy, other Galaxies, and the formation of Stars and Galaxies?

Current Observatories of Ultrahigh Energy Cosmic Rays

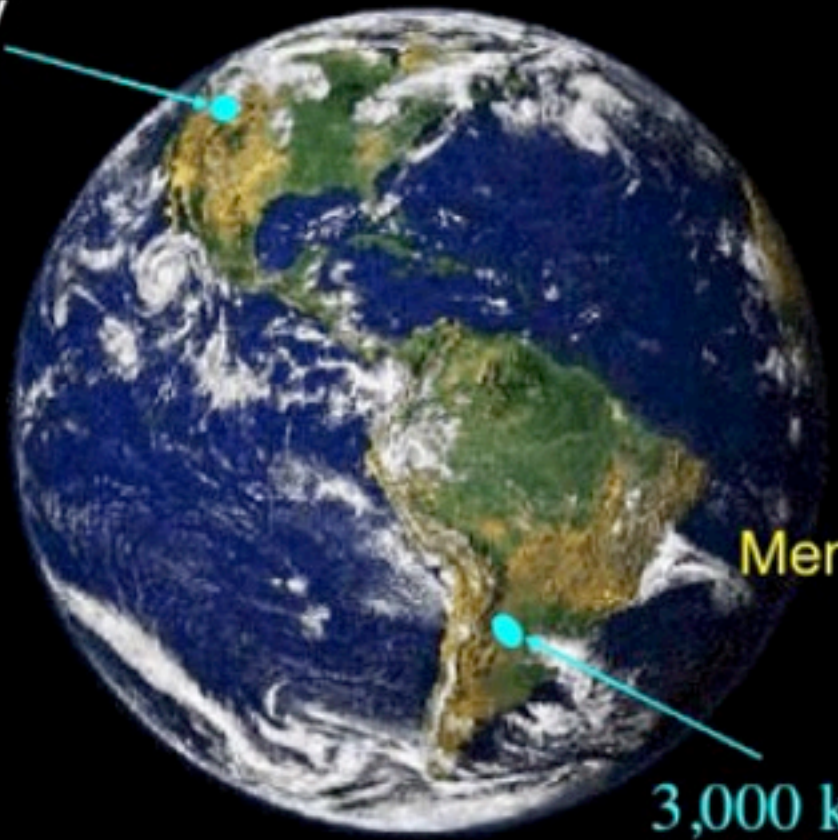
Telescope Array

Utah, USA

(5 country collaboration)

700 km^2 array

3 fluorescence telescopes



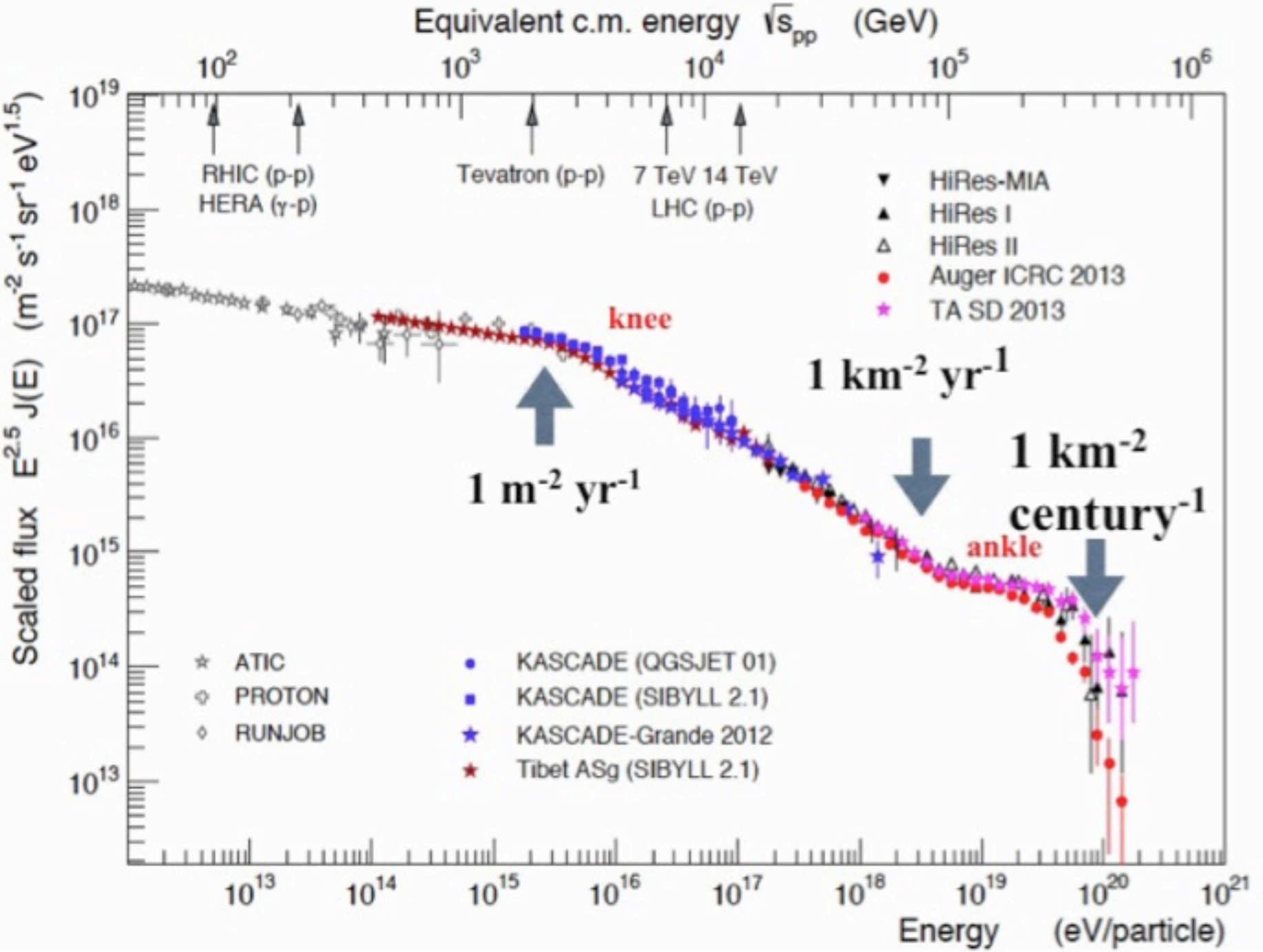
Pierre Auger Observatory

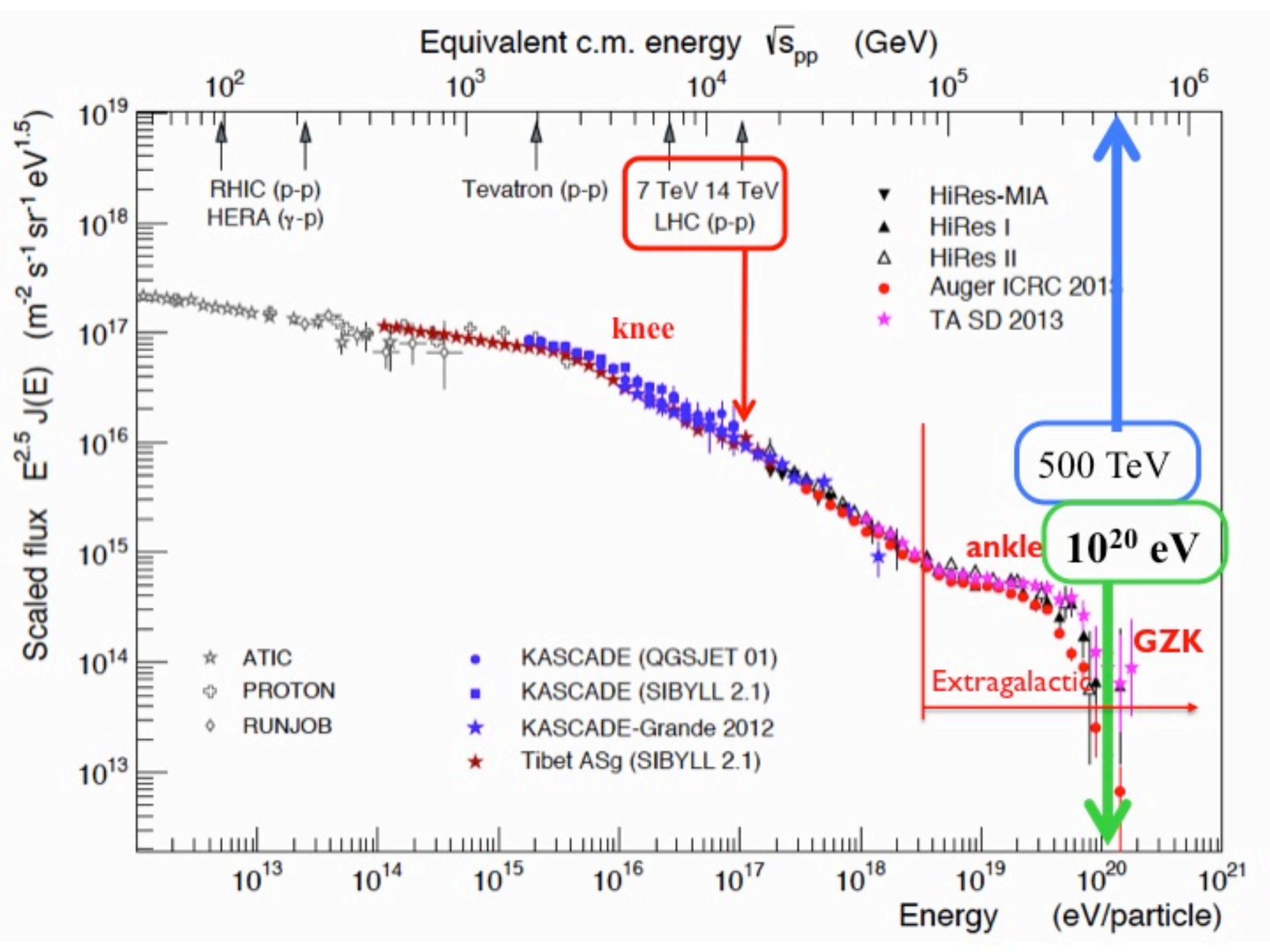
Mendoza, Argentina

(19 country collaboration)

3,000 km^2 array

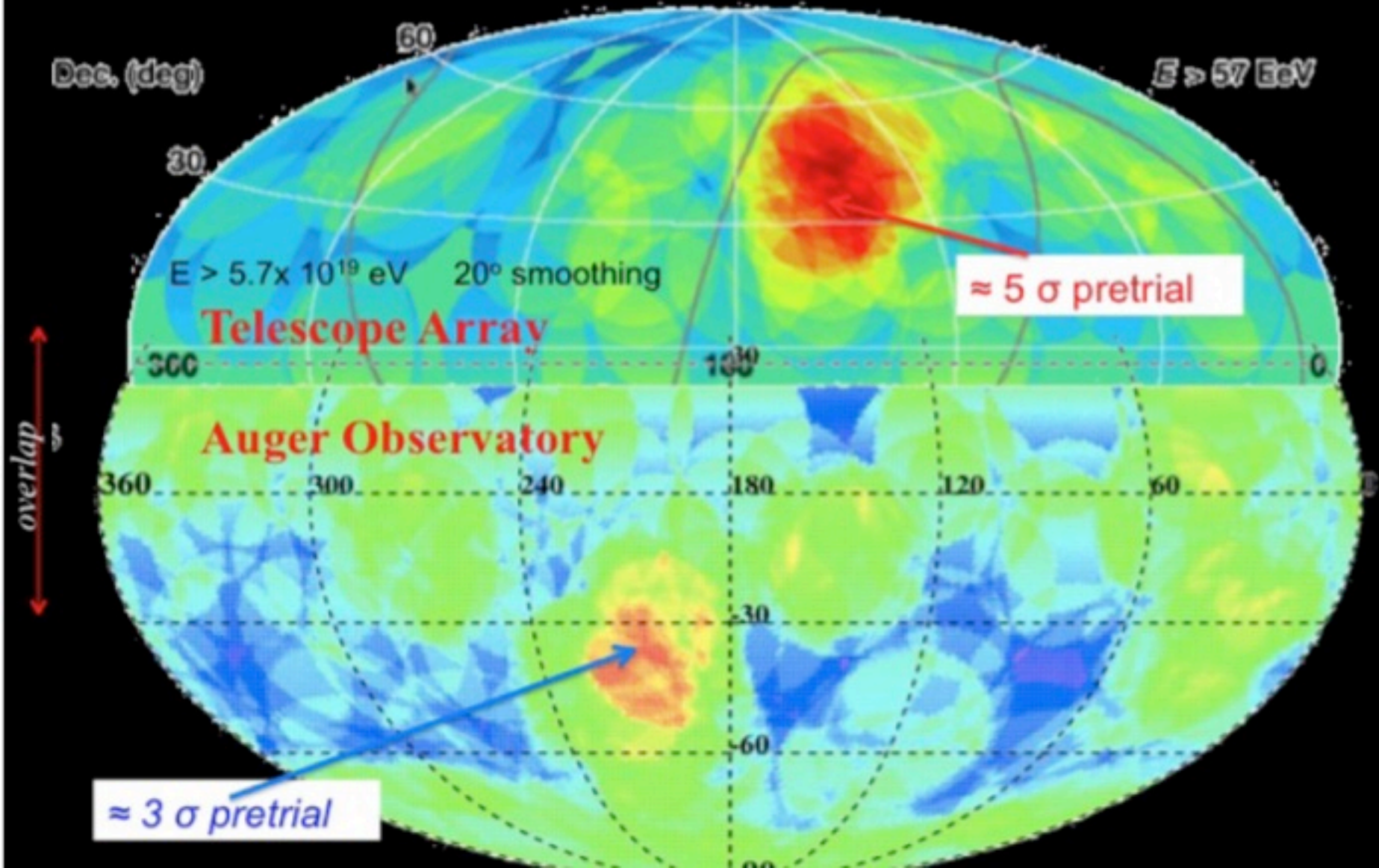
4 fluorescence telescopes


Equivalent c.m. energy $\sqrt{s_{pp}}$ (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)
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 2013
TA SD 2013
knee
1 km^{-2} yr^{-1}
1 m^{-2} yr^{-1}
1 km^{-2} century^{-1}
ankle
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}
ATIC
PROTON
RUNJOB
KASCADE (QGSJET 01)
KASCADE (SIBYLL 2.1)
KASCADE-Grande 2012
Tibet ASg (SIBYLL 2.1)
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}
Energy (eV/particle)


Equivalent c.m. energy $\sqrt{s}_{pp}$ (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)
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 201
TA SD 2013
knee
500 TeV
ankle
10^{20} eV
GZK
Extragalactic
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)

Anisotropy Hints > 60 EeV

Statistically limited



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

The EUSO program

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

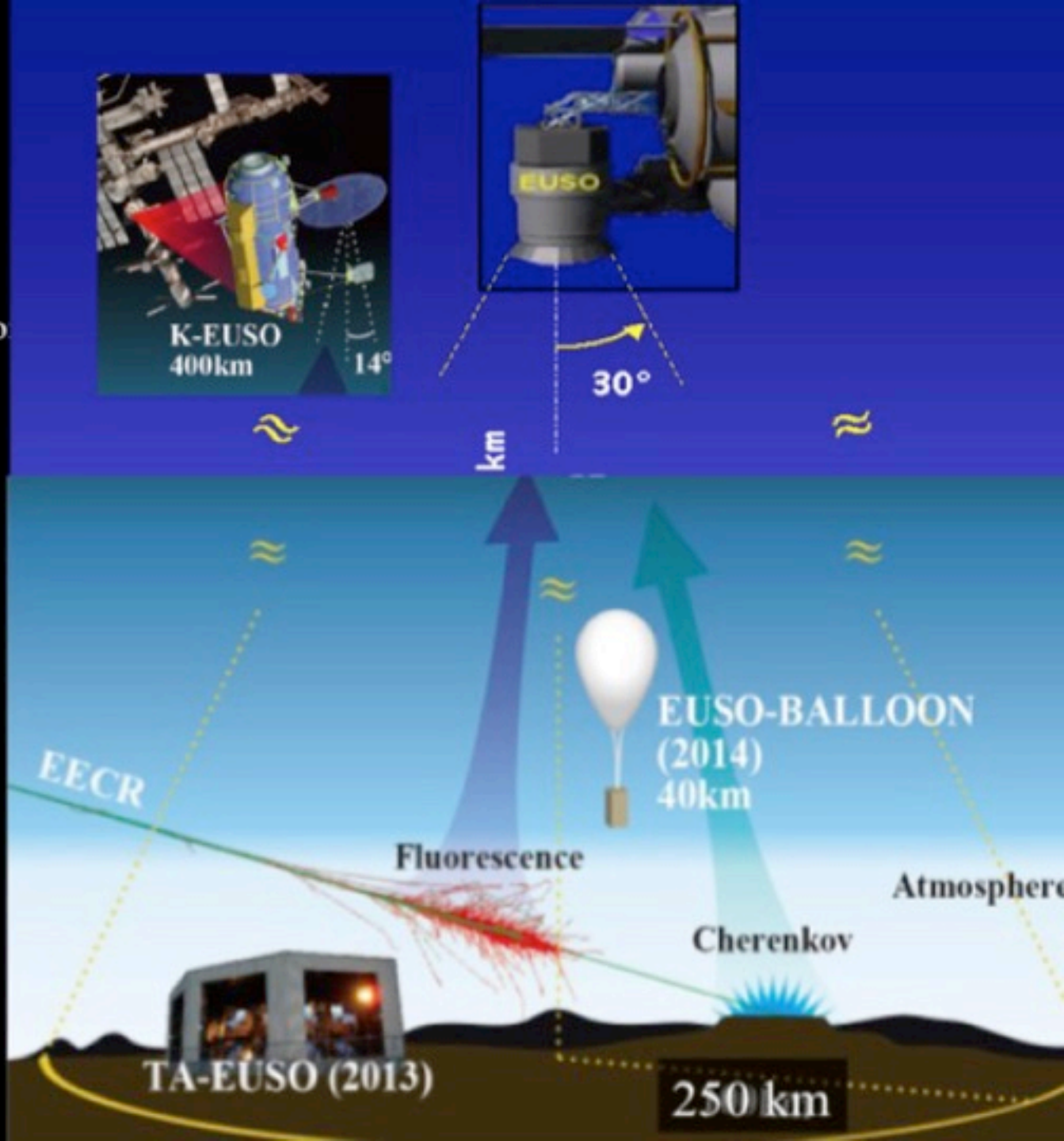
2. EUSO-BALLOON:
1st flight from Timmins,
Canada, August 2014

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

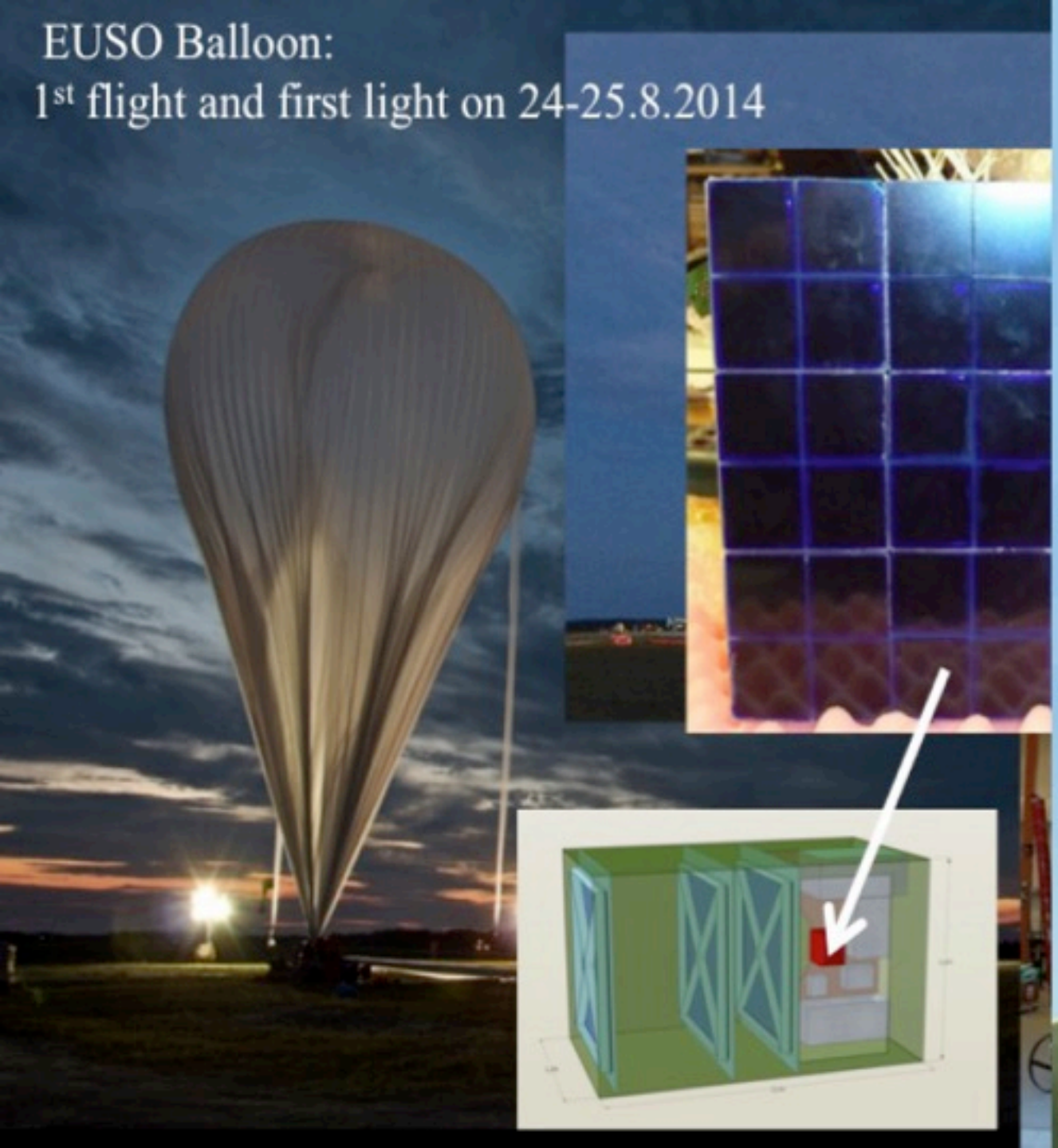
4. Mini-EUSO in the ISS
(2018)

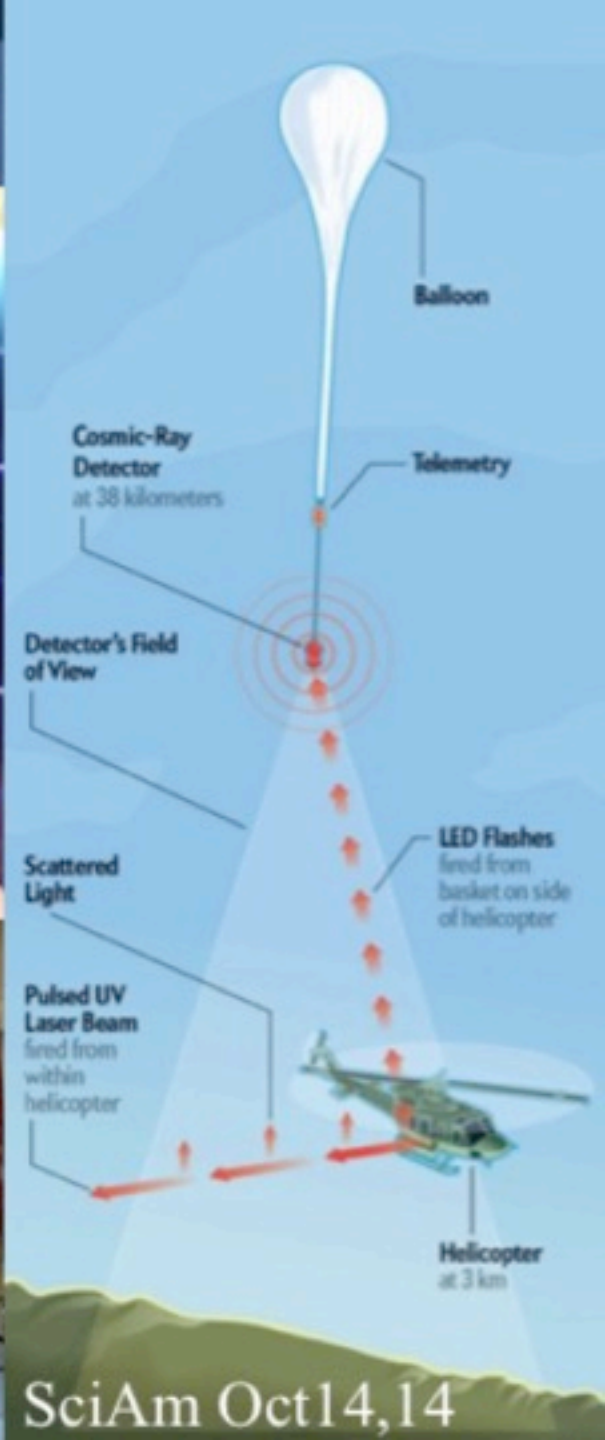
4. KLYPVE →
K-EUSO (2020)

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



EUSO Balloon:
1st flight and first light on 24-25.8.2014



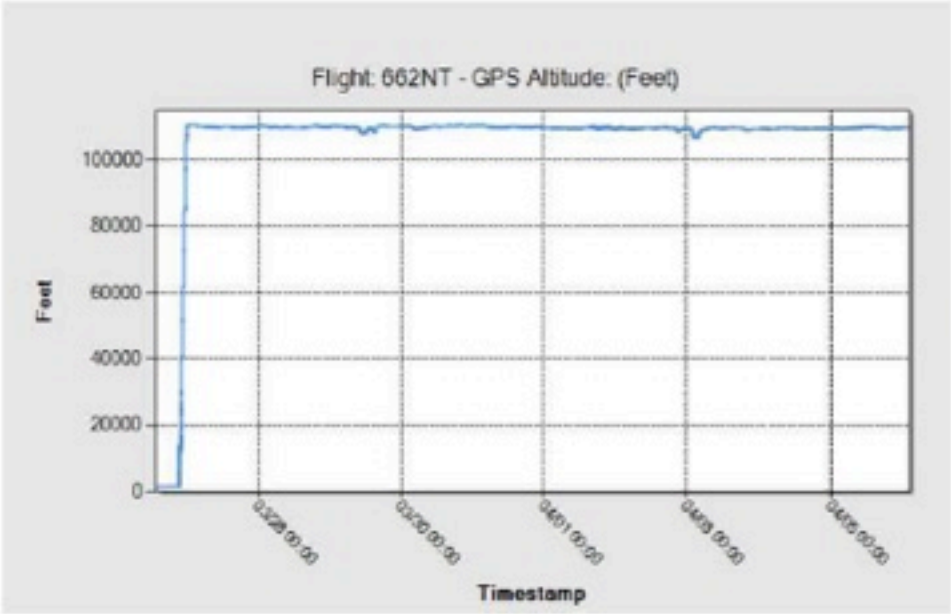


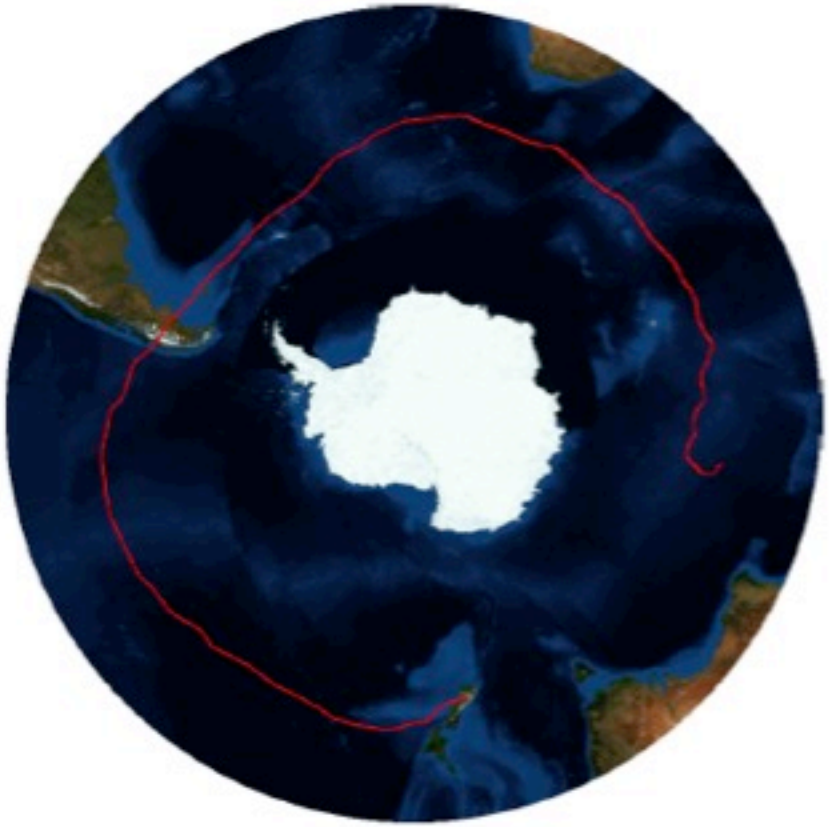
SciAm Oct14,14

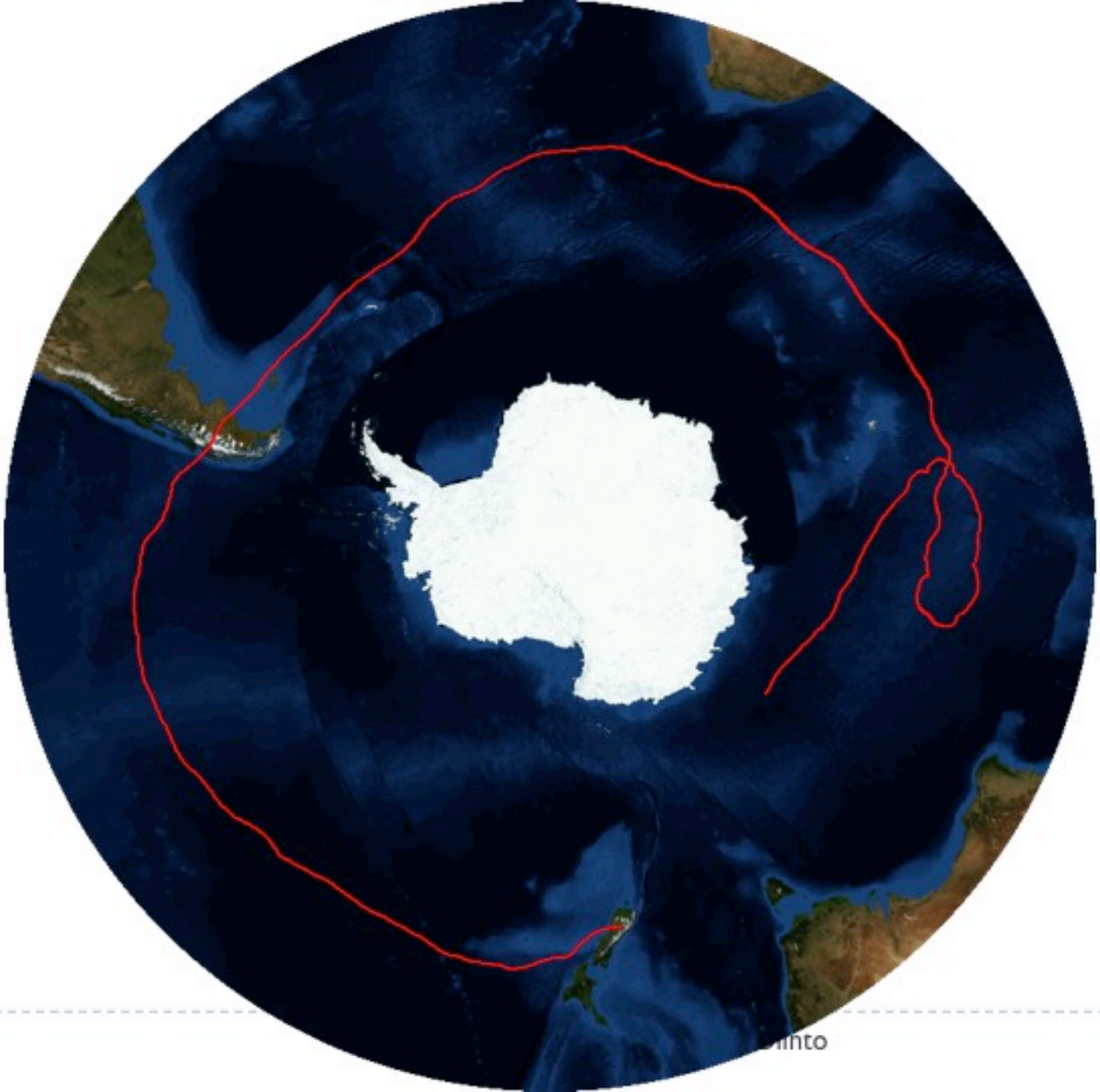
Astrophysics Division

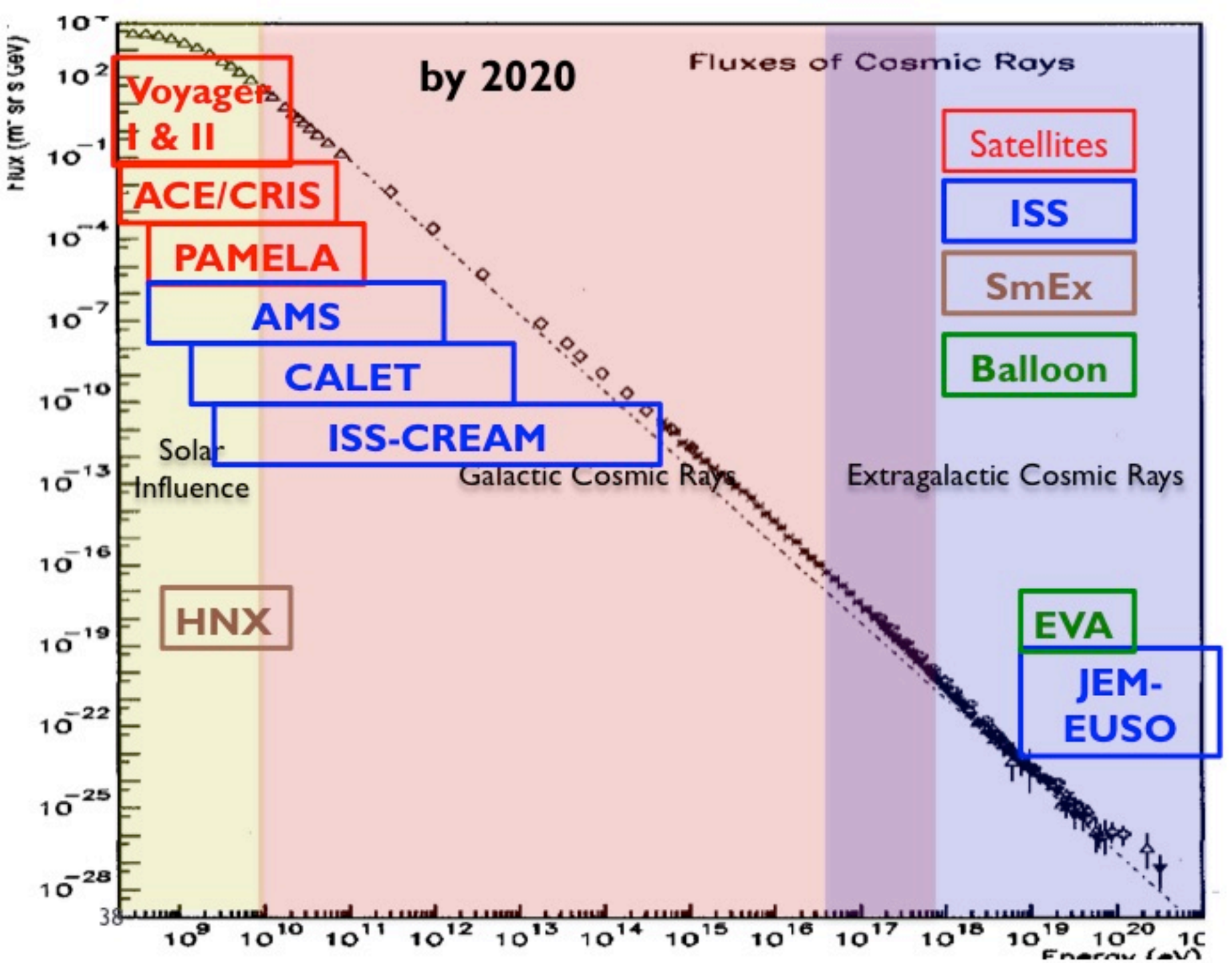
First NASA Balloon Launched from Wanaka, NZ

- Launched from Wanaka, NZ on morning of 3/27/15.
  - ✓ Afternoon of 3/26/15 EST.
- Balloon remains healthy 4/9/15 >14 days into the flight!
  - ✓ Floating at nearly altitude around 109,000 – 110,000 ft.





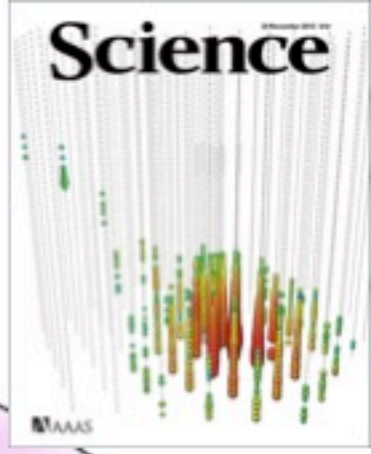



by 2020
Fluxes of Cosmic Rays
Voyager I & II
ACE/CRIS
PAMELA
AMS
CALET
ISS-CREAM
HNX
Satellites
ISS
SmEx
Balloon
EVA
JEM-EUSO
Solar Influence
Galactic Cosmic Rays
Extragalactic Cosmic Rays
Flux (m² sr s GeV)
Energy (eV)
38

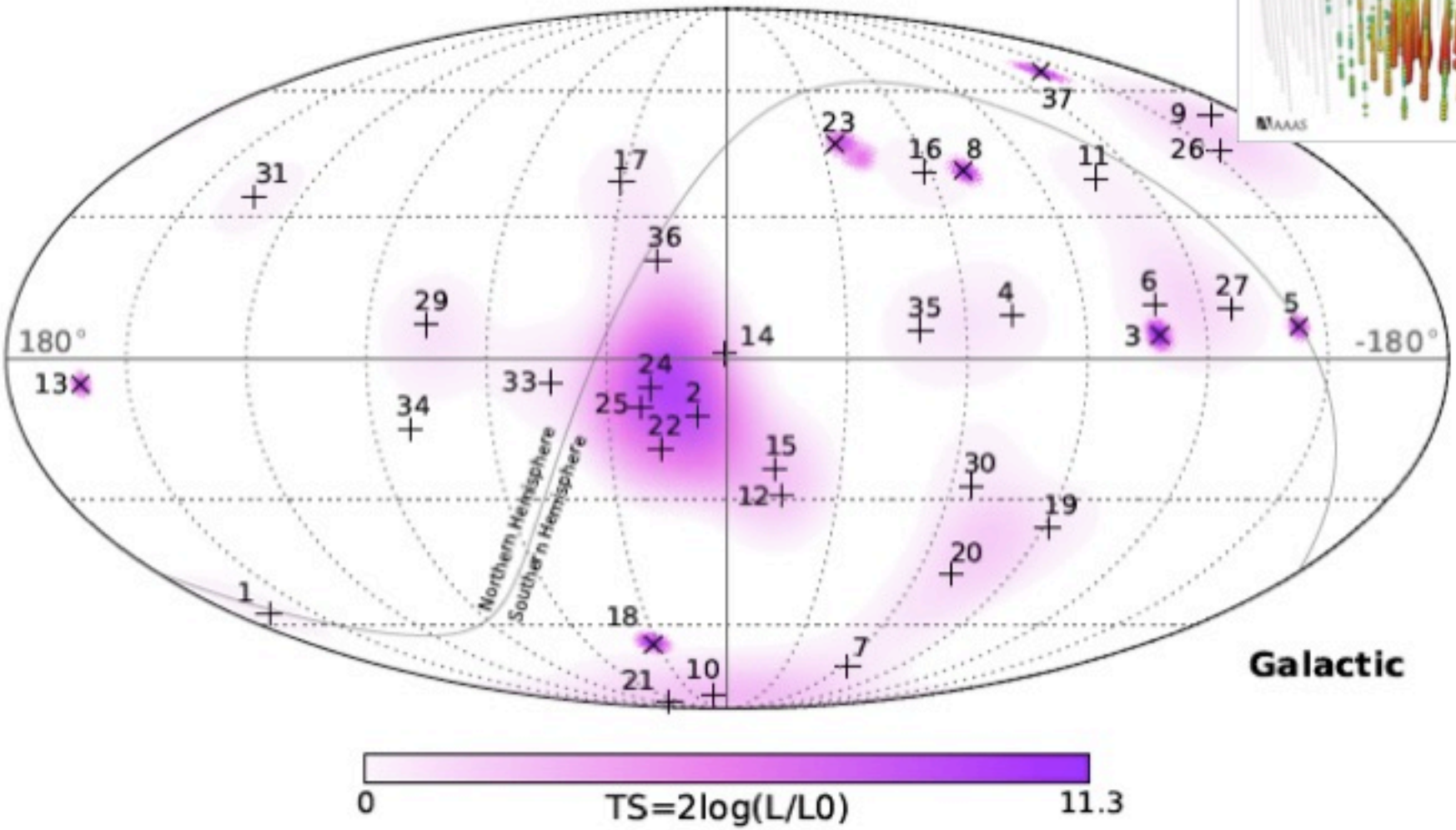
Questions Related to CR Science

- Origin of PeV neutrinos (IceCube)

IceCube 37 Events

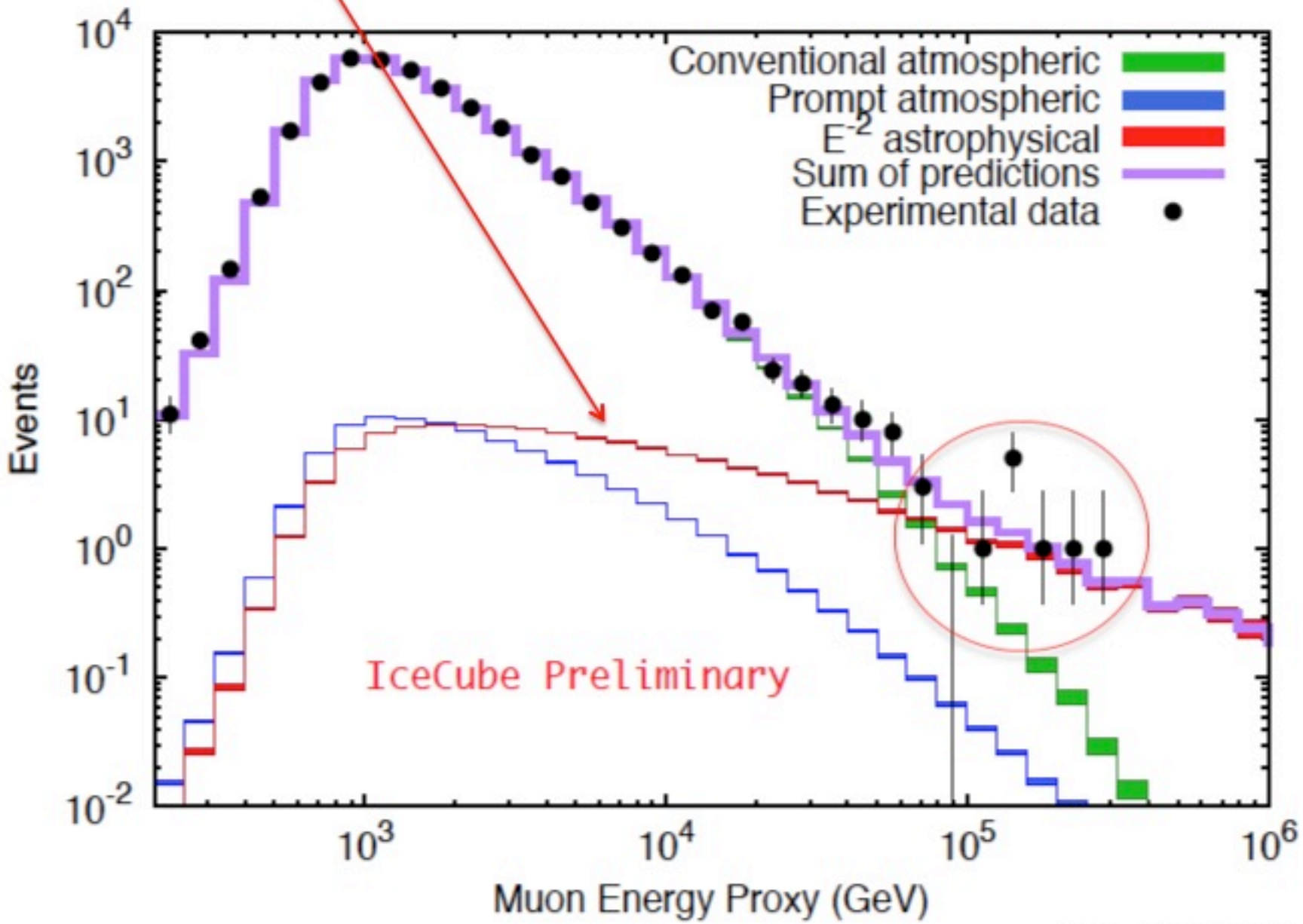


3 yr data; 30 TeV to 2 PeV



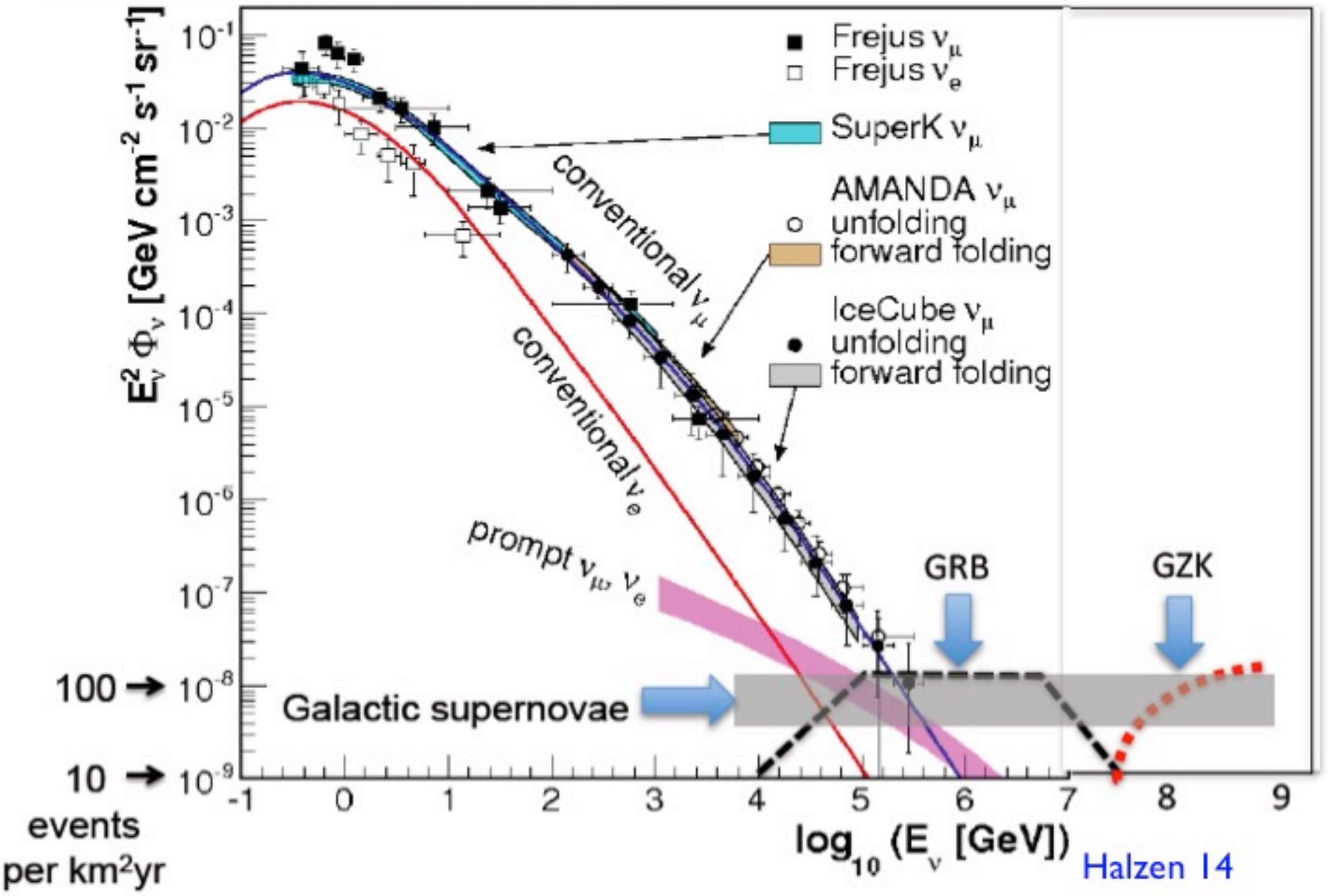
Phys. Rev. Lett. 113, 101101 (2014)

Cosmic Neutrino generated secondary muons



arXiv:1412.5106

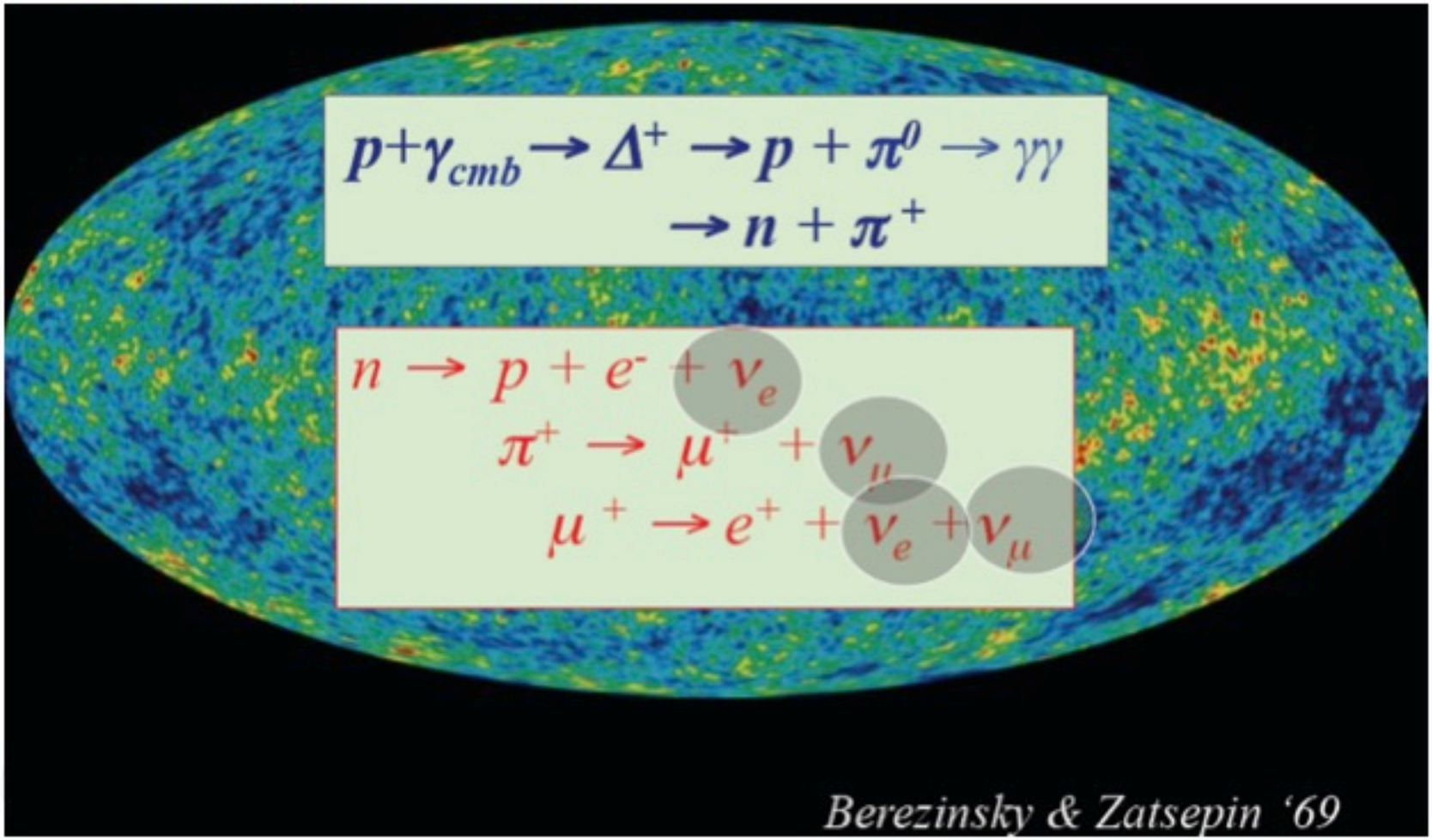
Galactic or XtraGal CRs?

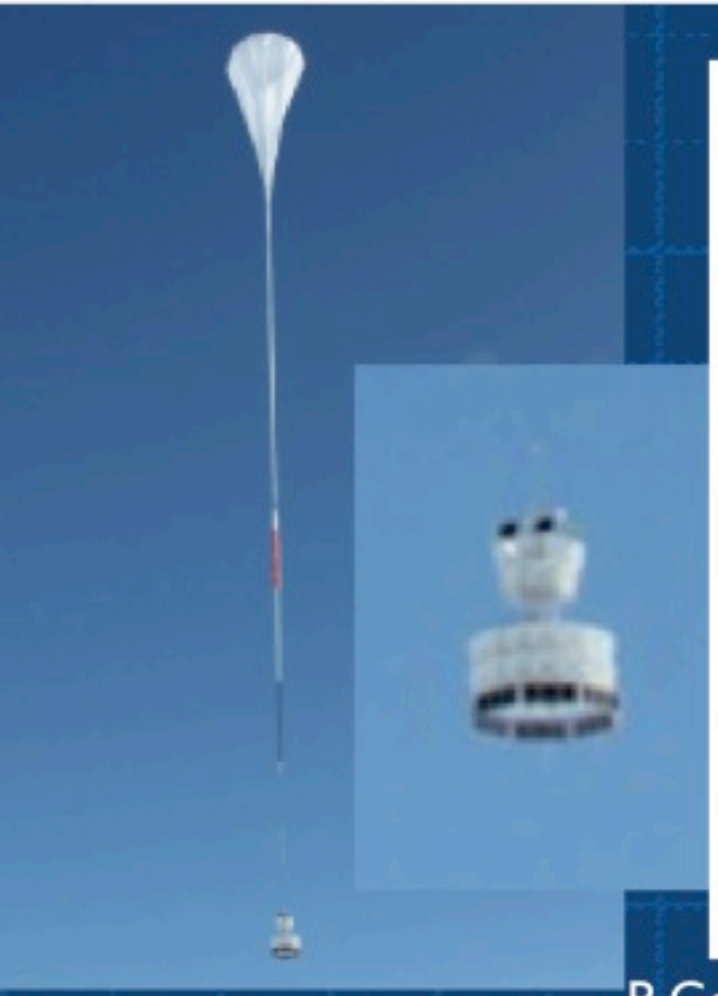


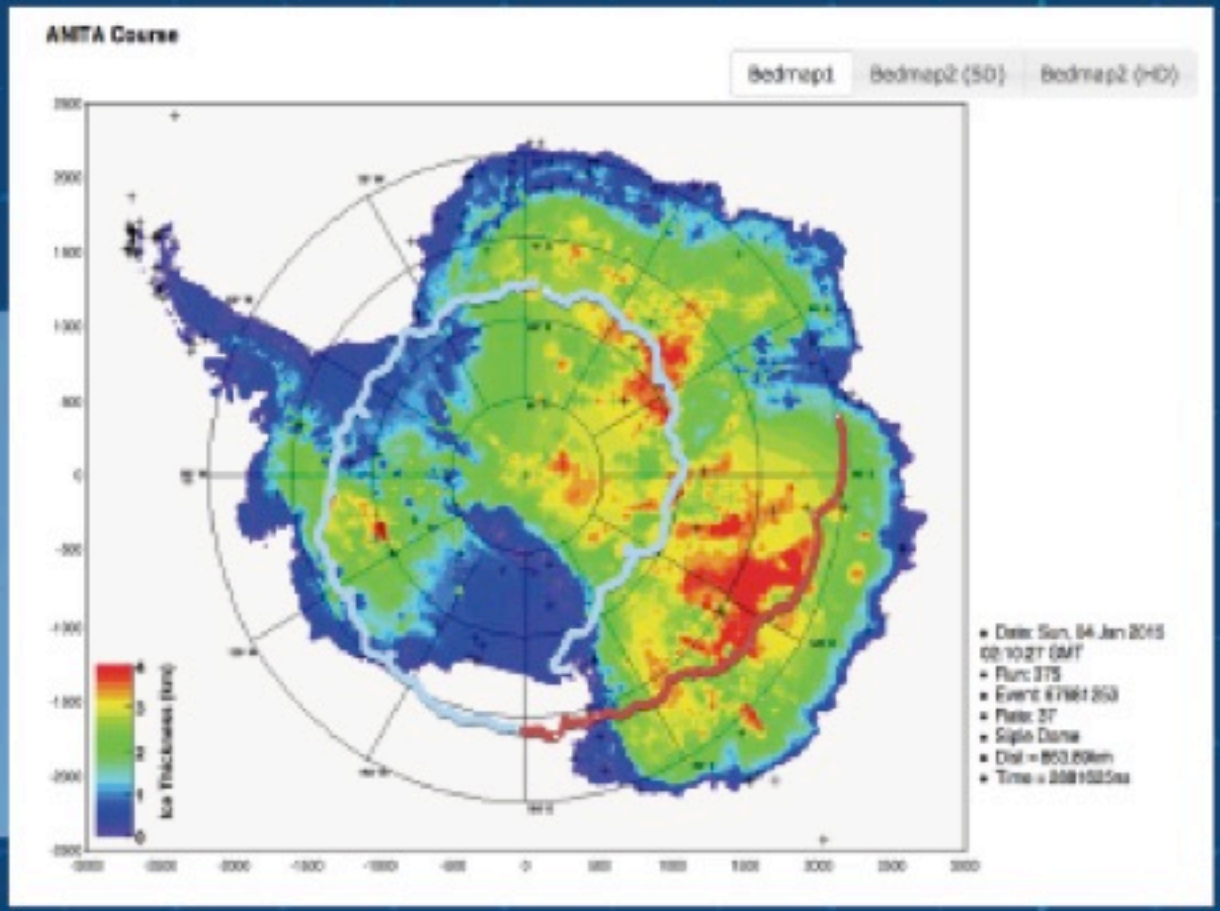
Halzen 14

Questions Related to CR Science

- Origin of PeV neutrinos (IceCube detections)
- GZK (BZ) Neutrinos?





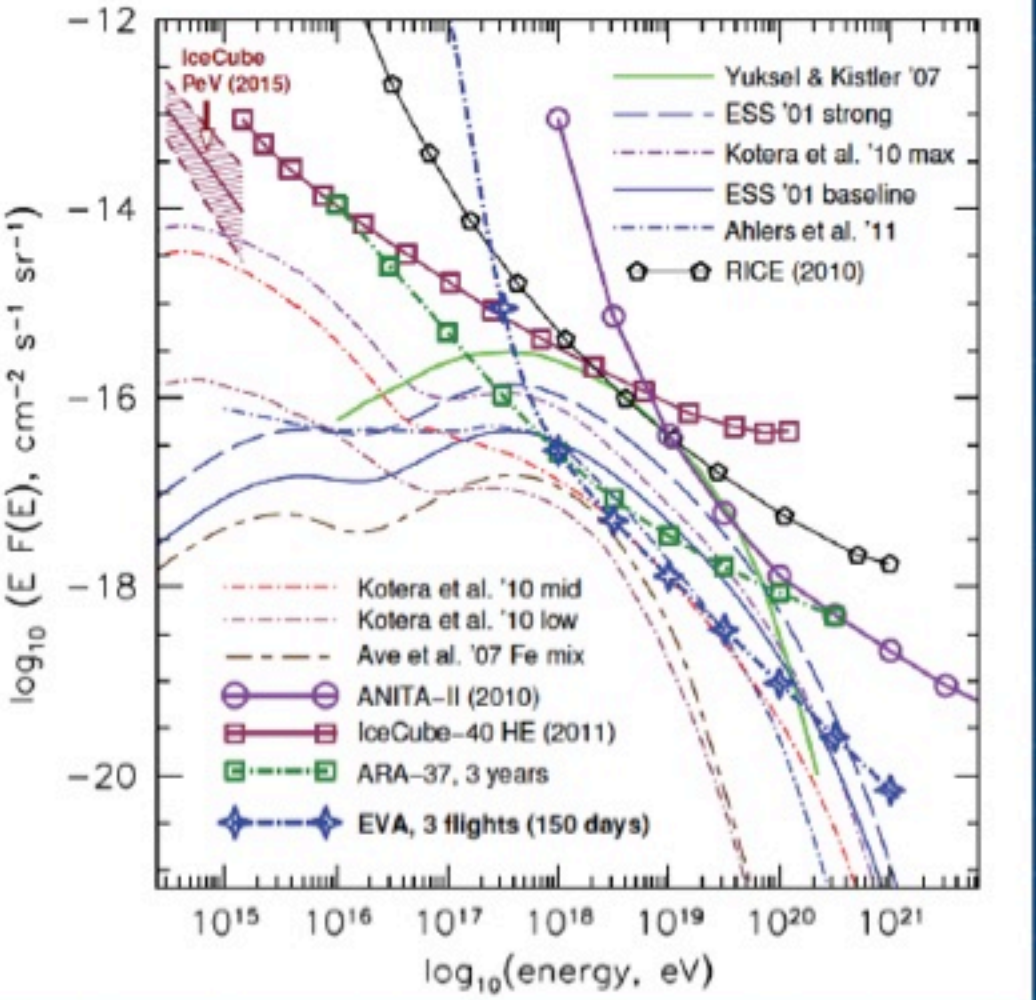


P. Gorham CosmicSIG

Left: ANITA-3 Launch, Dec. 2014, right, final payload track

HE+UHE neutrino fluxes/limits

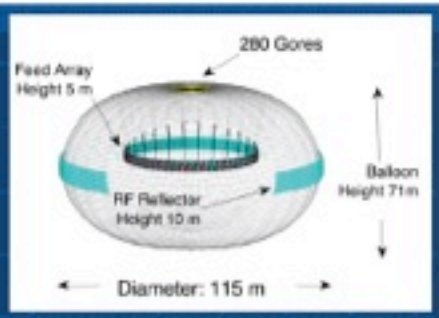
P. Gorham CosmicSIG

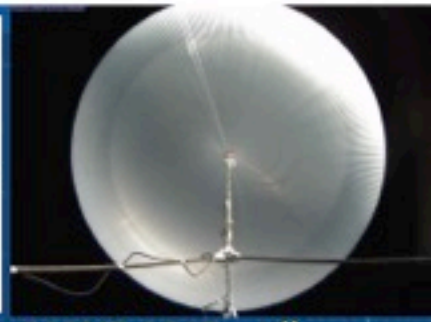


- HE fluxes (~PeV): IceCube sees a signal!
  - Unrelated to cosmogenic UHE neutrino flux? Probably.
  - But: this is an Unexpected & unpredicted flux → it is crucial to continue the search for UHE fluxes!
- Highest UHE flux predictions now constrained by radio methods, both embedded (eg. RICE/ARA) & balloon-based (ANITA)
  - RICE completed, ARA in development through end-of-decade
- Above ~3e18 eV, balloon-based methods are currently the only viable approach
  - Need ultra-large target volume
  - To go deeper than ANITA requires new technology → EVA
- Orbital detectors such as EUSO would extend this to ~ZeV neutrino energies (>10^{20} eV)

ExaVolt antenna (EVA)

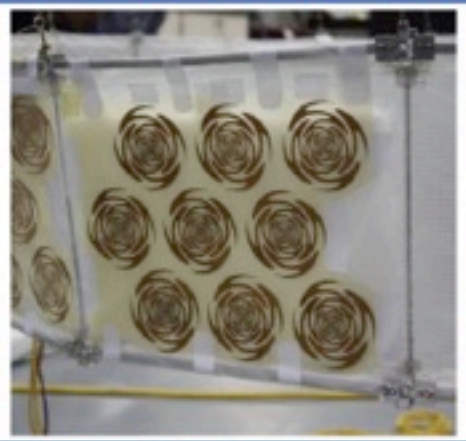
P. Gorham CosmicSIG



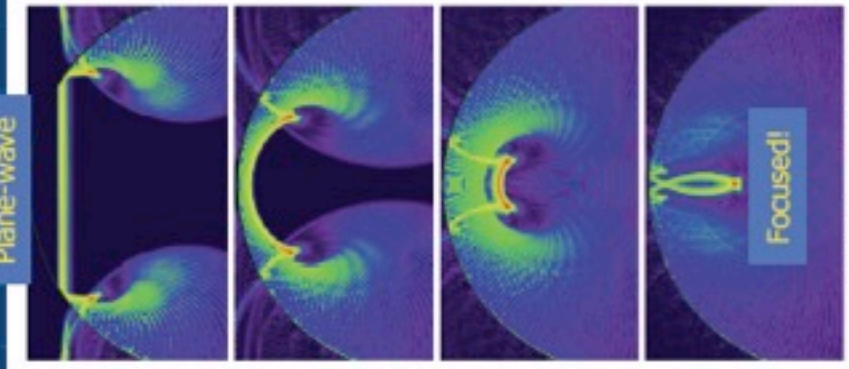


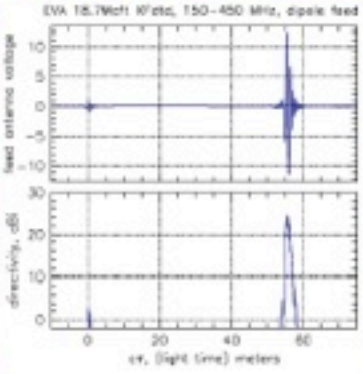
662NT 2015, still up: 18Mcft is reality!

Wallops: successful 1/20th scale model test, 2014



XFDTD simulation of 18Mcft EVA system: validated!





- Based on "super-pressure" NASA balloon technology
- Gives balloon with stable shape and altitude
- Reflective band near equator = toroidal radio dish
- Focus is in balloon interior, requires an inner membrane for patch-antenna feed array
- Gain estimates give 25-33 dBi using 3 independent methods (50-300x ANITA)
- Will require MIDEX-class Explorer Mission-of-opportunity at full scale

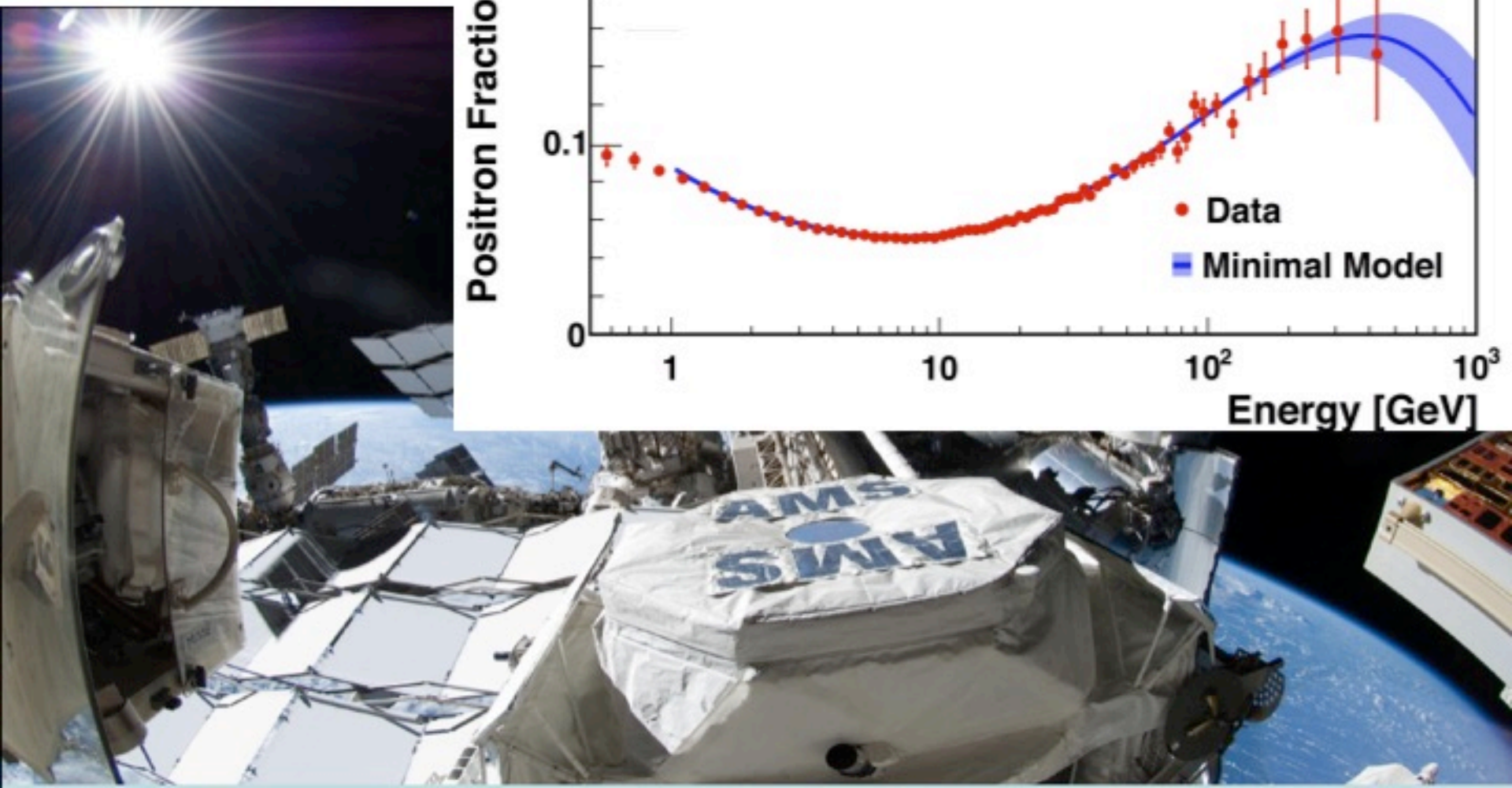
Questions Related to CR Science

- Origin of PeV neutrinos (IceCube detections)
- GZK Neutrinos?
- Indirect Dark Matter Searches
  - WIMP in the Galactic Halo: e+, e-; p, anti-p, γ , ν ...

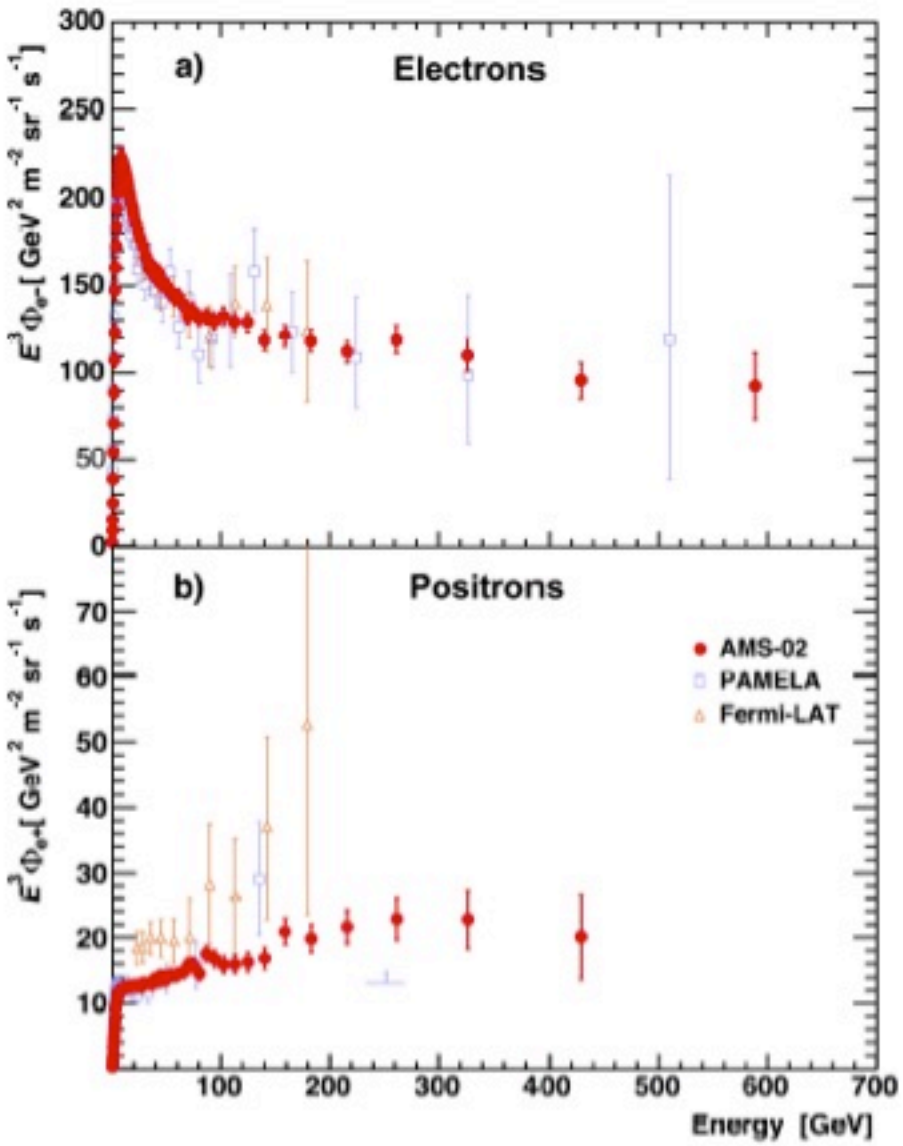
Session Y9: Invited Session: New Results on Cosmic Rays (Apr 14 2015 1:30PM, Key 5)

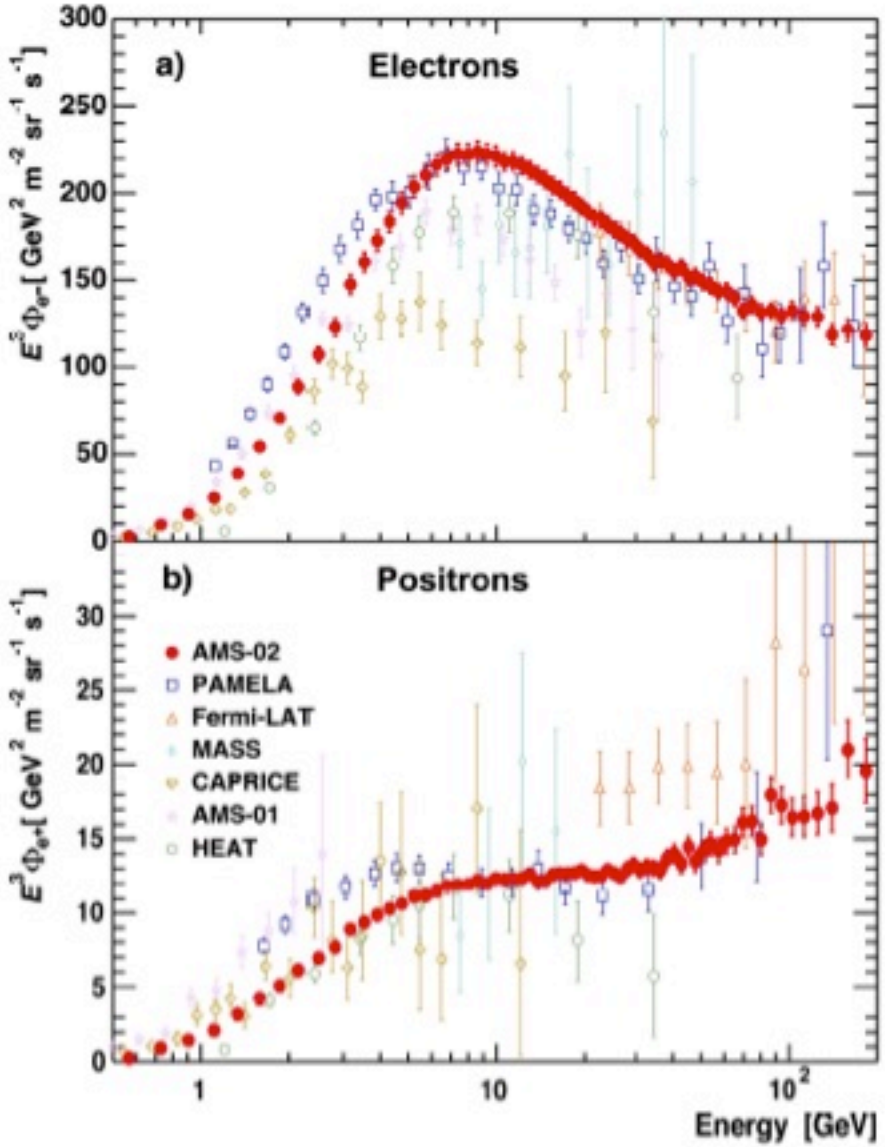
Cosmic Rays Recent Highlights

- AMS-02 (Alpha Magnetic Spectrometer) on the ISS
- positron fraction

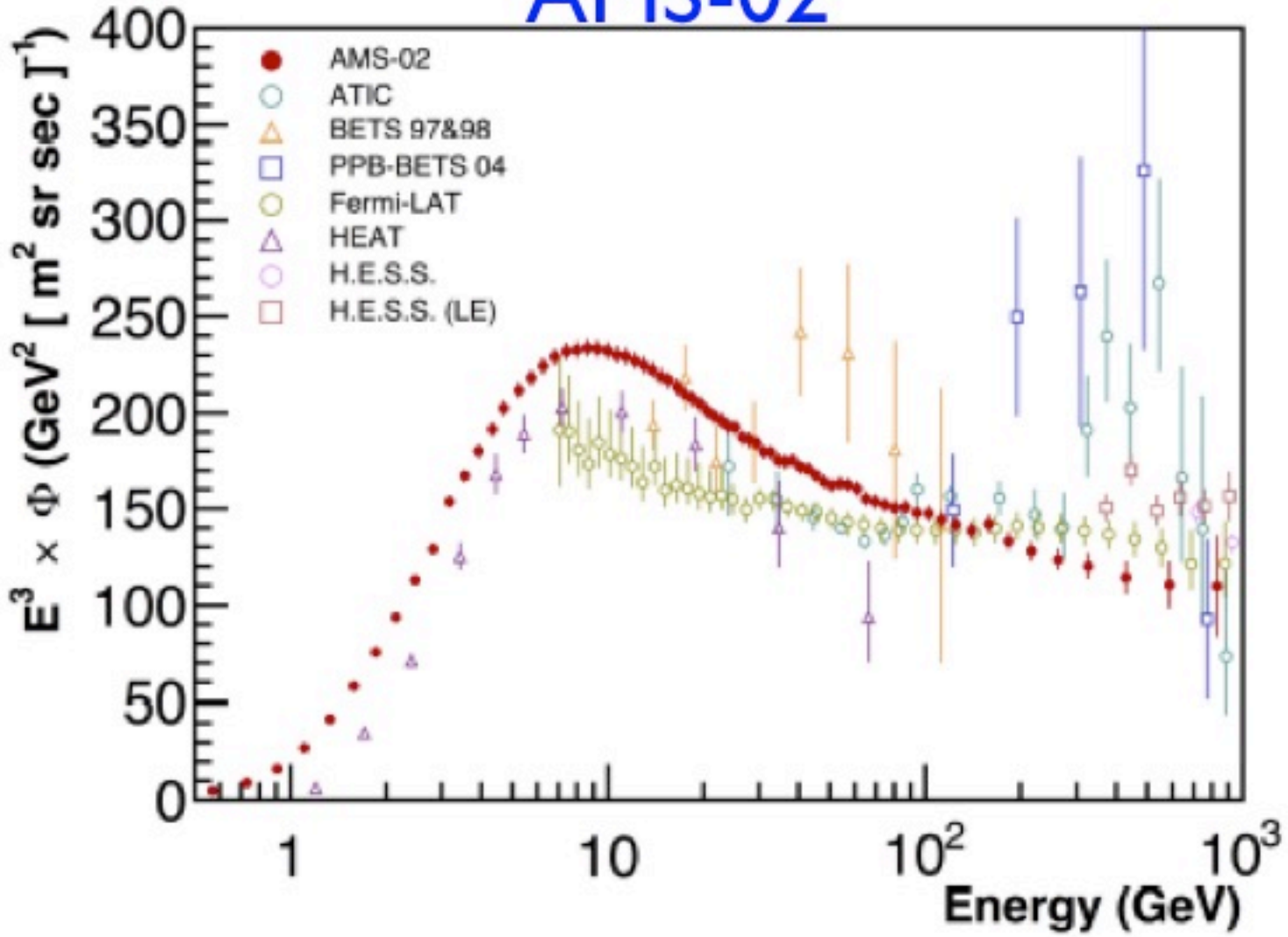


AMS-02

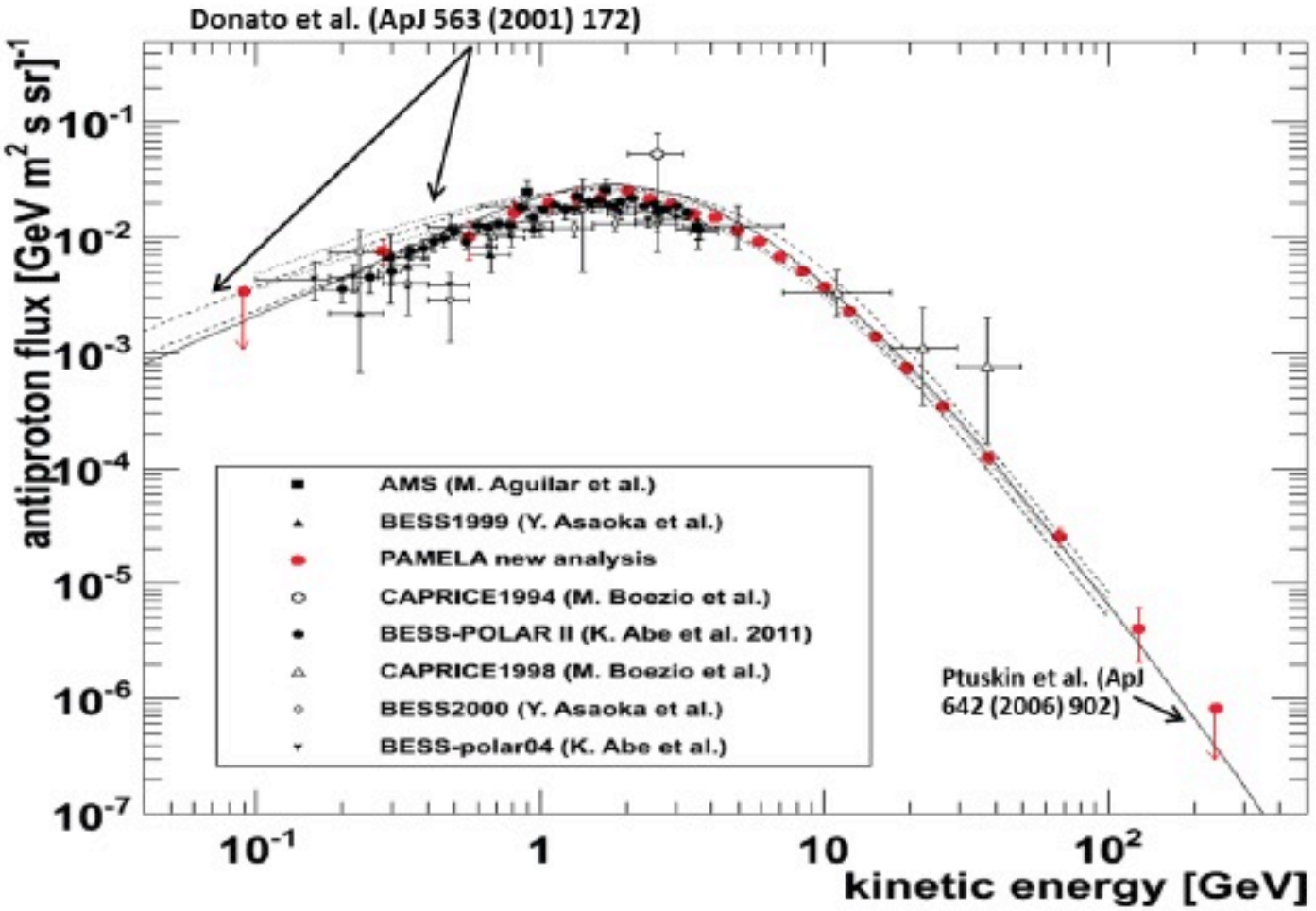

a)
Electrons
b)
Positrons
AMS-02
PAMELA
Fermi-LAT
Energy [GeV]


a)
Electrons
b)
Positrons
AMS-02
PAMELA
Fermi-LAT
MASS
CAPRICE
AMS-01
HEAT
Energy [GeV]

AMS-02


AMS-02
ATIC
BETS 97&98
PPB-BETS 04
Fermi-LAT
HEAT
H.E.S.S.
H.E.S.S. (LE)
$E^3 \times \Phi$ (GeV^2 [m^2 sr sec T^{-1}])
400
350
300
250
200
150
100
50
0
1
10
10^2
10^3
Energy (GeV)

Antiprotons



- BESS-Polar II and PAMELA spectra agree in shape but differ slightly (<10%) in absolute flux
- Both agree in shape with secondary calculations
- AMS-02 has not published antiproton measurements

Opportunities in Space for CR Science

- Ultra Heavy Nuclei
  - ACE/CRIS
  - Super-TIGER
  - HNX
- Precise Measurements from GeV to TeV
  - PAMELA
  - AMS
  - CALET
- Galactic Cosmic Rays up to the knee
  - CREAM, TRACER
  - ISS-CREAM
- Extragalactic Cosmic Rays
  - JEM-EUSO
  - OWL/PATEL
- Cosmic Neutrinos
  - ANITA
  - EVA

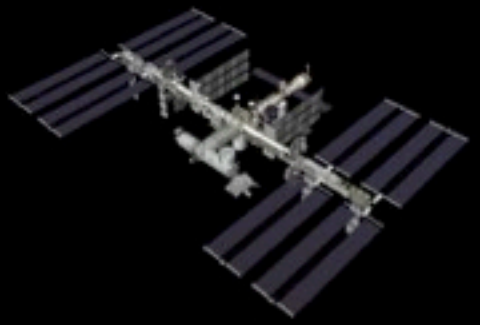
Open Questions in CR Science

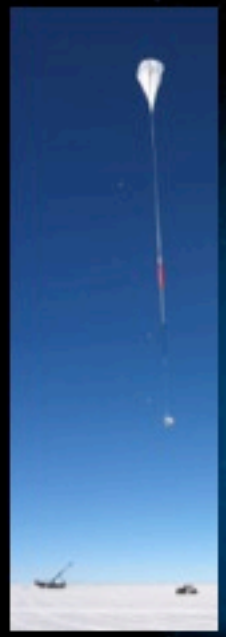
- Origin of Galactic Cosmic Rays (GCR):
  - What are the accelerators?
  - What are they accelerating?
  - How do they propagate in the Galaxy?
  - Where is the Transition between Galactic & ExtraGalactic CRs?
- Origin of ExtraGalactic Cosmic Rays (XGCR):
  - What are the accelerators?
  - What are they accelerating?
  - How do they propagate to Earth?
  - At what Energy COSMIC RAY ASTRONOMY begins?
- How do Cosmic Rays Affect the Earth, the Solar System, the ISM, the Galaxy, other Galaxies, and the formation of Stars and Galaxies?

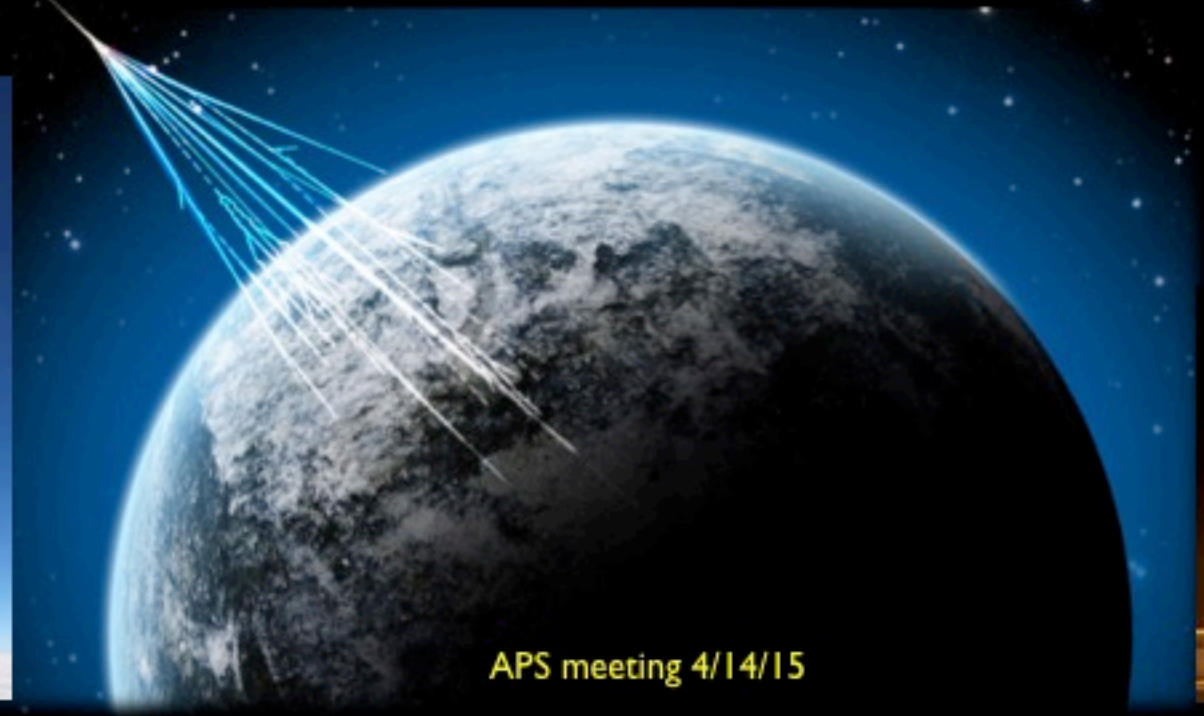
Questions Related to CR Science

- Origin of PeV neutrinos
- GZK Neutrinos?
- Indirect Dark Matter Searches
  - WIMP in the Galactic Halo: e+, e-; p, anti-p, γ , ν ...
- Probe of Particle Interactions above LHC energies
  - Ultrahigh Energy Cosmic Rays (UHECR) E_{cm} > 100 TeV
  - Ultrahigh Energy Neutrinos
- Searches for Exotic Components of Matter:
  - Antinuclei
  - Magnetic Monopoles
  - Strangelets
  - Qballs
  - Primordial Black Holes

The Origin of Cosmic Rays to be discovered from Space







APS meeting 4/14/15

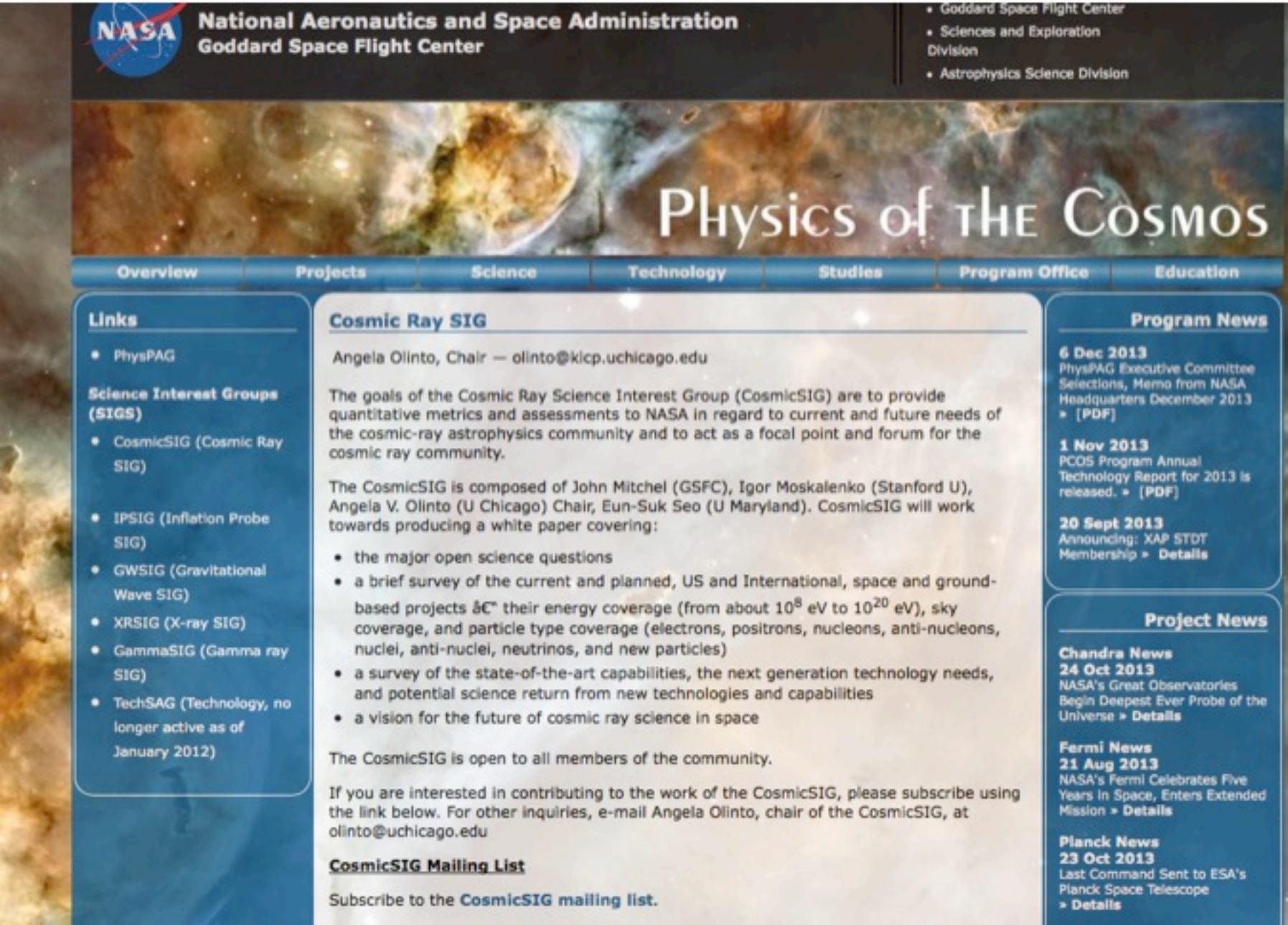
CosmicSIG Activities

- Committee formed April 2013
  - John Mitchel (GSFC), Igor Moskalenko (Stanford U), Angela Olinto (U Chicago) Chair, Eun-Suk Seo (U Maryland)
- Goals of CosmicSIG
  - Provide an assessment to NASA HQ and the PCOS program office of the status and the **current and future** needs of the **cosmic-ray astrophysics** community.
  - Act as a **focal point** and forum for the cosmic ray community.
- White Paper with Cosmic Ray vision for the next decade(s)
  - Gather input from Community
  - Survey current and future projects and missions and their science goals and coverage
  - Survey technology development needs for future progress in the field

Cosmic SIG

- NASA's candidate large mission concepts identify four missions that will provide significant improvements in the IR to UV, and X-ray wavelengths. However, such a program does not take research interests of the cosmic ray community into consideration.
- As highlighted in the NASA Astrophysics Roadmap *Enduring Quests Daring Visions* (December 2013) a "less apparent component of galaxies" and the intergalactic medium (IGM) are high-energy charged particles, collectively called *cosmic rays*. These dynamically important particles provide about a third of the interstellar medium (ISM) energy density, and their origin is still unclear. At low energies they may be accelerated by Galactic supernova remnants, pulsars, and interstellar shocks, while at ultrahigh energies their unknown sources are extragalactic. Acceleration of particles in yet to be understood processes in astrophysical sources and their escape into the interstellar and intergalactic medium, the role of cosmic rays in galactic dynamics, their connection to galactic and extragalactic winds and magnetic fields are some of the questions that can be addressed with MIDEX scale missions. The direct measurements of cosmic rays must complement the indirect information that is deduced from observations in radio to gamma-rays and neutrinos. A comprehensive program of cosmic ray studies must be a part of NASA's plan.
- The bulk of cosmic ray data have been obtained with great success by balloon-borne instruments. However, to address open questions in cosmic ray astrophysics, future missions require the exposure offered by spaceflight for rare species, such as isotopes, ultra-heavy elements, and high energies ("knee" and above). Isotopic composition measurements of $1 =< Z =< 28$ up to ~10 GeV/nucleon that are critical for understanding the interstellar propagation and the origin of elements are still to be accomplished. The cosmic ray composition in the knee (PeV) region holds keys to understanding the origin of cosmic rays. In addition to the forthcoming ISS-CREAM and CALET, a EUSO-like mission for ultrahigh energy cosmic rays and a Super-TIGER-like mission for ultra heavy nuclei could accomplish a vision of a complete cosmic ray observatory on the ISS.
- **Strong support of the Explorers and Probe categories of payloads would be needed for the completion of these missions over the next decade.**

http://pcos.gsfc.nasa.gov/sigs/cosmicsig.php



National Aeronautics and Space Administration
Goddard Space Flight Center

- Goddard Space Flight Center
- Sciences and Exploration Division
- Astrophysics Science Division

Physics of the Cosmos

Overview | Projects | Science | Technology | Studies | Program Office | Education

Links

- PhysPAG

Science Interest Groups (SIGS)

- CosmicSIG (Cosmic Ray SIG)
- IPSIG (Inflation Probe SIG)
- GWSIG (Gravitational Wave SIG)
- XRSIG (X-ray SIG)
- GammaSIG (Gamma ray SIG)
- TechSAG (Technology, no longer active as of January 2012)

Cosmic Ray SIG

Angela Olinto, Chair — olinto@kicp.uchicago.edu

The goals of the Cosmic Ray Science Interest Group (CosmicSIG) are to provide quantitative metrics and assessments to NASA in regard to current and future needs of the cosmic-ray astrophysics community and to act as a focal point and forum for the cosmic ray community.

The CosmicSIG is composed of John Mitchel (GSFC), Igor Moskalenko (Stanford U), Angela V. Olinto (U Chicago) Chair, Eun-Suk Seo (U Maryland). CosmicSIG will work towards producing a white paper covering:

- the major open science questions
- a brief survey of the current and planned, US and International, space and ground-based projects â€" their energy coverage (from about 10^8 eV to 10^{20} eV), sky coverage, and particle type coverage (electrons, positrons, nucleons, anti-nucleons, nuclei, anti-nuclei, neutrinos, and new particles)
- a survey of the state-of-the-art capabilities, the next generation technology needs, and potential science return from new technologies and capabilities
- a vision for the future of cosmic ray science in space

The CosmicSIG is open to all members of the community.

If you are interested in contributing to the work of the CosmicSIG, please subscribe using the link below. For other inquiries, e-mail Angela Olinto, chair of the CosmicSIG, at olinto@uchicago.edu

CosmicSIG Mailing List

Subscribe to the **CosmicSIG mailing list.**

Program News

6 Dec 2013
PhysPAG Executive Committee Selections, Memo from NASA Headquarters December 2013 » [PDF]

1 Nov 2013
PCOS Program Annual Technology Report for 2013 is released. » [PDF]

20 Sept 2013
Announcing: XAP STDT Membership » **Details**

Project News

Chandra News
24 Oct 2013
NASA's Great Observatories Begin Deepest Ever Probe of the Universe » **Details**

Fermi News
21 Aug 2013
NASA's Fermi Celebrates Five Years in Space, Enters Extended Mission » **Details**

Planck News
23 Oct 2013
Last Command Sent to ESA's Planck Space Telescope » **Details**