High Energy Cosmic Particles & SKA

OzSKA 2017

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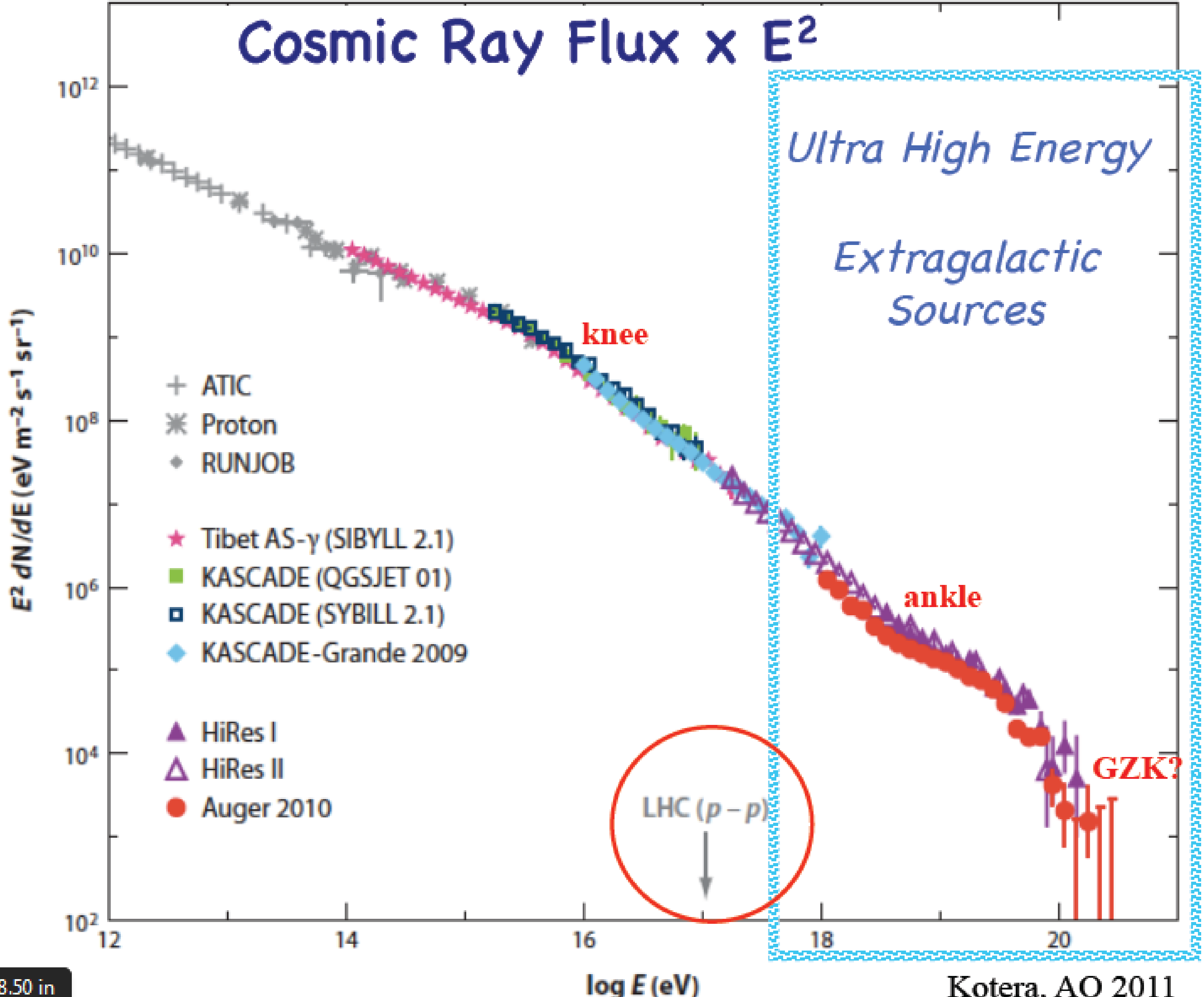
9 May2017

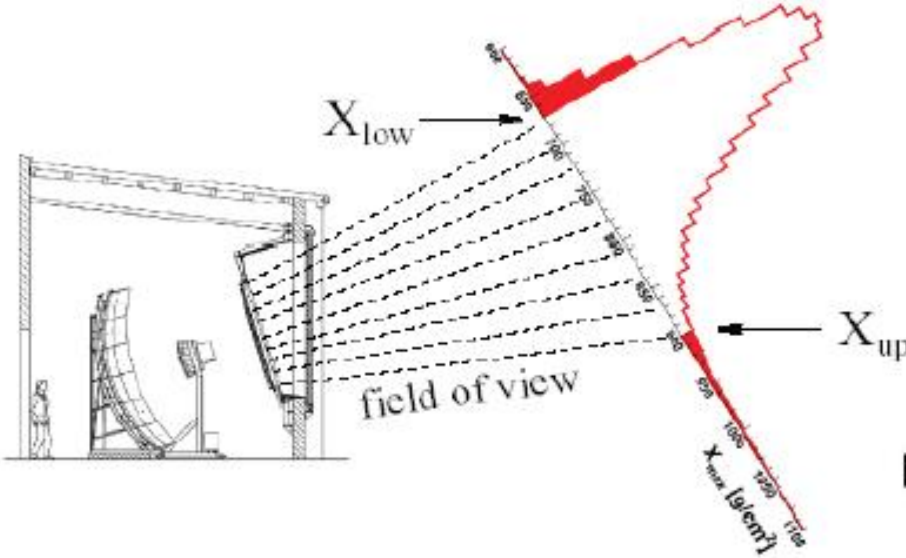
Overview

- Why ultra high energy cosmic rays have become very interesting
- Why radio astronomy and SKA
  - Atmospheric air showers
  - Lunar UHE neutinos
- The astroparticle physics community
  - Particles rather than photons (CTA – Miroslav Filipovic)
  - Same energy, similar culture
- SKA custom experiment policy

CSIRO

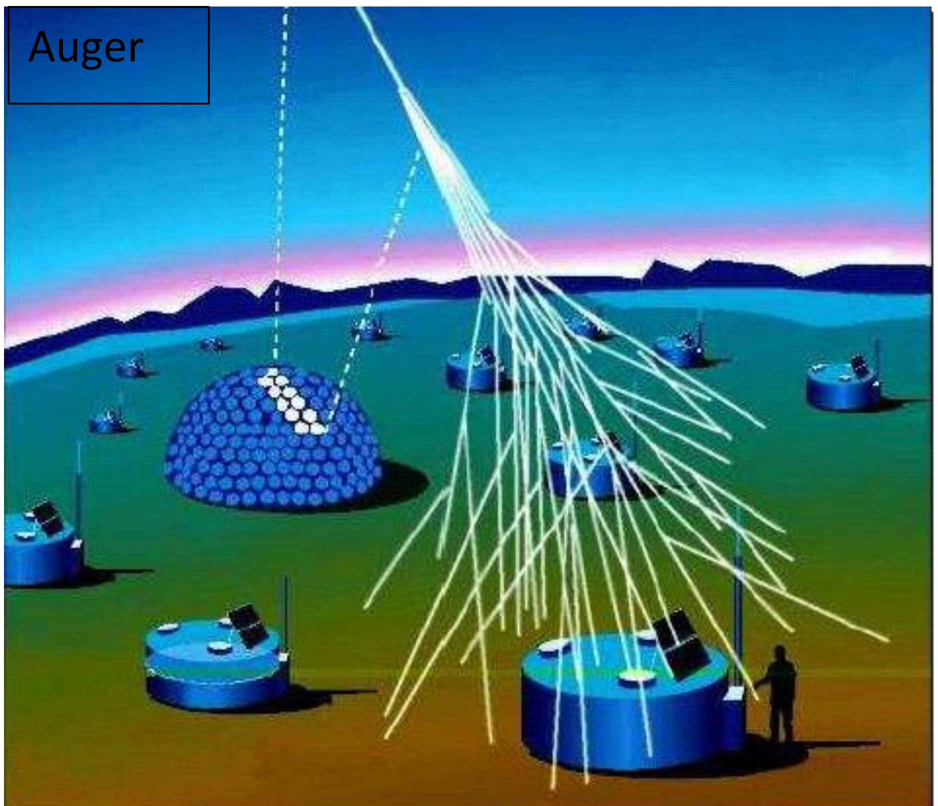


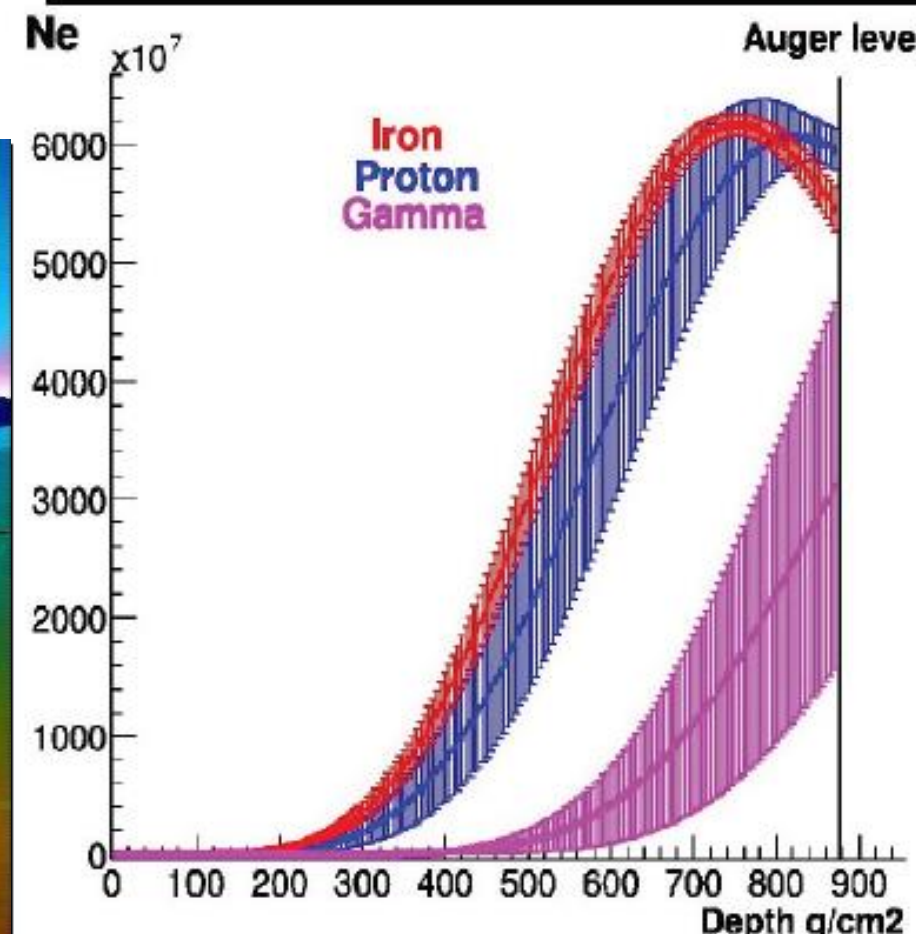
Kotera, AO 2011



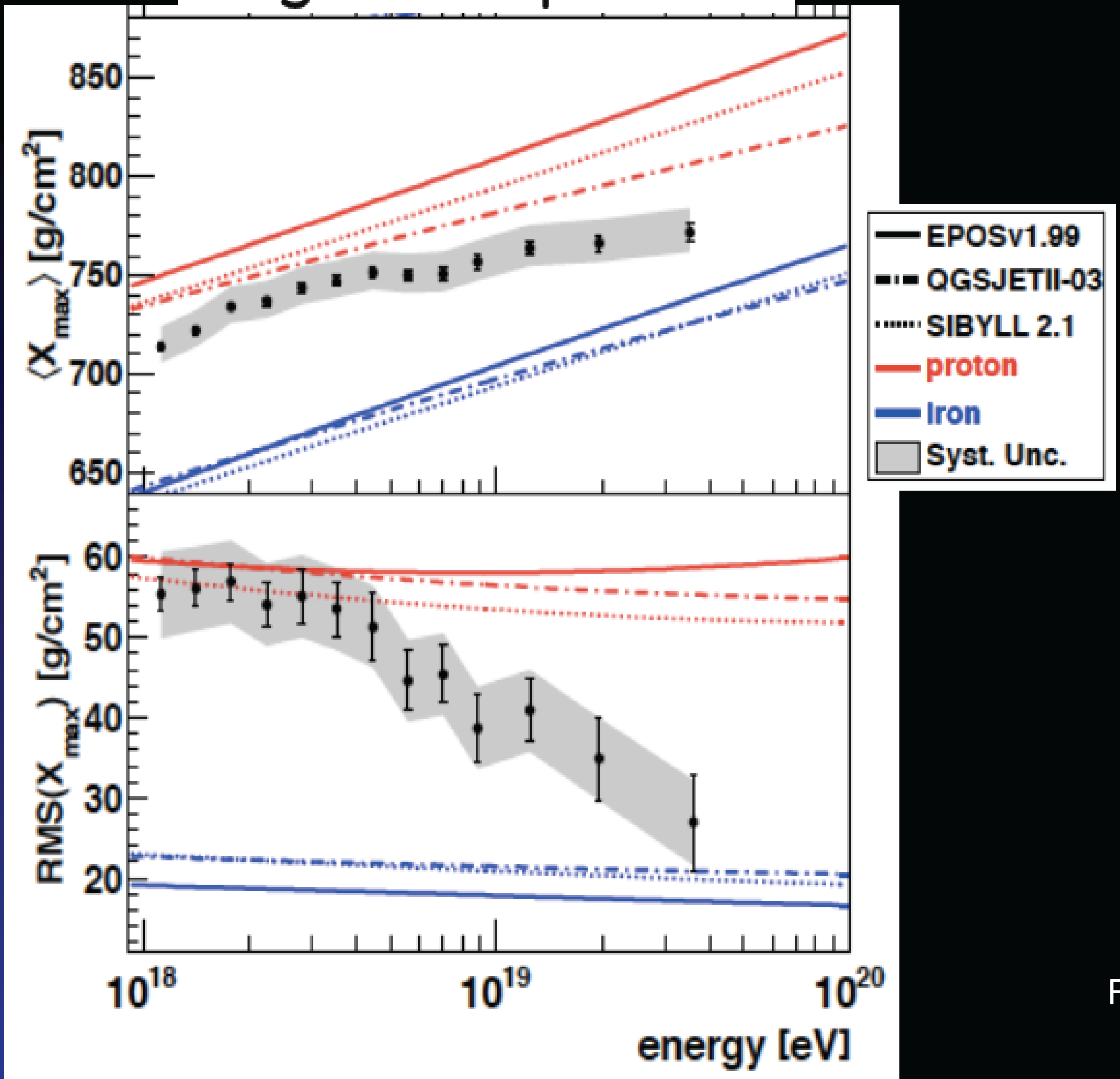
Composition observable: shower maximum

From Angela Olinto



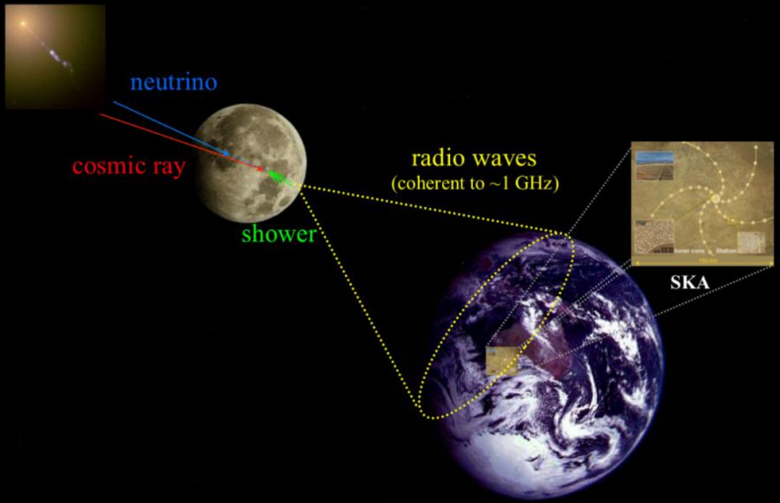


Auger Composition



From Angela Olinto

How to detect high-energy cosmic particles with the SKA



Justin Bray, University of Manchester

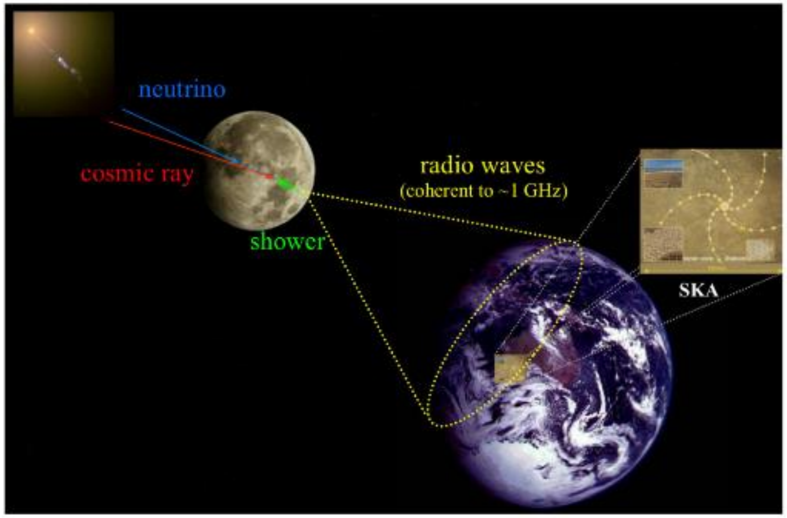
for the High-Energy Cosmic Particles Focus Group

Two techniques

Atmospheric detection

Area ~ 1 km^2
Energy $\gtrsim 10^{17}$ eV

Lunar detection



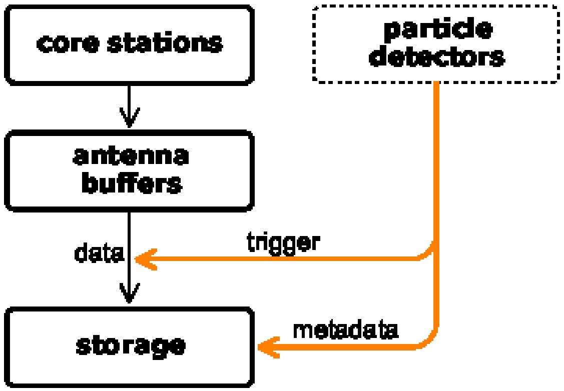
Area $\sim 10^5$ km^2
Energy $\gtrsim 10^{20}$ eV

SKA-LOW

Crome
Karlsruhe Institute of Technology

- German Cosmic Ray Facility
  - Particle physics community
- Searching for molecular bremsstrahlung.
  - Recombination time 10-100 nsec
- Array of three 3m fixed dishes
  - 3x3 multi-beam receivers
  - 3-4 GHz
- CROME have found the distribution over the ground is a ring so they are seeing some kind of anisotropic emission and not molecular bremsstrahlung.
  - *Smida et al 2013*
- Previous atmospheric radio emission models were wrong

Atmospheric Cosmic Ray Detection

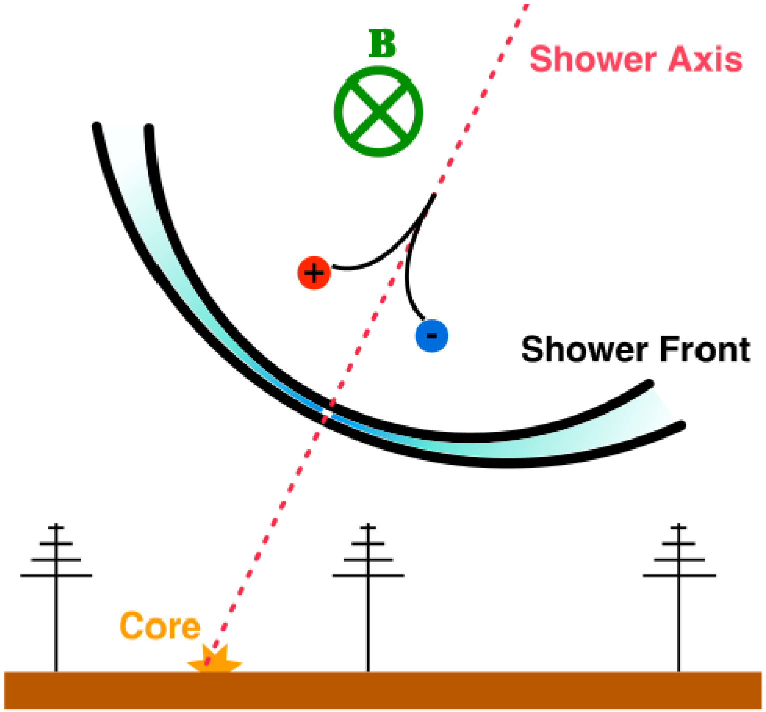


Data rate (core): 140 TB/s

Triggers:

- duration: 50 μs
- volume: 7 GB
- rate: 1/min
- data rate: 120 MB/s

Aim for commensality.



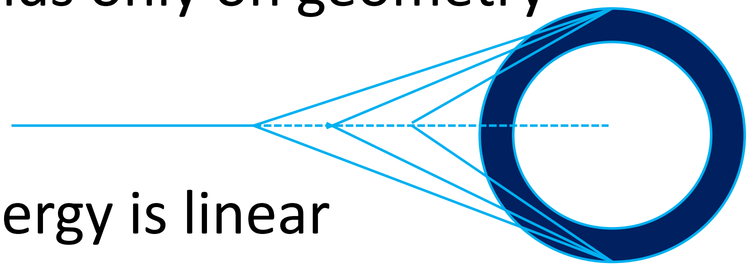
H. Schoorlemmer & K.D. de Vries

Radio: high precision

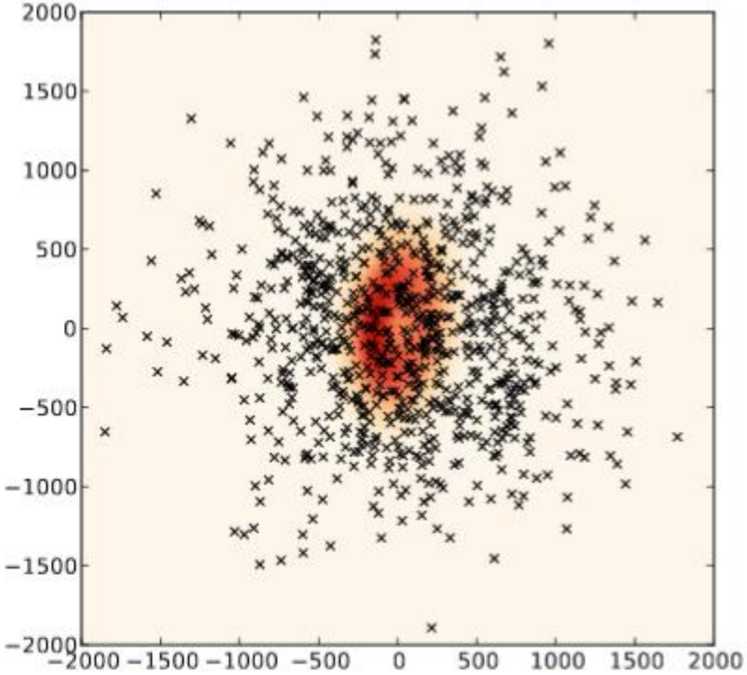
Particles: reliable trigger

Detecting the CR Cerenkof ring

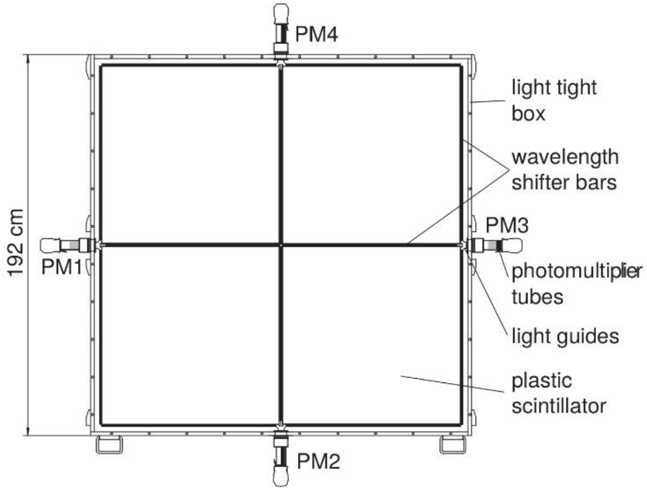
- Radio distribution on ground depends only on geometry – Cherenkov cone
  - ➢200m diameter ring , 10-20m thick



- Radio detection dependence on energy is linear
- SKA Low
  - ➢Energy range 10^{17} –10^{19} eV
  - ➢100s of antennas in core



Trigger – Spatial Coincidence Particle Detector



Antoni et al., NIMA 513 (2003), 490

Scintillation-type detector module.

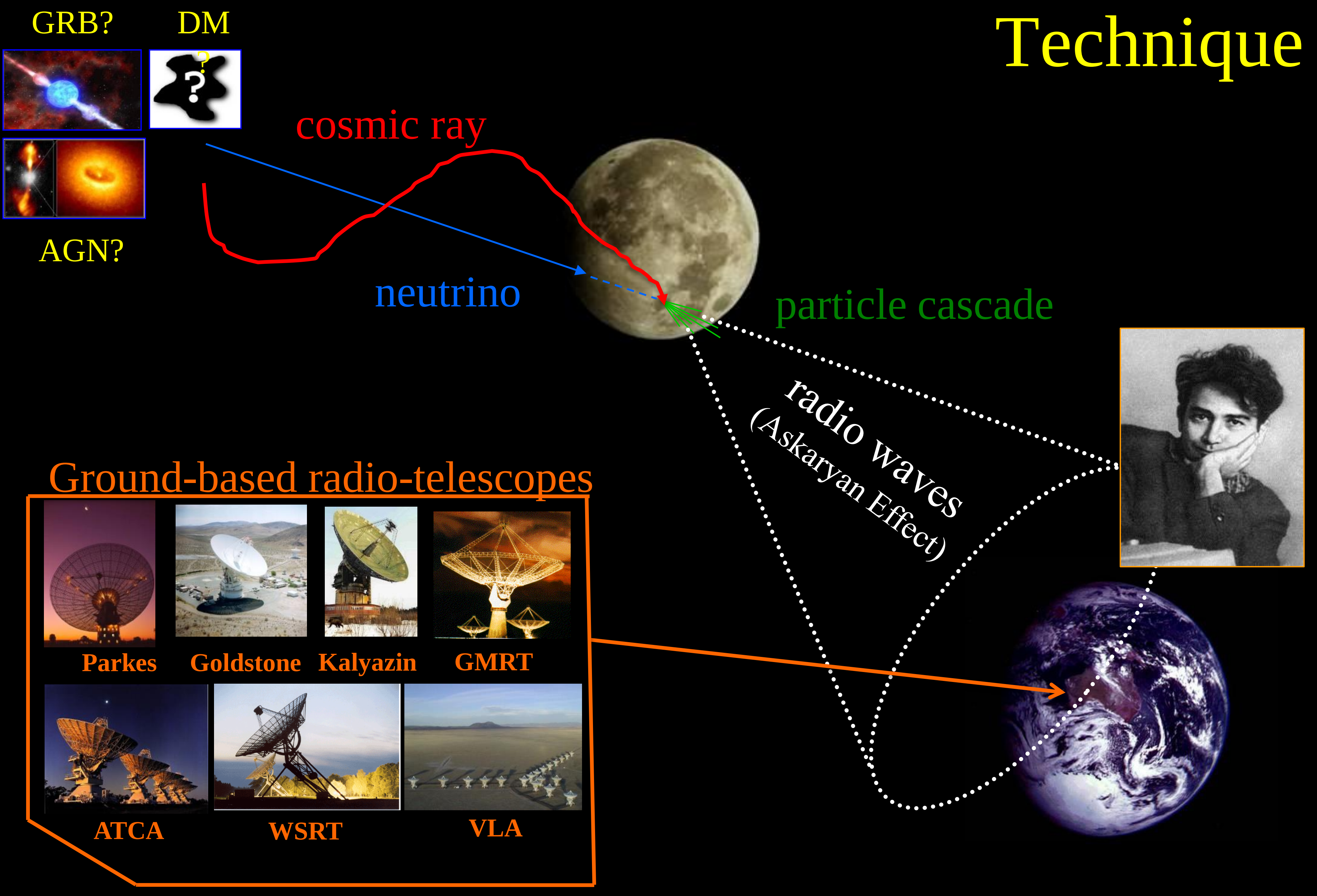
One of $\sim$ 200 from KASCADE experiment.

Kindly provided by A. Haungs et al., Karlsruhe.

Why use Radio ?

- UHE particle composition is the new big question
- Highest accuracy composition determination is now radio
  - LOFAR
- Optical Fluorescence detectors have low a duty cycle (10%)
  - Miss most rare events
  - Radio detectors have 100% duty cycle
- Need radio detection to measure composition above the GZK threshold at 10^{19} eV

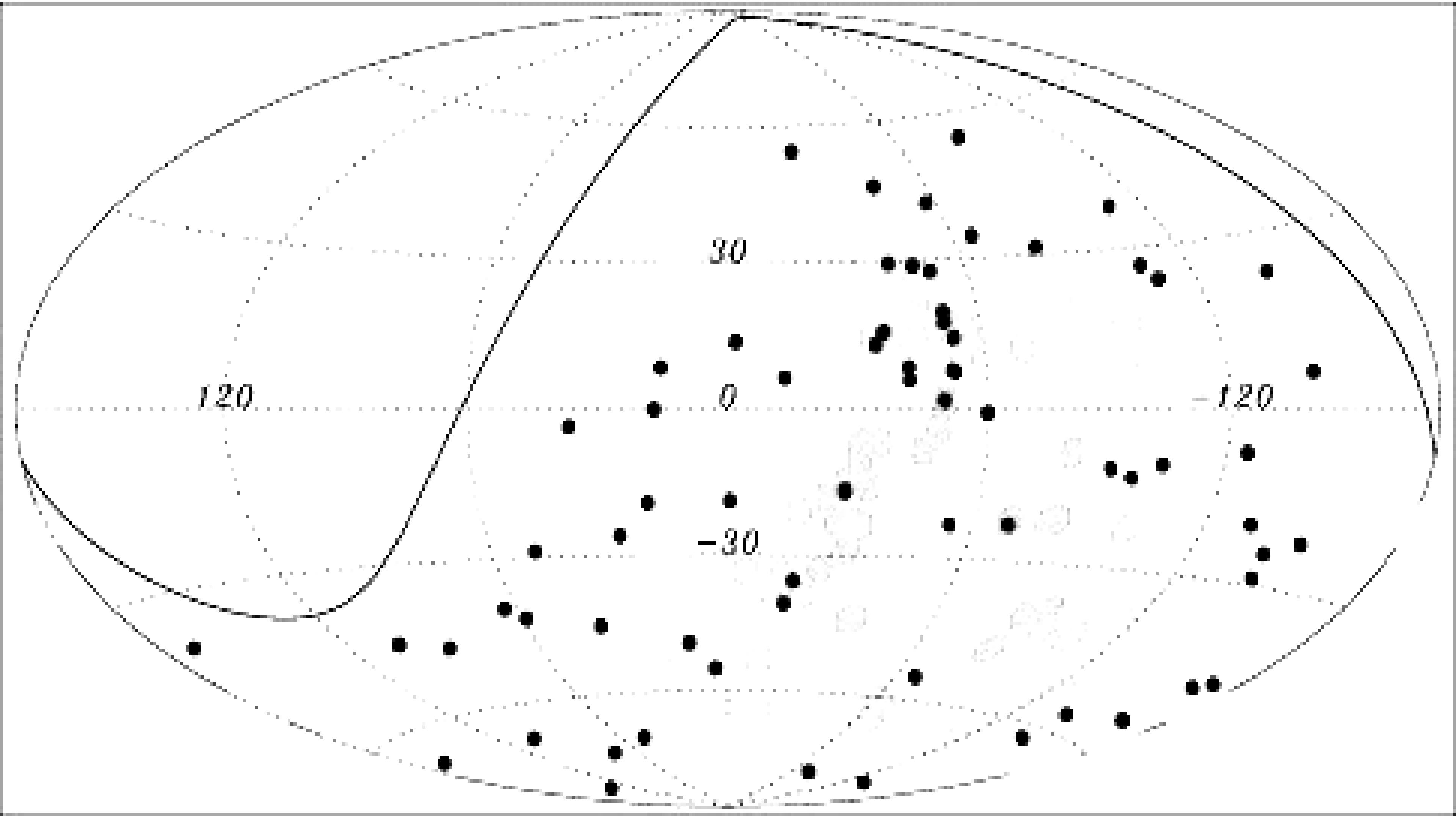
The Lunar Cerenkof Technique



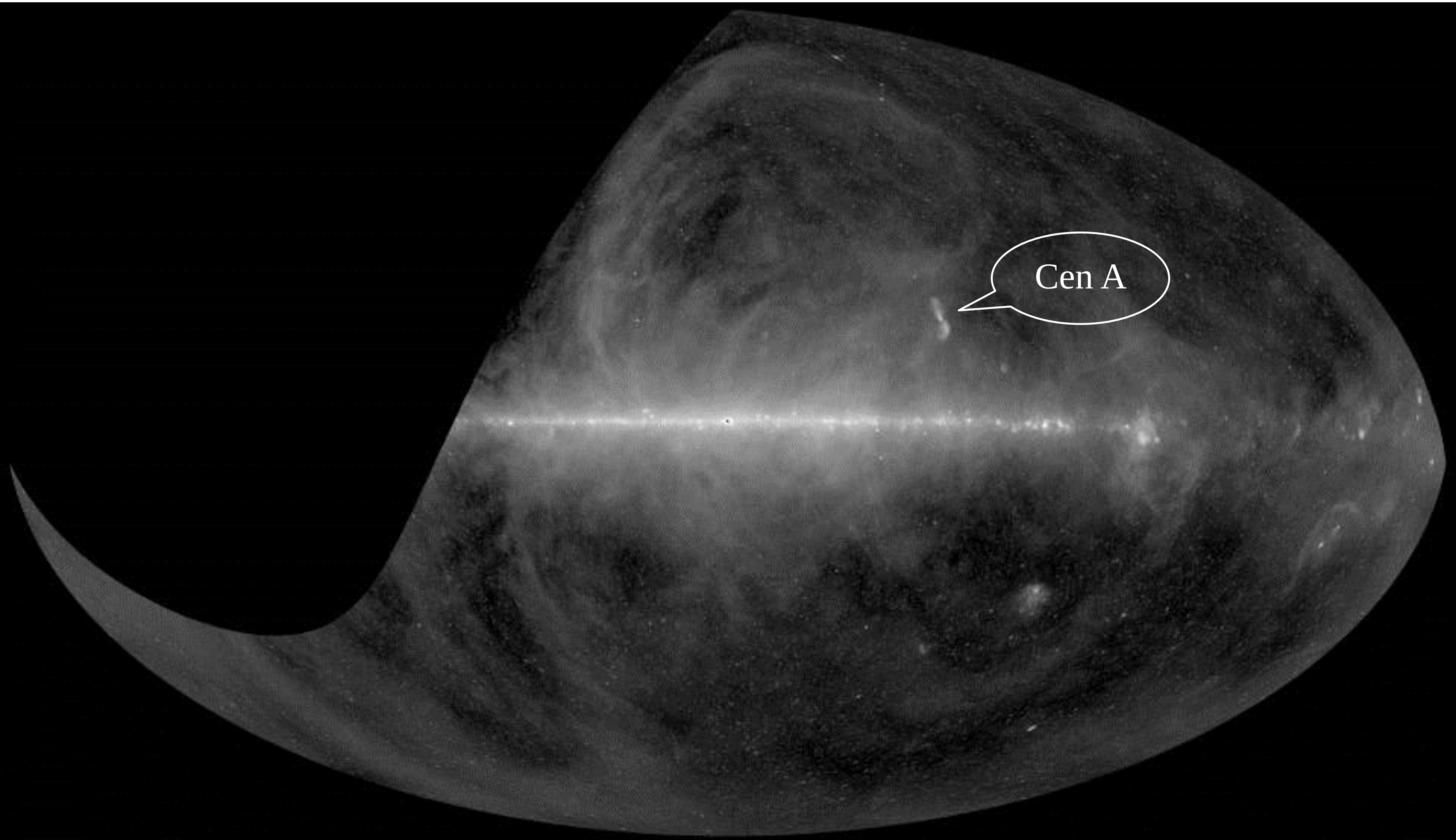
Centaurus A
the closest AGN

- Distance 3.4 Mpc
- Next closest comparable AGN M87 at 17 Mpc !
- Luminosity = 10^{42} ergs/sec
- Total Energy = 10^{60} ergs
  - in relativistic particles!
- Giant radio galaxy 0.5 Mpc in size
- Subtends a large angular size (8^{o})
- Auger detects 14 >55 EeV cosmic rays
  - 4.5 expected!
- UHE neutrinos come undeflected and un-absorbed from source
  - Universe is opaque to UHE protons

Auger Cosmic Rays

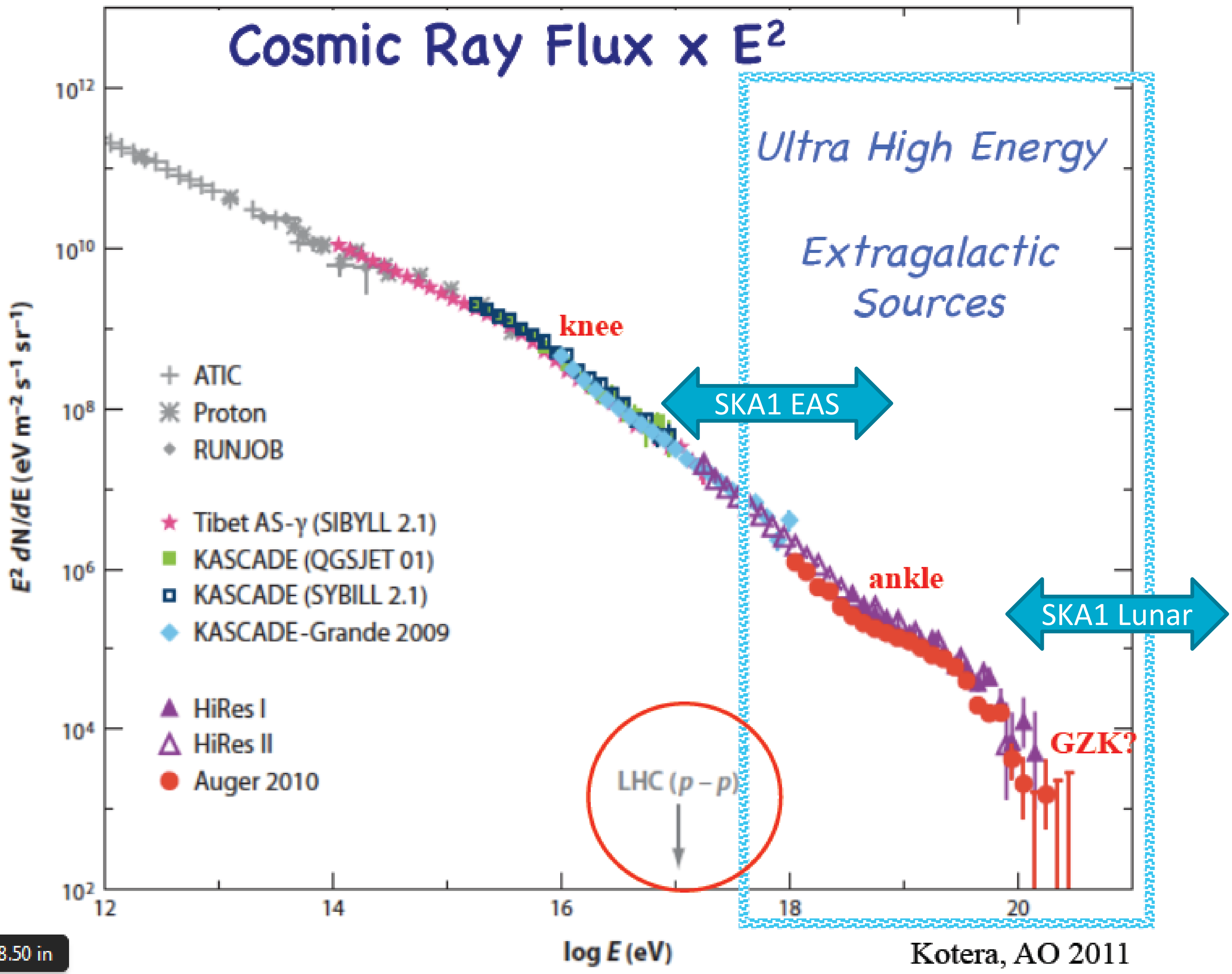


HIPASS Radio continuum



Summary

- High-energy particles can be detected with the SKA
  - Long integration times, large FoV
  - in the atmosphere – commensal, SKA Low
  - on the moon – targeted beams, SKA Low or Mid
- Both:
  - use buffer/trigger system
  - classed as custom experiments
- Atmospheric detection: use particle-detector located in core as trigger
  - Must be in the core
  - No RFI!
  - Can bury the detectors
- Lunar detection: needs a radio trigger



Kotera, AO 2011

High Energy Cosmic Particle Focus group

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Ken Gayley	University of Iowa	USA	
Nadir Hashim	Kenyatta University	Kenya	
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Evan Keane	SKA Organisation	UK	Office Contact

SKA custom experiment policy

- Response from the High Energy Particle Focus Group
  - *At first glance, this document seems to exclude the proposed high-energy cosmic-particle experiments proposed for the SKA, or at least to make them extremely difficult.*
- Limitations on custom experiment ports should emerge from the solutions suggested by the design consortia, rather than being matters of policy.
- Throughout the document, it appears that the trigger and buffered readout - are being treated differently from other SKA data products. We strongly urge the SKAO to treat buffered data like any other data product, with the right to trigger the buffers being analogous to the right to point beams.

CSIRO