

High Energy Cosmic Particles & SKA OZSKA 2017

Ron Ekers and Justin Bray 9 May2017

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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









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



Lunar detection



 $\begin{array}{l} {\rm Area} \sim 1 \ {\rm km^2} \\ {\rm Energy} \gtrsim 10^{17} \ {\rm eV} \end{array}$

 $\begin{array}{l} \mbox{Area} \sim 10^5 \ \mbox{km}^2 \\ \mbox{Energy} \gtrsim 10^{20} \ \mbox{eV} \end{array}$





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 μ s
- 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 10¹⁷ –10¹⁹ 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.

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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 10¹⁹ eV

The Lunar Cerenkof Technique

Ground-based radio-telescopes



GRB?

AGN?

DM





cosmic ray

neutrino

Goldstone Kalyazin



ATCA



WSRT

VLA



radio waves

Askaryan Erfect



Centaurus A the closest AGN

Distance 3.4 Mpc

Ekers

- Next closest comparable AGN M87 at 17 Mpc !
- Luminosity = 10⁴² ergs/sec
- Total Energy = 10⁶⁰ ergs
 ➢ in relativistic particles!
- Giant radio galaxy 0.5 Mpc in size
- Subtends a large angular size (8°)
- Auger detects 14 >55 EeV cosmic rays
 >4.5 expected!
- UHE neutrinos come undeflected and unabsorbed 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





High Energy Cosmic Particle Focus group

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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.

