UHE Cosmic Ray Air-Showers

ASKAP 2016

Sydney 6 June 2016

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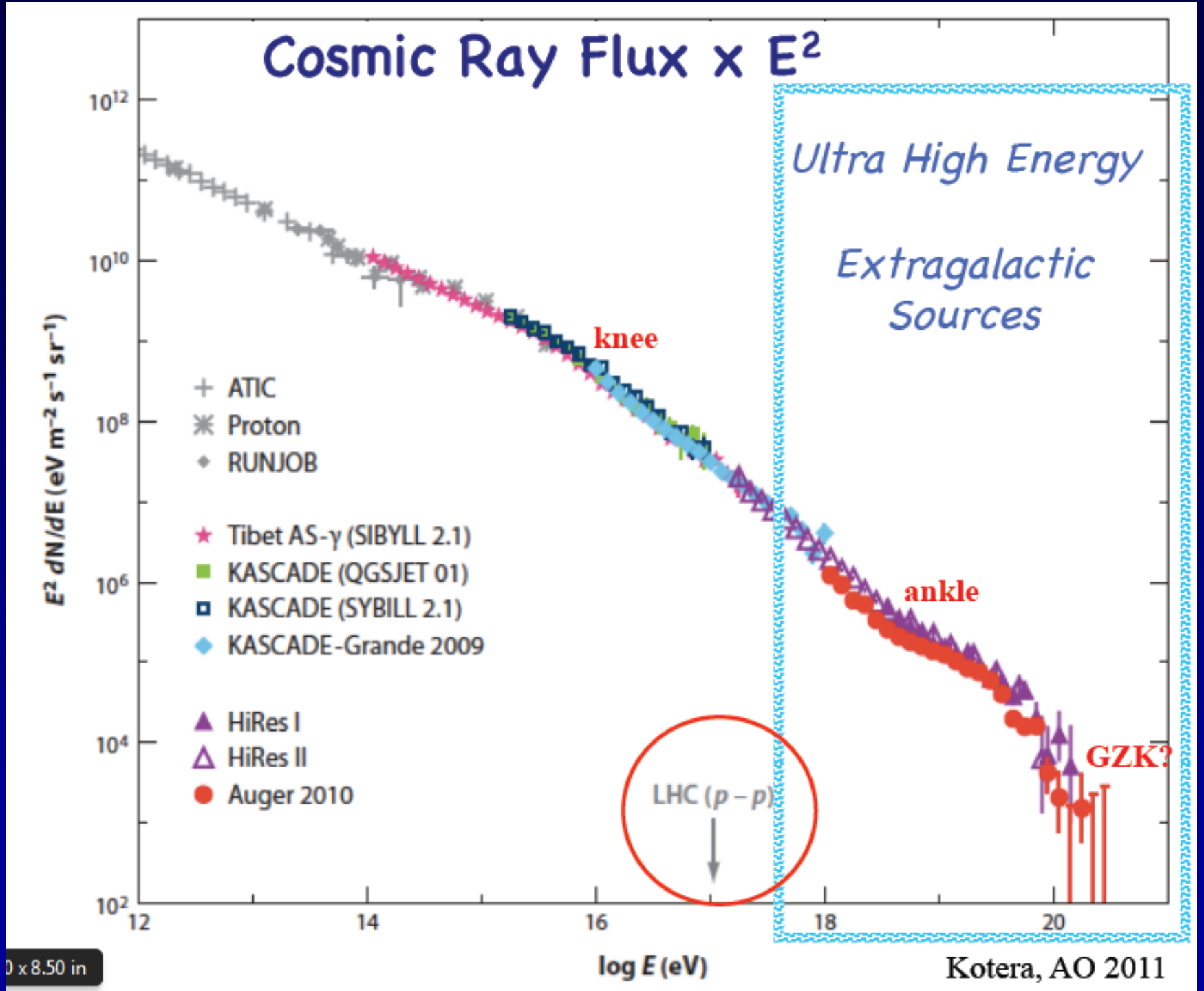
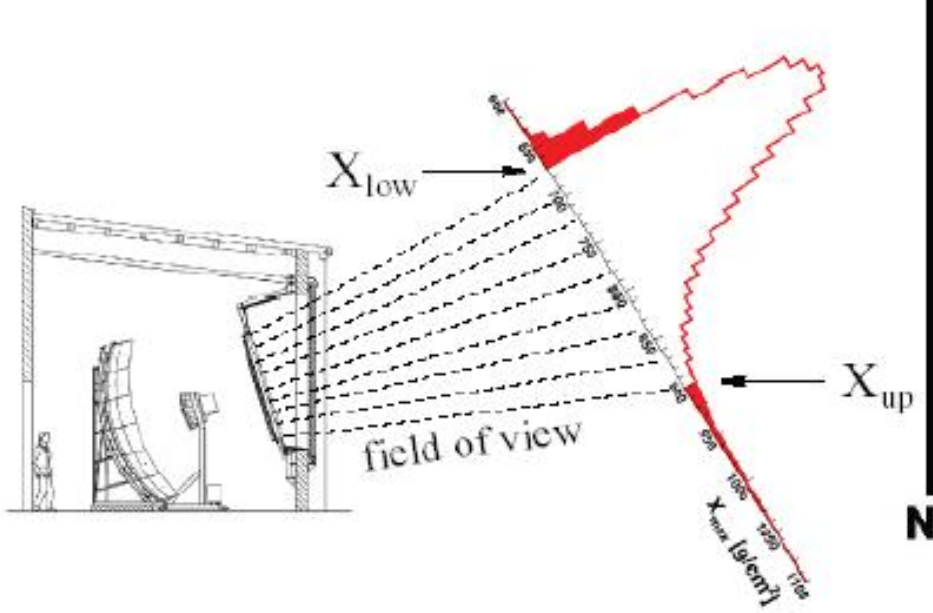
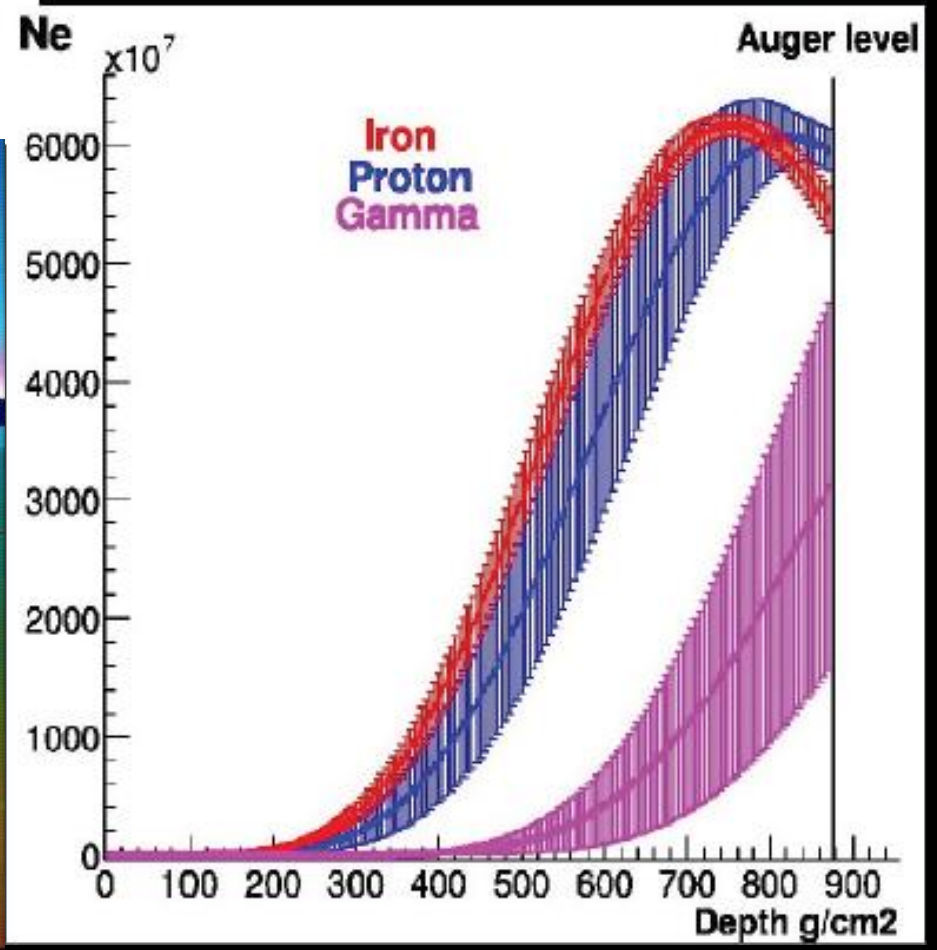
Overview

- Why UHE cosmic rays have become very interesting
- We can detect the radio emission from air-showers with Radio Telesopes
  - It might even be the best way!
- Using ASKAP as a particle detector

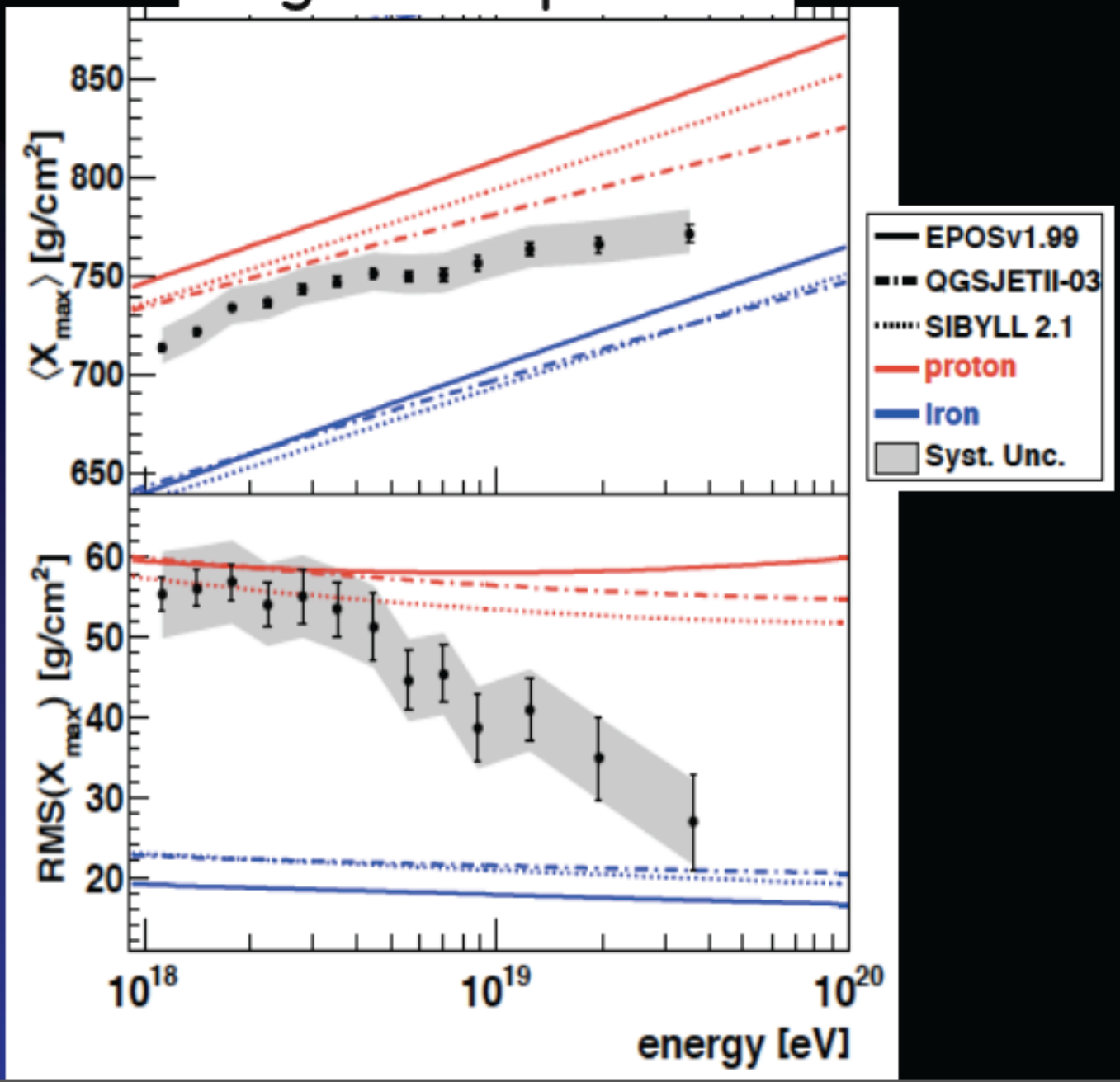

Cosmic Ray Flux x E²
Ultra High Energy
Extragalactic Sources
knee
ankle
GZK?
ATIC
Proton
RUNJOB
Tibet AS-γ (SIBYLL 2.1)
KASCADE (QGSJET 01)
KASCADE (SYBILL 2.1)
KASCADE-Grande 2009
HiRes I
HiRes II
Auger 2010
LHC (p – p)
E² dN/dE (eV m⁻² s⁻¹ sr⁻¹)
log E (eV)
10¹²
10¹⁰
10⁸
10⁶
10⁴
10²
12
14
16
18
20
Kotera, AO 2011



Composition observable: shower maximum



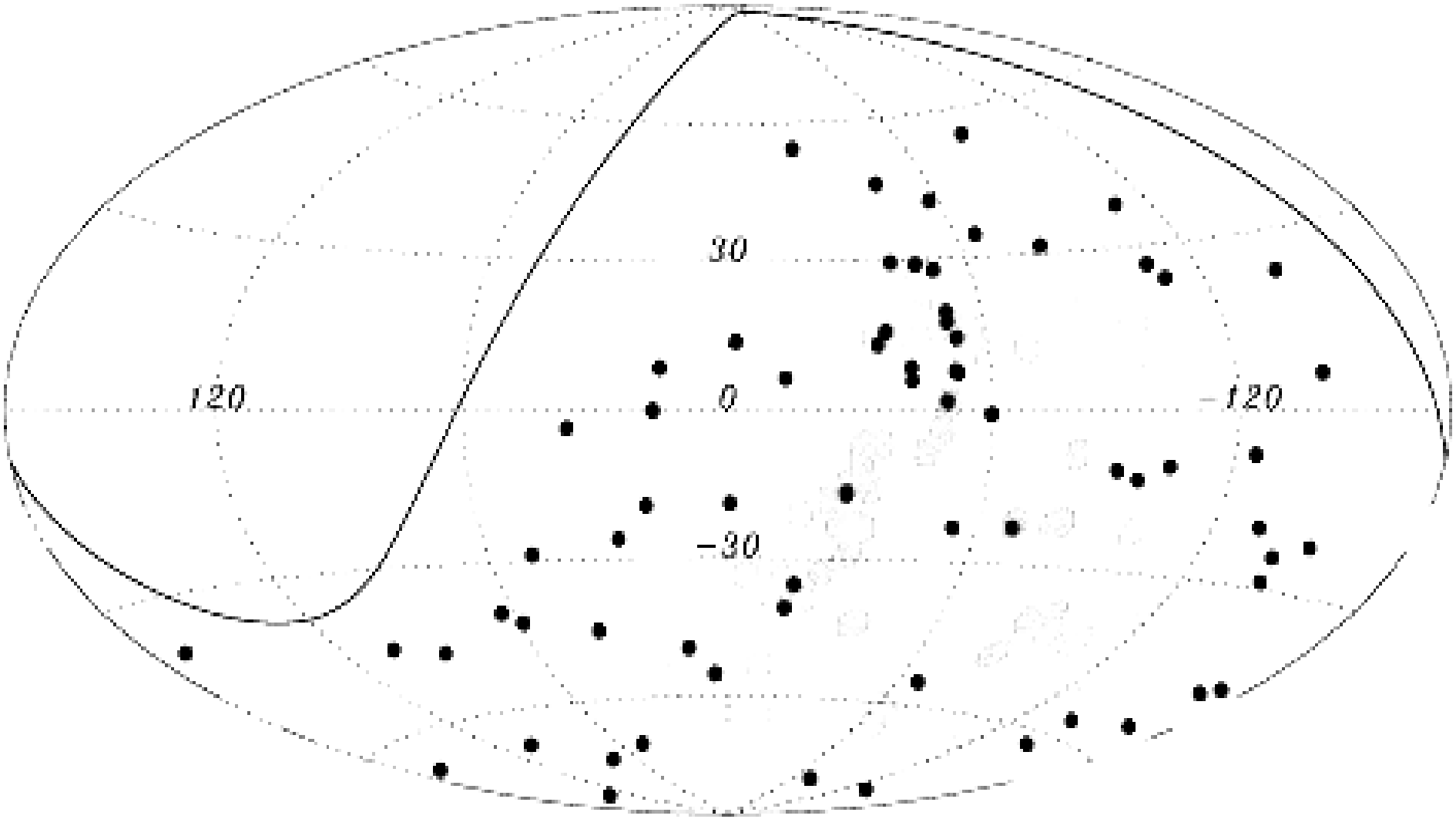
Auger Composition



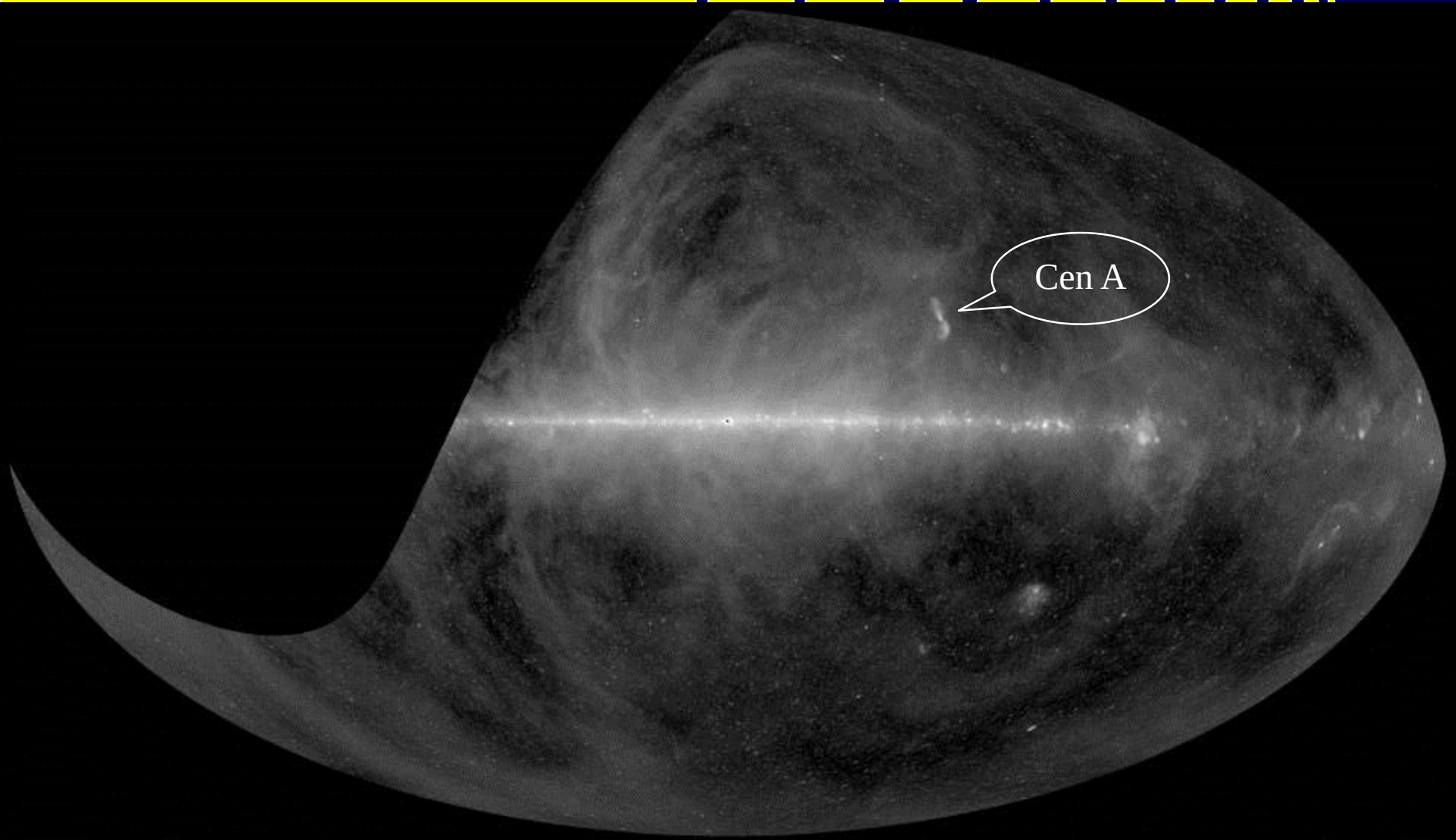
Centaurus A the closest AGN

- 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 13 >55 EeV cosmic rays
  - (2 expected)!

Auger Cosmic Rays



HIPASS Radio continuum



Crome
Karlsruhe Institute of Technology

- Searching for molecular bremsstrahlung.
  - Recombination time 10-100 nsec
- Array of three 3m fixed dishes
  - 3x3 multi-beam receivers
  - 3-4 GHz

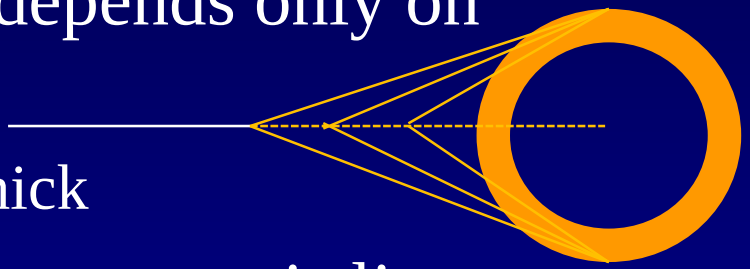
- CROME have found the distribution over the ground is a ring so they are seeing some kind of anisotropic emission and not molecular bremsstrahlung.
  - *Smida et al 2013*

Why Radio

- Fluorescence detectors have too low a duty cycle to see rare events (10%)
- Radio detectors have 100% duty cycle
- Need radio detection to measure composition etc above the GZK threshold at 10^{19} eV
- Need to calibrate the radio detection method
  - Existing arrays are too small to reach 10^{19} eV but modeling can be validated at lower energy
- Extraction of information from air-shower emission will require radio pulse detection

Detecting the CR Cerenkof ring

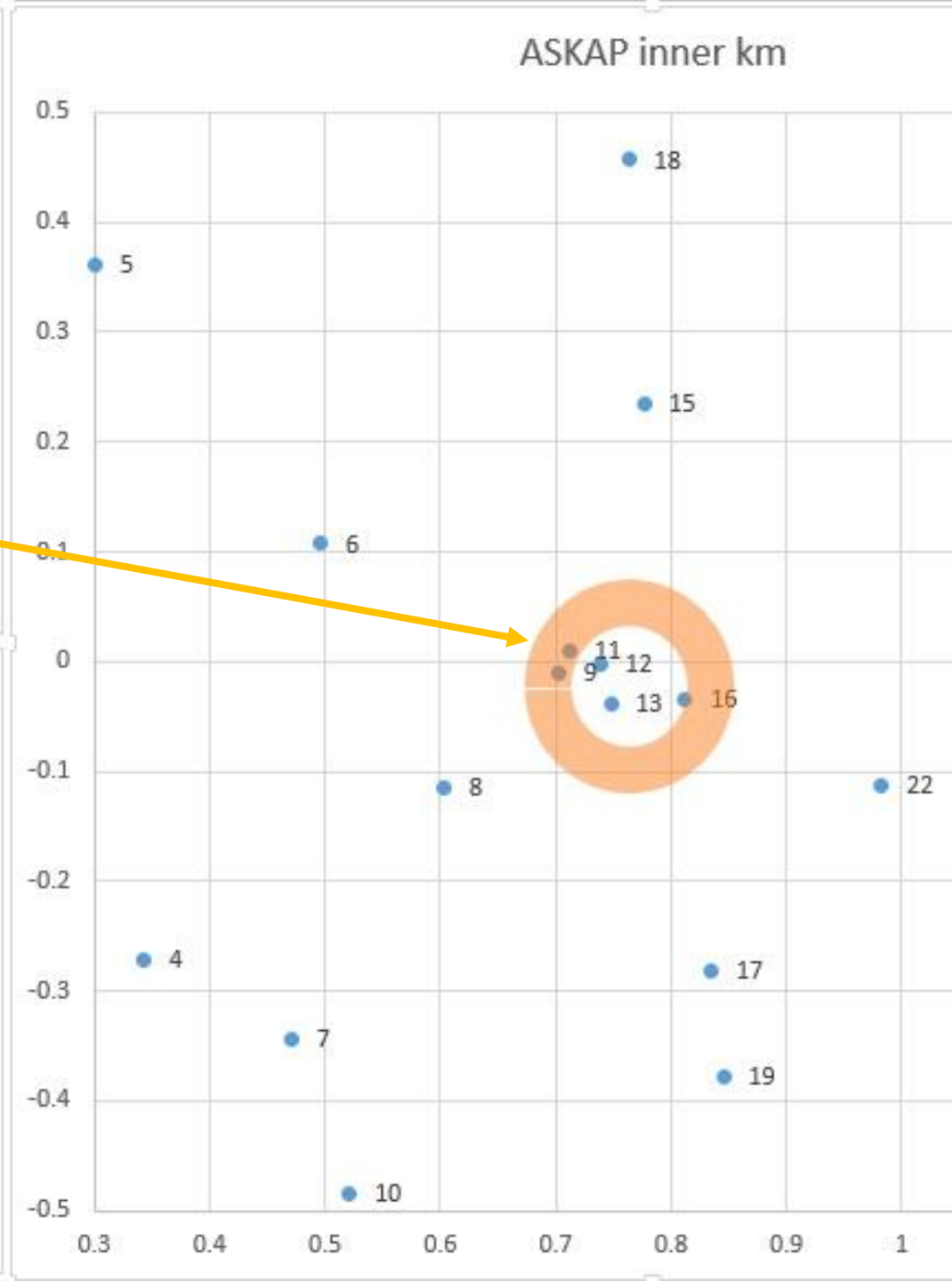
- Radio distribution on ground depends only on geometry – Cherenkov cone
  - 200m diameter ring , 10-20m thick



- Radio detection dependence on energy is linear
- Event rate goes as $E^{-2.7}$ and proportional to FoV
  - Scaling from Crome we have:
  - one event per day at $3x10^{16}$ eV in ASKAP FoV
  - At 10^{16} eV then rate is x $3^{2.7}$ = 20 per day
  - At 10^{17} eV rate is 1/20 per day
- To go to higher energies we need SKA survey

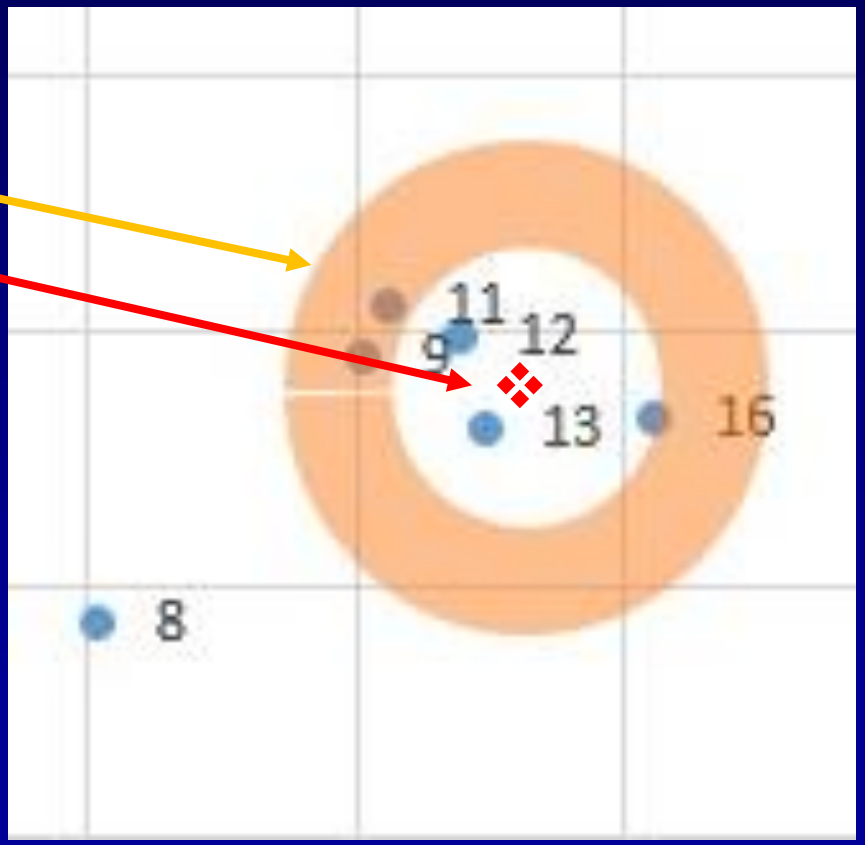
ASKAP & CR detection

- ASKAP inner km
  - Cherenkof ring



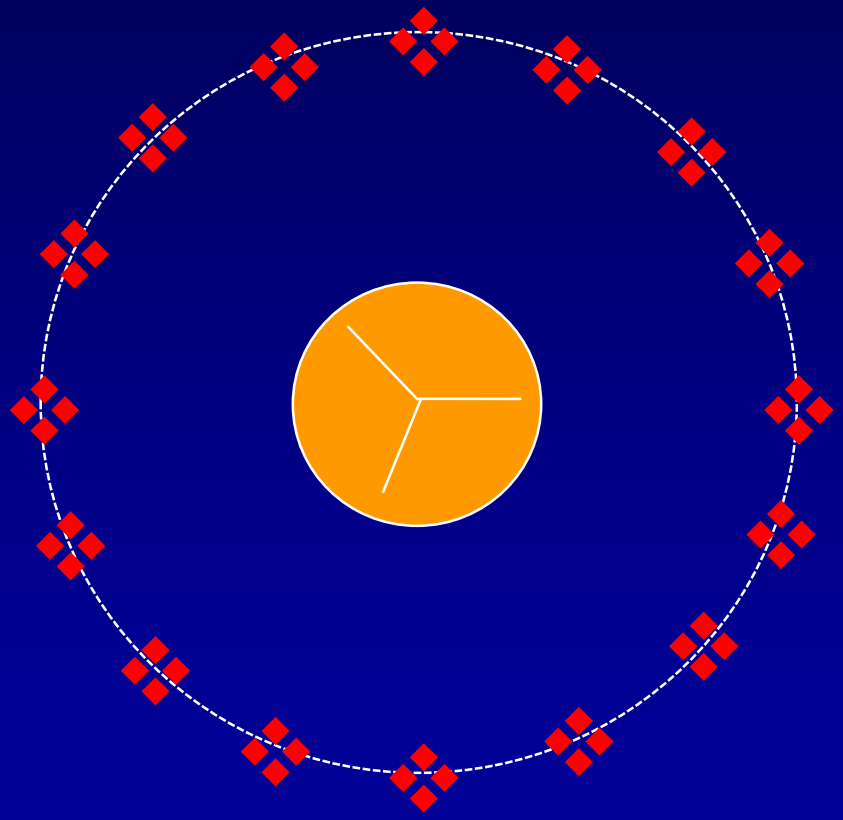
ASKAP & CR detection

- ASKAP inner km
  - Cherenkof ring
- Particle detector(s)
  - Only trigger on detectable events
  - Dump 1 μ sec data at η sec resolution
- Signal processing
  - raw ADC time-series data capture
  - production ASKAP hardware
  - Trigger synchronization!
    - » *John Tuthill*



The Parkes variation

- Need the PAF
  - large FoV for rate
  - Can measure the voltage distribution over the aperture!
- Circle the antenna with detectors
  - All radio detectable showers will trigger one of the detectors



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