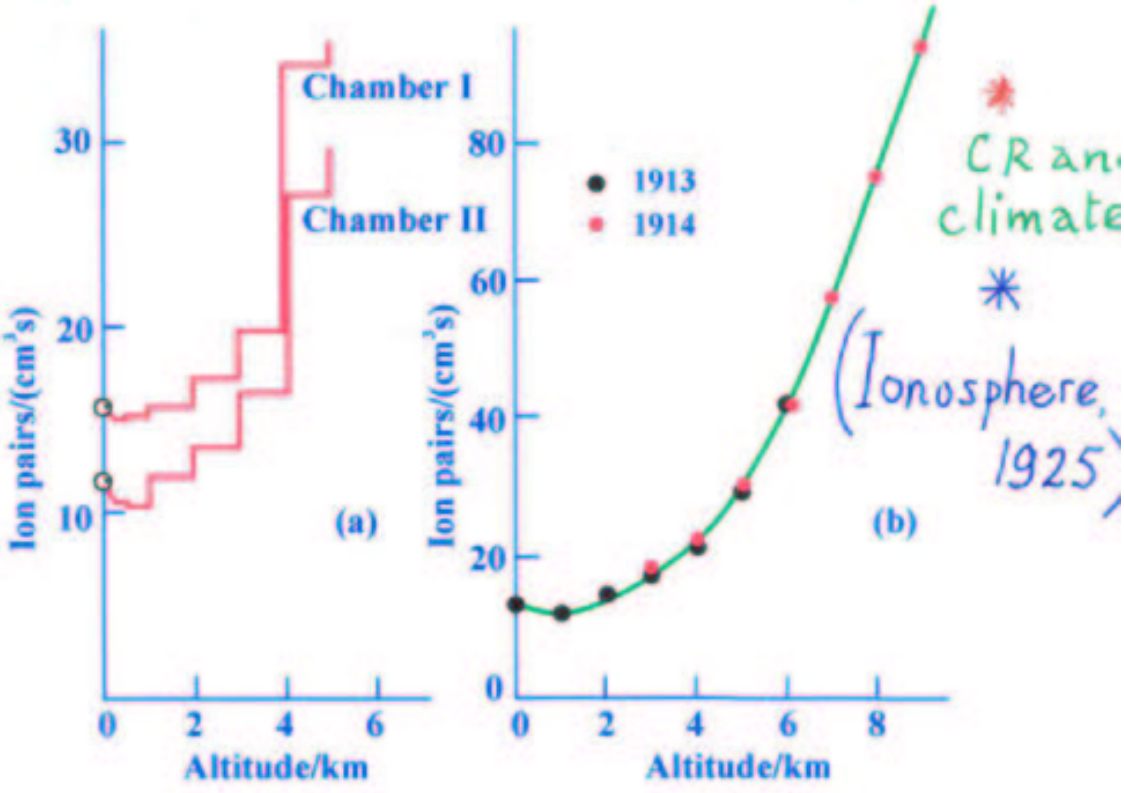
Discovery of Cosmic Rays Hess, 1912



Variation of ionization with altitude (a) Hess (1912); (b) Kolhörster (1913, 1914).

Lajos Janossy

Manchest

--1947--

1912 - 1978

Cosmic Ray Origin :

The Way Ahead

1. Predictions by the Great.
2. Discovery of C.R.- lessons...
3. Galactic or Extragalactic?
4. Gamma ray Astronomy.
   SNR ....
   Magellanic Clouds..
   Spectral changes - diffusion properties.
5. Energy Spectrum
   knee and ankle...
   Spectral structure; Single Source.
6. Mass composition
7. U.H.E. C.R.

A few decades hence, energy may be free, just like unmetered air

(J. von Neumann, 1956)

The possibility of travel in space seems at present to appeal to schoolboys more than to scientists

(Sir George Paget Thomson, 1956)

Space-travel is utter bilge

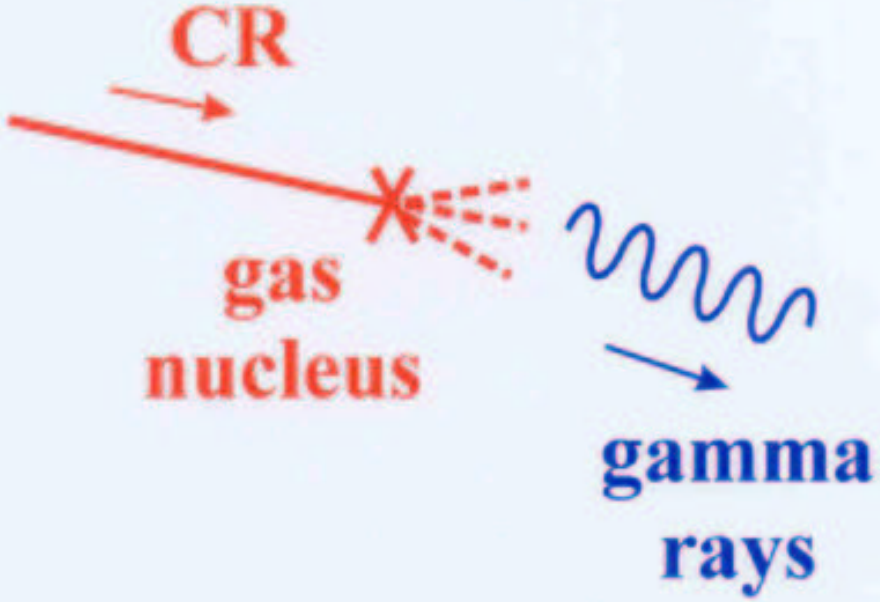
(Sir Richard van der Riet Woolley, Astronomer Royal, 1956)

Energy densities in the Galaxy

	$eVcm^{-3}$
Magnetic field ($B^2/8\pi$)	$\simeq 0.5$
Gas motion ($<\frac{1}{2} M\upsilon^2>$)	$\simeq 0.5$
Cosmic Rays (p..)	$\simeq 0.5$
Starlight [Blackett, 1933]	$\simeq 0.5$
(Cosmic microwave background, 2.7K)	$\simeq 0.24$

But, most $\neq$ f(R)
(Z)

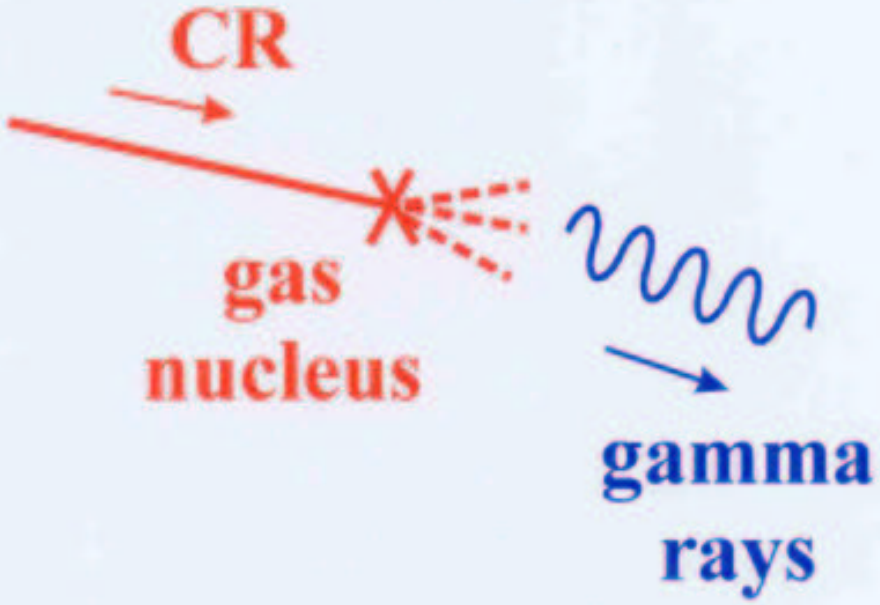
Gamma Ray Astronomy



(i) Gradient in Galaxy (Wdowczyk & W)

(ii) Magellanic Clouds (Sreekumar et al., Chi et al.,)

Gamma Ray Astronomy

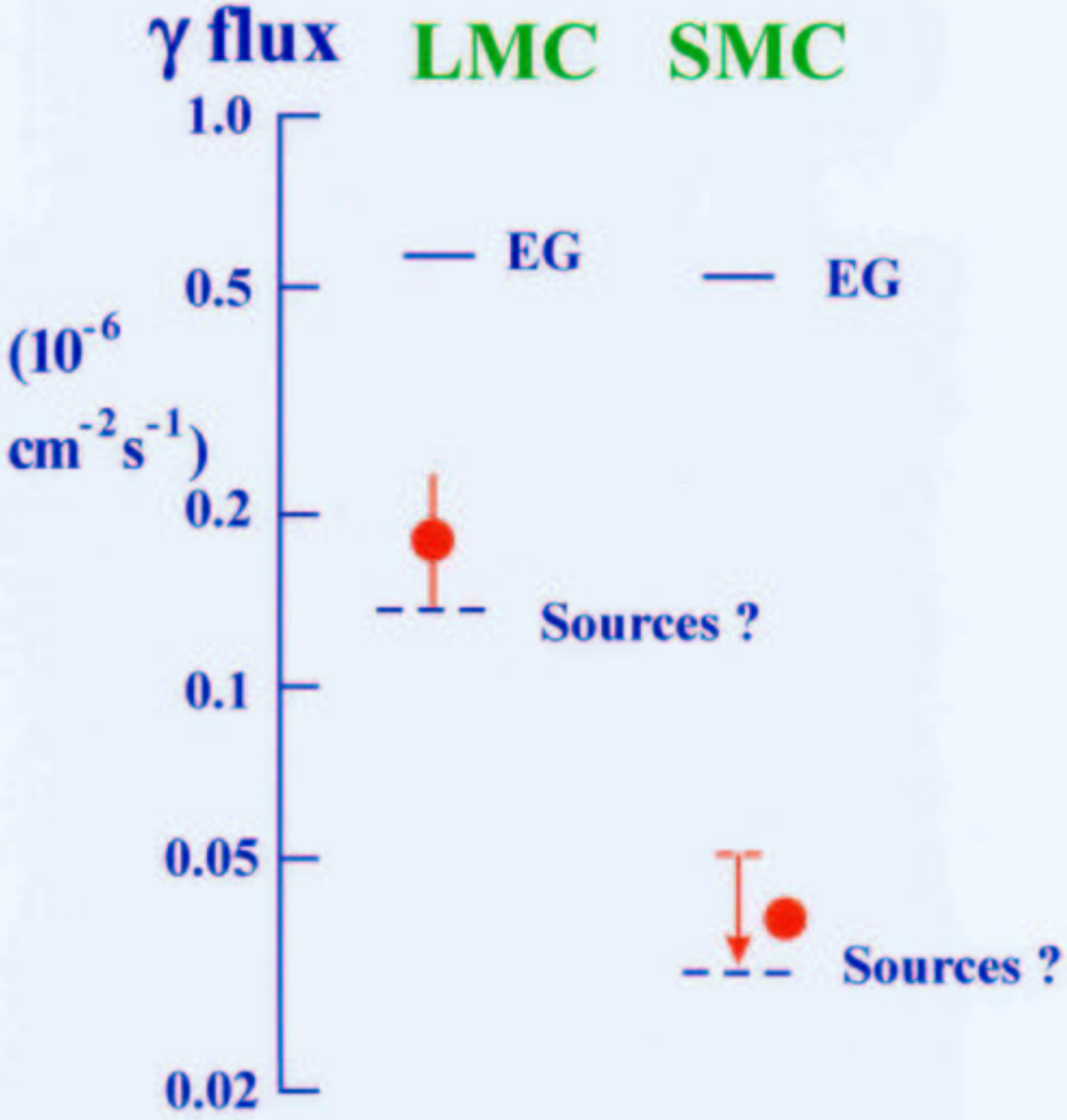


(i) Gradient in Galaxy (Wdowczyk & W)

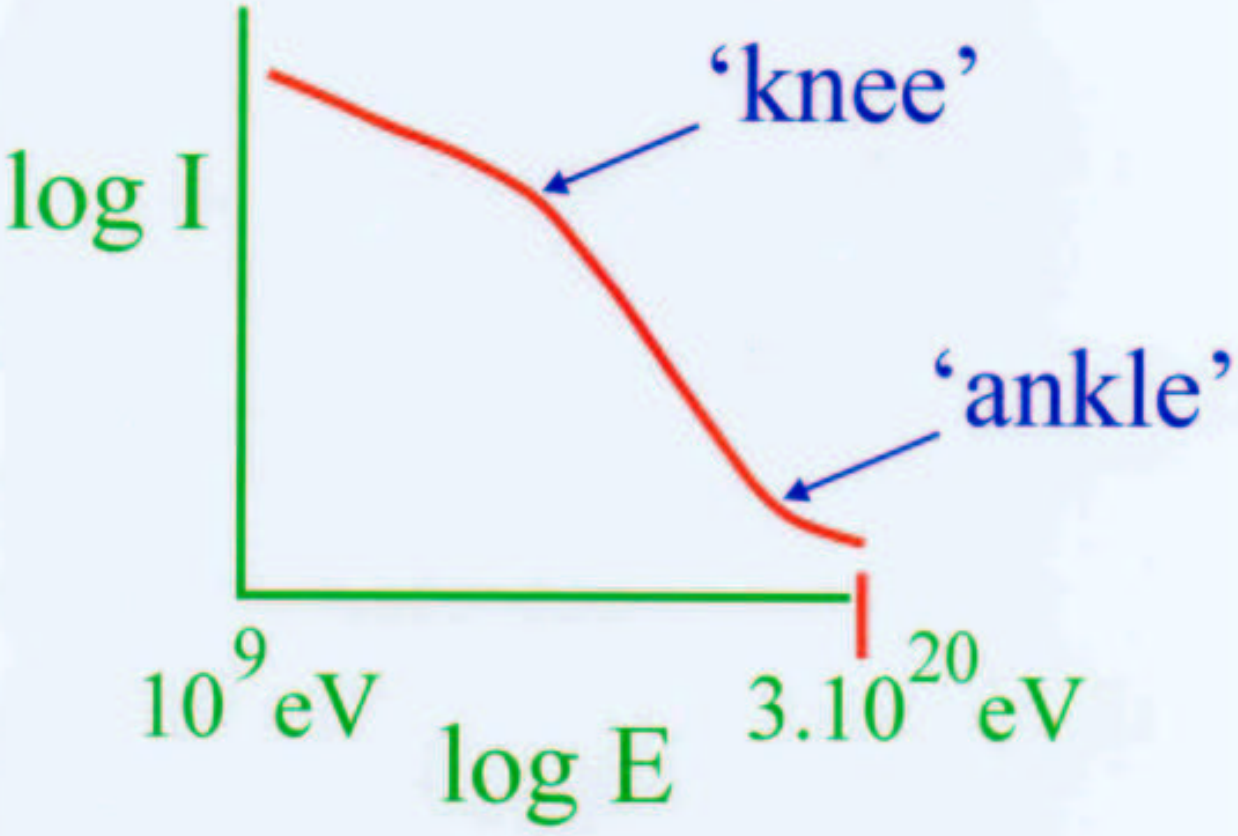
(ii) Magellanic Clouds (Sreekumar et al., Chi et al.,)

Magellanic Clouds

$E\gamma > 100MeV$

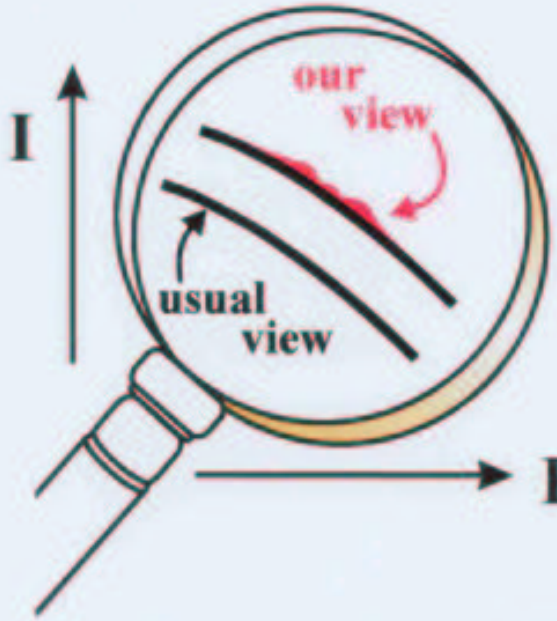


Energy Spectrum

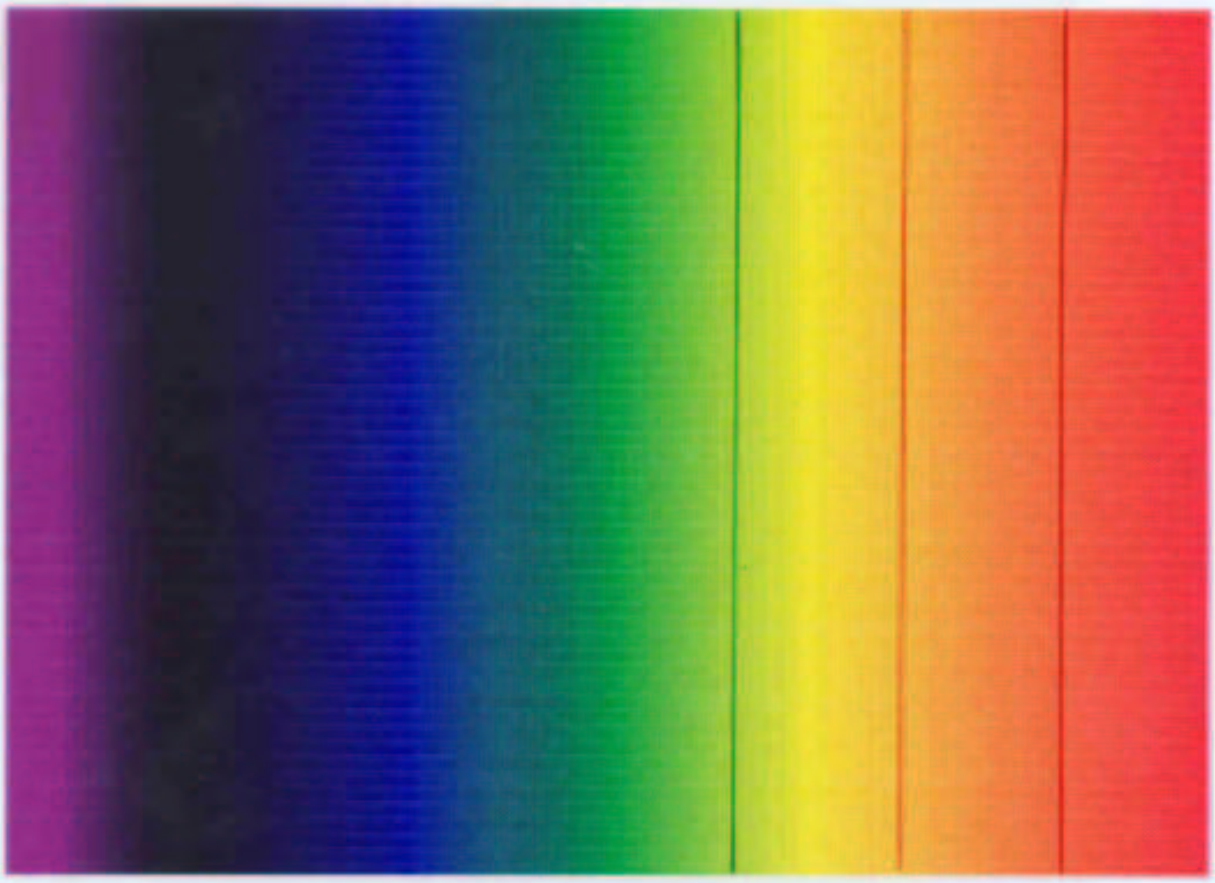


October, 1996 ...
A.D. Erlykin & A.W.W.

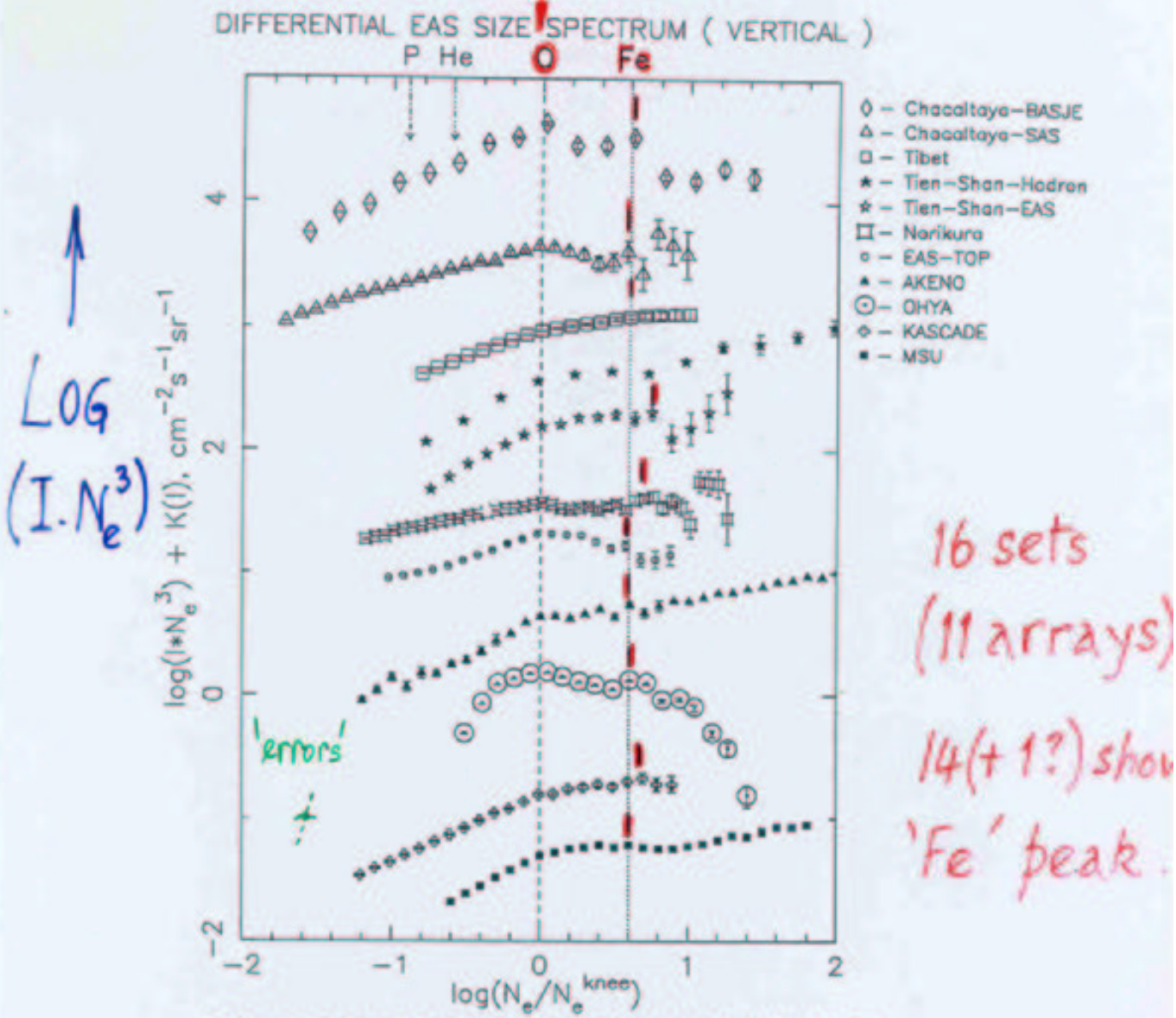
Tolya Erlykin
(Moscow)



A detailed look at the knee



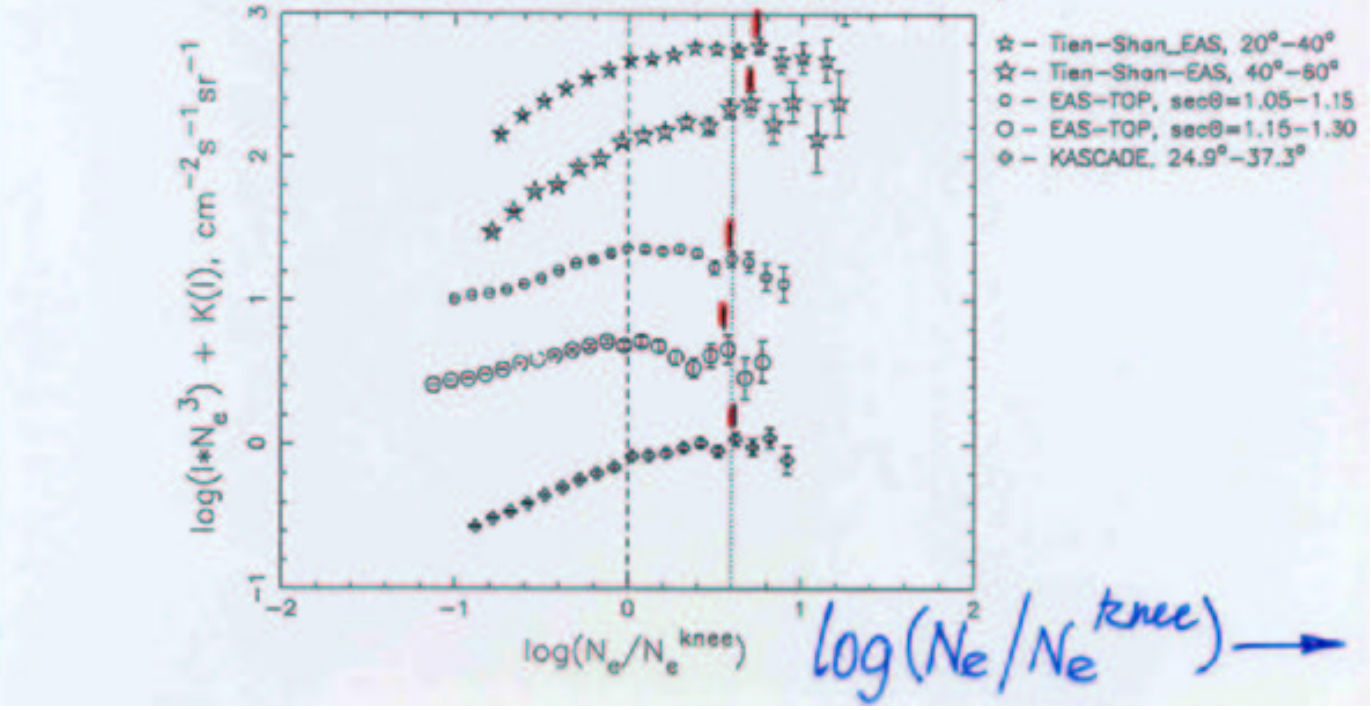
Normalised to 'KNEE'



LOG $(I.N_e^3)$ ↑

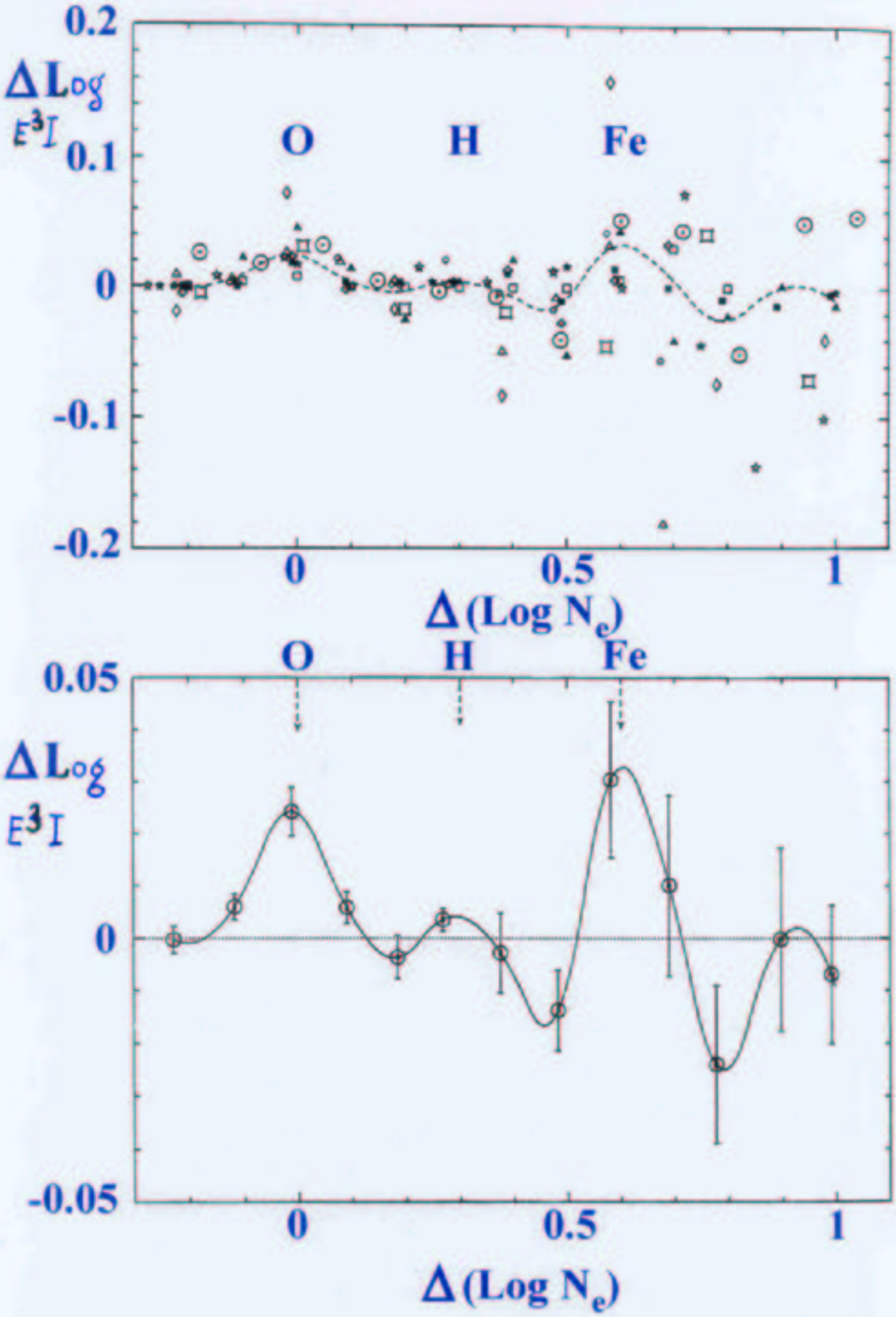
16 sets (11 arrays)

14(+1?) show 'Fe' peak.

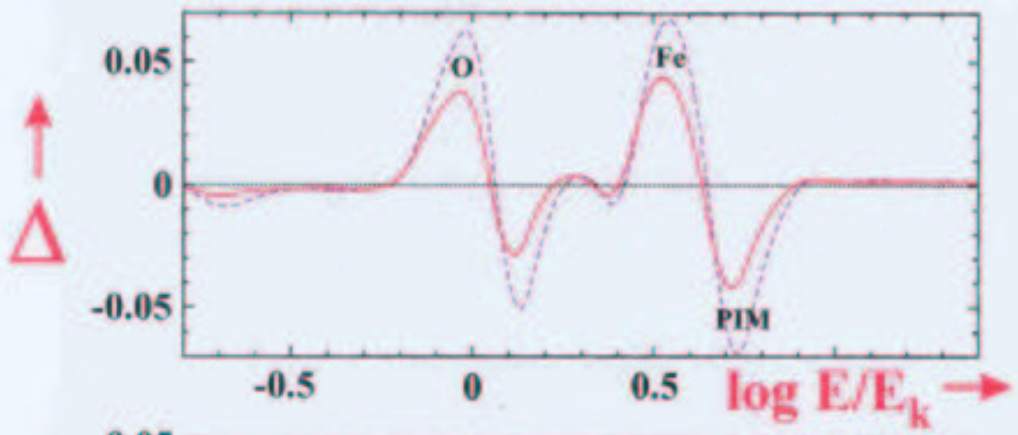


$\log(N_e/N_e^{knee})$ →

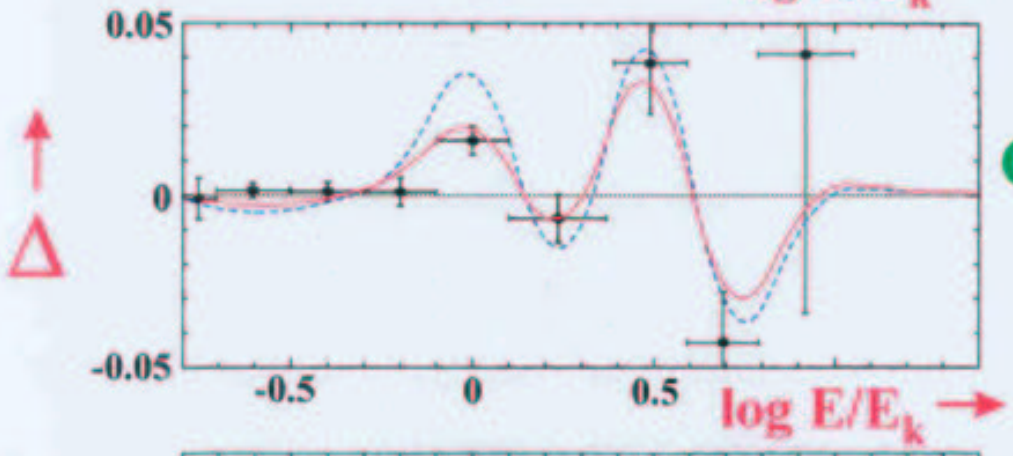
MEAN DISPLACEMENT OF INTENSITY POINTS FROM THE KNEE (VERTICAL EAS)



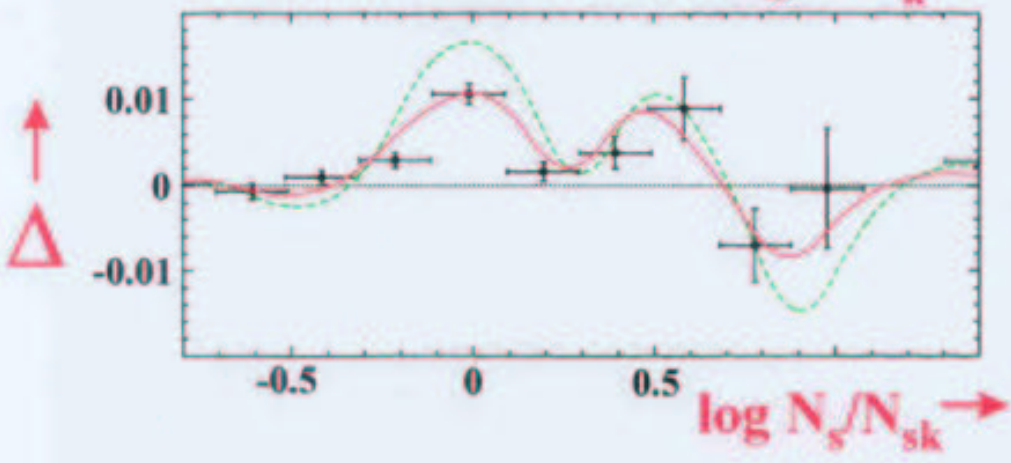
Excess over the running mean



Model



Cherenkov data



Size spectra

Nebula in the Large Magellanic Cloud

SNR Acceleration

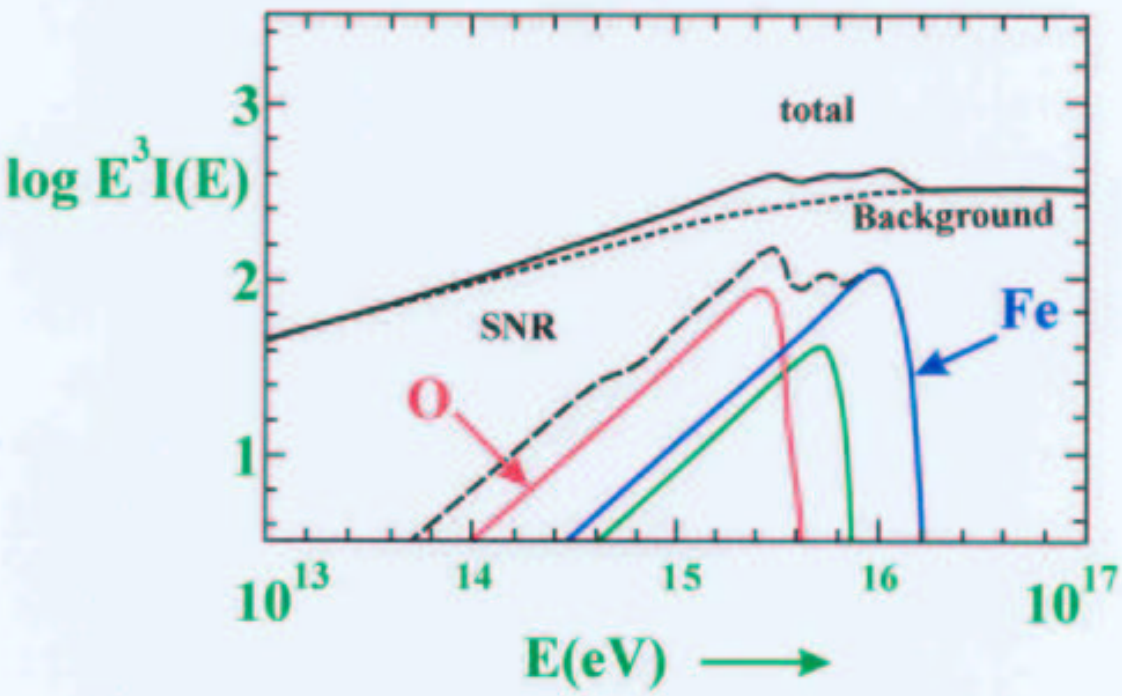
Axford... (1960's $\longrightarrow$)
Berezhko et al. (1996):

$$E_{max} = 4.43\ Z\ 10^5\ E_{51}^{1/2}\ M_{10}^{-1/6} \cdot (N_{0,\ 0.003})^{-1/3}\ B_3\ (GeV)$$

where E_{51} = SN energy in 10^{51} erg,
M_{10} = ejecta mass, in $10M_\odot$,
$N_{0,\ 003}$ = gas density, in $0.003\ cm^{-3}$,
B_3 = magnetic field in units $3\mu G$.

Spectral shape $\simeq E^{-2}$ to Emax

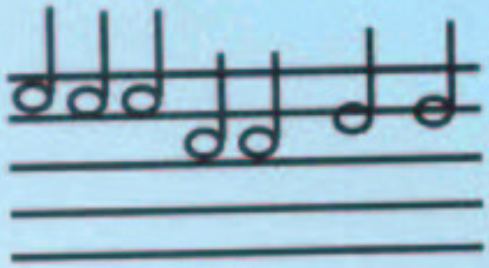
STRUCTURE OF THE SINGLE SNR SPECTRUM

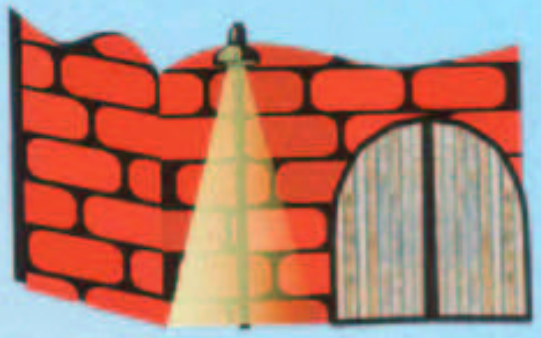


'Background' : other SNR below 10^{16} eV,
'Superbubbles' - Bykov.. - above ?

Marlene Dietrich
1933 "Song of Songs"
nach dem Roman 'Das hohe Lied' (Salomon

Courtesy Dr. K.-H. Kempert.





" Underneath the spectrum
by 3PeV,
one can see the oxygen as plain
as plain can be.

There's no doubt at all
the peaks are there
and we will swear
to keep them there,

for you Lili Marlene
our dear Lili Marlene"


There is the E-W Source
Nonsense!

"Cosmology is often wrong, but never in doubt ..."

L. D. Landau

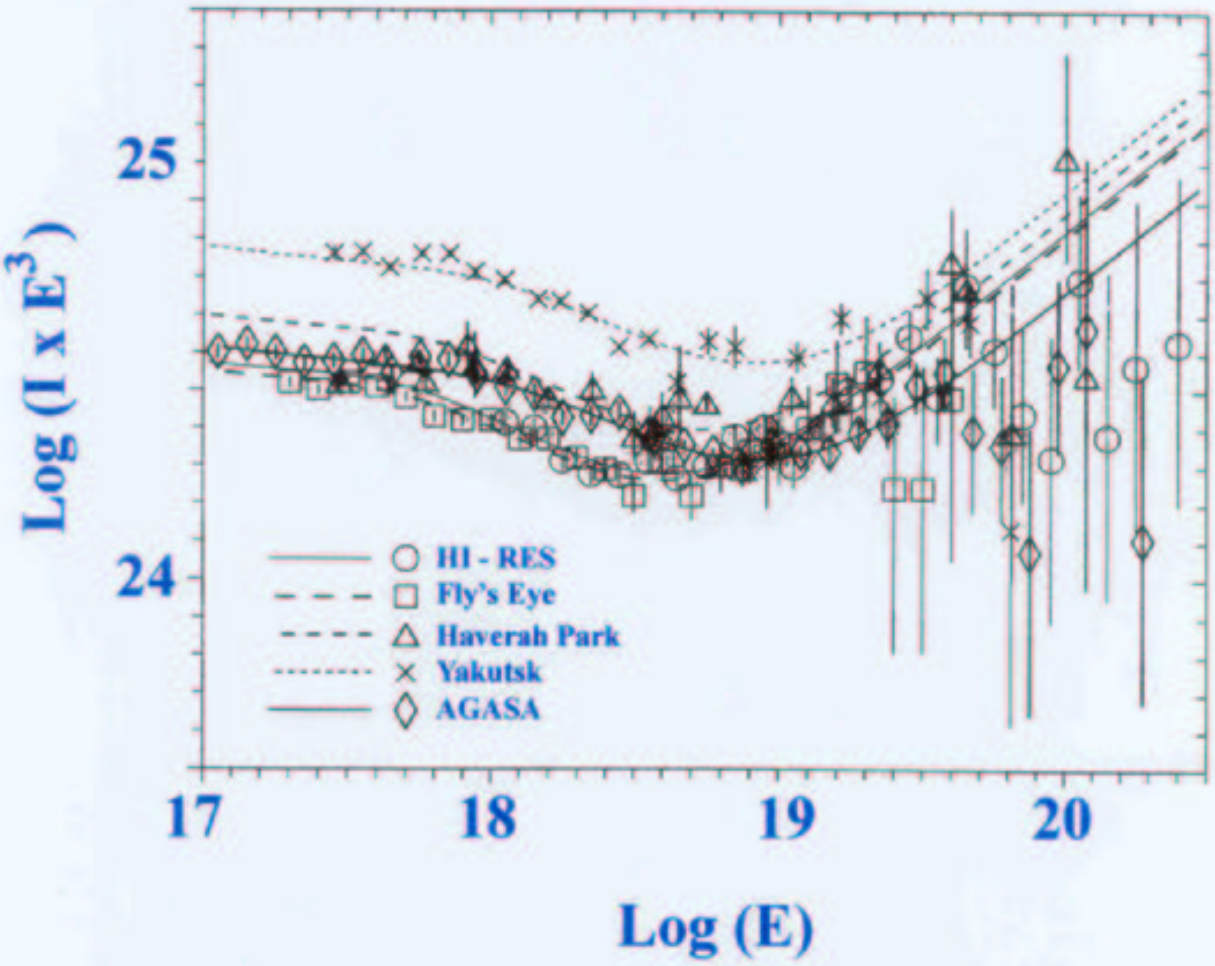
UHE Cosmic Rays

1. **CR Acceleration**
   - Galactic or EG ?
   - Top-down ? DM candidates (Clumpiness of DM Halo ?)
   - Down-up ? Nature of mechanism (Colliding galaxies etc.)
2. **Propagation**
   - (If EG) - Magnetic fields, diffusion
   - CMB (side step losses ?)
3. **Interactions in atmosphere**
   - Characteristics of
     - p - A
     - Z - A
     - γ - A, interactions (mainly high x-)

Spectra and directions of each Z

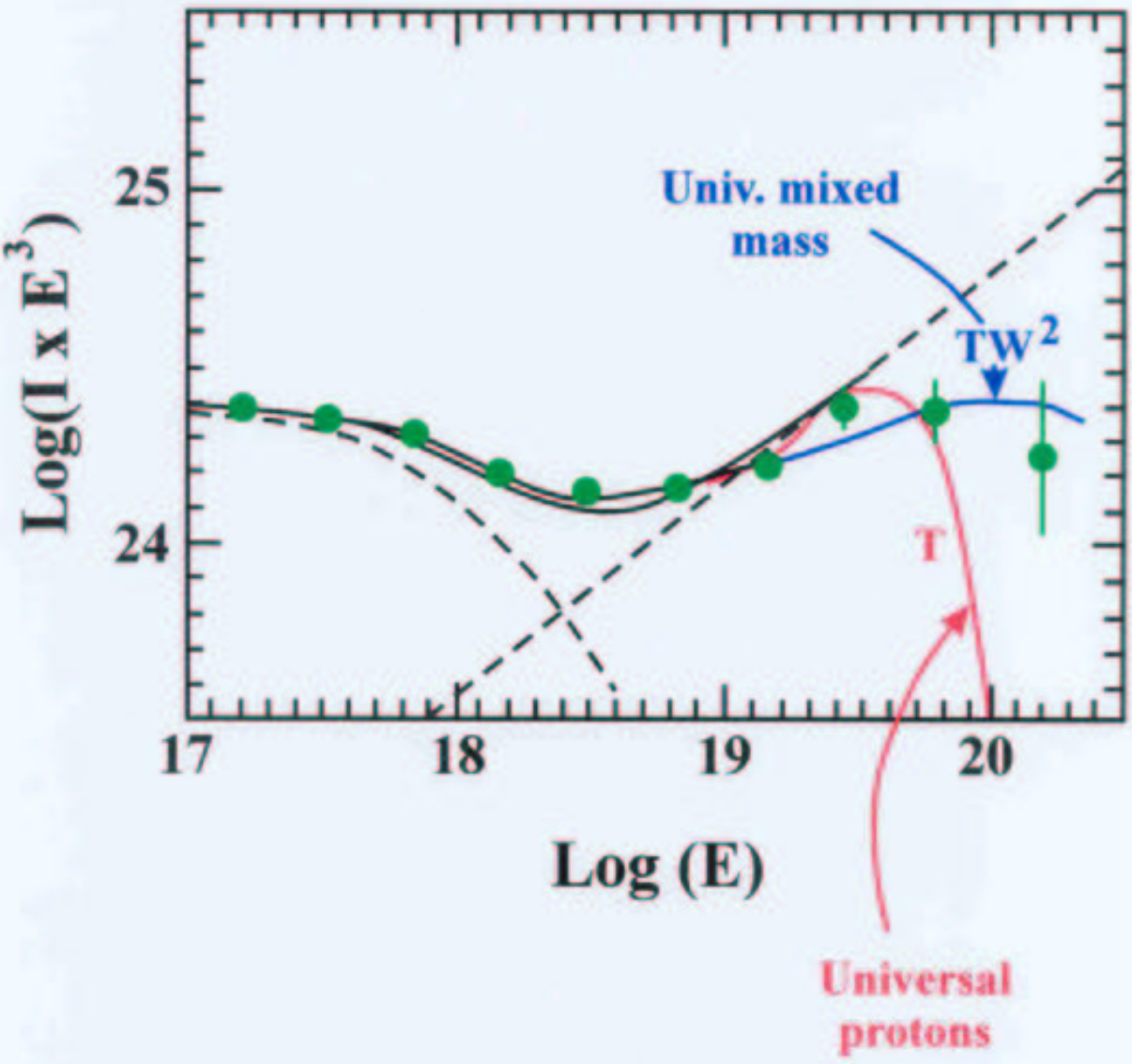
- Identification dependent on 3

Measured

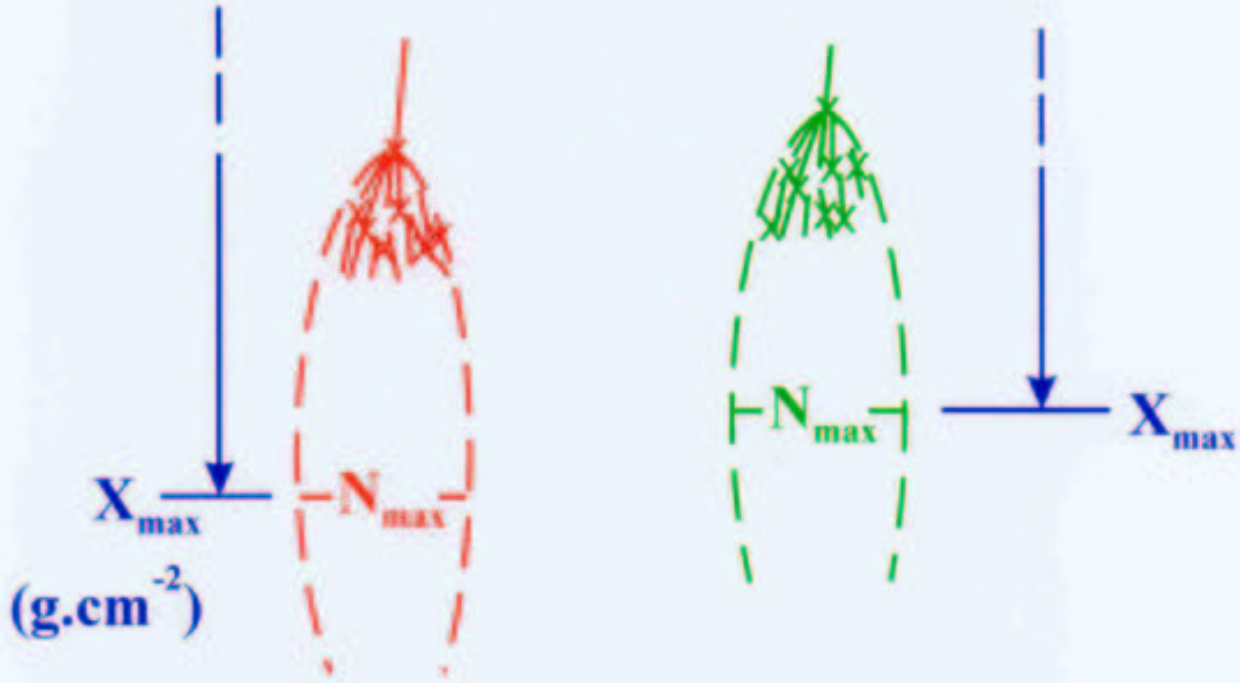

25
24
Log (I x E^3)
17
18
19
20
Log (E)
HI - RES
Fly's Eye
Haverah Park
Yakutsk
AGASA

'Normalised'

(Szabelski, Wibig & W.)



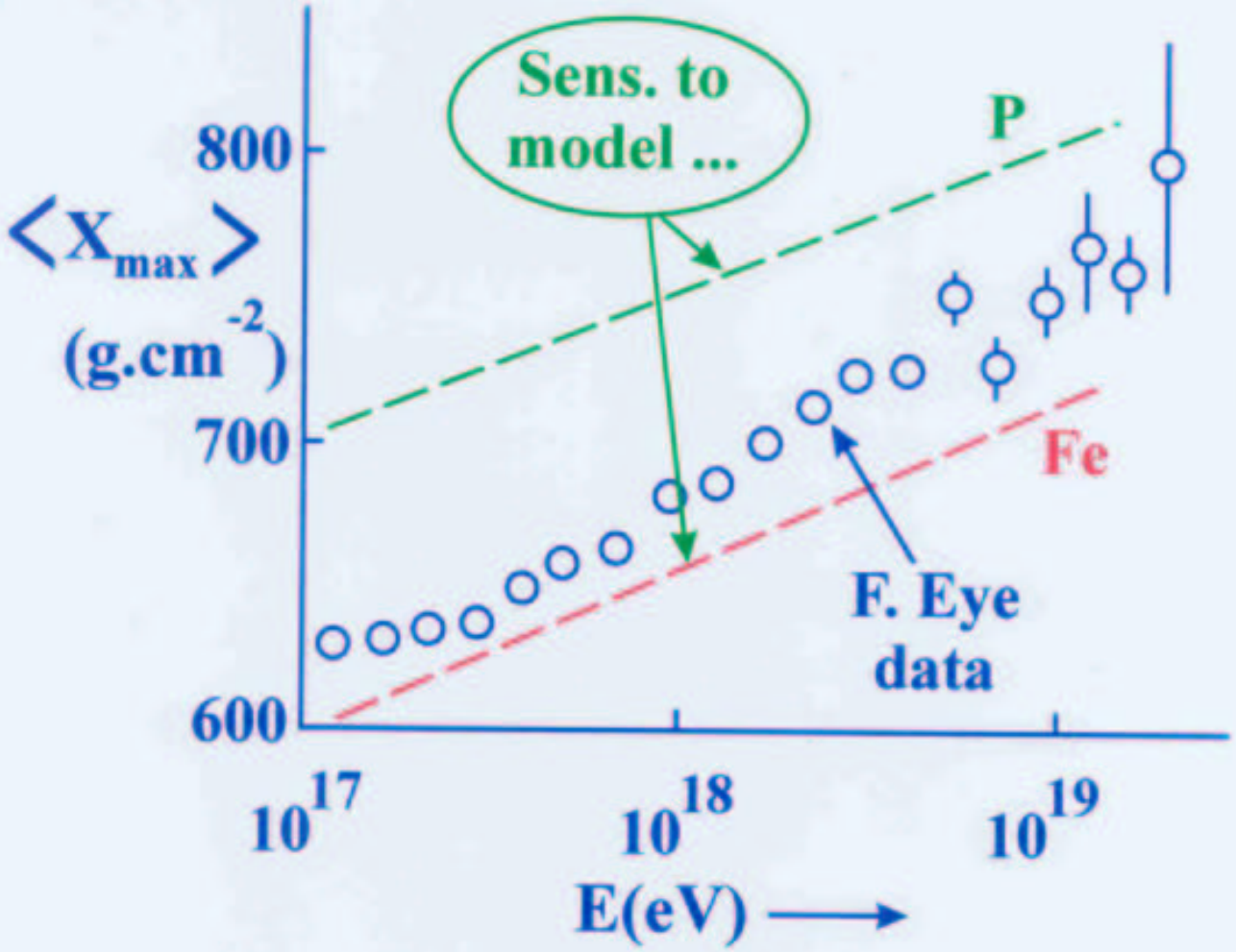
Mass Composition at Ultra High Energies



Proton **Iron**

Estimate 'depth of maximum'

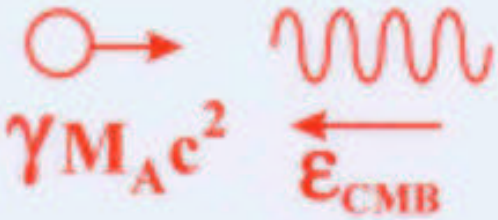
≃ QGS



still 'heavies' at 10^{19} eV ...

Eg nuclei - why prefer?

1. Less fragile than p



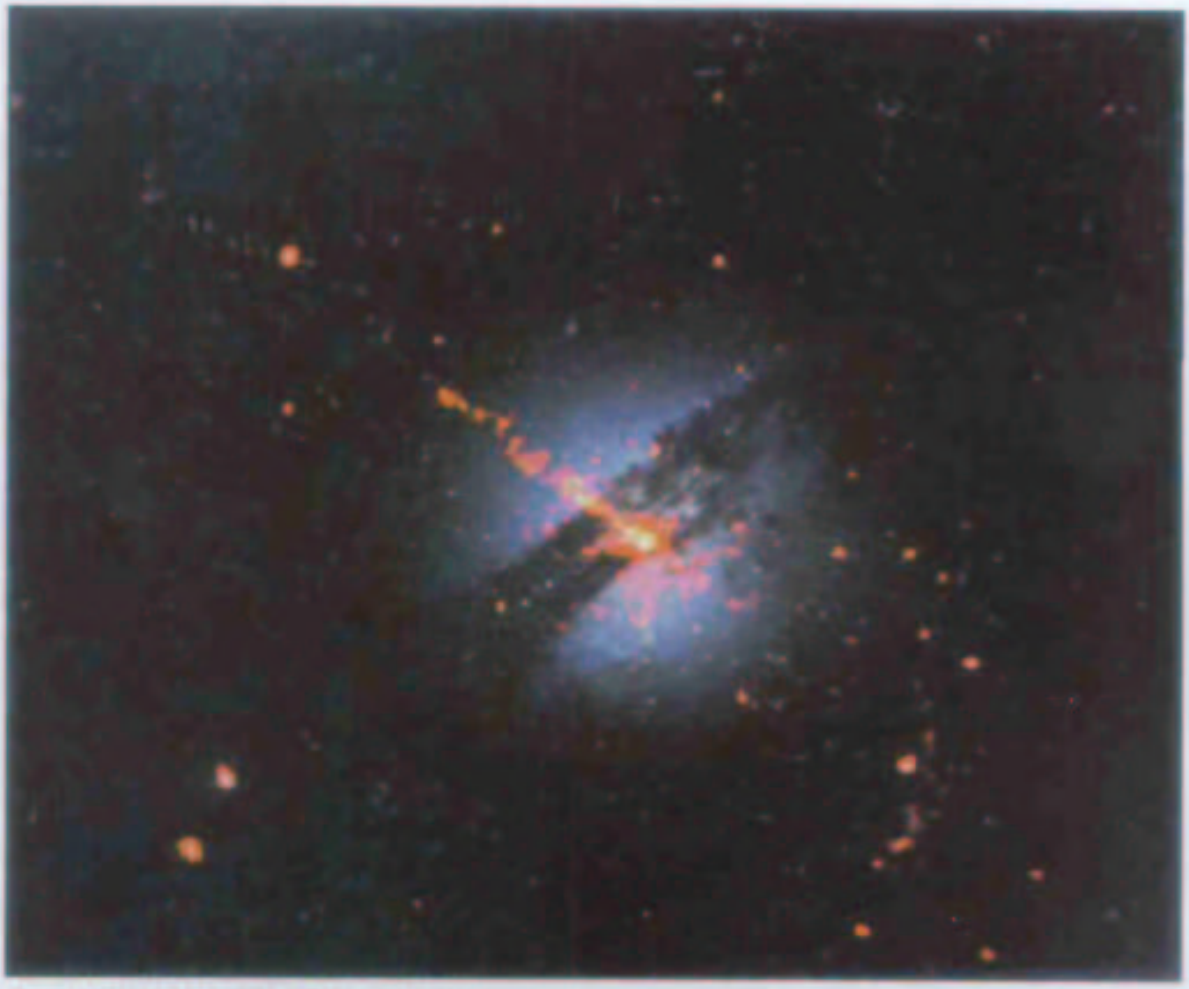
~7 x 10^{-4}eV

Need γ x 7 x 10^{-4} = 200MeV
for p
≈ 20MeV
for A

So A > 10 is 'more robust'

2. Magnetic deflection bigger - thus lack of (many) obvious sources

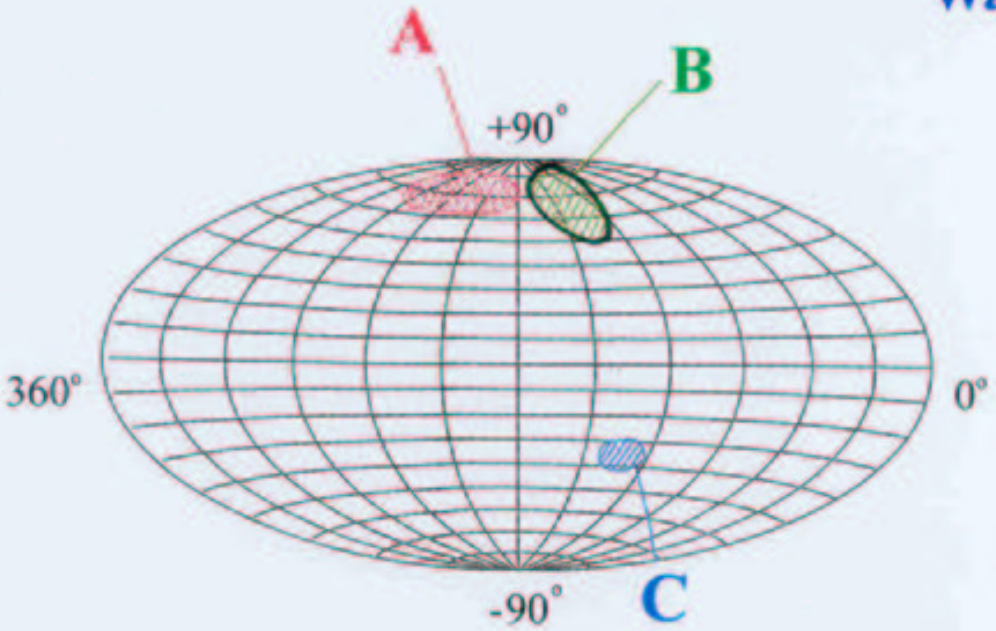
AGN: Centaurus A



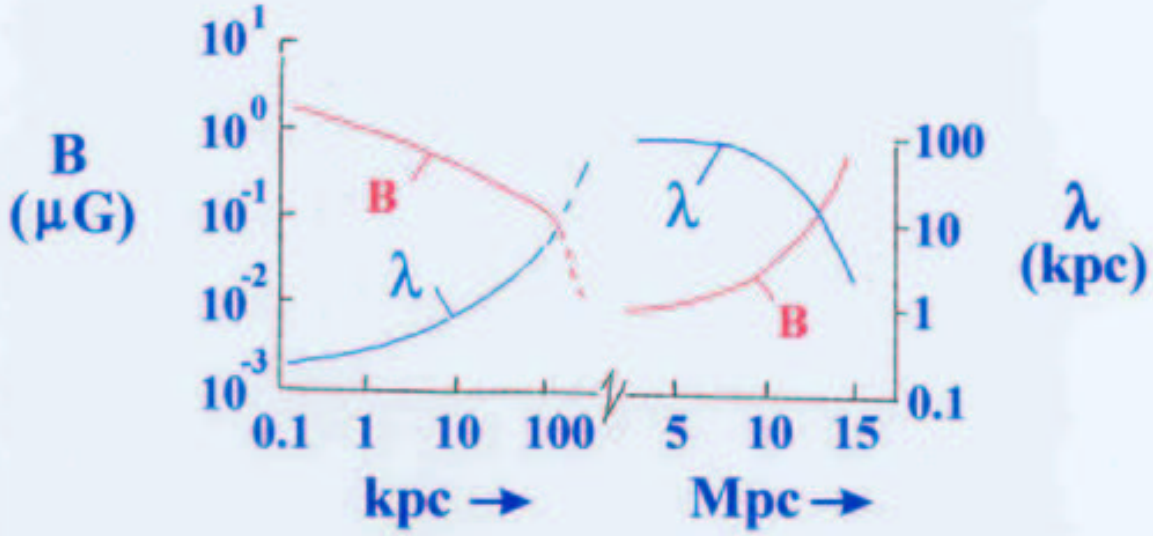
The X-ray jet from the active galaxy Centaurus A is shown here, superimposed upon an optical image of the galaxy. X-ray image: NASA/CXC/SAO. Optical image: AURA/NOAO/NSF.

Possible 'clumping' of EG particles away from G. Plane.

(Szabelski et. al. Watson ..)

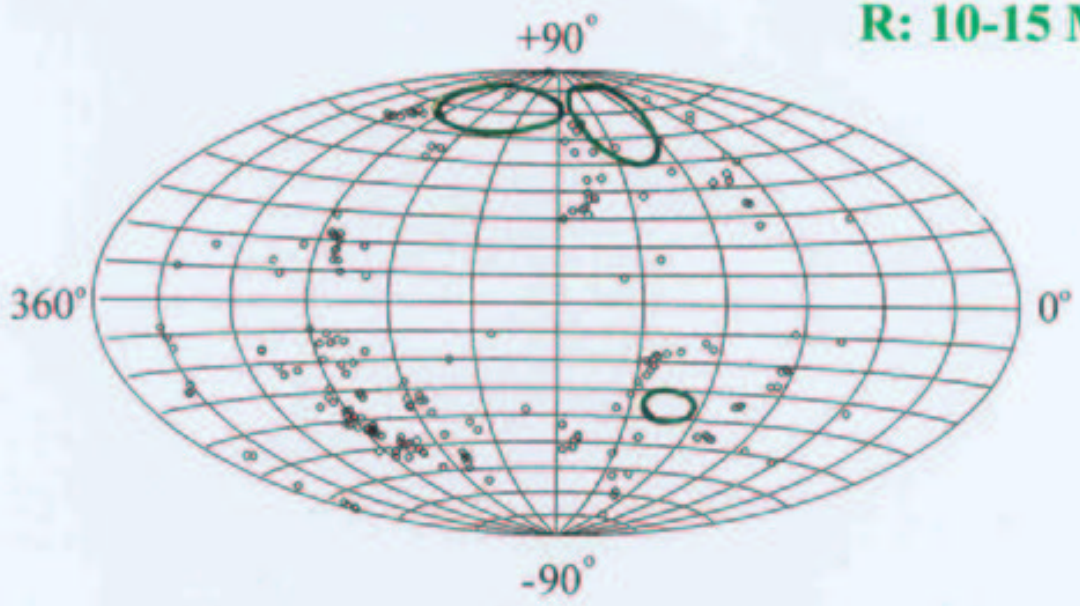


$E > 10^{19}$ eV



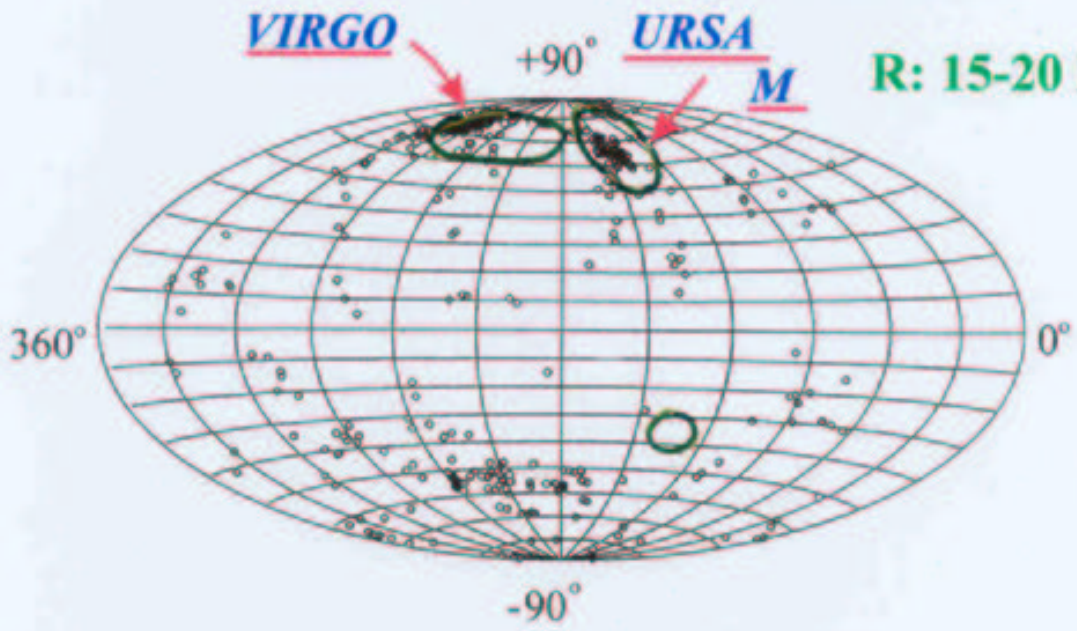
'Galaxies'

R: 10-15 Mpc

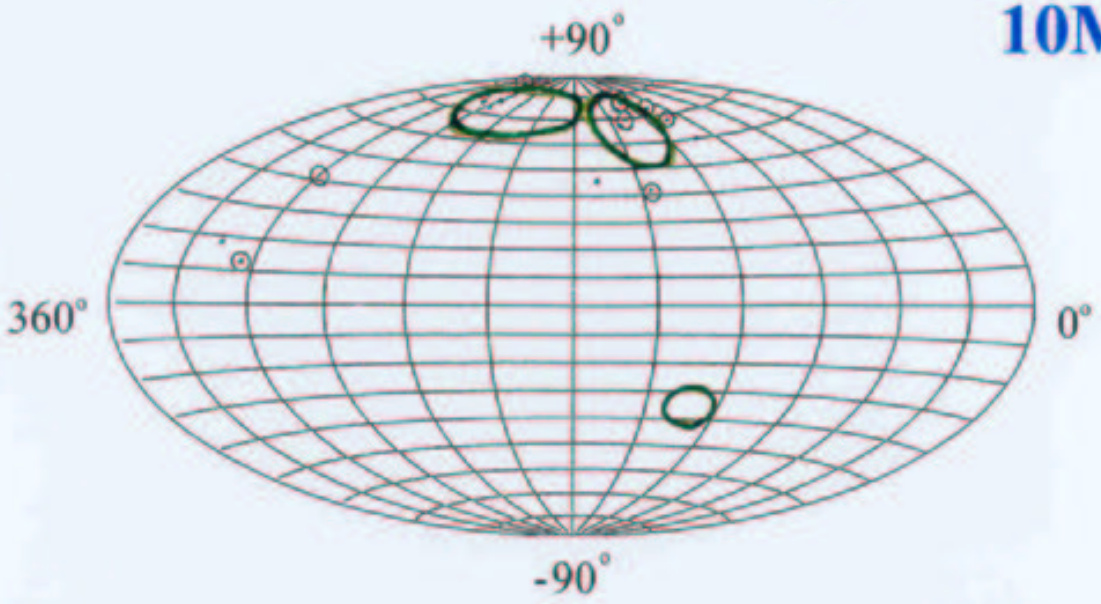


'Galaxies'

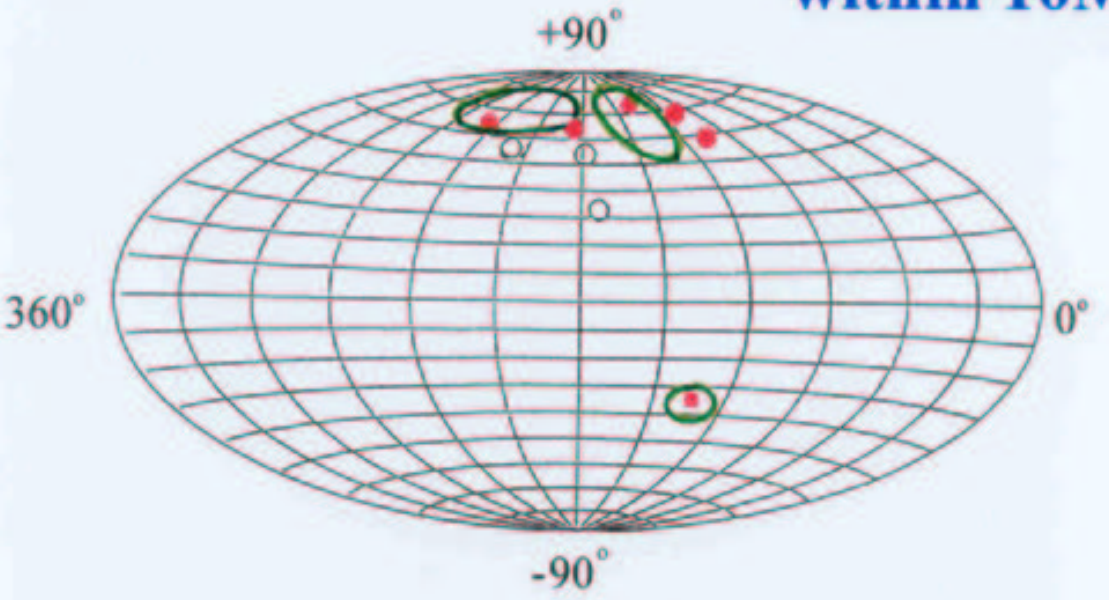
R: 15-20 Mpc



Seyferts within 10Mpc



Colliding galaxies within 10Mpc



Conclusions re UHE CR.

1. Almost certainly Galactic to approaching 10^{19} eV. Perhaps some 'sources' already seen.

2. Many heavy nuclei at $\simeq 10^{18}$ eV: should be neutrons present.

3. EG particles above 10^{19} eV, mainly.

   What are they? Z,p: AGN ...?

Z, p: galaxy collisions? γ : strings ...?

Rembrandt's 'The Night Watch'
Capt. Cocq., Lt. Ruytenburgh
(not 'Bull'!)