The history of cosmic ray studies after Hess

Claus Grupen

Siegen University

History
The golden years
A few words on accelerators
Renaissance of cosmic rays
Accelerators in the sky
A start into a new era

History

1895 Wilhelm Conrad Röntgen
Discovery of X rays

1896 Henri Antoine Becquerel
Discovery of radioactivity

1912 Victor Franz Hess
Discovery of cosmic rays

Particles or rays?

The New York Times

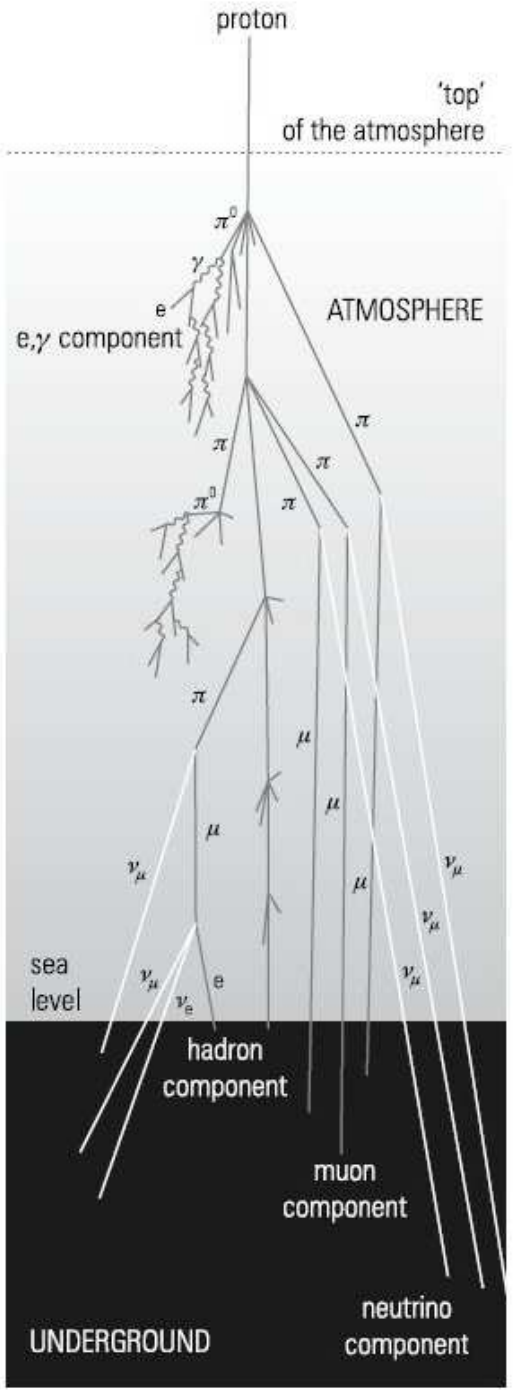
VOL. LXXXII....No. 27,370. December 31,1932

MILLIKAN RETORTS HOTLY TO COMPTON IN COSMIC RAY CLASH

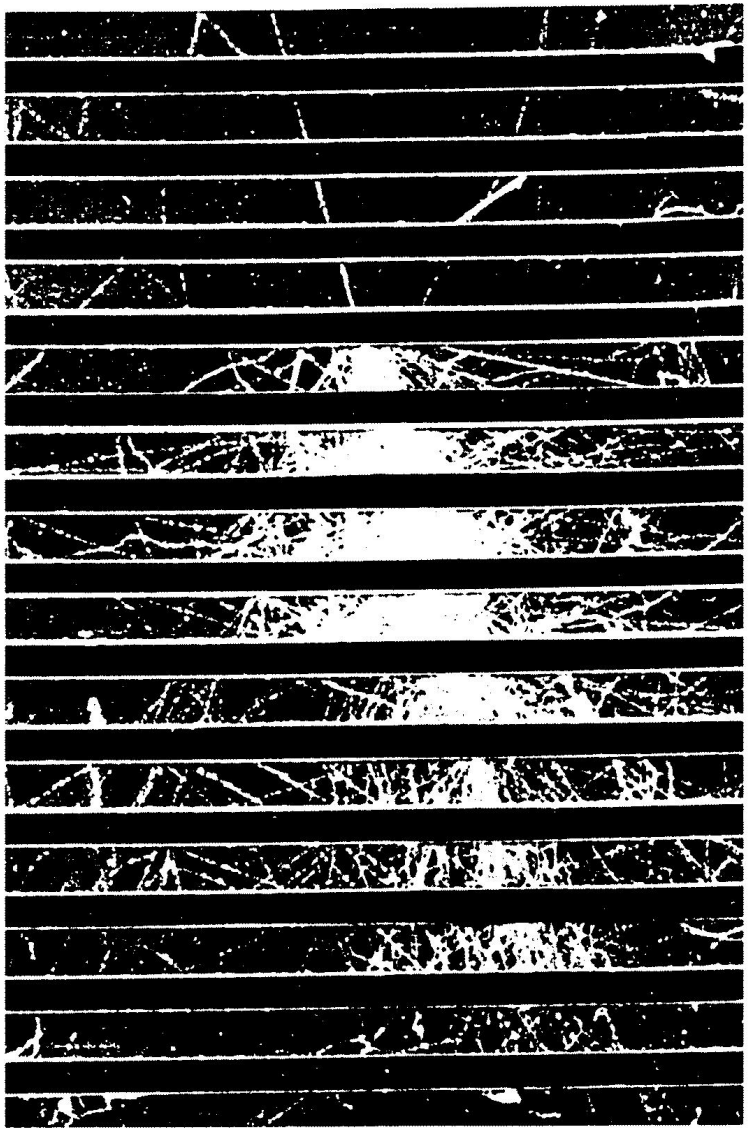
Debate of Rival Theorists Brings Drama to Session of Nation's Scientists.

THEIR DATA AT VARIANCE

New Findings of His Ex-Pupil Lead to Thrust by Millikan at 'Less Cautious' Work.



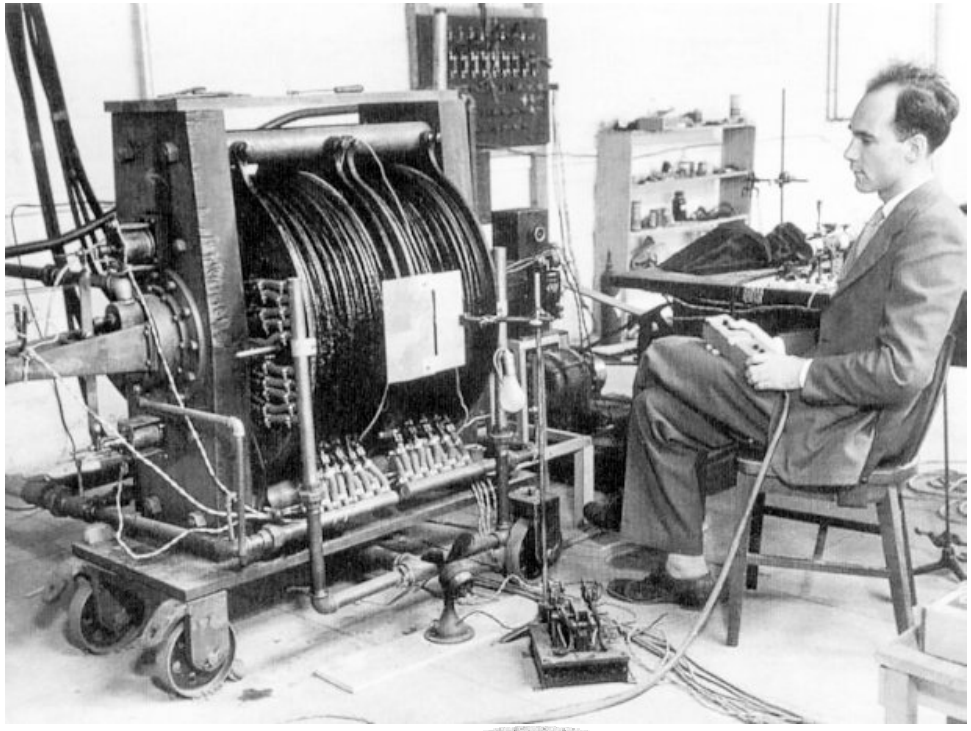
Cosmic ray induced cascade

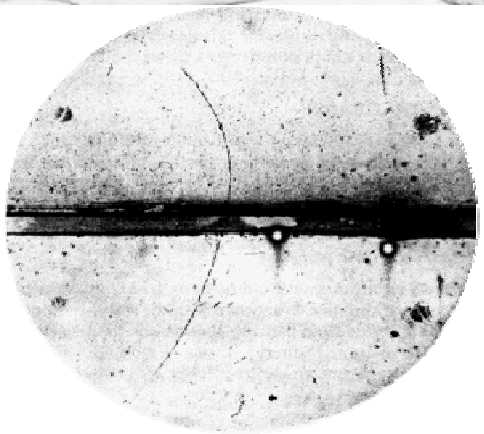


3027 m altitude; ~10 GeV proton

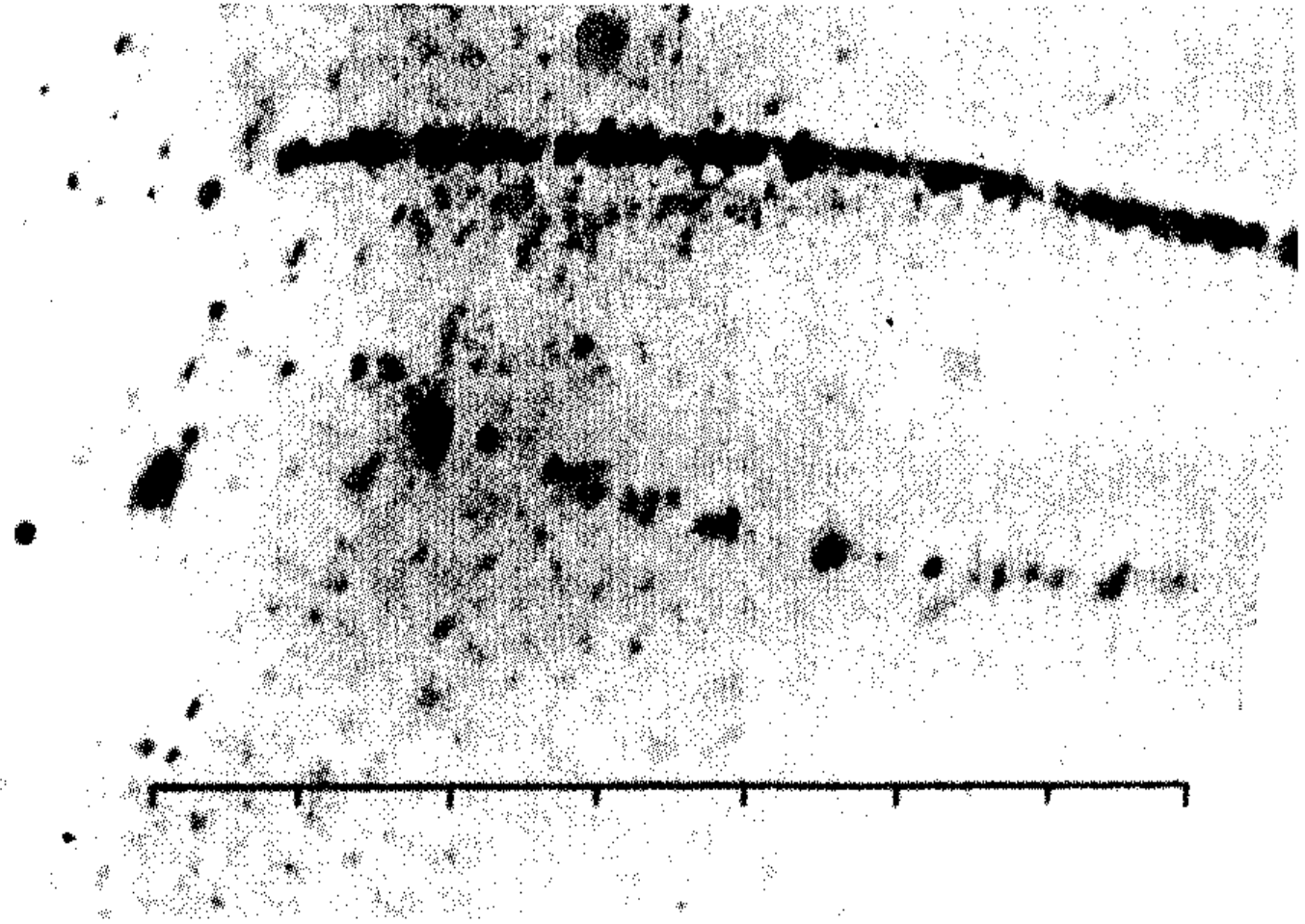
Fretter 1949

The golden years: discovery of the positron 1932



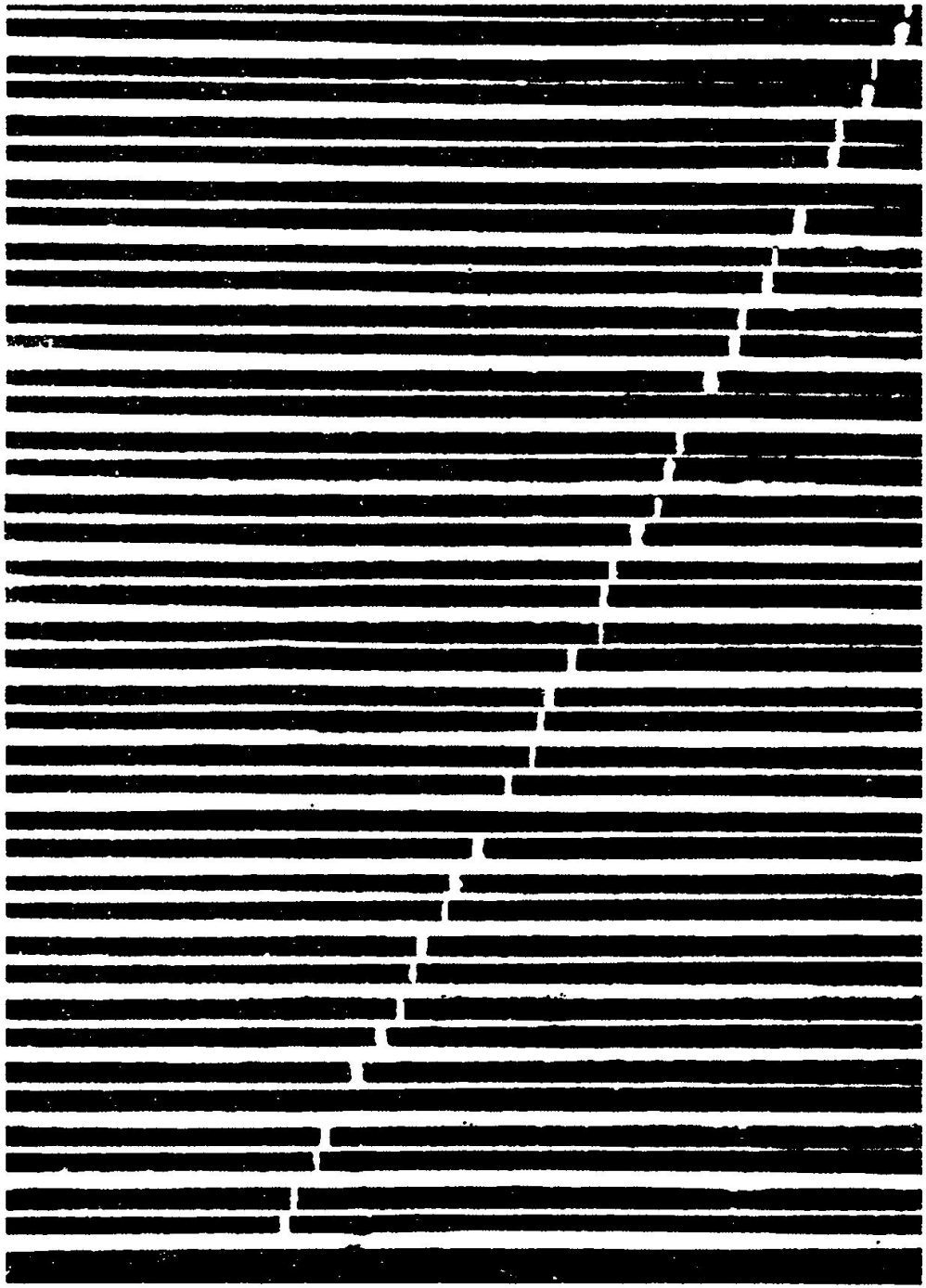


First indication of the muon by Paul Kunze in Rostock in 1932



muon

electron

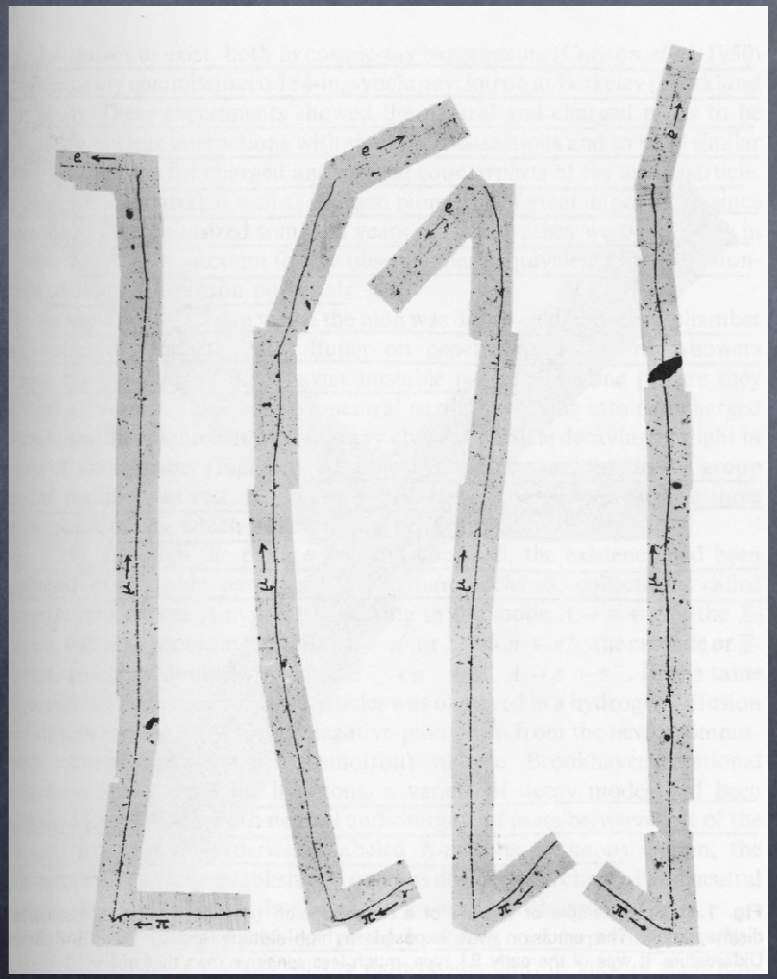


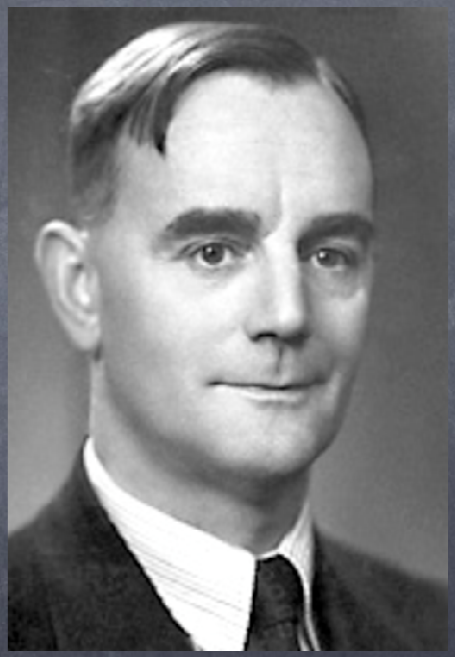
Discovery of the muon by Anderson and Neddermeyer 1937

Muon in a multiplate spark chamber (V.S. Kaftanov 1963)

Pion discovery 1947: Perkins, Powell, Occhialini, Lattes and Muirhed

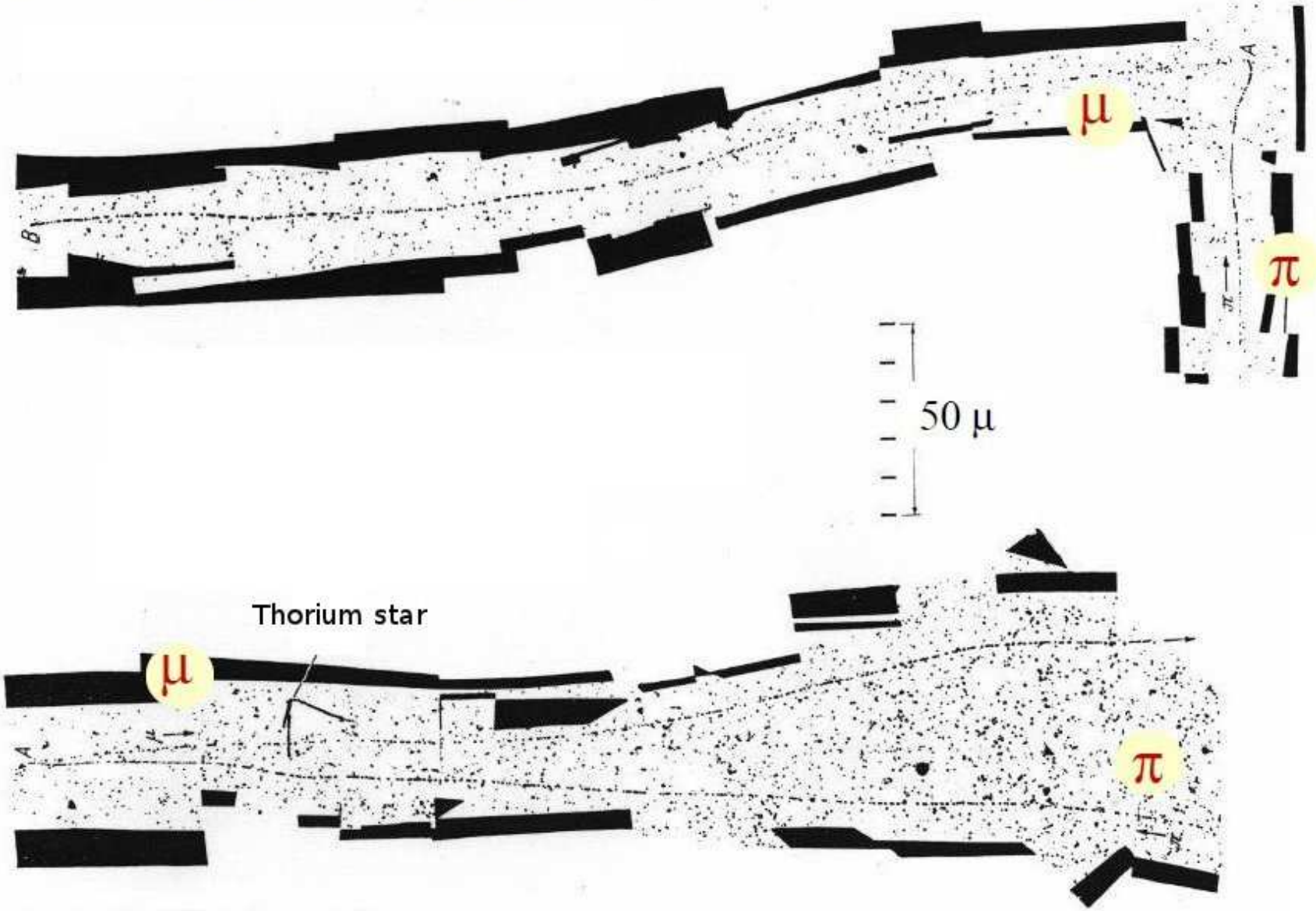
Nobel Prize 1950



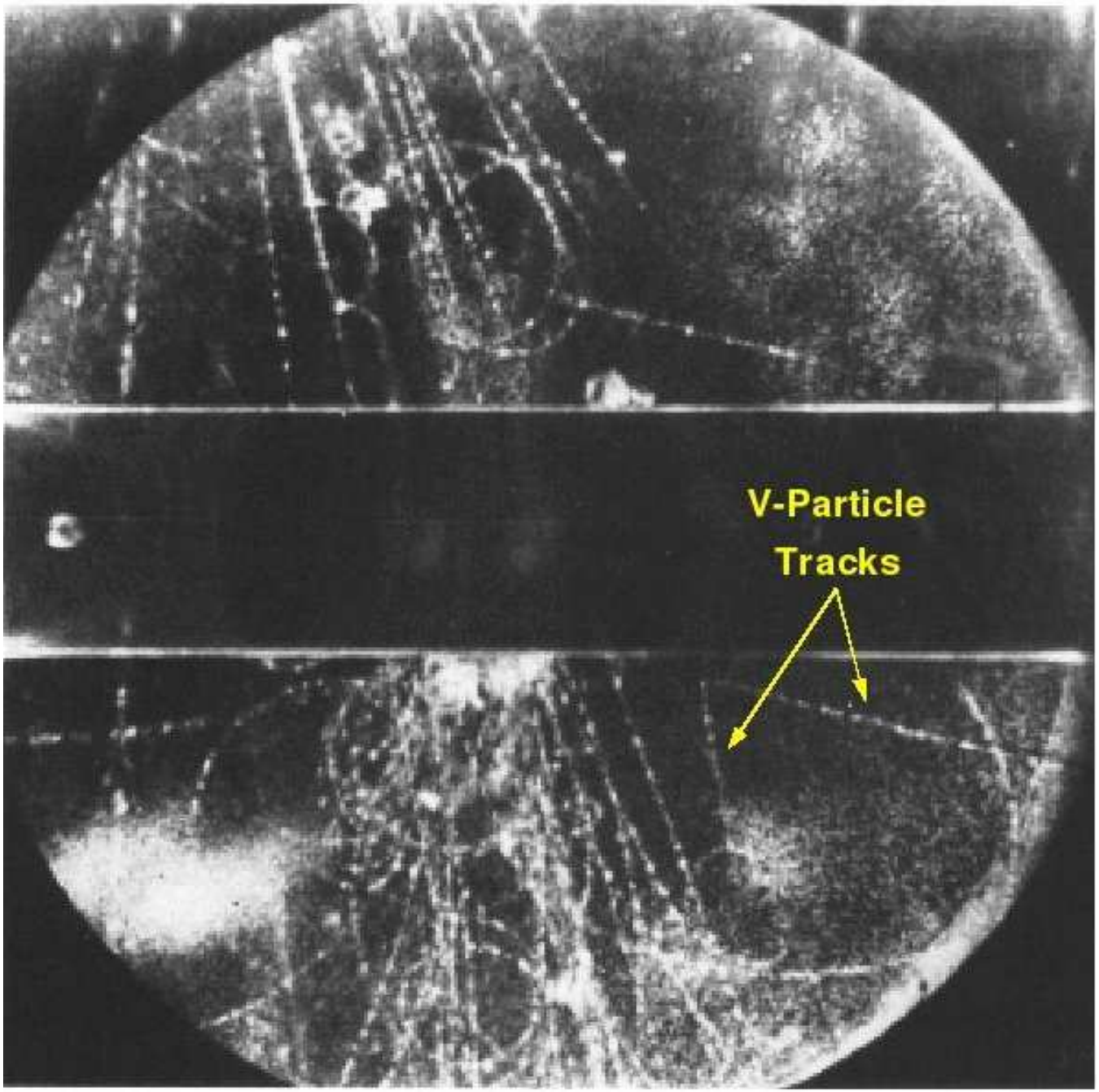


Powell

Discovery of $\pi \rightarrow \mu + \nu_\mu$ (C.F.Powell : 1947)

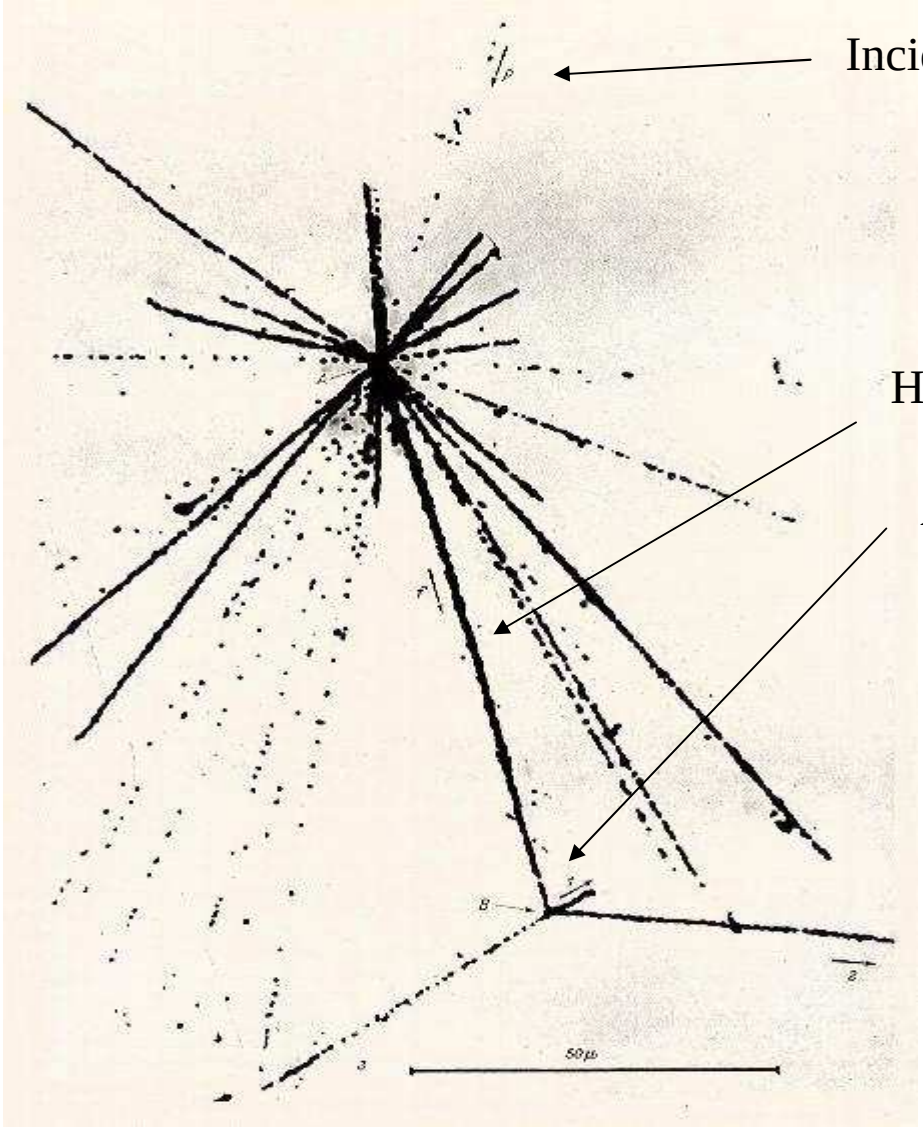


LATTES, MUIRHEAD, OCCHIALINI and POWELL; Nature **159**, 694 (1947).



Neutral Kaon
Discovery
1947
Rochester and
Butler

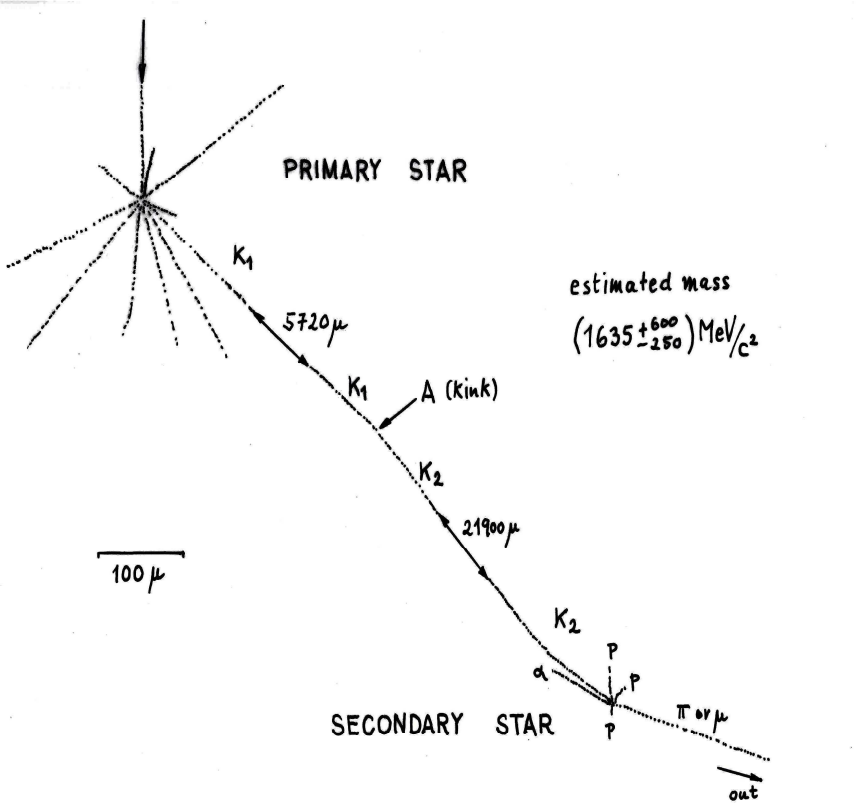
Observation of a Λ in cosmic rays



M. Danysz and J. Pniewski Phil. Mag. 44 (1953) 348

The missing link in the quark model

It is believed that an unidentified track found in 1954 in a stack of nuclear emulsions exposed to cosmic rays at 100 000 ft altitude by Yehuda Eisenberg was the path of an Omega minus!
M. Gell-Mann: “Perhaps it (the Omega minus) could explain the old Eisenberg event ...”



Alvarez:

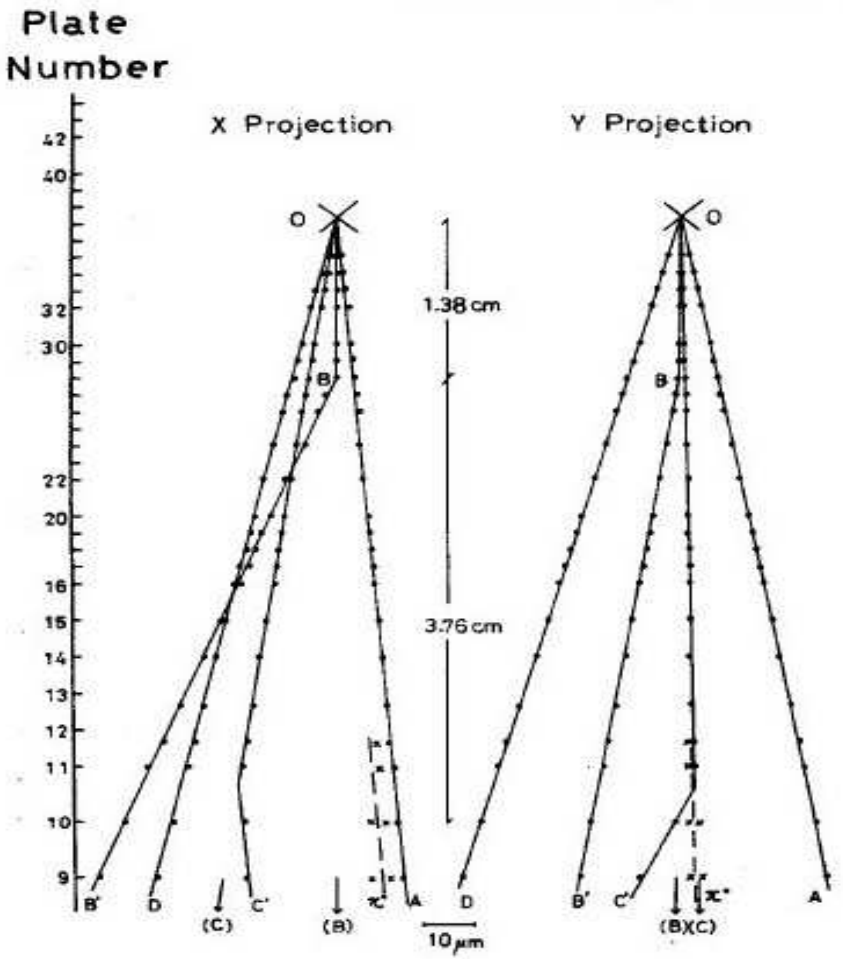
Y. Eisenberg; Phys. Rev. 96 (1954) 541

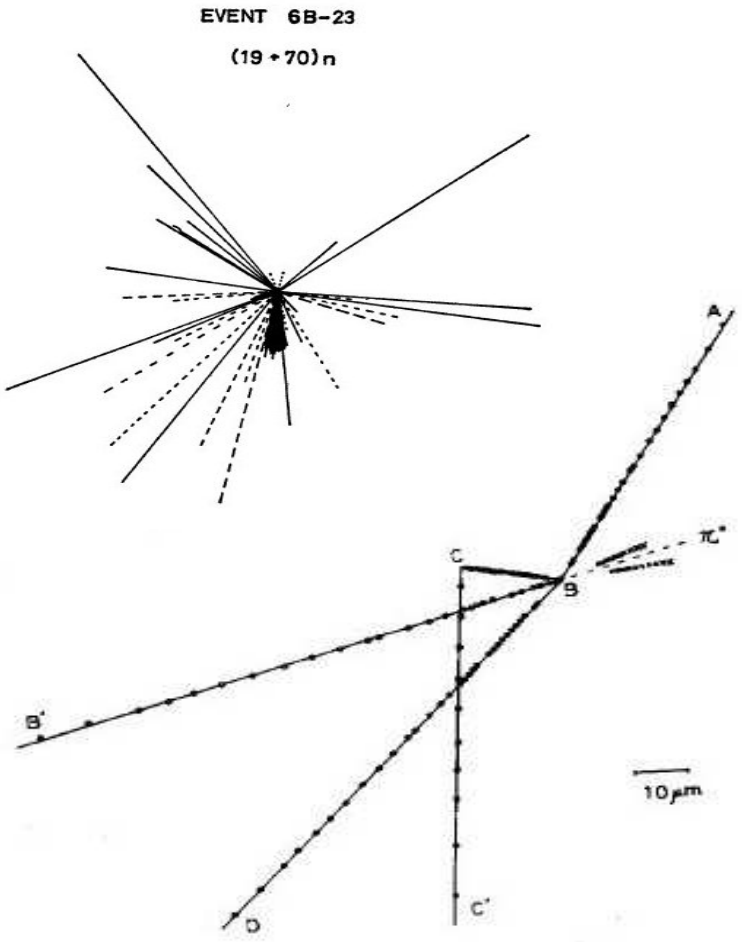
the Ω interacted with an Ag nucleus to give K^- Ξ Ag.

Discovery of X-particle (K.Niu : 1971)

Emulsion stack on a jet cargo air plane;
Estimated mass ~ 2 GeV; short-lived

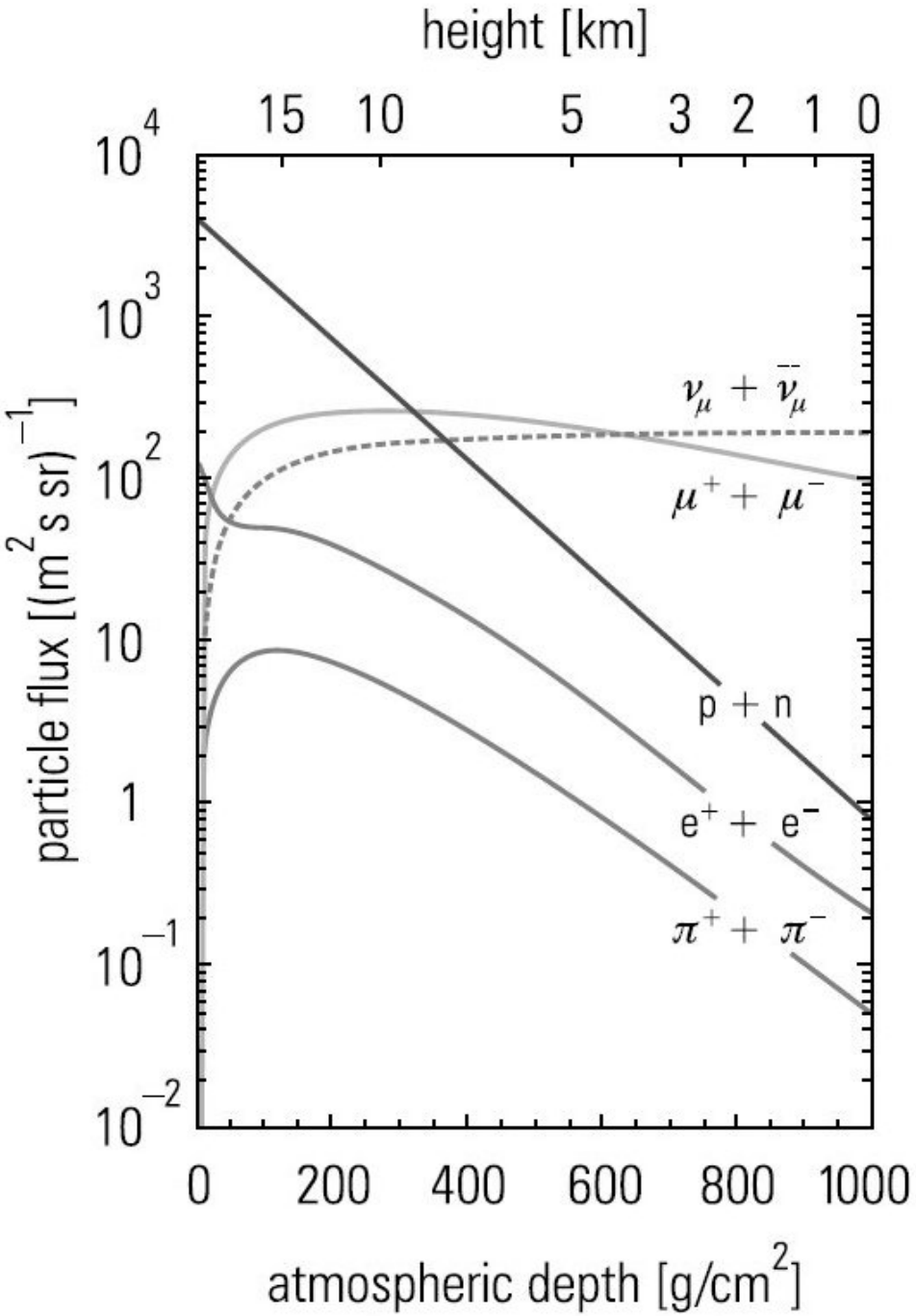
The charm ?!!





z Projection

Transformation in the atmosphere



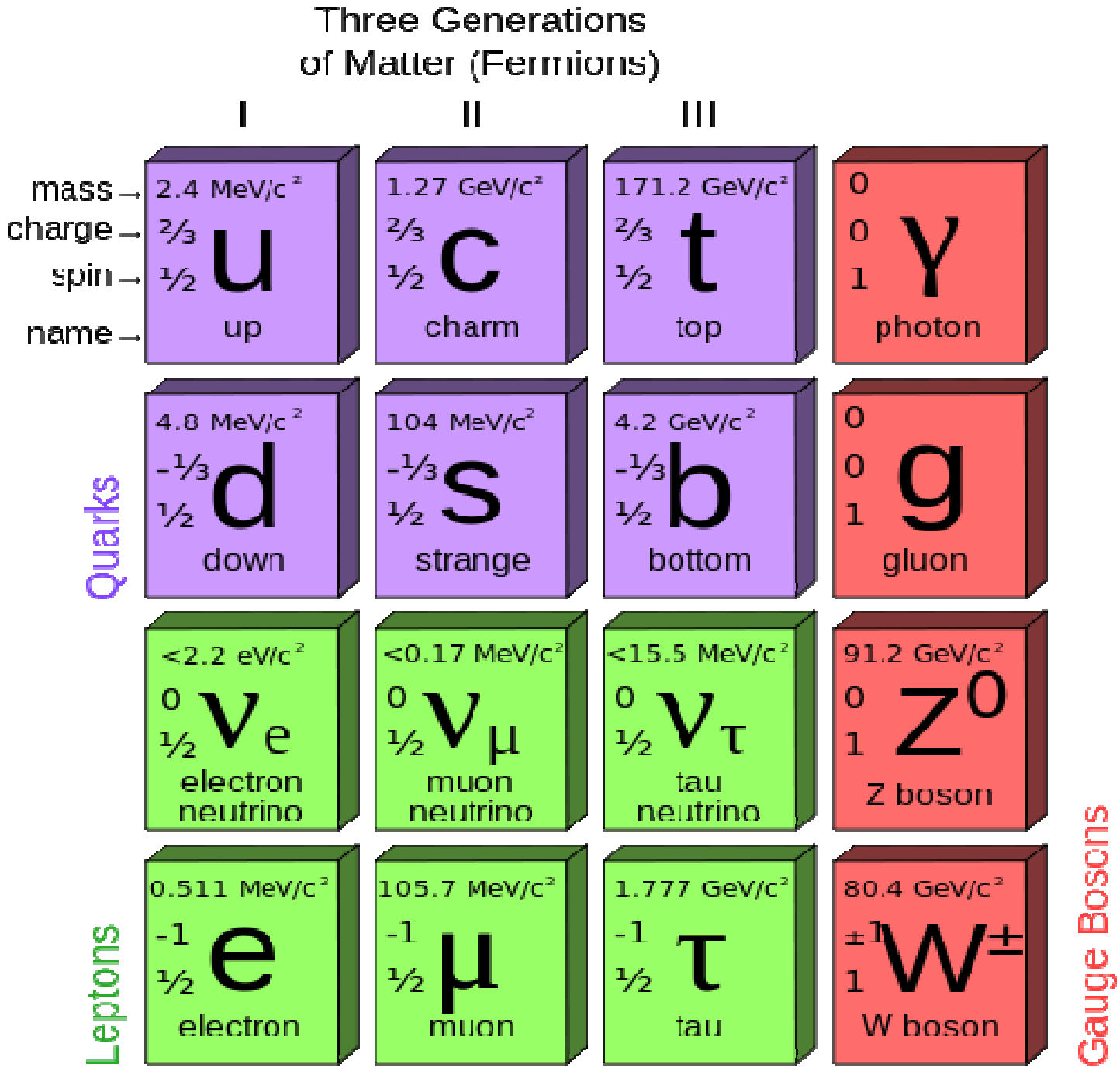
Accelerators and Storage Rings take over

Electron neutrino:
Cowan and Reines 1956

Muon neutrino :
Lederman, Schwartz, Steinberger 1962

Tau and Tau neutrino
Perl 1975

Gluon, DESY 1979 …. to name a few

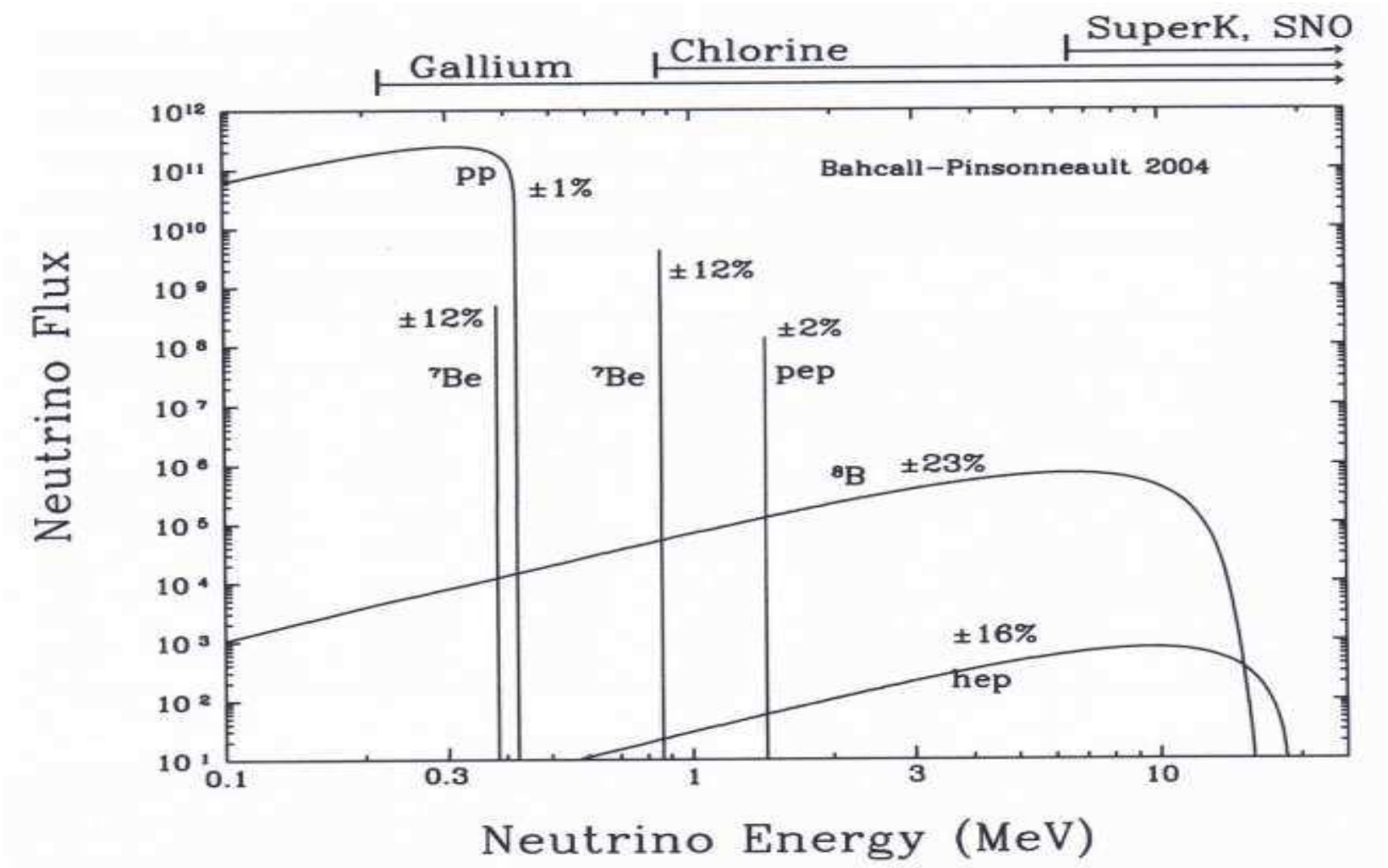

Three Generations
of Matter (Fermions)
I
II
III
mass →
charge →
spin →
name →
2.4 MeV/c²
⅔
½
u
up
1.27 GeV/c²
⅔
½
c
charm
171.2 GeV/c²
⅔
½
t
top
0
0
1
γ
photon
4.8 MeV/c²
-⅓
½
d
down
104 MeV/c²
-⅓
½
s
strange
4.2 GeV/c²
-⅓
½
b
bottom
0
0
1
g
gluon
<2.2 eV/c²
0
½
νe
electron neutrino
<0.17 MeV/c²
0
½
νμ
muon neutrino
<15.5 MeV/c²
0
½
ντ
tau neutrino
91.2 GeV/c²
0
1
Z⁰
Z boson
0.511 MeV/c²
-1
½
e
electron
105.7 MeV/c²
-1
½
μ
muon
1.777 GeV/c²
-1
½
τ
tau
80.4 GeV/c²
±1
1
W±
W boson
Quarks
Leptons
Gauge Bosons

Renaissance of Cosmic Rays

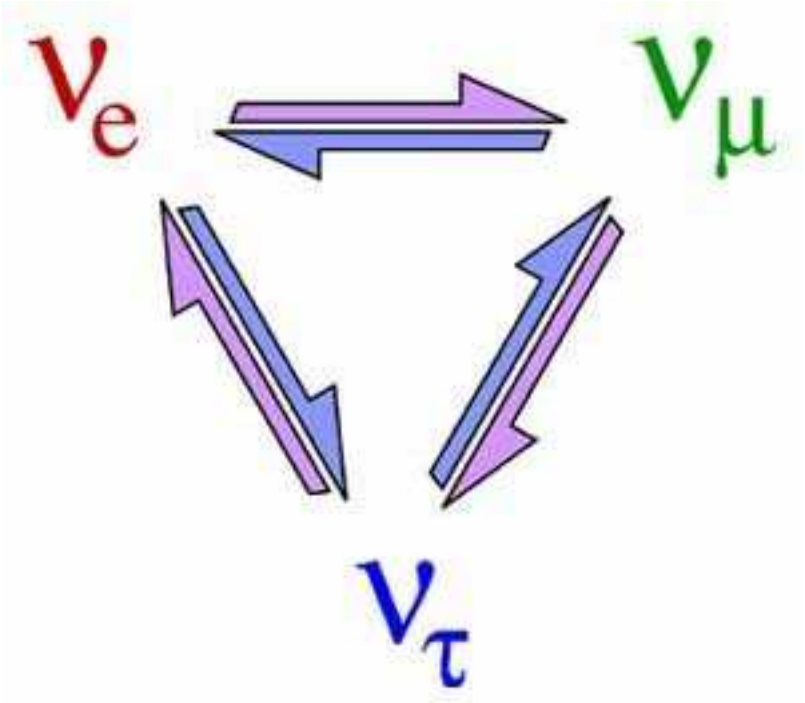
Ray Davis jun.

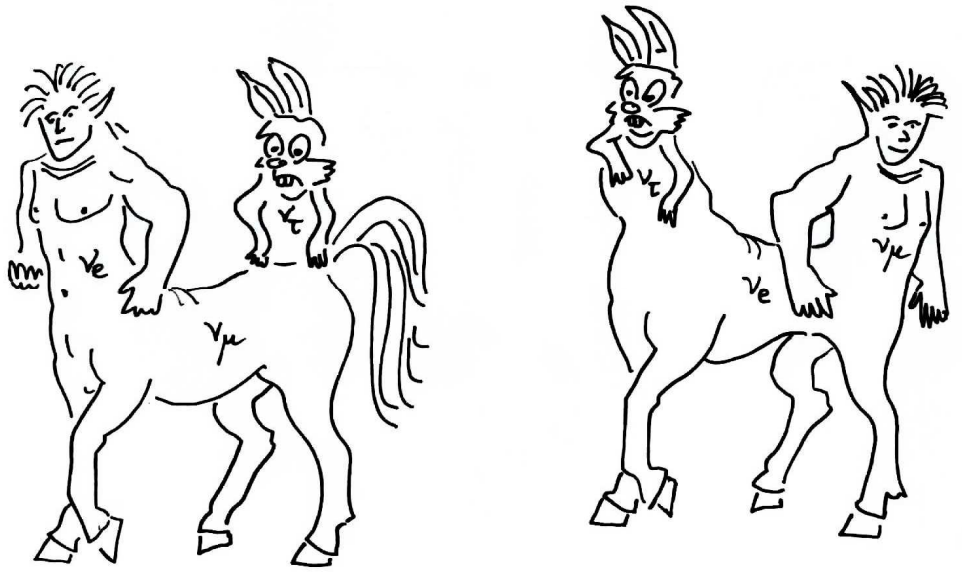
from 1967

Solar Neutrinos



Neutrino-Oscillations





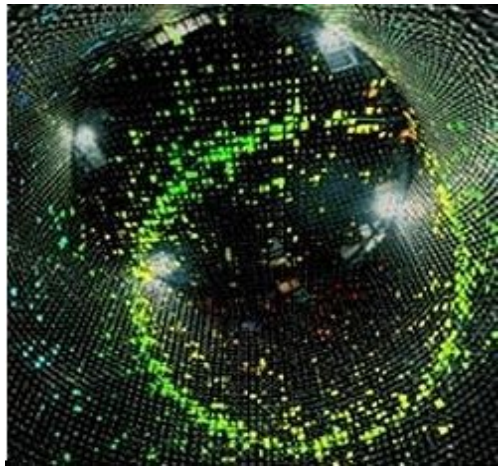
animalistic oscillations

Dependent on the mixing angle and the difference of the masses squared

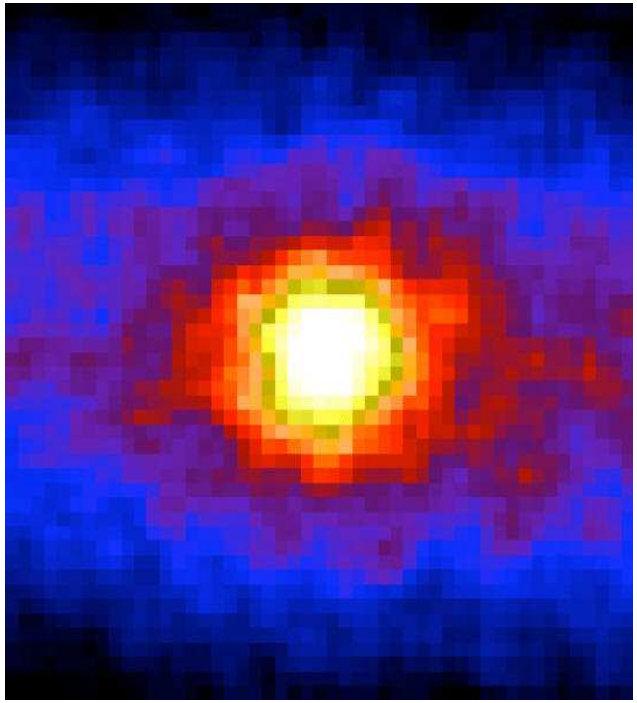
Super-Kamiokande Experiment

Masatoshi Koshiba

Cherenkov-Ring



Sun in the light of neutrinos



Supernova 1987 A

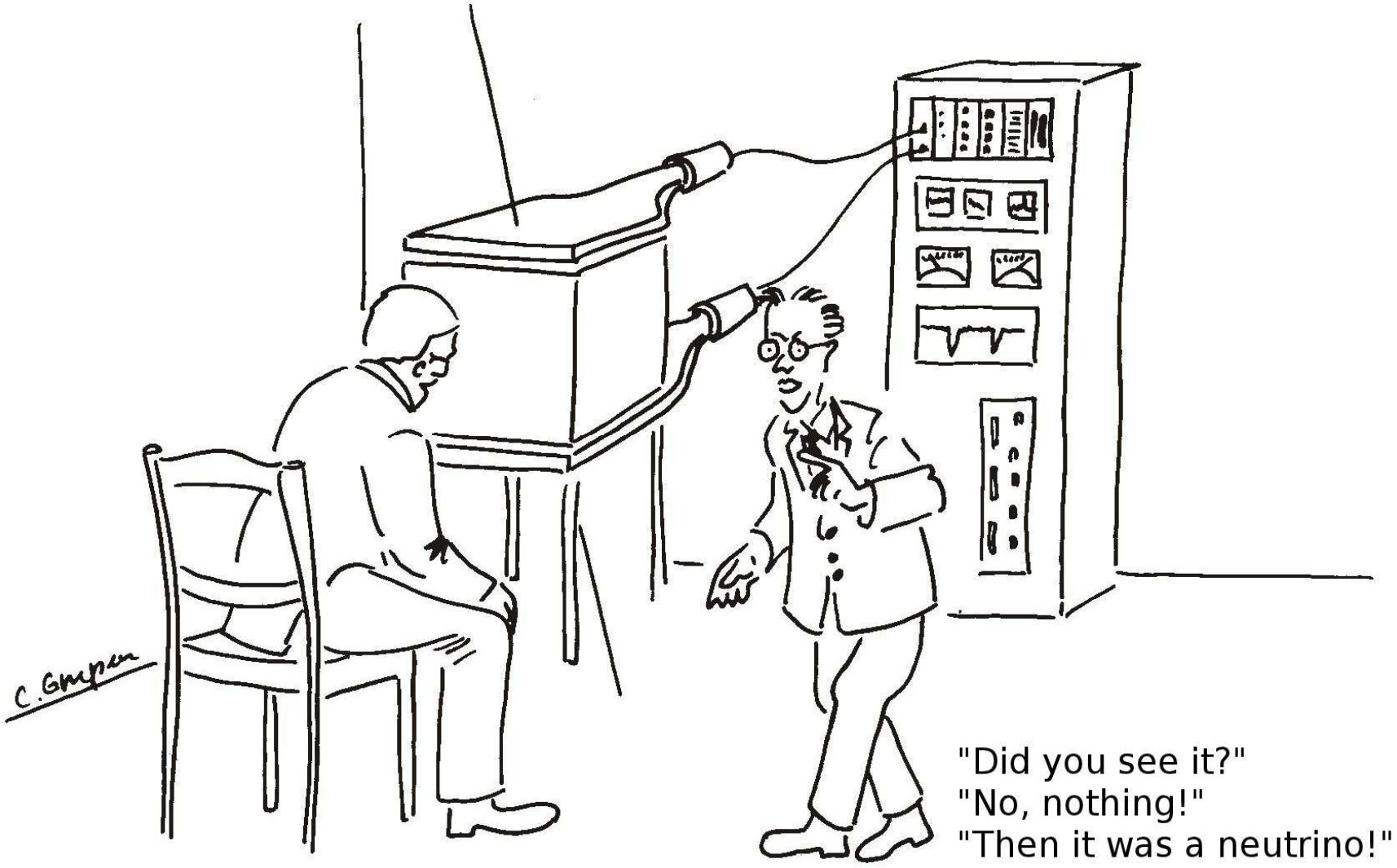
Supernova 1987 A

Supernova-Explosion
in the Large Magellanic Cloud
Distance 170 000 light years

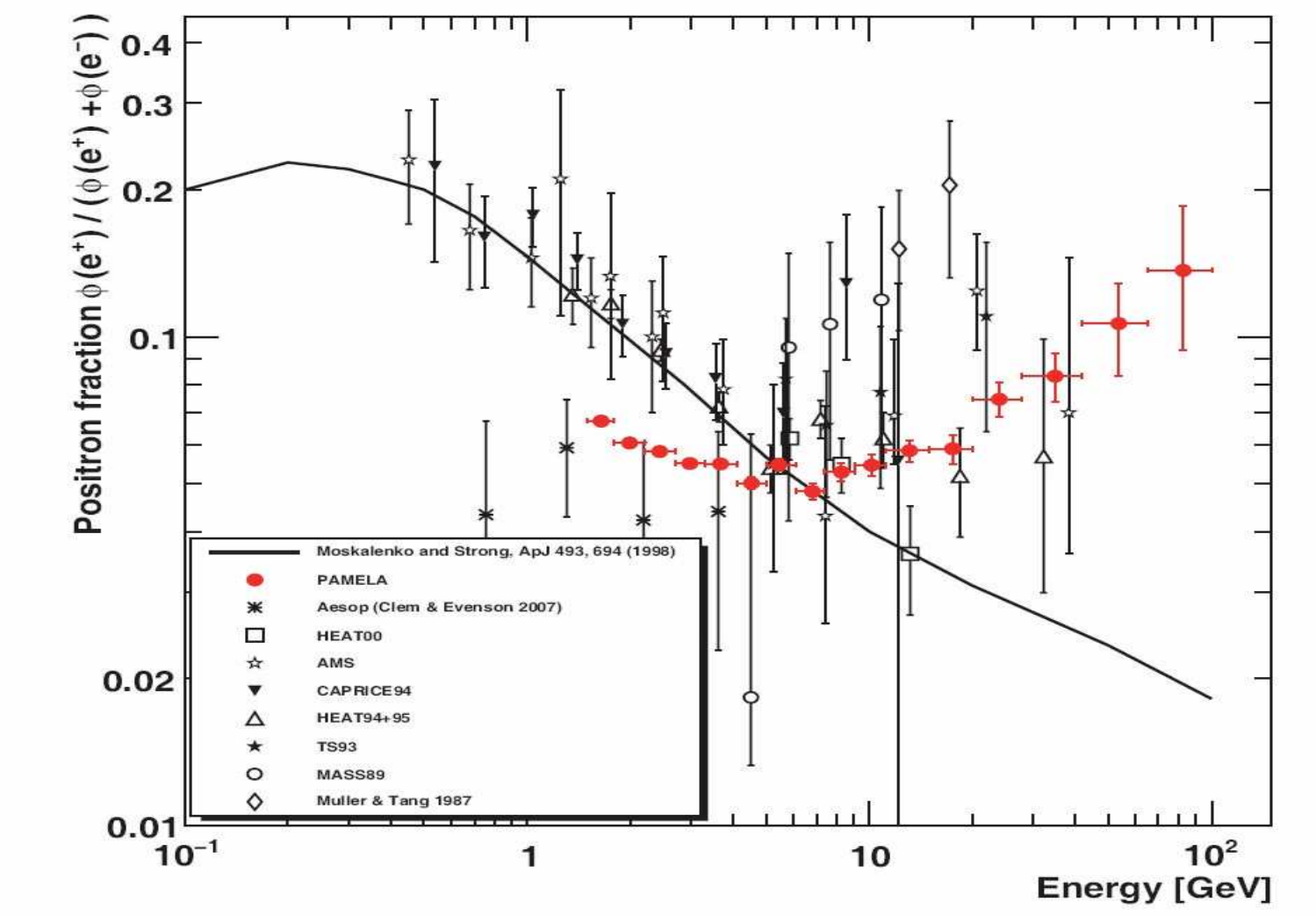
energy output 6×10^{46} Joule
(energy consumption 10^{21} Joule per year
for the whole world)

10^{58} neutrinos, only 19 measured in IMB and Kamiokande

Problems to measure neutrinos

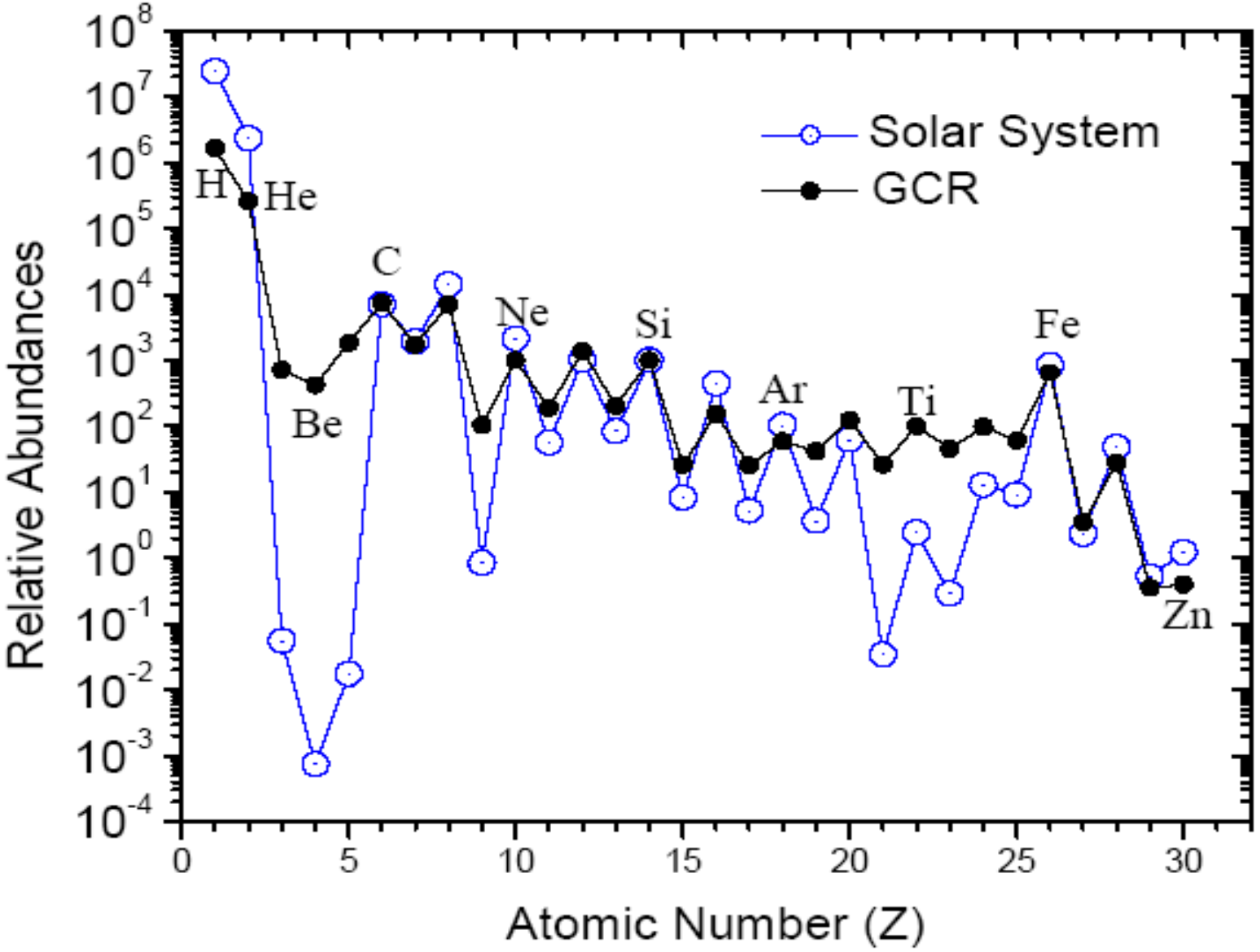


Positron spectra from PAMELA

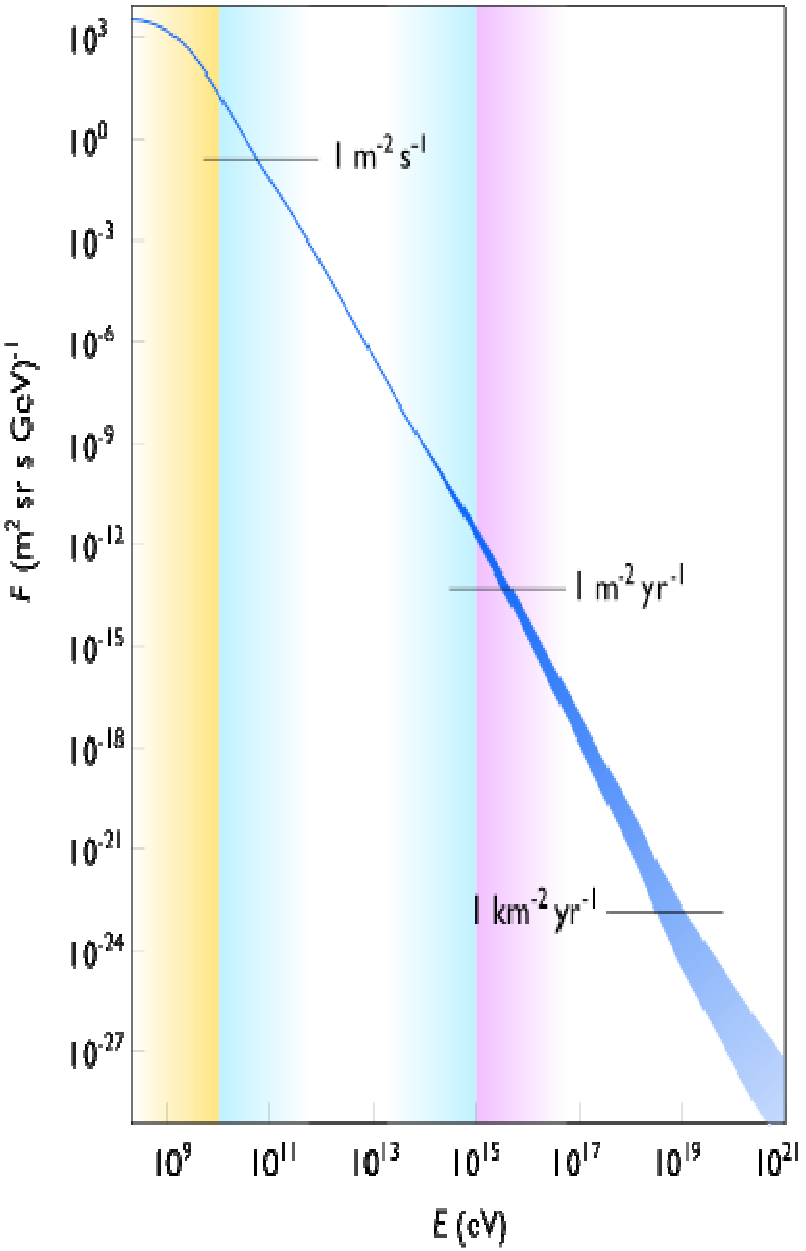


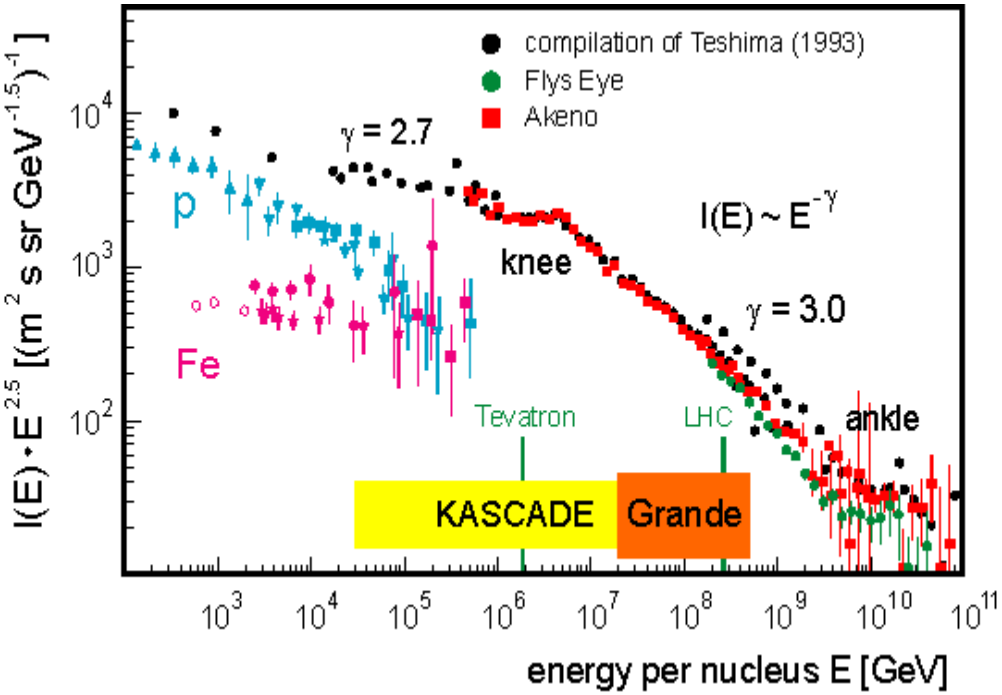
Origin of Cosmic rays?

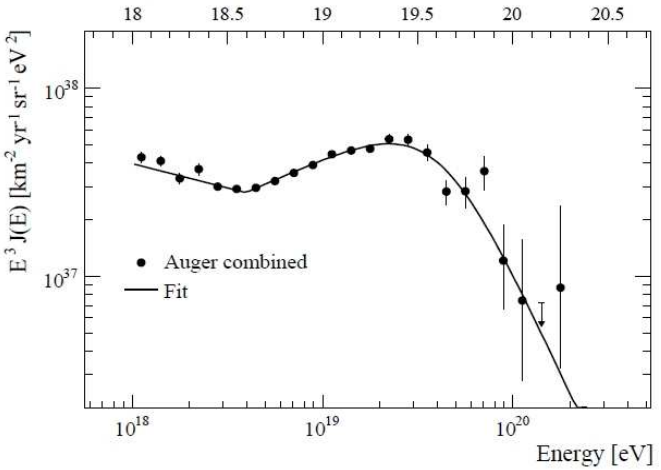
Elemental abundance



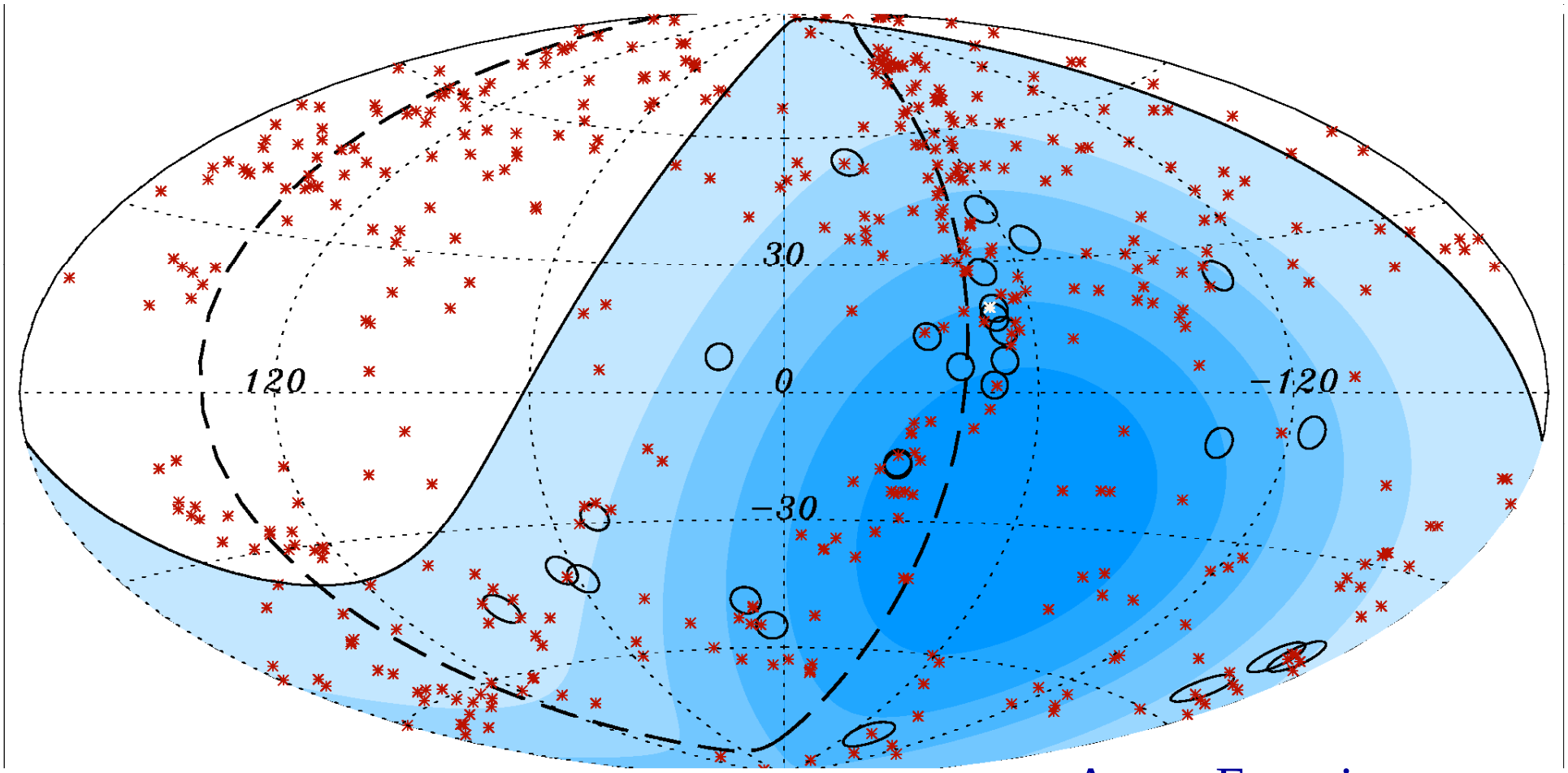
Extensive air showers





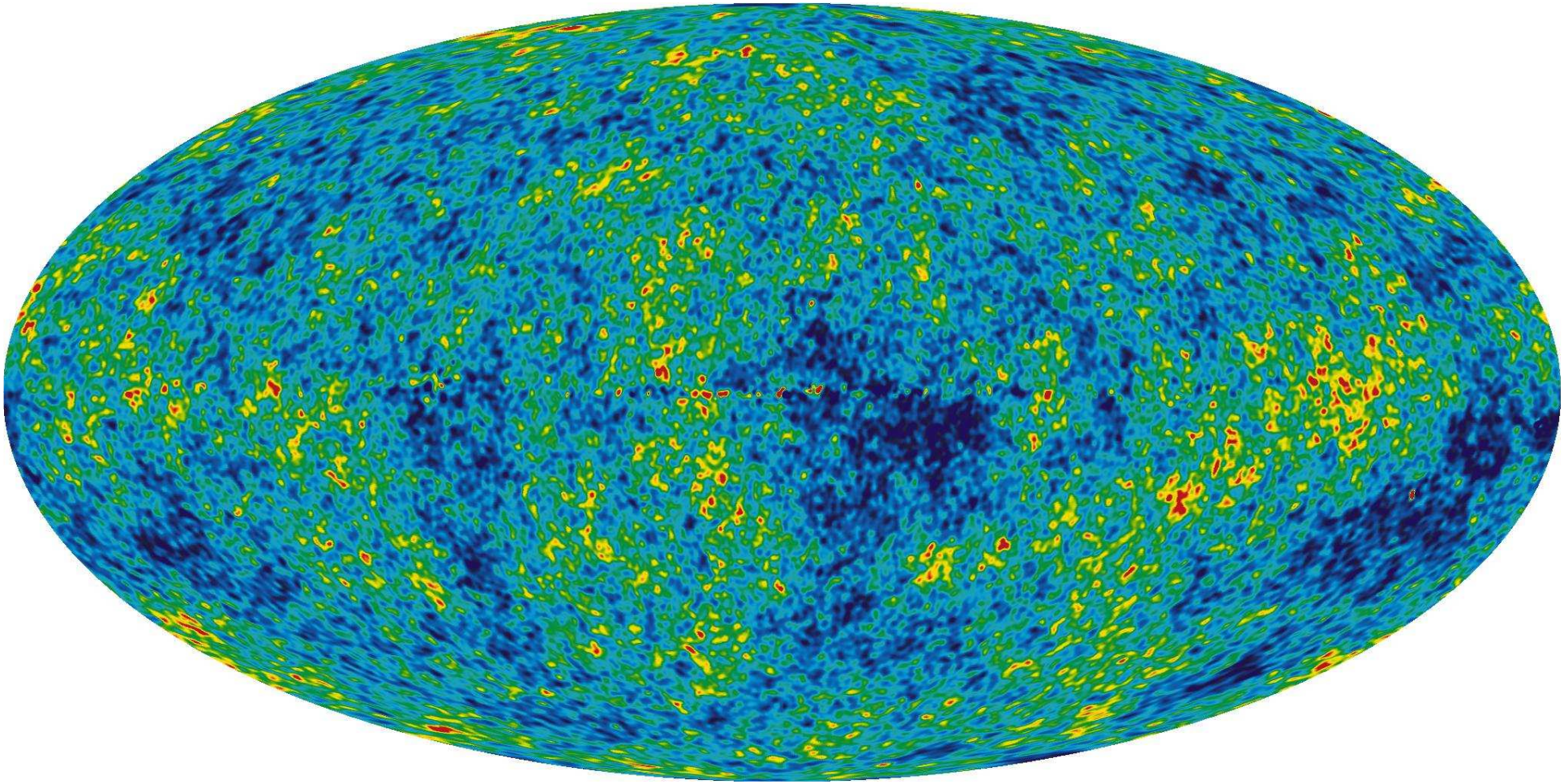


Where are the sources?



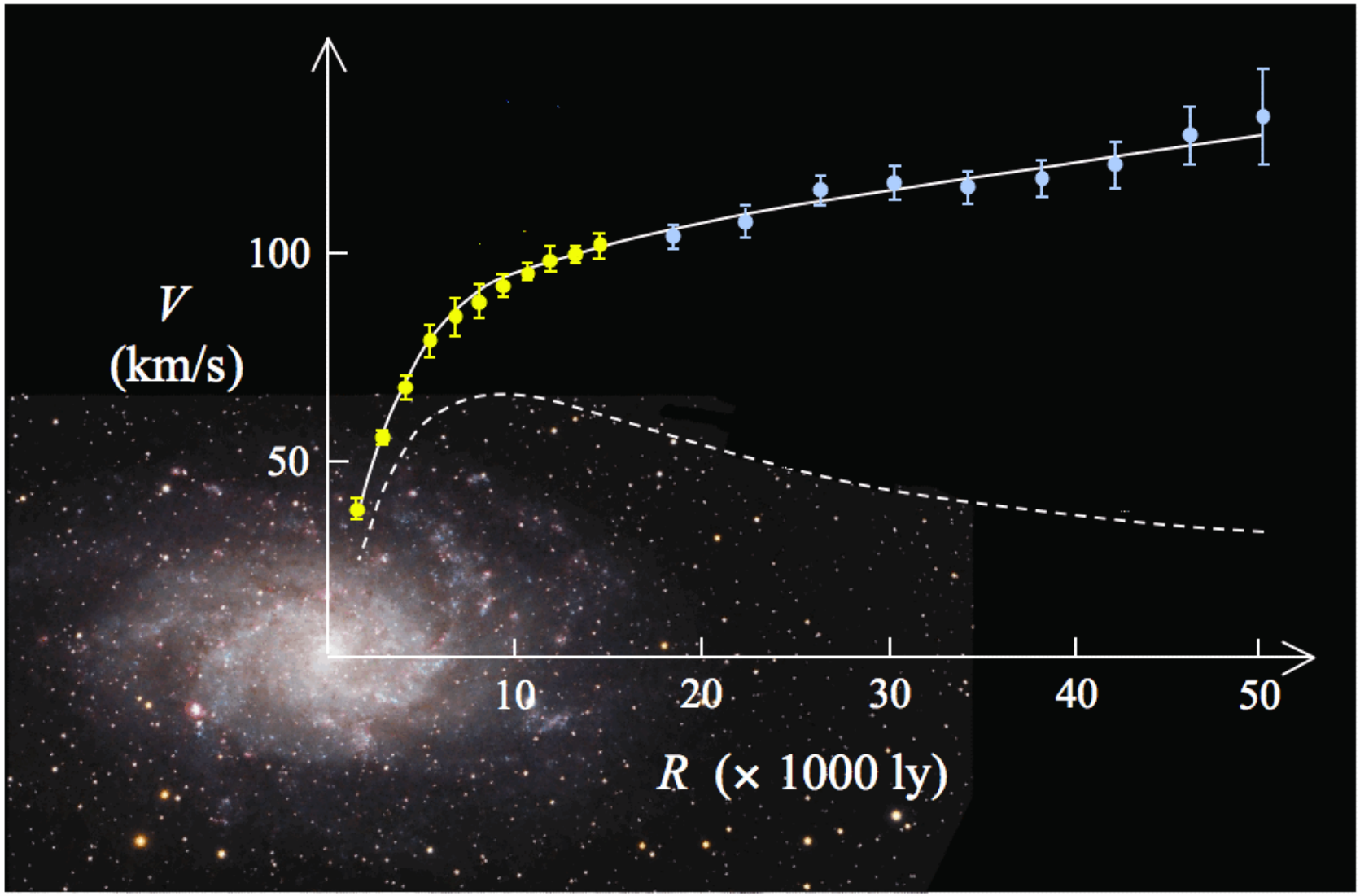
Auger Experiment

Echo of the Big Bang



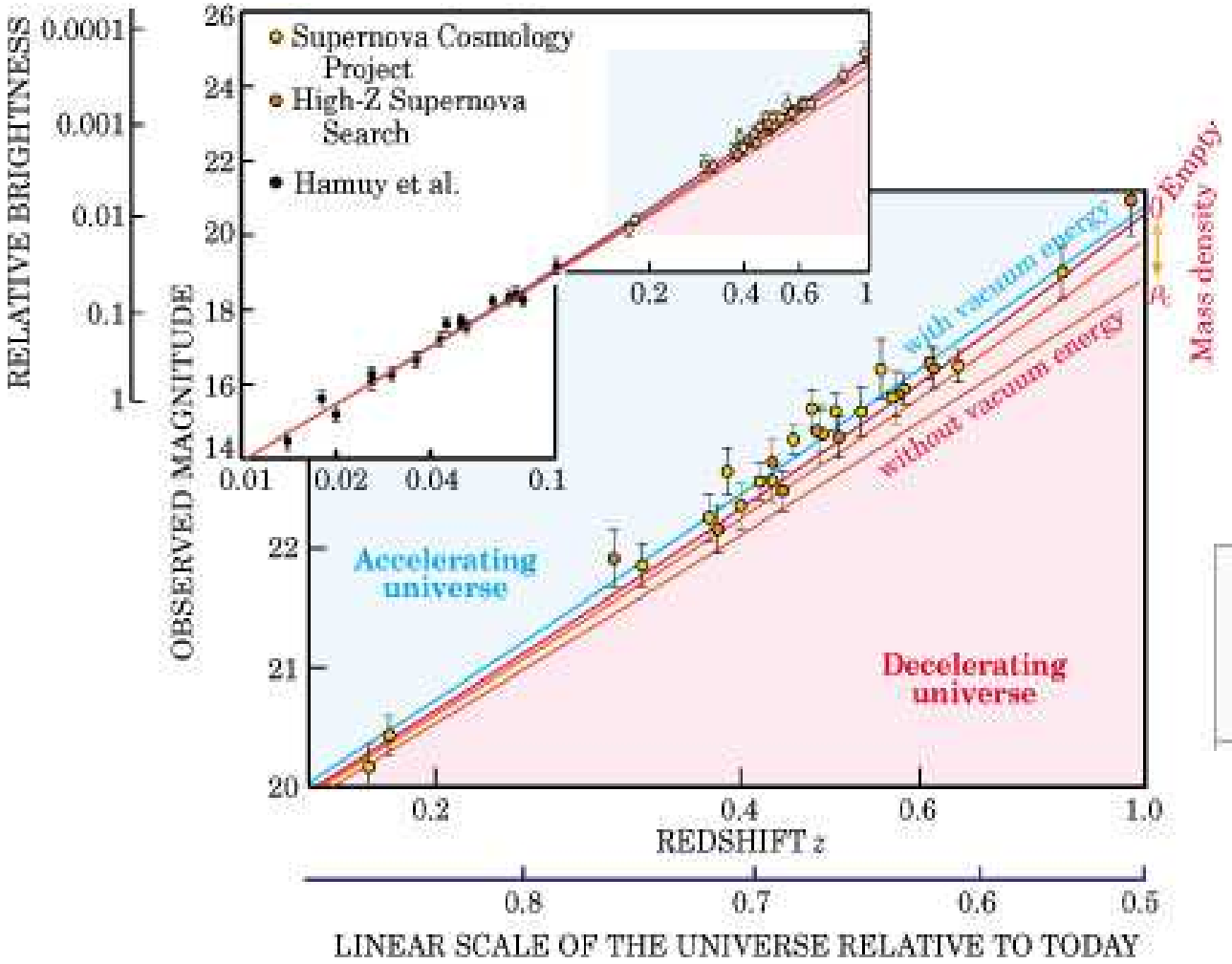
WMAP 2010

Evidence for dark matter



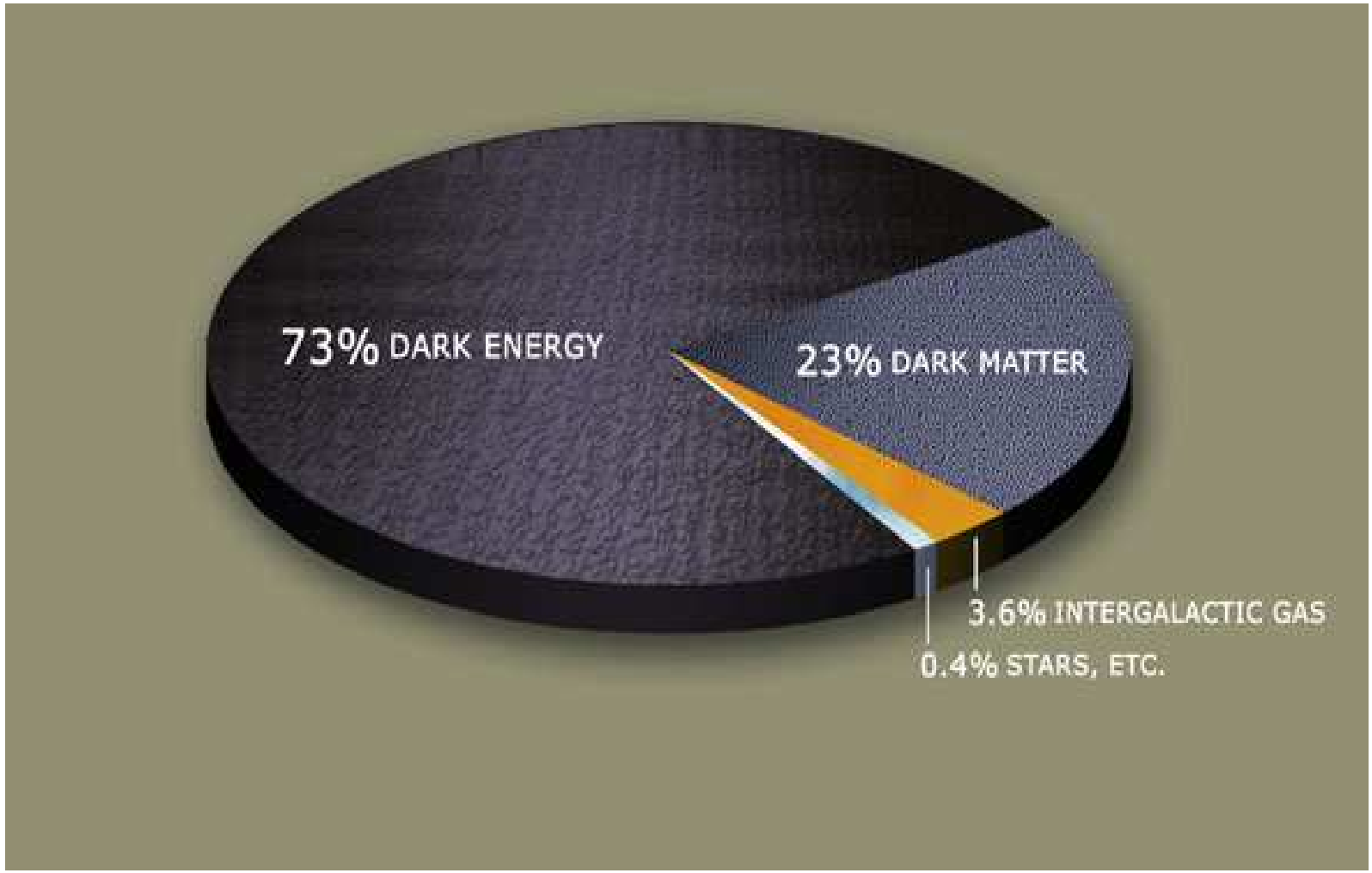
M33

Dark matter, dark energy

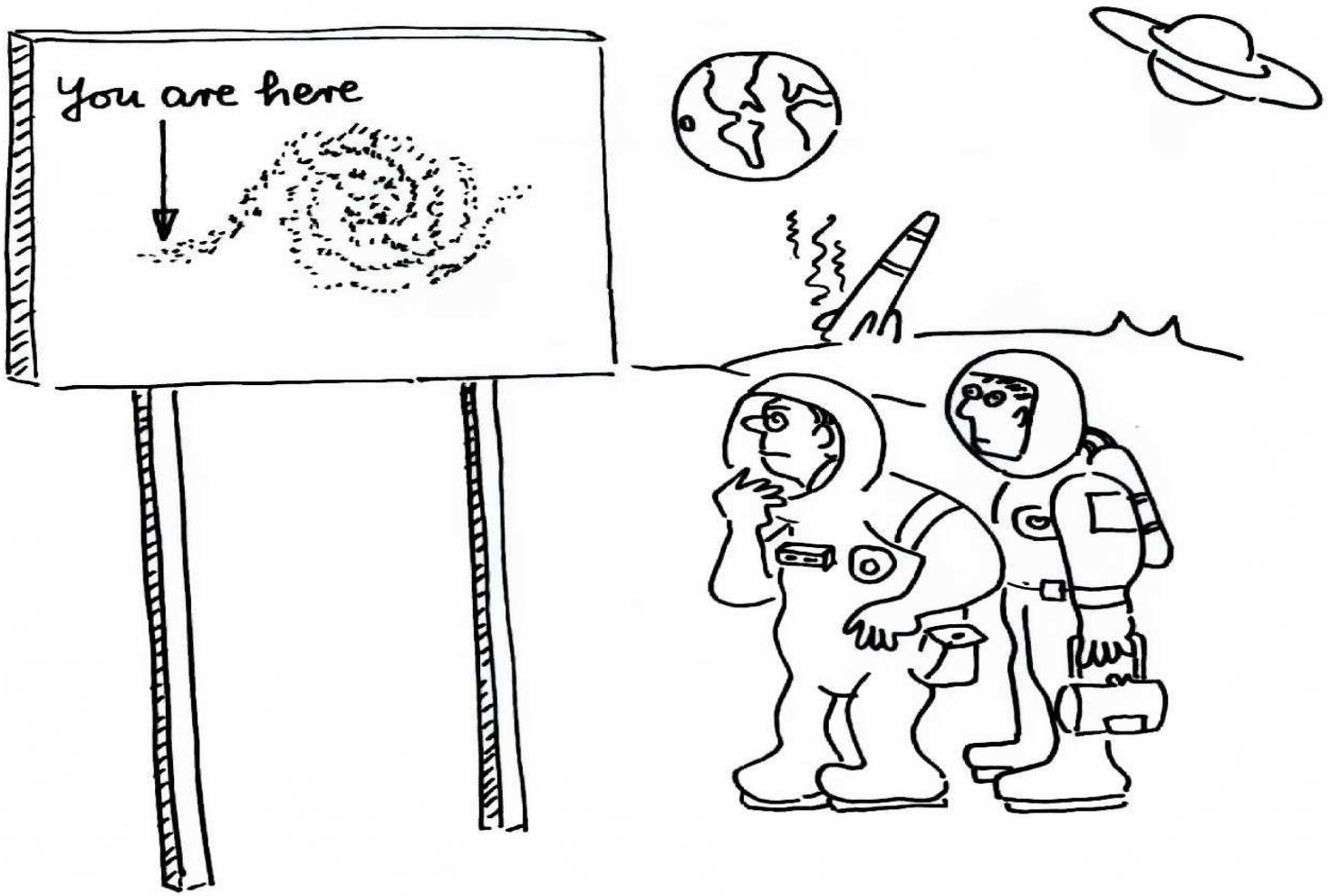


$$z = \frac{\lambda_{obsv} - \lambda_{emit}}{\lambda_{emit}}$$

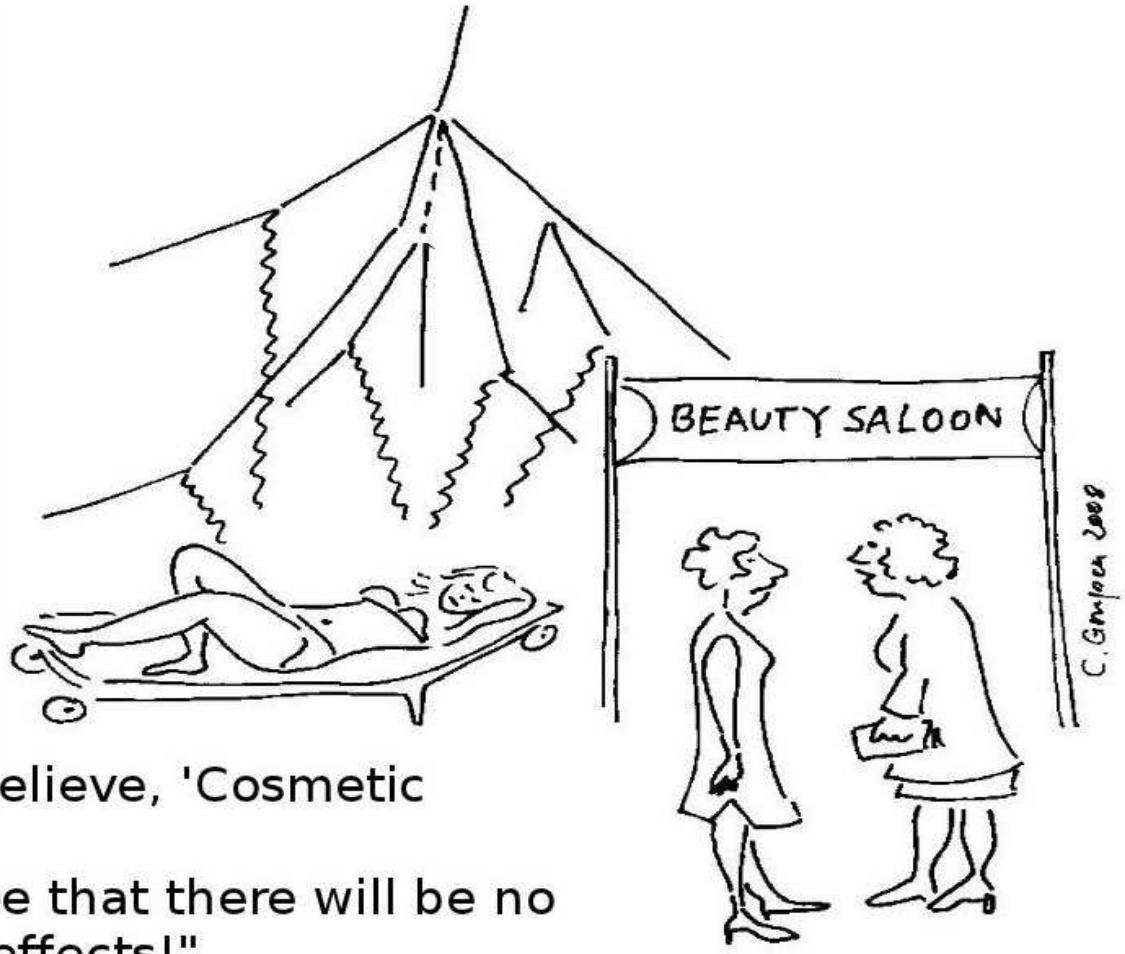
What makes up the Universe?



Manned space travel?



Positive effects of cosmic rays?



"The call it, I believe, 'Cosmetic Rays'.
They guarantee that there will be no negative side effects!"

Outlook

Cosmic rays is the birthplace of elementary particles

Since 1987 we experience a Renaissance of cosmic rays:

- Neutrino astronomy
- Gamma-ray astronomy
- Particle astronomy at the highest energies
- Gravitational wave astronomy (to come)

The highest energies provided by Nature
will never be reached at accelerators

Cosmic rays will continue to be a lab without competition