

Astroparticle Physics & Cosmology

1. Cosmic Rays
2. Messenger Particles
3. Scientific Realism
4. Unification
5. APP & Cosmology

Astroparticle Physics & Cosmology

1. Cosmic Rays

2. Messenger Particles

3. Scientific Realism

4. Unification

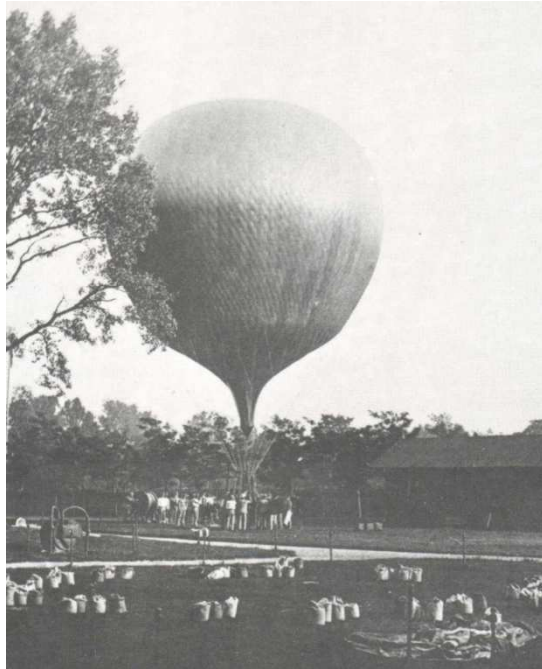
5. APP & Cosmology

1. Cosmic Rays

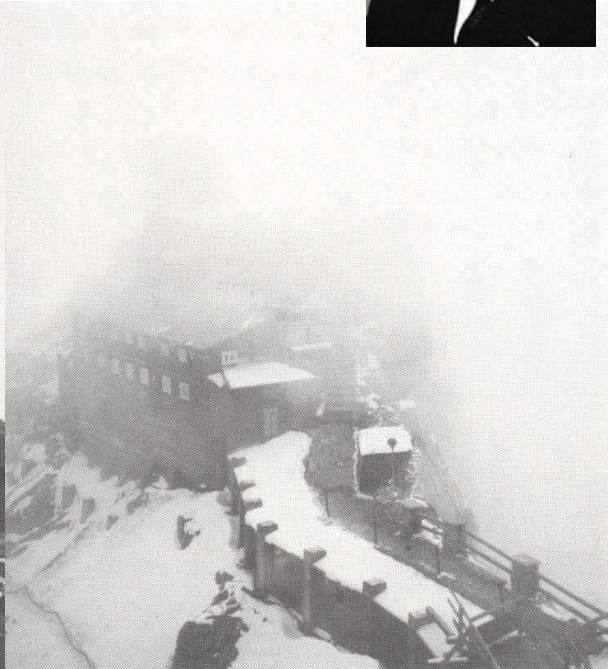


Victor Hess (1912):
Discovery

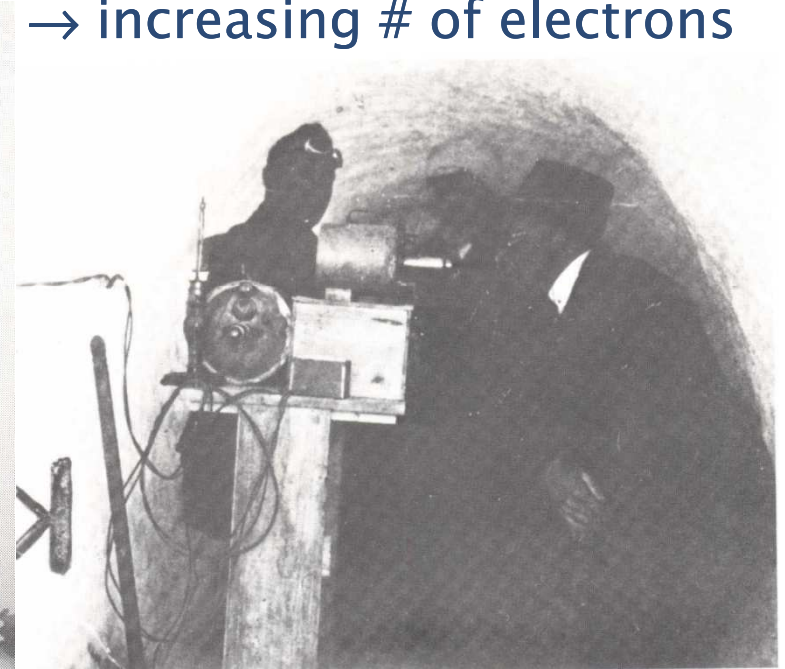
increasing height
→ increasing # of electrons



electrometer in balloon



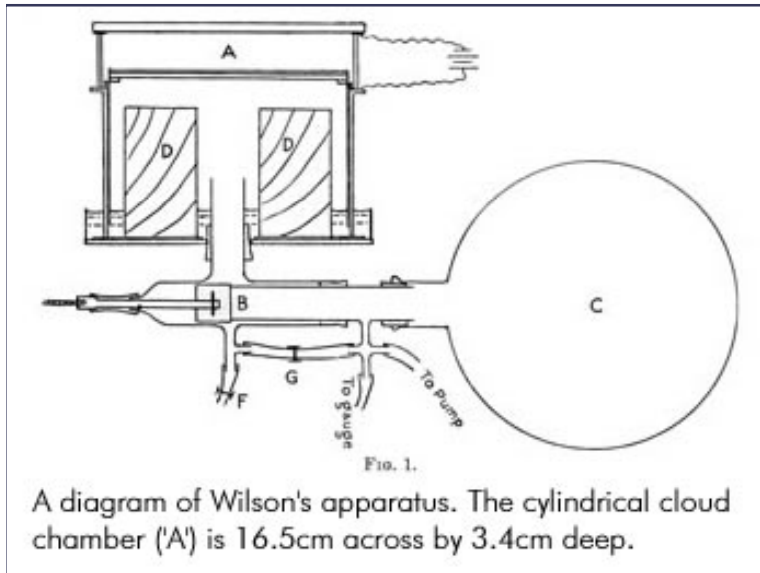
„Höhenstrahlungs-Labor“ (Zugspitze)



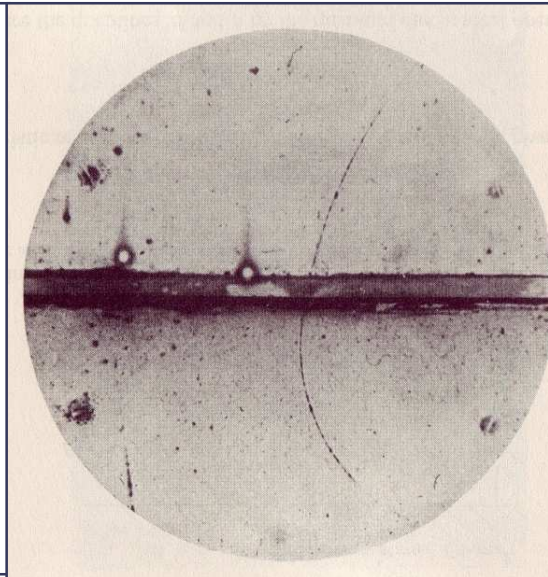
Eiger glacial

1. Cosmic Rays

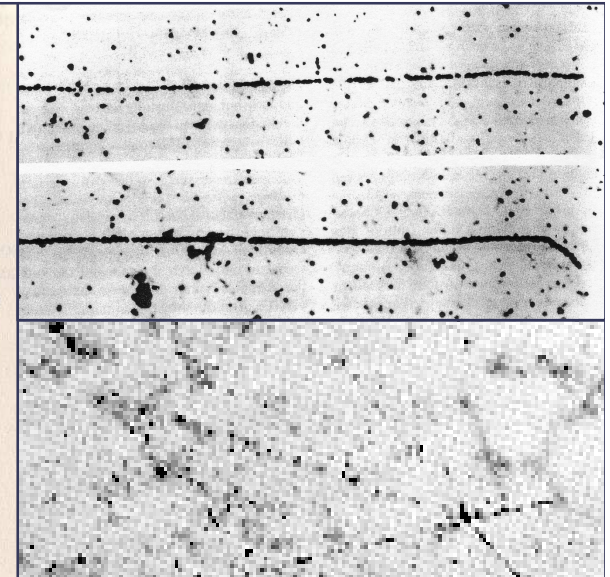
Robert Millikan (1920s):
Identification
extraterrestrial origin



cloud chamber (1911)



track of positron (1932)



nuclear emulsions (>1940)

Particle Detectors

1. Cosmic Rays

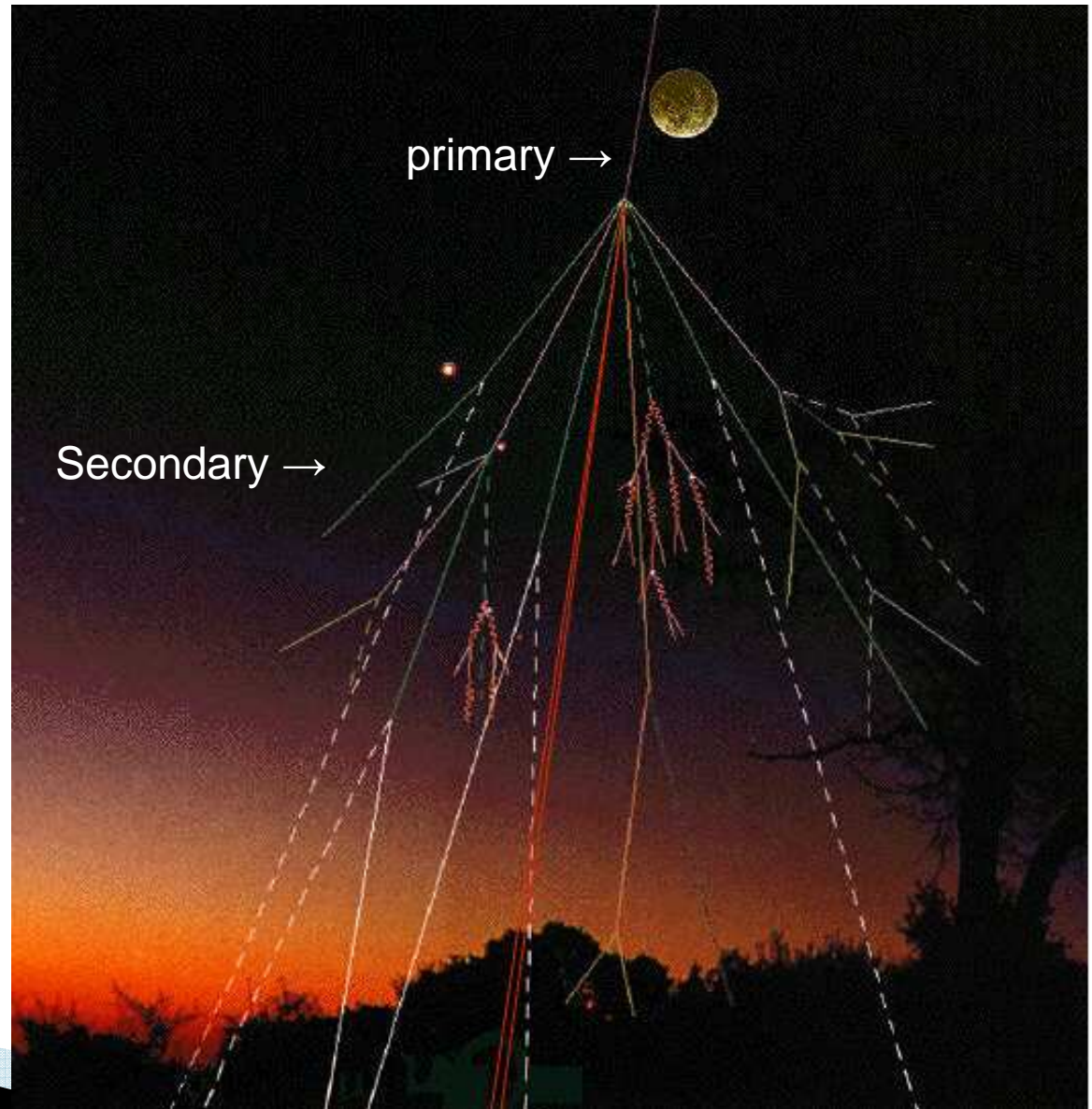
distinguish

primary &

secondary

CRs

(scattering in
atmosphere)

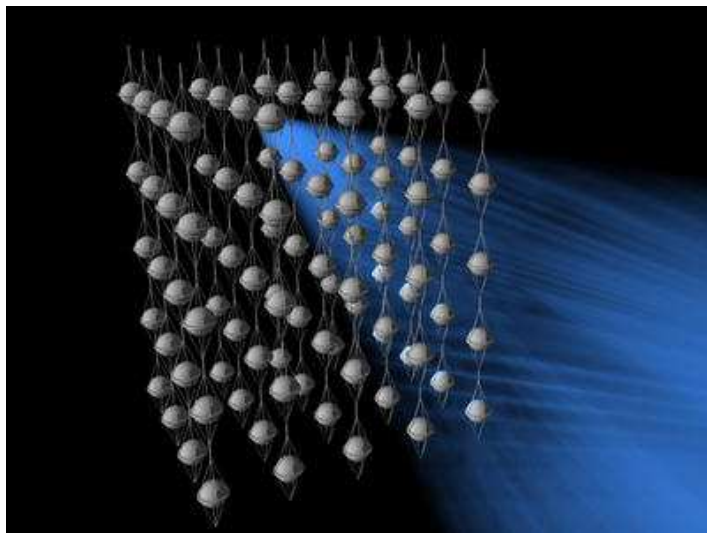


1. Cosmic Rays

CRs = particles & IR-waves

Astroparticle Physics (APP) makes the bridge
from particle physics to
astrophysics & cosmology

all kinds of **particle detectors**,
arranged as **telescopes**



MAGIC

Cherenkov
neutrino&gamma ray
telescopes

ICECUBE

brigitte.falkent
Astroparticle



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ology

1. Cosmic Rays

CRs = high & low energy rays

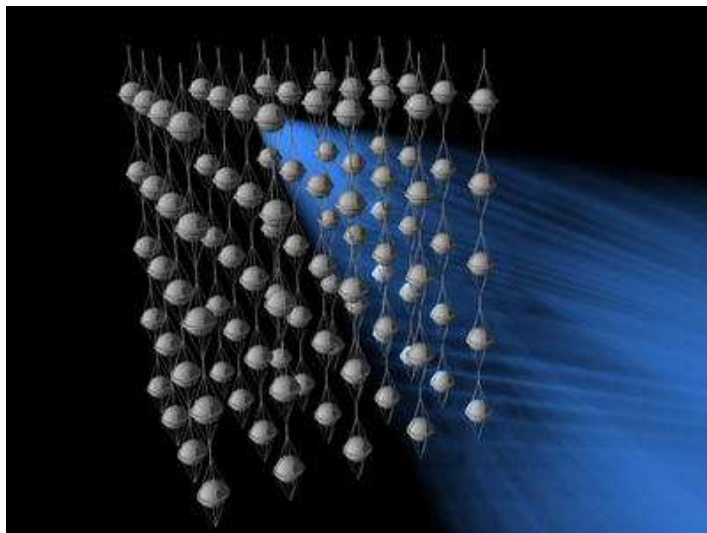
CRs = *many phenomena!*

Phenomena = Facts in Nature (Bogen & Woodward)

- effects (Photo, Zeemann, Bohm-Aharanov, Quantum Hall, ...)
- *explananda* of theories & *predictions* from theories

APP: → *Where do they Come From?*

→ *Measure & Explain the Spectrum !*



MAGIC

Cherenkov
neutrino&gamma ray
telescopes

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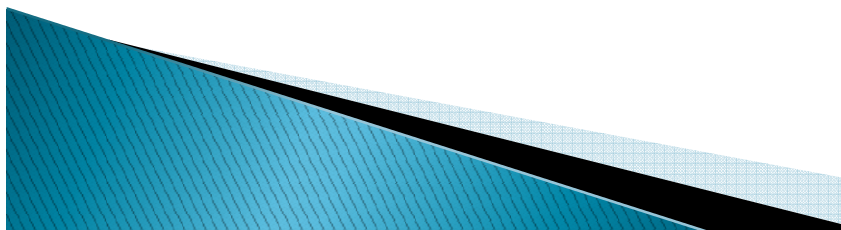
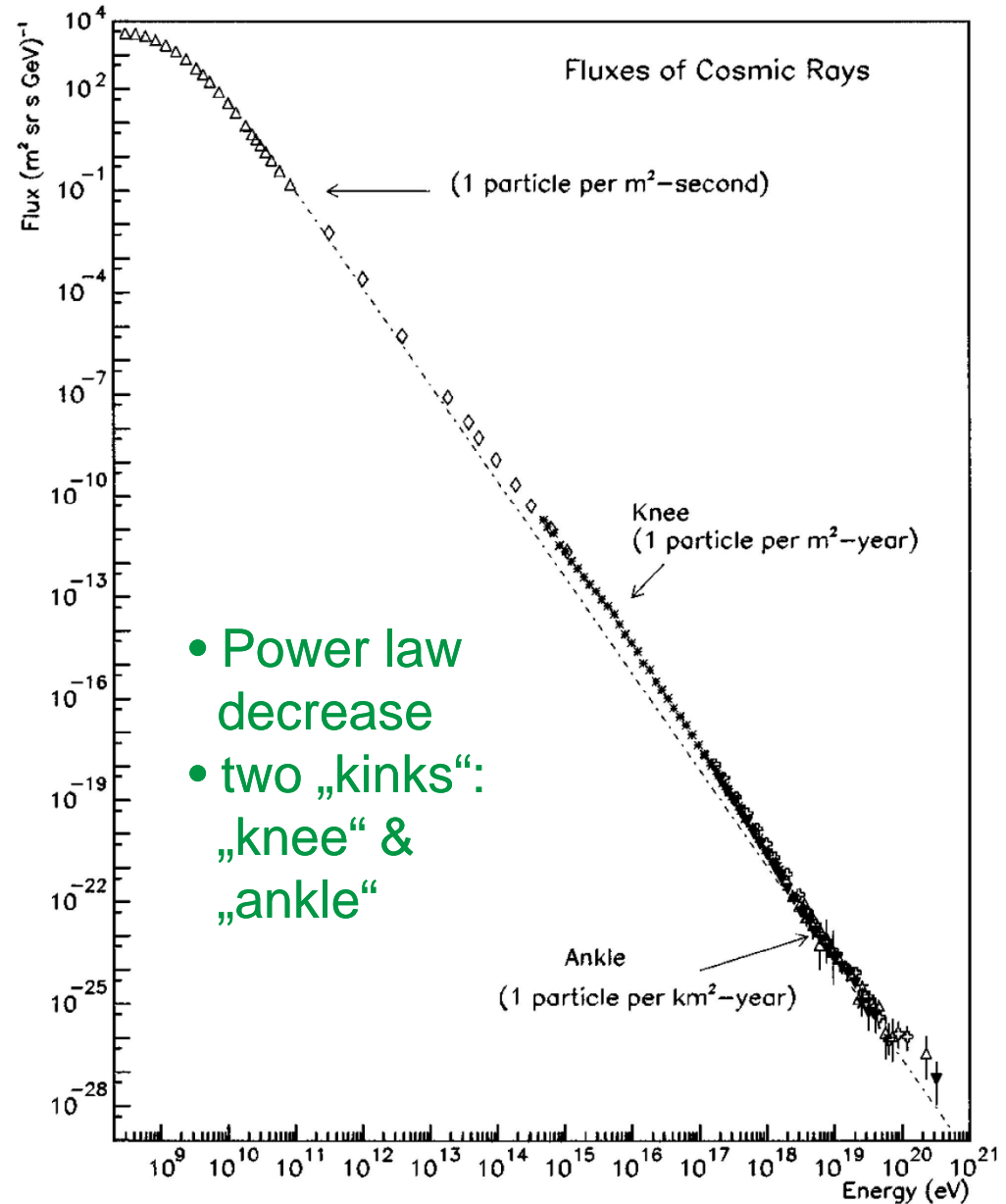


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ology

1. Cosmic Rays

- > 1930 unravelling particle content (C.D.Anderson, ...)
- > 1954 energy measurements of of charged CRs (B.Rossi)
- > 1964 discovery of 3K CMB (A.Penzias, R.Wilson)
- > 1967 gamma ray emission from our galaxy (satellites) gamma ray bursts (GBRs) (military defense satellites)
- > 1987 energy flux of charged & uncharged CR particles

All Particle Spectrum



1. Cosmic Rays

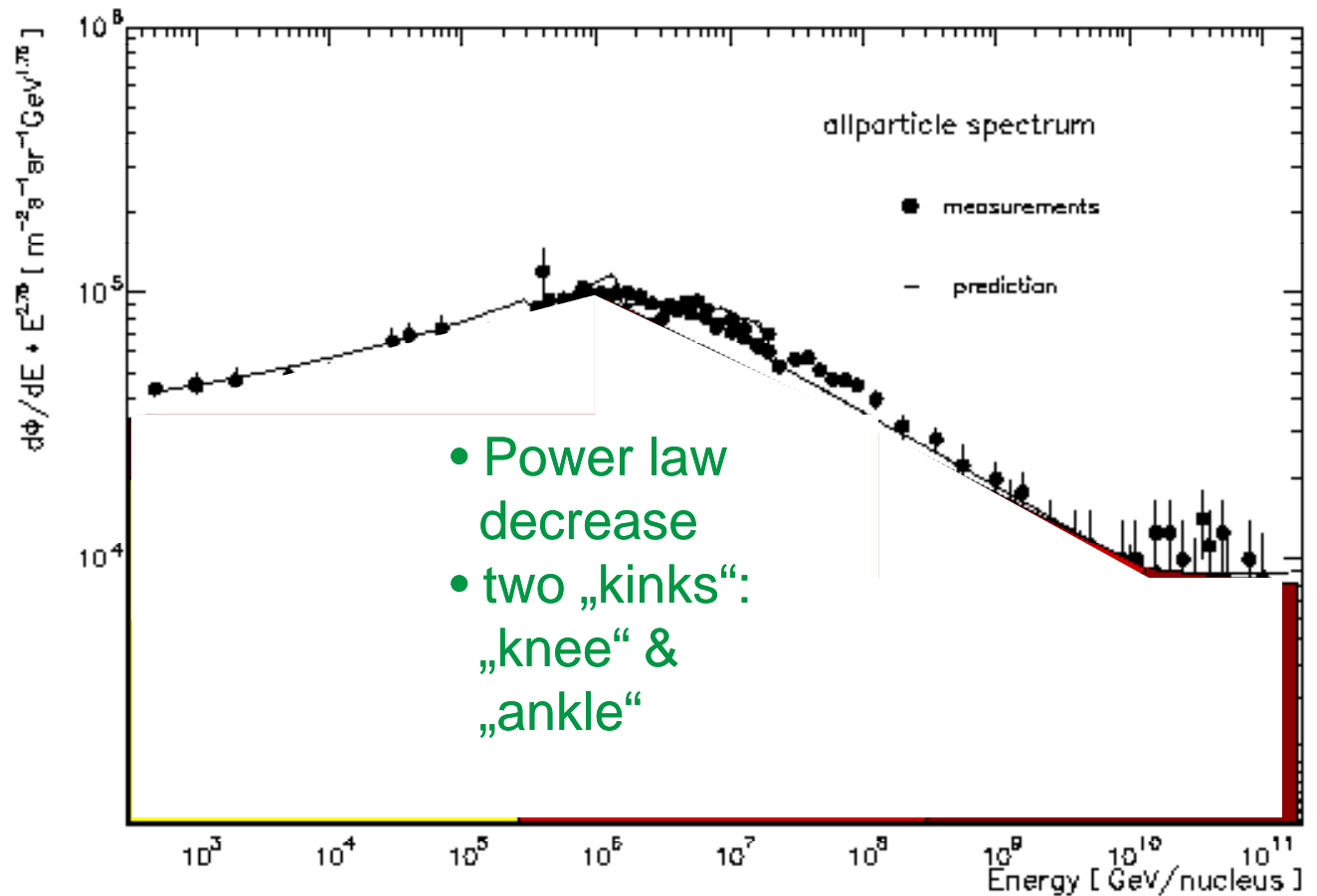
All Particle Spectrum

particle content of primary CRs:

charged particles:

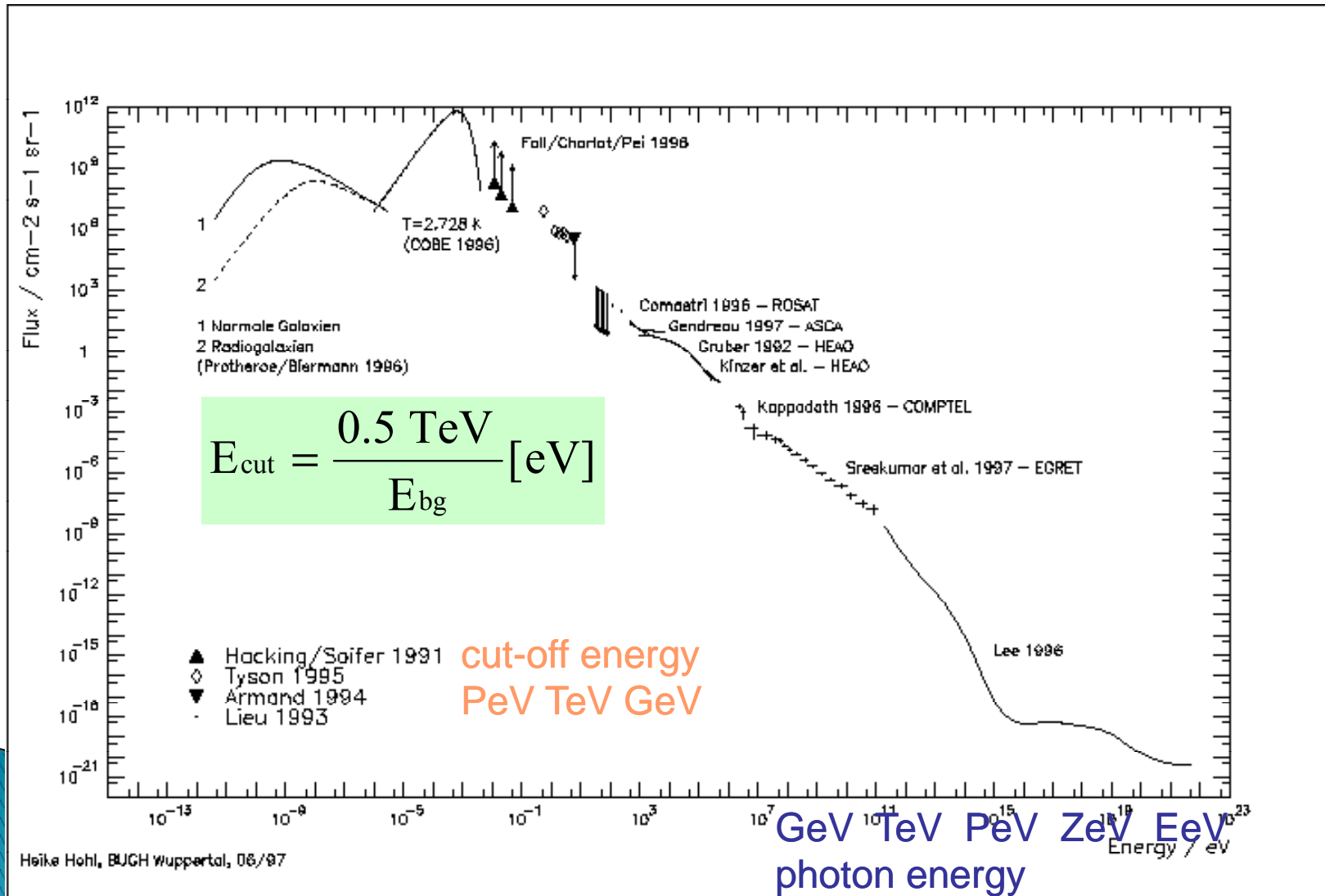
- 90 % protons
- 9 % α -particles
- 1 % electrons

(uncharged particles: photons & neutrinos)



1. Cosmic Rays

Grand Unified Photon Spectrum

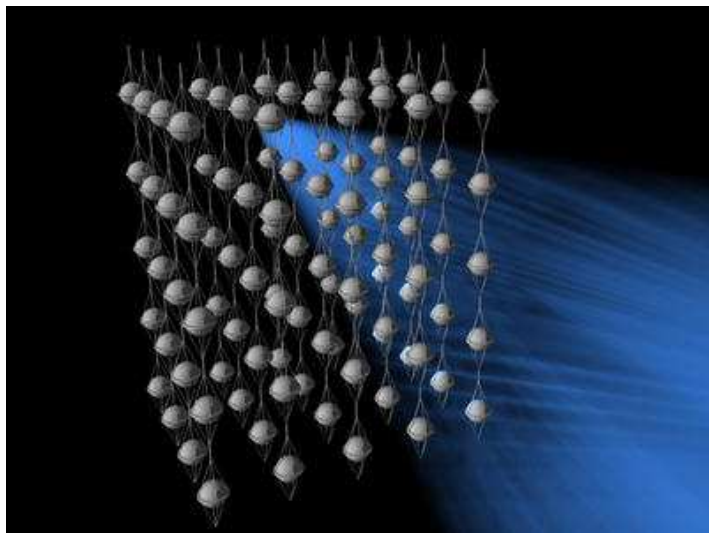


1. Cosmic Rays

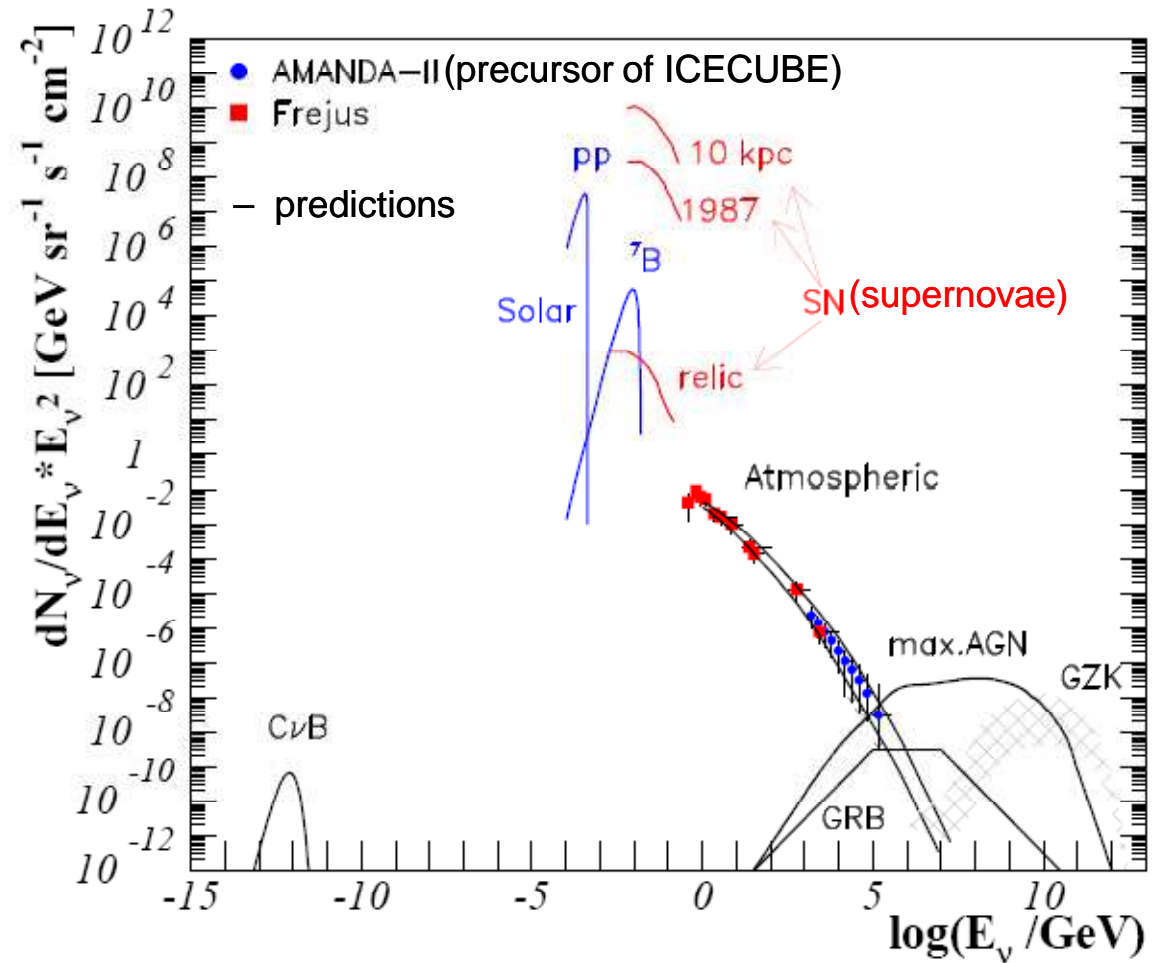
Hard to catch!

very low reaction rate

» look for *bottom-up* neutrino events, in mountains, ice, water



Astrophysical Neutrinos



Astroparticle Physics & Cosmology

1. Cosmic Rays

2. Messenger Particles

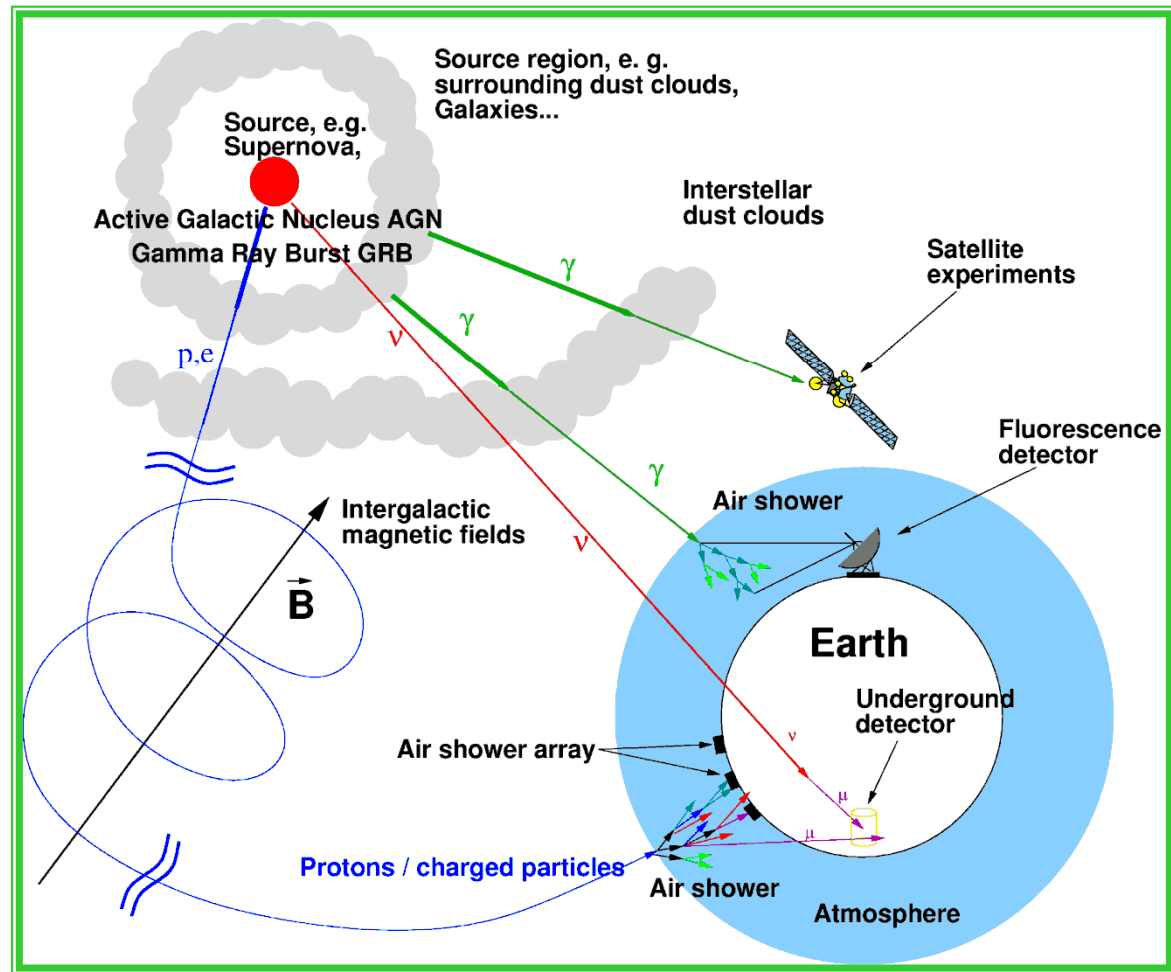
3. Scientific Realism

4. Unification

5. APP & Cosmology

2. Messenger Particles

CRs
carry
Information
from Cosmic
Sources



2. Messenger Particles

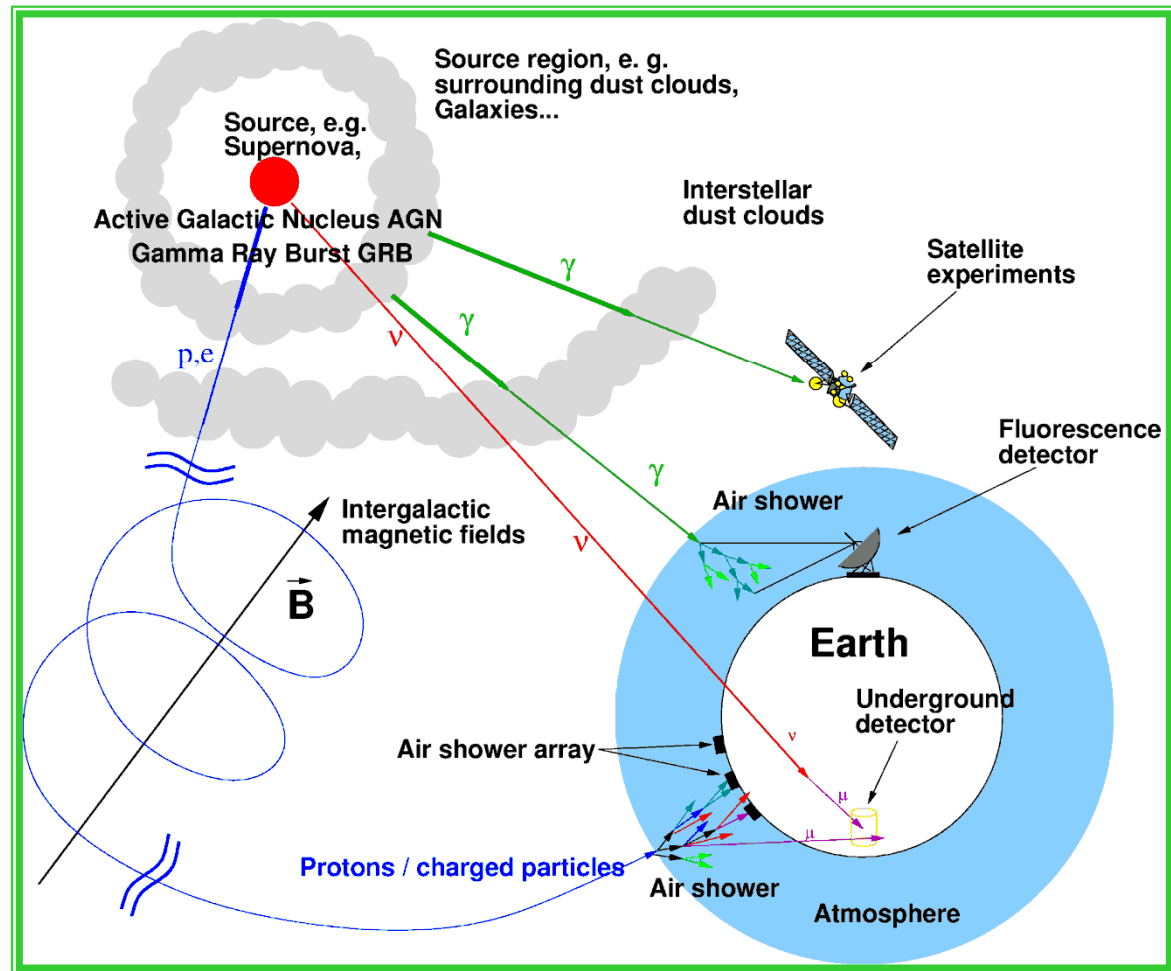
Information

= signal transmission from emitter to receiver

to read it out, you must know 2 of:

- cosmic source
- nature of signal
- interactions during transfer

Signal transmission = particle propagation from source to detector

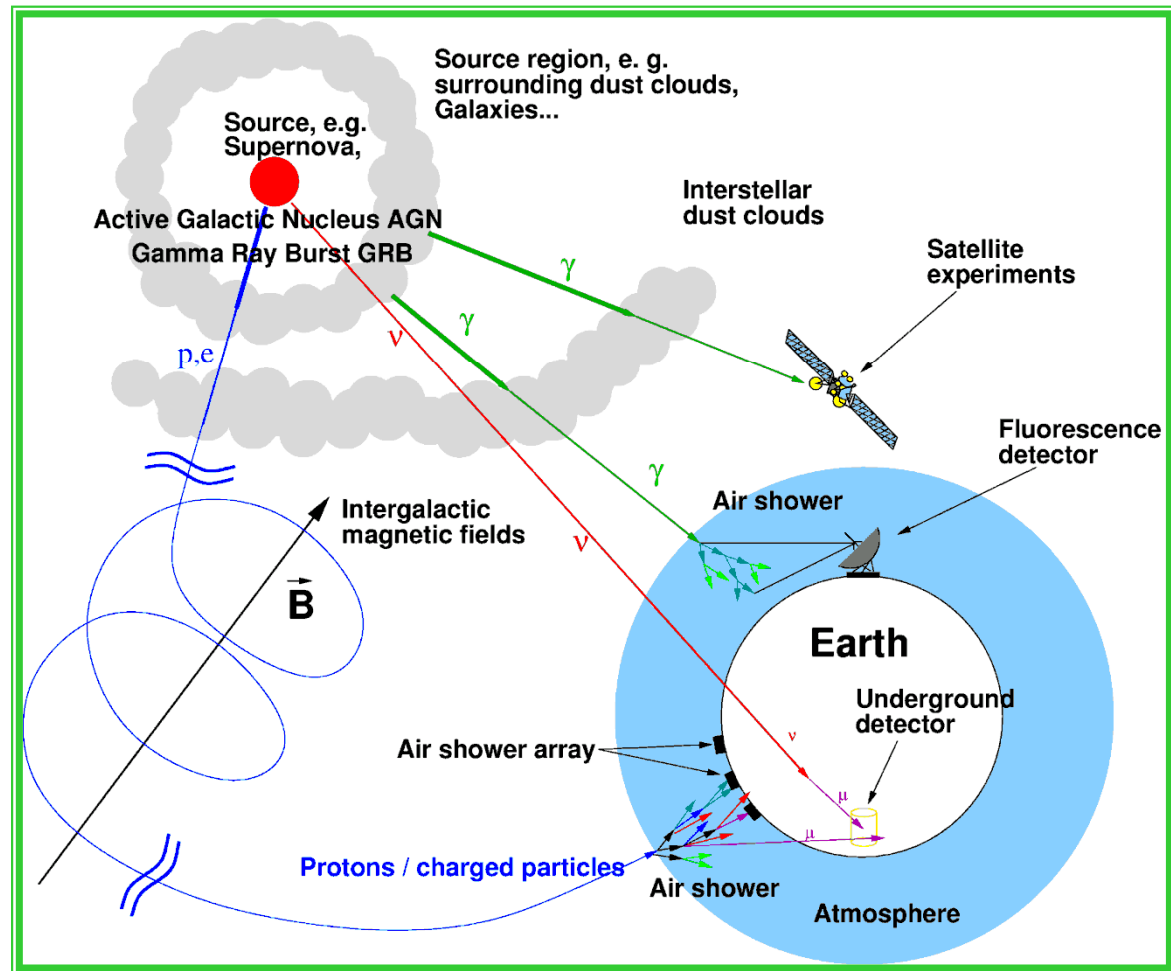


2. Messenger Particles

Only uncharged particles point to their source!

They allow „direct observation“ of source, no interactions during transfer (D.Shapere 1982)

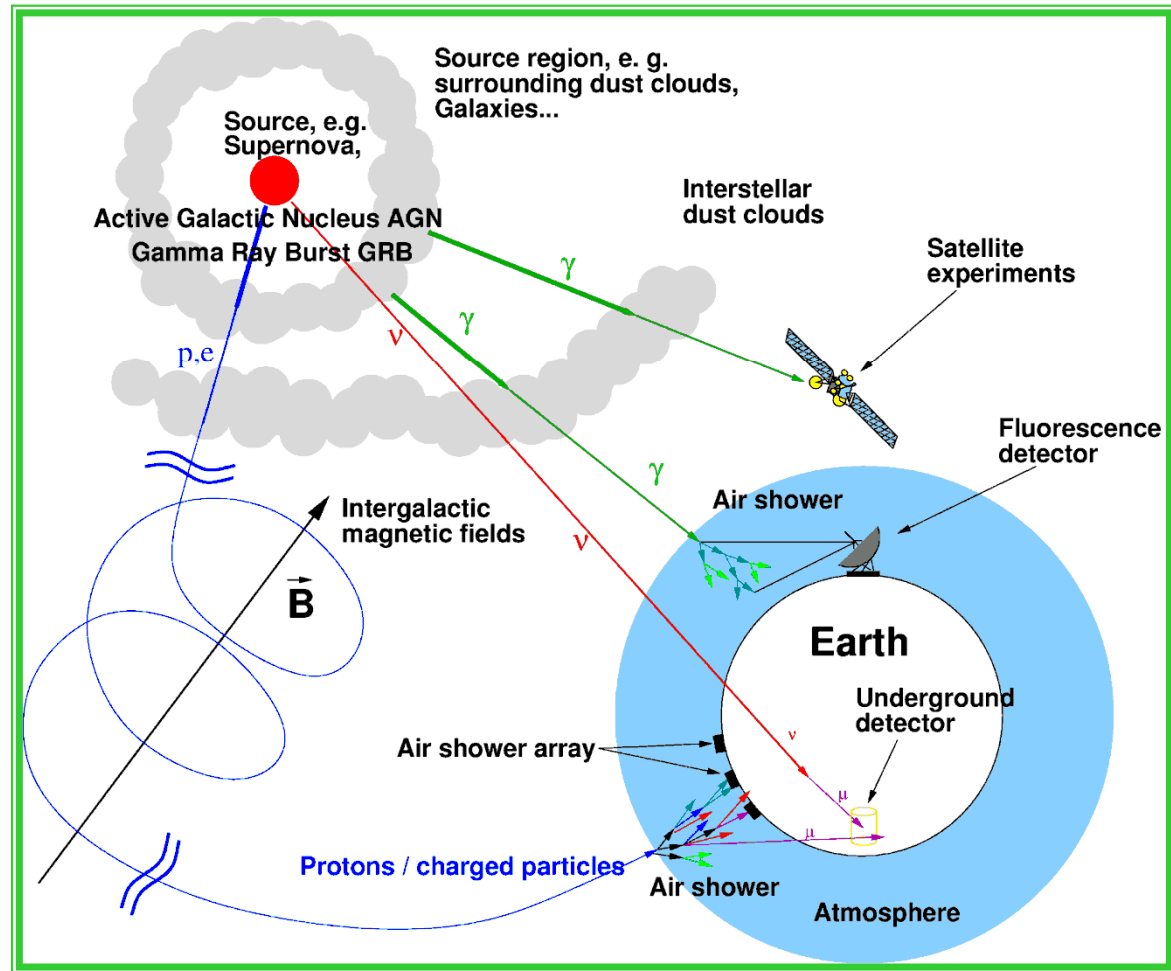
Particle propagation



2. Messenger Particles

Photon & neutrino telescopes observe extragalactic sources, like Galileo observed Jupiter moons
Proton detection does not!

Scientific Realism?



Astroparticle Physics & Cosmology

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3. Scientific Realism

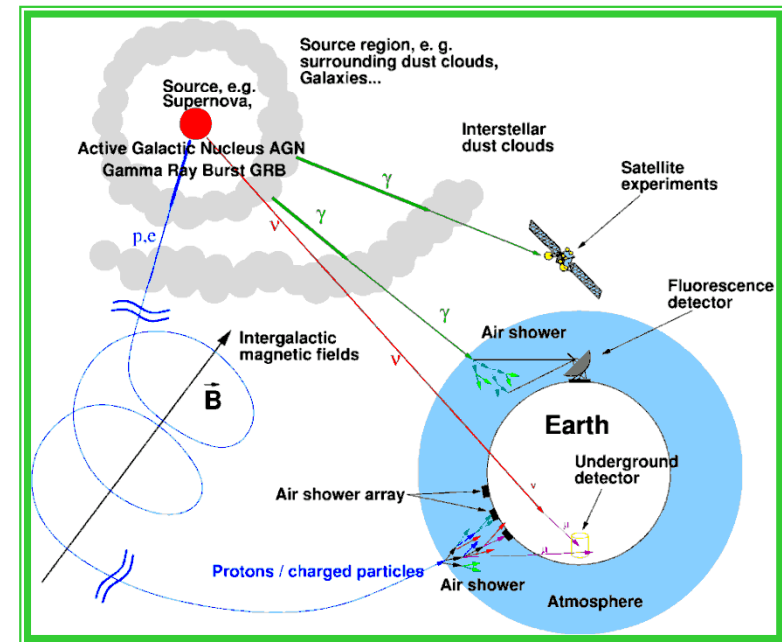
Be cautious!

Shapere's example: Observation of **sun** with **solar neutrinos**

Solar neutrino experiments

⇒ **neutrino oscillations**
(information about
messenger particles,
not source!)

Observation of **cosmic sources** depends
on **knowledge** of messenger particles
& their interactions !
„theory-ladenness“



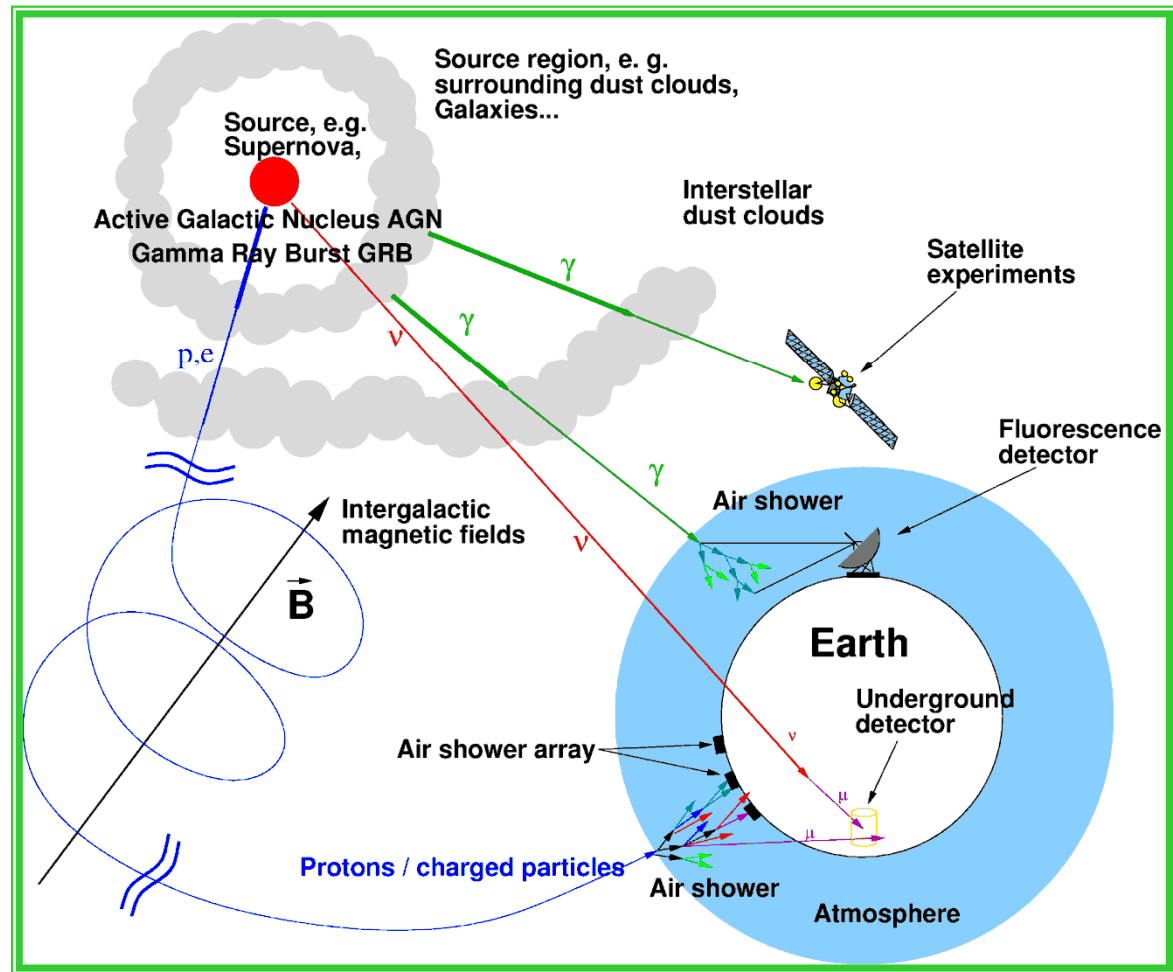
3. Scientific Realism

Sources & their activities

astrophysical data: luminosity & spectra & temporal evolution of

AGNs, GRBs, SNRs

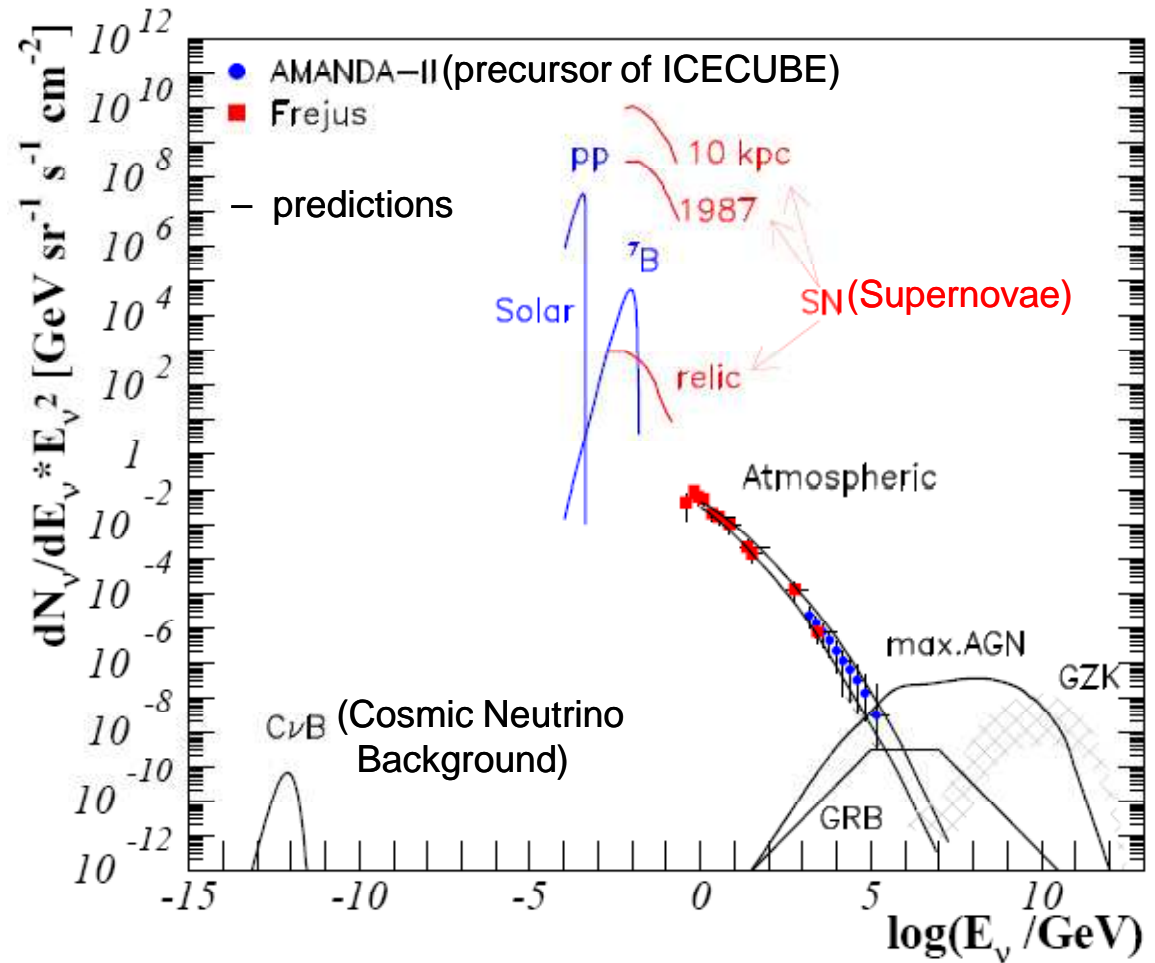
Extragalactic sources



3. Scientific Realism

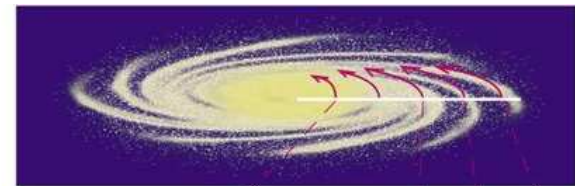
Sources & their activities:
astrophysical models of
AGNs,
GRBs,
SNRs
tested by gamma ray & neutrino telescopes!

Extragalactic sources

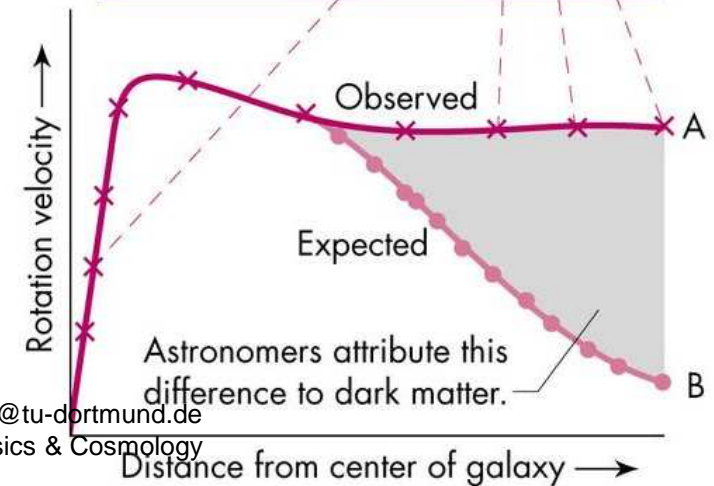
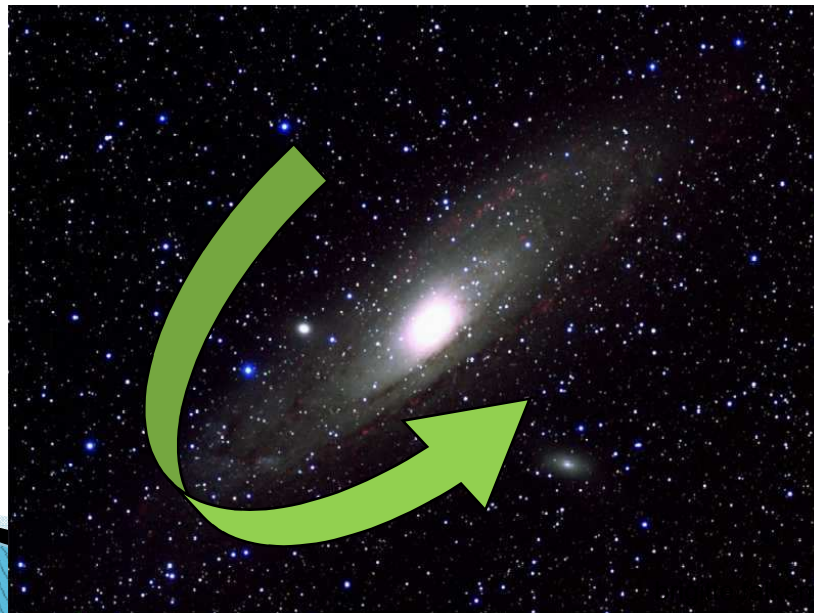


3. Scientific Realism Dark matter

Missing gravitational mass
astrophysical data (Fritz Zwicky, 1933):
Galaxies in Coma-Cluster do not behave
according to Newtonian gravitation



$$v = \sqrt{\frac{GM}{R}}$$



3. Scientific Realism

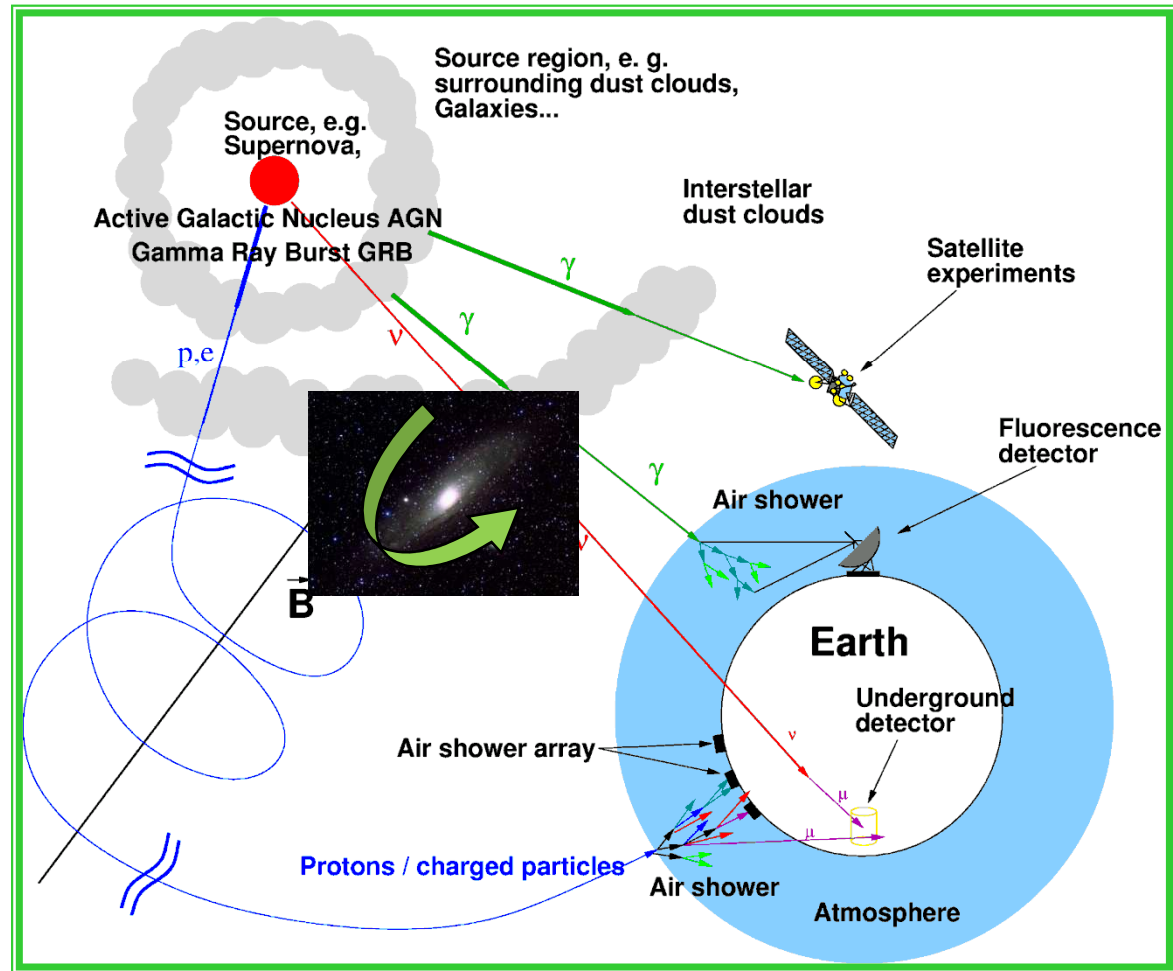
particle telescopes of APP

sensitive to WIMPS (Weakly Interacting Massive Particles)

suspected behind dark matter

produced during transfer

Dark matter

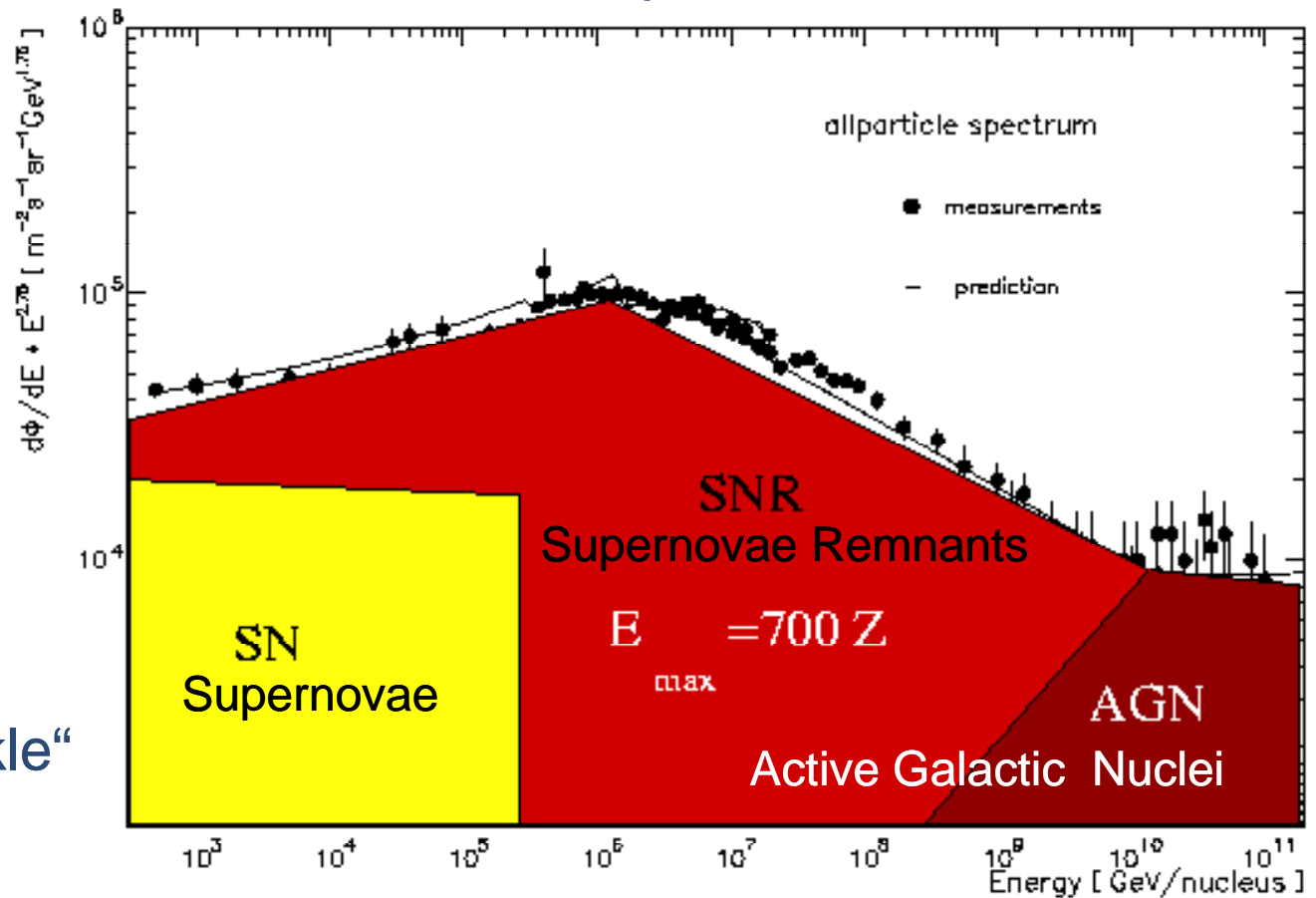


3. Scientific Realism

Astrophysical Explanation of All Particle Spectrum of CRs

Power law decrease
 $d\Phi/dE \cdot E^{2.70}$

- two „kinks“:
 „knee“ & „ankle“



3. Scientific Realism

How to explain CRs?

Where do 10^{21} eV CRs come from?

Goal of physics: to explain the phenomena

Explanation: *very* different views!

- » „true causes“ (Newton: particles & forces)
- » economy of thought (Mach: *no* Laws of Nature)
- » unification (Einstein, Planck: universal laws)
- » classification by analogies (Bohr: correspondence & complementarity)

in terms of: **concepts & models**

- » Do they describe *Physical Reality*?

3. Scientific Realism

In the practice of APP,
different attitudes coexist!

- Entity* realism: belief in **cosmic rays & cosmic sources**
(many cases of „direct“ observation / evidence)
- Causal* realism: **search** for causes of CRs
- Structural* realism: belief in **quantum laws / wave-particle duality**
(e.g., neutrino oscillations)
- Universal laws*: belief in **unity of nature**
(otherwise, the practice of APP makes no sense!)
- Realism of *models*: belief **only** in **specific models** of data, CRs &
sources based on **safe** background knowledge

beyond: Instrumentalistic views!

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4. Unification

Astro Particle Physics (APP)

– a *peculiar* discipline!

Phenomena: **cosmic rays (CRs)**

light & radio waves, gamma rays,
all kinds of subatomic particles

Disciplines: particle physics & astrophysics

Methods: *mixed*

Models: nuclear & particle physics & astrophysics

Detectors: particle detectors *arranged as* telescopes

Theory: **no theory on its own**

2 standard models &

2 incompatible theories

4. Unification

How to explain CRs?

In terms of a **unified explanation** ?

Goal of physics: to explain the phenomena

Astroparticle physics: to explain origin & spectra of cosmic rays

in terms of:

concepts & models

Are you
sure
what you
know?

- CRs = **messenger particles**

- carry **information** from **extragalactic sources**

- information may be **disturbed**

» do they describe *physical reality*?

Problem of APP: no *unified* foundations

» „*true causes*“ or *economy of thought*?

4. Unification

No unified theory
for **high** & **low** energy CRs !

Messenger particles:

- **high energy:** $e^\pm, p, \gamma, \nu, \dots$ Quantum Field Theory
 - Wave-particle duality (neutrino oscillations)
& “Standard model” of Particle Physics.
- **low energy:** **3K CMB** Special & General Relativity:
 - Signal Transmission restricted to **light cone**
& “Standard model” of Cosmology
- **No Quantum Gravity:**
 - **Information** generated & transmitted by interactions of quantum particles $\rightarrow ? \leftarrow$ cosmic sources

4. Unification

No unified theory
of quantum particles & cosmic sources!

2 standard models, but

quantum field theory \rightarrow  \leftarrow cosmology

Unification

of particle physics & *big bang* cosmology

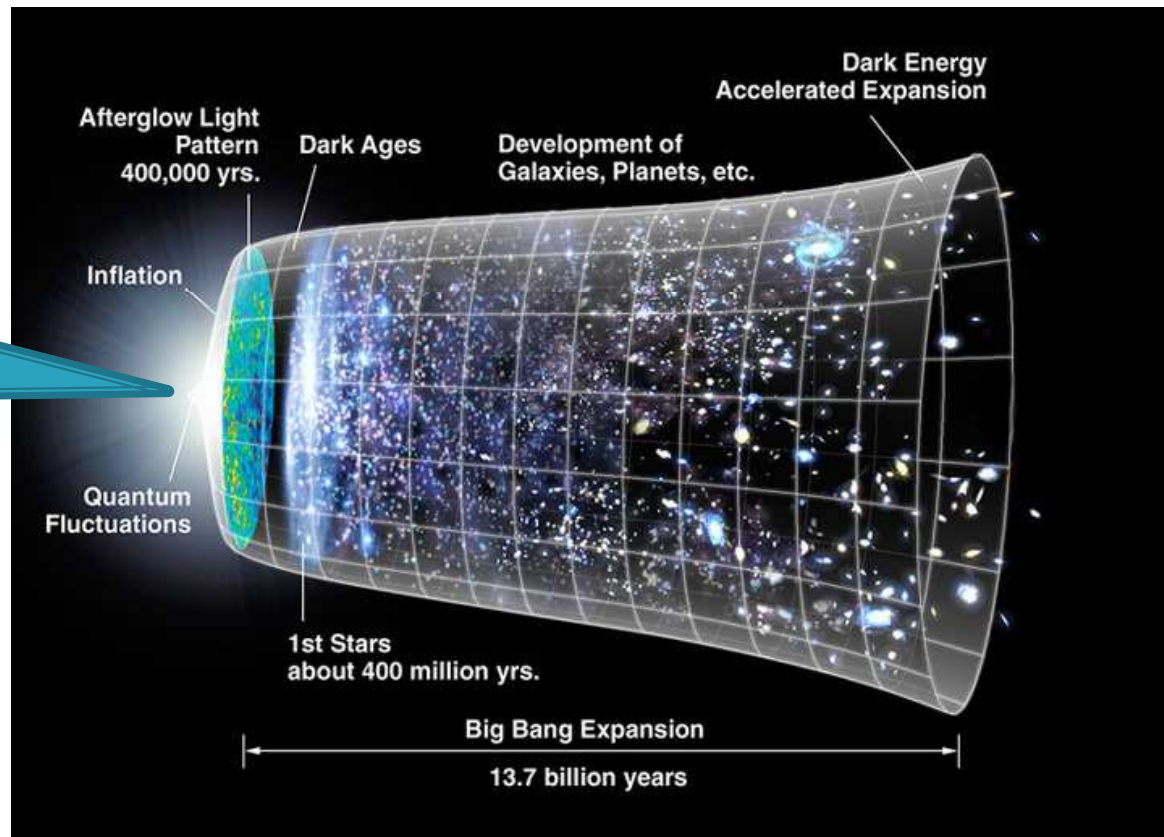
needs quantum realism *but there is none* !

(„Many Worlds“ = metaphysics, no physics
„hidden variables“ $\leftarrow?$ \rightarrow quantum field theory)

4. Unificaton

No unified theory of quantum particles & the universe!

Who measured the universe here?



4. Unification

Nevertheless,

APP makes the bridge!

How is this possible?

Modest pragmatic strategies of unification:

- ▶ **Methodological:** Particle Detectors Arranged as Telescopes („Piecemeal“ Physics á la N.Cartwright)
- ▶ **Phemenological:** „All Particle Spectrum“ (Belief in Unified descripton of CRs)
- ▶ **Conceptual:** Concept of „Messenger Particles“ (Entity realism & Causal realism)
- ▶ **Explanatory:** Models of Cosmic Sources & Acceleration Mechanisms & Propagation & Detection

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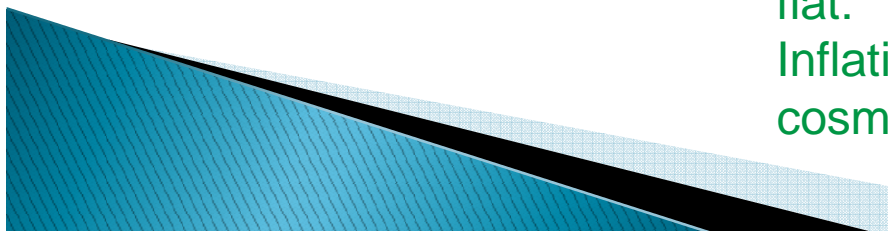
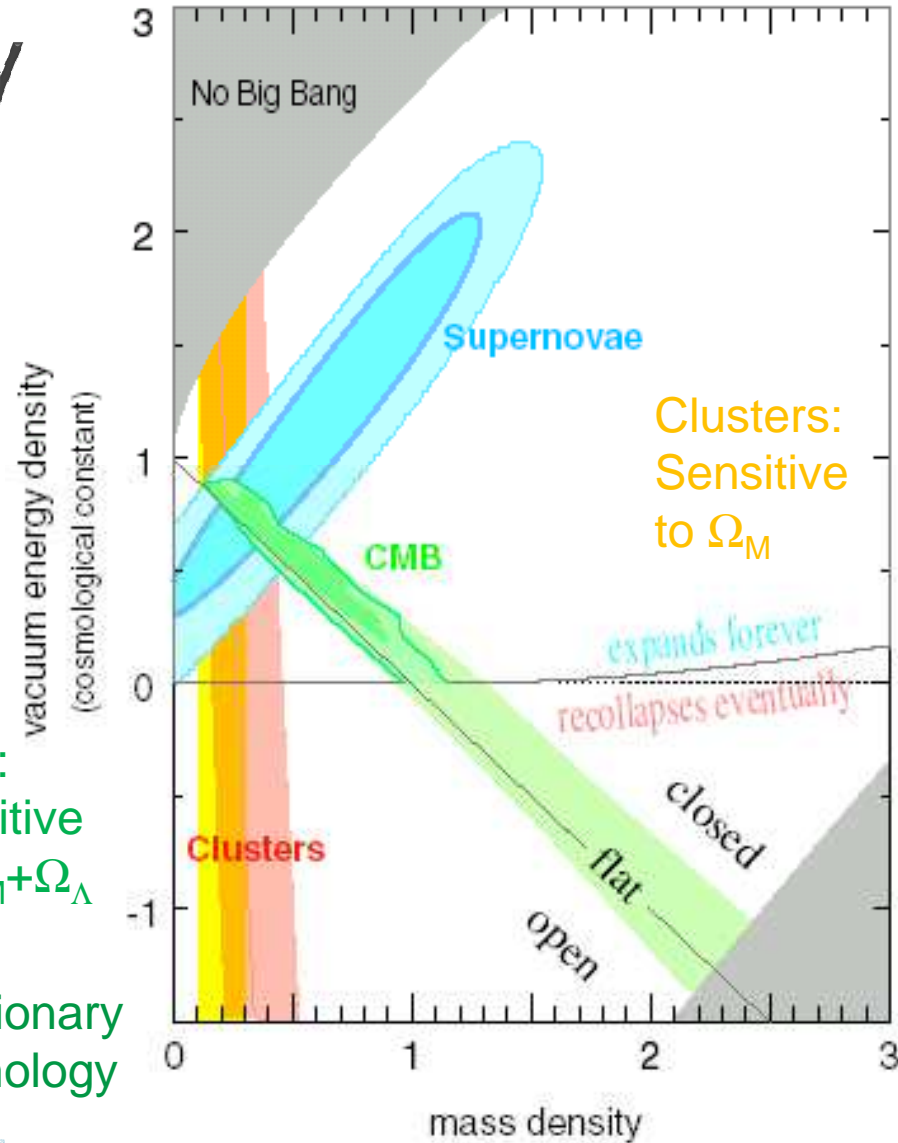
5. APP & Cosmology

APP contributes to test of cosmological models:

This diagram is part of *many* APP talks!

CMB: Sensitive to $\Omega_M + \Omega_\Lambda$
flat: Inflationary cosmology

Perlmutter, et al. (1999)
Jaffe et al. (2000)
Bahcall and Fan (1998)



Summary

1. Cosmic Rays

Particles from Cosmic Sources

2. Messenger Particles

Carry Information about Cosmic Sources

3. Scientific Realism (with caution)

Search for Causes & Trust in Unity of Nature

4. Unification

Strategies in Lack of a Unified Theory

5. APP & Cosmology

APP Contributes to the Tests of Cosmology