

Introduction to super-preshowers: a quest for unique signatures of New Physics

Piotr Homola

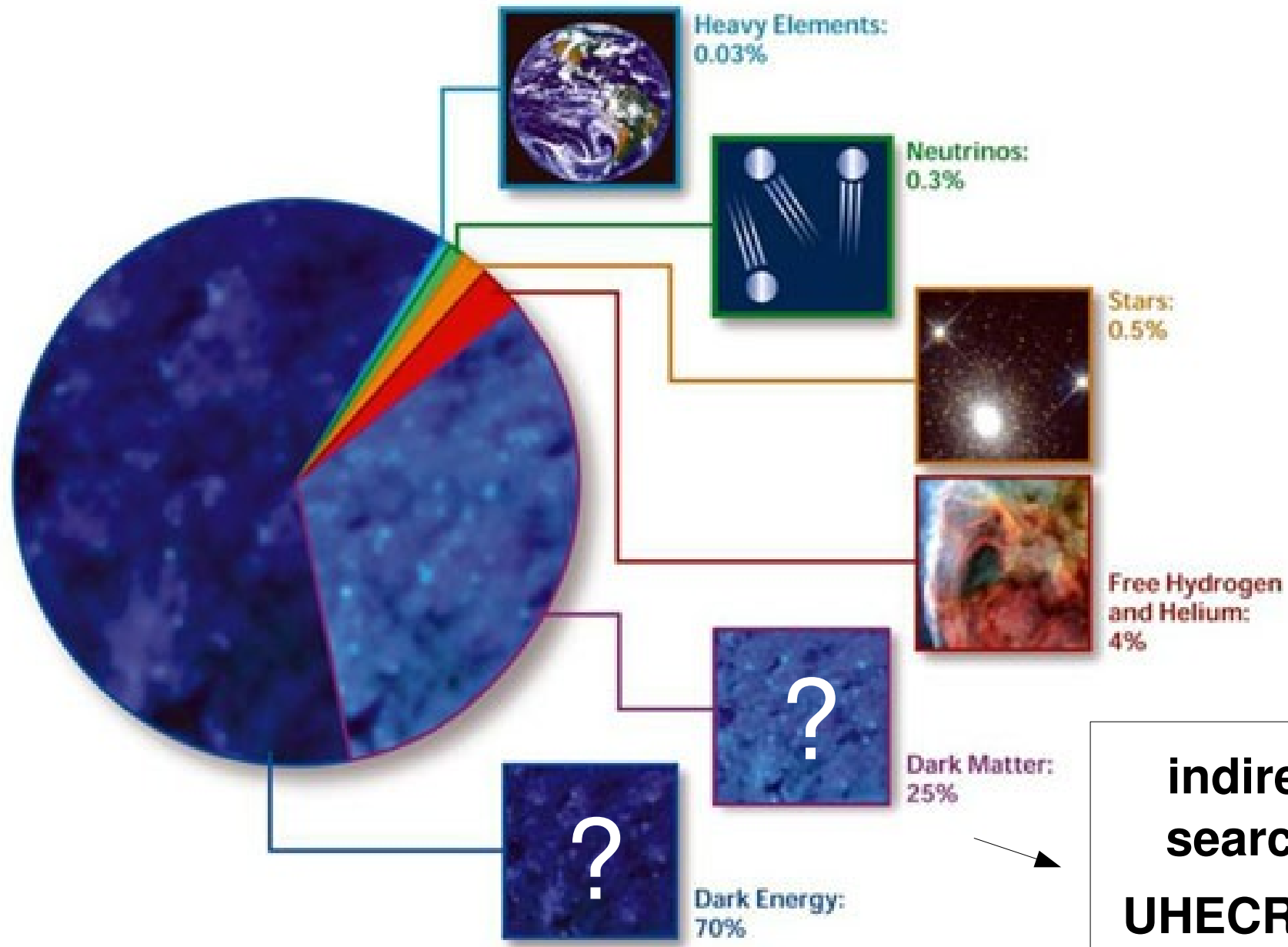
Institute of Nuclear Physics PAS, Krakow

CREDO Inauguration, Kraków, 30 August 2016



photo by theoryandpractice.org

COMPOSITION OF THE COSMOS



**indirect DM
search with
UHECR (γ_{UHE})!**

Photons as UHECR: testing astrophysical scenarios

Astrophysical scenarios

acceleration of nuclei (e.g. by shock waves)

+ „conventional interactions”, e.g. with CMBR

- sufficiently efficient astrophysical objects difficult to find
- small fractions of photons and neutrinos – mainly nuclei expected

???

Exotic scenarios (particle physics)

???

Decay or annihilation the early Universe relics

→ hypothetic supermassive particles of energies $\sim 10^{23}$ eV

→ decay to quarks and leptons → hadronization (mainly pions)

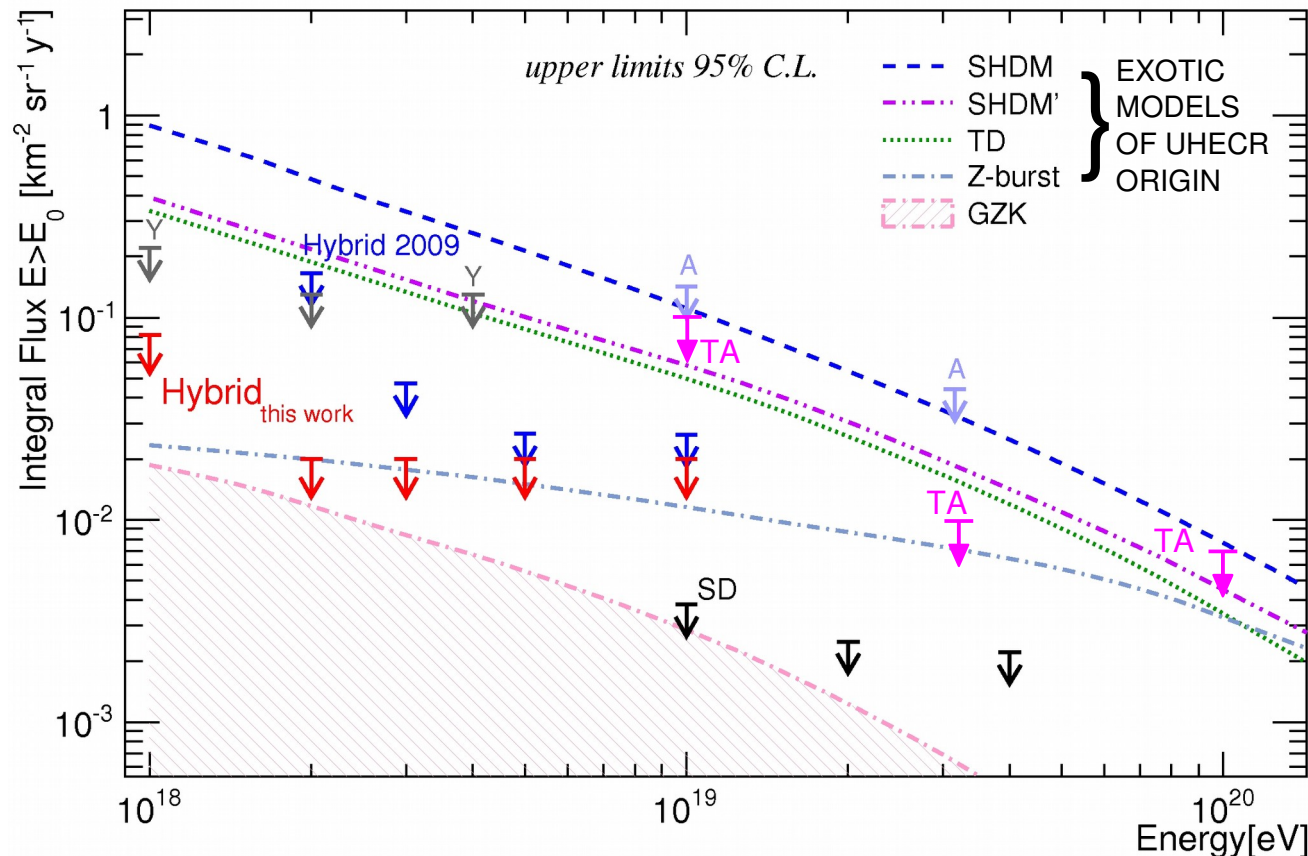
- large fraction of photons and neutrinos in UHECR flux

DARK MATTER!

UHECR composition paradigm: „no photons”

At the highest energies photon fractions < 1%

AUGER, ICRC 2011 + TA 2013



Hybrid – AUGER '11 (hybrid detector)

Hybrid 2009 – AUGER '09 (hybrid detector)

SD – AUGER '08 (surface detector)

A – AGASA '02

Y – YAKUTSK '07

TA – Telescope Array '13

SHDM, TD, Z Burst: Gelmini et al. '08

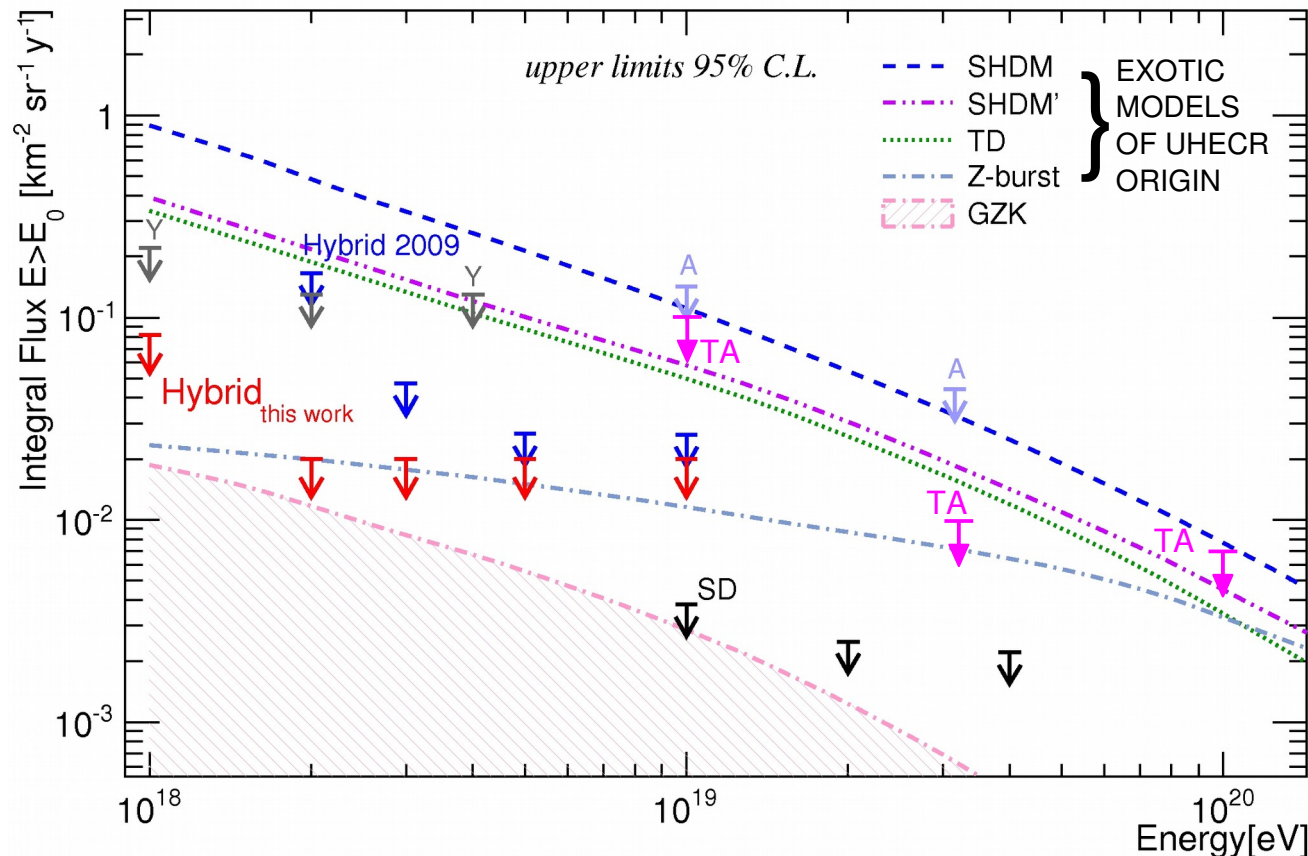
SHDM': Ellis et al. '06

→ **exotic (Dark Matter) scenarios severely constrained!**

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SHDM': Ellis et al. '06

→ **exotic (Dark Matter) scenarios severely constrained!** *)

*) **Understand well:** limits apply to single photons, **assume no screening** eg. within exotic models of interactions, structure of a photon and the spacetime structure that could manifest at UHE...

Experimental evidence about γ_{UHE}

γ_{UHE} $\xrightarrow{\text{no interactions / screening}}$ Earth

NOT OBSERVED

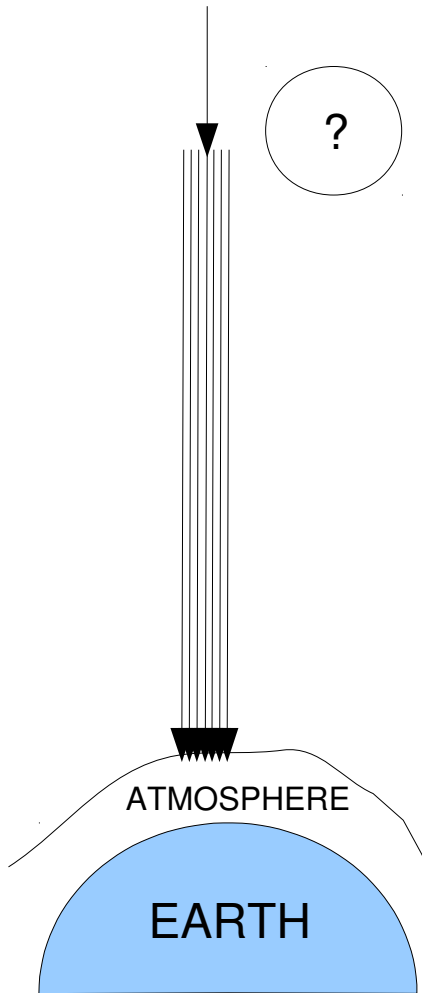
γ_{UHE} $\xrightarrow{\text{unexpected interactions, screening}}$ ELECTROMAGNETIC CASCADES (**SUPER-PRESHOWERS**) $\longrightarrow$ Earth

NOT TRIED SO FAR...

CREDO!

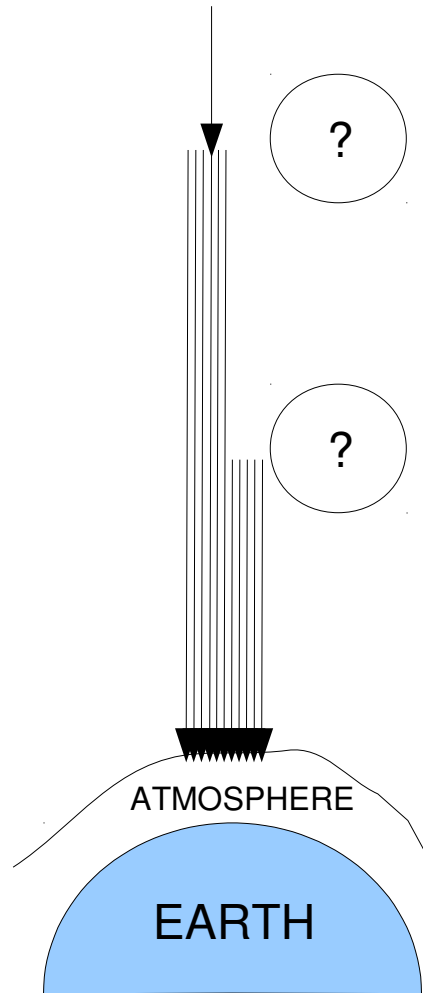
Classes of super-preshowers

A: γ_{UHE}
(e.g. 10^{20} eV)



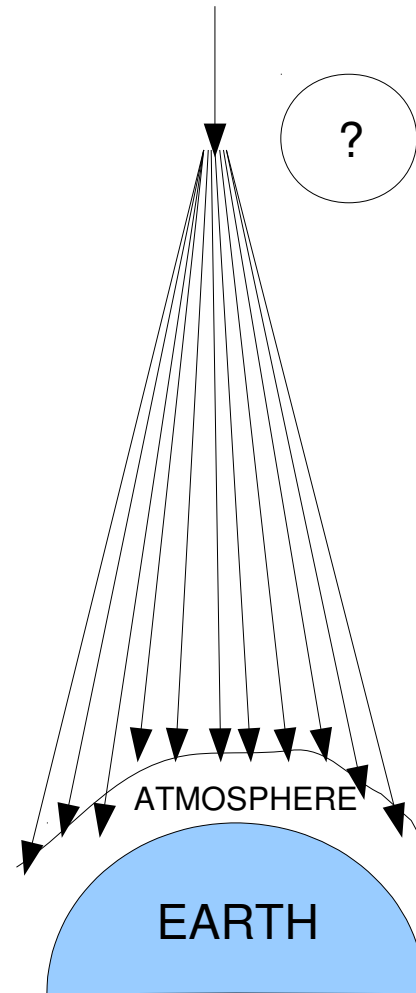
Δx : small
 Δt : small

B: γ_{UHE}
(e.g. 10^{20} eV)



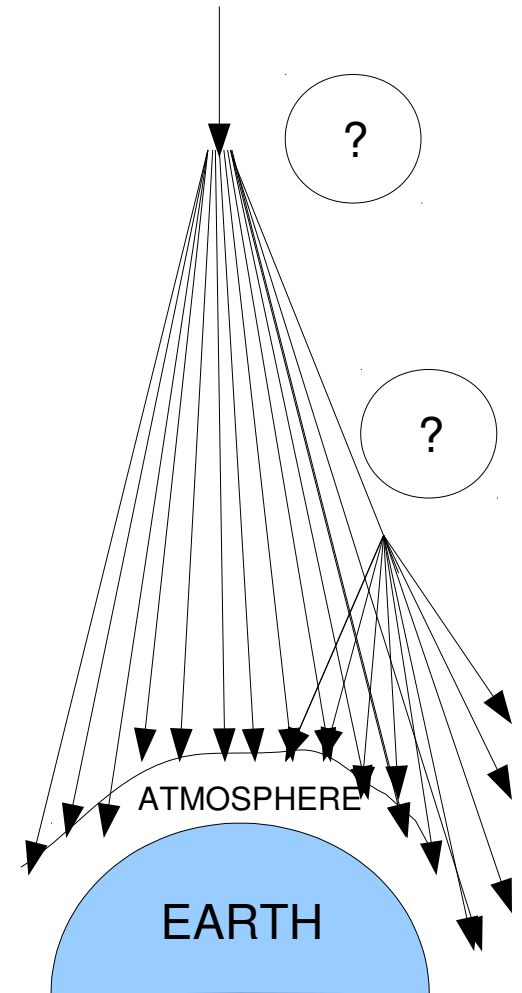
Δx : small
 Δt : large

C: γ_{UHE}
(e.g. 10^{20} eV)



Δx : large
 Δt : small

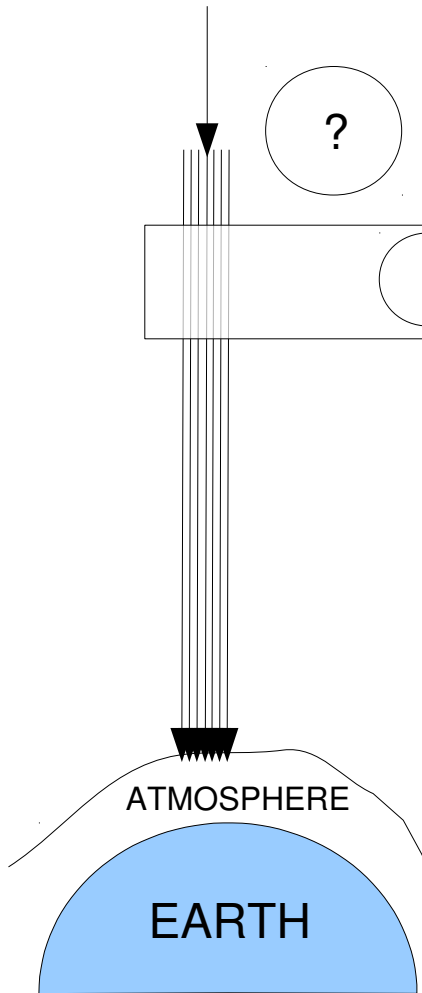
D: γ_{UHE}
(e.g. 10^{20} eV)



Δx : large
 Δt : large

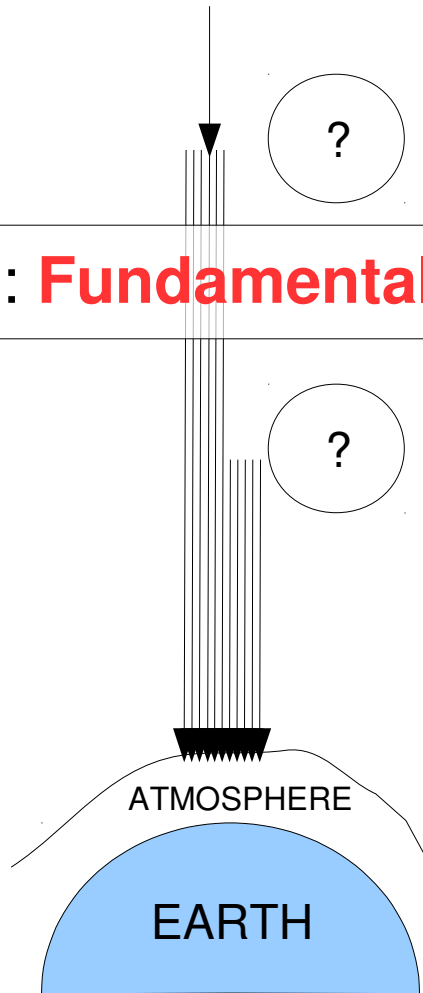
Classes of super-preshowers

A: γ_{UHE}
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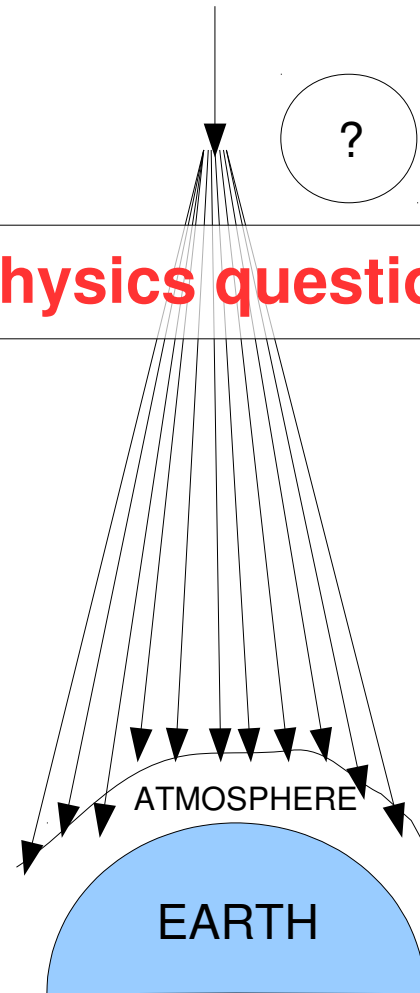
Δx : small
 Δt : small

B: γ_{UHE}
(e.g. 10^{20} eV)



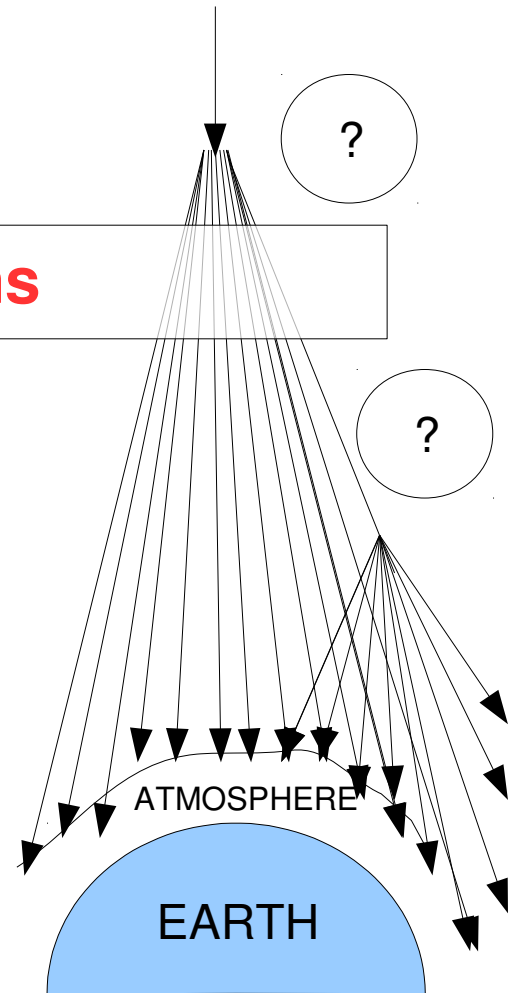
Δx : small
 Δt : large

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(e.g. 10^{20} eV)



Δx : large
 Δt : small

D: γ_{UHE}
(e.g. 10^{20} eV)



Δx : large
 Δt : large

? : **Fundamental physics questions**

Preshowers: a must to study UHE photons

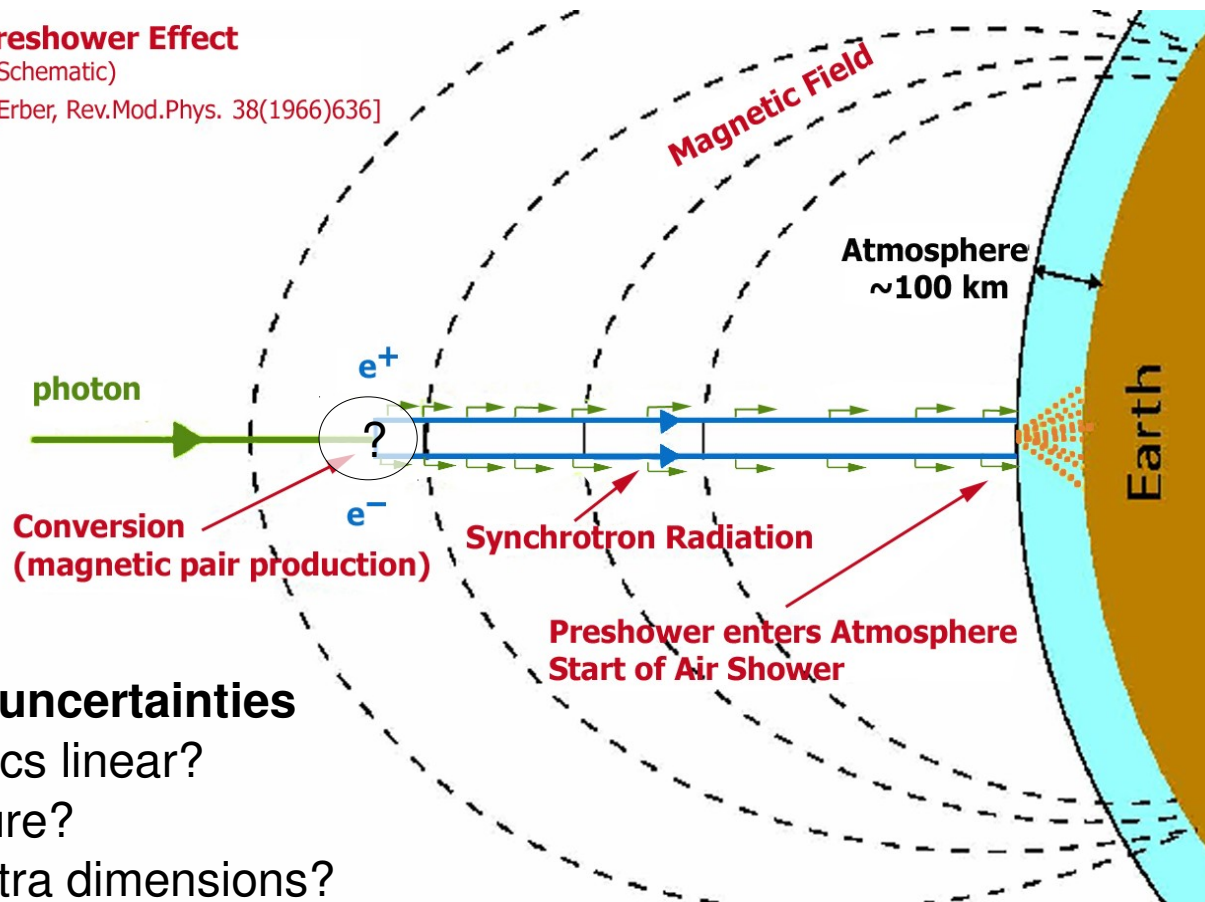
preshower:

→ contains typically 100 particles
(created at around 1000 km a.s.l.)

Preshower Effect

(Schematic)

[Erber, Rev.Mod.Phys. 38(1966)636]



? : **fundamental uncertainties**

- electrodynamics linear?
- photon structure?
- spacetime: extra dimensions?

→ dependence on E and $B_{\perp}$ (to be seen in data?)

“Classical” super-preshowers: vicinity of the Sun

C & D:

γ_{UHE}
(e.g. 10^{20}eV)

B_{SUN}

e^+e^-

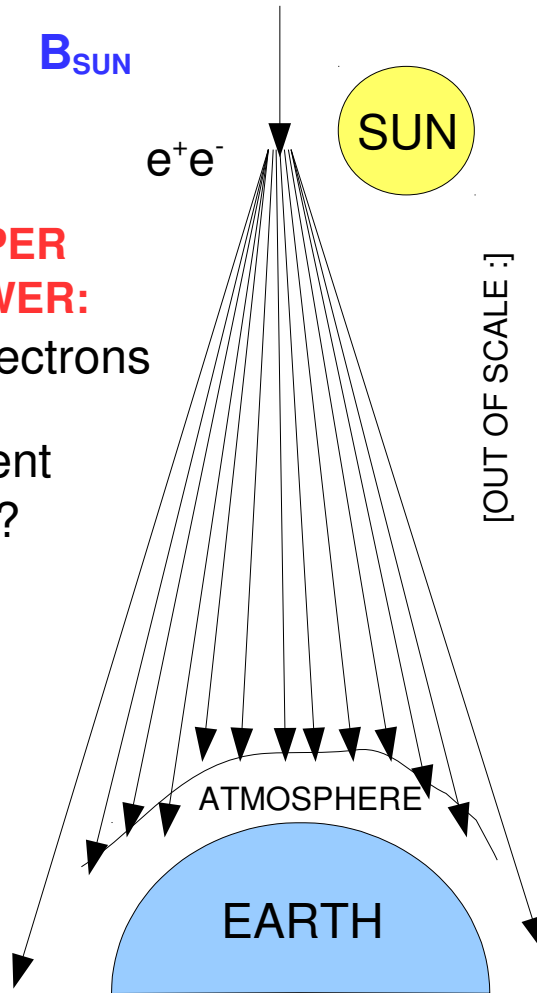
SUN

**SUN SUPER
PRESHOWER:**

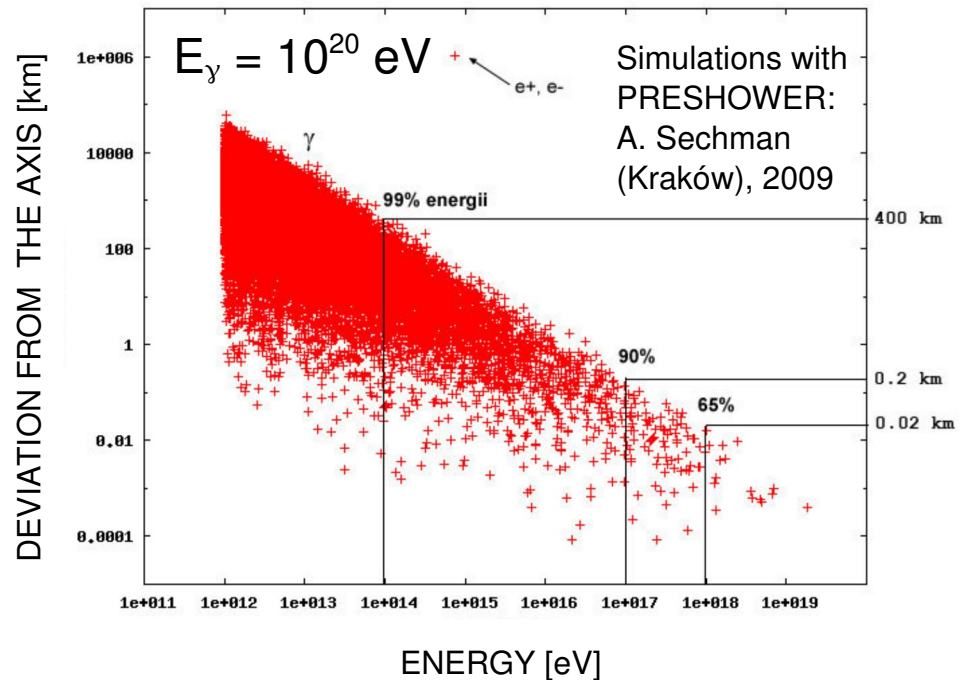
$>10^6(?) \gamma, \text{electrons}$

spatial extent
 $\sim 10^8 \text{ km}^2$?

[OUT OF SCALE :]

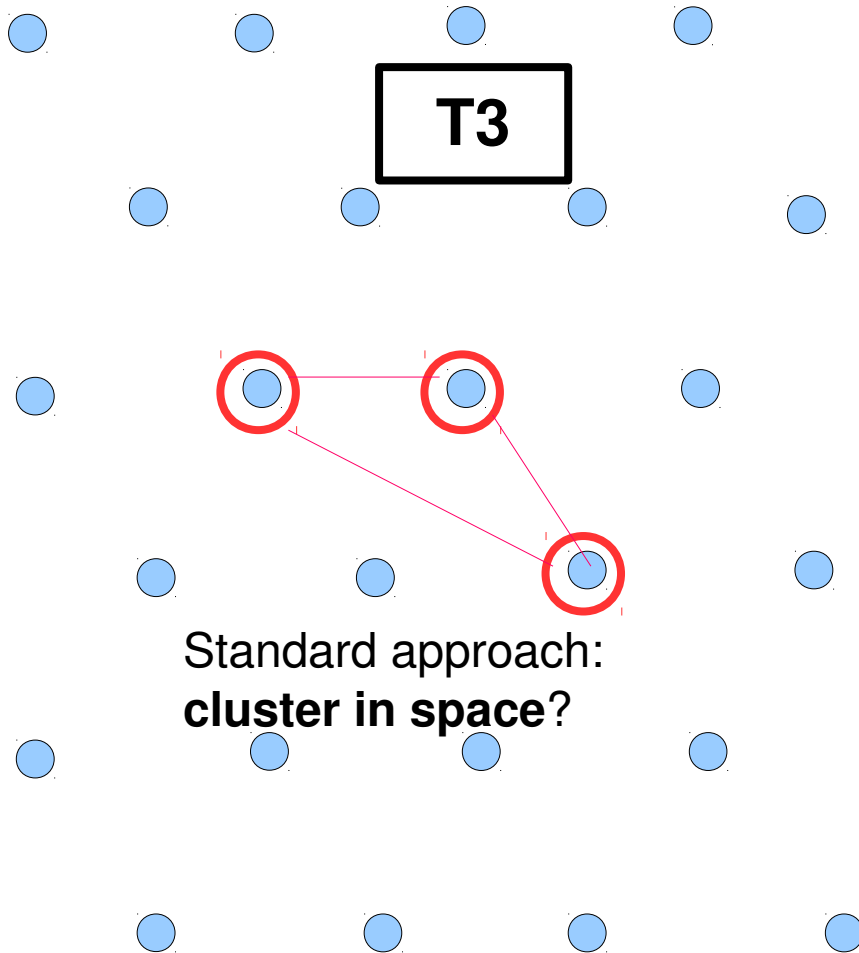


→ First calculations: W. Bednarek 1999
(low energies not treated → extent $\sim$ tens of km)



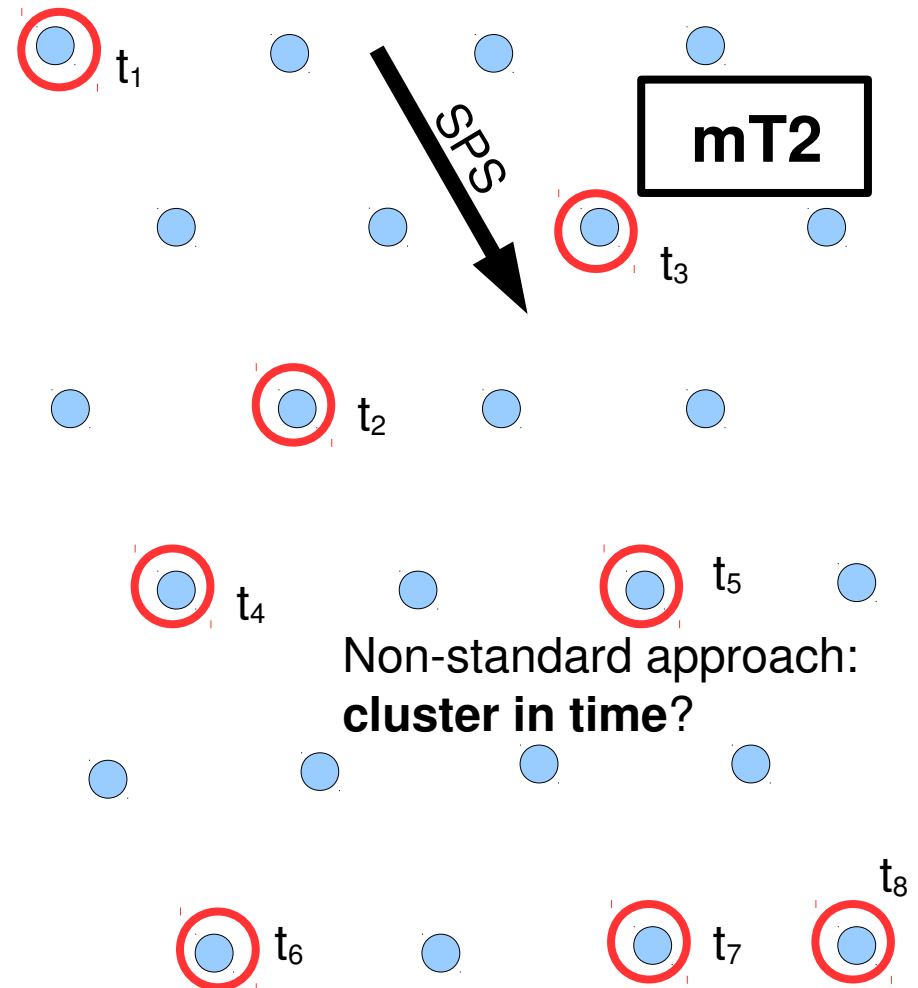
- front 10000 km wide?
- (over)compensates smaller solid angle?
- particle density on ground?
- **n isolated, time-ordered triggers?**

mT2: **NEW** easy trigger for super-preshowers



Standard approach:
cluster in space?

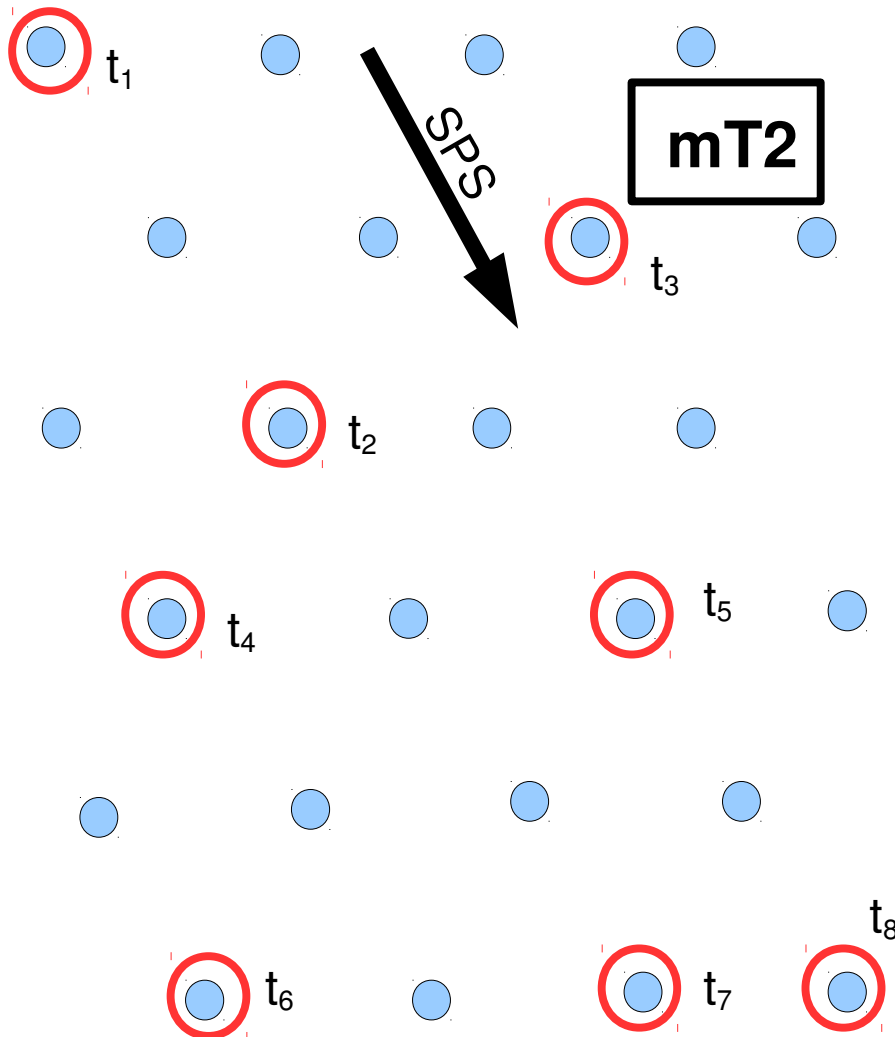
● : a cosmic-ray detector



Non-standard approach:
cluster in time?

- 1) $t_n - t_1 < \sim 1 \mu s$
- 2) $t_1 < \dots < t_n,$

mT2: **NEW** easy trigger for super-preshowers



Chance for a statistical coincidence for $n=30$, assuming T2 rate 100 Hz:

$$P_{\text{acc}} \approx 10/30! * 0.16^{30} = \text{ridiculously small chance}$$

sensitivity to $n_{\text{LOW}} < n < 30$
 $n_{\text{LOW}} = ?$

mT2: easy implementation,
no hardware manipulation,
no risk, ... → **why not?**

- 1) $t_n - t_1 < \sim 1 \mu\text{s}$
- 2) $t_1 < \dots < t_n$,

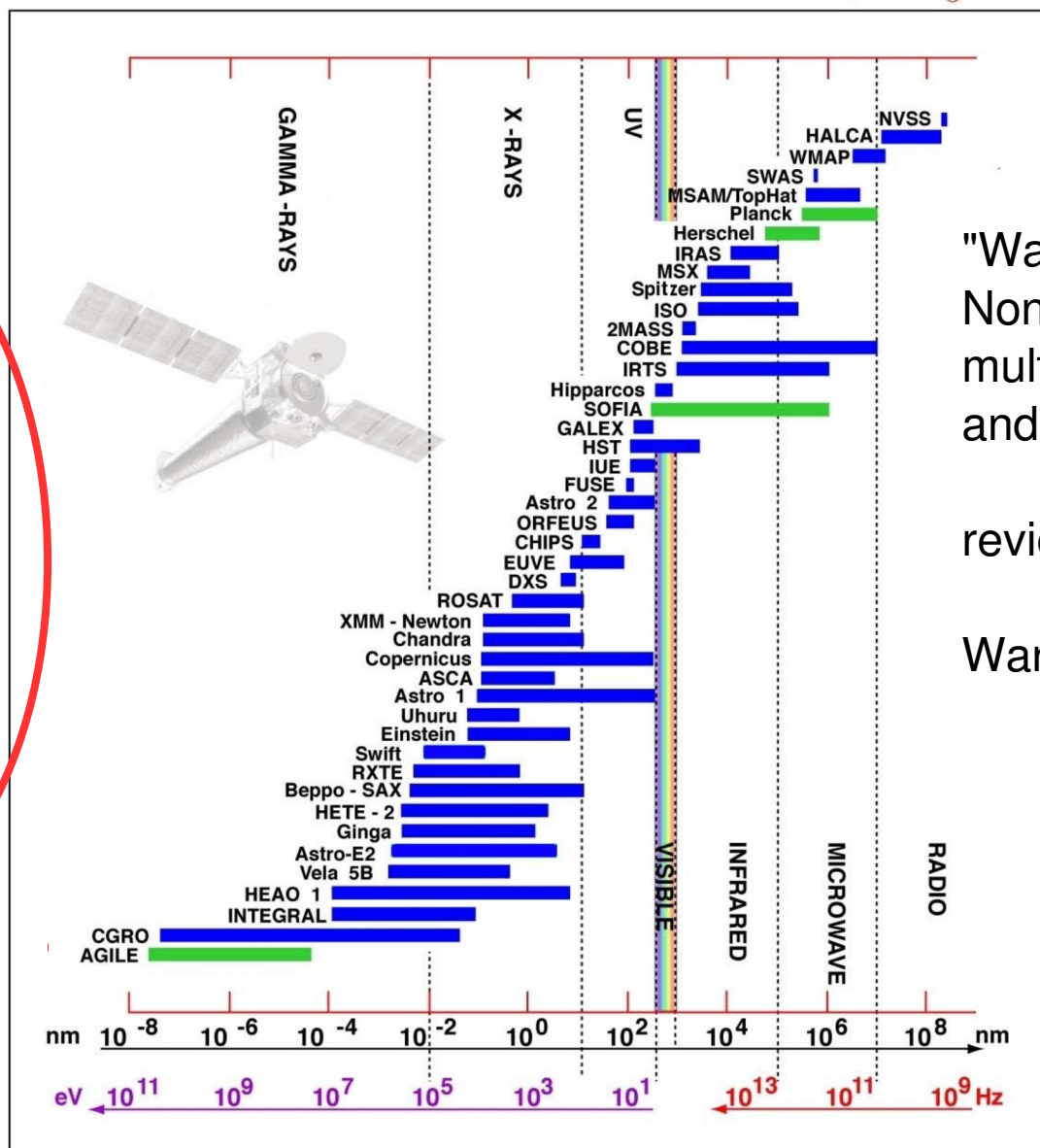
→ **unique signature**
(of New Physics?)



From gamma rays to radio

Why
nothing
here

???



"Warsaw Workshop on
Non-Standard Dark Matter:
multicomponent scenarios
and beyond",

review by C. Weniger

Warsaw, 2-5.06.2016

<http://nssdc.gsfc.nasa.gov/astro/astrolist.html>



PH:
Even more
ways for
indirect DM
search:

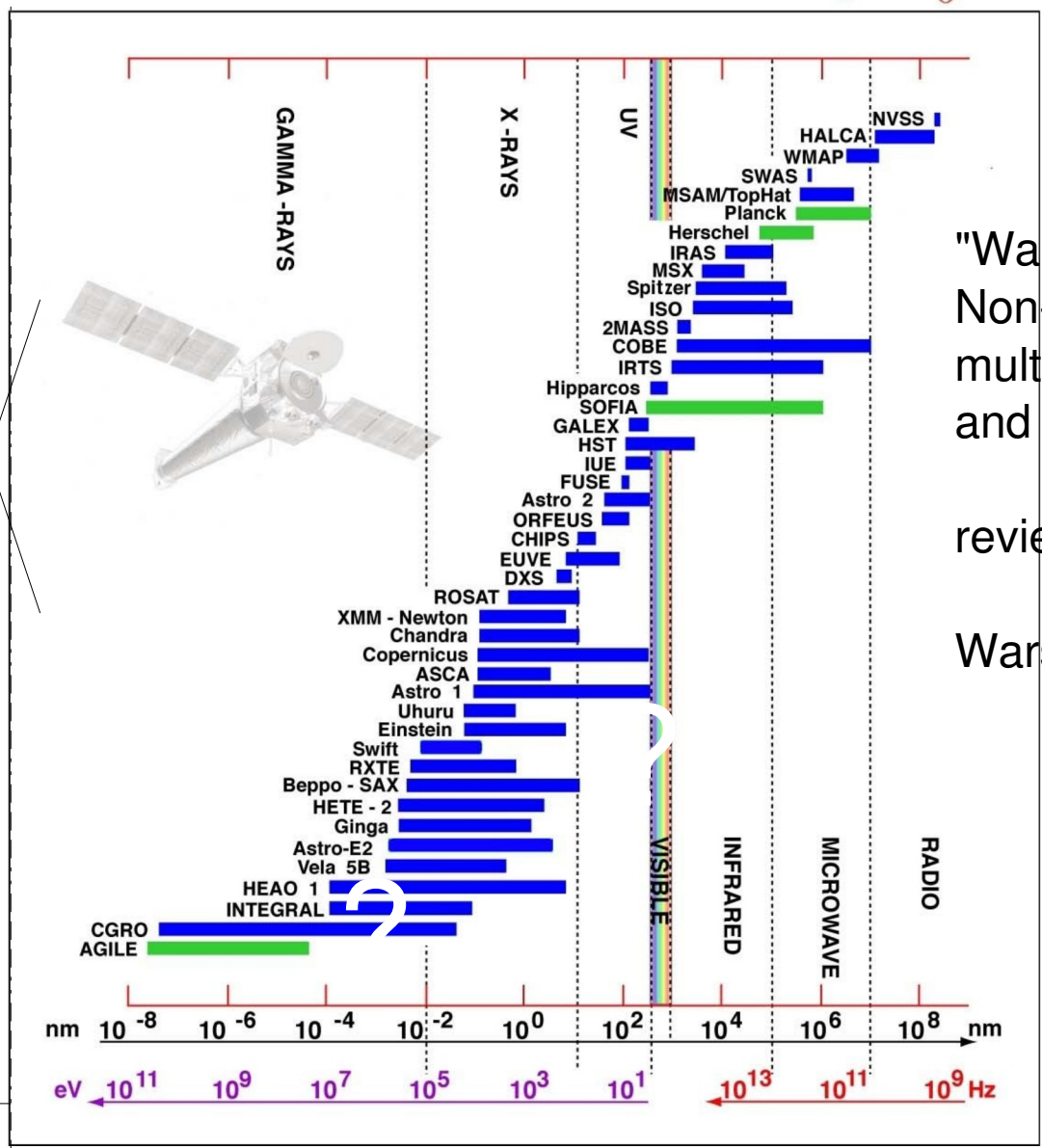
ultra-high
energy
photons
+
SUPER
PRESHOWERS?

- Pierre Auger Observatory
- Telescope Array
- CREDO

$>10^{19}$...

From gamma rays to radio

observation border



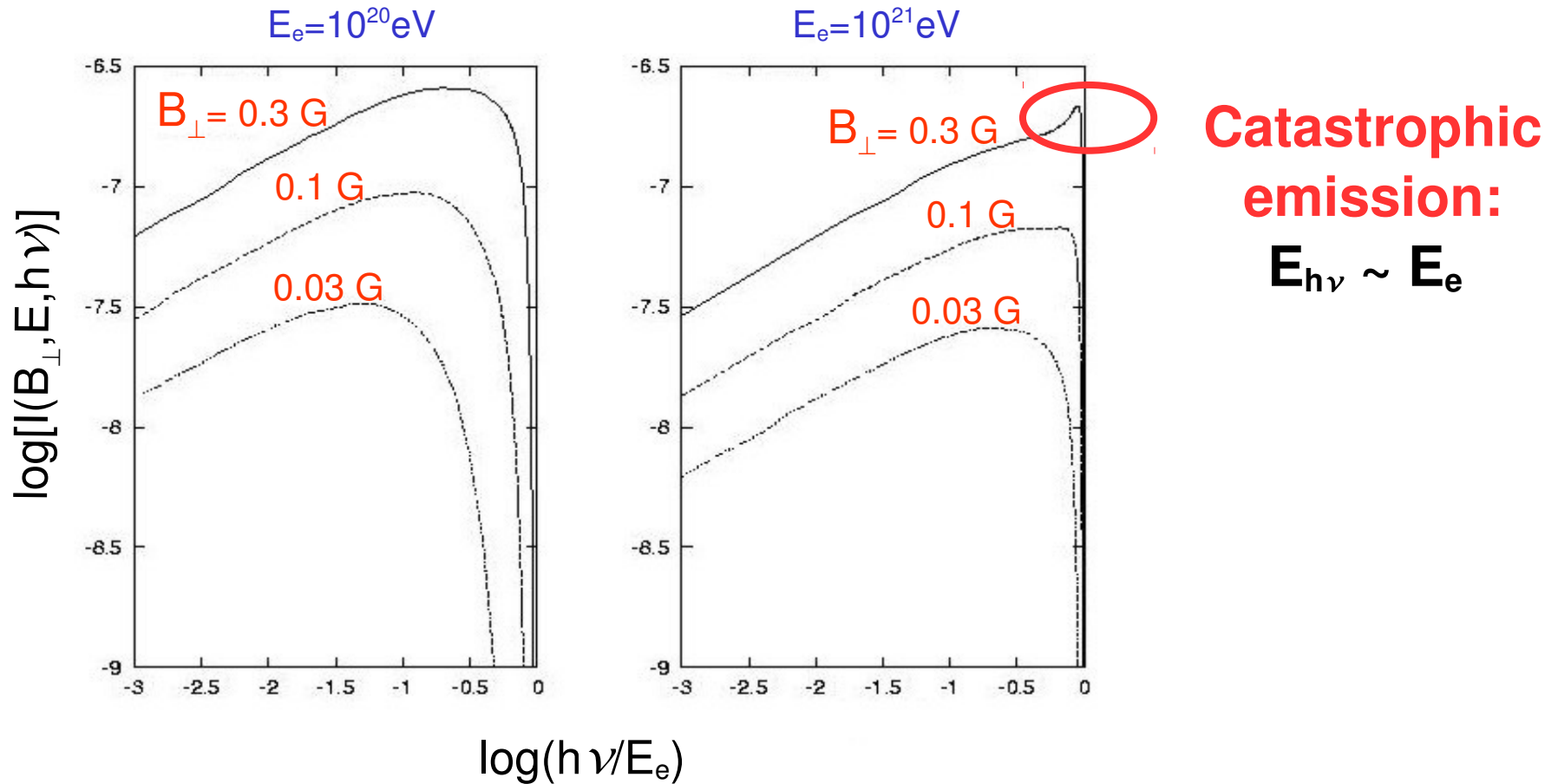
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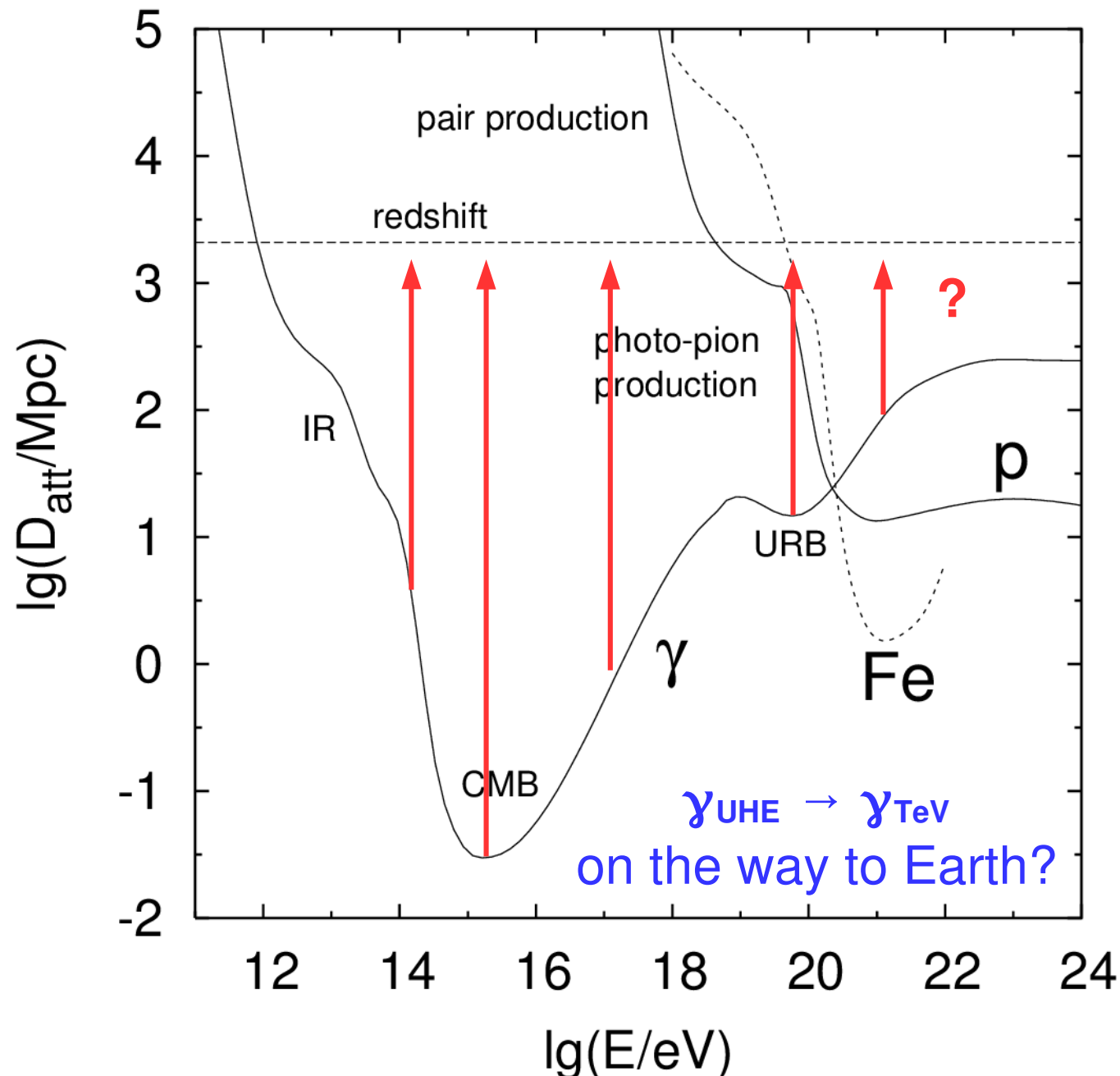
<http://nssdc.gsfc.nasa.gov/astro/astrolist.html>

Magnetic bremsstrahlung of ultrarelativistic electrons

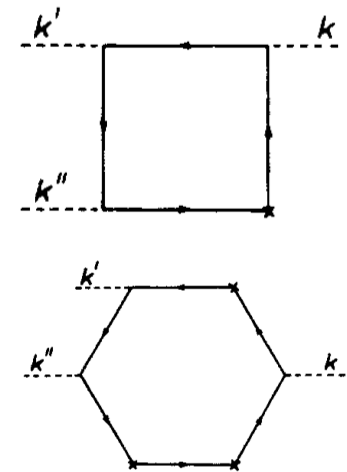


- probability of **catastrophic emission increases with E**
- **similarly for monopoles?** [question relevant for the Auger paper on monopoles]

γ_{UHE} travelling through the Universe: exotic example



**PHOTON
SPLITTING???**



HIGHER RATES IN
**NONLINEAR
ELECTRODYNAMICS?**

cf. Maccione & Liberati,
JCAP 08 (2008) 027