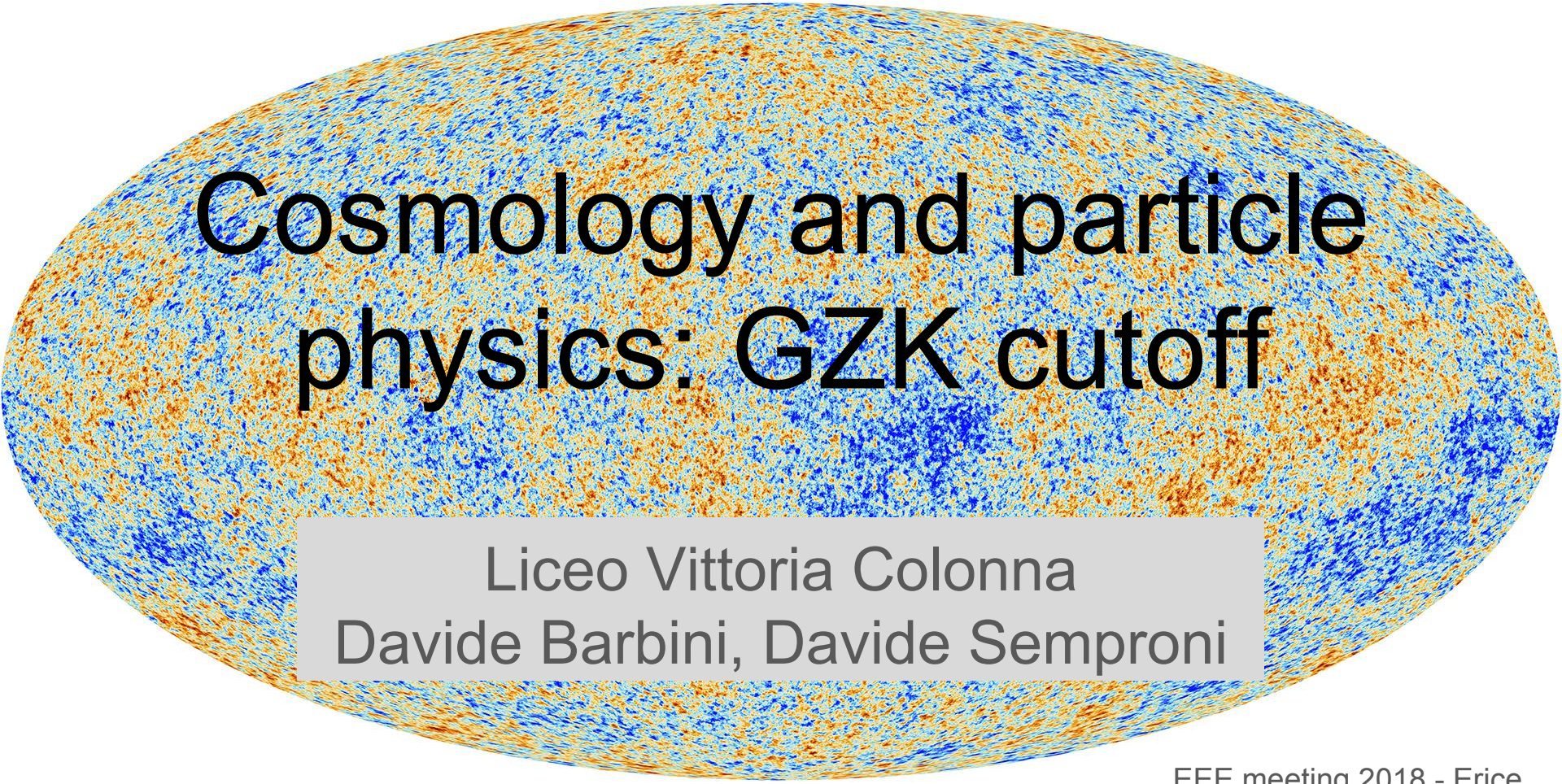

Cosmology and particle physics: GZK cutoff

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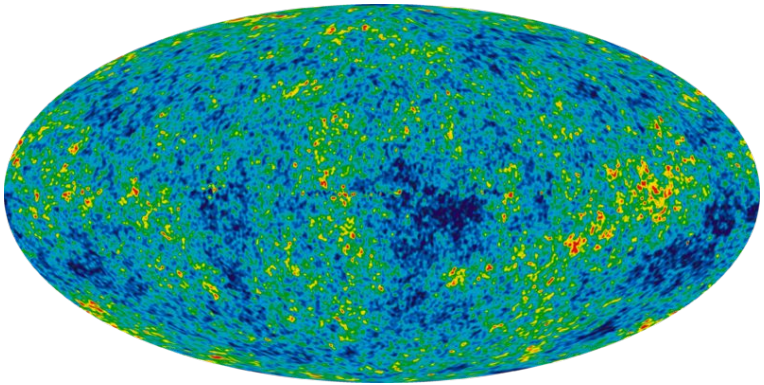
https://www.space.com/33892-cosmic-microwave-background.htm

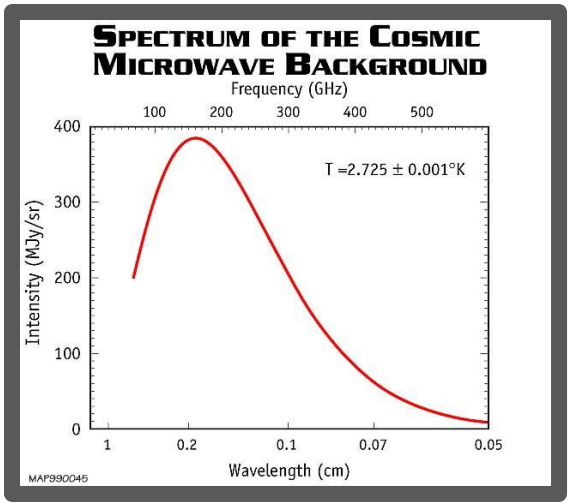
What is CMB?

CMB (cosmic microwave background) is a constant background radiation.

It has a very low energy, about 2.7K, and because of that it is mostly visible in the microwaves part of the electromagnetic spectrum. The density of energy of this radiation is 0.25eV/cm^3, or 500 photons/cm^3.



ESA&Planck satellite

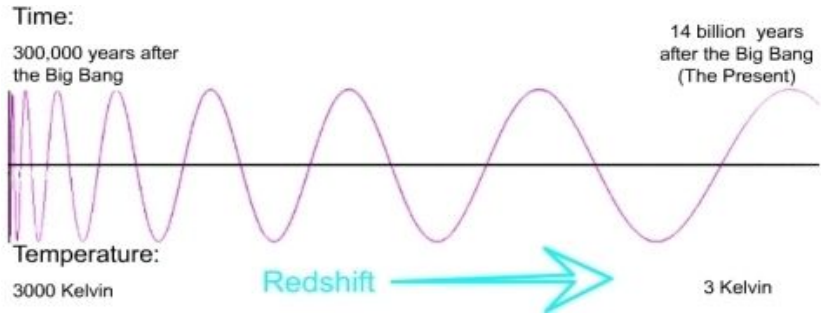


https://wmap.gsfc.nasa.gov/universe/bb_tests_cmb.html

Where does CMB come from?

CMB was originated 300’000 years after the Big Bang, when electrons started binding together to form matter and photons could travel great distances undisturbed.

Originally the energy of the particles was much higher, and the wavelength much shorter, but as the universe expanded the wavelength was stretched with it, resulting in the lower temperature we observe today.



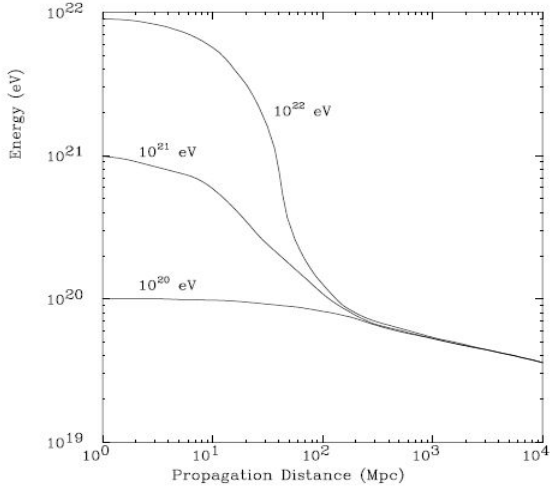
GZK cutoff

The GZK cutoff is the theoretical upper limit of protons' energy in cosmic rays.

It is caused by the interaction of these particles and CRB, as protons with more than 5×10^{19}eV of energy will react to produce pions, quickly losing their energy (20% decrease per reaction).

$$\gamma_{\mathrm{CMB}} + p \rightarrow \Delta^{+} \rightarrow p + \pi^{0},$$
$$\gamma_{\mathrm{CMB}} + p \rightarrow \Delta^{+} \rightarrow n + \pi^{+}.$$

A proton with an energy of 10^{20}eV will be able to only walk about 10 Mpc.



http://www.roma1.infn.it/exp/ams/LezioniAP/2011/AP_lez4_2011.pdf

Experimental proof

Since the 1990s three main observatories opened up for the study of high energy cosmic rays, in hope to find proof of the GZK cutoff theory.

The gathered data was off-putting, as rays with more than the 5×10^{19}eV limit were repeatedly found.

As of now, there is no agreed explanation on why these rays seem to be eluding the theoretical limit, and this is still one of the big unanswered question of modern physics.