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Study of the origins of ultra high energy cosmic rays

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What are Ultra High Energy Cosmic Rays (UHECR) ?

UHECR are nuclei which are accelerated up to 10^{21} eV.



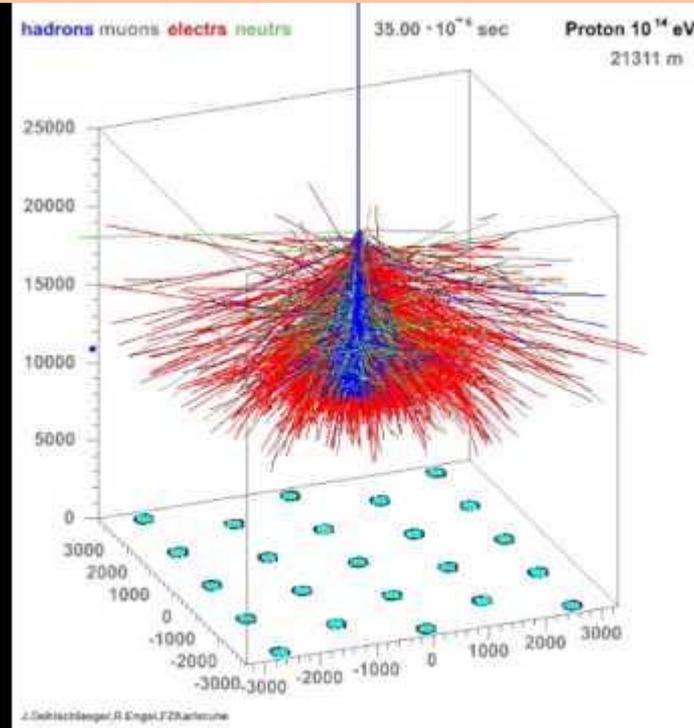
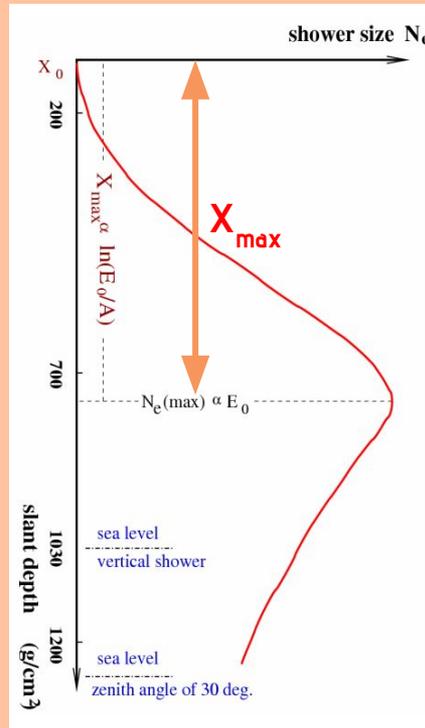
Nuclei reaches the earth



Hadronic shower

Three main observables:

- Arrival directions
- Energy
- X_{\max} : Depth of maximum shower (characteristic length of the shower, linked to the mass)



The Pierre Auger Observatory

Two detectors:

→ Telescopes measures X_{\max} , energy, arrival directions

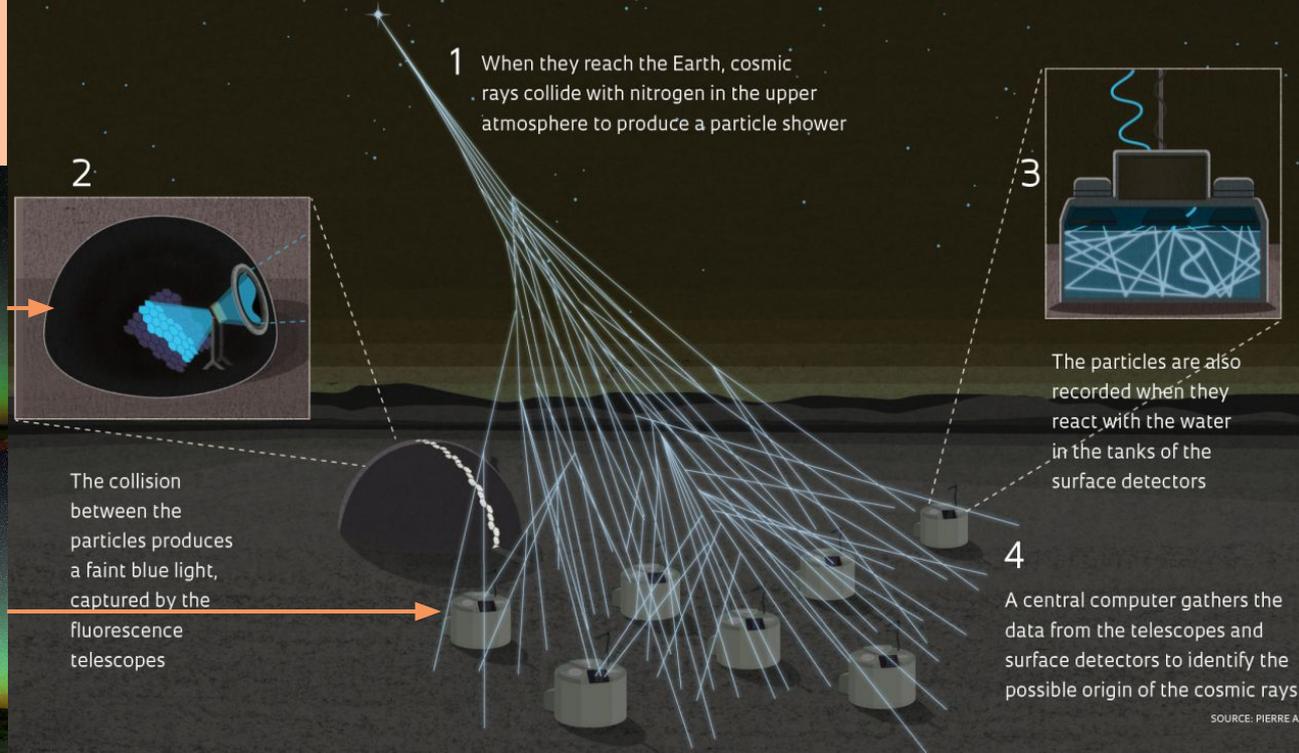
→ Surface detectors measures the energy and the arrival directions

3 000 km², 30 times Paris



Waiting for particles

The Pierre Auger Observatory combines two independent ways of detecting cosmic rays



Arrival directions: An extragalactic origin ? (2017)

Evidence of extragalactic origins

At $E > 8 \text{ EeV}$, a dipole is observed at more than the 5.2σ level of significance.

The cosmic ray dipole points 55° away from the 2MRS dipole

Definition rigidity:

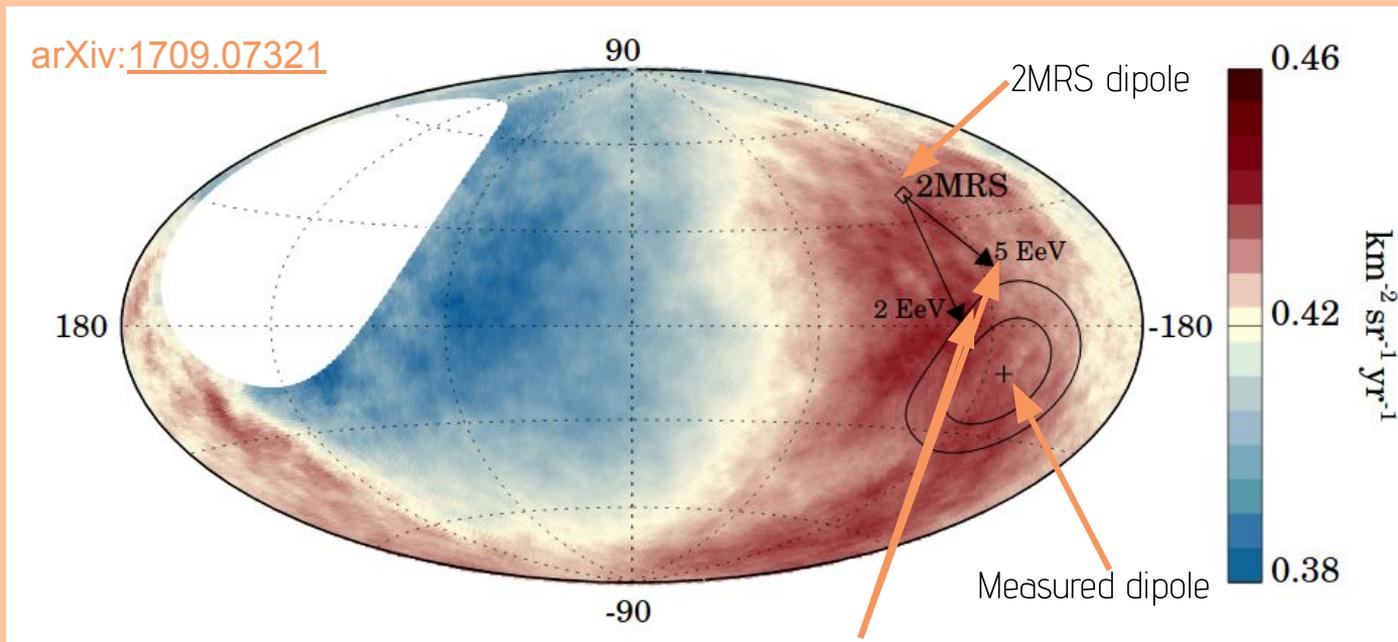
$$R = E/Z$$

with

E, the energy

Z, the charge

Measured flux for events above 8 EeV



Galactic magnetic field effect for
 $R = 2 \text{ EeV}$ & $R = 5 \text{ EeV}$

Arrival directions: An indication of the hosts galaxies ? (2018)

Comparing flux patterns

Idea: Compare the measured flux with the sky-map of extragalactic gamma-ray sources!.

Here: sky-map of starburst galaxies (SBG) compare to observed

Starburst galaxies = High Star Formation rate

4.0σ level of significance.

Model:

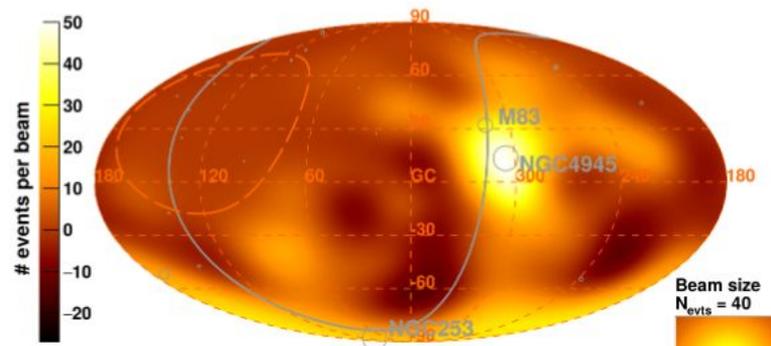
$$\Phi_{\text{model}} = \alpha \Phi_{\text{isotropy}} + (1-\alpha) \Phi_{\text{SBG}}$$

Two free parameters:

α , the isotropy fraction

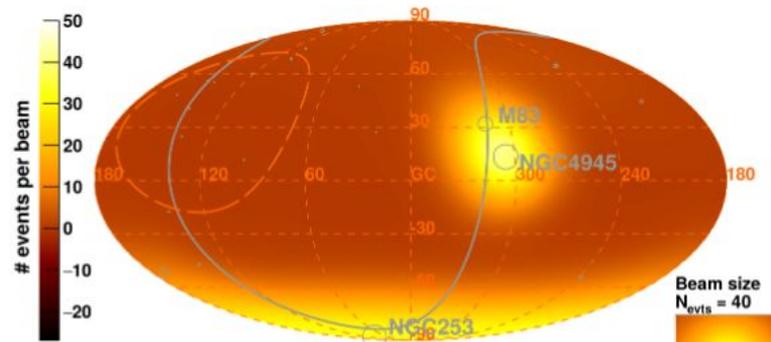
Beam size

Observed Excess Map - $E > 39$ EeV



[arXiv:180106160](https://arxiv.org/abs/180106160)

Model Excess Map - Starburst galaxies - $E > 39$ EeV



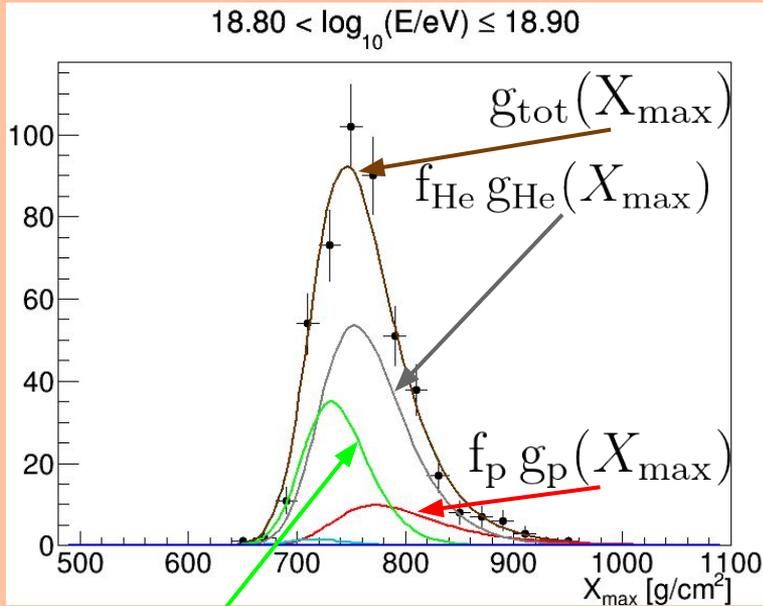
Study the composition

Goal: Get an idea of the composition of observed cosmic rays

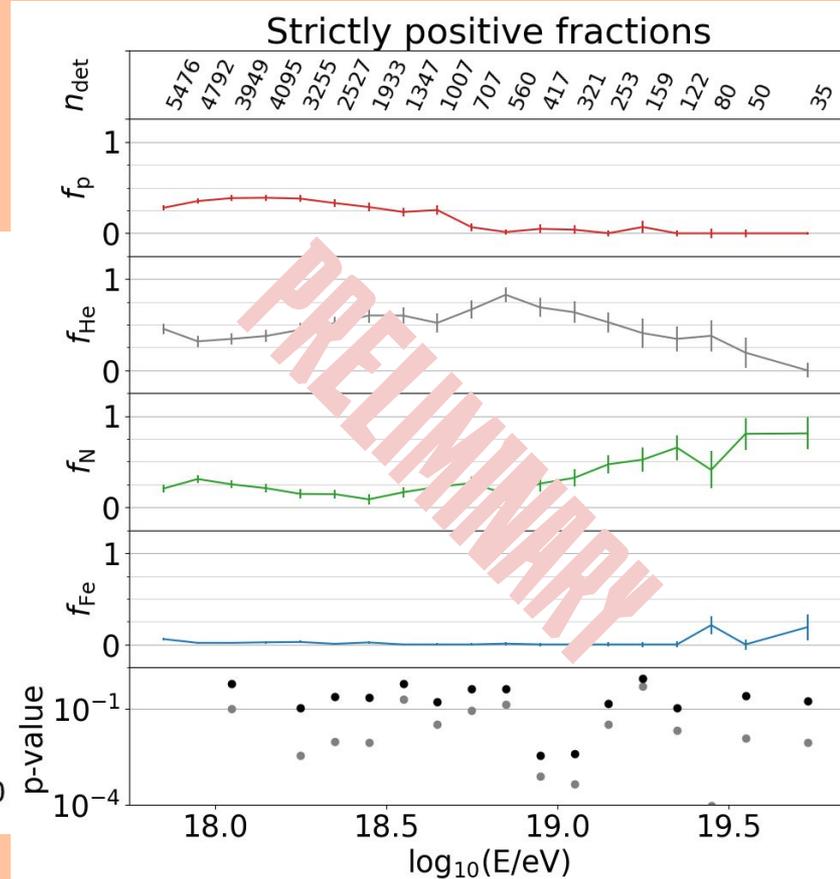
Method: For a given range in energy, Xmax histogram is reconstructed.

Xmax histograms are **fitted using 4 representatives** masses: **H, He, CNO, Fe**

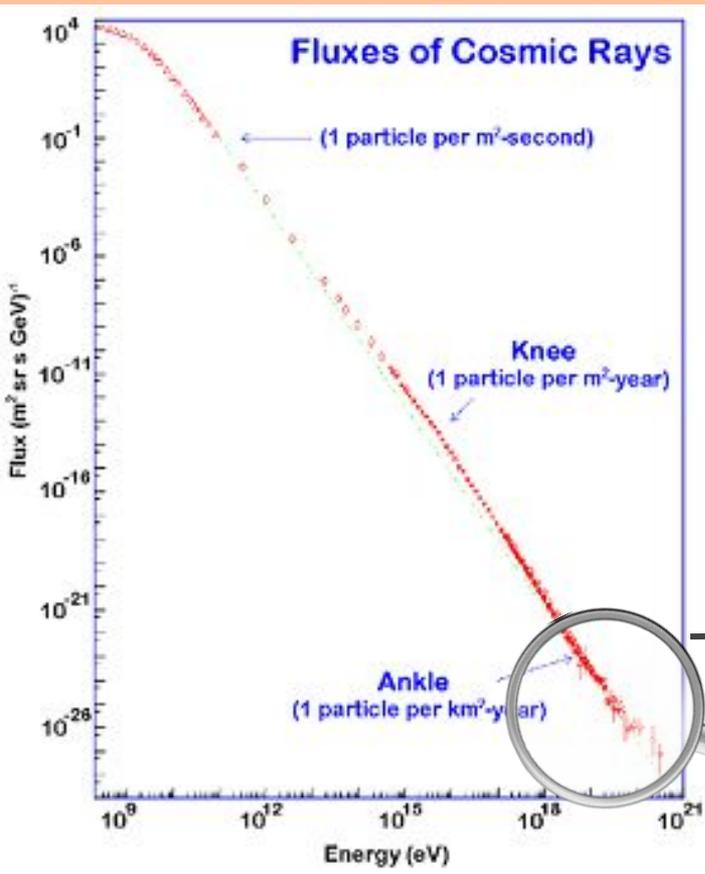
$$g_{\text{tot}}(X_{\text{max}}) = \sum_A f_A g_A(X_{\text{max}})$$



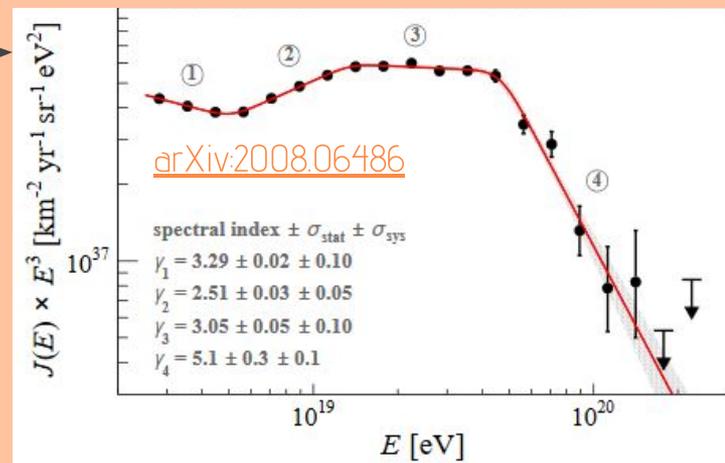
$$f_{\text{CNO}} g_{\text{CNO}}(X_{\text{max}})$$



Composition & energy spectrum



The energy spectrum
is given in the unit of
[#. $\text{km}^{-2}.\text{yr}^{-1}.\text{sr}^{-1}.\text{eV}^{-1}$]



An astrophysical model to describe the composition & the energy spectrum

Goal: Describe the Xmax data and the energy spectrum with a model.

Combined Fit:

→ Assuming a **1D distribution of sources** of UHECR.

→ **Inject representative masses** at the sources. (**H**, **He**, **CNO**, **Si**, **Fe**) given a **production rate q_{gen}** .

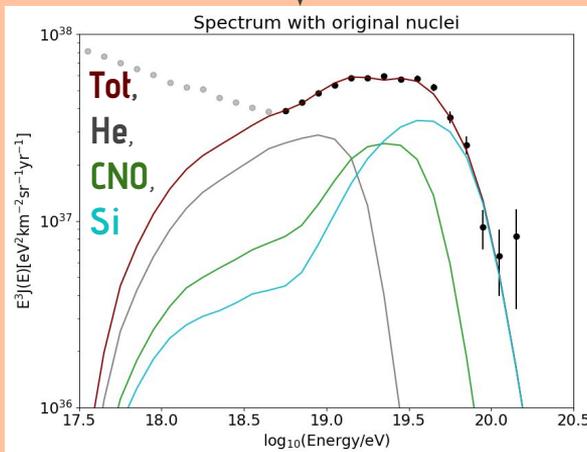
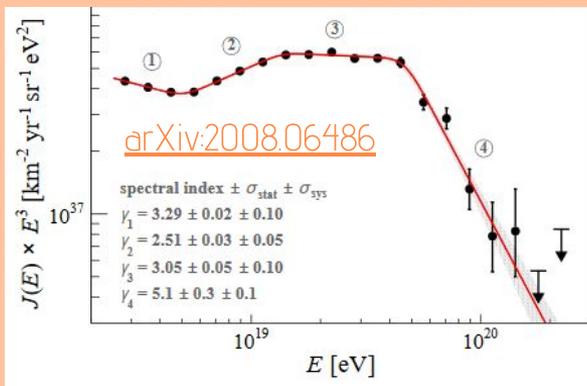
→ **Propagate nuclei** through cosmic microwave and infrared backgrounds

→ **Compare** the propagated nuclei with the spectrum and the Xmax distribution.

Parameters:

→ $f_{A'}$, fraction of injected elements

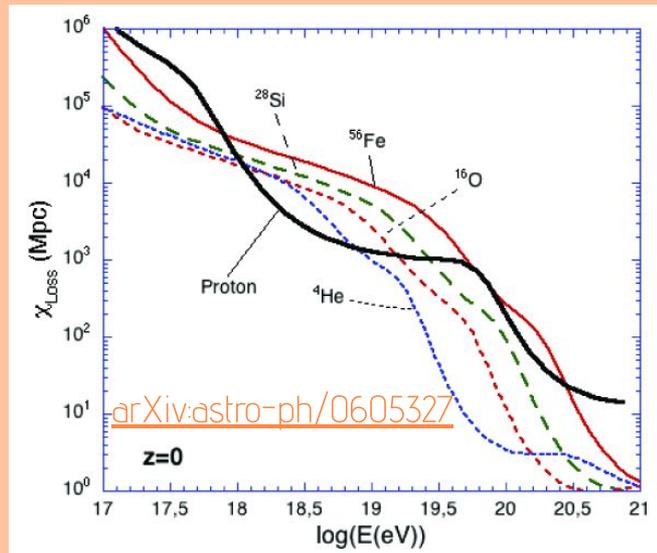
→ Two parameters for q_{gen}



Reason:

The energy and the composition gives an information about the distance of the sources.

λ_{Loss} is the attenuation length



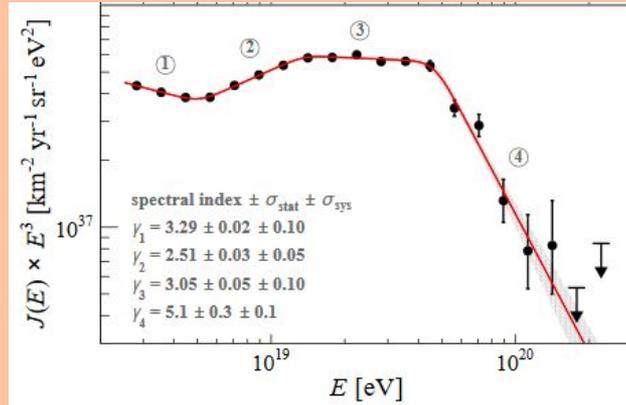
The next step

Goal: Have an astrophysical model which describes the **three observables**.

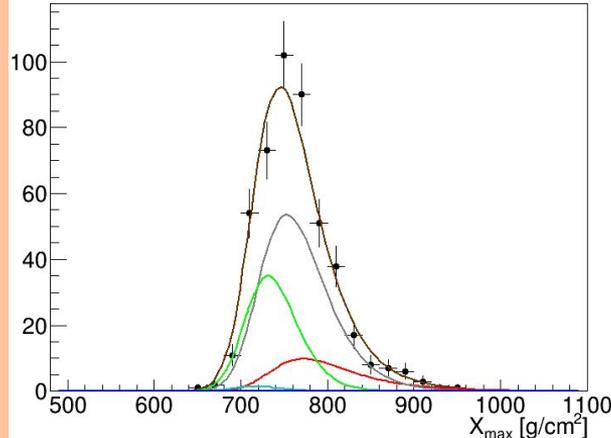
Idea: Implement anisotropy studies in the Combined Fit.

1D → 3D

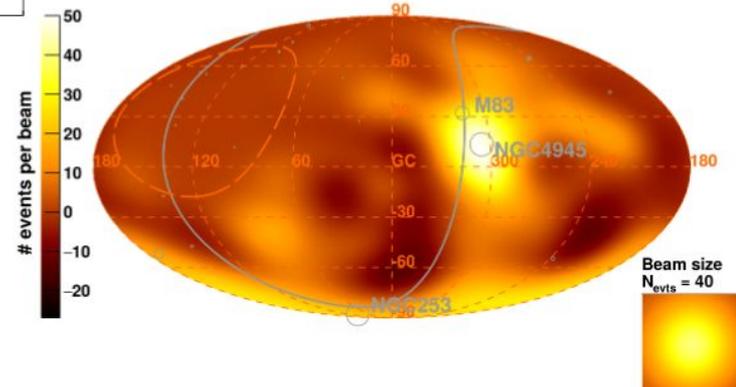
Hypothesis: Source follows the Star Formation Rate computed from 400,000 galaxies within 350 Mpc



$18.80 < \log_{10}(E/\text{eV}) \leq 18.90$



Observed Excess Map - $E > 39 \text{ EeV}$



Conclusion

The anisotropies studies makes us think, we are near discovering the host of UHECR sources.

Having a astrophysical model which can describes the three observables could constrain the sources in an unprecedented way.

PUB

Vous voulez en savoir plus sur l'expérience ?
Allez voir ma vidéo ;)



Je contrôle les télescopes du plus grand observatoire à rayons cosmiques au monde !

992 vues · il y a 5 mois



SulliBoy

Je suis doctorant en astrophysique des hautes énergies. Dans cette vidéo, je vous embarque avec moi en Argentine dans la ...