

Auger results and the sources of UHECRs

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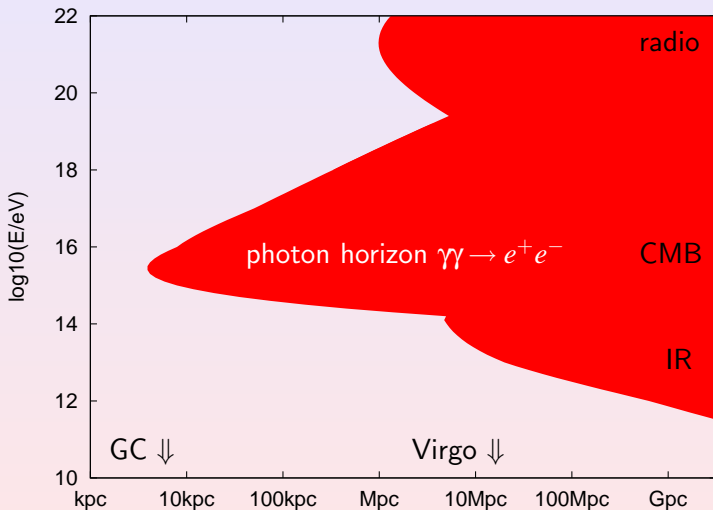


Outline of the talk

- 1 Motivation & expectations for UHECR astronomy
- 2 Auger data and their interpretation
- 3 Auto-correlation analysis
- 4 Cen A as UHECR source

What is the bonus of UHECR astronomy?

- astronomy with VHE photons restricted to few Mpc:



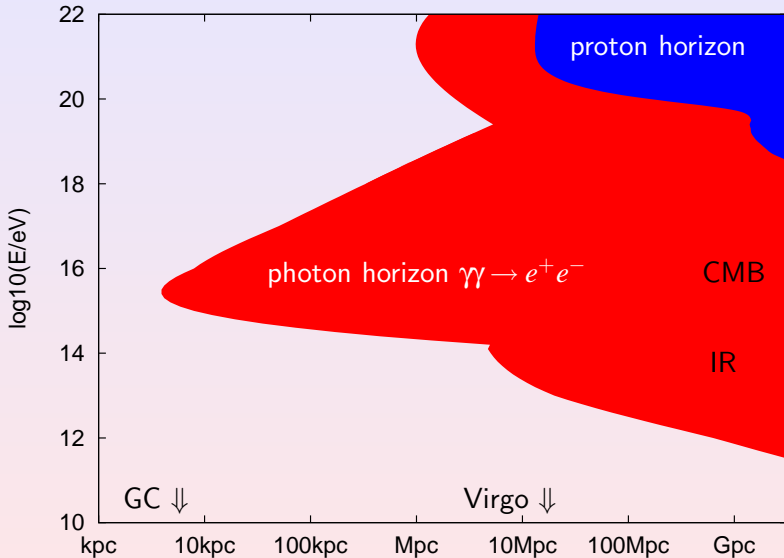
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- astronomy with HE neutrinos:
 - large λ_ν , but also large uncertainty $\langle \delta\vartheta \rangle \gtrsim 1^\circ$

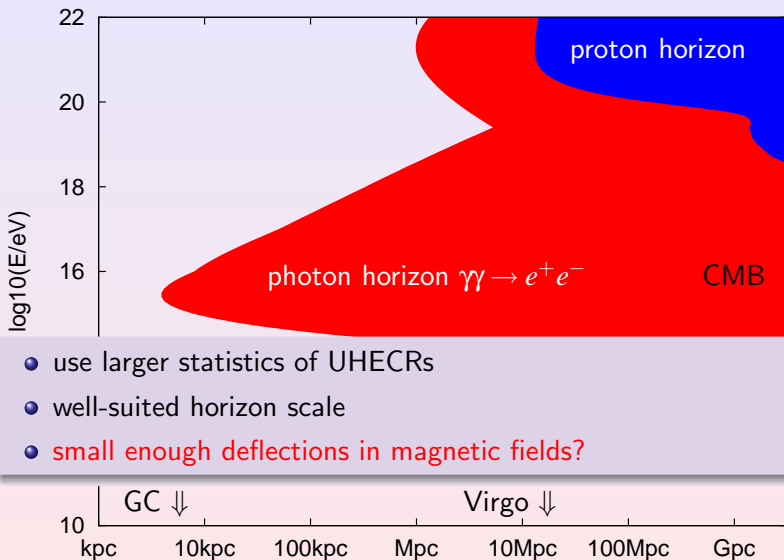
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 - small event numbers: \lesssim few/yr for PAO or ICECUBE
 - identification of steady sources challenging

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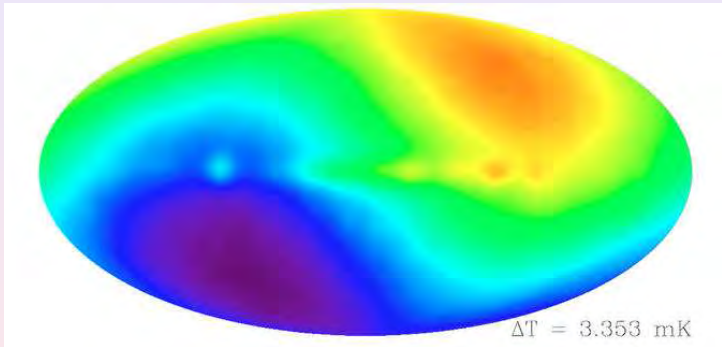
What is the bonus of UHECR astronomy?



- use larger statistics of UHECRs
- well-suited horizon scale
- small enough deflections in magnetic fields?

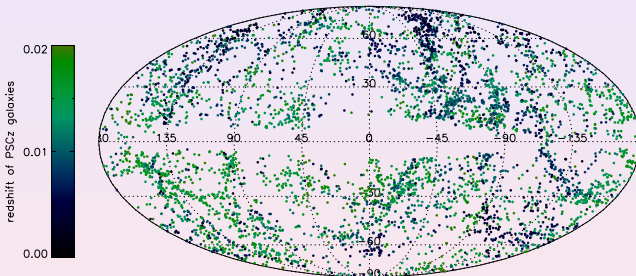
Possible anisotropies of extragalactic CRs:

- 1 Dipole anisotropy – cosmol. Compton-Getting effect
 - induced by motion of Sun relative to cosmological rest frame
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- 2 Anisotropies on medium scales



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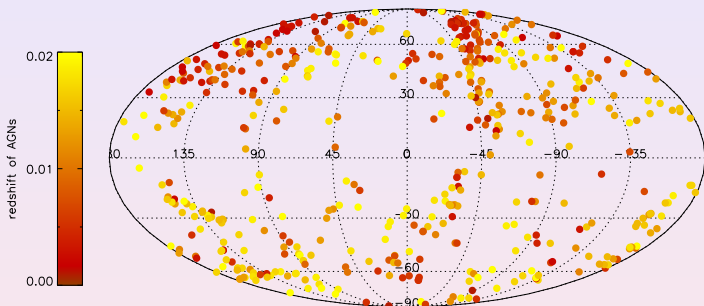
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- ④ Correlations with specific sources
 - requires small qB/E and small N_s
 - good source catalogue

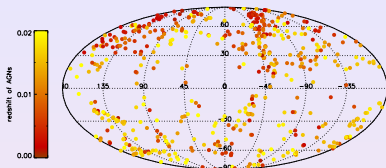
Correlations with AGNs: Auger analysis

AGN from VCC catalogue:



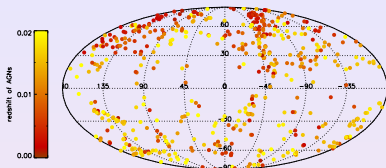
- mainly Seyfert galaxies
- expectation: $E_{\text{max}} \ll 10^{20} \text{eV}$ for most AGN in VCC

Correlations with AGNs: Auger analysis



- **first data set** with data $<$ May 2006 to **fix cuts**:
 $E_{\text{th}} = 56 \text{ EeV}$, $\ell_0 = 3.1^\circ$ and $d \leq 75 \text{ Mpc}$.
- **second data set** May 2006–August 2007:
13 events, **8 correlated**, **2.7 expected** $\Rightarrow p_{\text{ch}} \approx 2 \times 10^{-3}$

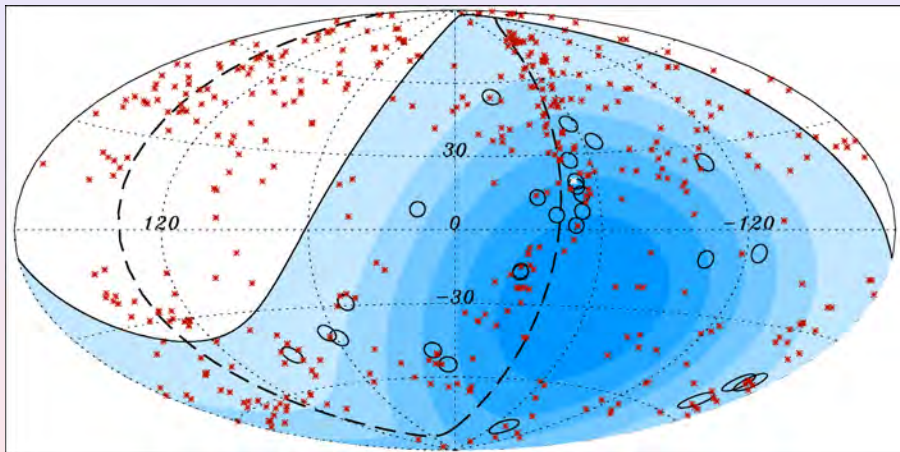
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- second data set May 2006–August 2007:
13 events, 8 correlated, 2.7 expected $\Rightarrow p_{\text{ch}} \approx 2 \times 10^{-3}$
- just a “3 σ effect”, **test against isotropy**, no propagation
- **not confirmed by HiRes**
- **AGN or something with similar distribution?**

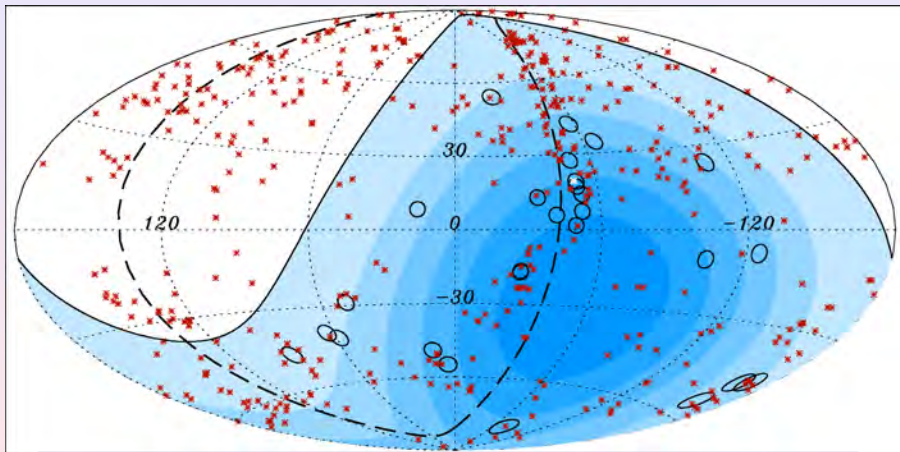
Correlations with AGNs: PAO analysis

- 27 CRs (\odot) and 472 AGN (*):



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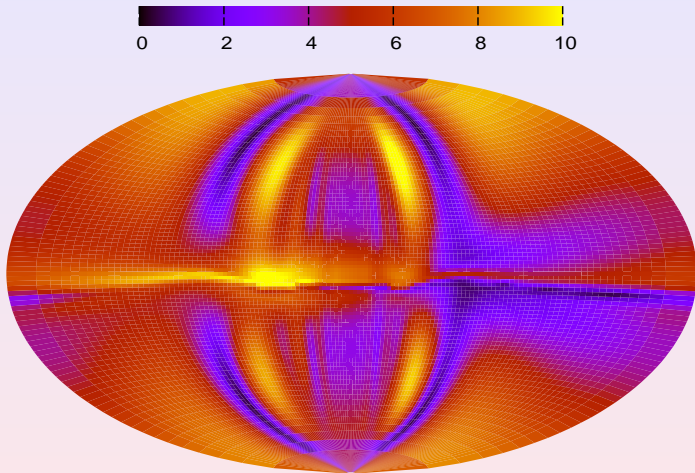
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correlated AGN are not promising UHECR sources

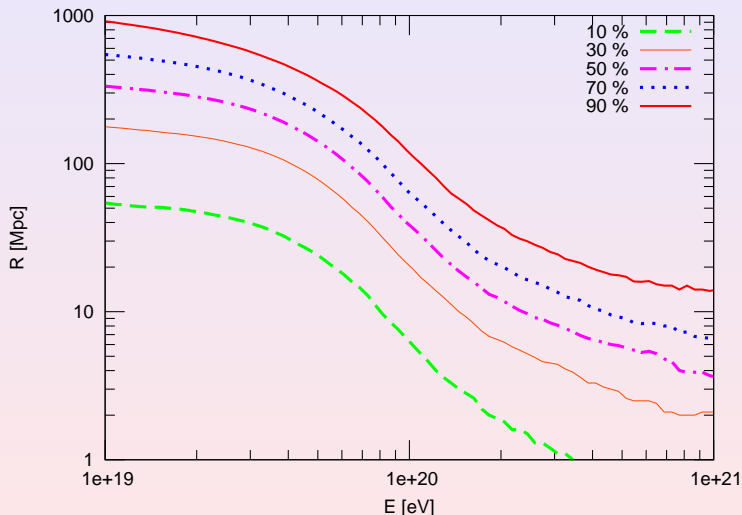
[Moskalenko et al. '08, Hardcastle et al. '08, Rachen '08, ...]

Deflections for $eE/Q = 4 \times 10^{19}$ eV in regular GMF:



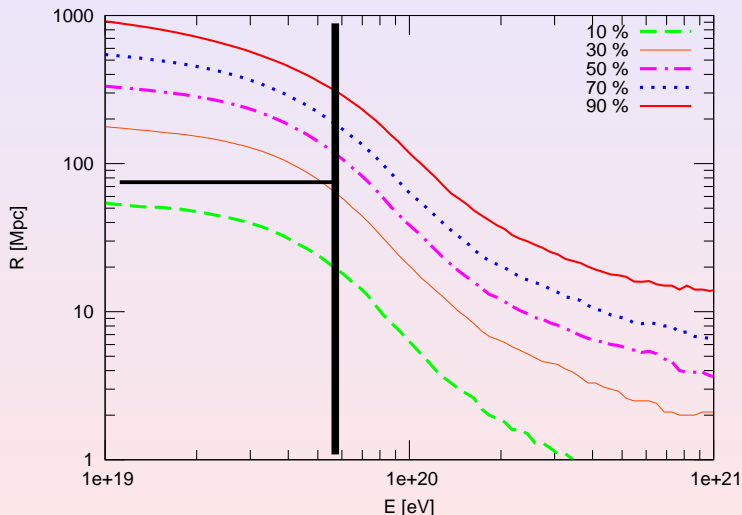
Energy threshold consistent with GZK horizon?

- 8 out of 13 CRs ($E \geq 57 \text{ EeV}$) correlated within 75 Mpc:



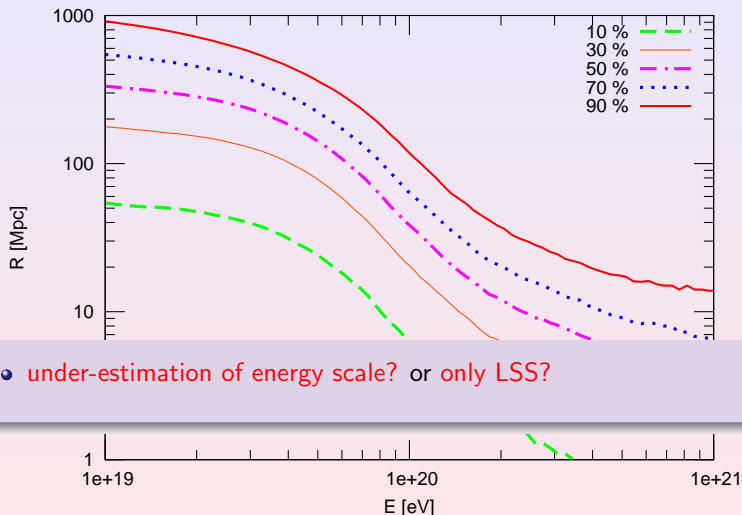
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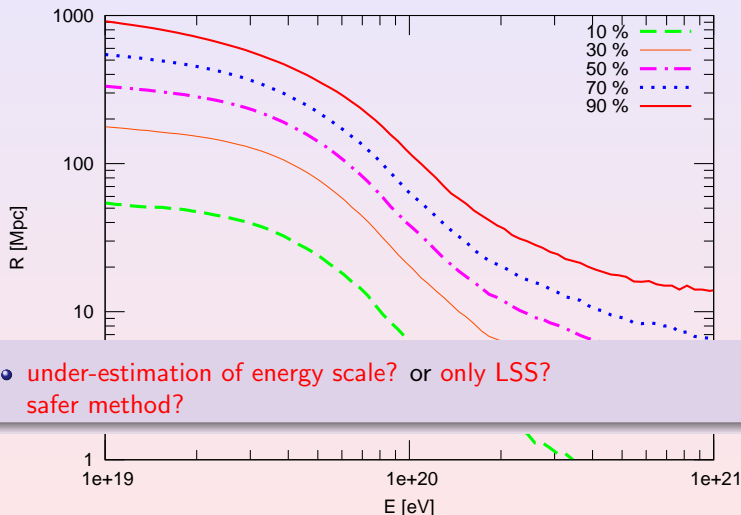
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- Use the **auto-correlation function**,

$$w(\vartheta) = \frac{DD(\vartheta)}{RR(\vartheta)} - 1,$$

where

- **DD** : number of **pairs in catalogue**
- **RR** : number of **pairs in random sets**

for **most popular sources of UHECRs**:

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for most popular sources of UHECRs: **AGN**

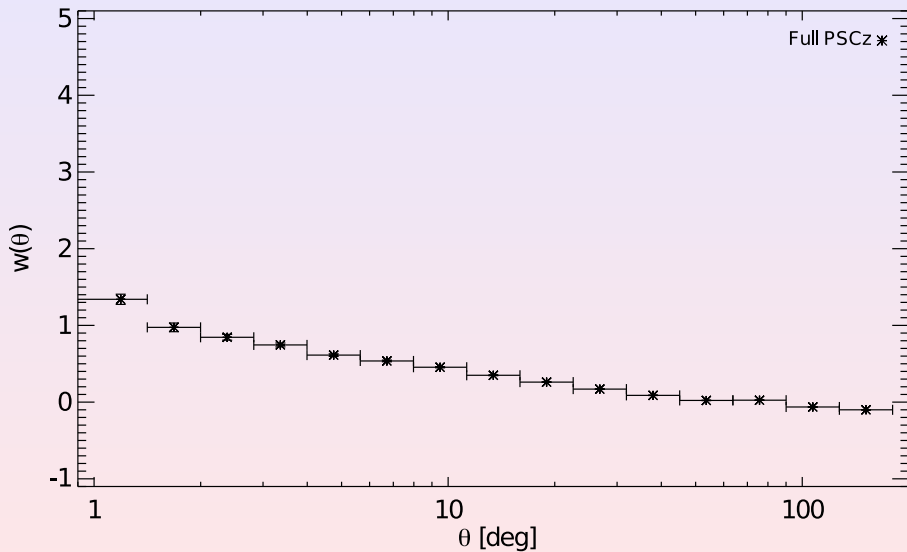


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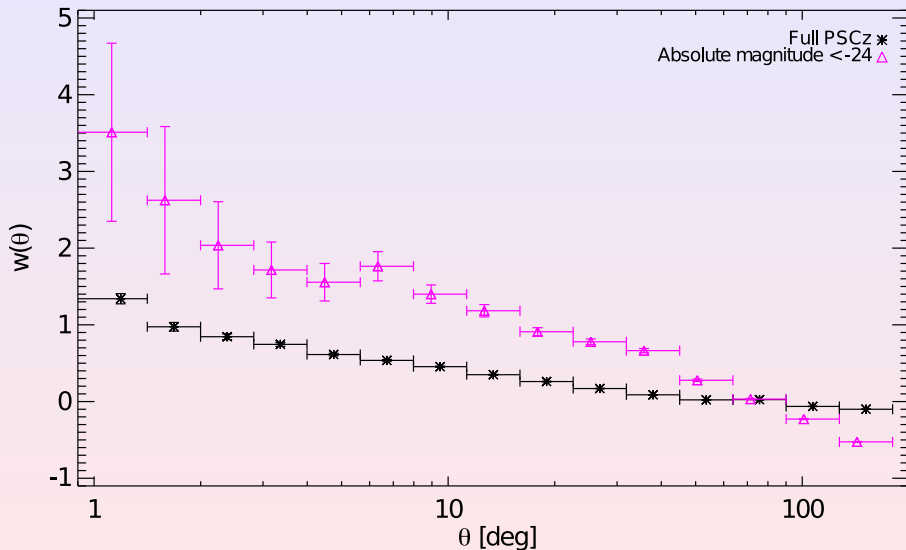
for most popular sources of UHECRs: AGN and **GRB**





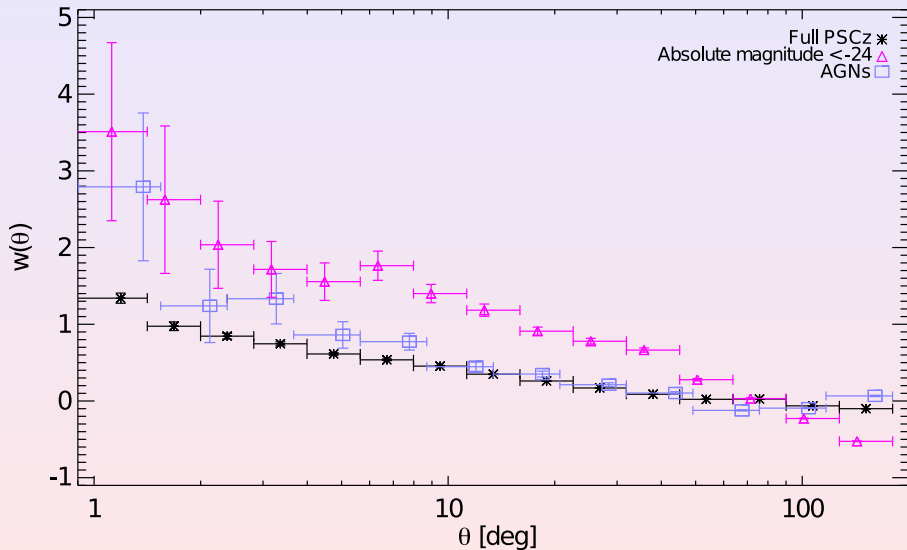
Auto-correlation function of different sources:

[A. Cuoco et al. '07]



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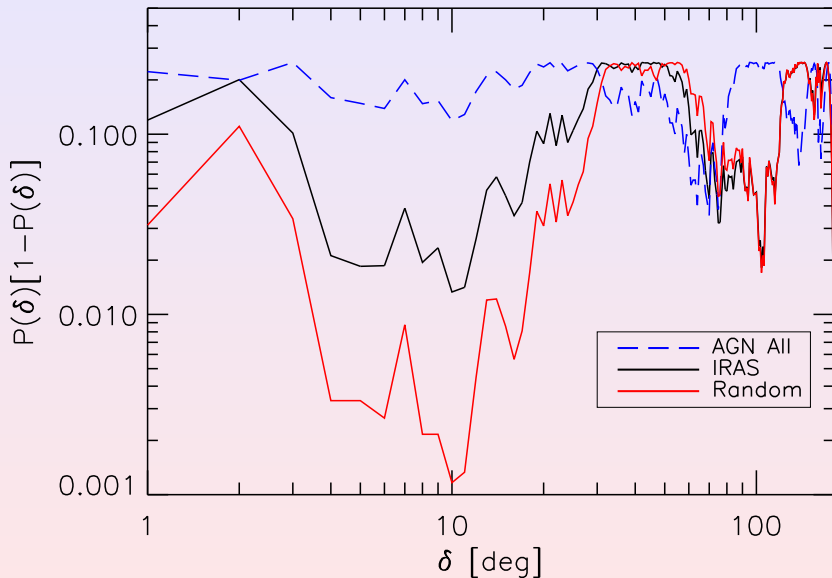


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- differences on all angular scales
- reduced dependence on B :
 - global comparison on all angular scales
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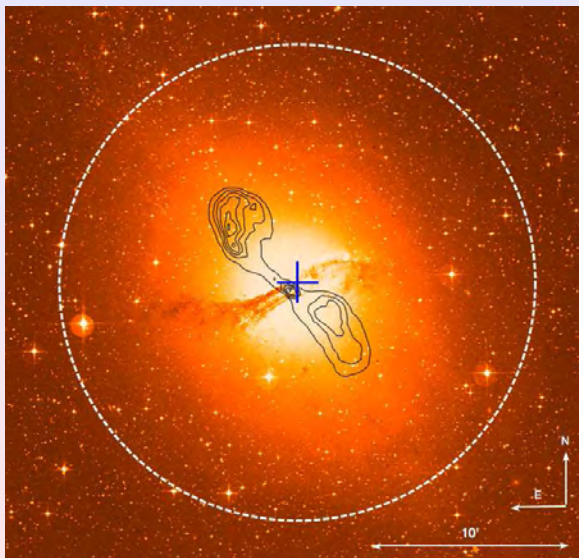
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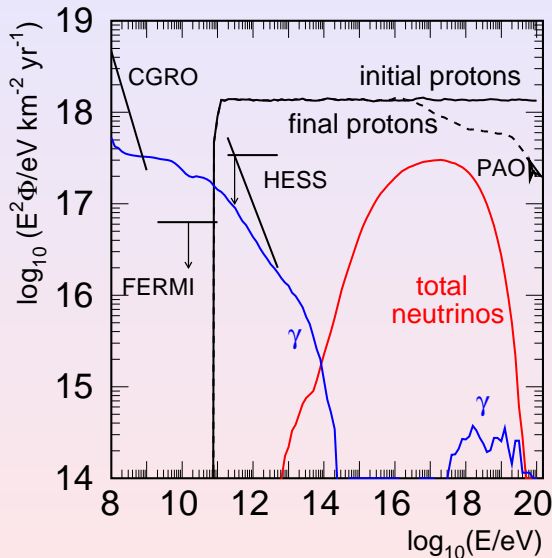
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Cen A as UHECR source?

[Romero et al. '96, Farrar, Piran '00, Rachen '08, ...]





- acceleration close to AGN core
- secondaries by $p\gamma$ interactions
- γ spectrum from cascading

- tension between horizon and fraction of correlated PAO events

Summary

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- **tension** between **chemical composition and correlation data** from PAO

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- deflections and lensing in cluster and Galactic fields important
- Cen A may be first source observed in TeV γ -rays and UHECRs