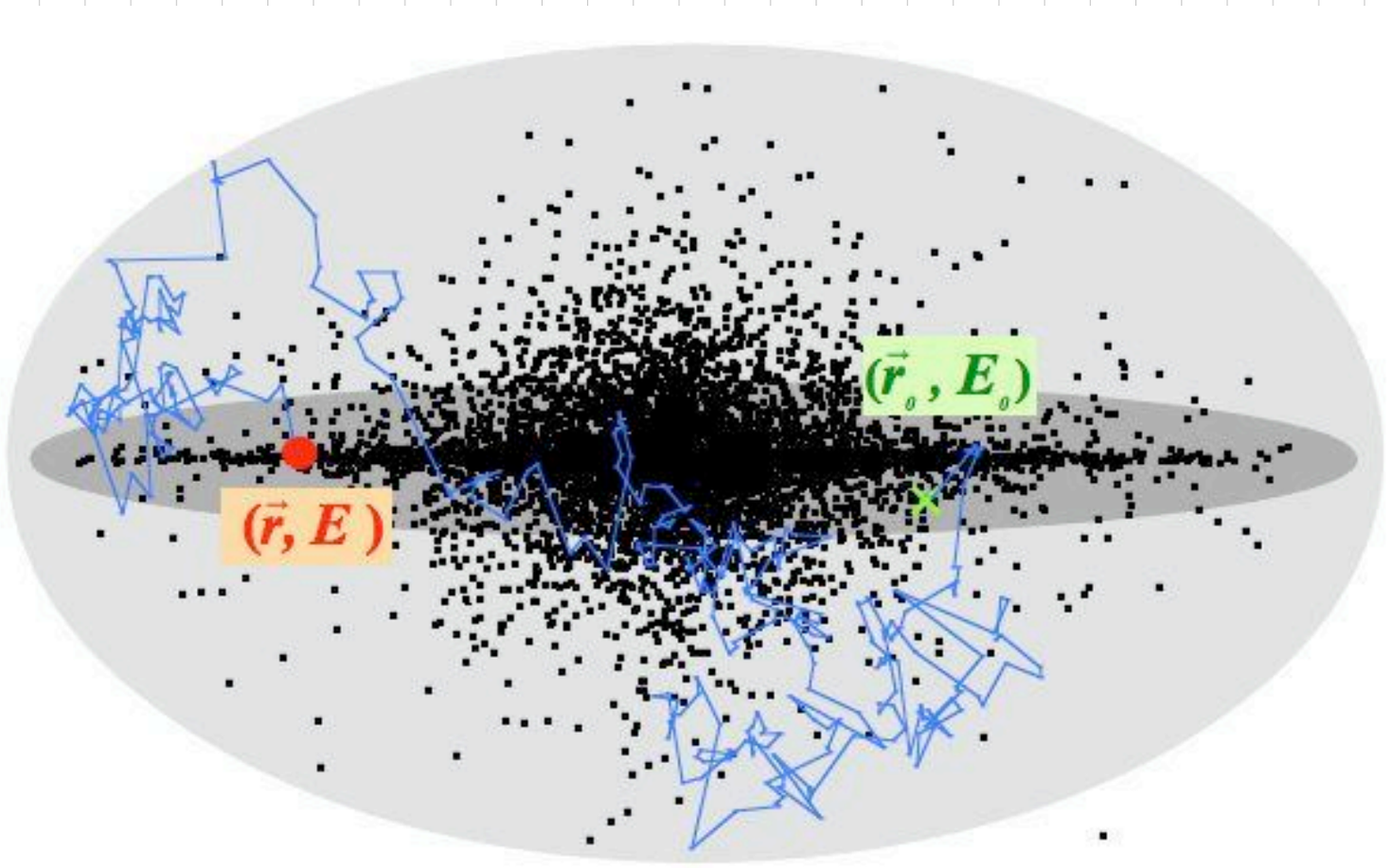
# Vorlesung 10:
## Ausbreitung der kosmischen Strahlung in der Galaxie

**Gleichung für Teilchentransport**
- Teilchendichte, Diffusion, Quellen
- Energieverlust während des Transports
- Quell- und Verlustterme durch Teilchenerzeugung

**Betrachtung von Grenzfällen**
- Punktförmige Quelle
- Unendlich ausgedehntes, homogenes Quellgebiet



# Vorlesung und Übungen : Daten

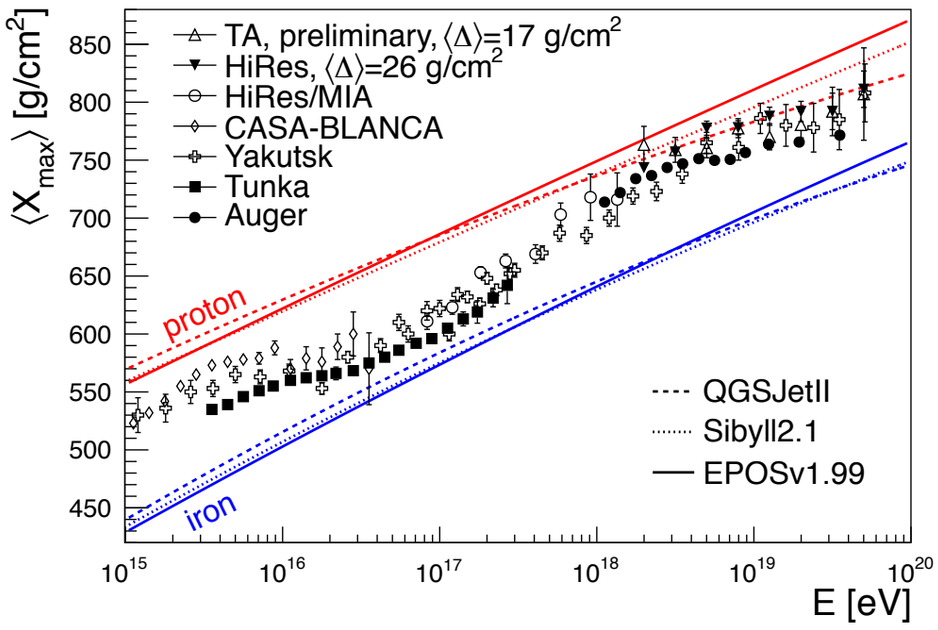
**Vorlesung: Dienstags**

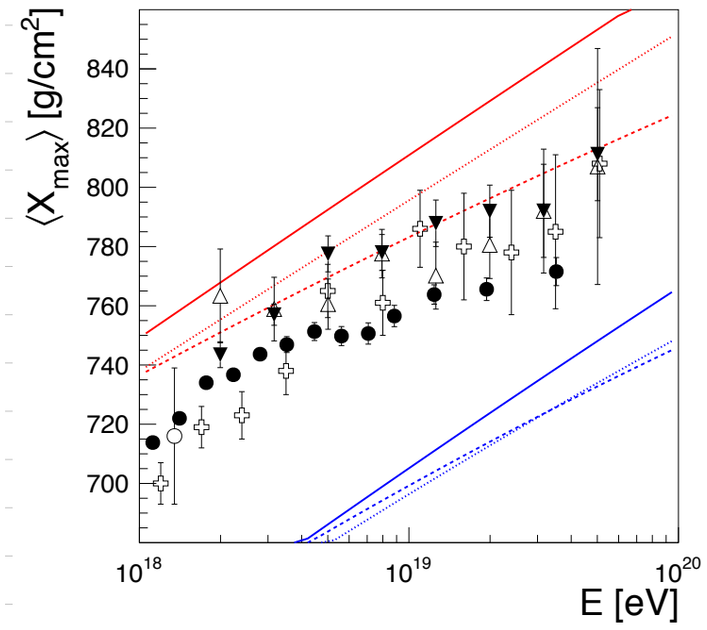
~~3. Nov. 2020~~
~~10. Nov. 2020~~
~~17. Nov. 2020~~
~~24. Nov. 2020~~
~~1. Dez. 2020~~
~~8. Dez. 2020~~
~~15. Dez. 2020~~
~~22. Dez. 2020~~
~~12. Jan. 2021~~
~~*19. Jan. 2021*~~
~~26. Jan. 2021~~
2. Feb. 2021
Ersatz für 19.1. 4. Feb. 2021
9. Feb. 2021
16. Feb. 2021

**Übungen: Donnerstags**
gehalten von Max Stadelmaier

~~19.11.2020 - Blatt 1~~
~~03.12.2020 - Blatt 2~~
~~17.12.2020 - Blatt 3~~
~~14.01.2021 - Blatt 4~~
11.02.2021 - Präsentation (Paul Filip)
18.02.2021 - Blatt 5

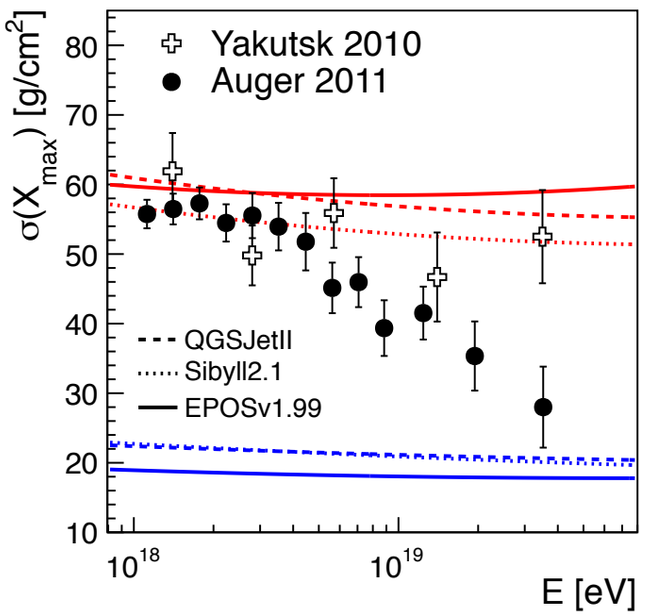
# $\langle X_{max} \rangle$ und Streuung

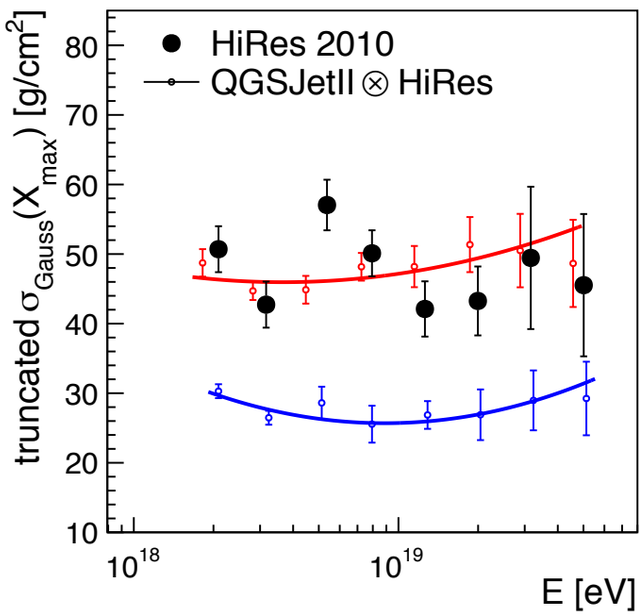


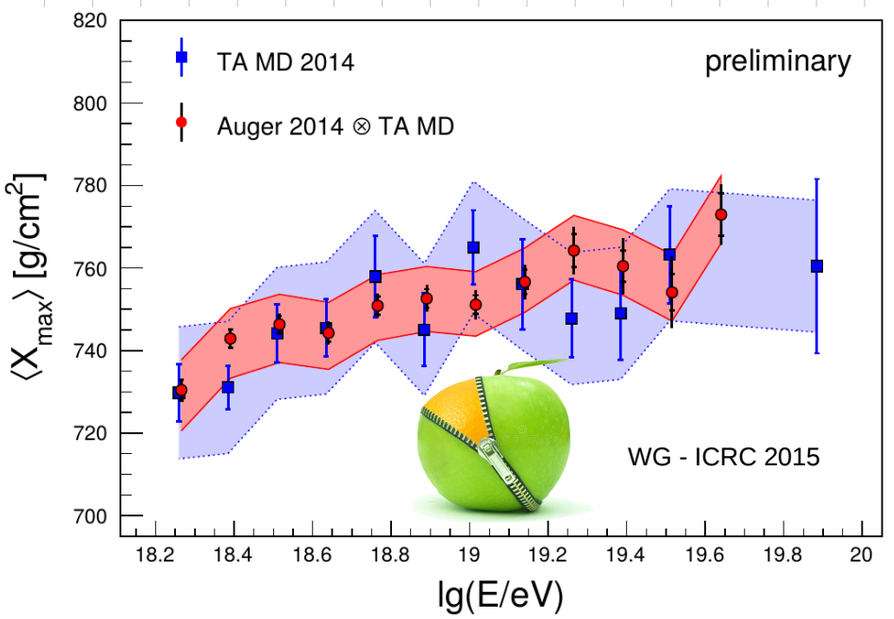




**TA**: all showers with $X_{max}$ in field of view (bias due to detector acceptance)

**Auger**: only shower geometries for which all $X_{max}$ values visible

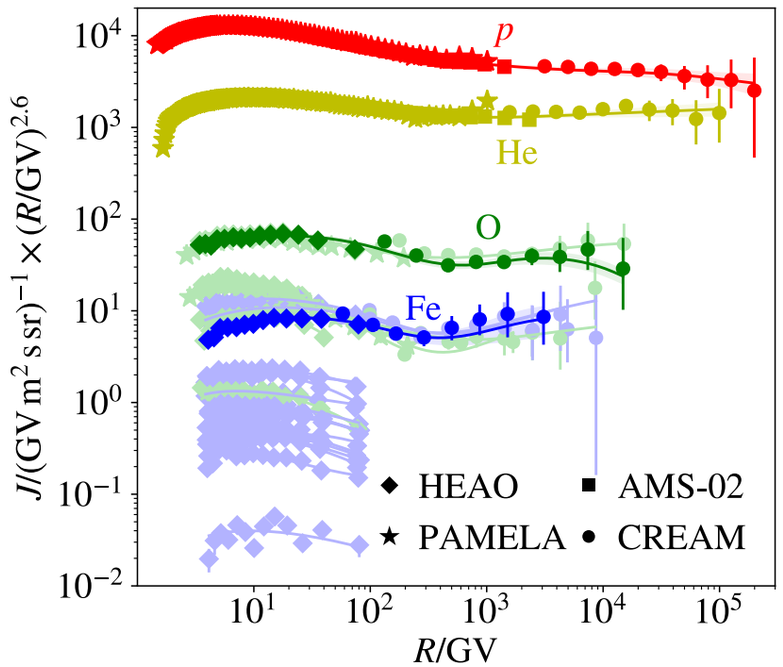


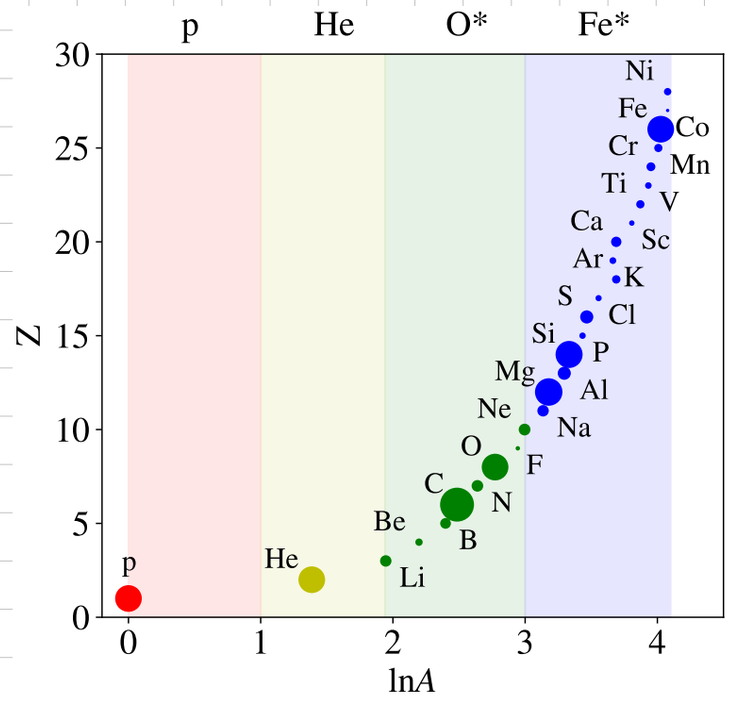



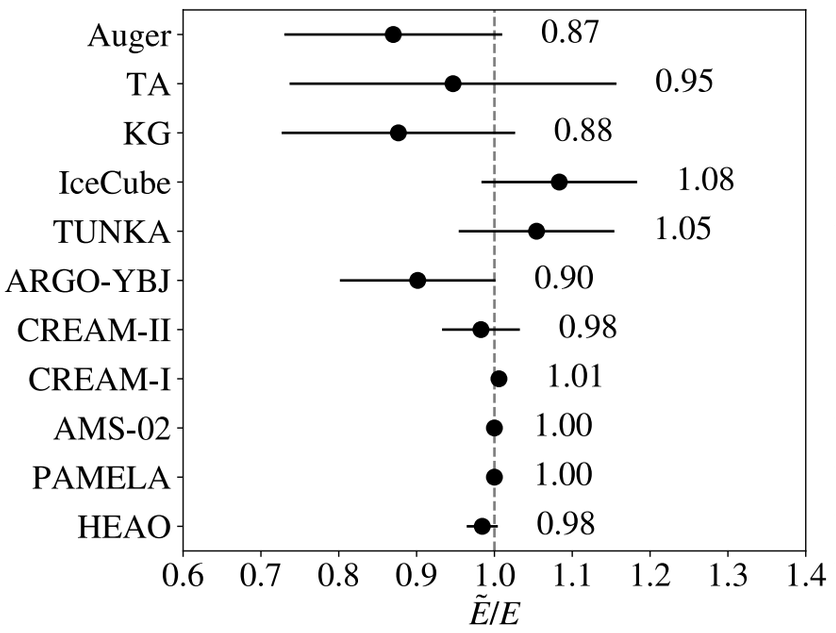



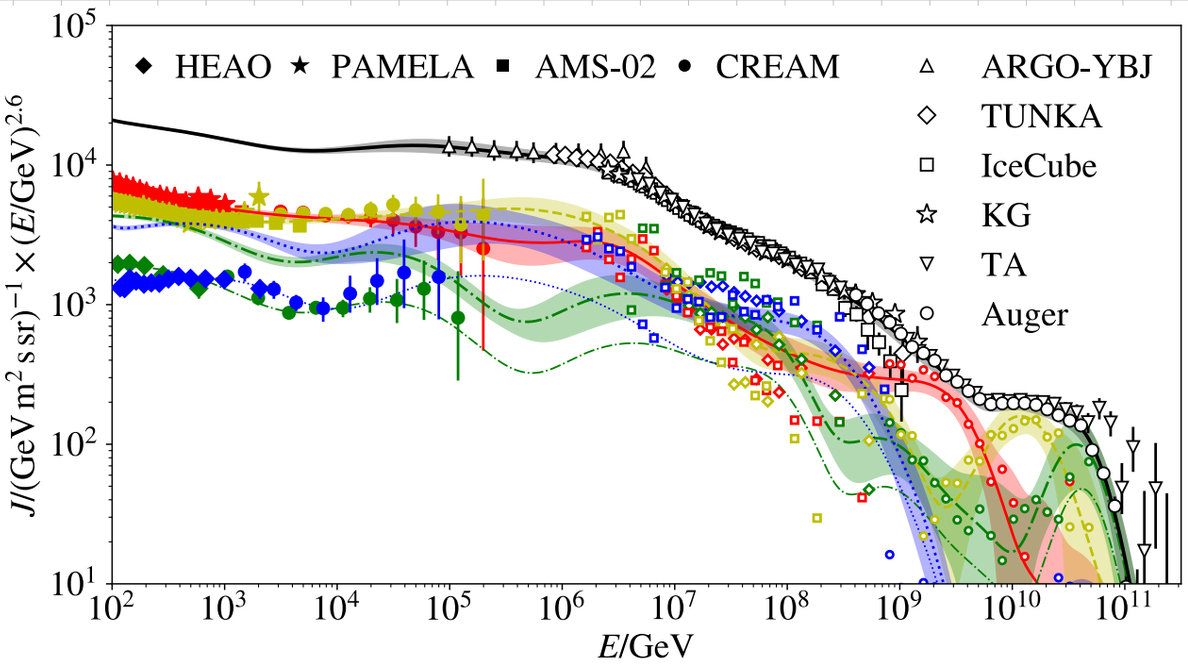

Unsicherheiten durch starke Modellabhängigkeit sehr groß

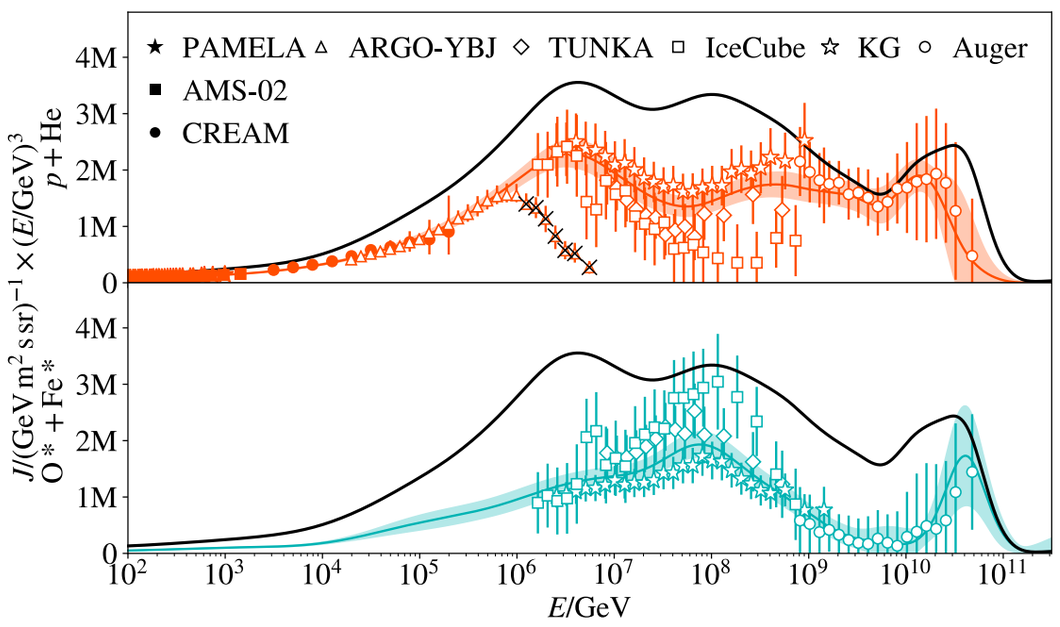
# Phänomenologische Beschreibung: Energiespektrum und Elementzusammensetzung




*Hans Dembinski et al , ICRC 2017*

# Dipolstruktur (Auger)

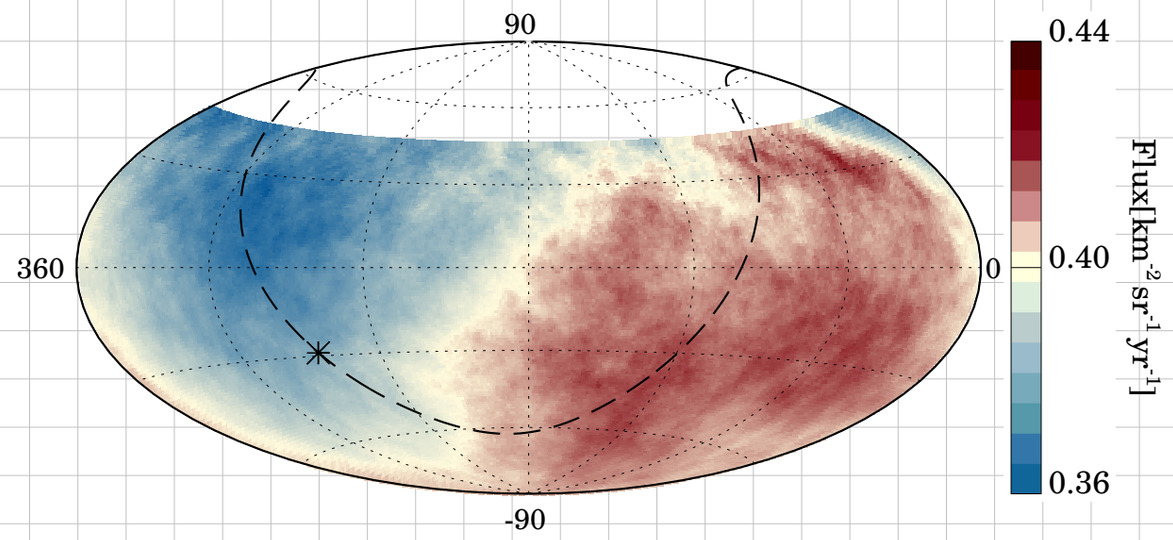



**Figure 1:** Map in Equatorial coordinates of the CR flux above 8 EeV, averaged on top-hat windows of 45° radius. The location of the Galactic plane is shown with a dashed line, and the Galactic center is indicated with a star.

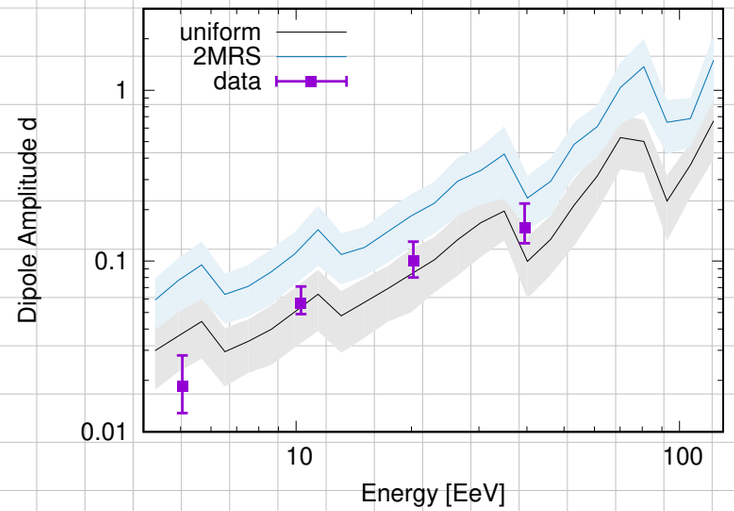



**Figure 2:** Energy dependence of the dipolar amplitude measured above 4 EeV. Also shown are the predictions from scenarios [12] with extragalactic sources.

# Einfluss des galaktischen Magnetfelds auf einen Dipol

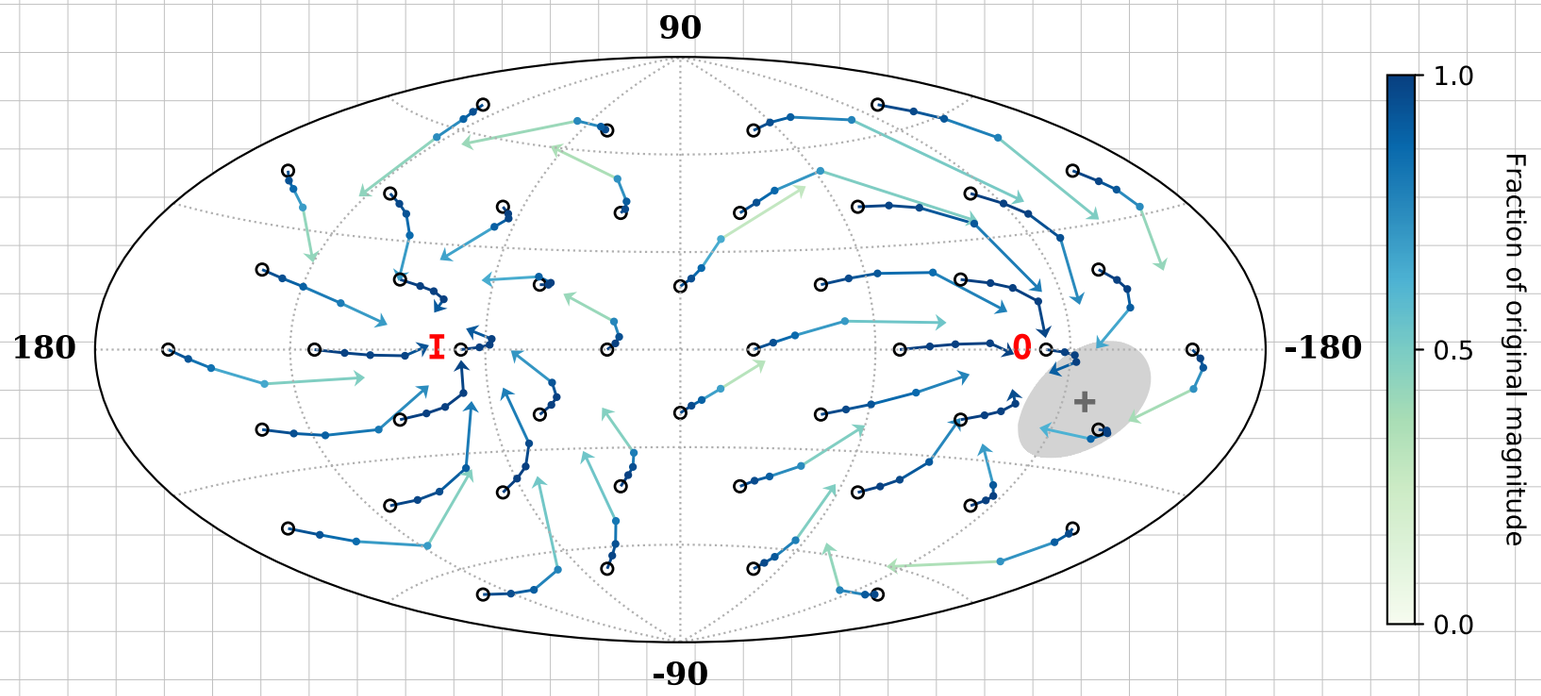



**Figure 7.** Change of the direction of the dipolar component of an extragalactic flux after traversing the Galactic magnetic field, modeled as in Jansson & Farrar (2012). We consider a grid (black circles) corresponding to the directions of a purely dipolar flux outside the Galaxy. Points along the lines indicate the reconstructed directions for different values of the particle rigidity: 32, 16, and 8 EV, and, at the tip of the arrow, 4 EV. The line color indicates the resulting fractional change of the dipole amplitude. The observed direction of the dipole for energies $E \geqslant 8$ EeV is indicated by the gray plus sign, with the shaded area indicating the 68% CL region. The labels ***I*** and ***O*** indicate the directions toward the inner and outer spiral arms, respectively.

# Dipolentwicklung mit Energie

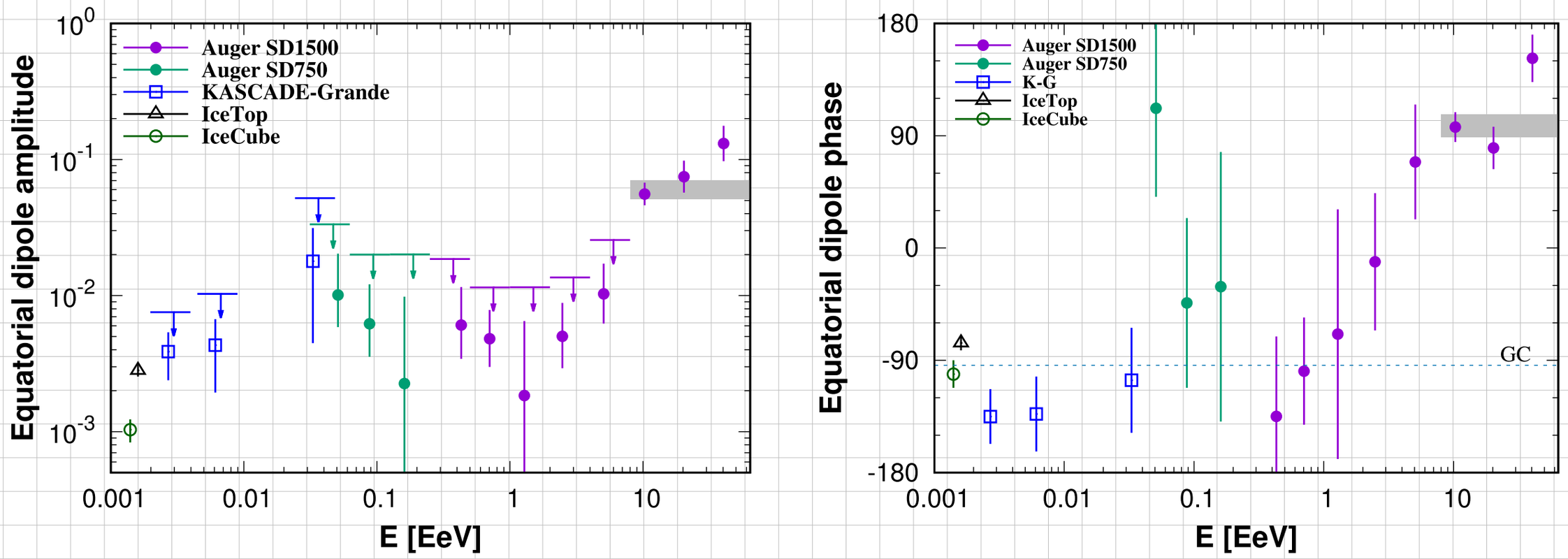
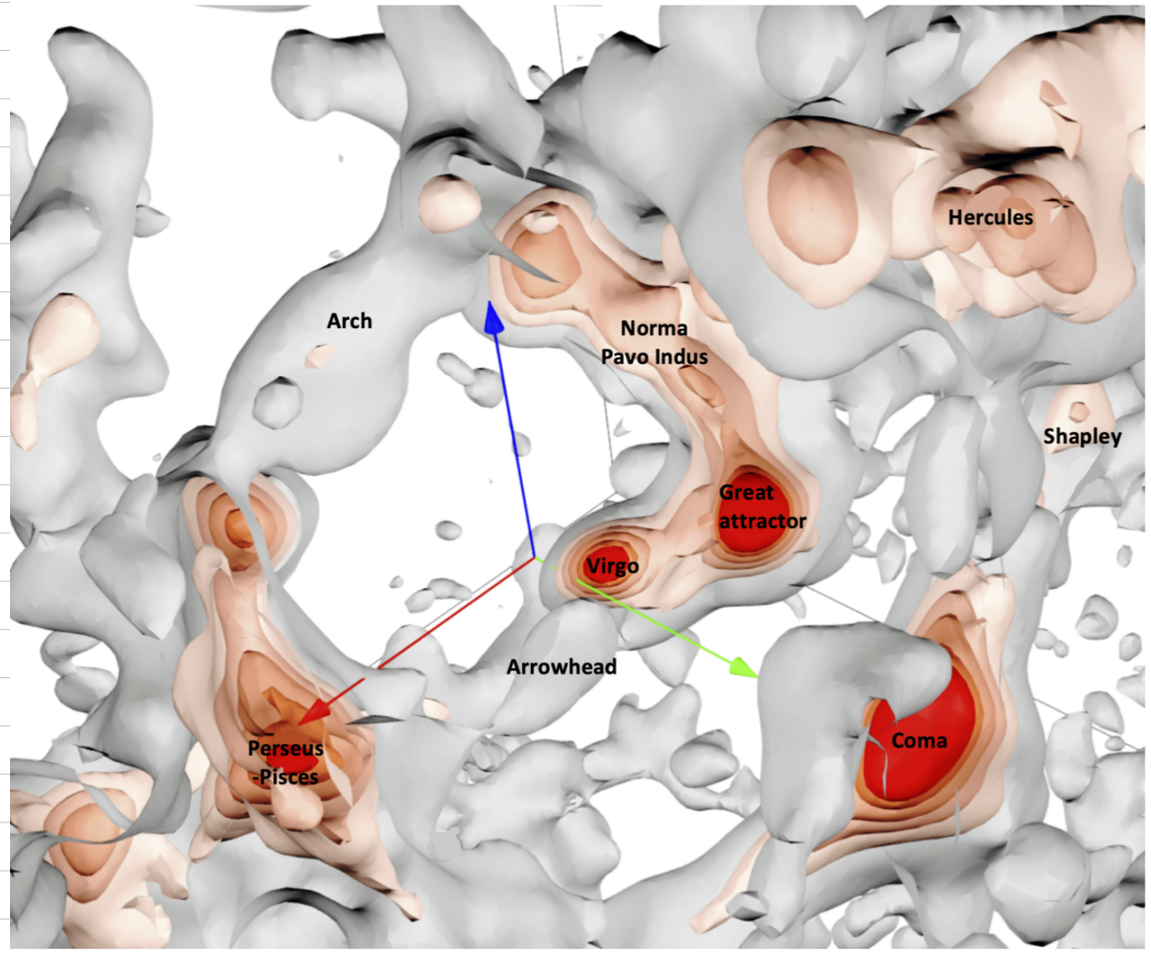


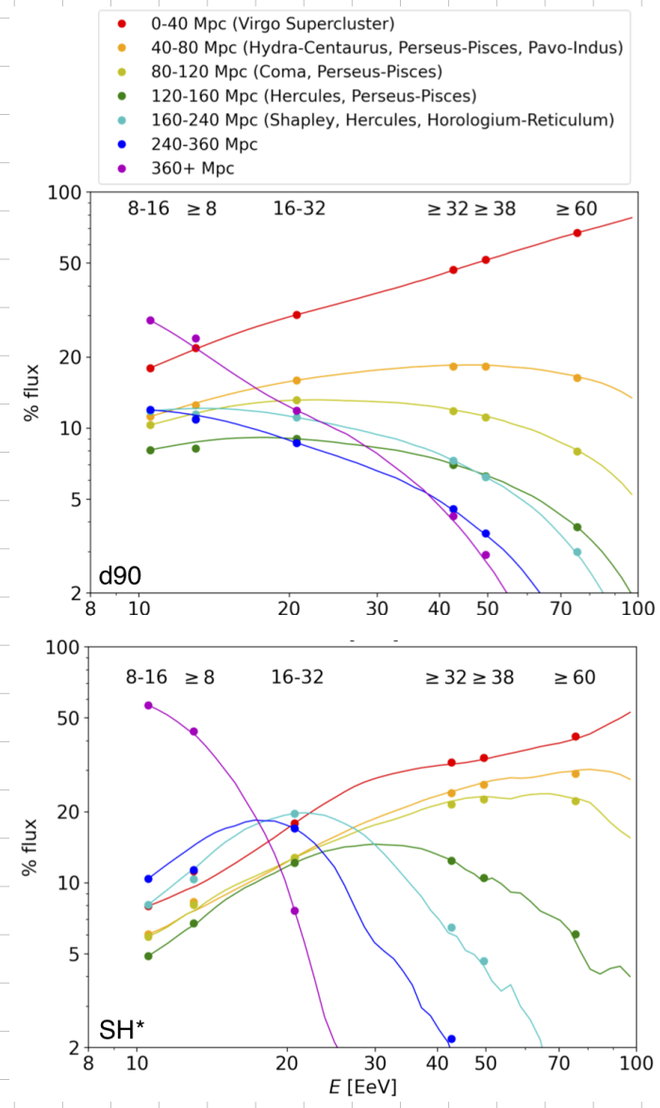

**Figure 1.** Reconstructed equatorial dipole amplitude (left) and phase (right). The upper limits at 99% CL are shown for all the energy bins in which the measured amplitude has a chance probability greater than 1%. The gray bands indicate the amplitude and phase for the energy bin $E \geqslant 8$ EeV. Results from other experiments are shown for comparison (IceCube Collaboration 2012, 2016; KASCADE-Grande Collaboration 2019).

https://doi.org/10.3847/1538-4357/ab7236

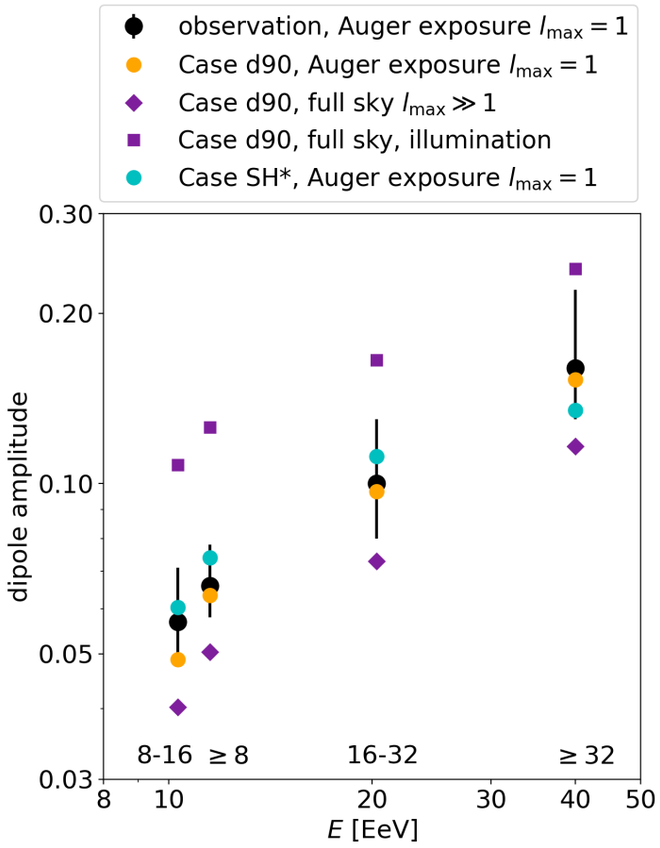
# The Imprint of Large Scale Structure on the Ultra-High-Energy Cosmic Ray Sky

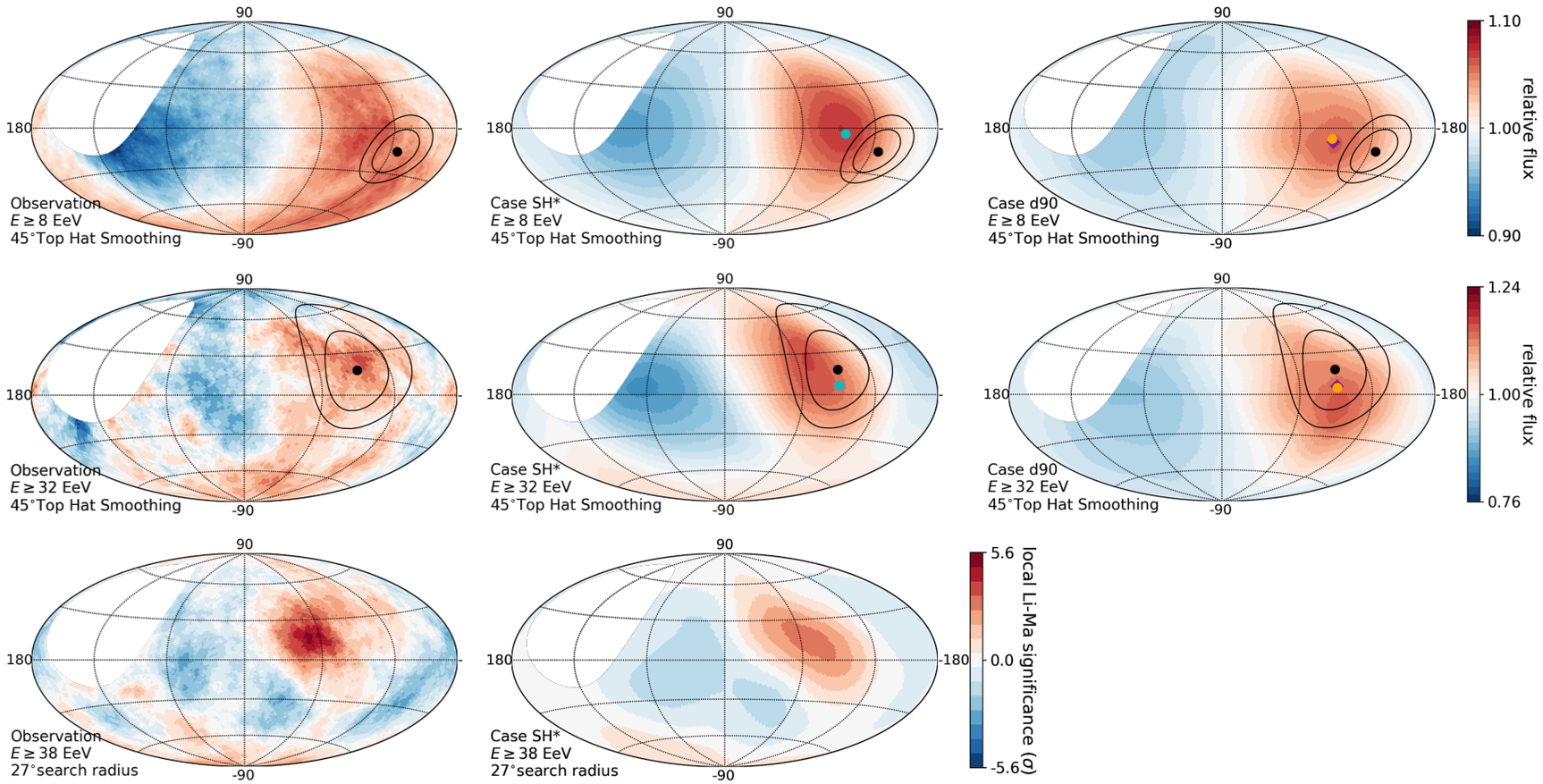


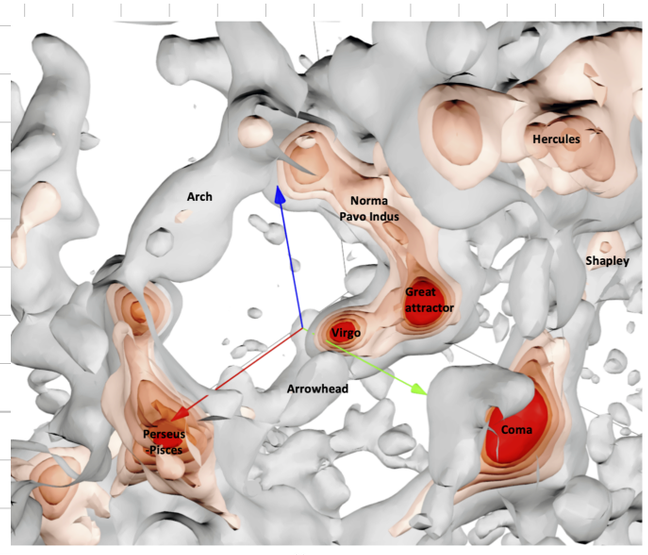

[https://sketchfab.com/3d-models/quasi-linear-construction-of-the-density-field- 91448f58ed5b4a30b5dc270a34fb4352



# The Imprint of Large Scale Structure on the Ultra-High-Energy Cosmic Ray Sky




*arXiv:2101.04564v2 [astro-ph.HE] 15 Jan 2021*

# Hotspot gesehen durch Teleskoce Array (TA)

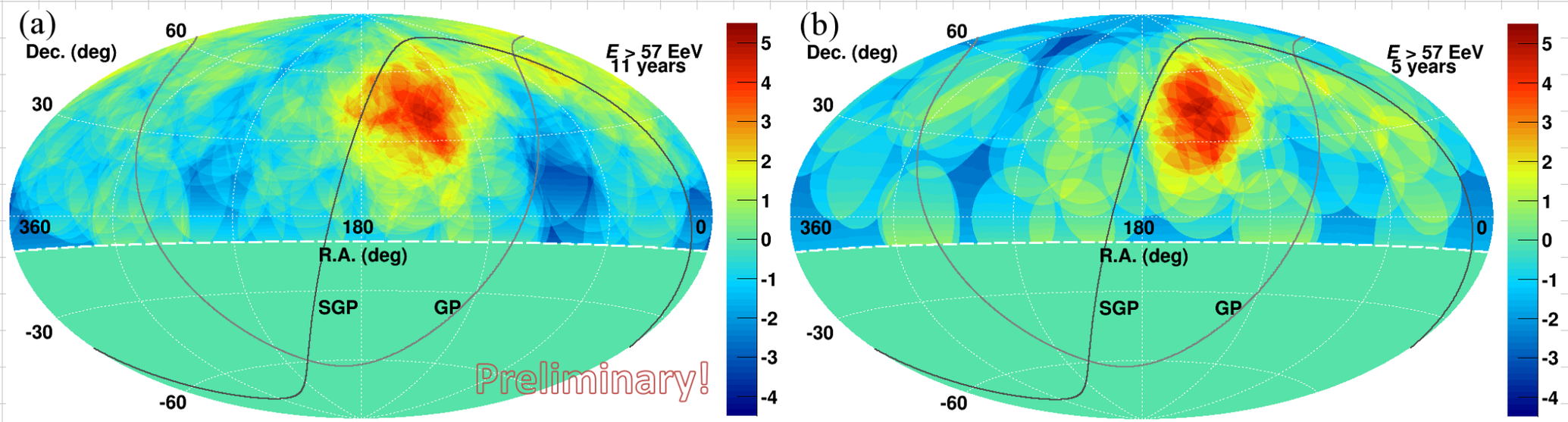
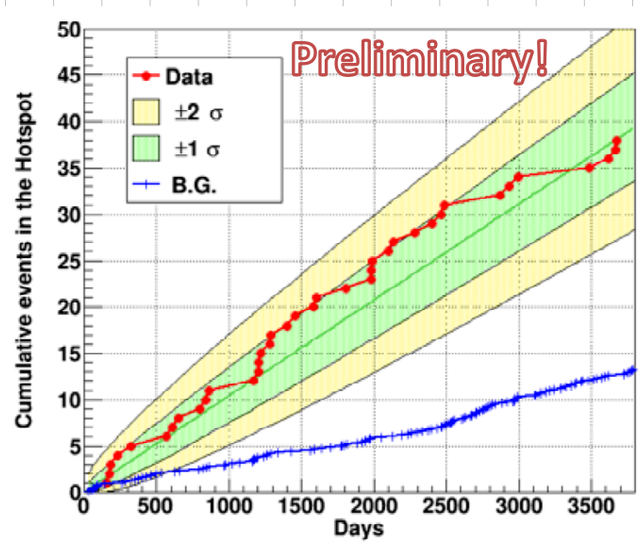
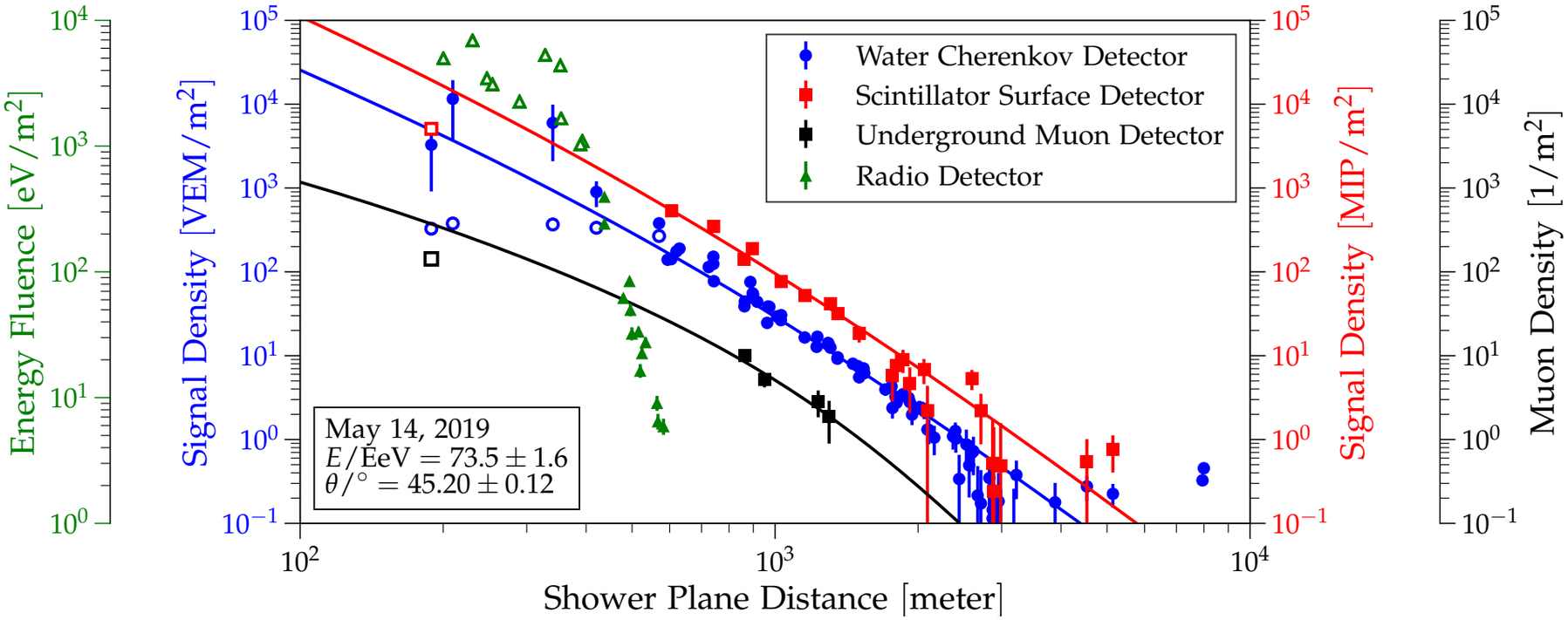
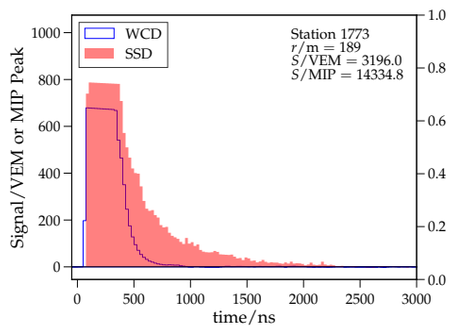


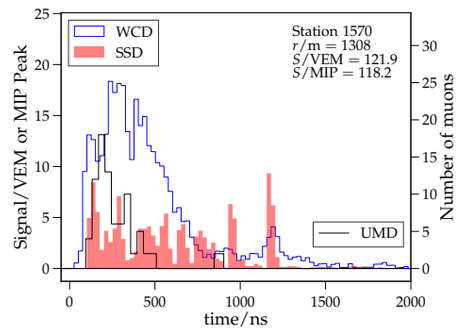

**Figure 1:** (a) A significance map of the UHECR events with $E > 57$ EeV for 11 years of TA data (May 2008 - May 2019) in the equatorial coordinates. Events are smoothed by 25° oversampling radius circle, which is defined in this paper. (b) A significance map of the UHECR events with $E > 57$ EeV for events observed in the 1st 5 years of TA data (May 2008 - May 2013). Events are smoothed by 20° oversampling radius circle according to our original paper [4]. The solid curves indicate supergalactic plane (SGP) and the galactic plane (GP).

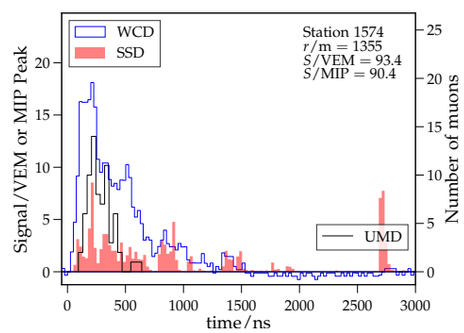


# AugerPrime
# Advent of multihybrid data



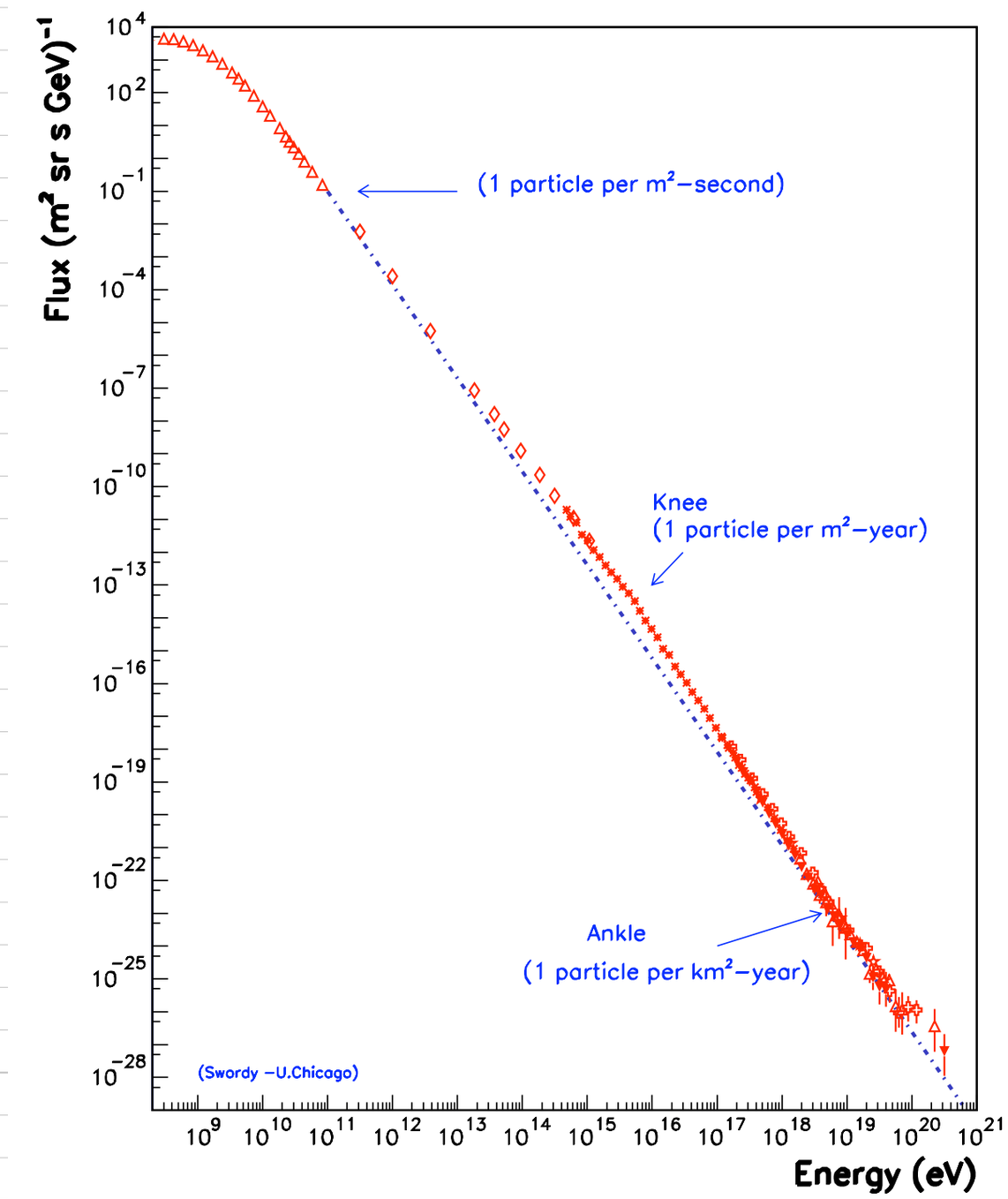



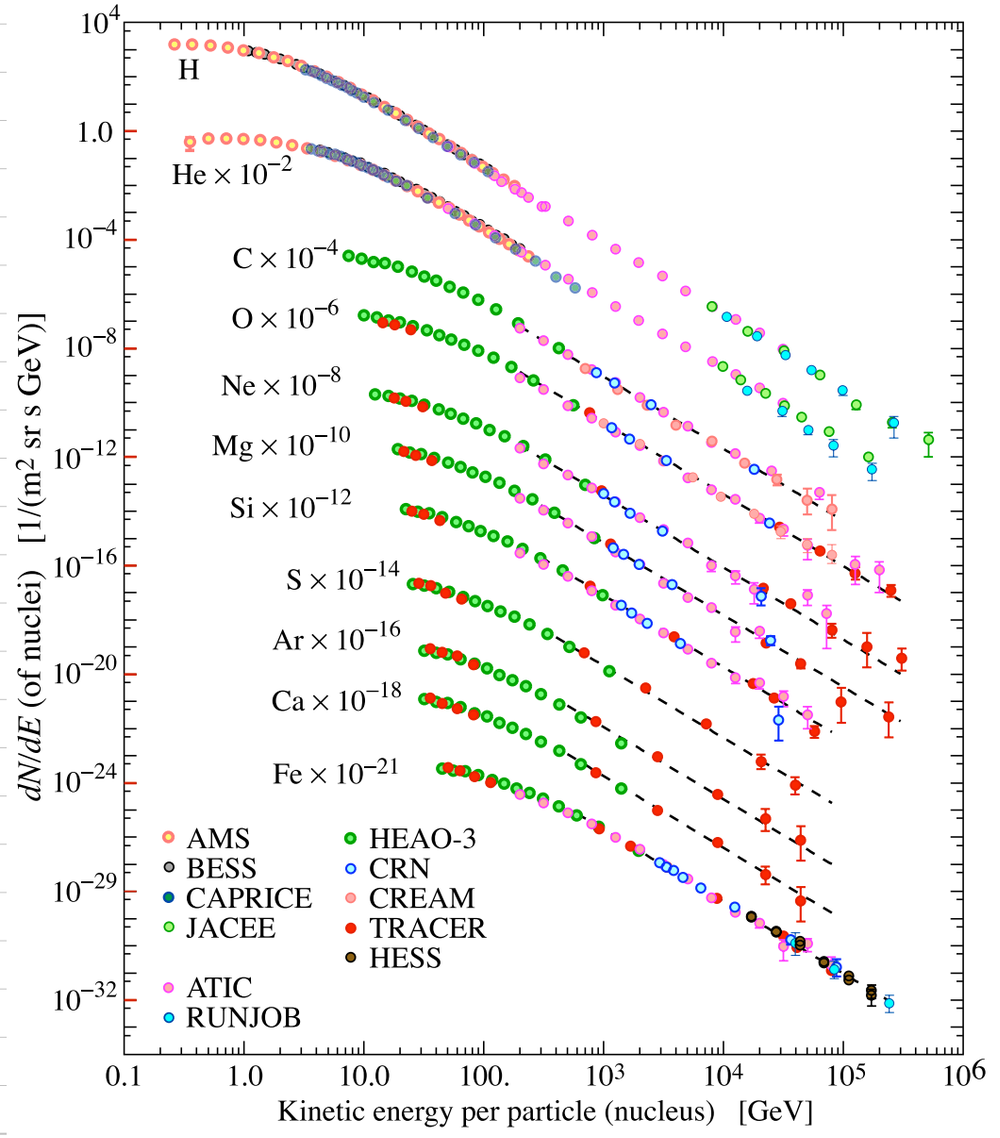



# Ausbreitung der kosmischen Strahlung in der Galaxie

# Eigenschaften der kosmischen Strahlung



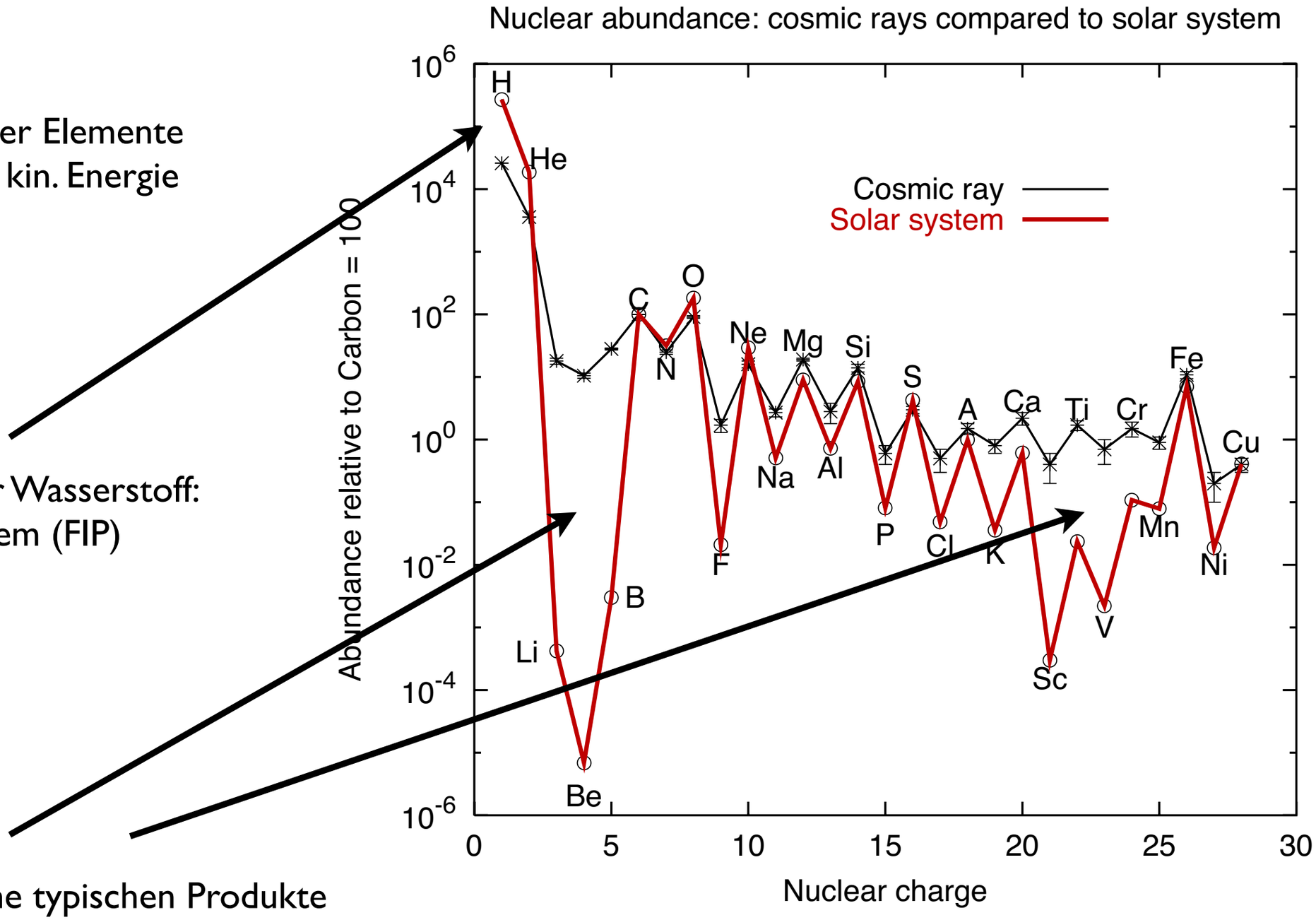



# Vergleich mit Häufigkeit im Sonnensystem

Darstellung der Elemente
bei ca. 1 GeV kin. Energie

Abweichung für Wasserstoff:
Injektionsproblem (FIP)

Elemente keine typischen Produkte
von SN Explosionen



# Isotropie der Ankunftsrichtungs-verteilung

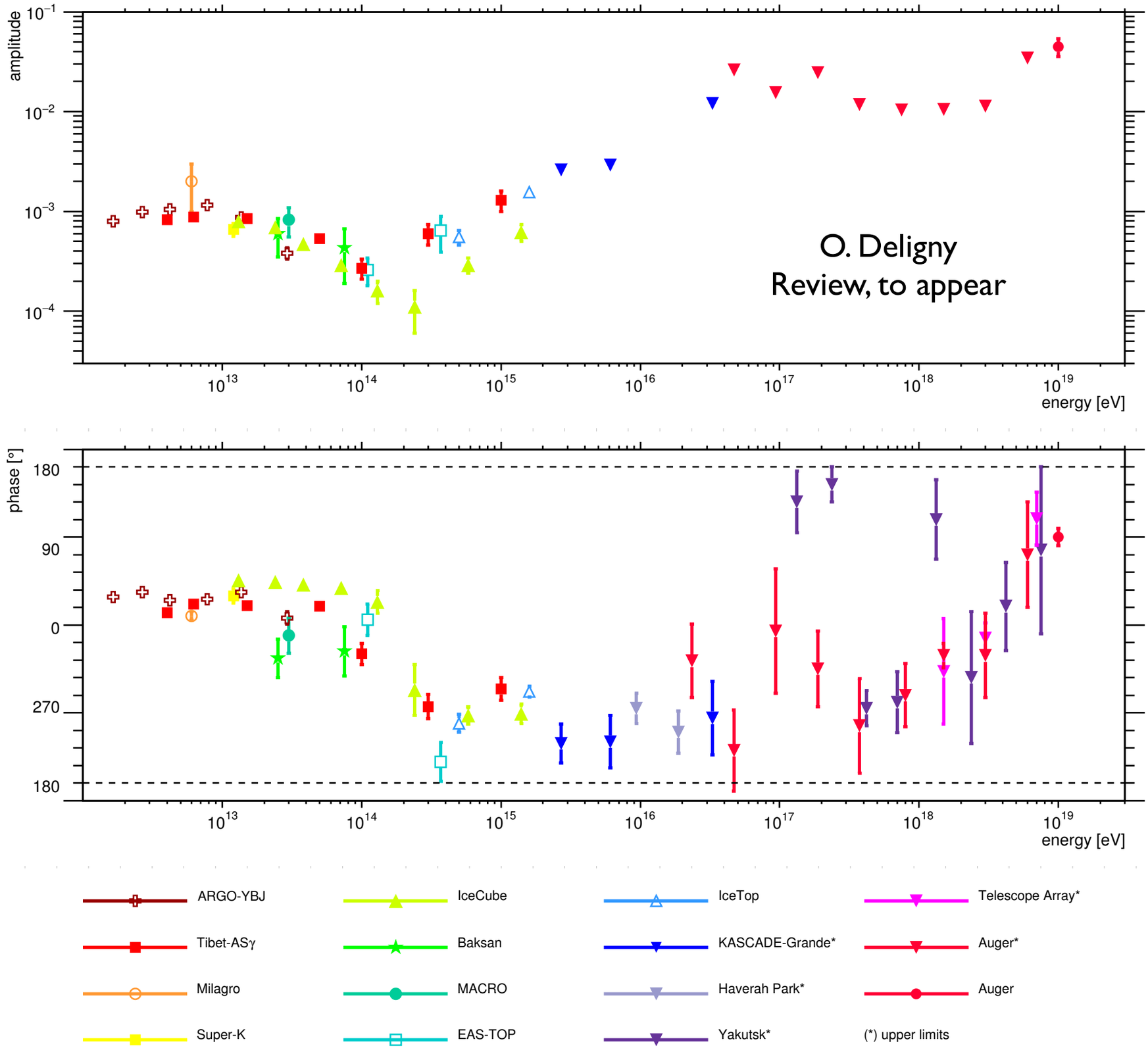



Figure 7: Amplitude (top) and phase (bottom) measurements of the first harmonic in right ascension as a function of energy, from various reports. Amplitudes drawn as triangles with apex pointing down are the most stringent upper limits up to date in the considered energy ranges.

*https://doi.org/10.1016/j.astropartphys.2018.08.005*

# Größenverhältnisse und galaktisches Magnetfeld

G. Giacinti M. Kachelrieß, D. V. Semikoz, G. Sigl

Prepared for submission to JCAP

*(Andromeda, M31)*

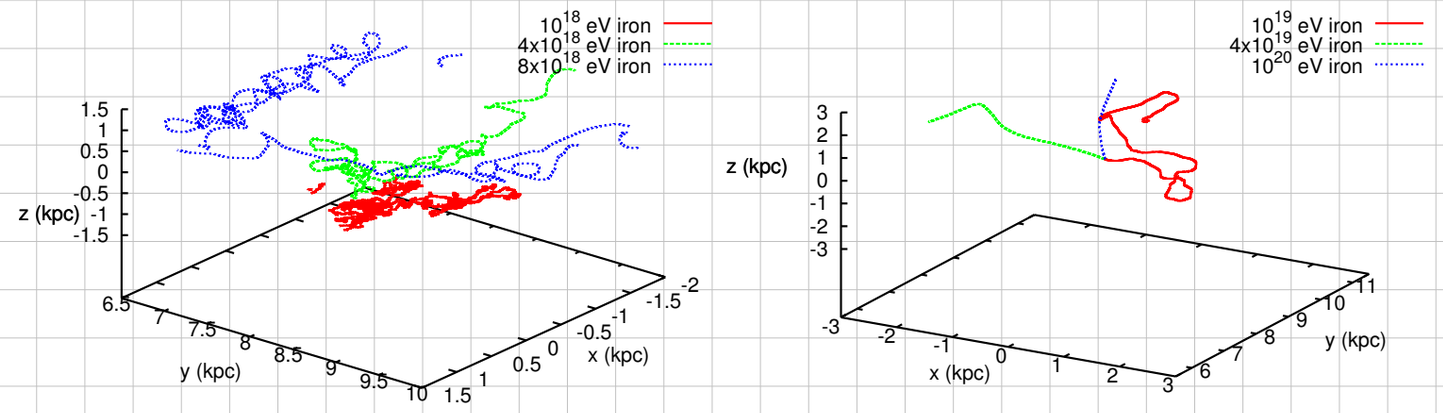
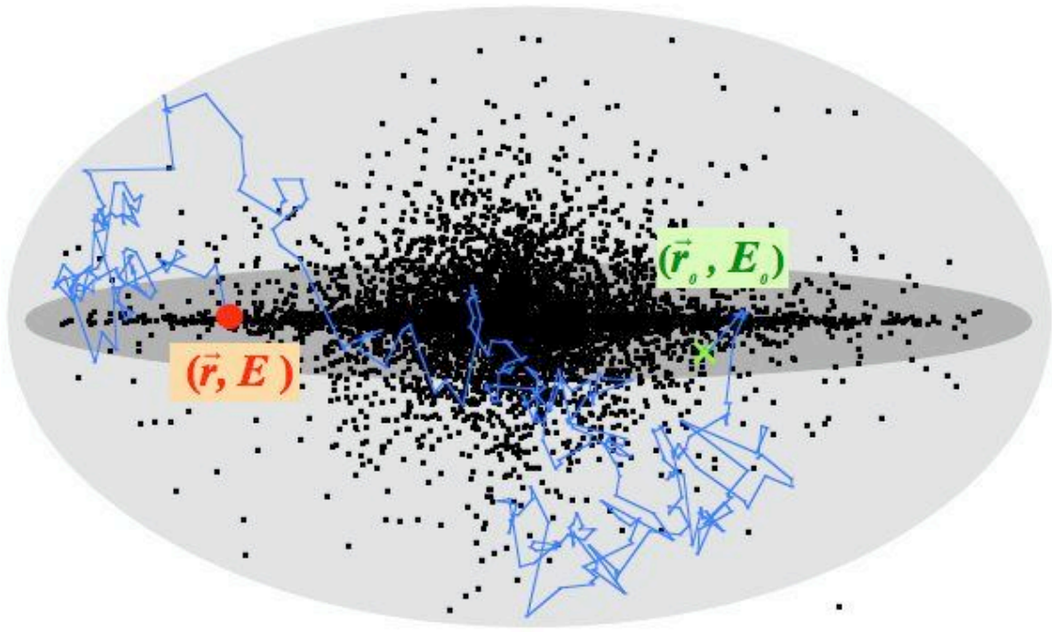



**Figure 1**. Trajectories of iron anti-nuclei backtraced from the Earth. **Left panel:** Energies equal to $(1, 4, 8) \times 10^{18}$ eV; **Right panel:** Energies equal to $(1, 4, 10) \times 10^{19}$ eV. For details on the Galactic magnetic field model, see text.

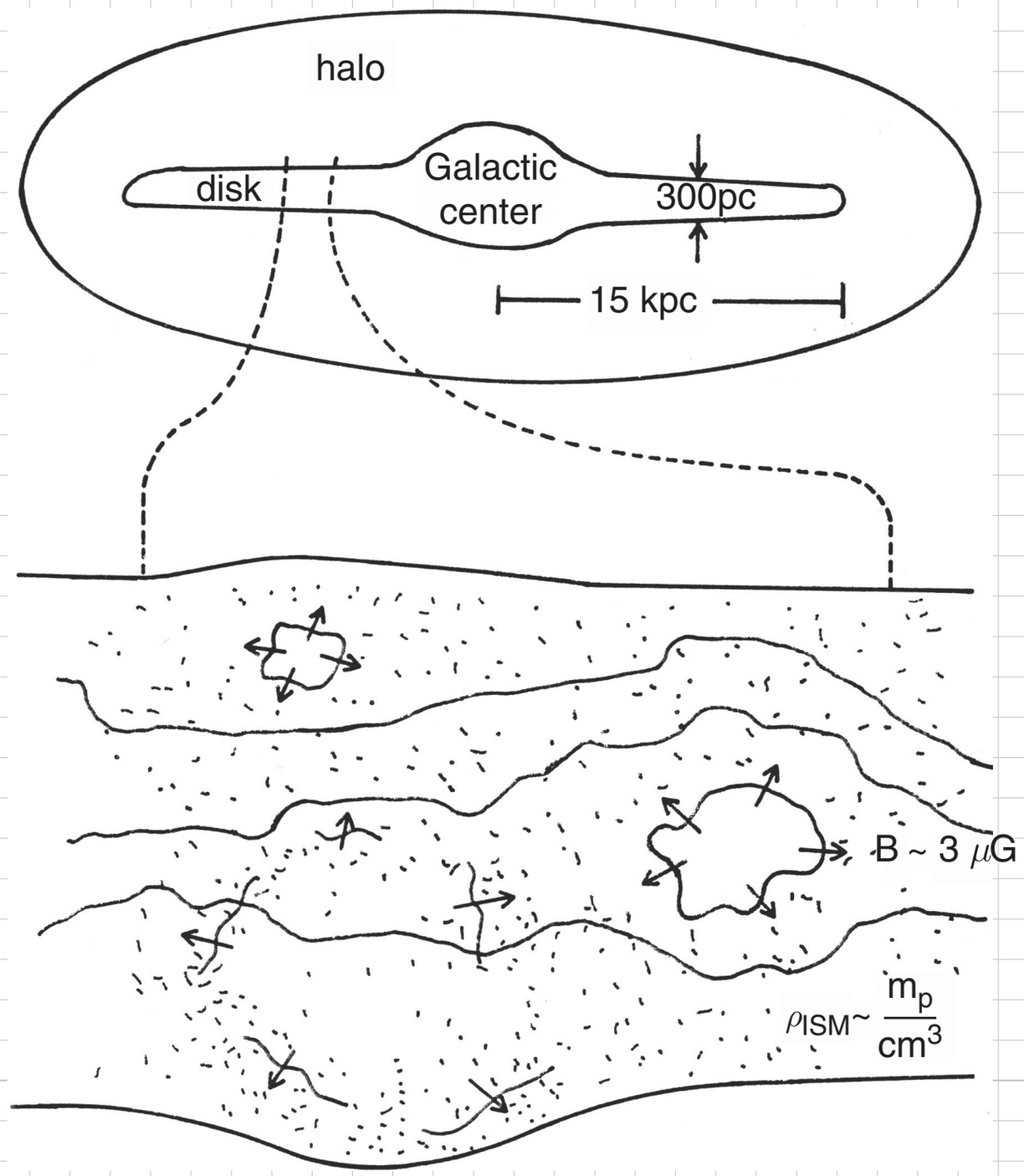
Magnetfeldkomponenten:
- Reguläre Feldkomponente: *Ballistische* Bewegung
- Turbulente Feldkomponente: Diffusion

$$R_L \simeq 1\,\mathrm{pc} \left(\frac{E}{10^{15}\,\mathrm{eV}}\right) \left(\frac{1\,\mu\mathrm{G}}{ZB}\right)$$




B=3μG=30 nT in der Nähe des Sonnensystems

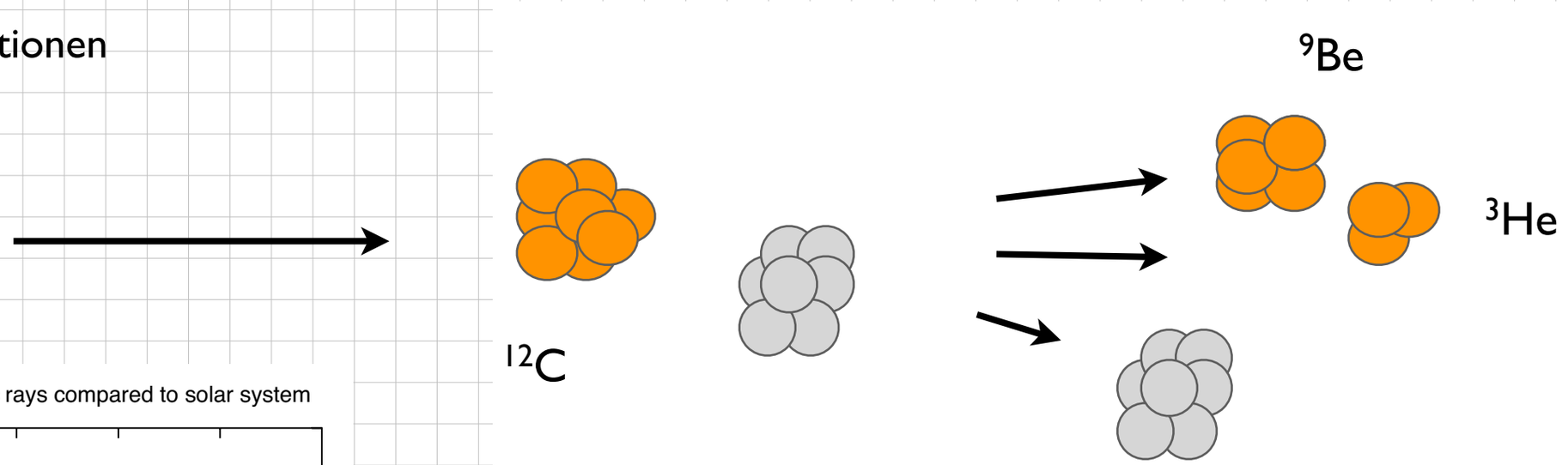
# Mögliche Quellen kosmischer Strahlung

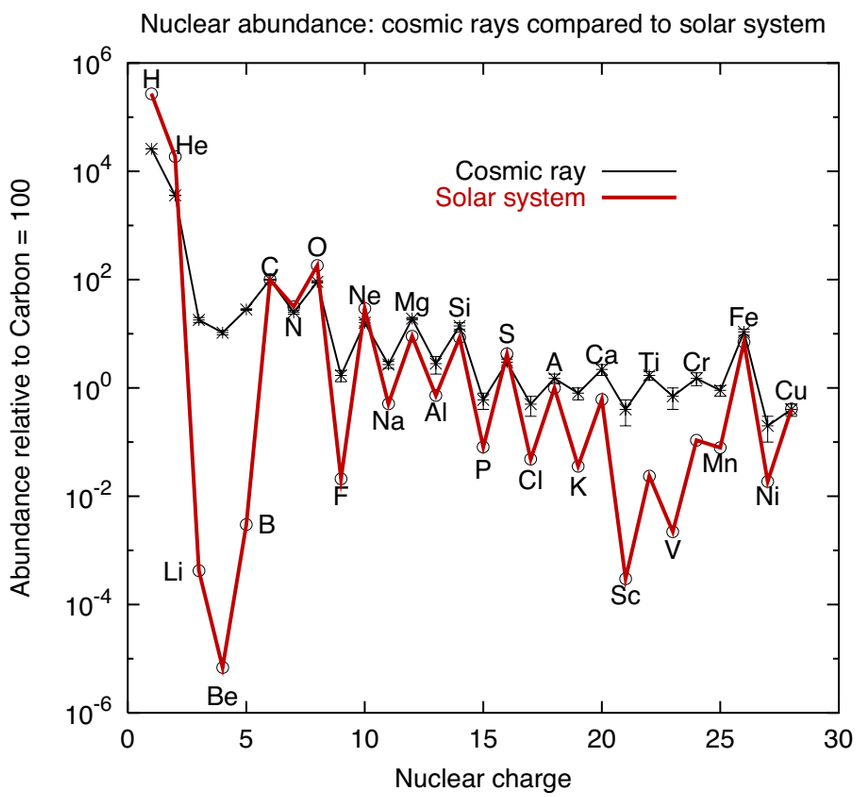


# Wechselwirkung mit interstellarem Medium

Restgas in der galaktischen Scheibe: ~1 Atom /cm³

Spallationsreaktionen




- Erklärung für Unterschiede in der Häufigkeit
- Energieabhängigkeit durch Entweichen von der Galaxie erwartet

# Transportgleichung: Übersicht

# Transportgleichung: Diffusion im Magnetfeld

# Exkurs: 1tes Ficksches Gesetz (Gastheorie)

# Transportgleichung: kontinuierliche Energieverluste