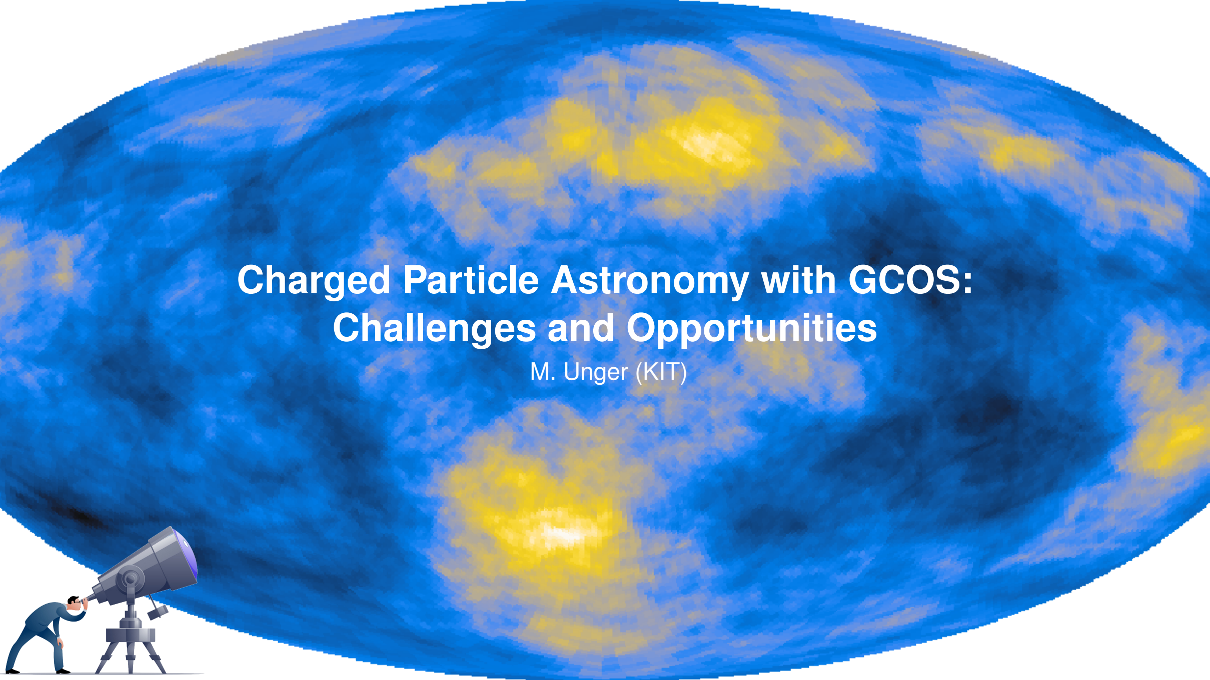
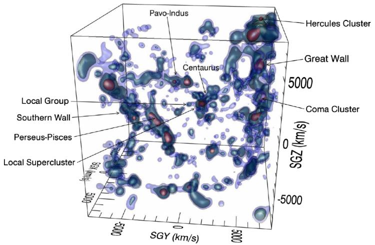


Charged Particle Astronomy with GCOS: Challenges and Opportunities

M. Unger (KIT)

Illustrating the Challenge

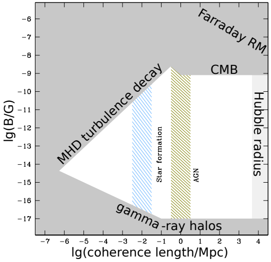
large-scale structure

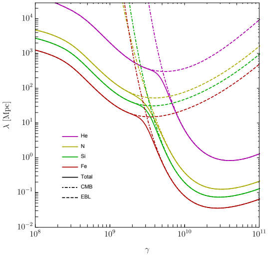


CosmicFlows Hoffman+2018

here: 2M++ density field, Carrick+2015

extragalactic propagation



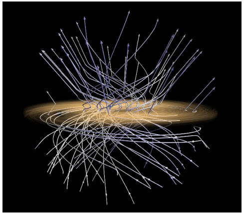


Durrer&Neronov 2013, J. Soriano (CUNY) 2018

here: neglect IGMF, attenuation via CRPropa

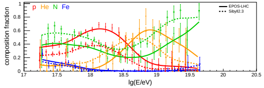
Galactic magnetic field

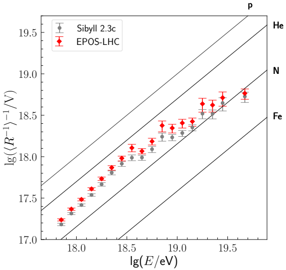
(coherent B and random b)



Jansson&Farrar 2012

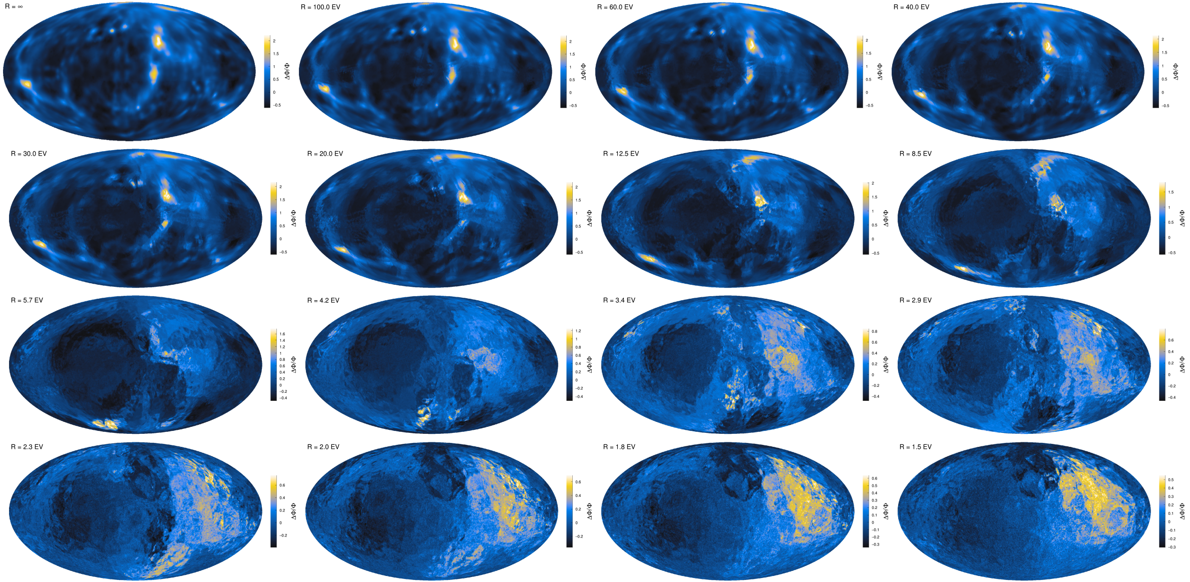
composition



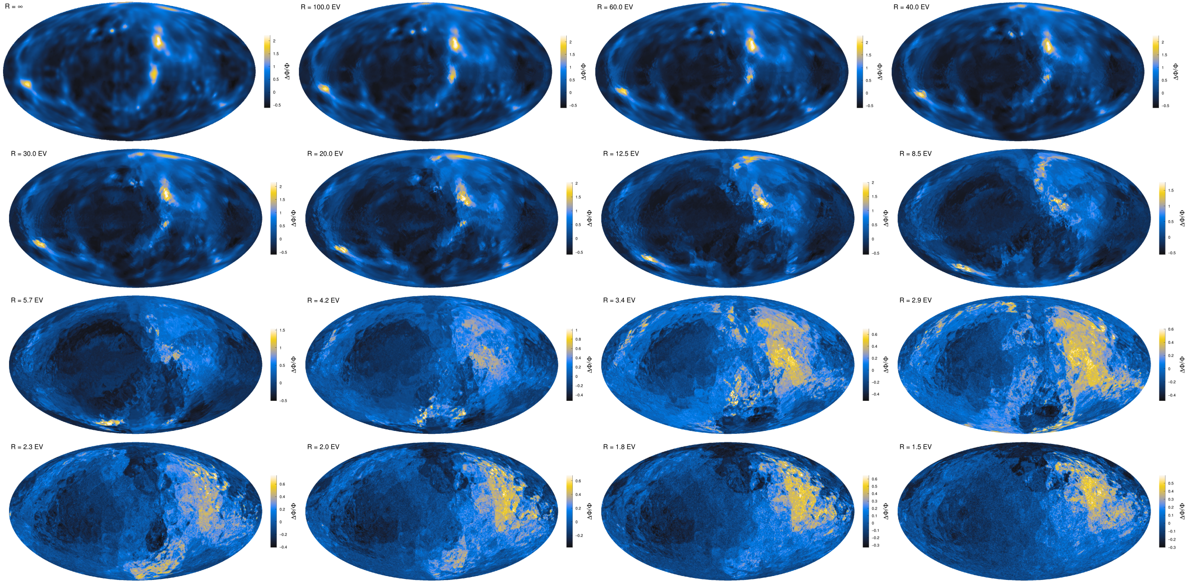


Auger 2014, O. Tkachenko (KIT)

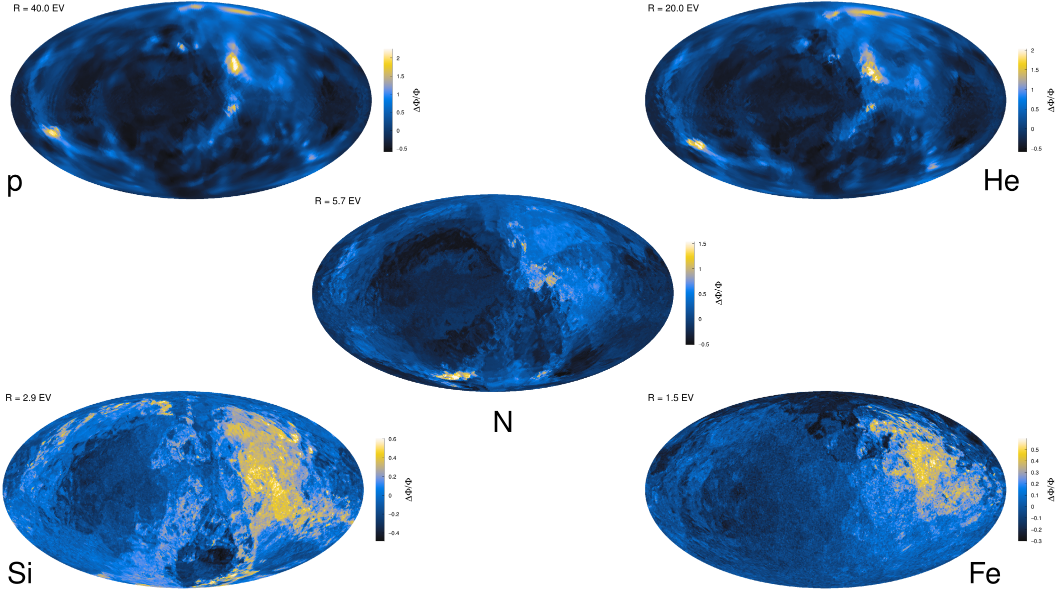
a) B, b, D_{max}=100 Mpc



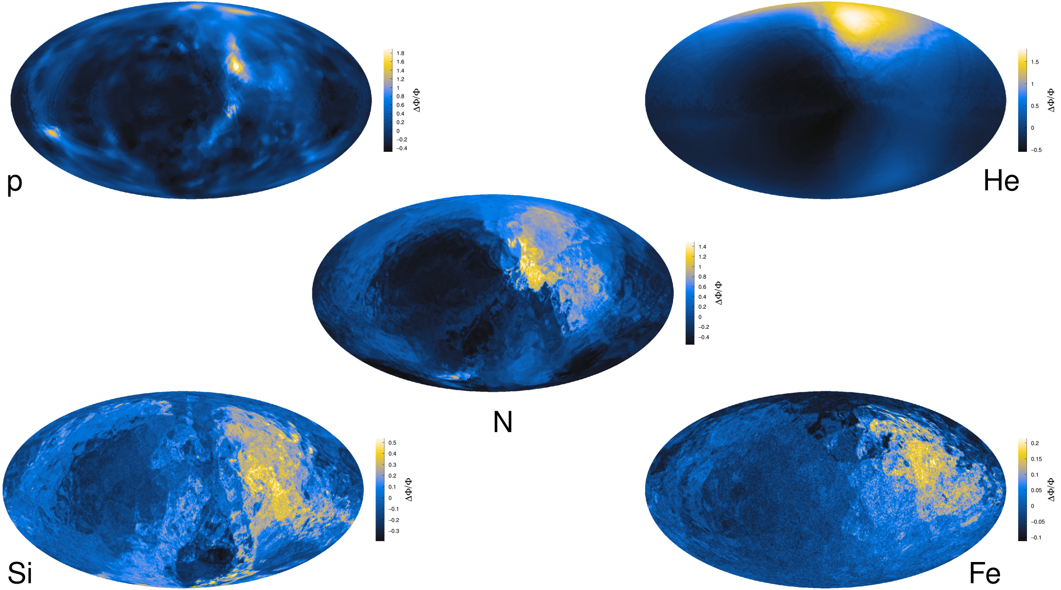
b) B, b, D_{max}=100 Mpc, different random realization



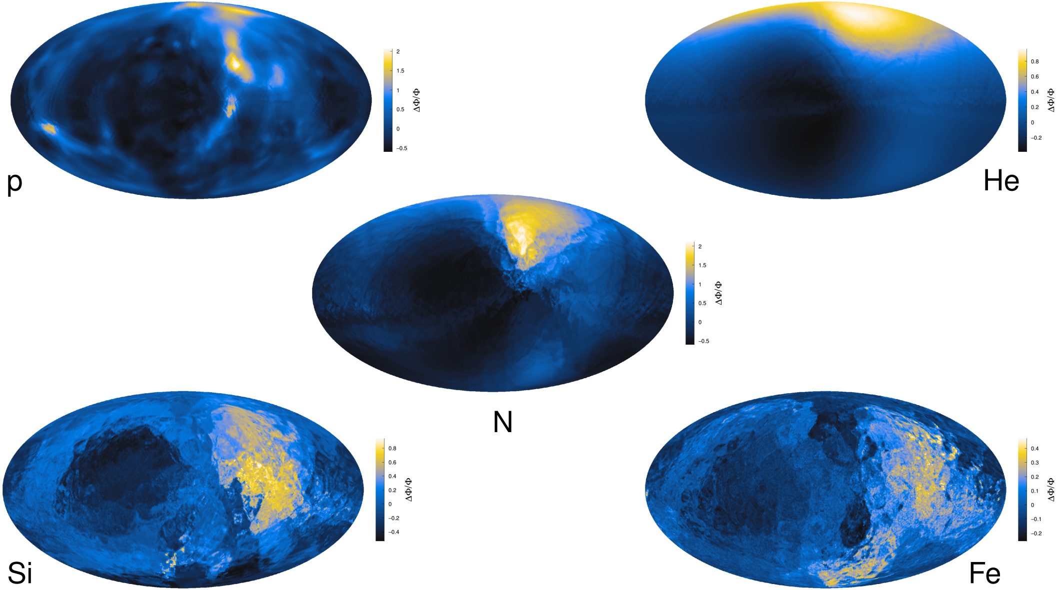
c) mixed composition ($E = 40$ EeV)



d) mixed composition & attenuation ($E = 40$ EeV)



d) mixed composition & attenuation ($E = 60$ EeV)



Shopping List

1) large exposure → high R
2) event-by-event charge

Wednesday

3) Z-calibration, EAS-uncertainties? → Tanguy, next session
4) UHE protons → AugerPrime / TAx4
5) improved GMF models (with uncertainties!) → this talk + IMAGINE
6) improved data analysis techniques → Glenny's talk
7) new GMF-related data:
   - LOFAR pulsars
   - PASIPHAE / PHAESTOS starlight polarization
   - ...

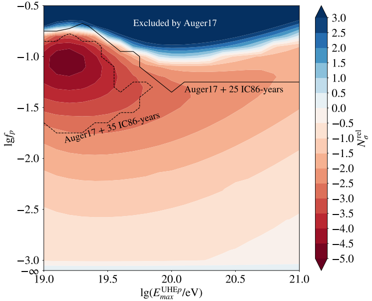
Marijke's talk

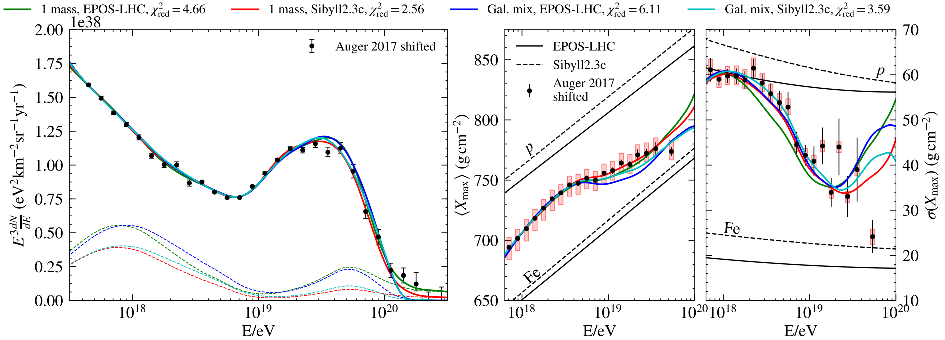
Protons at UHE?

energy fraction escaping source:

$$f_p = \frac{\int_{E_{\rm ref}}^{\infty} E\,Q_p \mathrm{d}E}{\int_{E_{\rm ref}}^{\infty} E\,(Q_p+Q_{\rm mix})\mathrm{d}E}$$

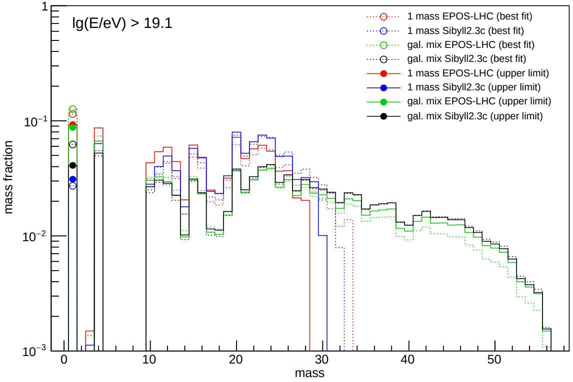
($Q_p \sim E^{\gamma_p}\, e^{-E/E_{\max}^{\mathrm{UHE}p}}$, $\gamma_p = -1$ and $E_{\rm ref} = 10^{19}$ eV)

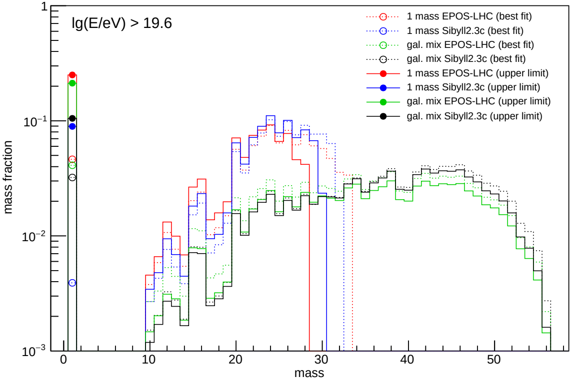




Protons at UHE?

low R_{max}, small He photo-disintegration pathlength at UHE
$\rightarrow$ideal window for proton-nucleus separation!

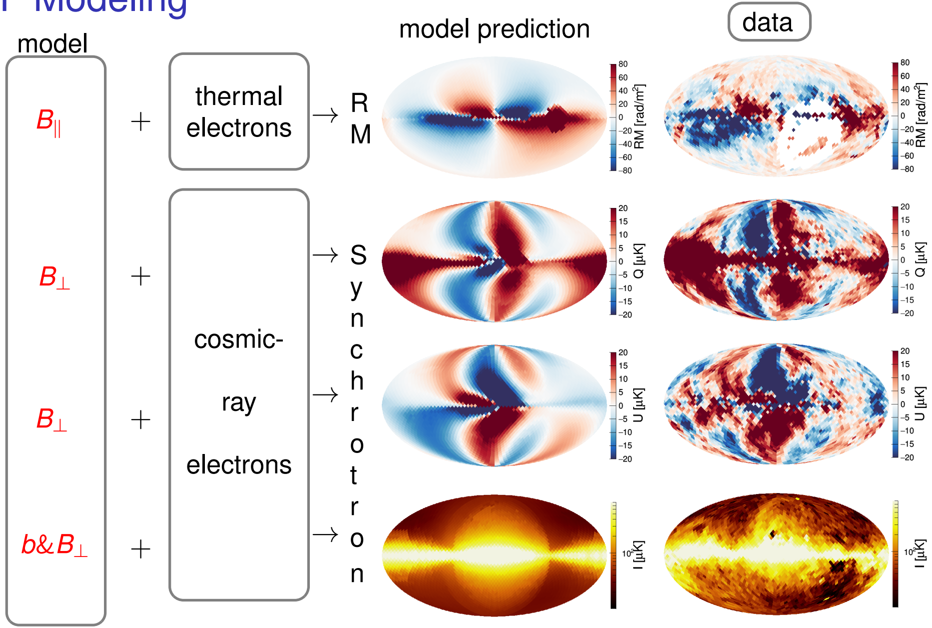




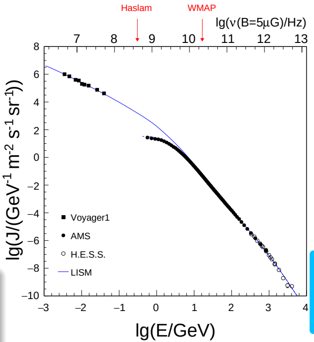
Composition fractions of Muzio+2019 models, plots from POEMMA UHECR paper, PRD2020

GMF Modeling

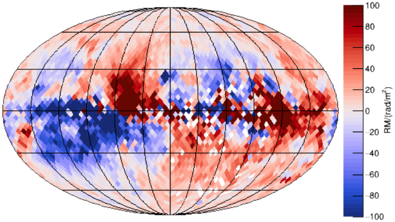
Jansson&Farrar 2012



GMF Modeling

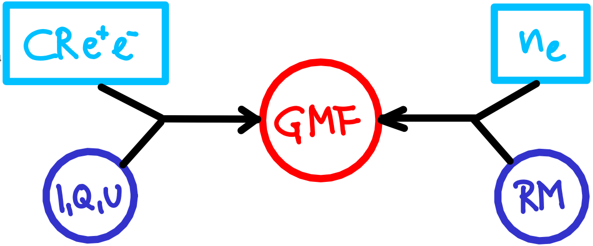


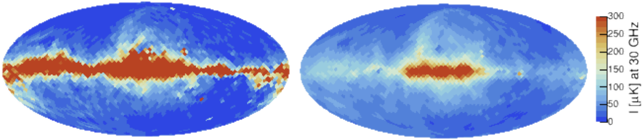
MU&Farrar in prep.

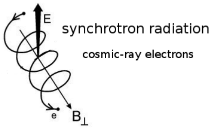


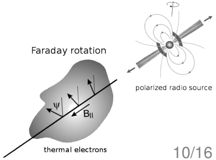
new data since JF12:

- full-sky RMs
- pulsars (RM&DM)
- precise $e^{\pm}$ at Earth
- final WMAP maps
- Planck maps

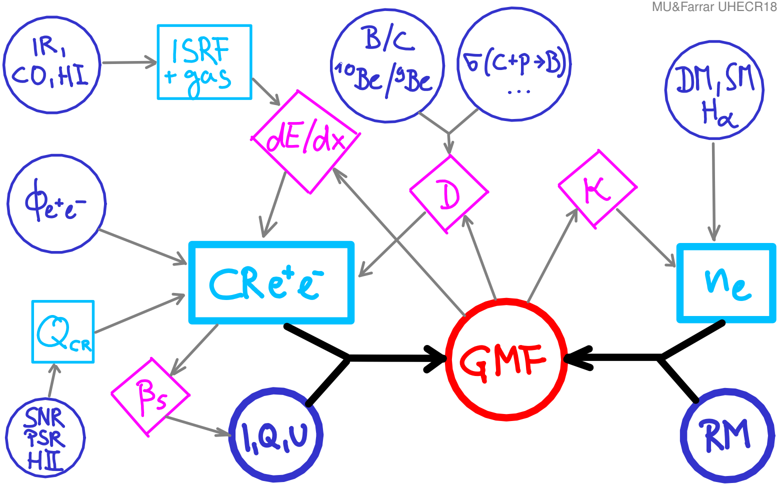








GMF Modeling



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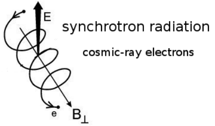
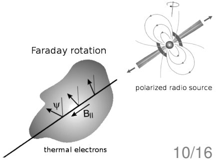
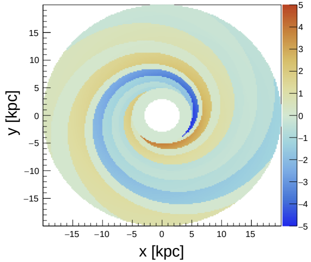


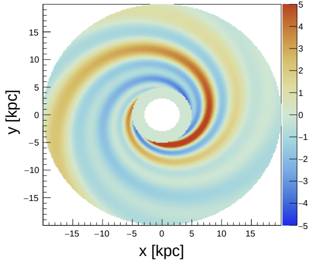


Model Developments

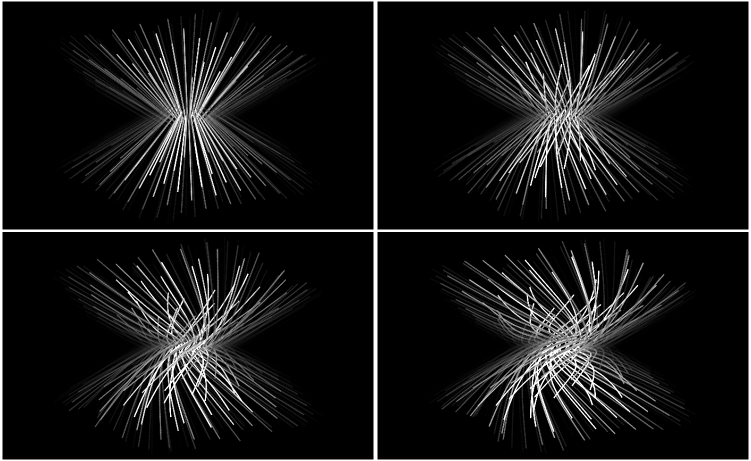
Brown+07 “wedge”-model:



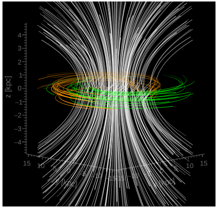
smooth spiral disk field:

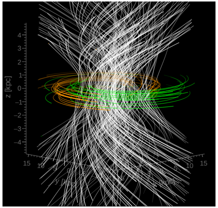


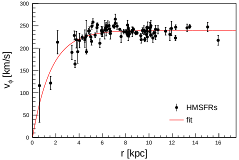
- evolve poloidal field via induction equation
- radial and vertical shear of Galactic rotation generates toroidal field

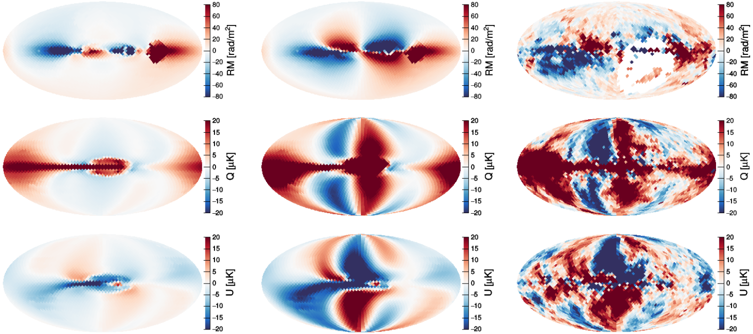


Model Developments





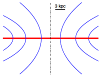


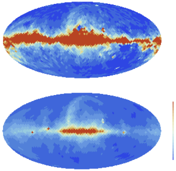


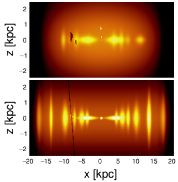
(a) t = 0 Myr (b) t = 70 Myr (c) data

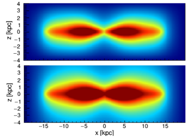
Model Variations and Refits

id	disk	toroidal	poloidal	NE	ncre	QU	misc	χ^2/ndf
Parametric models								
a	JF	JF	JF	01	GP_JF	W7	-	1.10
b	JF	JF	FTC	01	GP_JF	W7	-	1.09
c	JF	JFsym	FTC	01	GP_JF	W7	-	1.11
d	JF	JFsym	FTC	01	GP_JF	W7	warp	1.11
e	UF	JFsym	FTC	01	GP_JF	W7	-	1.09
f	UF	UF	UFa	01	GP_JF	W7	-	1.14
g	UF	UF	UFb	01	GP_JF	W7	-	1.09
Synchrotron products								
h	JF	JFsym	FTC	01	GP_JF	W9base	-	1.22
i	JF	JFsym	FTC	01	GP_JF	W9sdc	-	1.24
j	JF	JFsym	FTC	01	GP_JF	W9fs	-	1.11
k	JF	JFsym	FTC	01	GP_JF	W9fss	-	1.22
l	JF	JFsym	FTC	01	GP_JF	P15	-	0.78
Thermal electrons								
m	JF	JFsym	FTC	16	GP_JF	W7	-	1.21
n	UF	JFsym	FTC	16	GP_JF	W7	-	1.14
o	JF	JF	FTC	01	GP_JF	W7	$\kappa = -1$	1.05
p	JF	JF	FTC	01	GP_JF	W7	$\kappa = +1$	1.05
q	JF	JFsym	FTC	01	GP_JF	W7	HIM	1.12
Cosmic-ray electrons								
r	JF	JFsym	FTC	01	O13a	W7	-	1.13
s	JF	JFsym	FTC	01	O13b	W7	-	1.12
t	JF	JFsym	FTC	01	S10	W7	-	1.13



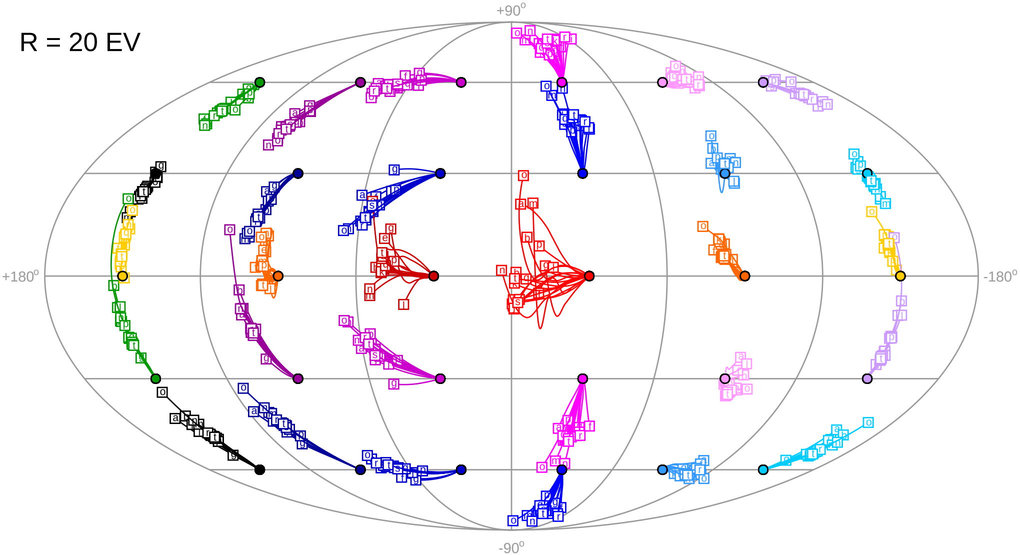






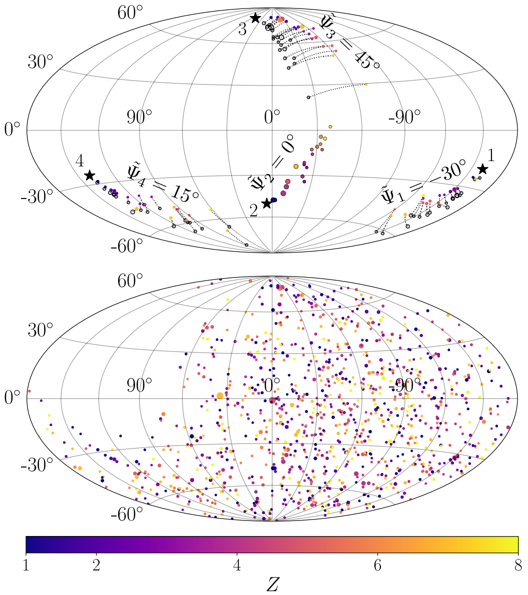
Model Variations – Effect on Backtracked Arrival Directions

R = 20 EV

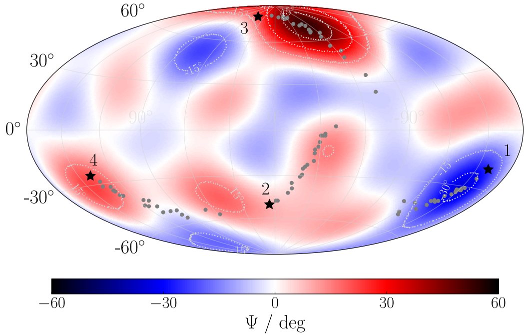


Model Pertubations?

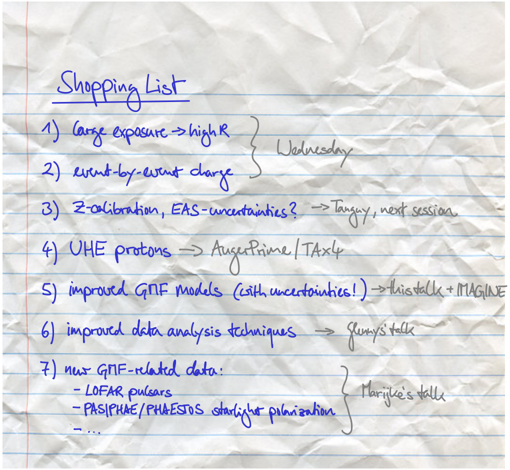
Wirtz, Bister & Erdmann, 2101.02890



- tangent deflection vector field
- fit multipole expansion of difference to e.g. JF12 (here: rotation angle ψ)
- $\ell_{\max} = 5 \rightarrow$36 fit parameters(!)



Summary – Charged Particle Astronomy With GCOS*



Challenges:

- $\langle R \rangle \leq 10^{19}$ eV for $E < 10^{20}$ eV
- need to isolate lightest air showers
- complicated interplay R (deflection) and E (attenuation)

Opportunites:

- UHECR spectrometry ($\theta_{\mathrm{defl}} \propto Z/E$) and tomography ($D_{\mathrm{max}} \propto E/A$)
- study GMF and EGMF
- "How isotropic can the UHECR flux be?"

di Matteo&Tinyakov 2017

* or any other next-generation UHECR observatory