

IMAGINE: the Galactic Magnetic Field with CRPropa

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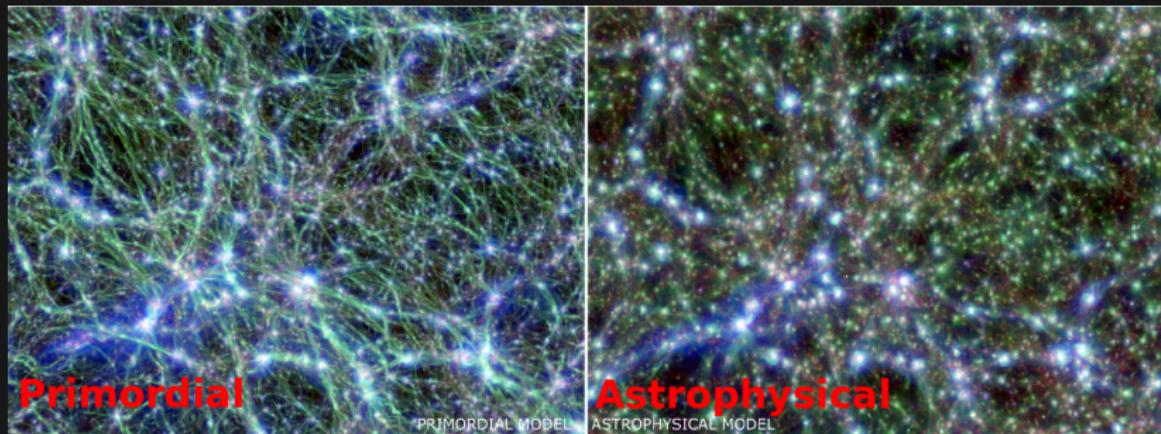
Supervisors: Marcus Brüggen, Franco Vazza

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My recent work

Propagation of UHECRs
learn about the intergalactic magnetic field & its origins
... tough business without sources ...
Hackstein et al. 2016 & 2018, MNRAS

6 constrained models available at crpropa.desy.de



My current work

PREFRBLE:

Predict Fast Radio Bursts to obtain Likelihood Estimates

Study origin of IGMFs with **Fast Radio Bursts**:

Hackstein et al. 2019, MNRAS

Result: < 100 FRBs with RM \Rightarrow **origin and strength of IGMF**
important for extragalactic UHECR propagation

\sim 50 RM of FRBs in pipeline (CHIME/FRB, Canada)
observations available by **spring of 2020!!!**

free access python package for observers and theorists
compare results by clicking a button

FRB newsletter by Emily Petroff: I can send the form around

The Galactic Magnetic Field

UHECRs are deflected by the GMF

Unger 2017 & Farrar 2014

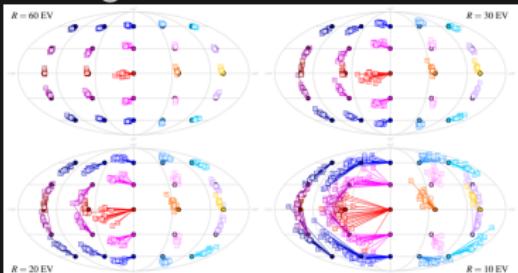
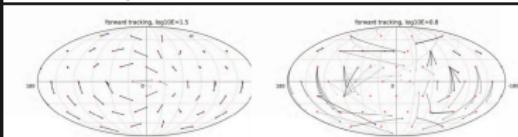


Figure 2: Backtracking of charged particles at different rigidities from a regular grid of initial directions (dots) through different models of the coherent GMF. The resulting directions outside of the Galaxy are denoted by squares and the letters correspond to the models listed in Table 1. The sky maps are in Galactic coordinates and the particle rigidities indicated in corners of each panel.



Problem: all kinds of θ and \vec{d} predicted by different GMF models

Reason: different 1.purpose, 2.observable and 3.parametrization

IMAGINE: one model to rule them all

J. Rachen,

astro.ru.nl/imagine



- ▶ consider all observables of the GMF & combine information
- ▶ model in different parametrization using Bayesian methods
- ⇒ provide a single model suitable for every astrophysical topic

IMAGINE: Boulanger et al. 2018

IMAGINE Consortium

combines knowledge of huge variety of astrophysical topics



Marijke Haverkorn (EG RM & synchrotron), Tess Jaffe (model),
Thorsten Enßlin (IFT), Anvar Shukurov (Math. Astrophysics),
Francois Boulanger (ISM), Jörg Hörandel (CRs),
and many more



How it works

generate model → compute observables → compare observations
→ adjust parameters → repeat
⇒ converge to find best fit model

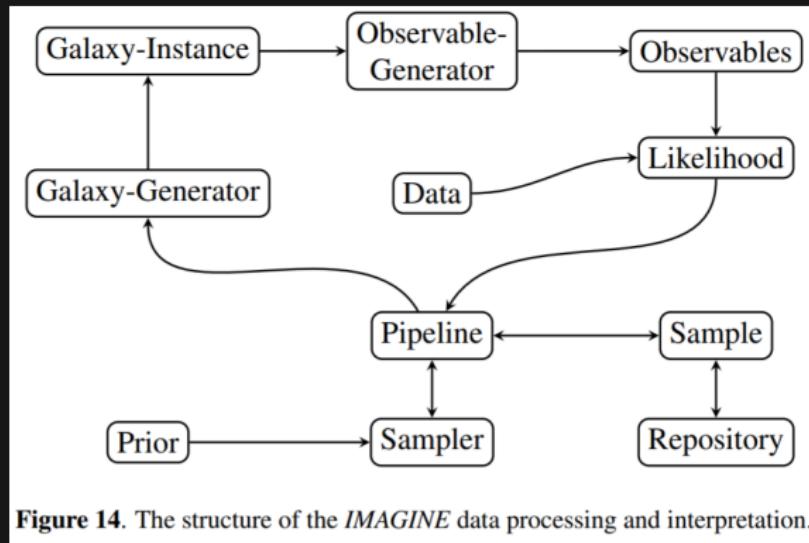
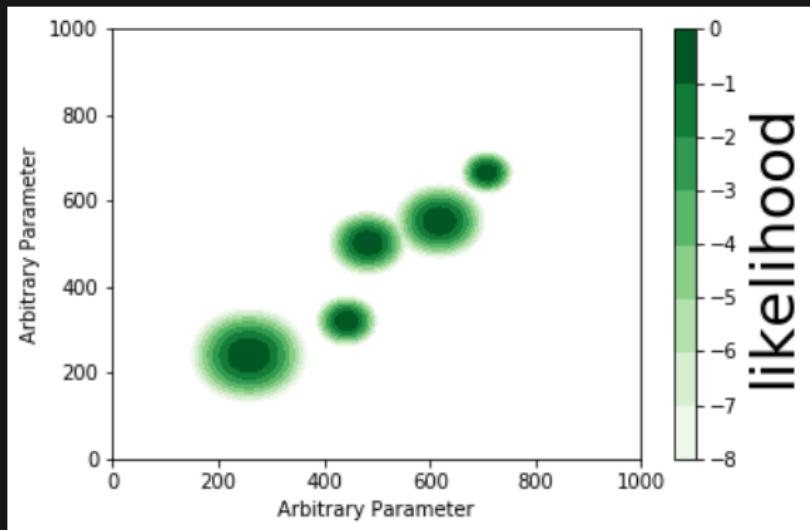


Figure 14. The structure of the *IMAGINE* data processing and interpretation.

How it works

generate model → compute observables → compare observations
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fast iteration ⇒ sample parameter space

IMAGINE includes galactic CRs,
but not UHECRS!

deliver (best?) information on halo field

Can we IMAGINE CRPROPA?

- ▶ fast iteration? but CRPopa is slow! ⇒ use in post-processing
- ▶ What UHECR observables to use? (Auger Dipole, ...)
- ▶ constrain islands in parameter space by
 - ▶ compare best fit of separate islands
 - ▶ sample space of individual islands
- ▶ no info on GMF without sources!
?use limited but exhaustive set of reasonable sources?
- ▶ What about the IGMF?
?representative set of models? (semi-)analytic approach?
- ▶ ...

IMAGINE Pros and Cons

Cons:

- ▶ tough piece of work
- ▶ perhaps low impact on final result

Pros:

- ▶ GMF model that entails UHECR data,
well suited to model UHECR deflection
- ▶ better constraints on B in MW-halo
- ▶ interdisciplinary collaboration with very smart guys
more people will know CRPropa
more users for growing usability
- ▶ drop as many IMAGINE jokes as you like!

Thanks for your opinion!

... and for the nice meeting!

Enjoy your lunch!

Dicussion: Conclusions

GMF use the best fit models in islands in parameter space
observabes all available global observables of UHECRs: large amount of isotropy, spectrum, composition (anisotropy), TA intermediate scales anisotropy, local generalized multiplets, ...

Sources representative sample of source scenarios:

Super-galactic plane, Radio galaxies (Rachen), starburst galaxies, ...

Individual source properties can be investigated, once a good IMAGINE model was found.

IGMF very strong vs. very weak IGMF model (Batista & Hackstein). Plus a purely turbulent = source spread scenario?

Energies all observables \Rightarrow full CRPropa run

composition best-fit extragalactic source composition?

CenA single source scenario: more idealized CRPropa run

Way to Go

1. prepare 2D EGMF prediction
 - ▶ run CRPropa, combining all source and IGM scenarios
 - ▶ collect particles that enter MW-DM-halo
2. pick best fit models of IMAGINE
 - ▶ consider (available) results of all telescopes, smooth overlap
 - ▶ backtrack observed UHECRs to border of MW-DM-halo
3. compare 1. and 2.
 - ▶ maps with identical pixelization
 - ▶ renormalize to 1 → likelihood function for directions
 - ▶ use difference of $P(\text{pix})$ to compute likelihood: !! care for $|P - P| = 0$ maximizes likelihood !!