A13,F17: 高エネルギー宇宙線強度の恒星時異方性の観測

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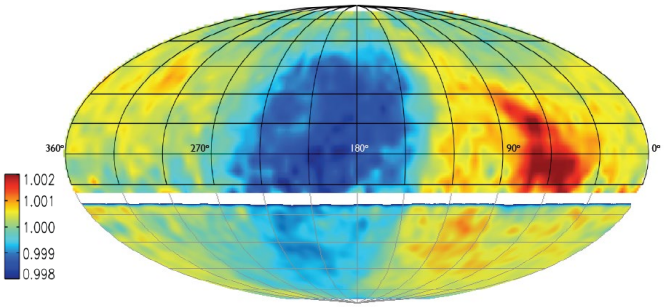
旅費：195千円（全額を次年度に繰越し）

Heliospheric modulation (distortion) in MHD model heliosphere



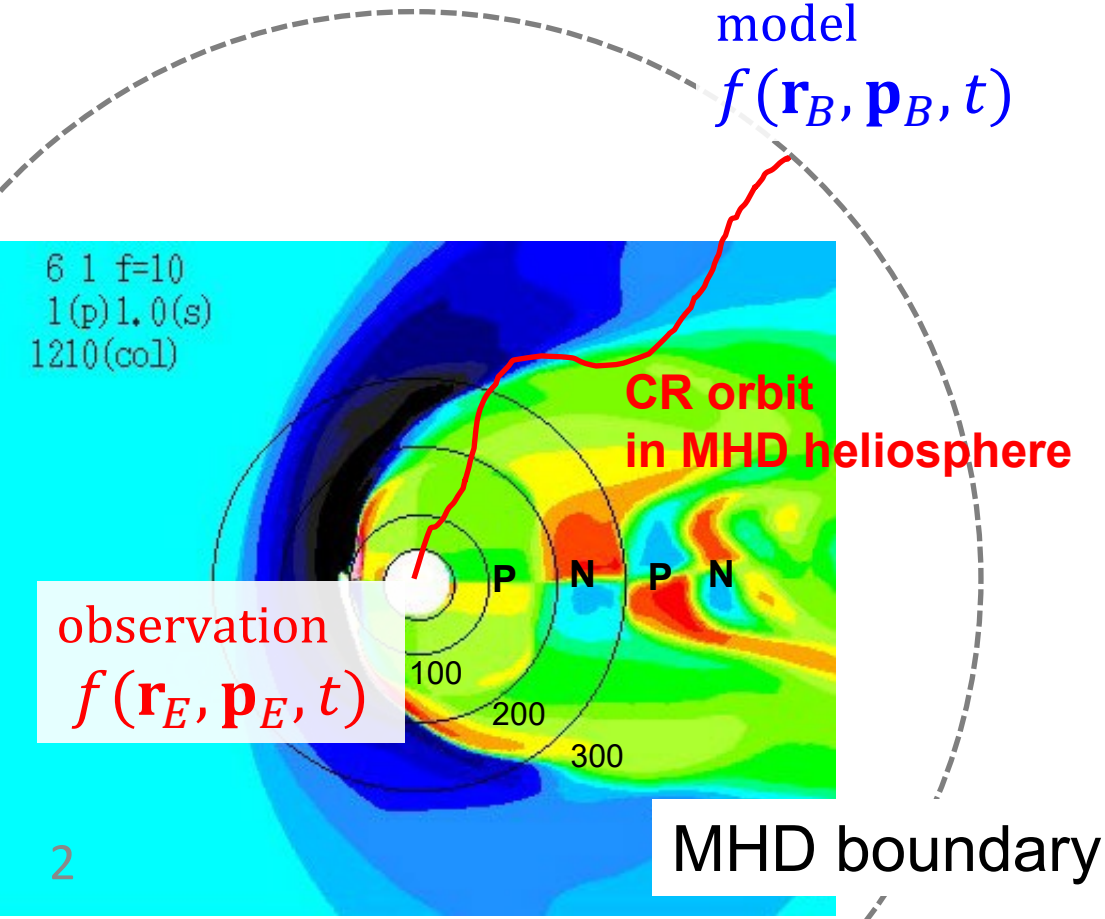
Tibet ASγ (7 TeV)
(Amenomori et al., Science, 314, 2006)

Ice Cube (20 TeV)
(Abbasi et al., arXiv:1005.2960v1, 2010)

Phase-space density of CRs: $f(\mathbf{r}, \mathbf{p}, t)$

$$Df = \frac{\partial f}{\partial t} + \frac{d\mathbf{r}}{dt} \cdot \frac{\partial f}{\partial \mathbf{r}} + \frac{d\mathbf{p}}{dt} \cdot \frac{\partial f}{\partial \mathbf{p}} = \left(\frac{\partial f}{\partial t}\right)_c \approx 0$$

$$\frac{d\mathbf{p}}{dt} = Ze\left(\mathbf{E} + \frac{d\mathbf{r}}{dt} \times \mathbf{B}\right)$$

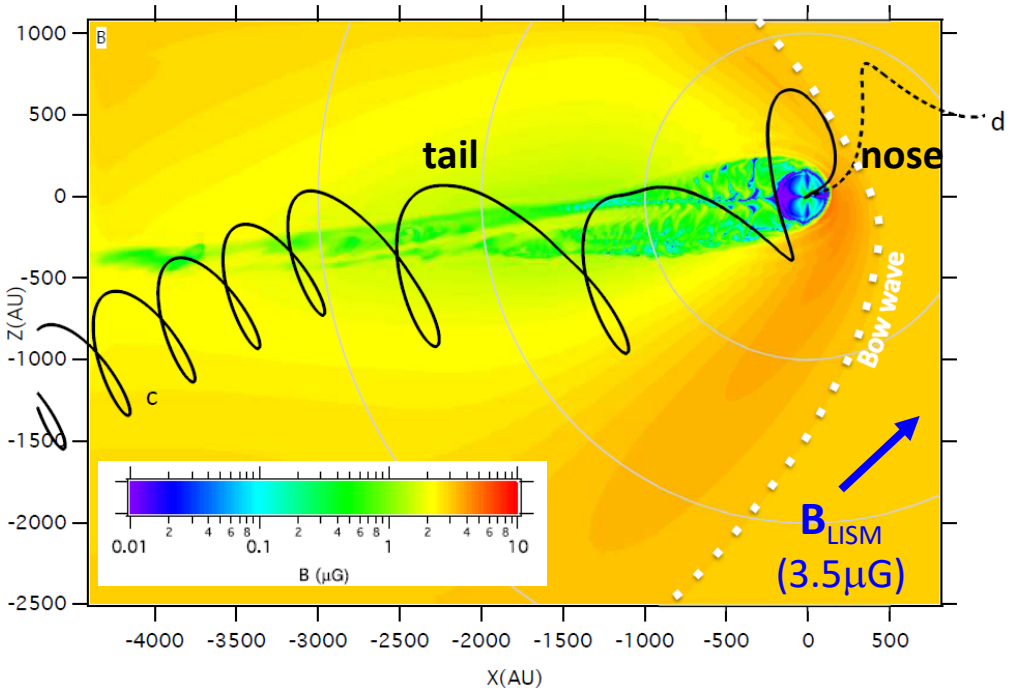


$$f(\mathbf{r}_E, \mathbf{p}_E, t) \approx f(\mathbf{r}_B, \mathbf{p}_B, t)$$

- Obtain model $f(\mathbf{r}_B, \mathbf{p}_B, t)$ best-fit to the observed $f(\mathbf{r}_E, \mathbf{p}_E, t)$.
- We use MHD heliosphere by ***N. Pogorelov*** for CR orbit calculation.
- Assume uni- and bi-directional anisotropy for $f(\mathbf{r}_B, \mathbf{p}_B, t)$.
- Take accounts of composition, E-spectrum and AS-array performance for quantitative best-fitting.

MHD model used in this work

By N. Pogorelov
Zhang+, ApJ, 889, 97 (2020)



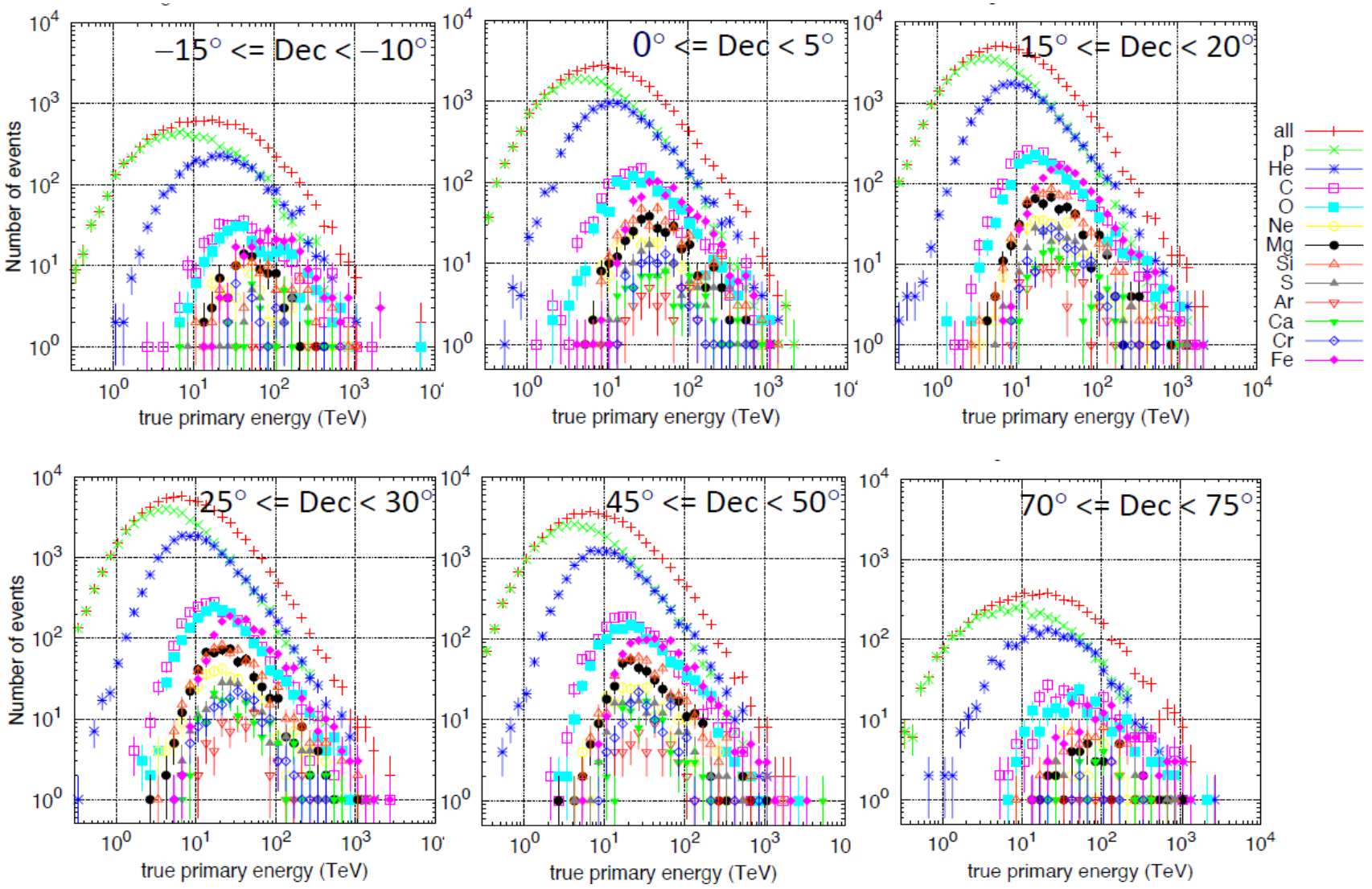
X: −10000 AU — 2000 AU
Y: −4000 AU — 4000 AU
Z: − 5000 AU — 5000 AU

Level0 Cartesian grid mesh size: 10 AU
Level1 Cartesian grid mesh size: 2.5 AU

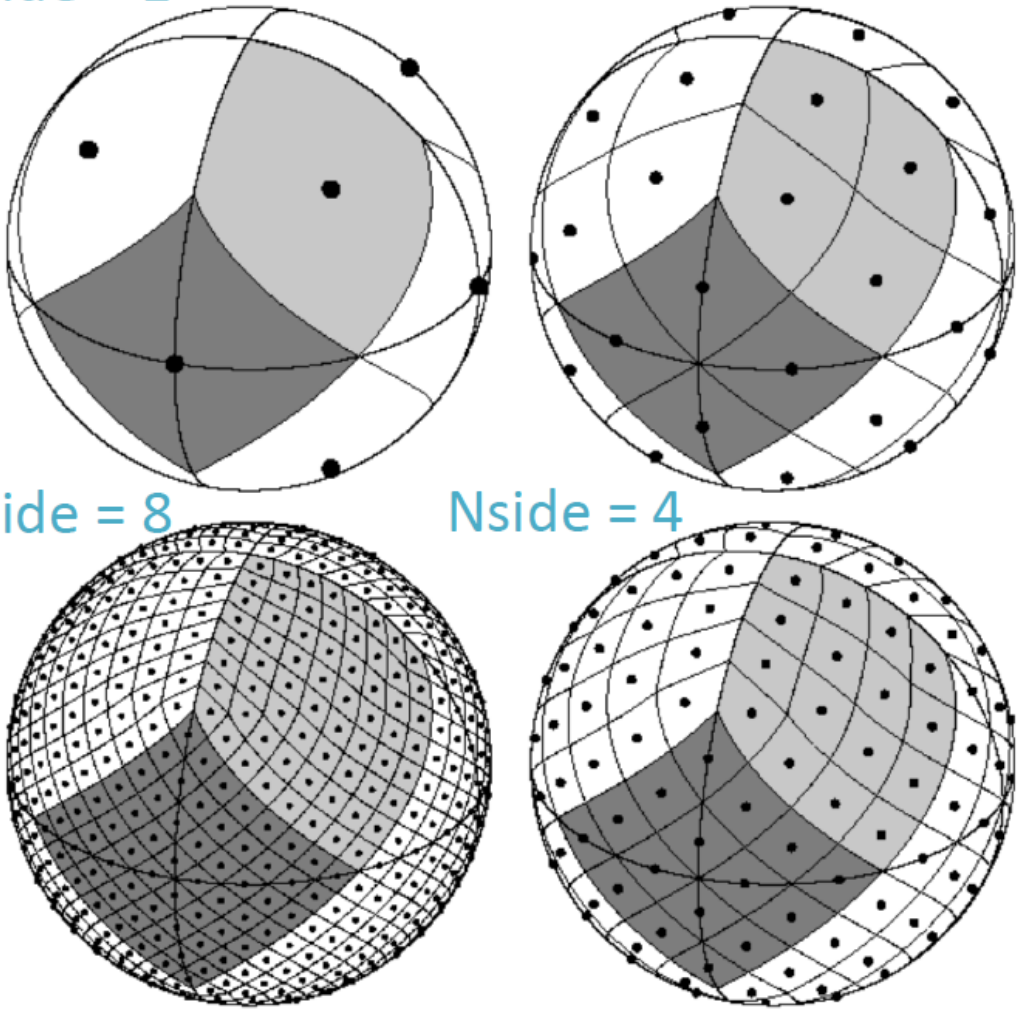
Model: $f(\mathbf{r}_B, \mathbf{p}_B, t) = f^{CG} + \sum_{l=1}^{L_{max}} \sum_{m=-l}^{l} f_l^m Y_l^m(\theta, \phi)$ θ, ϕ: Dec, R.A.

$N_{param.} = (L_{max} + 1)^2 - 1$ (= **440** for $L_{max} = 20$)

Weighting with composition & E-spectra by MC



HEALPix (Hierarchical Equal Area iso-Latitude Pixelation)



$N_{pix} = 12 * Nside^2$

$N_{ring} = 4*Nside - 1$

4*Nside pixels along equator

Tibet data

Nside=16

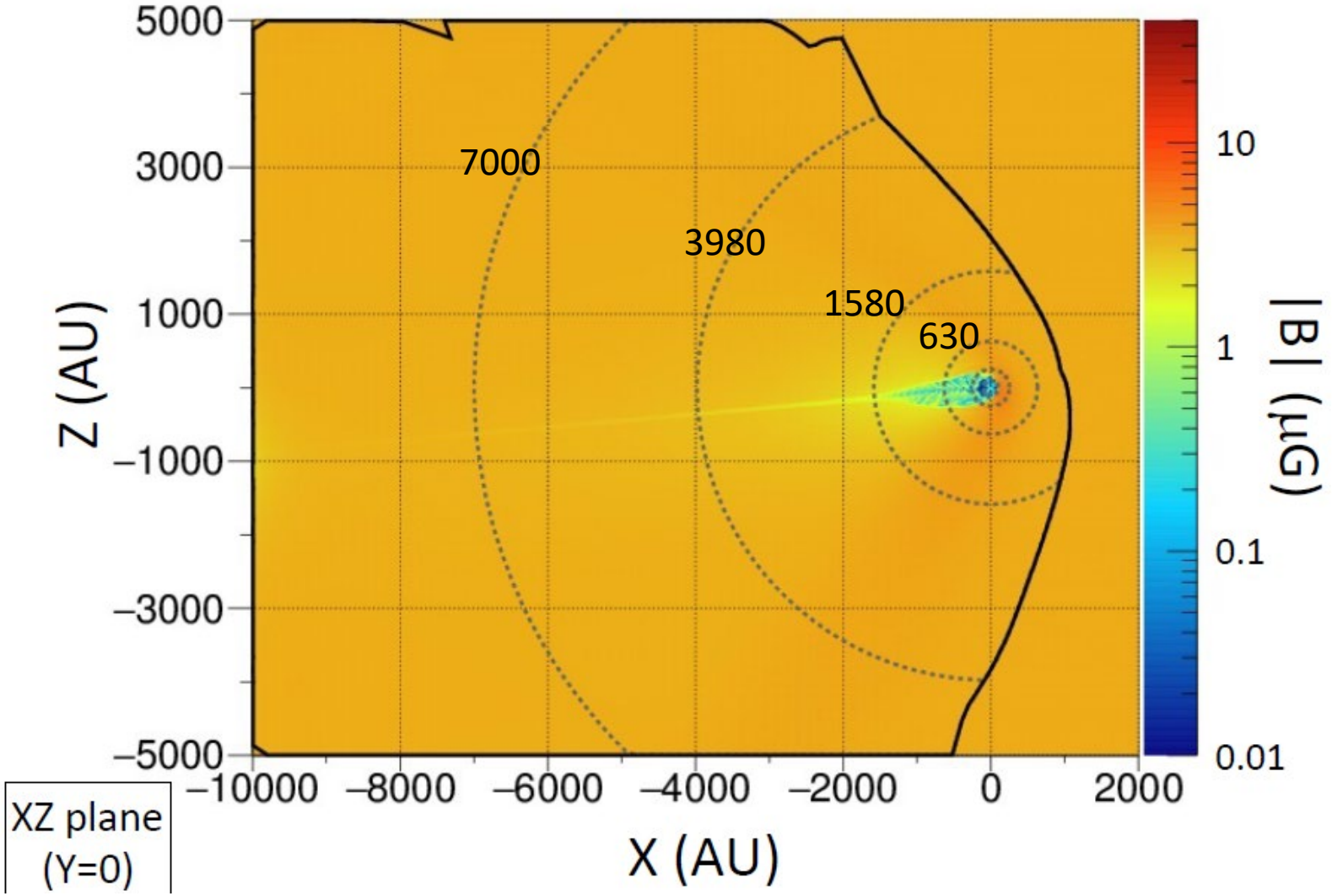
For $-20° < DEC < 80°$
2056 pixels, 37 rings
pixel size~5°×5°

CR trajectories

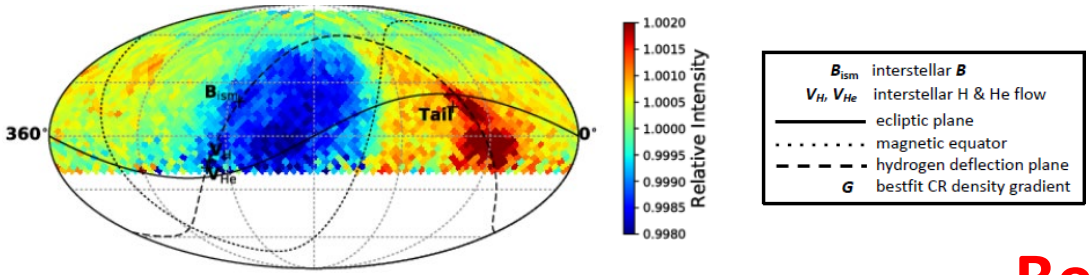
Nside=32

pixel size~1.8°×1.8°

Boundaries at r = 100, 250, 630, 1580, 3980, 7000 AU

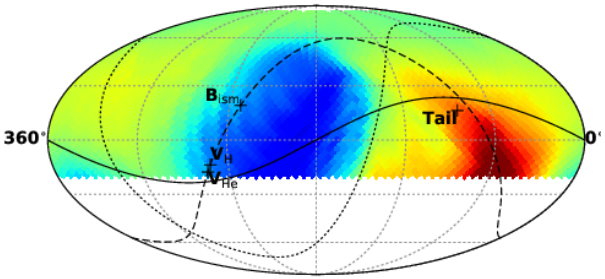


Observed at Earth

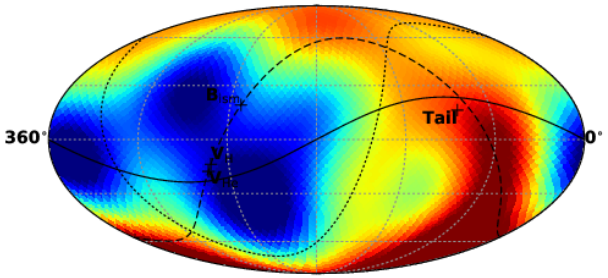


Reproduced at Earth

Best-fit at boundary ($r=r_B$)

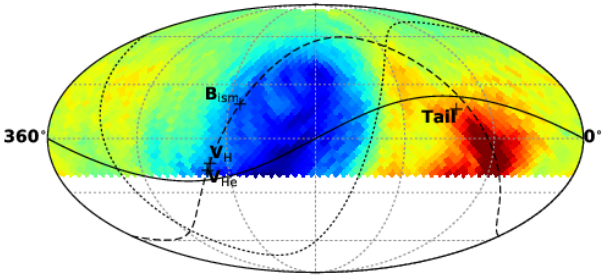


r_B= 630 AU

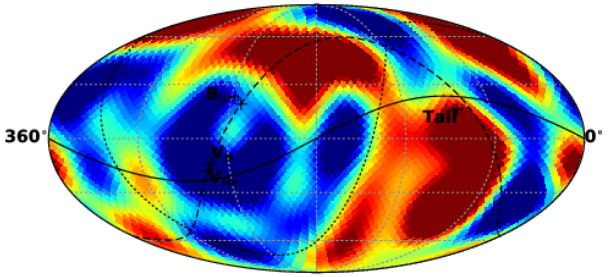


L_{max} = 4 ($N_{param.}$=26)

χ^2 / ndf = 0.962

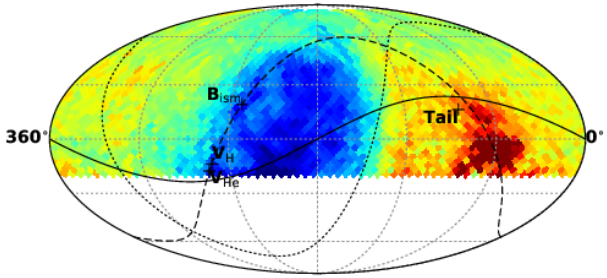


1580 AU

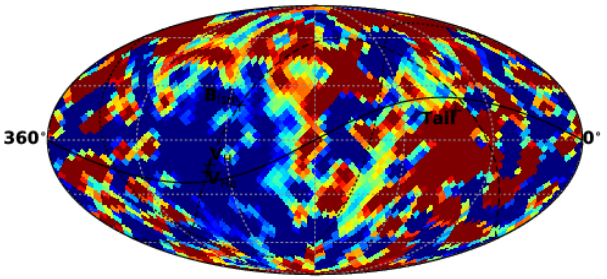


L_{max} = 8 ($N_{param.}$=80)

χ^2 / ndf = 0.982



3980 AU

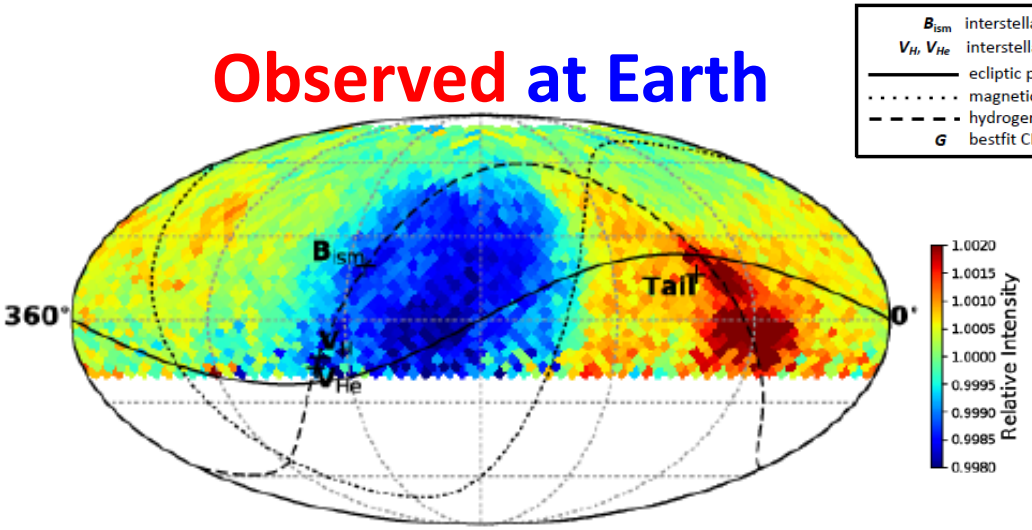


L_{max} = 20 ($N_{param.}$=440)

χ^2 / ndf = 0.942

Fitting with the averaged $f(\mathbf{r}_B, \mathbf{p}_B, t)$s at r_B=630, 1580, 3980, 7000 AU

Observed at Earth



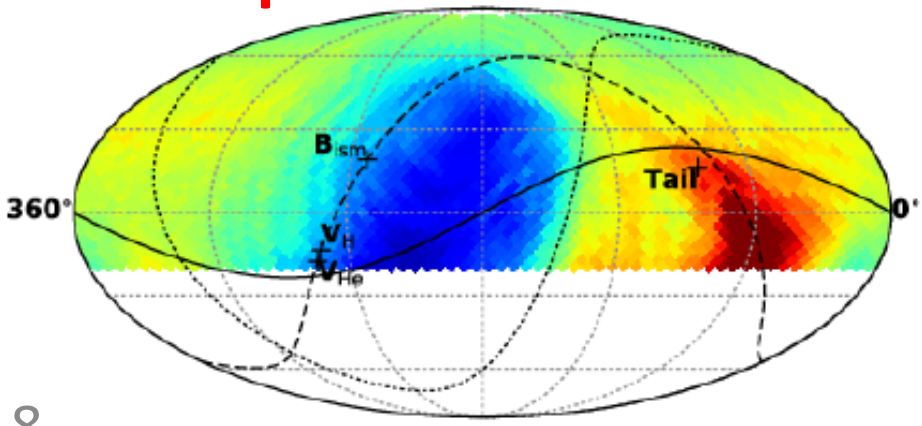
B_{ism} interstellar B
V_H, V_{He} interstellar H & He flow
ecliptic plane
magnetic equator
hydrogen deflection plane
G bestfit CR density gradient

$L_{max} = 5$

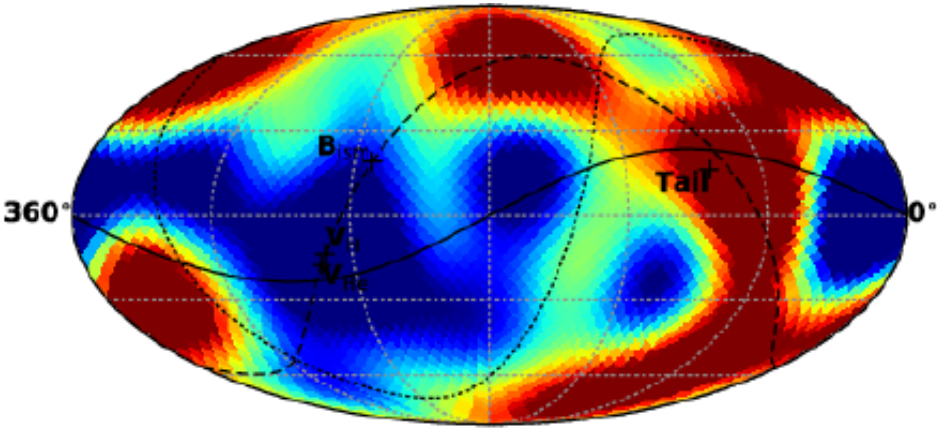
($N_{param.}$=35)

χ^2 / ndf = 1869 / 2021 = **0.925**

Reproduced at Earth

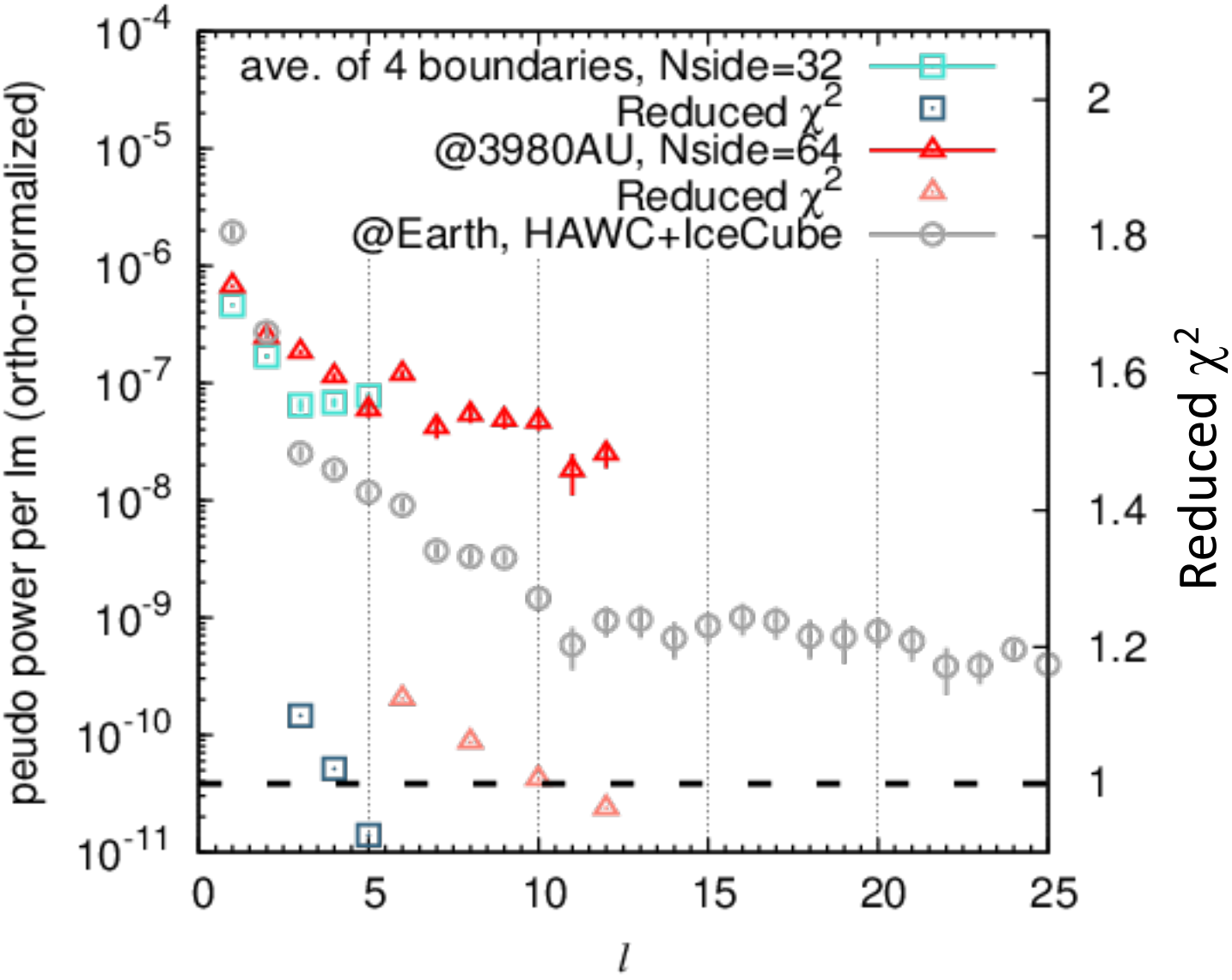


Best-fit at boundary ($r=r_B$)



Power spectrum

※ average は r = 630, 1580, 3980, 7000 AU での intensity を平均してフィットした結果



“To do” list.

- Discuss the heliospheric modulation of $f(\mathbf{r}_B, \mathbf{p}_B, t)$ by suppressing the apparent dependence on $\mathbf{r}_B$.
- Analyses with other MHD heliosphere models (e.g. models by Washimi+ & Opher+).
- Examine the observed E-dependence of anisotropy (below/above 100 TeV?).
- Analyses of sub-TeV anisotropy:
  - Solar cycle variation?
  - Solar modulation of amplitude?