New model of the coherent magnetic halo of the Milky Way and UHECR deflections

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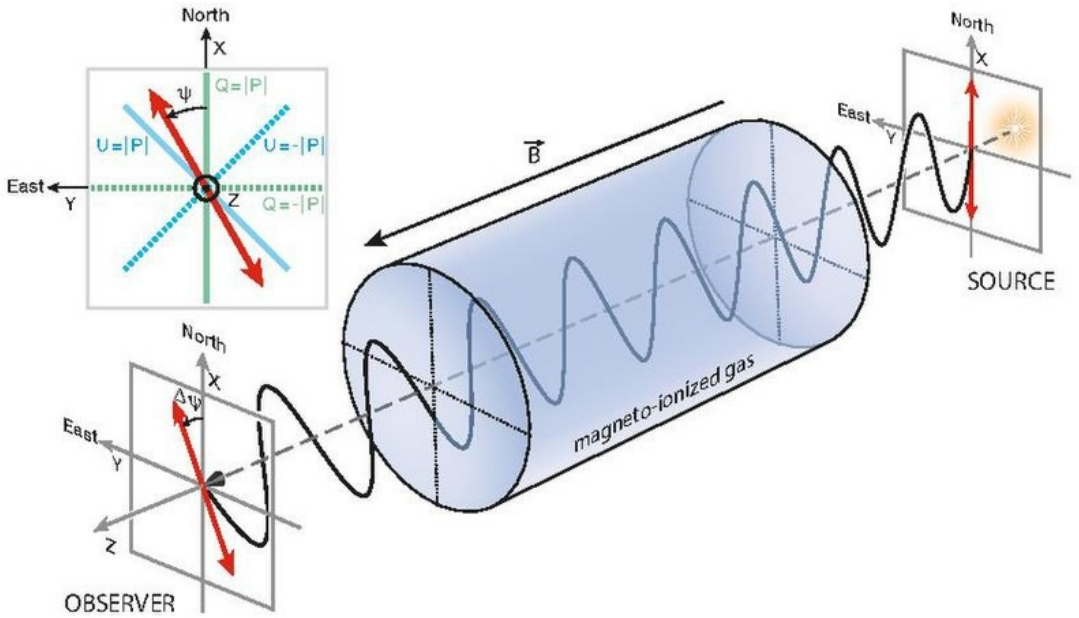
in collaboration with Dmitri Semikoz and Peter Tinyakov, arXiv:2407.02148

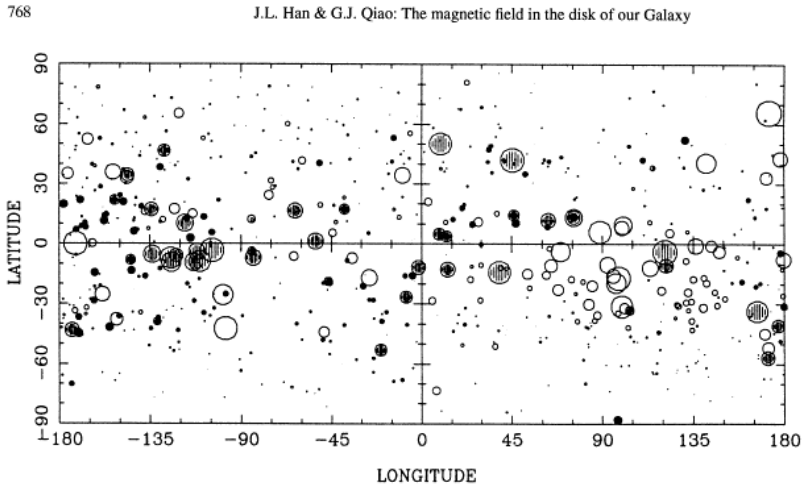
Why do we need new model of the coherent GMF?

- Previous models do not converge to the same values
- Different statistical approaches to the data
- Large portions of the sky masked out
- Do we need “striation” = order-random field?
- Pitch angle of the disk field?
- Self-consistent modelling of GMF
  and cosmic rays
- UHECR deflections

Data: extragalactic Faraday rotation measures (RM)

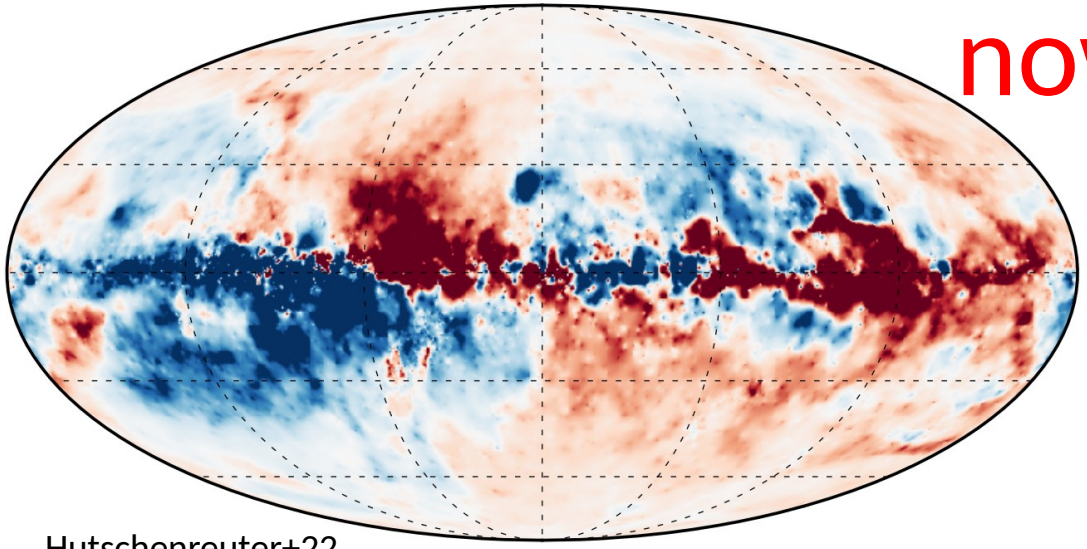
1994





extragalactic RM

now



Hutschenreuter+22

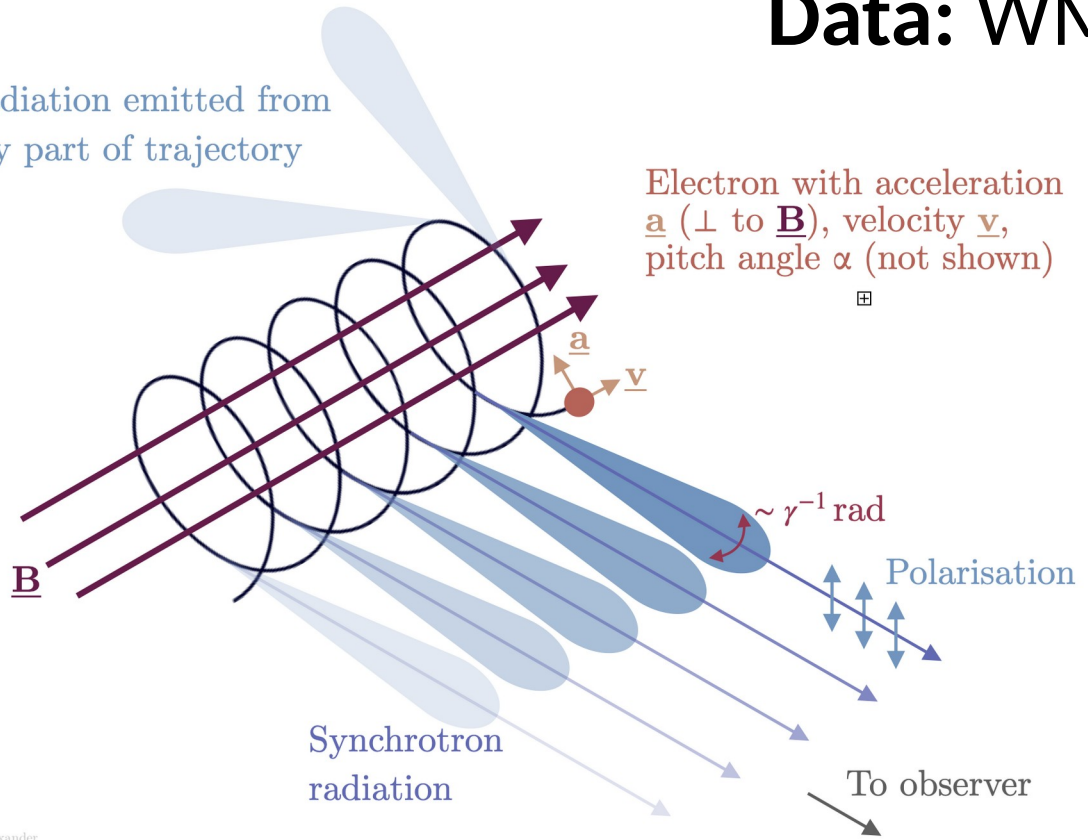
-100 rad/m^2 100

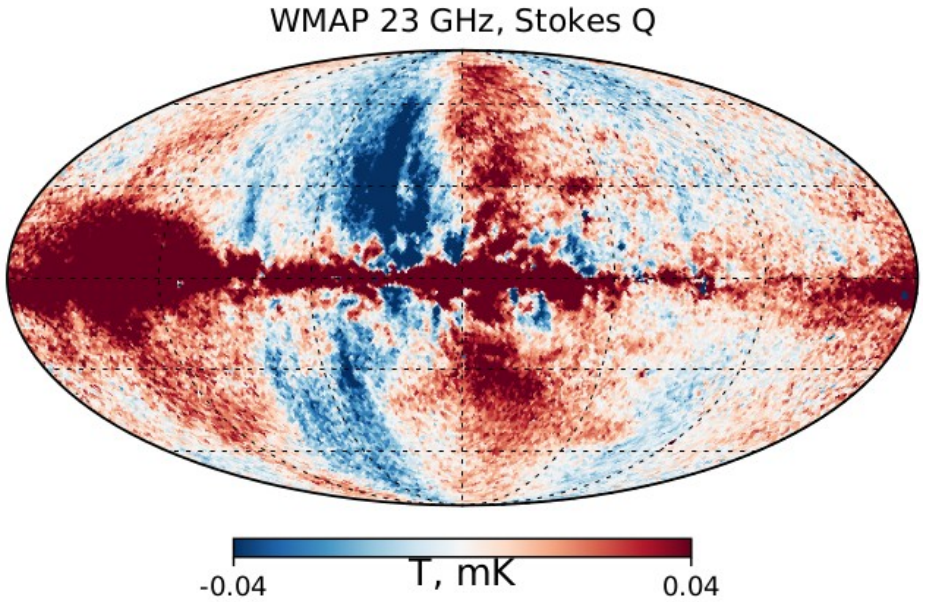
RM traces B field component parallel to LOS

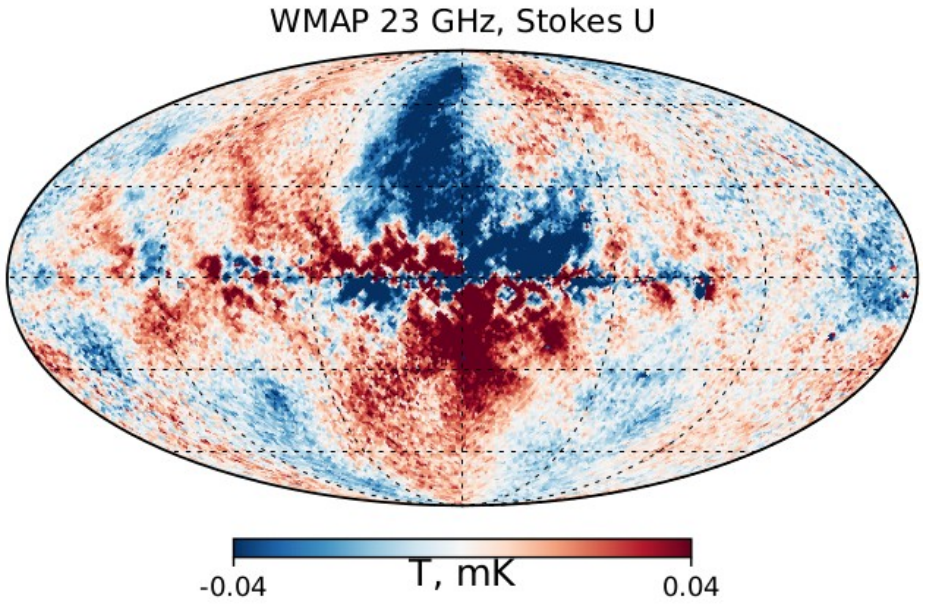
Brown – B mainly towards us

Blue – B mianly away from us

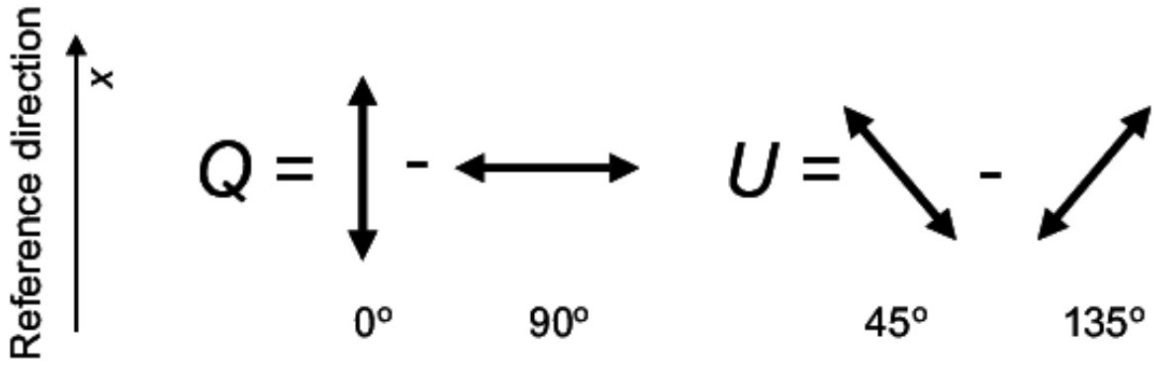
Data: WMAP 23 GHz synchrotron skymaps





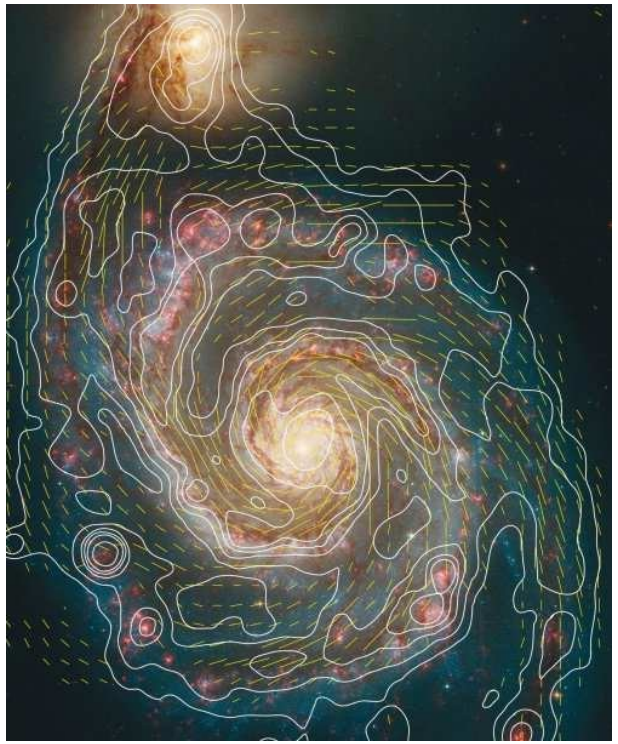


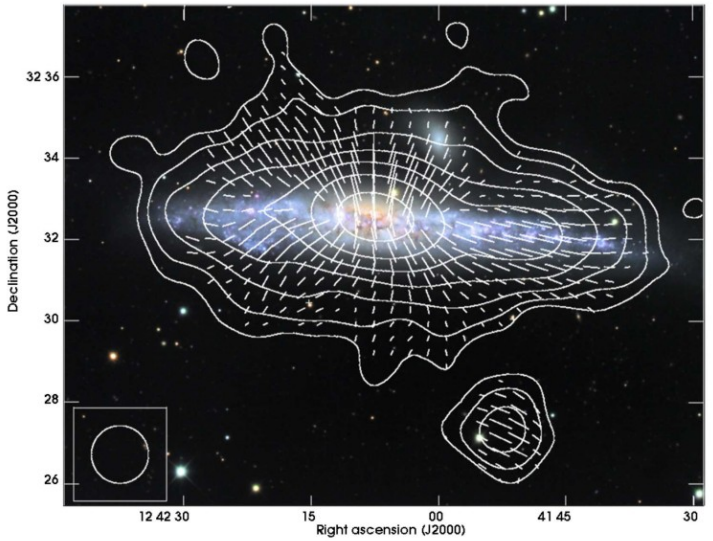
Stokes parameters



External galaxies: summary

- Turbulent and ordered B field can be identified in external galaxies
- Ordered field has several components: disk field, halo field, X-field
- We focus on the ordered field and assume that our Galaxy has the same components





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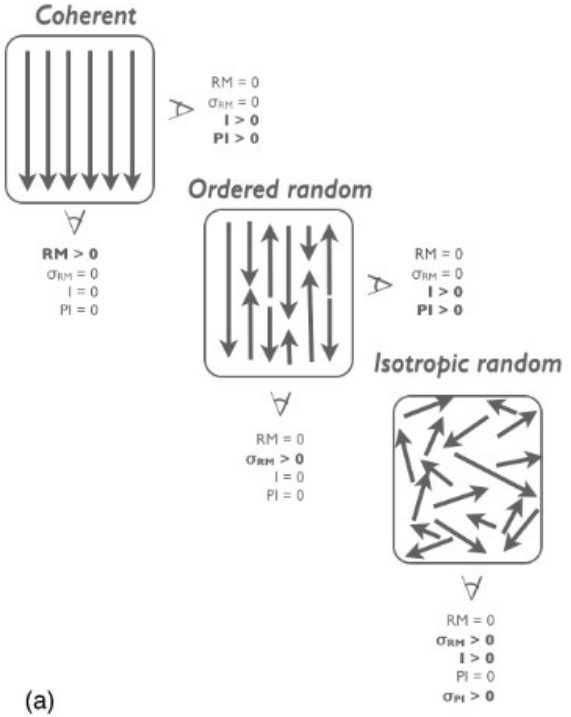
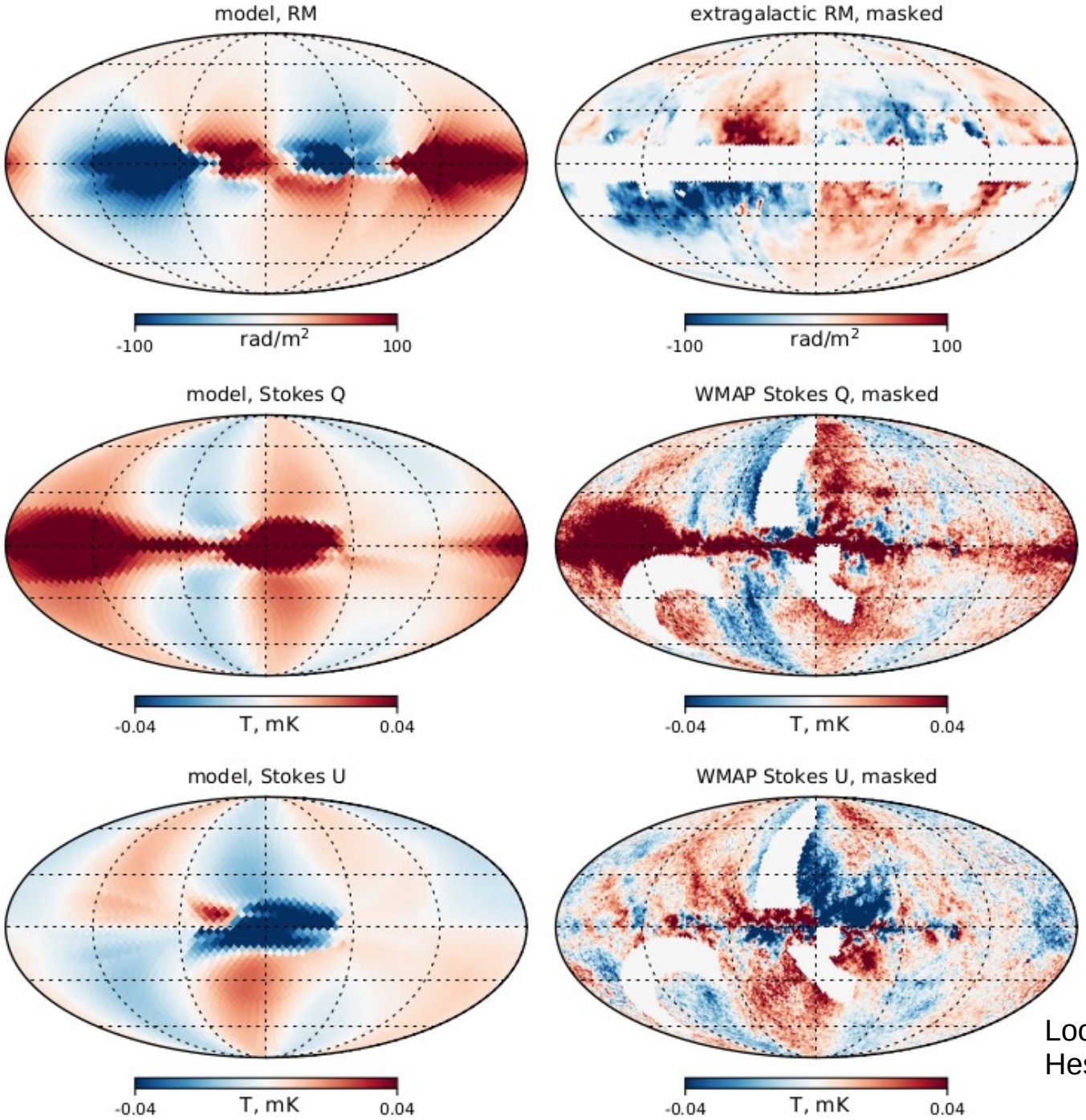
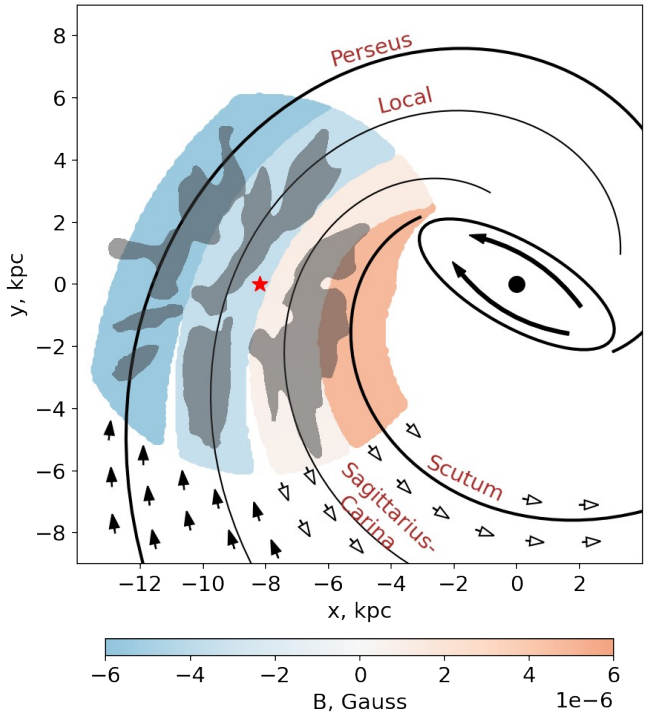


Jaffe+10



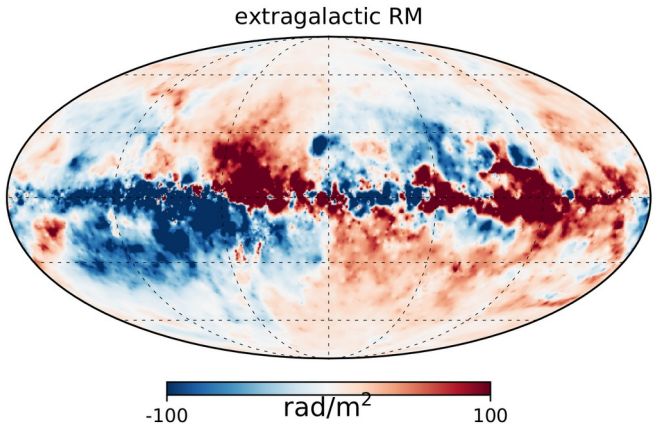
Our new model

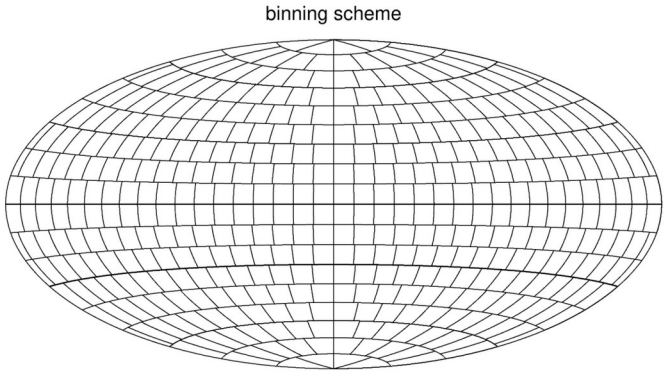


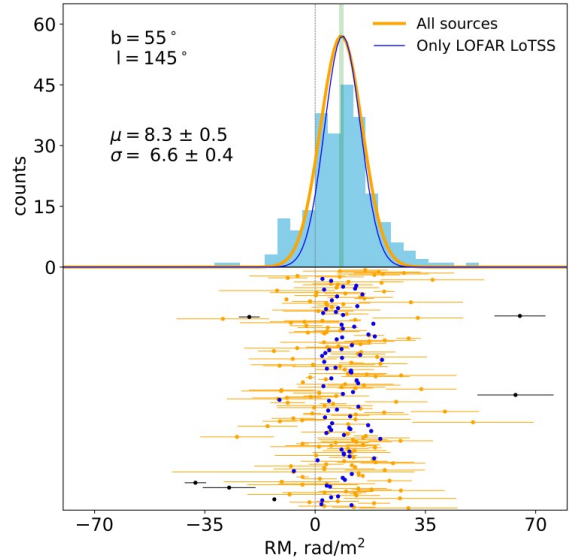
Main features: statistical approach, pitch angle, Fan Region, Local Bubble

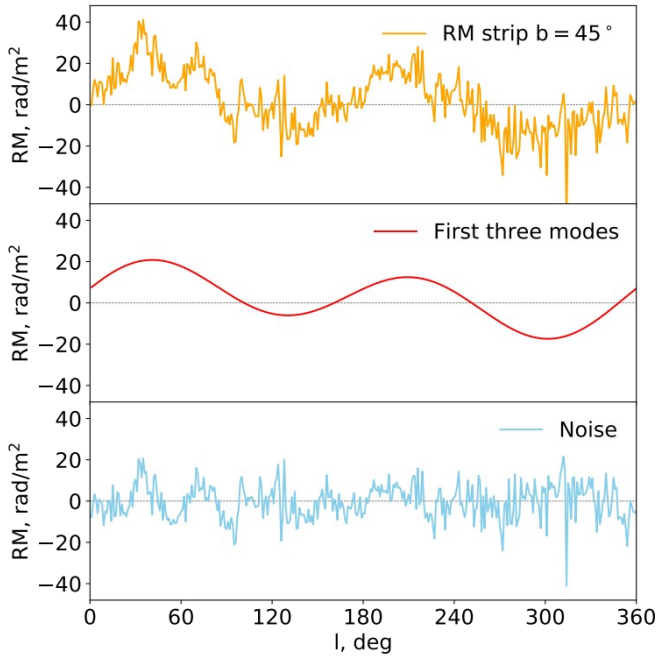
Loop I: see the talk by Heshou Zhang tomorrow

Estimation of data bins errorbars









- We are interested in global GMF structure – small details are not important
- Errors assignment procedure based on Fourier analysis

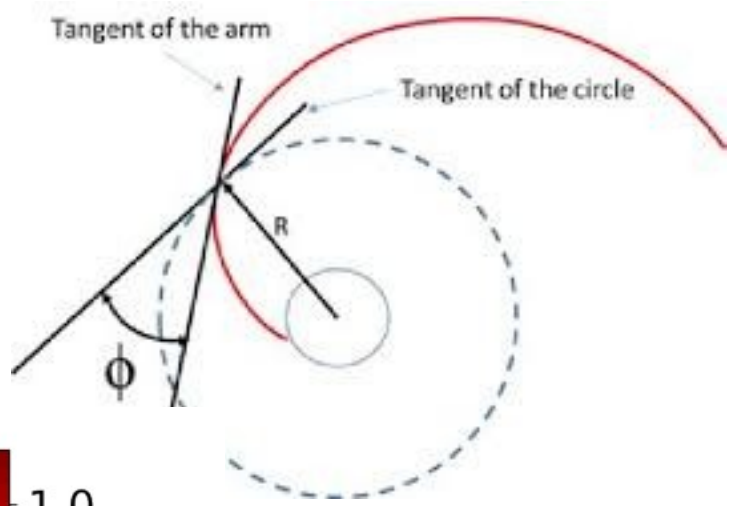
$$\sigma_{\mathrm{L}}^2 = 2 \sum_{k_0}^{\infty} \mathrm{sinc}^2\left(\frac{kL}{2}\right) S_k$$

- Better treatement of errorbars – better sensitivity to the data

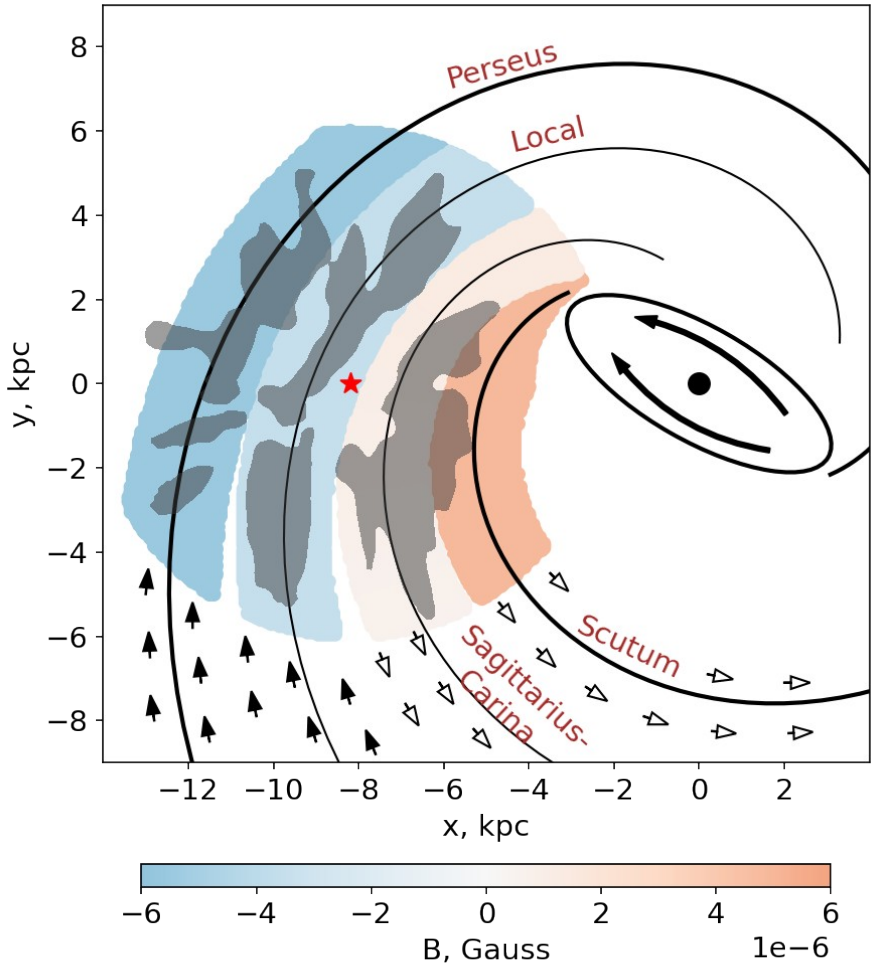
Pitch angle

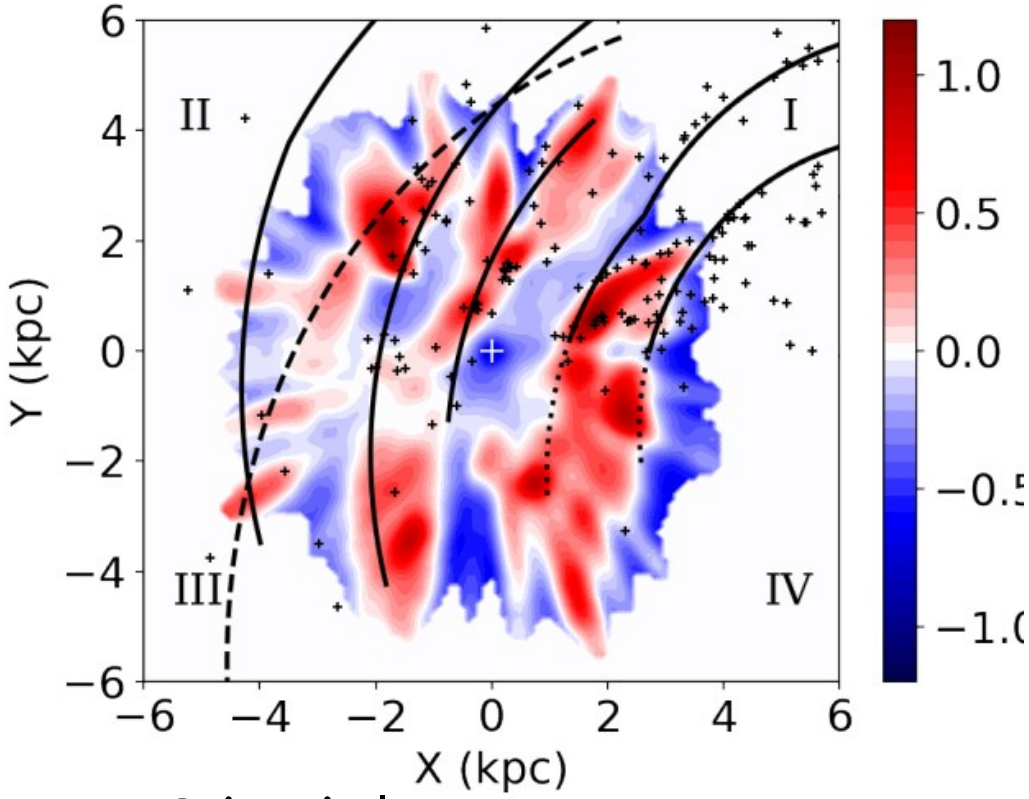
According to GAIA DR3 data the spiral arms are more inclined than previously thought

Our and Gaia pitch angle ~ 20 deg
In earlier studies pitch angle ~ 10 deg

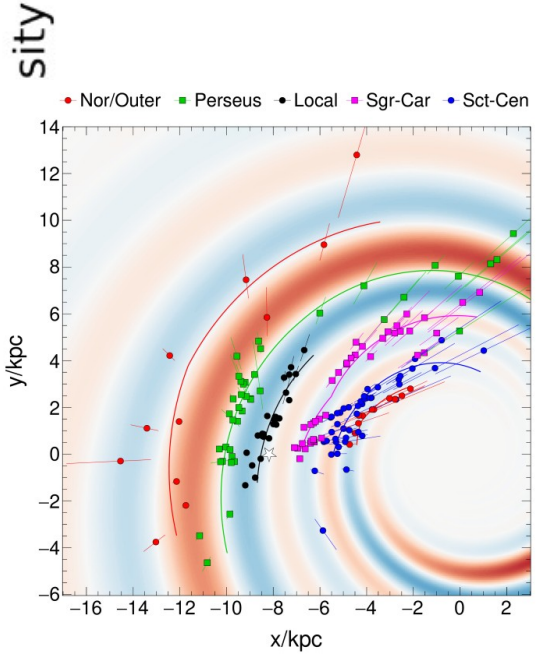


Our model





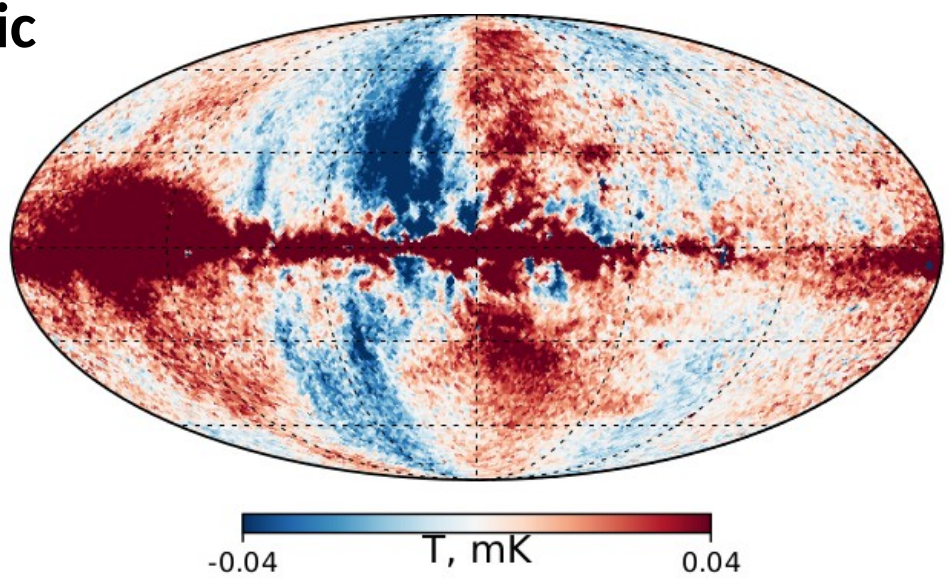
Gaia spiral arm segments, Poggio+21

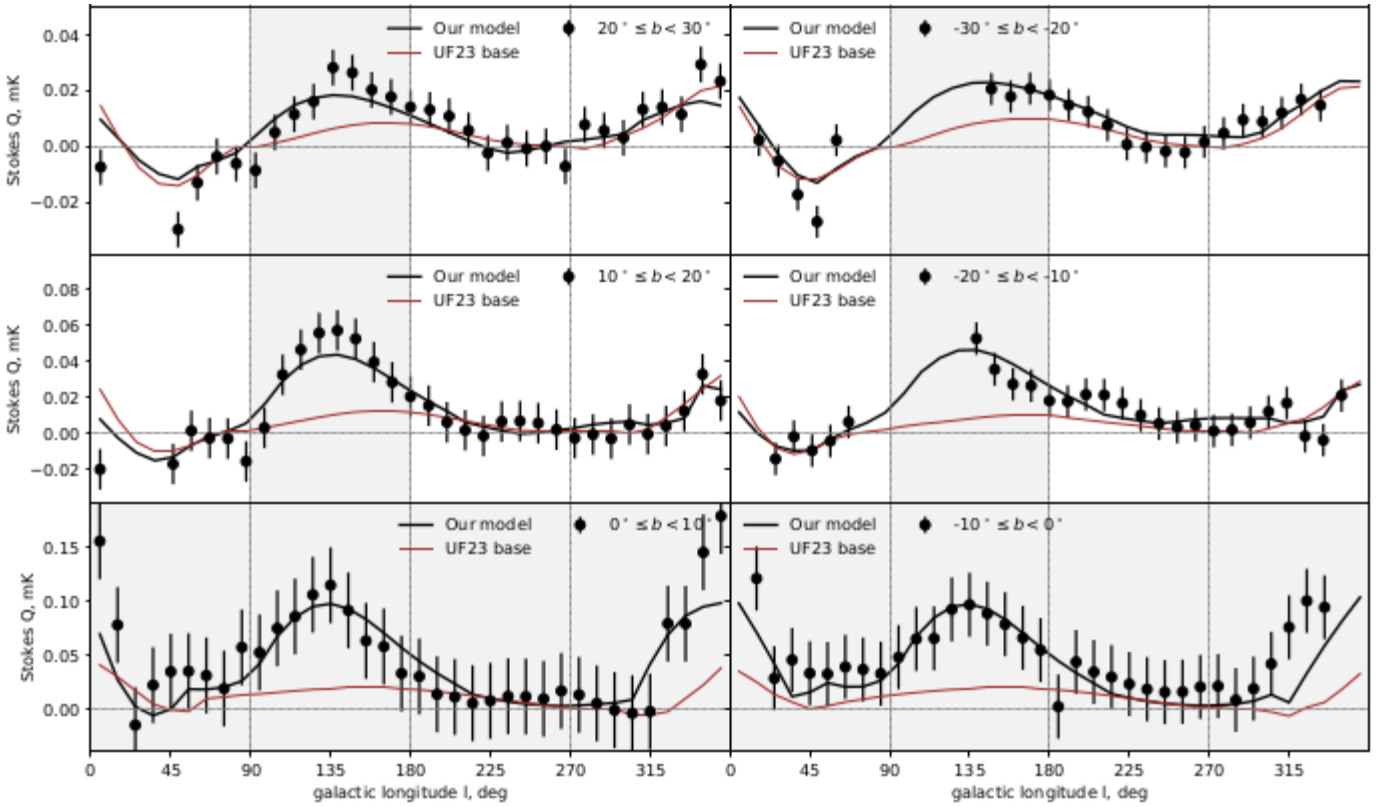


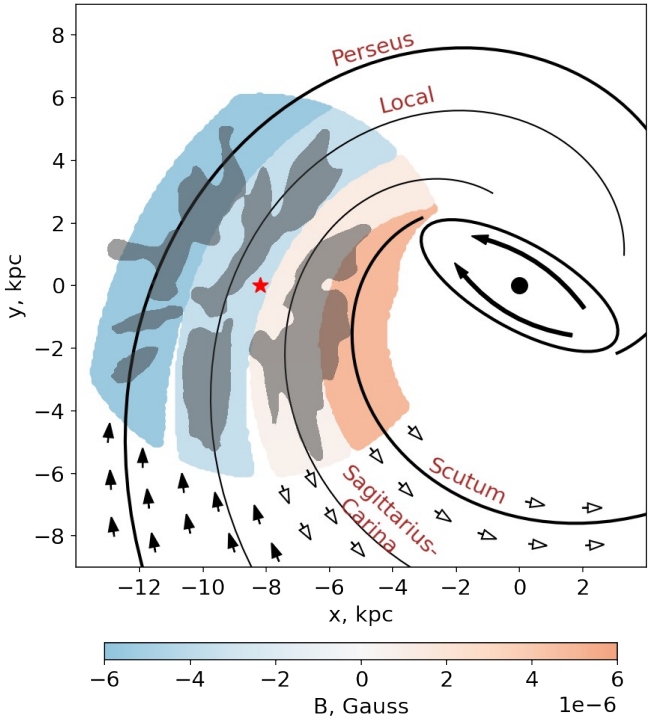
Unger&Farrar23

Fan Region – bright red spot in Stokes Q near the Galactic plane at 90 < l < 180 deg

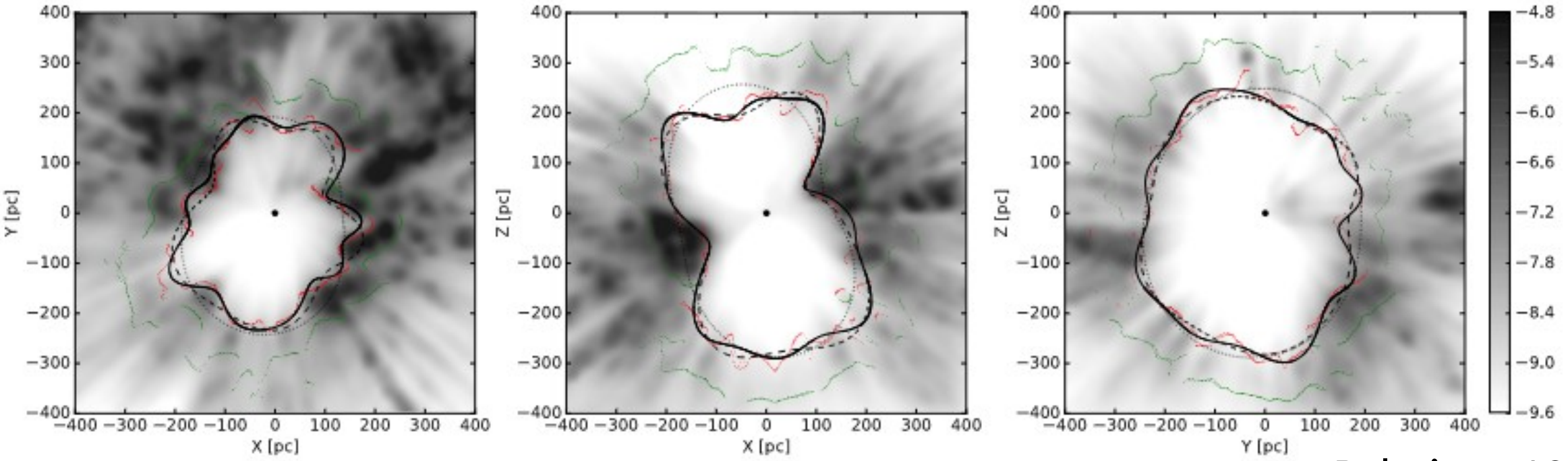
Hill+17: >30% of the Fan Region emission originates beyond 2 kpc from Sun – part of the large-scale GMF







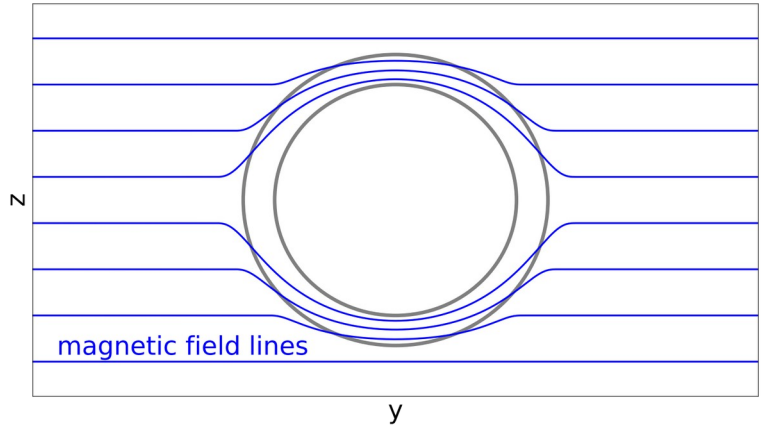
Local Bubble: shape of the wall



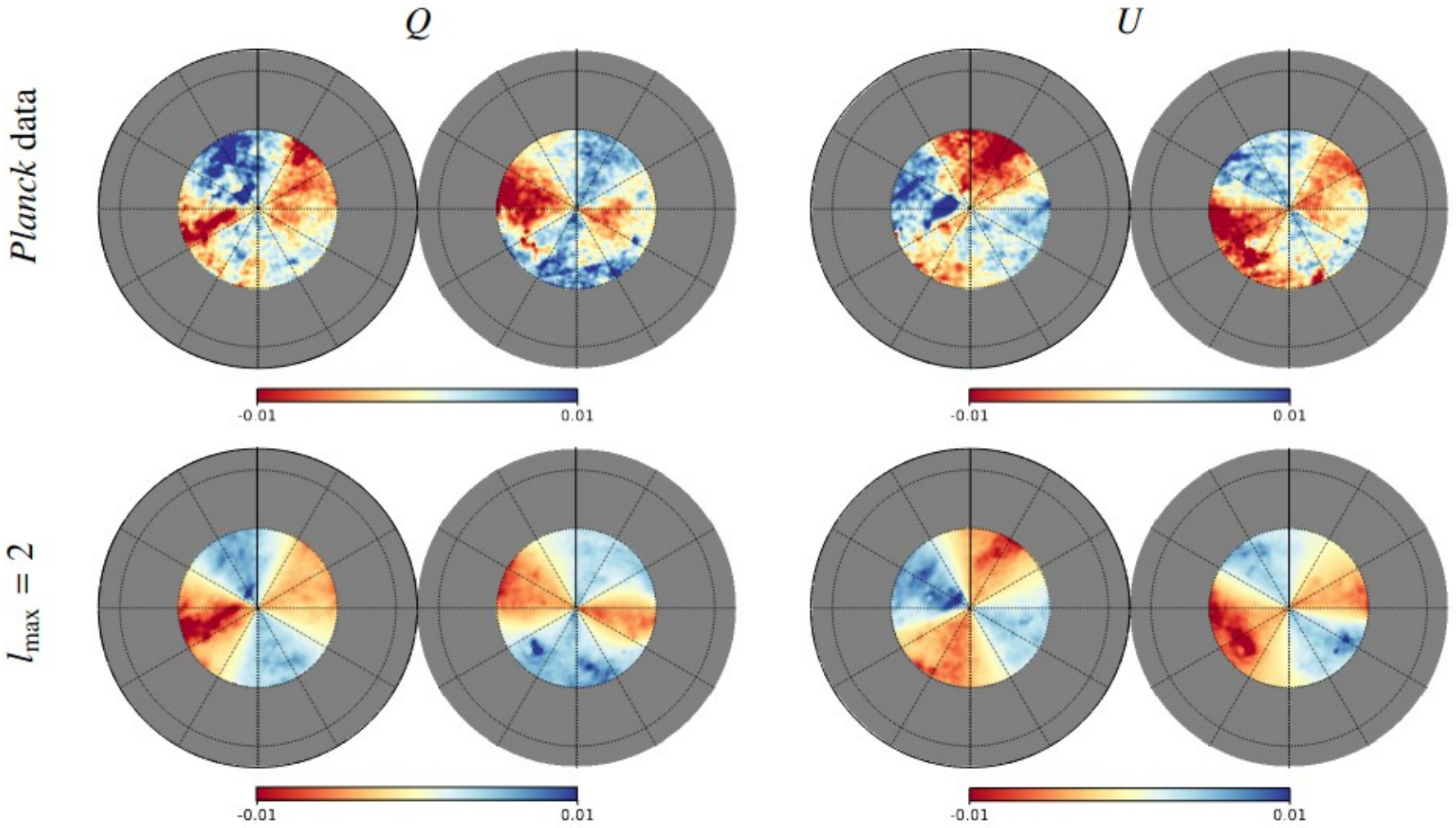
Pelgrims+19

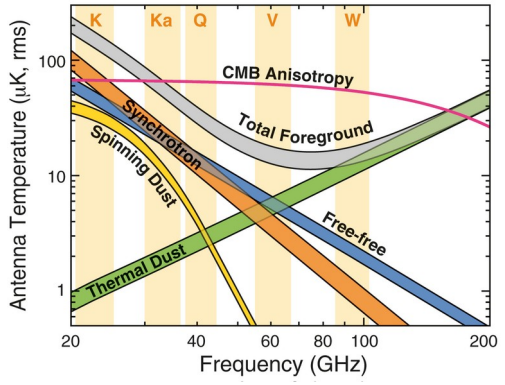
Z axis is perpendicular to the Galactic plane

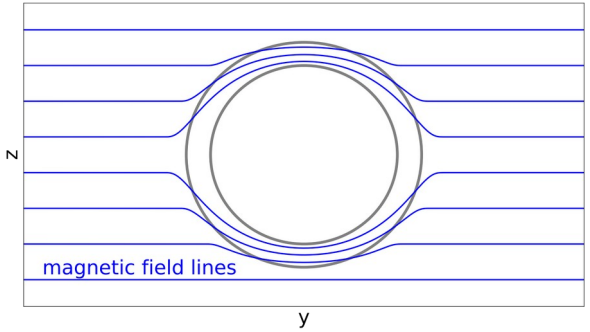
Compressed and highly ordered field in the Bubble Wall



Local Bubble and Planck 353 GHz



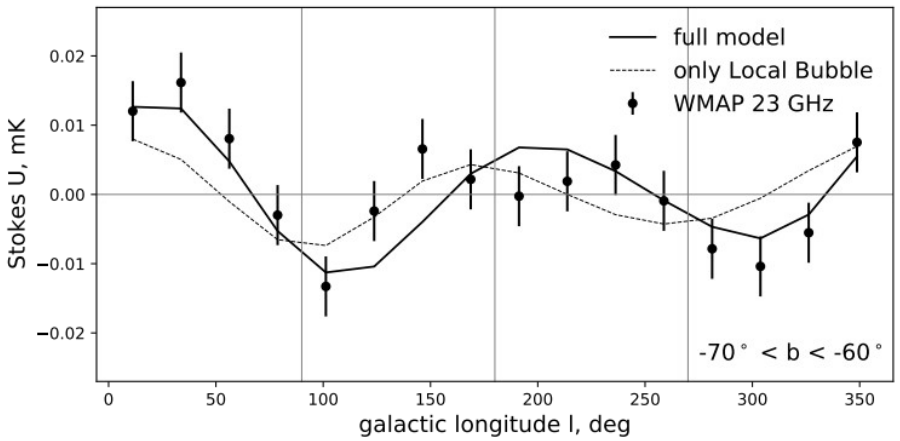


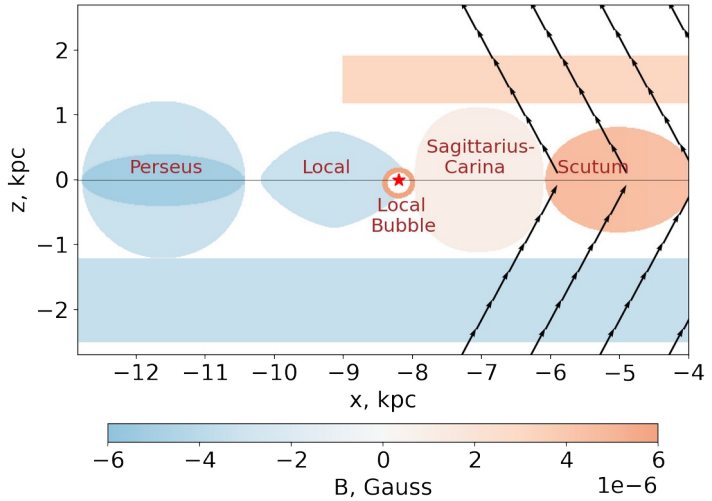


Pelgrims+19

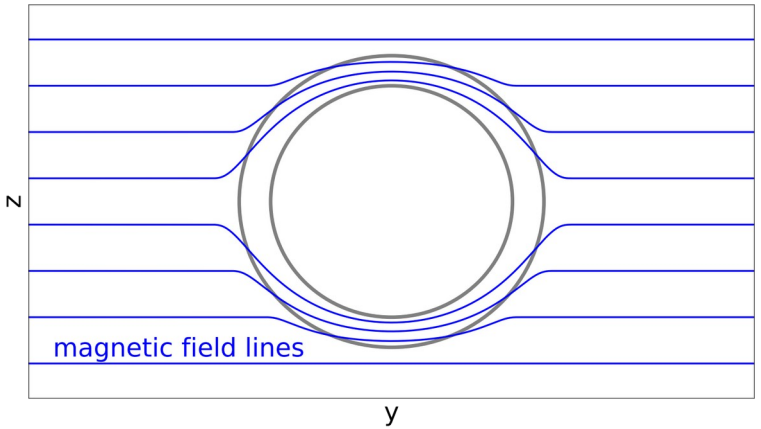
At the polar caps emission is dominated by the Local Bubble

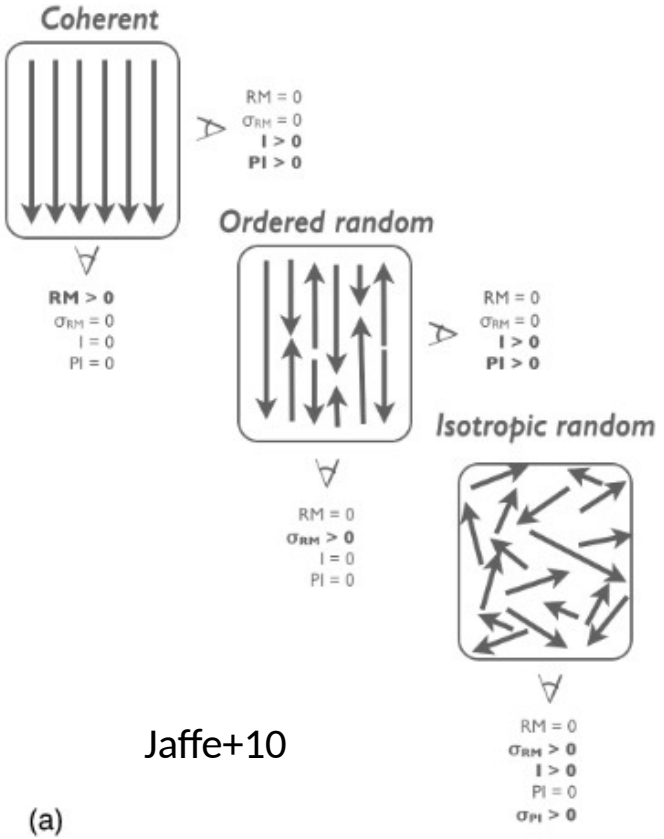
Local Bubble: missing part of the synchrotron emission?





PI(Local Bubble) ~ PI(Halo)

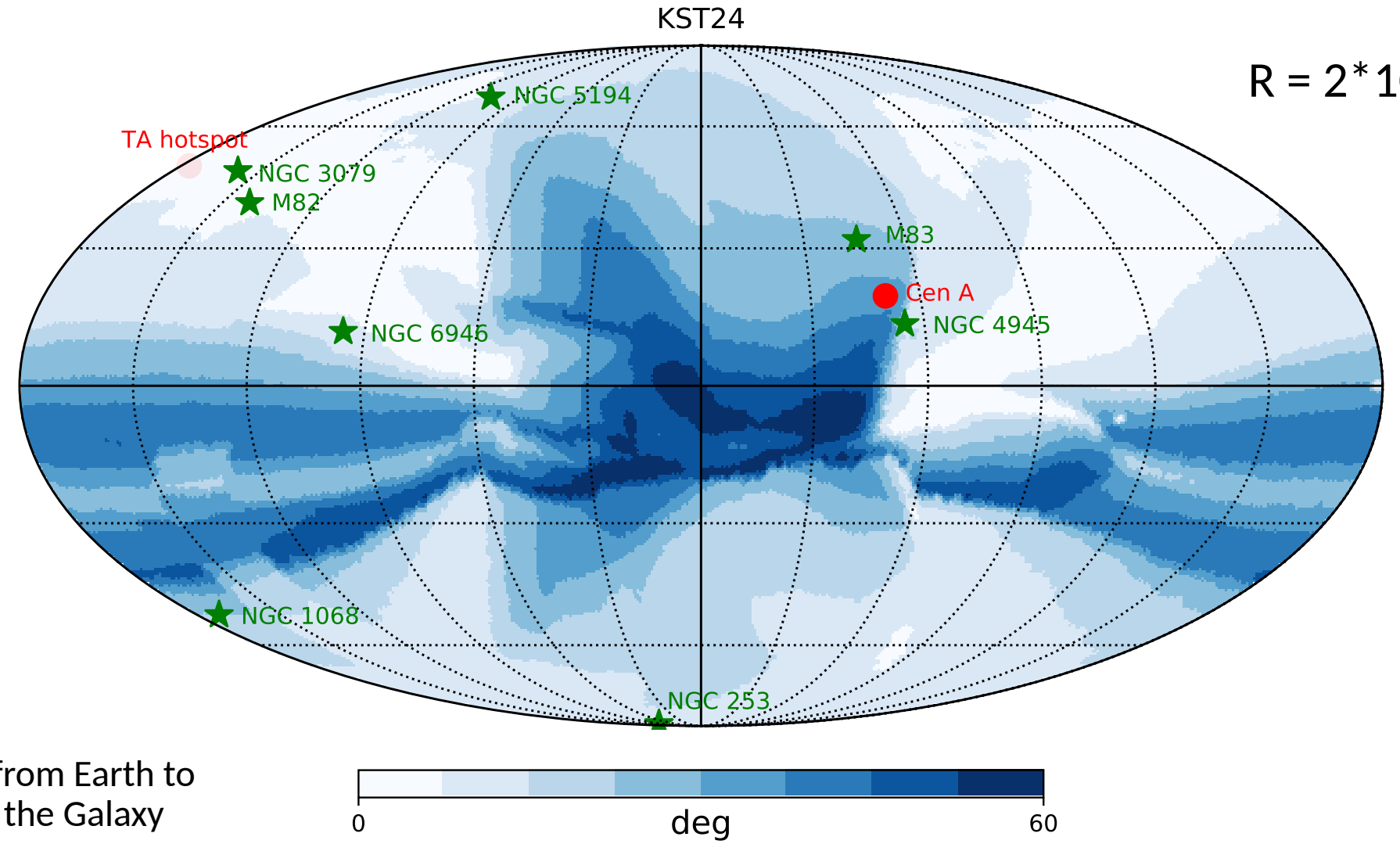




Jaffe+10

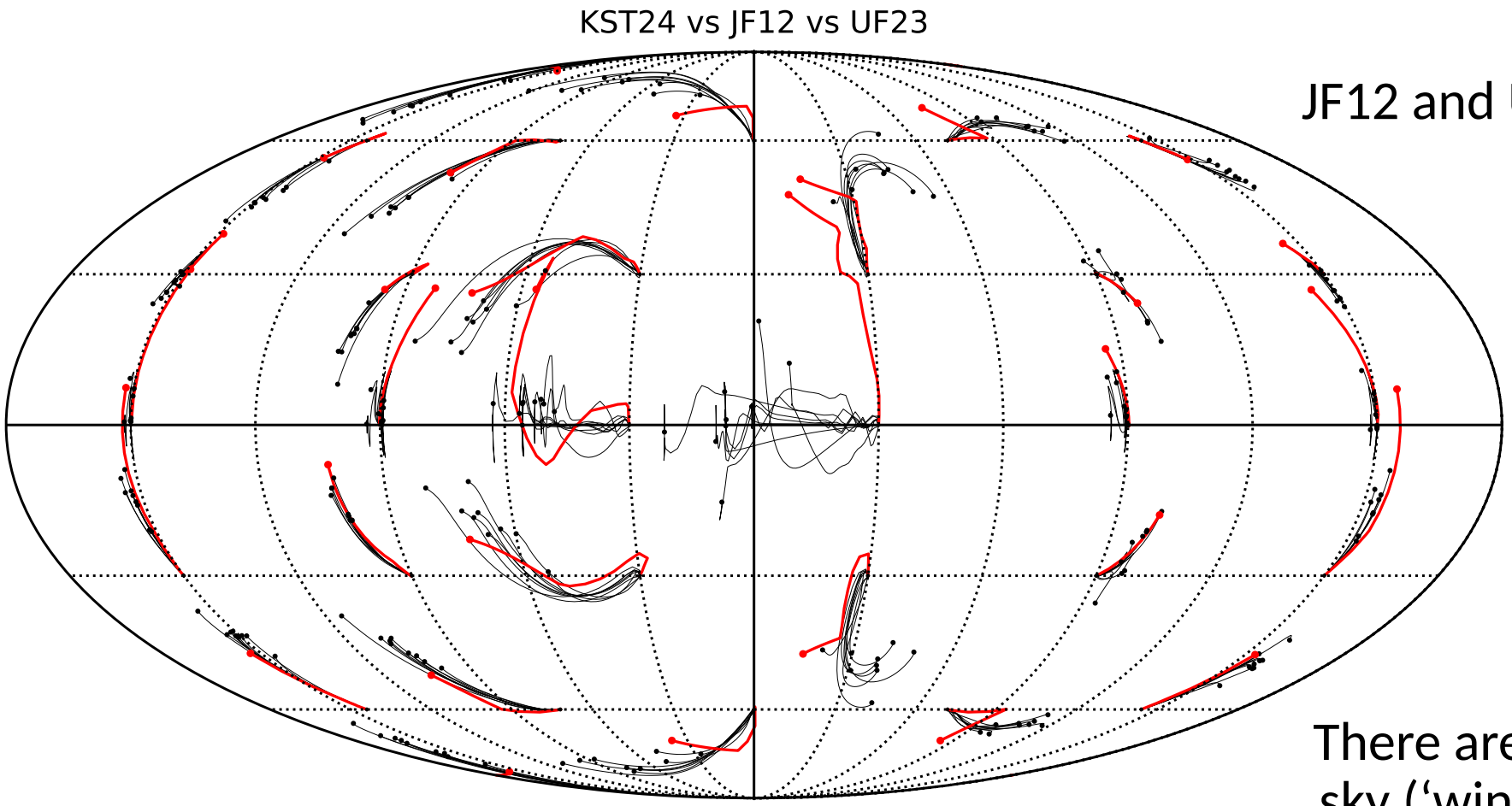
Taking into account the polarized synchrotron emission of the Local Bubble at 23 GHz, we found that striated fields (ordered random) are not needed. Local Bubble produces the missing part of the synchrotron brightness. Also it improves RM modeling and so prefered by the fit (compared to striated field which only improves synchrotron)

Angular deflections of UHECRs in KST24



Backtracking from Earth to the edge of the Galaxy

Comparison with JF12 and UF23

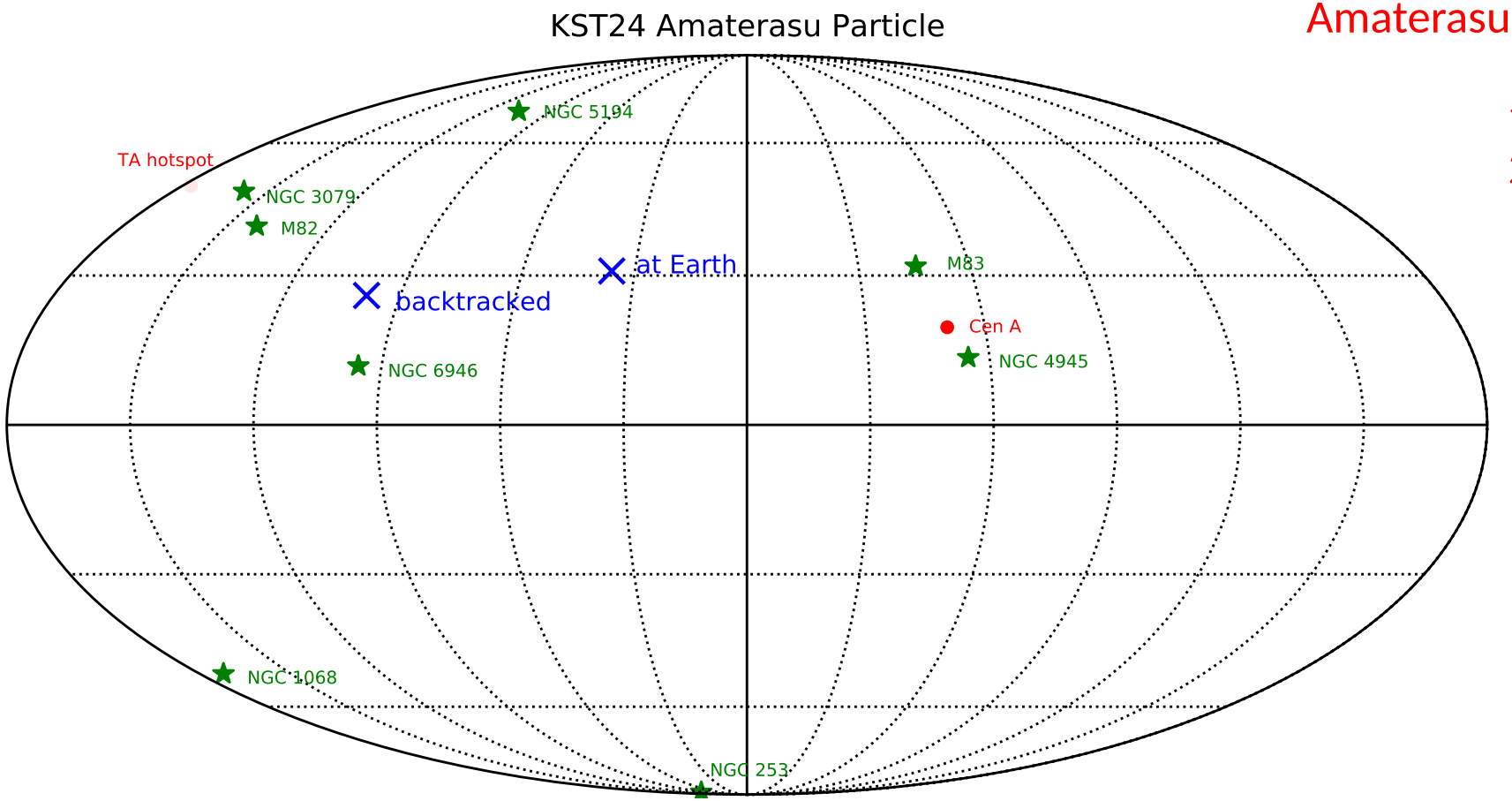


KST24 – red

JF12 and UF23 collection - black

There are stable regions in the sky (‘windows’) where UHECR deflections are similar across all models

KST24 and Amaterasu Particle



Amaterasu Particle was backtracked assuming:

1) E = 244 EeV
2) Z = 26 (iron)

Conclusions

- We developed new statistical procedure that allow us to treat all datasets on the same footing
- We pitch angle of the disk field was found to be 20 deg in agreement with Gaia data
- The Fan Region is naturally incorporated into the large-scale structure of the GMF
- Local Bubble is taken into account – no striated fields needed
- There are regions in the sky there JF12, UF23 and KST24 predict similar small deflections - ‘windows’