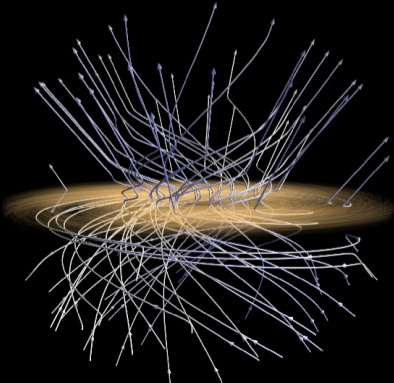
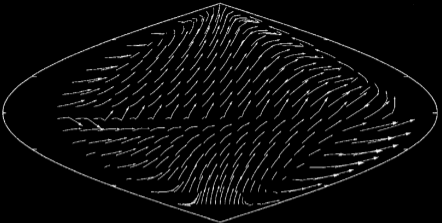


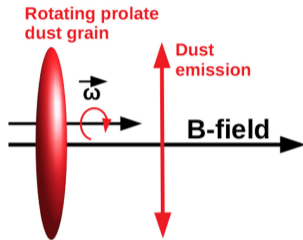
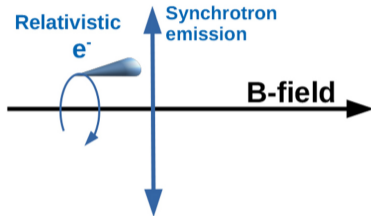
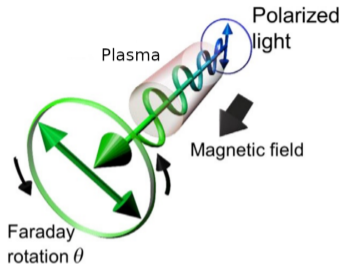
Constraining the Global Structure of the Coherent Galactic Magnetic Field

M. Unger (KIT) and G.R. Farrar (NYU)



Modeling of the Coherent Galactic Magnetic Field (GMF)

Observables: → see Katia's talk!



adapted from Hasegawa+13 and Pelgrims+18

Popular Models in UHECR:

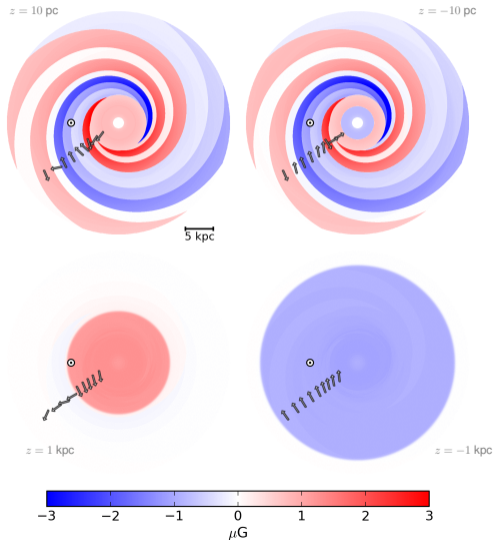
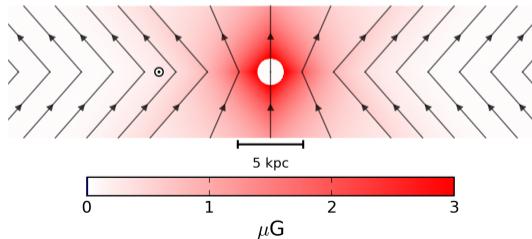
	S97	PT11	JF12	Planck16	TF17
extragalactic RMs	X	✓	✓	X	✓
polarized synchrotron	X	X	✓	✓	X
polarized dust	X	X	X	✓	X

Jansson&Farrar Global Magnetic Field Model (JF12)

R. Jansson & G.F. Farrar, ApJ 757 (2012) 14

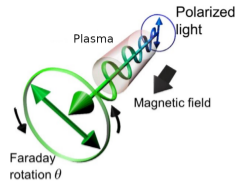
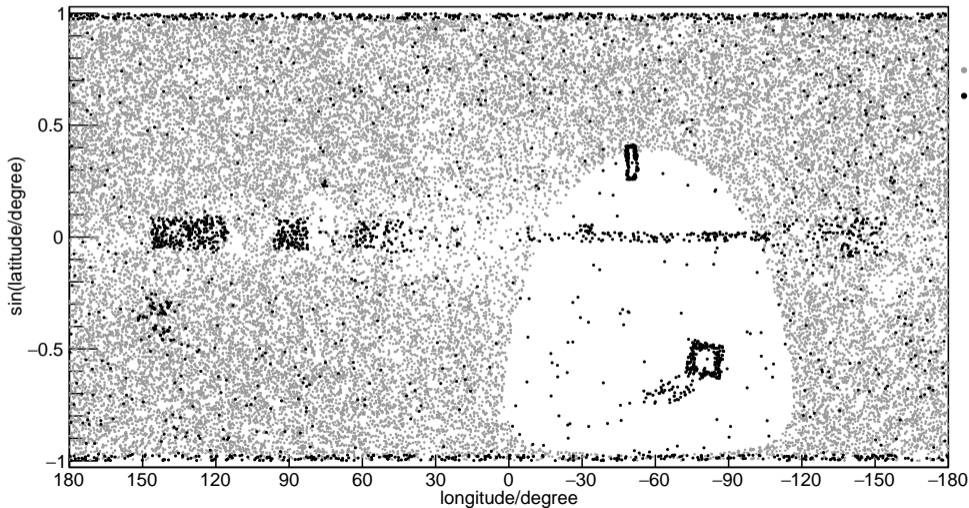
three divergence-free components:

- disk field, ($h \lesssim 0.4$ kpc)
- toroidal halo field ($h_{\text{scale}} \sim 5.3$ kpc)
- “X-field” (halo)
- 21 parameters adjusted to 6605 data points



Extragalactic Rotation Measures used for JF12

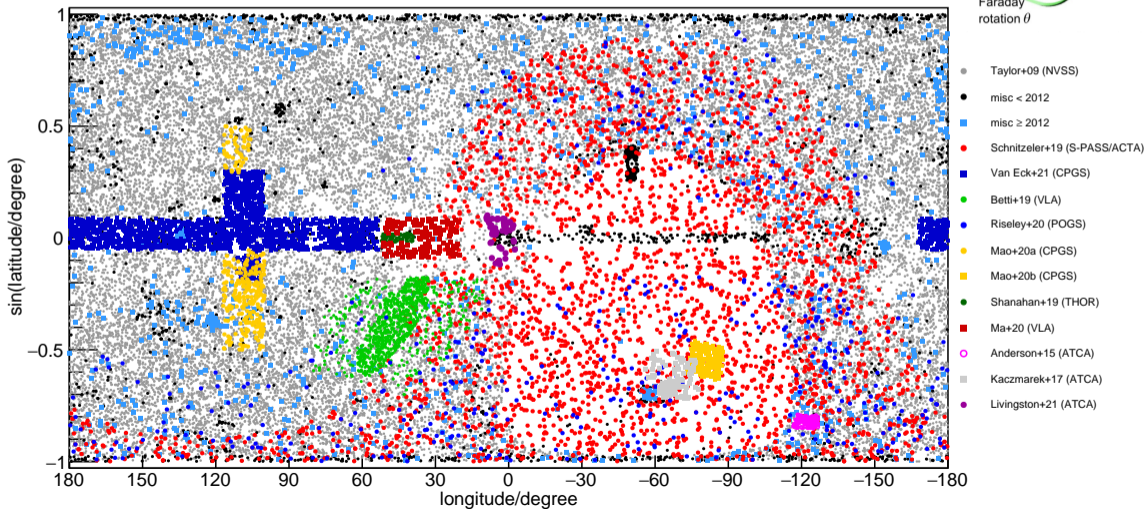
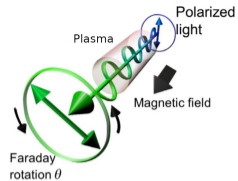
$$\theta = \theta_0 + \text{RM} \lambda^2$$



- Taylor+09 (NVSS)
- misc < 2012

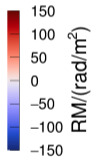
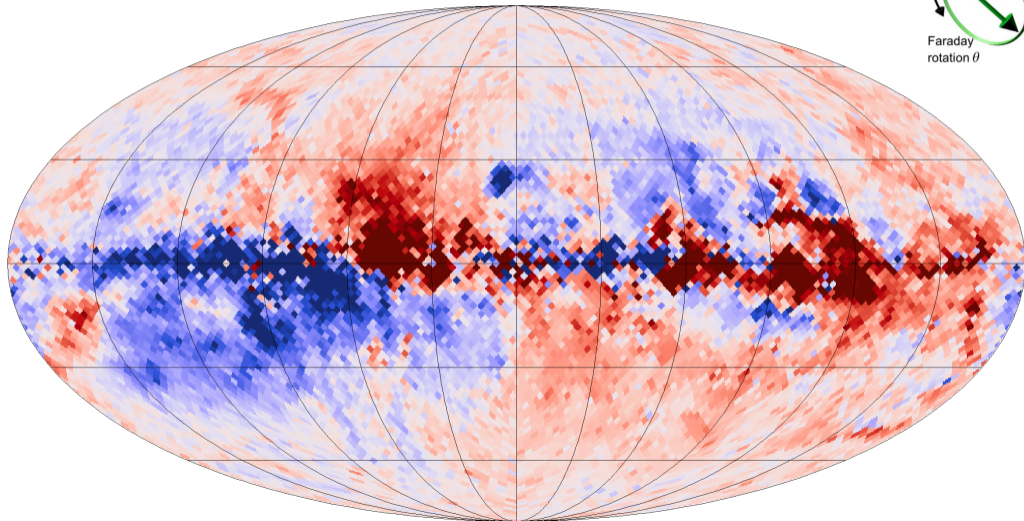
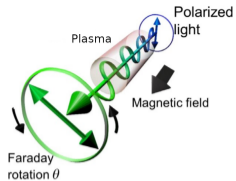
Extragalactic Rotation Measures 2022

$$\theta = \theta_0 + \text{RM} \lambda^2$$



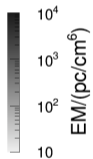
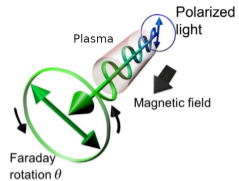
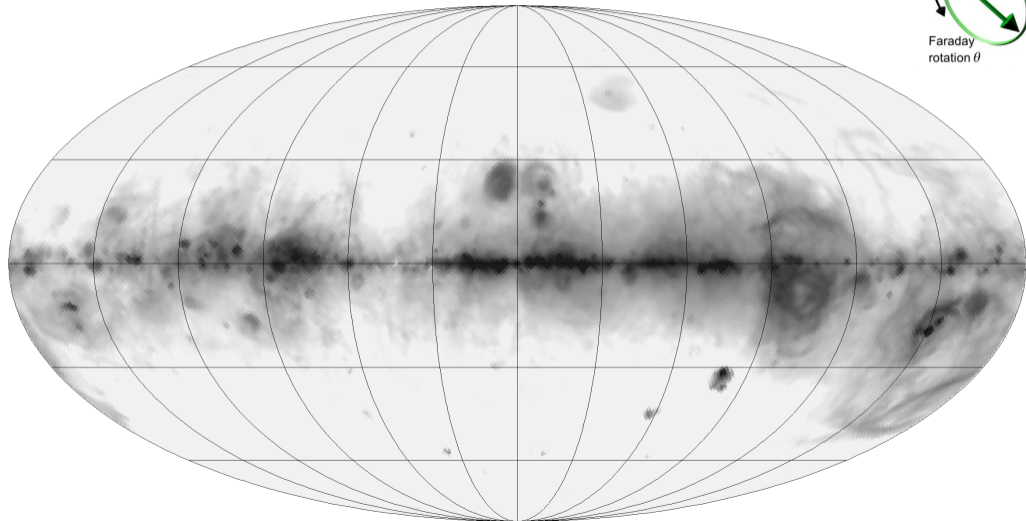
2022 RM Sky

$$\text{RM} \propto \int_{\text{source}}^{\text{observer}} B_{\parallel}(l) n_e(l) dl$$



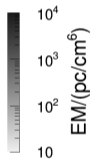
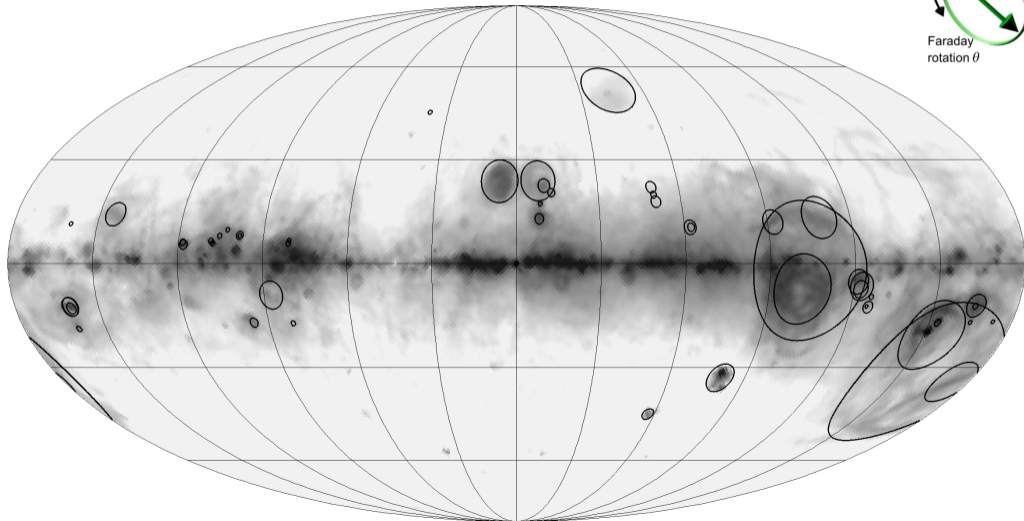
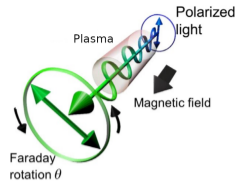
Foreground: HII Regions

$$EM \propto \int_{\text{source}}^{\text{observer}} n_e(l)^2 dl$$



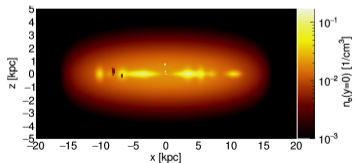
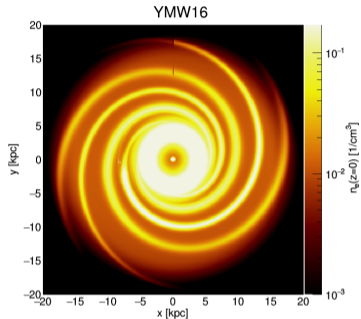
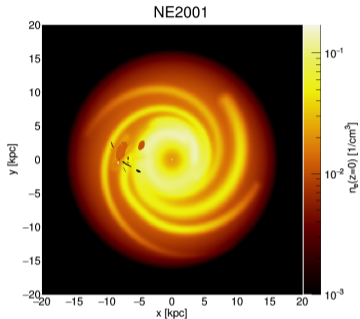
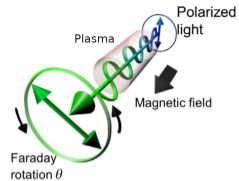
Foreground: HII Regions

$$EM \propto \int_{\text{source}}^{\text{observer}} n_e(l)^2 dl$$

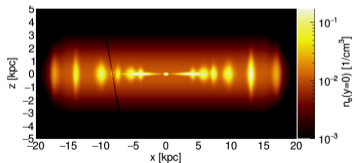


Thermal Electron Models

$$DM \propto \int_{\text{source}}^{\text{observer}} n_e(l) dl$$



112 pulsar DMs



189 pulsar DMs

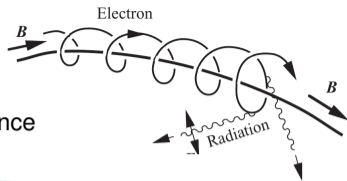
Polarized Synchrotron Emission



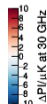
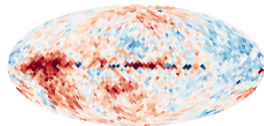
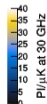
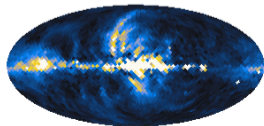
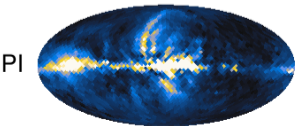
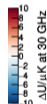
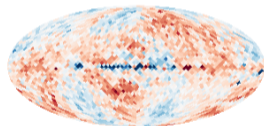
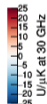
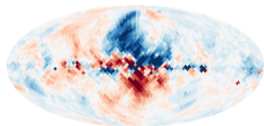
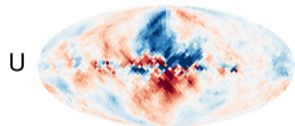
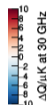
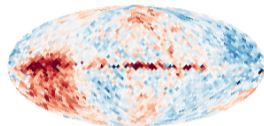
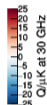
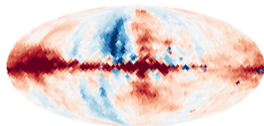
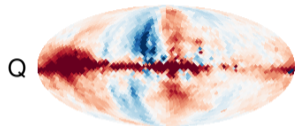
WMAP9



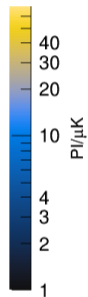
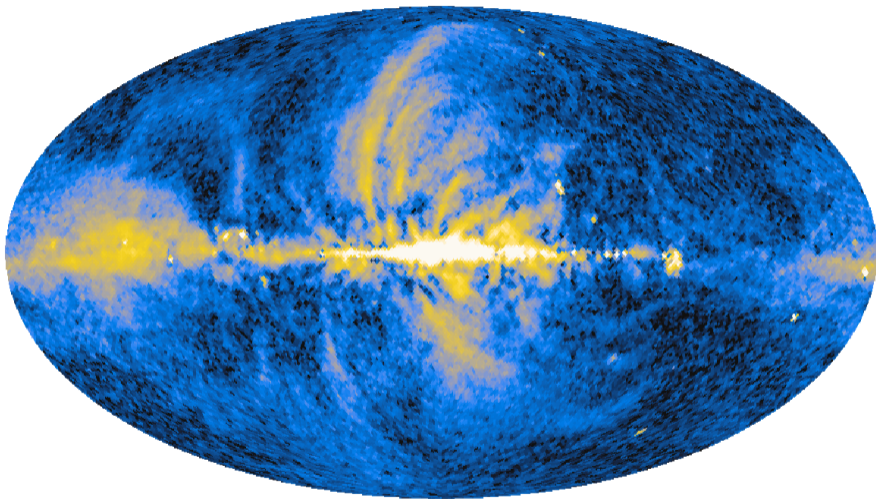
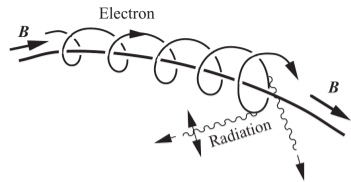
Planck R3.00



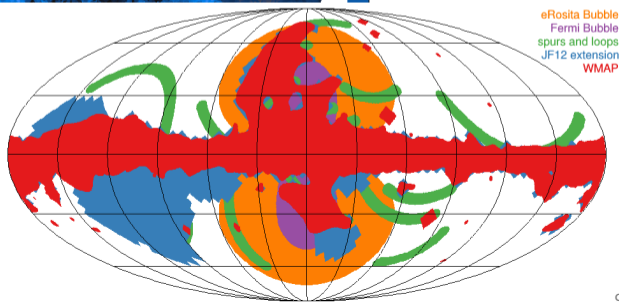
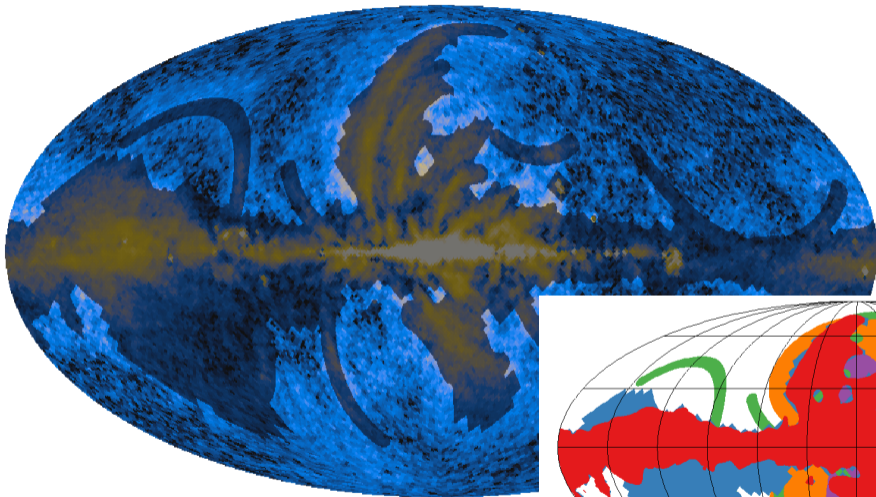
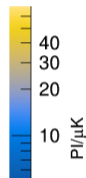
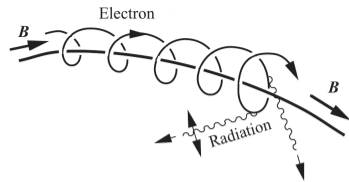
difference



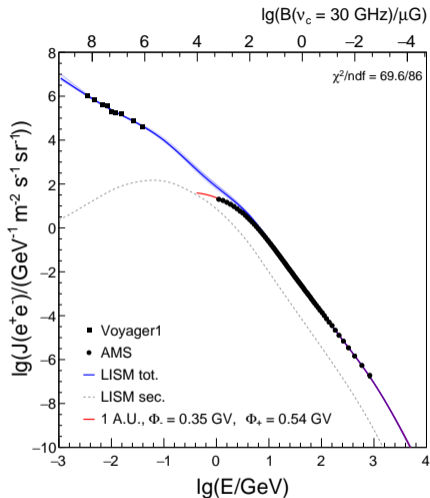
Combined WMAP-Planck Polarized Emission



Combined WMAP-Planck Polarized Emission

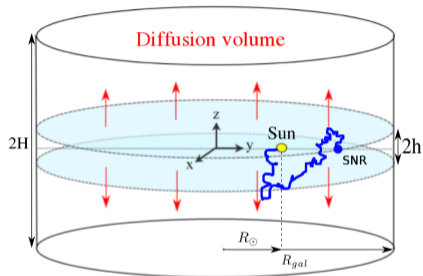
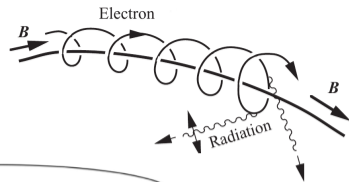


Cosmic-Ray Electron Model

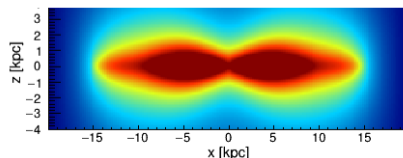


DRAGON calculation constrained at
Solar system and D_0/H from B/C

<https://github.com/cosmicrays/DRAGON>

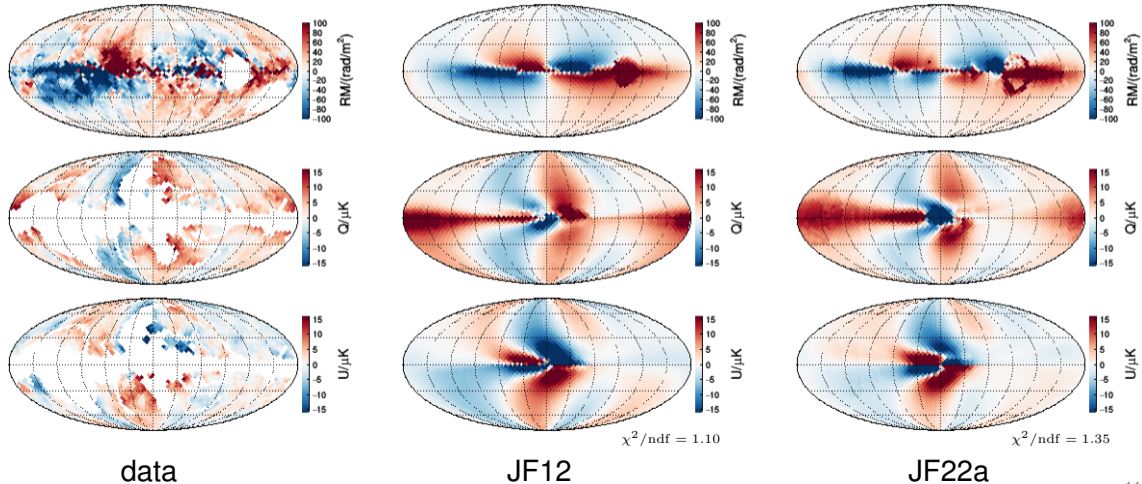


cosmic-ray electron density ($H = 10 \text{ kpc}$)



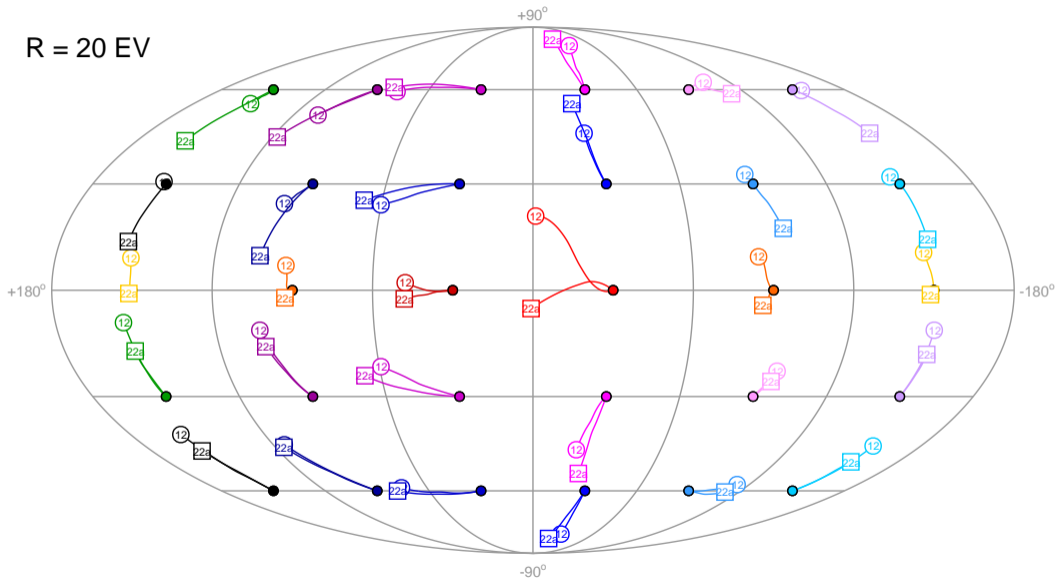
Refit of JF12

	JF12	JF22a
RM data	2011	2022
QU	WMAP7	WMAP9&Planck
RM mask	none	HII
PI mask	35%	35%+spurs
thermal electrons	NE2001	YMW16
cosmic-ray electrons	GALPROP E^{-3}	DRAGON PD 4 kpc
Xfield at GC	0 within $r = 1$ kpc	continuous



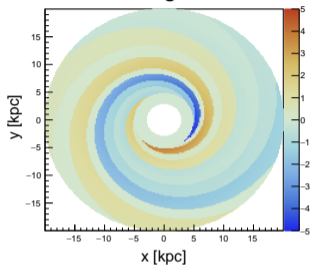
Deflections: JF12 vs JF22a

R = 20 EV

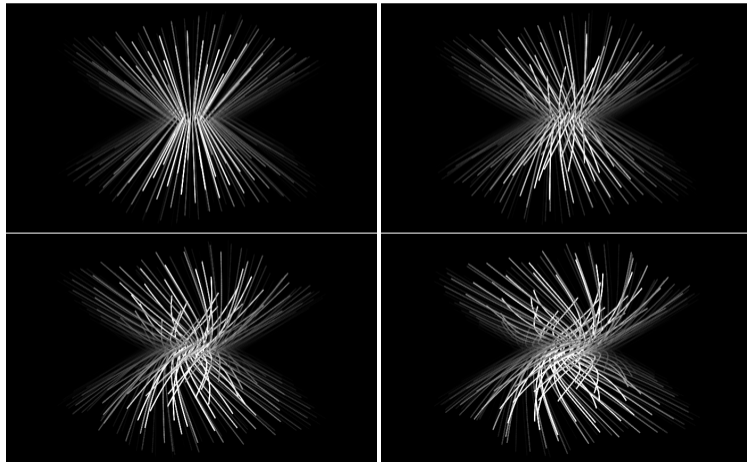


GMF Model Improvements

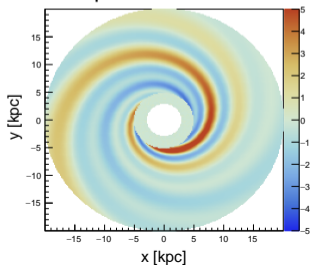
Brown+07 “wedge”-model:



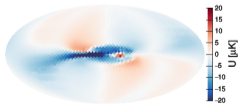
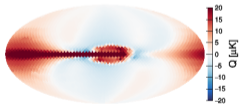
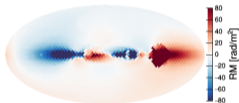
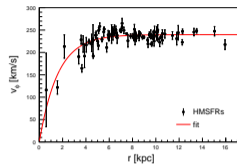
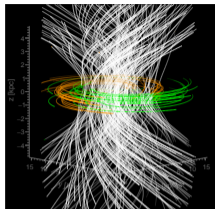
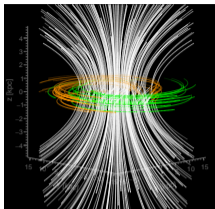
- evolve poloidal field via induction equation
- radial and vertical shear of Galactic rotation generates toroidal field



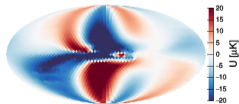
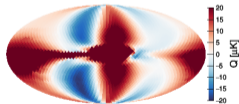
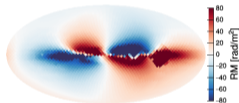
smooth spiral disk field:



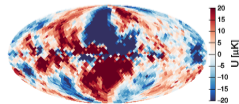
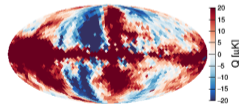
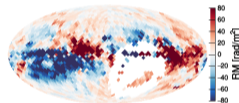
GMF Model Model Improvements



(a) $t = 0$ Myr



(b) $t = 70$ Myr



(c) data

Summary and Outlook

Re-tune of JF12 \rightarrow JF22:

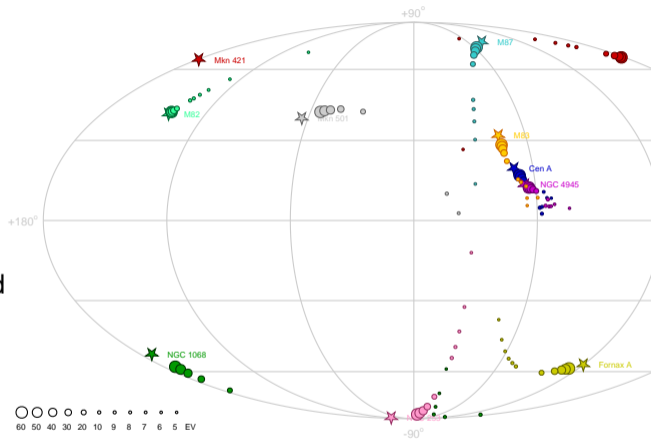
- new RM data
- new synchrotron sky maps
- improved auxiliary models (n_e and n_{cre})

Next Up: Model Improvements:

- disk-field discontinuities
- unified halo model: twisted poloidal field

Incomplete List of Uncertainties:

- scale height of n_{cre}
- n_e uncertainties
- $n_e - B$ correlations
- foregrounds: local bubble, spurs, ...



JF12 coherent deflections

Summary and Outlook

Re-tune of JF12 \rightarrow JF22:

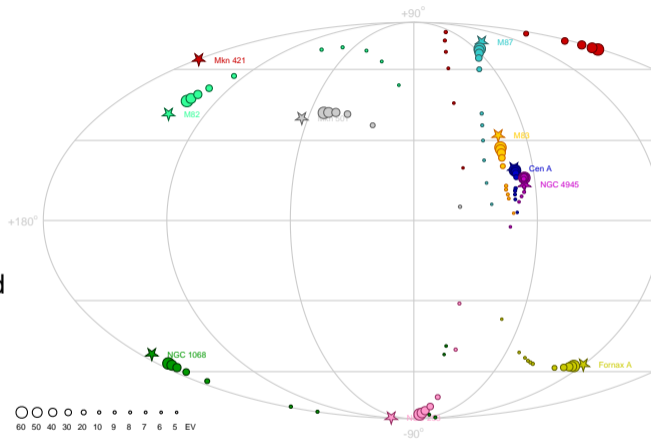
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Incomplete List of Uncertainties:

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JF22a coherent deflections