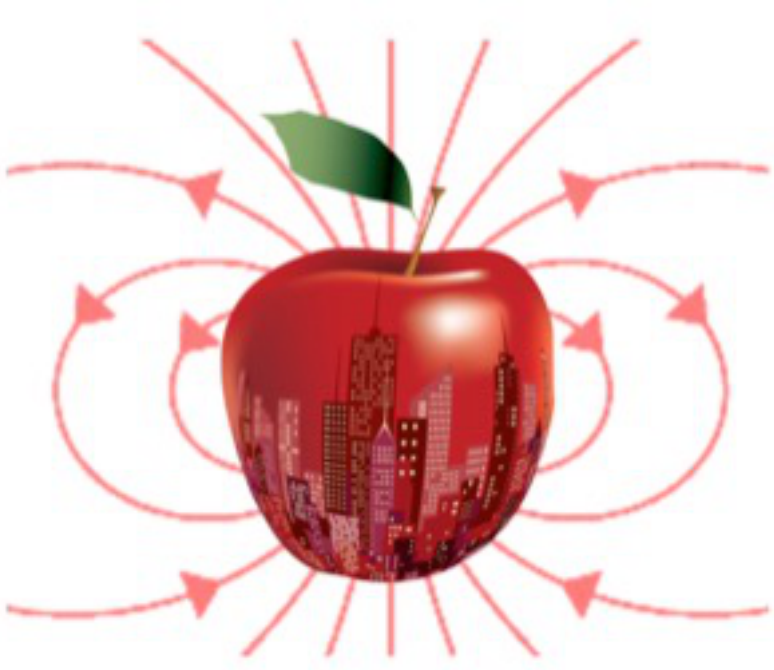
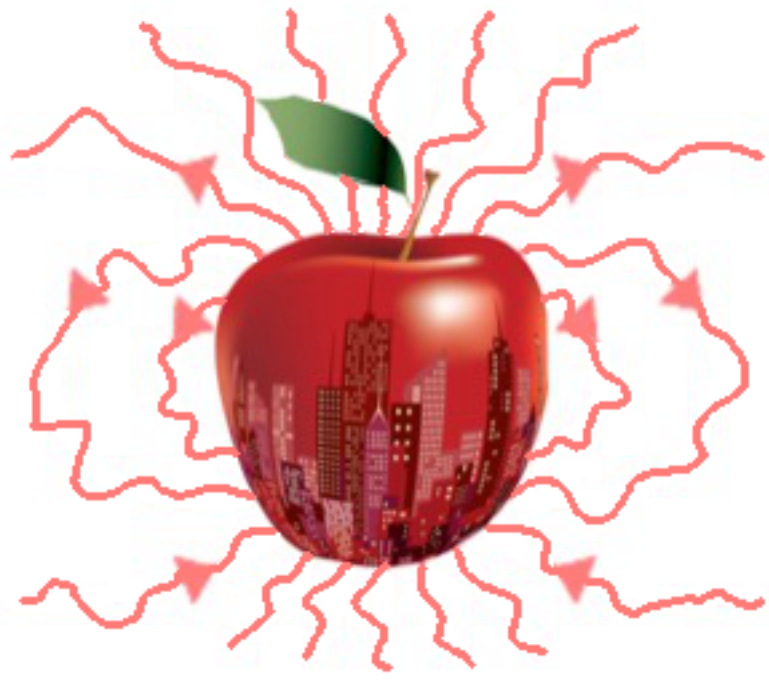
(Towards) Improved constraints on the structure of the Galactic random field

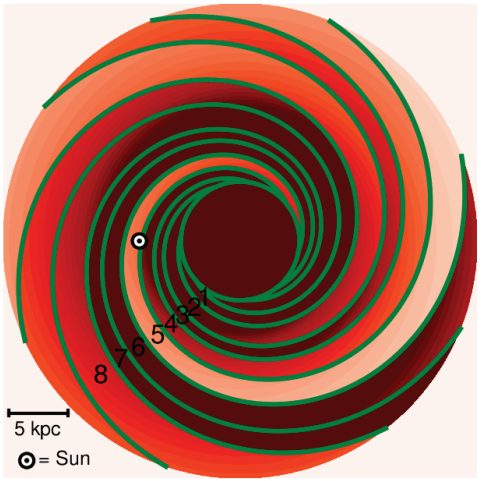
M. Unger (KIT) and G.R. Farrar (NYU)



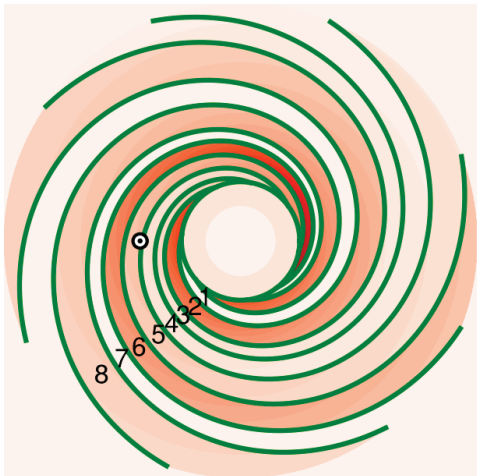


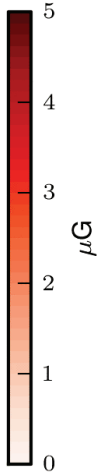
Jansson&Farrar Random Field Model (2012)

random disk



coherent disk

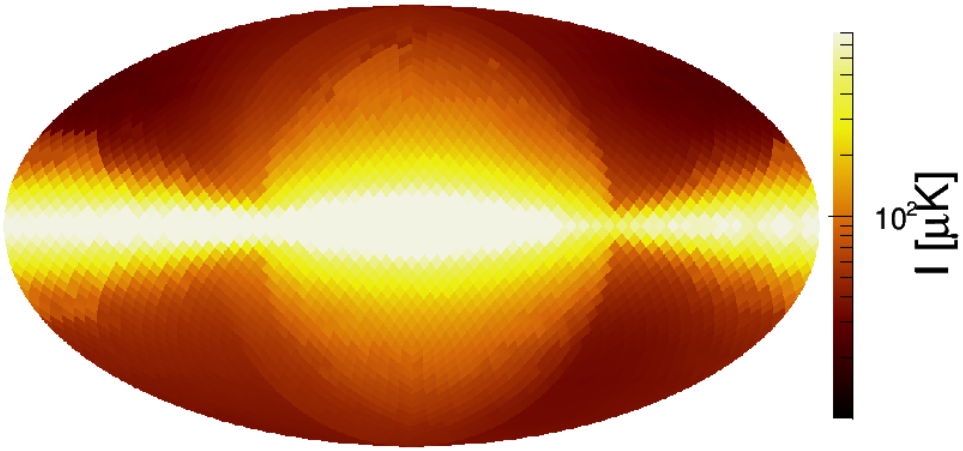




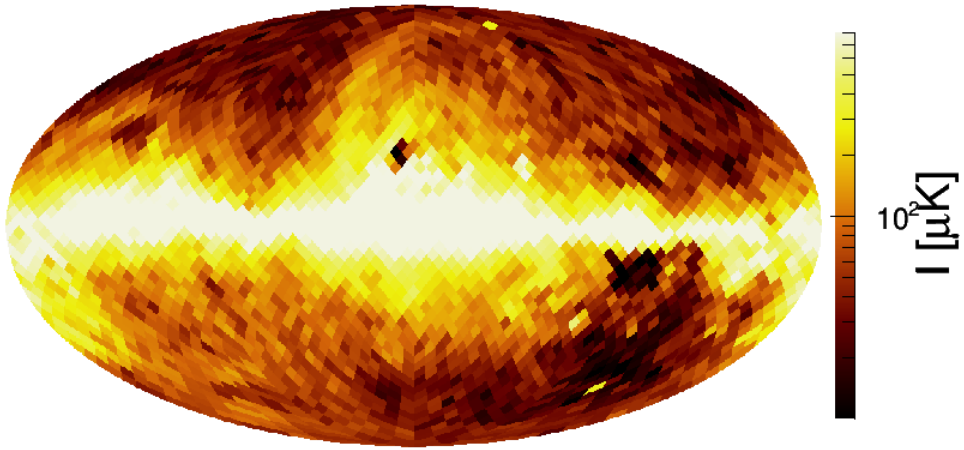
Best-fit Parameters of the Random Field, with 1σ Intervals

Field	Best-fit Parameters	Description
Disk component	$b_1 = 10.81 \pm 2.33\,\mu$G	Field strengths at $r = 5$ kpc
	$b_2 = 6.96 \pm 1.58\,\mu$G	
	$b_3 = 9.59 \pm 1.10\,\mu$G	
	$b_4 = 6.96 \pm 0.87\,\mu$G	
	$b_5 = 1.96 \pm 1.32\,\mu$G	
	$b_6 = 16.34 \pm 2.53\,\mu$G	
	$b_7 = 37.29 \pm 2.39\,\mu$G	
	$b_8 = 10.35 \pm 4.43\,\mu$G	
	$b_{\rm int} = 7.63 \pm 1.39\,\mu$G	Field strength at $r < 5$ kpc
	$z_0^{\rm disk} = 0.61 \pm 0.04$ kpc	Gaussian scale height of disk
Halo component	$B_0 = 4.68 \pm 1.39\,\mu$G	Field strength
	$r_0 = 10.97 \pm 3.80$ kpc	Exponential scale length
	$z_0 = 2.84 \pm 1.30$ kpc	Gaussian scale height

model

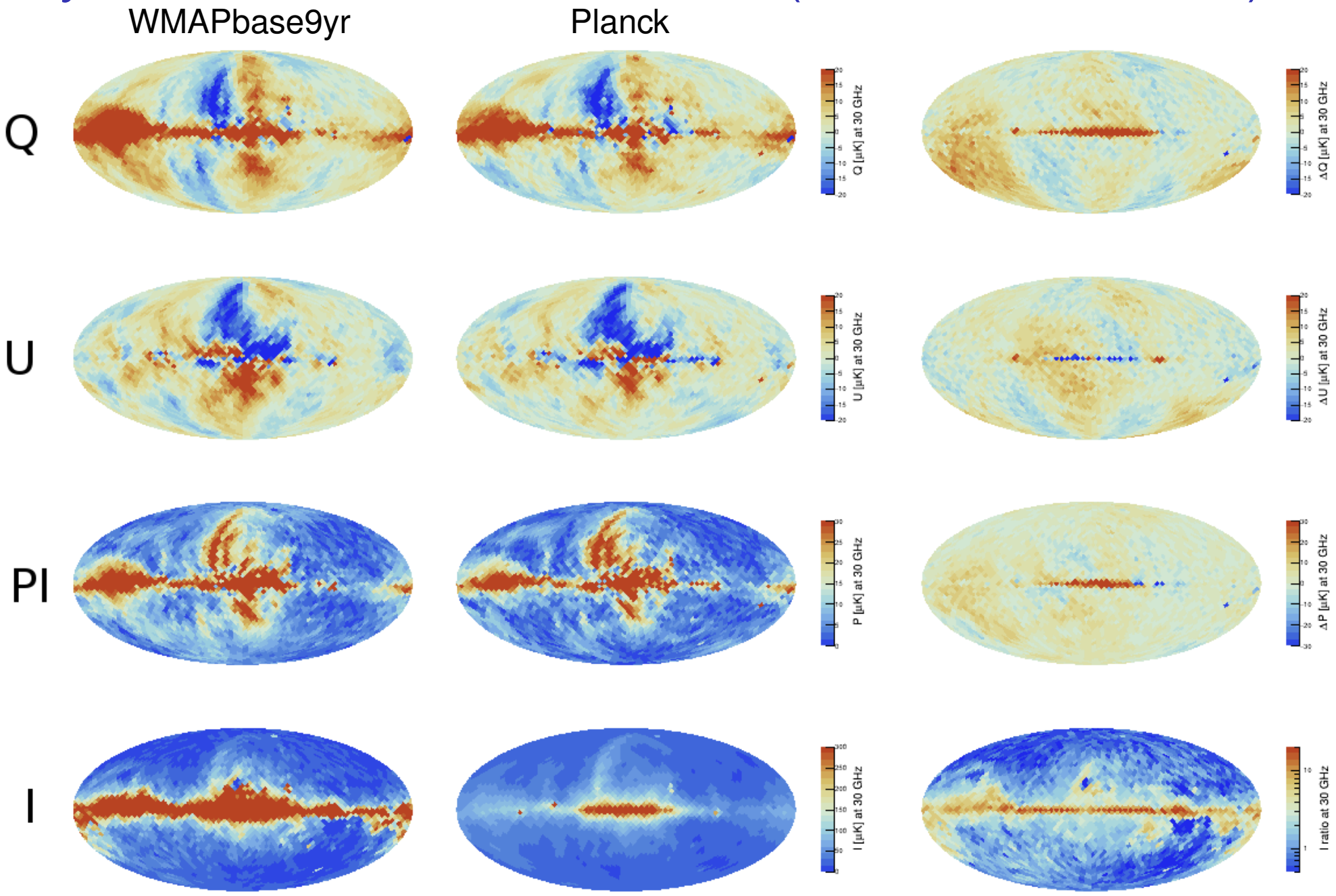


WMAP synchrotron intensity



R. Jansson & G.F. Farrar, ApJ **761** (2012) L11

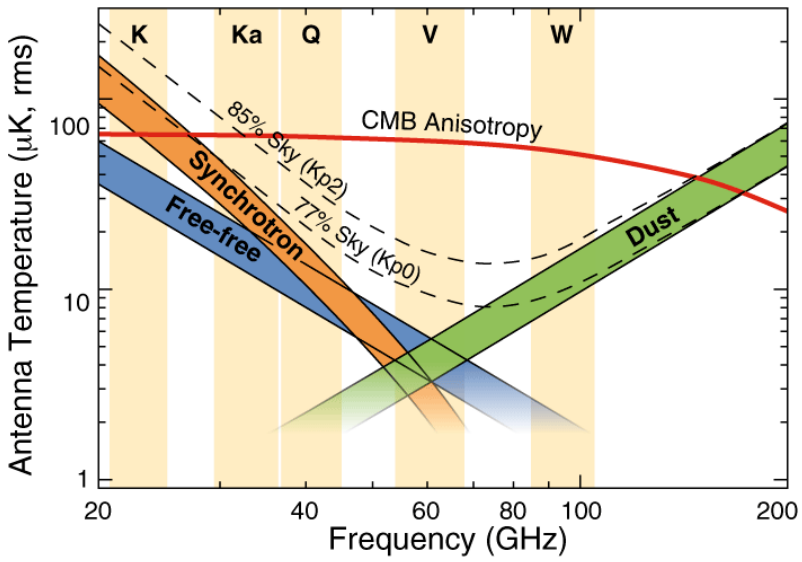
Synchrotron Emission Products (Planck and WMAP)



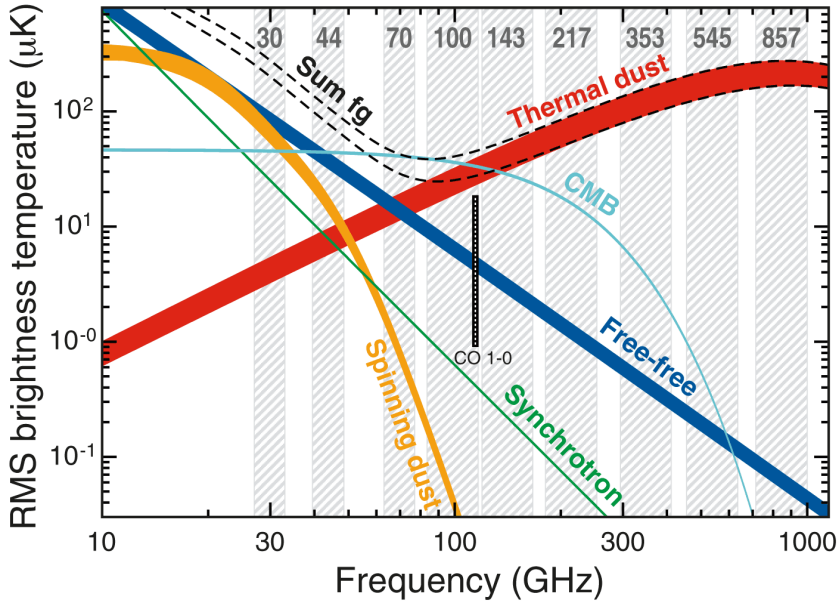
Synchrotron Emission

Component Separation:

WMAPbase9yr

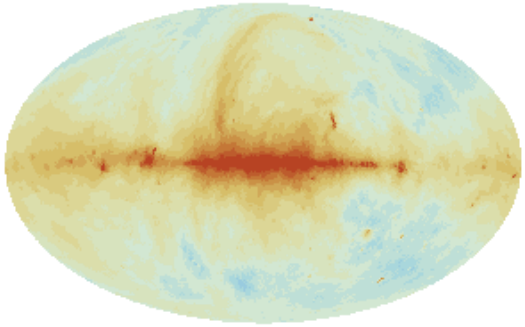


Planck

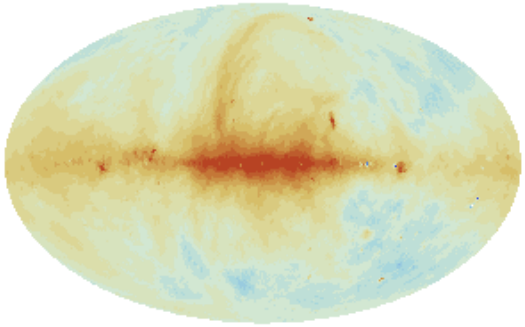


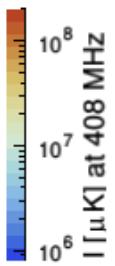
Planck vs. Haslam

Haslam

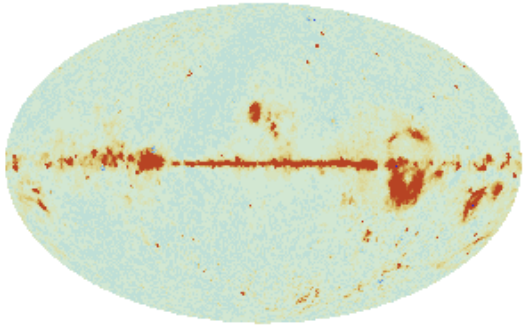


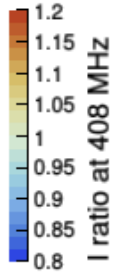
Planck





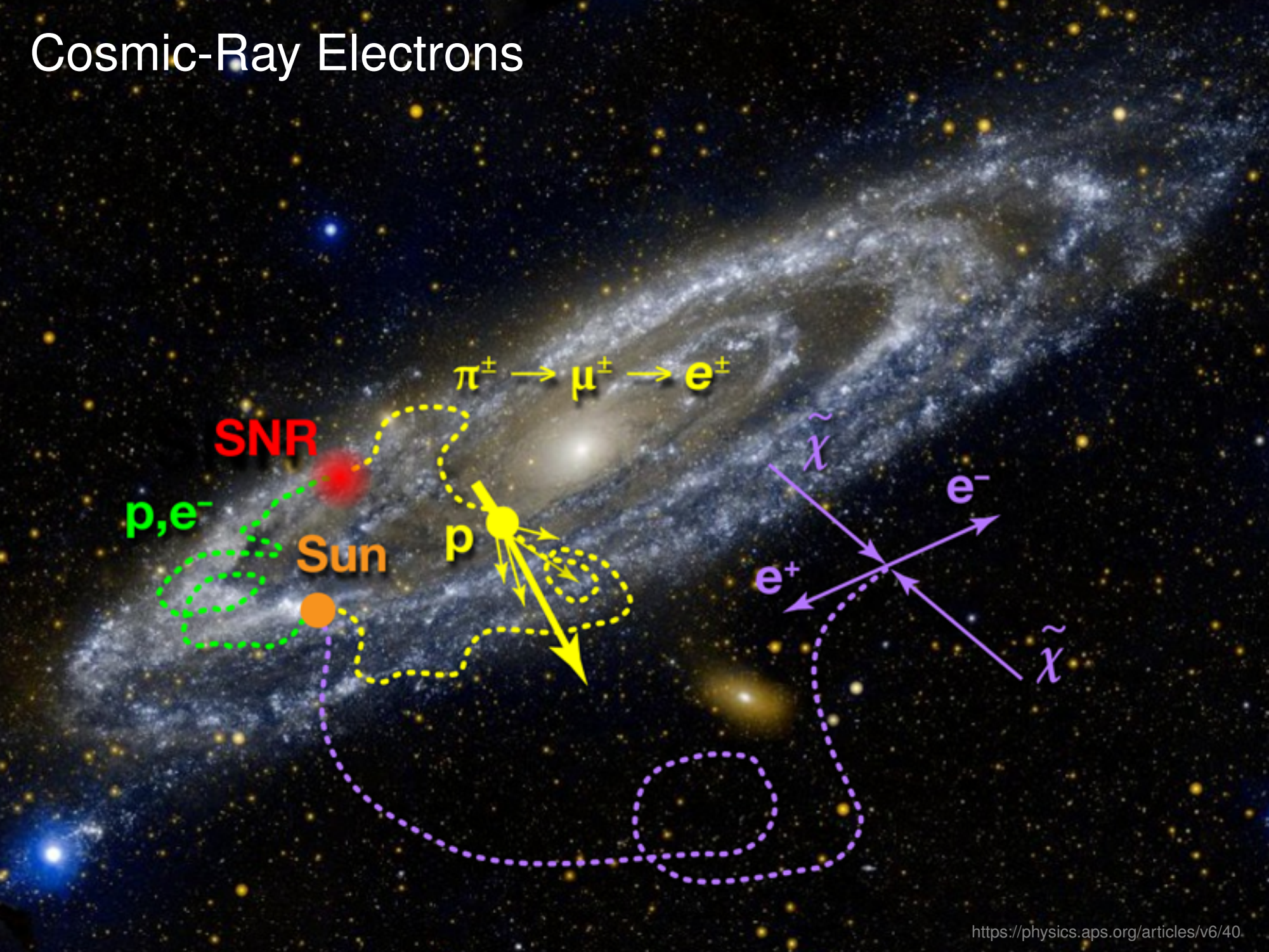
Haslam / Planck





destriped and mono/dipole subtracted Haslam from Remazeilles+14

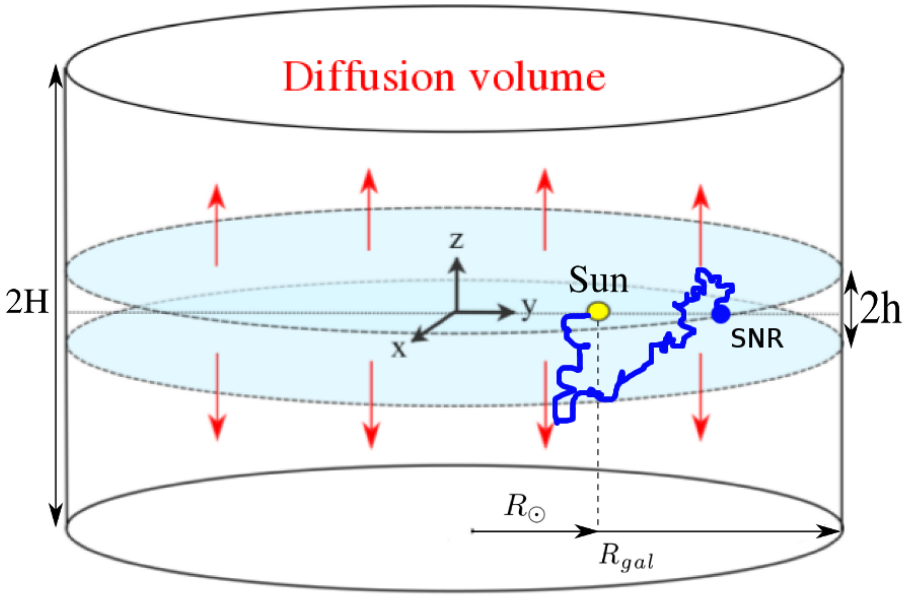
Cosmic-Ray Electrons

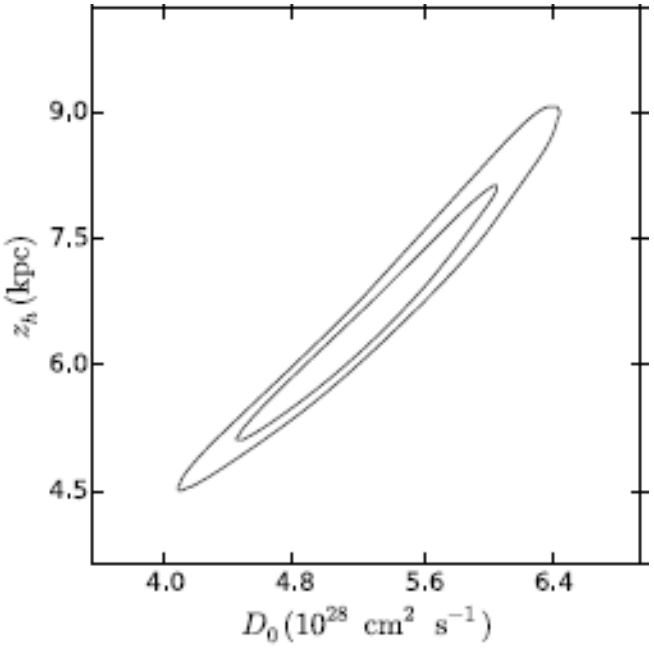


https://physics.aps.org/articles/v6/40

Cosmic-Ray Electrons

- **origin:**
  - primary e^-: acceleration in supernova remnants
  - secondary $e^\pm$: $p + p_{\rm ISM}$
  - primary $e^\pm$: pulsar wind nebulae
- **data:** cosmic-ray electron spectra at Earth, B/C, Be
- diffusion and cooling in Galactic magnetic field





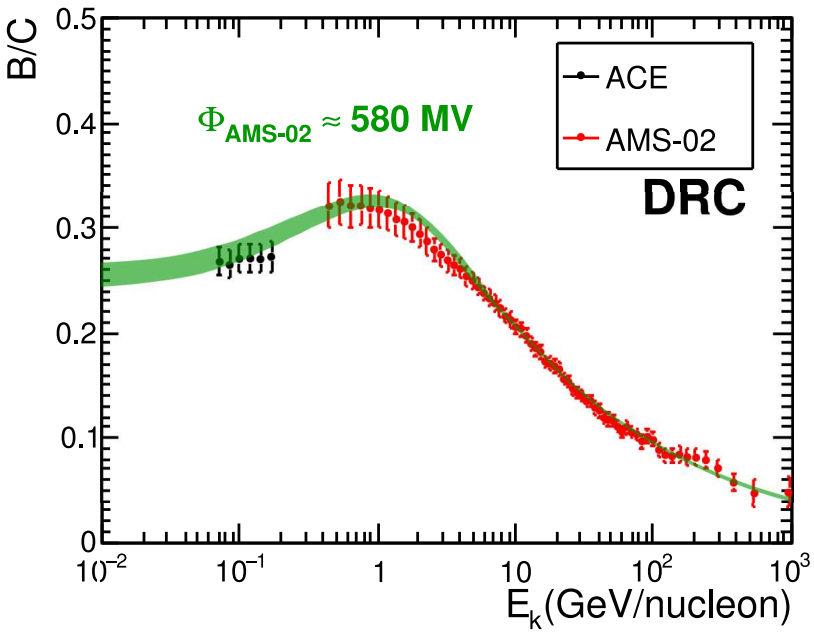
Y. Genolini et al, A&A. **580** (2015) A9

Yuana+2017

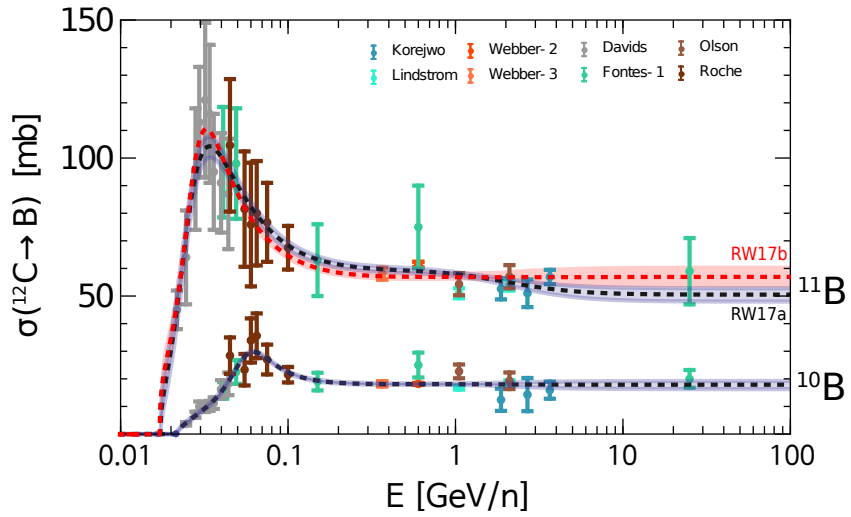
Diffusion Coefficient from B/C

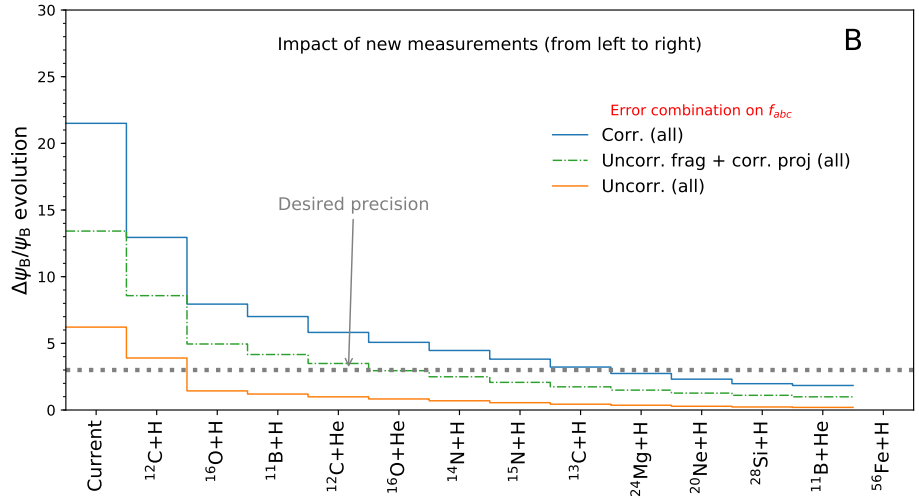
CR-grammage X ("target thickness") from secondary nuclei, e.g.
$C + p_{ISM} \rightarrow B + X$

$$(B/C) \sim \frac{(1 - e^{-X/\lambda_{prod}})\, e^{-X/\lambda_B}}{e^{-X/\lambda_{prod}}}.$$



Yuana+2017





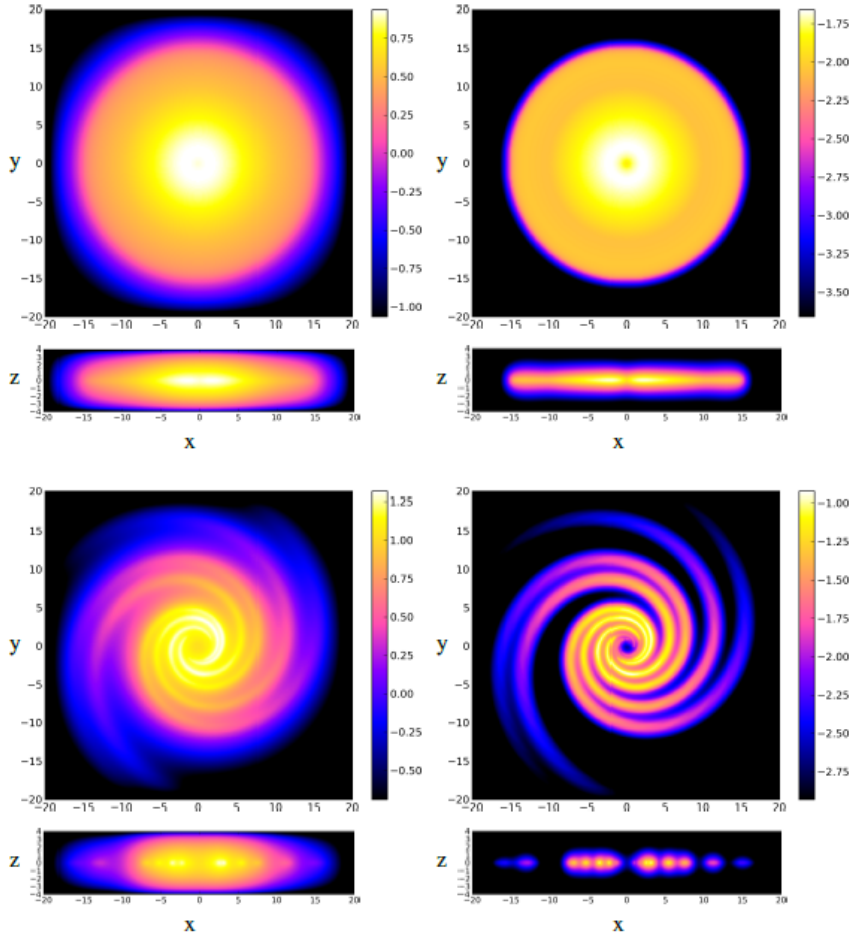
Reinert+2017, Génolini+2018

$$X \propto \rho \frac{hH}{D}, \quad D \propto (E/Z)^{\delta}$$

new measurements underway with NA61/SHINE at SPS/CERN

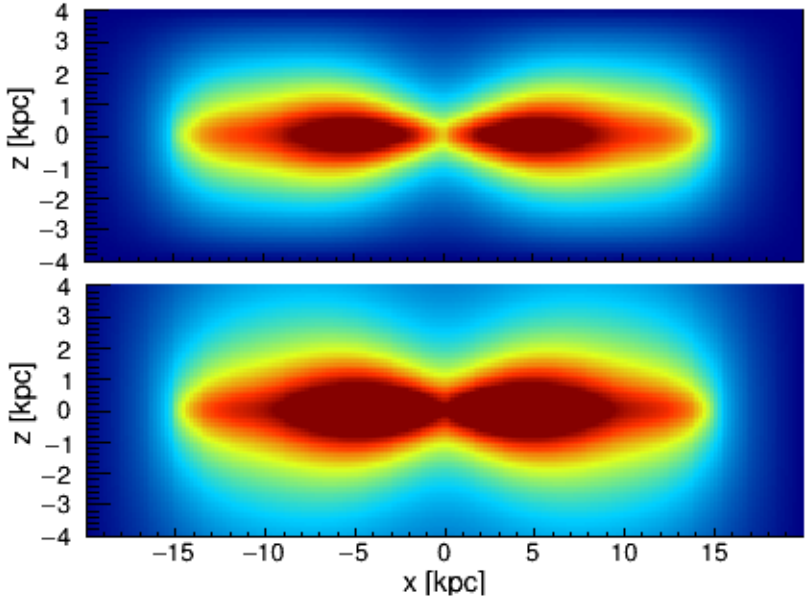
Cosmic-Ray Electron Models

1.1 GeV 1.1 TeV



M. Werner et al, Astropart.Phys. **64** (2015) 18

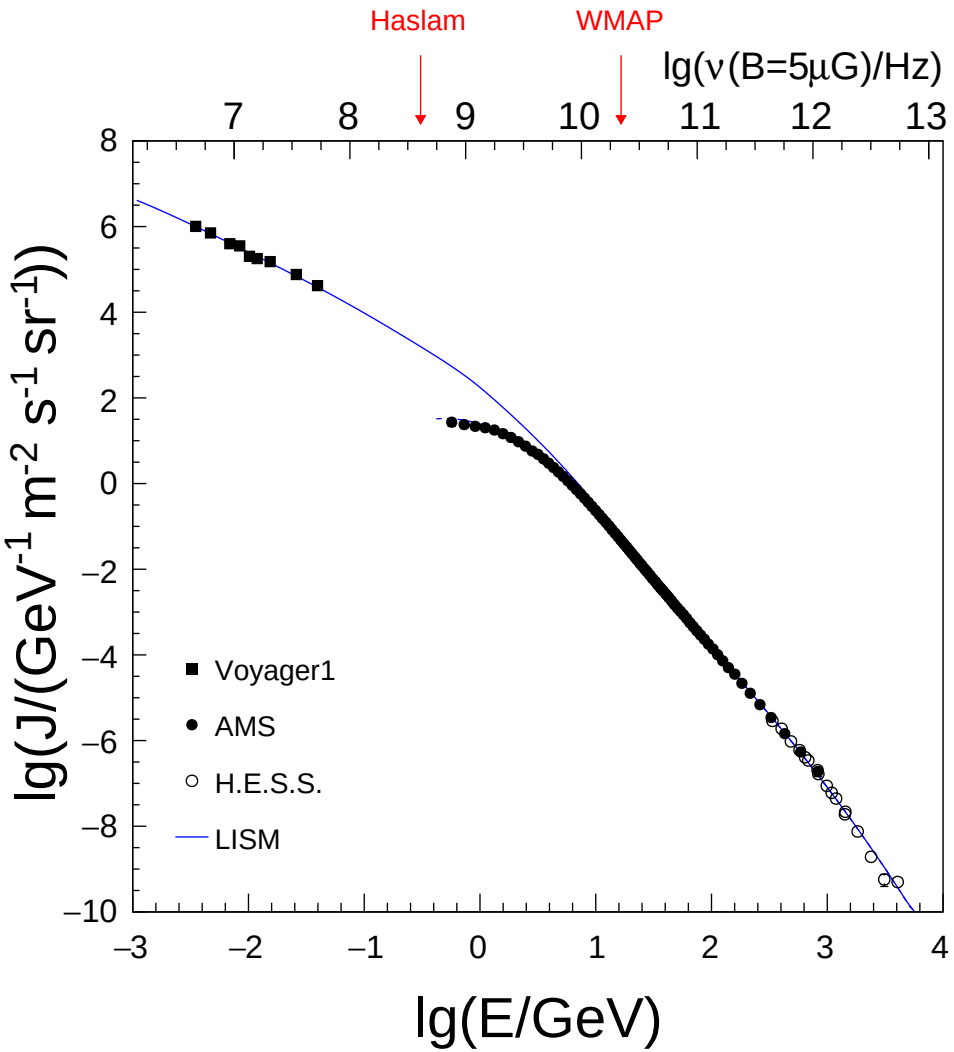
$H = 4$ kpc



$H = 10$ kpc

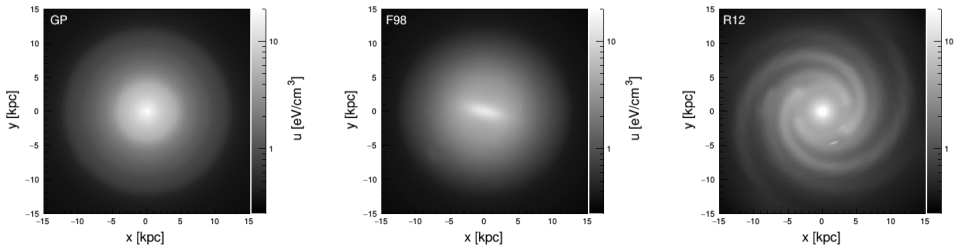
T. Jaffe, private communication

Improved Cosmic-Ray Electron Modeling (UF in prep.)

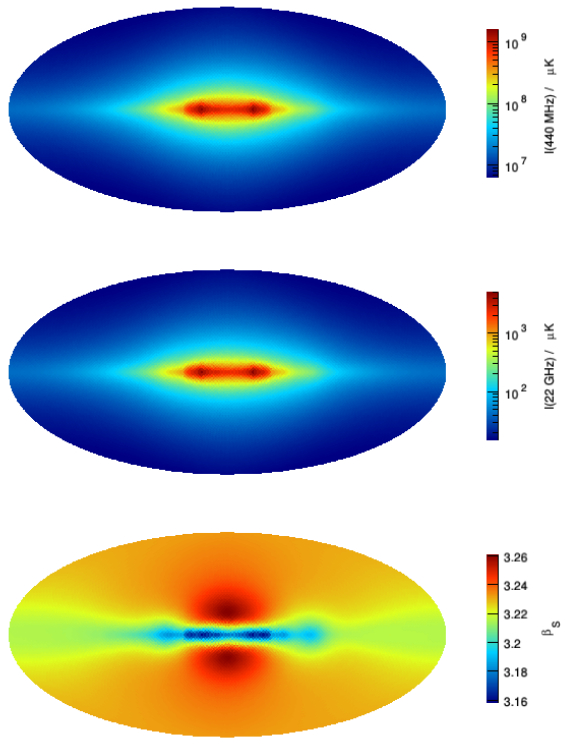


fit DRAGON simulations to $e^{\pm}$ data

- 3D ISRF energy density Porter+17



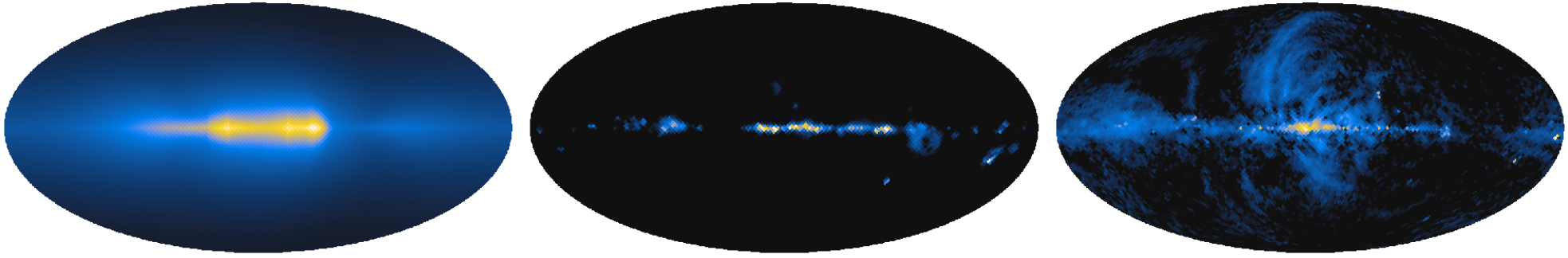
- 3D CR source distribution
- 3D GMF



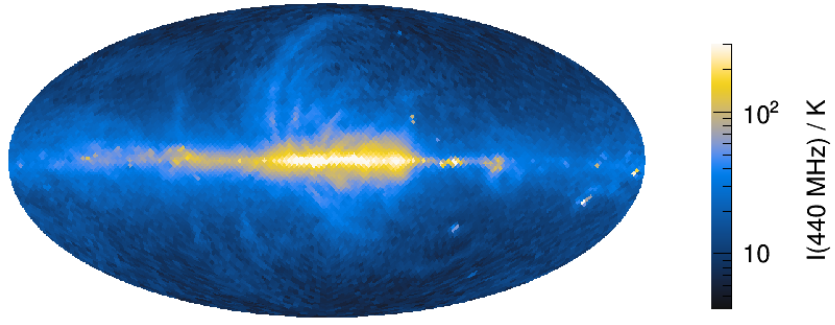
	PD1	DR	PD2
reference	Cummings+16	Orlando+18	DiBernardo+13
diffusion type	constant $[-h_z,\ h_z]$	constant $[-h_z,\ h_z]$	$\propto \exp(z/h_z)$
$\eta/\delta_1/\delta_2/R_{\rm br}$[GV]	1/-0.641/0.578/4.84	1/0.327/0.323/4.0	-0.40/0.57/–/–
D_0(10 GV) [10^{28} cm^2/s]	5.52	9.33	4.45
h_z [kpc]	4	4	4
$R_D = D_0/h_z$ [10^{28} cm^2/s/kpc]	1.38	2.33	1.11
v_A [km/s]	–	8.9	–

Deriving B_{rand} from I

$I(B_{\mathrm{rand}})$ + $I_{\mathrm{free\text{-}free}}$ + I_{coh}



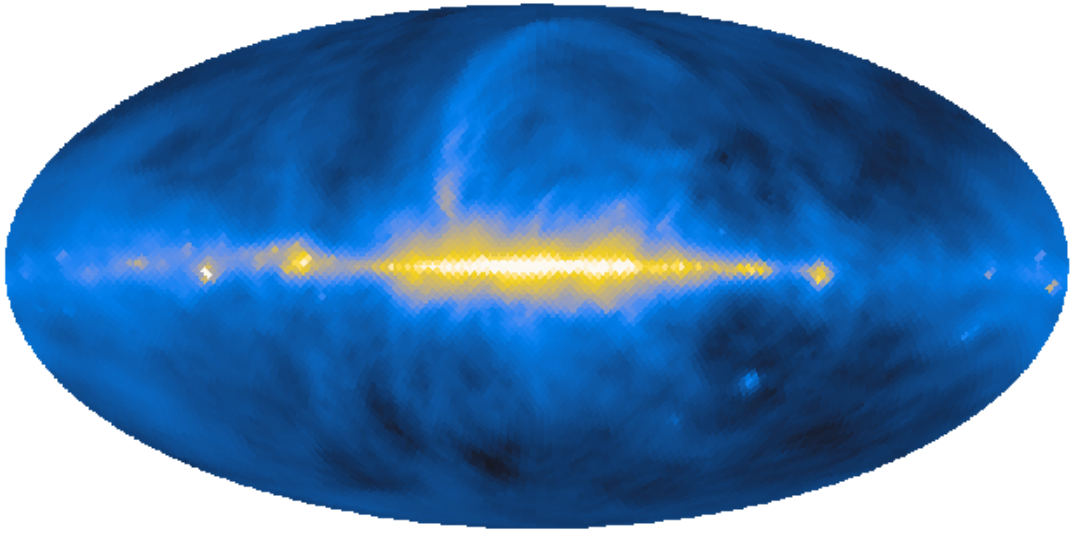
$=$

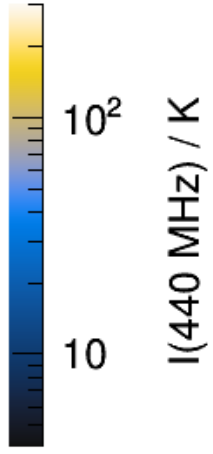


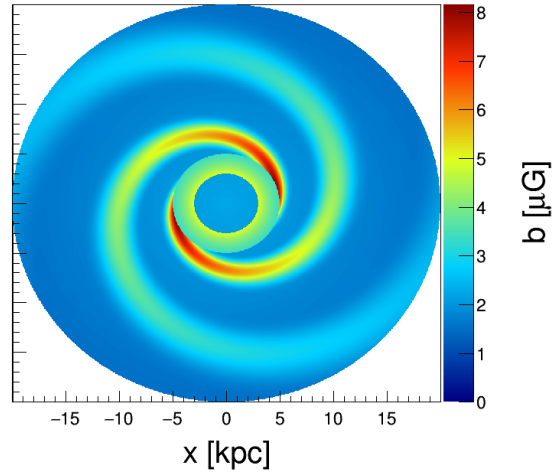
- fitted model prediction $I(B_{\mathrm{rand}})$ (using specific n_{cre} model)
- free-free from H_α data (de-attenuated and scattering-corrected, Bennet+15)
- $I_{\mathrm{coh}} = 1/\Pi \times (0.408/22.5)^{\beta_S} \times \mathrm{PI}$ (PI from WMAP, polarization fraction $\Pi \sim 0.7$)

Deriving B_{rand} from I (preliminary)

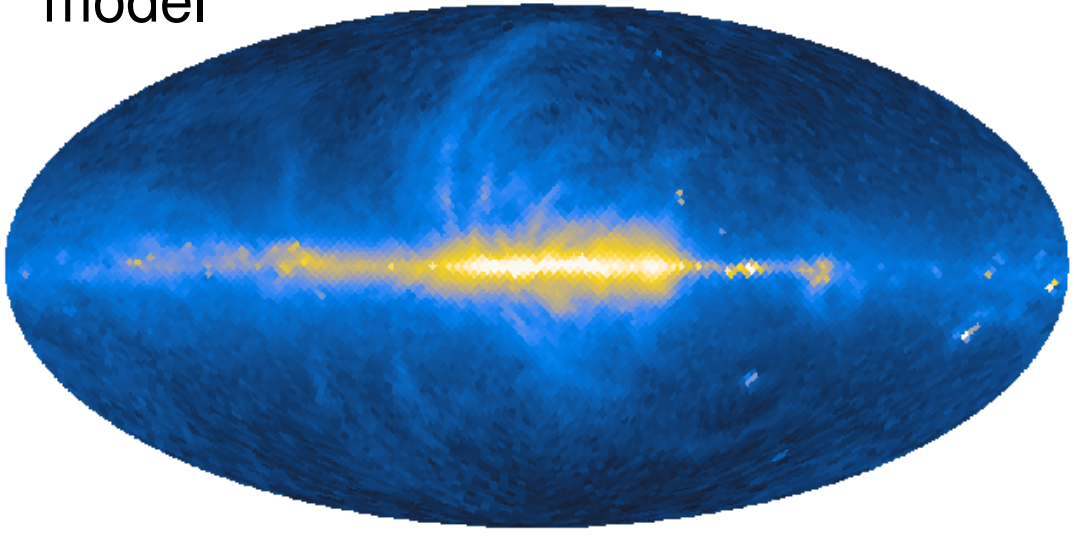
Haslam intensity

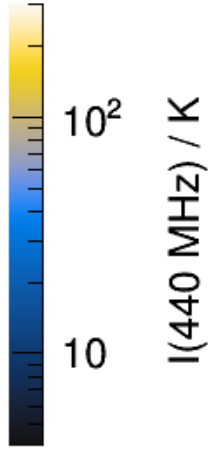






model

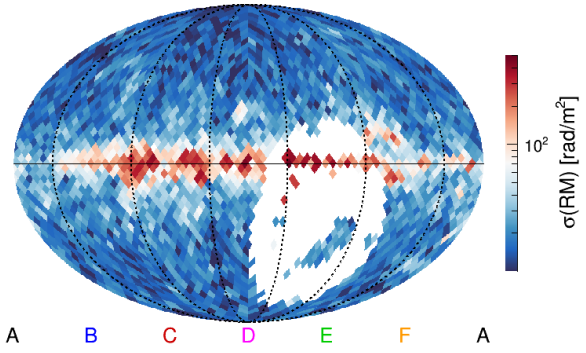


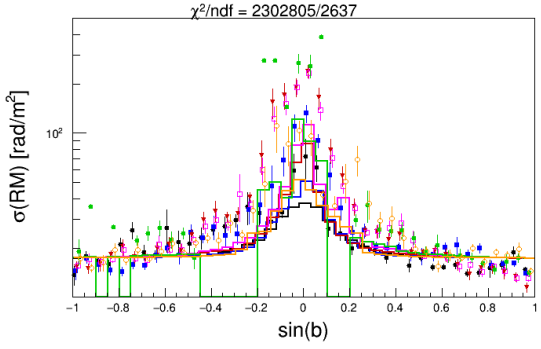


Outlook: RM Fluctuations

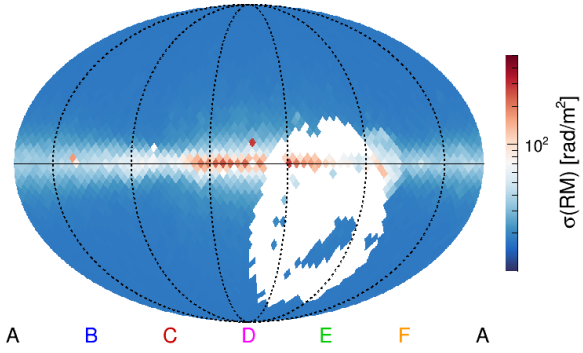
Sensitivity to coherence length?

data

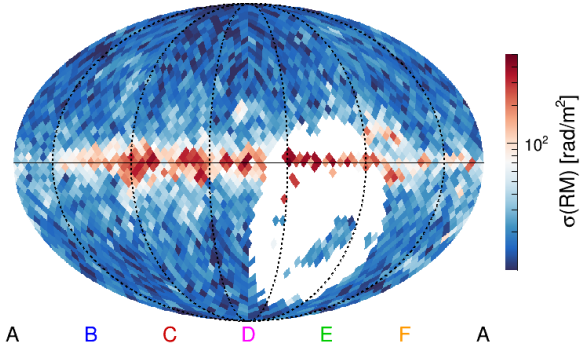


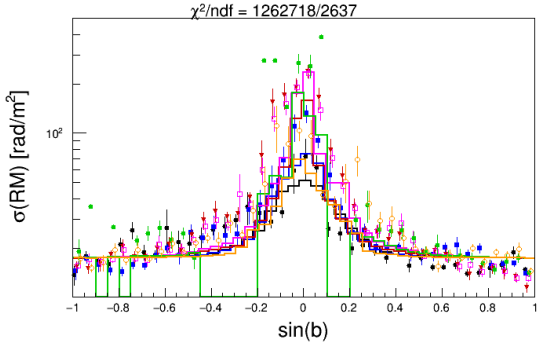


JF12, $l_{coh} = 10$ pc

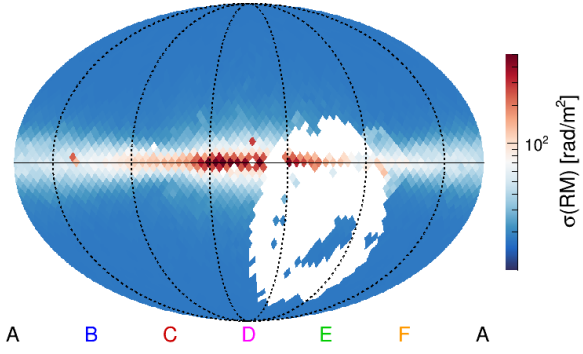


data



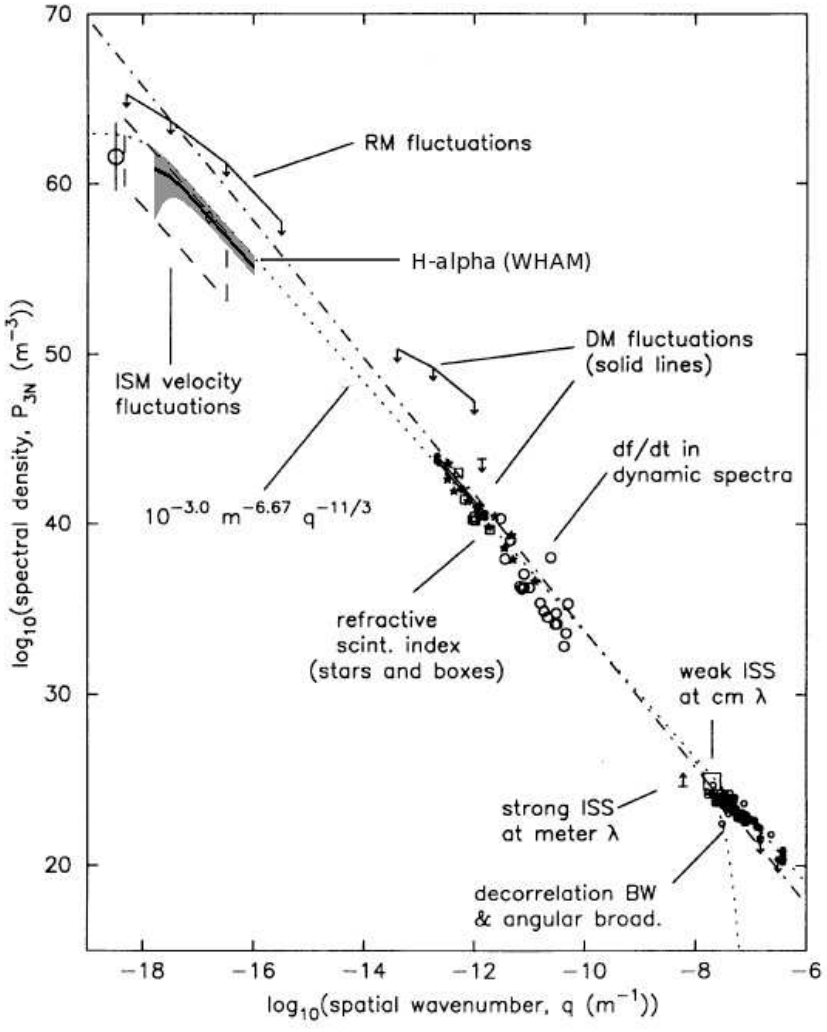


JF12, $l_{coh} = 100$ pc



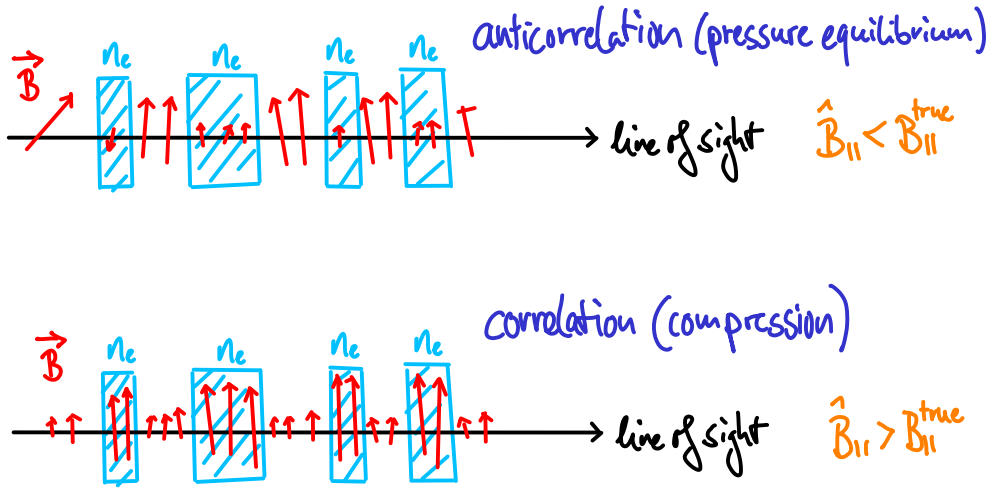
Outlook: RM Fluctuations

n_e fluctuations?



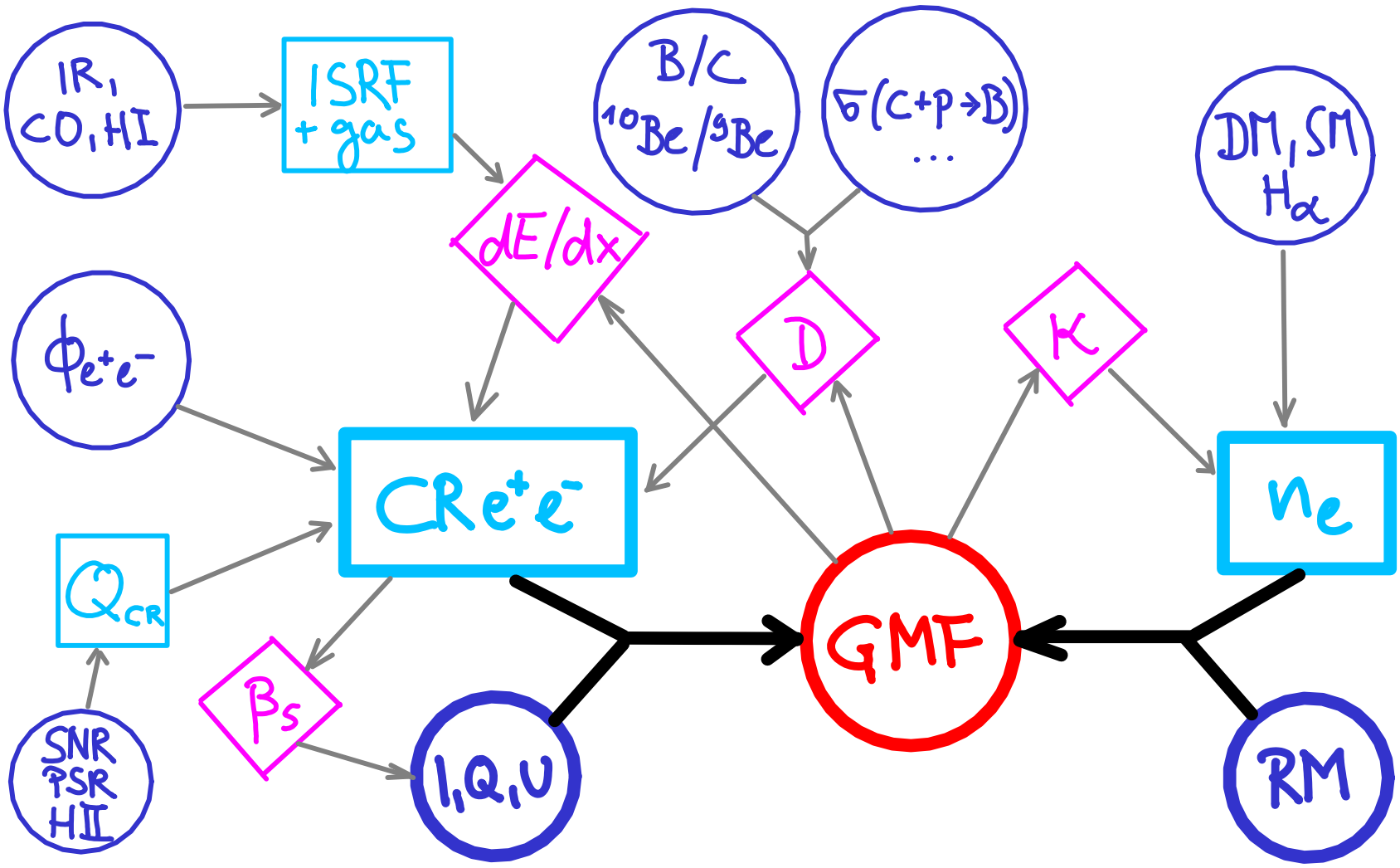
Chepurnov+2010, Armstrong+1995

$n_e - B$ correlation?



$$RM' = RM\left(1 + \frac{2}{3} K \frac{b^2}{B^2 + b^2}\right)$$ (Beck+03)

Summary


IR, CO, HI
ISRF + gas
B/C
$^{10}Be/^{9}Be$
$\sigma(C+p\to B)$ ...
DM, SM
H_α
dE/dx
D
K
$\phi_{e^+e^-}$
$CR_{e^+e^-}$
n_e
Q_{CR}
GMF
β_s
SNR PSR HII
I,Q,U
RM