Synchrotron and magnetic fields with GALPROP

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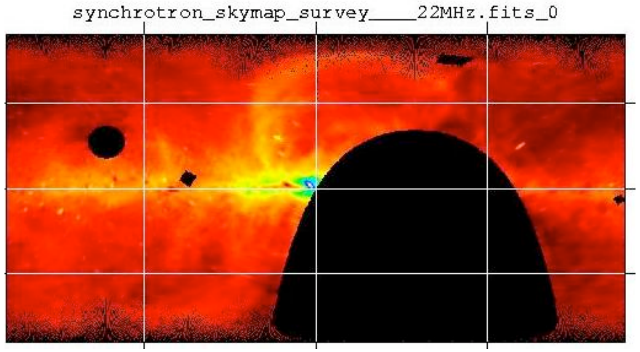
Aim

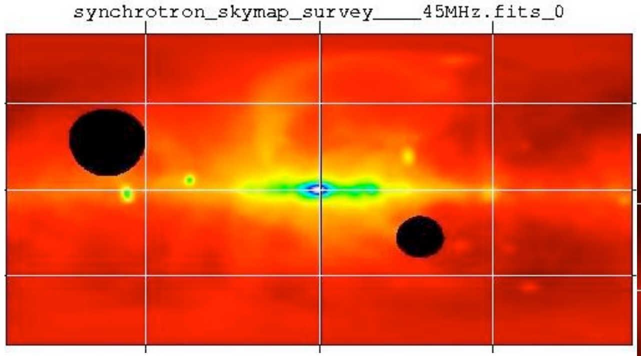
- Testing existing models of B
- Improving the models

Procedure

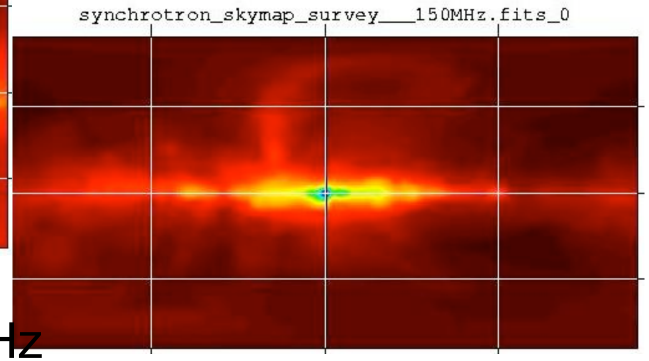
- Used CR sources distribution, and the electron spectrum that fits the FERMI intermediate latitude spectrum (see Strong's talk).
- 3D model of the regular field and random field component implemented in GALPROP
- Adjusting the value of total magnetic field to fit the synchrotron spectrum at the 408 MHz map
- Comparing synchrotron latitude and longitude profiles with the available radio surveys.



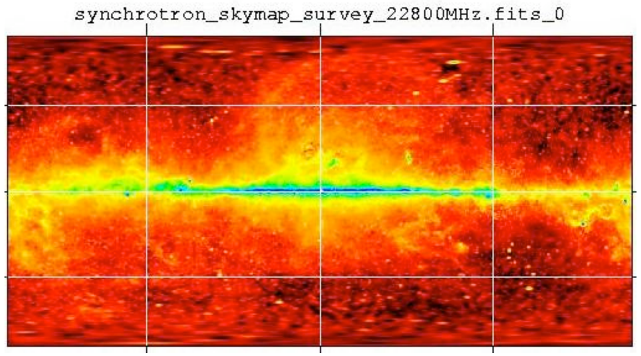
22 MHz



45 MHz



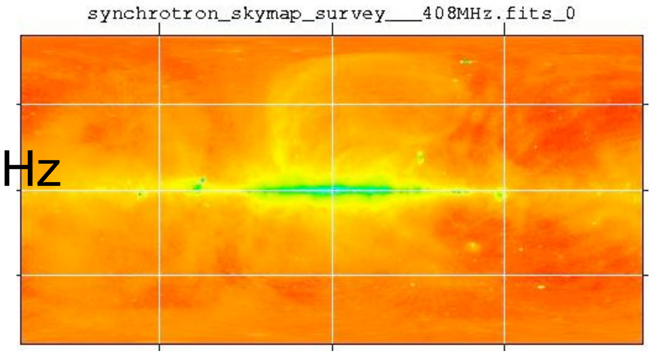
150 MHz

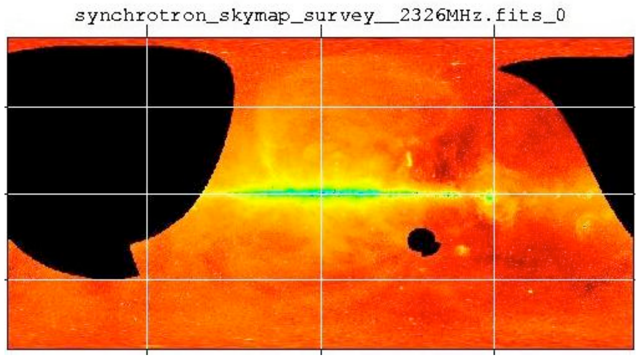


23 GHz

Continuum sky surveys

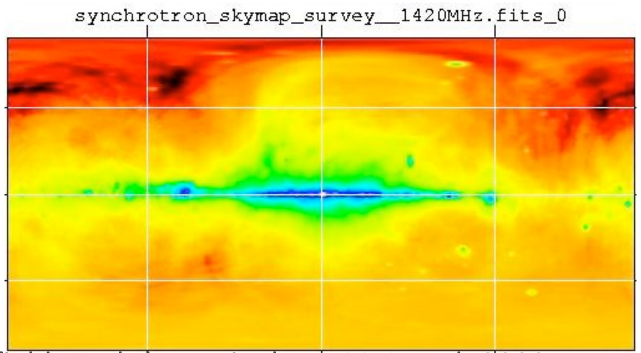
408 MHz



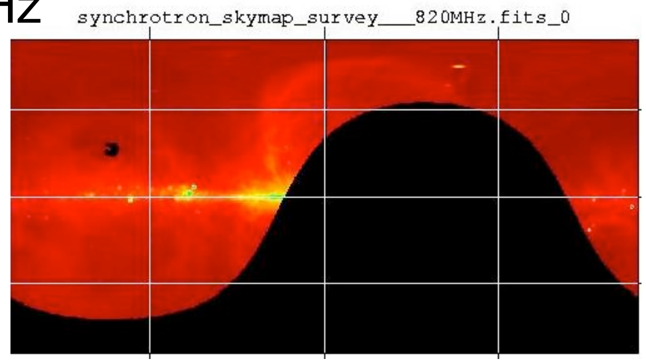


2.3 GHz

1.4 GHz



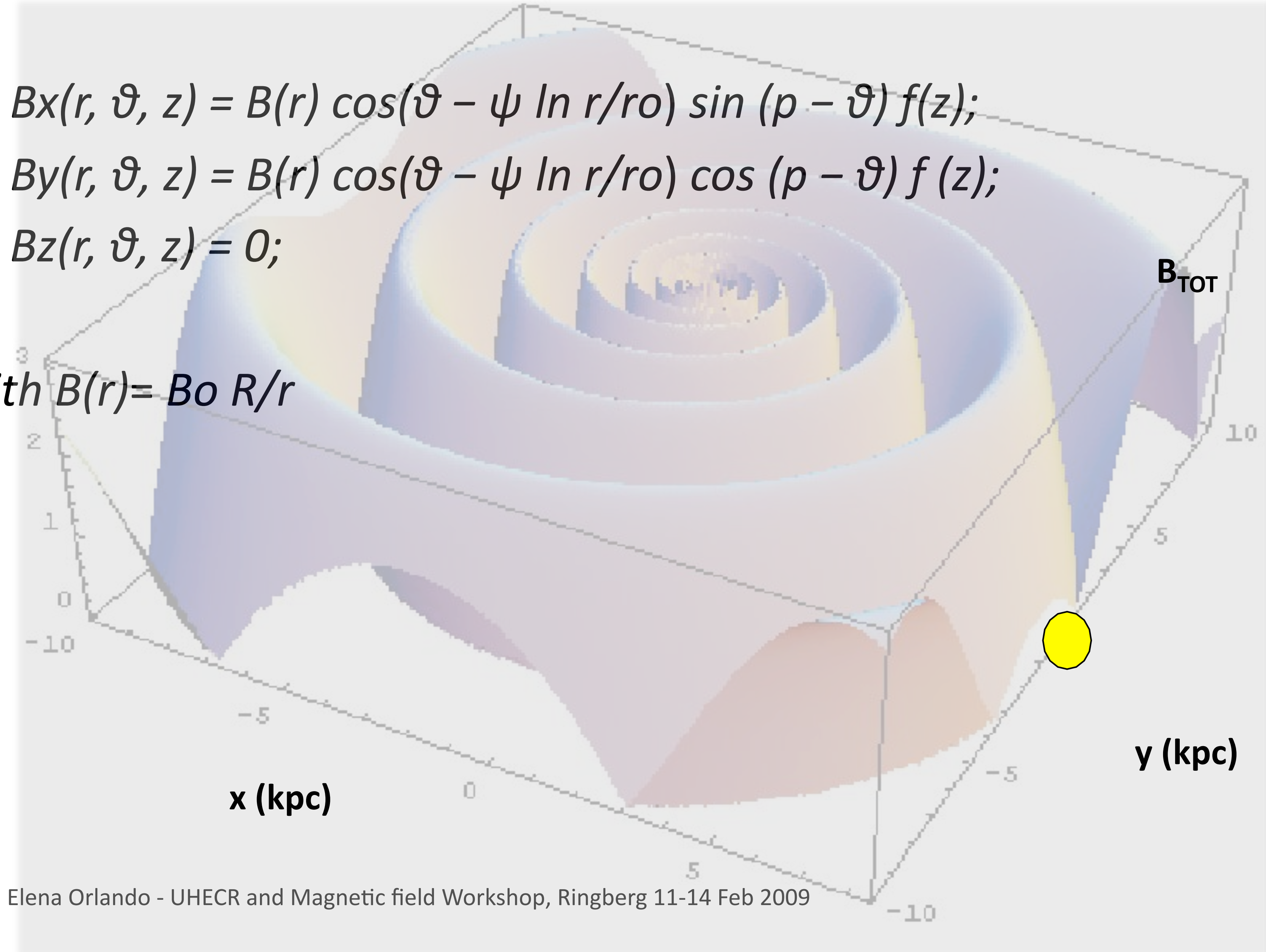
820 MHz



Spiral Magnetic field

- $Bx(r, \vartheta, z) = B(r) \cos(\vartheta - \psi \ln r/ro) \sin(p - \vartheta) f(z);$
- $By(r, \vartheta, z) = B(r) \cos(\vartheta - \psi \ln r/ro) \cos(p - \vartheta) f(z);$
- $Bz(r, \vartheta, z) = 0;$

with $B(r) = Bo\ R/r$



Tinyakov & Tkachev (2002) model

B(r) = Bo R/r for *r > 4kpc;*

B(r) = const for *r ≤ 4kpc;*

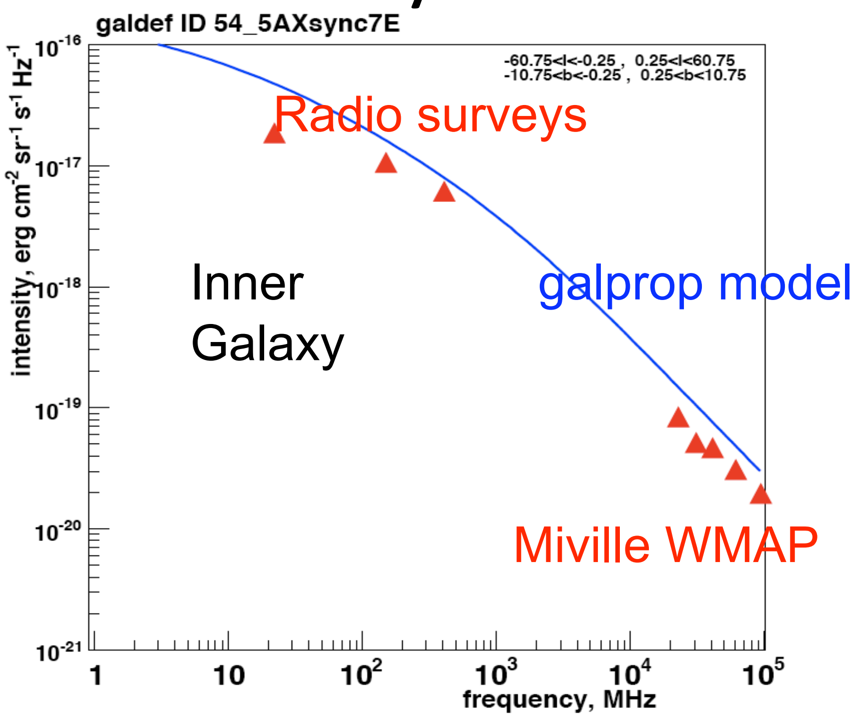
Bo = 8μG; p = −8°; ro = 10; B(local)=3.3μG

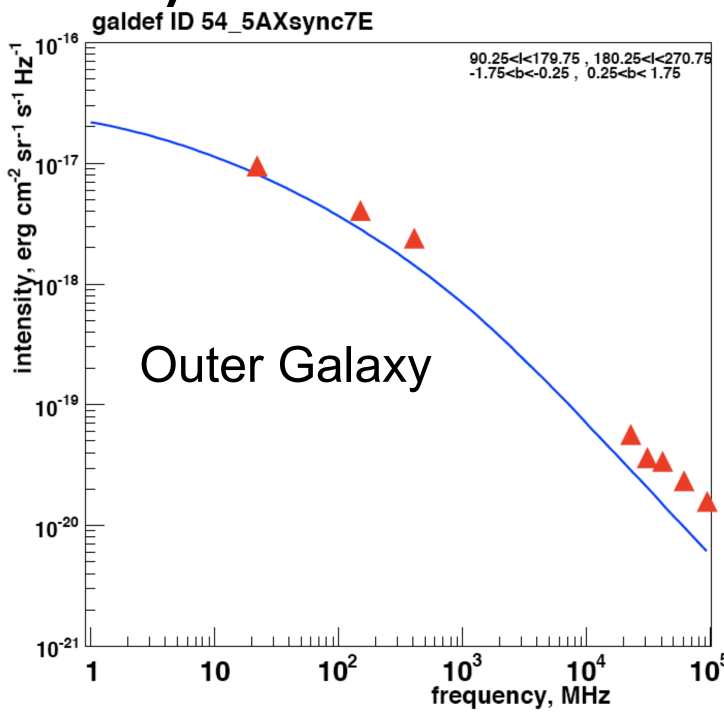
- *f (z) = sign(z) exp −(|z|/h) with h = 1.5kpc*

- no info on B random in TT(2002), hence we took 3 formulations:
  1) const. everywhere
  2) const in z=0, but decreasing with f(z)
  3) following the spiral structure, with a scale factor

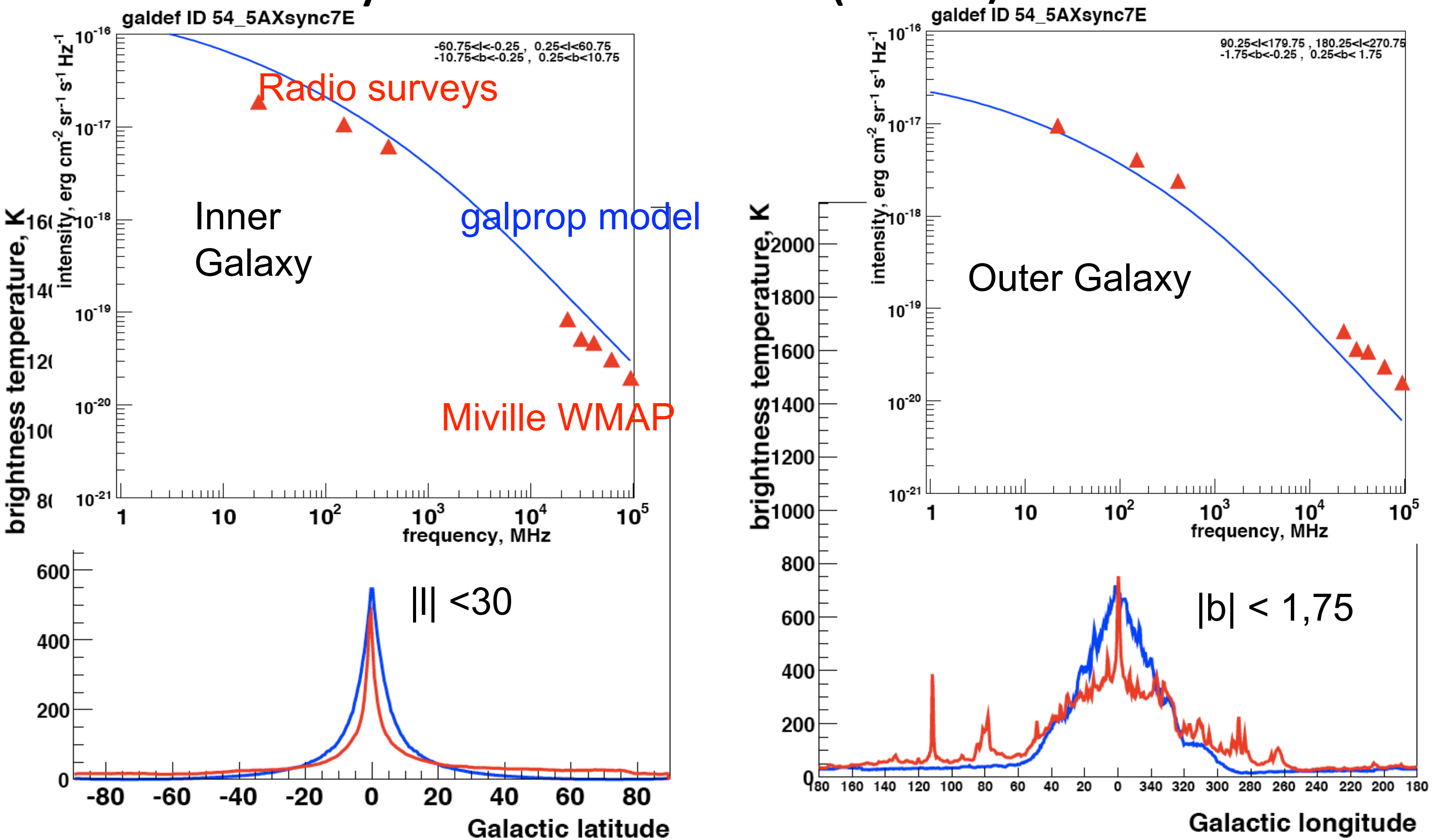
B random/B regular = 0.57 (Miville-Deschenes et al. 2008)

Tinyakov & Tkachev (2002) results





Tinyakov & Tkachev (2002) results



TINYAKOV & TKACHEV (2002) MODEL DOES NOT MATCH LATITUDE AND LONGITUDE PROFILES

Model 2 (new)

B(r) = Bo R/r *for r > 5 kpc;*

B(r) = const *for r ≤ 5 kpc;*

Bo = 8μG; p = −8.5◦; ro = 10; B(local)=3.3μG

- *f (z) = sign(z) exp −(|z|/h) with h = 1 kpc*

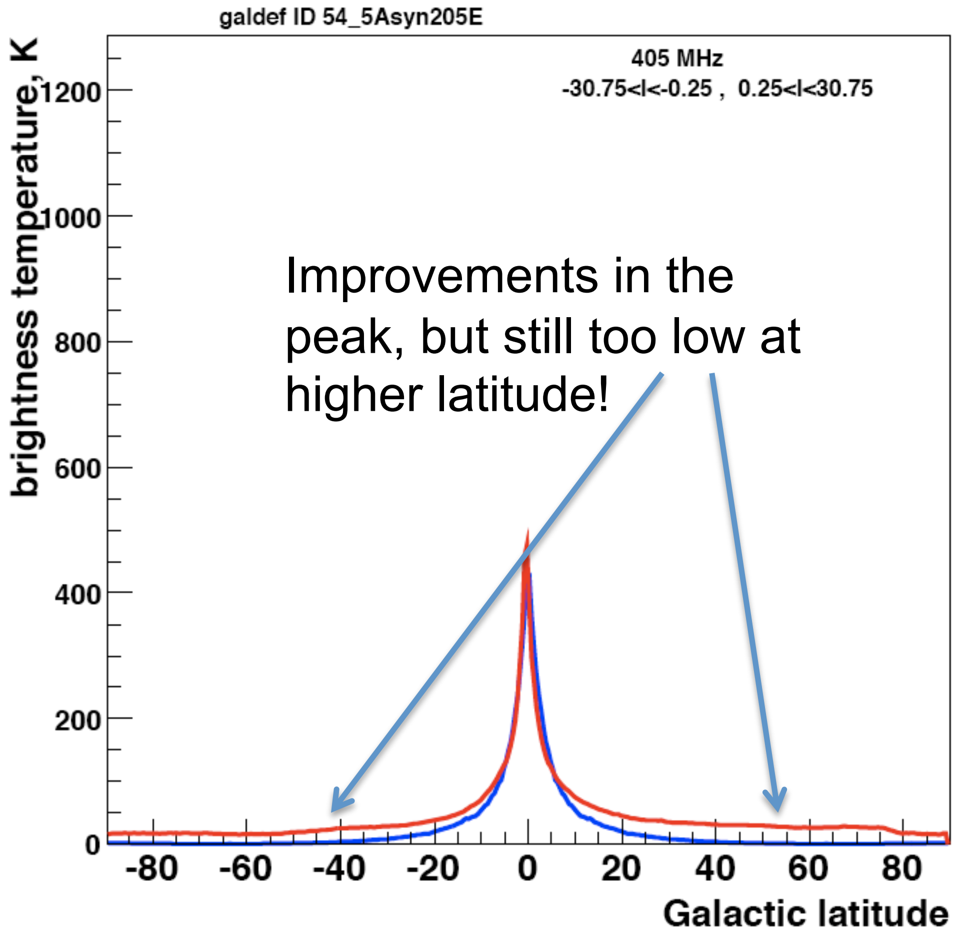
- B random 3 formulations:

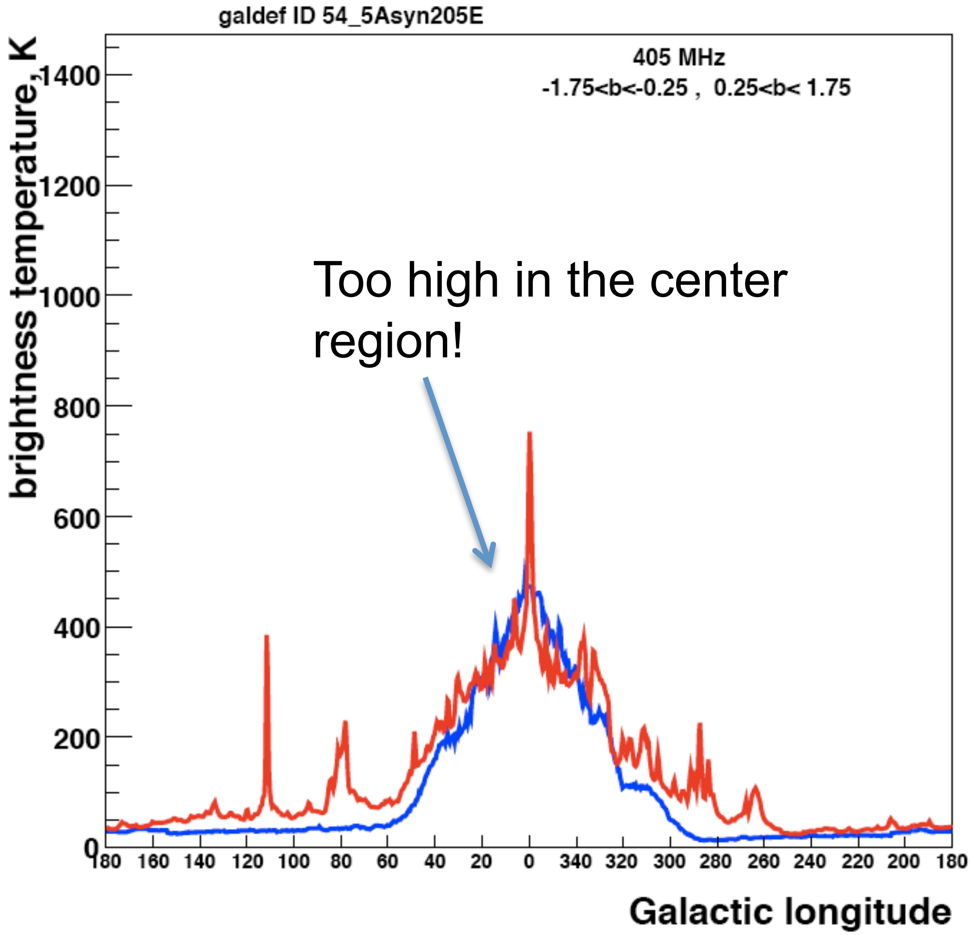
  1) const. everywhere (no improvements)

  2) const in z=0, but decreasing with f(z) (improved)

  3) following the spiral structure, with a scale factor (improved)

Model 2 results





Model 3 (+toroidal as in Sun et al. 2008)

B(r)=Bo=8 μG; *p = −8.5◦; ro = 10; Breg(local)=3.7 μG and Bran(local)=2 μG*

- *f (z) = sign(z) exp −(|z|/h) with h = 1 kpc*

Random following the spiral structure, with a scale factor

\+ HALO TOROIDAL FIELD (Sun et al. 2008)

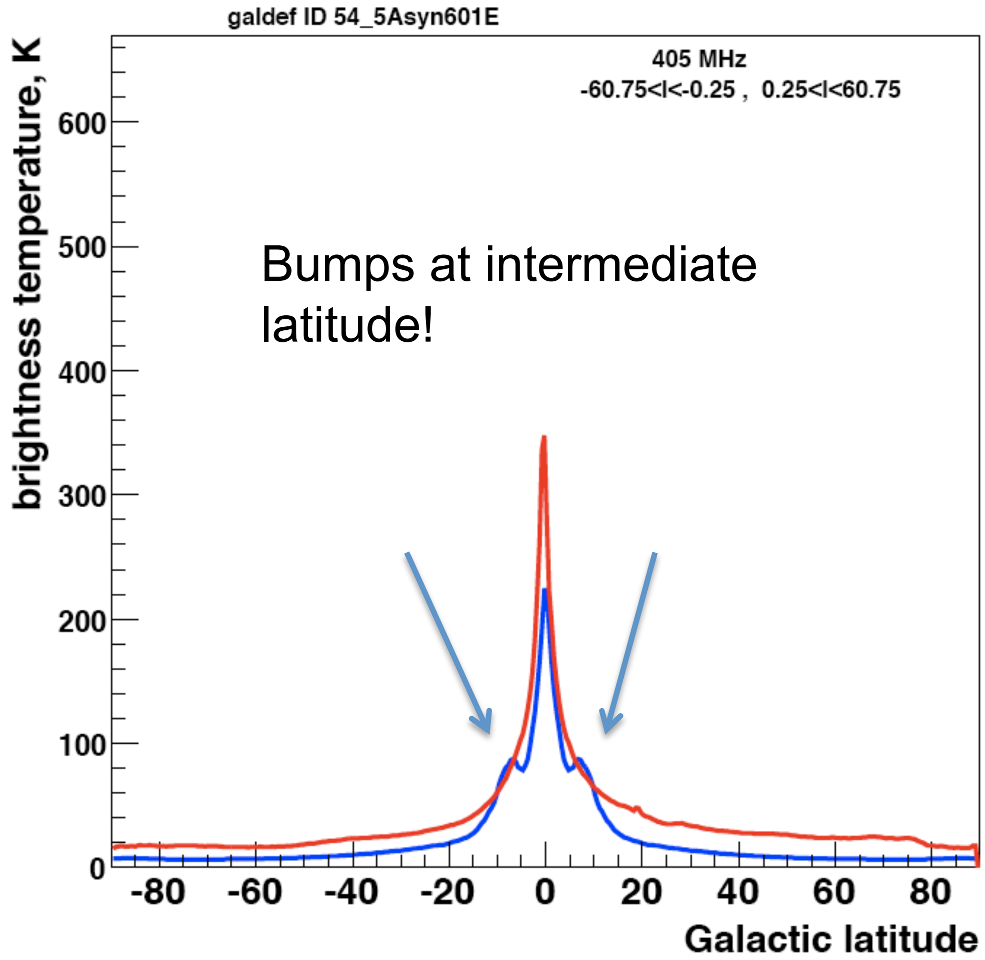
Bx = BT cos(φ)

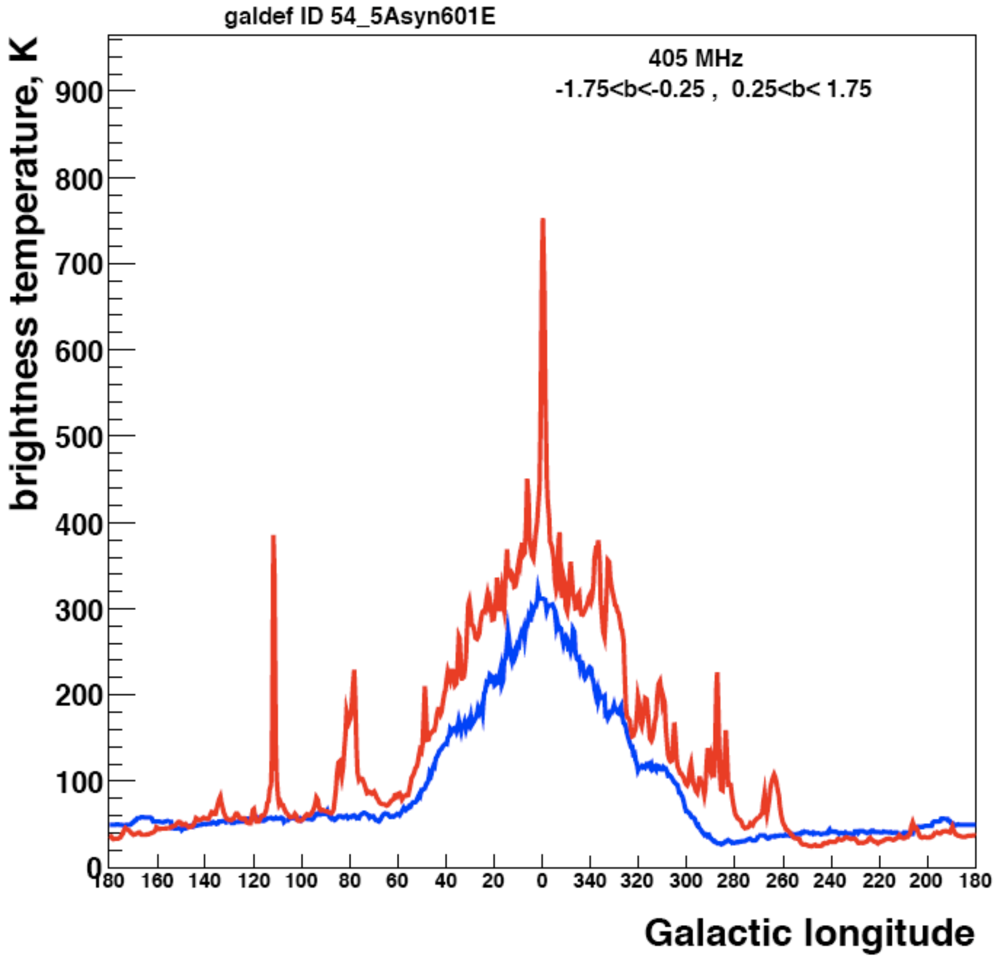
By = −BT sin(φ)

$$B_T = B_0^H \frac{1}{1+\left(\frac{|z|-z_0^H}{z_1^H}\right)^2} \frac{R}{R_0^H} \exp\left(-\frac{R-R_0^H}{R_0^H}\right)$$

zHo = 1.5 kpc,
*zH*1 = 0.2 kpc for |z| < *zHo*
*zH*1 = 0.4 kpc otherwise,
BHo = 10 μG (Prouza & smida 2003)
BHo = 2 μG (Sun et al. 2008)
and *RHo*= 4 kpc.

Model 3 (toroidal as in Sun et al. 2008) results





If *BHo* = 10 μG, showed in the plots, (Prouza & Smida 2003) the bumps are not in agreement with the data, but If *BHo* = 2 μG (Sun et al. 2008), the contribution of this model to the synchrotron and hence the bumps are not significant.

Dipole field: Prouza & Smıda (2003)

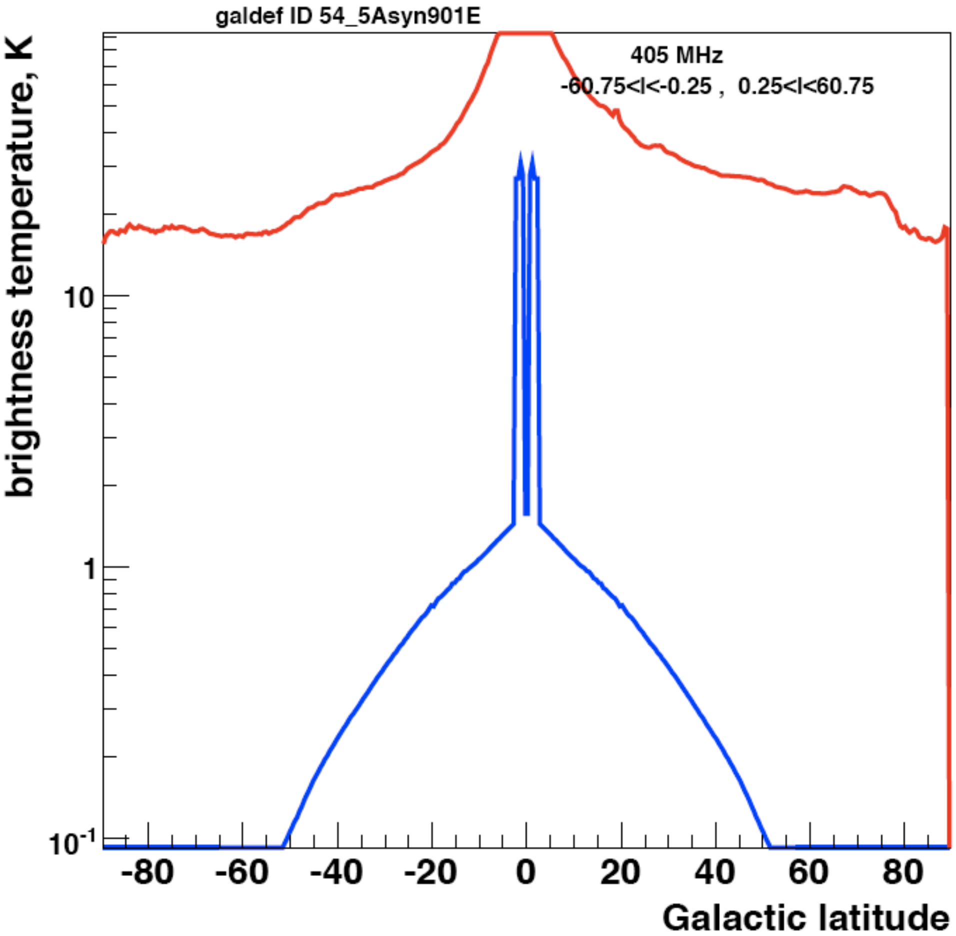
$$
\begin{aligned}
B_x &= -\frac{3K}{2r^3}\sin 2\beta \sin\theta \\
B_y &= -\frac{3K}{2r^3}\sin 2\beta \cos\theta \\
B_z &= -\frac{K}{r^3}(3\cos^2\beta - 1)
\end{aligned}
$$

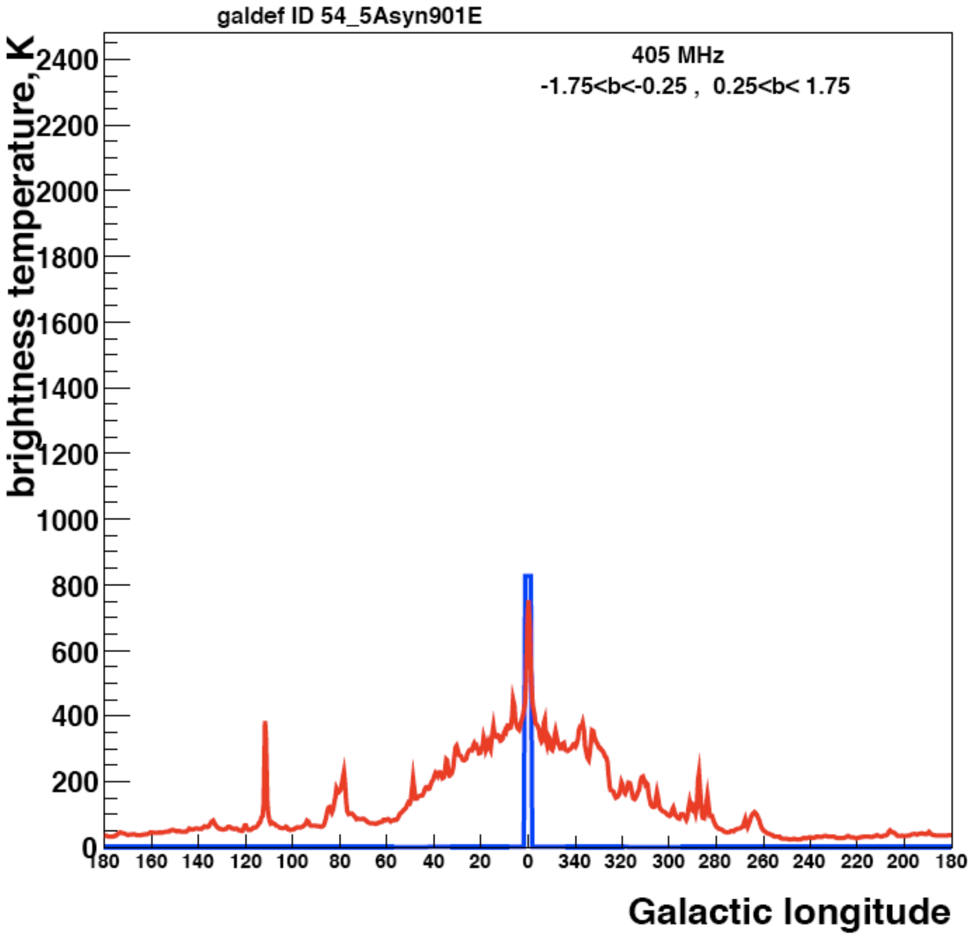
$0 < \beta < \pi$ from north to south pole

- cylinder (height 300 pc, diameter 100 pc) with constant strength = 2 mG

$K = 10^5$ G pc^3 for outer regions ($R > 5$ kpc),
$K = 200$ G pc^3 for central region ($R < 2$ kpc)
10^{-6} G constant for 2 kpc < *R* < *5 kpc*

Dipole field: Prouza & Smıda (2003)





No significant contribution of a dipole field out from the Galactic center. However it is possible to constrain the maximum B value in the central region < 2 mG!

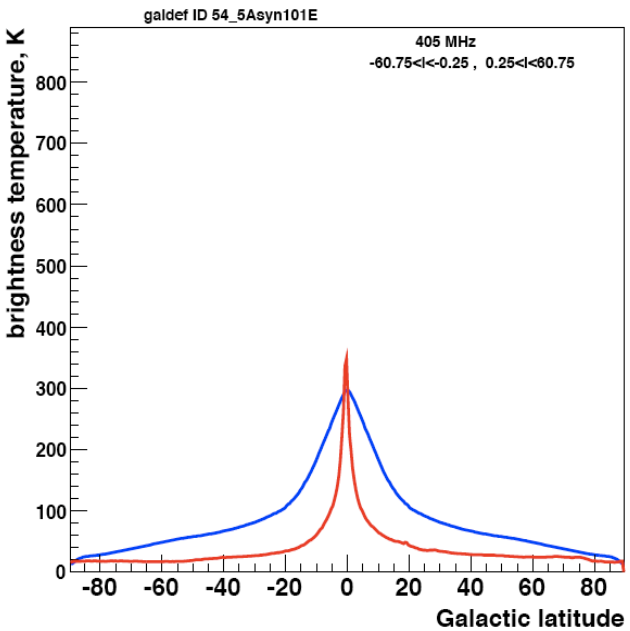
Miville-Deschenes et al. 2008

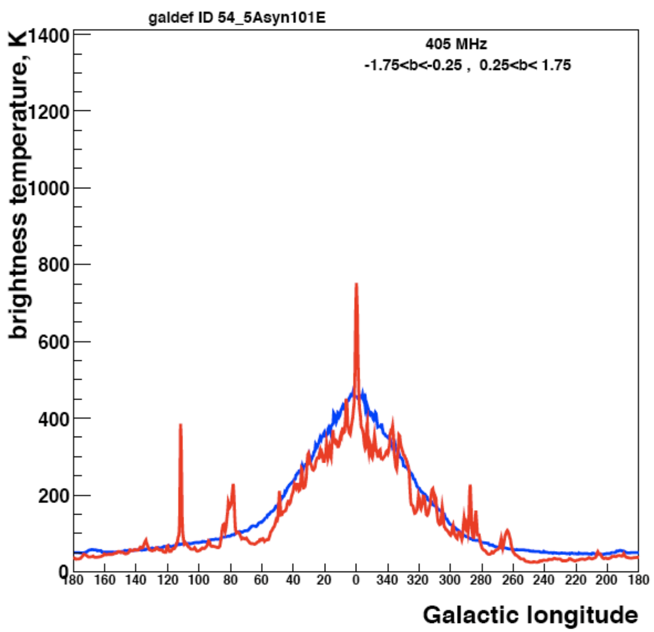
B(r) = Bo = const *everywhere*

Bo = 8μG; p = −8.5◦; ro = 11; Breg(local)=1,2 μG; Bran(local)=0,7 μG

- *f (z) = cos χ; with χ(z) = χo tanh(z/zH) and zH = 1 kpc and χo=8◦*

We took many models of random magnetic field, but no much difference





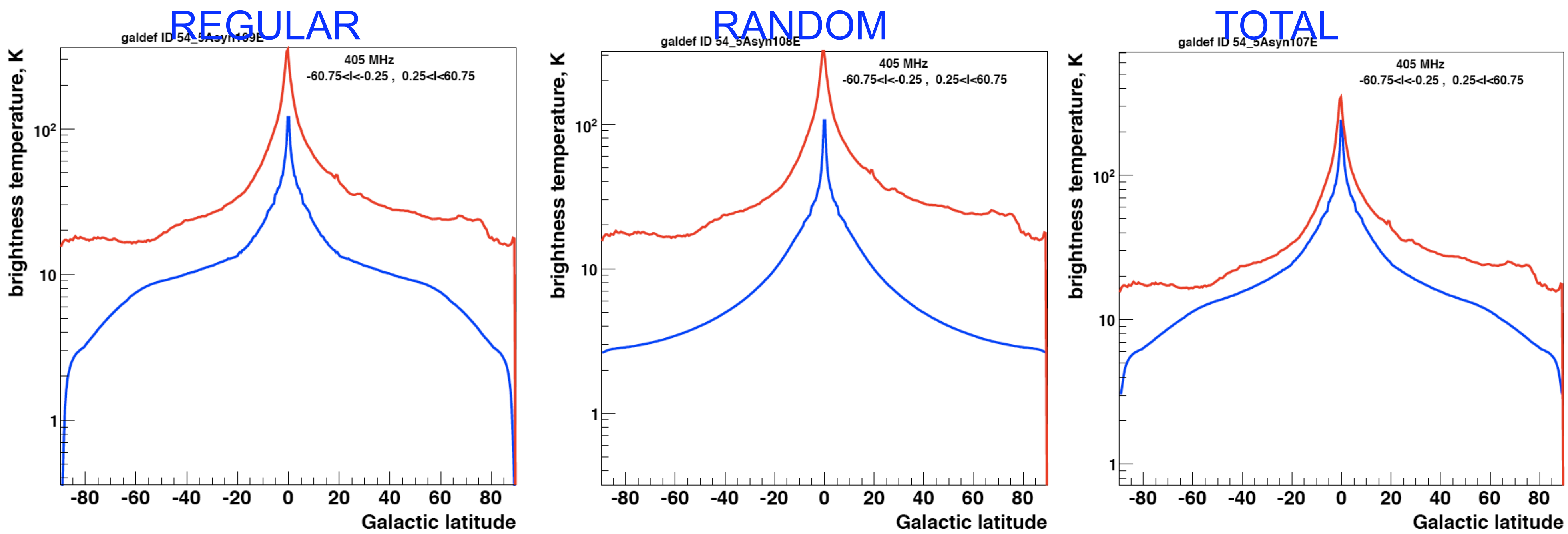
IT DOES NOT AGREE WITH DATA OUT OF THE PLANE

Model 4

B(r) = Bo = const   *everywhere*

Bo = 9 μG; p = −8.5∘; ro = 11; Breg(local)=1,4 μG; Bran(local)=5 μG

- *f (z) = cos χ; with χ(z) = χo tanh(z/zH) and zH = 0,1 kpc and χo=65∘*
- *Random field constant* in z=0, but decreasing with f(z)

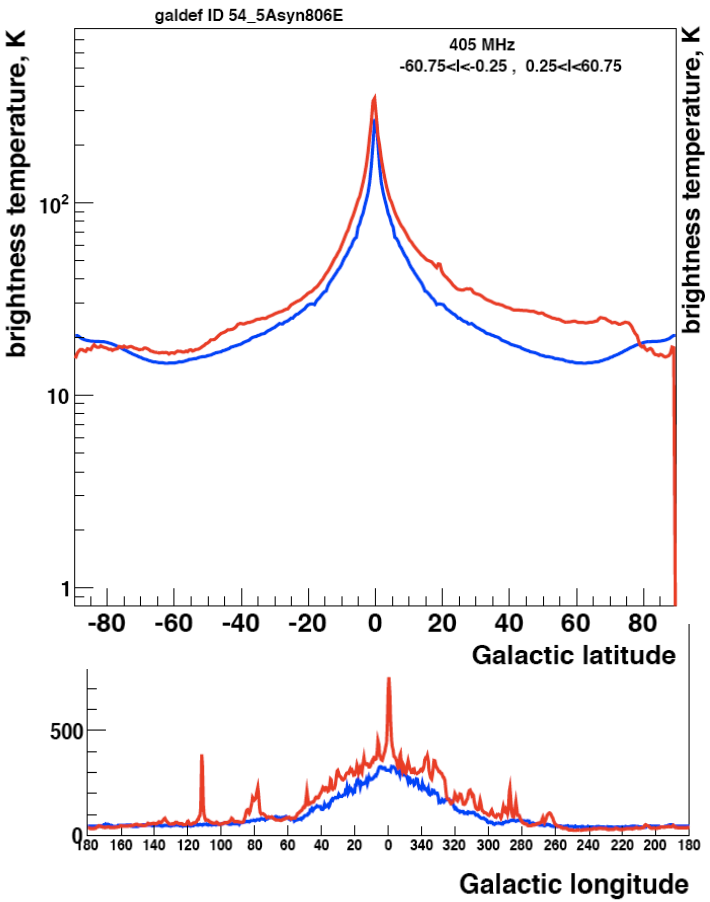


Model 5

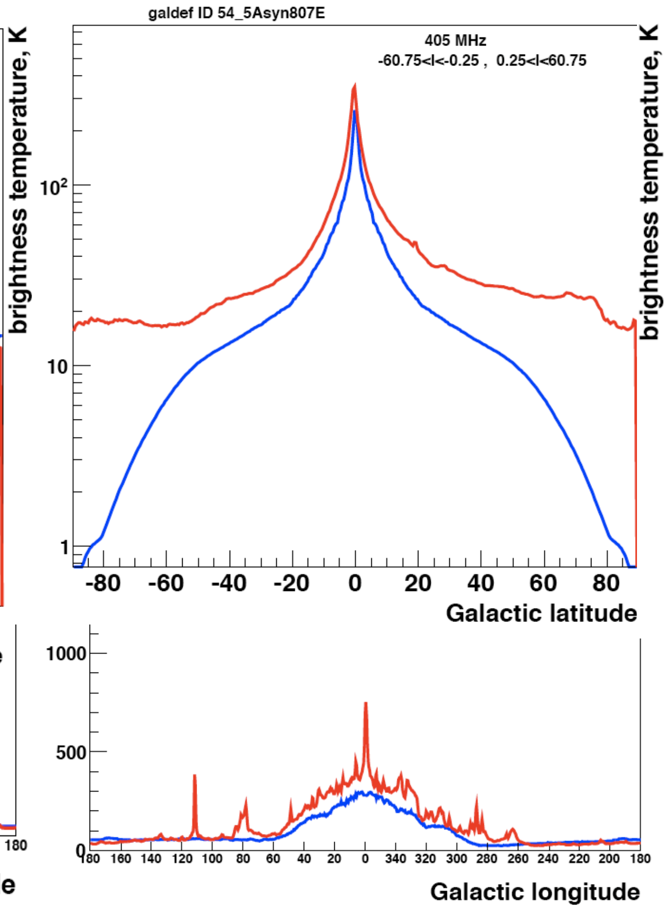
B(r) = Bo = 10 μG; ro = 11;

- *f (z) = cos χ; with χ(z) = χo tanh(z/zH) and zH = 0,2 kpc and χo=65◦*
- *Random field scaling with the regular*

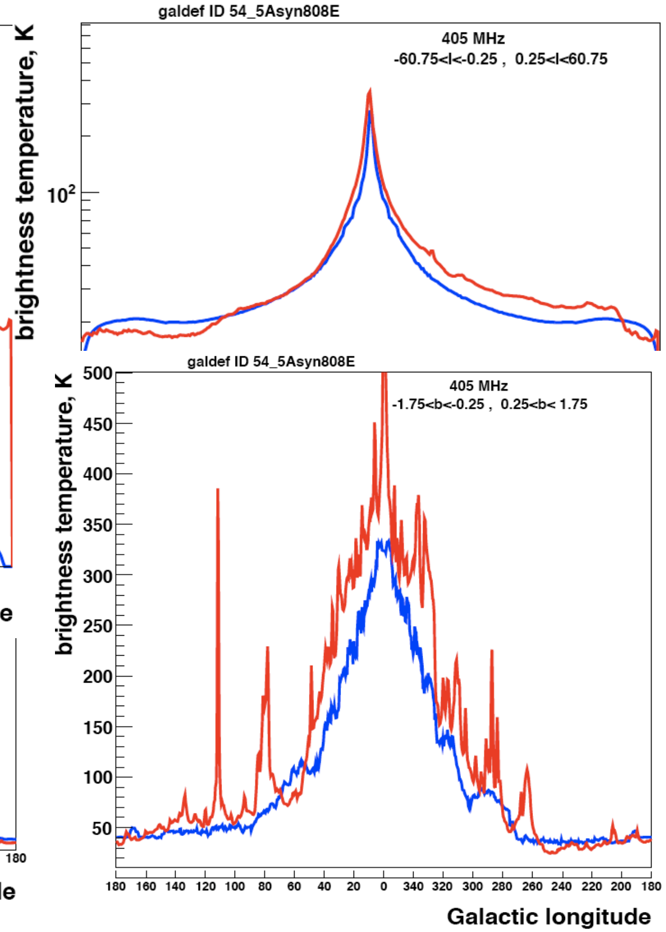
P=-5



p=-10



P=-6

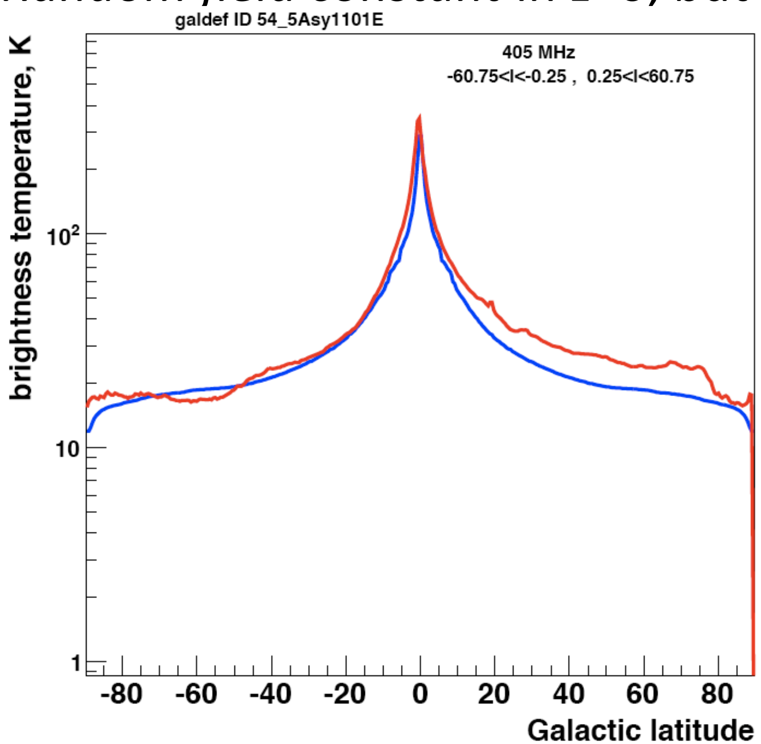


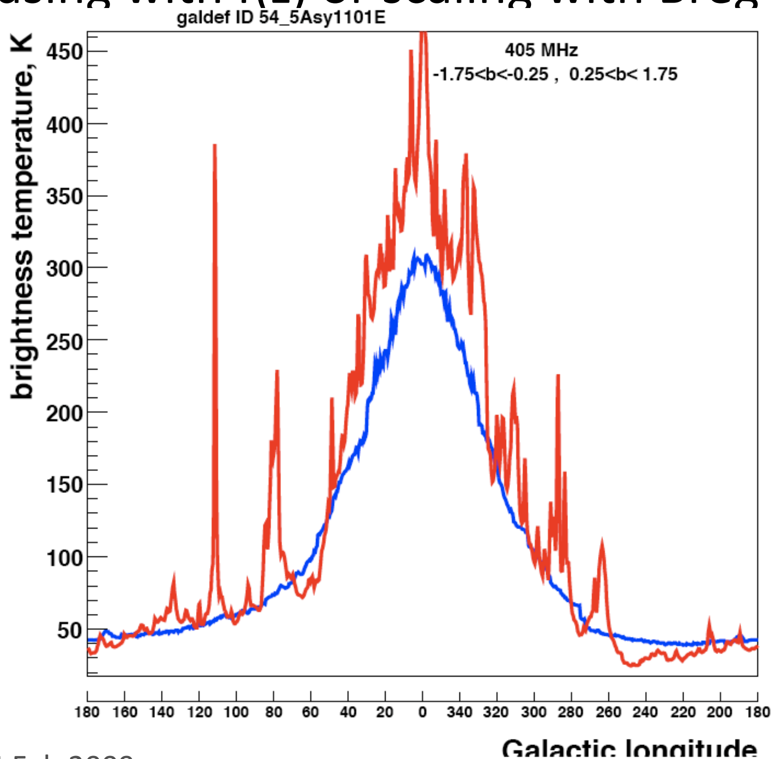
Best Galprop Model

B(r) = Bo = const *everywhere*

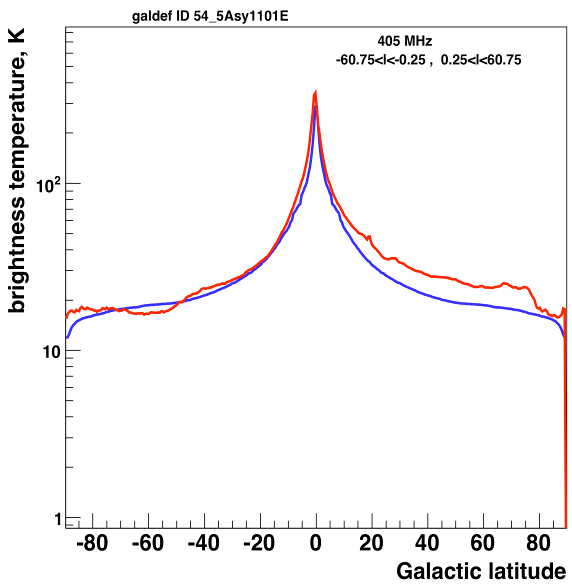
Bo = 9 μG; p = −8.5◦; ro = 12,3; Breg(local)=6,2 μG; Bran(local)~4-5 μG

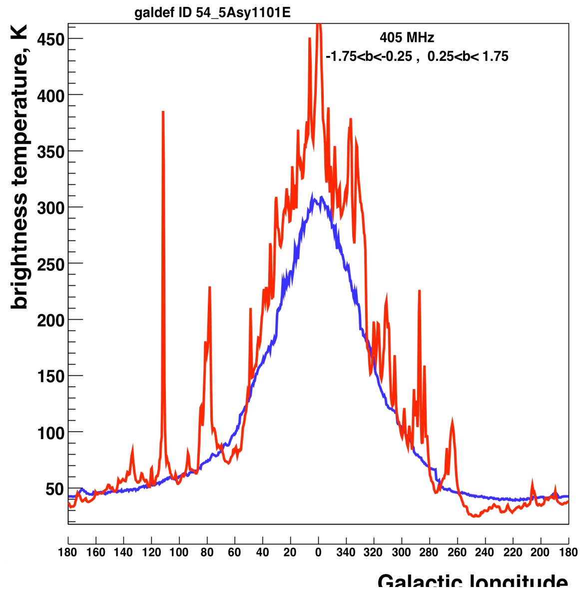
- *f (z) = cos χ; with χ(z) = χo tanh(z/zH) and zH = 0,2 kpc and χo=65◦*
- *Random field constant* in z=0, but decreasing with f(z) or scaling with Breg

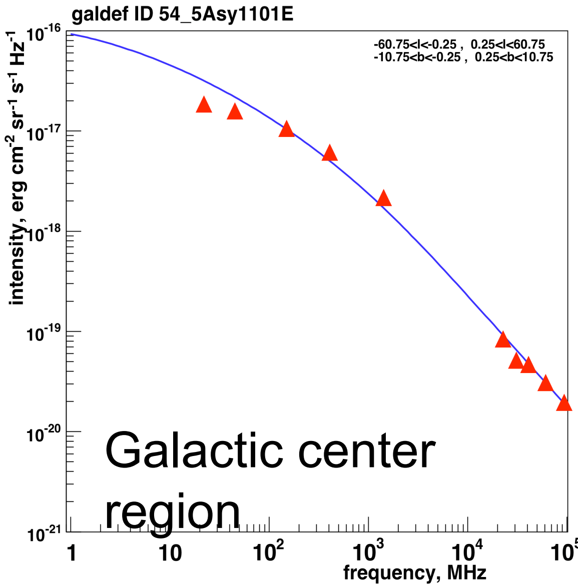


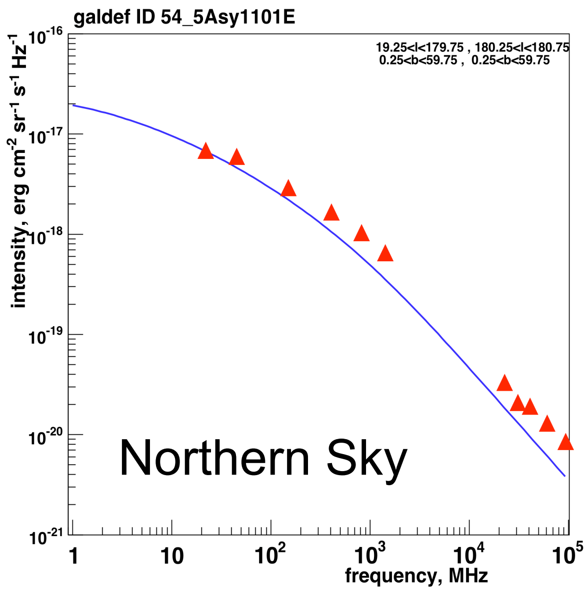


Best Galprop model no secondaries

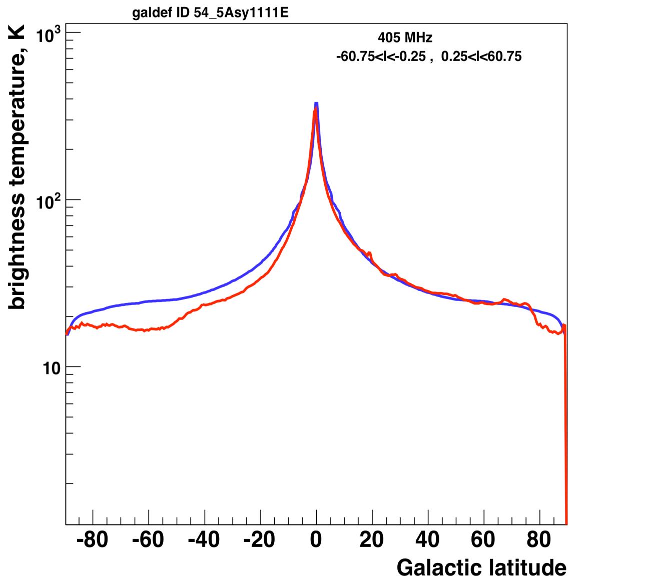


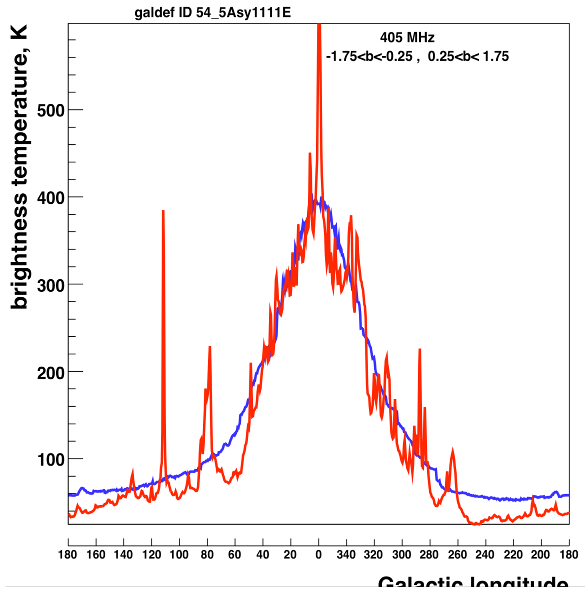


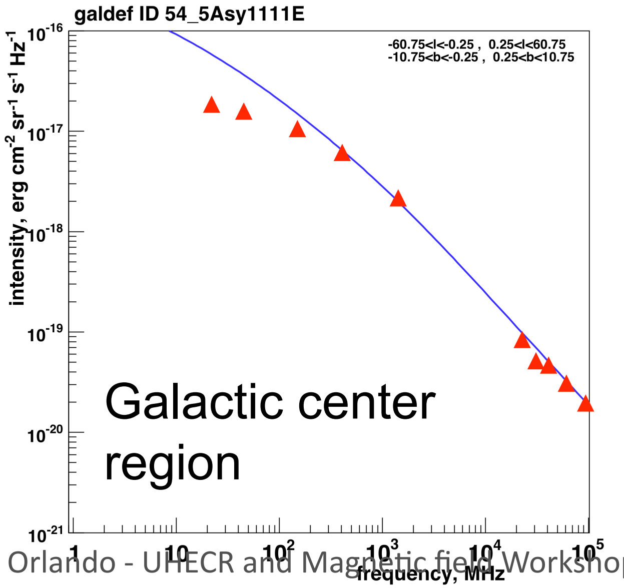


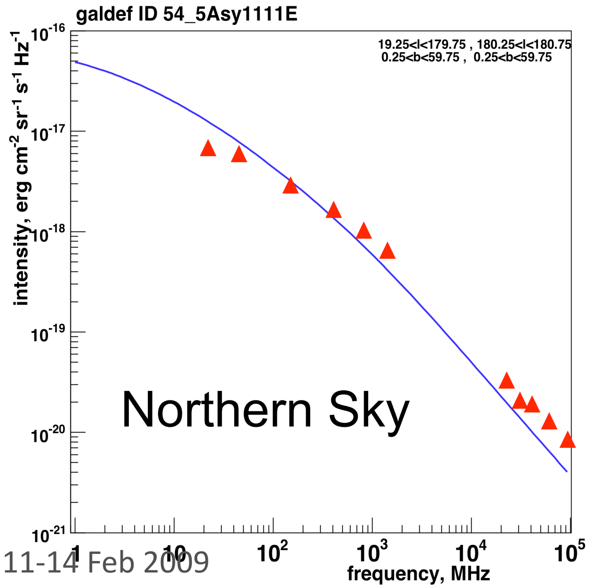


Best Galprop model with secondaries e- e+



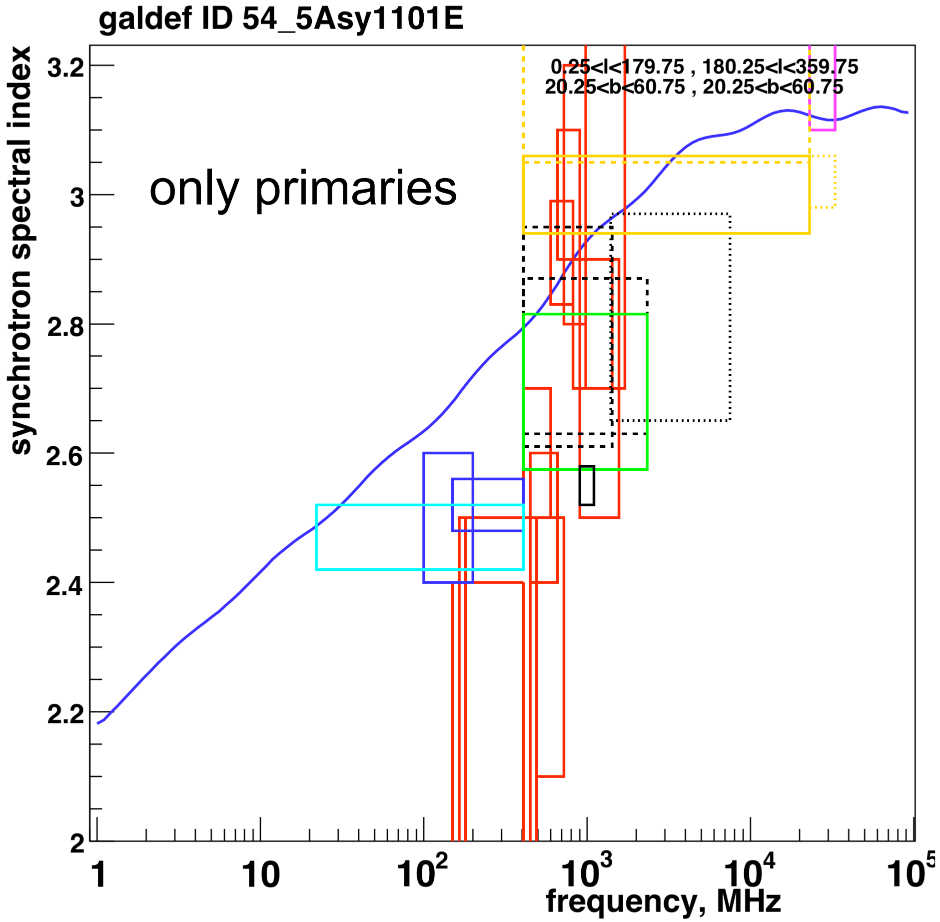


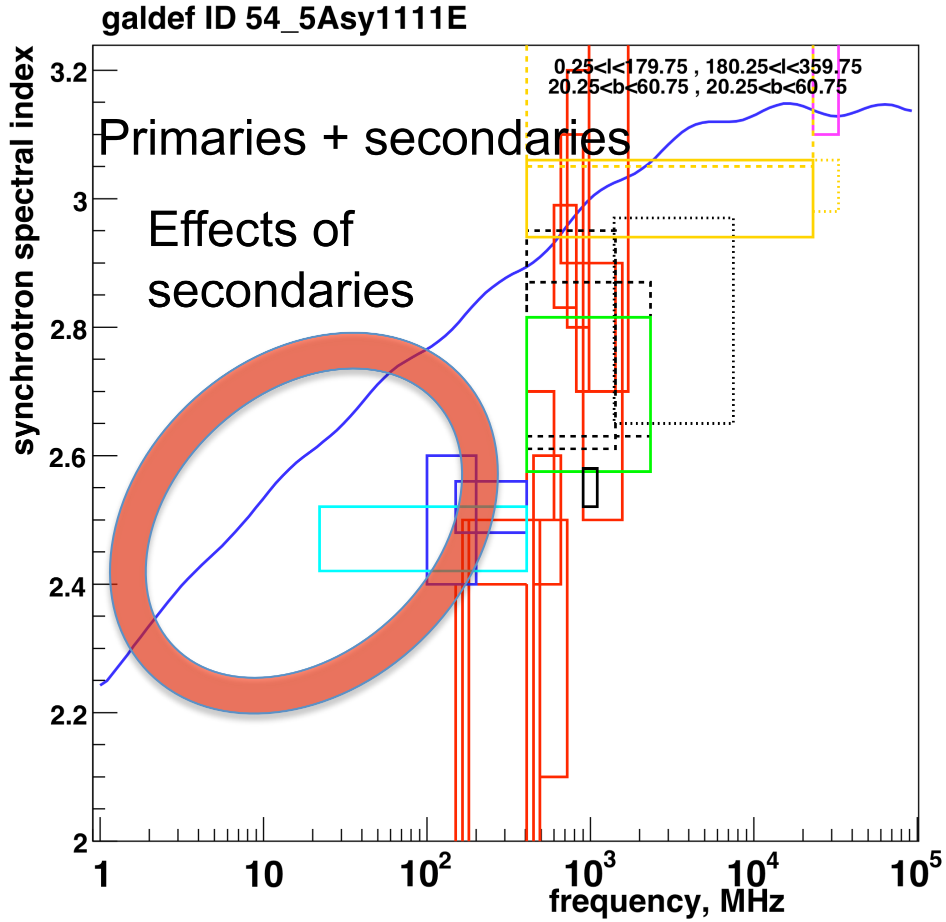




Spectral index

Spectral index ~ 2+(γ-1)/2 after propagation, with γ electron sp. index.

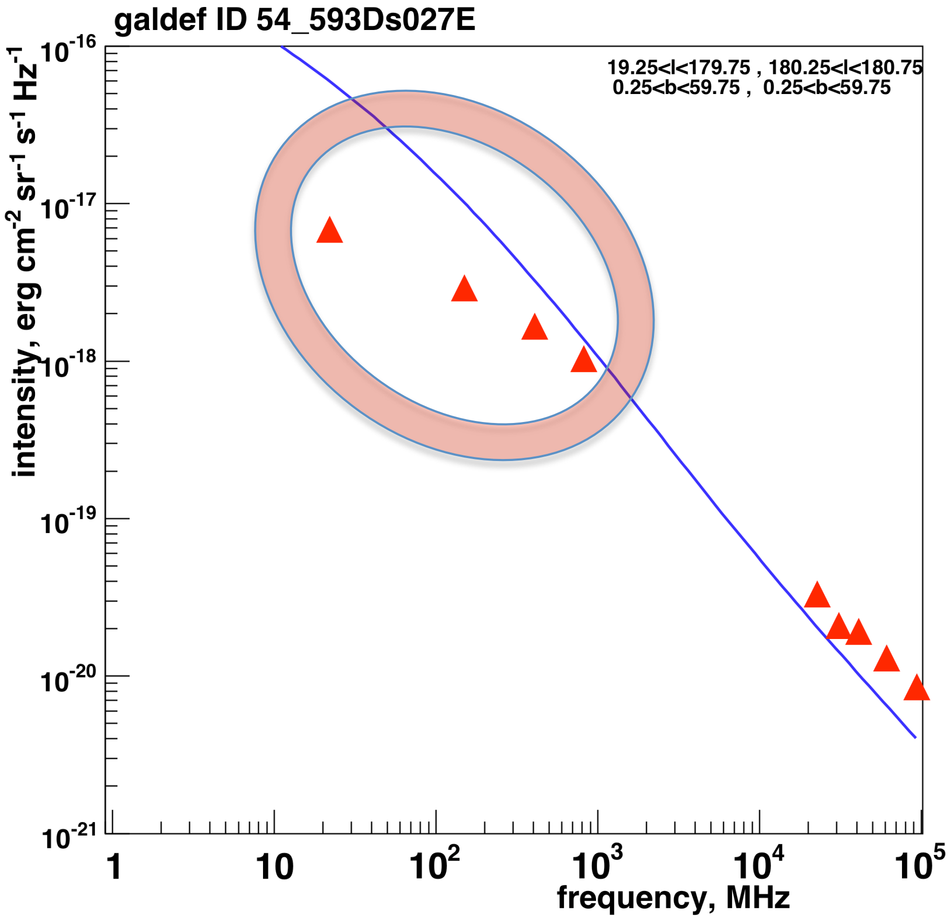


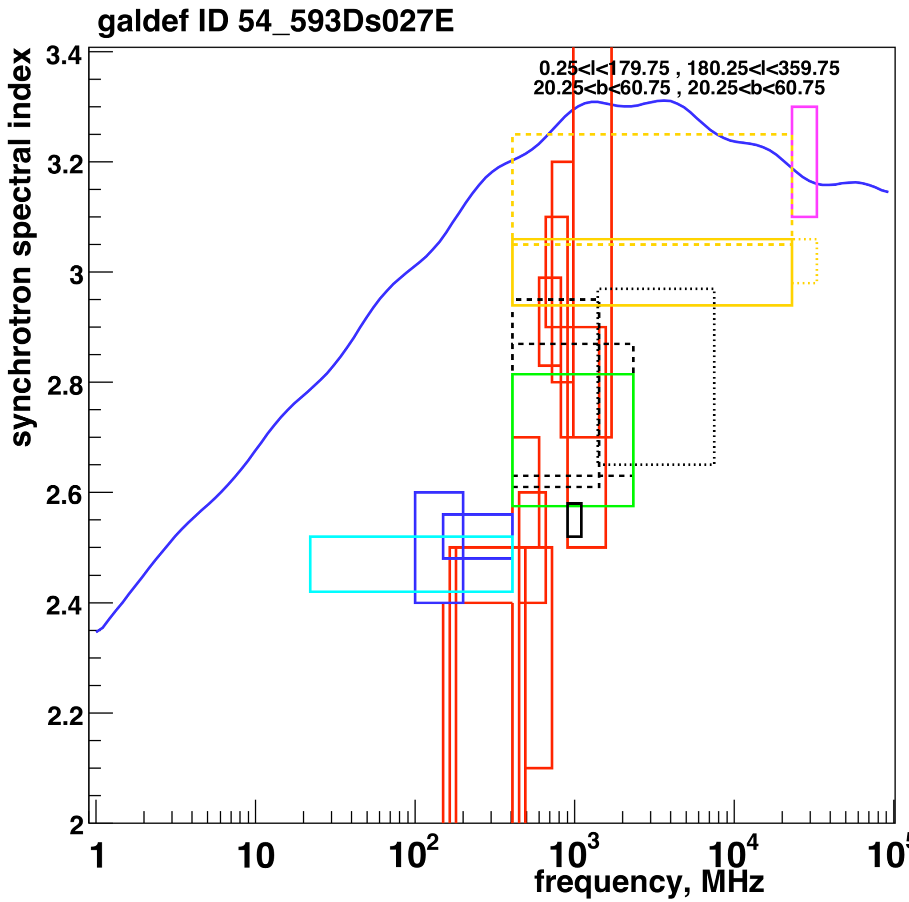


NOT SOLVED: THE SPECTRAL INDEX OBTAINED BY THE MODEL DOES NOT FIT THE OBSERVATIONS!

Evidence for break on the electron spectrum

An example WITHOUT the break (at 4 GeV) in the injection electron spectrum does not agree with the data





SYNCHROTRON DATA CONFIRM THE NEEDED OF A BREAK IN THE INJECTION ELECTRON SPECTRUM

Discussion

- Comparison of B models with data:
  - Tinyakov & Tkachev (2002) model does not match latitude and longitude profiles
  - Evidence of no radial dependence of B regular
  - A toroidal field with parameters as in Sun et al. 2008 does not give much contribution to the synchrotron emission.
  - Miville-Deschenes et al. 2008 model does not agree with synchrotron latitude profiles.

- One of the best models for galprop was defined

- Importance of secondary electrons and positrons

- Not solved: the Spectral index obtained by the model does not fit the observations below 400 MHz

- Evidence of the need for a break in the injection electron spectrum