The most updated results of Magnetic fields in our Milky Way

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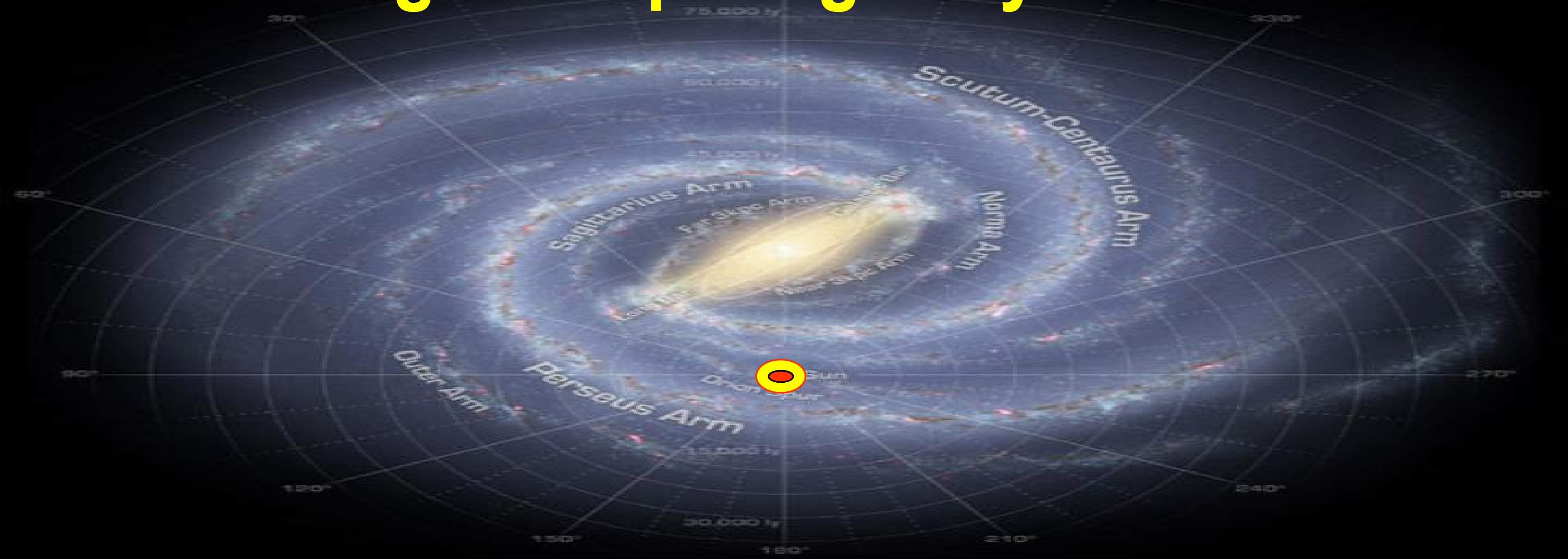
The Milky Way：
an edge-on spiral galaxy with a bar



Courtesy： R. Hurt 2008

Why to study the B-field of our Galaxy

- Galaxy: a necessary key step from stars to Universe!
- Important hints for B-origin: primordial or dynamo?
- Important roles in star formation
- Hydrostatic balance & stability in ISM:

  $B^2/8\pi = \rho\ v^2/2$ $B \sim 10^6 G$, $\rho = 10^{24} g cm^{-3}$, $v = 10 km\ s$-1

  (eg. Boilers & Cox 1990 for details)

- **Key info for cosmic rays – propagation!**
- Foreground for CMB?!

To understand the Galactic B-field, we have to measure first !

Knowledge on the Galactic B-field is far from complete!

How much do we know on the Galactic magnetic fields?

via what approach?

Observational B-tracers: What info out?

1. Polarization of starlight: ***perpendicular field in 2 or 3 kpc***

orientation // $B_{\perp}$ ------------- 9000 +? stars

2. Polarization at infrared, mm, submm: ***perpendicular field***

orientation // $B_{\perp}$ ------------- clouds or regions

3. Zeeman splitting: ***parallel field, in situ (masers, clouds)***

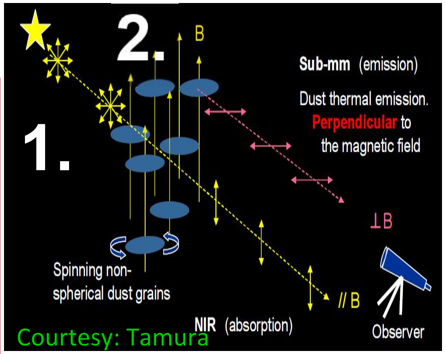
$\Delta \nu \propto B_{//}$ ------ 137 maser regions & 17 coulds

4. Synchrotron radiation: ***vertical field structures (added)***

total intensity $S \propto B_{\perp}^{2/7}$, p% $\propto B_{\perp u}^2 / B_{\perp t}^2$

5. Faraday rotation: ***parallel field, integrated (the halo & disk)***

$RM \propto \int n_e B_{//} ds$ ------ **1115** pulsars + **>3000** EGSes



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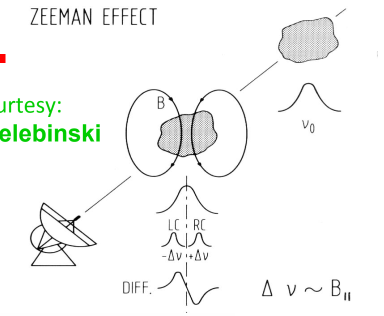

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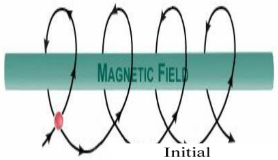

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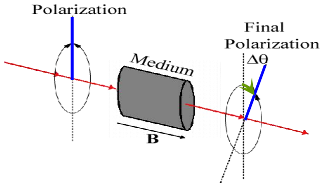
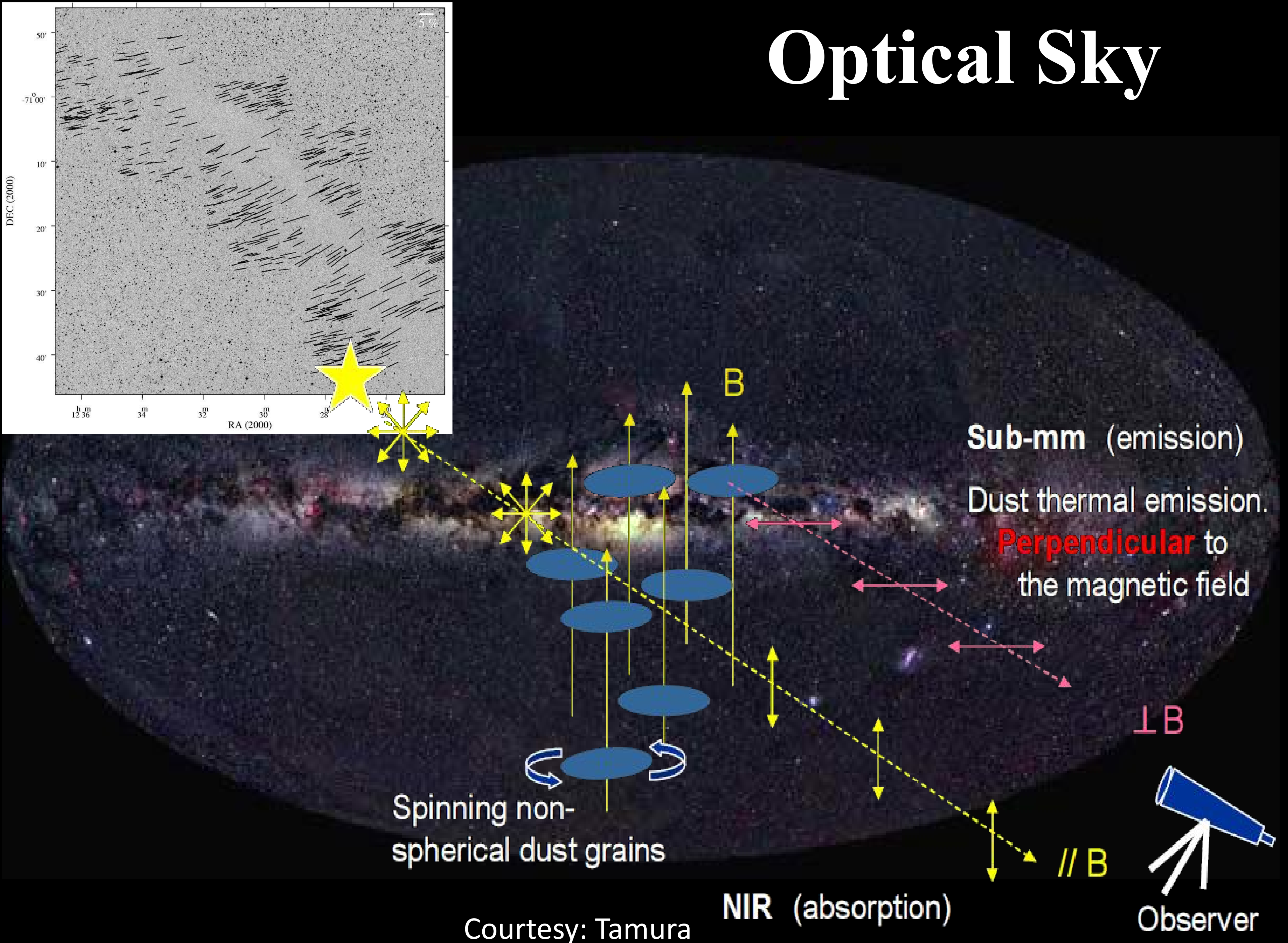


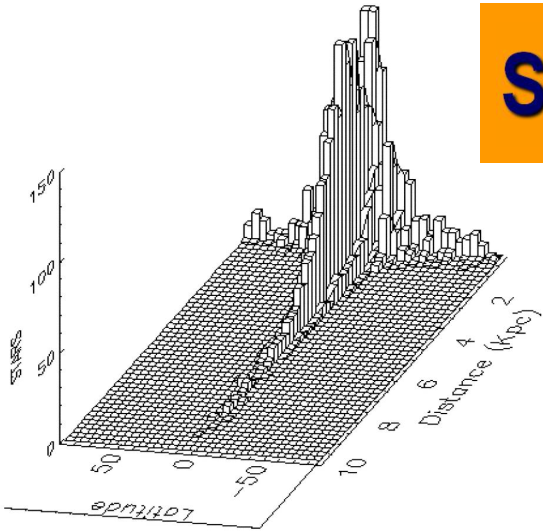
Optical Sky and dusts in the Milky Way

Optical Sky

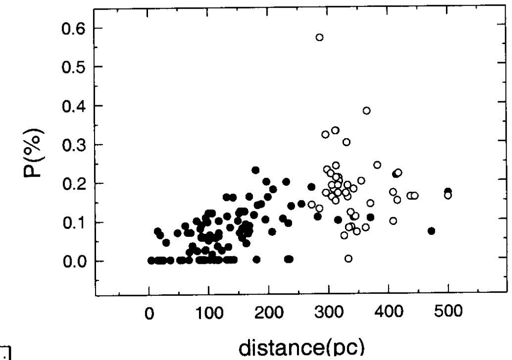


Courtesy: Tamura

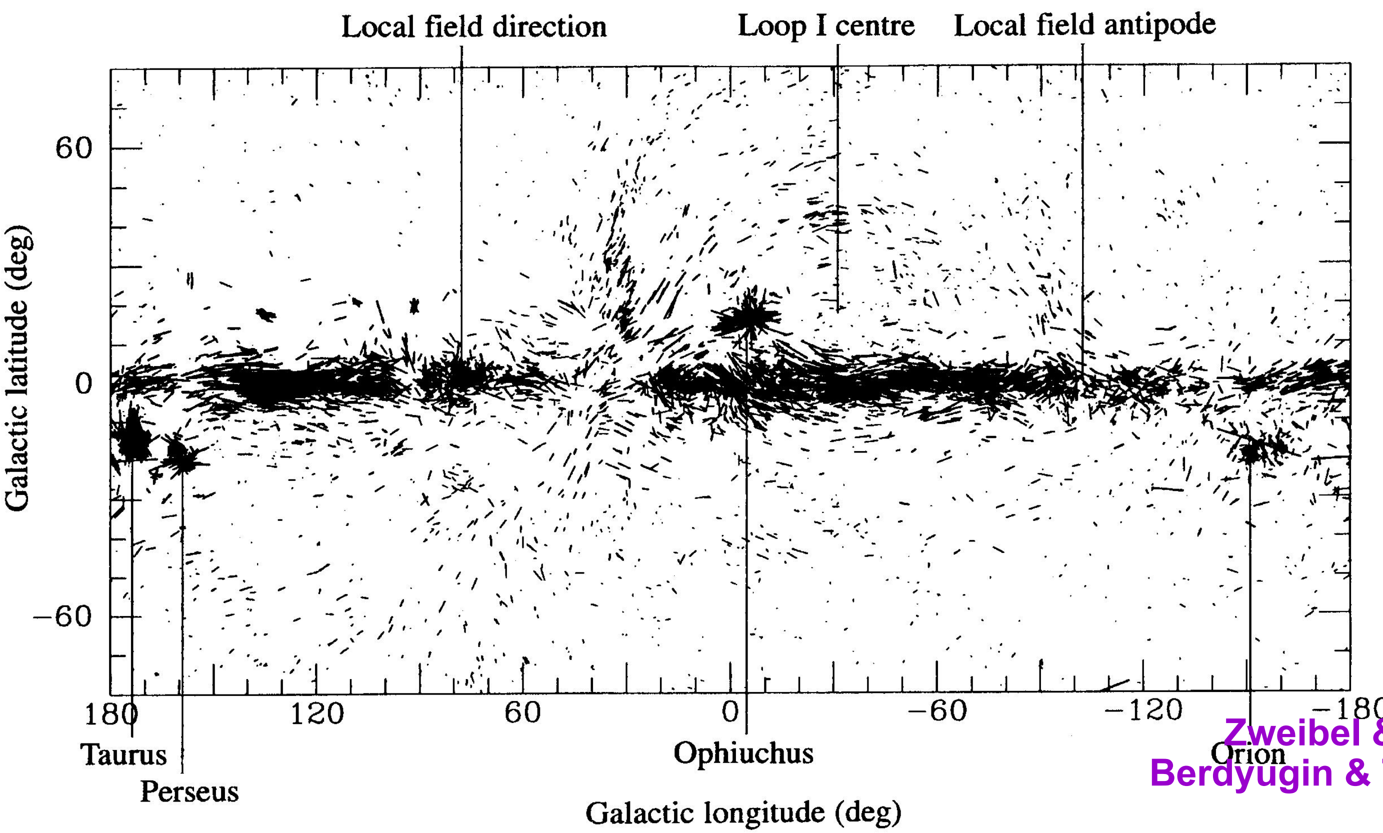
Starlight polarization: *local field // arm*

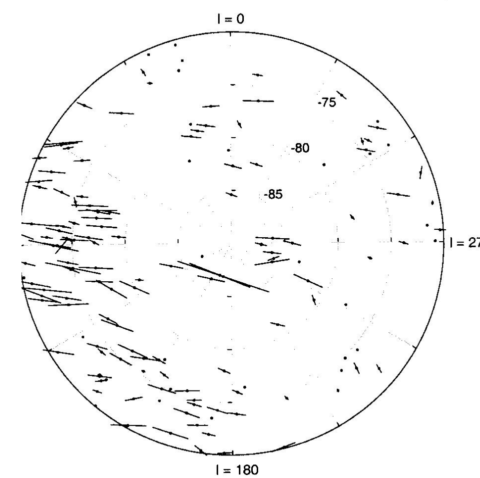


- 9000+ stars have polarization measured
- mostly nearby (1~2kpc)
- polarization percentage increases with distance



Polarization vs. distance dependence in the SGP area. ·w data are plotted with open circles





. Polarizations of the stars around the SGP. The length bar gives the amount of polarization, its direction gives ·ection of the polarization plane

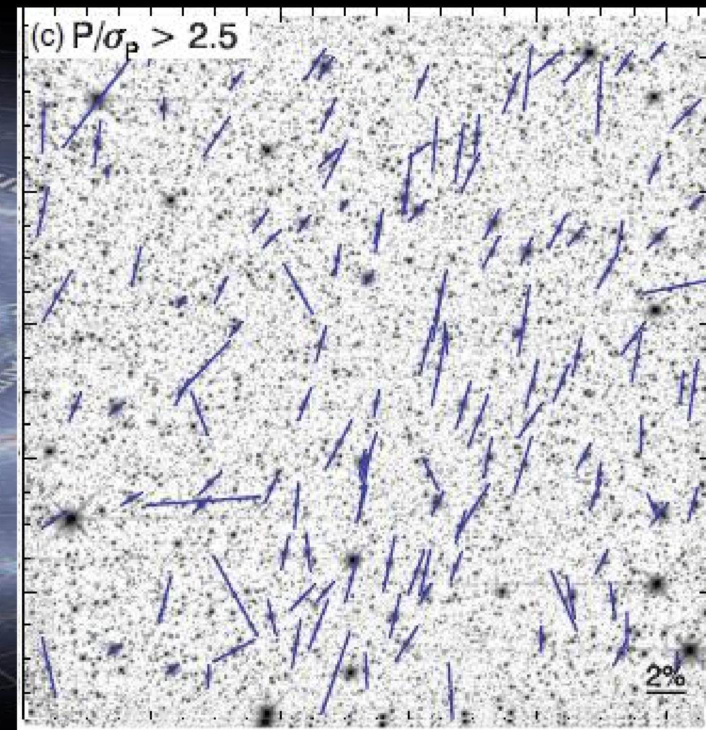
Zweibel & Heiles 1997, Nature 385,131
Berdyugin & Teerikorpi 2001, A&A 368,635

GALACTIC PLANE INFRARED POLARIZATION SURVEY (GPIPS):

Clemens et al. 2012 ApJS: 0.5 million stars; 18<l<56^{o} & |b|<1^{o}

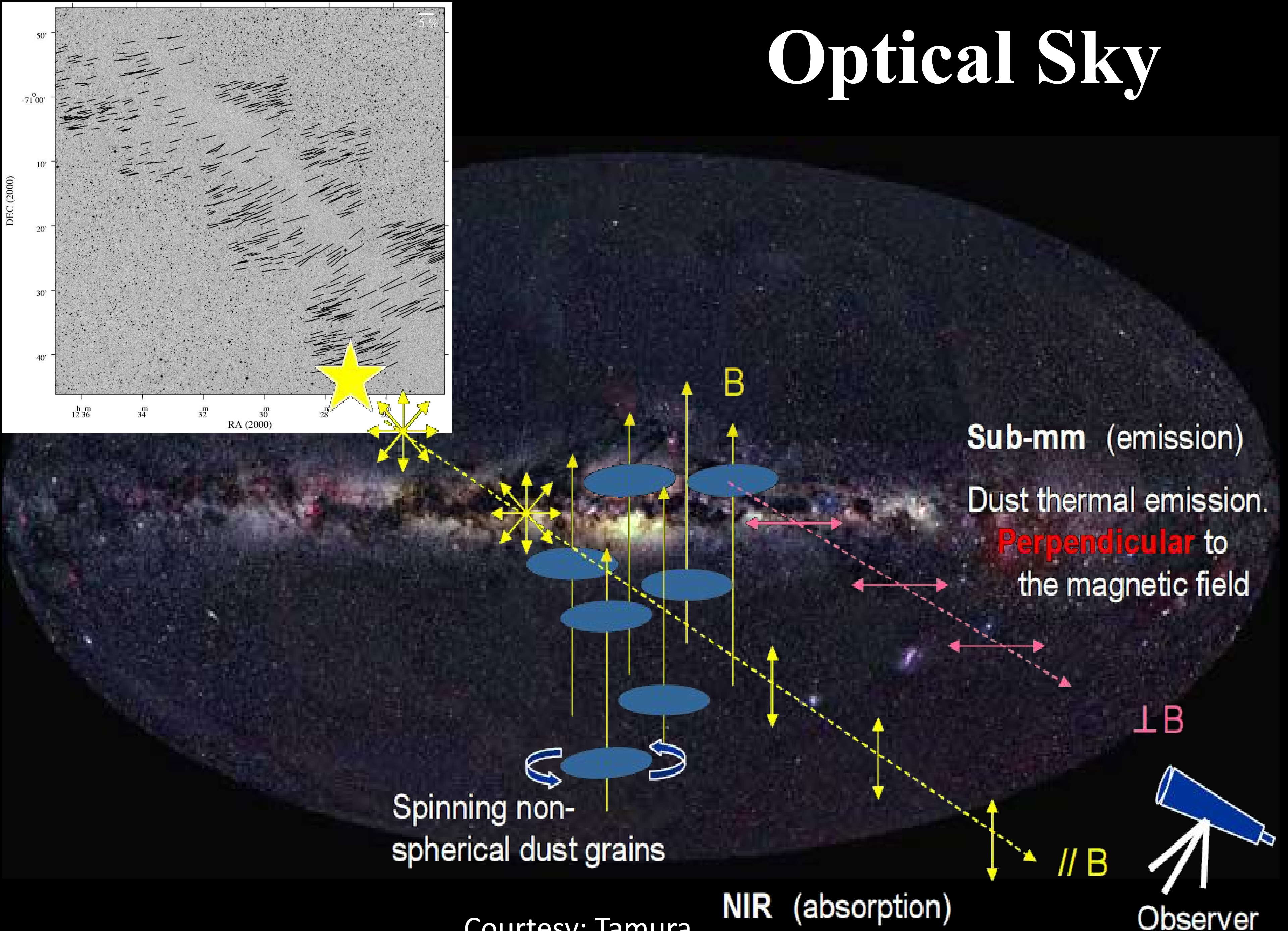
Shown co-added orientations due to dust.

Up to how much dusty!
No B strength,
no B direction!



- Magnetic fields in the disk: **B // Galactic Plane**
- Magnetic fields in filaments: **B // filaments**

Optical Sky



Courtesy: Tamura

Planck 2015: Best all-sky B-fields from dust emission

- Magnetic fields in the disk: **B // Galactic Plane**
- Magnetic fields in filaments: **B // filaments**

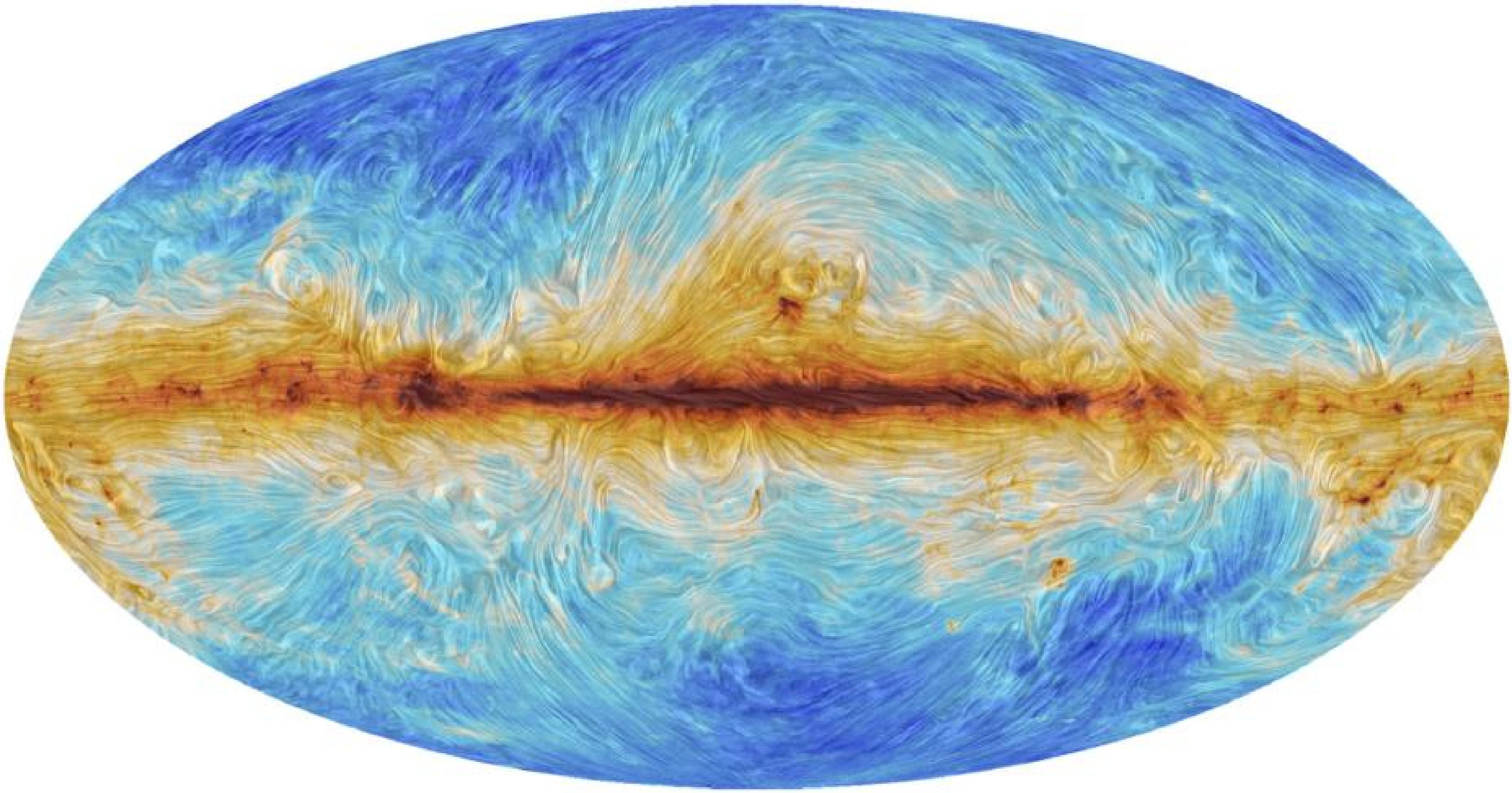
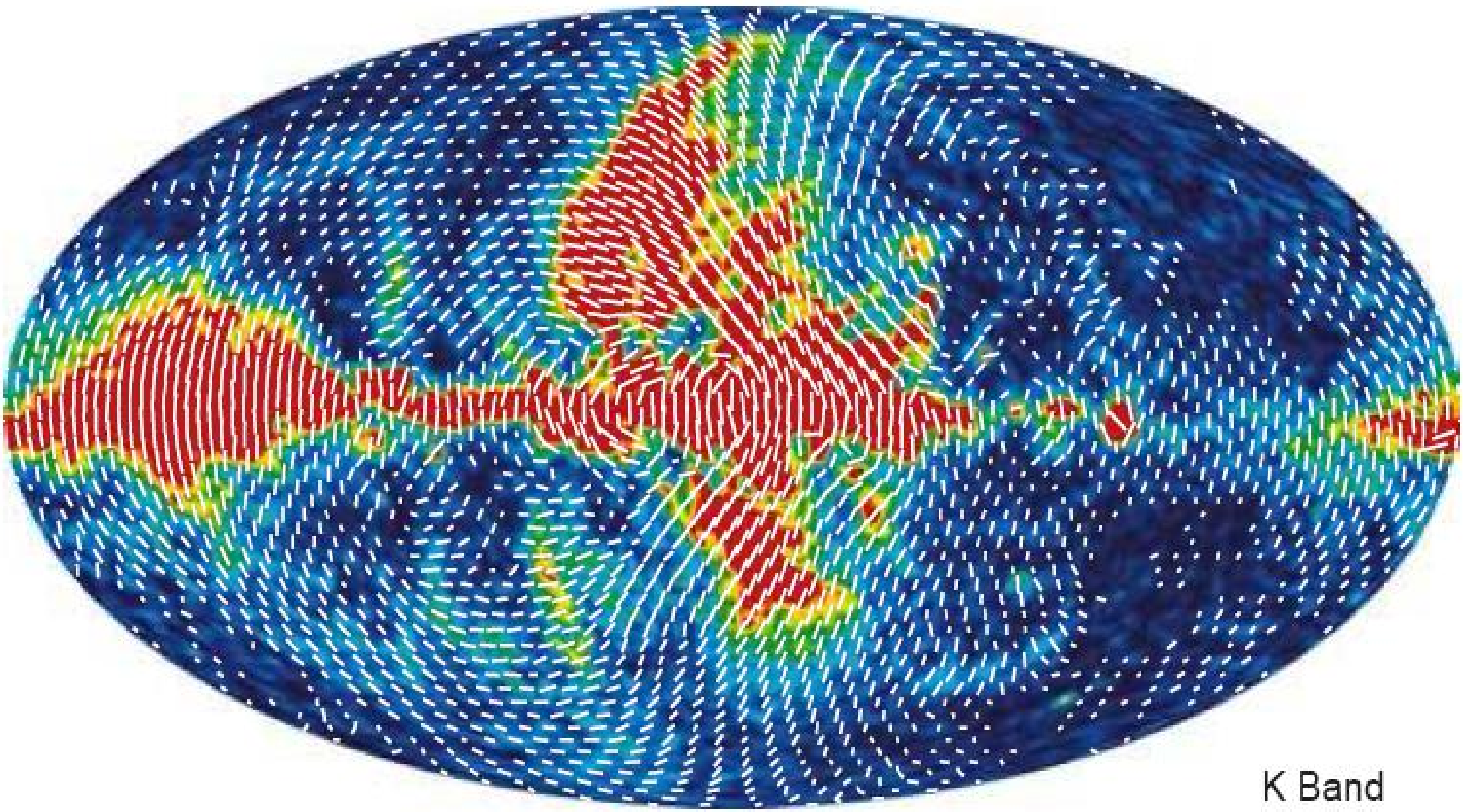


Fig. 22. All-sky view of the magnetic field and total intensity of dust emission measured by *Planck*. The colours represent intensity. The "drapery" pattern, produced using the line integral convolution (LIC, Cabral & Leedom 1993), indicates the orientation of magnetic field projected on the plane of the sky, orthogonal to the observed polarization. Where the field varies significantly along the line of sight, the orientation pattern is irregular and difficult to interpret.

Polarization at infrared, mm, submm

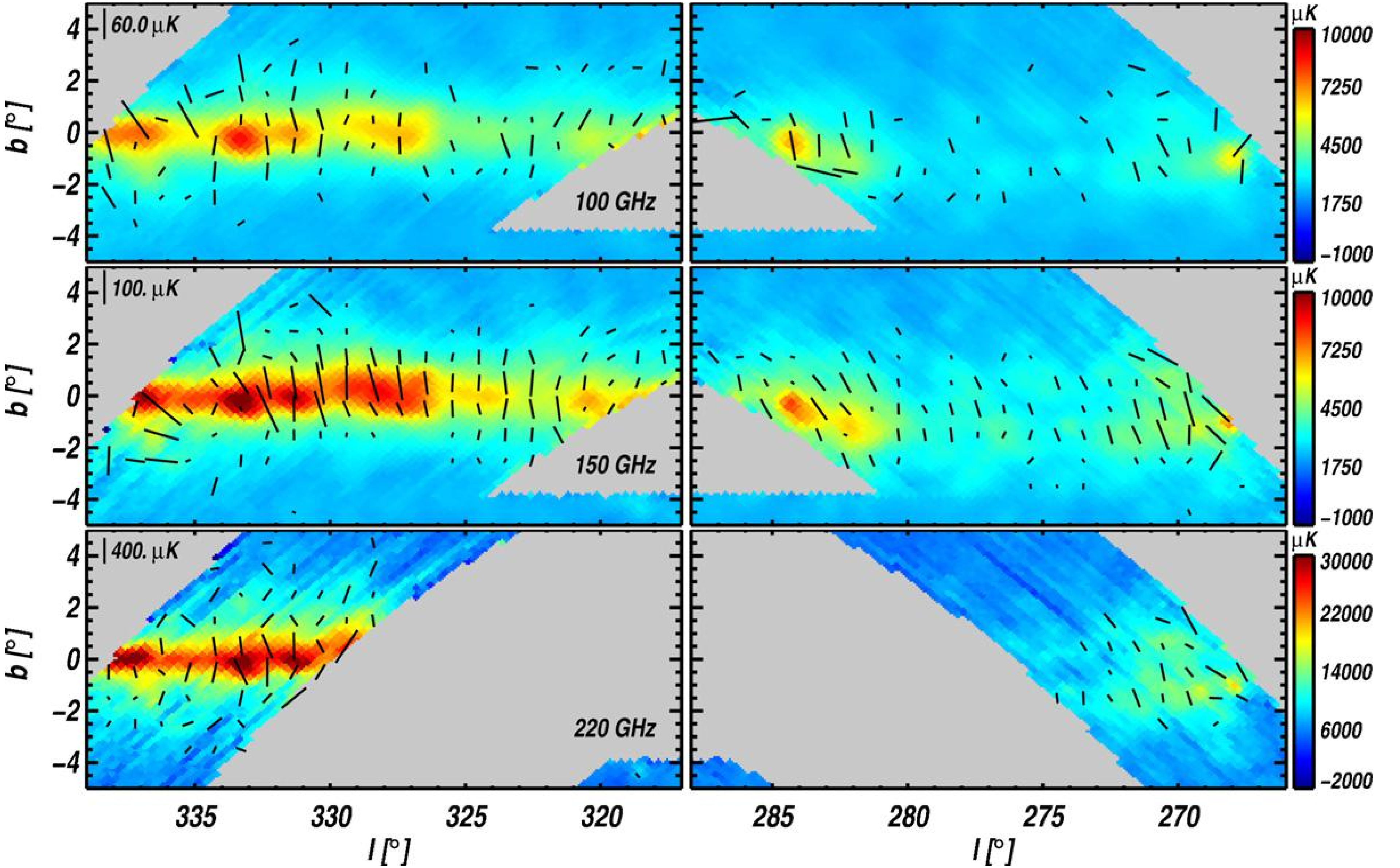


Excellent measurements for magnetic fields in clouds and filaments via dust there!

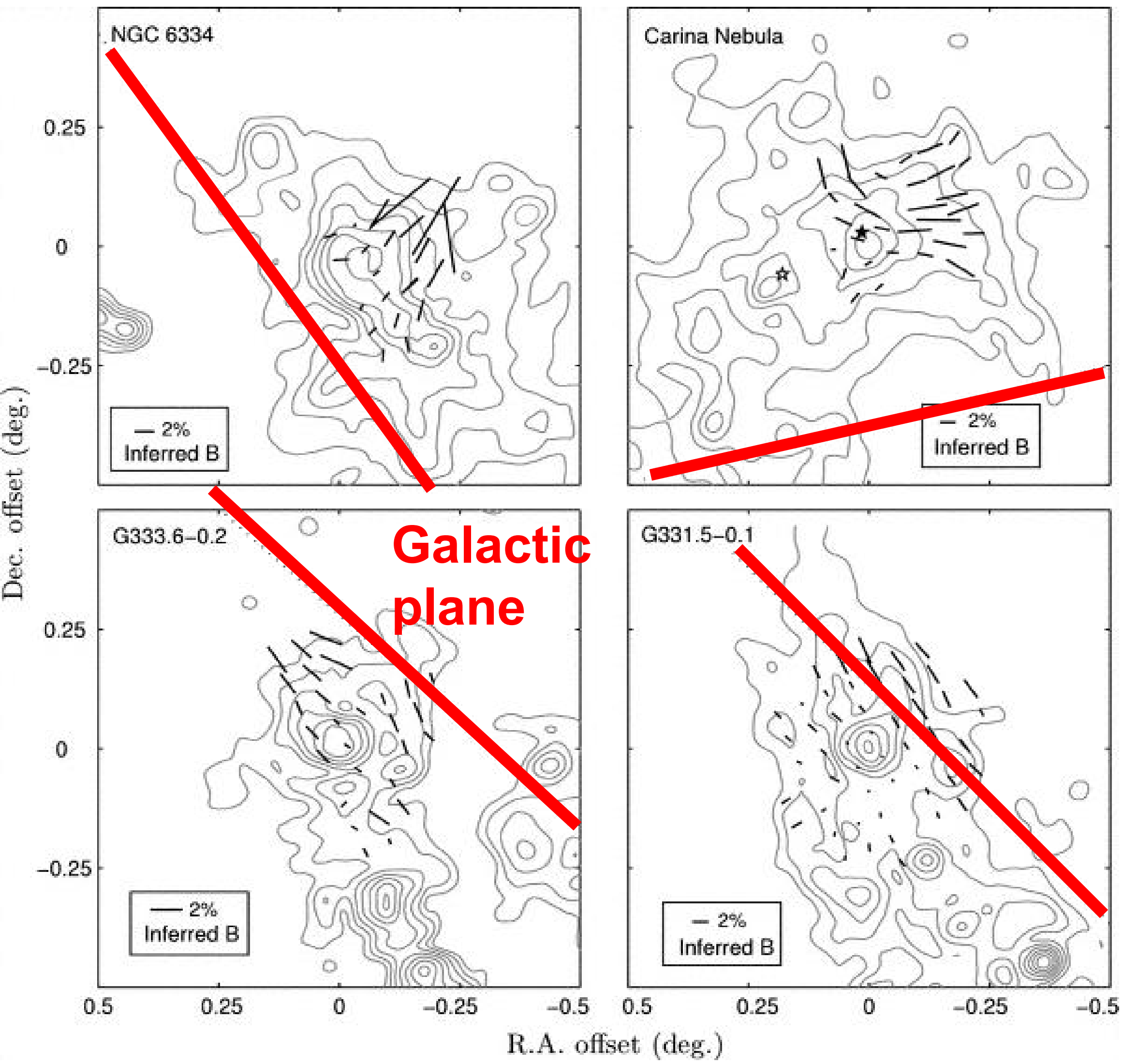
WMAP
Page et al. 2006

E. M. Bierman et al. 2011: ApJ

A MILLIMETER-WAVE GALACTIC PLANE SURVEY



Correlation of orientation of the fields in clouds with the large-scale Galactic B-field



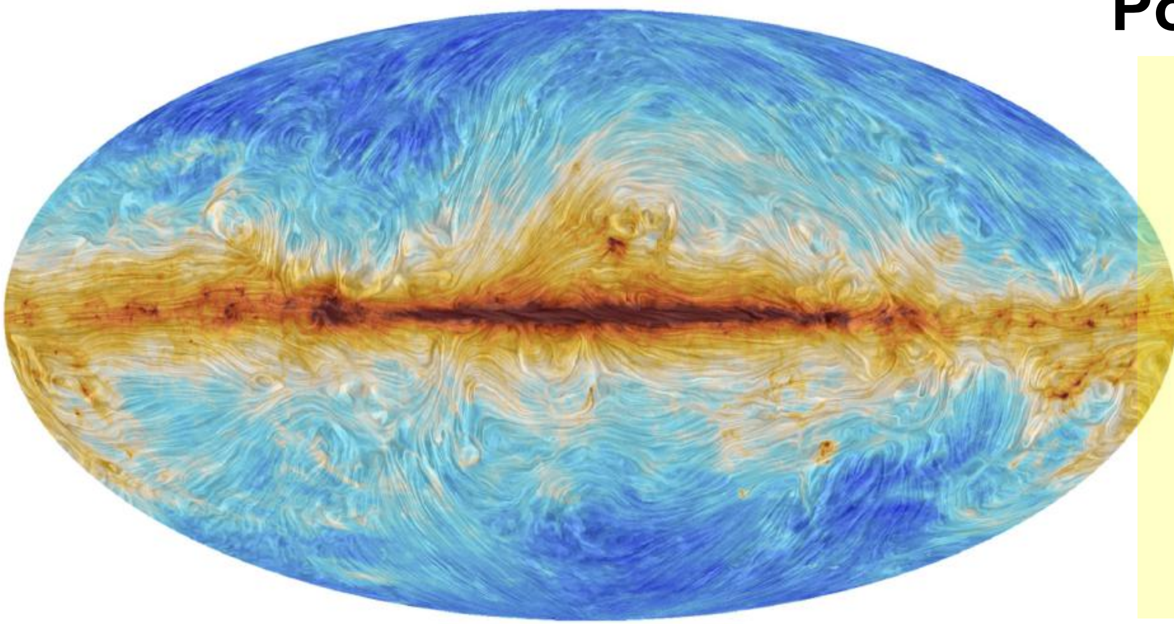
Li et al. 2006: ApJ 648, 340

(Results of SPARO 2003)

- **Mapped large-scale magnetic fields in four GMCs**
- **Statistically significant correlation with the orientation of the Galactic plane.**
- **Field direction tends to be preserved during the process of GMC formation.**

Planck 2015: Best all-sky B-fields from dust emission

- Magnetic fields in the disk: **B // Galactic Plane**
- Magnetic fields in filaments: **B // filaments**



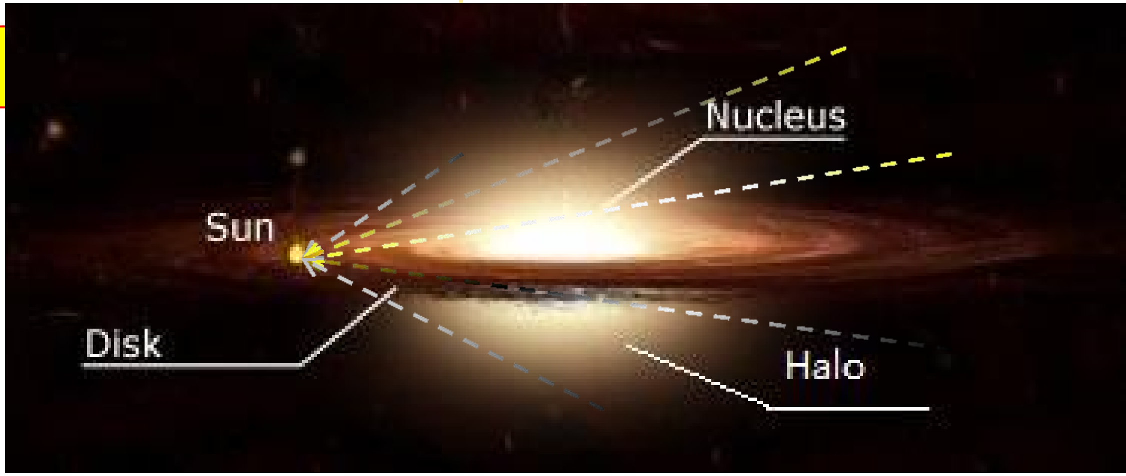
Polarized dust emission

Note:
Brightness-weighting-added B along the path!
Shown orientations. No B strength, no B direction!

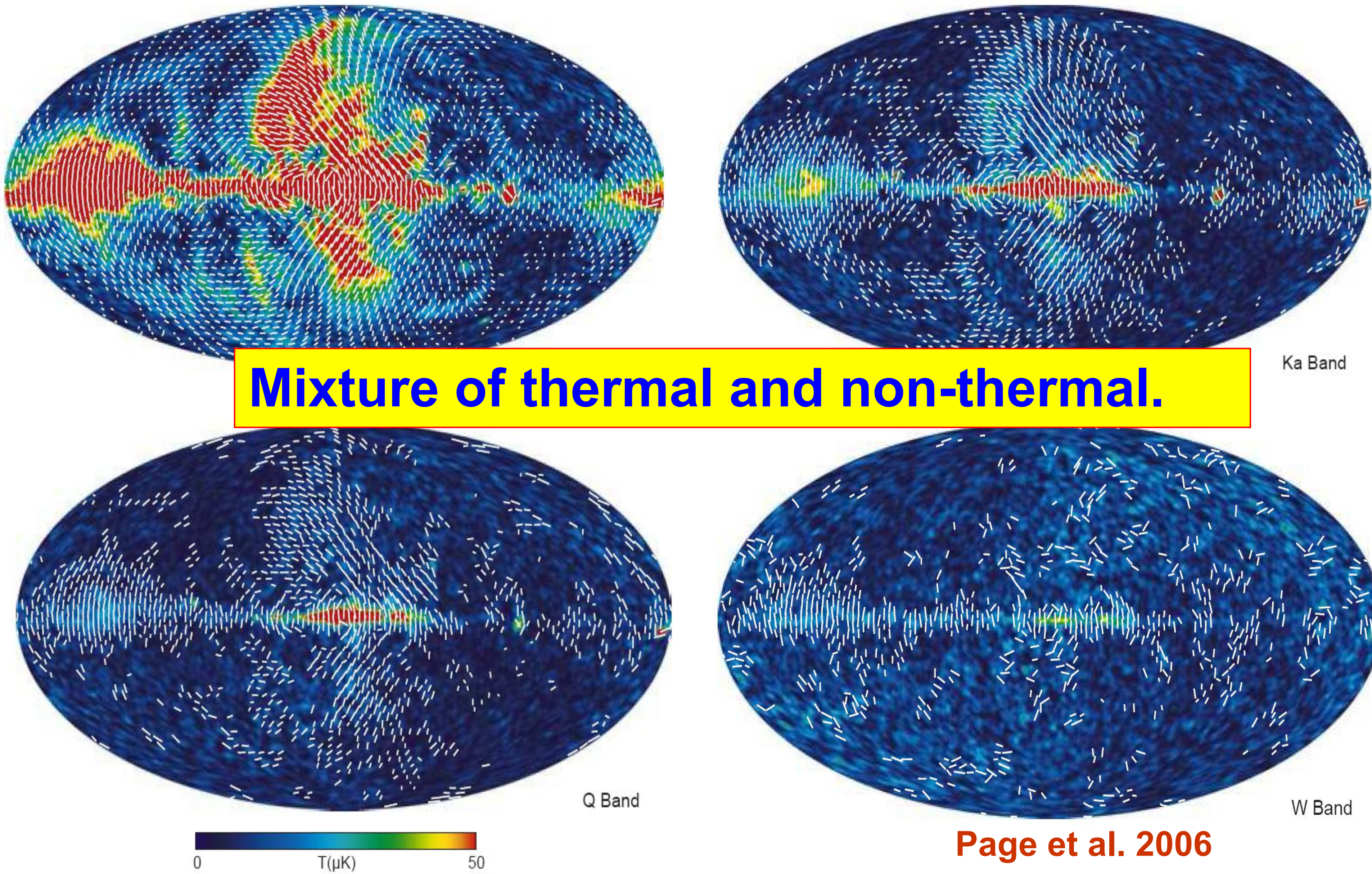
Sky maps from the local+halo fields?

the line of sight, the orientation pattern is irregular and difficult to interpret.

One can make a B-model to fit CMB data, but it is hard to unique the model. You can get constraints on any model.



all WMAPs show: B-field // GalacticPlane



Mixture of thermal and non-thermal.

Page et al. 2006

Planck 2015：Best all-sky synchrotron

- Magnetic fields in the disk: **B // Galactic Plane**
- Magnetic fields in filaments: **B // filaments**

@ 30GHz

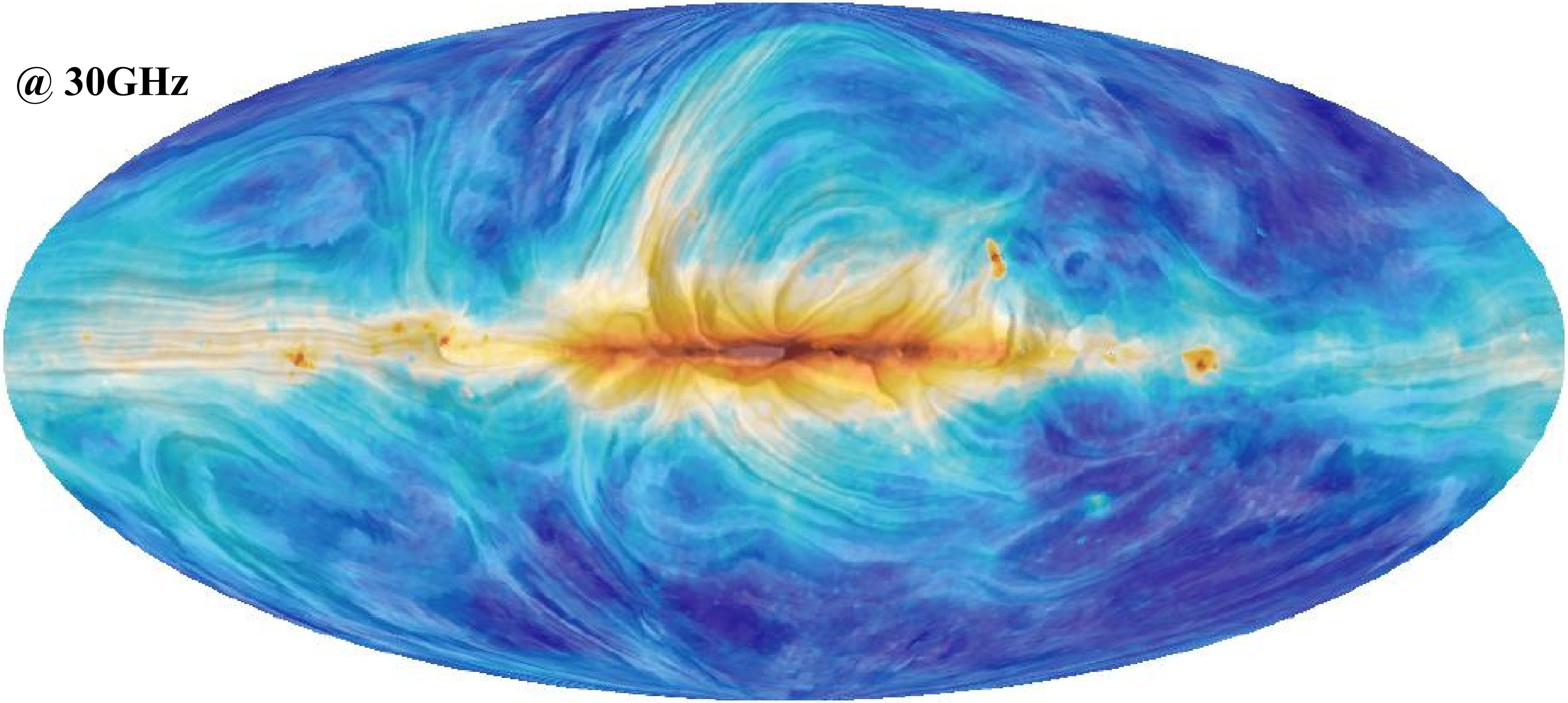
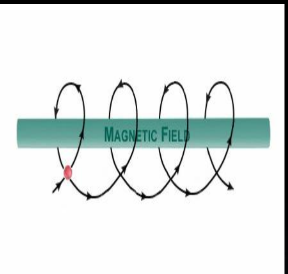
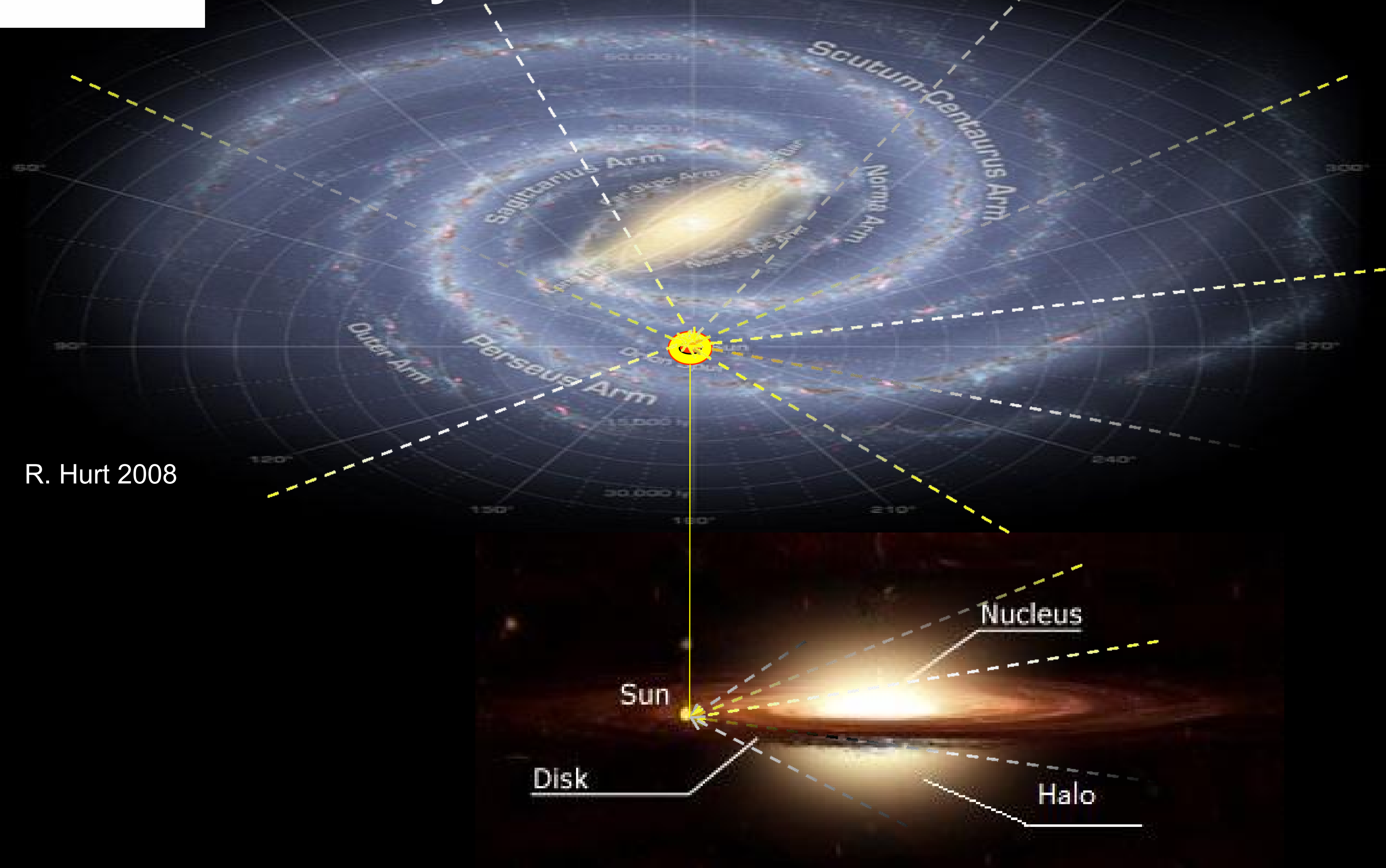


Fig. 20. All-sky view of the magnetic field and total intensity of synchrotron emission measured by *Planck*. The colours represent intensity. The "drapery" pattern, produced using the line integral convolution (LIC, Cabral & Leedom 1993), indicates the orientation of magnetic field projected on the plane of the sky, orthogonal to the observed polarization. Where the field varies significantly along the line of sight, the orientation pattern is irregular and difficult to interpret.



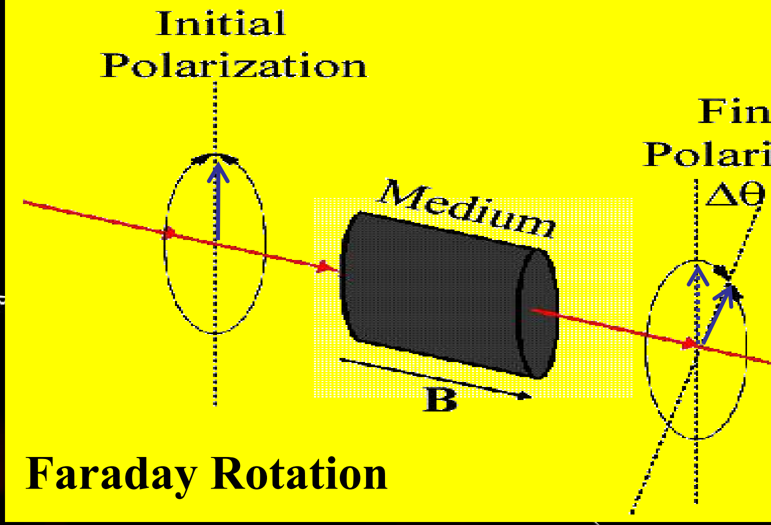
Synchrotron emission is co-added from all path with a weight of distance and strength and after Faraday rotation in the interstellar medium

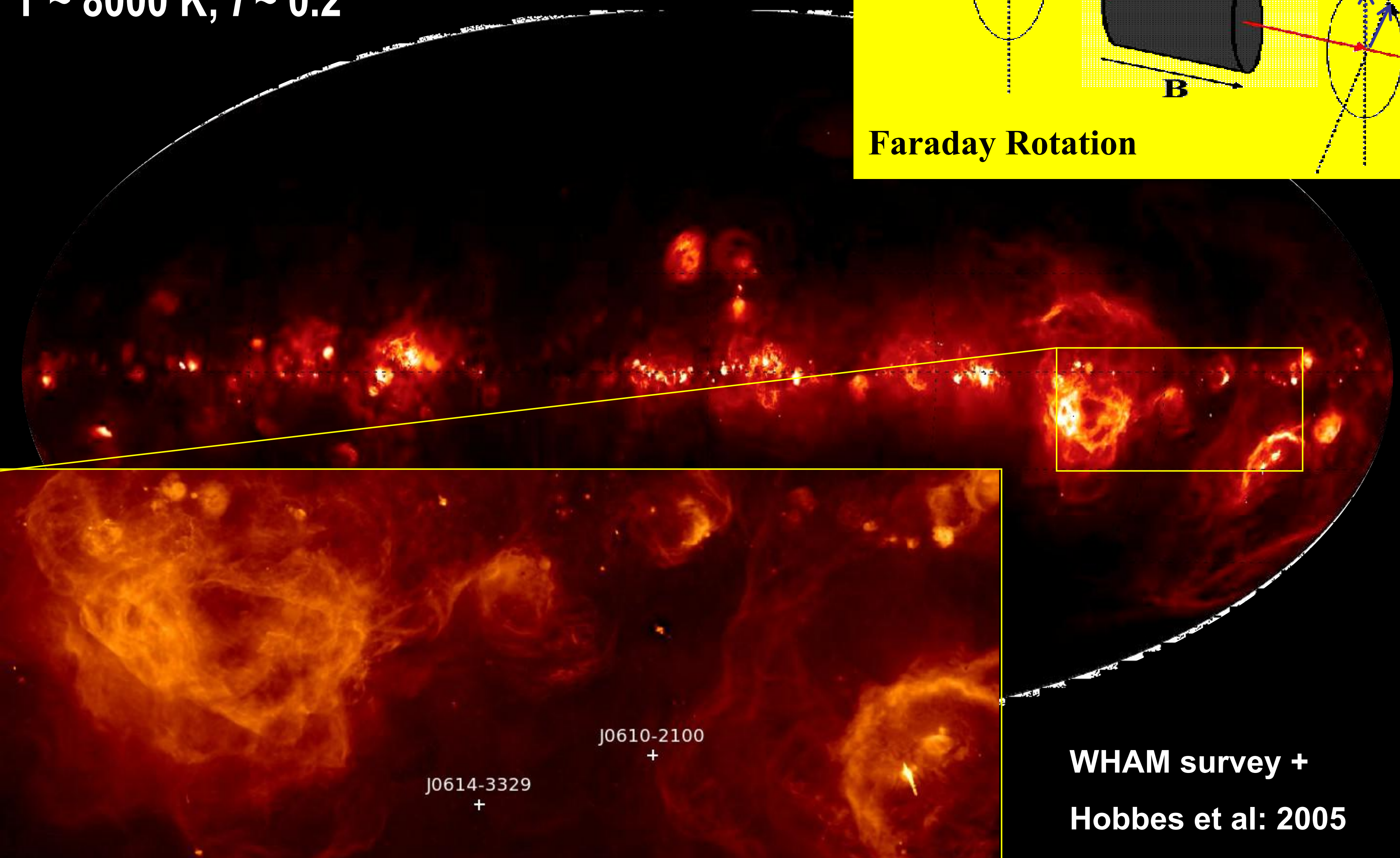


R. Hurt 2008

Ionized Interstellar Medium

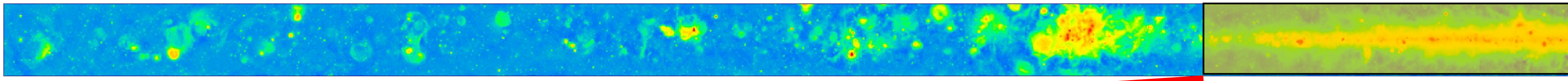
Warm ionized medium (WIM): $n \sim 0.1\ \mathrm{cm}^{-3}$; T ~ 8000 K; $f \sim 0.2$





WHAM survey +

Hobbes et al: 2005



Sun et al. 2011, A&A, 527, A74

Centr.freq: 4.8/4.963GHz

BW: 600 MHz/295 MHz

System temp.: 22 -25 K

HPBW: 9.5arcmin

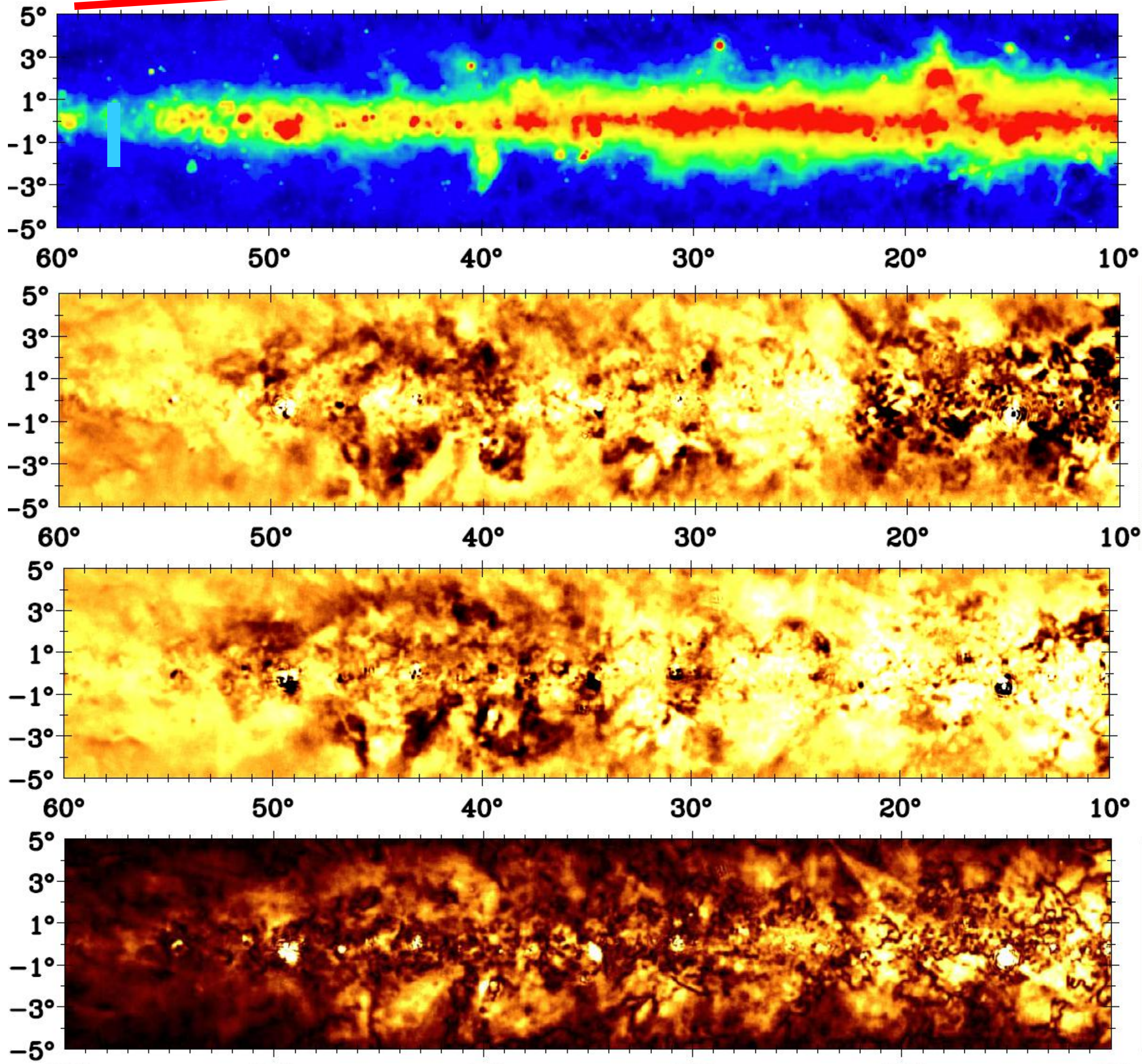
1st side lobe: 2%

Instr. polarization: <2%

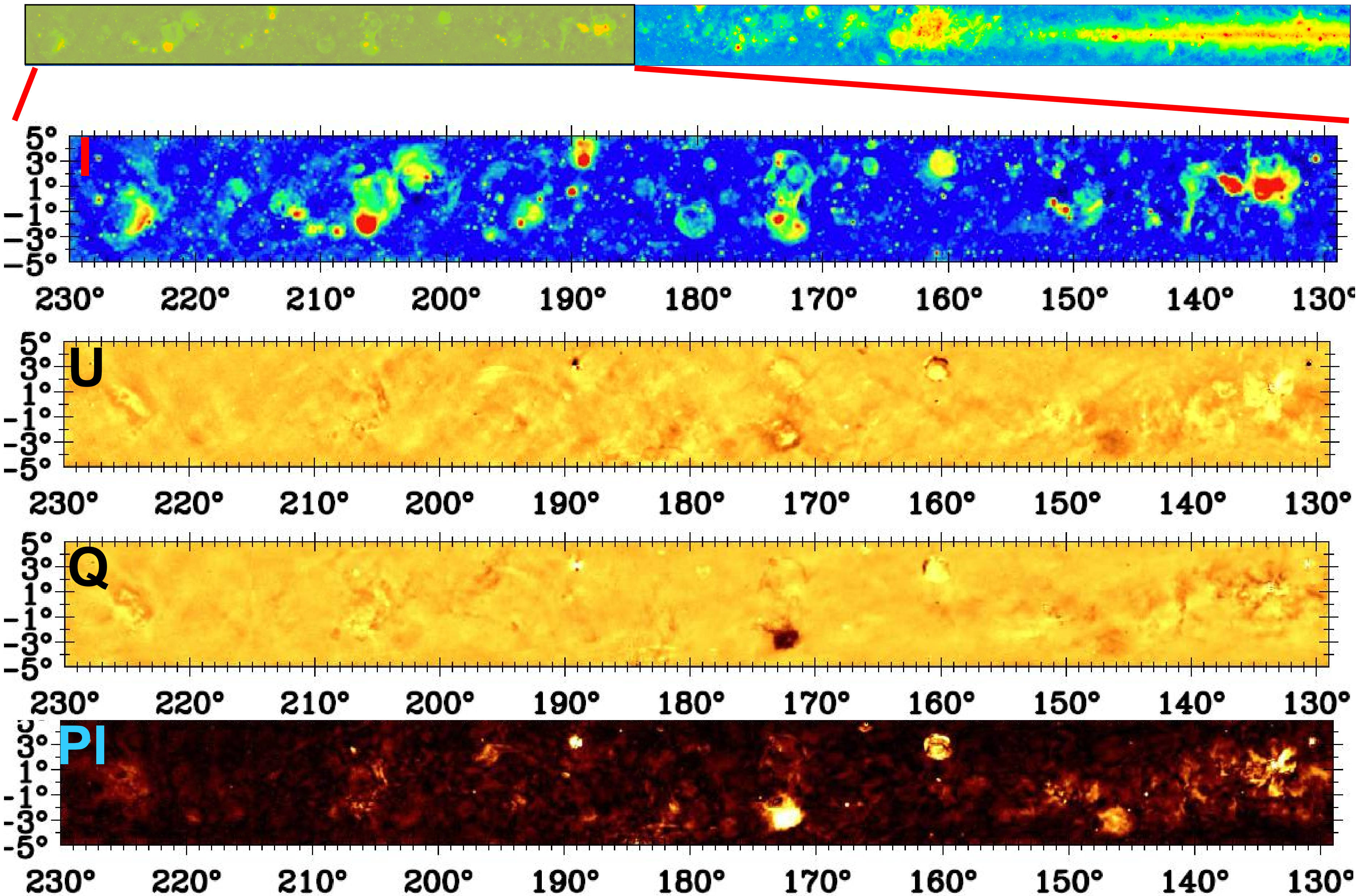
Beam efficiency: 67%

Gain: 0.164 K/Jy

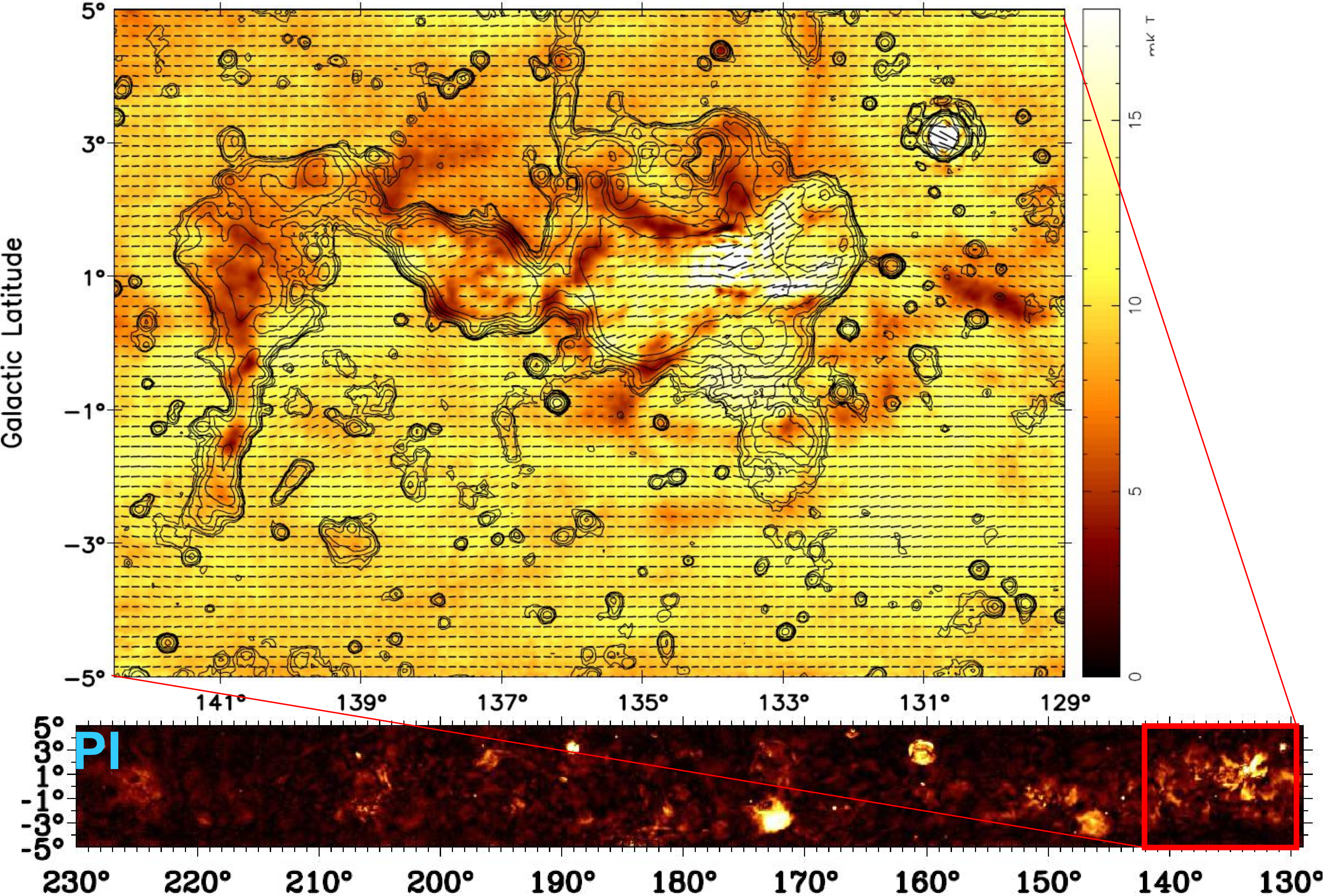
Obs: 2004.8—2009.4



The Sino-German 6cm polarization survey of the Galactic plane



129° ≤ l ≤ 230° : Gao et al. 2010, A&A, 515, A64



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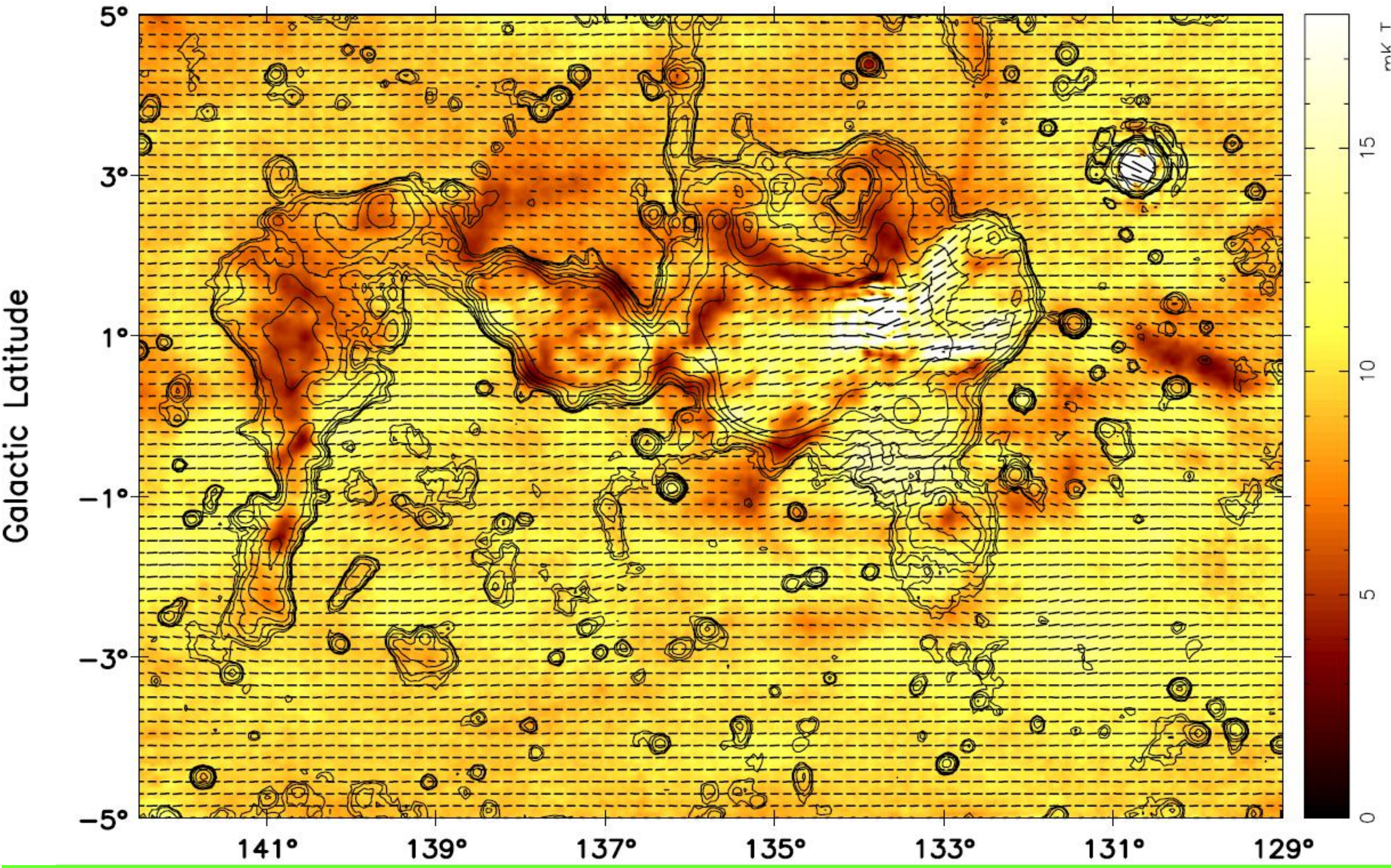


Synchrotron radio emission of Milky Way:

We see trees, but not forest!

129° ≤ l ≤ 230° : Gao et al. 2010, A&A, 515, A64

Planck 2015: **Best** all-sky synchrotron

- Magnetic fields in the disk: **B // Galactic Plane**
- Magnetic fields in filaments: **B // filaments**

@ 30GHz

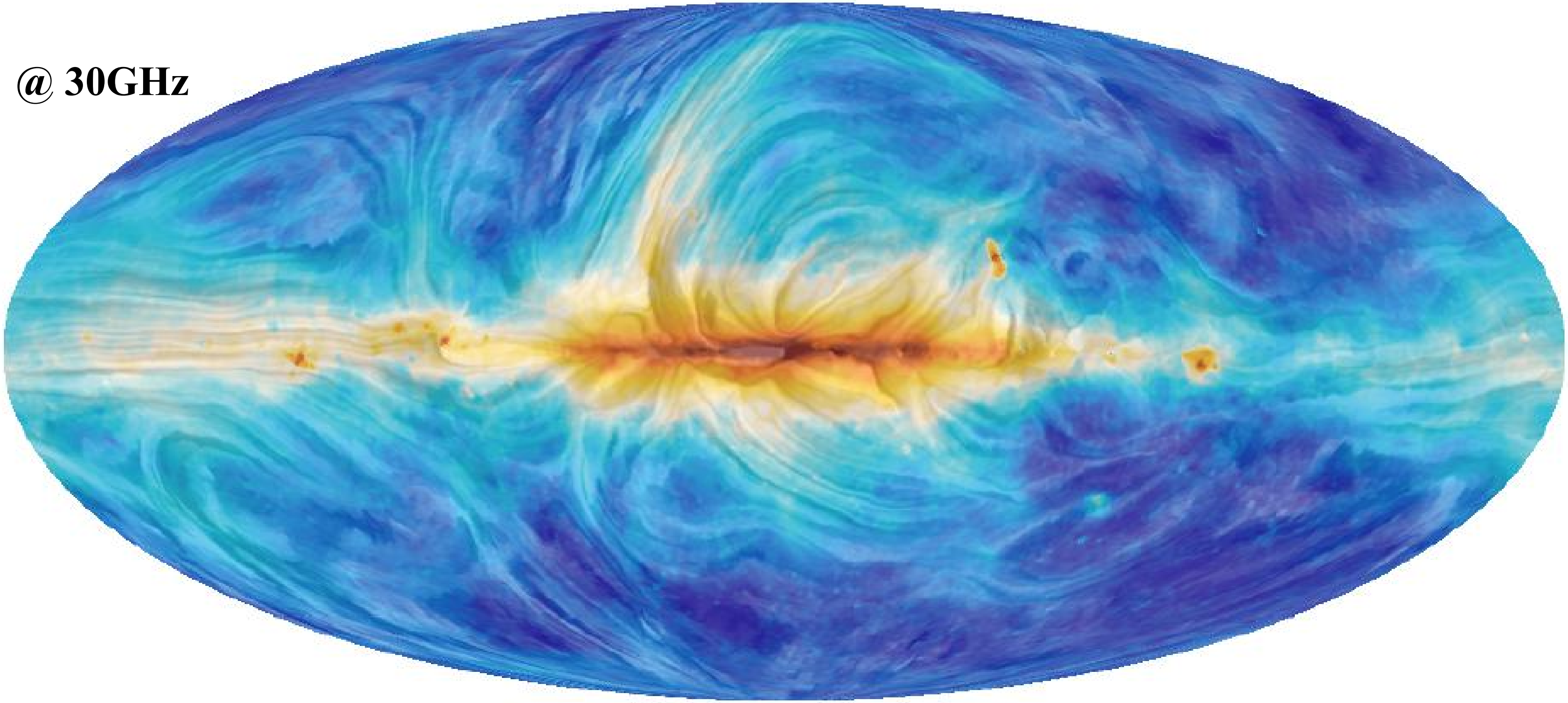
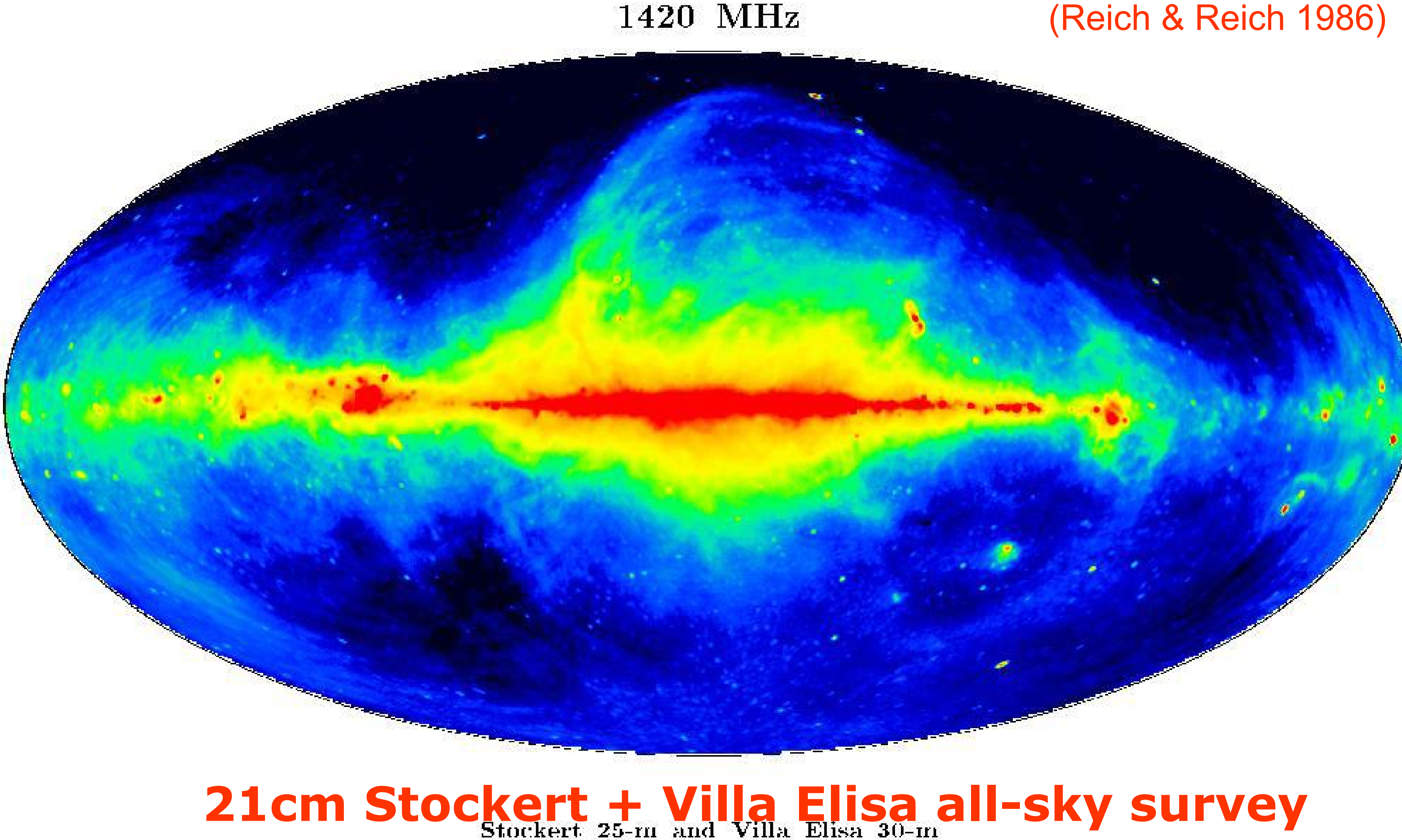


Fig. 20. All-sky view of the magnetic field and total intensity of synchrotron emission measured by *Planck*. The colours represent intensity. The "drapery" pattern, produced using the line integral convolution (LIC, Cabral & Leedom 1993), indicates the orientation of magnetic field projected on the plane of the sky, orthogonal to the observed polarization. Where the field varies significantly along the line of sight, the orientation pattern is irregular and difficult to interpret.

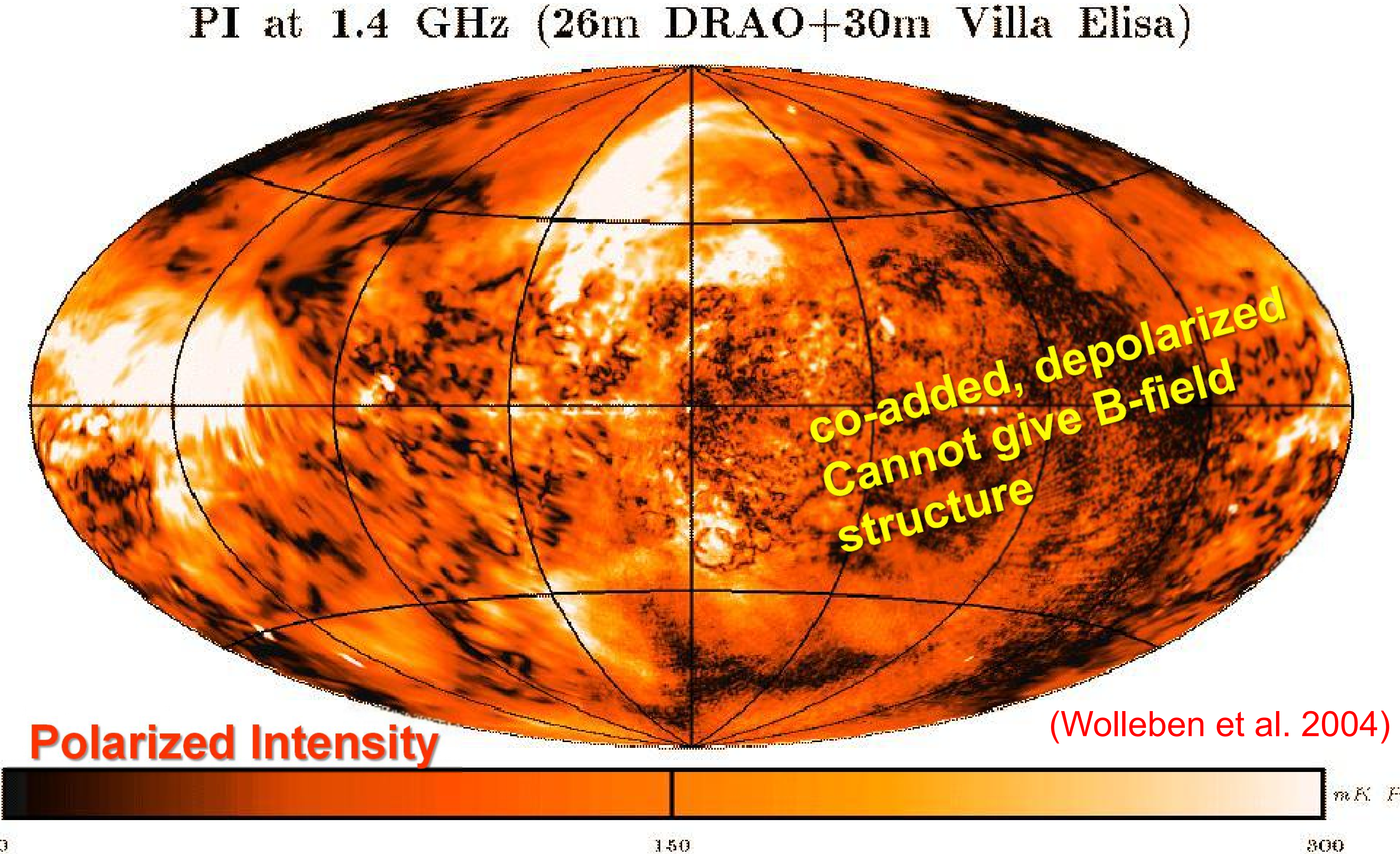
Total Intensity map

(Reich & Reich 1986)



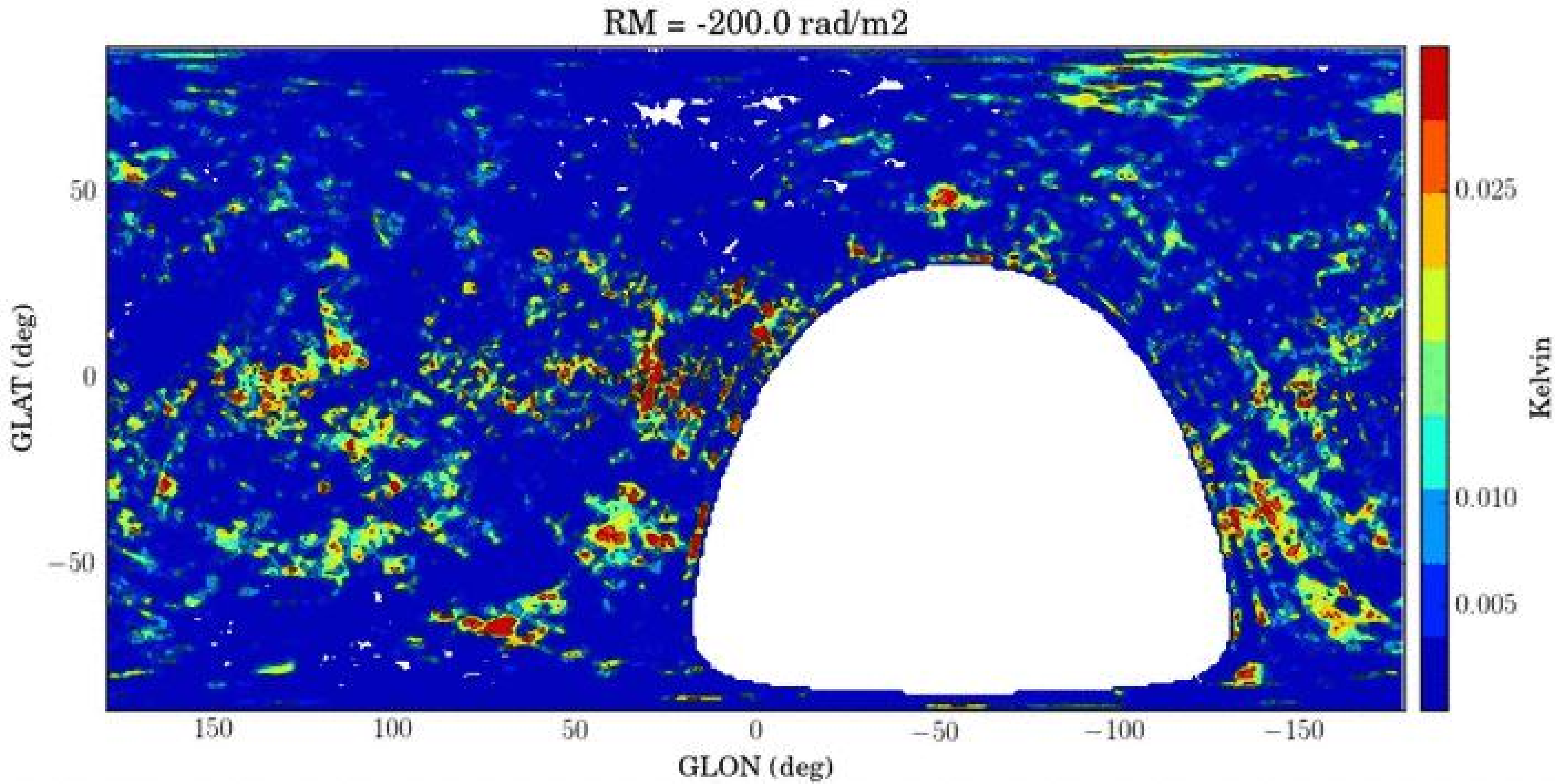
21cm Stockert + Villa Elisa all-sky survey

21cm DRAO+Villa Elisa all-sky polarization map



Polarized structures of diffuse emission seen at different RMs

yes for trees, not for forest!

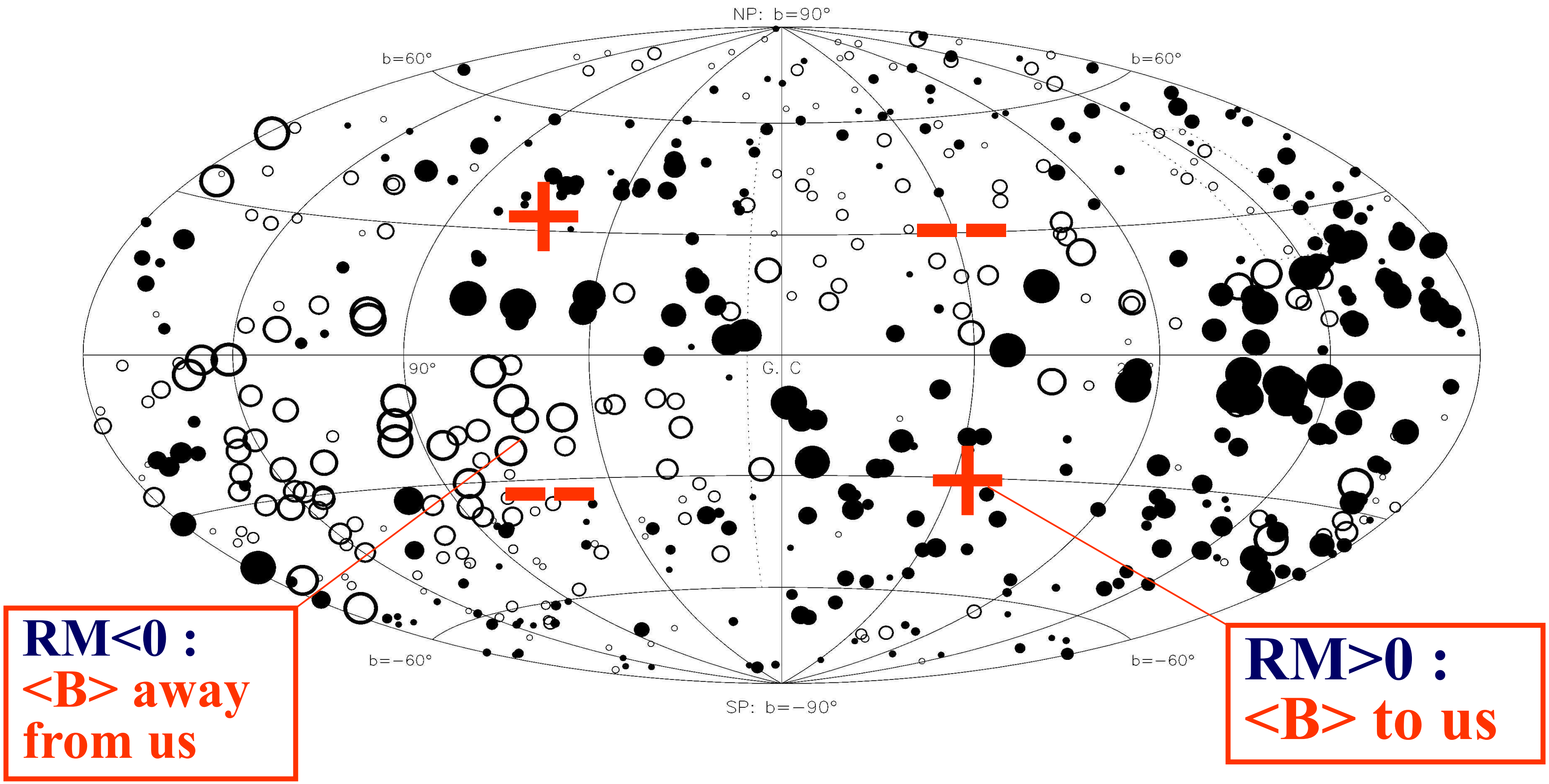


Sun et al. 2015

RMs of Extragalactic radio sources

RM Sky: Anti-symmetry!

Outliers omitted if very different from surroundings



RMs of Extragalactic radio sources

$$RM = \frac{e^3}{2\pi m_e^2 c^4} \int_{Source}^{us} [\frac{\lambda(l)}{\lambda_{obs}}]^2 n_e(l) \mathbf{B(l)} \bullet \mathbf{dl}$$

<B> to us: RM>0

$RM_{obs} = RM_{intrinsic} + RM_{InterGalactic} + RM_{MilkyWay}$

Common term!

- $RM_{intrinsic}$: RM intrinsic to the source;
  - They never know each other: uncorrelated ➔ Random!
  - Location of emission regions: ➔ Beam size?
- $RM_{InterGalactic}$: RM from intergalactic space;
  - weak correlated if with same intervening medium
  - Small values ??
- $RM_{MilkyWay}$: Foreground RM from our Galaxy;
  - Correlated ~10^o with same intervening ISM
  - Strongly depends on the Galactic coordiantes!

RMs of Extragalactic radio sources

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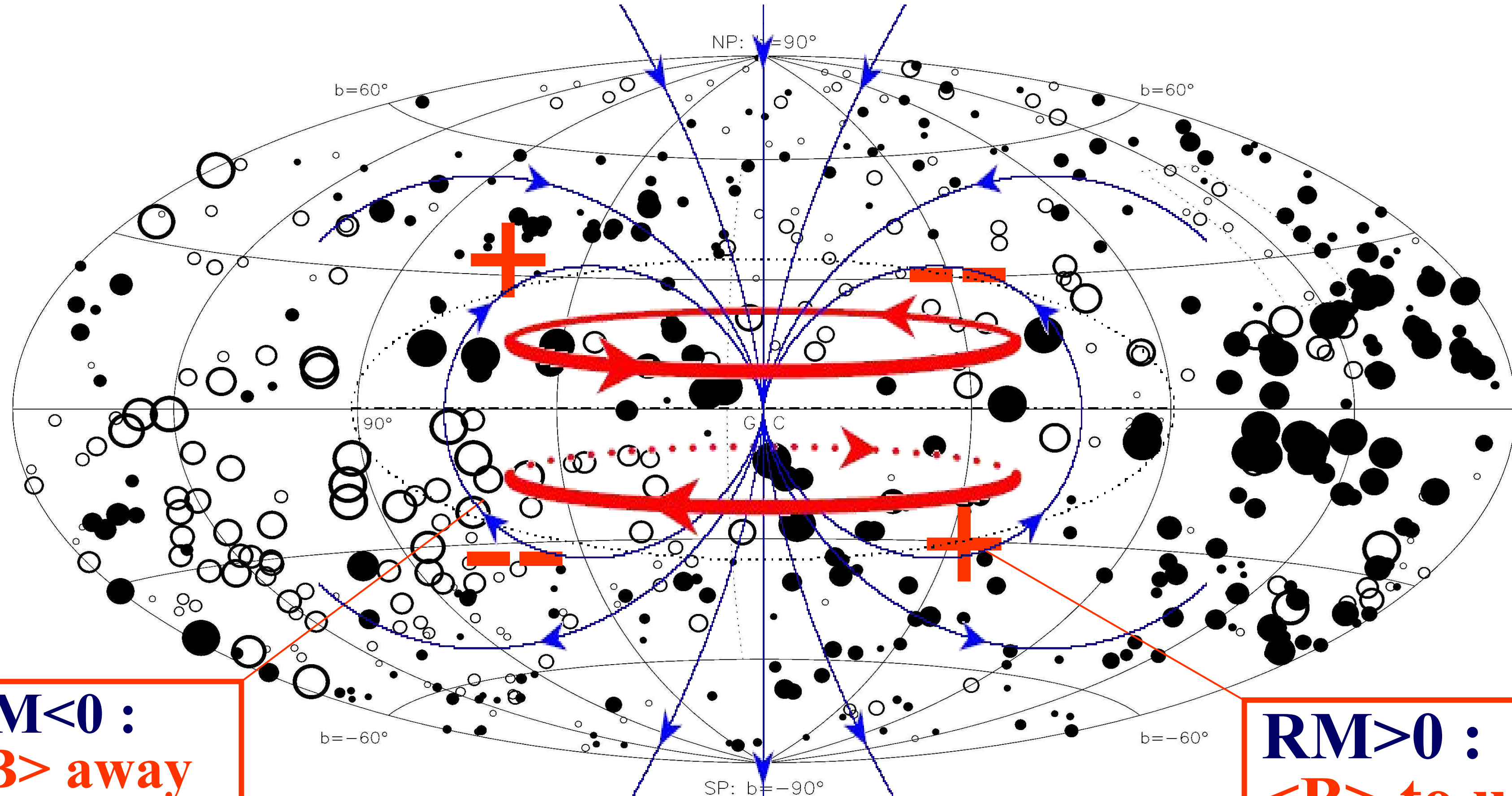
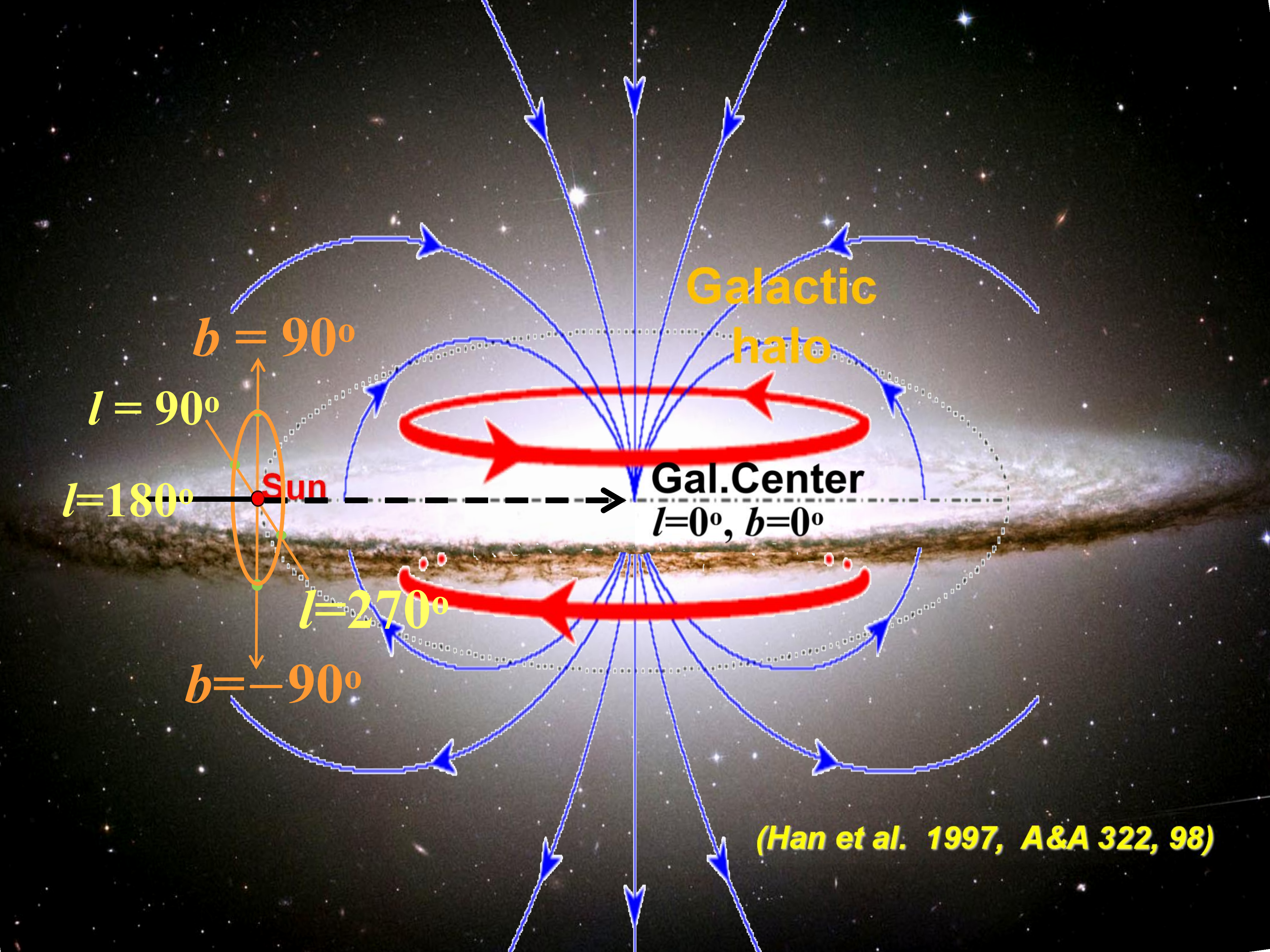
Outliers omitted if significantly different from surroundings

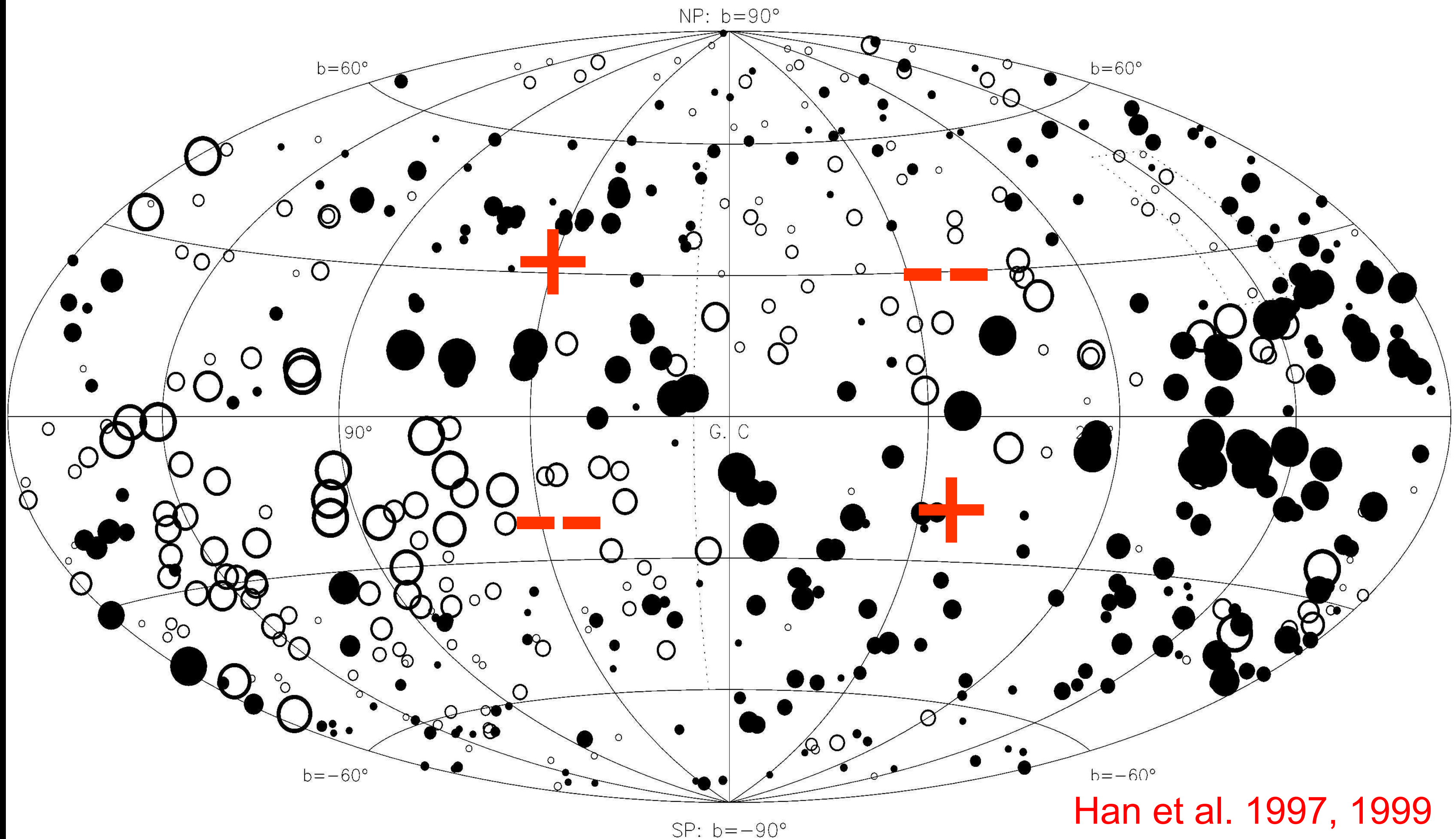


RM<0 :
<B> away from us

RM>0 :
<B> to us


Galactic
halo
b = 90°
l = 90°
l=180°
Sun
Gal.Center
l=0°, b=0°
l=270°
b=−90°
(Han et al. 1997, A&A 322, 98)

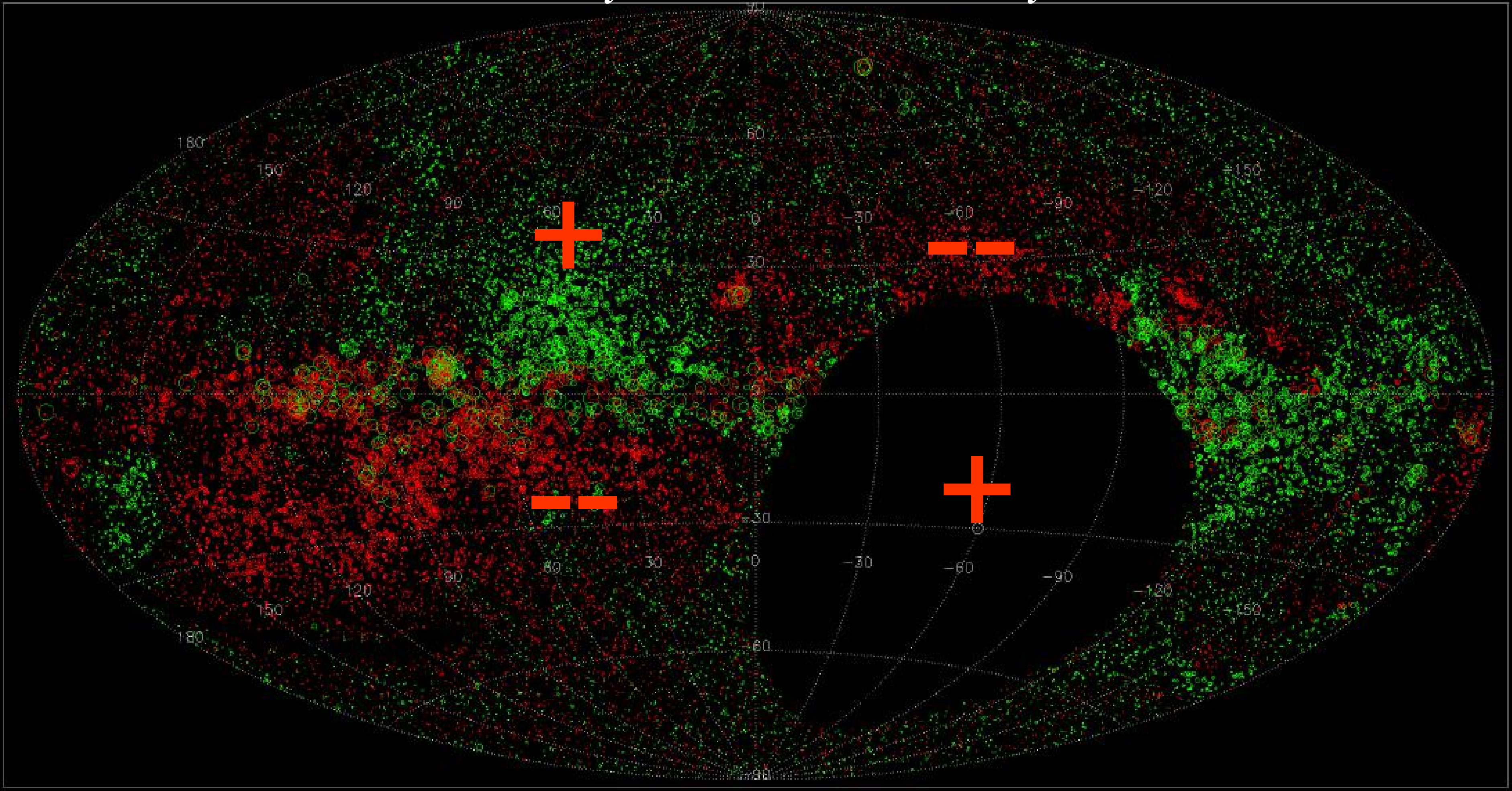
RM sky: Antisymmetry is confirmed!



Han et al. 1997, 1999

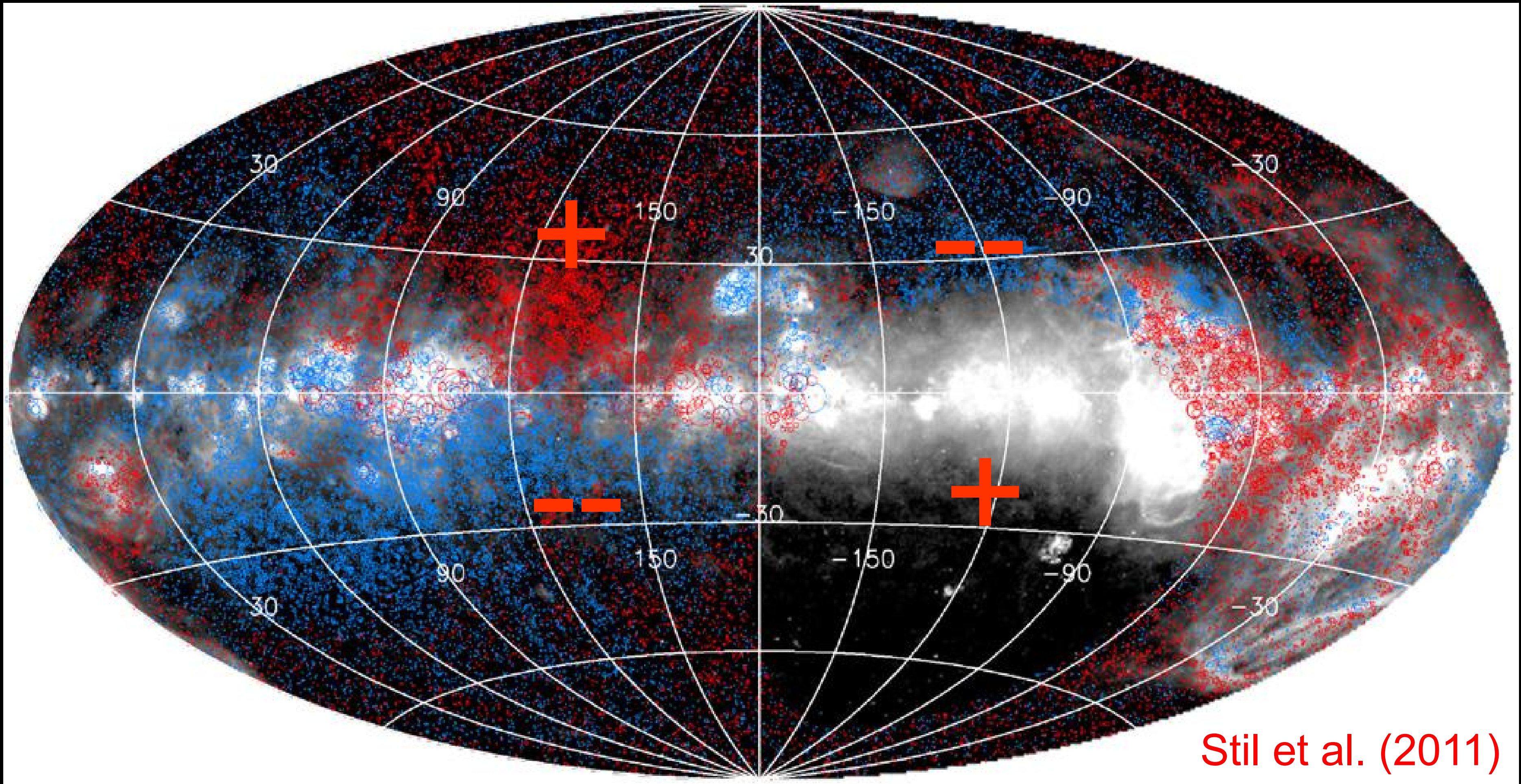
RM sky: Antisymmetry is confirmed!

NVSS RM catalog: RM estimated from only 2 IFs of NVSS data
Individually: cannot trust! Collectively: Ok!



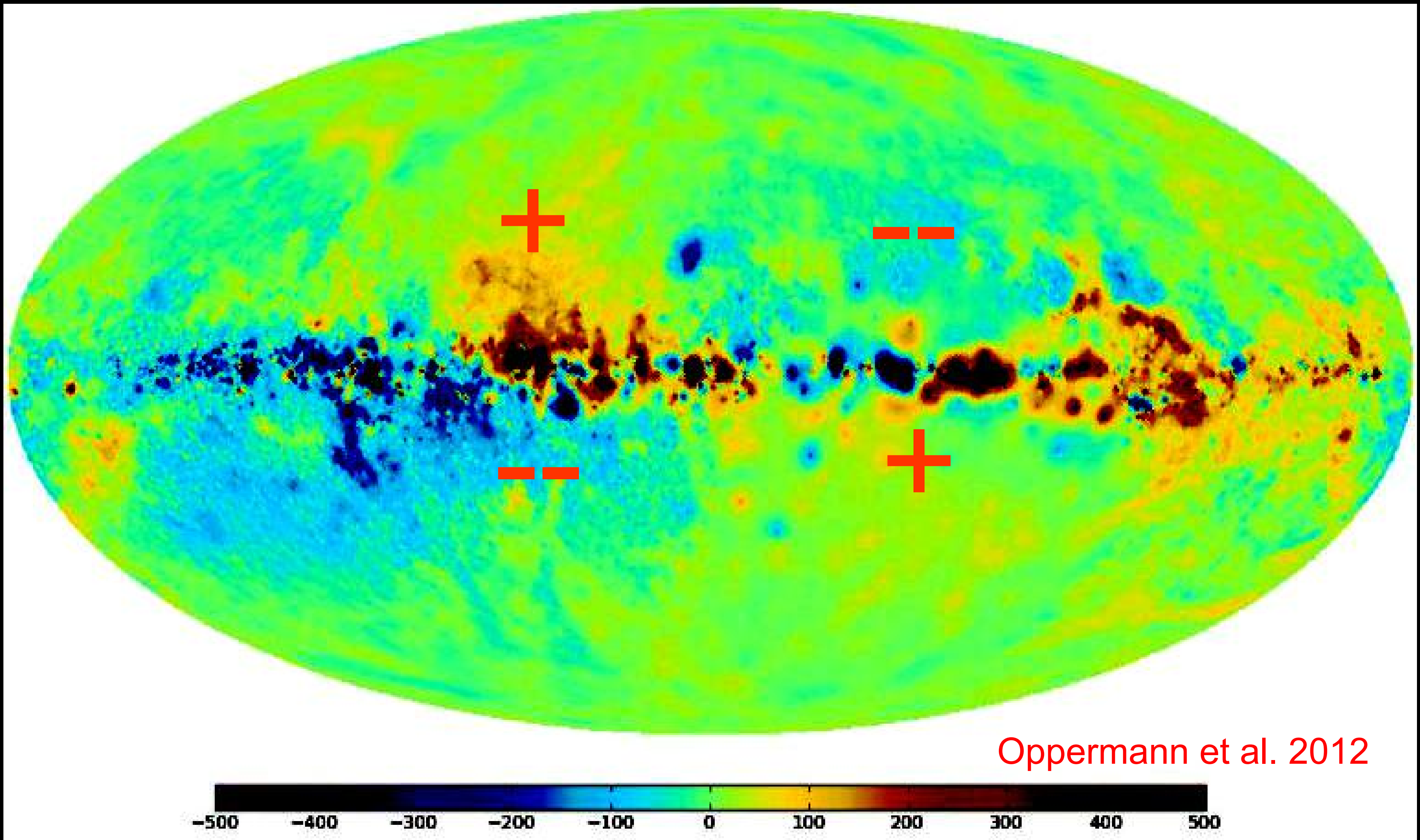
Taylor et al. (2009）

RM sky: Antisymmetry is confirmed!

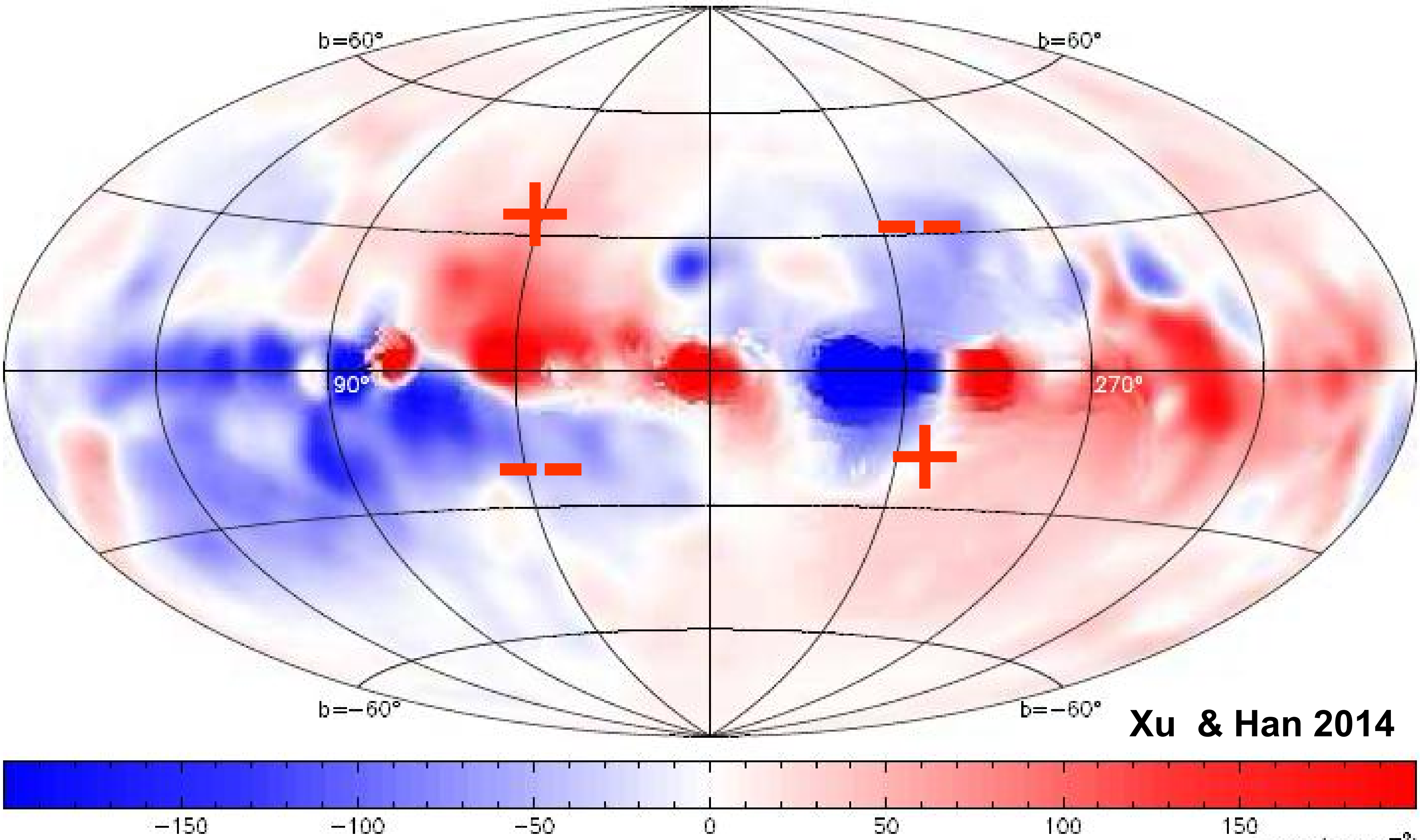


Stil et al. (2011)

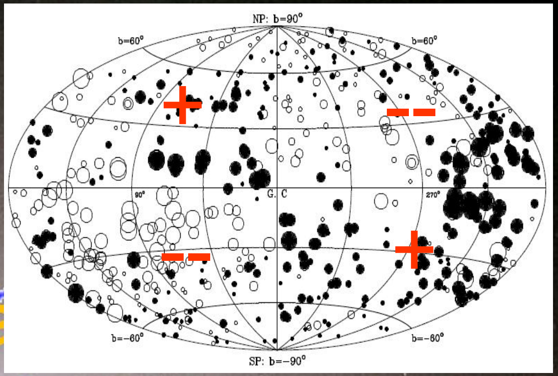
RM sky: Antisymmetry is confirmed!

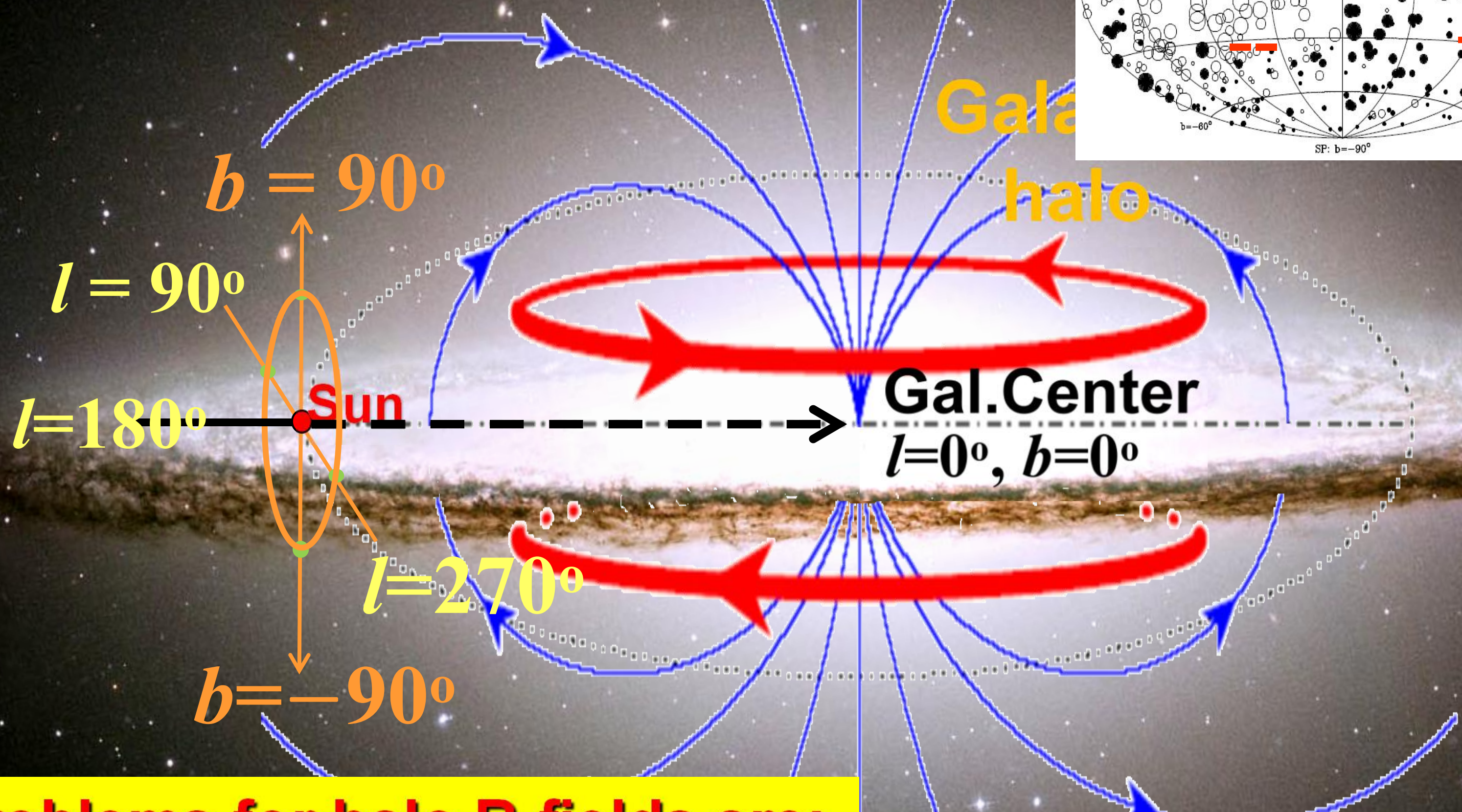


RM sky: Antisymmetry is confirmed!



$$RM = \frac{e^3}{2\pi m_e^2 c^4} \int_{Source}^{us} [\frac{\lambda(l)}{\lambda_{obs}}]^2 n_e(l) \mathbf{B(l) \bullet dl}$$



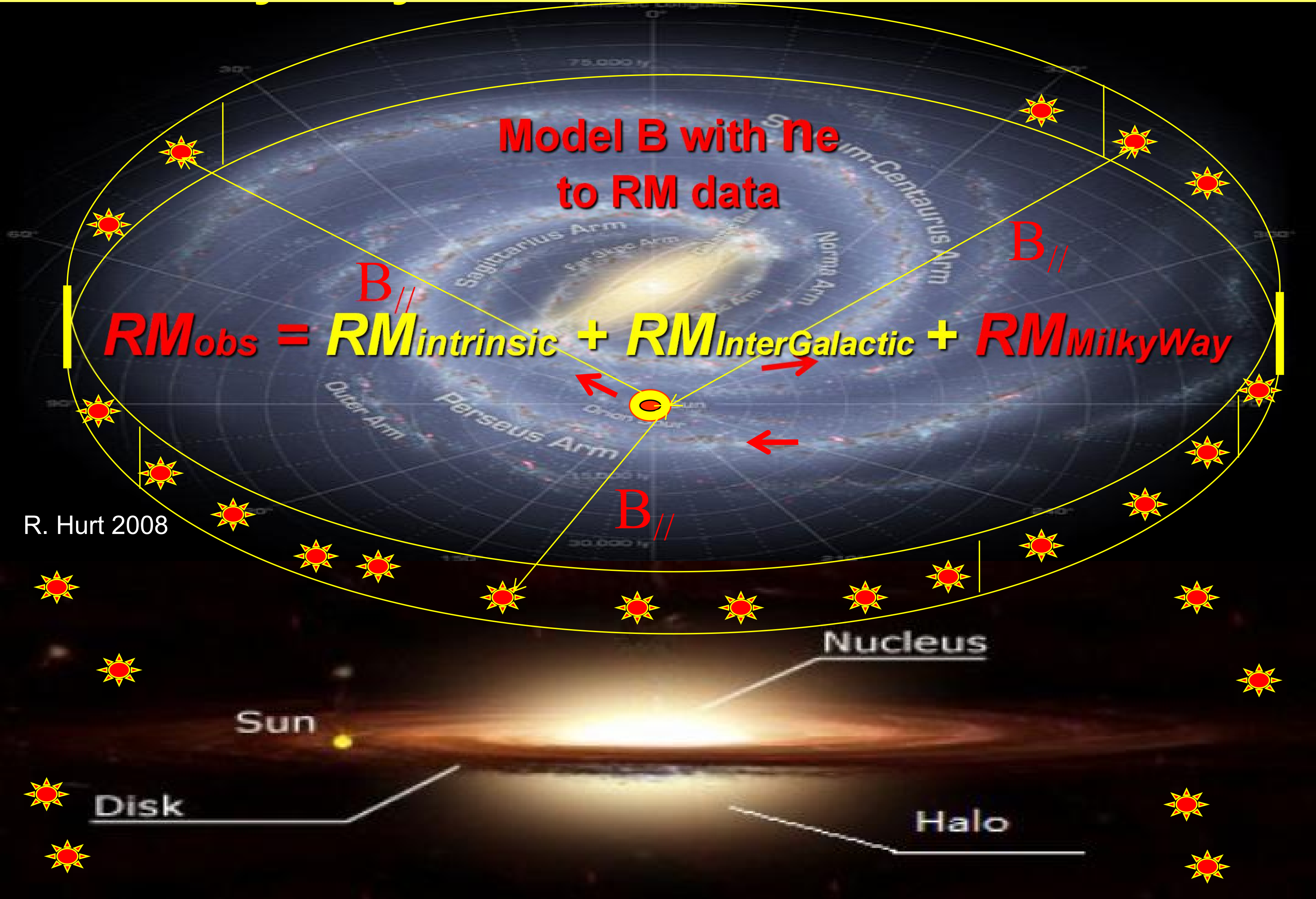


Problems for halo B-fields are:

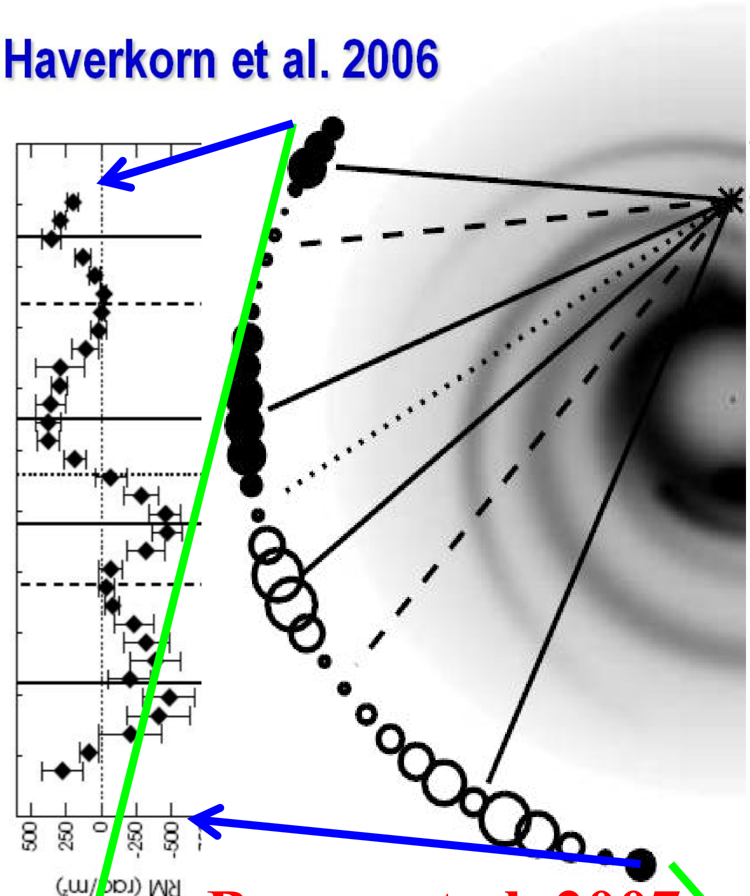
1. unknown scale height;
2. unknown radius range;
3. unknown field strength

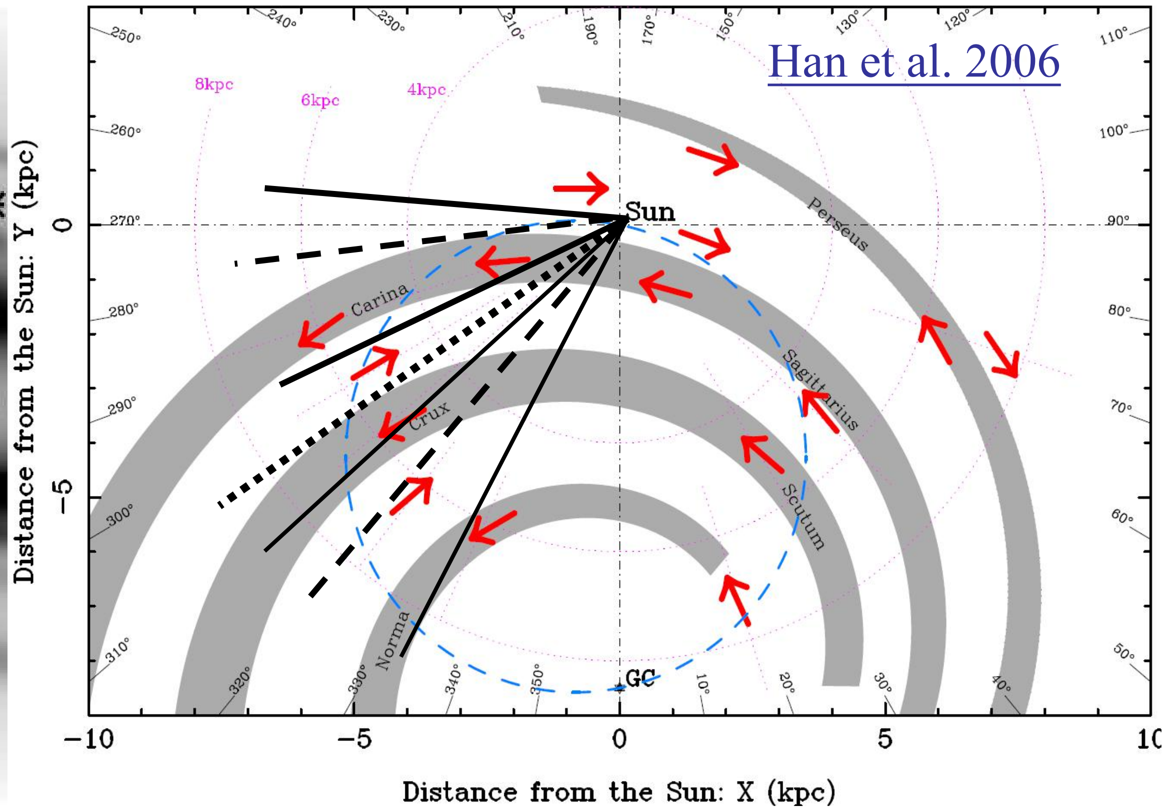
(Han et al. 1997, A&A 322, 98)

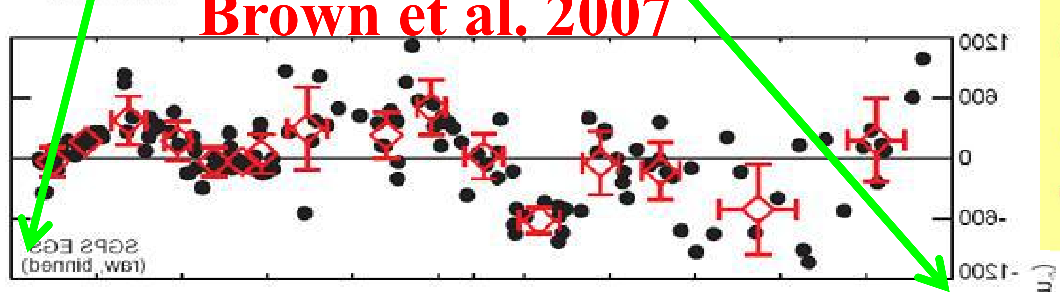
RMs of extragalactic sources: Integration of Ne*B//



RMs from extragalactic RM sources near Galactic plane: Consistent with B-Structure from pulsar data!

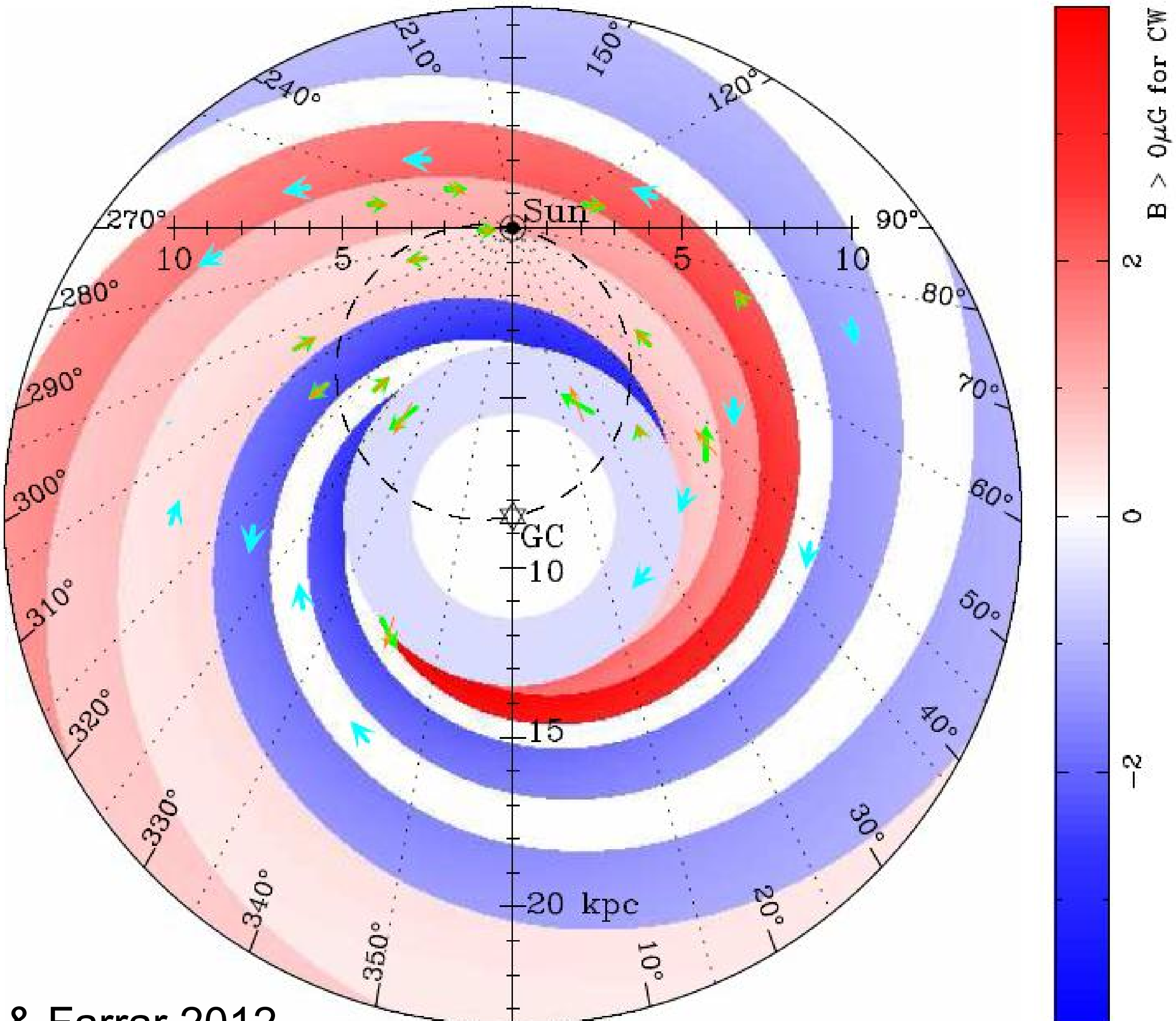






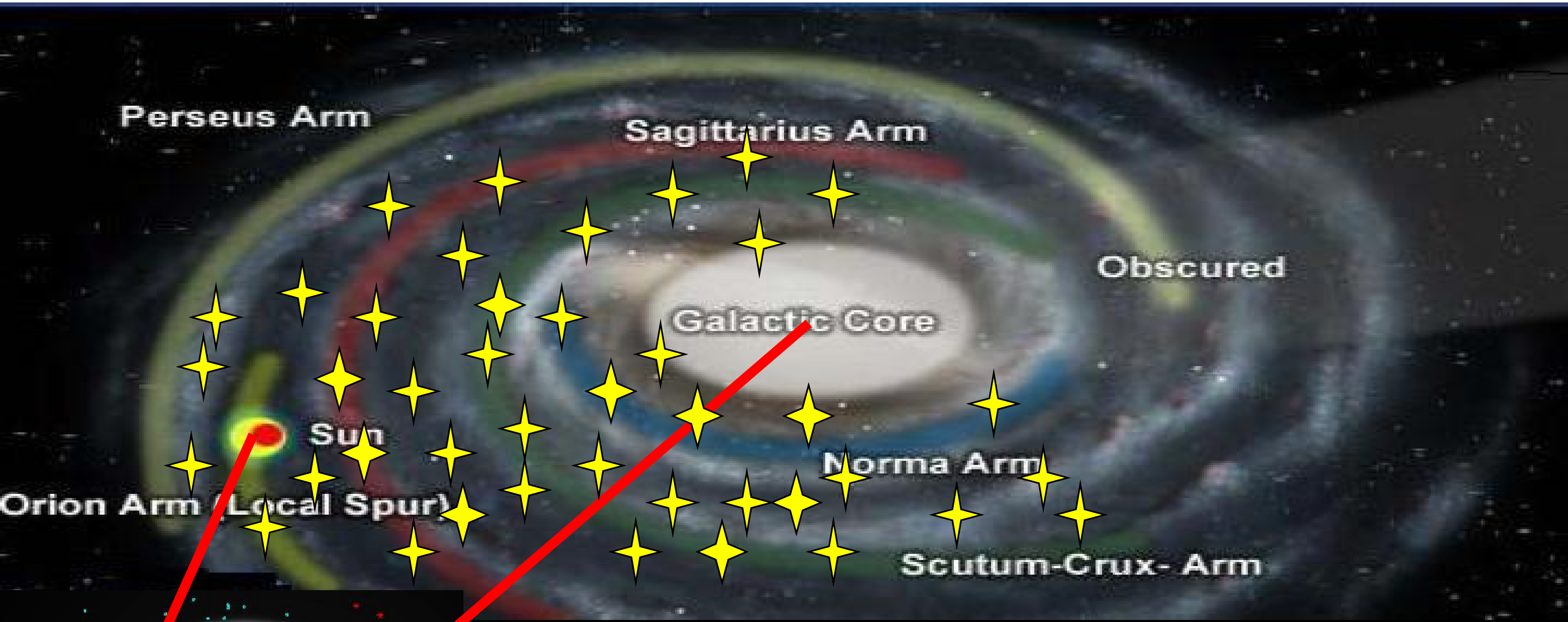
- **PSR and EGRs data show a consistent B-structure!**
- **Major RM contribution from tangential regions!**

Magnetic field model based on RMs of background sources



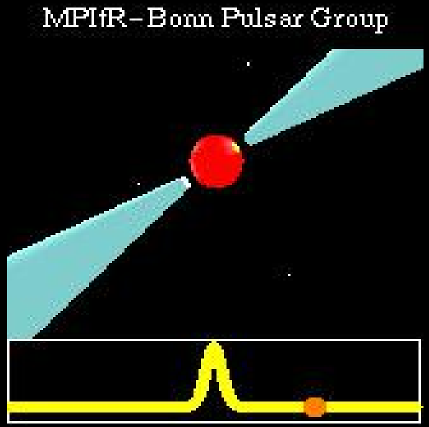
Jansson & Farrar 2012

Pulsars: Best probes for Ne and B-field



Widely spread in the Galaxy !

→ 3-D ne & B-field structure!



Pulsars as best probes for Galactic B-field

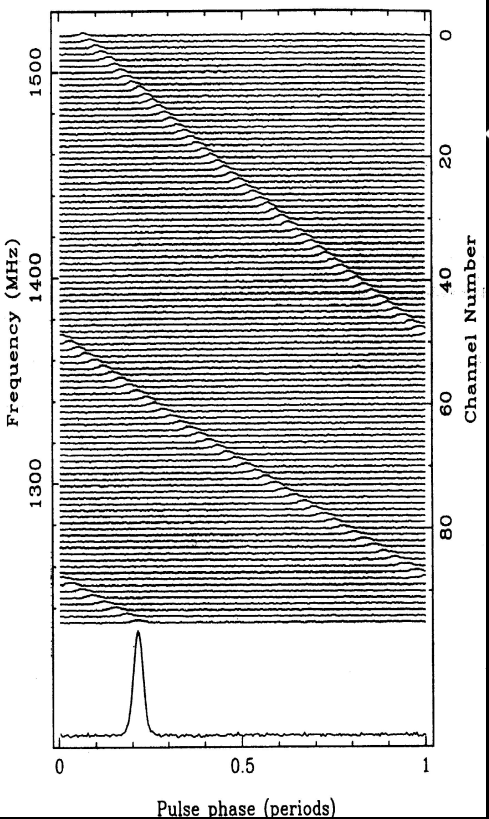
- Polarized + no intrinsic RM: Faraday rotation: RM>0, field toward us

$$RM = \frac{e^3}{2\pi m_e^2 c^4} \int_{PSR}^{Sun} \left[\frac{\lambda(l)}{\lambda_{obs}}\right]^2 n_e(l) \mathbf{B}(l) \bullet d\mathbf{l} = 0.820 \langle B_{\parallel} \rangle \int_0^{Dist} n_e dl$$

- n_e: can be measured:

$$DM = \int_0^{Dist} n_e dl$$

$$RM = \frac{PA_{\lambda 1} - PA_{\lambda 2}}{\lambda_1^2 - \lambda_2^2}$$



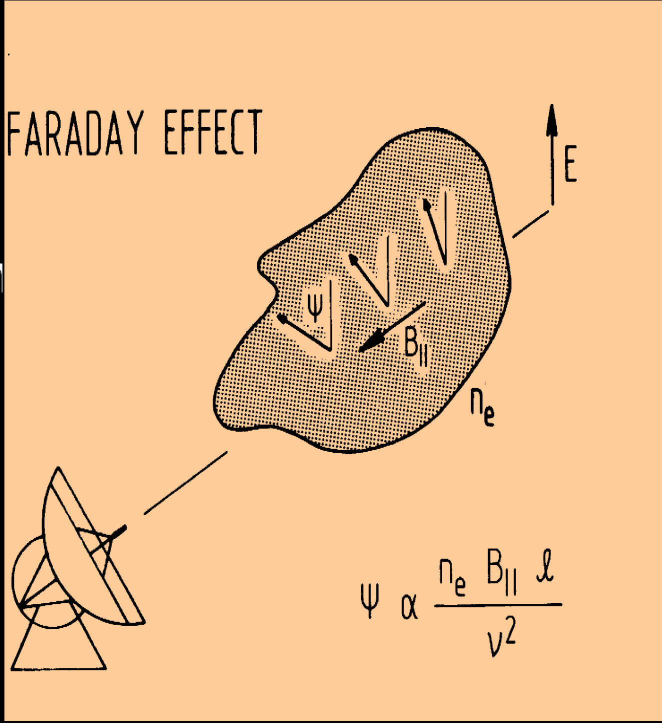
<== the delay tells DM

$$\Delta t = 8.3 \times 10^3 \, DM \frac{\Delta \nu}{\nu_{MHz}^3} \sec$$

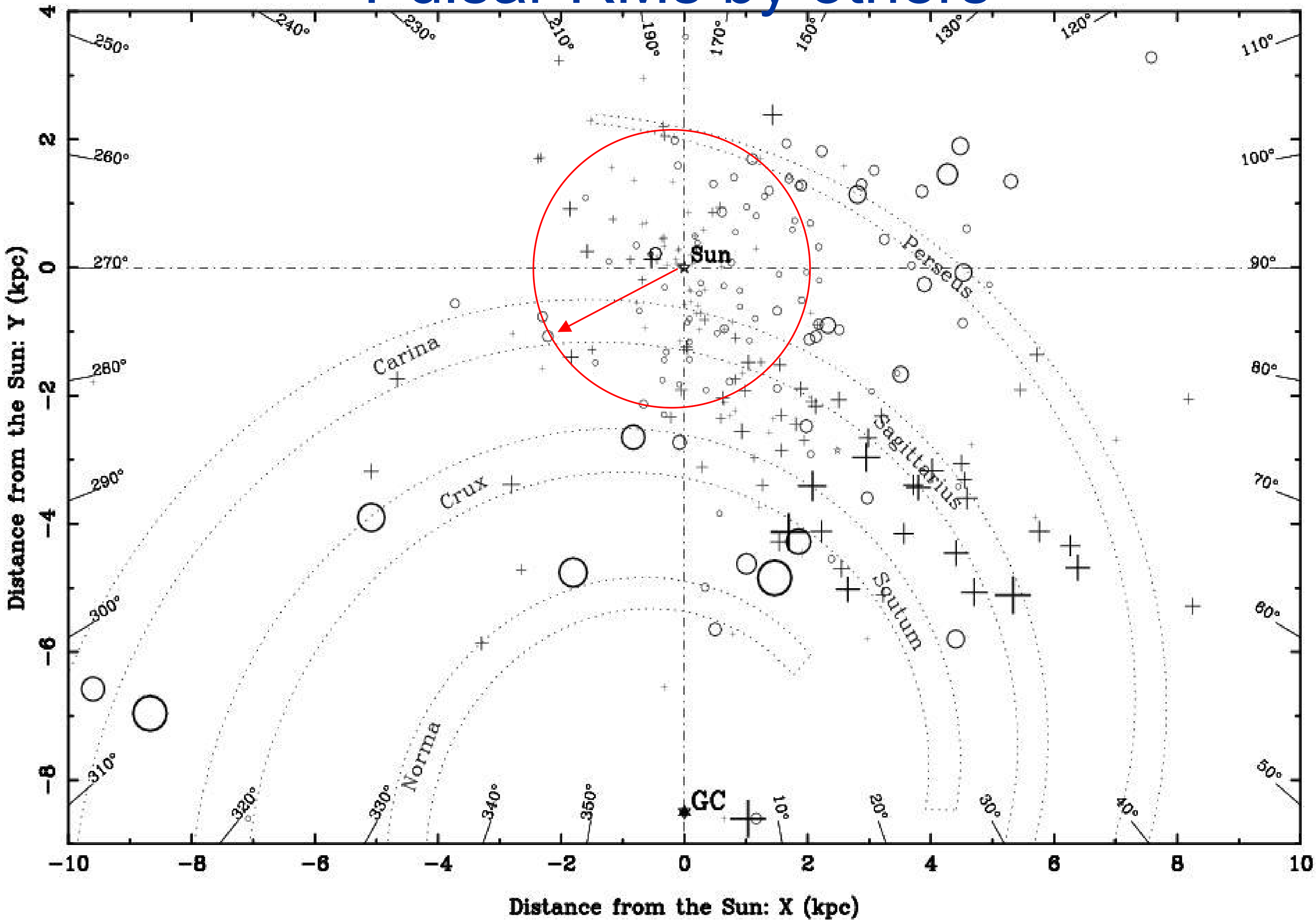
the rotation of position angles tells RM value

Average field strength can be **directly** derived

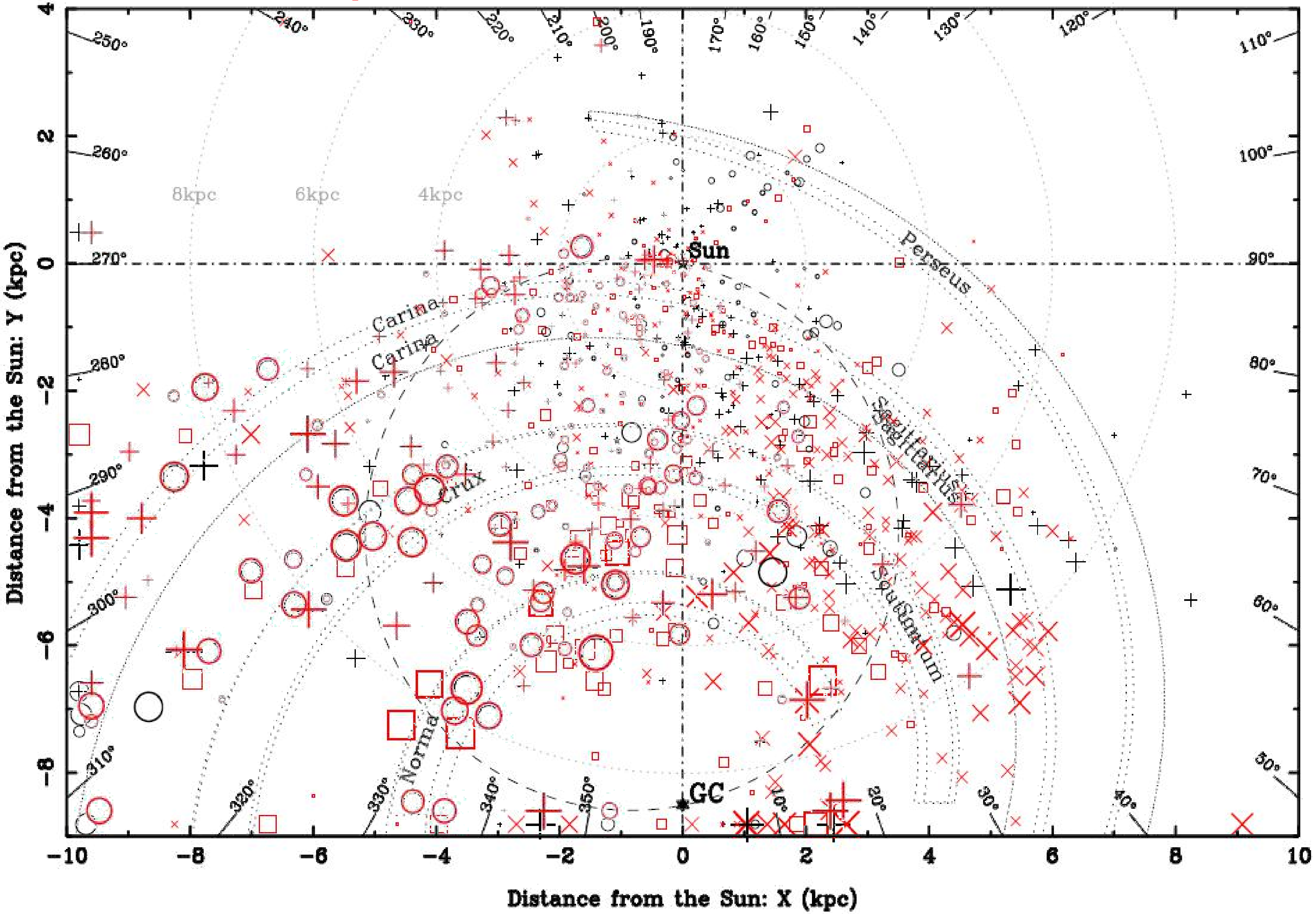
$$\langle B_{||} \rangle = 1.232 \frac{RM}{DM} \mu G$$



Pulsar RMs by others



Our pulsar RM measurements



We got Most of highly valued pulsar RMs

Authors	No. of RMs	No. New RMs
Hamilton & Lyne (1987)	163	119
Rand & Lyne (2004):	27	27
Qiao et al. (1995)	48	33
Van Ommen et al. (1997)	24	2
Han et al. (1999)	63	54
Crawford (2001):	7	7
Mitra et al. (2003):	11	11
Weisberg et al. (2003)	36	17
Han et al. (2006):	223	196
Han et al. (2018):	477	386

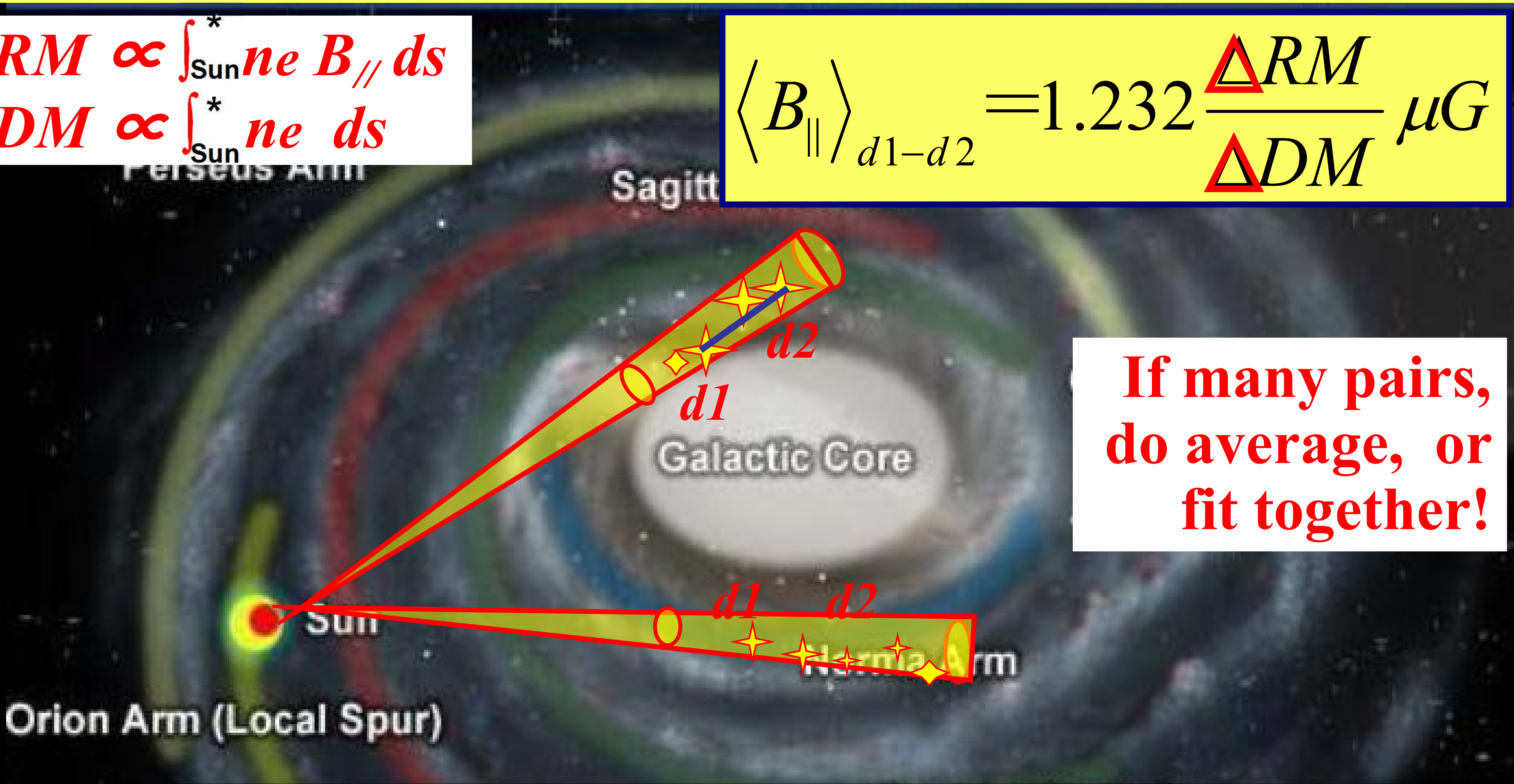
Total No. of pulsar RM published: → *1115*

Paired probes to *measure* B-field in a region

$$RM \propto \int_{Sun}^{*} n_e B_{//}\, ds$$

$$DM \propto \int_{Sun}^{*} n_e\, ds$$

$$\langle B_{\parallel} \rangle_{d1-d2} = 1.232 \frac{\Delta RM}{\Delta DM}\, \mu G$$



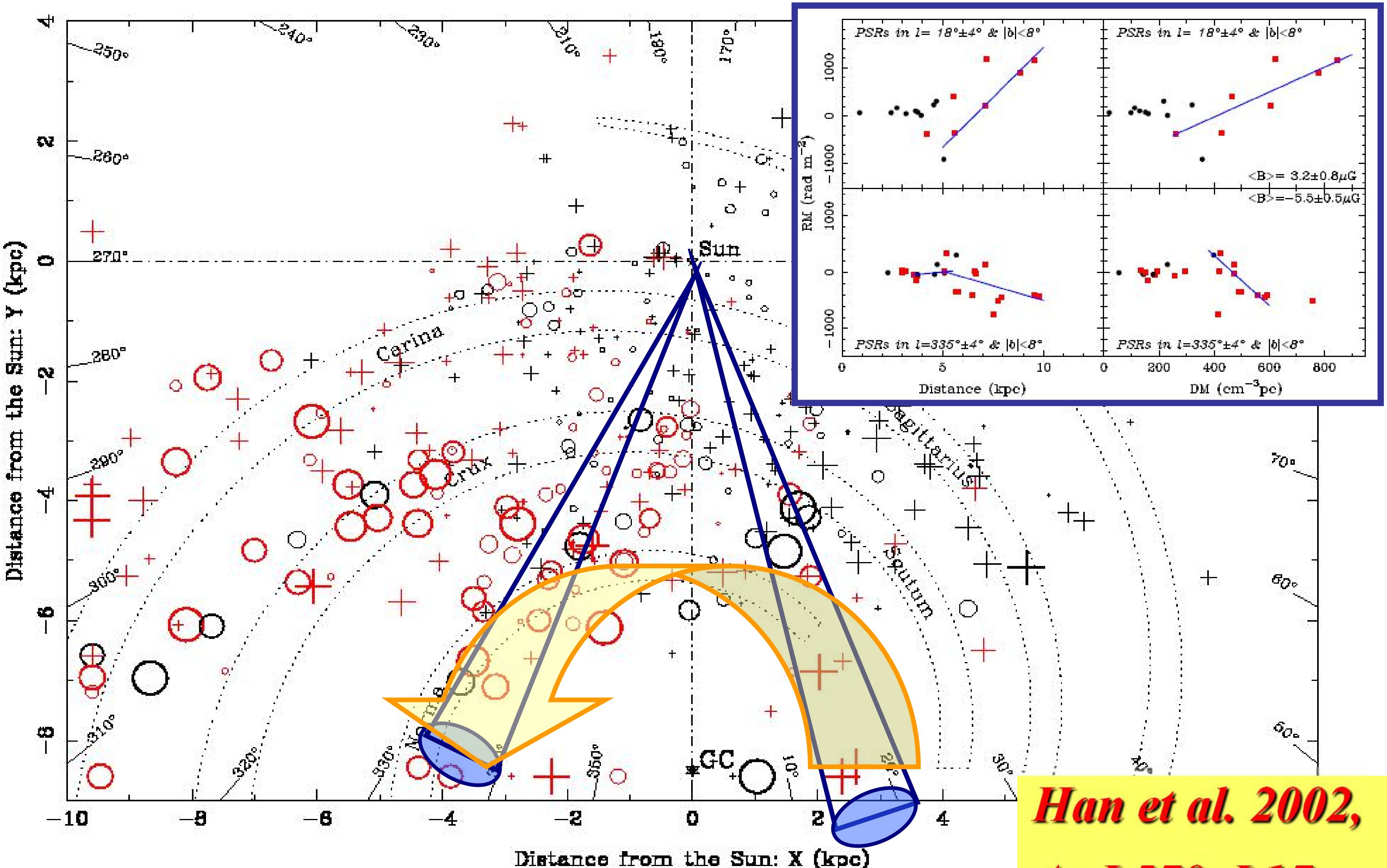
If many pairs, do average, or fit together!

Analysis is not limited to *modeling B all the path*, but can *measure B in the region* between! *Significant improvement!*

No worry about foreground bubbles! Less sensitive on Dist!

Measuring the B-field in the Norma arm

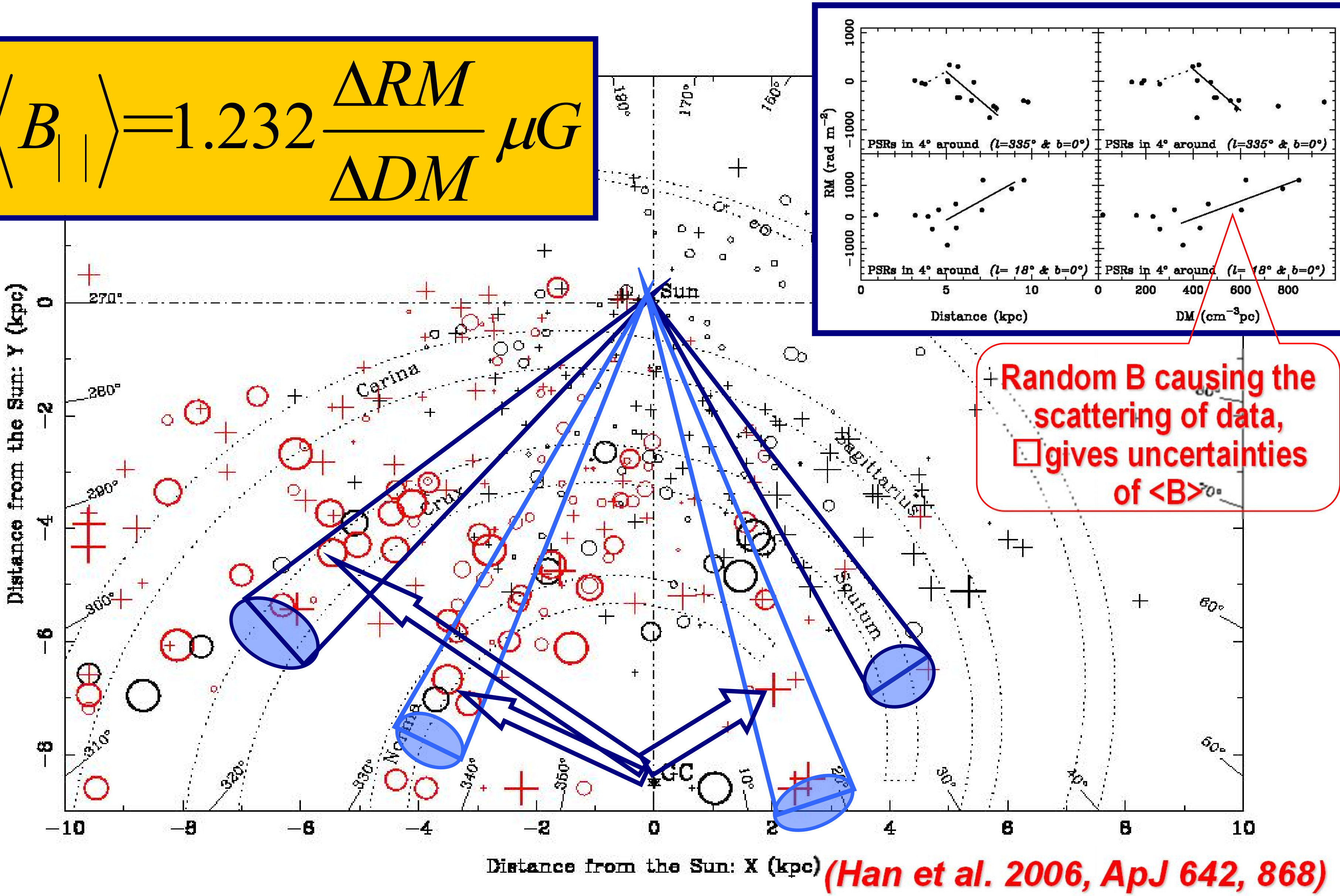
red: new measurements by Parkes 64m telescope



Han et al. 2002, ApJ 570, L17

Measuring B-field in tangential regions!

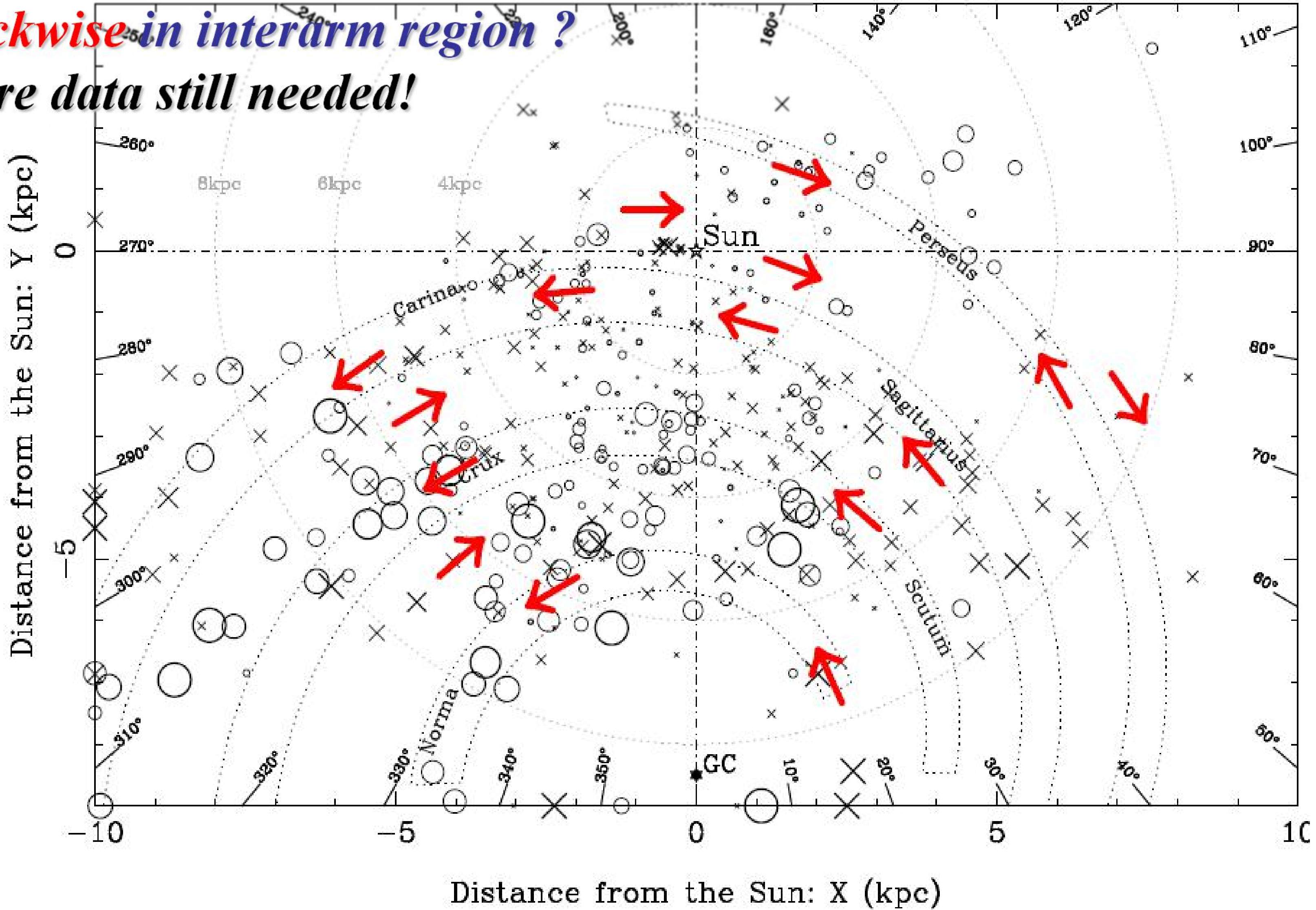
$$\langle B_{||} \rangle = 1.232 \frac{\Delta RM}{\Delta DM} \mu G$$



(Han et al. 2006, ApJ 642, 868)

Measured magnetic field in the Galactic disk by pulsar RM/DM *(Han et al. 2006, ApJ 642, 868)*

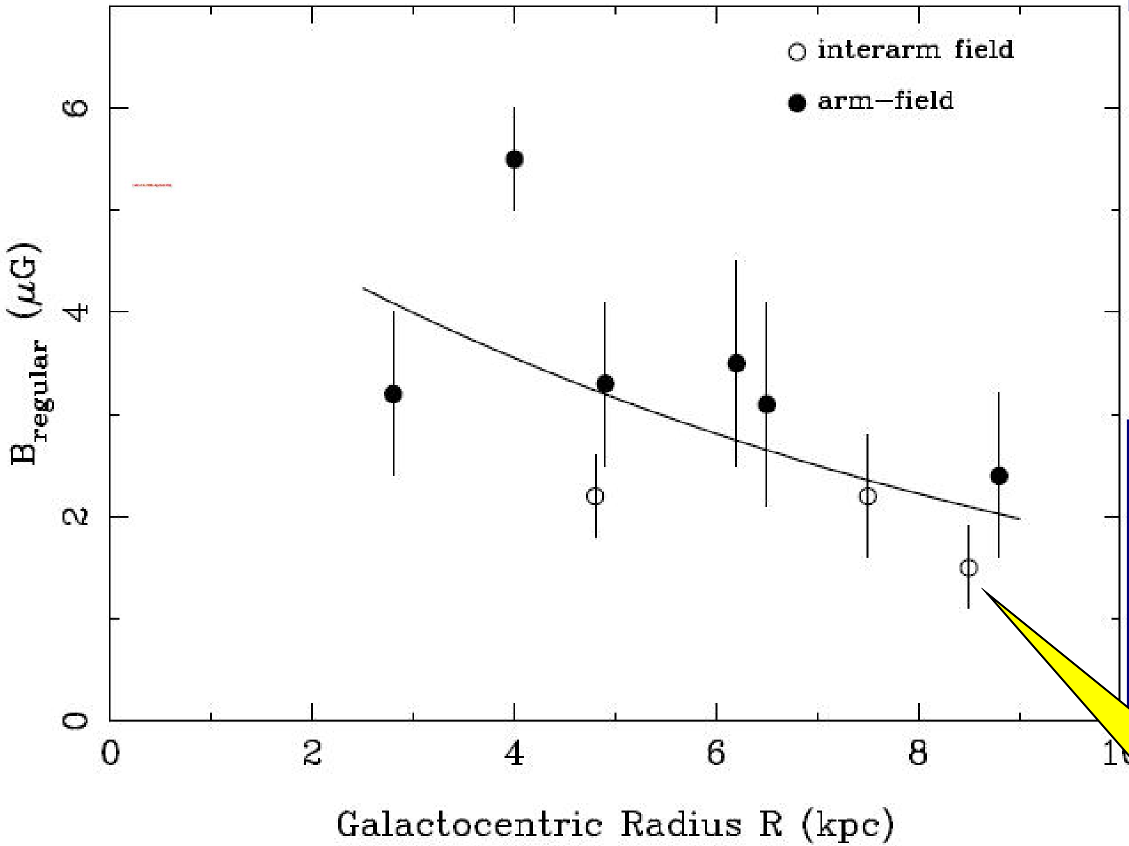
- *always counterclockwise in arm region!*
- *clockwise in interarm region ?*
- ***More data still needed!***

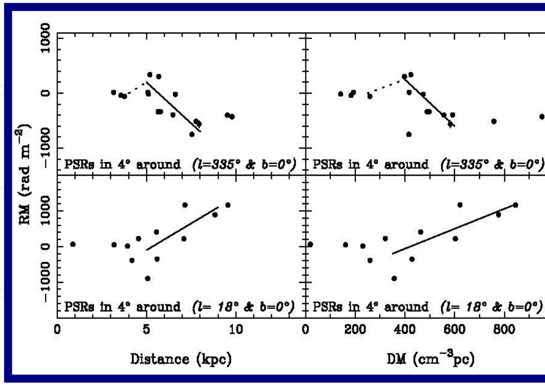


We measured radial dependence of regular field strength

(Han et al. 2006, ApJ 642, 868)

$$\langle B_{||} \rangle = 1.232 \frac{\Delta RM}{\Delta DM} \mu G$$





$$B_{regular}(R) = B_0 \bullet \exp\left[\frac{-(R - R_\oplus)}{R_B}\right]$$

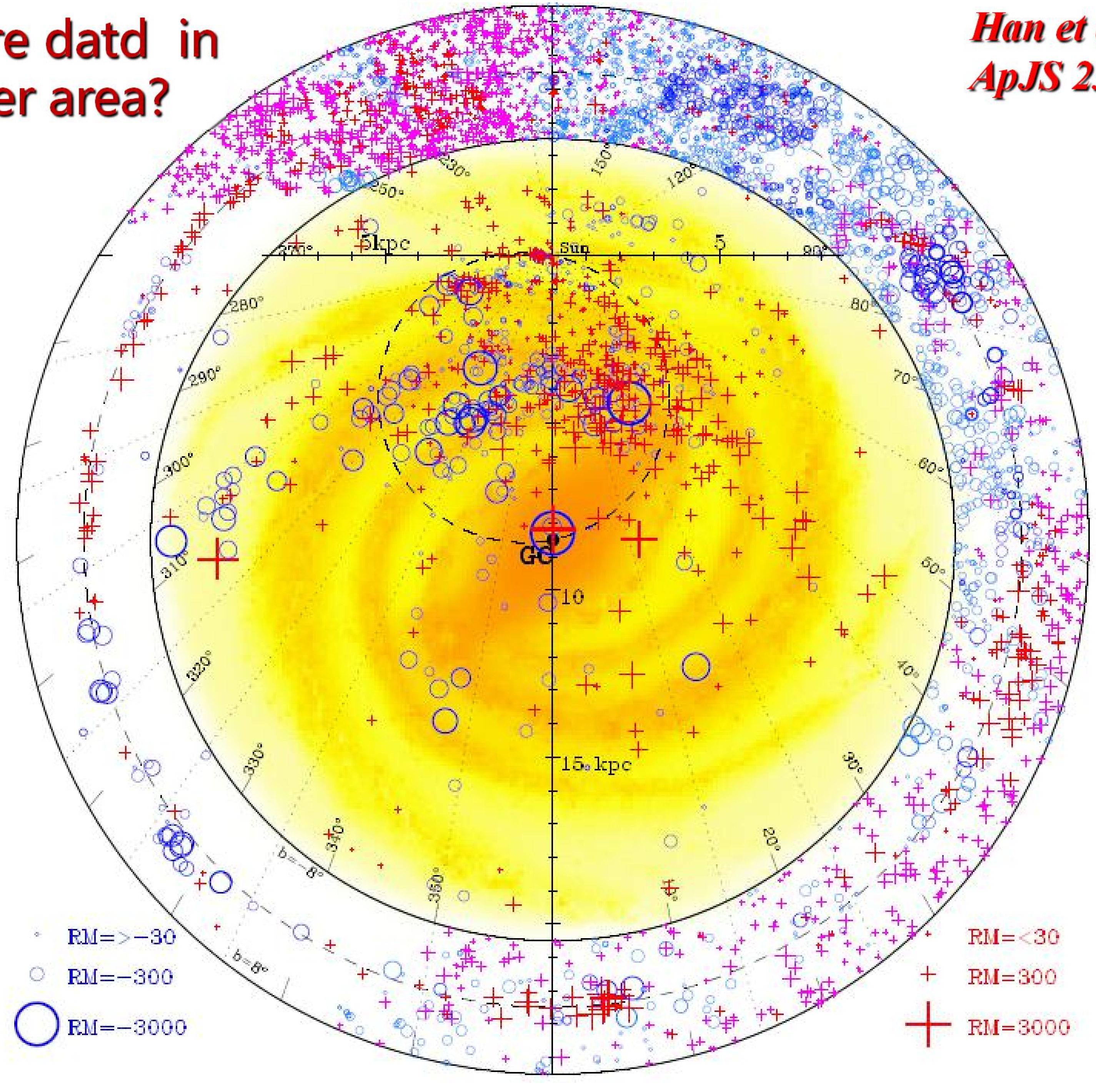
$$B_0 = 2.1 \pm 0.3 \mu G$$

$$R_B = 8.5 \pm 4.7 kpc$$

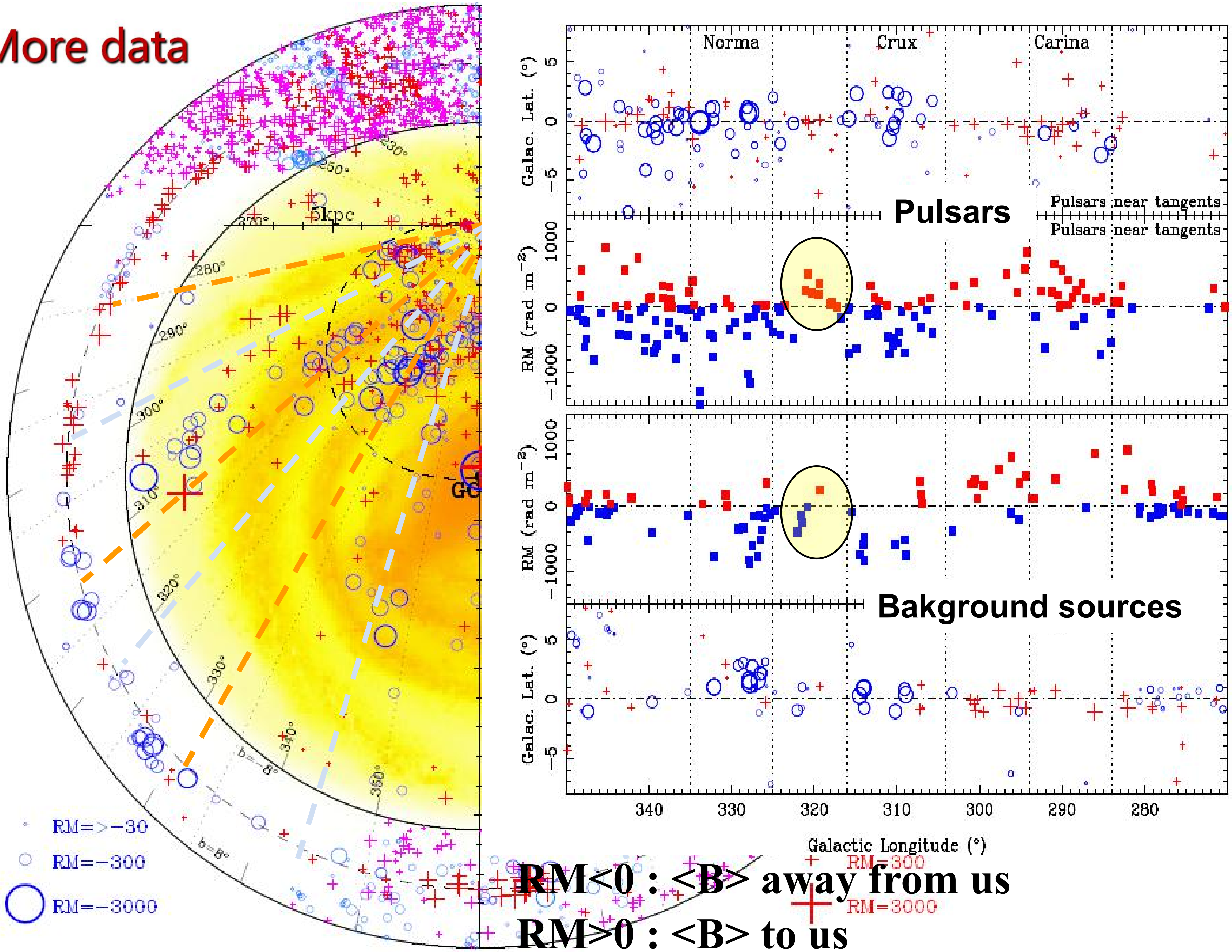
Uncertainties reflect random fields!

More datd in wider area?

Han et al. 2018
ApJS 234, 11



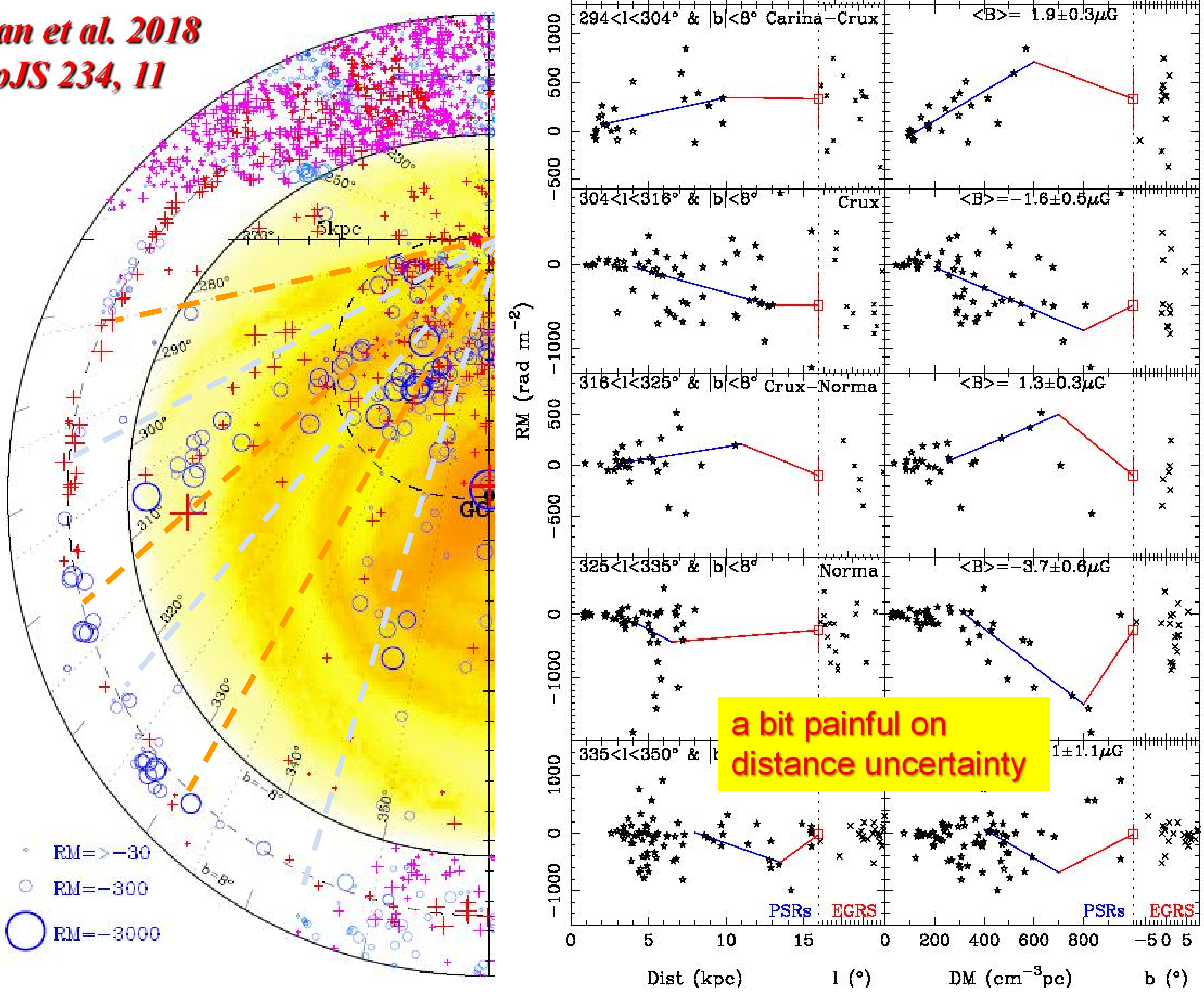
More data



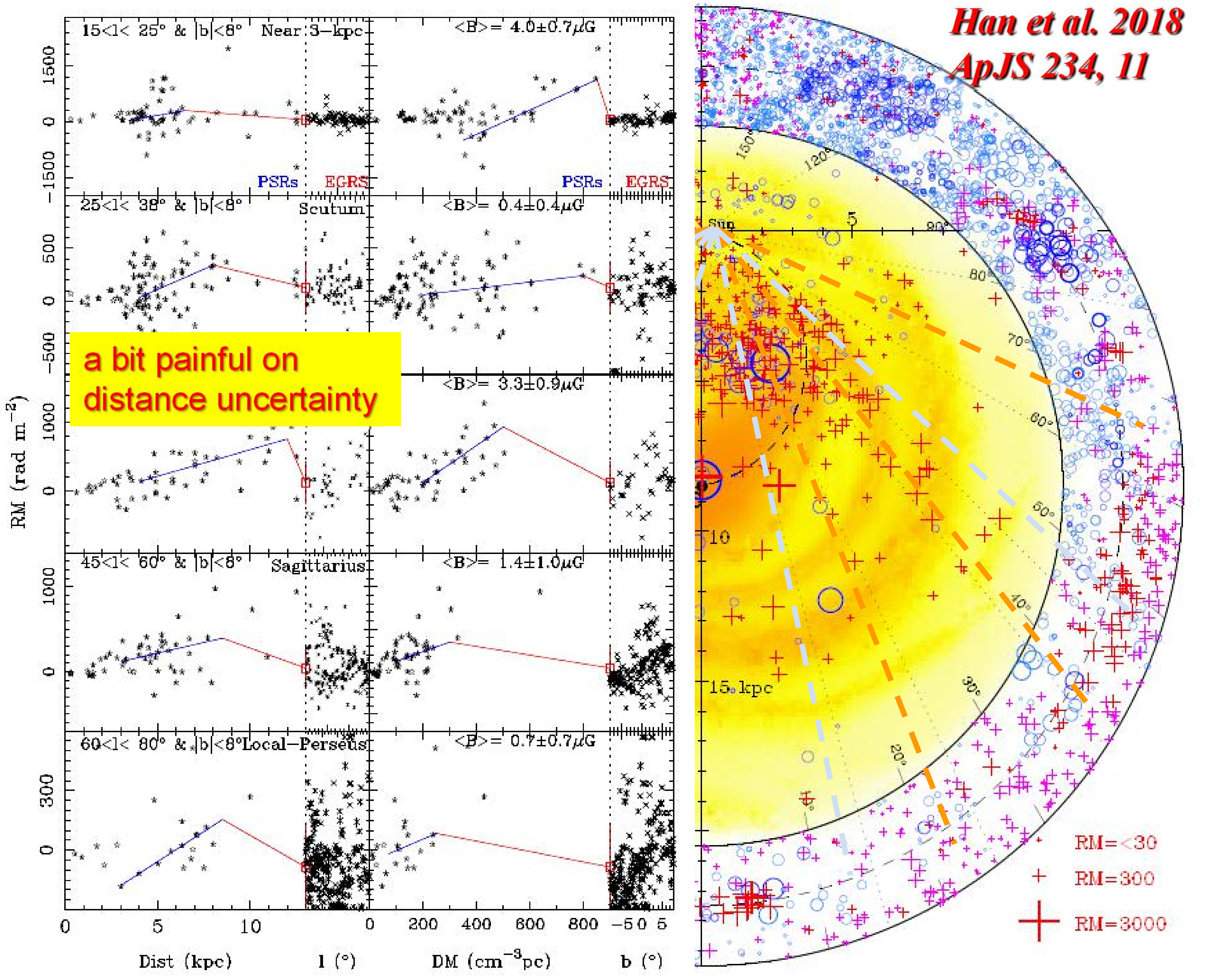
RM<0 : <B> away from us

RM>0 : <B> to us

Han et al. 2018
ApJS 234, 11



a bit painful on distance uncertainty



Han et al. 2018
ApJS 234, 11
a bit painful on
distance uncertainty
15<l< 25° & |b|<8° Near 3-kpc
<B>= 4.0±0.7μG
25<l< 38° & |b|<8° Scutum
<B>= 0.4±0.4μG
<B>= 3.3±0.9μG
45<l< 60° & |b|<8° Sagittarius
<B>= 1.4±1.0μG
60<l< 80° & |b|<8° Local-Perseus
<B>= 0.7±0.7μG
PSRs
EGRS
RM (rad m^{-2})
Dist (kpc)
l (°)
DM (cm^{-3}pc)
b (°)
Sun
15 kpc
RM=<30
RM=300
RM=3000

Han et al. 2018, ApJS, 234, 11

Table 2. Galactic disk zones and their magnetic fields

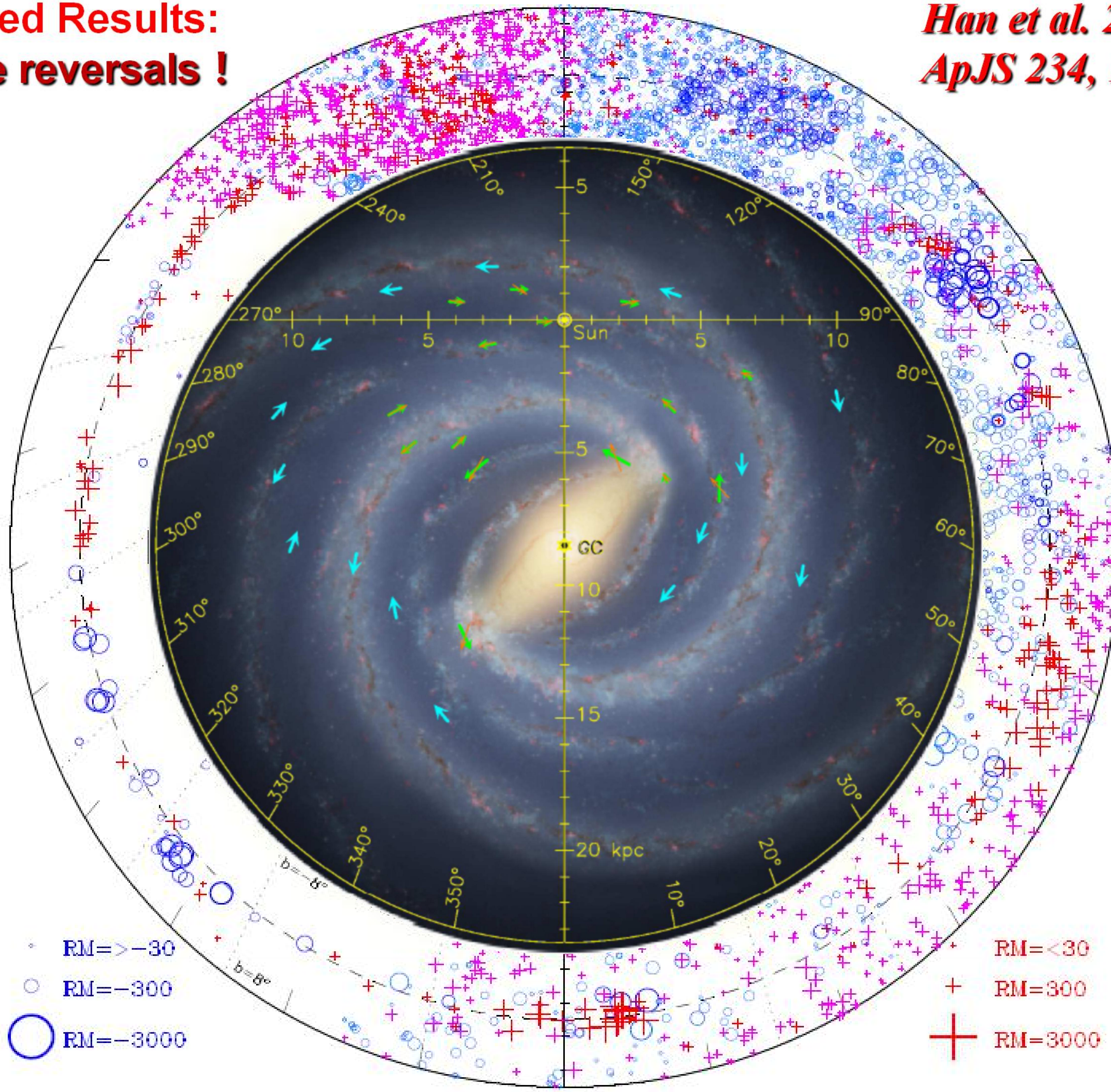
Region	l–Range (°)	D–Range (kpc)	DM–Range (cm^{-3} pc)	No. PSRs or EGRS	$B_{\|\|}$ (μG)	B-field Direction	Arrow l (°)	Arrow D (kpc)
Quadrant 1								
Near 3-kpc	15 – 25	3.5 – 6.5	350 – 850	25	$+4.0 \pm 0.7$	ccw	20	5.5
Near 3-kpc – EGRS	15 – 25	6.5 – E	850 – E	71		cw	20	11.0
Scutum	25 – 38	4.0 – 8.0	200 – 800	46	$+0.4 \pm 0.4$	ccw	32	7.0
Scutum – EGRS	25 – 38	9.5 – E	900 – E	78		–	– –	– –
Scutum – Sgr	38 – 45	4.0 – 12.0	200 – 500	25	$+3.3 \pm 0.9$	ccw	42	8.5
Scutum-Sgr – EGRS	38 – 45	12.0 – E	500 – E	37		cw	42	13.0
Sagittarius	45 – 60	3.0 – 8.5	100 – 300	30	$+1.4 \pm 1.0$	ccw	50	5.0
Sagittarius – EGRS	45 – 60	8.5 – E	300 – E	176		cw	50	8.5
Local – Perseus	60 – 80	3.5 – 8.0	70 – 250	14	$+0.7 \pm 0.7$	ccw	73	7.0
Local–Perseus – EGRS	60 – 80	8.0 – E	250 – E	225		cw	73	10.5
Local Q1-Q2	80 – 120	1.0 – 5.0	10 – 200	18	-1.4 ± 0.6	cw	105	2.5
Local Q1-Q2 – EGRS	80 – 120	5.0 – E	200 – E	576		ccw	105	4.0
Outer Q2	120 – 190	–	–			–	– –	– –
Outer Q3	190 – 250	0.0 – 3.5	0 – 130	13	$+1.3 \pm 0.4$	cw	235	2
Outer Q3 – EGRS	190 – 250	3.5 – E	130 – E	841		ccw	230	3.5
Local Q3-Q4	250 – 270	0.0 – 6.0	30 – 280	20	$+1.1 \pm 0.5$	cw	260	4.0
Local Q3-Q4 – EGRS	250 – 270	6.0 – E	280 – E	138		ccw	260	6.5
Outer Carina	270 – 282	0.1 – 1.1	50 – 250	23	$+0.8 \pm 0.5$	cw	276	0.7
Outer Carina – EGRS	270 – 282	–	250 – E	26		ccw	276	9.0
Quadrant 4								
Carina	282 – 294	2.0 – 4.0	250 – 550	22	-1.2 ± 1.0	ccw	288	3.0
Carina – EGRS	282 – 294	4.0 – E	550 – E	8		cw	288	11.0
Carina – Crux	294 – 304	2.0 – 10.0	100 – 600	21	$+1.9 \pm 0.3$	cw	299	7.0
Carina–Crux – EGRS	294 – 304	10.0 – E	600 – E	13		ccw	299	12.0
Crux	304 – 316	4.0 – 13.0	200 – 800	38	-1.6 ± 0.5	ccw	310	7.5
Crux – EGRS	304 – 316	13.0 – E	800 – E	13		cw	310	13.0
Crux – Norma	316 – 325	3.0 – 11.0	250 – 700	9	$+1.3 \pm 0.3$	cw	320	6.0
Crux-Norma – EGRS	316 – 325	11.0 – E	700 – E	6		ccw	320	12.0
Norma	325 – 335	4.0 – 6.5	300 – 800	15	-3.7 ± 0.6	ccw	330	6.5
Norma – EGRS	325 – 335	10.0 – E	900 – E	20		cw	330	12.5
Far 3-kpc	335 – 350	8.0 – 13.5	400 – 700	23	-3.1 ± 1.1	ccw	343	12.5
Far 3-kpc – EGRS	335 – 350	13.5 – E	700 – E	23		cw	343	15.5

Most updated Results:

Large-scale reversals !

Han et al. 2018

ApJS 234, 11



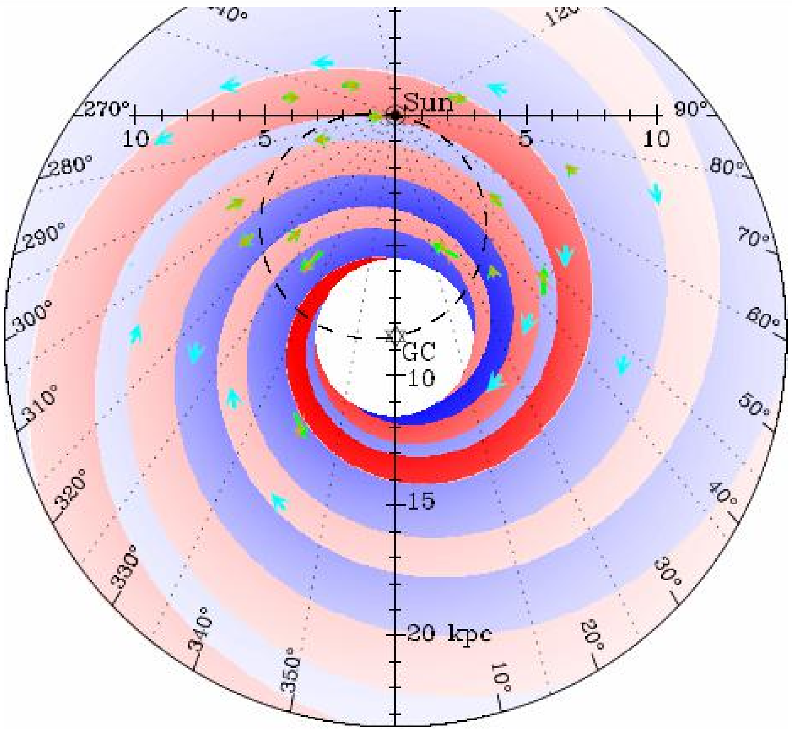
The global magnetic field model in the Galactic disk

Our model for the Galactic disk field assumes logarithmic spiral fields of pitch angle $\psi = 11^\circ$ (Hou & Han 2014) with a radial and z dependence given by

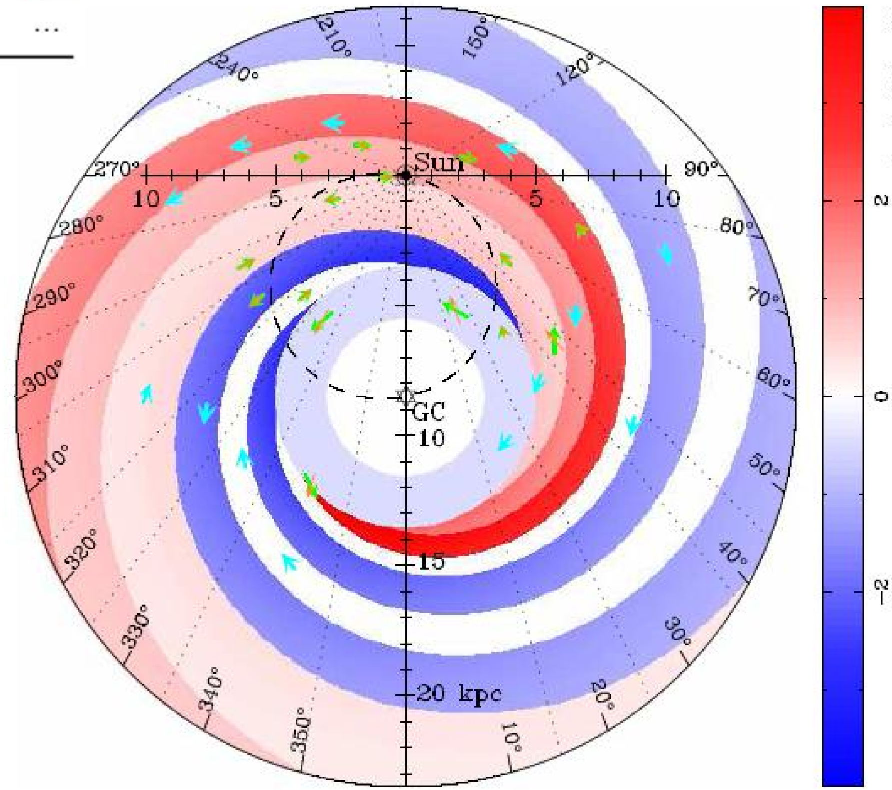
$$B(R, z) = B_0 \exp(-R_G/A)\exp(-|z|/H), \qquad (3)$$

Table 5
Radial Zones for the Model Spiral Disk Field

Index i	1	2	3	4	5	6	7
$R_s(i)$ (kpc)	3.0	4.1	4.9	6.1	7.5	8.5	10.5
$B_s(i)$ (μG)	4.5	−3.0	6.3	−4.7	3.3	−8.7	…



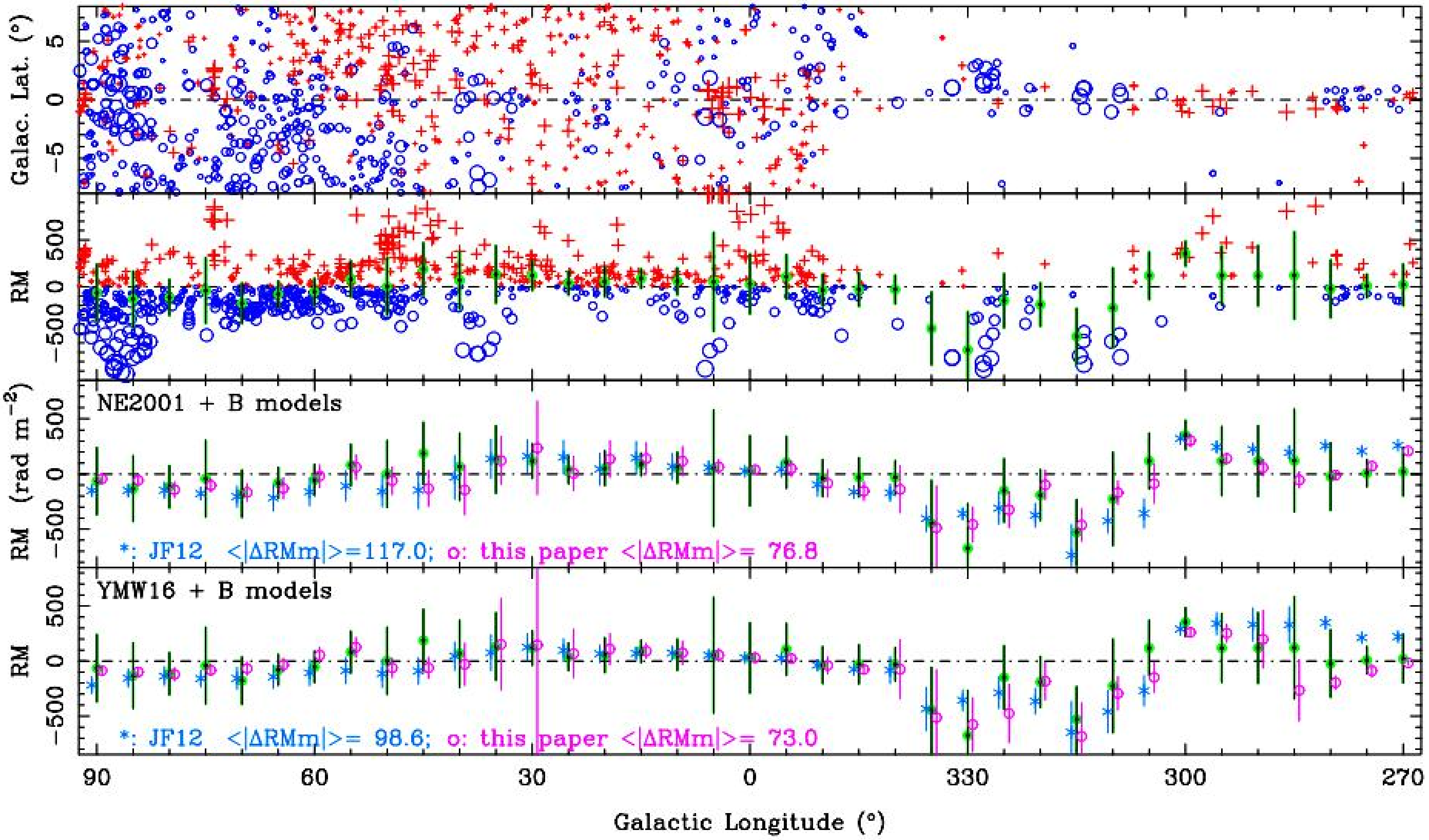
Based on RMs of pulsars and background sources



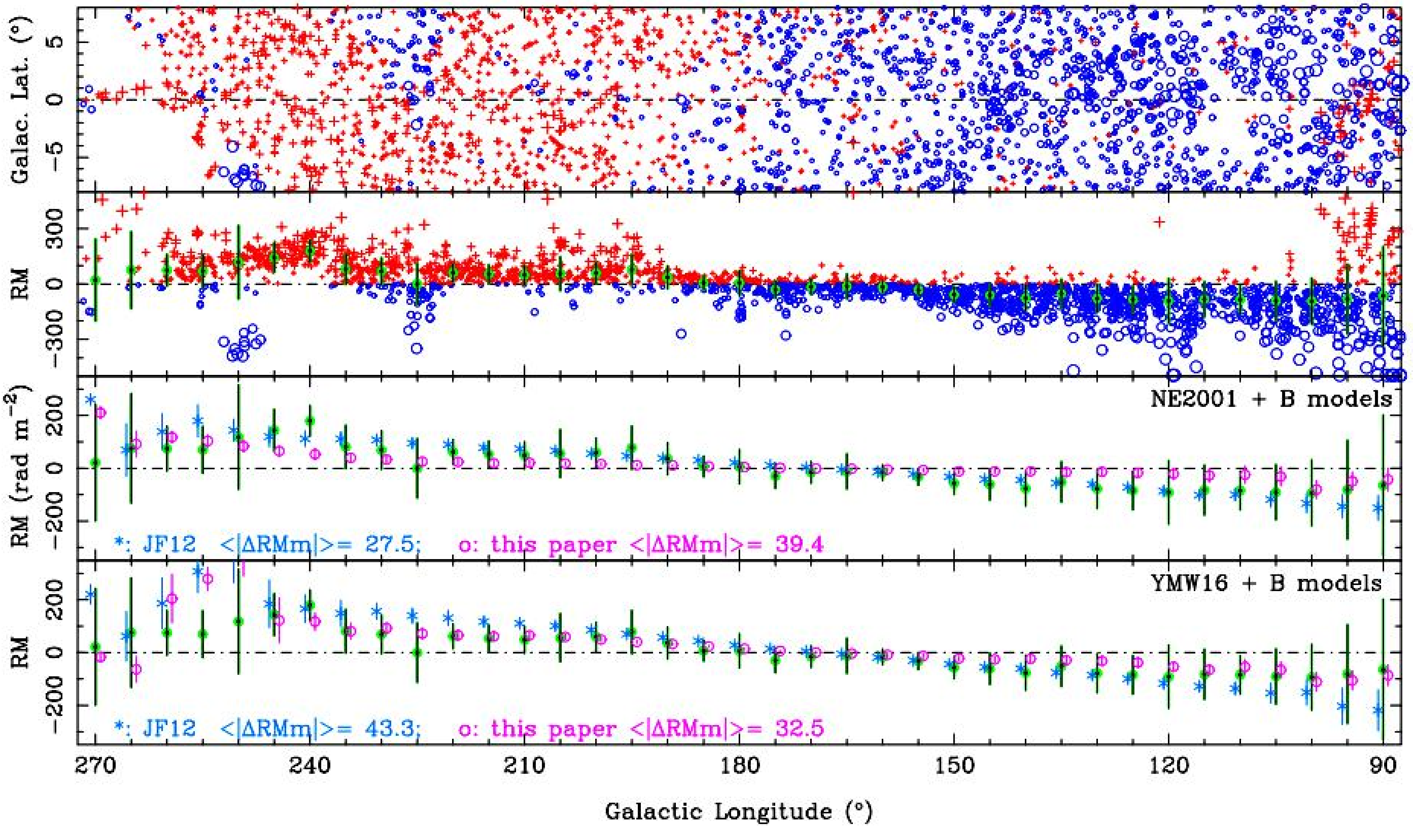
Based on RMs of background sources

Han et al. 2018 ApJS 234, 11

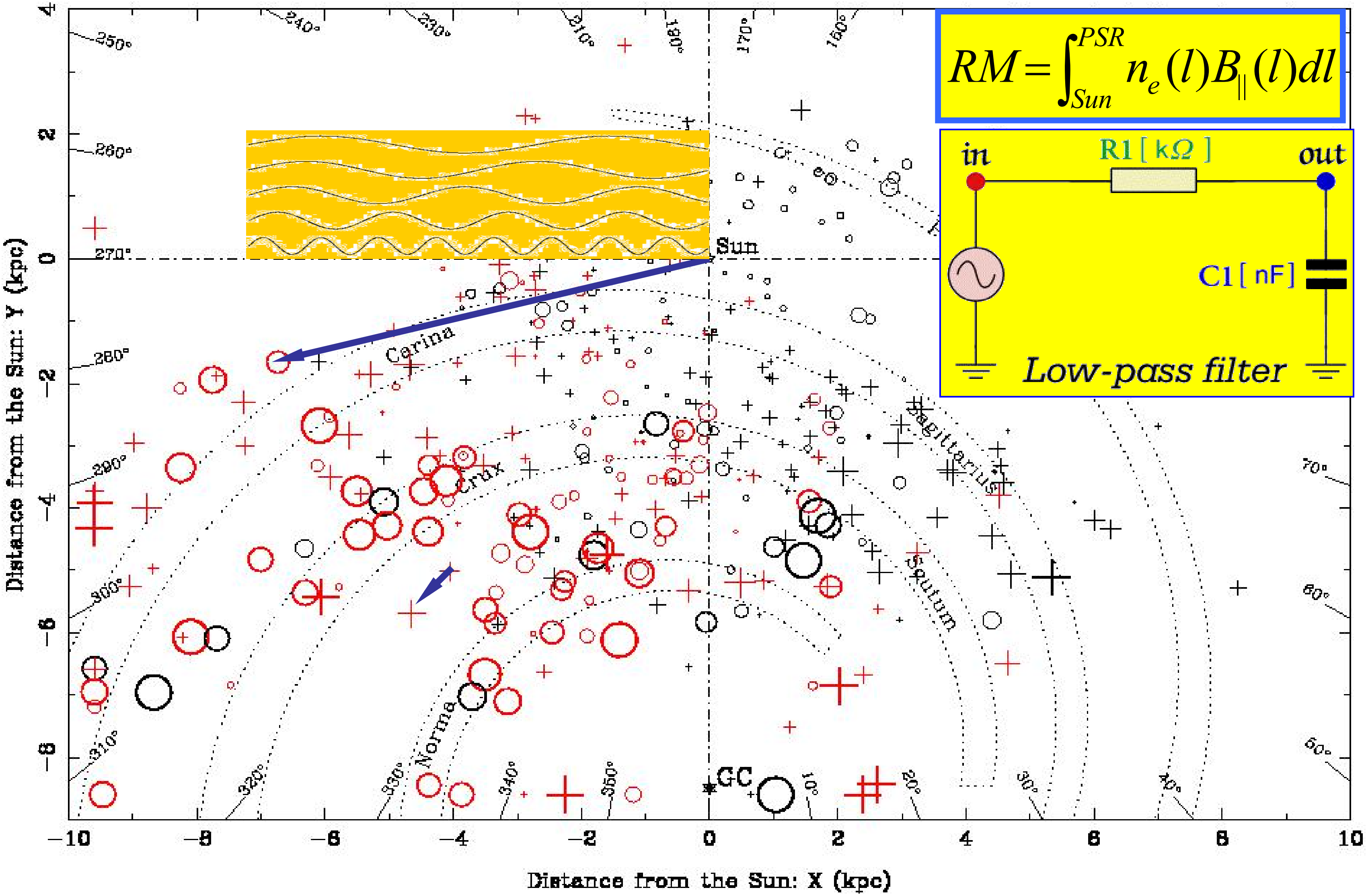
Comparison of two magnetic field models in the Galactic disk



Comparison of two magnetic field models in the Galactic disk



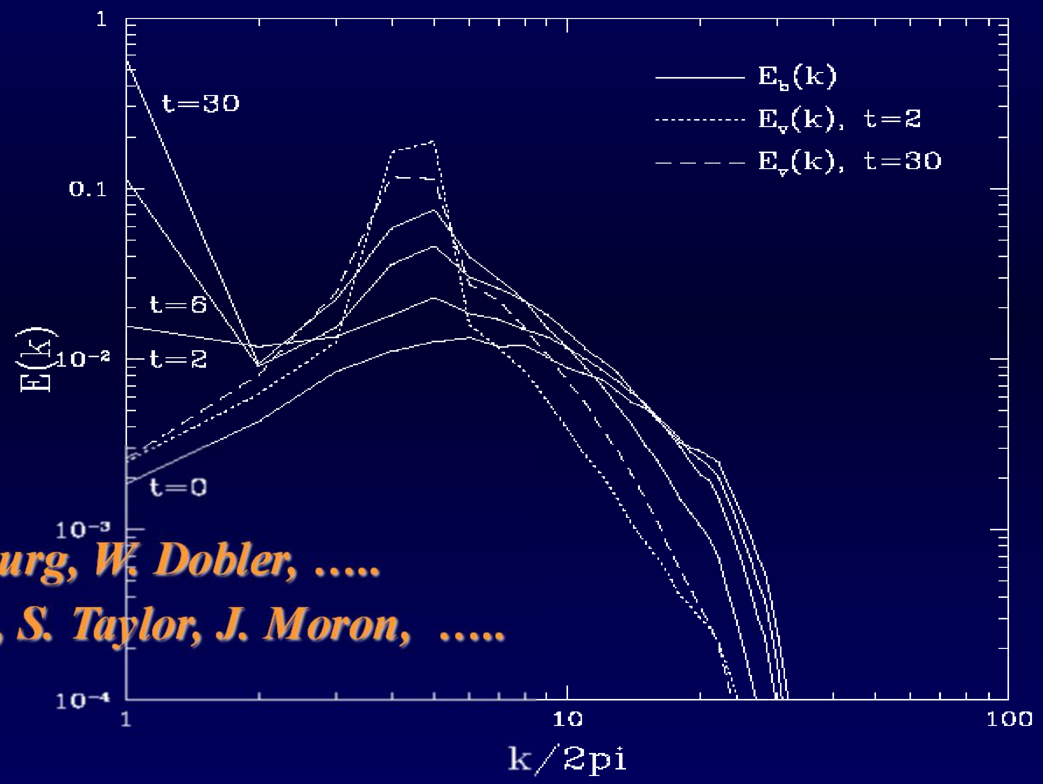
Measuring the *B-field fluctuation* vs *scales*
by using pulsar RMs and DMs



Many Simulations of dynamos

---- check spatial B-energy spectrum & its evolution

e.g. Magnetic energy distribution on different spatial scales (k=1/λ)



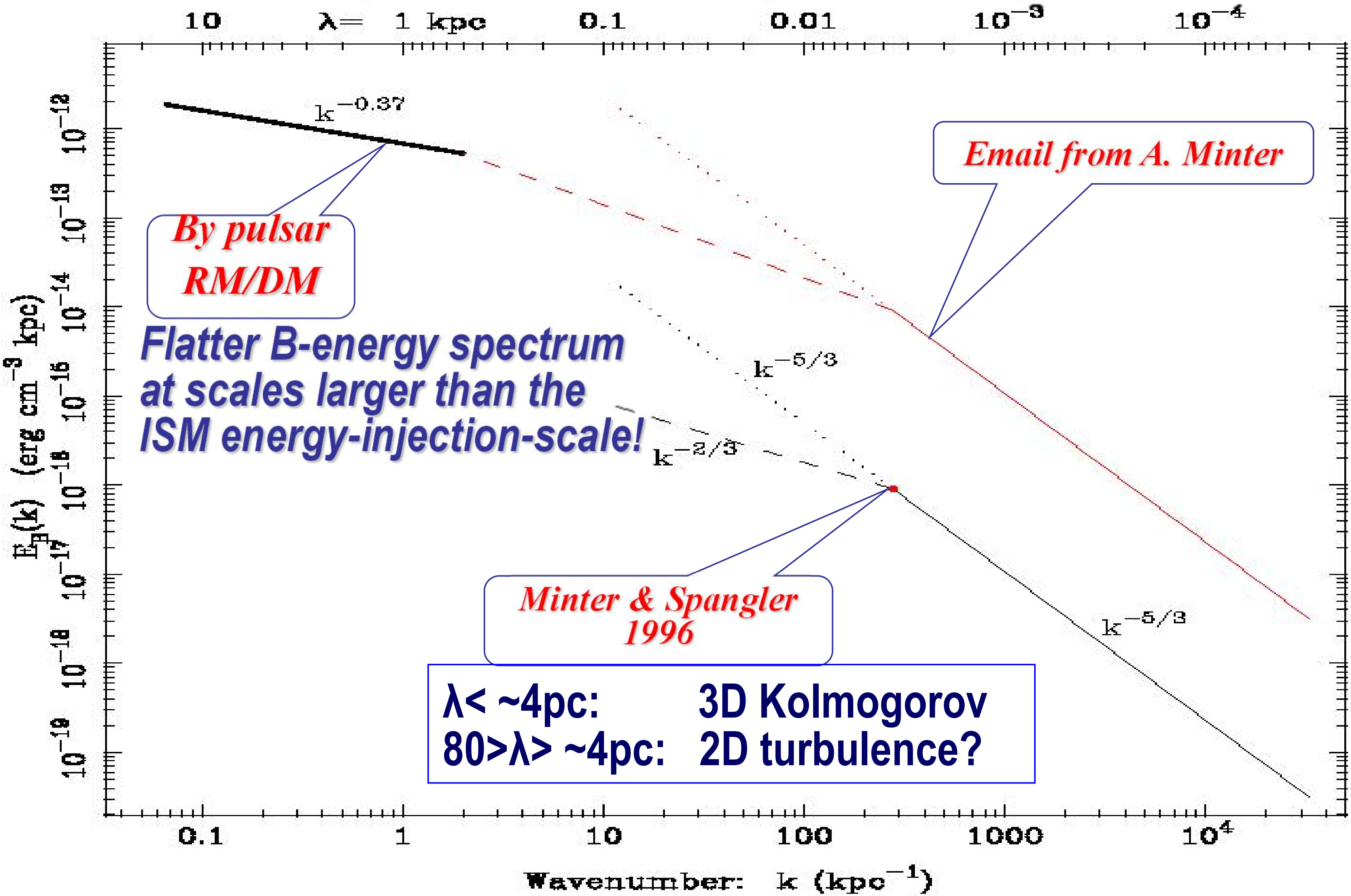
Many papers by

- *N.E. L. Haugen, A. Brandenburg, W. Dobler, …..*
- *A. Schekochihin, S.C. Cowley, S. Taylor, J. Moron, …..*
- *E. Blackman, J. Maron …..*
- *Others …..*

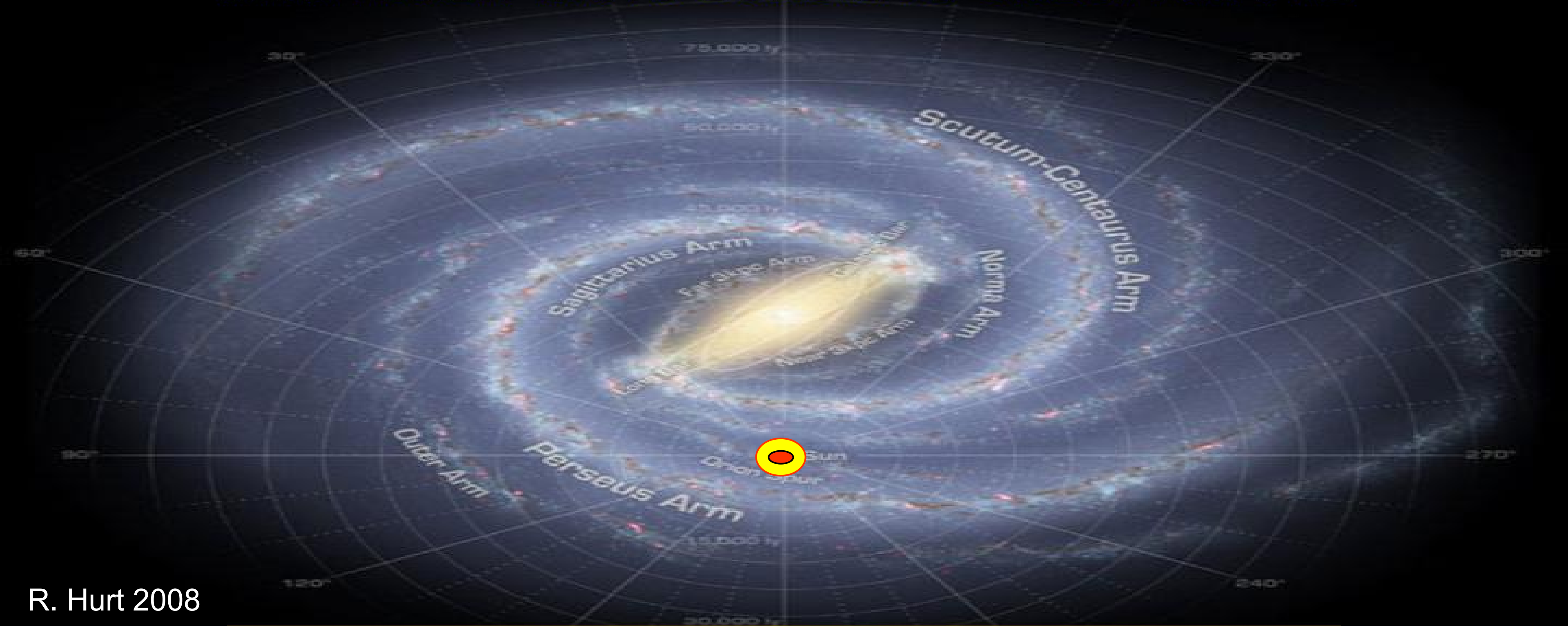
No measurements of the B-energy spectrum !

Spatial magnetic energy spectrum of our Galaxy

(Han et al. 2004, ApJ 610, 820)



The Galactic distribution of Zeeman data
with much more sensitive observations



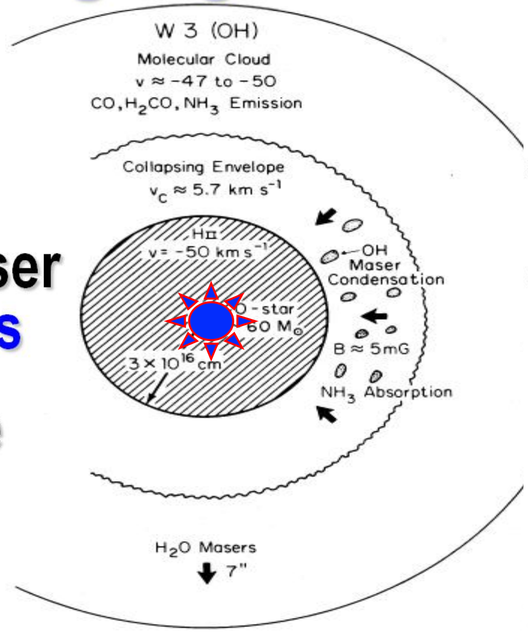
R. Hurt 2008

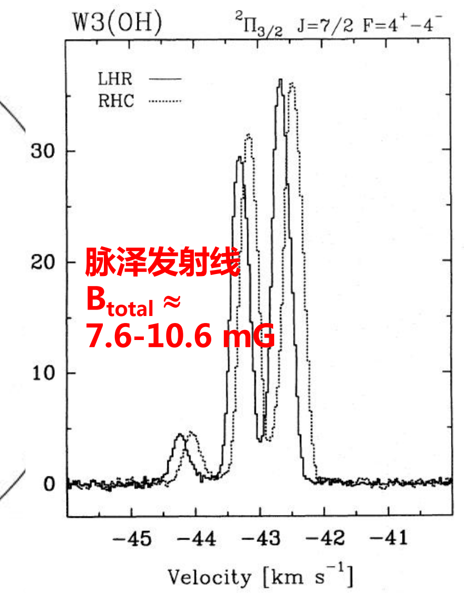
To trace the B-fields with spiral arms?

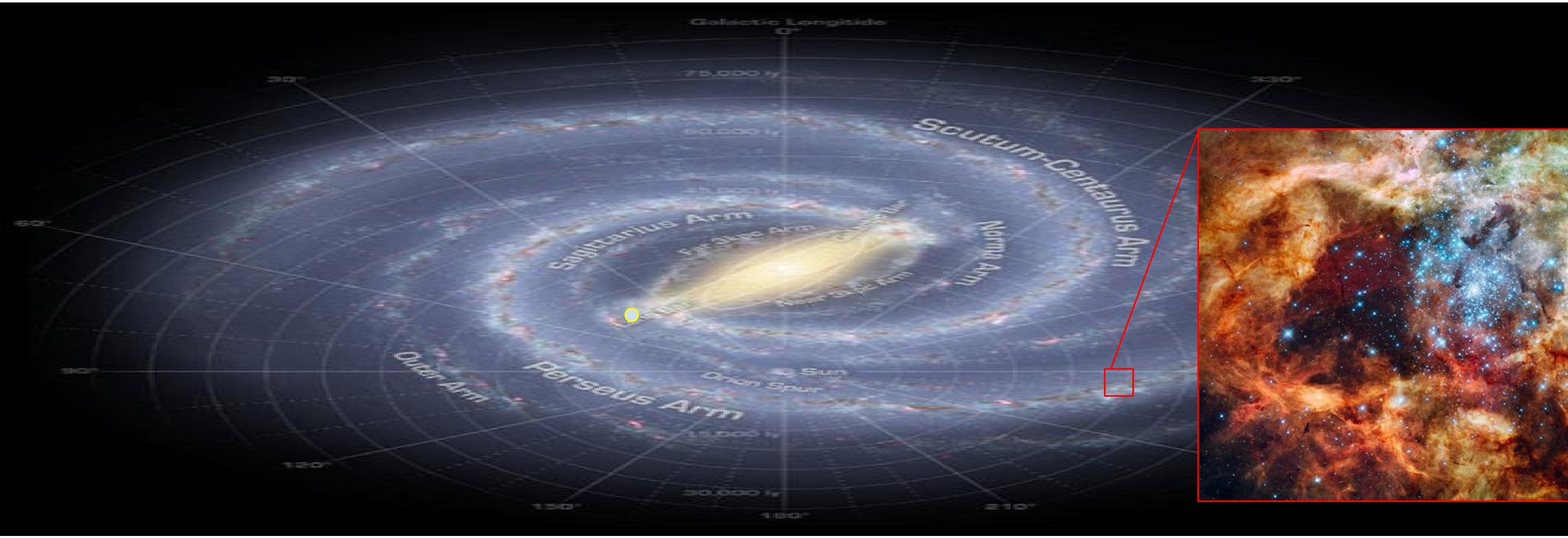
Maser spots in the star-forming region as B-field tracers

Han & Zhang (2007, A&A 464, 609)

- Collect Zeeman splitting data of maser spots in HII and star formation regions
- Spots in one region always have the same field orientation!







B-field from maser spots

Han & Zhang (2007, A&A 464, 609)

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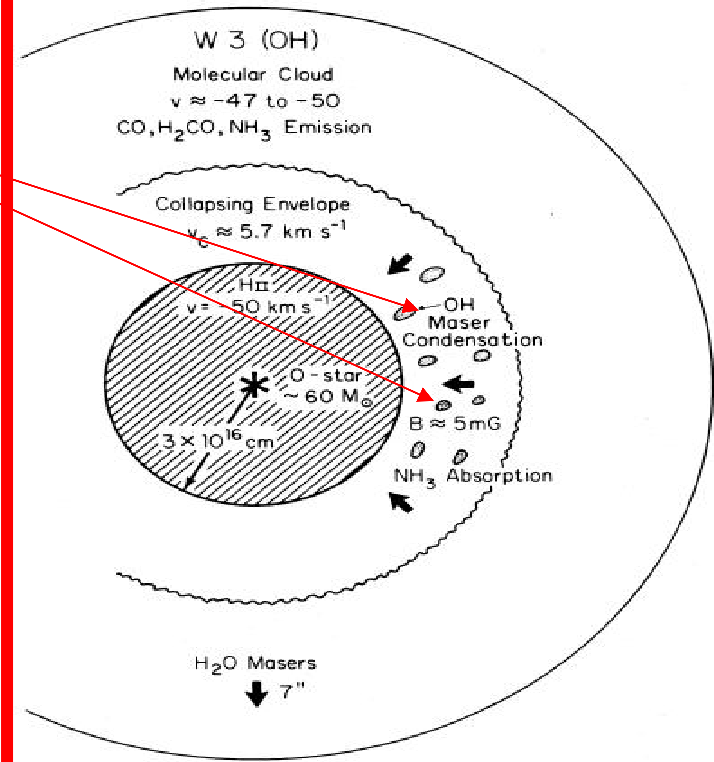
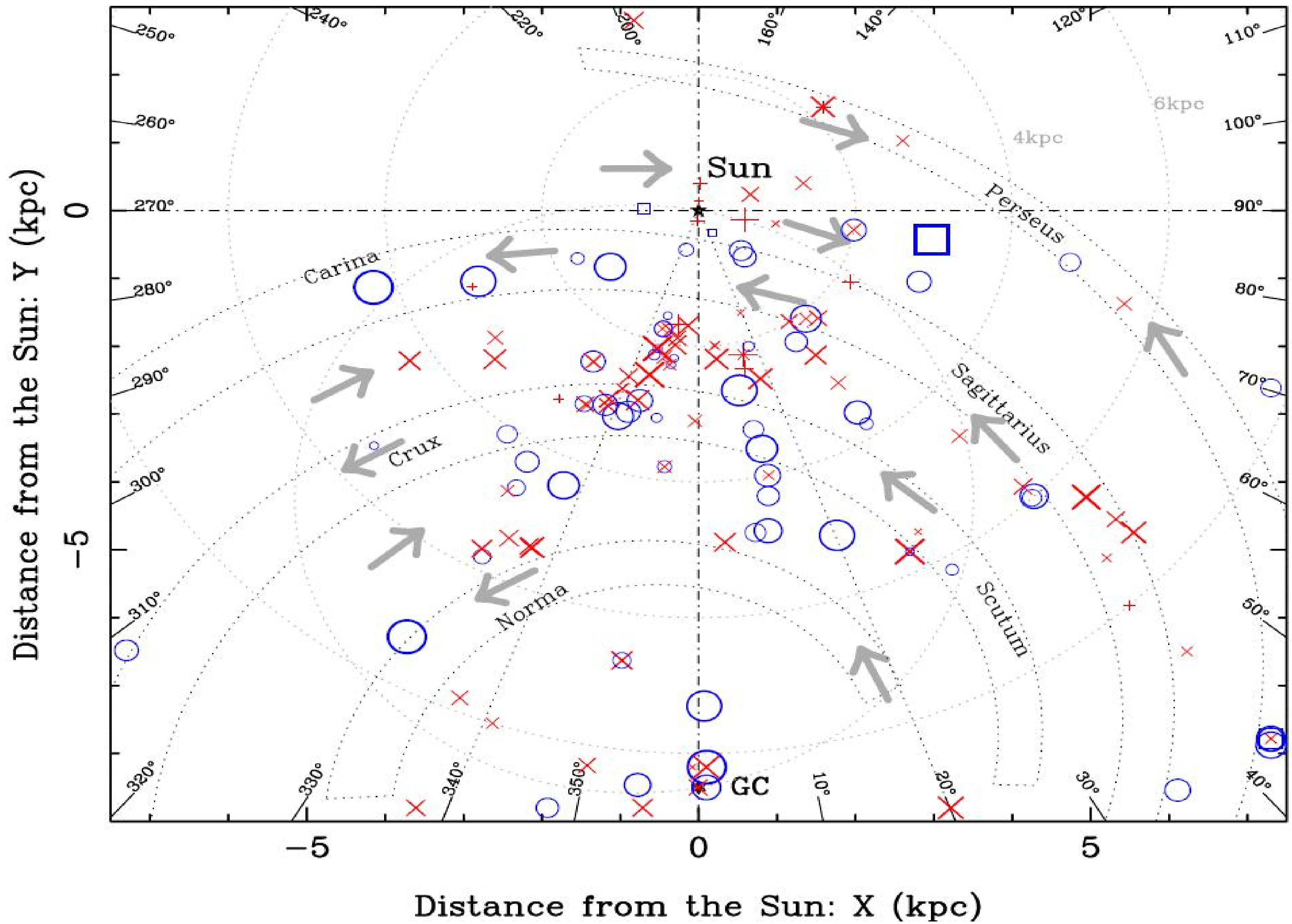


Source (GL+GB)	Alias name	Dist (kpc)	Freq (MHz)	B_l (mG)	B_m (mG)	B_u (mG)	Obs. telescope	Ref.
...	W3(OH)	2.2	13441	5.6	10.2	11.3	VLBA	bd98
...	W3 OH	2.2	6035	7.1	8.0	8.7	Eff	bdwc97
...	...	2.2	6031	3.3	4.7	8.1	Eff	bdwc97
...	...	2.2	13441	6.9	8.2	11.3	GBT	frm05
...	...	2.2	13434		10.3		GBT	frm05
G196.454−1.677	S269	3.8	1665	−4.2	*	−4.0	VLBA	fraz05
...	...	3.8	1665		−4.5		VLBA	fraz05
G208.994−19.38	Orion	0.5	1665		*	−2.5	VLBI	hmr+77
G213.706−12.606	Mon R2	0.9	1665	−2.6	−2.4*	−2.2	VLBA	fraz05
...	...	0.9	1667	−2.5	−2.5	−2.2	VLBA	fraz05
...	...	0.9	1665		−3.4		VLA-A	fram03
G285.263−0.050	...	4.3	6035		10.0		PKS	cv95

The Galactic distribution of Zeeman data

In situ AU-scale-B directions coherent in many kpc scale!



Blue:

Counterclockwise B

Red:

Clockwise B

Han & Zhang 2007, A&A 464, 609

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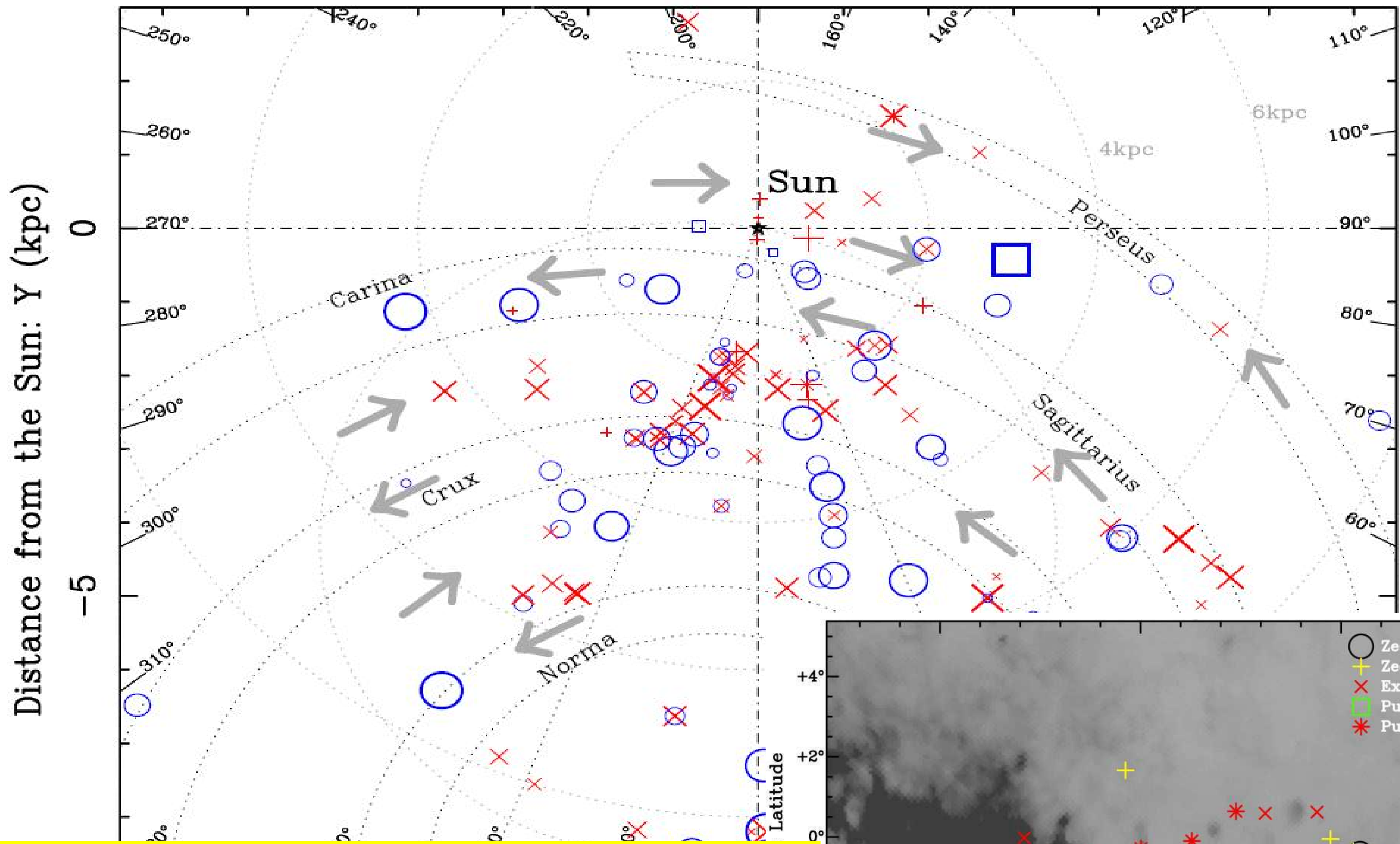

Blue: Counterclockwise B

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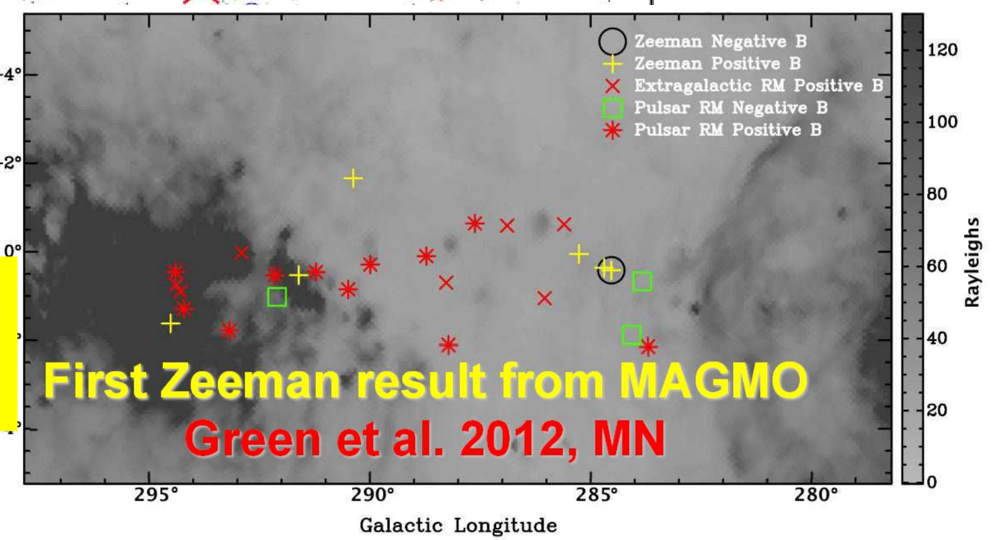

Maser B obs are complementary to PSRs for large scale B structures

Han & Zhang 2007, A&A 464, 609

The most updated results of Magnetic fields in our Milky Way

- **Diverse approaches reveal B field in the Milky Way**
- **Polarization due to dusts**
  - –Star light polarization: B// Galactic Plane or filaments
  - –Polarizations via CMB obs: B// Galactic Plane or filaments
- **Polarization of diffuse synchrotron emission**
  - –co-added from different distance, depolarized
  - –show many structures related to objects or filaments
  - –so do the polarization maps from different RMs of RM synthesis
- **Faraday Rotation of background radio sources (EGRs):**
  - –Excellent indication for B-field in the Galactic halo
  - –useful constrain for the B-field structure in the disk
- Faraday Rotation of pulsars:
  - –Best probes for B-field in the Galactic disk: structure and strength, because decomposition with ne --- farther B-directions conf. RMs of EGRs
  - –The unique measurements for $E_B(k)$
- Masers Zeeman splitting in star formation regions:
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No for large-scale B-field in the disk

Ok for large-scale B-field in the disk

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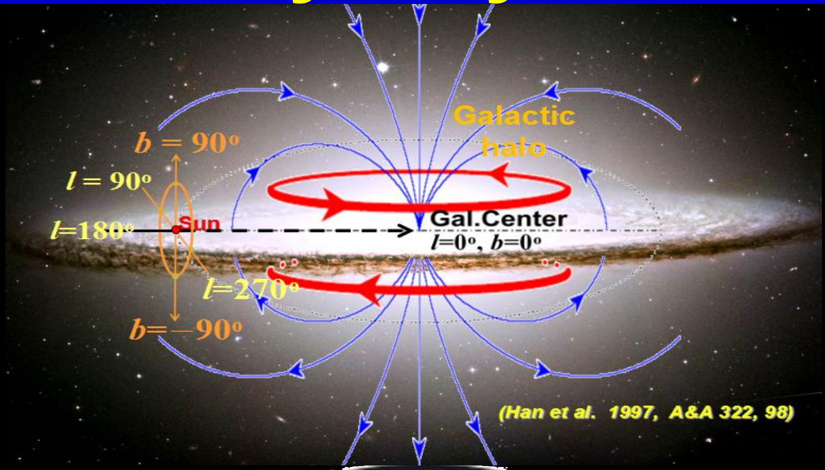

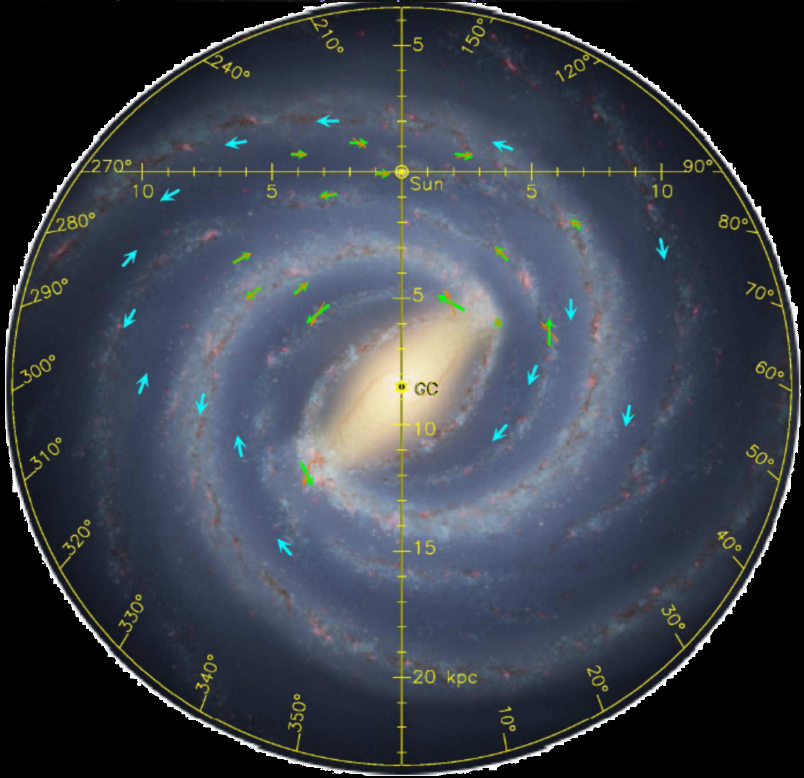

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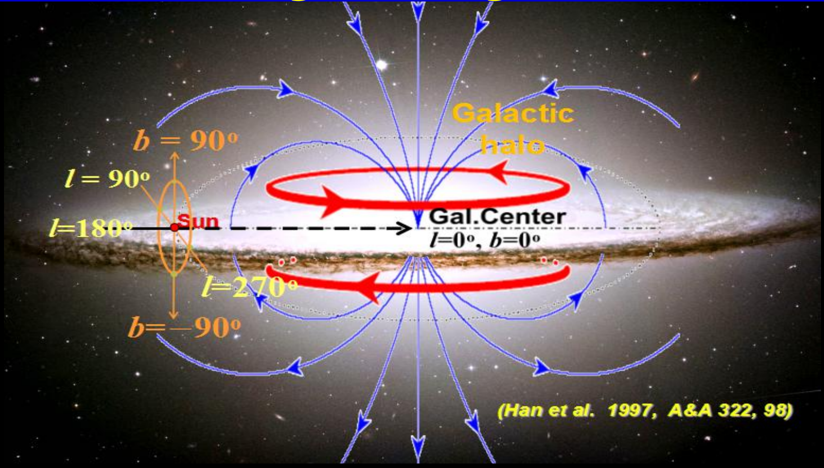
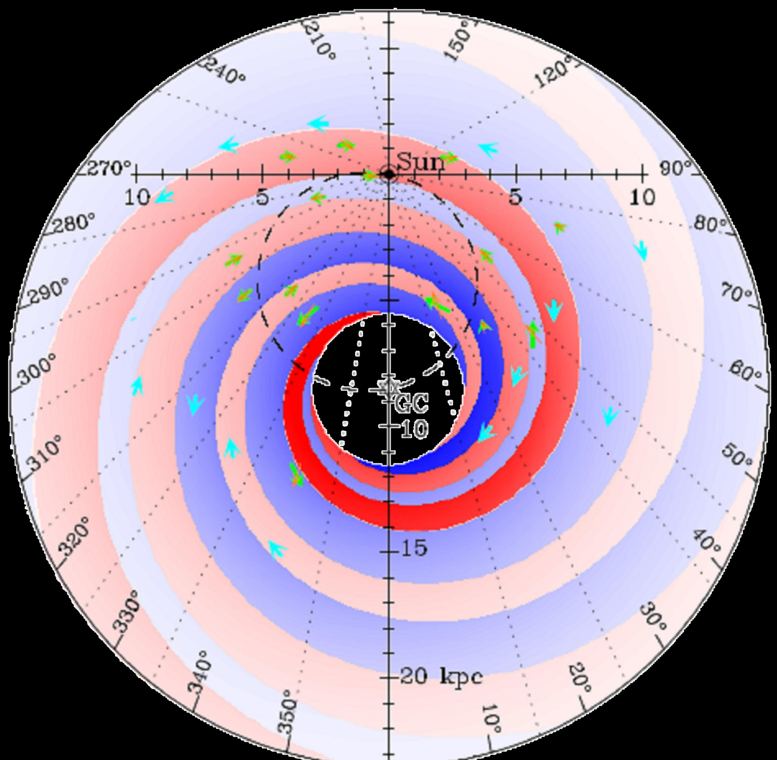
  - –show B correlations, and consistent with large-B structure
  - –potentially good probes for disk field





The most updated results of Magnetic fields in our Milky Way

See references for the Galactic magnetic fields:

Han JL, et al. 1997, A&A 322, 98
Han JL, et al. 1999, MNRAS 306, 371
Han JL, et al. 2004, ApJ 610, 820
Han JL, et al. 2006, ApJ 642, 868
Han JL, et al. 2018, ApJS 234, 11

a reference for the **Cosmic ray deflection in B-fields:**

Jiang YY, et al. 2010, ApJ 719, 459

a review on interstellar and intergalactic magnetic fields by

Han JL, 2017，ARA&A 55, 111

Thanks for your attension!