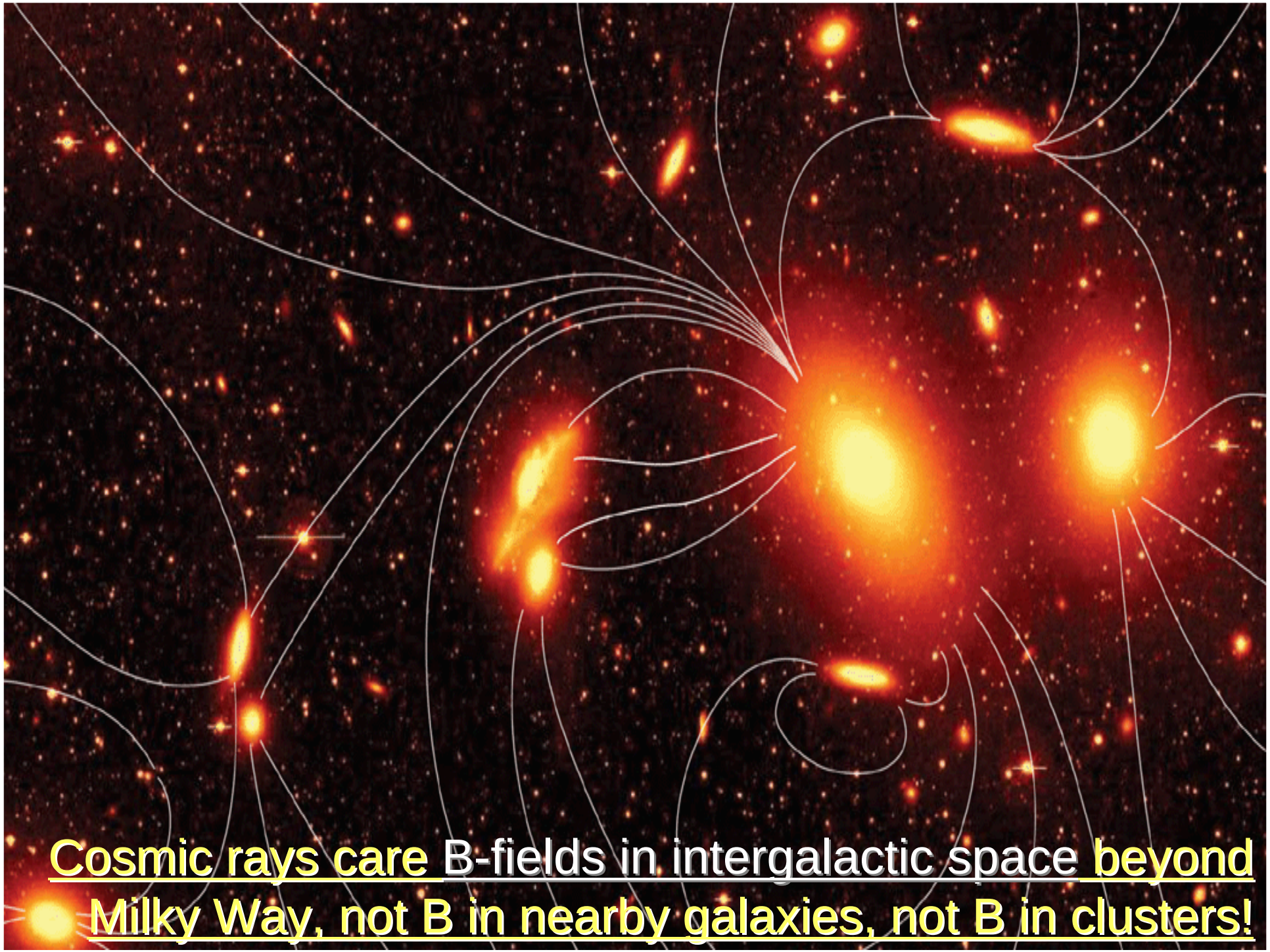
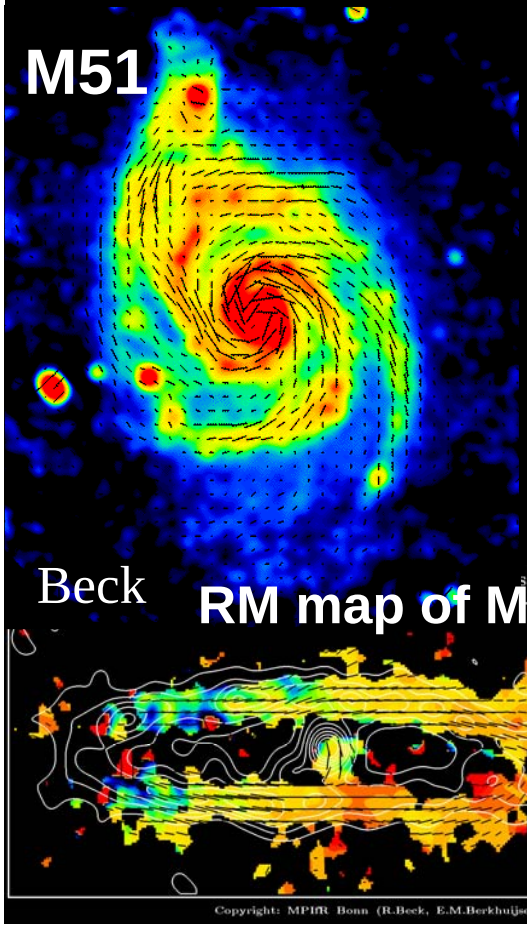

Cosmic rays care B-fields in intergalactic space beyond
Milky Way, not B in nearby galaxies, not B in clusters!

B-measurements beyond Milky Way:
Yes, observations for B in nearby galaxies!
Yes, evidence for B in intra-clusters!
Inter-cluster Radio Bridge!
But not yet B-fields in inter-galactic space !



Intracluster fields:

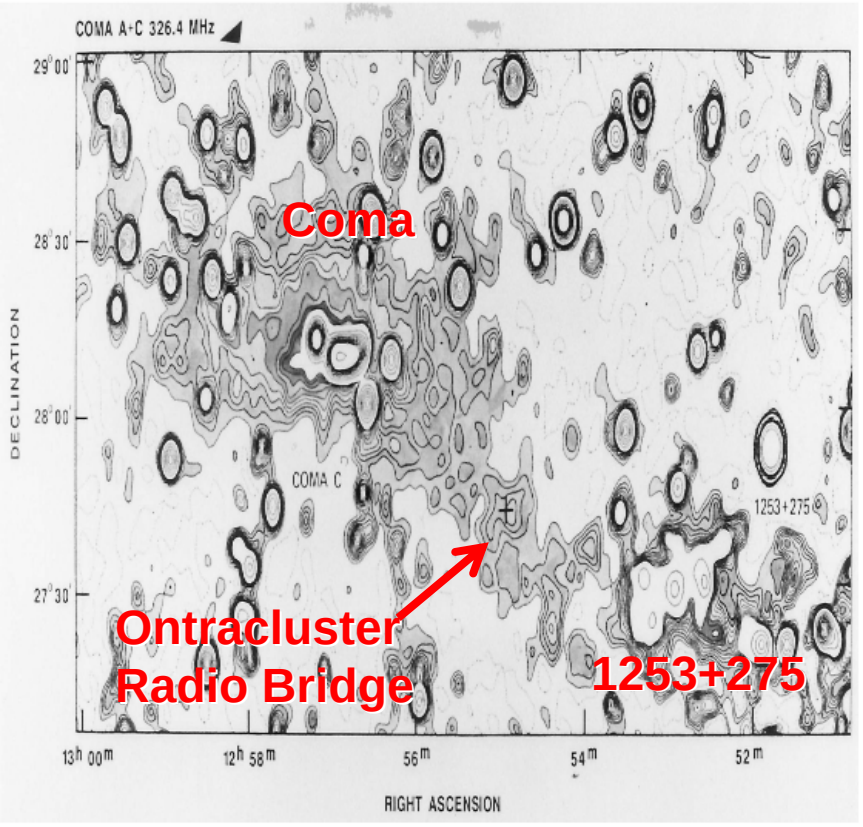
See:

Xu, Kronberg et al. 2006, ApJ

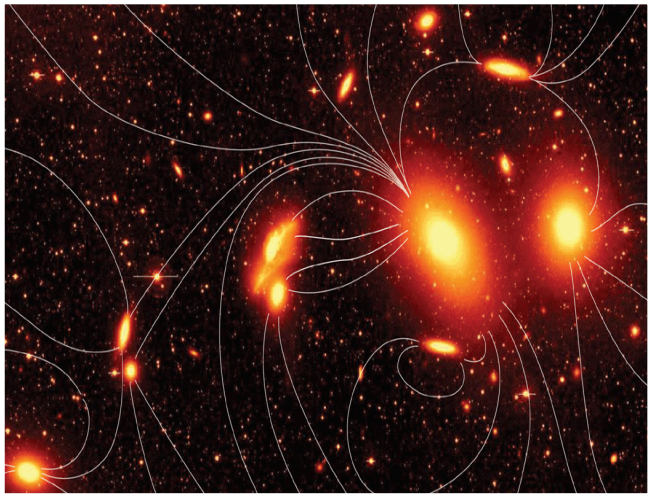
Clark et al. 2001, ApJL

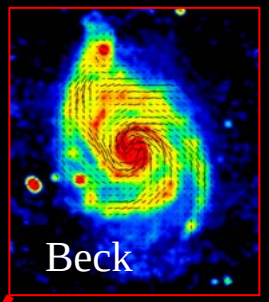
Kronberg et al. 2008, ApJ

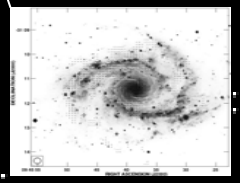
Adapted from: Kim, Kronberg, Giovannini and Venturi, NATURE, 1989



Beyond our Galaxy ≠ Extragalactic?
≠ Intracluster?
= Intergalactic?



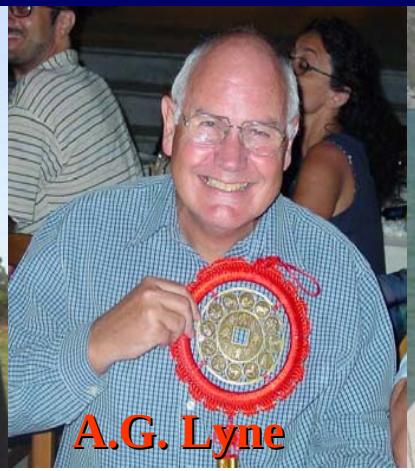


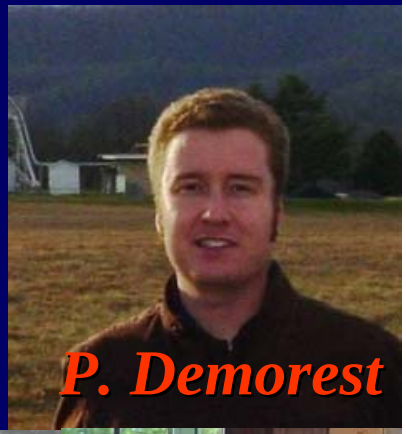


Cosmic rays care B-fields in intergalactic space beyond Milky Way, not B in nearby galaxies, not B in clusters!

Measurements of *Galactic magnetic fields*

JinLin Han
National Astronomical Observatories
Chinese Academy of Sciences
Beijing 100012, China
hjl@bao.ac.cn





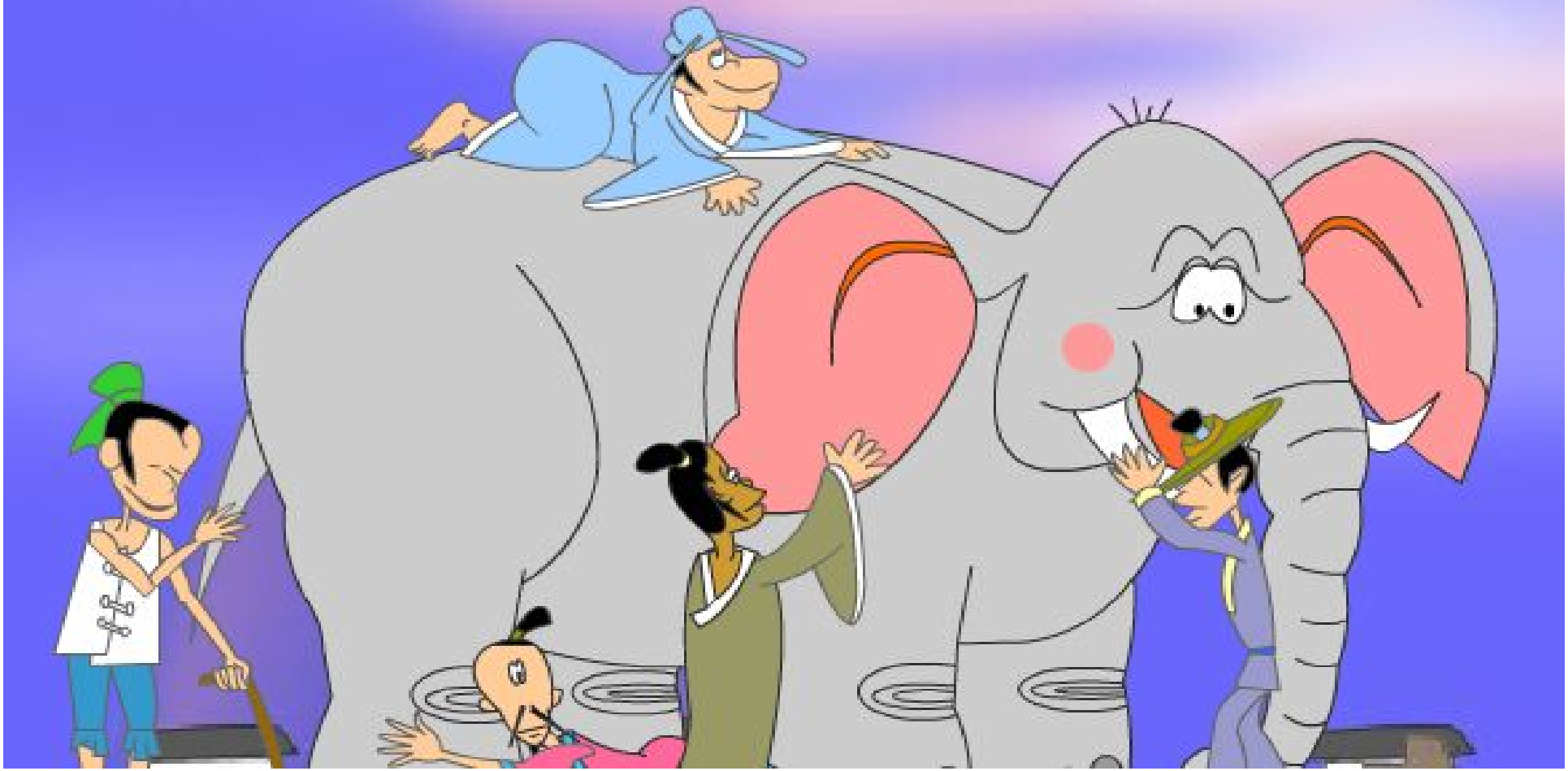
Measurements of *Galactic magnetic fields*

- Methods to measure
- Results of measurements
  - Galactic disk
  - Galactic center
  - Galactic halo
  - Random fields
- Conclusions

What shape should an elephant have?
-- depends on which part a blind touch?!

We touched and measured much more in the last decade

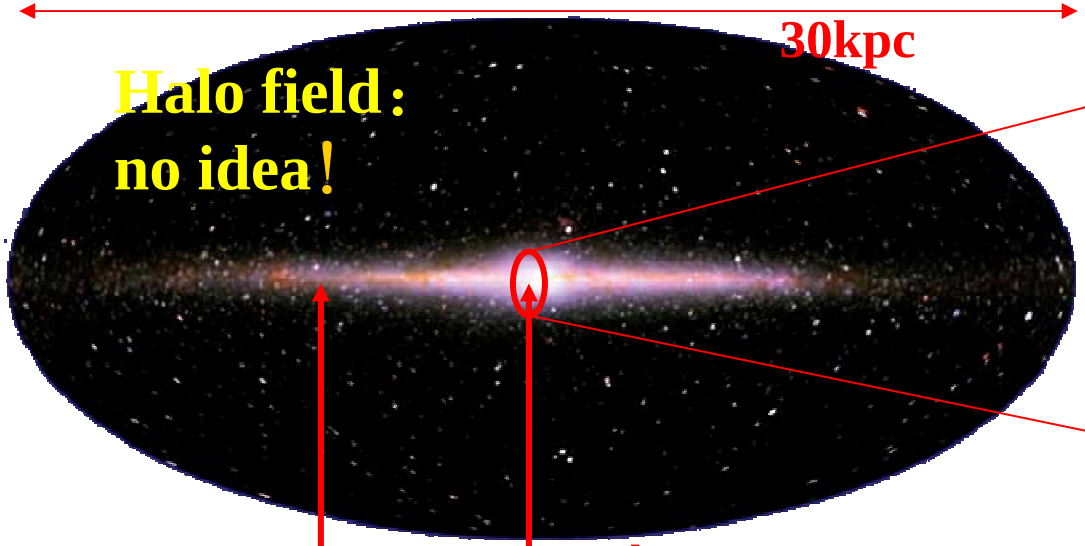
We need more measurements and put *all data* together!

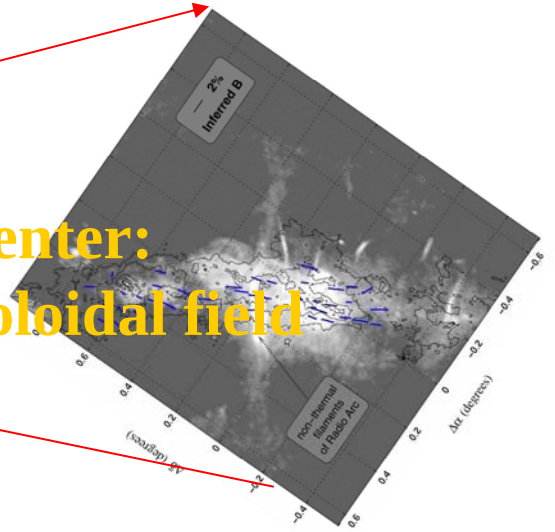


Galactic B-field：a decade ago

30kpc

Halo field：
no idea！

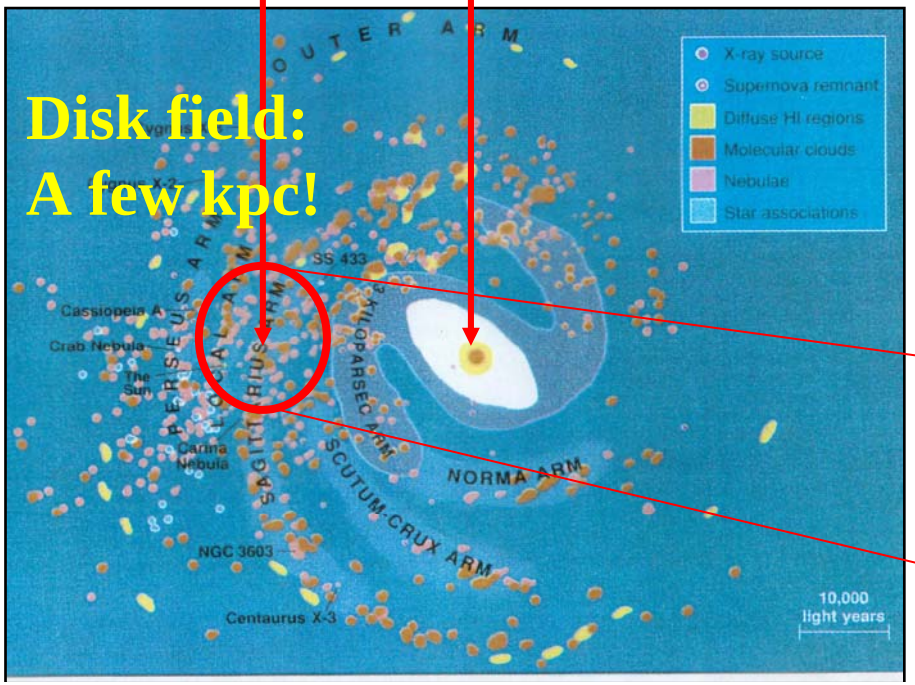




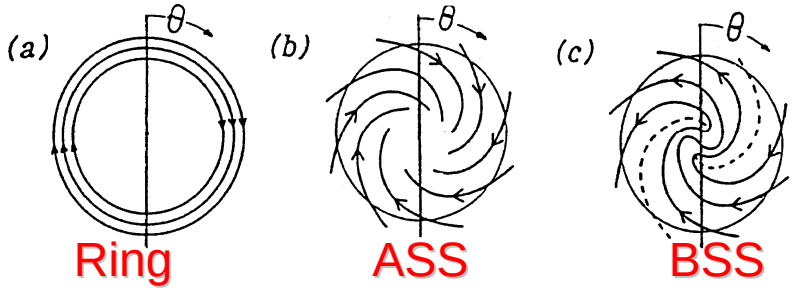
Center:
Poloidal field

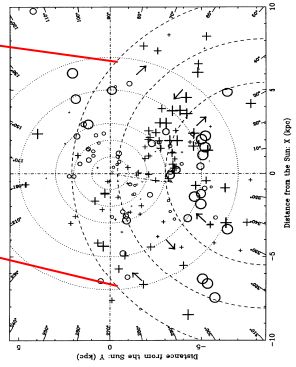
Sun

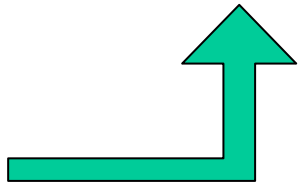
Galactic center



Disk field:
A few kpc!



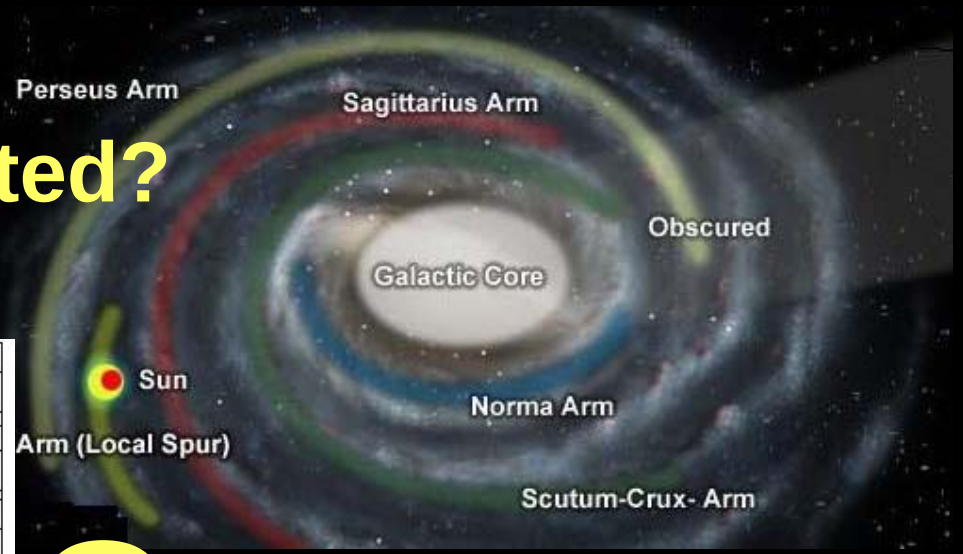


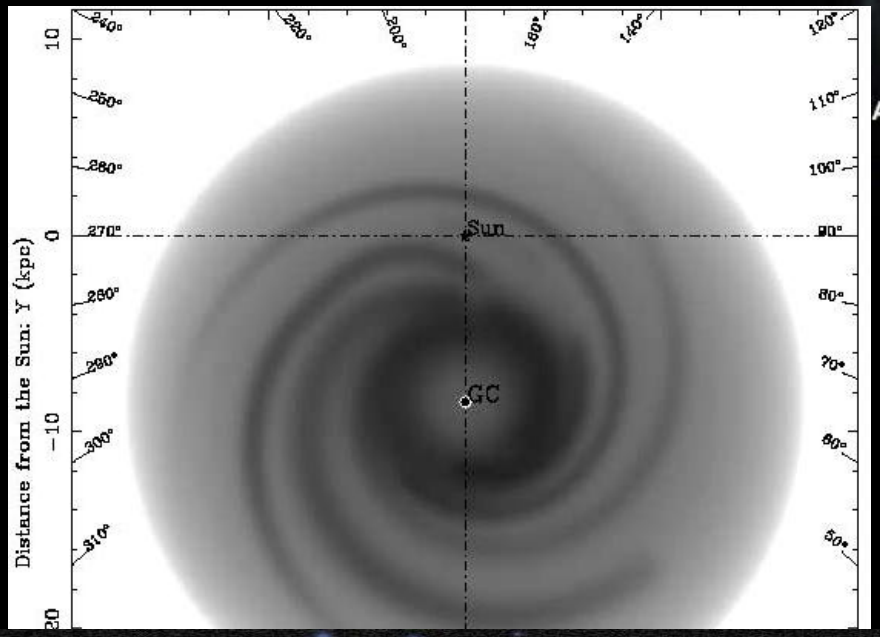


3 models: which?

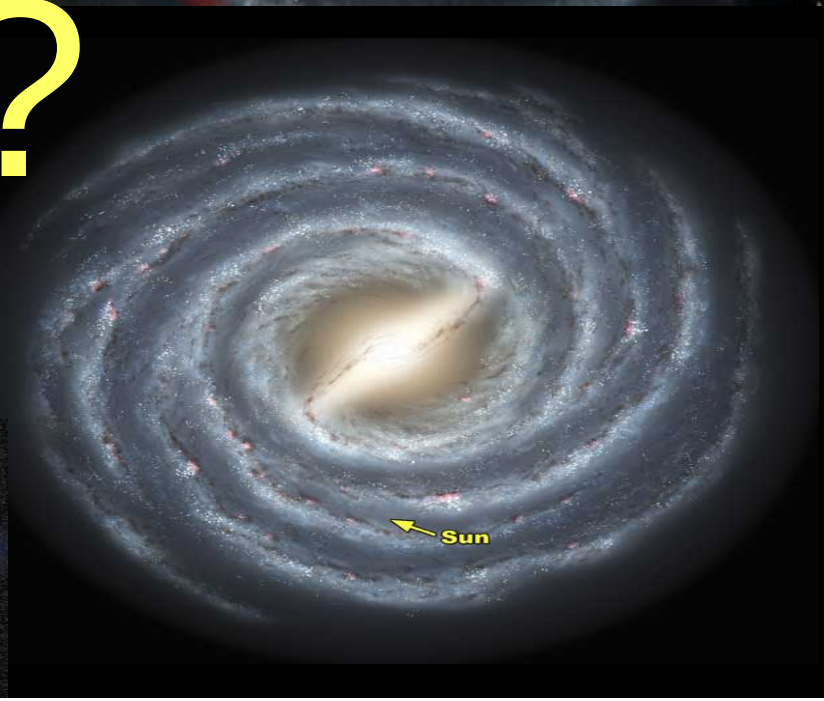
(Un)Known Structure of our Galaxy

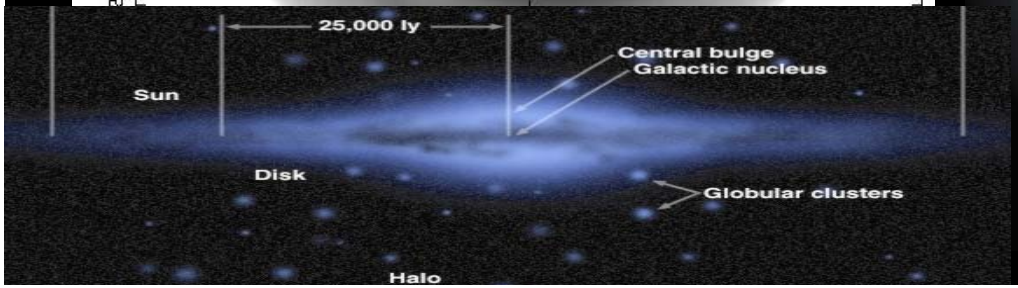
How many arms?
Where are arms located?
Is there a bar in GC?





?





Observational B-tracers: What info out?

- Polarization of starlight: *perpendicular field in 2 or 3 kpc*
  orientation // $B_{\perp}$ ---------- 9000 +? stars
- Polarization at infrared, mm, submm: *perpendicular field*
  orientation // $B_{\perp}$ ---------- clouds or regions
- Zeeman splitting: *parallel field, in situ (masers, clouds)*
  $\Delta\nu \propto B_{//}$ ------ 137 maser regions & 17 coulds
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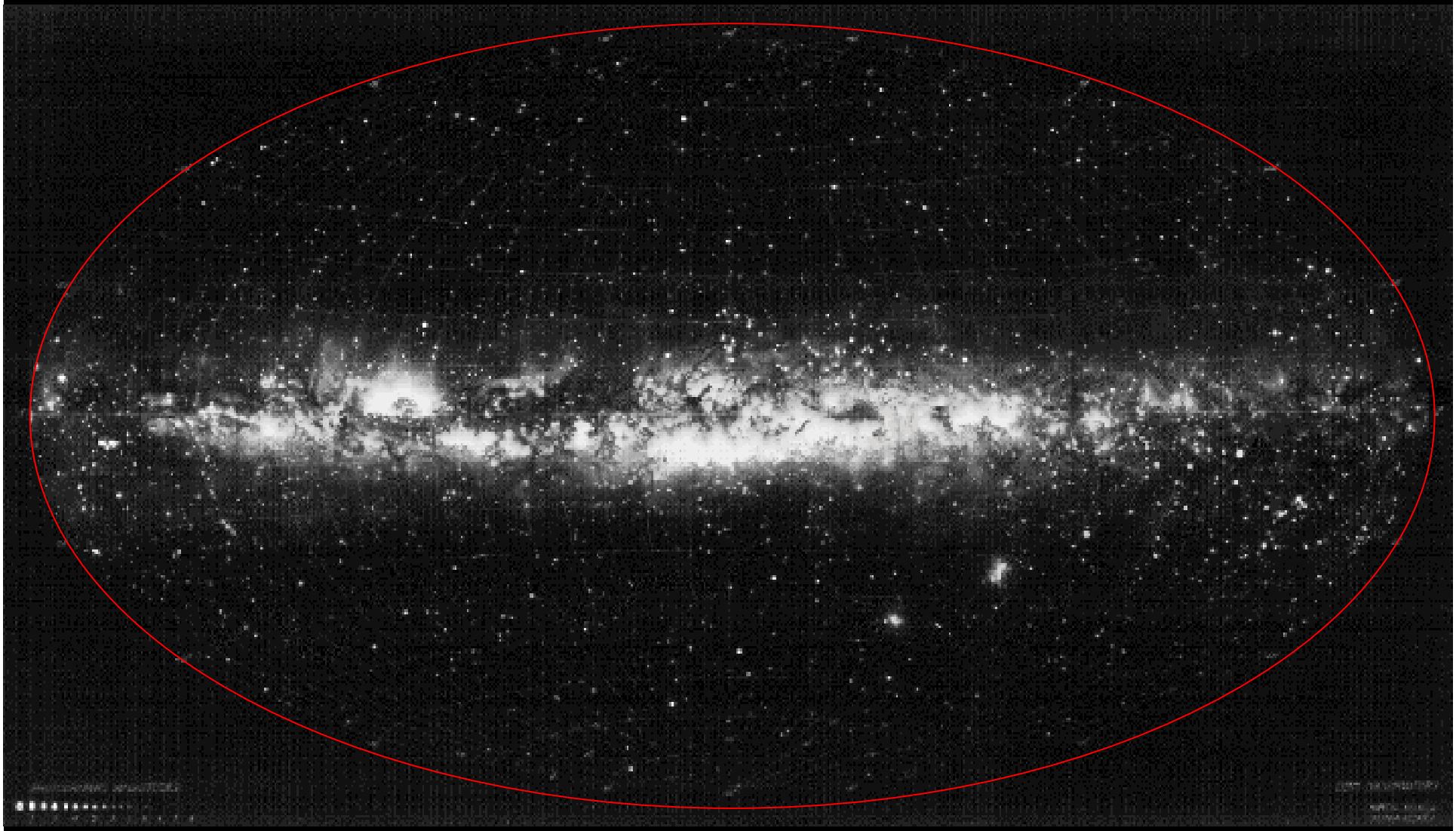
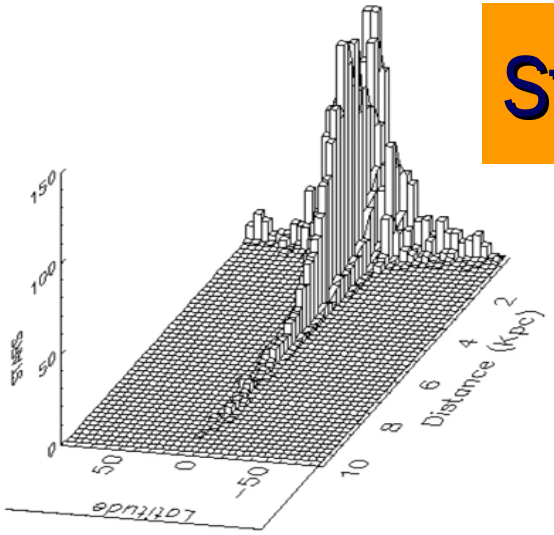
  $RM \propto \int n_e B_{//} ds$ ------ 1024 pulsars + >3000 EGSes

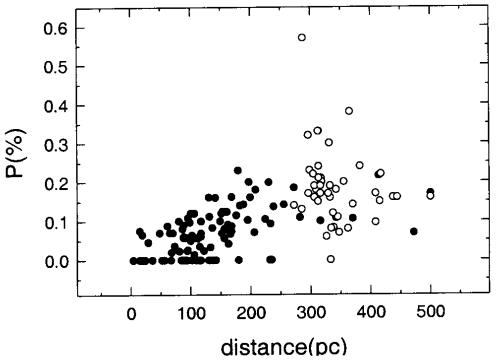
Optical Sky



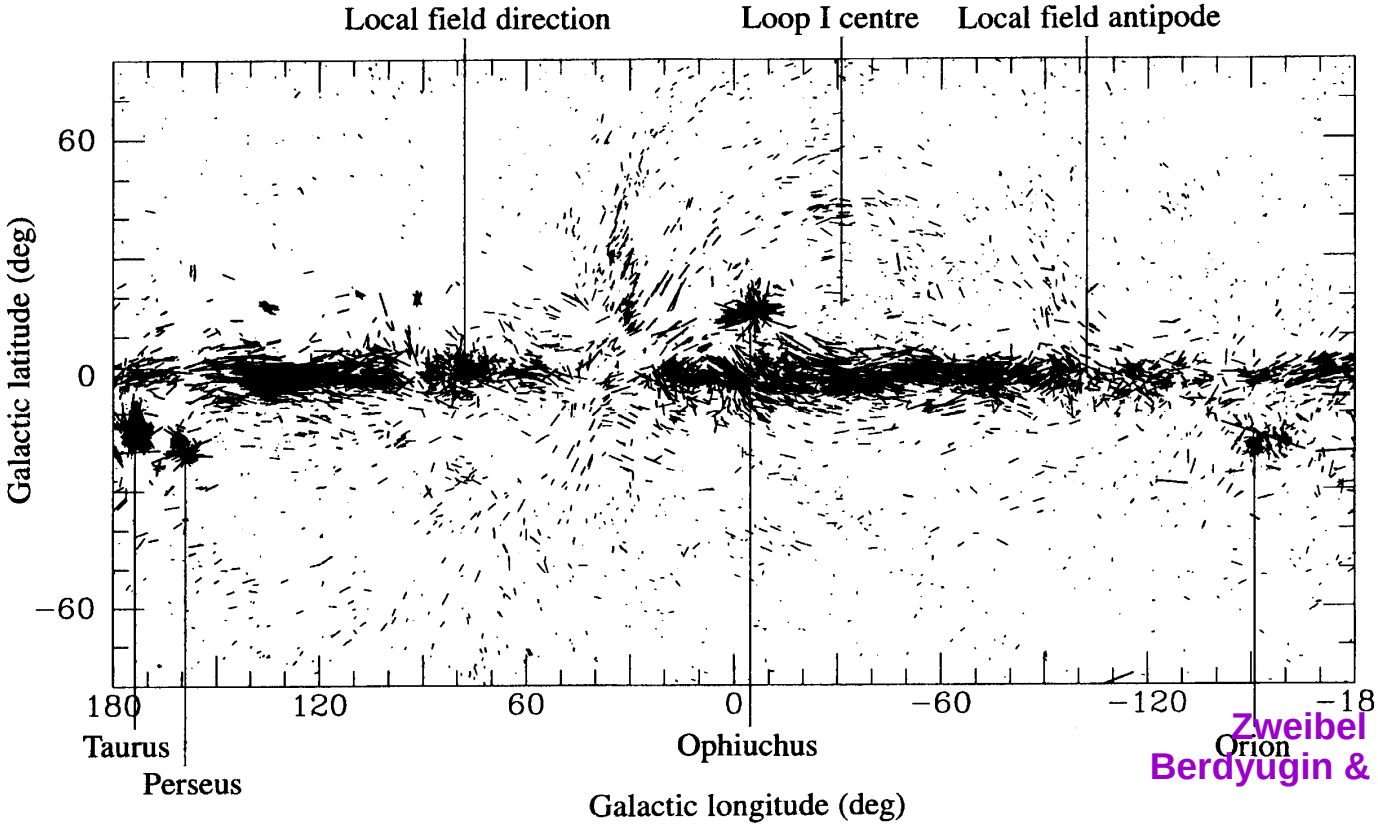
Starlight polarization: *local field // arm*

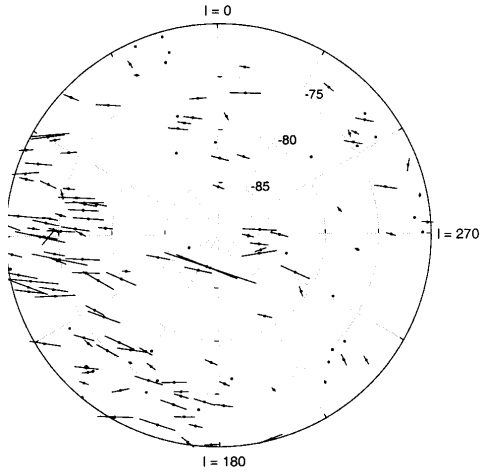


- 9000 stars have polarization measured
- mostly nearby (1~2kpc)
- polarization percentage increases with distance



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

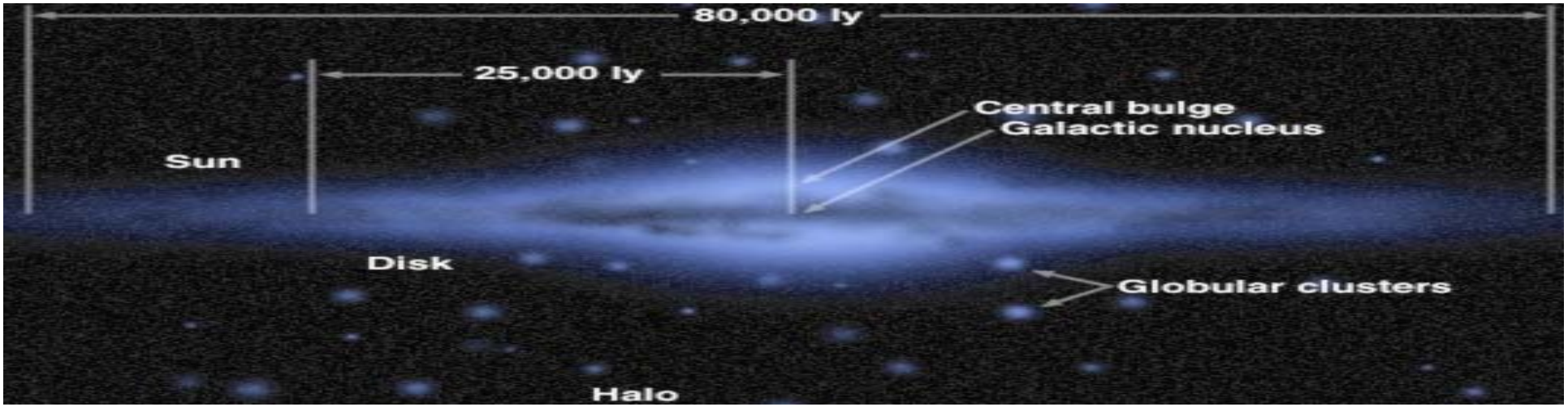




. Polarizations of the stars around the SGP. The length
bar gives the amount of polarization, its direction gives
ection of the polarization plane

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

Starlight polarization:
local field // arm
local field // Galactic plane



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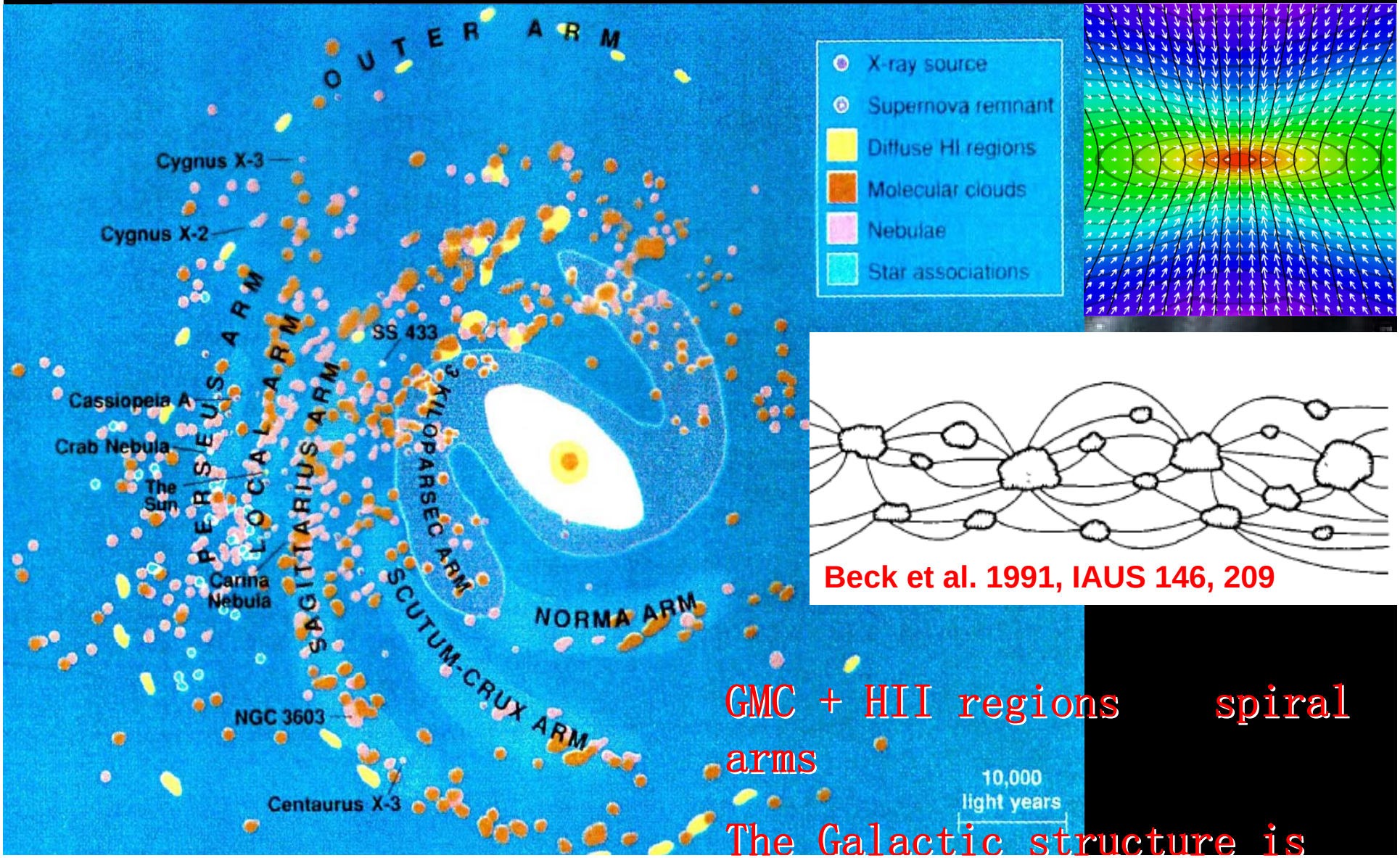
ISM ➔ Molecular clouds ➔ HII regions

all permeated by magnetic fields



Beck et al. 1991, IAUS 146, 209

GMC + HII regions spiral arms

The Galactic structure is

Polarization at mm, sub-mm, infrared

Working toward measure B-field of galactic scale

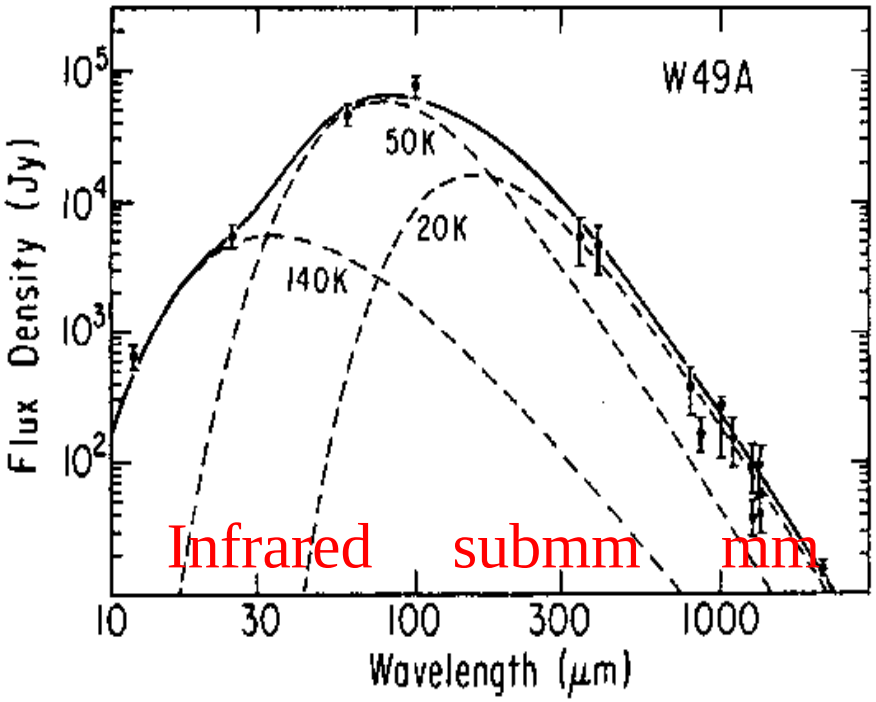
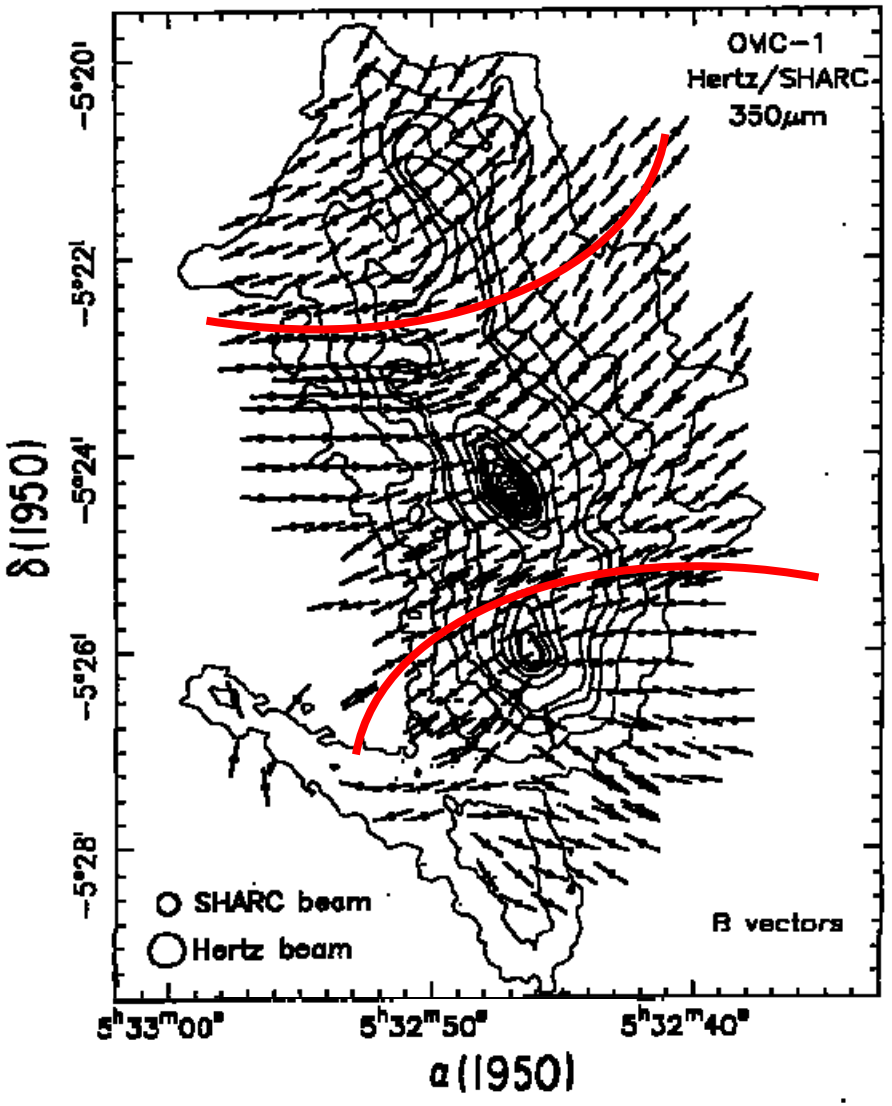


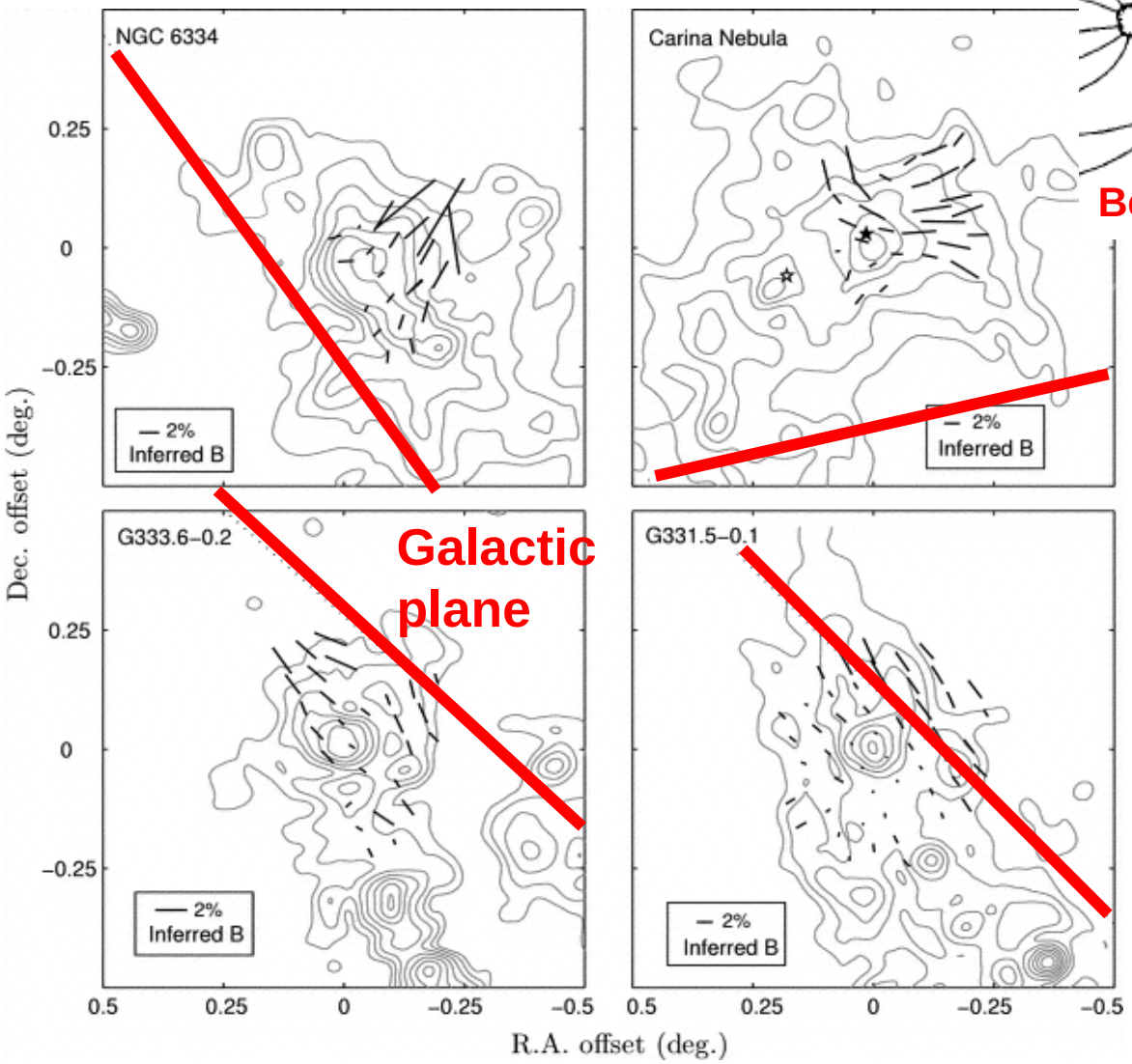
FIG. 2.—Total flux spectrum and derived temperature components of the molecular cloud W49A. Adapted from Sievers et al. 1991. (Area sampled includes warm component in core.)

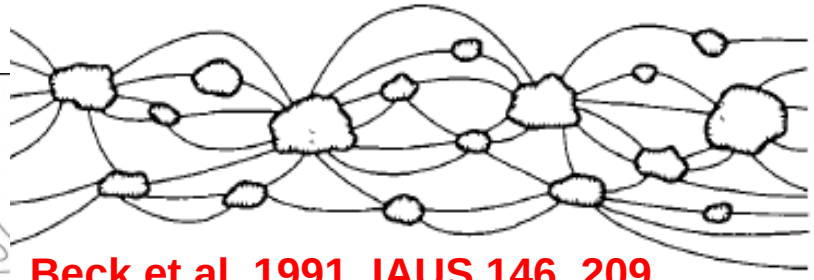


- Thermal emission (of dusts)
- Preferentially aligned by B

Hildebrand et al. PASP 112, 1215

Correlation of orientation of the fields in clouds with the large-scale G





Beck et al. 1991, IAUS 146, 209

- 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.

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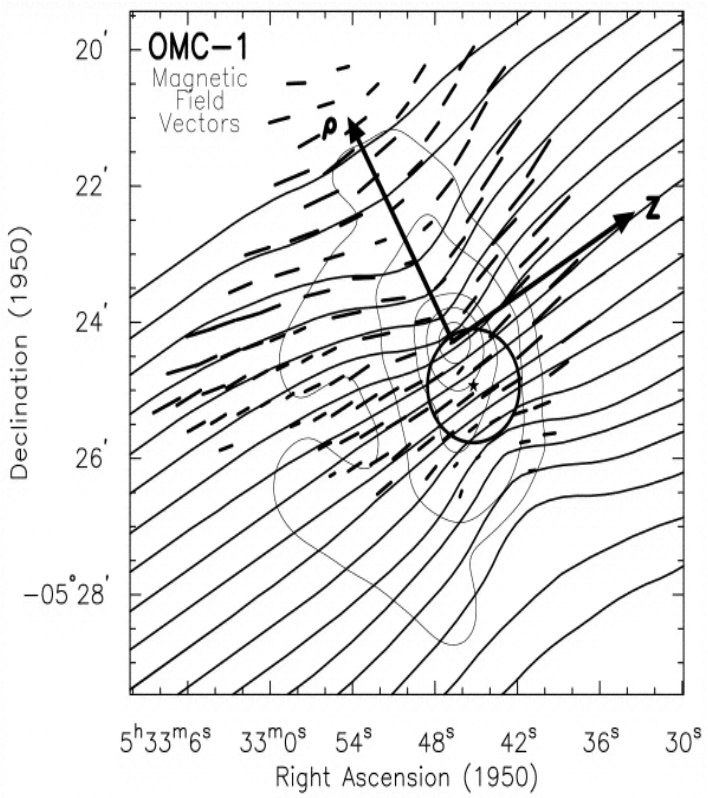
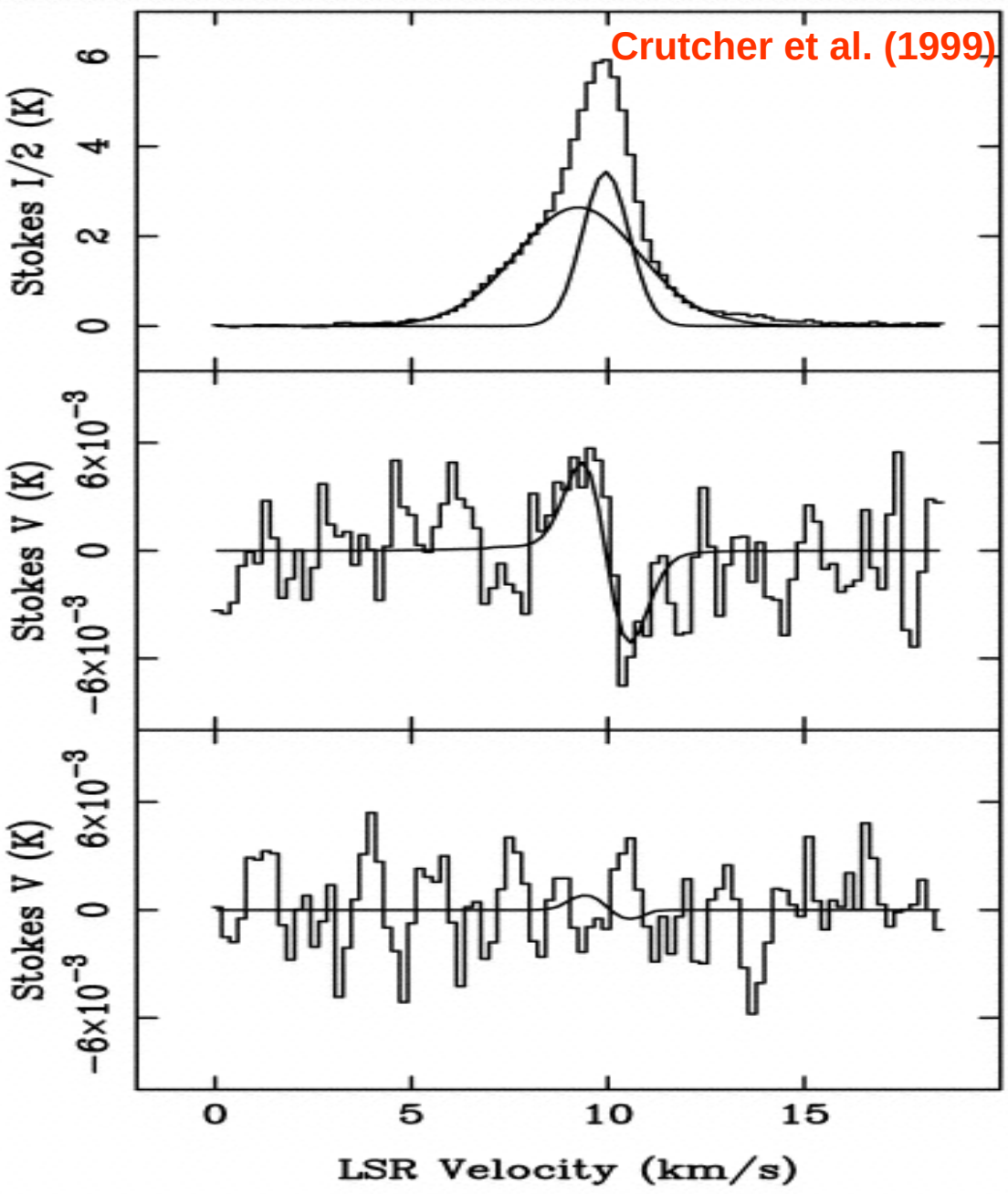
Polarization Mapping and Zeeman splitting of clouds

Schleuning (1998)

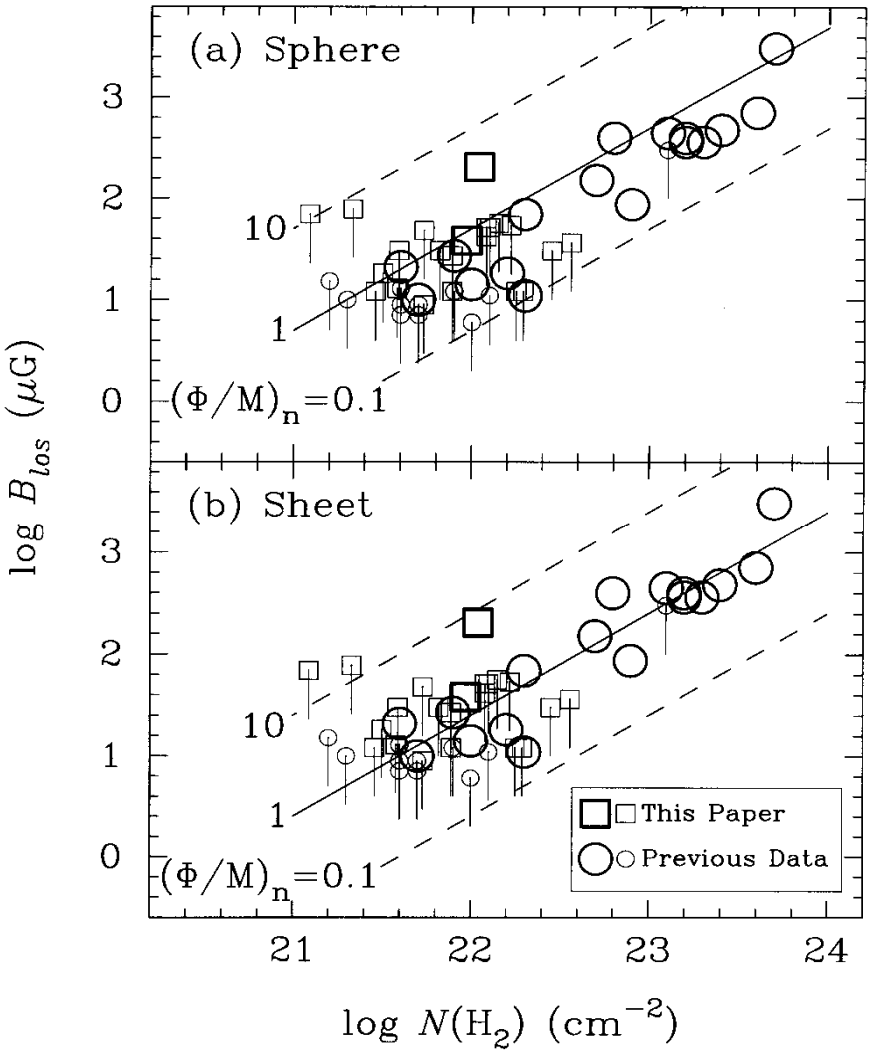


$n(H_2)$ 6 10^5,
$N(H_2)$ 2 10^{23},
B_{los} 0.4 mG,
c 1.3

Crutcher et al. (1999)



Zeeman Effect:
B in molecular clouds



MOLECULAR CLOUD ANALYSIS

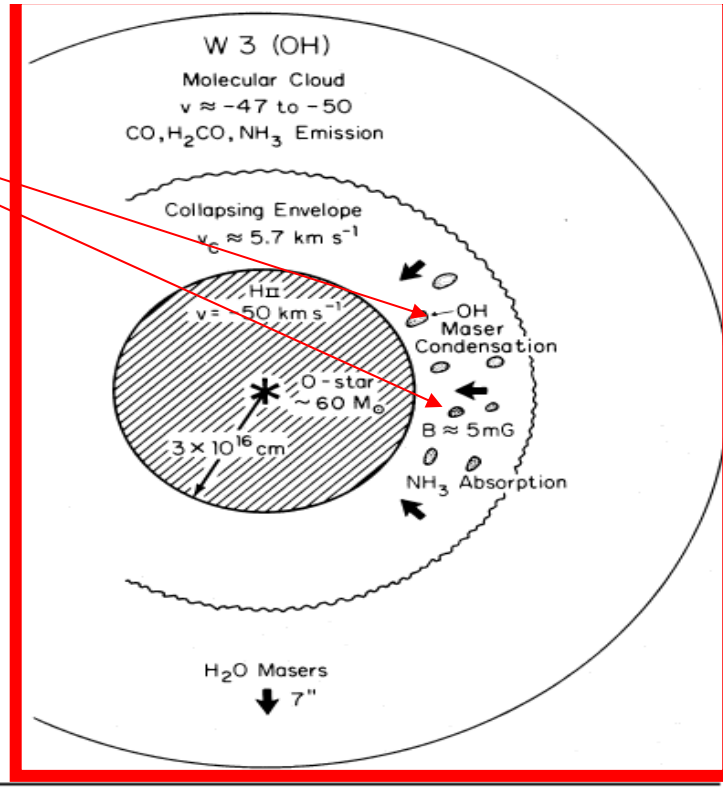
Name (1)	B_{los} (μG) (2)	Log B (μG) (3)	Log N [$N(H_2)$ cm^{-1}] (4)	$(\Phi/M)_n$ (Sphere) (5)	$(\Phi/M)_n$ (Sheet) (6)
		Parkes			
RCW 38	38	1.58	21.97	0.8	1.6
RCW 57 (v2)[a]	203	2.31	22.04	3.7	7.3
Carina MC	<30	<1.48	21.82	<0.9	<1.8
Cham I	<12	<1.08	21.89	<0.3	<0.6
		Crutcher 1999			
W3 OH	3100	3.49	23.7	1.2	2.4
DR 21 OH1	710	2.85	23.6	0.4	0.7
Sgr B2	480	2.68	23.4	0.4	0.8
M17 SW	450	2.65	23.1	0.7	1.4
W3 (main)	400	2.60	23.2	0.5	1.0
S106	400	2.60	22.8	1.3	2.5
DR 21 OH2	360	2.56	23.3	0.4	0.7
OMC-1	360	2.56	23.2	0.5	0.9
NGC 2024	87	1.9	22.9	0.2	0.4
S88B	69	1.84	22.3	0.7	1.4
B1	27	1.43	21.9	0.7	1.3
W49B	21	1.32	21.6	1.1	2.1
W22	18	1.26	22.2	0.2	0.5
W40	14	1.15	22.	0.3	0.6
ρ Oph 1	10	1.	21.7	0.4	0.8
L1544[d]	11	1.04	22.3	0.1	0.2
NGC 6334[e]	150	2.18	22.7	0.6	1.2
OMC-N4[f]	<300	<2.48	23.1	<0.5	<0.9
Tau G[f]	<7	<0.85	21.6	<0.4	<0.7
L183[f]	<15	<1.18	21.2	<1.9	<3.7
L1647[f]	<11	<1.04	22.1	<0.2	<0.3
ρ Oph 2[f]	<13	<1.11	21.6	<0.7	<1.3
TMC-1[f]	<12	<1.08	21.9	<0.3	<0.6
L1495W[f]	<9	<0.95	21.6	<0.5	<0.9
L134[f]	<10	<1	21.3	<1.0	<2.0
TMC-1C[f]	<9	<0.95	21.9	<0.2	<0.5
L1521[f]	<9	<0.95	21.7	<0.4	<0.7
L889[f]	<6	<0.78	22.	<0.1	<0.2
Tau 16[f]	<7	<0.85	21.7	<0.3	<0.6

Bourke et al. 2001, ApJ 554, 916

B-field from maser spots

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!



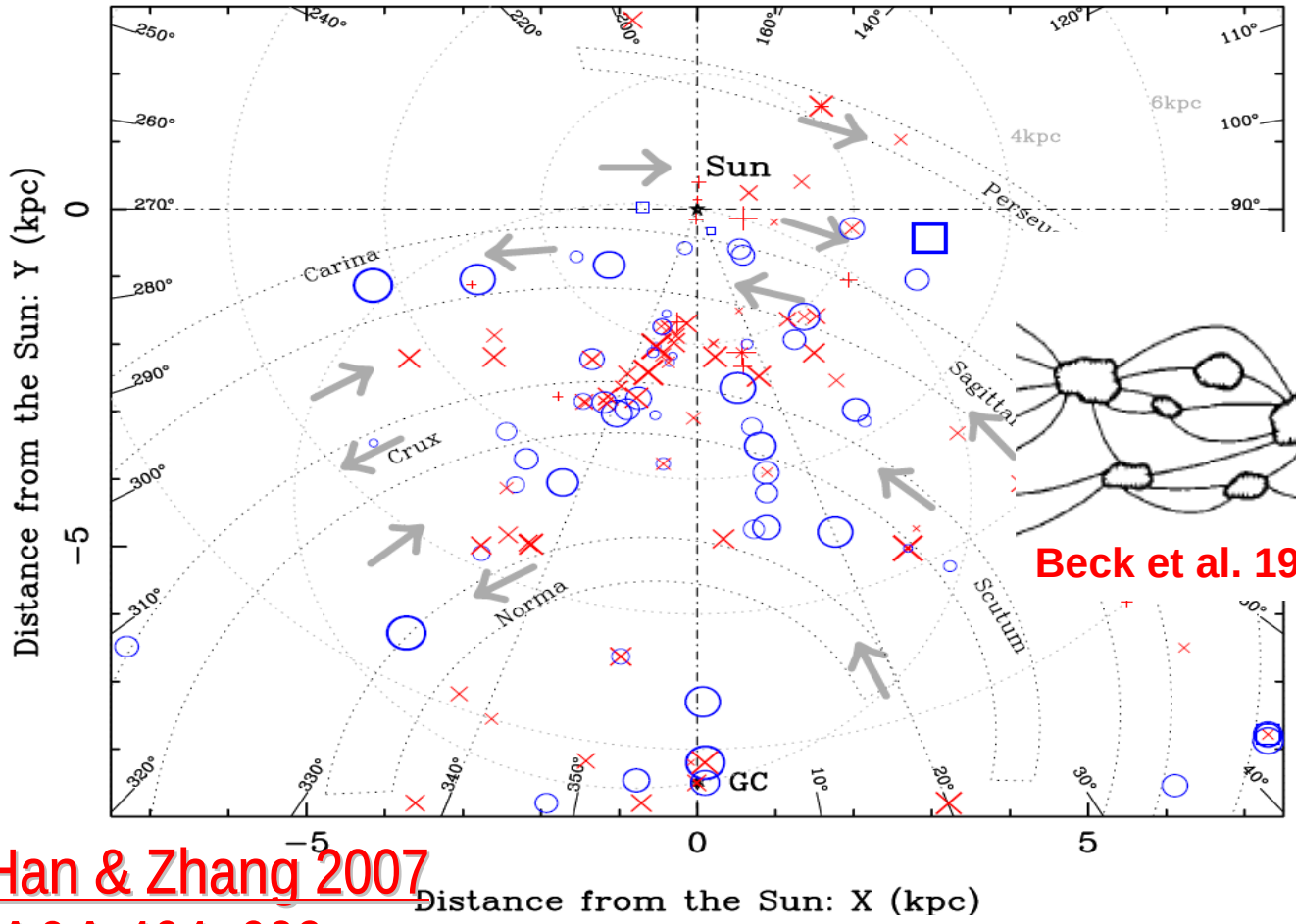
Source (GL+GB)	Alias name	Dist (kpc)	Freq (MHz)	B_l (mG)	B_m (mG)	B_u (mG)	Obs. telescope	Ref.
...	W3(OH)	2.2	13441	5.6	10.2	11.3	VLBA	bd98
...	W3 OH	2.2	6035	7.1	8.0	8.7	Eff	bdwc97
...	...	2.2	6031	3.3	4.7	8.1	Eff	bdwc97
...	...	2.2	13441	6.9	8.2	11.3	GBT	frm05
...	...	2.2	13434		10.3		GBT	frm05
G196.454−1.677	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

Structure in distribution of field directions

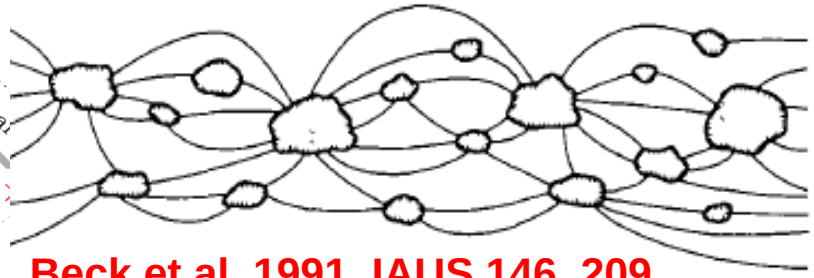
***In situ* au-scale-B correlated with kpc-B!**

Reversals: preserved from ISM to maser core!



Blue:

Counterclock-wise field



Beck et al. 1991, IAUS 146, 209

Red:

Clockwise field

Han & Zhang 2007
A&A 464, 609

We need more data, and better determined distances!

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- Faraday rotation: ***parallel field, integrated (the halo & disk)***
  $RM \propto \int n_e B_{//} ds$ ------ 1024 pulsars + >3000 EGSes

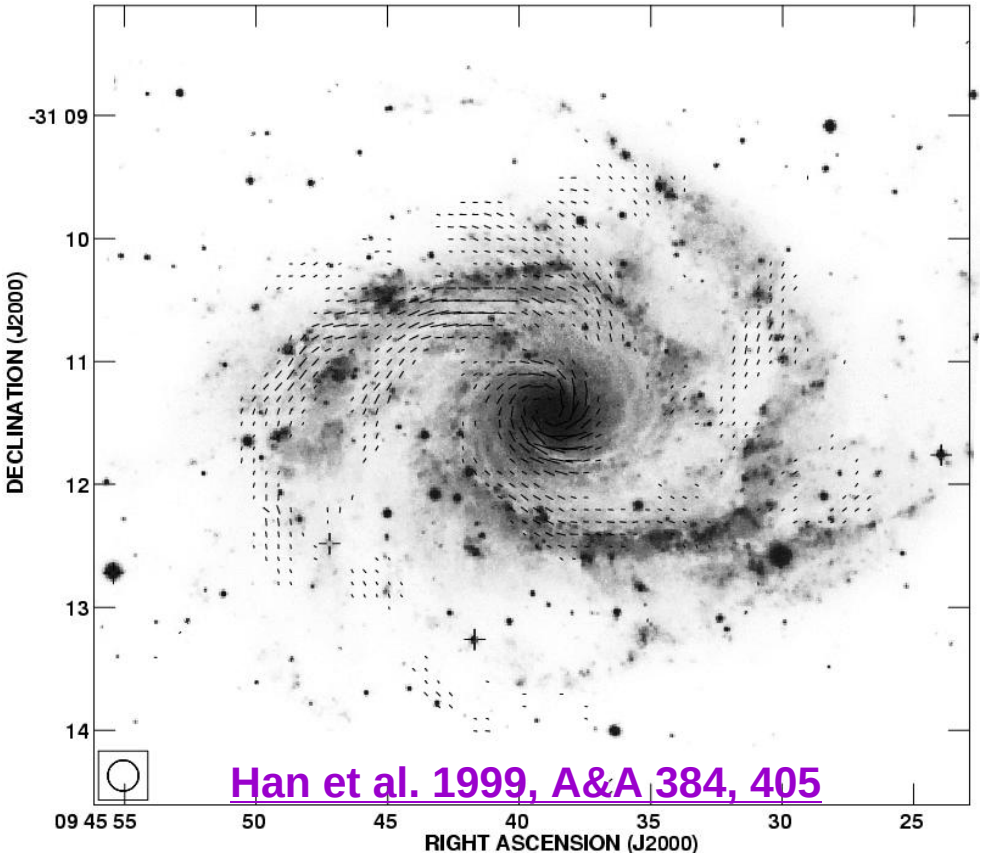
Synchrotron radiation: *transverse B-structures*

B-field structure from linearly polarized emission

Two Possible origins:

1. Large-scale magnetic field as vectors shown (conventional concept) !

2. Anisotropic random field compressed by large-scale density wave !

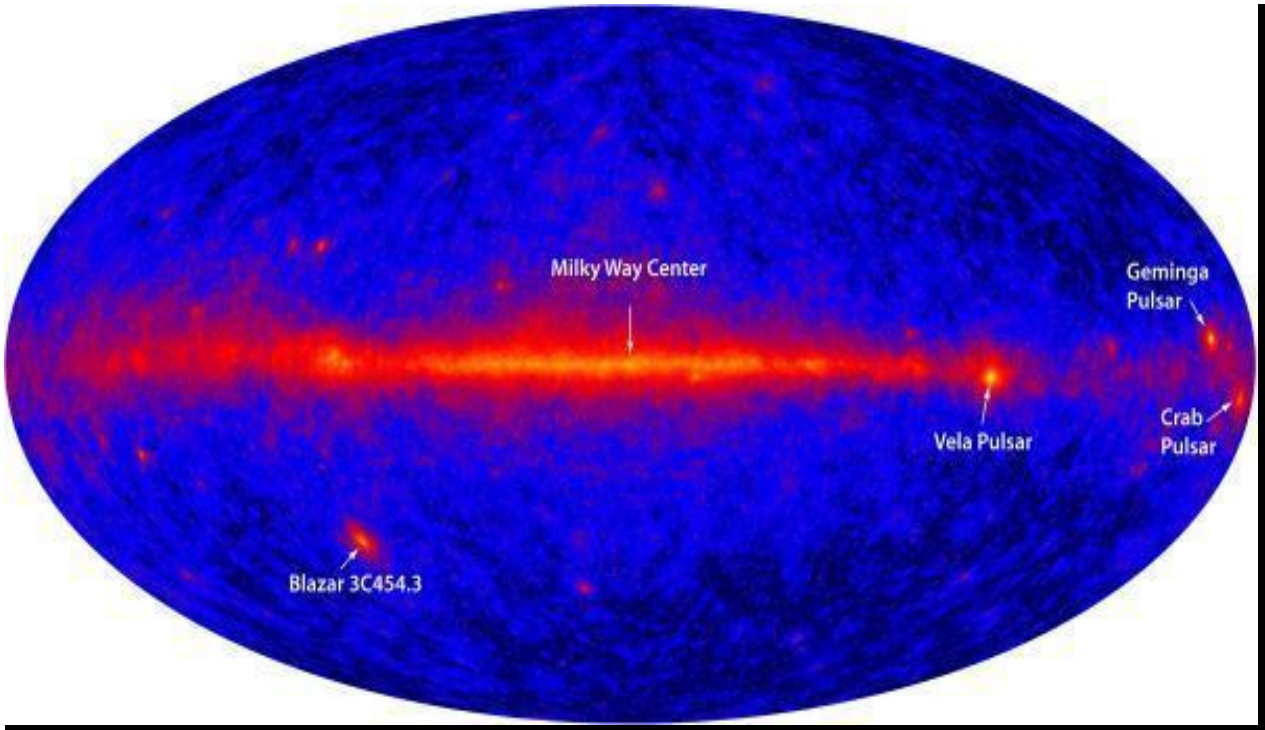


Han et al. 1999, A&A 384, 405

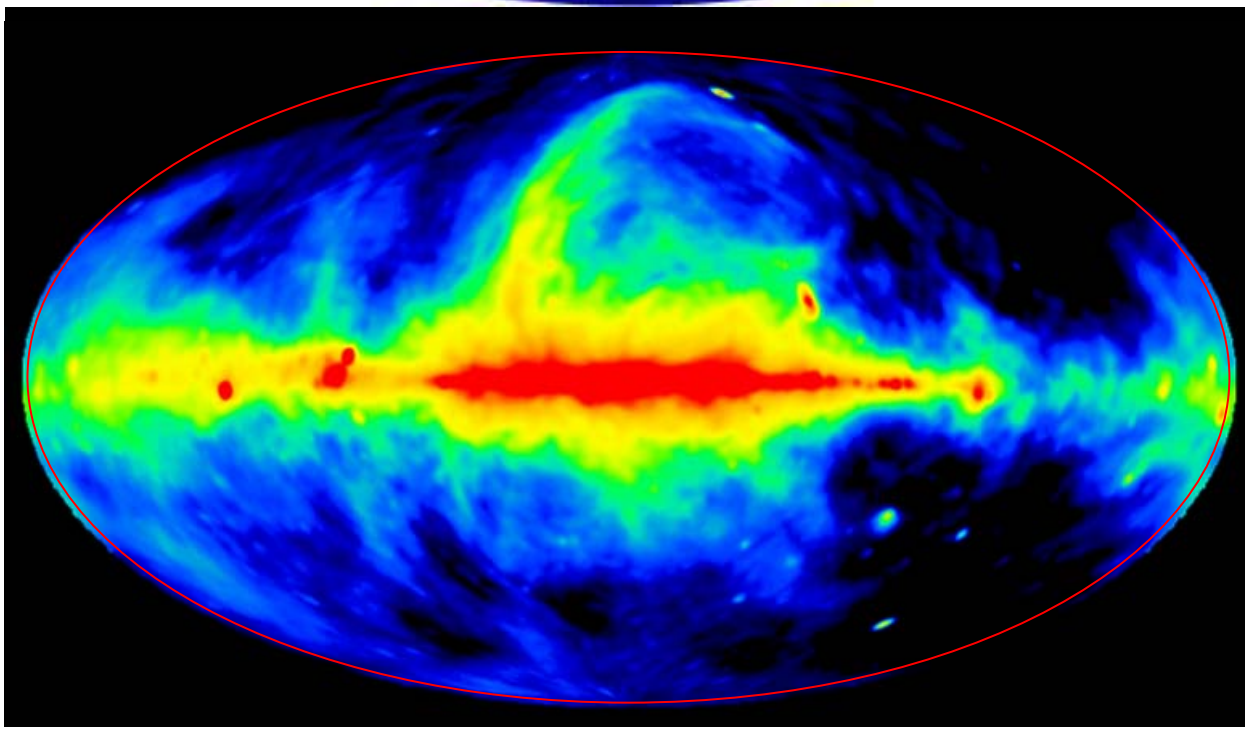
No information of B-*directions!*

RM maps helps on directions of (disk &) halo field!

MPIFR has a group working on this for 25 years!

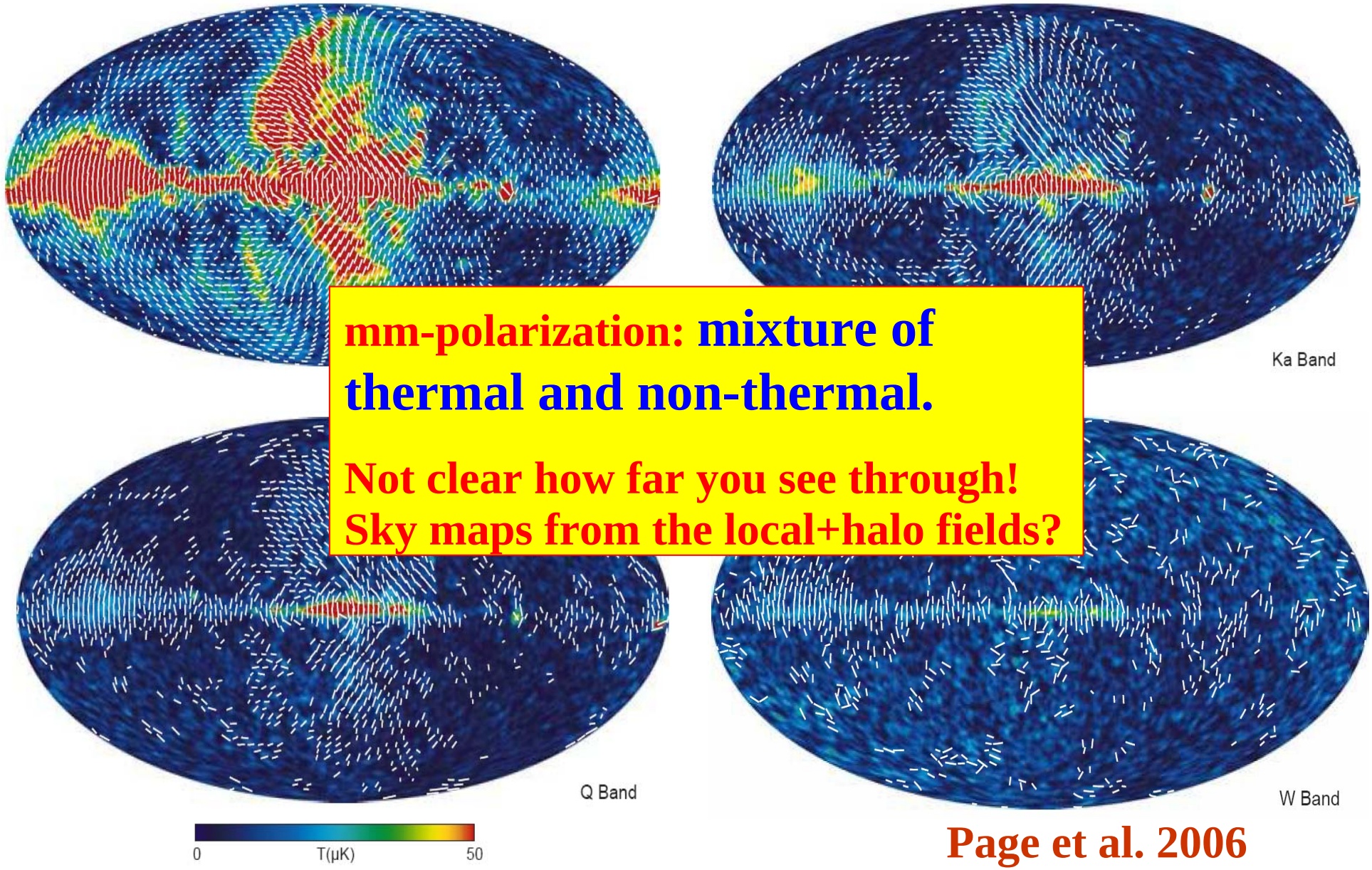


Gamma Sky



Radio Sky

all WMAPs show: B-field // GalacticPlane



mm-polarization: mixture of thermal and non-thermal.

Not clear how far you see through!
Sky maps from the local+halo fields?

Page et al. 2006

Polarization surveys of the Galactic plane

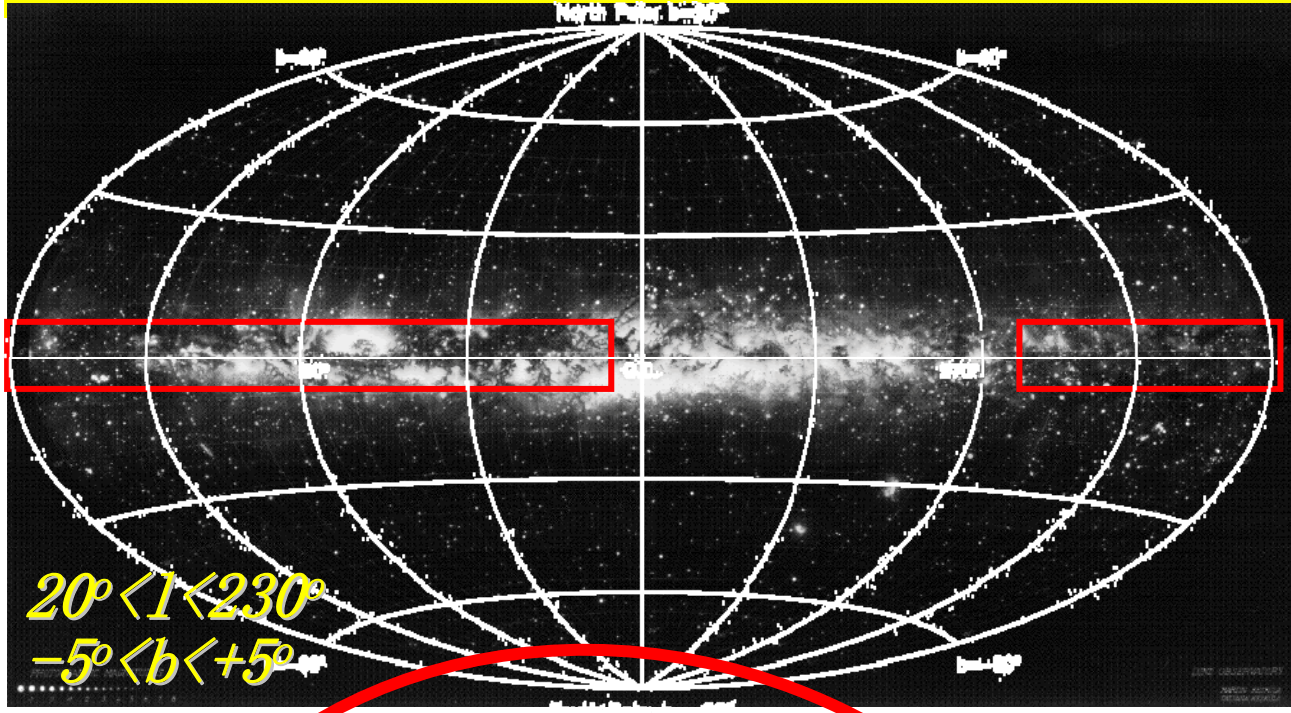
– show B-field structure

- Effelsberg Polarization Survey ©20cm
- Parkes 2.7GHz polarization survey
- Canadian Galactic plane survey (1.4GHz)
- Southern Galactic plane survey (1.4GHz)
- VLA Galactic plane survey (1.4GHz)
- Galactic Arecibo-LFA survey (1.4GHz)
- WRST: 350MHz survey
- I miss some?
- Sino-German polarization survey at 6cm

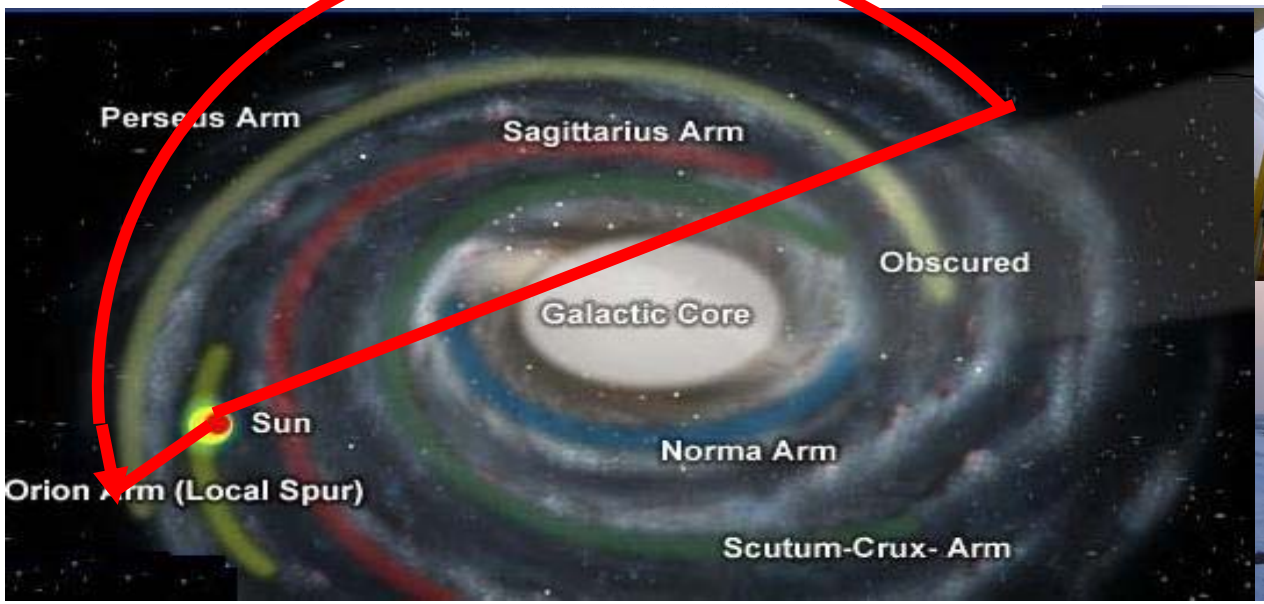
Higher Frequency, less Faraday depolarization!

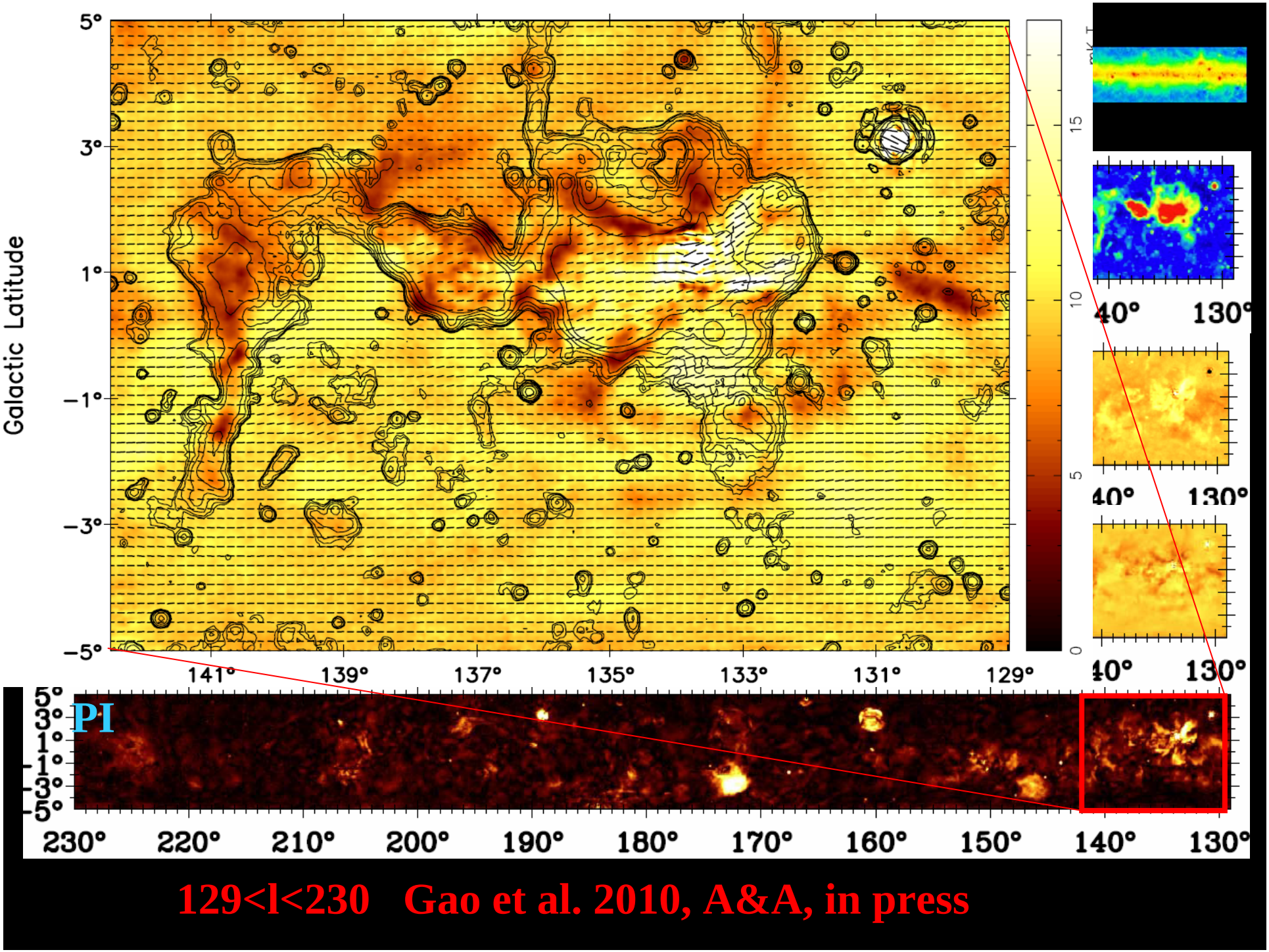
Greater depth or deeper insights into ISM!

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



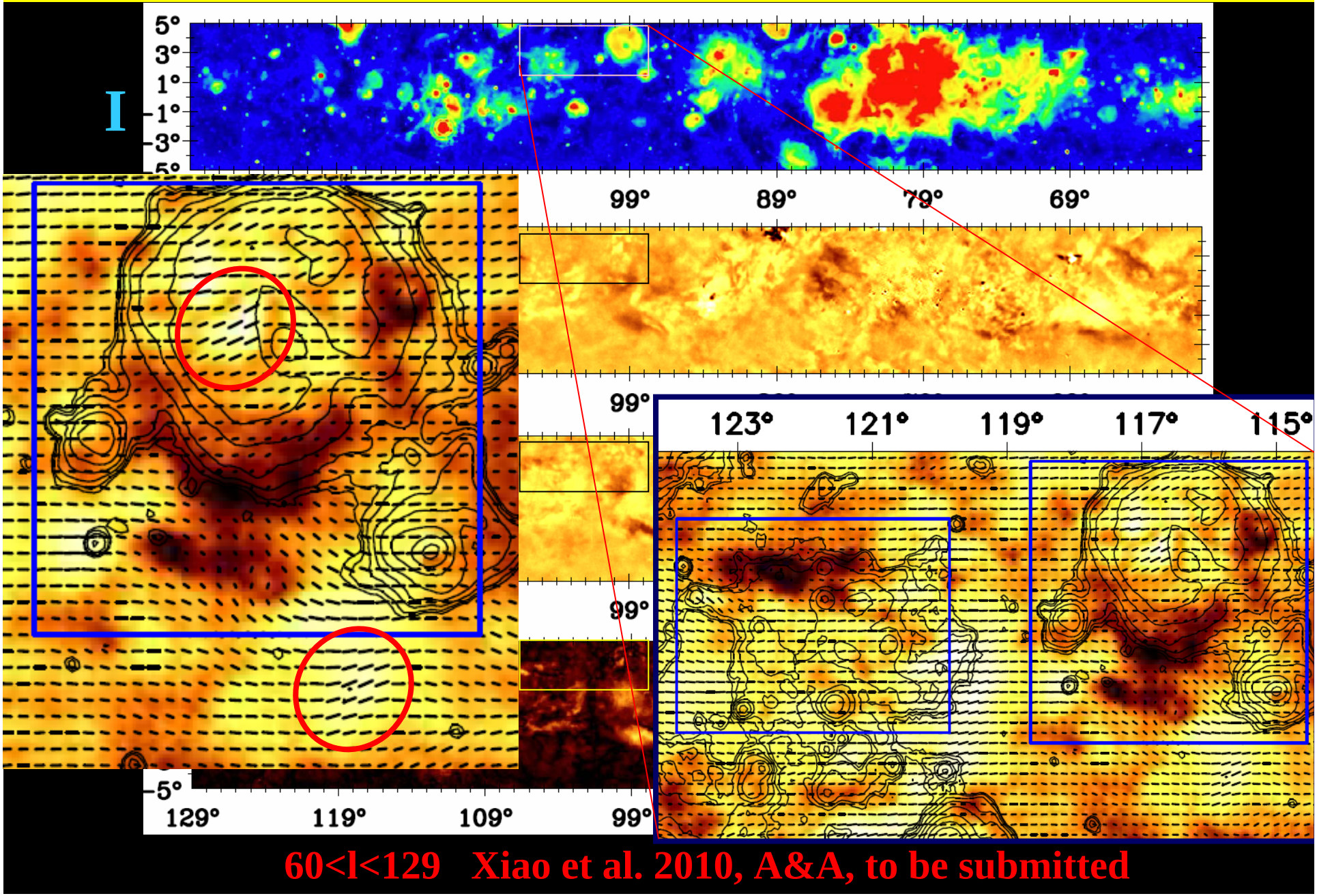
Centr.freq: 4.8/4.963GHz
BW: 600 MHz/295 MHz
System temp.: 22 -25 K
HPBW: 9.5arcmin
1st side lobe: 2%
Instr. polarization: <2%
Beam efficiency: 67%
Gain: 0.164 K/Jy
Obs: 2004.8—2009.4





129<l<230 Gao et al. 2010, A&A, in press

Depolarization in the periphery of HII regions



60<l<129 Xiao et al. 2010, A&A, to be submitted

Observational B-tracers: What info out?

- Polarization of starlight: ***perpendicular field in 2 or 3 kpc***
  orientation // $B_{\perp}$ ---------- 9000 +? stars
- Polarization at infrared, mm, submm: ***perpendicular field***
  orientation // $B_{\perp}$ ---------- clouds or regions
- Zeeman splitting: ***parallel field, in situ (masers, clouds)***
  $\Delta\nu \propto B_{//}$ ------ 137 maser regions & 17 coulds
- Synchrotron radiation: ***vertical field structures (added)***
  total intensity $S \propto B_{\perp}^{2/7}$, $p\% \propto B_{\perp u}^{2} / B_{\perp t}^{2}$
- Faraday rotation: ***parallel field, integrated (the halo & disk)***
  $RM \propto \int n_e B_{//} ds$ ------ 1024 pulsars + >3000 EGSes

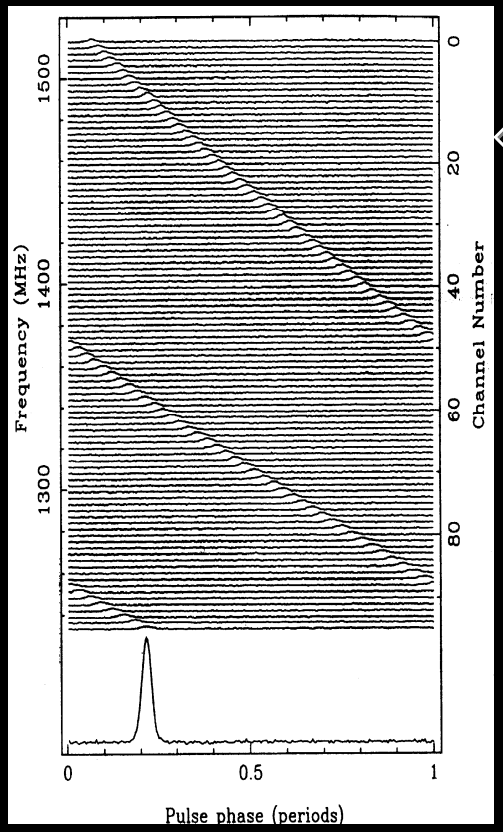
Pulsars as best probes for Galactic B-field

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

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

- n_e: can be measured:

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



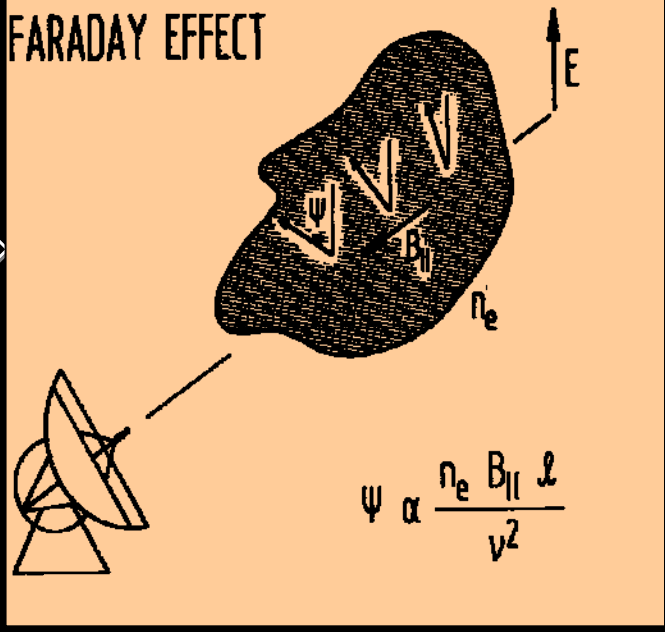
<== the delay tells DM

$$\Delta t = 8.3\times10^3\, DM\,\frac{\Delta\nu}{\nu_{MHz}^3}\,\mathrm{sec}$$

the rotation of position angles tells RM value ==>

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

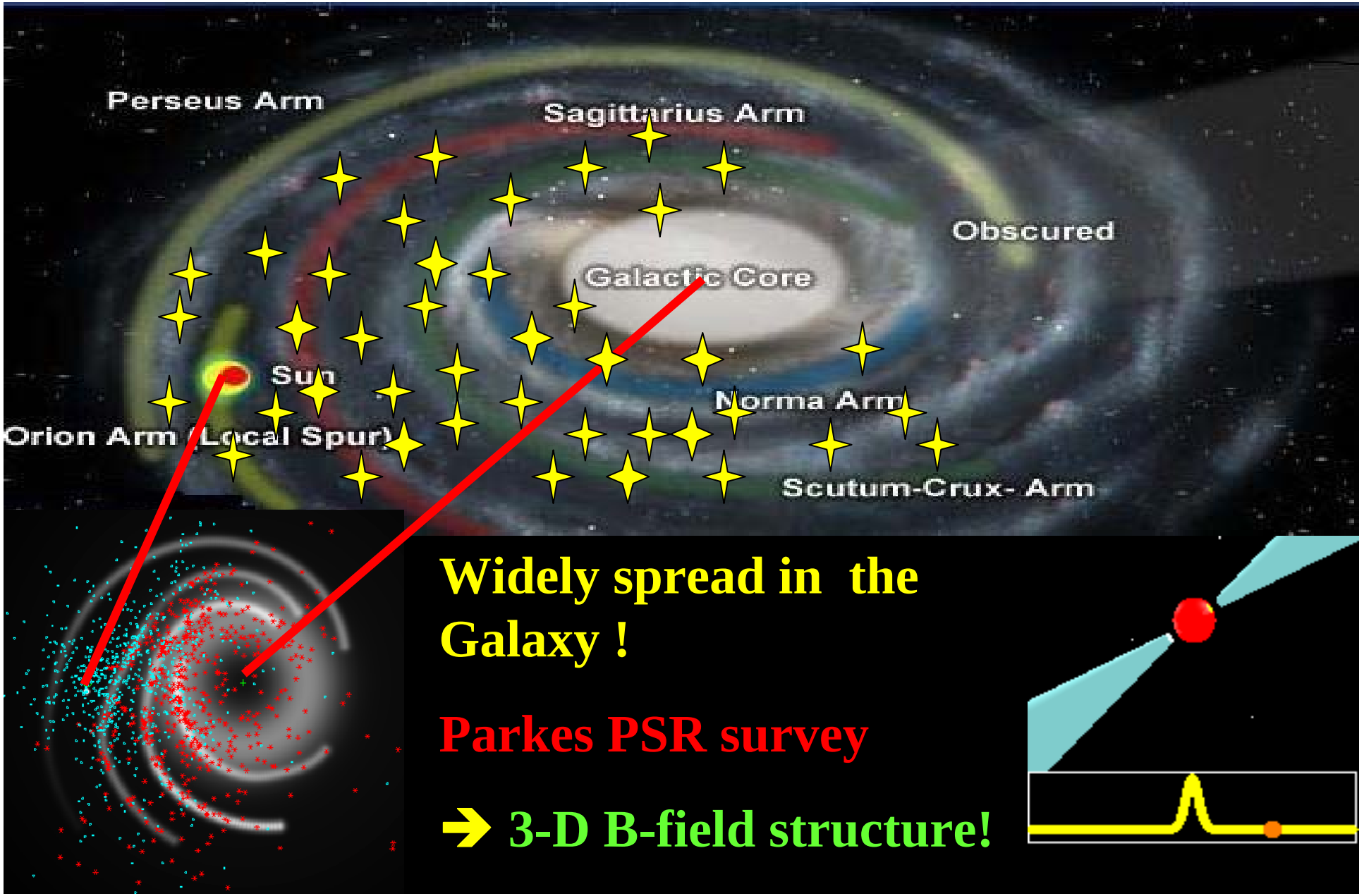
FARADAY EFFECT



Average field strength can be directly derived

$$\left\langle B_{\parallel}\right\rangle = 1.232\frac{RM}{DM}\,\mu G$$

Pulsars: Best probes for Galactic magnetic field



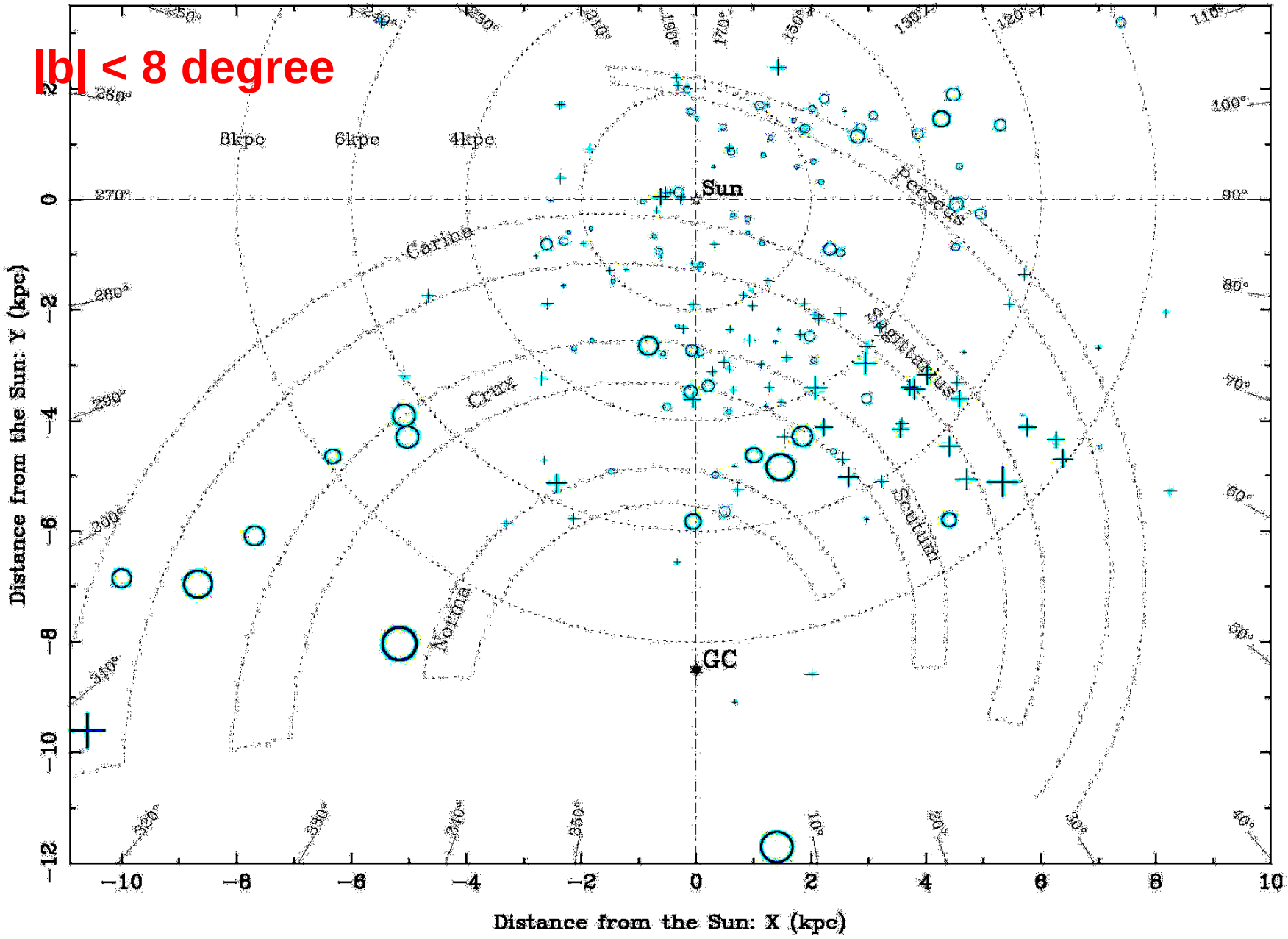
Major observations of pulsar RMs

Authors	No. of RMs	No. New RMs
Hamilton & Lyne (1987)	163	119
Rand & Lyne (2004):	27	27
Qiao et al. (1995)	48	33
Han et al. (1999)	63	54
Weisberg et al. (2003)	36	17
Han et al. (2006):	223	196
Noutsos et al. (2008)	150	43
Han et al. (2010 to submit!):	477	400

1st big step!

2nd big step!
>500 hours
at Parkes

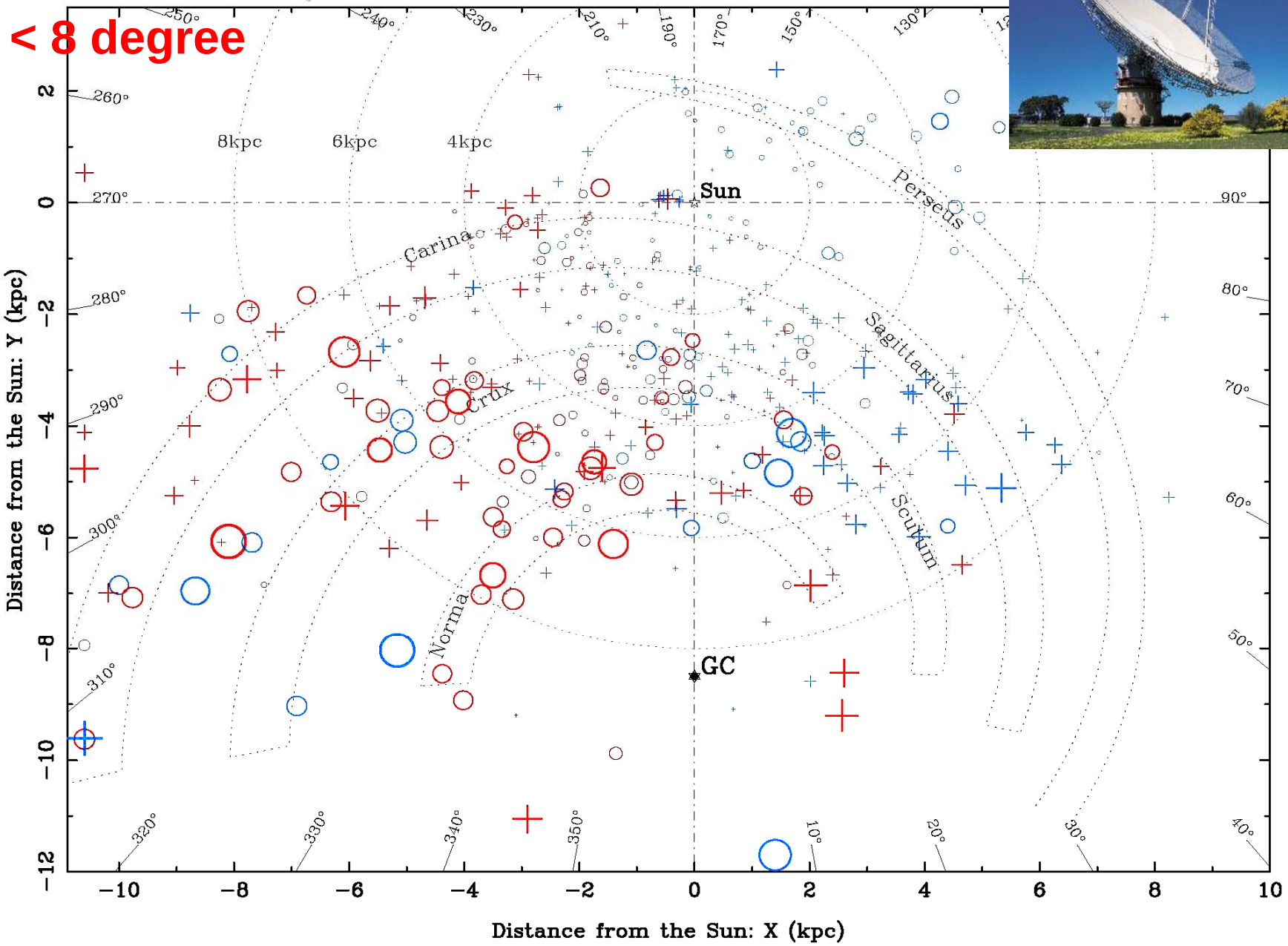
Pulsar RMs observed by others



63+223 RMs by Parkes

(Han et al. 1999, 2006)

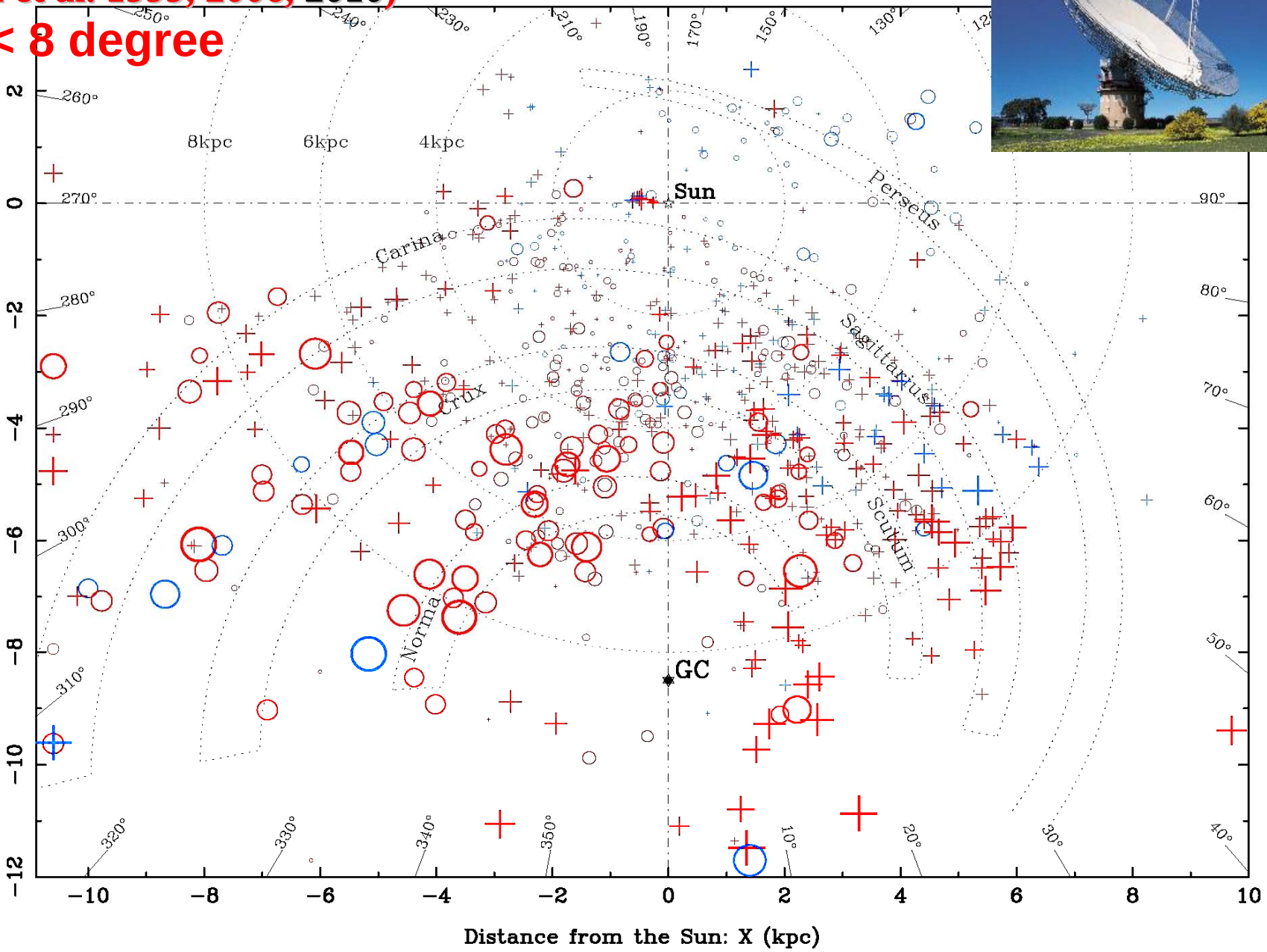
|b| < 8 degree



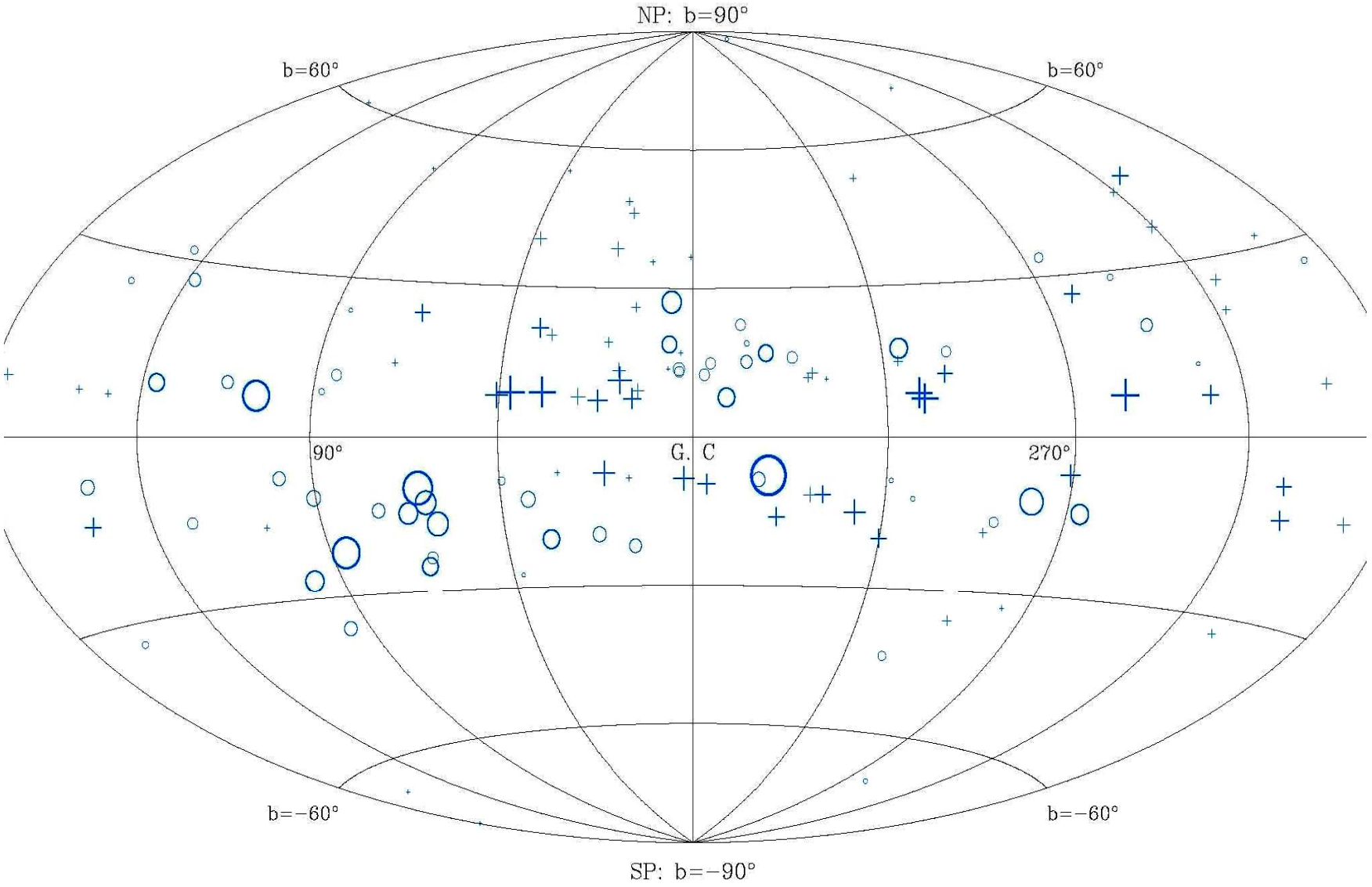
63+223+477 RMs by Parkes +GBT

(Han et al. 1999, 2006, 2010)

|b| < 8 degree

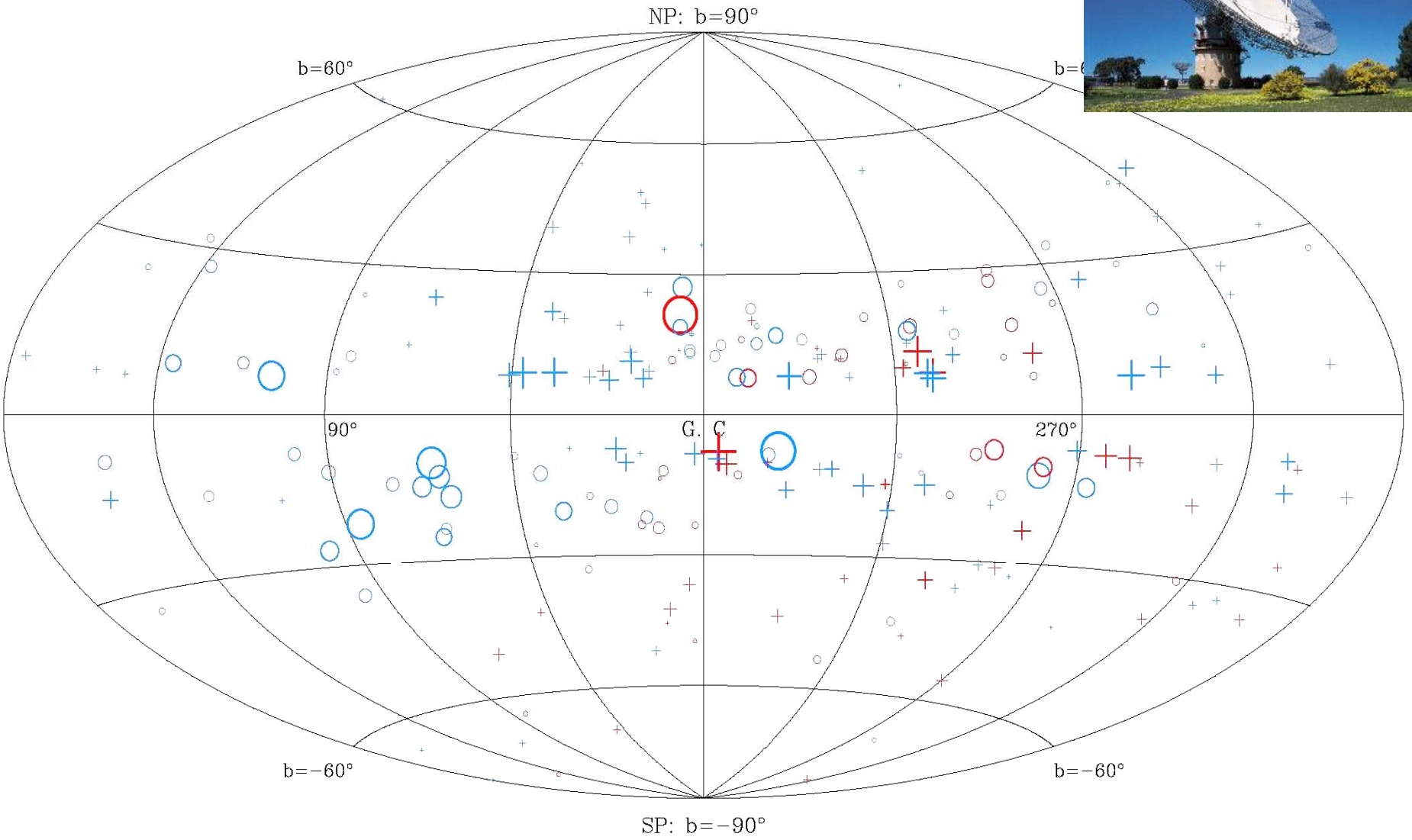


Pulsar RMs observed by others



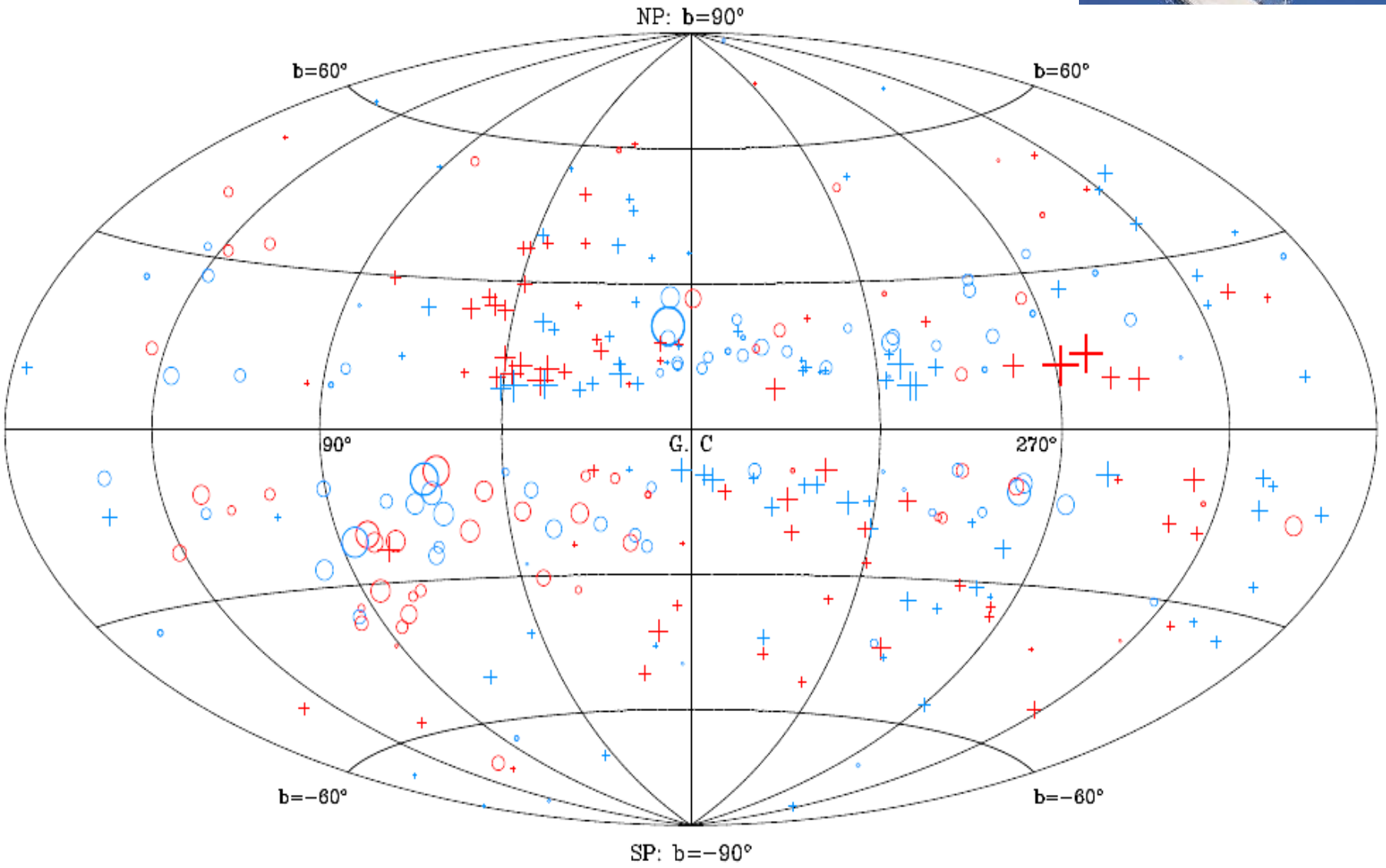
|b| > 8 degree

63+223 RMs by Parkes (Han et al. 1999, 2006)



|b| > 8 degree

63+223+477 RMs by Parkes +GBT
(Han et al. 1999, 2006, 2010)

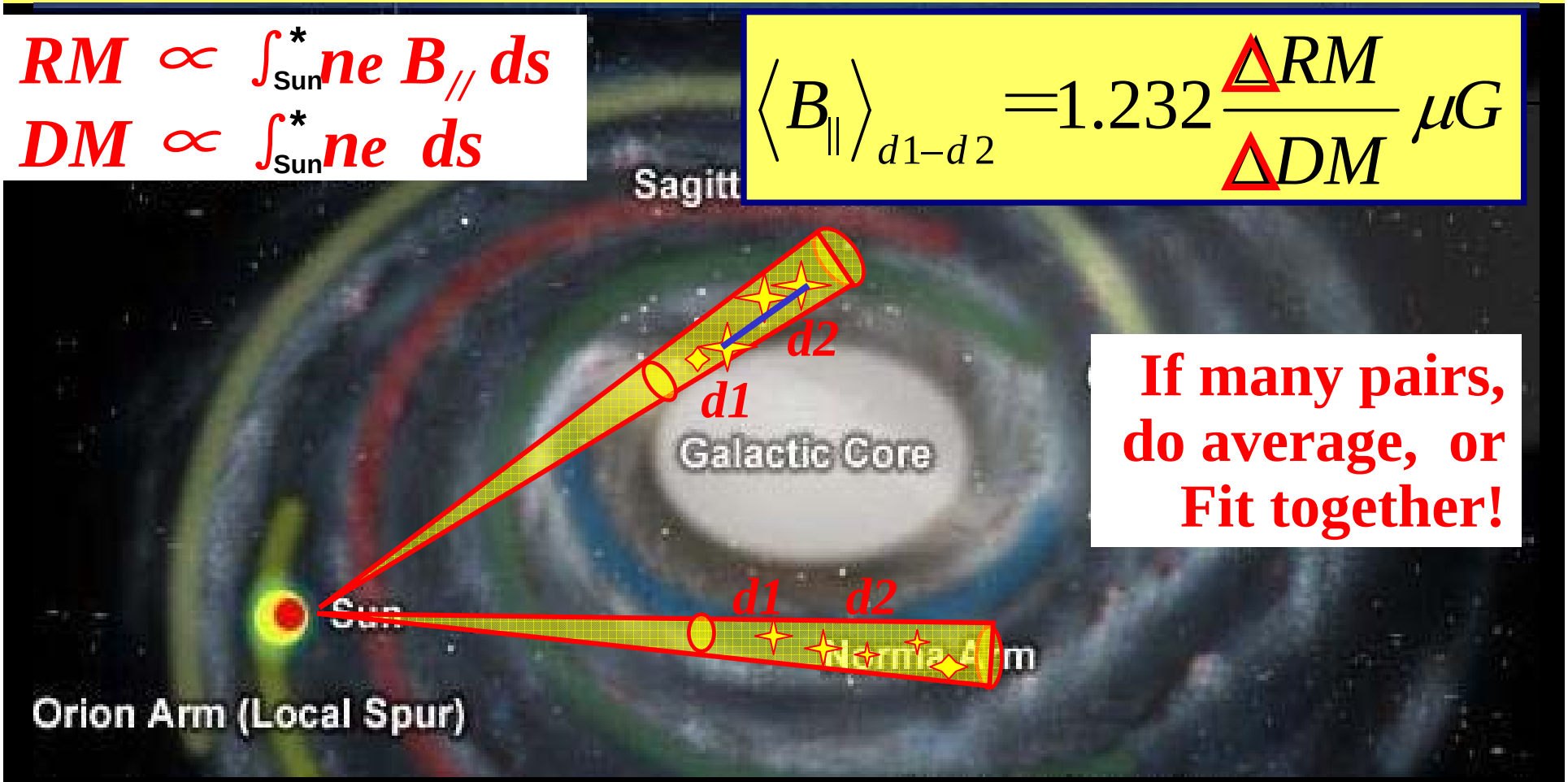


|b| > 8 degree

Paired probes to measure B-field in a region

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

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



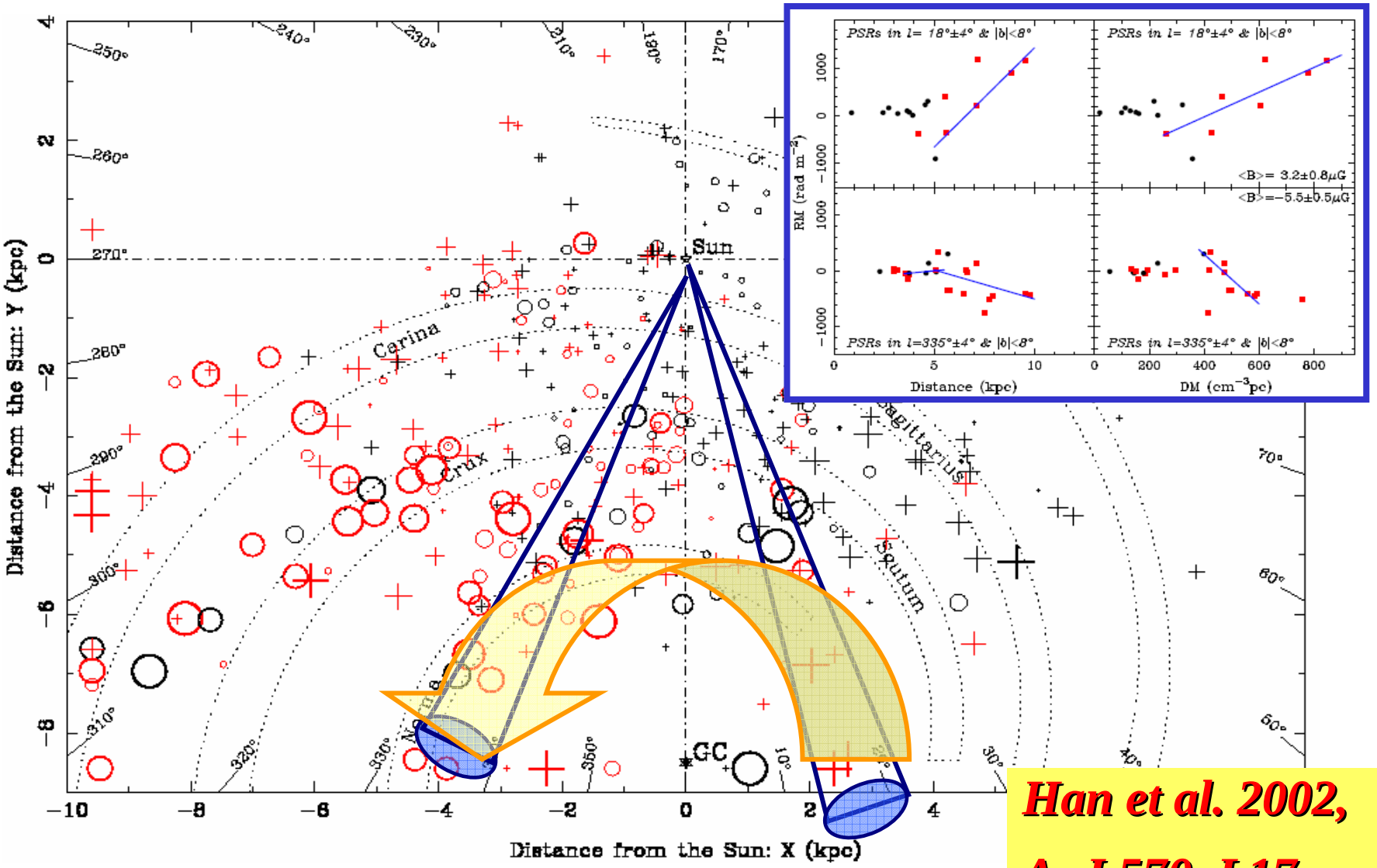
If many pairs, do average, or Fit together!

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

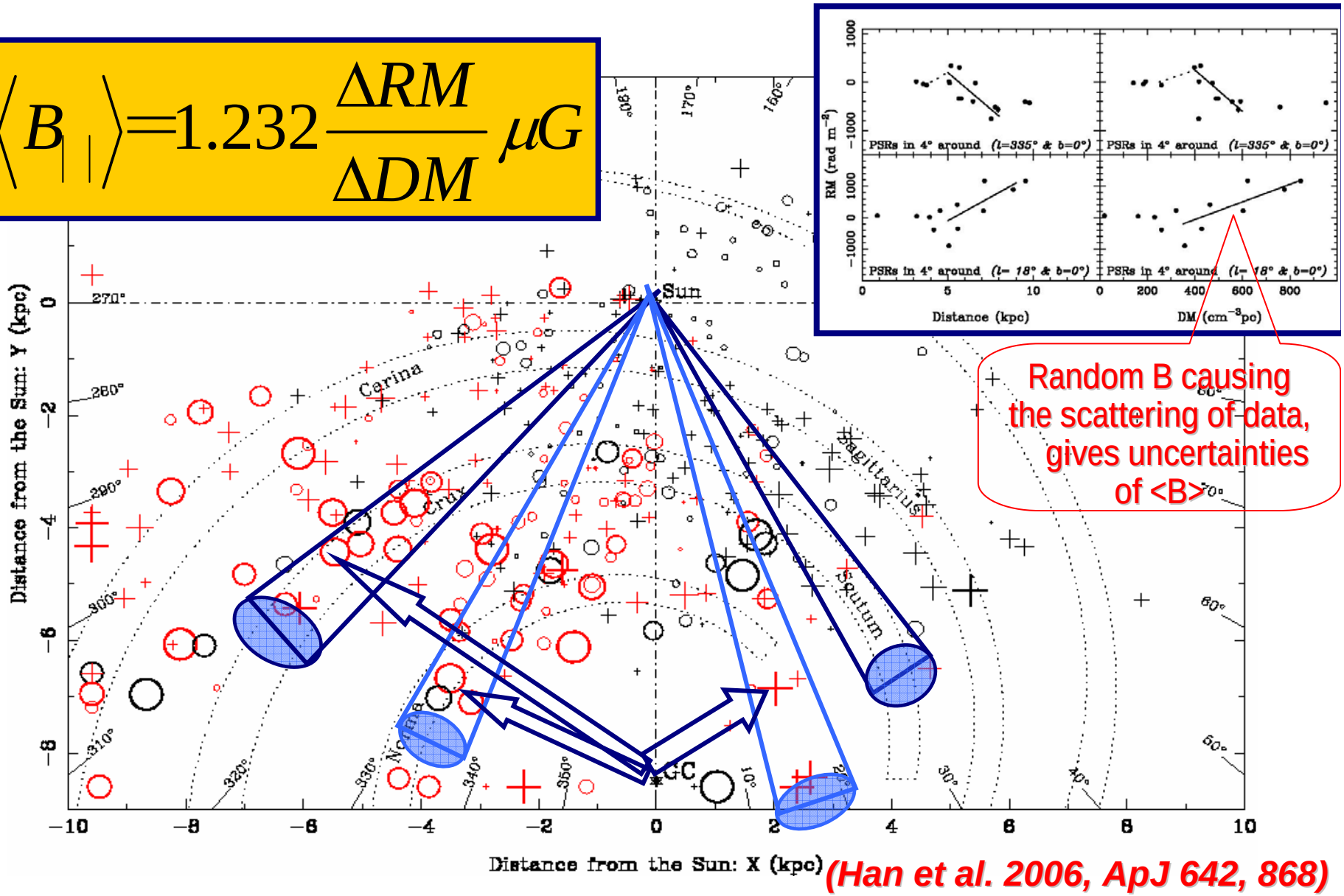
red: new measurements by Parkes 64m telescope



Han et al. 2002, ApJ 570, L17

Measuring B-field in tangential regions!

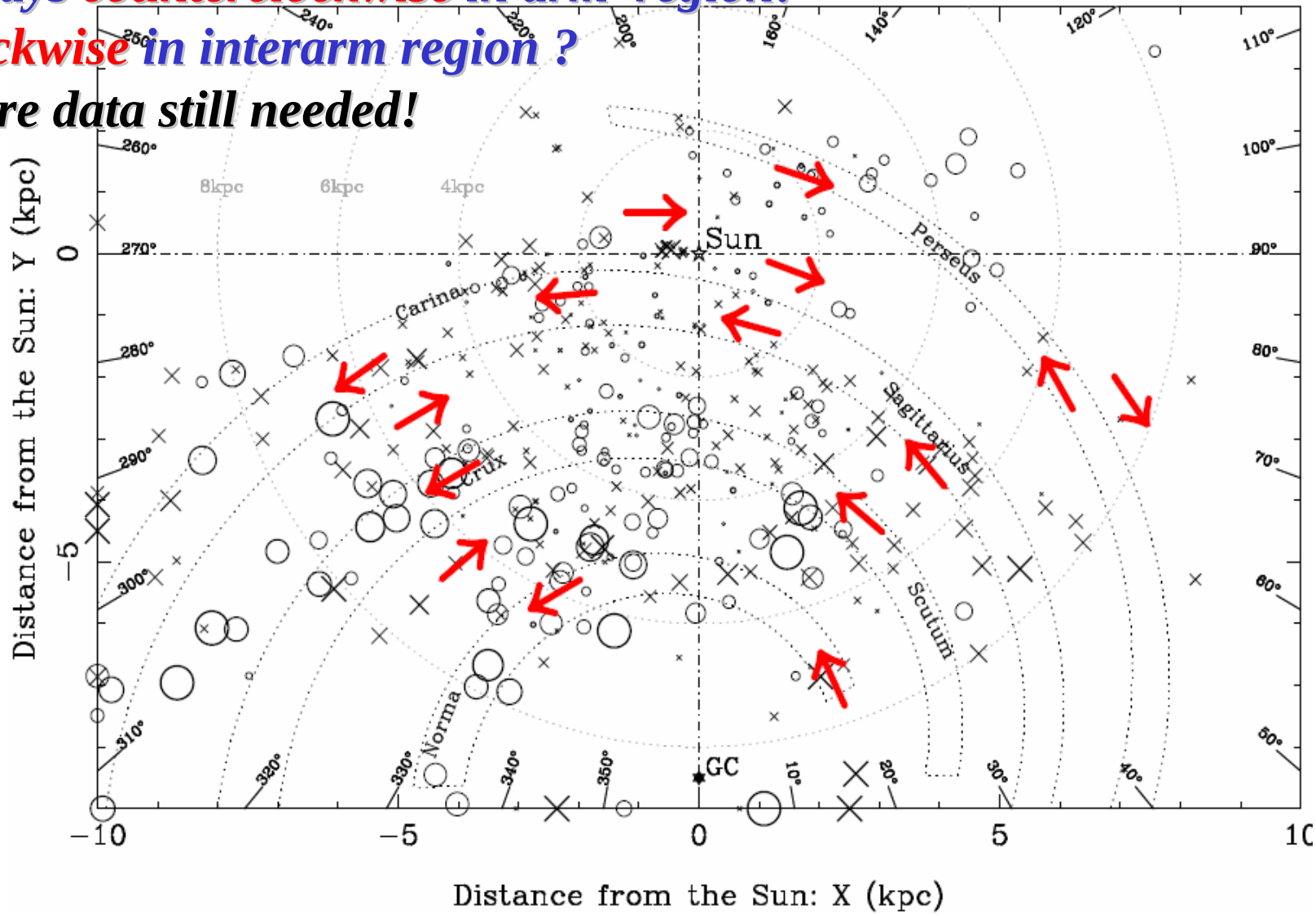
$$\langle B_{||} \rangle = 1.232 \frac{\Delta RM}{\Delta DM} \mu G$$



(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!***



Measured Radial dependence of regular field strength

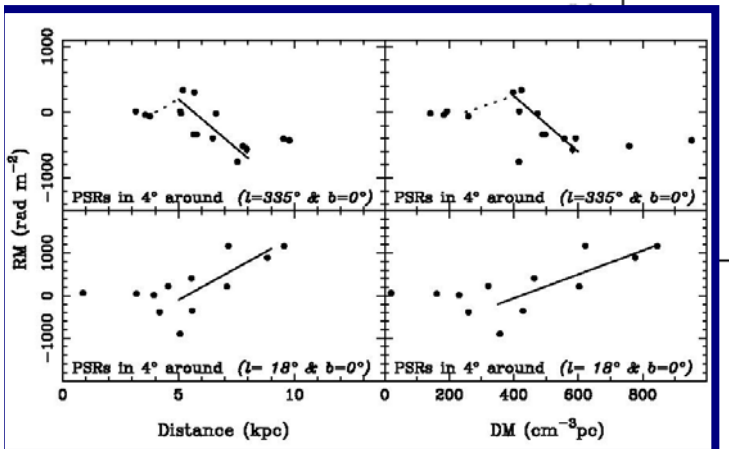
$$B_{\rm regular}(R) = B_0 \bullet \exp[\frac{-(R-R_\oplus)}{R_B}]$$

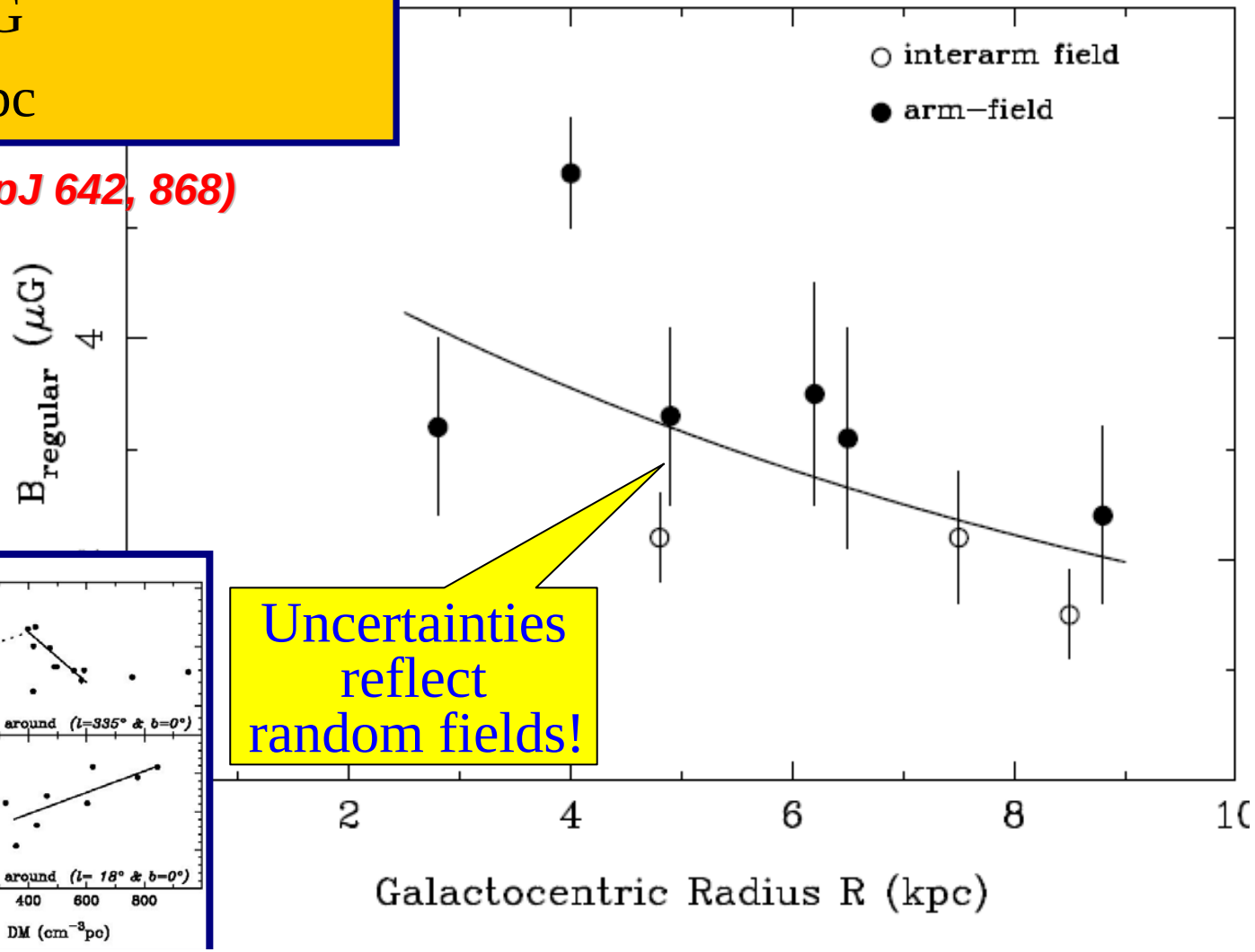
$$B_0 = 2.1 \pm 0.3\,\mu{\rm G}$$

$$R_B = 8.5 \pm 4.7\,{\rm kpc}$$

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

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



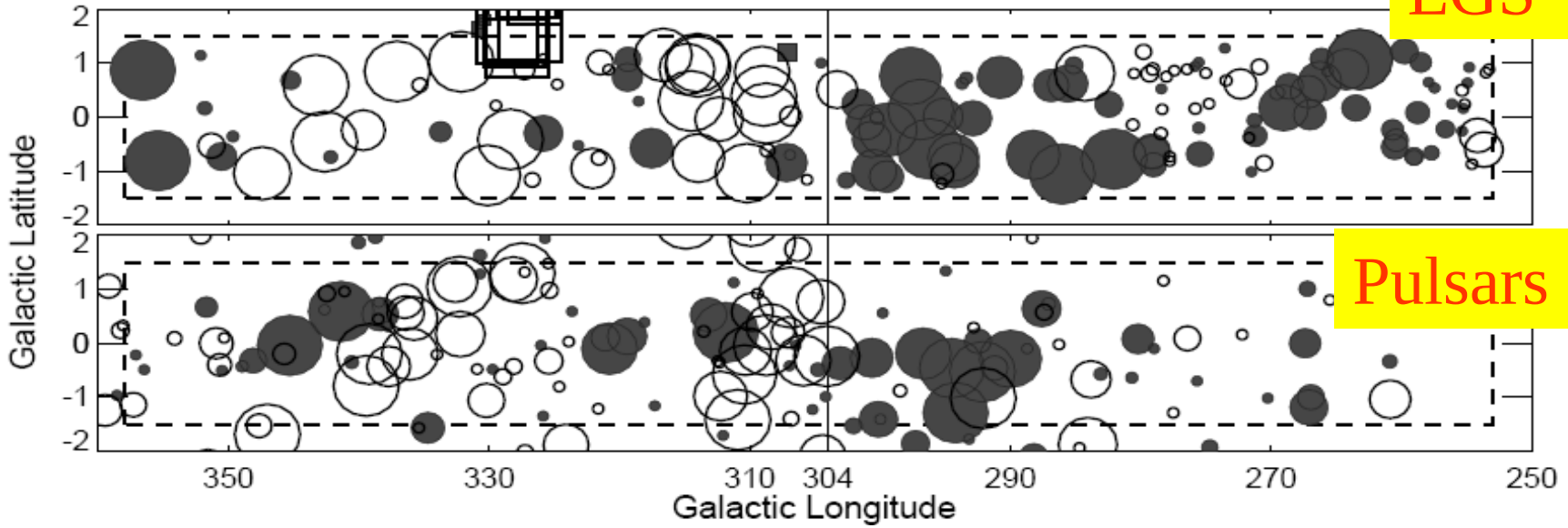


Uncertainties reflect random fields!

RMs from the southern Galactic plane

Brown et al. 2007

EGS



Pulsars

RMs of Extragalactic radio sources

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

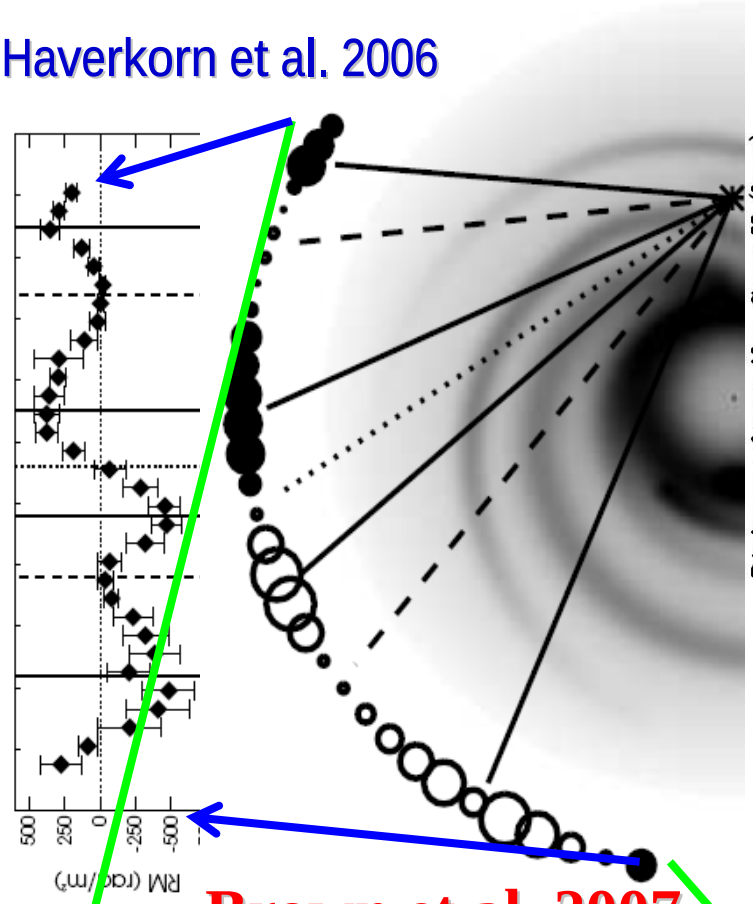
$$RM_{obs} = RM_{intrinsic} + RM_{InterGalactic} + RM_{MilkyWay}$$

Common term!

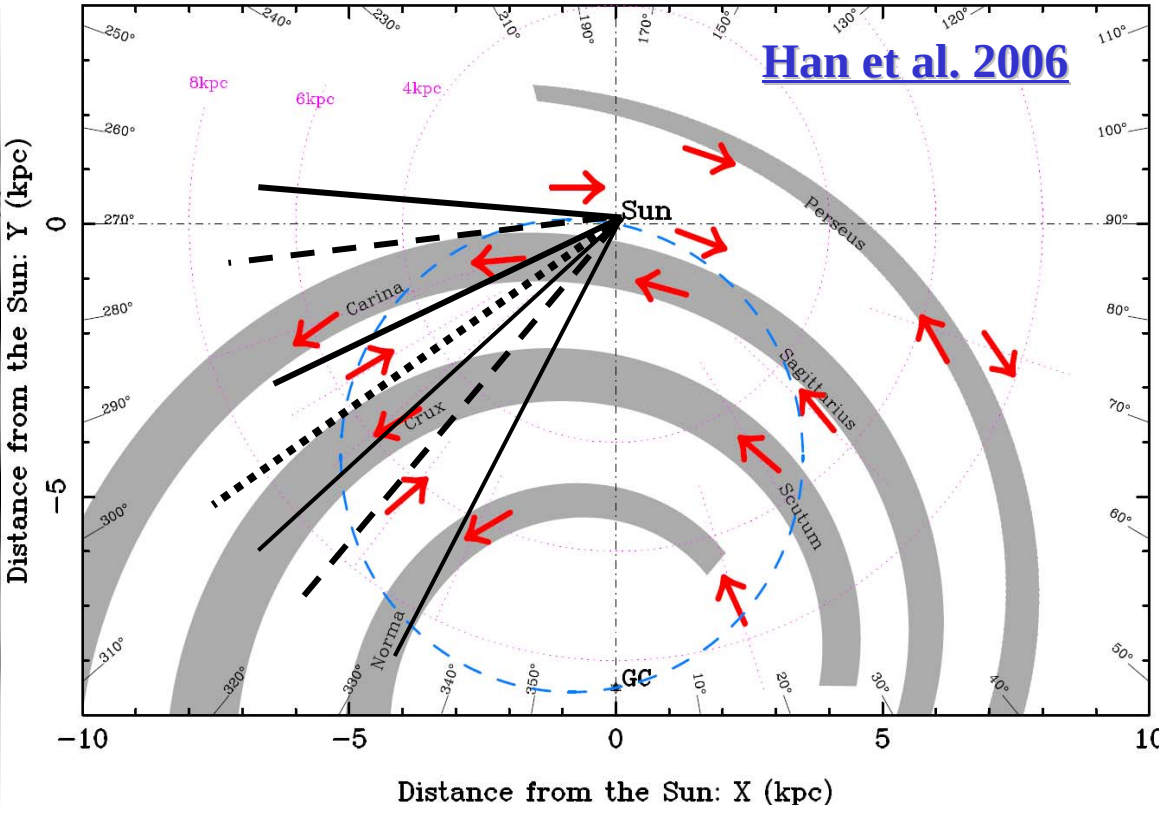
- $RM_{intrinsic}$ **: RM intrinsic to the source;**
  - **They never know each other: uncorrelated ➔ Random!**
  - **Location of emission regions: ➔ Beam size?**
- $RM_{InterGalactic}$ **: RM from intergalactic space;**
  - **weak correlated if with same intervening medium**
  - **Small values ??**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

RMs from radio sources behind the Galactic plane: Consistent with B-Structure from pulsar data!

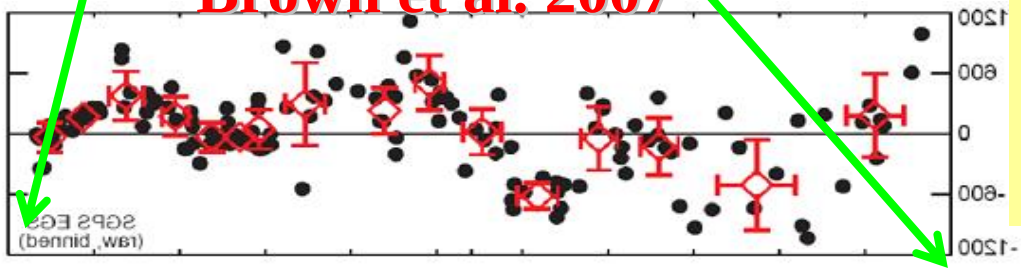
Haverkorn et al. 2006



Han et al. 2006

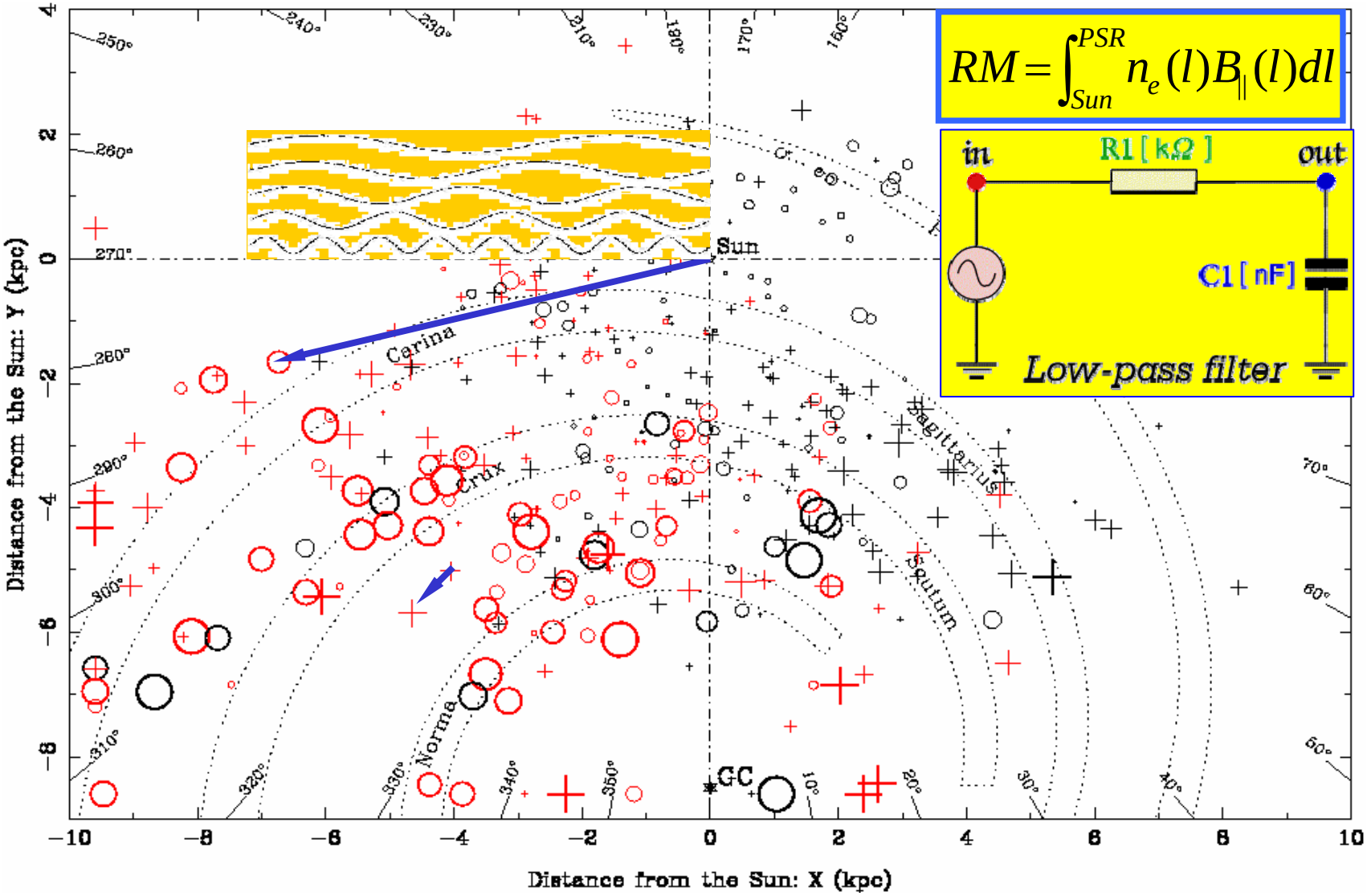


Brown et al. 2007



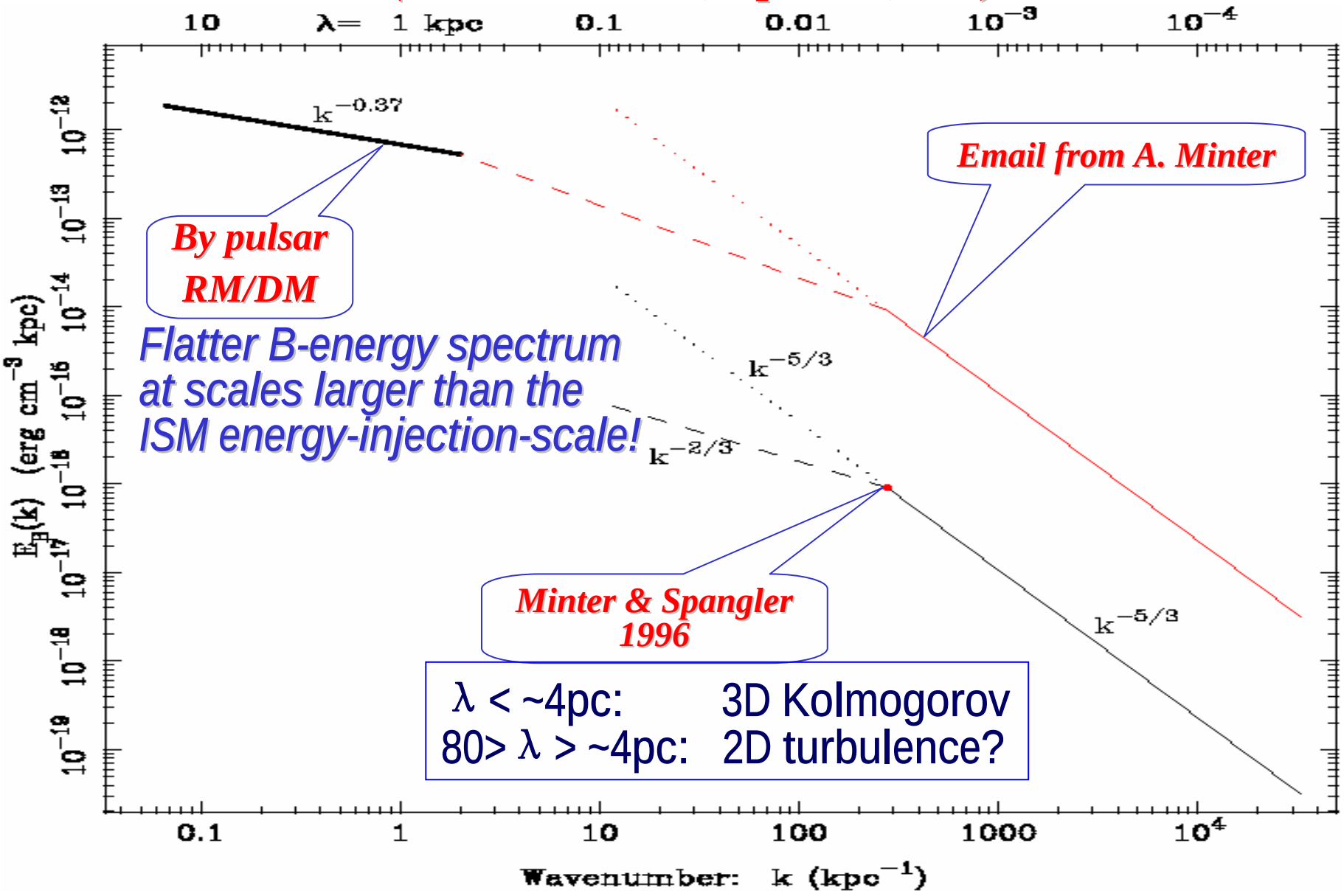
- PSR and EGRs data show a consistent B-structure!
- Dominant RM contribution from tangential regions!

Measuring the *B-field* ***fluctuation*** vs ***scales***



Spatial magnetic energy spectrum of our Galaxy

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

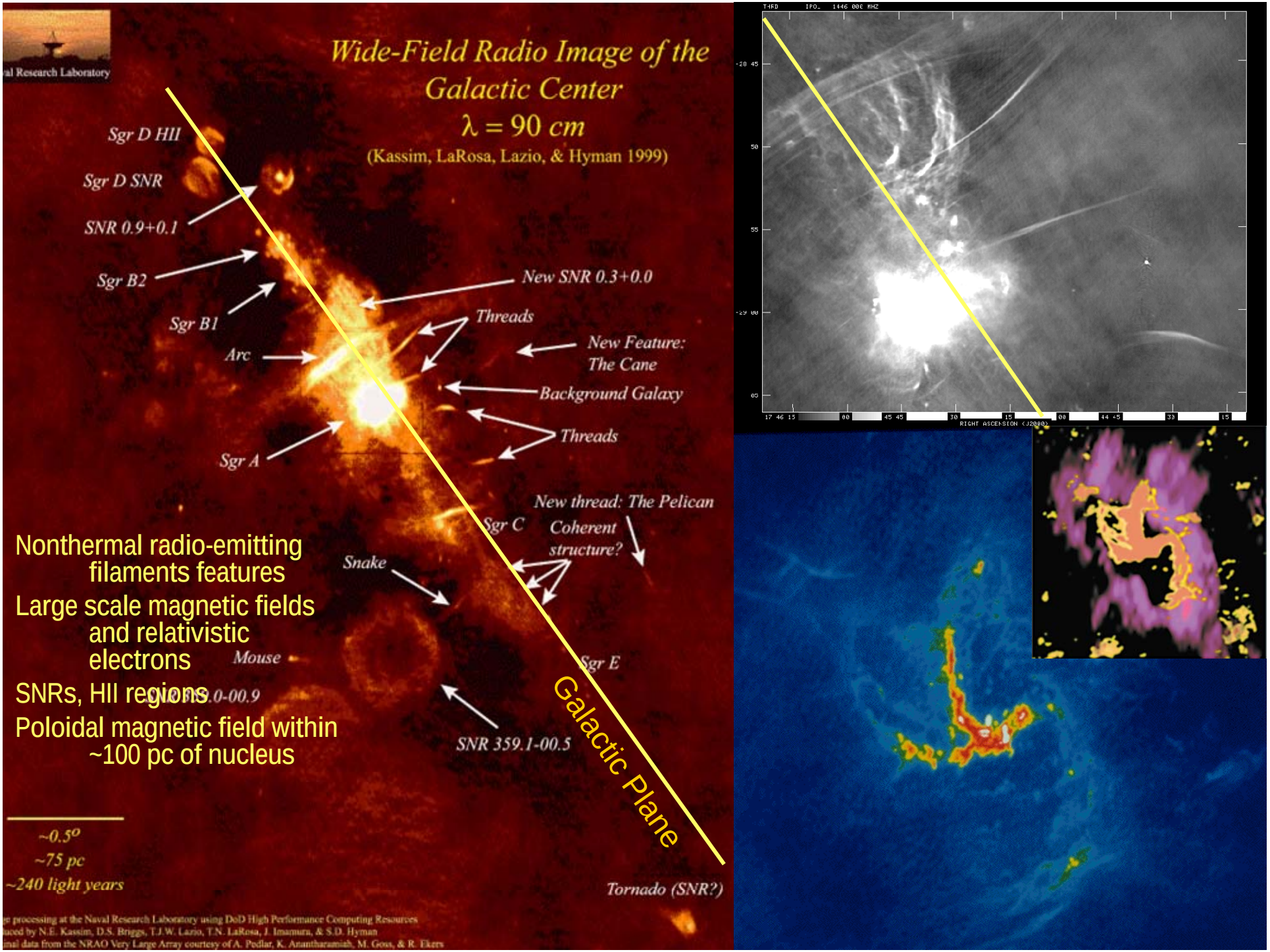


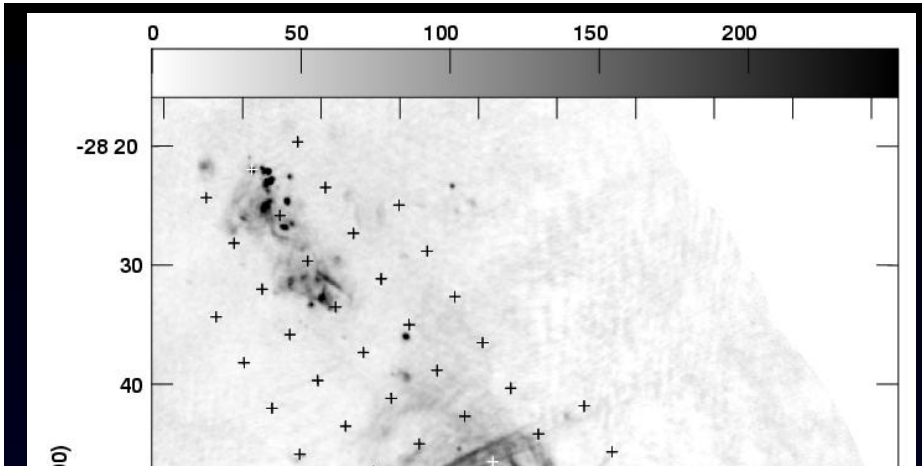
Measurements of *Galactic magnetic fields*

- Methods to measure
- Results of measurements
  - Galactic disk
  - Galactic center
  - Galactic halo
  - Random fields
- Conclusions

Galactic center: filaments and polarization

- **Poloidal fields**
  - Nonthermal filaments: more discosvery!
  - cm-polarization obs: RMs and intrinsic field
- **Toroidal fields**
  - submm, mm polarization: clouds
  - RMs of background radio sources
- **Field structure and field strength**
  - mG in filaments?
  - Zeeman splitting: mG field
  - uG in pervading regions?


Wide-Field Radio Image of the Galactic Center
λ = 90 cm
(Kassim, LaRosa, Lazio, & Hyman 1999)
Sgr D HII
Sgr D SNR
SNR 0.9+0.1
Sgr B2
Sgr B1
Arc
New SNR 0.3+0.0
Threads
New Feature: The Cane
Background Galaxy
Threads
Sgr A
New thread: The Pelican
Sgr C
Coherent structure?
Snake
Mouse
Sgr E
SNR 359.1-00.5
Galactic Plane
Tornado (SNR?)
~0.5°
~75 pc
~240 light years
Nonthermal radio-emitting filaments features
Large scale magnetic fields and relativistic electrons
SNRs, HII regions
Poloidal magnetic field within ~100 pc of nucleus

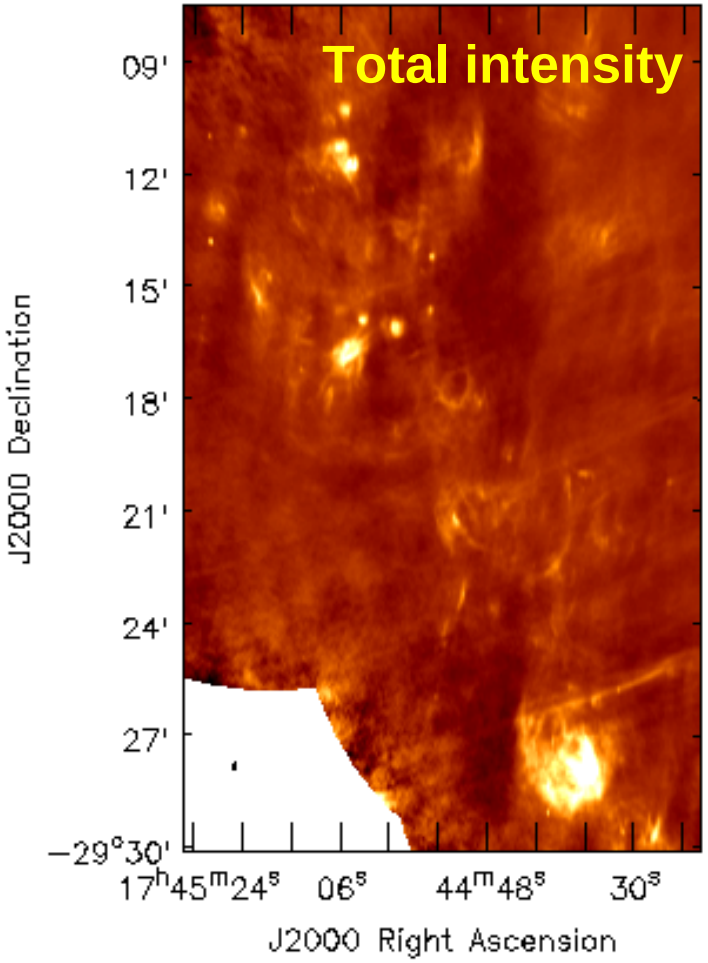


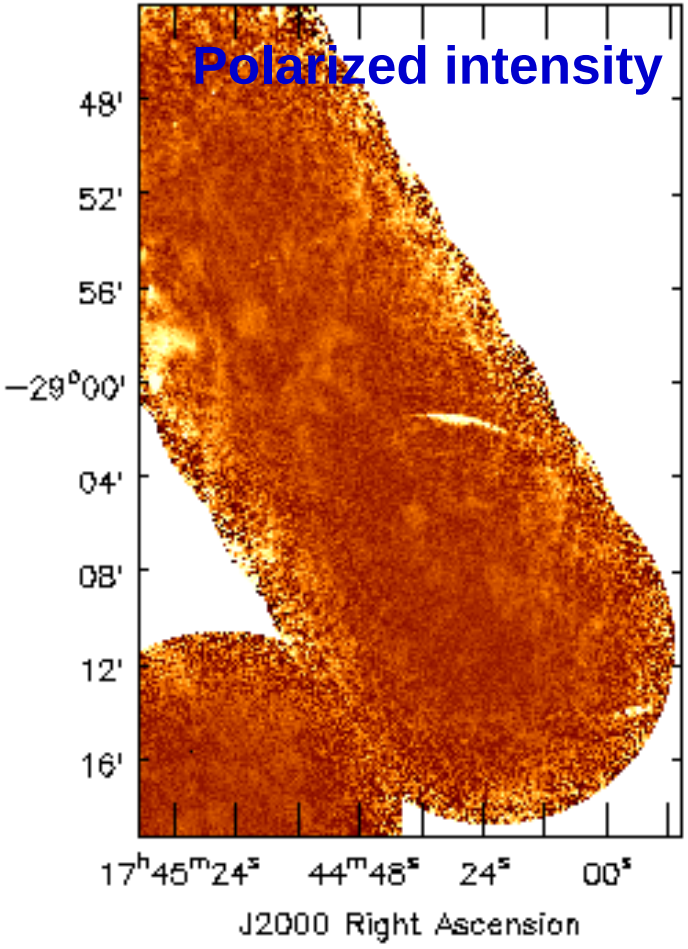
New Galactic Center Survey

D and C array - 4.9 GHz
Full polarization
~1 hour per pointing

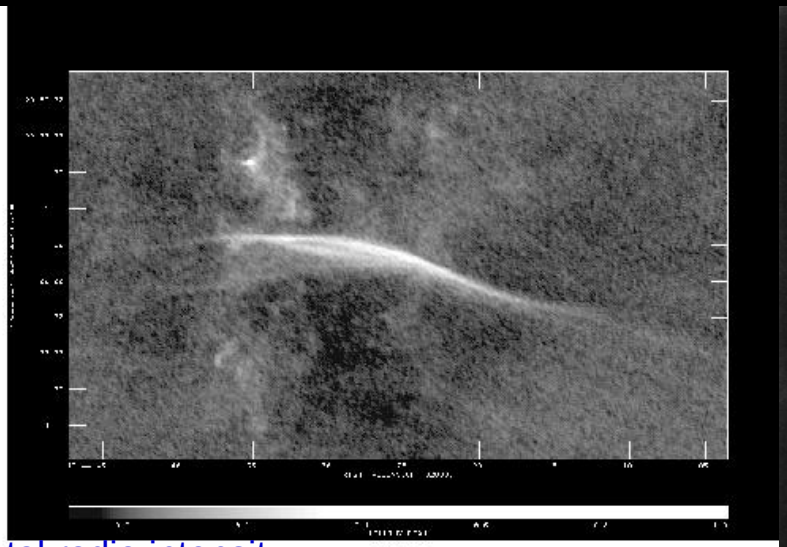
on
on

s
array
ep)



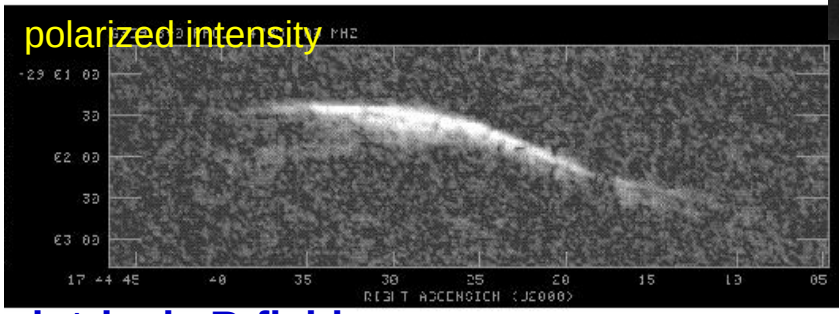


NTF G359.79+0.17

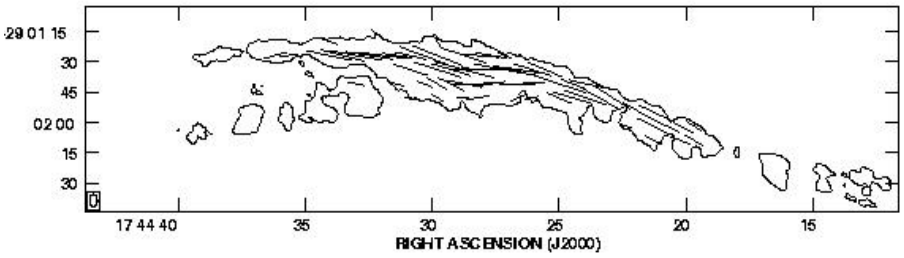


total radio intensity

polarized intensity

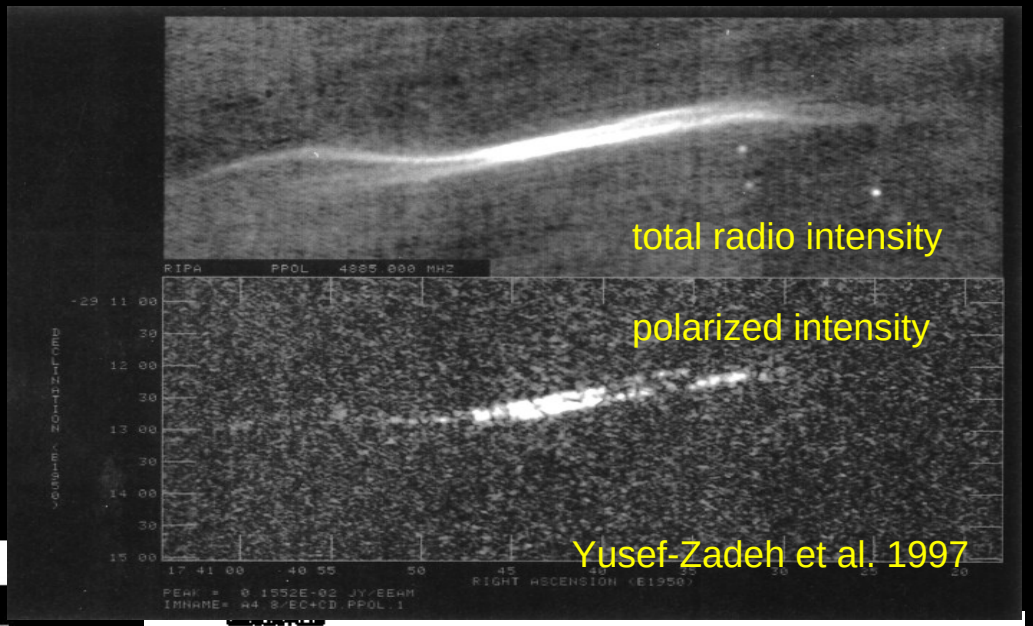


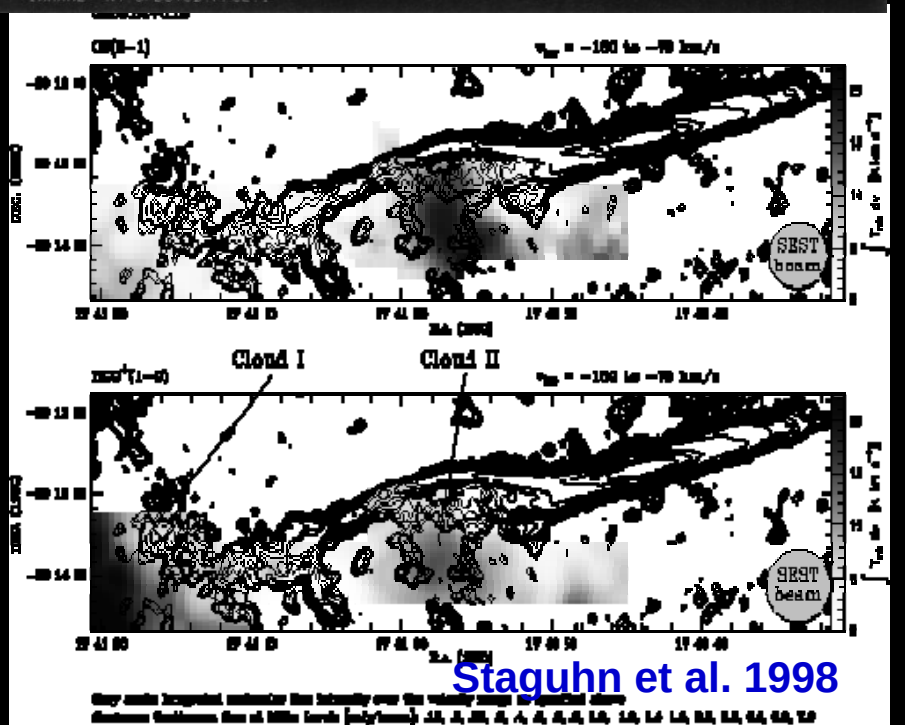
intrinsic B-field



Lang & Anantharamaiah, *in prep*.

NTF G359.79+0.17

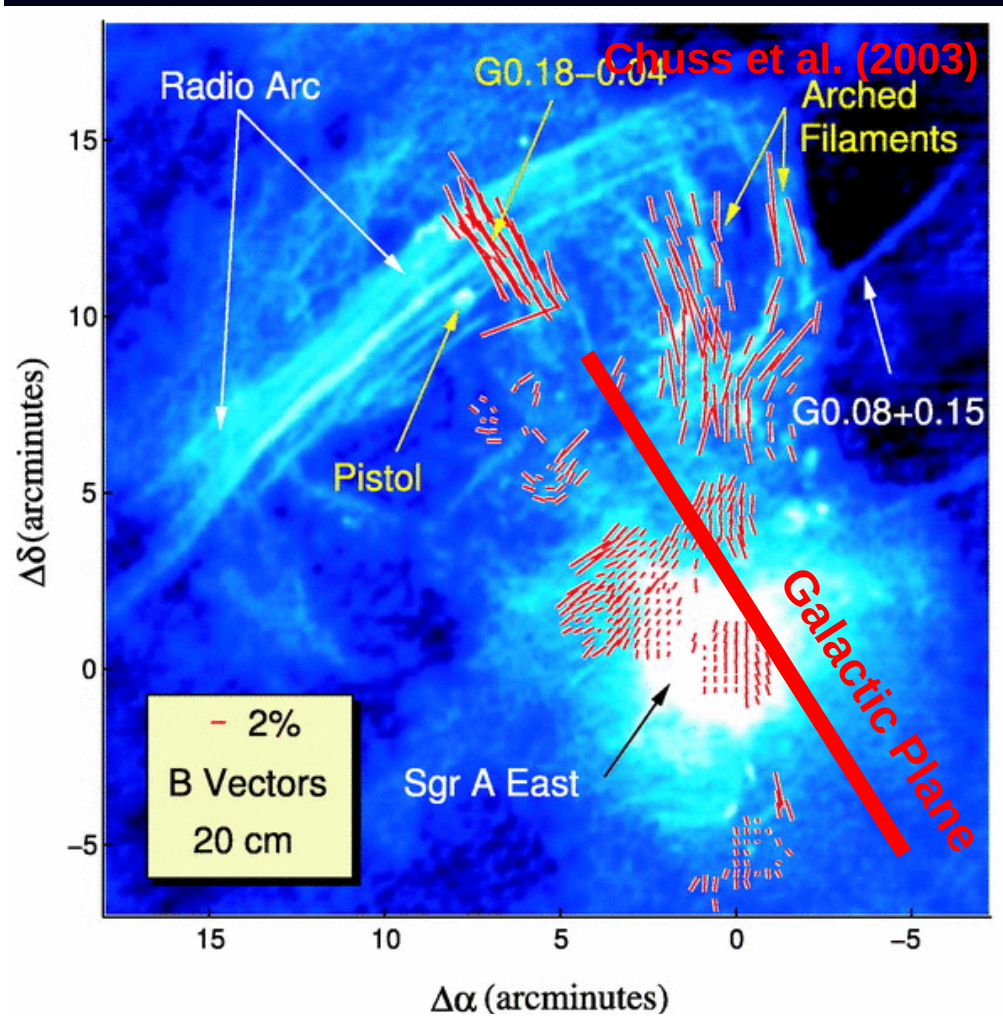




Staguhn et al. 1998

Magnetic fields in Galactic center

- traced by dust polarization (sub-mm and mm)
- oriented along the plane and perpendicular to NTFs
- a possiblility: poloidal field sheared into toroidal field?



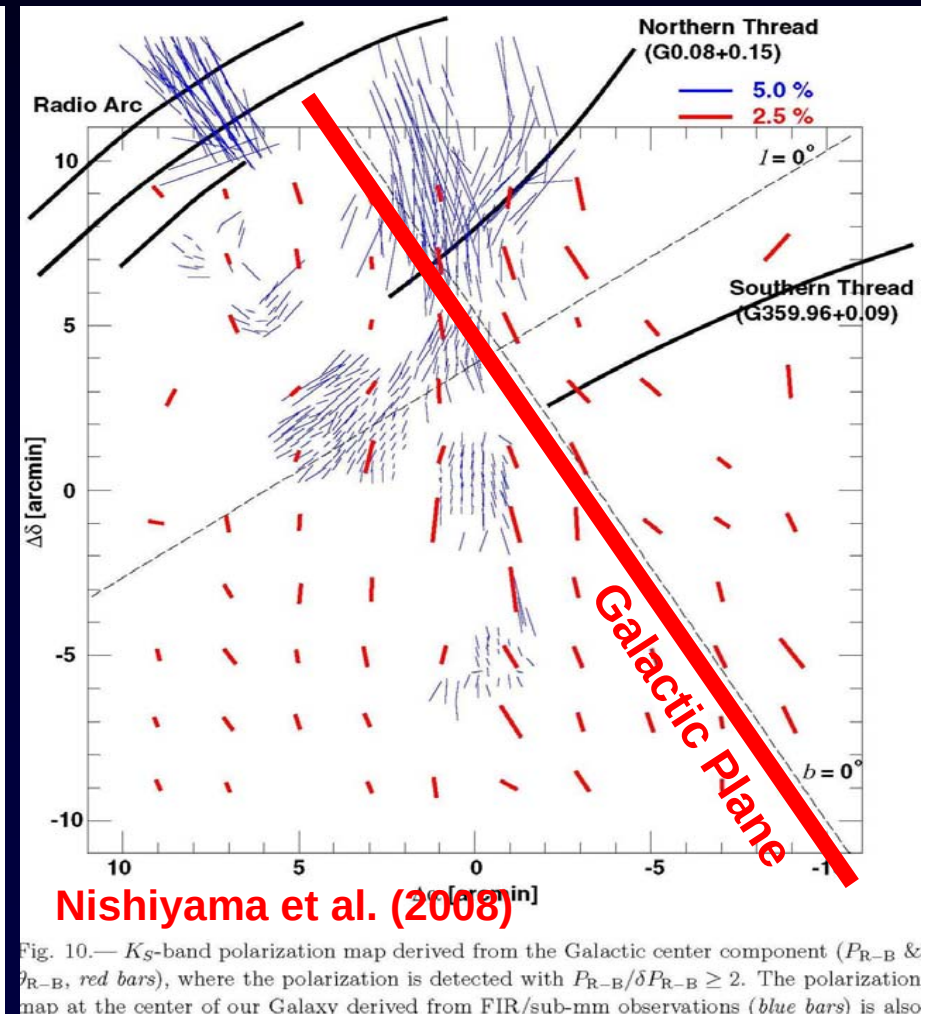
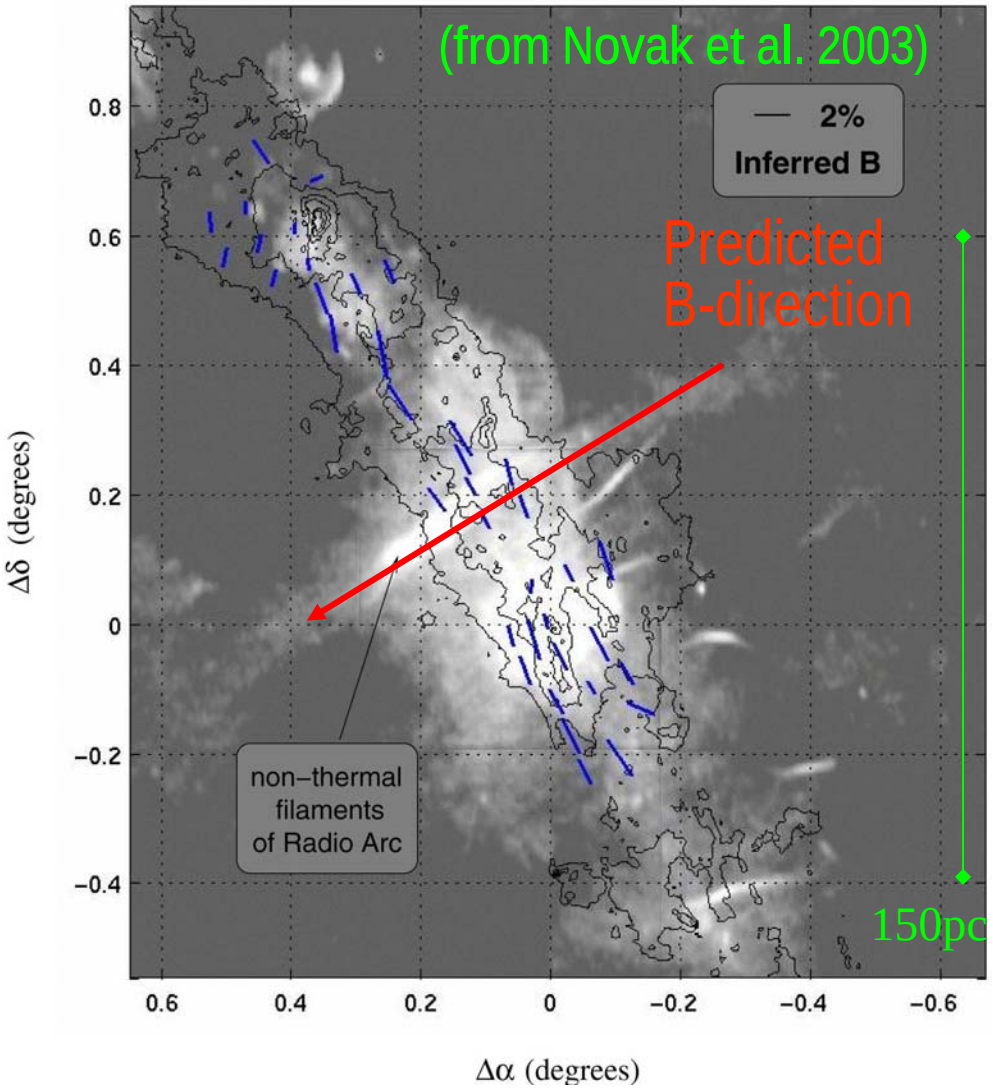


Fig. 10.— K_S-band polarization map derived from the Galactic center component (P_{R-B} & θ_{R-B}, *red bars*), where the polarization is detected with $P_{R-B}/\delta P_{R-B} \geq 2$. The polarization map at the center of our Galaxy derived from FIR/sub-mm observations (*blue bars*) is also

Poloidal & Toroidal fields near GC



Toroidal fields

(Novak et al. 2003, 2000)

- **permeated in the *central molecular zone (400pc*50pc)***
- sub-mm obs of p%
- toroidal field directions *determined by averaged RMs of plumes or SNR!*

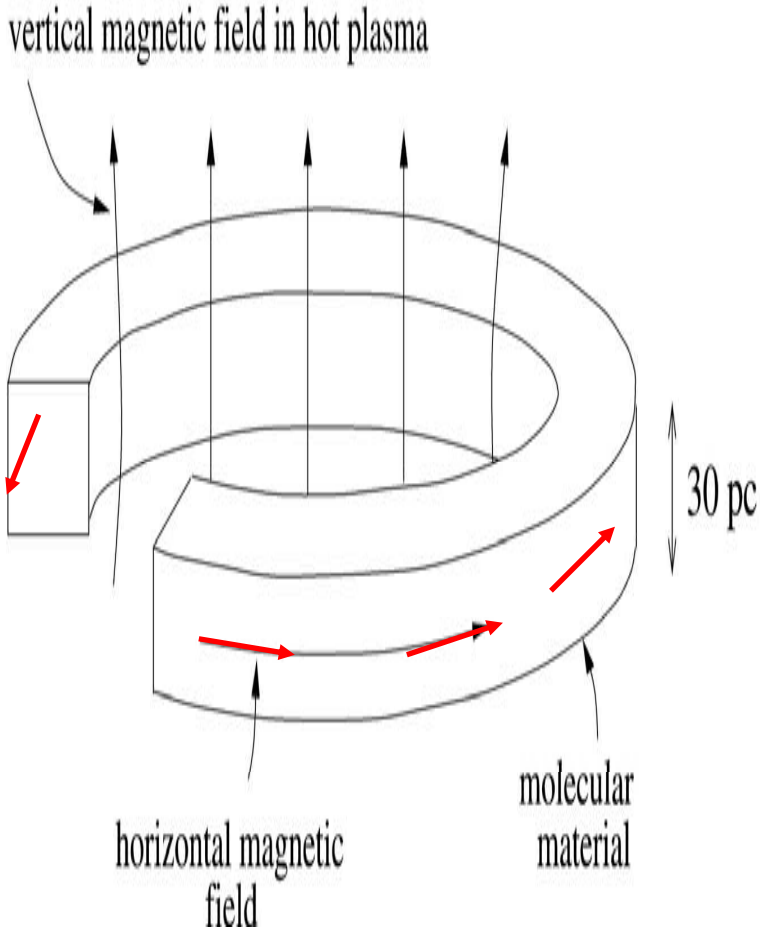
Poloidal field

filaments Unique to GC

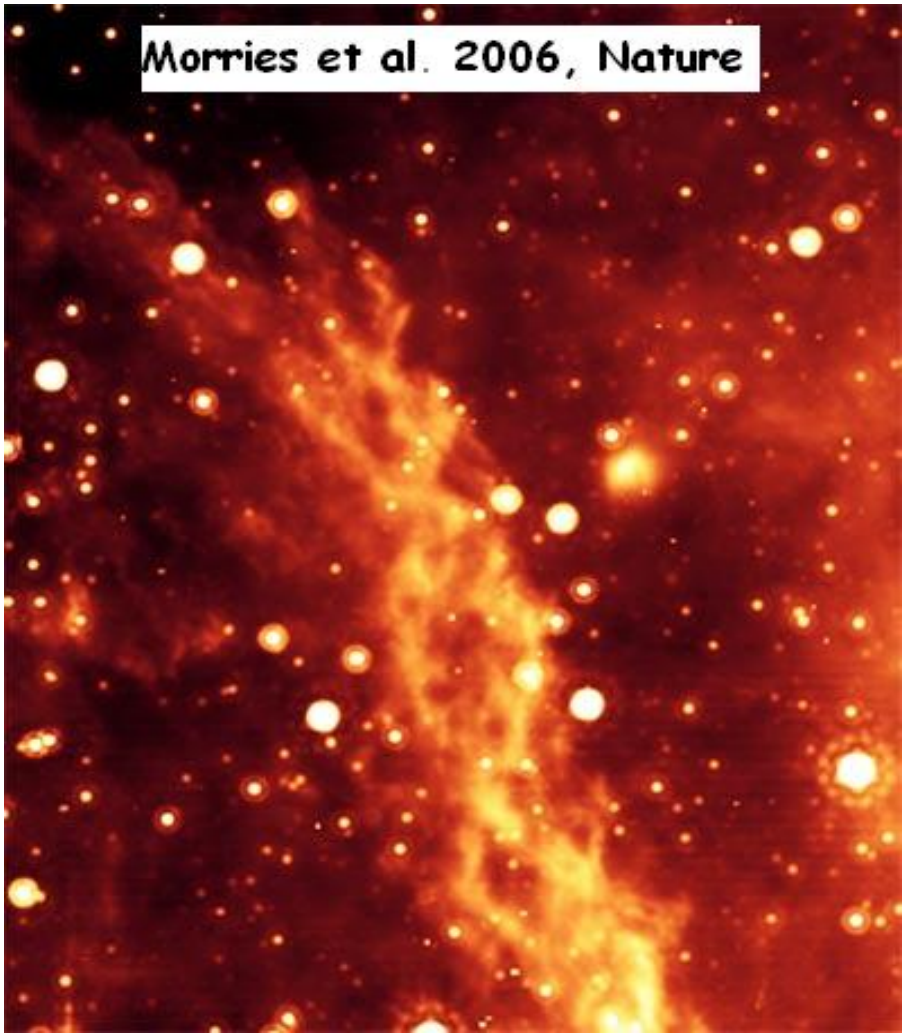
--- dipolar geometry!

(Morris 1994; Lang et al.1999)

Magnetic fields in our Galaxy: near GC

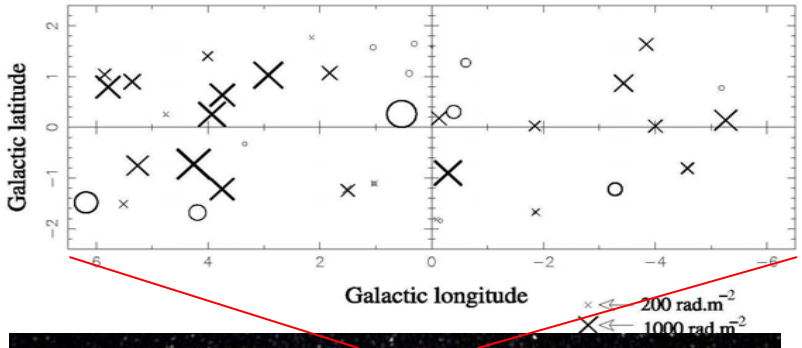


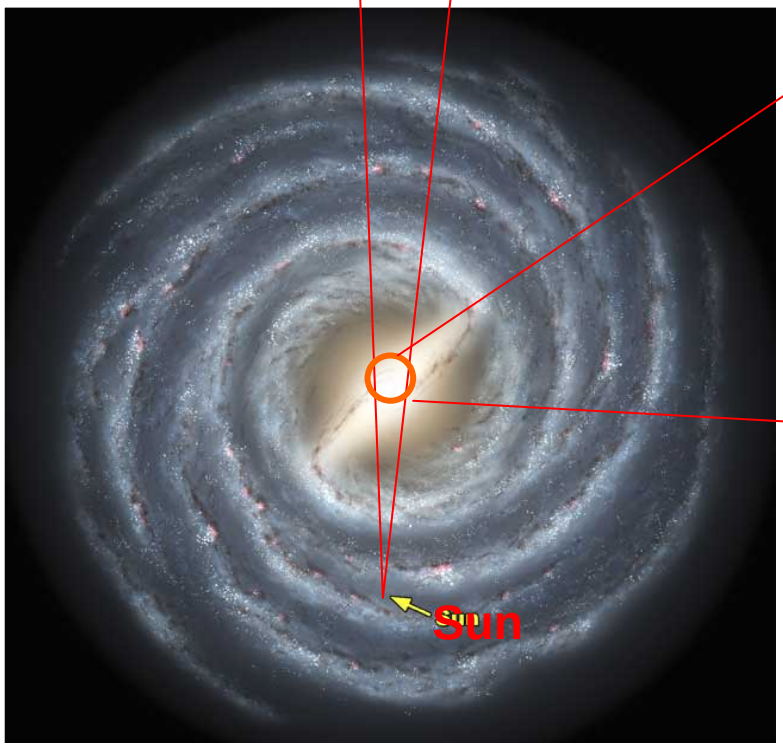
(from B.D.C. Chandran 2000)

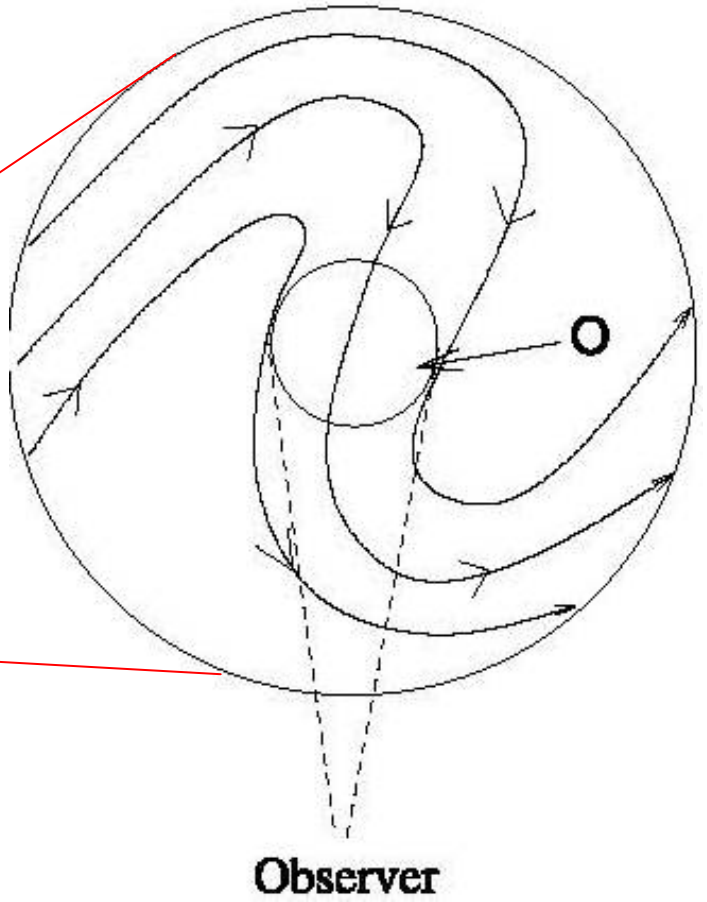


RMs of background radio sources for B-field in the GC region

(Roy et al. 2008)



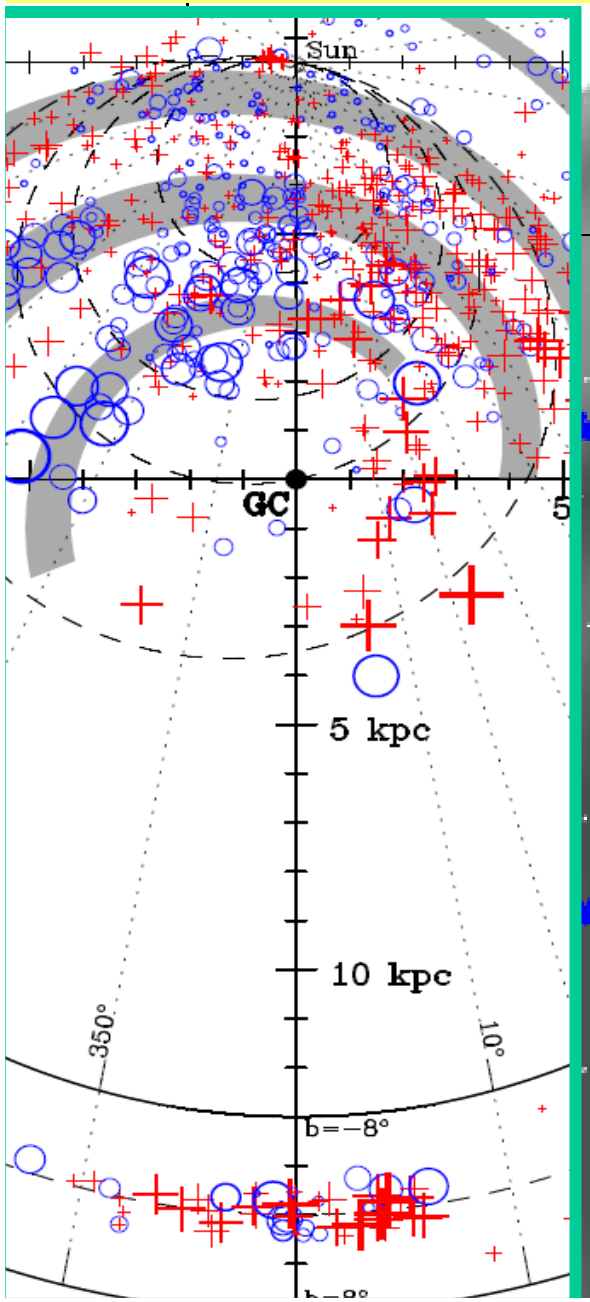


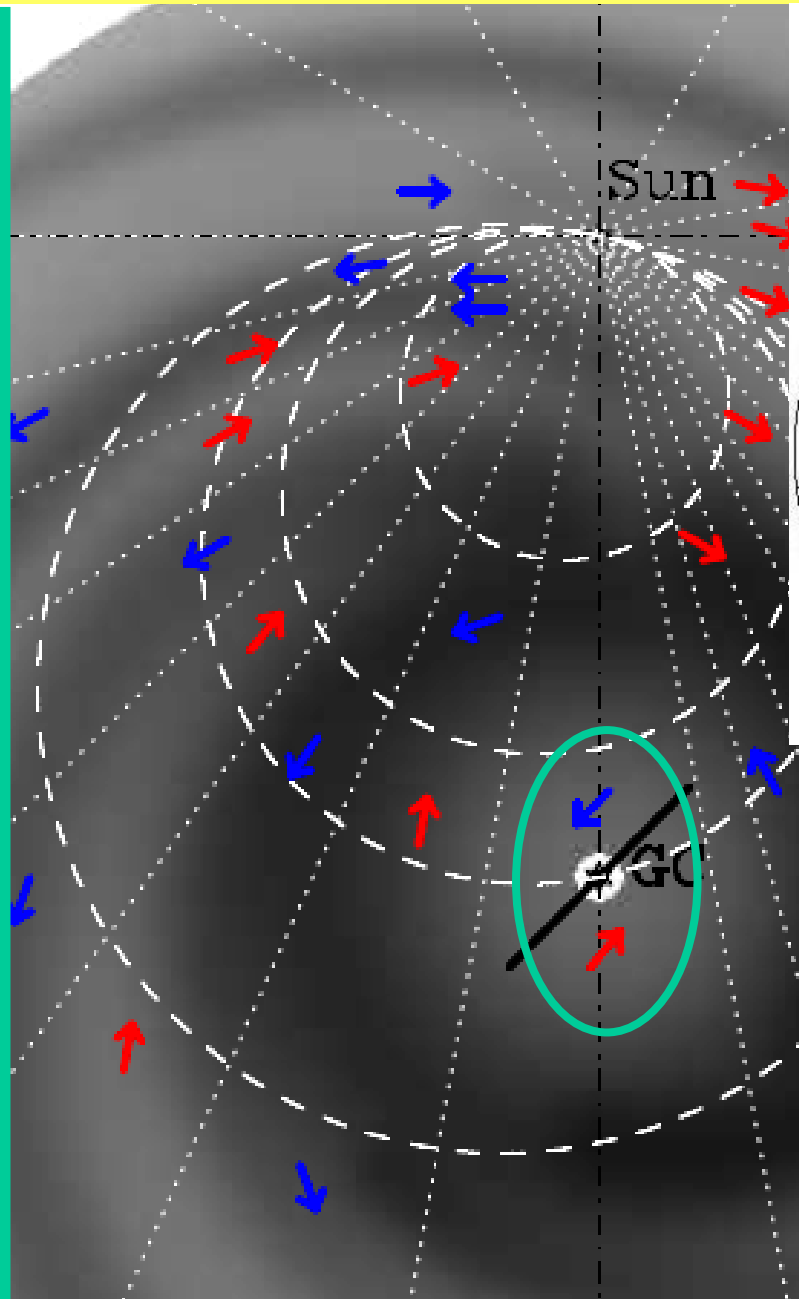


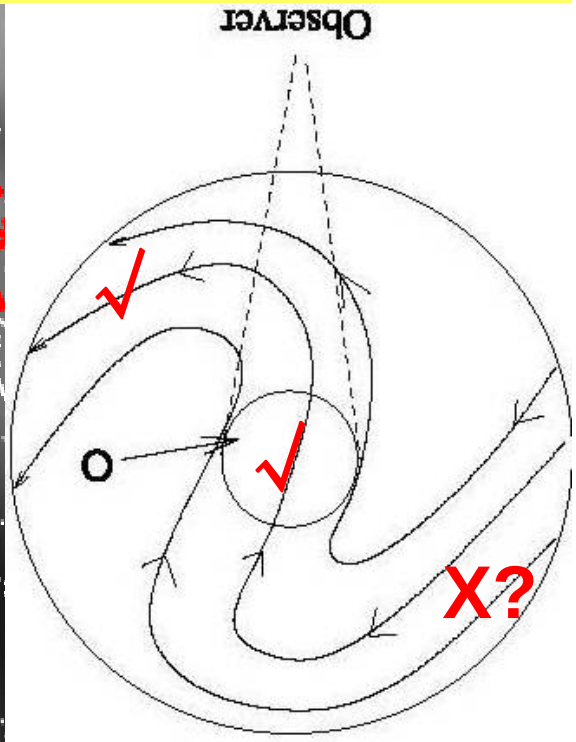
Galactic center: filaments and polarization

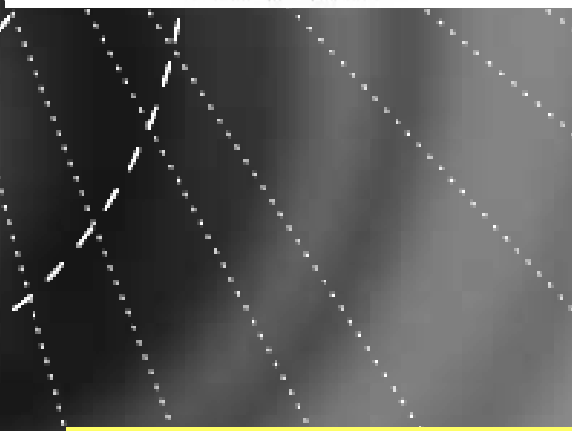
- **Poloidal fields**
  - Nonthermal filaments: more discosvery!
  - cm-polarization obs: RMs and intrinsic field
- **Toroidal fields**
  - submm, mm polarization
  - RMs of background radio sources
- **Field structure and field strength**
  - **mG in filaments: Yusef-Zadeh & Morris (1987)**
  - **Zeeman splitting of HI or OH lines: mG field**
    (Schwarz & Lasenby 1990; Killeen et al. 1992; Yusef-Zadeh et al. 1996, 1999)
  - **uG in pervading regions:**
    Nord et al. (2004); Roy et al. (2008): 20uG

Measured B-structure in the Galactic disk









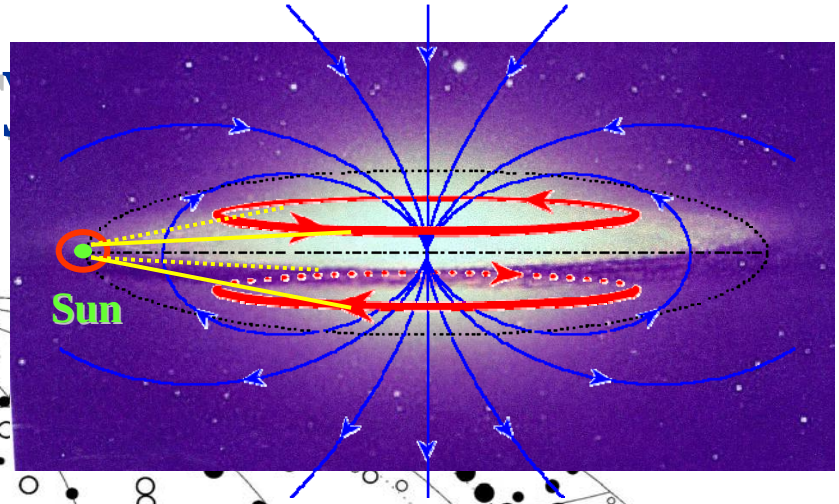
(Han et al. 2010, ApJ to be submitted)

Measurements of *Galactic magnetic fields*

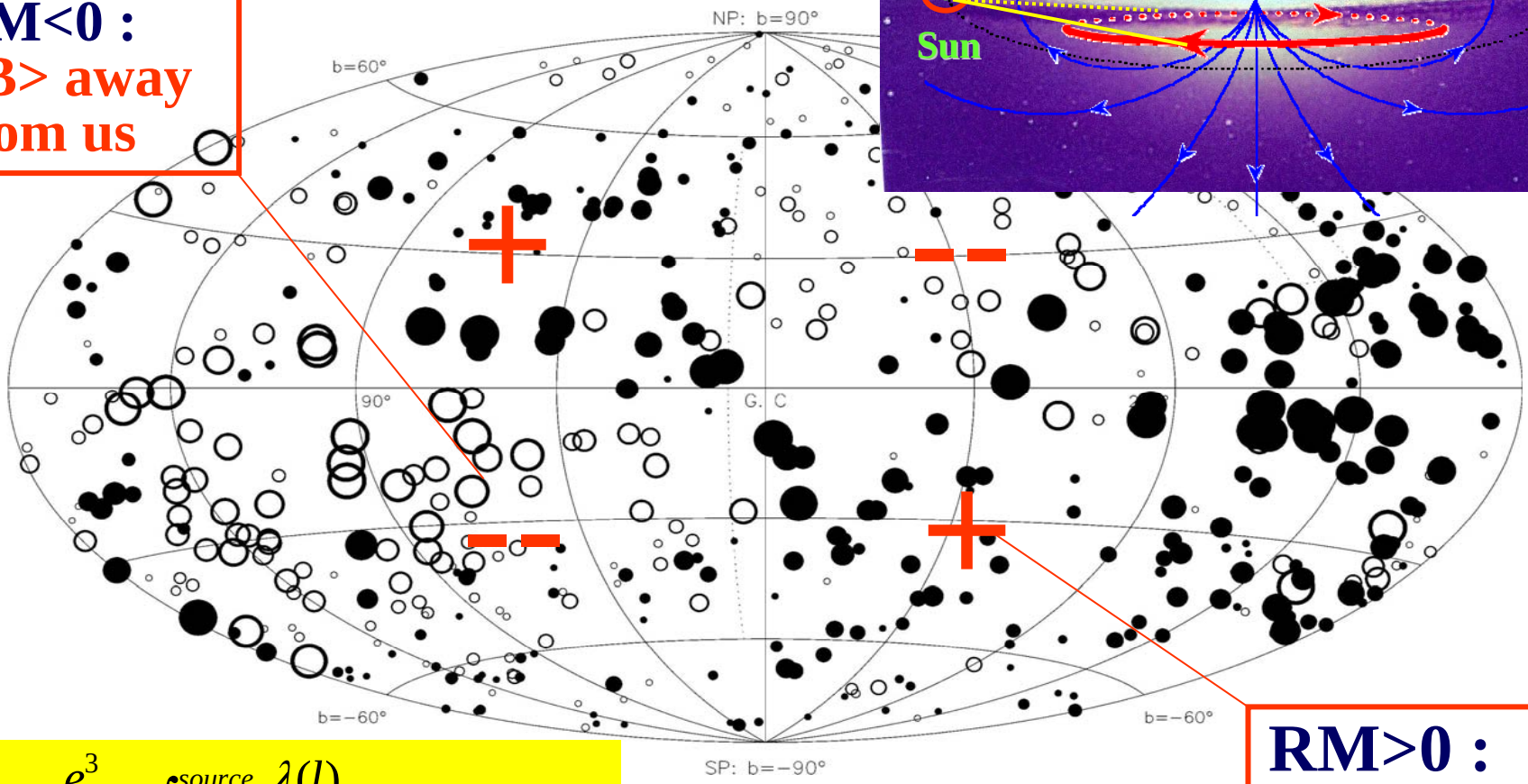
- Methods to measure
- Results of measurements
  - Galactic disk
  - Galactic center
  - Galactic halo
  - Random fields
- Conclusions

RM Sky: Anti-symmetry

Outliers significantly different from surroundings been filtered



RM<0 :
<B> away from us



RM>0 :
<B> to us

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

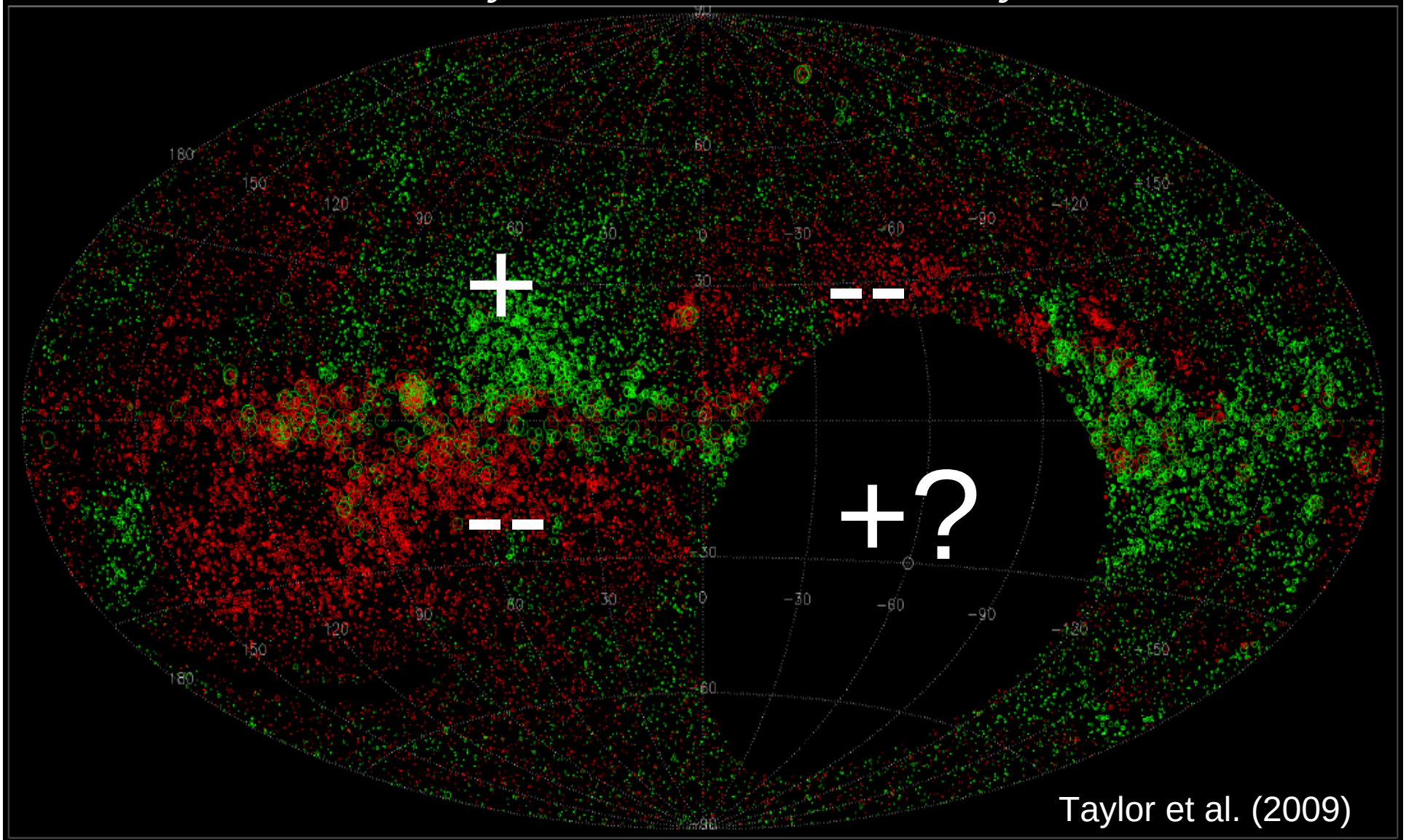
Milky Way: The largest edge-on Galaxy in the sky

Pulsars and extragalactic radio sources as probes

RM sky: Antisymmetry is confirmed!

Notice: RM estimated from only 2 IFs of NVSS data

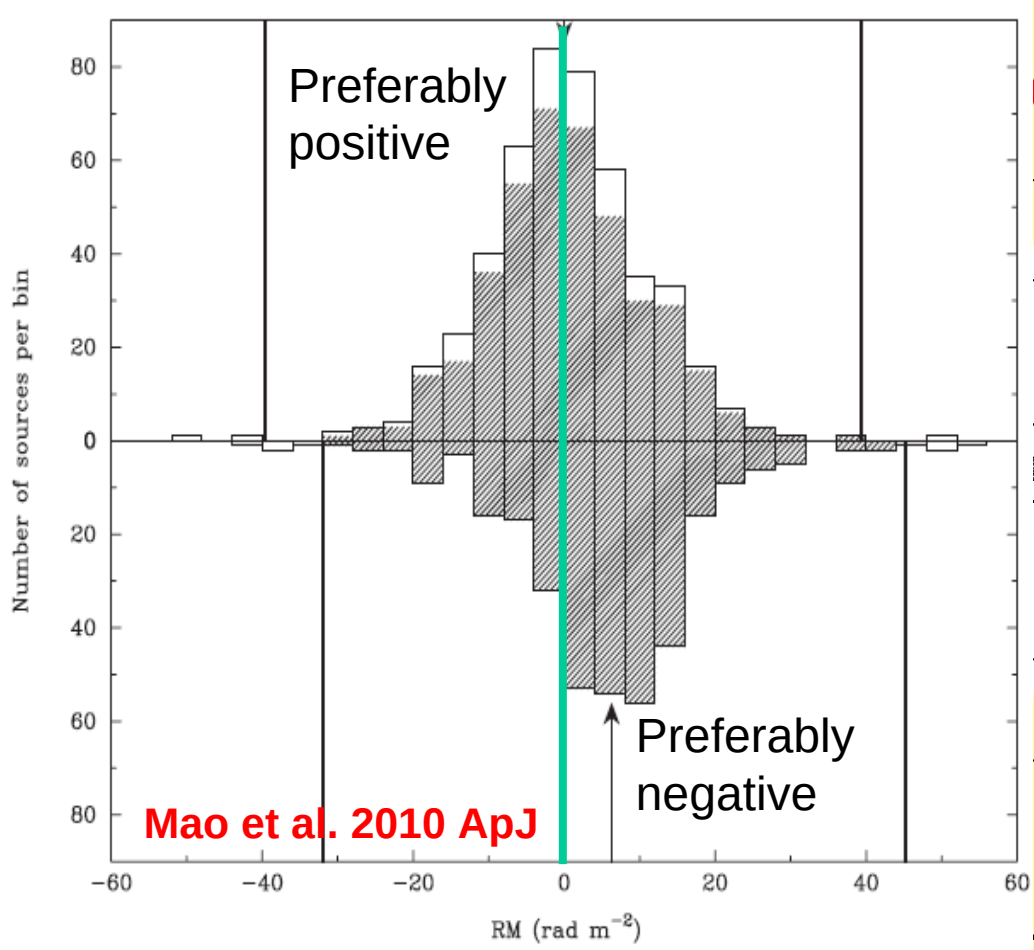
Individually: cannot trust! Collectively: Ok!



Taylor et al. (2009)

Local vertical components: from *poloidal field?*

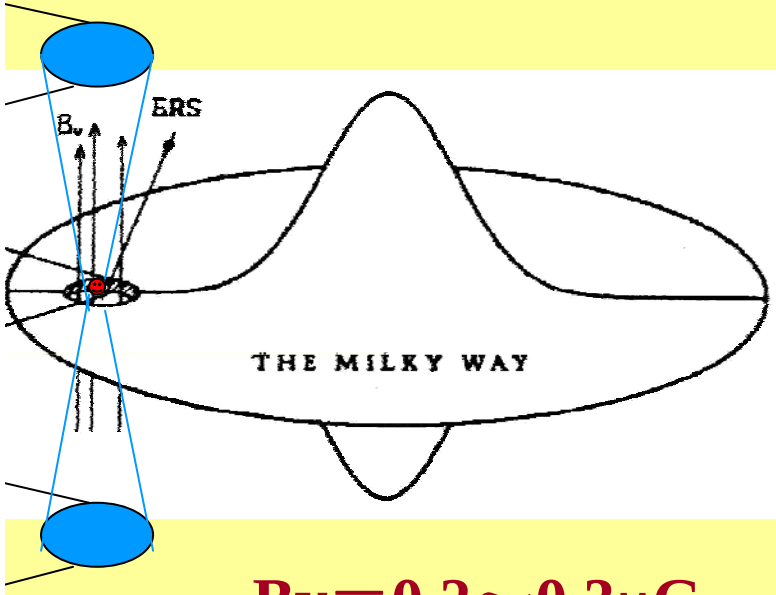
North Galactic Pole



South Galactic Pole

Unique measurement

Vertical B-component



Bv＝0.2～0.3μG

ting from SGP to NGP

(Effect of the NPS discounted already!)

(see Han & Qiao 1994; Han et al. 1999)

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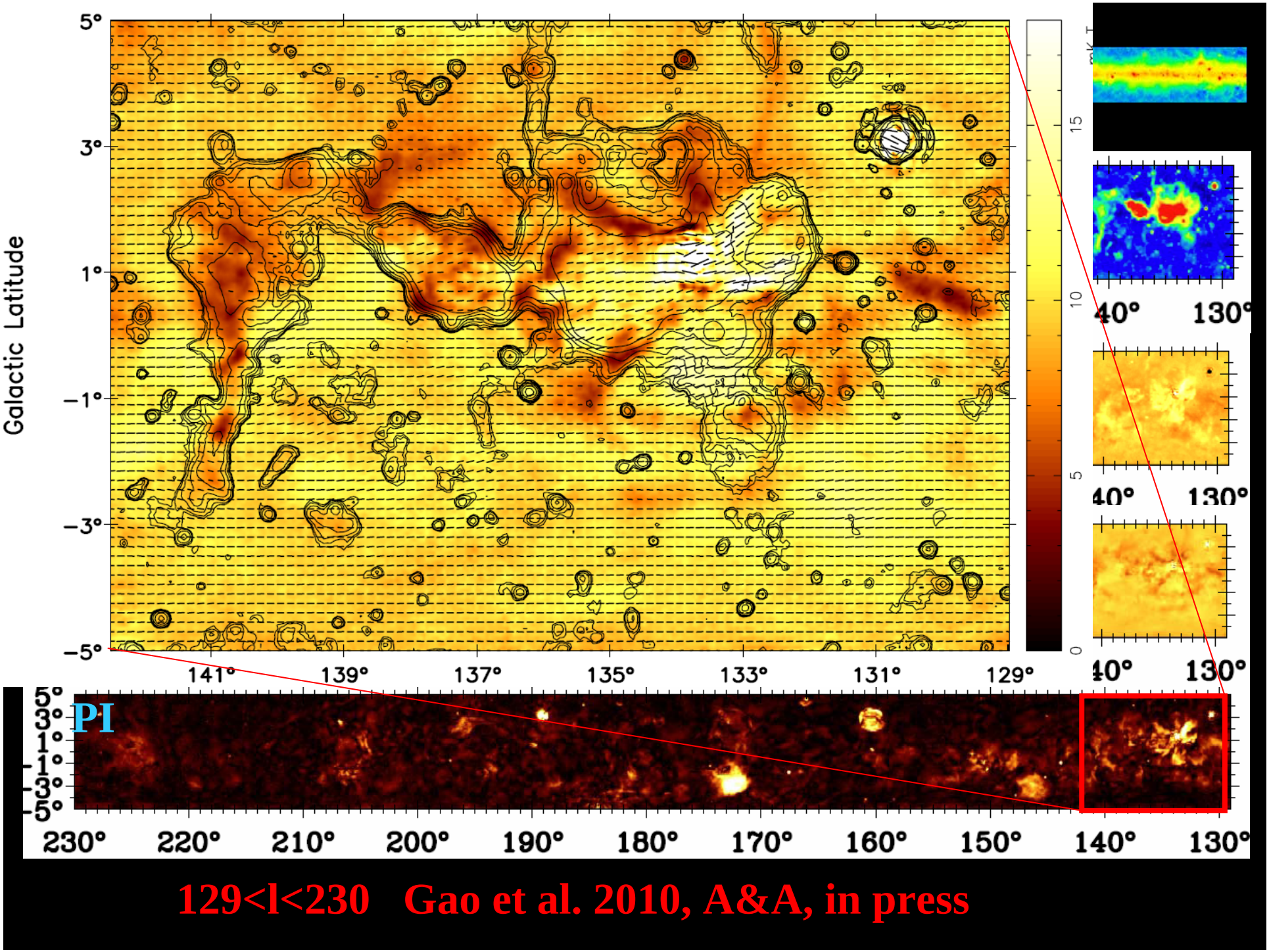
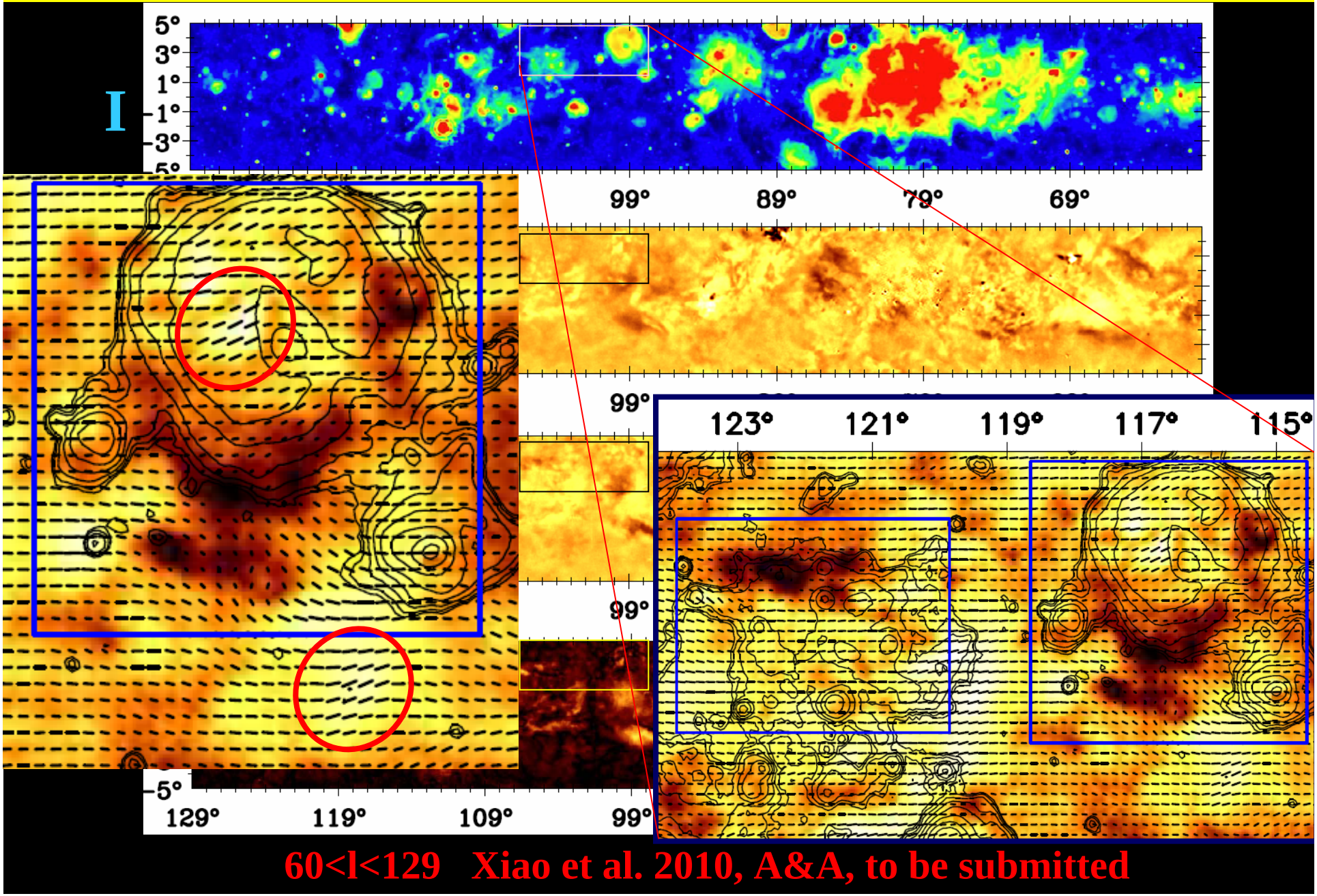


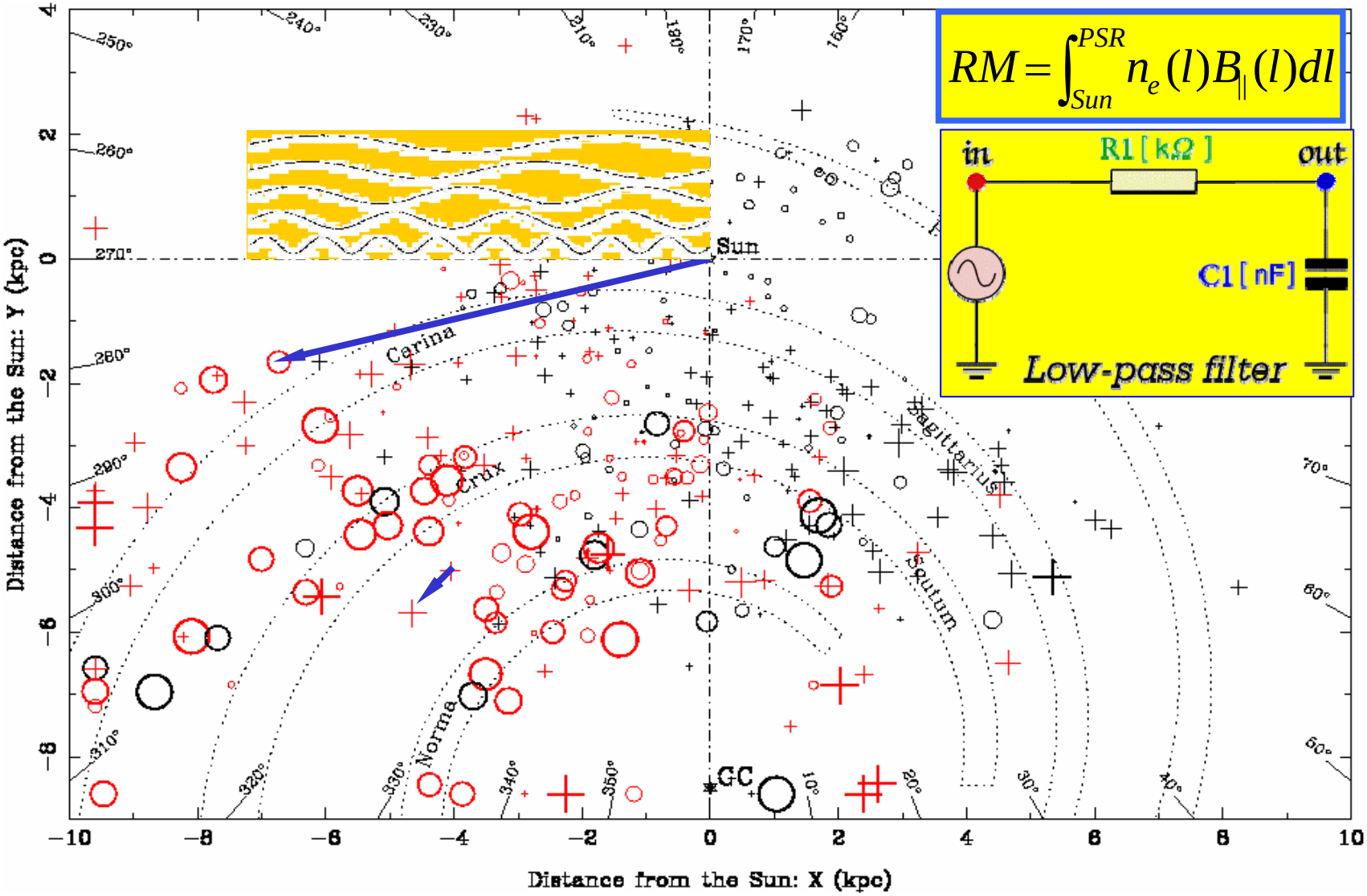
129<l<230 Gao et al. 2010, A&A, in press

Depolarization in the periphery of HII regions



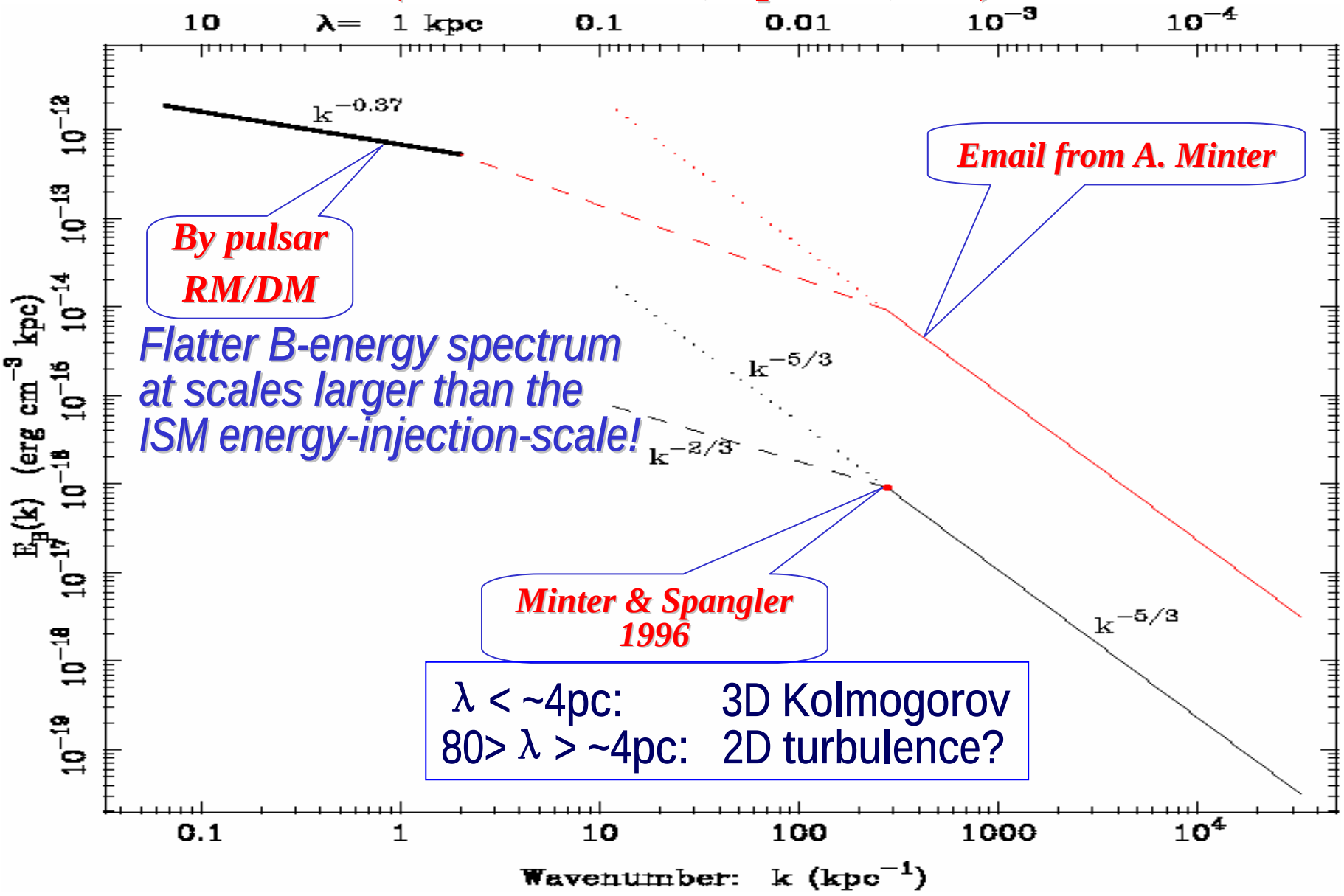
60<l<129 Xiao et al. 2010, A&A, to be submitted

Measuring the *B-field* ***fluctuation*** vs ***scales***



Spatial magnetic energy spectrum of our Galaxy

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



Measurements of *Galactic magnetic fields*

- Methods to measure
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  - Galactic disk
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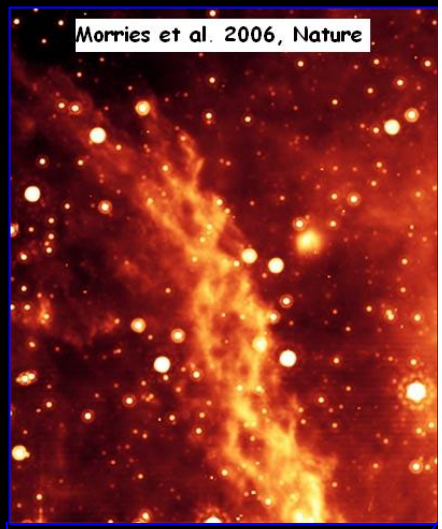
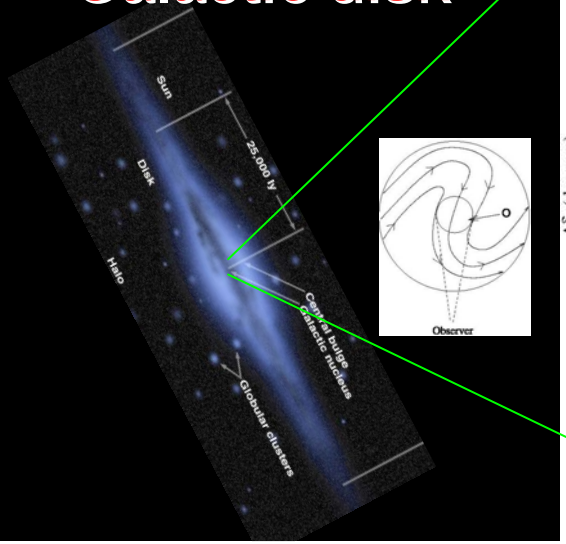
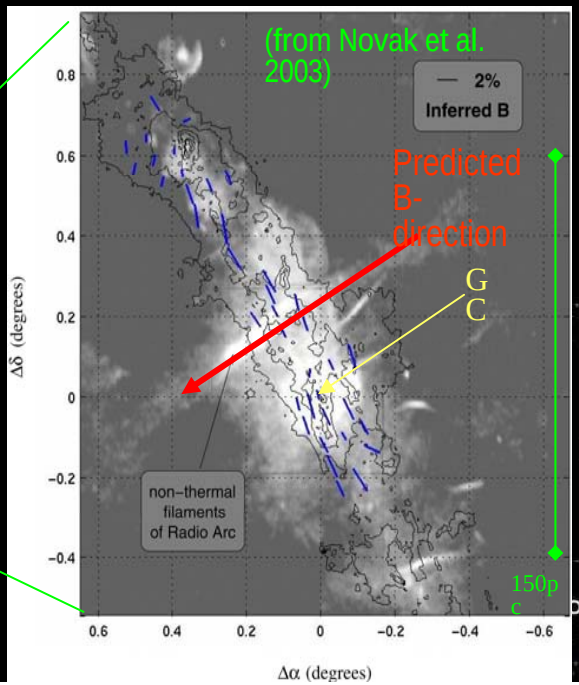
- Conclusions

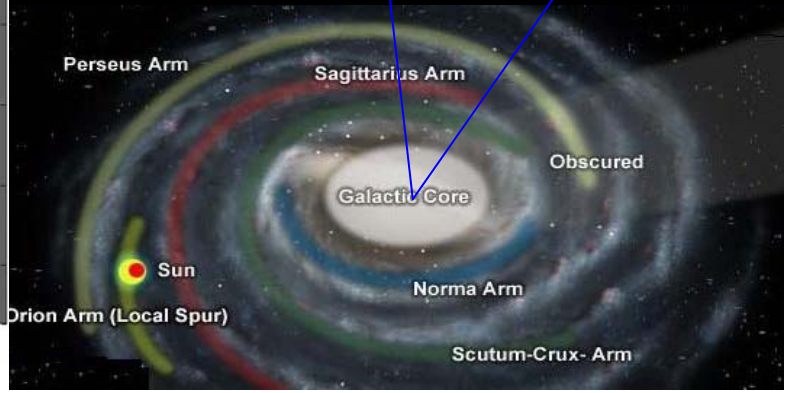
Conclusions

- Galactic center: Poloidal + Toroidal B-field
  - Radio filaments: more discovery
    (LaRosa et al. 04,05; Yusef-Zedah et al. 04; Nord et al. 04)
  - Submm Polarization + BiSpiral!
  - B-strength: mG or uG? (LaRosa et al. 05) Zeeman?
  - RMs of EGRs in center region (Roy et al. 05)
- Galactic halo
- Galactic disk



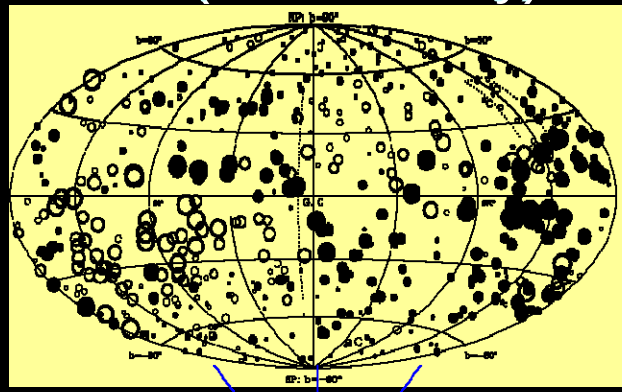


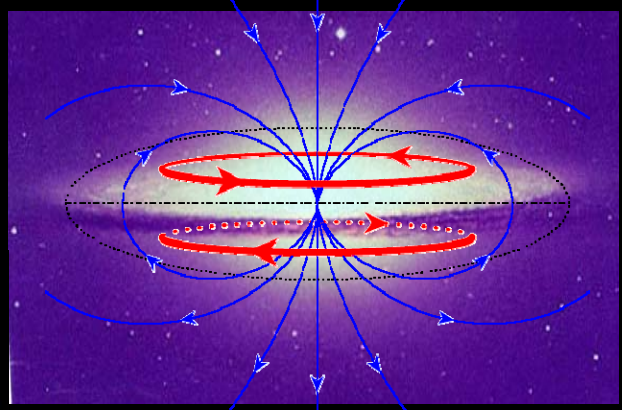


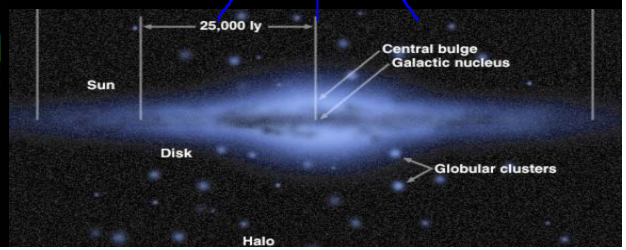


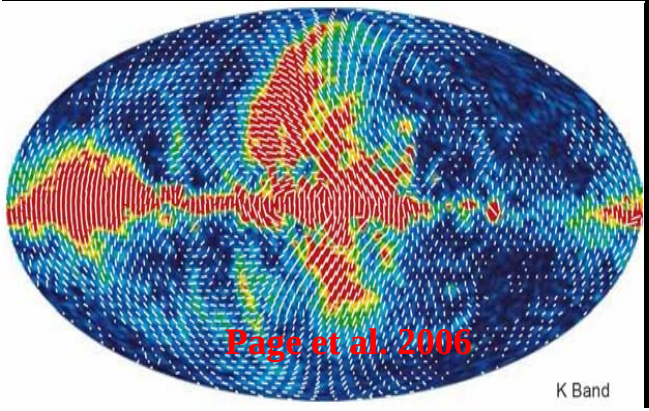
Conclusions

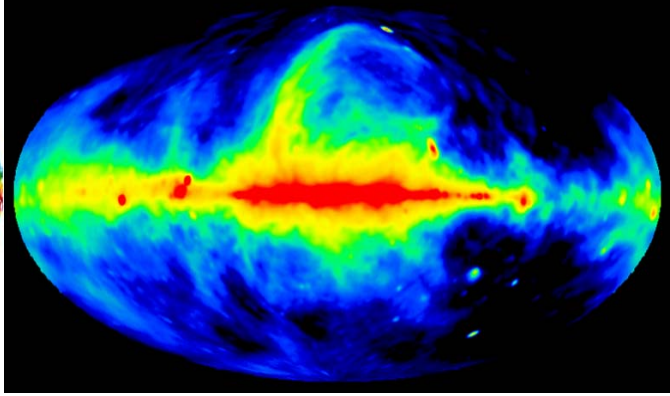
- Galactic center: Poloidal + Toroidal B-field
- Galactic halo: A0-mode B-field structures (Inner Galaxy)
  - Antisymmetric RM sky! (Han et al. 97,99)
  - Better RM sky (Taylor et al. 2009)
  - Polarization sky surveys (see Reich 06)
  - WMAPs: halo + local?(Papers)
  - Scale-height of B-disk (SK80; HQ94)
- Galactic disk





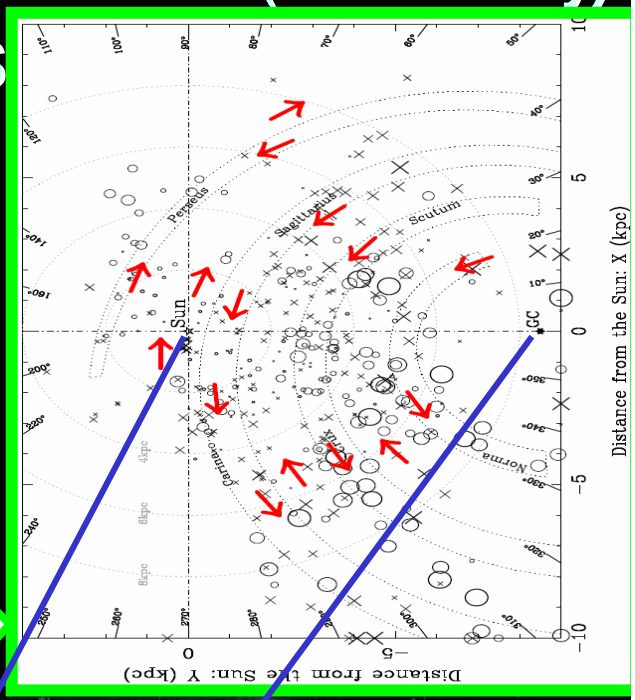


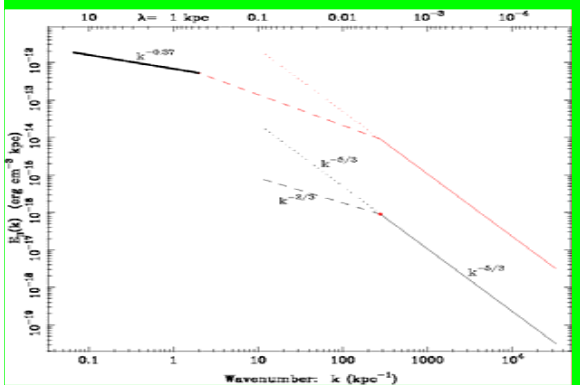


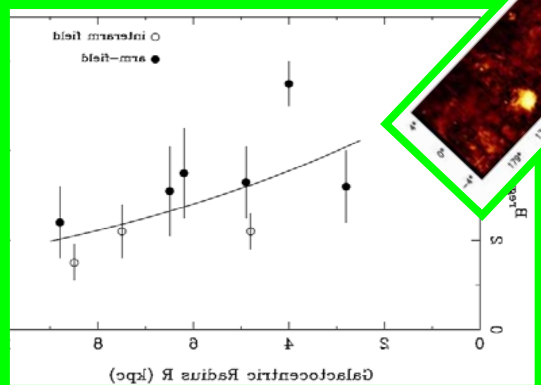


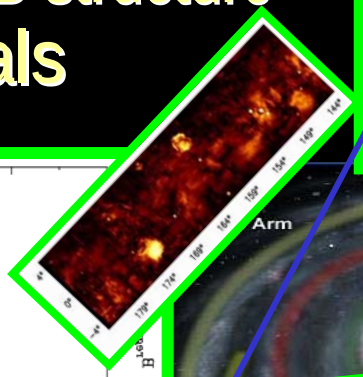
Conclusions

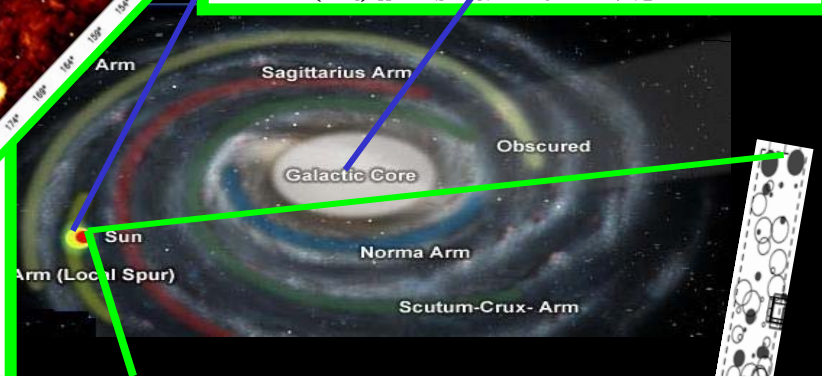
- Galactic center: Poloidal + Toroidal B-field
- Galactic halo: A0-mode B-field + structures (Inner Galaxy)
- Galactic disk: Measured B-reversals
  - Pulsar RMs – measuring
    - B-field: follow spiral arms!
    - measuring → reversals
    - B-field stronger towards GC
    - Statistics: B-energy spectrum
  - RMs of EGRs →Consistent B-structure
  - Clouds Zeeman → reversals



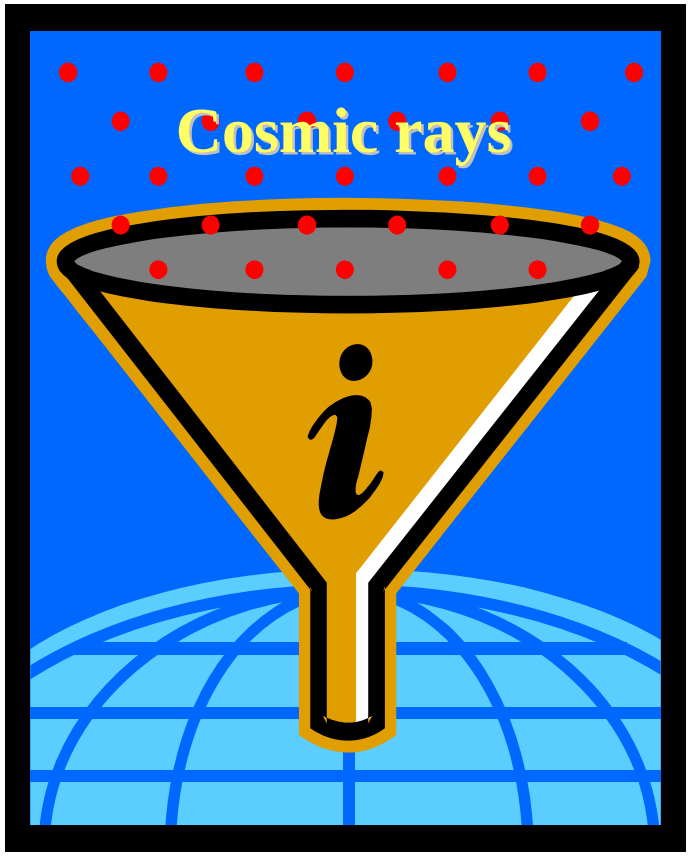








Thanks for your attention!



Han J.L. 2009, IAU Symp. 259, 455 (Invited Review)

Jiang Y.Y., Hou L.G. Han J.L. et al. 2010, ApJ 719, 459