

S-PASS and Giant Magnetised outflows from the Centre of the Milky Way

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The Universe as seen by Planck – Noordwijk - 4 April 2013

CSIRO ASTRONOMY AND SPACE SCIENCE

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Outline

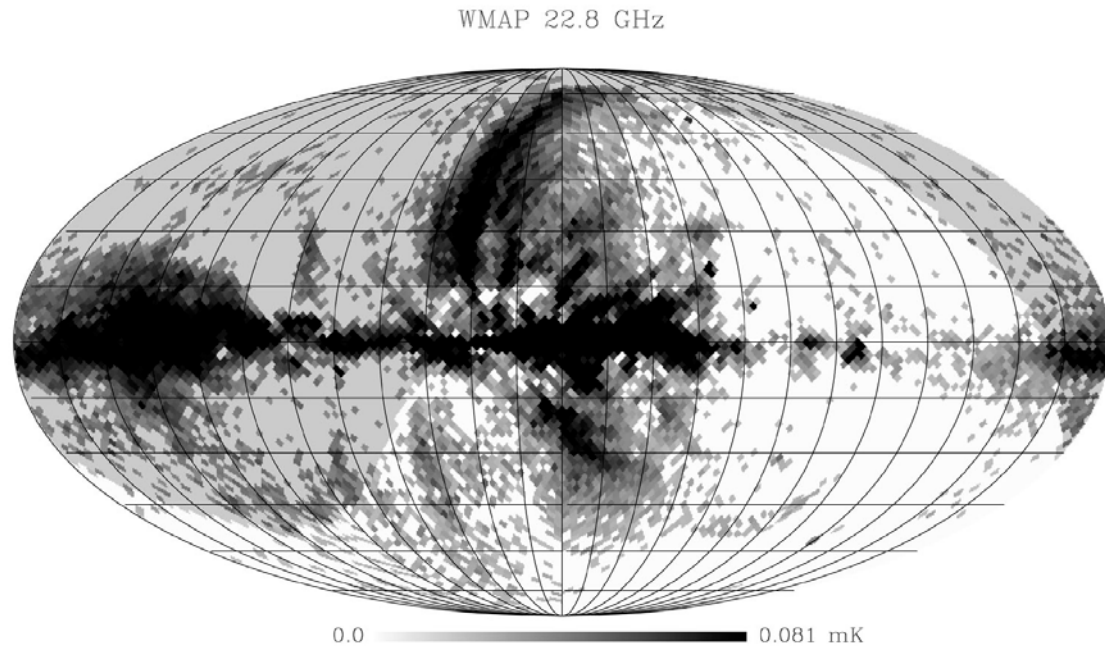
- S-PASS: S-band Polarization All Sky Survey
- Giant outflows from the Galactic Centre (radio counterpart of the Fermi Bubbles)

S-PASS: S-band Polarization All Sky Survey

- To survey the polarized emission of the entire southern sky at 2.3 GHz

- Dec $< 0^\circ$ (unshaded area);
- PARKES: 2.3 GHz ;
- 224 MHz BW (100+ ch);
- FWHM = 9';
- $\sigma_{\text{beam}} < 1.0$ mK;

- 2000 h
- 175 nights in 2.5 yrs (!)



- Started Oct 07, **completed in January 2010**
- **Goals: synchrotron emission, Galactic magnetic field, CMB foregrounds**

Polarization surveys: 1.4 GHz

- ALL SKY maps at **1.4 GHz**, FWHM $\sim 36'$
- Single channel surveys: no RM measures.
- FR modifications:
 - Galactic Disc strongly depo
 - FR modification at $|b| < 50^\circ$

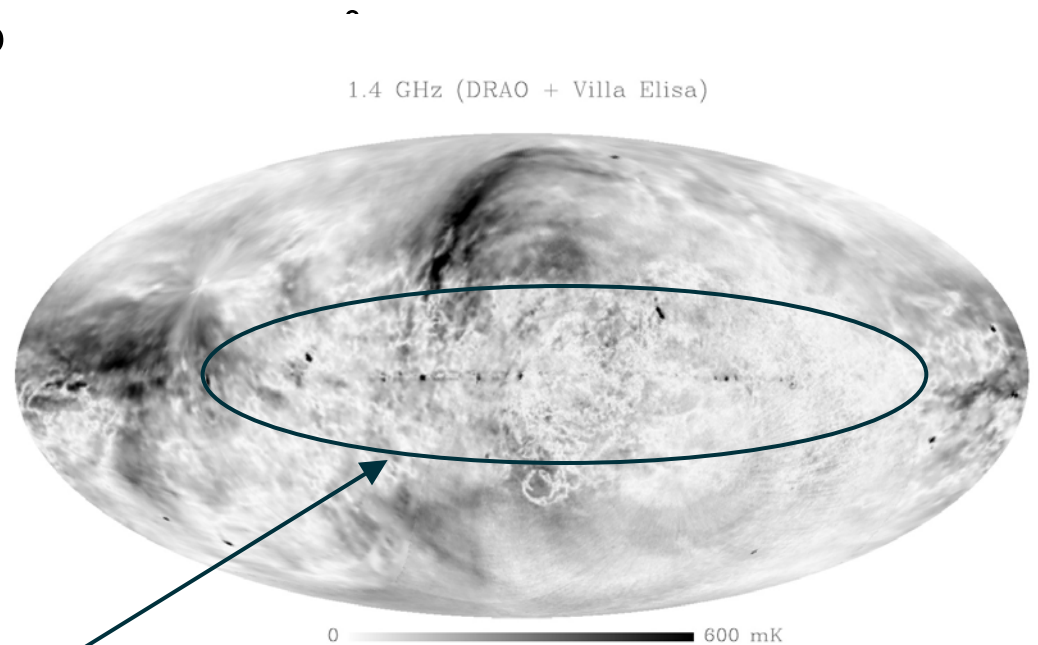


- **1.4 GHz: not sufficient**



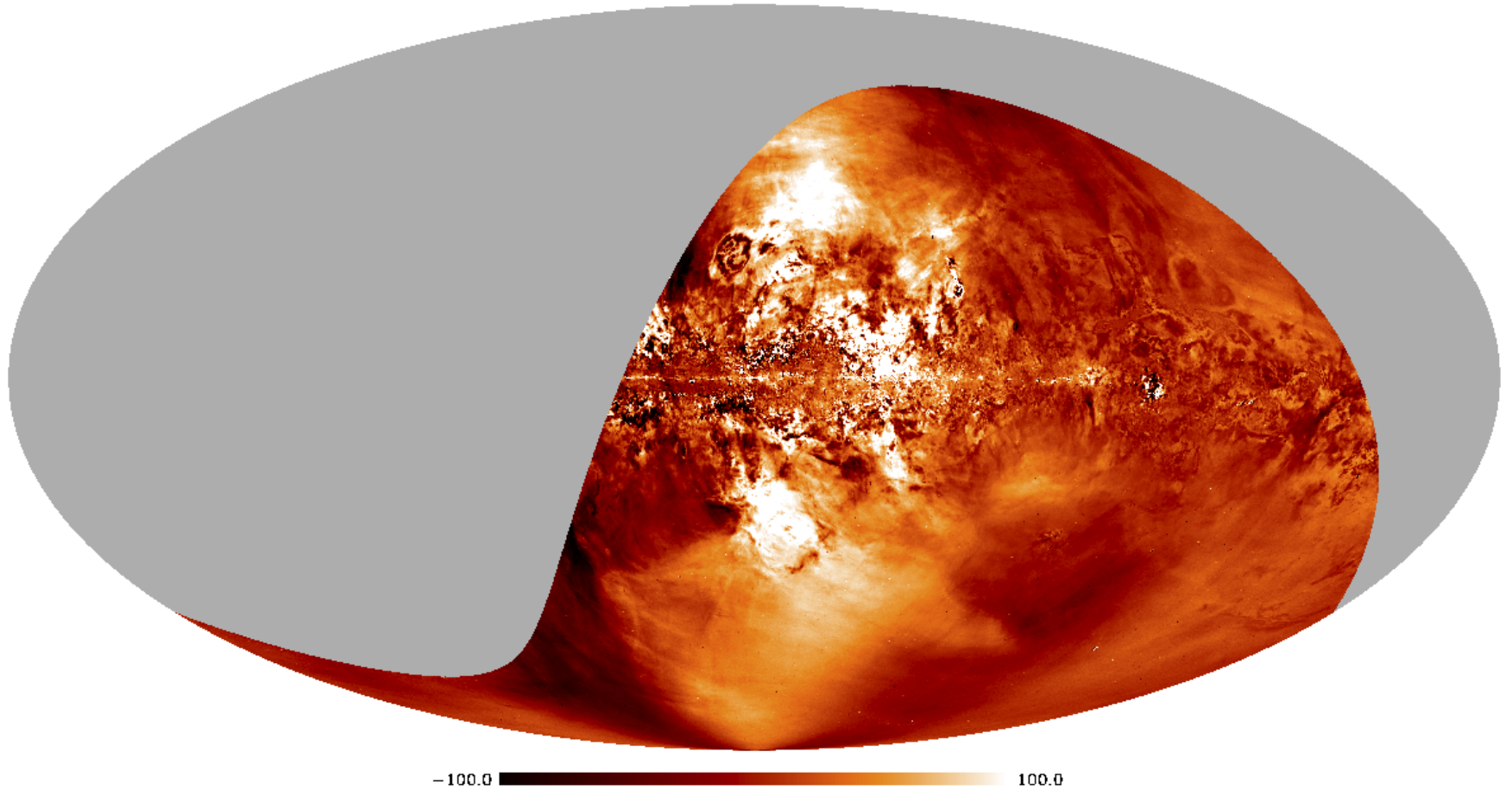
Higher frequency!!

depolarization



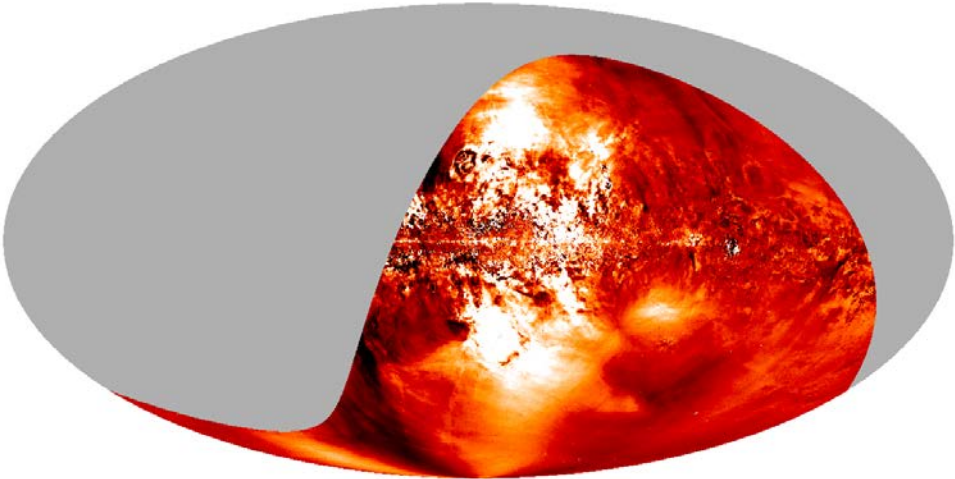
S-PASS: polarization maps

S-PASS: Stokes Q

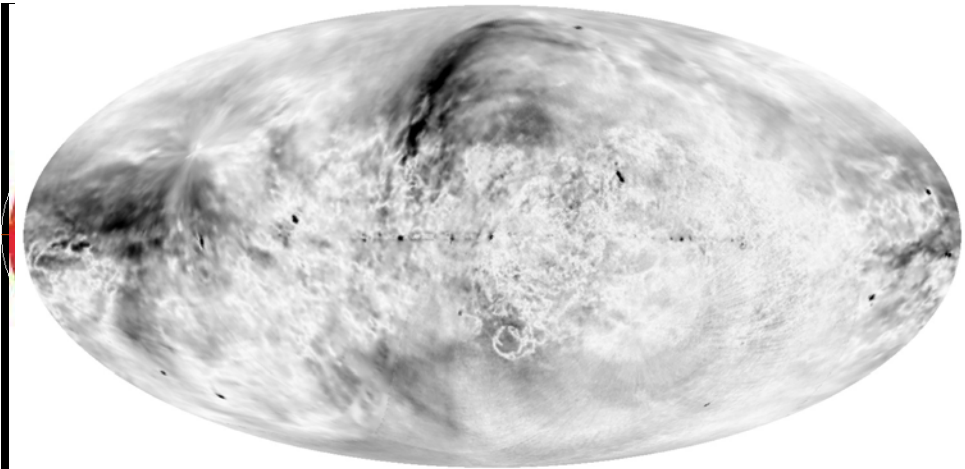


S-PASS and other data sets

S-PASS q



1.4 GHz (DRAO + Villa Elisa)



0 600 mK

SHASSA: H_{α}
WMAP 22.8 GHz



Giant magnetized outflows from the centre of the Milky Way (1)

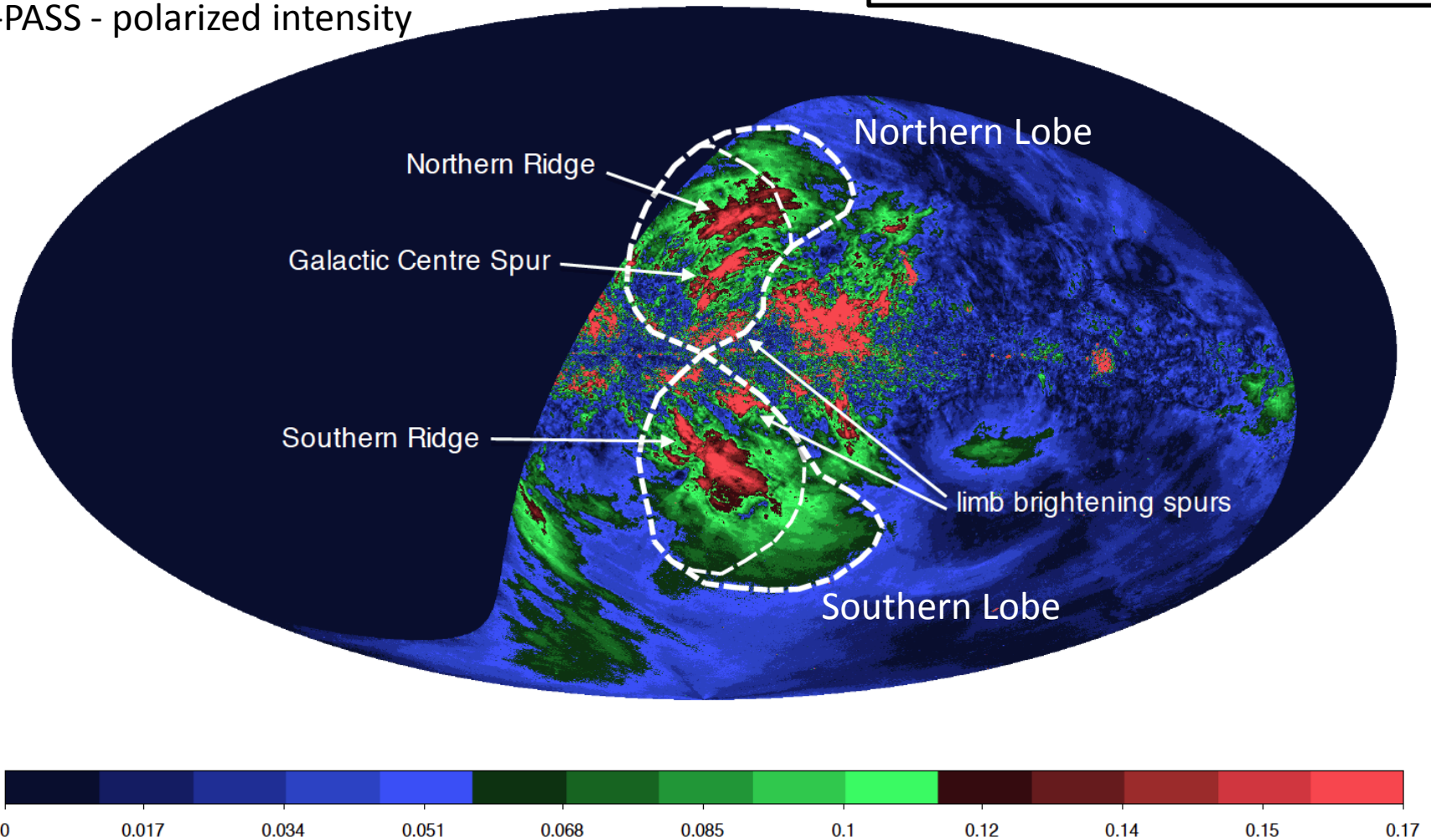
Carretti et al., 2013, Nature, 493, 66

- E. Carretti (PI)
- R. Crocker
- L. Staveley-Smith
- M. Haverkorn
- C. Purcell
- G. Bernardi
- B.M. Gaensler
- M.J. Kesteven
- S. Poppi

Polarized radio lobes

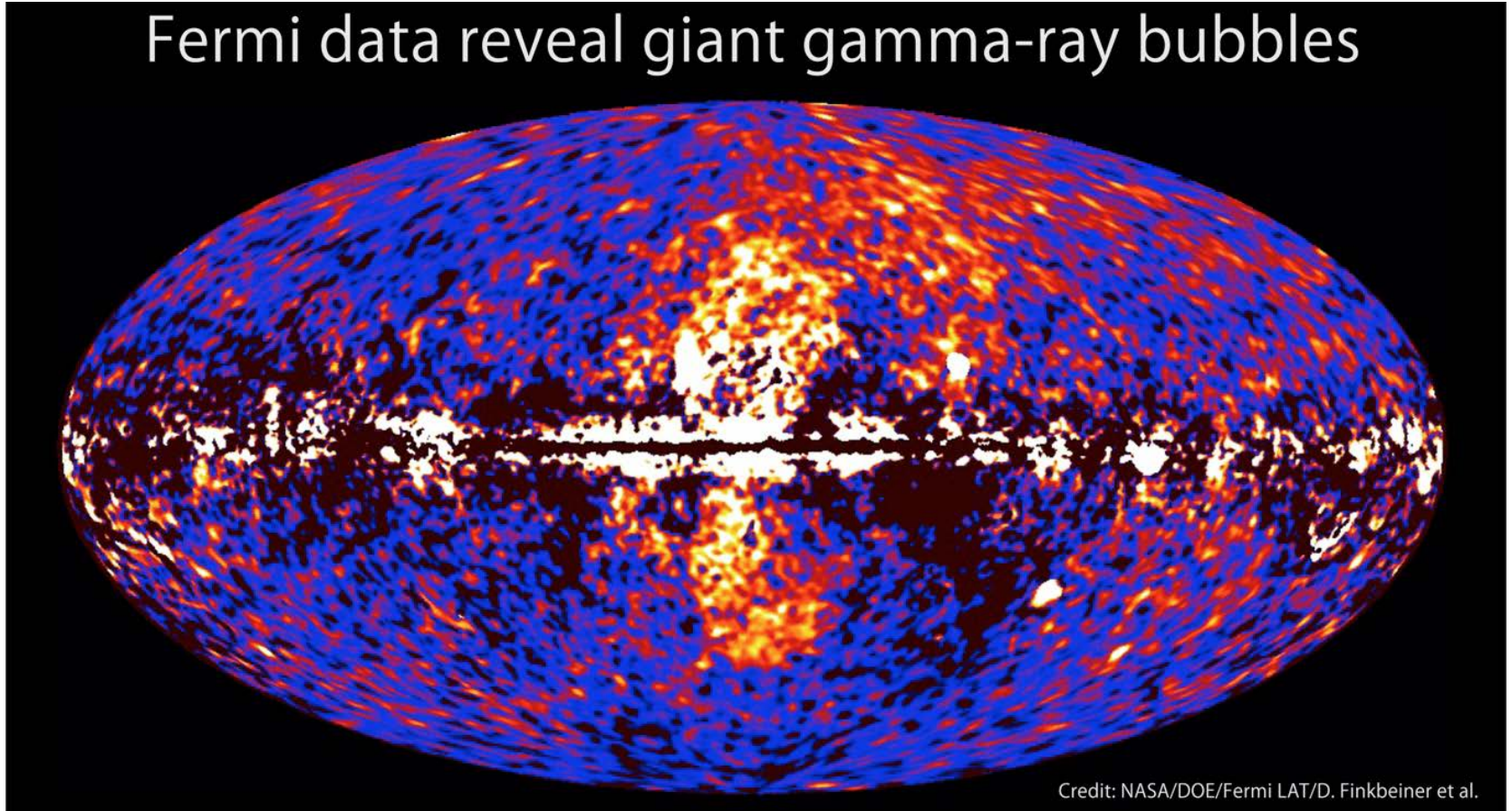
Carretti et al., 2013, Nature, 493, 66

S-PASS - polarized intensity



γ -ray Fermi Bubbles

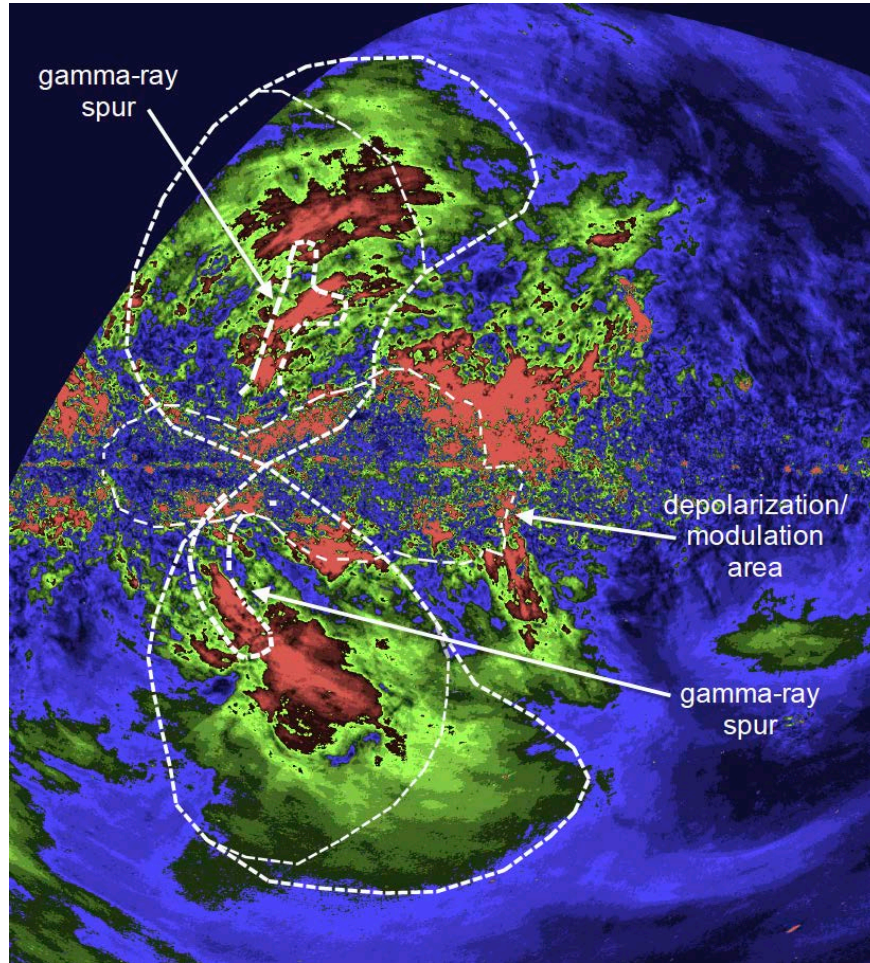
Fermi data reveal giant gamma-ray bubbles



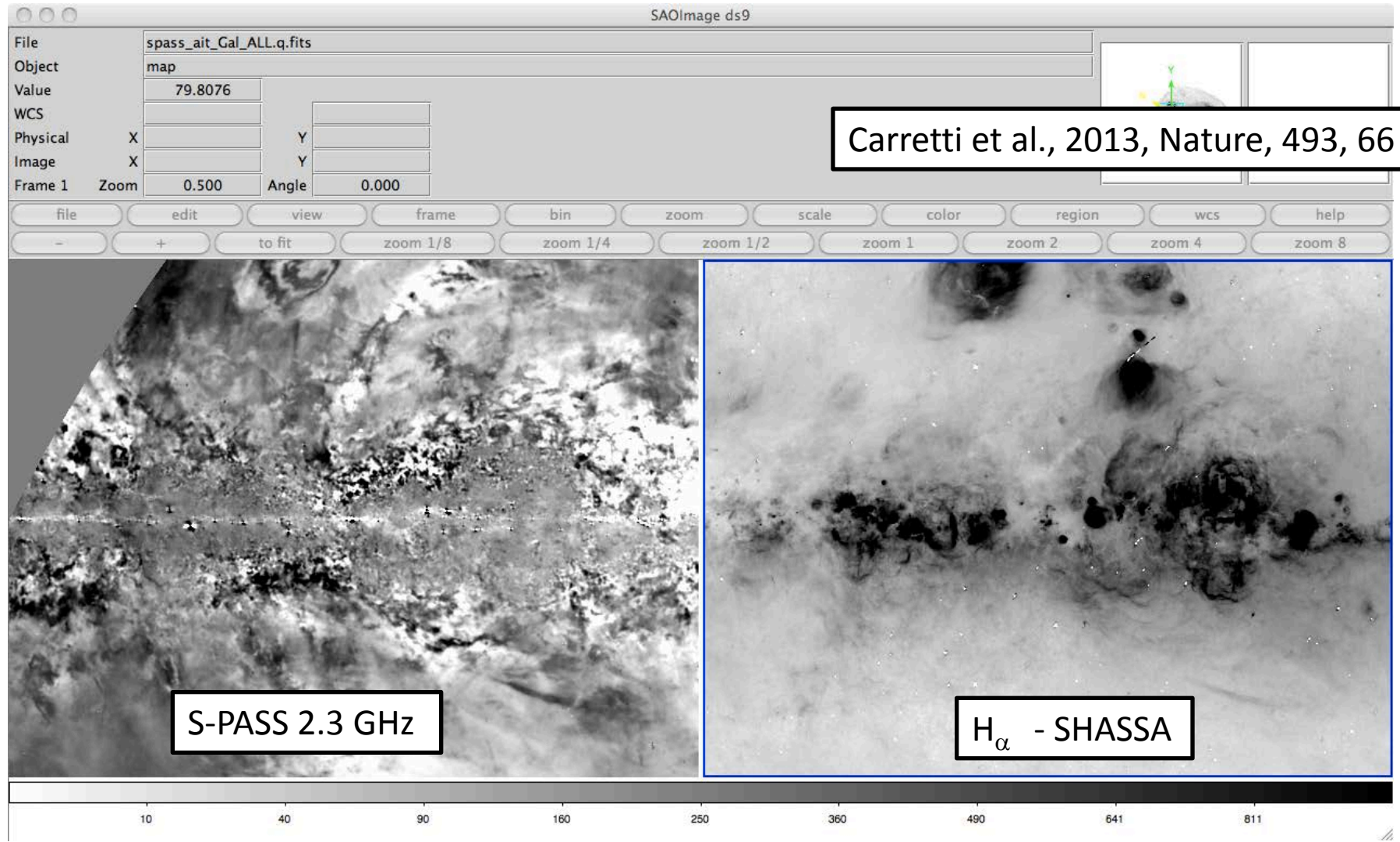
Su, Slatyer and Finkbeiner 2010 (ApJ)

Polarized radio lobes (2)

Carretti et al., 2013, Nature, 493, 66

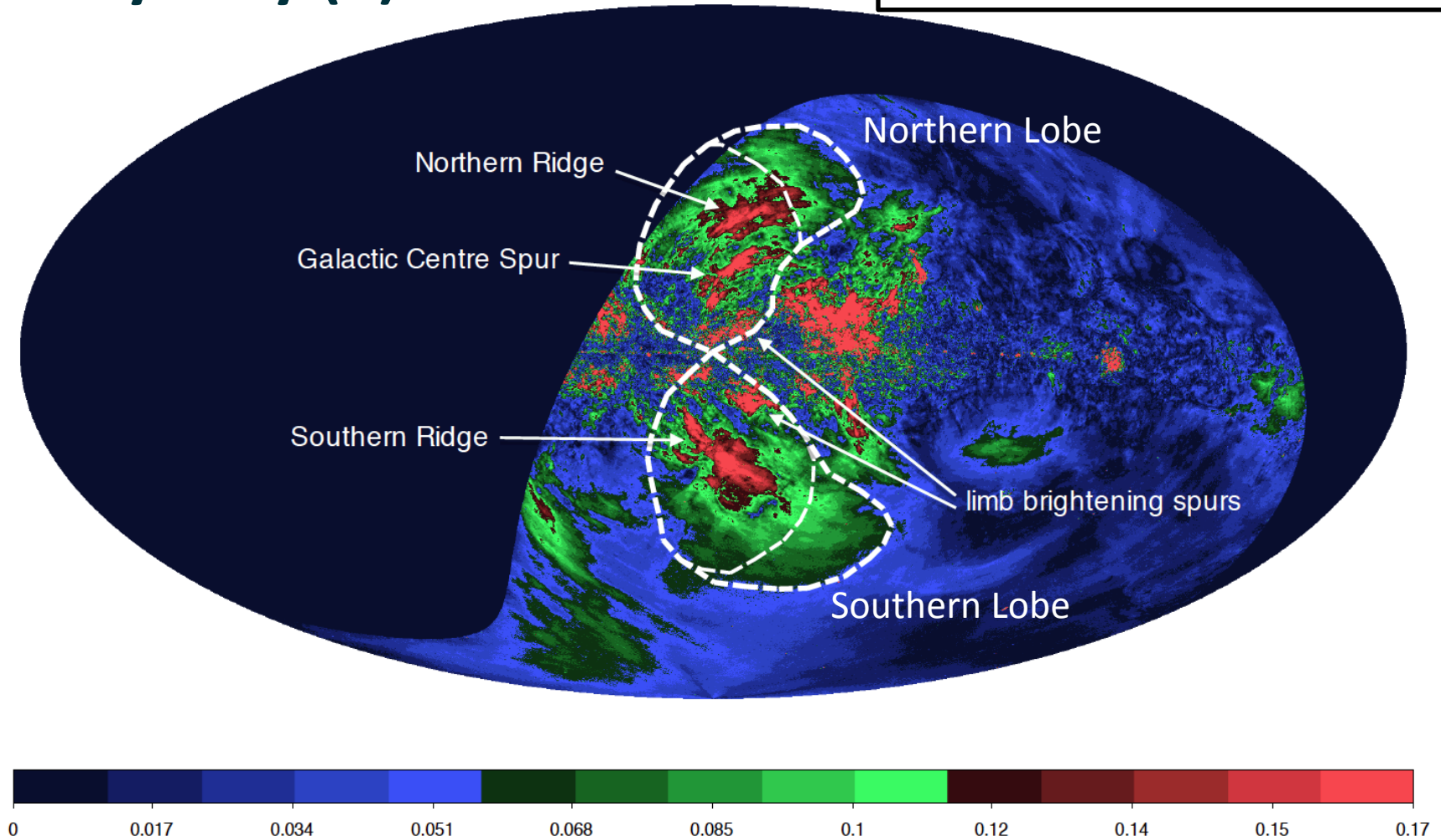


Depolarization area: Radio and H_{α}



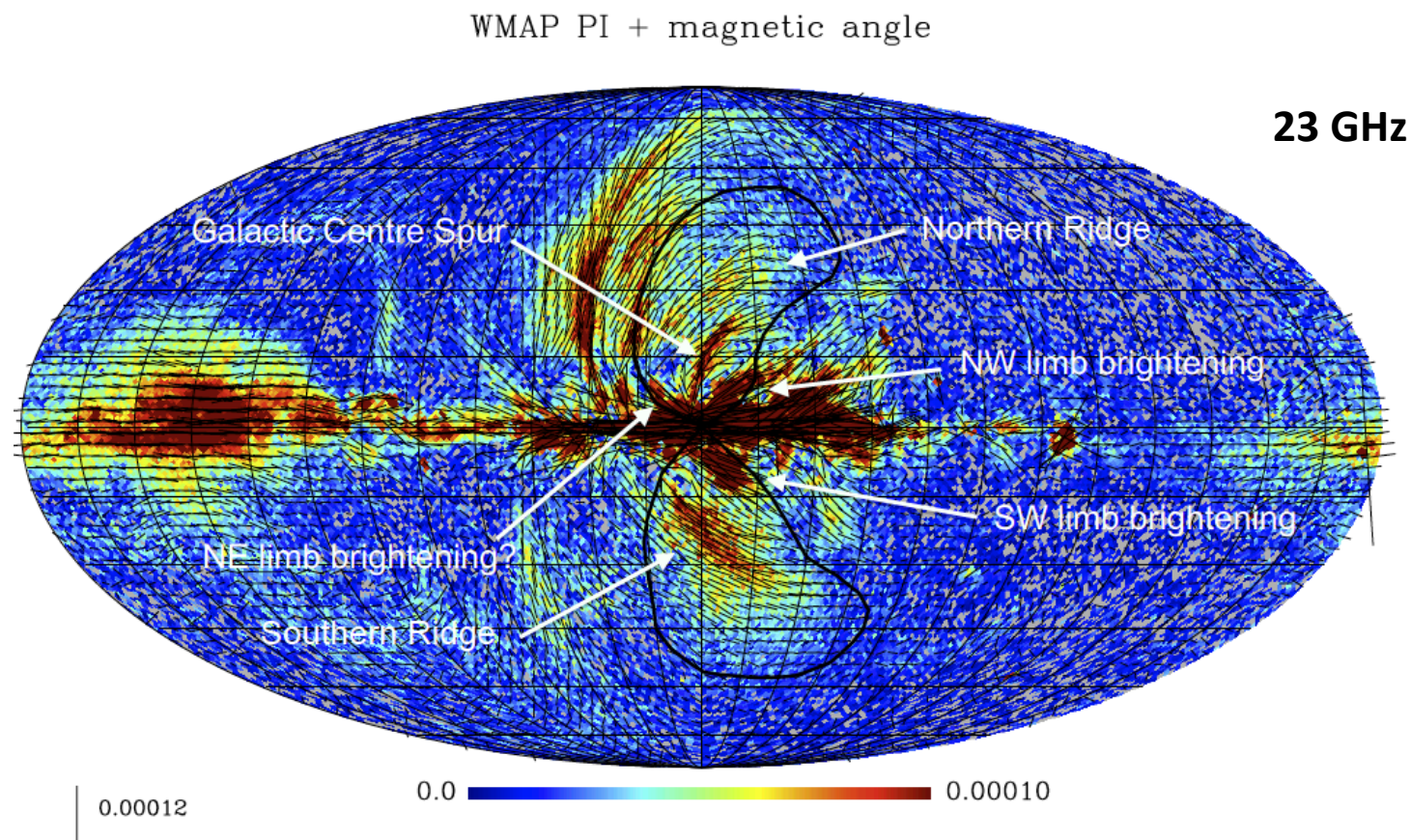
Giant magnetized outflows from the centre of the Milky Way (2)

Carretti et al., 2013, Nature, 493, 66



Giant magnetized outflows from the centre of the Milky Way (3)

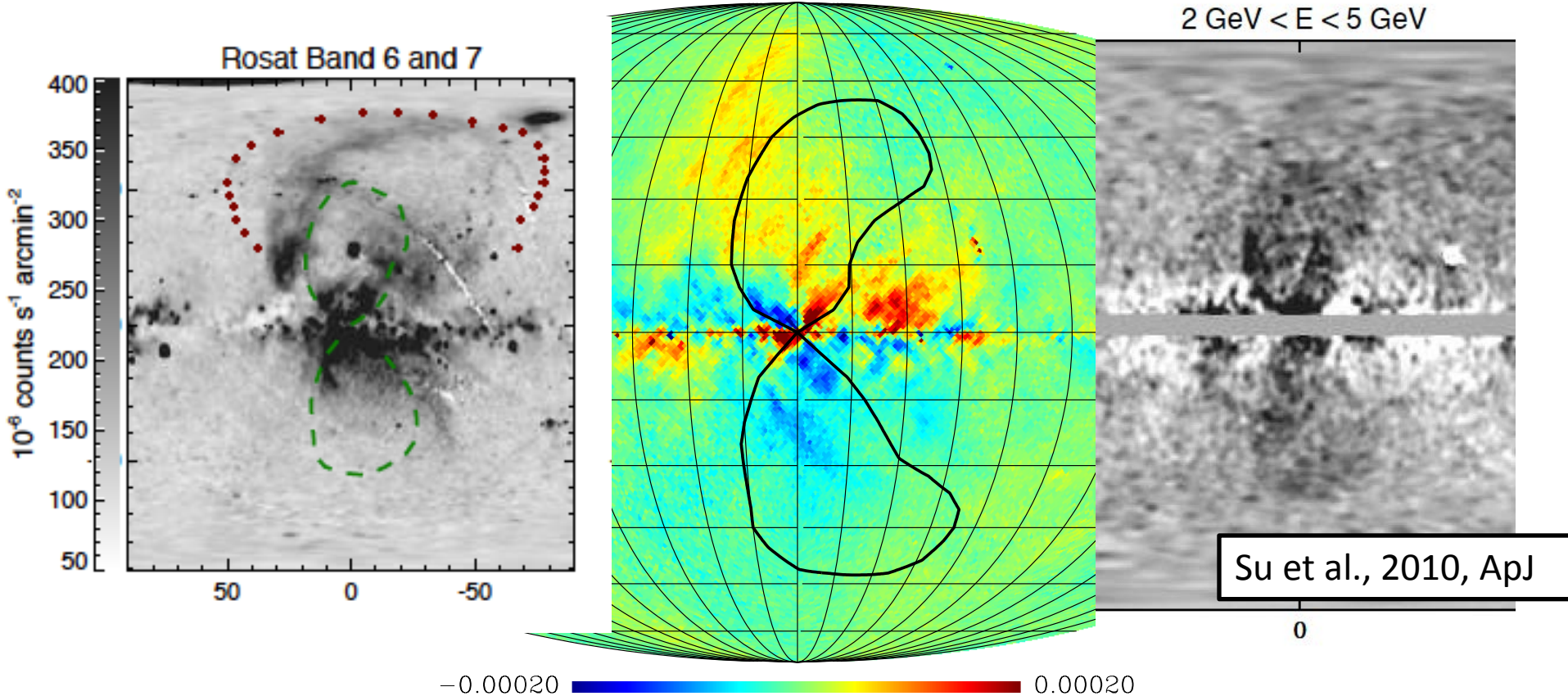
Carretti et al., 2013, Nature, 493, 66



Limb brightening structures at μ wave

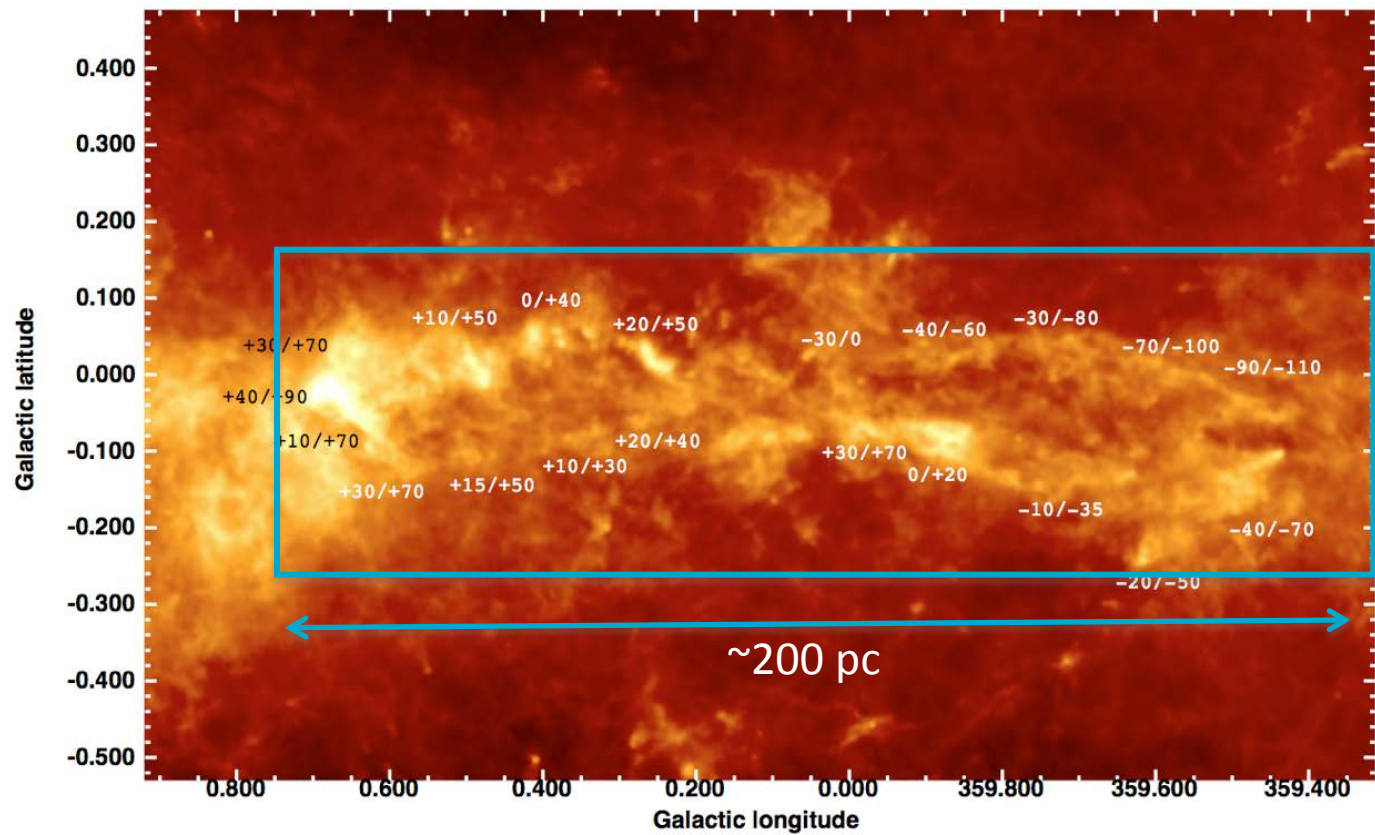
WMAP U

Carretti et al., 2013, Nature

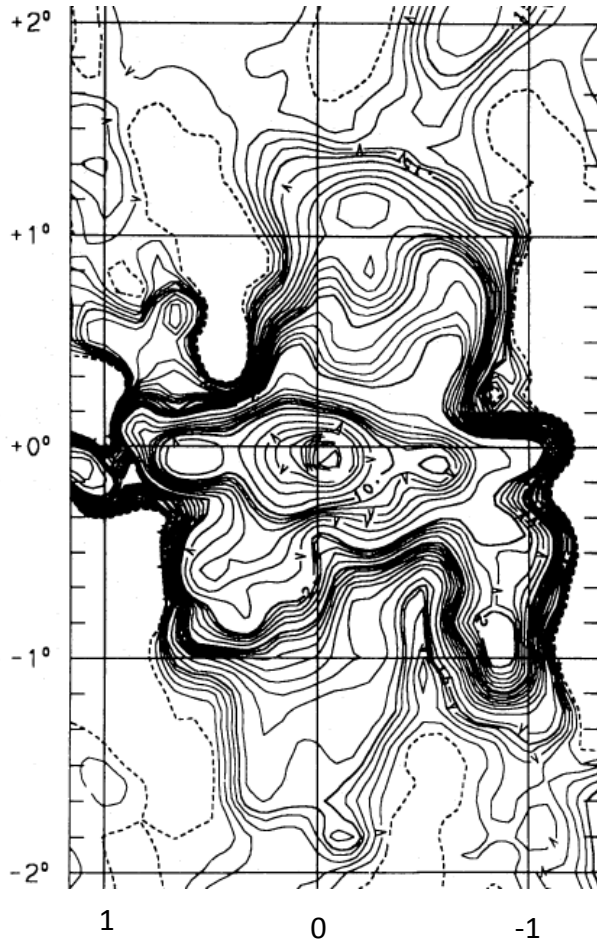


Star formation in the Galactic Centre region

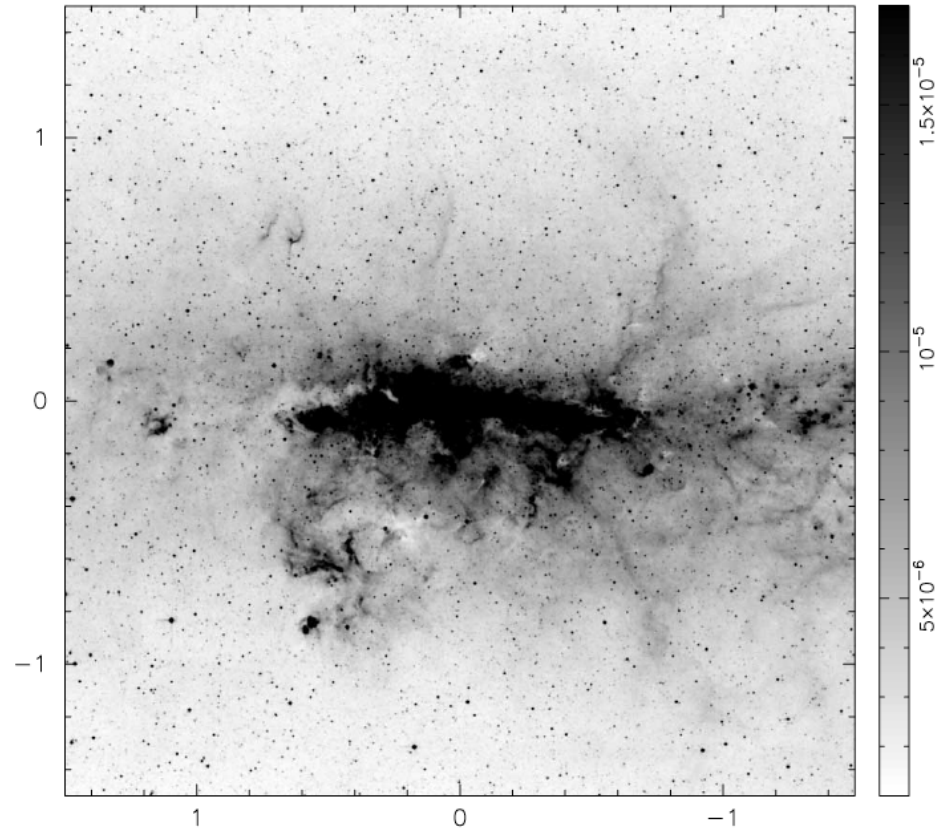
- Herschel – Spire 250 μm (Molinari et al., 2011)
- Central Molecular Zone:
=>Molecular gas ring: 10% star forming gas of the entire Galaxy
- Highly active star formation area of the Galaxy.



Outflows from the Galactic Centre



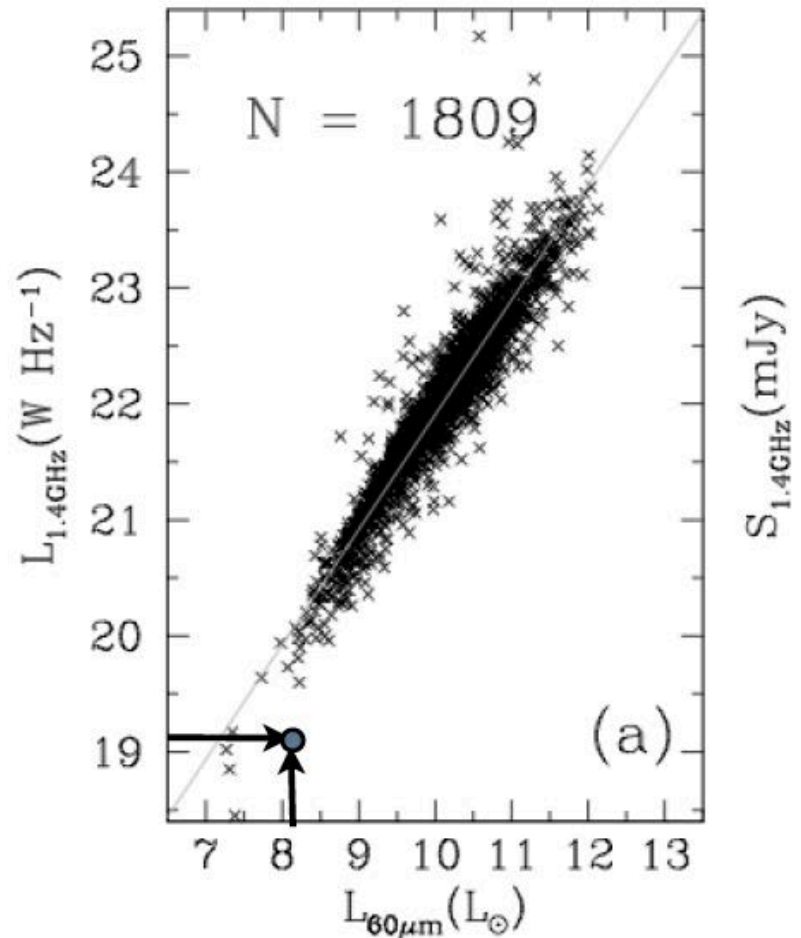
Radio - 2.7 GHz
Pohl et al., 1992, A&A



IR – MSX 8.3 μm
Bland-Hawthorn & Cohen, 2003, ApJ

Radio emission from Galactic Centre

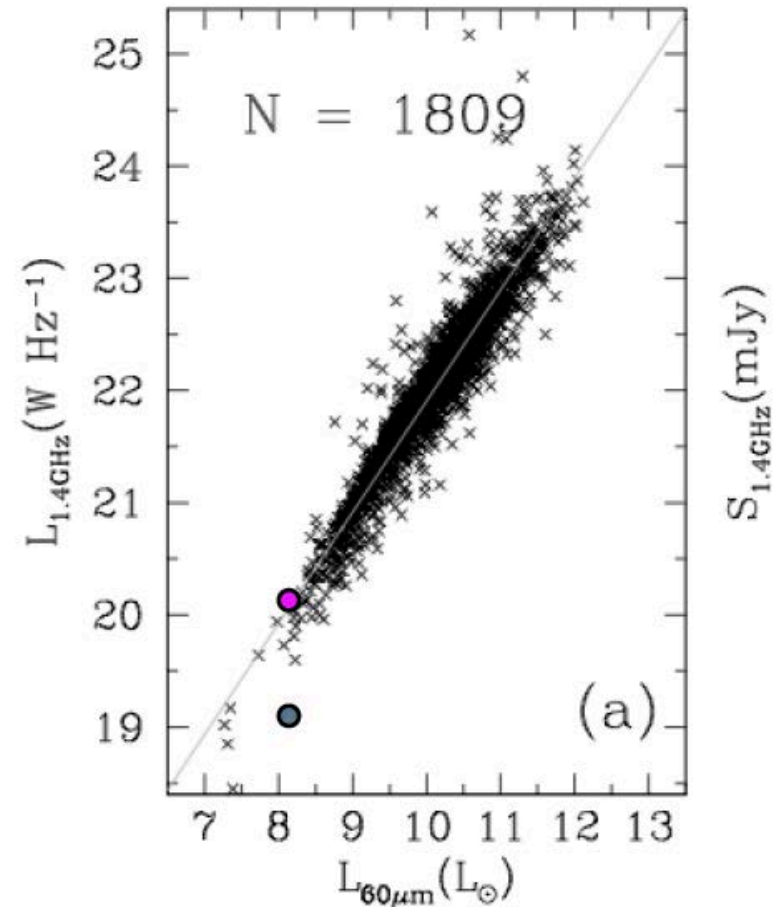
- Start formation in the Galactic Centre area (200pc)
- Radio Continuum in deficit compared to the expectation from FIR



Yun et al. 2001 ApJ 554, 803

Radio emission from the lobes

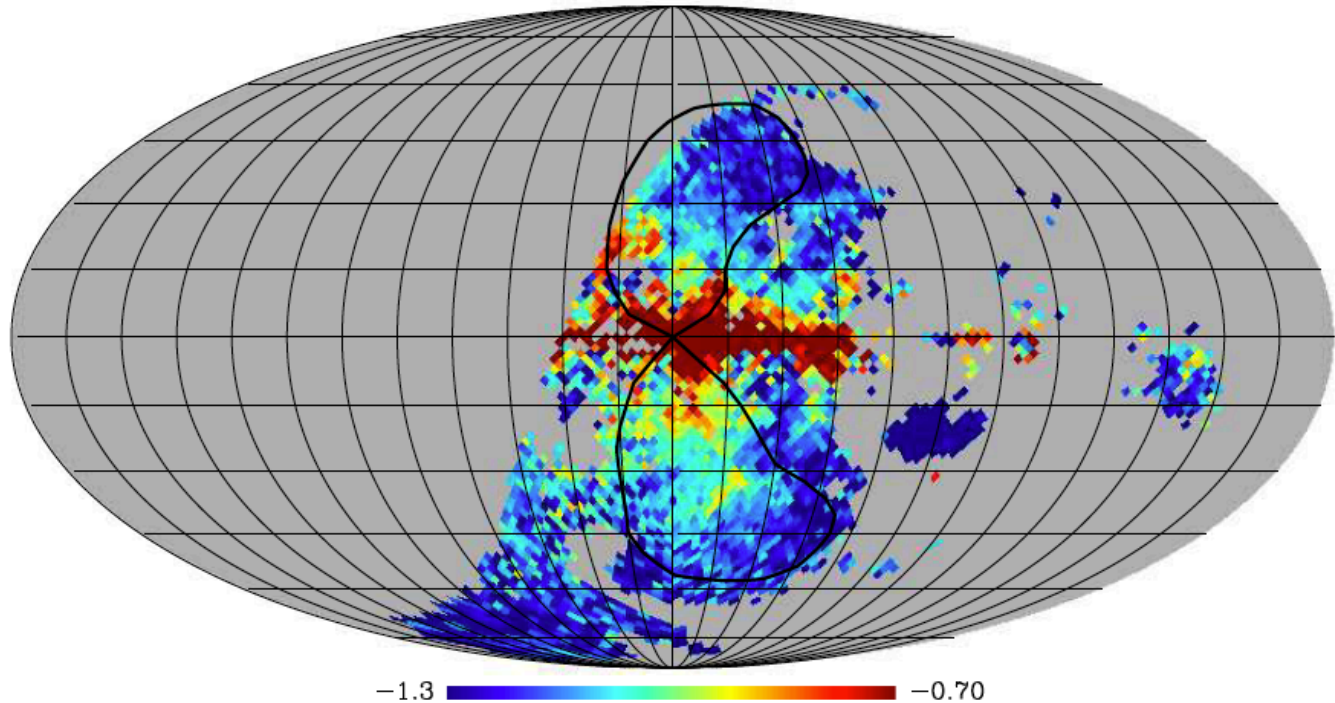
- 21 kJy @ 2.3 GHz
- Equates the missing RC
- RC emitting gas:
 - generated in the Galactic Centre
 - Then transported away as outflows



Yun et al. 2001 ApJ 554, 803

Spectral index (polarized)

alpha S-PASS/WMAP

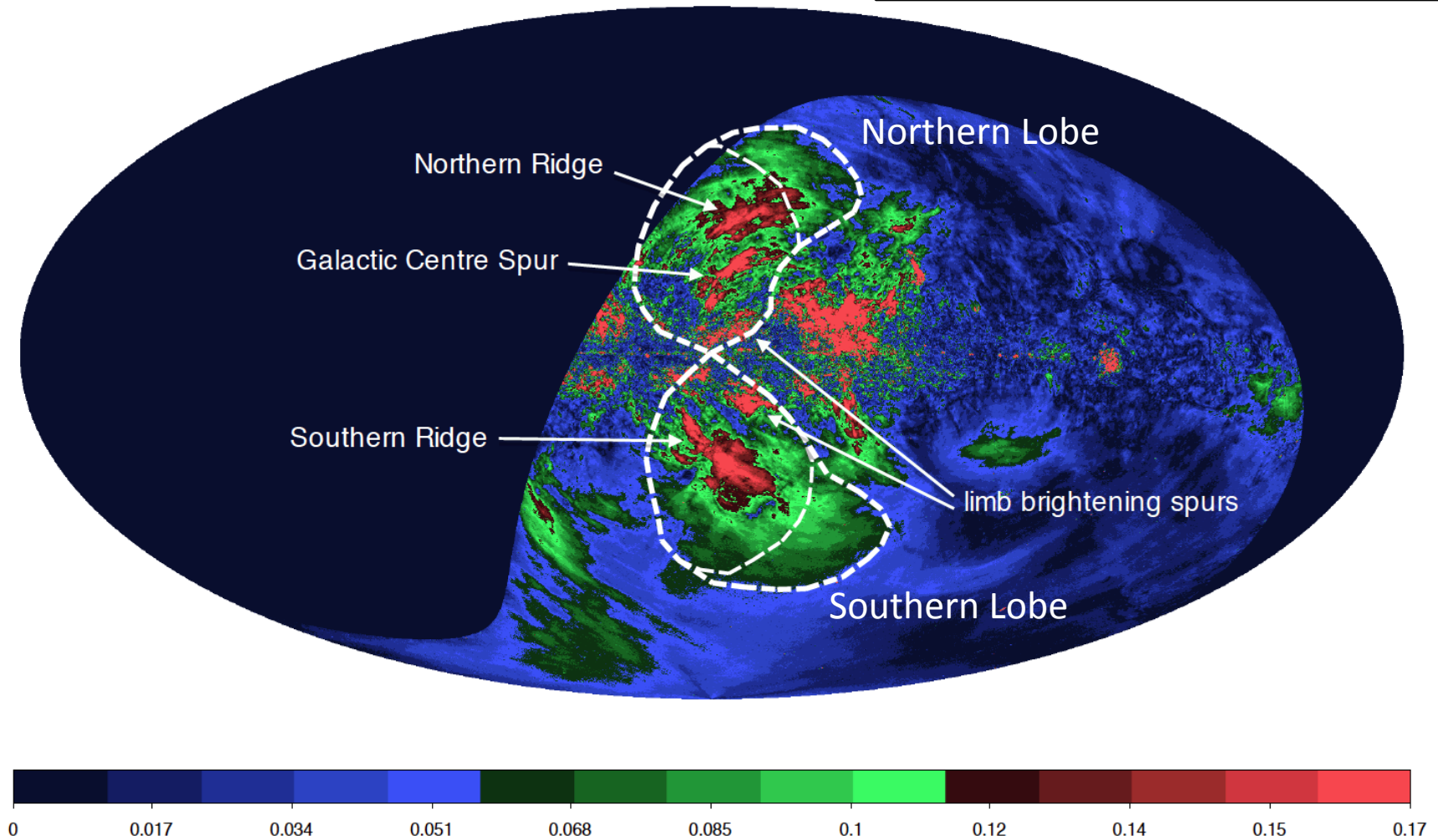


- Spectral index 2.3 GHz – 23 GHz (S-PASS - WMAP)
- $\alpha = -1.0$ to -1.2 ($S_v = A v^\alpha$)

Carretti et al., 2013, Nature, 493, 66

Lobes' Morphology

Carretti et al., 2013, Nature, 493, 66



Significant points

Carretti et al., 2013, Nature, 493, 66

- Deficit of radio emission in the central 200 pc (as expected from the measured star formation activity)
- Emission from the lobes: it accounts for the missing amount
- Morphology of the lobes
- Spectral index steepening at higher lats
- Star-forming driven outflows (not quasar-like outburst)

Significant points (2)

Carretti et al., 2013, Nature, 493, 66

- High polarization fraction, 25-30%
⇒ highly ordered magnetic field
- Magnetic fields 6-12 μG for Lobes, $\sim 15 \mu\text{G}$ for Ridges
- $U_B[\text{Lobes}] \sim (1 - 3) \times 10^{55} \text{ erg}$
- Massive energy and strong B transported into the Halo
- Key role in generating and sustaining the Galactic magnetic field?

Conclusions

- S-PASS: new view of the polarized sky
- S-PASS lobes: giant radio polarized outflows from the Galactic Centre
- Counterpart of the γ -ray Fermi bubbles
- Star-formation driven outflows
- Strong magnetic field from the Galactic Centre into the halo
- What role in generating and sustaining the Galactic magnetic field?

Thank you

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