Galactic Legacy Projects

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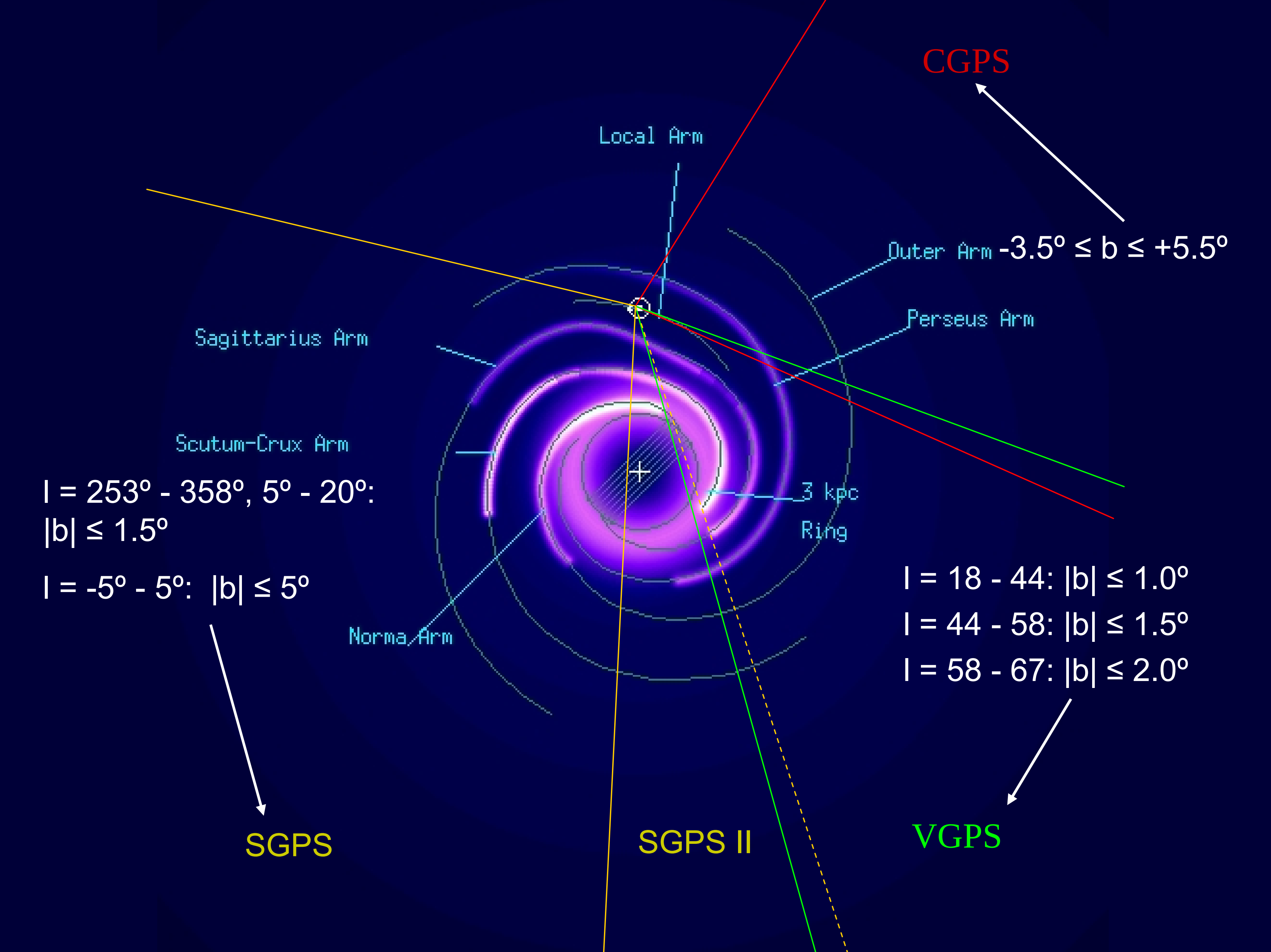
Outline

- Introduction: what “Legacy” projects can do for you
  - Recent Galactic legacy-type projects
- Possible future projects: positioning us for the SKA
  - NVSS with rotation measures
  - Galactic plane survey with full spectral polarization
    - VLA
    - GBT
  - Ammonia in star-forming regions
- What we need to make these happen
- Summary

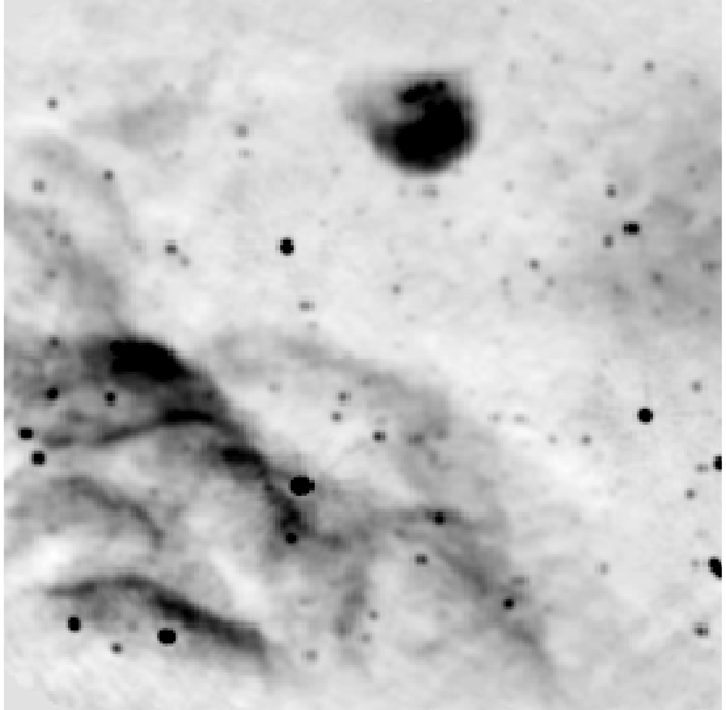
Recent "Legacy" Projects

- "Legacy" Projects produce datasets with broad, lasting value and highly cited papers
- Some recent Galactic Legacy projects at radio frequencies:
  - International Galactic Plane Survey: CGPS (Taylor et al), VGPS, (Stil et al), SGPS (McClure-Griffiths et al, Haverkorn et al)
  - Multi-Array Galactic Plane Imaging Survey (Becker, Helfand et al)
  - Galactic All-Sky Survey (McClure-Griffiths et al)
    - Before 2005: LDS-IAR survey, Hartmann, Burton et al; Kalberla et al,)
  - Boston University Galactic Ring Survey (Jackson et al)



CGPS
Local Arm
Outer Arm
-3.5º ≤ b ≤ +5.5º
Perseus Arm
Sagittarius Arm
Scutum-Crux Arm
l = 253º - 358º, 5º - 20º:
|b| ≤ 1.5º
l = -5º - 5º: |b| ≤ 5º
3 kpc
Ring
Norma Arm
l = 18 - 44: |b| ≤ 1.0º
l = 44 - 58: |b| ≤ 1.5º
l = 58 - 67: |b| ≤ 2.0º
SGPS
SGPS II
VGPS

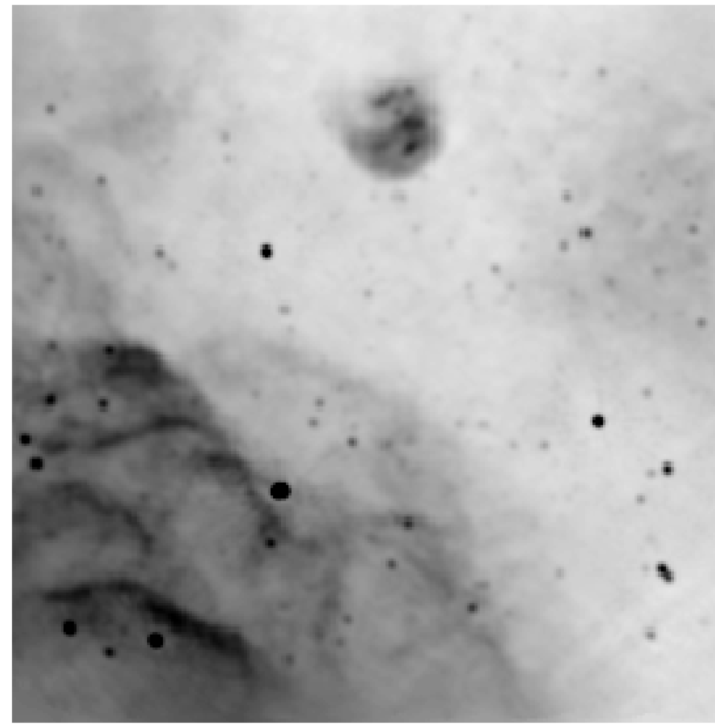
ATCA



1 deg

Parkes

ATCA + Parkes

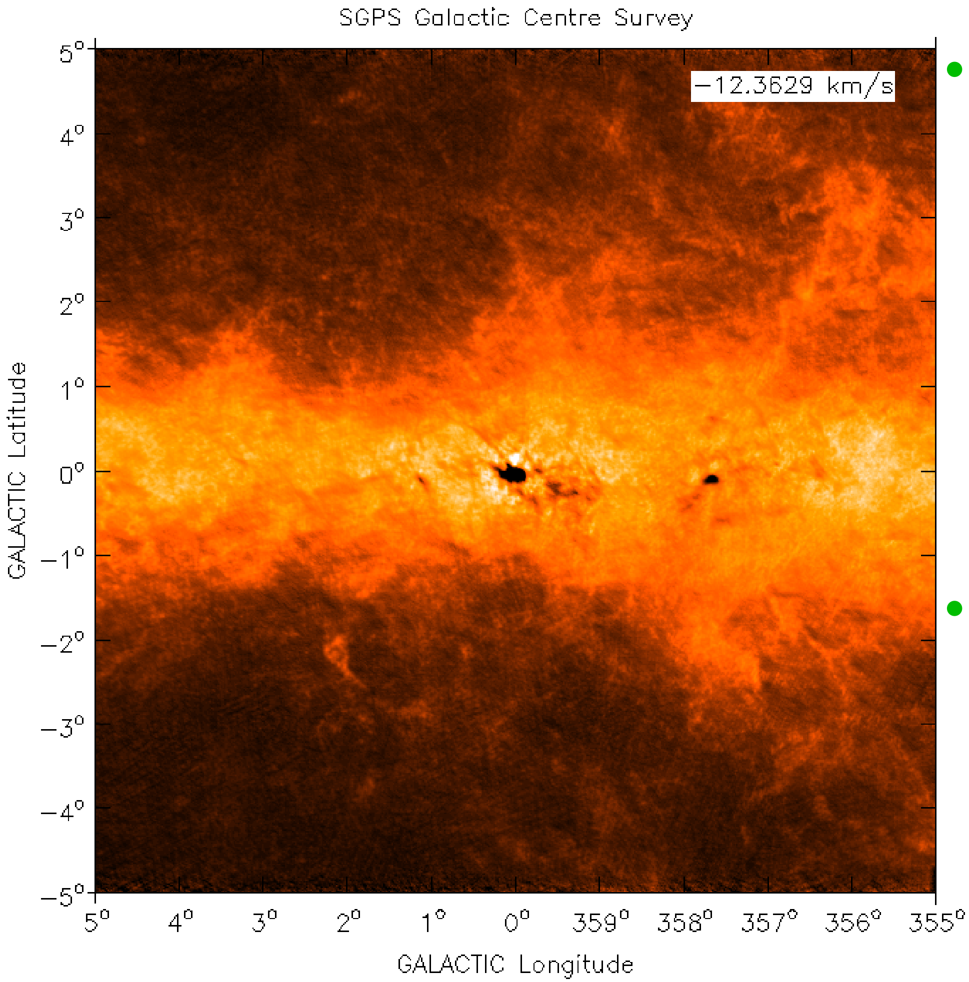


Why do the IGPS?

- Resolve the ISM simultaneously on scales of parsecs to kiloparsecs
- Hope to answer questions like:
  - What are the structural characteristics of the warm and cold HI
  - How is structure formed in the ISM?
  - What are the dynamics of the HI throughout the Galaxy?
  - What are the temperatures of the warm and cold HI?
  - What is the spiral structure of the Milky Way?

QuickTime™ and a
BMP decompressor
are needed to see this picture.

SGPS Galactic Centre Survey



- Extension to the SGPS to cover the Galactic Centre
  - Covers -5º ≤ *l* ≤+5º and -5º ≤ *l* ≤+5º
  - Angular resolution of 100”
  - 967 pointings
  - Sensitivity: 1 - 2 K
- Probes the dynamics of HI in the central 3 kpc of the Galaxy

Galactic All-Sky Survey: GASS

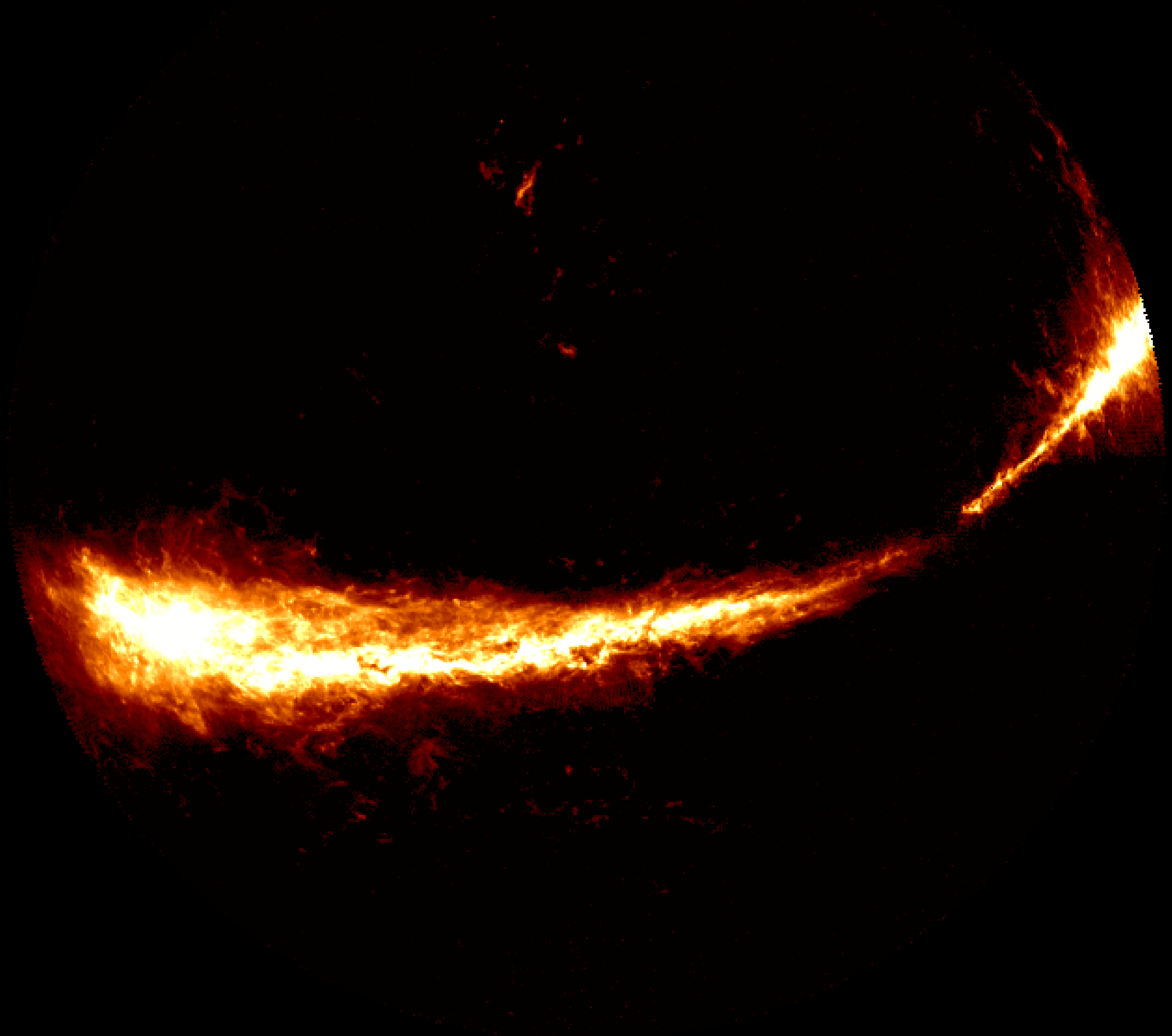
- Survey all atomic hydrogen (HI) emission south of δ□0º
  - Uses the Parkes 13 beam 21 cm multibeam receiver
- Velocity range: -450 km/s to 400 km/s
  - Focuses on HI associated with the Milky Way
  - HIPASS was -1200 km/s to 12700 km/s
- Velocity resolution: 0.8 km/s
  - HIPASS was 13 km/s
- Angular resolution: 14.4 arcmin
- Stray radiation corrected
- ~1800 hours observing, started in Jan 2005 to be completed by November 2006

To do sky north of δ□0º with the GBT would take ~10,000 hrs

Why do GASS?

- HI observed in all directions on the sky
  - Offers information about:
    - The structure and formation of the Milky Way and its halo
    - The interaction of the disk and halo
    - The nature of High Velocity Clouds
- Current HI surveys are:
  - High resolution (arcminute), but limited to +/- a few degrees around the plane (e.g. SGPS, CGPS)
  - All sky, but low resolution (~ degree)
- UV and optical absorption lines suggest that there is sub-degree structure but are limited to pinpointed lines of sight (e.g. Diplas & Savage 1994)
- Recent GBT and Arecibo observations also confirm sub-degree scale structure but they cannot survey the whole sky

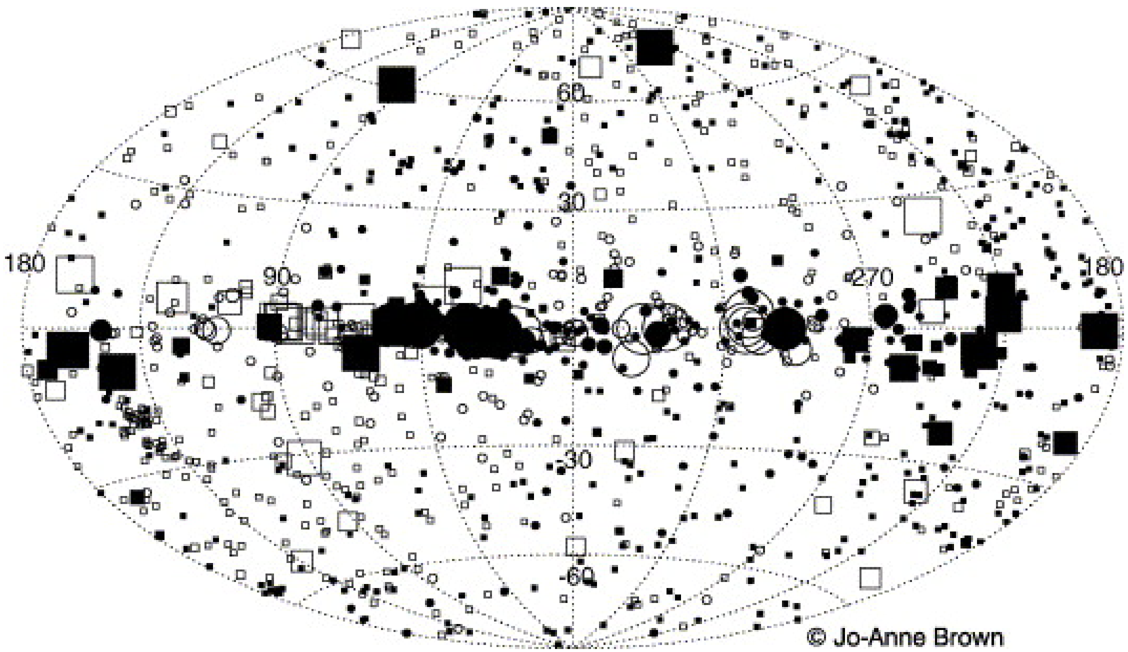
A view of GASS



Possible Future Legacy Projects

- Focus on projects with direct lead-ins to the SKA, i.e. magnetic universe
- NVSS repeat with Rotation Measures
  - Constrain the magnetic field of the Galaxy
  - Search for variability
- Galactic Plane Surveys with full spectral polarimetry
  - HI Zeeman of tangent point
  - Faraday tomography of the magneto-ionic medium
- Ammonia in star-forming regions

Rotation Measure grid



1203 RM sources known

316 pulsars (circles), 887 extragalactic (squares)

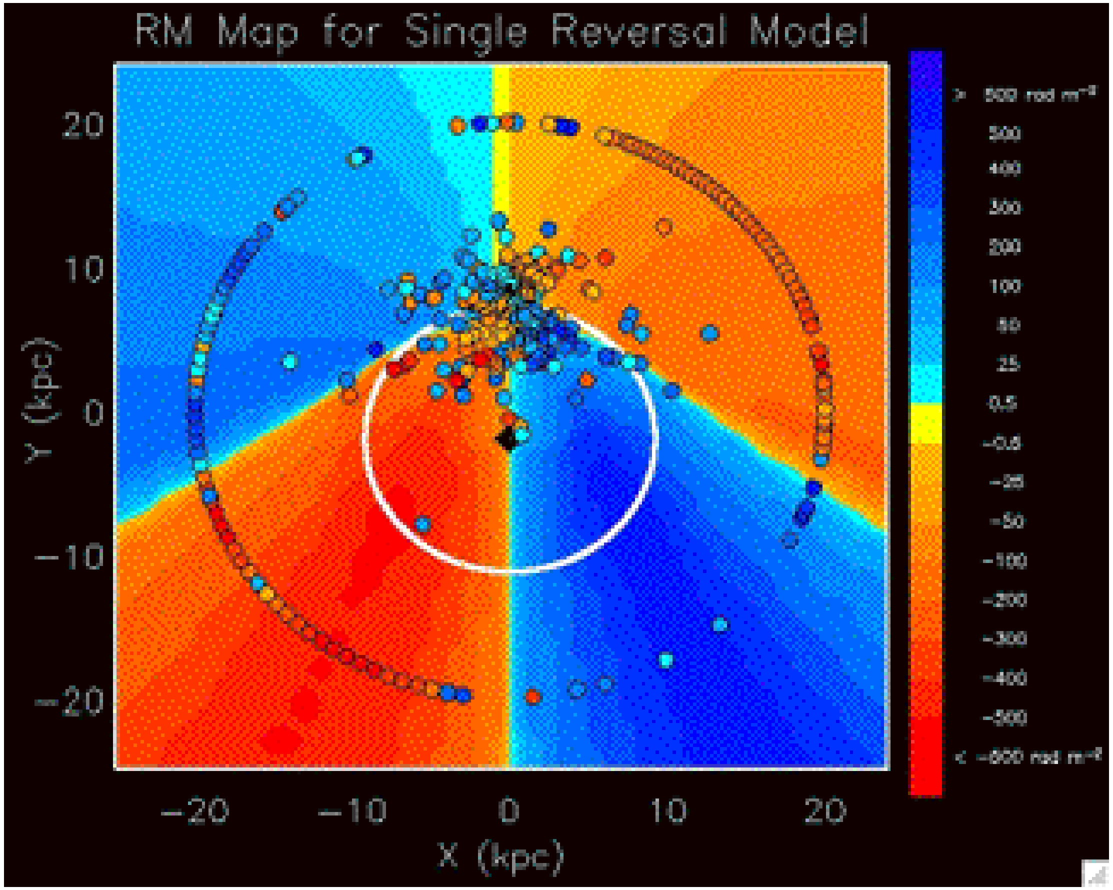
Positive RMs: solid

Negative RMs: open

- Supply a rotation measure "grid"
- With the EVLA capabilities of larger bandwidth and reduced system temperatures, it should be possible to repeat the NVSS with full polarimetric capabilities

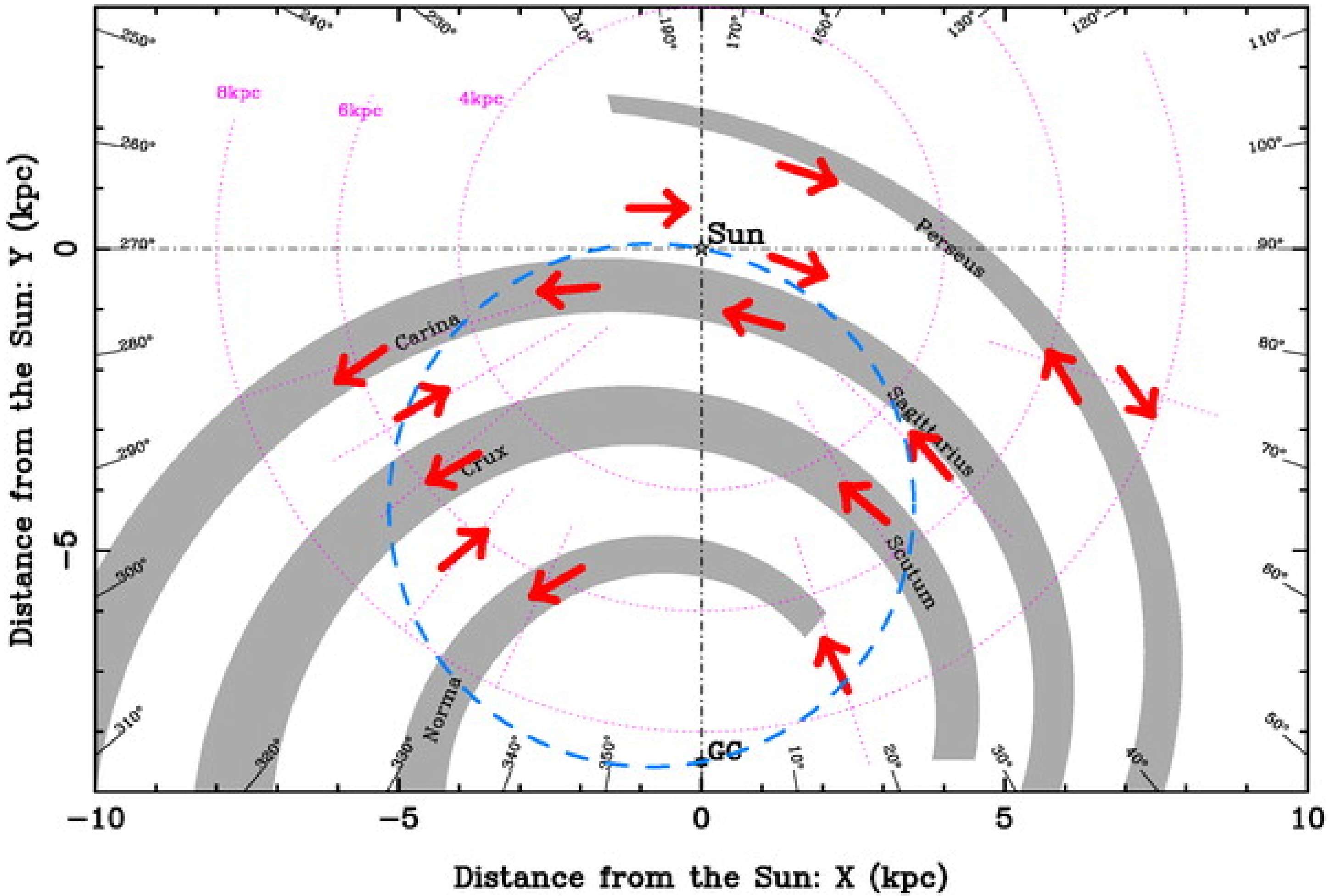
RM grid science

- Model the magnetic field of the Milky Way
  - Explore field reversals
  - Z-field strength
  - Probe dynamo theories
  - Complimented by pulsar surveys
- Search for magnetic fields/ionised gas in high velocity clouds



Brown et al, in prep

Milky Way Magnetic field



Han et al. (2006): Plus signs and crosses represent positive RMs, squares and circles represent negative RMs

RM Grid with the EVLA

- Use bandwidth of 500 MHz, with full polarization in ~0.5 MHz channels

$$\Delta RM = \frac{1}{2\mathcal{L}} \frac{1}{\lambda \Delta \lambda}$$

- For ΔRM > 5 rad m^{-2}, require S/N, $\mathcal{L}$ ~ 6 (Beck & Gaensler 2004)
- For the same integration time per pointing as the NVSS, expected rms is ~0.05 mJy/Bm
- Anticipated number of RM sources is ~120,000, 100 times the number known now!

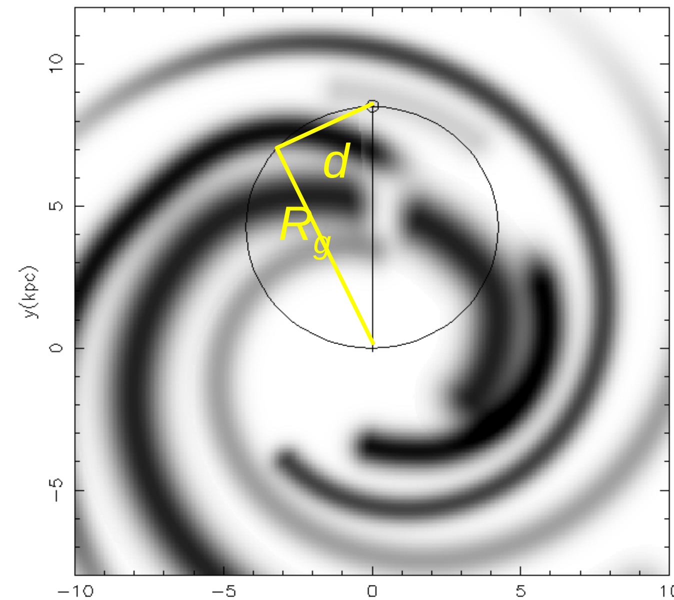
Zeeman survey of the Tangent Point

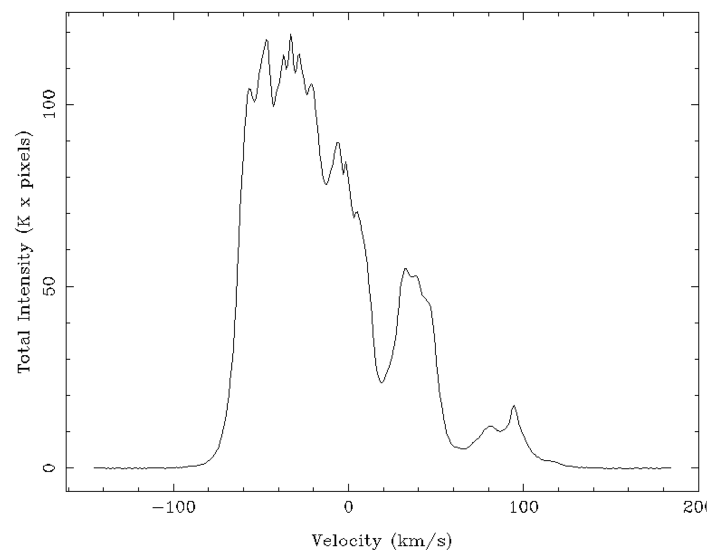
- HI Zeeman observations provide in situ measurements of the B-field
  - Depends on the derivative of the spectrum
- The terminal velocity at the tangent point in the inner Galaxy provides a steep spectrum at a known distance
- Zeeman peak-to-peak signal:

$$\Delta T_{pp} = 3 \times 10^{-4} \times (B_{\mu G}/\sigma_{v2}) \times T_b$$

- If B~6 μG (Heiles & Troland 2005), T_b ~ 120 K, ΔT_{pp} ~ 0.2 K

- GBT survey of l=10 - 90, |b|<0.5, with 9' resolution to 20 mK in 900 hrs





An HI Galactic Plane Survey?

- The EVLA correlator might offer the opportunity to do a full polarization survey with HI and continuum
- Multiple options:
  - Improve the sensitivity of the IGPS: σ=1 K $\rightarrow$0.1 K
    - Requires the E-array
  - Improve the resolution of the IGPS: θ = 1’ $\rightarrow$ 30”
    - Requires lots of time on the C array (mapping speed 0.025 deg^2/hr: 5200 hrs just for VGPS area!)
  - Improve the coverage of the IGPS
    - Extend to higher latitudes - requires better sensitivity (E-array)
  - Redo the IGPS with full spectro-polarimetry
    - Faraday Tomography of the Galactic plane: feasable with EVLA + GBT

Faraday Rotation Measure Synthesis

- Different frequencies trace different Faraday depths, ϕ:

$$\phi = 0.81 \int_{there}^{here} n_e \mathbf{B} \cdot d\mathbf{l} \text{ rad m}^{-2}$$

- By imaging the polarized continuum over a large frequency range with good spectral resolution, we can probe the magneto-ionic medium as a function of Faraday depth
  - Follow-up with HI absorption towards polarized background for distances to emitting regions
- Channel width determines the RM range and the total BW determines ΔRM

The GBT need

- Interpreting RMs without large scale structure is dangerous!
  - Imaging of the diffuse polarized background requires single dish data as well as the interferometric data
  - Need spectro-polarimetric imaging capabilities with the GBT (software)
- Most large scale surveys of diffuse emission will require GBT data to accompany VLA data

Ammonia survey with the GBT+VLA

- The GBT could do a survey of ammonia in the Galactic plane, tracing densities of $n \geq 10^5 cm^{-3}$
- Use GLIMPSE IR survey as a finder map of star forming regions
  - Derive kinematic distances to the regions
  - Explore temperature and density structure of star forming regions
- Angular resolution of 30" will complement the HI GPS (1'-2'), the Boston University GRS CO survey (46")
  - Follow-up with EVLA for matching resolution to GLIMPSE (1")

What we need

- EVLA to achieve polarization purity of -25 dB across the field
- EVLA to achieve correlator goals, i.e. $\Delta\nu$> 500 MHz at 1.4 GHz, full polarization in >1000 channels
- The E-Array for surface brightness sensitivity
- Software:
  - Spectro-polarimetric imaging for the GBT
  - Efficient large-scale mosaic imaging for the VLA
- Support for producing VO compliant public release data products?

Summary

- Legacy projects provide highly cited papers, general purpose datasets for large community use
- Possible Galactic projects for the future include:
  - RM grid with the EVLA
  - HI Zeeman at the tangent point with the GBT
  - Ammonia in star-forming regions with the GBT+EVLA
- Future HI surveys (Galactic Plane and high latitude) with the VLA would require the E-array
- An all-sky HI survey with the GBT will need a multibeam

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