S-PASS: S-band Polarization All Sky Survey

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Outline

• S-PASS goals: Polarized synchrotron emission

• B-Mode CMB Polarization foreground (to probe Inflation);
• Milky Way magnetic field: large scale structure.

• S-band Polarization All Sky Survey (S-PASS)
  • observing strategy
  • Maps
  • First results
CMB Polarization
Why to observe CMBP? (B-mode)

- $C^B$ measures the **tensor-to-scalar perturbations power ratio**: $T/S$.
- $T/S$: amount of primordial gravitational wave background generated by Inflation.

- $C^T$ and $C^E$: no sensitivity.
- $C^B$: linear dependence
- Measure of Inflation parameters

- No detection so far: $T/S < 0.20$ (95% C.L.)
CMB foregrounds

• But…

• CMB B-Mode is weak ⇒ 1-100 nK
• …and any astrophysics foreground emission can contaminate it.

• brightest: Galactic diffuse emission
  • Synchrotron (radio)
  • Dust (mm)
Galactic Synchrotron Foreground

- All high Galactic latitudes: $T/S \sim 0.3$ larger than the current upper limit (Page et al. 2007)

- Some selected areas: $T/S \sim 3 \times 10^{-3}$ larger than the current upper limit (Carretti et al. 2010)
Galactic Magnetic Field
Galactic Disc $B$: using pulsar RM

- RM pulsar distribution in the Galactic plane (Han et al. 2006)
Galactic Disc magnetic field: using EGS RMs

[van Eck et al. 2010]
Anti-symmetry in the inner Galaxy: local structure or signature of dynamo?

Extragalactic sources

Pulsars

Han et al 1997

An A0 dynamo...

...or an even field and the North Polar Spur?

Han 2003

Frick et al 2003

Han et al 1997

slide courtesy by M. Haverkorn
S-PASS
**S-PASS: S-band Polarization All Sky Survey**

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- **Aim:** to survey the polarized emission of the entire southern sky at 2.3 GHz
  - Dec < 0° (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**
Scanning strategy: requirements

- High speed (10+ deg/min)
  - coverage = 20,000 deg²
  - beam = 9’ => px = 4.5’
  - one pixel (!)

- ground emission
  - EL dependant

- absolute calibration
Mapping: standard basket weaving?

- All-sky class surveys

- basket weaving technique is an option
  - sky sub-divided in smaller areas then combined
Mapping: long AZ scans

- small area basket weaving: **not an option for S-PASS**
  - ground emission contamination (EL dependant)
  - high speed requires significant overhead for short scans (10°-20°)
  - short scans: mean emission on area scale is lost

- **New exotic/non-standard scanning strategies has been developed for S-PASS**
  - AZ scans
    - Long AZ scans at South Pole EL to cover all Dec in one haul (~115°)
    - uses the Sky rotation to observe all RA 24 hrs.
    - each day/night a zig-zag track is observed in the sky
    - one zig-zag per night: accurate start timing is required
Mapping: All-sky class surveys
AZ scan benefits

- **Long AZ scan benefits:**
  - smaller number of scans (12000 !) => lower overhead
  - ground emission: EL dependent => AZ scans are optimal.
AZ scan benefits

• Long AZ scan benefits:
  • smaller number of scans (12000 !) => lower overhead
  • ground emission: EL dependent => AZ scans are optimal.
  • but, mainly, **absolute calibration**
Absolute Calibration

- Data reduction requires baseline removing => mean signal lost

- Basket weaving can recover all but the mean emission on area size scale (mapped with scans)

- Scans conducted in two directions:
  - **East**: AZ = [65, 180] => Dec = [-90, 0] at “sky-rise”
  - **West**: AZ = [180, 295] => Dec = [-90, 0] at “sky-set”
Basket waving with AZ scans
Absolute Calibration

- Long scans allow to recover signal up to the size of the map
- **Not sufficient!**
- The (new) idea is to use the parallactic angle modulation of Q and U
- If the scan is sufficiently long, the variation of parallactic angle modulates even a constant signal of Q and U

- Mean signal is not fully lost: the baseline subtraction does not fully remove it (long scans essential)
- It can be reconstructed (M-L inversion problem).
Absolute Calibration: tests

# instances

\( \Delta Q \) [mK] \( \Delta U \) [mK]
S-PASS: abs calibrated maps

S-PASS I
S-PASS: abs calibrated maps

S-PASS Q
S-PASS and other data sets

SHASSA: H$_{\alpha}$
WMAP 22.8 GHz
ROSAT
Scanning Strategy

• Successful observation strategy

• Adopted by other projects at Parkes (STAPS, GMIMS - Maik’s talk)
  • … and at other telescopes

• Possible thanks to system flexibility and staff support…
RM point sources

- Dedicated pipeline optimised to point sources
- aim: to get an RMs catalogue (0.25 src/deg$^2$)
  - to fill the gap at DEC < -40°
  - to check NVSS RMs up to DEC = 0° (NVSS used two freq only)
  - to contribute understanding the **Halo field structure**

S-PASS: RM (compact srcs - preliminary)

5000+ sources
0.25 src/degree

250 rad/m²
S-PASS: RM (preliminary)
Conclusions

• S-PASS goals:

• CMB foregrounds
  • Cleaning => Need for accurate mapping

• Galactic magnetic field
  • LSS still unknown,
  • as well as the engine

• S-PASS: high S/N, small FR effects, absolute calibration

• SPASS: maps, first analysis