Large Scale Polarization Explorer

Science goal and performance

Francesco Piacentini (Univ. Roma La Sapienza) – for the LSPE collaboration
LSPE is a balloon payload aimed at:

- Measure large scale CMB polarization and temperature anisotropies
  - Explore large scales anomalies measured by Planck

- Constrain the B-modes of polarization
  - ell range [2-100]

- Improve the limit on tensor to scalar ratio $r$
  - $r = 0.03$, at 99.7% confidence

- Test and validate technologies for space application
  - Large Cold Achromatic Half Wave Plate (50 cm)
  - ESA ITT approved to G. Pisano (Manchester)
Payload – mission

- The Large-Scale Polarization Explorer is
  - a spinning stratospheric balloon payload
  - 15 days duration fight, North hemisphere, from Svalbard
  - in the polar night (700 W, on batteries)
  - using polarization modulators to achieve high stability

- Frequency coverage: 40 – 250 GHz (5 channels)

- Two instruments:
  - SWIPE (95, 145, 245 GHz):
    - Multimode large throughput horns
    - bolometers at 300 mK
    - Rotating, 4 K cold half wave plate + wire grid polarizer
  - STRIP (43, 90 GHz),
    - HEMT coherent polarimeters at 20 K,
    - same polarimeters as in QUIET
    - 49 modules at 43 GHz, 7 modules at 95 GHz for crosscheck of systematic effects

- Angular resolution: 1.5 – 2.3 deg FWHM
- Combined sensitivity: 10 uK arcmin per flight
Instruments details are presented in a poster
Observation strategy

- Spin rate = 3 rpm
- Latitude = 78 N
- Longitude, variable
- Elevation range
  - independent for the two instruments
  - 30 - 40 degrees above horizon
Sky coverage

23% of the sky is observed using the WMAP polarization mask

The same sky is observed every day (depending on the elevation changes strategy)
Calibration

**Sources**
- S/N sampling at 60 Hz
- Signal is intensity
- S/N for one detector

**Polarization angle and efficiency**
- Crab
- Moon limb
- Ground based calibration

**Beam mapping**
- In black: one scan
- In white: one day
  - More than 2000 samples per day
  - Increase S/N by ~45
  - Increase S/N by ~160 in 13 days

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<table>
<thead>
<tr>
<th>Source</th>
<th>Culmination (deg)</th>
<th>S/N per sample at 44 GHz</th>
<th>S/N per sample at 90 GHz</th>
<th>S/N per sample at 95 GHz</th>
<th>S/N per sample at 145 GHz</th>
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<tr>
<td>Moon</td>
<td>30</td>
<td>37500</td>
<td>200000</td>
<td>2000000</td>
<td>700000</td>
<td>2000000</td>
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<tr>
<td>Crab</td>
<td>34</td>
<td>20</td>
<td>18</td>
<td>22</td>
<td>23</td>
<td>28</td>
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<tr>
<td>Mars</td>
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<td>1.6</td>
<td>2</td>
<td>5.6</td>
<td>18</td>
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<tr>
<td>Jupiter</td>
<td>27</td>
<td>15</td>
<td>80</td>
<td>100</td>
<td>275</td>
<td>850</td>
</tr>
<tr>
<td>Saturn</td>
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<td>1.4</td>
<td>7</td>
<td>9</td>
<td>24</td>
<td>70</td>
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<tr>
<td>Uranus</td>
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<td>0.05</td>
<td>0.24</td>
<td>0.3</td>
<td>0.8</td>
<td>2.5</td>
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</table>
Expected performance – sensitivity

- STRIP - low frequency
Expected performance – sensitivity

- SWIPE – high frequency
Sensitivity – BB power spectrum

\( |(l+1)C_{l}/2\pi| (\mu K^2) \)

\( \Delta_{\text{bin}} = 3 \)

\( r = 0.1 \)

\( r = 0.03 \)

Multipole range: 10 to 100
Sensitivity – parameters ($r=0.03$)

- $\Omega_{\text{de}}^2$ vs. $r$
- $n_s$ vs. $r$
- $\Omega_\Lambda$ vs. $r$
- $\text{Age/Gyr}$ vs. $r$

Legend:
- Black: Planck 143GHz
- Red: Spider
- Blue: LSPE
Sensitivity – parameters ($r=0.001$)

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Large Scale Polarization Explorer

$r=0.01$ green line

Planck 143GHz
Spider
LSPE
Component separation

- We plan to adopt a weighting scheme that minimizes foregrounds residuals
  - Bonaldi, A.; Ricciardi, S. 2011 MNRAS
  - Here is based on LSPE only. In combination with Planck can improve even more
## Systematic effects

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<td>Sidelobes pickup of sky signal</td>
<td>Large shields, cold stop</td>
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<tr>
<td>Sidelobes pickup of Earth and Balloon</td>
<td>Large shields, cold stop</td>
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<td>Gain stability</td>
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<td>Compensation on scans</td>
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Half Wave Plate strategy: spin/step

- The HWP non-idealities such as:
  - Differential emission
  - Differential reflection
  - Differential phase shift
  - Slant incidence of radiation into HWP
  - Thermal fluctuations of HWP

- In the spinning case, this can generate a spurious signal,
  - angular dependent
  - With components at 4 times the angle
  - Systematic effect in the recovered polarization

- In the stepping case, this is step dependent offset
  - The offset is removed in any case
  - Signal modulation is provided by the scanning
  - Polarization is extracted by combing signals from the SAME detector at different time, with different HWP angles, same beam, same sidelobes
  - 1/f noise is treated by ML iterative mapmaking
Conclusion

- LSPE is exploring large scales, where Planck detected “anomalies”
- Night time polar balloon flight
- Designed for polarization purity
- Deep measure of polarized foreground
- Two 90 GHz channels with different technologies (HEMT, bolometers) for crosscheck of systematic effects
- Low frequency channel for optimal control of synchrotron polarized foregrounds
- Technology development for next generation space mission
- The $r=0.03$ at 99.7 confidence level is achievable
- Upper limit at $r=0.01$
- Timescale: launch on Winter 2014/15
Collaboration

- Dipartimento di Fisica, Sapienza Università di Roma, Italy
- Dipartimento di Fisica, Università degli Studi di Milano, Italy
- Dipartimento di Fisica, Università di Milano Bicocca, Italy
- IASF-INAF Via Gobetti 101, Bologna, Italy
- IASF-INAF, Milano, Italy
- OAT-INAF, Trieste, Italy
- Physics Department, University of Trieste, Italy
- IFAC-CNR, Firenze, Italy
- Dip. Meccanica e Tecnologie Industriali, Univ. di Firenze, Italy
- Cavendish Laboratory, University of Cambridge, UK
- Jodrell Bank Centre for Astrophysics, University of Manchester, UK
- IEIIT-CNR, Torino, Italy
- Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy
- Agenzia Spaziale Italiana, Roma, Italy
References

- The LSPE collaboration et al., *The Large-Scale Polarization Explorer (LSPE)*, Proc. SPIE 8446, Ground-based and Airborne Instrumentation for Astronomy IV, 84467A (September 24, 2012)


Half Wave Plate for SWIPE


- Dielectric embedded metal mesh

- Metallic grids with sub-wavelength anisotropic geometries able to mimic the behaviour of natural birefringent materials

- The current mesh HWP has measured performance, across a 20% bandwidth (78-100 GHz)
  - Transmission 0.9
  - differential phase-shift flatness and 180.4 ± 2.9 degrees
  - Cross-polarisation -35 dB

- ESA ITT grant to G. Pisano (Manchester) for large prototype development
STRIP-43 GHz – effect of $I \rightarrow Q/U$ leakage

Leakage > 0.1% can affect measurements significantly

This is the 0.1% limit
STRIP-43 GHz – effect of polarization angle uncertainty

EE Power Spectra (error on polarization angle)  BB Power Spectra (error on polarization angle)
STRIP-43 GHz – effect of cross-polarization

Effect of cross-polarization on BB power spectra

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SWIPE – polar angle
SWIPE – HWP phase shift error