Polarised Dust Emission in the Magellanic Clouds

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Dust Polarisation

- Grains are elongated and rotating
- Grains align partially on $B$
- Cross section depends on grain size
- Trace $B$ direction projected on the sky (like synchrotron)
The Magellanic Clouds

- Nearby: high resolution (~15pc) observations of dust, synchrotron and gas
- Low metallicity: LMC~1/2 and SMC ~1/6 solar, early Universe prototypes
- External vantage point: effect of galactic environment, known distance
- High galactic latitude: foreground contamination minimised

Fully mapped by the Spitzer SAGE and Herschel HERITAGE key programmes (Meixner ea 2006, 2013)
The Large Magellanic Cloud

• synchrotron & HI disk are more extended than SF region (esp. in south)
• HI & RC similar morphology, inc. “holes” — rarely seen in external galaxies
353GHz Polarized Sky: LMC

debiased DX9 Planck data (15’) no foreground subtraction
353GHz vs Visible: LMC

Blue: Planck 353GHz
Dark Blue: LMC stars
Red: MW stars

no foreground subtraction
Foreground Removal: $p$

- $I_{FG}$ from correlation with MW HI just outside LMC
- $p_{FG}$ of foreground from correlation of $P$ and $I$ with MW HI just outside LMC ($p_{FG} = 4.4\%$)
- $\psi_{FG}$ of foreground polarization from foreground stars interpolated over LMC
- $Q_{FG} = p_{FG} * I_{FG} * \cos(2*\psi_{FG})$
- $U_{FG} = p_{FG} * I_{FG} * \sin(2*\psi_{FG})$
Forefront Subtracted: LMC

Total Intensity + B vectors

Polarised Intensity + B vectors
Dust v s Synchrotron: LMC

Polarised Intensity + B vectors

1.4GHz Polarised Intensity + intrinsic polarisation angles

Figure 8, Mao et al (2013)
Polarisation Fraction: LMC

Polarisation Fraction

Polarisation Fraction vs N(H)

p decreases with N(H), similar to trend seen in MW

(Planck XIX, 2015)
353GHz Polarized Sky: SMC

debiased DX9 Planck data (15’)
no foreground subtraction
Foreground Subtracted: SMC

Total Intensity + B vectors

Polarised Intensity + B vectors
Polarisation Fraction vs $N(H)$

Polarisation Fraction decreases with $N(H)$, similar to trend seen in MW & LMC

(Planck XIX, 2015)
PILOT: Polarised Instrument to Observe the Tenuous ISM

Measures linear polarization of dust emission in the FIR/submm

$\lambda=240\mu m$, angular resolution: 1.4', instantaneous FoV $\sim 1^\circ \times 0.8^\circ$

Bolometer array with 2048 detectors

First flight on 20 September 2015 from Timmins. Two more flights foreseen (including southern hemisphere)
Key Science Objectives:

- the structure of the magnetic field from diffuse to dense ISM
- geometric and magnetic properties of dust grains
- understand polarized foreground
- complement Planck observations at $\lambda<850 \, \mu \text{m}$, with better accuracy and higher angular resolution

Observations: Galactic plane ($|b|<20^\circ$), molecular clouds, nearby cold cores, external galaxies, diffuse ISM, deep fields
• Equivalent Focal length: 1800 mm, F/2.5
• Image quality diffraction limited
• Distortion : < 5%
• Polarization rotation : < 5°
• Tolerance:
  translation M1 = ±0.3 mm
  rotation M1 = ±0.06°
Polarisation Measurement

45° Polarizer

Input polarization

Output polarization

Half-Wave Plate
Polarisation Measurement

45° Polarizer

Input polarization

Output polarization

Half-Wave Plate

detector
Main Components

- Detectors
- Polarizer
- Cooled M2 (background control)
- ICS: Internal Calibration Source (calibrate the response of the detectors)

Components:
- 45° Polarizer
- 2nd lens
- Rotating HWP
- Flat mirror
- M2
- ICS

A. Hughes, Magnetic Fields in the Universe, Cargese, October 2015
• Bolometer arrays developed by CEA/LETI
• Same technology as used on Herschel PACS
• Multiplexed bolometer arrays with a total of 2048 detectors
• Detectors cooled down to 0.3 K through closed-cycle He3 fridge
• NEP $\sim 2 \times 10^{-16}$ W/Hz$^{1/2}$
The day-time stellar sensor (Estadius) provides 5” accuracy while scanning up to 1°/sec
A balancing act between:

- science objectives
- calibration needs
- source visibility
- experiment constraints
Flight Plan: M31, Orion

M31

Orion MC

SNRp (5')
Flight Plan: Diffuse ISM, DF

Polaris

Deep Field
Timmins Flight Trajectory

Profil de la trajectoire du vol PILOT 2015

2015/09/21 00:56 TU - 2015/09/22 01:30 TU
Total: 24 hr
Ceiling: 18.4 hr

caution: non-linear time axis ...
### Science Observations

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<th>t obs</th>
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- **molecular clouds**
- **YSOs & cold cores**
- **diffuse ISM**
Total flight time = 24 h
Total time at ceiling = 18.4 h
Ceiling altitude = 39 km (3 hpa)
Scientific data = 14.8 h (80 % of ceiling)
Detectors setting, Fridge recycling, slews = 3.6 h (20 %)

In-flight instrument performance:
- Focal plane at 320 mK (as expected)
- 6 out of 8 arrays operational (as expected)
- Detector noise at expected levels (a few $10^{-16} \text{ W/Hz}^{1/2}$)
- Instrument PSF consistent with expectations
- Pointing accuracy (Estadius) nominal
Inflight Performance: PSF

preliminary PSF on Saturn on individual arrays

A. Hughes, Magnetic Fields in the Universe, Cargese, October 2015
First Look: Orion
• Fixing connectors to arrays 1 & 3
• Enlarging bandpass: potentially increase sensitivity by a factor of 3
• BICEP2, LMC & SMC, Galactic Plane, including Galactic Centre
**NIKA2 on IRAM 30m**
Polarisation at 1 & 2 mm
KIDS detectors
Resolution: 12”, 23”
FoV: 6.5 x 6.5 arcmin
e.g. 8hr, M51, 36” at 2mm

**ALMA Cycle 3:**
2 pointings (arm+spur in NGC1566)
350 GHz continuum (B7)
Scales: 1.4” to 5.7” (60 to 250pc)
Time: 7.5 hrs (12m only)