MUSCAT: The Mexico-UK Sub-mm Camera for Astronomy

Tom Brien
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On behalf of the MUSCAT collaboration
The MUSCAT Instrument

- Funded 50% UK & 50% Mexico under Newton Fund. £1M ($1.3M)
- Funding council goal: to develop closer UK-Mexico links and transfer knowledge
- Instrument Specification (first generation):
  - Single band @ 1.1 mm
  - 1,500 LEKID detectors at photon noise limit
  - ≈Full LMT field of view (approx. 3.8 arc minute)
  - 5.8 arc second resolution
  - Diffraction limited down to 850 μm
- Scientific goals:
  - Follow up H-Atlas sources and assign counterparts
  - Map star-forming regions beyond Gould belt (d > 400 pc)
- MUSCAT is designed to be easily upgradeable and can act as an on-sky demonstrator
The MUSCAT Team

**UK**
- Simon Doyle (PI)
- Pete Hargrave (Optics)
- Carole Tucker (Filters)
- Peter Ade (Filters)
- Sam Rowe (Readout)
- Tom Brien (Cryogenics, Integration)
- Andreas Papageorgiou (Pipeline)
- Ian Walker (Project Management)
- Amber Hornsby
- Steve Eales (Science – Galaxies, H-Atlas PI)
- Matt Smith (Science – Galaxies)
- Nicolas Peretto (Science – Star Formation)

**Mexico**
- David Hughes (PI)
- Edgar Castillo-Domínguez (System Design)
- Marcial Tapia
- Abel Perez
- Salvador Ventura
- Víctor Gómez
- José Miguel García
- Daniel Ferrusca
- Miguel Velázquez

**Other**
- Enzo Pascale (Data Analysis)
- Philip Mauskopf (Horn blocks)
- Pete Barry (Detectors)
Optics Design

• MUSCAT picks off LMT beam after M3, just before prime focus
• Two crossed-Dragone mirror pairs used. One warm, one cold
• f/2.8 optics filling > 95 % of the LMT FOV
Optics Design

- Lyot stop inside cryostat before M7
- High-quality, highly telecentric beams produced across 140 mm focal plane
- Optics design is diffraction limited down to $\lambda = 850 \, \mu m$
- Cold baffles protect against stray light
Cryostat Design

- Nested baffles from 300-K window down to 350-mK stage.
- Fully baffled design
Cryostat Design

• Cryostat design based on *standard* lab test cryostat
  • Russian-doll construction with vacuum, 50-K, 4-K and 450-mK shields
• “Easy” to open and change out components
• Vacuum can is Ø1 m; 450-mK, superconducting shield is Ø 0.6 m.
• Total mass is close to 300 kg excluding support structure
• PTC vibration dampening via rubber gaskets and OFHP copper braid
• Thermal isolation with stainless cross beams and SCUBA-2 sapphire joints
Joint Testing

• Individual sapphire joints have a degree of freedom, hinge like
  • Not great for a support, however teaming up and rotating removes this
• Lab ‘testing’ shows test rig distorts only 30 μm under 30 kg load
  • Distortion is elastic up to 30 kg (> MUSCAT 450-mK stage)
• See: Bintley et al. (Cryogenics, 47, 2007)
Joint Thermal Testing

![Graph showing thermal conductance vs. joint central temperature for Stainless Steel and Sapphire.](image-url)
Cryogenics

- Continuous cooling to < 100 mK provided by four helium-based cooling systems:
  - 300 K → 4 K: Cryomech PT-420-RM
  - 4 K → 1 K: CRC continuous sorption cooler
  - 4 K → 450 mK: CRC continuous sorption cooler
  - 450 mK → 100 mK: CRC miniature dilutor

100-mK Cooldown
Detectors

• First-generation MUSCAT: 1,500 1.1-mm LEKIDs
• Hex-packed across the focal plane with $1\frac{\lambda}{F}$ spacing
• Horn-coupled with anti-reflection layer
MUSCAT Band

- Upper (frequency) edges defined by metal-mesh filters
- Lower edge by waveguide cut-on
  - Simulated but to be tested in lab (measured in MUSCAT).
- Can add metal-mesh bandpass at 150 mK, if needed
Readout

• Focal plane made of six sub panels each with its own readout channel
  • Easily attainable 250:1 MUX ratio

• ASU HEMT LNAs at 4 K
  • 30 dB gain in a 0.5-3.0 GHz band

• ROACH-2 boards with MUSIC DAC/ADC cards
  • Readout band 0.6-1.1 GHz

• IF electronics are commercially-sourced and low risk
  • Prototype board currently undergoing lab characterisation
MUSCAT & The Future

• TolTEC will supersede first-generation MUSCAT at 1.1 mm upon arrival
• MUSCAT is designed to be easily upgradable
• Simple switch out of focal plane. 2\textsuperscript{nd} generation arrays currently considered include:
  • 850 μm array. LMT is capable of 850 μm operation. MUSCAT can enable new science at LMT
  • On-chip spectrometer; 100-mK platform can allow high sensitivity detectors to handle low in-band power
  • Multichroic pixels from on-chip filters
  • Also plan to explore increased MUX ratios
• Flat lenses (??)
Current Status

• Complete:
  • System Design
  • Cryogenic platform and baseline calibration
  • Cold optics
  • Filter fabrication

• Current work
  • Deployment candidate array testing (move to MUSCAT this week)
  • Warm mirror fabrication (some shared with SuperSPEC ETA 4 weeks)
  • Cryostat mounting plate for LMT and warm mirror mounts
  • Site preparation: 440-V supply extension, water cooling, mirror mounts

• Shipping in coming months. To be ready for good weather (Nov.)