SCUBA-2: a large-scale mapping machine for the JCMT

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Introduction

SCUBA on the JCMT provided the submillimetre revolution that is now sweeping through astrophysics. Excellent progress is being made on its replacement, SCUBA-2, which will be delivered to Hawaii in late 2006. At the heart of SCUBA-2 will be the first CCD-like array for submillimetre astronomy. It will offer imaging of a 50 sq-arcmin field-of-view at 850 and 450 microns simultaneously using two dc-coupled, monolithic arrays of ~10,000 bolometers. SCUBA-2 is expected to have a huge impact on the study of galaxy formation and evolution in the early Universe as well as star and planet formation in our own Galaxy. SCUBA-2's absorber-coupled pixels use superconducting transition edge sensors operating at ~120 mK for photon noise limited performance.

Key features of SCUBA-2:

Simultaneous observing at 450 and 850μm
Field-of-view: 50 sq-arcmin (~10 times the area of SCUBA)
Array architecture: 80×64 pixels in 2 arrays with spacing of 0.5Fλ (850) and Fλ (450)
Detectors: Superconducting transition edge sensors
Arrays: Micro-machined silicon detectors with hybridized SQUID multiplexer chips
Observing strategies: Novel fast survey and imaging modes

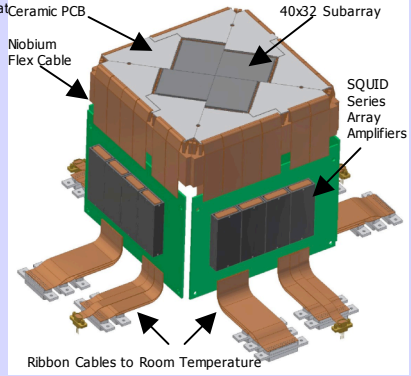
Science Drivers

Maximize the survey potential
→ map large areas of sky >100 times faster than SCUBA
Deep imaging
→ to the extragalactic confusion limit in less than a few hours (850μm)
Imaging at two colours simultaneously
→ study physical properties of dust emission
Improve the image fidelity and map dynamic range
→ have fully-sampled image planes; no sky chopping

Instrument Design

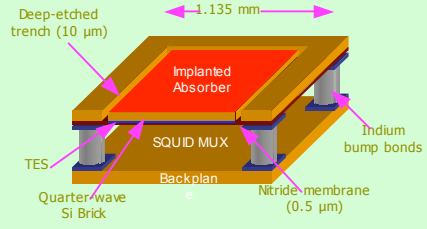
To achieve sky background limited performance the arrays are operated at ~120 mK. The cryostat is designed to operate without liquid cryogens to reduce operational costs. It uses a dilution refrigerator to cool the detector stage to 60 mK and the focal plane unit to 1 K. Pulse tube coolers cool the internal filters and optics at the 60 and 4 K stages.

A dichroic beamsplitter at the 1 K stage splits the beam into components of wavelength 450 and 840 μm and directs them to two focal plane units (FPU). Each FPU fills the field of view with four sub-arrays as shown below. The sub-arrays have been shrunk to 40x32 pixels from the original 40x40 for more reliable patterning of the MUX on a 3" wafer. Niobium flex cables bring the multiplexed signals to series array amplifiers. The niobium flexes also provide a thermal break between the 60 mK stage and the 1 K stage. Ribbon cables bring the amplified signals out of the cryostat to a readout card incorporating an FPGA. Output values will be co-added and stored in the FPGA before being sent over a fibre optic link to a data collection PC (one per sub-array) at



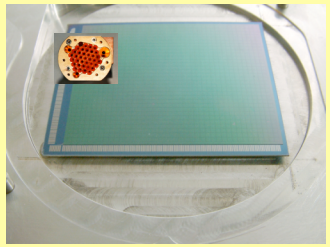
SCUBA-2 Focal Plane Unit.

SCUBA-2 Unit Cell



The array architecture is based on a hybrid design that consists of an upper detector support wafer and a lower SQUID multiplexer (MUX) wafer held together with indium bump bonds. The bump bonds also provide the electrical and thermal connections between the wafers. The use of a cryogenic multiplexer is crucial since it makes it possible to instrument the full field-of-view with a practical number of wires.

Prototype 850 micron sub-array with the SCUBA 850 array superimposed for scale



Current Status

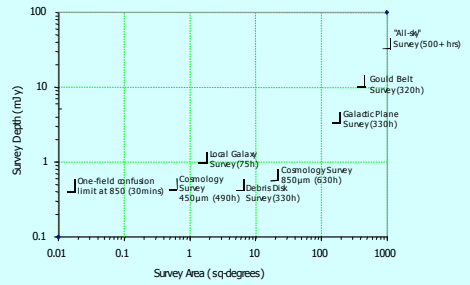
AIV is currently underway at the UK ATC - installation of the 4K box into the cryostat is shown (upper) and the first cooldown (lower). Delivery is expected in late autumn 2006.

Sensitivity Improvements

Parameter	450 μm		850 μm	
	SCUBA	SCUBA-2	SCUBA	SCUBA-2
Per-pixel NEFD (mJy / √Hz)	400	80	90	30
Pointsource NEFD (mJy / √Hz)	400	113	90	21
Pointsource extraction speed	1	13	1	18
Large area mapping speed	1	875	1	1250

SCUBA-2 Surveys

In July 2005 the JCMT Board approved a comprehensive Legacy Survey programme over a 2 year (extendable to 5 years) period. The SCUBA-2 surveys (2-year) are summarised below.



Galactic Plane survey: 200+ sq-degs to a depth of 4mJy at 850μm in 330 hrs
Gould Belt survey: Mapping of G-B molecular douds (~500 sq-degs) to 10mJy (850) in 320 hrs (inc. POL)
Debris Disk survey: Survey of 500 stars to 0.5mJy (850) in 370 hrs
Local Galaxy survey: Imaging of 150 galaxies down to 1mJy (850) in 75 hrs
Cosmology survey (850μm): 20 sq-degs (several fields) to 0.7mJy in 630 hrs
Cosmology survey (450μm): 0.7 sq-degs to 0.5mJy in 490 hrs
"All sky survey": 1000+ sq-degs down to <50mJy at 850μm

http://www.roe.ac.uk/atc/projects/scuba_two/