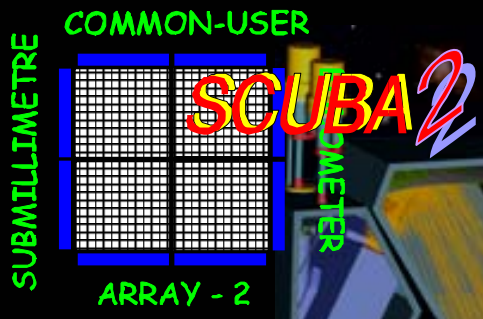

SCUBA-2 for the JCMT

Talk given at the 2007 RSE Cormack meeting, University of Strathclyde, 11th May 2007

Adam Woodcraft
http://woodcraft.lowtemp.org
SUPA, University of Edinburgh

SCUBA2

Science & Technology Facilities Council
UK Astronomy Technology Centre

SUPA
Scottish Universities Physics Alliance

Sub-mm astronomy

SUPA Scottish Universities Physics Alliance

- Sub-mm astronomy: wavelengths of a few hundred μm
  - Typically in “windows” around 450 and 850 μm (670 and 350 GHz) – atmosphere is largely opaque
- Lets us see cold things: peak in 10-K blackbody around 300μm
  - e.g. objects in formation (stars, planets, galaxies…)
  - Also lets us see far away (red shifted) warmer objects: peak in 40 K blackbody at red shift Z=3 is at 300 μm
  - Sub-mm emission usually “optically thin”; so we see the interior rather than just the surface of objects

Example: Eagle Nebula in visible light (Hubble Space Telescope):

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Example: sub-mm (850 μm) contours overlaid (SCUBA)

The Submm Revolution

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- Huge revolution over the past decade – very limited access to this region of the spectrum before

- SCUBA on JCMT has been largely responsible for this:
  - Built at UK ATC in Edinburgh
  - Produced similar advances that occurred in IR astronomy in the 1980's
  - At the peak of its productivity had a citation rate to rival that of the Hubble Space Telescope

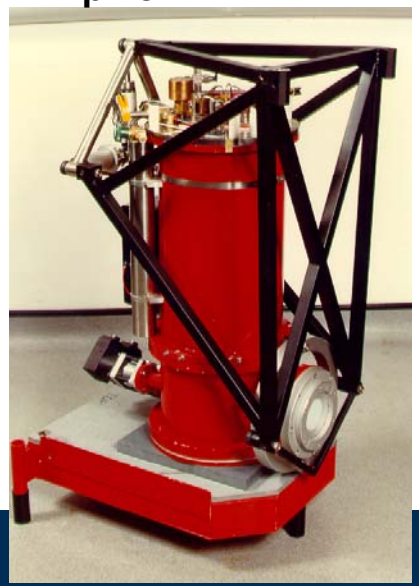
SCUBA on the JCMT

- One of the first imaging "arrays" for the submm
- 128 bolometers in two arrays
- Operated at 350/450 and 750/850μm
- Came into service in 1997
- Made a number of seminal discoveries
- Retired from service in 2005

Beyond SCUBA

- Instruments limited by small number of pixels
  - Gone from 1 pixel to 100s in a decade – need more!
- Detector development in relative infancy
- No big military or commercial applications (as yet…)
- Detectors not available "off-the-shelf" so have to make your own…

UKT14
1986-1996
1 pixel



SCUBA
1997-2005
128 pixels

?

Scientific motivation

"A unique scientific opportunity"

- Region encompasses the peak of emission from the high-z universe and of the dusty progenitors of stars
- Less than 1% of the far-IR/submm sky has been studied in any detail – it's largely unexplored territory!
- Potentially a huge void between the capabilities of existing facilities and the new generation interferometers

Scientific requirements

- Maximise the survey potential
  → Large field-of-view
- Deep imaging
  → Improved detector sensitivity
- Improved image fidelity
  → Fully-sampled image planes; no sky chopping
- Imaging at two colours simultaneously
  → Two separate focal planes

What is SCUBA-2?

- A wide-field imaging camera with up to 1000× the mapping capability of SCUBA
- Capable of carrying out large-scale surveys of the submillimeter sky
- Ultra-deep imaging to the (extragalactic) confusion limit
- Polarimetry and medium resolution spectroscopy also available

SCUBA-2

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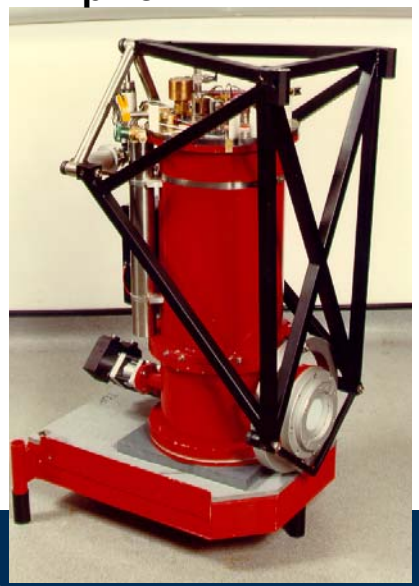
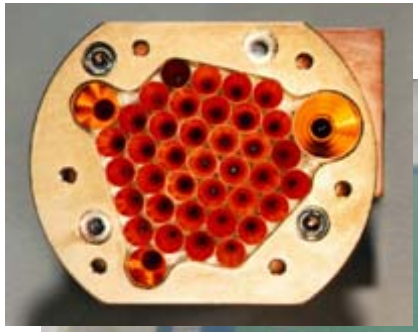


SCUBA
1997-2005
128 pixels

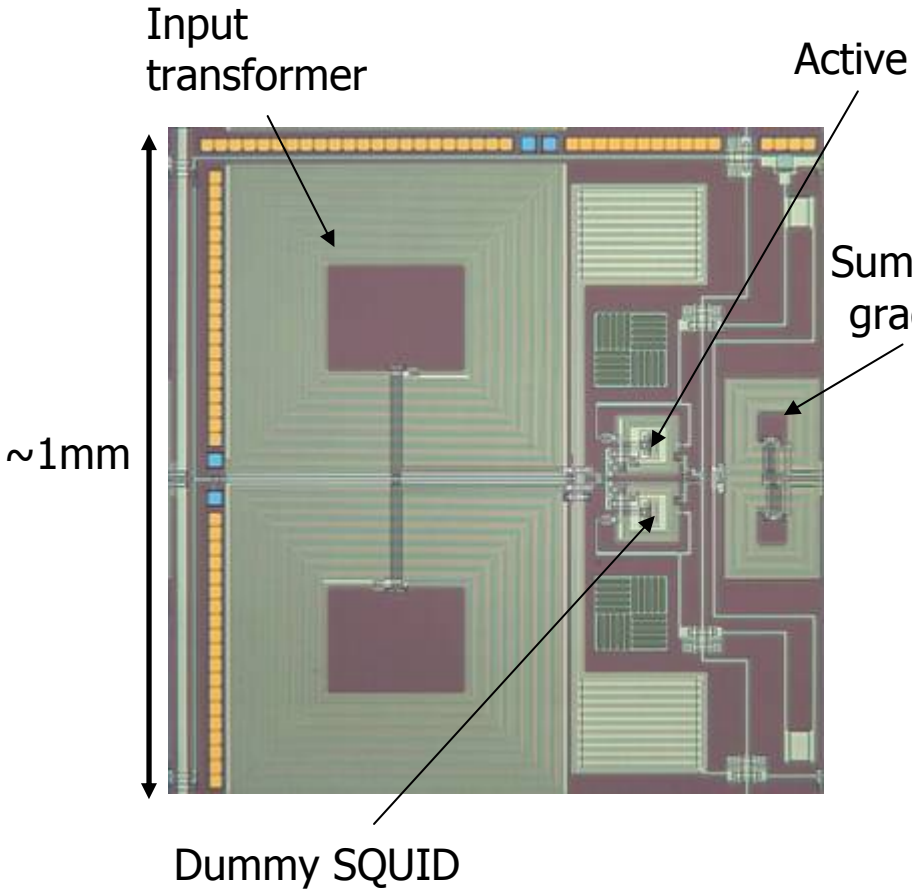
SCUBA-2
2007+
10240 pixels

Detector arrays

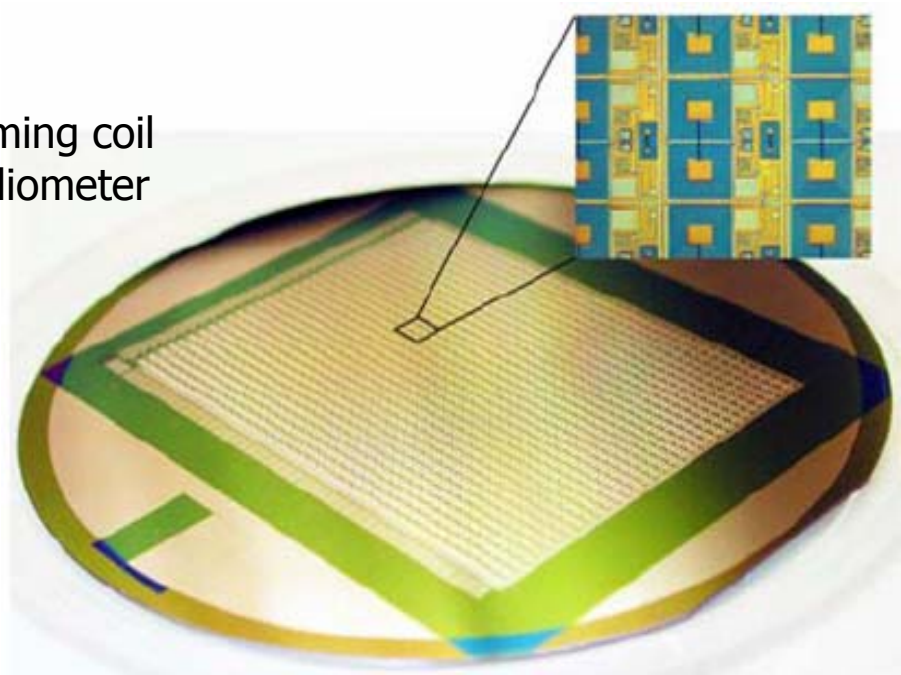
- Superconducting TES detector arrays
- Two independent focal planes
- 5120 pixels in each focal plane
- Each focal plane consists of 4 sub-arrays of 1280 pixels each



In-focal plane multiplexing



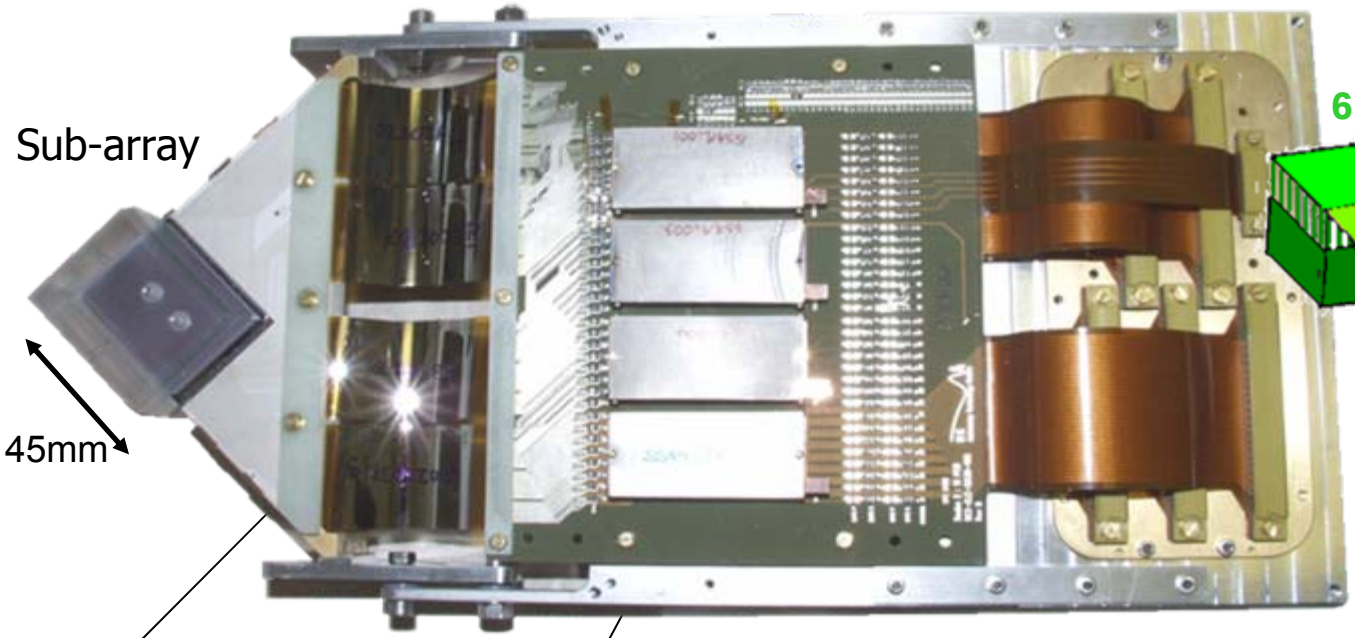
Pixel scale

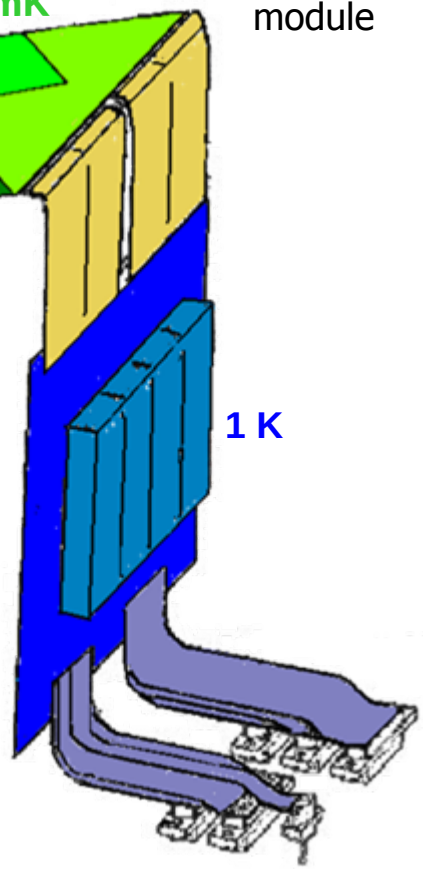


Array scale

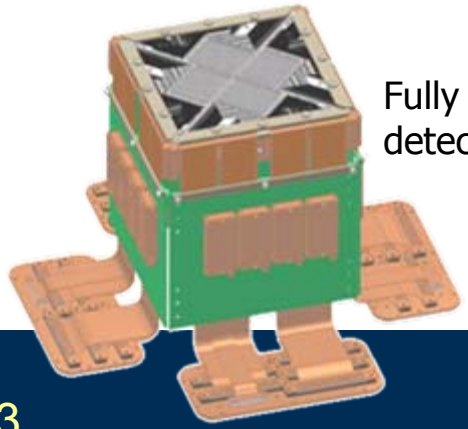
NIST National Institute of Standards and Technology

Sub-array module





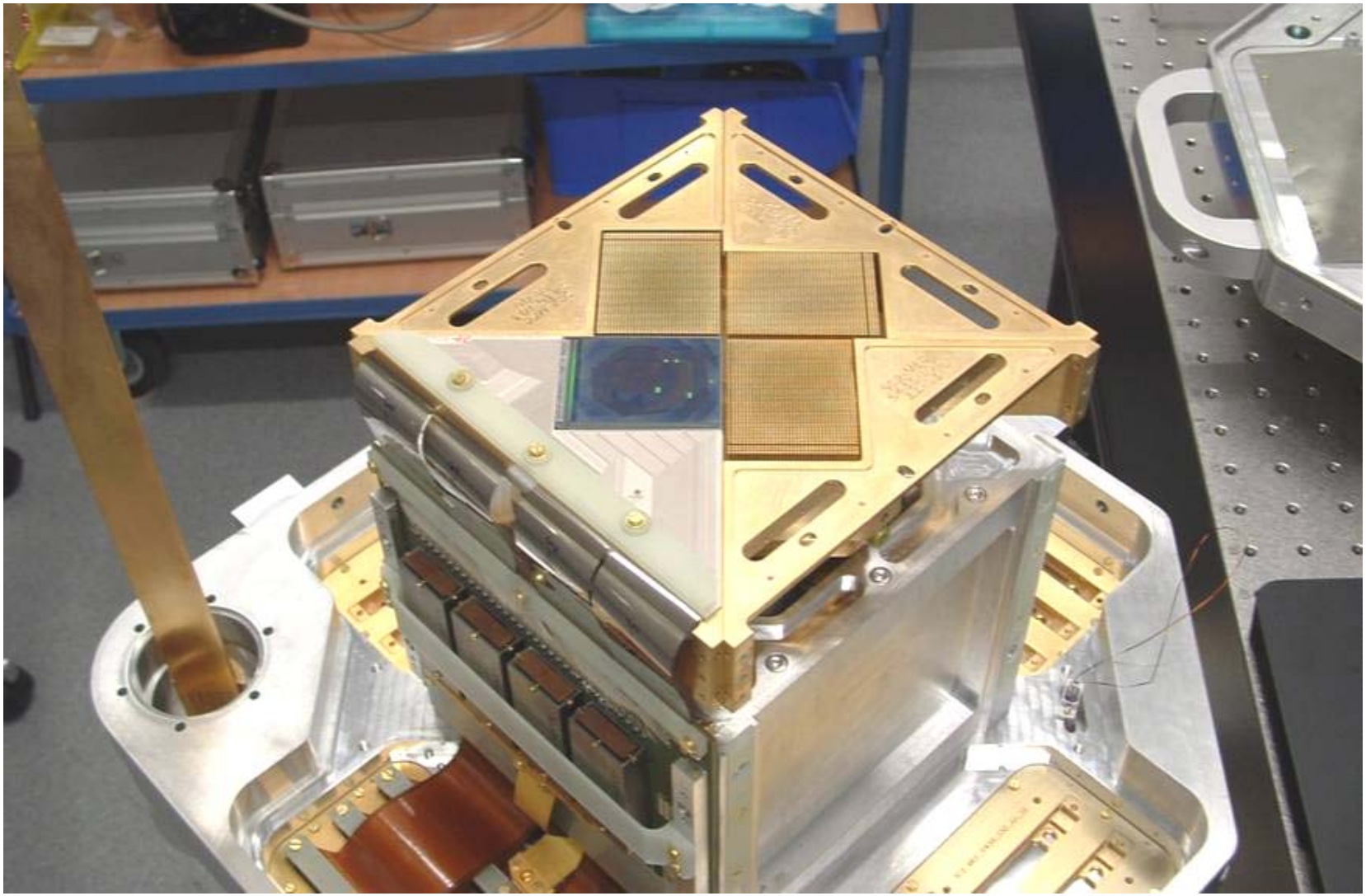
Folded sub-array module



Fully populated detector unit

Detector unit with one prototype array installed

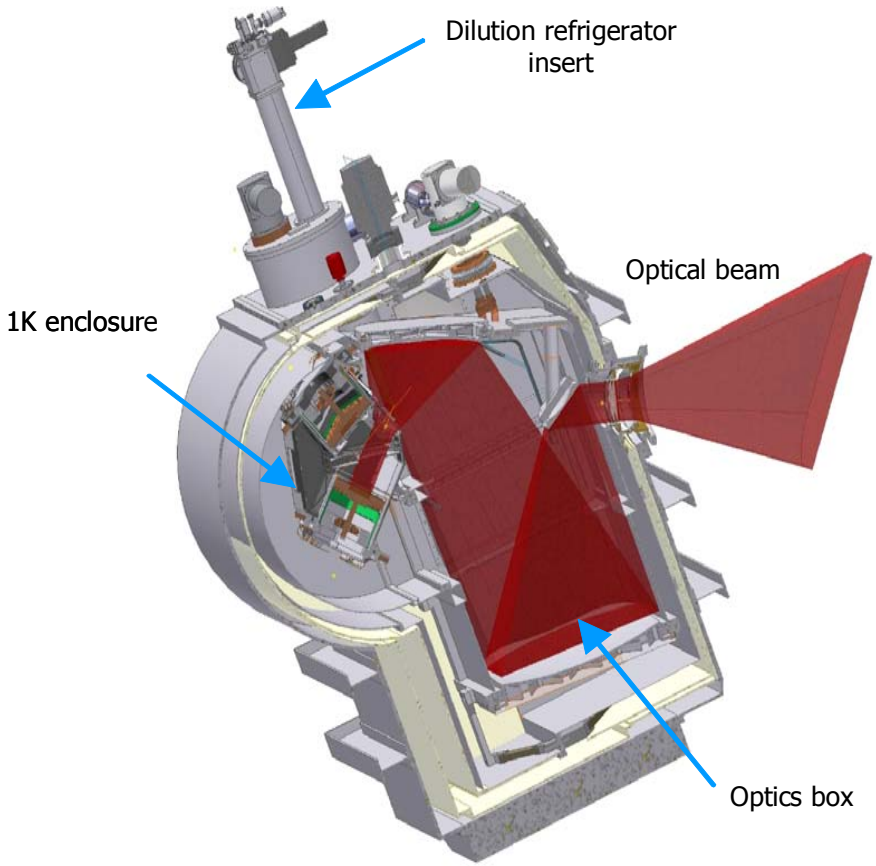
Focal plane layout



Cryostat design

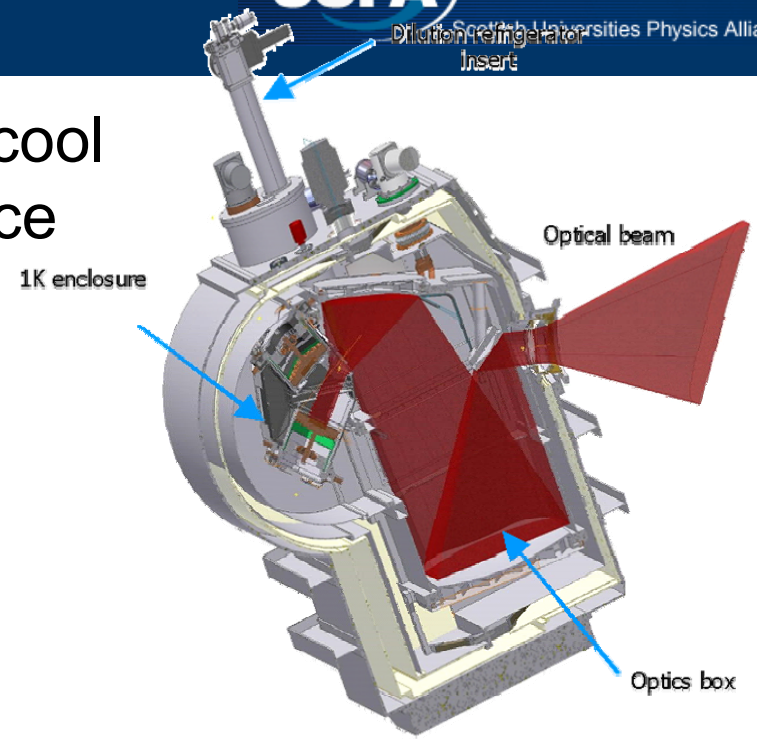
Key challenges:

- Low-temperature thermal design
- Cooling 300 kg of optics to 4K
- Getting all the signal cables out...
- Stray light control
- Magnetic shielding of SQUID circuitry in the multiplexer
- Liquid-cryo free operation



Size

- Instrument size driven by need to cool large mirrors to below 10 K (to reduce thermal background on arrays)



Final instrument

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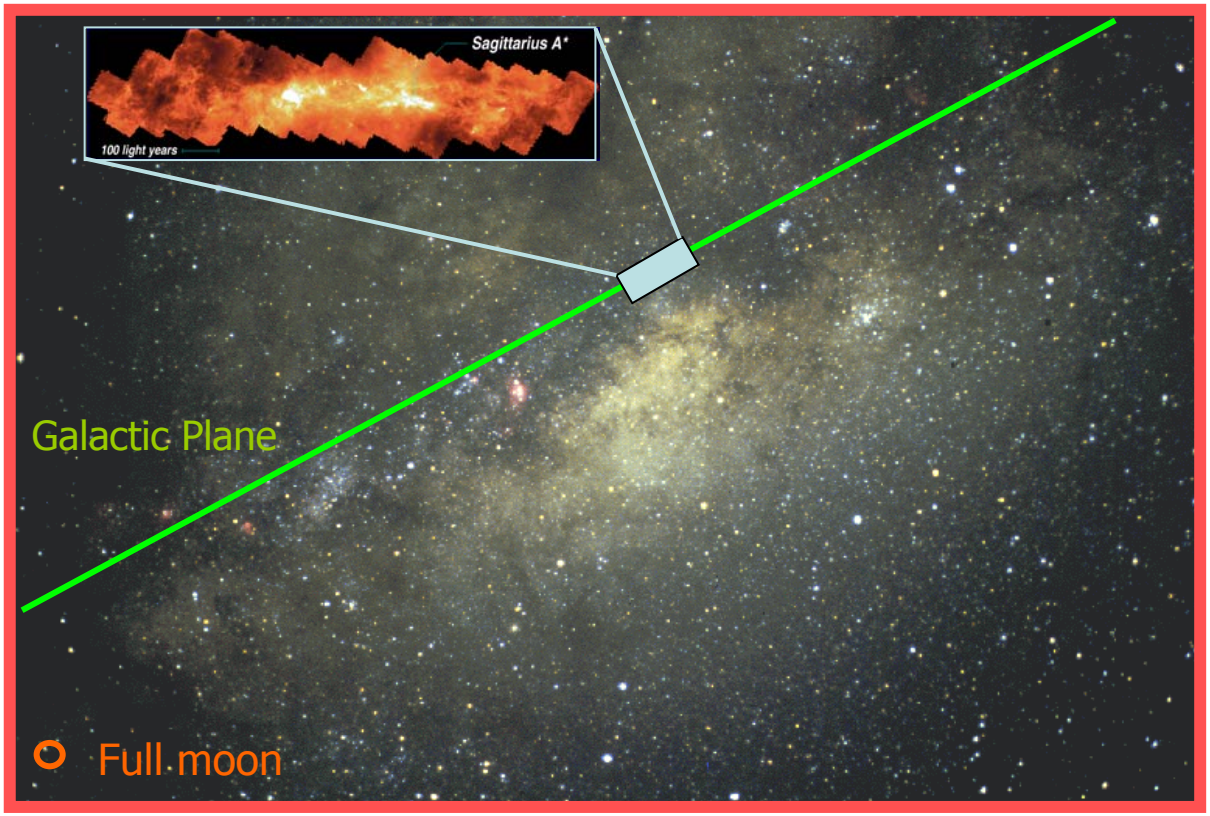
- Detector arrays operating at 100 mK
- Measured NEPs of $\sim 2.5 \times 10^{-17}$ W/√Hz
- 10,000+ pixels in two focal planes
- Two arrays installed with remaining 6 to be added in Hawaii

Survey potential



SCUBA Galactic Centre Survey

~15 shifts (or 120 hrs) over 2 years

of excellent weather telescope time

SCUBA-2 could map the ENTIRE AREA shown above (red rectangle) in just a couple of hours to the same S/N...

Legacy surveys

- Surveys allocated 55% of the UK/CN/NL time on the JCMT over 2 years
- Corresponds to 265 nights of 12-hr shifts – some 3,180 hours in total
- Approved in principle for a further 307 nights between 2009 – 2012
- Will utilise queue-based, flexible scheduling
- Seven survey programmes approved

SCUBA-2 Legacy Surveys

Debris Disk Legacy Survey
(Greaves, Holland and Matthews)

JCMT Galactic Plane Survey
(Moore, Shipman and Plume)

JCMT Gould Belt Legacy Survey
(Ward-Thompson, Johnstone, Di Francesco, Hatchell and Hogerheijde)

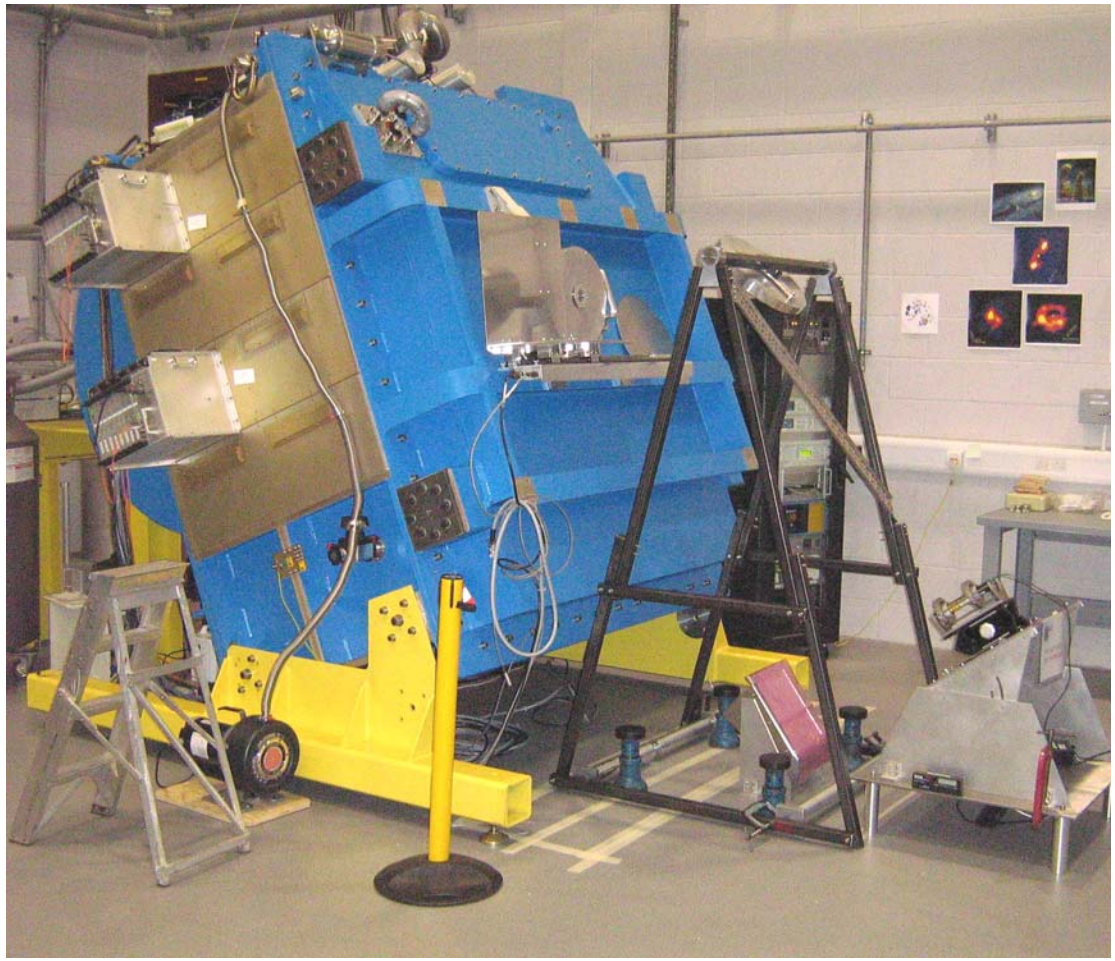
Physical Processes in Galaxies in the Local Universe
(Wilson, Israel and Serjeant)

SCUBA-2 Cosmology Legacy Survey
(Smail, Dunlop, Halpern and van der Werf)

SCUBA-2 "all-sky" Survey
(Thompson, Serjeant, Jenness and Scott)

Current status

- Instrument is now essentially complete – nearing delivery standard
- Testing is underway of commissioning-grade sub-arrays – one for each wavelength
- Instrument verification is also underway; optical tests, operational modes etc.



Summary

SUPA Scottish Universities Physics Alliance

- SCUBA-2 will be the first wide-field, ultra-sensitive camera for submm astronomy

- The technology is state-of-the-art and represents a great investment on behave of the funding agencies

- The survey science addresses many of the fundamental questions in modern-day astronomy

- Delivery to the JCMT is planned for summer 2007 with survey science starting early next year

Institutions

Science & Technology Facilities Council
UK Astronomy Technology Centre

Instrument design, construction, testing, commissioning: *ATC, Edinburgh*

NIST National Institute of Standards and Technology

Multiplexer and TES devices: *NIST, Boulder*

SMC Scottish Microelectronics Centre

The University of Edinburgh

Detector micromachining: *University of Edinburgh*

Cardiff University
Prifysgol Caerdydd

"1-K box" design and construction, detector test programme, filters/dichroic: *Cardiff University*

UBC

University of Waterloo

Warm electronics: *University of British Columbia,* MUX testing, *University of Waterloo*

UKIRT JCMT Joint Astronomy Centre

Telescope infrastructure: *Joint Astronomy Centre, Hawaii*

Science & Technology Facilities Council
UK Astronomy Technology Centre