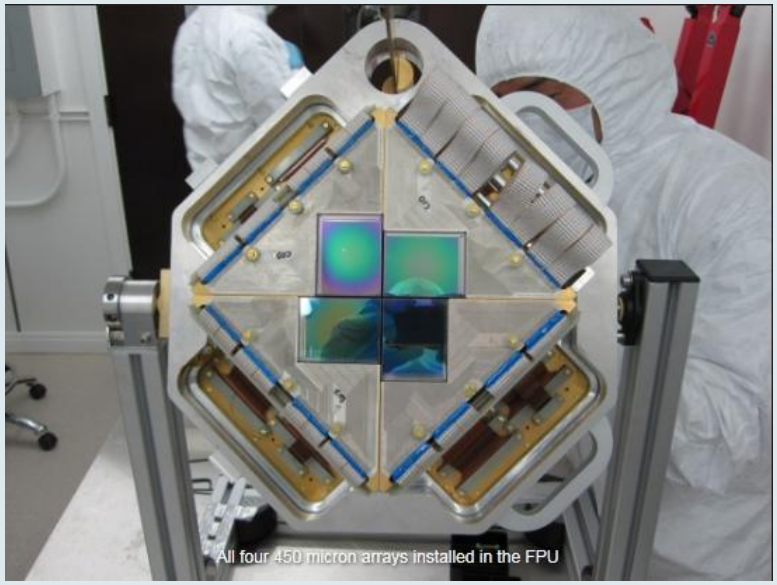
Status of SCUBA-2 and enhancing the performance of the TES Arrays

Dan Bintley, Wayne Holland, Mike MacIntosh



Acknowledgements

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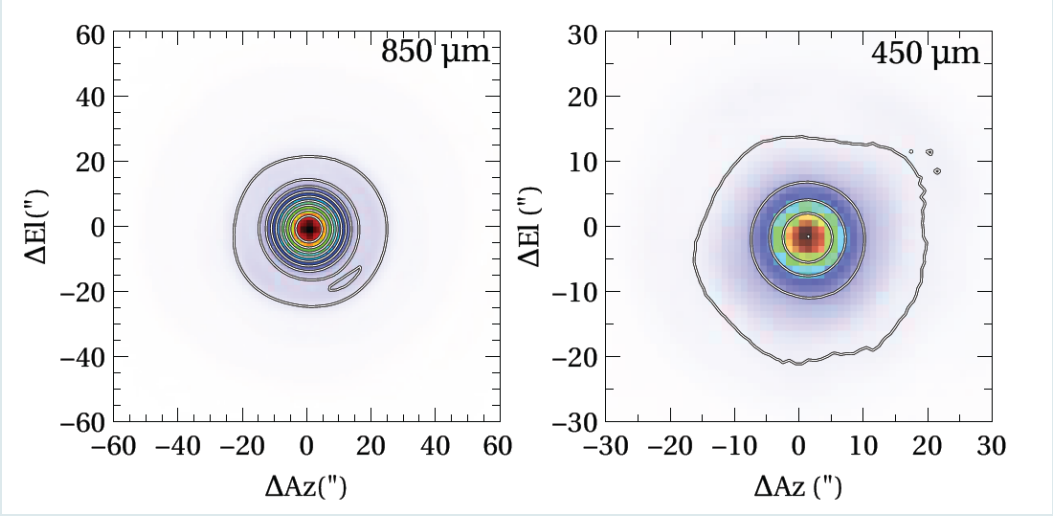
Plus many more: Damian Audley, Fred Gannaway, Eric Schulte

SCUBA-2 has been 10+ years in the making

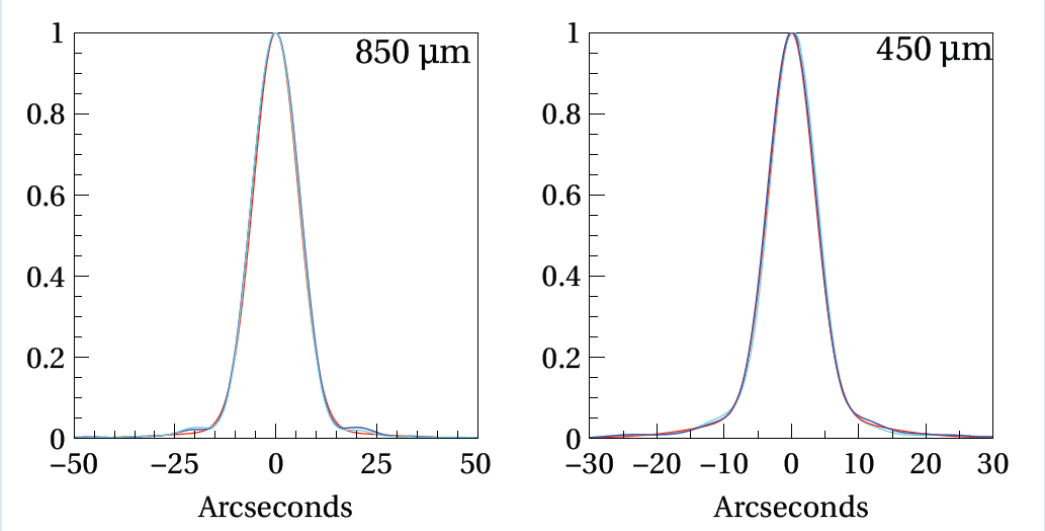
Introduction

- SCUBA-2 is a 10,000 pixel bolometer camera on the JCMT, operational since October 2011.
- Two focal planes, each with four 32 by 40 MoCu TES sub-arrays with inline 2-D TD SQUID MUX.
- Observe simultaneously at 850μm and 450μm with a 43 sq-arcmin field of view.
- A survey instrument: - a square degree of sky can be mapped to 10mJy/beam at 850μm in less than 90 minutes.

On sky calibration



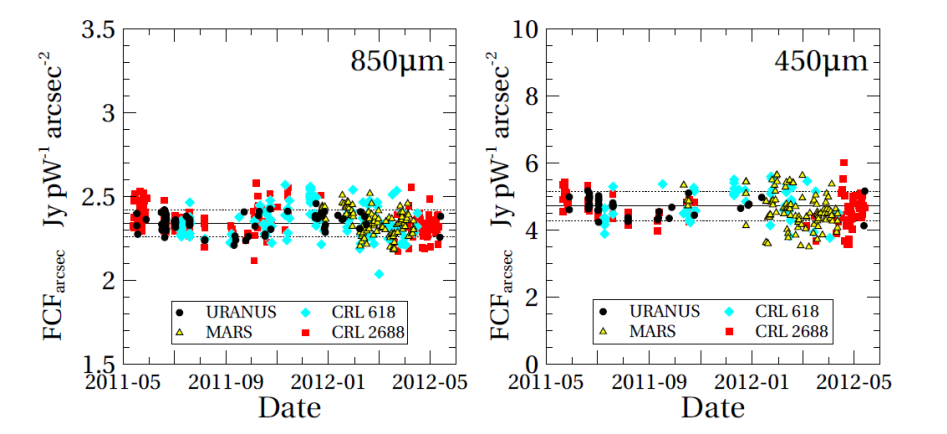
Made over 500 individual observations of primary calibrator sources (Mars, Uranus) and secondary sources (CRL618, CRL2688, plus 7 others).

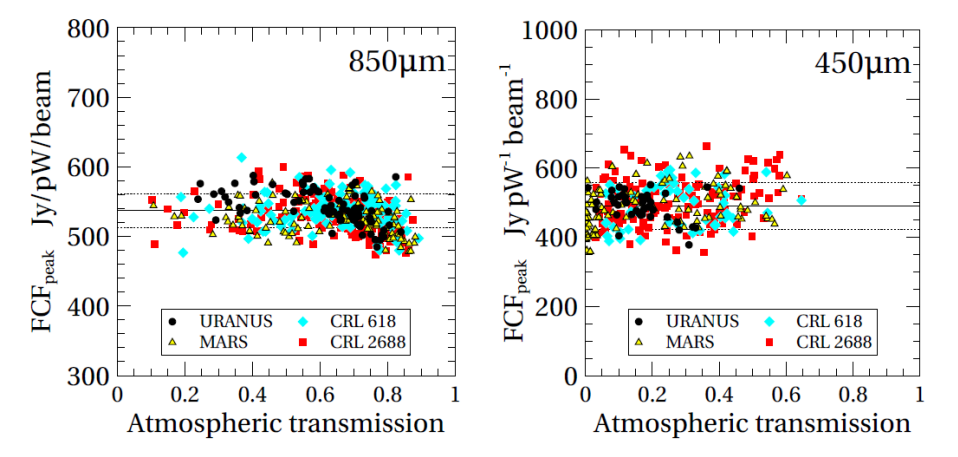


Measured the SCUBA-2 beam shape and focal plane distortion to enable accurate aperture photometry.

Here showing maps of Uranus and the beam and diffraction patterns.

On sky calibration 2





Calculate a Flux Conversion Factor (FCF) from detector units (pW) to astronomical units (Jy).

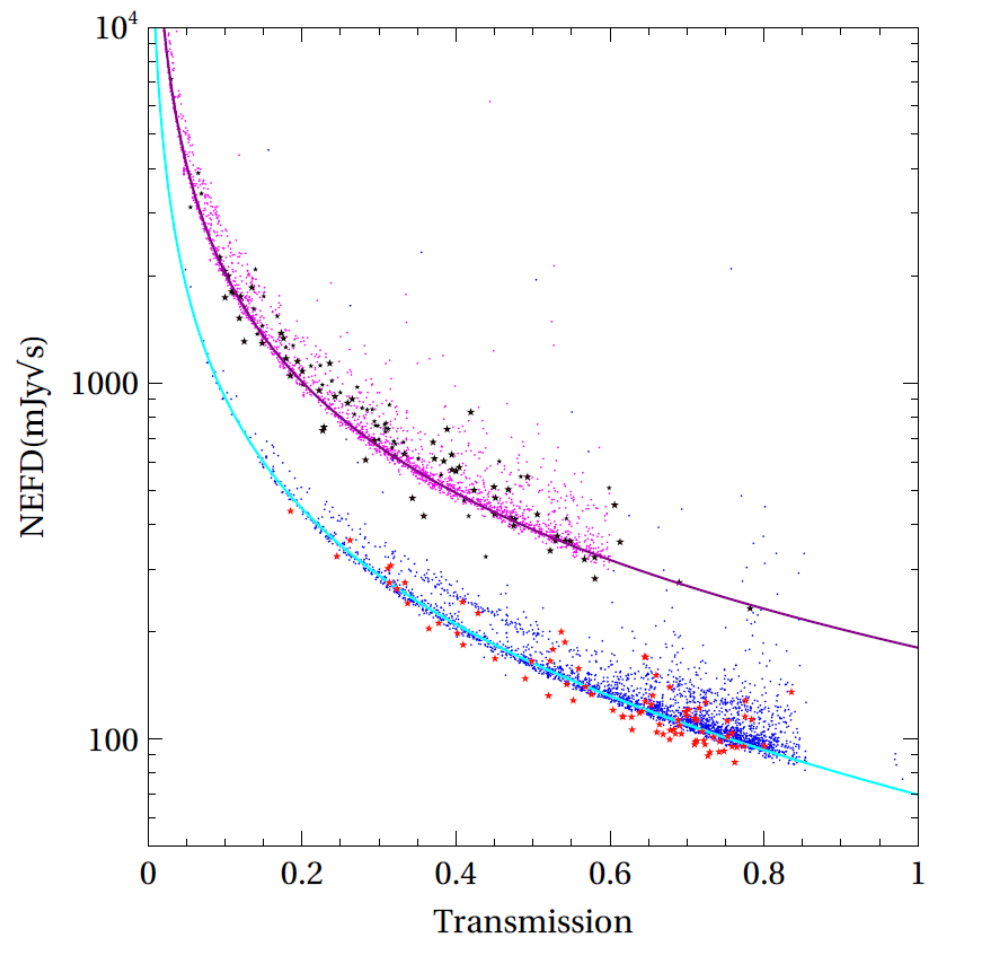
Each night, many calibrators are observed.

The error on the relative flux calibration is less than 5% at 850μm and ~ 10% at 450μm. **A factor of 2 improvement over SCUBA.** Mostly due to the use of a line of sight water vapour meter.

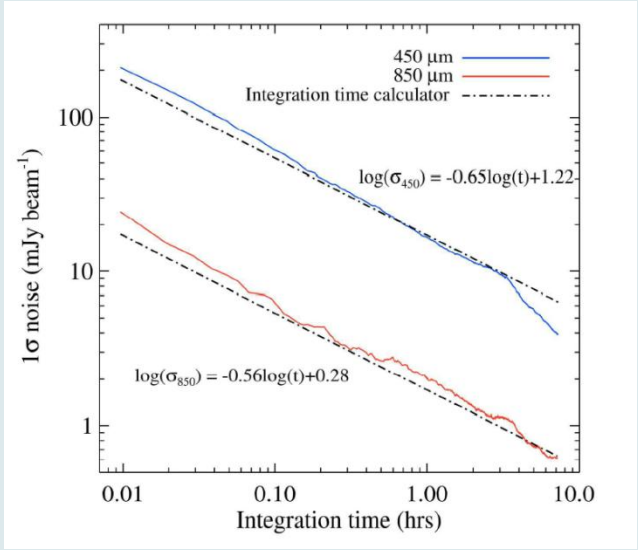
Dempsey 2013

http://cdsads.u-strasbg.fr/abs/2013MNRAS.430.2534D

On sky sensitivity



Measured NEFD for each waveband as a function of fractional sky transmission



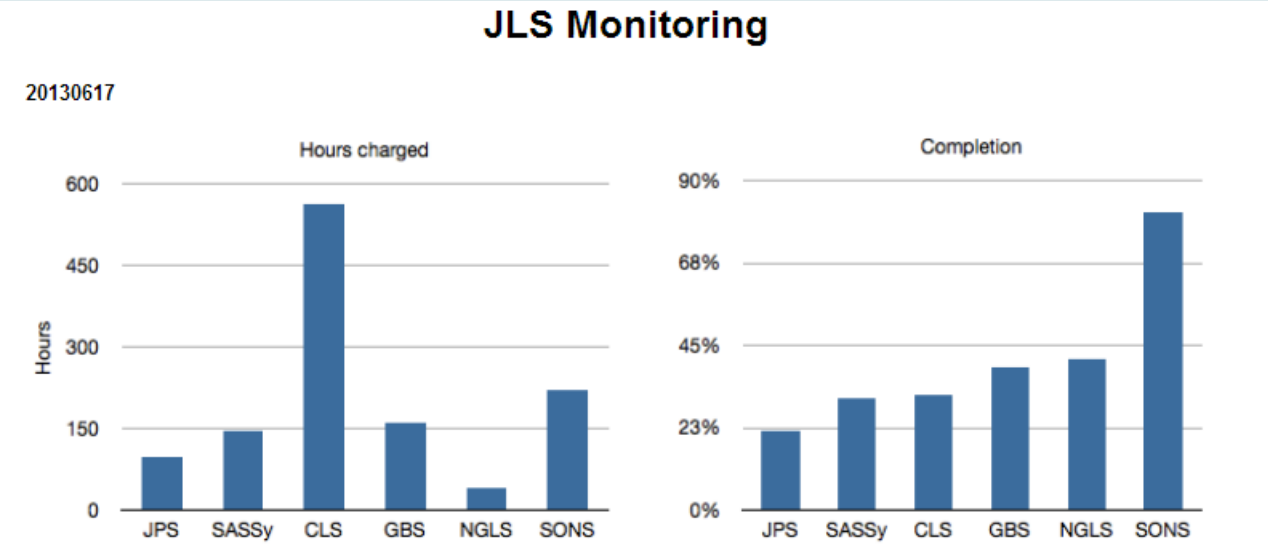
Measured RMS noise in 3 arcmin DAISY image vs integration time

Holland 2013

http://cdsads.u-strasbg.fr/abs/2013MNRAS.430.2513H

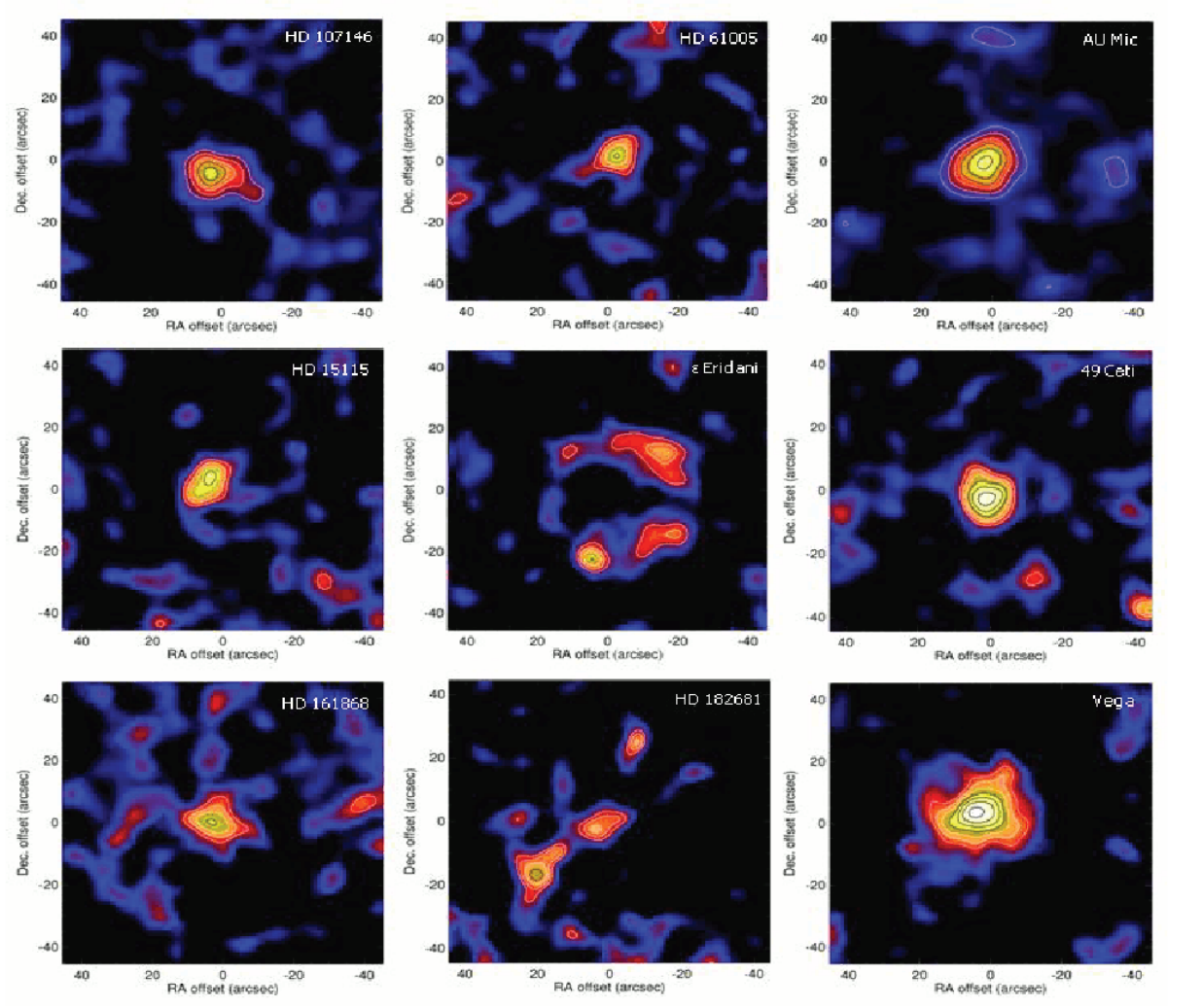
JCMT Legacy Surveys

- 65% of time allocated to JLS – which started Feb 2012 (35% to PI led projects).



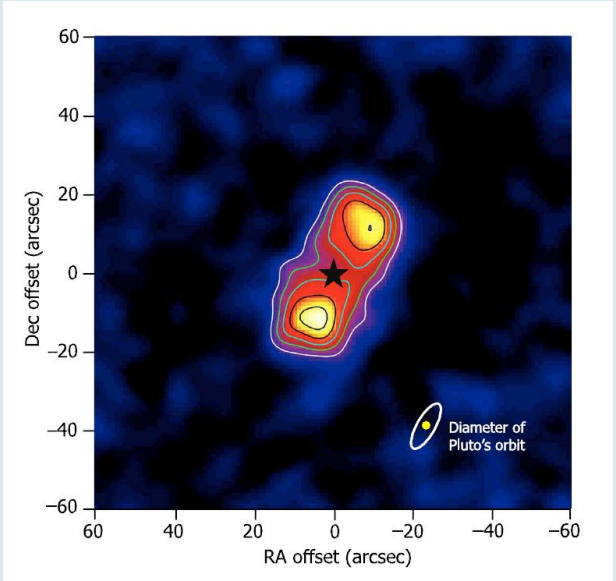
- Share a few of the published images

JCMT Legacy Surveys



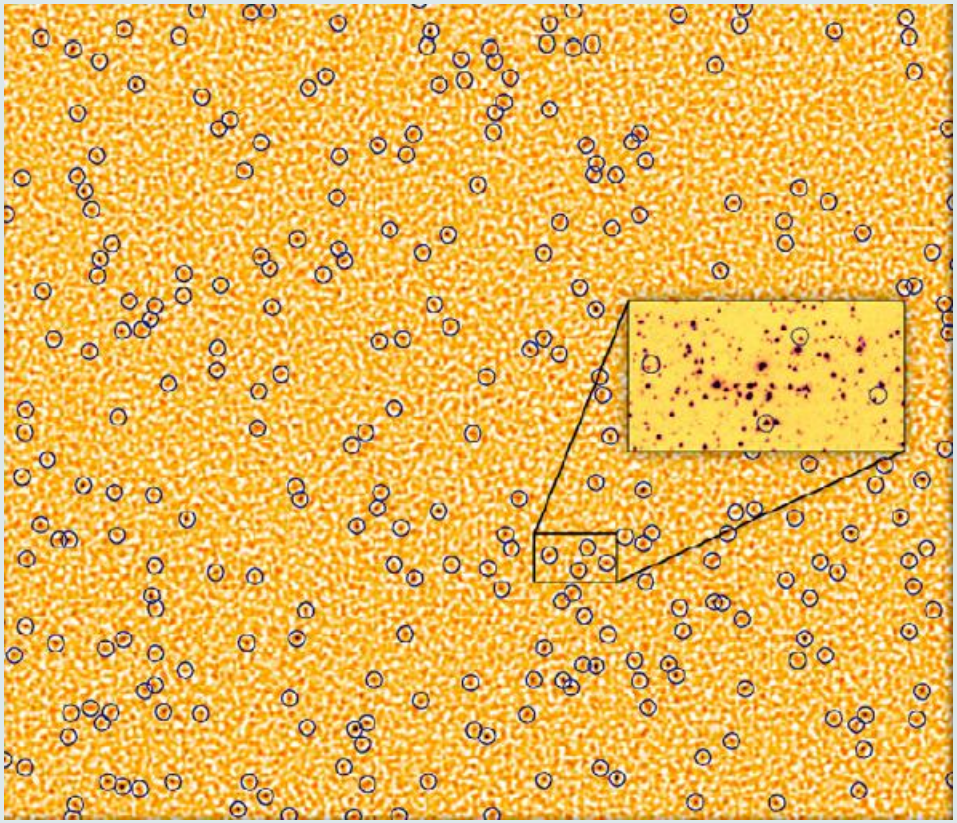
SONS (nearby stars)

Images of debris discs around nearby stars



Images SONS team

JCMT Legacy Surveys



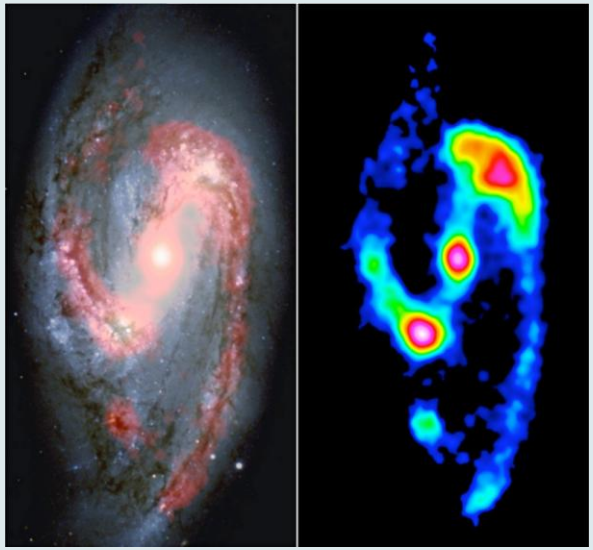
Images CLS team

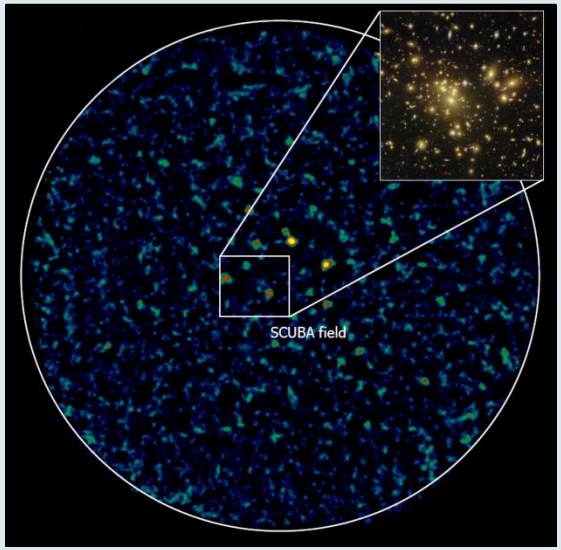
CLS (cosmology)

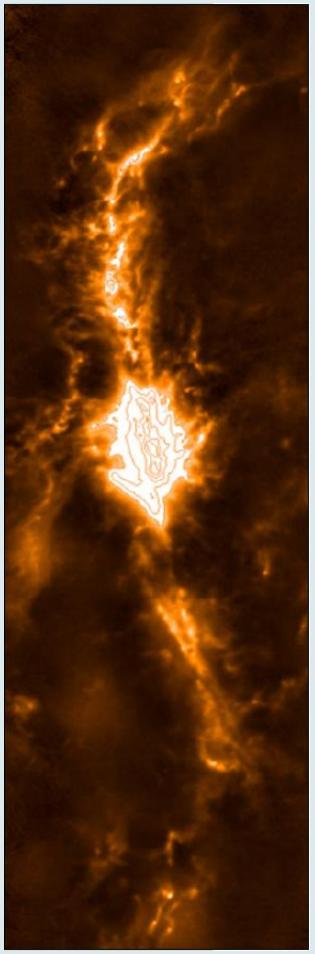
A sq-degree sized 850μm map in the UKIDSS Ultra Deep Survey field. SCUBA-2 detects hundreds of sources; far-infrared galaxies and active galactic nuclei out to z~5 or above.

The insert is a Spitzer image which identifies counterparts to the brighter and low redshift examples.

Other survey team images





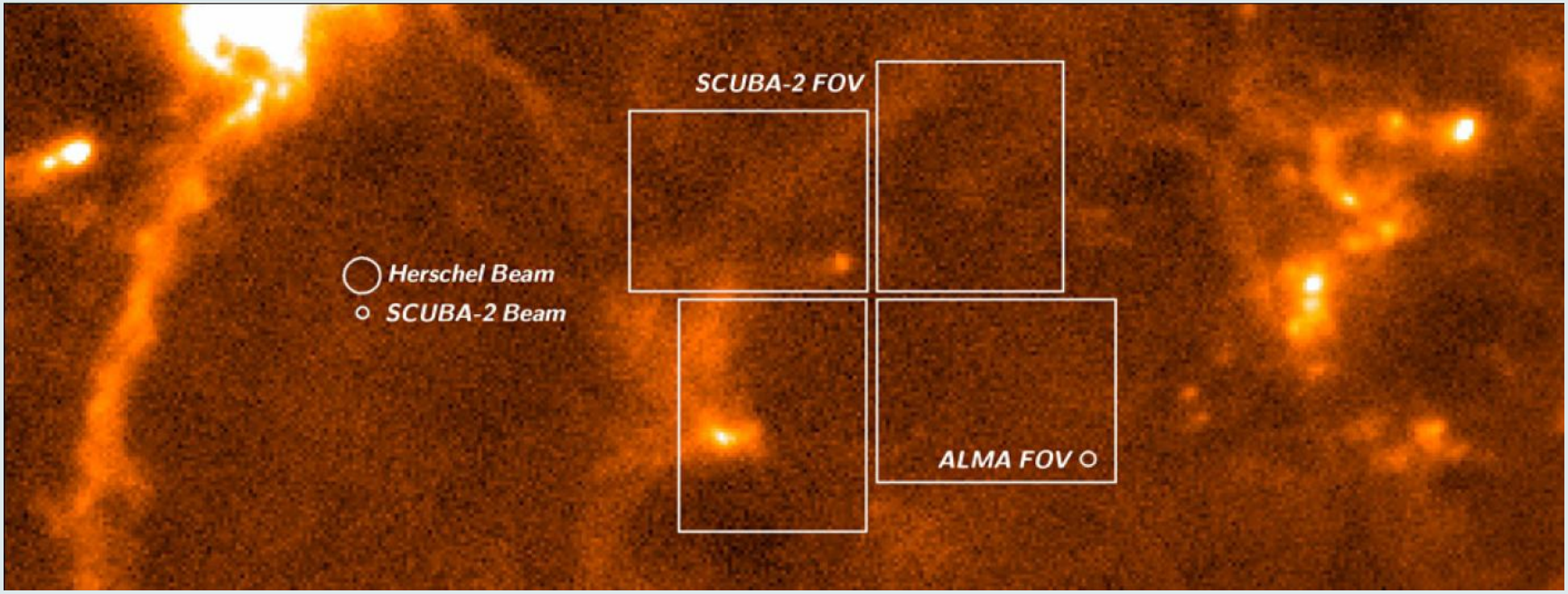


M66 at 850μm (NGS (galaxy) team). **Abell 1689** a massive lensing galaxy cluster (GT team) and 850μm map of **Orien's integral shaped filament** (GBS (Gould Belt) team)

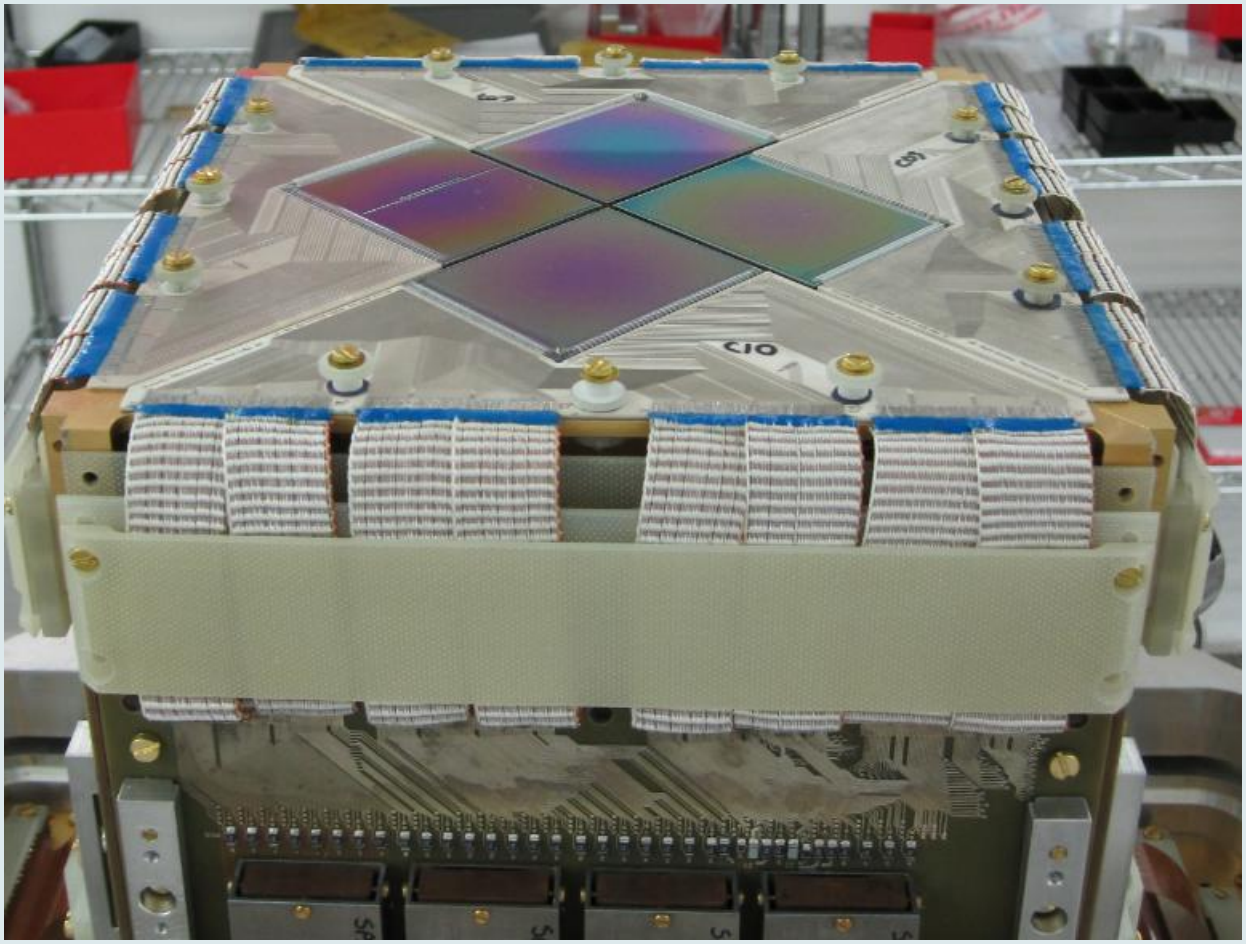
Impact of SCUBA-2

This is part of a SCUBA-2 450μm map of a massive star forming region.

The SCUBA-2 beam size and field of view compared to ALMA (500μm) and SPIRE are shown.



SCUBA-2 sub-array performance



SCUBA-2 array performance has been good.
Stable from cool down to cool down and over 11 months continuous operation in 2012

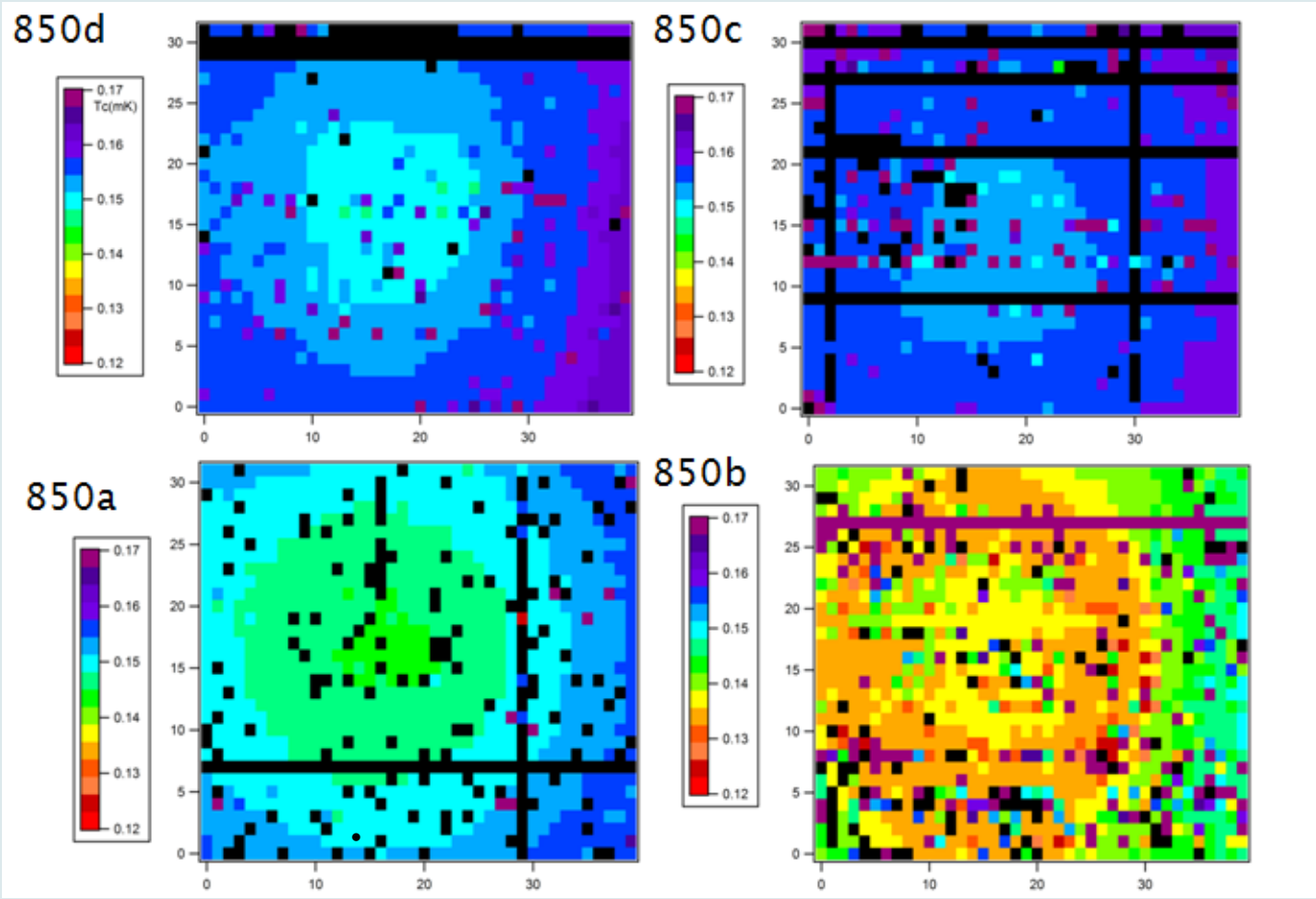
We can 'see' and measure sky noise or rather with the cold shutter open – the background photon noise, roughly at same level to dark detector noise.

SCUBA-2 detector properties

Tc for 850μm focal plane – 10mK variation with radial pattern.

Similar for 450μm focal plane.

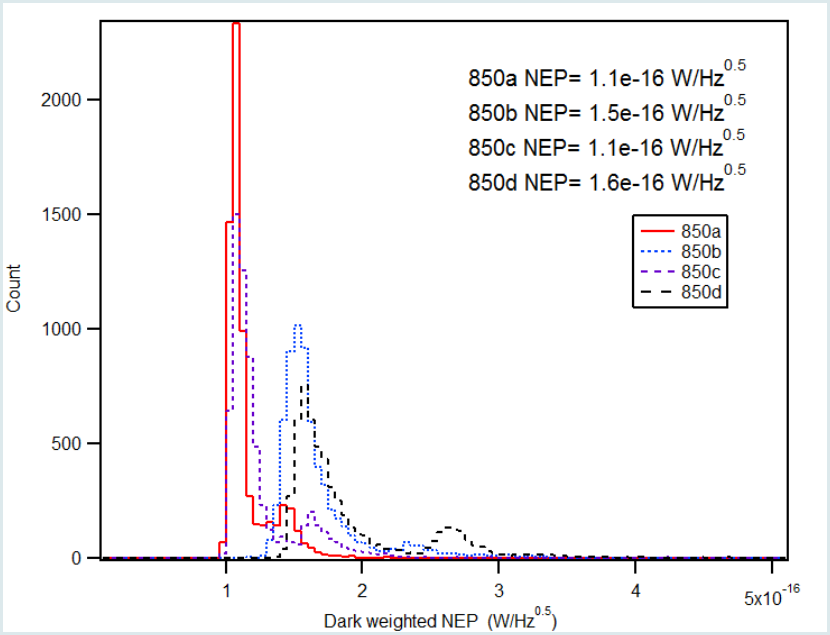
Measured G is higher than target values. However we have higher total power handling – which turns out to be useful.

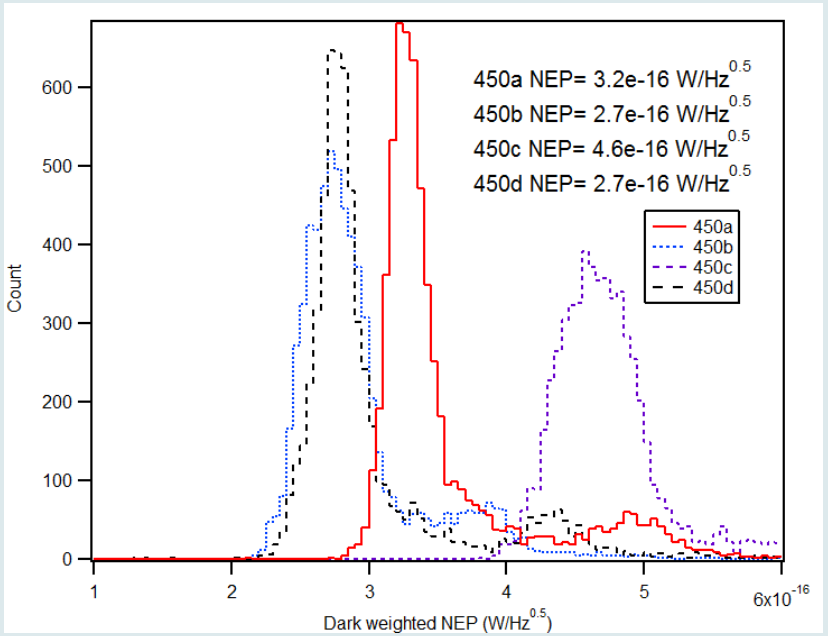


SCUBA-2 array performance

	850μm sub-arrays				450μm sub-arrays			
	s8a	s8b	s8c	s8d	s4a	s4b	s4c	s4d
Tc (mK)	145	130	154	147	212	205	203	198
G (nW/K)	4.3	2.8	3.7	5.7	4.9	6.1	8.5	6.1
Phonon NEP (W/√Hz)	7.2×10^{-17}	5.6×10^{-17}	7.0×10^{-17}	8.2×10^{-17}	1.1×10^{-17}	1.2×10^{-17}	1.4×10^{-17}	1.1×10^{-17}
Responsivity (A/W)	1.77×10^{6}	1.16×10^{6}	1.35×10^{6}	1.04×10^{6}	0.46×10^{6}	0.43×10^{6}	0.38×10^{6}	1.00×10^{6}
Dark NEP (W/√Hz)	1.1×10^{-16}	1.5×10^{-16}	1.1×10^{-16}	1.6×10^{-16}	3.2×10^{-16}	2.7×10^{-16}	4.6×10^{-16}	2.7×10^{-16}
Total Power (pW)	72	38	71	100	300	324	375	328

Dark Noise Performance





Dark NEP histograms for each sub-array; (right) 850 focal plane (left) 450 focal plane. These comprise all the dark noise observations from Feb 2012 to June 2012: 6,500 NEP measurements in total. **The measured dark NEP is higher than the expected phonon noise limited NEP**.

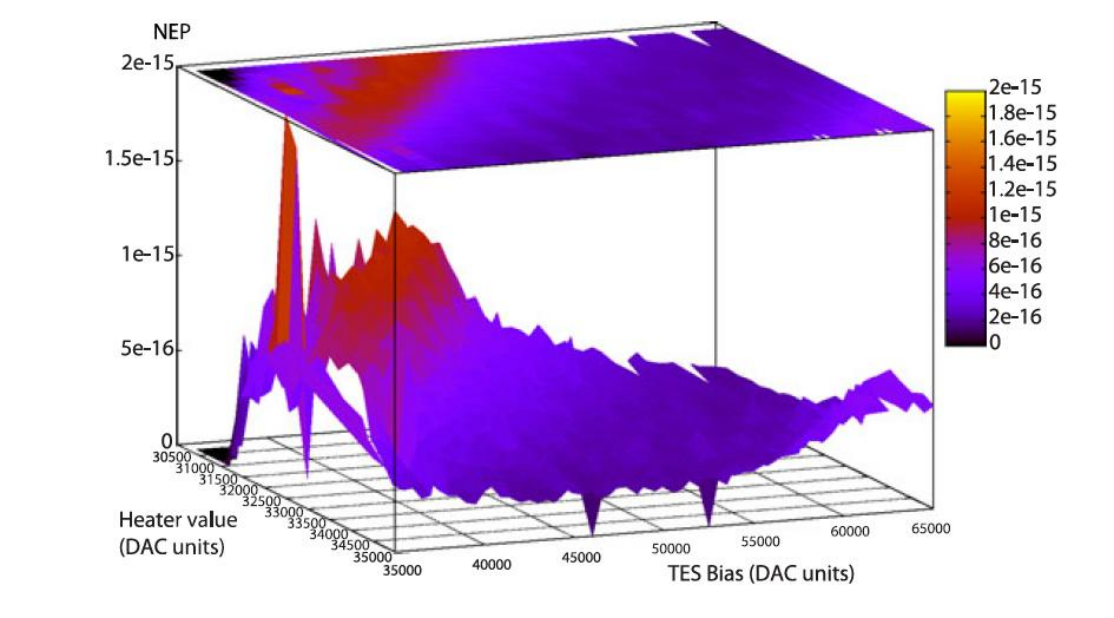
SCUBA-2 optimisation

Each sub-array has a single heater and TES bias setting

TES bias and heater setting

Early on in the commissioning we did a large search of the bias and heater phase space, measuring the dark NEP at each point for all sub-arrays.

From such plots, we selected the optimum settings for TES bias and the heater.

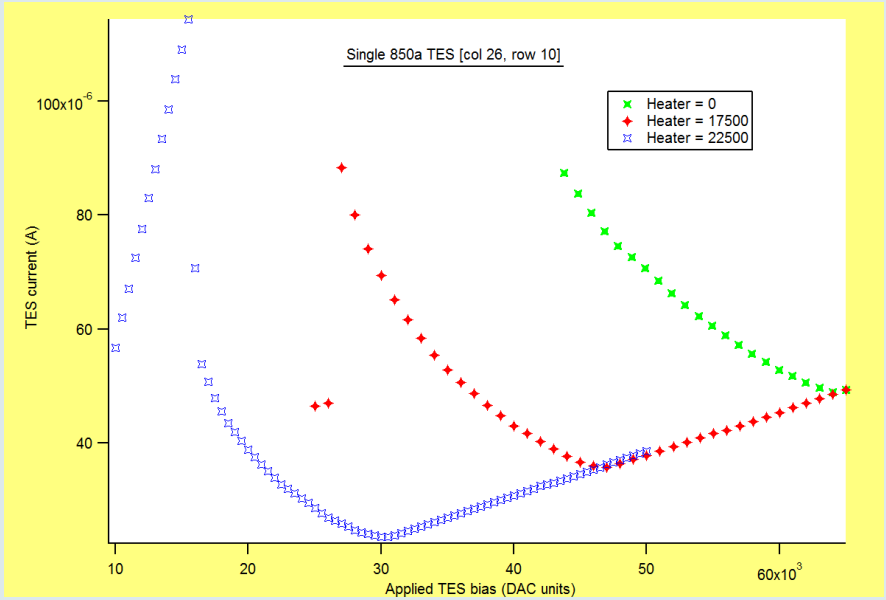


Noise investigation

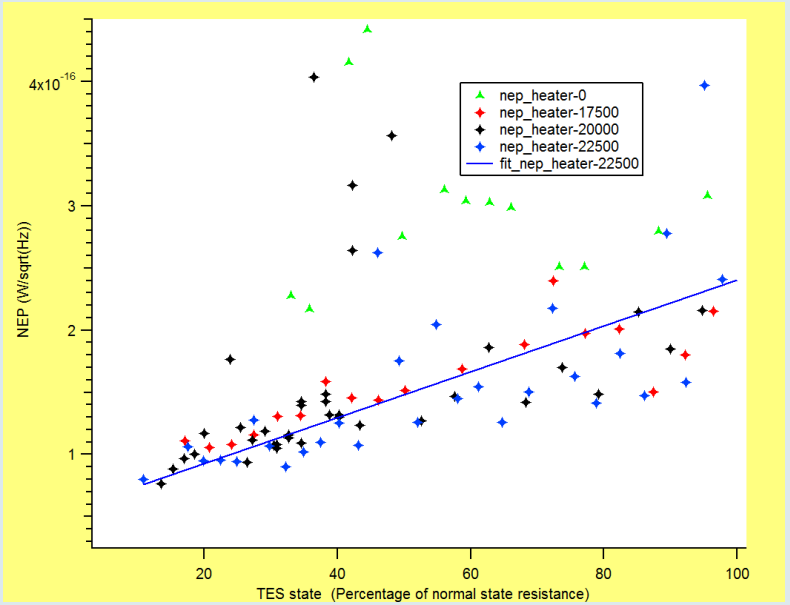
- Have been reviewing performance of detectors
  - Environmental factors
    - Magnetic pickup
    - rf pick-up
    - Stray light
  - Array setup
    - Optimum TES bias and heater

Given the spread of Tc over the detector wafers and a variation of G we know that a single heater and TES bias is a limitation. The yield of working bolometers and corresponding SQUIDs on the MUX is over 90% on all sub-arrays – we operate with closer to 70%

SCUBA-2 single pixel measurements



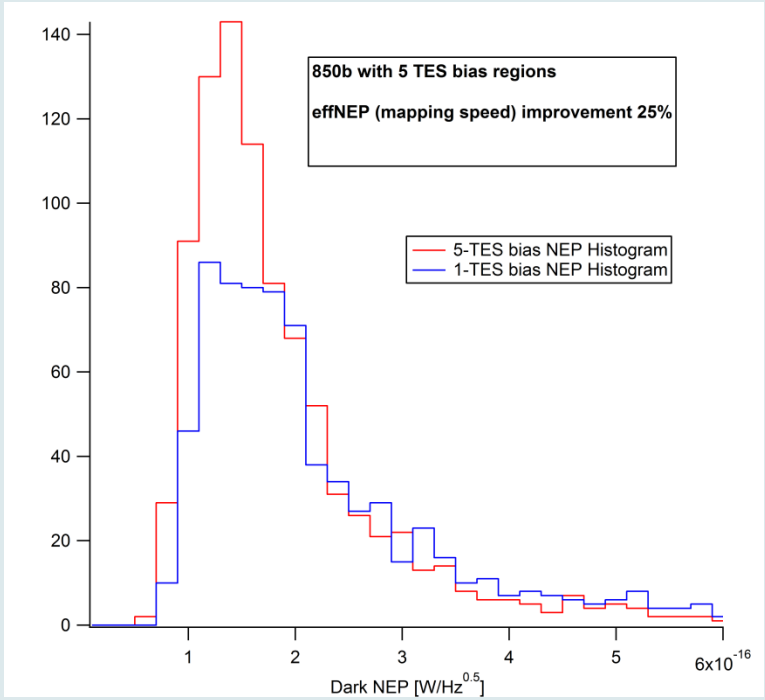
Raw data single pixel IV curves



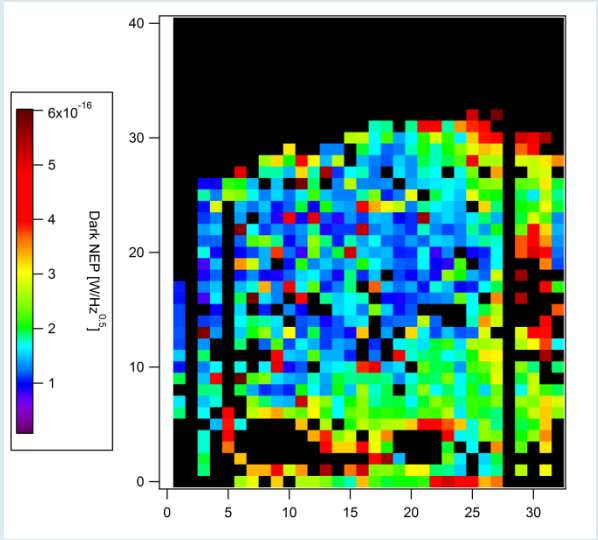
Measured Dark NEP at each point of IV curve

Initially on best sub-array (8a) - measured NEP of individual TES at each point on IV curves, for a range of heater values. At lower TES bias than we bias the whole sub-array, the measured NEP is achieving the expected phonon noise limited value.

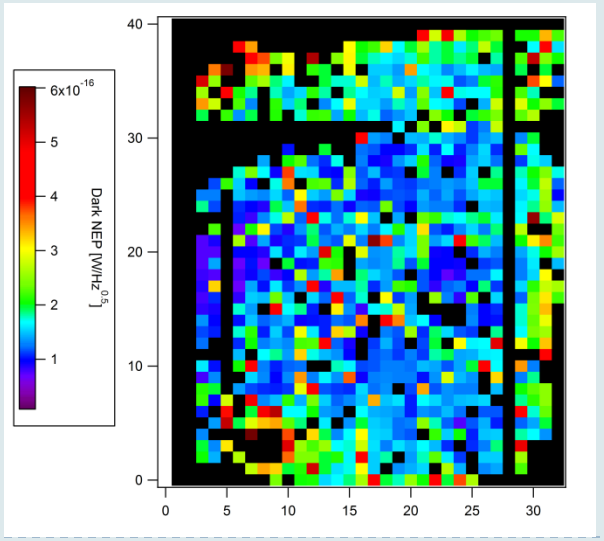
Explore – fitting multiple TES bias or heater lines



Multiple TES biased regions could improve the mapping speed of 850b and 850d significantly.



850b NEP ‘map’ with Single Bias and heater



NEP ‘map’ with 5-TES bias regions and single heater

Conclusion

- SCUBA-2 is working well.
- Superb survey instrument, that compliments ALMA and future instruments on CCAT.
- Started to investigate low cost ways to enhance the performance of the TES arrays
  - Including the possibility of retrofitting multiple bias line to some of the sub-arrays.

Didn't mention the fridge or ancillary instruments that are currently being commissioned (FTS2 and POL2).