Design of the SCUBA-2 QuickLook display and Data Reduction Pipeline

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1. SCUBA-2 is a second generation submillimetre camera for the 15-m James Clerk Maxwell Telescope (JCMT). It will operate simultaneously at 850 and 450 µm, has a field of view 8 arcminutes in diameter, and will produce images of very high fidelity.

SCUBA-2 (Holland et al. 2003) will have up to 10,000 pixels in two arrays. Unlike its predecessor, SCUBA, there will be no need to `jiggle-map' at 850 µm to produce a fully-sampled image (although it will still be necessary at 450 µm), and the bolometers are DC-coupled to the sky (i.e. no chopping) which means images will be sensitive to structure on all spatial scales, as well as lowering the confusion limit by a factor of √2. Atmospheric noise removal will be achieved through rapid sampling of the astronomical signal (up to 200 Hz).

SCUBA-2 will therefore be capable of mapping the sky up to 1000 times faster than SCUBA, allowing sensitive and truly wide-field submillimetre maps covering many square degrees to be made. The first submillimetre all-sky survey (with 7-14 arcsec resolution) looks a distinct reality with SCUBA-2. Delivery is expected to be May 2006.

2. SCUBA-2 will have two primary observing modes: Imaging of areas similar to the array size, and Scanning for making large (degree-scale) maps. In addition a polarimeter and Fourier transform spectrometer (FTS) will be available.

Imaging: used for making images comparable with the size of the field of view, or mosaicking several such fields together. Produces an image every 1-5 seconds.

STARE: simplest mode, co-added 200 Hz data. Requires stable flat-field. Frames mosaicked to fill in gaps between the subarrays (**Figure 1**).

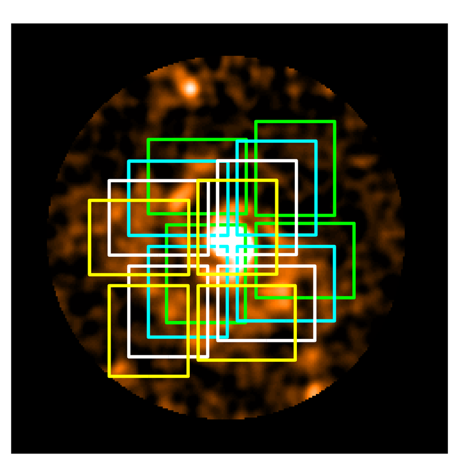


Figure 1: STARE mode. Frames are offset by 45° to optimize coverage.

DREAM (Dutch REal-Time Acquisition Mode): rapidly move secondary mirror so that adjacent pixels observe the same area of sky. Relative offsets between bolometers can then be solved for (**Figure 2**).

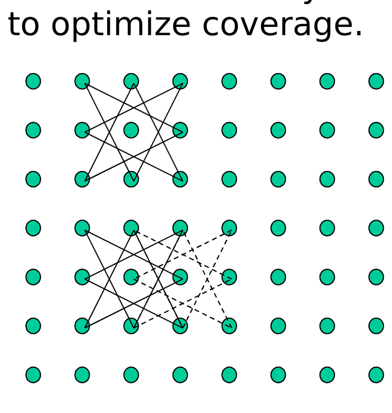


Figure 2: DREAM mode. Secondary mirror moves so that each bolometer observes multiple points.

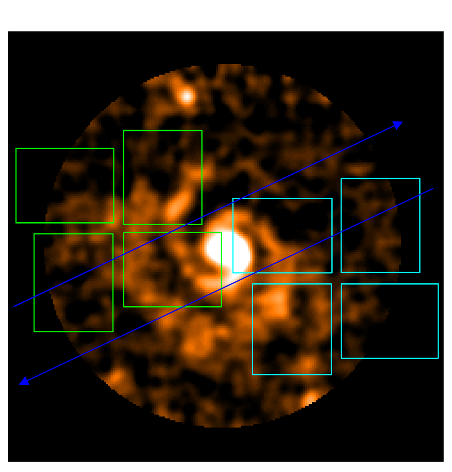
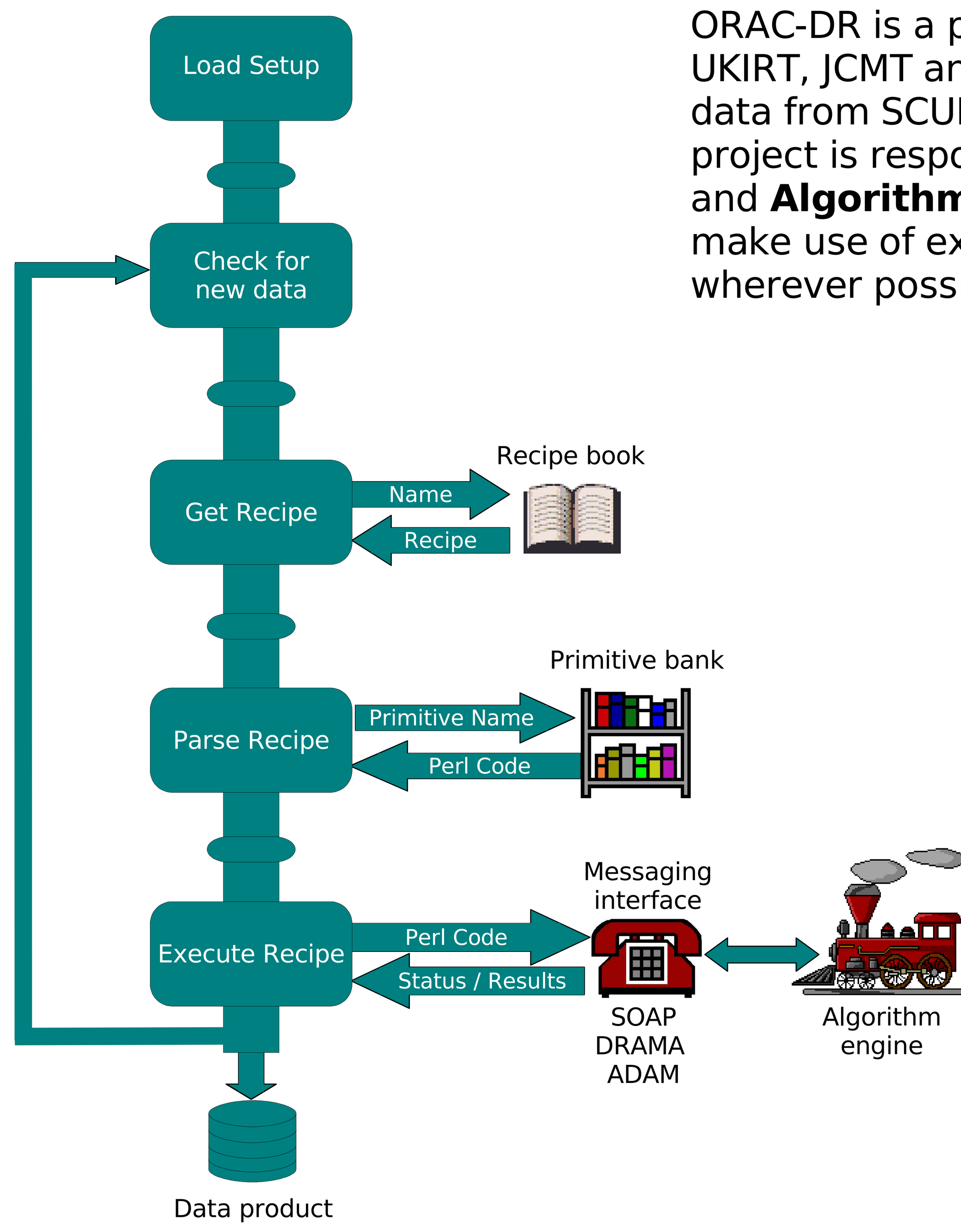


Figure 3: Scan-map mode. Array is scanned across the sky continuously.

Scan-map: for mapping large areas. Telescope slews and electronics read out continuously (**Figure 3**). Read-out rate is up to 200 Hz, leading to a maximum scan rate of 600 arcsec/sec for Nyquist sampling at 450 µm (25 times faster than SCUBA). Scanning pattern could be conventional raster or `box-scan'.

Polarimeter/FTS: Both instruments will utilize the STARE mode. Rapid operation (e.g. wave-plate rotation and mirror scanning) will be used to minimize the effects of sky variations.

Figure 4: ORAC-DR pipeline components



3. The data reduction pipeline will use the existing ORAC-DR infrastructure, which must deal with the high data rates necessary for accurate sky-noise removal and fast mapping speed.

ORAC-DR is a proven pipeline technology employed on UKIRT, JCMT and the AAT and is flexible enough to handle data from SCUBA-2. The SCUBA-2 data reduction (DR) project is responsible for writing new **Recipes**, **Primitives** and **Algorithm engines** where necessary, although we will make use of existing algorithms and Starlink applications wherever possible.

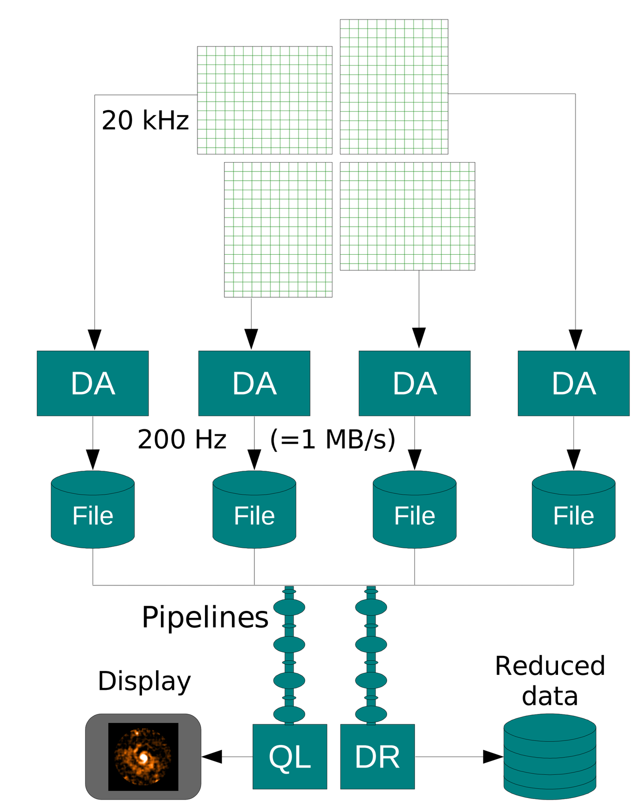


Figure 5: Schematic data flow for one of the bolometer arrays

The key challenge for dealing with data from SCUBA-2 is the high read-out and data storage rate – up to 200 frames per second for each subarray at each wavelength. The internal data acquisition (DA) electronics sample at 20 kHz. A schematic view for one wavelength is shown in **Figure 5**. The uncompressed file size is approximately 1 MB per 40x32 pixel subarray for a total output of 8 MB/s for both wavelengths, or roughly 0.5 TB per night of observing (16 hours). Data compression will reduce these values by a factor of ~2.

4. The pipeline will produce high quality images in near real time. The pipeline will also monitor the incoming data to provide diagnostic information for assessing instrument performance, observing conditions and data quality. An offline mode will enable more interactive reduction of the data.

The practical definition of real-time is to reduce 16 hours' data in no more than 16 hours. As far as possible, the pipeline must yield well-calibrated and scientifically-meaningful images, free from imaging artefacts (e.g. cosmic rays, bolometer drifts).

The higher sensitivity of SCUBA-2 and the production of fully-sampled images on timescales of 1 second will allow for significant improvements in the calibration accuracy of the pipeline. For example, real-time updates to the telescope pointing may be derived through a shift-and-add approach on a bright point source. Centroid measurements on a compact source will yield estimates of the submillimetre seeing.

5. Feedback will be provided through a Quick Look (QL) pipeline which will display minimally-processsed images as quickly as possible. Further diagnostics will be plotted via a Stripchart monitor.

The QL pipeline is similar to the full pipeline, differing only in the recipes applied to the incoming data. Simple despiking, coadding and regridding onto a preferred frame (e.g. RA/Dec) will enable the observer to make online assessments of the data. Images generated in DREAM/STARE mode will be displayed as they come in. Scan-map data taken at 200 Hz will be processed and displayed before the next scan is completed.

The Stripchart tool will monitor various parameters and pass updates to one or more plots for tracking the variation in, e.g., the flux conversion factor, seeing, and any other parameter generated as by the pipeline.