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Automated Reduction and Calibration of SCUBA Archive Data Using ORAC-DR

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Abstract. The Submillimetre Common User Bolometer Array (SCUBA) instrument has been operating on the James Clerk Maxwell Telescope (JCMT) since 1997. The data archive is now sufficiently large that it can be used for investigating instrumental properties and the variability of astronomical sources.

This paper describes the automated calibration and reduction scheme used to process the archive data with particular emphasis on the pointing observations. This is made possible by using the ORAC-DR data reduction pipeline, a flexible and extensible data reduction pipeline that is used on UKIRT and the JCMT.

1. Introduction

The Submillimetre Common User Bolometer Array (SCUBA) (Holland et al. 1999) consists of two arrays of bolometers (or pixels); the Long Wave (LW) array has 37 pixels operating in the 750 micron and 850 micron atmospheric transmission windows, while the Short Wave (SW) array has 91 pixels for observations at 350 micron and 450 micron. Each of the pixels has diffraction-limited resolution on the telescope (approximately $14''$and $8''$FWHM respectively), and are arranged in a close-packed hexagon. Both arrays have approximately the same field-of-view on the sky (diameter of $2.3'$), and can be used simultaneously by means of a dichroic beamsplitter.

2. The SCUBA Archive

All data from the JCMT are archived in Hilo (Tilanus et al. 1997) and at the Canadian Astronomy Data Centre (CADC). The SCUBA data rate is on average only 100 MB per night (peak of 200 MB/night). This is relatively small, and all

SCUBA data ever taken (since 1996) are available on disk for instant access. The current archive totals approximately 50 GB.

The data headers are stored in a Sybase database with a web front-end to simplify searches. We provide the ability to return the location of the data to users rather than the data itself to minimize the disk requirements for local researchers. To give some idea of the number of observations in the archive, there are approximately 2500 850 micron map observations of Uranus, our primary calibrator.

3. ORAC-DR

ORAC-DR (Economou et al. 1999; Jenness & Economou 1999) is a modular and flexible data reduction system initially developed for the United Kingdom Infrared Telescope (UKIRT) as part of their ORAC project and subsequently used by the James Clerk Maxwell Telescope (JCMT) for automating the reduction of data from SCUBA. The primary design goals of ORAC-DR were to simplify data reduction whilst observing and to provide near-publication quality results. This approach can also be applied to the processing of archive data, allowing time-dependent data such as telescope efficiencies, stability of secondary calibrators, and the flux changes of variable astronomical sources such as blazars to be processed with minimal effort.

4. Calibration

The accuracy of the calibration is critical for automated reduction of large datasets. If the error on the calibration is too large it becomes impossible to determine long-term trends in data since they are likely to be swamped by calibration errors. The calibration of submillimetre continuum data requires two different pieces of information:

- the amount of flux absorbed by the atmosphere (the atmospheric extinction) usually represented by a sky opacity (tau);
- the sensitivity of the telescope and the instrument; this is called the flux conversion factor (FCF) and is expressed in terms of janskys per volt.

4.1. Extinction Correction

Currently, the best method of correcting data for sky opacity is to use a combination of the CSO tau data (generating a 225 GHz data point every 10 minutes) and the SCUBA 850 micron skydips (taken infrequently throughout the night) and to fit a polynomial to the data. This has the advantages of reducing the instrumental scatter in the CSO data and allows for a human to assess the usefulness of the night for calibration; if the tau data are difficult to fit the night is not used for automated reduction. The comparison between CSO tau and skydip data is also important since the tau meter looks at a fixed azimuth whereas skydip data are taken at the current telescope azimuth. When the skydip data and CSO tau data do not agree it is usually because the extinction is dependent on azimuth. More details on the opacity correction can be found in Archibald et al. (2000).

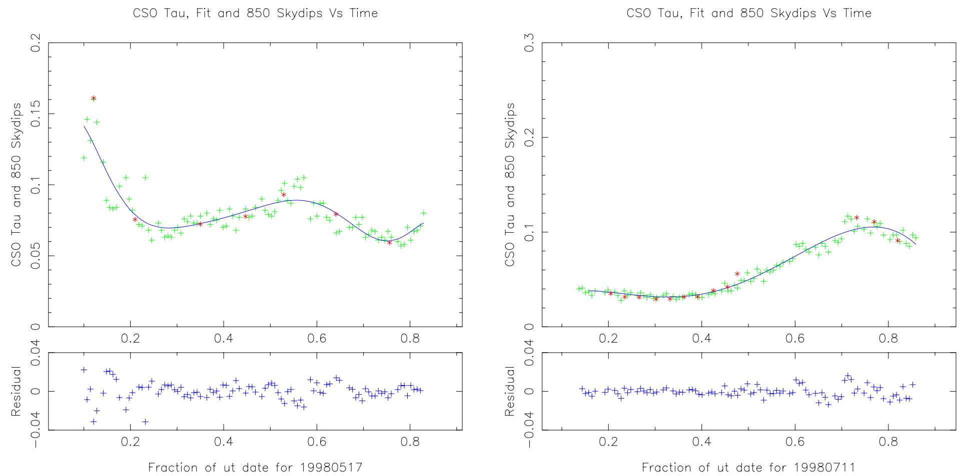


Figure 1. Two nights of CSO tau (crosses) and SCUBA skydip data (stars, scaled to CSO tau values) with corresponding polynomial fits.

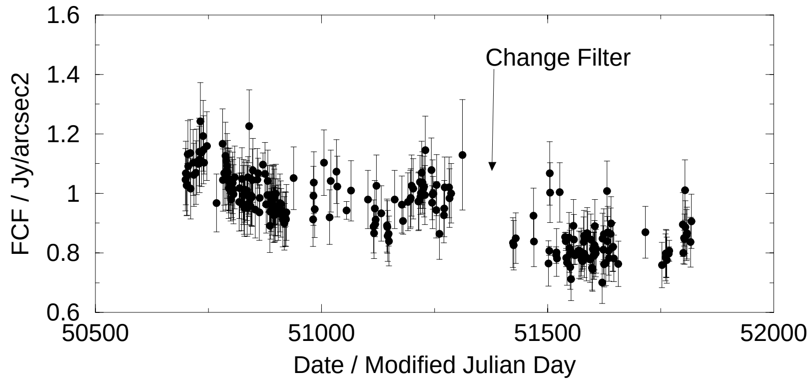
The polynomial fitting (e.g Figure 1) has been performed for every single night since SCUBA began operating and provides a crucial quality control to guarantee that data are only processed if the sky is stable enough. This is very important when 1000 observations are to be reduced and they can not all be examined by hand.

4.2. Flux Conversion Factors

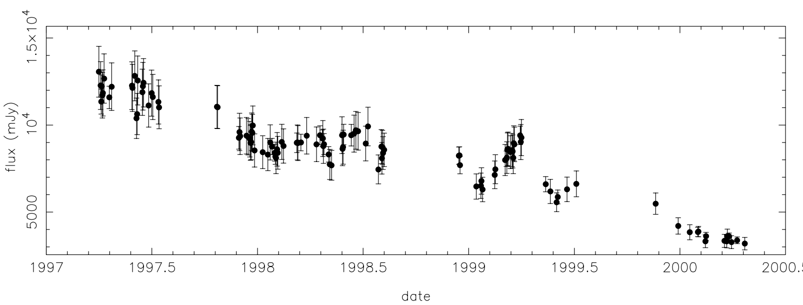
The flux conversion factor depends on the dish shape, the filter profiles and other instrumental factors. It is therefore expected to change when filters are changed or the dish is out of shape, although at 850 microns it is approximately constant for most conditions. The FCF has been determined at 850 microns by reducing the calibrators Uranus and CRL 618 using the polynomial fits described above. Figure 2a shows the FCF determined from observations of CRL 618 and reduced using ORAC-DR. The variation is less than 10 per cent and the shift in sensitivity at MJD 51400 is caused by an upgrade to the 850 micron filter. These data indicate that an accuracy of 10 per cent can be achieved when processing 850 micron archive data using this automated system.

5. Initial Results

The calibration techniques described above were applied to the pointing data present in the archive. These data provide a homogeneous dataset since every pointing is observed using the same technique and at the same wavelength. Automatic reduction of these data has allowed us to determine more accurate fluxes of our secondary calibrators and to provide numerous blazar light curves (Robson et al, 2001). An example light curve for 3C 273 is shown in Figure 2b. It should be noted that analysis of the full pointing archive is simply impossible without the use of an automated system.



(a)



(b)

Figure 2. (a) Flux conversion factor determined for CRL 618 at 850 microns. (b) Light curve for 3C 273 at 850 microns.

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