Quasar Redshifts from S-CAM Observations: Direct Colour Determination of ~12 Gyr-Old Photons

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CDs have revolutionised astronomy in the last quarter of the 20th century, yet measuring energy distributions of celestial objects still requires the indirect methods of filter photometry or dispersive spectroscopy. The development of superconducting tunnel junction (STJ) detectors (Perryman et al., 1993; Peacock et al., 1996, 1997) has opened up the possibility of measuring individual optical photon energies directly. The first time-and spectrally-resolved observations of cataclysmic variables and pulsars using these techniques have been reported (e.g., Perryman et al., 1999, 2001; Bridge et al., 2002), and the first direct measurements of the redshifts of quasars using an imaging detector with intrinsic energy resolution were published early this year (de Bruijne et al., 2002). Examples of observed and modelled spectra are shown in Figure 1. The overall shape of these spectra, in particular the falloff at low energy channels (long wavelengths), is due to the combined response of the instrument and telescope. In practice, the Ly-$\alpha$ line and the associated break at shorter wavelengths contribute most to the response range.

Information on each detected photon consists of arrival time, coordinates of the junction, and an energy channel $E$ in the range $0-255$. Laboratory measurements have confirmed that all junctions have a highly linear energy response, so that an incident photon of energy $E_p$ is assigned to an energy channel $E \sim 42.5 \cdot E_p [\text{eV}] - 2.0$ (de Bruijne et al., 2002).

Results

We determined quasar redshifts $z$ by fitting the calibrated observed energy distributions with a single template HST quasar spectrum, i.e., by minimising the function $\chi^2(z)$ (de Bruijne et al., 2002). Examples of observed and modelled spectra are shown in Figure 1. The overall shape of these spectra, in particular the falloff at low energy channels (long wavelengths), is due to the combined response of the instrument and telescope. In practice, the Ly-$\alpha$ line and the associated break at shorter wavelengths contribute most to the redshift determination.

Figure 2 compares the best-fit redshifts with the literature values. QSO 0000–263 ($z=4.1$; $V=17.5$ mag), where $\sim 350$ source photons s$^{-1}$ were recorded (Figure 3). We therefore conclude that efficient low-resolution spectroscopy of faint extragalactic sources is possible with STJ devices, enabling the determination of redshift. Extraction of detailed physical information from the spectra presented here is limited by the modest resolving power of S-Cam2 ($\Delta \lambda \sim 8$). A significant improvement in energy resolution is,
however, foreseen in the future (e.g., Rando et al., 2000), promising enhanced physical diagnostic capabilities. It has, for example, been shown that an STJ detector with $\Re \sim 20$ would allow the determination of galaxy morphological type and perhaps emission and absorption line ratios (Jakobsen, 1999; Mazin & Brunner, 2000).

STJ instrument development within ESA is currently also aimed at producing larger format arrays, to facilitate sky subtraction and possibly allow for multi-object spectroscopy, and at extending the wavelength response further to the red. The latter objective, which is consistent with the fundamental device response characteristics, would open up a larger accessible redshift range.

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References:


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The CIRSI-INT IR Survey


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The Isaac Newton Telescope has been used in conjunction with the Cambridge InfraRed Survey Instrument (CIRSI), to undertake a wide area deep IR survey in the J and H bands. This article gives a brief introduction to the survey and presents some initial results. In the spirit of the INT Wide Field Camera Survey program (Walton et al., 2001; http://www.ing.iac.es/Astronomy/ /science/wfs/; http://www.ast.cam.ac.uk/~wfcsur/) we are making reduced data products publicly available. A preliminary data release is planned for April 2002 with a complete release planned in the Summer 2002. The survey observations have been used in conjunction with optical CCD data from the INT Wide Angle Survey to undertake a survey for low and intermediate redshift quasars (z < 3) free from the potential biasing effect of dust absorption. The results of these observations are reported to illustrate the utility of the survey data for combined optical-IR survey projects.

CIRSI-INT IR Survey

With a field of 4×7.80′×7.80′ at the prime focus of the 2.5m Isaac Newton Telescope, the Cambridge InfraRed Survey Instrument, CIRSI (Mackay et al., 2000), is currently the largest field of view IR imager in operation. The camera, a mosaic of 4 Rockwell HgCdTe HAWAII IR arrays, is capable of observing in the J and H bands at the INT. The physical construction of the detector arrays prevents them being butted together.

Figure 3. Top: $\chi^2(z)$ using the first $x=1,...,21$ seconds of data of QSO 0000–263 ($z=4.1$). The dashed and solid lines indicate the literature and best-fit redshifts, respectively. Bottom: as top panels, but showing the observed QSO spectra (black) and best-fit models (grey). Panels have differing vertical scales.