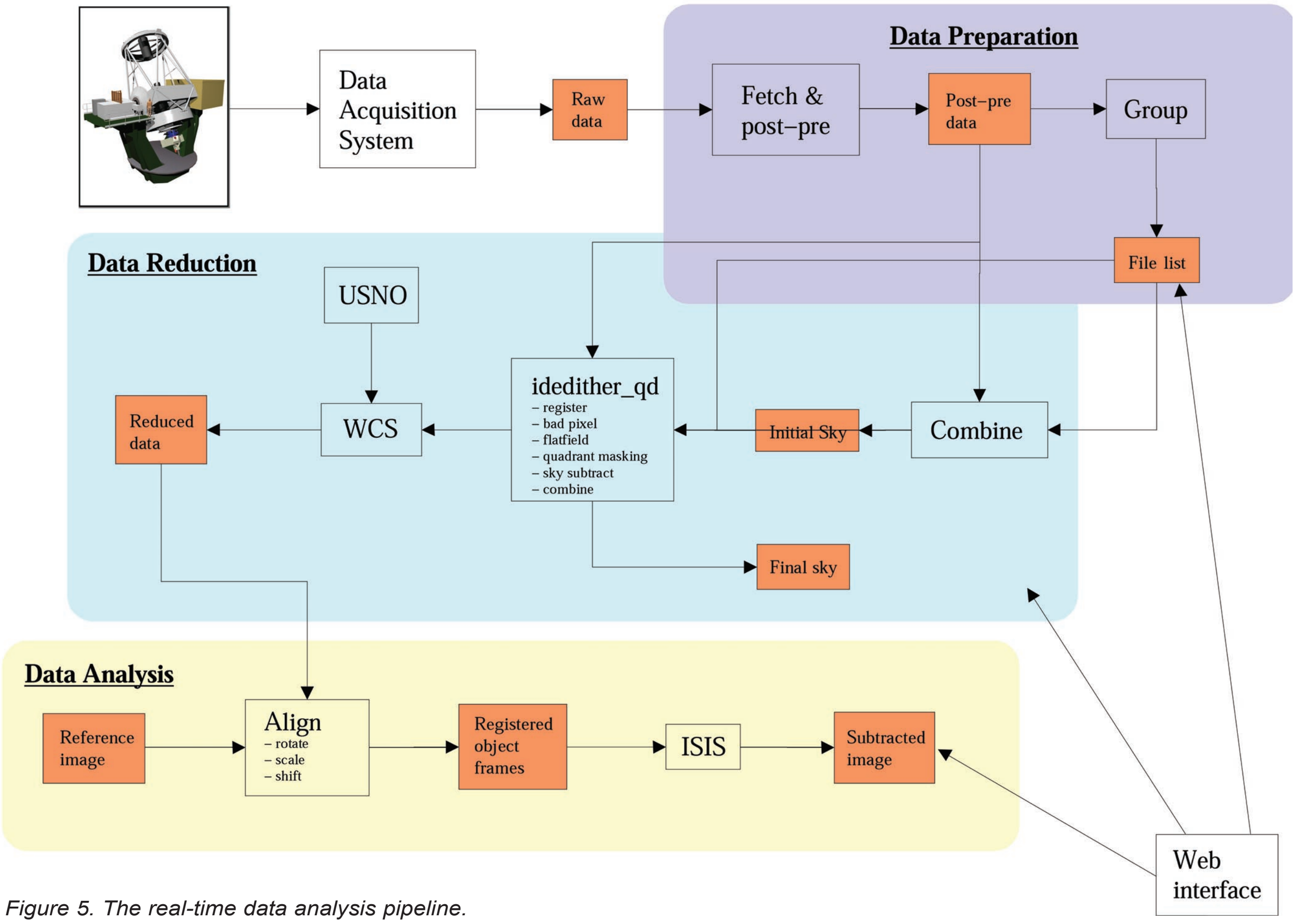


*Figure 5. The real-time data analysis pipeline.*

# The INGRID MDS ERO Survey

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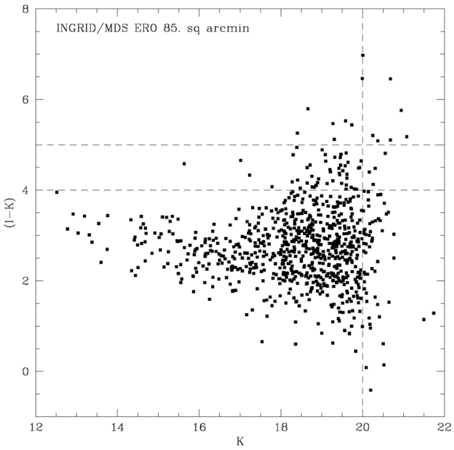
We are taking advantage of the wide-field near-infrared imaging capabilities of INGRID on the WHT to construct a deep, wide area survey for Extremely Red Objects (EROs) in archival Hubble Space Telescope Medium Deep Survey (MDS) fields.

The last five years have seen a growing appreciation of the diversity of galaxy properties at $z \gtrsim 1-2$. In part this has come about from an impressive growth in our observational knowledge of galaxies at these redshifts —driven by the availability of powerful new instruments on 4- and 8-m class telescopes. However, an equal role has been played by the realisation of the necessity of a multi-wavelength approach to studies of galaxy evolution at $z \gtrsim 1$. Thus a range of surveys spanning wavebands from the X-ray, near- and mid-infrared, submillimeter and out to the radio, have complimented the traditional view based on UV/optical observations. These new studies have all tended to stress the role of dust obscuration in censuring our view of the galaxy population at high redshifts, and especially in disguising the extent of activity in the most active environments, both AGN and star-forming systems. This is much more of a concern due to the very strong evolution seen in obscured populations, which result in them dominating the bolometric emission at high redshifts (e.g. Haarsma et al., 2000; Smail et al., 2002).

One of the most striking themes to arise from this new multi-wavelength view of galaxy formation is the ubiquity of optically-faint, but bright near-infrared counterparts to sources identified in many wavebands: in the X-ray (Cowie et al., 2001; Page et al., 2001), the mid-infrared (Pierre et al., 2001; Smith et al., 2001), submillimeter (Smail et al., 1999; Lutz et al., 2001) and radio (Richards, 1999; Chapman et al., 2002). This has resulted in a renaissance in interest in such Extremely Red Objects —a class of galaxies which had previously been



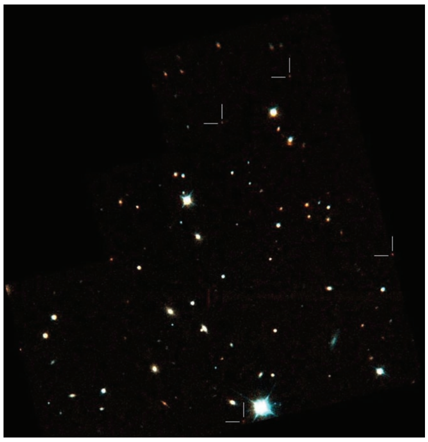



*Figure 1 (left). Preliminary I–K, K colour-magnitude diagram from 85 sq. arcmins of data from our survey. These data cover 17 HST WFPC2 fields — with typical integration times of 6.0 ks in the I (F814W) passband and 3.0 ks in the K-band with INGRID. The INGRID data for this survey was taken in typically good conditions, 0.5–0.9" FWHM, while the HST imaging has nominally 0.1" resolution, although poor signal to noise for the reddest galaxies targeted here, I-K ≳ 4–5. We catalogue a total of 55 galaxies brighter than K=20 and redder than I–K=4, of which 7 are redder than I–K=5. The equivalent sample for the full survey will have around 170 and 20 respectively. Figure 2 (right). A "true colour" I/$K_s$ image of one of our fields. An extreme ERO, I–K>5, is visible to the south-east of the brightest star. Other (I–K>4) EROs are indicated by arrows. The unusual shape of the image arises from the coverage of the WFPC2 image. The field is ~4' in diameter — meaning that the WFPC2 field is completely covered by INGRID, irrespective of the roll angle of HST when the observations were taken. The image reaches 5σ point source sensitivities of K~20 and I~26.*

viewed as a curiosity with little relevance to our understanding of galaxy formation and evolution — comprising a mere 5–10% of the population down to $K$=20.

The ERO class is photometrically-defined — one frequently used definition is $I–K \geq 4$ (or a more extreme selection of $I–K \geq 5$). This very red optical-near-infrared colour is intended to effectively isolate two broad populations of galaxies at $z \gtrsim 1$: those which are red by virtue of the presence of large amounts of dust (resulting from active star formation), as well as passive systems whose red colours arise from the dominance of old, evolved stars in their stellar populations. The very different nature of these two sub-classes, dusty starbursts and evolved ellipticals, has prompted efforts to disentangle their relative proportions (Pozzetti & Mannucci, 2000) so that well-defined samples can be used to test galaxy formation models (Daddi et al., 2000; Smith et al., 2002; Firth et al., 2002).

One particularly powerful approach is to use the morphology of the ERO to distinguish regular, relaxed ellipticals from disturbed and dusty starbursts.

A common misconception is that the key to a successful ERO survey is to obtain deep NIR imaging — in fact, the observationally most demanding aspect is achieving the necessary depth in the optical to identify that a galaxy is an ERO. For this reason, we have chosen to concentrate our survey on fields for which deep, high-quality archival optical imaging already exists. These fields come from the Medium Deep Survey (Griffiths et al., 1994) who have amassed over 500 deep HST/WFPC2 images of intermediate/high-Galactic latitude blank fields. These represent high-resolution (0.1") and very deep ($I$~27) images of random areas of extragalactic sky. Using a sample taken from the 100 deepest $I$-band MDS fields (covering an effective area of 500 sq. arcmin) we are able to obtain morphological information (sufficient to distinguish compact, regular evolved early-type galaxies from the more distorted starbursts) for galaxies as faint as $I$=25. Six nights of INGRID time in November 2000 and a further six in May 2001 have resulted in over 50 MDS fields being imaged in $K_s$ and more than 30 of these also in $J$, to 5σ limiting magnitudes of $K_s$=20 and $J$=22.5. It is thanks to the generous field of view of INGRID that such a survey is possible in a reasonable amount of telescope time. In contrast UFTI on UKIRT would take a factor of 3–4 longer to tile each MDS field. These data will form the basis of a sample of EROs with which we can undertake NIR spectroscopy on 8-m class telescopes, selected from an area an order of magnitude larger than the Cimatti et al. (2000) survey.

Preliminary results are shown in Figure 1. From 85 square arcmins, 55 EROs are found with $I–K \geq 4$ and 7 with $I–K \geq 5$. The samples from the full survey of 260 sq. arcmin will be 170 and 20 respectively. A colour image of one field made from INGRID data is illustrated in Figure 2. This survey is supported by the Leverhulme Trust. ¤

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