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The Wide Field Survey on the Isaac Newton Telescope

J. R. Lewis, P. S. Bunclark, M. J. Irwin, R. G. McMahon

Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, England

N. A. Walton

Isaac Newton Group, Apartado 321, 38780 Santa Cruz de la Palma, The Canary Islands, Spain

Abstract. In this paper we report on the INT Wide Field Survey, which is based on the Wide Field Camera (WFC) on the 2.5m Isaac Newton Telescope (INT) on La Palma. The WFC comprises four 4k x2k thinned EEV CCDs and offers the equivalent of a 33 x 33 arcmin field, sampled at 0.33 arcsec/pixel, thereby providing a powerful tool for executing high resolution, deep, optical imaging surveys.

In order to optimize the scientific return of the WFC, a large scale public access wide field survey (WFS) program was initiated in 1998, to run for a duration of up to five years. A novel hybrid strategy, emphasizing the multi-use quality of the data, was employed in selecting the science to be undertaken,

The programs currently comprising the WFS are a survey covering 100 square degrees to a depth of m(R) = 24 in up to six passbands (UBg′r′i′z). Smaller encapsulated programs provide: deeper surveys to m(R) = 26 over selected areas for the study of galaxy clustering and deep Galactic studies; multi-epoch observations of several regions for variability and proper motion studies; and short timescale repeat observations for an intermediate-redshift supernova program. The survey data are provided on-line in a pipeline-processed form via a WWW access site, shortly after they are obtained.

We discuss some of the scientific goals of the survey as well as the data processing pipeline and data products. In addition we briefly discuss a complimentary survey being done in the infrared using the Cambridge Infrared Survey Instrument (CIRSI).

See `http://www.ast.cam.ac.uk/~mike/casu/WFCsur/WFCsur.html` for further information about the survey. The WFS data are available at `http://archive.ast.cam.ac.uk/wfsurvey/wfsurvey.html`. Information on CIRSI is at `http://www.ast.cam.ac.uk/~optics/cirsi`.

1. INT Wide Field Camera

The Wide Field Camera on the 2.5m Isaac Newton Telescope comprises four closely packed thinned coated EEV 2k x 4k CCDs. The coverage of each of the chips is 22.8 x 11.4 arcmin, making a total field of 0.29 square degrees.

Currently the readout time is approximately one minute – this will reduced to approximately 30 seconds late in 2000. The total amount of data at readout is approximately 71 MB for each exposure (16 bit pixels). A recent upgrade of the DAS now means that the data are stored in multi-extension FITS files (previously data were dumped to four simple fits files). Typical observations yield between 5-10 GB of data per night. These data are archived on single DDS-3 tapes for later transfer to Cambridge for processing.

The autoguider consists of a thinned 2k x 2k Loral CCD mounted in the same cryostat as the science chips, giving the advantages of guiding at the same wavelength with absolutely no differential flexure. The autoguider system uses an APM-style image centroiding algorithm and provides relative transparency and seeing estimates.

2. The INT Wide Field Survey

In order to exploit the capabilities of the new Wide Field Camera on the INT, the Isaac Newton Group Board approved a program to carry out a major CCD based multi-color survey over a course of 4-5 years. A primary feature of this plan was that data would be made available almost immediately in a reduced form to astronomers in the UK and the Netherlands. This would aid rapid scientific exploitation of the data. The rest of the community would have access to the data after one year.

The *INT Wide Field Survey* (WFS) is actually an umbrella term for a number of different scientific programs. The largest of these, the *INT Wide Angle Survey* (WAS), includes sub-projects ranging from the cosmological to a search for solar system objects. Were all these programs to be carried out under normal time allocation procedures, the total on-sky time required is almost 600 nights. However if these programs are combined, that number shrinks to about 100 nights. Merging the requirements of many programs results in a highly efficient observing strategy and this is the basic philosophy of the WFS. The WAS is also the project that coordinates efforts with other programs on issues such as filter and field selection in order to maximize the scientific return of the WFS as a whole.

The WFS is designed to be complementary to other major surveys (e.g SDSS). Unique features include: (1) choice of fields visible in both hemispheres; (2) inclusion of U band; (3) good coverage with deep radio surveys; (4) wide RA coverage for efficient follow-up; and (5) choice of SDSS filter bandpasses.

3. Wide Field Survey Data Pipeline

A detailed description of **wfcred** the IRAF-based data reduction pipeline for the WFS is given in Lewis et al. (1999), but we briefly recap here. The amount of data generated during the WFS makes it imperative that we develop a pipeline to handle the large data sets in a reasonably automatic way. Although most of the processing of target frames is routine and automatic, we found it difficult or impossible to create, update and maintain master calibration images automatically. So although the processing of the master calibration images is done automatically, the applications which do this have many tools that can be used to assess the suitability of input frames and the quality of output data in an interactive way.

Once the calibration frames have been constructed (if needed) the target frames go through a number of processing steps. In the order in which they occur, these are:

Bad pixel replacement Bad pixels and dud partial columns are flagged in a master file and are then interpolated over using neighboring regions.

De-biasing and trimming Stacked bias frames using the default clear and readout speeds show some low level repeatable structure due to various electronic effects, therefore full 2-D bias removal is necessary.

Non-linearity correction Linearity tests using sequences of dome flats revealed significant, and similar, non-linearities over the whole dynamic range in all of the chips. A non-linearity correction is applied via a Look Up Table (LUT) to all data. This non-linearity arises in the ADC and is observed to be stable with time.

Flat-fielding
For each observing run a sequence of master sky flats is constructed. Because of readout overheads it is impossible to generate complete sky flats in, say, Ugriz each night, hence flats from several nights are combined to produce master flats.

Gain correction Although processed independently, the mean flat-field sky level in each passband is used to place all the CCDs on the same zero-point system, i.e.. sky in deep frames is the same for all CCDs to better than 0.5%, the residual non-linearity level. This step grossly simplifies photometric calibration and mosaicing of images.

Astrometry First, a dead-reckoning astrometric World Coordinate System (WCS), accurate to 5–10 arcsec is written to the FITS headers using the nominal telescope pointing, rotator angle and camera geometry. Following this, an astrometric solution based on the derived positions of GSC objects visible in the data frames is used to define a more accurate astrometric solution automatically. Currently the external accuracy of this astrometry is limited by the GSC accuracy to about 0.5–1 arcsec. Further improvements of this are underway using deeper Schmidt plate-based astrometry. Preliminary results suggest the final internal astrometric error will be well within 0.1 arcsec for the whole mosaic.

Defringing Both I and Z-band data frames suffer from significant sky fringes while R-band images also shows weak fringing due to the red tail of the Harris glass filter. We find that the SDSS r' filter shows no sky fringing. The SDSS i' filter also has less fringing than the I-band filter due to the sharp cutoff at 8500 Å. Fringe patterns in the i′, I and particularly Z-band, can show significant variations on a nightly basis, making them difficult to remove completely. We have developed algorithms for automatically removing the sky fringes using fixed fringe pattern masks, that generally reduce the fringing level by a factor of 10 or more.

Photometry A series of selected Landolt standard fields (Landolt 1992) are observed each survey night to monitor and calibrate the photometry to the Johnson-Kron-Cousins photometric system. We are establishing secondary standards in each field as well.

Object detection Each pipeline processed frame is analyzed using a stand-alone automated object detection and parameterization algorithm based on ideas presented in Irwin (1985, 1996). Generated catalogs include position, luminosity and shape information. The object detection algorithm also monitors seeing, sky brightness and noise levels.

The reduced data are placed on line in Cambridge. A catalog of observations is available for searching through a WWW interface. Reduced data, master calibration frames and non-linearity corrections are also available via the web interface.

4. The Cambridge Infrared Survey Instrument

The Cambridge Infrared Survey Instrument (CIRSI) is a panoramic wide field near infrared imaging camera which uses 4 Rockwell HgCdTe 1024^2 detectors. The survey instrument is as scientifically versatile and as easy to use as a large format CCD camera and was first used on the INT in Dec 1997. It is particularly well-suited for surveys of star-forming regions, low mass stars, distant galaxies, clusters and QSOs.

We plan to carry out a survey using CIRSI centered predominantly on the WFS survey zero declination strip $\alpha = 9 - 15$. This will be a $0.5°$ strip or 45 deg^2 in total. We will also be surveying the WFS 1610+41 field (10 deg^2). 10% (5 deg^2) of the survey will be carried out in survey fields that will be also be covered by XMM fields. The proposed allocation is constrained by the availability of CIRSI on the INT and the amount of data that we believe we can process.

References

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