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WORKING GROUP ON SKY SURVEYS

(GROUPE DE TRAVAIL POUR LE RELEVE DU CIEL)

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1. Overview

The triennium since 1999 has seen a huge amount of progress with Sky Surveys in all wavelength ranges, with the promise of even bigger and better surveys to come in the near future. Many of the surveys mentioned in our previous report (IAU Trans. XXIVA, p318) have been completed and the data are in some cases already in the public domain. There were several relevant conferences during the triennium, one of which directly involved the WG, "The New Era of Wide Field Astronomy" meeting in Preston in August 2000 (Clowes et al. 2001).

Keeping track of information and status has become a major challenge. The Working Group now has its own website at http://www.skysurveys.org, set up by Brian McLean, Quentin Parker and Belinda Wilkes with the aim of providing a one-stop place from which astronomers can find out about existing surveys at all wavelengths. The website is still being actively developed and input from members of the community on new sites is very welcome. Readers anxious to learn about any specific survey should go directly from here to the website, since the remainder of this report can only summarise a few of the many activities.

Recent survey highlights include: the first optical spectroscopic surveys to pass the 100K mark, with the completion of the Anglo-Australian 2dF Galaxy Redshift Survey (2dFGRS) and the companion 2QZ quasar survey, and the start of the Sloan Digital Sky Survey (SDSS); the multi-colour CCD photometric imaging survey of substantial amounts of the sky to an unprecedented accuracy, also by the SDSS, and the deep ESO Imaging Survey (EIS); and the completion of the all-sky photographic sky surveys in three colours (BRI) by the Palomar (Oschin) and UK Schmidt Telescopes. The on-line availability of digitised data from the Schmidt surveys, when combined with several recent dedicated astrometric surveys, means that the goal of having positions accurate to ~ 100 mas for all optical objects is now attainable. More specialised surveys include narrow-band Hα surveys; one recently completed on the UKST was almost certainly the last big photographic survey, marking the end of an era which began about 50 years ago with the Palomar Sky Surveys.

All of the above are surveys at optical wavelengths, but in many ways the most important developments are the advent of accurate, deep, wide-field surveys at infrared, radio and X-ray wavelengths. These include the 2MASS all-sky and DENIS southern hemisphere near-infrared surveys; the Parkes multi-beam HI southern radio surveys (HIPASS) and the Canadian Galactic Plane Survey; FIRST, SUMSS and other radio surveys for sources at various frequencies over substantial fractions of the sky; the start of deep X-ray surveys by Chandra and XMM-Newton; and the advent of Gamma-ray surveys. Returning to optical wavelengths but in space, HST has surveyed the Deep Field South (HDS) to produce a second extremely deep sample of the optical universe (Williams et al, 2000).

For the future, good progress is being made with many new facilities. Among the most significant, considering their scope and likely impact over a wide range of astronomy and astrophysics, will be the giant new international radio telescopes, the ALMA mm-wave array in Chile and the Square Kilometre Array (SKA). Work continues on the UK VISTA near-infrared survey telescope, now closely linked with the ESO VST optical survey telescope; meanwhile, a new NIR survey camera, UKIDSS, will soon be commissioned on UKIRT (Warren, 2002). The LAMOST multi-fibre survey telescope is being developed in China and several other facilities with an order of magnitude increase in number of fibres or collecting area are proposed. Meanwhile, the 6dF multi-fibre system on the UKST has started its spectroscopic survey of all galaxies brighter than K mag 12.75 in the southern sky. New space astrometric satellites such as DIVA and GAIA are being planned, following the enormous success of Hipparcos. A related international Radial Velocity Experiment (http://www.aip.de./RAVE) is planned, to obtain optical spectra of tens of millions of stars in order to understand the formation and history of our Galaxy.

The arrival of huge new databases in the public domain, in every accessible wavelength range, means that the Virtual Observatory is already becoming a reality. We must learn how to use these databases in the most effective ways, while taking proper account of their inbuilt 'features' and limitations. Large databases provide the opportunity for finding relatively weak signals in huge samples, but only if systematic errors can be fully corrected, and for finding very rare objects, but only if the incidence of spurious data can be kept to very low levels.

The following sections give more details on some specific surveys.

2. The Sloan Surveys

The SDSS will eventually be by far the largest optical imaging and spectroscopic survey, using dedicated facilities for both tasks. It consists of two parallel surveys: a five-colour CCD imaging survey which to date covers some 3500 square degrees of sky and provides optical photometry of unrivalled precision and uniformity, and which must supersede the older photographic sky surveys once it becomes fully available; and a spectroscopic survey which already contains about 280,000 objects out of an eventual total of 2 million, selected from the photometric catalogue. The main objectives of this work are large scale cosmological studies of galaxies and quasars, but many stellar and Galactic projects are also being done. The first major public data release is scheduled for January 2003. See http://www.sdss.org for more information.

3. The 2dF Surveys

The Two-degree Field (2dF) instrument on the Anglo-Australian Telescope (AAT) completed its initial very large redshift surveys during 2002. Two surveys were carried out concurrently within two strips in RA, one running through the SGP and the other along the equator in the N Galactic Cap. The 2dFGRS obtained spectra for more than 220,000 galaxies over 5% of the sky, mapping out the structure of the local universe to redshift $z \sim 0.3$. The first 100,000 spectra were publicly released in June 2001 and the full data set will be released during the first half of 2003. The data have already been used for many cosmological investigations, and for studies of the galaxies themselves. Some highlights include: the precise determination of the galaxy power spectrum and a clear demonstration of redshift space distortions; new measures of several of the fundamental cosmological parameters; determinations of the galaxy bias parameter; and even an upper limit to the neutrino mass fraction. The galaxies have been used to determine luminosity functions, spectral types, star formation rates, the nature of radio galaxies and the effects of clustering. For a recent summary and lists of publications see Colless (2002) or visit http://www.mso.anu.edu.au/2dFGRS. The 2QZ contains spectra for more than 20,000 quasars and maps the structure of the universe on larger scales, out to redshifts beyond $z = 3$. It is being used both to determine cosmological parameters and to better understand the nature of quasars themselves. The

first 10,000 spectra were released in mid-2001 (Croom et al., 2001). For up-to-date information on the 2QZ and the many publications arising from it, see http://www.2dfquasar.org.

4. Astrometric and Photographic Surveys

Three fundamental astrometric catalogues have appeared during the triennium. The Carlsberg Meridian Telescope group published the CMC12 catalogue (D.Evans et al., Cambridge) of 6.3 million equatorial stars while Bordeaux Observatory (Rapaport et al., 2001) published the M2000 catalogue of 2.3 million stars. Both catalogues are accurate to 35 to 100 mas, depending on magnitude. In March 2000 the first instalment of the USNO CCD Astrograph Catalog (UCAC1) was released (Zacharias et al., 2000), containing positions (25 to 70 mas) and proper motions (2 to 15 mas/yr) for 27 million stars with $\delta < -15$ and $8 < B < 16$. By the end of June 2002 over 82% of the whole sky was covered.

Several groups have independently digitised the photographic sky surveys from the large Schmidt telescopes and made the data available on-line. The STScI dataset is available on-line from a number of data centers throughout the world. Images in at least 3 optical pass bands (BRI) can be accessed for any position in the sky. A preliminary version of the second generation catalogue (GSC-II), containing over a billion objects, was released to the community in June 2001 and a final version will be available by mid-2003. The APM on-line UKST B_J, R southern catalogue was finished during 2001 and completes the APM high latitude sky surveys (http://www.ast.cam.ac.uk/~mike/apmcat). The SuperCOSMOS 3-colour Sky Survey (SSS) is now complete in the southern hemisphere (http://www-wfau.roe.ac.uk/sss; Hambly et al. 2001). The scanning of all applicable Schmidt survey plates, together with all plates from the Lick/Yale/San Juan Proper Motion program, has also been completed on the USNO PMM machine (Platais et al. 2001). The USNO B catalog will include positions, magnitudes and proper motions for about a billion stars.

The UKST Hα survey (Parker, Phillipps et al. 2002) covers the S Galactic Plane and the two Magellanic Clouds with matched pairs of Hα and short red photographic exposures; SuperCOSMOS digitisation of all the plates is nearing completion: see http://www-wfau.roe.ac.uk/sss/halpha.

5. Infrared Surveys

The availability of the 2MASS JHK (http://www.ipac.caltech.edu/2mass) and DENIS IJK (http://denisexg.obspm.fr) surveys has revolutionised NIR astronomy. Not only are these surveys immensely valuable in themselves, but they are publicly available in a way that makes it very simple to reliably cross-identify the IR sources with objects in other catalogues, so that the NIR data can be added to such datasets. More than that, the infrared data are uniform across the sky and relatively unaffected by dust, so they can be used to check the calibration of optical photometry (e.g. for the 2dFGRS), or as relatively unbiassed input lists for other surveys (e.g. the 6dF redshift survey).

6. Radio Surveys

Major developments in the radio astronomy include the completion of the HI Parkes All-Sky Survey (HIPASS), which covers the 70% of the sky accessible from Parkes. This has generated catalogues of high velocity clouds, made maps of the Magellanic System and detected many external galaxies. The Canadian Galactic Plane Survey has mapped the HI in the N Milky Way. For external sources, the VLA FIRST 20 cm survey of the N and S Galactic Caps is also nearing completion, providing arcsec accuracy positions and radio images for nearly 1 million sources, while the Sydney University SUMSS 843 MHz survey is mapping the sky and generating source lists south of $-30°$ declination.

7. X-ray Surveys

Chandra and XMM-Newton are able to probe much fainter X-ray flux levels than ever before and allow us for the first time to identify unique optical/radio counterparts to most of the X-ray sources. Two Chandra deep fields have now been observed. The low background and 0.5″resolution of Chandra results in these surveys reaching X-ray flux limits $100-1000$ times fainter than earlier surveys and are able to resolve over 80% of the Cosmic X-ray Background (CXRB) into discrete sources. Complementing the deep surveys, wide area serendipitous surveys to $\sim 10\times$ brighter flux limits are being carried out using both the Chandra and XMM-Newton archival data. These surveys will provide larger samples of intermediate flux level sources which are rare in the deep fields. The two projects plan to combine some complementary datasets, taking full advantage of Chandra's superior spatial resolution and XMM-Newton's $4\times$ greater collecting area.

8. Gamma-ray Surveys

Wide field surveys for Gamma-ray Bursts (GRBs) have recently been successful in rapidly locating the source of the radiation. Notably BeppoSAX (Boella et al. 1997), which was operated from April 1996 to April 2002, but also the all-sky IPN (Cline et al. 1992) and lately HETE-2 (Vanderspek et al. 1999) have provided positions, based on which the long lasting afterglow emission in the X-ray, optical and/or radio wave-bands have been identified for now more than 50 long/soft GRBs. This has led to a revolution in our knowledge of GRBs and, we hope, towards an understanding of the phenomenon (or phenomena).

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Chairperson of the Working Group

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