

*The deepest, coolest look at the Universe is underway*

# The UKIRT

## Infrared Deep Sky Survey

Steve Warren and Andy Lawrence

recognised only in 1995, but now we know of hundreds. Near-infrared surveys are thus central to our emerging knowledge of brown dwarfs.

UKIDSS actually comprises five surveys. Two of them concentrate on faint cool sources in our Milky Way Galaxy: the Galactic Clusters Survey (GCS) will search for low-mass stars and brown dwarfs in a dozen nearby star clusters, and thereby establish the proportions of stars of different masses and any dependence on variables

**UKIDSS is the largest and most sensitive survey of the heavens in infrared light**

Surveys – cataloguing what is out there in the sky – have always been central to astronomy, and have led to many important advances in our understanding of the Universe. The UKIRT Infrared Deep Sky Survey (UKIDSS) is the latest to be launched, and is the largest and most sensitive survey of the heavens in infrared light. It has recently released its first year of data, cataloguing more than 100 million stars and galaxies, revealing very distant galaxies and quasars, as well as nearby stars that are extremely cool.

UKIDSS began in May 2005, and is a 7-year programme to survey the sky at infrared wavelengths. It employs the UK's new Wide Field Camera (WFCAM) mounted on the UK Infrared Telescope (UKIRT) on Hawaii. Built at the UK ATC in Edinburgh, WFCAM includes four large area near-infrared detectors. The camera's wide field-of-view, combined with the large collecting aperture of UKIRT (3.8 metres across), makes it the most powerful near-infrared survey instrument in the world. About half of the available time on the telescope is devoted to the survey with WFCAM.

The new survey follows on from two recently completed large imaging surveys which provide the highest definition maps of the Universe to date: the Two Micron All

Sky Survey (2MASS) which began in 1997 and covers the whole sky at near-infrared wavelengths; and the Sloan Legacy Survey (SLS), which began in 2000, scans the sky at optical wavelengths, and is deeper but covers a smaller area – 15 per cent of the sky. UKIDSS is able to combine the strengths of SLS and 2MASS, reaching 10 to 1000 times deeper into the Universe than 2MASS and able to see cool, low-mass objects like brown dwarfs not detectable at the visible wavelengths of the SLS. Brown dwarfs are stars of such low mass that they never get hot enough to start nuclear burning, and are therefore cool – so are visible in the infrared, but practically invisible at optical wavelengths. The first brown dwarf was

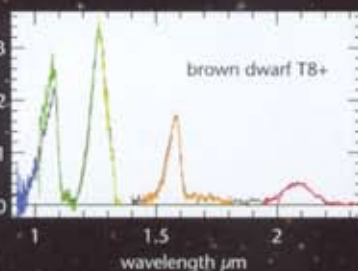
UKIDSS image of the Serpens Cloud core

Fish-eye view of WFCAM mounted on UKIRT

## The coolest brown dwarf

One of the goals of UKIDSS is to identify and characterise brown dwarfs that are even cooler than those so far found – with temperatures down to less than 700K. The figure below plots the spectrum of a cool brown dwarf discovered in UKIDSS in September 2006, named ULAS J0034. Its spectrum was obtained with the Gemini South telescope, and the different colours correspond to the different sections of the spectrum produced by the instrument. The black line plots the spectrum of the T8 brown dwarf

The newly-discovered UKIDSS source ULAS J0034



2MASS0415, until now the coolest known brown dwarf. Although rather similar, the measured strengths of the strong absorption features, due to water and methane, indicate that ULAS J0034 is of slightly cooler temperature, and therefore appears to be the coolest brown dwarf known.

such as age and environment; the Galactic Plane Survey (GPS) will produce a new deep atlas of the disc of the Milky Way within a thin belt 10 degrees wide. Because the density of stars increases so strongly towards the plane of the Galactic disc, the GPS will be by far the largest astronomical survey ever undertaken – cataloguing around a billion new sources.

The three other surveys cover regions away from the obscuring effects of the Galactic plane, and primarily target distant galaxies and quasars. They provide complementary combinations of depth and area: the Large Area Survey (LAS) will cover two-thirds of the area scanned by the SLS to

a matching depth; the Deep ExtraGalactic Survey (DXS) is of intermediate depth; and the deepest – the Ultra Deep Survey (UDS) – will reach 100 times deeper than the LAS, but with a much narrower focus.

## Five surveys

Such deep infrared surveys are important because the further a galaxy is away from us – and of course therefore seen further back in time – the more its light is shifted into the infrared part of the spectrum. The result is that distant, highly evolved galaxies such as ellipticals (p.22) will be extremely faint at optical wavelengths, but readily detectable in the near infrared. By detecting the oldest galaxies at any redshift we can quantify how many stars were born at earlier epochs. The LAS, DXS, and UDS go successively deeper and reach successively higher redshifts, so can chart the build-up of stars in galaxies over cosmic time.

The billion sources anticipated in the GPS highlight the scope of the problem of processing and archiving the data, and providing access to it. The data volume is approximately 1 terabyte per week – equivalent to more than 1000 CDs. To deal with this data deluge, a dedicated automated processing 'pipeline' has been built at the Institute of Astronomy in Cambridge. It first removes any artefacts due to the instrument, and then processes and catalogues the sources. The processed data are then stored at the UKATC for astronomers to access, through a web interface, for their own particular needs.

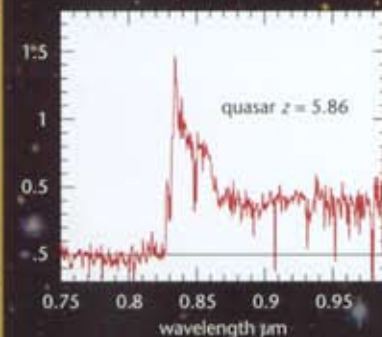
By the end of last year, UKIDSS had already detected 10 times more light from sources in the sky than the total amount from 2MASS, from a volume of space half again as large. The plan is to expand the survey by a further 10 times by the end of 2012.

The Survey made its first major release of data in July 2006, and follow-up studies began immediately. Some of the first results are shown opposite. They already indicate that UKIDSS will succeed in achieving its main science goal – that of extending our knowledge of the evolution of the Universe by surveying the earliest galaxies and the very coolest stars. **F**

## Searching for the earliest quasars

Another goal is to extend the search for quasars (primordial, highly active galaxies) to higher redshifts, beyond the limit of 6.4 (corresponding to when the Universe was 6 per cent of its present age) already reached by SLS. Analysis of the spectra of the highest redshift quasars found by SLS,

The first high-redshift quasar discovered in UKIDSS



suggests that they belong to the epoch when the Universe was 'reionised'. About 300,000 years after the Big Bang, the charged particles (protons and electrons) comprising matter combined, and the Universe became neutral. Then some time later on (but not later than a time corresponding to a redshift of 6.4), matter collapsed under gravity into the first galaxies, and the released energy ionised, flooding the Universe with light. By finding quasars at higher redshifts we can pinpoint this epoch. The plot above shows the spectrum of the first high-redshift (5.86) quasar found in UKIDSS. The discovery of one quasar with a redshift of nearly 6 is in line with what has been found so far, so we can be reasonably confident of finding quasars with redshifts beyond 6.4 over the next 2 years as the area covered by the Survey increases.

Dr S. Warren is Reader in Astrophysics at Imperial College London and Professor A. Lawrence is Regius Professor of Astronomy at the University of Edinburgh. Emails: [sjw4@imperial.ac.uk](mailto:sjw4@imperial.ac.uk) and [al@roe.ac.uk](mailto:al@roe.ac.uk)