Digital Detectors in Wide-field Imaging

LITE: the Large Imaging Telescope

This paper presents a new German-French project aimed at a very deep CCD survey in the southern hemisphere. It is based on a 2.5m class telescope with a field of 1.5 degrees or more, dedicated to high-resolution, deep CCD imaging. This telescope is intended to become a complement to the ESO VLT and to be installed in the Paranal area. The operations should start in 1999.

Accompanying imaging observations are essential for the optimal use of the VLT. For large scale structure studies, the VLT allows us to measure redshifts in a 30 arcmin field-of-view of galaxies of magnitude 23 or even fainter. They are too faint to be reliably detected on Schmidt plates, so the input observation catalogue must be obtained from deep CCD imaging. In this example, outstanding image quality is needed to make a clear separation between faint galaxies and stars. The best compromise for obtaining such images is a middle size telescope of about 2.5m diameter and equipped with a wide field CCD camera.

This project was originally designed for observations of mainly cosmological interest. It has the technical capabilities to cover a much broader range of astrophysical problems. The consortium is now working on several programmes, galactic structure and low mass star luminosity function, the study of variable stars, properties of nearby galaxies, luminosity function and morphology-density relation of galaxies, survey of emission line galaxies and quasars, large scale structures combined with redshift measurements with the VLT, gravitational lensing effect due to dark matter distribution on very large scale, a very deep multicolour survey to study galaxy evolution on cosmological time scale, detection of supernovas up to z=0.5, and a second generation experiment for detection of brown dwarfs by micro lensing effects on stars in the Magellanic Clouds.

We have adopted a new optical concept worked out at the Tautenburg Observatory, with the assistance of Ray Wilson from ESO. It is a modified version of the 3 mirror Paul-Baker telescope which provides a plane focal surface at the 'prime focus' location, behind the secondary mirror. A preliminary design study has shown that for a telescope with 2.5m diameter and focal ratio f/4, image quality of 0.4 arcsec can be obtained at the edge of a 2.5 degree field, and significantly better towards the centre. As a baseline, the CCD camera will be organized around thin, back-side illuminated Thomson CCDs, each with 2048 x 2048 pixels and 15 micron length. These CCDs are being developed for the VLT, and the thick version should become available in 1993 and the thin one in 1994. The three-side buttability allows us to make strips of 2 CCD width. A 1 square degree surface can be covered with 36 CCDs. Readout time of the whole array will be as low as 30 seconds, thanks to a parallel acquisition system. Cryogenic temperatures will be provided by a closed cycle cooler in order to simplify the operations.

Projects similar to ours are under development, in particular the Sloan Digital Sky Survey (SDSS) in the USA. We wish to emphasize the differences between our project and the SDSS. The main goal of the SDSS is to make a survey over a large fraction of the entire sky (~π steradian), both in photometry and in spectroscopy, and with the same telescope. However, the use of the SDSS 2.5m telescope for spectroscopic measurements will naturally limit the observations to moderately faint galaxies only. The necessity of the all sky survey pushes towards the largest possible field, but at the detriment of image quality, and to a transit instrument which simplifies the operations.

In our case, the spectroscopic observations are planned with the much larger VLT, which, of course, can reach much deeper. Due to the increasing number of objects at fainter magnitudes, we cannot expect to cover a large fraction of the sky. On the contrary, we shall only be able to obtain images significantly deeper than the SDSS by limiting the sky coverage. For LITE, the priority of optimisation is then image quality first, and field-of-view second. In addition, the pointing mode of operation is more suitable for very deep imaging than a transit mode. While many scientific areas are common to both instruments, the trade-offs are different, and the scientific programmes will be different too.

We believe that the combination of the VLT and LITE will offer a unique capability of probing the deep sky and will become a prominent instrument for future cosmological studies.

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The Hitchhiker Parallel Camera and Studies of Faint Galaxies

The Hitchhiker camera is a parallel observing instrument attached to the 4.2m William Herschel Telescope on La Palma. It performs simultaneous CCD imaging in an off-axis field while the telescope continues its normal scientific programmes, greatly increasing the efficiency of data acquisition. The camera images a 6 x 4 arcminute field centred 7 arcminutes from the optical axis with an image scale of 0.3 arcsec per pixel. A dichroic beam splitter allows data to be collected in two colours simultaneously. Over its three years of operation, a library of deep CCD frames has been built up covering a total area over 1 square degree, enabling survey work to be pursued.

Hitchhiker data have been used for studies of faint galaxy number counts, populations of faint field galaxies and of a medium redshift cluster. Current research programmes include studies of the distributions of galaxies, searches for low surface brightness galaxies, searches for candidate primeval galaxies, faint stars and Galactic structure. We present here results obtained from a number of our deepest frames and discuss their implication with regard to our understanding of the distant Universe.

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WWFPP: the Bonn Wide-Field Photometer/Polarimeter

The WWFPP has been built at the 'Astronomische Institut der Universität Bonn' to be used for surface photometry and surface polarimetry of galaxies, galaxy groups and diffuse galactic objects particularly the high latitude galactic cirrus. The two major components of the instrument are a focal reducer (reduction: 0.45) and a nitrogen cooled large area CCD (LO-RAL: 2048^2 $15\mu x 15\mu$ pixels). The CCD detector system was developed in Bonn. At a 2m f/8 telescope the WWFPP field of view is about 15′ x 15′ with 0.43″ per pixel.

B, V, R, I and $H\alpha$ filters are currently available. A Twin-Wollaston prism in the parallel beam section of the focal reducer is used for polarization observations. In combination with masks in the telescope focal plane four polarization directions (0, 45, 90, 135 degrees) are observed simultaneously, so that the complete set of linear Stokes parameters I, Q, U can be derived from a single exposure.

First observations with the WWFPP were made at the 1.82m telescope of the 'Osservatorio Astronomico di Padova' at Asiago.

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Near-Infrared Imaging with a Schmidt Telescope

We have carried out wide-field imaging observations in near-infrared bands with a large format array camera attached to the prime focus of the 105cm Schmidt telescope at the Kiso Observatory. The image sensor used is Platinum-Silicide shottky barrier diode array supplied by Mitsubishi Electric Co. The array size is 512 x 512 pixels, and the pixel size is 26 micron x 20 micron. The field of view is 14′ x 11′, and the image scale is 1.6″ x 2.5″/pixel (binned into 512 x 256 pixels). The pixel size is smaller than the typical seeing size at Kiso, so we can take seeing limited images. The quantum efficiency of the sensor is low. But, owing to the excellent uniformity and stability, low read-out noise of this sensor and small F-ratio of the telescope, the calibration accuracy of 0.1% of sky-level was achieved in an image obtained through 70 min. exposure in the H-band. Although our camera does not have a mechanism such as a ryot stop to reduce any thermal emission, it was confirmed that the contribution of thermal emission from inside of the telescope was negligible in the J and H-band. We will present the performance of our camera system, some images of nearby galaxies, and future prospects for observations.

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Wide-field Imaging and Photometry with a 2k x 2k CCD

The Ford 2048 x 2048 CCD with UV coating is used at the BAO 60/90/180 cm Schmidt focal plan, giving a field of one square degree and spatial resolution of 1.67 arcsec per pixel. The paper reviews the following topics:

1. basic performances of the system;
2. importance and results of anti-blooming tech for large field CCD;
3. flat fielding for large field CCD;
4. photometric properties of compressed image, and
5. special filter holder for up to 32 filters with least obstacle in optical path used for multi-colour narrow band photometry.

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Experience with Large Mosaic Cameras

Over the last few years, we have demonstrated that a large mosaic CCD camera with a number of (> 10) CCD chips can be built and successfully used for wide-field imaging observations. In this symposium, we will show our past, present and future development/implementation of large mosaic cameras. Building a mosaic camera requires proper thermal, mechanical and electrical design. We built our first mosaic camera two years ago. It has 16 CCD chips and 2000 x 8000 pixels total. This camera has been operative for two years and is being used for wide-field observation with the 105cm Kiso Schmidt telescope. We are now developing three different mosaic cameras. The first one is the upgrade of the current 2 x 8 camera to 8 x 8 mosaic, which uses 64 1000 x 1000 pixel CCDs. The second mosaic camera, which a group at Princeton University (led by J. Gunn) and we are developing, is truly a 'monster'. It has 30 Tektronix 2048 x 2048 CCDs (most of them thinned) and 12K x 10K pixels total. We will use this camera for the Sloan Digital Sky Survey. This will be the most powerful camera for wide-field imaging in this century. The last camera is being developed for the prime focus of the Japanese 8.3m telescope (Subaru). This camera is a tightly placed mosaic with 10K x 10K pixels. We are collaborating with G. Luppino at the University of Hawaii who has very successful experience in tightly placed mosaicing. Finally, the analysis and reduction software for the mosaic camera will be briefly described.

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