SkyMapper and the Southern Sky Survey
a resource for the southern sky

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Summary. SkyMapper is amongst the first of a new generation of dedicated, wide-field survey telescopes. The 1.3m SkyMapper telescope features a 5.7 square degree field-of-view Cassegrain imager and will see first light in late 2007. The primary goal of the facility is to conduct the Southern Sky Survey a six colour, six epoch survey of the southern sky. The survey will provide photometry for objects between 8th and 23rd magnitude with global photometric accuracy of 0.03 magnitudes and astrometry to 50 mas. This will represent a valuable scientific resource for the southern sky and in addition provide a basis for photometric and astrometric calibration of imaging data.

1 The SkyMapper Telescope

The SkyMapper telescope is a 1.3m telescope currently under construction by the Australian National University’s Research School of Astronomy and Astrophysics in conjunction with Electro Optic Systems of Canberra, Australia. The telescope will reside at Siding Spring Observatory in central New South Wales, Australia.

The telescope is a modified Cassegrain design with a 1.35m primary and a 0.7m secondary. Corrector optics are of fused silica construction for maximum UV throughput and a set of six interchangeable filters can be placed in the optical path. The facility will operate in an automated matter with minimal operator support. Further details on all aspects of our programme can be found in [2].

2 Detectors and Filters

The focal plane is comprised of 32 2k×4k CCDs from E2V, UK. Each CCD has 2048 × 4096, 15 micron square pixels. The devices are deep depleted, backside illuminated and 3-side buttable. They possess excellent quantum efficiency from 350nm-950nm (see Figure1), low read noise and near perfect cosmetics.
Fig. 1. Spectral response of SkyMapper CCDs as measured in the laboratory. The shaded area encloses the range in response exhibited.

Fig. 2. The predicted throughput of the Southern Sky Survey filter set, excluding atmospheric absorption.

The SkyMapper imager will utilise the recently developed STARGRASP controllers developed for the Pan-STARRS project by Onaka and Tonry et al. of the University of Hawaii [6]. Twin 16-channel controllers enable us to read out the array in 12 seconds with $\sim 4-5$ electron read noise.

Figure 2 shows the expected normalised throughput of our system. The filter set is based upon the Sloan Digital Sky Survey filter set with three important modifications: the movement of the red edge of the $u$ filter to the blue, the blue edge of the $g$ filter to the red, and the introduction of an intermediate band $v$ filter (essentially a DDO38 filter). At this time coloured glass fabrication of filters of these bandpasses offers the best solution for spatial uniformity compared to the competing interference film technology. Our filters are sourced from MacroOptica of Russia.
3 The Southern Sky Survey

Performing the Southern Sky Survey is the primary preoccupation of the SkyMapper telescope. The survey will cover the $2\pi$ steradians of the southern hemisphere reaching $g=23$ at a signal-to-noise of 5 sigma. For stars brighter than $g=18$ we require global accuracy of 0.03 magnitudes and astrometry to better than 50 milli arc seconds.

The survey’s six epochs are designed to capture variability on the time scales of days, weeks, months and years over the five year expected lifetime of the survey. The 5 sigma limits attained after one 110 second epoch and after the full six epochs are given in Table 1. In all bands we attain limits slightly deeper ($\sim 0.5$ mag) than the Sloan Digital Sky Survey.

|       | u   | v   | g   | r   | i   | z   |
|-------|-----|-----|-----|-----|-----|-----|
| 1 epoch | 21.5 | 21.3 | 21.9 | 21.6 | 21.0 | 20.6 |
| 6 epochs | 22.9 | 22.7 | 22.9 | 22.6 | 22.0 | 21.5 |

4 Global Photometric Calibration

The greatest impediment to deriving accurate photometry from wide field imaging cameras is the accurate description of the illumination correction. The illumination correction corrects for geometry of the optics and inclusion of scattered light in the system (see Patat and Freudling these proceedings).

During commissioning we will develop an illumination correction for each filter via dithered observations of a field. We will then rotate the instrument and repeat the dithered observations to ensure we rigorously understand the illumination correction for the system. We will establish six such reference fields at declinations of around $-25^\circ$ and spaced in right ascension. Each field will be 4.6 degrees square following the dither pattern.

During the first year of operation we will perform the Five-Second Survey, a rapid survey in photometric conditions to provide all-sky standards between 8-16th magnitude. The Five-Second Survey will consist of a set of at least three images of a field in all filters.

During Five-Second observing we will observe the two highest of our six reference fields every ninety minutes. This will ensure photometry is obtained on a highly accurate standard instrumental system. The Five-Second Survey will provide a network of photometric and astrometric standards to anchor the deeper main survey images. Furthermore, it enables the main survey to proceed in non-photometric conditions.
We will establish the six reference fields to include stars with photometry in the Walraven system \cite{1}. As demonstrated by Pel & Lub (ibid), the Walraven system zeropoint is highly accurate: the closure solution over $2\pi$ in right ascension has rms of less than 1 millimag. In addition, the Walraven stars we have selected are spectrophotometric standards from the work of Gregg et al. \cite{5}. The use of these standards will provide absolute flux calibration for our system.

5 A Filter Set for Stellar Astrophysics

The majority of science goals identified for SkyMapper are based on the identification of stellar populations. It was therefore fundamental to the science output of the telescope that we choose a filter set that offers optimal diagnostic power for the important stellar characteristics of effective temperature, surface gravity and metallicity. Below I will discuss some specific examples.

Through an exploration of colour parameter space derived from model stellar atmospheres and filter bandpasses we arrived at the filter set shown in Figure 2. The filter set possesses two filters, $u$ and $v$, distinctly either side of the Balmer Jump feature at 3646Å.

![Figure 3](image)

Fig. 3. Precision of determined surface gravity from our filter set as a function of temperature and surface gravity (error bars show estimated uncertainties at each point for photometric uncertainties of 0.03mag in each filter).
5.1 Blue Horizontal Branch Stars

In Figure 3 we show the uncertainty in the derived stellar surface gravity as a function of temperature for a range of surface gravities with photometric uncertainties of 0.03 mag. per filter. In the case of A-type stars we expect to determine surface gravity to $\sim 10\%$. The sensitivity to surface gravity arises from the $u-v$ colour which measure the Balmer Jump and the effect of H$^-$ opacity, both of which increase with surface gravity. It is at these temperatures that we find blue horizontal branch stars (BHBs). Due to their characteristic absolute magnitude BHBs are standard candles for the Galactic halo.

A line of sight through the halo inevitably contains a mixture of local main-sequence A-type and blue straggler stars. However as is shown in Figure 3 the SkyMapper filter set enables us to clearly distinguish the BHBs of interest on the basis of their lower surface gravity. Simulations show that we will be able to derive a sample of BHBs to 130kpc with less than 5% contamination.

5.2 Extremely Metal-Poor Stars

In the case of cooler stars (F0 and cooler) the $u$ and $v$ filters indicate the level of metal line blanketing blueward of $\sim 4000\AA$. Figure 4 shows the $v-g$, $g-i$ colour-colour diagram for a range of metallicities and surface gravities. The $v-g$ colour has a strong dependency on the metallicity and little dependency on the surface gravity hotter than K0 ($g-i \sim 1.7$).

![Fig. 4. $v-g$ vs. $g-i$ for stars of solar metallicity (dashed lines) and for a range of surface gravity (solid lines). Open circles are stars from the sample of [1] and the star symbol is HE1327-2326 from [3].]
This enables us to cleanly separate the extremely metal-poor stars in the halo from the vast bulk of the halo at $\text{[Fe/H]}<-2$. Our simulations show we should find of order 100 stars with $\text{[Fe/H]}<-5$.

6 Data Products and Their Possible Application to ESO Calibration

The first SkyMapper data product will be the Five-Second Survey of 8-16th magnitude stars in the southern hemisphere. Two main survey data releases will follow. The first data release will occur when three images in each filter have been reduced for a field and the second (reaching 23rd magnitude in $g$) when the full set of six have been obtained and undergone quality control.

The survey will provide sufficient density and spectral sampling of standard stars to enable photometric calibration of any field imaged in any broadband filter in the southern hemisphere. The largest source of dispersion in transformations between photometric systems is due to the lack of knowledge of the surface gravity and metallicity of the sample. The SkyMapper photometric system provides a prior on both these points of uncertainty. Consequently we will be able to provide improved transformations from our photometric system to any other system. Scheduled observations on, for instance VLT or VST, may then dispense with photometric standards and also proceed under non-photometric conditions.

References

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