Status of SuperWASP I (La Palma)

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Received 12 July 2004; accepted 2 August 2004; published online 31 October 2004

Abstract. SuperWASP is an ultra-wide field (over 300 sq. degrees) photometric survey project designed to monitor stars between 7 – 15 mag to high precision and with high cadence over long (≥2 months) timescales. The primary science goal of this project is the detection of exoplanetary transits, as well as NEOs and optical transients. The resulting photometric catalogue will be made public via a web-based interface. The SuperWASP instrument consists of an array of cameras each with a 7.8° x 7.8° field of view, guided by a robotic fork mount and sited in a fibreglass enclosure at the Observatorio de Roque de los Muchachos (ORM), La Palma, Canary Islands. In this progress report, we describe the specifications of the instrument, its semi-automated operation and pipeline data reduction.

Key words: techniques: photometric – surveys – planetary systems

1. Introduction

Since the detection of the first exoplanetary transits (Charbonneau et al. 2002, Henry et al. 2002, Konacki et al. 2003, Bouchy et al. 2004), interest in ultra-wide angle photometric surveys has grown tremendously. Such surveys need to monitor ≥50,000 stars with photometry better than 1% over long (≥2 months) periods of time and with high cadence.

There are many current surveys dedicated to transit detection (see Horne 2003 for a summary). Among these, a common strategy is to observe tens of thousands of bright (≈7 – 15 mag) stars over very wide fields of view (several tens of square degrees). Large numbers of stars are required as the random orientations of planetary orbits imply that only ~10% of ‘hot Jupiters’ will exhibit transits. Additionally, only a fraction of field stars will be the G–M type main sequence dwarfs favoured by this technique although this can be optimised by careful field selection (see Section 3). A sample of bright stars can be observed with very small instruments (e.g. 10 cm diameter telescopes) which can be constructed and run by private groups. The instrument can then be dedicated solely to the task, allowing fields to be observed with the necessary frequency (~1 frame every 1–2 minutes) for the required timescale.

The SuperWASP-I station (Pollacco et al. 2004) consists of an array of CCD cameras, covering a field of view currently 304.2 square degrees. This station began continuous observations in April 2004, with the primary science aim of detecting exoplanetary transits. The data will also be mined for Near-Earth Objects and optical transients. Section 2 describes the specifications of this instrument, while Sections 3–5 address the data acquisition and reduction. Our first results are discussed in Section 6.

2. Instrument specifications

SuperWASP is an array of cameras supported by an OMI fork mount, as shown in Figure 1. There are currently 5 cameras...
in operation, soon to be increased to the full complement of 8. Each camera consists of a 200mm f/1.8 Canon lens plus a 2048 × 2048 thinned, back-illuminated e2v CCD made by Andor. Each has a field of view of 7.8° × 7.8° and a read out time of 4s.

The equipment is housed in a fibreglass enclosure with a hydraulically operated roll-away roof. The enclosure has its own GPS time and position signal and weather station, and is sited at the ORM, La Palma, Canary Islands.

3. Data acquisition

The Telescope Control System (TCS) operates a Data Acquisition System (DAS) for each camera. This is done through the Talon software, which also controls the mount. Exposures and pointing are controlled via perl scripts.

Our transit detection goal requires us to observe in a “stare mode” strategy: we observe a set of fields continuously for months at a time. For this mode we have selected an “stare mode” strategy: we observe a set of fields continuously for this mode we have selected an “stare mode” strategy: we observe a set of fields continuously for months at a time. For this mode we have selected an ar-

4. Raw data storage and transfer

The SuperWASP project has a very large data stream. Each exposure produces an 8.4 MB FITS file per camera (uncompressed) and hence with all 5 cameras operating, each expo- sure results in 42 MB of data. With ~500 science exposures per clear night plus an additional 35 calibration (bias, flat, dark) frames, the data rate is ~23 GB per night, or around 6 TB per year. Automated data reduction is therefore a necessity.

Each night’s data is stored on the DAS computers until the following morning, when a script automatically writes the data to DLT tape. The enclosure has a DLT autoloader which holds up to 8 DLTs. This allows us to store about a fortnight’s worth of data before the tapes need to be exchanged and returned to Queen’s University, Belfast for pipeline processing.

5. Data reduction pipeline

The data reduction pipeline has been constructed by Consortium members and uses predominantly custom-written software combined with a few well-known STARLINK packages. The pipeline breaks down into several well-defined stages, which we discuss in turn.

5.1. Frame identification

The dataset drawn off a single DLT tape consists of a mix of biases, flat fields, dark and science frames of various different fields, taken over several nights. The first stage of the pipeline is therefore to sort the required data using frame statistics and exposure time. Masterbias, flat and dark frames are then prepared automatically.

5.2. Astrometry

The pipeline requires a pre-existing catalogue of objects covering an area wider than the field of view and centred on the current field (we prepare sub-catalogues from Tycho 2 and USNO B). The STARLINK package SExtractor (Chipperfield 2003) provides preliminary aperture photometry on every object it detects in the frame.

A custom-written astrometry program then matches the catalogue object list to the SExtractor output for each frame. This program looks for matches in angles and areas between triangles of stars and compiles a catalogue of objects present on both lists. The matching list allows an iterative, 6-parameter astrometric fit to be performed, including a determination of the optical axis and barrel distortion. The complete object list for the frame consists of those stars identified in the Tycho 2 and deeper USNO B catalogues plus any unidentified objects found by SExtractor. In this way we ensure transient targets are measured.

5.3. Photometry

We investigated several widely available photometry packages and eventually concluded that none of them could adequately deal with the ultra-wide fields. We therefore developed our own photometric software. This software applies bad pixel masks throughout. This stage of the pipeline begins by performing a quadratic sky fit, followed by aperture photometry of all objects for three different apertures. A blending...
index is also computed for each star in each frame. The measured fluxes together with image header data and catalogue information (where available) are output as a FITS binary table.

5.4. Post-processing

This stage of the pipeline is designed to remove the bare minimum of trends from the data prior to ingest into the photometric archive; the idea being that the archive will be mined for data which has had the minimum of manipulation. However, we perform iterative fits to remove trends due to atmospheric extinction and location of a star on the CCD. We use a 3-parameter fit to the magnitude residuals to remove the trend with airmass, and up to a 10-parameter cubic fit to deal with the positional variations. The code outputs FITS binary tables with completed columns for corrected magnitude and magnitude error as well as the relevant image header, position, airmass and Heliocentric Julian Date information (the latter two vary significantly across each frame). The pipeline is automated up to this stage.

5.5. Archive ingest

The data are transferred to Leicester¹ for archive ingest. This is achieved in four automated stages, each of which uses custom-written tools in C and the MySQL C API to interface to the database

Stage 1: A list of all catalogue targets present is compiled and compared with the WASP catalogue. New objects are included with IAU-compatible names. They are assigned to a 5° × 5° sky tile on the basis of their co-ordinates.

Stage 2: The photometric data are split from the input files into intermediate per-sky-tile files.

Stage 3: The photometric points within each sky tile are re-ordered to ensure that the photometric points for a given star are on consecutive rows.

Stage 4: These files are assigned an internal filename and moved to their final location within the archive. Their metadata are registered in the archive DBMS. The archive interrogation tools are under development, and the data will be made publically available via a web-based interface.

6. First results

Figure 2 illustrates the precision achievable with data from the SuperWASP-I station. It shows that bright stars can be measured to a precision of ~6 millimags, sufficient to detect exoplanetary transits. These results are preliminary, being derived from commissioning data, and we aim to arrive at ~2-3 millimag precision as soon as possible.

Of course, surveys of this nature also provide high quality lightcurves on numerous variable stars, many of which are previously undetected. Figure 3 shows a selection of variable stars, including two RR Lyraes and many W UMa-type eclipsing binaries.”

¹ The SW archive is hosted by LEDAS (www.ledas.ac.uk)

Fig. 2. RMS plotted against instrumental mean magnitude as an indicator of photometric precision achieved. The solid lines represent the theoretical noise limit.

Fig. 3. Phased lightcurves of a selection of variable stars.

7. Summary

SuperWASP-I was inaugurated in April 2004 and is now gathering its first season of survey data. The station is currently staffed, but the operation is largely automated. Several issues remain to be addressed before unattended operation can begin, including the incorporation of the roof operation and weather station into the TCS. In terms of software effort, the pipeline set-up and data transfer to the archive is being examined. Finally, we plan to begin the construction of a second station in South Africa next year.

References

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