

## CURRENT STATUS OF THE SUPERWASP PROJECT

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### ABSTRACT

We present the current status of the SuperWASP project, a Wide Angle Search for Planets. SuperWASP consists of up to 8 individual cameras using ultra-wide field lenses backed by high-quality passively cooled CCDs. Each camera covers 7.8 x 7.8 sq degrees of sky, for nearly 500 sq degrees of sky coverage. SuperWASP I, located in LaPalma, is currently operational with 5 cameras and is conducting a photometric survey of a large numbers of stars in the magnitude range  $\sim 7$  to 15. The collaboration has developed a custom-built reduction pipeline and aims to achieve better than 1 percent photometric precision. The pipeline will also produce well sampled light curves for all the stars in each field which will be used to detect: planetary transits, optical transients, and track Near-Earth Objects. Status of current observations, and expected rates of extrasolar planetary detections will be presented. The consortium members, institutions, and further details can be found on the web site at: <http://www.superwasp.org>.

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transits, ranges from 1 (Brown 2003) to a few per 20,000 stars surveyed. Follow-up observations will be needed to separate true transit events from false detections, such as grazing eclipses in a system of two main-sequence stars. There are currently nearly two dozen photometric surveys underway (Horne 2003), and here we present the current status of the Wide Angle Search for Planets (called SuperWASP). SuperWASP covers a wider area of sky and more stars than any other current survey.

### 1.1. SCIENCE OBJECTIVES

SuperWASP was designed to cover a large area of sky and achieve photometric accuracy of a few millimag. These specifications make SuperWASP ideal for monitoring several 10's of thousands of stars to search for transiting extrasolar planets, discovery and follow-up of optical transients (including optical flashed from  $\gamma$ -ray bursts), and the discovery and tracking of near-Earth objects and asteroids. Naturally SuperWASP is also well suited for a variety of wide field imaging and temporal studies, such as discovery and monitoring of variable stars, stellar flares and other periodic and aperiodic celestial phenomenon. First results from the study of variable stars in the Pleiades have been presented by Lister et al. (2004).

## 1. INTRODUCTION

The search for extrasolar planets (ESP) has been dominated by radial velocity surveys (Mayor & Queloz 1995; Marcy & Butler 1998; Udry et al. 2000). These surveys have found Jupiter-sized planets orbiting 6% of nearby Sun-like stars. About 1/3 of these exoplanets have been found in very close orbits ( $a \approx 0.05$  AU) with periods  $< 4$  days. A transit of such a hot-Jupiter will dim the host star by  $\sim 0.01$  mags. This was detected for G-star ( $V=7.7$ ) HD 209458 (Charbonneau et al. 2000). Recently, 3 transiting candidates from the Optical Gravitational Lensing Experiment have been confirmed as ESP (Konacki, M. et al. 2003; Konacki, M. et al. 2004; Bouchy et al. 2004), as well as, the first ESP from the Trans-Atlantic Exoplanet Survey network (Alonso et al. 2004).

Future transit detections will provide the planet's radius, mass, and density. The expected number of such

## 2. INSTRUMENTATION

The SuperWASP I telescope in LaPalma was designed based on the success of the prototype WASP0 instrument (Kane et al. 2004). The SuperWASP telescope in LaPalma is contained in its own commercially available enclosure with a hydraulically operated roll-away roof, and its own GPS and weather station. Commercially available components were used where available to keep costs down and decrease construction time. The telescope mount is a rapid slewing fork mount ( $\approx 10^\circ/\text{sec}$ ). To meet the science requirements of a covering a large area of sky with high photometric precisions the combination of Canon 200-mm f/1.8 lenses and Andor e2v 2kx2k back illuminated CCDs was chosen. The CCDs are passively cooled with a Peltier cooler and have a very short 4-sec readout time. This combination of lens and camera gives a field of view of  $7.8^\circ \times$

$7.8^\circ$  ( $\sim 61$  sq degrees). This set-up covers from 7–15 magnitude for typical 30 seconds exposure and can achieve  $<1\%$  photometric precision for magnitudes up to 12. The complete instrument will have 8 cameras and cover 490 sq degrees! The current observing configuration for 2004 is with 5 cameras (Figure 1.).



Figure 1. The 5 SuperWASP Cameras in LaPalma.

## 2.1. OBSERVATIONAL STRATEGY

The SuperWASP instruments were commissioned and 'on-sky' in November 2003. Observations were resumed after the winter break and the telescope was inaugurated on 16 April 2004. Observers were present for the 2004 observing season to monitor the systems and make improvements as the telescope moved from automated to robotic operations. The initial observing strategy was tailored toward searching for exoplanet transits. This strategy was to observe fields with a large number of stars, but to avoid the Galactic plane where over crowded fields would make reductions impossible. Based on the Besancon galactic model a declination of  $+28$  was chosen with the telescope stepping through RA centered on the current LST but within the  $\pm 4.5$  hr hour angle limit of the mount. A maximum of 8 fields are observed with a duration of  $\approx 1$  minute per field. This 1 minute includes the 30 second exposure, 4 seconds read-out and the time for the telescope to slew and settle at the field. Such observations provide well sampled light curves with a maximum of 8 minutes per measurement. This observing strategy provides over 6 hours of coverage for the 6 fields centered on LST at midnight, and over 4 hrs of coverage on 10 fields per night.

A typical field contains  $\sim 25,000$  stars per camera at magnitudes brighter than 13. Considering that only 14–19% of these stars are late-type (F–M) stars, we therefore expect  $\sim 4000$  F–M dwarf stars per field per camera. If 1% of these have hot-Jupiter companions (Lineweaver & Grether 2003) and we expect 10% of these to show transits (Horne 2003), we therefore expect to detect  $\approx 4$  transits per camera per field for  $\approx 40$  clear nights of monitoring (see

Table 1). This would give 120 to 200 transit candidates for all 5 cameras from monitoring 6 to 10 fields, respectively.

There are many different types of stellar systems that can show behavior mimicking a planets transit (see Brown 2003 for example). Therefore, transit candidates will be followed-up with additional optical photometry and low resolution spectroscopy to confirm that a planet is the true cause of the transit. Deeper imaging on 1 – 2 meter class telescope will be used to confirm that the transit is not caused by a foreground or background grazing eclipsing system and to also obtain photometric colors for determining spectral type. The transit depth is inversely proportional to the radius of the primary star squared (Horne 2003). Therefore, the transit depth will be deepest for the later type stars. If the transit candidate passes these initial follow-up observational tests then higher resolution (few m/s) radial velocity observation will be obtained to derive the orbital parameters.

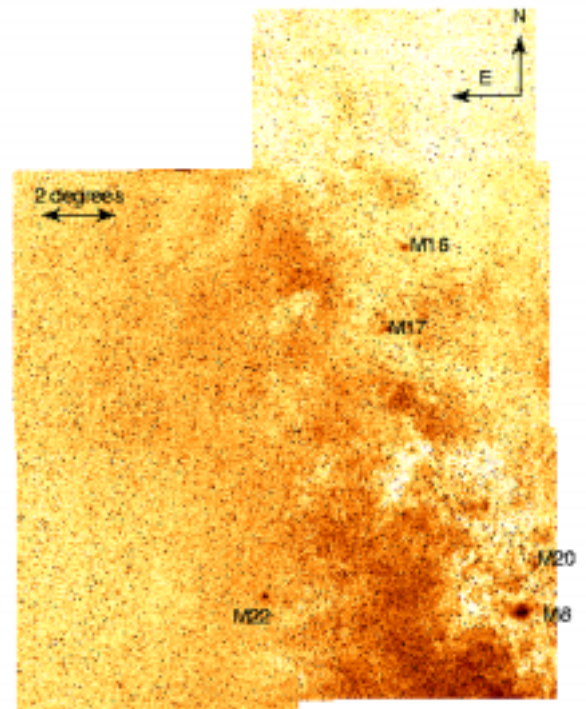


Figure 2. SuperWASP 5 Camera mosaic centered near M25 (RA 18:31, Dec -19:15). Image dimensions are  $\sim 15^\circ \times 20^\circ$  and exposure time is 1 second. Several Messier objects are noted.

## 3. DATA REDUCTION

An individual camera image is 8.4 MB and stored in FITS format. About 600 images are obtained per clear night per camera for a typical 9 hours of observing (including calibrations). Thus, for 8 cameras about  $\sim 40$  GB/per night is collected and stored on DLT before being ingested into

Table 1. Number of extrasolar planets and expected number of transits

Number of ESP	Reference
300 per 25,000 <sup>a</sup>	Lineweaver & Grether (2003)
100 per 2000	current Doppler Surveys
ESP Transit Predictions	
1 per 25,000	Brown 2003
9 per 25,000	Horne (2003)
4 per 25,000	This work

<sup>a</sup>5–9% of Sun-like stars

the custom-built data reductions pipeline (Street et al. 2004). Data are compressed with the *cfitsio* routine *imcopy*, which uses the lossless Rice algorithm and obtains up to a factor of  $\approx 2$  compression.

### 3.1. PIPELINE

The collaboration has built a custom data reduction pipeline with the goal of obtaining a few millimag photometric precision for stars with  $V < 12$ . The pipeline uses custom written f77 programs combined with shell scripts and several STARLINK packages. The pipeline creates master biases, darks, and flat fields for each night of observations. Each science exposure is bias subtracted, dark corrected, flat fielded, and the astrometric solution is computed using reference stars from the USNO-B1.0 and Tycho catalogs. Aperture photometry is performed with a package custom-built to deal with the ultra-wide fields. Bad pixel masks are applied to each frame and a blending index is assigned for every object detected. Fluxes are computed in 3 different apertures and outputted, along with other source attributes to a FITS binary table. Trends (such as airmass) are removed from the data and the binary table is ingested by the archive.

### 3.2. ARCHIVE

This public archive is hosted at Leicester within LEDAS (Leicester Database and Archive Service) and can be accessed at <http://www.ledas.ac.uk/>. A list of all cataloged targets is compiled from the ingested FITS tables and compared with the WASP catalog. New objects are assigned IAU-compatible names and all objects are assigned to a  $5^\circ \times 5^\circ$  sky tiles based on their coordinates. Photometric data are split from the input files and stored as intermediate per-sky-tiles. Photometric points within each sky-tile are re-ordered to insure that they are in consecutive rows for a given star. These files are registered within the archive DBMS along with their names, location, and various meta-data. The archive can then be interrogated and the photometric data extracted as a single, coherent per-object light curve for longer term temporal analysis.

The object catalog is expected to contain  $> 3 \times 10^6$  objects per year.

## 4. FUTURE GOALS

SuperWASP I in LaPalma will be fully robotic for the 2005 observing season. All-sky survey and transient follow-up observations will be added to the planet transit search program. Improvements to the transient follow-up observations will include real-time quick reduction of images with the coordinates of any new transient sent to the Liverpool telescope for real-time follow-up. A sister telescope to SuperWASP I in LaPalma is under construction in South Africa and first light is expected in mid-2005.

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