2005 Observations with the PASS prototype

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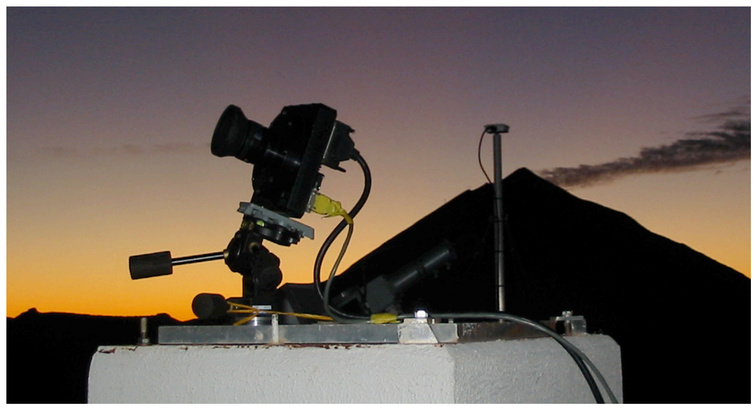
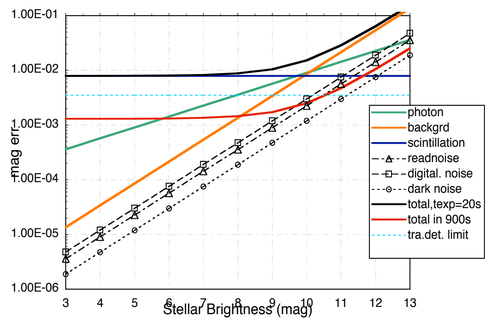


Fig. 1 The prototype of PASS at Teide observatory ; consisting of an 2k x2k Apogee CCD camera with a 50mm Nikon lens. Mt. Teide is in the background. Above image was taken before the adding of a permanent enclosure (image below)





Dominating is:
scintillation < 10mag
stellar photon noise ~10mag
sky photon noise >10.5mag

The instrument is optimized for the faint end (10.5mag) of the sample range.

Fig. 3 Predicted noise sources at a typical good observing site (scintillation for 2400m altitude, sky-brightness 21.45 mag), in moonless nights (from Deeg et al. 2004a). All lines (except the red one) are assumed for a single 20 second exposure. The red line is the mag error in 900 sec when summing individual 20sec exposures. The dashed blue line 'tra. det. limit.' indicates the photometric precision (about 3mmag) that is required to detect giant planet transits in 900 sec integrations. Stars brighter than 5th mag are being saturated (not shown)

dates	pointing direction	comment
Jan - Sep 2004	various	short sequences of one or several nights
22 Oct 04 - 20 Jan 05	dec ~ +55°, HA~0h	not useful due to large image motions
21 Mar 05 - 20 Jun 05	dec+58°, HA +1.0h RA ~ 8-21h	about 40 nights of data
since 21 Jun 05, ongoing	dec+29°, HA -0.06h RA ~ 13-1h	includes HD209458

Table 1: Overview of the pointings performed by the PASS prototype. Due to the fixed nature of PASS they are indicated by declination and hour angle, with an indication of the right ascension range that has been covered.

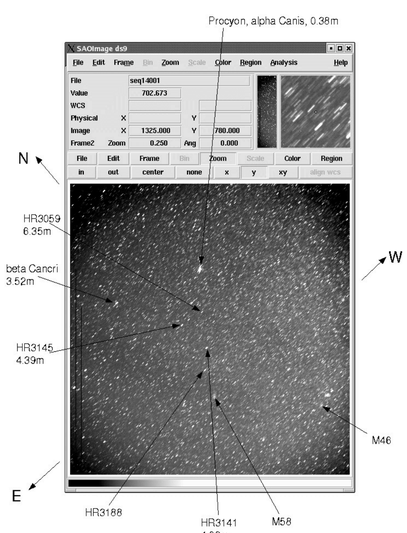


Fig. 4 PASS prototype image. The field of view is about 30° x 30°. For a few brighter stars, their V magnitudes are given. In the amplified sub-image (upper right), stars with 11th mag may be identified visually with ease. This image was taken with 60 sec exposure time; newer observations are being taken with 20 sec exposures, where star trails are 3x shorter.

Overview:

The 'Permanent All Sky Survey' (PASS) will consist of arrays of wide angle CCD cameras, that will permanently survey the entire visible sky from several observing sites. Its major objectives are the detection of planetary transits and the permanent tracking of any variable or transient phenomena in the entire sky. A prototype with one CCD camera has been set up at Teide Observatory, Tenerife, and has been in regular operation since April 2005. Its major aim is a demonstration of the achievability of the required photometric precision, and the acquisition of data that serve as a base for the development of a data analysis pipeline. Here we given an overview over the ongoing observations and the quality control that has been implemented.

Introduction:

The Objectives of PASS:

i) The detection of giant planet transits (Fig. 2) of *all* stars in the sky, with a magnitude limit of V ~ 10,5. About 30 planets may be detected.

ii) Detection of any temporal astronomical phenomena:

- •Detection and follow-up of stellar variabilities with low amplitudes (up to 0.1%, depending on stellar brightness and frequency)
  - -variable stars of any kind; esp. long periodic ones
  - -flares
- •Detection of novae, supernovae
- •Recording of frequency and direction of meteorites
- •Detection of optical counterparts to gamma rays and 'optical flashes'
- •stellar occultations (e.g. by Kuiper-belt objects)

iii) Sky quality and meteorological statistics (sky brightness, extinction, cloud cover, satellites and airplanes racks)

The concept

PASS will consist of several arrays of wide angle CCD cameras, with commonly available optics (F~50mm) for photographic cameras and CCD cameras available for advanced amateurs (**Fig. 1**), that would cover the entire visible sky at a given observing site (**Fig. 2**) in the search for planetary transits. The cameras would be placed on a common **fixed mount,** which has the advantages of mechanical simplicity and avoids any guiding errors. With images taken at exactly the same sequence of sidereal times every night, stars will move over exactly the same pixels every night, which allows a very precise calibration of pixel, and inter-pixel response functions. Only the psf of the stellar images would vary, but from observations of many nights the response of the CCD below the stellar track can be characterized for all commonly appearing psf-widths. To cover the entire sky, one array in the northern hemisphere and one in the South would be required, but multiple instrument locations would increase temporary coverage and duty cycle.

The Baseline Instrument:

A system based on f=50mm/f1.4 lenses for common high quality 36mm SLR cameras (Canon or Nikon for example), with CCD chips of about 25mm side length and 1x1k or 2x2k pixels (available with cooling and electronics from several vendors) would have a field of view (fov) of about 30°. With such a fov, 15 cameras give complete coverage of the sky above 30° altitude. The instrument should need to be mounted on a sturdy platform, and be covered with a completely removable enclosure with a size of about 2 x 1.5 x 1.5m. With a pixel size of 50" (in a 2k x2k chip), an adjustment for precession (maximum 50"/yr) may have to be undertaken every few months.

Images with exposure times of about 20 seconds are obtained in synchronization with sidereal time. This synchronization allows the taking of images at identical hour angles every night, which allows the direct application of difference imaging techniques between images taken at identical sidereal times, but in different nights. The data volume for a single camera in 8 hours of observations is about 10 Gbyte; image compression techniques that take advantage of the similarity between consecutive images should allow significant reductions.

Survey Coverage:

The sky above 30° altitude has a spatial angle of $\Omega_{>30} = 1\pi$ sterad. Thus, anytime a quarter of the entire sky will be observed by one array. The amount of time that a star can be observed during the course of a year depends primarily on its declination and on the observatory's geographical latitude **(Fig. 4).** With a southern and a northern site, coverage of at least 1200 hours should be achieved in 3 years for stars at any declination, which will allow the detection of planets with orbital periods of several weeks. Desirable is however also a distribution of instruments along longitude, which will increase temporal coverage, and especially, the daily observing duty cycle. Higher duty cycles would give a higher probability of 'capturing' transits. This would would increase the accessible orbital periods with reduced aliasing effects and would also decrease the detection size limit due to the presence of more transits.

The entire sky has about 250 000 stars to magnitudes of V~10.5, on which photometry of sufficient quality may be obtained (**Fig. 3**). Assuming that 25% of these are Main Sequence stars suitable for transit detection, and 1% of them have close giant planets, and that their probability for correct alignment to produce transits is 5%, about 30 planets should be detected.

The main motivation of PASS is however *not* the detection of huge numbers of planets but:

Due to the brightness of the sample stars, planets detected by PASS produce transits with relatively high S/N and would constitute the best sample for any detailed follow-up studies on larger telescopes.

PASS prototype observations

A prototype of the PASS instrument has been mounted at Teide Observatory, Tenerife (**Fig. 1**). The aims of the prototype are :

-Demonstration of the achievability of the required photometric precision

-Acquisition of real observational data that serve for the development of a data analysis chain

-Optimization of instrumental set-up and observational procedures

The prototype operates currently with one Apogee 2k x 2k CCD camera; the addition of a second camera within the same enclosure is possible. The optics consist of Nikon 50mm lenses, with typical settings of f/2.0 apertures. The camera is controlled by a script which synchronizes exposures with the sidereal time, and starts or ends observations depending on the hour of twilight. Operation is semi-automatic; the only manual interactions are the starting of that script and the opening/closing of the dome. Exposures lasting 20 seconds are normally being taken twice a minute. A more detailed descriuption is given in Deeg et al. (2004b). The instrument has been in operation since 2004, but only with the addition of a stable enclosure in April 2005, regular stable observations can been performed (**Table 1**). The current pointing towards +29º declination was chosen to include the transiting system HD209458. Since stars will cross the field of view in somewhat over 2 hours, no complete coverage of a transit is achievable yet, but partial recording of transit events on 24 June, 16 and 23 August, and on 7 October 2005 is intended.

Data Handling and Quality Control

A typical image taken by the prototype is shown in **Fig. 4**. Data currently undergo the following procedure: adding of astrometric information, archiving, and quality control. A photometric analysis based on image-subtraction techniques is currently under development in the frame of a PhD thesis project and will be presented elsewhere.

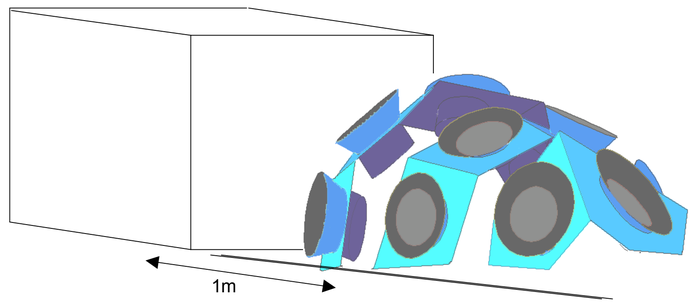


Fig. 2 Outline of the PASS experiment, here drawn with 10 cameras. The box in the background is the removable enclosure.

One first concern with the PASS instrument has been pointing stability. The instrument is mounted fixed and stars will move across the field. However, stars should appear at exactly the same sport every night in images taken at the same sidereal time (**Fig. 5**). While early tests (see Table 1) showed large motions, a much improved pointing stability with an rms of 0.4 pixels has been achieved between April and June 2005. The remaining residuals may arise from flexions of the mount or optics (possibly from temperature changes, currently under investigation), or from errors in the timing (which we are confident to be minor).

Nightly observing runs result in approximately 1000 images, requiring 8 Gbyte of storage space. For an efficient data analysis, a quality control routine is therefore been developed, which allows the rejection of poor data, and the classification of useable ones. Evaluation of the individual nights is based on a measurement of the sky brightness in the four image corners and in the center (**Fig. 6, top**). Based on comparisons with low-resolution movies from nightly data (**Fig. 6, bottom**), it has been found that these brightness levels, and the standard deviation among them, provide a reliable indicator of a night's meteorological quality. An automatic quality classification based on graphs like this is currently under development.

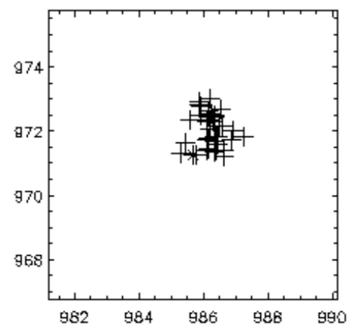


Fig. 5 Position variation of a stellar psf in images taken at the same sidereal time during 40 nights in April-June 2005. The scale is in pixel units, with 1 pixel = 50 arcsec.

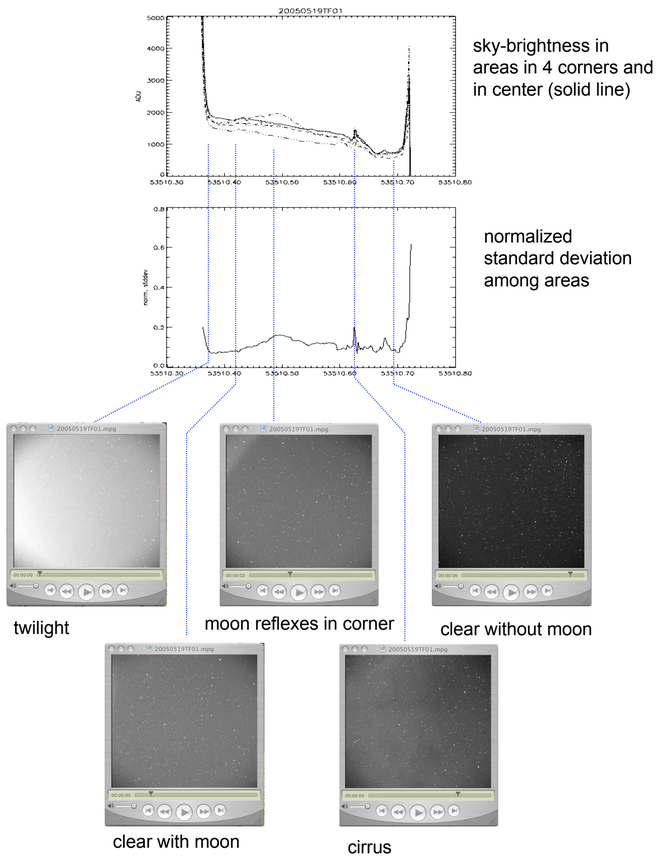


Fig. 6.Top: Nigthly quality control plot for a mostly clear night with 3/4 moon, which was setting in the early morning. Bottom: Corresponding frames in a low-resolution movie of nightly data with interpretation.

Future development of PASS

The principal goal of the current prototype is the undertaking of a feasibility study, for which the basic data set shall be obtained until the onset of the next winter. A thorough analysis of these data will show, if modifications to the instrument design or to the observing procedure will be required. A complementary system of two further cameras with more efficient CCD detectors is scheduled to start operation this fall as part of the WASP planet detection project in La Palma. When instrument design, observing routines and data analysis have matured, the adding of further cameras or instrument locations would lead to a start of the Permanent All Sky Survey. In this context, a location at Dome C is a particularly interesting possibility (see Deeg at al. 2005). It should be noted that the PASS project is still in its early phase and **we expect that it provides the opportunity to cover a wide range of topics and objectives. Its initiators welcome any expression of interest towards a participation in this project**.

References:

PASS Web-site: www.iac.es/proyecto/PASS

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