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Update and recent results of the STARE instrument

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Abstract. The STARE telescope of the High Altitude Observatory (HAO), Boulder is maintained by the Instituto de Astrofísica de Canarias (IAC) at the Observatorio del Teide (OT) on Tenerife. The STARE instrument has been updated in spring 2006 and forms part of the TrES network, which consists of two more telescopes located in the USA (PSST, Lowell Observatory; Sleuth Mt. Palomar). In this paper an overview over STARE's update and first results from recent observations are given.

1. The STARE instrument

STARE is a field-flattened Schmidt wide-field camera with a Newtonian optical design. The focal length is 286 mm and the aperture is 99 mm. This results in a f-number of 2.9. For data acquisition a 2048 x 2048 back-side-illuminated CCD from Princeton Instruments is used. The field-of-view is 5.5°x 5.5°. Stare is mounted on an equatorial fork mount. The principal scientific purpose of the system is the detection of transiting extrasolar planets. For the detection of Hot Giant planets, high-cadence photometry with a precision of an r.m.s. of a few millimagnitudes for large numbers of stars is needed (Alonso *et al.* 2004).

2. Updates

To improve the performance of the instrument, STARE was updated in July 2006. There are two new main components which were replaced: First the old front-side illuminated CCD was changed for a new back-side illuminated CCD. This increased the sensibility in the optical wavelength range. The higher sensibility allows to search deeper for stars and to decrease the exposure time. Furthermore, the new CCD has a shorter readout time, resulting in a higher

Table 1: STARE characteristics

Focal length:	286 mm
Aperture:	99 mm
F-number:	2.9
Field-of-view:	5.5°x 5.5°
Detector:	2048 x 2048 px
Pixel size: 13 μm x 13 μm	

duty cycle. The second upgrade is the new mount. The old MEADE mount was substituted with a new, more stable mount from MATHIS instruments. This new mount improved the tracking behaviour of the telescope and decreased the maintenance interval. The new control PCs and improved tracking made the guide camera redundant. The telescope is guiding with the main CCD where a program correlates the images with a master image and sends the correction to the control PC.

3. Reduction procedure

The raw images are further processed at the IAC headquarter. In a first step the images have to be calibrated. Therefore a combined bias and dark image is subtracted. After this subtraction, the images are divided by the bias and dark corrected flat-field. Since a big shutter at the tube entrance is used, a special flat-field correction is applied. This flat-field also corrects for differences between the effective shutter closing and opening times for each position on the CCD (Alonso 2005). After the images are calibrated, a photometric image reduction, based on the DAOPHOT/ALLSTAR technique (Stetson 1987; Alard and Lupton 1998), is performed. The image reduction results in light curves of typically 10,000 stars per field, which are first binned in 9 min. and then are searched for transit signals utilizing the Box Least Square fitting algorithm (Kovács *et al.* 2002). The BLS algorithm tries to fit a box, regarded as a possible transit, to the light curve. All detections are inspected visually. This finally gives a list of transit candidates. Different techniques are then applied to discard stellar binaries and diluted triples systems. For a follow-up, spectra from the transiting system are collected. Furthermore a high precision light curve can place constrains on the masses and radii of the central star and the potential planet.

4. Red noise characteristics

For the red noise characterization, the approach of Pont *et al.* (2006) is used. In this approach one eliminates any known systematics from the light curve. Therefore, for calculating the noise, non-variable stars are chosen by inspecting the light curves of different stars. Figures 1 shows for that sample of stars the r.m.s. over magnitude for individual points, σ_i (blue circles). The red triangles are the r.m.s. of a sliding average over a transit duration of 3 hours, which expresses the amplitude of systematics in an 3 hour interval (Pont *et al.* 2006). The green crosses are calculated according to $\frac{\sigma_i}{\sqrt{N}}$, where N is the number of points in a 3 hour interval. A 2nd order polynomial was fitted to the r.m.s. values, solid line.

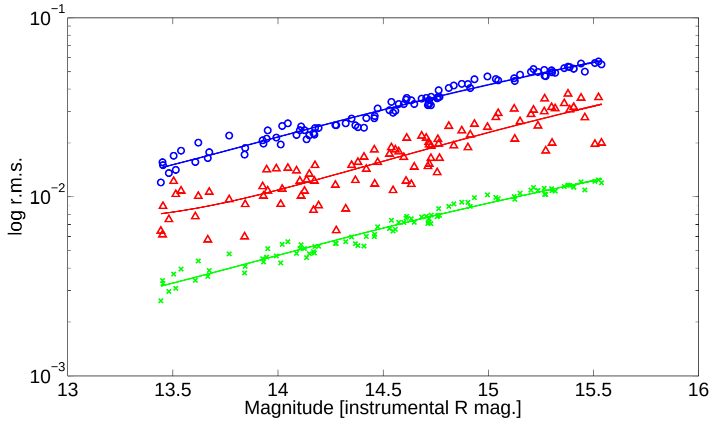

Figure 1: Root-mean-square in light curve of 100 non-variable stars, spanning an observation of several days with the updated STARE instrument. The symbols are explained in the text.

5. Conclusions

Red noise emanates from systematic effects like for example, detector characteristics, telescope tracking and atmospheric influences. Comparing the different r.m.s. values in Figure 1, one can see that in the STARE data is a correlated red noise component present. This component increases the noise in the data and makes it harder to achieve the millimagnitude r.m.s. necessary to observe planetary transits. It can be noted that, the relation red noise to white noise has no clear dependence on magnitude. The telescope observed this year only for a short time; longer observing spans will lead to a better characterization of its new setup.

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