Calibration of the HESSI Roll Angle System at Jungfraujoch

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Introduction

The Roll Angle System (RAS) is part of the HESSI instrument [1] to be launched by NASA in March 2001. HESSI will observe the full Sun with state-of-the-art spatial resolution (between 2 and 36 arcsec) and energy resolution (< 1 keV FWHM, increasing to 5 keV at 20 MeV) in the energy range 3 keV to 20 MeV. Within the 2 years lifetime we expect to observe several thousands of flares at energy >25 keV and several hundreds at energy >300 keV. Imaging is done by recording the intensity modulation through a set of 9 rotating bi-grid collimators spaced at 1.55m distance and subsequent Fourier-transformation [2]. The spatial resolution in case of spacecraft jitter depends critically on a precise knowledge of the momentary viewing direction. Also, in order to provide precise correlation with observations at other wavelengths we require an absolute pointing accuracy of 1 arcsec. Two precise aspect systems are implemented to position/correct the time-tagged photon events on ground: (a) the Solar Aspect System (SAS) which will yield sub-arcsec knowledge of the radial pointing offset with respect to the Sun center and (b) the RAS which will provide precise knowledge (1 arcmin at 1σ level, corresponding to 1 arcsec at the solar limb) on the roll angle of the rotating spacecraft (15 rpm). Contrary to two-dimensional star sensors the one-dimensional scanner type is not commercially available - especially for the relatively high HESSI rotation speed - and only few examples have been described in the literature. The performance of the RAS was tested by the observation of real celestial objects. In the following we shall describe the RAS calibration at Jungfraujoch.

Jungfraujoch calibration measurements

Ground calibration of the assembled flight model was performed at the Jungfraujoch Research Station at an altitude of 3600 m. This location combines better atmospheric ‚seeing' with the beneficial side effect of convenient CCD cooling. The RAS was mounted on a horizontally rotating support and could be set to scan the sky continuously over about 50° between two end-switches. Due to a longer delay at one end-switch the characteristic time periodicity shown in Fig.2 was obtained.

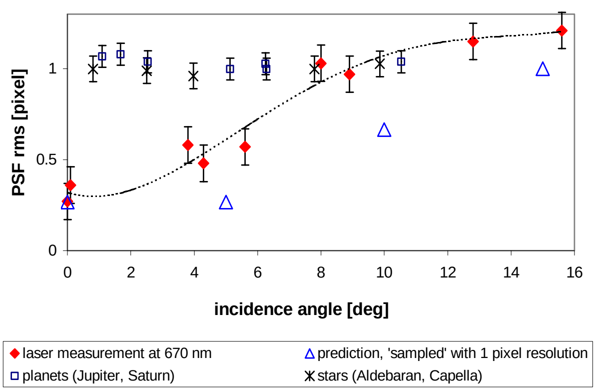

Fig.1: PSF rms versus angle of incidence. Details are given in the text.

Focal length adjustment was achieved by minimizing the width of the point-spread-function (PSF) upon varying the

focal length. Doing this for several objects with different wavelength distributions resulted in a PSF which is independent of CCD position, as intended (see Fig.1). The predicted width (triangles) of the PSF as a function of incidence angle, calculated with the CCD responsivity spectrum and ‚sampled' with 1 pixel resolution, agrees reasonably with a lab measurement using a red laser collimator (diamonds, with trendline) . One pixel corresponds to 13 micron or 0.9 arcmin for the f / 1.4, 50 mm Leica lens.
Fig.2 shows CCD source position versus time, plotted with sufficient time resolution to see the characteristic periodicity of each object. Although a number of random events are present in this 'raw data plot' the true celestial objects can be easily separated by the requirements (a) of the correct periodicity and (b) to follow a straight line. The weakest source observed was Hipparcos 29655 with a visual magnitude of m_V=3.65 and of type M3 (third from bottom in Fig.2).

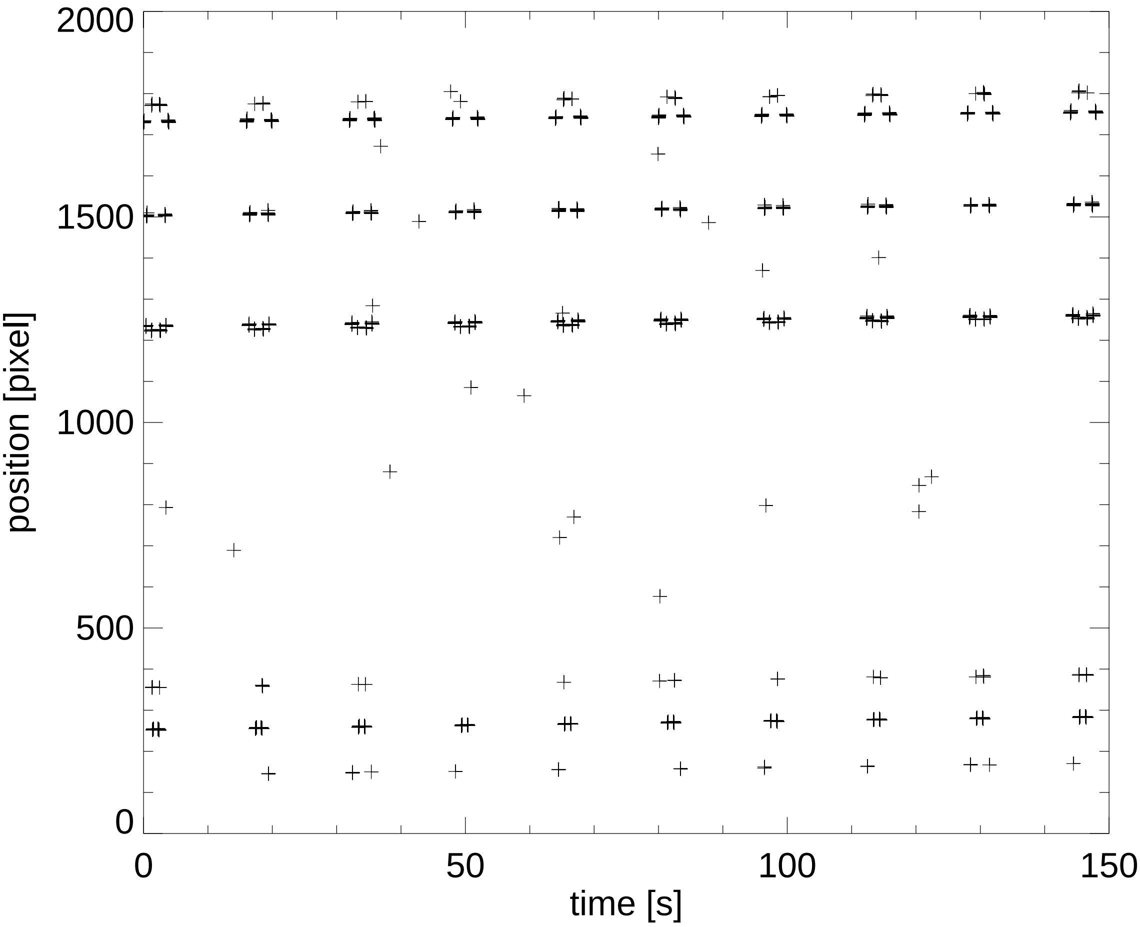

Fig.2: CCD position vs. time for Hipp. 25336 (m_V=1.64), Hipp. 30343 (m_V=2.89), Hipp. 29655 (m_V=3.65), Hipp. 25428 (m_V=1.65) together with Hipp. 21421 ('Aldebaran', m_V=0.87)), Jupiter, Saturn and Hipp. 23015 (m_V=2.69) (from bottom to top). The periodic long / short time structure is characteristic for the azimuth of each object and is due to a longer delay at one end-switch.

Stellar scintillation introduced a large amount of signal amplitude spread which made the determination of the PSF width and of the effective RAS sensitivity from weak objects ($m_V \geq 1$) unreliable. For Aldebaran we took 4 measurements, spread over two hours, which show a variation of the effective sensitivity between 74% and 81% (of the nominal prediction). We therefore consider 80% a lower limit taking into account the possibility of some residual haze that we cannot exclude. Thus, the RAS sensitivity is as predicted and the required accuracy will be achievable.

References:

[1] R.P Lin et al, SPIE Proc. 3442 (1998), 2-12.
[2] R. Henneck et al, SPIE Proc. 3765 (1999), 518-523,
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