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Wavefront sensing for Themis: a case study for next generation solar telescopes like EST

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Abstract. Wavefront sensing is one of the most challenging problem in solar Adaptive Optics (AO) due to the presence of extended and low contrast AO-targets on the solar scene. We show preliminary results of wavefront modal phase estimation on THEMIS Solar Telescope data, using two approaches: Zernike (ZE) and Karhunen-Loeve (K-L) polynomial expansions. We have analyzed Shack-Hartmann (SH) dataset, and the wavefront phases were reconstructed. A study of pros and cons of the two different modal expansions has been carried out. These results could be particularly helpful in developing and studying design and performances for next generation solar telescopes based upon annular pupils.

Key words. Instrumentation: adaptive optics – Techniques: high angular resolution

1. Introduction

Solar AO, in contrast to non-solar case, has to work on extended and poorly contrasted targets.

In order to achieve a good wavefront description, the correlation technique has to be carried out on SH subpupils images in order to estimate local wavefront slope from their respective image shifts.

We present preliminary results of wavefront sensing at Themis Solar Telescope using a SH sensor.

2. Dataset and wavefront slope measurements

In this work we used SH sensor data acquired at Themis Solar Telescope on 3 August 2006 while slope measurements have been estimated through the Sum of Absolute Differences correlation method on 30 SH subpupils (Fig.1)

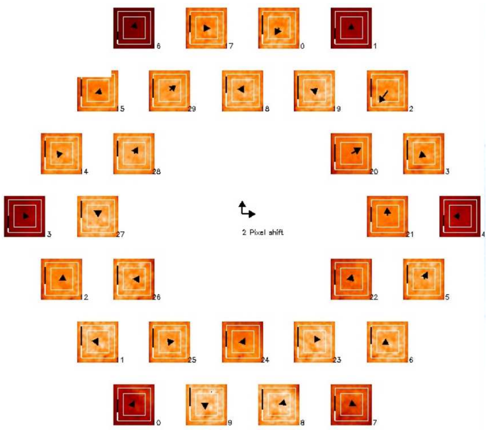

Fig. 1. SH setup (30 subpupils) with measured shifts superimposed (Black arrows).

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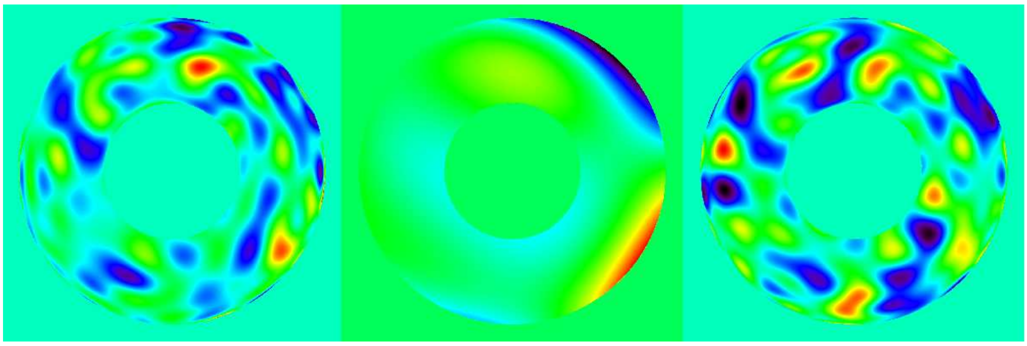

Fig. 2. (Left) Wavefront reconstruction with up to 200 ZE modes. (Center) The same phase reconstructed with up to 10 ZE polynomials. (Right) The same wavefront reconstructed with only 10 K-L modes. It is worth noting that the first K-L mode contains already most of the high spatial frequency features. Tip and tilt components have been forced to be ZE modes for convenience in K-L expansion.

3. Modal wavefront reconstruction

To accurately describe wavefront aberrations, we used a modal phase reconstruction based, at first, upon ZE polynomials (Noll, R.J. 1976) and then on K-L functions (Dai 1996), both defined over annular pupil. The study of this particular optical scheme is helpful in developing next generation European Solar Telescope, giving us the possibility to test wavefront reconstruction performance on annular pupils with large central obscuration, typical of Ritchey-Chretien optical configuration.

K-L decomposition makes use of Principal Component Analysis to choose a suitable subset of eigenvectors, constructed as a combination of ZE modes.

K-L, in contrast to ZE polynomials, are statistically independent and so they represent a better basis for phase reconstruction. Fig.2 shows that using the same number of components, K-L functions (right) result in a quite better wavefront description with respect to ZE polynomials (center). This method ensures very high performance, speeding up the real-time calculation while maintaining the same accuracy.

4. Reconstruction fitting error

Given a reference phase, built with up to 200 ZE mode, we tried to reconstruct this phase using ZE and K-L approaches with different number of modes. This analysis has underlined how K-L modes are more efficient in describing wavefront, even at low order modes with respect to ZE ones. At low order K-L fitting error is always lower than ZE reconstruction error.

References

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