Adaptive Optics at THEMIS Solar Telescope: robust sensing and control in harsh turbulence.

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We present the Adaptive Optics (AO) system developed by the Airi Team at the Centre de Recherche Astrophysique de Lyon for THEMIS 90-cm Solar telescope, in the Canary Islands (Spain). The goal of this development has been to build a low-cost robust AO system able to face the daytime turbulence conditions observed on THEMIS, correcting in the visible at more than 1kHz, and able to adapt to the quickly varying conditions without parameters to be adjusted during operation. This AO system has been the opportunity to put in practice ideas and solutions studied by the Airi team during the preceding decade.

In this communication, we explain the key elements of this innovative adaptive optics system: (i) its model-based wavefront sensing on solar granulation [1], (ii) its real-time estimation of the measurements precision and correlations [2], (iii) its closed-loop control based on iterative pseudo open-loop Maximum a Posteriori reconstruction [3], (iv) its online calibration method. Since December 2020 when AO loop has been first closed on the sun, it has demonstrated a great potential for THEMIS, in particular for the studies of the sun magnetic field allowing to image fine structures of about 0.2-arcsecond size, corresponding approximately to the diffraction limit of the telescope.

Finally, we present the perspectives of improvement of THEMIS AO control using a predictive model of the incoming aberrations.

References.

[1] Thiébaut É., Tallon M., Denis L., Langlois M., Béchet C., Moretto G., and Gelly B. (2018), Innovative real-time processing for solar adaptive optics, in [SPIE Astronomical Telescopes and Instrumentation, Adaptive Optics Systems VI], 10703, 107031I.
[2] Tallon M., Thiébaut E., Tallon-Bosc I., Gelly B., and Denis L. (2022), Solar wavefront sensing at themis with self-calibrated reference image and estimation of the noise covariance, in [SPIE Astronomical Telescopes and Instrumentation, Adaptive Optics Systems VII], 12185–91.
[3] Thiébaut É., Tallon M., Tallon-Bosc I., Gelly B., Douet R., Langlois M. and Moretto G. (2022), Closing the loop as an inverse problem: the real-time control of Themis adaptive optics, in [SPIE Astronomical Telescopes and Instrumentation, Adaptive Optics Systems VII], 1218507.