Image Quality of data products of PHI/HRT of the Solar Orbiter spacecraft

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INTRODUCTION

The High Resolution Telescope (PHI/HRT) of the Polarimetric and Helioseismic Imager (SO/PHI) [1] onboard the Solar Orbiter spacecraft (SO) [2] provides near diffraction limited observations of the solar surface. We use the technique of Phase Diversity (PD) to calculate the Point Spread Function (PSF) of PHI/HRT at different orbital positions from the Sun. The aim is to restore the observed data which are affected by the Heat Rejection Entrance Window (HREW) of the telescope, especially at the closest distances to the Sun.

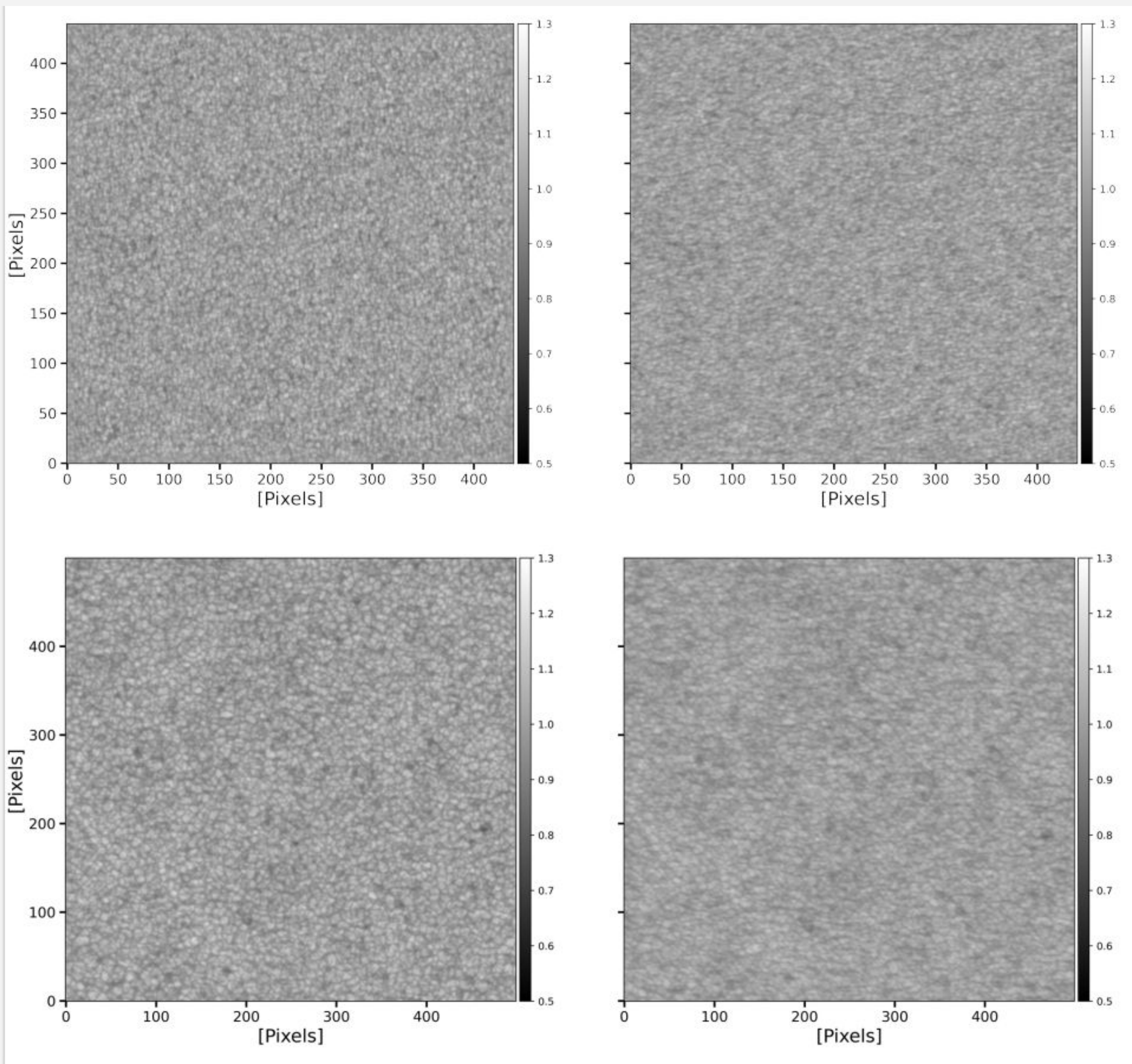

Fig. 1 Focused (left column) and defocused (right column) images of a quiet-Sun region in the continuum during NECP on April 20, 2020 at a distance of 0.82 AU (top row) and during RSCW2 on February 23, 2021 at a distance of 0.52 AU (bottom row).

The PD image pair consists of a focused image that has been degraded by the unknown aberrations and another image which is manually defocused by a certain well defined value (half a wavelength), in addition to being affected the unknown aberrations. We show in Figure 1 the PD image pairs during two observational campaigns: the Near Earth Commissioning Phase (NECP) and the second Remote Sensing Checkout Window (RSCW2) during the cruise phase of SO.

To characterise the wavefront error, we use Zernike Polynomials following Noll's expansion scheme of orthonormal polynomials [3].

METHODS

We refer to the PD algorithm presented in [4]. The PD algorithm is run on small sub-regions (256x256 px) of the PD image pairs to test for the dependence of the wavefront error on the field of view (Figure 2).

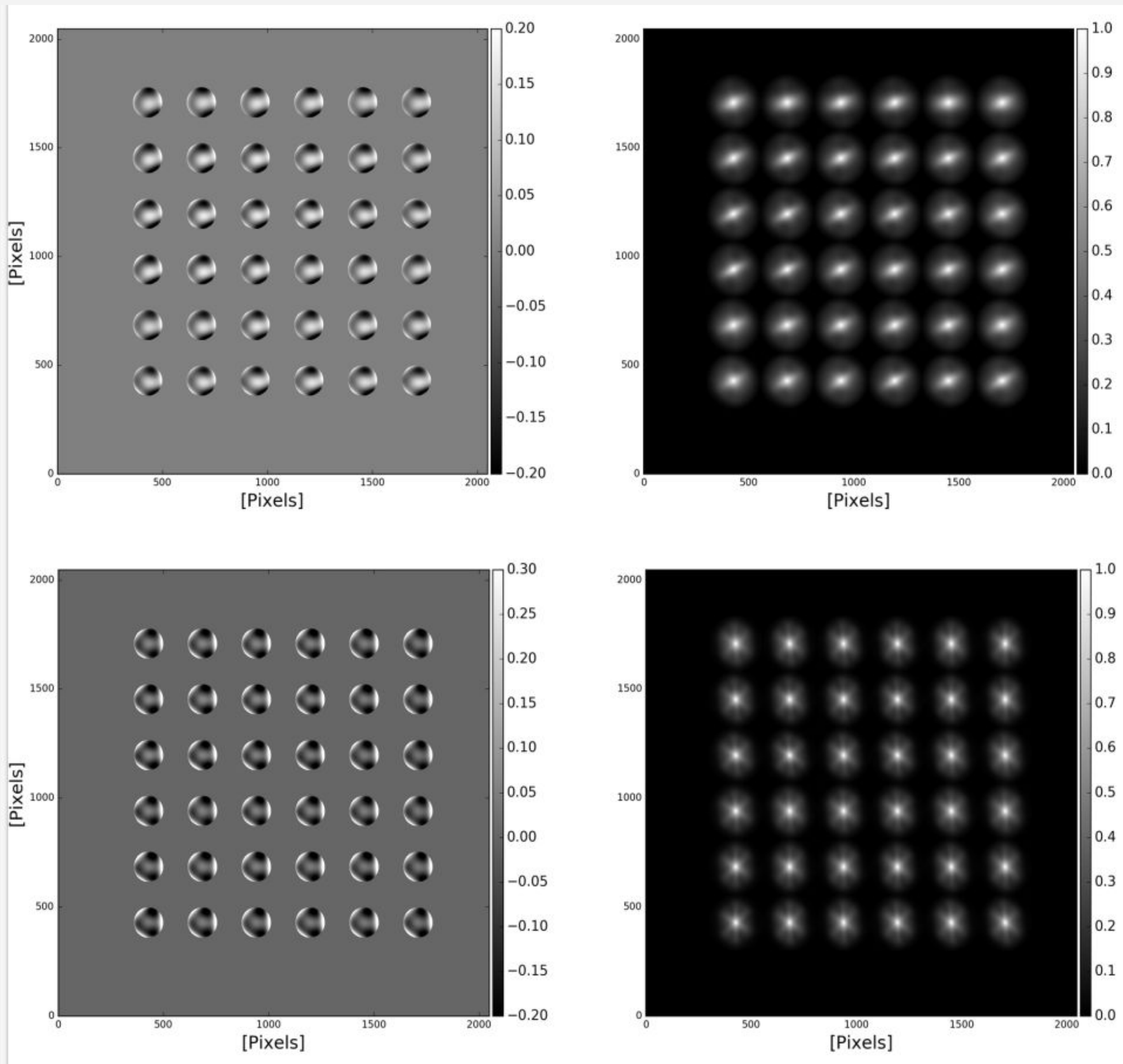

Fig. 2 The wavefront error (left column) and MTF (right column) distribution across the SO/PHI-HRT FOV during PHI-5 at 0.8 AU and STP-136 at 0.523 AU.

The first 10 Zernike coefficients are employed in the fitting routine because they are enough to capture the wavefront error. The total RMS wavefront error increases from $\lambda/10$ at 0.82 AU to $\lambda/7$ at 0.523 AU.

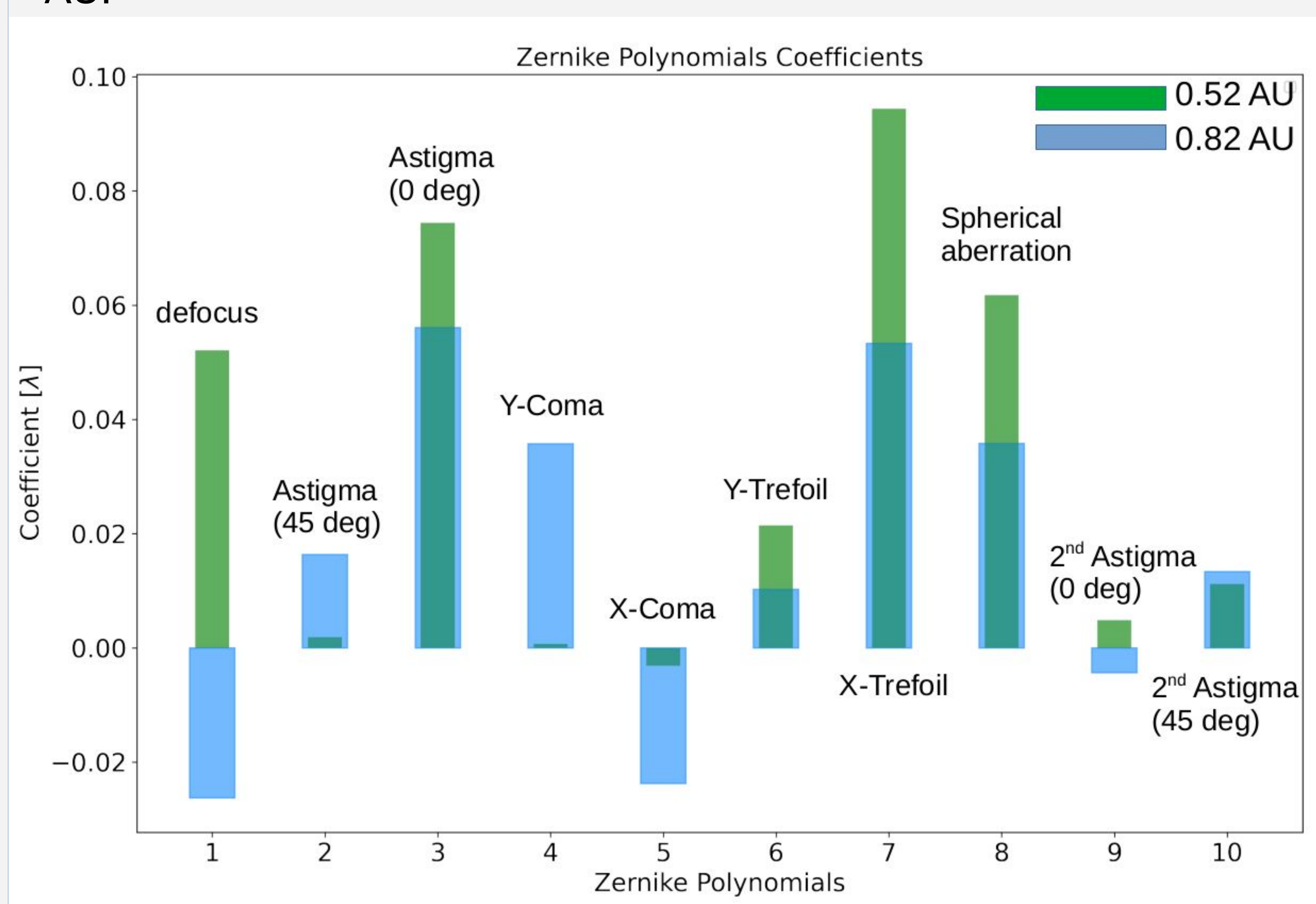

Fig. 3 The averaged Zernike polynomials over the sub-regions of the field of view for both observational campaigns.

RESULTS

The averaged PSF at each orbit is computed by Fourier Transform of the MTFs in Figure 2. We use Richardson-Lucy algorithm for the deconvolution of the focused scenes in Figure 1. After the restoration of each scene, the RMS contrast of the quiet-Sun granulation increases from 4% to 10% in both datasets.

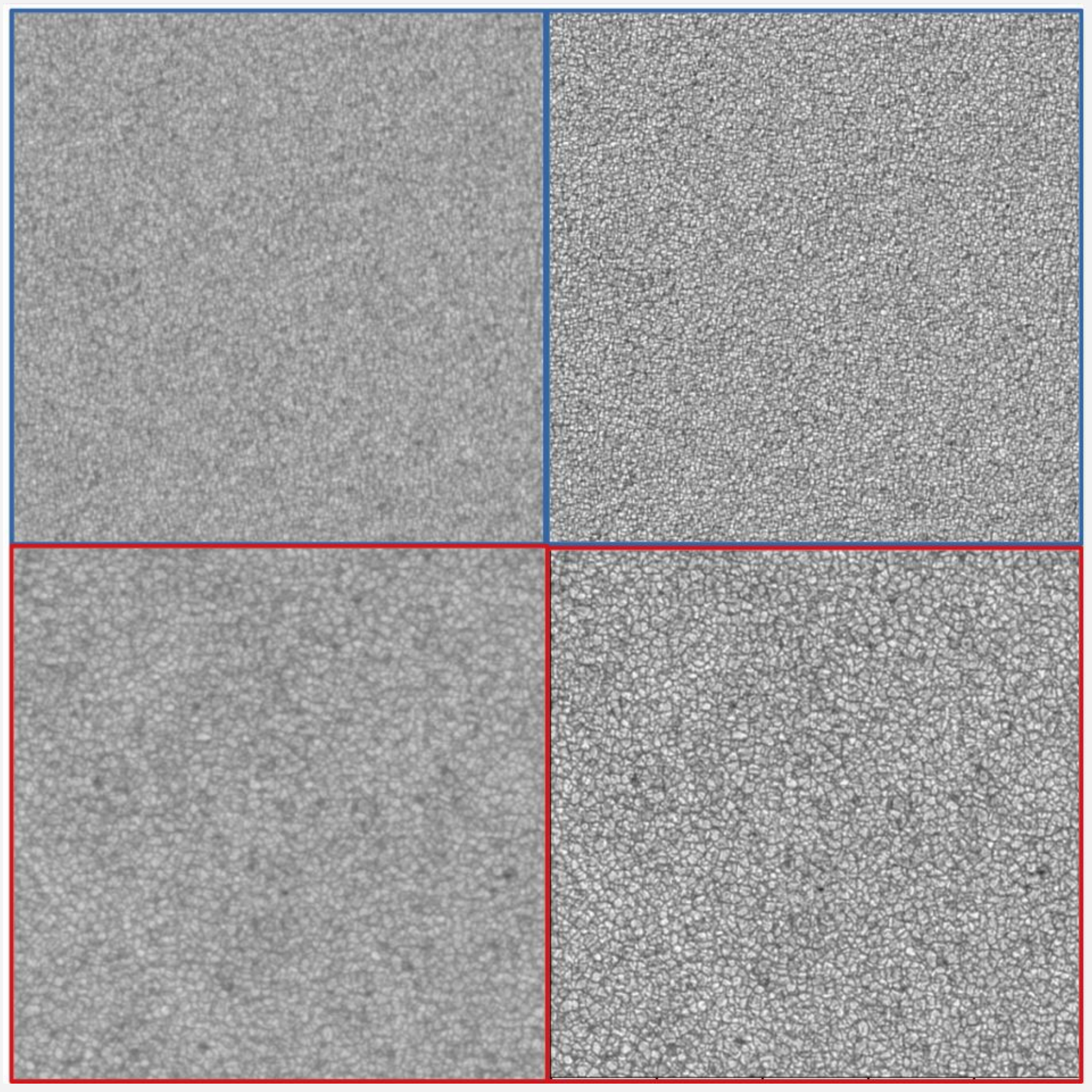

Fig. 4 The raw (left column) and restored (right column) quiet-Sun images taken at 0.82 AU (top row) and 0.52 AU (bottom row).

CONCLUSIONS

The PHI/HRT telescope is equipped with a focus mechanism which allows for taking image pairs for phase diversity analysis. We have shown that the phase diversity technique allows for capturing the optical aberrations of the PHI/HRT telescope at each orbital position from the Sun. The wavefront quality decreases with Solar Orbiter distance to the Sun but the phase diversity technique ensures the restoration of the same image quality data.

REFERENCES

1. Solanki, S. K., del Toro Iniesta, J. C., Woch, J., et al. 2020, A&A, 642, A1
2. Müller, D., St. Cyr, O. C., Zouganelis, I., et al. 2020, A&A, 642, A1
3. Noll, R. J. 1976, J. Opt. Soc. Am., 66, 207
4. Löfdahl, M. G. & Scharmer, G. B. 1994, ApJS, 107, 24

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