

# 8th April 2024 Total Solar Eclipse E-KPol Observation Campaign

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## Introduction

Total Solar Eclipses (TSE) offer a significant advantage over conventional coronagraphs: the Moon acts as a perfect natural occulter, eliminating instrumental stray light and drastically reducing sky brightness to reveal both the inner and outer corona.

The solar physics team at the Astrophysical Observatory of Turin (OATo) organized an observational campaign in Mexico, Torreón, with the two main objectives: the study of the physical parameters of the coronal plasma using the E-KPol polarimeter telescope and the test of new instruments prototypes, E-CorMag and Strato-CorMag. These were designed to investigate the coronal magnetic field through the Hanle effect by observing the polarization properties of the green Fe XIV line (530 nm). In this context, E-KPol was essential, providing the K-Corona continuum for the isolation of the emission line signal.

## The Instrument

E-KPol (Eclipse K-corona Polarimeter)<sup>2,3,4</sup> is a telescope, equipped with a polarimeter, designed to observe and measure the polarized component of the solar K corona during total solar eclipses. It has been developed at the Astronomical Observatory of Turin (OATo) and has taken part in multiple eclipses (2006 Libya, 2010 French Polynesia, 2019 Chile<sup>5</sup> and 2024 Mexico).

The telescope's polarimetric assembly consists of a quarter wave (QW) plate to convert the incoming linear polarization into circular, an electro-optical Liquid Crystal Variable Retarder (LCVR), to introduce a phase retardance, and a linear polarizer (LP) to analyze the modulated radiation.

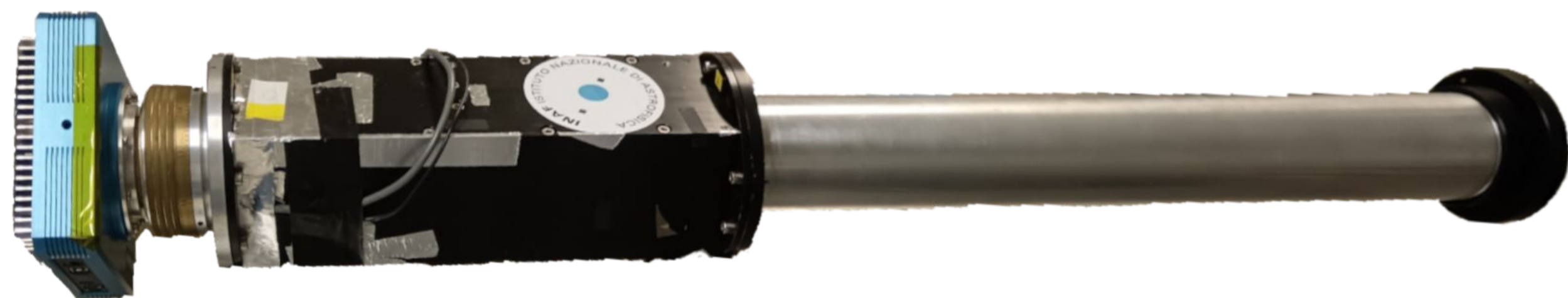


Figure 2. E-KPol telescope.

## Stokes parameters and polarization

From a four image sequence,  $m_i$ , with the LCVR set at different voltages,  $\delta_i$ , the Stokes parameters, I Q U, can be derived through demodulation.

Linear polarization properties, such as the polarized brightness (pB) and the angle and degree of linear polarization (AoLP and DoLP) can be obtained from the Stokes parameters.

$$\begin{pmatrix} m_0 \\ m_1 \\ m_2 \\ m_3 \end{pmatrix} = \frac{1}{2} \begin{pmatrix} 1 & \cos \delta_0 & \sin \delta_0 & 0 \\ 1 & \cos \delta_1 & \sin \delta_1 & 0 \\ 1 & \cos \delta_2 & \sin \delta_2 & 0 \\ 1 & \cos \delta_3 & \sin \delta_3 & 0 \end{pmatrix} \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$$

$$pB = \sqrt{Q^2 + U^2}$$

$$DoLP = \frac{pB}{I} = \frac{\sqrt{Q^2 + U^2}}{I}$$

$$AoLP = \frac{1}{2} \arctan\left(\frac{U}{Q}\right)$$

## Radiometric calibration

The on-site radiometric calibration could not be performed due to varying cloud coverage the day of the eclipse. The images have been calibrated with the help of an additional instrument, K-Cor (K-Coronagraph), located at the Mauna Loa observatory, which operated the day after the eclipse.

By comparing K-Cor images with E-KPol ones, a calibration value has been derived, allowing for the calibration of the coronal images in  $B_{\odot}$  units.

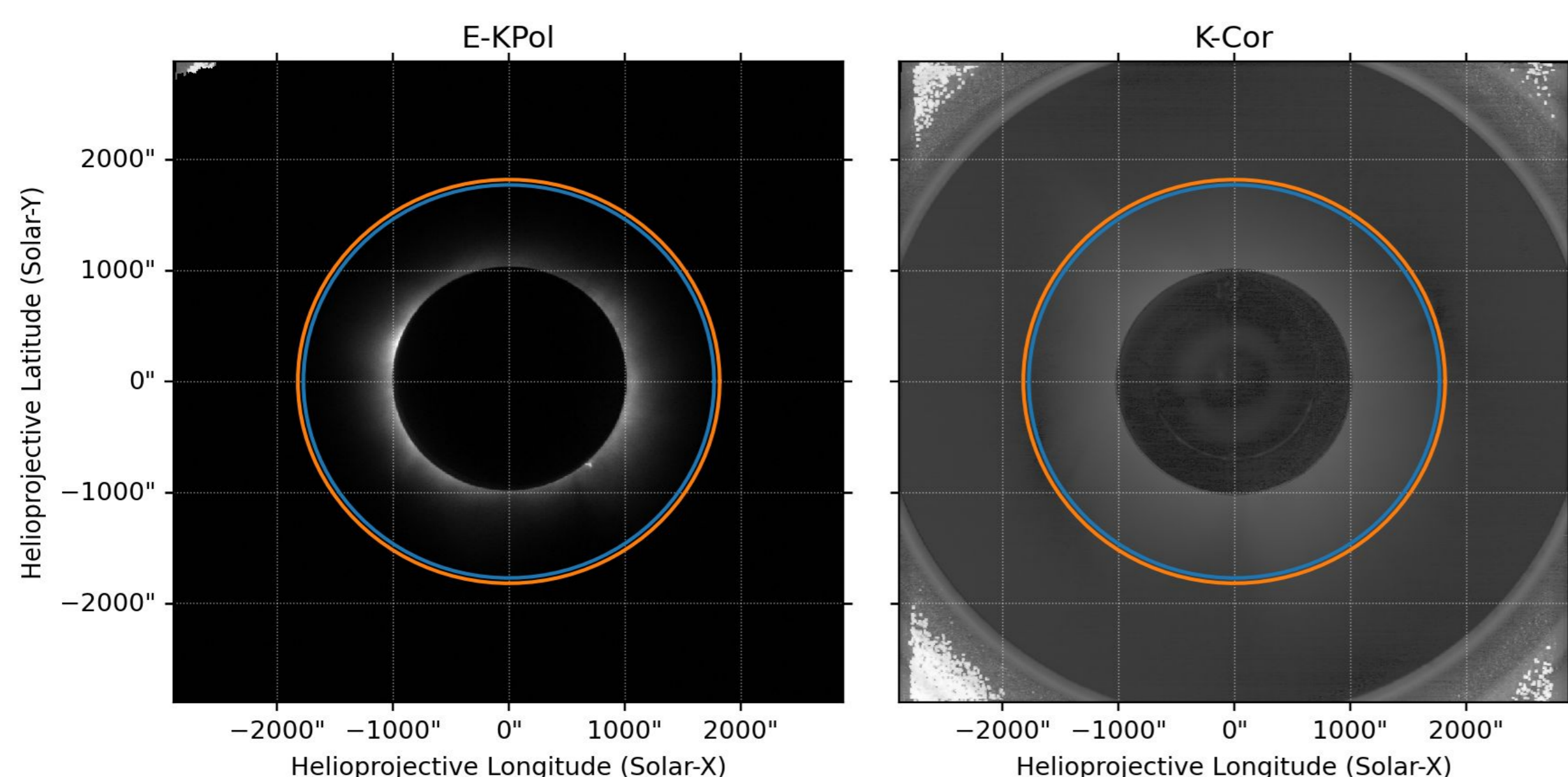


Figure 3. Comparison between E-KPol [Left] and K-Cor [Right] polarized brightness (pB) images. The blue and orange circles define the annular regions where the mean intensity is calculated and compared with the corresponding K-Cor reference data to derive the radiometric calibration factor.

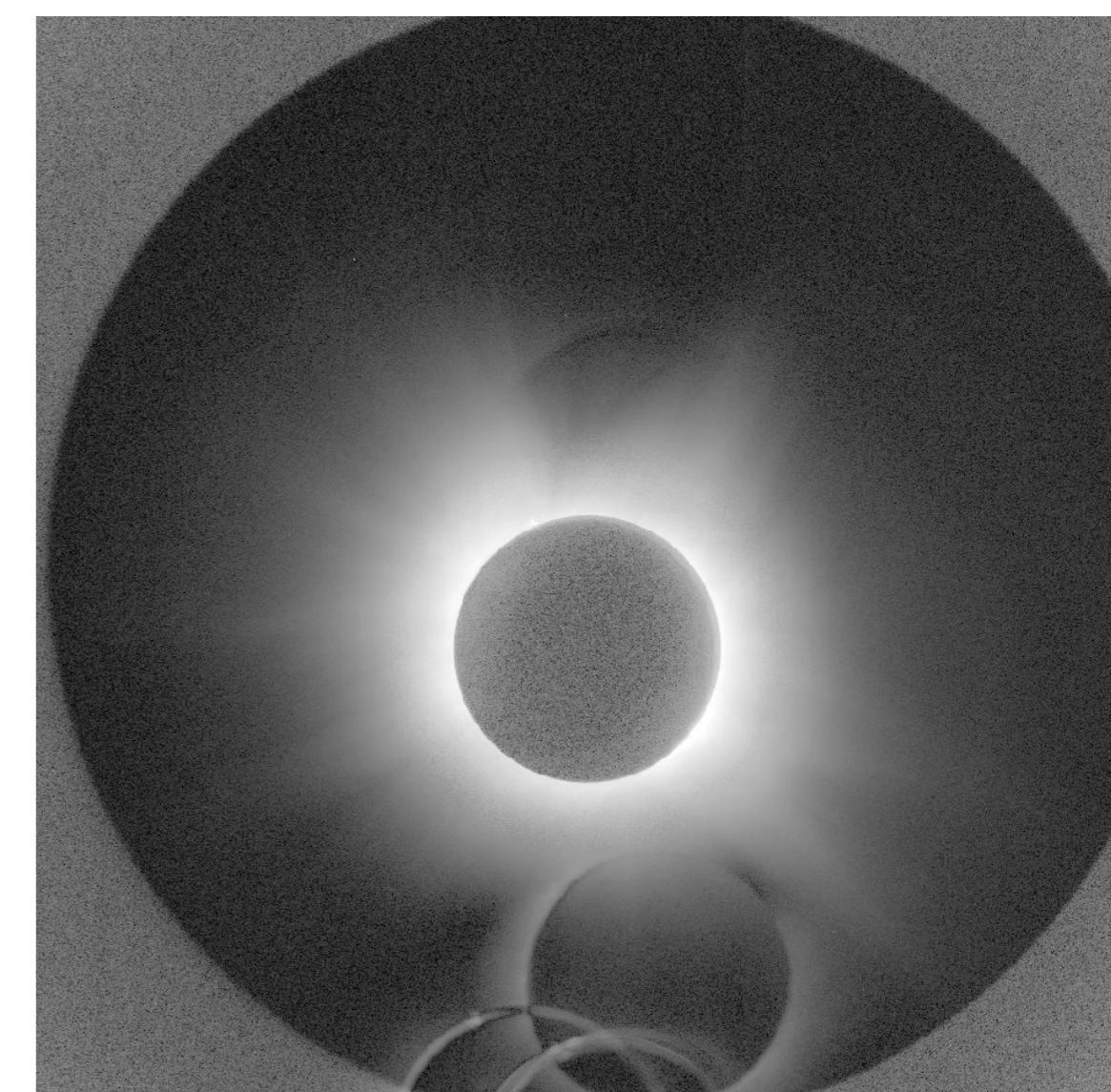


Figure 1. E-KPol eclipse image in logarithmic scale (merging between the 0.6 s and 8 s exposure times).

## AoLP and DoLP

Optimal sequences were selected by observing DoLP and verifying that AoLP aligned with theoretical expectations, showing polarization tangential to the solar limb.

To maximise the signal to noise ratio (SNR), these selected frames were merged into a final composite image.

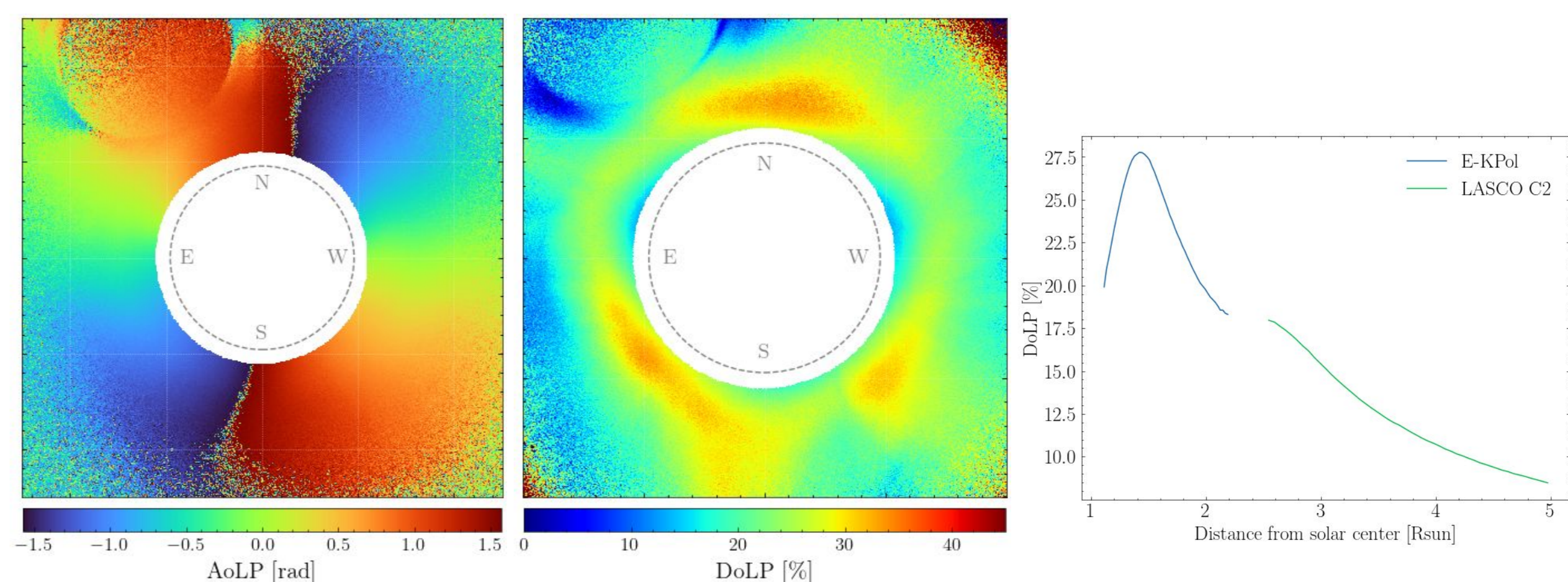


Figure 4. Left: Angle of Linear Polarization merged image. Center: Degree of Linear Polarization merged image.

Right: DoLP averaged profile compared to the LASCO C2 one. E-KPol profile is slightly lower than LASCO C2, this discrepancy could be attributed to the depolarization effects caused by the presence of clouds.

## Electron density

Under the assumption of local spherical symmetry, electron density profiles can be derived from the pB ones applying Van de Hulst inversion method<sup>1</sup>, yielding a full electron density map.

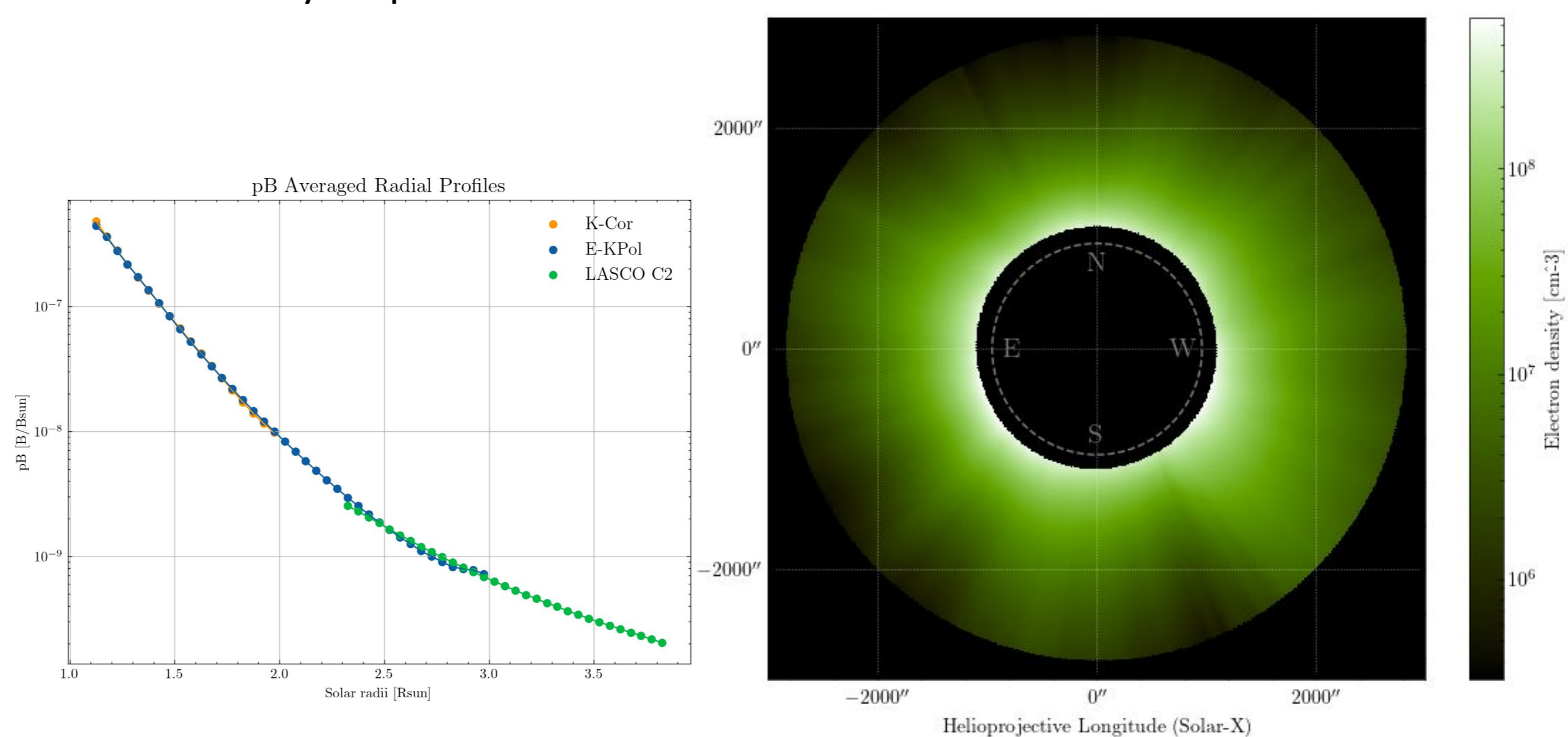


Figure 5. Left: E-KPol pB averaged radial profile (blue) compared to K-Cor (orange) and LASCO C2 (green). The agreement at higher distances from the solar center with LASCO C2 data shows the quality of the radiometric calibration. Right: Electron density map (logarithmic scale) obtained using Van de Hulst method.

## References

1. Van de Hulst, H. C. (1950). The electron density in the solar corona.
2. Fineschi S. et al. (2005). KPol: liquid crystal polarimeter for K-corona observations from the SCORE coronagraph.
3. Zangrilli L. et al. (2006). E-KPol: liquid crystal polarimeter for eclipse observations of the K-corona.
4. Capobianco G. et al. (2012). Electro-optical polarimeters for ground-based and space-based observations of the solar K-corona.
5. Liberatore A. et al. (2019). Polarimetric Study of the Solar Corona During the Total Solar Eclipse on July 2, 2019 with a Liquid-Crystal Polarimeter.

