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Imaging Stokes polarimeter based on liquid crystals for the study of the K-solar corona

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Abstract. We describe the project of an imaging Stokes polarimeter based on liquid crystals, for the study of the K-solar corona. Liquid crystals retarders are electrically variable waveplates. The change of the retardance, induced by a variable applied voltage, is a function of the wavelength. As observations of the visible coronal continuum are usually made over the band 450-600 nm, we are interested in studying the properties of these retarders as a function of the wavelength. This polarimeter is thought to be implemented on ground-based and space-borne coronagraphs.

Key words. instrumentation: polarimeters – Sun: corona

1. Introduction

The visible light continuum coronal emission arises from Thomson scattering of the solar disc radiation by free electrons in the coronal medium (K-corona), and from the radiation scattered by coronal dust particles (F-corona). Measurements of the K-corona intensity provide information on the coronal medium electron density. The K-corona emission turns out to be linearly polarized, as light scattered by coronal electrons is incident from a particular direction: unpolarized light is emitted isotropically from the solar disc and electrons scatter it; for a sufficient distant position of the scattering electrons the Sun can be considered as a point source and an observer will see radiation with the electric field vibrations in a plane parallel to the solar limb. In the following we describe the project for an imaging Stokes polarimeter based on liquid crystals, for the study of the K-solar corona, to be assembled in the Optics Laboratory of the Astronomical Observatory of Torino. This instrument is thought to be implemented on ground-based telescopes for solar eclipse observations, and on space-borne coronagraphs, such as the HERSCHEL/UVCI (He Resonant Scattering in Corona and Heliosphere / UV and Visible-light Coronagraphic Imager) sounding rocket project.

2. Polarimeter concept

In most astronomical applications the degree of polarization, represented by the normalized Stokes parameters Q/I, U/I (linear polarization), or V/I (circular polariza-

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tion), is small (i.e. $\sim 10\%$). It can however be measured very accurately with modulation techniques. In order to achieve accuracies better than 1% in polarization measurements for solar and stellar astronomy, a signal-to-noise of S/N$\sim 10^4$ is required. At these accuracies, the dominant sources of noise - a part from the photon statistics - are the stability of the sky (i.e. seeing), telescope, and detector. The instrumental and environmental instabilities with frequencies up to 10 Hz could be removed by modulating the polarization signal up to 100 Hz. The central innovation proposed here is to replace mechanically rotating retarders of a polarimeter with liquid crystals variable retarders (LCVR), that are electro-optically driven and have no moving parts. Spatial and temporal modulation techniques are used in ground-based polarimetric observations. The spatial modulation technique has the advantage of giving simultaneous measurements, but the disadvantage of using different optical paths and detectors. Temporal modulation uses the same optical path and hence a unique detector response, but the sequential measurements are taken under different observing conditions. We propose to develop a new imaging polarimeter exploiting both techniques, in the same device. The two orthogonal states of linear polarization are separated, creating two images (spatial modulation), and by using two LCVR the ellipticity of the radiation going through the two paths are rapidly changed (temporal modulation).

3. Instrument and LCVR description

The polarimeter outline is constituted of: i) an optical bandpass filter, centered on the wavelength of operation of the LCVR ($\sim$ 530 nm); ii) a fixed quarter wave retarder with fast axis at $0°$; iii) a LCVR with fast axis at $45°$; iv) a linear polarizer with transmission axis at $0°$. All the components are placed in a telecentric beam, so that variations in either transmission or polarization axis across the elements are averaged over the field of view. Liquid crystals retarders are electrically variable waveplates. Retardance is altered by applying a variable, low voltage waveform, with the birifrangence decreasing with the increasing voltage, causing a reduction in retardance. The change of the LCVR retardance induced by the variable voltage, is usually given for a fixed wavelength.

The coronal polarized brightness (pB) is weakly λ-dependent, therefore the wider the polarimeter bandpass the higher is the S/N ratio. The retardance of LCVR is λ-dependent. Therefore, the polarimeter response as a function of λ must be characterized in order to determine the wider filter bandpass that can be utilized for the pB measurement. Fixed retardance waveplates can be made achromatic (Pancharatnam 1955). An attempt to construct an achromatic liquid crystals waveplate has been made by Kohns et al. (1996). Variable LCVR retardance vs. λ will be characterized as part of the development of the polarimeter. The Mueller matrix of the LCVR will be measured with a Fourier spectropolarimeter (FSP). The FSP is comprised of a monochromator for the λ selection, and a linear polarizer followed by a rotating fixed $\lambda/4$ achromatic plate, which generate a known input polarization into the LCVR to be characterized. The output polarization will be measured by another rotating $\lambda/4$ achromatic plate, and a linear polarizer acting as an analyzer. By rotating the two $\lambda/4$ plates, the polarized signal will be modulated, and from its Fourier analysis the 16 elements of the Mueller matrix can be determined as a function of λ. This procedure allows us to determine the bandpass width $\Delta\lambda$ of the polarimeter filter to be selected. The same characterization will be done for the assembled polarimeter system containing the LCVR.

References

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