DOI 10.59277/RoAJ.2023.1-2.05

POLARIZATION MEASURING ASTRONOMICAL INSTRUMENT: AN IMPROVED METHOD

ADRIAN SABIN POPESCU

Astronomical Institute of the Romanian Academy,
Str. Cutitul de Argint 5, 040557 Bucharest, Romania
Email*: sabinp@aira.astro.ro*

Abstract. This work deals with a new theoretical method proposed with the intent of improving the quality of astronomical polarimetric data. The theoretical method is applied to one of the simplest possible birefringent type polarizer device constructs, being a hybrid measurement procedure between the fixed position angles and the continuous rotation records of the modulator (in our case, the quarter-wave plate) methods. It can be suitable for some astronomical applications in Planetary Science and Stellar Astrophysics, as their polarimetric parameters (polarization degree, polarization angle and Stokes parameters) have relatively stable values, allowing for the iterative proposed procedure. The validity of the procedure is expected to be practically proven by comparing the quality of the polarization parameters obtained with it, on the proposed instrument, with the results obtained with a similar standardized instrument on the market.

Key words: astronomy, instruments, polarimetry.

1. INTRODUCTION

To completely describe an electromagnetic wave, one needs to know its intensity, frequency, the direction of propagation (by Poynting's vector) and the orientation of the electric (or magnetic) field oscillations relative to a coordinate system. These requirements will translate to the four main areas within observational Astronomy: photometry, spectrometry, astrometry and polarimetry. This shows how important is polarimetry, as one of the fields dealing with the measurement of time-dependency of electromagnetic radiation parameters.

By harnessing the power of polarized electromagnetic radiation and its all-encompassing four Stokes parameters for linear and circular polarization, as well as the polarization degree, we have the opportunity to unlock a wealth of new knowledge about phenomena that are highly anisotropic or asymmetric.

At the beginning of the 19^{th} century, an important property of some crystals, named dichroism, made possible the construction of the first polarization measuring device. As a result of passing white light through a dichroic crystal, and then through a suitably oriented doubly refracting crystal, the two emerging beams would have different colors. This property was discovered by Wollaston (1804), who observed that the light transmitted by potassium chloropalladite (K_2PdCl_4) appeared red or green as function of the light path relative to the crystal axes.

At present, most of the optical elements used in polarization measuring instruments operate on the birefringence principle. This is the property of some specific crystals to have their refractive indices determined by the orientation of the electric vector of the incoming radiation. Many of these modern polarimetric instruments are described by Serkowski (1974). Most of them need, aside from the birefringent crystal, a modulator and a detector system. The modulator is, in most cases, a rotatable wave plate with its transmittance sensitive (as a function of the wave plate's crystal axis) to the vibration directions of the electric perturbations within the incoming beam. The polarization measurements can be done with this modulator rotated at specific fixed positions or by integrating the value of the transmitted intensity over specific angular domains, for a continuously rotating wave plate. When intending to measure linear polarization and its Stokes parameters U and Q, it is enough to use a half-wave plate, while when wanting to measure also the circular polarization and its associated V Stokes parameter, we should use a quarter-wave plate.

Finally, as the last ingredient of a successful measurement, we should take into account the purpose for which some specific devices and methods can be employed. From this point of view there are basically five types of polarimeters (Keller *et al.*, 2015):

- General purpose polarimeters;
- High-sensitivity polarimeters, which are polarimeters used to measure small polarizations or to measure small variations in an object's polarization;
- High spectral resolution polarimeters, which are, mainly, used to study the magnetic field of different stars by analyzing the Zeeman splitting in spectral lines;
- High contrast polarimeters, which are polarimeters that can be used to directly image exoplanets or circumstellar discs;
- High time resolution polarimeters, which are polarimeters that measure the polarimetric properties of very dynamic events such as the afterglow of gamma ray bursts.

In our case, for the phenomena in which we want an iterative improvement of precision, we should have at least some tens of minutes of stability (constancy) of the polarimetric parameters. So, for being able to use our method to the measurement of the polarization of variable stellar objects and also of solar system's planets and Near Earth Objects (NEO), topics to which our colleagues from the Romanian Astronomical Institute's departments activity relate, we should qualify in the class of "general purpose" polarimeters and, at the same time, to be able to account for "high-sensitivity" (same as high-precision) polarization data.

2. THE POLARIZATION MEASURING INSTRUMENT

Out of the most precise instruments of its class used at the present time, as the simplest (and cheapest) benchmark instrumental design, we propose a particular case that, essentially, consists of a continuously rotating quarter-wave plate retarder placed in front of a fixed "dual beam" (D.B.) Foster or Wollaston prism (see Figure 1). As in the case of any polarimetric instrumental construct, the dependence of the output signal (recorded intensity) on the Stokes vector of the incoming light can be expressed in terms of products of the Mueller matrices of the individual constructive elements of the instrumental ensemble (with care towards the matrix multiplication order reflected by the order in which the light interacts with these elements). These Mueller matrices encode effects as changes in the differential transmission for the polarization vibrations (transmittance), phase delays affecting the orthogonal vibrations (retardation) or rotation of the direction of vibration of the linear polarization or of the major axis of the polarization ellipse. In the next section of this paper, based on this instrumental concept, we will create our method to be used in the mentioned astronomic polarimetric studies.

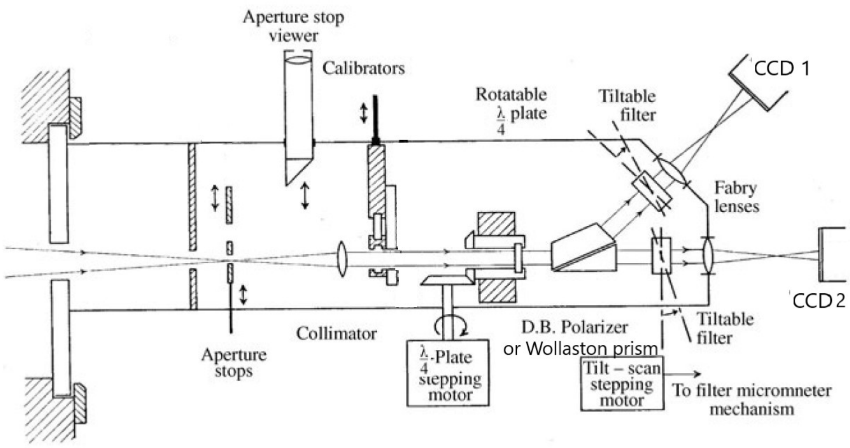

Fig. 1 – The proposed polarimeter (adapted after Clarke *et al.* (1975)) intended to be installed on a telescope, as part of the instrumental setup dedicated to polarization related studies. Its different components are described in the text.

The main constitutive components of the proposed instrument are:

1. **Adjustable aperture and aperture stopper**. Is used for narrowing or widening the field of view (FoV) for different angular size objects or photon emission rates. Another reason for an adjustable aperture is, for example, to have in the FoV only the studied star, or the star plus its surrounding (envelope or ejecta), or

the studied star and a standard calibration star for the spectral range of interest (which might be closer or further away in angular separation from our target star). According to Pospergelis (1965), the field stop must have a knife edge of strictly circular shape, with a minimal reflecting surface at its edge. The aperture should be made with a non-metallic material such as ebonite, and the beam must pass through the hole symmetrically. If these conditions are not met, spurious linear polarization of up to 0.1% may arise.

2. **Collimator**. Lens used for changing the diverging light into a parallel beam.

3. **Calibrator (compensator)**. It is an optical ensemble (maybe a device with applied voltage tuned to produce an adjustable phase delay) used for the telescope's phase delay correction (see, for example Clarke, 2010, pg. 119-120) This delay is introduced by the telescope's mirrors or lenses. The compensator is to be mounted after the telescope and before the optical components of the polarimeter.

4. **Rotatable quarter-wave plate retarder**. As part of the process of determining light's state of polarization, the retarder is having the purpose of changing the phase relation between the orthogonally resolved components of a beam of light. The retarders that introduce phase delays of $\pi/2$ are called quarter-wave, while the ones that introduce phase delays of π are known as half-wave retarders. Quarter-wave retarders are used to convert from circular to linear, or from linear to circular polarized light. Taking advantage of the phase delay introduced between the two orthogonal components of the electric field of the incident light, the half-wave retarders change (rotate), in a measurable way (by Mueller matrices), the vibrational direction of the light relative to the reference axis of the retarder. For alternative retarder choices (tunable wave plates involving nematic liquid crystals, or a mesh of transparent material with an externally applied electric field) see, for example, Chapter 6.3.3, pg. 117-118, from Clarke (2010).

5. **Polarizer of Foster or Wollaston prism type**. Different choices available for the Wollaston prism (calcite or quartz crystal) are presented in Chapter 6.2.2, pg. 104-107, from Clarke (2010). Either way, the Foster type of prism design presented by Clarke (2010) is the desired one for our instrument. For it, the crystal is to be cut so that the optic axis lies in the plane of the entrance face of the first prism and, also, in the plane of the exit face of the second prism, the optic axes in the prisms being parallel to each other. With this design, the extraordinary ray experiences no change of refractive index at the interface and passes straight through the prisms, while the ordinary ray suffers total internal

reflection at the cement interface. The exit face is cut to allow the ordinary ray to emerge at normal incidence and the angles of the prisms are to be chosen to give a convenient beam divergence angle.

6. **Tiltable narrow-band interference filters**. Are used for selecting the spectral domain of interest from the two orthogonally polarized beams coming from the beamsplitter. By tilting the filters in the collimated beams, the passband central wavelength can be moved to a shorter wavelength.
7. **Fabry lenses**. They provide an image of the telescope's objective lens. By imaging the objective lens rather than the object, they prevent the small movements of the image across the sensor.
8. **Synchronized and identical CCD cameras**. Used as sensors, to record the two polarized signals.
9. **A commercially distributed polarimetric camera**. Its first purpose will be (by placing it on the telescope instead of our polarimeter) to find what "calibrators" we need to cancel the phase delay and the polarization introduced by the telescope's optics (on an "artificial star" and a standard star). Its second purpose will be to check the validity of our hybrid theoretical method and see to what degree it improves the values of the Stokes parameters given by this commercial device.
10. **Depolarizer**. Thick lens to be used for calibration with an "artificial star" (centered on the spectral domain of interest on which the research will be done). For more details see Chapter 6.5, pg. 120-121, from Clarke (2010).

3. POLARIZATION MEASURING METHODS

In general, the primary signals obtained from polarimetric observations, representing the two directions of vibration known as the ordinary (or "o-ray") and extraordinary (or "e-ray"), need to be interpreted according to the design of the used equipment. The ordinary ray denotes the electric field component perpendicular to the plane formed by the polarizer crystal's optic axes (or the plane of incidence), being found in the literature with the symbol $\perp$. The extraordinary ray denotes the electric field component parallel to the plane formed by the polarizer crystal's optic axes (or the plane of incidence), being found in the literature with the symbol $||$. In observational astronomy, for an easy conversion, the plane of incidence is described with respect to equatorial coordinates, in such a way that, when the polarization angle (the position angle of the direction of vibration) is zero, the polarization transmission axis runs in the N-S direction, and aligned with Declination.

If we are having an instrument that consists only of a rotating (with fixed steps) polarizer, after applying the Mueller calculus to the source's Stokes vector, the measured parameter I' will be:

$$I'(\alpha) = \frac{1}{2}(I + Q\cos 2\alpha + U\sin 2\alpha) , \tag{1}$$

where α is the angle made by the principal axis of the polarizer with respect to the axial frame describing the original Stokes parameters (here, relative to the Q parameter).

In fact, the actual intensity signal $S_{\|}(\alpha)$ obtained at the detector involves also parameters that describe the detector's response to unit intensity, $G_{\|}(\alpha)$, and the temporal variation of the signal, $T(t)$, for source independent reasons (atmospheric scintillation and secular changes in atmospheric extinction):

$$S_{\|}(\alpha) = \frac{1}{2}G_{\|}(\alpha)T(t)\,[I + Q\cos 2\alpha + U\sin 2\alpha] . \tag{2}$$

$G_{\|}(\alpha)$ accounts also for the possibility that the detector signal is affected by the rotational position of the polarizer relative to the field oscillation and by its directional sensitivity with respect to the direction of vibration of the light that illuminates it.

Now, for the same case of a rotating polarizer, lets consider the beam split into its orthogonal components. With the development of two-dimensional detectors such as CCDs, orthogonally resolved images can now be recorded simultaneously, and their intensities can be automatically recorded (while time correlated) with two identical CCD cameras.

For having the orthogonal component of (2), we must take $\alpha + \pi/2$ instead of α. In this case, the recorded signal for the second beam will be:

$$S_{\perp}(\alpha) = \frac{1}{2}G_{\perp}(\alpha)T(t)\,[I - Q\cos 2\alpha - U\sin 2\alpha] . \tag{3}$$

By exploring the simultaneous signals from orthogonally resolved beams, Hiltner (Hiltner, 1951, 1952) demonstrated the coherence of the intensity scintillation which both carry.

If we insert a depolarizer in the beam coming from an "artificial star" and we assume that its transmittance is identical for the orthogonal beams (true for a narrow enough emission band from the considered calibration light source), the ratio of the two outputs may be then represented by:

$$\frac{S'_{\|}(\alpha)}{S'_{\perp}(\alpha)} = \frac{G_{\|}(\alpha)}{G_{\perp}(\alpha)} . \tag{4}$$

In this way, by observing an "artificial star" and deriving, from (4), the factor to be applied to the ratio of the orthogonal beams signals of a targeted astronomical object (in the spectral domain of the calibration source), we can cancel the observational differences introduced by the use of two detectors. And this happens because each of the CCD cameras from Figure 1 is observing only one of the orthogonal beams.

For the elimination of scintillation noise, the next step would be to take the same ratio of orthogonal signals, but this time by observing a calibration star of known (or zero) polarization, situated in the same FoV and close enough to the studied science object, for it to be affected by the same atmospheric turbulence. If no standard star from the standard stars catalogues is available for the mentioned calibration purposes, an "artificial laser star" could be used instead.

The last "calibration" which can be done for the proposed instrumental device is the calibration with a bought, factory produced and standardized polarimetric camera. With it, we will be able to check the validity of our instrument's obtained values for different polarization parameters (as degree or angle of polarization) and also asses to what degree they're improved from a "commercial" produced device. This bought device should be checked on the same "artificial star" as our custom made device. Calibrating with the bought device might have also another purpose: finding how the telescope changes the polarimetric parameters and what "calibrators" are needed to nullify these effects.

Let's now replace the measuring device and consider that we have a system consisting of a rotating half-wave plate prior to a fixed polarizer. This principle was employed by Lyot (1948) in prototype instruments using polarimetric cells.

The system has the advantage of alleviating the issues of spurious signals that might be generated by the detector's sensitivity to the direction of polarization that illuminates it (solved by keeping the polarizer fixed). A disadvantage of using a simple wave plate is that its phase delay suffers from spectral dispersion and can only be considered as providing a half-wave retardation over the limited spectral range for which was calibrated with the "artificial star".

As for the rotating polarizer, after applying the Mueller calculus for the considered optical elements, we obtain:

$$S_{\|}(\alpha) = \frac{1}{2} G_{\|}(\alpha) T(t) \left[I + Q \cos 4\alpha + U \sin 4\alpha \right] . \tag{5}$$

A similar signal $S_{\perp}(\alpha)$ is also available with an anti-phase modulation for measurements made with a two-beam fixed polarizer.

Now, instead of discrete records (at fixed positional angles), for even better removal of the atmospheric noise, we could use a continuous high speed rotation of the modulator (sampling and integrating over circular sectors), coupled with the use of the orthogonal beams ratios.

Klare *et al.* (1972) used tree recording channels: the first channel recorded the signal continuously; the second channel integrated over [0, $\pi/2$] and [π, $3\pi/2$] degrees; the third channel integrated over [$\pi/4$, $3\pi/4$] and [$5\pi/4$, $7\pi/4$] degrees. Thus, the three recorded measurements over *N* complete cycles may be written:

$$\begin{aligned} S_{\parallel 1} &= N\int_0^{2\pi} S_{\parallel}(\alpha)\,d\alpha = N\pi I\ , \\ S_{\parallel 2} &= N\int_0^{\frac{\pi}{2}} S_{\parallel}(\alpha)\,d\alpha + N\int_{\pi}^{\frac{3\pi}{2}} S_{\parallel}(\alpha)\,d\alpha \\ &= 2N\int_0^{\frac{\pi}{2}} S_{\parallel}(\alpha)\,d\alpha = N\left(\frac{\pi}{2}I + U\right)\ , \\ S_{\parallel 3} &= N\int_{\frac{\pi}{4}}^{\frac{3\pi}{4}} S_{\parallel}(\alpha)\,d\alpha + N\int_{\frac{5\pi}{4}}^{\frac{7\pi}{4}} S_{\parallel}(\alpha)\,d\alpha \\ &= 2N\int_{\frac{\pi}{4}}^{\frac{3\pi}{4}} S_{\parallel}(\alpha)\,d\alpha = N\left(\frac{\pi}{2}I - Q\right)\ . \end{aligned} \tag{6}$$

The main problem with this development is that is able to study only the linear polarization and its Stokes parameters, but isn't capable to say anything about the circular polarization and its *V* parameter. In these conditions, we will return to the continuous recording with a rotating modulator only after we will find a convenient way to describe also the circular polarization by a similar relation to the ones used for the linear polarization parameters in (6) and, so, to completely determine the polarization vector.

For this to be possible, instead of rotating the polarizer or a half-wave plate, we will need at least one rotating quarter-wave plate in front of a fixed polarizer. In this case, Clarke (2010) considers that the measured signal is represented by:

$$I'(\alpha) = \frac{1}{2}\left[I + \frac{Q}{2} + \frac{1}{2}\left(Q\cos 4\alpha + U\sin 4\alpha\right) - V\sin 2\alpha\right]\ . \tag{7}$$

Because, as we already saw in (2) and (5), the actual signal will be $S_{\parallel}(\alpha)$ and it will contain the product $G_{\parallel}(\alpha)\,T(t)$, we will be able to write for this optical construction:

$$S_{\parallel}(\alpha) = \frac{1}{2}G_{\parallel}(\alpha)\,T(t)\left[I + \frac{Q}{2} + \frac{1}{2}\left(Q\cos 4\alpha + U\sin 4\alpha\right) - V\sin 2\alpha\right] \tag{8}$$

and, for its orthogonal component, in which we replace α with $\alpha + \pi/2$:

$$S_{\perp}(\alpha) \quad = \quad \frac{1}{2} G_{\perp}(\alpha) T(t) \left[I + \frac{Q}{2} - \frac{1}{2}\left(Q\cos 4\alpha + U \sin 4\alpha\right) + V \sin 2\alpha \right]. \quad (9)$$

Our stringent need is an expression for the parallel signals analogous to the ones from (6) and of their perpendicular counterparts determined by integrating over $S_{\perp}(\alpha)$ on the same domains as for $S_{\|}(\alpha)$. With these known, we could do the three ratios $S_{\| m}/S_{\perp m}$, where $m = \{1, 2, 3\}$. For a real astronomical object studied through this method, we can stop our data acquisition only when all three values of $S_{\| m}/S_{\perp m}$, computed "live" (at the time of the observation), converge to 1 (with the allowed precision given by the time interval). This will happen after enough cycles *N* done by the quarter-wave retarder, equivalent to an $N\,t$ integration time, where *t* is the time of one rotation. In this way, we will be certain that we have good statistics for the data and, finally, be able to start applying post-processing polarization statistical methods, as the ones described in chapter 5 of Clarke (2010).

With this said, we can return to the theoretical issue that remained to be addressed: what are the $S_{\| m}$ for a polarimeter with a rotating quarter-wave retarder and what is their relation with the Stokes parameters?

Having the same reasoning as Clarke (2010) and the same formula (7), but with different notations, Goldstein (2003) replaces α with $\omega\, t$, converting it to a truncated Fourier series:

$$I(\omega t) \quad = \quad \frac{1}{2}\left[A - B \sin 2\omega t + C \cos 4\omega t + D \sin 4\omega t\right] , \qquad (10)$$

with:

$$\begin{aligned} A &= S_0 + \frac{S_1}{2} \\ B &= S_3 \\ C &= \frac{S_1}{2} \\ D &= \frac{S_2}{2} \end{aligned} \qquad (11)$$

where S_0, S_1, S_2 and S_3 are the Stokes parameters in Goldstein's notation. For consistency we will go back to our previous α angle notation. From the Fourier analysis on the above relations we find:

$$
\begin{aligned}
A &= \frac{1}{\pi}\int_0^{2\pi} I(\alpha)\,d\alpha \\
B &= \frac{2}{\pi}\int_0^{2\pi} I(\alpha)\sin 2\alpha\,d\alpha \\
C &= \frac{2}{\pi}\int_0^{2\pi} I(\alpha)\cos 4\alpha\,d\alpha \\
D &= \frac{2}{\pi}\int_0^{2\pi} I(\alpha)\sin 4\alpha\,d\alpha
\end{aligned}
\tag{12}
$$

Solving (11) we obtain for the Stokes parameters:

$$
\begin{aligned}
S_0 &= A - C \\
S_1 &= 2C \\
S_2 &= 2D \\
S_3 &= B
\end{aligned}
\tag{13}
$$

with *A*, *B*, *C* and *D* given by (12).

As the observational conditions will change for a large integration time, we will have to consider not only a simple multiplication by *N* rotations of the integral results as we did in (6), but to take into account that the integral value over one cycle will be different from the one for the previous cycle. This means a sum of these *N* integrals. In consequence, for computing the Stokes parameters for this instrumental construction, first we will have to compute the *A*, *B*, *C* and *D* coefficients from (12) for the parallel and perpendicular beams, but with sums over *N* rotation cycles.

The explicit formulas for the coefficients of the parallel beam will be:

$$
\begin{aligned}
A_{\|} &= \frac{1}{\pi}\sum_{r=1}^{N}\int_0^{2\pi} S_{\|}(\alpha)\,d\alpha \\
B_{\|} &= \frac{2}{\pi}\sum_{r=1}^{N}\int_0^{2\pi} S_{\|}(\alpha)\sin 2\alpha\,d\alpha \\
C_{\|} &= \frac{2}{\pi}\sum_{r=1}^{N}\int_0^{2\pi} S_{\|}(\alpha)\cos 4\alpha\,d\alpha \\
D_{\|} &= \frac{2}{\pi}\sum_{r=1}^{N}\int_0^{2\pi} S_{\|}(\alpha)\sin 4\alpha\,d\alpha
\end{aligned}
\tag{14}
$$

where $\alpha = \omega t$ and $S_{\|}(\alpha)$ is the one given in (8). In the same manner, we can write the explicit form for the coefficients of the perpendicular beam:

$$
\begin{aligned}
A_\perp &= \frac{1}{\pi}\sum_{r=1}^{N}\int_0^{2\pi} S_\perp(\alpha)\,d\alpha \\
B_\perp &= \frac{2}{\pi}\sum_{r=1}^{N}\int_0^{2\pi} S_\perp(\alpha)\sin 2\alpha\,d\alpha \\
C_\perp &= \frac{2}{\pi}\sum_{r=1}^{N}\int_0^{2\pi} S_\perp(\alpha)\cos 4\alpha\,d\alpha \\
D_\perp &= \frac{2}{\pi}\sum_{r=1}^{N}\int_0^{2\pi} S_\perp(\alpha)\sin 4\alpha\,d\alpha
\end{aligned}
\tag{15}
$$

with $S_\perp(\alpha)$ from (9).

Even if our theoretical development previously described starts to diverge from the Arnoldt (2011) approach (which is following closely Goldstein (2003) theory), his data sampling and analysis would be a valuable guideline to our observational method, by assessing what other errors and corrections might arise in practice while working with this class of instruments (containing a continuously rotating quarter-wave plate).

4. THE METHOD

For the phenomenon of interest, on a single rotation of the modulator plate, our goal will be to make as many records possible, at different angles, for both orthogonal signals. Then we transfer them to the computer. Here we interpolate the signal values and construct a function to follow closely the variations of each of the orthogonal signals. We integrate the resulting functions for a complete rotation of the waveplate and compute the coefficients from (14) and (15) where, for the moment, N is 1. After this we do the corresponding ratio between the coefficients obtained for the two orthogonal beams (the equivalent of the discussed $S_{\parallel m}/S_{\perp m}$ ratios), specifically $A_\parallel/A_\perp$, $B_\parallel/B_\perp$ and $C_\parallel/C_\perp$. If all these ratios are equal to 1 (or fall in, lets say, a 10% error range from it) we stop the recording and go to the (13) relations to compute the Stokes parameters and, after, the polarization degree and angle. If the mentioned coefficient ratios aren't close to 1, the computer will command the microcontroller to start another data acquisition. And the above process repeats, the only difference being that the rotation number has to be indexed in N, the result of the integration for the current cycle adding to the previous N – 1 previous results in the (14) and (15) relations, before computing the coefficient ratios. The measurement will stop and the computation of the Stokes parameters will start at the point when the coefficient ratios will be close to 1 in a limit set a priori. For optimization and minimization of overhead times, it can be set that the transfer and computations occur each 10 (or 100) waveplate rotations.

5. CONCLUSIONS

This paper is a manifest for the need of improvement in polarimetric measurements and in their use as complementary means, aside photometric and spectrometric methods, in describing the electromagnetic phenomena and their astronomical sources' properties.

As an example, the advantages of the polarimetric method are clearly illustrated by Cellino *et al.* (2014) who highlight among its benefits, compared to the competing thermal radiometric method used in asteroid sizes and albedos determinations, the removal of the simultaneity requirement of measurements in V and in the thermal IR wavelengths, as is advisable in thermal radiometry (and which is almost never satisfied, requiring also satellite data for the IR spectral range, otherwise affected by atmospheric extinction), and the availability of measurement opportunities that would come with the development of polarization ground observing facilities, which won't be limited by factors as operational lifetimes or coverage as satellites are.

The vast majority of existing polarimetric instruments dedicated to Astronomy (Keller *et al.*, 2015) sacrifice precision for the sake of constructive and computational simplicity. Not many new polarimetric instruments are constructed with the intent of measuring more than linear polarization and most of them miss the opportunity of improving their data quality by working with continuous rotating wave plates, using instead fixed position measurements. On the other hand, having only a half-wave plate as part of your polarization measuring instrument has as a consequence the loss of important information about the studied phenomena, such as, for example, information about its magnetic fields and about their interaction with matter. This simplifies the life and knowledge of complex codes and methods for the end user, but also deprives it of the best data possible.

For interest renewal in polarimetry to happen, there is also a dire necessity for the implementation of new, and even of not so new but neglected methods (as is the one based on the continuous rotating wave plate).

Our new method, in essence, based on a continuously rotating wave plate, is drafted on the best existing instrumental concept, able to measure both linear and circular polarization. This method is accompanied by a detailed description of the way in which different needed calibrations are done. At the present time, our proposed method waits for validation, this requiring the physical construction of the proposed device and its testing on a telescope.

The final goal of this instrumental device and of its related method would be to establish a new research direction in Romania and a new auspicious climate for international collaborations between different research departments and groups, by using polarimetric measurements in multidisciplinary Astrophysics projects. This endeavor would call for the development and placement in Romania of an instrument (telescope and polarimeter) dedicated to astrophysical polarimetric data acquisitions.

Acknowledgements. I want to thank the reviewer for the useful comments and remarks that helped in achieving clarity and correctitude of the information contained in this paper.

REFERENCES

Arnoldt, S.: 2011, *Rotating Quarter-Wave Plate Stokes Polarimeter*, Bachelorarbeit in Physik, Vorgelegt der Mathematischen-Naturwissenschaftlichen Fakultät der Universität Bonn.

Cellino A.. Bagnulo, S.: 2014, *IAU Symp.* **10**, 313, Symposium S305: *Polarimetry: From the Sun to Stars and Stellar Environments*.

Clarke, D., McLean, I.S.: 1975, *Mon. Not. Roy. Astron. Soc.* **172**, 545.

Clarke, D.: 2010, *Stellar Polarimetry*, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.

Goldstein, D.: 2003, *Light: Second Edition, Revised and Expanded*, Marcel Dekker, Inc., New York, p. 117.

Hiltner, W.A.: 1951, *The Observatory* **71**, 234.

Hiltner, W.A.: 1952, *Astron. J.* **57**, 13.

Keller, C. U., Snik, F., Harrington, D. M., Packham C.: 2015, *Polarimetry of Stars and Planetary Systems*, Eds. L. Kolokolova et al., Chapter *Instrumentation*, 35–61, Cambridge Univ. Press.

Klare, G., Neckel, Th., Schnur, G.: 1972, *Astron. Astrophys.* **5**, 239.

Lyot, B.: 1948, *Un polarimètre photoélectrique*, Comptes rendus des séances de l'Académie des Sciences, **226**, 25.

Pospergelis, M.M.: 1965, *Sov. Astron.* **9**, 398.

Serkowski, K.: 1974, *Polarization techniques*, in Methods of Experimental Physics, Eds. M.L. Meeks & N.P. Carleton, **12**, Astrophysics: Part A – Optical & Infrared, Academic Press, New York.

Wollaston, W.H.: 1804, *Philos. Trans. R. Soc.* **94**, 419.

Received on 21 March 2023