



Science with a Large Field-of-view Polarization Survey: The Large Array Survey Telescope Polarization Node (LAST-P)

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Abstract

Optical polarimetry provides information on the geometry of the emitting region, the magnetic field configuration and the properties of dust in astrophysical sources. Current state-of-the-art instruments typically have a small field of view (FoV), which poses a challenge for conducting wide surveys. We propose the construction of the Large Array Survey Telescope Polarization Node (LAST-P), a wide-field array of optical polarimeters. LAST-P is designed for high-cadence ($\lesssim 1$ day) polarization monitoring of numerous astrophysical transients, such as the early phases of gamma-ray bursts, supernovae, and novae. Furthermore, LAST-P will facilitate the creation of extensive polarization catalogs for X-ray binaries and white dwarfs, alongside a large FoV study of the interstellar medium. In survey mode, LAST-P will cover a FoV of 88.8 deg^2 . With a 15×1 minutes exposure, the instrument will be capable of measuring polarization of sources as faint as Gaia Bp-magnitude ~ 20.9 . The precision on the linear polarization degree will reach 0.7%, 1.5%, and 3.5% for sources with magnitudes 17, 18, and 19, respectively, for a seeing of $2.7''$, air mass of about 1 for observations in dark locations. We propose three distinct non-simultaneous survey strategies, among them an active galactic nuclei (AGN) strategy for long-term monitoring of ~ 200 AGN with < 1 day cadence. In this paper, we present the predicted sensitivity of the instrument and outline the various science cases it is designed to explore.

Unified Astronomy Thesaurus concepts: Active galactic nuclei (16); Extragalactic astronomy (506); Relativistic jets (1390); Gamma-ray bursts (629); Astronomical instrumentation (799); Optical observatories (1170); Photometry (1234); Polarimetry (1278); Polarimeters (1277); White dwarf stars (1799)

1. Introduction

Systematic mapping of both the static and transient sky is responsible for many discoveries in modern astronomy. A large number of instruments provides excellent coverage of the sky in terms of multi-band optical photometry (Shappee et al. 2014; Chambers et al. 2016; Tonry et al. 2018; Bellm et al. 2019; Dyer et al. 2020). However, the community is currently limited to measure the polarization of the optical emission. Crucial information is encoded in the polarization degree (PD) and the polarization angle (PA), as, for example, the geometry of the emitting region and magnetic fields (Blinov & Pavlidou 2019; Hovatta & Lindfors 2019; Zhang 2019;

Marscher & Jorstad 2021); the nature of the acceleration mechanism (Barnier & Done 2024) and accelerated particles (Zhang & Böttcher 2013).

Technical advances in telescopes and cameras design allow us to build a modular, cost-efficient telescope system (Ofek & Ben-Ami 2020). One such example is the Large Array Survey Telescope (LAST, Ben-Ami et al. 2023; Ofek et al. 2023a) installed at the Weizmann Astrophysical Observatory. The first LAST node will include 72 (currently 40 are operational) telescopes with a large field-of-view (FoV) of $2.2 \times 3.4 \approx 7.4 \text{ deg}^2$, totalizing a FoV of 532.8 deg^2 for the entire array. The next logical step is to use the multiple small telescopes approach (Ofek & Ben-Ami 2020) for polarimetry. Here, we suggest the construction of the Large Array Survey Telescope Polarization Node (LAST-P), a new survey telescope for polarimetry. With four polarization filters installed across four co-mounted telescopes observing the same FoV, we will be able to determine the linear PD and polarization PA of all sources in the field. Similar to traditional

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single-dish telescopes relying on dual (Appenzeller 1967) or quadruple beam splitting (e.g. Ramaprakash et al. 2019), LAST-P will simultaneously derive the Stokes parameters without the need to rotate filters, thereby suppressing systematic errors caused by atmospheric or target variability. Uniquely, however, our design offers a much larger FoV, allowing for surveys and monitoring programs to be conducted with high cadence.

We propose an array of 48 telescopes on 12 mounts, with four telescopes per mount in a configuration similar to the LAST array. With each mount observing a 7.4 deg^2 FoV, the complete LAST-P system will achieve a combined instantaneous FoV of 88.8 deg^2 . This FoV is orders of magnitude larger than that of existing polarimetric instruments, such as RoboPol ($\approx 0.052 \text{ deg}^2$; King et al. 2014a), the Nordic Optical Telescope’s ALFOSC instrument ($\approx 0.011 \text{ deg}^2$; Benn & Møller 2009), and the Wide Area Linear Optical Polarimeter ($\approx 0.25 \text{ deg}^2$; Kypriotakis et al. 2024). The large FoV of LAST-P allows for the simultaneous monitoring of large celestial patches. This not only facilitates the high-cadence (e.g., daily) observation of numerous sources, but also significantly enhances our ability to detect transient events in both flux and polarization, including those on the fastest timescales (Kiehlmann et al. 2021).

This paper explores the science cases enabled by this new instrument, serving as the primary motivation for its development and construction. We also report on the current status of the project and discuss the path forward. We begin by describing the current design of the instrument, and the estimated capabilities of the future LAST-P in Section 2. Section 3 delves into the extragalactic and Galactic science cases that LAST-P will enable, focusing on the transient polarimetric sky. Finally, Section 4 outlines the prospects for future developments in the coming years.

2. Instrument and Methods

2.1. Experimental Setup

LAST is a high-cadence imaging survey, currently comprised of 40 out of a planned 72 telescopes. Each telescope combines a Celestron 27.9 cm F/2.2 Rowe–Ackermann Schmidt Astrograph (RSA) with a 61 megapixel CMOS sensor, providing a wide 7.4 deg^2 FoV. The system has a plate scale of $1.25''$ per pixel, and its on-sky image quality is typically $\approx 1.6''$ at the field center, degrading to $\sim 3''\text{--}4''$ at the corners (Ofek et al. 2023b).

With science cases focused on the transient sky (Ben-Ami et al. 2023), LAST operates as a discovery machine, utilizing a real-time pipeline for autonomous detection of new sources (Ofek et al. 2023a), handling a very high (3.3 Gbits) data production rate. The system’s effectiveness has been demonstrated through early results, including the study of the fast blue optical transient AT2022tsd (Ofek et al. 2025), analysis of

the ejecta from the DART-Dimorphos collision (Ofek et al. 2024), and numerous community alerts on new transient detections (e.g., Broussard et al. 2023, 2024a, 2024b; Garrappa et al. 2024).

The LAST-P design envisions that the four telescopes on each mount will be equipped with a 1.25 inch Baader Bessel R-filter (from the UBVRI set) and a linear polarization filter. To evaluate the polarizer’s efficiency, we use the 25.0 mm Thorlabs LPVISC100 as a proxy. This component features a high extinction ratio—a measure of its ability to block light polarized perpendicular (90°) to the filter’s axis. This ratio exceeds 10^4 across our entire range of interest (550 nm–800 nm) and surpasses 10^6 in the 550 to 650 nm wavelength range (Thorlabs Inc. 2016). These polarizers, which consist of prolate ellipsoid nanoparticles embedded in sodium-silicate glass, were fixed at relative orientations of 0° , 45° , 90° , and 135° . Mechanical tolerances in the adapter introduce an alignment uncertainty of several degrees, causing systematic errors in both the PA and the PD. These instrumental effects are corrected by calibrating against a high-polarization standard. In contrast, the camera-to-telescope alignment achieves significantly higher precision, as it is actively determined for each image via astrometric plate-solving.

To validate the LAST-P concept, we implemented a prototype utilizing a single telescope mount from the existing LAST array. Each of the four telescopes was equipped with an R-filter and a linear polarizing filter, fixed at relative orientation angles of 0° , 45° , 90° , and 135° . This configuration facilitates the intensity measurements necessary to determine the Stokes parameters (I , Q , U ; Serkowski 1962), from which the linear PD and PA of the sources are derived. Detailed results from this test setup will be presented in a forthcoming instrument performance publication, following design refinements aimed at mitigating and accurately characterizing systematic uncertainties. In this work, we focus on estimates derived from the performance of LAST (Ofek et al. 2023a) and the transmittance calculations presented below.

2.2. Transmittance

We analyzed the throughput characteristics of LAST-P to evaluate the impact of the color and polarization filters. While a method to derive the effective transmission of the LAST system has been already discussed thoroughly in Garrappa et al. (2025), this section is based on our laboratory measurements. We used a flux calibration setup at DESY (Zeuthen, Germany), as described in Küsters et al. (2022) to characterize the filters and sensors identical to those used in our instrument setup.

Figure 1 displays the system’s transmittance as a function of wavelength for four distinct configurations: “Camera only,” “R Filter + Polarizer,” “R Filter Only,” and “Polarizer Only.”

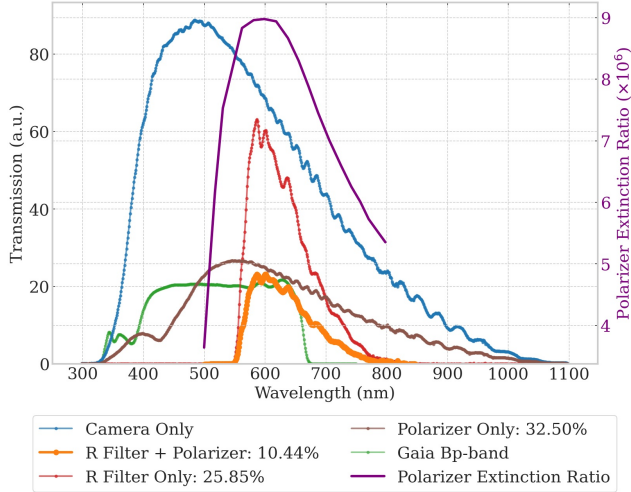


Figure 1. System throughput as function of the wavelength for various instrumental configurations. Configurations plotted include: “Camera only” (bare sensor QE), “R Filter + Polarizer,” “R Filter Only,” and “Polarizer Only.” The legend for filter configurations displays their transmittance, representing the system’s lambda-weighted throughput relative to the “Camera only” baseline. The “Gaia Bp-band” curve shows its “transmission” normalized to the peak of the “R filter + Polarizer Only” system. On the right axis we show the polarizer extinction ratio (purple curve), obtained from Thorlabs Inc. (2016), showing an excellent performance in the region of interest.

To quantify the effective throughput for each configuration, we calculated a lambda-weighted integral of the processed QE curves ($T(\lambda)$), following the methodology in Garrappa et al. (2025) (see Equation (17)): $\int T(\lambda) \lambda d\lambda$. The transmission factor (transmittance) for each filter setup was then determined by dividing its lambda-weighted integral by that of the “Camera only” configuration. These transmittance, quoted in the legend of Figure 1, quantify the throughput relative to the bare camera system.

Our estimates indicate that incorporating the polarization filter reduces the system’s lambda-weighted throughput to $\approx 33\%$ of the “Camera only” value. When both the R-filter and the polarization filter are used, the throughput is further reduced to $\approx 10\%$. While atmospheric Rayleigh scattering reduces throughput, its effect is most significant at blue wavelengths. Given that our instrumental design employs an R-filter, which largely blocks this spectral region, the impact on our measurements is small and has therefore not been included in this analysis. For all estimates in this work, we use the Gaia Bp magnitude to maintain consistency with our previous work Ofek et al. (2023a).

2.3. Estimated Photometric Capability of LAST-P

The LAST system achieves a 5σ limiting magnitude of $m_{\text{lim},0} \approx 19.6$ mag (Gaia B_p) in a single $t_0 = 20$ s exposure (Ofek et al. 2023a). To derive the sensitivity of the new setup with the R-filter and polarization filter, we incorporate the

measured noise sources into a unified signal-to-noise ratio (SNR) model. This methodology, fully detailed in Appendix, anchors the instrument’s performance to the measured $m_{\text{lim},0}$ and it explicitly accounts for both detector properties and the total $\approx 10\%$ throughput reduction due to the added R-filter and polarization optics. For an observation of 15 exposures of 60 s each ($t_{\text{total}} = 900$ s), the projected limiting magnitude is estimated to be 20.4. A darker site would result in lower background noise, yielding an anticipated 50%–60% enhancement in the SNR. This 50%–60% enhancement corresponds to an increase of approximately 0.5 in the dark sky brightness, and hence, on the limiting magnitude. The following estimates (also summarized in Table 1) use these improved dark sky conditions in the extrapolations, since the location of LAST-P is not yet defined but will be preferentially in a darker location. This yields a projected 5σ detection limit of $m_{\text{lim}} \approx 20.9$ mag for the co-added sequence for the same observing conditions at the LAST site. The limiting magnitude worsens to $m_{\text{lim}} \approx 19.4$ mag ($m_{\text{lim}} \approx 19.0$ mag) for a shorter exposure of $T_{\text{total}} = 60$ s ($T_{\text{total}} = 30$ s). We caution, however, that our estimates include systematic uncertainties for photometry but not yet for polarimetry. A detailed study of instrumental polarization requires the finalized instrument design and is planned for a future stage.

2.4. Estimated Polarimetric Capability of LAST-P

To assess the polarimetric potential of LAST-P, we map the photometric SNR to the expected uncertainties in PD, PA, and the Minimum Detectable Polarization (MDP).

While the exact reduction of polarimetric data involves error propagation (detailed in Appendix), we utilize the simplified approximations derived in Appendix A.4 to estimate the instrument’s theoretical sensitivity. The absolute uncertainty in the PD scales inversely with the SNR:

$$\sigma_{\text{PD}} \approx \frac{1}{\text{SNR}} \quad (1)$$

Similarly, the PA uncertainty depends on the source’s intrinsic polarization:

$$\sigma_{\text{PA}} [^\circ] \approx \frac{28.65^\circ}{\text{PD} \cdot \text{SNR}} \quad (2)$$

We also calculate the MDP in percentage at the 99% confidence level (see Appendix A.3):

$$\text{MDP} \approx 368.4 \times \frac{1}{\text{SNR}}. \quad (3)$$

Table 1 summarizes these capabilities for a 15×60 s observing sequence. These estimates rely on the derived 5σ limiting magnitude of $m_{\text{lim}} \approx 20.9$, assuming a representative delivered image quality (FWHM) of $2''.7$ (Ofek et al. 2023a), and using the SNR scaling developed in Appendix. For

Table 1
Estimated Polarimetric Precision for the Survey Mode

Mag	SNR	σ_{PD} (absolute %)	MDP (99%) (%)	σ_{PA} (deg)		
				PD = 5%	PD = 10%	PD = 15%
17.0	143	0.7	2.6	4.0	2.0	1.2
18.0	66	1.5	5.6	8.7	4.3	2.9
19.0	28	3.5	13.1	20.3	10.2	6.8

Note. Estimates derived from a limiting magnitude of $m_{lim} \approx 20.9$ mag for a 15×60 s co-added observation. For the Deep Mode of observation, the estimates improve by a factor of 2. σ_{PA} values are based on the small-angle approximation. MDP is calculated at the 99% confidence level from Equation (A15). Additional estimates can be found in Table 3.

estimates with different exposure times and source magnitudes we refer the reader to Appendix A.5.

We emphasize that these estimates reflect the statistical photon-noise limit; in practice, the achievable precision may be further constrained by systematic uncertainties, such as instrumental polarization residuals and sky subtraction errors.

2.5. Survey Strategy

The main advantage of our instrument is its wide FoV, which enables polarization monitoring of a large number of sources with high cadence. Following the standard LAST photometric observing strategy (Ben-Ami et al. 2023), we plan to operate three distinct non-simultaneous strategies: a *high-cadence* survey, a *low-cadence* survey, and an *AGN* strategy.

In the high-cadence survey, the same sky regions will be visited three times per night. Depending on source density and on the scientific interest of each region, we will adopt either the survey mode (with one unit centered on each field) or the deep mode (with four units co-pointed for increased sensitivity), as discussed above.

We assume an average of 5 hr per night dedicated to survey observations, excluding calibration and follow-up time for Targets of Opportunity. With three visits per region, 15 observations per visit, and 1 minute per observation, this corresponds to a total of $3 \times 15 \times 1$ minutes = 45 minutes per region. This allows coverage of up to 6 regions per night (accounting for overheads due to re-pointing). The instrument has a FoV of 88.8 deg^2 . We therefore cover $6 \times 88.8 = 532.8 \text{ deg}^2$ per night in survey mode, and $532.8/4 = 133.2 \text{ deg}^2$ per night in deep mode (four telescopes observing the same region).

Given that we consider the same geographical latitude as for the LAST site, sources can be observed on average down to a declination of -30° , corresponding to a total accessible sky area of $A \approx 31,000 \text{ deg}^2$. This represents 75% of the full available sky, not accounting for limitations due to constraints on the maximum allowed air mass. Therefore, approximately 58 nights are required to cover the entire visible sky at least once in the high-cadence survey mode. Depending on our science goals, it may be beneficial to repeatedly observe the

same sky-region over an extended period, e.g., a full week. This strategy is particularly valuable during the early phases of the survey; it enables validation of our measurements, as well as cross-correlation of variability on timescales longer than a day with data from existing instruments.

In the low-cadence survey, our goal is to cover the largest possible area of the sky as quickly as possible, while still using the standard sequence of 15×1 minutes exposures. To survey the full available sky area of $\approx 31,000 \text{ deg}^2$ using a FoV of 88.8 deg^2 , we require 349 distinct pointings. This corresponds to a total of 87.2 hr of observation. Assuming 5 hr of observing time per night for the survey, the entire region can be covered in approximately 18 nights. This estimates accounts for time lost to re-pointing between fields to complete a full-sky pass, considering the available area of about $31,000 \text{ deg}^2$.

A third survey strategy, focused on bright AGN, will also be implemented. As part of the AGN strategy, each field is observed in survey mode three times over the same night, using 1 minute exposures per-visit. This approach enables coverage of 120 distinct regions per night, each spanning 88.8 deg^2 . It results in a total nightly coverage of approximately $10,656 \text{ deg}^2$, or about 34% of the accessible sky. Under this strategy, an estimated number of 200 AGNs from the GaiaunWISE catalog (Shu et al. 2019) with Gaia Bp-band magnitude brighter than 16 could be monitored with cadence of less than a day (See Section 3.1.1 for details on AGN science). The precision on the PD (PA) of the daily monitored sources with 1 minute exposures would be as low $\approx 1.3\%$ (3.8°) for 16 mag sources with a PD of 10% (see Table 3 for more estimates).

We emphasize that these estimates do not take into account seasonal variations in sky visibility or fluctuations in the total number of observing hours available per night. Rather, they serve as the baseline for developing optimized survey strategies. Table 2 summarizes the survey strategies and modes discussed in this section.

In addition to conducting a continuous survey and responding to community alerts, LAST-P will issue its own rapid photometric and polarimetric alerts for transient events. A key function of these alerts is to facilitate coordinated

Table 2

Summary of Sky Coverage and Time Estimates for Each Observing Mode and Strategy

Strategy	Mode	Sky Area per Night	Full Available Sky in
High-Cadence	Survey	532.8 deg ²	58 days
High-Cadence	Deep	133.2 deg ²	233 days
Low-Cadence	Survey	1,721.5 deg ²	18 days
AGN	Survey	10,656 deg ²	...

optical and gamma-ray observations. LAST-P is also designed to enhance multi-wavelength science by participating in joint campaigns with other observatories. Based on approved proposals, it will perform simultaneous observations with high-energy facilities such as the Cherenkov Telescope Array Observatory (CTAO, CTA Consortium 2019) and the Imaging X-ray Polarimetry Explorer (IXPE, Weisskopf et al. 2016). These distinct operational modes support the diverse science cases detailed below.

3. Science with LAST-P

This section outlines the primary extragalactic and Galactic science cases that LAST-P will address.

3.1. Extragalactic Science

3.1.1. AGN

The linear polarization of AGN, particularly blazar jets, provides a powerful diagnostic of jet magnetic-field geometry, particle acceleration, and flow dynamics. Optical synchrotron emission can originate from the compact core, in moving plasmoids or shocks, or within turbulent jet plasma (Marscher & Jorstad 2021). Contemporaneous polarization observations of blazars in the optical, as well as in the X-ray band, now available due to IXPE, reveal a wavelength-dependent, stratified shock structure where the PD systematically decreases toward longer wavelengths (Liodakis et al. 2022; Kouch et al. 2024). Multi-zone models further predict higher-amplitude variations for the X-ray signal compared to longer wavelengths, together with random rotations of the PA, consistent with a moving shock scenario interacting with turbulent magnetic fields. In turbulent environments, randomly oriented zones compete and their polarization vectors partially cancel each other. Smoother and more systematic PA rotations may indicate coherent jet structures, such as a knot propagating along a helical magnetic field. The dominant orientation of the PA rotations may be linked to the rotational direction of the ergosphere of the black hole or of the accretion disk (Shishkina et al. 2024).

Changing-look active galactic nuclei (CL-AGN) are objects whose broad Balmer emission lines appear or disappear on timescales of months to years. This behavior is explained by two competing models, variable obscuration and changes in

the accretion state. The obscuration model proposes that a dusty cloud moves into our line of sight, blocking the nucleus. In this case, only highly polarized, or infrared, scattered light would be visible; the “hidden” broad lines should still be detectable in this polarized spectrum (e.g., the $\sim 16\%$ polarized scattered light from NGC 1068; Antonucci & Miller 1985). Conversely, the changing-state model suggests the engine itself dims due to a drop in the supermassive black hole accretion rate. This intrinsic change would stop the production of broad lines and result in a very low degree of polarization. Observational evidence favors the latter model, since CL-AGN have consistently been found to have low polarization (Hutsemékers et al. 2019; Ricci & Trakhtenbrot 2023). This suggests that changes in the accretion rate are the primary driver for most such events. However, the rapid timescales of these changes are more consistent with disk instabilities than with the orbital periods of torus clouds. Such instabilities may even temporarily launch short-lived radio jets in some CL-AGN, further reinforcing the transient accretion nature of their behavior (Birmingham et al. 2025). The LAST-P survey will significantly expand the sample of changing-look AGN with polarization measurements. This will enable a robust population study to better distinguish between competing models and clarify the primary cause of this spectral variability.

Polarization measurements of AGN also help constrain acceleration mechanisms. In highly magnetized AGN jets, magnetic reconnection is likely to dominate over shock acceleration. In reconnection scenarios, the PD in the X-ray regime is expected to be lower than in the optical, with a distinct temporal evolution compared to shock-driven processes (Di Gesu et al. 2022). In addition, an extremely high PD ($>40\%$) in the optical regime during a flare, contrasted with a much lower PD in the X-ray band ($<10\%$), may help break the degeneracy between hadronic and leptonic models, favoring the latter. This has e.g., been argued for BL Lac during an observation campaign in 2023 November (Agudo et al. 2025).

A further key aspect to investigate is the reported temporal association between several GeV flares observed by Fermi-LAT and large events exhibiting systematic rotations of the optical PA (Blinov et al. 2018). This association hints at a common acceleration site for the optical and gamma-ray-emitting particles in these cases. Such observations are important for gamma-ray analyses of AGN, due to the poor spatial resolution ($\sim 0.1\text{--}1^\circ$) of gamma-ray instruments. Although this correlation has been observed for several gamma-ray flares (Sorcia et al. 2014; Casadio et al. 2015; Kiehlmann et al. 2016; Blinov et al. 2018; Shishkina et al. 2024), these events do not exhibit distinctive properties that clearly distinguish them from other flares; this leaves the underlying mechanism open for investigation. By observing the same AGN contemporaneously with VHE gamma-ray observations from Imaging Atmospheric Cherenkov

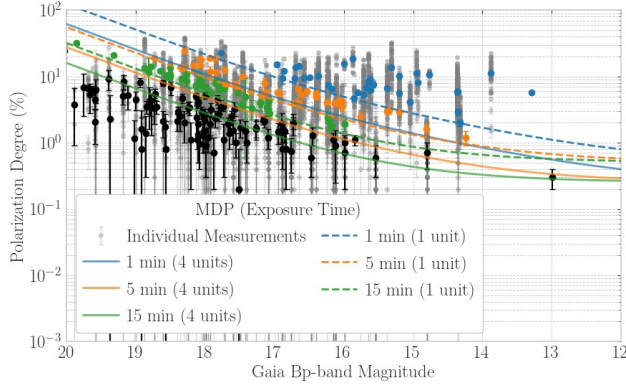


Figure 2. Polarization degree of AGN from the RoboPol AGN catalog (Blinov et al. 2021). Gray points indicate individual observations, while colored points show the median polarization degree for each source. The color scale represents the minimum exposure time required for our instrument (assuming four telescopes, i.e., one unit) to achieve the sensitivity needed to detect that polarization, while black points represent AGN that fall outside the 15×1 minutes curve for one unit. Colored dashed and solid lines indicate the MDP curves of LAST-P for different exposure times using survey mode (one unit) and deep mode (four units), respectively. Typical seeing of $2.7''$ and air mass of approximately 1 are assumed.

Telescopes, we aim to test whether VHE gamma-ray flares may also be accompanied by PA rotations.

Large variations in PD and PA on sub-hour timescales have been reported in a high-cadence strategy by Liodakis et al. (2024), which combined data from different instruments. This study, along with others (e.g., Kiehlmann et al. 2021), underscores the critical need for a high-cadence survey instrument capable of systematically detecting rapid PA rotations. A facility that combines high-cadence, wide-field, and polarimetric monitoring is therefore essential to fully leverage the diagnostic potential of time-resolved AGN polarization.

We use data from the RoboPol AGN catalog (Blinov et al. 2021) cross-correlated to the Gaia DR3 catalog (Riello et al. 2021) to evaluate the monitoring capabilities of our instrument under different observation strategies. Figure 2 presents these data alongside the MDP sensitivity curves of LAST-P for various exposure times. With a typical 15×1 minutes observation, our instrument would be able to monitor up to 116 of the 221 AGN from this catalog. Moreover, exposure times can be adapted based on expectations for where each AGN will fall in the brightness-magnitude phase-space (Figure 2). For instance, BL-Lacertae is typically bright (R -band AB-magnitude ~ 12) with PDs around $\sim 15\%$, placing them well above the first blue dashed sensitivity curve.

The large FoV of our instrument will enable simultaneous monitoring of multiple AGNs within a single observation, particularly in survey mode, which covers 88.8 deg^2 per pointing. Therefore, we will observe and monitor a larger number of AGN than present in the current RoboPol AGN

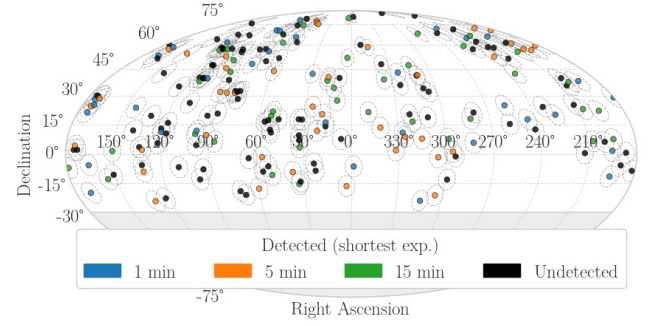


Figure 3. Spatial distribution of AGNs observed by RoboPol (Blinov et al. 2021). Colored dots represent AGNs, where the color encodes the minimum exposure time needed to measure their PD. Dashed gray circles show the FoV of our instrument (88.8 deg^2) centered on each AGN. The gray region below declination -30° is hardly accessible to LAST-P due to its assumed future geographic location.

catalog. In fact, based on the *Gaia*WISE AGN catalog (Shu et al. 2019), we identify a total of 2400 sources with Gaia Bp-band magnitudes brighter than 17, an AGN classification probability exceeding 99%, and declinations above -30° . These would be accessible to LAST-P, expected to yield PD uncertainties of 0.7%, PA uncertainty of 2° (for a PD of 10%), and MDP of 2.6% over 15×1 minutes exposures. For the 60 s exposures (see AGN strategy in Section 2.5), LAST-P will reach PD uncertainty of 1.3%, PA uncertainties of 3.8° (for a PD of 10%), and a MDP of 4.9% for the ~ 200 *Gaia*WISE AGN brighter than Bp-magnitude 16. Figure 3 displays the spatial distribution of AGNs observed by RoboPol, with the gray circles illustrating the coverage area of our instrument around each source. The color scale represents the minimum exposure time required to measure the PD of each AGN, based on the median values from RoboPol. The sky-region accessible to LAST-P closely matches that of RoboPol, ensuring high complementarity with existing data.

3.1.2. Gamma-Ray Bursts

Gamma-ray Bursts (GRBs) are considered the most energetic explosions in the Universe. They are mostly discovered by observations of their bright prompt gamma-ray emission using dedicated gamma-ray telescopes, such as the Swift Burst Alert Telescope (BAT; Barthelmy et al. 2005; Lien et al. 2016). Owing to real-time alerts by gamma-ray telescopes, there has been numerous detections of long-lived afterglows after the initial prompt GRB emission at wavelengths across the electromagnetic spectrum (e.g., Costa et al. 1997; van Paradijs et al. 1997; Galama et al. 1998). Most recently they have also been detected at TeV energies (e.g., Acciari et al. 2019; H.E.S.S. Collaboration 2021; The LHAASO Collaboration 2023).

The characteristic prompt gamma-ray emission of GRBs is produced by highly relativistic bipolar outflows, as a result of

presumably either a merger of compact object binaries (e.g., Tanvir et al. 2013, for spectrally hard *short GRBs*), or a collapse of massive stars (e.g., Hjorth et al. 2003, for *long GRBs*). Short GRBs are interpreted to be associated with gravitational wave emission from compact binary mergers (e.g., Abbott et al. 2017), and long GRBs are associated with some core-collapse Supernovae (SNe). However, the majority of detected GRBs lack an observed counterpart (either gravitational wave signal or associated supernova). The afterglow emission of GRBs is interpreted as synchrotron radiation emitted when the jet ejected material is decelerated by the ambient medium by a pair of shocks, i.e., a forward shock that propagates into the circumburst medium (e.g., Kobayashi 2000) and a reverse shock that crosses the ejecta.

By measuring the polarization of the short-lived reverse shock emission, it may be possible to distinguish between magnetically dominated (Komissarov et al. 2009; Zhang & Yan 2011) and baryonic jet models (Woosley 1993; Medvedev & Loeb 1999). Significant levels of polarization (PD of 5%–30%) have been detected during the first couple of minutes after the burst (see Figure 4), which points to a large-scale ordered magnetic field rather than a pure baryonic jet. High levels of polarization can be explained by the modeling of the reverse shock emission in mildly magnetized jets (Mundell et al. 2013; Japelj et al. 2014). However, prompt observations of the TeV-detected GRB 190114C hint that the most energetic jets could be highly magnetized (Jordana-Mitjans et al. 2020). A statistical approach with fast-follow-up polarimetry is required to further constrain models in the low PD regime ($P < 2\%$; Inoue et al. 2011). In addition, forward shock polarimetric measurements allow the study of the angular structure of jets (e.g., Wiersema et al. 2014), as well as of the dust properties of the host galaxies of GRBs (e.g., Jordana-Mitjans et al. 2021).

A study on the potential of independent discovery of GRBs using LAST-P was performed by (Sadeh 2024). In the current work, we focus on rapid follow-up observations, given external science alerts. GRB alerts from the BAT have small uncertainty in the position of the event (i.e., $\approx 1' - 4'$ at 90% confidence; Barthelmy et al. 2005). This has allowed successful follow-up of GRBs, starting seconds to minutes post-burst, using robotic instruments. In particular robotic facilities with polarimetric capabilities have opened a window into the early evolution of the polarization signal (MASTER; Kornilov et al. 2012, Liverpool Telescope; Guidorzi et al. 2006, Kanata Telescope; Kawabata et al. 2008, Skinakas Observatory; King et al. 2014b). Given that Swift/BAT detects an average of 88 GRBs per year, with around 51% exhibiting detectable optical afterglows,⁷ we expect to follow up and detect roughly 9 GRBs annually with LAST-P. This includes potential detections during the prompt emission

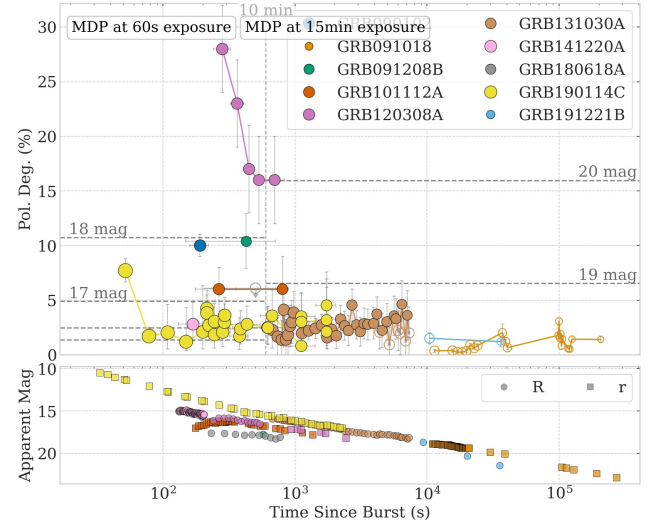


Figure 4. Top panel: evolution of optical afterglow PD for a GRB sample. Data points are sized according to the apparent R -magnitude measurement closest in time, with brighter magnitudes corresponding to larger points. Points falling below the relevant sensitivity threshold for their associated magnitude are shown unfilled. On the left side we consider the sensitivity (MDP) for an exposure of 60 s and on the right for an exposure of 15×1 minutes in the deep mode of observation. The dashed lines represent the MDP for sources with magnitudes 18, 17, 16, 15 (in the <10 minutes region) and with magnitudes 20 and 19 (in the >10 minutes region) from top to bottom. Bottom panel: the corresponding apparent magnitude (R or r according to available data). Data compiled from: GRB 090102 (Steele et al. 2009; Gendre et al. 2010), GRB 091018 (Wiersema et al. 2012), GRB 091208B (Cano et al. 2009; Uehara et al. 2012), GRB 101112A (Steele et al. 2017), GRB 120308A (Mundell et al. 2013; Steele et al. 2017), GRB 131030A (King et al. 2014c), GRB 141220A (Jordana-Mitjans et al. 2021), GRB 180618A (Jordana-Mitjans et al. 2022), GRB 190114C (Jordana-Mitjans et al. 2020), GRB 191221B (Buckley et al. 2021; Chen et al. 2024).

phase, depending on the timing of the alerts and the response time of our planned automatic follow-up system.

When the relative angle between the line of sight of the observer and the jet of the GRB is larger than the relativistic beaming angle of the GRB, the characteristic prompt gamma-ray emission is very weak, most likely undetectable. The propagation of the relativistic jet through the stellar envelope is expected to inject energy into the stellar shocked material, producing cocoon emission (Nakar & Piran 2017). For such scenarios, low and rather constant polarization is expected (Gill & Granot 2018; Nakar et al. 2018).

LAST-P will measure GRBs during $t \approx 0.5 - 10$ minutes post-burst, allowing to explore a regime with sparse polarimetric data (see Figure 4). The deep mode will be employed to allow us to detect faint GRBs and/or achieve good PD statistics for a reduced exposure time in the prompt phase. The exposure time will be automatically adjusted from 5 s up to 60 s, as 53% of the GRBs detected by BAT have a duration of $\gtrsim 35$ s (Lien et al. 2016). The individual observations would later be stacked, increasing the sensitivity for fainter

⁷ https://swift.gsfc.nasa.gov/archive/grb_table/stats/

afterglows. Polarization detected during forward shock emission has been systematically lower than that of the early time reverse shock emission. Therefore, the observing benchmark would be 15 minutes exposures for $\gtrsim 10$ minutes post-burst. Correspondingly, we expect to achieve polarimetric precision of $\approx 1.8\%$ for sources brighter than 19 mag, using the deep mode of observation. Furthermore, the large FoV and high cadence of LAST-P will allow a confident mapping and subtraction of the polarization induced by Galactic dust in the line of sight, using large statistics of field stars.

Figure 4 presents a compilation of PD and apparent R -band magnitude measurements for several GRB afterglows as a function of time post-trigger. These observations are compared to the estimated sensitivity of LAST-P for a total exposure of 1 minute over a period of up to 10 minutes in deep mode. We note that the sensitivity of LAST-P is estimated in the G -band. While all early time measurements fall within the expected reach of LAST-P, observations become challenging as the afterglow fade, particularly for events reaching magnitudes as low as 20. With a 30 s exposure during the early stages of a GRB (within the first 10 minutes), LAST-P would be able to resolve variations in the PD as low as 3.8% (1.9%) at magnitude 17 (16) in survey mode.

Complementing alerts from BAT and GBM (subject to their operational status), we anticipate following up on triggers from the recently launched Space-based multiband astronomical Variable Objects Monitor mission (SVOM; Wei et al. 2016), the Einstein Probe Mission (Yuan et al. 2022), and the Vera C. Rubin Observatory’s LSST (Hambleton et al. 2023). Overall, the fast cadence of LAST-P will provide new insights into the early optical emission of GRBs. We expect the instrument to contribute invaluable data for multiwavelength and multi-messenger analyses of GRBs.

3.1.3. Supernovae

Instruments such as LAST-P, with its high cadence monitoring survey, have the potential to perform early stage SN polarimetry. Measuring intrinsic SN polarization is complicated by foreground contamination from the interstellar medium (ISM) in the Milky Way and as part of the host galaxy. While some methods exist to partially correct for such effects (Nagao et al. 2023), continuous monitoring can be crucial. For instance, it can be used to separate the time-variable SN polarization from the relatively constant galactic ISM component, especially when high-cadence observations are available.

Polarimetry of SN types probes the geometry of the event (e.g., Livneh & Katz 2022). Type Ia SNe typically show low broadband continuum polarization. In addition, they can exhibit strong line polarization before peak luminosity, which may be linked to the composition of the ejecta and to the viewing angle. Core-collapse SNe (Types II, Ib, Ic) show

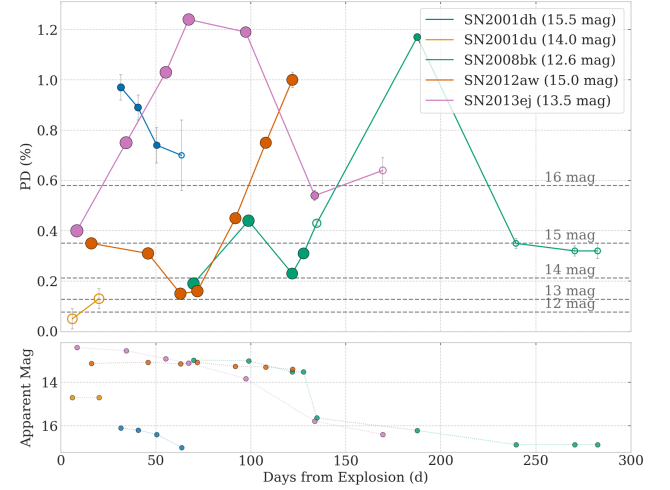


Figure 5. Top panel: PD as function of time for the supernova sample (Nagao et al. 2024). Data points are sized according to the apparent magnitude measurement closest in time extracted from astrocatalogs et al. (2025), with brighter magnitudes corresponding to larger points. Points falling below the relevant sensitivity threshold for their associated magnitude are shown partially transparent. Dashed lines represent the MDP for a 15×1 minutes exposure in deep mode of observation for sources with magnitudes 16, 15, 14, 13, 12 from top to bottom. Bottom panel: apparent R -band magnitude evolution is shown for all objects, except for SN 2008bk, for which the V -band magnitude is plotted.

evidence for asphericity, often suggesting asymmetries aligned along a specific axis (e.g., the existence of a jet). In Type II SNe, the PD is often modest initially, but can increase significantly (to $\approx 1\%$ or more) at later times (tens to hundreds of days post-explosion); e.g., as the photosphere recedes through the hydrogen envelope, the aspherical inner core is revealed (see e.g., for a review, Wang & Wheeler 2008).

Figure 5 shows the magnitude and PD for several Type II SNe (Nagao et al. 2024), given the relative sensitivity of LAST-P in the G band. The increase in the PD generally correlates with decreasing brightness. This was first observed in SN 1987A, where the PA remained constant, indicating a stable asymmetry axis (Jeffery 1991). Core-collapse SNe also often exhibit loops in the Stokes Q - U plane, due to wavelength-dependent polarization variations linked to ejecta structure. LAST-P can potentially observe PD changes in most of the SN shown in the figure. As the PDs of SNe are expected to be relatively small, multiple stacked exposures would be necessary.

Type Ib/c SNe (lacking outer hydrogen/helium) tend to show higher polarization than Type II SNe (e.g., SN 1997X reached PD $\approx 7\%$), suggesting significant explosion asymmetries (Wang et al. 2001). While sharing common features, peculiar SNe like the double-peaked SN 2005bf (Tominaga et al. 2005) benefit from polarimetry for classification and physical understanding. The link between long-duration GRBs and energetic, aspherical core-collapse SNe has been

established. While most core-collapse SNe have no detected GRB counterpart, some bright SNe may be linked to quite dim GRBs (e.g., SN 1998bw, Woosley et al. 1999). Asymmetries can arise from jets, accretion outflows, asymmetric neutrino emission, magnetorotational effects, or clumpy ejecta. Therefore, polarimetric SN observations are powerful diagnostics. They can be used to probe explosion mechanisms; the SN-GRB connection; and interstellar dust properties in host galaxies via foreground polarization characterization. LAST-P will complement the All-Sky Automated Survey for Supernovae (ASAS-SN, Christy et al. 2023) with its approximately 250 SNe brighter than G peak magnitude 16 detected or recovered from 2018 to 2020 (Neumann et al. 2023). For Gaia Bp magnitude of 16, LAST-P will be able to detect polarization (MDP) down to 0.7% using deep mode observations in a 15×1 minutes exposure.

3.1.4. Tidal Disruption Events

Tidal disruption events (TDEs) occur when a stellar object is torn apart by the tidal forces of a supermassive black hole at the center of a galaxy. So far, multi-wavelength observations and polarimetry of TDEs have proven useful to provide some hints regarding jet physics in supermassive black holes (e.g., Floris et al. 2025; Jordana-Mitjans et al. 2025). They have allowed the discovery of a few relativistic jets in TDEs among the general population of thermal TDEs (e.g., Bloom et al. 2011; Higgins et al. 2019; Lee et al. 2020; Wiersema et al. 2020). In particular, the detection of variable polarization in Swift J2058+0516 (PD of $<5.3\%$ to $8.1 \pm 2.5\%$; Wiersema et al. 2020) and AT2019dsg ($P = 9.2\% \pm 2.7\%$ to $P = 2\%$; Lee et al. 2020) suggested the presence of a relativistic outflow. Leloudas et al. (2022) shows the PD of three TDEs decreasing since the time of detection, as well as a continuum PD that is independent of the wavelength, suggesting electron scattering as the dominant source of polarization in TDEs. The shock generated by the collision of the stellar debris stream with itself has arisen as an additional explanation for the extremely high host-corrected PD of 25% of TDE2020mot (Liodakis et al. 2023). Other explanations for optical emission of TDEs such as reprocessing of the inner disk remain plausible (Guillochon et al. 2014; Patra et al. 2022).

Only about 1%–10% of detected TDEs exhibit a relativistic jet. The presence of such a jet can be inferred through synchrotron emission, which inevitably produces a polarized optical signal. Therefore, LAST-P can contribute to the rapid identification of transient sources as TDEs, which is crucial for enabling timely multi-wavelength follow-up observations. Interest in TDEs has also grown within the VHE gamma-ray community (Chen et al. 2016). While current-generation instruments have been actively searching for such events, none have been detected to date (e.g., Aleksić et al. 2013; Lypova et al. 2023). TDEs have also been studied as potential

sources of neutrinos via the acceleration of ultra-high-energy cosmic rays (Guépin et al. 2018).

The wide-field monitoring capabilities of LAST-P will facilitate the discovery of nearby, bright TDEs (e.g., Lee et al. 2020). Subsequent issued alerts would enable quick follow-up observations by the community. The high-cadence observing strategy of LAST-P will support simultaneous monitoring of the brightness evolution of multiple transients, contributing to estimates of the mass of the supermassive black hole of the host galaxy; population studies; and the classification of different TDE types. The Vera C. Rubin Observatory (Hambleton et al. 2023) will survey the entire available southern sky every few nights, detecting up to ~ 1000 TDEs per year (Bricman & Gomboc 2020). The sub-day cadence of LAST-P will complement this survey, enabling time-resolved observations of the early evolution of the brightest TDEs. Assuming a TDE detection rate of approximately 50 events per year across $20,000 \text{ deg}^2$ for sources brighter than $g = 19 \text{ mag}$ (Figure 6 in Szekerczes et al. 2024), we estimate that LAST-P, operating in high-cadence survey mode and covering about $31,000 \text{ deg}^2$ of sky every 58 days (Table 2), could detect approximately 77 TDEs per year. The Transient Name Server (TNS, International Astronomical Union 2025) lists 29 confirmed TDEs last year (2024 October–2025 October). In this context, we realistically expect to secure spectroscopic confirmation for 10–20 of our TDE candidates annually, assuming no major increase in spectroscopic resources. In deep mode, following up on confirmed TDEs, the PD uncertainty for a TDE with Gaia Bp-magnitude 18 would be as low as 0.8%, with an MDP of 2.9%.

3.1.5. Fast Blue Optical Transients

Fast Blue Optical Transients (FBOTs, Rest et al. 2018; Margutti et al. 2019), are optical transients with a time above half-maximum of less than 12 days (Drout et al. 2014), usually fading within 30 days. Their radiated bolometric luminosities $L \approx 10^{43} \text{ erg s}^{-1}$ are detected in fast-cadence surveys. They are too fast and have weak hydrogen lines in their spectra, contrary to TDEs (Chrimes et al. 2024). FBOTs have mostly been associated with star-forming galaxies, suggesting collapsing massive stars as progenitors (Drout et al. 2014). A recent demographic study of FBOTs by Ho et al. (2023) found a diverse population. While some FBOTs are classified as hydrogen- or helium-rich core-collapse SNe (Types II/Ib/Ib), interacting SNe, wind shock breakout events (Ofek et al. 2010), or events powered by low mass Ni^{56} ejecta (Ofek et al. 2021), some remains not well understood. Three of these events are particularly notable as their observed properties challenge standard supernova models. The observational characteristics of FBOTs are largely defined by a few archetypal events, beginning with AT2018cow (“the Cow”). These events are distinct from other luminous transients such

as TDEs, primarily by their significantly faster evolution and bluer colors. FBOTs are distinguished by its rapid rise time ($t_{\text{rise}} \approx 3.5$ days), high peak luminosity ($L_{\text{peak}} > 10^{44} \text{ erg s}^{-1}$), and a luminous, persistent soft X-ray counterpart implying a long-lived central engine (Prentice et al. 2018; Rivera Sandoval et al. 2018). While sharing many of these characteristics, ZTF18abvkwla (“the Koala”) was exceptional for its radio emission, which was an order of magnitude more luminous than that of AT2018cow (Ho et al. 2020, 2023). The classification of these events as a distinct population was solidified with AT2020xnd (“the Camel”), the first unambiguous analog to AT2018cow to be discovered and confirmed in real time. This event provided clear evidence for a powerful engine launching a relativistic outflow ($v > 0.5c$), as inferred from its exceptionally fast-evolving and luminous radio synchrotron emission (Perley et al. 2021). The extreme properties of these events suggest a powering mechanism beyond the radioactive decay typical of SNe, pointing towards compact object engines or extraordinary circumstellar interactions.

Several physical interpretations have been proposed to explain their properties. One class of models involves the interaction of supernova ejecta with a dense circumstellar medium, leading to rapid deceleration and bright emission (Ginzburg & Balberg 2014; Rest et al. 2018). Another related scenario involves mildly relativistic jets shocking their way out of the star, forming a surrounding “cocoon” (Coppejans et al. 2020; Gottlieb et al. 2022). Alternatively, the power source may be a compact central engine. Proposed engines include fall-back accretion onto the compact remnant (Kashiyama & Quataert 2015), energy injection from a newborn millisecond magnetar (Hotokezaka et al. 2017), or accretion onto a neutron star or black hole (Cenko et al. 2012; Margalit & Metzger 2016).

For AT2018cow, observations revealed a polarization spike of $P = 7\% \pm 1\%$ at 5.9 days post-burst, which later settled to a constant $P \approx 2\%$ (Maund et al. 2023). This time-dependent polarization suggests an initially aspherical geometry, potentially explained by a shock breakout through an optically thick disk or a Compton-disk reflection model, the latter of which also accounts for an accompanying hard X-ray spike (Margutti et al. 2019). A second FBOT with polarization measurement, AT2024wpp, showed a polarization of $P \leq 0.5\%$ between 6.1 and 14.4 days post-detection, consistent with the later, outflow-driven phase of AT2018cow (Pursiainen et al. 2025). However, constraining FBOT models is challenging due to their low detection rate of at most 0.1% of the local core-collapse supernova rate (Ho et al. 2023). Large FoV surveys like LAST-P are therefore essential to systematically measure the polarization evolution of these events.

3.2. Galactic Science

3.2.1. Interstellar Medium

In the optical to infrared range, polarization of starlight may arise from elongated dust grains that align with the local magnetic field. This phenomenon provides a powerful diagnostic for the geometry and strength of the Galactic magnetic field (GMF, Andersson et al. 2015), particularly when combined with precise astrometric distances from Gaia. Line-of-sight depolarization of starlight is a potential systematic effect, particularly for sightlines towards the Galactic plane or regions with complex magnetic topologies (Panopoulou et al. 2022). Optical polarization measurements of individual stars are relatively unbiased, avoiding major limitations like the beam depolarization that affects radio observations of diffuse synchrotron emission.

Simultaneous measurements of the PD and PA for stars across a range of distances would enable us to create a three-dimensional (3D) tomographic map of dust-grain polarization. This, in turn, would reveal the structure of the GMF responsible for aligning those grains (Mandarakas et al. 2024). Regions where the PA varies rapidly with distance may indicate the presence of depolarizing layers; these can be masked to avoid contaminating the inferred magnetic field structure. Efforts in this direction have already been taken (Pelgrims et al. 2024). They have led to the discovery of complex dust clouds in a very limited region of the sky, which LAST-P has the potential to build upon.

3.2.2. Star-forming Regions

Young stellar objects (YSOs) such as Classical T Tauri stars and Herbig Ae/Be stars often exhibit variable optical polarization due to dynamic changes in their circumstellar environments (Manset & Bastien 2000; Vink et al. 2005). Gradual PA variations may indicate disk precession or evolving scattering angles, while stochastic PD changes can reveal clumpy accretion or inner disk shadowing effects. Optical polarimetry therefore constitutes an important probe of the geometry and evolution of these environments.

For context, Herbig Ae/Be stars have an average a PD of 3% and a 1σ spread of 3.4% (Vink & Harries 2015). These stars have *R*-band AB magnitudes larger than magnitude 7. Classical T Tauri stars have an average PD of 1.6% and 1σ spread of 1.8% (Vink & Harries 2015). Their *R*-band AB magnitudes generally also fall between 7 and 14 (Herbst et al. 1994). At magnitude 14, LAST-P can measure down to a PD of 0.7% in 15×1 minutes exposures, as part of our survey mode. This covers the vast majority of Herbig Ae/Be stars and of Classical T Tauri stars.

With its wide FoV and high-cadence survey mode, LAST-P would also be able to monitor entire star-forming regions. This capability enables the construction of polarization light curves

for thousands of optically visible YSOs. In addition to studying known sources, LAST-P would identify new YSO candidates through polarization variability alone. This would compliment traditional infrared color-based selection methods.

3.2.3. Galactic Novae

Novae are explosive stellar events that provide key insights into stellar evolution (Bode & Evans 2008). Polarization observations help reveal the geometry and physical processes during the eruption. At peak brightness (typically magnitudes, 4–6), novae exhibit higher PD, within 1–5%; this indicates asymmetric ejection of material (e.g., Kawabata et al. 2001). As a nova evolves and the ejecta expand, the PD decreases to 0.2%–1% over a period of several months. This happens due to the isotropization of the material, and to the cooling of the shell of the nova. In late phases, residual PD from the interstellar medium may still be detectable. Typically, a few months after the explosion, the *R*-band magnitude can reach values as faint as 10–14, depending on the distance, extinction, and on the intrinsic properties of the nova.

LAST-P, with its wide FoV, is well-suited for detecting novae across large regions of the sky. Despite their typically low polarization, novae are bright enough for LAST-P to measure PDs as small as 0.07% (magnitude 10 sources in a total of 15 minutes exposure split into smaller exposures to avoid saturation). While detection of polarization becomes more challenging in later stages, LAST-P can still measure PDs as low as 0.7% for novae at magnitude 14.

The wide coverage and high temporal cadence mean that LAST-P is capable of detecting novae in their early phases, and of tracking their evolution over time. We expect to perform early detections of novae and to provide alerts to the community for follow-up observations. The estimated nova eruption rate in the Milky Way is $43.7^{+19.5}_{-8.7} \text{ yr}^{-1}$ (De et al. 2021). As discussed above, LAST-P would survey 75% of the available sky every 18 days. We therefore expect to detect most novae that explode within the surveyed sky-region. For illustration, LAST-P would have had access to 62% of the 174 novae detected between 2008 and 2024 by Mukai (2025), as shown in Figure 6.

3.2.4. Galactic X-Ray Binaries and Microquasars

X-Ray binaries (XRBs) are systems where a compact object, such as a stellar-mass black hole or neutron star, accretes matter from a companion star, usually via an accretion disk. Many XRBs undergo transient outbursts. These are periods of dramatically increased luminosity across multiple wavelengths, presumably triggered by accretion instabilities. The latter fuel enhanced activity in the corona and are associated with relativistic jets (Lipunov et al. 2016). High-energy X-ray emission is typically ascribed to the hot inner accretion flow or corona. Radio emission traces the large-scale jets. Optical and

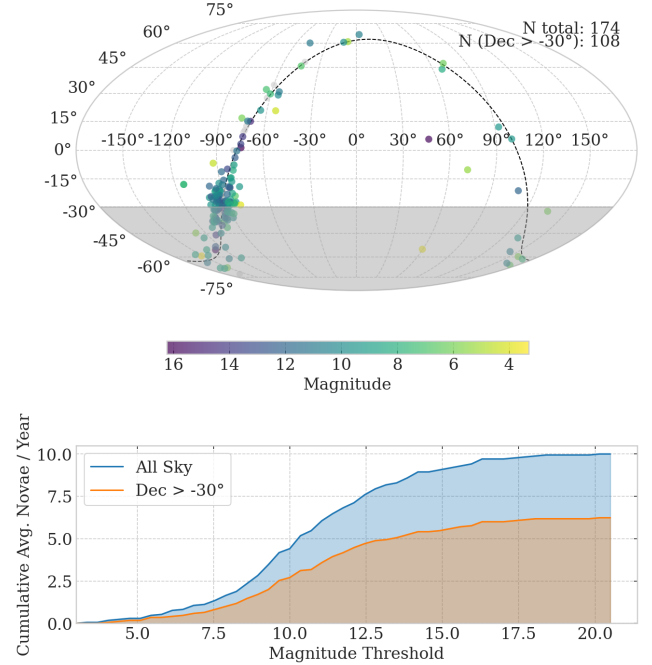


Figure 6. Sky distribution (top) and cumulative discovery rates (bottom) for novae in the *Koji* list of galactic Novae Mukai (2025). In the top panel, points with available V AB-magnitude are shown as part of the color scale. The Galactic Plane (dashed line) and the southern sky (decl. $< -30^\circ$; shaded gray area) are indicated. The bottom panel shows the average number of novae discovered per year (using data between 2008 and 2024) brighter than the magnitude threshold for the full sample (blue), as well as for a decl. $> -30^\circ$ subsample (orange).

infrared (OIR) emission, on the other hand, reveals a more complex scenario. OIR light often contains contributions from the thermal emission of the accretion disk; the companion star itself; synchrotron emission from the base of the jet; and reprocessing of X-rays within the system. Hence, optical polarimetry provides a valuable probe of the geometry of accretion flows. It may be used to model the contribution of relativistic jets in X-ray binaries via scattering and synchrotron emission.

Our benchmark for the expected magnitudes and polarization degrees of XRBs is Kravtsov et al. (2022). For such a sample, we find that only V4641 Sgr and V404 Cyg are detectable targets by a 15×1 minutes exposure in survey mode. The other sources within this sample are predicted to be below the detection threshold of LAST-P. This is primarily due to their faintness or to their low intrinsic polarization. Nonetheless, the capabilities of LAST-P allow for a broad survey. Figure 7 shows that 299 known XRBs are accessible to LAST-P, representing a large, unexplored population for optical polarimetry. Even in cases where our instrument would not significantly detect polarization, the measurements would constrain the potential contribution of non-stellar components to the overall spectra of XRBs.

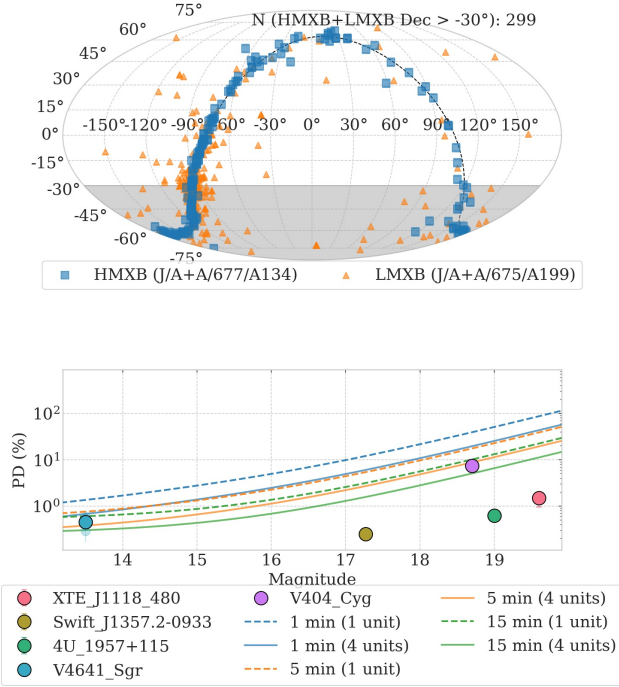


Figure 7. Top: sky distribution of high-mass XRBs (HMXBs; blue squares) and low-mass XRBs (LMXBs; orange triangles, Avakyan et al. 2023; Neumann et al. 2023). The Galactic Plane and Center are shown in black; the gray area indicates the region, decl. < -30° . Bottom: Polarization degree in the R band versus R magnitude for the sample of Kravtsov et al. (2022). Fainter points represent individual measurements; larger points indicate median or single-observation values per source. Dashed and solid lines respectively indicate the sensitivity (MDP) for our survey and deep modes of observation, given different exposure times.

Microquasars, a subset of X-ray binaries characterized by relativistic jets, are increasingly important targets for the gamma-ray astronomy community. Their jets can inflate extended radio lobes. They are assumed to create powerful shocks as they interact with the surrounding interstellar medium, accelerating particles to extreme energies. Such particle acceleration sites are responsible for the VHE gamma-ray emission detected from sources such as SS 433 by H.E.S.S. (H.E.S.S. Collaboration 2024). Other sources observed by LHAASO (LHAASO Collaboration 2024) are also potentially of interest, e.g., making microquasars key science targets for the upcoming CTAO (Abe et al. 2025). Broad optical synchrotron lobes mirroring the gamma-ray structure are not visible in SS 433. However, the jet-ISM interaction in the form of shock-excited filaments is seen in the optical regime within the W50 nebula. Measuring the corresponding PD and PA would allow us to map the magnetic field structures in the region.

3.2.5. White Dwarfs

White dwarfs (WDs) are dense remnants of low-to-intermediate mass stars. Due to their simple atmospheric composition and lack of strong intrinsic polarization

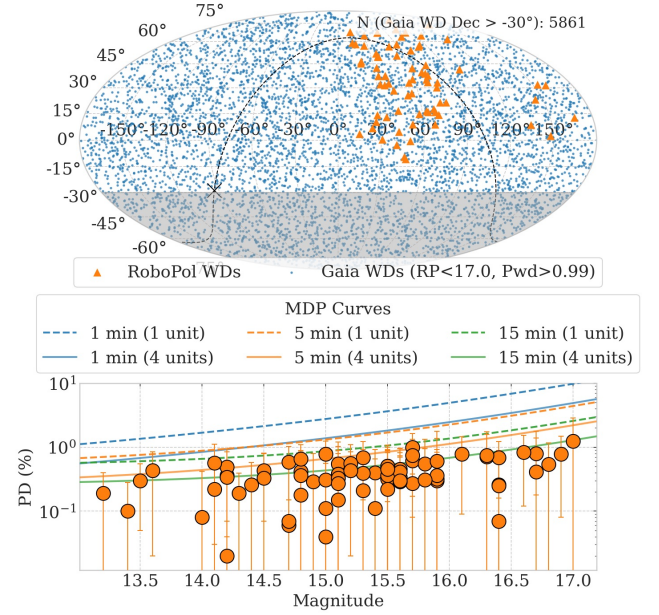


Figure 8. Top: sky distribution of WDs, showing the RoboPol sample (orange triangles, Žejmo et al. 2016). High-probability ($P_{\text{WD}} > 0.99$) WD candidates with RP magnitude smaller than 17 from the Gaia EDR3 catalog are indicated by blue markers (Gentile Fusillo et al. 2021; Gentile-Fusillo et al. 2021). The Galactic Plane and Center are respectively shown as a dark line and a shaded region. Bottom: PD (Žejmo et al. 2016) versus Gaia DR3 RP magnitude. Lines represent the MDP curves for LAST-P given various exposure times, as indicated.

mechanisms (in the non-magnetic majority), they are widely assumed to possess low (or zero) intrinsic polarization. Indeed, the majority of the PDs of WDs measured by RoboPol (Figure 8 bottom) are compatible with zero. This makes WDs ideal standard stars for calibrating instrumental polarization. They can also be used to determine the foreground polarization induced by aligned dust grains in the ISM within our Galaxy.

As shown in Figure 8 (top), white dwarfs (WDs) are not strongly concentrated along the Galactic Plane due to their proximity to Earth. This wide spatial distribution is advantageous, providing a network of potential low-polarization calibrators across the entire sky (Žejmo et al. 2016).

A sub-type of WDs are magnetic WDs. These can exhibit polarization due to cyclotron emission or magneto-optical effects. Some WDs also possess dusty debris disks, where scattering can induce low levels of polarization (Ferrario et al. 2015). Furthermore, WDs in close binary systems can exhibit polarization from scattering in accretion flows or outflows. The sensitivity of LAST-P reaches an MDP down to $\sim 0.87\%$ ($\sim 0.44\%$) PD for stars brighter than magnitude ≈ 15 in survey mode (deep mode) and 15×1 minutes exposure. LAST-P therefore offers the capability to not only utilize numerous WDs for instrumental calibration across its FoV but also to search for subtle intrinsic polarization signals in WDs. This may potentially unveil weak magnetic fields, debris disks, or

binary interactions. For illustration, the lower panel of Figure 8 shows the expected sensitivity of LAST-P relative to the measured polarization of the RoboPol sample (Žejmo et al. 2016).

4. Conclusions and Summary

In this paper, we presented LAST-P, the planned polarization node of the Large Survey Telescope. Our instrument is a cost-effective solution for building a novel wide-field telescope with polarimetric capabilities. LAST-P benefits from both the hardware and software developed for LAST (Ofek et al. 2023b), which is currently undergoing commissioning in Israel.

LAST-P will operate in two distinct modes. In survey mode, the 12 units, each composed of four telescopes, point at different sky regions, collectively covering 88.8 deg^2 . This mode enables full-sky coverage every 18–58 days depending on the cadence strategy. LAST-P can measure sources down to Bp-magnitude 20.9 in survey mode, depending on observation conditions. For magnitude 18 sources observed with a 15×1 minute exposure, the precision in the PD and PA reaches 1.5% and 4.3° , respectively, assuming a source with a PD of $\approx 10\%$ (Table 1). In deep mode, where four units simultaneously observe the same field, the improved SNR enhances sensitivity, achieving a PD precision of 0.75% (PA of 2.15°) under similar conditions. Although initial tests have already been conducted, we plan a series of upgrades to the array, aimed at reducing overall instrumental polarization and minimizing systematic uncertainties in the polarization measurements.

LAST-P is designed to explore a diverse range of Galactic and extragalactic sources. Its high-cadence (sub-day) strategy will enable the monitoring of the largest sample of AGN in optical polarization to date. This will substantially increase the number of AGN with detected PA rotations. Such observations will provide critical insight into the connection between gamma-ray flares and PA variability. Polarimetric observations of GRBs from the earliest moments after the explosion will shed light on jet composition and structure. We also aim to investigate the outflows in SNe and the link between SNe and GRBs. Thanks to its wide FoV, LAST-P will contribute to the discovery and classification of rare transients, such as TDEs and FBOTs. Our detections will be coordinated with the broader multiwavelength and multi-messenger community in order to maximize their scientific potential.

LAST-P will also map the interstellar medium using polarized starlight. It will probe the polarization properties of variable stars such as Herbig Ae/Be and classical T Tauri stars, and will contribute to the largest catalog of low-polarization sources, focusing on white dwarfs. It will also study Galactic novae and X-ray binaries. This includes microquasars, where polarization data can reveal the geometry

of ejected material and the formation mechanisms of relativistic jets.

A unifying theme across all these science cases is asymmetry; in outflows, in explosions, and as caused by jets. Polarized light offers a unique window into the physical geometry and emission mechanisms of such systems. LAST-P will thus make a significant contribution to our understanding of non-thermal astrophysical processes in the era of multi-messenger astronomy.

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Appendix Polarization and Uncertainty Equations

In this appendix, we detail the analytical formulas used to derive the SNR, the polarization parameters, their corresponding uncertainties, and the detection limits from photometric intensity reference measurements (Ofek et al. 2023a).

A.1. SNR Estimates for LAST-P

The polarimetric precision (σ_{PD} , MDP, σ_{PA}) is fundamentally governed by the SNR. We employ a SNR estimate, which correctly combines all independent noise sources using the root sum square method.

The total SNR for a source of magnitude m in a co-added sequence is defined in terms of total collected electrons (e^-):

$$\text{SNR}(m) = \frac{N_*(m)}{\sqrt{N_*(m) + N_{\text{sky,new}} + \sigma_{\text{fixed}}^2 + \sigma_{\text{sys}}^2(m)}} \quad (\text{A1})$$

where $N_*(m)$ are the source photon counts, $N_{\text{sky,new}}$ are the background photon counts (reduced by filter throughput), σ_{fixed}^2 is the variance contribution from non-photon noise (dark and readout noises), and σ_{sys}^2 is the variance contribution from the remaining systematic uncertainties.

A.1.1. Derivation of Variables

The parameters are calibrated assuming a dark-sky site ($21.5 \text{ mag arcsec}^{-2}$), an aperture of $2 \times \text{FWHM}$ ($A_{\text{aperture}} \approx 91.6 \text{ arcsec}^2$ for the typical seeing of $2''.7$), and a total exposure time of $T_{\text{total}} = N_{\text{frames}} \cdot t_{\text{exp}}$. A filter throughput factor of $\eta_{\text{filter}} = 0.1044$ is applied to all photon-dependent rates to account for the light absorption caused by the addition of a R -filter and a polarization filter (see Section 2.2).

1. σ_{fixed}^2 : Total fixed noise variance. This variance represents the total contribution from detector effects across all co-added frames ($N_{\text{frames}} = 15$), remaining independent of the filter throughput. It combines the Dark Current ($R_{\text{dark}} = 8 \times 10^{-3} e^- \text{ pix}^{-1} \text{ s}^{-1}$) and the Read Noise ($\sigma_{\text{read}} = 2.7e^-$, Table 4 in Ofek et al. 2023a).

First, the number of pixels in the aperture (N_{pix}) is derived. The aperture radius is defined as $2 \times \text{FWHM}$ ($5''.4$), which is converted to pixels using the system's $1''.25 \text{ pix}^{-1}$ pixel scale, calculated as $N_{\text{pix}} = \pi \cdot (5''.4/1''.25 \text{ pix}^{-1})^2 \approx 58.6$ pixels.

The total fixed noise variance is then calculated:

$$\sigma_{\text{fixed}}^2 = N_{\text{frames}} \cdot N_{\text{pix}} \cdot (\sigma_{\text{read}}^2 + R_{\text{dark}} \cdot t_{\text{exp}}) \approx 6836e^2$$

2. $N_{\text{sky,new}}$: Total Background Photon Counts. The surface brightness of the sky ($S_{\text{sky}} = 21.5 \text{ mag arcsec}^{-2}$) is converted to the total magnitude within the $A_{\text{aperture}} \approx 91.6 \text{ arcsec}^2$ aperture ($m_{\text{sky,new}}$):

$$\begin{aligned} m_{\text{sky,new}} &= S_{\text{sky}} - 2.5 \log_{10}(A_{\text{aperture}}) \\ &\approx 21.5 - 2.5 \log_{10}(91.6) \approx 16.59 \text{ mag} \end{aligned} \quad (\text{A2})$$

The initial unfiltered background counts (N_{sky}) are derived by anchoring the system sensitivity to the observed single-frame 5σ limit of $m_{\text{lim}} = 19.6 \text{ mag}$ at $t_0 = 20 \text{ s}$ (Ofek et al. 2023a). We account for 0.5 mag to account for the increase in sensitivity in regions with darker skies (Ofek et al. 2023a), hence we start with $m_{\text{lim}} = 20.1 \text{ mag}$. The limiting rate R_{lim} is related to the

unfiltered background rate R_{sky} by:

$$R_{\text{lim}} = R_{\text{sky}} \cdot 10^{-0.4(m_{\text{lim}} - m_{\text{sky,new}})}$$

The unfiltered background rate R_{sky} is found by solving the single-frame SNR equation for R_{sky} :

$$5 = \frac{R_{\text{lim}} t_0}{\sqrt{(R_{\text{lim}} + R_{\text{sky}}) t_0 + \sigma_{\text{fixed},1}^2}} \quad (\text{A3})$$

where R_{lim} is substituted using the magnitude relationship. The variables used in the equation solution are: $\sigma_{\text{fixed},1}^2$ is the single-frame fixed variance, calculated as $\sigma_{\text{fixed},1}^2 = N_{\text{pix}} \cdot (\sigma_{\text{read}}^2 + R_{\text{dark}} \cdot t_0) \approx 436e^2$ using $t_0 = 20 \text{ s}$, $N_{\text{pix}} = 58.6$, and the detector parameters. This solution yields $R_{\text{sky}} \approx 847.7$ and the total unfiltered background counts $N_{\text{sky}} = R_{\text{sky}} \cdot T_{\text{total}} \approx 762,970e^-$. This value is then scaled by η_{filter} :

$$N_{\text{sky,new}} = N_{\text{sky}} \cdot \eta_{\text{filter}} \approx 79,654e^-$$

The combined background noise “floor” used in the denominator is $N_{\text{sky,new}} + \sigma_{\text{fixed}}^2 \approx 86,490e^2$.

3. $Z_{\text{R,new}}$: The zero point rate is a constant that defines the source flux for $m = 0$. Hence, the source flux for a source magnitude m is $R_*(m) = Z_{\text{R,new}} \cdot 10^{-0.4m}$. $Z_{\text{R,new}}$ is calculated from the unfiltered rate (R_{sky}) and the aperture magnitude ($m_{\text{sky,new}} \approx 16.59 \text{ mag}$), and then scaled by η_{filter} :

$$Z_{\text{R,new}} = R_{\text{sky}} \cdot 10^{0.4m_{\text{sky,new}}} \cdot \eta_{\text{filter}} \approx 3.85 \times 10^8 e^-/\text{s}$$

Therefore, the the source flux for a source magnitude m is $R_*(m) \approx 3.85 \times 10^8 \cdot 10^{-0.4m} e^-/\text{s}$ and the source photon counts for a total exposure of $T_{\text{total}} = 900 \text{ s}$ is $N_*(m) \approx 3.465 \times 10^{11-0.4m} e^-$.

4. σ_{sys}^2 : The systematic uncertainties. For this initial analysis, the systematic error variance (σ_{sys}^2) is estimated using the LAST pipeline’s reported bright-end relative photometric precision. Ofek et al. (2023b) states a relative precision of 3millimag in a single 20s image, but to represent the stability inherent in the co-added sequence, we adopt a standard deviation of $\sigma_{m,\text{sys}} = 1.5 \text{ millimag}$ for the magnitude measurements. The variance converts this magnitude uncertainty into the electron count domain (e^2) using the expression:

$$\sigma_{\text{sys}}^2(m) = \left[N_*(m) \cdot \frac{\ln(10)}{2.5} \cdot (1.5 \times 10^{-3}) \right]^2.$$

This SNR model assumes controlled systematic uncertainties; additional errors from the full photometric/polarimetric pipeline stability, as well as system instabilities, will be quantified in future work following instrument commissioning.

Substituting the numerical values for the 15×60 s co-add:

$$\text{SNR}(m) = \frac{3.465 \times 10^{11-0.4m}}{\sqrt{3.465 \times 10^{11-0.4m} + 2.29 \times 10^{17-0.8m} + 86490}} \quad (\text{A4})$$

A.2. Exact Data Reduction Formulas

We calculate the normalized Stokes parameters, q and u , from intensity measurements taken at four polarization filter angles (I_0 , I_{45} , I_{90} , I_{135}):

$$q = \frac{I_0 - I_{90}}{I_0 + I_{90}} \quad (\text{A5})$$

$$u = \frac{I_{45} - I_{135}}{I_{45} + I_{135}} \quad (\text{A6})$$

The PD and PA are derived as:

$$\text{PD} (\%) = 100 \times \sqrt{q^2 + u^2} \quad (\text{A7})$$

$$\text{PA} = \frac{1}{2} \arctan\left(\frac{u}{q}\right) \quad (\text{A8})$$

where the PA is typically adjusted to the range $[0^\circ, 180^\circ]$.

To determine the measurement errors during data reduction, we propagate the photometric flux uncertainties (σ_{I_i}) into the Stokes parameters:

$$\sigma_q = \frac{2}{(I_0 + I_{90})^2} \sqrt{(I_{90}\sigma_{I_0})^2 + (I_0\sigma_{I_{90}})^2} \quad (\text{A9})$$

$$\sigma_u = \frac{2}{(I_{45} + I_{135})^2} \sqrt{(I_{135}\sigma_{I_{45}})^2 + (I_{45}\sigma_{I_{135}})^2} \quad (\text{A10})$$

The uncertainty in PD (σ_{PD}) is calculated from σ_q and σ_u :

$$\sigma_{\text{PD}} = \frac{\sqrt{(q\sigma_q)^2 + (u\sigma_u)^2}}{\sqrt{q^2 + u^2}} \quad (\text{A11})$$

Finally, the uncertainty in the polarization angle (σ_{PA}), in radians, is:

$$\sigma_{\text{PA}} = \frac{1}{2(q^2 + u^2)} \sqrt{(u\sigma_q)^2 + (q\sigma_u)^2} \quad (\text{A12})$$

A.3. Minimum Degree of Polarization (MDP)

To quantify the sensitivity limit of the instrument, we define the Minimum Detectable Polarization (MDP). Following Weisskopf et al. (2010) and Elsner et al. (2012), the MDP is given by:

$$\text{MDP} = \sigma \cdot 1.43 \frac{\sigma_{\text{tot}}}{S_{\text{tot}}} \times 100, \quad (\text{A13})$$

where:

1. σ is the chosen significance level (e.g. $\sigma = 2.576$ for a 99% c.l. limit);
2. $S_{\text{tot}} = \sum_{i=1}^4 \text{counts}_{\text{cam}i}$ is the total source signal from the four cameras;
3. $\sigma_{\text{tot}} = \sqrt{\sum_{i=1}^4 \sigma_i^2}$ is the combined uncertainty (including background) added in quadrature.

This formulation includes a factor of 1.43 to account for the Rician bias inherent in measuring the positive-definite polarization degree at low SNR ratios.

A.4. Sensitivity Estimation Approximations

To estimate the theoretical capabilities of LAST-P (Section 2.3), we assume that the source has low intrinsic polarization ($I_0 \approx I_{90} \approx I_{\text{tot}}/2$). Under these conditions, the error propagation formulas above simplify to functions of the photometric SNR.

Defining the total signal S_{tot} and total uncertainty σ_{tot} over the aperture, the ratio $\sigma_{\text{tot}}/S_{\text{tot}}$ simplifies to the inverse of the global SNR:

$$\frac{\sigma_{\text{tot}}}{S_{\text{tot}}} \approx \frac{1}{\text{SNR}} \quad (\text{A14})$$

Substituting this approximation into Equation (A13), the MDP simplifies to a direct function of the SNR and the required confidence level (σ):

$$\text{MDP} \approx 1.43 \times \sigma \times \frac{1}{\text{SNR}} \times 100 \quad (\text{A15})$$

For a 99% confidence level ($\sigma = 2.576$), this constant factor is 3.684.

Similarly, for the PD uncertainty, defining the total intensity $I_{\text{tot}} = I_0 + I_{90}$ and assuming uniform noise $\sigma_I \approx \sqrt{I_{\text{tot}}}$, Equation (A9) approximates to:

$$\sigma_q \approx \sigma_u \approx \frac{\sigma_{\text{tot}}}{S_{\text{tot}}} \approx \frac{1}{\text{SNR}} \quad (\text{A16})$$

Substituting these approximations into Equation (A11), the absolute uncertainty in the PD simplifies to:

$$\sigma_{\text{PD}} \approx \frac{\sqrt{q^2(1/\text{SNR})^2 + u^2(1/\text{SNR})^2}}{\sqrt{q^2 + u^2}} = \frac{1}{\text{SNR}} \quad (\text{A17})$$

For the PA, substituting into Equation (A12) yields:

$$\sigma_{\text{PA}} \approx \frac{1}{2(q^2 + u^2)} \frac{1}{\text{SNR}} \sqrt{u^2 + q^2} = \frac{1}{2 \cdot \text{PD} \cdot \text{SNR}} \quad (\text{A18})$$

This demonstrates that while σ_{PD} depends only on the signal strength, σ_{PA} is inversely proportional to the source's intrinsic polarization. These approximated forms (Equations (A15), (A17) and (A18)) are used to generate the theoretical precision estimates in Table 1.

Table 3

Estimated Sensitivity of LAST-P Grouped by Exposure Time for Several Magnitudes

mag	Exposure	SNR	PD uncert (%)	PA uncert (deg)	MDP (%)
8	30 s	700	0.14	0.41	0.53
	60 s	711	0.14	0.40	0.52
	900 s	723	0.14	0.40	0.51
12	30 s	366	0.27	0.8	1.0
	60 s	462	0.22	0.6	0.8
	900 s	691	0.14	0.4	0.5
15	30 s	95	1.0	3.0	3.9
	60 s	133	0.7	2.1	2.8
	900 s	426	0.2	0.7	0.9
16	30 s	53	1.9	5.4	6.9
	60 s	75	1.3	3.8	4.9
	900 s	270	0.4	1.1	1.4
17	30 s	27	3.8	10.8	14
	60 s	38	2.7	7.6	9.8
	900 s	143	0.7	2.0	2.6
18	30 s	12.1	8.2	24	30
	60 s	17.1	5.8	17	21
	900 s	66.1	1.5	4.3	5.6
19	30 s	5.1	19	56	72
	60 s	7.3	13.7	40	51
	900 s	28.2	3.5	10	13
20	30 s	2.1	...	...	...
	60 s	3.0	...	...	...
	900 s	11.5	9	25	32

Note. σ_{PA} values are based on the small-angle approximation and on a source with PD of 10%. MDP is calculated at the 99% confidence level from Equation (A15). Values are not shown for $SNR < 5$. The limiting magnitudes for the total exposures of 30, 60 and 900 s are 19.0, 19.4, and 20.9, respectively.

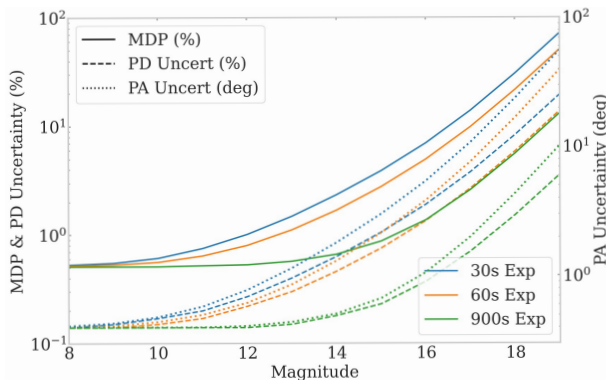


Figure 9. Polarimetric sensitivity as a function of source magnitude for three different exposure times (30, 60, and 900 s). The left y-axis displays the MDP (solid lines) and the uncertainty in PD (σ_{PD} , dashed lines) in percentage. The secondary y-axis (right) shows the uncertainty in PA (σ_{PA} , dotted lines) in degrees.

A.5. Additional Sensitivity Estimates

We utilize Equation (A1) to estimate the SNR for some magnitudes for different exposures and Equations (1), (2), (3) for estimating the PD, PA, and MDP, respectively. These estimates are shown in Table 3 and for better visualization in Figure 9. The systematic uncertainties, governed by the adopted photometric stability limit of $\sigma_{m,sys} = 1.5$ millimag, introduce a sensitivity “floor” that restricts the best achievable precision to $SNR_{max} \approx 720$, resulting in polarization limits of $\sigma_{PD} \approx 0.15\%$, $\sigma_{PA} \approx 0.40^\circ$ (for $PD = 10\%$), and an $MDP \approx 0.51\%$.

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