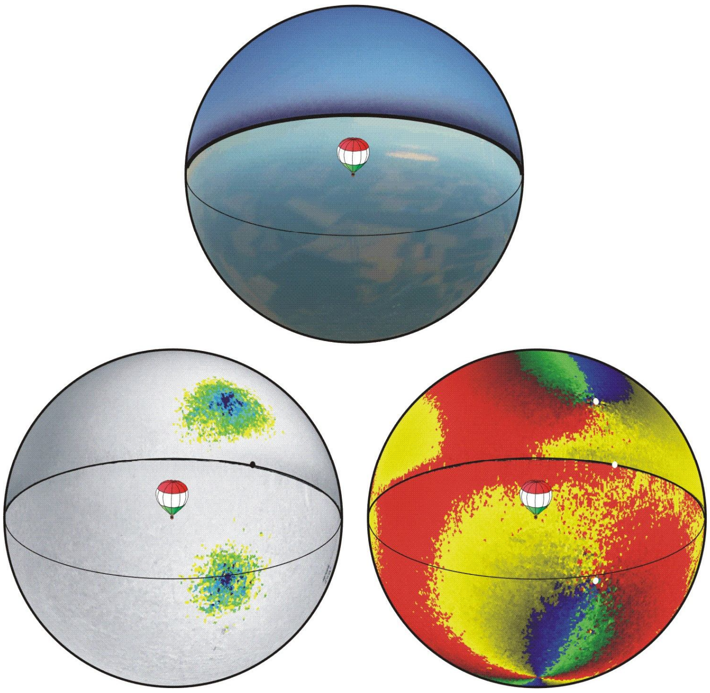
POLARIZATION PATTERNS IN NATURE

Imaging Polarimetry with Atmospheric Optical and Biological Applications

D.Sc. Thesis

Doctor of the Hungarian Academy of Sciences



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Caption for the Cover Picture

Patterns of the radiance I (top), degree of linear polarization p (bottom, left) and angle of polarization α (bottom, right) of skylight and earthlight displayed on the surface of a sphere and measured by 180° field-of-view imaging polarimetry in the blue (450 nm) part of the spectrum from a hot air balloon at an altitude of 4000 m. In the p- and α-patterns the dots from the top toward the bottom show the positions of the Arago neutral point, the antisolar point and the fourth neutral point, respectively. The colour codes of p and α are given in Fig. 7.4.7. More details can be found in Chapter 7.4.

PREFACE

This treatise summarizes my results achieved in the fields of imaging polarimetry and insect polarization sensitivity. Its subject is twofold: it gathers typical polarization patterns occurring in the nature and surveys some polarization-sensitive insects and their polarization-guided behaviour. My research attempts to build a bridge between these two physical and biological fields. The majority of this treatise is part of my monograph entitled *Polarized Light in Animal Vision – Polarization Patterns in Nature* written together with my friend and mentor, Professor Dezső Varjú (from the University of Tübingen, Germany), and published recently by the Springer-Verlag.

Imaging polarimetry helps to understand and reveal the message hidden in polarization patterns of the optical environment not directly accessible to the human visual system, but measurable by polarimetry and perceived by many animal species. This technique can be efficiently used e.g. in atmospheric optics, remote sensing and biology. Earlier, the polarizational characteristics of natural optical environments could be presented only in form of graphs or pairs of photographs taken through linear polarizers with two orthogonal directions of their transmission axes. Due to the imaging polarimetric methods developed by me, the polarization patterns can be visualized as high resolution colour-coded maps of the degree and angle of linear polarization of light.

In the first half of the treatise (Chapters 1–15), after giving a brief history of the discovery of phenomena concerning light polarization, I deal with typical polarization patterns of the natural optical environment. Sunrise/sunset, clear skies, cloudy skies, moonshine and total solar eclipses all mean quite different illumination conditions, which affect the spatial distribution and strength of celestial polarization. I present the polarization patterns of the sky and its unpolarized (neutral) points under sunlit, moonlit, clear, cloudy and eclipsed conditions as a function of the solar elevation. The polarization pattern of a rainbow is also shown. That part of the spectrum is derived in which perception of skylight polarization is optimal under partly cloudy skies. The reader becomes acquainted with the polarization of the solar corona and can follow how the polarization pattern of the sky changed during a total solar eclipse. I also treat the polarizational characteristics of water surfaces, mirages and certain aspects of the underwater polarized light field. It is explained why water insects are not attracted by mirages.

The second half of the treatise (Chapters 16–24) is devoted to the description of some typical behavioural mechanisms indicating how insects use certain natural polarization patterns. I present several case studies of known behavioural patterns in insects determined or influenced by polarization sensitivity. The role of the reflection-polarization patterns of water surfaces in the water detection by insects is discussed. I illustrate how reflection-polarization patterns of anthropogeneous origin can deceive water-seeking polarotactic insects. The natural environment is more or less affected by the human civilization and is overwhelmed by man-made objects, such as crude or waste oil surfaces, asphalt roads, glass surfaces, or plastic sheets used in the agriculture, for instance. I explain why these surfaces are more attractive to water-seeking polarotactic insects than the water surface itself. I reveal why do mayflies or dragonflies lay their eggs *en masse* on dry asphalt roads or car-bodies. I show how dangerous can open-air oil reservoirs be for polarotactic insects and why do oil surfaces function as efficient insect traps. Some other biological functions of polarization sensitivity, such as contrast enhancement and camouflage breaking, for instance, are also discussed. I also present my experimental results on the polarization-sensitive optomotor reaction in two water insect species. Due to the interference of polarization and colour sensitivity, polarization-induced false colours could be perceived by polarization- and colour-sensitive visual systems. I calculate and visualize these false colours by means of a computer model of butterfly retinae, and investigate their chromatic diversity. On the basis of my polarimetric measurements in the field I explain why is it worth flying at dusk for polarotactic water-seeking acquatic insects. Finally, some misinterpretations, misleading nomenclatures, misbelieves and errors concerning polarized light and polarization sensitivity are discussed and corrected.

In addition to reliance on my own contributions to the field, I have quoted from the numerous publications of many other investigators with appropriate reference given in each case. While the bibliography at the end of this treatise is not complete, it is fairly representative of the field.

Gábor Horváth Göd (Hungary), 7 September 2003

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