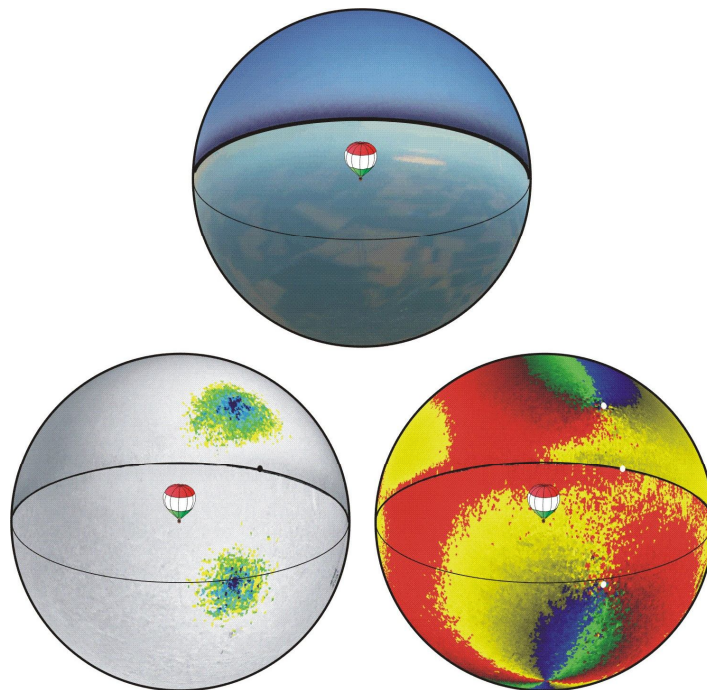


POLARIZATION PATTERNS IN NATURE

Imaging Polarimetry with Atmospheric Optical and Biological Applications

D.Sc. Thesis

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Dr. habil. Gábor Horváth

Loránd Eötvös University
Faculty of Natural Sciences
Department of Biological Physics
Biooptics Laboratory

Budapest, Hungary

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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 aquatic insects. Finally, some misinterpretations, misleading nomenclatures, misbeliefs 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

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TABLE OF CONTENTS

Caption for the Cover Picture	II
PREFACE	III
ACKNOWLEDGMENTS	V
TABLE OF CONTENTS	VI
1 Brief History of the Discovery of Phenomena Concerning Light Polarization	1
2 Polarimetry: From Point-Source to Imaging Polarimeters	8
2.1 Different Ways of Qualitative Demonstration of Polarization in the Optical Environment	10
2.2 Elements of the Stokes and Mueller Formalism of Polarization	12
2.3 Principle of Polarimetry with Polarization-Insensitive Detectors	14
2.4 Polarimetry of Circularly Unpolarized Light by Means of Intensity Detectors	15
2.5 Point-Source, Scanning and Imaging Polarimetry	16
2.6 Sequential and Simultaneous Polarimetry	17
2.7 Colour Coding and Visualization of Polarization Patterns	18
2.8 Field of View of Imaging Polarimetry	18
2.9 Narrow Field-of-View Imaging Polarimetry with Photographic Technique	19
2.9.1 A Forerunner of Imaging Polarimetry Using Savart Filter	19
2.9.2 Simultaneous Photographic Polarimeter	19
2.9.3 Sequential Photographic Polarimeters	20
3 Video Polarimetry	31
3.1 Simultaneous Video Polarimeters	31
3.2 Sequential Imaging Polarimeters Using Liquid Crystal Polarizers	33
3.3 Mueller Matrix Sequential Imaging Polarimeter	34
3.4 Sequential Imaging Polarimeter Using Beamsplitter and Liquid Crystal Polarizer	35
3.5 Rotating-Analyzer Sequential Video Polarimeter	35
3.6 Sequential Stereo Video Polarimetry: Visualizing Polarization Patterns in Three Dimensions	36
3.7 Ultraviolet-Sensitive Rotating-Analyzer Sequential Video Polarimeter	37
3.8 Sequential Video Polarimeters using Microscopes	38
3.8.1 Polarization Video Microscopy	38
3.8.2 Differential Polarization Laser Scanning Microscopy	38
4 Space-Borne Measurement of the Polarizational Characteristics of Earthlight: The POLDER Instrument	46
5 180° Field-of-View Imaging Polarimetry	51
5.1 Simultaneous Full-Sky Imaging Polarimeter with a Spherical Convex Mirror	51
5.2 Sequential Full-Sky Imaging Polarimeter with a Fisheye Lens and a CCD	52
5.3 Portable 180° Field-of-View Sequential Rotating-Analyzer Imaging Photopolarimeter	53
5.4 Portable 3-Lens 3-Camera Full-sky Simultaneous Imaging Photopolarimeter	54
6 Future Polarizational Cameras	60
6.1 Polarization-Sensitive Chips	60
6.2 Polarizational Cameras	60
7 Polarizational Characteristics of the Sky	62
7.1 Skylight Polarization	62
7.1.1 The Importance of Skylight Polarization in Atmospheric Science	62
7.1.2 Measuring Skylight Polarization	63
7.2 Celestial Polarization Measured by Video Polarimetry in the Tunisian Desert	64
7.3 Video Polarimetry of the Arago Neutral Point of Skylight Polarization	70
7.4 First Observation of the Fourth Neutral Polarization Point in the Atmosphere	74
7.4.1 The Last Neutral Point of Atmospheric Polarization	74
7.4.2 Conditions of the Hot Air Balloon Flights to Observe the Fourth Neutral Point	76
7.4.3 Measurement of the Polarization Patterns of Earthlight by 180° Field-of-View Imaging Polarimetry	77
7.4.4 Control Measurement of the Polarization Patterns of the Full Sky at Sunrise	78
7.4.5 Characteristics of the Fourth Neutral Point	78
7.4.6. Origin and Characteristics of the Principal Neutral Points	81
7.4.7 Why the Fourth Neutral Point has not been Observed in Previous Air- or Space-Borne Polarimetric Experiments?	83
7.4.8 Concluding Remarks	86
7.5 24-Hour Change of the Polarization Pattern of the Summer Sky North of the Arctic Circle	95
7.6 How the Clear-Sky Angle of Polarization Pattern Continues Underneath Clouds: Full-Sky Measurements and Implications for Animal Orientation	99
7.7 Cloud Detection with the Use of Ground-Based Full-Sky Imaging Polarimetry	108
7.7.1 Algorithmic Cloud Detection	108
7.7.2 Radiometric Detection of Colourless Clouds	110
7.7.3 Radiometric Detection of Overexposed and Underexposed Parts of the Sky Image	110
7.7.4 Polarimetric Detection of Clouds on the Basis of the Degree and Angle of Linear Polarization	111
7.7.5 Detection of Clouds by Radiometric, Polarimetric and Combined Algorithms	111

7.8 Polarization Pattern of the Moonlit Clear Night Sky at Full Moon: Comparison of Moonlit and Sunlit Skies	120
7.9 Imaging Polarimetry of the Rainbow	125
8 Which Part of the Spectrum is Optimal for Perception of Skylight Polarization?	130
8.1 A Common Misbelief Concerning the Dependence of the Degree of Skylight Polarization on Wavelength	130
8.2 Why do Many Insects Perceive Skylight Polarization in the UV?	131
8.2.1 Is the Celestial Polarization Pattern More Stable in the UV?	132
8.2.2 Was the UV Component of Skylight Stronger in the Past?	133
8.2.3 Relatively Large Proportion of UV Radiation in Skylight?	135
8.2.4 Mistaking Skylight for Ground-Reflected Light?	135
8.2.5 Confusion of Motion and Form for Celestial Polarization?	136
8.2.6 Have been UV Receptors Originally Skylight Detectors and Involved Only Later Into the E-vector Detecting System?	137
8.2.7 Maximizing "Signal-to-Noise Ratios" by UV Photopigments Under Low Degrees of Skylight Polarization?	137
8.2.8 In the Spectral and Intensity Domain the Celestial Band of Maximum Polarization is Less Pronounced in the UV than in the Blue	138
8.2.9 The Proportion of Celestial Polarization Pattern Useful for Animal Orientation is Higher in the Blue than in the Green or Red	138
8.2.10 Perception of Skylight in the UV Maximizes the Extent of the Celestial Polarization Pattern Useful for Compass Orientation Under Cloudy Skies	139
8.3 Resolution of the UV-SKY-POL Paradox	142
8.4 E-Vector Detection in the UV also Maximizes the Proportion of the Celestial Polarization Pattern Useful for Orientation Under Canopies	142
8.5 Analogy Between Perception of Skylight Polarization and Polarotactic Water Detection Considering the Optimal Spectral Range	143
8.6 Analogy of the UV-SKY-POL Paradox in the Polarization Sensitivity of Aquatic Animals	144
8.7 Why do Crickets Perceive Skylight Polarization in the Blue?	144
8.8 Concluding Remark	145
9 Polarization of the Sky and the Solar Corona During Total Solar Eclipses	156
9.1 Structure of the Celestial Polarization Pattern and its Temporal Change During the Eclipse of 11 August 1999	156
9.1.1 Temporal Change of the Celestial Polarization Pattern During the Eclipse	157
9.1.2 Spectral Characteristics of Skylight Polarization During Totality	160
9.1.3 Origin of the E-vector Pattern During Totality	160
9.2 Neutral Points of Skylight Polarization Observed During the Totality of the Eclipse on 11 August 1999	170
9.2.1 Origin of the Zenith Neutral Point During Totality	171
9.2.2 Origin of Another Neutral Points at Totality	172
9.2.3 Relation of the Unique Neutral Point Observed During the Eclipse on 11 August 1999 to Earlier Observations on Anomalous Neutral Points	174
9.3 Imaging Polarimetry of the Solar Corona During the Total Solar Eclipse on 11 August 1999	182
10 How the Polarization of Skylight Changes due to Reflection from the Deflector Panels in Deflector Loft and Mirror Experiments Studying Avian Orientation	185
11 Reflection Polarization of Rayleigh Skylight at the Air-Water Interface	192
11.1 Reflectivity, Reflection-Polarization Ellipse, Degree and Angle of Linear Polarization of Light Reflected from the Water Surface	192
11.2 Polarization Patterns of Single-Scattered Rayleigh Skylight Reflected from the Flat Water Surface as a Function of the Solar Zenith Angle	194
11.3 Effect of Clouds on the Reflection-Polarization Pattern of the Water Surface	195
12 Reflection-Polarization Patterns of the Flat Water Surface Measured by Imaging Polarimetry	208
12.1 Reflection-Polarization Patterns of Freshwater Habitats Measured by Video Polarimetry	208
12.2 Reflection-Polarization Pattern of the Flat Water Surface Measured by 180° Field-of-View Imaging Polarimetry	209
13 Polarization of Light Reflected from Cow-Dung and its Biological Relevance	219
14 Polarization Pattern of a Fata Morgana: Why Aquatic Insects are not Attracted by Mirages?	222
15 Polarizational Characteristics of the Underwater World	228
15.1 Underwater Polarized Light Field	228
15.2 Underwater Polarized UV Light and the UV Polarization Sensitivity in Fishes	231
15.3 Underwater Refraction-Polarization Patterns of Skylight Perceived by Aquatic Animals through the Snell Window of the Flat Water Surface	233
15.3.1 Refraction-Polarization Ellipses, Degree and Angle of Linear Polarization of Refracted Light	233
15.3.2 Refraction-Polarization Patterns of Skylight Visible Through Snell Window Versus the Solar Zenith Angle	234
16 Multiple Choice Experiments on Dragonfly Polarotaxis: Dragonflies Find Crude Oil Visually More Attractive than Water	248
17 How can Dragonflies Discern Bright and Dark Waters from a Distance? The Degree of Linear Polarization of Reflected Light as a Possible Cue for Dragonfly Habitat Selection	260
17.1 Comparison of the Dragonfly Fauna in Dark and Bright Waters	261
17.2 Comparison of the Reflection-Polarizational Characteristics of Dark and Bright Waters	262
17.3 The Degree of Linear Polarization of Reflected Light as a Possible Cue for Dragonfly Habitat Selection	263
18 Oil Reservoirs and Plastic Sheets as Polarizing Insect Traps	272
18.1 Oil Lakes in the Desert of Kuwait as Massive Insect Traps	272
18.2 The Waste Oil Reservoir in Budapest as a Disastrous Insect Trap for Half a Century	274
18.2.1 Surface Characteristics of Waste Oil Reservoirs	275
18.2.2 Insects Trapped by the Waste Oil	276

18.2.3 Behaviour of Dragonflies Above Oil Surfaces	277
18.3 Dual-Choice Field Experiments Using Huge Plastic Sheets	278
18.3.1 Reflection-Polarizational Characteristics of the Plastic Sheets	279
18.3.2 Insects Attracted to the Shiny Black Plastic Sheets and their Behaviour	280
18.4 The Possible Large-Scale Hazard of "Shiny Black Anthropogenic Products" for Aquatic Insects	281
19 Why do Mayflies Lay Eggs on Dry Asphalt Roads? Water-Imitating Horizontally Polarized Light Reflected from Asphalt Attracts Ephemeroptera	299
19.1 Multiple-Choice Experiments with Different Test Surfaces	301
19.2 Swarming Behaviour of Mayflies	301
19.3 Multiple-Choice Experiments with Swarming Mayflies	303
19.4 Influence of Temperature on the Reaction of Mayflies to the Test Surfaces	304
19.5 Reflection-Polarizational Characteristics of the Swarming Sites of Mayflies	305
19.5.1 Reaches of a Mountain Creek	305
19.5.2 Sections of an Asphalt Road	306
19.5.3 Test Surfaces Used in the Multiple-Choice Experiments	306
19.6 Role of Different Cues in the Reproductive Behaviour of Mayflies Above Asphalt Roads	307
19.6.1 Olfaction, Wind and Air Humidity	307
19.6.2 Temperature	307
19.6.3 Colour and Radiance	308
19.6.4 Reflection Polarization	308
19.7 Comparison of the Attractiveness of Asphalt Roads and Water Surfaces to Mayflies	310
19.8 An Efficient Method to Study Ephemeropteran Swarming Behaviour in the Field	312
19.9 Possible Measures to Prevent Mayfly Egg-Laying onto Asphalt Roads	312
20 Reflection-Polarizational Characteristics of Car-Bodies: Why are Water-Seeking Insects Attracted to the Bodywork of Cars?	318
20.1 Attractiveness of the Bodywork of Cars to Certain Insects	318
20.2 Automotive Clearcoat Damage by Dragonfly Eggs	318
20.3 Influence of Colour of Paint	319
21 Polarization-Sensitive Optomotor Reaction in Invertebrates	321
21.1 Crabs	322
21.2 Honeybees	322
21.3 Flies	322
21.4 Rose Chafers	324
21.5 Optomotor Reaction to Over- and Underwater Brightness and Polarization Patterns in the Waterstrider <i>Gerris lacustris</i>	324
21.6 Optomotor Response to Over- and Underwater Brightness and Polarization Patterns in the Backswimmer <i>Notonecta glauca</i>	328
22 Polarization-Induced False Colours	344
22.1 Polarization-Dependent Colour Sensitivity and Colour-Dependent Polarization Sensitivity	344
22.2 Polarizational False Colours of Leaves and Flowers Perceived by <i>Papilio</i> Butterflies	346
22.2.1 Computation of the Spectral Loci of Colours Perceived by a Polarization- and Colour-Sensitive Retina	347
22.2.2 Polarization-Induced False Colours Perceived by the Polarization and Colour-Sensitive Model Retina	350
22.2.3 Reflection-Polarizational Characteristics of Plant Surfaces	353
22.2.4 Do Polarization-Induced False Colours Influence the Weakly Polarization-Sensitive Colour Vision of <i>Papilio</i> Butterflies Under Natural Conditions?	355
22.3 Polarizational False Colours Perceived by a Highly Polarization-Sensitive Retina Rotating in Front of Flowers and Leaves	357
22.4 Camouflage Breaking via Polarization-Induced False Colours and Reflection Polarization	358
22.5 Is Colour Perception or Polarization Sensitivity the More Ancient?	359
23 Why is it Worth Flying at Dusk for Aquatic Insects?	374
23.1. Measurement and Computation of the Reflection-Polarizational Characteristics of the Water Dummies	375
23.2. Calculation of the Area of the Water Dummies in which they are Considered as Water by a Hypothetical Polarotactic Insect	377
23.3. The Reflection-Polarizational Patterns of the Water Dummies	377
23.4. Areas of the Dummies Detected as Water	379
23.5. Discussion	381
24 Correction of Some Misinterpretations, Misleading Nomenclatures, Misbelieves and Errors Concerning Polarized Light and Polarization Sensitivity	397
24.1 The Relative Positions of the Arago, Babinet and Brewster Neutral Points	397
24.2 Correction of Some Misleading Representations of the Celestial E-vector Pattern	398
24.3 Misleading Nomenclatures	399
24.3.1 "Perception of Polarized Light" versus "Perception of Light Polarization"	399
24.3.2 "Linear Polarization" versus "Totally Linear Polarization" and "Partial Polarization" versus "Partial Linear Polarization"	400
24.4 The Celestial Hemisphere Rotates Around the Pole-Point Rather than Around the Zenith	400
24.5 The Light Reflected by the Water Surface is not Always Horizontally Polarized	401
24.6 Arago has Discovered the Skylight Polarization Rather than Malus	402
24.7 The E-Vector Patterns of Real Skies Differ from those of Rayleigh Skies	403
24.8 Four Measurements are not Enough to Determine the Spectral and Polarizational Characteristics of Linearly Polarized Multichromatic Light	404
24.9 A Common Methodological Error: Brightness Patterns Induced by Selective Reflection of Linearly Polarized Light from Black Surfaces	405
24.10 The Alleged Viking Navigation by Skylight Polarization	409
REFERENCES	414-435