

Suppressing a Sea of Starlight : enabling technology for the direct imaging of exoplanets

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Curriculum Vitae

I was born on May 11th, 1987 in Geulle, Meerssen and as a kid went to the local primary school 'in 't Riet'. As long as I can remember I loved astronomy, technology and history. In 1999 I went to high school at the Stella Maris College in Meerssen with a specialization on Science and Technology in the final few years and graduated in 2005. I had claimed for many years that I was going to study Archeology but decided in my fifth year of high school to study my other passion, Astronomy, in Leiden. In retrospect, I couldn't have made a better decision.

During my Bachelor's research project I worked with Henk Hoekstra on the impact of the combination of intrinsic alignments in galaxy clusters and foreground/background galaxy contamination on weak-lensing based mass estimates of the galaxy clusters. I received my Bachelor's degree in 2009. During my Master's study I first worked under supervision of Jarle Brinchmann on determining the dependence of stellar mass estimates of SDSS galaxies on the assumed star formation history. Secondly, I worked under supervision of Ignas Snellen and Ernst de Mooij on testing the use of consumer cameras for accurate photometry of the brightest stars in the sky. This was essentially a feasibility study for the later MASCARA project. During this time, Ernst and Ignas provided the opportunity to go on (my first) observing run with the 4 meter William Herschel Telescope in La Palma, Spain to take photometric observations of secondary transits of exoplanets in the NIR. I received my Master's degree in October 2011. While I was a student I also gave many tours at the Old Observatory and was co-chair of the student association for astronomy 'L.A.D. F. Kaiser'.

In November 2011 I started my PhD under supervision of Matthew Kenworthy. He was quickly joined by Frans Snik and Christoph Keller after the dissolution of Sterrenkundig Instituut Utrecht. Initially my work focused on building an Adaptive Optics testbed to test focal-plane wavefront sensing techniques but the focus quickly shifted to the very promising application of liquid crystal manufacturing techniques to the Apodizing Phase Plate coronagraph. I collaborated with the Geometric-Phase Photonics Lab at North Carolina State University to get multiple iterations of broad-band coronagraphs manufactured and also spent one week working in their lab to test the coronagraph. Furthermore, in the process of getting the coronagraph on-sky at the Large Binocular Telescope (USA) and the Clay Telescope (Chile) I collaborated with a team of astronomers at the University of Arizona. Finally, I spent several nights observing at the Clay telescope to test the coronagraph on-sky.

I presented my work at conferences, workshops and schools in Leiden, Noordwijk, Amsterdam, Groningen and Montreal (in both 2014 & 2015) and at seminars in Raleigh, USA and Santiago, Chile. Furthermore I attended the CfAO Adaptive Optics Summer School in Santa Cruz, California in 2012. As part of my teaching duties I assisted Henk Hoekstra with 'Sterrenkundig Practicum 2' for three years where we taught the second year students what to expect from professional astronomical research. This included three weeklong trips to the 2.5 meter Isaac Newton Telescope in La Palma where the students were familiarized with the observational aspect of astronomical research. Furthermore I assisted in assembling, testing and calibration of the new student telescope at the Old Observatory. Starting 2016 I will work as a Postdoc for one year with Ignas Snellen to construct and rollout the southern station of MASCARA on La Silla, Chile.

Acknowledgments

This thesis would not be possible without the assistance and support of many people in Leiden and abroad. First of all, I am grateful for the support given by colleagues around the world and in Leiden, including the support during my undergraduate studies. I thank Erik, David, Niels, Aart and Eric for their help with computers and offices. As well as the secretaries Anita, Liesbeth, Alexandra, and of course Jeanne to keep the observatory running. Evelijn's assistance on financial matters and travel support was invaluable.

I am grateful to Ernst and Ignas for giving me the opportunity to spend 11 days on La Palma as a rookie. My gratefulness also extends to Henk, whom I joined three consecutive years in the classroom and on La Palma. Remko's guidance on all things optical and mechanical was invaluable during this thesis. I would also like to thank Xander for sharing his knowledge and experience with PhD projects. The 'Gäölse' translation was done by Jos Tilmans as my own attempt resembled an inconsistent patchwork of dialects. His incredible feat deserves a special mention.

I am very thankful to my collaborators in Raleigh and Tucson for not only making our crazy ideas possible, but also getting the coronagraph on-sky within record time. Their support was crucial to get this done.

Sharing six different offices² over the years with numerous inhabitants was an inspiring experience. Officemates Carolina Ödman (outreach) and Martin Weiss (history) showed what an amazingly varied environment Leiden Observatory is to work in. Both Marissa's zeal in achieving her goals and knowing when to wind down & relax are admirable. I hope your dream of becoming an astronaut and going to space comes true. You deserve it. Many thanks go out to Jesse³ for allowing me to join him in his office. I never anticipated the great time we would have while sharing offices. Both in terms of practical jokes and solving scientific conundrums. My current office mates Stephanie, Jos, Christian, and Rob provide a very vibrant working environment and make it possible to get instant feedback on various topics.

Former group members Gerard, Tim, Maria, Laurens and Ritse still form a source of (comedic) relief. I was fortunate to be able to share thoughts and ideas with Tiffany during my PhD. Furthermore, I can not forget David Huijser's role during my undergraduate studies by challenging me in homework assignments, exams and videogames.

I am indebted to Harry Timmermans who guided me many years and introduced me to genealogical research. Sascha, thank you for your unwavering support throughout the years and in years to come. I would like to end by dedicating this thesis to my parents, and Maria and Leon. If one of you had been missing I would have been a different person.

²as a historical reference and in chronological order: Oort 454, 553, 462, 564, 568, 571 ³future director of ESO

List of acronyms

80PM: Eight-Octant Phase Mask ADI: Angular Differential Imaging AGPM: Annular Groove Phase Mask ALC: Apodized Lyot Coronagraph AMZ: Angel-Mach-Zehnder AO: Adaptive Optics APCMLC: Apodized Pupil Complex Mask Lyot Coronagraph APP: Apodizing Phase Plate AU: Astronomical Unit BLC: Band-Limited Lyot Coronagraph CCD: Charge Coupled Device CMOS: Complementary Metal Oxide Semiconductor DM: Deformable mirror dOTF: Differential Optical Transfer Function DPM: Disk Phase Mask DZPM Dual Zone Phase Mask E-ELT: European Extremely Large Telescope EE: Encircled Energy ELT: Extremely Large Telescope EPICS: Exo-Planet Imaging Camera and Spectrograph FFT: Fast Fourier Transform FP: Focal Plane FQPM: Four-Quadrant Phase Mask FWHM: Full Width Half Maximum GPI: Gemini Planet Imager gvAPP: grating vector Apodizing Phase Plate HARMONI: High Angular Resolution Monolithic Optical and Near -infrared Integral field HDR: High Dynamic Range HLC: Hybrid Lyot Coronagraph HST: Hubble Space Telescope HWP: Half-Wave Plate IFU: Integral Field Unit LBT: Large Binocular Telescope LHC: Left-handed Circular LMIRCam: Large Binocular Telescope mid-infrared camera LOCI: Locally Optimized Combination of Images

MagAO: Magellan Adaptive Optics METIS: Mid-infrared E-ELT Imager and Spectrograph MICADO: Multi-Adaptive Optics Imaging Camera for Deep Observations MMTO: MMT Observatory MTR: Multi-Twist Retarder NACO: NAOS-CONICA NCP: Non-common path NCPA: Non-common path aberrations NWO: Nederlandse Organisatie voor Wetenschappelijk Onderzoek OVC: Optical Vortex Coronagraph PCA: Principal Component Analysis PDI: Polarization Differential Imaging PG: Polarization Grating PIAA(C): Phase Induced Amplitude Apodization (Coronagraph) PIAACMC: PIAA Complex Mask Coronagraph **PP: Pupil Plane** PPA: Pupil Plane Apodization PSF: Point spread function PSI: Phase-Sorting Interferometry QWP: Quarter-Wave Plate **RDI:** Reference Differential Imaging RHC: Righthanded Circular **RV: Radial Velocity** ScexAO: Subaru Coronagraphic Extreme Adaptive Optics SD: Spectral Deconvolution SDI: Simultaneous / Spectral Differential Imaging SLM: Spatial Light Modulator SP: Shaped Pupil SPHERE: Spectro-Polarimetric High-contrast Exoplanet REsearch instrument SR: Strehl Ratio UV: Ultraviolet IR: Infrared vAPP: vector Apodizing Phase Plate VLT: Very Large Telescope VVC: Vector Vortex Coronagraph WFS: Wavefront sensor