# Painting with starlight : optical techniques for the high-contrast imaging of exoplanets

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# List of Publications

## Refereed Publications

1. *The coronagraphic Modal Wavefront Sensor: a hybrid focal-plane sensor for the high-contrast imaging of circumstellar environments*
   **M. J. Wilby**, C. U. Keller, F. Snik, V. Korkiakoski, A. G. M. Pietrow
   2017, A&A 597, A112
2. *Laboratory verification of Fast & Furious phase diversity: Towards controlling the low wind effect in the SPHERE instrument*
   **M. J. Wilby**, C. U. Keller, J.-F. Sauvage, K. Dohlen, T. Fusco, D. Mouillet, J.-L. Beuzit
   2018, A&A 615, A34
3. *These are not the voids you're looking for: Using Ceres to calibrate SPHERE-IRDIS coronagraphic DPI observations of TW Hydrae*
   **M. J. Wilby**, J. de Boer, R. G. van Holstein, C. Ginski, J. Girard, A. Boccaletti, C. U. Keller
   In preparation
4. *First direct detection of a polarized companion outside a resolved circumbinary disk around CS Chamaeleonis*
   C. Ginski, M. Benisty, R. G. van Holstein, A. Juhasz, T. O. B. Schmidt, G. Chauvin, J. de Boer, **M. J. Wilby**, C. F. Manara, P. Delorme, F. Ménard, P. Pinilla, T. Birnstiel, M. Flock, C. U. Keller, M. Kenworthy, J. Milli, J. Olofsson, L. Perez, F. Snik, N. Vogt
   2018, A&A 616, A79

## Proceedings Articles

1. *Designing and testing the coronagraphic Modal Wavefront Sensor: a fast non-common path error sensor for high-contrast imaging*
   **M. J. Wilby**, C. U. Keller, S. Y. Haffert, F. Snik, V. Korkiakoski, A. G. M. Pietrow
   2016, Proc. of SPIE Vol. 9909, Adaptive Optics Systems V, 990921
2. *A "Fast and Furious" solution to the low-wind effect for SPHERE at the VLT*
   **M. J. Wilby**, C. U. Keller, J.-F. Sauvage, T. Fusco, D. Mouillet, J.-L. Beuzit, K. Dohlen
   2016, Proc. of SPIE Vol. 9909, Adaptive Optics Systems V, 99096C
3. *The Leiden EXoplanet Instrument (LEXI): a high-contrast high-dispersion spectrograph*
   S. Y. Haffert, **M. J. Wilby**, C. U. Keller, I. A. G. Snellen
   2016, Proc. of SPIE Vol. 9908, Ground-based and Airborne Instrumentation for Astronomy VI, 990867

4. *On-sky results of the Leiden EXoplanet Instrument (LEXI)*
   S. Y. Haffert; **M. J. Wilby**; C. U. Keller; I. A. G. Snellen; D. S. Doelman; E. H. Por; M. van Kooten; S. P. Bos; J. Wardenier
   2018, Proc. of SPIE Vol. 10703, Adaptive Optics Systems VI, 1070323

5. *Multiplexed holographic aperture masking with liquid-crystal geometric phase masks*
   D. S. Doelman, P. Tuthill, B. Norris, **M. J. Wilby**, E. H. Por, C. U. Keller, M. J. Escuti, F. Snik
   2018, Proc. of SPIE Vol. 10701, Optical and Infrared Interferometry and Imaging VI, 107010T

6. *Focal plane wavefront sensing and control strategies for high-contrast imaging on the MagAO-X instrument*
   K. Miller, J. R. Males, O. Guyon, L. M. Close, D. Doelman, F. Snik, E. Por, **M. J. Wilby**, C. Bohlman, J. Lumbres, K. van Gorkom, M. Kautz, A. Rodack, J. Knight, N. Jovanovic, K. Morzinski, L. Schatz
   2018, Proc. of SPIE Vol. 10703, Adaptive Optics Systems VI, 107031T

7. *Review of high-contrast imaging systems for current and future ground-based and space-based telescopes II. Common path wavefront sensing/control and Coherent Differential Imaging*
   N. Jovanovic, O. Absil, P. Baudoz, M. Beaulieu, M. Bottom, E. Cady, B. Carlomagno, A. Carlotti, D. S. Doelman, K. Fogarty, R. Galicher, O. Guyon, S. Haffert, E. Huby, J. Jewell, C. U. Keller, M. A. Kenworthy, J. Knight, J. Kuhn, K. Miller, J. Mazoyer, M. N'Diaye, L. Pueyo, A.J. Riggs, G. Ruane, D. Sirbu, F. Snik, J. K. Wallace, **M. J. Wilby**, M. Ygouf
   2018, Proc. of SPIE Vol. 10703, Adaptive Optics Systems VI, 107031U

# Curriculum Vitae

I was born on the 25th of July 1992 in Hemel Hempstead, a small commuter town in Hertfordshire, UK. When I was seven my parents and I moved to the coastal town of Paignton, in Devon, and it was under the dark skies of the Dartmoor national park that I developed a fascination with astronomy. While attending Torquay Boys' Grammar School I was also fortunate enough to have access to the school's own (sadly much under-used) on-site observatory: I will never forget the thrill of seeing the surface details of Mars with my own eyes for the first time, whilst balancing precariously on a step-ladder in order to reach the eyepiece.

In 2010 it was this passion for astronomy that inspired me to move to the other end of the country to start my undergraduate degree in Physics with Astronomy at Durham University. During this time I met a fantastic group of like-minded amateur astronomers, with whom I spent many a night standing on observatory hill, trying to maintain enough feeling in my fingers to operate the AstroSoc telescopes. The degree itself was also fascinating: alongside high-quality theoretical lectures and programming courses, one of my bachelor projects involved tracking Jovian and Martian trojan asteroids from night to night with the department's roof-mounted telescopes, in order to compute their orbits. For my master's thesis I tried my hand at a more theoretical topic, modelling the infall and merger of satellite galaxies with their host under the supervision of Prof. Shaun Cole in the Institute for Computational Cosmology.

Two lecture series which particularly inspired me during this period covered the topics of exoplanets and the optical instrumentation which enables their detection. For this reason, in September 2014 I once again upped sticks and this time left the country for Leiden, to pursue a PhD with Prof. Christoph Keller in the high-contrast imaging group. The purpose of this thesis has been to address some of the current technical limitations of direct exoplanet imaging, in order to pave the way for the next generation of ELT-class planet-finding instruments. This has included many fantastic (but exhausting) observing trips to the Roque de Muchachos Observatory on La Palma to test out new instrumentation, as well as a memorable side-project observing the northern lights in arctic Norway.

With my doctorate in hand, I now intend to move back to the UK and turn to the dark side: having recently completed the month-long *Science to Data Science* programme in London, I plan to leave academia for the glitz and glamour of the data science industry. I will nonetheless very much miss being a professional astronomer, as it remains a subject that is very close to my heart.

# Acknowledgements

This thesis is the product of four years of intense study, hard work and self-development, which would not have been possible without the support of a huge number of people both in Leiden and further afield. I am hugely grateful to the network of PhDs, postdocs, staff members and non-sterrewacht friends who have enlightened, challenged, assisted, and generally kept me (mostly) sane throughout this journey. It is difficult to thank everyone properly in just a couple of pages, so I apologise in advance if I accidentally miss anyone out.

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I have been very fortunate to be part of the Leiden high-contrast imaging group, and to see it grow substantially during my time at the sterrewacht. Frans, Gilles, Emiel, David, Maaike and Steven, as (pseudo-)office mates over the years you have ensured that there has always been a crazy idea or four bouncing around to keep us entertained. I'm also grateful to Jos, Christian and Rob, for keeping me in touch with the SPHERE observational community, and the various ways in which the instruments we build can be (mis-)used. Michiel and Sebastiaan: you were the ones who gave me my day-one crash course in optical lab work with ExPo and its AO system (though I'm sorry for my lack of success in mastering the latter!). Our regular observing trips to the WHT have been a real highlight of my PhD, so thanks to everyone who has been part of the ExPo and LEXI observing teams over the years, and helped keep our oxygen- and sleep-deprived brains functioning after the 3 AM dip. A big thanks as well to the WHT staff and support astronomers, especially Jürg, Luis, Neil, Émilie, Frank, Fiona and Richard, for always being ready to lend a hand when it all starts going wrong!

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lands, including (but certainly not limited to) the idiosyncrasies of the Dutch tax system. Chris, thank you for many enlightening discussions about the difference between the British and Canadian culture. I'm definitely also going to miss your unique shared sense of humour with Ann-Sofie. Eva and Valeria: it's a shame we didn't start the baking club earlier in the PhD (or maybe it was for the best, at least for my waistline!). Geert Jan and Andrew: I wish you both all the best for your North American adventure - Andrew, good luck with Trump! Luke, thank you for bringing a touch of Yorkshire to the sterrewacht. Ann-Sofie, Jeroen & Andrej: you have introduced me to an unexpected new passion in the form of swing dance, which I will definitely keep up after the PhD. Allison & Alex, thank you for the many lovely meals, kitty sitting, and for soundly thrashing me at a wide variety of board games. Nico & Wijnand: it's been great getting to know you guys (and Shaffy!) and I wish you all the best for the future.

I hope we will all stay close friends in the coming years, despite all ending up in different parts of the globe!

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Finally, to my parents, who have always encouraged me to strive and fulfil my ambitions, and who are a source of sound, experienced advice whenever the path ahead is not clear. I can imagine how tough it must have been to say goodbye to your only child when I first moved to Durham to start my university education, and I have only moved further away since! You'll be glad to hear I'm not thinking of moving to New Zealand any time soon. Thank you for being a pillar of certainty upon which I can always rely. And of course, to Charlotte: thank you so much for taking the leap of faith and moving to Leiden with me, and for your unwavering support and understanding over these past four years. Completing this PhD has at times seemed like a insurmountable task, and I really could not have done it without you by my side. If nothing else you must have proof-read pretty much all of this thesis at one point or another! Here's to pastures new, and many more years (and adventures) to come. And lastly I have to thank Áine, for two years of stimulating (if mostly uni-directional) conversations, and in helping us both to define a new level of insanity.

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