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Chaotic Dynamics in N-body systems

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Curriculum Vitae

“Life is nothing without a little chaos to make it interesting.”

– Amelia Atwater-Rhodes

I was born on 12 May 1985 (Mother’s day) in Leidschendam, only 15 km away from Leiden. After a few months we moved to Waddinxveen, where I later attended elementary school at the Koningin Beatrix school. My main interests in life were playing football at the local club V. V. Waddinxveen and painting landscapes in the popular style of Bob Ross, which resulted in an exhibition at the local library in 1997.

Following elementary school, I remained in Waddinxveen to attend high school at the Coenecoop College (Atheneum, Natuur & Techniek). It was when I was aged 13 that I watched the TV series “From the Earth to the Moon” on the Apollo missions, and seeing Neil and Buzz bounce around on the Moon triggered the realisation that the world is bigger than my local street. I started reading books on astronomy, including “A Brief History of Time” by Stephen Hawking. This book inspired my final high school research project on “de Oerknal” (the Big Bang) under supervision of mr. Guiking and mw. Persoon. My free time was spent playing rock guitar.

Whereas many hobbies came and went, my passion for astronomy remained and I decided to study Astronomy at Leiden Observatory. My Bachelor research project was in collaboration with Willem de Pous, under supervision of Michiel Hogerheijde and Olja Panić. We simulated the emission of a proto-planetary disk using the code RATRAN. This was my first experience with numerical modelling of astronomical systems.

Having obtained the BSc title, I continued at Leiden to do my Masters in Astronomy. For my minor Master research, under supervision of Jarle Brinchmann, I data-mined the SDSS catalogue for candidate dual AGN. We worked mostly with IDL, which introduced me to scripting and the handy program TOPCAT. I was also student assistant for the first year course Practical Astronomy.

During the annual Science Day at Leiden Observatory, I attended a talk by a newly arrived professor in Computational Astrophysics. As soon as the particles moved over the screen, I instantly knew that

this was the research field for me, and immediately arranged to do my major Master research with Simon Portegies Zwart on stellar dynamics and N-body methods. It was from this research that the N-body code Brutus was developed, which uses arbitrary-precision arithmetic. I was fortunate to have found the right topic for me, with the right supervisor, at the right time.

On completion of my Masters, I left academia to work at the space division of the software company Logica in Rijswijk. Only one week into this role I was given the opportunity to continue my astronomy career at Leiden Observatory, and therefore resigned. Over the last four years I have worked on my PhD under supervision of Simon Portegies Zwart, where we investigated the topics presented in this thesis.

I have attended many conferences and workshops in a variety of places, including Leiden (Modest11), Ameland (NAC12), Noordwijkerhout (NAC14), Nunspeet (NAC15), Dwingeloo (NOVA school), Bonn (Modest14, Aarseth N-body Meetings), Heidelberg (Computational Astrophysics), Berlin (Formation of the Solar System II), Daresbury (Hardware Acceleration), Paris (Stellar Dynamics), Sesto (N-body dynamics), Philadelphia (work visit to Steve McMillan) and New Orleans (Supercomputers). On several occasions I presented my work through a poster and in Bonn and Paris I gave a talk on my work on Brutus and Comet Halley.

Publications

1. *Punctuated Chaos in Dynamical Systems*
Boekholt, T. C. N., Pelupessy, F. I., Heggie, D. C. and Portegies Zwart, S. F.
Submitted to MNRAS (Chapter 6)
2. *On the Reliability of N-body Simulations*
Boekholt, T. C. N. and Portegies Zwart, S. F.
ComAC, Vol. 2, p. 2, March, 2015 (Chapter 2 and 4)
3. *A Keplerian-based Hamiltonian splitting for gravitational N-body simulations*
Gonçalves Ferrari, G., **Boekholt, T. C. N.** and Portegies Zwart, S. F.
MNRAS, 440, 719-730, May, 2014 (Chapter 3)
4. *On the Minimal Accuracy Required for Simulating Self-gravitating Systems by Means of Direct N-body Methods*
Portegies Zwart, S. F. and **Boekholt, T. C. N.**
ApJL, 785, L3, April, 2014 (Chapter 5)
5. *The evolution of the Sun's birth cluster and the search for solar siblings in the simulated Gaia catalogue*
Martinez-Barbosa, C. A., Brown, A. G. A., **Boekholt, T. C. N.**, Portegies Zwart, S. F., Antiche, E. and Antoja T.
Submitted to MNRAS

Acknowledgements

"We know the age of the Universe to within one percent. For most of my friends I have no idea what their exact age is to within one percent. The Universe is probably my most accurate acquaintance at the moment." – Piet Hut

Four years of PhD research has made me grow both scientifically and as a person. Apart from studying, doing research and attending conferences, I learnt that communication and discussion with colleagues is crucial, both for receiving constructive feedback and for getting new ideas. I have had the privilege to meet many interesting people at Leiden Observatory and at conferences abroad.

First of all, I would like to thank my supervisor Simon Portegies Zwart. Four years ago you made me an offer I could not refuse ³. Without your guidance and belief in my capabilities, this thesis would not be here. I have enjoyed our collaboration and look forward to many more projects to come.

Secondly, I wish to thank my direct collaborators, some of whom I produced a publication with. A special thanks goes out to Douglas Hoggie, I still remember my mobile phone disrupting our first meeting at Modest11. I have learnt a lot from our collaboration since, both as a scientist and as a person and also greatly appreciate your feedback and contributions to this entire thesis.

It is a pleasure to thank Guilherme Gonçalves Ferrari for our many discussions on N-body related topics. I truly learnt a lot from you, and I hope we can investigate many more topics in the future⁴.

I would like to thank Steve McMillan for receiving me twice at Drexel University in Philadelphia. I enjoyed these work visits very much and learnt a lot about three-body scattering. Many thanks to Joshua Wall and Michael Brewer for their hospitality during my visits.

It was an honour to be part of the AMUSE team, including Arjen, Inti, Nathan, Evghenii, Niels, Michiko, Masaki, Bernadetta, Steven, Jeroen, Dan, Alex, Carmen, Davide, Stefania, Edwin, Tjibaria, Adrian, Lucie, Silvia, Nora, Thomas, Martha and Maria. The weekly group

³The Godfather, 1972

⁴Both astronomical and non-astronomical!

meetings and frequent discussions have broadened my knowledge ranging from binary evolution, to capturing stones, tidal fields, secular dynamics, supernova shocks, initial conditions and post-Newtonian effects. The AMUSE project can count on a bright future!

The CC Club was also essential to my PhD experience. Because of the many nationalities present at the Observatory, it is a good opportunity to get a taste of other cultures, both culinary and cinematic. I treasure some of my fondest memories from these events and I thank Noel, Susy, Carmen, Jose, Guilherme, Lucie, Alan, Silvia, Emilio, Liliana, Yuri, Ainil, Tofan, Rosa and Paula.

Many thanks to my non-astronomy friends, Marc, Connie, Rene, Dilara, Robert, Dion, Mouade, Vincent, Nastassia, Ryan, Jeroen and Raynor. Trying to explain my work keeps being a challenge, but is always good practice.

I thank my parents, Ralph and Sylvia, and the rest of the family, Philip, Charles, Jamie, Jessica and Remko for their support and for providing a relaxed haven to retire to. A special thanks to Zacky, Evy, Toby, and also Vicky, whose original questions keep me on my guard. Last but not least, I wish to thank Ann, Josh, Rebecca, Gemma and Kirsty for showing me that there is a life outside of science and work. Without Ann's love and support since my Bachelors, I probably would not have made it this far.

