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Complex processes in simple ices : laboratory and observational studies of gas-grain interactions during star formation

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CURRICULUM VITAE

I was born the 27th of August 1982 to Christina and Tomas Öberg in Nyköping, Sweden; a town most noted for Nyköping Gästabud (Banquet) in 1317 when King Birger entertained his two brothers regally before throwing them into the castle dungeon, the dungeon key into the moot and left the brothers to starve to death. At the age of six, the family relocated to the beautiful naval town Karlskrona, in the south of Sweden, where I attended primary, secondary and high school (Chapmanskolan) – my high school senior project was supervised by my father and resulted in my first publication. Equally enticed by history, literature, art and science during most of these years I decided to focus on a science career and after a challenge from my father I applied and was admitted to the California Institute of Technology (Caltech).

At Caltech I pursued research projects in physical chemistry and astrochemistry under the supervision of Prof. Jack Beauchamp and Prof. Geoffrey Blake, resulting in two publications. The summer between junior and senior year I first visited Leiden, with a Caltech summer research fellowship, and at the end of the summer, Leiden University and Prof. Dr. Ewine van Dishoeck had become my top choice for graduate school. I received my B.Sc. in chemistry, cum laude, 2005 and took up a Ph.D. position under the supervision of Prof. Dr. Ewine van Dishoeck and Prof. Dr. Harold Linnartz in Leiden the same fall.

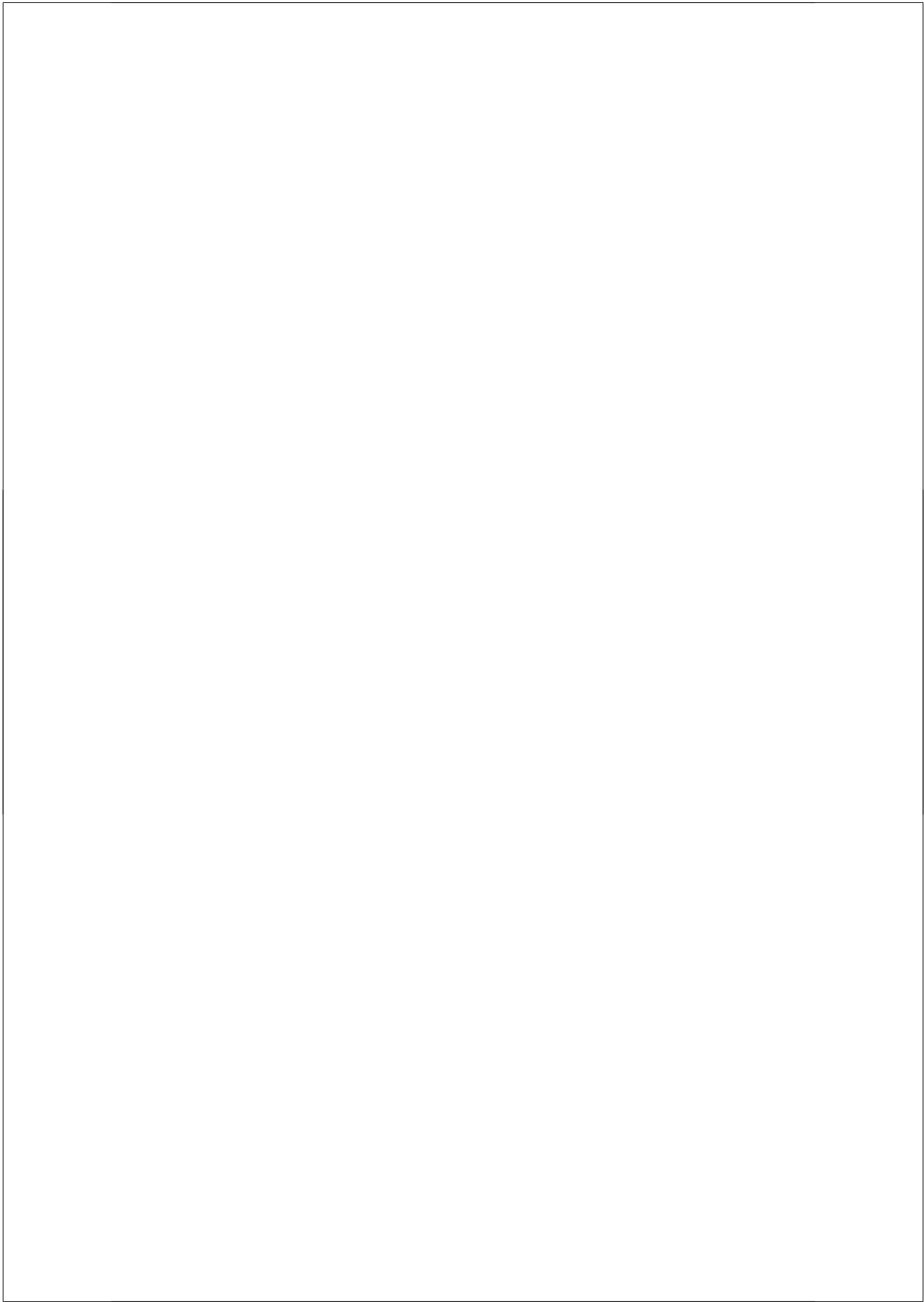
During the following four years I researched the chemistry of interstellar ices through laboratory simulations in the Raymond and Beverly Sackler Laboratory for Astrophysics, ice observations with the *Spitzer Space Telescope* and gas observations with the IRAM 30m telescope (Pico Veleta, Spain) and the JCMT (Hawaii, U.S.A.). The result is this thesis. The different chapters have been presented at conferences in Paris (France), Belfast (UK), London (UK), Hong Kong (China), Arcachon (France) and Green Bank (U.S.) and at visits to Estec (Netherlands) and a number of U.S. institutes including University of Arizona, UC Santa Cruz, Berkeley, the Harvard-Smithsonian Center for Astrophysics and University of Michigan. In addition, I have had longer working visits to Université de Cergy-Pontoise in Paris, France. In Leiden I also supervised two M.Sc. projects and was a teaching assistant for courses on Pulsars and on research for B.Sc. students.

In October I will start a three-year postdoctoral position as a Hubble fellow at the Harvard-Smithsonian Center for Astrophysics (Cambridge, U.S.).

Refereed papers

1. *Formation rates of complex organics in UV irradiated CH₃OH-rich ices I: Experiments (Chapter 10)*
Öberg K. I. ; Garrod, R. T.; van Dishoeck, E. F.; Linnartz, H., 2009, accepted for publication in *Astronomy & Astrophysics*
2. *Quantification of segregation dynamics in ice mixtures (Chapter 5)*
Öberg K. I. ; Fayolle, E. C.; Cuppen, H. M.; van Dishoeck, E. F.; Linnartz, H., 2009, accepted for publication in *Astronomy & Astrophysics*
3. *Photodesorption of ices II: H₂O and D₂O (Chapter 9)*
Öberg K. I. ; Visser, R.; van Dishoeck, E. F.; Linnartz, H., 2009, *Astrophysical Journal*, volume 93, pages 1209-1218
4. *Photodesorption of ices I: CO, N₂ and CO₂ (Chapter 8)*
Öberg K. I. ; van Dishoeck, E. F.; Linnartz, H., 2009, *Astronomy & Astrophysics*, volume 496, pages 281-293
5. *Cold gas as an ice diagnostic toward low mass protostars (Chapter 12)*
Öberg K. I. ; Bottinelli, S.; van Dishoeck, E. F., 2009, *Astronomy & Astrophysics*, volume 494, pages L13-L16
6. *The c2d Spitzer spectroscopic survey of ices around low-mass young stellar objects, III. CH₄ (Chapter 3)*
Öberg K. I. ; Boogert, A.C.A.; Pontoppidan, K.M.; Blake, G.A.; Evans, N.J.; Lahuis, F.; van Dishoeck, E.F., 2008, *Astrophysical Journal*, volume 678, pages 1032-1041
7. *The c2d Spitzer spectroscopic survey of ices around low-mass young stellar objects, II. CO₂*
Pontoppidan, K. M.; Boogert, A. C. A.; Fraser, H. J.; van Dishoeck, E. F.; Blake, G. A.; Lahuis, F.; **Öberg, K. I.**; Evans, N. J., II; Salyk, C., 2008, *Astrophysical Journal*, volume 678, pages 1005-1031
8. *The c2d Spitzer spectroscopic survey of ices around low-mass young stellar objects, I. H₂O and the 5-8 μm bands*
Boogert, A. C. A.; Pontoppidan, K. M.; Knez, C.; Lahuis, F.; Kessler-Silacci, J.; van Dishoeck, E. F.; Blake, G. A.; Augereau, J.-C.; Bisschop, S. E.; Bottinelli, S.; Brooke, T. Y.; Brown, J.; Crapsi, A.; Evans, N. J., II; Fraser, H. J.; Geers, V.; Huard, T. L.; Jørgensen, J. K.; **Öberg, K. I.**; Allen, L. E.; Harvey, P. M.; Koerner, D. W.; Mundy, L. G.; Padgett, D. L.; Sargent, A. I.; Stapelfeldt, K. R., 2008, *Astrophysical Journal*, volume 678, pages 985-1004
9. *Photodesorption of CO ice (Chapter 7)*
Öberg K. I. ; Fuchs, G.W.; Awad, Z.; Fraser, H.J.; Schlemmer, S.; van Dishoeck, E. F.; Linnartz, H., 2007, *Astrophysical Journal Letters*, volume 662, pages L23-L26

10. *Band profiles and band strengths in mixed H₂O:CO ices*
Bouwman, J.; Ludwig, W.; Awad, Z.; **Öberg K. I.**; Fuchs, G.W.; van Dishoeck, E. F.; Linnartz, H., 2007, *Astronomy & Astrophysics*, volume 476, pages 995-1003
11. *Effects of CO₂ on band profiles and band strengths of H₂O in mixed H₂O:CO₂ ices (Chapter 4)*
Öberg K. I.; Fraser, H.J.; Boogert, A.C.A.; Bisschop, S.E.; Fuchs, G.W.; van Dishoeck, E. F.; Linnartz, H., 2007, *Astronomy & Astrophysics*, volume 462, pages 1187-1198
12. *Desorption rates and sticking coefficients of CO and N₂ interstellar ices*
Bisschop, S. E.; Fraser, H. J.; **Öberg, K. I.**; van Dishoeck, E. F.; Schlemmer, S., 2006, *Astronomy & Astrophysics*, volume 449, pages 1297-1309
13. *Simple optical sensors for amine vapors based on dyed silica microspheres*
Öberg, K. I.; Hodyss, R.; Beauchamp J. L., 2006, *Sensors and Actuators*, volume 115, pages 79-85
14. *Competition between CO and N₂ desorption from interstellar ices*
Öberg K. I.; van Broekhuizen, F.; Fraser, H. J.; Bisschop, S. E.; van Dishoeck, E. F.; Schlemmer, S., 2005, *Astrophysical Journal*, volume 621, pages L33-L36
15. *Methane abundance variations toward the massive protostar NGC 7538 IRS 9*
Boogert, A. C. A.; Blake, G. A.; **Öberg, K. I.**, 2004, *Astrophysical Journal*, volume 615, pages 344-353
16. *Distribution and levels of brominated flame retardants in sewage sludge*
Öberg K.; Öberg, T.; Warman, C., 2002, *Chemosphere*, volume 48, pages 805-809



AFTERWORD

I feel, and have always felt, with Kant that the starry heavens above me and the moral law within me are most worthy of our investigation and our wonder. The Sterrewacht taught me how to study the stars. Its expectation of excellence and dedication challenged me to make this thesis as good as it possibly could be, its continuous support made the hard work possible – it made it fun. Credit also to the dedicated support staff at the Sterrewacht, who have always been quick to help when I have encountered computer problems or needed assistance with paper work.

The roots of this thesis go deeper than my arrival to Leiden. They go first and foremost to my extraordinary family, whose passion for exploring and preserving this world trained me to be a researcher long before I knew what it was, and who continue to inspire everything I do. Pappa, Mamma, Lars and Erik, I know I have lived far away for a long time, but knowing that you are there whenever it matters is my foundation. Lars and Erik you have been the guardians of my mind, ensuring that it never lost touch with exploring topics outside of science – my lasting passion for the humanities is credit to you.

Nine years ago, a dedicated group of high school teachers gave me the confidence to apply to Caltech. Caltech was a birth through fire experience into science, which taught me to think, to ask questions and to solve problems as I scarce had thought my mind capable of. I cannot imagine a better training ground for a scientist than I was given there, both in the class room and in the research groups of Jack Beauchamp and Geoffrey Blake - the ground work for this thesis was laid there. Geoff first introduced me to the wonders of astrochemistry and gave me my first telescope experience. The telescope was the Keck at Hawaii, and no surprise I have been in the field ever since. Caltech may be a scientist's playground but without my adopted family, Bernadette, Courtney, Hesper, Jackie and Vicki, I would probably have gone insane under the workload – I really cannot wait to be back in the U.S. with you.

The actual thesis work began four years ago when I started by Ph.D. project in the astrochemistry and laboratory astrophysics groups at the Sterrewacht. It has been a privilege to be your colleague and I have enjoyed our, sometimes rather lively, discussions about science and life outside of it. I am a better experimentalist, a better observer and even learned some modeling because of you. My Ph.D. had a flying start because of the previous work of Willem Schutte, Fleur van Broekhuizen, Helen Fraser, Stephan Schlemmer and Guido Fuchs in the Sackler lab, especially on CRYOPAD, and their impact on seven of the thesis chapters is thus considerable. I also learned to teach during the past two years, thanks to Saskia and Edith, who showed great patience in training me to be a supervisor. My learning experiences during my Ph.D. have not been limited to Leiden; this thesis has benefitted from discussions and collaborations within the Spitzer *c2d* team, especially Adwin Boogert and Klaus Pontoppidan, and with Sandrine Bottinelli and Rob Garrod and many others.

Several of my colleagues and collaborators have become dear friends, and while there is too little space to mention you all – I have been too fortunate in the number of good people surrounding me – if I could dedicate the thesis a second time, it would be to you. My past and current office mates, Bastiaan, Claire, Kalle, Saskia and Suzanne, have often been first to share both my frustrations and my triumphs and being able to vent to you pulled me through the less triumphant times. Suzanne you were my first friend here and having you in Leiden for two years made the hard times less hard and the good times better. Tonie and Christian, and Jeanette, I am sorry to abandon you – your care and distracting capabilities have ensured that I never really lost myself in work. To you and my other fellow Scandinavians: it has been amazing to have a bit of home here in Leiden.

At the end, I am overwhelmed with how my life has worked out during the past eight years. I had rather outrageous dreams of the kind of career I wanted in high school. Or so I thought. Because of your support and your belief in me, reality has been better.

Two things fill the mind with ever-increasing wonder and awe,
the more often and the more intensely the mind of thought is drawn to them:
the starry heavens above me and the moral law within me.

Translation from Critique of Practical Reason by Immanuel Kant

