



Universiteit
Leiden
The Netherlands

Spectroscopy and chemistry of interstellar ice analogues

Bouwman, J.

Citation

Bouwman, J. (2010, October 12). *Spectroscopy and chemistry of interstellar ice analogues*. Retrieved from <https://hdl.handle.net/1887/16027>

Version: Corrected Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/16027>

Note: To cite this publication please use the final published version (if applicable).

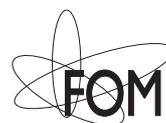
Spectroscopy and Chemistry of
Interstellar Ice Analogues

Spectroscopy and Chemistry of Interstellar Ice Analogues – Jordy Bouwman
Thesis Universiteit Leiden - Illustrated - With summary in Dutch - With references
ISBN/EAN 978-90-9025686-3

Printed by Ipskamp Drukkers

Cover by Ruud Engelsdorp

This work is part of the research programme of the Foundation for Fundamental Research on Matter (FOM), which is part of the Netherlands Organisation for Scientific Research (NWO).



Spectroscopy and Chemistry of Interstellar Ice Analogues

PROEFSCHRIFT

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van de Rector Magnificus prof. mr. P. F. van der Heijden,
volgens besluit van het College voor Promoties
te verdedigen op dinsdag 12 oktober 2010
klokke 13.45 uur

door

Jordy Bouwman
geboren te Haarlem
in 1979

Promotiecommissie:

Promotor: Prof. dr. H. V. J. Linnartz
Copromotor: Dr. L. J. Allamandola NASA Ames Research Center

Overige Leden: Prof. dr. K. Kuijken
Prof. dr. A. G. G. M. Tielens
Prof. dr. M. R. S. McCoustra Heriot-Watt University
Prof. dr. J. Oomens FOM Rijnhuizen
Dr. H. M. Cuppen

1	Introduction	1
1.1	Astrochemistry	1
1.2	The interstellar cycle of matter	3
1.3	Mid-IR absorption bands – Interstellar ices	4
1.3.1	Composition of interstellar ices	5
1.3.2	Ice formation and grain chemistry	7
1.4	Mid-IR emission bands – Polycyclic Aromatic Hydrocarbons	9
1.4.1	The PAH building block – Carbon	10
1.4.2	The origin of interstellar PAHs	11
1.4.3	PAHs in interstellar ices?	13
1.5	Laboratory spectroscopic ice studies	13
1.5.1	Mid-IR ice spectroscopy	14
1.5.2	Near-UV/VIS absorption ice spectroscopy	15
1.6	Outline of this thesis	16
I	Mid-IR absorption spectroscopy	19
2	Band profiles and band strengths in mixed H₂O:CO ices	21
2.1	Introduction	22
2.2	Experiment and data analysis	24
2.3	Results	28
2.3.1	Influence of CO on water bands	28
2.3.2	Influence on the CO band	33
2.4	Discussion	36
2.5	Conclusions	38

3	The c2d spectroscopic survey of ices. IV NH₃ and CH₃OH	39
3.1	Introduction	40
3.2	Astronomical observations and analysis	42
3.2.1	Local continuum	43
3.2.2	Template	43
3.2.3	NH ₃ ice column densities and abundances	46
3.3	Laboratory work and analysis	50
3.4	Comparison between astronomical and laboratory data	56
3.4.1	8–10 μm range	56
3.4.2	The 3 and 6 μm ranges	57
3.4.3	Nitrogen ice inventory	63
3.5	Conclusion	63
3.6	Appendix	64
4	IR spectroscopy of PAH containing ices	79
4.1	Introduction	80
4.2	Experimental technique	81
4.3	PAH:H ₂ O spectroscopy	84
4.4	PAH ice photochemistry	86
4.4.1	PAH:H ₂ O photoproducts	88
4.4.2	Concentration effects and time dependent chemistry	93
4.4.3	Ionization efficiency in CO ice	96
4.4.4	Temperature effects	96
4.5	The non-volatile residue	97
4.6	Astrophysical implications	100
4.6.1	High-mass protostars	101
4.6.2	Low-mass protostars	102
4.6.3	PAH contributions to the 5–8 μm absorption	103
4.7	Conclusions	104
II	Near-UV/VIS absorption spectroscopy	107
5	Optical spectroscopy of VUV irradiated pyrene:H₂O ice	109
5.1	Introduction	110
5.2	Experimental	111
5.3	Spectroscopic assignment	114
5.4	Chemical evolution of the ice	118
5.5	Astrophysical implications	120
5.6	Conclusion	121

6	Pyrene:H₂O ice photochemistry: ion-mediated astrochemistry	123
6.1	Introduction	124
6.2	Experimental technique	125
6.3	Band assignments and band strength analysis	126
6.3.1	Neutral pyrene bands	128
6.3.2	Pyrene cation bands	129
6.3.3	HCO bands in Py:CO	130
6.3.4	The 400 nm band carrier	131
6.3.5	The 405 nm band carrier	133
6.3.6	Broad absorption feature	134
6.4	Py:H ₂ O ice photochemistry at different temperatures	135
6.5	Astrochemical Implications	140
6.6	Conclusions	142
7	Ionization of PAHs in interstellar ices	145
7.1	Introduction	146
7.2	Experimental technique	146
7.3	PAH:H ₂ O spectroscopy	148
7.3.1	Anthracene (C ₁₄ H ₁₀)	149
7.3.2	Pyrene (C ₁₆ H ₁₀)	151
7.3.3	Benzo[ghi]perylene (C ₂₂ H ₁₂)	152
7.3.4	Coronene (C ₂₄ H ₁₂)	152
7.4	PAH ionization rates	153
7.5	Astrophysical implication	156
7.6	Conclusions	159
8	Future challenges	161
	Bibliography	165
	Nederlandse samenvatting	173
	Publications	179
	Curriculum vitae	181
	Nawoord	183

