



Universiteit  
Leiden  
The Netherlands

## Hot chemistry and physics in the planet-forming zones of disks

Bast, J.E.

### Citation

Bast, J. E. (2013, January 10). *Hot chemistry and physics in the planet-forming zones of disks*. Retrieved from <https://hdl.handle.net/1887/20396>

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/1887/20396>

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

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/20396> holds various files of this Leiden University dissertation.

**Author:** Bast, Jeanette Elisabeth

**Title:** Hot chemistry and physics in the planet-forming zones of disks

**Issue Date:** 2013-01-10

HOT CHEMISTRY AND PHYSICS IN THE  
PLANET-FORMING ZONES OF DISKS

Hot Chemistry And Physics In The Planet-Forming Zones Of Disks  
copyright © 2012 Jeanette Bast  
Thesis Universiteit Leiden - Illustrated - With summary in Dutch and English -  
With references  
ISBN: 978-94-6182-206-2  
Printed by Offpage.nl  
Cover: Photo and design by Eva Polakovičová (eeeeefa@gmail.com)

# HOT CHEMISTRY AND PHYSICS IN THE PLANET-FORMING ZONES OF DISKS

## 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 donderdag 10 januari 2013  
klokke 15.00 uur door

Jeanette Bast  
geboren te Stockholm, Zweden in 1979

Promotiecommissie

Promotores: Prof. dr. E. F. van Dishoeck  
Prof. dr. A. G. G. M. Tielens

Overige Leden: Prof. dr. K. Kuijken  
Prof. dr. C. W. M. Fridlund  
Prof. dr. G. A. Blake California Institute of Technology  
Dr. M. R. Hogerheijde  
Dr. A. M. Mandell NASA Goddard Space Flight Center

To my parents,

for teaching me to stand up, learn and move on,  
whenever failure comes into your life.



# Contents

---

1	Introduction	1
1.1	The formation of planetary systems . . . . .	2
1.2	A chemical and physical inventory of planet-forming zones . . . . .	5
1.2.1	Probing planet-forming regions with infrared observations . . . . .	7
1.3	This thesis . . . . .	11
1.4	Main conclusions . . . . .	14
1.5	Future prospects and outlook . . . . .	15
2	Single peaked CO emission line profiles from the inner regions of protoplanetary disks	17
2.1	Introduction . . . . .	19
2.2	Observations and sample . . . . .	22
2.2.1	Data reduction . . . . .	23
2.3	Line profiles . . . . .	25
2.3.1	$^{12}\text{CO}$ line profiles . . . . .	25
2.3.2	Keplerian disk model . . . . .	27
2.3.3	Line profile parameter . . . . .	32
2.3.4	Model line profile parameters . . . . .	34
2.3.5	$P_{10}$ -value versus the line-to-continuum ratio and source selection . . . . .	35
2.4	Characteristics for the sources with broad single peaked lines . . . . .	37
2.4.1	Line profiles of CO isotopologues and the $v = 2 - 1$ CO lines . . . . .	37
2.4.2	Excitation temperatures . . . . .	42
2.4.3	Lack of extended emission . . . . .	46
2.5	Discussion . . . . .	48
2.5.1	Rotating disk . . . . .	49
2.5.2	Disk wind . . . . .	50
2.5.3	Funnel flow . . . . .	51
2.6	Conclusions . . . . .	52

## Contents

3	First detection of near-infrared line emission from organics in young circumstellar disks	55
3.1	Introduction . . . . .	57
3.2	Observations and data reduction . . . . .	58
3.3	Line identification and LTE slab modeling . . . . .	61
3.4	Disk radiative transfer modeling . . . . .	73
3.4.1	Disk modeling results . . . . .	75
3.5	Comparison with chemical models . . . . .	78
3.6	Conclusions . . . . .	81
4	Investigation of HCN excitation in protoplanetary disks	83
4.1	Introduction . . . . .	84
4.2	HCN emission at 3 and 14 $\mu\text{m}$ . . . . .	86
4.3	Observations . . . . .	86
4.4	Radiative transfer models and their results . . . . .	87
4.4.1	A standard disk model using LTE . . . . .	87
4.4.2	Non-LTE excitation of HCN using a slab model . . . . .	92
4.4.3	Non-LTE slab model including radiative pumping . . . . .	93
4.4.4	Results introducing non-LTE and radiative pumping of HCN	95
4.5	Summary and conclusions . . . . .	98
5	Exploring organic chemistry in planet-forming zones	101
5.1	Introduction . . . . .	103
5.2	Observations . . . . .	106
5.2.1	IRS 46 and GV Tau . . . . .	106
5.2.2	Data reduction . . . . .	107
5.3	Results . . . . .	108
5.3.1	Spectra . . . . .	108
5.3.2	$\text{C}_2\text{H}_2$ , HCN and $\text{CO}_2$ . . . . .	108
5.3.3	Other molecules . . . . .	113
5.3.4	High resolution spectra . . . . .	115
5.4	Discussion . . . . .	125
5.4.1	Warm chemistry . . . . .	125
5.4.2	Surface chemistry . . . . .	129
5.4.3	Comparison of models with observations . . . . .	129
5.4.4	Comparison with protostars, other disks and comets . . . . .	130
5.5	Conclusions . . . . .	131
	Appendices	133
	Bibliography	143
	Nederlandse samenvatting	153
	English summary	161

## Contents

Publications	169
Curriculum Vitae	171
Acknowledgements	173

