



Universiteit
Leiden
The Netherlands

Inextricable ties between chemical complexity and dynamics of embedded protostellar regions

Drozdovskaya, M.N.

Citation

Drozdovskaya, M. N. (2016, October 6). *Inextricable ties between chemical complexity and dynamics of embedded protostellar regions*. Retrieved from <https://hdl.handle.net/1887/43439>

Version: Not Applicable (or Unknown)

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

Downloaded from: <https://hdl.handle.net/1887/43439>

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

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/43439> holds various files of this Leiden University dissertation

Author: Drozdovskaya, Maria

Title: Inextricable ties between chemical complexity and dynamics of embedded protostellar regions

Issue Date: 2016-10-06

INEXTRICABLE TIES BETWEEN
CHEMICAL COMPLEXITY AND DYNAMICS OF
EMBEDDED PROTOSTELLAR REGIONS

MARIA NIKOLAYEVNA DROZDOVSKAYA



© Maria Nikolayevna Drozdovskaya 2016

Niets uit deze uitgave mag worden verveelvoudigd, opgeslagen in een geautomatiseerd gegevensbestand of openbaar gemaakt worden in enige vorm of op enige wijze zonder voorafgaande schriftelijke toestemming van de auteur.

Inextricable Ties between Chemical Complexity and Dynamics of Embedded Protostellar Regions,
PhD Thesis, Leiden University

Outer cover and bookmark image: iStockphoto.com/Cappan (Stock photo ID: 62958243).
Inner cover images: iStockphoto.com/VladNikon (Stock photo ID: 70821061) and iStockphoto.com/Lubushka (Stock photo ID: 87709453).

Outer, inner cover and bookmark design: Maria Nikolayevna Drozdovskaya.

ISBN/EAN: 978-94-028-0328-0

Printed by Ipkamp Printing, Enschede, The Netherlands.

**INEXTRICABLE TIES BETWEEN
CHEMICAL COMPLEXITY AND DYNAMICS OF
EMBEDDED PROTOSTELLAR REGIONS**

PROEFSCHRIFT

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van de Rector Magnificus Prof. mr. C.J.J.M. Stolker
volgens besluit van het College voor Promoties
te verdedigen op donderdag 6 oktober, 2016
klokke 11.15 uur

door

MARIA NIKOLAYEVNA DROZDOVSKAYA

Мария Николаевна Дроздовская

geboren te Moskou, USSR

op 14 september, 1989

PROMOTIECOMMISSIE

PROMOTOR:

Prof. Dr. E. F. van Dishoeck

CO-PROMOTOR:

Dr. C. Walsh

OVERIGE LEDEN:

Prof. Dr. Y. Aikawa

University of Tsukuba

Prof. Dr. E. Herbst

University of Virginia

Prof. Dr. H. V. J. Linnartz

Prof. Dr. H. J. A. Röttgering

Dr. M. R. Hogerheijde

For my parents
I am eternally grateful that you gave me the impossible

Для моих родителей
Я бесконечно благодарна за то что вы мне дали невозможное

CONTENTS

1	INTRODUCTION	1
1.1	Astrochemical spring	1
1.2	Makings of planetary systems	3
1.3	The chemical connection	5
1.4	Observing astrochemistry	7
1.5	Modeling astrochemistry	8
1.6	Experimenting astrochemistry	11
1.7	This thesis: infant chemical complexity	12
1.8	Outlook: mature chemical complexity	14
2	METHANOL ALONG THE PATH FROM ENVELOPE TO PROTOPLANETARY DISC	15
2.1	Introduction	15
2.2	Models	17
2.2.1	Physical framework	17
2.2.2	Chemical network	23
2.2.3	Methanol chemistry	25
2.2.4	Caveats	26
2.3	Results	27
2.3.1	Physical evolution	27
2.3.2	Chemical evolution	29
2.3.3	Methanol ice in discs	34
2.4	Astrophysical implications	37
2.4.1	Comparisons to previous works	38
2.4.2	Application to comets	40
2.5	Conclusions	41
2.6	Acknowledgements	42
3	THE COMPLEX CHEMISTRY OF OUTFLOW CAVITY WALLS EXPOSED: THE CASE OF LOW-MASS PROTOSTARS	43
3.1	Introduction	43
3.2	Physicochemical model	46
3.2.1	Physical setup	46
3.2.2	Complex organic molecule chemistry	48
3.3	Results	50
3.3.1	Physical structure	50
3.3.2	Initial abundances	57
3.3.3	Abundance maps	58
3.3.4	Parameter study	62
3.4	Discussion	67
3.4.1	Morphology	67
3.4.2	Comparison with observations	69
3.4.3	Lifetimes of complex organics	69
3.4.4	Episodic accretion and dynamics	70
3.5	Conclusions	71
3.6	Acknowledgements	72
3.7	Appendix	72

4	COMETARY ICES IN FORMING PROTOPLANETARY DISC MIDPLANES	83
4.1	Introduction	83
4.2	Models	85
4.2.1	Initial conditions: ‘hot’ disc start versus ‘cold’ cloud start scenarios	88
4.3	Results	89
4.3.1	Dominant simple ices	90
4.3.2	Sensitivity of results to chemical parameters	95
4.3.3	Trace complex organic ices	98
4.3.4	Comparison to planet population synthesis models	101
4.4	Discussion	105
4.4.1	Dynamics, chemistry and inheritance	105
4.4.2	Comparison to other disc models	106
4.4.3	Implications for population synthesis models	107
4.4.4	Comparison with comets	108
4.5	Conclusions	109
4.6	Acknowledgements	110
4.7	Appendix	110
5	THE ALMA-PILS SURVEY: THE SULFUR CONNECTION BETWEEN PROTO-STARS AND COMETS - IRAS 16293-2422 AND 67P/C-G	113
5.1	Introduction	113
5.2	IRAS 16293-2422 observations	115
5.3	Results	117
5.3.1	SO ₂	119
5.3.2	SO	119
5.3.3	OCS	119
5.3.4	CS	120
5.3.5	H ₂ CS	121
5.3.6	H ₂ S	121
5.3.7	Other species	122
5.4	Discussion	122
5.4.1	Comparison with single dish observations	122
5.4.2	Comparison with ROSINA data on 67P/C-G	125
5.4.3	Comparison with models	126
5.5	Conclusions	127
5.6	Acknowledgements	128
5.7	Appendix	128
	BIBLIOGRAPHY	133
	PUBLICATIONS	155
	BIOGRAPHICAL SKETCH	157