

University of Groningen

Infrared emission features

Boersma, Christiaan

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:
2009

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Boersma, C. (2009). Infrared emission features: probing the interstellar PAH population and circumstellar environment of Herbig Ae/Be stars Groningen: s.n.

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.



rijksuniversiteit
groningen

**Infrared emission features: probing the interstellar
PAH population and circumstellar environment of
Herbig Ae/Be stars**

PROEFSCHRIFT

ter verkrijging van het doctoraat in de
Wiskunde en Natuurwetenschappen
aan de Rijksuniversiteit Groningen
op het gezag van de
Rector Magnificus, dr. F. Zwarts,
in het openbaar te verdedigen op
vrijdag 11 december 2009
om 16:15 uur

door

Christiaan Boersma

geboren op 16 april 1979
te Leeuwarden

Promotores: Prof. dr. A.G.G.M. Tielens

Prof. dr. L.B.F.M. Waters

Copromotor: Dr. L.J. Allamandola

Beoordelingscommissie: Prof. dr. C. Dominik

Prof. dr. L.B. d'Hendecourt

Prof. dr. M.C. Spaans

ISBN: 978-90-367-3930-6

ISBN: 978-90-367-3929-0 (*electronic version*)

Foar '*Beppe Anne*'

Cover:

Artist impression of a slightly flaring protoplanetary disk embedded in a cloud of Polycyclic Aromatic Hydrocarbon molecules (*artwork by Niels Bos*).

Financial support by the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO; Grant R 78-405), SETI, travel support by the Leids Kerkhoven-Bosscha Fonds (LKBF), the Kapteyn Fonds and the Groninger Universiteits Fonds (GUF) are gratefully acknowledged. This work has been made possible through a research grant from The Nederlands Onderzoekschool voor Astronomie (NOVA).

Printed by Ipkamp Drukkers, Enschede, The Netherlands.

Contents

Introduction	ix
Polycyclic Aromatic Hydrocarbons - PAHs	x
Carbon	x
The Unidentified Infrared bands	xii
The spectrum	xiv
Origin and evolution of PAHs	xviii
PAHs in regions of star and planet formation	xx
This thesis	xxiv
I Polycyclic Aromatic Hydrocarbons	1
1 The 5.25 and 5.7 μm PAH emission features	3
1.1 Introduction	4
1.2 The astronomical emission features in the 5 – 6 μm region	5
1.2.1 Observations	5
1.2.2 Analysis	6
1.3 PAH spectroscopy in the 5 – 6 μm region	10
1.3.1 Experimental studies	10
1.3.2 Theoretical studies	12
1.3.3 The origin of the PAH bands in the 5 – 6 μm range	15
1.4 Astrophysical considerations	26
1.5 Summary and conclusion	32
2 The 15 – 20 μm PAH emission features: probes of individual PAHs?	35
2.1 Introduction	36
2.2 Observations	38
2.2.1 Astronomical spectra from 15 – 20 μm	38
2.2.2 Decomposition of the astronomical spectra	40
2.2.3 The 15 – 20 μm features	44
2.3 PAH spectroscopic properties from 15 – 20 μm	51
2.3.1 Synthetic PAH spectra	51
2.3.2 The influence of structure, composition, charge and size	54
2.3.3 ‘Blind’ search	60
2.3.4 Summary	61

2.4	Astronomical implications	62
2.4.1	PAH di-cations	63
2.4.2	Pendent rings	63
2.4.3	PAH temperature	64
2.4.4	PAH size	65
2.4.5	PAH 15 – 20 μm plateau	67
2.4.6	Individual PAHs	69
2.5	Summary and conclusions	69
II	PAHs in regions of star and planet formation	73
3	Characteristics of IR emission features in Herbig Ae stars	75
3.1	Introduction	76
3.2	Data	77
3.3	Analysis	79
3.3.1	Results	82
3.3.2	Profiles	82
3.4	Discussion	87
3.4.1	The profiles	88
3.4.2	Extended PAH band emission	88
3.4.3	Origin of the variations	94
3.4.4	Implications	94
3.5	Summary and conclusions	95
4	A spatial study of the mid-IR emission in four Herbig stars	97
4.1	Introduction	98
4.2	The sources	99
4.3	Observations and reduction	100
4.3.1	IRAC	101
4.3.2	TIMMI2	101
4.3.3	VISIR	104
4.3.4	ISO-SWS	108
4.4	Analysis and results	108
4.4.1	IRAS 06084-0611	112
4.4.2	CD-42 11721	115
4.4.3	TY CrA	115
4.4.4	HD 176386	119

4.5	Discussion and astronomical implications	119
4.5.1	Silicate dust	119
4.5.2	PAHs	120
4.5.3	Morphology	120
4.5.4	Band strengths	122
4.5.5	PAH emission from Herbig A vs Herbig B stars	123
4.6	Summary and conclusions	124
III	The future	127
5	The NASA Ames PAH IR Spectroscopic Database	129
5.1	Introduction	130
5.2	The computational PAH database	131
5.2.1	Computational method	131
5.2.2	The content of the computational PAH database	131
5.3	Converting absorption spectra into emission spectra	134
5.3.1	Single excitation photon, single PAH emission model	136
5.4	Web access	139
5.5	Outlook	141
5.6	Applications	143
5.6.1	The 15 – 20 μm region	143
5.6.2	The far-IR	144
5.7	Summary	152
6	Summary and future prospects	153
6.1	Summary	153
6.2	Future prospects	156
Nederlandse samenvatting		159
Stof		159
In dit proefschrift		163
Bibliography		169
Acknowledgements		175

