



Universiteit
Leiden
The Netherlands

Mid-infrared spectroscopy of starbursts : from Spitzer-IRS to JWST-MIRI

Martínez-Galarza, J.F.

Citation

Martínez-Galarza, J. F. (2012, June 19). *Mid-infrared spectroscopy of starbursts : from Spitzer-IRS to JWST-MIRI*. Retrieved from <https://hdl.handle.net/1887/19113>

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/1887/19113>

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

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/19113> holds various files of this Leiden University dissertation.

Author: Martínez-Galarza, Juan Rafael

Title: Mid-infrared spectroscopy of starbursts : from Spitzer-IRS to JWST-MIRI

Date: 2012-06-19

Mid-Infrared Spectroscopy of Starbursts: From Spitzer-IRS to JWST-MIRI

Mid-Infrared Spectroscopy of Starbursts: From Spitzer-IRS to JWST-MIRI

Juan Rafael Martínez Galarza

Thesis Universiteit Leiden - Illustrated - With summary in Dutch and Spanish - With references

ISBN/EAN 978-94-6182-123-2

Printed by Offpage.nl

Cover: The starburst galaxy IC 342 imaged by the Spitzer Space Telescope, Credit: NASA/JPL-Caltech/J. Turner (UCLA). Artist concept of JWST, Credit: NASA. An artist impression of IC 342 by Lara Versari.

Cover design by Daniel Camilo Gómez

Mid-Infrared Spectroscopy of Starbursts: From Spitzer-IRS to JWST-MIRI

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 19 juni 2012
klokke 16.15 uur

door

Juan Rafael Martínez Galarza
geboren te Bogotá, Colombia
in 1981

Promotiecommissie

Promotor: Prof. dr. E. F. van Dishoeck

Co-promotor: Dr. B. Brandl

Overige Leden: Prof. dr. K. Kuijken

Prof. dr. F. Israel

Prof. dr. G. Wright

Prof. dr. M. A. Dopita

Dr. I. Kamp

Dr. B. Groves

The University of Edinburgh

Australia National University

Rijksuniversiteit Groningen

Max Planck Institut für Astronomie

Para mis padres, por regalarme este Universo.

*El brillo de las estrellas
es una noticia tardía, me dijiste,
esa luz que vemos no es sino un navío
de jaulas doradas
que guardan especies muertas.*

-Robert Max Steenkist

Contents

1	Introduction	1
1.1	Massive star formation and the history of the Universe	2
1.2	Starbursts systems	3
1.2.1	Definition of a starburst	4
1.2.2	Giant H II regions as the building blocks of starbursts	5
1.3	SED fitting of starbursts	11
1.3.1	χ^2 minimization	11
1.3.2	Bayesian approach	11
1.4	Future observations with the James Webb Space Telescope	12
1.4.1	JWST	12
1.4.2	Sensitivity	13
1.4.3	Spatial resolution	13
1.4.4	MIRI spectrometry	13
1.4.5	Starbursts and MIRI	14
1.5	This thesis	15
I	Bayesian SED Fitting of Starbursts	17
2	The physical conditions in starbursts derived from Bayesian fitting of mid-IR SEDs: 30 Doradus as a template	19
2.1	Introduction	20
2.2	The 30 Doradus region	21
2.2.1	Properties of the 30 Doradus region	22
2.2.2	The integrated mid-IR spectrum of 30 Doradus	24
2.2.3	Individual sources	24
2.3	Modelling the SEDs of starbursts	27
2.3.1	Literature on SED modelling	27
2.3.2	The physical concept behind the model	27
2.3.3	Model parameters	29

Contents

2.3.4	Attenuation by diffuse dust	31
2.4	Fitting routine	31
2.4.1	Probability Distribution Functions	31
2.4.2	Model priors	32
2.4.3	Uncertainties and model resolution	33
2.5	Results	35
2.5.1	Nebular lines ratios as age diagnostics.	36
2.5.2	Integrated spectrum	37
2.5.3	Individual sources	43
2.5.4	Age averaged case	46
2.6	Summary and conclusions	48
3	Ongoing massive star formation in NGC 604	51
3.1	Introduction	52
3.2	Data reduction and ancillary datasets	53
3.2.1	IRS data	54
3.2.2	IRAC photometry	56
3.2.3	PACS photometry	56
3.2.4	HST-WFPC2 F555W data	57
3.2.5	Chandra X-ray Observatory-ACIS data	57
3.3	Analysis	57
3.3.1	Distribution of the emission	58
3.3.2	Infrared spectra	61
3.3.3	Electron density	64
3.3.4	Hardness of the radiation field	67
3.3.5	[Si II] emission	70
3.3.6	H ₂ emission	71
3.3.7	SED modeling	72
3.4	Discussion	75
3.4.1	Notable sources	75
3.4.2	The evolutionary stage of NGC 604	76
3.4.3	Ongoing and triggered star formation in NGC 604	82
3.5	Conclusions	83
4	Outlook: recent star formation in nuclear starbursts	85
4.1	Introduction	86
4.2	Sample of galaxies	87
4.2.1	Selection criteria	87
4.2.2	Basic properties	88
4.2.3	Morphologies	90
4.2.4	Measurements from the literature	90
4.3	Results	92
4.3.1	MIR spectra of the selected galaxies	92
4.3.2	Bayesian fitting of the spectra	94

4.4	Discussion	97
4.4.1	Star formation rates	97
4.4.2	Pressure, compactness and their relation to massive clusters	98
4.4.3	Molecular gas content and feedback in starbursts	99
4.5	Summary and outlook	100
II	MIRI Wavelength Calibration	103
5	Mid-infrared IFU spectroscopy from space: wavelength calibration of JWST-MIRI	105
5.1	Introduction	106
5.2	MIRI: an overview	107
5.2.1	The MIRI field of view on the sky	107
5.2.2	Integral field spectroscopy with MIRI	107
5.3	Setup and measurements	108
5.3.1	The MIRI Telescope Simulator (MTS)	108
5.3.2	Measurements	110
5.4	Analysis	111
5.4.1	Cube reconstruction	111
5.4.2	Etalon analysis	113
5.4.3	Fringing	116
5.4.4	Line shape and resolving power	120
5.5	Summary and outlook	122
6	The spectral properties of JWST-MIRI: calibration of the Flight Model	125
6.1	Introduction	126
6.2	Observations	127
6.2.1	The test campaign and the observational setup	127
6.2.2	Test data	128
6.2.3	Data reduction	129
6.2.4	Reduced data	131
6.3	Analysis	133
6.3.1	Wavelength characterisation	133
6.3.2	Uncertainties	140
6.4	Results and discussion	144
6.4.1	The resolving power of the MRS	144
6.4.2	Variations of R with wavelength and position in the field	145
6.4.3	Line shape and spectral ghosts	147
6.4.4	Wavelength stability	147
6.5	Summary	153
Bibliography		155

Contents

Nederlandse Samenvatting	161
Resumen en Español	169
Curriculum Vitae	177
Acknowledgements	179