



Universiteit
Leiden
The Netherlands

Paving the path between low- and high-mass star formation : dynamics probed by Herschel far-infrared spectroscopy

San Jose Garcia, I.

Citation

San Jose Garcia, I. (2015, June 18). *Paving the path between low- and high-mass star formation : dynamics probed by Herschel far-infrared spectroscopy*. PhD Thesis. Retrieved from <https://hdl.handle.net/1887/33224>

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/1887/33224>

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

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/33224> holds various files of this Leiden University dissertation

Author: San José García, Irene

Title: Paving the path between low- and high-mass star formation : dynamics probed by *Herschel* far-infrared spectroscopy

Issue Date: 2015-06-18

Paving the path between
low- and high-mass star formation

Dynamics probed by *Herschel* far-infrared spectroscopy

Paving the path between low- and high-mass star formation

Dynamics probed by *Herschel* far-infrared spectroscopy

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof.mr. C. J. J. M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op donderdag 18 juni 2015
klokke 12.30 uur

door

Irene San José García

geboren te Elche de la Sierra, Spanje
in 1986

Promotiecommissie

Promotores:	Prof. dr. E. F. van Dishoeck Prof. dr. F. F. S. van der Tak	Rijksuniversiteit Groningen Space Research Organisation Netherlands
Co-promotor:	Dr. J. C. Mottram	
Overige leden:	Prof. dr. H. V. J. Linnartz Prof. dr. H. Beuther Dr. M. Tafalla Dr. M. T. Beltrán Prof. dr. H. J. A. Röttgering	Max-Planck-Institut für Astronomie, Heidelberg Observatorio Astronómico Nacional, Madrid Osservatorio Astrofisico di Arcetri

A mis padres y a mis hermanos

ISBN: 978-94-6259-719-8

Borja Cuéllar. Cover illustration and graphic design.

Contents

1. Introduction	1
1.1. Star formation process	2
1.1.1. Low-mass young stellar objects	2
1.1.2. High-mass young stellar objects	5
1.2. From low- to high-mass	7
1.3. Methodology	10
1.3.1. Molecules as diagnostics	10
1.3.2. CO and H ₂ O as key molecular tracers	12
1.3.3. Analysis tools	13
1.4. <i>Herschel</i> Space Observatory - HIFI	15
1.4.1. WISH	16
1.5. This thesis	17
2. <i>Herschel</i>-HIFI observations of high-<i>J</i> CO and isotopologues in YSOs	21
2.1. Introduction	23
2.2. Observations	24
2.2.1. Sample	24
2.2.2. HIFI observations	24
2.2.3. JCMT ground-based observations	26
2.2.4. Decomposition method	27
2.3. Results	28
2.3.1. Characterisation of the line profiles	30
2.3.2. Correlations with bolometric luminosity	32
2.3.3. Kinetic temperature	35
2.4. Discussion	37
2.4.1. Broad and narrow velocity components	37
2.4.2. CO and dynamics: turbulence versus outflow	39
2.4.3. High- <i>J</i> CO as a dense gas tracer	41
2.5. Conclusions	41
2.A. Characterisation of the HIFI data	44
2.A.1. ¹² CO <i>J</i> =10–9 line profiles	44
2.A.2. ¹³ CO <i>J</i> =10–9 line profiles	44
2.A.3. C ¹⁸ O line profiles	46
2.B. JCMT data	48
3. Infall versus turbulence as the origin of line broadening in YSOs	59
3.1. Introduction	61
3.2. Observations	62
3.2.1. Sample	62
3.2.2. C ¹⁸ O observations	62
3.2.3. HCO ⁺ observations	63
3.2.4. Characteristics of the observed line profiles	64
3.3. Modelling of the observations	64
3.3.1. Source structure	65
3.3.2. Non-thermal motions: parameters	65
3.3.3. Fitting method: iteration technique	66
3.3.4. Abundance profiles	67
3.4. Results	71

3.4.1. Velocity field study within the sample	71
3.4.2. Models with radius-dependent turbulence	76
3.5. Discussion	77
3.5.1. Comparison with other studies	77
3.5.2. Origin of turbulence	78
3.5.3. Turbulent core accretion and competitive accretion	78
3.5.4. Infall and rotation: disentangling the non-thermal emission	80
3.6. Conclusions	81
3.A. Best-fit models	83
3.A.1. Low-mass YSOs	83
3.A.2. High-mass YSOs	84
3.B. Additional information and figures	86
3.B.1. Iteration technique: details	86
4. Linking low- to high-mass YSOs with <i>Herschel-HIFI</i> observations of water	91
4.1. Introduction	93
4.2. Observations	94
4.2.1. Sample	94
4.2.2. Water observations	94
4.2.3. Additional ^{12}CO observations	95
4.2.4. Reduction of the H_2O data	96
4.2.5. Decomposition method	96
4.2.6. Association with physical components	97
4.3. Results	98
4.3.1. Water line profile characterisation	98
4.3.2. Comparison of the H_2O and ^{12}CO line profiles	99
4.3.3. Line luminosity study	102
4.3.4. Integrated intensity ratios	104
4.3.5. Intensity ratios versus velocity for H_2O and ^{12}CO	106
4.3.6. Excitation conditions	108
4.4. Discussion	110
4.4.1. Disentangling the dynamical properties of H_2O and CO emission	110
4.4.2. Excitation condition across the luminosity range	111
4.4.3. From Galactic to extragalactic sources	113
4.5. Conclusions	114
4.A. Spectra of the excited water lines	116
4.B. Specific sources	116
4.C. Additional figures	124
5. <i>Herschel-HIFI</i> observations of the WILL and Cygnus samples	129
5.1. Introduction	131
5.2. Observations	132
5.2.1. Sample	132
5.2.2. HIFI observations	133
5.2.3. Reduction of the HIFI data	134
5.2.4. Decomposition method	134
5.2.5. Linking velocity and physical components	136
5.3. Results	138
5.3.1. Characterisation of the line profiles	138
5.3.2. Analysis of the decomposition process	140
5.3.3. Analysis of the broad velocity component for H_2O spectra	144
5.3.4. Line luminosity study	147
5.4. Discussion	149
5.4.1. Comparison with WISH results	149

5.4.2. WILL and Cygnus samples	150
5.4.3. Environmental exploration of the Cygnus X region	151
5.5. Conclusions	153
5.A. <i>FWZI</i> analysis	155
5.A.1. H ₂ O spectra	155
5.A.2. CO spectra	156
5.B. WILL data	158
5.B.1. Specific sources	158
5.C. Cygnus data	184
Bibliography	206
Samenvatting	213
Publications	219
Curriculum Vitae	221
Acknowledgments	223

