



## UvA-DARE (Digital Academic Repository)

### Warm gas in protoplanetary disks

van der Plas, G.

**Publication date**  
2010

[Link to publication](#)

#### **Citation for published version (APA):**

van der Plas, G. (2010). *Warm gas in protoplanetary disks*. [Thesis, fully internal, Universiteit van Amsterdam].

#### **General rights**

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), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

#### **Disclaimer/Complaints regulations**

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: <https://uba.uva.nl/en/contact>, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

---

# Contents

---

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Star and planet formation . . . . .	1
1.2	Spectral Energy Distributions and disk geometry . . . . .	5
1.3	Composition and spatial distribution of gas . . . . .	6
1.3.1	Molecular Hydrogen . . . . .	7
1.3.2	Carbon Monoxide . . . . .	8
1.3.3	[OI] . . . . .	9
1.3.4	PAHs . . . . .	10
1.4	Disk geometry as traced by gas and dust . . . . .	11
1.5	The astronomical toolkit . . . . .	12
1.5.1	Spectroscopy . . . . .	12
1.5.2	Astrometry . . . . .	15
1.5.3	Modeling . . . . .	15
1.6	This Thesis . . . . .	16
<b>2</b>	<b>The Structure of Protoplanetary Disks Surrounding Three Young Intermediate Mass Stars I. Resolving the disk rotation in the [OI] 6300 Å line.</b>	<b>21</b>
2.1	Introduction . . . . .	22
2.2	Observations and Data Reduction . . . . .	23
2.3	Stellar Parameters . . . . .	28
2.3.1	HD 101412 . . . . .	30
2.3.2	HD 135344B . . . . .	32
2.3.3	HD 179218 . . . . .	33
2.4	Data Analysis . . . . .	34
2.4.1	Method . . . . .	34
2.4.2	Results . . . . .	36

2.5	Discussion and Conclusions . . . . .	41
<b>3</b>	<b>Evidence for CO depletion in the inner regions of gas-rich protoplanetary disks</b>	<b>45</b>
3.1	Introduction . . . . .	46
3.2	Observations and data reduction . . . . .	47
3.3	Observational Analysis . . . . .	48
3.4	Results . . . . .	50
3.5	A Simple Model . . . . .	53
3.6	Discussion . . . . .	54
<b>4</b>	<b>The structure of disks around Herbig Ae/Be stars as traced by CO ro-vibrational emission.</b>	<b>59</b>
4.1	Introduction . . . . .	60
4.2	Sample description . . . . .	61
4.3	Observations and data reduction . . . . .	62
4.4	Results . . . . .	65
4.4.1	General description of the spectra . . . . .	65
4.4.2	CO rotational temperature . . . . .	65
4.4.3	Kinematics . . . . .	70
4.4.4	Spatially resolved CO and continuum emission . . . . .	73
4.4.5	CO absorption . . . . .	76
4.4.6	Other lines . . . . .	76
4.4.7	Summary of observed trends in the CO emission . . . . .	76
4.5	Discussion . . . . .	78
4.5.1	CO rotational temperature . . . . .	78
4.5.2	CO vibrational temperature . . . . .	78
4.5.3	Correlations between CO line width and temperature . . . . .	79
4.5.4	CO compared to other gas tracers . . . . .	81
4.5.5	A qualitative interpretation of the observed trends . . . . .	88
4.6	Where is the CO? . . . . .	89
4.6.1	Keplerian fits to the line profiles . . . . .	90
4.6.2	A comparison to CO emission from T Tauri stars . . . . .	91
4.7	Conclusions . . . . .	95

<b>5</b>	<b>A CRIRES search for near-IR H<sub>2</sub> emission from Herbig Ae/Be stars</b>	<b>97</b>
5.1	Introduction . . . . .	98
5.2	Observations and Data Reduction . . . . .	99
5.3	Results and Analysis . . . . .	105
5.3.1	Line ratios and excitation mechanism. . . . .	109
5.3.2	Line modeling with Keplerian flat disk models . . . . .	110
5.3.3	H <sub>2</sub> , CO, and [OI] emitting regions. . . . .	115
5.4	Discussion and Conclusions . . . . .	116
5.A	Appendix . . . . .	122
<b>6</b>	<b>A theoretical study of CO ro-vibrational emission from disks around Herbig Ae/Be stars.</b>	<b>123</b>
6.1	Introduction . . . . .	124
6.2	The Model . . . . .	126
6.2.1	PRODIMO Code . . . . .	126
6.2.2	Model Parameters . . . . .	127
6.3	Physical/Chemical structure of the models . . . . .	130
6.3.1	The standard model . . . . .	130
6.3.2	Parameter study . . . . .	133
6.4	Observables . . . . .	137
6.4.1	SED . . . . .	137
6.4.2	Line profiles . . . . .	139
6.4.3	Rotational diagram . . . . .	146
6.5	Observations confront the model . . . . .	150
6.5.1	CO observational trends . . . . .	150
6.5.2	Model behaviour . . . . .	154
6.6	Discussion . . . . .	154
6.7	Conclusions and future outlook . . . . .	156
6.A	Appendix . . . . .	157
	<b>Samenvatting</b>	<b>163</b>
	<b>Summary</b>	<b>167</b>

<b>Bibliography</b>	171
<b>List of publications</b>	179
<b>Acknowledgments</b>	181