

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/49240> holds various files of this Leiden University dissertation

Author: Schwarz, Henriette

Title: Spinning worlds

Issue Date: 2017-06-01

Spinning Worlds

Roterende Werelden

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 1 juni 2017
klokke 11:15 uur

door

Henriette Schwarz
geboren te Hørsholm, Denemarken
in 1986

Promotiecommissie

Promotor: Prof. dr. I. A. G. Snellen

Co-promotor: Dr. M. A. Kenworthy

Overige leden: Prof. dr. H. J. A. Röttgering

Prof. dr. C. Keller

Prof. dr. E. F. van Dishoeck

Dr. J-M. Désert

Dr. J. L. Birkby

(University of Amsterdam)

(Harvard University)

"Astronomers, like burglars and jazz musicians, operate best at night."
– Miles Kington

Contents

1	Introduction	1
1.1	Star and planet formation	2
1.2	Finding exoplanets	5
1.3	Atmospheric characterisation	6
1.3.1	Transits, eclipses, and phase curves	7
1.3.2	High-contrast imaging	8
1.4	High-dispersion spectroscopy	9
1.4.1	High-dispersion spectroscopy for time-differential observations	9
1.4.2	High-dispersion spectroscopy + high-contrast imaging	10
1.5	This thesis	12
1.5.1	Chapter 2 - Evidence against a thermal inversion in a hot Jupiter	12
1.5.2	Chapters 3, 4 & 5 - first survey of planetary spin	12
	References	14
2	Evidence against a strong thermal inversion in HD 209458 b	21
2.1	Introduction	22
2.1.1	Hot-Jupiter atmospheres	22
2.1.2	Thermal inversion layers	23
2.1.3	High-resolution spectroscopy	24
2.1.4	HD 209458 b	25
2.1.5	Re-evaluation of previous CO abundance	26
2.1.6	Outline	27
2.2	Observations	28
2.3	Data analysis	28
2.3.1	Extracting the one-dimensional spectra	28

2.3.2	Bad-pixel correction and wavelength calibration	29
2.3.3	Removing telluric contamination	30
2.4	Search for the planet signal	31
2.4.1	Model spectra	32
2.4.2	Cross-correlation analysis	34
2.5	Results	37
2.5.1	MS models	38
2.5.2	Water models	38
2.5.3	Estimating expected CO signals	40
2.6	Discussion	42
2.7	Conclusion	44
	References	46
3	The slow spin of GQLupi b and its orbital configuration	55
3.1	Introduction	55
3.2	The GQLupi system	57
3.3	Observations	58
3.4	Data analysis	59
3.4.1	Basic data reduction	59
3.4.2	Extraction of spectra for each slit position	62
3.4.3	Removal of telluric and stellar spectrum	62
3.5	Measuring the signal from the companion	64
3.5.1	The model spectra	65
3.5.2	Cross-correlation analysis	66
3.5.3	Measuring the companion $v \sin(i)$ and RV	67
3.5.4	Measuring the systemic velocity and the host star $v \sin(i)$	67
3.6	Results	68
3.6.1	Detection of CO and H ₂ O	68
3.6.2	Companion $v \sin(i)$ and RV	70
3.6.3	Host star $v \sin(i)$ and v_{sys}	71
3.6.4	Orbital constraints for GQLupi b	72
3.7	Discussion	72
3.7.1	The slow spin of GQLupi b	72
3.7.2	The orbital orientation of GQLupi b	76
3.7.3	The systemic velocity and $v \sin(i)$ of GQLupi A	77
3.8	Summary and conclusions	79
	References	80

4 Spin measurement of the substellar companion GSC 6214-210 b	89
4.1 Introduction	89
4.2 The GSC 06214-00210 system	91
4.3 Observations	92
4.4 Data analysis	93
4.4.1 Extraction of the companion spectrum	94
4.4.2 Wavelength calibration and the systemic velocity	94
4.4.3 Removing the stellar and telluric background	96
4.5 Measuring the $v \sin(i)$	97
4.5.1 The template spectra	97
4.5.2 Cross-correlation analysis	99
4.6 Results & Discussion	100
4.7 Conclusions	106
References	107
5 Spin measurements of young sub-stellar companions: The case of HIP 78530 b	113
5.1 Introduction	113
5.2 The HIP 78530 system	114
5.3 Observations	116
5.4 Data analysis	117
5.4.1 Basic data reduction	117
5.4.2 Extraction of spectra for each slit position	119
5.5 Cross-correlation analysis	121
5.5.1 Molecular detection maps	121
5.5.2 Measuring the companion $v \sin(i)$ and RV	121
5.6 Results	122
5.7 Towards a comparative study of exoplanet spin	128
5.8 Conclusions	133
References	134
Samenvatting	139
Summary	143
Curriculum Vitae	147
List of publications	149
Acknowledgements	153

