

# Towards the near-infrared detection of exoplanets

Jason James Neal

Tese de doutoramento apresentada à  
Faculdade de Ciências da Universidade do Porto  
Astronomia

2018

TOWARDS THE NIR DETECTION OF EXOPLANETS

by

Jason James Neal

A thesis submitted in conformity with the requirements  
for the degree of Doctor of Philosophy  
Graduate Department of Departamento de Física e Astronomia  
University of Porto

© Copyright 2018 by Jason James Neal

*To my wife Jessica,  
children Timothy and Amelia;  
For always supporting me.*

## Acknowledgements

this work could not have been completed without the Phd fellowship.

J.J.N. acknowledges support from FCT through the PhD::Space fellowship PD/BD/52700/2014.

This work was financed by FEDER - Fundo Europeu de Desenvolvimento Regional funds through the COMPETE 2020 - Programa Operacional Competitividade e Internacionalização (POCI), and by Portuguese funds through FCT - Fundação para a Ciência e a Tecnologia in the framework of the project POCI-01-0145-FEDER-028953 and POCI-01-0145-FEDER-032113.”

This work was also supported by Fundação para a Ciência e a Tecnologia (FCT) (Portugal) research grants through national funds and from FEDER through COMPETE2020 by the following grants: UID/FIS/04434/2013 & POCI-01-0145-FEDER-007672, PTDC/FIS-AST/1526/2014 & POCI-01-0145-FEDER-016886, and PTDC/FIS-AST/7073/2014 & POCI-01-0145-FEDER-016880.

# Abstract

The contents of this work focus on detecting exoplanets in the nIR.

It starts of with reduction of nir spectra from CRIRES.

In chapters 4 we approach a differential subtraction technique to separate the spectra from the faint companion. Contrasting the result to other recent detections. In chapter 4 a second technique is developed in which the BD companions are attempted to be recovered from the  $\nearrow$ -infrared spectra by fitting to a complex model of two synthetic stellar spectra. Finding the technique unsuitable for the data on hand.

Focusing on BD as they should have a stronger flux ratio than planets.

In chapter 6 we change focus towards RV precision of M-dwarf stars. Calculating th theoretical precision of stellar spectra t. Useful for the next-generation of near-infrared spectrographs to detect planets around M-dwarf stars.

Some thought on future are also provided.

## Resumo

Thesis abstract in Portuguese

# Todo list

■ read and quote . . . . .	4
Figure: example to point to . . . . .	5
■ finish this . . . . .	6
■ Add original caption to 1.4 . . . . .	6
■ Move location / adjust from paper . . . . .	10
■ this section is completed i think . . . . .	12
■ this section is completed i think . . . . .	13
■ ADAPT TThis section to explain the models more generally. Move the usage back to Reduction section . . . . .	13
■ telluric model correction methods original . . . . .	13
■ Look at . . . . .	14
■ FINISH . . . . .	14
■ FINISH . . . . .	14
■ a good reference that mentions the uv and optical uses could be good? . . . . .	14
■ . . . . .	16
■ I don't know where I am going with this section. . . . .	17
■ . . . . .	17
■ FIXup this table . . . . .	18
■ fix Figure 3.3 . . . . .	18
■ move . . . . .	18
■ Check if it is mentioned how these get corrected/ if the impact the wavelength solution. . . . .	19
■ Note: Useful information about MIR reduction in the VISIR manual . . . . .	19
■ Reword . . . . .	20
■ Pedro it is my understanding that the ESO pipeline did not exist/was not publicly available when you created DRACS, correct? . . . . .	20
■ is footnote correct "instruments optics" . . . . .	22
■ Check optimal extraction parameters, may have reduced the extraction width by too much?? Need to check changing it. . . . .	24
■ finish this sentence in caption . . . . .	25
■ CHANGE the figure here . . . . .	26
■ check this statement . . . . .	26

■ citation . . . . .	27
■ citation . . . . .	27
Figure: An image of some reduced spectra from eta Tel and Barnard's star???	27
■ fix-up get a good citation, number of lines . . . . .	28
■ paper for harps Th-Ar lines . . . . .	28
■ cite crires manual, and a paper about sky lines? . . . . .	28
Figure: example figures illustrating this method . . . . .	29
Figure: Example of coordinates and the fit. Can I calculate some errors on the polynomial coord fit.	29
■ explain the fit Figure 3.8 . . . . .	30
Figure: Would a table of polynomial wavelength solutions along with errors be any use? . . . . .	31
■ Add pictures of wavelength calibrations . . . . .	31
Figure: Diagram of idea of combined detector fitting? . . . . .	31
Figure: comparison between a Gasgano wavelength solution and the manual one. This has not be done by me before. . . . .	32
■ See Solene's paper regarding Telluric correction with models and reference spectra . . . . .	32
■ See solenes paper for matereial here . . . . .	33
■ Expand this section. . . . .	33
■ Should this be more in the introduction? . . . . .	33
Figure: The telluric spectrum around 2 $\mu$ m showing the 2.1 $\mu$ m window of low telluric absorption .	33
■ Add telluric spectra for nIR band? the plot from Molecfit? . . . . .	34
■ Still uneven line coverage on all detectors in this small range . . . . .	34
■ H <sub>2</sub> O corrections . . . . .	34
■ ADAPT this section to the usage of the models. . . . .	34
■ telluric model correction methods original . . . . .	34
■ ADD non-H <sub>2</sub> O fitting corrections. . . . .	36
Figure: Plots showing some examples the telluric correction with and without H <sub>2</sub> O separated . . .	36
■ Rotate orbital parameter table. . . . .	38
■ I still assume this is a mistake . . . . .	39
■ Check why the ordering number is incorrect for HD202206. If it is correct like this and is numbered incorrectly in the header then we should mention this. . . . .	39
■ rotate table? . . . . .	39
■ I am not sure if this is the best location for this section. . . . .	40
■ equations for companion rv with the masses still included. include 180 degree angle phase change also . . . . .	40
■ Fix caption position here . . . . .	40
■ recalculate values that are less than 1 . . . . .	40
■ put in advanced concepts chapter???	42
■ this ignores $\gamma$ . . . . .	42
Figure: simulated example of combined binary spectra, and the subtraction, with a clear companion visible . . . . .	43
■ Should I predict when the best time to observed these targets are is? e.g. in 2020 x and x will have sufficient RV change in one period to achieve a detection. . . . .	46
■ change RV scale for hd4747 orbit . . . . .	46



■ Fix plot titles . . . . .	46
■ Check M2sini labels - can we get M2 only for those that we know . . . . .	46
■ Should RV of companion be scale by m2sini only or m2 if known? . . . . .	46
■ Increase size of diff amp plots to two . . . . .	50
■ They get a result???	53
■ move . . . . .	53
Figure: includegraphics images/HD211847 example pcolors.pdf . . . . .	60
Figure: includegraphics images/HD211847 example pcolors.pdf . . . . .	60
Figure: images HD211847 result pcolors.pdf . . . . .	63
Figure: images/visualize result residuals.pdf . . . . .	63
Figure: images/inject recovery hd30501.pdf . . . . .	65
Figure: images/chi2 shape investigation sigmas.pdf . . . . .	65
■ finish this line . . . . .	68
■ Try cross correlation at a different wavelength 2.3 micron? . . . . .	69
■ Try cross correlation with much larger wavelength range. 50, 100, 600, 1 000 nanometres? . . . . .	69
■ Try my simulations with much larger wavelength range. 50, 100, 600 nanometres? . . . . .	69
■ this doesn't seem right . . . . .	70
■ rv method . . . . .	70
■ put in introduction?? . . . . .	70
■ Check mission statements for these . . . . .	70
■ For example from Figueira 2016 see figure . . . . .	70
Figure: An example from Figueira et al. 2016 . . . . .	70
■ find mayor queloz precision achieved . . . . .	71
■ what reference . . . . .	71
■ History of Precision calculations . . . . .	71
■ add $\delta A$ to plots . . . . .	72
■ intensity change from connes is vertically in the slice d lambda . . . . .	72
■ Finish this equation (9 of bouchy 2001) . . . . .	74
■ Try the symbolic package from PC . . . . .	74
■ explain snr . . . . .	75
■ It is convenient to use this version when comparing observed spectra with different S/N.? . . . .	75
■ Does spectrograph pipelines such as HARPS use these equations to measure estimate/precision? . . . . .	75
■ It is convenient to use this version when comparing observed spectra with different S/N.? . . . .	76
■ top view diagram of rotation? . . . . .	76
■ define fwhm0 . . . . .	77
■ CHECKTHISRESUSLT!!!!!! . . . . .	77
Figure: Example of CARMENES spectra before and after correction . . . . .	78
■ Add figure here . . . . .	79
■ Add figure here . . . . .	79
■ finish this . . . . .	79
■ works of software testing in research. . . . .	82
Figure: uncomment this one . . . . .	84
■ cite the equation when I refer to it . . . . .	87

■ Check this if it is previous . . . . .	88
■ weighted sum equation . . . . .	88
■ Should I show the working of analytical working out of this in an appendix, or here? . . . . .	88
■ did I check this was equivalent . . . . .	88
■ put this some where . . . . .	88
■ put this line elsewhere. . . . .	88
■ add conclusions not affected . . . . .	89
■ is this needed . . . . .	90
■ SNR plot/diagram . . . . .	90
■ Check how to cite priv communication properly . . . . .	91
■ Include correct links . . . . .	91
■ comparison of plots . . . . .	91
■ NIR analysis work . . . . .	94
■ Precision table needs fixed up . . . . .	95
■ check direction and magnitude in table . . . . .	96
■ Maybe transpose Table B.1 to be shorter? . . . . .	98
■ CHANGE # into the ESO identification number 1b 2a etc . . . . .	98
■ Is this significant?? . . . . .	98
■ is detector two significant as well? . . . . .	98
■ change scale on delta flux of HD 162020-2 chip 1 (it is too large atm) . . . . .	98
Figure: Corner plot of single detector? . . . . .	104
Figure: Corner plot fixed gaps . . . . .	104
Figure: Corner plot variable gaps . . . . .	104
■ remove vertical lines . . . . .	104
■ fill in table . . . . .	105
Figure: Residuals between individual fitting and the variable gap fits . . . . .	105
■ Fix up at end . . . . .	106

# Contents

<b>Todo list</b>	<b>vi</b>
<b>List of Tables</b>	<b>xiii</b>
<b>List of Figures</b>	<b>xvi</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Towards the characterization of Exoplanets . . . . .	1
1.2 Detection methods . . . . .	1
1.2.1 Radial Velocitmetry . . . . .	2
1.2.2 Transit and TTV . . . . .	3
1.2.3 Direct detection . . . . .	3
1.2.4 Astrometry . . . . .	3
1.2.5 Microlenseing . . . . .	3
1.2.6 Detecting atmospheres . . . . .	3
1.2.7 Transmission spectroscopy . . . . .	3
1.2.8 Reflection in optical . . . . .	3
1.2.9 Phase variations . . . . .	3
1.2.10 High resolution spectroscopy . . . . .	3
1.2.11 Stellar and planetary formation . . . . .	3
1.2.12 Exoplanet distribution . . . . .	3
1.3 Main Section 2 . . . . .	4
1.4 Recent detections in Companion spectra. . . . .	4
1.4.1 model fitting transit stars (not actual title, more other similar methods) . . . . .	4
1.4.2 Earths atmosphere . . . . .	5
1.5 Paper Introduction . . . . .	6
1.6 Motivation . . . . .	9
<b>2 Fundamental concepts about spectroscopy and RV</b>	<b>10</b>
2.0.1 RV calculation . . . . .	10
2.1 Estimating Companion-host Flux ratio . . . . .	11
2.1.0.1 Baraffe tables . . . . .	12

2.1.1	Companion K . . . . .	13
2.2	Telluric correction . . . . .	13
2.2.1	Telluric models . . . . .	13
2.2.1.1	TAPAS . . . . .	13
2.2.2	Tapas models . . . . .	13
2.3	Synthetic Stellar models . . . . .	14
2.3.1	PHOENIX-ACES . . . . .	14
2.3.2	BT-Settl . . . . .	14
2.3.2.1	Vacuum wavelengths . . . . .	14
2.3.3	Differential techniques . . . . .	15
<b>3</b>	<b>Spectroscopic reduction</b>	<b>16</b>
3.1	Summary of dataset . . . . .	16
3.2	NIR spectroscopy . . . . .	16
3.2.1	General reduction Concepts . . . . .	17
3.2.1.1	Dark Current . . . . .	17
3.2.1.2	Flat-field . . . . .	17
3.2.1.3	Nodding and Jitter . . . . .	18
3.2.2	Th-Ar lamp calibration . . . . .	19
3.2.3	Extraction . . . . .	19
3.3	Pipeline Comparison . . . . .	20
3.3.1	ESO CRIRES pipeline . . . . .	21
3.3.2	DRACS . . . . .	21
3.3.3	Pipeline comparison and selection . . . . .	22
3.3.3.1	Reduction issues . . . . .	24
3.3.4	Reduction experience: . . . . .	27
3.4	Post reduction stages . . . . .	27
3.4.1	Wavelength calibration . . . . .	28
3.4.1.1	Telluric correction . . . . .	32
3.4.2	Tapas models . . . . .	34
3.4.3	Issues with TAPAS . . . . .	34
3.4.3.1	Telluric masking . . . . .	35
3.4.4	Wavelength masking . . . . .	35
3.4.5	Barycentric correction . . . . .	36
<b>4</b>	<b>Separating the spectra of faint companions</b>	<b>37</b>
4.1	techniques . . . . .	37
4.2	Motivation . . . . .	37
4.3	Motivation and target selection . . . . .	37
4.3.1	The Data . . . . .	38
4.3.2	CRIRES data . . . . .	38
4.3.3	Calculations using observed times . . . . .	40
4.4	Direct Subtraction Method . . . . .	41
4.4.1	Results of spectral differential analysis . . . . .	43

4.5	Orbital Solutions . . . . .	44
4.5.1	Relative differential amplitude . . . . .	50
4.5.1.1	Differential scheduling challenges copy from paper . . . . .	52
4.6	Direct recovery in the mIR . . . . .	52
4.7	Summary . . . . .	53
<b>5</b>	<b>Companion Recovery using synthetic models</b>	<b>54</b>
5.1	Main Section 1 . . . . .	54
5.2	Binary synthetic spectral recovery . . . . .	54
5.2.1	Synthetic PHOENIX-ACES models . . . . .	54
5.2.2	$\chi^2$ method . . . . .	55
5.2.3	Computed model spectra . . . . .	56
5.2.3.1	Single component model . . . . .	56
5.2.3.2	Binary model . . . . .	57
5.2.3.3	Effective radius . . . . .	57
5.2.4	Re-normalization . . . . .	58
5.2.5	Reducing parameters . . . . .	58
5.3	Results . . . . .	60
5.3.1	Simulated binaries . . . . .	60
5.3.2	HD211847 observation . . . . .	62
5.3.3	Companion injection-recovery . . . . .	63
5.3.4	Junk from paper about BT-settl . . . . .	66
5.3.5	Incremental changes . . . . .	68
5.3.6	Note about a target - discussion of results . . . . .	68
5.3.6.1	Wavelength range . . . . .	68
<b>6</b>	<b>Information content of nIR Spectra</b>	<b>70</b>
6.1	Overview . . . . .	70
6.2	Radial velocity precision . . . . .	71
6.2.1	Fundamental photon noise limitation . . . . .	71
6.2.1.1	summarize . . . . .	76
6.2.2	Prepare phoenix acs models . . . . .	76
6.2.3	Rotation convolution . . . . .	76
6.2.4	Instrumental Convolution . . . . .	77
6.2.5	Numerical Convolution . . . . .	77
6.3	. . . . .	78
6.3.1	Bands . . . . .	79
6.3.2	Comparing models to CARMENES. . . . .	79
6.4	Metallicity NaN effects . . . . .	80
6.5	Updating RV precision software . . . . .	82
6.5.1	Automated testing . . . . .	82
6.5.2	Performance . . . . .	82
6.5.3	Model extension . . . . .	83
6.6	Numerical Gradient . . . . .	83

6.6.1	Masking Function . . . . .	87
6.6.1.1	Masking order . . . . .	88
6.6.2	Atmospheric masking bug . . . . .	88
6.6.3	SNR scaling . . . . .	89
6.7	SPIRou and NIRPS ETC . . . . .	90
6.8	Updated Figueira 2016 results . . . . .	91
6.9	metallicity / logg extension . . . . .	91
6.10	Application to CARMENES spectra . . . . .	91
<b>7</b>	<b>Conclusions</b>	<b>93</b>
7.1	Conclusions from Paper . . . . .	93
7.2	Future Work . . . . .	94
<b>A</b>	<b>RV Precision Tables</b>	<b>96</b>
<b>B</b>	<b>Artefacts in Optimal Extraction</b>	<b>98</b>
<b>C</b>	<b>Multi-dectector wavelength calibration</b>	<b>104</b>
<b>D</b>	<b>PhD output</b>	<b>106</b>
D.1	Publications . . . . .	107
D.2	Talks and Seminars . . . . .	111
D.3	Posters . . . . .	112
D.4	Attended Conferences and Schools . . . . .	115
D.5	Outreach . . . . .	117
D.6	Other . . . . .	118
	<b>Bibliography</b>	<b>119</b>

# List of Tables

2.1	Estimated flux ratios given the companion mass ( $M_2$ or $M_2 \sin i$ ) from Table 4.2. . . . .	12
4.1	Stellar parameters of the host stars. $V$ is the apparent magnitude taken from SIMBAD (Wenger et al., 2000). Distances were calculated from the GAIA DR2 parallax measurements. . . . .	38
4.2	Orbital parameters for the BD companions obtained from the literature. <b>Yes need rotating.</b>	39
4.3	Details about the each CRIRES observation. The number of artefacts removed in Section 3.3.3.1 as well as the SNR of the combined spectra is provided. The last three columns are the calculated RV of both host and largest companion, from the orbital solution, as well as the RV difference between the two components. . . . .	40
4.4	Estimated orbital semi-amplitude and RV separation of the companion, given the companion mass ( $M_2$ or $M_2 \sin i$ ) from Table 4.2 and observation times from Table 4.3. . . . .	41
5.1	Full parameter space of the PHOENIX-ACES spectral grid. . . . .	55
5.2	Input and recovered parameters on simulations and an observation when applying a single ( $C^1$ ) and binary ( $C^2$ ) models. The $\log g$ and metallicity were fixed at $\log g_1 = 4.50$ , $\log g_2 = 5.0$ and $[\text{Fe}/\text{H}] = 0.0$ equally for both components. Gaussian noise was added to both simulations with a SNR of 150. Here $m$ and $n$ are the number of data points and parameters used in each model. . . . .	59
5.3	Upper mass limits of target companions assuming a companion $\log g = 5.0$ . Masses are derived from Baraffe et al. (2015) evolutionary models using $T_{\text{eff}}$ and $\log g$ . The flux ratio $F_2/F_1$ is the absolute flux ratio between the cut-off temperature and the target host star.	66
6.1	The wavelength ranges of the nIR spectral bands. . . . .	79
6.2	CARMENES library target selection spanning the M-dwarf spectral range. . . . .	79
6.3	csv2tex table . . . . .	80

6.4	The affect of the numerical gradient function on RV precision. The band label VIS and NIR indicate the full visible and nIR bands while CARM <sub>VIS</sub> and CARM <sub>NIR</sub> indicate the two wavelength bands of the CARMENES spectrograph. $\Delta\lambda$ is a wavelength shift applied to move the FFD values between pixels for this comparison only. The M0 spectra used here had no rotation, or instrument broadening preformed and was normalized to a maximum of 1 in each band. The precision values given here are for accessing the relative precision change due to the different gradient methods. . . . .	86
6.5	Relative RV precision difference for Condition #2 due to spectral splitting and order of applying the pixel mask. The ratio are the difference between Split and Masked implementations with the same gradient calculation. The last column is the ratio between the Masked versions using the FFD and numpy gradient methods and are consistent with Table 6.4. Results a for an M0 spectral type, with $v \sin i = 1.0$ and $R=100\,000$ . . . . .	89
A.1	RV precisions from the PHOENIX-ACES and BT-Settl synthetic spectral libraries. The PHOENIX-ACES values are the updated values from Table A.1 of Figueira et al. (2016). .	98
A.1	continued. . . . .	99
A.1	continued. . . . .	100
A.1	continued. . . . .	101
A.1	continued. . . . .	102
A.2	RV precisions calculated for the NIRPS ETC. Reference band SELF. . . . .	102
A.2	continued. . . . .	103
A.2	continued. . . . .	104
A.2	continued. . . . .	105
A.2	continued. . . . .	106
A.2	continued. . . . .	107
A.2	continued. . . . .	108
A.2	continued. . . . .	109
A.2	continued. . . . .	110
A.2	continued. . . . .	111
A.2	continued. . . . .	112
A.2	continued. . . . .	113
A.2	continued. . . . .	114
A.3	RV precisions calculated for the SPIRou ETC. Same simulations as Table A.1 but with the SNR relative to the centre of each individual band. . . . .	114
A.3	continued. . . . .	115
A.3	continued. . . . .	116
A.3	continued. . . . .	117
A.3	continued. . . . .	118
A.3	continued. . . . .	119
B.1	Identification of all the optimally reduced nod spectra which had artefacts that were replaced by the rectangular extractions, corrected for bad pixels. The numbers represent the position in the nod cycle ABBAABBA. The number of the observation for each target is given by #. . . . .	99



B.2	Tally of nod cycle positions in which their optimally reduced spectra were affected and were replaced. . . . .	99
C.1	Example fitting parameters obtained for HD30501 observation 2 under different scenarios.	105

# List of Figures

1.1	Number of exoplanet detections per year separated by method (data from exoplanet.eu October 2018). . . . .	2
1.2	Distance mass diagram (data from exoplanet.eu October 2018) . . . . .	4
1.3	M-R relationship Chen and Kipping (2016) . . . . .	5
1.4	Reproduction of Figure 1 of Smette et al. (2015) showing telluric absorption form 0.30 $\mu\text{m}$ . Original caption: . . . . .	7
2.1	By Lasunncty at the English Wikipedia, CC BY-SA 3.0, <a href="https://commons.wikimedia.org/w/index.php?curid=8971">https://commons.wikimedia.org/w/index.php?curid=8971</a>	
3.1	Master dark frames for exposure times of 3 and 180 seconds. Each master is created by averaging 3 images in which the detector received no incident light. Both frames are on the same scale and show dark current grows with exposure time. The colour has been inverted so that black is the recorded measurement. . . . .	17
3.2	A flat-field image for detector #2 before (left) and after (right) the non-linearity corrections are performed. . . . .	18
3.3	Illustration of the nodding technique. Left: Sample slice of successive images at nod positions A and B, and their difference A-B for detector #1. Right: A vertical slice along the slit at column 512 (middle of detector). The background level observed in A and B is effectively removed by the subtraction. . . . .	19
3.4	Example Th-Ar calibration lamp frames for each detector. These are the raw frames in which dark current correction has not been performed (i.e the dark current is still visible on the bottom corners). . . . .	20
3.5	Comparison between the ESO pipeline and DRACS pipeline. For two observations HD30501-1 and HD202206-1. The blue lines are the extracted spectra from the ESO pipeline, the orange dashed lines are the optimal extraction from the DRACS pipeline, while the green dash-dotted line is the DRACS extraction after dealing with artefacts in the optimal extraction addressed in Section 3.3.3.1. The wavelength information applied to the spectra here comes from the ESO pipeline. . . . .	23

3.6	DRACS reduction of HD202206-1 detector 2 with a single pipeline parameter changed. Left: Pipeline with the “doslit.resize” set to “no”. Right: The same but with “doslit.resize” set to “yes”. During the order tracing the aperture size is automatically adjusted but the <b>finish this sentence</b> . Setting the resize parameter for <b>apextract?</b> . Changing this one parameter removed one large artefact but kept the other. One large artefact is removed, one is not. . . . .	25
3.7	Example of an artefact in the optimally extracted spectra from detector #2 of <b>HDXXXXXX</b> . The top panel contains the 8 normalized nod spectra obtained using optimal extraction. The middle panel shows nod spectra using only rectangular extraction. The bottom panel shows the difference between a combined spectrum using optimal nods only and a combined spectrum in which the identified nods are replaced with their rectangular counterparts as per Section 3.3.3.1. A vertical offset is included between each spectra for clarity. The nod spectra are in observation order from top to bottom. . . . .	26
3.8	Wavelength calibration example. The equation of the fitted line for these points is $\lambda = -1.85e^{-7}x^2 + 1.16e^{-2}x + 2111.86$ with each coefficient shown to two decimal places only. Error bars the line width set to around 0.04 nm. . . . .	30
3.9	An example spectra for each target and each detector 1–4 in order of increasing wavelength. The solid lines are the spectra while the black dashed lines are the telluric models used for wavelength correction, showing good alignment with the spectra. . . . .	32
4.1	(Top) A reduced CRIRES observation of HD 30501 (blue) for detector 1 between 2112–2124 nm along with the tapas telluric absorption model (orange dashed) used for the wavelength calibration and telluric correction. (Middle) The telluric corrected spectra. (Bottom) (blue) Differential spectra for HD 30501 between observations 1 and 3. (orange dashed) Simulated “perfect” differential using PHOENIX-ACES spectra with parameters $T_{\text{eff}} = 2500$ K, $\log g = 5.0$ , and $[\text{Fe}/\text{H}] = 0.0$ , with the same $\Delta RV$ as the observations. The shaded regions indicate where the telluric green and host star blue spectra are $> 4\%$ deep. . . . .	45
4.2	RV orbital single companion Keplerian for the HD 4747. The left hand plot shows the RV curve for one full orbit while the right hand panel shows the RV curve over 6 months (Period 89). The solid black line indicates the RV of the host star (with scale on the left), while the blue dashed line indicates the RV of the companion (with scale on the right axis). The orange crosses and red stars indicate the times at which observations were obtained for the target, for the host and companion respectively. . . . .	47
4.3	Same as Figure 4.2 but for HD 162020. . . . .	47
4.4	Same as Figure 4.2 but for HD 167665. . . . .	47
4.5	Same as Figure 4.2 but for HD 168443b. Analysed as if this was a single companion. . . .	48
4.6	Same as Figure 4.2 but for HD 168443c. Analysed as if this was a single companion. . . .	48
4.7	Same as Figure 4.2 but for HD 202206B. Analysed as if this was a single companion. . . .	48
4.8	Same as Figure 4.2 but for HD 202206c. Analysed as if this was a single companion. . . .	49
4.9	Same as Figure 4.2 but for HD 211847. . . . .	49
4.10	Same as Figure 4.2 but for HD 30501. . . . .	49

- 4.11 Simulated relative amplitude of differential spectra at different companion  $\Delta RV$  separations revealing the diminished amplitude at very small orbital separations. The solid blue line shows the maximum relative amplitude of the differential signal (from a shifted copy of itself) of a PHOENIX-ACES spectrum with  $T_{\text{eff}} = 2500 \text{ K}$ ,  $\log g = 5.0$ ,  $[\text{Fe}/\text{H}] = 0.0$  in the wavelength region 2110–2123 nm. The maximum difference is normalized by the median amplitude between  $\pm 7\text{--}10 \text{ km s}^{-1}$ , representing a complete line separation. The orange (dashed) and green (dot-dashed) lines represent the relative amplitude of a differential spectrum of a spectrum containing a single Gaussian and single Lorentzian absorption line respectively, each with a unitary amplitude and a  $\text{FWHM} = \lambda/R$ . The solid vertical lines indicate the estimated companion  $\Delta RV$  in these observations while the dashed vertical lines indicate the RV corresponding to the FWHM at this wavelength and resolution. . . . 51
- 5.1  $\chi^2$  results for companion recovery of a simulated binary observation of a Sun-like star ( $T_{\text{eff}1} = 5800 \text{ K}$ ) with an M-dwarf companion ( $T_{\text{eff}2} = 4000 \text{ K}$ ). The top right plot shows the application of a single component model ( $C^1$ ) while the other three are using a binary model ( $C^2$ ). Both left hand panels show the distribution of host temperature and host RV. The top right panel shows the distribution for host and companion temperature, and the bottom right the companion temperature and radial velocity. The red circle and yellow star indicate the location of the simulation input and recovered parameters respectively. The white line shows a  $3\text{-}\sigma$  confidence level about the minimum  $\chi^2$  solution grid point. Each box is centred on the parameter values and shows the grid resolution. . . . . 60
- 5.2 Similar to Figure 5.1,  $\chi^2$  results for companion recovery of a simulated binary observation similar to HD 211847, ( $T_{\text{eff}1} = 5800 \text{ K}$ ,  $T_{\text{eff}2} = 3200 \text{ K}$ ). The top right plot shows the application of a single component model ( $C^1$ ) while the other three are using a binary model ( $C^2$ ). Both left hand panels show the distribution of host temperature and host RV. The top right panel shows the distribution for host and companion temperature, and the bottom right the companion temperature and radial velocity. The red circle and yellow star indicate the location of the simulation input and recovered parameters respectively. The white line shows a  $3\text{-}\sigma$  confidence level about the minimum  $\chi^2$  solution grid point. Each box is centred on the parameter values and shows the grid resolution. . . . . 60
- 5.3  $\chi^2$  result grid for observation 2 of HD 211847, similar to Figs. 5.1 and 5.2. The top right plot shows the application of a single component model ( $C^1$ ) while the other three are using a binary model ( $C^2$ ). Both left hand panels show the distribution of host temperature and host RV. The top right panel shows the distribution for host and companion temperature, and the bottom right the companion temperature and radial velocity. The red circles indicate the literature values or calculated parameters for the target while the yellow star indicates the minimum  $\chi^2$  solution. The error bar on the  $T_{\text{eff}1}$  is from the literature while the error bars on  $rv_1$  and  $rv_2$  are calculated by propagating the orbital parameter uncertainties through the radial velocity equation. The white line shows a  $3\text{-}\sigma$  confidence level about the minimum  $\chi^2$  solution grid point, not always visible here due to the large  $\chi^2$  values. . . . . 63

5.4	Comparison between the observed HD 211847 spectrum (blue) and the best fit synthetic binary model (orange dashed) for each detector. The bottom section of each panel shows the residuals between the parts of the observation used in the $\chi^2$ fit and recovered binary model ( $O - C^2$ ) in purple. The red dashed line shows the difference between the recovered binary model and the binary model with the exact same parameters except for the estimated companion temperature of 3 200 K ( $C^2[3200\text{ K}] - C^2$ ). The grey shading indicated the wavelength regions where masking has been applied. The thinner masked regions that match with cuts in the observed spectra are where the centres of deep ( $>5\%$ ) telluric lines that have been masked out are. . . . .	64
5.5	Result of simulated injection-recovery of synthetic companions on HD 30501. The blue dots and orange triangles indicate the recovered companion temperature for the observed and synthetic spectra respectively. The $\pm 100\text{ K}$ error bars are the grid step of the synthetic models. The black dashed diagonal shows the 1:1 temperature relation. The grey shaded region indicates the $\pm 1\,000\text{ K}$ temperature range explored. Gaussian noise added to the synthetic spectra was derived from the observed spectra. . . . .	65
5.6	(top) Companion temperature verses $\chi^2$ for simulations with different injected companion temperatures. Other fixed parameters for these fully synthetic simulations was $T_{\text{eff}1} = 5\,200\text{ K}$ , $\text{logg}_1 = 4.5$ , $\text{logg}_2 = 5.0$ , and both $[\text{Fe}/\text{H}] = 0.0$ . A fixed Gaussian noise corresponding to a SNR of 300 was used. (bottom) A close up view of $\chi^2 < 15$ . The three horizontal grey lines indicate the 1, 2, 3 sigma with 2 degrees of freedom. The vertical dotted lines indicate the location of the minimum $\chi^2$ recovered for each companion. The black solid vertical in both panels shows the 2 300 K cut-off of the PHOENIX-ACES models . . . . .	65
6.1	Mass of discovered planets verse year. From Exoplanet.eu . . . . .	72
6.2	Arbitrary spectral line with a shift $\delta\lambda$ , inspired by Connes (1985). $\Lambda$ is the wavelength range considered. . . . .	73
6.3	Quality factor changes across spectral type and bands for variations in $[\text{Fe}/\text{H}]$ and NaN. Broadening values are $R=100\,000$ and $v \sin i = 1.0\text{ km s}^{-1}$ . Top: Quality factor variation of $[\text{Fe}/\text{H}]$ between -1.0 to 1.0 at a fixed NaN=4.5. Bottom: Quality factor variation of NaN between 4 and 5.5 with fixed $[\text{Fe}/\text{H}] = 0.0$ . Note a higher quality factor corresponds to an increased RV precision. . . . .	81
6.4	Visualization of the numerical gradient of some spectral lines. Top: The two spectral regions of a stellar spectrum the left hand slide contains short lines near the normalized continuum while on the right a single deep absorption line is shown. Bottom: The numerical gradients for the spectra shown in the top panels; the original FFD method is displayed with <i>blue squares</i> while numpy gradient is shown with <i>green stars</i> . The <i>orange circles</i> are the FFD version shifted to the mid-points between pixels for illustrative purposes. . . . .	85
6.5	Left: Figueria et al 2016, Right, Updated values from this work computed with eniric. . . . .	91

B.1	Artefact example for the second detector of HD 4747. The top panel contains the eight normalized nod spectra obtained using optimal extraction. The middle panel shows nod spectra using only rectangular extraction. The bottom panel shows the difference between a combined spectrum using optimal nodes only and a combined spectrum in which the identified nodes are replaced with their rectangular counterparts as per Section 3.3.3.1. A vertical offset is included between each spectra for clarity. The nod spectra are in observation order from top to bottom. In this example there are artefacts in the 5th (purple) and eighth (grey) nod spectra around 700 and 500 pixels respectively. . . . .	100
B.2	Same as Figure B.1 but for the first detector of the second observation of HD 162020. In this example there are several large spikes observed in the rectangular extraction but they do not appear to effect the optimally extracted nodes. <span style="color: red;">reduce scale of delta flux (to large atm).</span> . . . . .	101
B.3	Same as Figure B.1 but for the third detector of the second observation of HD 167665. In this example a small spike in the first spectrum (blue) around pixel 450 causes a extended dip in the optimally extracted nod. . . . .	101
B.4	Same as Figure B.1 but for the 1st detector of the second observation of HD 202206. In this example there are several large spike but only one produces an artefact. This is on the 5th nod (purple) around pixel 800. . . . .	102
B.5	Same as Figure B.1 but for the fourth detector of the first observation of HD 168443. In this example a barely visible spike on the 7th nod (pink) causes a deviation in the optimal nod around pixel 610. There is also a second small spike on the eighth nod (grey) around pixel 850, between two spectral lines. . . . .	102
B.6	Same as Figure B.1 but for the second detector of the second observation of HD 211847. In this example two large spikes around 800 and 1000 in the 7th nod (pink) create large deviations in the optimally reduced spectra. A spike in the first nod (blue) around pixel 700 also causes a bump. There is also some extra noise in the first nod around pixel 350. .	103
B.7	Same as Figure B.1 but for the second detector of the second observation of HD 30501. In this example there are artefact causing spikes in four places. The second nod (orange) around pixel 950, the 6th nod (brown) around pixel 20 and two spikes in the 7th nod (pink) around pixels 400 and 550. . . . .	103



# Appendix A

## RV Precision Tables

The updated relative RV precision results attainable from nIR spectra are presented in the following tables. Table A.1 shows the precision results for the same M-dwarfs analysed in (Figueira et al., 2016). That is stellar temperatures 3900, 3500, 2800, 2600K corresponding to spectral types M0, M3, M6, M9 respectively.  $\log g=4.5$  and  $[\text{Fe}/\text{H}]=0.0$ . The rotation applied are  $v \sin i=1, 5, 10 \text{ km s}^{-1}$  and instrumental profiles with  $R = 60\text{k}, 80\text{k}, 100\text{k}$ .

Columns 2-4 contain the RV precision calculated using PHOENIX-ACES spectra, as done in Figueira et al. (2016). These values differ from two effects. There is small difference in Conditions 1 and 3 from the change in numerical differentiation implemented (see Section 6.6). The values for Condition 2 however, are completely different due to the implementation error in the telluric masking discovered (see Section ??).

In columns 5-7 are the same RV precision calculation but using the BT-Settl spectral library instead (with same spectral parameters), a recent addition in *eniric*.

These can be created with *eniric* with the following shell incantation (after installation and configuration).

```
phoenix_precision.py -t 3900 3500 2800 2600 \    # Temperature
                    -l 4.5 -m 0.5 \             # Logg and Metalicity
                    -r 60000 80000 100000 \      # Resolutions
                    -v 1.0 5.0 10.0 \           # Rotational velocities
                    -b Z Y J H K \              # Wavelength bands
                    --snr 100 \                 # Relative SNR
                    --ref_band J                # SNR reference band
```

*eniric* was also used to calculate RV precision for the NIRPS and SPIRou.

For SPIRou the requested precisions were provided with the SNR relative to the centre of each individual band. The values are provided in Table A.3 and can be generated with the following code, note the change in.

This has the effect of Z Y band precisions being **lower** and H and K band precisions being **higher**. compared to Table ??

```
phoenix_precision.py -t 3900 3500 2800 2600 -l 4.5, -m 0.5 \
                    -r 60000 80000 100000 -v 1.0 5.0 10.0 -b Z Y J H K \
```

check direction  
and magnitude  
in table



—snr 100 —ref\_band self

For NIRPS RV precisions with an instrumental resolution of 75 000 was requested to match the NIRPS instrument, and provided relative to the  $J$  and  $H$ -bands. The results for the NIRPS precision relative to the  $J$ -band are given in Table ??, and can be reproduced with the following code.

```
phoenix_precision.py -t 3900 3500 2800 2600 -l 4.5, -m 0.5 \
-r 60000 75000 80000 100000 -v 1.0 5.0 10.0 \
-b Z Y J H K —snr 100 —ref_band H \
```

**Table A.1:** RV precisions from the PHOENIX-ACES and BT-Settl synthetic spectral libraries. The PHOENIX-ACES values are the updated values from Table A.1 of Figueira et al. (2016).

Simulation (SpTp - Band - $v.sini$ - R)	PHOENIX-ACES			BT-SETTL		
	Cond. 1 $\sigma_{RV}$ [m/s]	Cond. 2 $\sigma_{RV}$ [m/s]	Cond. 3 $\sigma_{RV}$ [m/s]	Cond. 1 $\sigma_{RV}$ [m/s]	Cond. 2 $\sigma_{RV}$ [m/s]	Cond. 3 $\sigma_{RV}$ [m/s]
3900-Z-1.0-60k	9.7	15.5	10.0	9.4	15.3	9.7
3900-Z-1.0-80k	6.4	10.4	6.6	6.6	10.7	6.8
3900-Z-1.0-100k	4.7	7.8	4.9	5.2	8.5	5.3
3900-Z-5.0-60k	14.2	22.6	14.6	13.0	21.0	13.4
3900-Z-5.0-80k	10.9	17.6	11.3	10.1	16.4	10.5
3900-Z-5.0-100k	9.2	14.8	9.5	8.6	13.9	8.9
3900-Z-10.0-60k	24.5	38.6	25.3	21.8	35.1	22.4
3900-Z-10.0-80k	20.3	32.2	21.0	18.1	29.2	18.7
3900-Z-10.0-100k	17.8	28.2	18.3	15.9	25.6	16.3
3900-Y-1.0-60k	9.6	11.5	9.8	12.5	15.0	12.7
3900-Y-1.0-80k	6.0	7.1	6.0	8.3	10.0	8.4
3900-Y-1.0-100k	4.2	5.1	4.3	6.3	7.5	6.3
3900-Y-5.0-60k	15.5	18.4	15.7	18.6	22.3	18.9
3900-Y-5.0-80k	11.6	13.8	11.8	14.3	17.0	14.4
3900-Y-5.0-100k	9.7	11.5	9.8	11.9	14.3	12.1
3900-Y-10.0-60k	30.8	36.8	31.2	34.8	41.6	35.2
3900-Y-10.0-80k	25.2	30.1	25.5	28.6	34.3	29.0
3900-Y-10.0-100k	21.8	26.0	22.1	24.9	29.9	25.2
3900-J-1.0-60k	15.7	41.7	16.6	16.2	45.6	17.1
3900-J-1.0-80k	10.5	26.9	11.0	11.5	31.4	12.2
3900-J-1.0-100k	7.9	19.6	8.3	9.2	24.4	9.7
3900-J-5.0-60k	22.7	63.6	24.0	21.8	65.6	23.1
3900-J-5.0-80k	17.5	48.1	18.5	17.1	50.2	18.2
3900-J-5.0-100k	14.8	40.3	15.6	14.6	42.1	15.4
3900-J-10.0-60k	38.6	122.9	41.0	35.4	122.3	37.7
3900-J-10.0-80k	32.0	100.7	34.0	29.5	100.5	31.4
3900-J-10.0-100k	28.0	87.6	29.8	25.9	87.5	27.6
3900-H-1.0-60k	7.2	11.4	7.4	7.6	11.9	7.8
3900-H-1.0-80k	5.0	8.0	5.1	5.4	8.4	5.5

**Table A.1:** continued.

Simulation	PHOENIX-ACES			BT-SETTL		
	Cond. 1	Cond. 2	Cond. 3	Cond. 1	Cond. 2	Cond. 3
3900-H-1.0-100k	4.0	6.3	4.0	4.2	6.6	4.3
3900-H-5.0-60k	10.1	15.9	10.3	10.8	16.8	11.0
3900-H-5.0-80k	7.9	12.4	8.0	8.3	13.1	8.5
3900-H-5.0-100k	6.6	10.5	6.8	7.0	11.0	7.2
3900-H-10.0-60k	17.5	27.3	17.9	18.8	29.4	19.2
3900-H-10.0-80k	14.5	22.7	14.9	15.6	24.4	16.0
3900-H-10.0-100k	12.7	19.9	13.0	13.6	21.3	14.0
3900-K-1.0-60k	14.5	63.7	15.5	13.7	63.2	14.6
3900-K-1.0-80k	9.7	43.6	10.4	9.6	45.2	10.3
3900-K-1.0-100k	7.4	33.6	8.0	7.6	36.1	8.1
3900-K-5.0-60k	21.7	90.3	23.2	19.4	85.4	20.8
3900-K-5.0-80k	16.6	70.0	17.7	15.0	67.0	16.1
3900-K-5.0-100k	13.9	59.2	14.8	12.6	56.9	13.5
3900-K-10.0-60k	39.4	155.8	42.1	34.2	142.8	36.6
3900-K-10.0-80k	32.6	128.9	34.9	28.4	118.5	30.4
3900-K-10.0-100k	28.5	112.5	30.5	24.8	104.0	26.6
3500-Z-1.0-60k	8.4	13.9	8.7	8.4	14.0	8.6
3500-Z-1.0-80k	5.2	8.8	5.4	5.6	9.4	5.7
3500-Z-1.0-100k	3.7	6.3	3.8	4.2	7.1	4.3
3500-Z-5.0-60k	13.2	21.3	13.6	12.3	20.1	12.7
3500-Z-5.0-80k	10.0	16.4	10.3	9.4	15.5	9.7
3500-Z-5.0-100k	8.3	13.6	8.6	7.9	13.0	8.2
3500-Z-10.0-60k	24.6	39.1	25.4	21.9	35.1	22.5
3500-Z-10.0-80k	20.3	32.4	20.9	18.1	29.1	18.6
3500-Z-10.0-100k	17.6	28.2	18.2	15.8	25.4	16.3
3500-Y-1.0-60k	8.5	10.1	8.6	11.3	13.3	11.4
3500-Y-1.0-80k	5.2	6.2	5.2	7.4	8.7	7.4
3500-Y-1.0-100k	3.6	4.3	3.7	5.5	6.5	5.5
3500-Y-5.0-60k	13.9	16.5	14.1	17.1	20.2	17.3
3500-Y-5.0-80k	10.4	12.3	10.5	13.0	15.3	13.1
3500-Y-5.0-100k	8.6	10.2	8.7	10.9	12.8	11.0
3500-Y-10.0-60k	28.2	33.5	28.5	32.4	38.4	32.8
3500-Y-10.0-80k	23.0	27.3	23.3	26.7	31.5	27.0
3500-Y-10.0-100k	19.9	23.6	20.1	23.2	27.4	23.5
3500-J-1.0-60k	15.1	38.4	15.9	16.7	47.9	17.8
3500-J-1.0-80k	9.8	24.0	10.3	11.8	32.6	12.5
3500-J-1.0-100k	7.1	17.1	7.5	9.3	25.1	9.9
3500-J-5.0-60k	22.5	60.2	23.8	22.9	69.2	24.4
3500-J-5.0-80k	17.3	45.4	18.3	17.9	52.9	19.0

**Table A.1:** continued.

Simulation	PHOENIX-ACES			BT-SETTL		
	Cond. 1	Cond. 2	Cond. 3	Cond. 1	Cond. 2	Cond. 3
3500-J-5.0-100k	14.5	37.8	15.3	15.2	44.4	16.2
3500-J-10.0-60k	39.9	117.8	42.4	37.9	129.4	40.5
3500-J-10.0-80k	33.0	96.4	35.1	31.5	106.4	33.7
3500-J-10.0-100k	28.8	83.7	30.6	27.6	92.6	29.5
3500-H-1.0-60k	7.7	12.4	7.9	7.7	12.4	7.9
3500-H-1.0-80k	5.4	8.8	5.6	5.4	8.8	5.5
3500-H-1.0-100k	4.3	6.9	4.4	4.3	6.9	4.4
3500-H-5.0-60k	10.7	17.1	10.9	10.9	17.5	11.2
3500-H-5.0-80k	8.3	13.3	8.5	8.4	13.5	8.6
3500-H-5.0-100k	7.1	11.3	7.2	7.1	11.4	7.3
3500-H-10.0-60k	18.1	28.7	18.5	19.5	31.4	20.0
3500-H-10.0-80k	15.0	23.9	15.4	16.1	26.0	16.6
3500-H-10.0-100k	13.1	20.9	13.5	14.1	22.7	14.5
3500-K-1.0-60k	13.5	49.0	14.4	12.1	43.8	13.0
3500-K-1.0-80k	9.0	32.7	9.6	8.4	30.1	8.9
3500-K-1.0-100k	6.8	24.8	7.3	6.5	23.3	7.0
3500-K-5.0-60k	20.4	71.7	21.7	17.6	62.6	18.8
3500-K-5.0-80k	15.5	55.2	16.5	13.5	48.4	14.4
3500-K-5.0-100k	13.0	46.4	13.9	11.4	40.8	12.1
3500-K-10.0-60k	37.5	126.6	39.9	31.8	109.6	34.0
3500-K-10.0-80k	30.9	104.6	33.0	26.3	90.7	28.1
3500-K-10.0-100k	27.0	91.3	28.8	23.0	79.3	24.6
2800-Z-1.0-60k	4.4	8.4	4.5	4.0	7.6	4.2
2800-Z-1.0-80k	2.6	5.1	2.7	2.6	4.8	2.7
2800-Z-1.0-100k	1.8	3.6	1.9	1.9	3.5	1.9
2800-Z-5.0-60k	7.2	13.7	7.5	6.3	11.7	6.6
2800-Z-5.0-80k	5.4	10.3	5.6	4.8	8.8	4.9
2800-Z-5.0-100k	4.4	8.5	4.6	4.0	7.3	4.1
2800-Z-10.0-60k	14.6	27.3	15.2	12.6	22.8	13.0
2800-Z-10.0-80k	11.9	22.4	12.4	10.3	18.6	10.6
2800-Z-10.0-100k	10.3	19.3	10.7	8.9	16.2	9.2
2800-Y-1.0-60k	5.8	7.4	5.9	11.7	14.0	11.9
2800-Y-1.0-80k	3.7	4.8	3.8	7.6	9.1	7.7
2800-Y-1.0-100k	2.7	3.5	2.7	5.6	6.7	5.7
2800-Y-5.0-60k	8.7	10.7	8.8	17.7	21.3	17.9
2800-Y-5.0-80k	6.7	8.3	6.8	13.5	16.2	13.7
2800-Y-5.0-100k	5.6	7.0	5.7	11.3	13.6	11.4
2800-Y-10.0-60k	14.7	17.5	14.9	32.5	39.0	32.9
2800-Y-10.0-80k	12.2	14.6	12.4	26.8	32.1	27.1

**Table A.1:** continued.

Simulation	PHOENIX-ACES			BT-SETTL		
	Cond. 1	Cond. 2	Cond. 3	Cond. 1	Cond. 2	Cond. 3
2800-Y-10.0-100k	10.7	12.8	10.8	23.3	28.0	23.6
2800-J-1.0-60k	8.8	23.2	9.3	11.0	31.7	11.8
2800-J-1.0-80k	5.5	14.4	5.8	7.6	21.5	8.1
2800-J-1.0-100k	4.0	10.2	4.2	5.8	16.3	6.2
2800-J-5.0-60k	13.5	35.9	14.3	15.6	45.3	16.7
2800-J-5.0-80k	10.3	27.3	10.9	12.1	35.1	13.0
2800-J-5.0-100k	8.6	22.8	9.1	10.2	29.6	10.9
2800-J-10.0-60k	24.3	63.8	25.7	26.7	78.5	28.5
2800-J-10.0-80k	20.1	52.9	21.2	22.2	65.1	23.7
2800-J-10.0-100k	17.5	46.1	18.5	19.4	57.0	20.7
2800-H-1.0-60k	6.6	12.8	6.9	5.7	11.1	5.9
2800-H-1.0-80k	4.4	8.5	4.6	3.9	7.5	4.0
2800-H-1.0-100k	3.3	6.4	3.5	3.0	5.8	3.1
2800-H-5.0-60k	9.8	18.8	10.2	8.4	16.4	8.7
2800-H-5.0-80k	7.5	14.4	7.8	6.5	12.6	6.7
2800-H-5.0-100k	6.3	12.1	6.5	5.4	10.5	5.6
2800-H-10.0-60k	17.8	34.7	18.4	15.6	31.0	16.2
2800-H-10.0-80k	14.7	28.7	15.2	12.9	25.5	13.3
2800-H-10.0-100k	12.8	25.0	13.3	11.2	22.2	11.6
2800-K-1.0-60k	8.2	27.0	8.7	7.1	22.9	7.5
2800-K-1.0-80k	5.4	17.9	5.7	4.8	15.6	5.1
2800-K-1.0-100k	4.0	13.5	4.3	3.7	12.0	4.0
2800-K-5.0-60k	12.4	39.7	13.2	10.3	33.3	11.0
2800-K-5.0-80k	9.4	30.5	10.0	7.9	25.6	8.4
2800-K-5.0-100k	7.9	25.6	8.4	6.6	21.5	7.1
2800-K-10.0-60k	23.0	70.7	24.6	19.1	59.6	20.4
2800-K-10.0-80k	19.0	58.5	20.3	15.8	49.3	16.8
2800-K-10.0-100k	16.6	51.1	17.7	13.8	43.0	14.7
2600-Z-1.0-60k	3.7	7.7	3.9	3.4	6.5	3.6
2600-Z-1.0-80k	2.2	4.6	2.3	2.2	4.2	2.3
2600-Z-1.0-100k	1.5	3.2	1.6	1.6	3.0	1.7
2600-Z-5.0-60k	6.1	12.5	6.4	5.4	10.0	5.6
2600-Z-5.0-80k	4.6	9.4	4.8	4.0	7.6	4.2
2600-Z-5.0-100k	3.8	7.8	3.9	3.4	6.3	3.5
2600-Z-10.0-60k	12.3	24.9	12.9	10.6	19.6	11.0
2600-Z-10.0-80k	10.1	20.4	10.5	8.7	16.0	9.0
2600-Z-10.0-100k	8.7	17.6	9.1	7.5	13.9	7.8
2600-Y-1.0-60k	4.8	6.3	4.9	7.7	9.2	7.8
2600-Y-1.0-80k	3.0	4.0	3.1	5.0	5.9	5.0

**Table A.1:** continued.

Simulation	PHOENIX-ACES			BT-SETTL		
	Cond. 1	Cond. 2	Cond. 3	Cond. 1	Cond. 2	Cond. 3
2600-Y-1.0-100k	2.1	2.9	2.2	3.6	4.4	3.7
2600-Y-5.0-60k	7.2	9.1	7.3	11.7	14.2	11.9
2600-Y-5.0-80k	5.6	7.0	5.6	8.9	10.8	9.0
2600-Y-5.0-100k	4.7	5.9	4.7	7.4	9.0	7.5
2600-Y-10.0-60k	12.1	14.6	12.2	22.0	26.3	22.2
2600-Y-10.0-80k	10.1	12.2	10.2	18.0	21.6	18.3
2600-Y-10.0-100k	8.8	10.7	8.9	15.7	18.8	15.9
2600-J-1.0-60k	6.4	17.1	6.8	8.1	24.0	8.6
2600-J-1.0-80k	4.0	10.5	4.2	5.4	16.0	5.8
2600-J-1.0-100k	2.8	7.4	3.0	4.1	12.0	4.4
2600-J-5.0-60k	10.0	26.9	10.6	11.7	35.0	12.5
2600-J-5.0-80k	7.6	20.4	8.0	9.0	26.9	9.6
2600-J-5.0-100k	6.3	17.0	6.7	7.6	22.6	8.1
2600-J-10.0-60k	18.1	47.2	19.1	20.8	60.7	22.2
2600-J-10.0-80k	15.0	39.2	15.8	17.2	50.4	18.3
2600-J-10.0-100k	13.0	34.2	13.8	15.0	44.1	16.0
2600-H-1.0-60k	5.2	10.2	5.4	4.6	9.1	4.8
2600-H-1.0-80k	3.4	6.7	3.5	3.1	6.2	3.2
2600-H-1.0-100k	2.6	5.1	2.7	2.4	4.7	2.5
2600-H-5.0-60k	7.8	15.4	8.0	6.8	13.5	7.0
2600-H-5.0-80k	5.9	11.7	6.2	5.2	10.3	5.4
2600-H-5.0-100k	5.0	9.8	5.2	4.4	8.6	4.5
2600-H-10.0-60k	14.2	28.9	14.7	12.6	25.5	13.0
2600-H-10.0-80k	11.7	23.8	12.1	10.3	21.0	10.7
2600-H-10.0-100k	10.2	20.7	10.6	9.0	18.3	9.4
2600-K-1.0-60k	6.2	20.2	6.6	5.7	18.8	6.1
2600-K-1.0-80k	4.0	13.2	4.3	3.9	12.9	4.2
2600-K-1.0-100k	3.0	9.9	3.2	3.0	9.9	3.2
2600-K-5.0-60k	9.4	30.1	10.0	8.3	27.2	8.9
2600-K-5.0-80k	7.1	23.0	7.6	6.4	20.9	6.8
2600-K-5.0-100k	6.0	19.3	6.4	5.3	17.6	5.7
2600-K-10.0-60k	17.4	54.0	18.6	15.2	48.5	16.2
2600-K-10.0-80k	14.4	44.7	15.3	12.5	40.1	13.4
2600-K-10.0-100k	12.5	39.1	13.4	10.9	35.0	11.7

**Table A.2:** RV precisions calculated for the NIRPS ETC. Reference band SELF.

Simulation ( $T_{\text{eff}}$ -Band- $v.sini$ -R)	$\sigma_{RV}$ (Cond. 1) [m/s]	$\sigma_{RV}$ (Cond. 2) [m/s]	$\sigma_{RV}$ (Cond. 3) [m/s]
4000-Z-1.0-75k	6.9	11.2	7.1
4000-Z-1.0-100k	4.7	7.7	4.9
4000-Z-5.0-75k	11.2	18.2	11.6
4000-Z-5.0-100k	9.0	14.5	9.3
4000-Z-10.0-75k	20.5	32.6	21.1
4000-Z-10.0-100k	17.2	27.4	17.8
4000-Y-1.0-75k	6.8	8.1	6.8
4000-Y-1.0-100k	4.4	5.2	4.4
4000-Y-5.0-75k	12.5	14.9	12.6
4000-Y-5.0-100k	9.8	11.7	9.9
4000-Y-10.0-75k	26.4	31.6	26.8
4000-Y-10.0-100k	21.9	26.2	22.2
4000-J-1.0-75k	11.3	29.3	11.9
4000-J-1.0-100k	7.8	19.7	8.2
4000-J-5.0-75k	18.1	50.1	19.1
4000-J-5.0-100k	14.5	39.7	15.3
4000-J-10.0-75k	32.3	102.4	34.3
4000-J-10.0-100k	27.2	85.5	28.9
4000-H-1.0-75k	5.4	8.5	5.5
4000-H-1.0-100k	3.9	6.2	4.0
4000-H-5.0-75k	8.2	13.0	8.4
4000-H-5.0-100k	6.6	10.4	6.7
4000-H-10.0-75k	15.0	23.5	15.4
4000-H-10.0-100k	12.6	19.7	12.9
4000-K-1.0-75k	10.4	47.3	11.1
4000-K-1.0-100k	7.3	33.7	7.8
4000-K-5.0-75k	17.2	73.5	18.4
4000-K-5.0-100k	13.7	59.0	14.6
4000-K-10.0-75k	33.4	132.8	35.7
4000-K-10.0-100k	28.0	111.8	29.9
3900-Z-1.0-75k	7.0	11.4	7.2
3900-Z-1.0-100k	4.7	7.8	4.9
3900-Z-5.0-75k	11.5	18.6	11.9
3900-Z-5.0-100k	9.2	14.8	9.5
3900-Z-10.0-75k	21.2	33.6	21.8
3900-Z-10.0-100k	17.8	28.2	18.3
3900-Y-1.0-75k	6.6	7.9	6.7
3900-Y-1.0-100k	4.2	5.1	4.3
3900-Y-5.0-75k	12.3	14.7	12.5

**Table A.2:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
3900-Y-5.0-100k	9.7	11.5	9.8
3900-Y-10.0-75k	26.3	31.4	26.6
3900-Y-10.0-100k	21.8	26.0	22.1
3900-J-1.0-75k	11.5	29.5	12.1
3900-J-1.0-100k	7.9	19.6	8.3
3900-J-5.0-75k	18.5	50.9	19.6
3900-J-5.0-100k	14.8	40.3	15.6
3900-J-10.0-75k	33.4	104.9	35.4
3900-J-10.0-100k	28.0	87.6	29.8
3900-H-1.0-75k	5.4	8.6	5.5
3900-H-1.0-100k	4.0	6.3	4.0
3900-H-5.0-75k	8.3	13.0	8.5
3900-H-5.0-100k	6.6	10.5	6.8
3900-H-10.0-75k	15.1	23.6	15.5
3900-H-10.0-100k	12.7	19.9	13.0
3900-K-1.0-75k	10.6	47.3	11.3
3900-K-1.0-100k	7.4	33.6	8.0
3900-K-5.0-75k	17.5	73.8	18.7
3900-K-5.0-100k	13.9	59.2	14.8
3900-K-10.0-75k	34.0	133.7	36.3
3900-K-10.0-100k	28.5	112.5	30.5
3800-Z-1.0-75k	6.9	11.3	7.2
3800-Z-1.0-100k	4.7	7.7	4.8
3800-Z-5.0-75k	11.7	18.7	12.0
3800-Z-5.0-100k	9.3	14.9	9.6
3800-Z-10.0-75k	21.7	34.2	22.4
3800-Z-10.0-100k	18.2	28.7	18.8
3800-Y-1.0-75k	6.5	7.7	6.5
3800-Y-1.0-100k	4.1	4.9	4.2
3800-Y-5.0-75k	12.1	14.4	12.3
3800-Y-5.0-100k	9.5	11.3	9.6
3800-Y-10.0-75k	26.0	31.0	26.3
3800-Y-10.0-100k	21.5	25.7	21.8
3800-J-1.0-75k	11.5	29.3	12.1
3800-J-1.0-100k	7.8	19.4	8.2
3800-J-5.0-75k	18.7	51.2	19.8
3800-J-5.0-100k	14.9	40.5	15.8
3800-J-10.0-75k	34.1	106.2	36.2
3800-J-10.0-100k	28.7	88.6	30.4
3800-H-1.0-75k	5.5	8.8	5.7

**Table A.2:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
3800-H-1.0-100k	4.1	6.4	4.1
3800-H-5.0-75k	8.4	13.2	8.6
3800-H-5.0-100k	6.7	10.6	6.9
3800-H-10.0-75k	15.2	23.7	15.6
3800-H-10.0-100k	12.8	20.0	13.1
3800-K-1.0-75k	10.7	46.0	11.4
3800-K-1.0-100k	7.5	32.5	8.0
3800-K-5.0-75k	17.7	72.6	18.9
3800-K-5.0-100k	14.0	58.2	15.0
3800-K-10.0-75k	34.4	132.6	36.7
3800-K-10.0-100k	28.8	111.5	30.8
3700-Z-1.0-75k	6.8	11.1	7.0
3700-Z-1.0-100k	4.5	7.4	4.6
3700-Z-5.0-75k	11.6	18.7	12.0
3700-Z-5.0-100k	9.2	14.8	9.5
3700-Z-10.0-75k	22.0	34.6	22.7
3700-Z-10.0-100k	18.4	29.1	19.0
3700-Y-1.0-75k	6.3	7.5	6.3
3700-Y-1.0-100k	4.0	4.8	4.0
3700-Y-5.0-75k	11.9	14.1	12.0
3700-Y-5.0-100k	9.3	11.0	9.4
3700-Y-10.0-75k	25.6	30.4	25.9
3700-Y-10.0-100k	21.2	25.2	21.4
3700-J-1.0-75k	11.4	28.8	12.0
3700-J-1.0-100k	7.7	18.9	8.1
3700-J-5.0-75k	18.8	50.9	19.9
3700-J-5.0-100k	15.0	40.2	15.8
3700-J-10.0-75k	34.7	106.0	36.8
3700-J-10.0-100k	29.1	88.4	30.9
3700-H-1.0-75k	5.7	9.0	5.8
3700-H-1.0-100k	4.2	6.6	4.3
3700-H-5.0-75k	8.5	13.4	8.7
3700-H-5.0-100k	6.8	10.8	7.0
3700-H-10.0-75k	15.3	24.0	15.7
3700-H-10.0-100k	12.9	20.2	13.2
3700-K-1.0-75k	10.6	43.7	11.4
3700-K-1.0-100k	7.5	30.7	8.0
3700-K-5.0-75k	17.7	70.1	18.9
3700-K-5.0-100k	14.0	56.0	15.0
3700-K-10.0-75k	34.5	128.8	36.8



**Table A.2:** continued.

Simulation	$\sigma_{RV}(\text{Cond. 1})$	$\sigma_{RV}(\text{Cond. 2})$	$\sigma_{RV}(\text{Cond. 3})$
3700-K-10.0-100k	28.9	108.3	30.9
3600-Z-1.0-75k	6.3	10.5	6.6
3600-Z-1.0-100k	4.1	6.9	4.3
3600-Z-5.0-75k	11.2	18.2	11.6
3600-Z-5.0-100k	8.9	14.4	9.2
3600-Z-10.0-75k	21.8	34.5	22.5
3600-Z-10.0-100k	18.2	28.9	18.8
3600-Y-1.0-75k	6.0	7.2	6.1
3600-Y-1.0-100k	3.8	4.6	3.9
3600-Y-5.0-75k	11.5	13.6	11.6
3600-Y-5.0-100k	9.0	10.6	9.1
3600-Y-10.0-75k	24.9	29.6	25.2
3600-Y-10.0-100k	20.6	24.5	20.9
3600-J-1.0-75k	11.1	27.9	11.7
3600-J-1.0-100k	7.5	18.1	7.8
3600-J-5.0-75k	18.7	49.8	19.7
3600-J-5.0-100k	14.8	39.3	15.7
3600-J-10.0-75k	34.7	104.0	36.9
3600-J-10.0-100k	29.1	86.7	30.9
3600-H-1.0-75k	5.8	9.2	5.9
3600-H-1.0-100k	4.3	6.8	4.3
3600-H-5.0-75k	8.6	13.7	8.8
3600-H-5.0-100k	6.9	11.0	7.1
3600-H-10.0-75k	15.4	24.3	15.8
3600-H-10.0-100k	13.0	20.5	13.3
3600-K-1.0-75k	10.3	39.8	11.0
3600-K-1.0-100k	7.2	27.8	7.7
3600-K-5.0-75k	17.2	64.7	18.4
3600-K-5.0-100k	13.7	51.6	14.6
3600-K-10.0-75k	33.7	120.0	36.0
3600-K-10.0-100k	28.2	100.8	30.2
3500-Z-1.0-75k	5.8	9.7	6.0
3500-Z-1.0-100k	3.7	6.3	3.8
3500-Z-5.0-75k	10.6	17.3	10.9
3500-Z-5.0-100k	8.3	13.6	8.6
3500-Z-10.0-75k	21.1	33.8	21.8
3500-Z-10.0-100k	17.6	28.2	18.2
3500-Y-1.0-75k	5.8	6.9	5.8
3500-Y-1.0-100k	3.6	4.3	3.7
3500-Y-5.0-75k	11.0	13.1	11.2

**Table A.2:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
3500-Y-5.0-100k	8.6	10.2	8.7
3500-Y-10.0-75k	24.0	28.5	24.3
3500-Y-10.0-100k	19.9	23.6	20.1
3500-J-1.0-75k	10.7	26.6	11.3
3500-J-1.0-100k	7.1	17.1	7.5
3500-J-5.0-75k	18.3	48.1	19.3
3500-J-5.0-100k	14.5	37.8	15.3
3500-J-10.0-75k	34.4	100.5	36.5
3500-J-10.0-100k	28.8	83.7	30.6
3500-H-1.0-75k	5.8	9.4	6.0
3500-H-1.0-100k	4.3	6.9	4.4
3500-H-5.0-75k	8.8	14.0	9.0
3500-H-5.0-100k	7.1	11.3	7.2
3500-H-10.0-75k	15.6	24.8	16.0
3500-H-10.0-100k	13.1	20.9	13.5
3500-K-1.0-75k	9.8	35.7	10.5
3500-K-1.0-100k	6.8	24.8	7.3
3500-K-5.0-75k	16.4	58.2	17.5
3500-K-5.0-100k	13.0	46.4	13.9
3500-K-10.0-75k	32.2	108.7	34.4
3500-K-10.0-100k	27.0	91.3	28.8
3400-Z-1.0-75k	5.3	8.9	5.5
3400-Z-1.0-100k	3.3	5.7	3.5
3400-Z-5.0-75k	9.8	16.3	10.2
3400-Z-5.0-100k	7.7	12.8	8.0
3400-Z-10.0-75k	20.2	32.7	20.8
3400-Z-10.0-100k	16.8	27.2	17.3
3400-Y-1.0-75k	5.5	6.6	5.6
3400-Y-1.0-100k	3.5	4.2	3.5
3400-Y-5.0-75k	10.5	12.4	10.6
3400-Y-5.0-100k	8.2	9.7	8.3
3400-Y-10.0-75k	22.3	26.4	22.5
3400-Y-10.0-100k	18.5	21.9	18.7
3400-J-1.0-75k	10.2	25.0	10.8
3400-J-1.0-100k	6.7	15.9	7.1
3400-J-5.0-75k	17.6	45.6	18.6
3400-J-5.0-100k	14.0	35.9	14.7
3400-J-10.0-75k	33.6	95.5	35.7
3400-J-10.0-100k	28.1	79.4	29.9
3400-H-1.0-75k	5.9	9.7	6.0

**Table A.2:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
3400-H-1.0-100k	4.3	7.1	4.4
3400-H-5.0-75k	8.9	14.5	9.2
3400-H-5.0-100k	7.2	11.7	7.4
3400-H-10.0-75k	16.0	25.8	16.4
3400-H-10.0-100k	13.4	21.7	13.8
3400-K-1.0-75k	9.2	31.8	9.8
3400-K-1.0-100k	6.4	22.2	6.8
3400-K-5.0-75k	15.4	52.0	16.4
3400-K-5.0-100k	12.2	41.4	13.0
3400-K-10.0-75k	30.5	97.5	32.4
3400-K-10.0-100k	25.5	81.8	27.2
3300-Z-1.0-75k	4.8	8.2	5.0
3300-Z-1.0-100k	3.0	5.2	3.1
3300-Z-5.0-75k	9.1	15.3	9.4
3300-Z-5.0-100k	7.1	11.9	7.3
3300-Z-10.0-75k	19.0	31.3	19.7
3300-Z-10.0-100k	15.8	26.0	16.4
3300-Y-1.0-75k	5.8	7.1	5.9
3300-Y-1.0-100k	3.8	4.6	3.8
3300-Y-5.0-75k	10.3	12.2	10.4
3300-Y-5.0-100k	8.1	9.7	8.2
3300-Y-10.0-75k	19.9	23.5	20.1
3300-Y-10.0-100k	16.6	19.6	16.8
3300-J-1.0-75k	9.5	23.0	10.1
3300-J-1.0-100k	6.2	14.6	6.6
3300-J-5.0-75k	16.7	42.5	17.7
3300-J-5.0-100k	13.2	33.3	13.9
3300-J-10.0-75k	32.3	89.0	34.3
3300-J-10.0-100k	27.0	74.0	28.6
3300-H-1.0-75k	5.9	10.0	6.1
3300-H-1.0-100k	4.3	7.2	4.4
3300-H-5.0-75k	9.1	15.2	9.4
3300-H-5.0-100k	7.3	12.2	7.5
3300-H-10.0-75k	16.5	27.3	16.9
3300-H-10.0-100k	13.9	22.9	14.2
3300-K-1.0-75k	8.7	28.9	9.2
3300-K-1.0-100k	6.0	20.2	6.4
3300-K-5.0-75k	14.6	47.2	15.5
3300-K-5.0-100k	11.5	37.6	12.3
3300-K-10.0-75k	28.8	88.8	30.7

**Table A.2:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
3300-K-10.0-100k	24.1	74.6	25.7
3200-Z-1.0-75k	4.3	7.5	4.5
3200-Z-1.0-100k	2.7	4.7	2.8
3200-Z-5.0-75k	8.3	14.2	8.6
3200-Z-5.0-100k	6.5	11.1	6.7
3200-Z-10.0-75k	17.8	29.8	18.4
3200-Z-10.0-100k	14.7	24.7	15.3
3200-Y-1.0-75k	5.5	6.7	5.6
3200-Y-1.0-100k	3.6	4.4	3.6
3200-Y-5.0-75k	9.7	11.6	9.8
3200-Y-5.0-100k	7.6	9.2	7.7
3200-Y-10.0-75k	18.4	21.7	18.6
3200-Y-10.0-100k	15.4	18.2	15.6
3200-J-1.0-75k	8.7	20.6	9.2
3200-J-1.0-100k	5.6	13.0	5.9
3200-J-5.0-75k	15.5	38.5	16.3
3200-J-5.0-100k	12.2	30.2	12.9
3200-J-10.0-75k	30.3	80.8	32.1
3200-J-10.0-100k	25.3	67.2	26.8
3200-H-1.0-75k	5.9	10.3	6.1
3200-H-1.0-100k	4.2	7.4	4.3
3200-H-5.0-75k	9.3	15.9	9.6
3200-H-5.0-100k	7.4	12.7	7.7
3200-H-10.0-75k	17.0	29.0	17.5
3200-H-10.0-100k	14.3	24.4	14.7
3200-K-1.0-75k	8.2	26.9	8.7
3200-K-1.0-100k	5.7	18.8	6.1
3200-K-5.0-75k	13.8	43.9	14.7
3200-K-5.0-100k	10.9	34.9	11.6
3200-K-10.0-75k	27.4	82.7	29.2
3200-K-10.0-100k	22.9	69.4	24.4
3100-Z-1.0-75k	4.0	7.3	4.2
3100-Z-1.0-100k	2.5	4.6	2.6
3100-Z-5.0-75k	7.8	13.8	8.1
3100-Z-5.0-100k	6.1	10.8	6.3
3100-Z-10.0-75k	16.7	29.0	17.3
3100-Z-10.0-100k	13.9	24.1	14.4
3100-Y-1.0-75k	5.5	6.8	5.6
3100-Y-1.0-100k	3.6	4.5	3.7
3100-Y-5.0-75k	9.4	11.3	9.5

**Table A.2:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
3100-Y-5.0-100k	7.5	9.0	7.5
3100-Y-10.0-75k	17.3	20.5	17.5
3100-Y-10.0-100k	14.5	17.2	14.7
3100-J-1.0-75k	7.7	17.9	8.1
3100-J-1.0-100k	5.0	11.2	5.2
3100-J-5.0-75k	13.9	34.0	14.7
3100-J-5.0-100k	11.0	26.6	11.6
3100-J-10.0-75k	27.7	71.5	29.3
3100-J-10.0-100k	23.1	59.4	24.4
3100-H-1.0-75k	5.8	10.4	6.0
3100-H-1.0-100k	4.1	7.4	4.3
3100-H-5.0-75k	9.3	16.4	9.6
3100-H-5.0-100k	7.4	13.1	7.7
3100-H-10.0-75k	17.3	30.6	17.9
3100-H-10.0-100k	14.5	25.6	15.0
3100-K-1.0-75k	7.7	25.2	8.2
3100-K-1.0-100k	5.4	17.6	5.7
3100-K-5.0-75k	13.1	41.3	13.9
3100-K-5.0-100k	10.3	32.8	11.0
3100-K-10.0-75k	26.0	77.9	27.7
3100-K-10.0-100k	21.7	65.4	23.1
3000-Z-1.0-75k	3.6	6.8	3.8
3000-Z-1.0-100k	2.3	4.2	2.4
3000-Z-5.0-75k	7.1	12.9	7.4
3000-Z-5.0-100k	5.5	10.0	5.7
3000-Z-10.0-75k	15.3	27.1	15.9
3000-Z-10.0-100k	12.7	22.5	13.2
3000-Y-1.0-75k	5.0	6.3	5.1
3000-Y-1.0-100k	3.3	4.2	3.4
3000-Y-5.0-75k	8.6	10.4	8.7
3000-Y-5.0-100k	6.8	8.3	6.9
3000-Y-10.0-75k	15.7	18.6	15.9
3000-Y-10.0-100k	13.2	15.7	13.3
3000-J-1.0-75k	7.9	20.4	8.3
3000-J-1.0-100k	5.1	13.1	5.4
3000-J-5.0-75k	13.9	37.0	14.7
3000-J-5.0-100k	11.0	29.1	11.6
3000-J-10.0-75k	26.7	72.6	28.3
3000-J-10.0-100k	22.3	60.8	23.7
3000-H-1.0-75k	5.6	10.3	5.8

**Table A.2:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
3000-H-1.0-100k	3.9	7.3	4.1
3000-H-5.0-75k	9.1	16.5	9.4
3000-H-5.0-100k	7.2	13.2	7.5
3000-H-10.0-75k	17.2	31.4	17.8
3000-H-10.0-100k	14.4	26.3	14.9
3000-K-1.0-75k	7.2	23.5	7.7
3000-K-1.0-100k	5.0	16.4	5.3
3000-K-5.0-75k	12.2	38.6	13.0
3000-K-5.0-100k	9.6	30.7	10.2
3000-K-10.0-75k	24.2	73.0	25.8
3000-K-10.0-100k	20.3	61.2	21.6
2900-Z-1.0-75k	3.3	6.2	3.4
2900-Z-1.0-100k	2.0	3.9	2.1
2900-Z-5.0-75k	6.4	11.8	6.6
2900-Z-5.0-100k	4.9	9.2	5.1
2900-Z-10.0-75k	13.8	25.1	14.4
2900-Z-10.0-100k	11.4	20.8	11.9
2900-Y-1.0-75k	4.6	5.8	4.6
2900-Y-1.0-100k	3.0	3.9	3.0
2900-Y-5.0-75k	7.8	9.6	7.9
2900-Y-5.0-100k	6.2	7.6	6.3
2900-Y-10.0-75k	14.2	16.8	14.3
2900-Y-10.0-100k	11.9	14.2	12.0
2900-J-1.0-75k	7.1	18.6	7.5
2900-J-1.0-100k	4.6	12.0	4.9
2900-J-5.0-75k	12.5	33.5	13.3
2900-J-5.0-100k	9.9	26.4	10.5
2900-J-10.0-75k	24.0	64.3	25.5
2900-J-10.0-100k	20.1	53.9	21.3
2900-H-1.0-75k	5.3	9.9	5.4
2900-H-1.0-100k	3.7	6.9	3.8
2900-H-5.0-75k	8.6	16.1	8.9
2900-H-5.0-100k	6.9	12.8	7.1
2900-H-10.0-75k	16.5	31.2	17.1
2900-H-10.0-100k	13.8	26.1	14.3
2900-K-1.0-75k	6.6	21.6	7.0
2900-K-1.0-100k	4.5	15.0	4.8
2900-K-5.0-75k	11.1	35.5	11.8
2900-K-5.0-100k	8.8	28.3	9.4
2900-K-10.0-75k	22.1	67.3	23.6

**Table A.2:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
2900-K-10.0-100k	18.5	56.5	19.7
2800-Z-1.0-75k	2.9	5.7	3.0
2800-Z-1.0-100k	1.8	3.6	1.9
2800-Z-5.0-75k	5.7	10.9	5.9
2800-Z-5.0-100k	4.4	8.5	4.6
2800-Z-10.0-75k	12.4	23.3	13.0
2800-Z-10.0-100k	10.3	19.3	10.7
2800-Y-1.0-75k	4.1	5.3	4.2
2800-Y-1.0-100k	2.7	3.5	2.7
2800-Y-5.0-75k	7.1	8.7	7.2
2800-Y-5.0-100k	5.6	7.0	5.7
2800-Y-10.0-75k	12.7	15.2	12.9
2800-Y-10.0-100k	10.7	12.8	10.8
2800-J-1.0-75k	6.1	16.0	6.5
2800-J-1.0-100k	4.0	10.2	4.2
2800-J-5.0-75k	10.9	28.9	11.5
2800-J-5.0-100k	8.6	22.8	9.1
2800-J-10.0-75k	20.9	55.0	22.1
2800-J-10.0-100k	17.5	46.1	18.5
2800-H-1.0-75k	4.8	9.3	5.0
2800-H-1.0-100k	3.3	6.4	3.5
2800-H-5.0-75k	8.0	15.3	8.2
2800-H-5.0-100k	6.3	12.1	6.5
2800-H-10.0-75k	15.3	29.9	15.9
2800-H-10.0-100k	12.8	25.0	13.3
2800-K-1.0-75k	5.9	19.5	6.3
2800-K-1.0-100k	4.0	13.5	4.3
2800-K-5.0-75k	10.0	32.2	10.6
2800-K-5.0-100k	7.9	25.6	8.4
2800-K-10.0-75k	19.8	60.9	21.1
2800-K-10.0-100k	16.6	51.1	17.7
2700-Z-1.0-75k	2.6	5.3	2.7
2700-Z-1.0-100k	1.6	3.3	1.7
2700-Z-5.0-75k	5.2	10.2	5.4
2700-Z-5.0-100k	4.0	7.9	4.2
2700-Z-10.0-75k	11.3	21.9	11.8
2700-Z-10.0-100k	9.3	18.1	9.7
2700-Y-1.0-75k	3.7	4.8	3.7
2700-Y-1.0-100k	2.4	3.2	2.4
2700-Y-5.0-75k	6.4	8.0	6.5

**Table A.2:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
2700-Y-5.0-100k	5.1	6.4	5.2
2700-Y-10.0-75k	11.5	13.8	11.6
2700-Y-10.0-100k	9.7	11.6	9.8
2700-J-1.0-75k	5.2	13.6	5.5
2700-J-1.0-100k	3.4	8.7	3.5
2700-J-5.0-75k	9.3	24.9	9.9
2700-J-5.0-100k	7.4	19.6	7.8
2700-J-10.0-75k	18.0	47.1	19.1
2700-J-10.0-100k	15.1	39.5	16.0
2700-H-1.0-75k	4.3	8.3	4.4
2700-H-1.0-100k	3.0	5.8	3.1
2700-H-5.0-75k	7.1	13.9	7.4
2700-H-5.0-100k	5.7	11.0	5.9
2700-H-10.0-75k	13.8	27.6	14.3
2700-H-10.0-100k	11.5	23.1	12.0
2700-K-1.0-75k	5.2	17.2	5.5
2700-K-1.0-100k	3.5	11.9	3.8
2700-K-5.0-75k	8.8	28.5	9.4
2700-K-5.0-100k	6.9	22.7	7.4
2700-K-10.0-75k	17.4	54.0	18.6
2700-K-10.0-100k	14.6	45.3	15.5
2600-Z-1.0-75k	2.5	5.2	2.6
2600-Z-1.0-100k	1.5	3.2	1.6
2600-Z-5.0-75k	4.8	9.9	5.1
2600-Z-5.0-100k	3.8	7.8	3.9
2600-Z-10.0-75k	10.5	21.3	11.0
2600-Z-10.0-100k	8.7	17.6	9.1
2600-Y-1.0-75k	3.3	4.4	3.4
2600-Y-1.0-100k	2.1	2.9	2.2
2600-Y-5.0-75k	5.9	7.4	6.0
2600-Y-5.0-100k	4.7	5.9	4.7
2600-Y-10.0-75k	10.5	12.7	10.6
2600-Y-10.0-100k	8.8	10.7	8.9
2600-J-1.0-75k	4.4	11.7	4.7
2600-J-1.0-100k	2.8	7.4	3.0
2600-J-5.0-75k	8.0	21.6	8.5
2600-J-5.0-100k	6.3	17.0	6.7
2600-J-10.0-75k	15.6	40.8	16.5
2600-J-10.0-100k	13.0	34.2	13.8
2600-H-1.0-75k	3.7	7.4	3.9



**Table A.2:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
2600-H-1.0-100k	2.6	5.1	2.7
2600-H-5.0-75k	6.3	12.4	6.5
2600-H-5.0-100k	5.0	9.8	5.2
2600-H-10.0-75k	12.2	24.8	12.7
2600-H-10.0-100k	10.2	20.7	10.6
2600-K-1.0-75k	4.4	14.4	4.7
2600-K-1.0-100k	3.0	9.9	3.2
2600-K-5.0-75k	7.6	24.3	8.1
2600-K-5.0-100k	6.0	19.3	6.4
2600-K-10.0-75k	15.0	46.5	16.0
2600-K-10.0-100k	12.5	39.1	13.4
2500-Z-1.0-75k	2.5	5.5	2.6
2500-Z-1.0-100k	1.6	3.5	1.6
2500-Z-5.0-75k	4.8	10.4	5.0
2500-Z-5.0-100k	3.7	8.2	3.9
2500-Z-10.0-75k	10.3	22.0	10.9
2500-Z-10.0-100k	8.6	18.3	9.0
2500-Y-1.0-75k	3.1	4.2	3.1
2500-Y-1.0-100k	2.0	2.7	2.0
2500-Y-5.0-75k	5.5	7.1	5.6
2500-Y-5.0-100k	4.4	5.7	4.4
2500-Y-10.0-75k	9.9	12.2	10.0
2500-Y-10.0-100k	8.4	10.3	8.5
2500-J-1.0-75k	3.7	10.0	3.9
2500-J-1.0-100k	2.4	6.3	2.5
2500-J-5.0-75k	6.8	18.7	7.3
2500-J-5.0-100k	5.4	14.7	5.7
2500-J-10.0-75k	13.5	35.7	14.3
2500-J-10.0-100k	11.3	29.9	11.9
2500-H-1.0-75k	3.3	6.5	3.4
2500-H-1.0-100k	2.3	4.4	2.4
2500-H-5.0-75k	5.5	11.0	5.7
2500-H-5.0-100k	4.4	8.7	4.5
2500-H-10.0-75k	10.7	21.9	11.1
2500-H-10.0-100k	9.0	18.3	9.3
2500-K-1.0-75k	3.8	11.8	4.0
2500-K-1.0-100k	2.6	8.0	2.7
2500-K-5.0-75k	6.5	20.5	6.9
2500-K-5.0-100k	5.1	16.2	5.5
2500-K-10.0-75k	12.8	39.8	13.7

**Table A.2:** continued.

Simulation	$\sigma_{RV}(\text{Cond. 1})$	$\sigma_{RV}(\text{Cond. 2})$	$\sigma_{RV}(\text{Cond. 3})$
2500-K-10.0-100k	10.8	33.4	11.5

**Table A.3:** RV precisions calculated for the SPIRou ETC. Same simulations as Table A.1 but with the SNR relative to the centre of each individual band.

Simulation ( $T_{\text{eff}}$ -Band- $v.sini$ -R)	$\sigma_{RV}(\text{Cond. 1})$ [m/s]	$\sigma_{RV}(\text{Cond. 2})$ [m/s]	$\sigma_{RV}(\text{Cond. 3})$ [m/s]
3900-Z-1.0-60k	9.9	16.0	10.3
3900-Z-1.0-80k	6.6	10.7	6.8
3900-Z-1.0-100k	4.9	8.1	5.1
3900-Z-5.0-60k	14.5	23.2	15.0
3900-Z-5.0-80k	11.2	18.0	11.6
3900-Z-5.0-100k	9.4	15.2	9.7
3900-Z-10.0-60k	25.0	39.4	25.8
3900-Z-10.0-80k	20.7	32.9	21.4
3900-Z-10.0-100k	18.1	28.8	18.7
3900-Y-1.0-60k	10.0	11.9	10.1
3900-Y-1.0-80k	6.2	7.4	6.3
3900-Y-1.0-100k	4.4	5.3	4.5
3900-Y-5.0-60k	15.9	19.0	16.1
3900-Y-5.0-80k	12.0	14.3	12.1
3900-Y-5.0-100k	10.0	11.8	10.1
3900-Y-10.0-60k	31.6	37.8	32.0
3900-Y-10.0-80k	25.8	30.8	26.1
3900-Y-10.0-100k	22.4	26.7	22.6
3900-J-1.0-60k	15.7	41.7	16.6
3900-J-1.0-80k	10.5	26.9	11.0
3900-J-1.0-100k	7.9	19.6	8.3
3900-J-5.0-60k	22.7	63.6	24.0
3900-J-5.0-80k	17.5	48.1	18.5
3900-J-5.0-100k	14.8	40.3	15.6
3900-J-10.0-60k	38.6	122.9	41.0
3900-J-10.0-80k	32.0	100.7	34.0
3900-J-10.0-100k	28.0	87.6	29.8
3900-H-1.0-60k	7.3	11.5	7.4
3900-H-1.0-80k	5.1	8.1	5.2
3900-H-1.0-100k	4.0	6.4	4.1
3900-H-5.0-60k	10.2	16.0	10.4
3900-H-5.0-80k	7.9	12.5	8.1
3900-H-5.0-100k	6.7	10.5	6.8

**Table A.3:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
3900-H-10.0-60k	17.5	27.3	17.9
3900-H-10.0-80k	14.5	22.7	14.8
3900-H-10.0-100k	12.7	19.8	13.0
3900-K-1.0-60k	10.5	46.3	11.3
3900-K-1.0-80k	7.1	31.8	7.6
3900-K-1.0-100k	5.4	24.5	5.8
3900-K-5.0-60k	15.7	65.4	16.8
3900-K-5.0-80k	12.0	50.8	12.8
3900-K-5.0-100k	10.1	42.9	10.8
3900-K-10.0-60k	28.5	112.6	30.4
3900-K-10.0-80k	23.6	93.1	25.2
3900-K-10.0-100k	20.6	81.2	22.0
3500-Z-1.0-60k	8.3	13.7	8.6
3500-Z-1.0-80k	5.2	8.7	5.4
3500-Z-1.0-100k	3.7	6.3	3.8
3500-Z-5.0-60k	12.9	20.9	13.3
3500-Z-5.0-80k	9.8	16.0	10.1
3500-Z-5.0-100k	8.2	13.4	8.5
3500-Z-10.0-60k	24.0	38.1	24.8
3500-Z-10.0-80k	19.7	31.5	20.4
3500-Z-10.0-100k	17.2	27.5	17.7
3500-Y-1.0-60k	8.7	10.3	8.8
3500-Y-1.0-80k	5.3	6.3	5.4
3500-Y-1.0-100k	3.7	4.5	3.8
3500-Y-5.0-60k	14.1	16.7	14.3
3500-Y-5.0-80k	10.6	12.5	10.7
3500-Y-5.0-100k	8.8	10.4	8.9
3500-Y-10.0-60k	28.5	33.9	28.8
3500-Y-10.0-80k	23.2	27.6	23.5
3500-Y-10.0-100k	20.1	23.9	20.3
3500-J-1.0-60k	15.1	38.4	15.9
3500-J-1.0-80k	9.8	24.0	10.3
3500-J-1.0-100k	7.1	17.1	7.5
3500-J-5.0-60k	22.5	60.2	23.8
3500-J-5.0-80k	17.3	45.4	18.3
3500-J-5.0-100k	14.5	37.8	15.3
3500-J-10.0-60k	39.9	117.8	42.4
3500-J-10.0-80k	33.0	96.4	35.1
3500-J-10.0-100k	28.8	83.7	30.6
3500-H-1.0-60k	7.6	12.2	7.8

**Table A.3:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
3500-H-1.0-80k	5.4	8.7	5.5
3500-H-1.0-100k	4.2	6.9	4.3
3500-H-5.0-60k	10.5	16.7	10.7
3500-H-5.0-80k	8.2	13.1	8.4
3500-H-5.0-100k	6.9	11.1	7.1
3500-H-10.0-60k	17.6	28.0	18.1
3500-H-10.0-80k	14.6	23.3	15.0
3500-H-10.0-100k	12.8	20.4	13.1
3500-K-1.0-60k	9.9	35.8	10.6
3500-K-1.0-80k	6.6	24.0	7.0
3500-K-1.0-100k	5.0	18.2	5.3
3500-K-5.0-60k	14.8	52.3	15.8
3500-K-5.0-80k	11.3	40.2	12.1
3500-K-5.0-100k	9.5	33.8	10.1
3500-K-10.0-60k	27.2	92.1	29.1
3500-K-10.0-80k	22.5	76.0	24.0
3500-K-10.0-100k	19.6	66.3	20.9
2800-Z-1.0-60k	3.8	7.3	3.9
2800-Z-1.0-80k	2.3	4.5	2.4
2800-Z-1.0-100k	1.6	3.2	1.7
2800-Z-5.0-60k	6.1	11.6	6.4
2800-Z-5.0-80k	4.6	8.8	4.8
2800-Z-5.0-100k	3.8	7.3	4.0
2800-Z-10.0-60k	12.2	22.8	12.7
2800-Z-10.0-80k	9.9	18.7	10.4
2800-Z-10.0-100k	8.6	16.2	9.0
2800-Y-1.0-60k	5.6	7.1	5.7
2800-Y-1.0-80k	3.6	4.7	3.7
2800-Y-1.0-100k	2.6	3.4	2.7
2800-Y-5.0-60k	8.3	10.1	8.4
2800-Y-5.0-80k	6.4	7.9	6.5
2800-Y-5.0-100k	5.4	6.7	5.5
2800-Y-10.0-60k	13.8	16.4	13.9
2800-Y-10.0-80k	11.4	13.7	11.6
2800-Y-10.0-100k	10.0	12.0	10.1
2800-J-1.0-60k	8.8	23.2	9.3
2800-J-1.0-80k	5.5	14.4	5.8
2800-J-1.0-100k	4.0	10.2	4.2
2800-J-5.0-60k	13.5	35.9	14.3
2800-J-5.0-80k	10.3	27.3	10.9

**Table A.3:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
2800-J-5.0-100k	8.6	22.8	9.1
2800-J-10.0-60k	24.3	63.8	25.7
2800-J-10.0-80k	20.1	52.9	21.2
2800-J-10.0-100k	17.5	46.1	18.5
2800-H-1.0-60k	6.5	12.6	6.8
2800-H-1.0-80k	4.4	8.5	4.6
2800-H-1.0-100k	3.3	6.4	3.5
2800-H-5.0-60k	9.6	18.3	9.9
2800-H-5.0-80k	7.3	14.1	7.6
2800-H-5.0-100k	6.2	11.8	6.4
2800-H-10.0-60k	17.2	33.5	17.8
2800-H-10.0-80k	14.2	27.6	14.7
2800-H-10.0-100k	12.4	24.1	12.8
2800-K-1.0-60k	6.3	20.8	6.7
2800-K-1.0-80k	4.2	13.9	4.5
2800-K-1.0-100k	3.1	10.5	3.4
2800-K-5.0-60k	9.5	30.4	10.1
2800-K-5.0-80k	7.2	23.3	7.7
2800-K-5.0-100k	6.0	19.6	6.4
2800-K-10.0-60k	17.5	53.7	18.7
2800-K-10.0-80k	14.4	44.4	15.4
2800-K-10.0-100k	12.6	38.8	13.4
2600-Z-1.0-60k	3.0	6.2	3.1
2600-Z-1.0-80k	1.8	3.8	1.9
2600-Z-1.0-100k	1.3	2.7	1.4
2600-Z-5.0-60k	4.8	9.8	5.0
2600-Z-5.0-80k	3.6	7.4	3.8
2600-Z-5.0-100k	3.0	6.2	3.2
2600-Z-10.0-60k	9.5	19.2	9.9
2600-Z-10.0-80k	7.7	15.7	8.1
2600-Z-10.0-100k	6.7	13.6	7.1
2600-Y-1.0-60k	4.4	5.8	4.5
2600-Y-1.0-80k	2.8	3.8	2.9
2600-Y-1.0-100k	2.0	2.7	2.1
2600-Y-5.0-60k	6.5	8.2	6.6
2600-Y-5.0-80k	5.1	6.4	5.1
2600-Y-5.0-100k	4.3	5.4	4.3
2600-Y-10.0-60k	10.7	12.9	10.8
2600-Y-10.0-80k	8.9	10.8	9.0
2600-Y-10.0-100k	7.8	9.5	7.9

**Table A.3:** continued.

Simulation	$\sigma_{RV}$ (Cond. 1)	$\sigma_{RV}$ (Cond. 2)	$\sigma_{RV}$ (Cond. 3)
2600-J-1.0-60k	6.4	17.1	6.8
2600-J-1.0-80k	4.0	10.5	4.2
2600-J-1.0-100k	2.8	7.4	3.0
2600-J-5.0-60k	10.0	26.9	10.6
2600-J-5.0-80k	7.6	20.4	8.0
2600-J-5.0-100k	6.3	17.0	6.7
2600-J-10.0-60k	18.1	47.2	19.1
2600-J-10.0-80k	15.0	39.2	15.8
2600-J-10.0-100k	13.0	34.2	13.8
2600-H-1.0-60k	5.2	10.3	5.4
2600-H-1.0-80k	3.5	6.9	3.6
2600-H-1.0-100k	2.7	5.2	2.8
2600-H-5.0-60k	7.7	15.3	8.0
2600-H-5.0-80k	5.9	11.7	6.1
2600-H-5.0-100k	5.0	9.8	5.2
2600-H-10.0-60k	13.9	28.4	14.5
2600-H-10.0-80k	11.5	23.3	11.9
2600-H-10.0-100k	10.0	20.4	10.4
2600-K-1.0-60k	5.0	16.2	5.3
2600-K-1.0-80k	3.3	10.7	3.5
2600-K-1.0-100k	2.5	8.0	2.6
2600-K-5.0-60k	7.4	23.9	7.9
2600-K-5.0-80k	5.7	18.3	6.1
2600-K-5.0-100k	4.8	15.4	5.1
2600-K-10.0-60k	13.7	42.5	14.6
2600-K-10.0-80k	11.3	35.1	12.1
2600-K-10.0-100k	9.9	30.7	10.5

# Bibliography

- Adibekyan, V. Z., Sousa, S. G., Santos, N. C., Mena, E. D., Hernández, J. I. G., Israelian, G., Mayor, M., and Khachatryan, G.: 2012, *Astronomy and Astrophysics* **545**, A32
- Allard, F.: 2013, *Proceedings of the International Astronomical Union* **8**(S299), 271, 00007
- Allard, F., Homeier, D., and Freytag, B.: 2010, *arXiv:1011.5405 [astro-ph]*, 00066
- Andreasen, D. T., Sousa, S. G., Delgado Mena, E., Santos, N. C., Tsantaki, M., Rojas-Ayala, B., and Neves, V.: 2016, *Astronomy and Astrophysics* **585**, A143
- Artigau, E., Kouach, D., Donati, J.-F., Doyon, R., Delfosse, X., Baratchart, S., Lacombe, M., Moutou, C., Rabou, P., Parès, L. P., Mischeau, Y., Thibault, S., Reshetov, V. A., Dubois, B., Hernandez, O., Vallée, P., Wang, S.-Y., Dolon, F., Pepe, F. A., Bouchy, F., Striebig, N., Hénault, F., Loop, D., Saddlemyer, L., Barrick, G., Vermeulen, T., Dupieux, M., Hébrard, G., Boisse, I., Martioli, E., Alencar, S. H. P., do Nascimento, J.-D., and Figueira, P.: 2014, in *Proc.SPIE*, Vol. 9147, p. 914715, International Society for Optics and Photonics, 00047
- Artigau, E., Malo, L., Doyon, R., Figueira, P., Delfosse, X., and Astudillo-Defru, N.: 2018, *The Astronomical Journal* **155**, 198
- Asplund, M., Grevesse, N., Sauval, A. J., and Scott, P.: 2009, *Annual Review of Astronomy and Astrophysics* **47**, 481
- Astudillo-Defru, N., Bonfils, X., Delfosse, X., Ségransan, D., Forveille, T., Bouchy, F., Gillon, M., Lovis, C., Mayor, M., Neves, V., Pepe, F., Perrier, C., Queloz, D., Rojo, P., Santos, N. C., and Udry, S.: 2015, *Astronomy and Astrophysics* **575**, A119
- Baraffe, I., Chabrier, G., Barman, T., Allard, F., and Hauschildt, P. H.: 2003, *Astronomy and Astrophysics* **402**(2), 701, 00000
- Baraffe, I., Homeier, D., Allard, F., and Chabrier, G.: 2015, *Astronomy and Astrophysics* **577**, A42, 00280
- Barnes, J. R., Barman, T. S., Jones, H. R. A., Leigh, C. J., Cameron, A. C., Barber, R. J., and Pinfield, D. J.: 2008, *Monthly Notices of the Royal Astronomical Society* **390**(3), 1258

- Barros, S. C. C., Gosselin, H., Lillo-Box, J., Bayliss, D., Mena, E. D., Brugger, B., Santerne, A., Armstrong, D. J., Adibekyan, V., Armstrong, J. D., Barrado, D., Bento, J., Boisse, I., Bonomo, A. S., Bouchy, F., Brown, D. J. A., Cochran, W. D., Cameron, A. C., Deleuil, M., Demangeon, O., Díaz, R. F., Doyle, A., Dumusque, X., Ehrenreich, D., Espinoza, N., Faedi, F., Faria, J. P., Figueira, P., Foxell, E., Hébrard, G., Hoggatpanah, S., Jackman, J., Lendl, M., Ligi, R., Lovis, C., Melo, C., Mousis, O., Neal, J. J., Osborn, H. P., Pollacco, D., Santos, N. C., Sefako, R., Shporer, A., Sousa, S. G., Triaud, A. H. M. J., Udry, S., Vigan, A., and Wyttenbach, A.: 2017, *Astronomy & Astrophysics* **608**, A25
- Bean, J. L., Miller-Ricci Kempton, E., and Homeier, D.: 2010, *Nature* **468**, 669, 00283
- Benedict, G. F. and Harrison, T. E.: 2017, *The Astronomical Journal* **153**, 258
- Bertaux, J. L., Lallement, R., Ferron, S., Boonne, C., and Bodichon, R.: 2014, *Astronomy and Astrophysics* **564**, A46, 00041
- Bevington, P. R. and Robinson, D. K.: 2003, *Data Reduction and Error Analysis for the Physical Sciences*, McGraw-Hill, p.g. 208-212
- Birkby, J. L., de Kok, R. J., Brogi, M., Schwarz, H., and Snellen, I. a. G.: 2017, *The Astronomical Journal* **153**(3), 138
- Bonfanti, A., Ortolani, S., and Nascimbeni, V.: 2016, *Astronomy and Astrophysics* **585**, A5
- Bouchy, F., Doyon, R., Artigau, E., Melo, C., Hernandez, O., Wildi, F., Delfosse, X., Lovis, C., Figueira, P., Canto Martins, B. L., González Hernández, J. I., Thibault, S., Reshetov, V., Pepe, F., Santos, N. C., de Medeiros, J. R., Rebolo, R., Abreu, M., Adibekyan, V. Z., Bandy, T., Benz, W., Blind, N., Bohlender, D., Boisse, I., Bovay, S., Broeg, C., Brousseau, D., Cabral, A., Chazelas, B., Cloutier, R., Coelho, J., Conod, U., Cumming, A., Delabre, B., Genolet, L., Hagelberg, J., Jayawardhana, R., Käußl, H.-U., Lafrenière, D., de Castro Leão, I., Malo, L., de Medeiros Martins, A., Matthews, J. M., Metchev, S., Oshagh, M., Ouellet, M., Parro, V. C., Rasilla Piñeiro, J. L., Santos, P., Sarajlic, M., Segovia, A., Sordet, M., Udry, S., Valencia, D., Vallée, P., Venn, K., Wade, G. A., and Saddlemyer, L.: 2017, *The Messenger* **169**, 21, 00000
- Bouchy, F., Pepe, F., and Queloz, D.: 2001, *Astronomy and Astrophysics* **374**(2), 733, 00258
- Brogi, M., de Kok, R. J., Albrecht, S., Snellen, I. A. G., Birkby, J. L., and Schwarz, H.: 2016, *The Astrophysical Journal* **817**(2), 106, 00000
- Brogi, M., de Kok, R. J., Birkby, J. L., Schwarz, H., and Snellen, I. A. G.: 2014, *Astronomy and Astrophysics* **565**, A124, 00000
- Brogi, M., Snellen, I. A. G., de Kok, R. J., Albrecht, S., Birkby, J., and de Mooij, E. J. W.: 2012, *Nature* **486**, 502, 00000
- Burrows, A., Marley, M., Hubbard, W. B., Lunine, J. I., Guillot, T., Saumon, D., Freedman, R., Sudarsky, D., and Sharp, C.: 1997, *The Astrophysical Journal* **491**, 856
- Chabrier, G. and Baraffe, I.: 2000, *Annual Review of Astronomy and Astrophysics* **38**(1), 337, 00483
- Chen, J. and Kipping, D. M.: 2016, *The Astrophysical Journal* **834**(1), 17



- Ciddor, P. E.: 1996, *Applied Optics* **35**(9), 1566
- Clough, S. A. and Iacono, M. J.: 1995, *Journal of Geophysical Research: Atmospheres* **100**(D8), 16519, 00002
- Collaboration, G., Brown, A. G. A., Vallenari, A., Prusti, T., Bruijne, D., J, J. H., Babusiaux, C., and Bailer-Jones, C. a. L.: 2018, *ArXiv e-prints* p. arXiv:1804.09365
- Connes, P.: 1985, *Astrophysics and Space Science* **110**(2), 211
- Connes, P., Martic, M., and Schmitt, J.: 1996, *Astrophysics and Space Science* **241**(1), 61
- Correia, A. C. M., Udry, S., Mayor, M., Laskar, J., Naef, D., Pepe, F., Queloz, D., and Santos, N. C.: 2005, *aap* **440**, 751, 00000
- Cotton, D. V., Bailey, J., and Kedziora-Chudczer, L.: 2014, *Monthly Notices of the Royal Astronomical Society* **439**, 387, 00007
- Crepp, J. R., Gonzales, E. J., Bechter, E. B., Montet, B. T., Johnson, J. A., Piskorz, D., Howard, A. W., and Isaacson, H.: 2016, *The Astrophysical Journal* **831**, 00004
- Czekala, I., Andrews, S. M., Mandel, K. S., Hogg, D. W., and Green, G. M.: 2015, *The Astrophysical Journal* **812**(2), 128, 00022
- Czesla, S., Molle, T., and Schmitt, J. H. M. M.: 2018, *Astronomy and Astrophysics* **609**, A39
- de Kok, R. J., Brogi, M., Snellen, I. A., Birkby, J., Albrecht, S., and de Mooij, E. J.: 2013, *Astronomy and Astrophysics* **554**, A82, 00086
- Deeg, H.: 1998, in *Brown Dwarfs and Extrasolar Planets*, Vol. 134 of *ASP Conference Series #134*, p. 216
- Dorn, R. J., Finger, G., Huster, G., Kaeufl, H.-U., Lizon, J.-L., Mehrgan, L., Meyer, M., Pirard, J.-F., Silber, A., Stegmeier, J., and Moorwood, A. F. M.: 2004, in *Optical and Infrared Detectors for Astronomy*, Vol. 5499, pp 510–518, International Society for Optics and Photonics
- Dorn, R. J., Follert, R., Bristow, P., Cumani, C., Eschbaumer, S., Grunhut, J., Haimerl, A., Hatzes, A., Heiter, U., and Hinterschuster, R.: 2016, in *Ground-Based and Airborne Instrumentation for Astronomy VI*, Vol. 9908, p. 99080I, International Society for Optics and Photonics, 00002
- Edlén, B.: 1953, *JOSA* **43**(5), 339
- ESO: 2017, *ESO Call for Proposals - P101*
- Ferluga, S., Floreano, L., Bravar, U., and Bédalo, C.: 1997, *Astronomy and Astrophysics Supplement Series* **121**(1), 201, 00012
- Figueira, P., Adibekyan, V. Z., Oshagh, M., Neal, J. J., Rojas-Ayala, B., Lovis, C., Melo, C., Pepe, F., Santos, N. C., and Tsantaki, M.: 2016, *Astronomy and Astrophysics* **586**, A101, 00002
- Figueira, P. and Neves, S.: 2015, *Astro Homus*, CAUP

- Figueira, P., Pepe, F., Melo, C. H. F., Santos, N. C., Lovis, C., Mayor, M., Queloz, D., Smette, A., and Udry, S.: 2010, *Astronomy and Astrophysics* **511**, A55, 00057
- Freudling, W., Romaniello, M., Bramich, D. M., Ballester, P., Forchi, V., García-Dabó, C. E., Moehler, S., and Neeser, M. J.: 2013, *Astronomy and Astrophysics* **559**, A96
- Gray, D. F.: 2005, *The Observation and Analysis of Stellar Photospheres*, Cambridge University Press, 3 edition
- Gullikson, K., Dodson-Robinson, S., and Kraus, A.: 2014, *The Astronomical Journal* **148**(3), 53, 00015
- Hadrava, P.: 2009, *arXiv:0909.0172 [astro-ph]*, 00013
- Halbwachs, J.-L., Arenou, F., Mayor, M., Udry, S., and Queloz, D.: 2000, *Astronomy and Astrophysics* **355**, 581, 00198
- Hatzes, A. P. and Cochran, W. D.: 1992, Vol. 40, p. 275
- Hatzes, A. P. and Rauer, H.: 2015, *The Astrophysical Journal Letters* **810**, L25
- Hoeijmakers, H. J., Kok, D., J. R., Snellen, I. a. G., Brogi, M., Birkby, J. L., and Schwarz, H.: 2015, *Astronomy and Astrophysics* **575**, A20
- Horne, K.: 1986, *Publications of the Astronomical Society of the Pacific* **98**, 609, 01548
- Husser, T.-O., von Berg, S. W., Dreizler, S., Homeier, D., Reiners, A., Barman, T., and Hauschildt, P. H.: 2013, *Astronomy and Astrophysics* **553**, A6, 00243
- Kaeufl, H.-U., Ballester, P., Biereichel, P., Delabre, B., Donaldson, R., Dorn, R., Fedrigo, E., Finger, G., Fischer, G., Franza, F., Gojak, D., Huster, G., Jung, Y., Lizon, J.-L., Mehrgan, L., Meyer, M., Moorwood, A., Pirard, J.-F., Paufigue, J., Pozna, E., Siebenmorgen, R., Silber, A., Stegmeier, J., and Wegerer, S.: 2004, *Ground-based Instrumentation for Astronomy* **5492**, 1218, 00000
- Kerber, F., Nave, G., Sansonetti, C. J., and Bristow, P.: 2009, *Physica Scripta* **2009**(T134), 014007, 00009
- Kolbl, R., Marcy, G. W., Isaacson, H., and Howard, A. W.: 2015, *The Astronomical Journal* **149**, 18
- Kostogryz, N., Kürster, M., Yakobchuk, T., Lyubchik, Y., and Kuznetsov, M.: 2013, *Astronomische Nachrichten* **334**(7), 648, 00000
- Ku, H. H.: 1966, *Notes on the Use of Propagation of Error Formulas*, National Bureau of Standards
- Lillo-Box, J., Leleu, A., Parviainen, H., Figueira, P., Mallonn, M., Correia, A. C. M., Santos, N. C., Robutel, P., Lendl, M., Boffin, H. M. J., Faria, J. P., Barrado, D., and Neal, J.: 2018, *arXiv:1807.00773 [astro-ph]*
- Maldonado, J. and Villaver, E.: 2017, *Astronomy and Astrophysics* **602**, A38
- Martins, J. H. C., Santos, N. C., Figueira, P., Faria, J. P., Montalto, M., Boisse, I., Ehrenreich, D., Lovis, C., Mayor, M., Melo, C., Pepe, F., Sousa, S. G., Udry, S., and Cunha, D.: 2015, *Astronomy and Astrophysics* **576**, A134

- Mathar, R. J.: 2007, *Journal of Optics A: Pure and Applied Optics* **9**(5), 470
- Mayor, M. and Queloz, D.: 1995, *Nature* **378**(6555), 355
- Meier, R. J.: 2005, *Vibrational Spectroscopy* **39**(2), 266
- Moutou, C., Vigan, A., Mesa, D., Desidera, S., Thébault, P., Zurlo, A., and Salter, G.: 2017, *Astronomy and Astrophysics* **602**, A87, 00001
- Murray, C. D. and Correia, A. C. M.: 2010, in S. Seager (ed.), *Exoplanets*, pp 15–23, University of Arizona Press, 00000
- Nemravová, J. A., Harmanec, P., Brož, M., Vokrouhlický, D., Mourard, D., Hummel, C. A., Cameron, C., Matthews, J. M., Bolton, C. T., Božić, H., Chini, R., Dembsky, T., Engle, S., Farrington, C., Grunhut, J. H., Guenther, D. B., Guinan, E. F., Korčáková, D., Koubský, P., Kříček, R., Kuschnig, R., Mayer, P., McCook, G. P., Moffat, A. F. J., Nardetto, N., Prša, A., Ribeiro, J., Rowe, J., Rucinski, S., Škoda, P., Šlechta, M., Tallon-Bosc, I., Votruba, V., Weiss, W. W., Wolf, M., Zasche, P., and Zavala, R. T.: 2016, *Astronomy and Astrophysics* **594**, A55
- Nicholls, C. P., Lebzelter, T., Smette, A., Wolff, B., Hartman, H., Käufl, H.-U., Przybilla, N., Ramsay, S., Uttenthaler, S., Wahlgren, G. M., and others: 2017, *Astronomy and Astrophysics* **598**, A79, 00000
- Passegger, V. M., Berg, S. W.-v., and Reiners, A.: 2016, *Astronomy and Astrophysics* **587**, A19, 00006
- Peck, E. R. and Reeder, K.: 1972, *JOSA* **62**(8), 958
- Pilyavsky, G., Mahadevan, S., Kane, S. R., Howard, A. W., Ciardi, D. R., de Pree, C., Dragomir, D., Fischer, D., Henry, G. W., Jensen, E. L. N., Laughlin, G., Marlowe, H., Rabus, M., von Braun, K., Wright, J. T., and Wang, X. X.: 2011, *apj* **743**, 162, 00014
- Piskorz, D., Benneke, B., Crockett, N. R., Lockwood, A. C., Blake, G. A., Barman, T. S., Bender, C. F., Bryan, M. L., Carr, J. S., Fischer, D. A., Howard, A. W., Isaacson, H., and Johnson, J. A.: 2016, *The Astrophysical Journal* **832**(2), 131
- Piskunov, N. E. and Valenti, J. A.: 2002, *Astronomy and Astrophysics* **385**(3), 1095, 00257
- Quarteroni, A., Sacco, R., and Saleri, F.: 2000, *Numerical Mathematics*, No. 37 in Texts in applied mathematics, Springer, New York
- Quirrenbach, A., Amado, P. J., Caballero, J. A., Mundt, R., Reiners, A., Ribas, I., Seifert, W., Abril, M., Aceituno, J., Alonso-Floriano, F. J., Ammler-von Eiff, M., Antona Jiménez, R., Anwand-Heerwart, H., Azzaro, M., Bauer, F., Barrado, D., Becerril, S., Béjar, V. J. S., Benítez, D., Berdiñas, Z. M., Cárdenas, M. C., Casal, E., Claret, A., Colomé, J., Cortés-Contreras, M., Czesla, S., Doellinger, M., Dreizler, S., Feiz, C., Fernández, M., Galadí, D., Gálvez-Ortiz, M. C., García-Piquer, A., García-Vargas, M. L., Garrido, R., Gesa, L., Gómez Galera, V., González Álvarez, E., González Hernández, J. I., Grözing, U., Guàrdia, J., Guenther, E. W., de Guindos, E., Gutiérrez-Soto, J., Hagen, H.-J., Hatzes, A. P., Hauschildt, P. H., Helmling, J., Henning, T., Hermann, D., Hernández Castaño, L., Herrero, E., Hidalgo, D., Holgado, G., Huber, A., Huber, K. F., Jeffers, S., Joergens, V., de Juan, E., Kehr, M., Klein, R., Kürster, M., Lamert, A., Lalitha, S., Laun, W., Lemke, U., Lenzen, R., López del Fresno, M., López Martí, B., López-Santiago, J., Mall, U., Mandel, H., Martín, E. L., Martín-Ruiz, S.,

- Martínez-Rodríguez, H., Marvin, C. J., Mathar, R. J., Mirabet, E., Montes, D., Morales Muñoz, R., Moya, A., Naranjo, V., Ofir, A., Oreiro, R., Pallé, E., Panduro, J., Passegger, V.-M., Pérez-Calpena, A., Pérez Medialdea, D., Perger, M., Pluto, M., Ramón, A., Rebolo, R., Redondo, P., Reffert, S., Reinhardt, S., Rhode, P., Rix, H.-W., Rodler, F., Rodríguez, E., Rodríguez-López, C., Rodríguez-Pérez, E., Rohloff, R.-R., Rosich, A., Sánchez-Blanco, E., Sánchez Carrasco, M. A., Sanz-Forcada, J., Sarmiento, L. F., Schäfer, S., Schiller, J., Schmidt, C., Schmitt, J. H. M. M., Solano, E., Stahl, O., Storz, C., Stürmer, J., Suárez, J. C., Ulbrich, R. G., Veredas, G., Wagner, K., Winkler, J., Zapatero Osorio, M. R., Zechmeister, M., Abellán de Paco, F. J., Anglada-Escudé, G., del Burgo, C., Klutsch, A., Lizon, J. L., López-Morales, M., Morales, J. C., Perryman, M. A. C., Tulloch, S. M., and Xu, W.: 2014, in *Procceedings of SPIE: Ground-Based and Airborne Instrumentation for Astronomy V*, Vol. 9147, p. 91471F
- Rodler, F., Lopez-Morales, M., and Ribas, I.: 2012, *The Astrophysical Journal Letters* **753**(1), L25, 00077
- Rothman, L., Gordon, I., Babikov, Y., Barbe, A., Chris Benner, D., Bernath, P., Birk, M., Bizzocchi, L., Boudon, V., Brown, L., Campargue, A., Chance, K., Cohen, E., Coudert, L., Devi, V., Drouin, B., Fayt, A., Flaud, J.-M., Gamache, R., Harrison, J., Hartmann, J.-M., Hill, C., Hodges, J., Jacquemart, D., Jolly, A., Lamouroux, J., Le Roy, R., Li, G., Long, D., Lyulin, O., Mackie, C., Massie, S., Mikhailenko, S., Müller, H., Naumenko, O., Nikitin, A., Orphal, J., Perevalov, V., Perrin, A., Polovtseva, E., Richard, C., Smith, M., Starikova, E., Sung, K., Tashkun, S., Tennyson, J., Toon, G., Tyuterev, V., and Wagner, G.: 2013, *Journal of Quantitative Spectroscopy and Radiative Transfer* **130**, 4, 01706
- Rothman, L., Gordon, I., Barbe, A., Benner, D., Bernath, P., Birk, M., Boudon, V., Brown, L., Campargue, A., Champion, J.-P., Chance, K., Coudert, L., Dana, V., Devi, V., Fally, S., Flaud, J.-M., Gamache, R., Goldman, A., Jacquemart, D., Kleiner, I., Lacome, N., Lafferty, W., Mandin, J.-Y., Massie, S., Mikhailenko, S., Miller, C., Moazzen-Ahmadi, N., Naumenko, O., Nikitin, A., Orphal, J., Perevalov, V., Perrin, A., Predoi-Cross, A., Rinsland, C., Rotger, M., Šimečková, M., Smith, M., Sung, K., Tashkun, S., Tennyson, J., Toth, R., Vandaele, A., and Vander Auwera, J.: 2009, *Journal of Quantitative Spectroscopy and Radiative Transfer* **110**(9-10), 533, 00000
- Sahlmann, J., Segransan, D., Queloz, D., Udry, S., Santos, N. C., Marmier, M., Mayor, M., Naef, D., Pepe, F., and Zucker, S.: 2011, *Astronomy and Astrophysics* **525**, A95, 00115
- Santerne, A., Brugger, B., Armstrong, D. J., Adibekyan, V., Lillo-Box, J., Gosselin, H., Agüichine, A., Almenara, J.-M., Barrado, D., Barros, S. C. C., Bayliss, D., Boisse, I., Bonomo, A. S., Bouchy, F., Brown, D. J. A., Deleuil, M., Mena, E. D., Demangeon, O., Díaz, R. F., Doyle, A., Dumusque, X., Faedi, F., Faria, J. P., Figueira, P., Foxell, E., Giles, H., Hébrard, G., Hojjatpanah, S., Hobson, M., Jackman, J., King, G., Kirk, J., Lam, K. W. F., Ligi, R., Lovis, C., Loudén, T., McCormac, J., Mousis, O., Neal, J. J., Osborn, H. P., Pepe, F., Pollacco, D., Santos, N. C., Sousa, S. G., Udry, S., and Vigan, A.: 2018, *Nature Astronomy* **2**(5), 393
- Santerne, A., Díaz, R. F., Moutou, C., Bouchy, F., Hébrard, G., Almenara, J.-M., Bonomo, A. S., Deleuil, M., and Santos, N. C.: 2012, *Astronomy and Astrophysics* **545**, A76
- Santos, N. C., Adibekyan, V., Figueira, P., Andreasen, D. T., Barros, S. C. C., Delgado-Mena, E., Demangeon, O., Faria, J. P., Oshagh, M., Sousa, S. G., Viana, P. T. P., and Ferreira, A. C. S.: 2017, *Astronomy and Astrophysics* **603**, A30, 00001

- Santos, N. C., Israelian, G., and Mayor, M.: 2004, *aap* **415**, 1153, 00000
- Santos, N. C., Israelian, G., Mayor, M., Bento, J. P., Almeida, P. C., Sousa, S. G., and Ecuivillon, A.: 2005, *aap* **437**, 1127, 00000
- Schlaufman, K. C.: 2018, *The Astrophysical Journal* **853**, 37
- Schwarz, G.: 1978, *The Annals of Statistics* **6**(2), 461
- Seifahrt, A., Käuff, H. U., Zängl, G., Bean, J. L., Richter, M. J., and Siebenmorgen, R.: 2010, *Astronomy and Astrophysics* **524**, A11
- Skrutskie, M. F., Cutri, R. M., Stiening, R., Weinberg, M. D., Schneider, S., Carpenter, J. M., Beichman, C., Capps, R., Chester, T., Elias, J., Huchra, J., Liebert, J., Lonsdale, C., Monet, D. G., Price, S., Seitzer, P., Jarrett, T., Kirkpatrick, J. D., Gizis, J. E., Howard, E., Evans, T., Fowler, J., Fullmer, L., Hurt, R., Light, R., Kopan, E. L., Marsh, K. A., McCallon, H. L., Tam, R., Van Dyk, S., and Wheelock, S.: 2006, *The Astronomical Journal* **131**, 1163
- Smette, A., Sana, H., Noll, S., Horst, H., Kausch, W., Kimeswenger, S., Barden, M., Szyszka, C., Jones, A. M., Gallenne, A., Vinther, J., Ballester, P., and Taylor, J.: 2015, *Astronomy and Astrophysics* **576**, A77, 00067
- Snellen, I. A. G., Brandl, B. R., Kok, D., J. R., Brogi, M., Birkby, J., and Schwarz, H.: 2014, *Nature* **509**, 63, 00000
- Snellen, I. A. G., Kok, D., J. R., Mooij, D., W, E. J., and Albrecht, S.: 2010, *Nature* **465**(7301), 1049
- Soderblom, D. R.: 2010, *Annual Review of Astronomy and Astrophysics* **48**, 581, 00241
- Sorahana, S., Yamamura, I., and Murakami, H.: 2013, *The Astrophysical Journal* **767**(1), 77
- Sousa, S. G., Santos, N. C., Mayor, M., Udry, S., Casagrande, L., Israelian, G., Pepe, F., Queloz, D., and Monteiro, M. J. P. F. G.: 2008, *aap* **487**, 373, 00390
- Tody, D.: 1993, in R. J. Hanisch, R. J. V. Brissenden, and J. Barnes (eds.), *Astronomical Data Analysis Software and Systems II*, Vol. 52 of *Astronomical Society of the Pacific Conference Series*, p. 173, 00000
- Tsantaki, M., Sousa, S. G., Adibekyan, V. Z., Santos, N. C., Mortier, A., and Israelian, G.: 2013, *aap* **555**, A150, 00077
- Udry, S., Mayor, M., Naef, D., Pepe, F., Queloz, D., Santos, N. C., and Burnet, M.: 2002, *Astronomy and Astrophysics* **390**(1), 267, 00158
- Ulmer-Moll, S., Figueira, P., Neal, J. J., Santos, N. C., and Bonnefoy, M.: 2018, *Astronomy and Astrophysics*, in review
- Vacca, W. D., Cushing, M. C., and Rayner, J. T.: 2003, *Publications of the Astronomical Society of the Pacific* **115**(805), 389, 00000
- Wenger, M., Ochsenbein, F., Egret, D., Dubois, P., Bonnarel, F., Borde, S., Genova, F., Jasiewicz, G., Laloë, S., Lesteven, S., and Monier, R.: 2000, *Astronomy and Astrophysics Supplement Series* **143**, 9

- Whitworth, A., Bate, M. R., Nordlund, A., Reipurth, B., and Zinnecker, H.: 2007, *Protostars and Planets V* pp 459–476, 00087
- Zechmeister, M., Reiners, A., Amado, P. J., Azzaro, M., Bauer, F. F., Béjar, V. J. S., Caballero, J. A., Guenther, E. W., Hagen, H.-J., Jeffers, S. V., Kaminski, A., Kürster, M., Launhardt, R., Montes, D., Morales, J. C., Quirrenbach, A., Reffert, S., Ribas, I., Seifert, W., Tal-Or, L., and Wolthoff, V.: 2018, *Astronomy and Astrophysics* **609**, A12
- Zucker, S. and Mazeh, T.: 2001, *The Astrophysical Journal* **562**(1), 549, 00060