

THE EFFECTS OF TELLURIC LINES IN RADIAL VELOCITY SEARCHES FOR PLANETS WITH IODINE CELL AS CALIBRATORS¹

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ABSTRACT

Tellurics are bad and you really don't want them. Here's how to get rid of them.

Subject headings: instrumentation

1. INTRODUCTION

We are going to cite Artigau et al. (2014); Cunha et al. (2014) and Rothman et al. (2013).

2. DATA AND DATA ANALYSIS TOOLS

Introduction to Keck/HIRES CPS data, data reduction, Doppler code. Our adoption of Doppler code.

Introduction to the standard star(s) in this paper?

ZZZ Table: standard star stellar properties? esp. coordinates to highlight BC ranges?

3. EFFECTS OF TELLURIC LINES

3.1. Simulated Data

This is where TERRASPEC got introduced.

ZZZ Plots:

- telluric line atlas in the optical? just to demonstrate where they are.
- telluric free simulations to demonstrate RV precision, vs. year, vs. BC
- telluric injected simulations to demonstrate effects, vs. year, vs. BC
- RV vs. BC for chunks with and without telluric lines before and after injection

3.2. On-Sky Data

Should this be the first?

ZZZ Plots:

- RV vs. year/time, RV vs. BC
- RV from chunks with and without telluric lines, vs. BC

3.3. Where and How Telluric Lines Enter the Data

Should this subsection be moved to the first? It enters the epoch data as well as the empirically derived stellar template.

ZZZ Plots:

- fitting plots showing data (with telluric highlighted) and DSST (tellurics highlighted) and the mismatch

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4. CORRECTING FOR THE EFFECTS OF TELLURIC LINES

4.1. Masking out the Telluric Lines

ZZZ Plot:

- Illustration of choice of mask
- RV vs. BC before and after for all, telluric, and non-telluric chunks
- simulation results showing no aliases introduced by masking

4.2. Removing the Telluric Contamination from Stellar Templates

ZZZ Plot:

- selected chunk before and after cleaning
- ?RV vs. BC using cleaned template, no masking, single mask?, double mask?

4.3. Modeling Telluric Lines in the Star+Iodine Spectra

ZZZ Plot:

- RV vs. BC using cleaned template plus full telluric modeling
- RV vs. BC using cleaned template plus full modeling plus some masking?

4.4. Results for A Different RV Standard Star

I think this is a must! At least one more star, hopefully two.

5. SUMMARY AND FUTURE WORK

Gaussian processes!

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REFERENCES

- Artigau, É., Astudillo-Defru, N., Delfosse, X., et al. 2014, in Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, Vol. 9149, Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, 5
- Cunha, D., Santos, N. C., Figueira, P., et al. 2014, *A&A*, 568, A35
- Rothman, L. S., Gordon, I. E., Babikov, Y., et al. 2013, *J. Quant. Spec. Radiat. Transf.*, 130, 4