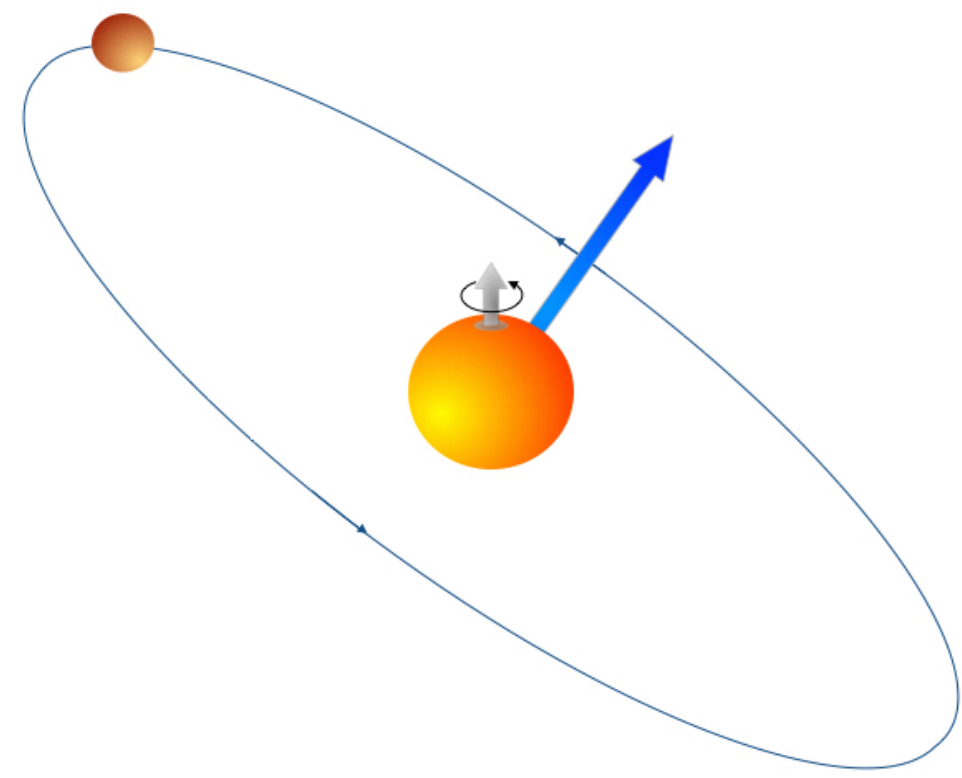# Calculating Vsin(i) of Young Planet-hosting Stars

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Background

The spin-orbit alignment of extra-solar planets in young systems can provide insight on their migratory history: An aligned system might indicate that the exoplanet formed through interactions with the disk. We can obtain a transiting system's spin-orbit relation by calculating the Vsin(i) of the host star.

A physical representation of a spin-orbit misalignment
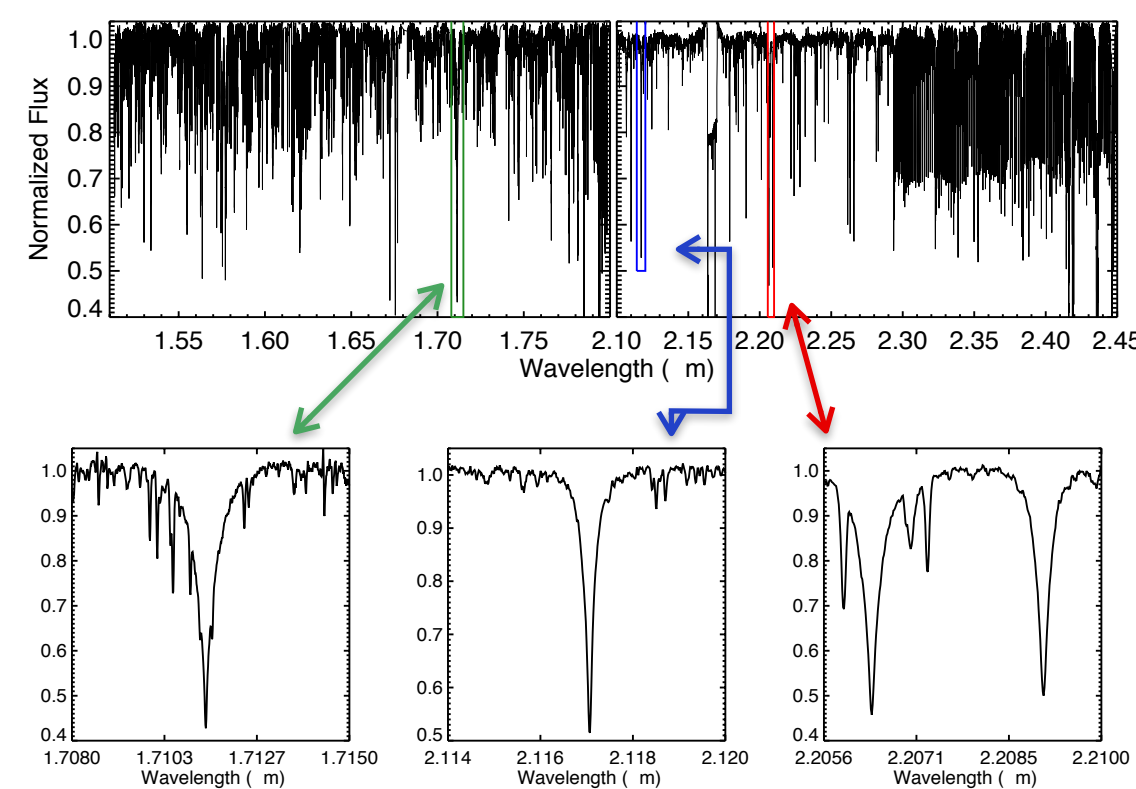*Source: http://web.gps.caltech.edu/*

The Vsin(i) of a star is its rotational velocity at the equator multiplied by the sine of the inclination. As you can see, the Vsin(i) will always be less than the equatorial velocity.
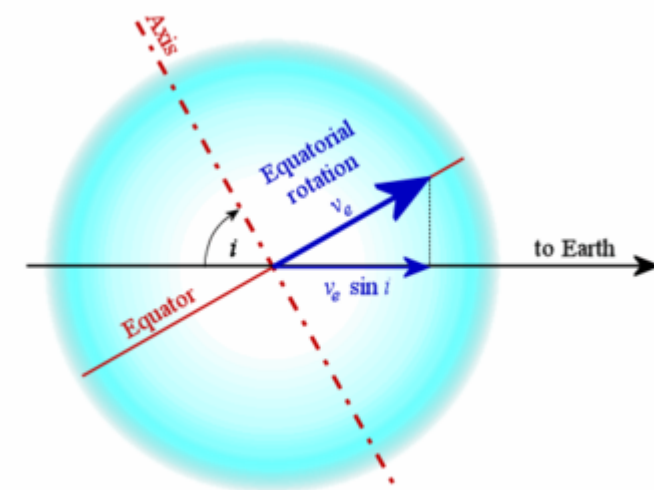
A diagram of the physical representation of a star's Vsin(i)

Using Spectroscopy to find our Vsin(i)

Absorption lines in the IGRINS spectral range
Source: Dr. Andrew Mann

We can use spectroscopy as a tool to determine the Vsin(i) of a star through the rotational broadening on its spectral lines. The rotational broadening observed in a star's spectral lines is due to the rotational velocity of the star with respect to our plane of vision.

As the star spins on its axis, half of the star will be rotating towards us while the other half rotates away from us. This leads to an emission (or absorption) line that is not perfectly straight, but slightly broadened.


Spectral-line broadening

broadening

wavelength → wavelength
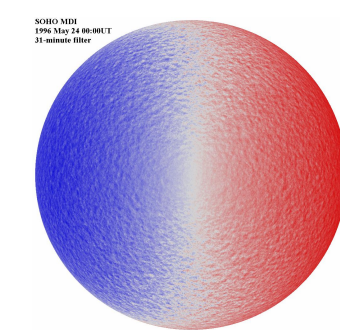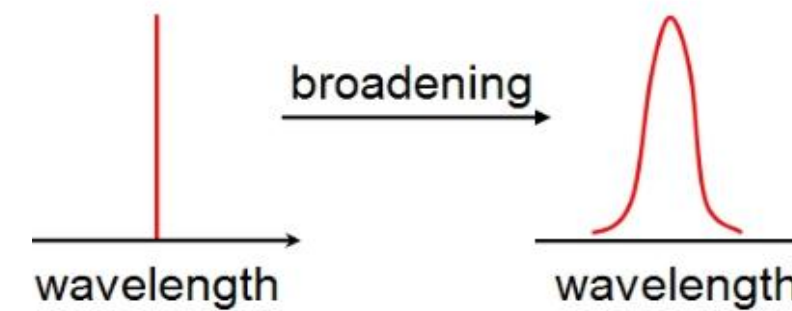
Spectral line-broadening as a result of the star's rotational velocity

Objectives

- Develop a program that fits a model's spectral lines onto the star's broadened spectral lines
- Have our program produce a Vsin(i) value of the star, using our optimized model
- Extract an inclination value from our Vsin(i)
- Compare the calculated inclination of the star with respect to the exoplanet's orbital inclination (which is around 85°-90° because it is a transiting system)

Telluric Reduction

Tellurics are a result of light scattering off of molecules in the earth's atmosphere and creating noise on the incoming data. To remove the tellurics, we used a relatively featureless hot, rapidly rotating star as our standard star. We divided the spectrum of the target star by our standard to eliminate as many of the tellurics as possible to produce a new set of telluric-reduced data.
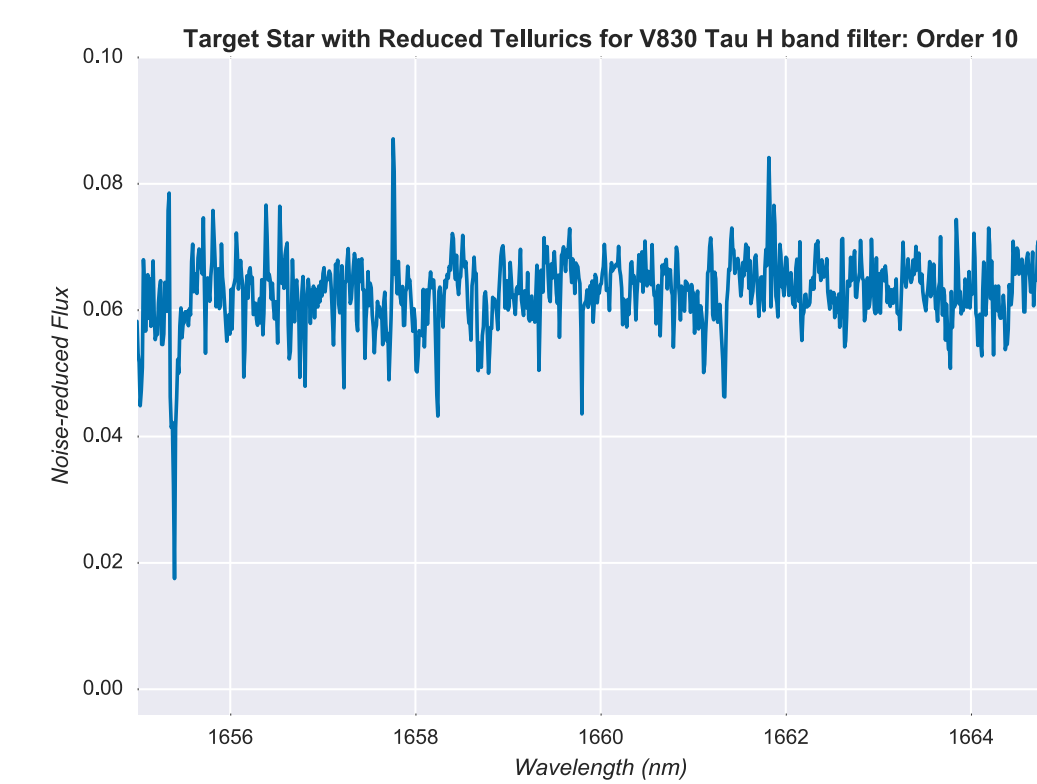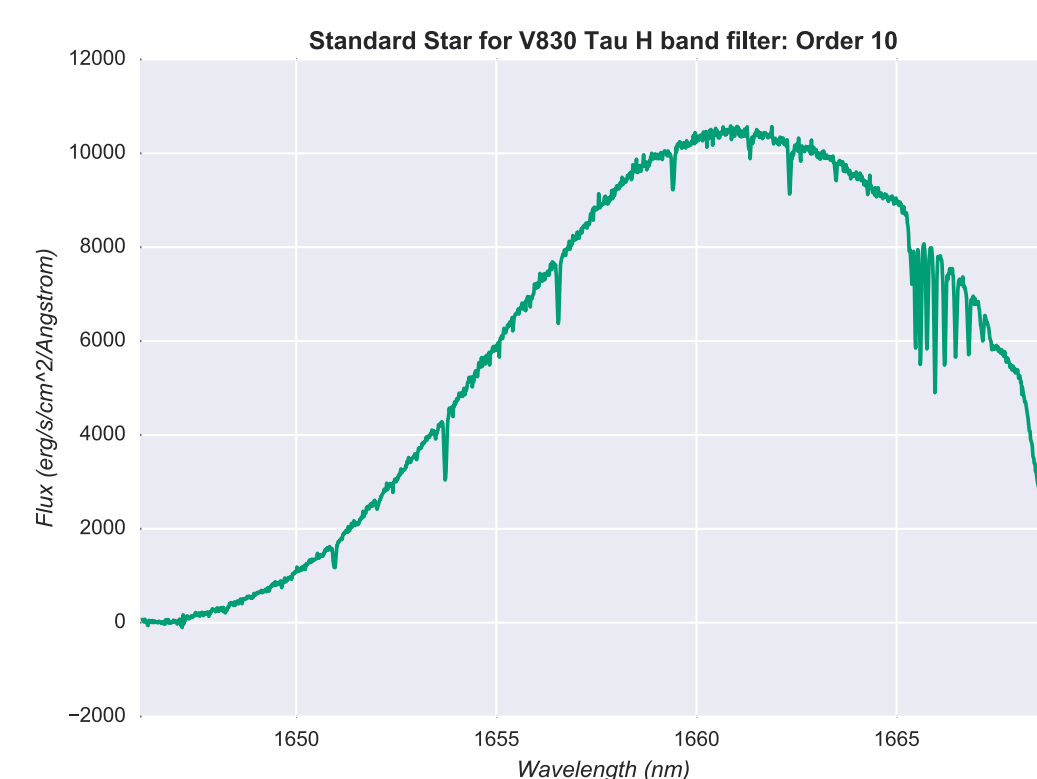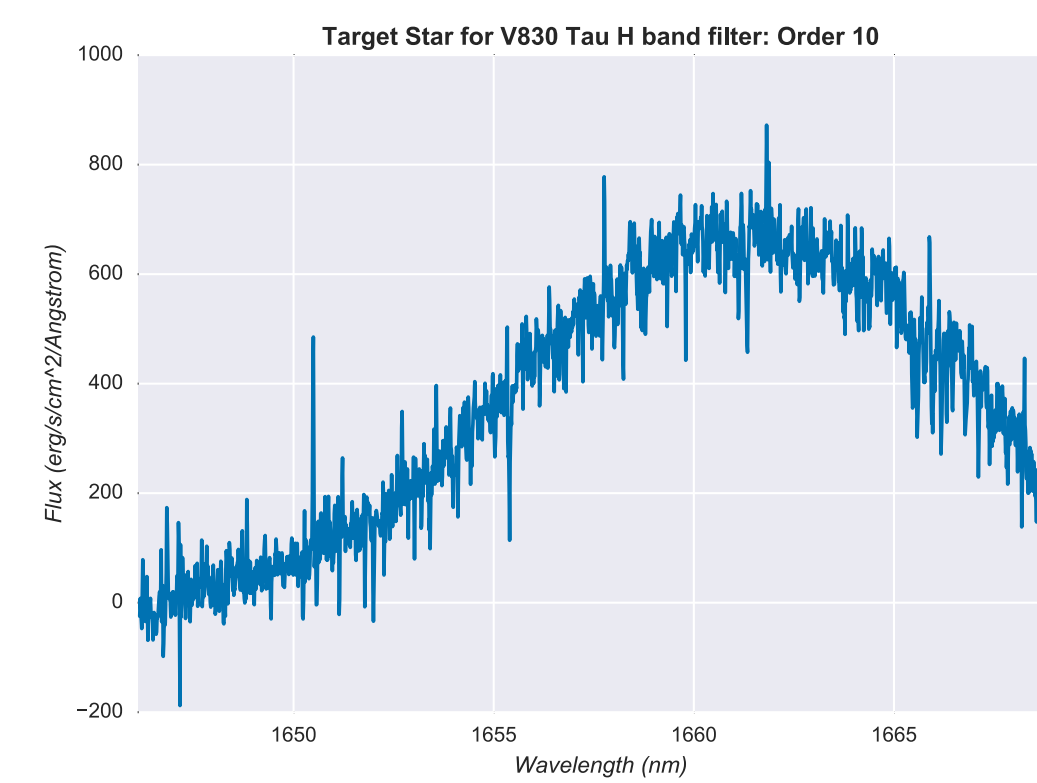
The Data:
We used stellar spectra taken from the Immersion GRating INfrared Spectrometer (IGRINS) in the McDonald Observatory. Targets were observed in the NIR H and K bands.


The Standard:
Our standard was an A0 star that was observed under the same airmass as our target star.


The Results:
The raw data was divided by our A0 standard which eliminated most of the telluric lines.

Model Fitting

We developed a program with correction parameters that would fit the model spectra onto our target spectra. This program would then produce a Vsin(i) value close to the Vsini(i) of our target star, which we can use to determine the inclination of the star relative to our point of view.
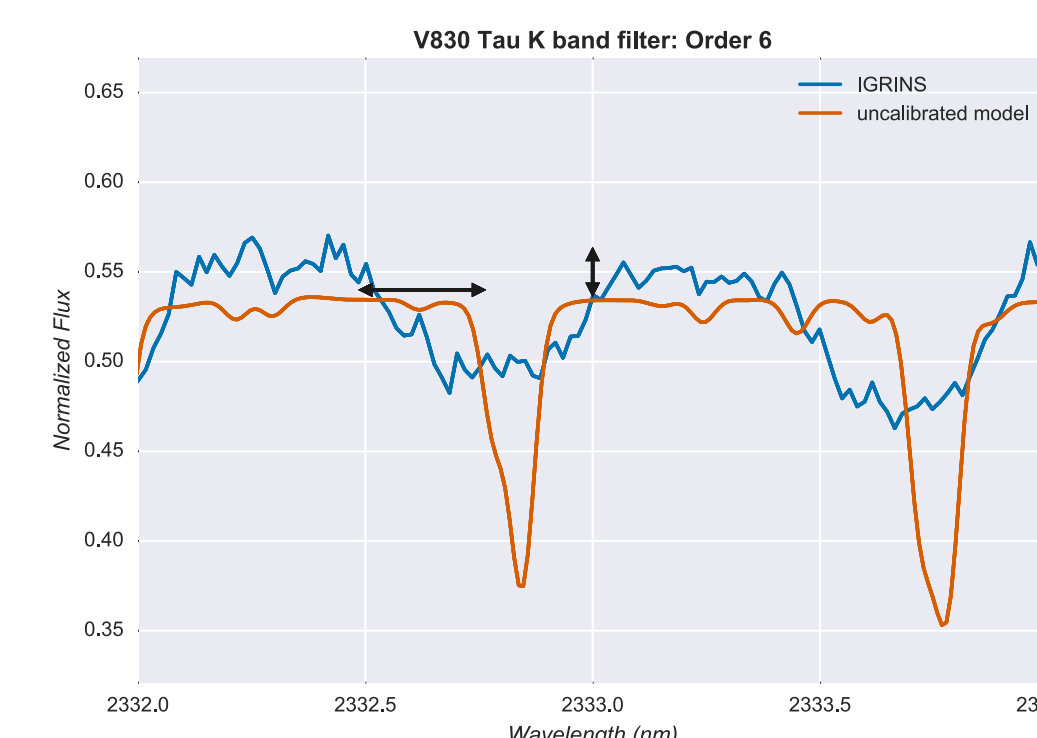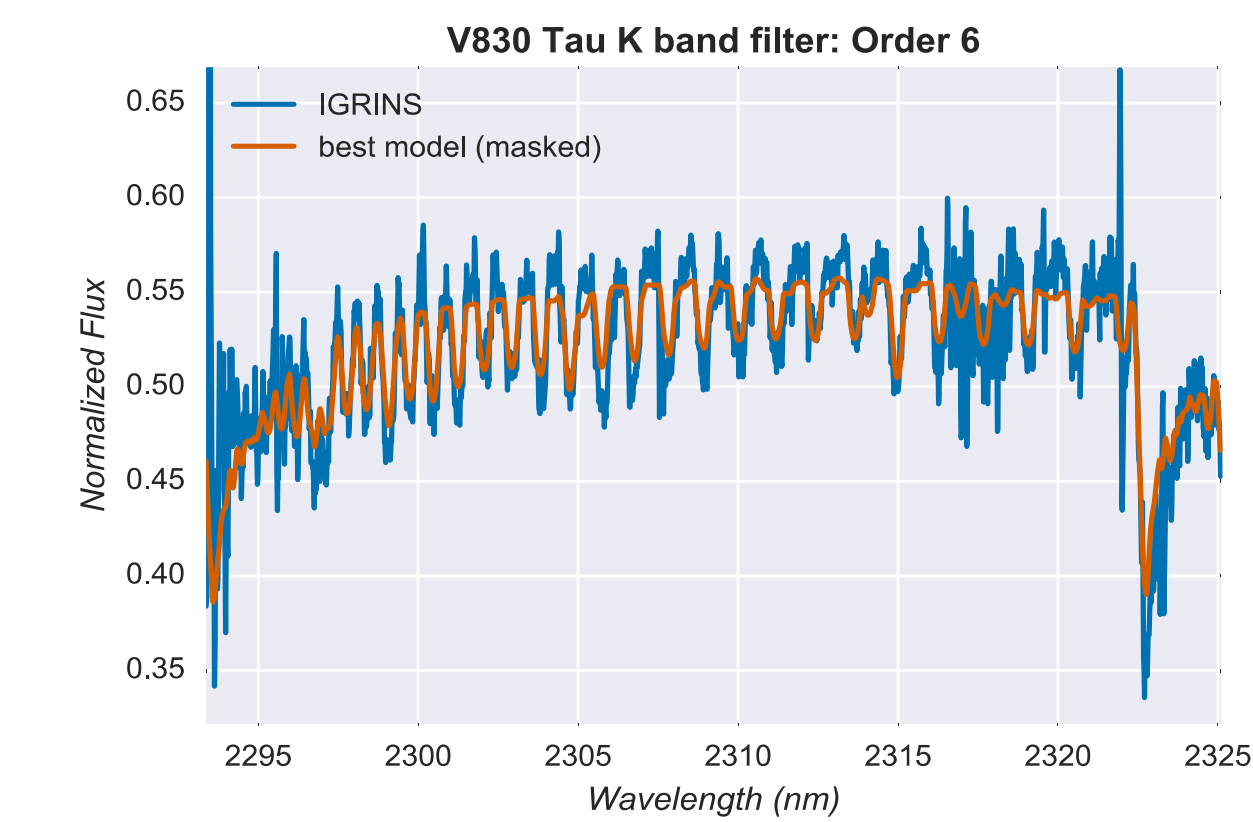

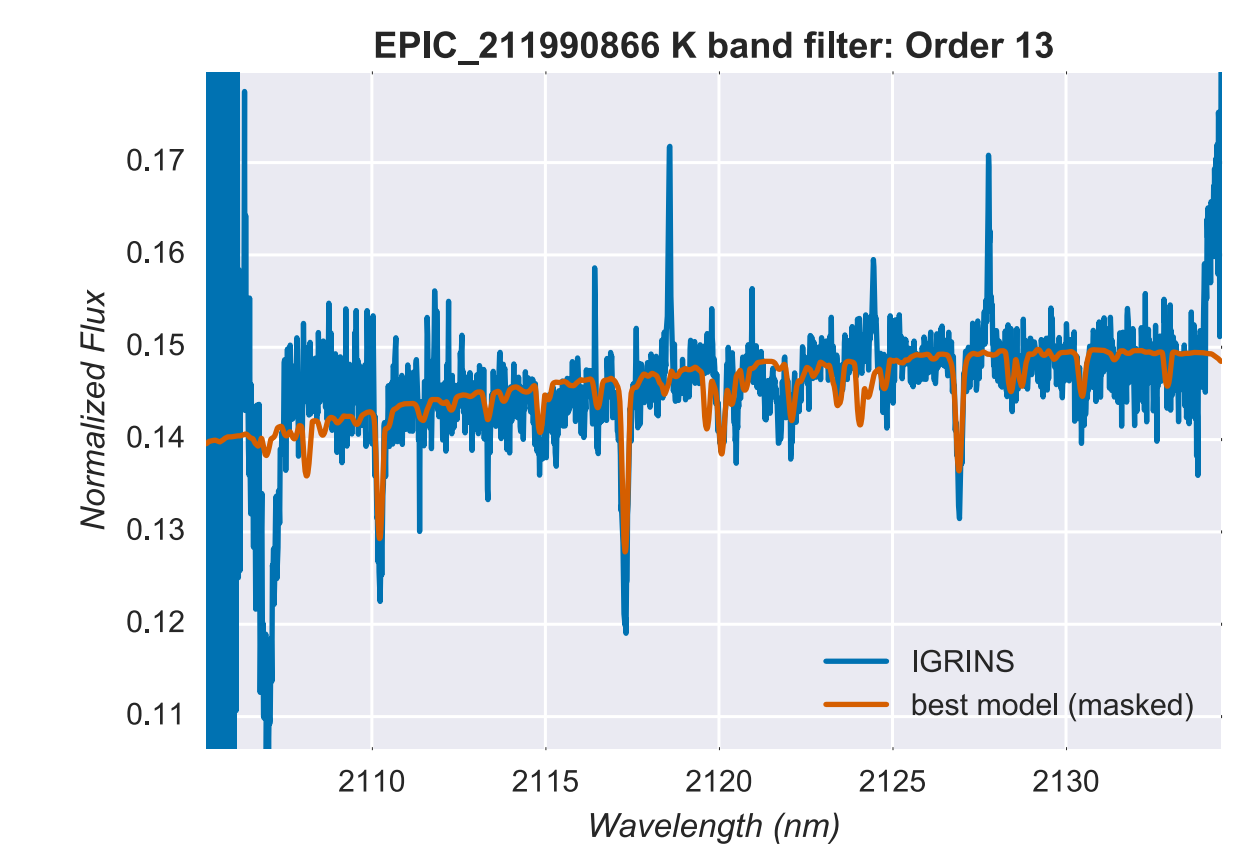*IGRINS spectrum plotted against our unoptimized model*
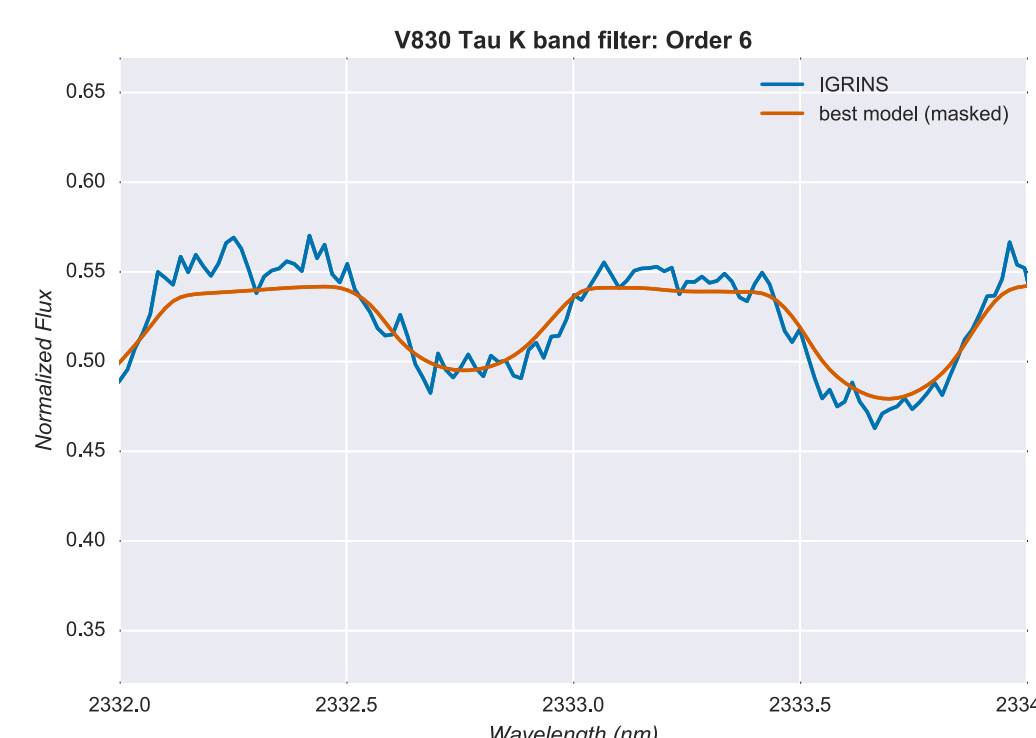
IGRINS spectrum plotted against our model after applying the optimization parameters

Results and Conclusions

Target name: V830 Tau
Calculated Vsin(i): 30.1 km·s⁻¹ ± 3.4
Literature Vsin(i): 30.5 km·s⁻¹ ± 0.5

Target name: EPIC 211990866
Calculated Vsin(i): 15.7 km·s⁻¹ ± 2.1
Calculated inclination: ≥ 78.0°

During our data analysis, we noticed the accuracy of our Vsin(i) values decreased as we observed stars with a slower radial velocity: Our values would tend to have larger uncertainties as we fit our model to spectra with less rotational broadening in these spectral lines.

Telluric Model Fitting
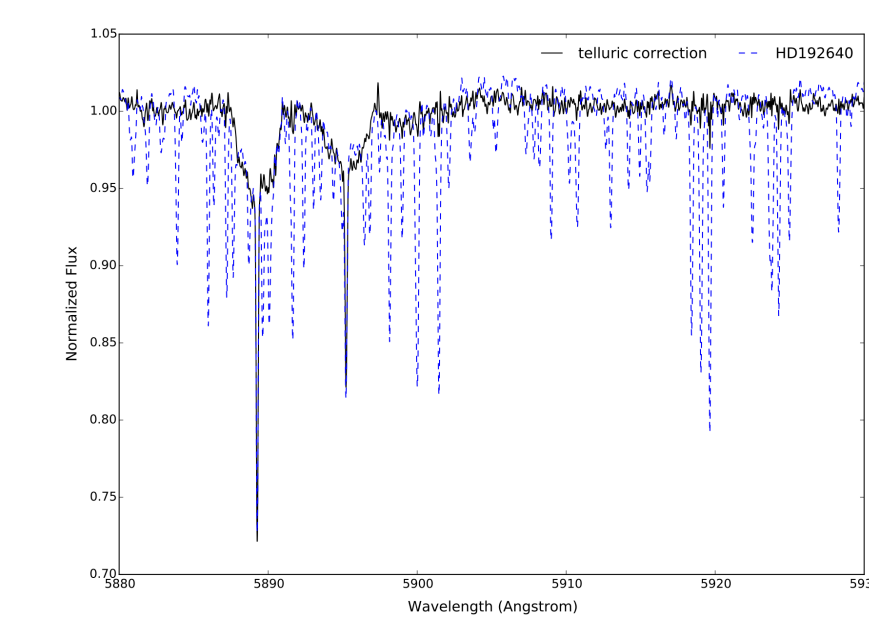
- Improves noise-reduction from tellurics
- Standard star no longer required
- Air mass under which data was taken does not matter

Source: http://glentner.github.io/SLiPy/

References

[1] Mann, A., et al., 18, Aug. 2016, AJ, Published.
[2] Mann, A., et al., 11, Jan. 2017, AJ, Published.
[3] Mann, A., et al., 08, Feb. 2016, ApJ, Published.
[4] Donati, J.F., et al., 09, Sep. 2015, MNRAS, Published.

Acknowledgements
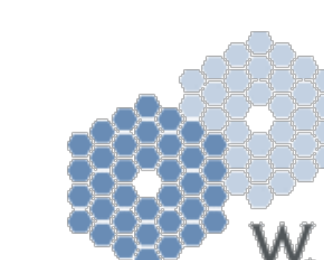
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