viper - Velocity and IP EstimatoR

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Introduction

viper (Köhler et al. 2025) is a **publicly available**[1] and user-friendly code that is able to process data from various spectrographs. The code is developed for echelle spectra; and additional instruments can easily be added.

viper uses a **least-square fitting** to model the stellar RV as well as the temporal and spatial variable IP, following the procedure from Butler et al. (1996). The method has been extended by adding a term for the telluric transmission to enable the processing of NIR data:

$$S(x) = k\,[T_{cell}(\lambda)\,T_{atm}(\lambda, v_{atm})\,S_{star}(\lambda, v_{star})] \otimes IP$$

Here T_{atm} represents the telluric model, which is a product of the transmission of individual molecules. This simple model allows the calculation of RVs for observations in the NIR as well as a telluric correction.

viper can calculate the RV values for various instruments, using a gas cell and/or telluric lines for the wavelength calibration, or utilising pre-calibrated wavelengths from stabilised instruments.

[1] https://mzechmeister.github.io/viper_RV_pipeline

Telluric correction

viper can be used solely for the telluric correction (from visible to the NIR). It has been successfully tested on spectra from **CRIRES⁺, XSHOOTER, GIANO-B, UVES** and others. The correction takes just a few seconds and even **works for brown dwarfs**, as well as for spectra with a low S/N.

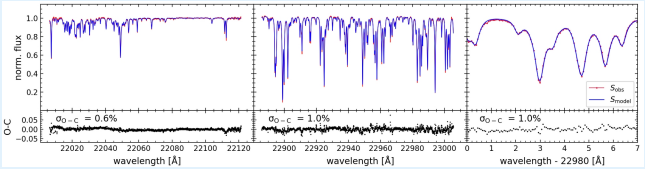


Fig: Telluric correction of a telluric standard.

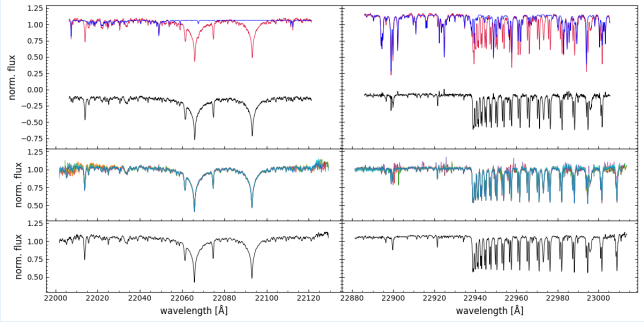
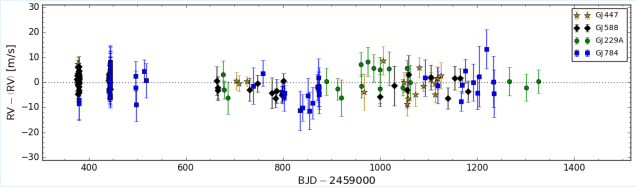


Fig: Telluric correction of the M dwarf GJ588.

RV results

Applying viper to RV standards observed with **CRIRES⁺**, an RV precision of **3 m/s** was achieved over a period of several years.



Furthermore, with the help of viper, we were able to discover a **planetary-mass exo-satellite** orbiting a brown dwarf, achieving an RV precision 1–2 magnitudes better than in previous studies of similar objects (Nature paper by Hoy et al., 2026).