Evaluating Gaussian Process Models of Stellar Activity in Radial Velocity Data

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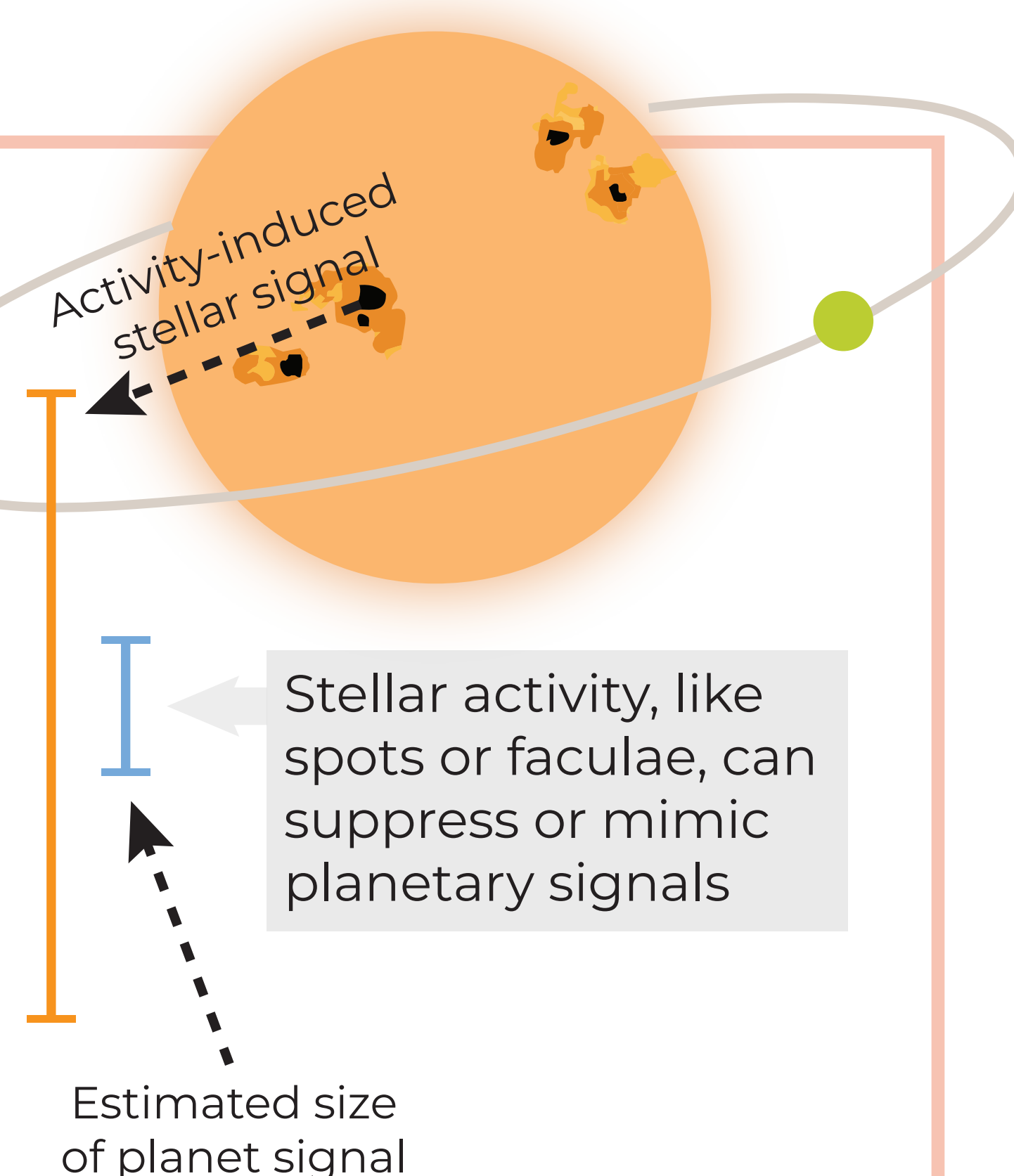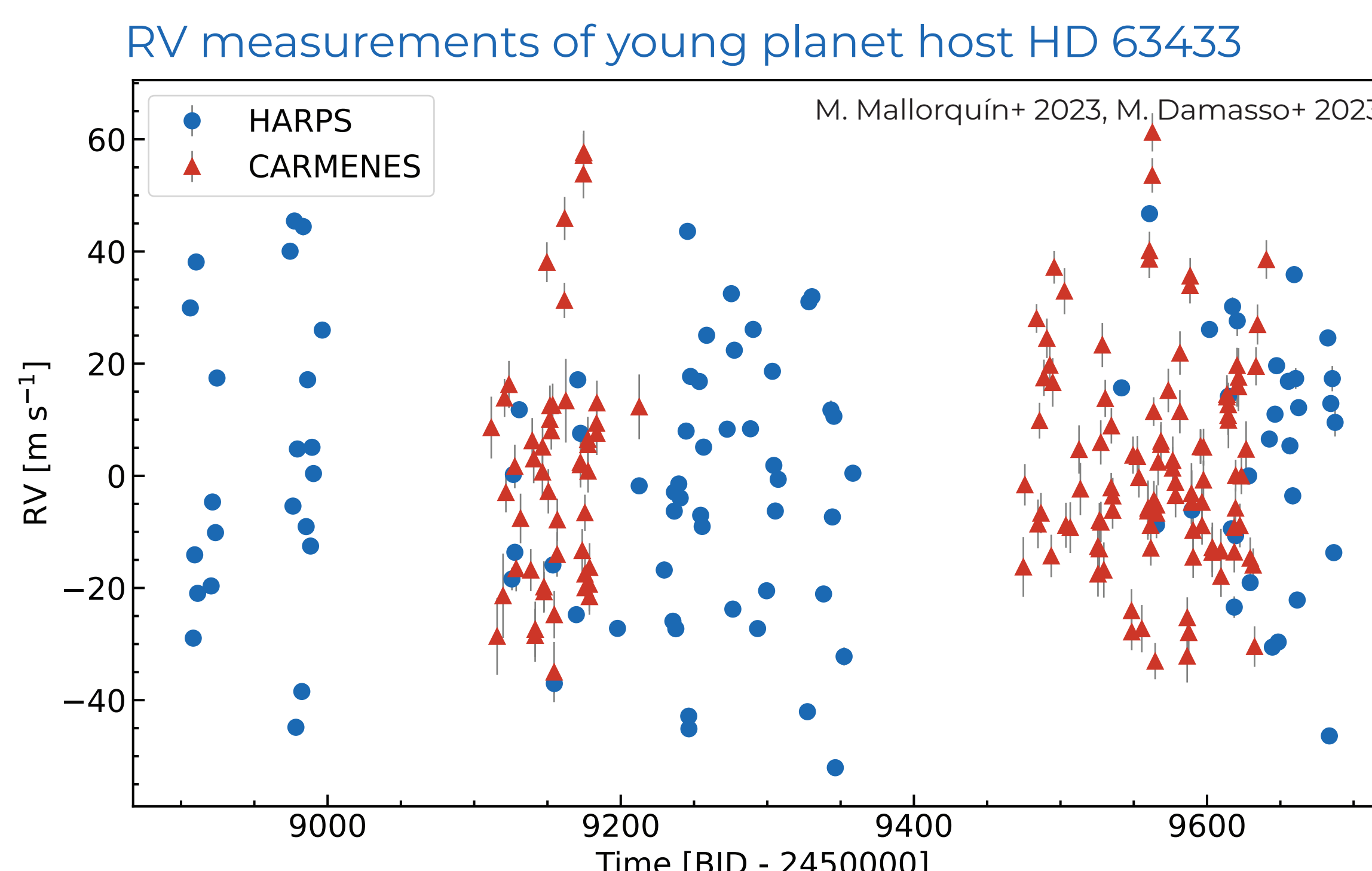[1] Massachusetts Institute of Technology, [2] University of California, Santa Cruz

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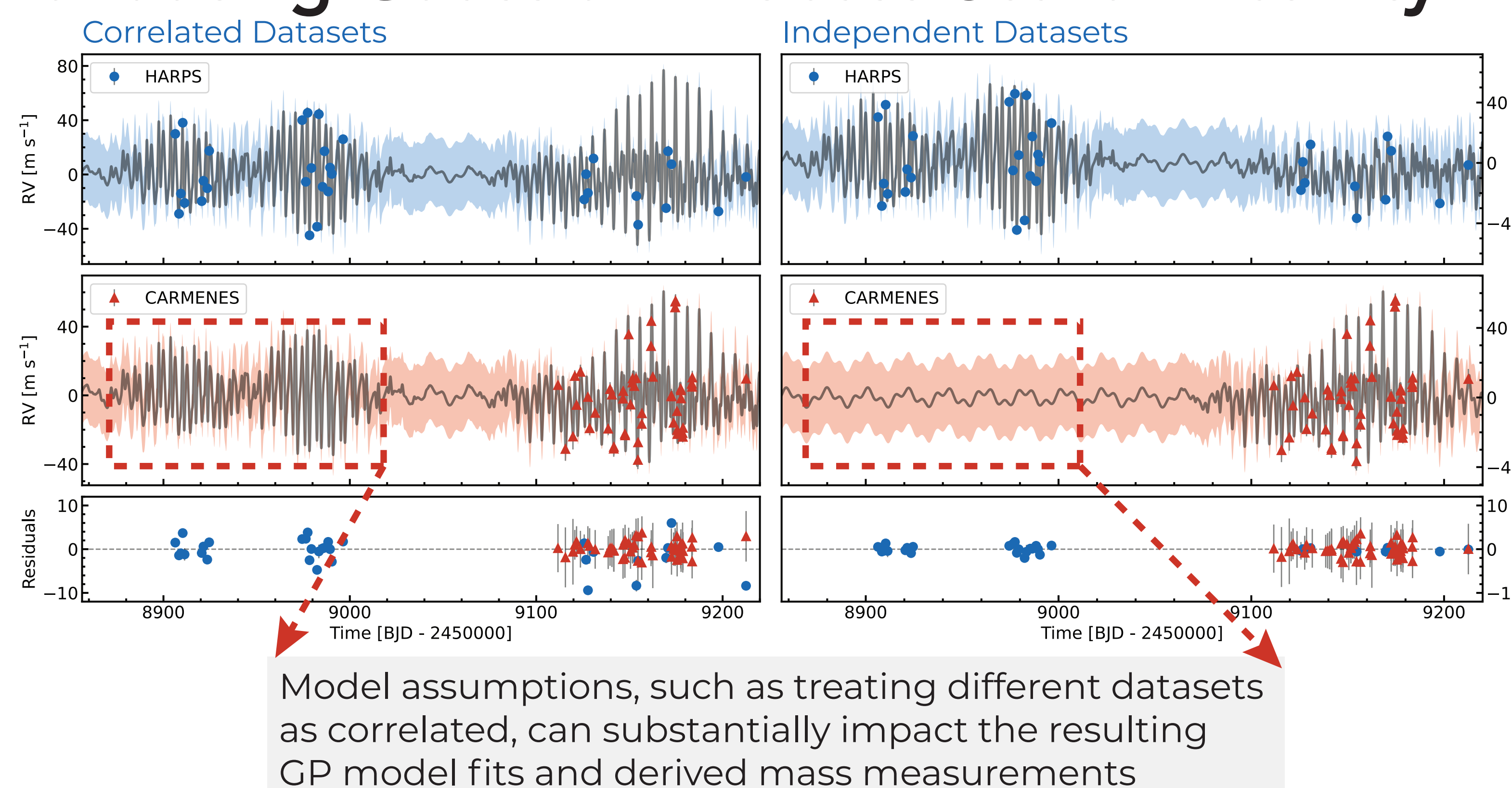## Stellar Activity Limits Young Planet Characterization

- Young stars and their planets provide critical insight into the physical processes that control planetary formation and evolution

- High stellar activity in young stars complicates radial velocity (RV) analysis and obscures the planetary signals we aim to detect and model

Addressing stellar noise is key to revealing young planet properties

RV measurements of young planet host HD 63433 — HARPS, CARMENES — M. Mallorquín+ 2023, M. Damasso+ 2023

Activity-induced stellar signal

Stellar activity, like spots or faculae, can suppress or mimic planetary signals

Estimated size of planet signal

The Case for Cross-Validating Gaussian Process Stellar Activity Models

- Gaussian Process (GP) regression is widely used to model stellar activity in radial velocity data
(Aigrain & Foreman-Mackey 2023)

- Yet, there is no established way to evaluate the predictive performance of these models, *a problem that has led to overfitting and unreliable mass estimates* (Blunt+ 2023)

Correlated Datasets / Independent Datasets — HARPS, CARMENES, Residuals — Time [BJD - 2450000]

Model assumptions, such as treating different datasets as correlated, can substantially impact the resulting GP model fits and derived mass measurements

Cross-validation assesses model predictiveness and improves our confidence in evaluating and interpreting GP stellar activity models used to infer planet masses.

Streamlining Cross-Validation With eurydice

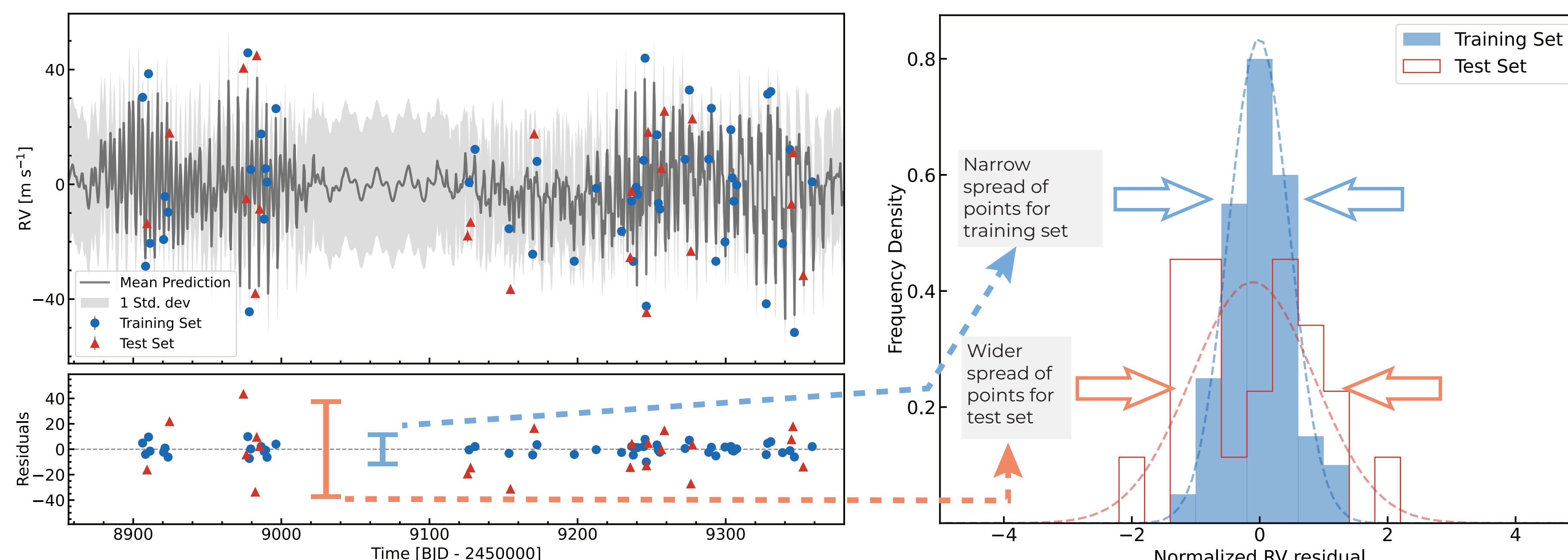**eurydice** is an open-source Python package designed to cross-validate GP models of stellar activity

1 Train and optimize your GP model of choice separately

2 Pass the GP model and data (split into train & test sets) to **eurydice**

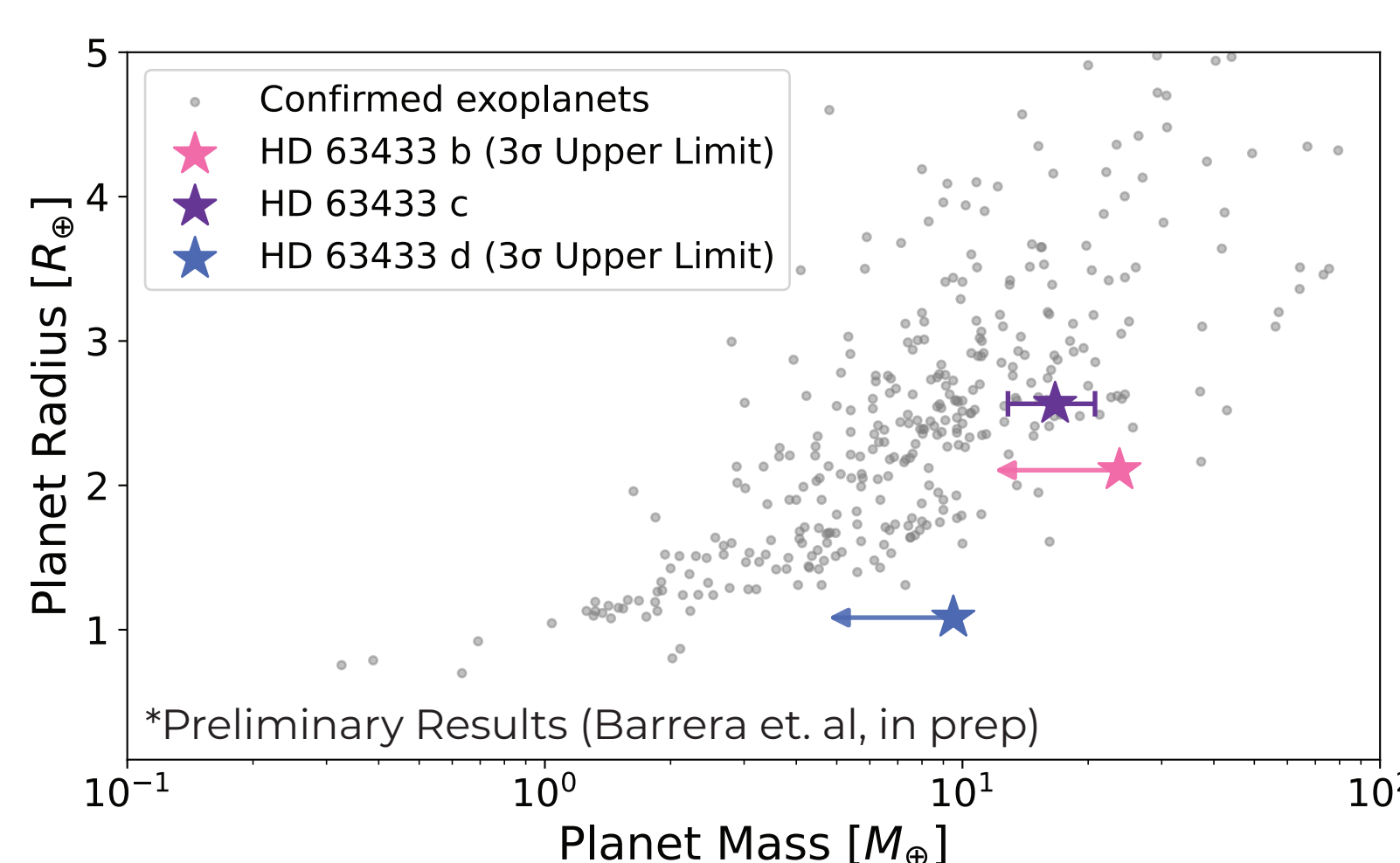**3** **eurydice** conditions the model on the training set

4 **eurydice** cross-validates the model's predictive performance on the test set

Cross-validation of stellar activity models for HD 63433 with eurydice — Mean Prediction, 1 Std. dev, Training Set, Test Set — Residuals — Time [BJD - 2450000]

Training Set / Test Set — Narrow spread of points for training set — Wider spread of points for test set — Normalized RV residual

Visualizations helps us see how well the model predicts new data by comparing residuals from training and test sets

eurydice streamlines cross-validation to help identify overfitting and non-predictive behavior in GP stellar activity models

Next steps:
We aim to improve the stellar activity fit for HD 63433 by incorporating new data and evaluating how different modeling techniques and assumptions impact updated mass estimates

Confirmed exoplanets, HD 63433 b (3σ Upper Limit), HD 63433 c, HD 63433 d (3σ Upper Limit) — Planet Radius [$R_\oplus$] vs Planet Mass [$M_\oplus$] — *Preliminary Results (Barrera et. al, in prep)

eurydice is actively being developed in a public repository on GitHub and will continue to be updated to the radial velocity community's needs and feedback

Follow along here!