BioSpace25 - Biodiversity insight from Space
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A Bayesian Framework for Sensor-Agnostic Plant Trait Prediction Using Imaging Spectroscopy

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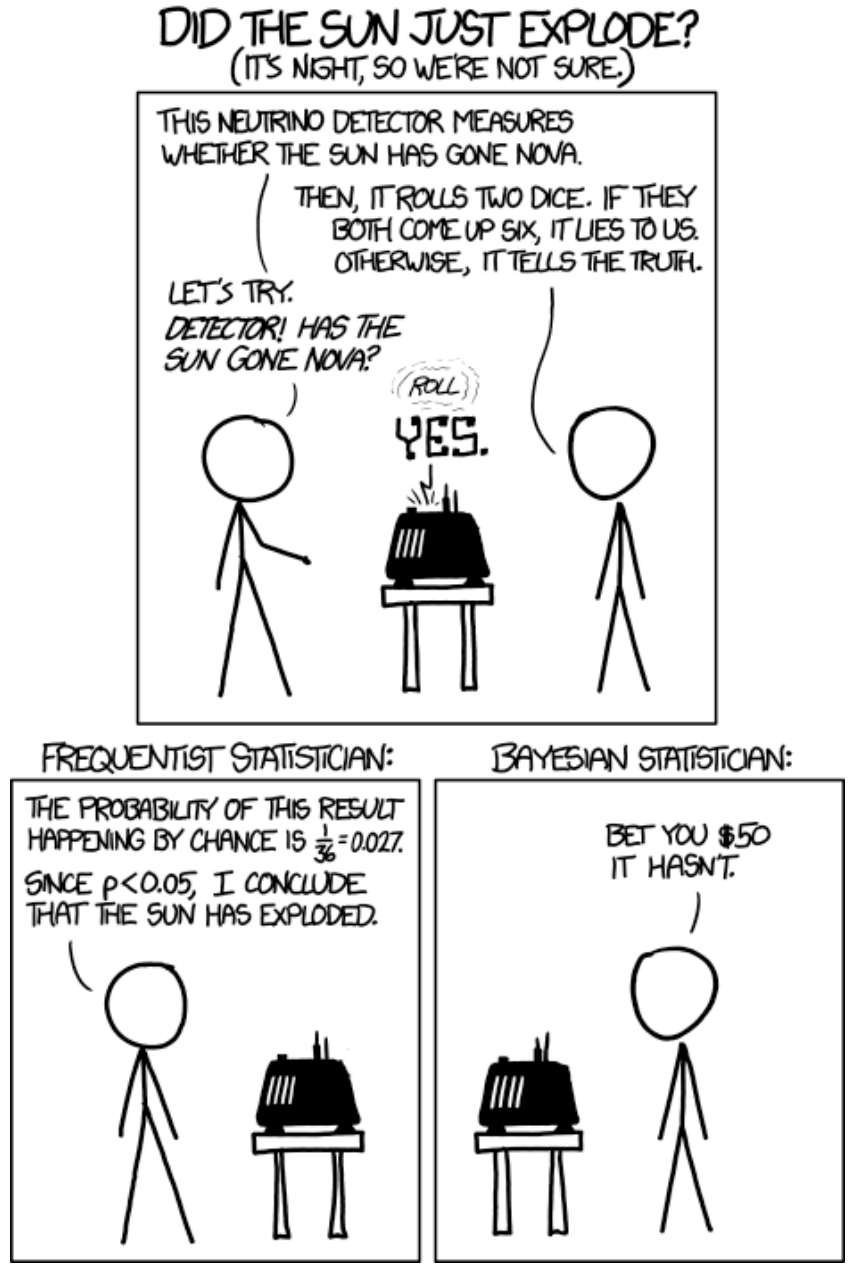
Objective

- Develop a Bayesian regression algorithm for predicting traits using spectra.
- Our proposed Bayesian approach enables:
  - ✓ working on the original spectral scale
  - ✓ full uncertainty quantification
  - ✓ use of prior knowledge.
  - ✓ modeling non-linearities
  - ✓ Developing instrument-aware trait algorithms



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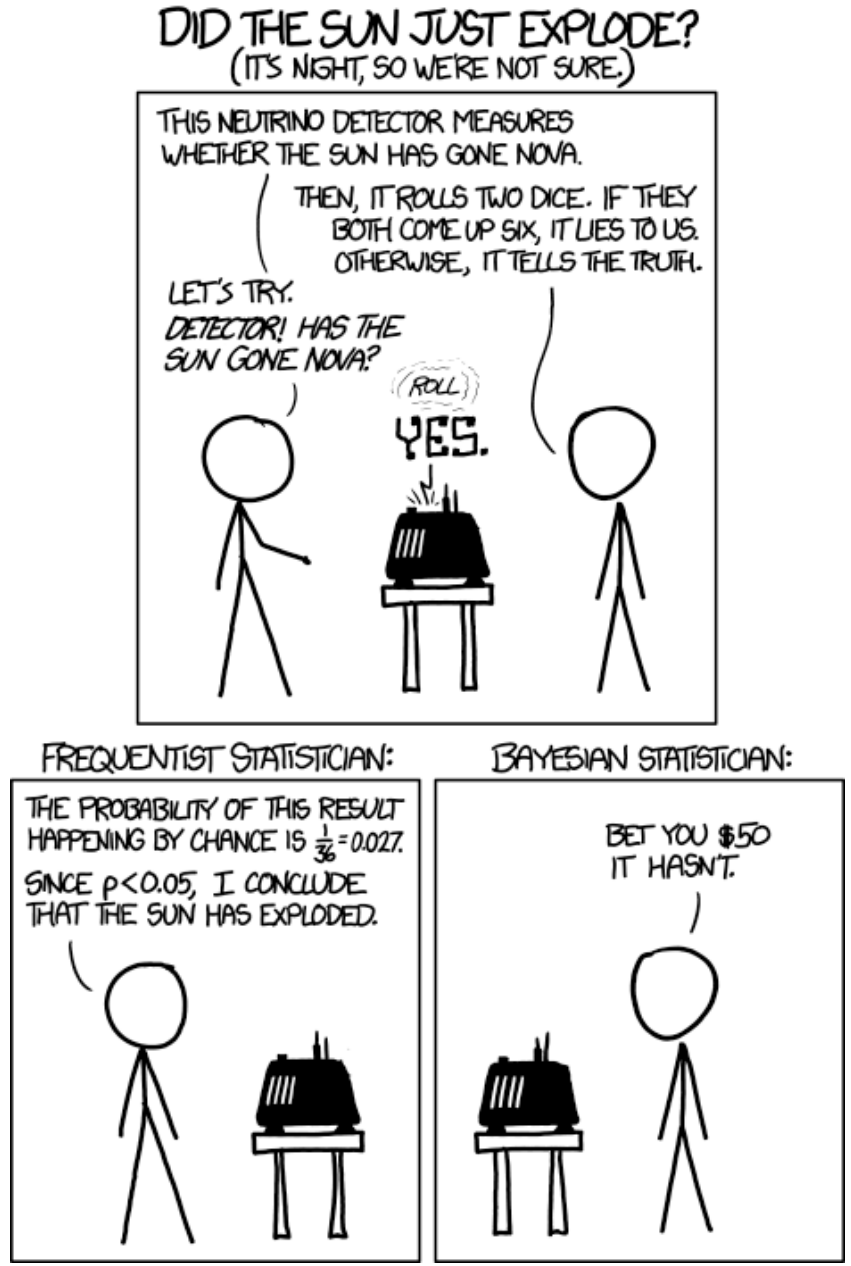
  - ✓ Intuitive, flexible and FUN !!!



Bayesian Approach

Trait

Reflectance Spectra

$$trait \sim N(\theta^*, \sigma^*)$$

$$\theta^* = \beta_0^* + \beta_1^* x_1 + \ldots + \beta_p^* x_p$$

$$\beta_i \sim horsehoe()$$

$$\sigma \sim halfCauchy(0, \alpha)$$

Use all spectra on original scale to fit the Bayesian model

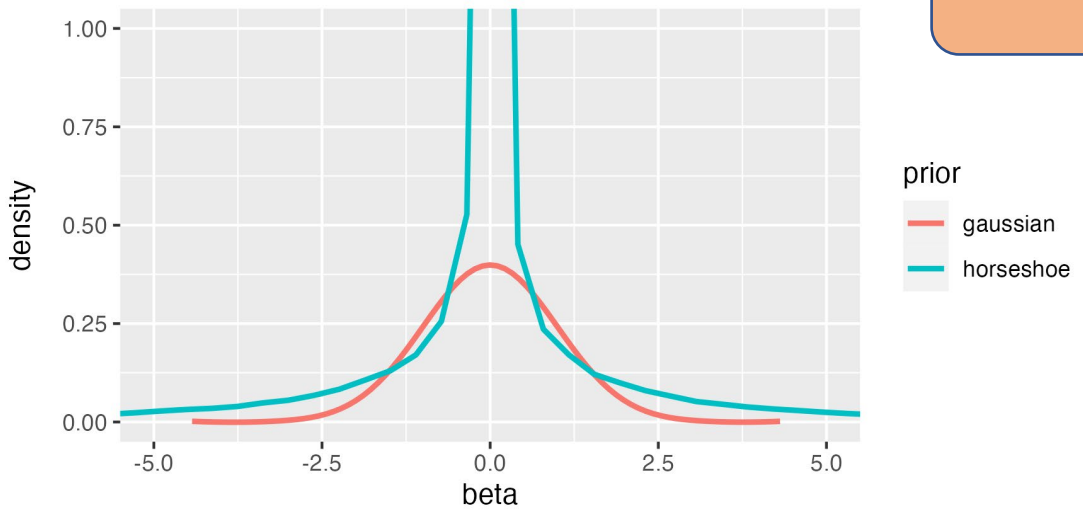
Derive a reduced Bayesian model with handful of spectra

Bayesian Linear Regression

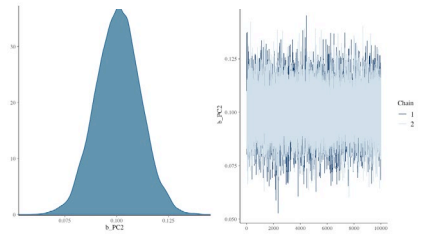
Parameter probability distributions for Bayesian Linear Regression

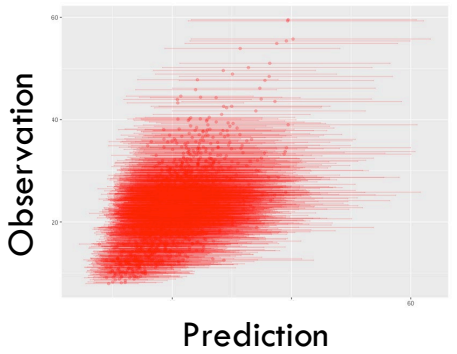
Predictive distribution

Enhanced interpretability and fast computation



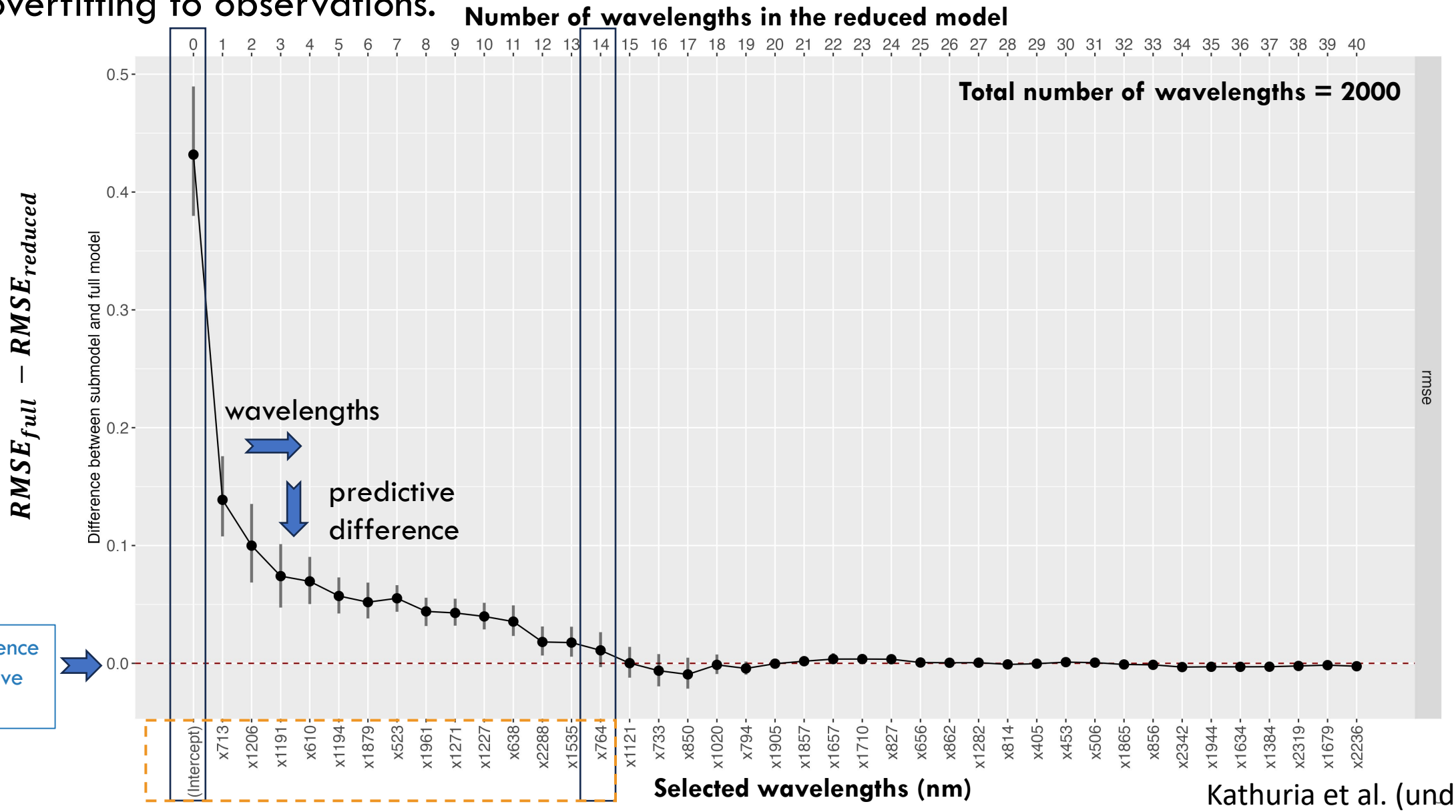
Parameter Uncertainty





Deriving reduced Bayesian model

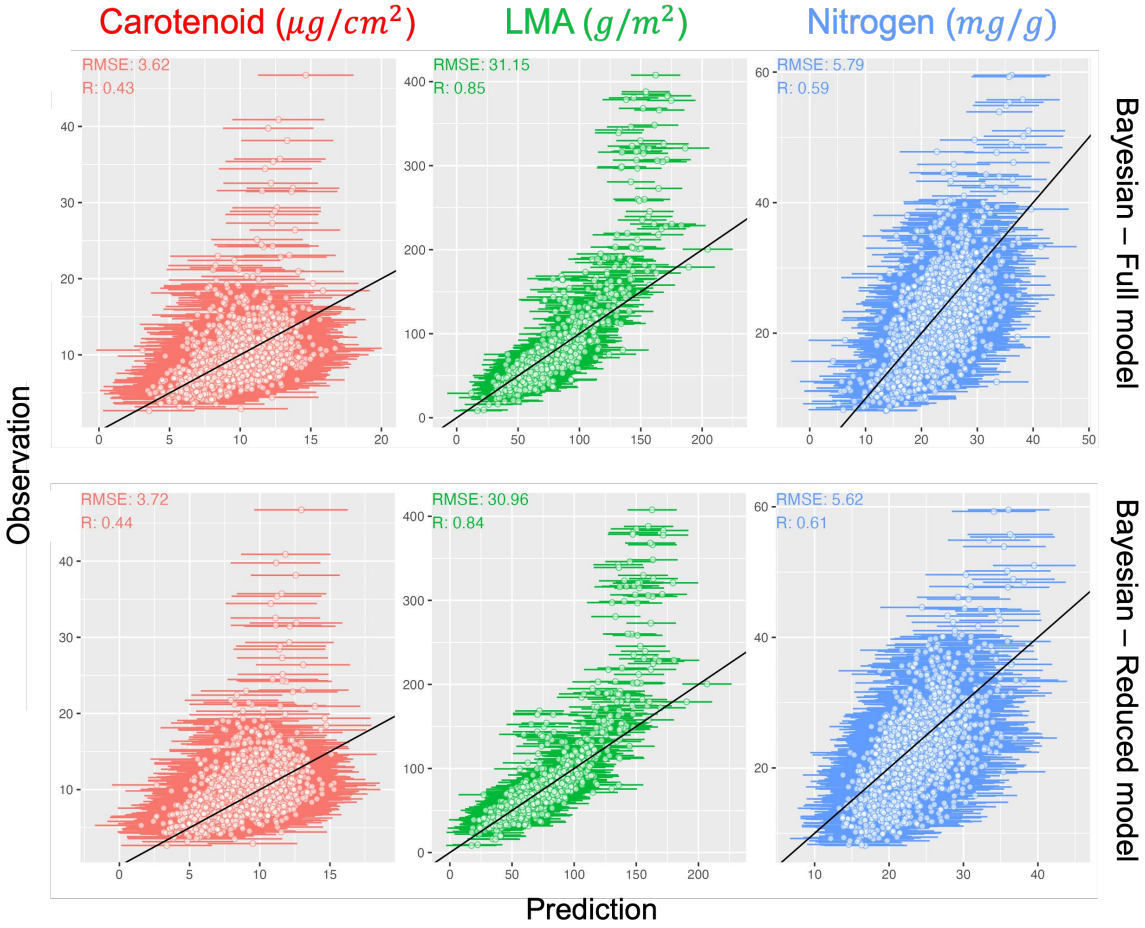
- Simulations from the trained full model are used to select a reduced model preventing overfitting to observations.

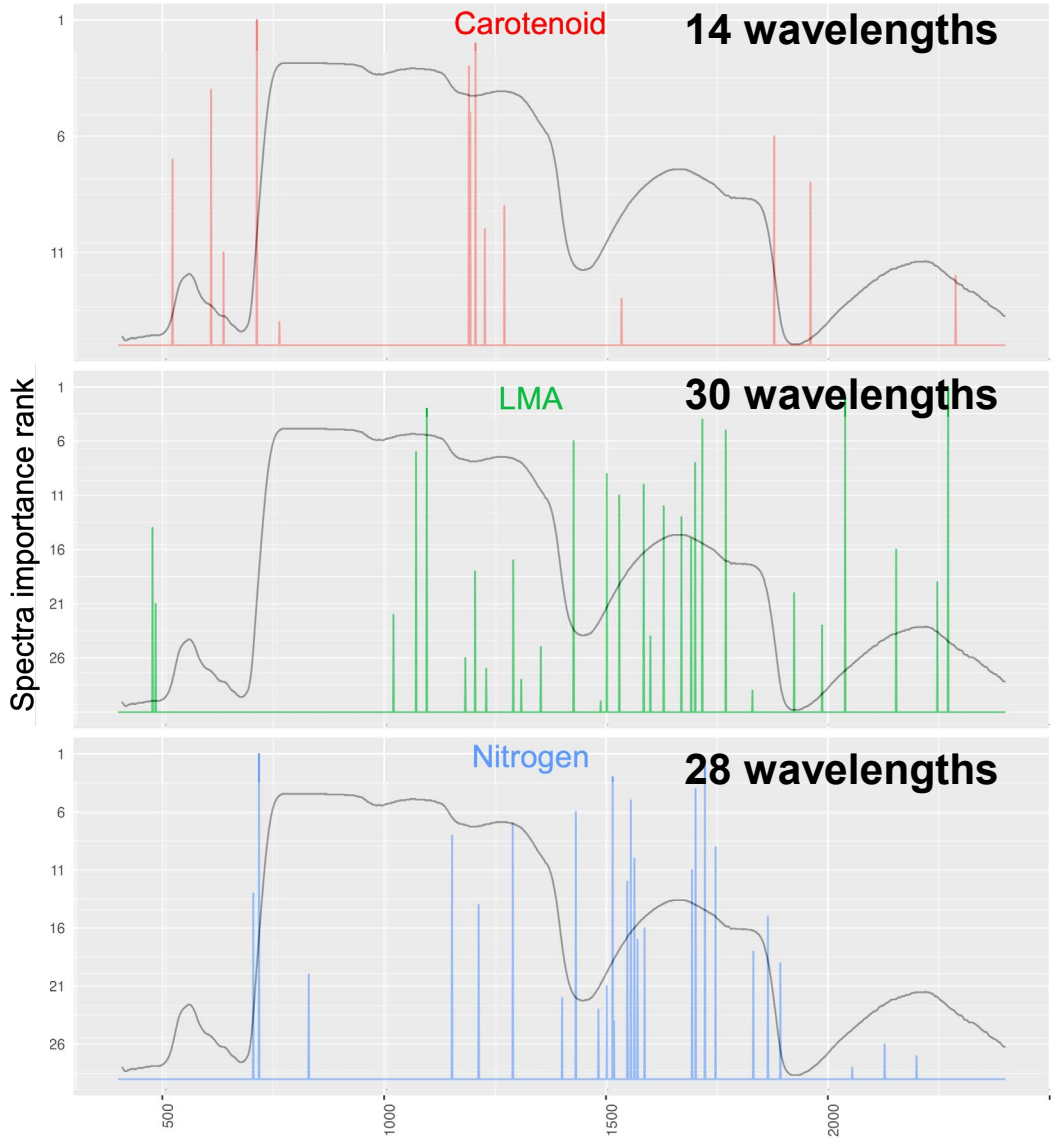


Kathuria et al. (under review)

Posterior predictions and relevant spectra
Leaf scale – ECOSIS (~ 2000 bands)

EcoSIS: Ecosystem Spectral Information System





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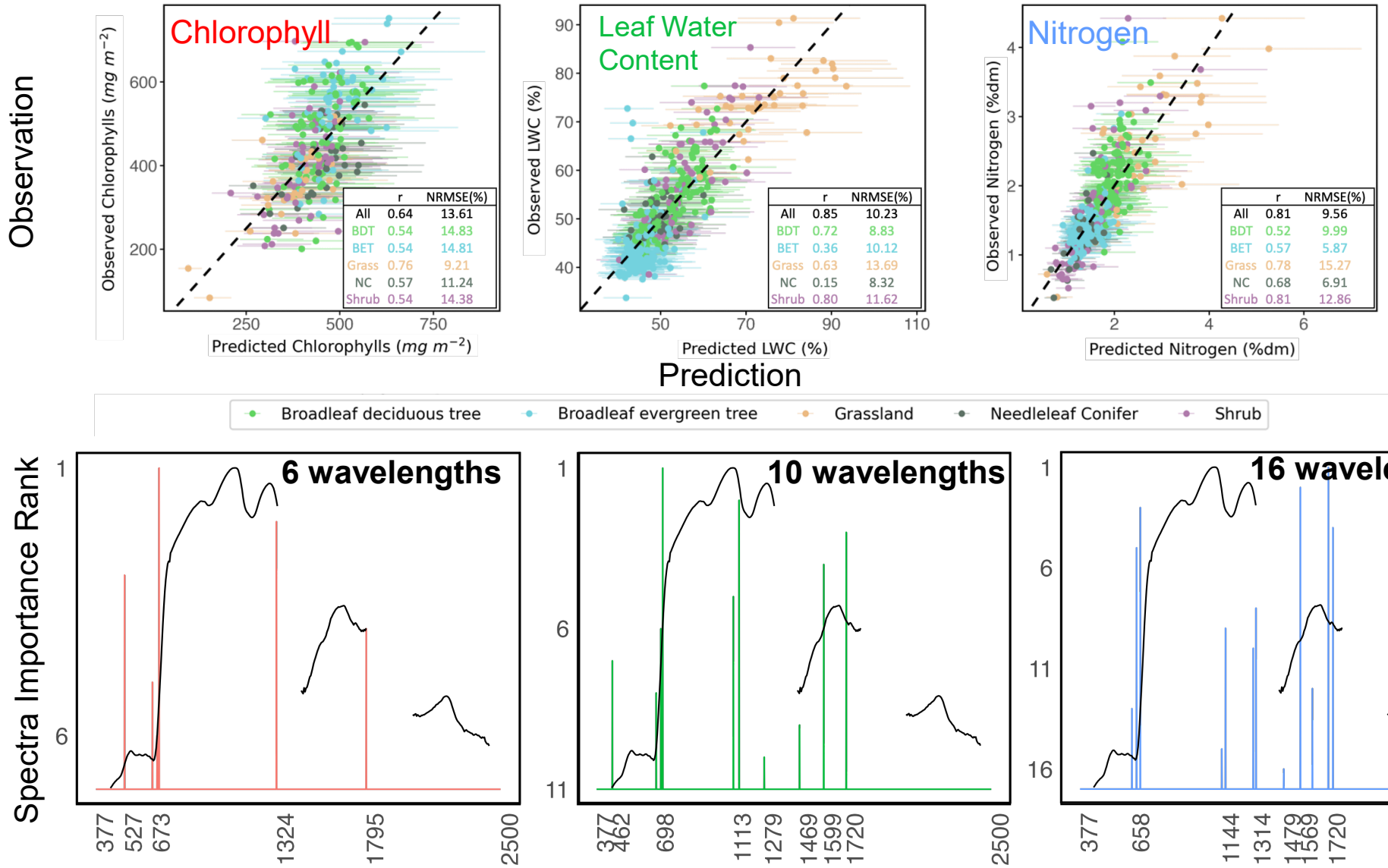
Posterior predictions and relevant spectra
Airborne scale – AVIRIS-NG (~ 400 bands)



Extensions to the Bayesian Approach

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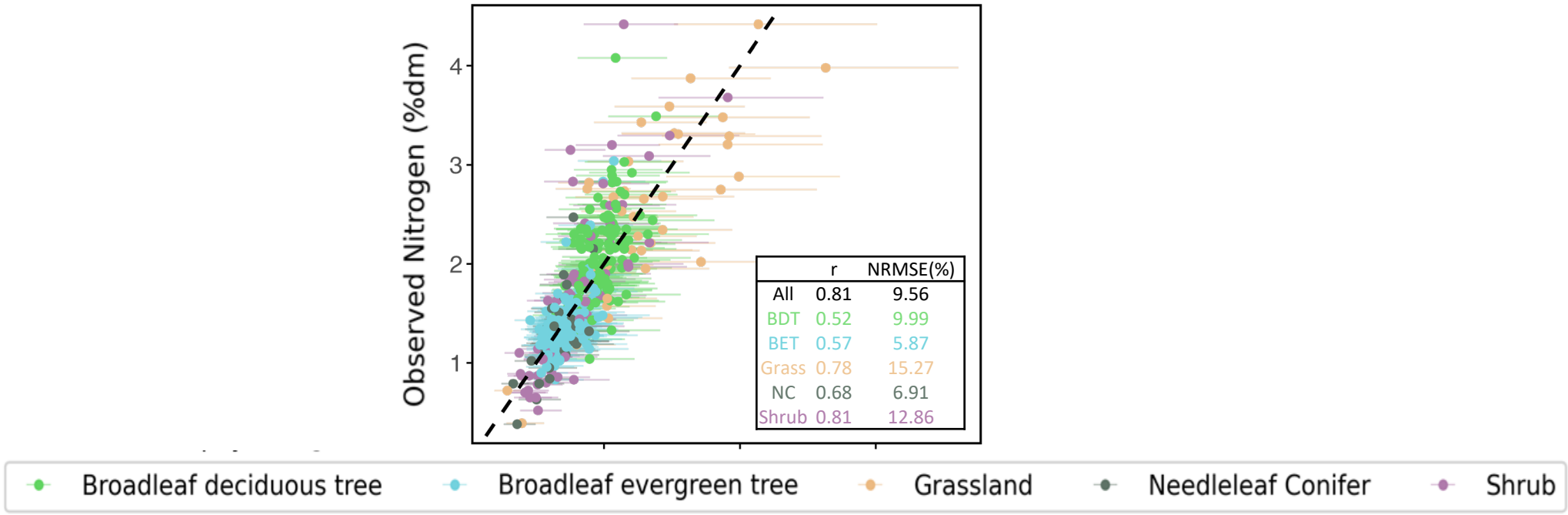
- Weighted Bayesian regression based on under-sampled plant forms



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- Weighted Bayesian regression based on under-sampled plant forms in training data.
- Hierarchical Modeling to model group-specific variations (such as at broadleaf, needle leaf, etc.)

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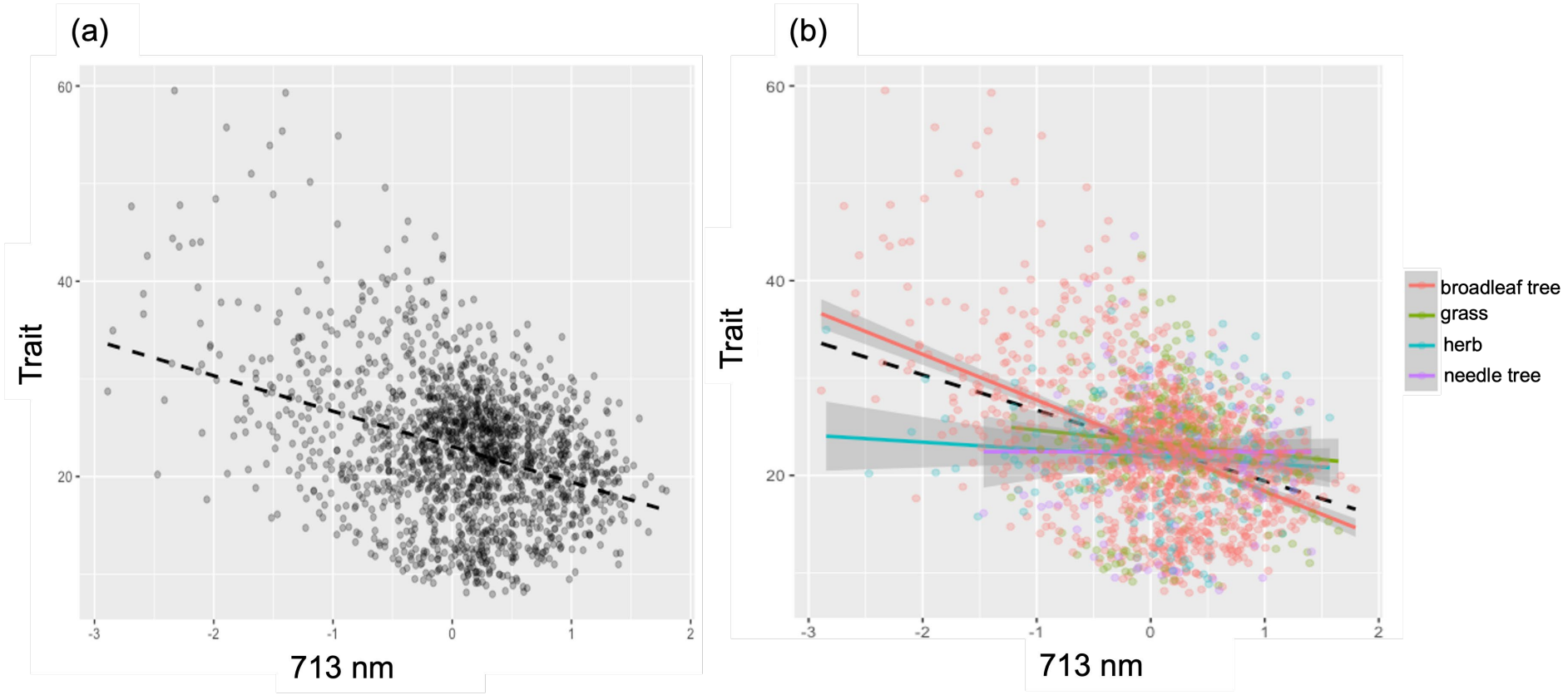

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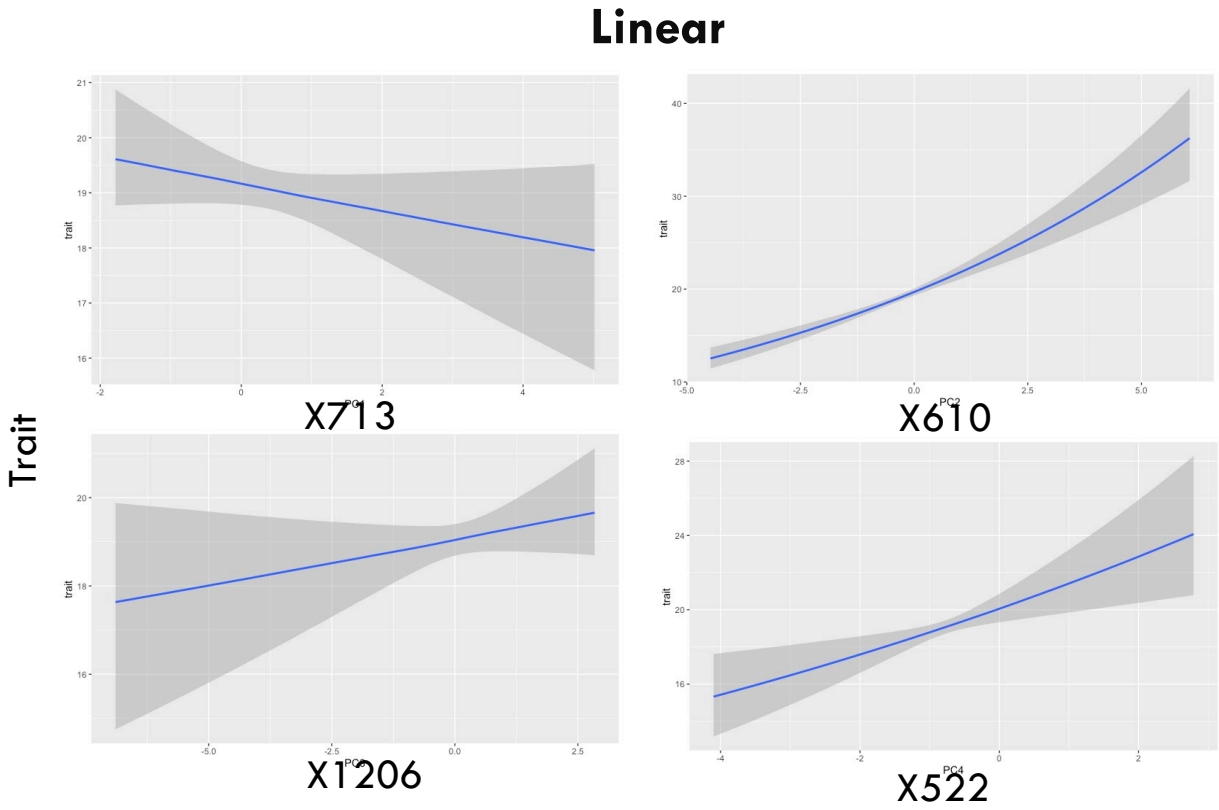

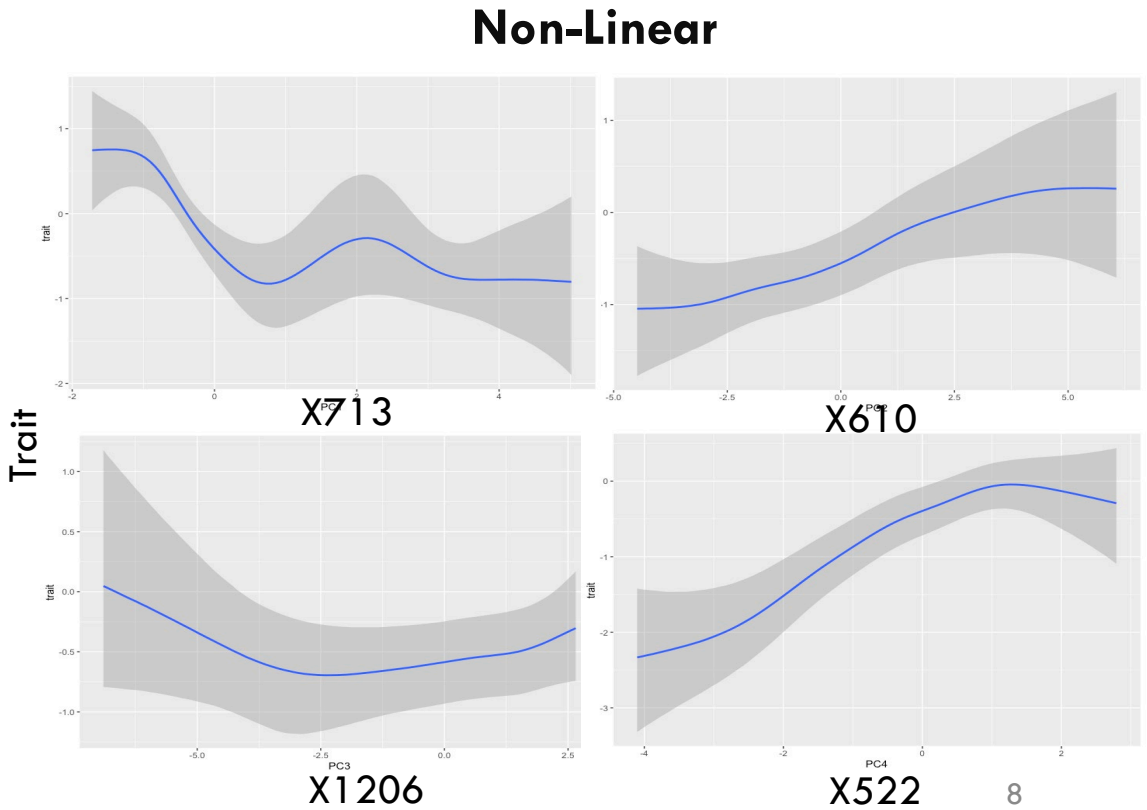

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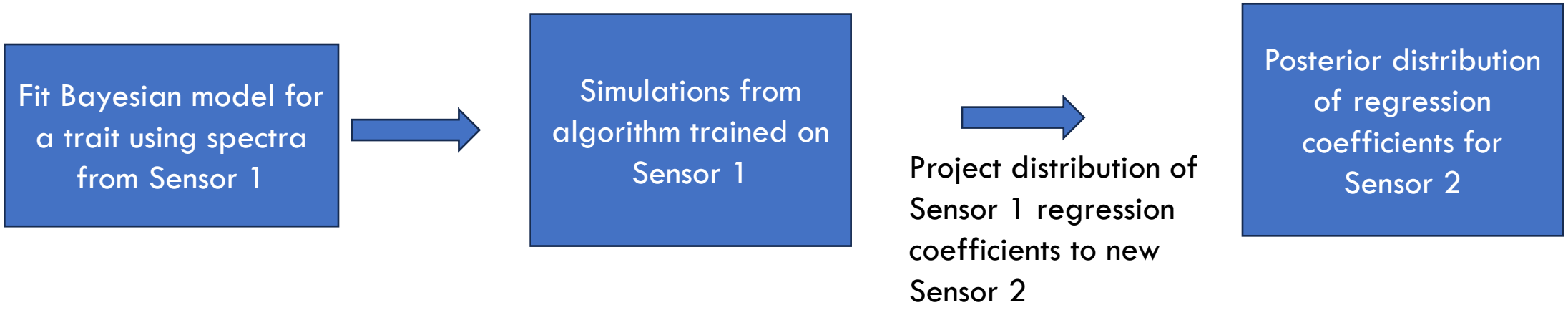
- Non-linear effects of spectra on traits using kernels.
- Developing **instrument-aware trait algorithms**, which harmonize trait predictions from one sensor (eg EMIT, SBG) to another (e.g., ENMAP, CHIME) without resampling spectra.



- W
- Hie
- Nc
- De

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spect

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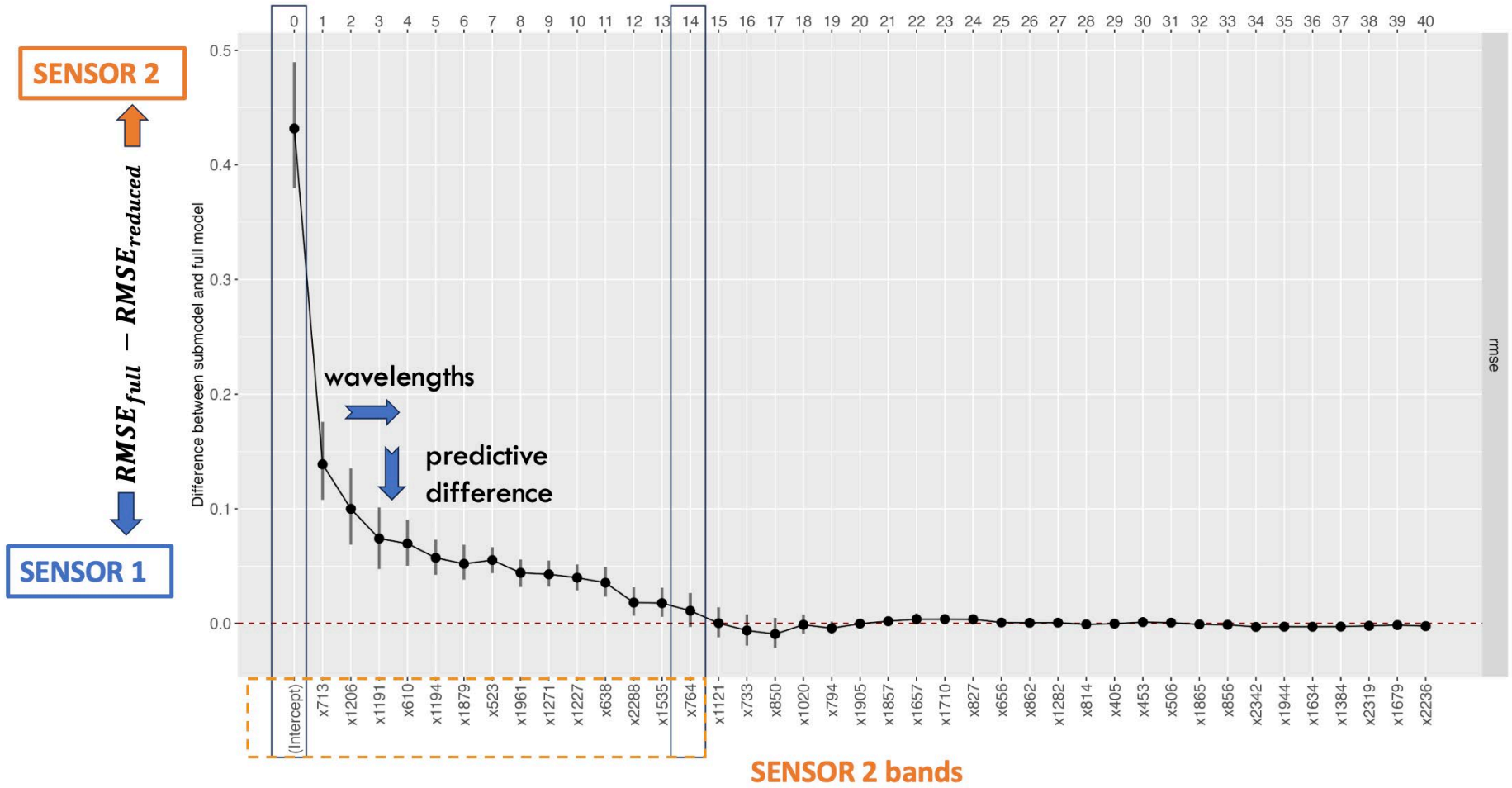


Fit Bayesian model for a trait using spectra from Sensor 1

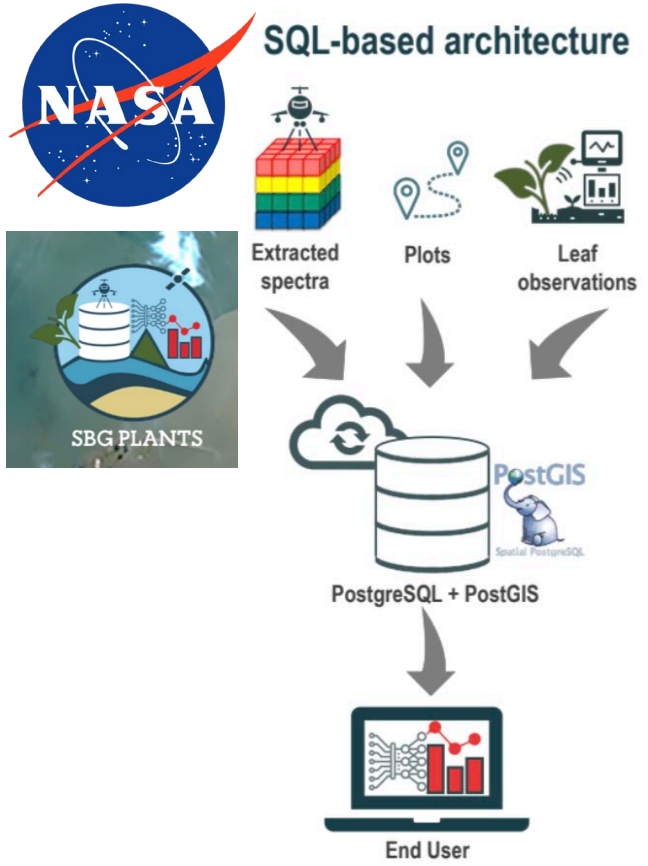
Simulations from algorithm trained on Sensor 1

Project distribution of Sensor 1 regression coefficients to new Sensor 2

Posterior distribution of regression coefficients for Sensor 2

Suggestions

- Global Open access database with paired data of traits and remote sensing spectra.
- Coordination of joint field campaigns to have coincident remote sensing spectra from more than one remote sensing instrument.



SBG PLANTS will integrate **field and airborne data** along with **metadata** and connect users interactively with tools to facilitate the **modelling of transferable and sensor-agnostic algorithms**. These algorithms are designed to retrieve the SBG VSWIR terrestrial ecosystem demonstration **products**, such as **chlorophyll**, **nitrogen**, and **leaf water content**.

Leads: **Yoseline Angel** (NASA Goddard)
Dana Chadwick (NASA JPL)

THANKYOU