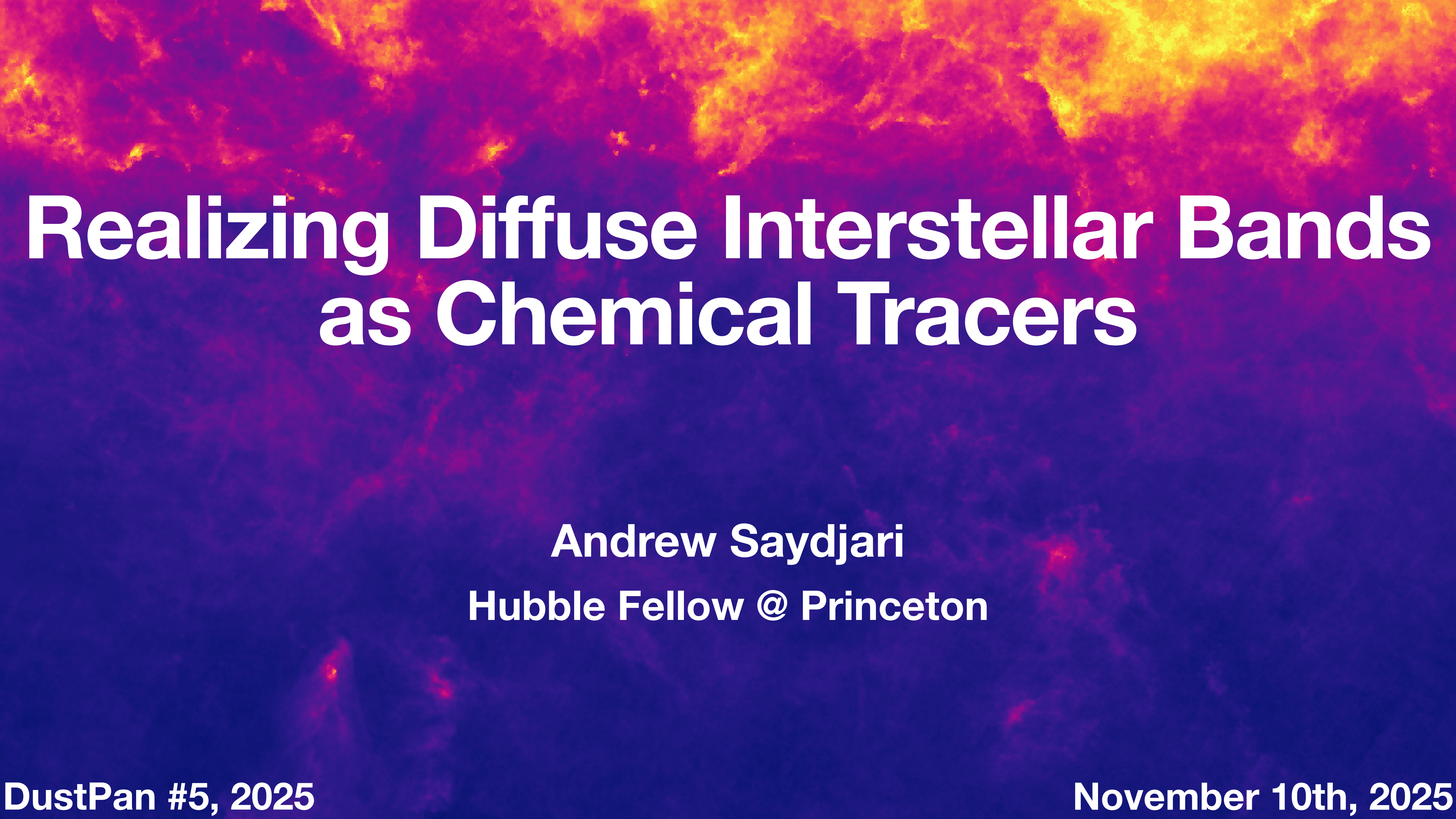


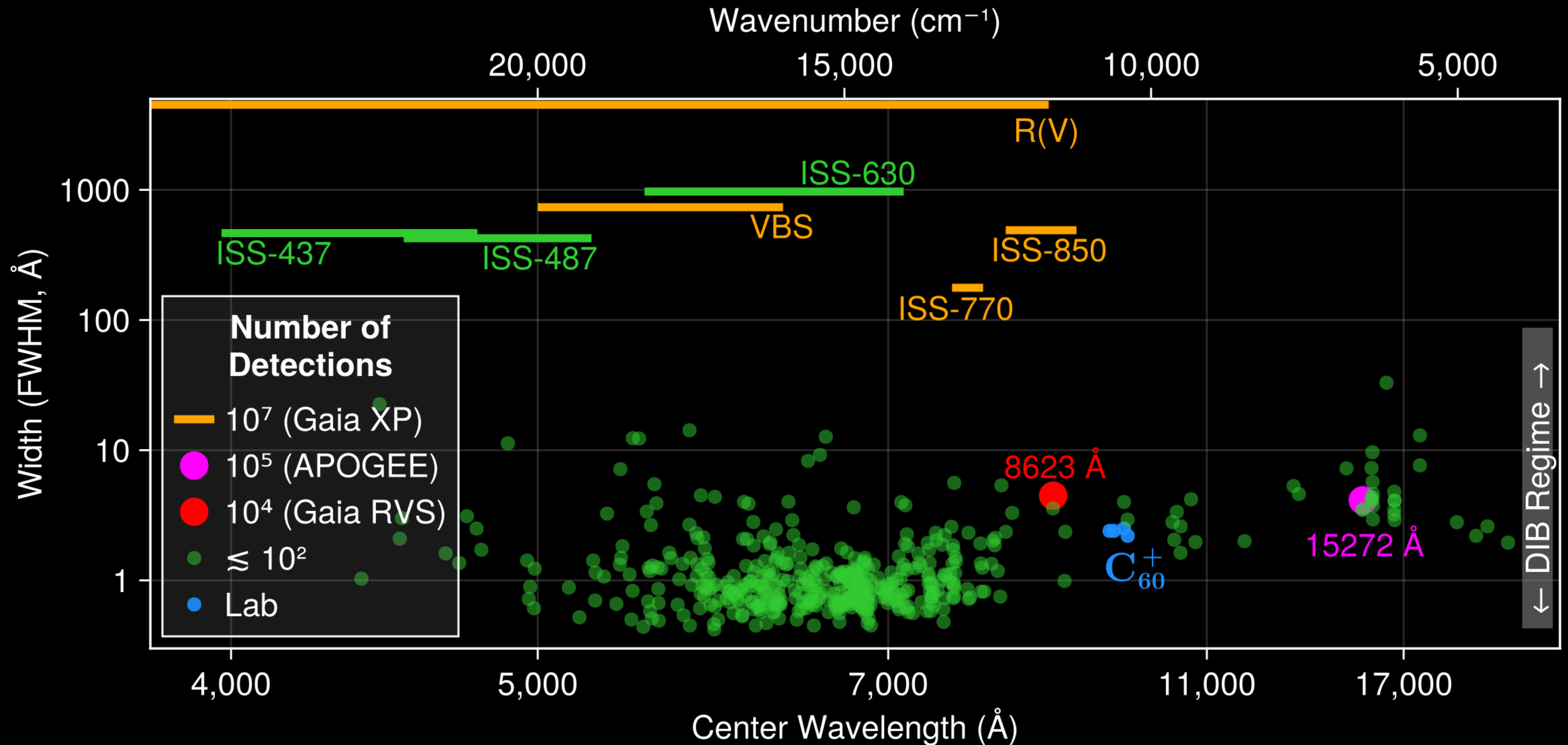


Realizing Diffuse Interstellar Bands as Chemical Tracers

Andrew Saydjari
Hubble Fellow @ Princeton

**Does the chemical composition of dust also
change with $R(V)$ variation?**

Extinction Curve Features: Across all Scales!



Broad Feature Catalog: GaiaXP

Cov-aware PCA

Interpretation:

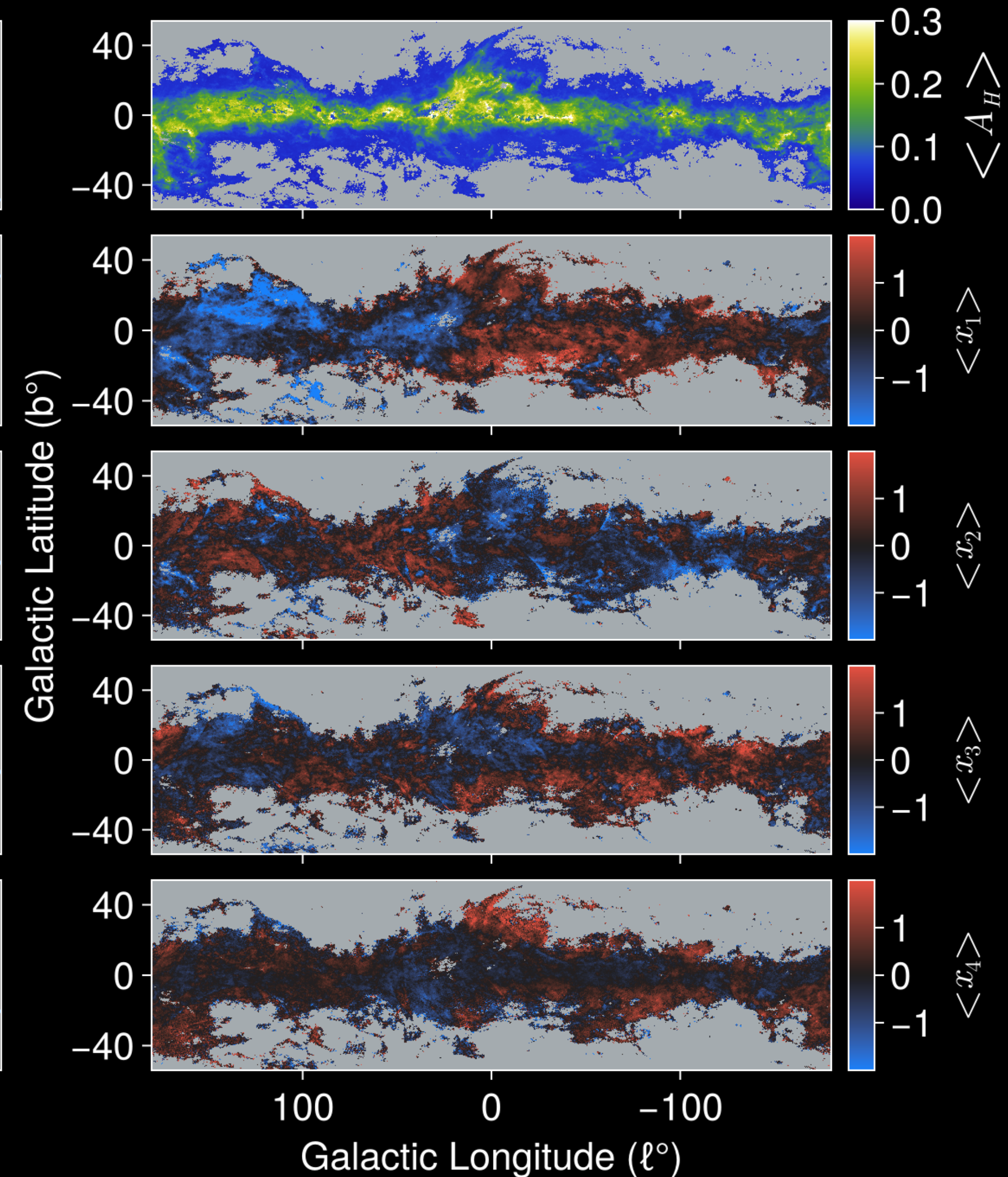
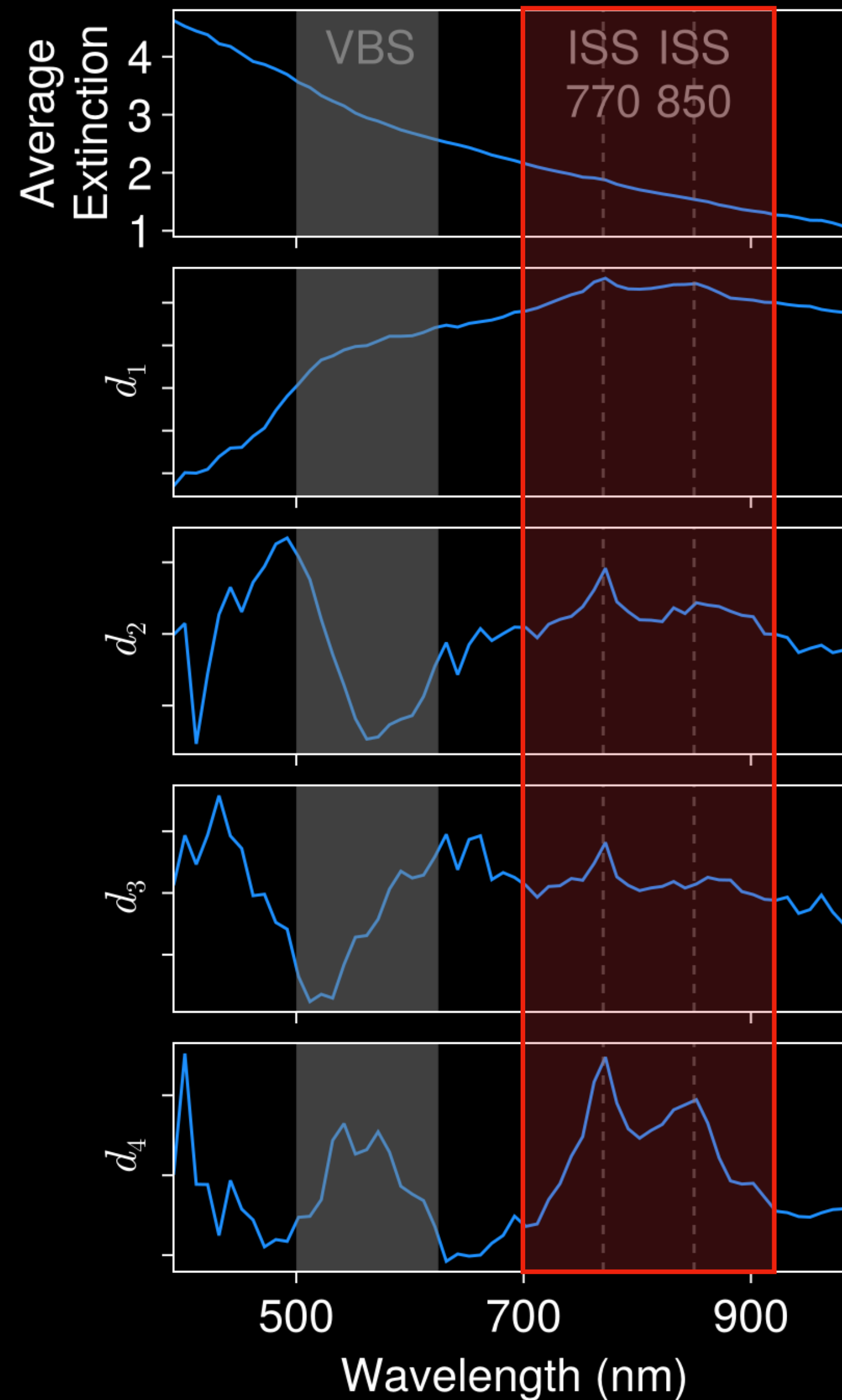
$$x_1 \propto R(V)$$

x_i parameterize
ISS variation

Key Choice:

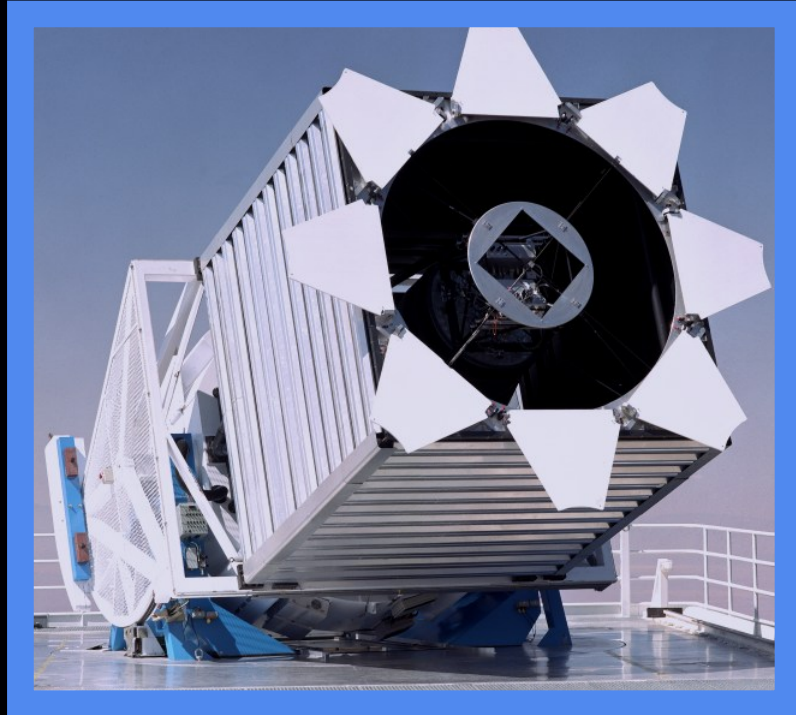
**All of the ISS
Point Up**

Green+2025

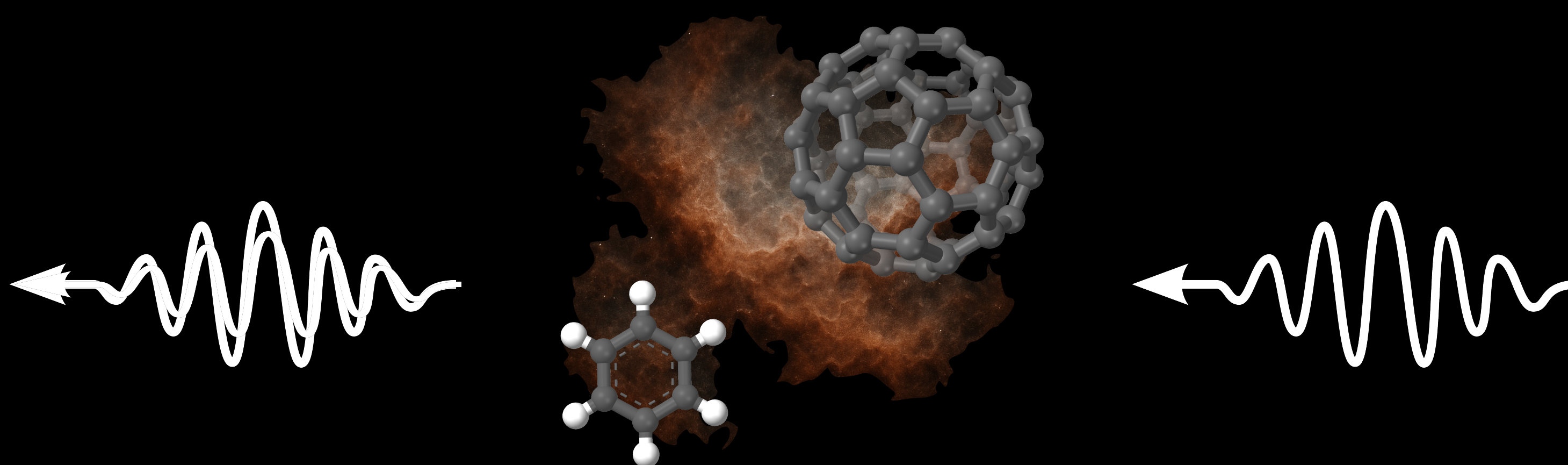
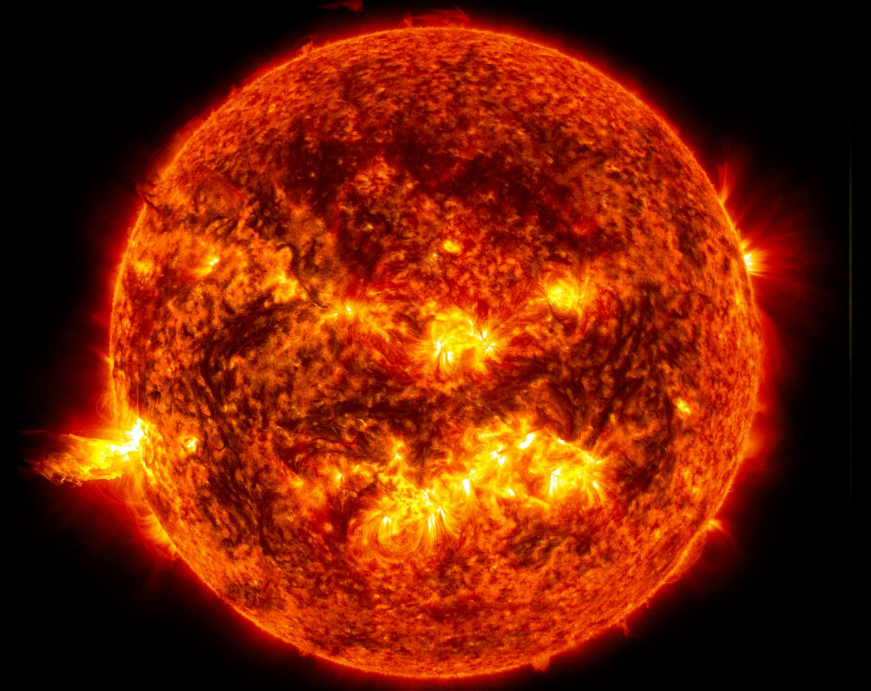


Diffuse Interstellar Bands

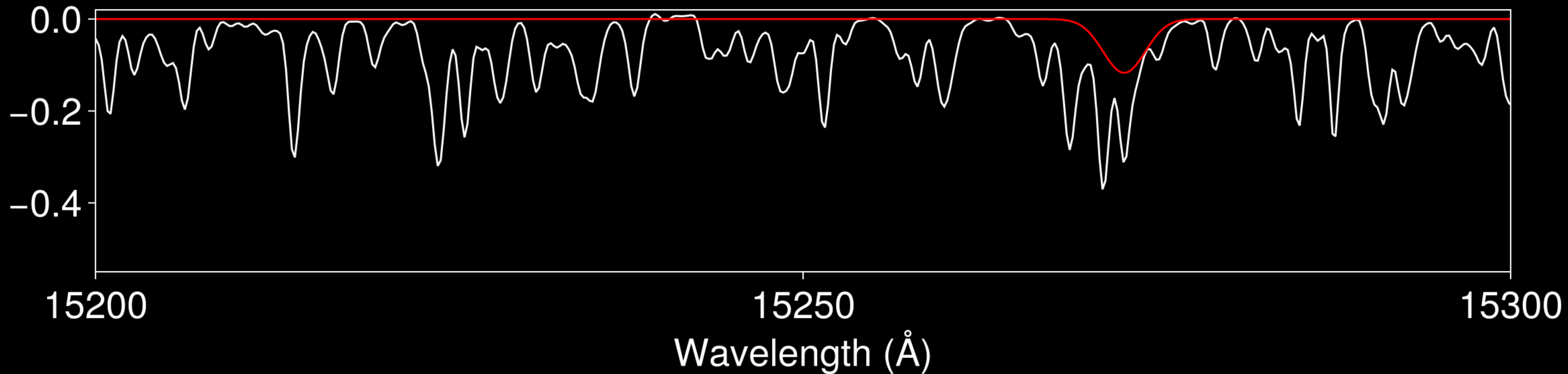
APOGEE
2.5m, NM



Star



Fraction Absorbed



Narrow Feature Catalog: APOGEE

Observed
Spectrum



Sum
Exactly

=

to the
Data!

Sky

Continuum



+

Lines



+

Continuum



x

Star

Lines



x

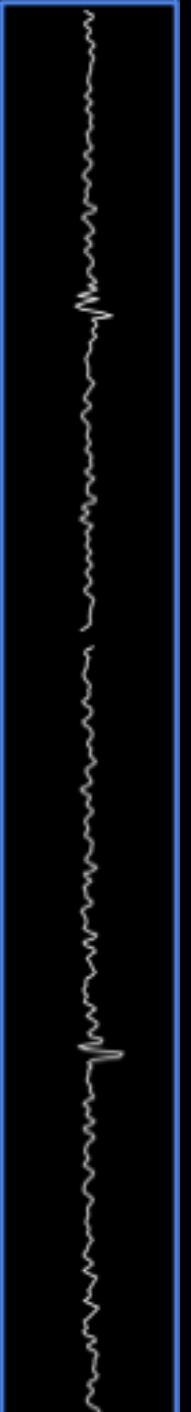
ISM

Absorption



+

Residual



Sky Fibers

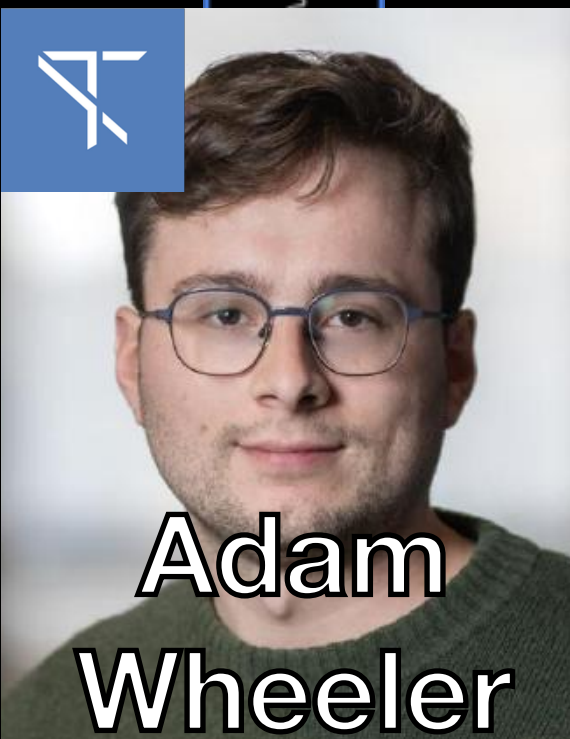
Hot
Stars

Hybrid:
Theory/Data

Gaussian

Ran all DR17 visits (2.6 M)

Fast: 7s/star <https://star.jl>



Adam
Wheeler

Residuals Correlating with Extinction

Residuals

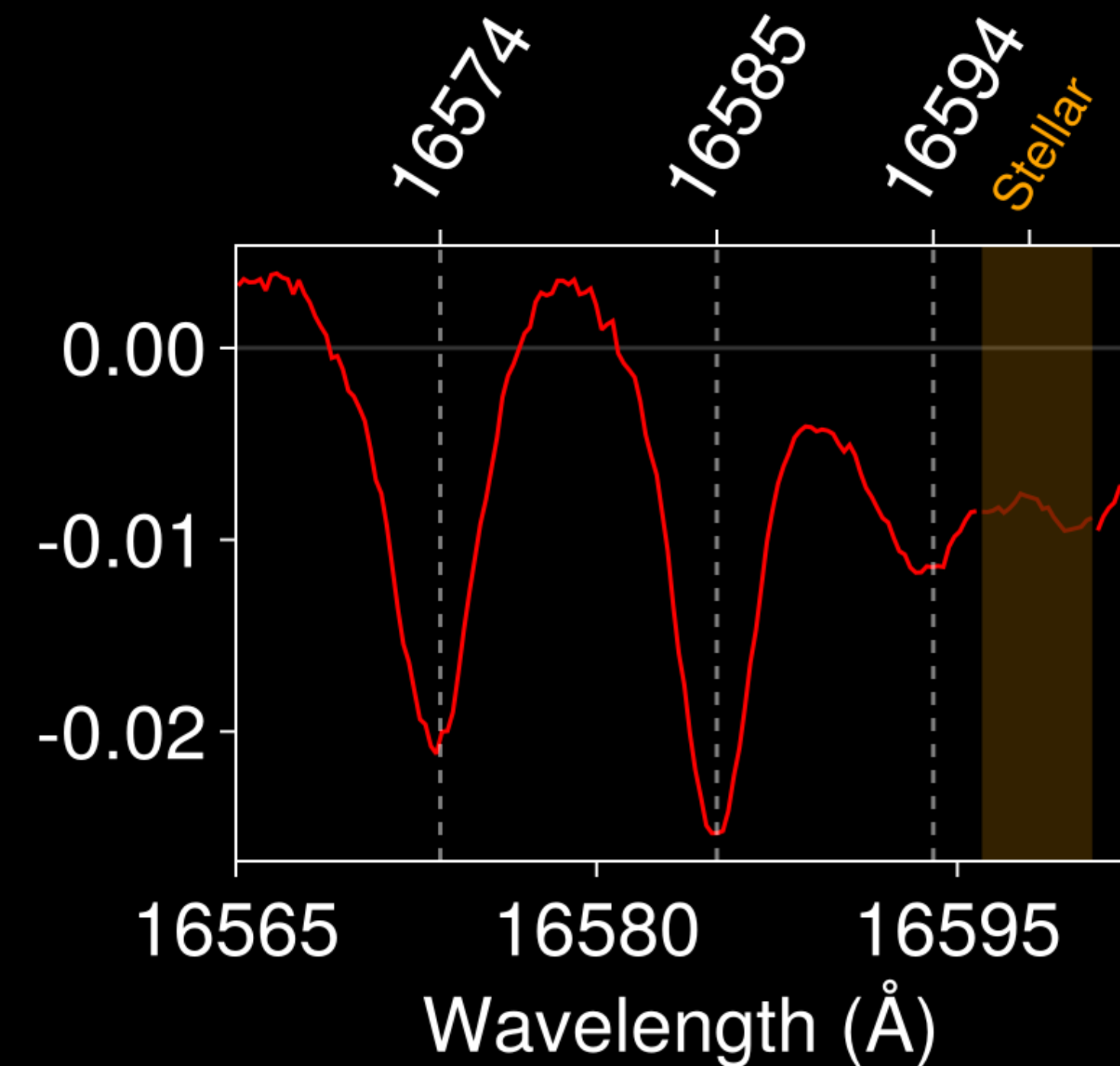
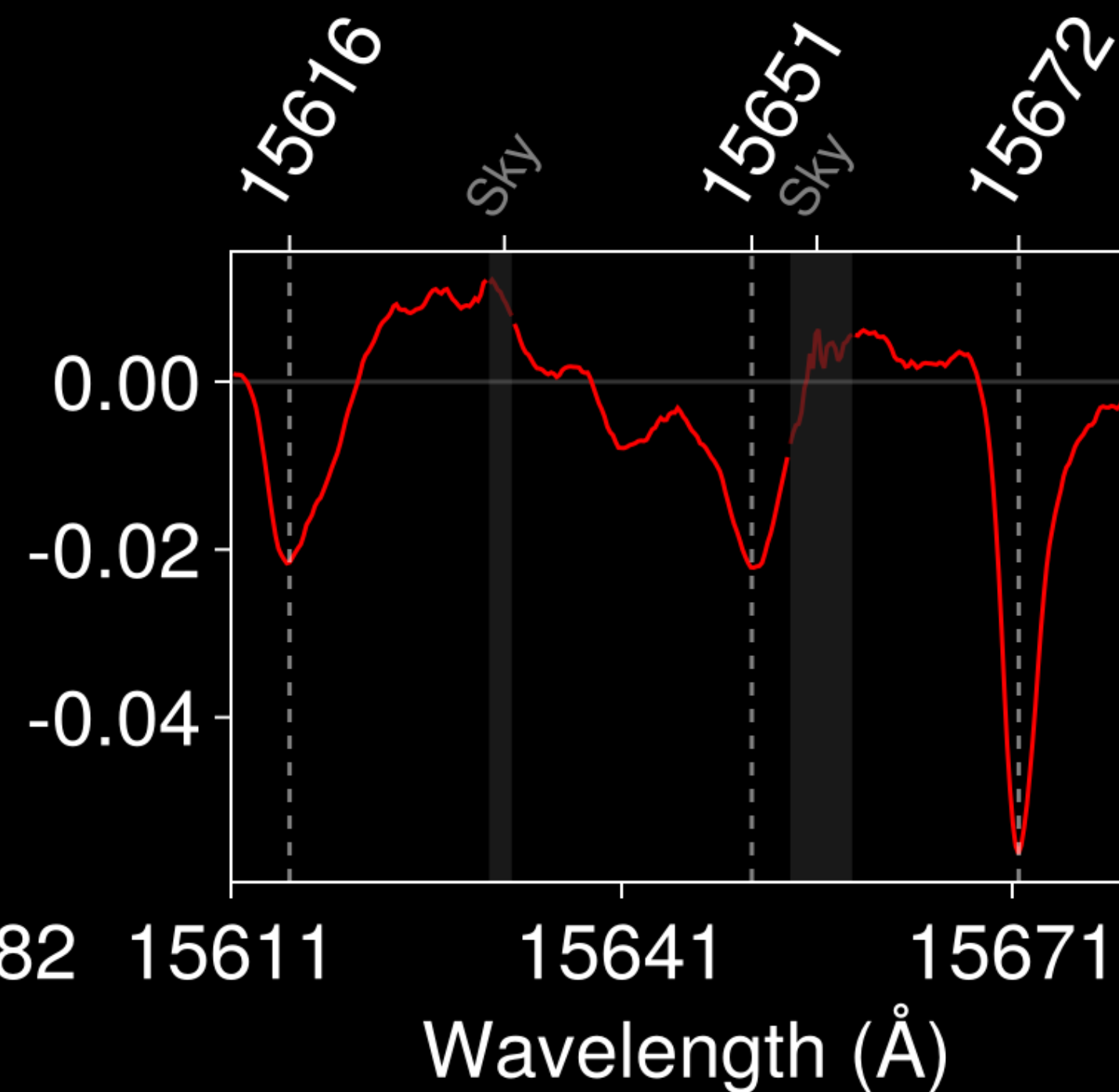
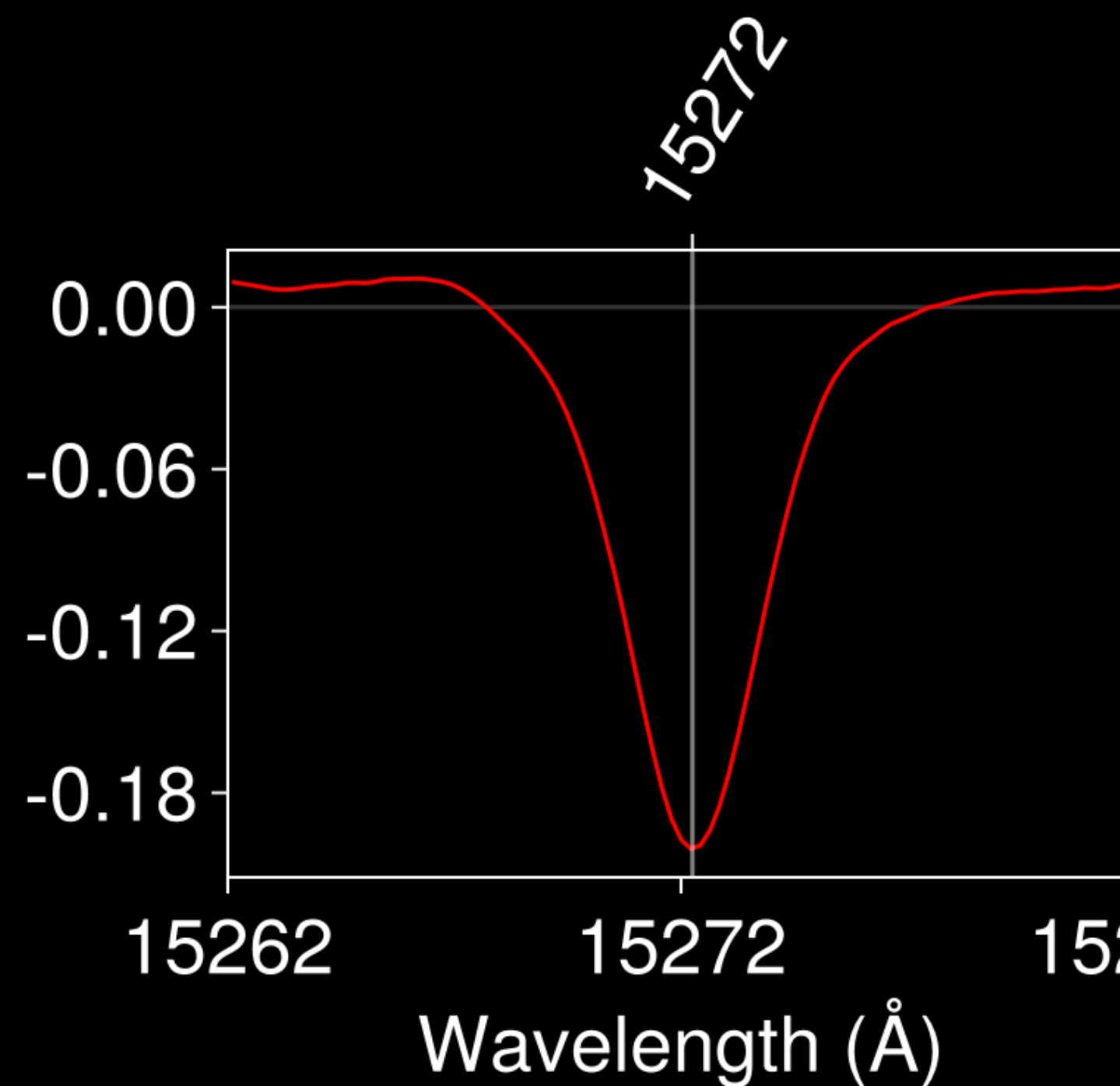
Slope

Extinction

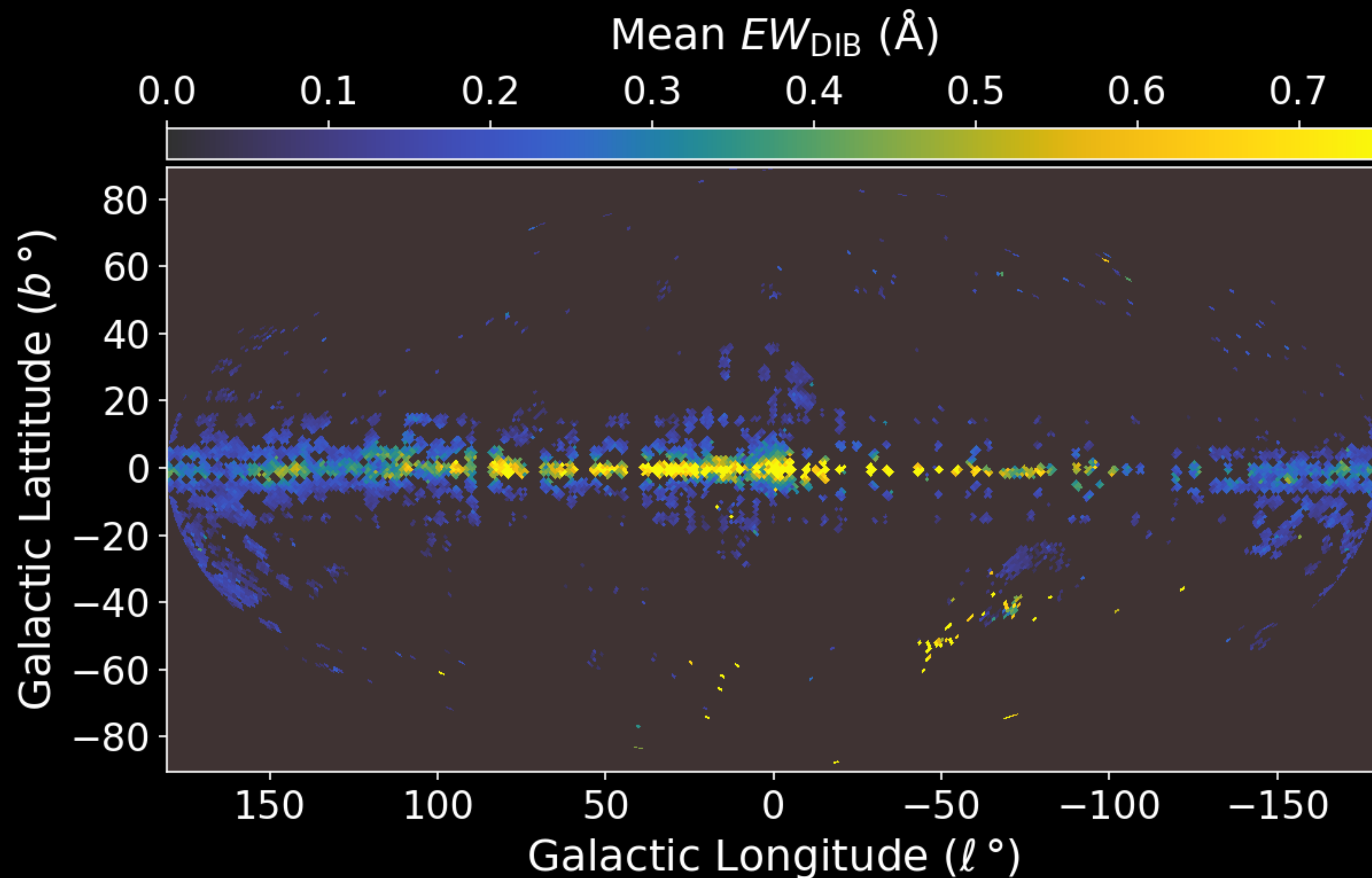
Linear Response Model:

$$r(\lambda) \equiv \frac{\delta F}{F}(\lambda) \approx \frac{dr}{dA_H}(\lambda) \times A_H$$

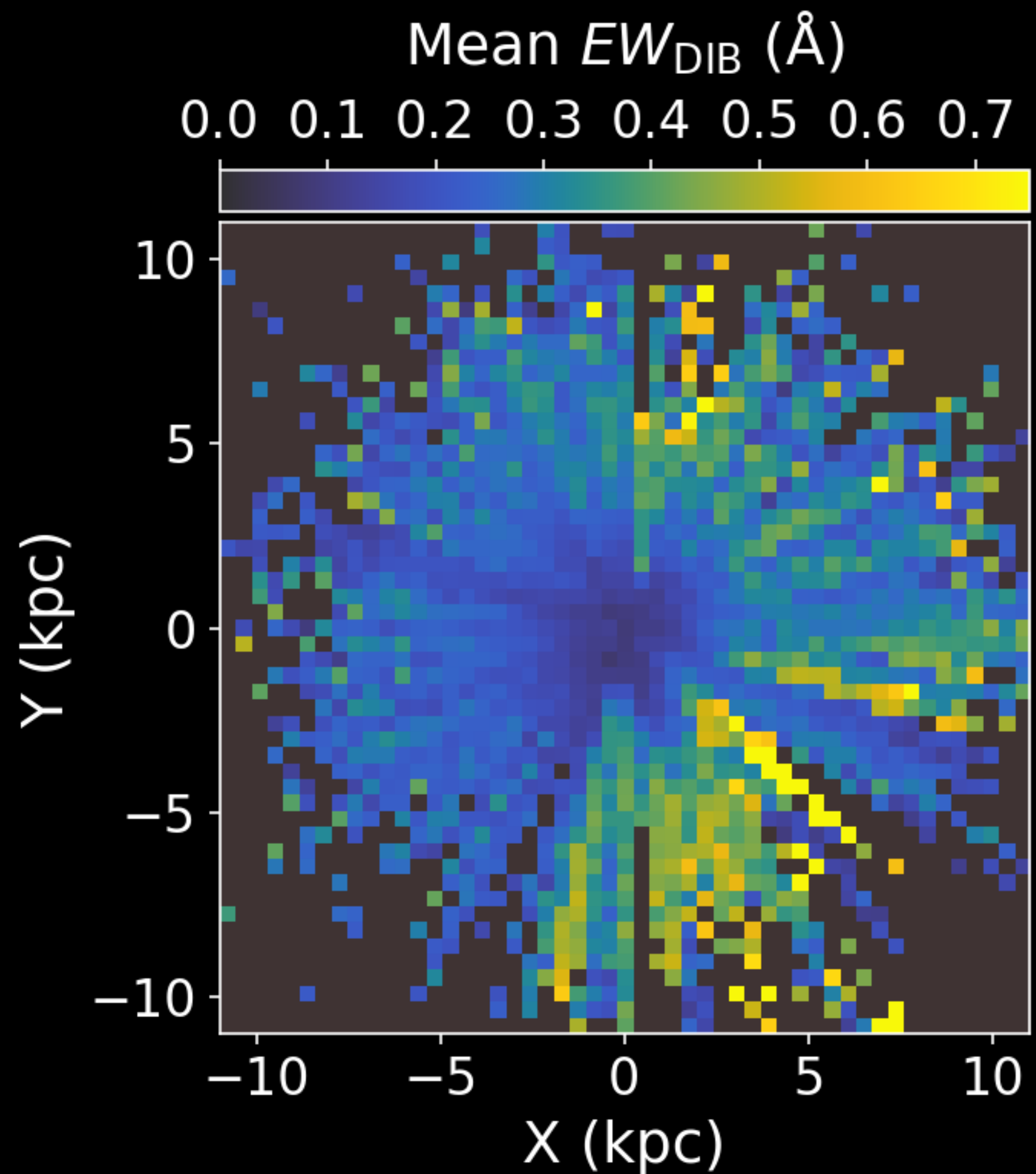
$$\frac{dr}{dA_H}(\lambda)$$



DIB Catalog: Spatial Distribution

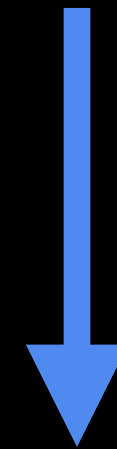


Largest DIB Catalog:
~150 K Detections of 15272 $\text{\AA}$ DIB



SDSS-V:
~5x Expected!

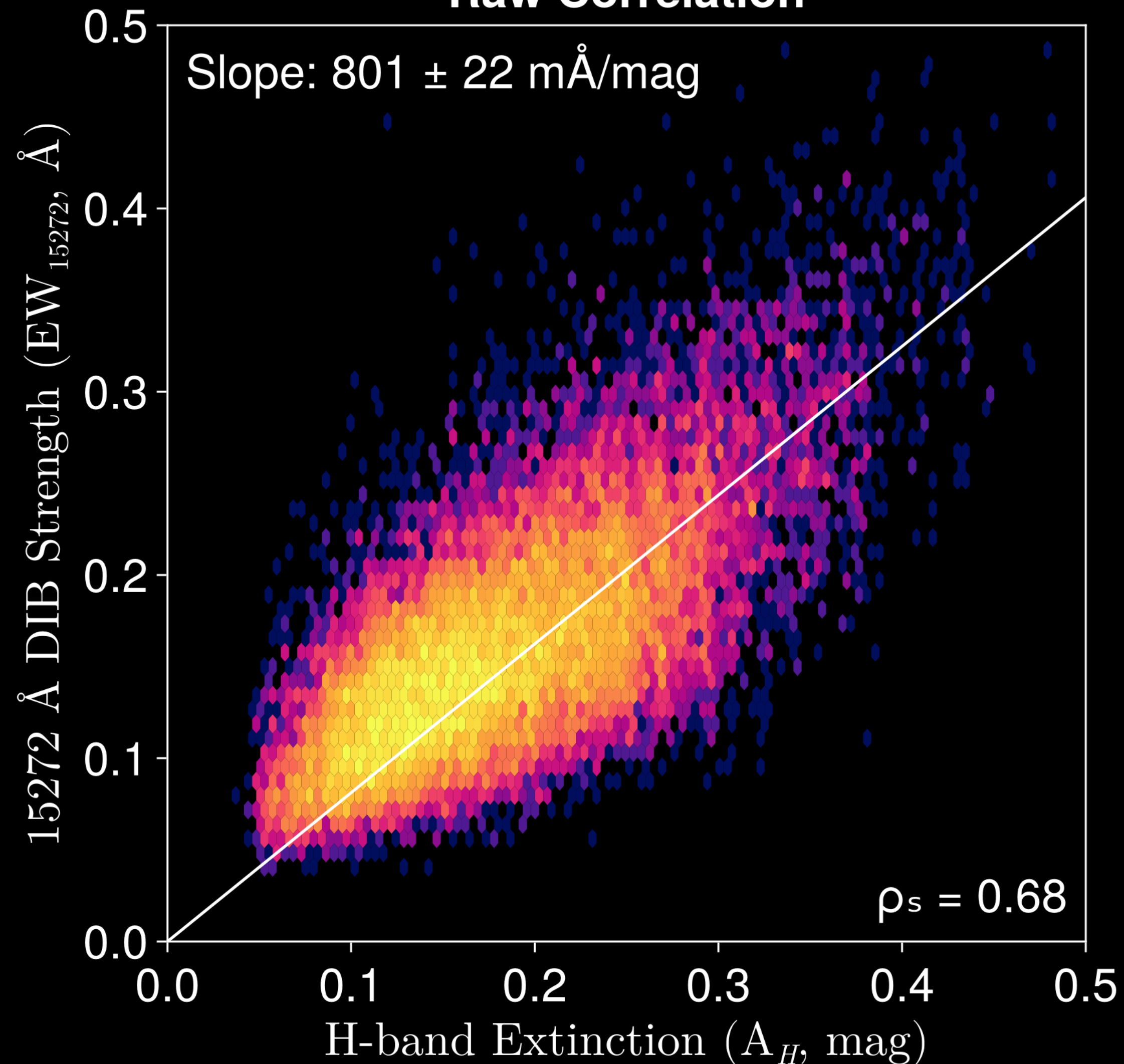
Does the chemical composition of dust also change with $R(V)$ variation?



Does scatter in DIB strength vs. extinction correlate with $R(V)$?

How much of this scatter is real?

Raw Correlation



Need robust uncertainties to answer!

Conventional Model

DIB Strength

Slope

Extinction

$$EW \approx \frac{dEW}{dA_H} \times A_H + \sum_{i=1}^4 \frac{dEW}{dA_H dx_i} \times x_i A_H$$

Slope

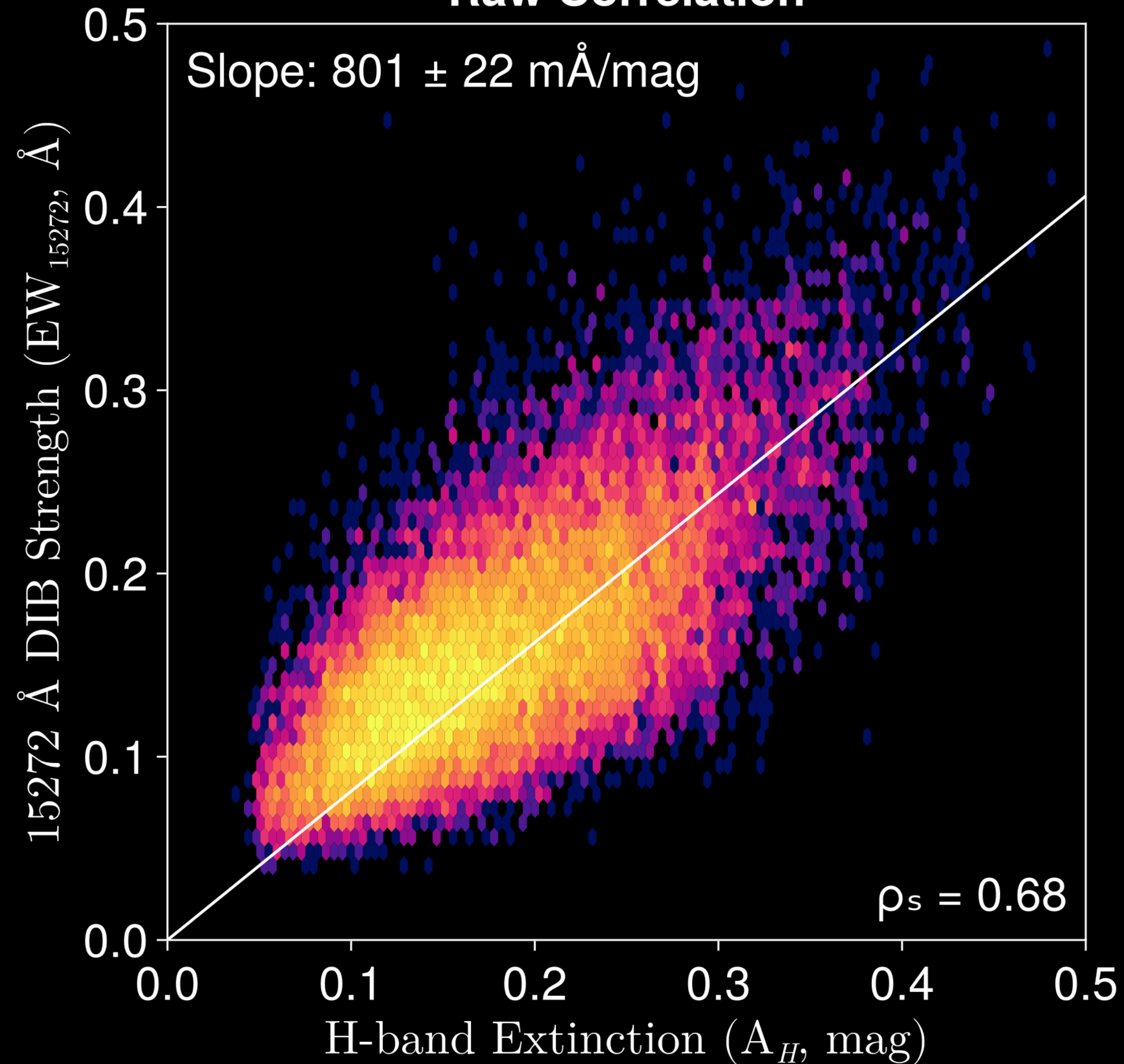
Extinction Curve Parameters

Model Expansion:

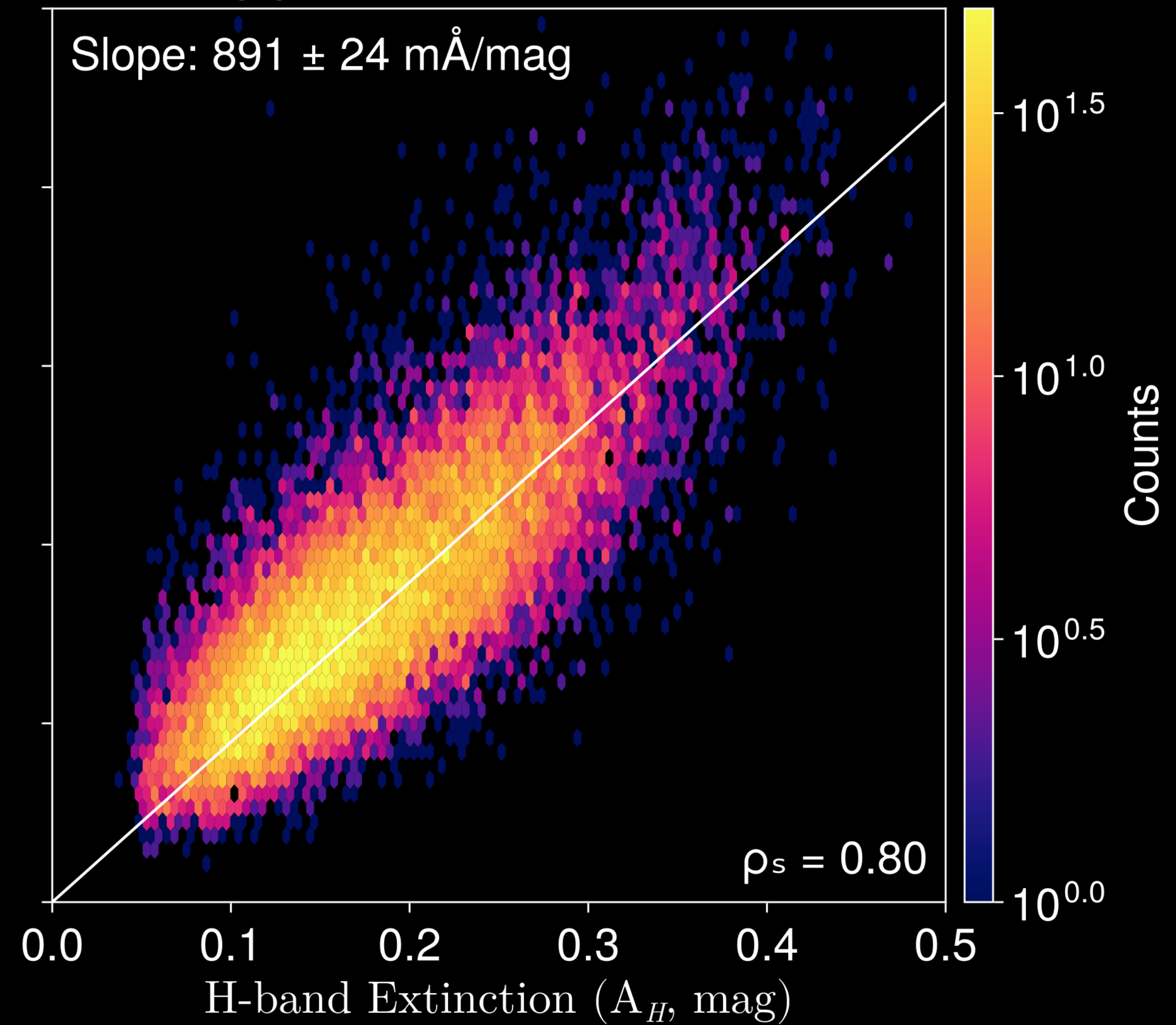
What if we include R(V)+?

How much of this scatter is real?

Raw Correlation



R(V)+ Corrected Correlation



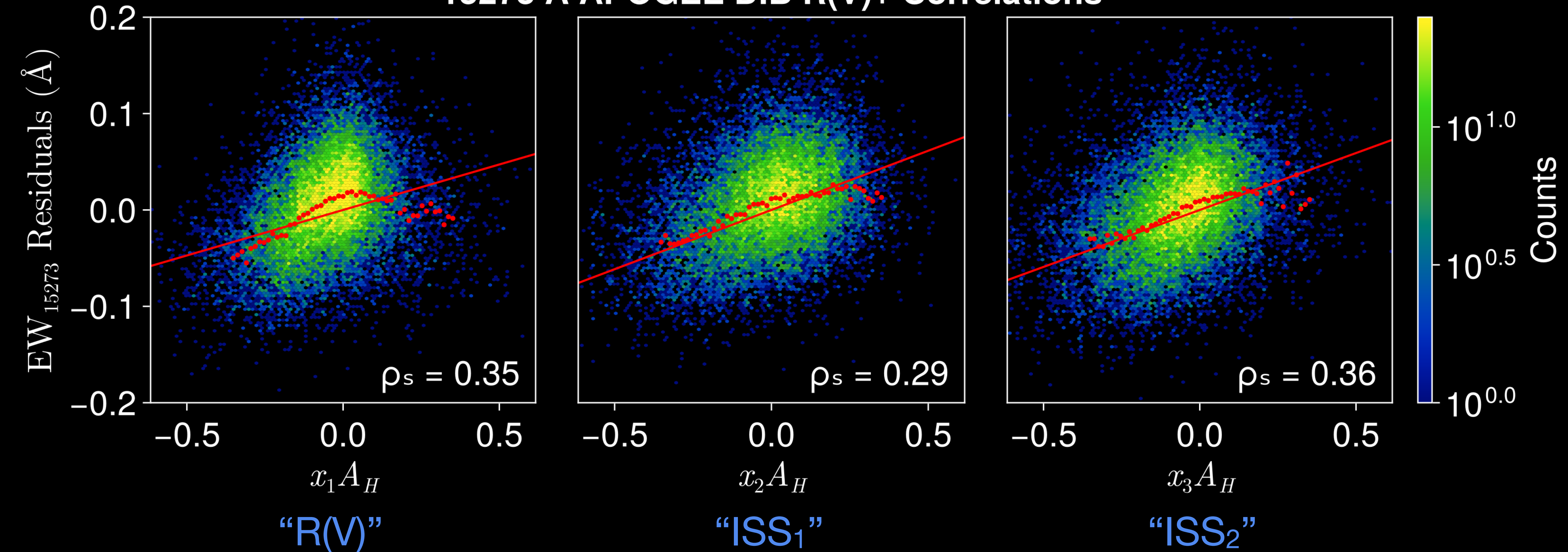
Need robust uncertainties to answer!

~20% Change in Predicted EW!

Extinction Features Correlate Across all Scales!

$$EW \approx \frac{dEW}{dA_H} \times A_H + \sum_{i=1}^4 \frac{dEW}{dA_H dx_i} \times x_i A_H \quad \text{DIB strengthens as ISS strengthens!}$$

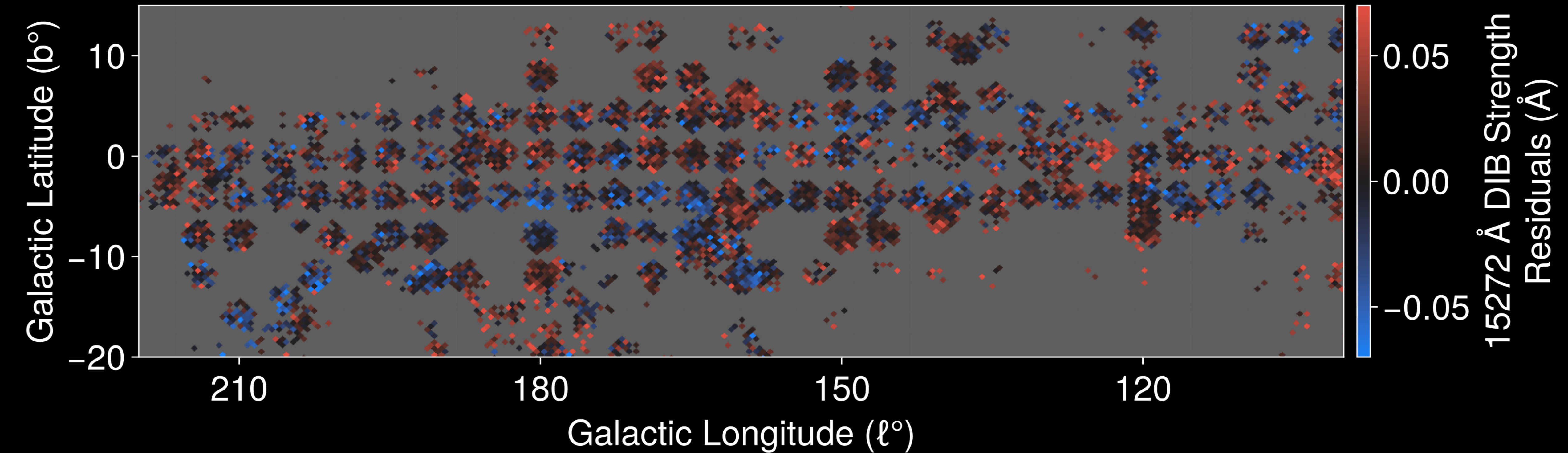
15273 Å APOGEE DIB R(V)+ Correlations



Significantly Reduces Spatial Structure

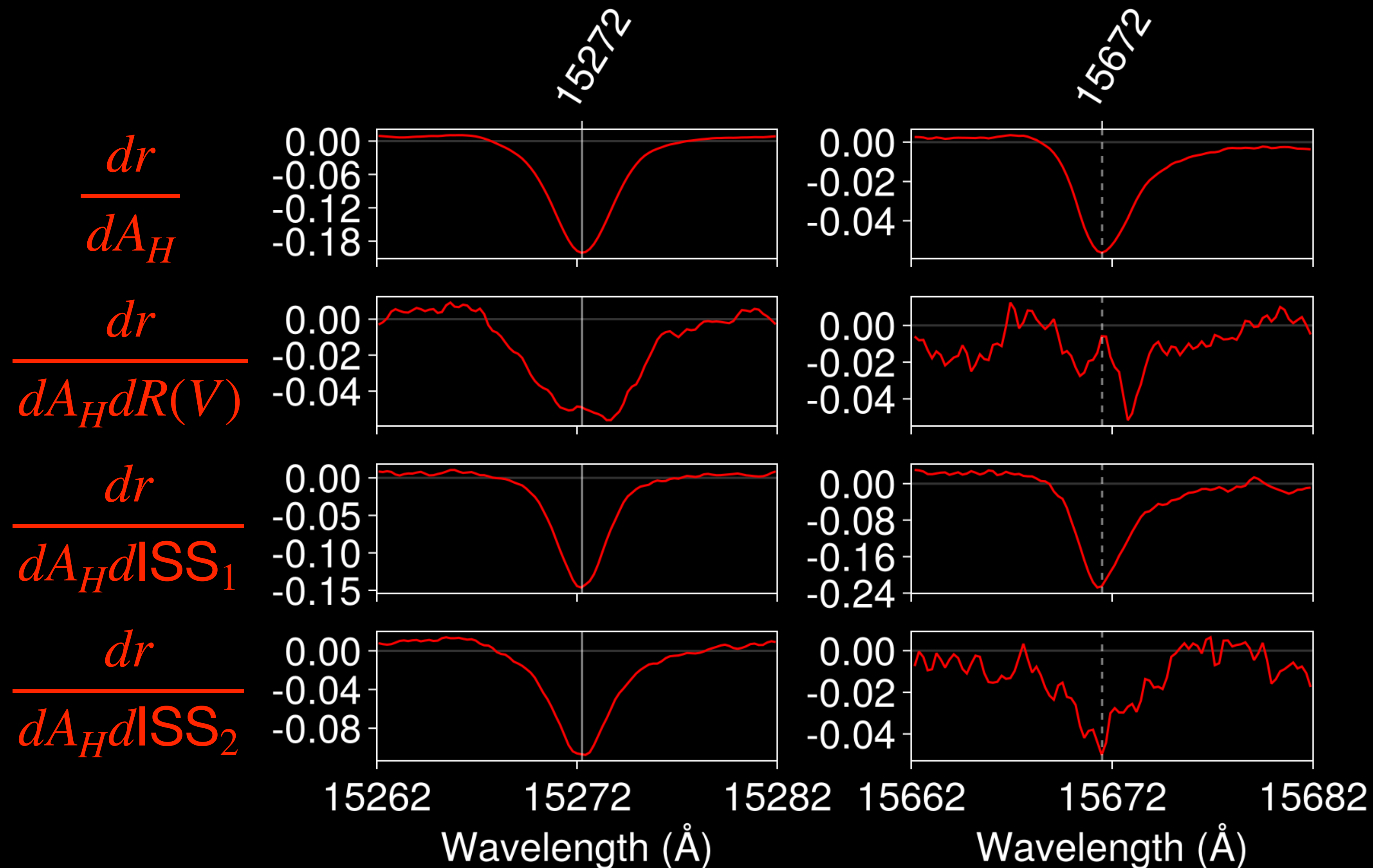
$$EW \approx \frac{dEW}{dA_H} \times A_H \quad \longrightarrow \quad EW \approx \frac{dEW}{dA_H} \times A_H + \sum_{i=1}^4 \frac{dEW}{dA_H dx_i} \times x_i A_H$$

R(V)+



$$\frac{\delta F}{F}(\lambda) \approx \frac{dr}{dA_H}(\lambda) \times A_H \quad \longrightarrow \quad \frac{\delta F}{F}(\lambda) \approx \frac{dr}{dA_H}(\lambda) \times A_H + \sum_{i=1}^4 \frac{dr}{dA_H dx_i}(\lambda) \times x_i A_H$$

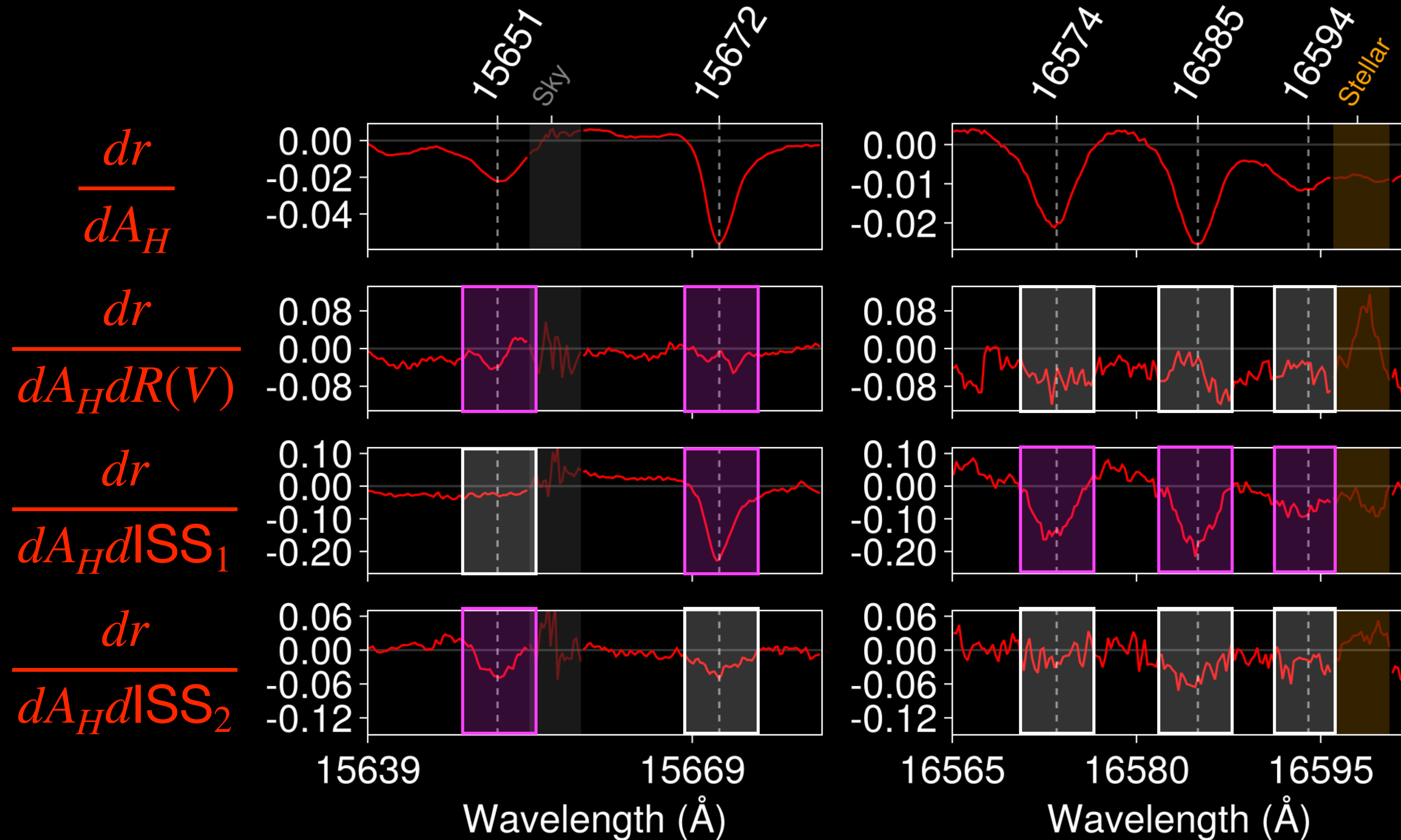
Response Function of Spectral Residuals



$$\frac{\delta F}{F}(\lambda) \approx \frac{dr}{dA_H}(\lambda) \times A_H + \sum_{i=1}^4 \frac{dr}{dA_H dx_i}(\lambda) \times x_i A_H$$

2 Principal Components of Response Function

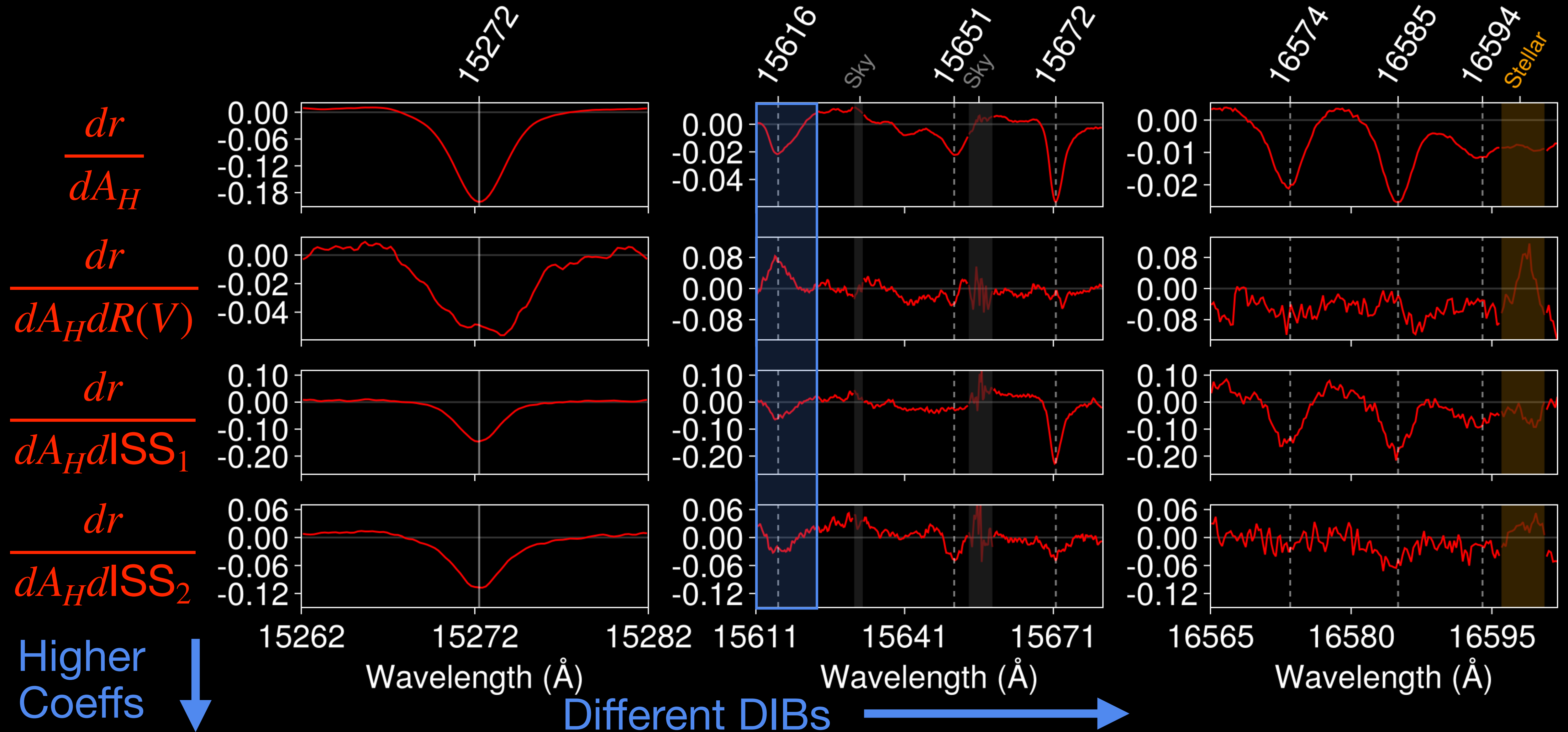
Different DIB Response “Signatures”



DIBs are separated by the “signature” of their responses

Different signatures imply different chemistries or ionizations

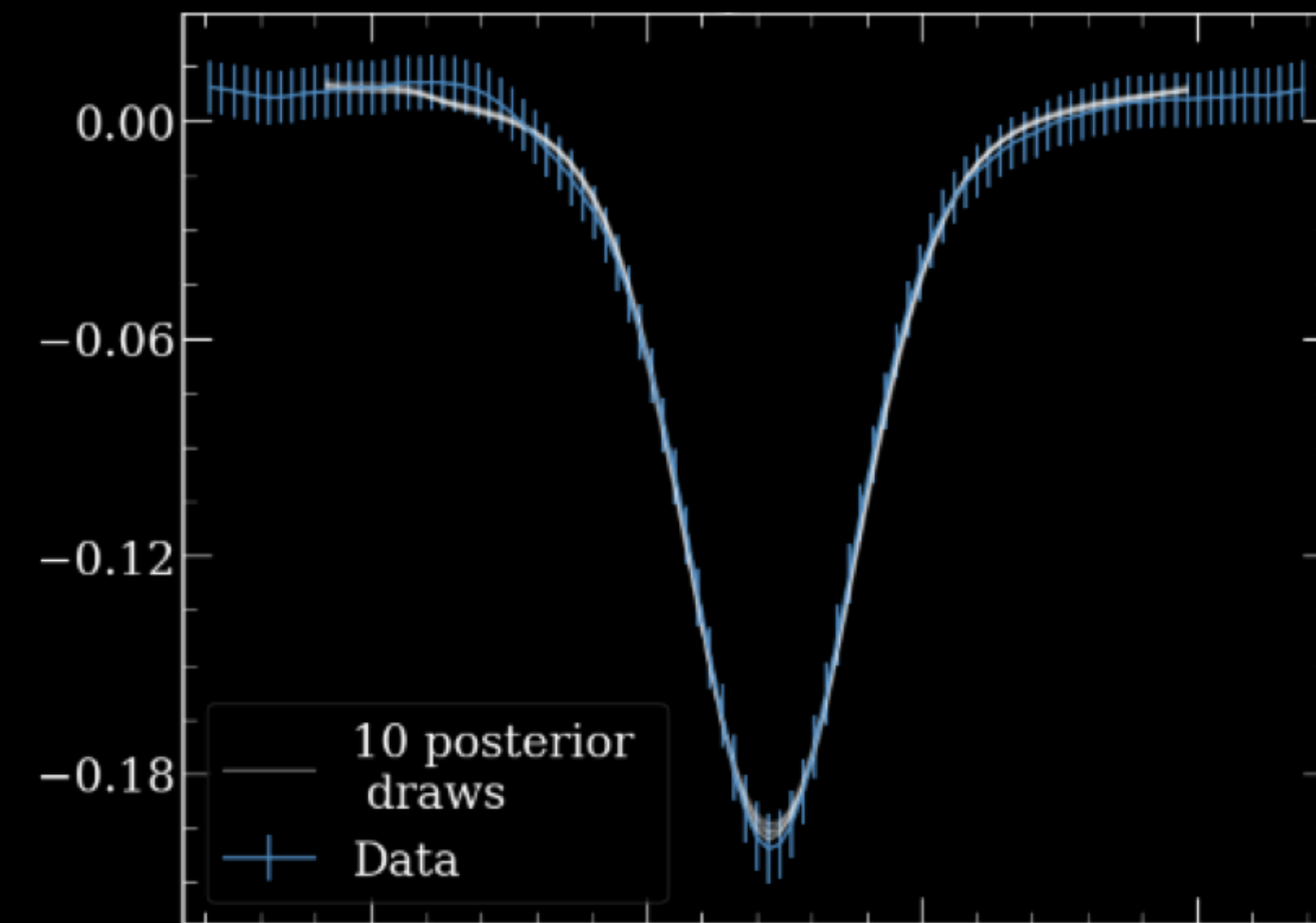
Chemical Composition Variation!



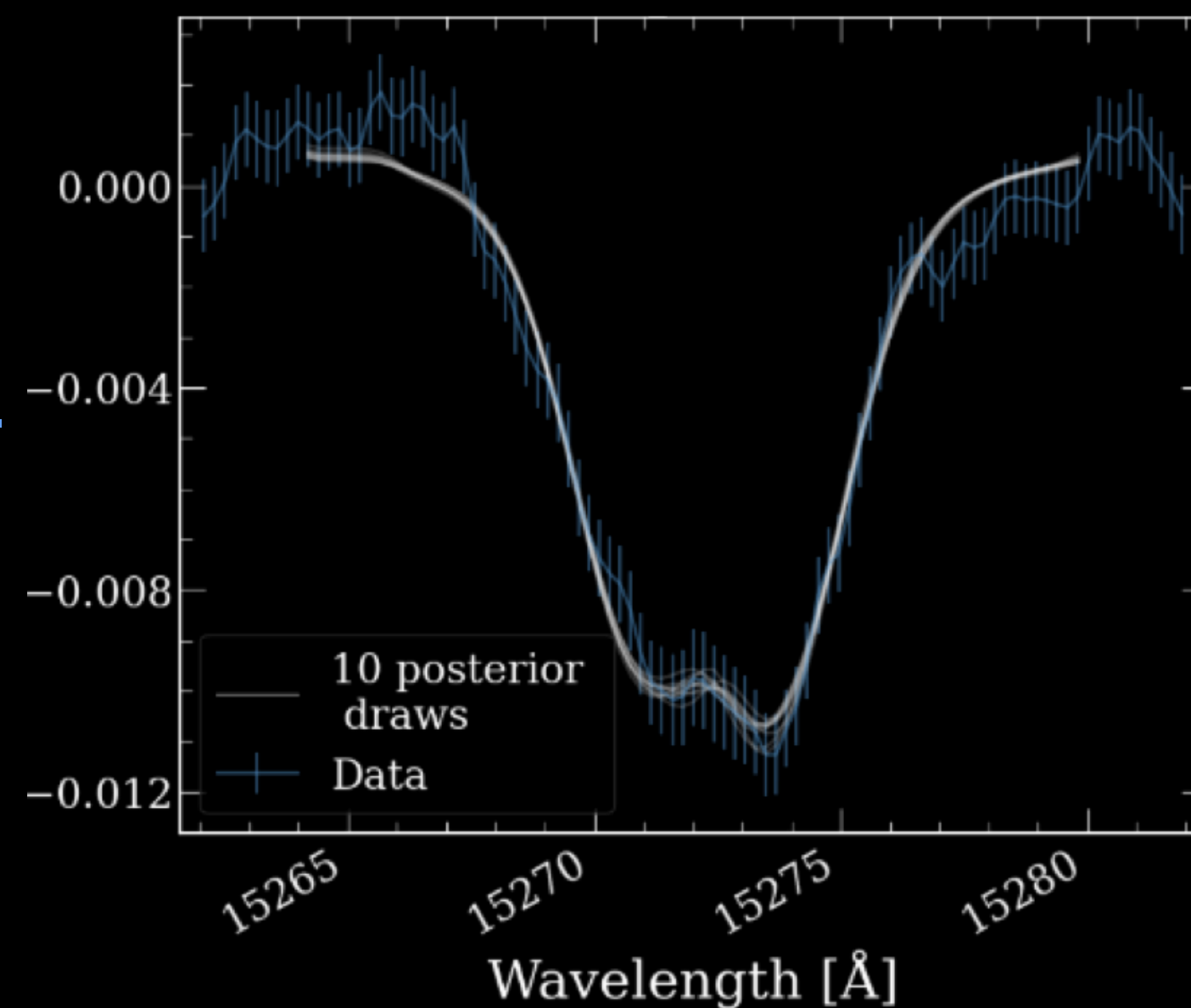
Ongoing: Rotational Lineshape Model

Joint fit with d/dT

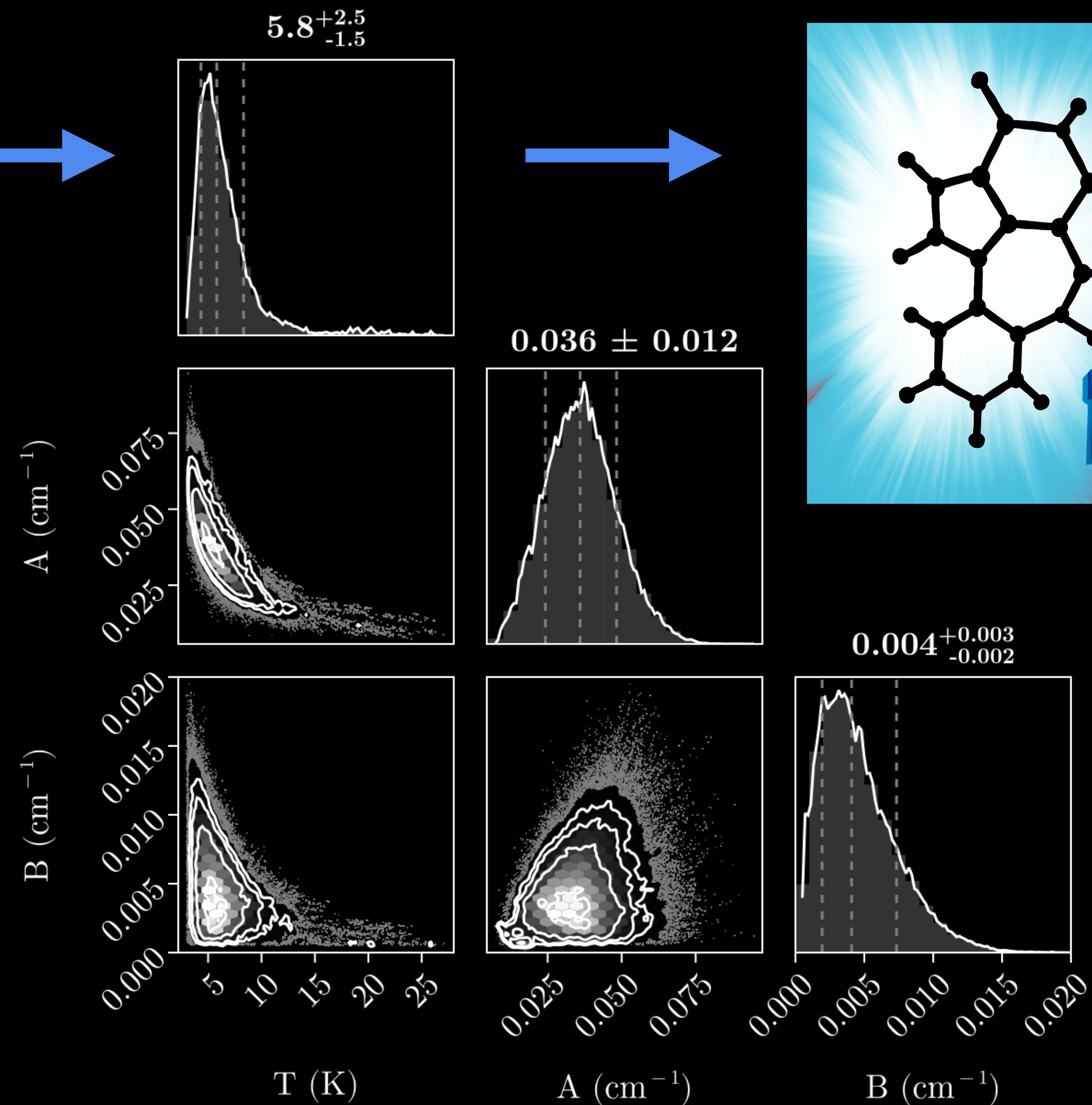
$$\frac{dr}{dA_H}$$



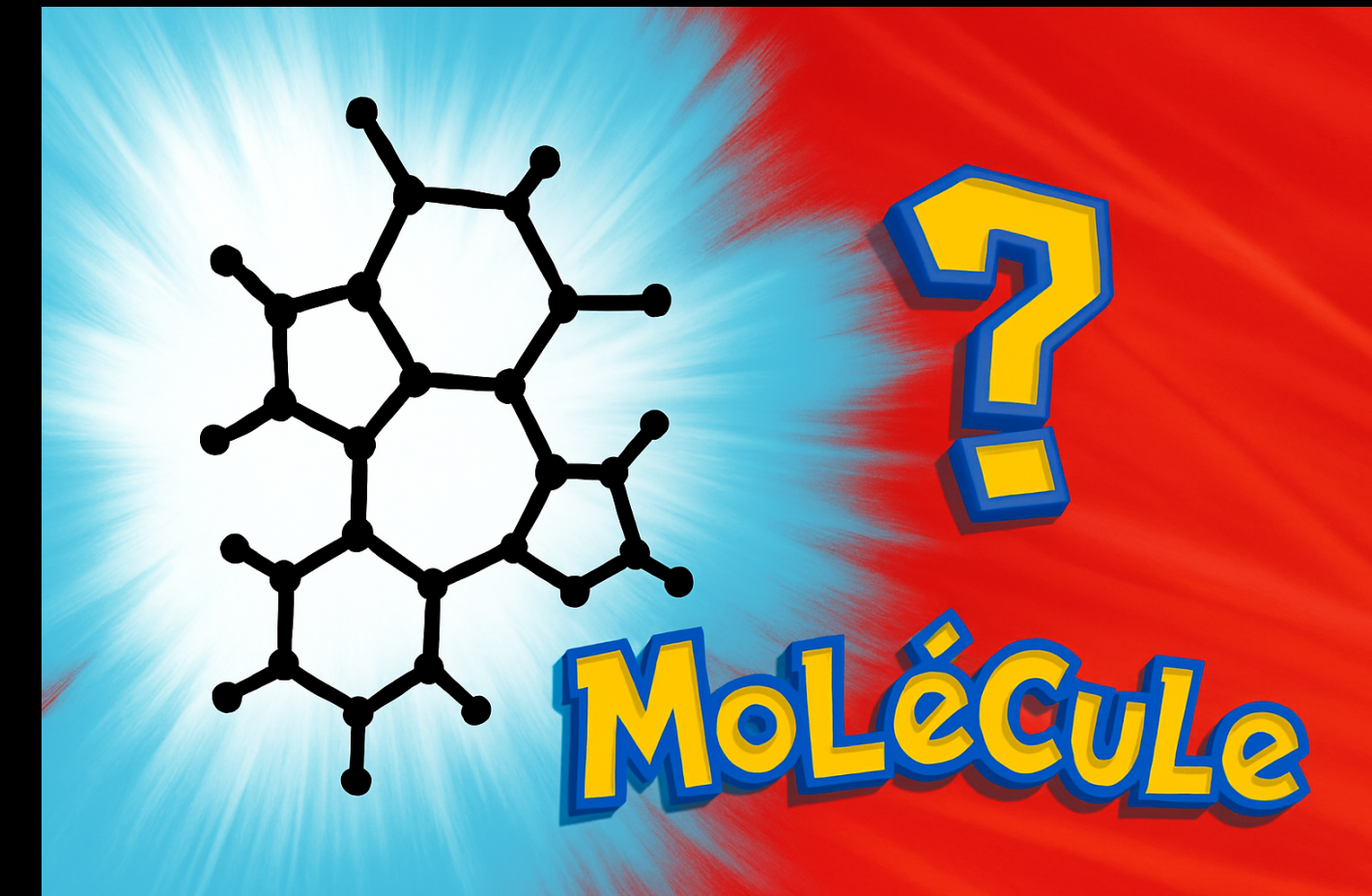
$$\frac{dr/dA_H}{dR(V)}$$



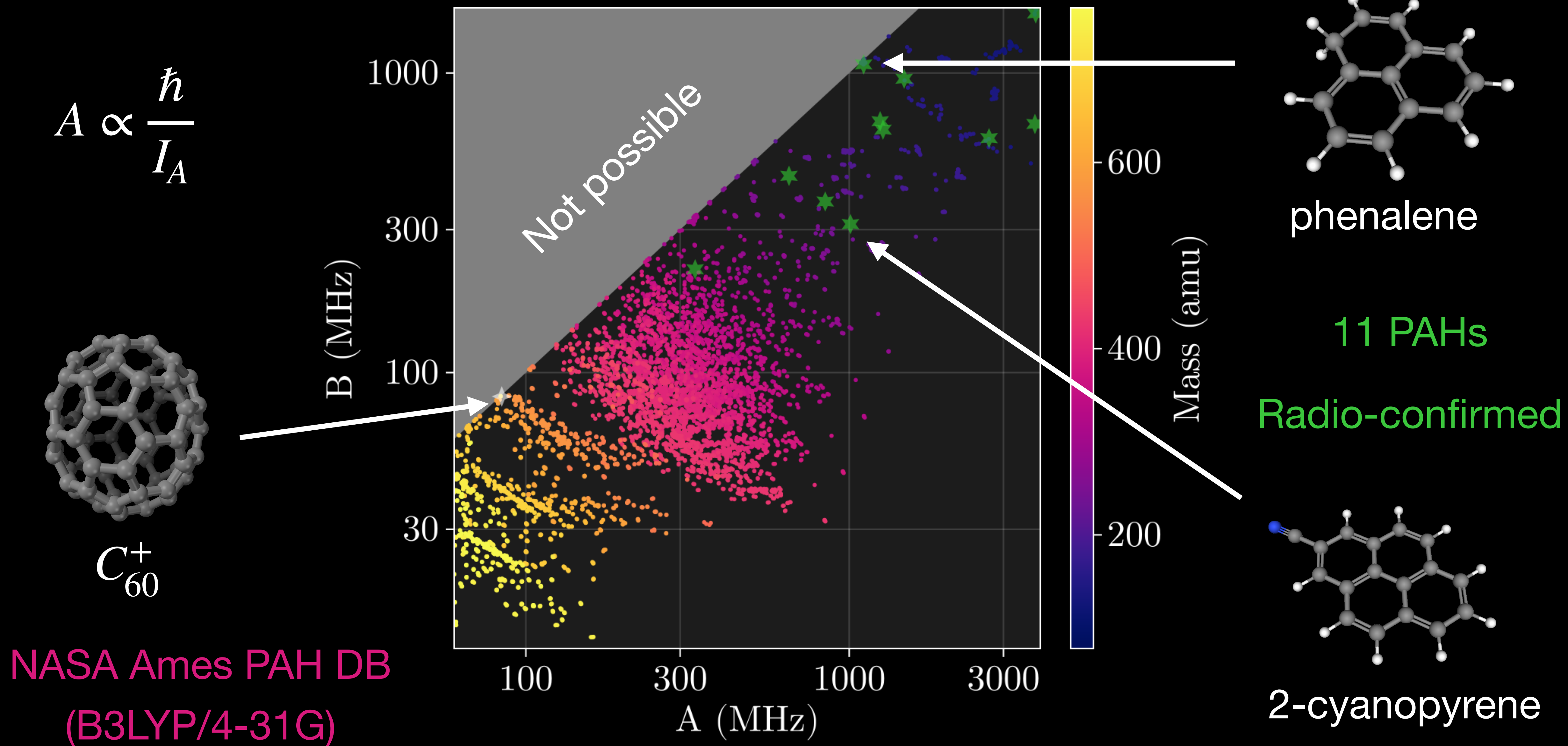
Posterior
(e.g. moments of inertia)



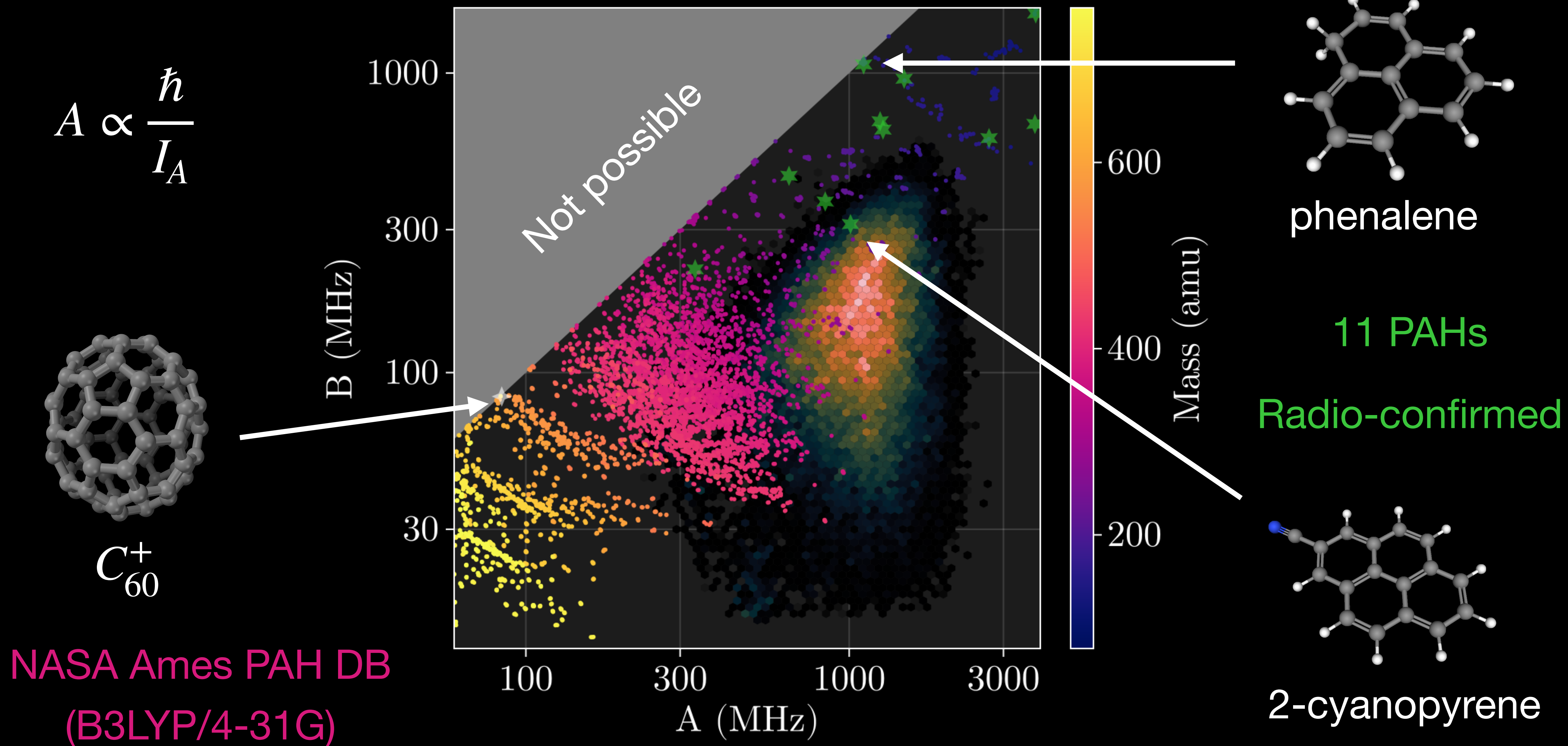
Geometric
Constraints



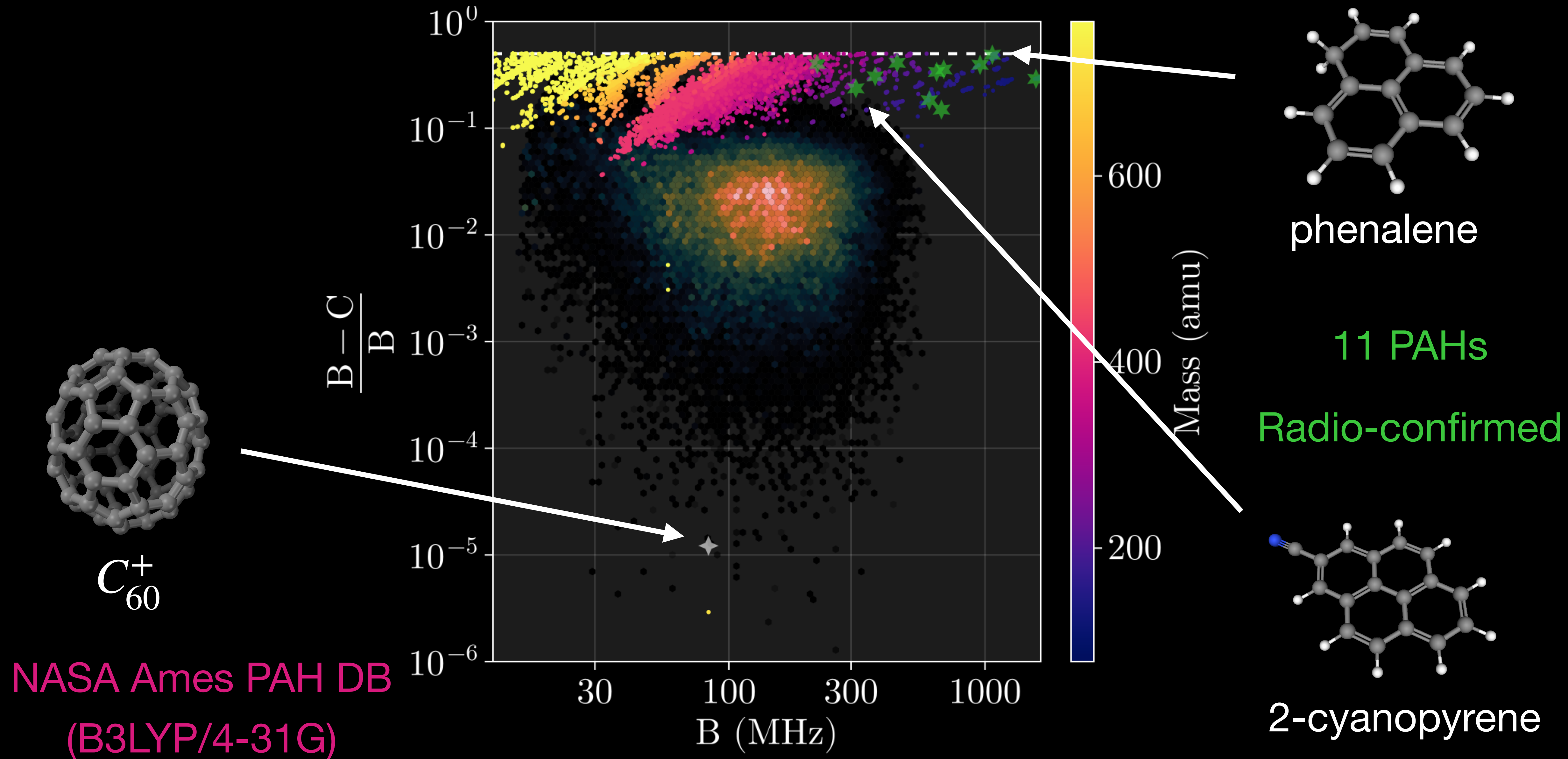
Where are we in chemical space?



Where are we in chemical space?



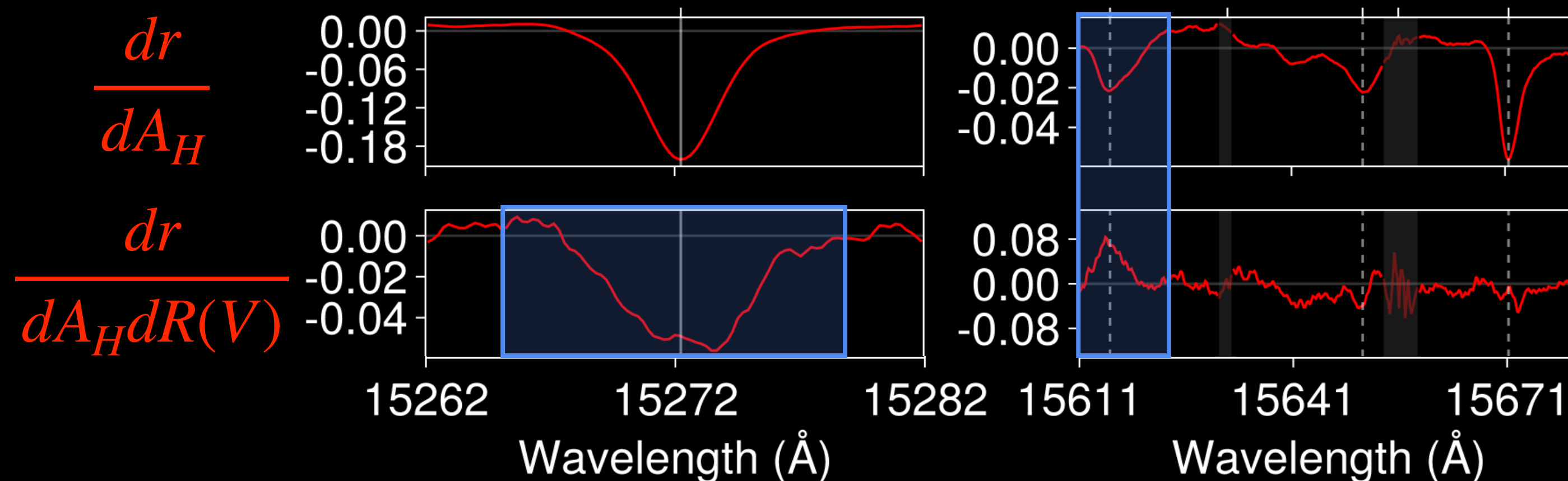
Challenging the planar PAH picture



Chemical Complexity of Interstellar Dust

Summary

- Yes! Chemical variation with $R(V)$
- Correlation between all scales of extinction curve features
- $R(V)+$ has 20% Effect on EW
- Anomalous 15616 Å
Line shape variations



Paper



Future

