Reading Between the Bumps: Intermediate Scale Structures in Optical Extinction Curves

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Abstract

The features of interstellar extinction curves serve as powerful diagnostics for interstellar dust, revealing information about its composition, size distribution, and the physical and chemical processes that shape it. Extinction features tend to be categorized based on width, as they probe different carriers. These extinction features include narrow interstellar absorption features from Na, Ca and K, and diffuse interstellar bands (DIBs) with widths on the scale of ~0.1-1.0 nm. On the intermediate scale, the well-known 2175A with a width of ~427A is thought to originate from carbonaceous grains. Massa et al 2020, reported three new intermediate-scale structures (ISS). Their analysis found that strength two of the three of these ISS features correlate with the 2175A bump strength, but none were correlated with the total-to-selective extinction ratio, R(V). Since then, three additional candidate ISS features were identified in the literature at 0.770, 0.540, 0.850 micron, all with widths greater than any known DIB. To help identify their carriers, we used 70 different lines-of-sight to study the three original ISS features as well as the candidate features. Furthermore, in this study we identified 9 more candidate ISS features observed in these sightlines. Lastly, we present an analysis of all these ISS features, on how they relate to the extinction curve parameters, to each other, and the 2175A bump feature.

Methodology

The Data: We use the Fitzpatrick et al. (2019), sample containing 72 lines of sight and extend it with an additional 19 lines of sight high-resolution HST/STIS spectroscopic data.

Measuring the Extinction Curve:

Extinction curves were derived used forward modeling of the stellar spectrophotometry

Fitting the stellar SED in the optical and UV was done in two steps, to constrain stellar parameters like, T_{eff}, log(g), and v_{turb}:

1. DLS fitting with `LevMarLSQFitter`
2. These parameters were then inputs for MCMC fitting, conducted with the `emcee` python package.

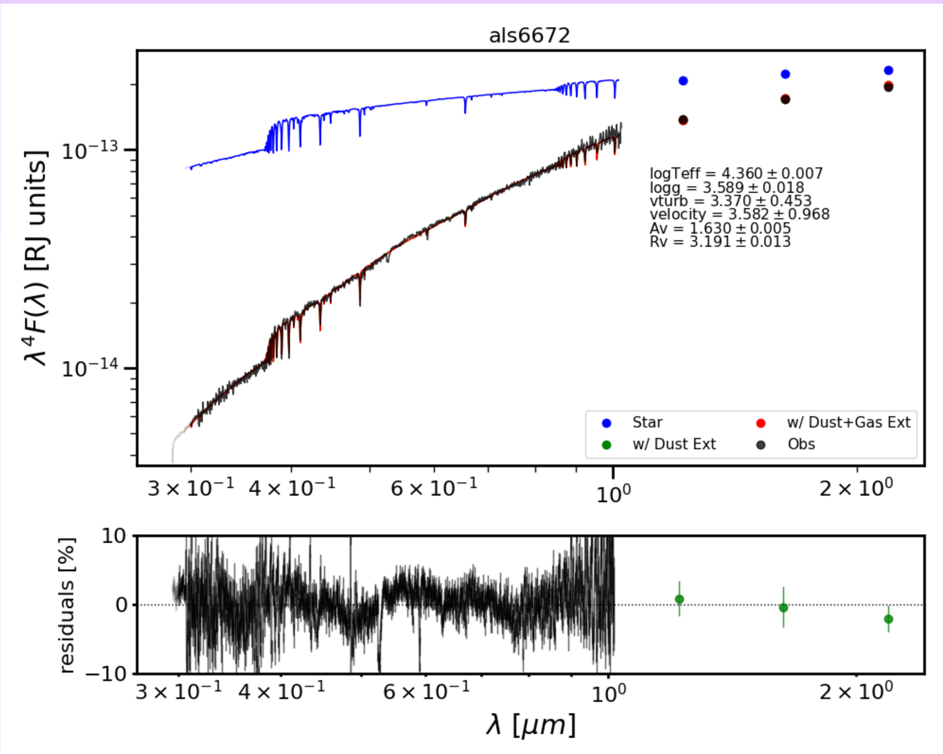
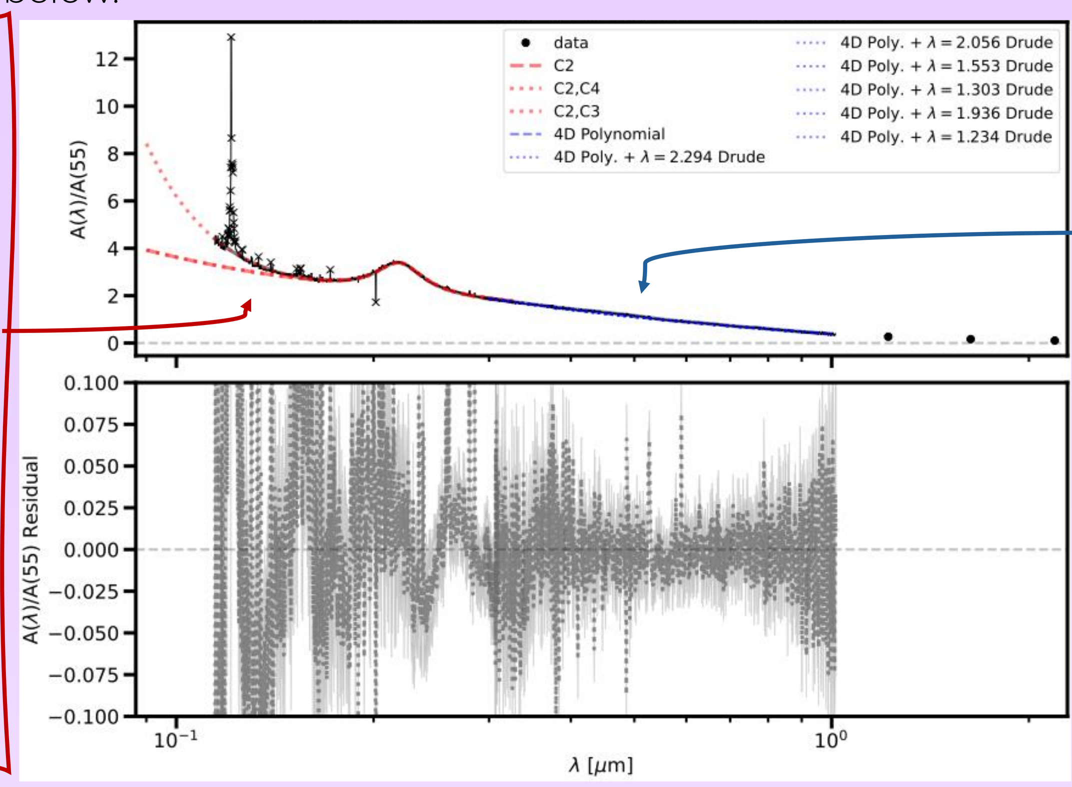


Fig 1. An example of fitting the stellar SED

Fitting Extinction Curves:

The extinction curves measured from the previous step was fitted using the function forms shown below.

$$\frac{A(x)}{A(55)} = c_1 + c_2 + c_3 D(x, x_o, \gamma) + c_4 F(x)$$



$$\frac{A(x)}{A(55)} = \sum_{j=0}^{N_p} E_j x^j + \sum_{i=1} F_i D(x, x_i, \gamma_i)\gamma_i^2$$

Fig 2. An example of fitting the extinction curve derived from the previous step

Results

Broad spectral features (>0.015 µm) are challenging to isolate due to overlapping signals and noise. Following Massa et al. (2020), we analyze the extinction curve residual, $r(x - 55)$.

- Prominent interstellar, hydrogen, and DIB lines are interpolated over.
- Outliers are removed using `sigma_clip` routine from `astropy`
- the mean residuals of the remaining curves are computed for analysis
- residuals were convolved with a Gaussian to retain only features wider than 150 A

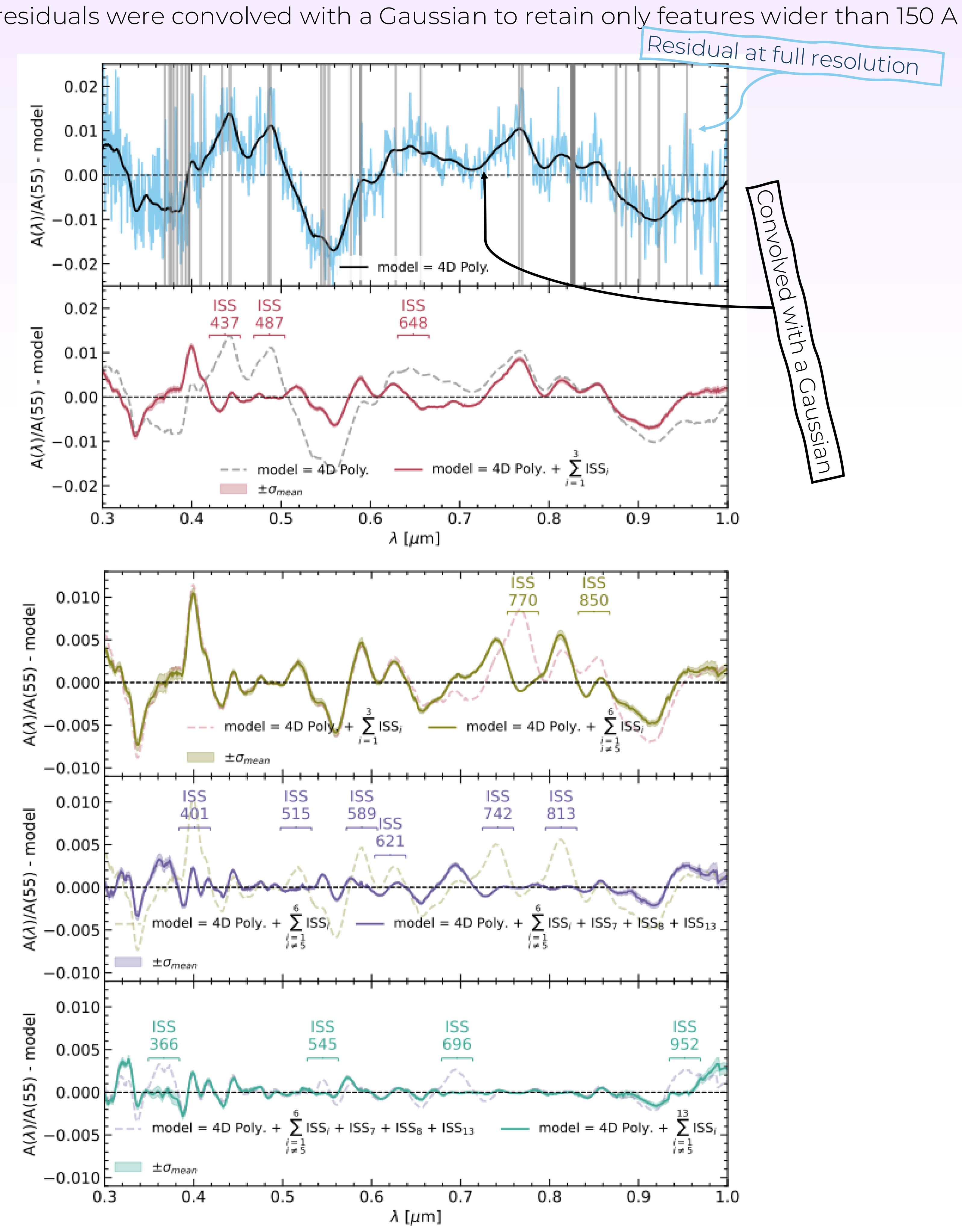


Fig 3. Residuals of fitting the optical extinction curves, including ISS features.

Future Work

Are the candidate ISS features, dust features? → correlation with A(V)
Do the candidate ISS features correlate with the 2175 A bump? → correlation with B_3
Are the ISS features from the same species of grains? → correlation between F_i

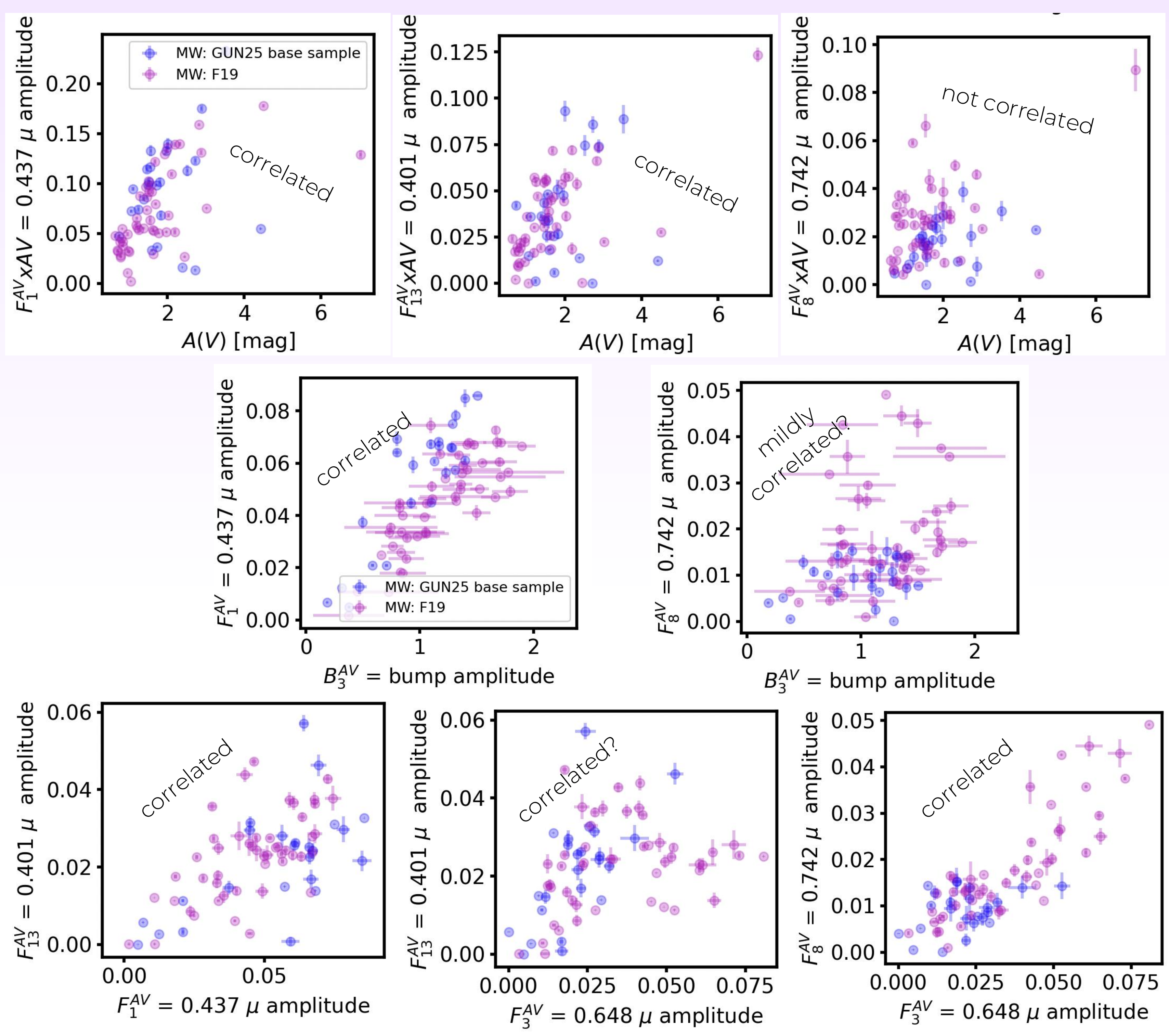


Fig 4. ISS feature parameters vs. extinction curve parameters, or other ISS feature parameters

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