Dust Science in the Ultraviolet

Brandon Hensley
Princeton University

UVEX Community Workshop
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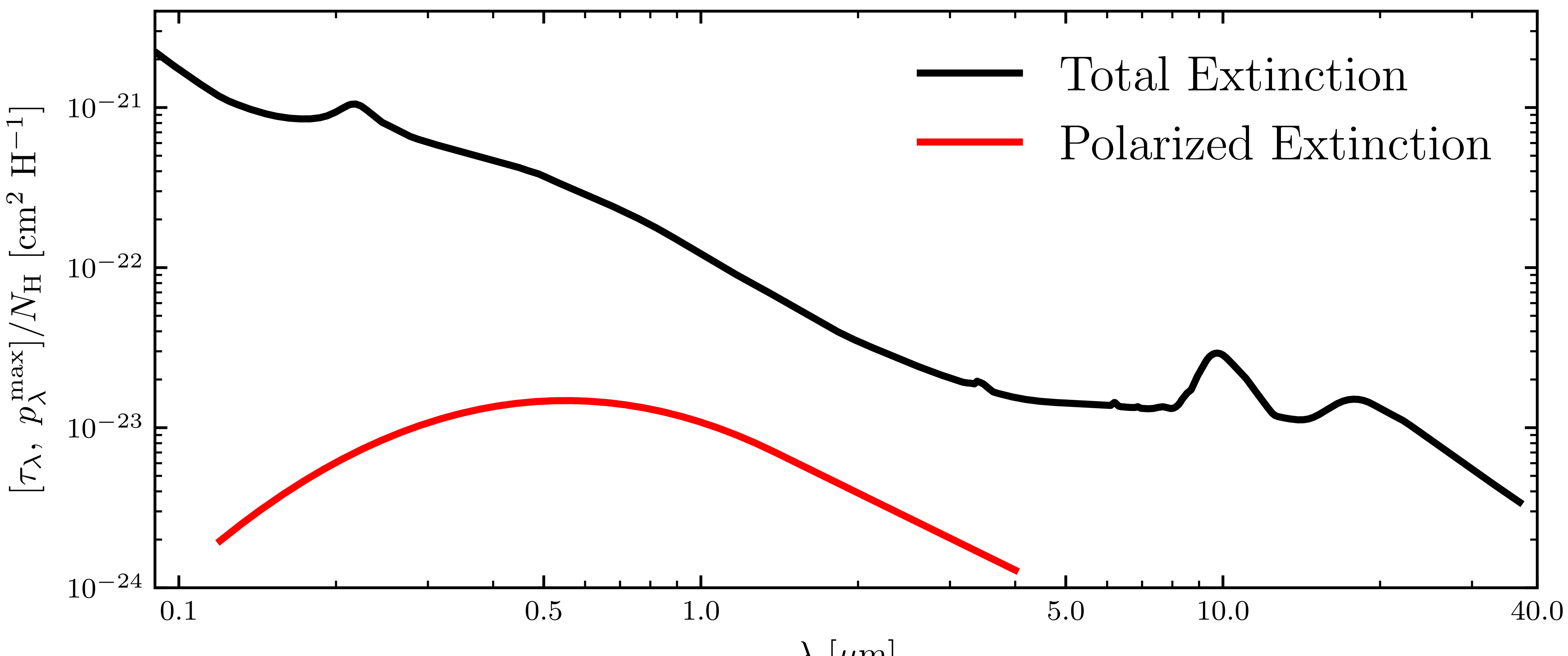
Image: Helix Nebula, GALEX/Spitzer/WISE

The Interstellar Extinction Curve

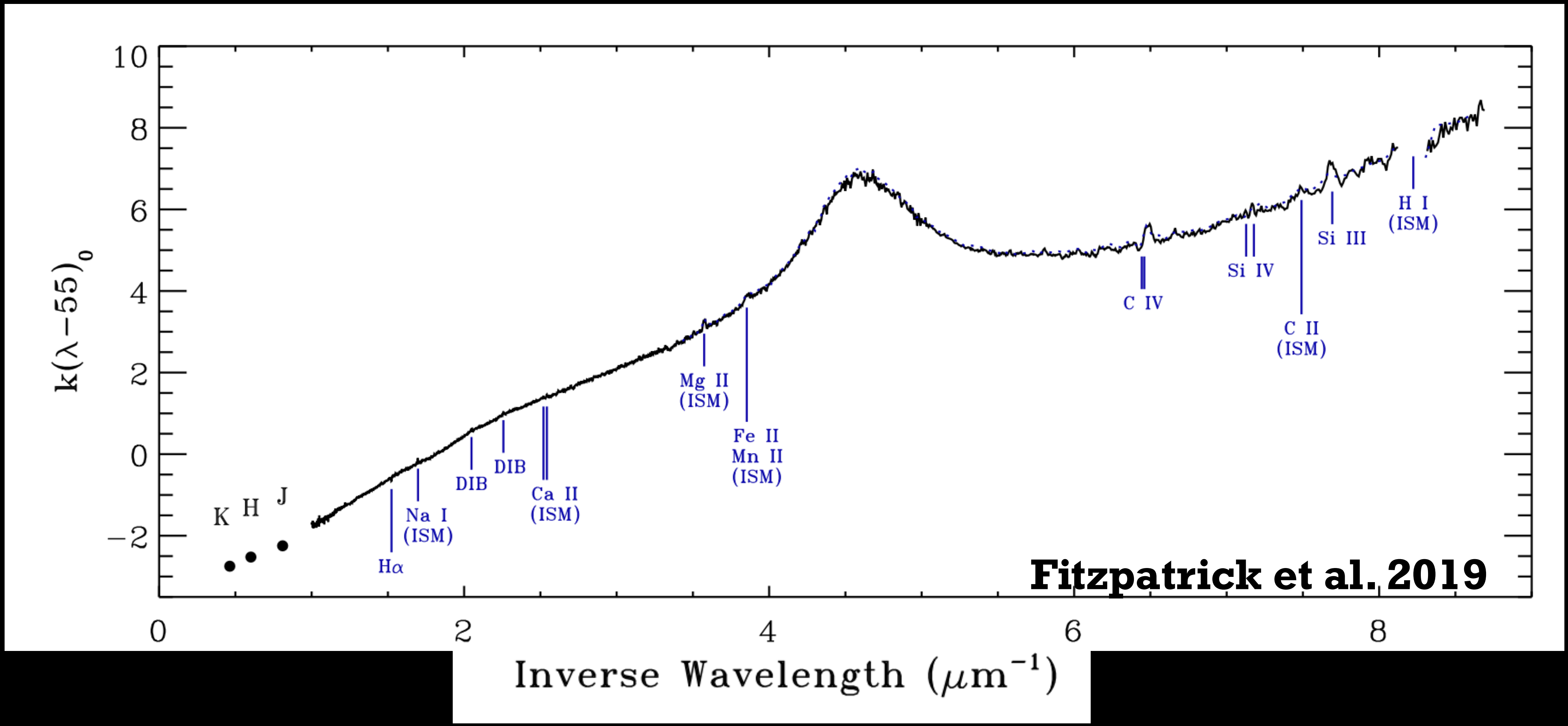
- Fingerprints of dust properties: composition, size



BH & Draine 2021

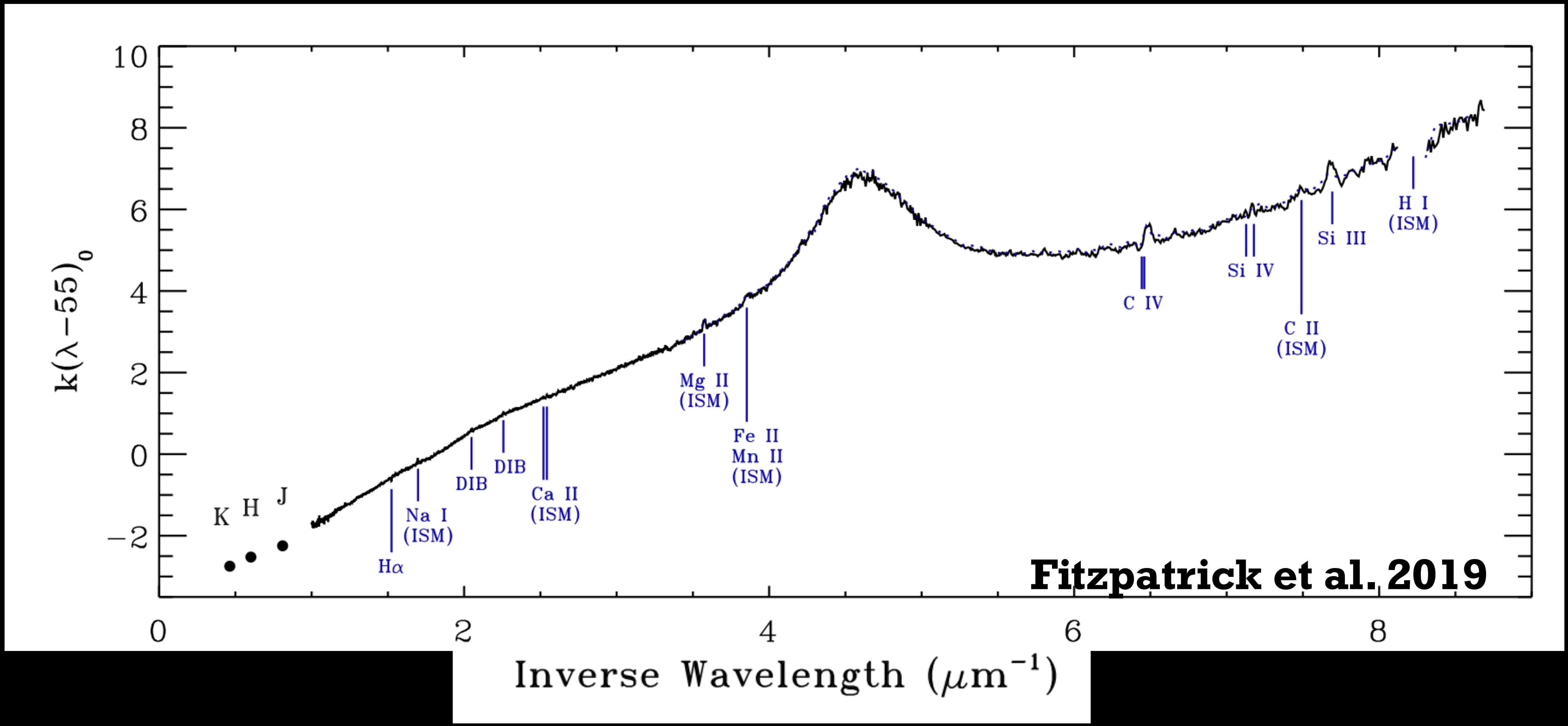
The UV Extinction Curve

- Based on Hubble (2900-5700Å) and IUE (1150-3200Å) data toward 72 stars



UV Extinction Feature(s)

- Prominent “bump” at 2175Å (= 4.6 μm^{-1}): requires a lot of dust mass!
- No other features



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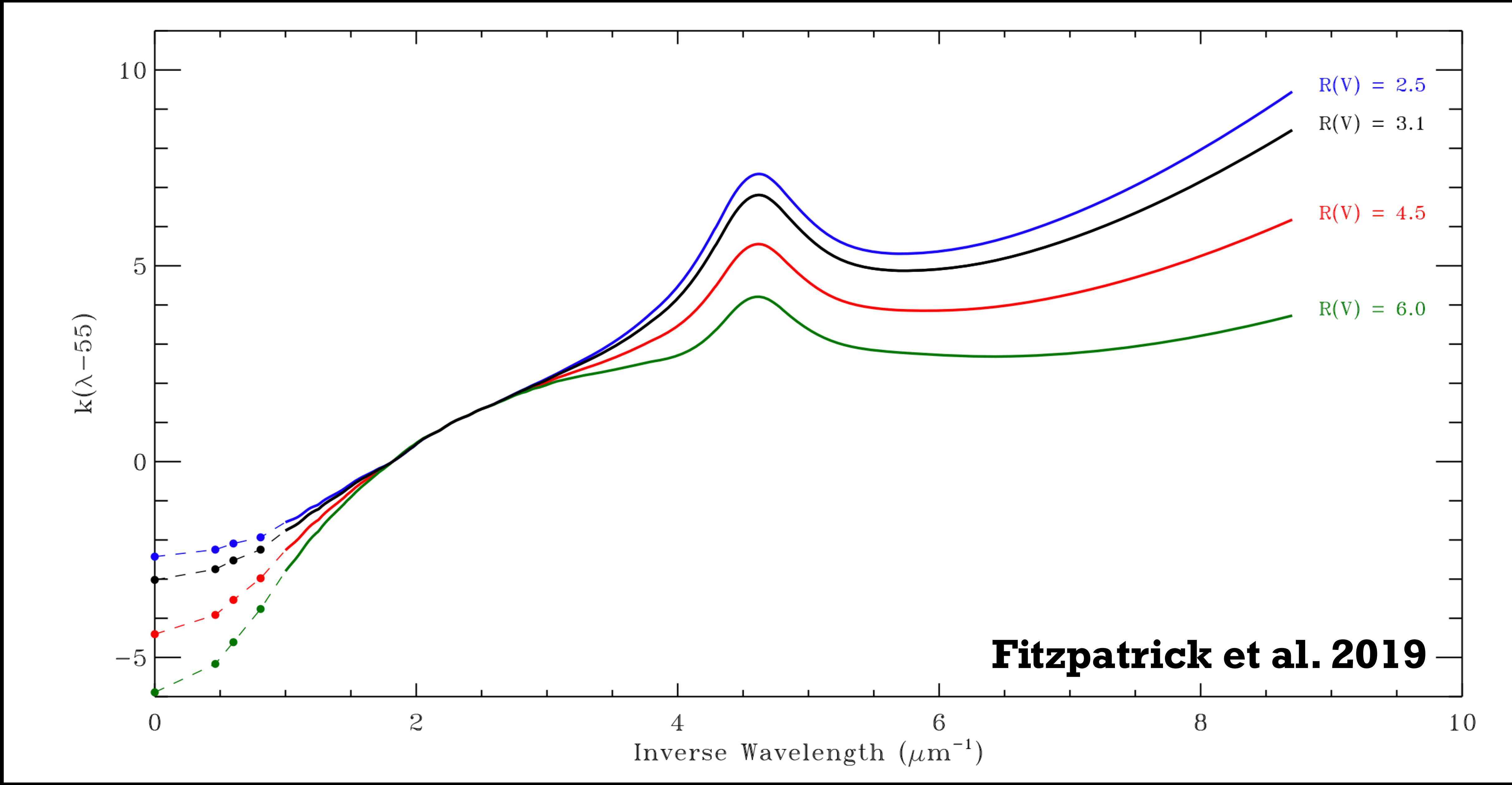
Gordon et al. 2009, on 72 FUSE+IUE extinction curves:

We found a 3σ upper limit of ~0.12A(V) on features with a resolution of 250 (~4Å width) and 3σ upper limits of ~0.15A(V) for $\lambda^{-1} < 9.6\mu m^{-1}$ and ~0.68A(V) for $\lambda^{-1} > 9.6\mu m^{-1}$ on features with a resolution of 10^4 (~0.1Å width)

Dust Evolution

- Variation with optical extinction (e.g., R_V)

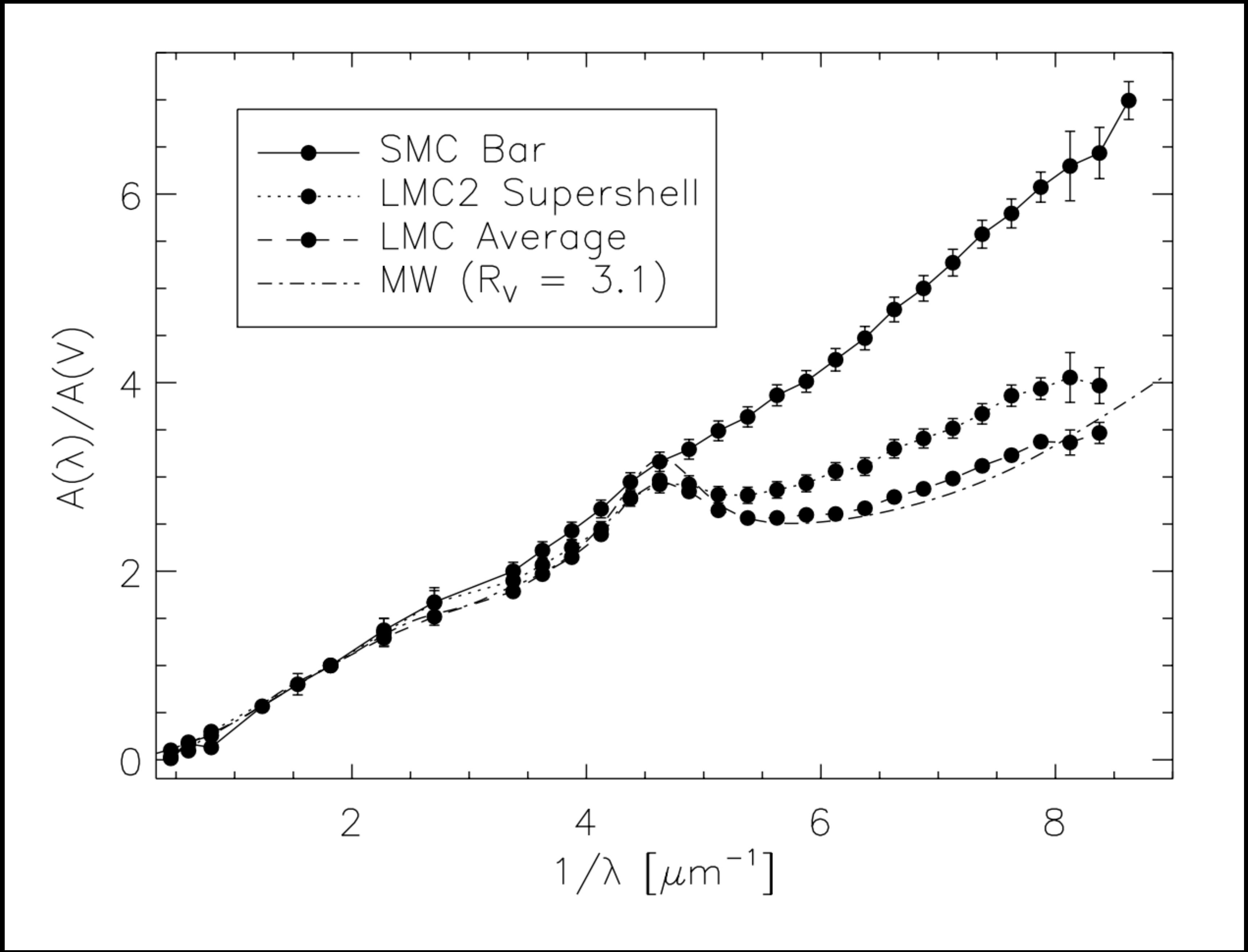


Dust Evolution

- Variation with environment

- Note: MW contains many environments with different extinction curves!

Gordon et al. 2003



To High Redshift

- How to extrapolate our understanding of the Local Universe to high z?

Witstok et al. 2023

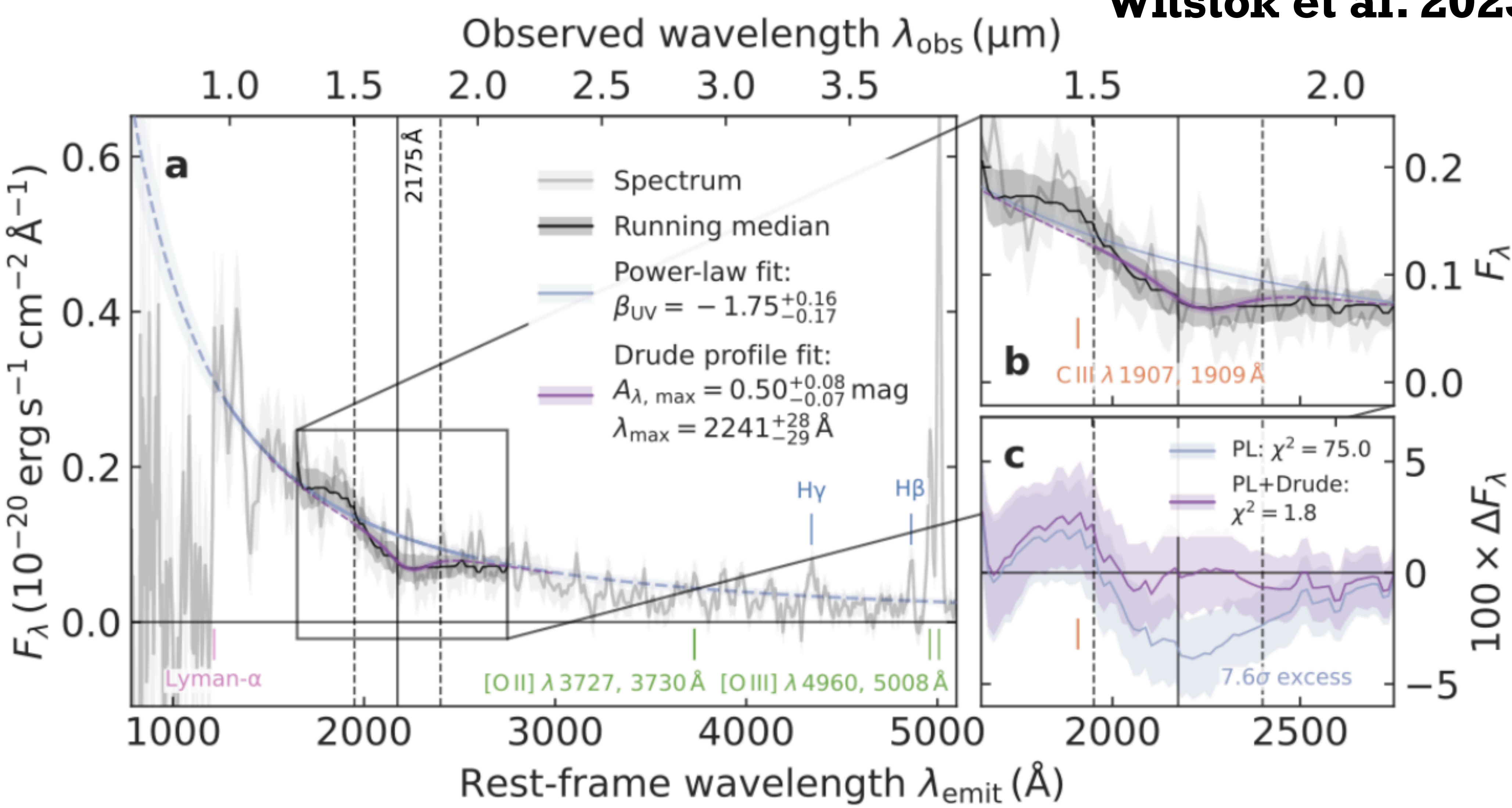


Fig. 1 | Spectrum taken by *JWST*/NIRSpec of JADES-GS-z6-0 at redshift z = 6.71. a,

A Challenge: Statistical Samples

- Our knowledge of spectroscopic UV extinction based on a very modest sample of stars (hundreds)
- UV extinction probes grain size and composition, and appears to vary substantially in different environments: many effects to disentangle
- UVEX will be a game changer in both sensitivity and sample size

Outline

- UV continuum extinction
- The 2175Å feature
- The Diffuse Galactic Light
- Assorted other features
- Summary and outlook

UV Continuum Extinction

- UV extinction rises toward short wavelengths
- => grains of size comparable to wavelength down to nanoparticle scales
- => extinction curve shape very sensitive to both the grain size distribution and to the composition of the grains

2175Å Basics

- Not very well correlated with the FUV extinction (e.g., Greenberg & Chlewicki 1983)

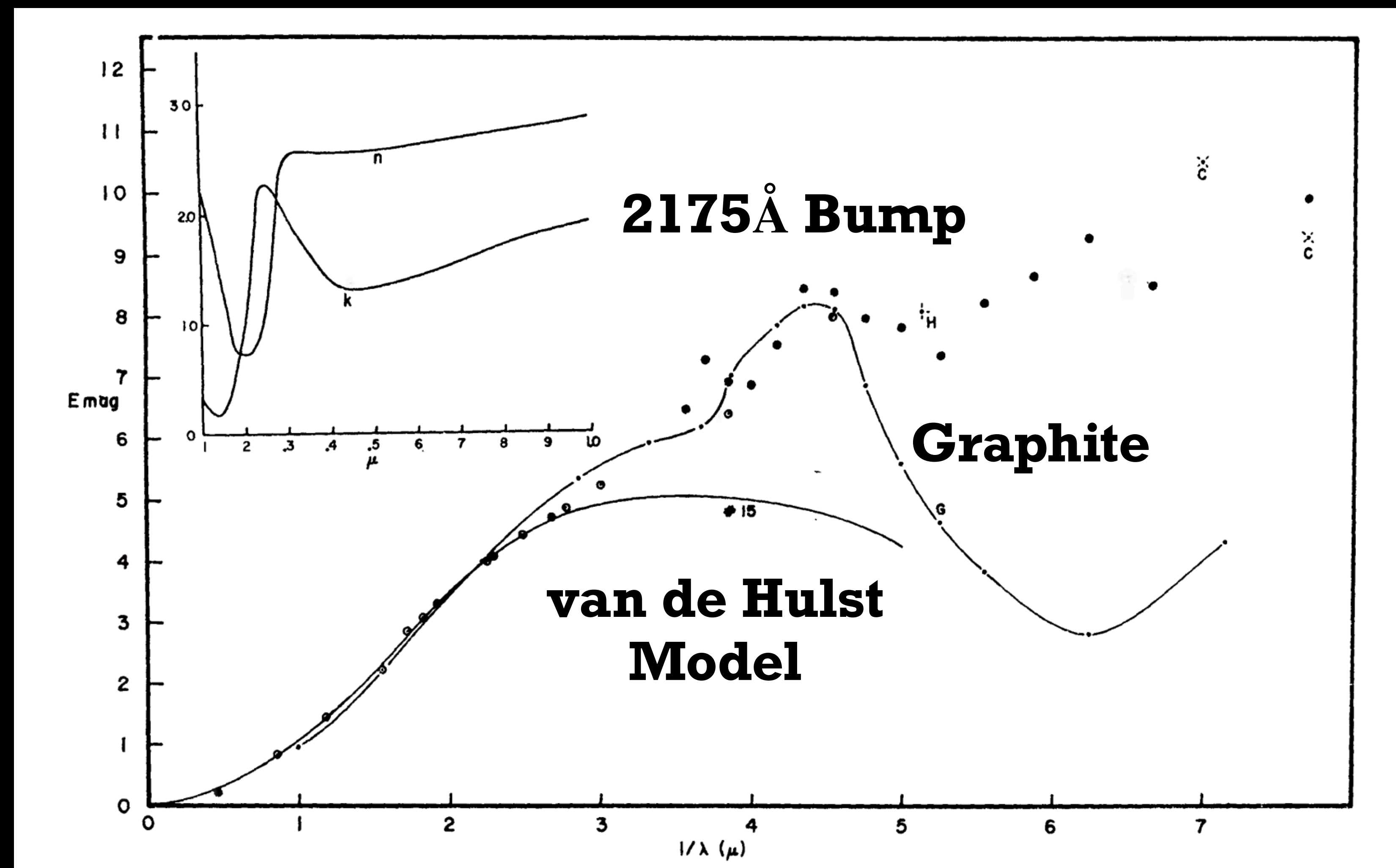
- Central wavelength constant…

- …but width varies from (at least) 360–600Å FWHM (Fitzpatrick & Massa, 1986; sample: 45 reddened stars and 10 standards)

- Strength varies greatly, from unobserved throughout much of the SMC to strong feature in the diffuse ISM of the MW

Models: Graphite

Stecher & Donn 1965



Inverse Wavelength

- Earliest hypothesis (Stecher & Donn 1965), reasonable match to observed feature in the laboratory

- Silicate+graphite models became default for their ability to explain the ISM extinction curve

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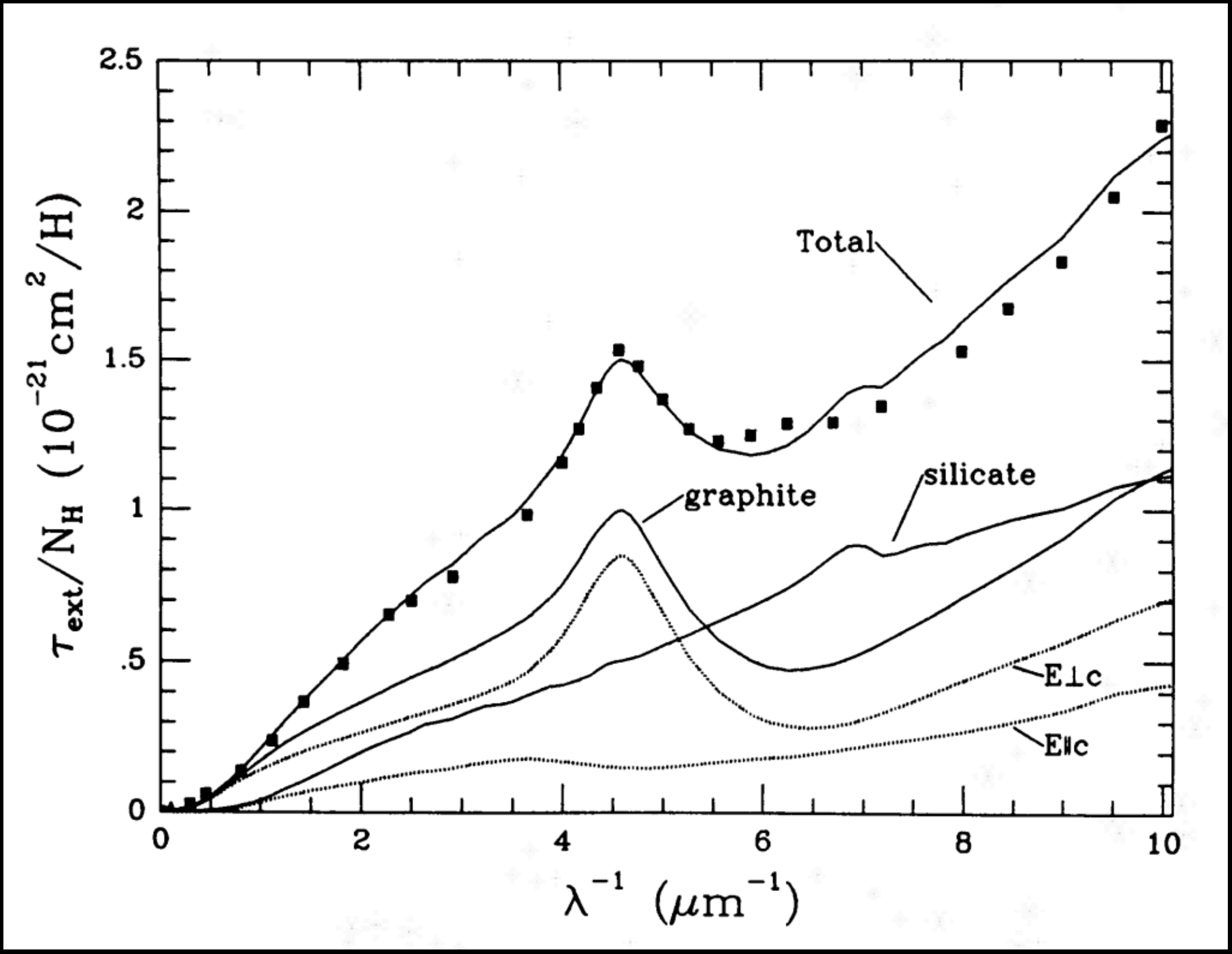
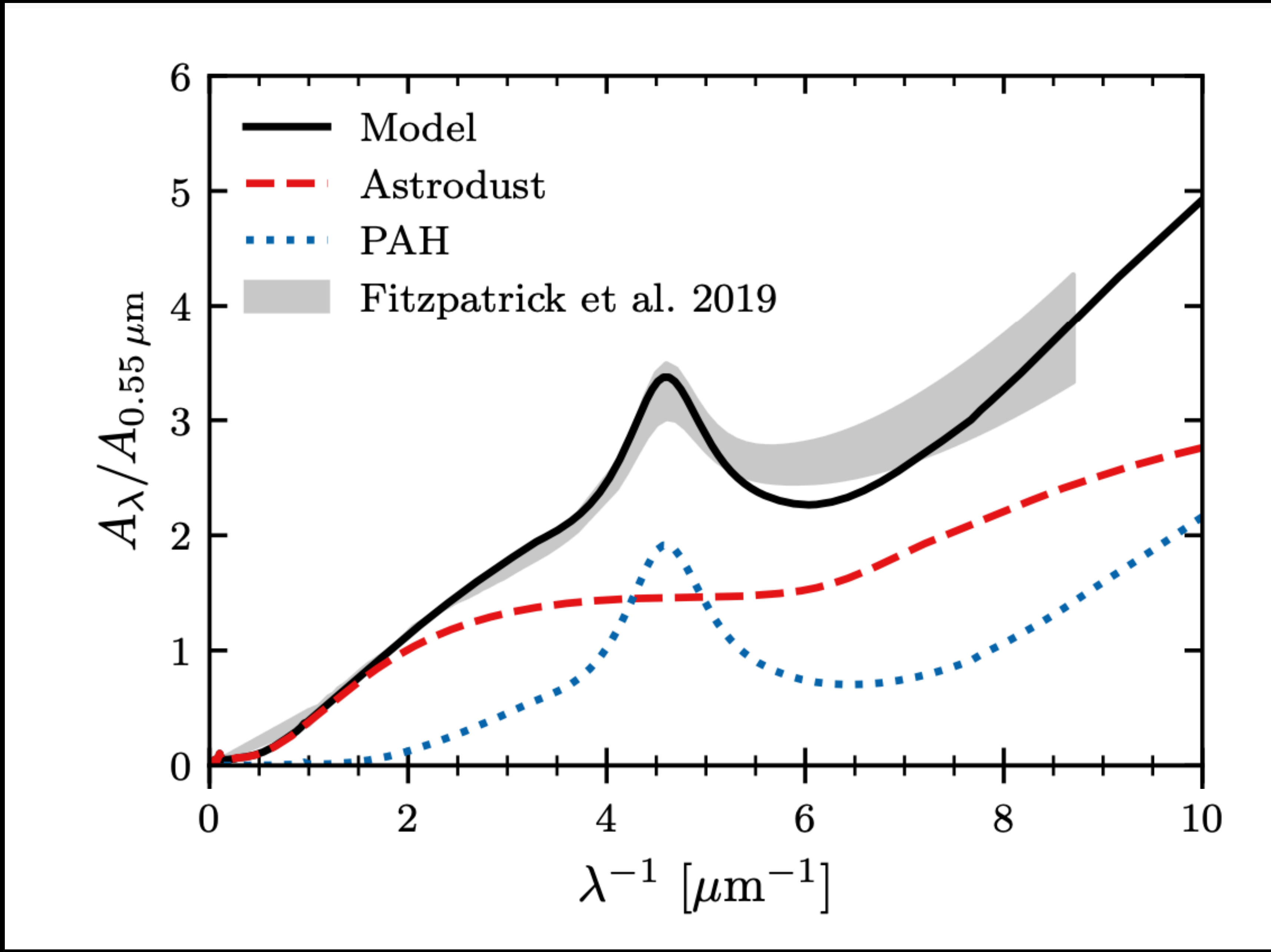
Draine & Lee 1983



Models: PAHs

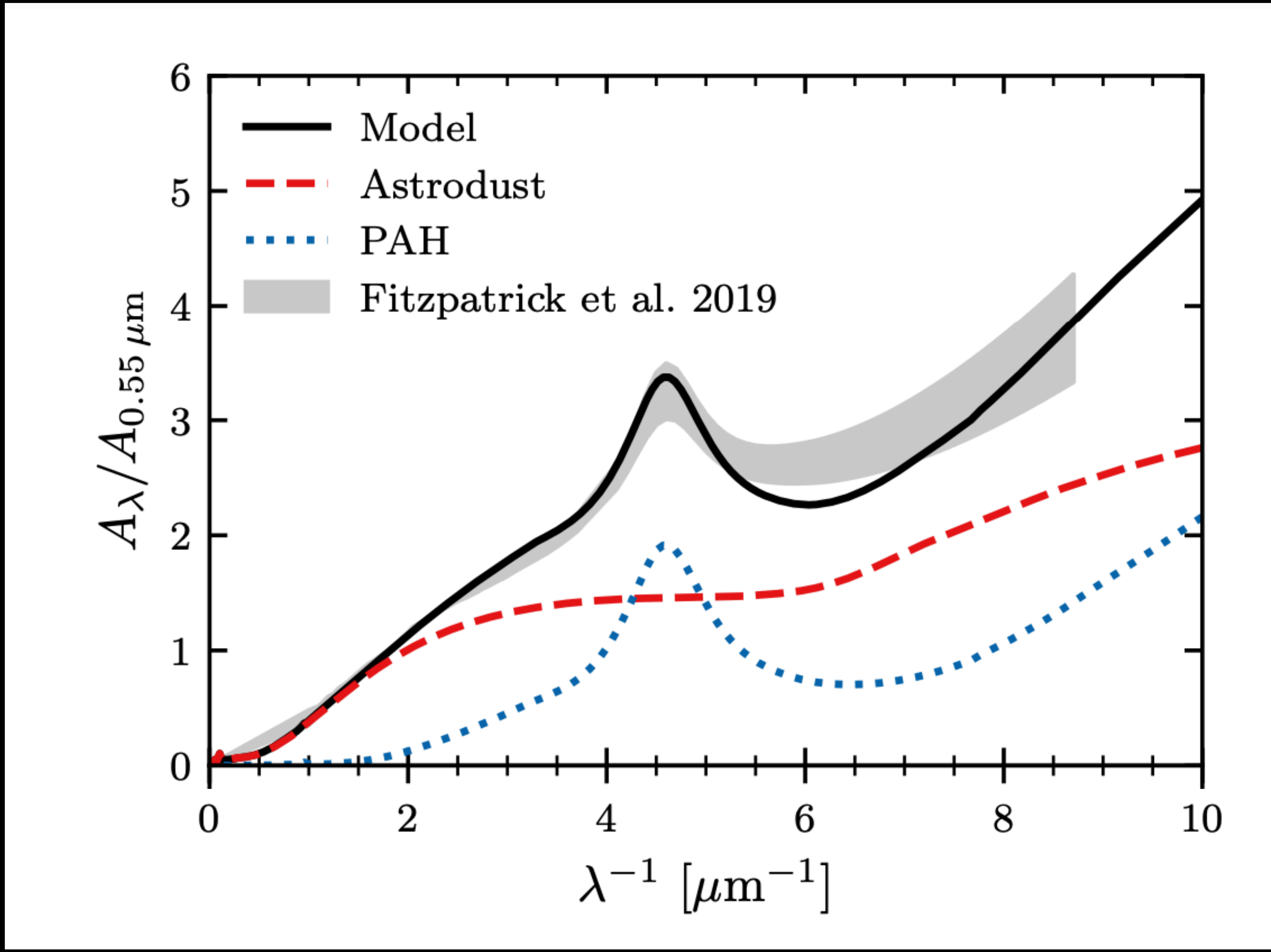
BH & Draine 2022



- PAH backbones resemble graphite, can get features with the right shape and strength
- In BH & Draine 2022, feature mostly from particles < 10 nm in size

Models: PAHs

BH & Draine 2022



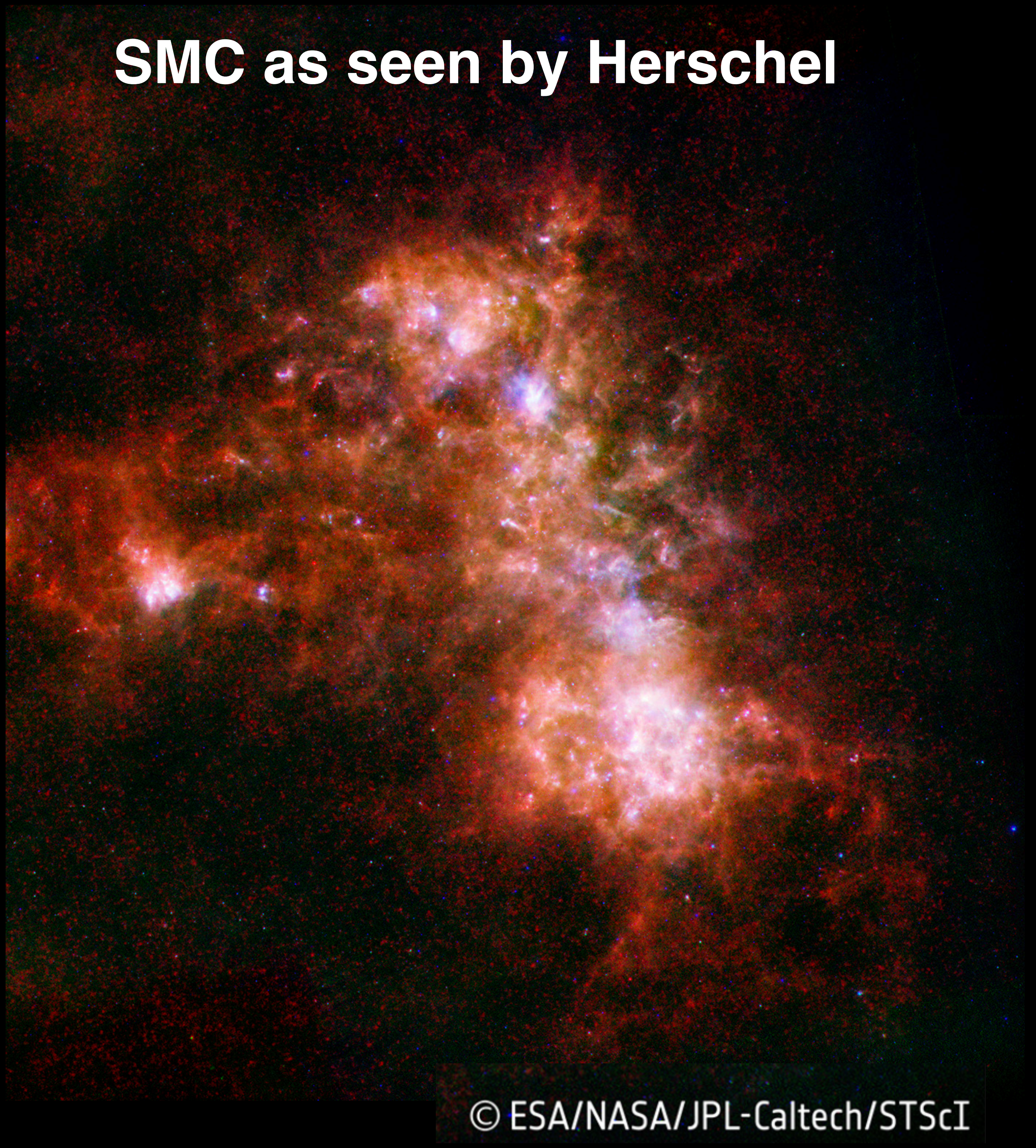
- Nice feature that the bump and the FUV rise come from distinct populations with distinct sizes (~nm vs ~10nm)

A Problem

- Broad feature arising from subunits of bigger structure —> a lot of room for variation
- Not surprising that width varies, but why is the central wavelength so fixed?

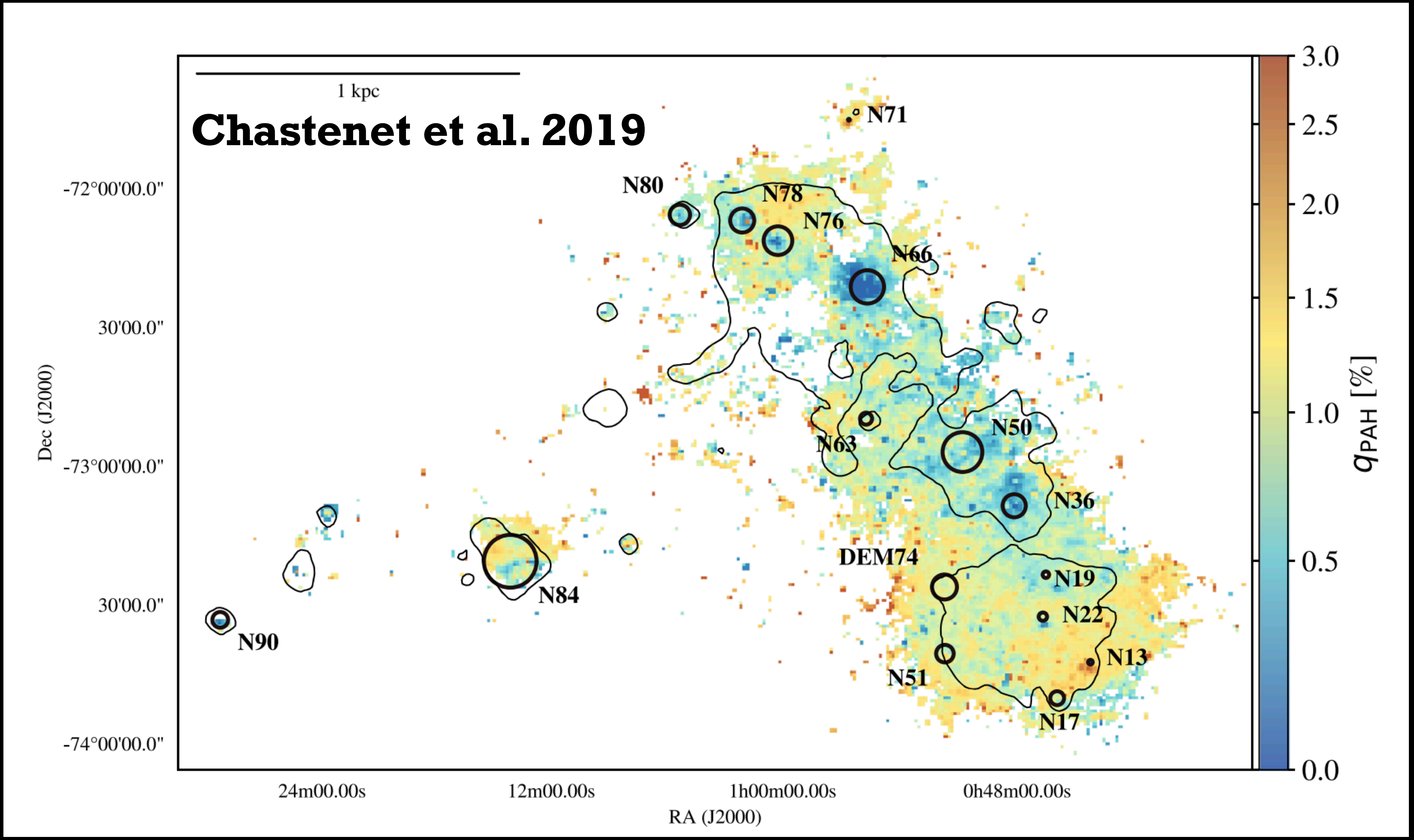
PAHs and Metallicity

- If PAHs are the carrier of the bump, expect a general correlation with MIR emission features
- SMC is highly deficient in PAHs and in the 2175Å
- A guide to modeling low metallicity systems?



PAHs and Metallicity

- Fraction of dust in PAHs ~5x less in SMC than in MW



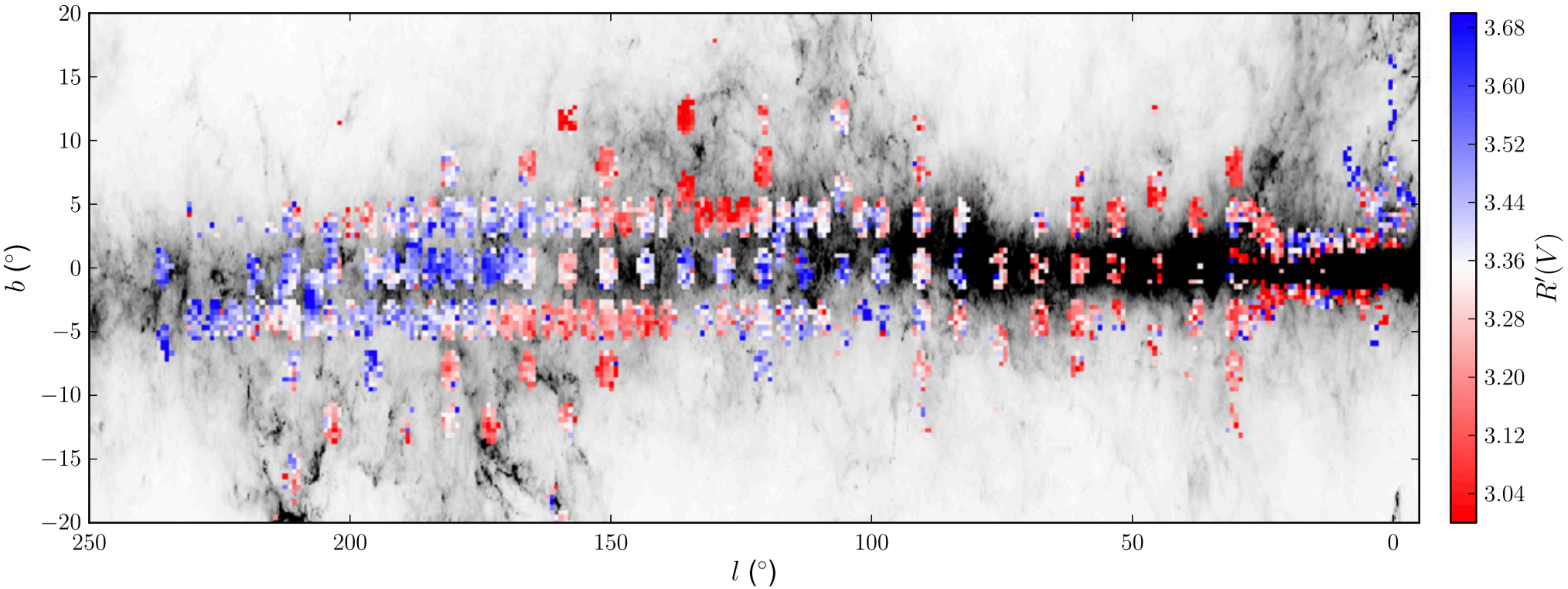
PAHs and Metallicity

- Broader theme: how does dust evolve in different environments, e.g., as a function of column density, metallicity, star formation history
- Still piecing together this story in the Local Universe, much less high-z
- UV is a critical piece of this puzzle via its sensitivity to many aspects of dust physics

A Dust Evolution Puzzle

- Shape of the optical extinction law varies on large spatial scales… hard to reconcile with simple changes to the grain size distribution
- Will we see this in the UV?

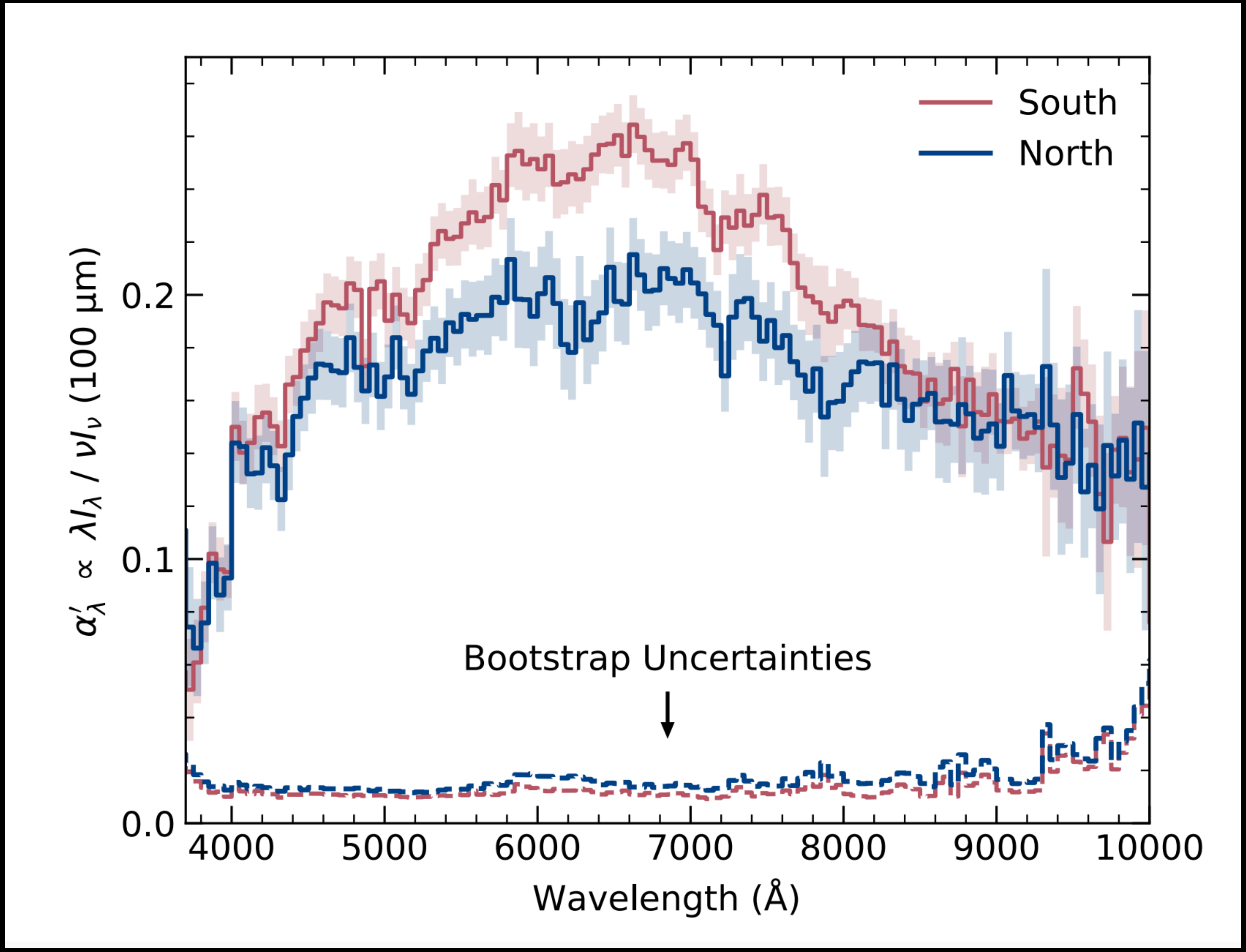
Schlafly et al. 2016



Diffuse Galactic Light

- The “blank sky” is not blank!
- Light scattered off of dust grains + ISM emission
- Constrains models of dust scattering: spatial distribution + size distribution + composition

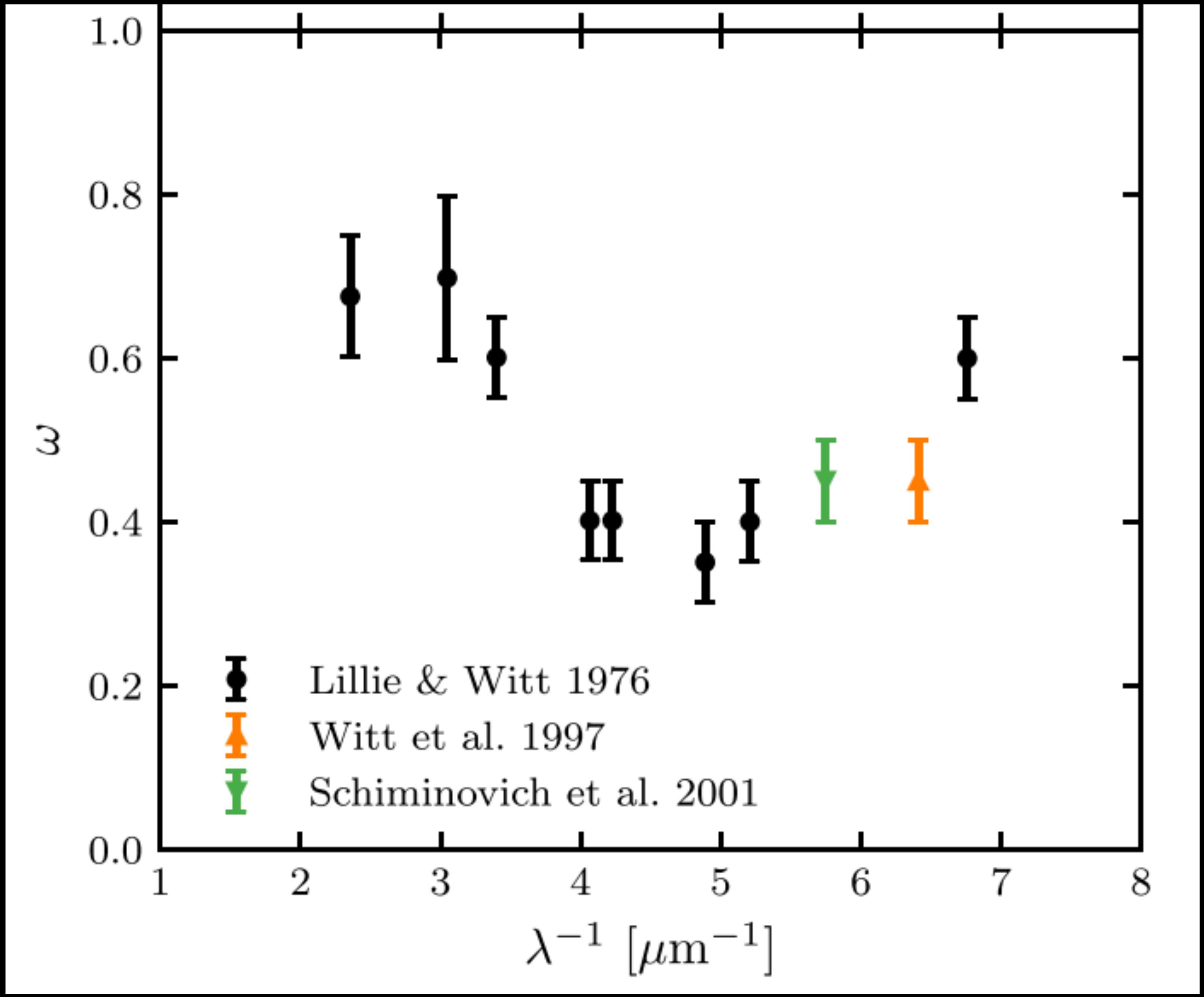
BOSS DGL Spectrum
Chellew, Brandt, BH+ 2022



Dust Albedo

- Diffuse Galactic light has (with assumptions) furnished constraints on UV albedo

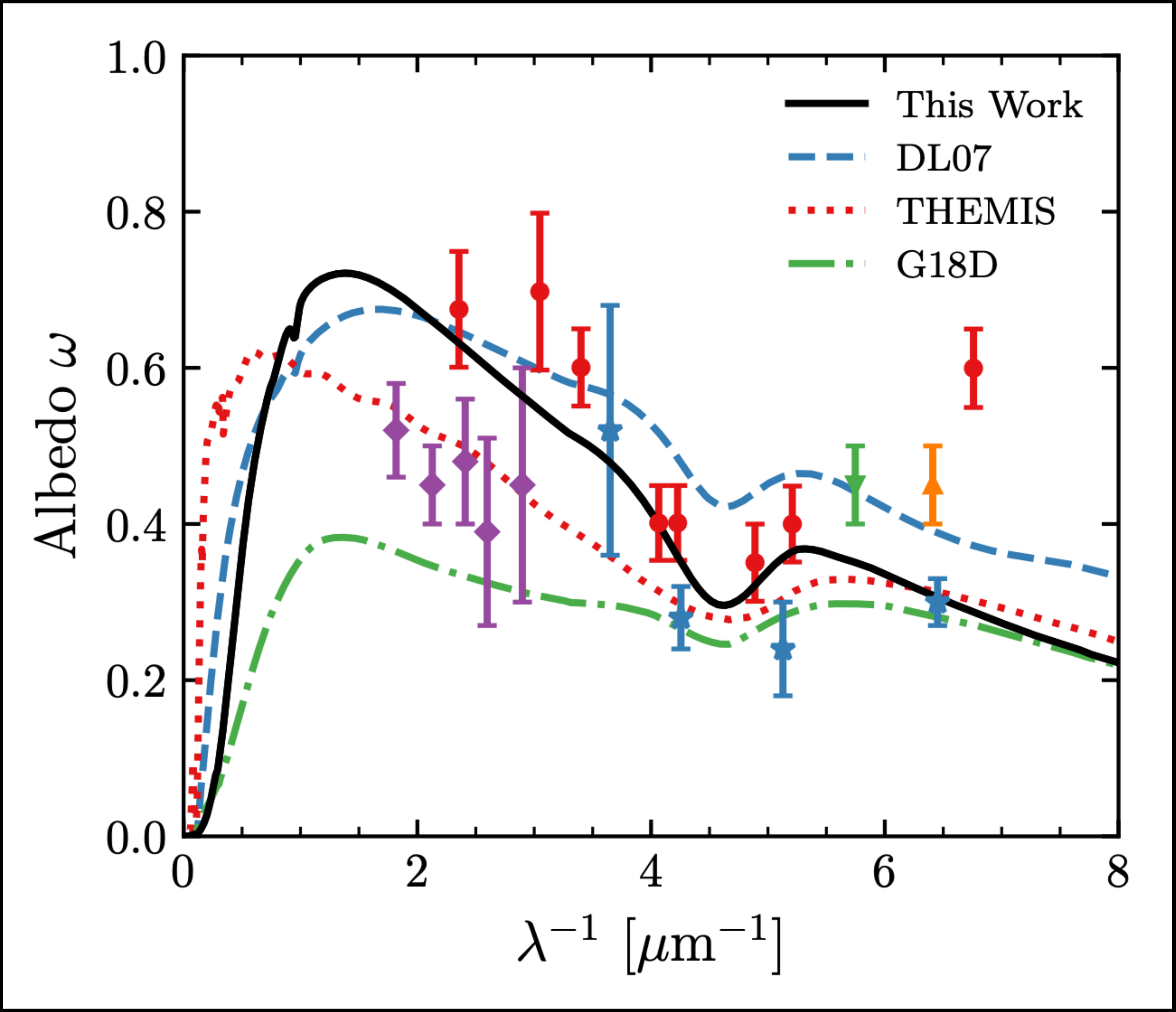
Dust albedo constraints
BH & Draine 2021



Dust Albedo

BH & Draine 2022

- Provides a test of models



Assorted Other Features

- UV features might exist but be very broad: can we detect any broad structure using big samples + more sensitive data? More diverse lines of sight?

- No DIBs in the UV… yet?

Summary and Outlook

- UV extinction is a window into interstellar nanoparticles whose nature we're still figuring out

- UVEX surveys will enable correlation analyses simply not possible with existing data to disentangle the effects of environment on dust properties

- Builds the foundation for interpreting high-z observations and broadly for understanding the cycling of metals in the ISM