

Multi-wavelength dust extinction in the Milky Way and Local Group

Marjorie Decleir

European Space Agency (STScI)



STScI | SPACE TELESCOPE
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Presentation outline and disclaimer

Part I: Introduction

Part II: Current knowledge and challenges

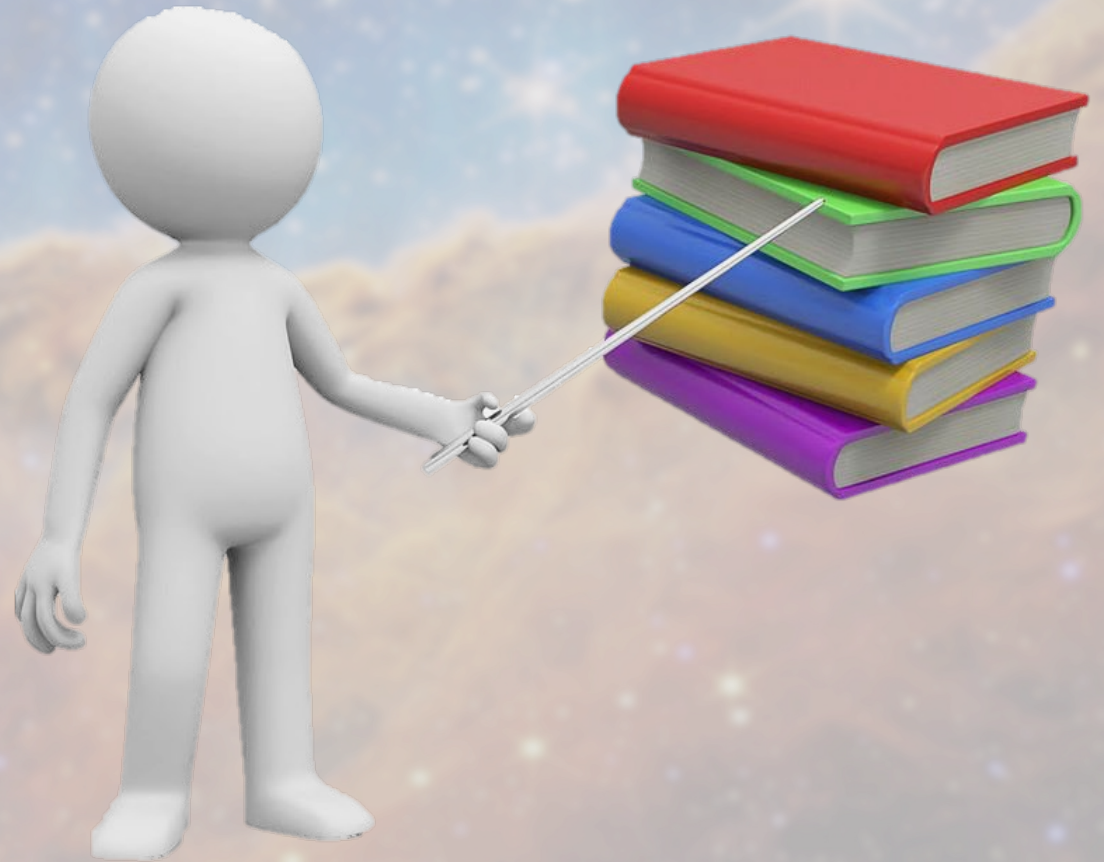
Part III: Future



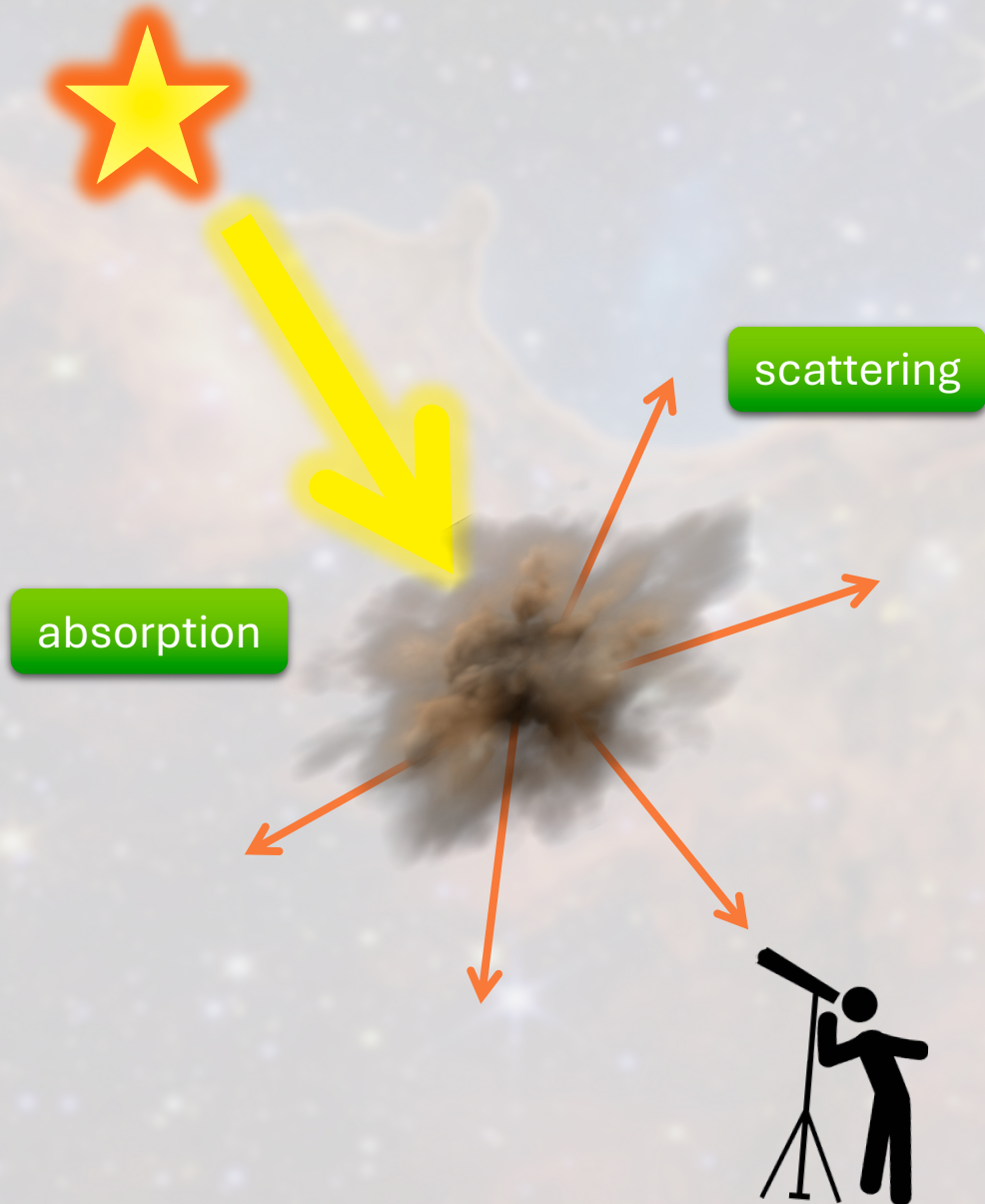
This overview is not comprehensive and biased



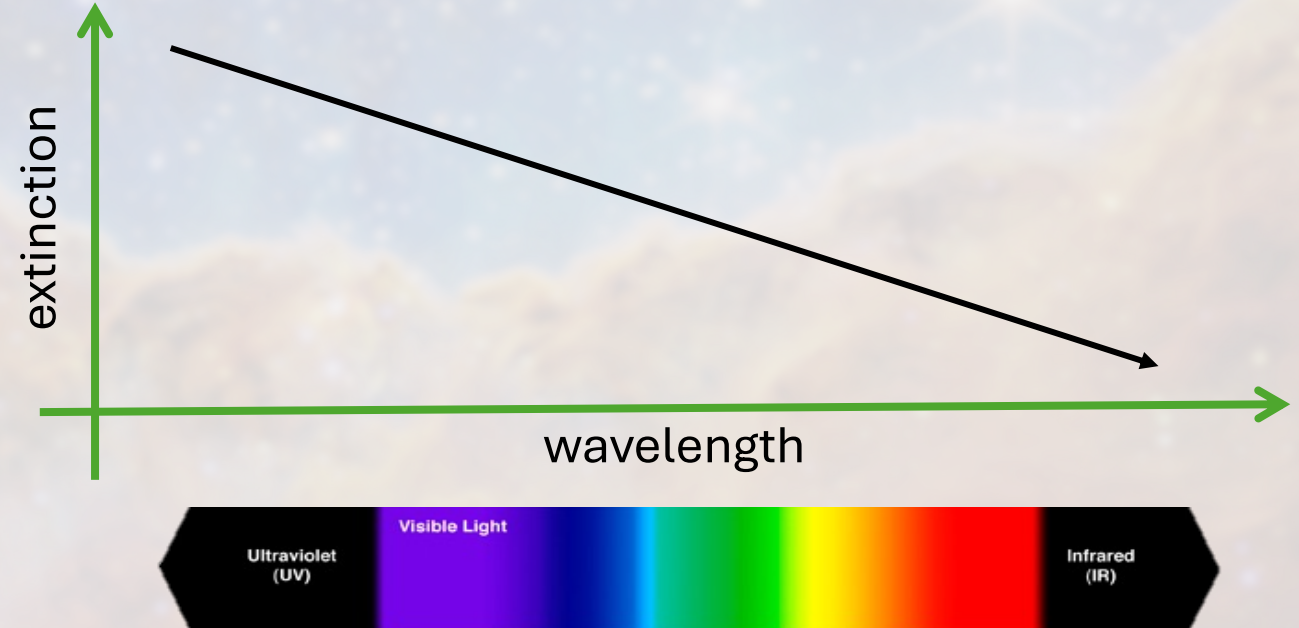
Part I: Introduction



What is dust extinction?



extinction = absorption + scattering

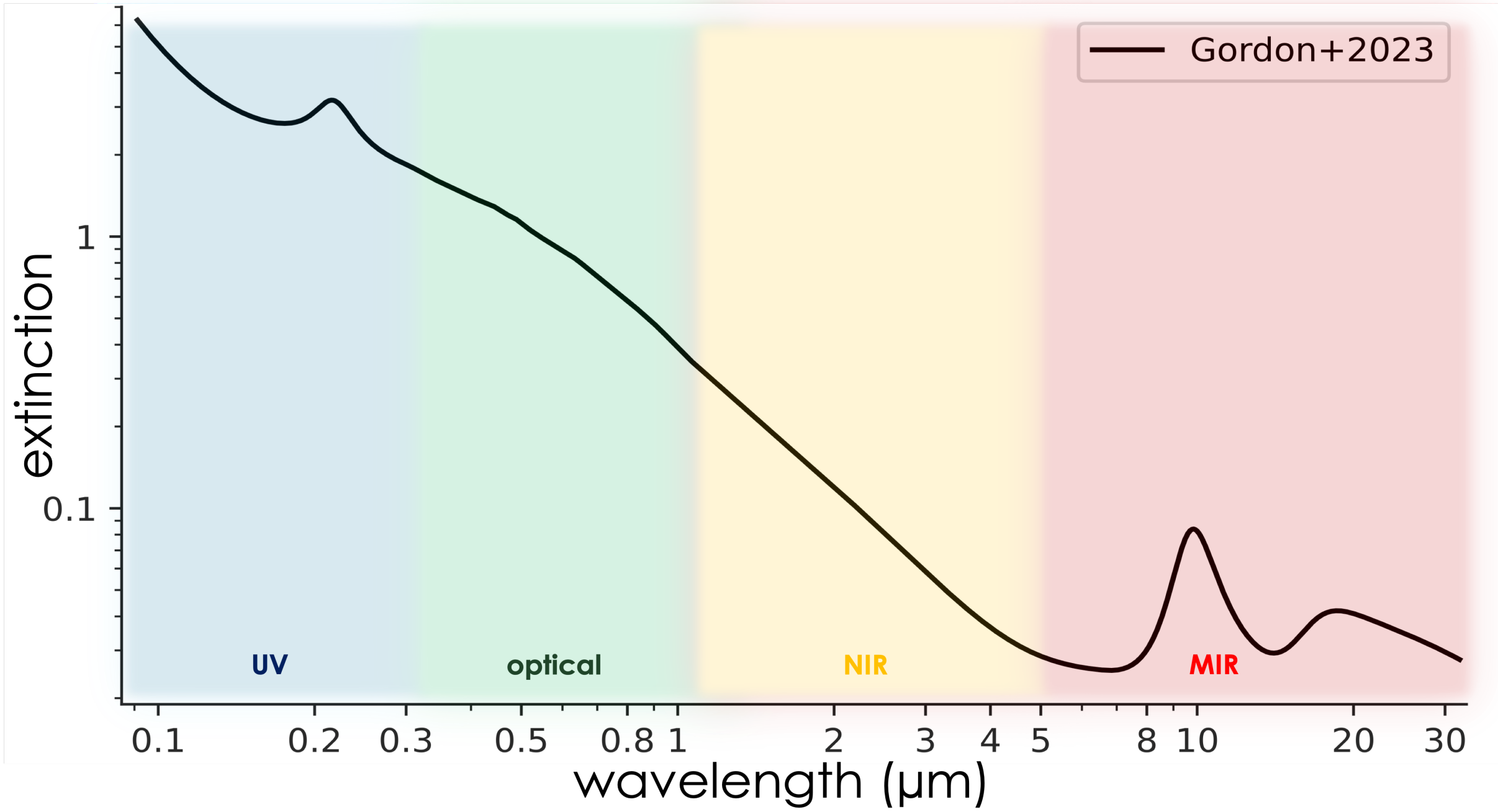


Extinction decreases with wavelength
→ “reddening”

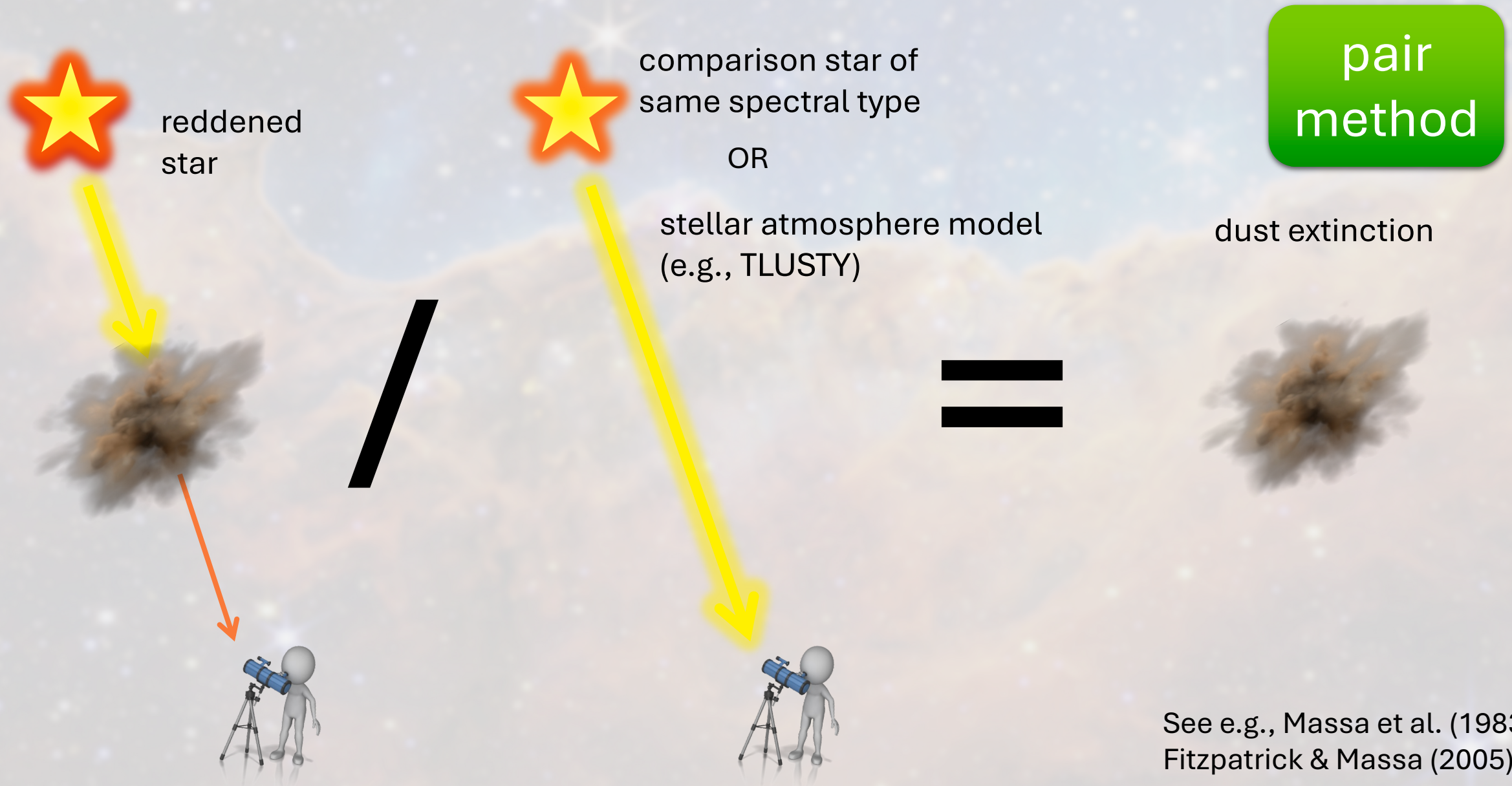
Extinction $\neq$ Attenuation!
→ Attenuation depends on geometry

See talk by Samir Salim (Thu)

Extinction curves



How do we measure extinction curves?



How do we measure extinction curves?

Basic measurement using pair method:

$$\begin{aligned} E(\lambda - V) &= m_{red}(\lambda - V) - m_{comp}(\lambda - V) \\ &= m_{red}(\lambda) - m_{comp}(\lambda) - m_{red}(V) + m_{comp}(V) \end{aligned}$$

$E(\lambda - V)$ = differential extinction = color excess
→ measurement relative to V-band
(to avoid distance assumptions)

Normalize to compare between different sightlines with different amounts of dust:

$$\frac{E(\lambda - V)}{E(B - V)}$$

Historically (e.g. Fitzpatrick & Massa 1990)

$$\frac{A(\lambda)}{A(V)}$$

Recently more commonly used, because easier to interpret (e.g. Gordon et al. 2023)
But requires knowledge of $A(V)$!

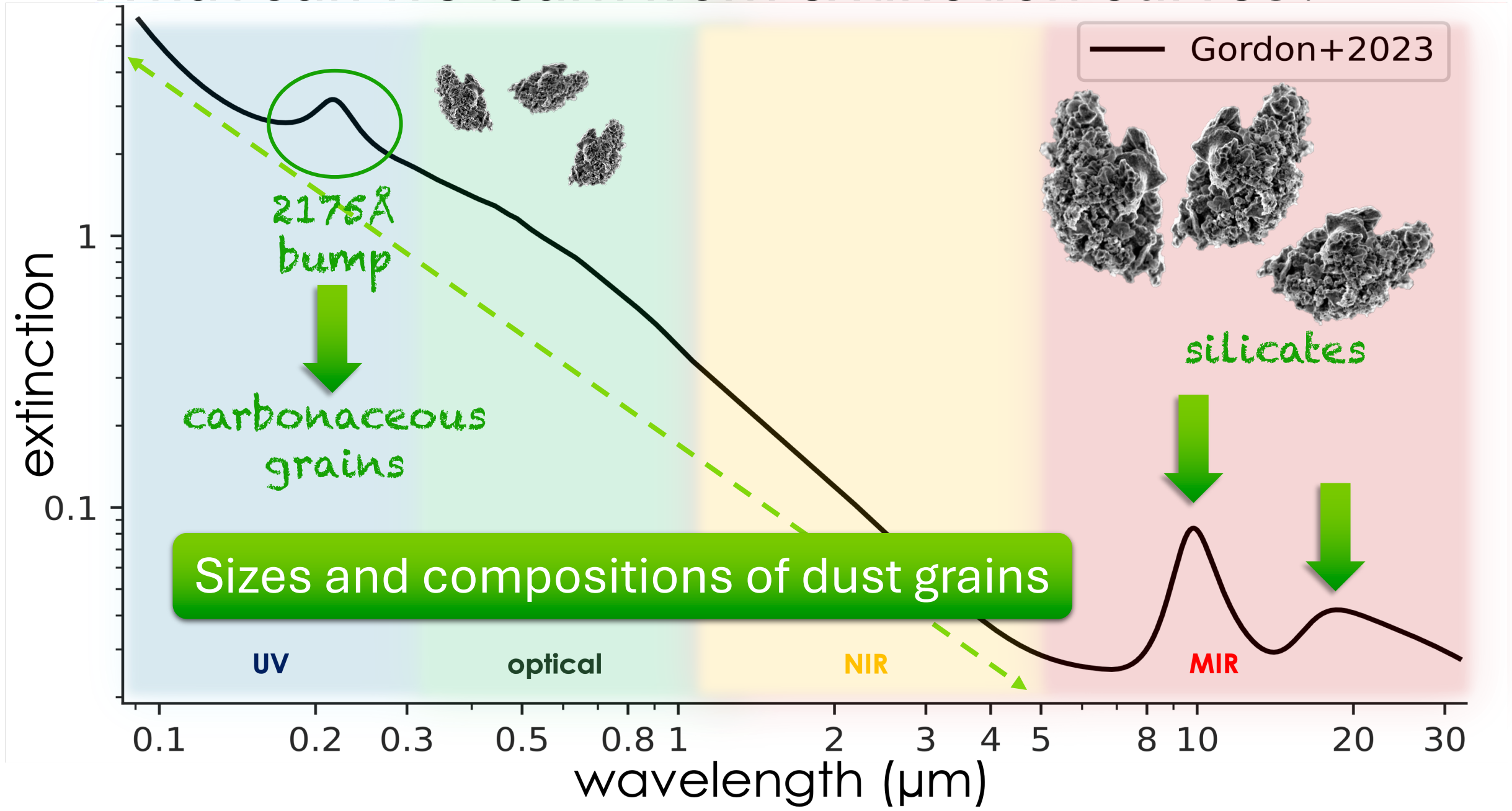
$A(\lambda)$ = absolute extinction

$$E(\lambda - V) = A(\lambda) - A(V)$$

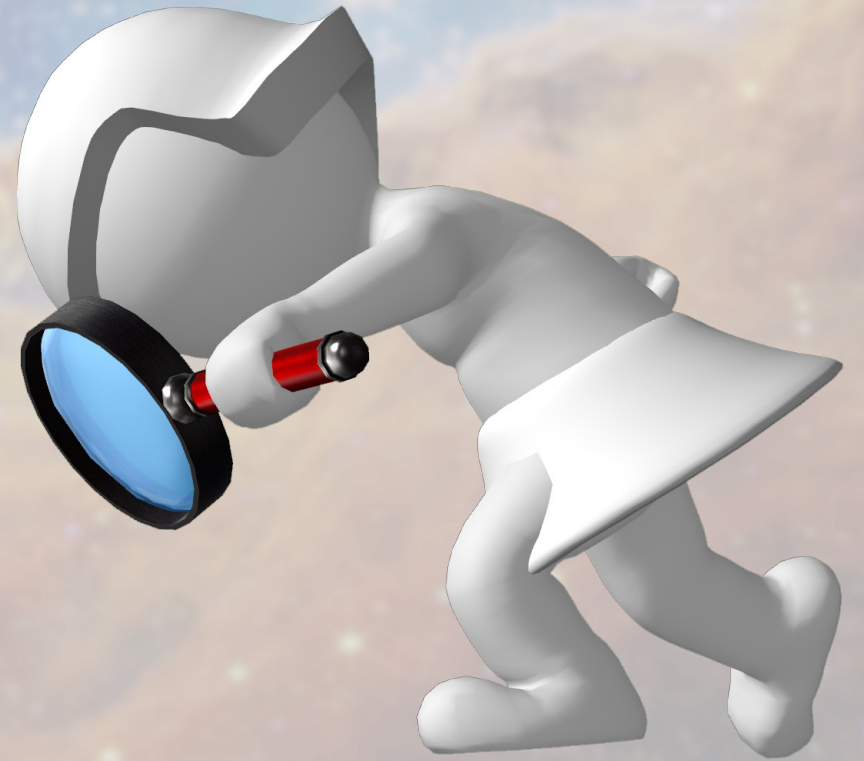
$$\rightarrow E(\infty - V) = -A(V)$$

Extrapolation of extinction to “infinite” wavelengths,
e.g. $A(V) \cong -1.1 E(K - V)$ (Gordon et al. 2021)

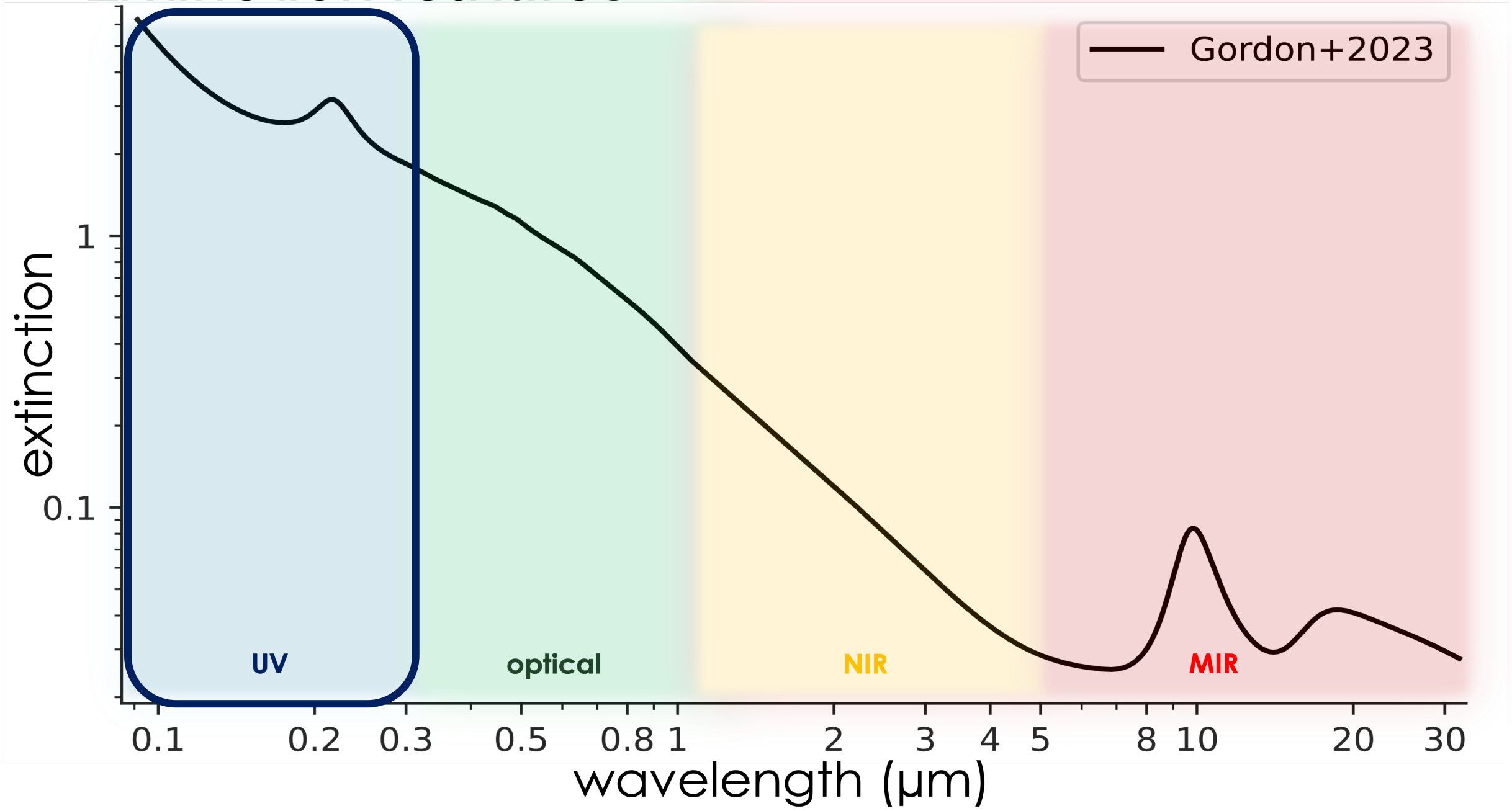
What can we learn from extinction curves?



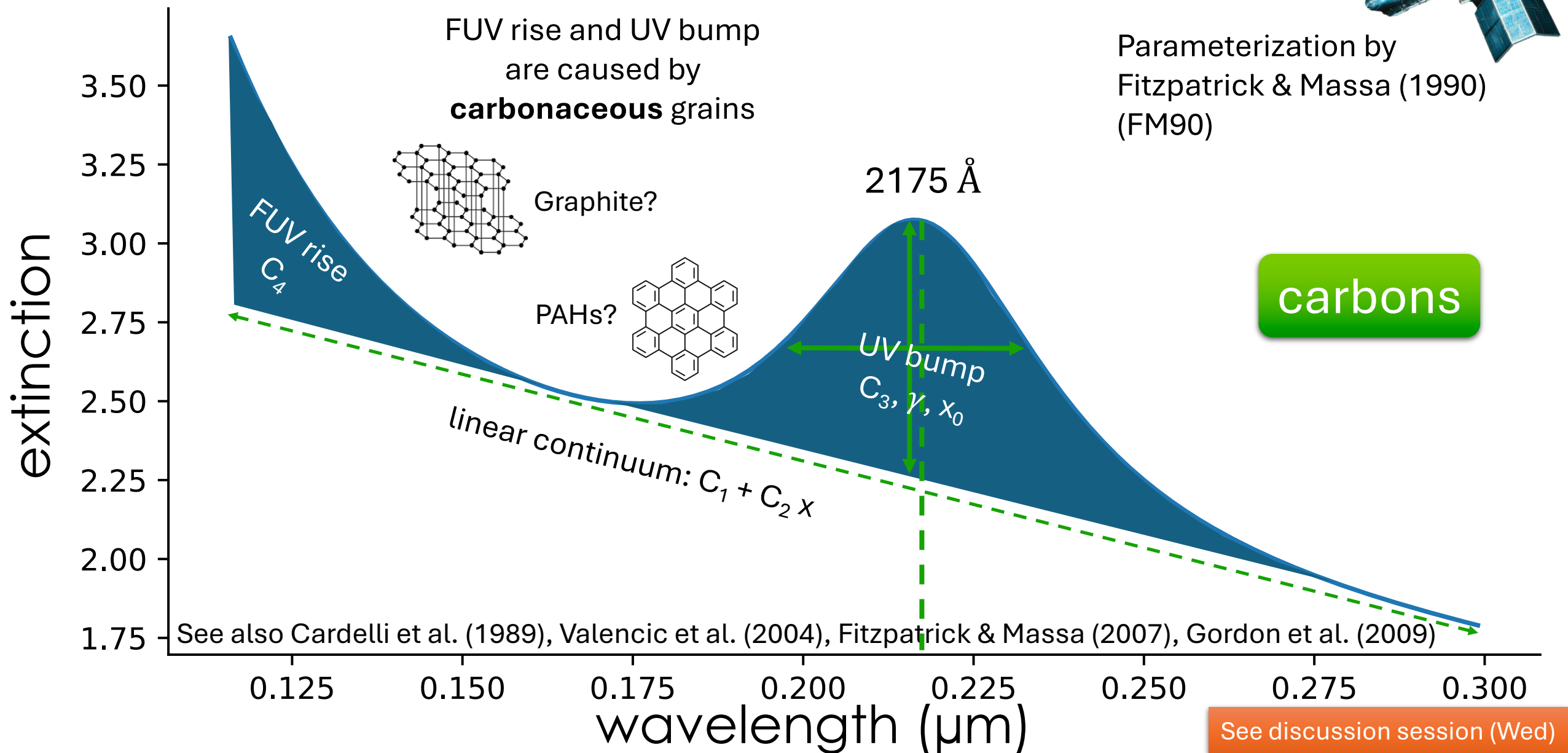
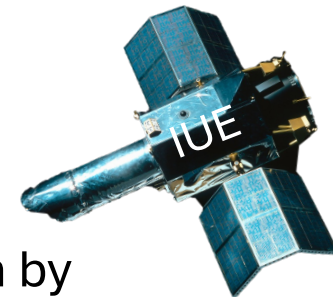
Part II: Current knowledge and challenges

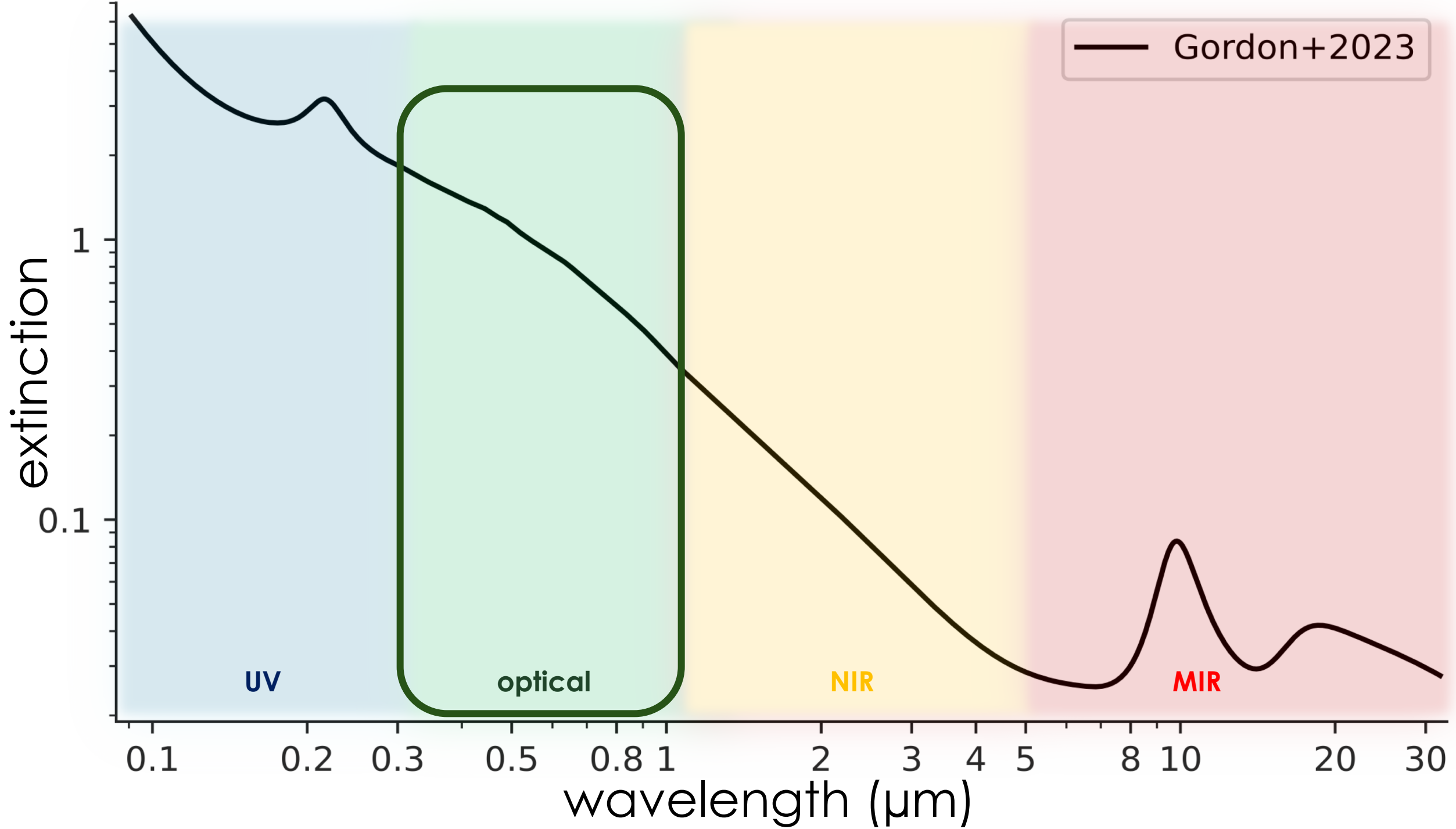


Extinction features



UV extinction features

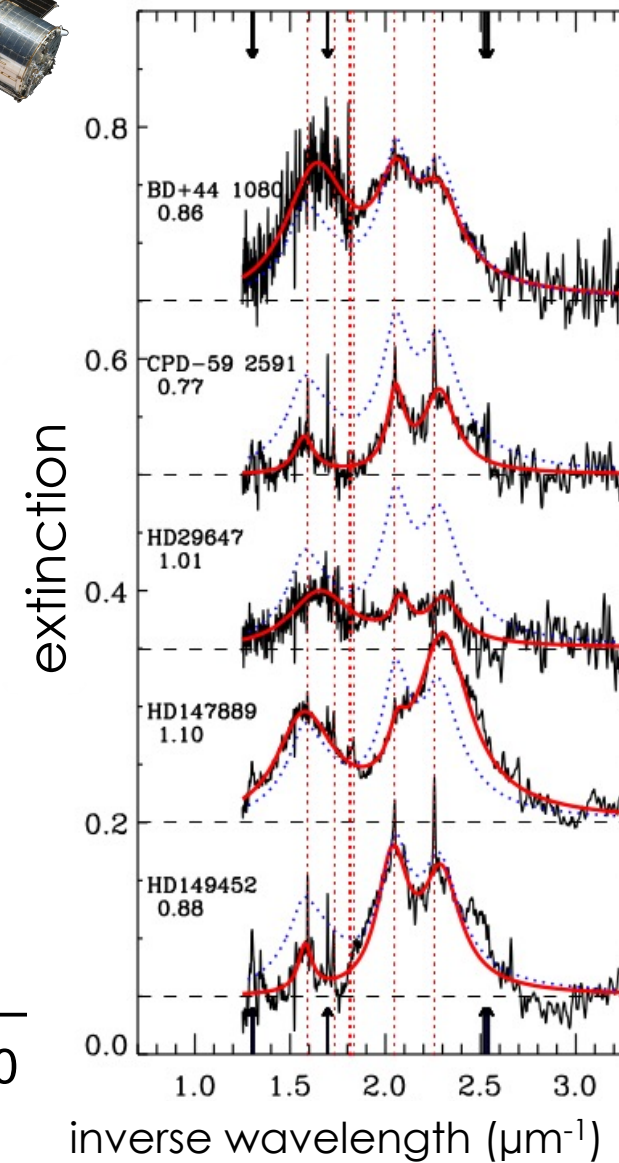
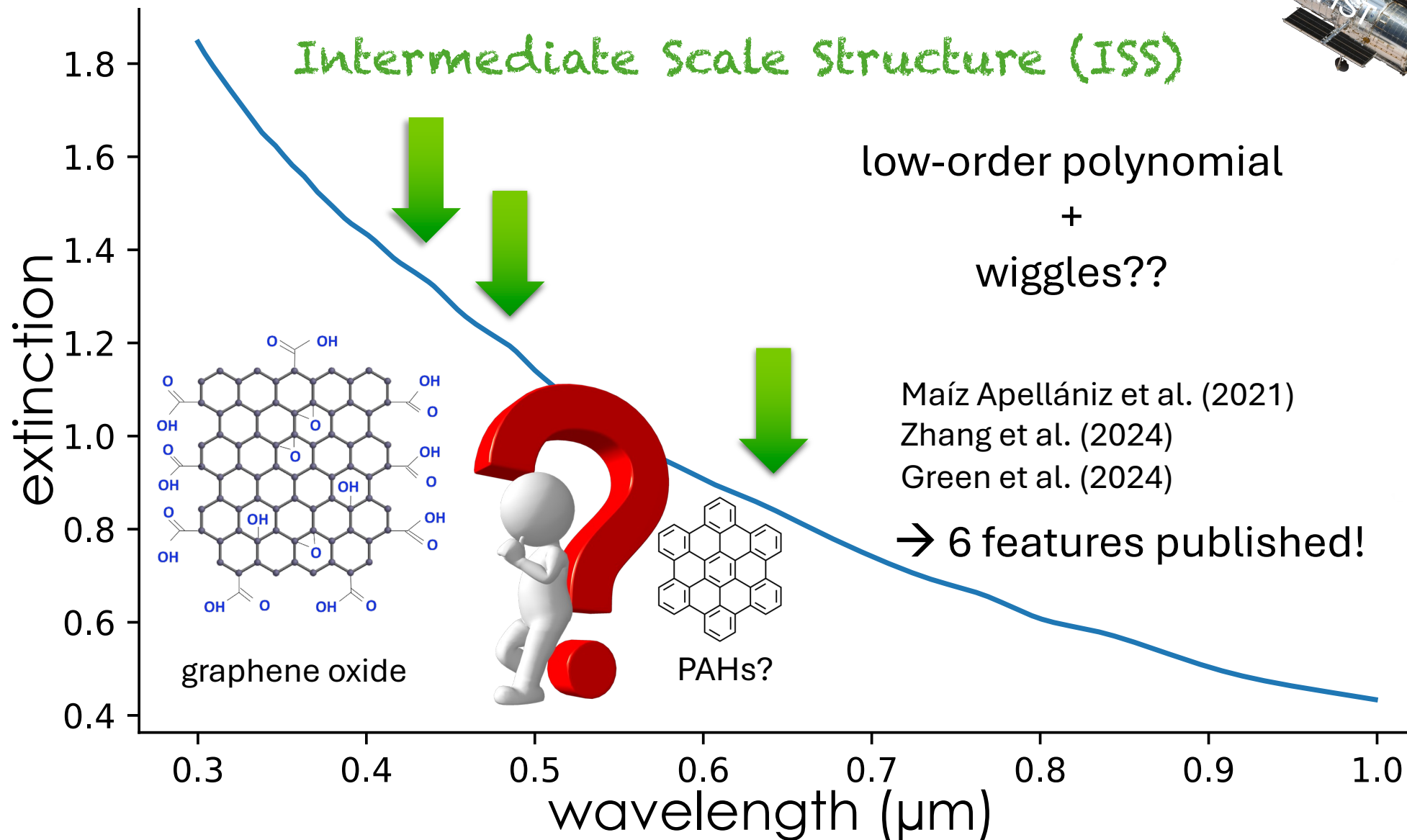
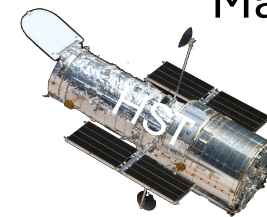




Optical extinction curves

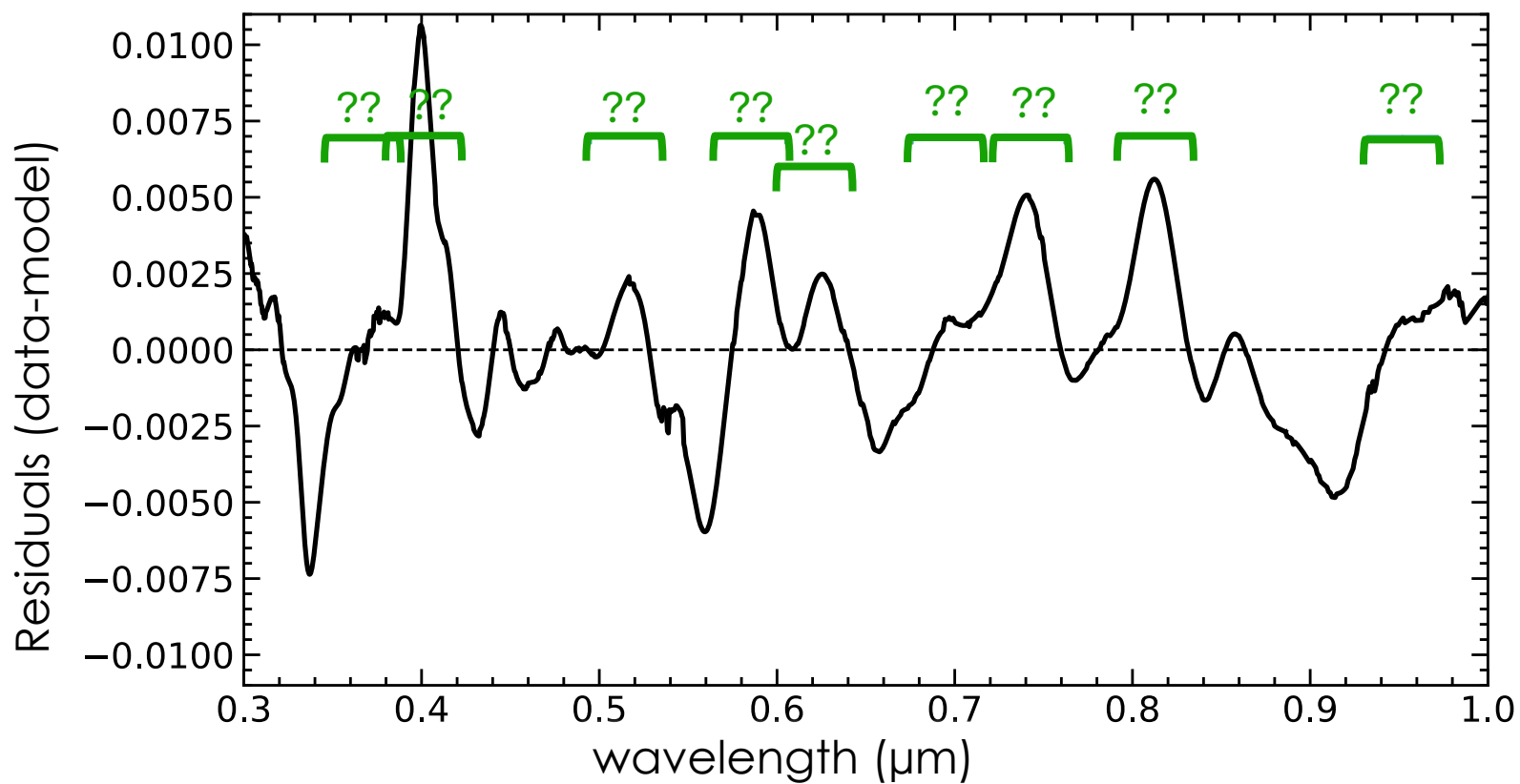
Fitzpatrick et al. (2019)

Massa et al. (2020)



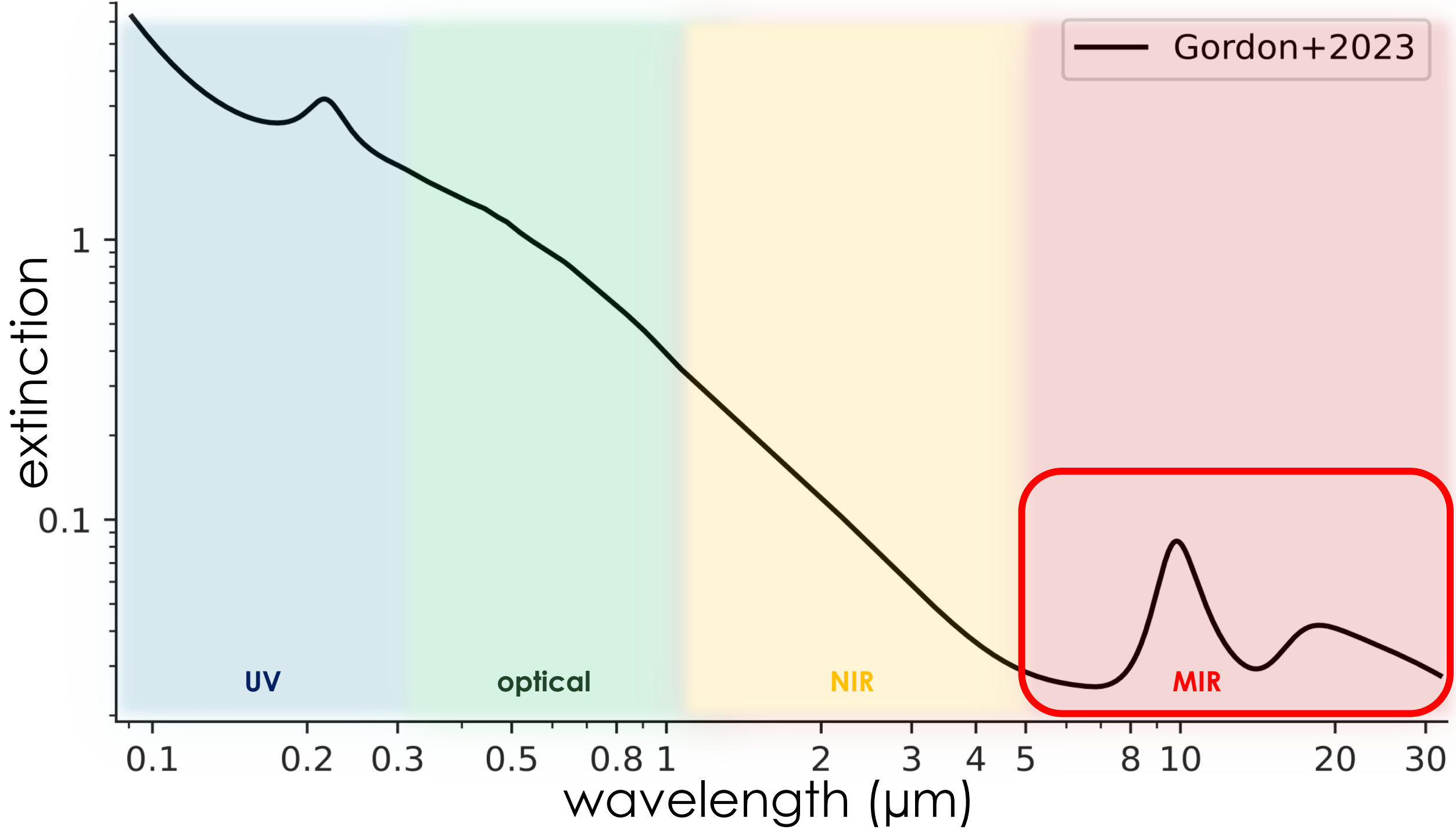
more ISS features?!

See poster by Chamani Gunasekera



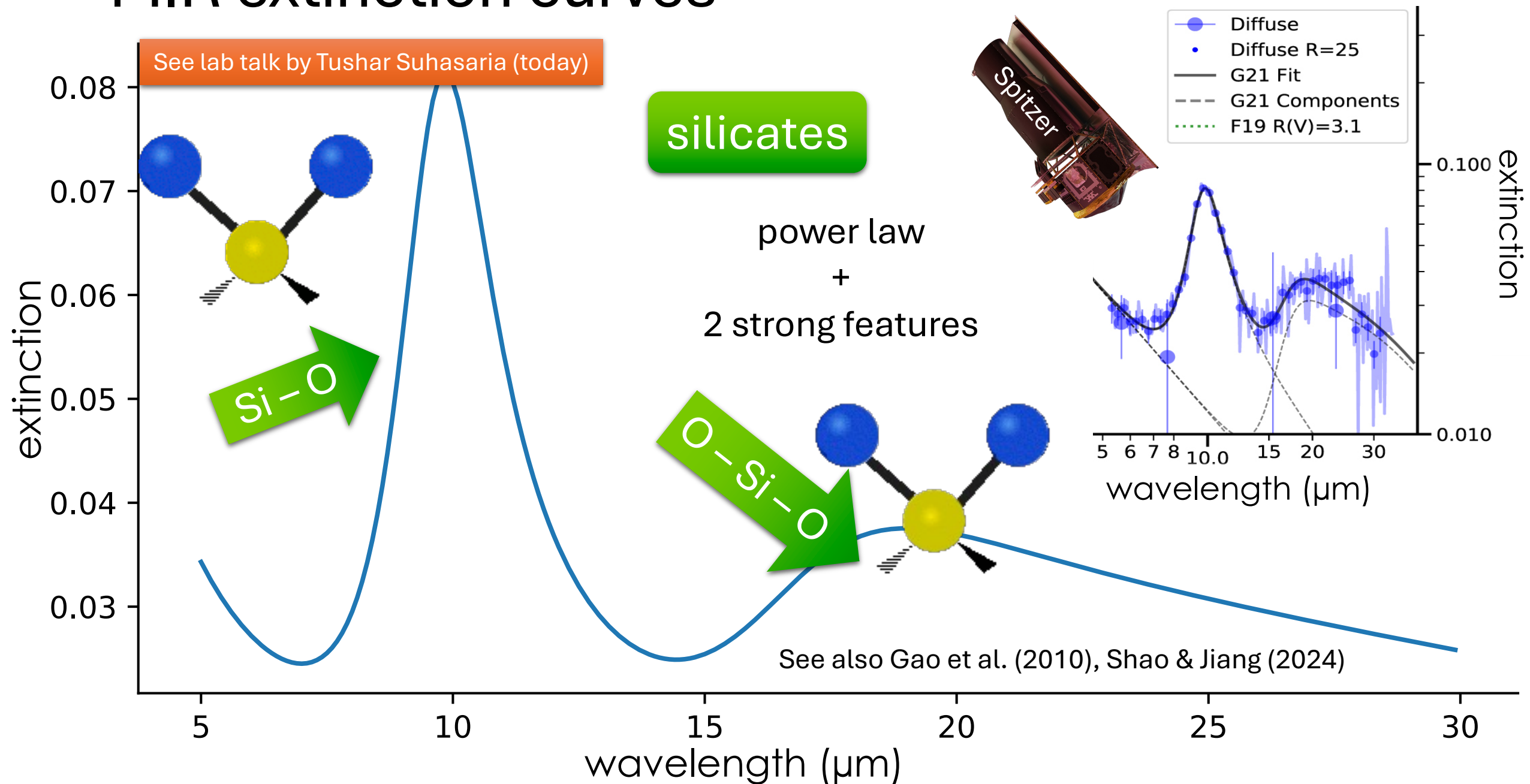
Also Diffuse Interstellar Bands!

See talks by Chuanyu Wei and
Andrew Saydjari (today)



MIR extinction curves

Gordon et al. (2021)



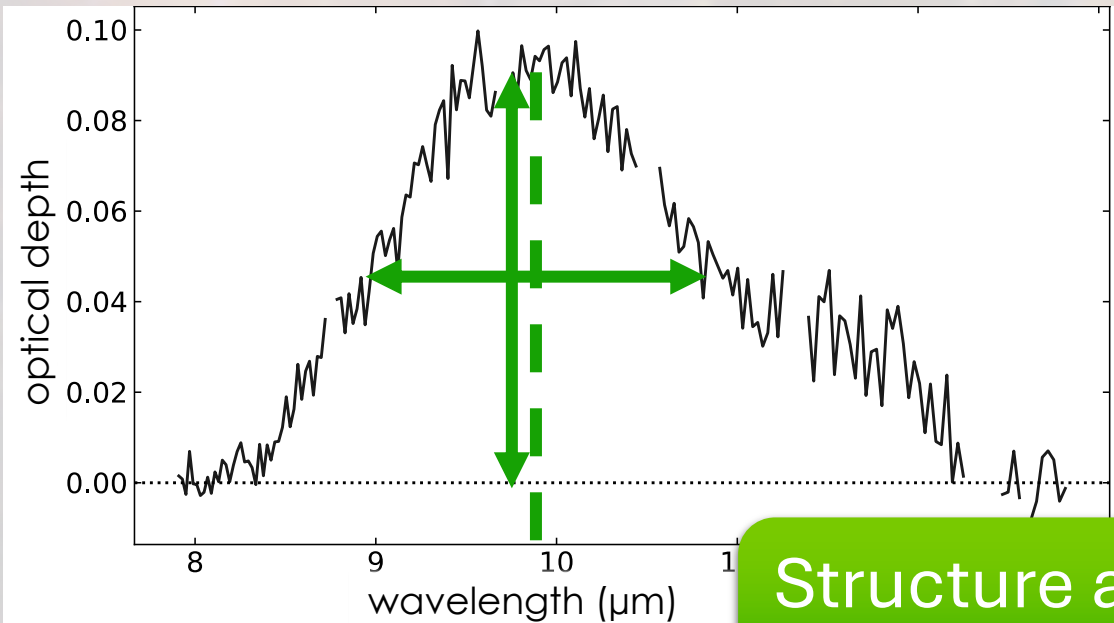
Silicate features with JWST (MIRI MRS)

MEAD

Measuring Extinction and Abundances of Dust

Decleir et al. (2025)

9 sightlines with low $A(V)$ (~ 1.2 – 2.5)

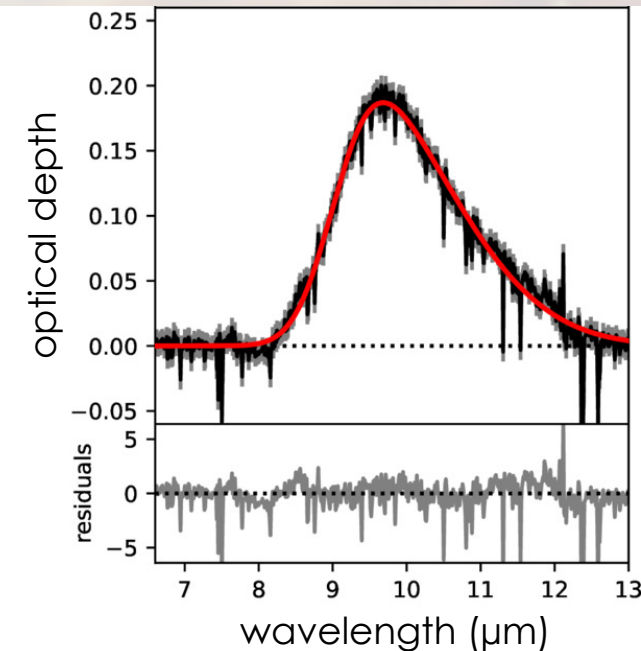
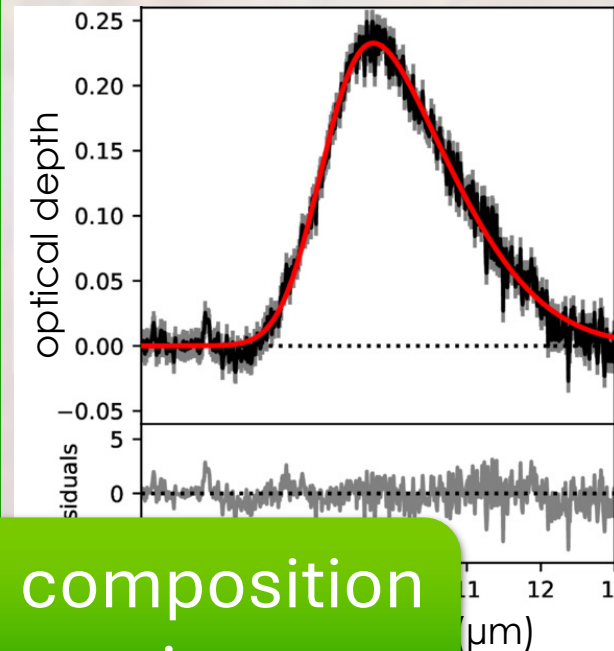


WISCI

Webb Investigation of Silicates, Carbons and Ices

Zeegers et al. (2025)

12 sightlines with higher $A(V)$ (~ 4 – 7)



Structure and composition
of silicate grains

strength $\rightarrow$ how much silicate?
shape $\rightarrow$ what type of silicates?

See talk by Chuanyu Wei (today)

Silicate feature

Fit with skewed Gaussian

→ Detailed properties of feature

Variation in feature properties



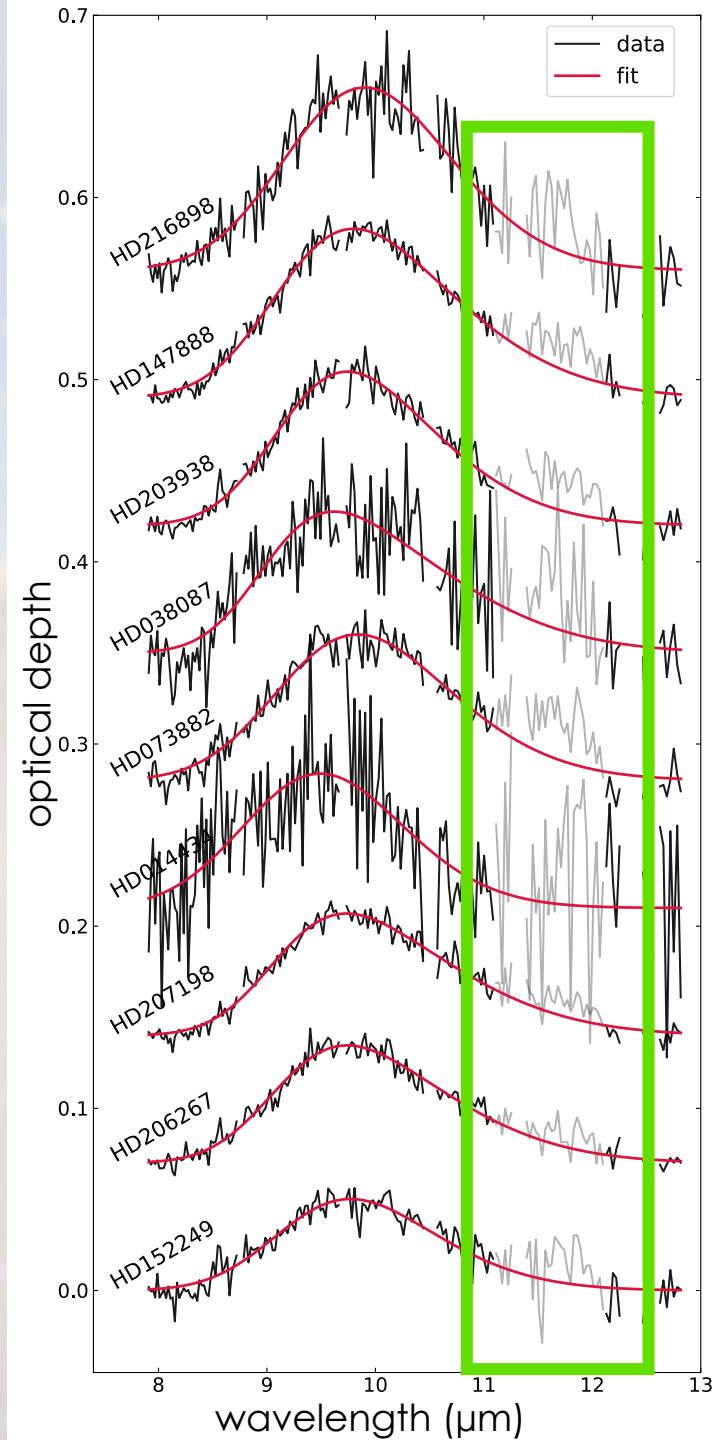
Variation in silicate grain properties

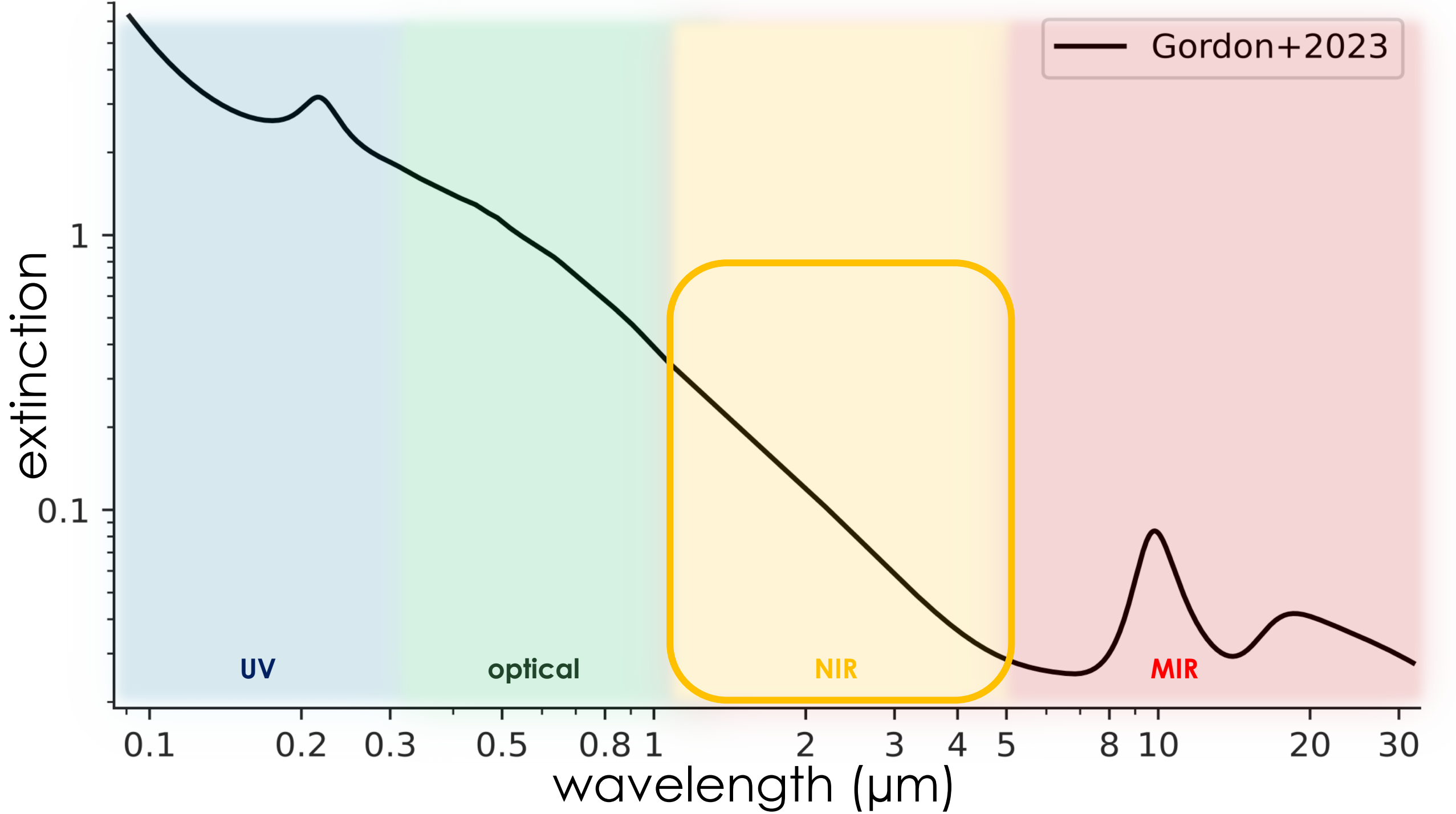
Silicate feature strength correlates with $A(V)$ and $N(H)$,
and with $N(Mg)$, $N(Fe)$ and $N(O)$ in dust!

Mg- and Fe-rich silicates

MEAD

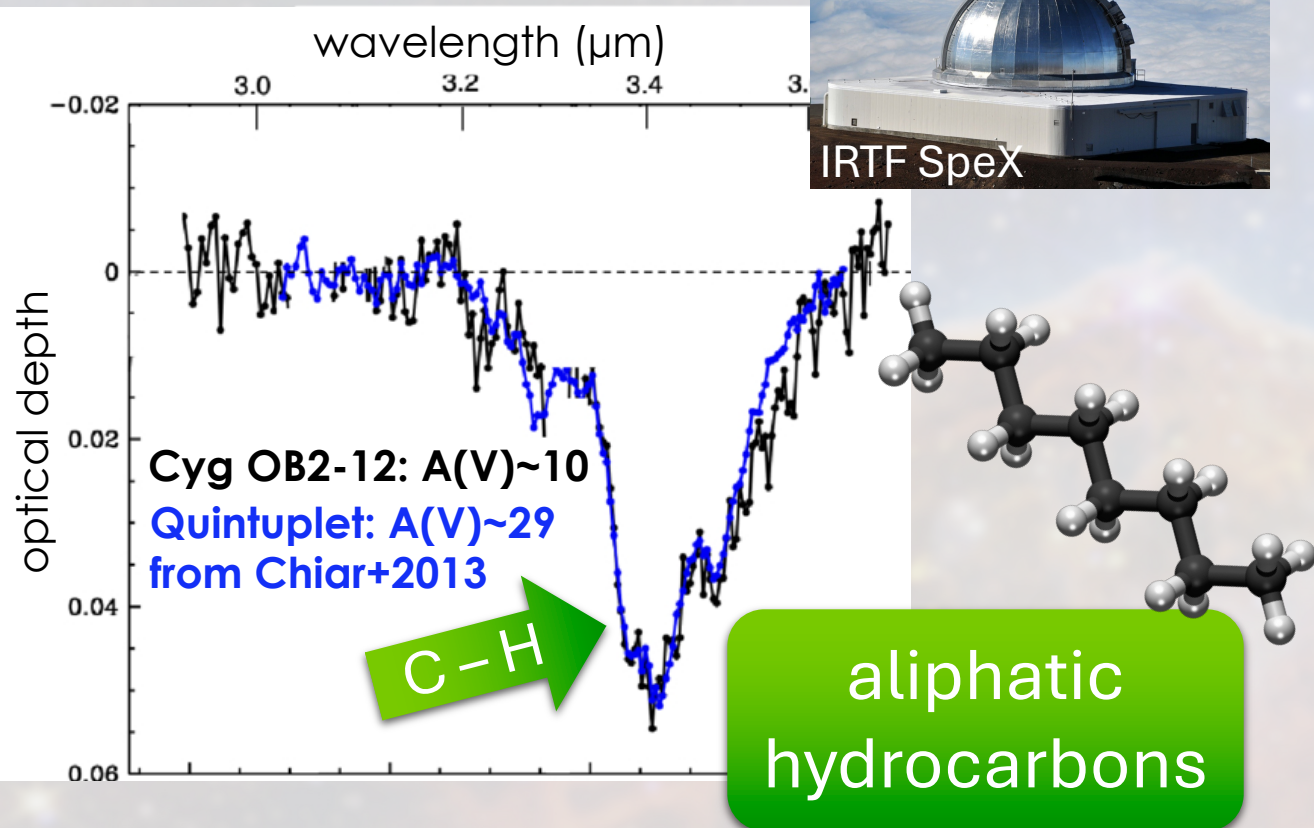
Decleir et al. (2025)



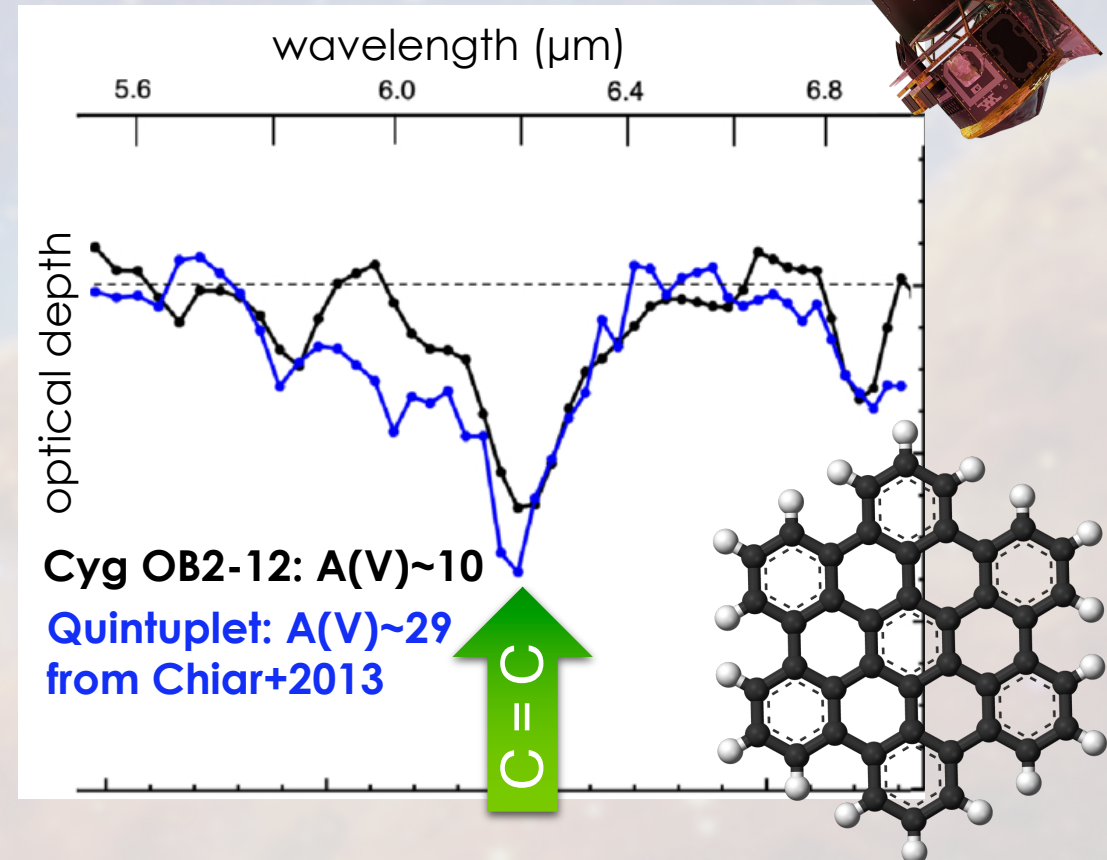
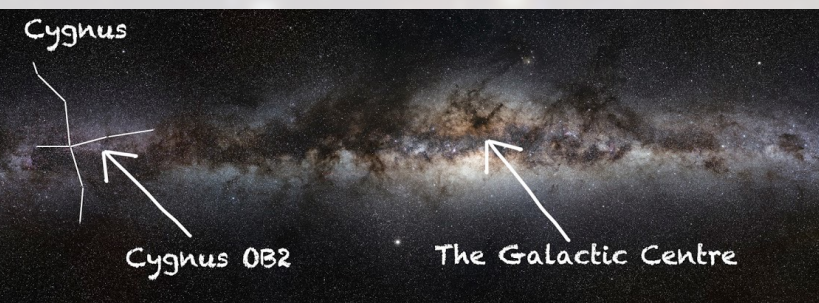


NIR extinction features

Pendleton et al. (2025)



See also Pendleton et al. (1994), Hensley & Draine (2020)



See also Chiar et al. (2000), Hensley & Draine (2020)

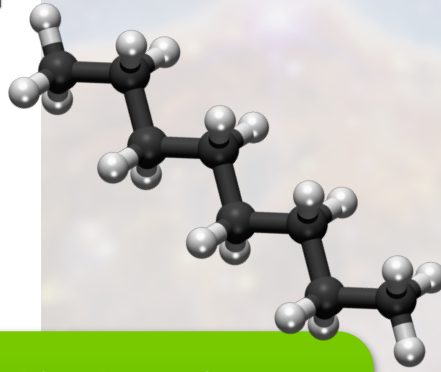
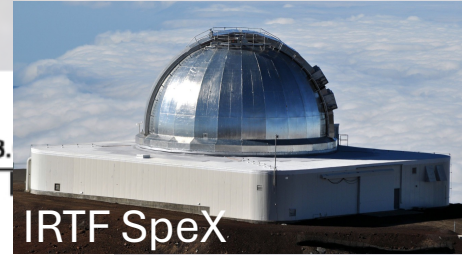
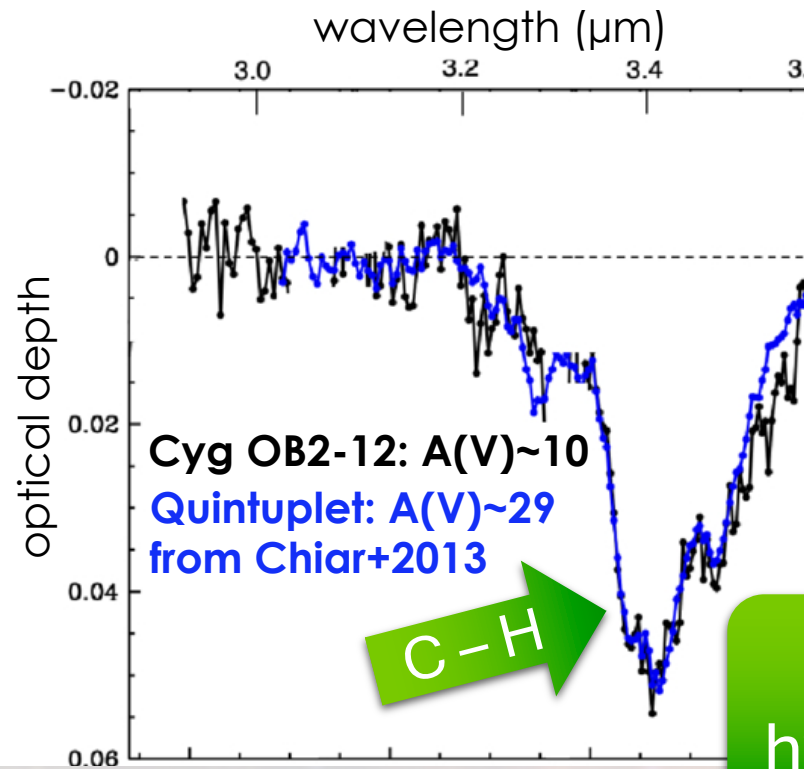
lots of dust
dense

aromatic
hydrocarbons

See lab talk by Cornelia Jäger (today)

NIR extinction features

Pendleton et al. (2025)

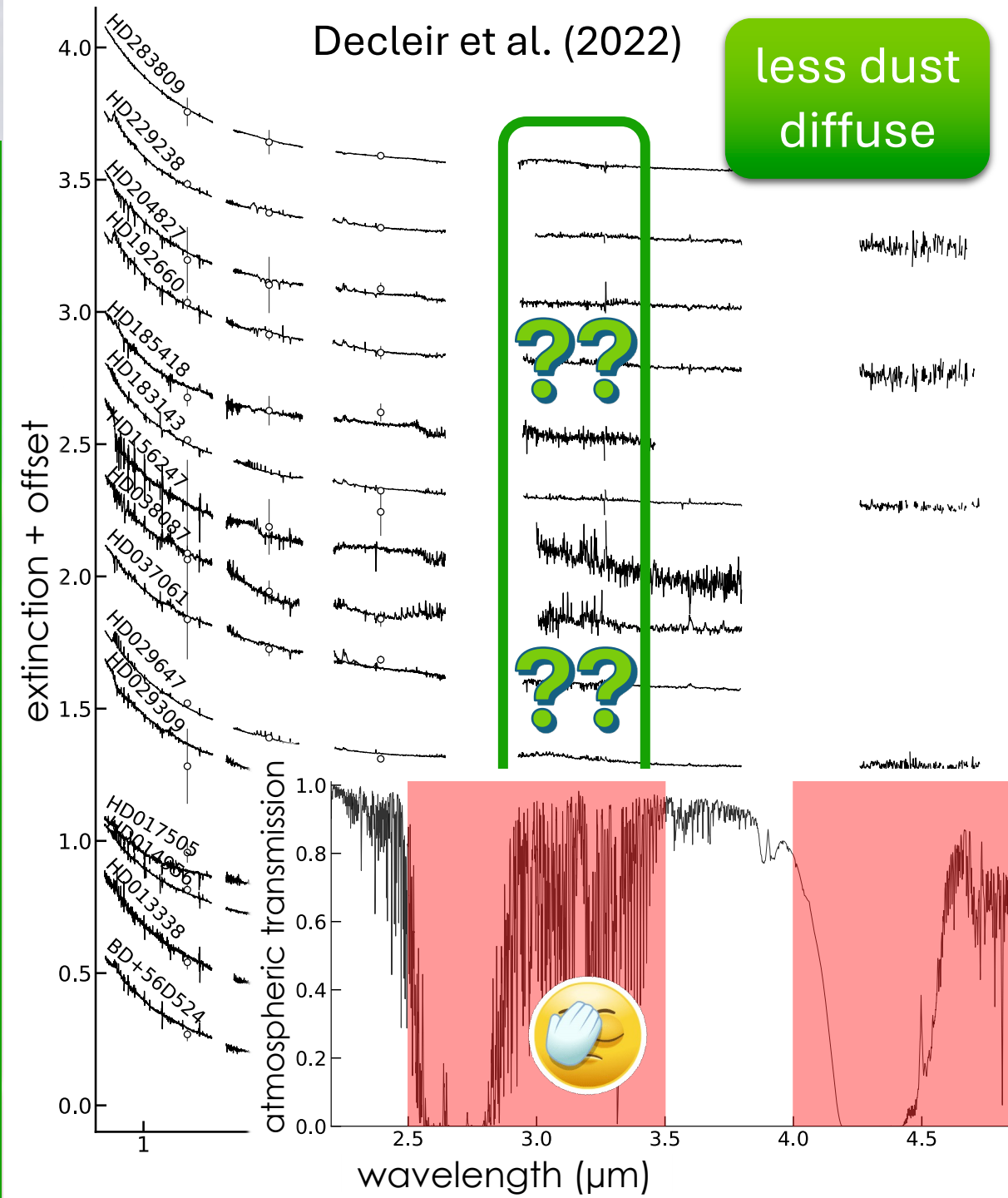


aliphatic
hydrocarbons

See also Pendleton et al. (1994), Hensley & Draine (2020)



lots of dust
dense

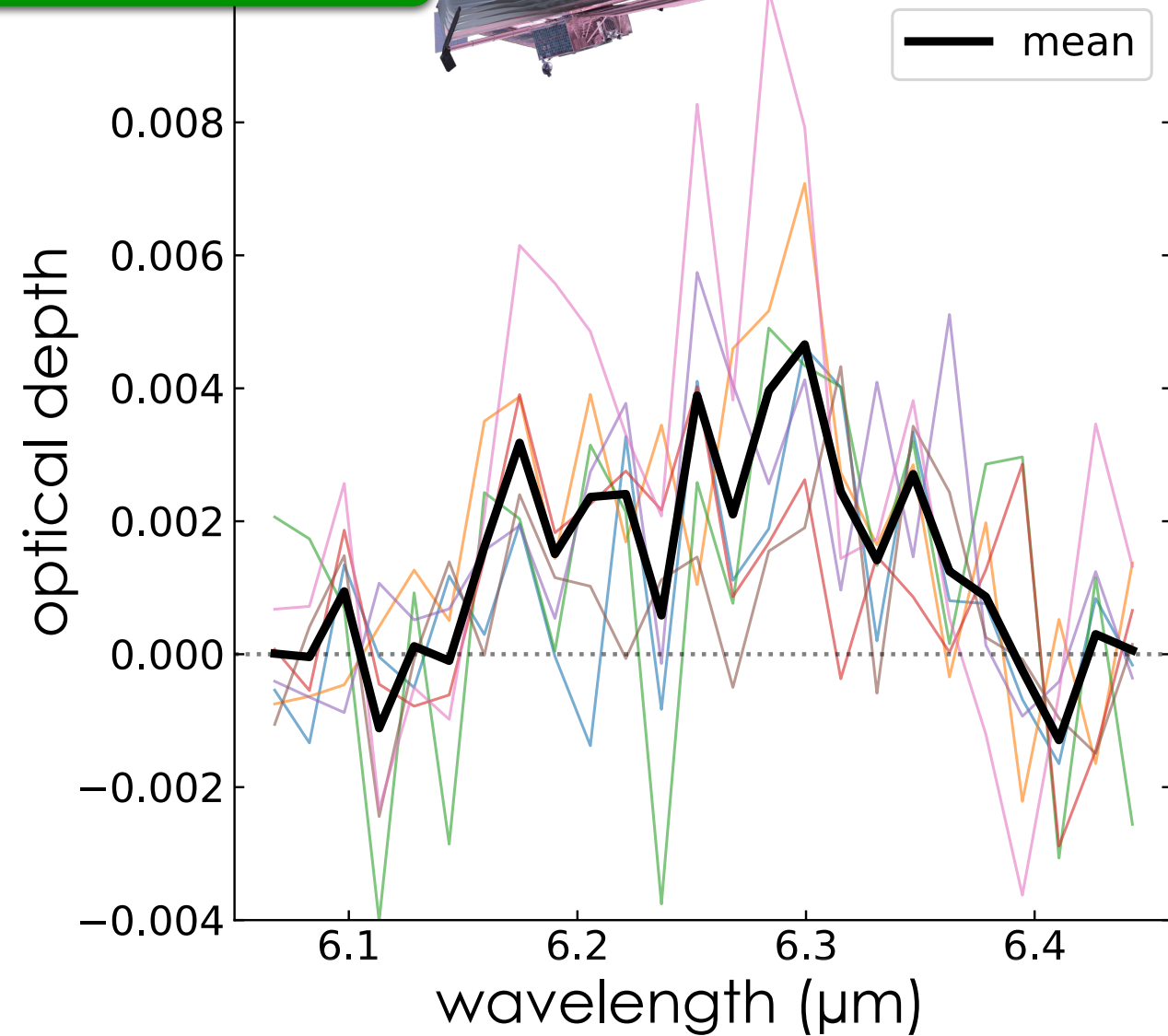
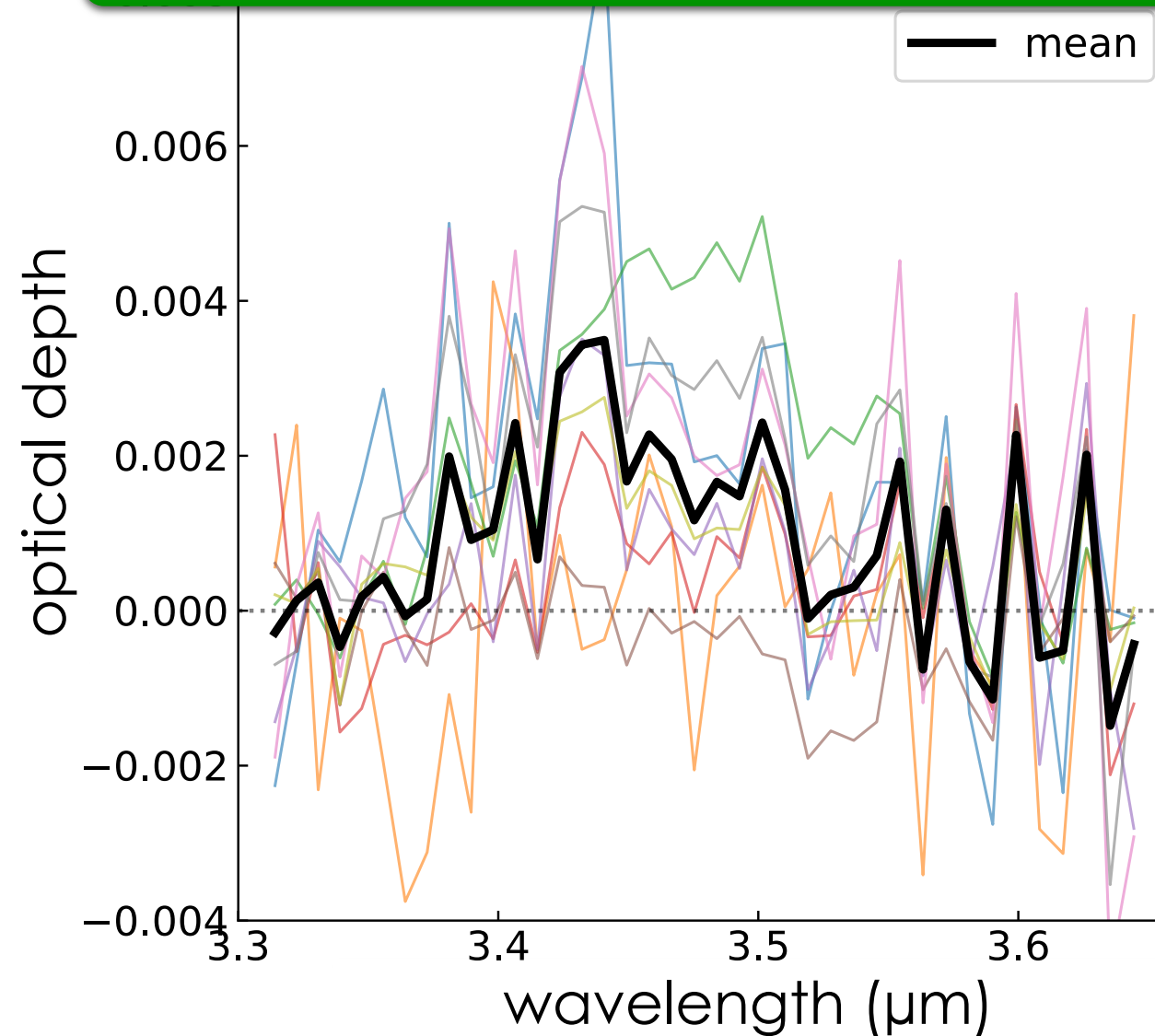
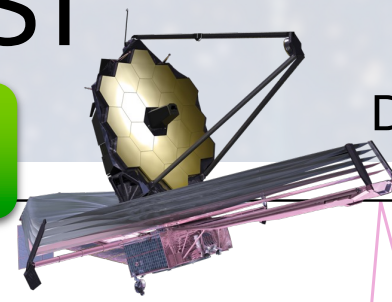


Carbonaceous features with JWST

MEAD

Decleir et al. (2025)

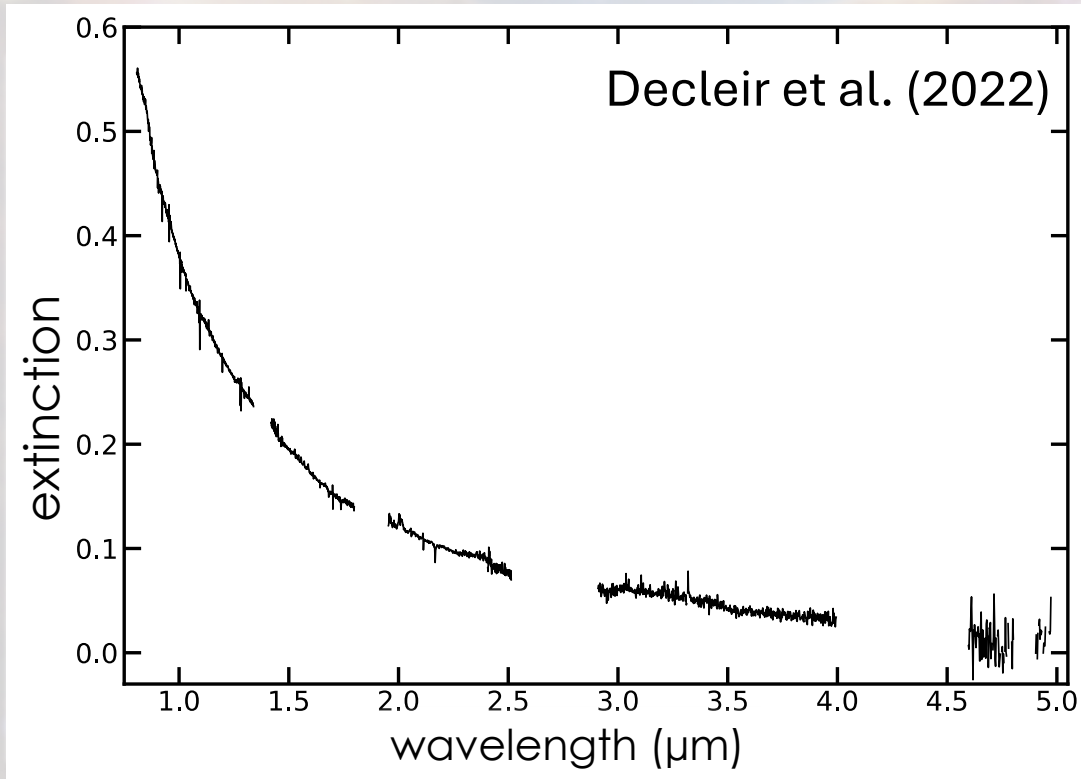
First detection of hydrocarbons in $A(V) < 2.5$!



Diffuse vs. Dense Dust

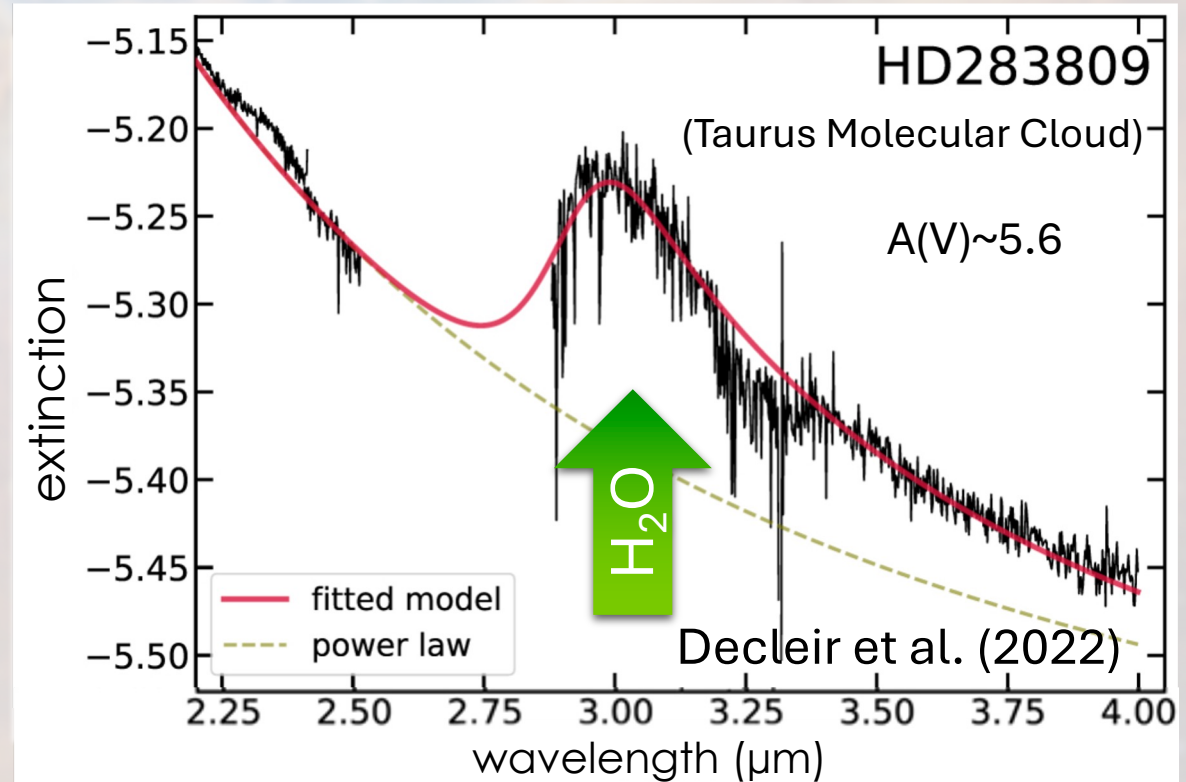
diffuse

- Low $A(V)$ s ($\lesssim 3$)
- No ice (no 3.0 μm H₂O ice feature)



dense

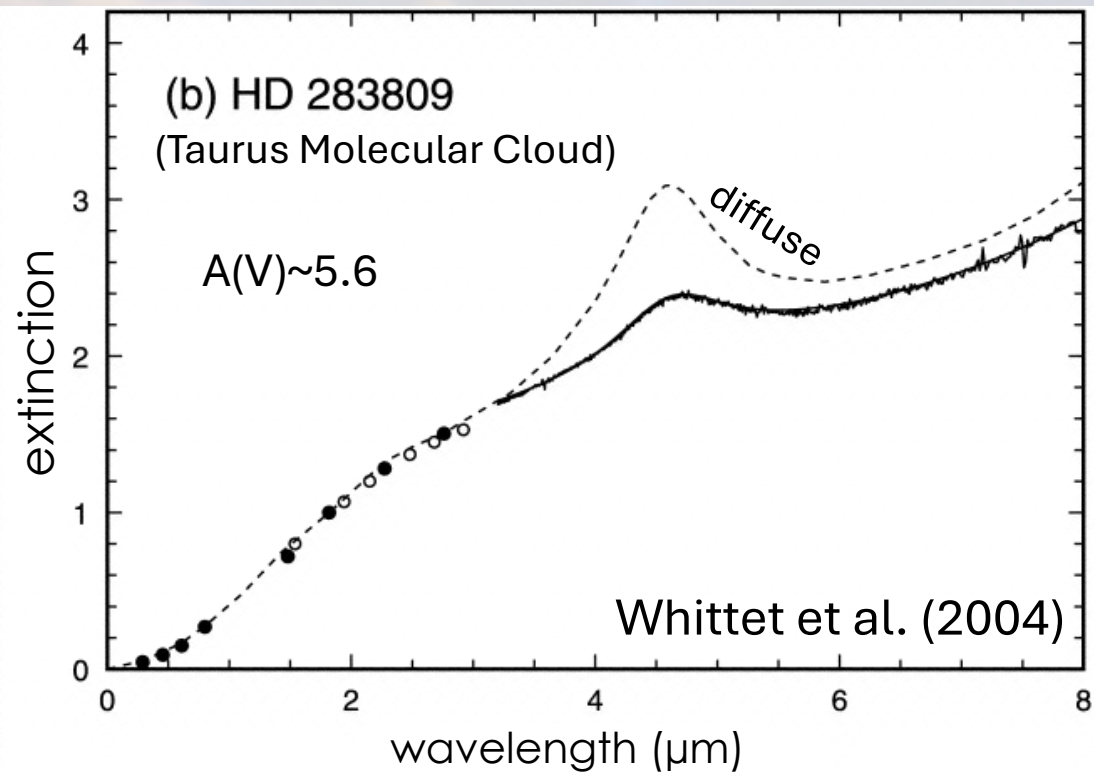
- “High” $A(V)$ s (but not perfect diagnostic)
- Ice (3.0 μm H₂O ice feature)



See also e.g. Whittet et al. (1988), Smith et al. (1993)

Extinction in dense sightlines

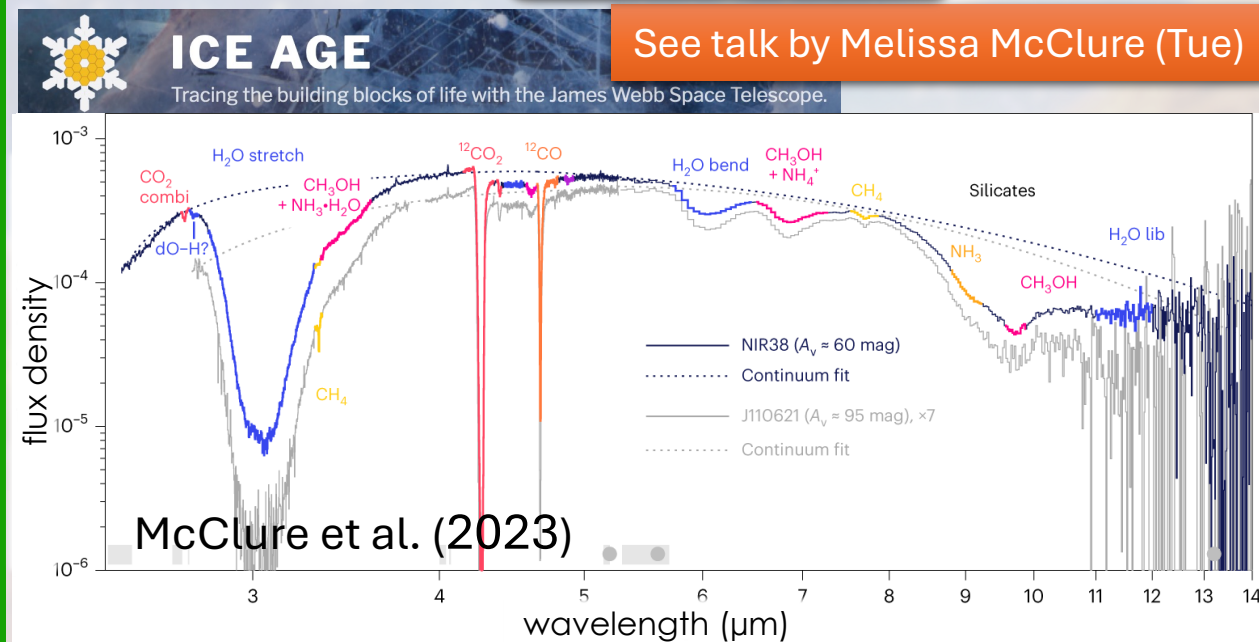
dense



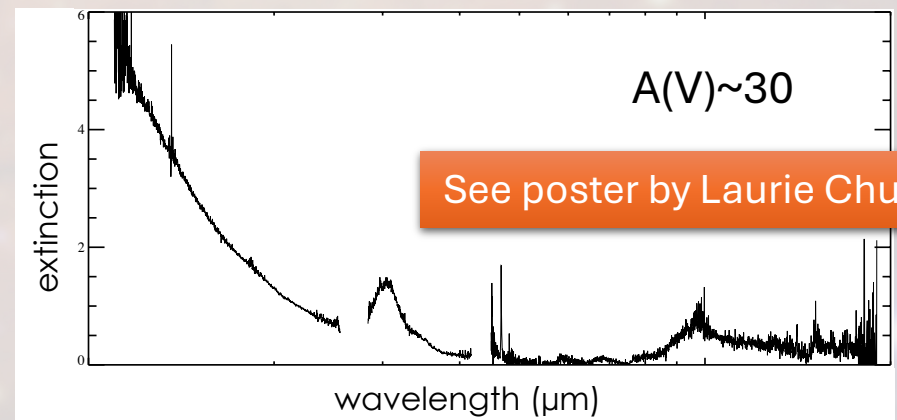
- Flatter UV extinction
- Weaker UV bump

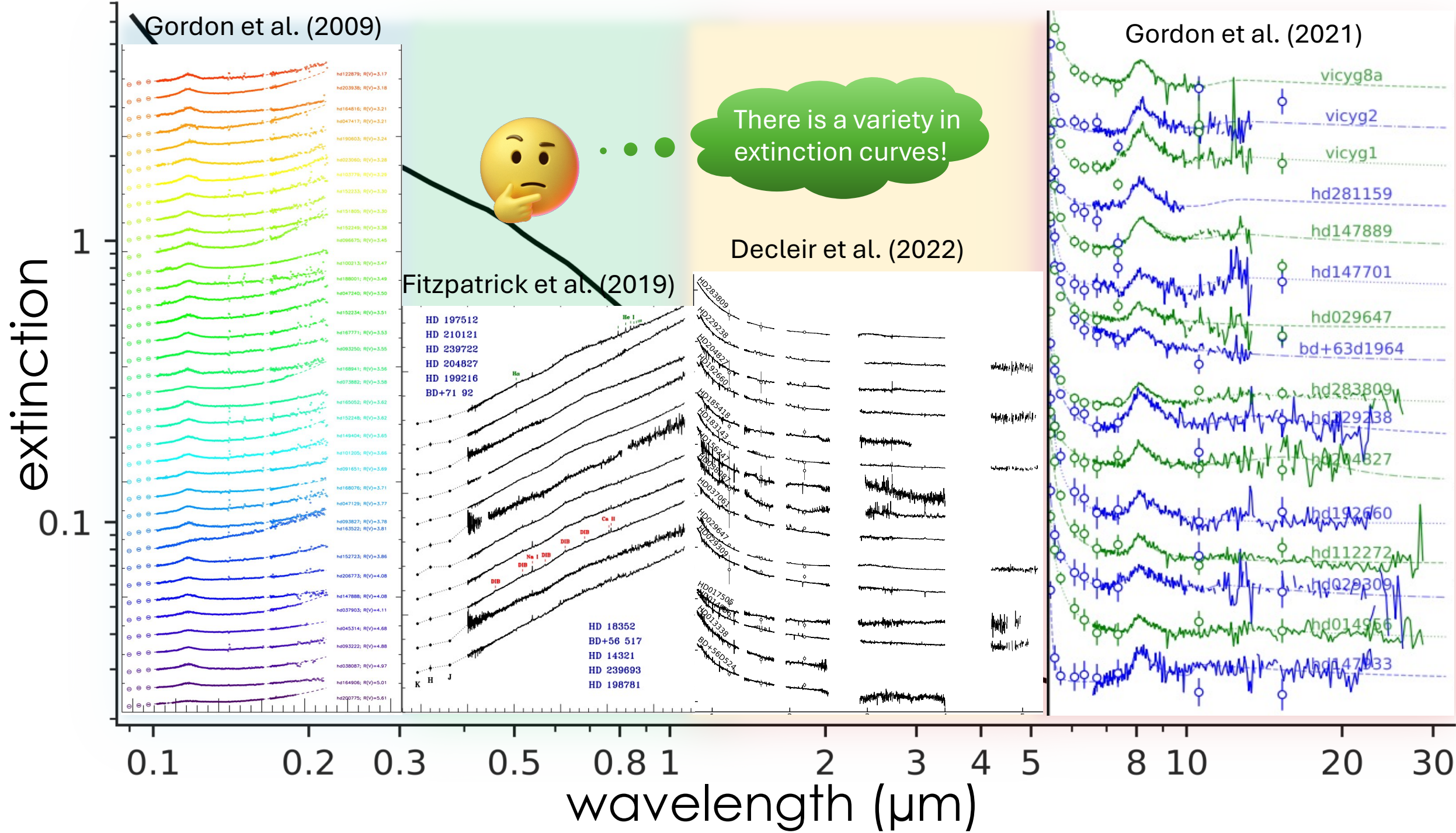
Different dust properties

very dense



See also e.g. Boogert et al. (2011, 2015)





Order in the chaos

$R(V)$ -
dependent
extinction

Cardelli et al. (1989):

Linear relationship between extinction
and $1/R(V)$ in the UV and optical

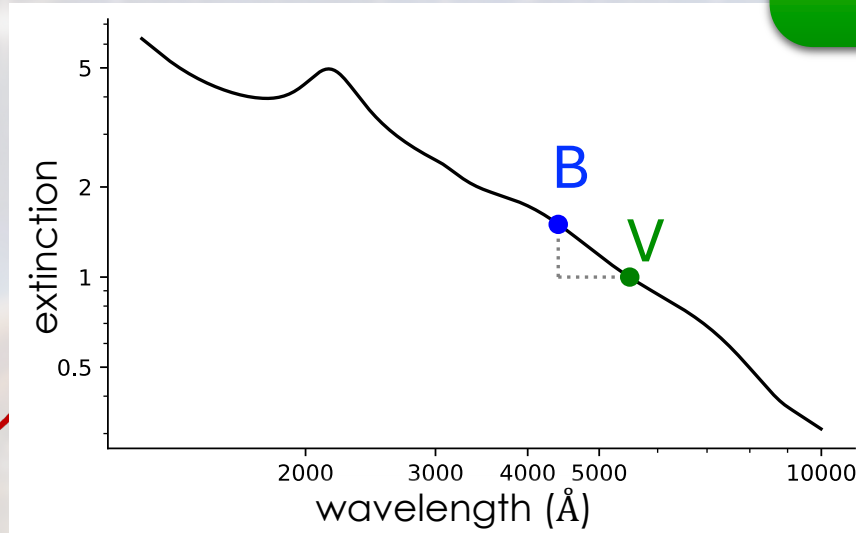
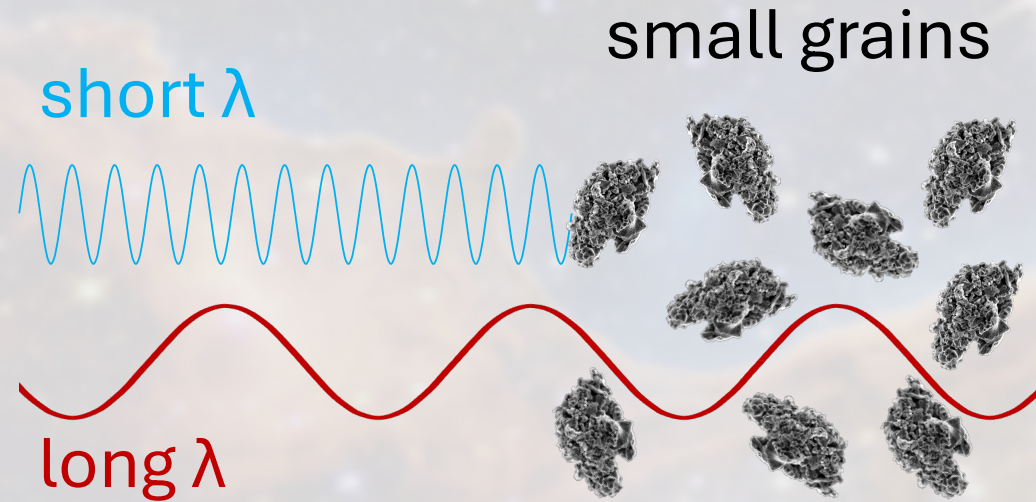
$$R(V) = \frac{A(V)}{E(B-V)} = \text{total-to-selective extinction ratio}$$

Milky Way average: $R(V) = 3.1$

$R(V)$ is a tracer of the average dust grain size

$R(V) \sim$ dust grain size

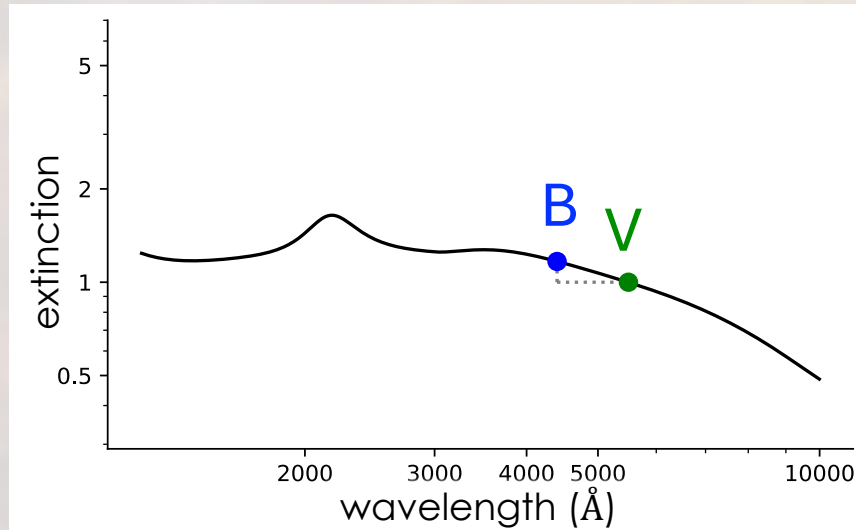
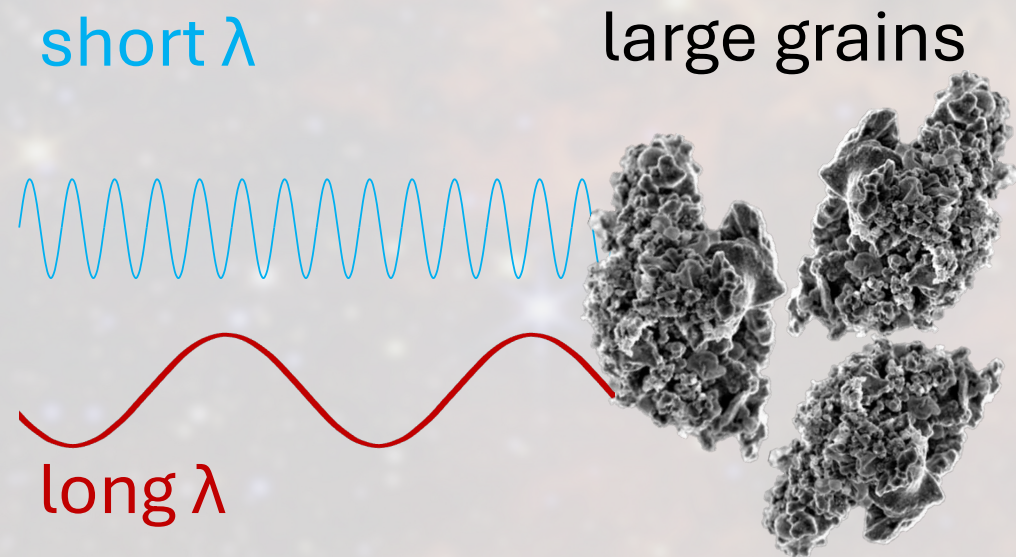
$$R(V) = \frac{A(V)}{E(B - V)}$$



short λ more extinguished than long λ

→ steep extinction curve

large $E(B-V)$
= small $R(V)$



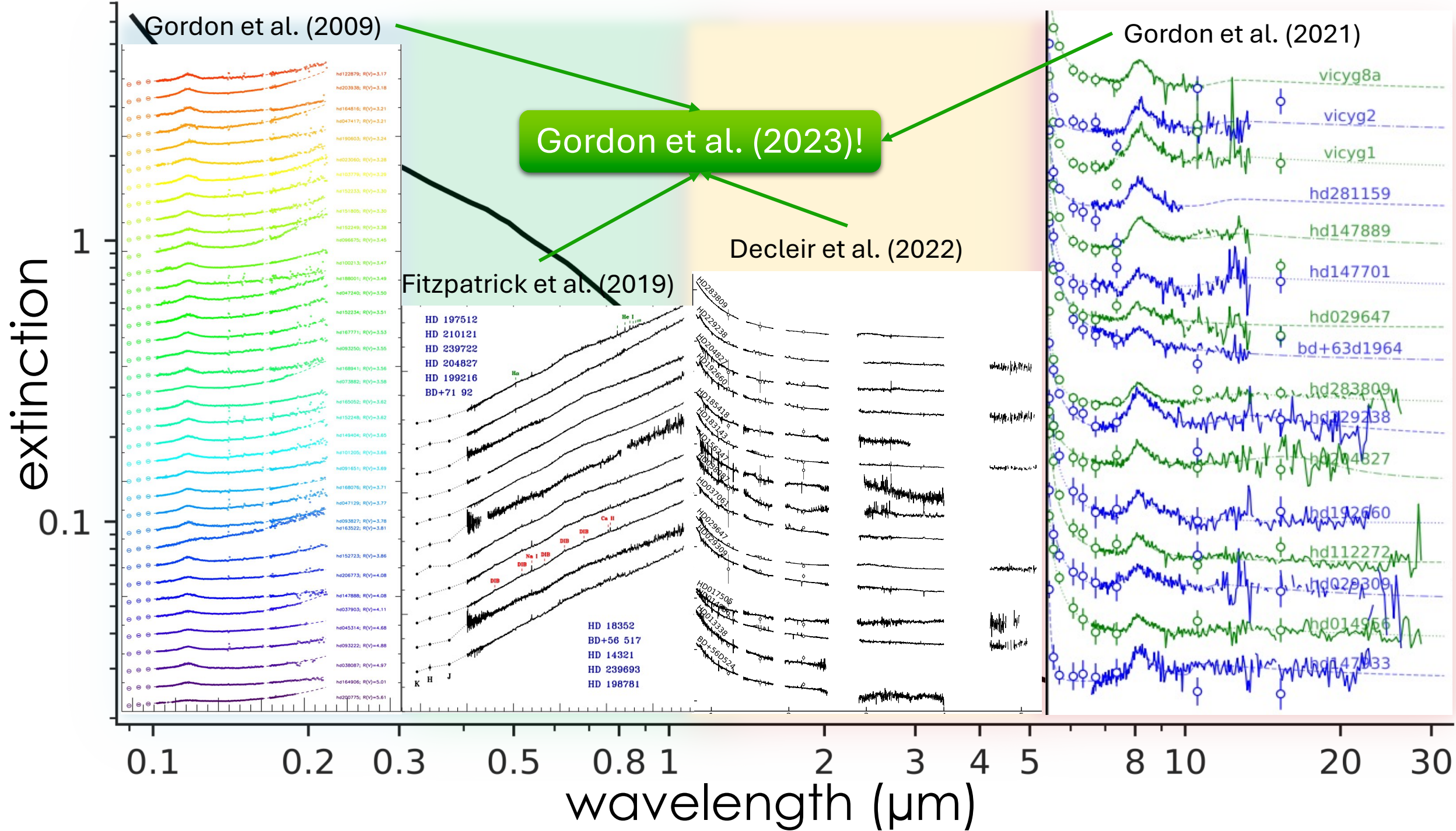
all λ extinguished $\pm$ equally

→ flat extinction curve

small $E(B-V)$
= large $R(V)$

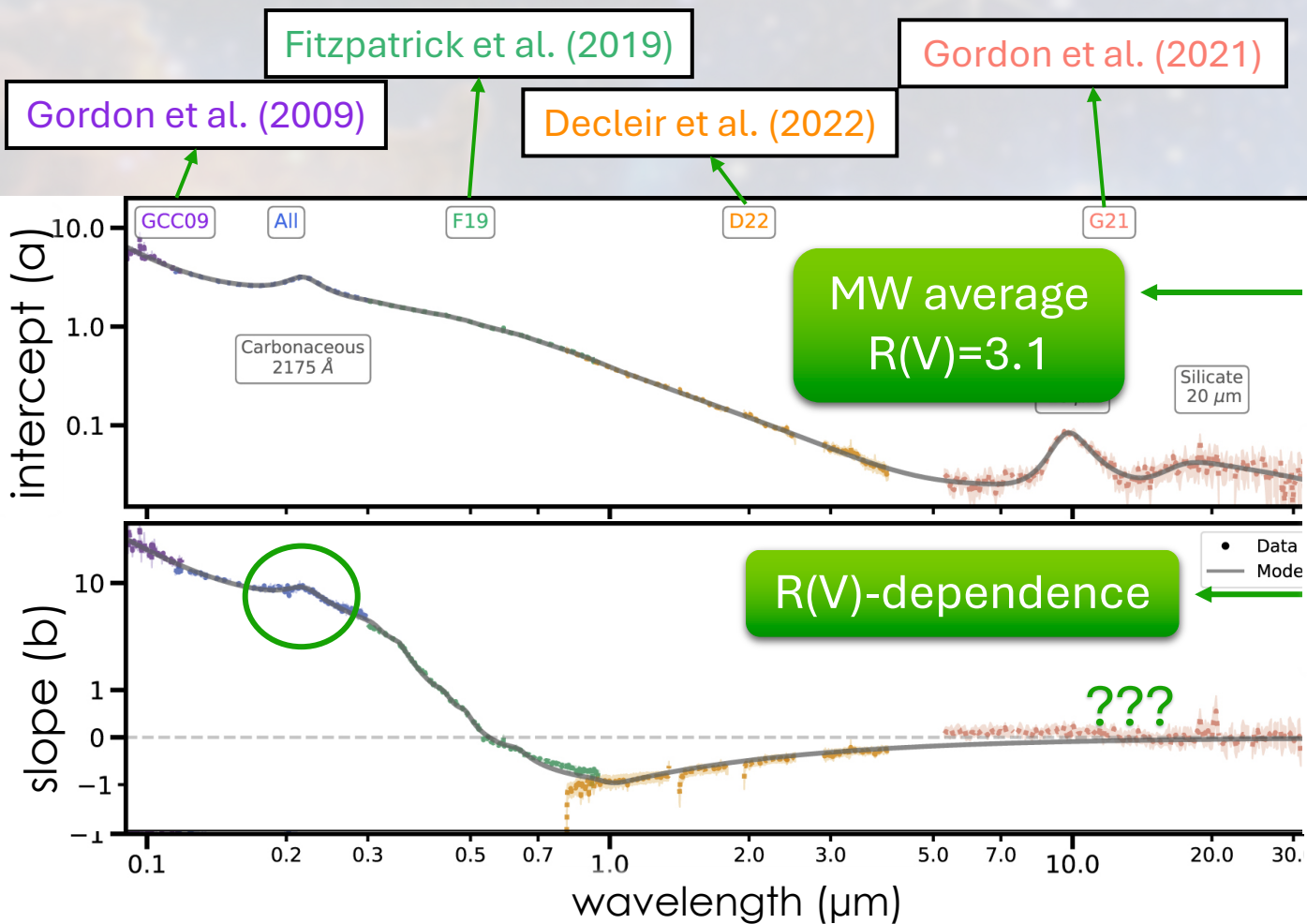
R(V)-dependent extinction curve

$$\frac{A(\lambda)}{A(V)} = a(\lambda) + b(\lambda) [1/R(V) - 1/3.1]$$

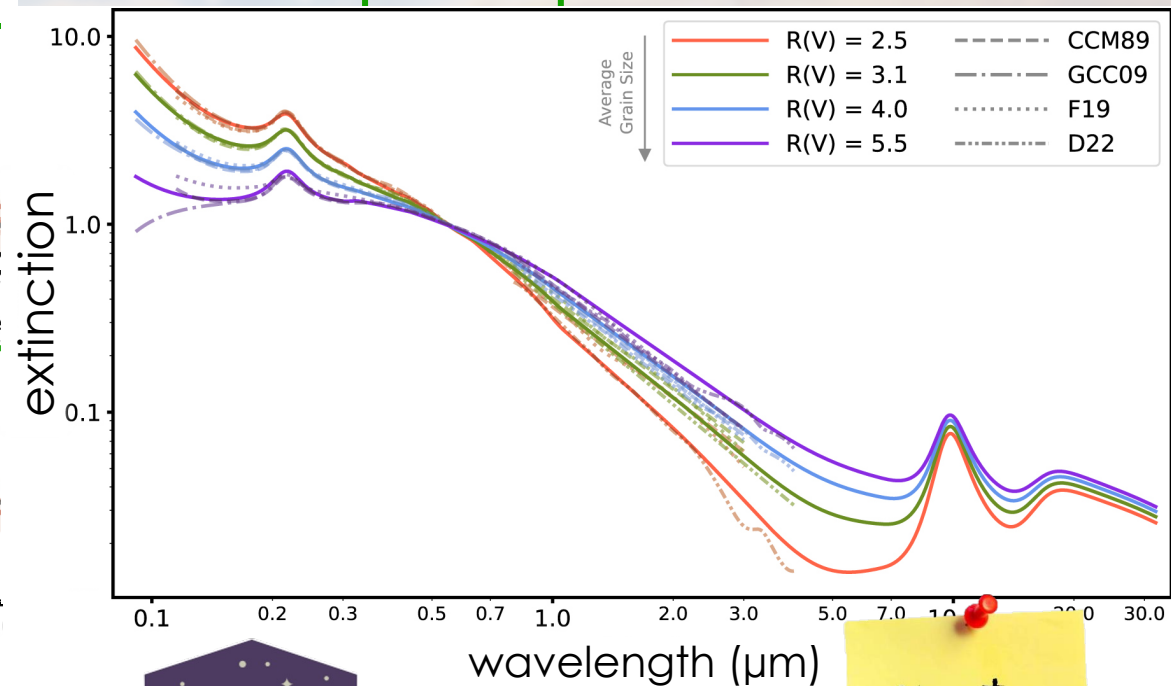


R(V)-dependent extinction curve

Gordon et al. (2023)



$$\frac{A(\lambda)}{A(V)} = a(\lambda) + b(\lambda) [1/R(V) - 1/3.1]$$

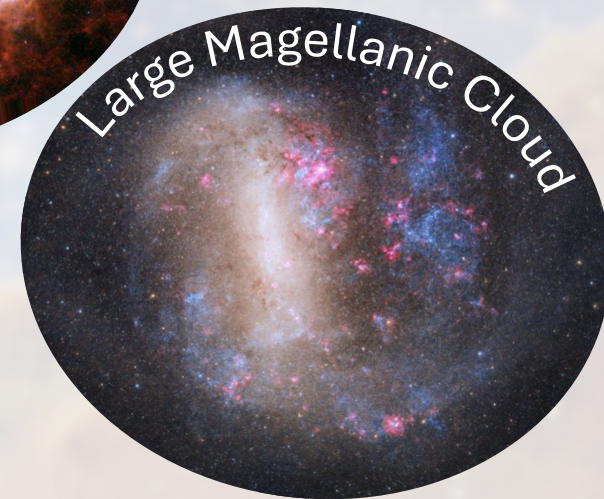
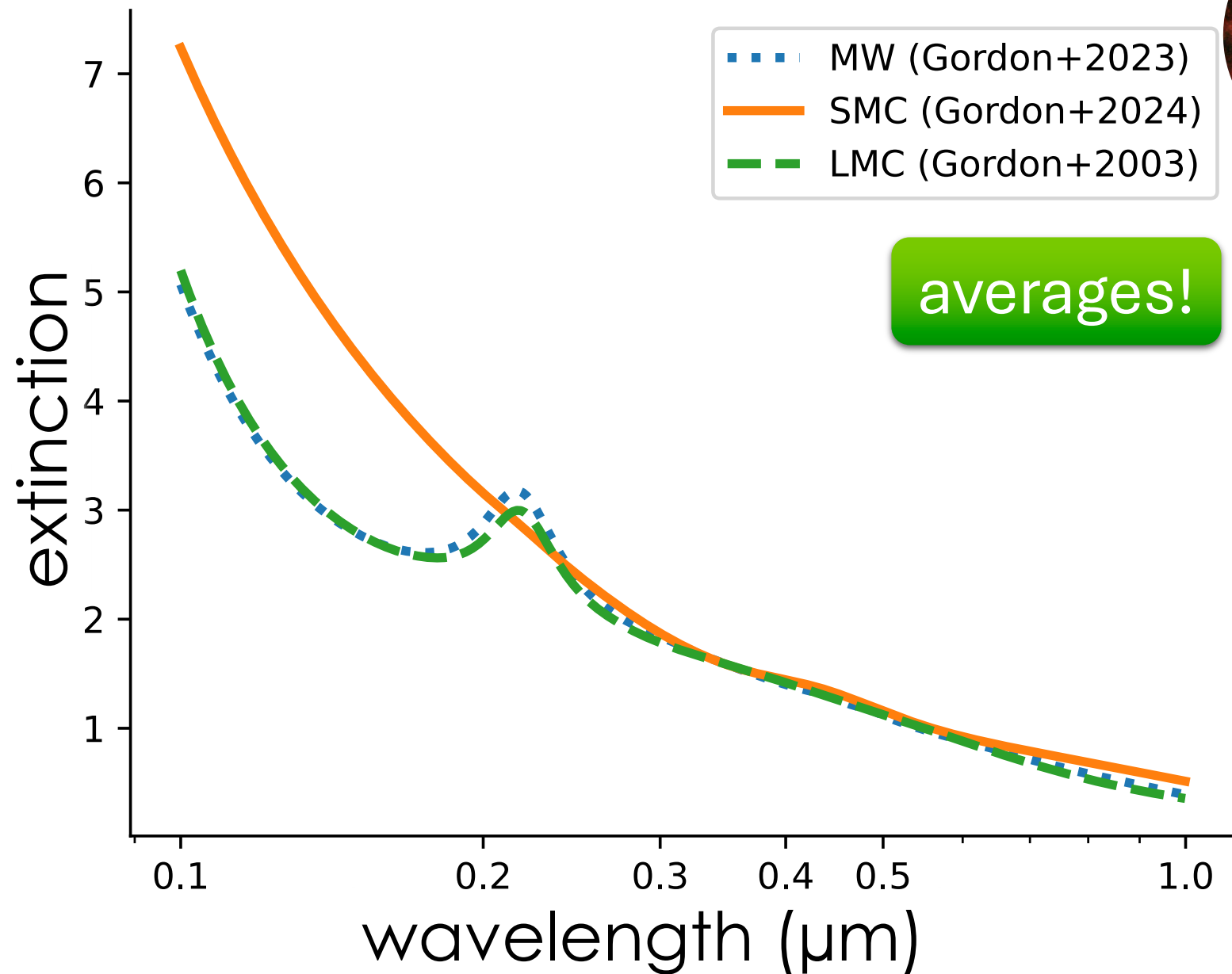


Use It
Now!

Available in the `dust_extinction` python package
(Gordon et al. 2024)!



Beyond the Milky Way?

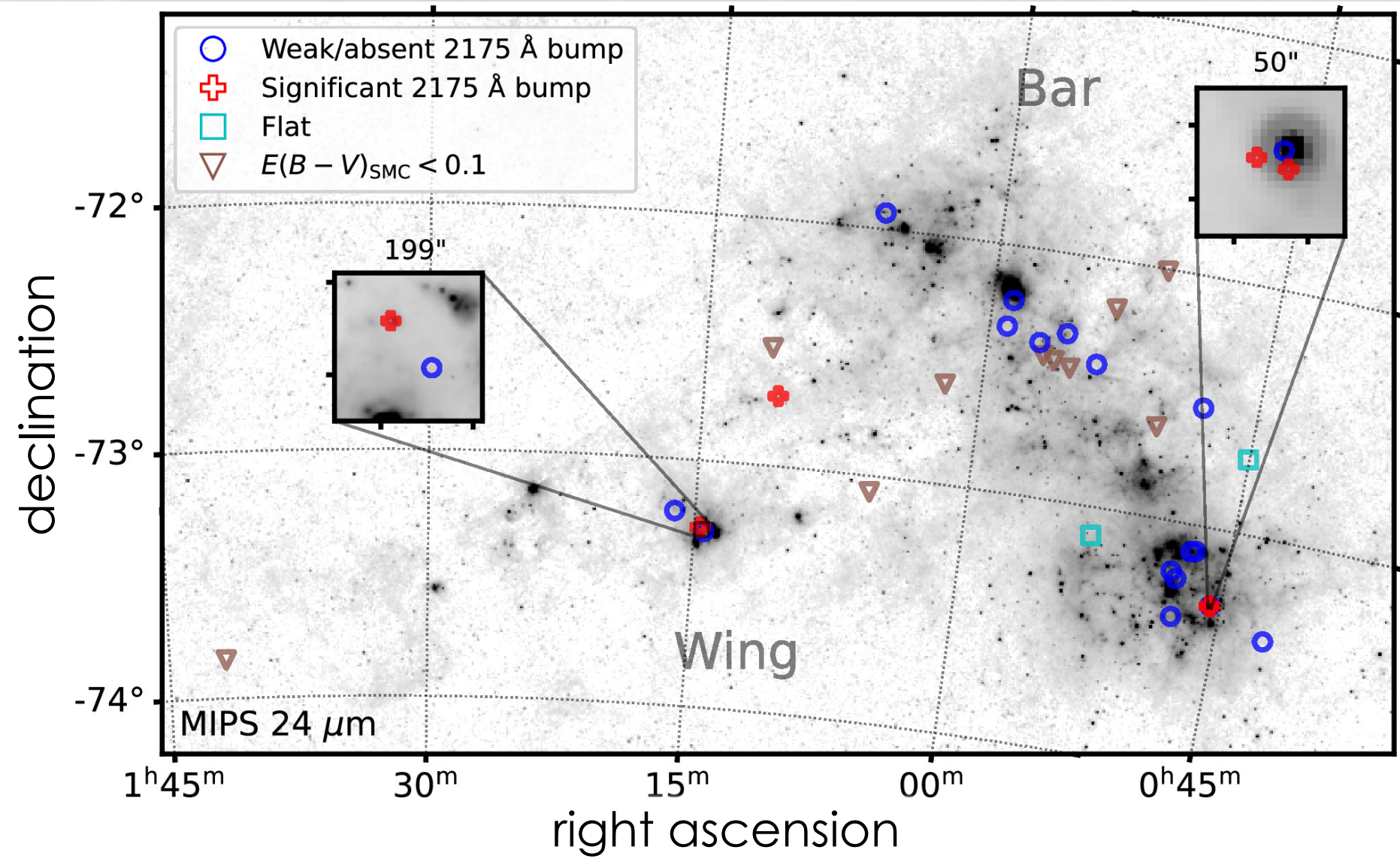


Variation in extinction curves between galaxies

See also Misselt et al. (1999)

Beyond the MW: Small Magellanic Cloud

Gordon et al. (2024)



Sightlines with and without bump throughout SMC!

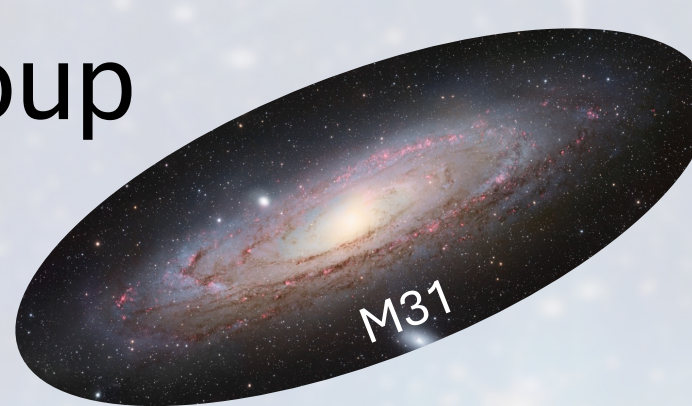
spatial variations

See also Maíz Apellániz & Rubio (2012)

Beyond the MW: Local Group

R(V)-dependent relationship is not enough to explain all variation

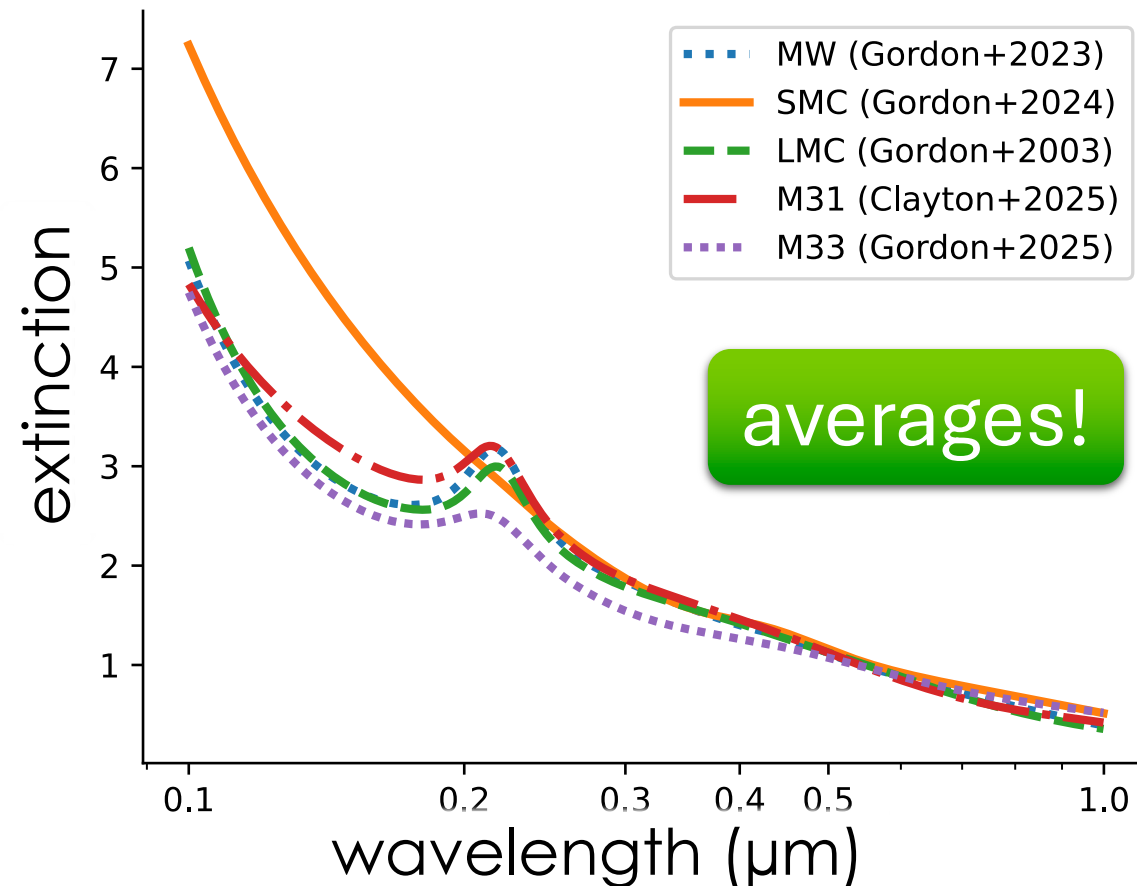
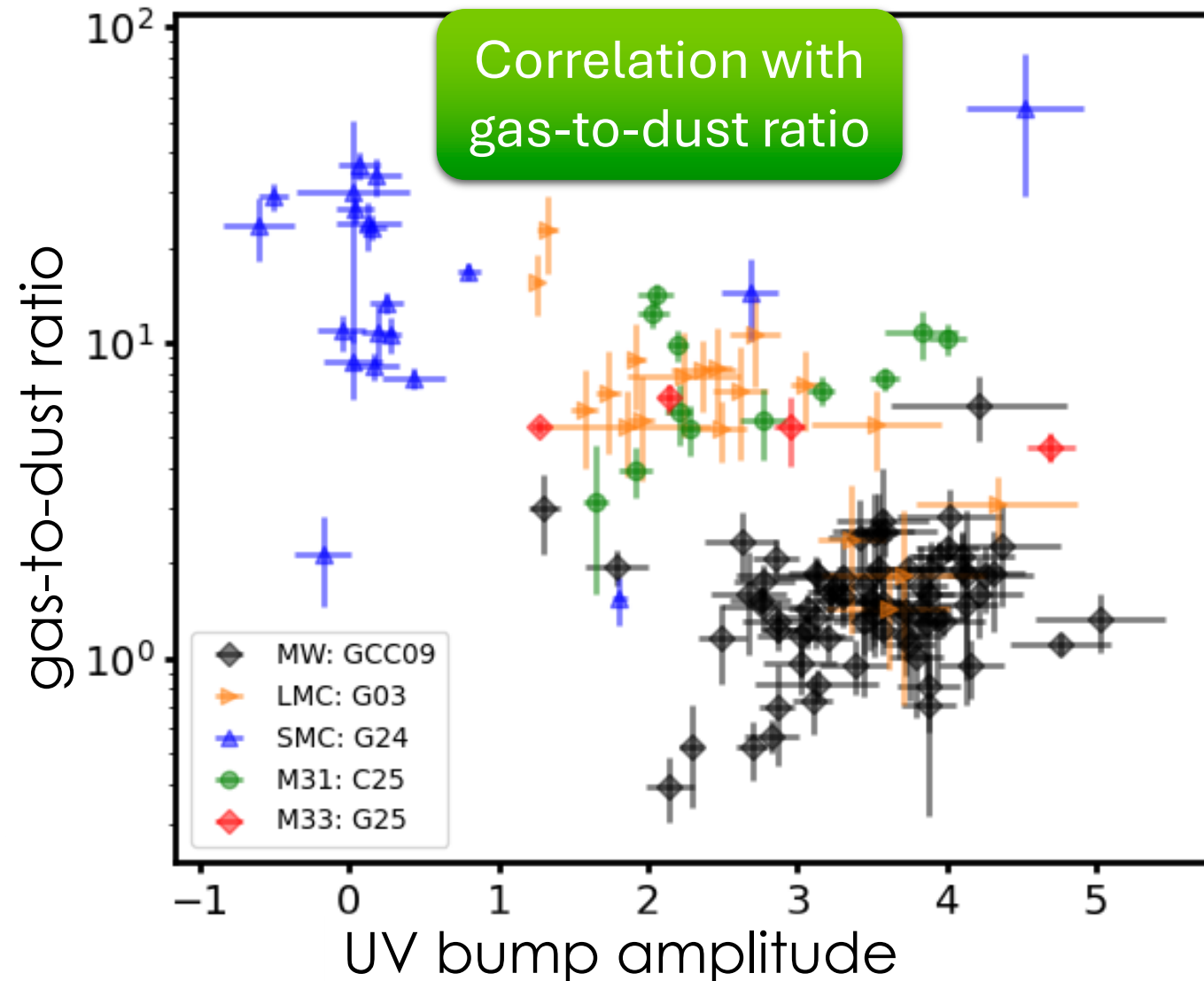
See poster by Karl Gordon



Clayton et al. (2025)



Gordon et al. (subm.)



Part III: Future



What's next?

- More JWST observations (incl. MEAD, WISCI + a NIRSpec survey)
 - More NIR-MIR extinction curves
 - Carbonaceous and Silicate features
- SPHEREx: Spectro-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer (2025, NASA/JPL)
 - many NIR extinction curves in dense and diffuse MW regions
 - Ices!
- UVEX: Ultraviolet Explorer (2030, NASA/Caltech)
 - ~1000 UV extinction curves in LMC/SMC
- UVESS: Ultraviolet Extinction Sky Survey (concept, ANU)
 - ~3000 Milky Way UV extinction curves



See talk by Roberta Paladini (Friday)



See poster by Andrew Battisti

More data → Better statistics!

Multi-wavelength dust extinction

- Extinction curves: size + composition of dust grains
- Features at all wavelengths:
 - UV bump, optical ISS, NIR carbonaceous, MIR silicate features
- Dense dust $\neq$ diffuse dust (need more data)
- Milky Way variations are $R(V)$ dependent ($\sim$ grain size)
- Variations beyond the MW correlated with gas-to-dust ratio
- Much more is coming!

Questions?
mdecleir@stsci.edu

