Direct Imaging Wavelength Range Implications for Biosignatures

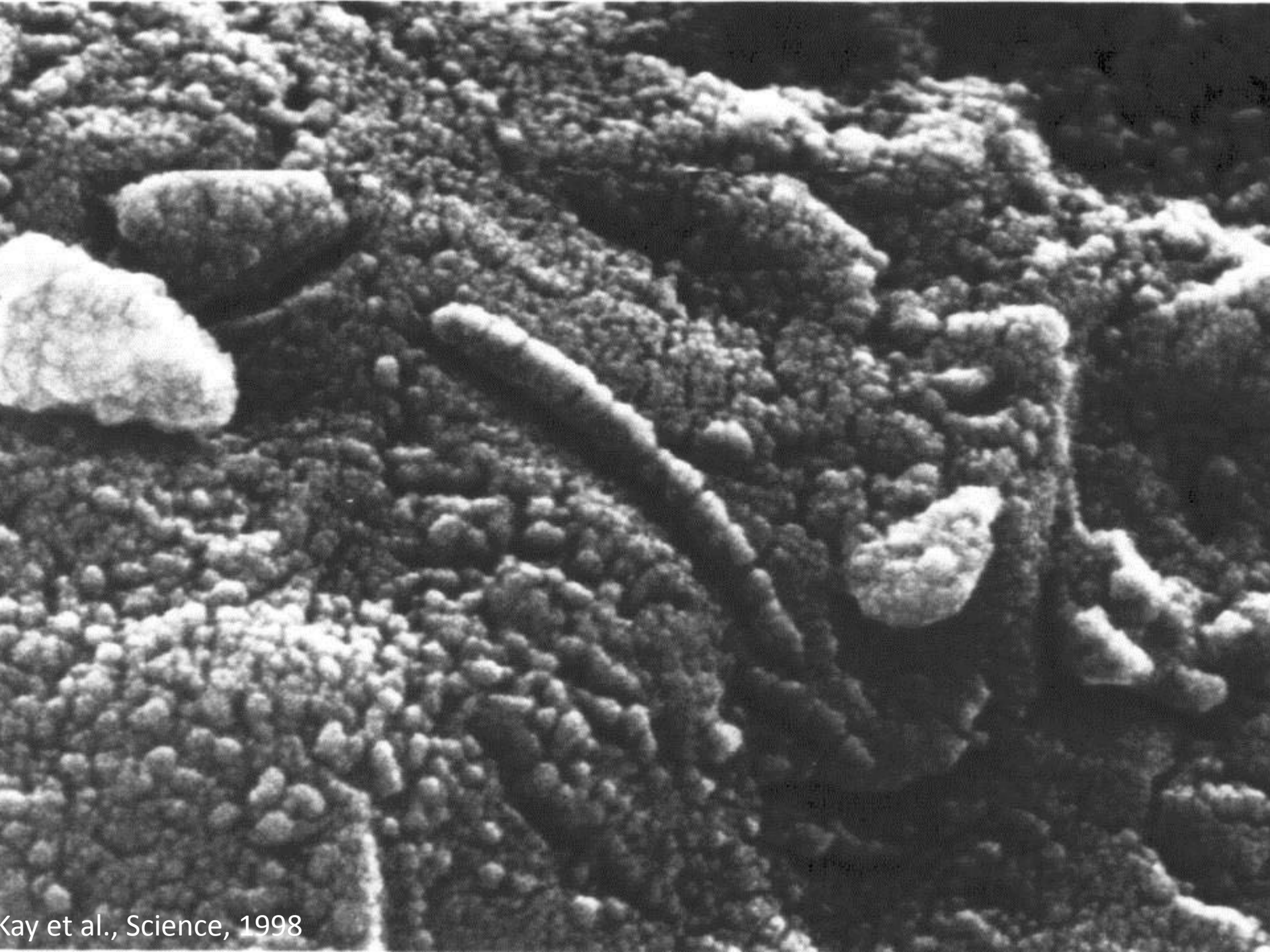
Shawn Domagal-Goldman, Aki Roberge, Victoria Meadows, Eddie Schwieterman, Giada Arney, Chris Stark, Avi Mandell, Matt Bolcar, Karl Stapelfeldt, Mark Clampin, Sonny Harman, Harley Thronson,

and years of insights from colleagues at

the Virtual Planetary Laboratory and the ATLAST team

ExoPag SIG #1 @ ExoPAG-12

Chicago, IL, June 14, 2015



Kay et al., Science, 1998

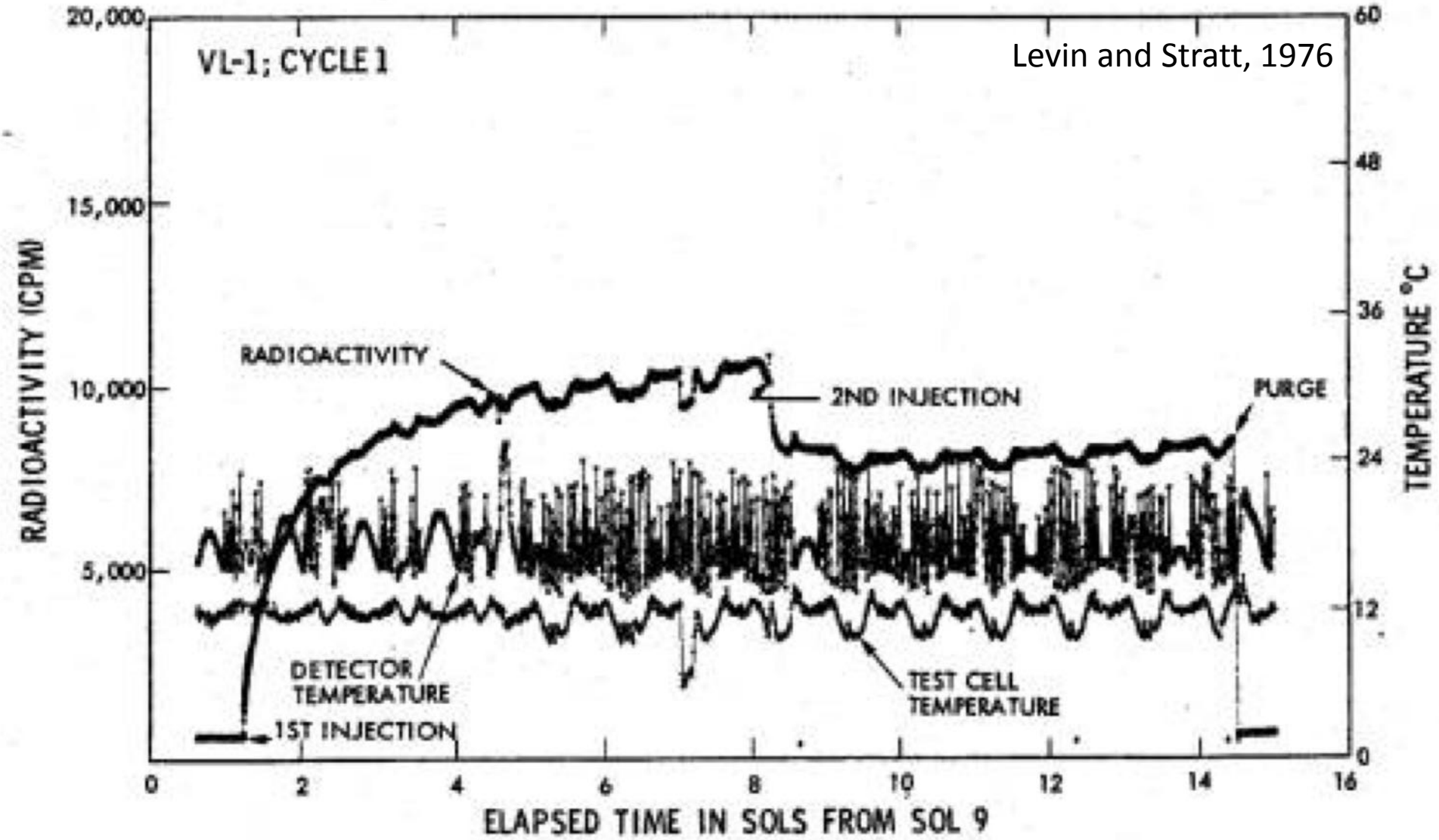
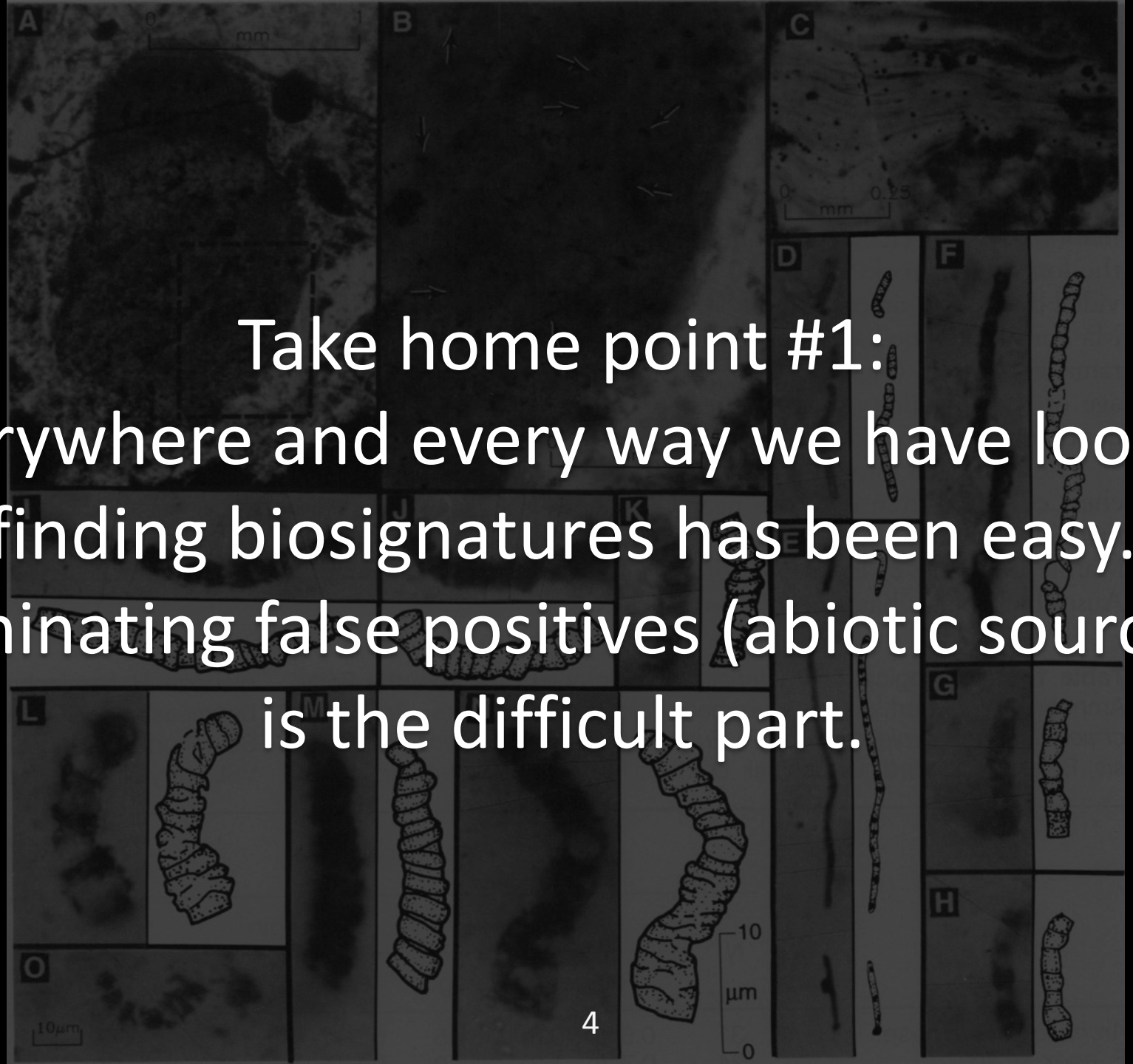


Fig. 1. Plot of LR data from first sample analysis on VL1. An active sequence was used on a fresh surface sample. Radioactivity was measured at 16-minute intervals throughout the cycle except for the first 2 hours after the first nutrient injection when readings were taken every 4 minutes. Radioactivity data include a background count of 490 cpm prior to the onset of the cycle. Detector and test cell temperatures were monitored every 16 minutes.



Take home point #1:
Everywhere and every way we have looked finding biosignatures has been easy.
Eliminating false positives (abiotic sources) is the difficult part.

Schopf, *Science*, 1993

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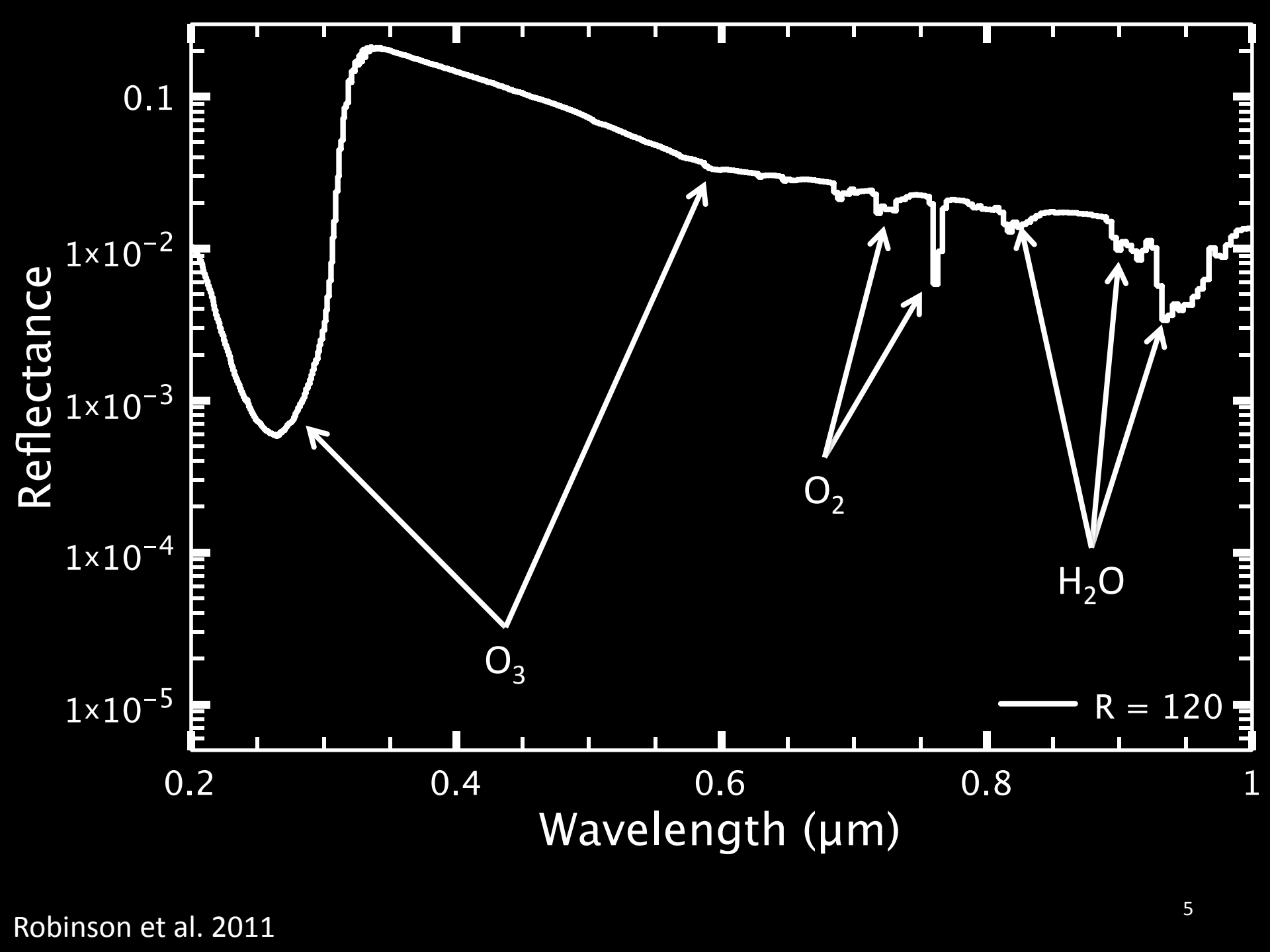


Robinson et al. 2011

Mechanism	Star Type	False Positive	Identifiers
Photochemistry (Domagal-Goldman et al., 2014; Gao et al., 2015, Hu and Seager, 2014, Tian et al., 2014, Harman et al., in prep.)	F, M, K	O_3, potentially O_2	High CO_2, high CO, low CH_4
Atmospheric Loss (Luger and Barnes, 2014)	M	Extremely high (>90%) O_2 and O_3,	Low CH_4, >10 bars total pressure, ~pure O_2
No cold trap (Wordsworth, 2014)	All? Unclear.	Extremely high (>90%) O_2 and O_3.	Low pressure, low CH_4

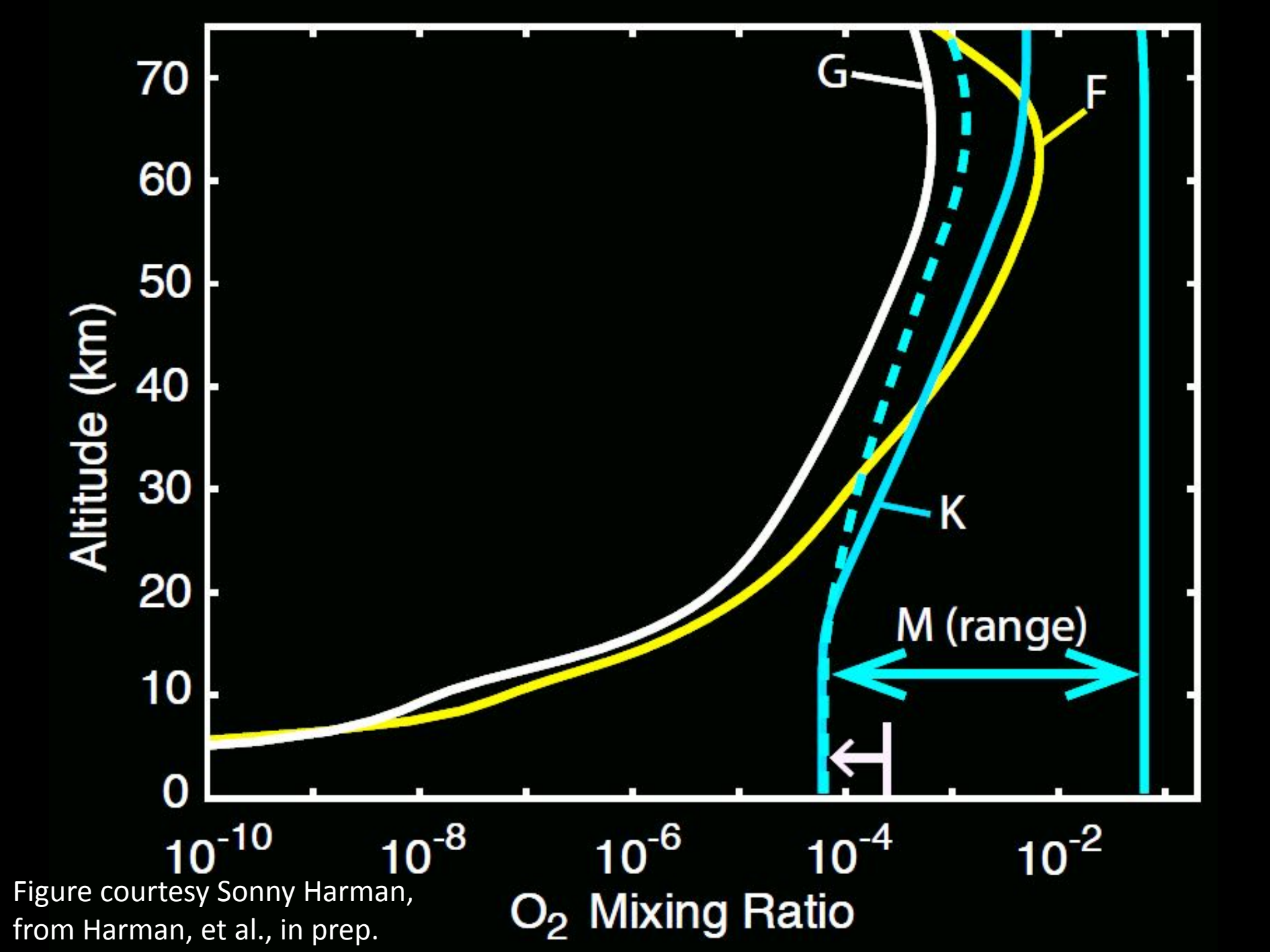
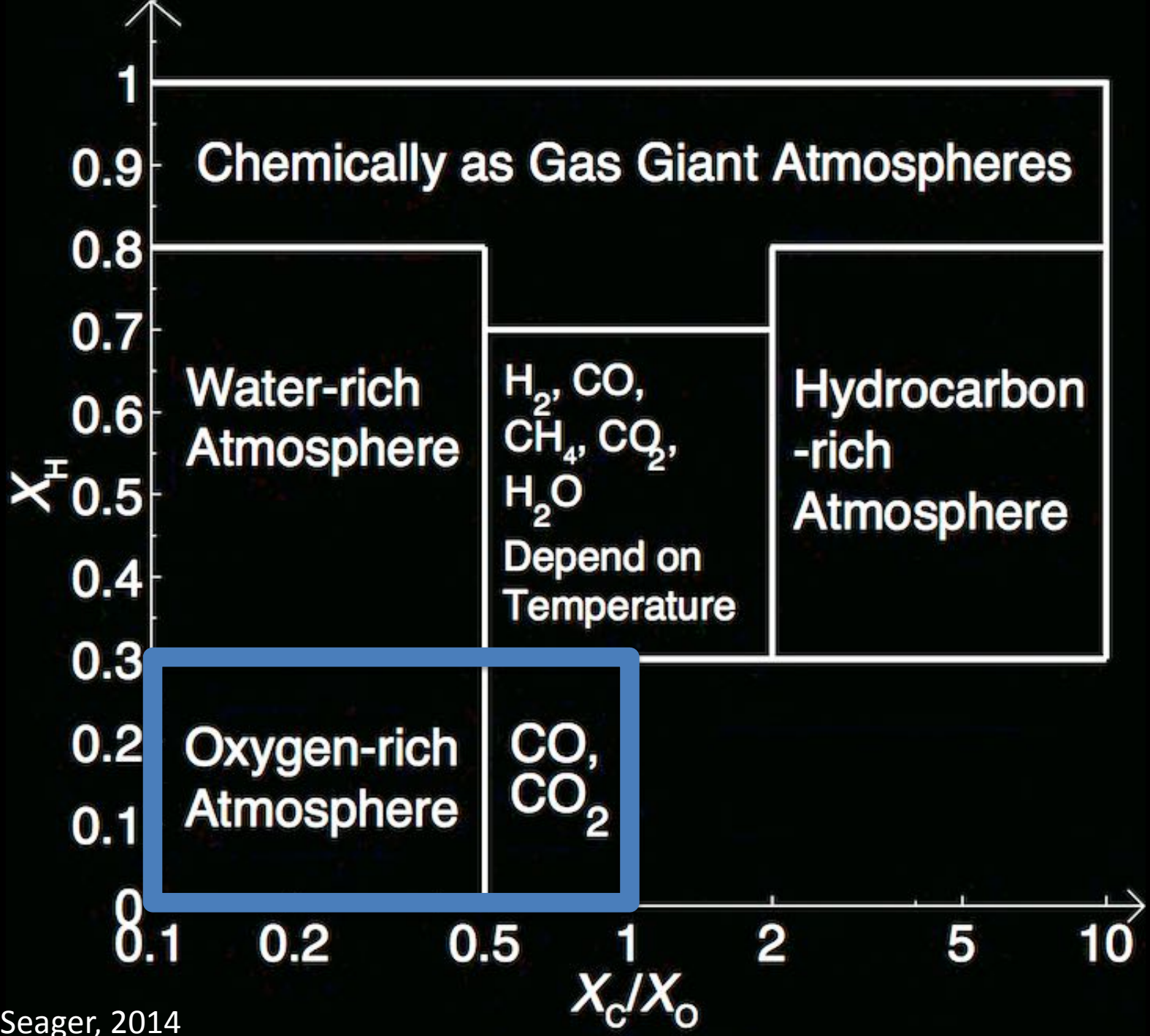
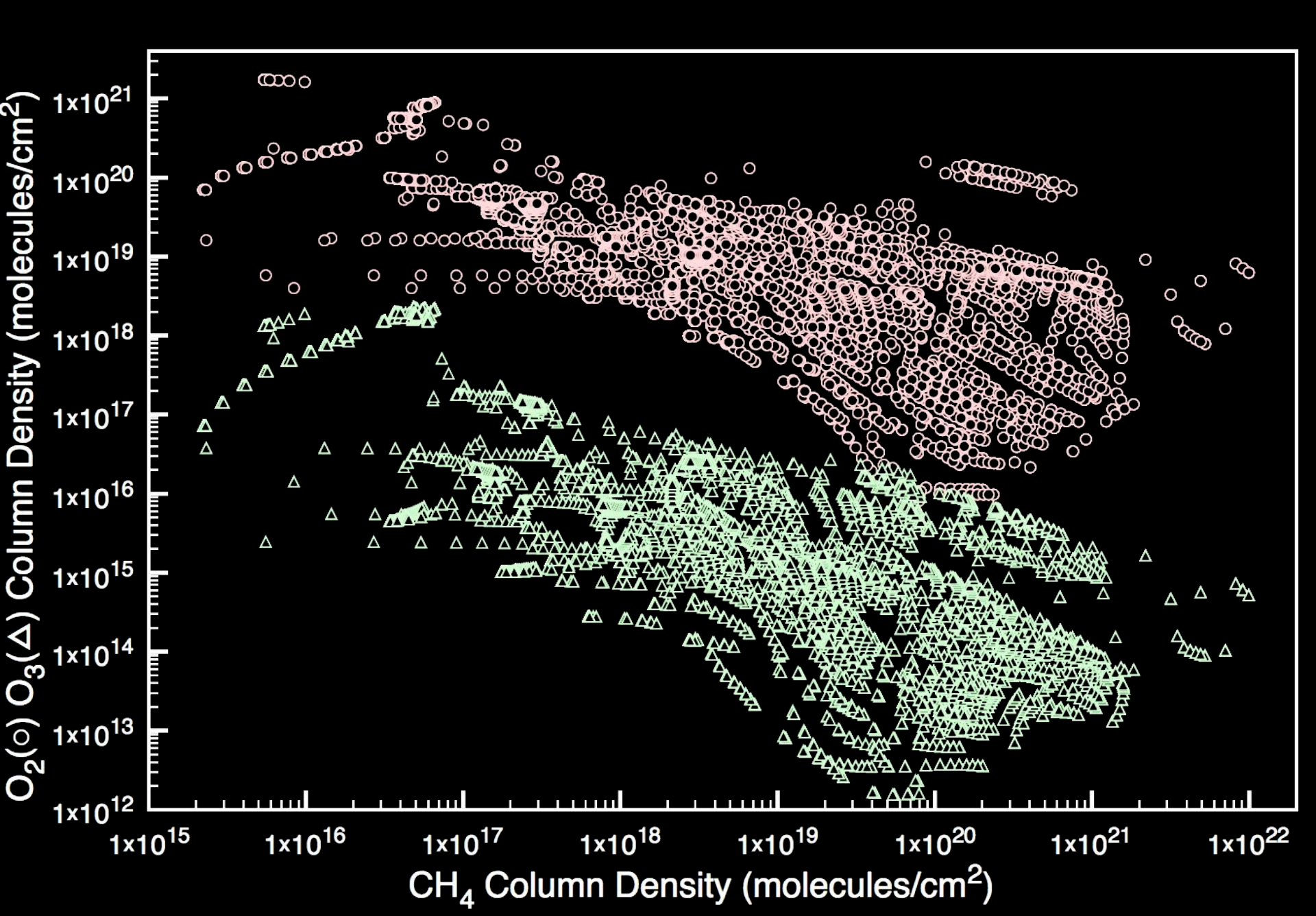


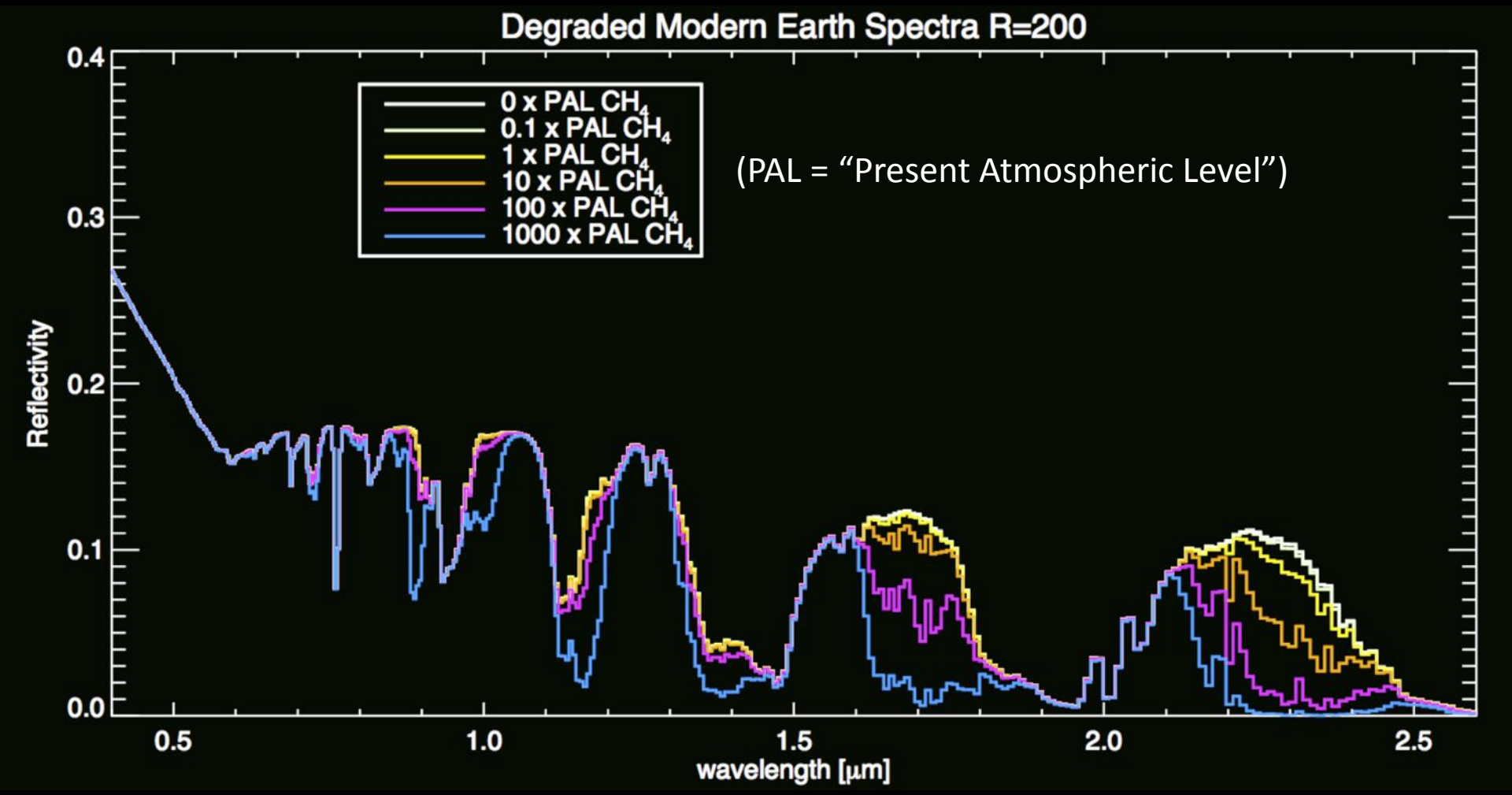
Figure courtesy Sonny Harman, from Harman, et al., in prep.



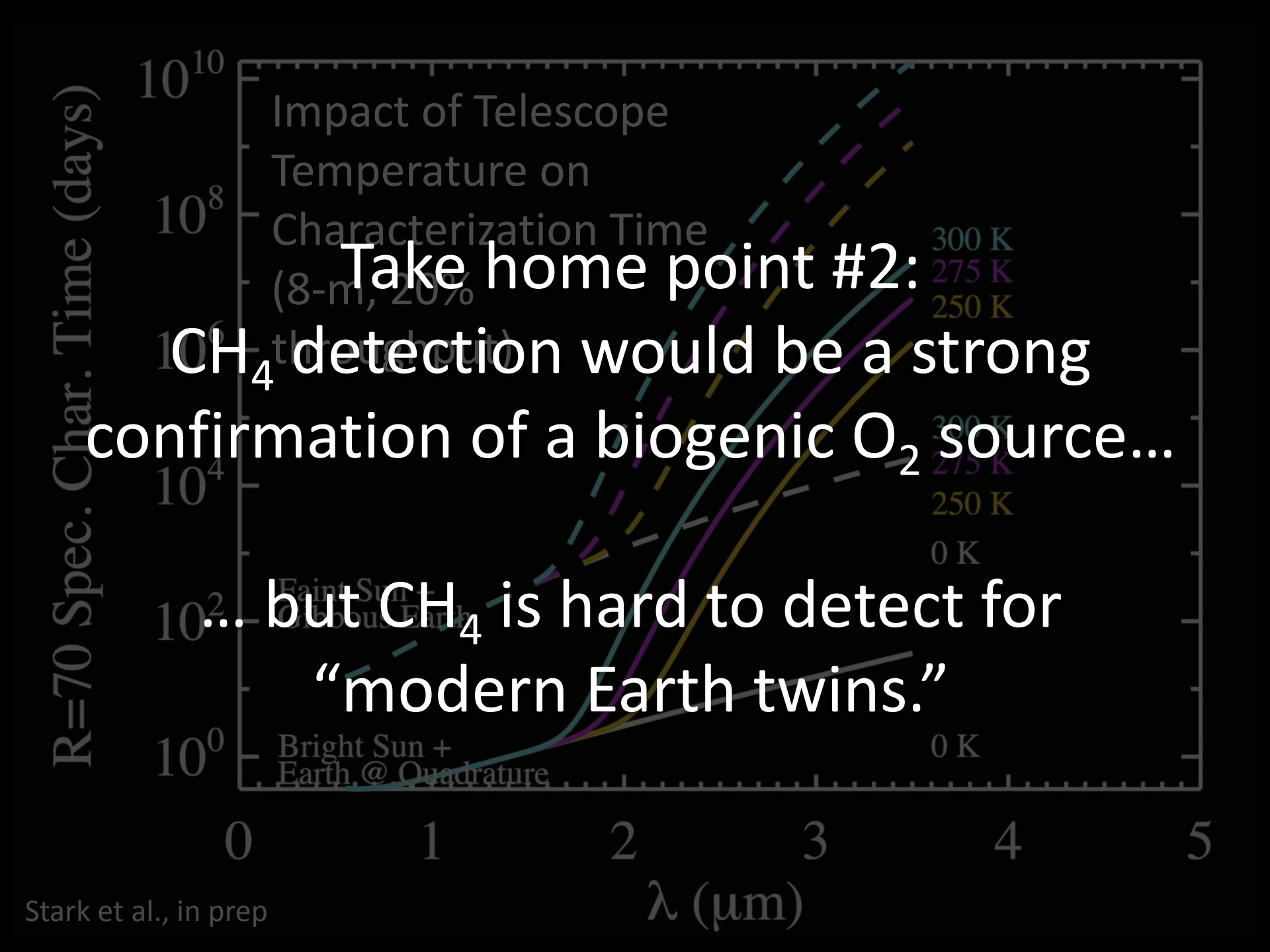
Hu and Seager, 2014



Domagal-Goldman et al., 2014



Schwieterman et al., in prep.



Take home point #2:

CH_4 detection would be a strong confirmation of a biogenic O_2 source…

… but CH_4 is hard to detect for "modern Earth twins."

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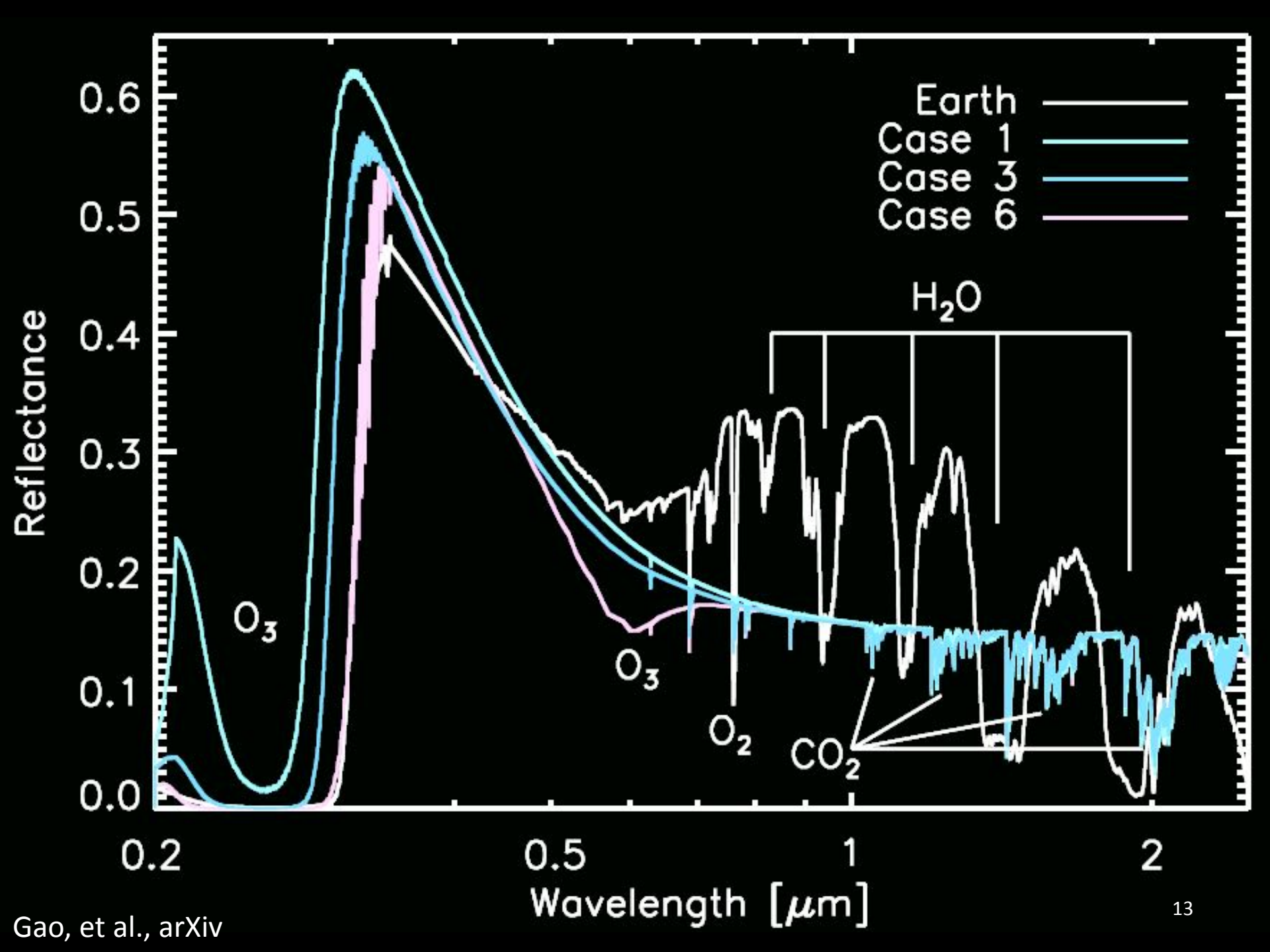
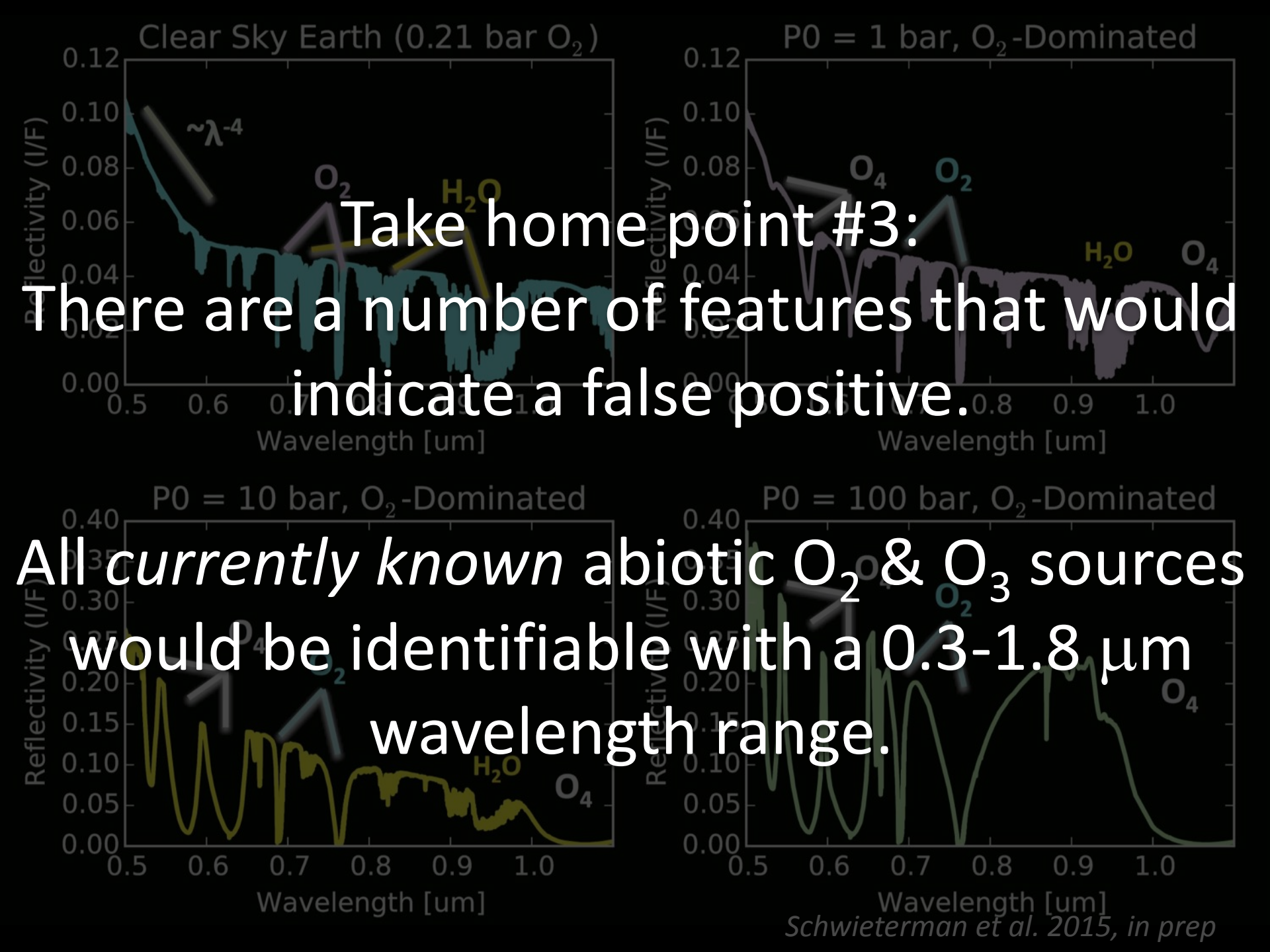


Gao, et al., arXiv



Take home point #3:
There are a number of features that would indicate a false positive.

All *currently known* abiotic O_2 & O_3 sources would be identifiable with a 0.3-1.8 μm wavelength range.

Schwieterman et al. 2015, in prep

What we could say

- For a mission that goes out to 1.0 μm (any Temp.): "We found the presence of biosignature gases (O_2 and O_3) on that planet, but did not comprehensively search for abiotic sources of those gases."
- For a mission that goes out to 1.8 μm ($T \leq 275$ K) "We found the presence of biosignature gases (O_2 and O_3) on that planet, and searched for but did not find signs (CO_2, CO, O4, pressure) that these gases were created by abiotic processes."
- For a mission that goes out to 2.5 μm ($T \leq 250$ K) "We found the presence of biosignature gases (O_2 and O_3) on that planet, and secondary features (CH_4) inconsistent with abiotic processes."

Implications for LUVOIR and HabEx

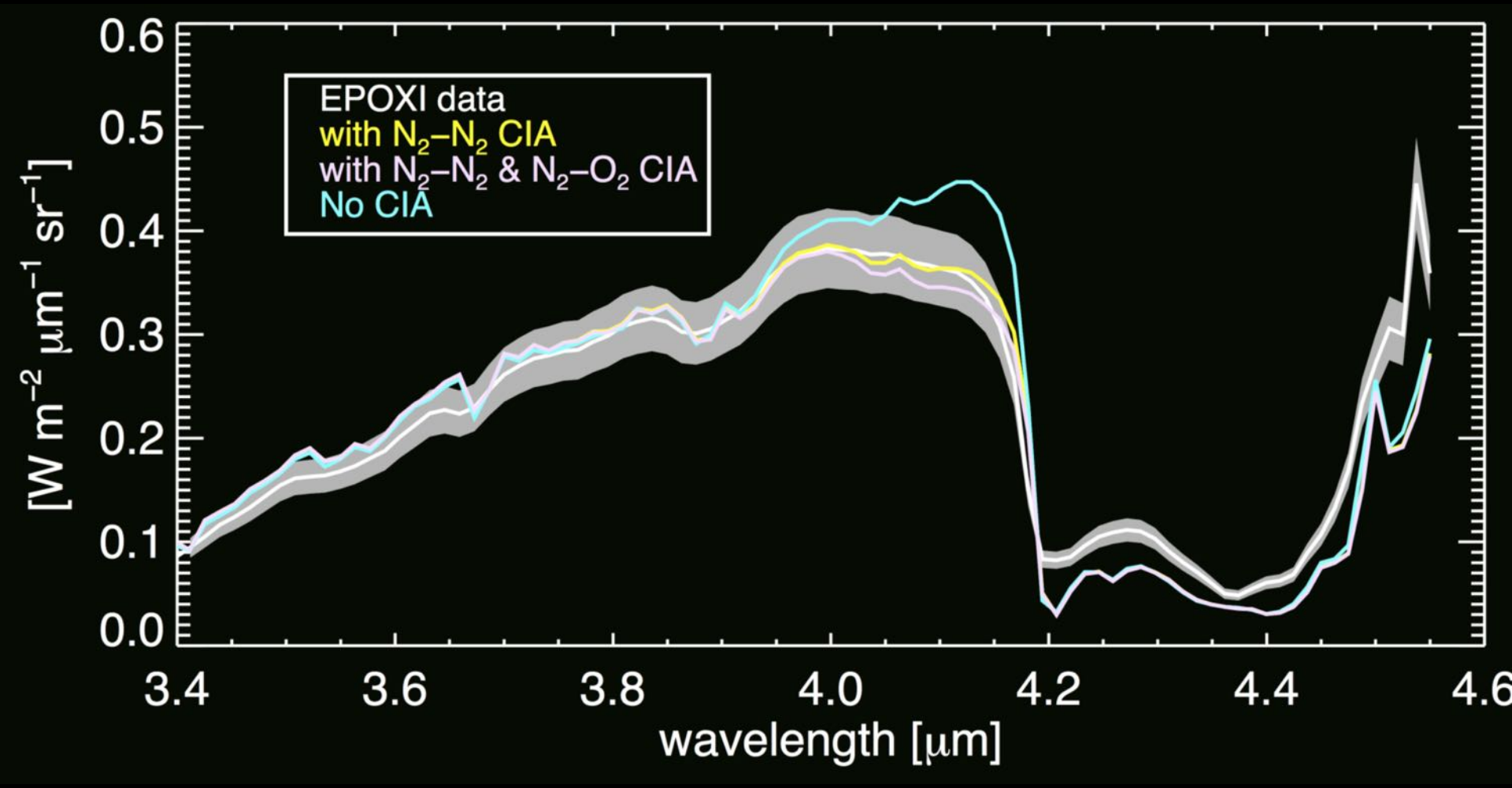
Getting to ~2 μm would be strongly preferred

- Might not be necessary if we obtain high spectral resolution and time-dependent spectra.
- This is a trade against telescope temperature and associated cost.

However, viewing planets in habitable zones at longer wavelengths is a challenge.

- For coronagraphs, longer wavelength requires better coronagraph and/or larger telescope diameter, since IWA = C x (λ / D).
- For starshades, longer wavelength requires larger starshade diameter and greater telescope/starshade separation = longer retargeting times.

At 2 μm, both types of missions limited by collecting area and telescope thermal background.



Slide courtesy Eddie Schwieterman, figures from Schwieterman et al., 2015

R = 70, SNR = 10, Earth-Sun-1 Zodi 10 pc. Away.

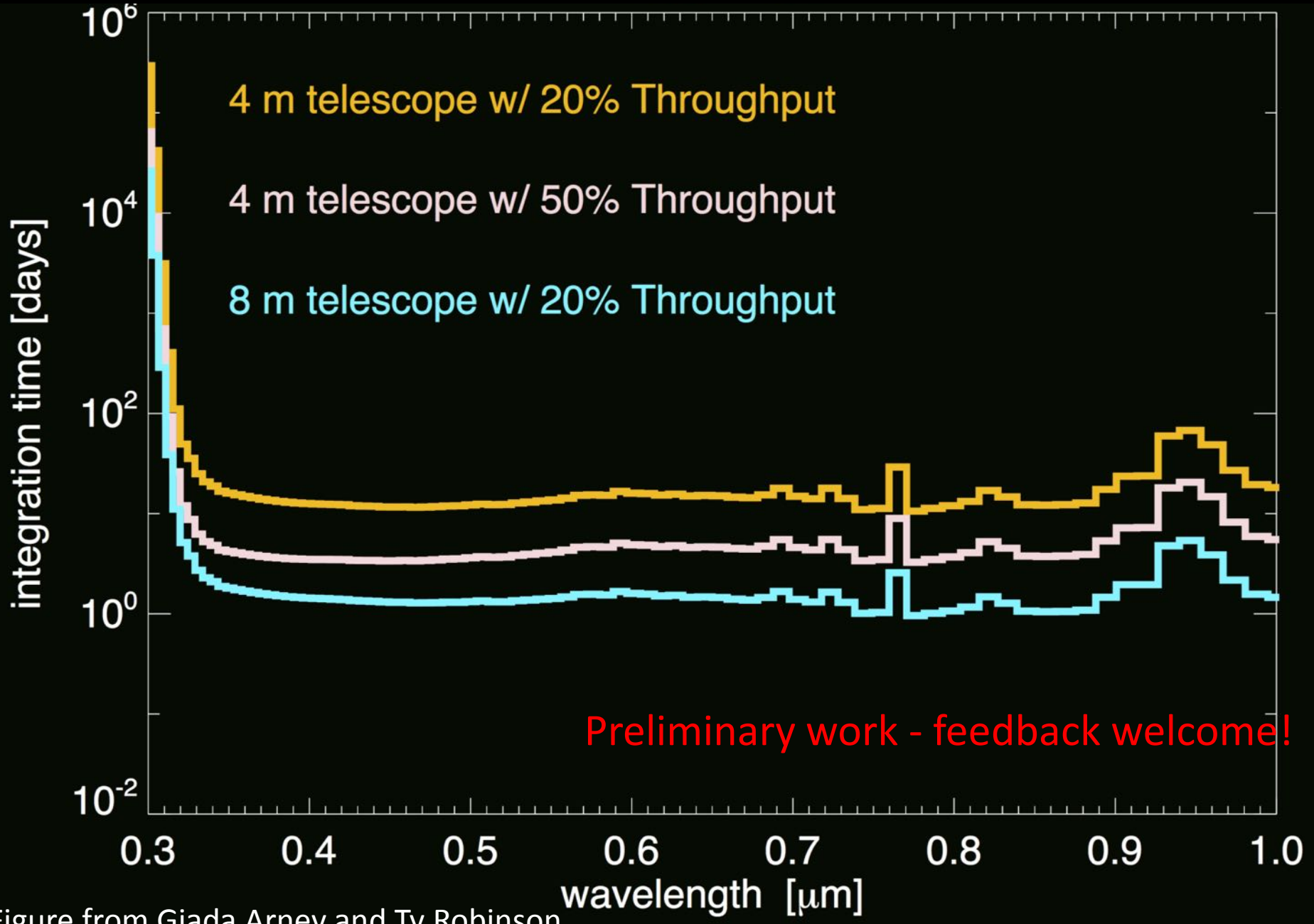


Figure from Giada Arney and Ty Robinson

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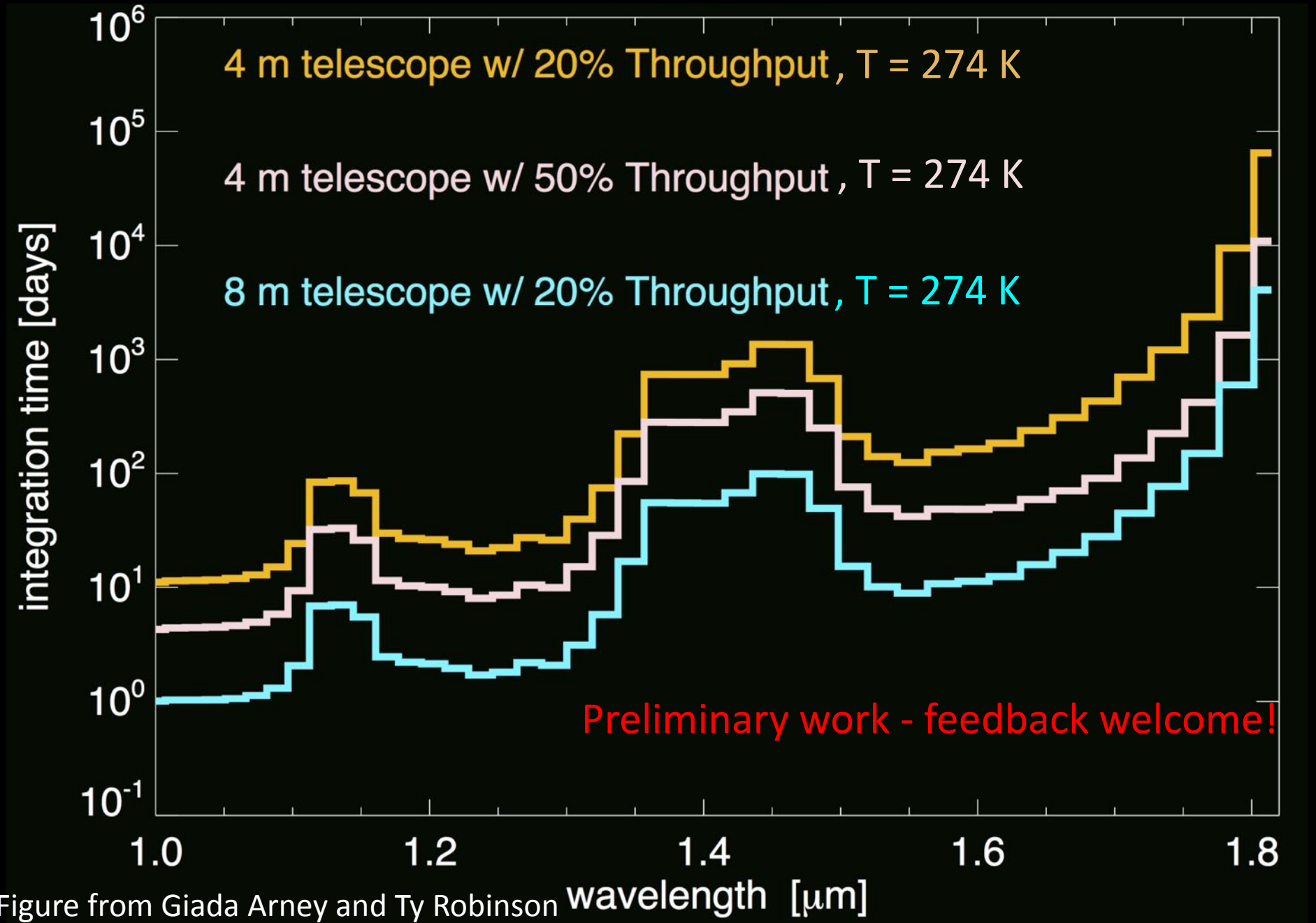

Figure from Giada Arney and Ty Robinson