Direct Imaging Wavelength Range Implications for Biosignatures

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and years of insights from colleagues at
the Virtual Planetary Laboratory and the ATLAST team

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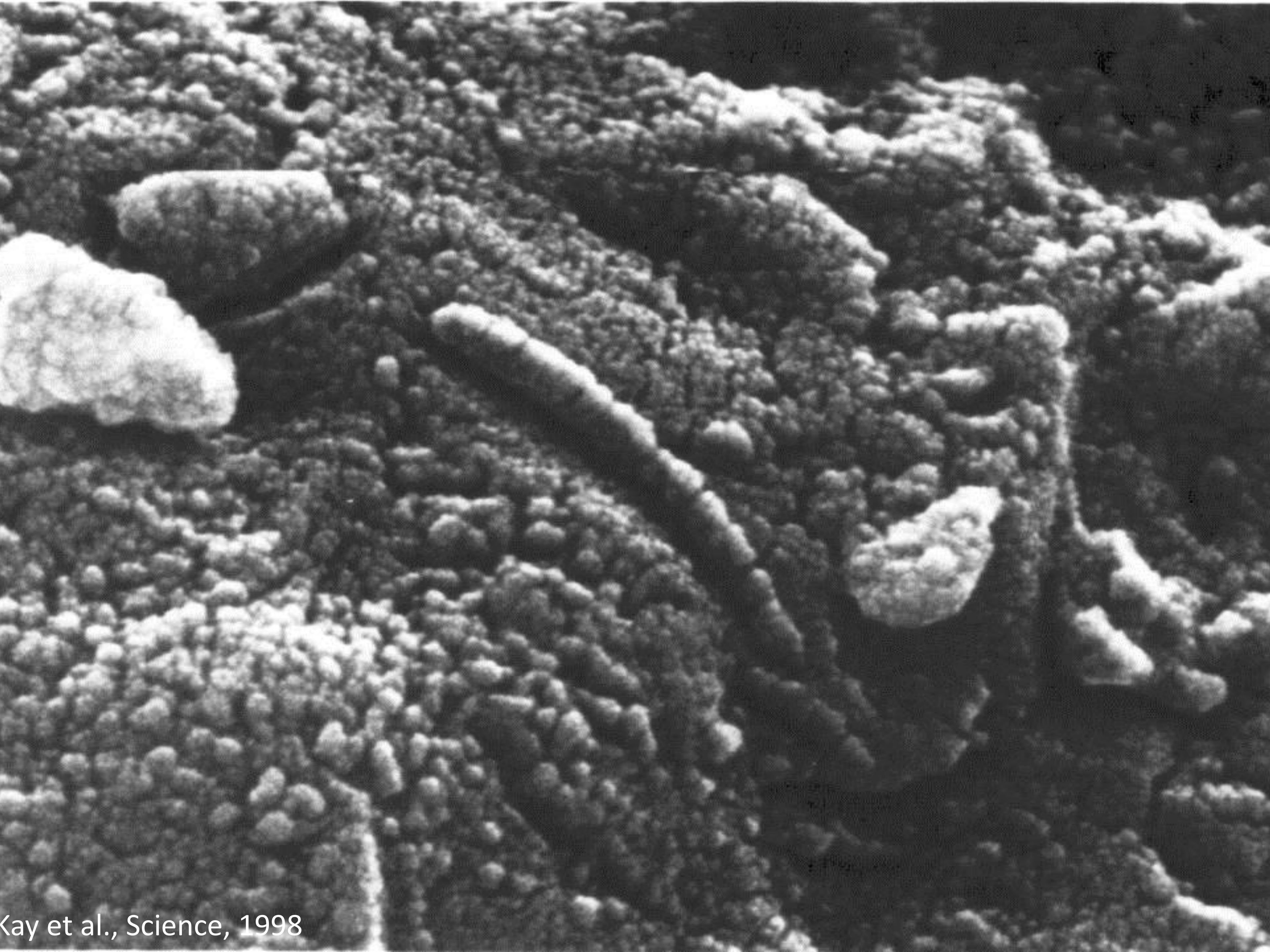


Kay et al., Science, 1998

Levin and Stratt, 1976

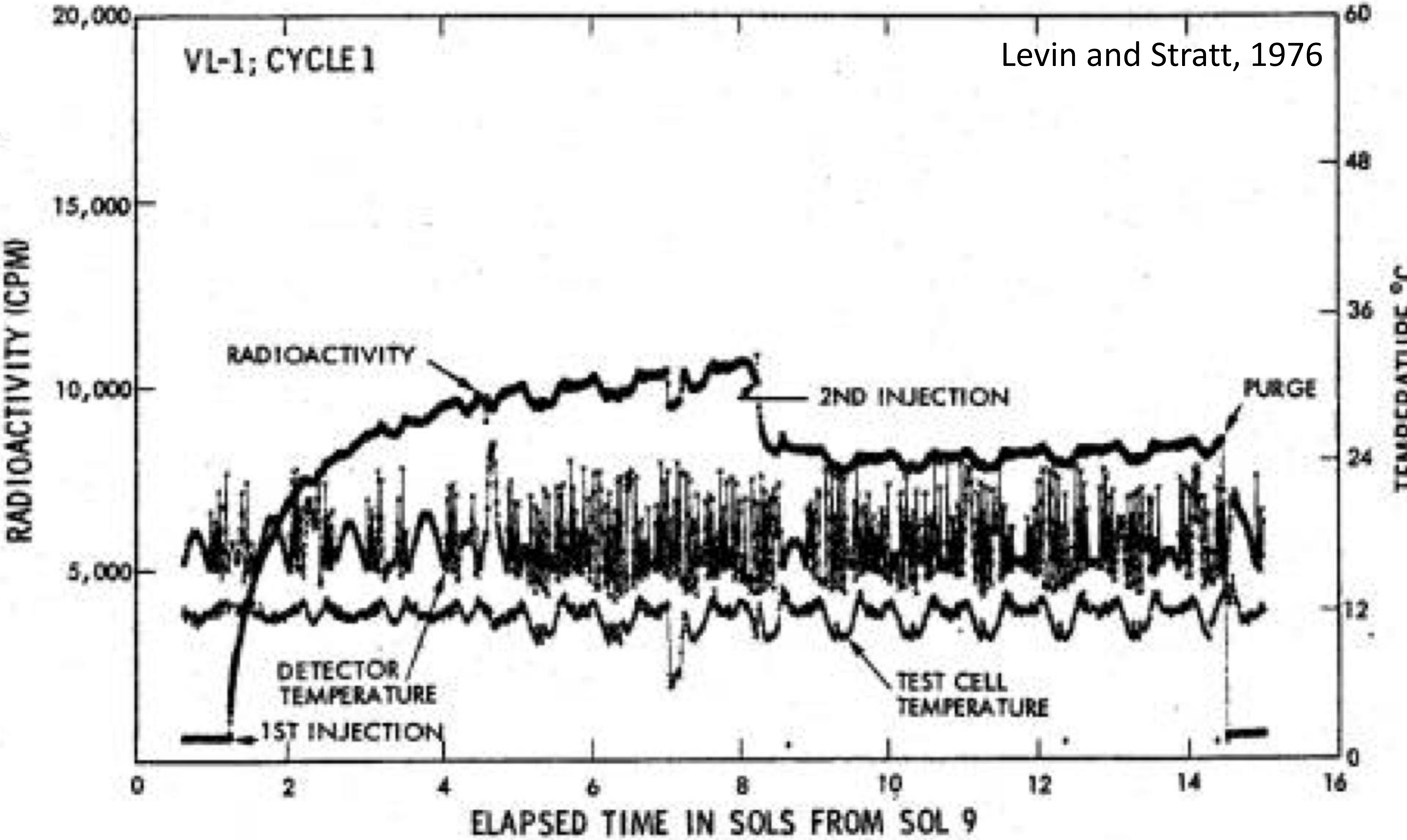
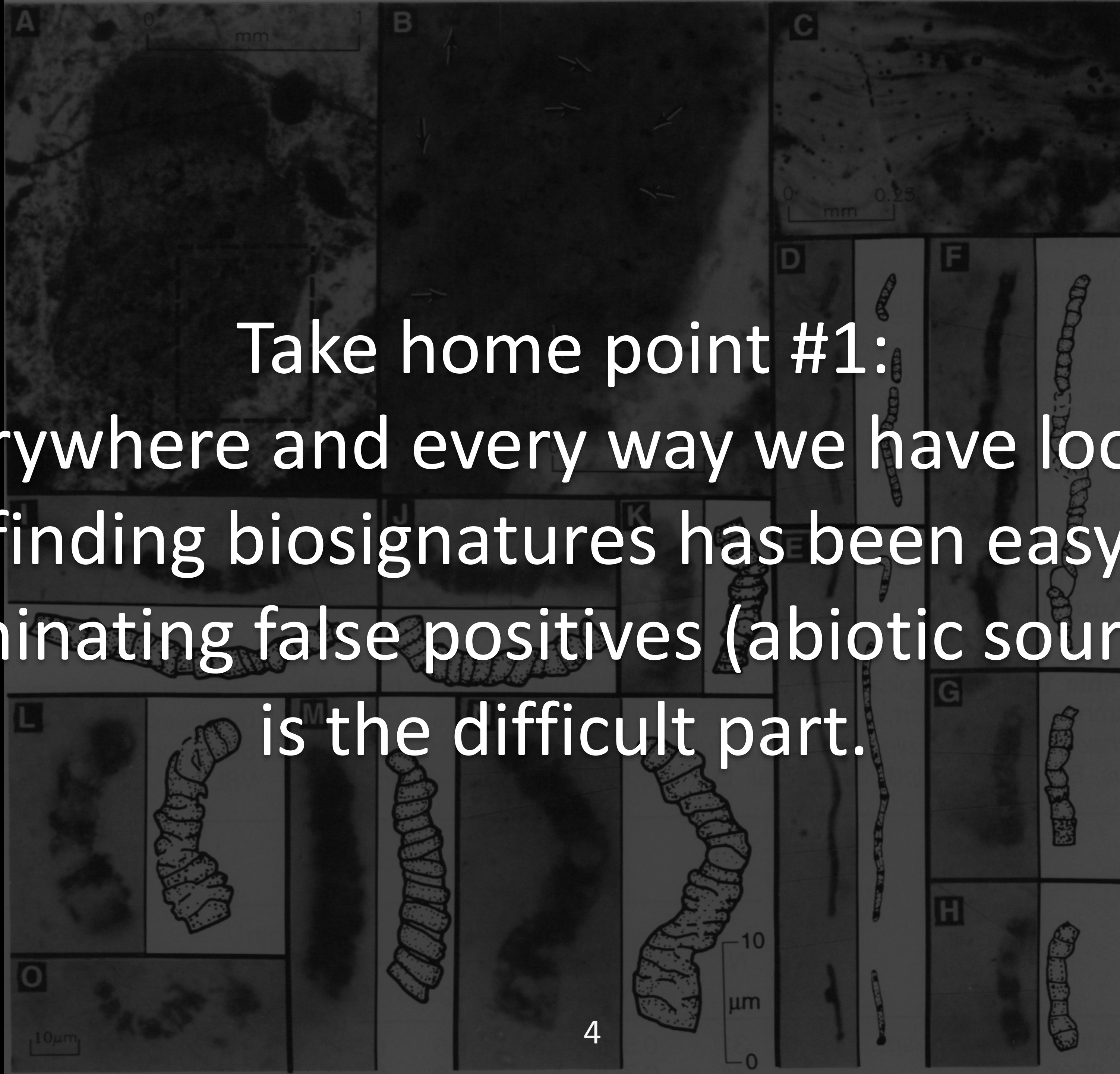


Fig. 1. Plot of LR data from first sample analysis on VL1. An active sequence was used on a fresh surface sample. Radioactivity was measured at 16-minute intervals throughout the cycle except for the first 2 hours after the first nutrient injection when readings were taken every 4 minutes. Radioactivity 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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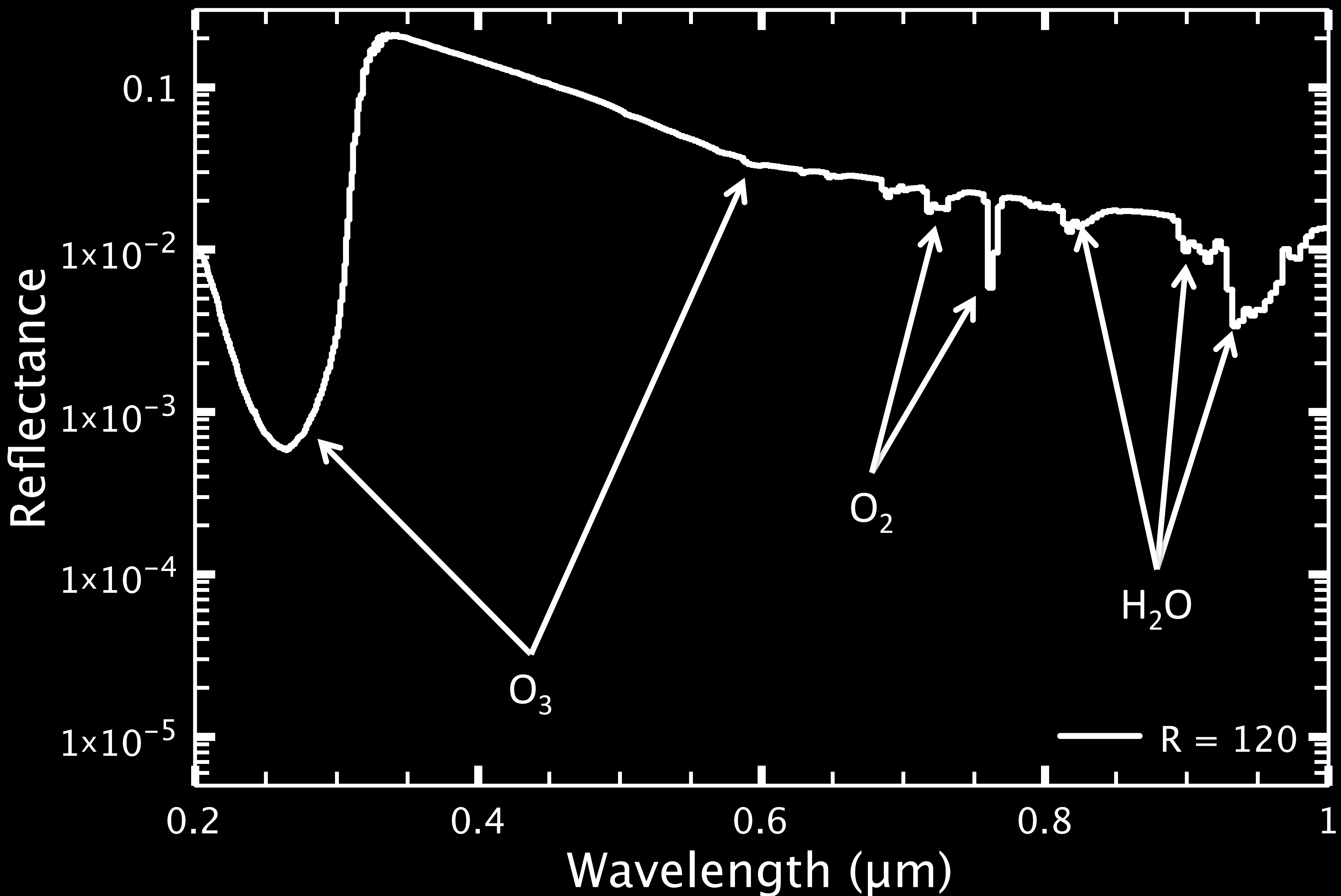


Robinson et al. 2011

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

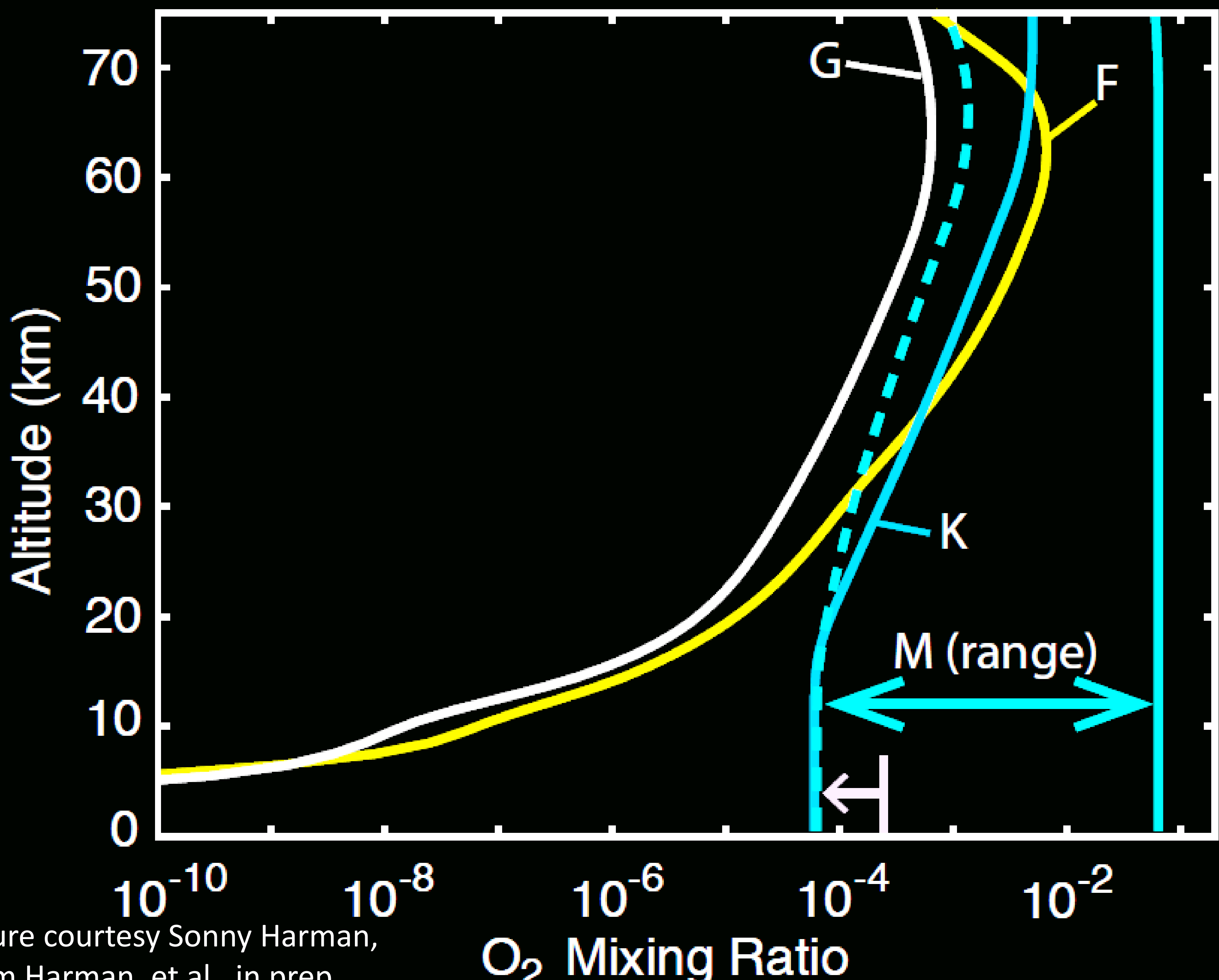
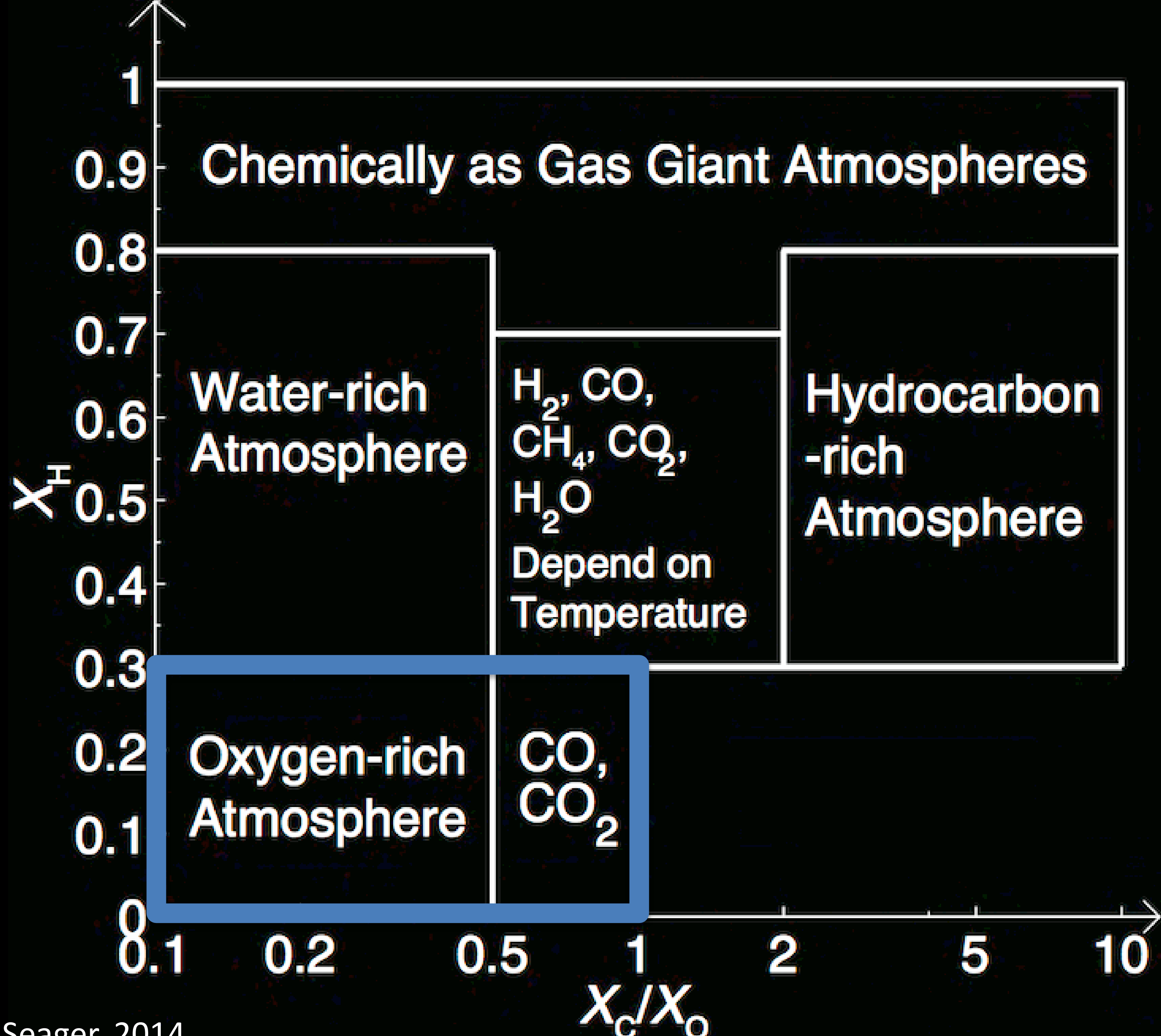
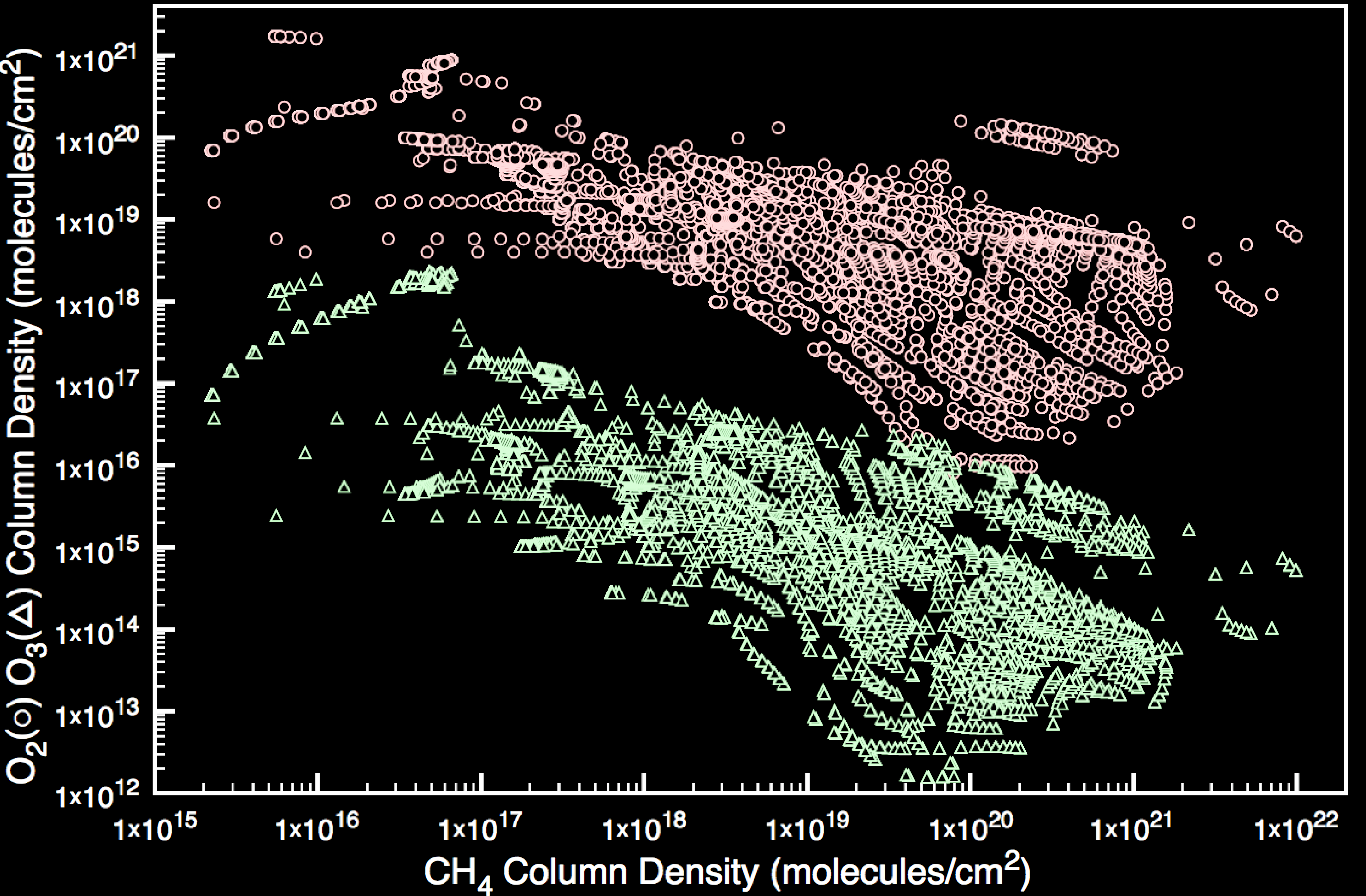


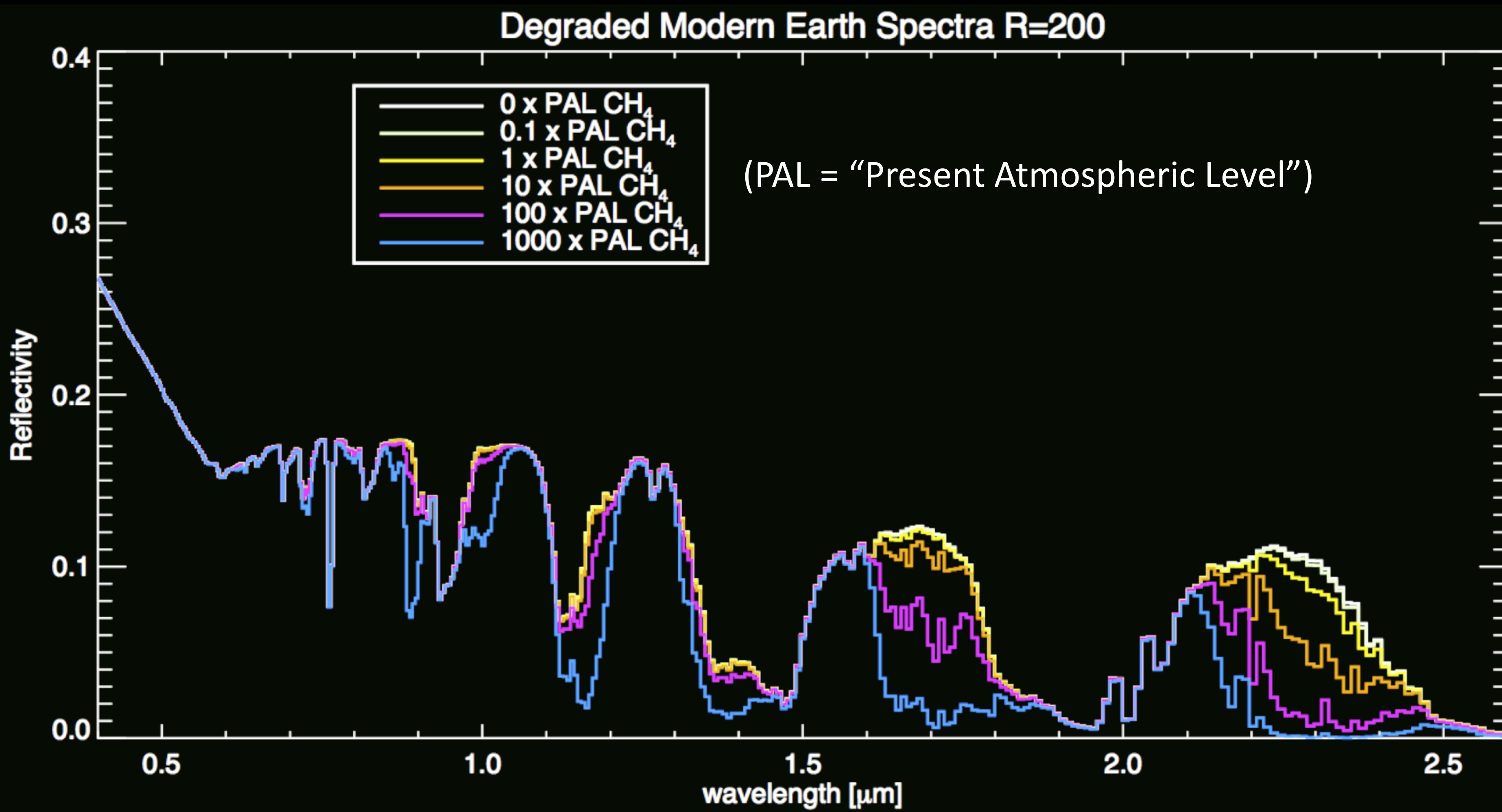
Figure courtesy Sonny Harman, from Harman, et al., in prep.



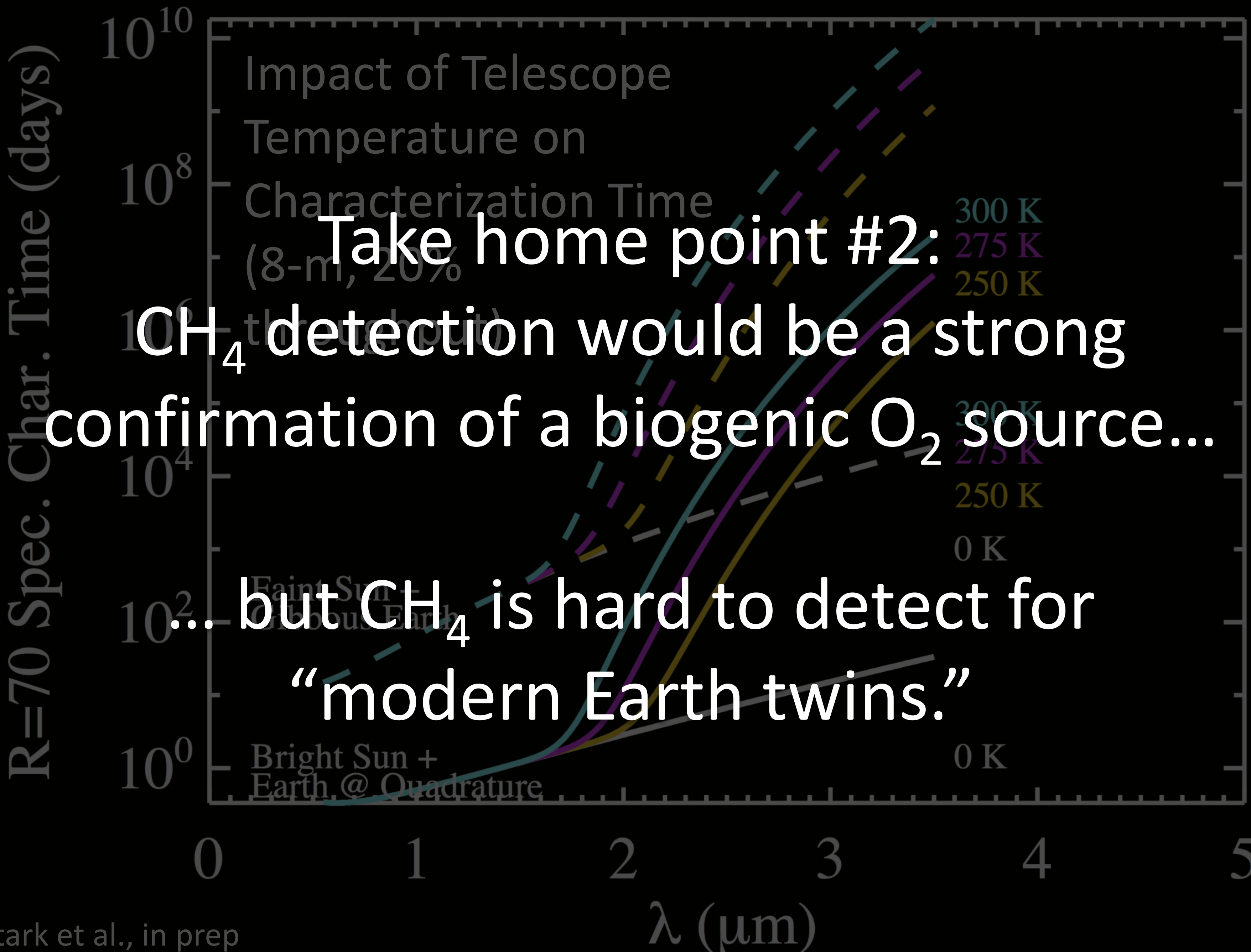
Hu and Seager, 2014



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."

Stark et al., in prep

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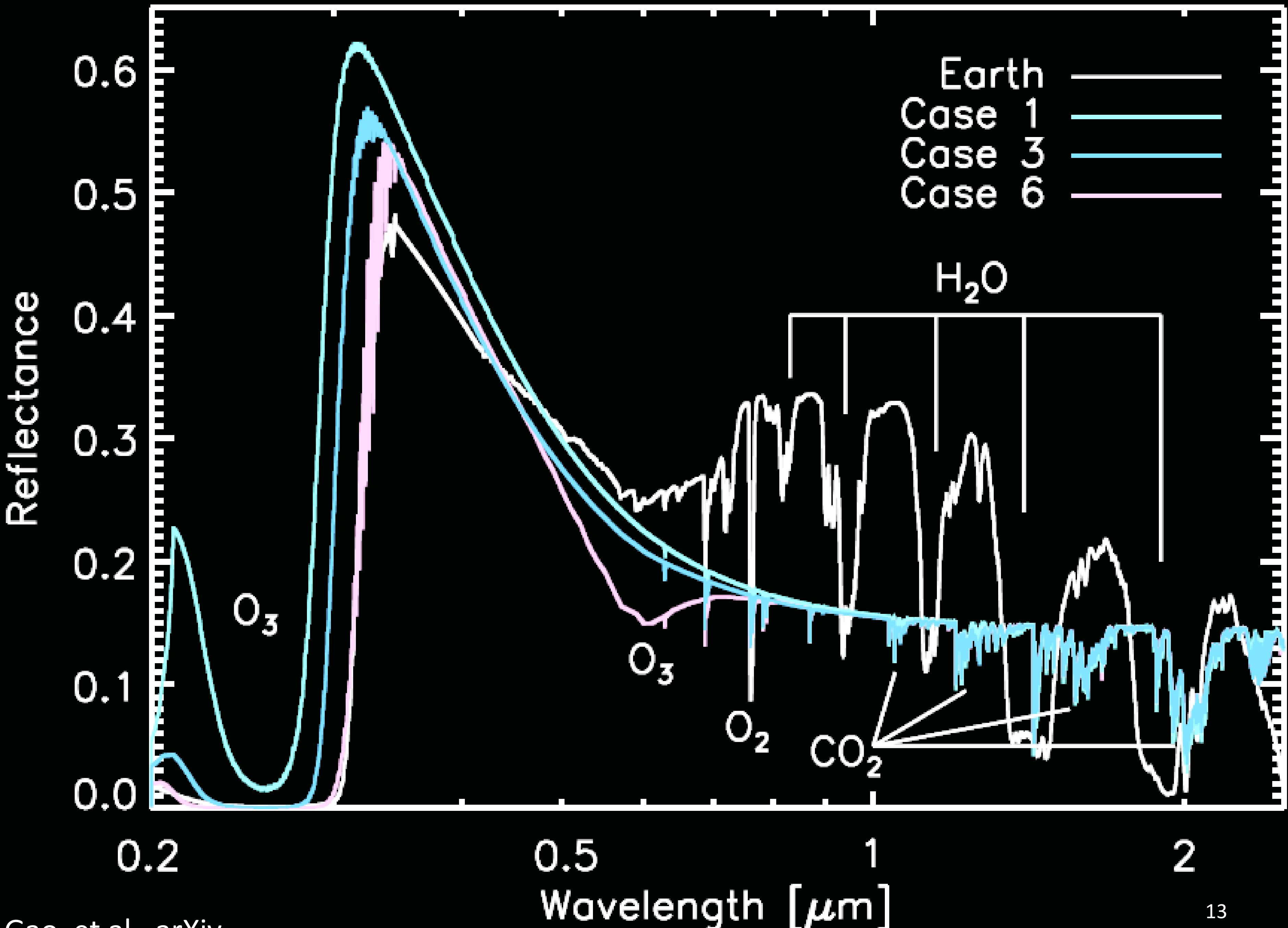
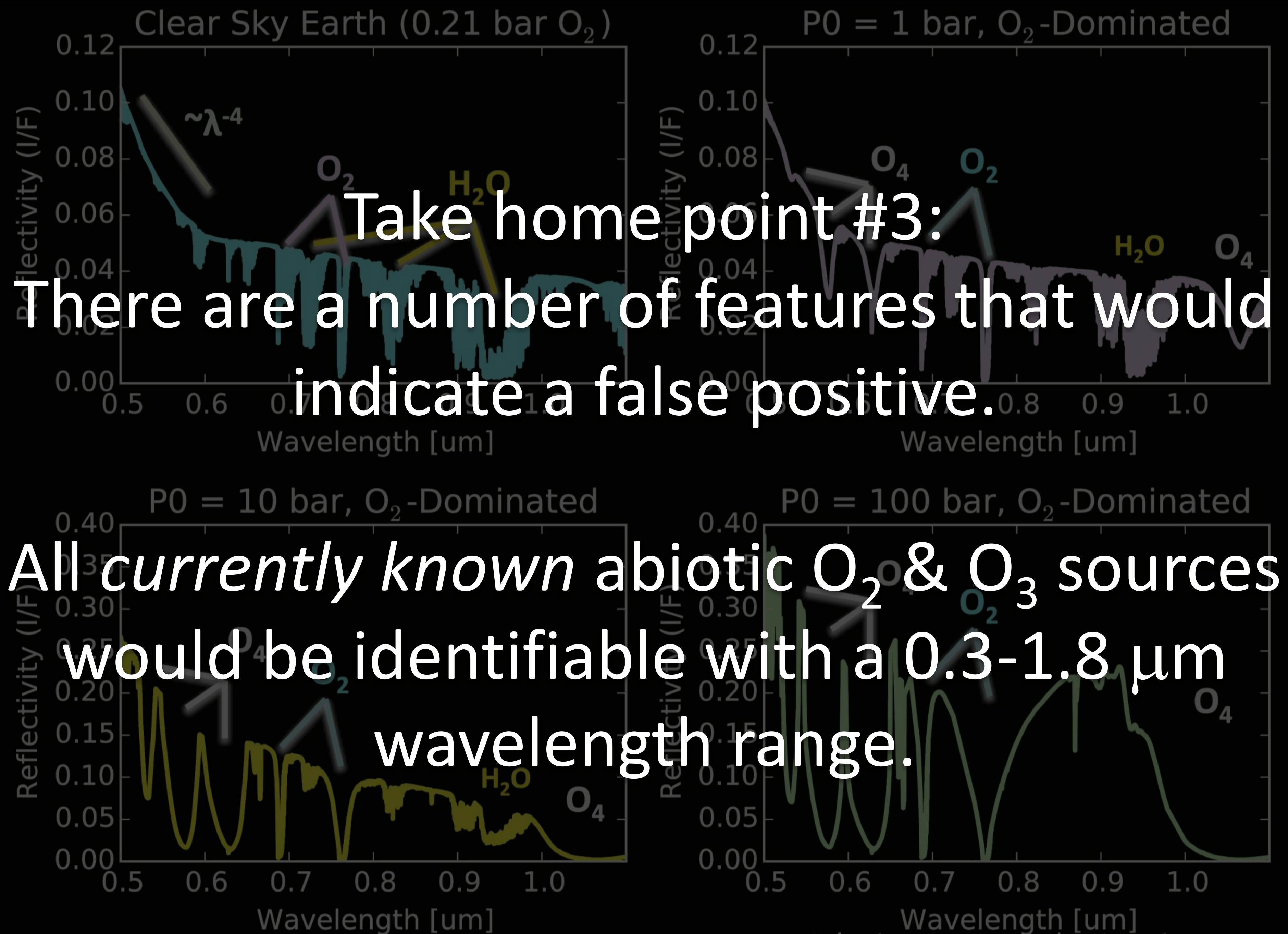


Gao, et al., arXiv



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

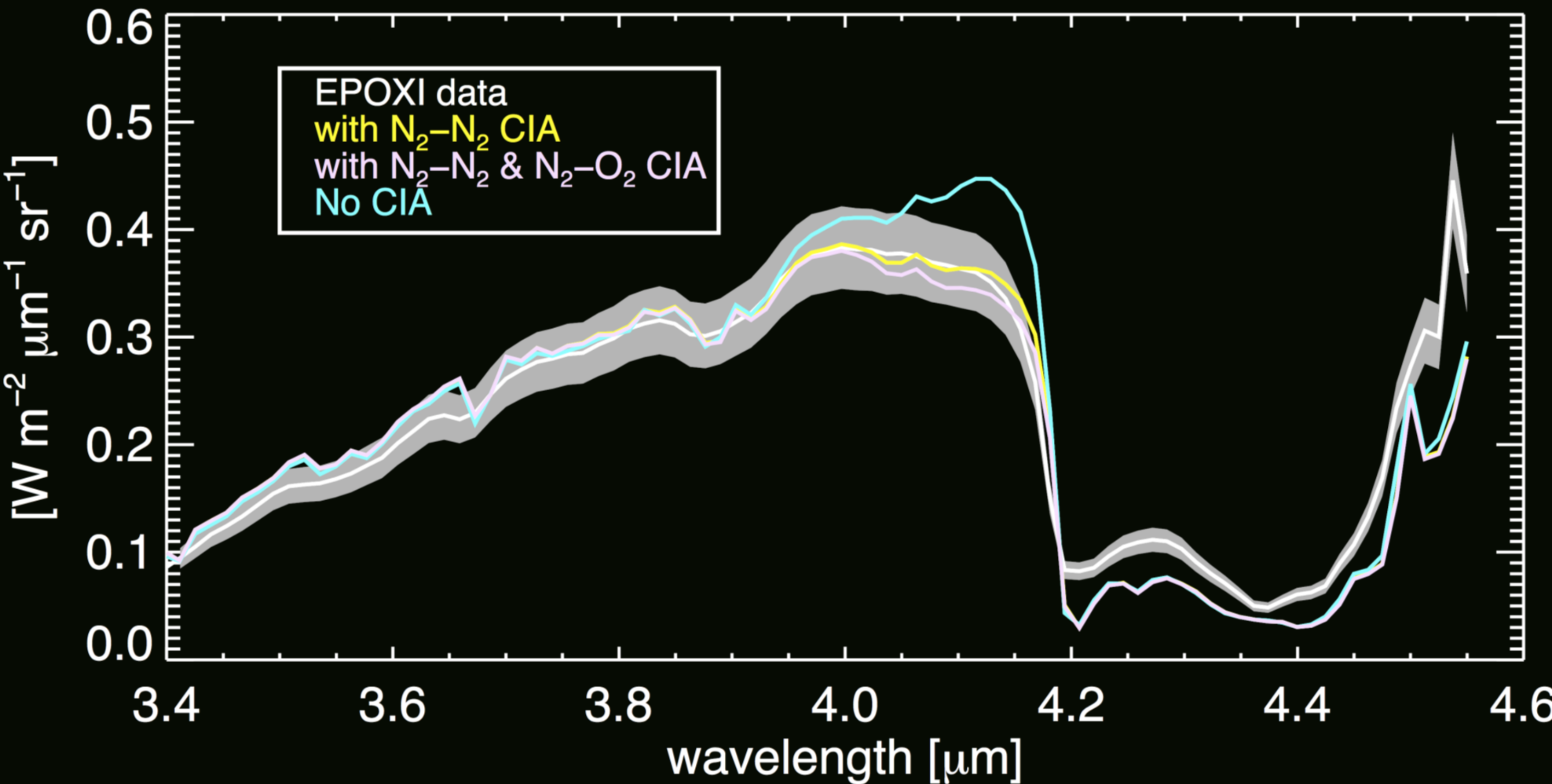
Getting to ~2 μm would be strongly preferred

- 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.

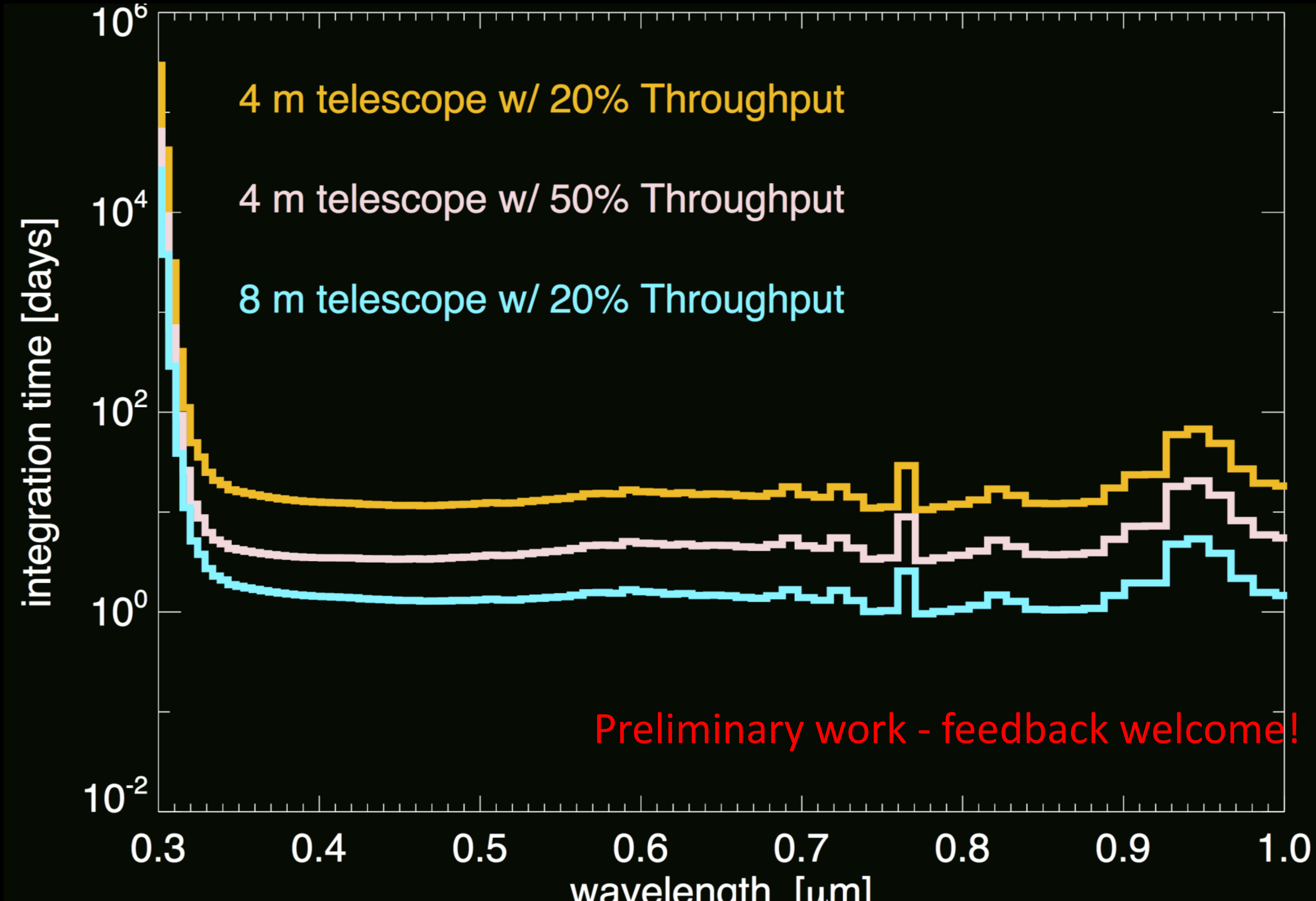


Figure from Giada Arney and Ty Robinson

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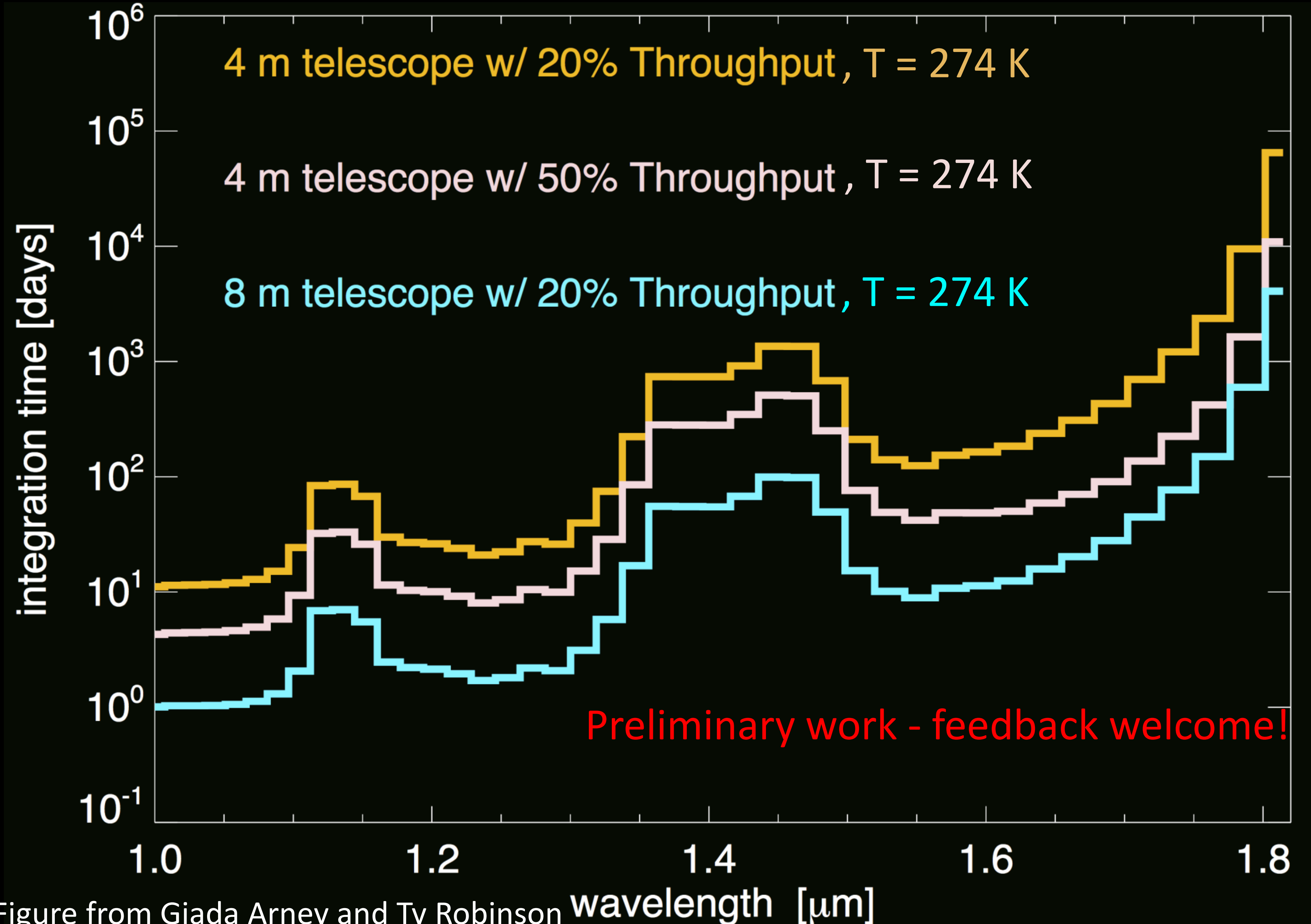

Figure from Giada Arney and Ty Robinson