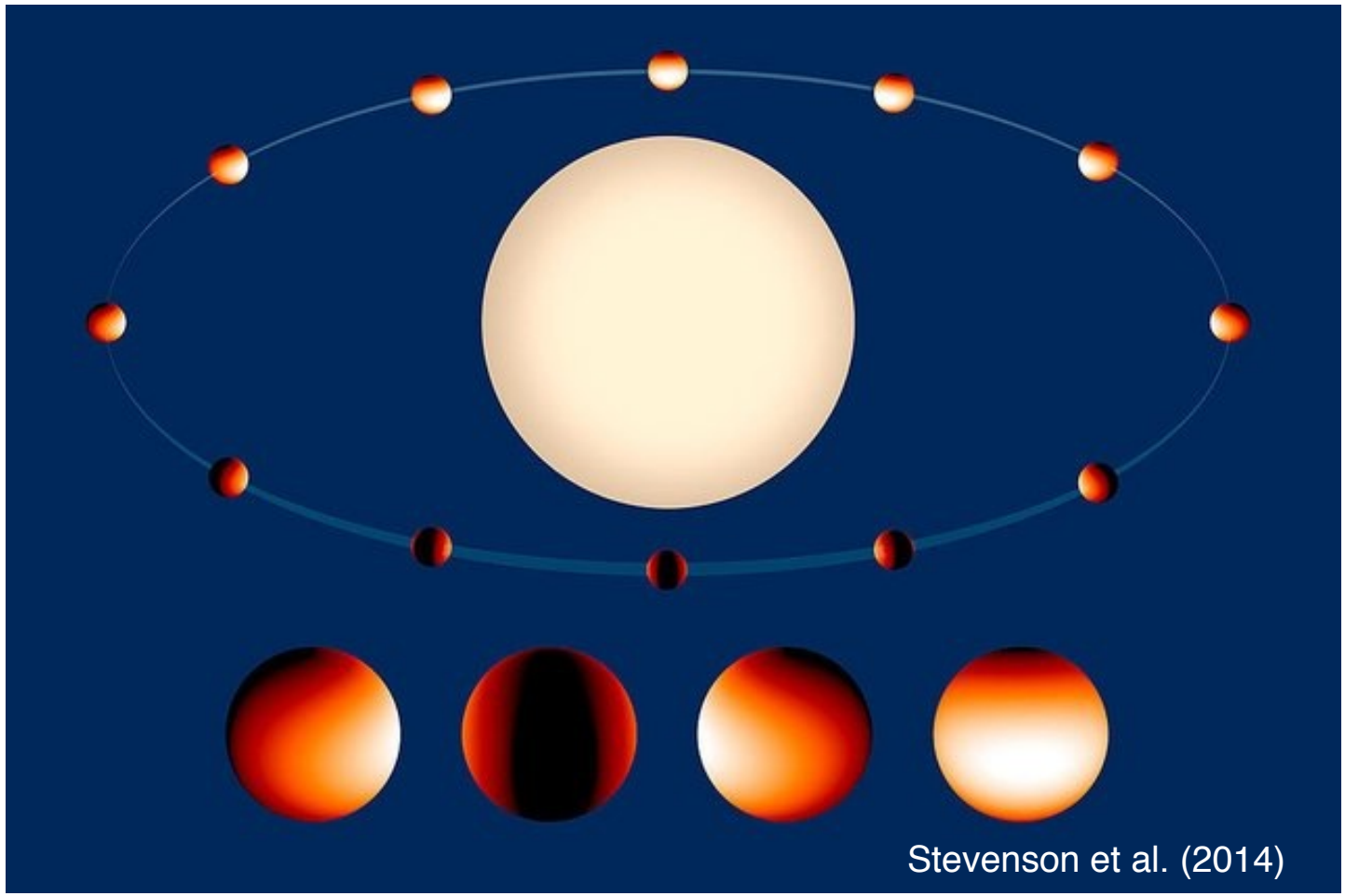
Spectroscopic Phase Curves of Exoplanets in the ARIEL Era



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ESTEC

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Acknowledgments

Jacob
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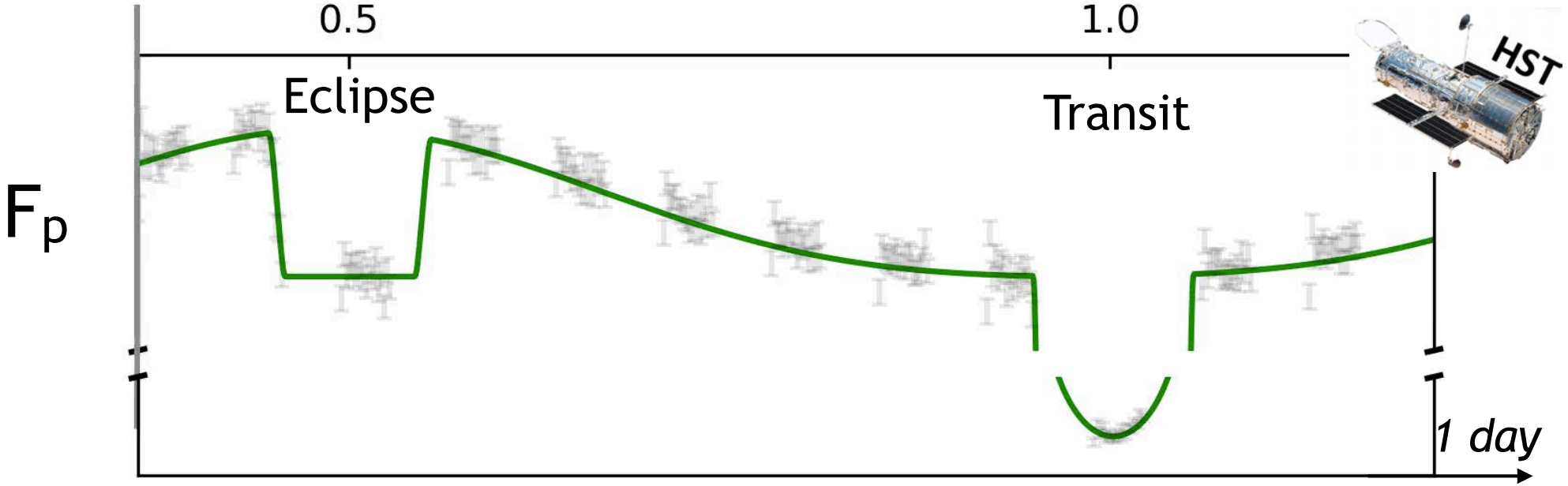
Bob
Jacobs (PhD1)

+ Contribution from Billy Edwards (UCL)

Spectroscopic Phase Curves

(HST/WFC3 WASP-18b)

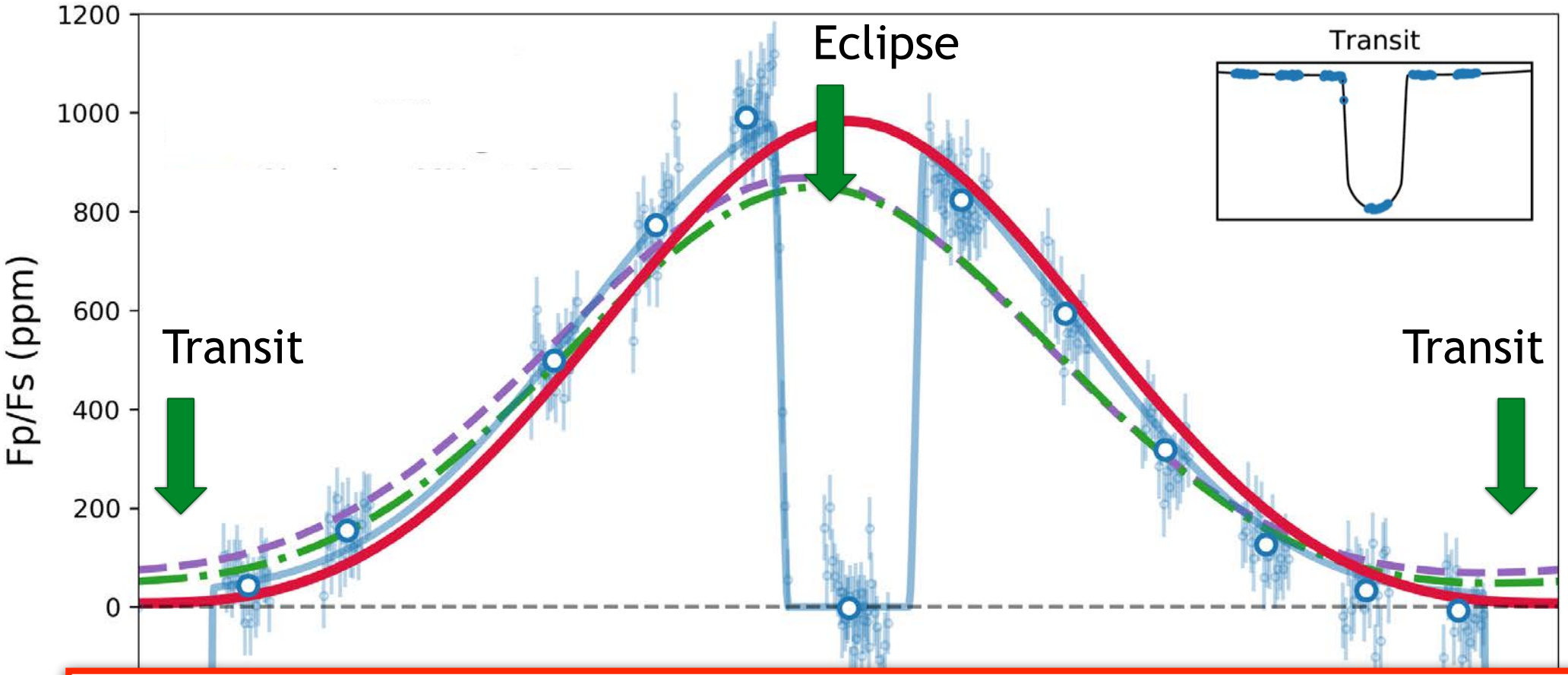
Arcangeli, Désert et al. (2019)



Measuring the atmospheric dynamics of WASP-18b

GCM Models by Vivien Parmetier

Arcangeli, et al. (2019)

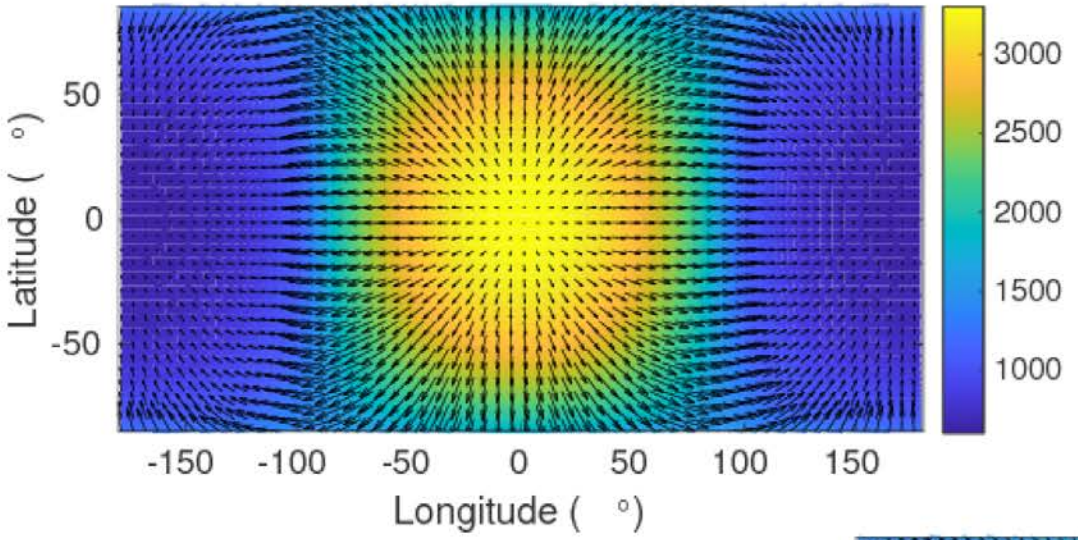


- *Tidally locked:* peak at 1000 ppm => L_{day}/L_{night}>15 => Tday=2800K & Tnight<1400K
- *Heat poorly redistributed:* Large D/N contrast => radiative timescale << dynamic timescale (advection and waves).
- *Expected:* hot-spot offset ~15° Strong degrees => eastward equatorial jet stream
- *In stark contrast* to modest day/night difference of hot-Jupiters (similar irradiation)

Comparison to Global Circulation Models

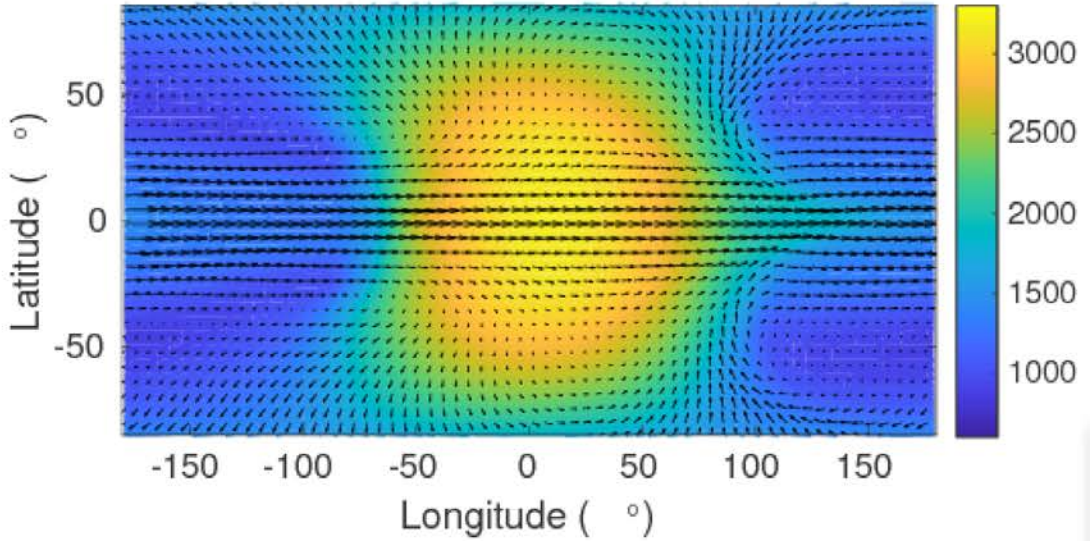
GCM Models from Vivien Parmentier

Arcangeli et al. (2019)



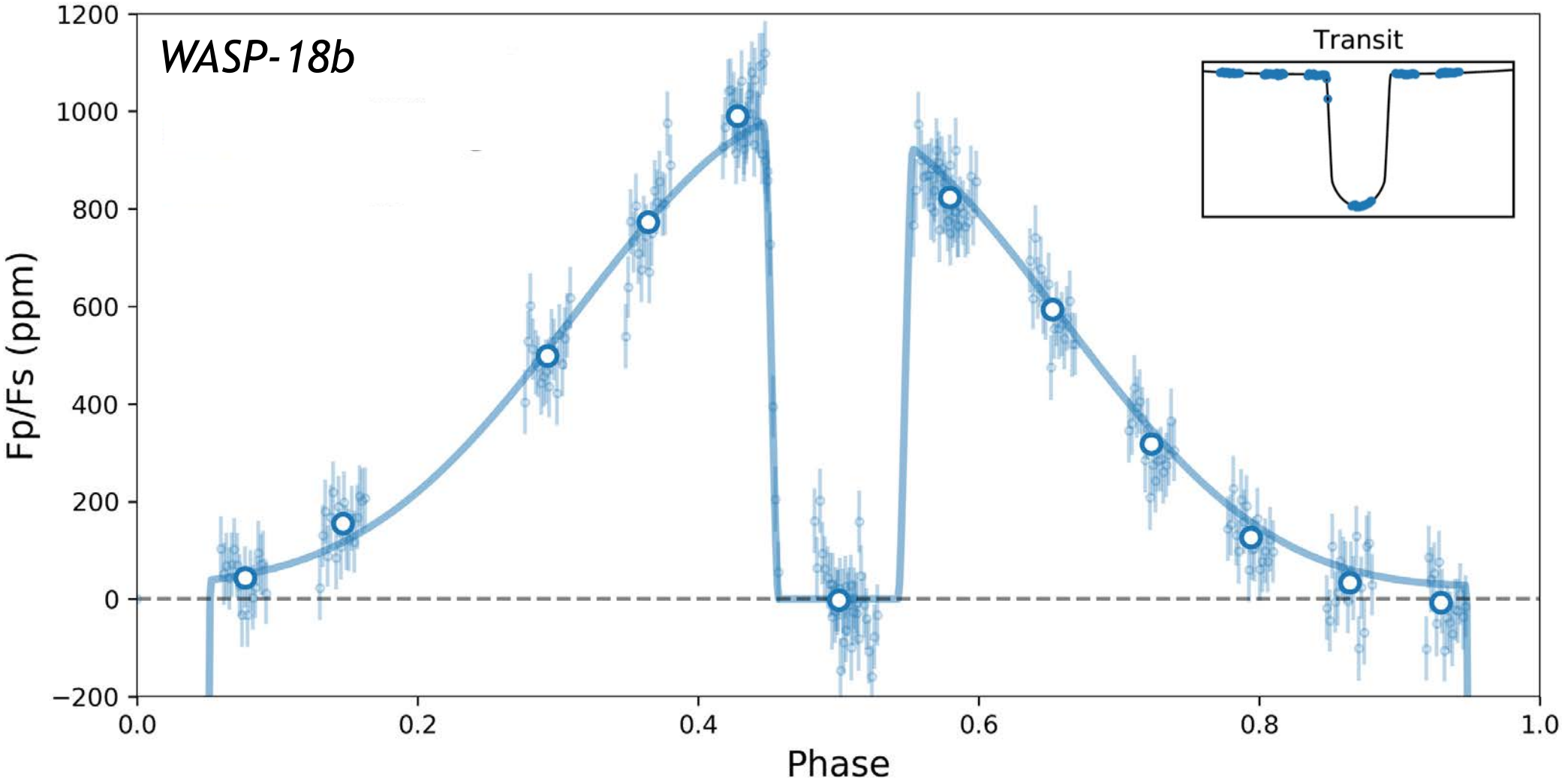
Strong drag:
e.g. 10^3 s
Day-Night circulation

Weak drag:
e.g. 10^6 s
Super-rotating
equatorial winds



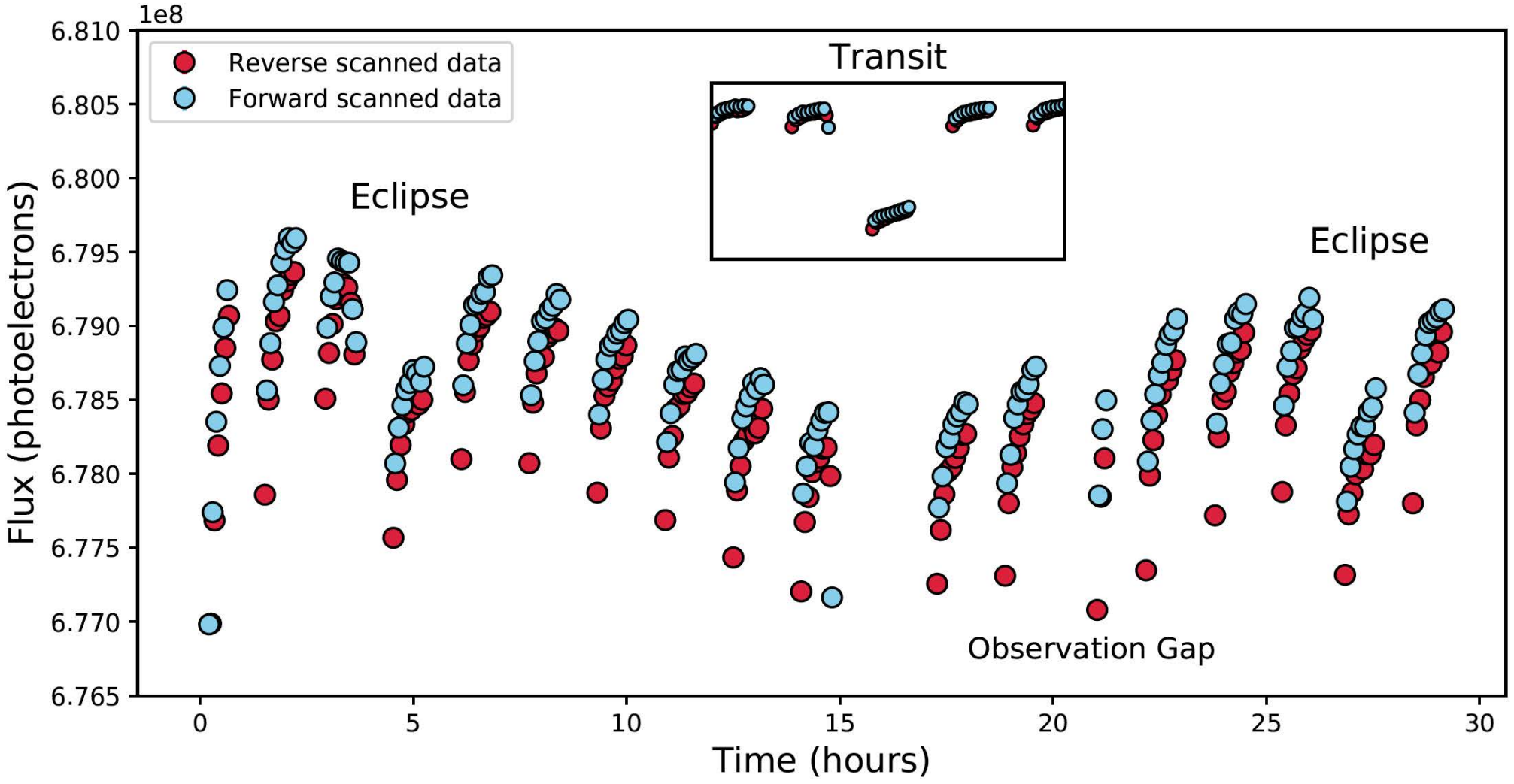
Challenges for Phase Curves with HST

Arcangeli et al. (2019)



Challenges for Phase Curves with HST

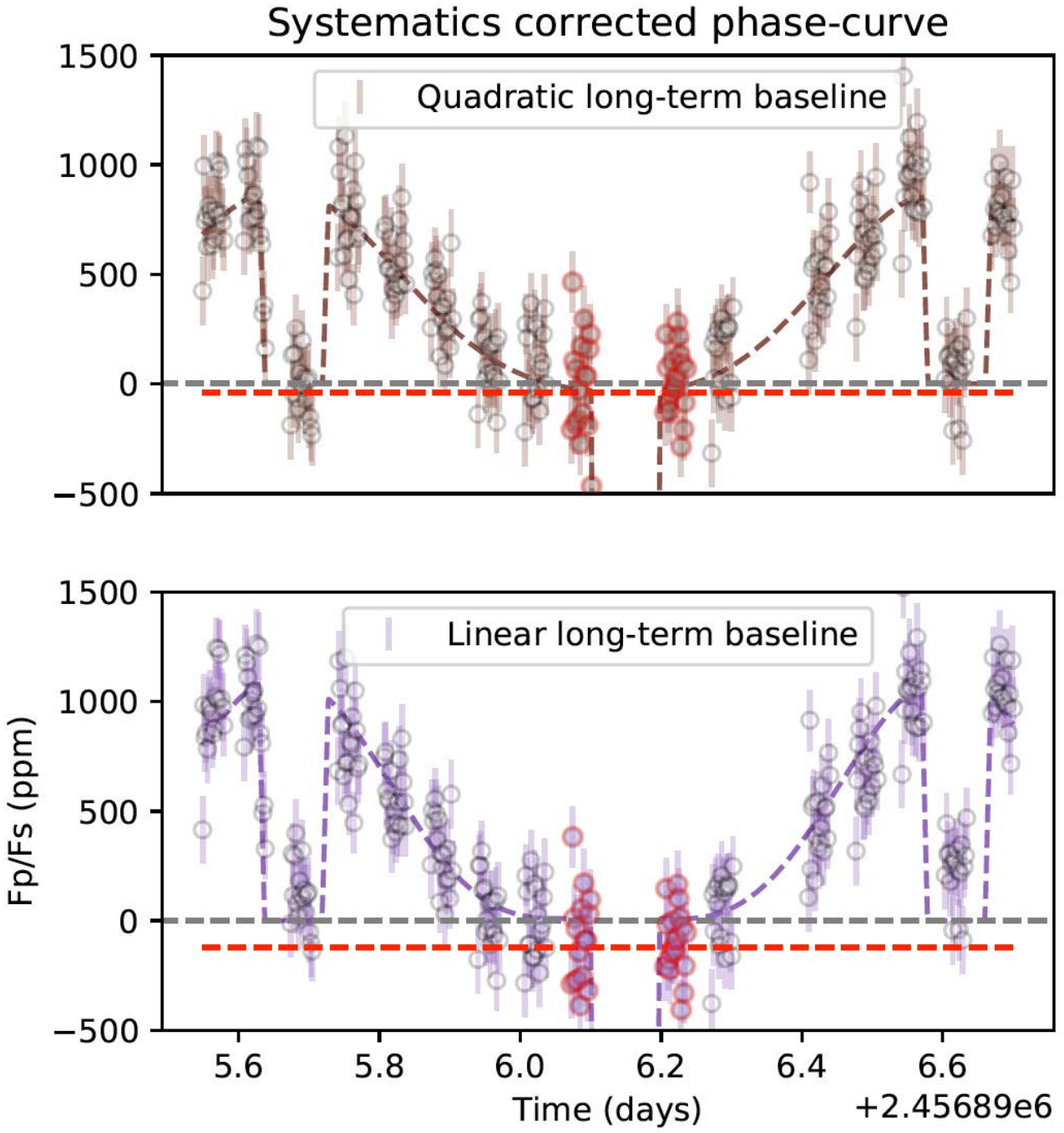
Raw data



Arcangeli et al. (2019)

Challenges for Phase Curves with HST

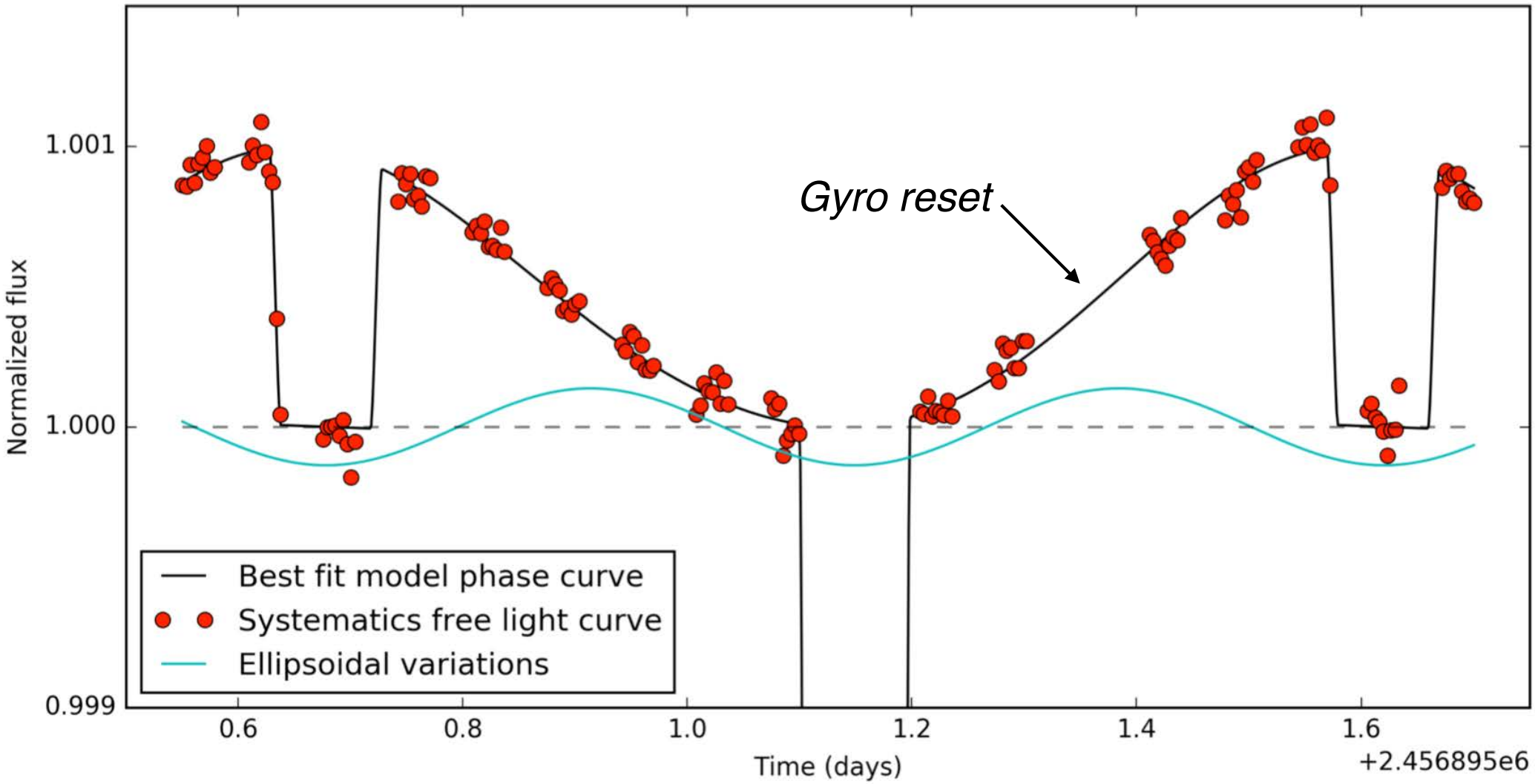
Long term baseline: From eclipse to eclipse



Arcangeli et al. (2019)

Challenges for Phase Curves with HST

From eclipse to eclipse

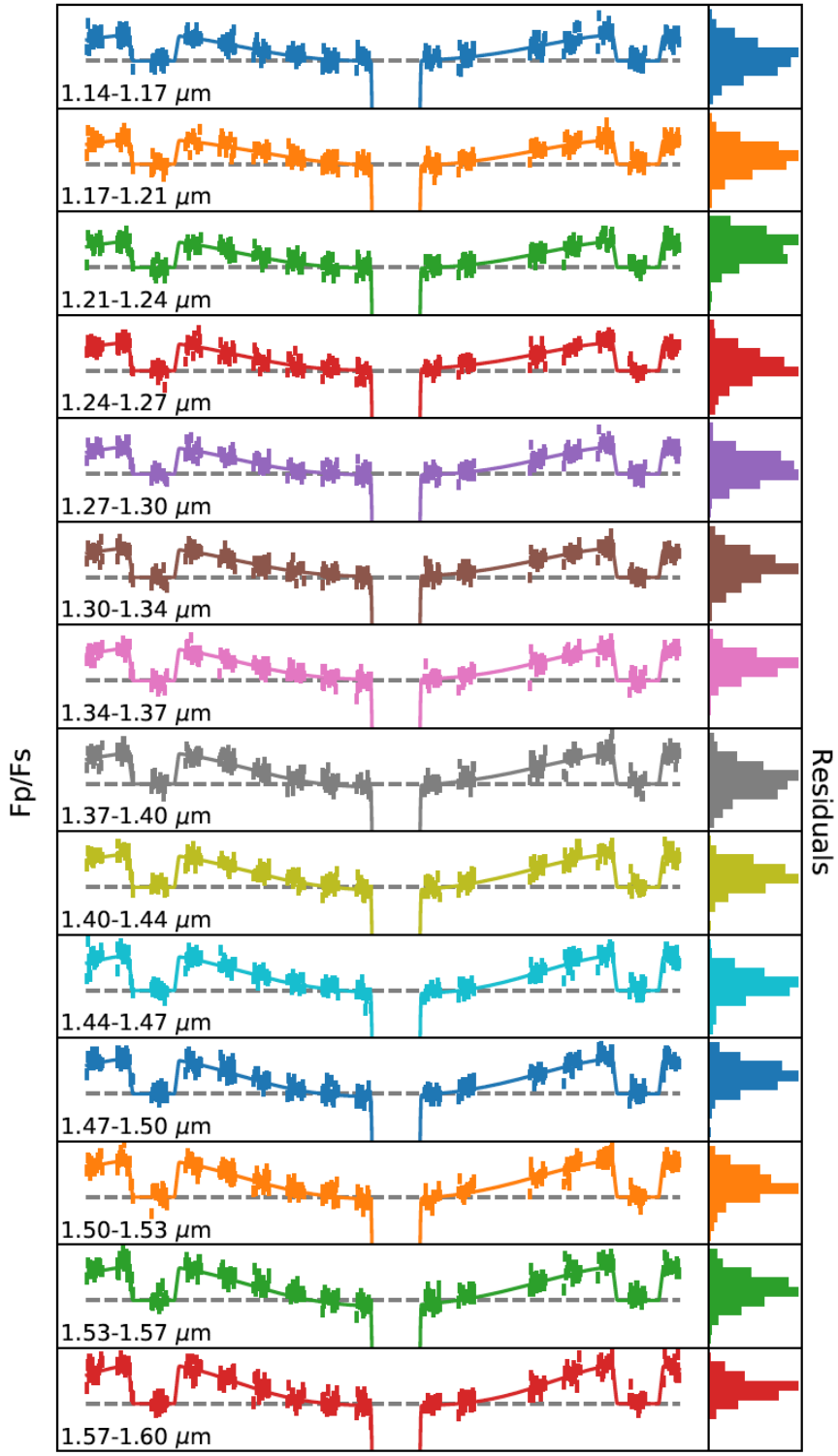


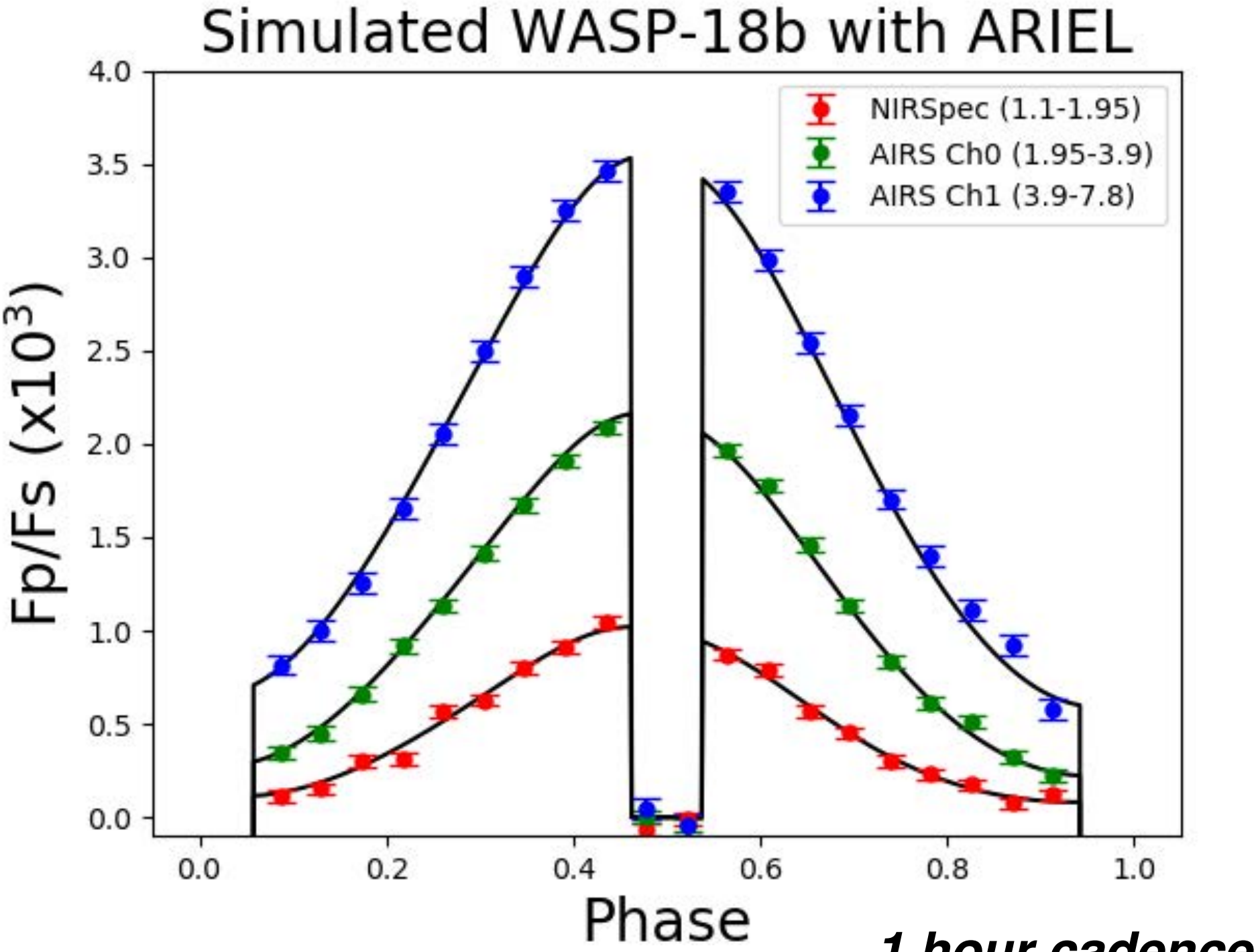
Arcangeli et al. (2019)

Challenges for Phase Curves with HST

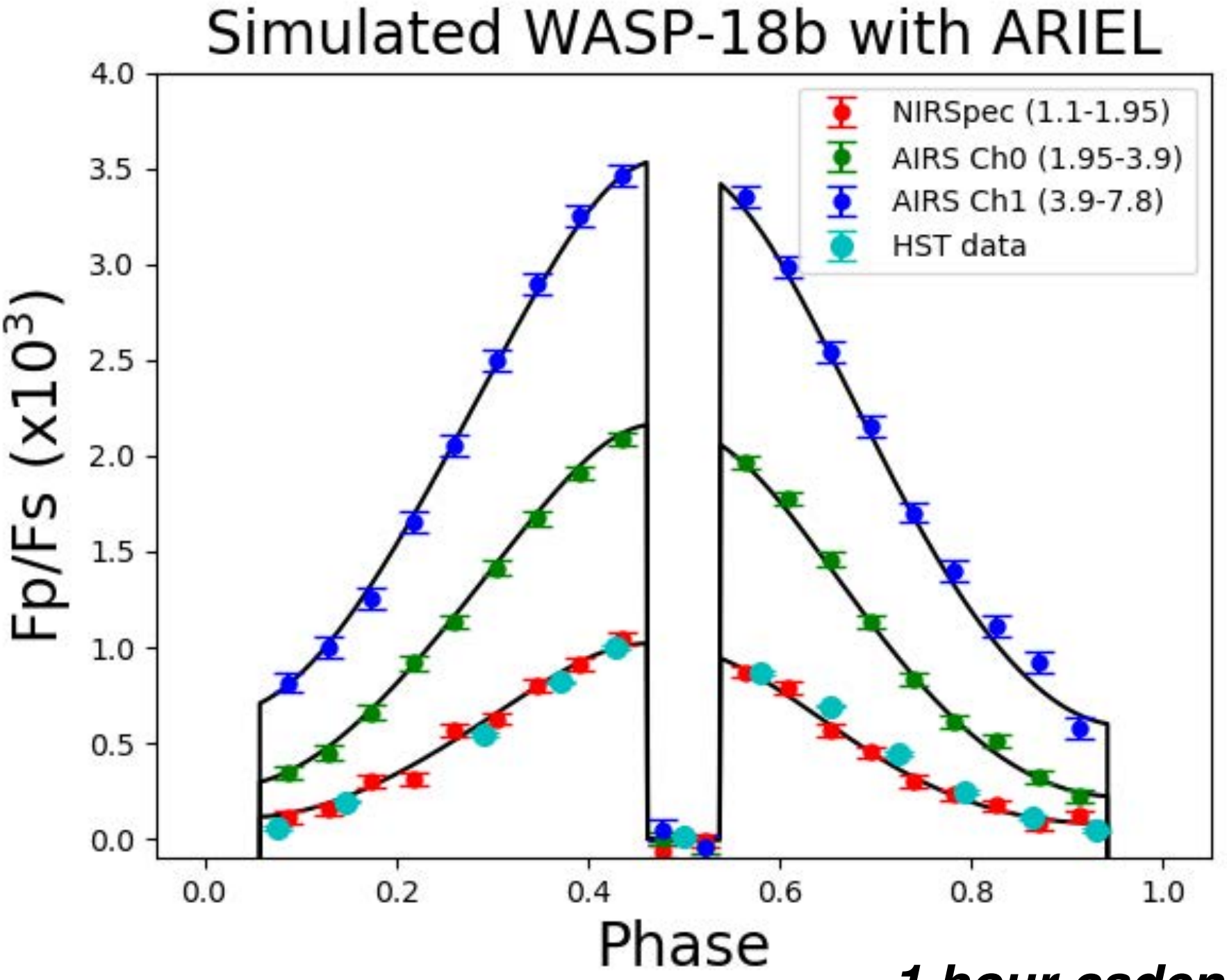
Wavelength Dependent Systematics

Arcangeli et al. (2019)

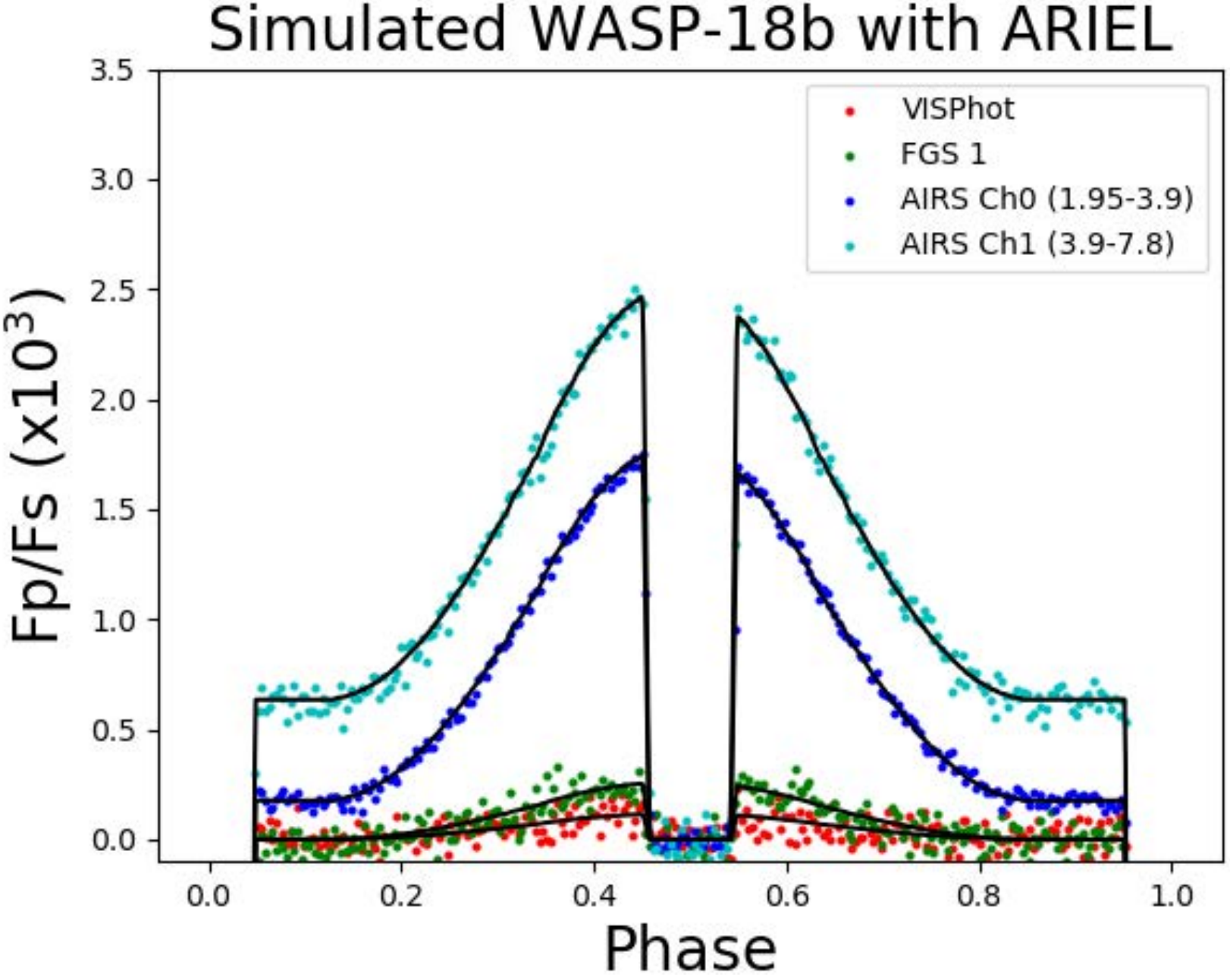


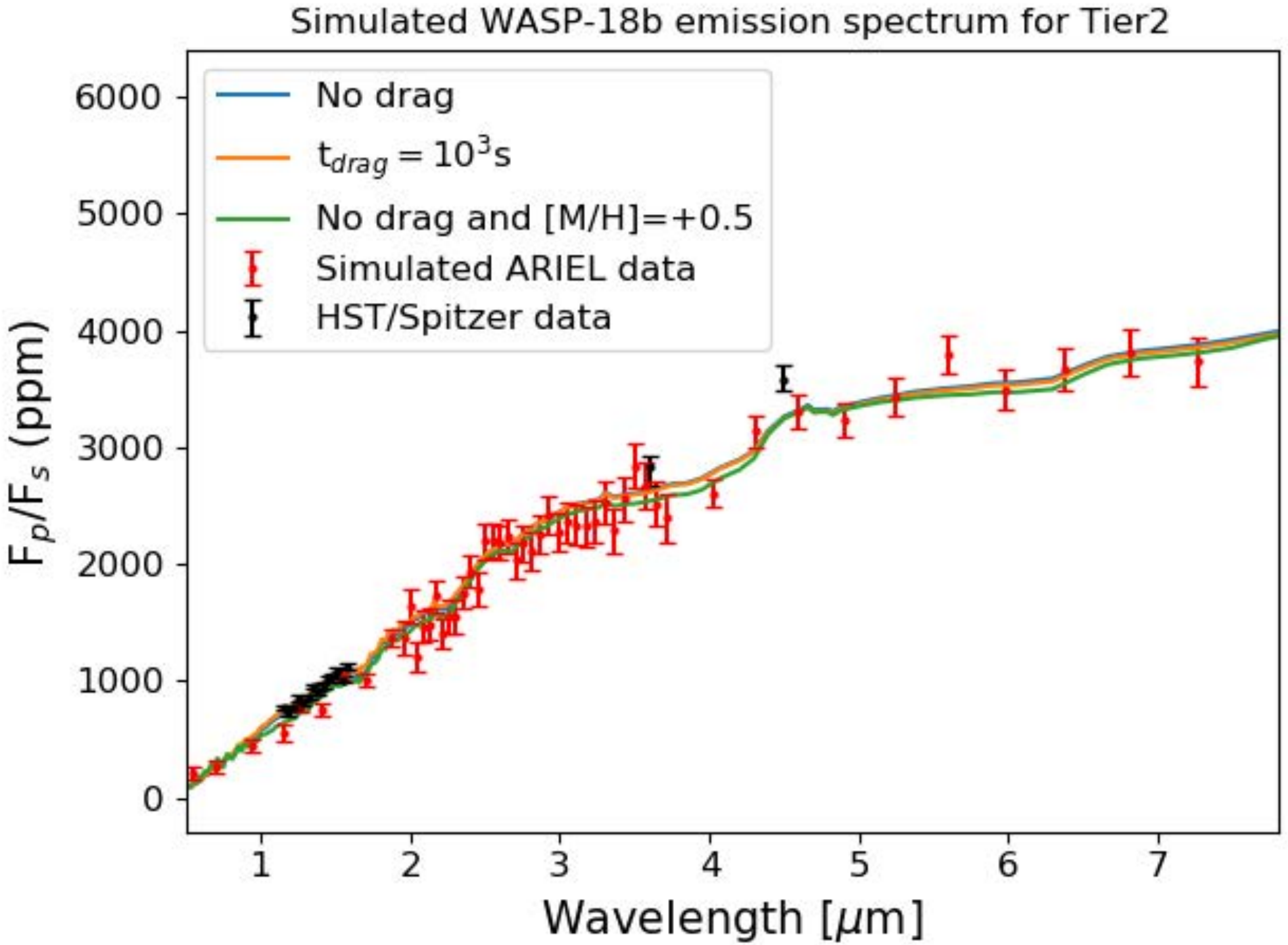


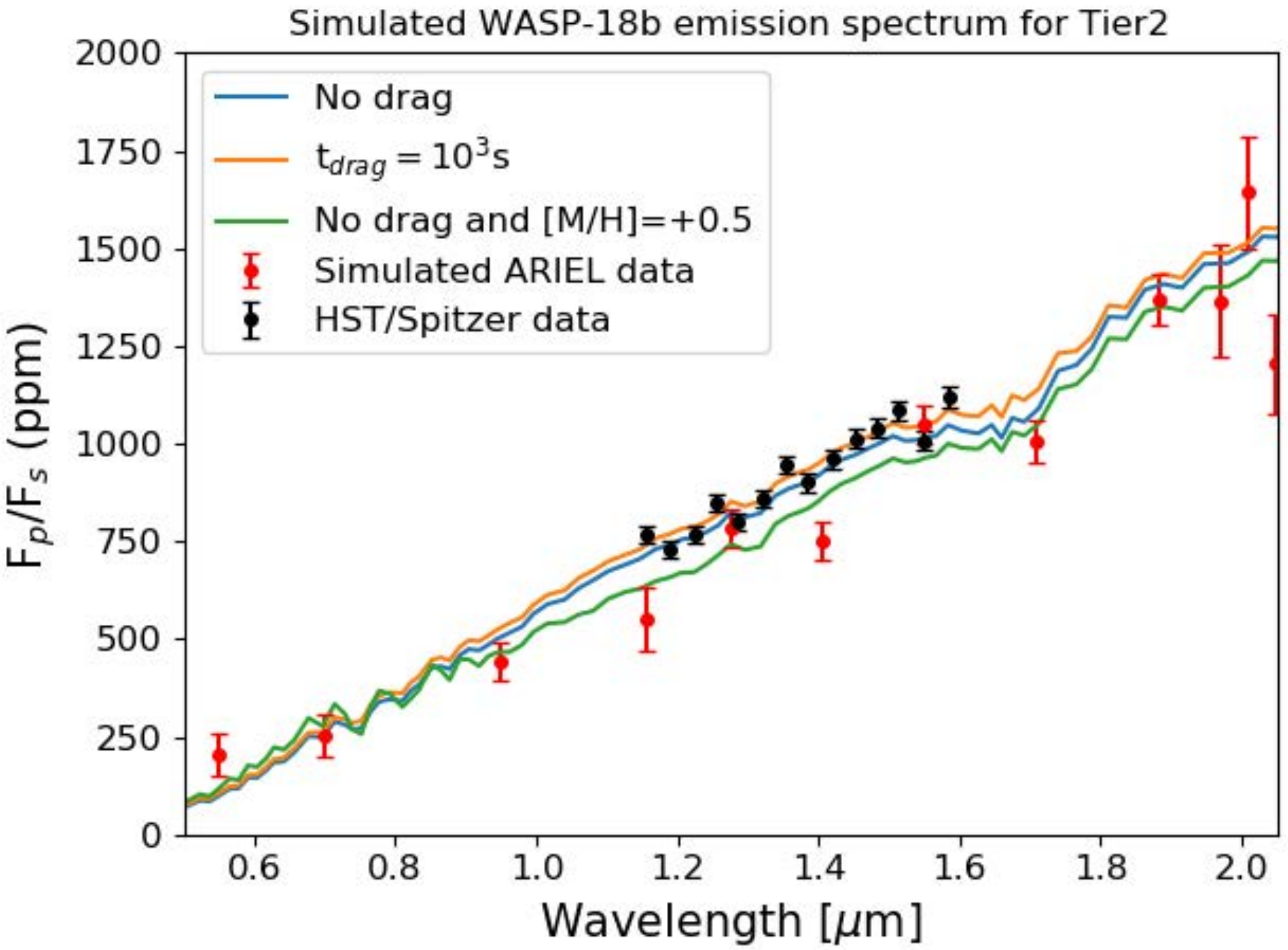
1 hour cadence

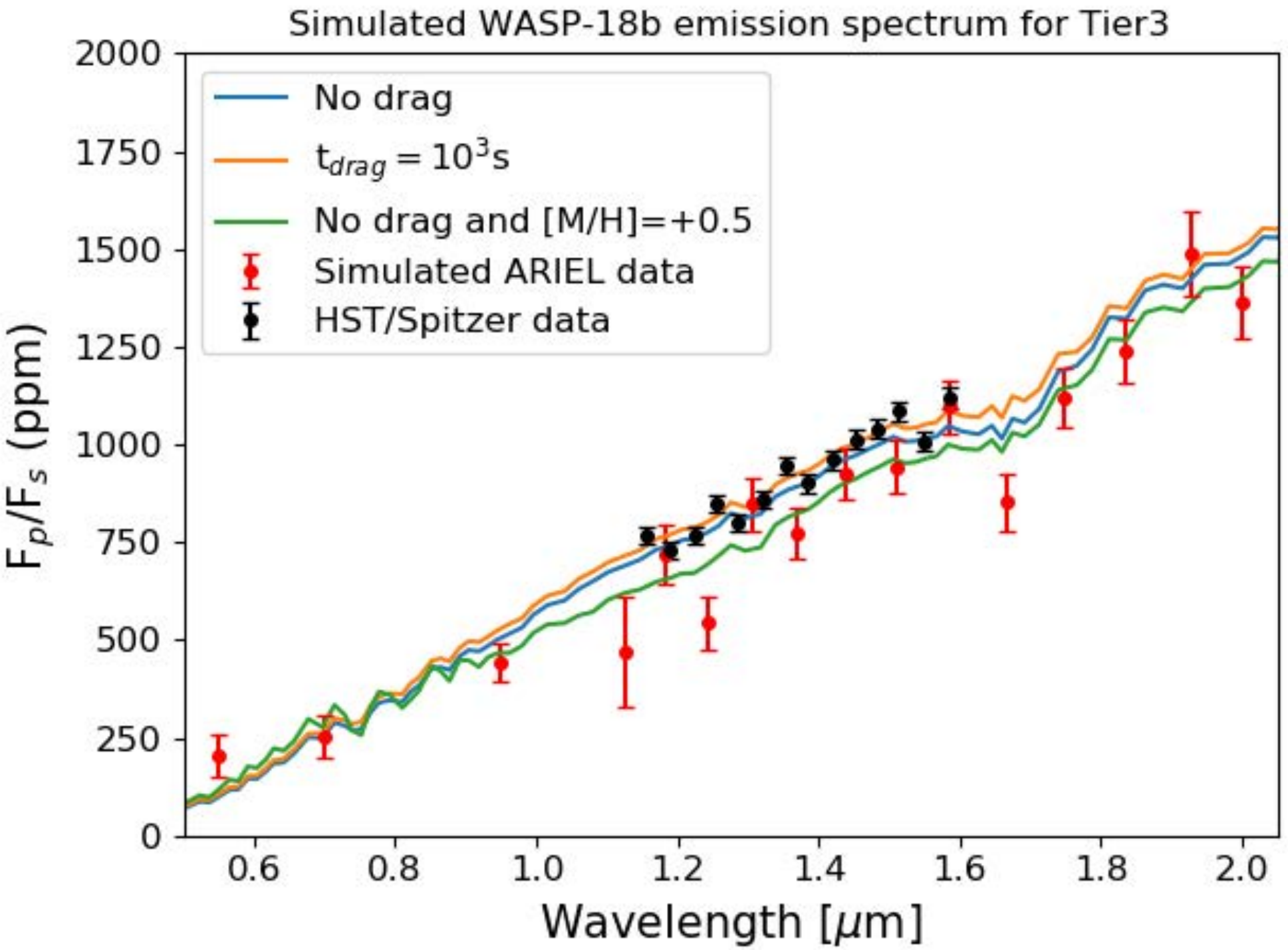


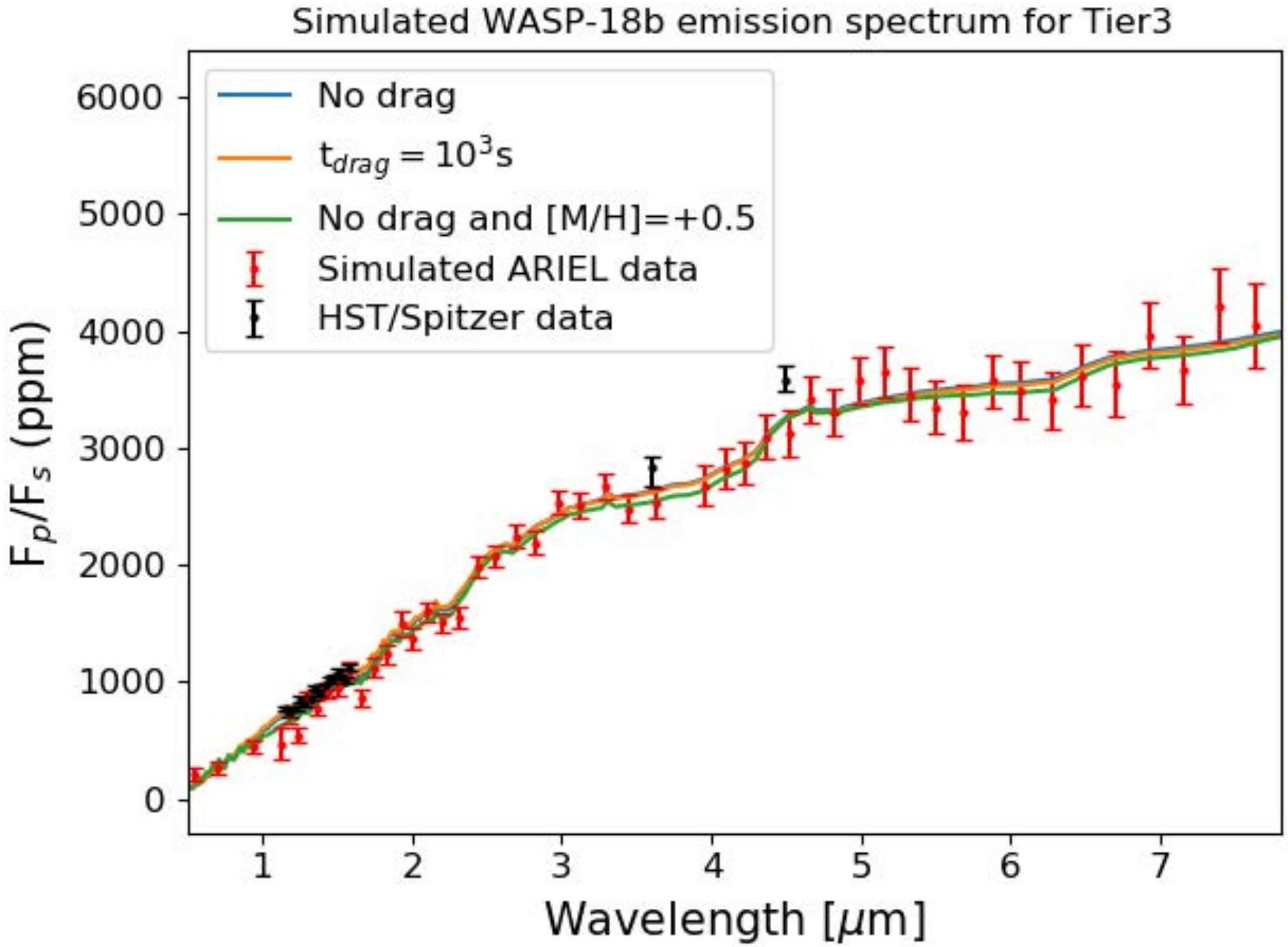
1 hour cadence


Simulated WASP-18b with ARIEL
VISPhot
FGS 1
AIRS Ch0 (1.95-3.9)
AIRS Ch1 (3.9-7.8)
Fp/Fs (x10^3)
Phase
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.2
0.4
0.6
0.8
1.0


Simulated WASP-18b emission spectrum for Tier2
No drag
$t_{drag} = 10^3$s
No drag and [M/H]=+0.5
Simulated ARIEL data
HST/Spitzer data
F_p/F_s (ppm)
0
1000
2000
3000
4000
5000
6000
1
2
3
4
5
6
7
Wavelength [μm]

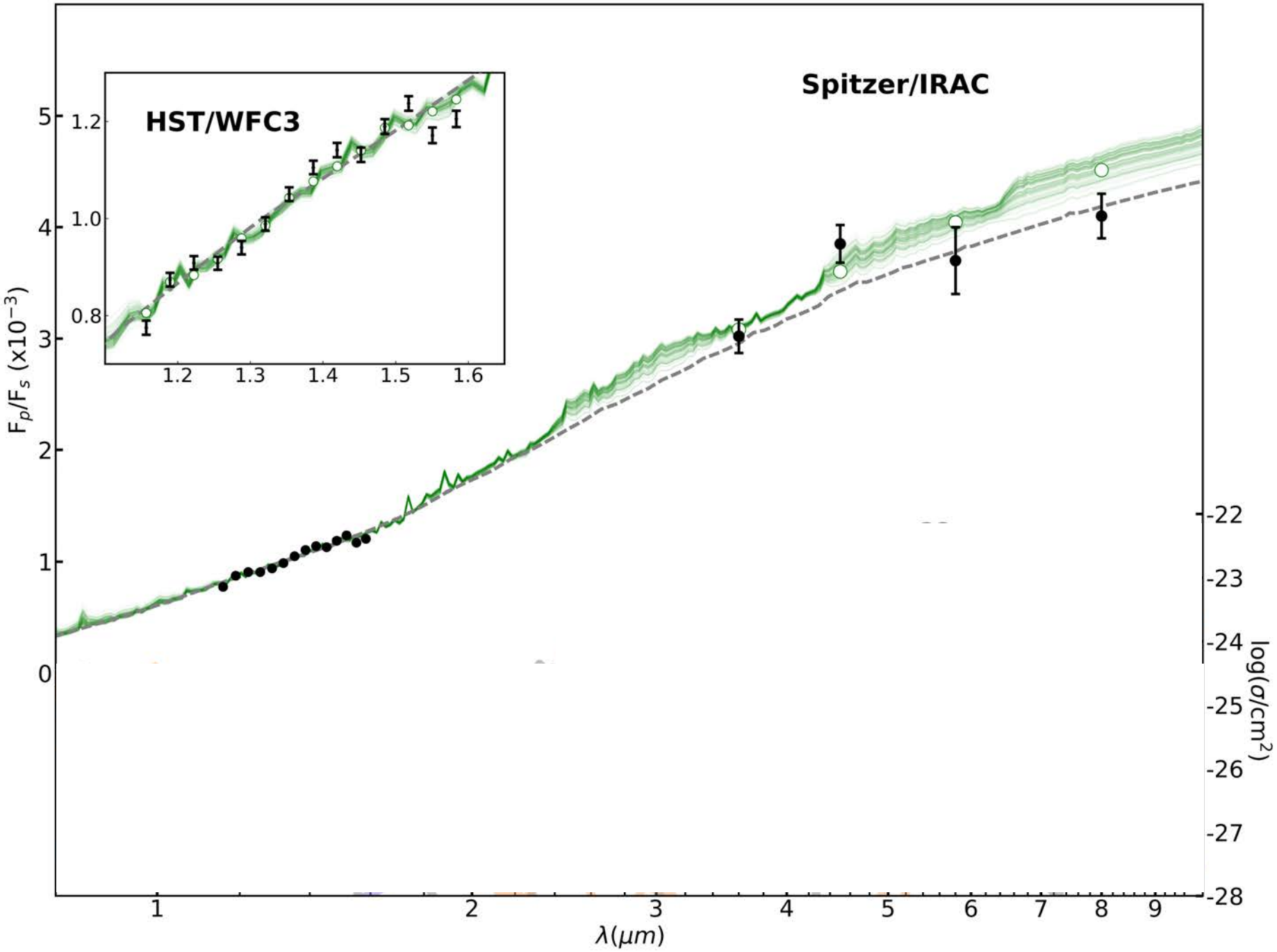

Simulated WASP-18b emission spectrum for Tier2
No drag
$t_{drag} = 10^3$s
No drag and [M/H]=+0.5
Simulated ARIEL data
HST/Spitzer data
F_p/F_s (ppm)
Wavelength [μm]
0
250
500
750
1000
1250
1500
1750
2000
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0


Simulated WASP-18b emission spectrum for Tier3
No drag
$t_{drag} = 10^3$s
No drag and [M/H]=+0.5
Simulated ARIEL data
HST/Spitzer data
F_p/F_s (ppm)
Wavelength [μm]
0
250
500
750
1000
1250
1500
1750
2000
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0


Simulated WASP-18b emission spectrum for Tier3
No drag
$t_{drag} = 10^3$s
No drag and [M/H]=+0.5
Simulated ARIEL data
HST/Spitzer data
F_p/F_s (ppm)
Wavelength [μm]
0
1000
2000
3000
4000
5000
6000
1
2
3
4
5
6
7

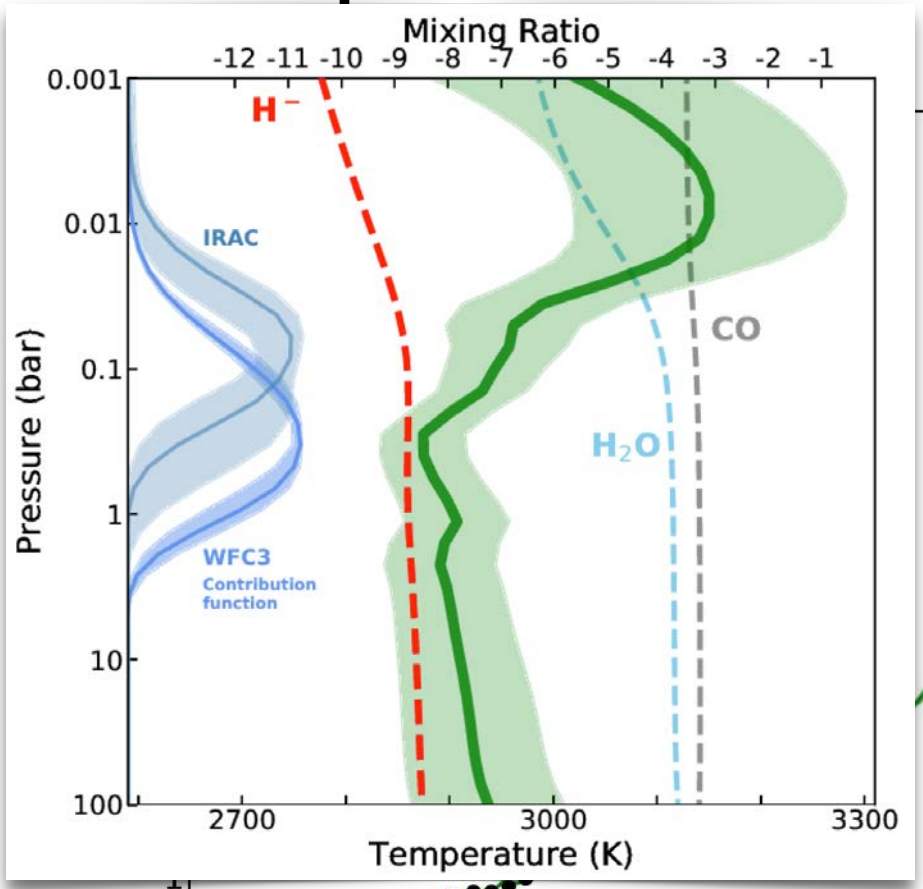
Composition and Structure of an UHJ (WASP-18b)

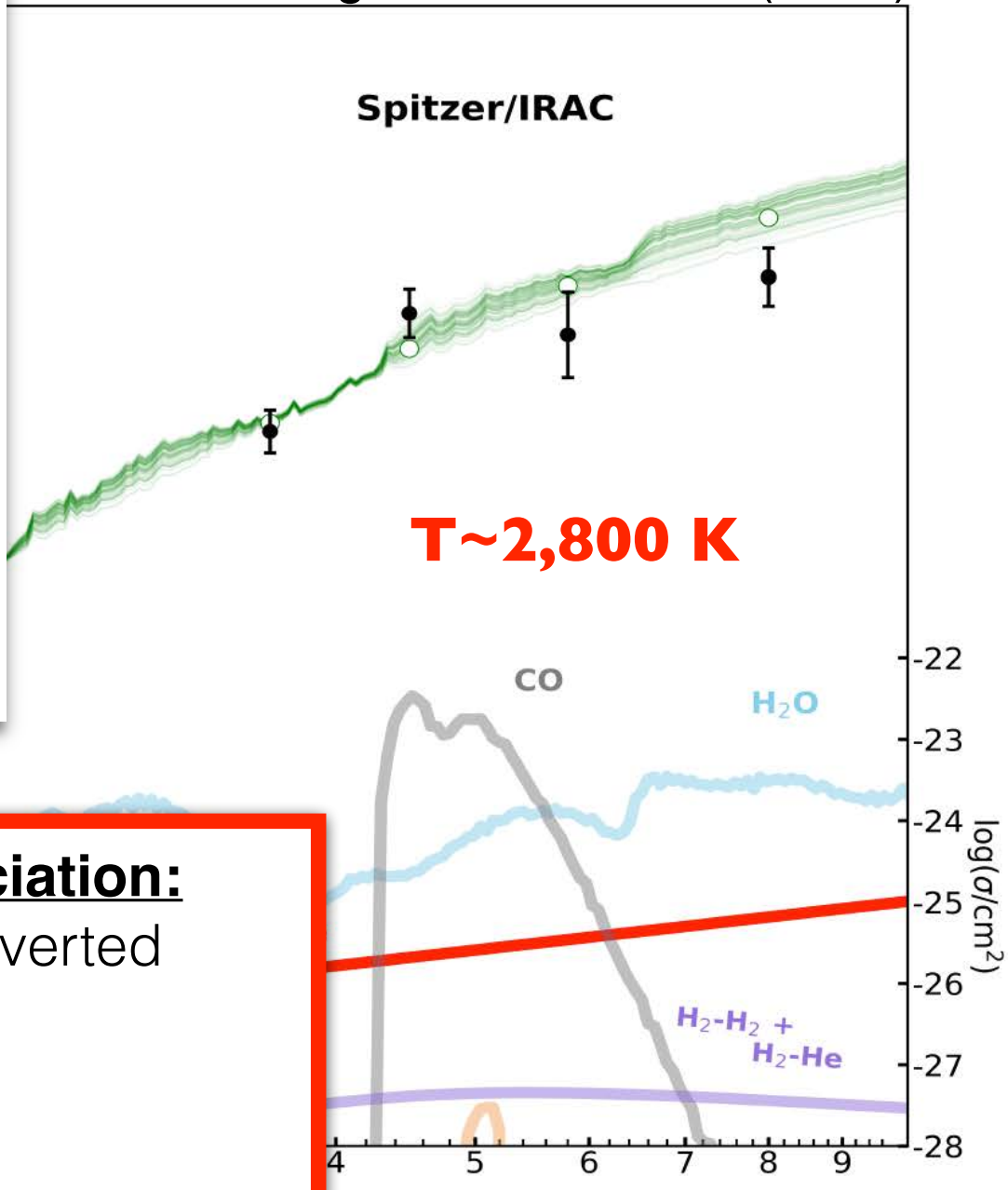
Arcangeli et al. (2018)



Composition and Structure of an UHJ (WASP-18b)

Arcangeli, Désert et al. (2019)





H- and molecular dissociation:

=> Lack of cooling: TP inverted

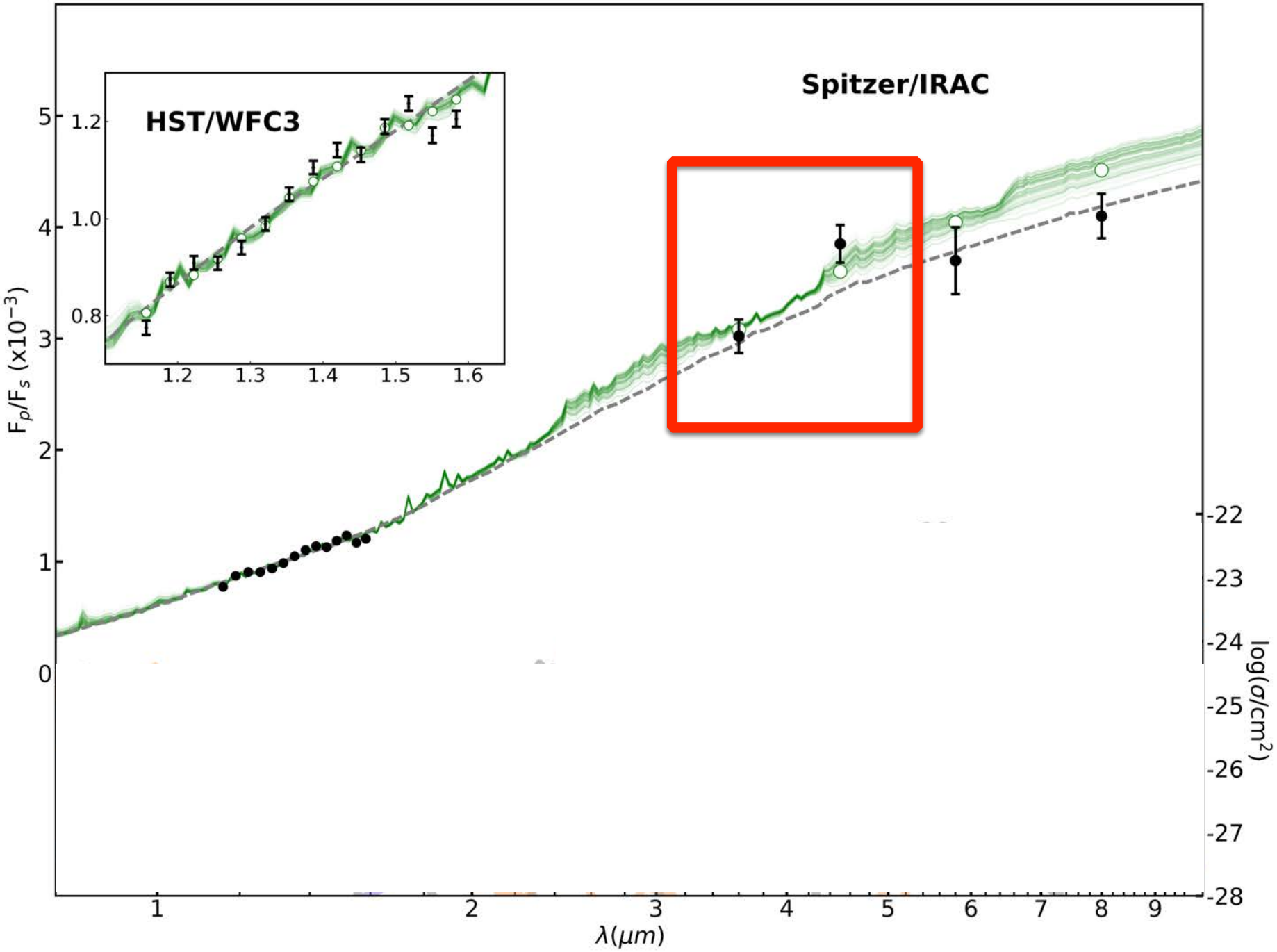
=> Solar metallicity

[M/H]=0.03 +/- 0.28

C/O < 0.75 (3-Sigma)

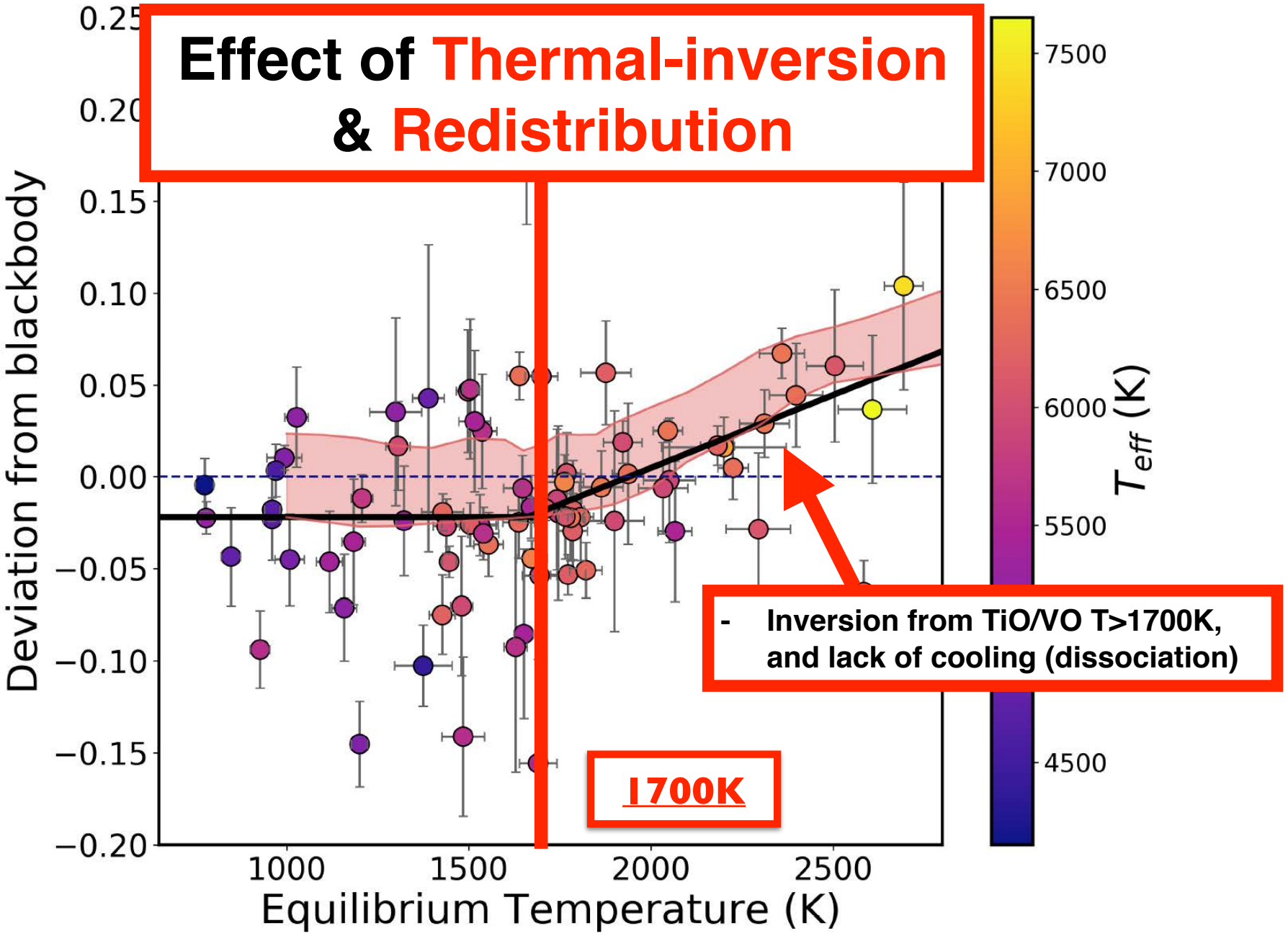
Composition and Structure of an UHJ (WASP-18b)

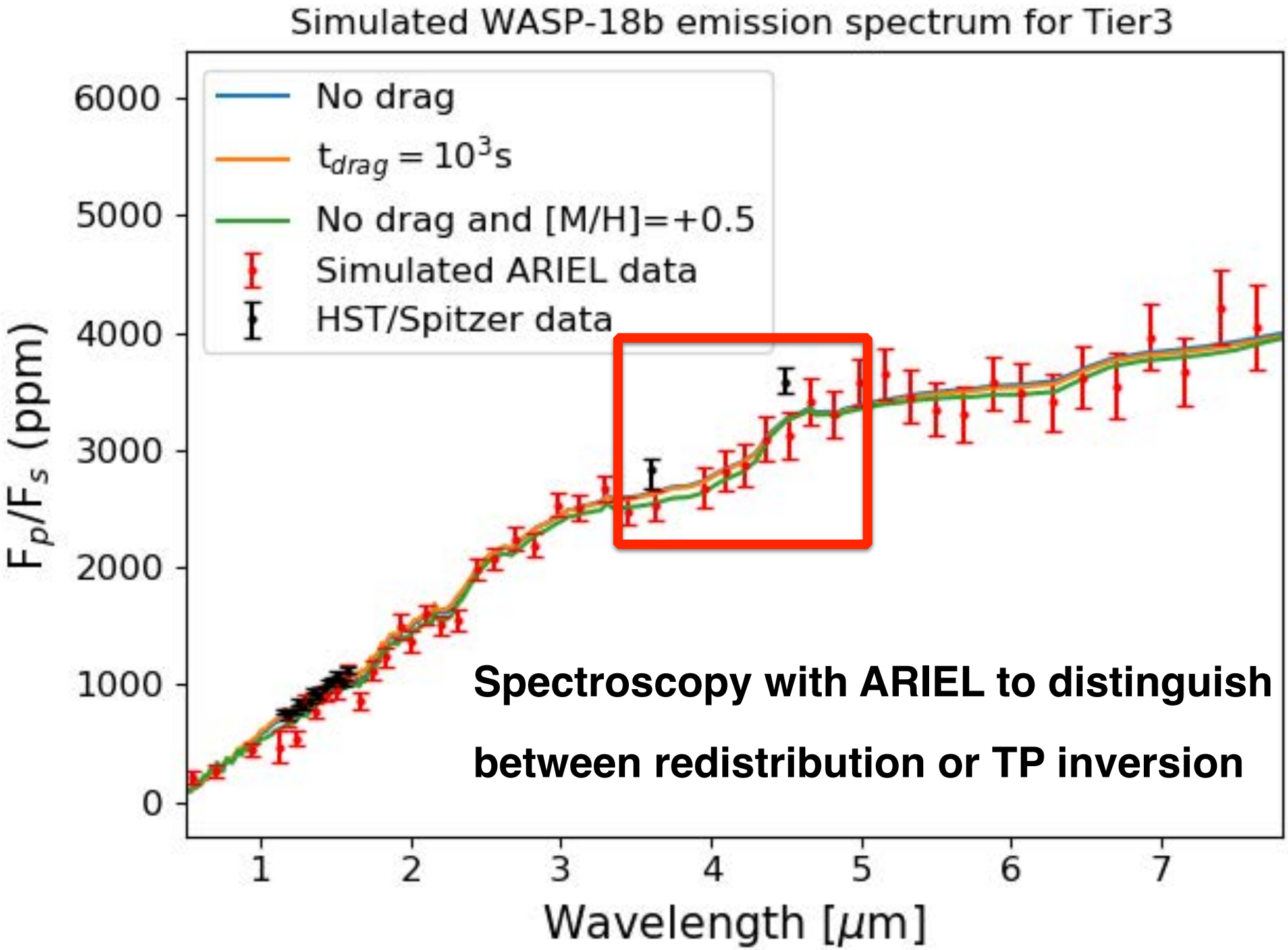
Arcangeli, Désert et al. (2018)



A Transition Between Hot- and Ultra-Hot Jupiters

Baxter, Désert et al. (submitted)




Simulated WASP-18b emission spectrum for Tier3
No drag
$t_{drag} = 10^3$s
No drag and [M/H]=+0.5
Simulated ARIEL data
HST/Spitzer data
F_p/F_s (ppm)
Wavelength [μm]
Spectroscopy with ARIEL to distinguish between redistribution or TP inversion

Conclusion

- Planets are 3D, particularly true when tidally locked
- Spectroscopic phase curves with HST:
  - main limitations due to HST's orbit
  - mostly limited to planet with period less than a day, beyond that the analysis and interpretation can be challenging
- ARIEL: precision to test GCM models (e.g., winds, drag, metallicity)
- ARIEL should mitigate these issues: continuous light curves at multiple wavelengths
- We find a trend towards UHJs (hotter at 4.5um)- this could be due to thermal inversion or poor redistribution => ARIEL