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NASA

National Science Foundation

the David & Lucile Packard Foundation

image:
J. W. Thompson

Hubble **WFC3** Observations of the Super-Earth **GJ1214b's** Atmosphere

late M dwarf

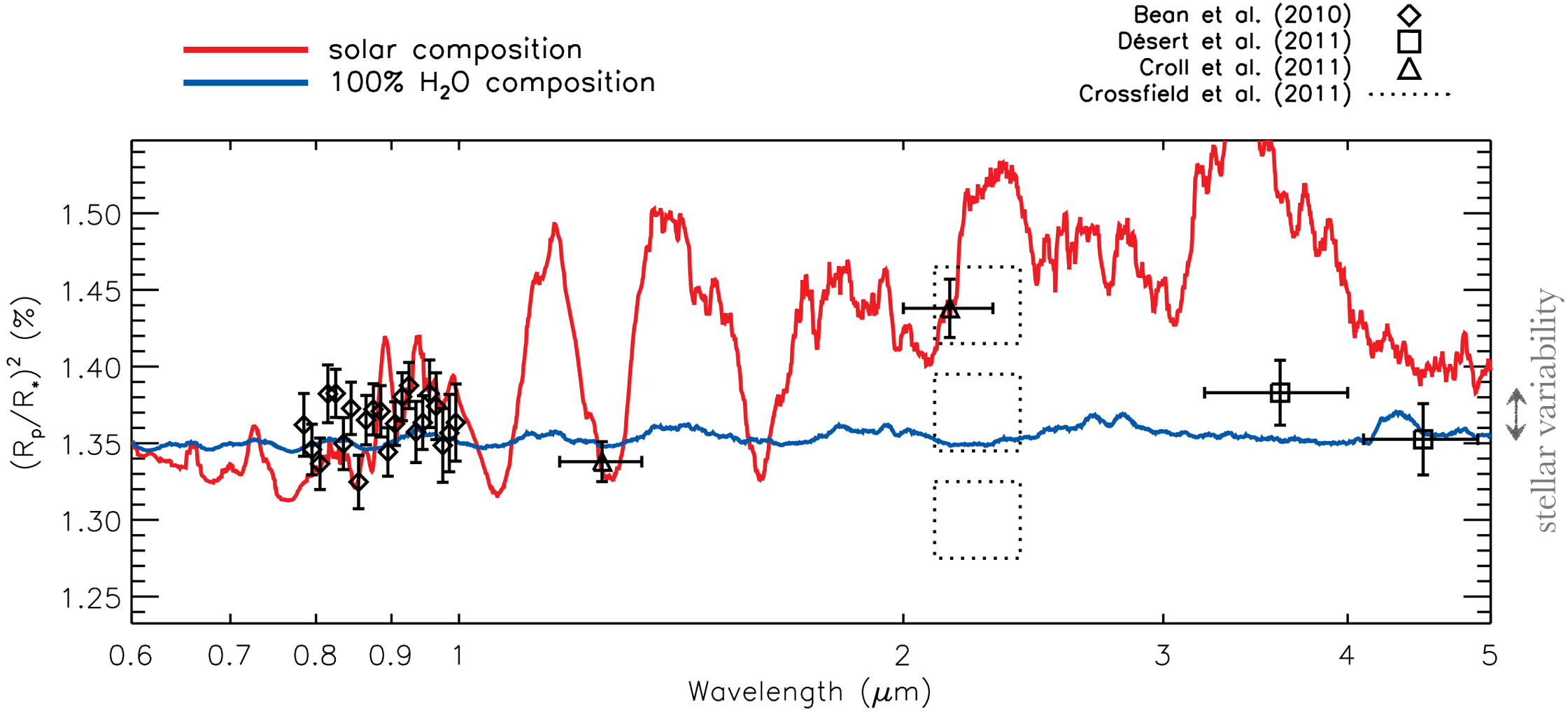
GJ1214b

2.7 $R_\oplus$

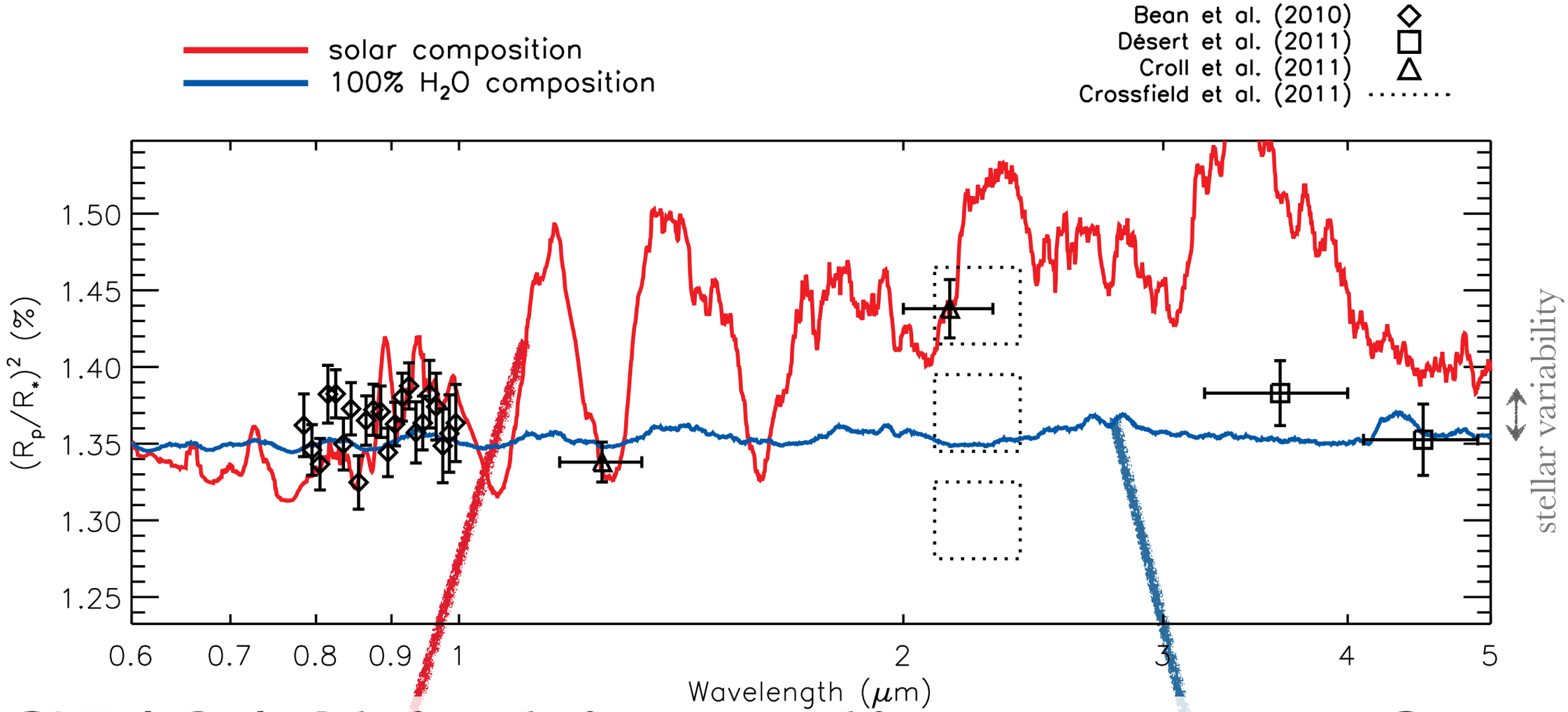
6.5 $M_\oplus$

image:
J. W. Thompson

observations of GJ1214b's **transmission spectrum**



models from
Miller-Ricci (Kempton) & Fortney (2010)



GJ1214b's big radius comes from

dense core with puffy envelope

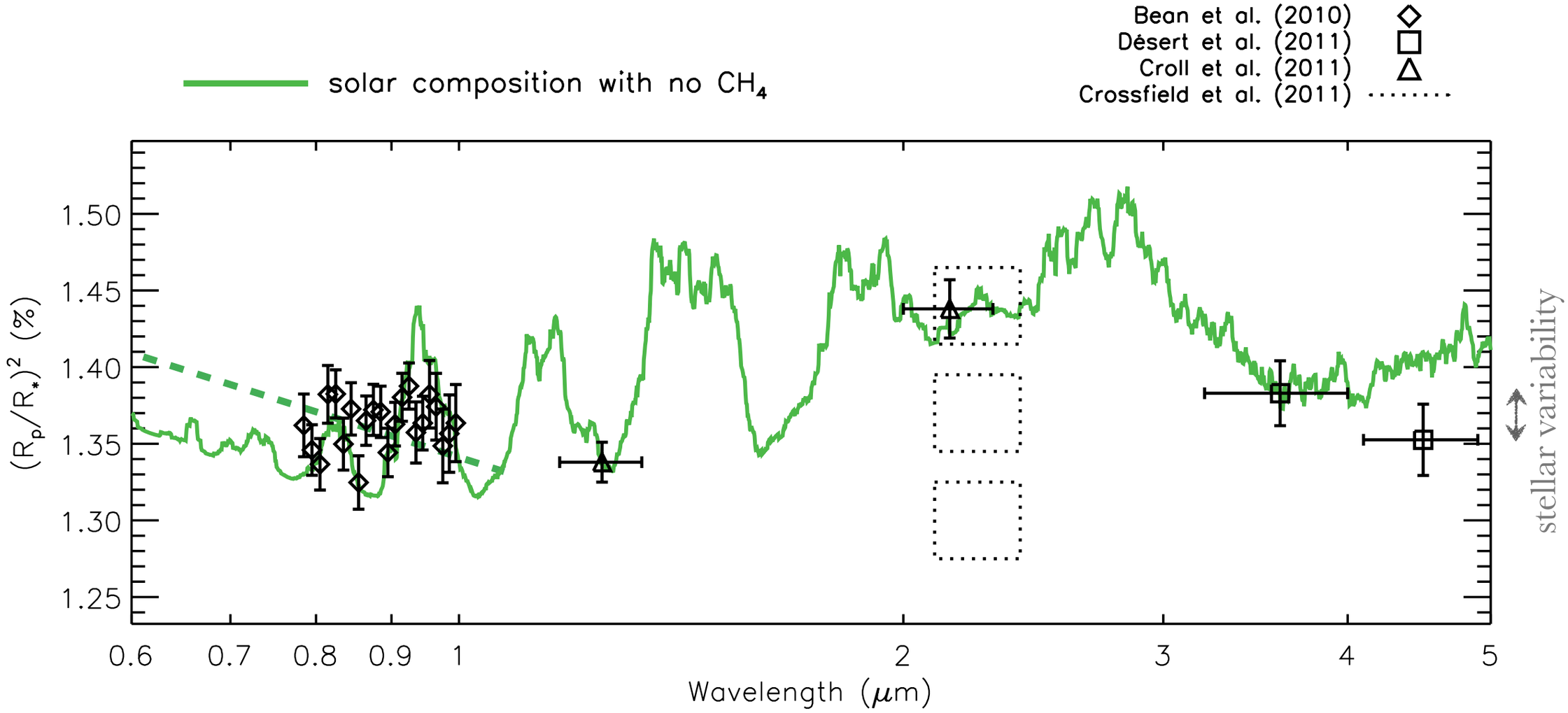
(primordial H/He? outgassed H_2?)

low density core

(water-world?)

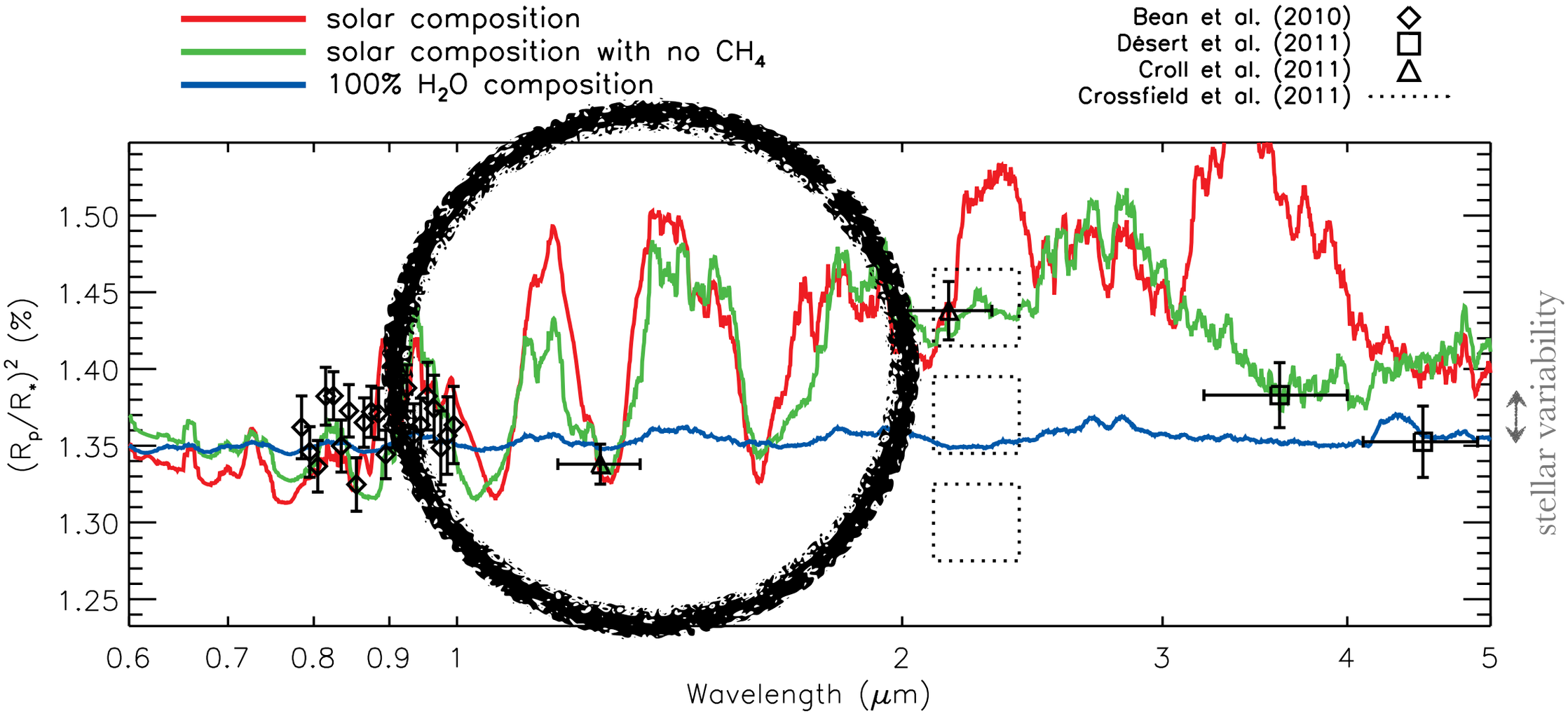
see Adams et al. (2008), Rogers & Seager (2010), Nettelmann et al. (2011)

observations of GJ1214b's **transmission spectrum**

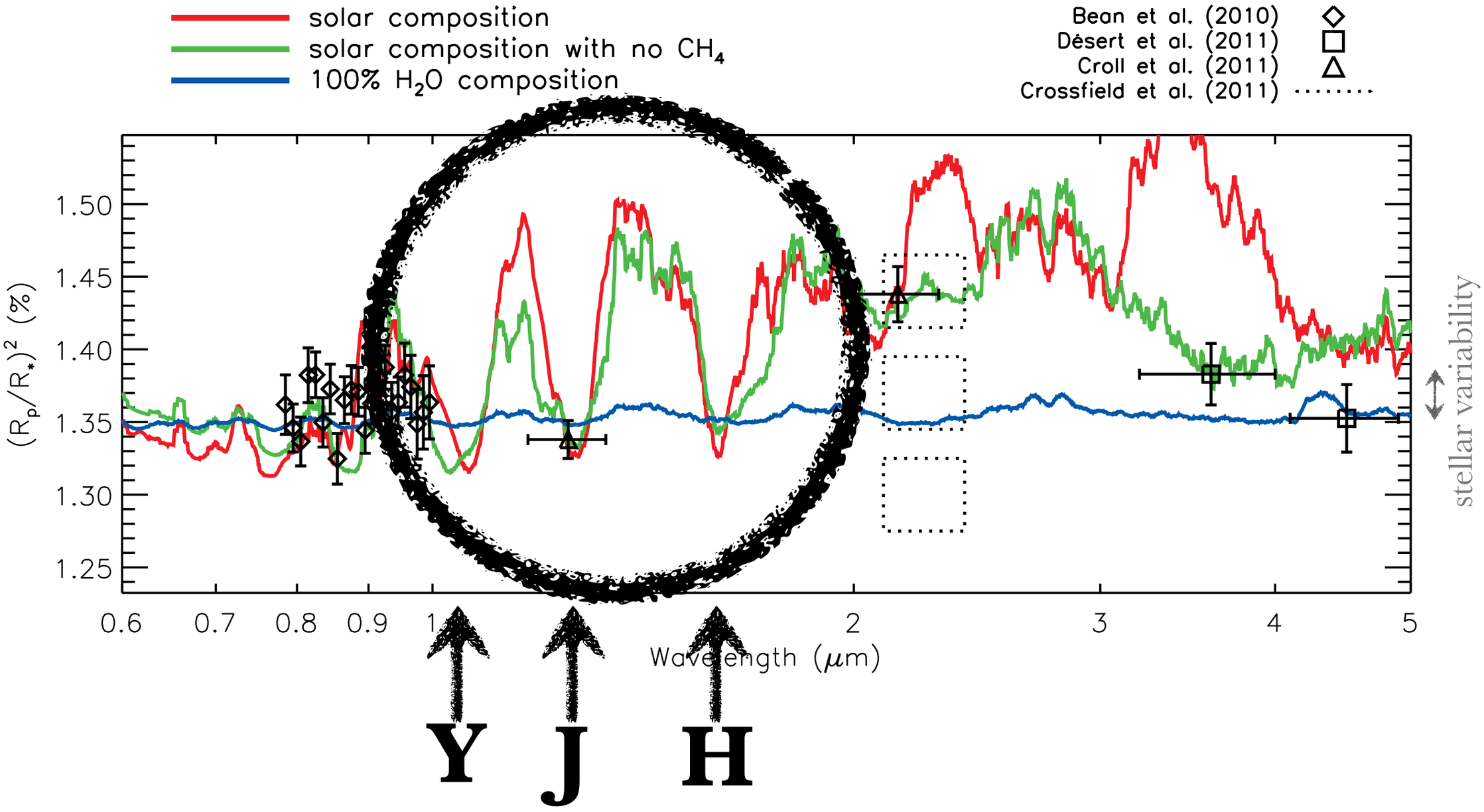


see Kempton, Zahnle, & Fortney (2011), Crossfield et al. (2011)

observations of GJ1214b's **transmission spectrum**

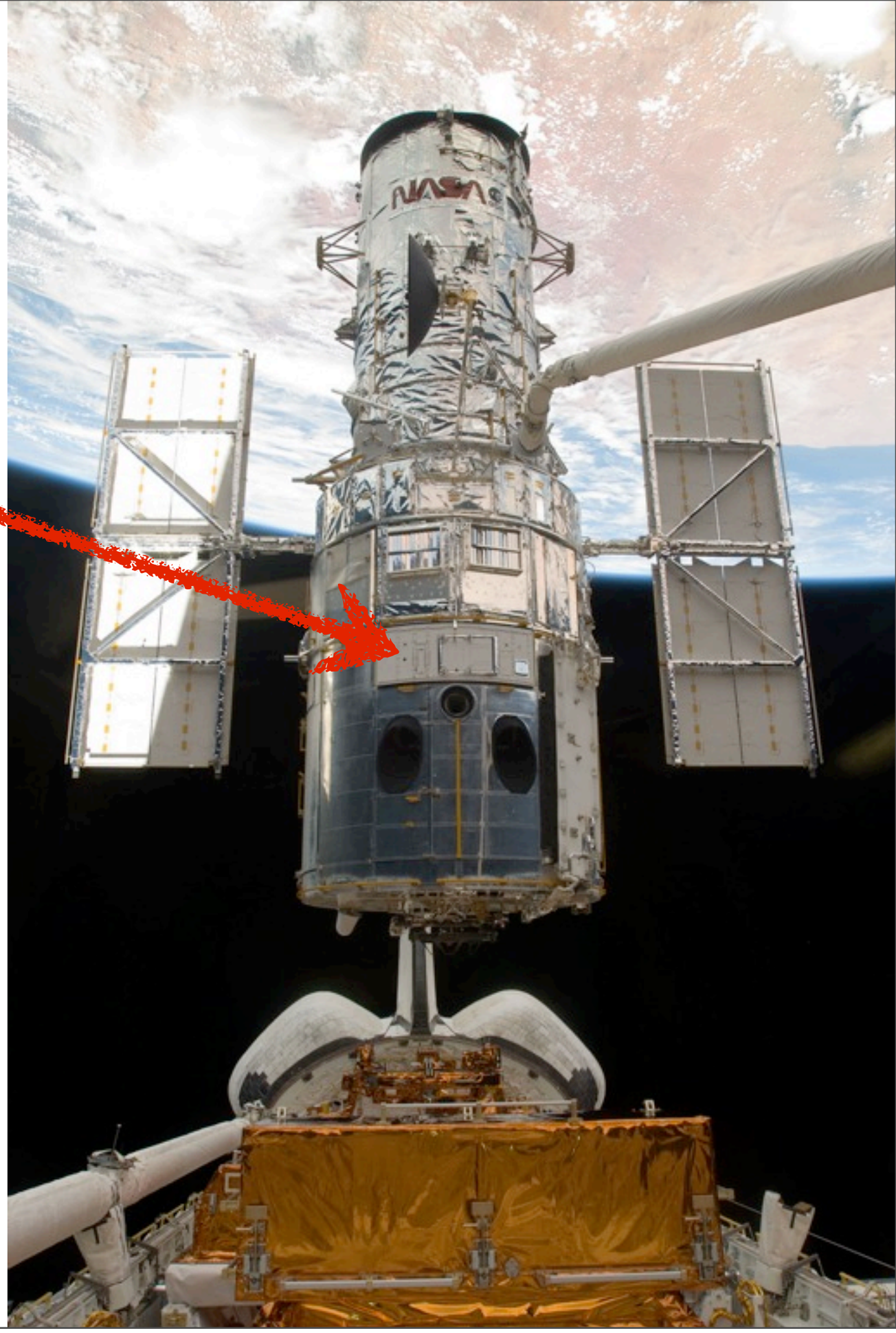


observations of GJ1214b's **transmission spectrum**

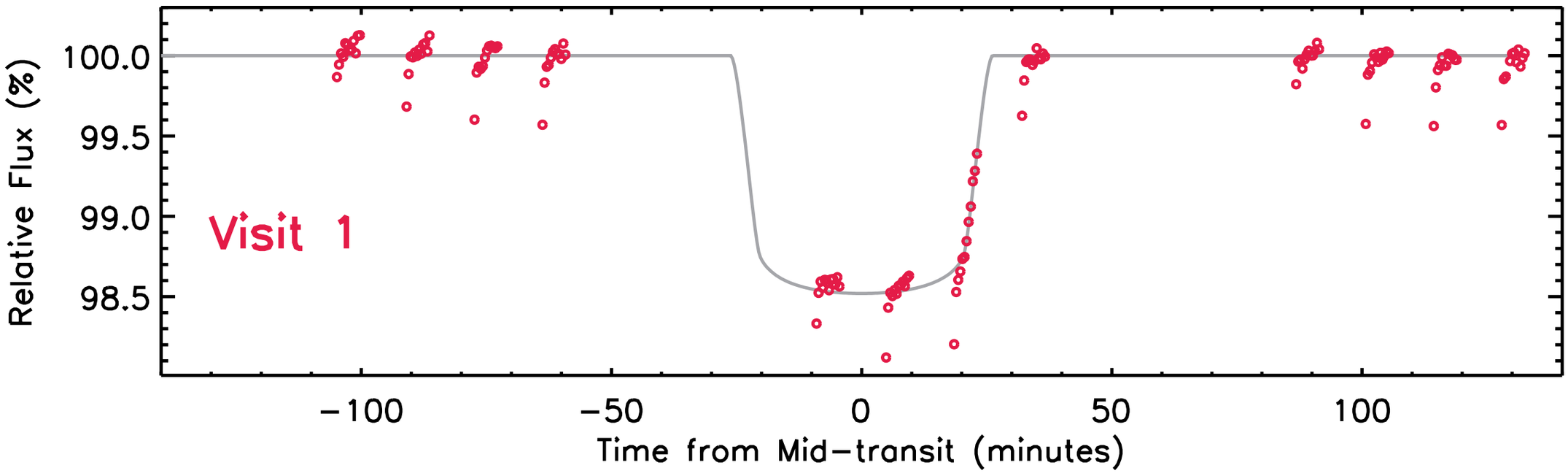


Hubble
Wide Field
Camera 3
(WFC3)

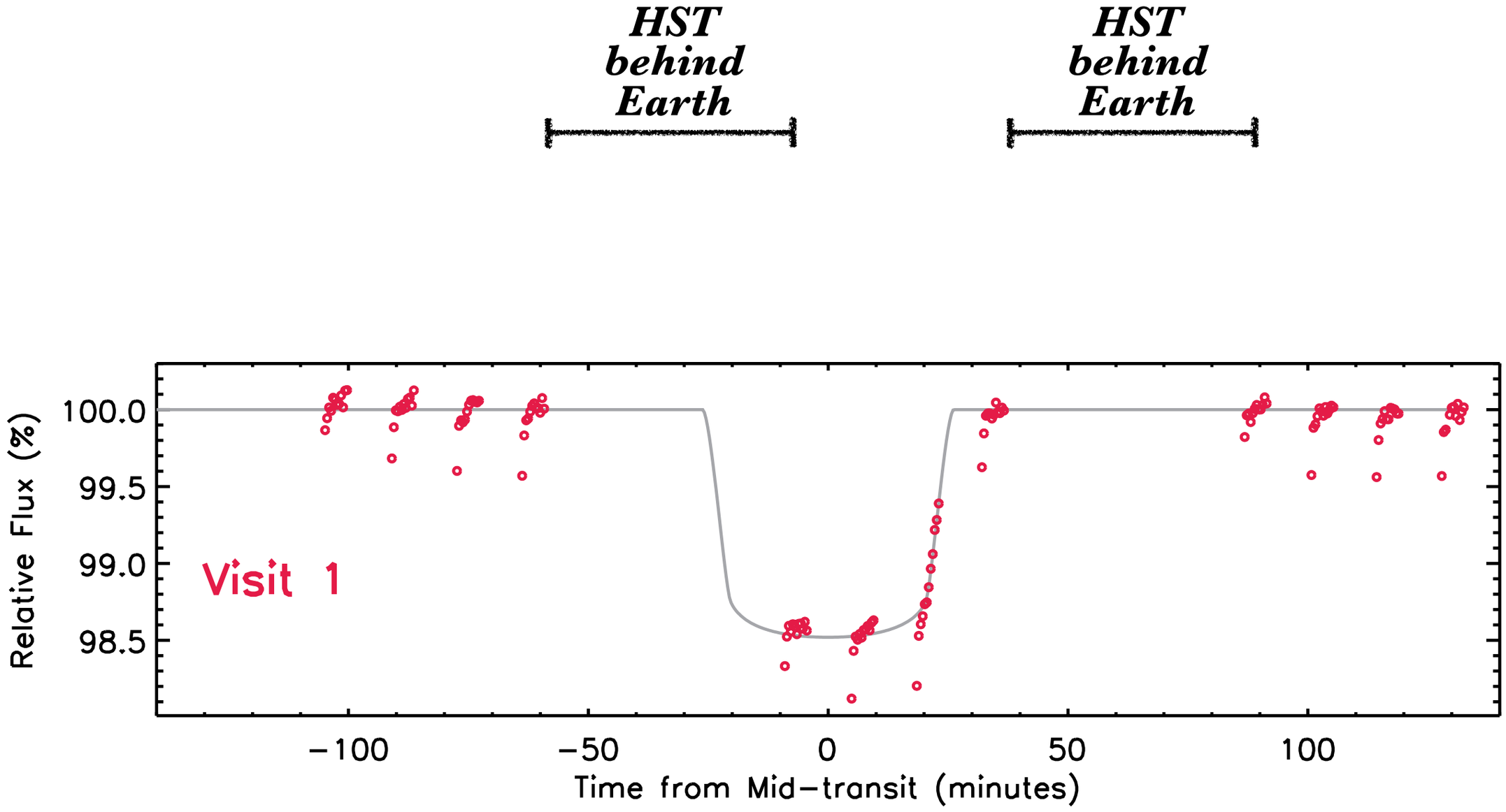
three transits
of
GJ1214b
with
1.1-1.7μm
grism spectroscopy
(WFC3/IR G141;
P.I. = Z. Berta)



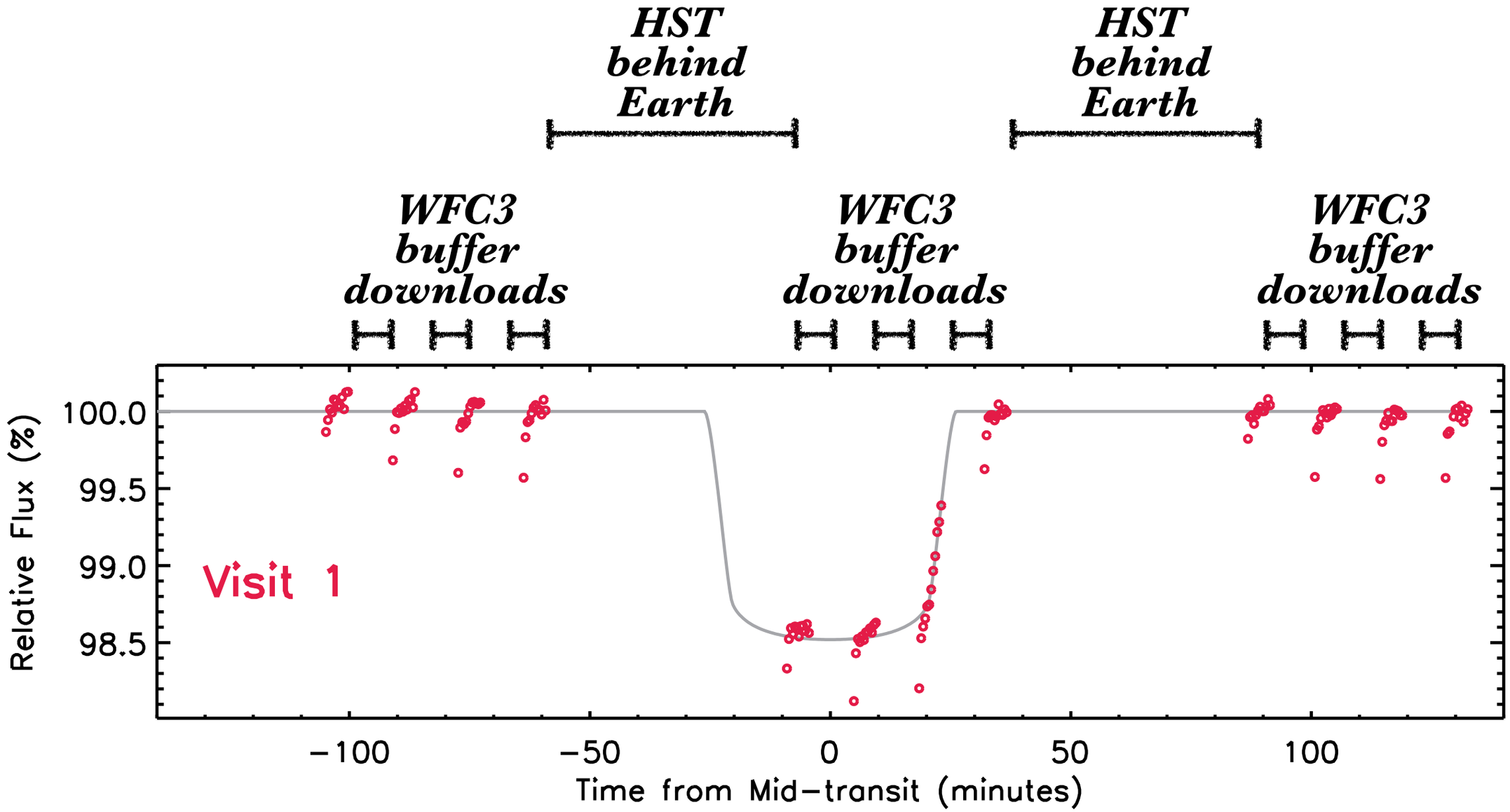
WFC3
GJ1214b
white light



WFC3
GJ1214b
white light



WFC3
GJ1214b
white light



WFC3
GJ1214b
white light

“ramp”
could be caused by
charge-trapping
(i.e. persistence)

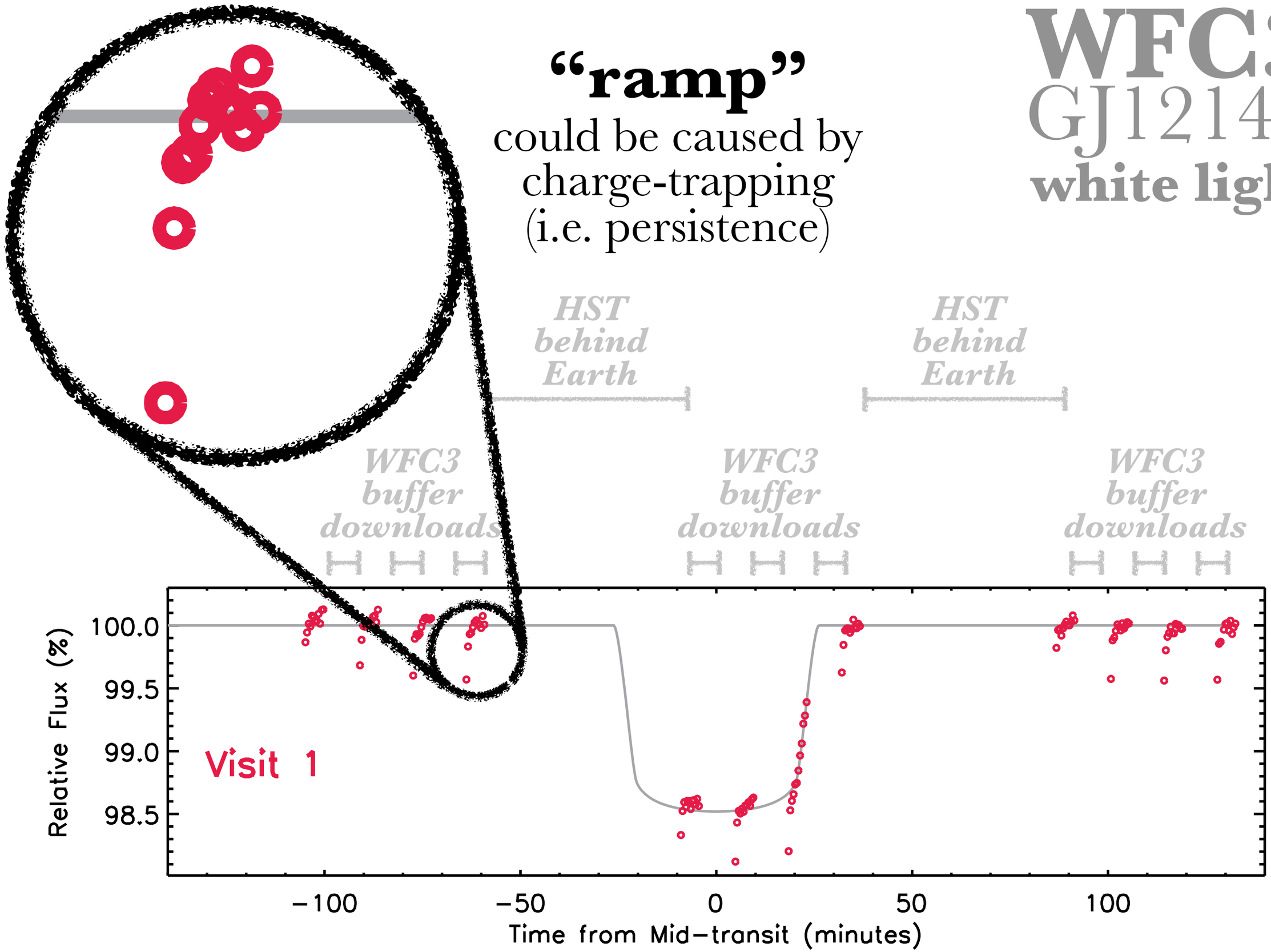
HST behind Earth

HST behind Earth

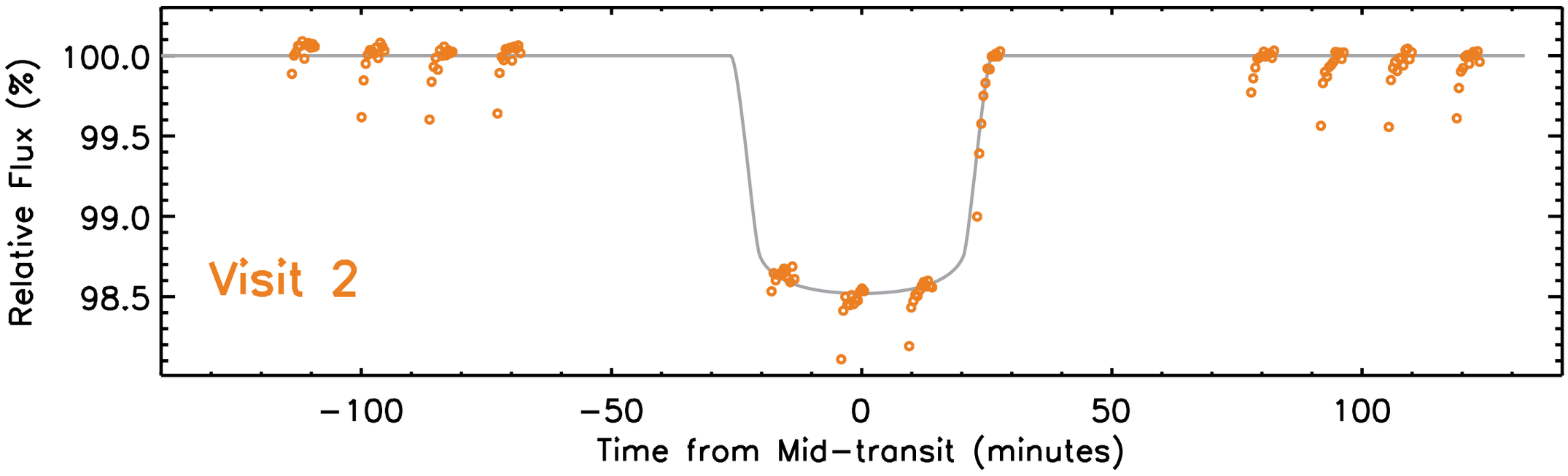
WFC3 buffer downloads

WFC3 buffer downloads

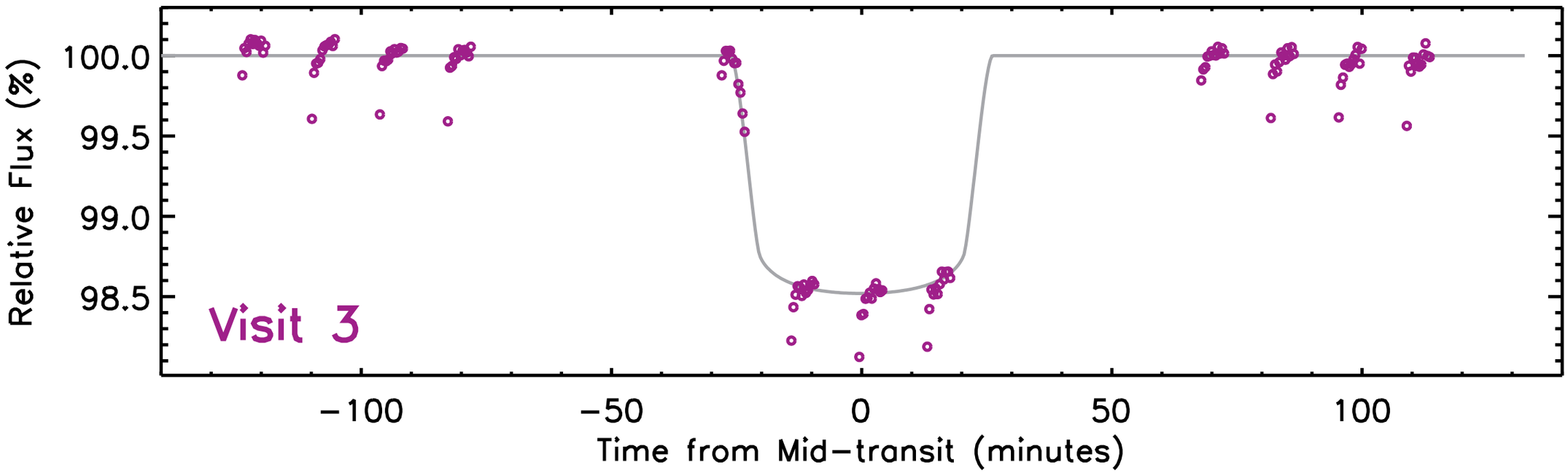
WFC3 buffer downloads



WFC3
GJ1214b
white light

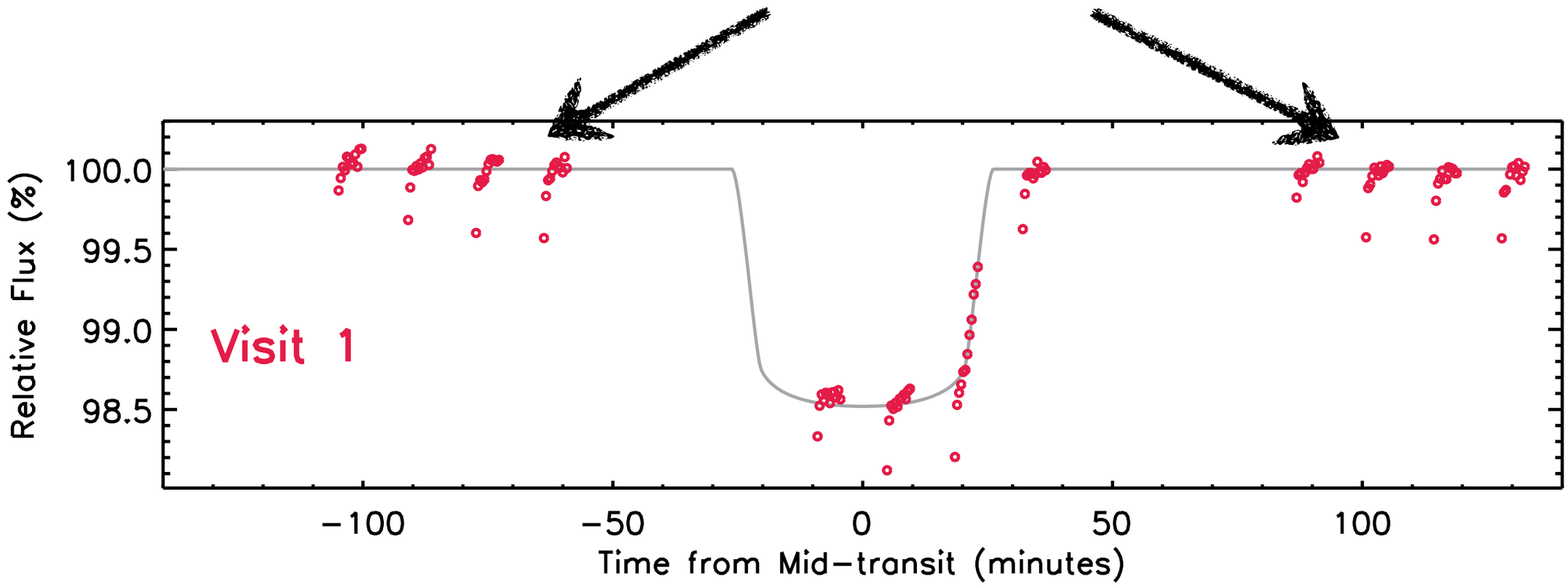


WFC3
GJ1214b
white light



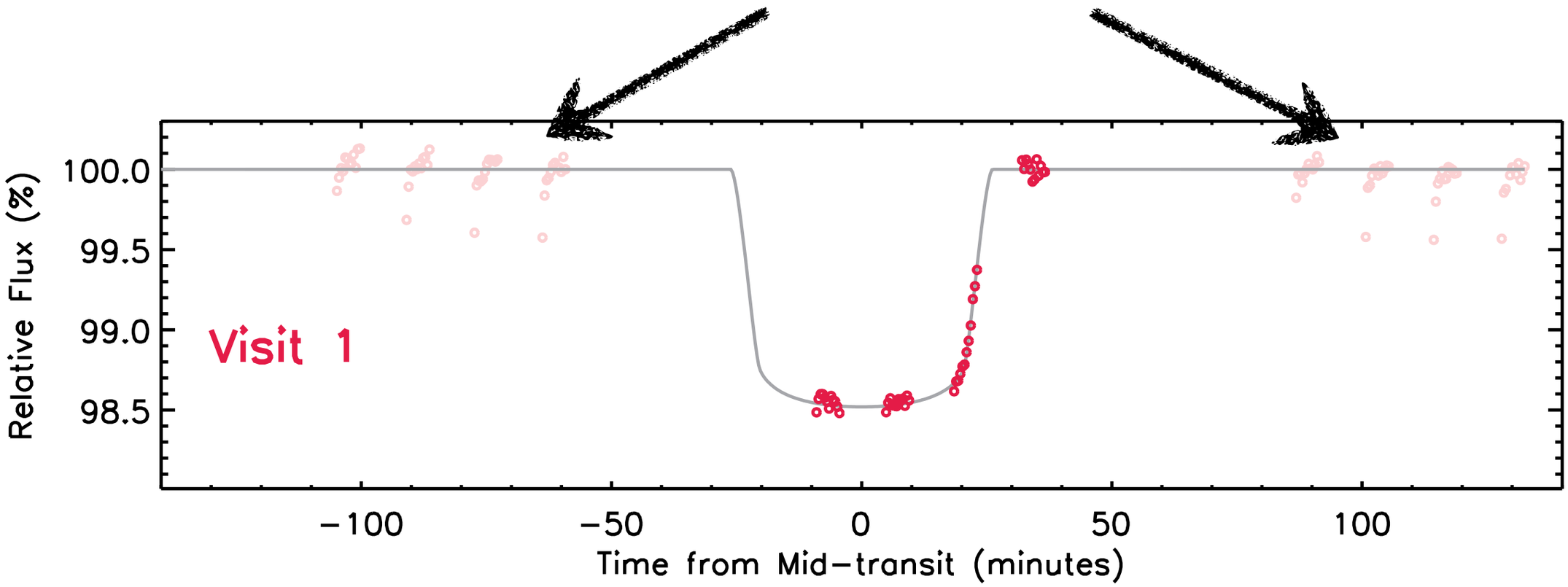
WFC3
GJ1214b
white light

a simple correction:
divide in-transit orbit
by out-of-transit orbits

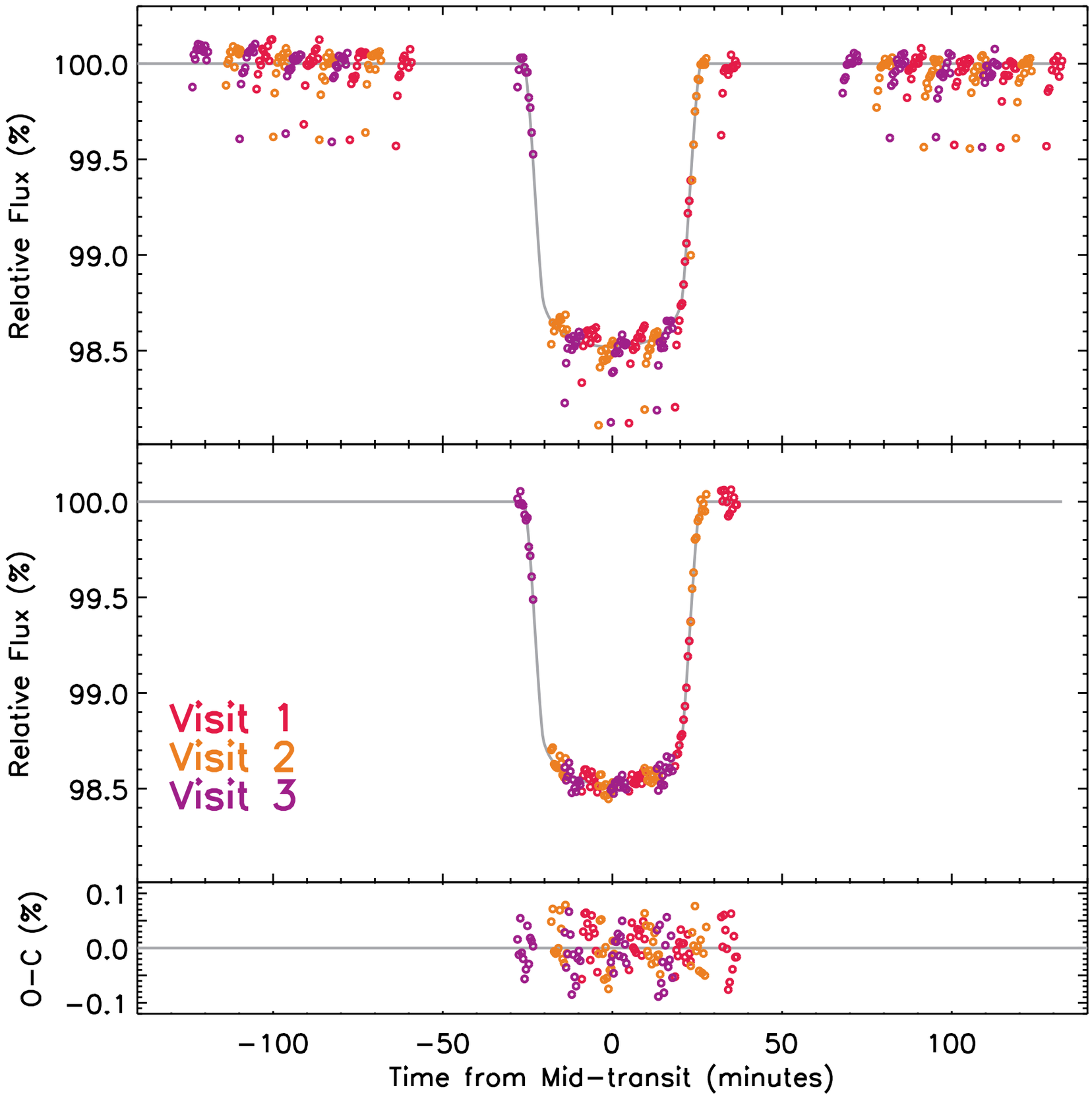


WFC3
GJ1214b
white light

a simple correction:
divide in-transit orbit
by out-of-transit orbits



WFC3
GJ1214b
white light



predicted RMS

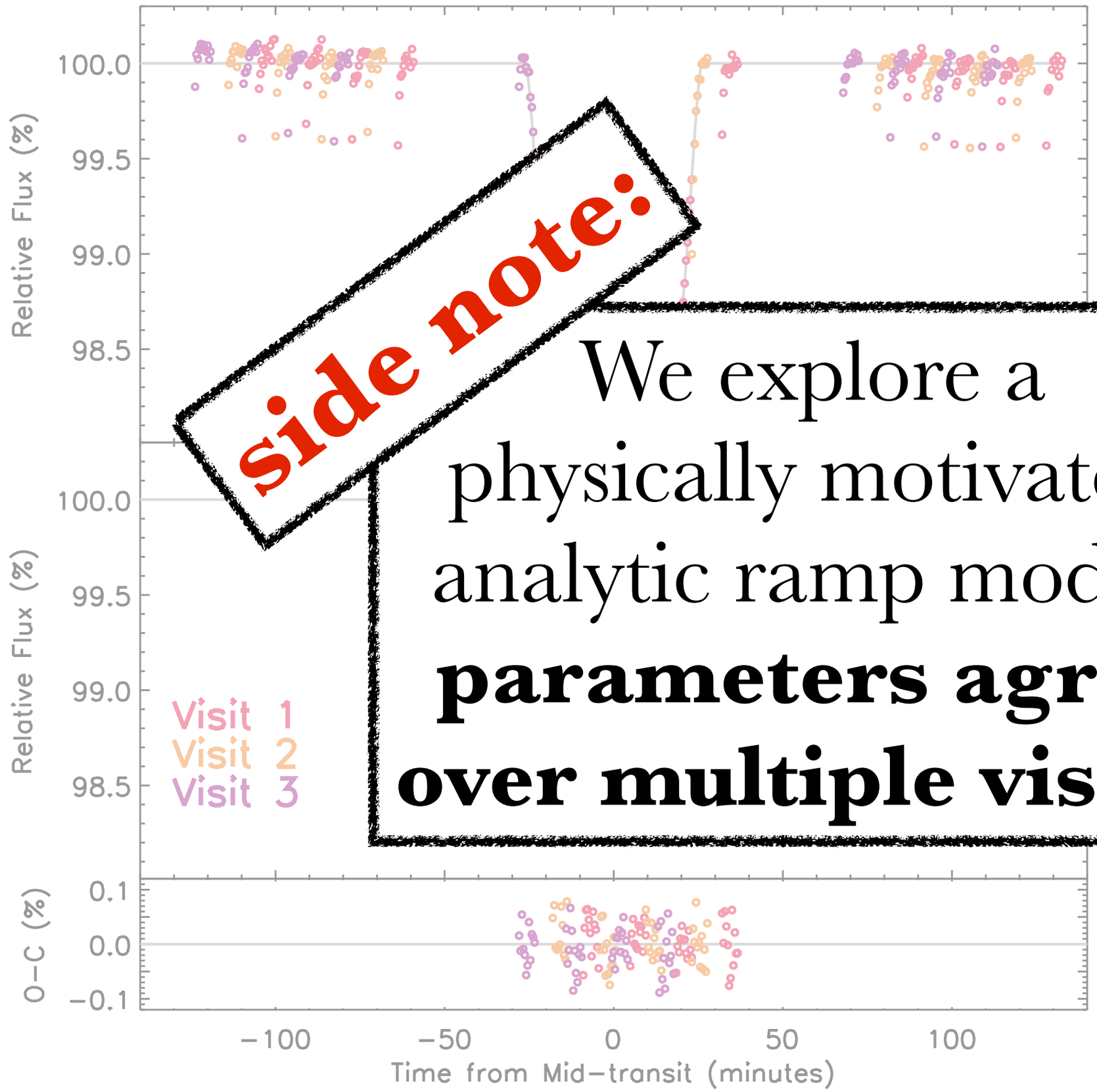
= 385 ppm

= $(3/2)^{1/2}$ x photon noise

measured RMS

= 373 ppm

WFC3
GJ1214b
white light



side note:

We explore a physically motivated analytic ramp model; **parameters agree over multiple visits.**

licted RMS

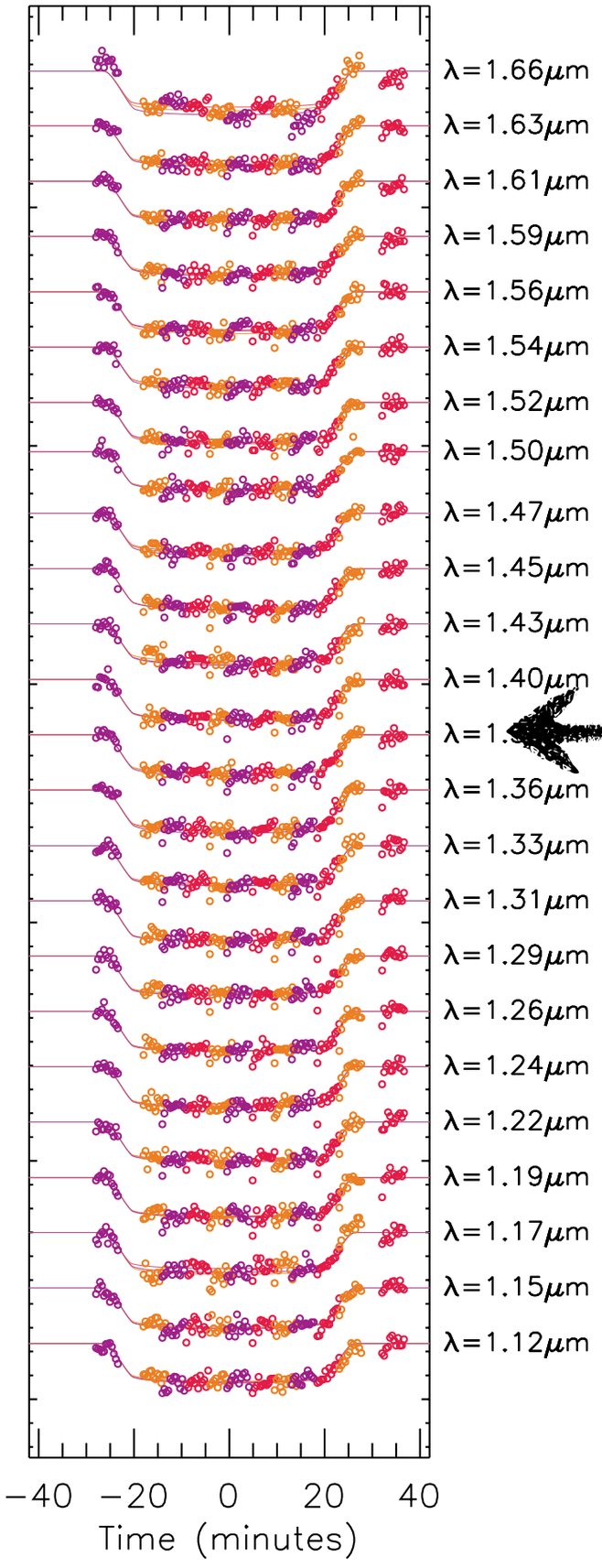
385 ppm

$^{1/2}$ x photon noise

measured RMS

= 373 ppm

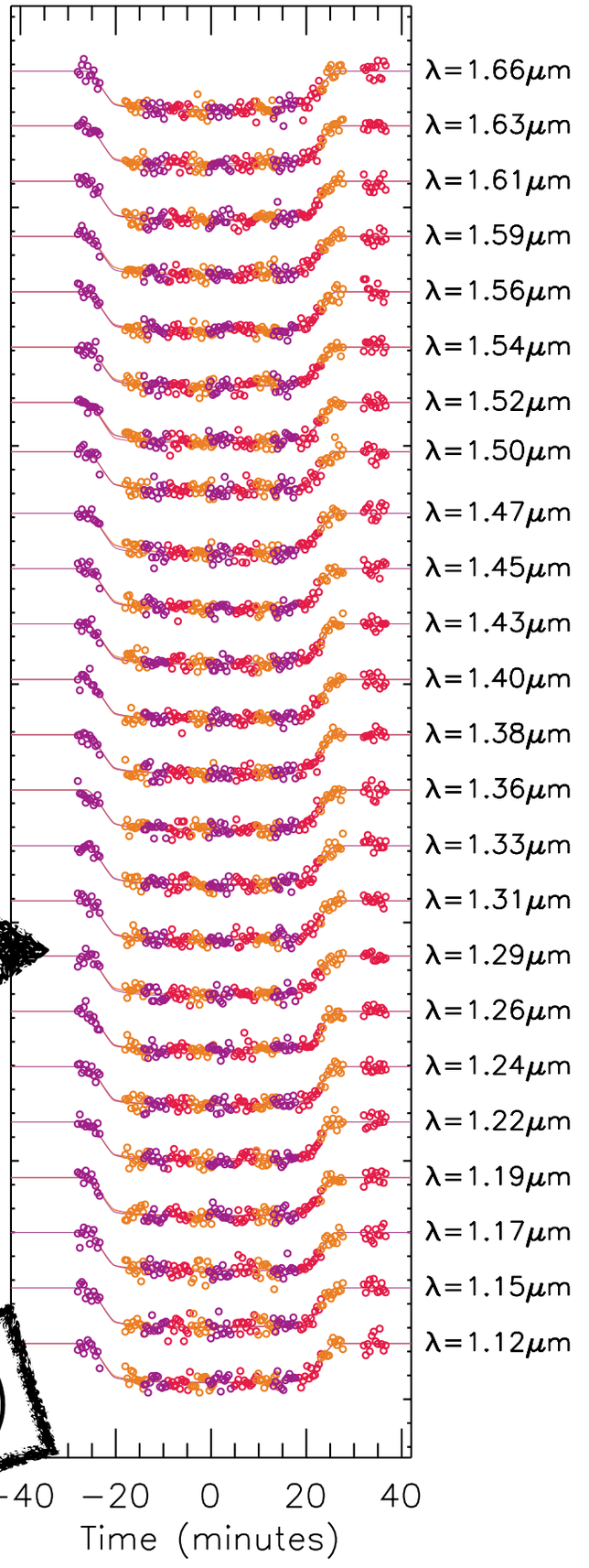
WFC3
GJ1214b
spectroscopic light curves



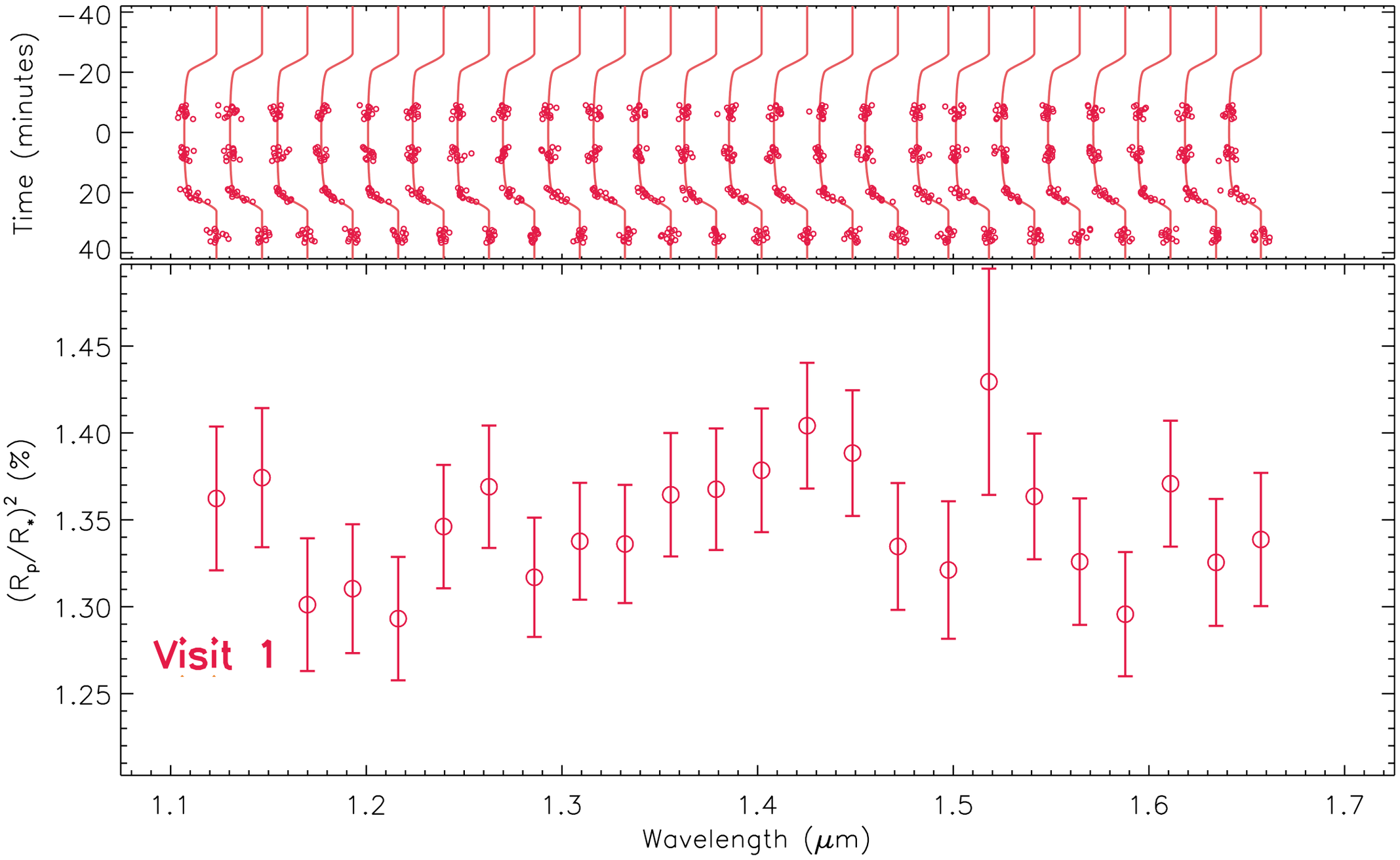
before

after dividing by the out-of-transit orbits

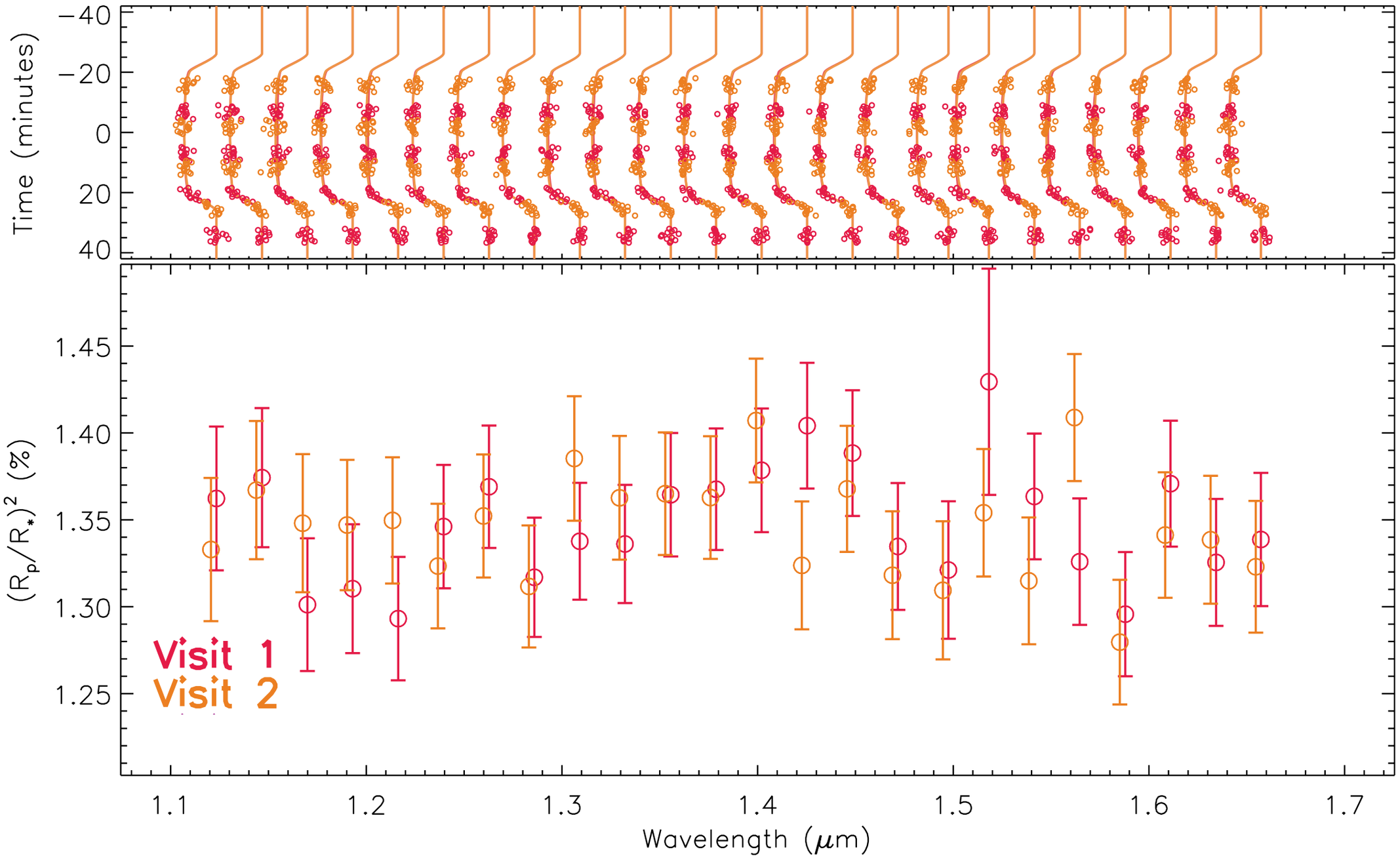
(photon-limited!)



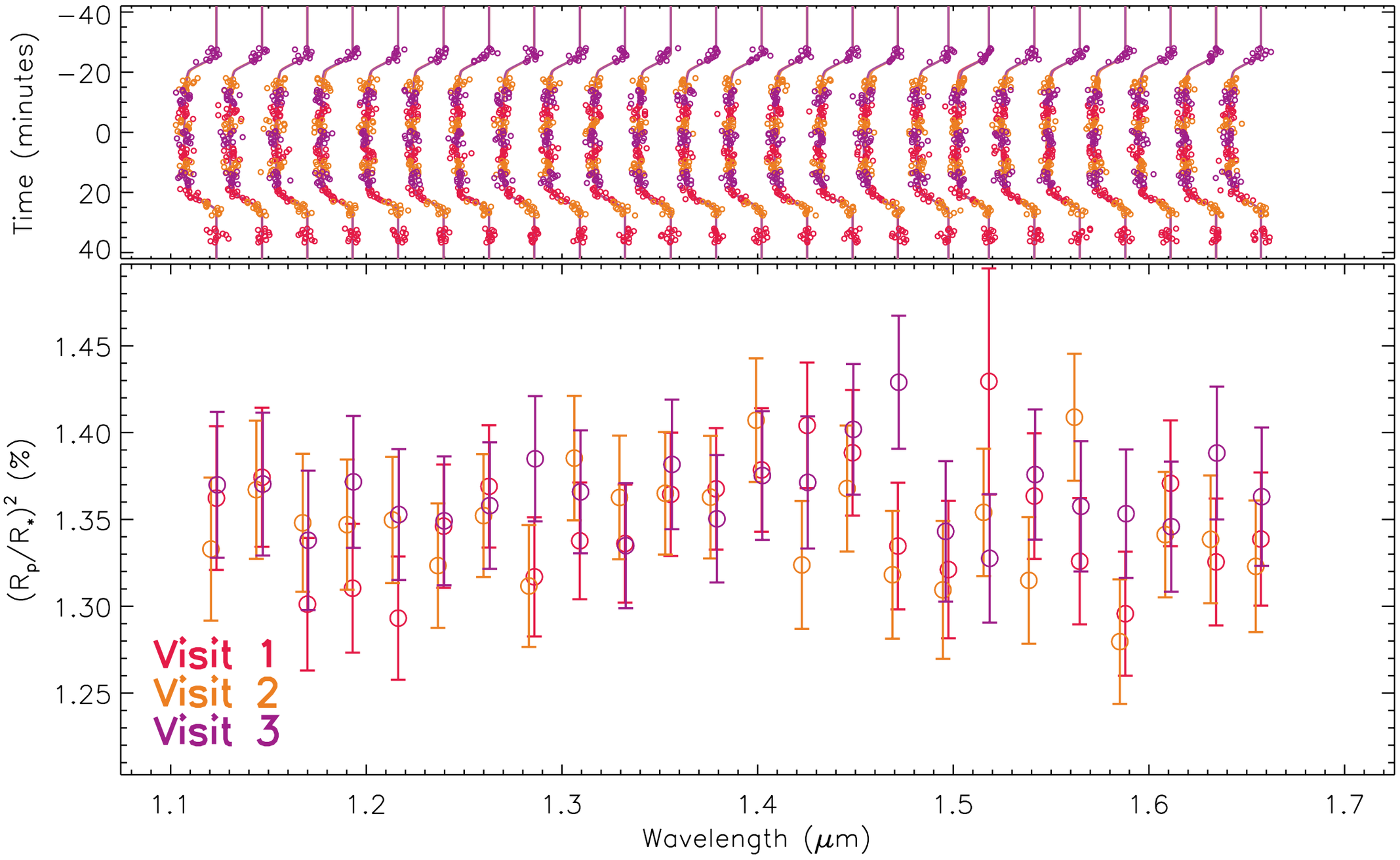
measuring GJ1214b's WFC3 **transmission spectrum**



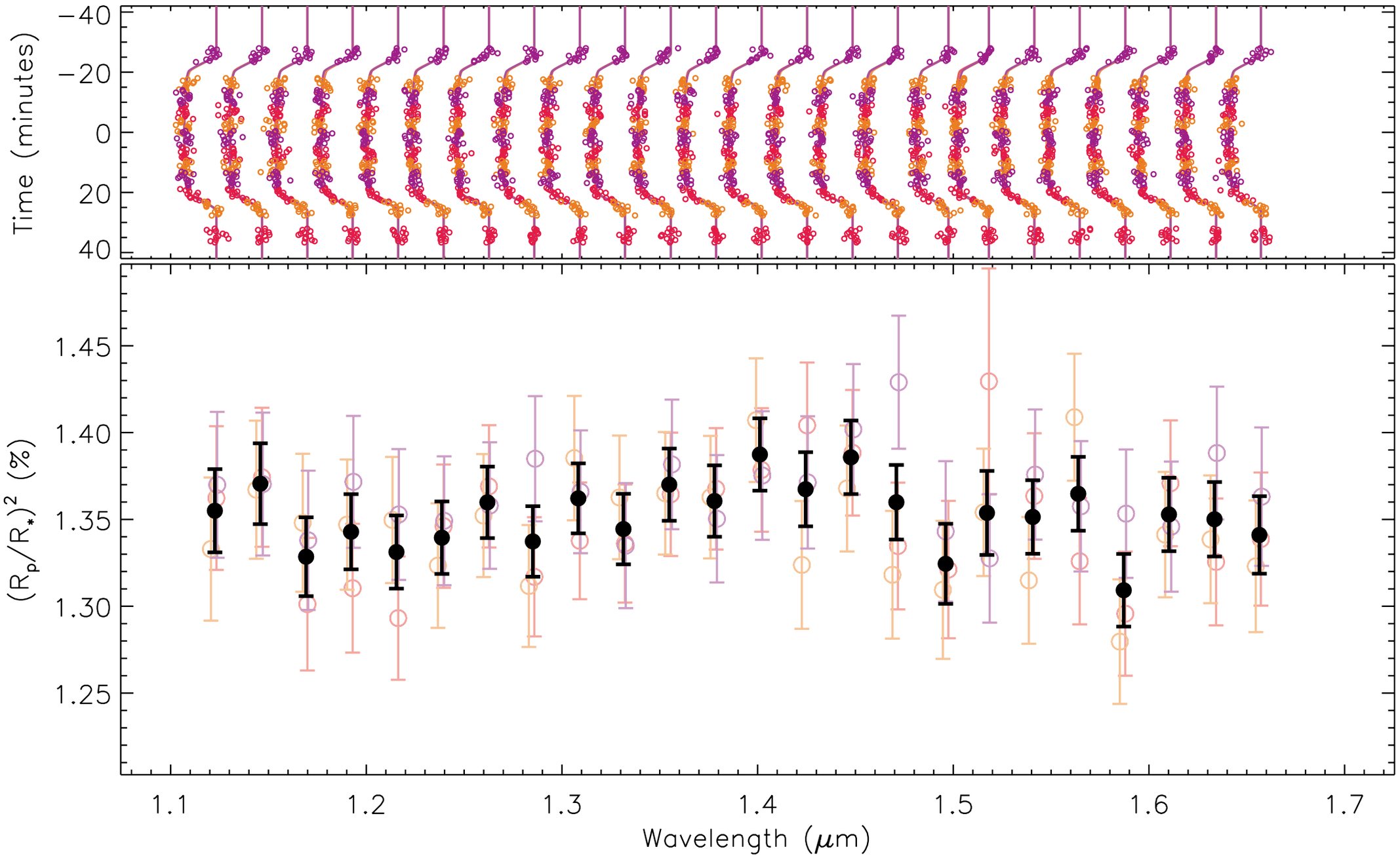
measuring GJ1214b's WFC3 **transmission spectrum**



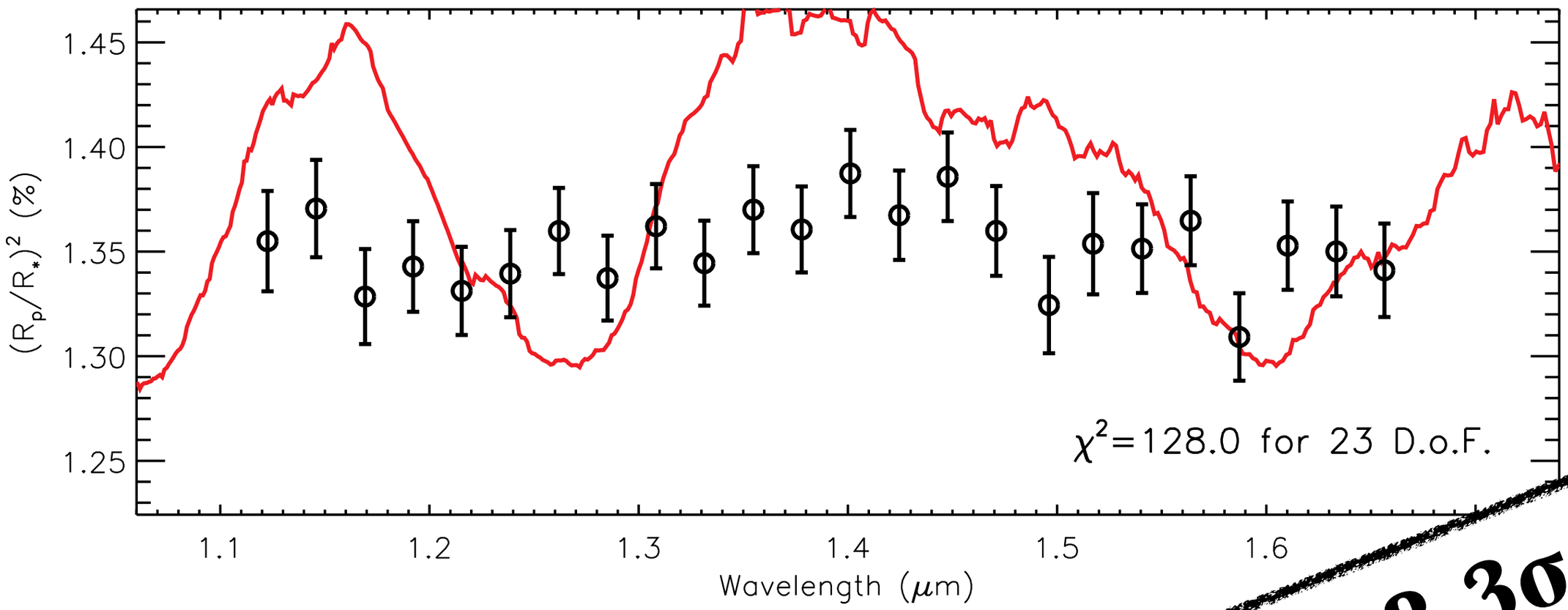
measuring GJ1214b's WFC3 **transmission spectrum**



measuring GJ1214b's WFC3 transmission spectrum



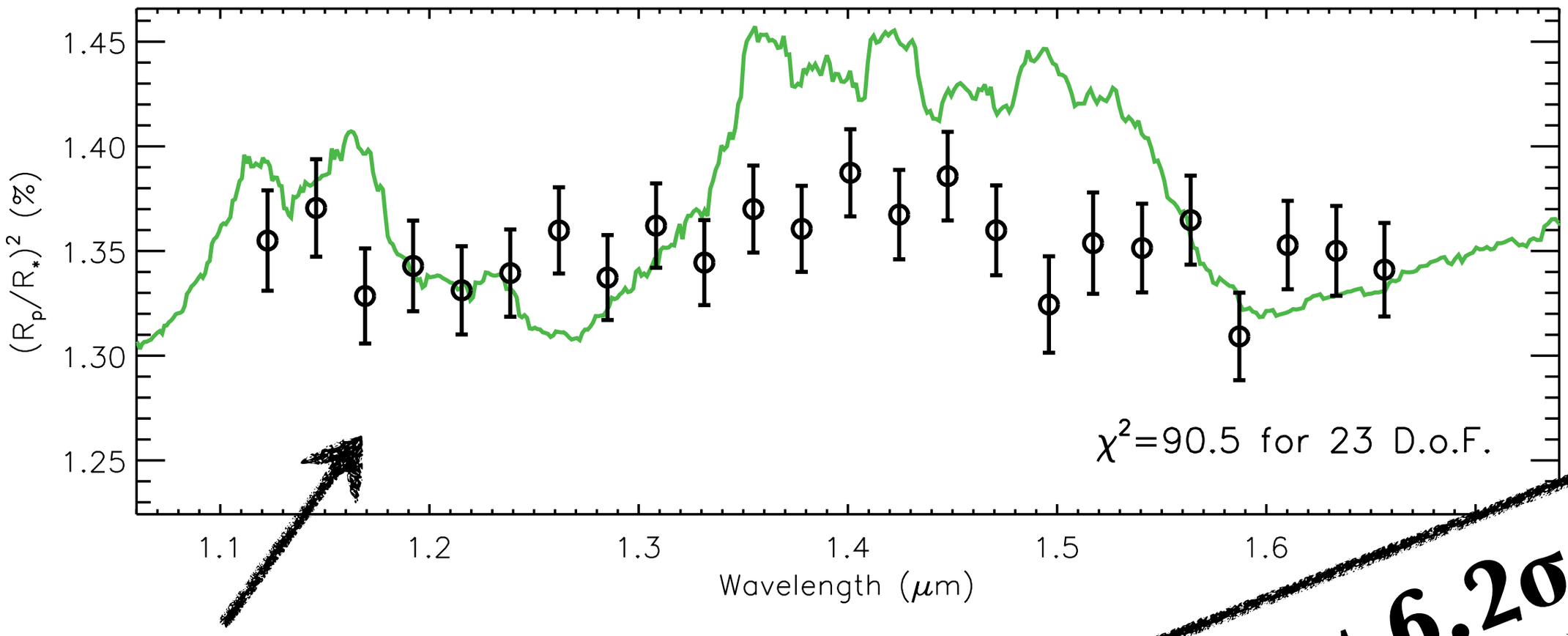
modeling GJ1214b's WFC3 **transmission spectrum**



ruled out at 8.3σ

models from Miller-Ricci (Kempton) & Fortney (2010)

modeling GJ1214b's WFC3 transmission spectrum

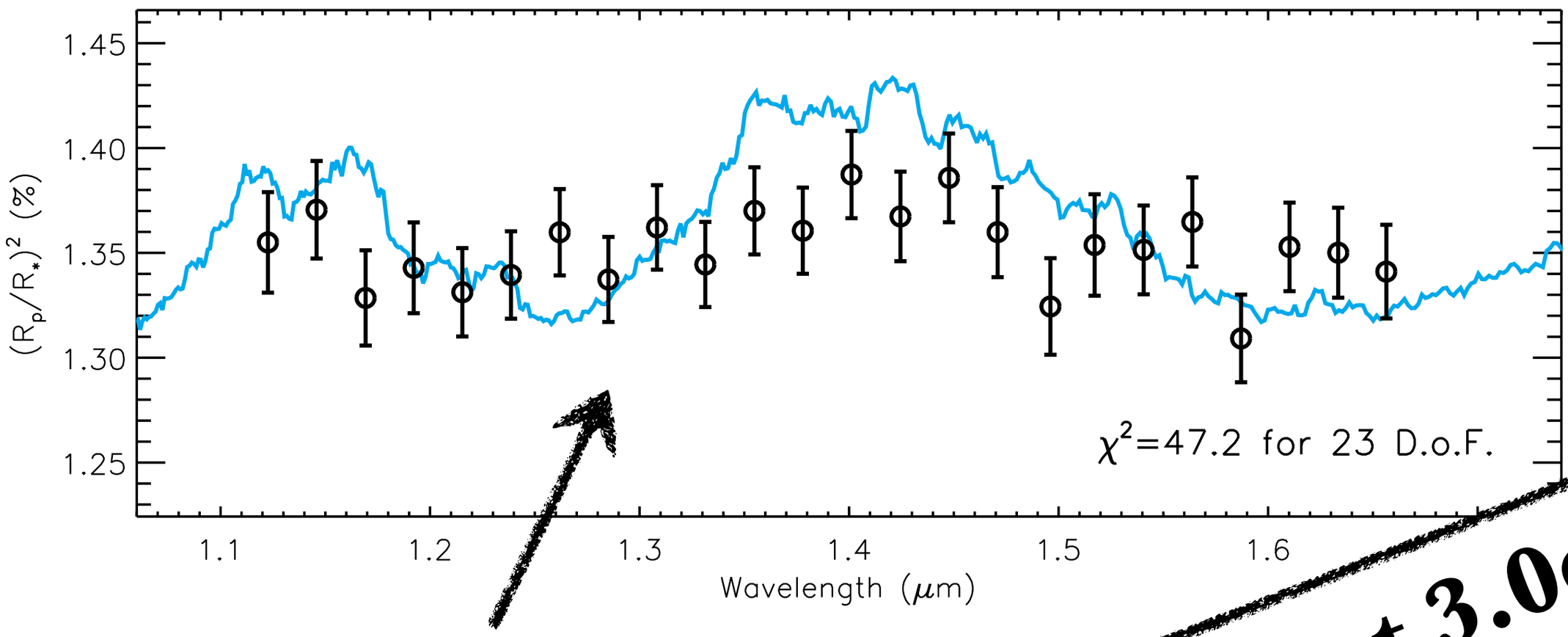


no-methane atmosphere is difficult to sustain, even with extreme photochemistry

ruled out at 6.2σ

see Kempton, Zahnle, & Fortney (2011)

modeling GJ1214b's WFC3 **transmission spectrum**

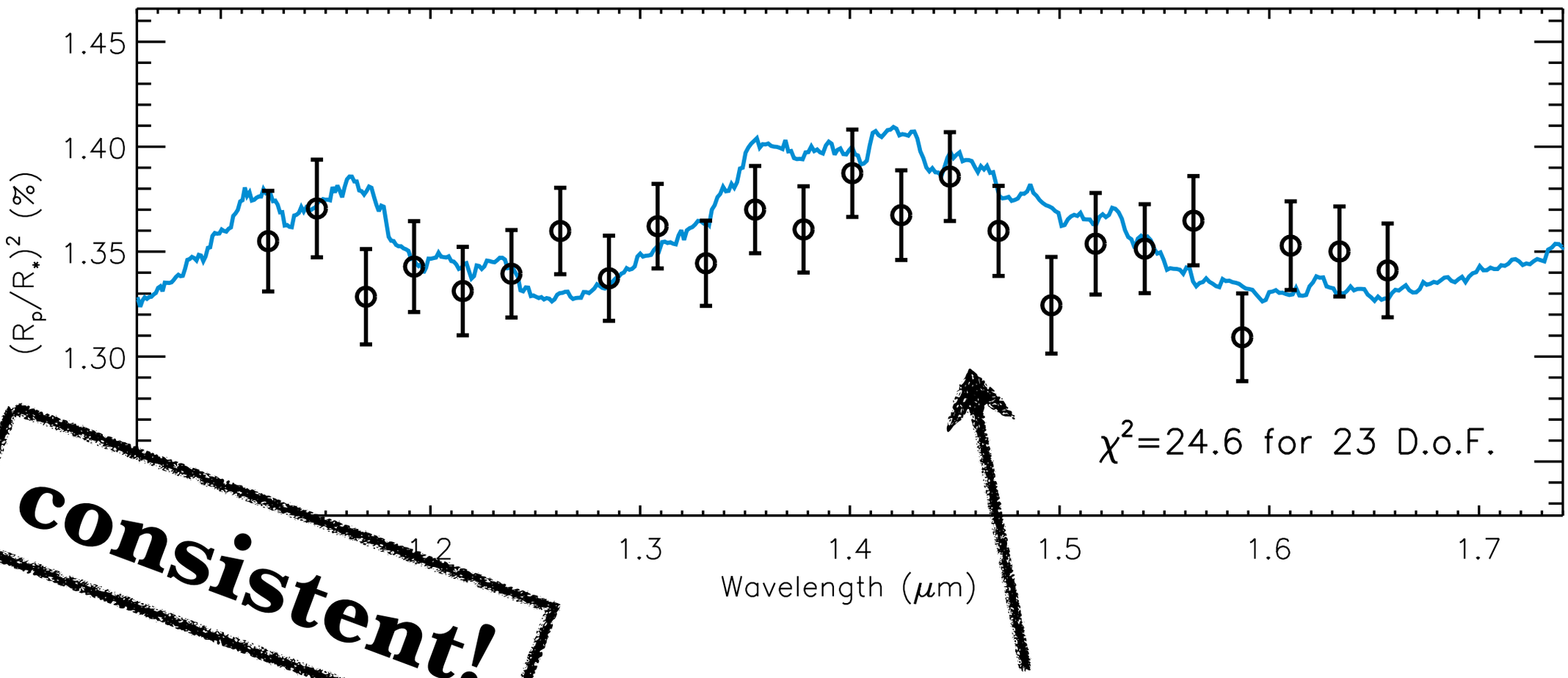


increasingly **water-rich** atmospheres have larger mean molecular weights

disfavored at 3.0σ

models from Miller-Ricci (Kempton) & Fortney (2010)

modeling GJ1214b's WFC3 transmission spectrum

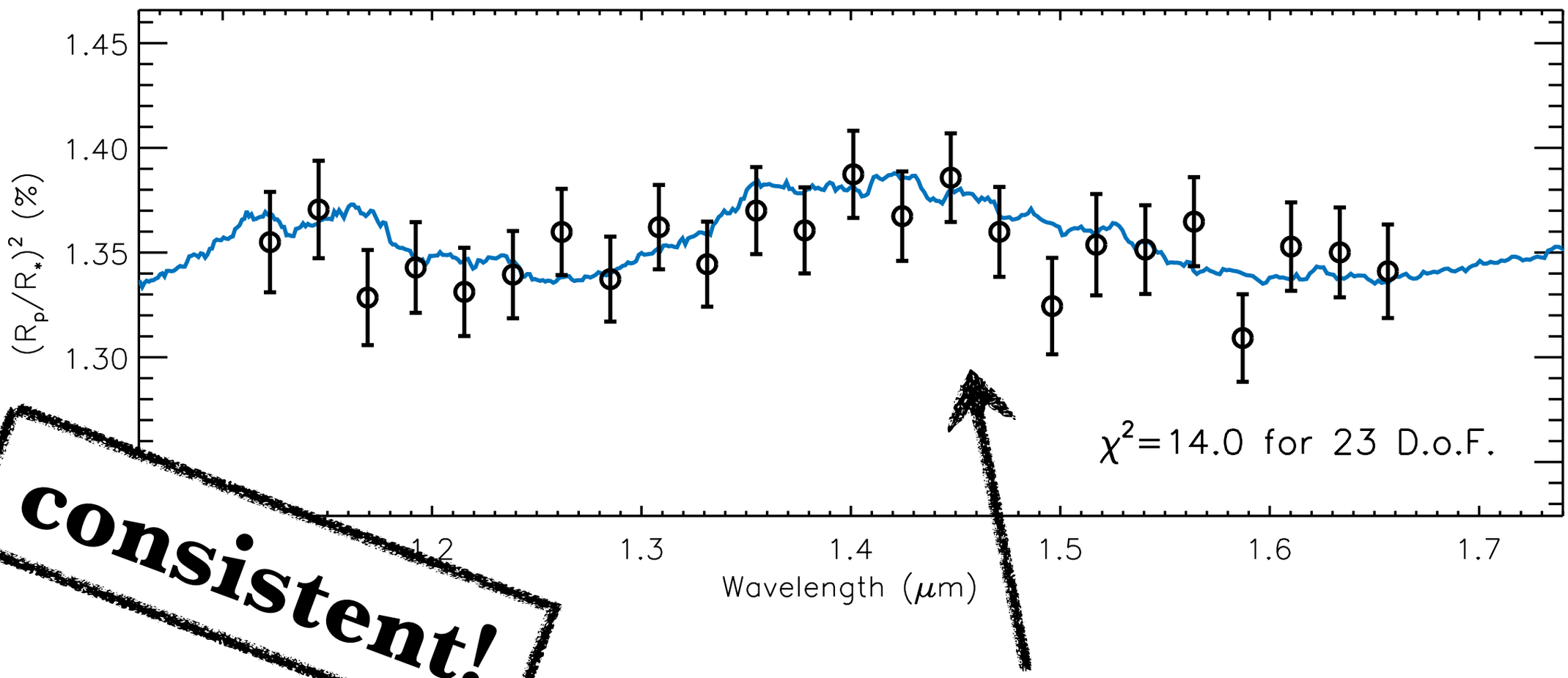


consistent!

water fractions above 20% (70% by mass) are good fits to the WFC3 spectrum

models from Miller-Ricci (Kempton) & Fortney (2010)

modeling GJ1214b's WFC3 **transmission spectrum**



consistent!

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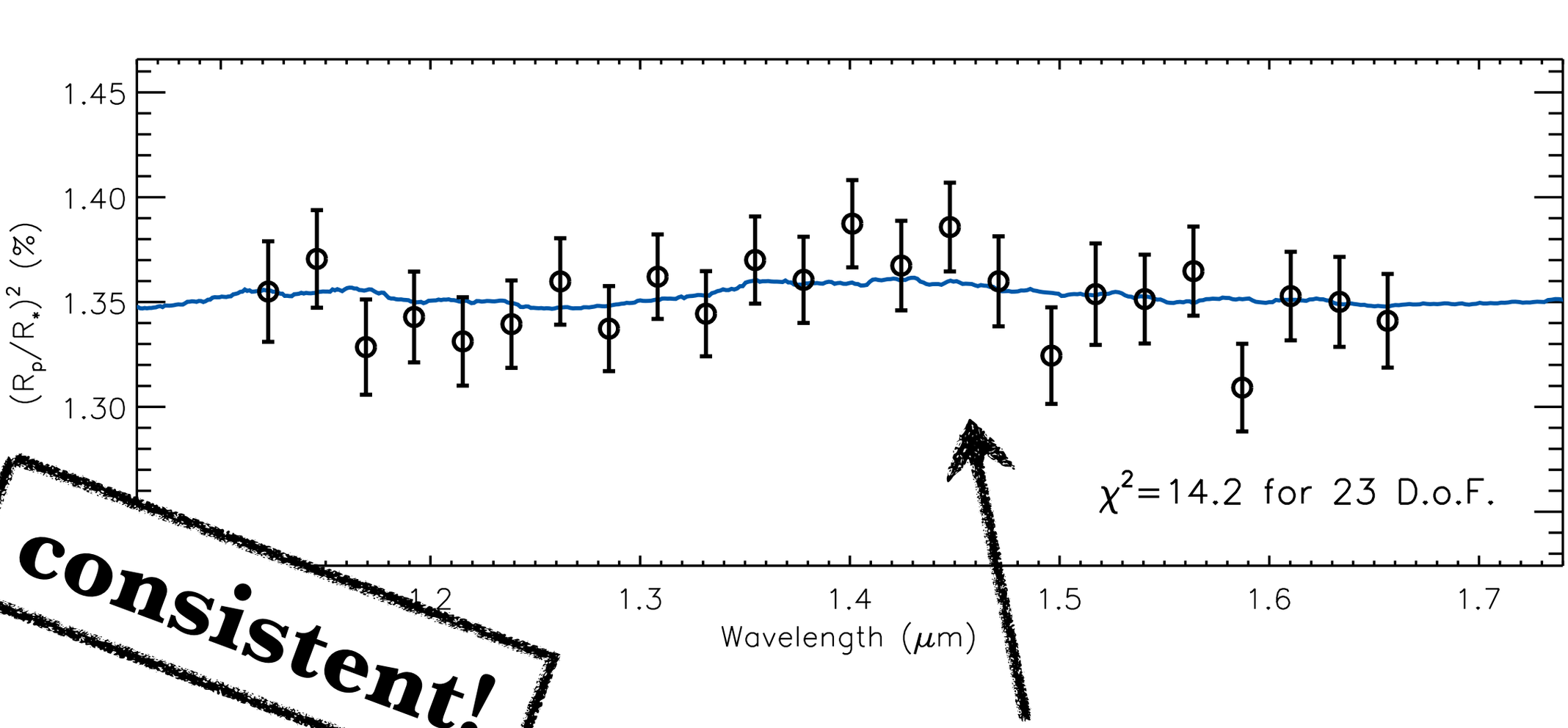
models from Miller-Ricci (Kempton) & Fortney (2010)

modeling GJ1214b's WFC3 transmission spectrum



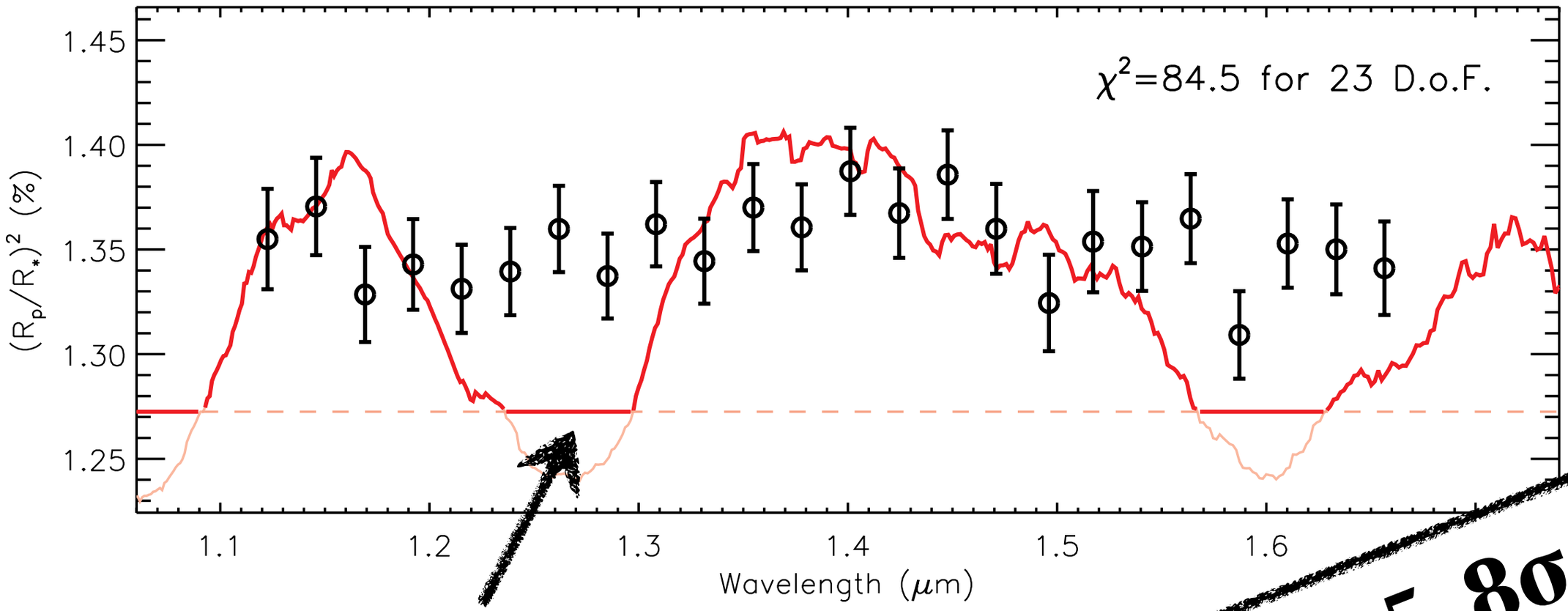
consistent!

models from
Miller-Ricci (Kempton) & Fortney (2010)

water fractions above 20% (70% by mass) are good fits to the WFC3 spectrum

modeling GJ1214b's WFC3 transmission spectrum

solar composition with clouds at 100 mbar

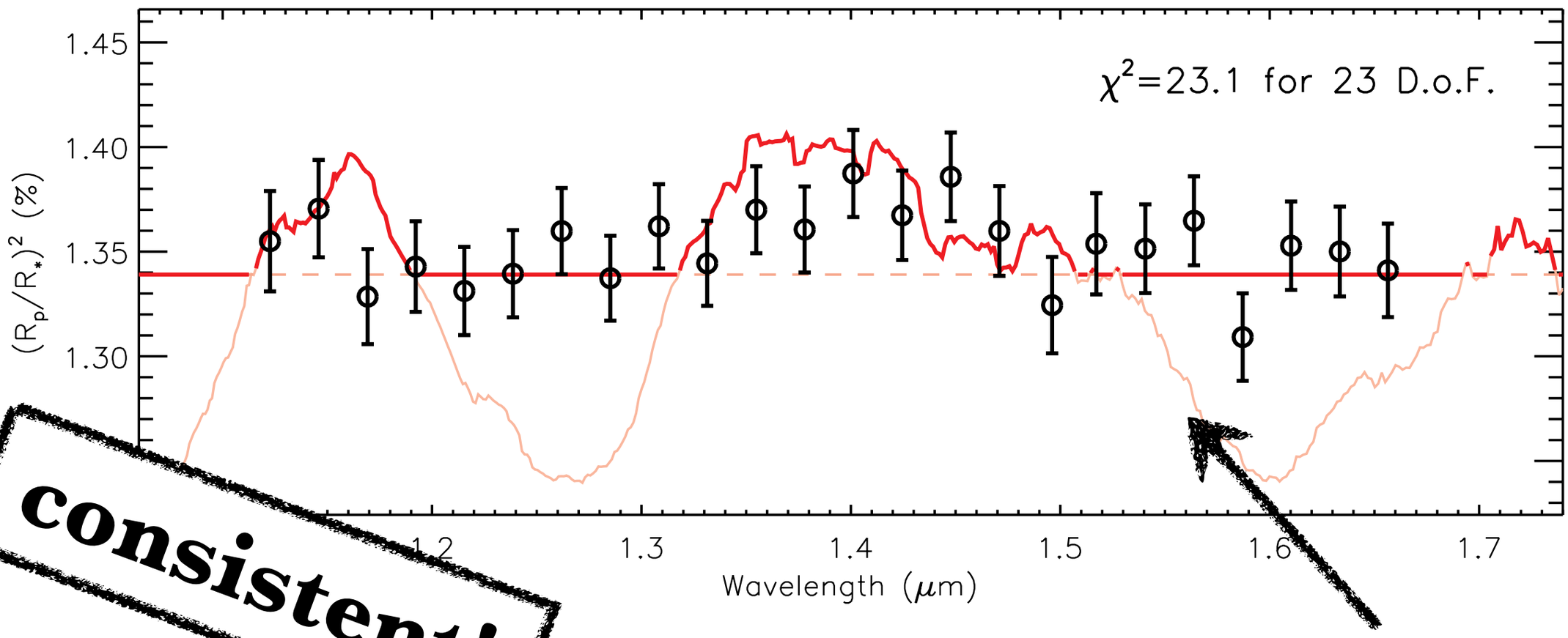


200 mbar **cloud layer**
invoked for flat spectrum
in the optical (KCl, ZnS?)

ruled out at 5.8σ

see Kempton, Zahnle, & Fortney (2011)

modeling GJ1214b's WFC3 transmission spectrum



consistent!

a **cloud layer** at higher altitudes would be necessary to mask WFC3 features

see Kempton, Zahnle, & Fortney (2011)

WFC3 **(1)** observations suggest **GJ1214b** has a **water-rich** atmosphere (and interior!) or thick **high altitude clouds**.

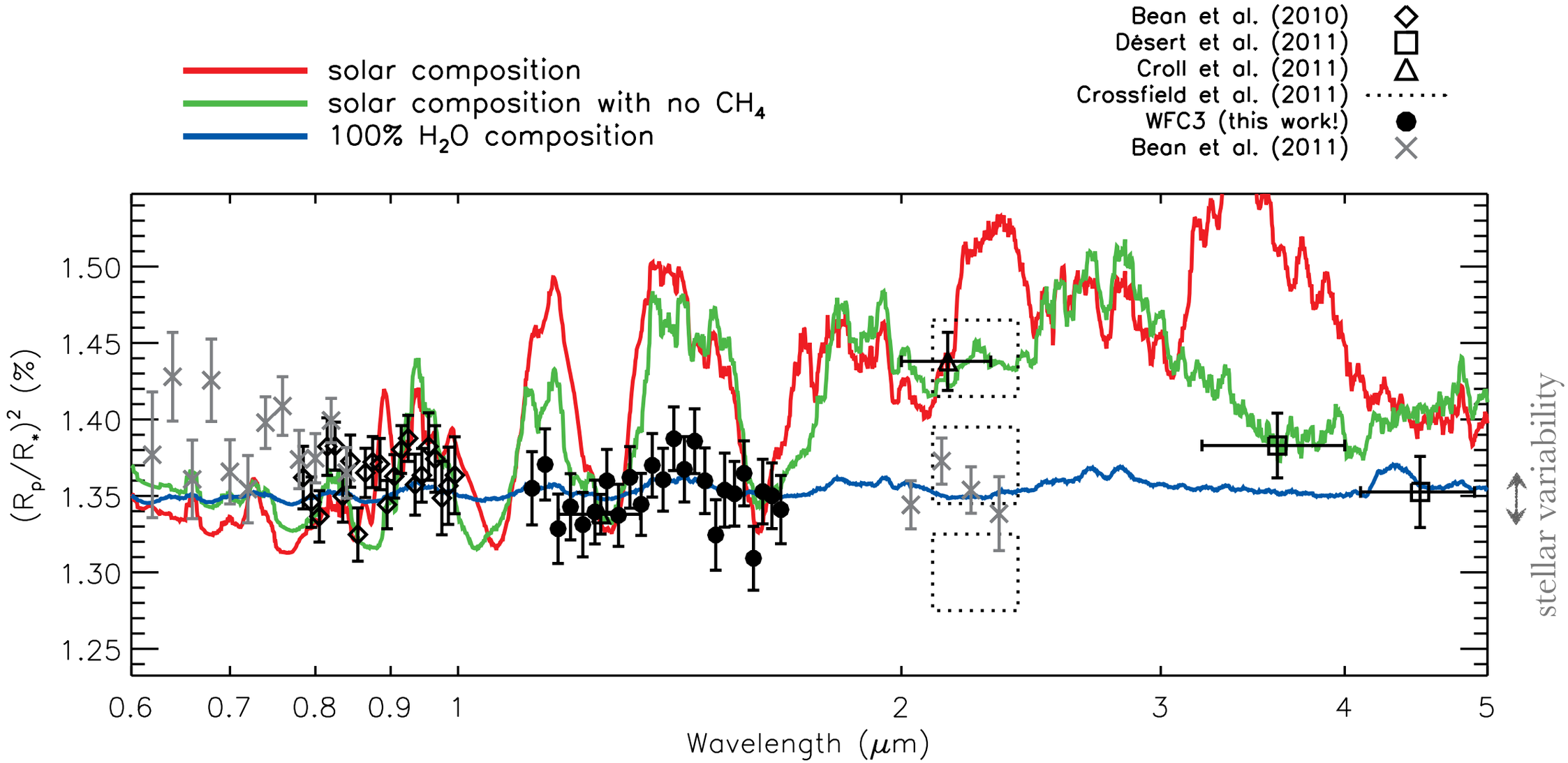
image:
J. W. Thompson

(2)

WFC3 can be a robust tool for studying exoplanet atmospheres; it is more stable than **NICMOS.**

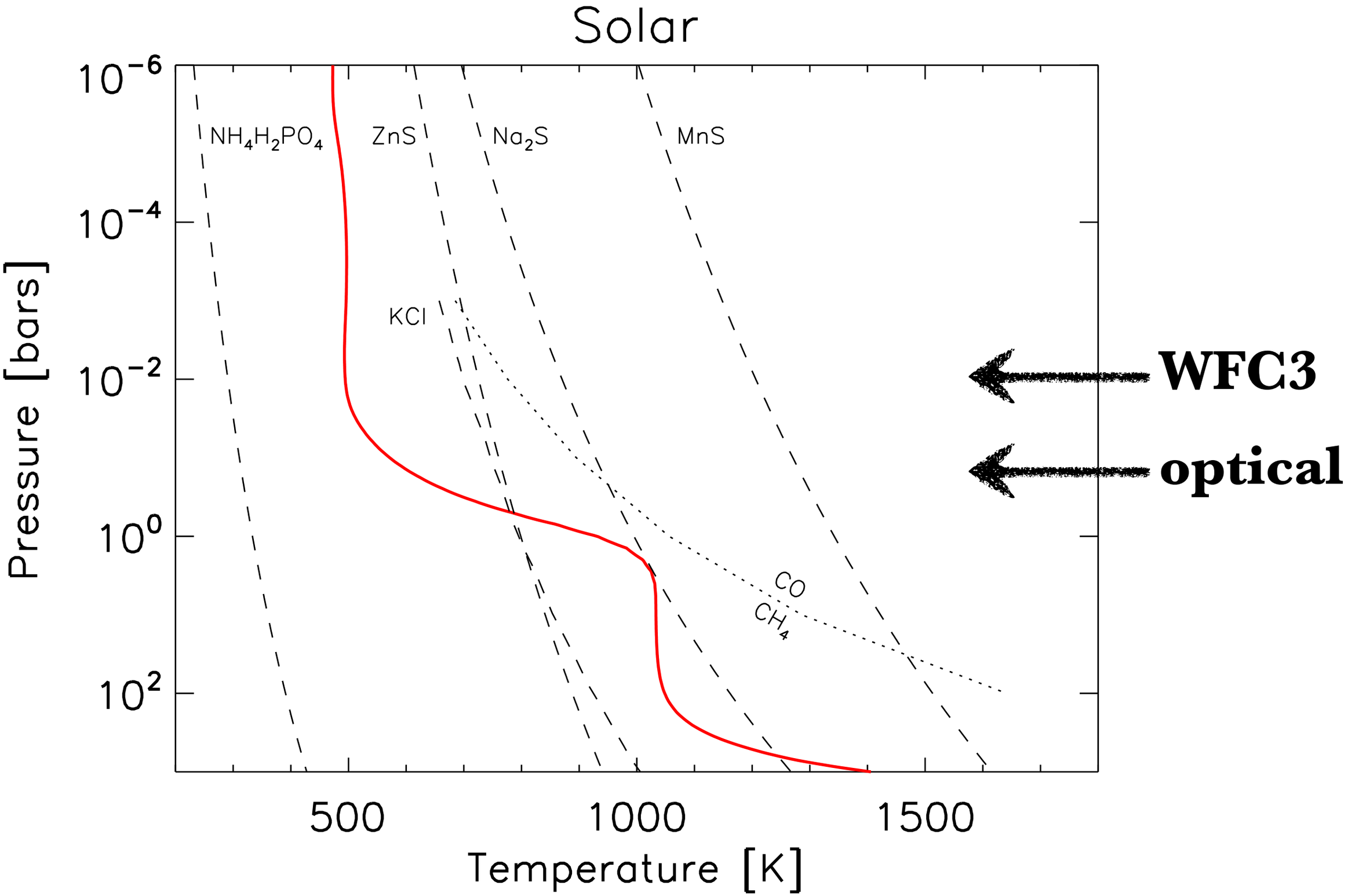
image:
J. W. Thompson

a nearly complete **transmission spectrum** of a 2.7 $R_\oplus$ exoplanet



Berta et al. (soon to be submitted)

image:
J. W. Thompson

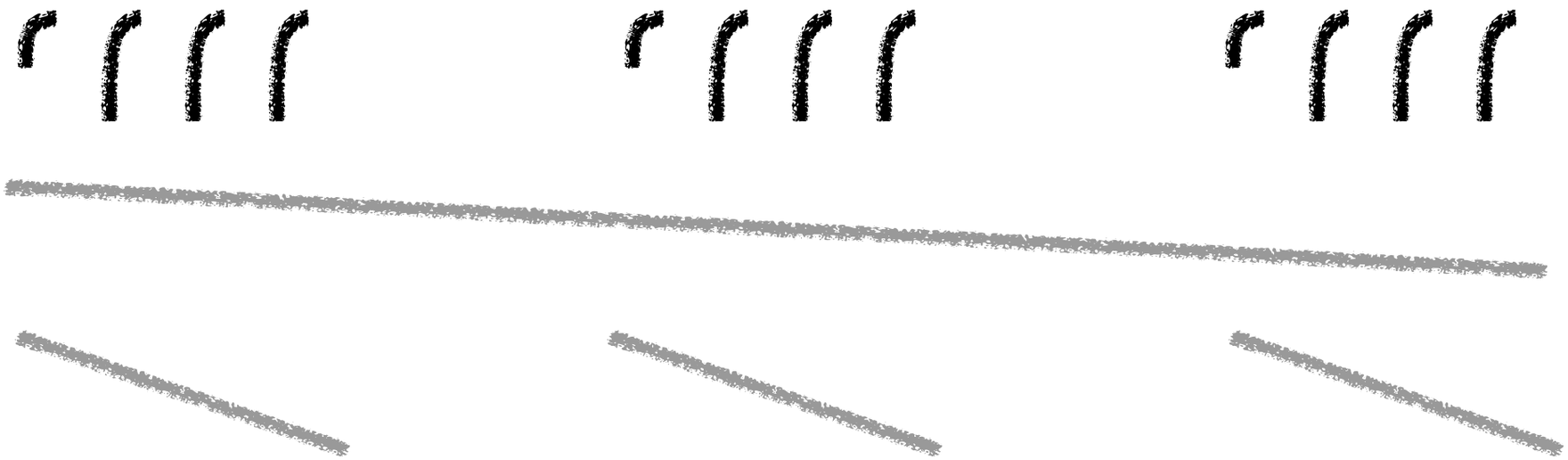


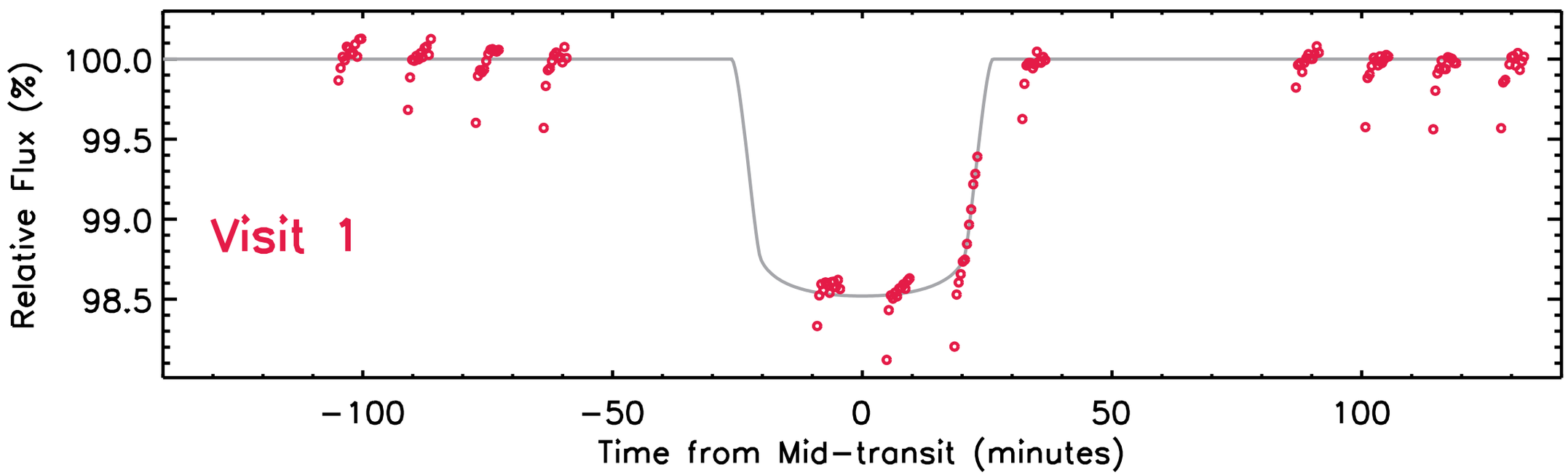
see Kempton, Zahnle, & Fortney (2011)

WFC3
GJ1214b
white light

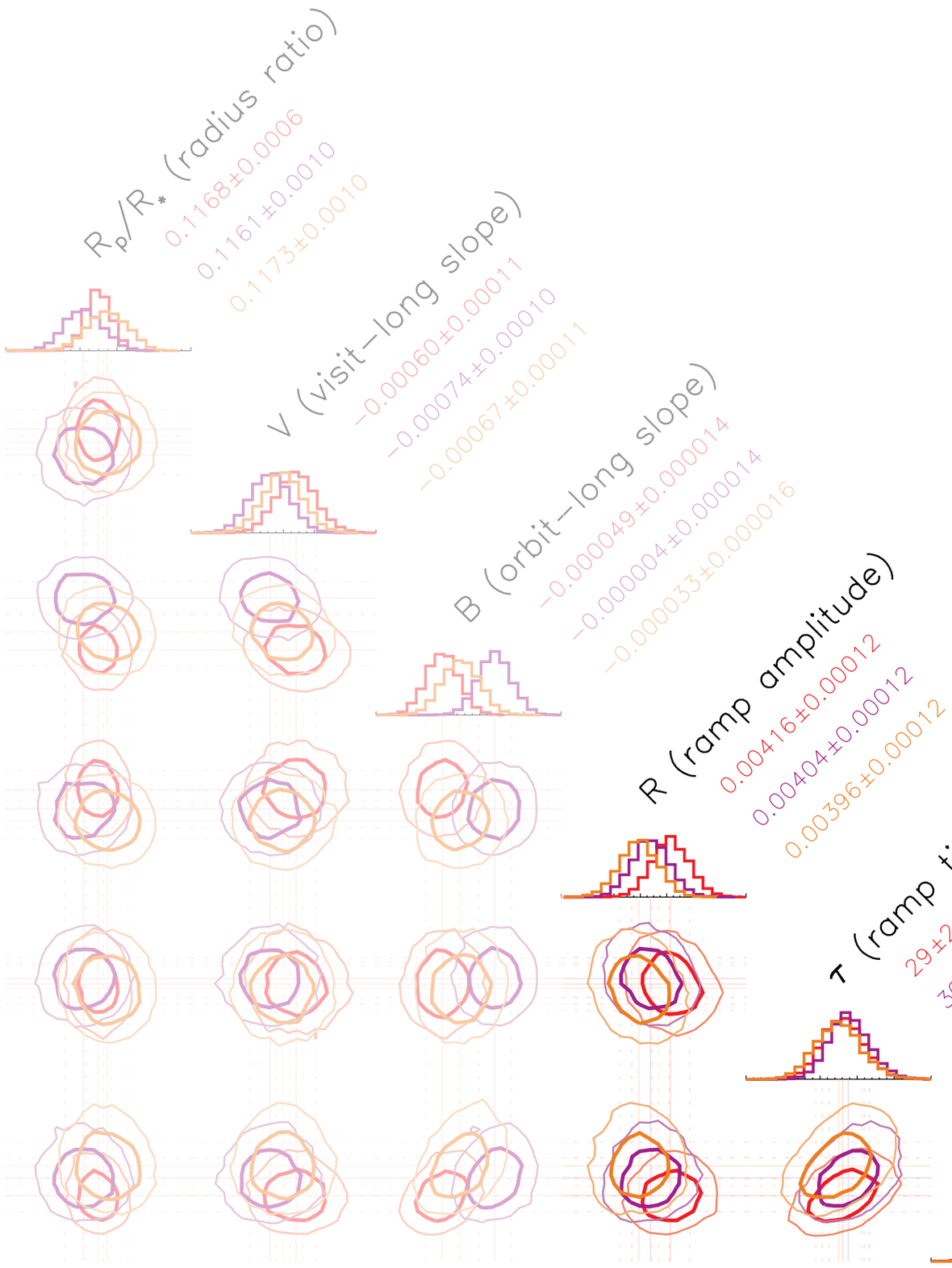
an analytic systematics model:

exponential ramp
(charge-trapping?)
+
visit-long slope
(?)
+
orbit-long slope
(focus/pointing drifts?)





WFC3
GJ1214b
white light



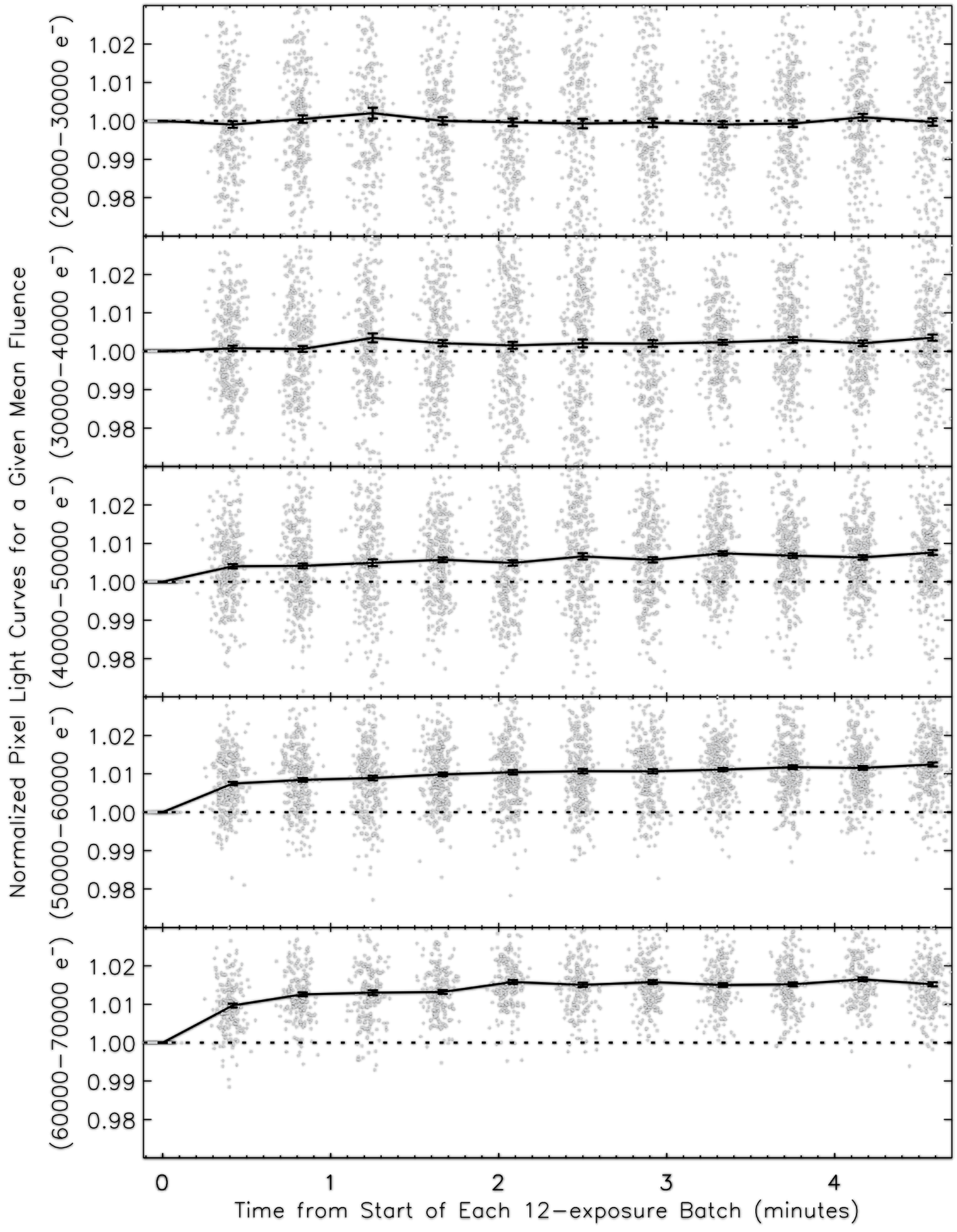
ramp parameters don't vary from visit to visit!

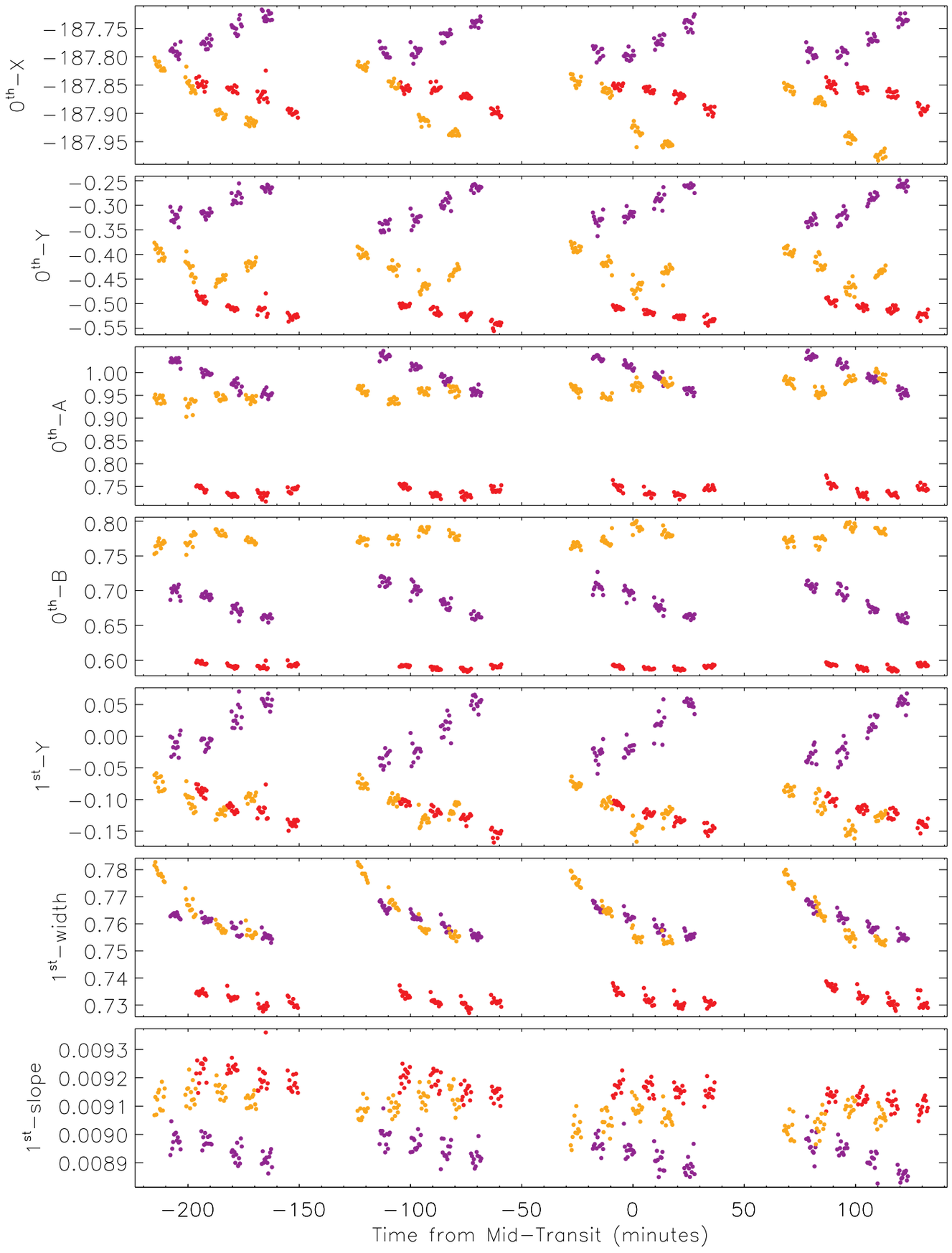
(probably set by illumination cadence, which was the same across the 3 visits)*

side note:
be nice to WFC3!

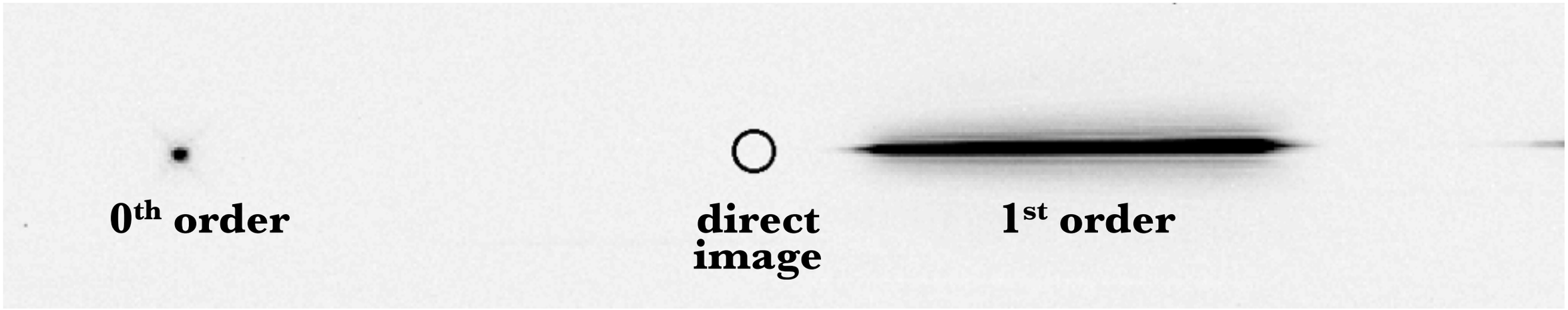
Visit 1
Visit 2
Visit 3

The more light pixels receive, the worse their ramp.





Positions + shapes vary, but they repeat from orbit to orbit within each visit.



WFC3 is in focus.