Transmission spectra of exoplanet atmospheres

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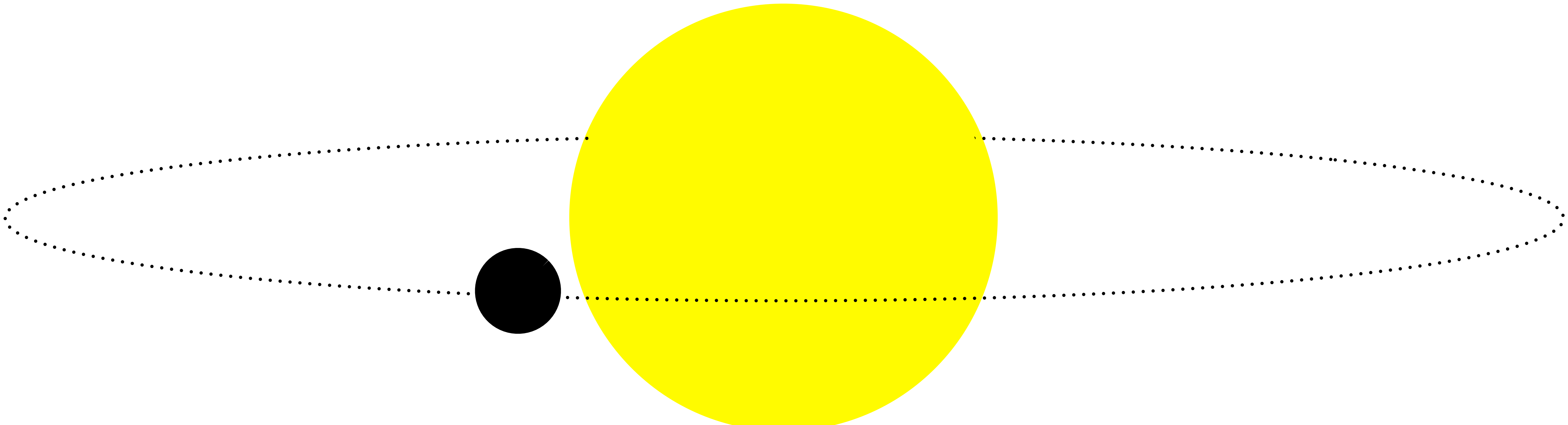
David K. Sing (U Exeter)
J.-M. Désert (Harvard)

PLATO

Primary transit



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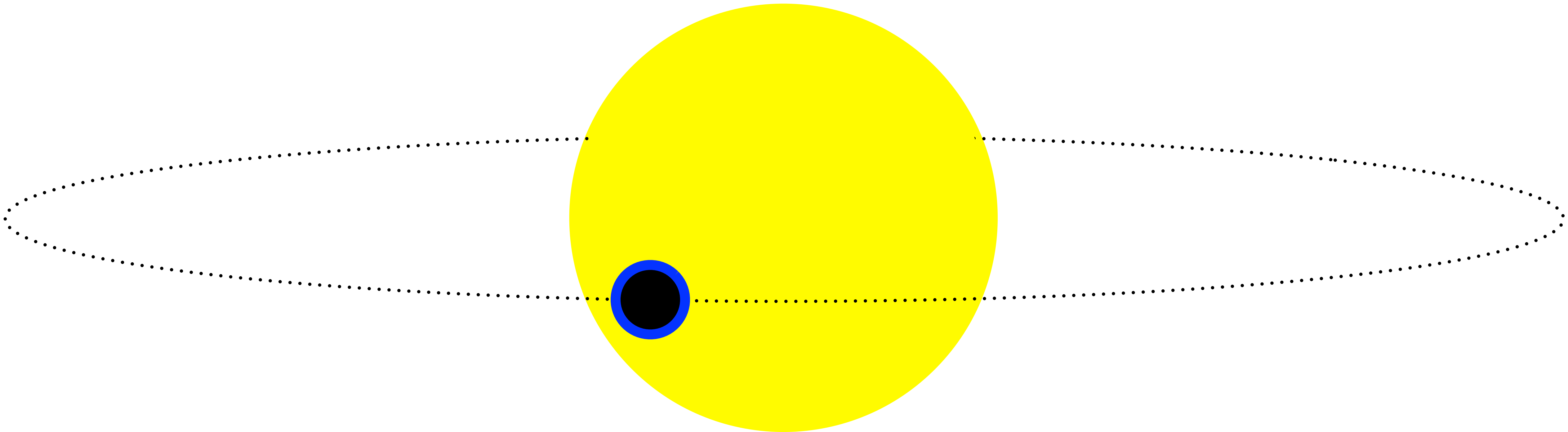
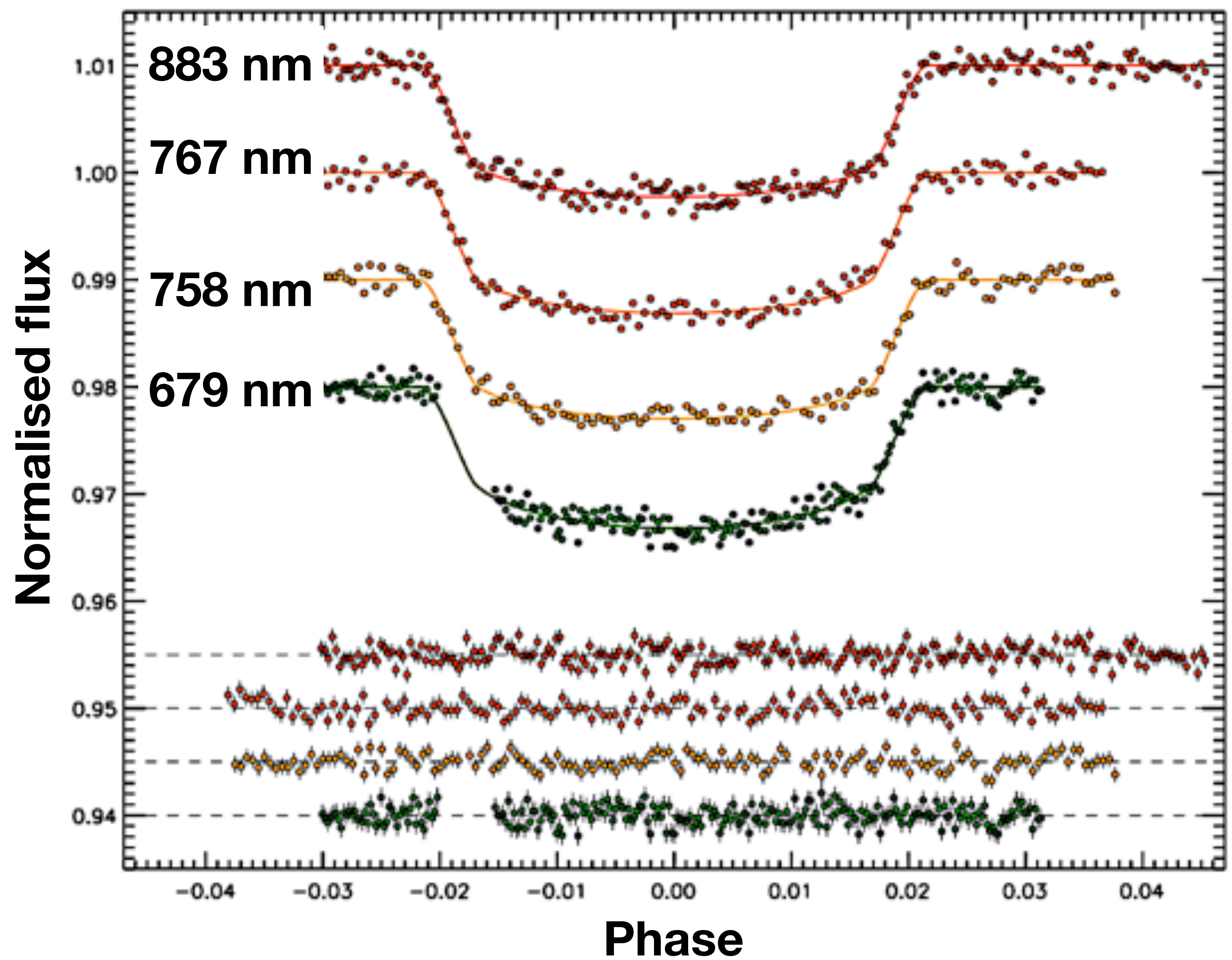


The planet (partially) eclipses the star

Transmission spectroscopy through the limb

Chromatic variations of the optically-thick radius



GranTeCan
spectrophotometry
hot jupiter XO-2b
Sing *et al.* (2011)

$$\Delta F/F(\lambda) \approx \left[R_p(\lambda)/R_\star\right]^2$$

larger absorptions = larger radius/altitude

Seager & Sasselov (2000) • Brown (2001) • Hubbard *et al.* (2001) • Ehrenreich *et al.* (2006)

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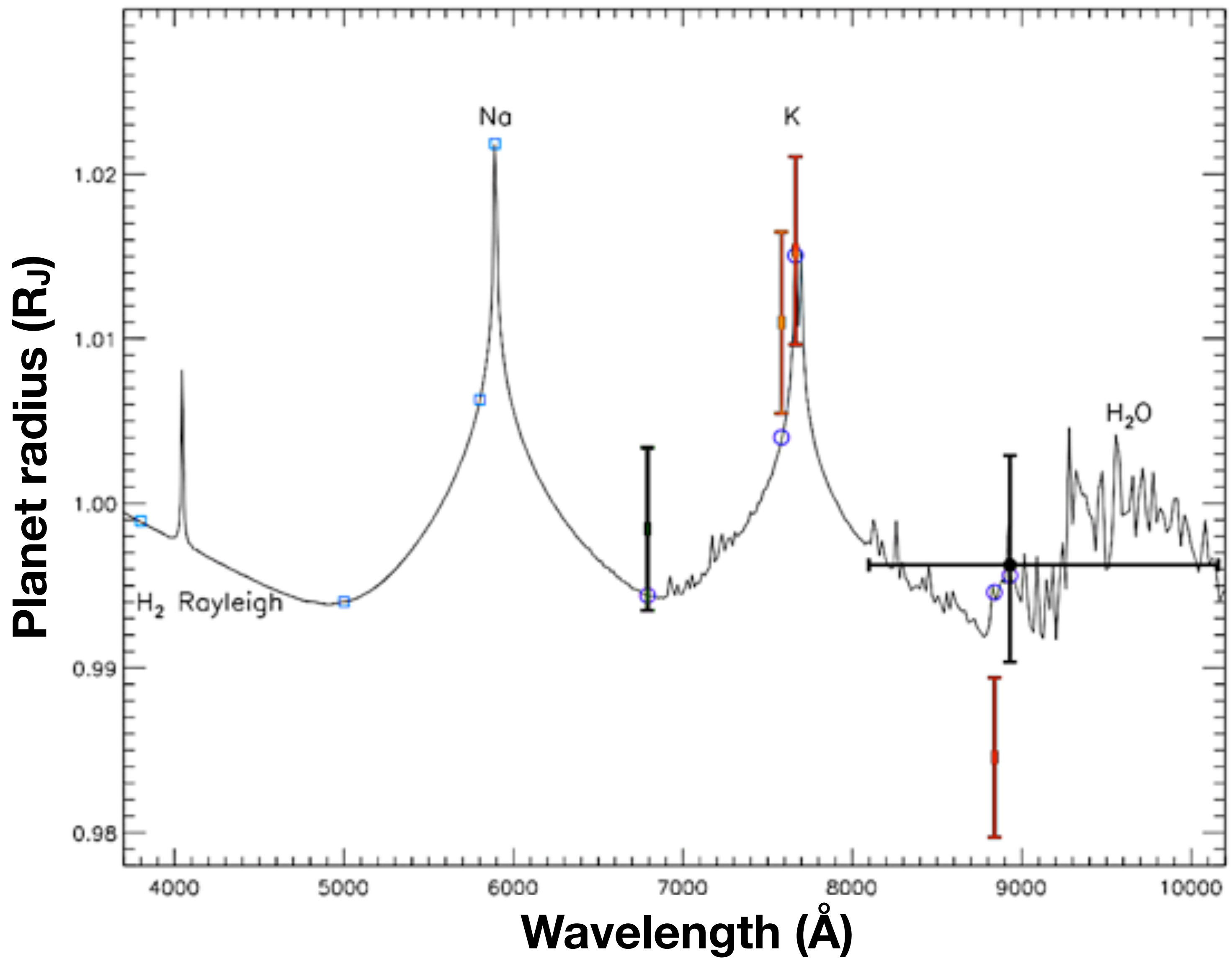

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Fortney *et al.* (2010)

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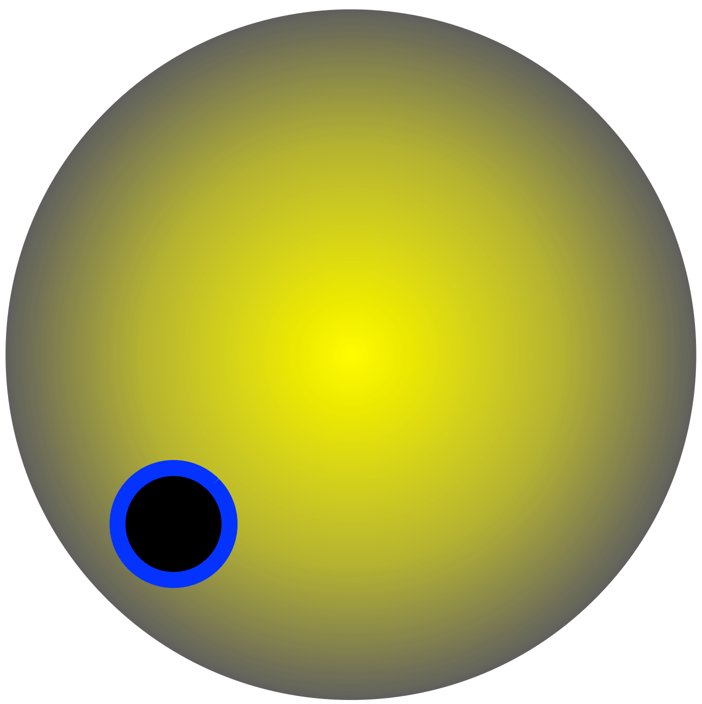


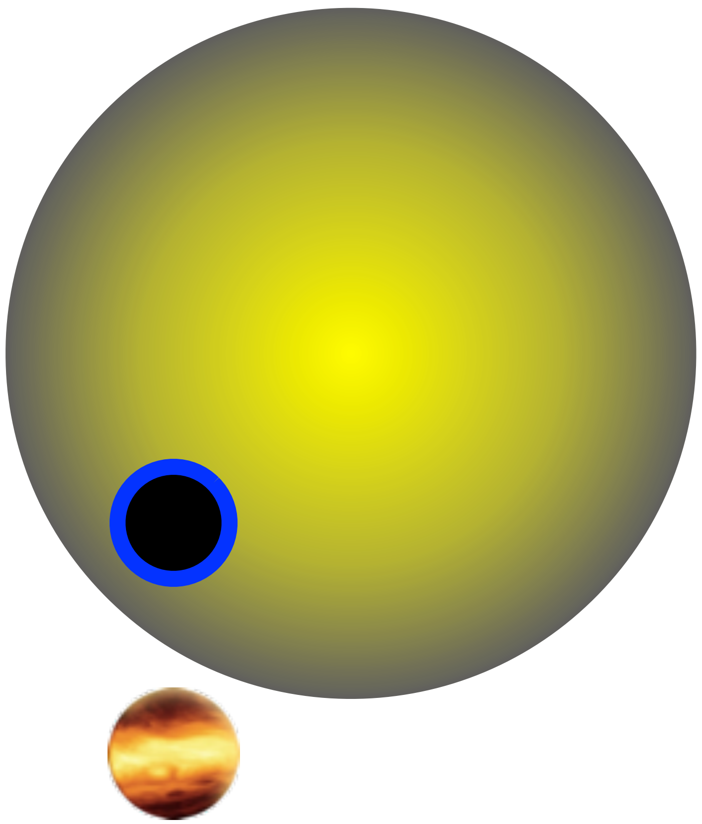
$$(\Delta F/F)_{\rm atmo} \approx 2(\Delta F/F)_p \, (H/R_p)$$

scale height

$$H = k_B T/\mu g$$

Winn (2010)

Chromatic variations of the optically-thick radius



$$(\Delta F/F)_{\mathrm{atmo}} \approx 2(\Delta F/F)_p \, (H/R_p)$$

10^{-4}–10^{-3} | 10^{-2} | ~500 km

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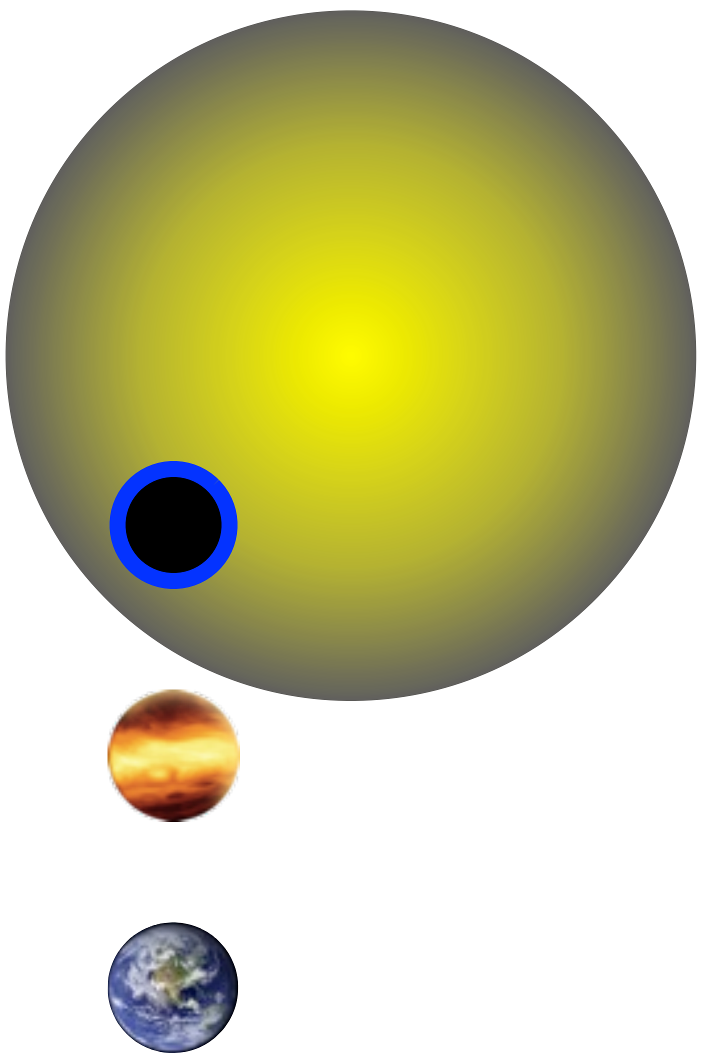

$$(\boldsymbol{\Delta F/F})_{\mathbf{atmo}} \approx 2(\Delta F/F)_p \, (H/R_p)$$

$(\Delta F/F)_{atmo}$	$(\Delta F/F)_p$	H
10^{-4}–10^{-3}	**10^{-2}**	**~500 km**
10^{-6}–10^{-7}	**10^{-5}**	**~10 km**

scale height

$$H = k_B T/\mu g$$

Winn (2010)

Brighter star, better atmospheric detection

$$S/N \propto \sqrt{F_\star}$$

A background light source is required for transmission spectroscopy:

the transited star

Space- & **ground**-based results, from **UV** to **NIR**

- In the **visible** from the **ground** with Subaru & GranTeCan
  High-resolution detection of atmospheric tracers (Na & K)

- In the **visible**/**NIR** from **space** with the *HST*
  HD 209458b: temperature inversion & diffusion
  HD1897333b: diffusion by haze

- In the **UV** from **space** with the *HST*
  Atmospheric evaporation of hot jupiters

- In the **NIR** from **space** with *Spitzer* & *HST*/Nicmos
  Molecular composition of hot gas giants

Focus on a couple of studies

- In the **visible** from the **ground** with Subaru & GranTeCan
  High-resolution detection of atmospheric tracers (Na & K)

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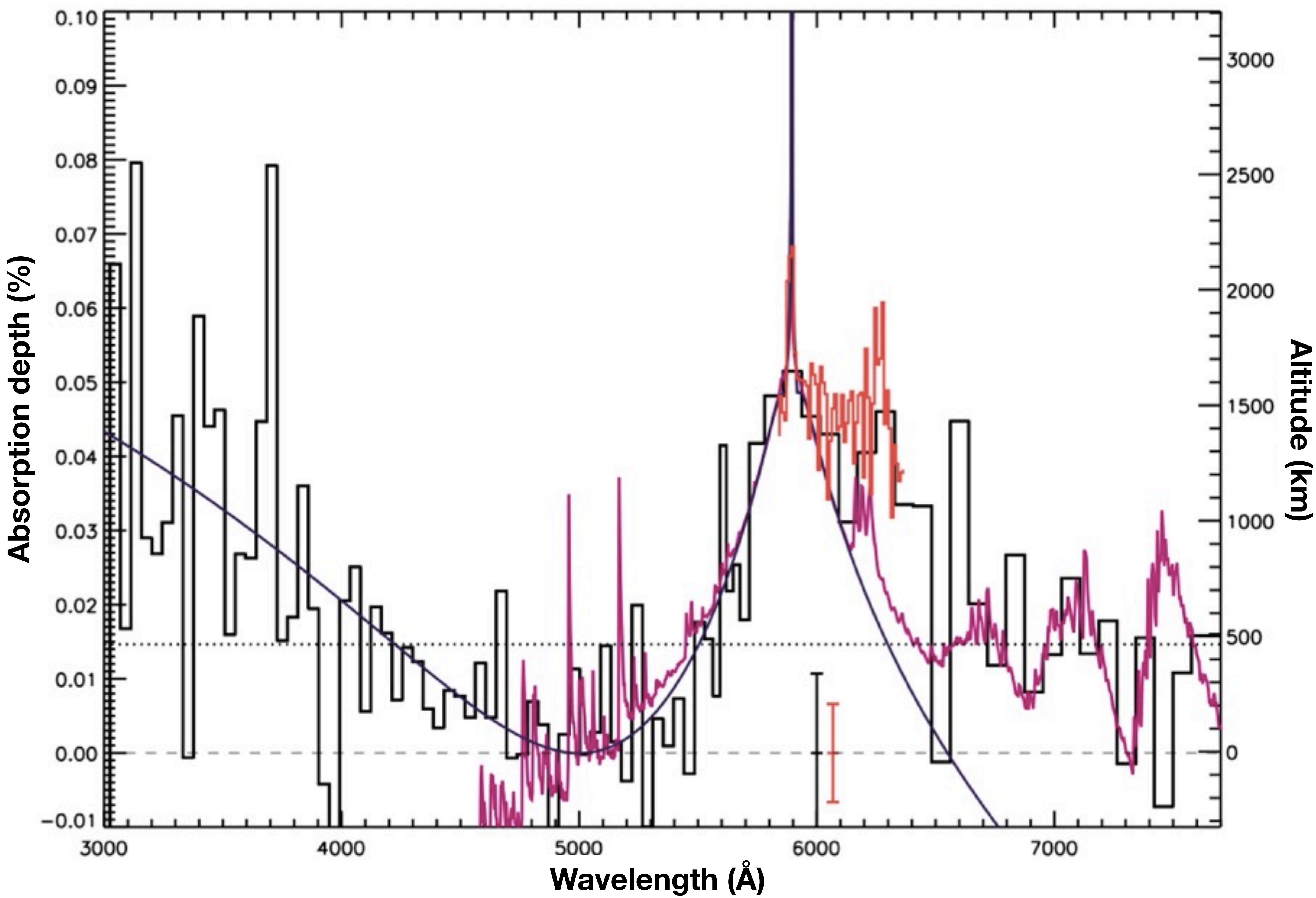
Atmospheric properties of a **hot jupiter**



Charbonneau *et al.* (2002) • Sing *et al.* (2008a,b) • Snellen *et al.* (2008) • Lecavelier *et al.* (2008) • Désert *et al.* (2008)

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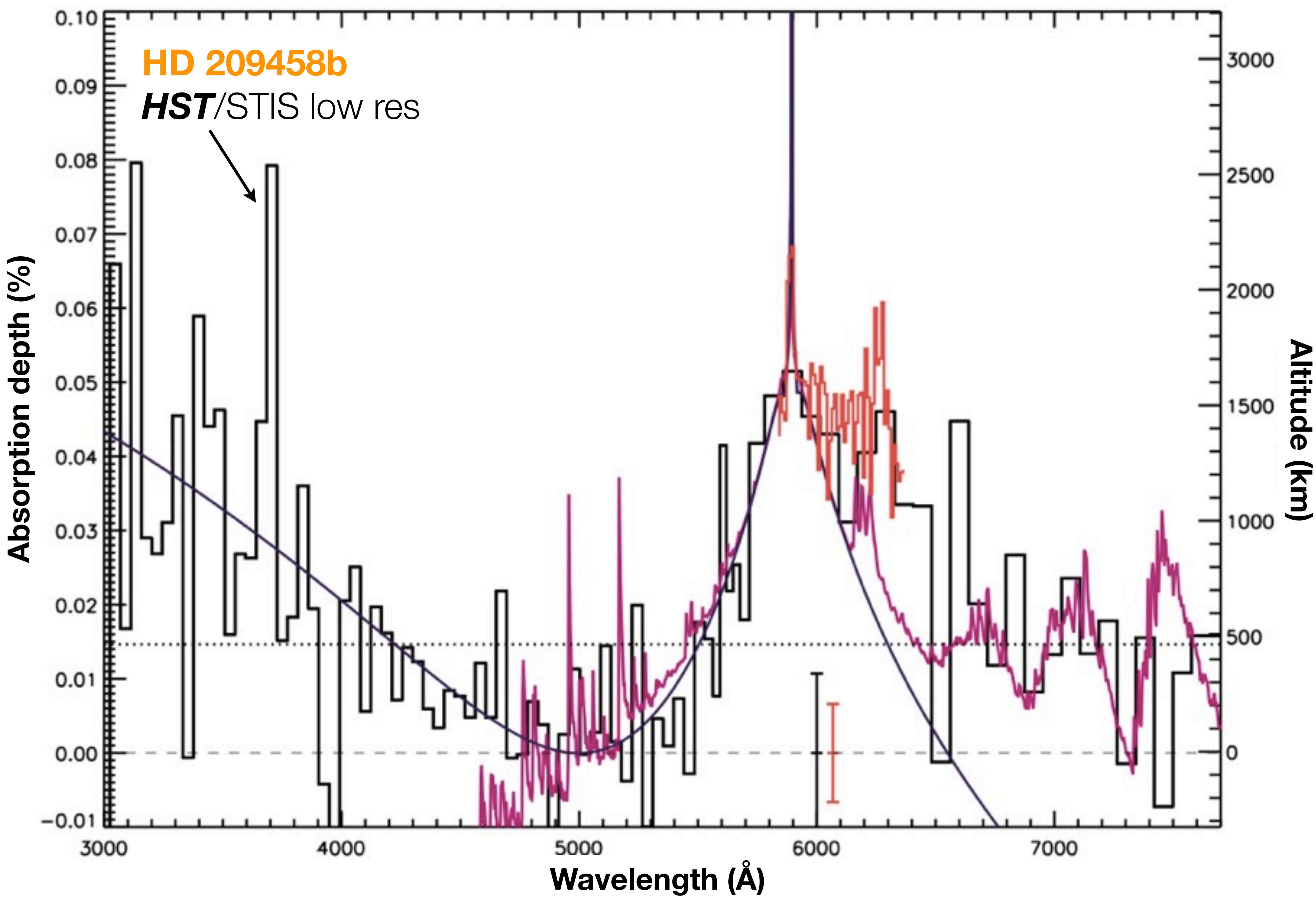

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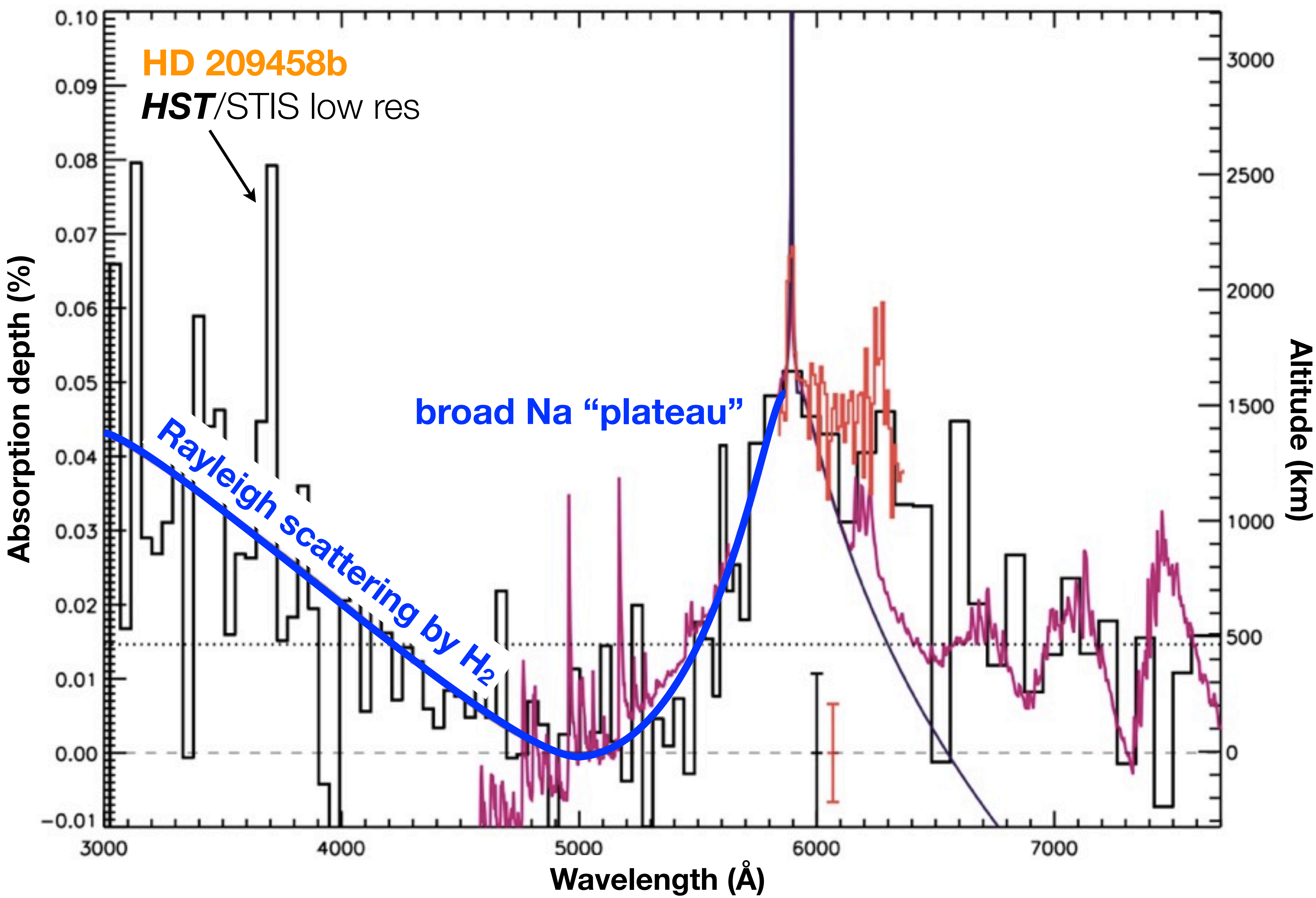

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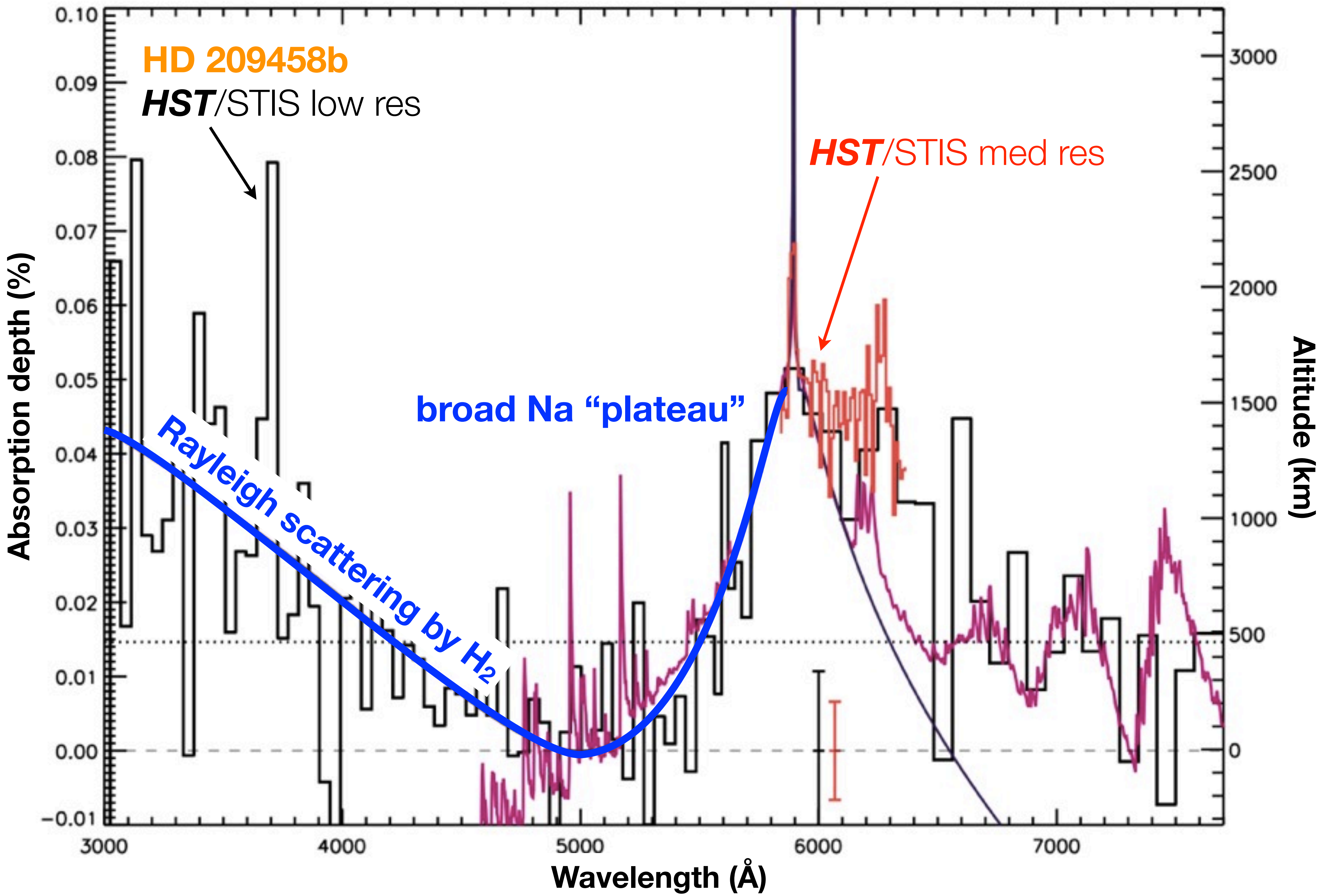

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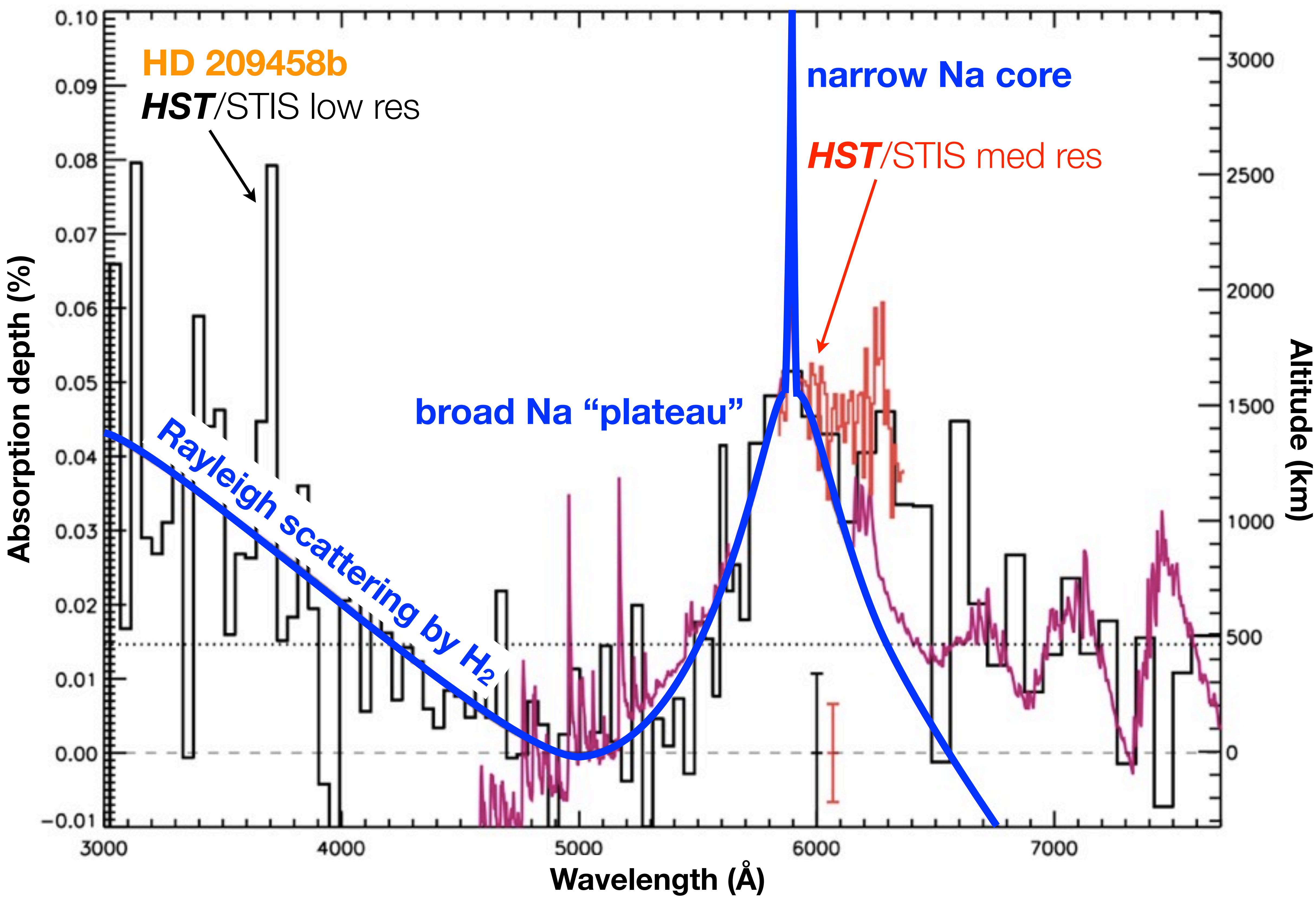

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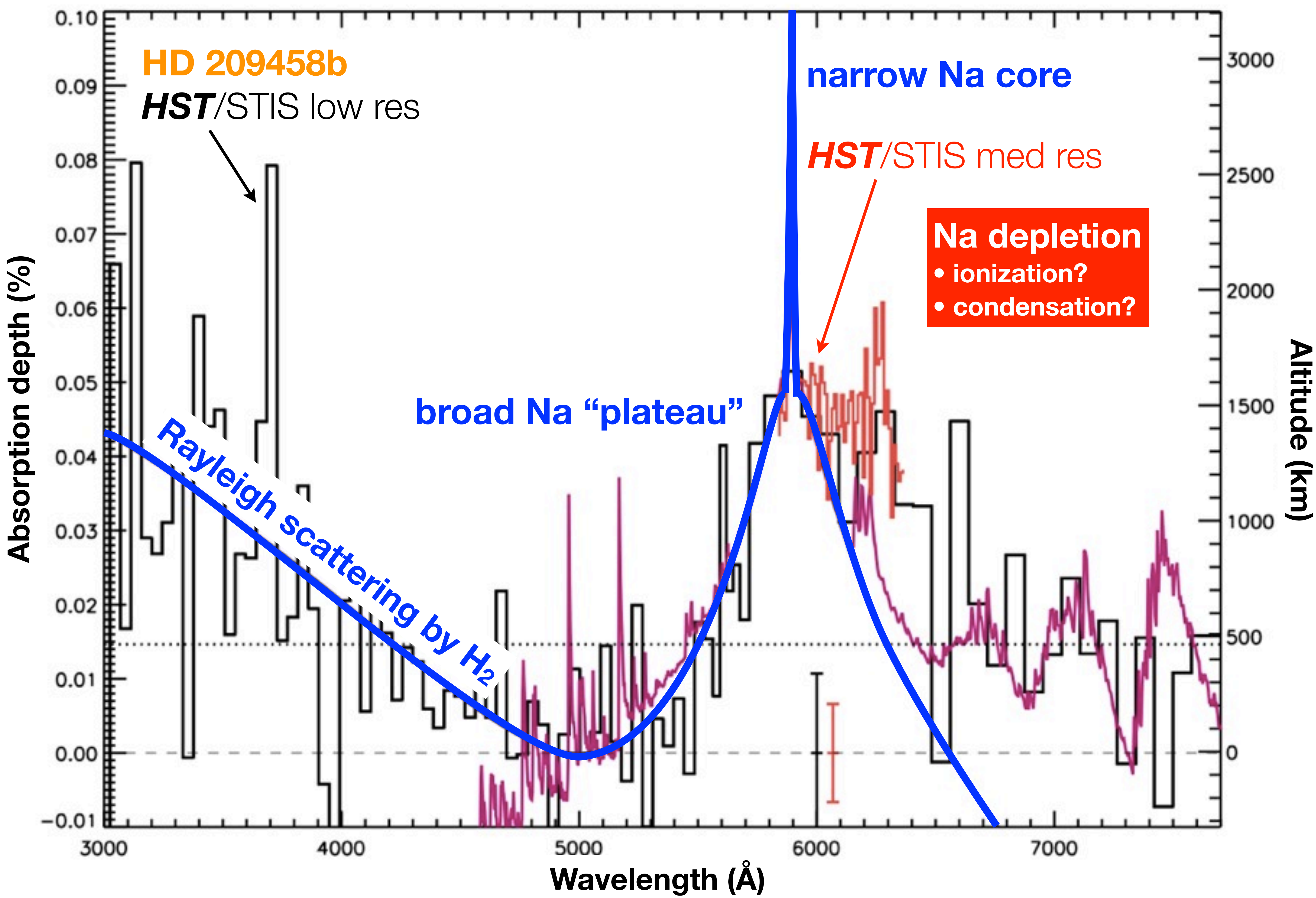

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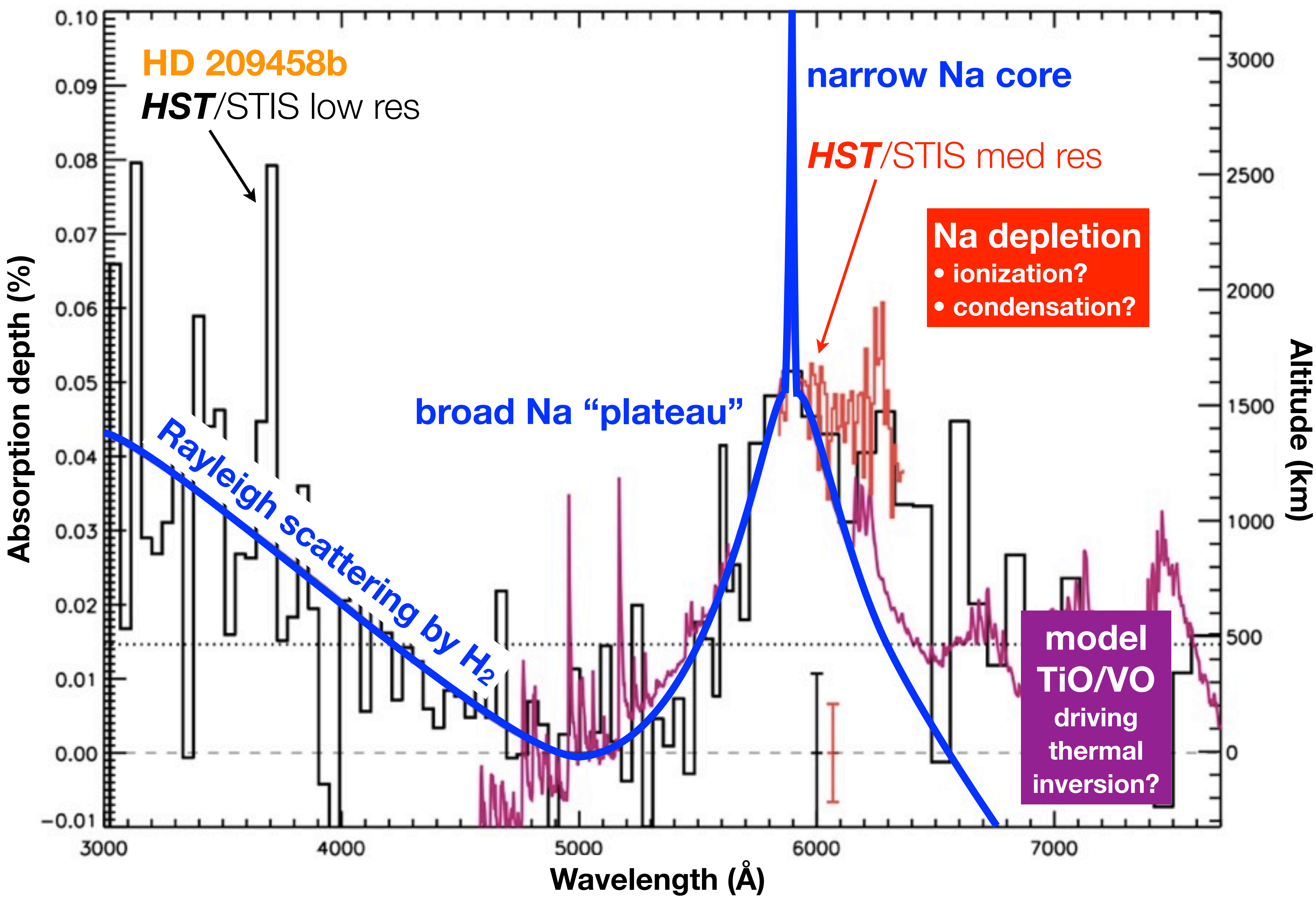

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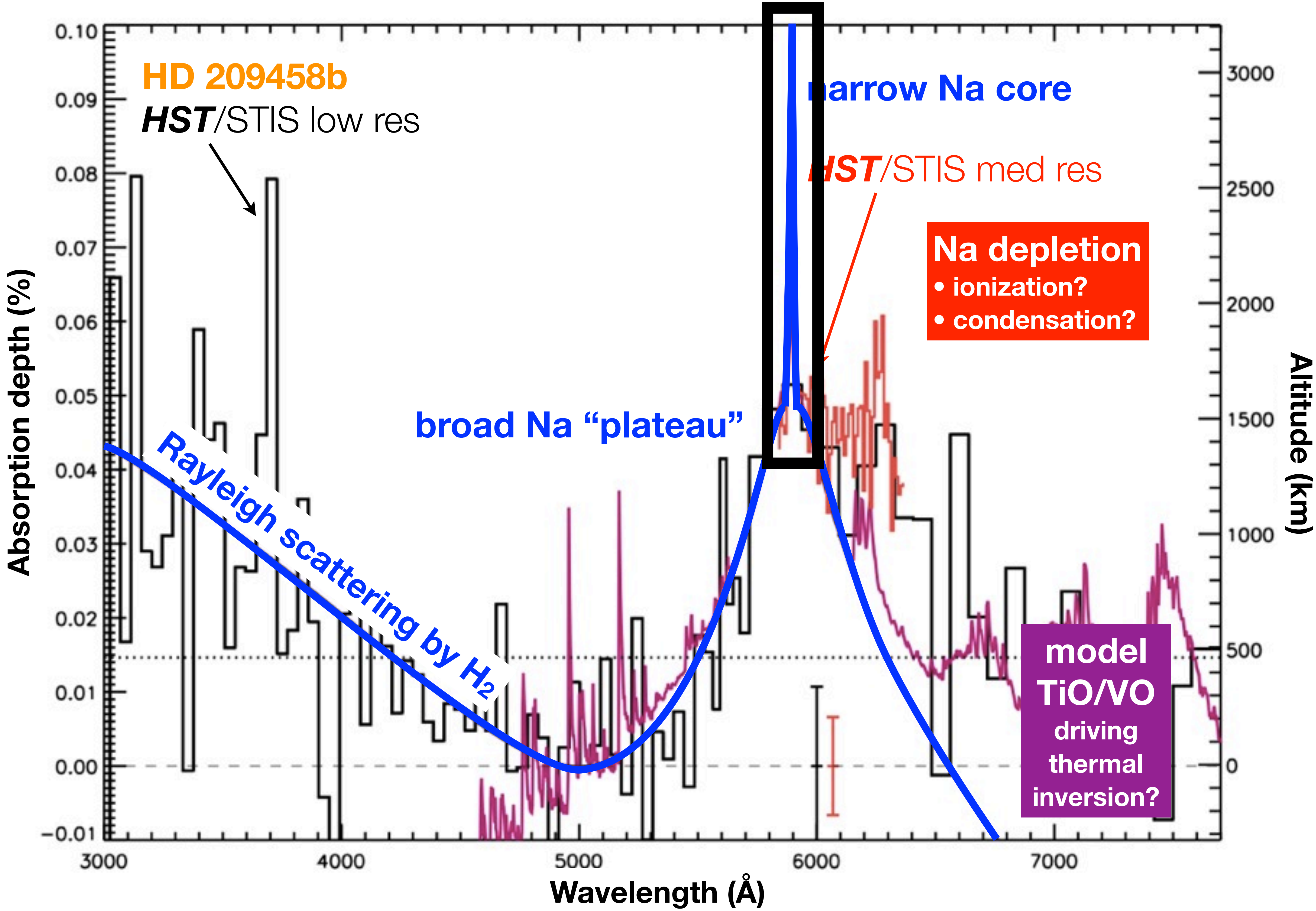

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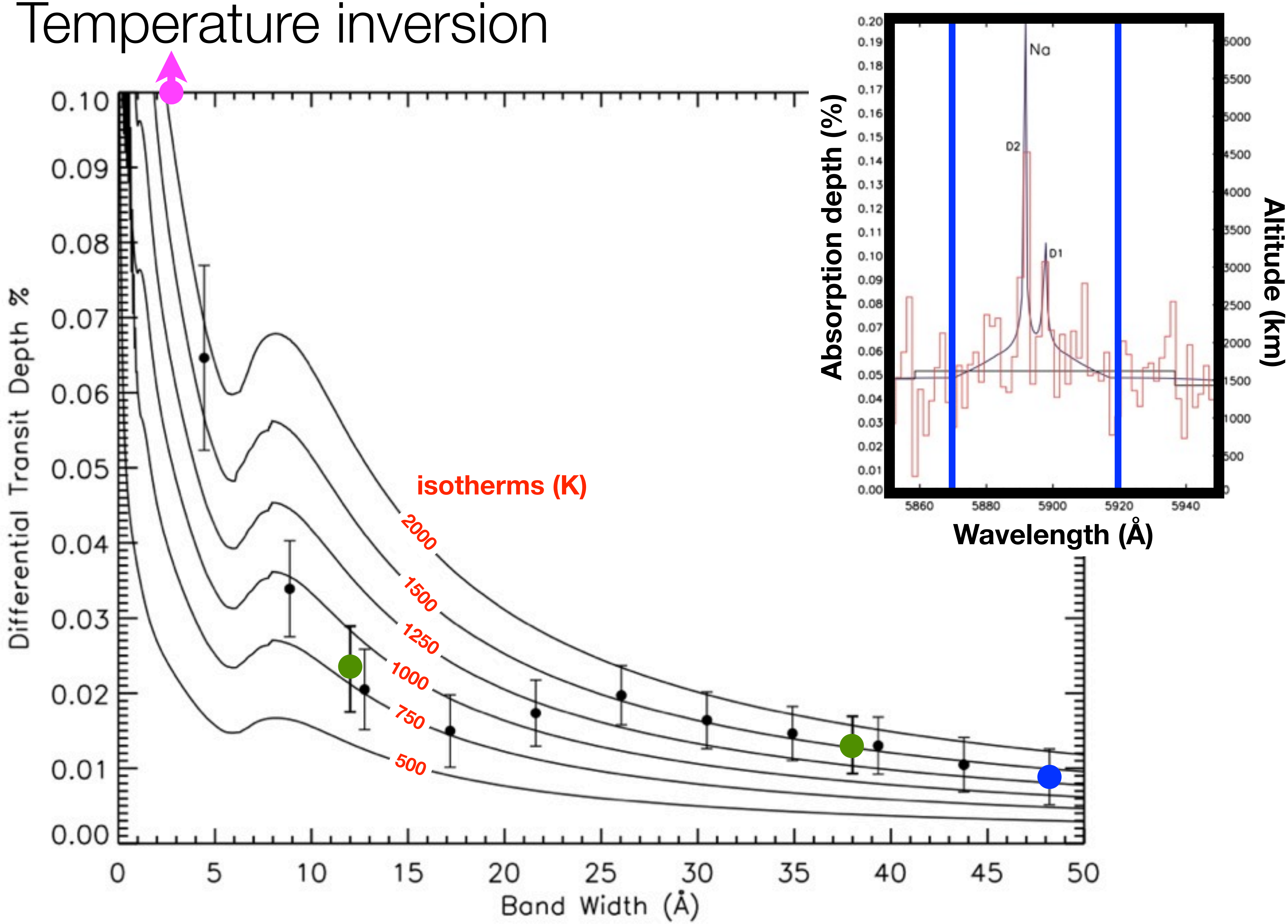
Temperature inversion



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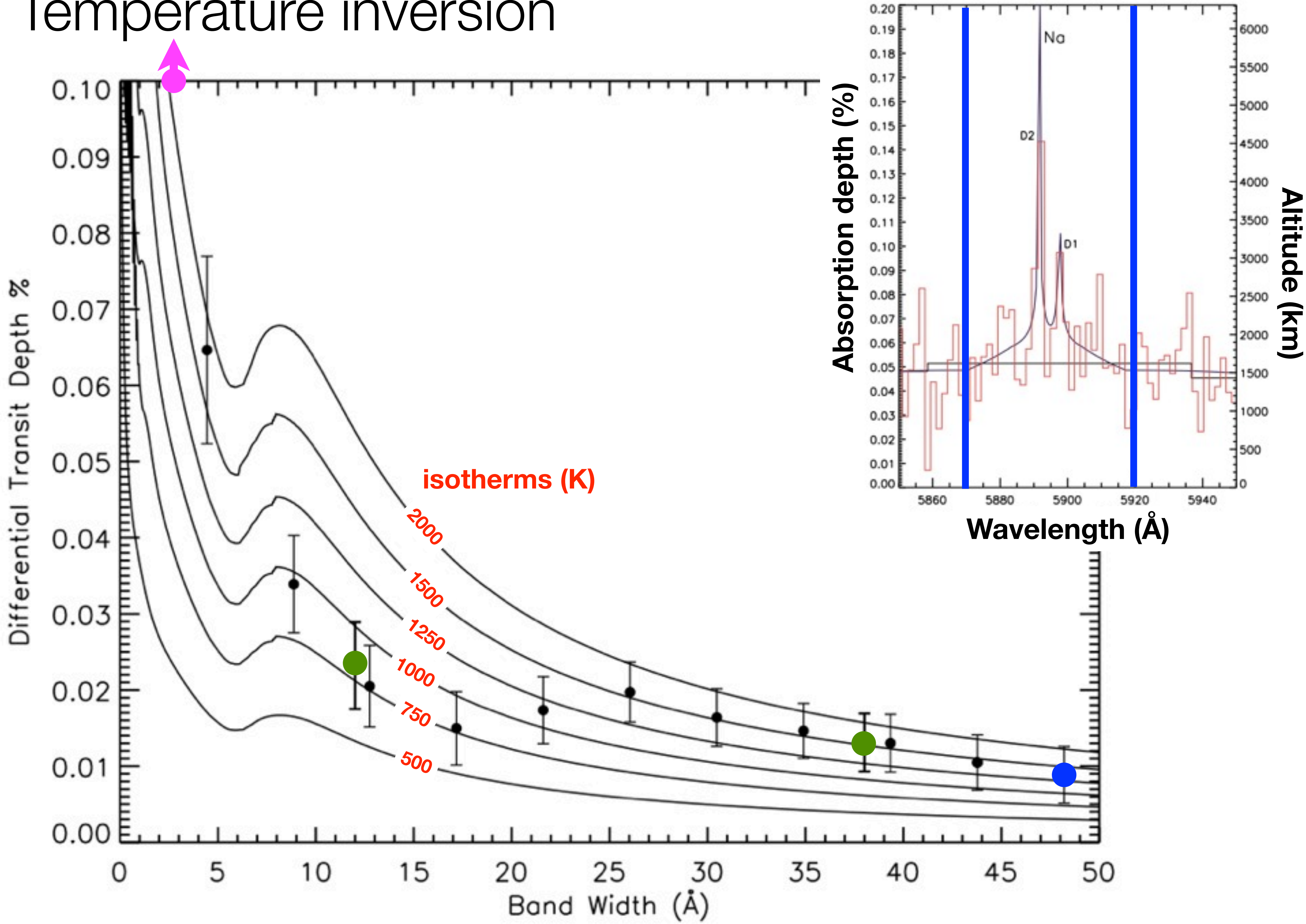

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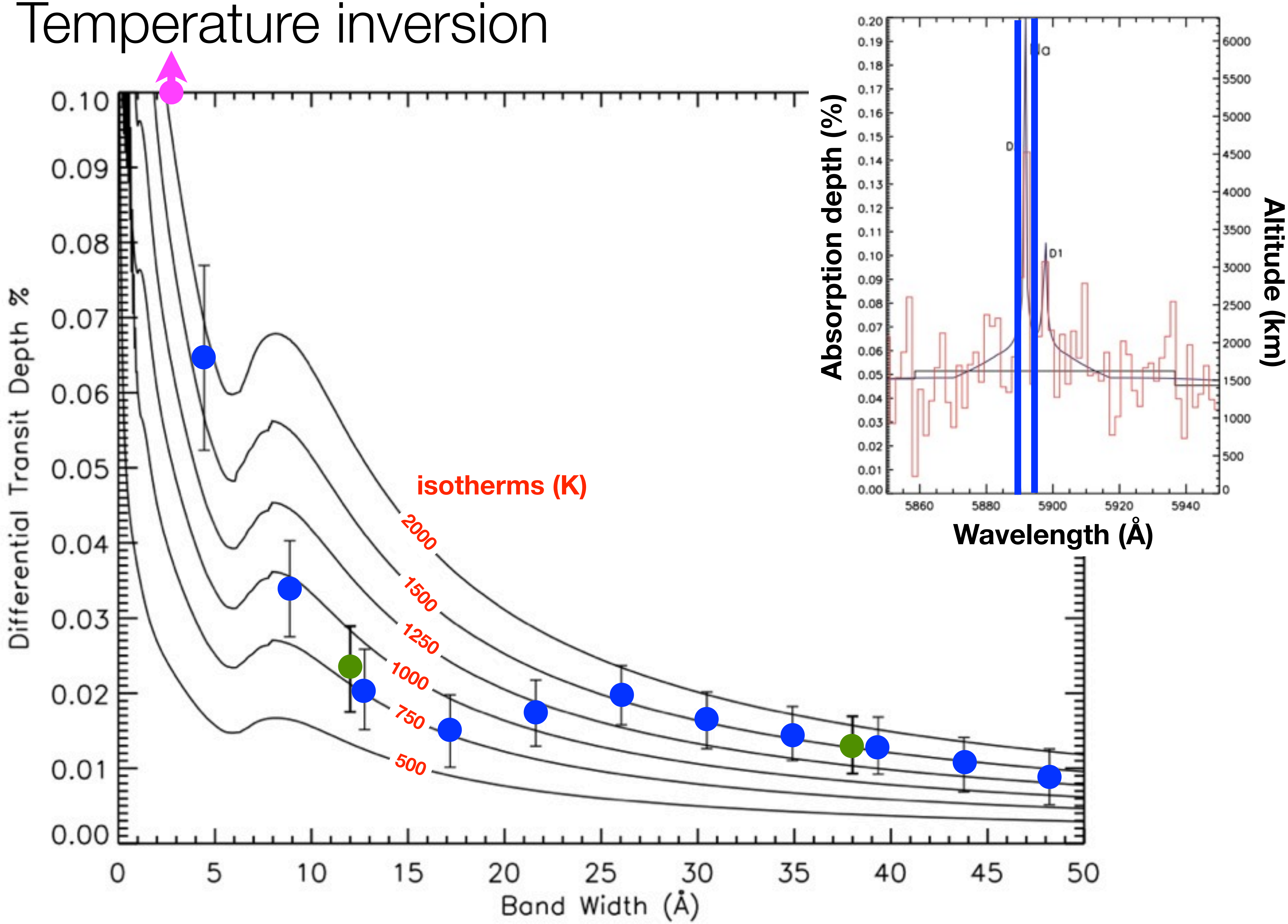

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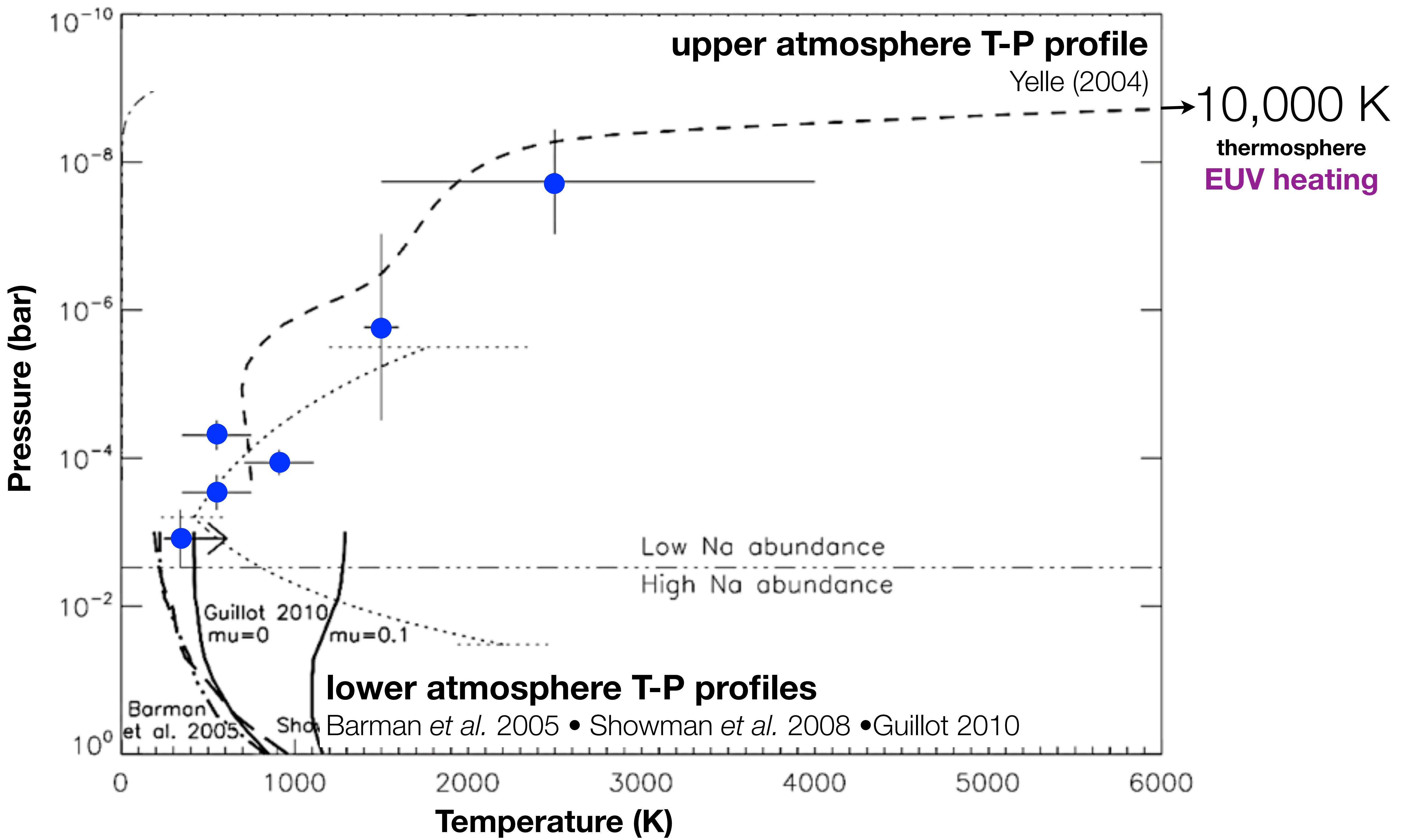
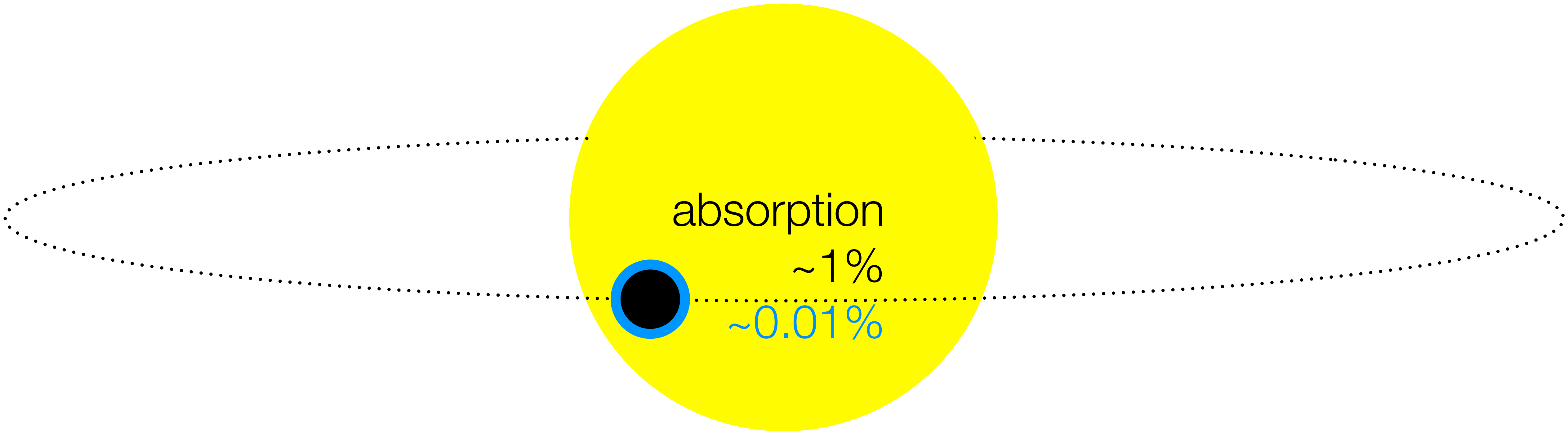
Connection to the upper atmosphere



Vidal-Madjar *et al.* (2011)

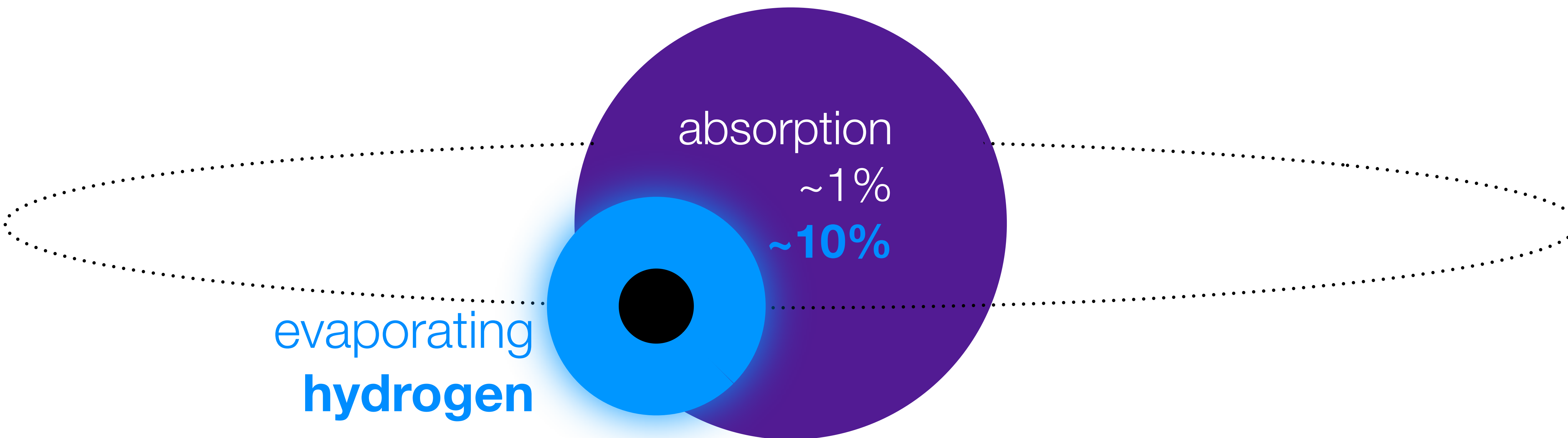
Primary transit



The planet (partially) eclipses the star

➡ Transmission spectroscopy through the limb

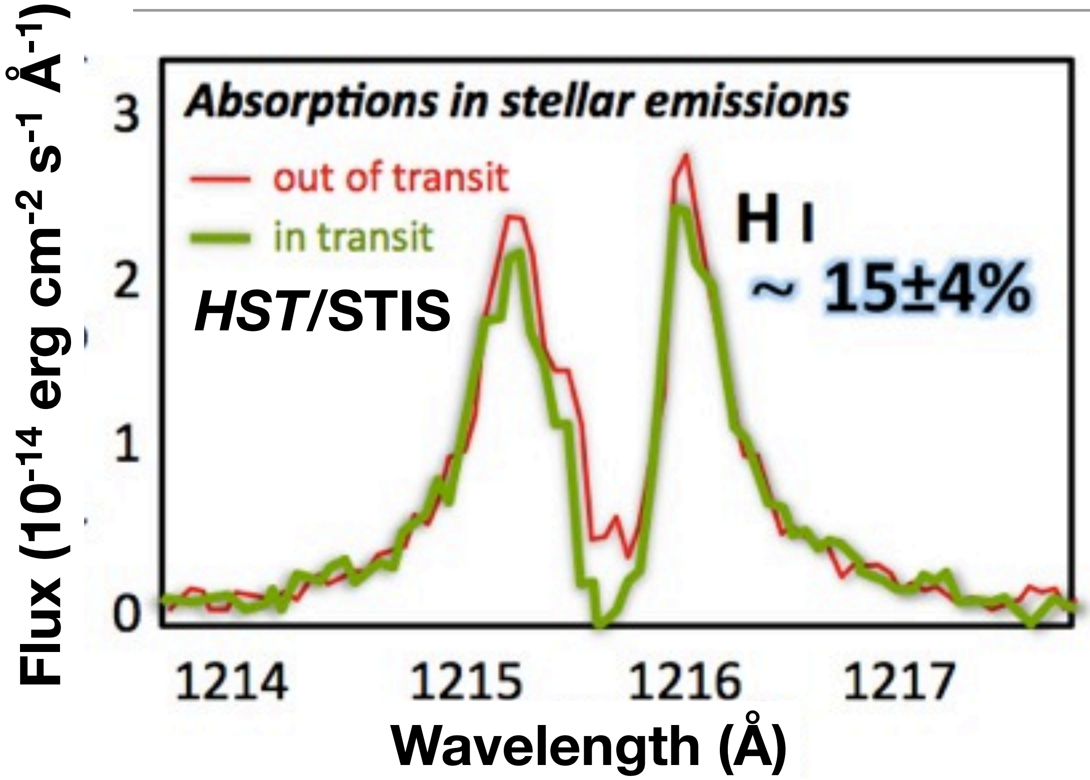
Primary transit in the **UV**

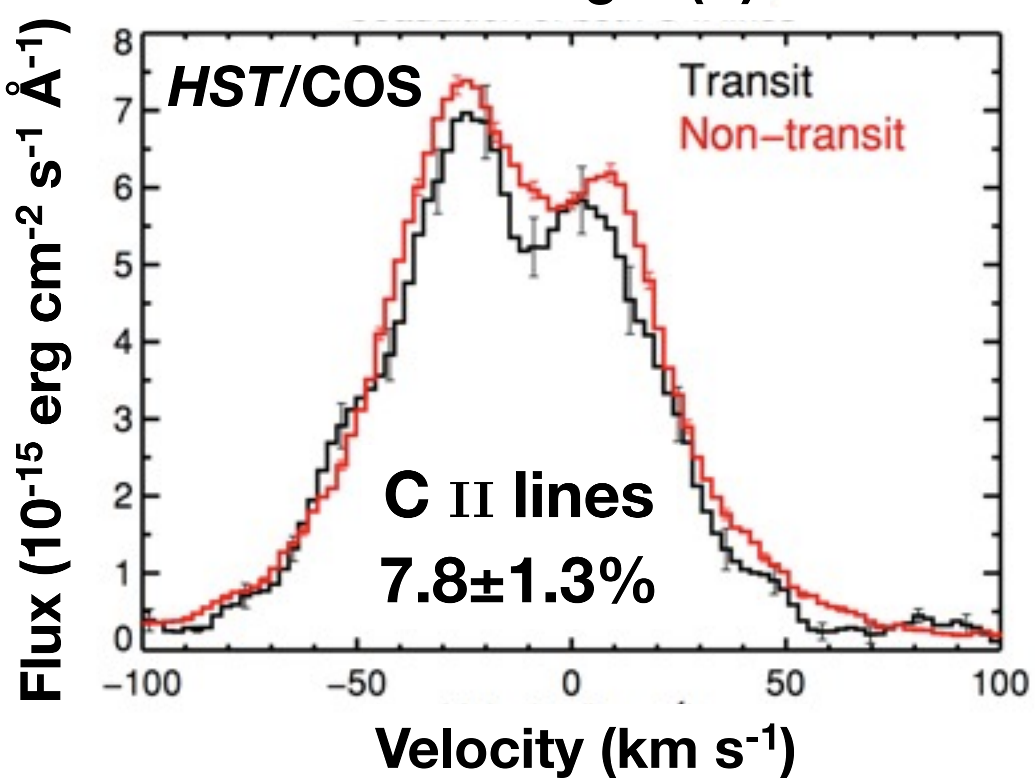


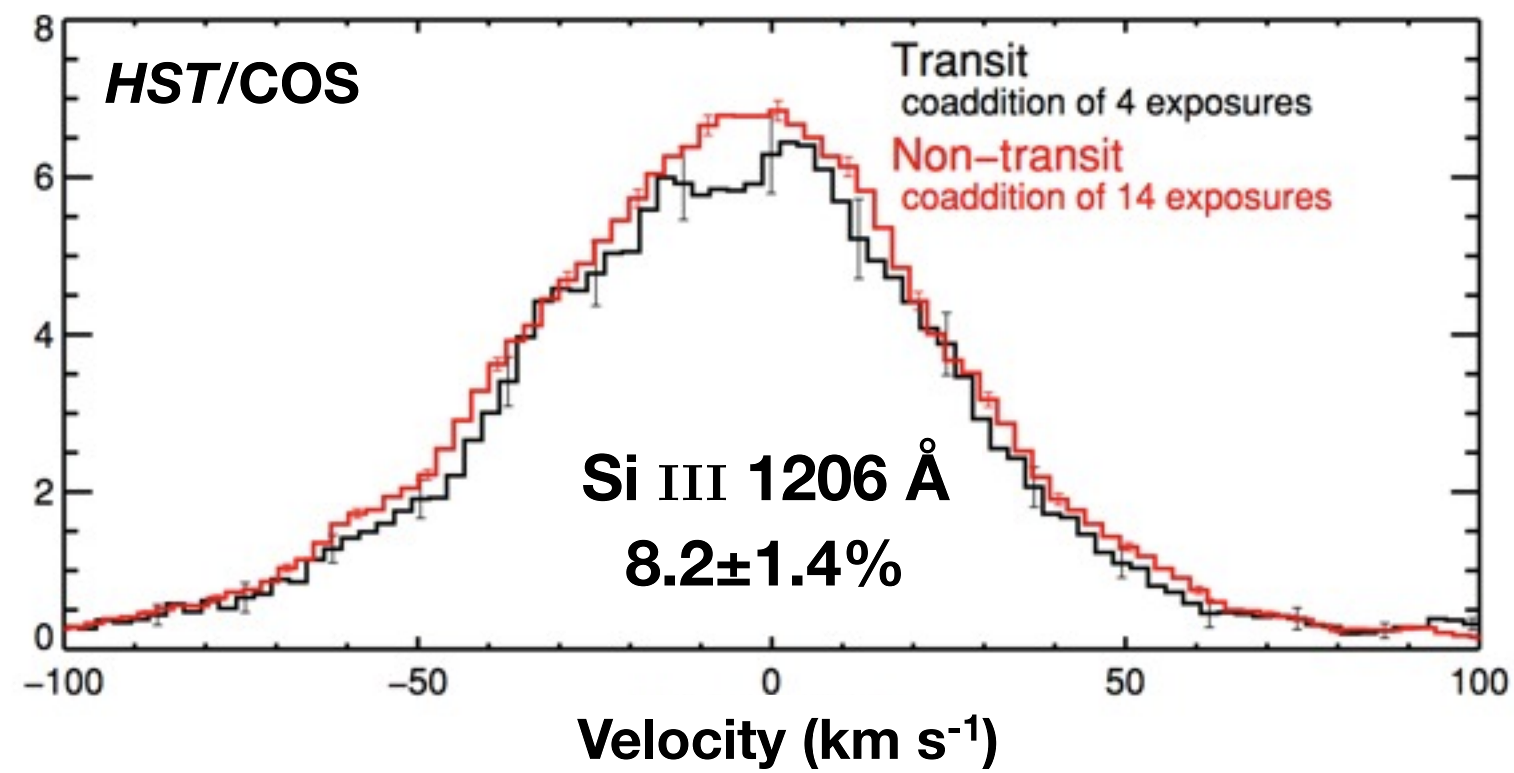
Transits in **H I Lyman-α** (1216 Å)

➡ Exospheric studies (dynamics & composition)

Escape of light & **heavy** elements from HD209458b







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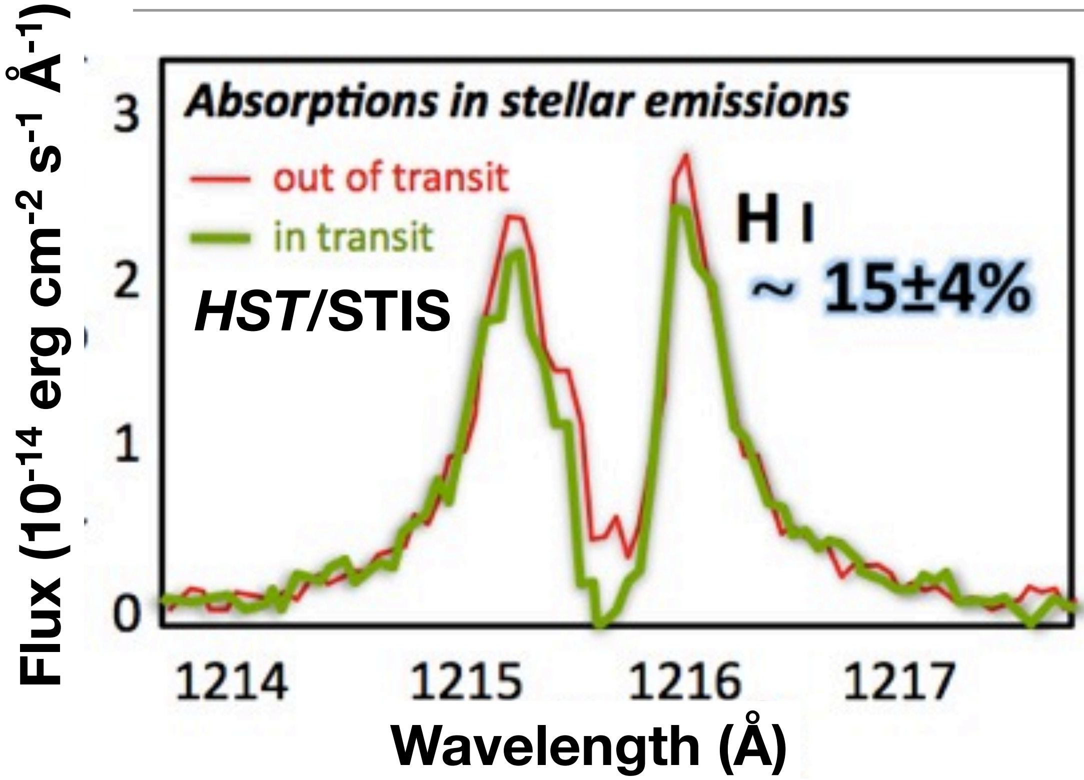
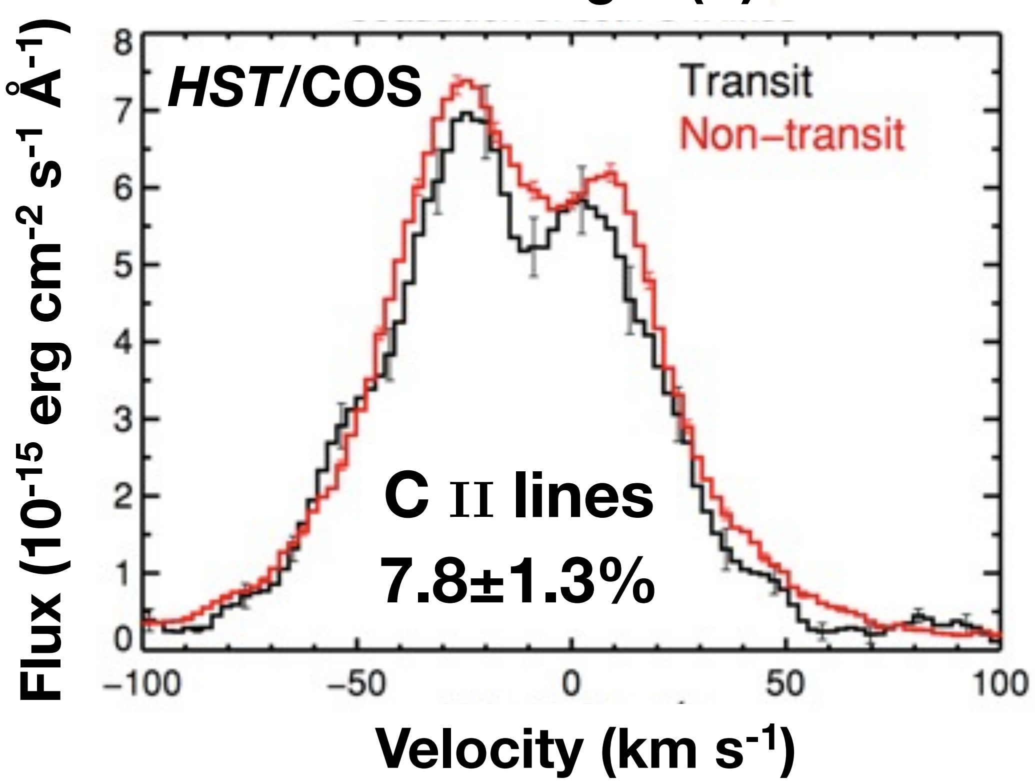
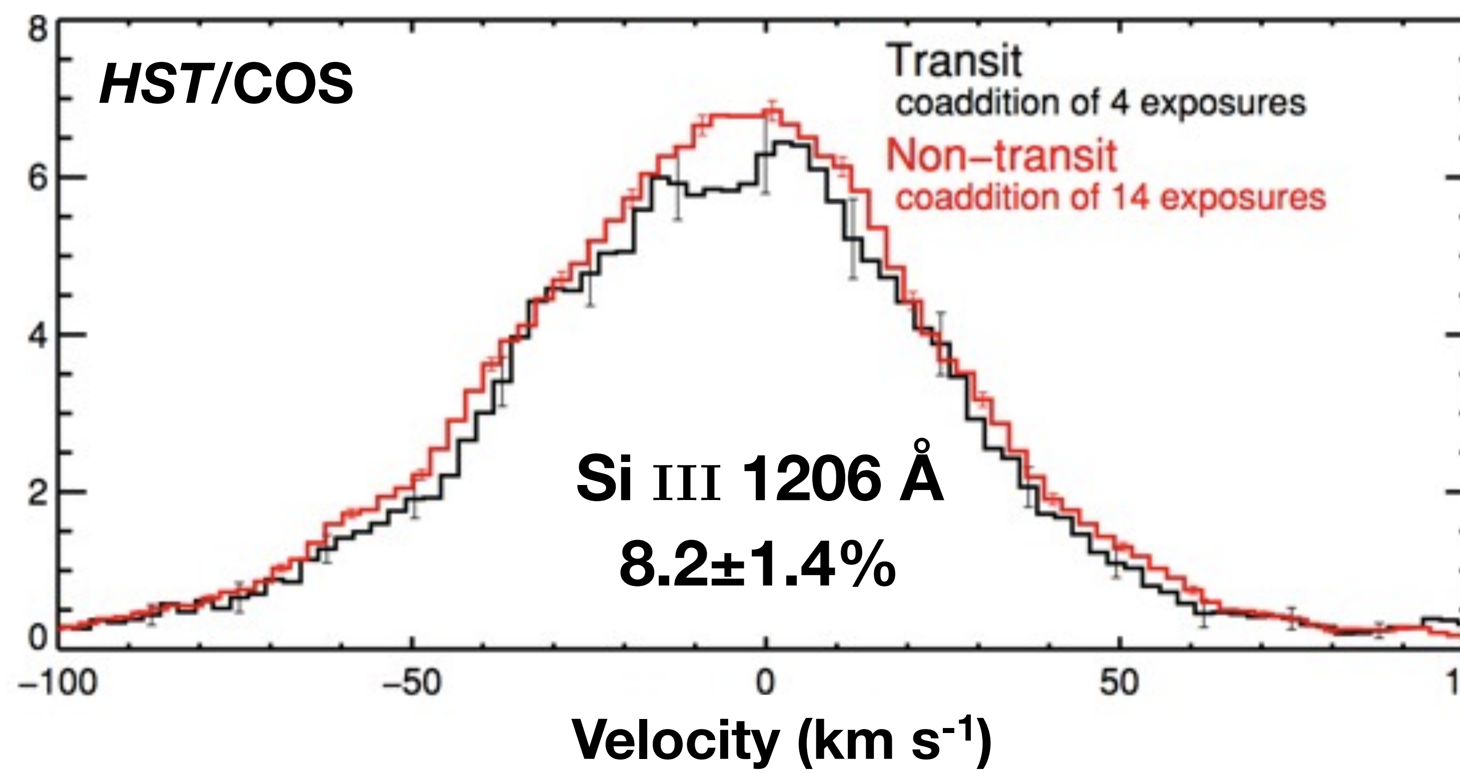


➡ Hydrodynamical mass loss

H flow carrying up heavier species





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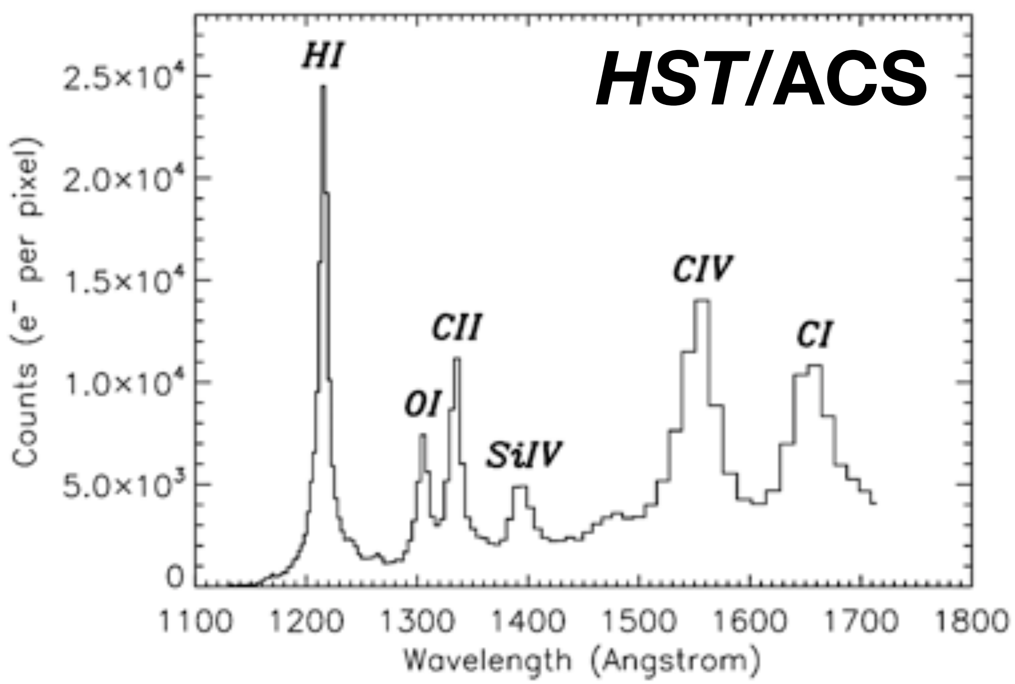
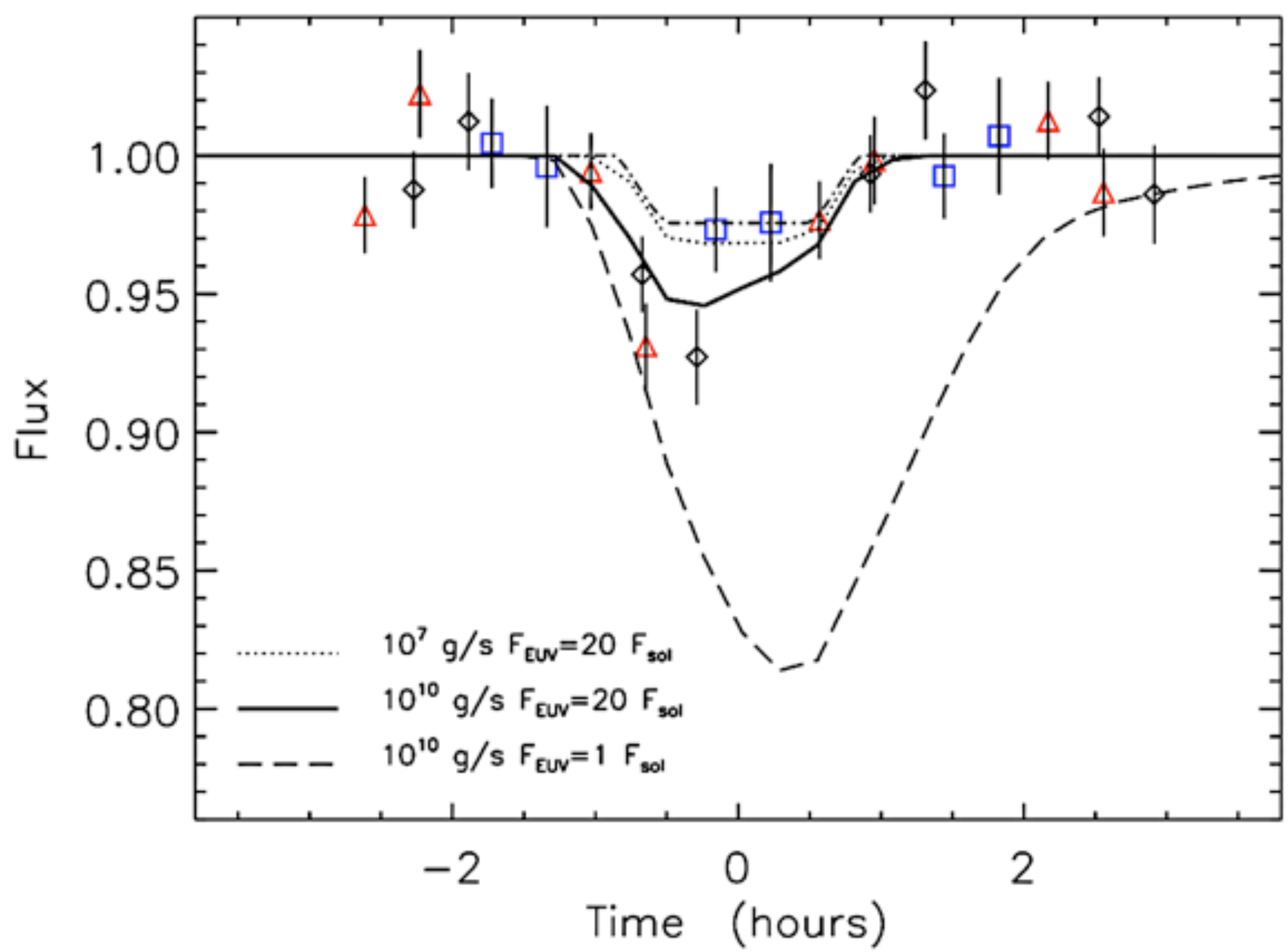
Another case of evaporating hot jupiter: **HD 189733b**





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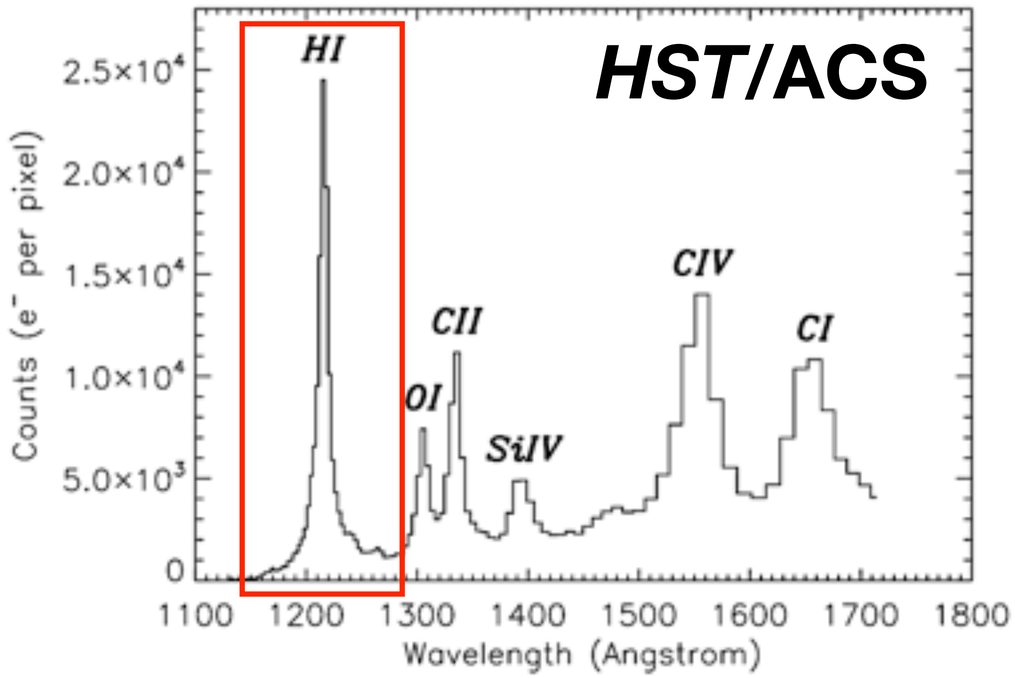

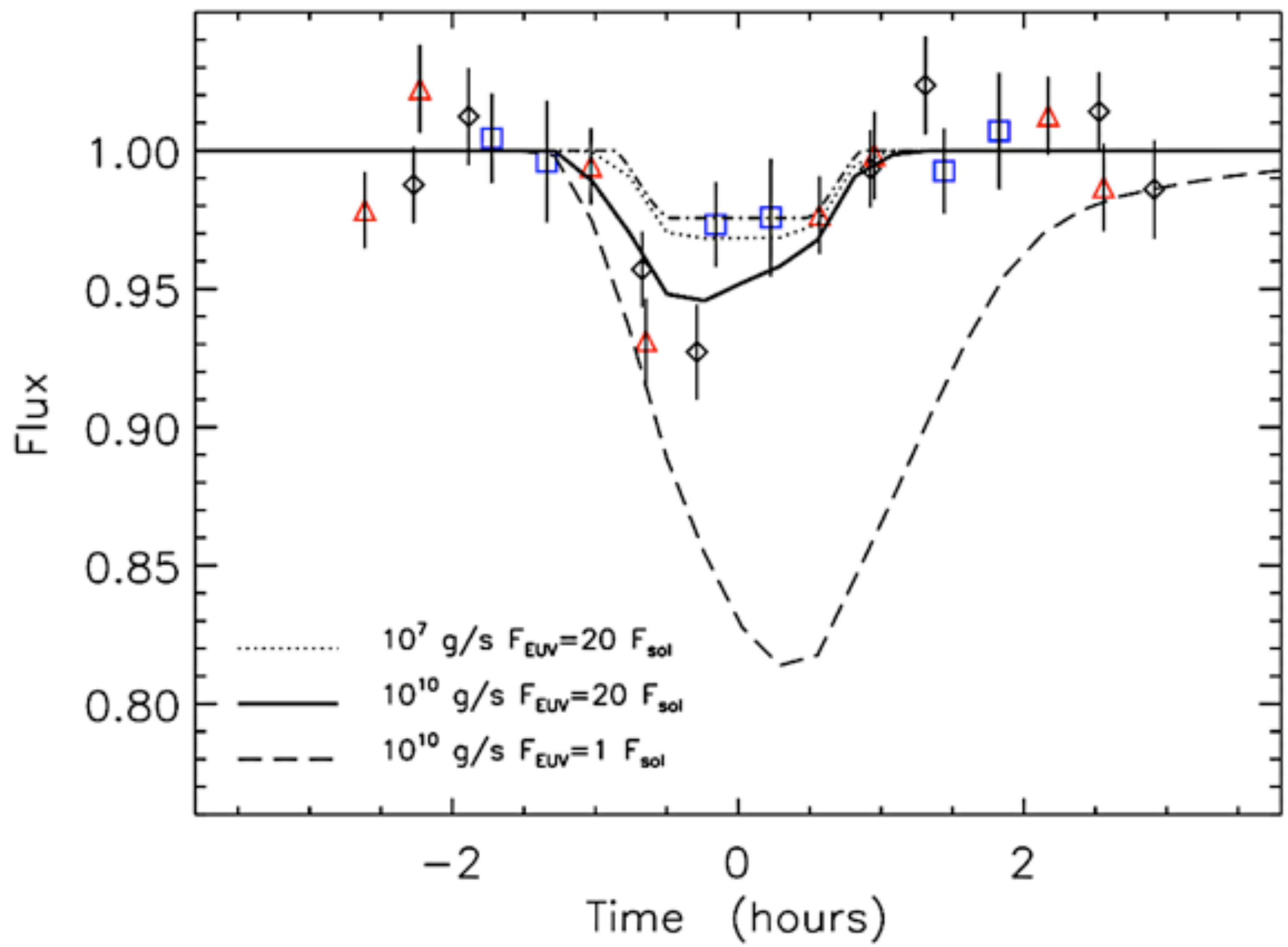

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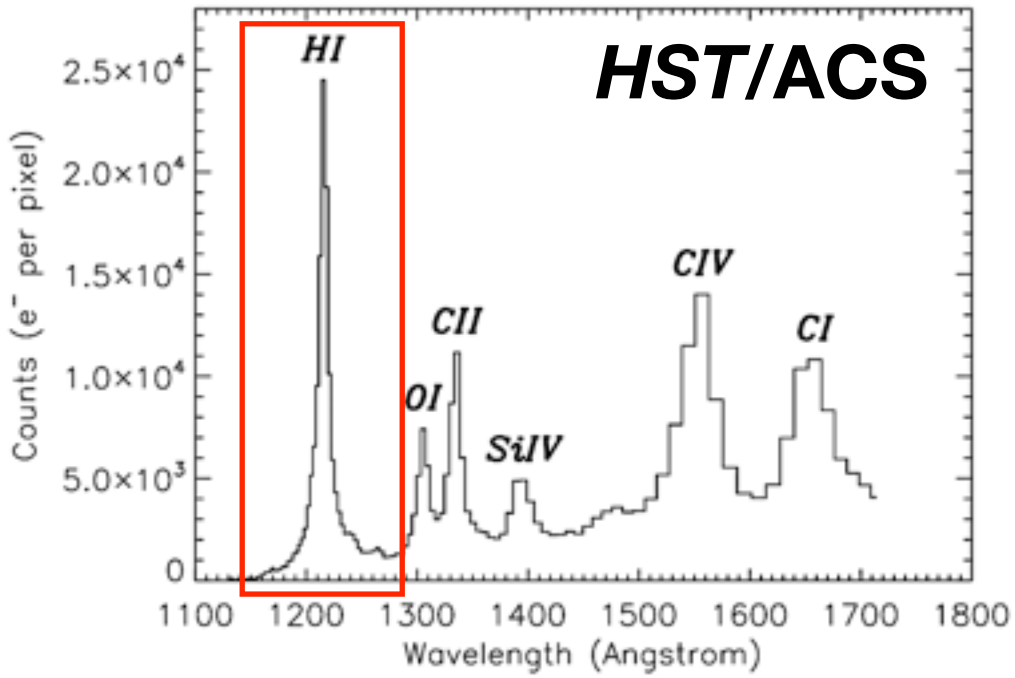

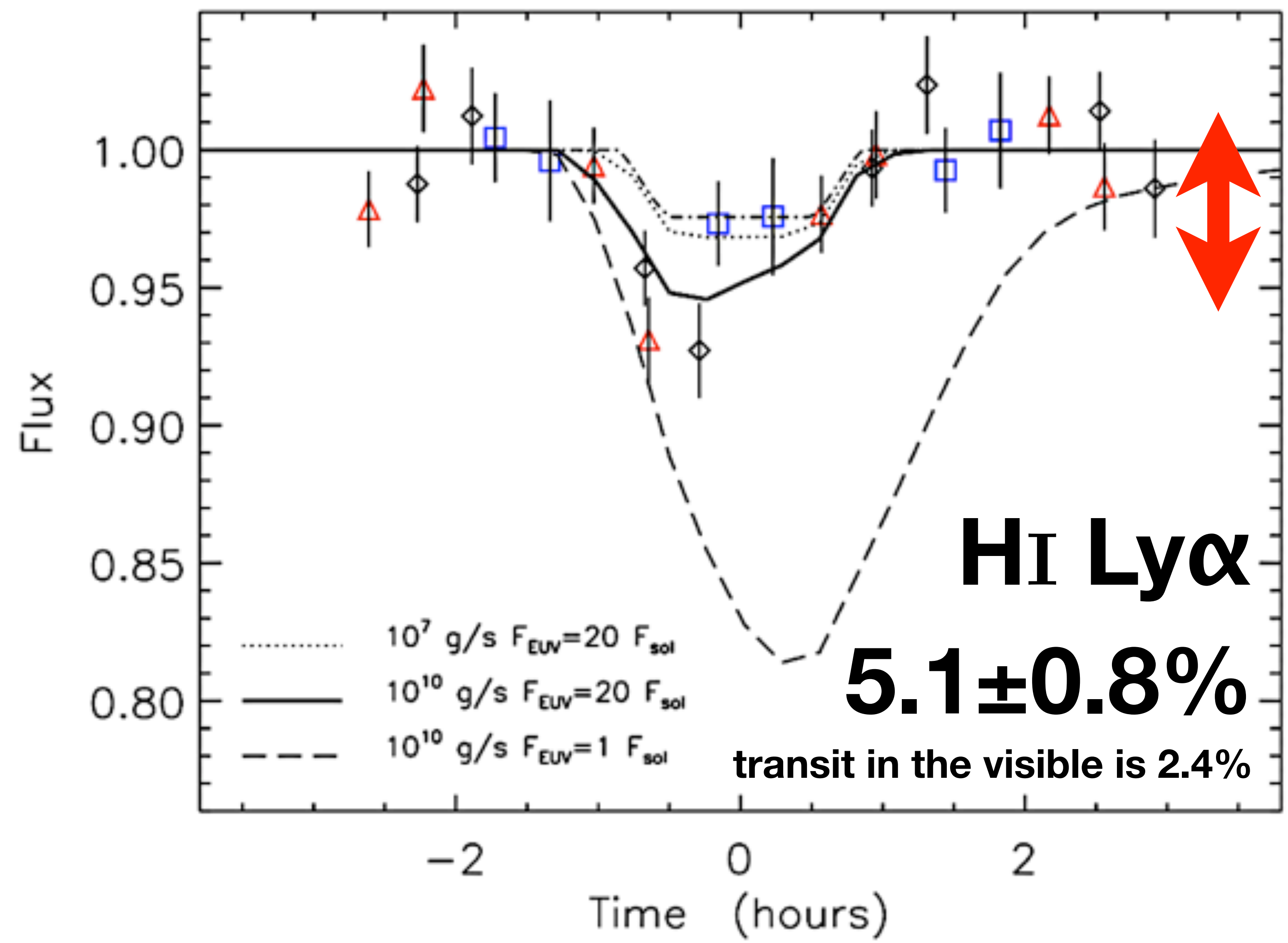

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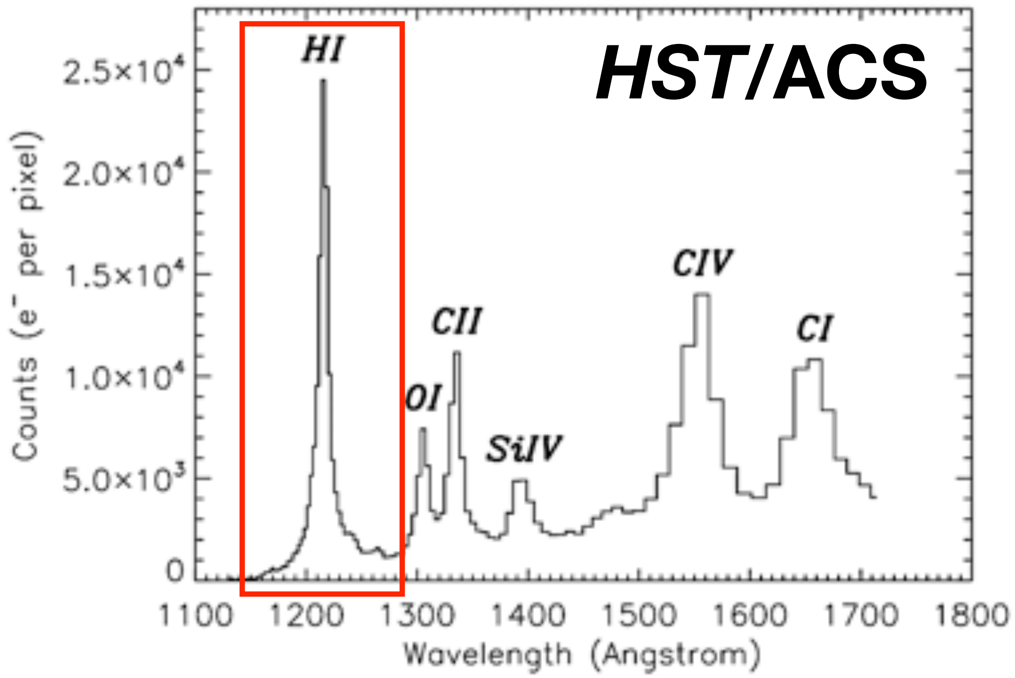
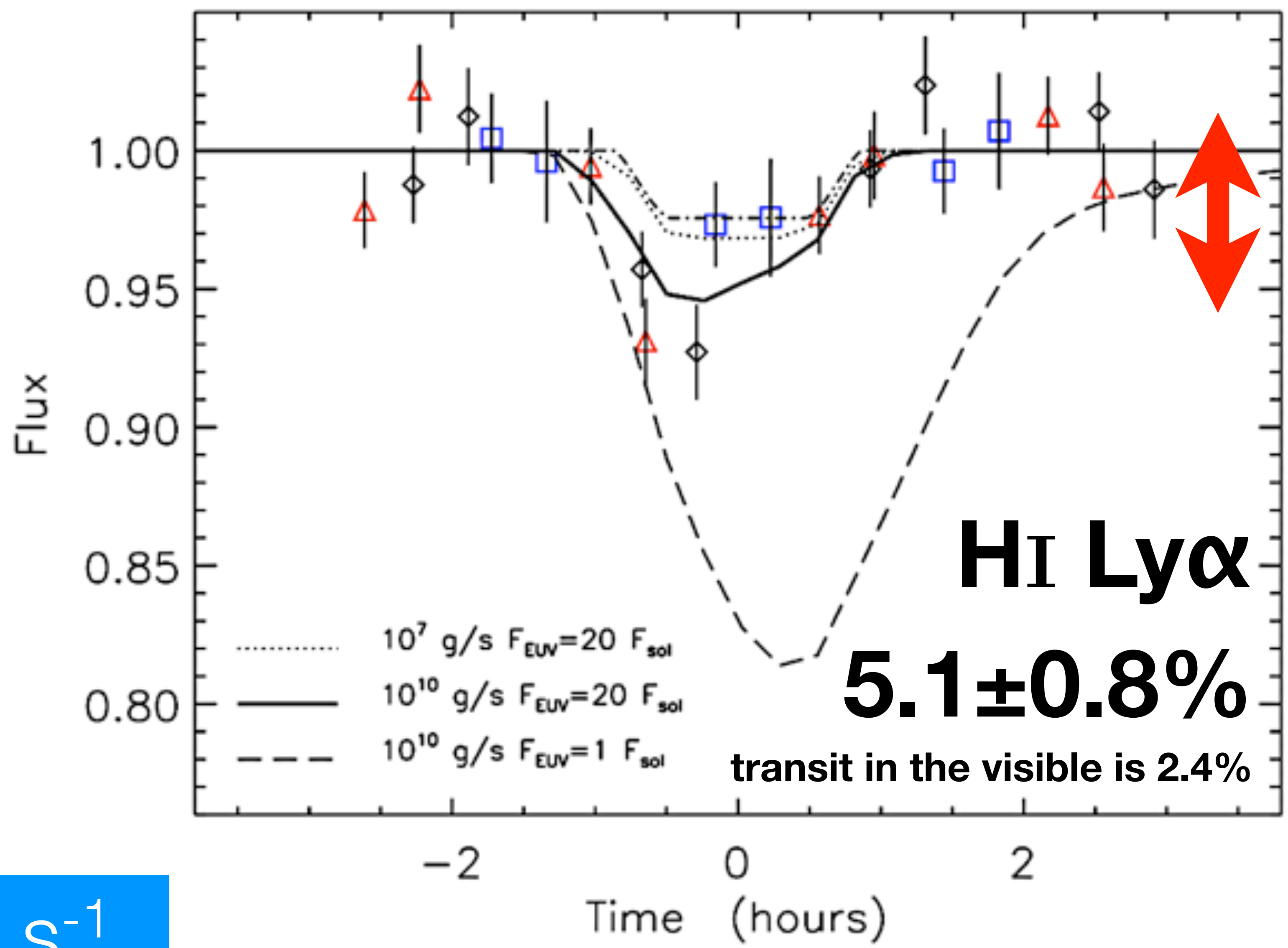




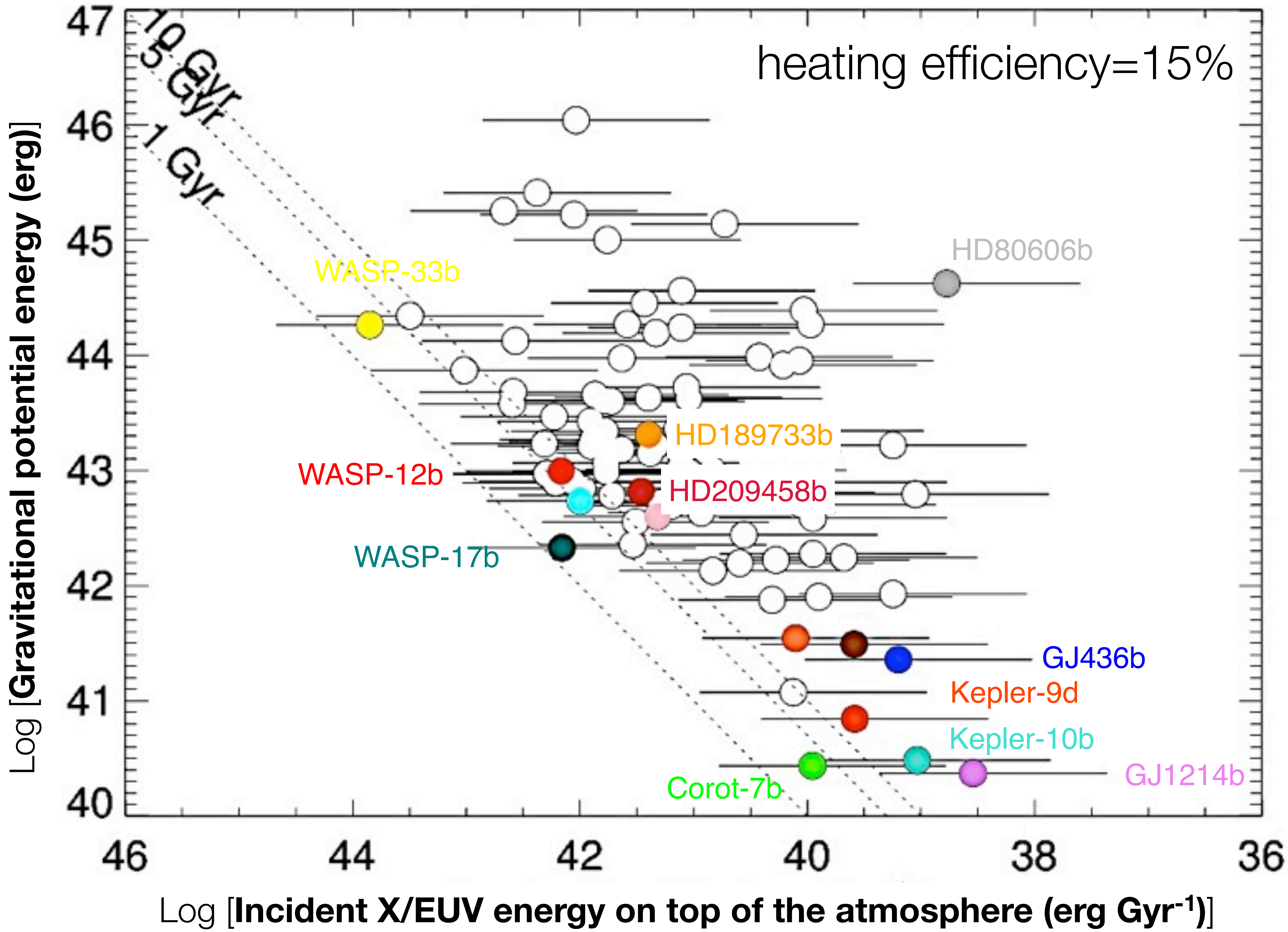
mass-loss rate ~ 10^{10} g s^{-1}

hot jupiters are stable

➡ lifetime estimations

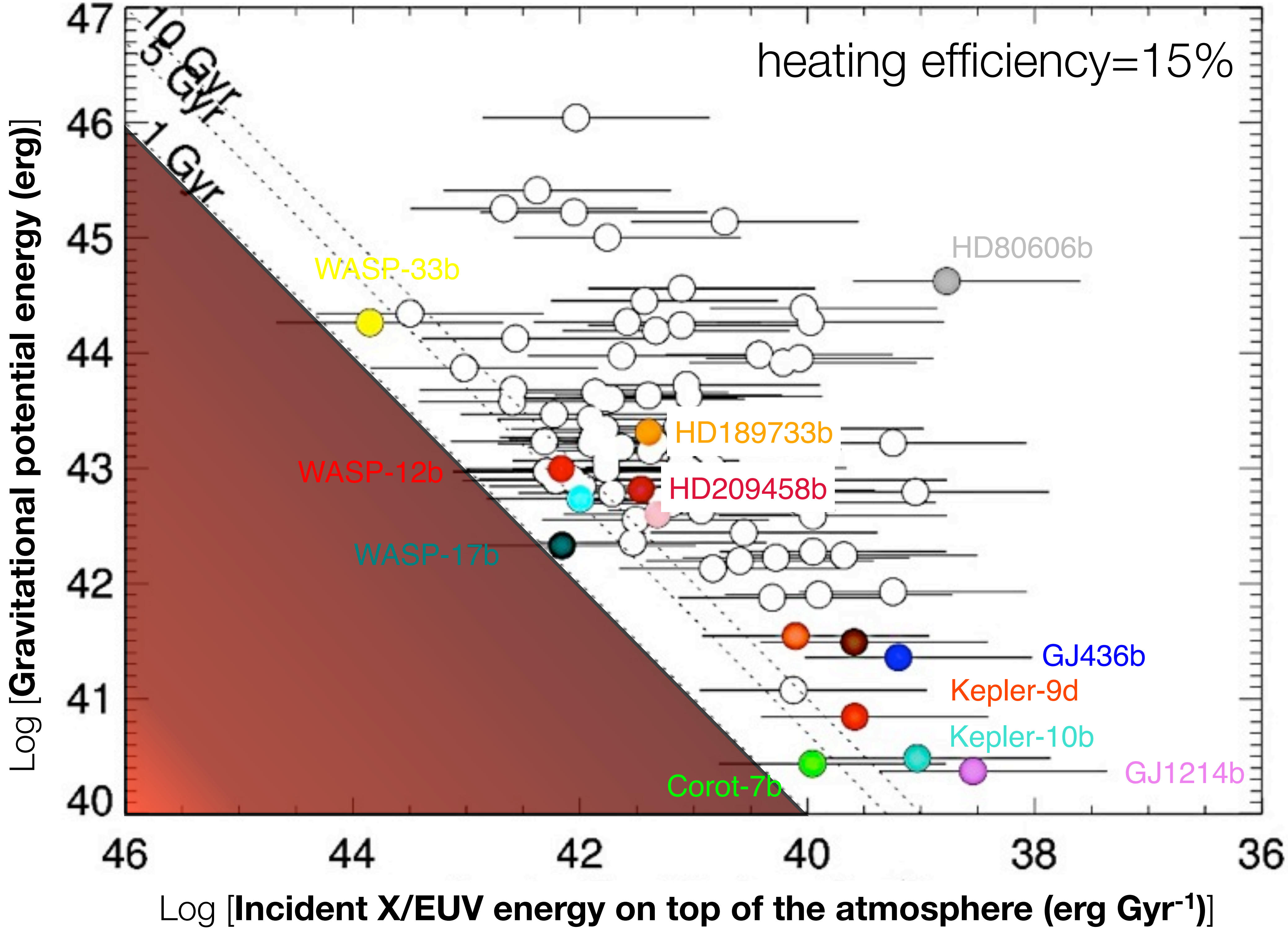
Lecavelier des Etangs *et al.* (2010)

Lifetime



Ehrenreich & Désert (2011) • also: Lecavelier (2007) • Davies & Wheatley (2009) • Lammer *et al*. (2009)

Lifetime



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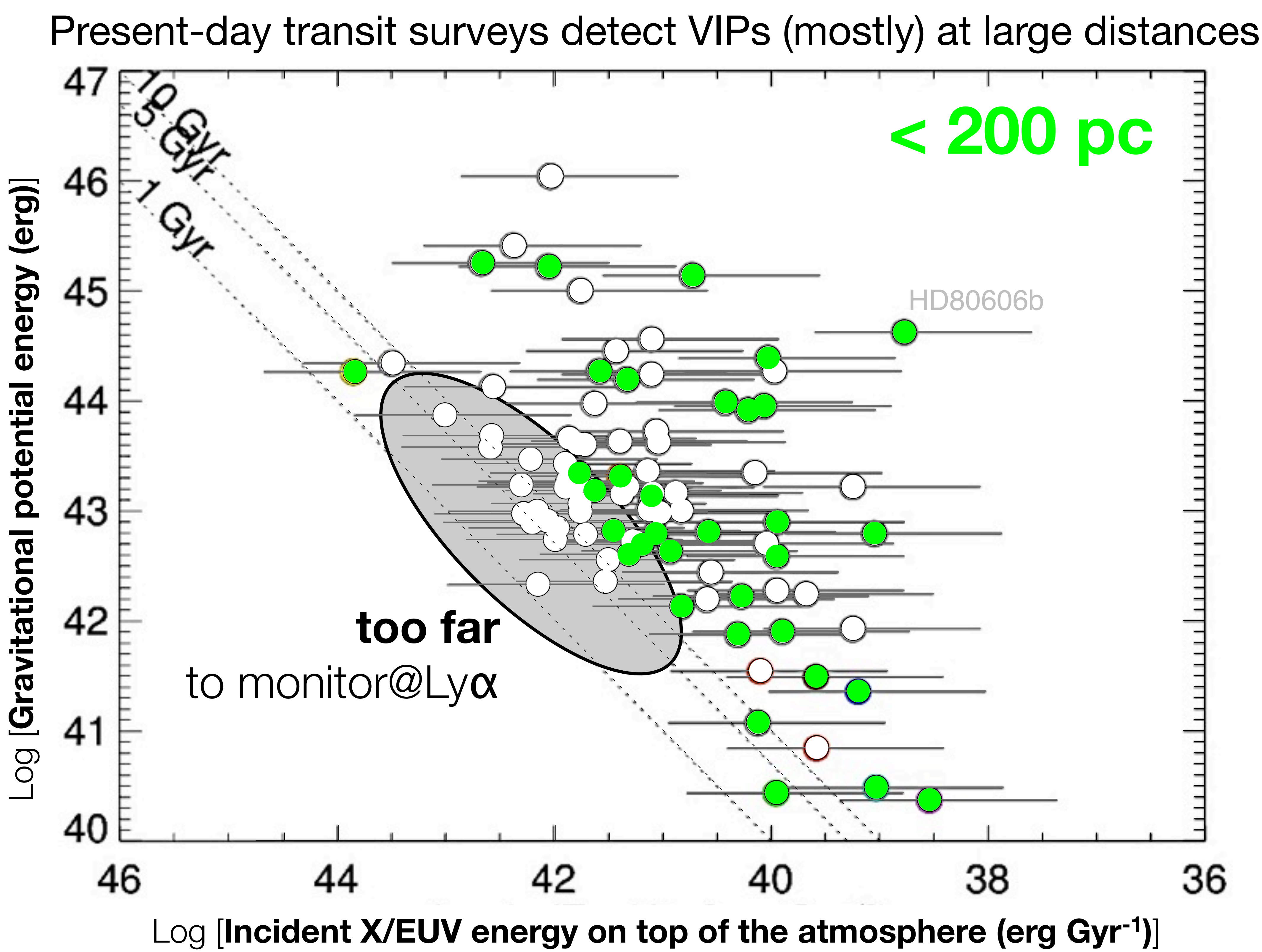
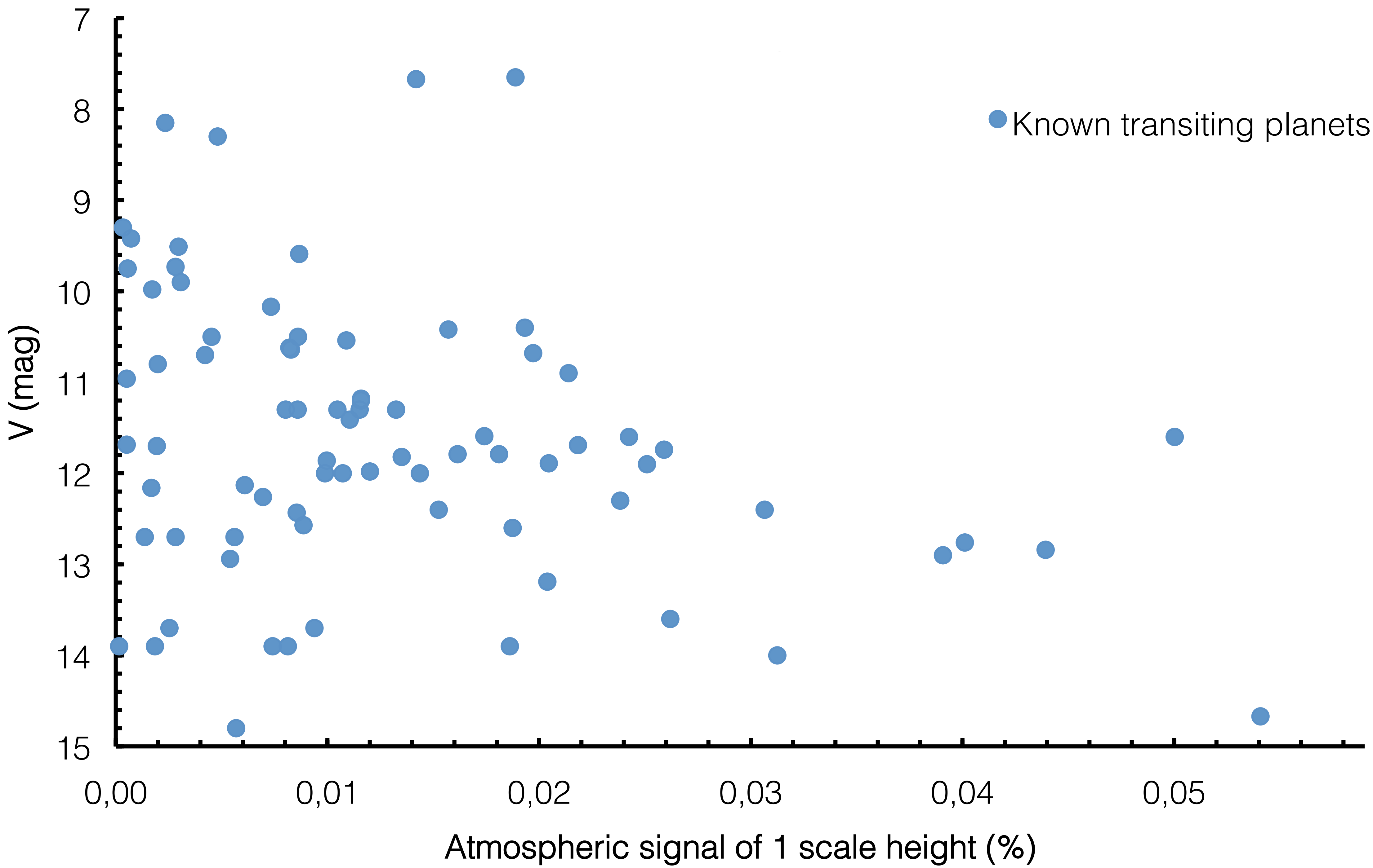


Atmospheric tracer (HI) absorbed by ISM ➡ nearby targets necessary!

PLATO will survey 5000+ nearby M-dwarf stars bright@Lyα

Why we need PLATO



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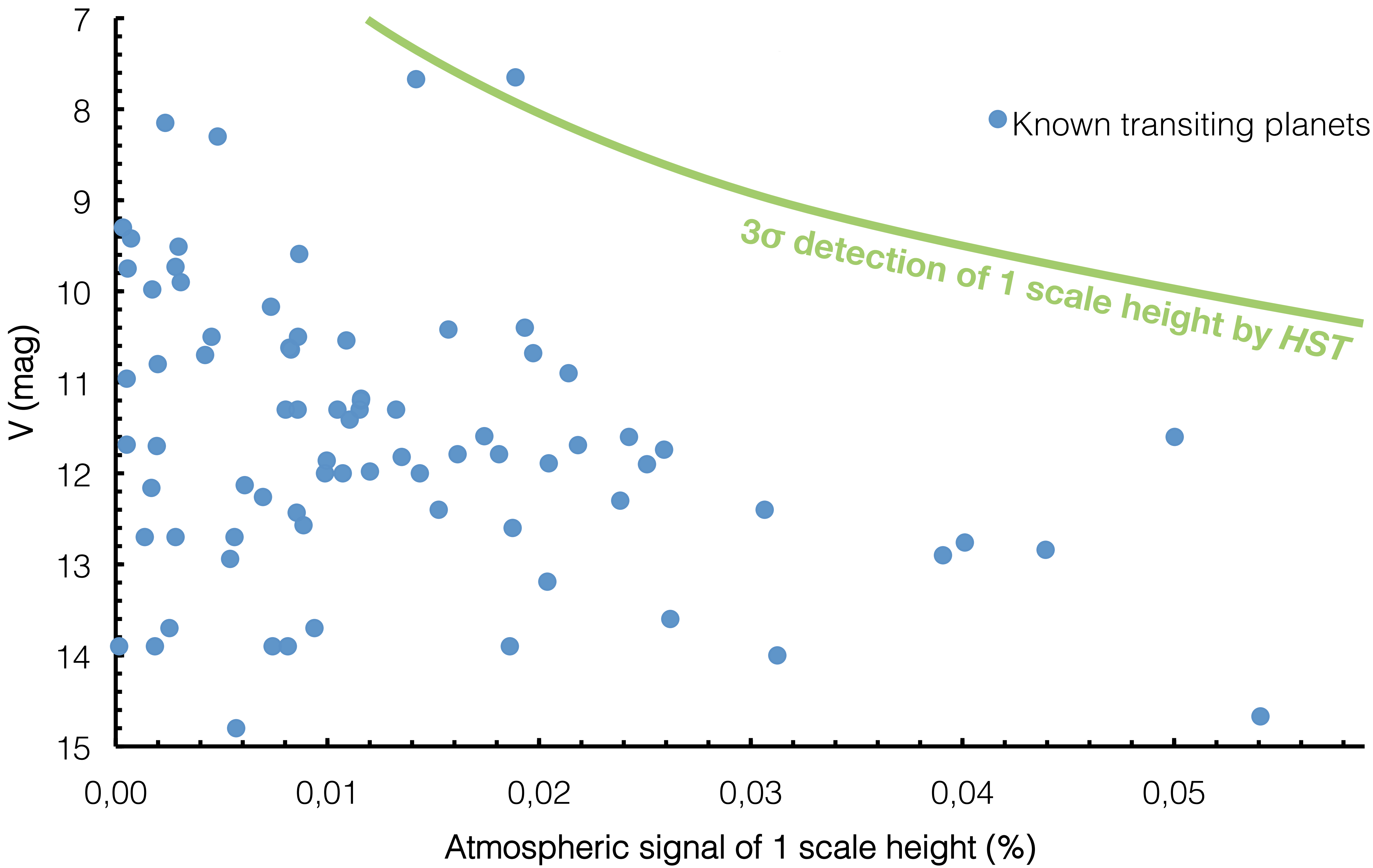

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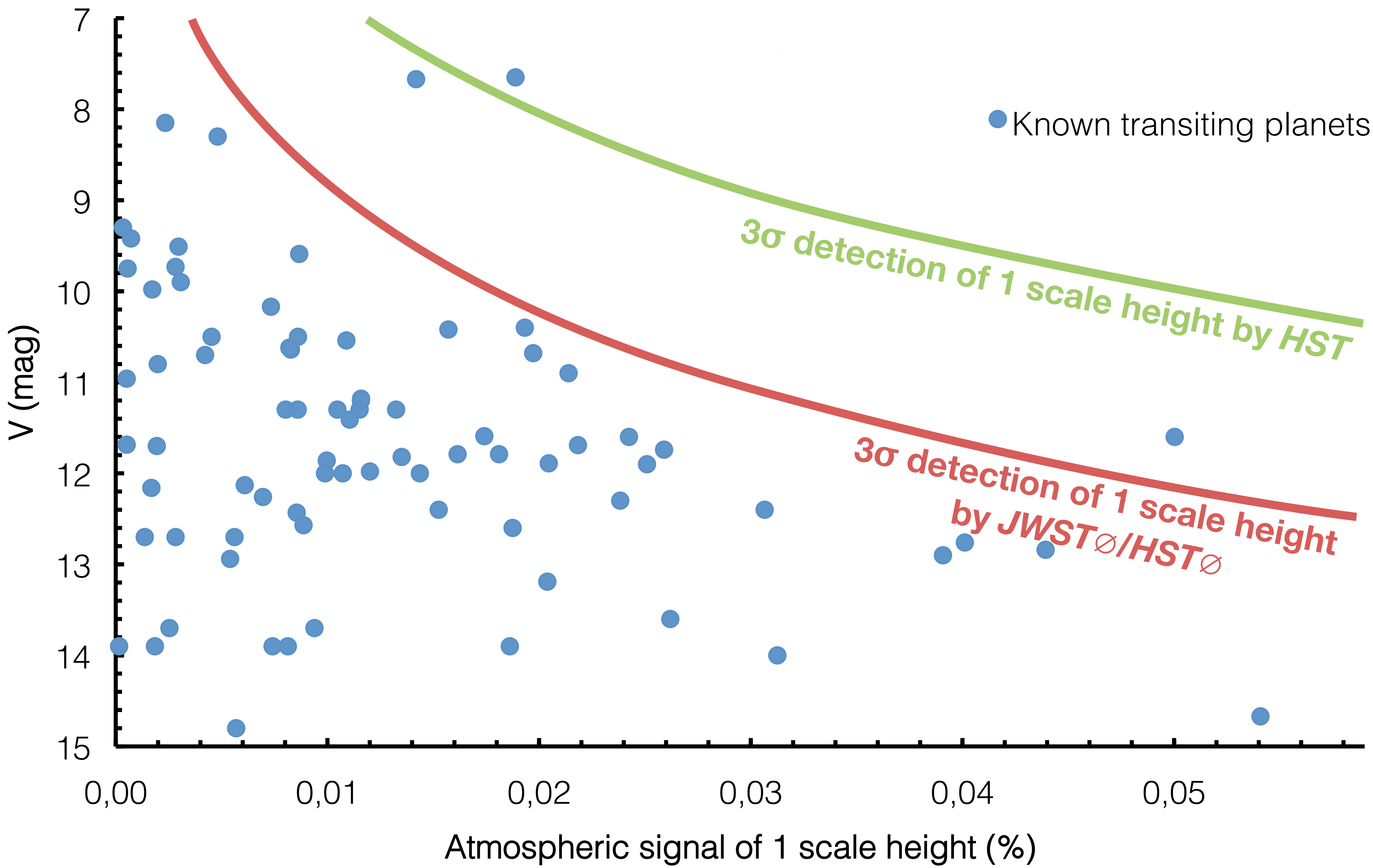

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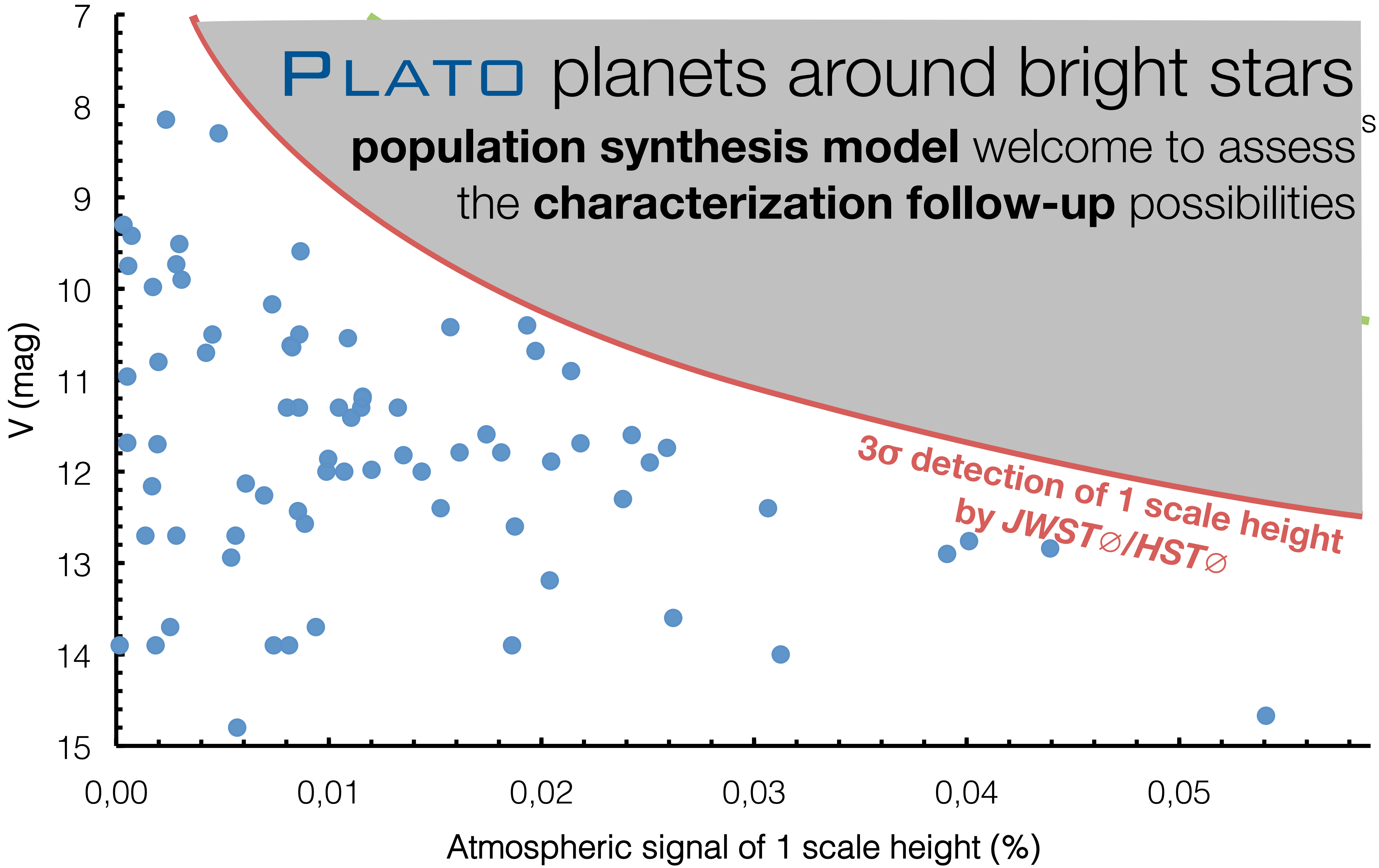

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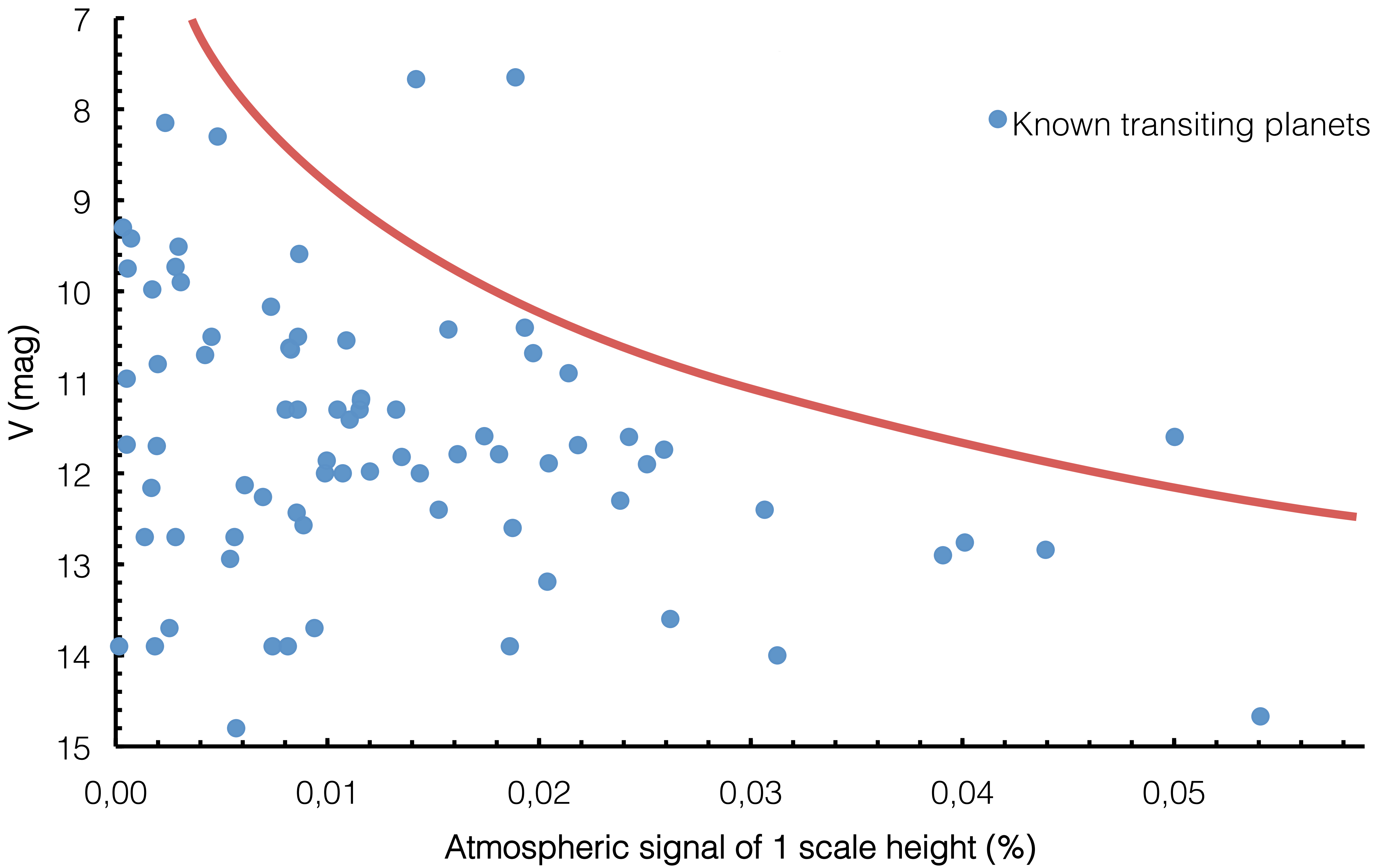

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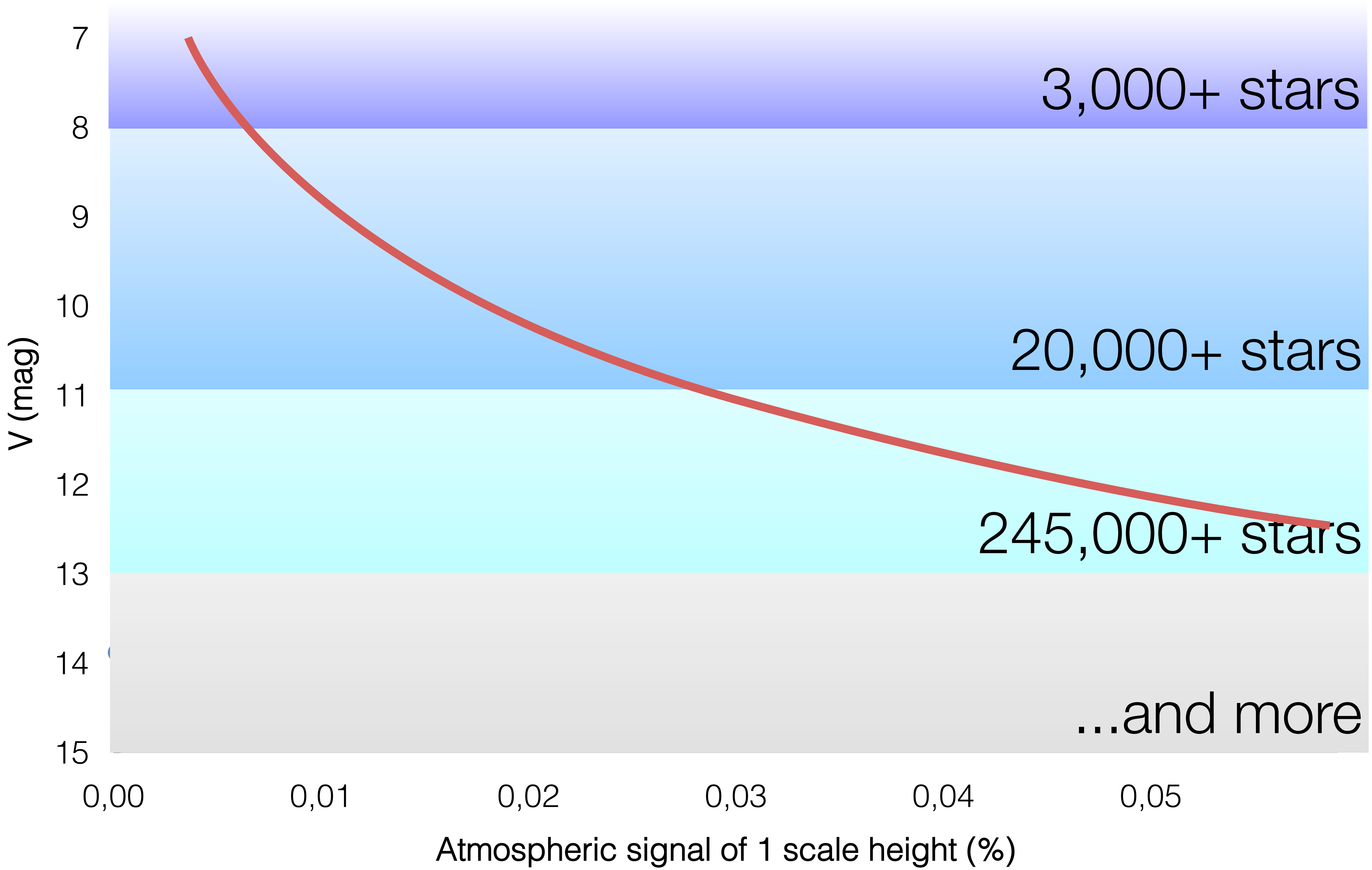

Thank you!