Challenges in Exoplanet Research for the UV

David Sing

UNIVERSITY OF EXETER

Challenges in UV Astronomy
Garching 7 Oct 2013

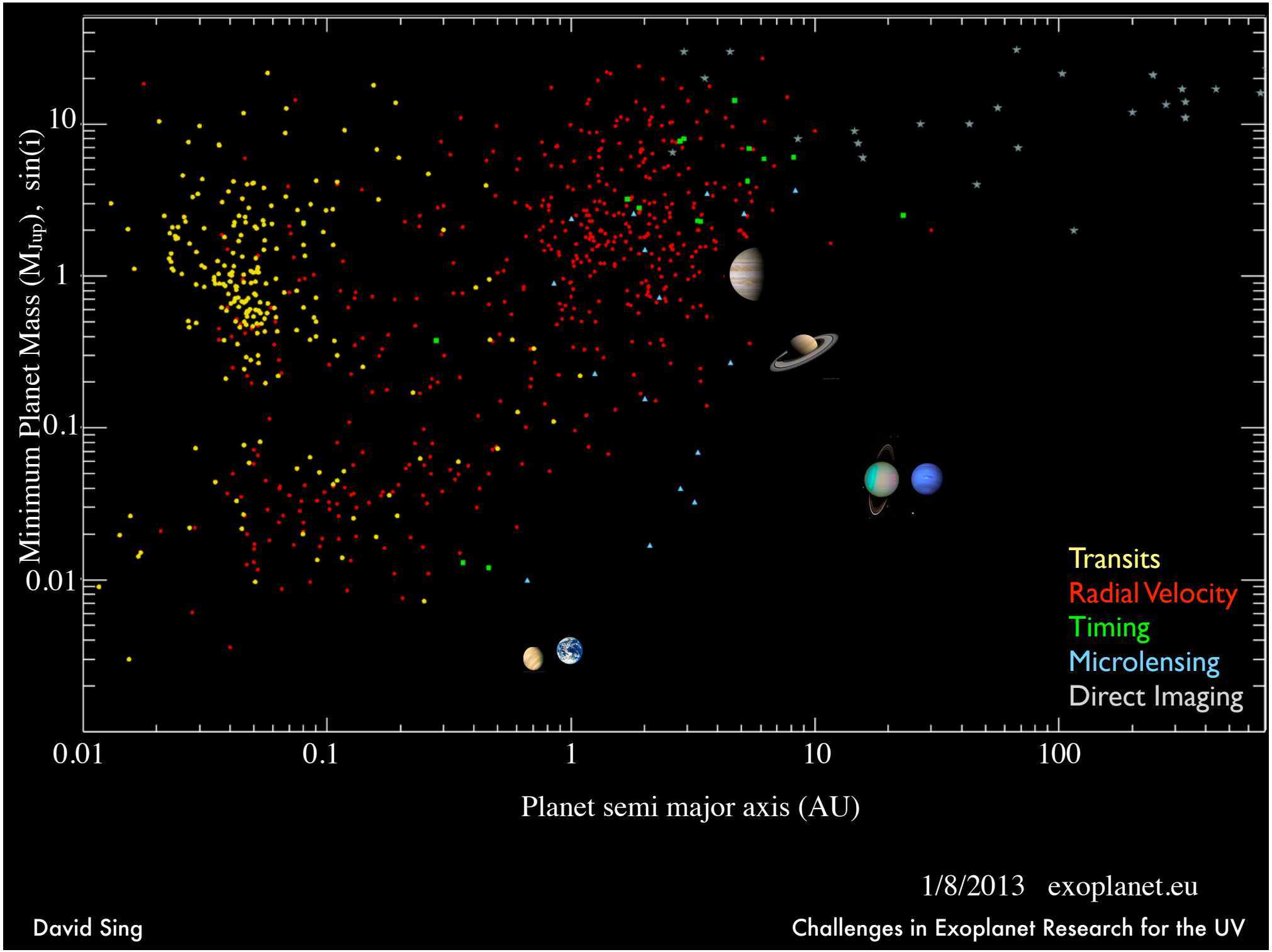
ESO
erc European Research Council Established by the European Commission
Science & Technology Facilities Council

Collaborators

Catherine Huitson	Exeter, UK / U of Colorado
Alain Lecavelier des Etangs	IAP, France
Alfred Vidal-Madjar	IAP, France
V. Bourrier	IAP, France
Gilda Ballester	U of Arizona
Jean-Michel Desert	U of Colorado
D. Ehrenreich	Geneva, Switzerland

Outline

- Exoplanet Overview
- Exoplanet Results
  - Escaping Atmospheres
  - Hot Jupiters
- Future Science
  - Escape Mechanism
  - Smaller Planets


Minimum Planet Mass (M_{Jup}), sin(i)
10
1
0.1
0.01
0.01
0.1
1
10
100
Planet semi major axis (AU)
Transits
Radial Velocity
Timing
Microlensing
Direct Imaging
1/8/2013 exoplanet.eu
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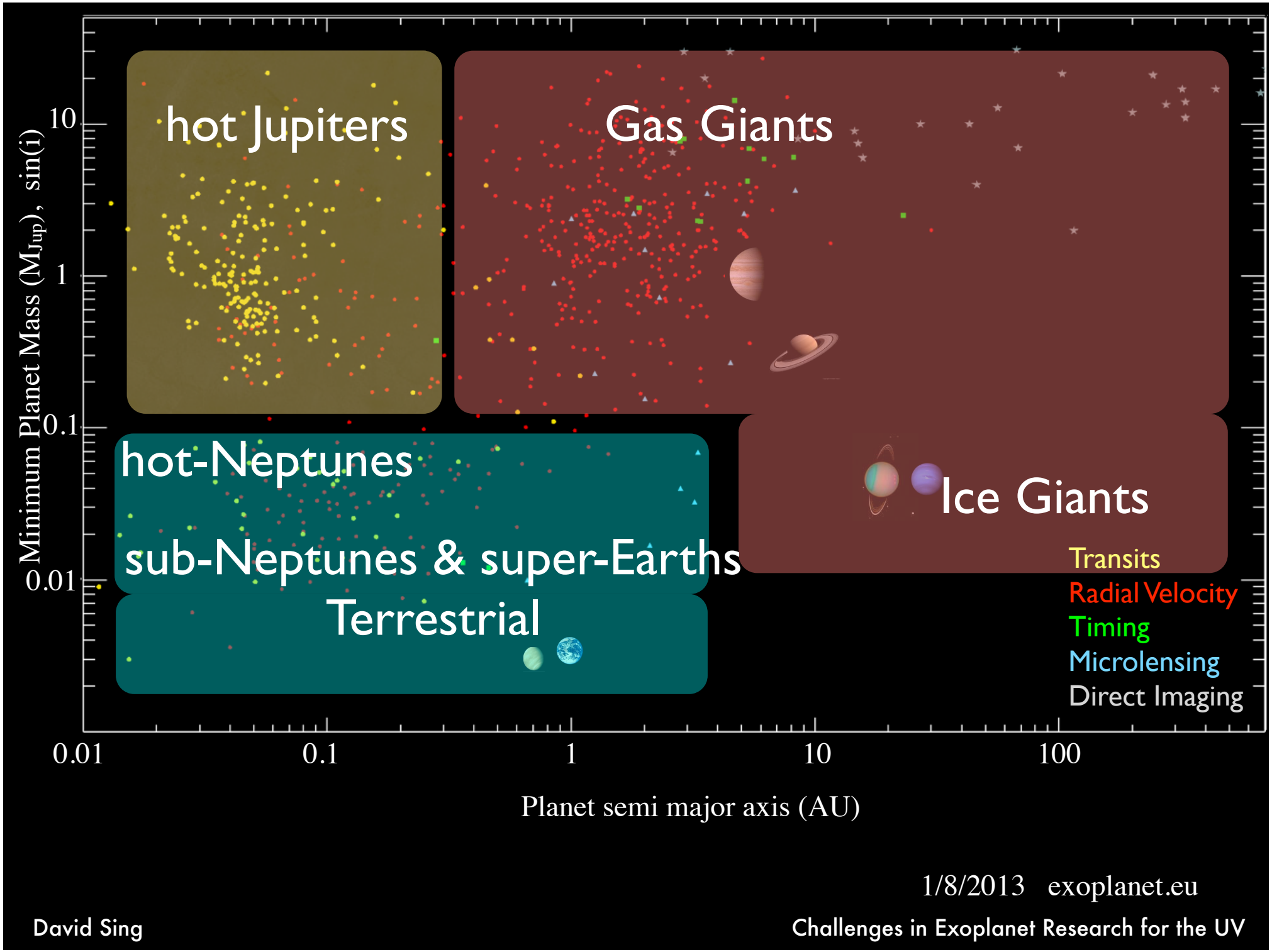
hot Jupiters
Gas Giants
hot-Neptunes
sub-Neptunes & super-Earths
Terrestrial
Ice Giants
Transits
Radial Velocity
Timing
Microlensing
Direct Imaging
Minimum Planet Mass (M_{Jup}), sin(i)
10
1
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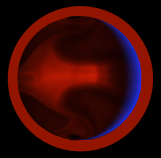
Planet semi major axis (AU)
1/8/2013 exoplanet.eu

Exoplanet Transit Spectra



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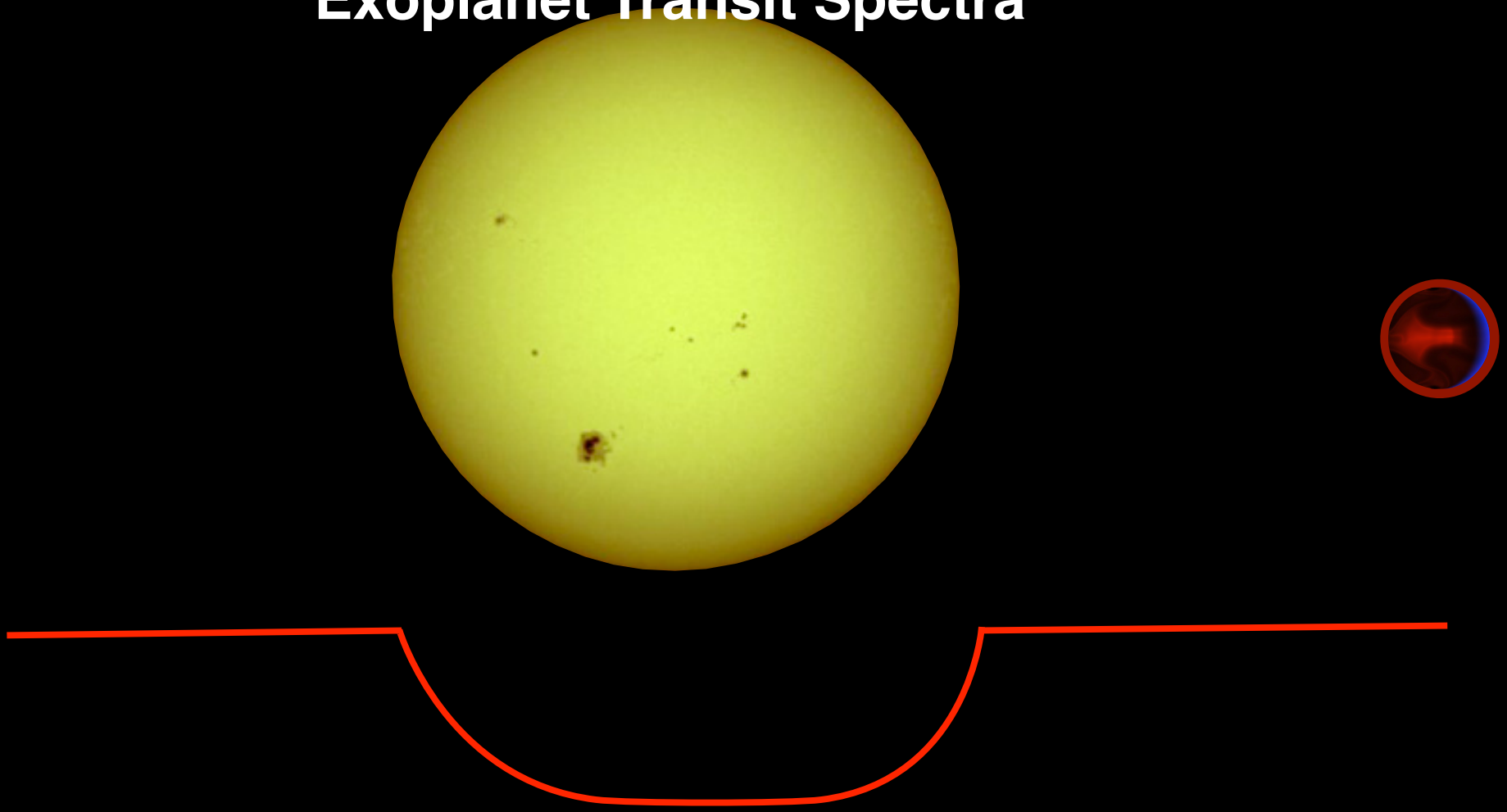
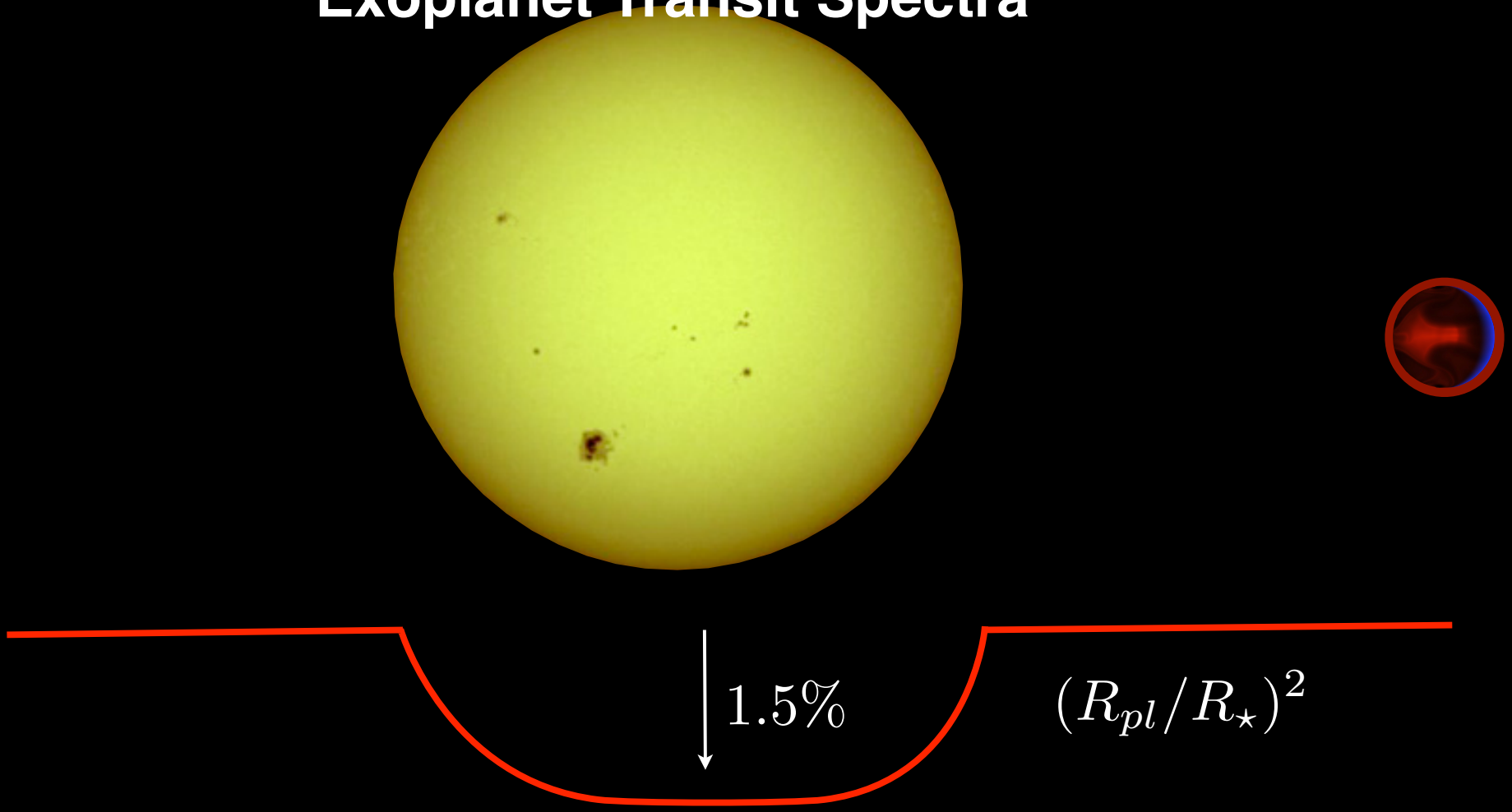
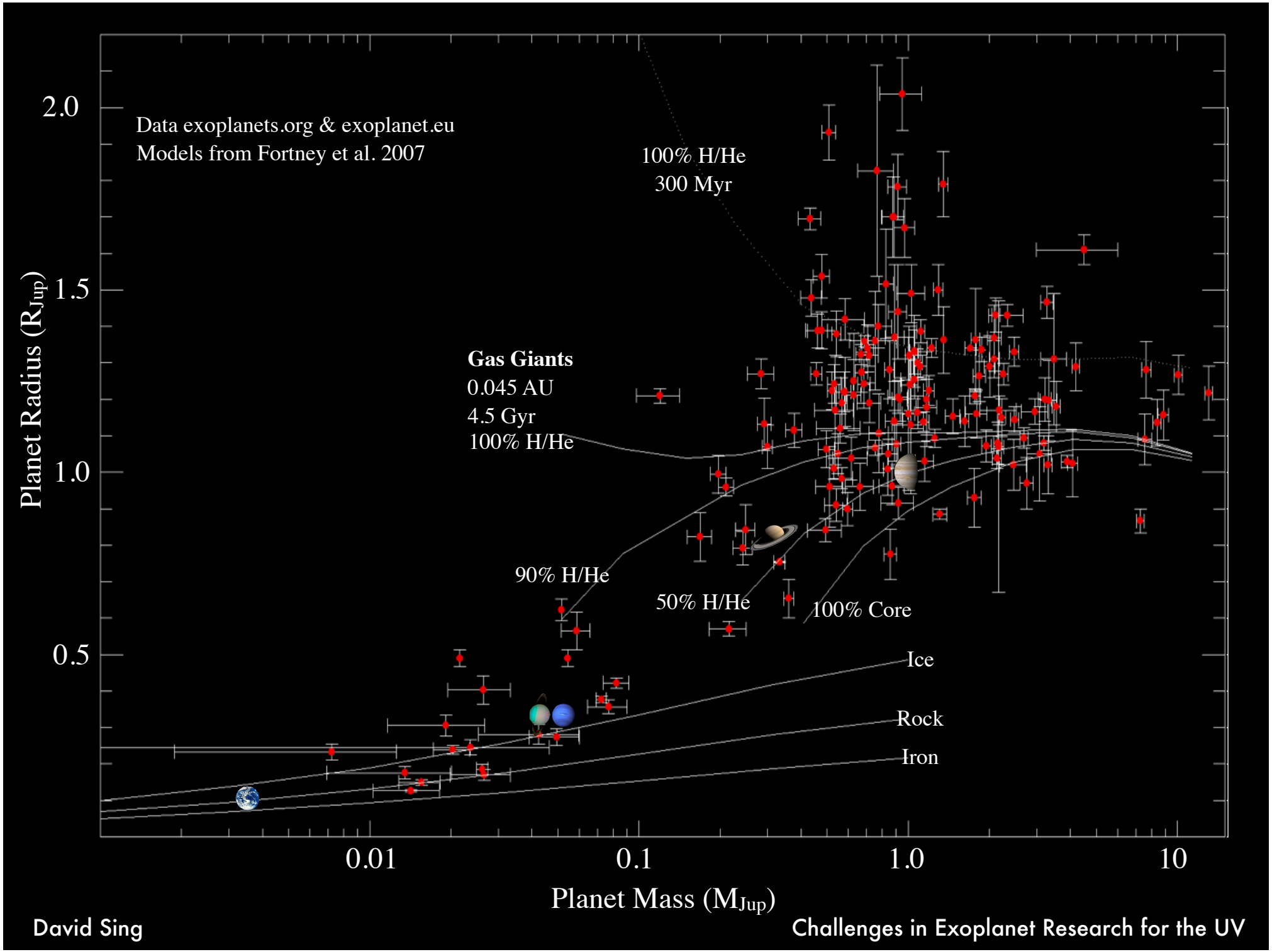
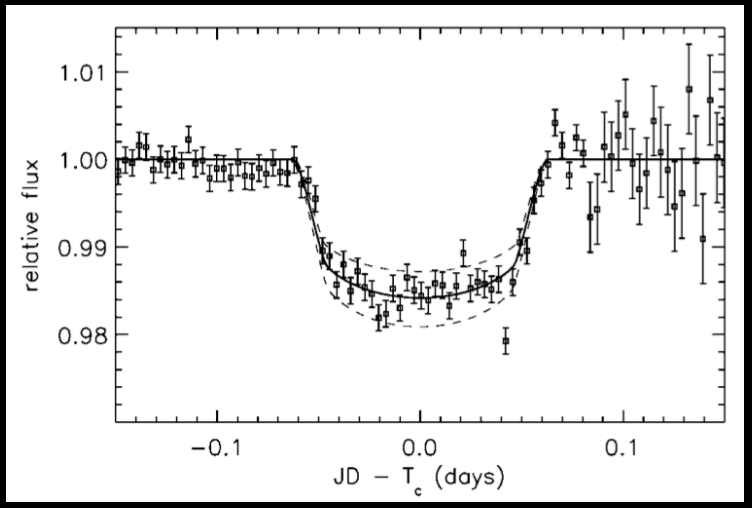


Exoplanet Transit Spectra

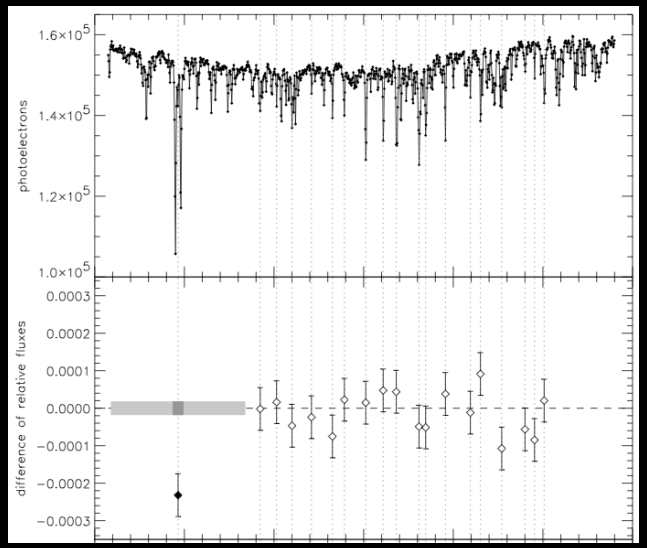



Data exoplanets.org & exoplanet.eu
Models from Fortney et al. 2007
100% H/He
300 Myr
Gas Giants
0.045 AU
4.5 Gyr
100% H/He
90% H/He
50% H/He
100% Core
Ice
Rock
Iron
Planet Radius (R_{Jup})
Planet Mass (M_{Jup})
2.0
1.5
1.0
0.5
0.01
0.1
1.0
10

Transiting Planets



First Transiting Planet: Charbonneau et al. (2000)

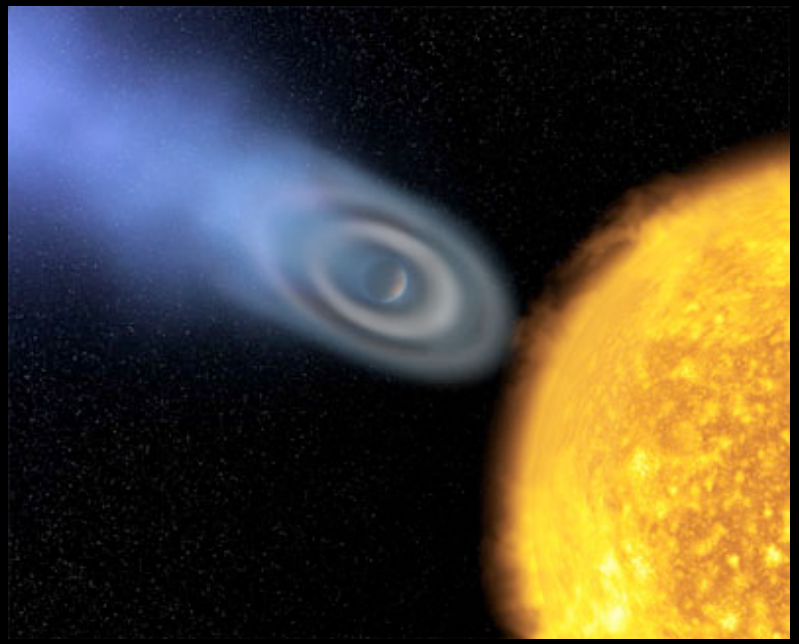


Na Signal

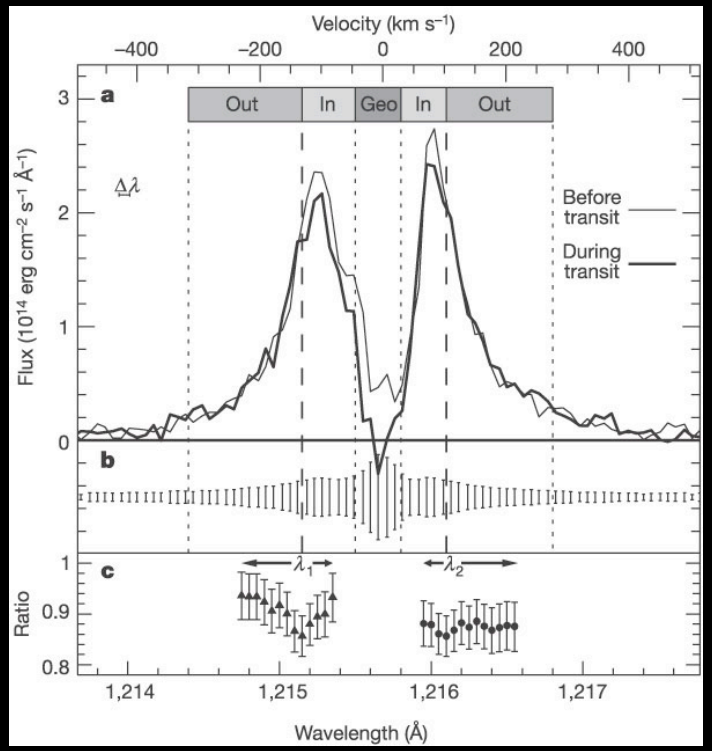
↓0.02%

Detection of Atmospheric Na: Charbonneau et al. (2002)

HD209458b

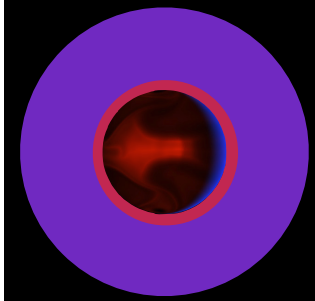


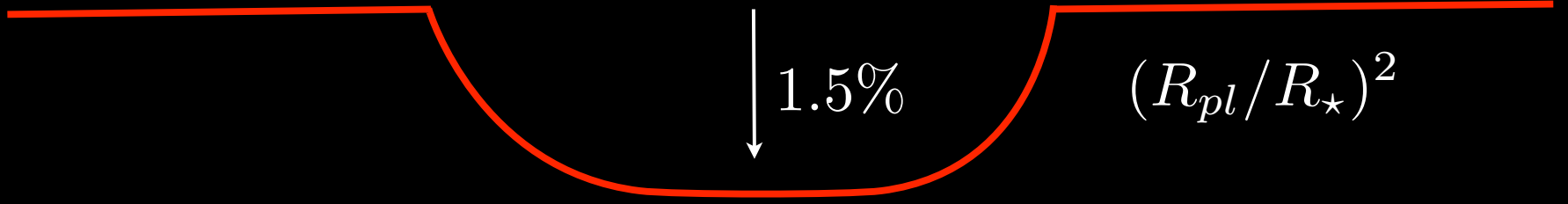
HD209458b



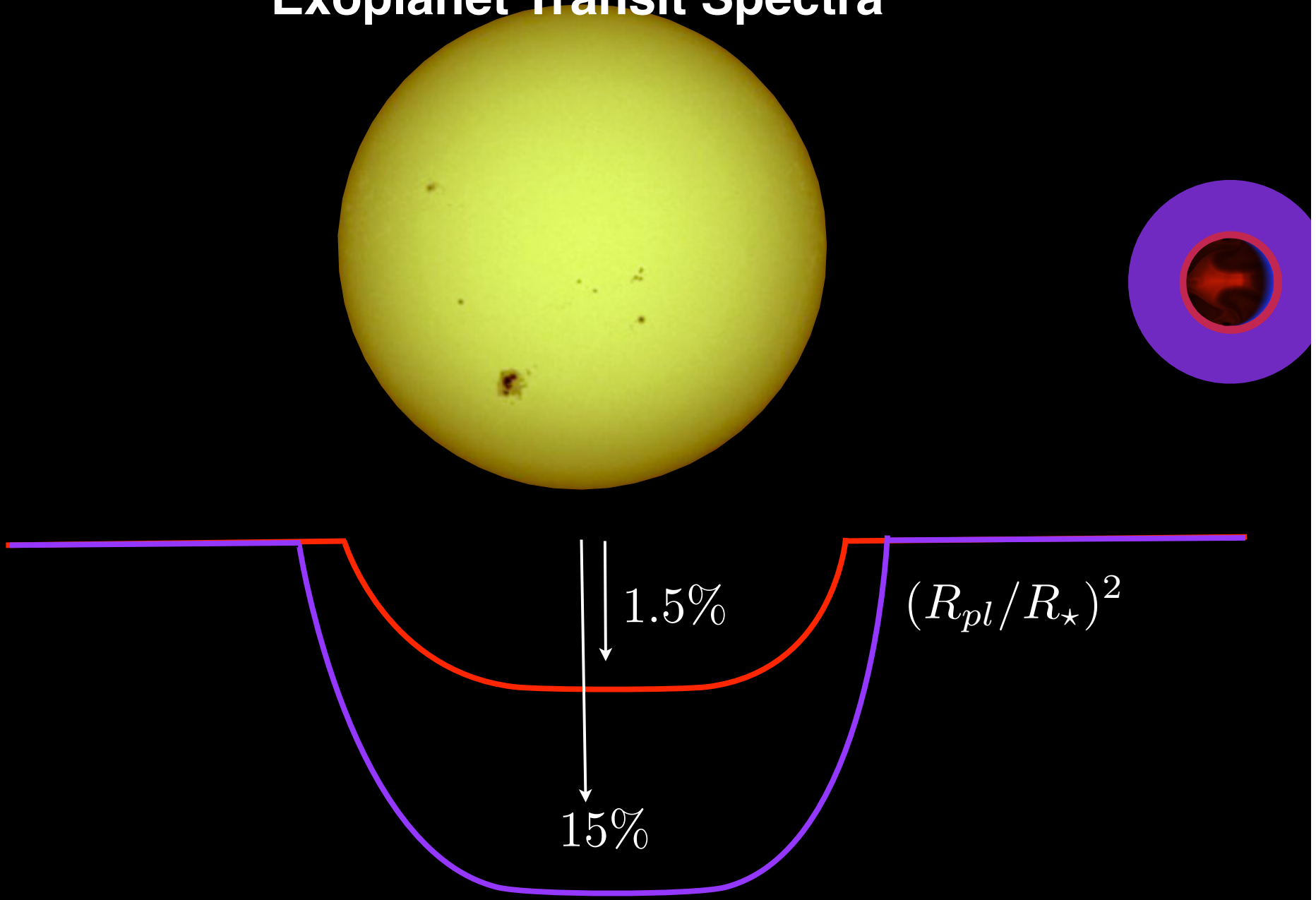
- A. Vidal-Madjar et al. (2003)
- extended hydrogen exosphere
- high velocities
- escaping atmosphere? Tail? (Ben-Jaffel 2008; Vidal-Madjar 2008)

Exoplanet Transit Spectra

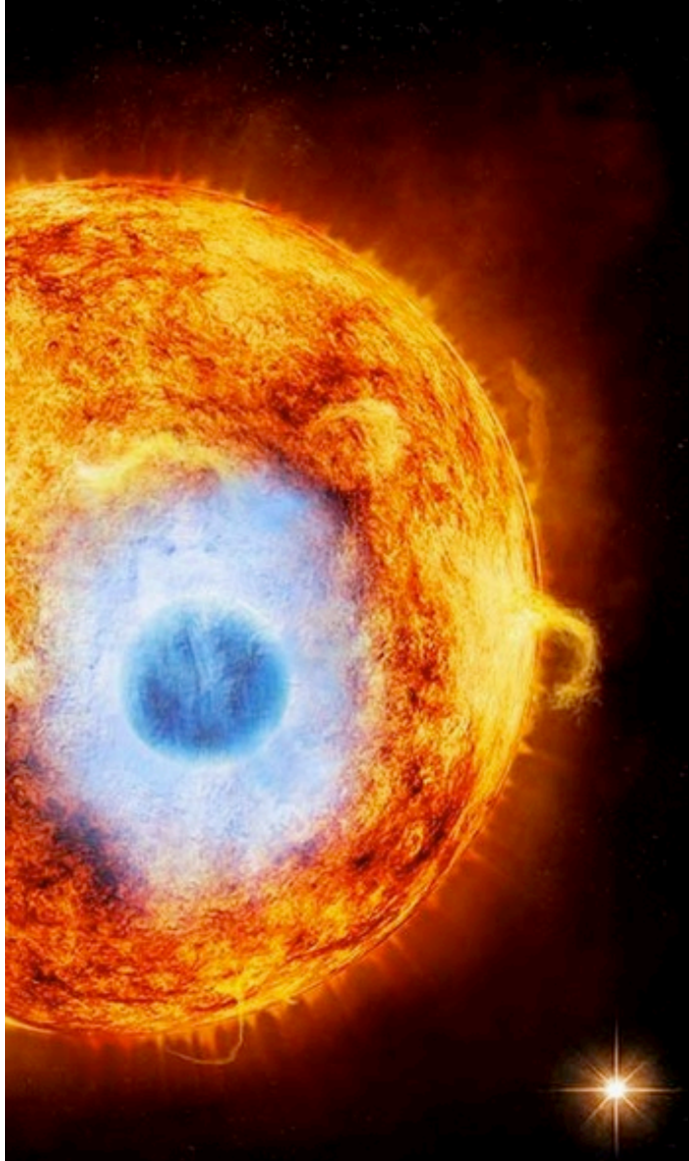




Exoplanet Transit Spectra

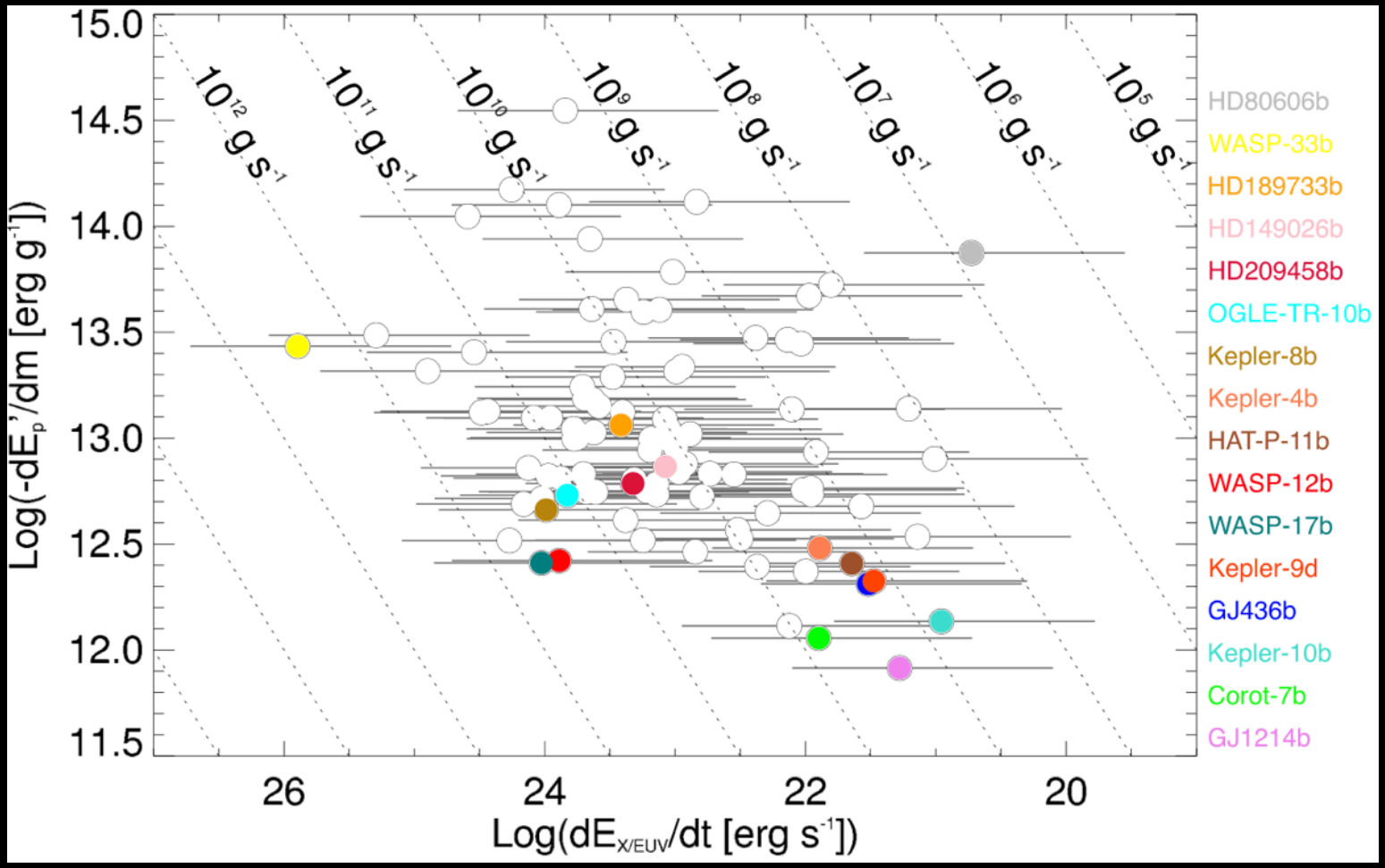


Extended Atmospheres: Interpretation



EUV & X-ray heating

- Jeans Escape
- Hydrodynamic 'Blow-Off'
  Yelle (2004), Garcia Munoz (2007), Koskinen (2012)...
- Charge exchange
  Holmstrom et al (2008)



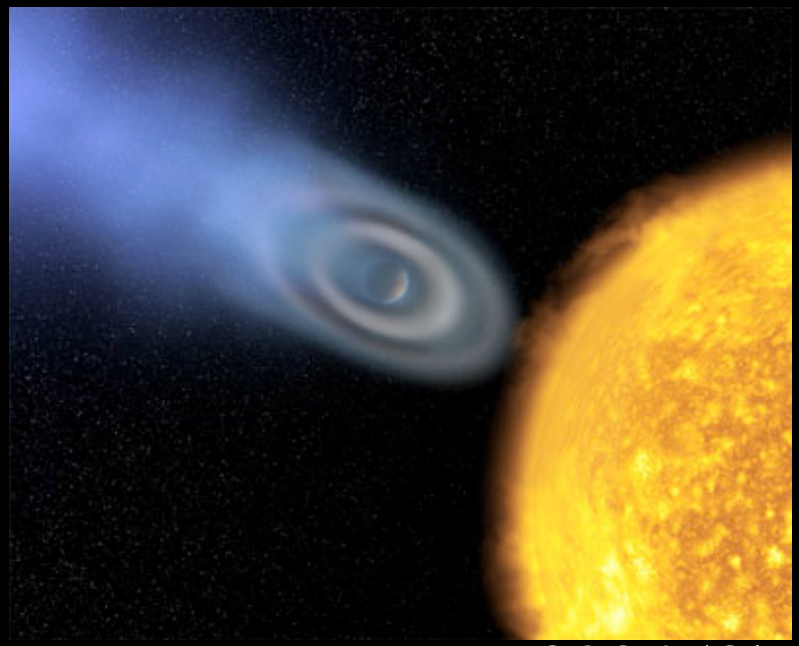
Ehrenreich & Desert (2011)

Order of Magnitude: Energy limited Mass Loss, Lecavelier et al (2007)

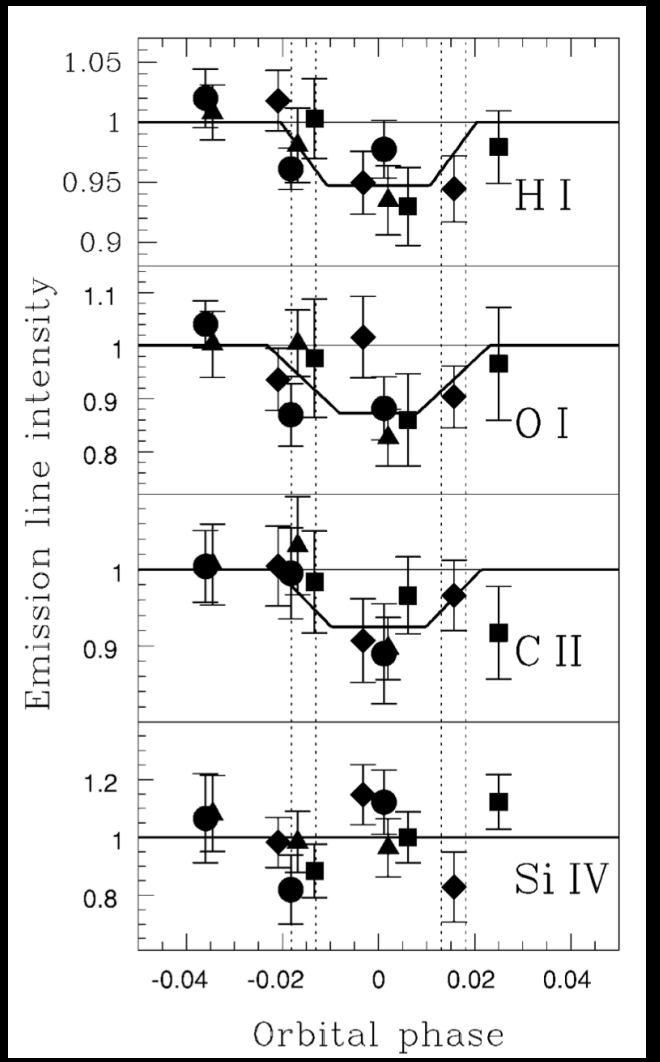
PdV. Compare Gravitational Energy to Stellar Flux (X-Ray & EUV)

Heating efficiency "fudge factor"

HD209458b

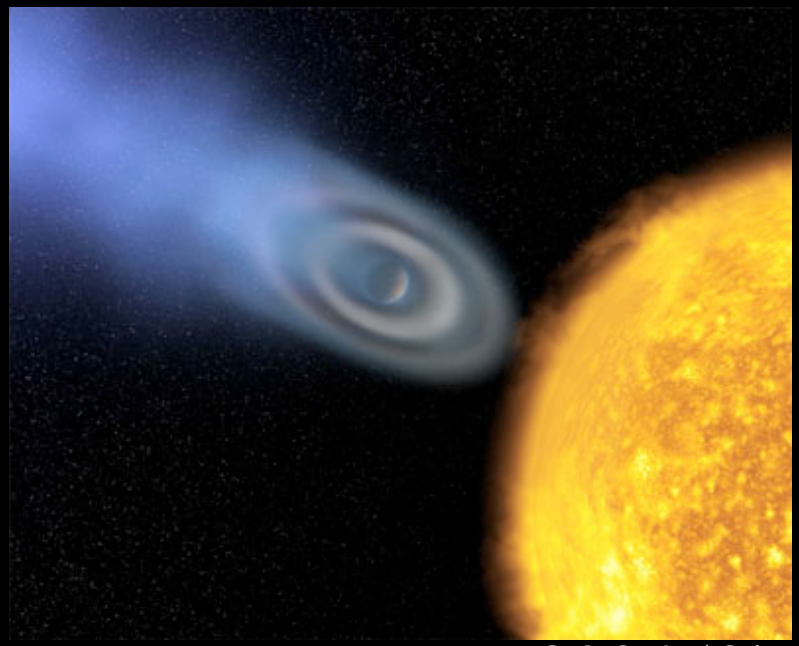


HD209458b

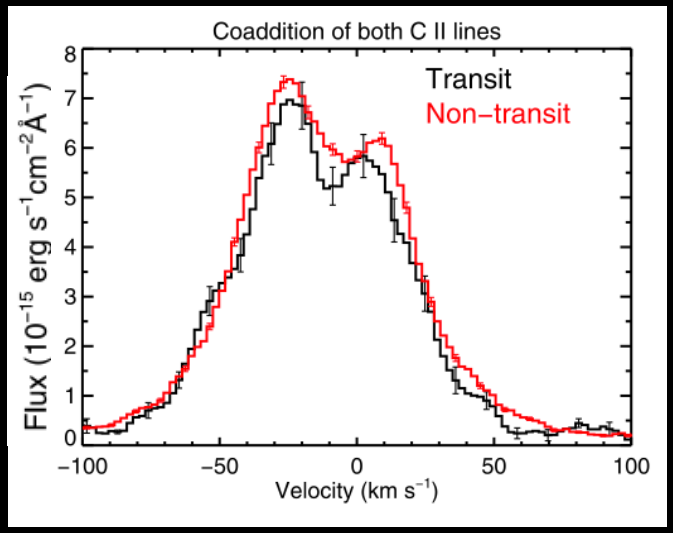


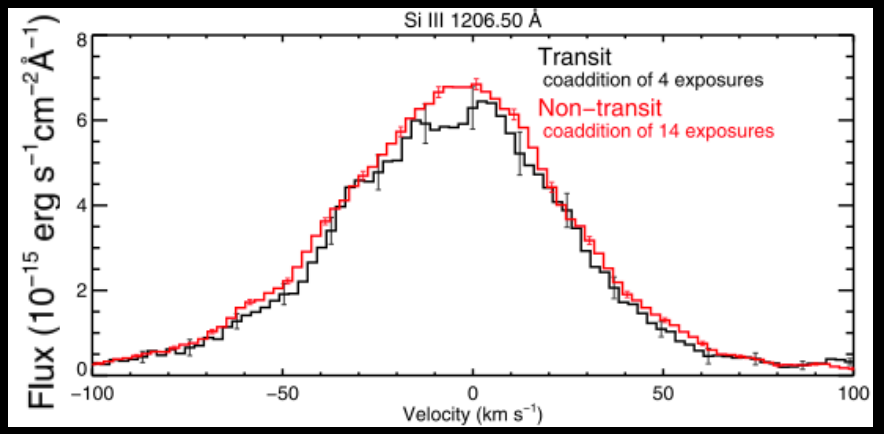
- A. Vidal-Madjar et al. (2004)
- extended O I, C II exosphere

HD209458b



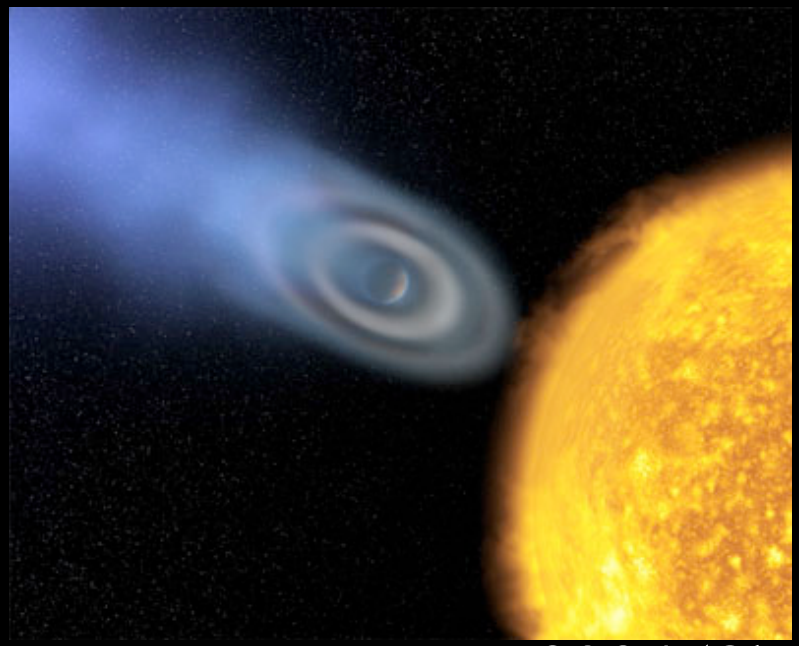
HD209458b



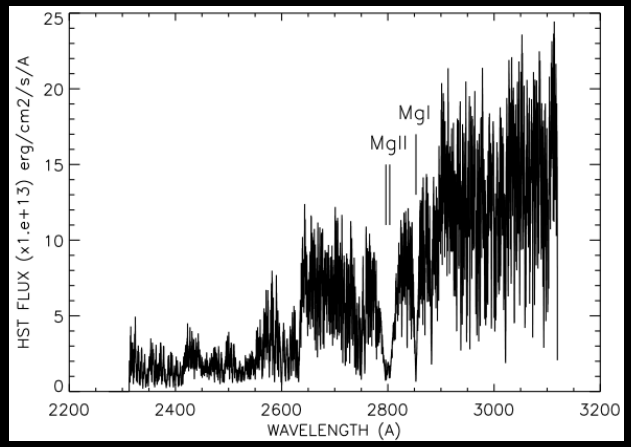


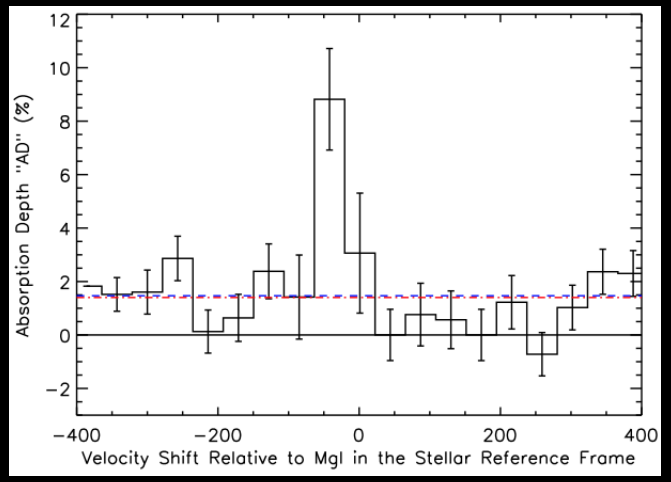
- Linsky et al. (2010)
- France et al. (2011)
- extended C II, Si III exosphere; ~8%

HD209458b - Mg



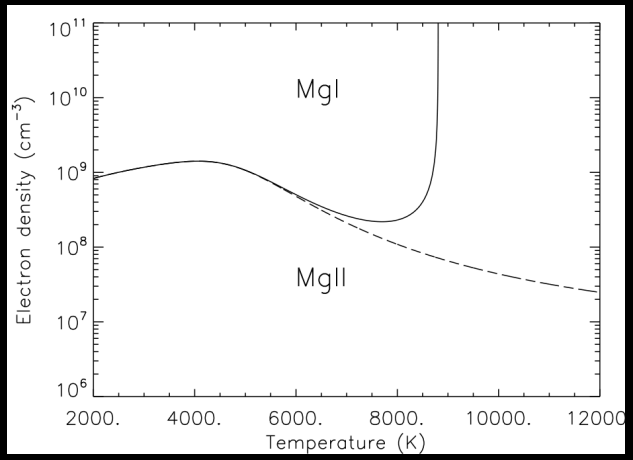
HD209458b

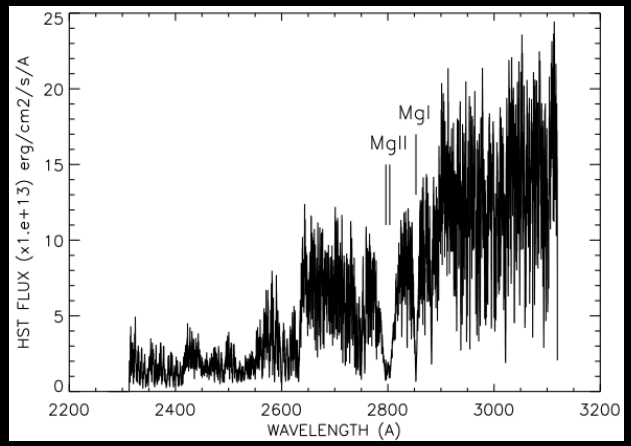


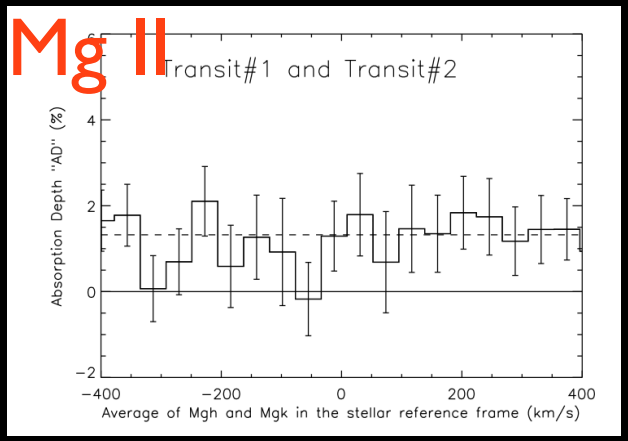


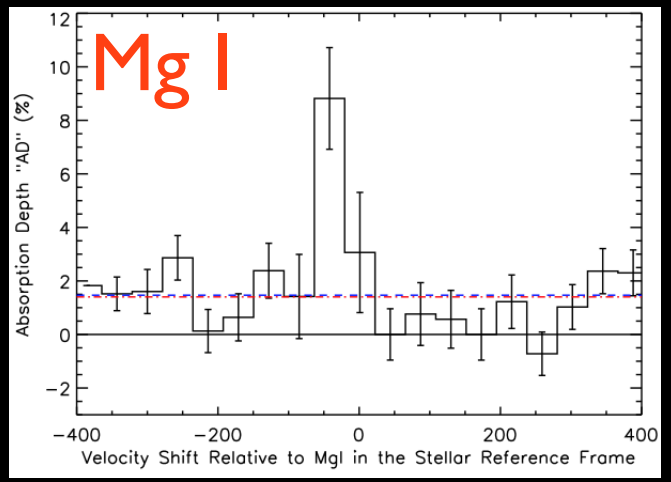
- A. Vidal-Madjar et al. (2013, in press)
- extended Mg I
- Hydrodynamic ‘blow off’

HD209458b - Mg







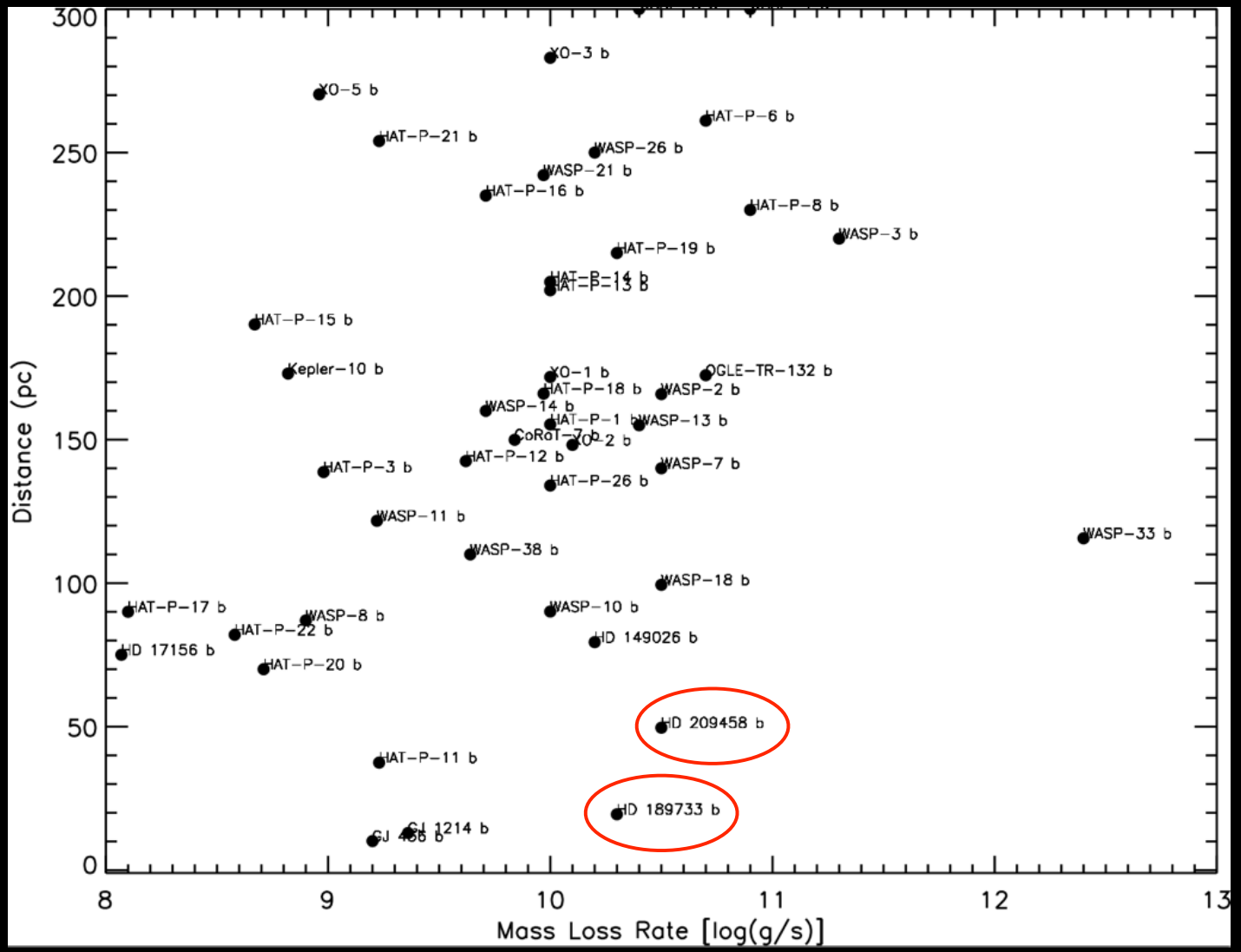


Mg I but no Mg II

Vidal-Madjar et al. (2013, in press)

electron density > 10^8 - 10^9 /cm^3 T< 9000 K

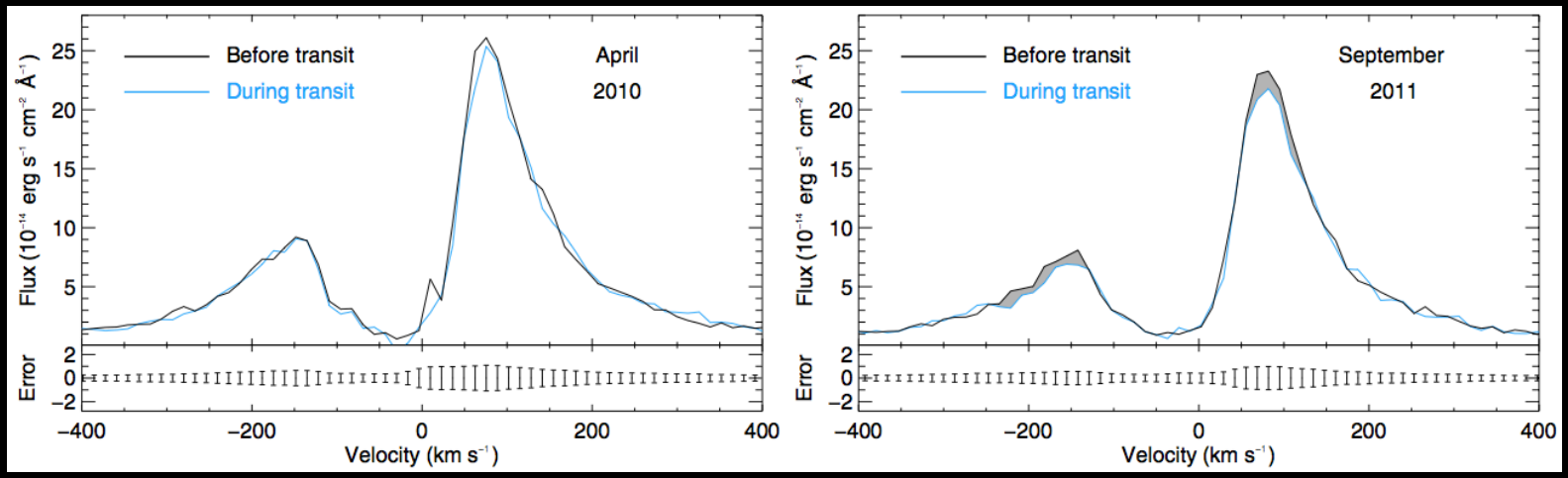
7.8 Rp ; 3x10^7 g/s; ~solar abund



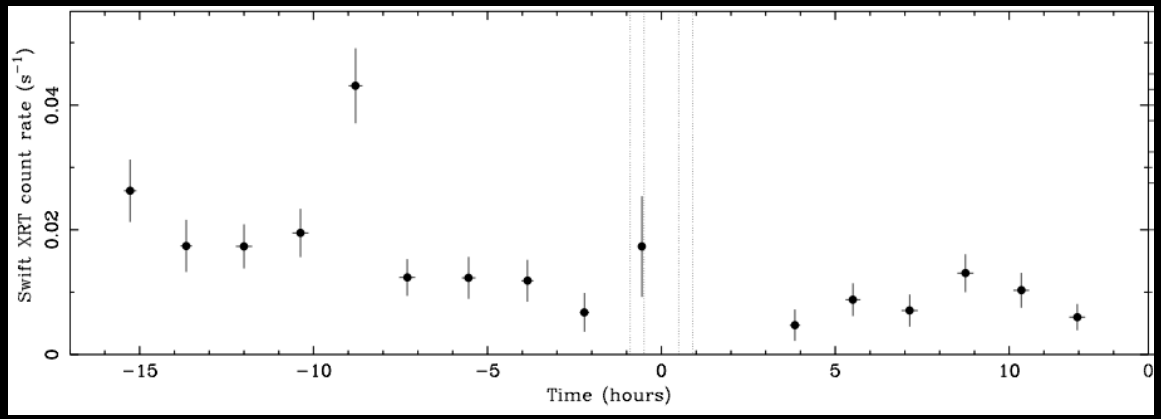
Mass Loss rates from Ehrenreich & Desert (2011)

Only Nearby systems are UV detectable

HD189733b - variability



HD189733b

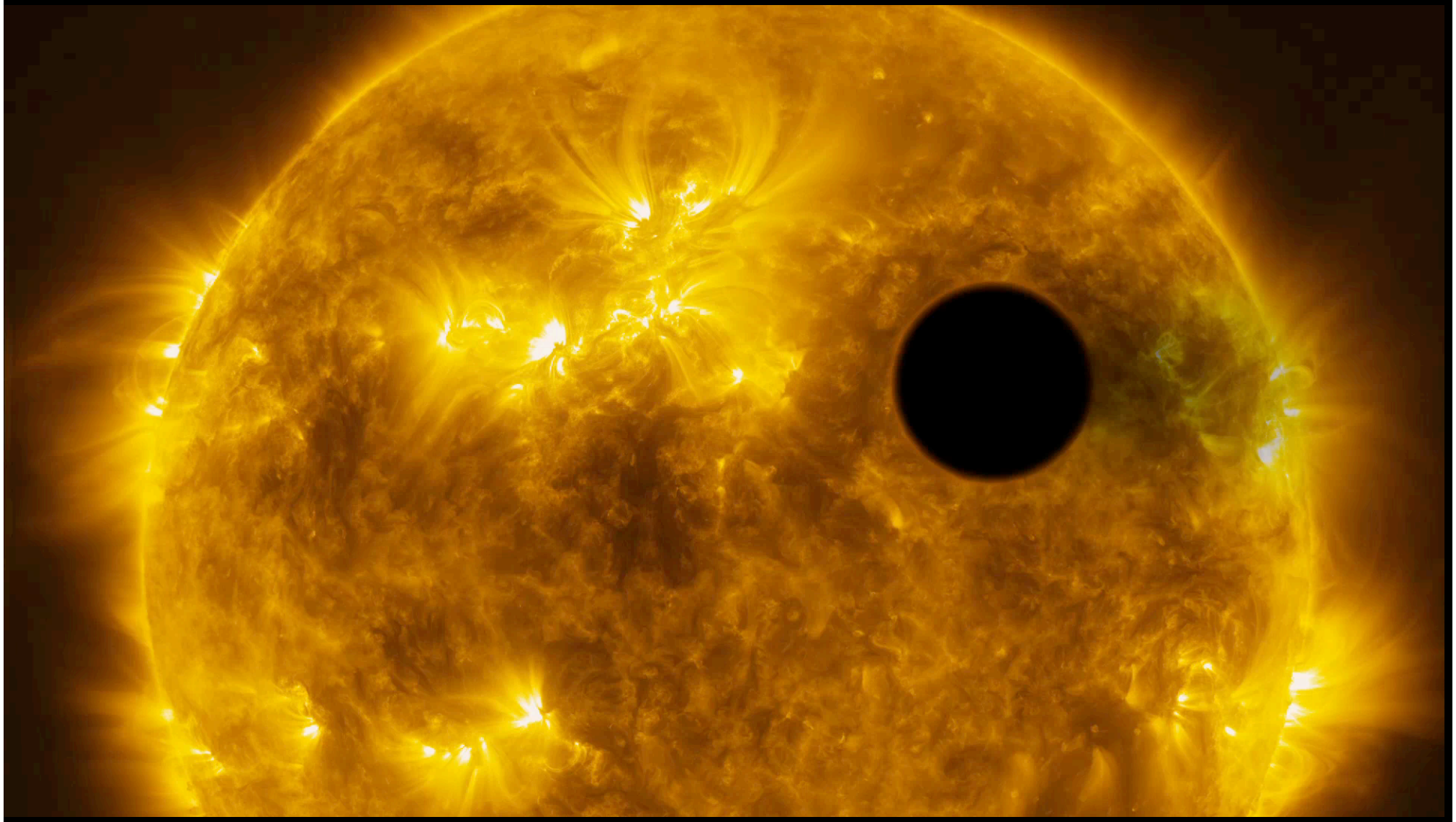


- Lecavelier et al. (2010, 2012)
- H I; 14.4±3.6% depth
- Variability

HD189733b

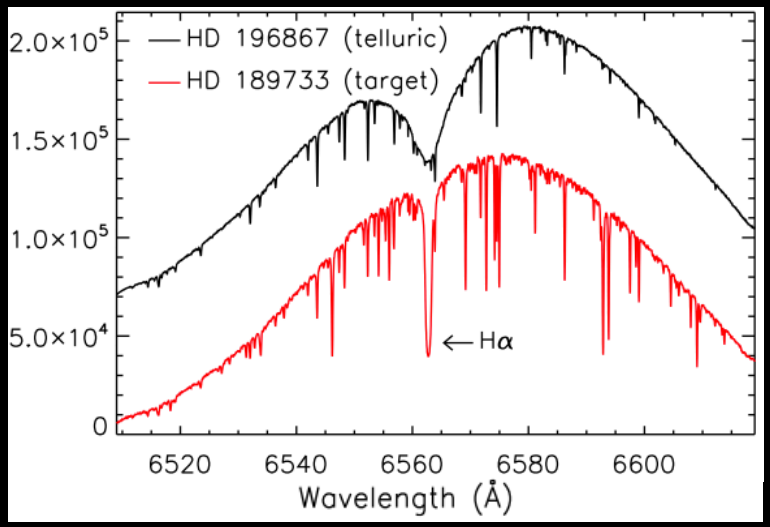
Lecavelier et al. (2012)

HD189733b



Lecavelier et al. (2012)

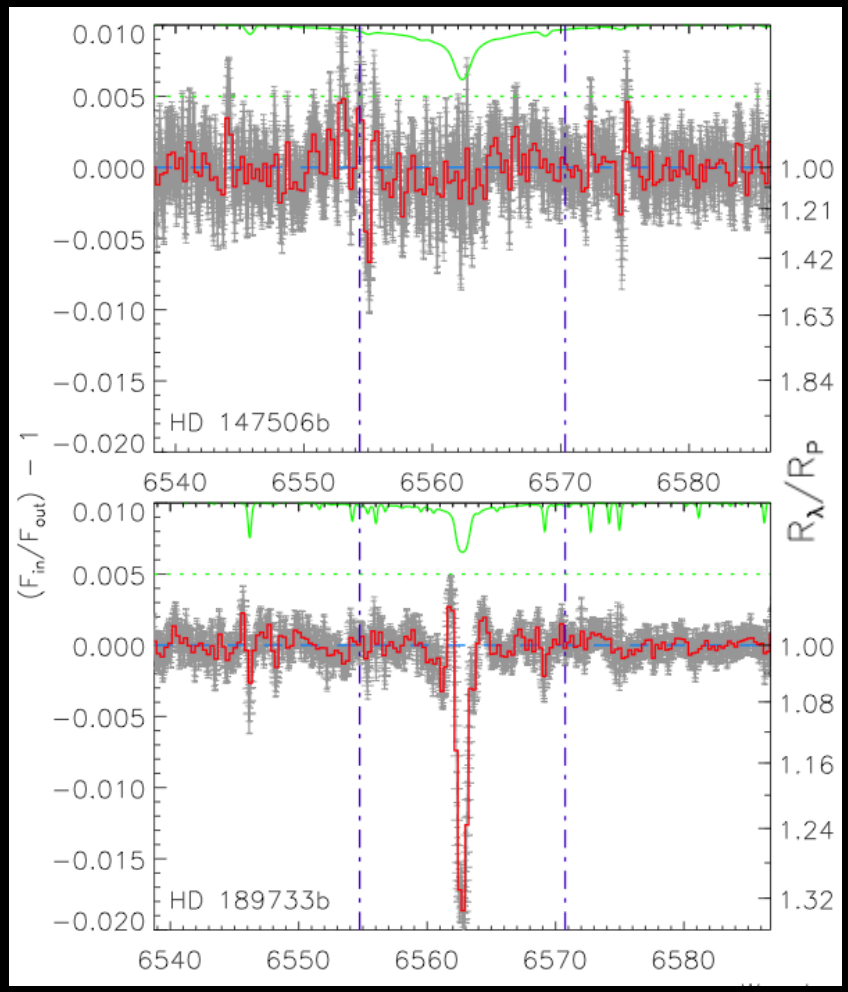
HD189733b - hot hydrogen



high resolution

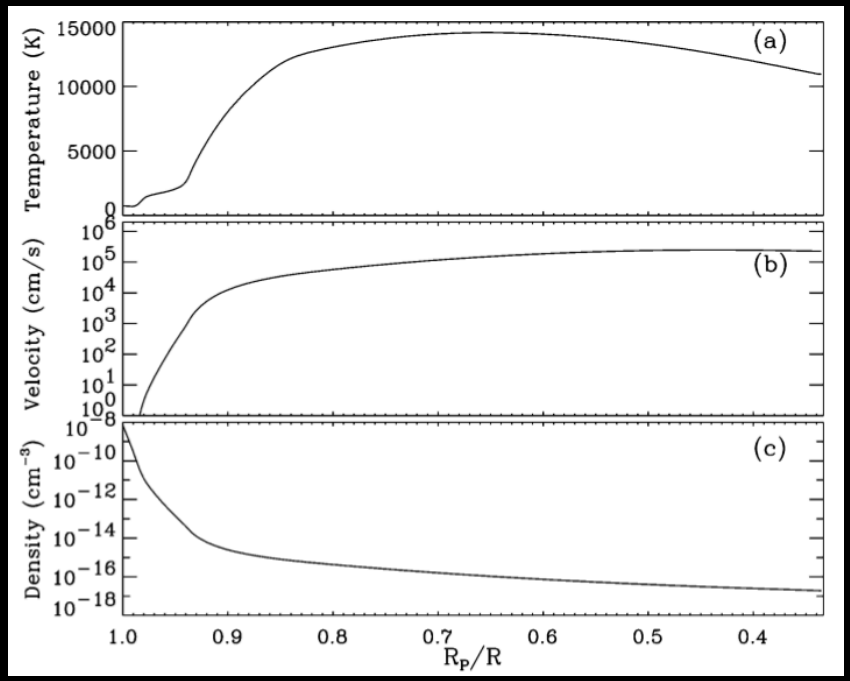
difference in line shape

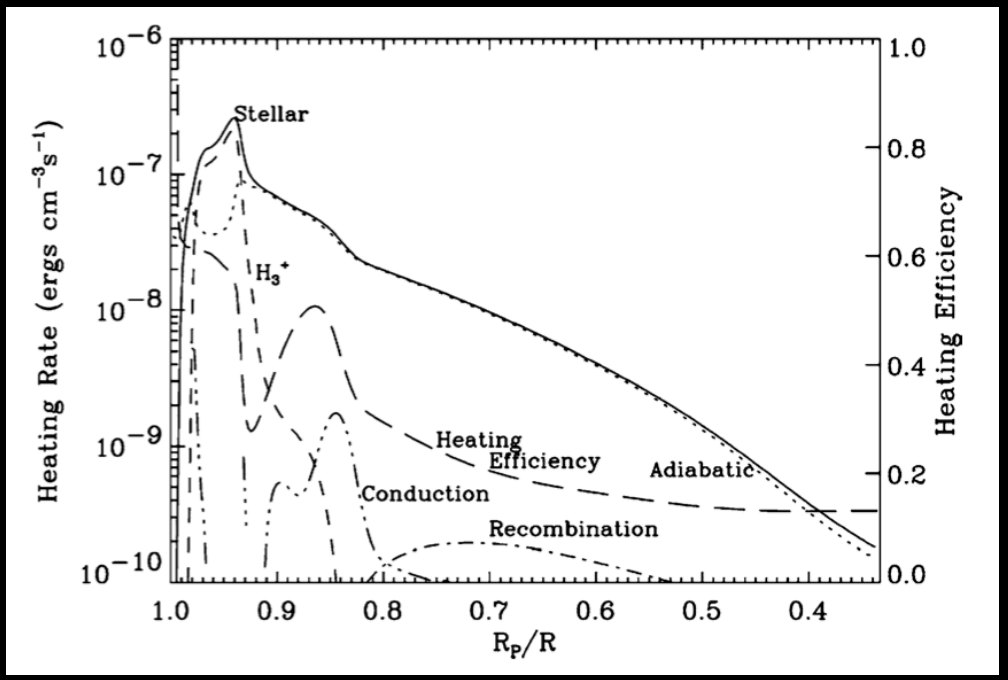
in/out of transit



- Jensen et al. (2011)
- $H\alpha$
- Hydrodynamic 'blow off'

HD189733b - hot hydrogen





Yelle (2004)

- Balmer --> hot temperatures

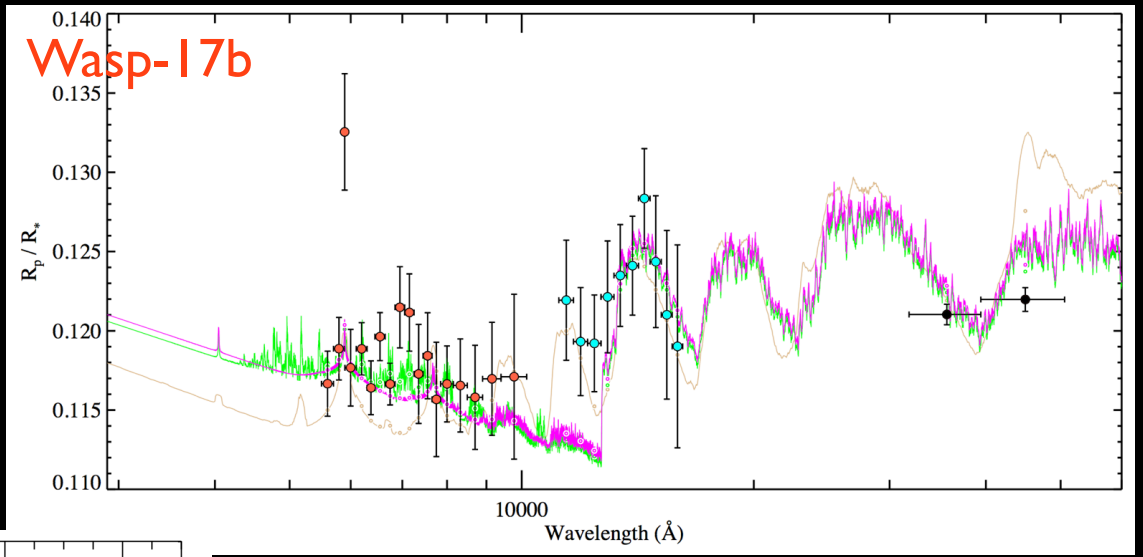
NUV - absolute abundances

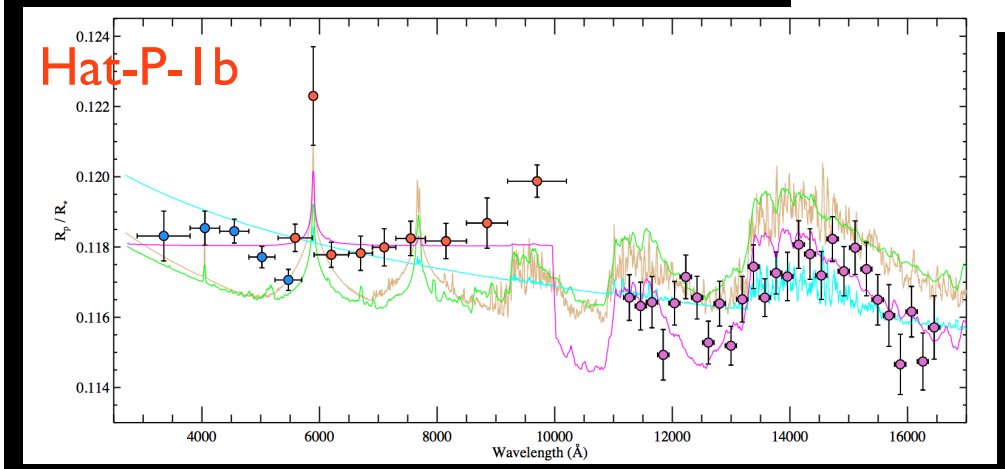
Large HST Program

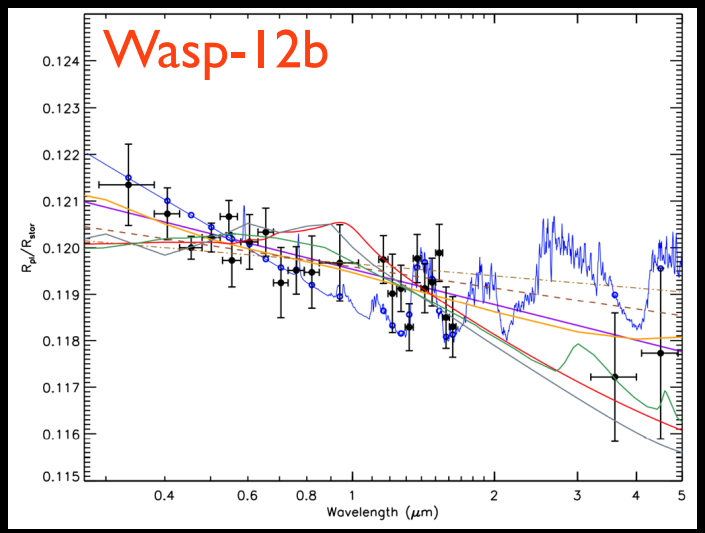
124 Orbits

2/3 in NUV

Nikolov, Sing et al. (2013)





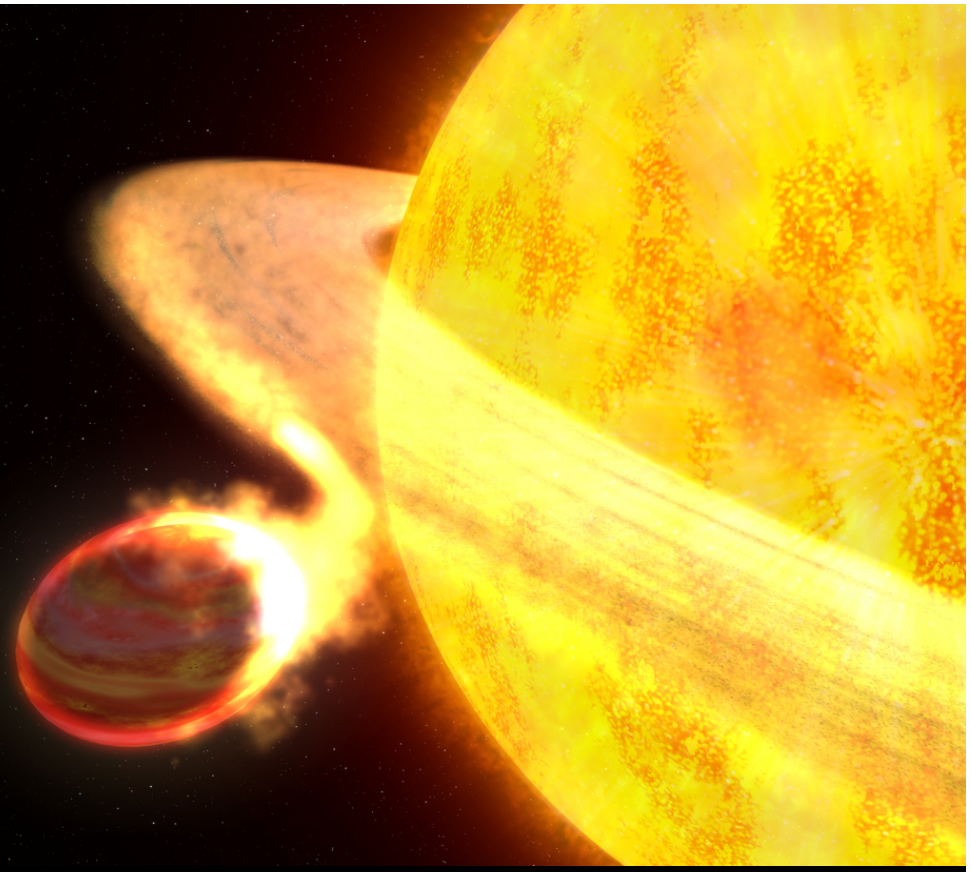


H_2 Rayleigh scattering in NUV

Slope gives T; Absolute abundances

Sing et al. (2013)

Wasp-12b



- Metals, Mg II
- Early ingress?
- Possible Shocks

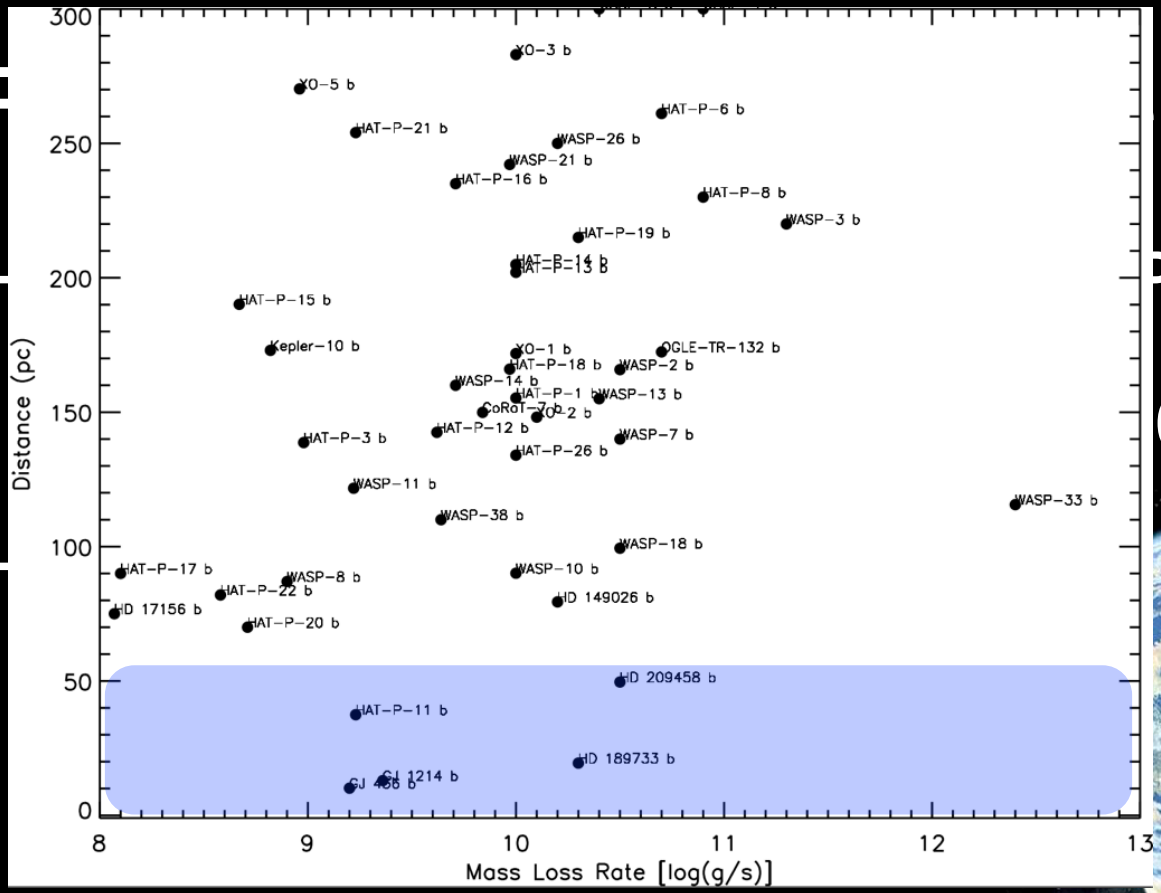
Future Space Based Observations

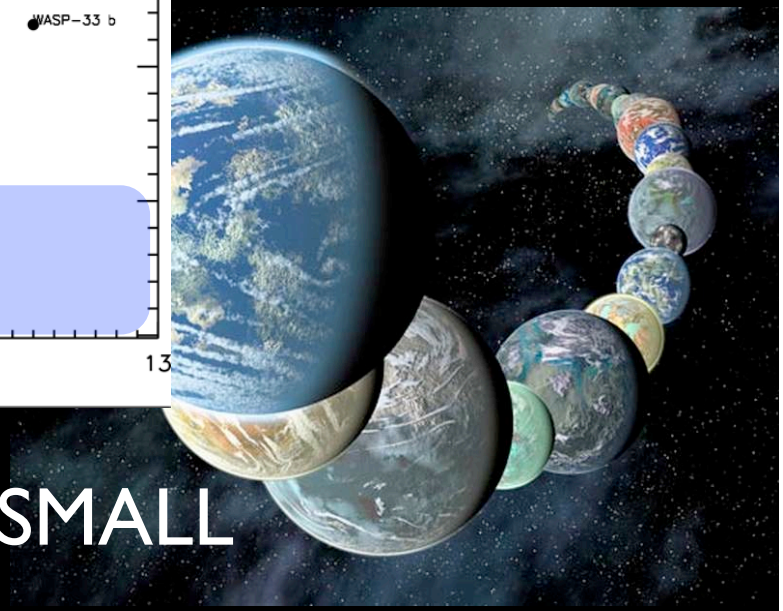
- HUGE interest in Bright Transiting Planets
  - Tess, NGTS, Mascara, PLATO 2.0, ...
- Huge interest in Mdwarfs
  - Mearth, WTS...

- Lots of upcoming NEARBY & SMALL exoplanets
- Very Large potential for UV followup

F rvations

- H Planets
- H 0, ...





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- Very Large potential for UV followup

Future Exoplanet Observations

Even after 10+ years...

All Exoplanet Atmospheric detections have been with instruments NOT designed for the purpose

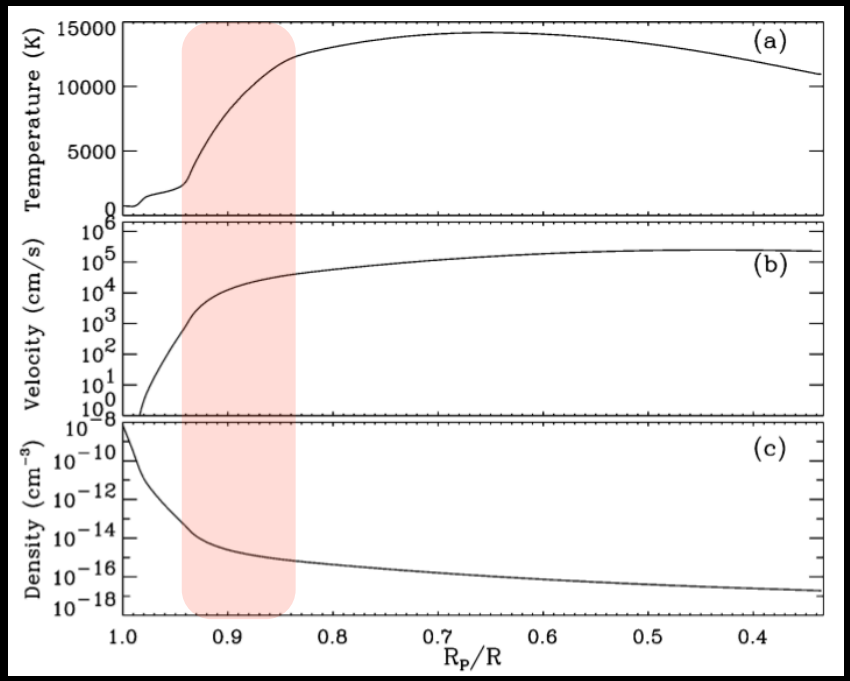
Thinking ahead can help optimise instruments and software

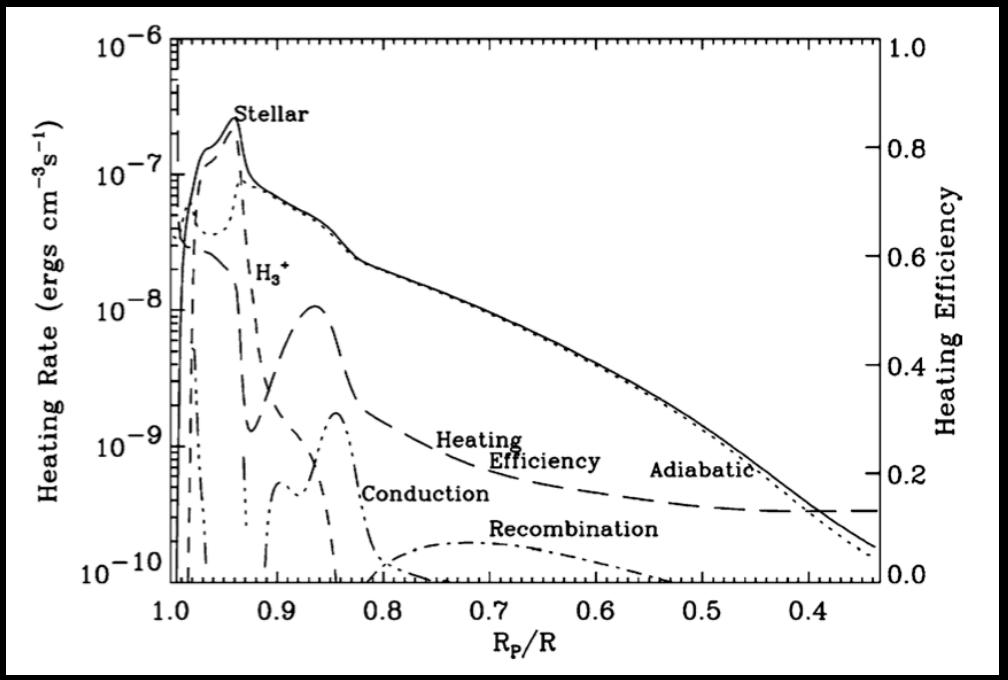
Future Ground Based Observations

- Ballmer Series Detections
  - Temperature Structure
  - Escape Mechanism
- Metals in Lower & Upper Atmo.

- Very Large Apertures gives access to most exoplanets known

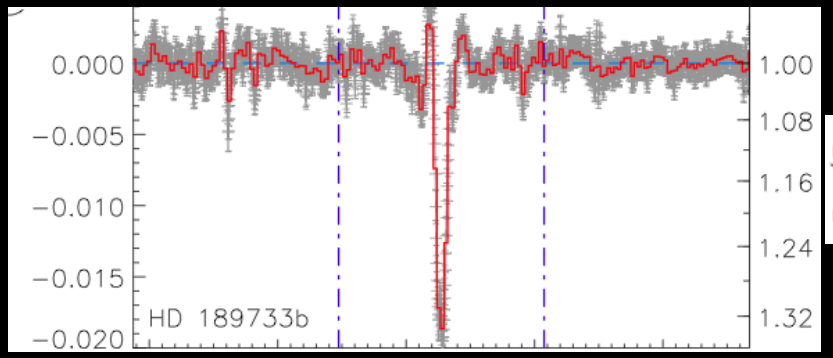
Constrain Atmospheric Escape



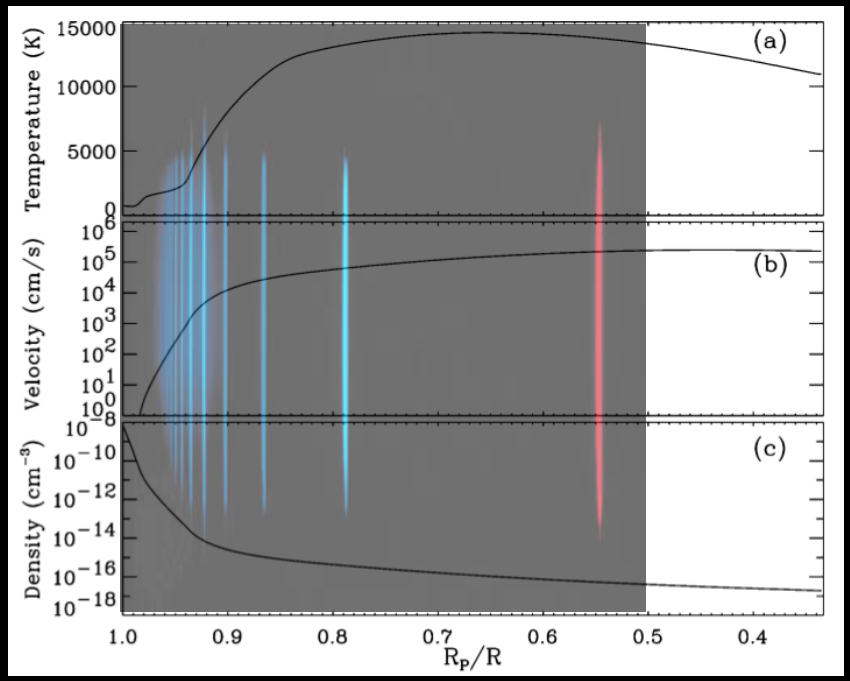


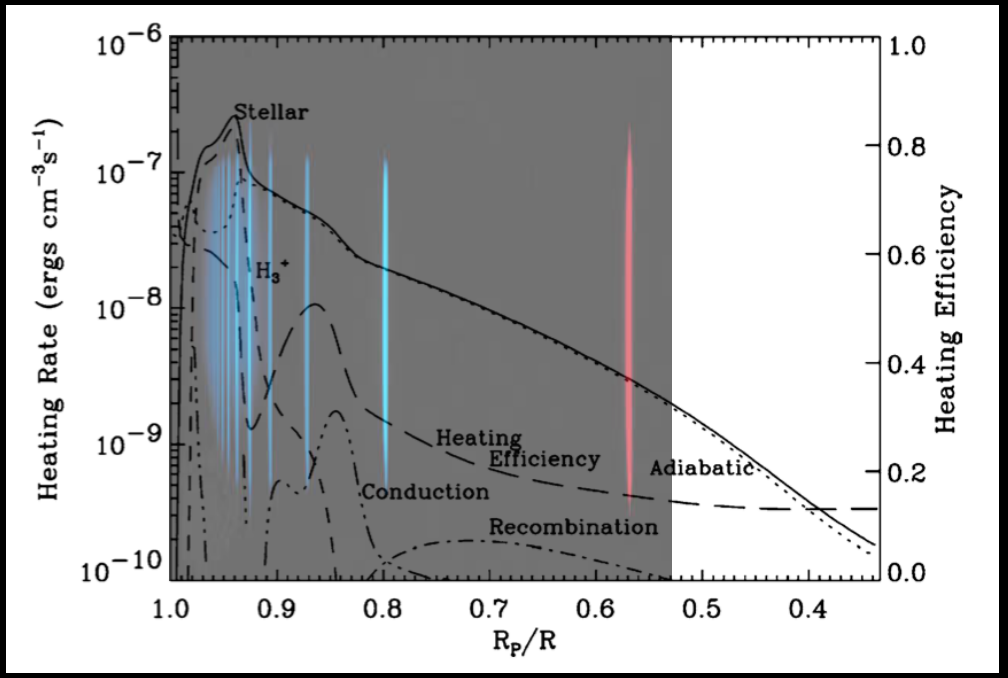
Yelle (2004)

Study the STRUCTURE of atmospheric escape



HD189733b - hot hydrogen





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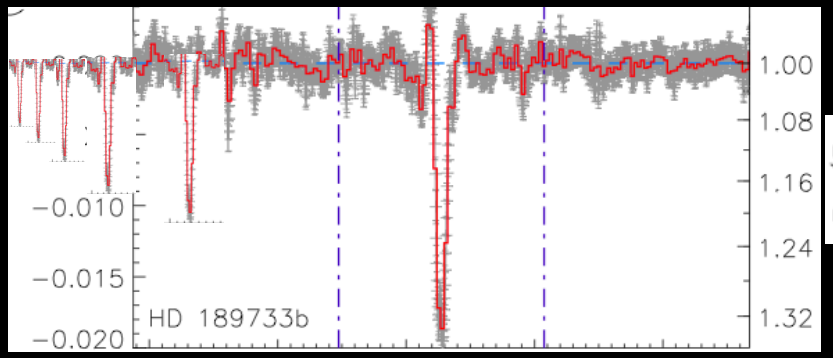

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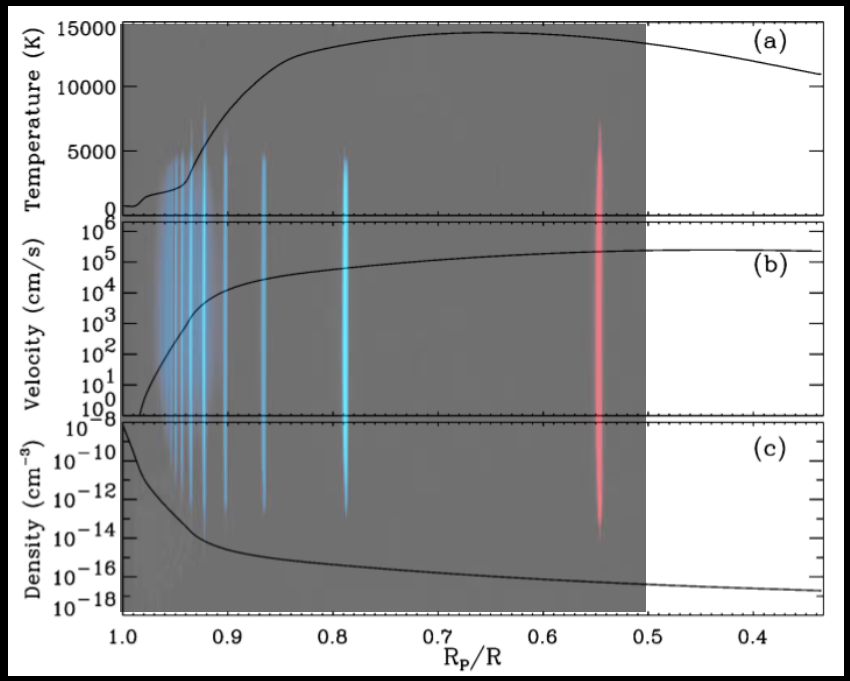
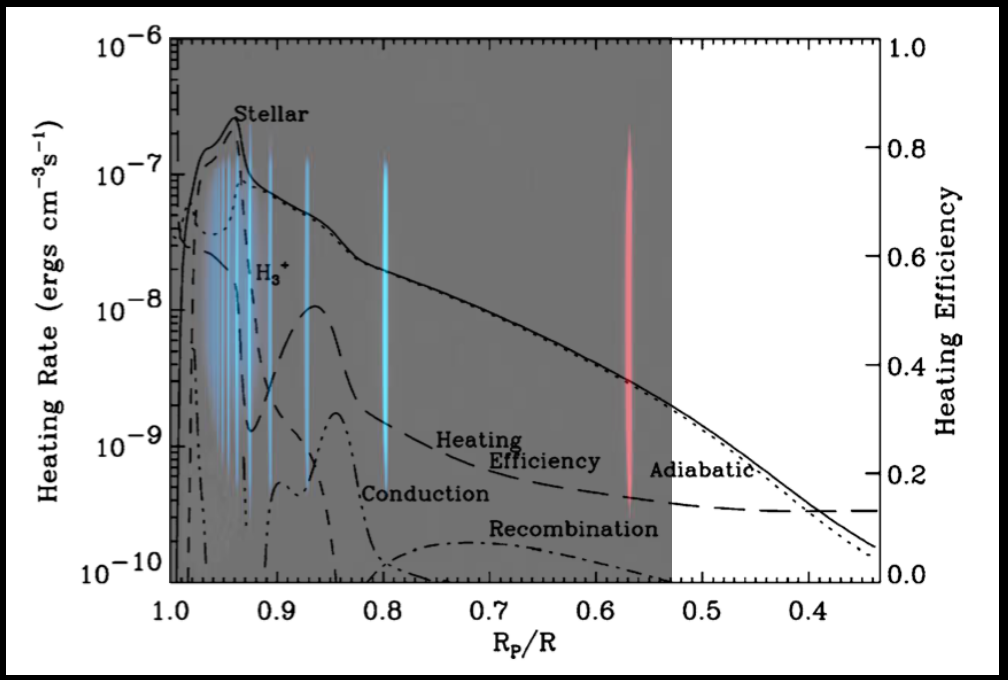
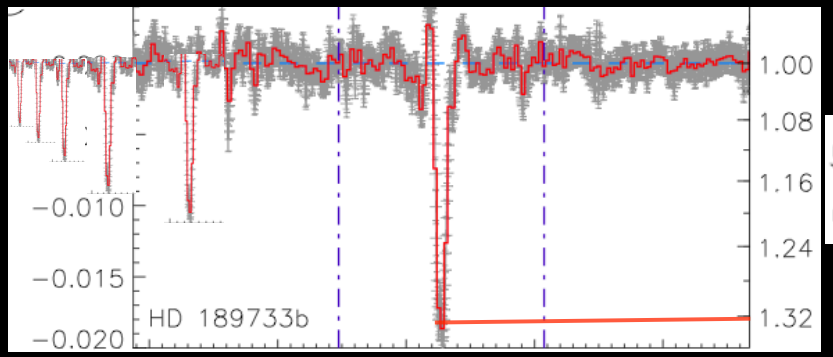


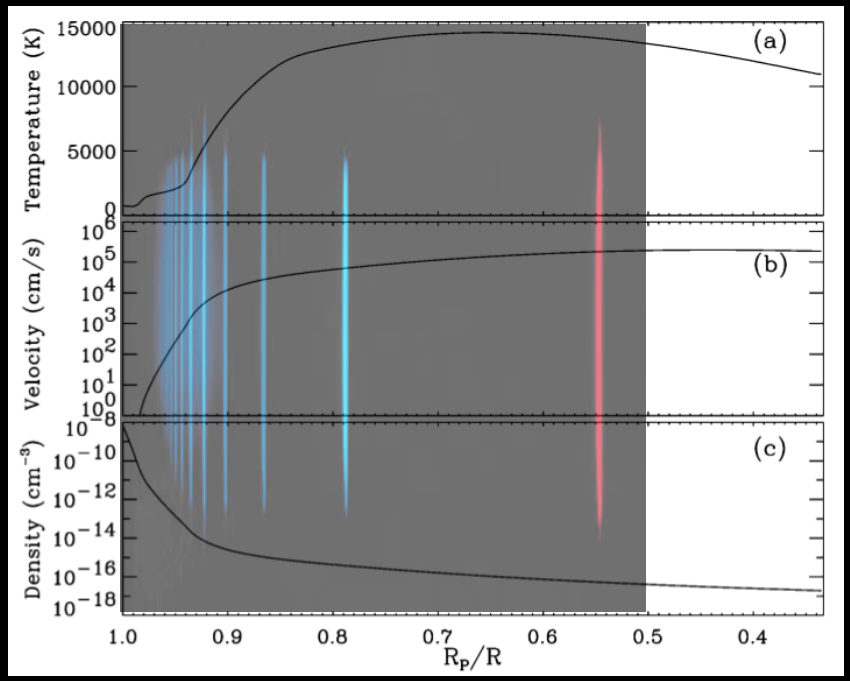


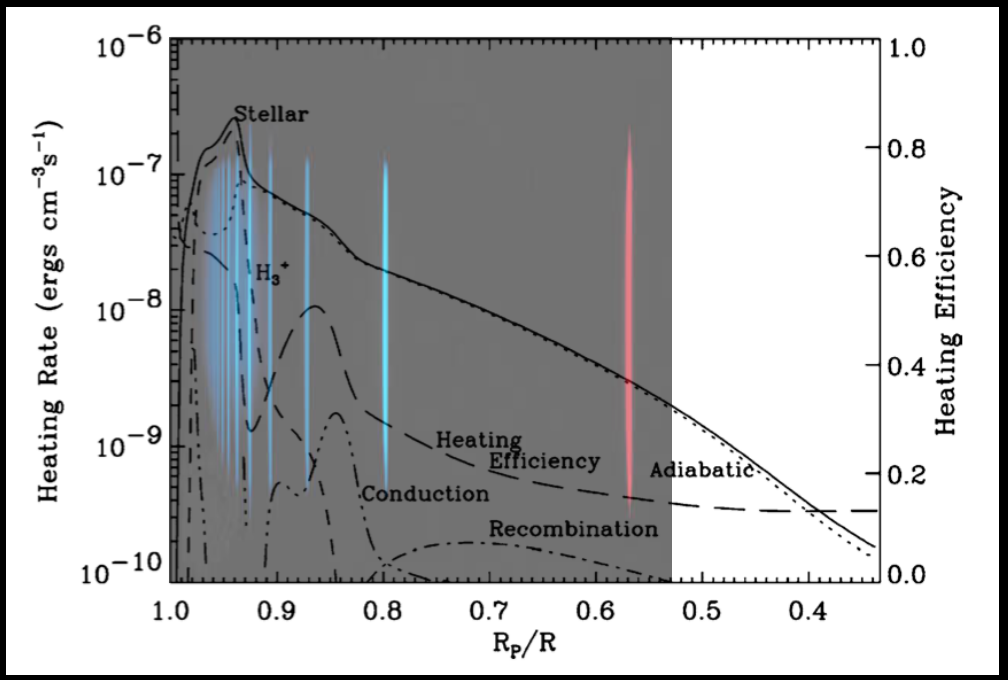
Yelle (2004)

Study the STRUCTURE of atmospheric escape



HD189733b - hot hydrogen





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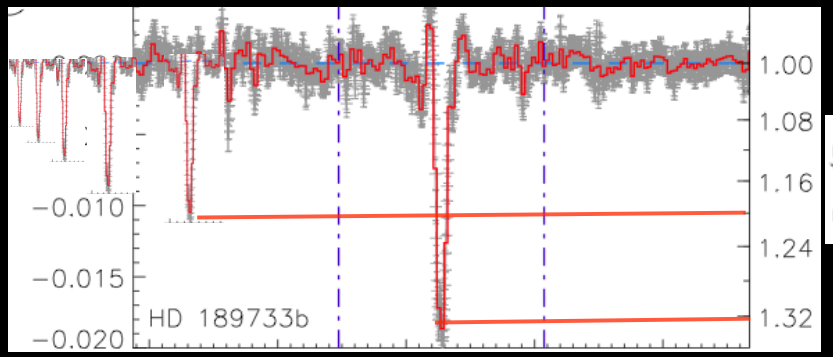

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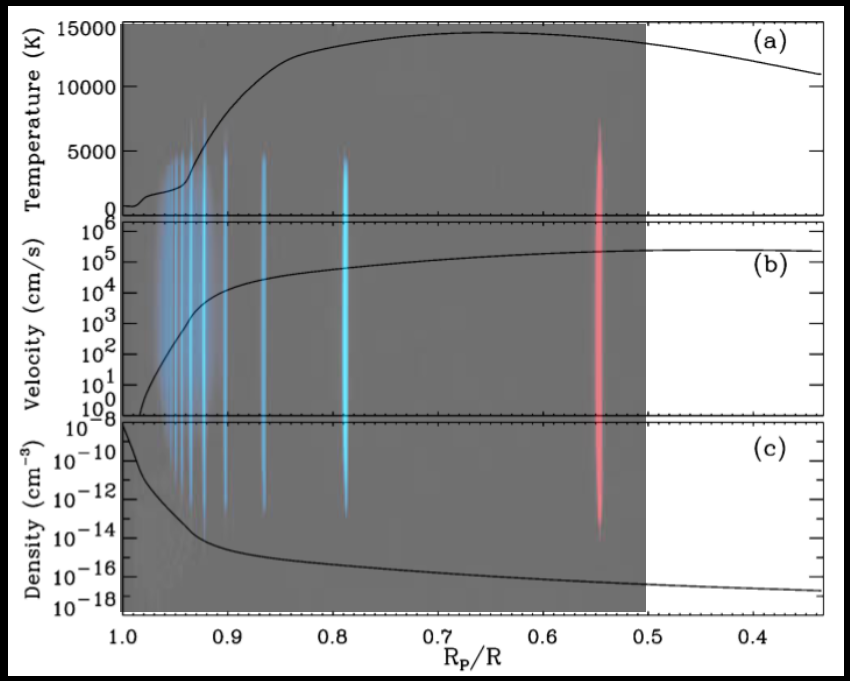

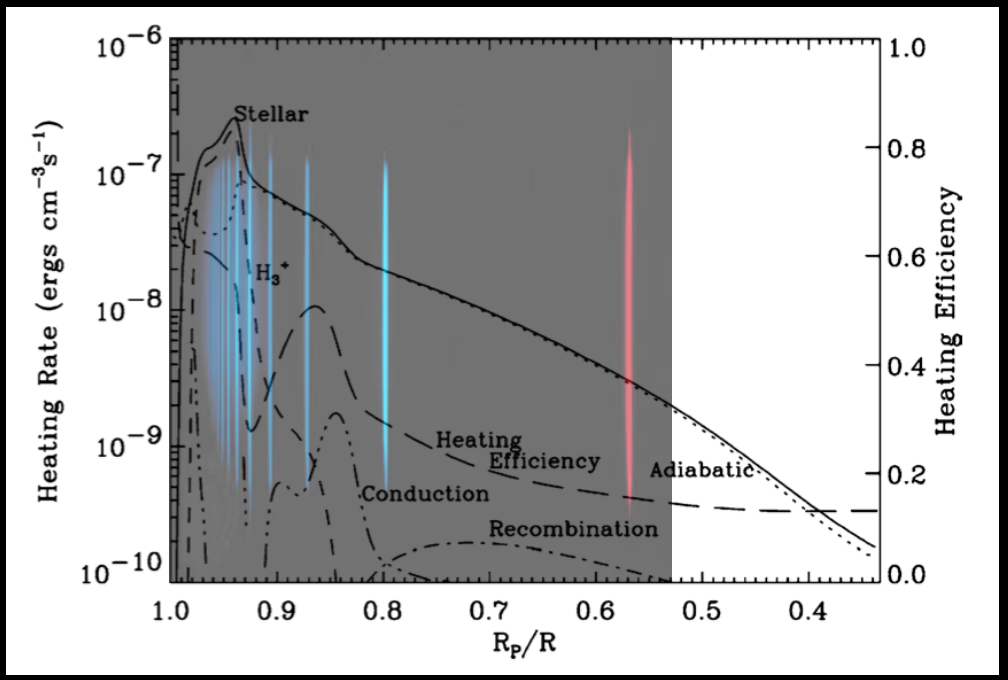

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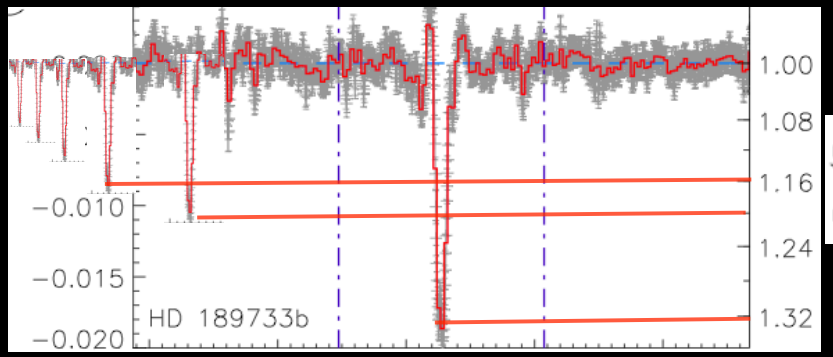

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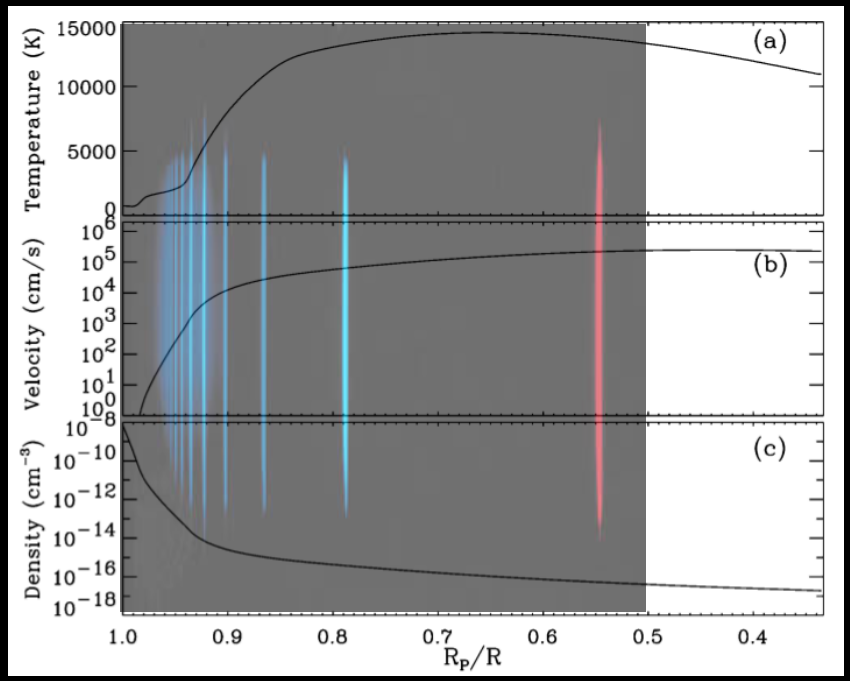

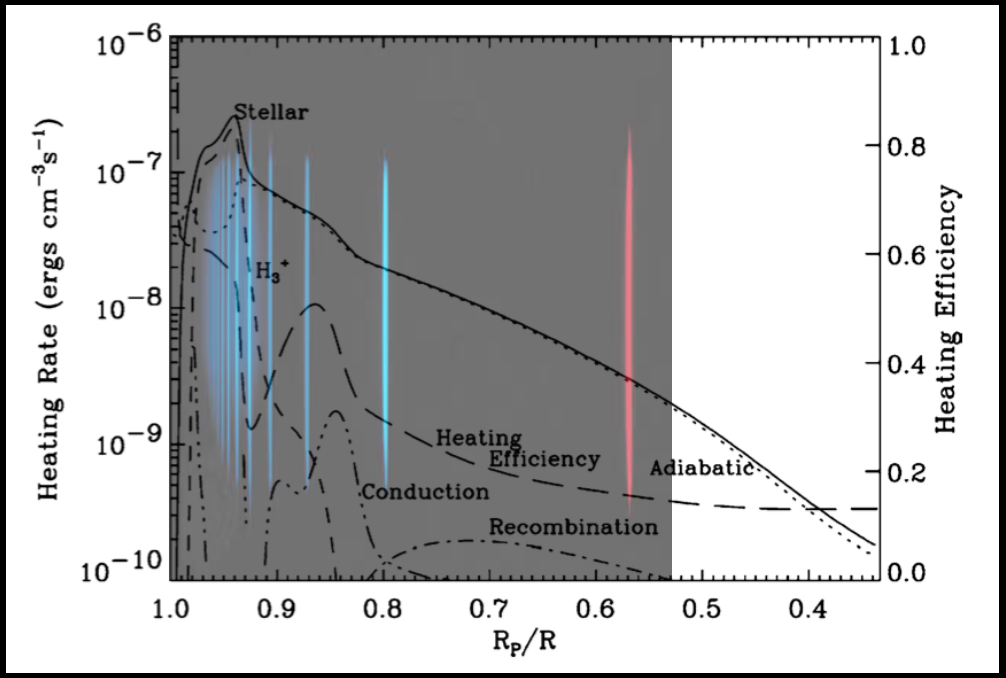

Yelle (2004)

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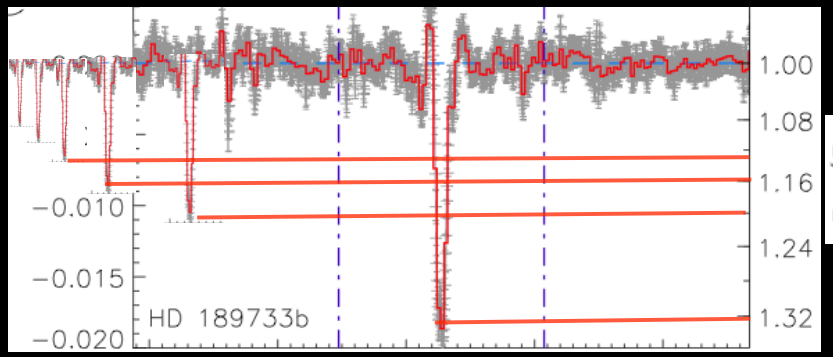

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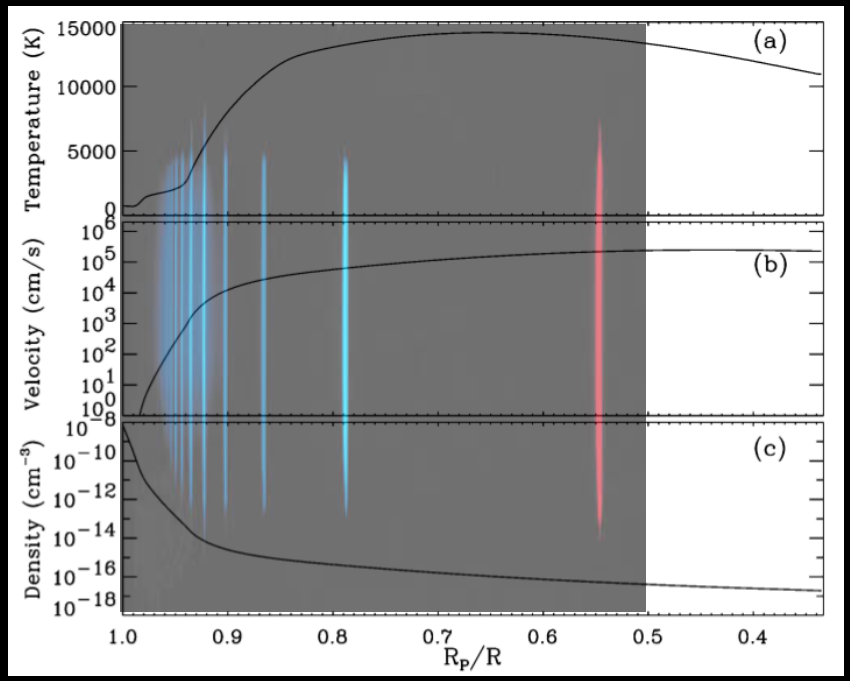

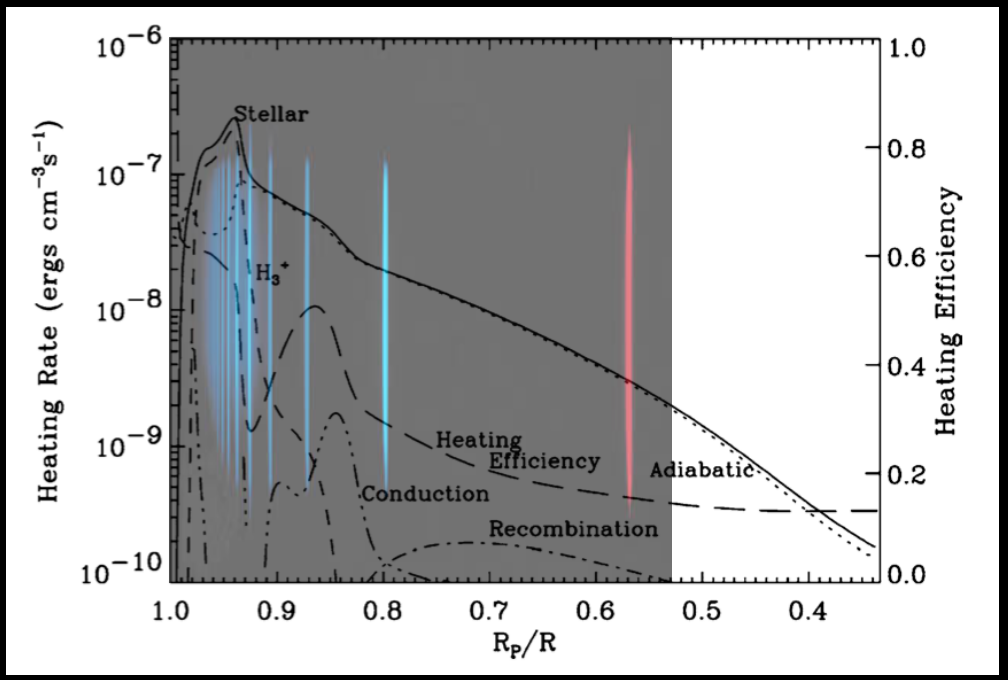

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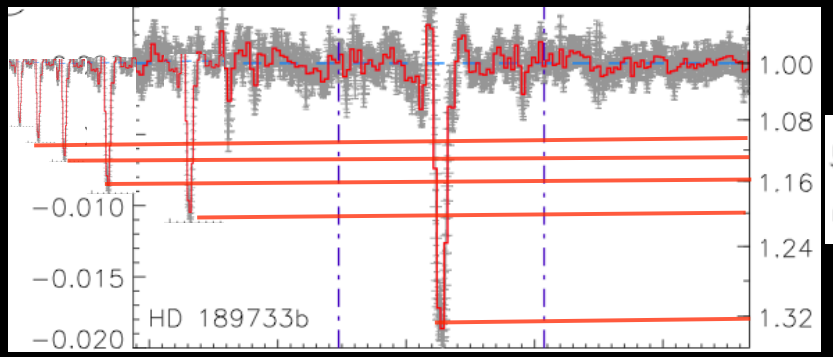

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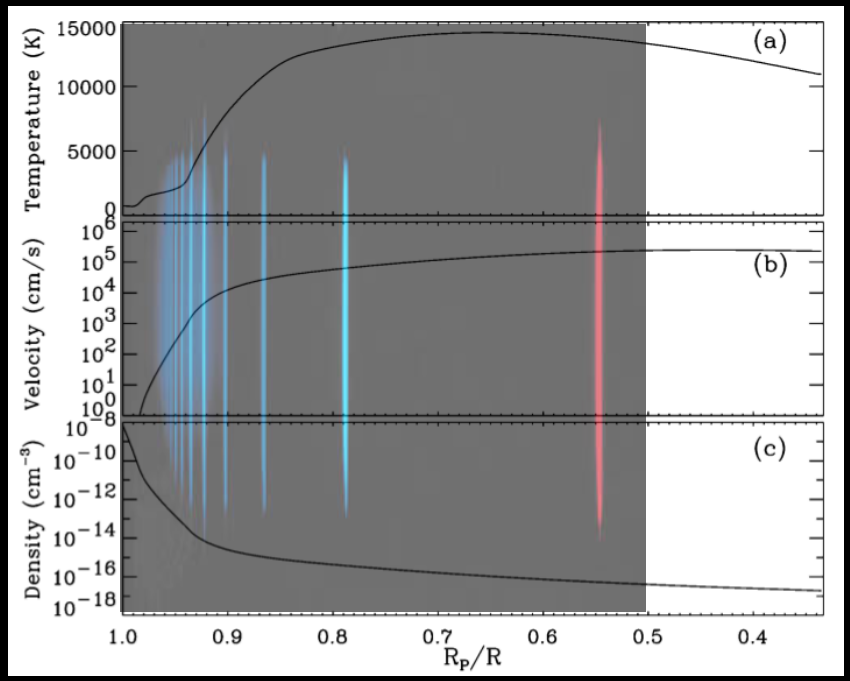

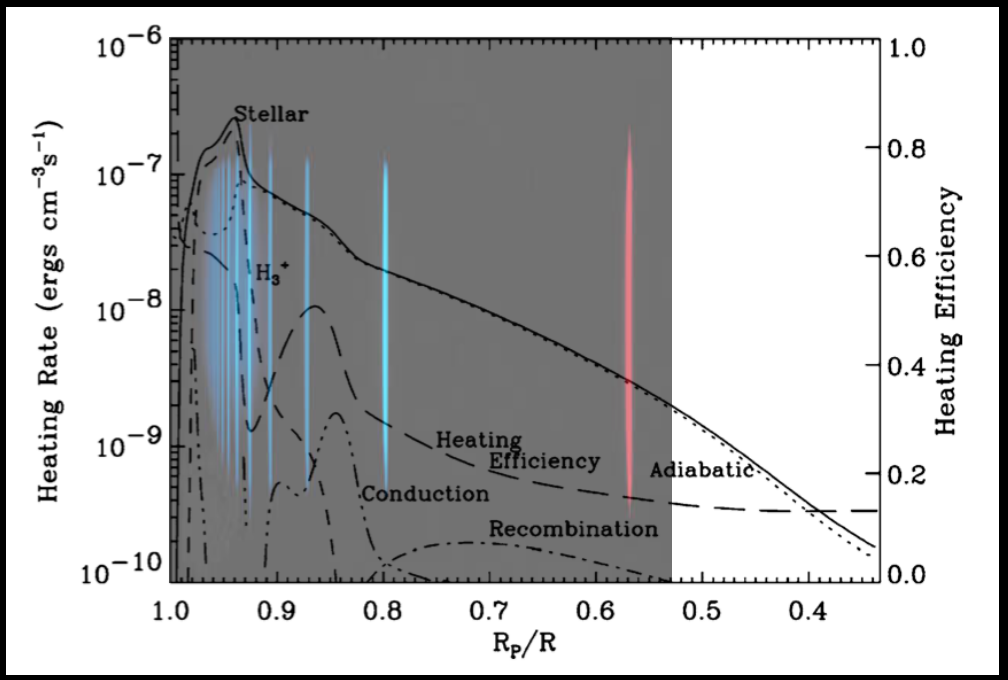

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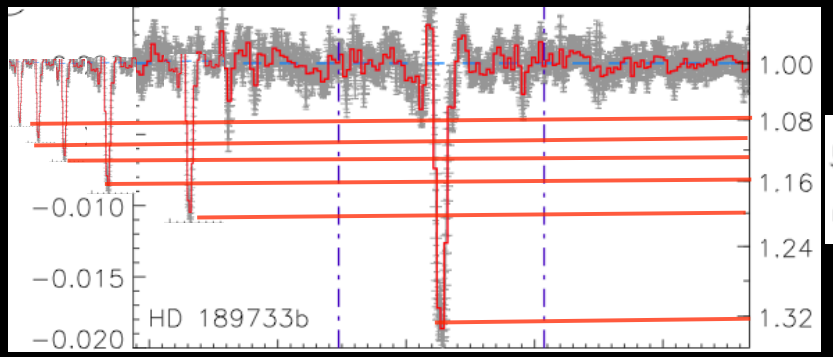


Future Ground Based Observations

- UV constrains atmo escape

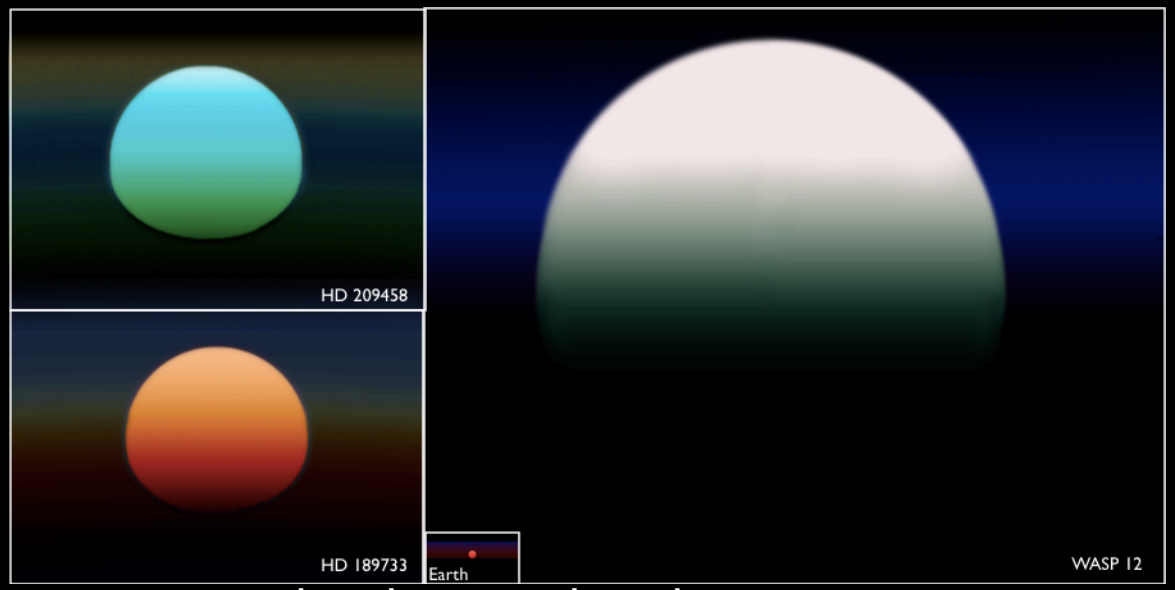
  close in planets

- Lots of BRIGHT transits to come

  super-Earths & Neptunes

- Constrain Escape mechanism with multiple species & ionisation states

Job add



rendered sunsets based on transmission spectra

2 ERC funded postdocs at Exeter (5 yrs each)

- observer
- theorist/modeller

AAS job register add out Now