Star-Planet interaction

Characterization of Exoplanet Atmosphere – Magnetosphere Environments

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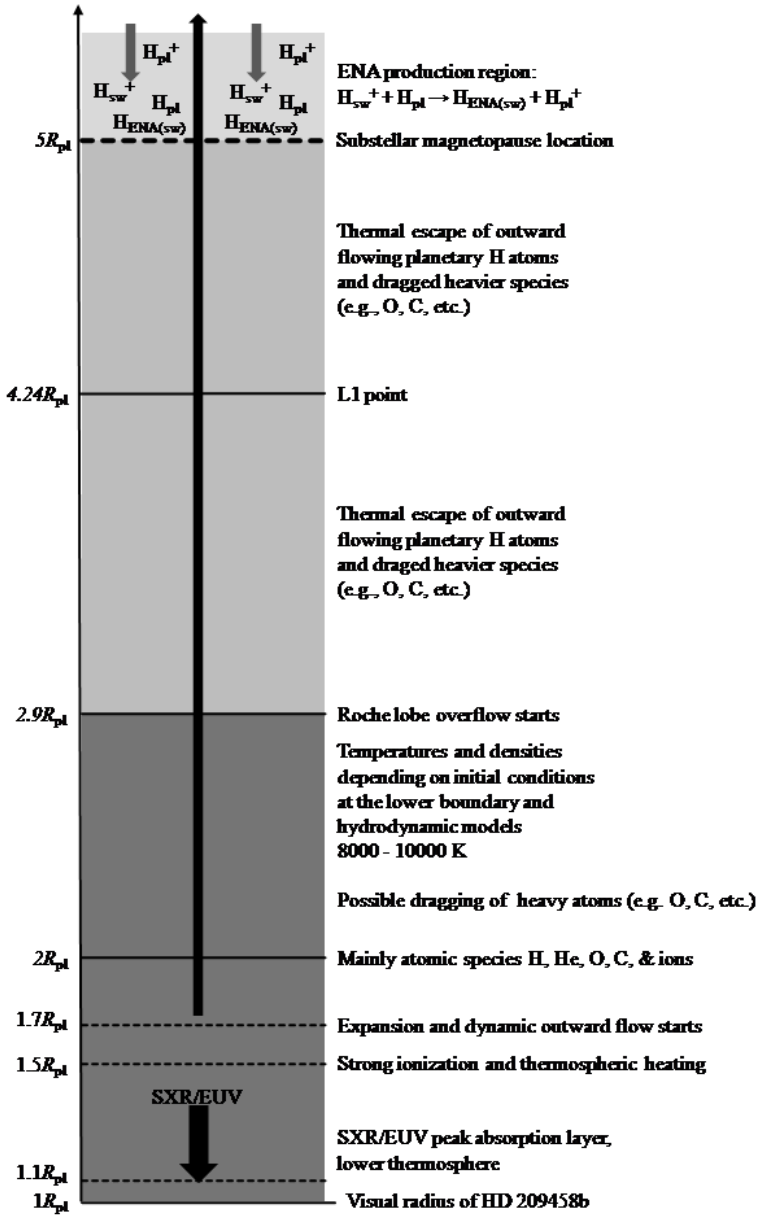
Upper atmosphere and near exoplanet environment



Importance of star-exoplanet interaction

Indication of planetary obstacle (magnetosphere, ionosphere, combination, ...
Stellar wind plasma parameters near the exoplanet
Upper atmosphere n & T Transition of $H_2 \rightarrow H$ in lower thermosphere
→ structure of the upper atmosphere and atmospheric escape

HST / UV observations

- Ly-α absorption
  Atmosphere expansion ≈ 3 planetary radii
  Hydrogen escape from HD 209458b
  estimated lower mass loss rate $\geq 10^{10}$ g s^{-1}

[Vidal-Madjar et al., Nature, 2003] [Koskinen et al., ApJ, 2010]

- Carbon and oxygen at Roche lobe: HD 209458b
  [Vidal-Madjar et al., ApJ, 2004]

- Carbon, oxygen, Si at Roche lobe: HD 209458b
  [Linsky et al., ApJ, 2010]

Recent non-detection of auroral and dayglow emissions of molecular hydrogen from HD209458b can be seen as an additional constraint which excludes upper atmosphere temperatures >10000 K and 7000 K yields the best fit → n_0=3-4 × 10^{13} m^{-3} at about 2.8R_{pl}

HST UV transit observations in Lyman-α

Absorption in the stellar Lyman-α line at 1215.67 Å

[Vidal-Madjar et al., Nature, 2003 → Ben-Jaffel, ApJ, 2007; 2008]

An extended upper atmosphere around the extrasolar planet HD209458b

A. Vidal-Madjar*, A. Lecavelier des Etangs*, J.-M. Désert*, G. E. Ballester†, R. Ferlet*, G. Hébrard* & M. Mayor‡

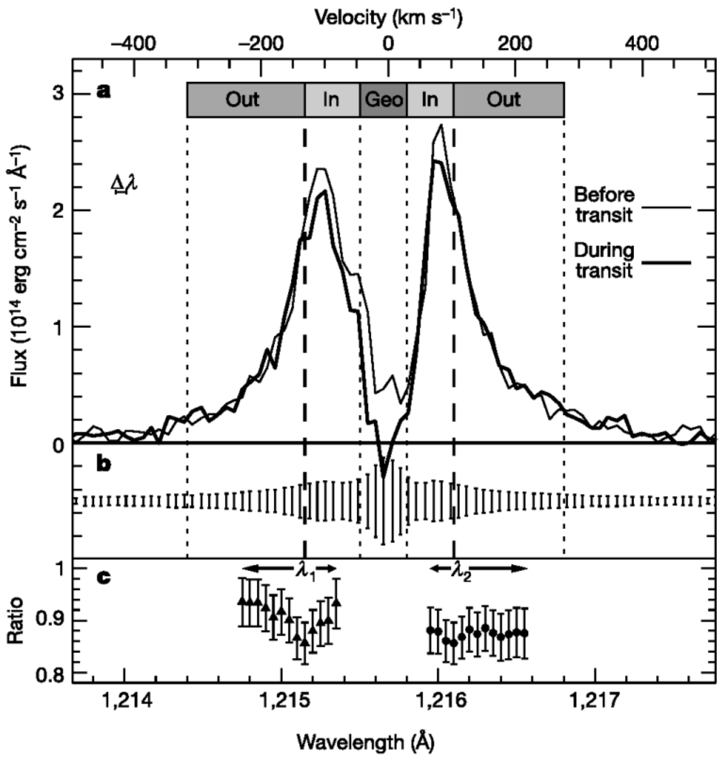
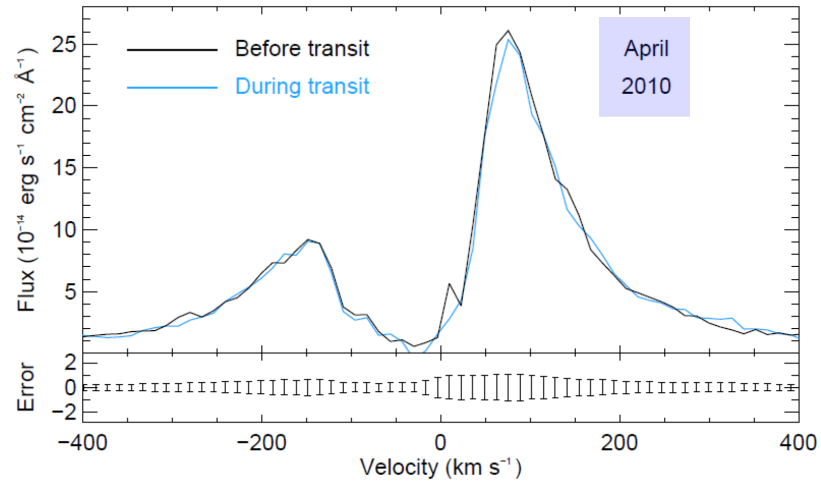


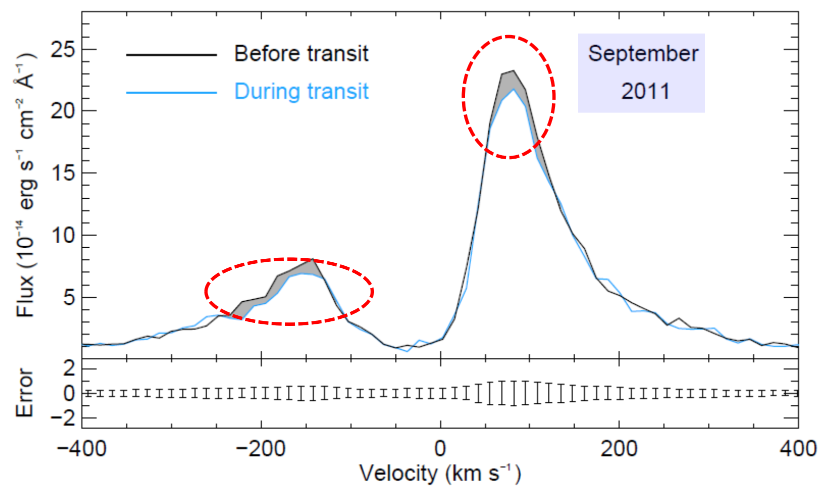
Figure 2 The HD209458 Lyman α profile observed with the G140M grating.

[Lecavelier des Etangs et al., A&A, 2012]

Temporal variations in the evaporating atmosphere of the exoplanet HD 189733b

A. Lecavelier des Etangs[1,2], V. Bourrier[1,2], P. J. Wheatley[3], H. Dupuy[1,2], D. Ehrenreich[4], A. Vidal-Madjar[1,2], G. Hébrard[1,2], G. E. Ballester[5], J.-M. Désert[6], R. Ferlet[1,2], and D. K. Sing[7]





Stellar wind – exosphere – magnetosphere interaction

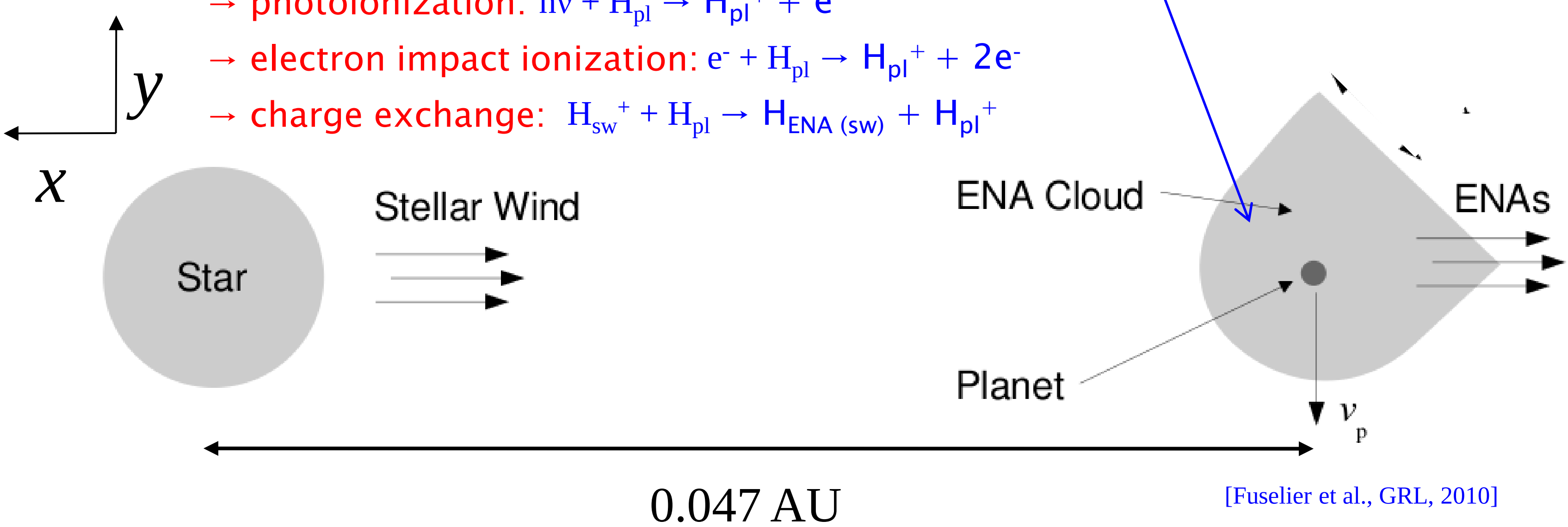
Losses of planetary H atoms:

→ photoionization: $h\nu + H_{pl} \rightarrow H_{pl}^{+} + e^{-}$

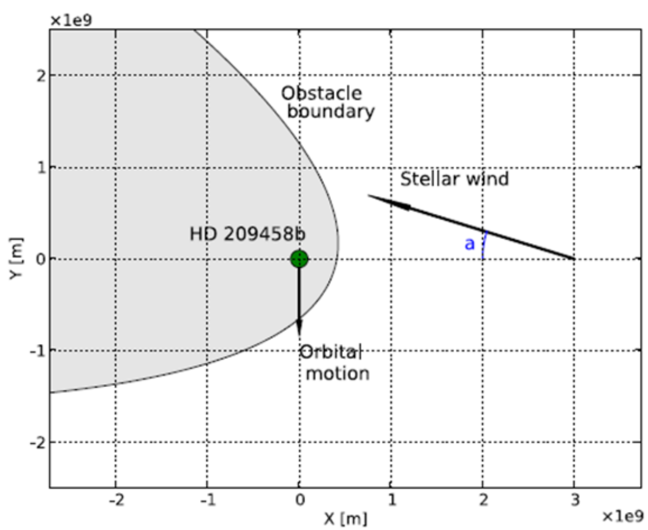
→ electron impact ionization: $e^{-} + H_{pl} \rightarrow H_{pl}^{+} + 2e^{-}$

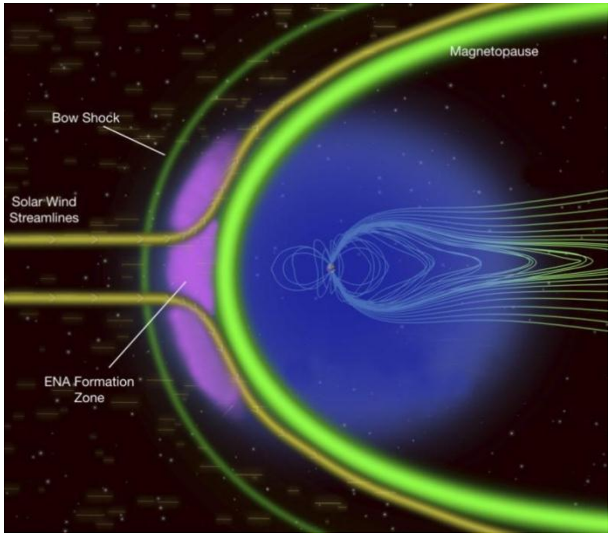
→ charge exchange: $H_{sw}^{+} + H_{pl} \rightarrow H_{ENA\,(sw)} + H_{pl}^{+}$

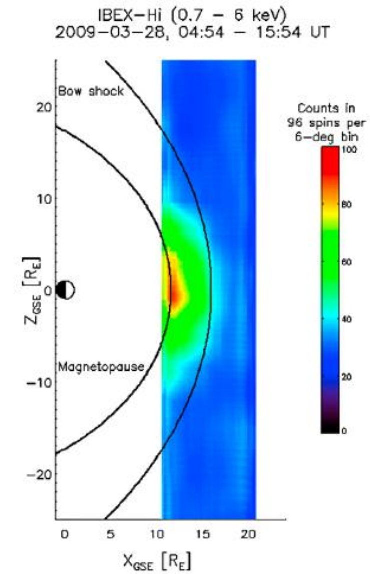
Expanded thermosphere–exosphere



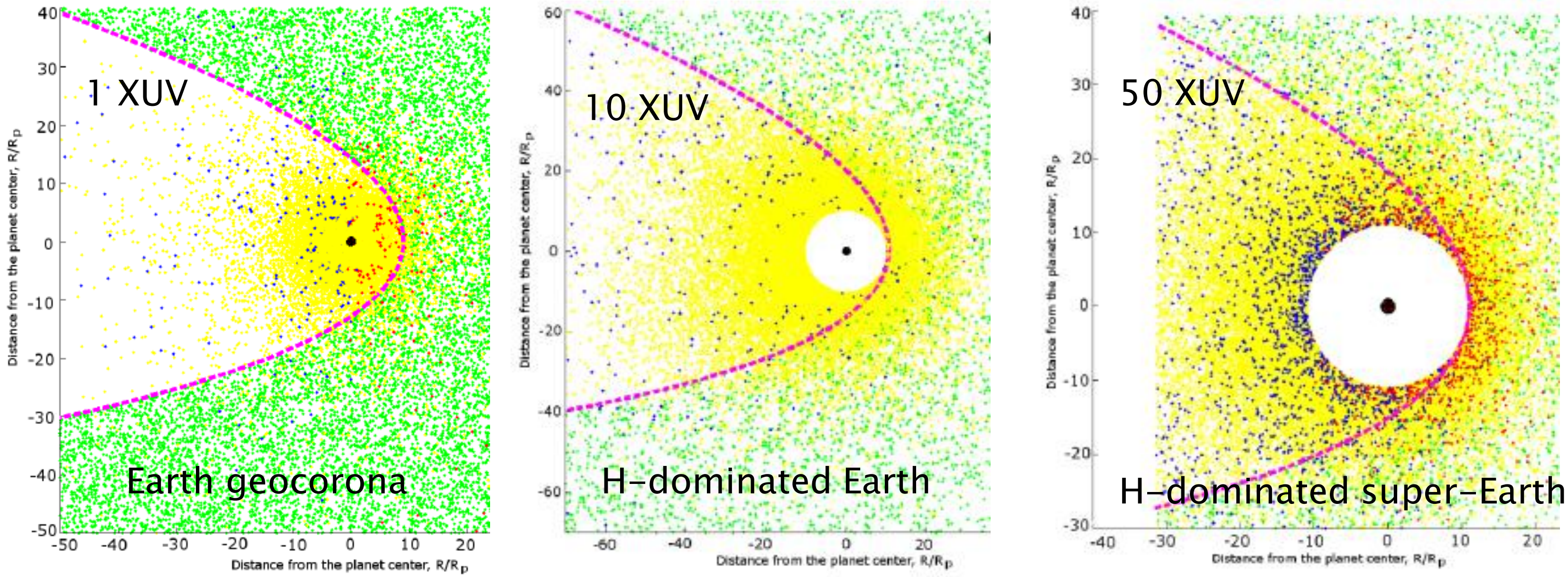
[Fuselier et al., GRL, 2010]



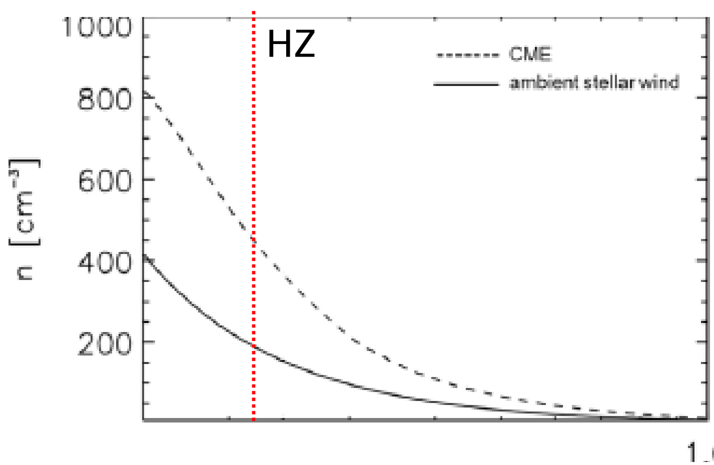




Exosphere–stellar wind plasma interaction modelling



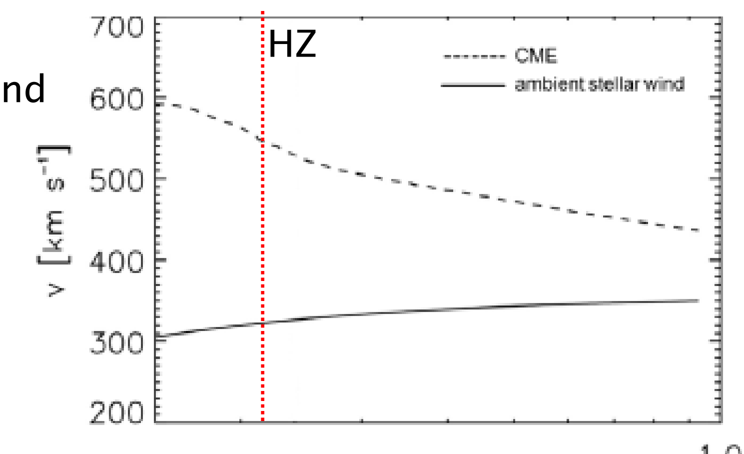
[Kislyakova et al., Astrobiology, submitted, 2013]



1.0

d [AU]

M star wind



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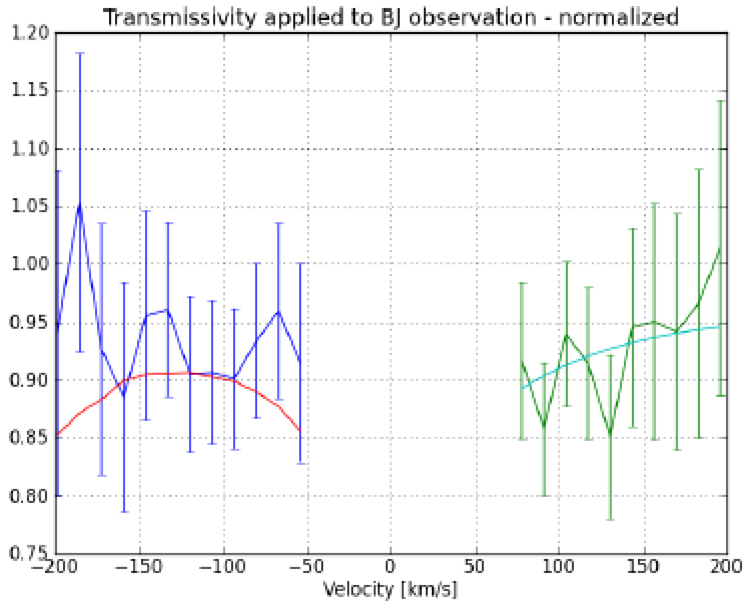
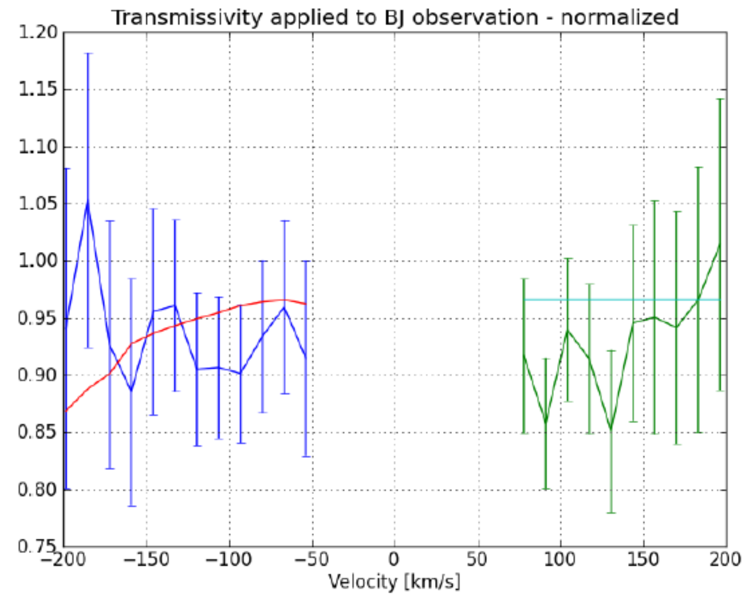
d [AU]

- Charge-exchange with stellar proton: $H^+_{sw} + H_{pl} \rightarrow H^{ENA}_{sw} + H^+_{pl}$
- Ionization (photoionization, electron impact ionization)
- Scattering of an UV photon (radiation pressure)
- Elastic collision with another hydrogen atom
- Gravitational effects (besides gravity - tidal, coriolis, centrifugal forces)

DSMC – stellar wind exosphere interaction model runs → HD 209458b





[Kislyakova et al., in preparation, 2013]

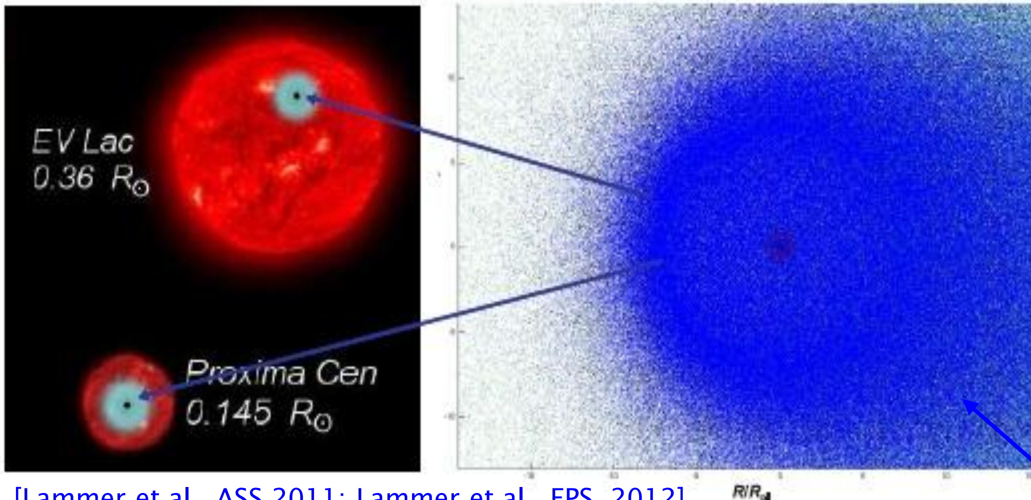
Three effects acting together → the efficiency of processes depend on: EUV, UV, stellar wind, H column content, atmosphere temperature and magnetopause obstacle (B-field)

- Radiation pressure + ionization processes → information on stellar and plasma properties
- ENAs → information on stellar wind parameters and magnetic properties
- Doppler broadening (DB) → information on atmosphere structure

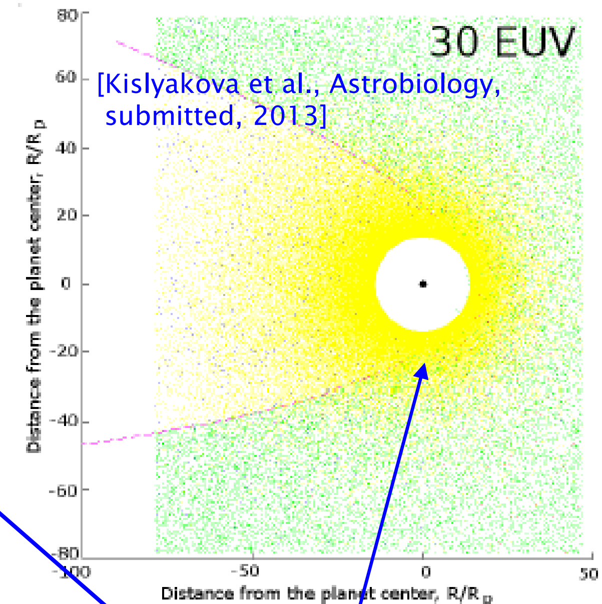
DB is the broadening of spectral lines due to the Doppler effect caused by the velocity distribution of the particles. Different particle velocities yield different (Doppler) shifts
→the cumulative effect of which is the line broadening

For HD 189733b thermal Doppler broadening alone can not explain the observed Lyman-α absorption, because the column content of the H atoms is too low!

Hydrogen-cloud modeling and observations around Earth-size exoplanets



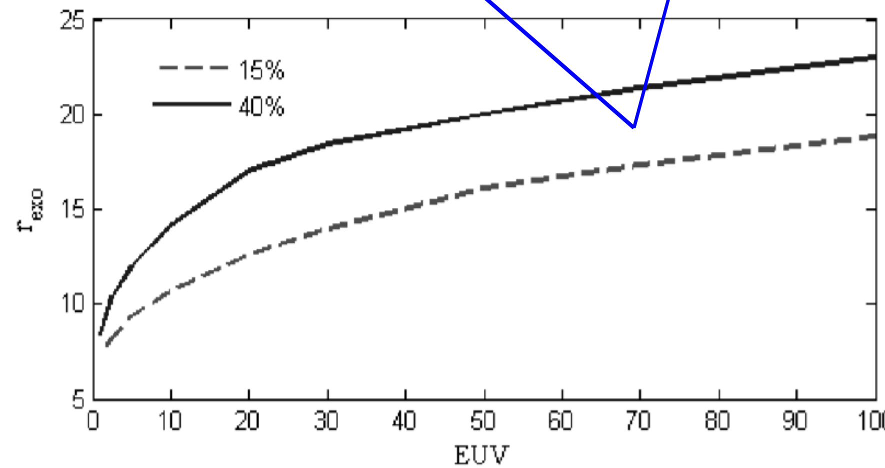
[Lammer et al., ASS 2011; Lammer et al., EPS, 2012]



[Kislyakova et al., Astrobiology, submitted, 2013]

Upper atmosphere and stellar plasma interaction models & observations of hydrogen clouds & ENAs with space observatories such as the WSO-UV around transiting Earth-size exoplanets within orbits of dwarf stars will enhance our understanding how the atmospheres of Earth-like planets survive during the active young star periods → bright stars!

→ how Earth-like habitable planets evolve!



[Lammer, Briefs in Astronomy, 2013]

Testing atmosphere evolution & stellar winds by hydrogen-cloud observations