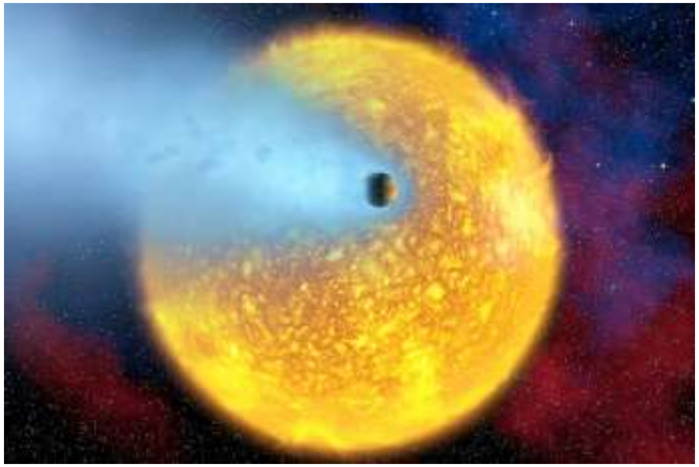

Investigating Atmospheric Escape with ARIEL (?)

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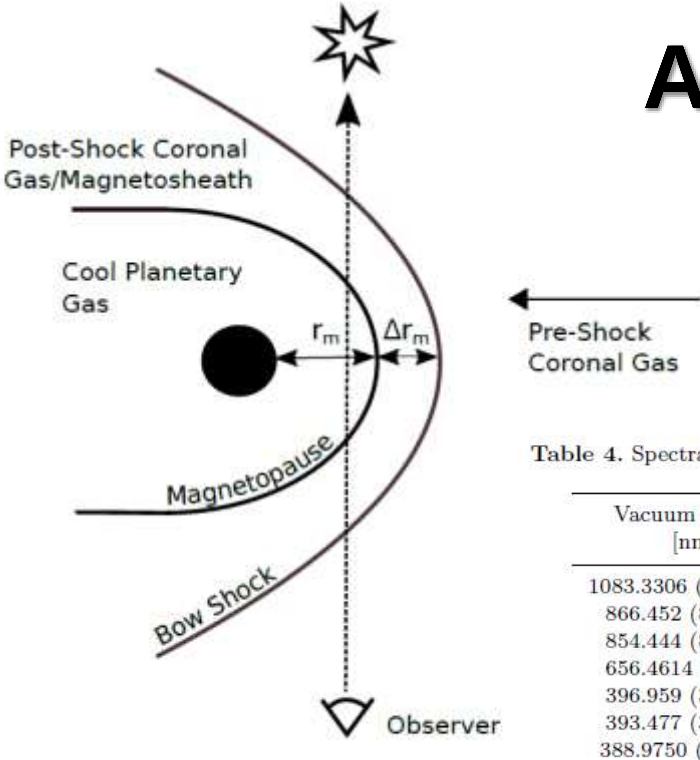
Atmosperic Mass Loss

- It can substantially alter an exoplanet's bulk composition
- Evaporation-induced mass-loss likely the base for the 'Fulton Gap' observed in the small-radius regime of strongly-irradiated planets
- It is also the likely explanation for the observed paucity of short-period sub-Jupiter planets
- Understanding how atmospheric escape effects shape the present-day close-in planet population (at all sizes/masses) is key for retracing evolutionary pathways and evaluate planet formation theories.
- Empirical constraints based on detection of extended atmospheres are much needed, but to-date there are only few.
- One of the difficulties is related to the identification of robust, unambiguous proxies of atmospheric escape in transmission

Atmospheric Escape: Diagnostics

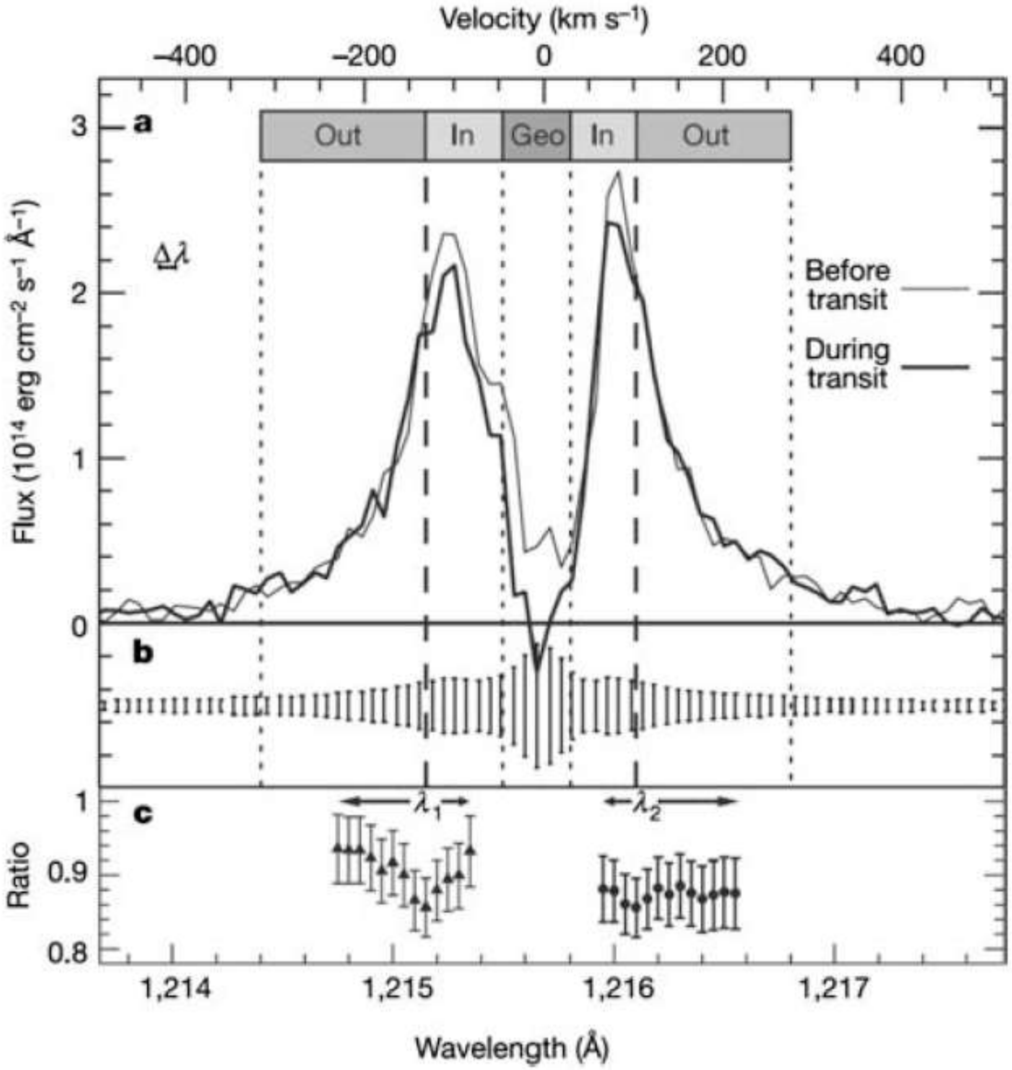


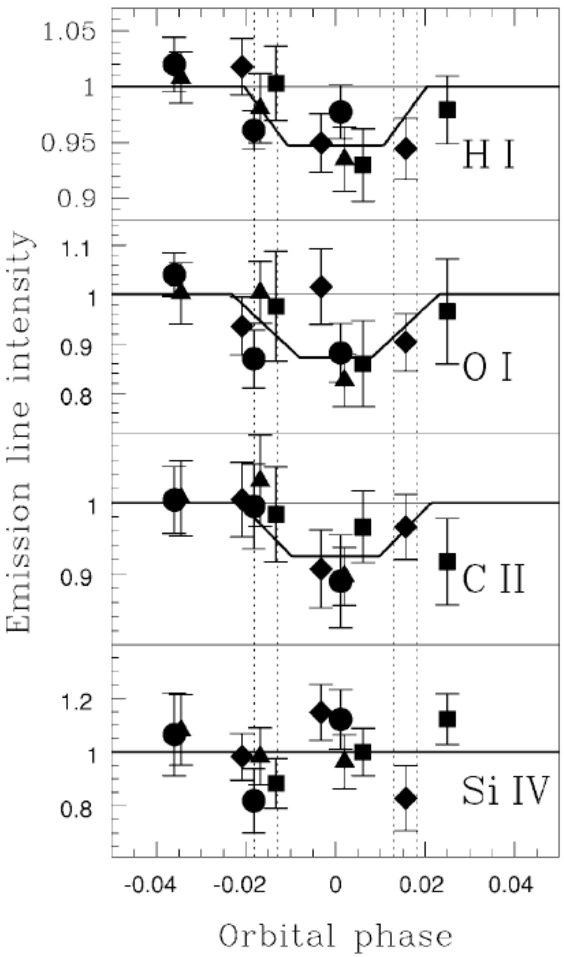
Turner et al. 2016

Table 4. Spectral lines predicted for the planetary gas by CLOUDY.

Vacuum (Air) λ [nm]	Species	Transit Depth [%]	Previously Observed	Vacuum λ [nm]	Species	Transit Depth [%]	Previously Observed
1083.3306 (1083.303)	He I	0.28	N	167.079	Al II	0.26 (blend)	N
866.452 (866.214)	Ca II	0.052	N	166.217	S I	0.26 (blend)	N
854.444 (854.209)	Ca II	0.026	N	165.7	C I	0.36	N
656.4614 (656.28)	H-alpha	0.021	Y (1)	157.591	Co II	0.03	N
396.959 (396.847)	Ca II	0.16	N	156.133	C I	0.314	N
393.477 (393.366)	Ca II	0.19	N	153.1	Si II	0.24	N
388.9750 (388.865)	He I	0.019	N	150	Fe II	0.015	N
336.571 (336.474)	Ti II	0.044	N	147.274	Ni II	0.0535	N
323.8078 (323.714)	Ti II	0.036	N	140.037	Ni II	0.049	N
318.8667 (318.775)	He I	0.01	N	137.573	Ni II	0.083	N
285.2965 (285.213)	Mg I	0.24	Y (2)	135.605	S I	0.065	N
280.3531 (280.271)	Mg II	0.623	Y (3)	133.5	C II	0.44	Y (4)
258.9746 (258.897)	Mn II	0.11	N	132.4117	Ni II	0.294 (blend)	N
251.8226 (2517.47)	Si I	0.01	N	131.477	C I	0.215 (blend)	N
239.9997 (2399.27)	Fe II	0.217	N	130.766	Si II	0.362 (blend)	N
233.5123 (233.441)	S IV	0.0192 (blend)	N	126.332	Si II	0.381	N
233.5321 (233.46)	S IV	0.0192 (blend)	N	125.6	S II	0.162	N
221.500 (221.431)	Si I	0.025	N	125.068	C I	0.223	N
206.156 (206.09)	Co II	0.095	N	124.75	C I	0.33	N
202.6477 (202.582)	Mg I	0.84	N	123.329	C I	0.31	N
186.2789	Al III	0.03 (blend)	N	121.567	Lyman-alpha	12.4 (blend)	Y (5)
185.4716	Al III	0.03 (blend)	N	120.651	Si III	0.58 (blend)	Y (6)
185.3047	Si 1	0.03 (blend)	N	117.959	Si II	0.38	N
181.399	Si II	0.2 (blend)	N	116.681	C I	0.42 (blend)	N
181.7313	Mg I	0.08 (blend)	N	116.598	C I	0.42 (blend)	N
1786	Fe II	0.28	N	116.236	C I	0.42 (blend)	N
176.793	Si I	0.0843 (blend)	N	113.206	C I	0.64 (blend)	N
175.1823	C I	0.15 (blend)	N	113.112	N I	0.64 (blend)	N
174.424	Ni II	0.318 (blend)	N	113.046	C I	0.64 (blend)	N

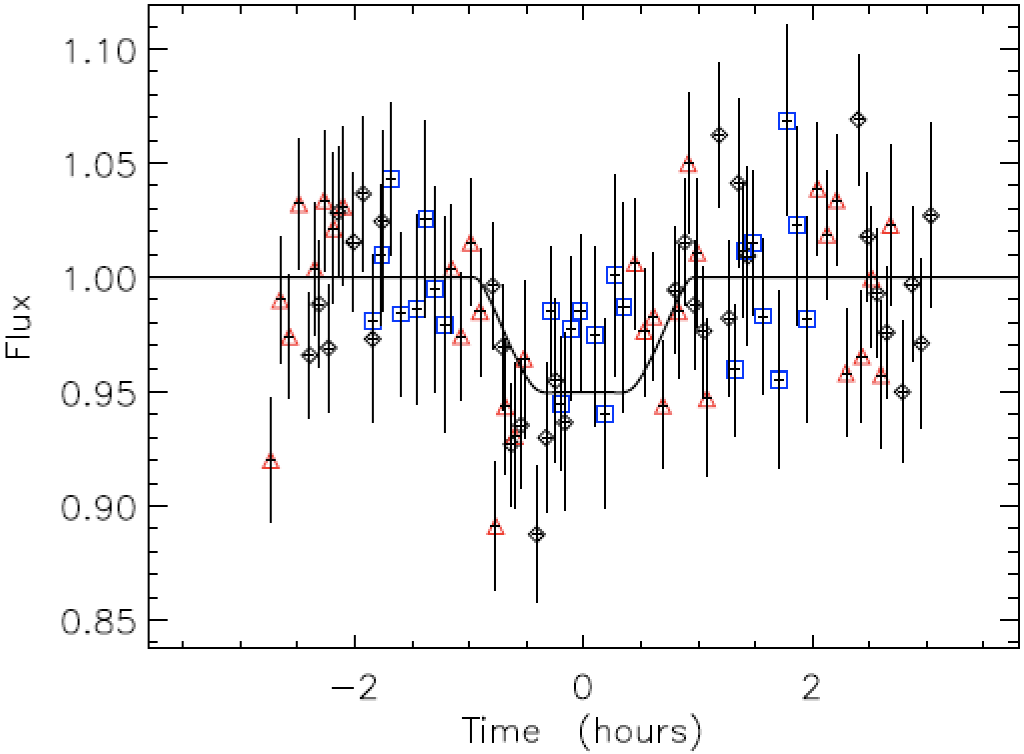
Ly α: HD 209458b

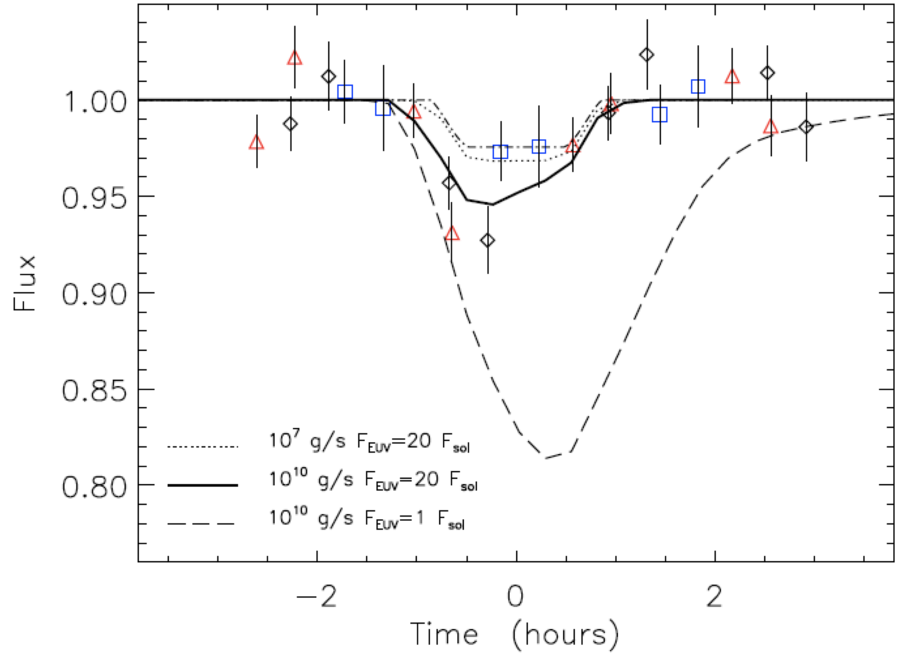




Vidal-Madjar et al. 2003

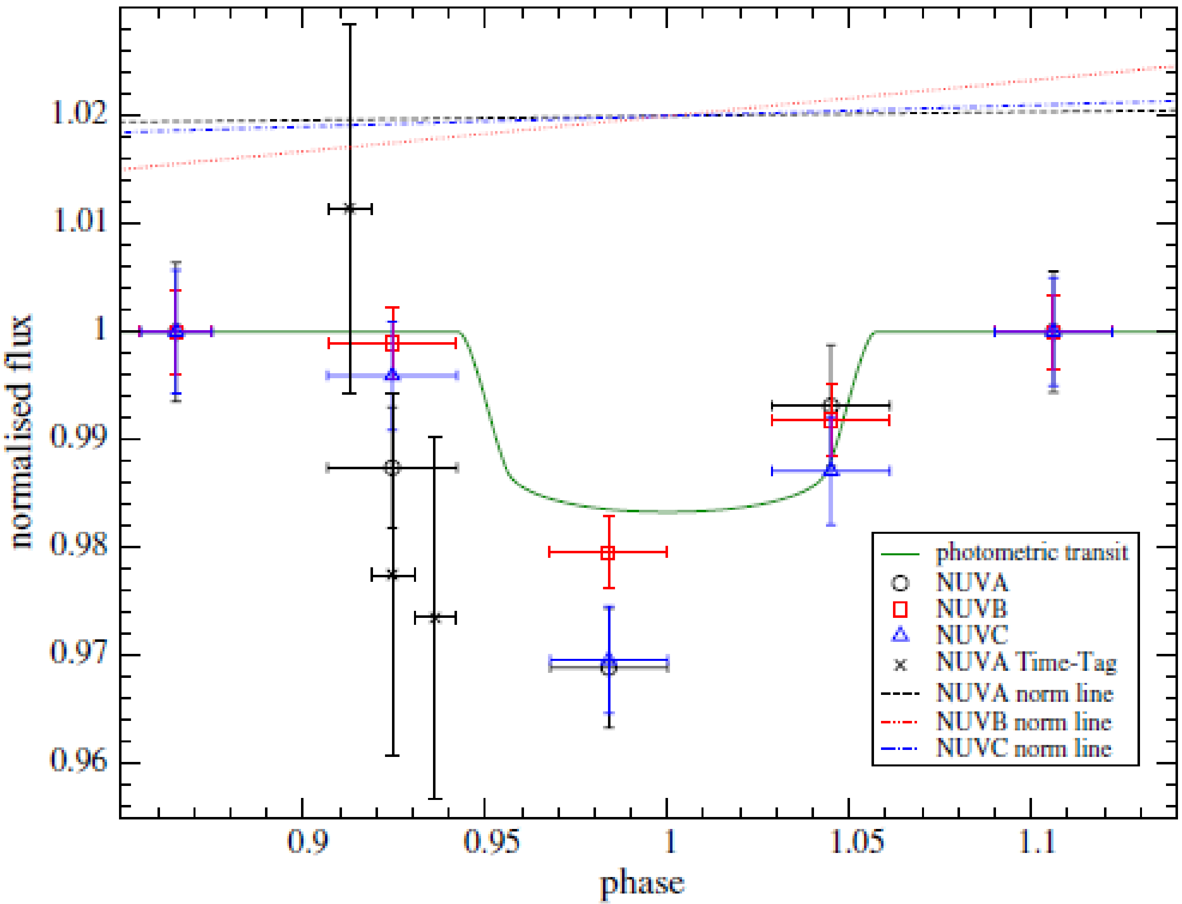
Ly α: HD 189733b





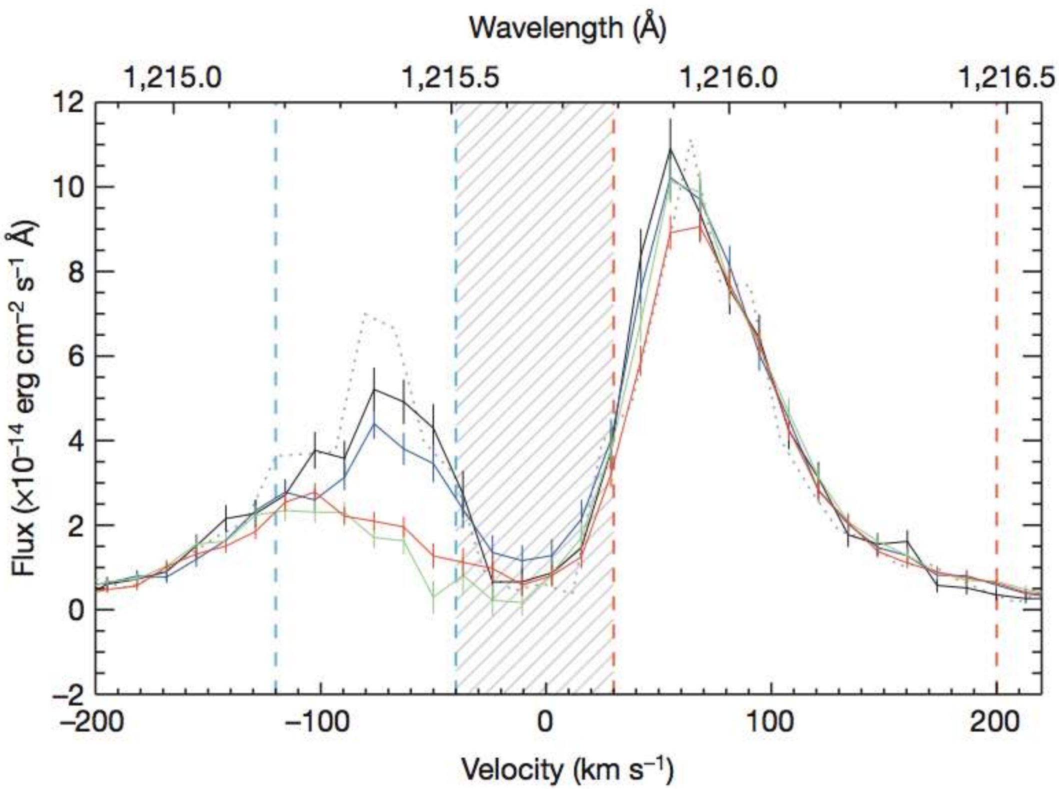
Lecavelier des Etangs et al. 2010

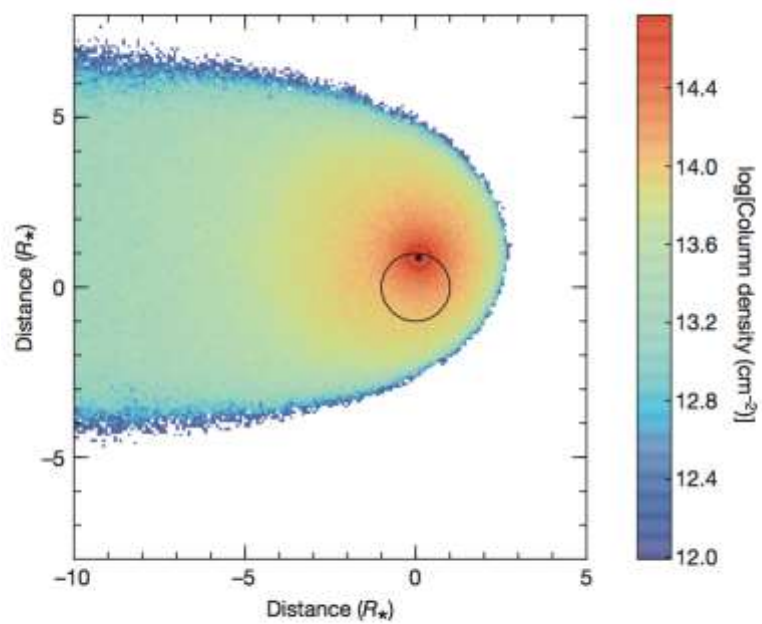
NUV (Mg II et al.): WASP-12b



Fossati et al. 2010

Ly α: GJ 436b

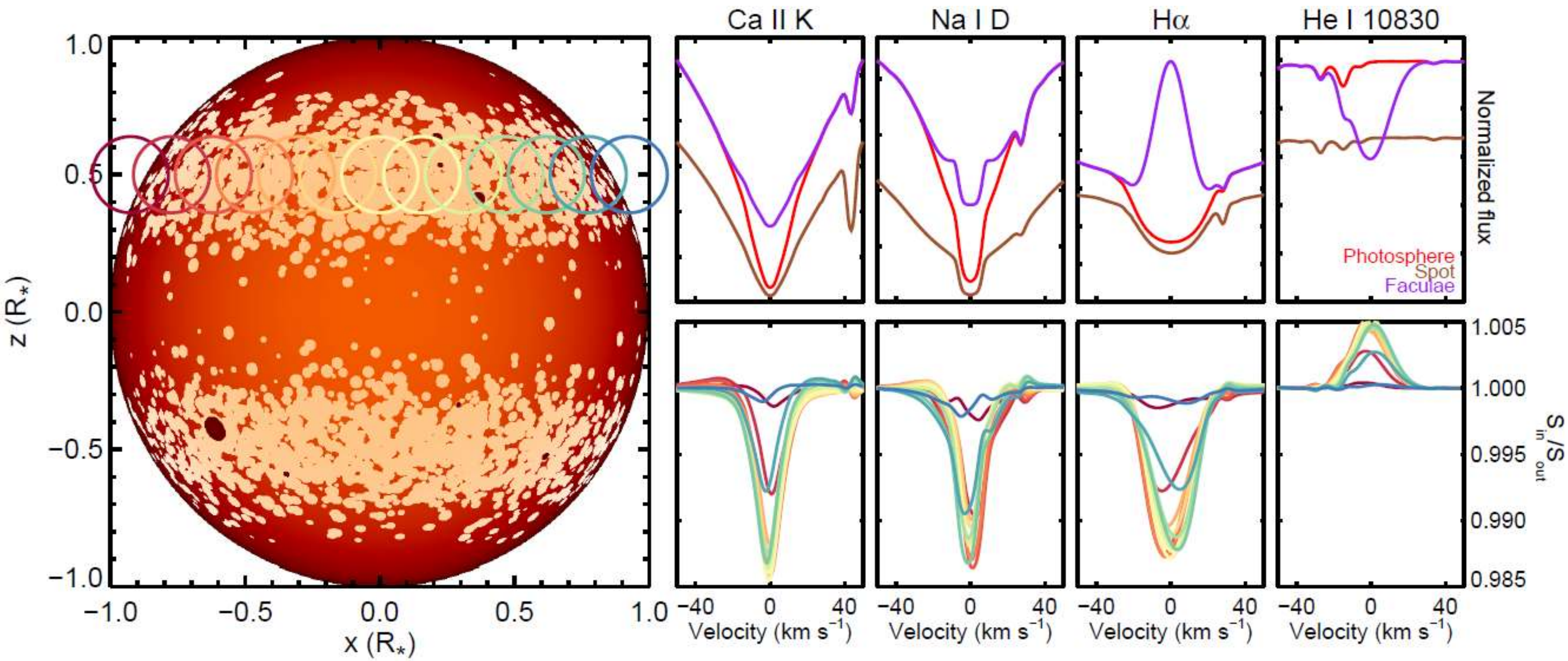




Ehrenreich et al. 2015

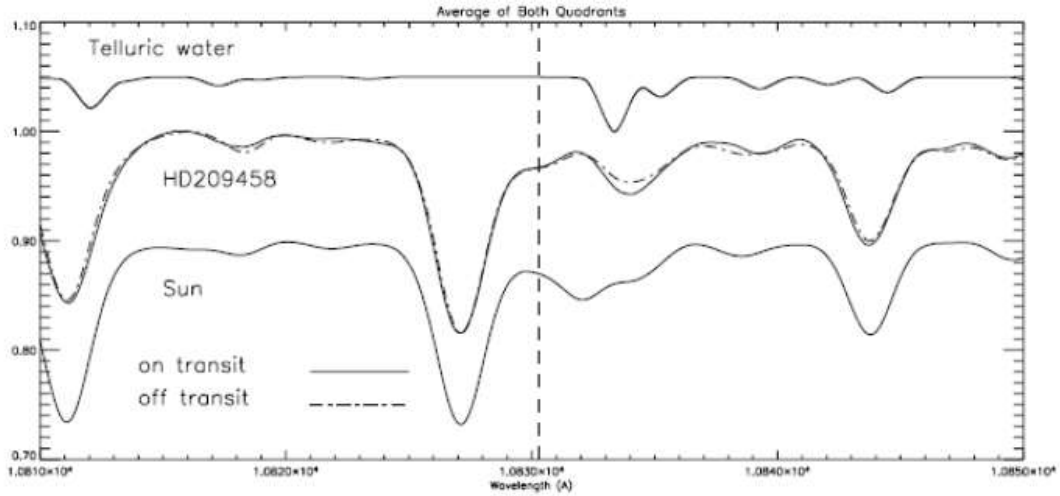
Bourrier et al. 2016

Other Diagnostics



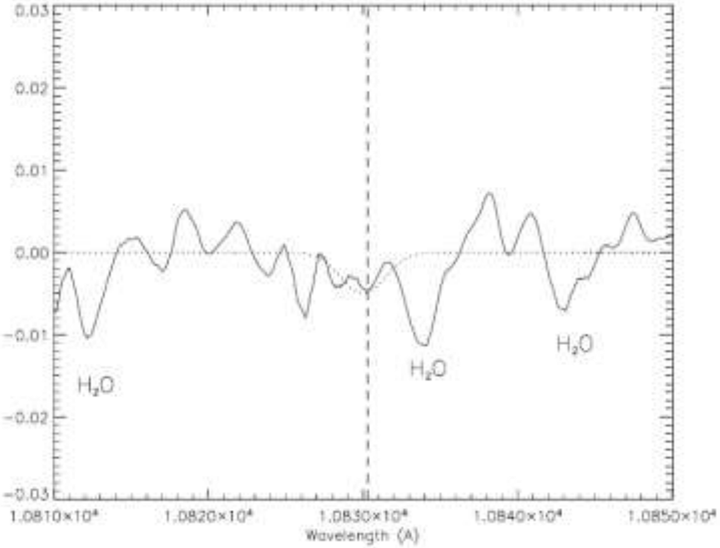
Cauley et al. 2018

- Use of Ly α limited by geocoronal emission and ISM (see before)
- Ca II K, Na I, Hα all produce contamination effects in active stars
- Absorption signatures from active regions can reach 0.3%
- On the contrary, **He I** is seen in *emission* so it dilutes absorption features rather enhancing them.



Moutou et al. 2003

He I: HD 209458b



- TARGET: HD209458b
  Observations of a primary transit (15 June 2001) with the spectroscopic mode of ISAAC on the VLT (R=5800)

→The search for a HeI feature originating in the planet exosphere has been conducted with three methods.

(1) visual inspection

(2) comparison of the temporal behaviour at 10 830 Å in transit, with the same function out-of-transit

(3) introduction of a fake feature of a varying amplitude and width and 3σ-detection of this feature.

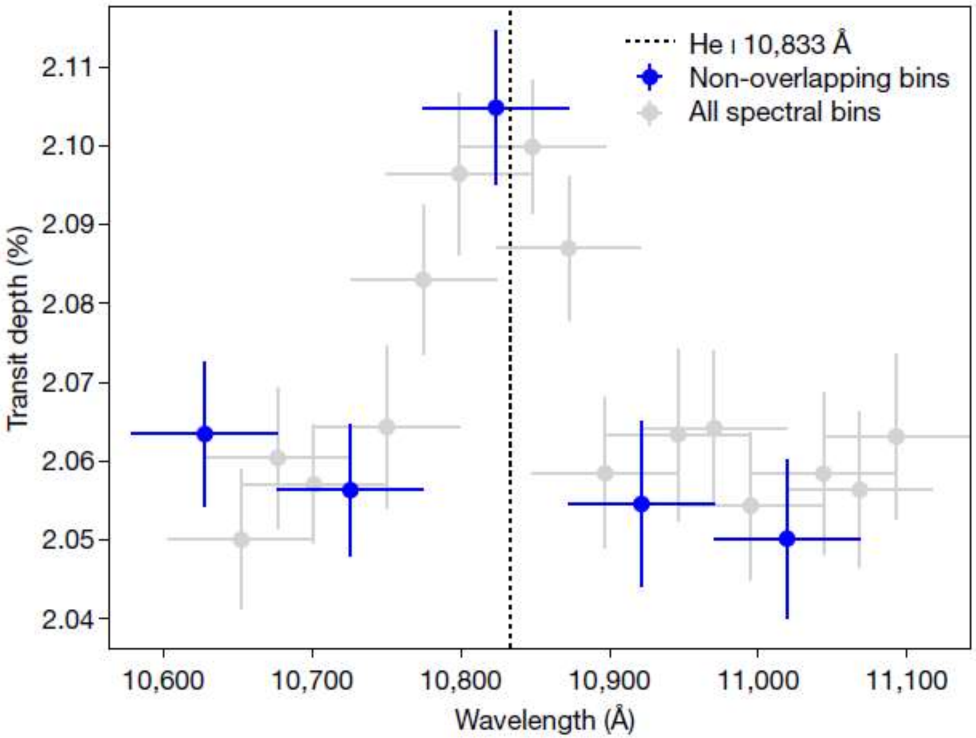
The detection of the HeI feature is not reported.

The data set is strongly affected by instrumental limitations:

-spectral resolution

-fringing

He I: WASP-107b



Spake et al. 2018

- TARGET: WAPS-107b
- Observations of a primary transit (31 May 2017) with Wide Field Camera 3 (WFC3), onboard the Hubble Space Telescope (HST).

→From the obtained infrared transmission spectrum **the narrow absorption feature of excited metastable helium at 10,833 angstroms has been identified with a transit depth $(R_p/R_s)^2$ of 2.105% ± 0.010%.**

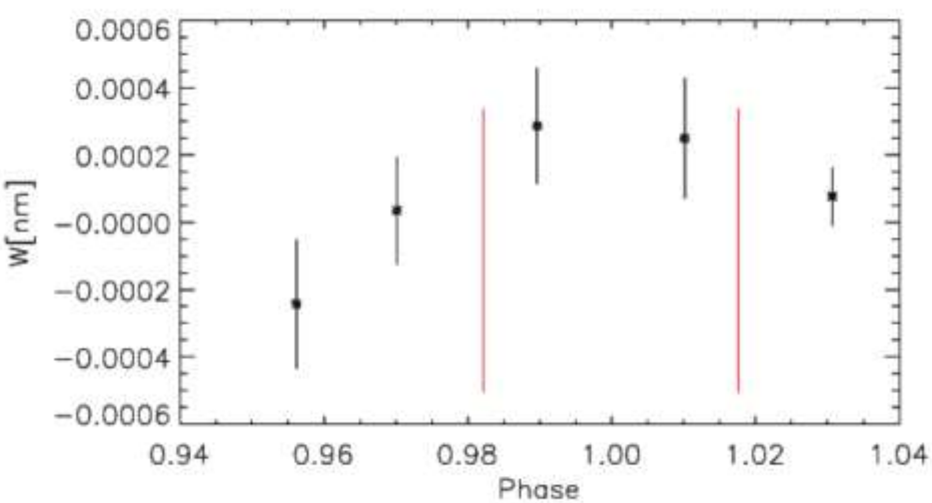
- various alternative explanations for the signal have been ruled out.

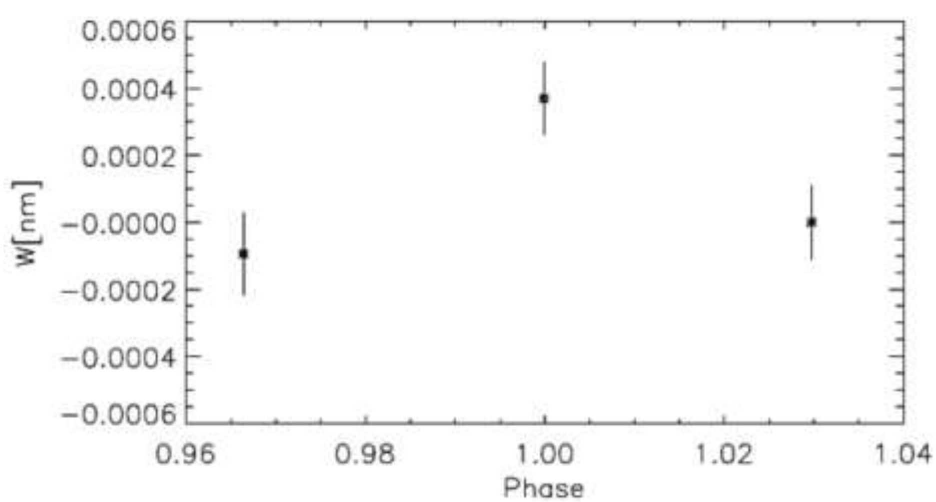
→WASP-107b is losing the 0.1–4 per cent of its total mass per billion years and may have a comet-like tail of gas shaped by radiation pressure.

WASP-107b is a heavily bloated sub-Saturn: M=0.12 Mjup, R=0.94 Rjup
He I absorption is detected at 4.5 σ, with a feature of amplitude 0.049 ± 0.011 % over a 98 Angstrom bandpass

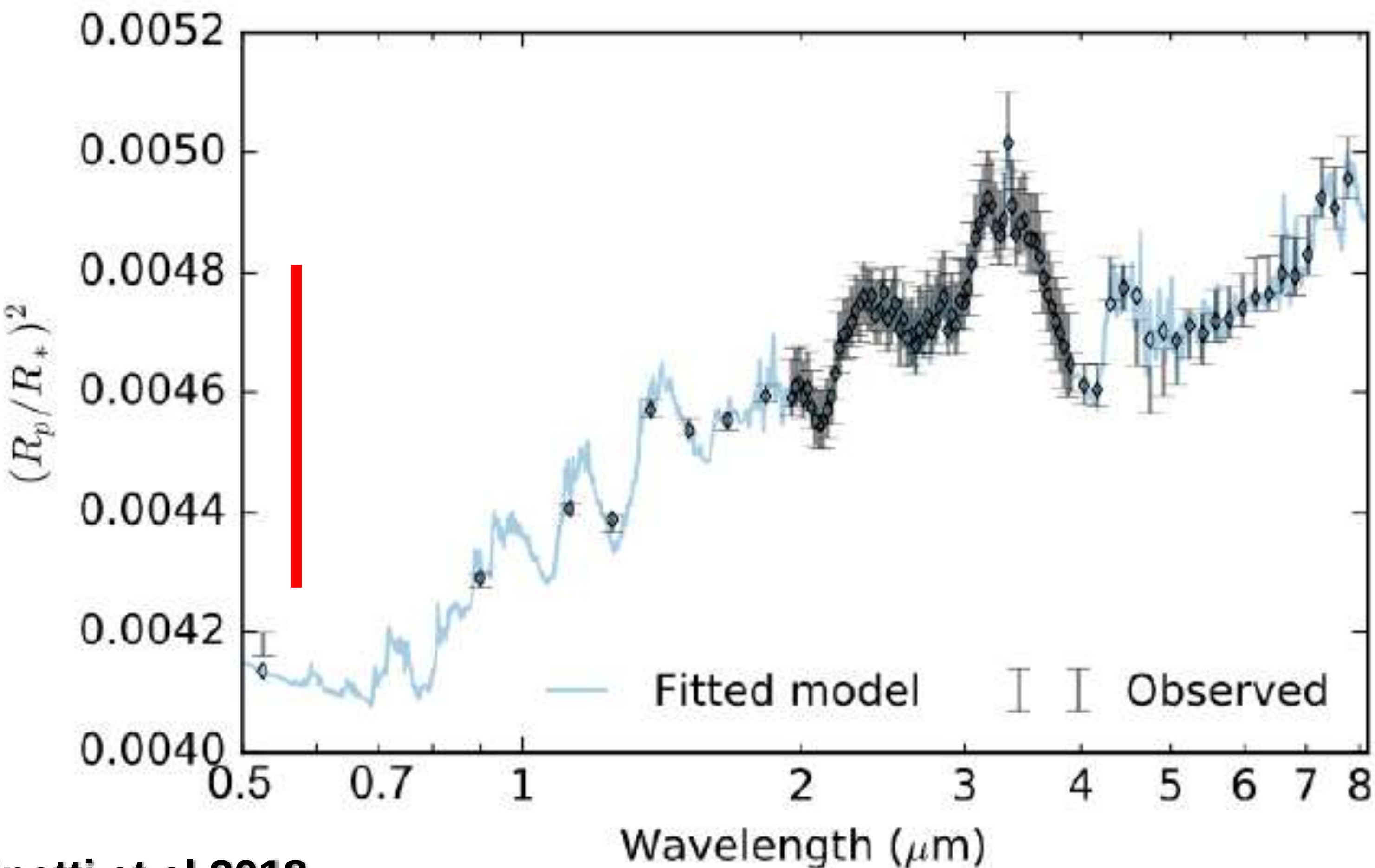
Atmospheric Escape: HRS

- Ongoing analysis of GIANO-B spectra of transiting planets collected within the context of the GAPS2 large programme at TNG
- Compute average pre-, during, and post-transit transmission spectra
- Determine absorption strength of He I @ 1.083 μm via EW measurements
- Preliminary 3-σ detection in one of the targets (check for repeatabilty)





A Test Case: HAT-P-11b



Tinetti et al.2018

ARIEL could provide high SNR measurements of atmospheric escape, but…

Atmospheric Escape with ARIEL?

Wavelength range	Required R & SNR			Scientific motivation
	Tier 1	Tier 2	Tier 3	
VISPhot **0.5 – 0.55 µm**	Integrated band SNR ≥ 200 on the Stellar SNR SNR ≥ 7 on the exoplanet (goal)			• Correction stellar activity (optimised early stars) • Measurement of planetary albedo • Detection of Rayleigh scattering/clouds
FGS1 **0.8 – 1.0 µm**	Integrated band SNR ≥ 200 on the Stellar SNR SNR ≥ 7 on the exoplanet (goal)			• Correction stellar activity (optimised late stars) • Measurement of planetary albedo • Detection of clouds
FGS2 **1.05 – 1.2 µm**	Integrated band SNR ≥ 200 on the Stellar SNR SNR ≥ 7 on the exoplanet (goal)			• Correction stellar activity (optimised late stars) • Detection of clouds
NIRSpec **1.25 – 1.95 µm**	R: 10 averaged bands for 1.25 – 7.8 µm SNR ≥ 7	R ≥ 10 SNR ≥ 7	R ≥ 10 SNR ≥ 7	• Correction stellar activity (optimised late stars) • Detection of clouds • Detection of molecules (esp. TiO, VO, metal hydrides) • Measurement of planet temperature (optimised hot) • Retrieval of molecular abundances • Retrieval of vertical and horizontal thermal structure • Detection time variability (weather/cloud distribution)
AIRS **(Channels 0 & 1)** **1.95 – 7.8 µm**		R ≥ 50 for λ<3.9µm; R ≥ 15 for (λ>3.9µm) SNR ≥ 7	R ≥ 100 for (λ<3.9µm); R ≥ 30 for (λ>3.9µm) SNR ≥ 7	• Detection of atmospheric chemical components • Measurement of planet temps. (optimised warm-hot) • Retrieval of molecular abundances • Retrieval of vertical and horizontal thermal structure • Detection time variability (weather/cloud distribution)

1) Can the spectral range of NIRSpec be further adjusted?
2) Can a higher resolution mode (not 20-25, but closer to 100) be included?

Summary

- Systematic study of atmospheric escape an excellent opportunity for ARIEL
- He I line at 1.083 μm probes the uppermost atmospheric layers

  -> a robust proxy for mass loss
- The line falls for free in ARIEL's spectral range
- Make an effort to adjust NIRSpec configuration
- A WG on upper atmospheres has just been setup. Good news, especially if it will deal with extended atmospheres too.
- We can contribute a) to the science case, b) data analysis expertise (coming the HRS side of the matter)