Exoplanets and X-rays: an intimate relationship

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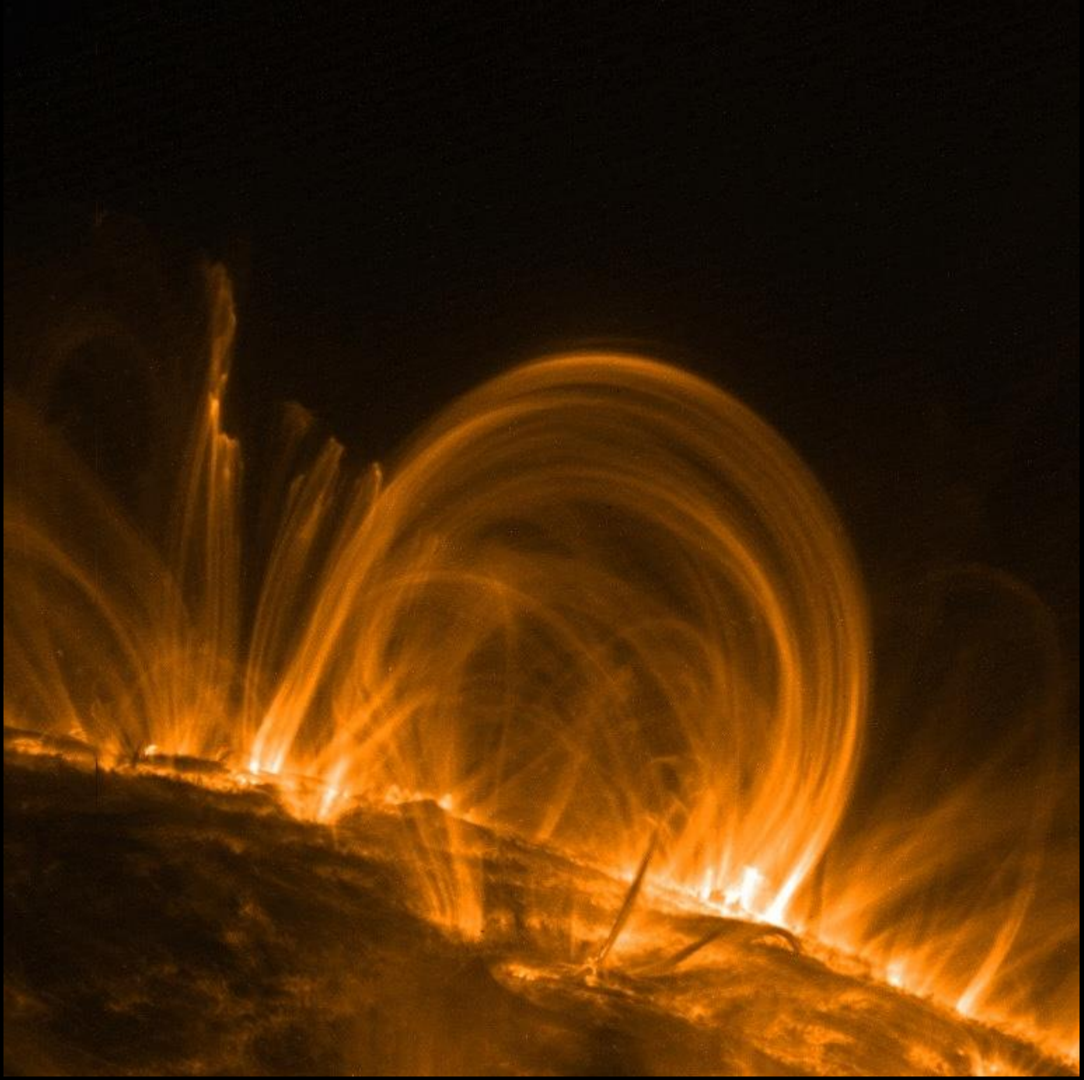
EXCELENCIA MARÍA DE MAEZTU

XUV ionizing radiation

Photons with $\lambda < 912$ Å ionizes H atoms, and may generate secondary UV photons. Strong effects on planets:

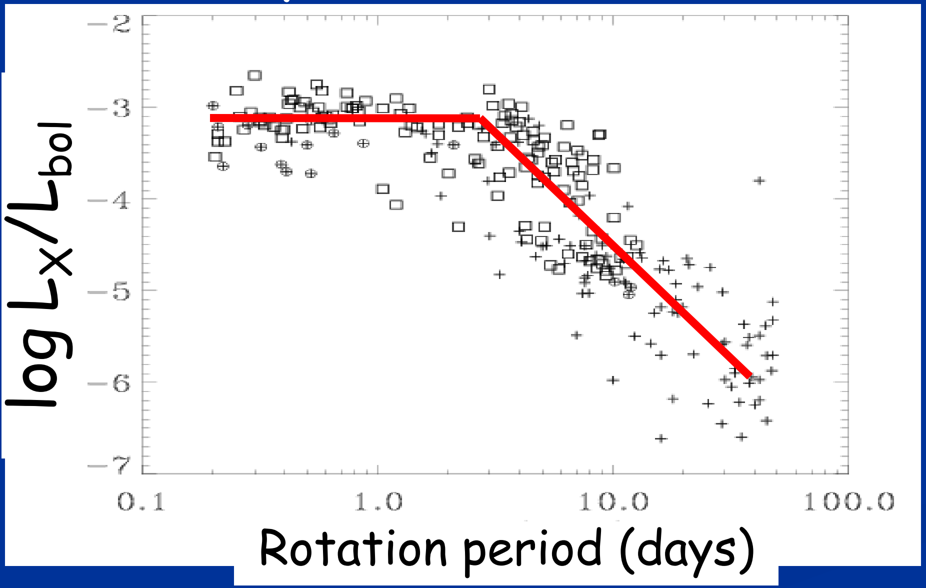
1. Earlier dissipation of protoplanetary disk (<10 Myr) → Settles initial planet mass
2. Atmospheric evaporation
3. Photochemistry changes.
4. Life evolution (XUV friend or foe?)

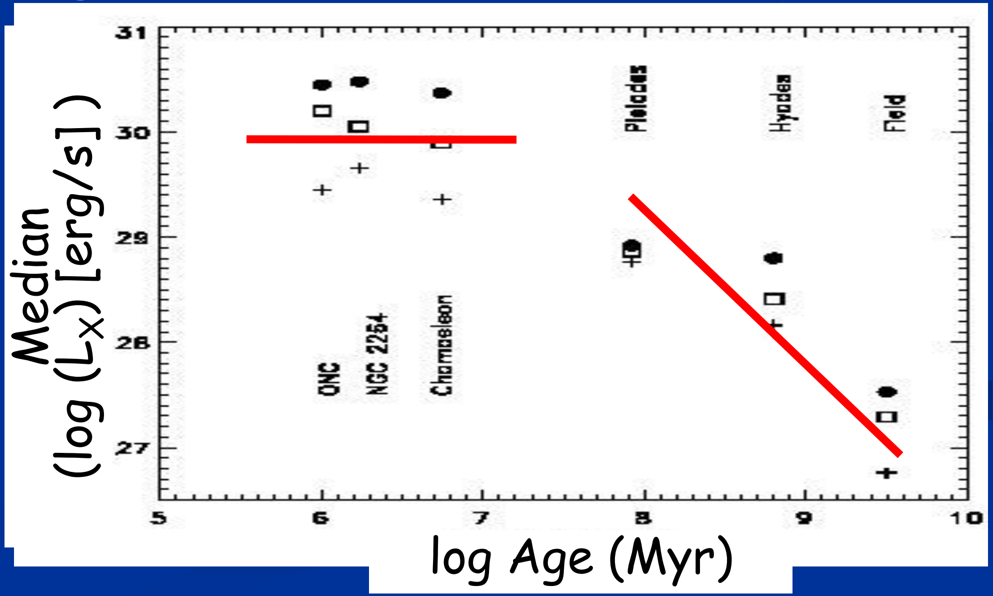


All flux in X-rays, EUV and FUV (≈1-1300 Å) is originated in the corona, transition region and upper chromosphere.

X-rays evolution with time

- Late type stars (F, G, K, M) have a corona.
- Activity depends on rotation. Rotation depends on age
- X-rays will decrease as star gets older (slower rotator)





XUV* ionizing radiation

First Ionization Potential of some elements (below Lyman α)

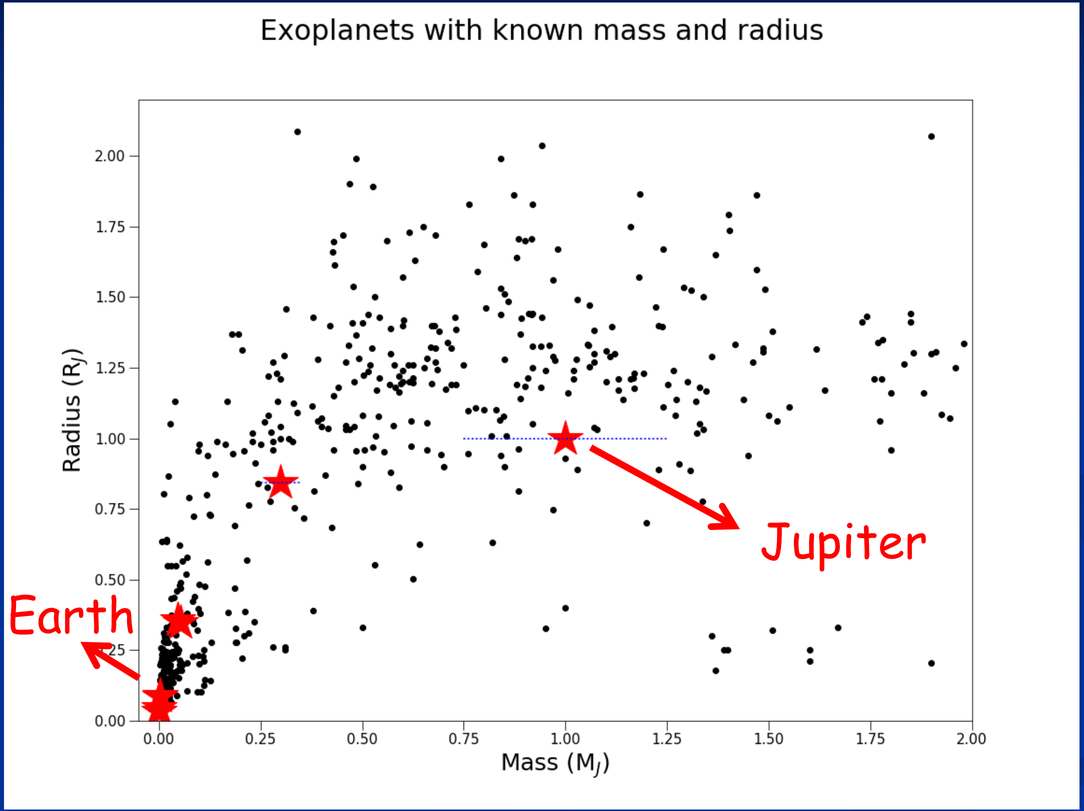
Element	FIP	λ (Å)
He	24.59	504.2
Ne	21.56	575.1
Ar	15.76	786.7
N	14.53	853.3
O	13.61	911.0
H	13.60	911.6
C	11.26	1101.1
S	10.36	1196.8

The XUV photons have some effects:

1. Ionize H (and He) in the ISM
2. Neutral atoms become vulnerable to stellar wind
3. Photochemistry in the planet atmosphere
4. Trigger some interesting lines (e.g. He I 10830 Å)

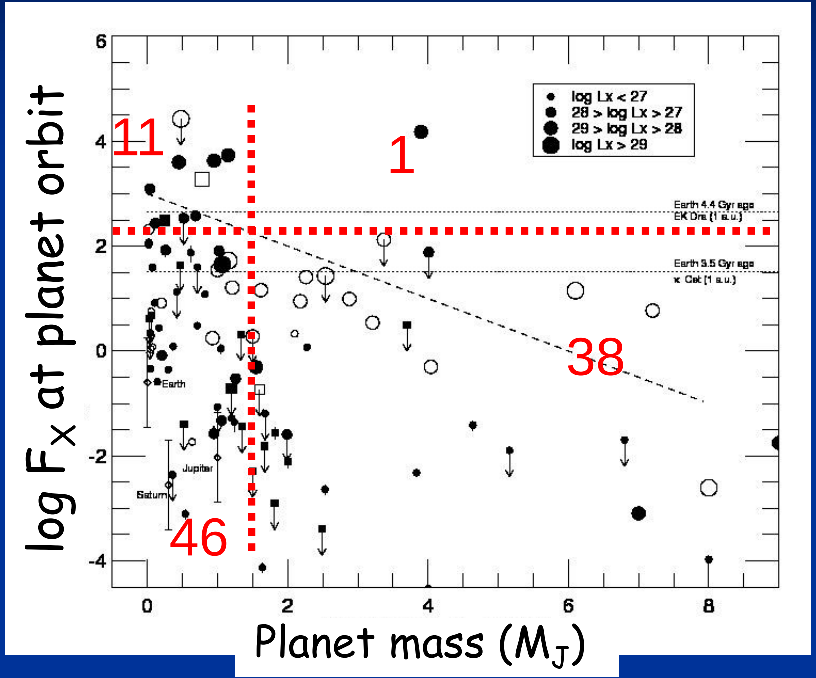
(*): X-rays: 1-100 Å, EUV: 100-920 Å

Transiting planets have short period orbits, thus they are very close to the star (bias)…



… they receive much XUV radiation, they are inflated

X-ray flux vs planet mass



Sanz-Forcada et al. (2010, 2011)

● Dwarfs ○ ROSAT ◊ Solar System

■ Subgiants ● XMM/Chandra

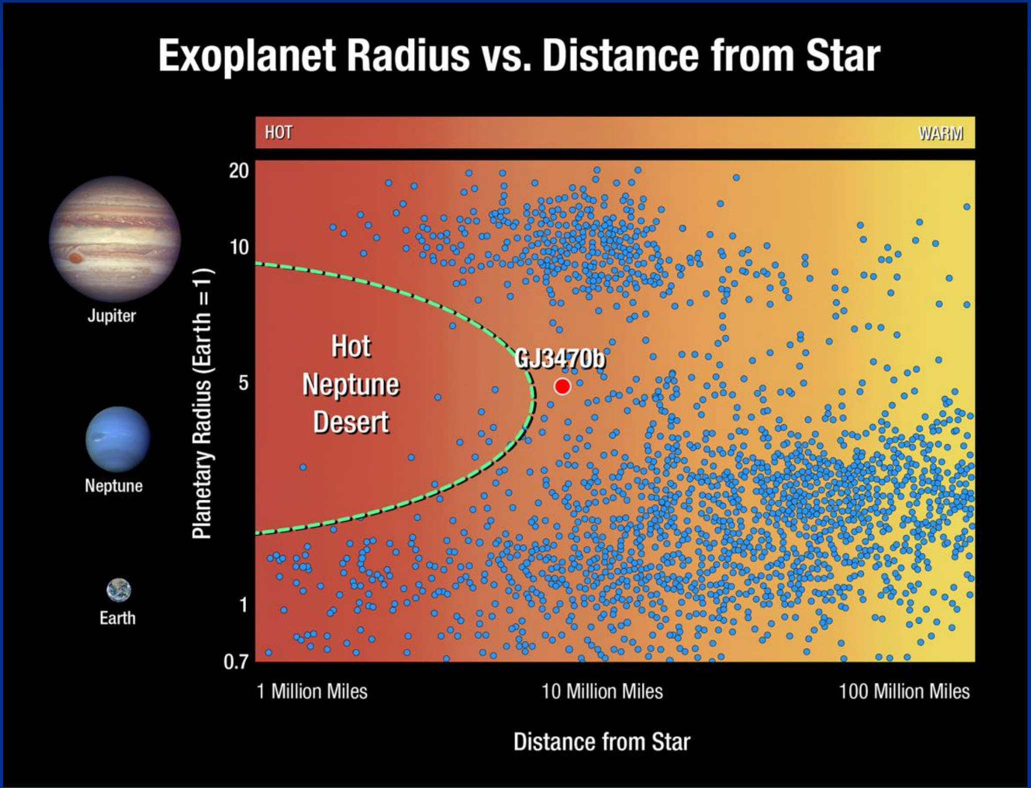
Lack of massive planets being irradiated.

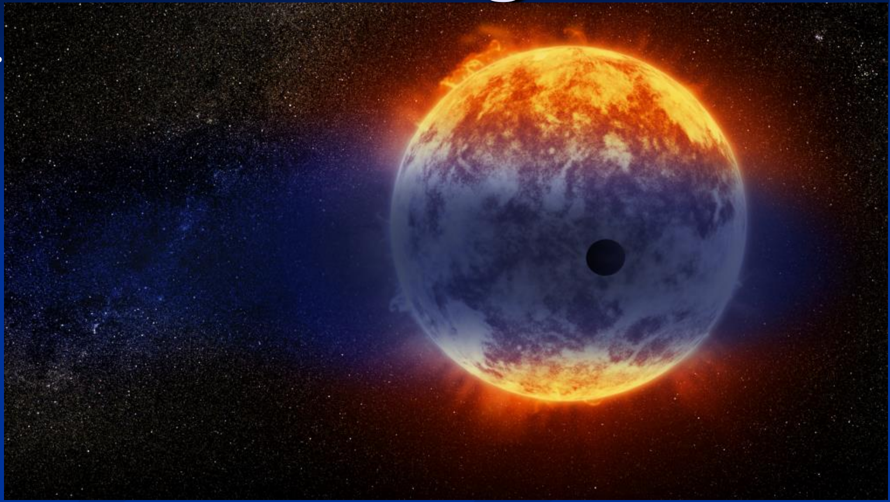
Possible explanations:

- Rapid mass loss during first Gyr
- Effects of planet formation
- A combination of both

Planet mass loss in low mass regime

Bourrier, …, Sanz-Forcada, et al. (A&A 2018).
35% absorption in Lyman α (HST)





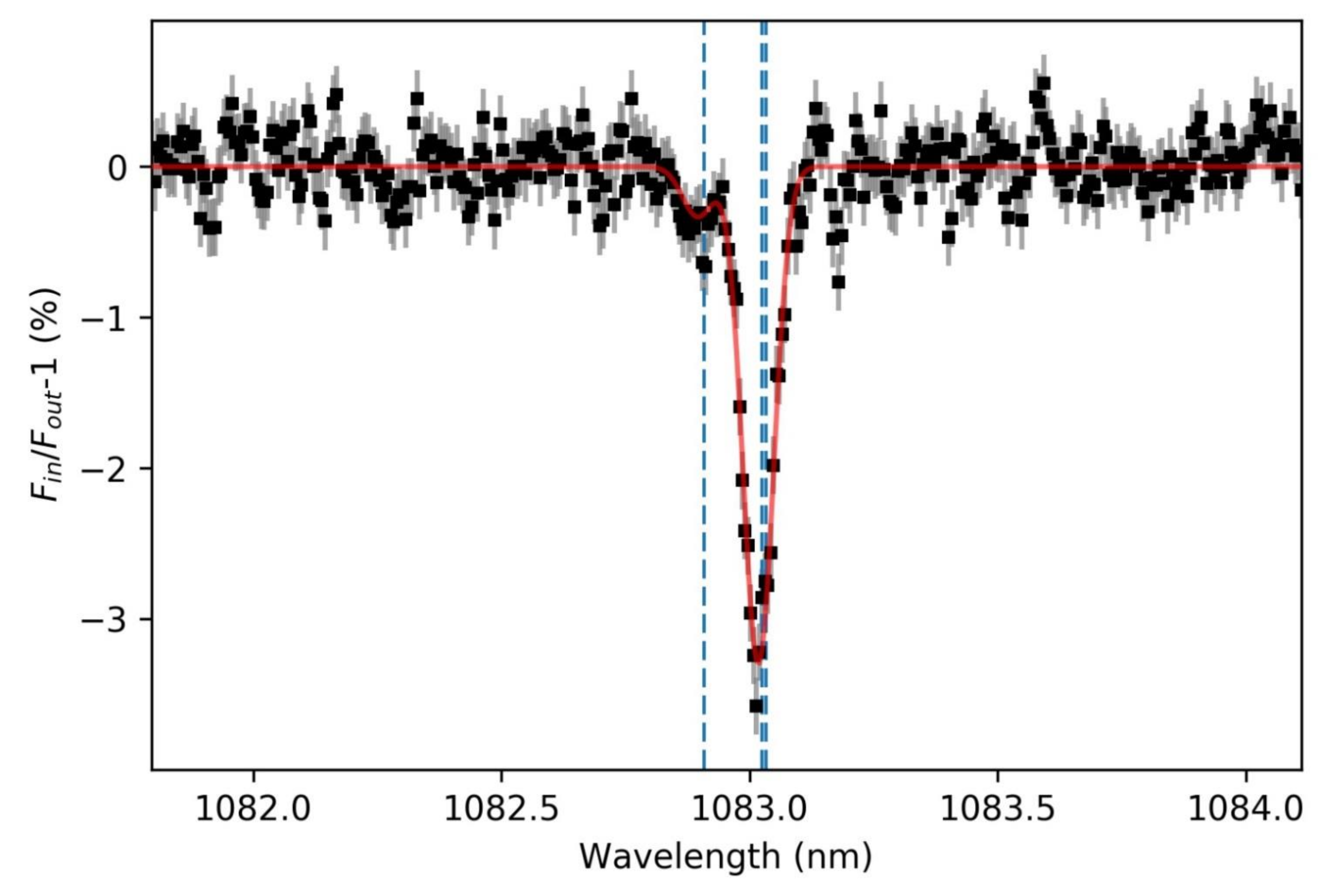
Low mass planets lose atmosphere quickly to leave just the rocky core.

H Lyman α studies limited by ISM absorption.

CARMENES: WASP-69 b + others

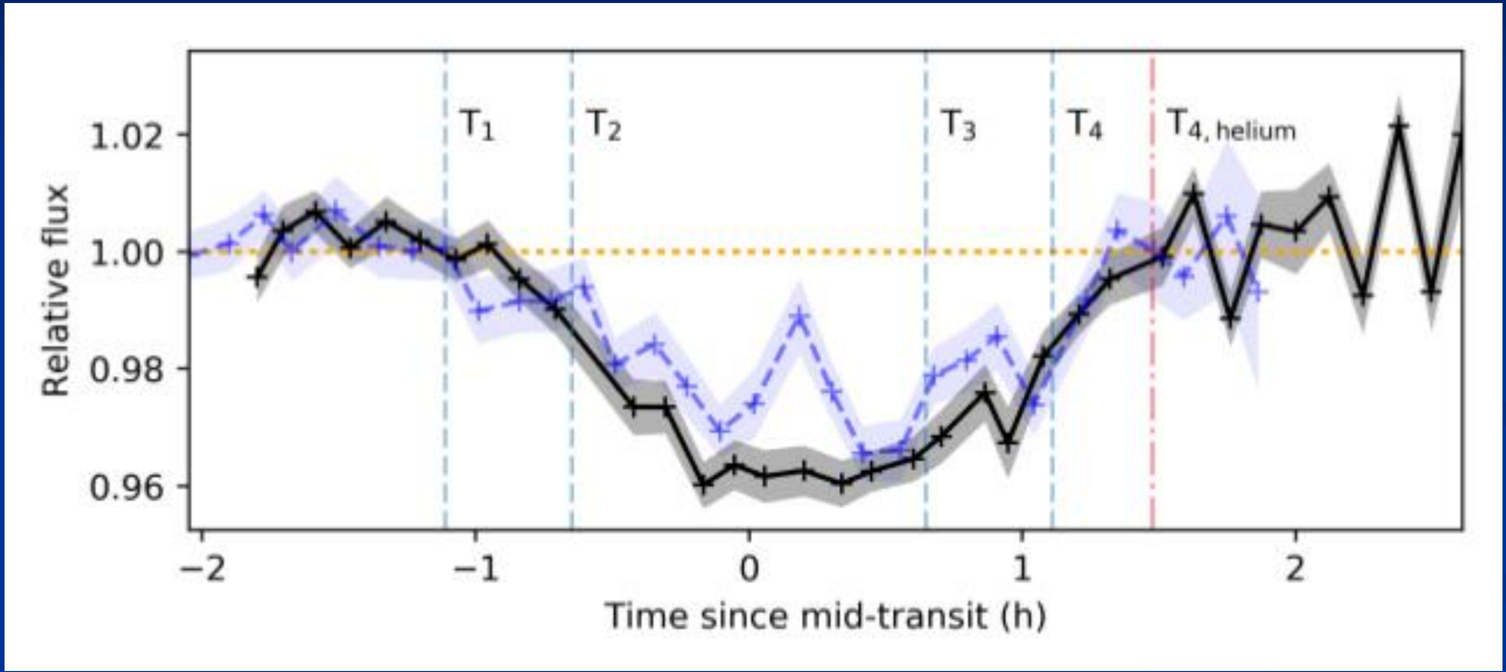
Net absorption of 3.86 ± 0.25% and 3.00 ± 0.31% (1st and 2nd transit)

Wind velocity 3.58 ± 0.23 km/s (day -> night)



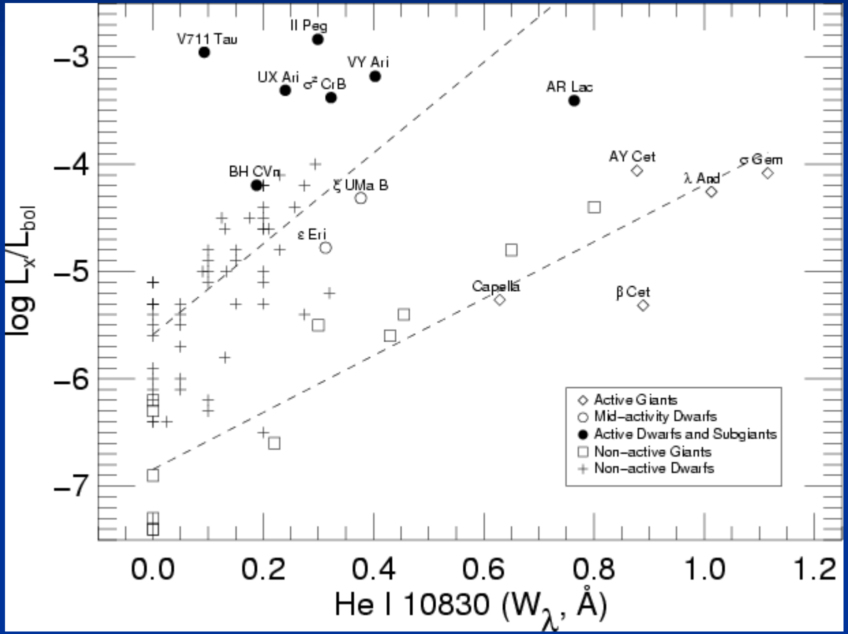
Nortmann+ (2018)

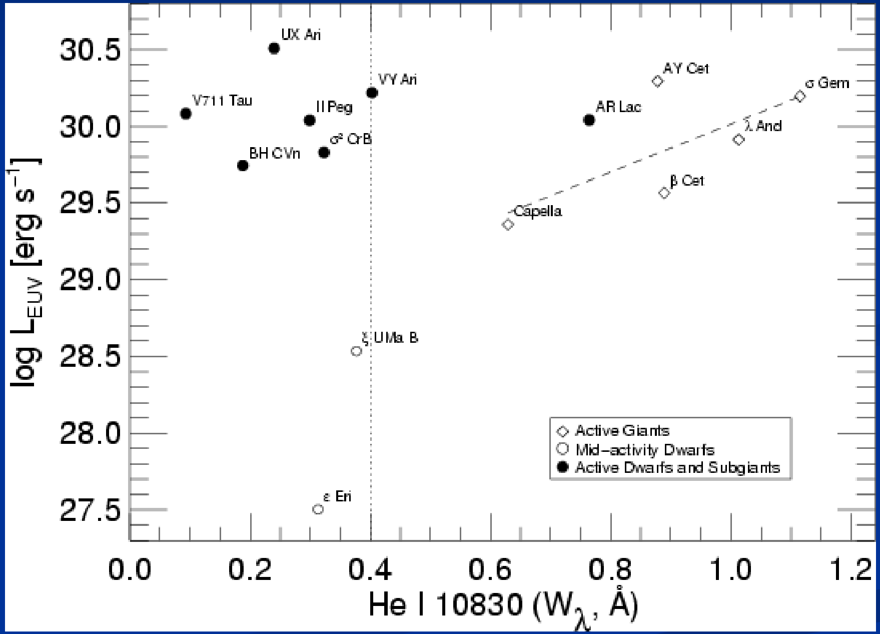
First time planet winds are measured !



Assymetric transit: egress indicates a cometary tail
Wind velocity of tail (after T_4): 10.69 ± 1.00 km/s (day -> night)

What makes a planet detectable in He I 10830?





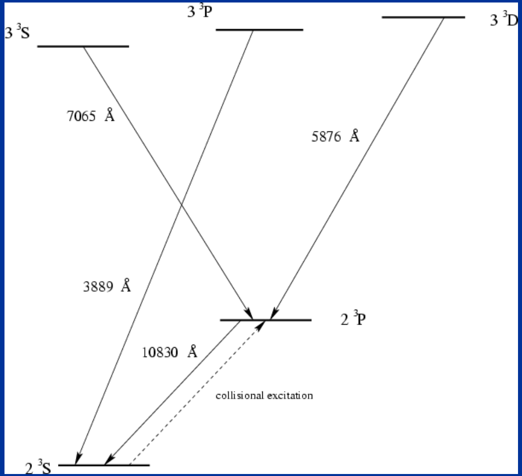
Sanz-Forcada & Dupree (2008)

He line in cool stars is related to X-rays and EUV

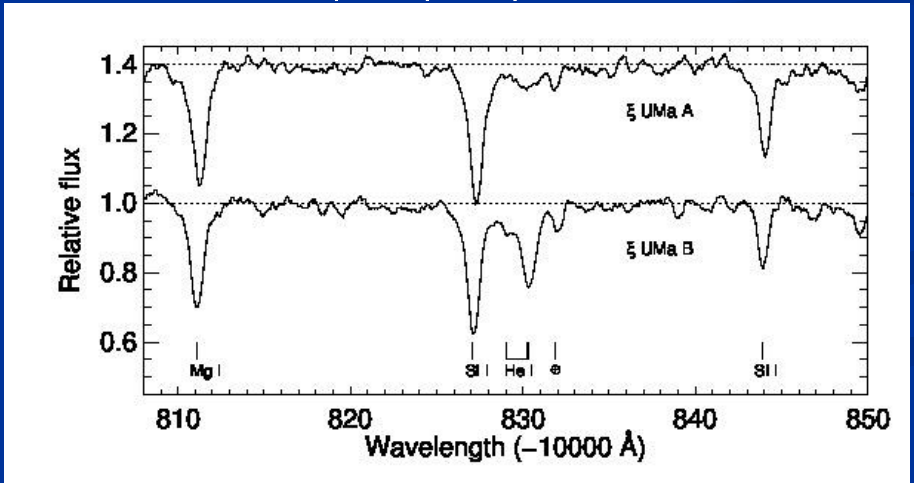
The He I 10830 line

Need to populate the 2^3S level. Two mechanisms of formation:

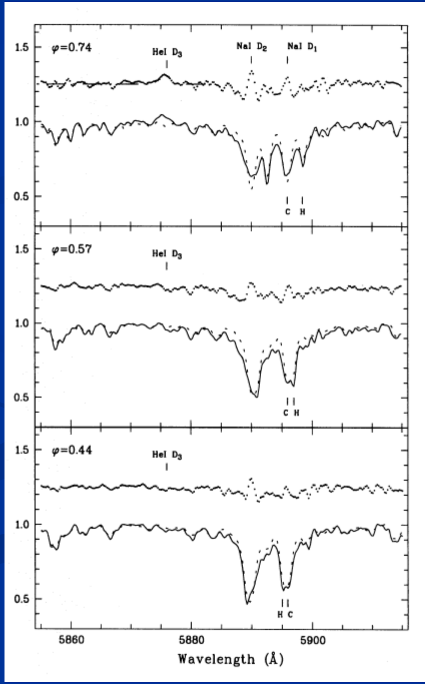
- Collisional excitation in a hot environment (>20,000 K)
- Photoionization (<504 Å) and recombination with cascade to the metastable level 2^3S



Sanz-Forcada & Dupree (2008)



Montes+ (1996)



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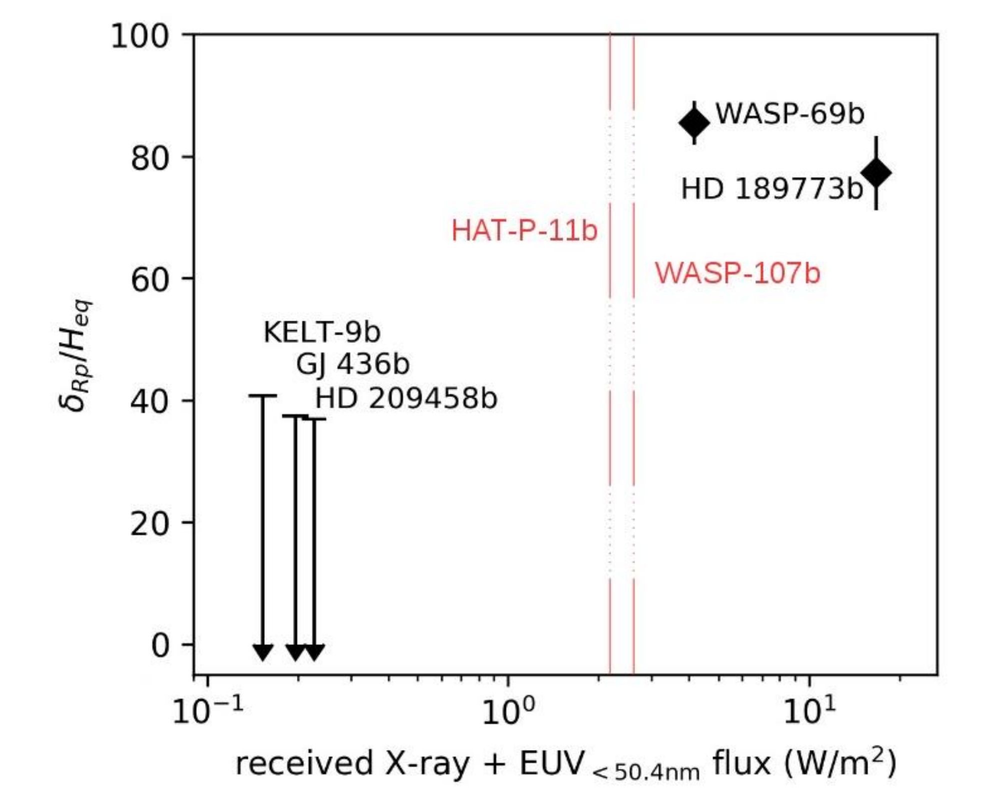
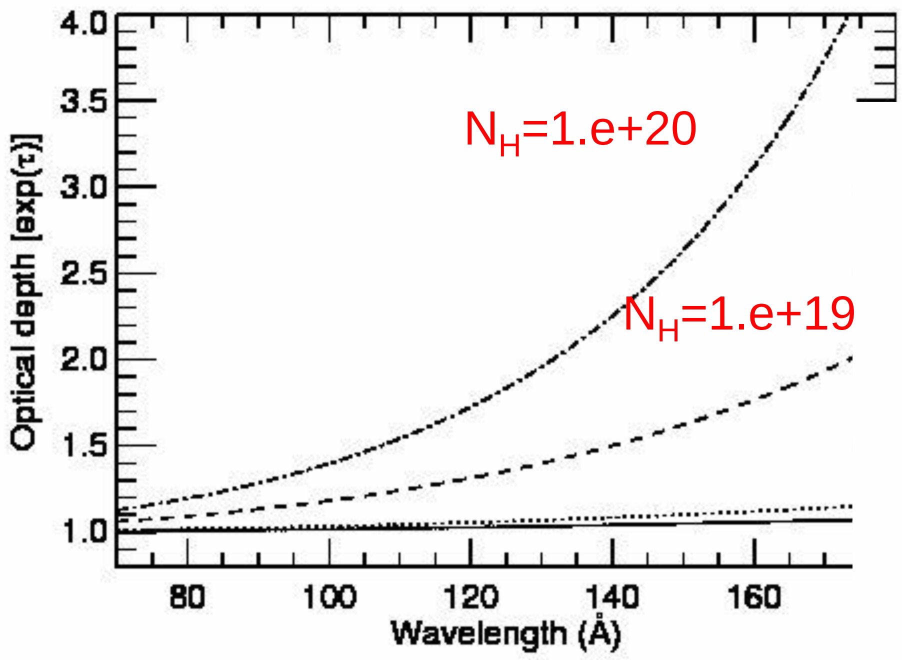
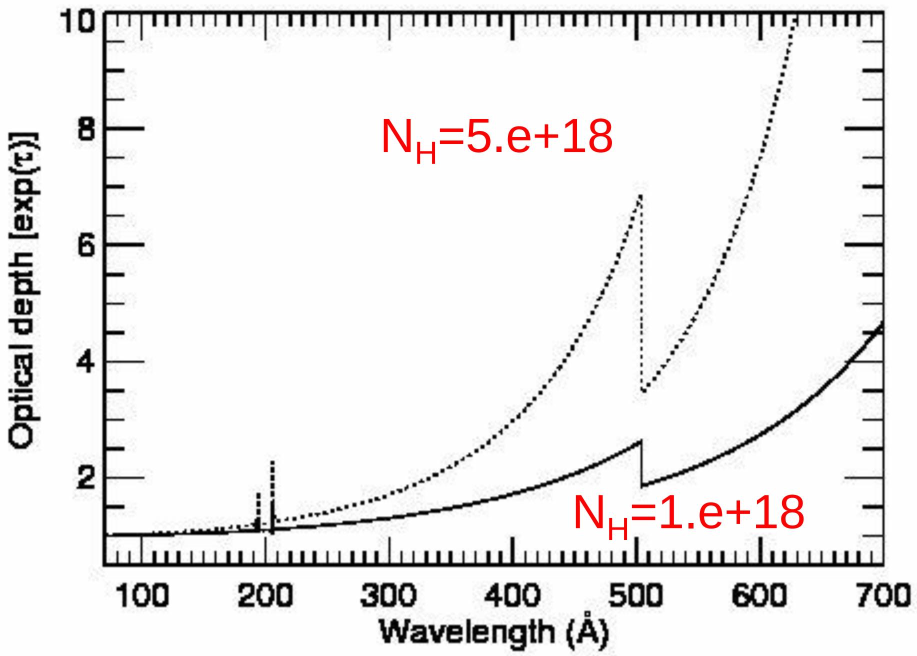


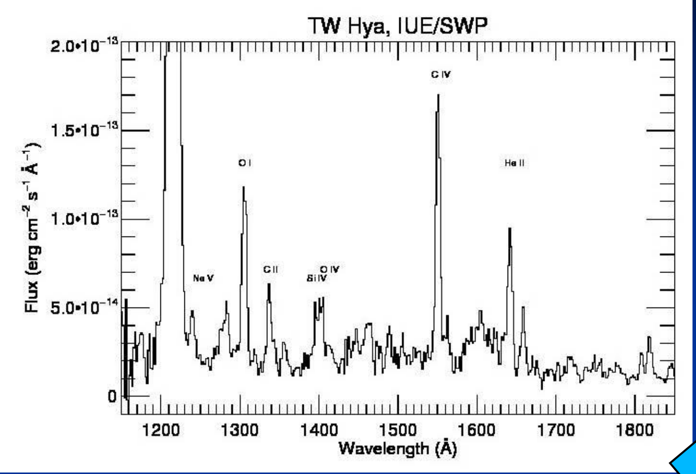
X-rays (1-100 Å) o.k. EUV (100-920 Å) absorbed by interstellar medium



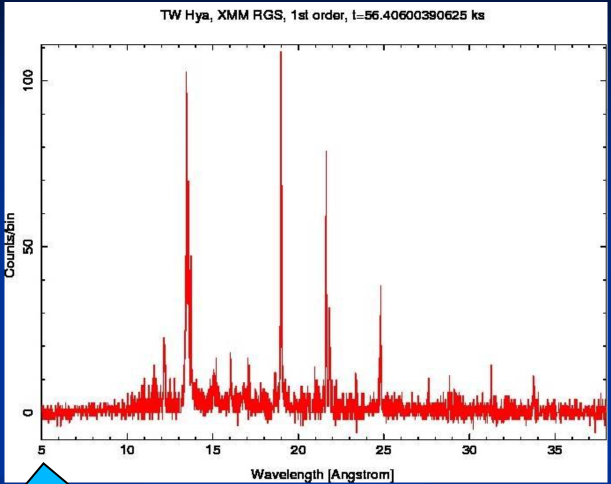
For λ < 912 Å



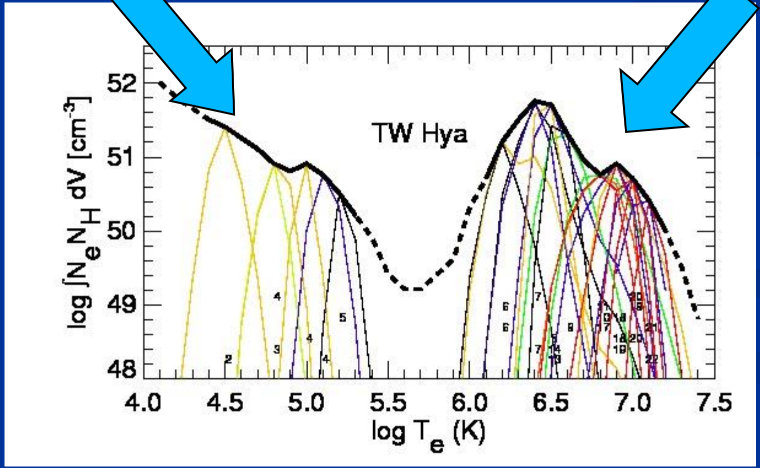
Coronal models



UV lines



X-rays or EUV lines



EMD (thermal structure)

ATHENA

- Only HST in UV
- X-rays from XMM-Newton, Chandra, smaller missions
- ATHENA: further and fainter targets, better spectral resolution → better models