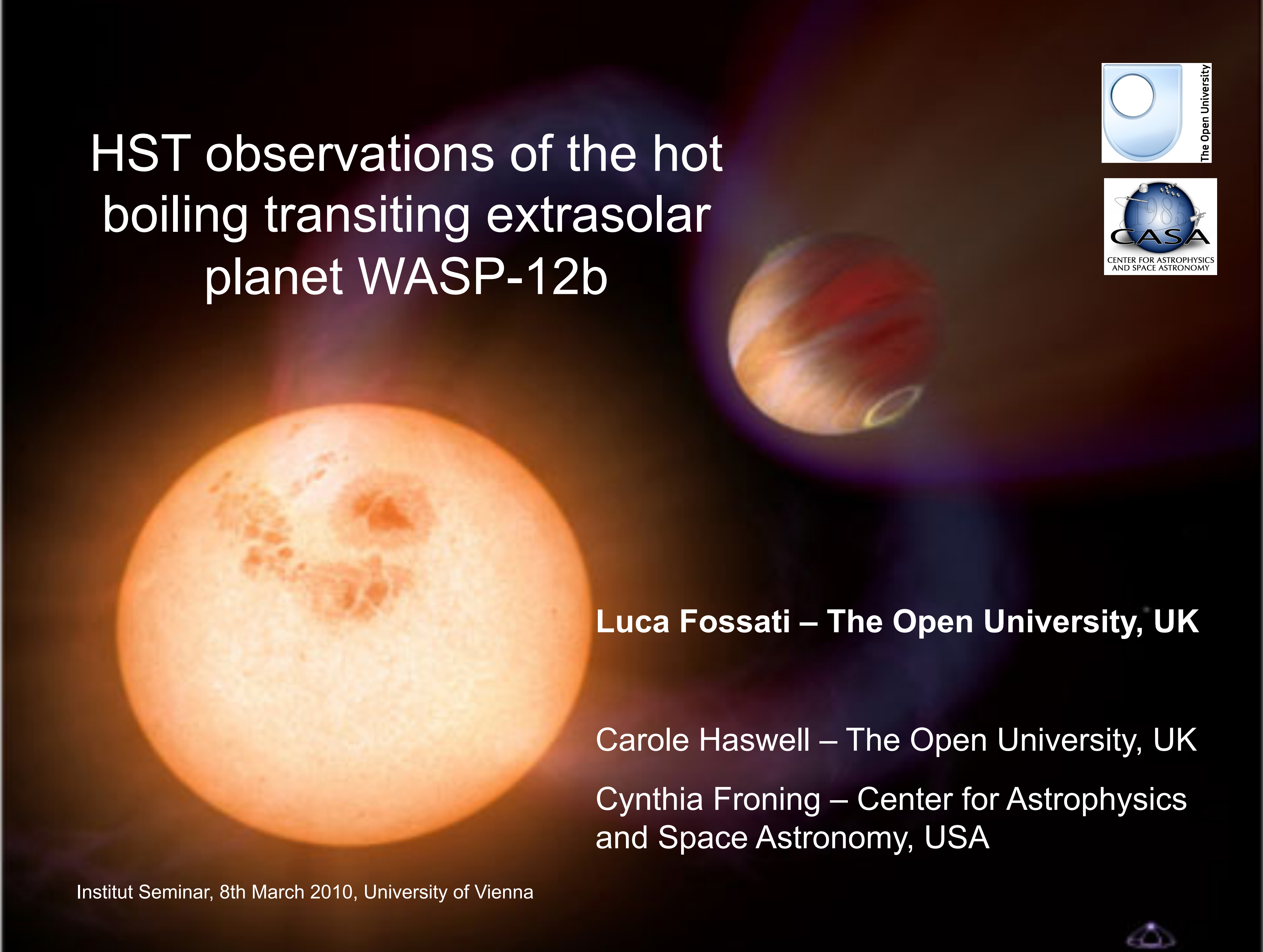


HST observations of the hot boiling transiting extrasolar planet WASP-12b

Luca Fossati – The Open University, UK

Carole Haswell – The Open University, UK

Cynthia Froning – Center for Astrophysics and Space Astronomy, USA

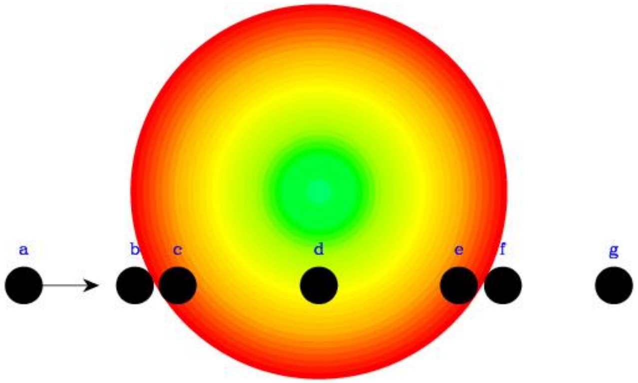
Institut Seminar, 8th March 2010, University of Vienna

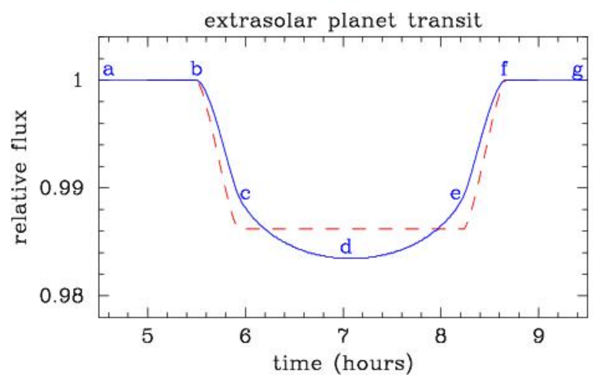
Exoplanets

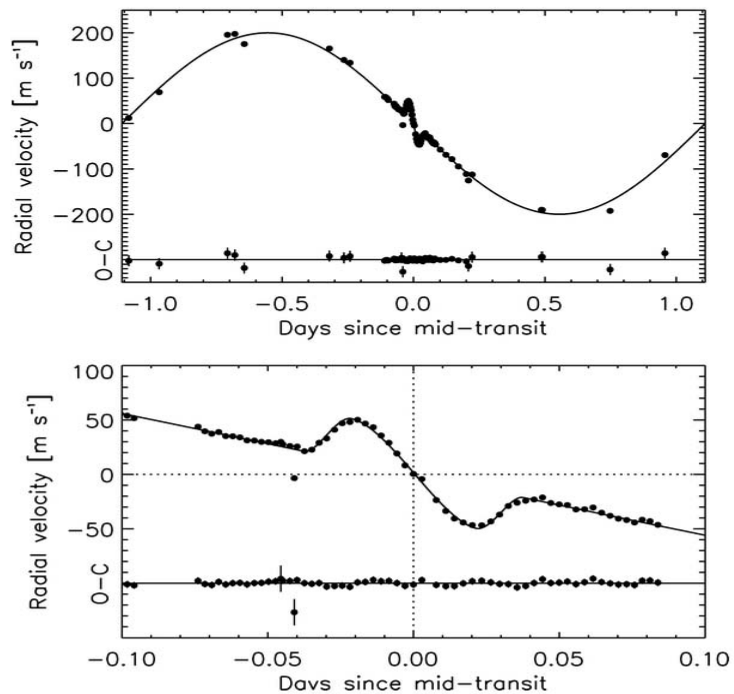
Up to now (08/03/2010 in the morning) we know 430 exoplanets:

339 detected by radial velocity or astrometry
69 detected by transit
9 detected by microlensing
9 detected by direct imaging
6 detected by timing

Transit light curve and radial velocity curve --> planet, stellar, and orbital parameters + system geometry

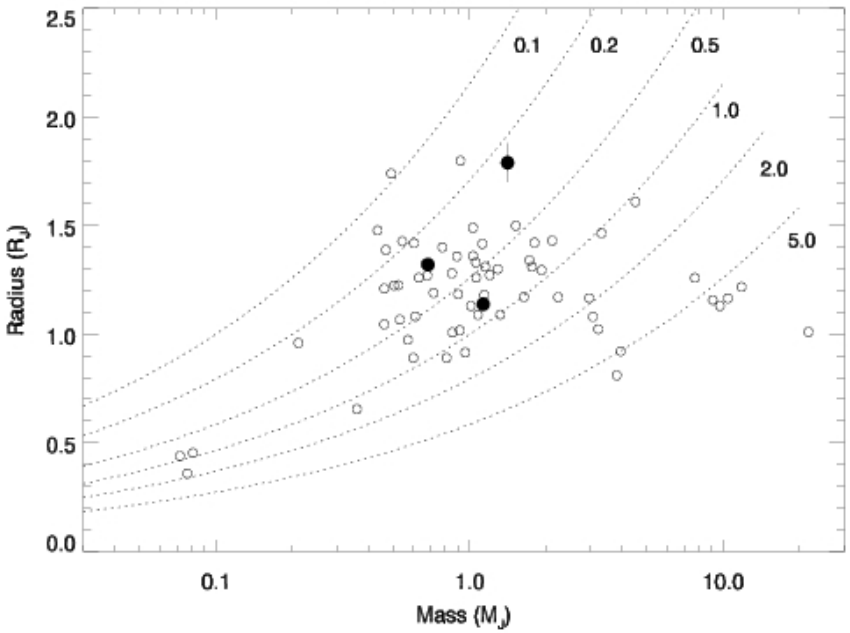






Inflated exoplanets

Most of the exoplanets we know are Jupiter-like or giant exoplanets



Radius controlled by:

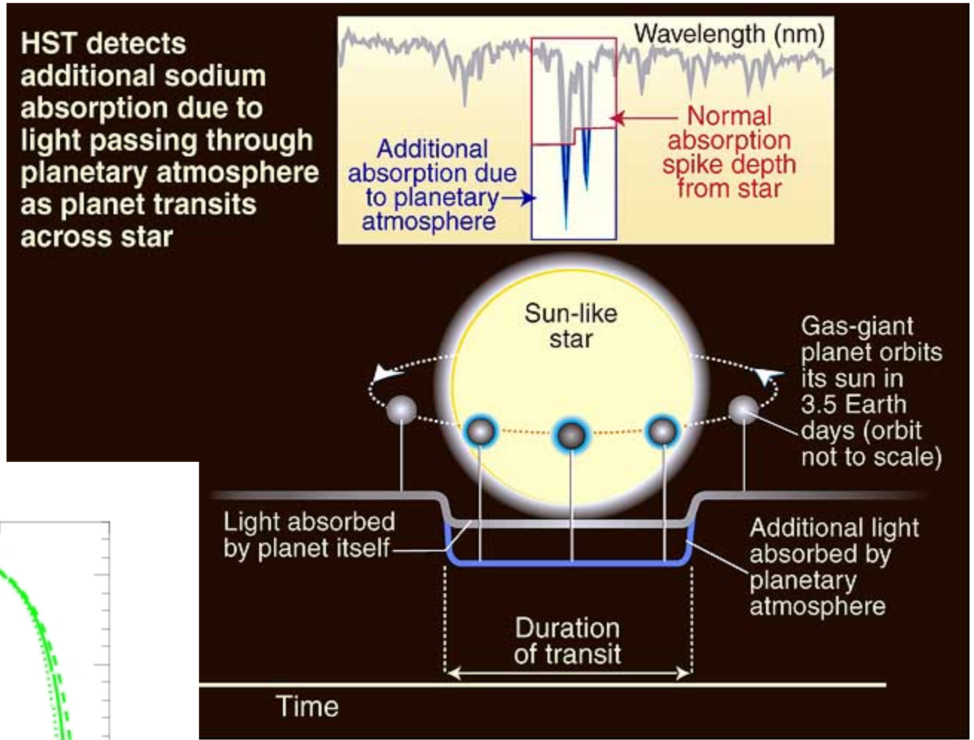
- Mass
- Stellar flux at the planet
- Atmospheric composition
- Presence and mass of the inner core
- Age
- Circulation day/night

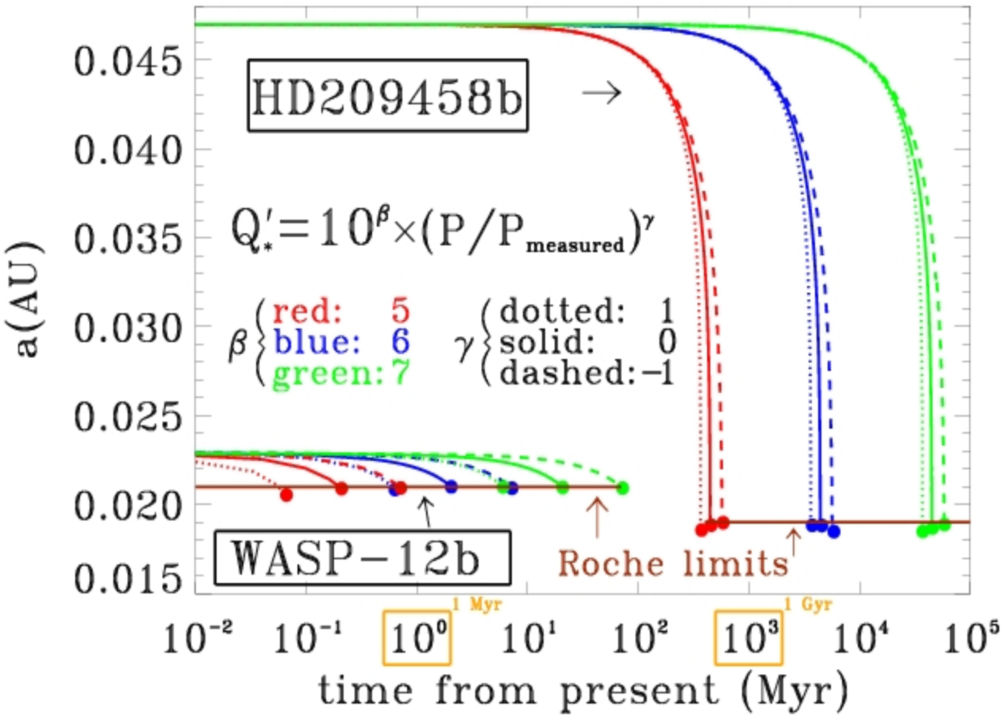
Inflated giant planet: planets for which their radius is larger than predicted using simple evolution model for a solar composition gaseous planet, e.g. HD209458

Inflated kamikaze exoplanets

Abnormal radius:
• High metallicity
• Extra-energy source (tidal heating)
(Guillot 2006, Burrows 2007)

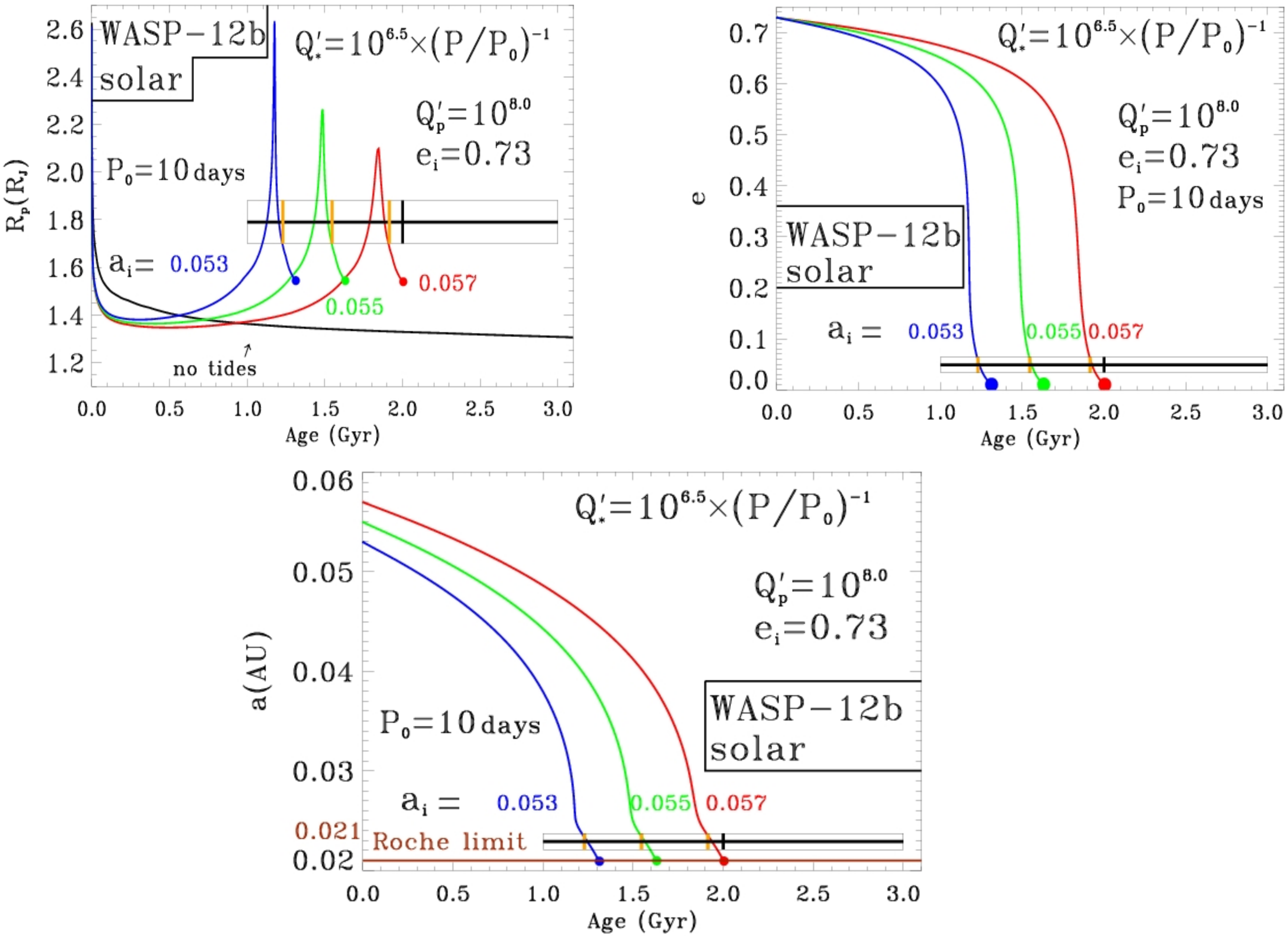
Why interesting?
• Atmosphere/exosphere easier to detect
• Peculiar formation and evolution





Planets form far from the star and move inwards till...

Inflated kamikaze exoplanets



The WASP-12 system

The star:

V*mag*: 11.7

T*eff*: 6300+/-200 K

[M/H]: 0.3+/-0.1

Vsin*i* < 2.2 +/-1.5 km/s

Age: 2+/-1 Gyr

The orbit:

Period: 1.09 days

Transit: 0.122 days

SM Axis: 0.0229 AU

Eccentricity: 0.049

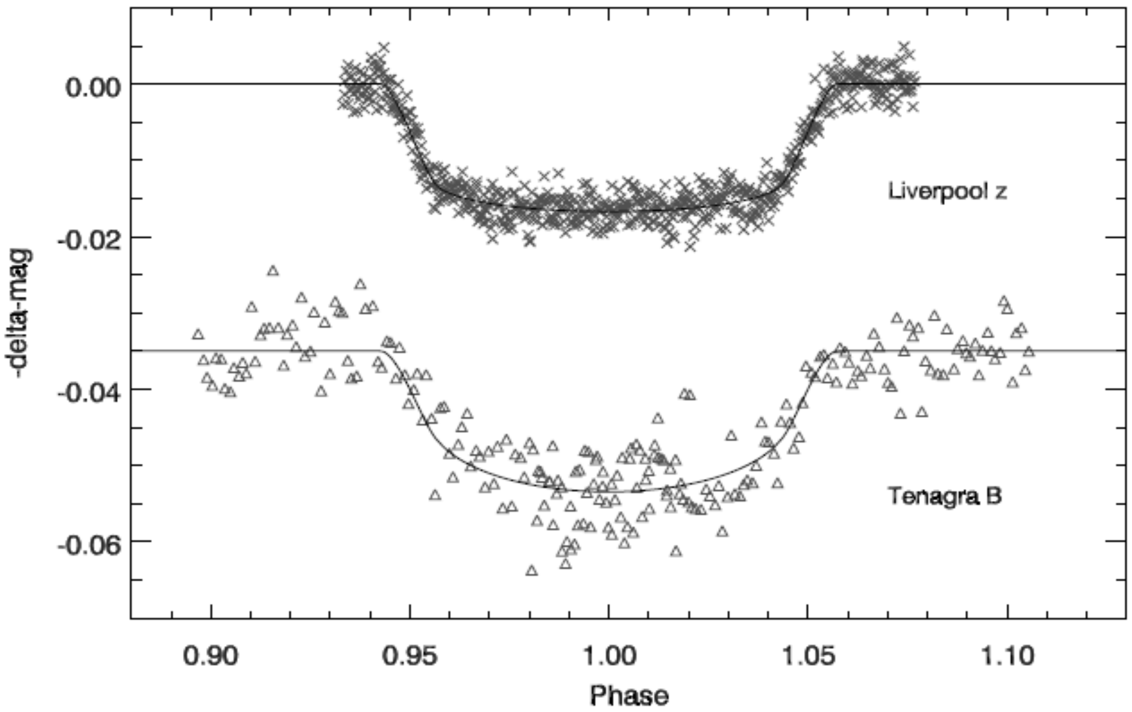
The planet:

Mass: 1.41+/-0.10 M_J

Radius: 1.79+/-0.09 R_J

T*eq*: 2516+/-36 K

Hebb et al. 2009



The COS/HST observations

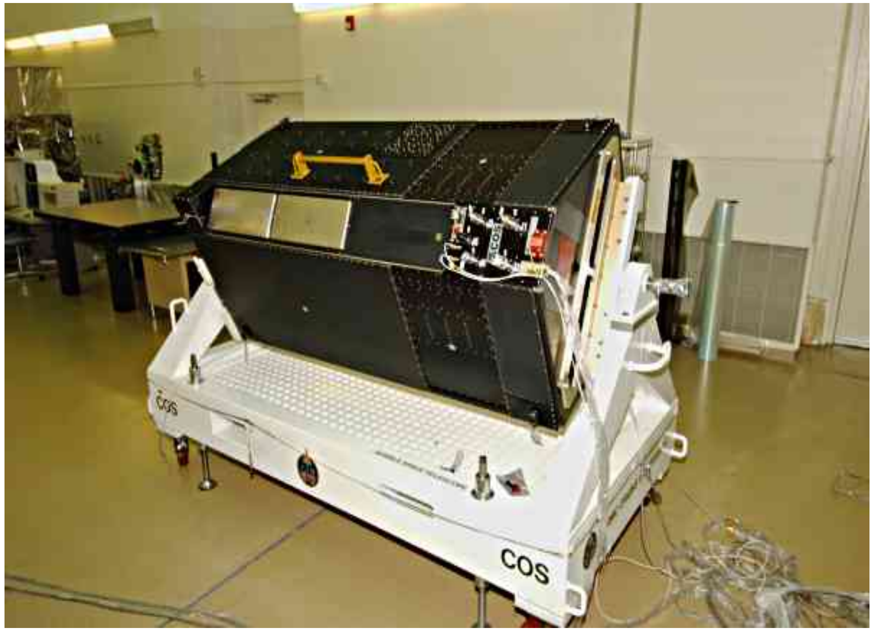
Cosmic Origin Spectrograph (COS)
– SM4

- Far UV (FUV)

- **Near UV (NUV)**

TIME-TAG mode (time resolution: 32ms)

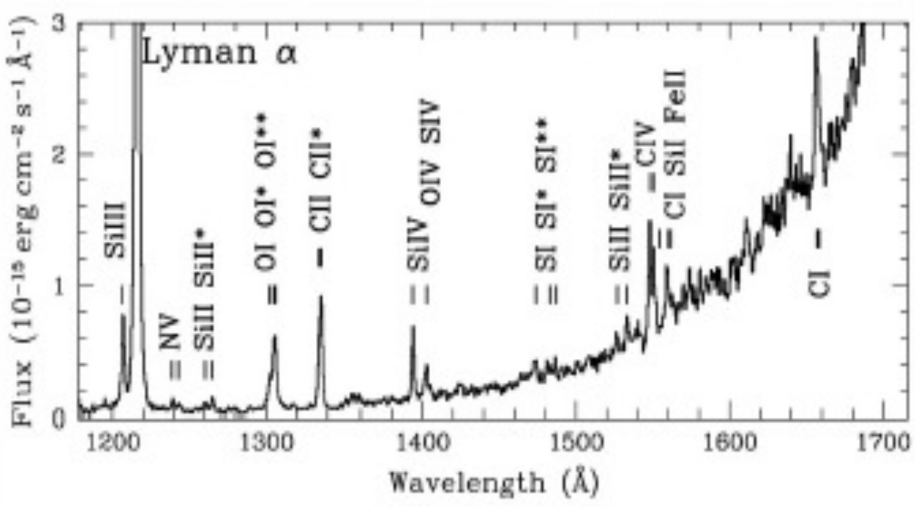
# row #	TIME s	RAWX pixel	RAWY pixel
1	0.	309	300
2	0.	969	737
3	0.032	694	308
4	0.032	386	179
5	0.032	444	547
6	0.032	64	299
7	0.032	811	204
8	0.064	281	276
9	0.064	783	439
10	0.064	897	397
11	0.064	516	284
12	0.064	431	707
13	0.064	764	587
14	0.096	409	369
15	0.096	505	825
16	0.096	539	570



The COS/HST observations

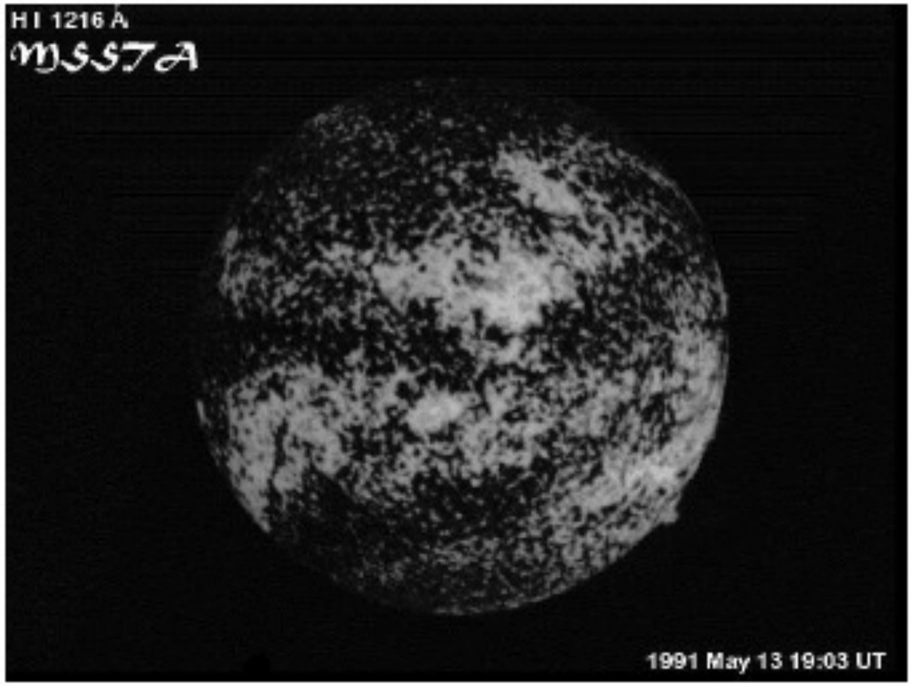
TIME-TAG MOVIE:

NUV vs. FUV

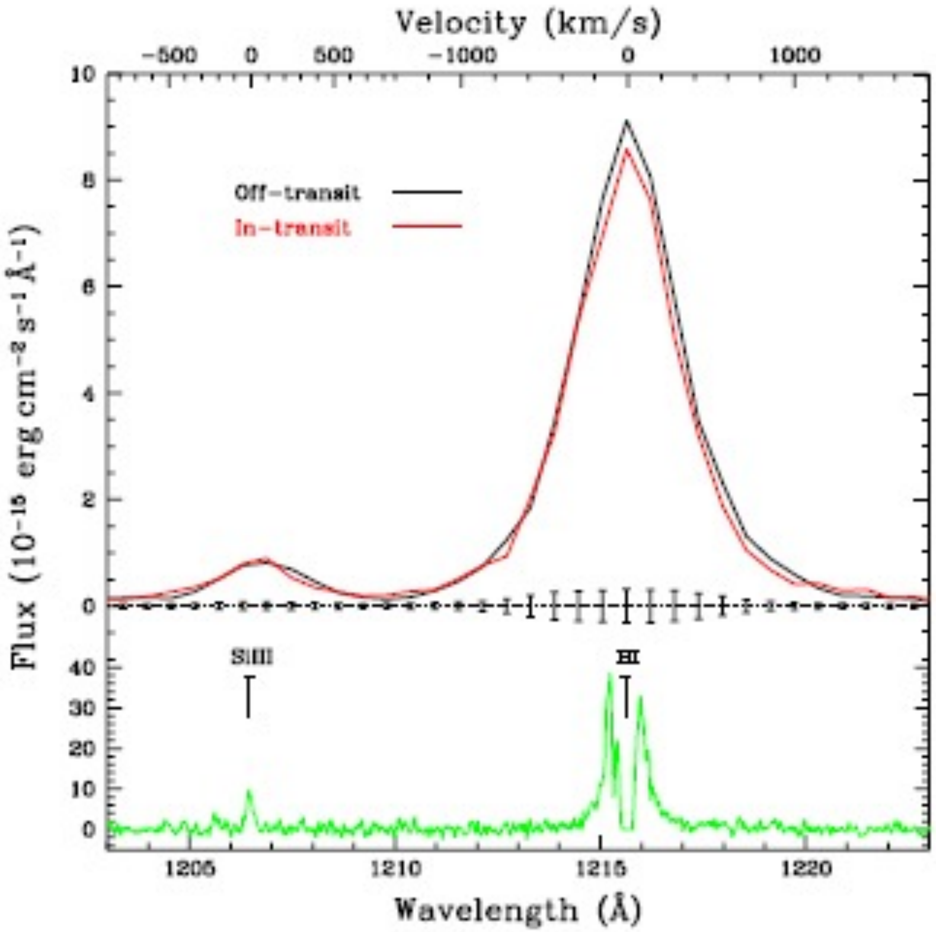


Vidal-Madjar et al. 2004

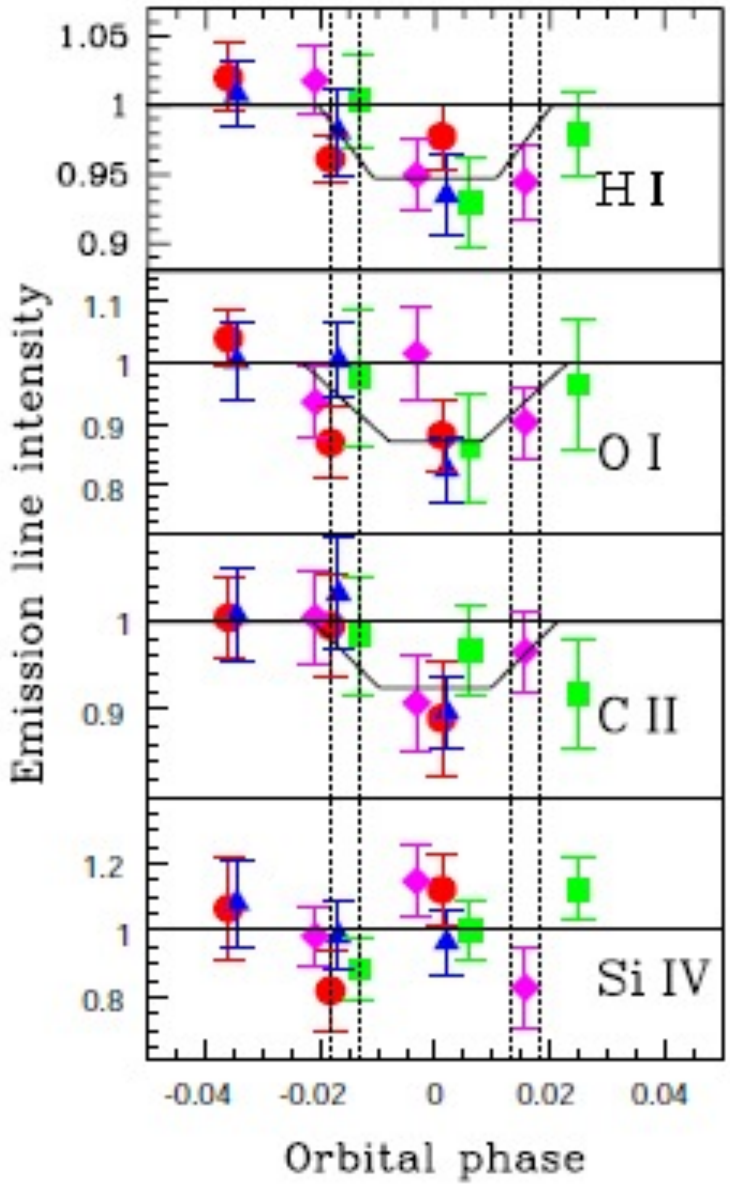
Sun in Ly alpha light



NUV vs. FUV



Vidal-Madjar et al. 2004



The COS/HST observations

COS - NUV - TIME-TAG

GRISM: G285M/2676

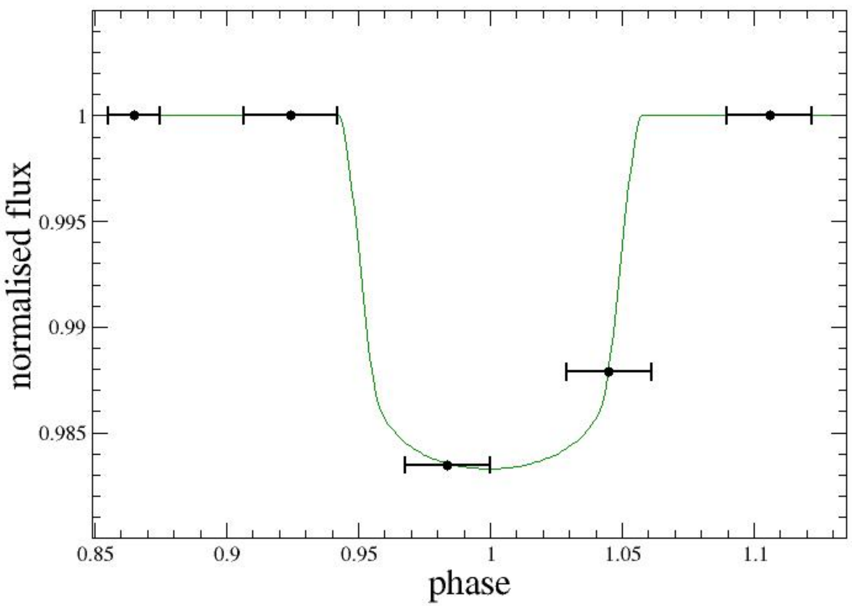
NUVA: 2539 – 2580 Å

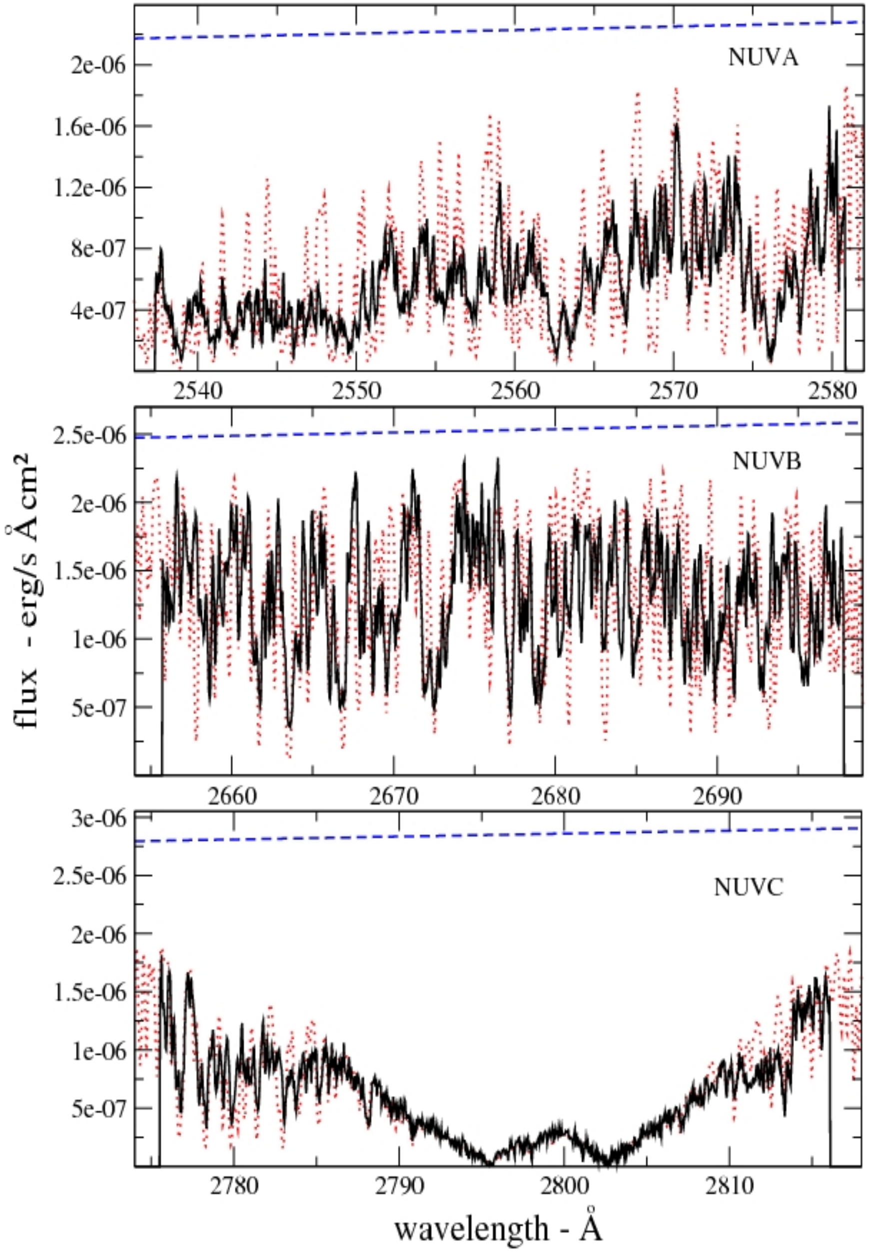
NUVB: 2655 – 2696 Å

NUVC: 2770 – 2811 Å

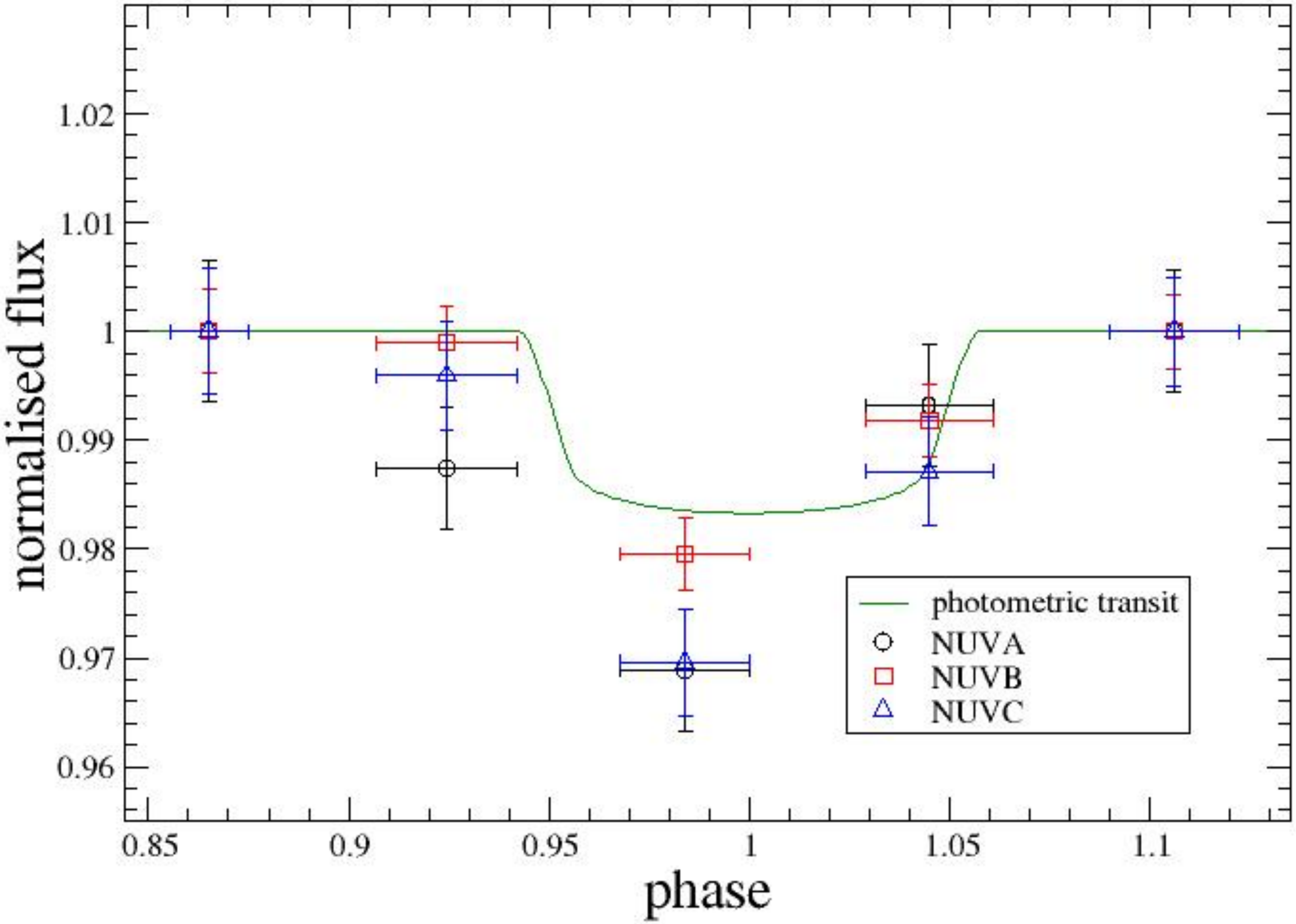
R ~ 20 000   SNR ~ 8 – 10

5 HST orbits ~ 3000 sec each





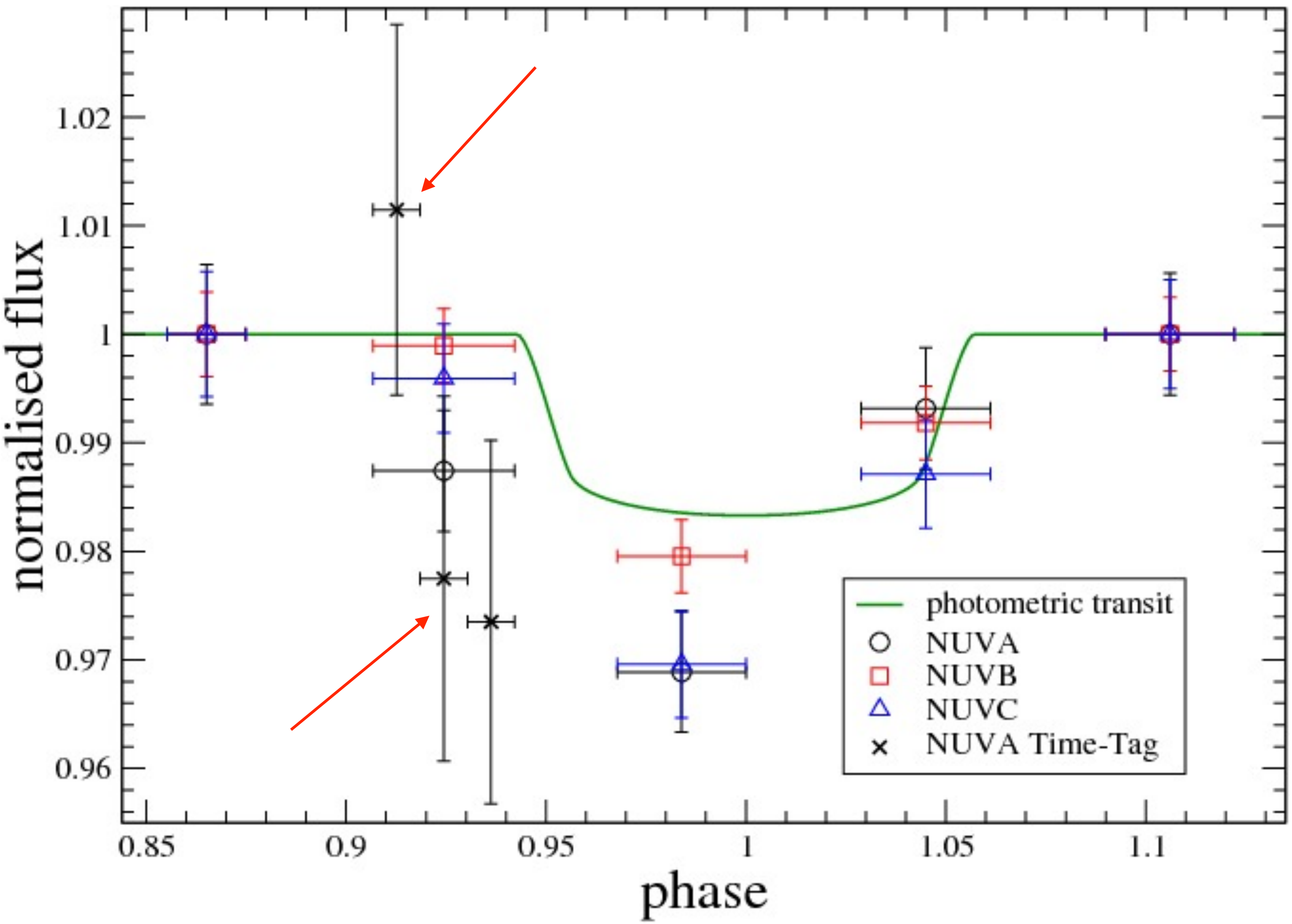
The wavelength dependent transit light curve



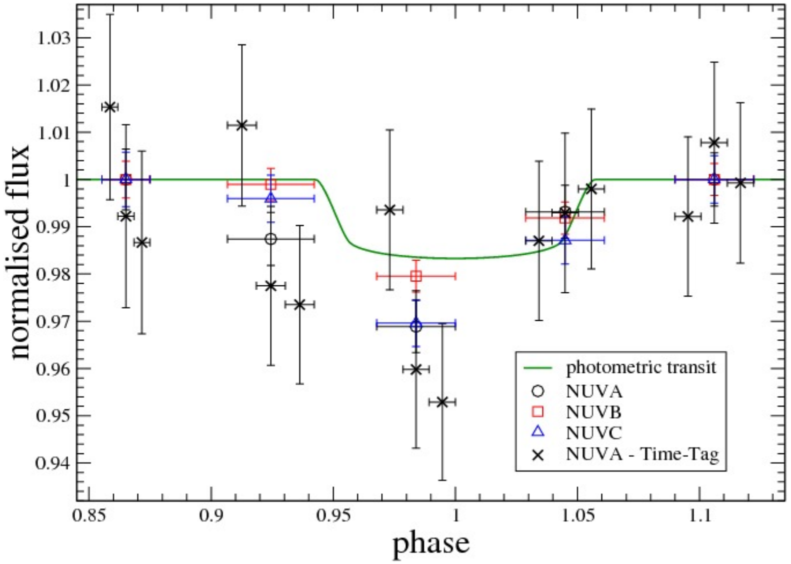
Roche lobe: 2.36R_J

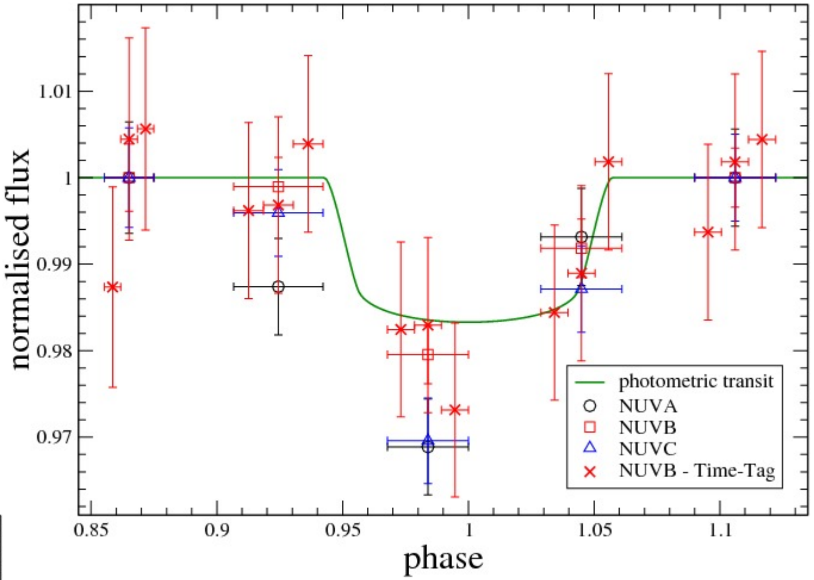
NUVA: **2.69**+/-0.24 NUVB: 2.18+/-0.18 NUVC: **2.66**+/-0.22

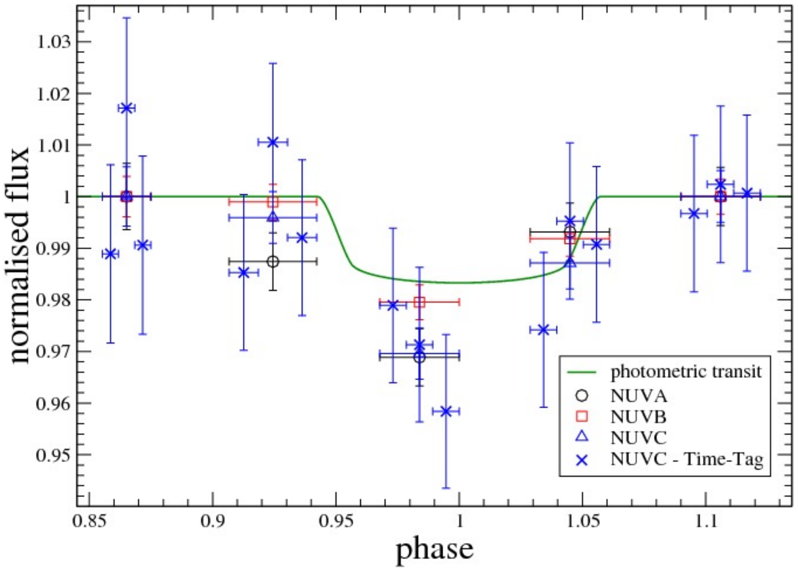
The wavelength dependent transit light curve



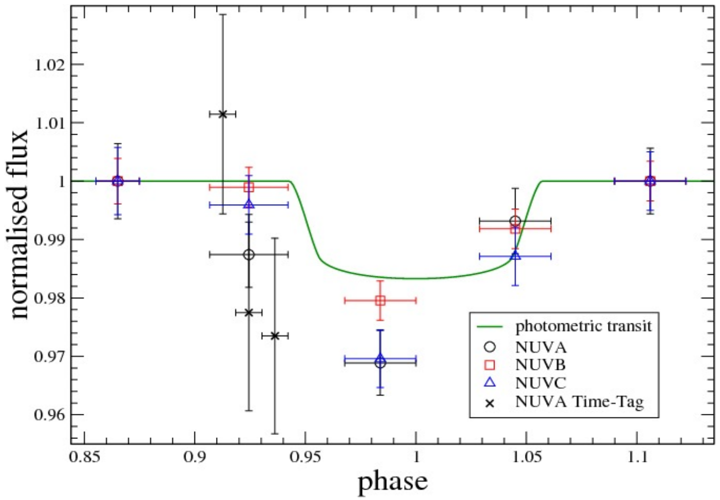
The wavelength dependent transit light curve



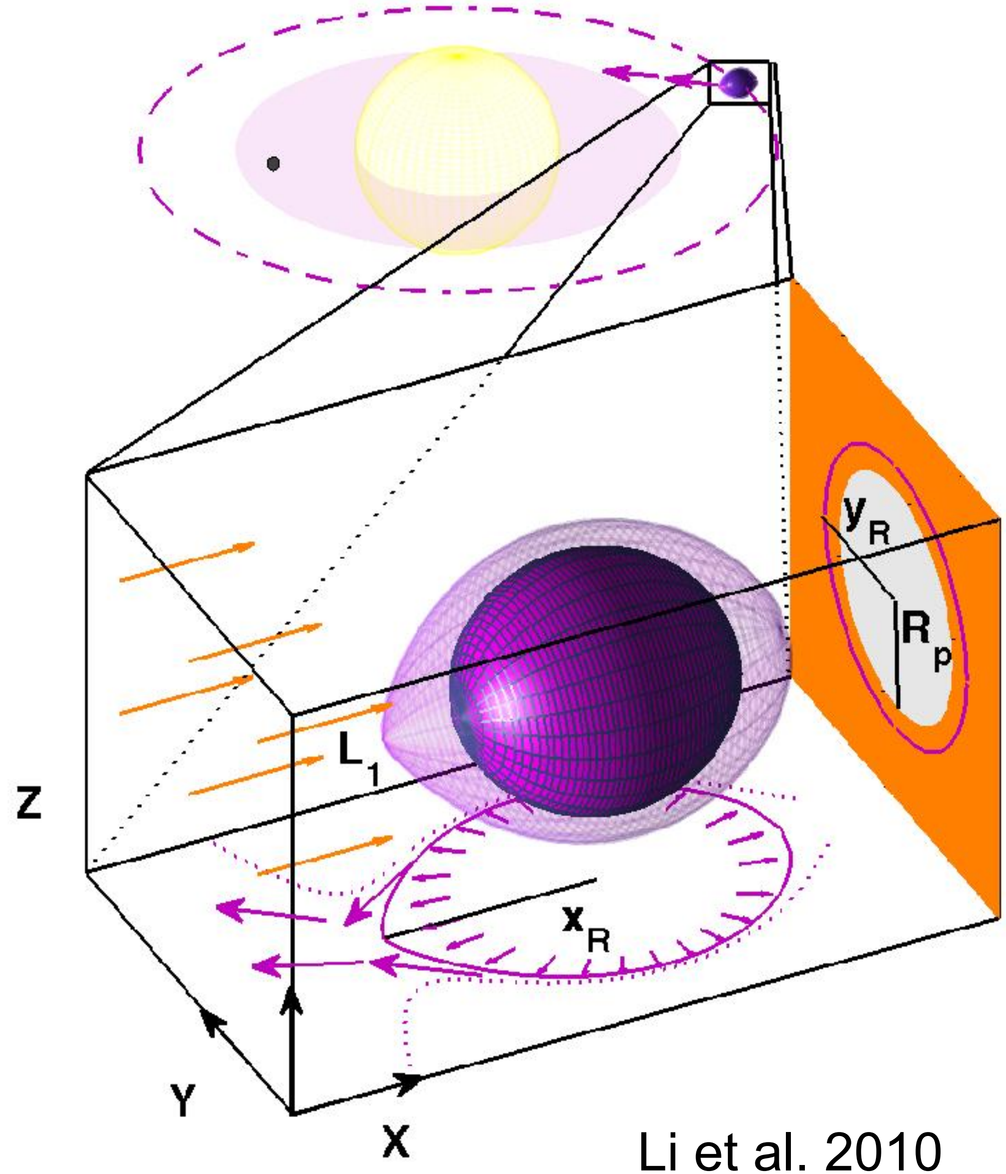




The wavelength dependent transit light curve



Circumstellar disk/torus

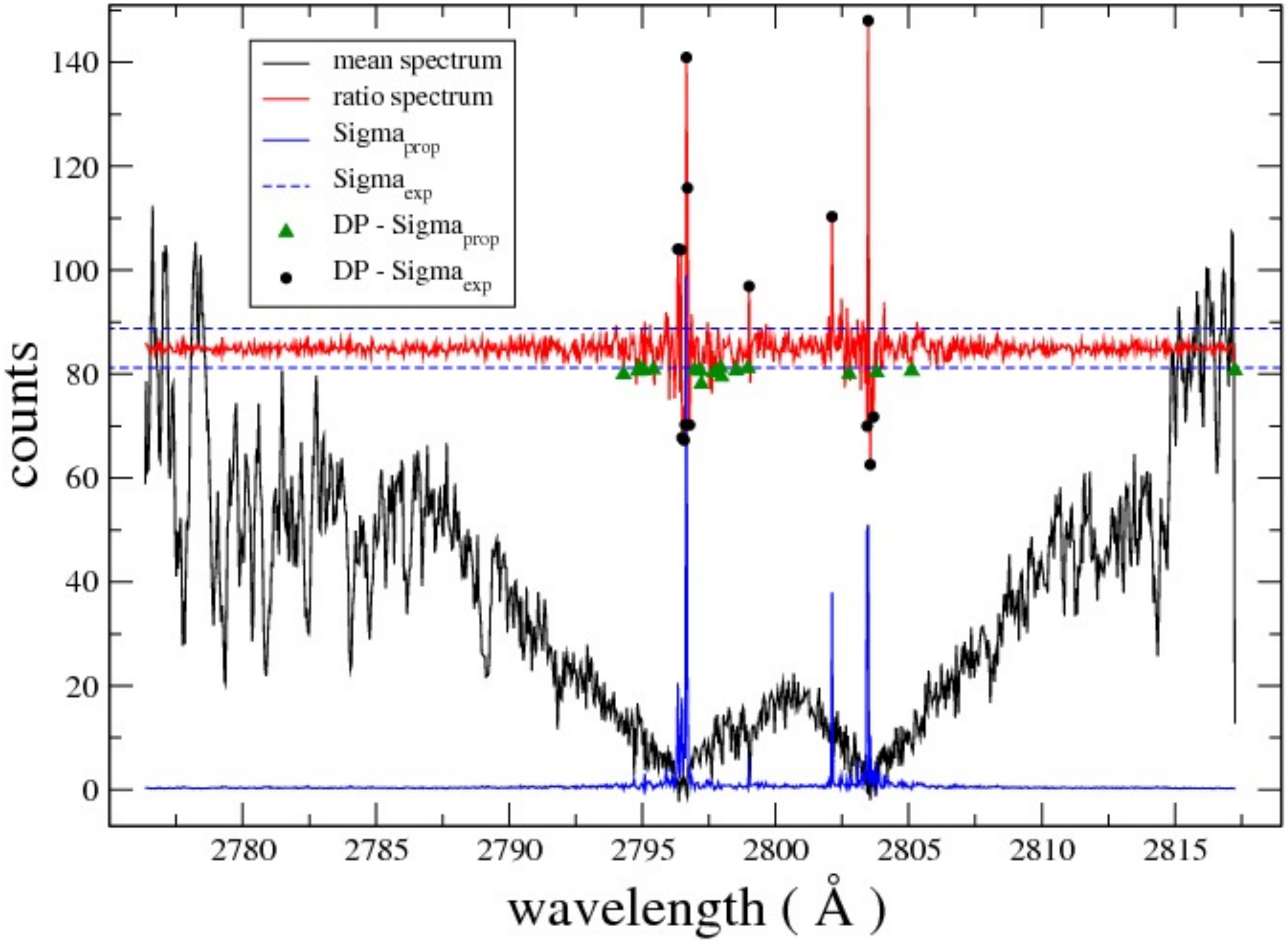


Li et al. 2010

The composition of the planet exosphere

$d_i = t_i / s_i$; $\sigma_{d_i|exp}$ = standard deviation from the mean ; $\sigma_{d_i|prop}$ = proper uncertainty

t_i: in-transit spectrum ; s_i: sum spectrum ; poissonian error bars for t_i and s_i



1024 x 3 points

→

3 x 3 points deviating 3σ

The composition of the planet exosphere: NUVC

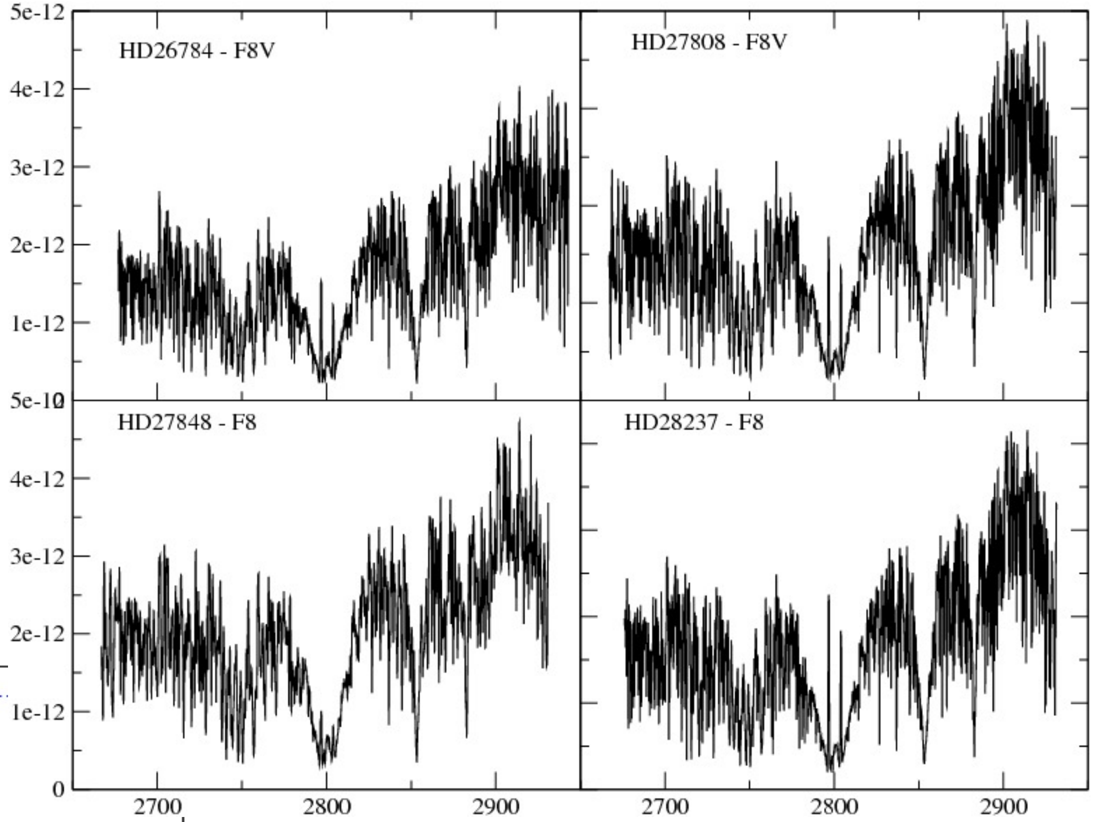
Wavelength	Resonance	Wavelength	Resonance
$3x\sigma_{d_i\vert exp}$	line	$3x\sigma_{d_i\vert prop}$	line
		5DP: 2793.234 – 2794.353	MgII@2795.528
8DP: 2795.272 – 2795.711	MgII@2795.528		
		8DP: 2795.911 – 2797.907	MgII@2795.528
2797.947	MnI@2798.269*		
2801.059	MnI@2801.082		
		1DP: 2801.697	MgII@2802.705
4DP: 2802.375 – 2802.614	MgII@2802.705		
		2DP: 2802.734 – 2804.049	MgII@2802.705

The composition of the planet exosphere

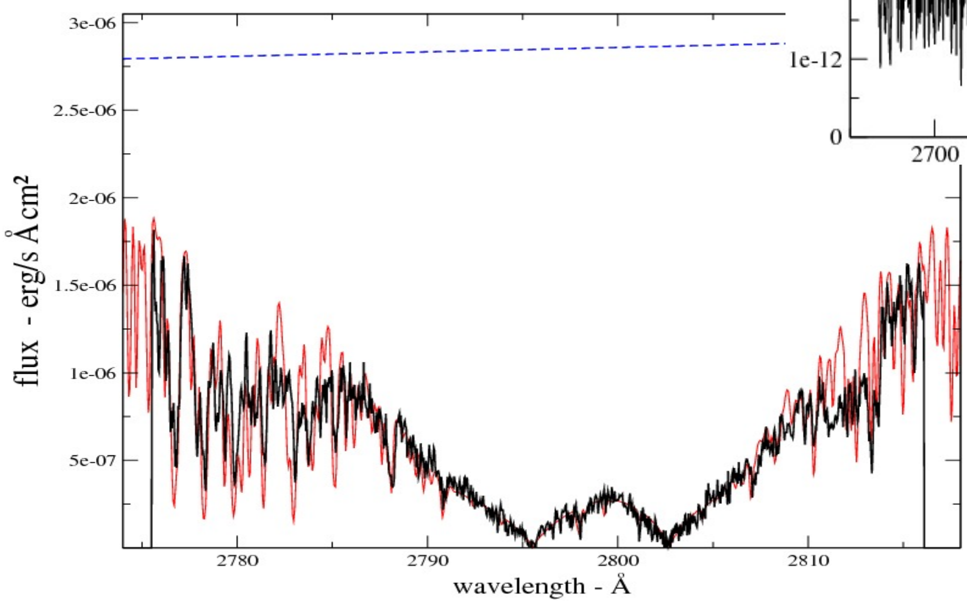
Wavelength	Resonance	Wavelength	Resonance
$3x\sigma_{d_i\|exp}$	line	$3x\sigma_{d_i\|prop}$	line
2540.876	ScII@2540.822	3DP: 2540.703 – 2540.876	ScII@2540.822
		2543.893	NaI@~2543.86
		2563.348	ScII@2563.190*
2DP: 2563.391 – 2563.477	ScII@2563.190*		
		2563.563	ScII@2563.190*
3DP: 2575.999 – 2576.127	MnII@2576.106		
2683.003	VII@2683.090		

ScII@2563.190 and MnI@2798.269: Δλ ~ planet escape velocity

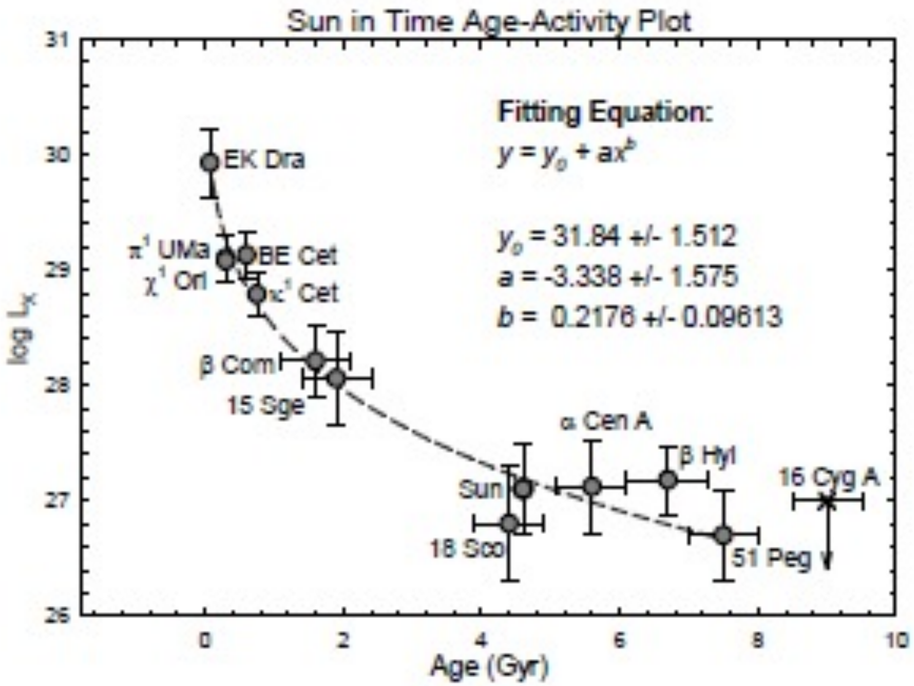
The peculiarities of the WASP-12 system

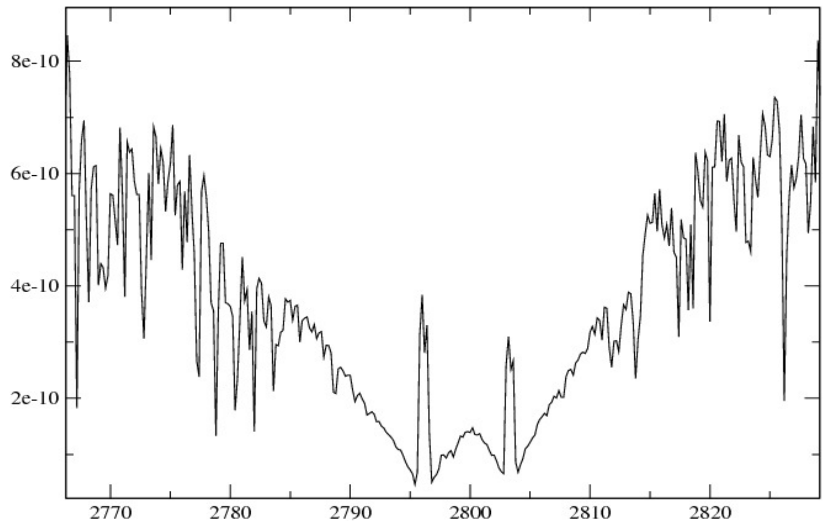


Lack of Mg2 line core emission

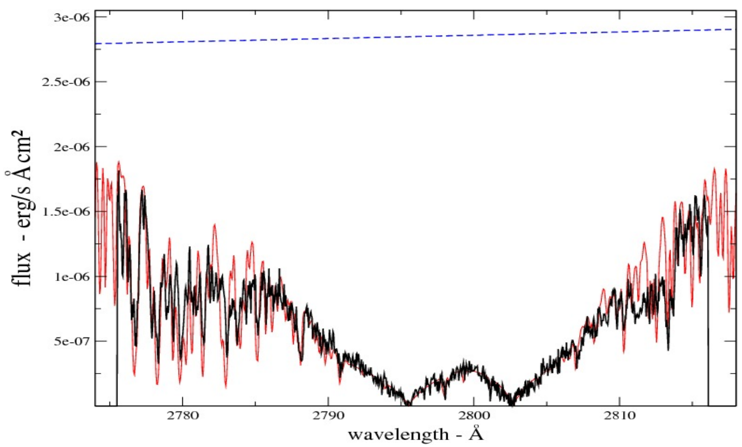


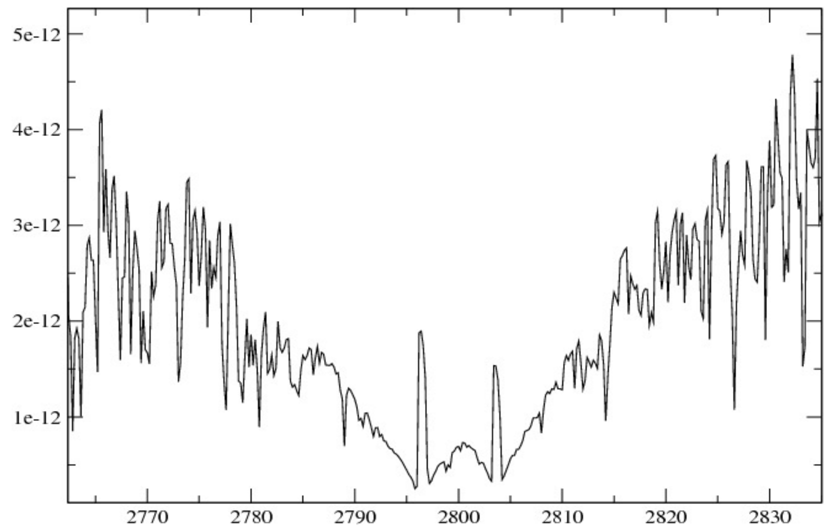
The peculiarities of the WASP-12 system



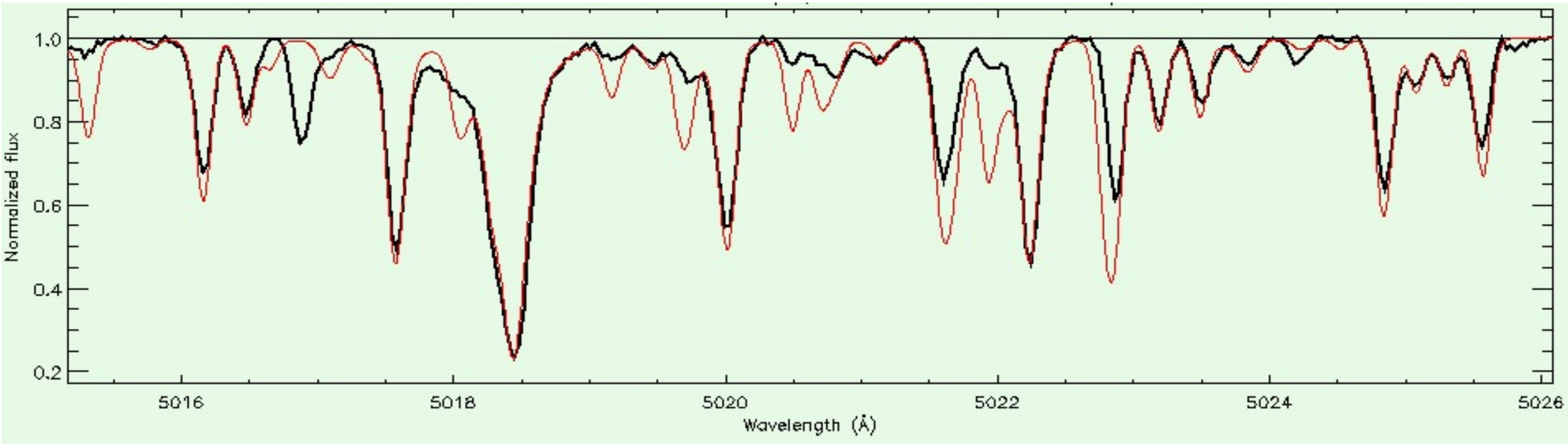


Alpha Cen A (up) – 18Sco (down)

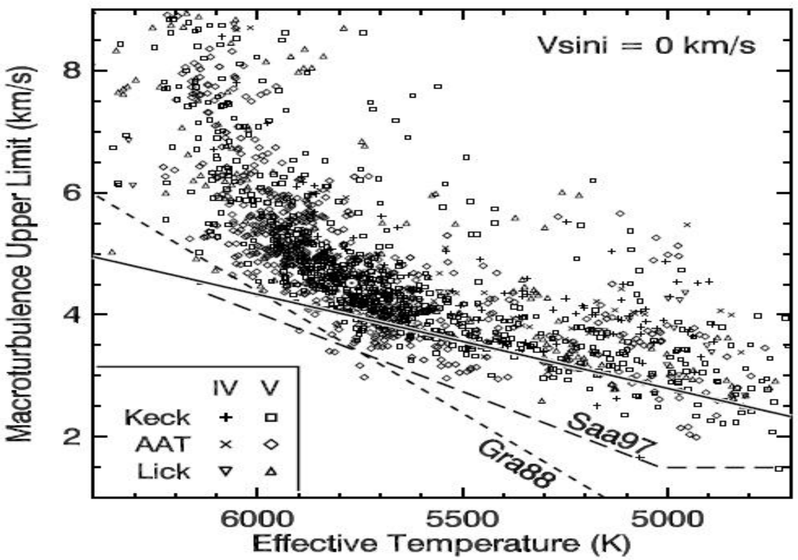


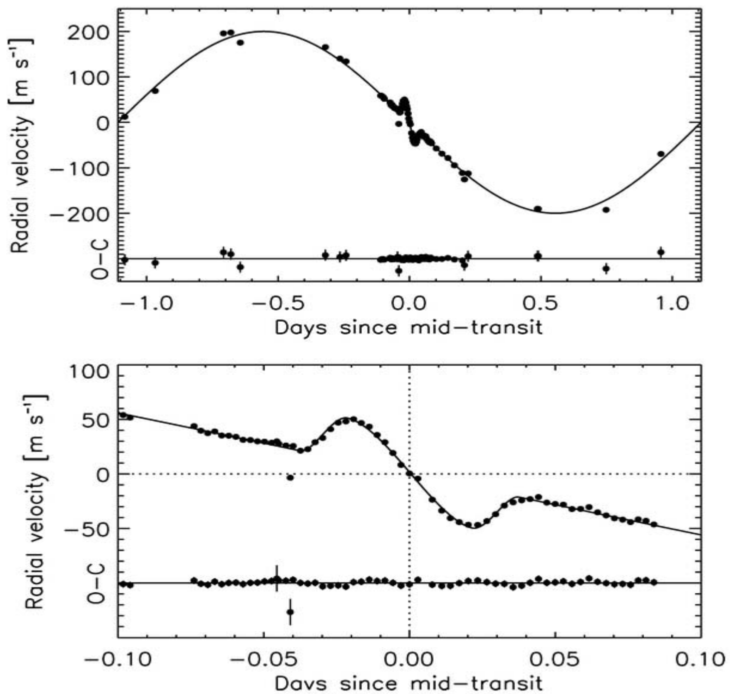


The peculiarities of the WASP-12 system

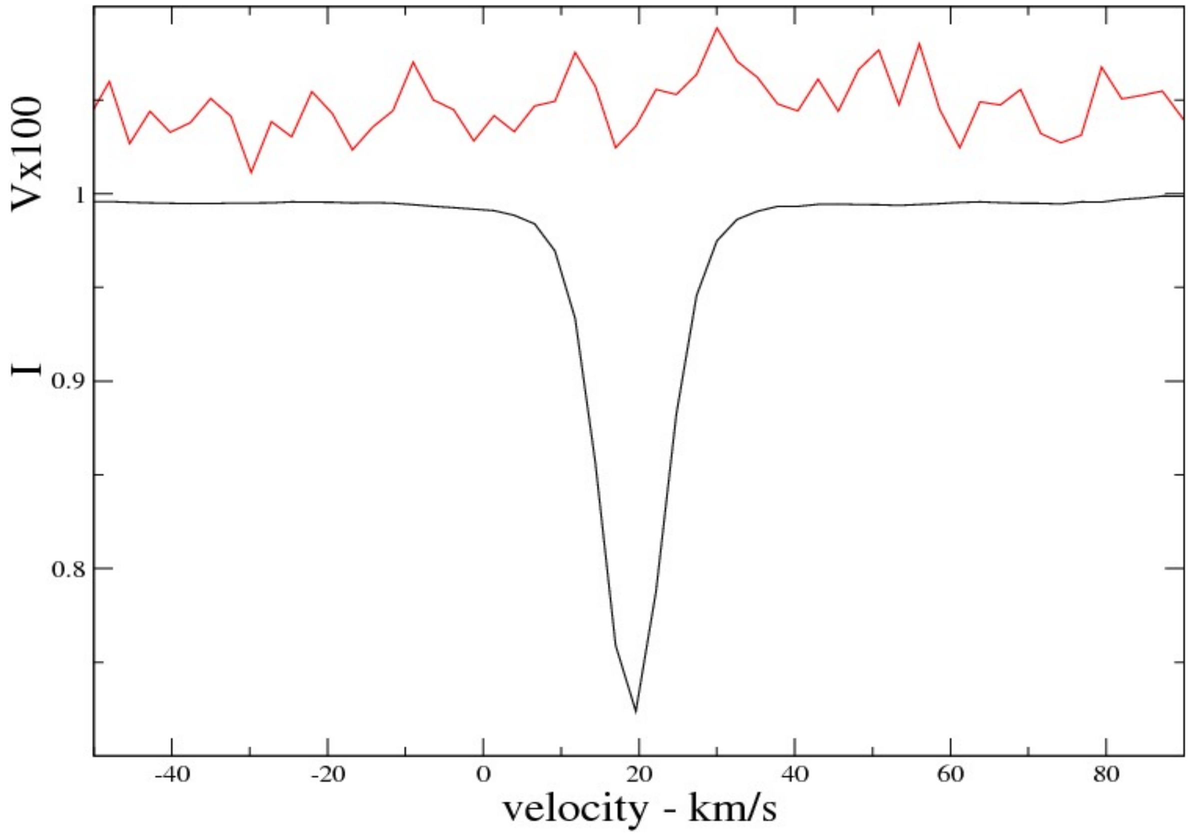


Vsini = 2.2km/s – Vmac = 4.8 km/s





The peculiarities of the WASP-12 system



No global magnetic field, but there still be the possibility of localized magnetic fields (e.g. solar spots)

The peculiarities of the WASP-12 system

We have: no line-core emission, (possible) low Vsini, relative young stellar age

Possible solution to the puzzle:
- No line-core emission due to absorption from the disk around the star that we know is metal-rich (formed by the planet)
- low Vsini due to a small “i” (star seen pole-on)
- relative young age is not a problem anymore

Conclusions

- WASP-12 observed during the planet transit along 5 HST orbits with COS/NUV

- planet transit detected in all three observed regions, two exceed the Roche lobe -> planet is losing mass

- depth of the planet transit dependent on the amount of line absorption

- detection of an early ingress -> circumstellar disk/torus produced by the material lost by the planet

- detection of MgII, NaI, ScII, VII, MnI, MnII lines produced by the planet exosphere

- WASP-12 system peculiarities (no emission-low Vsini-age) explained with disk+stellar inclination

Work in progress...

Spectroscopic detailed abundance analysis to detect any sign of pollution

Analysis of the second HST visit on WASP-12 (more 5 orbits to cover the rest of the light curve

HIRES @ KECK time requested to observe the RM effect of WASP-12

70 HST orbits requested to observe selected targets to analyse:
- the planet mass-loss mechanism
- the disk
- the planet metallicity