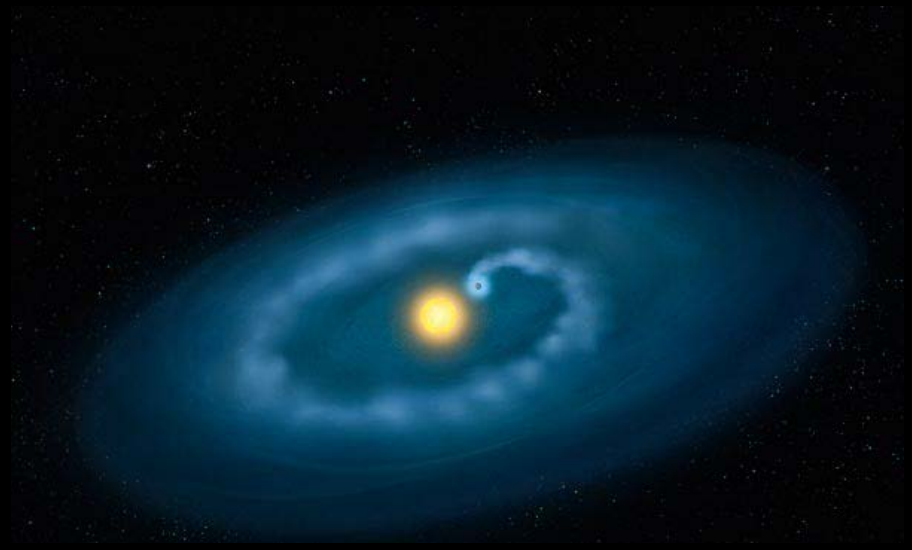
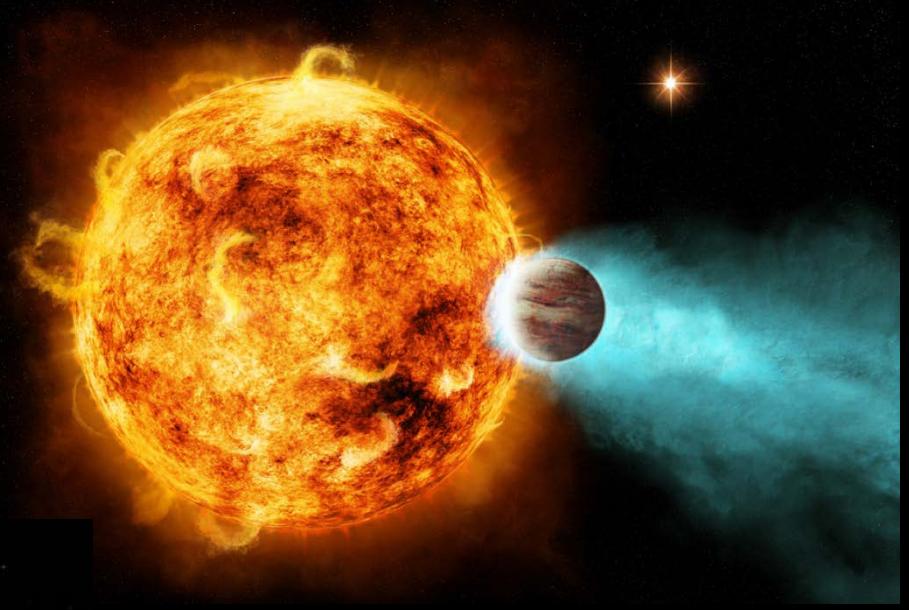
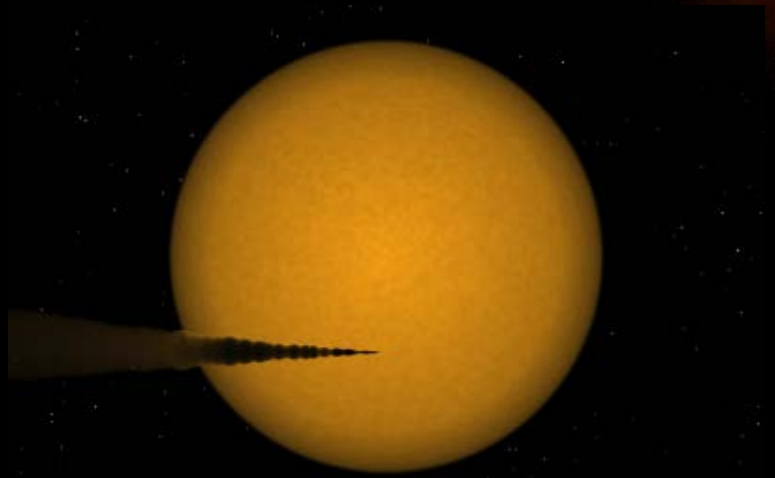
Enshrouded close-in Exoplanets







Carole Haswell, The Open University

Principal Collaborators: Luca Fossati, Tom Ayres, Jakub Bochinski

Outline

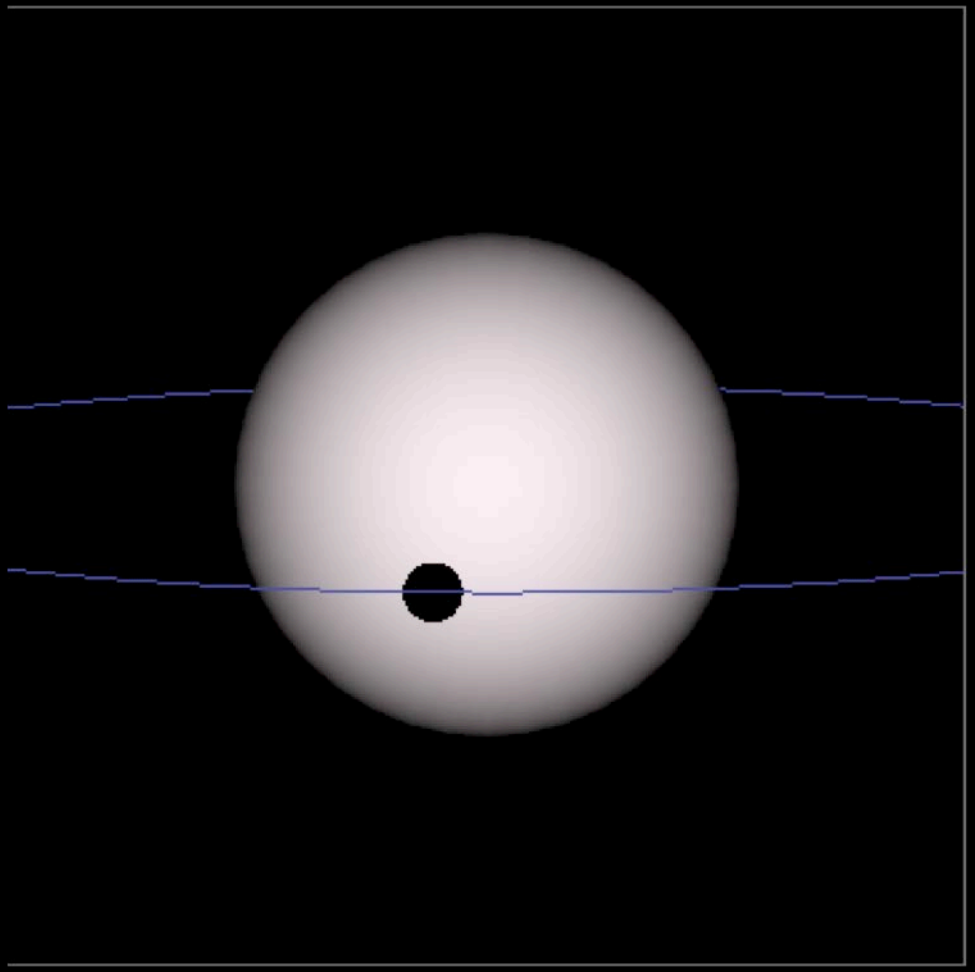
- motivation: Mg II line profiles

- optical activity indicators
  - comparison with survey data
  - archival Keck/HIRES data on transiting exoplanet host stars
  - several enshrouded hot Jupiter systems

- KIC 1255
  - Close-in rocky planet
  - Enshrouded in dust & metal-rich vapour
  - Short-lived catastrophic end-point

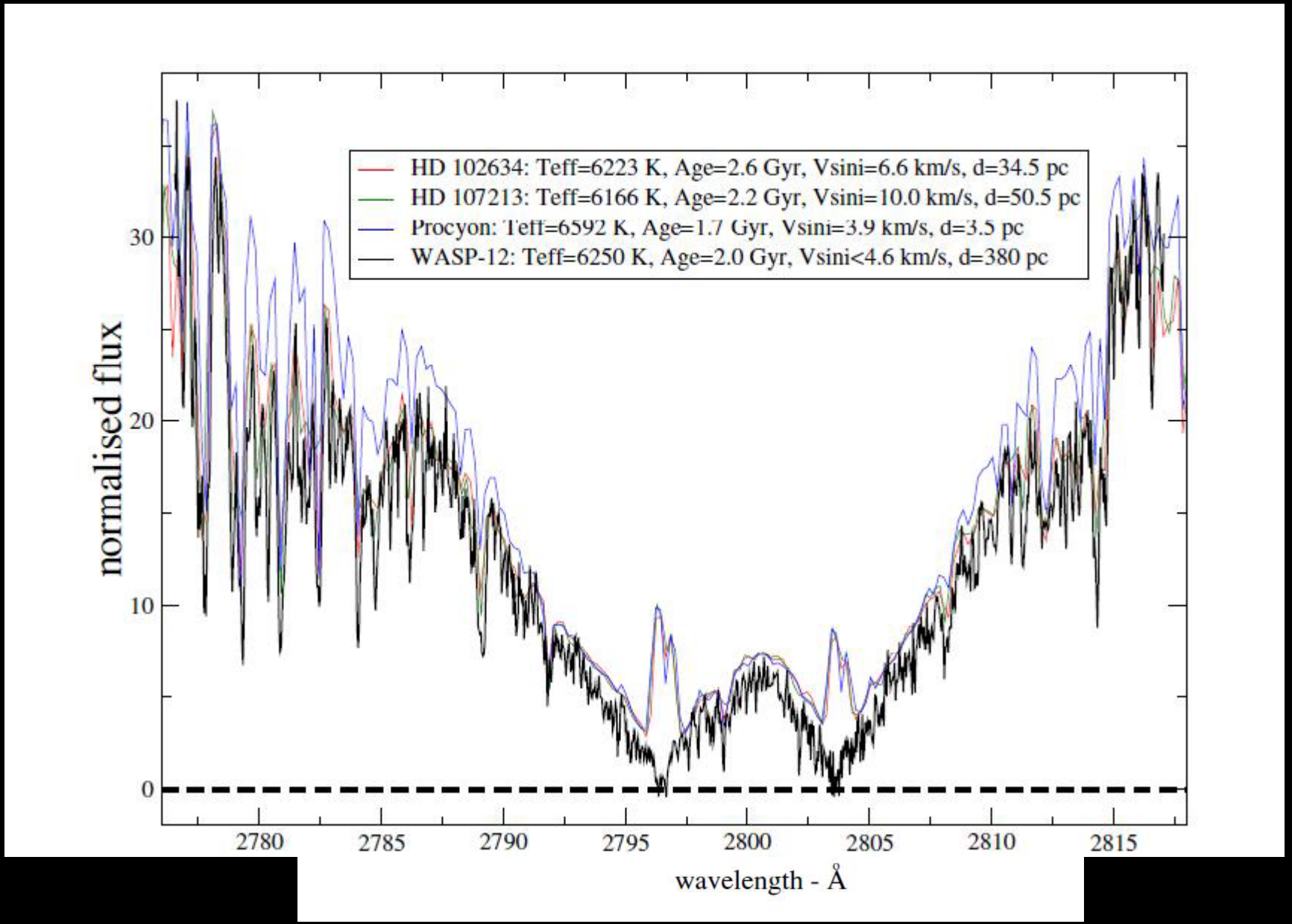
- population of KIC 1255 precursors?
  - Detectable by enshrouding of system?

WASP-12 b – an extreme hot Jupiter



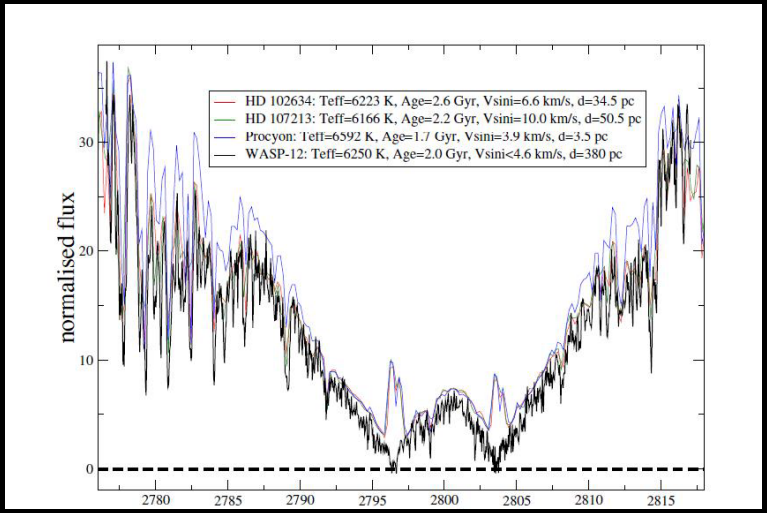
Hebb et al 2009

Near-UV Mg II Line Profiles



Haswell et al 2012

Near-UV Mg II Line Profiles



Haswell et al 2012

No known dwarf star as inactive as WASP-12

Below basal activity level which is independent of age and rotation

NATIONAL GEOGRAPHIC

Connect: Search

Home Video Photography Animals Environment Travel Adventure Television

Daily News | The Magazine | Maps | Science | Education | Games | Events | Blogs | Movies | Ex

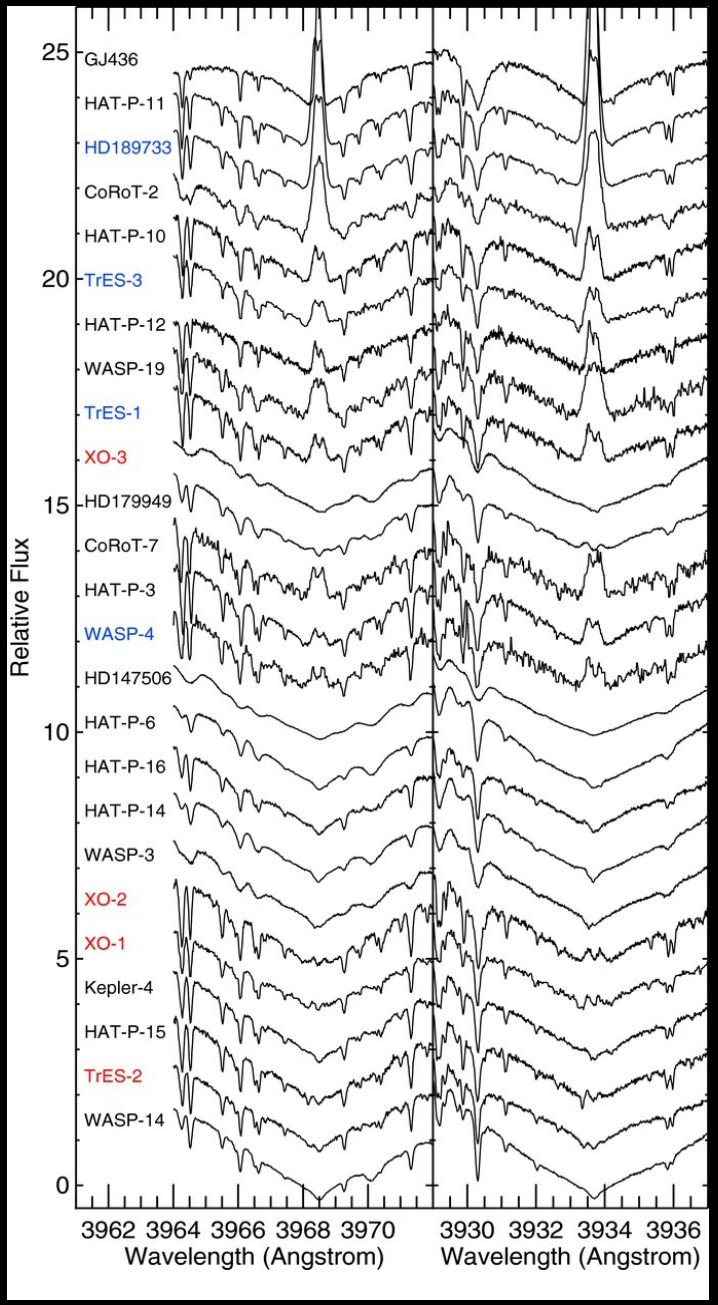
NATIONAL GEOGRAPHIC Daily News

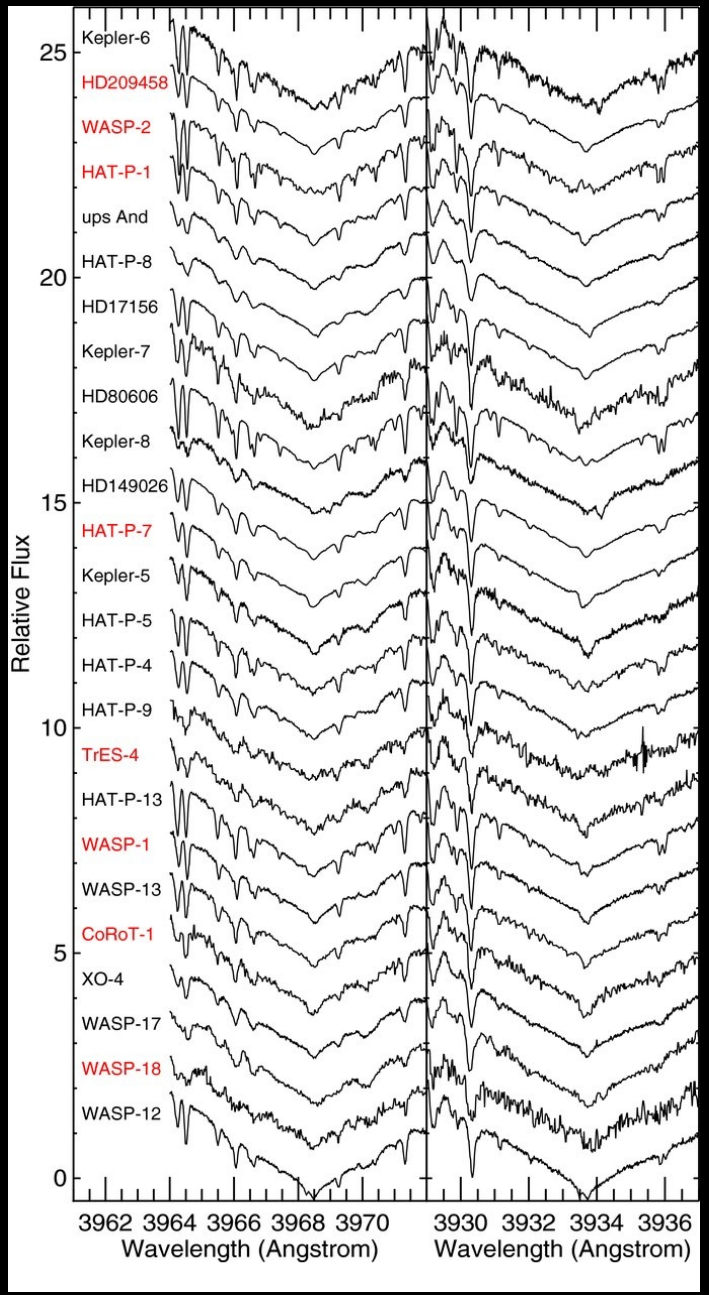
Home Animals Ancient Energy Environment Travel/Cultures Space/Tech Water Weird News Photos

Giant Planet Being Blown Away Behind a Cloudy Veil

A gas giant's atmosphere is turning into its own death shroud.

Optical Ca II H&K Line Profiles



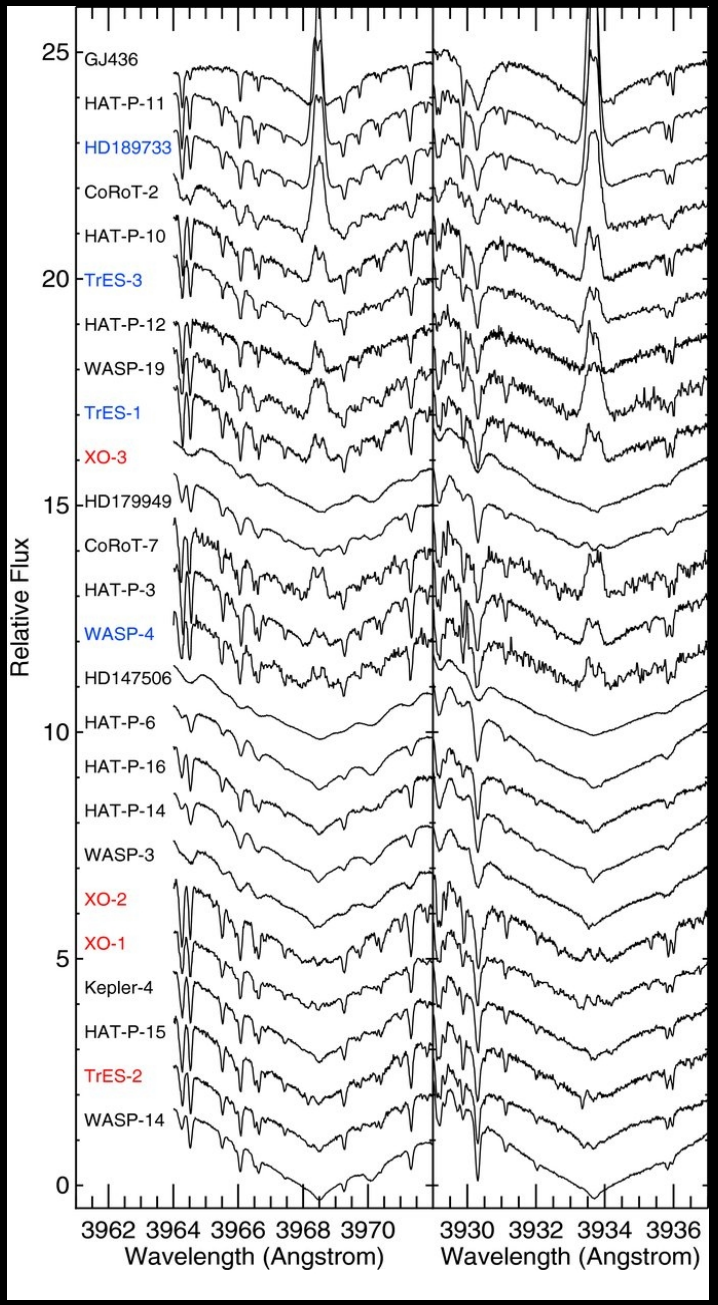


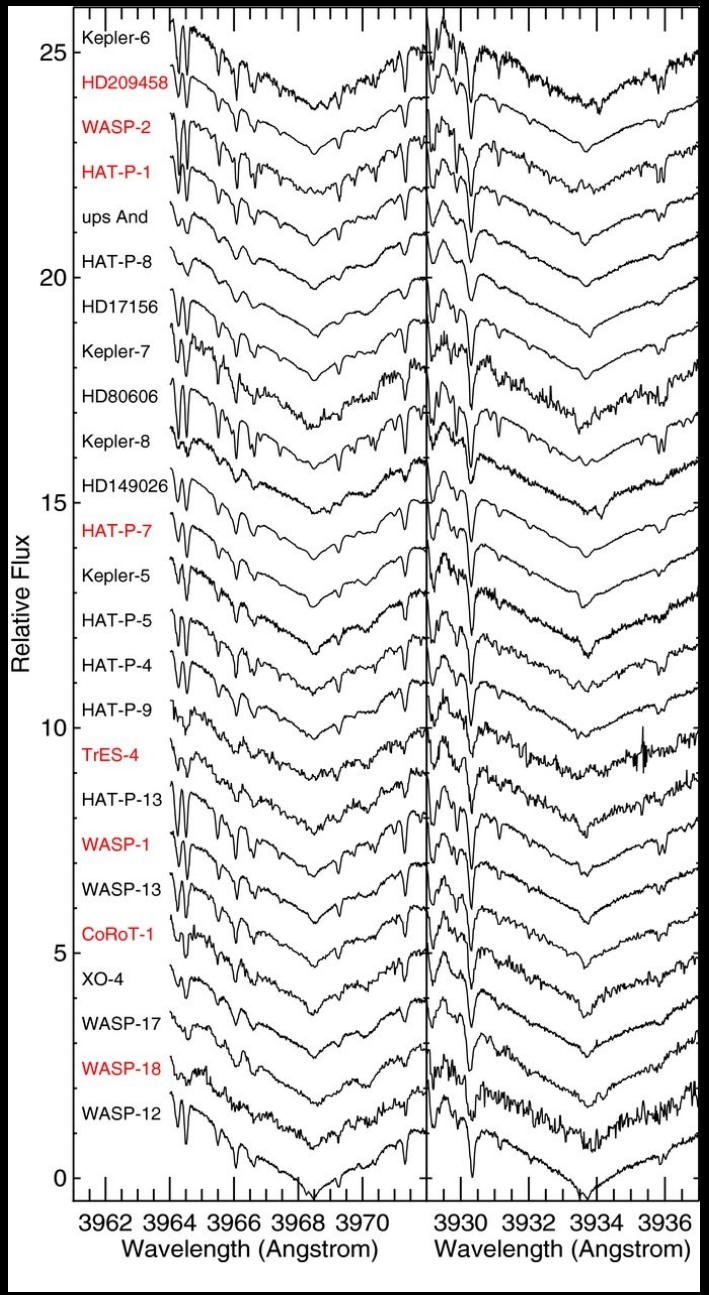
Knutson et al 2010

correlation between stellar activity and hot Jupiter atmosphere type.

Stellar irradiation affects planet atmosphere?

Optical Ca II H&K Line Profiles



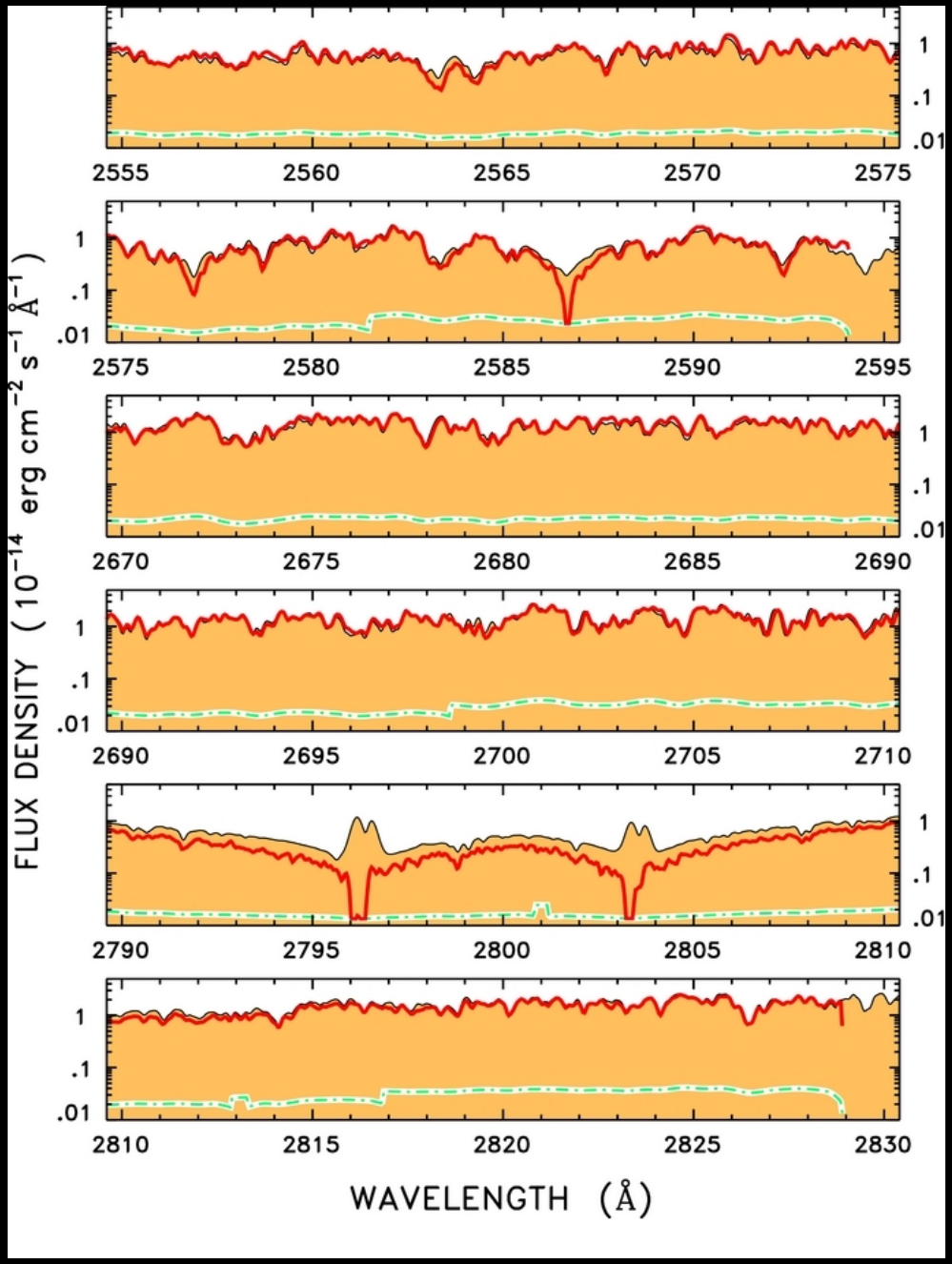


stellar activity and hot Jupiter atmosphere type.

Haswell et al 2012

Planetary mass loss absorbs the activity-indicating line core flux

Activity indicating Line Profiles



WASP-12 (red line)
α Cen (black line)

Planetary mass loss absorbs the activity-indicating flux in WASP-12

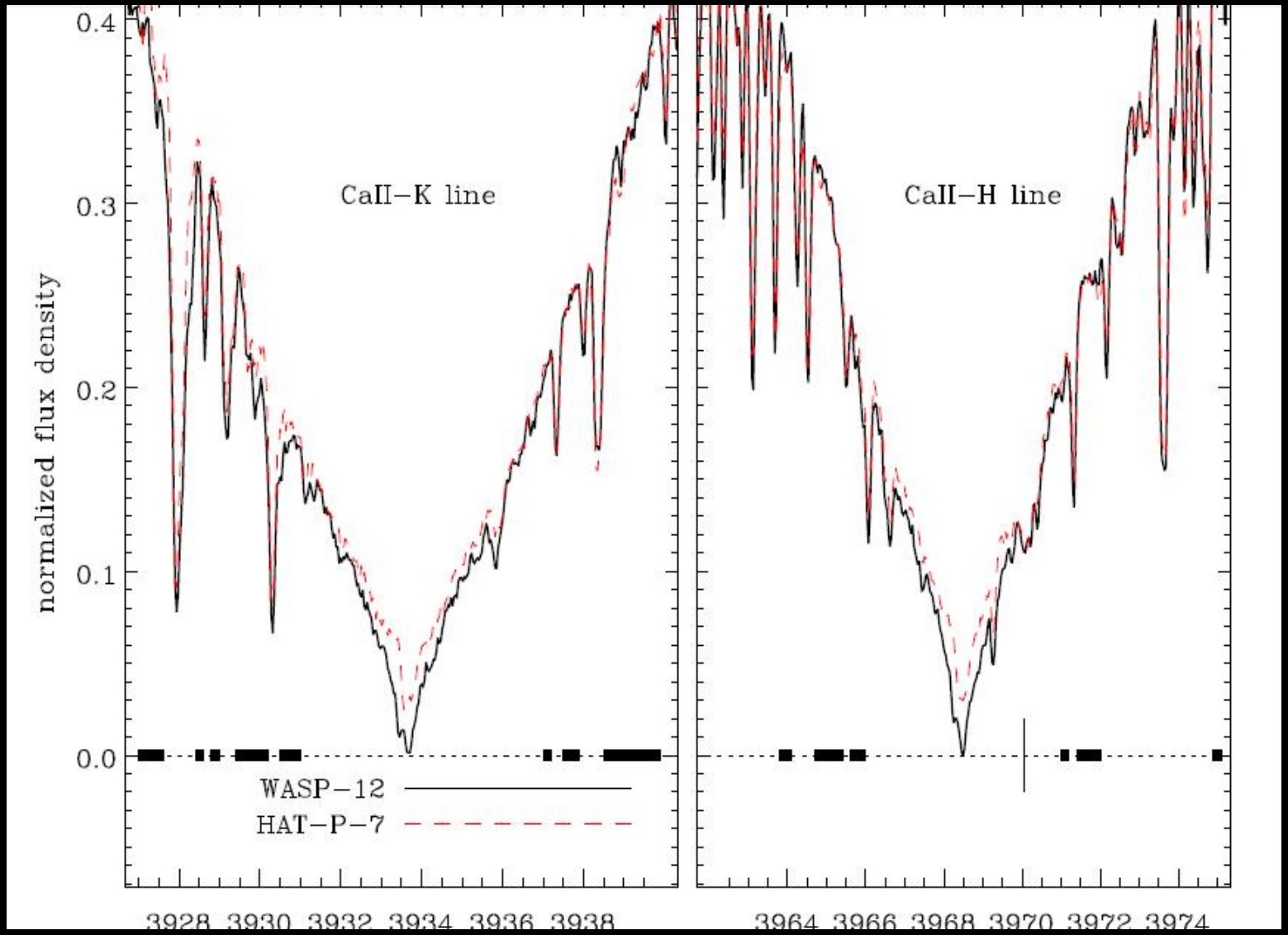
Resonance lines:

Fe II 2586
Mg II h&k
Mn II 2577

- absorbed in WASP-12
- introduce flare to light curves

Haswell et al 2012

Optical Ca II H&K Line Profiles

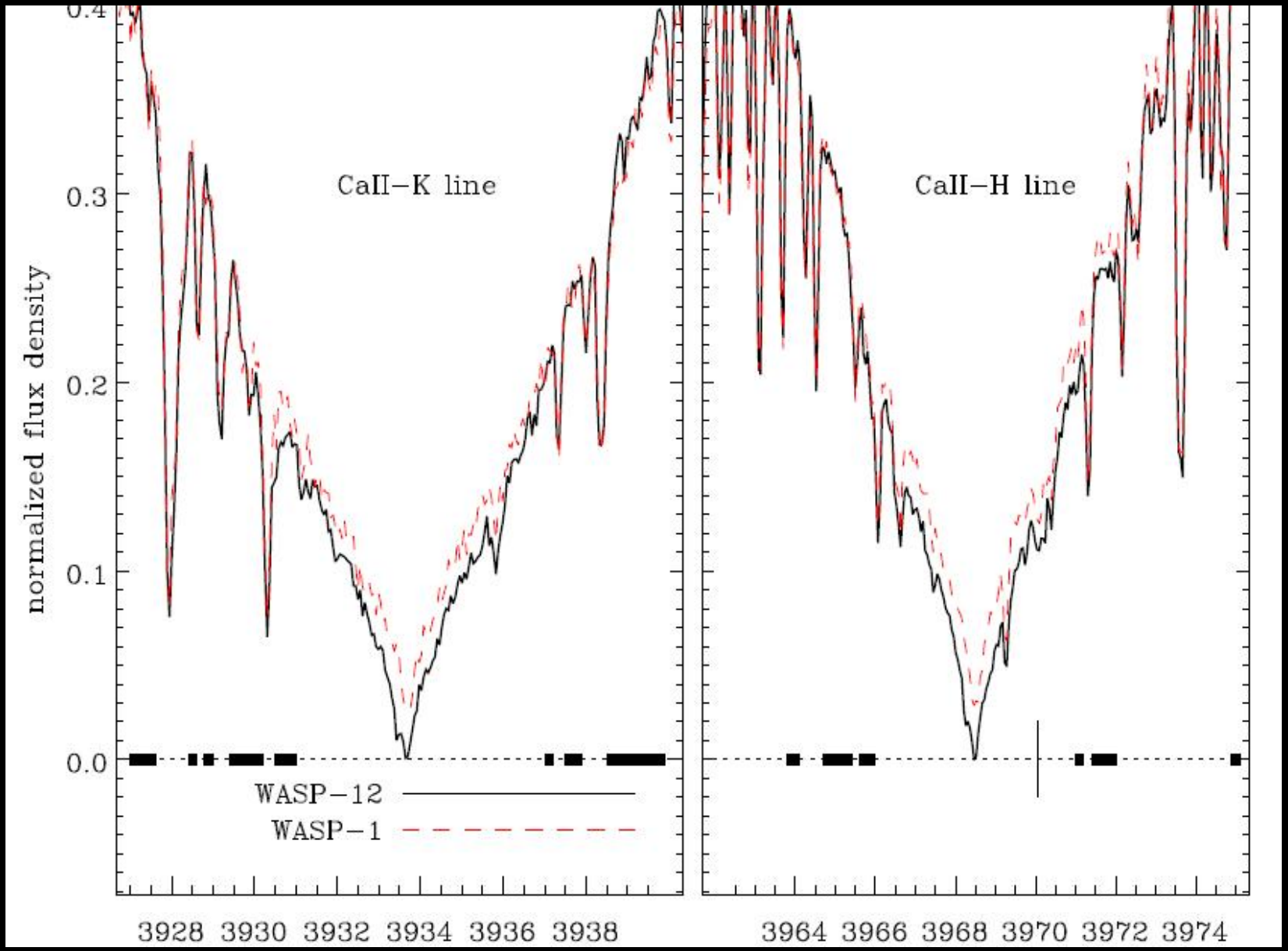


Central 4A of WASP-12 Ca II H&K lines depressed below all other stars.

Diffuse gas absorbs line core flux

Fossati, Ayres, Haswell, Bohlender, Kochukhov & Floer 2013, ApJLett

Optical Ca II H&K Line Profiles

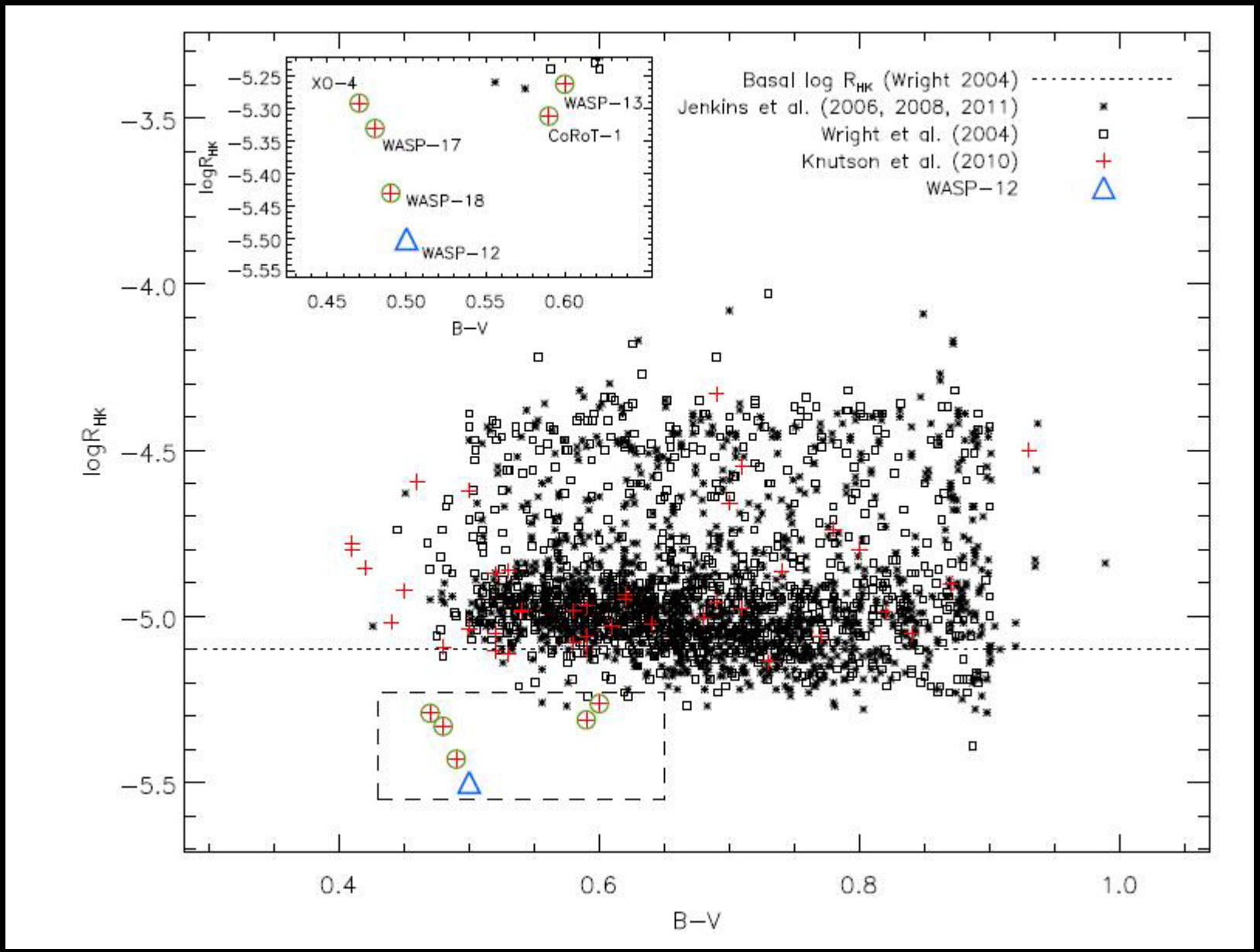


Central 4A of WASP-12 Ca II H&K lines depressed below all other stars.

Diffuse gas absorbs line core flux

Fossati, Ayres, Haswell, Bohlender, Kochukhov & Floer 2013, ApJLett

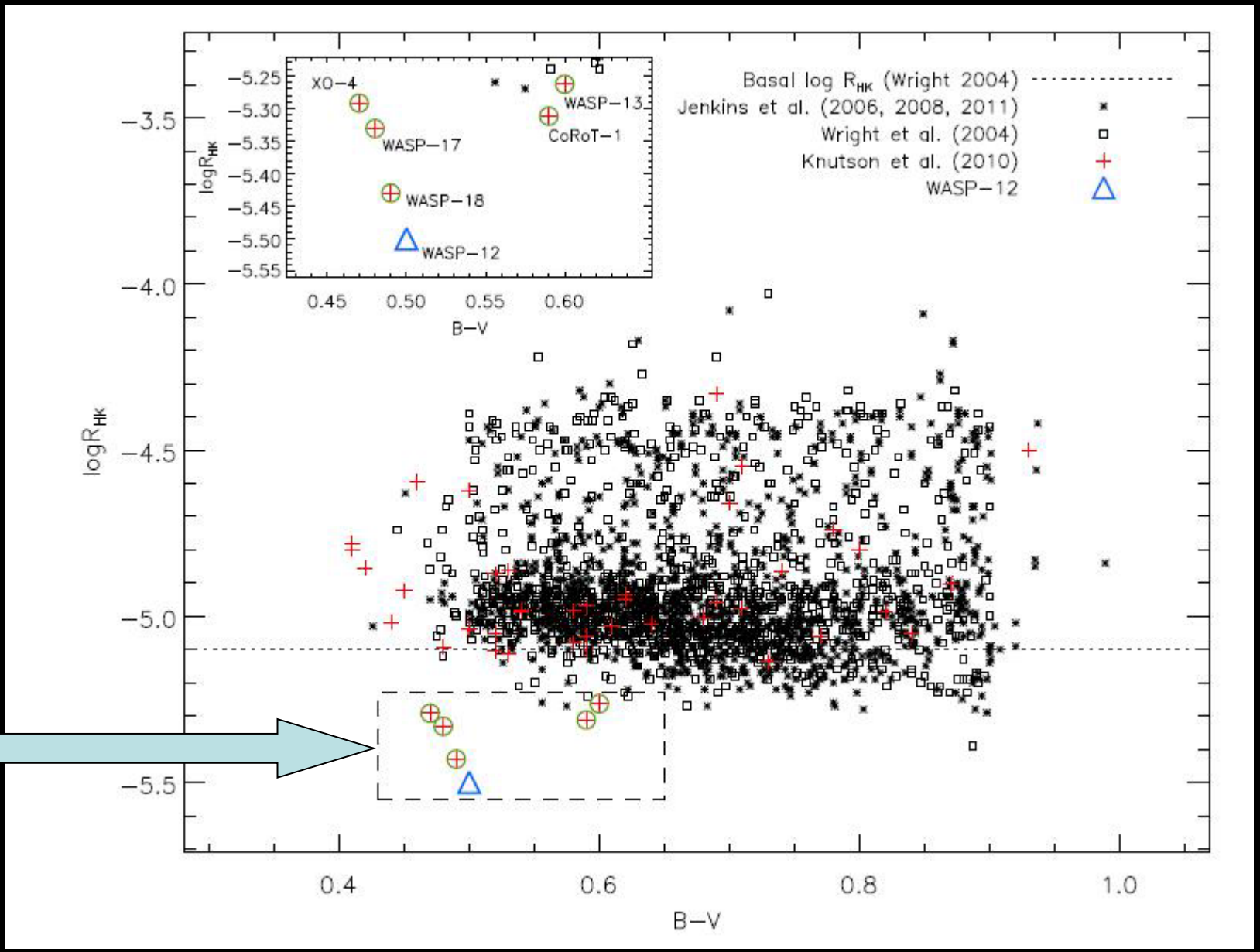
Activity: characterised by R_{HK}



Line core Emission strength

Fossati, Ayres, Haswell, Bohlender, Kochukhov & Floer 2013, ApJLett

Activity: characterised by R_{HK}



Line core emission quenched by diffuse gas

Fossati, Ayres, Haswell, Bohlender, Kochukhov & Floer 2013, ApJLett

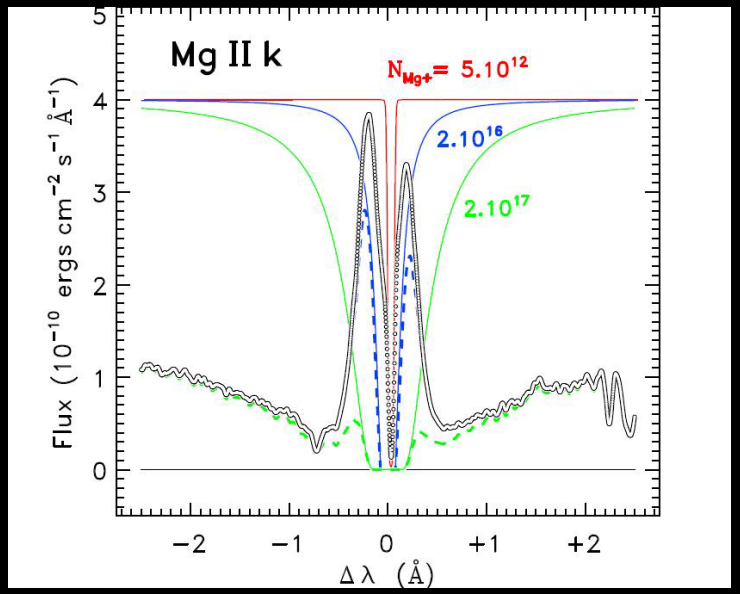
Could the absorption be interstellar?

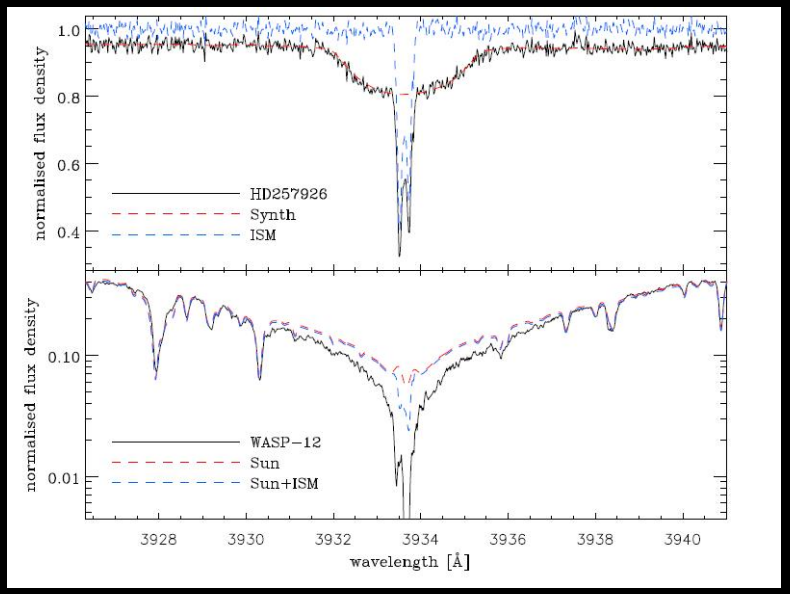
No!

ISM would need to be 10x denser than usual

ISM along WASP-12 sightline is too diffuse.

ISM absorption is in sharp components

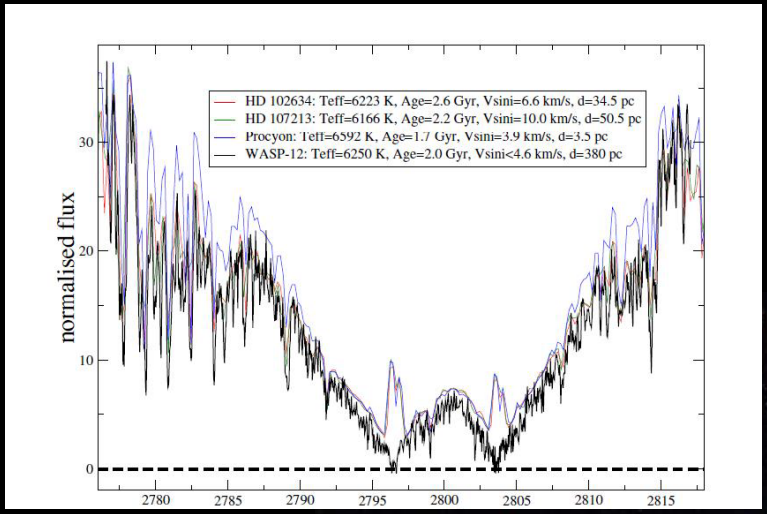




Haswell et al 2012, ApJ, 760, 79

Fossati, Ayres, Haswell, Bohlender, Kochukhov & Floer 2013, ApJLett

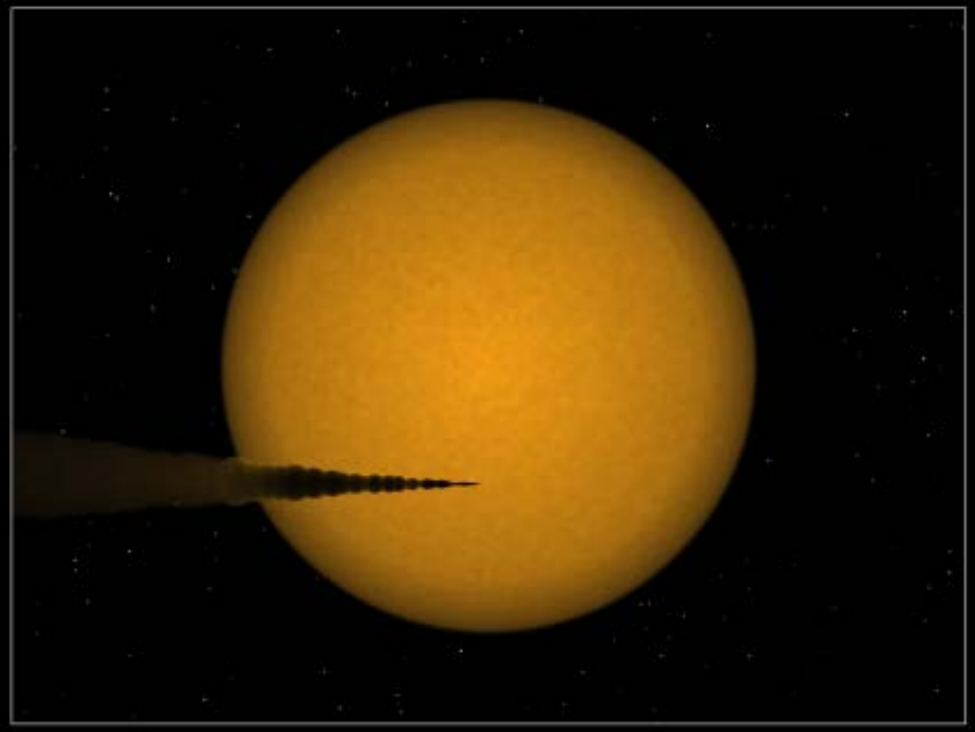
The WASP-12 system is shrouded in diffuse gas



Haswell et al 2012

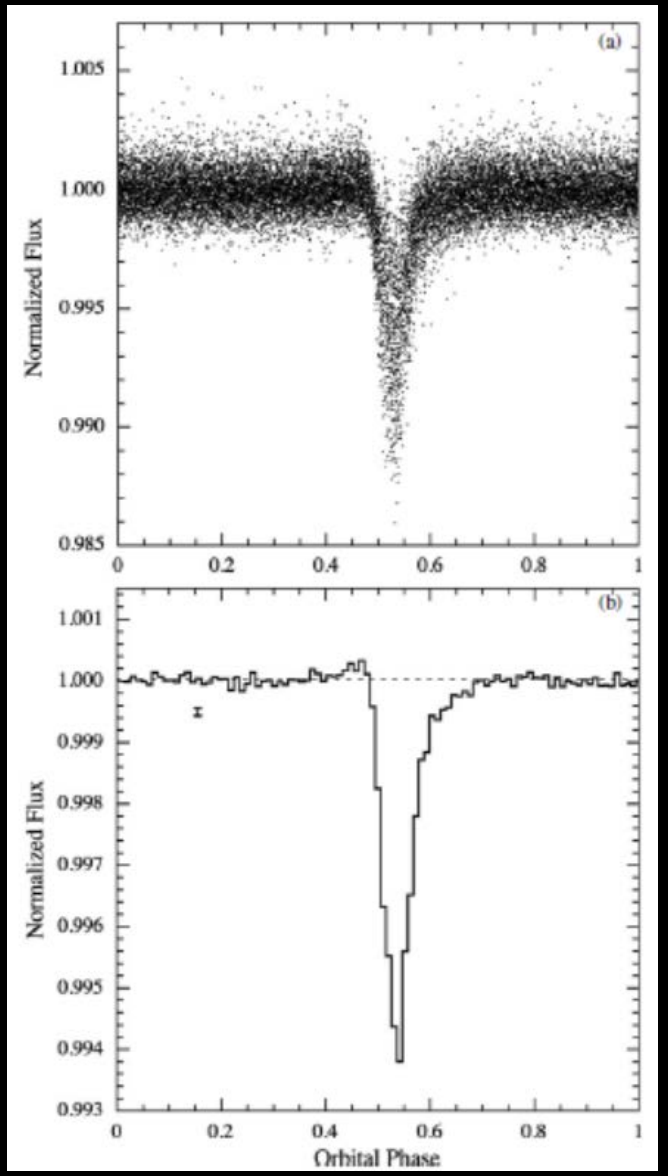
The stellar disc is obscured at all observed phases.

A disintegrating close-in rocky planet KIC 1255



Artist's Impression of Disintegrating Exoplanet KIC 12557548 (Brogi et al. 2012)

Image credit: C.U.Keller (2012), Leiden Observatory, Leiden University, keller@strw.leidenuniv.nl

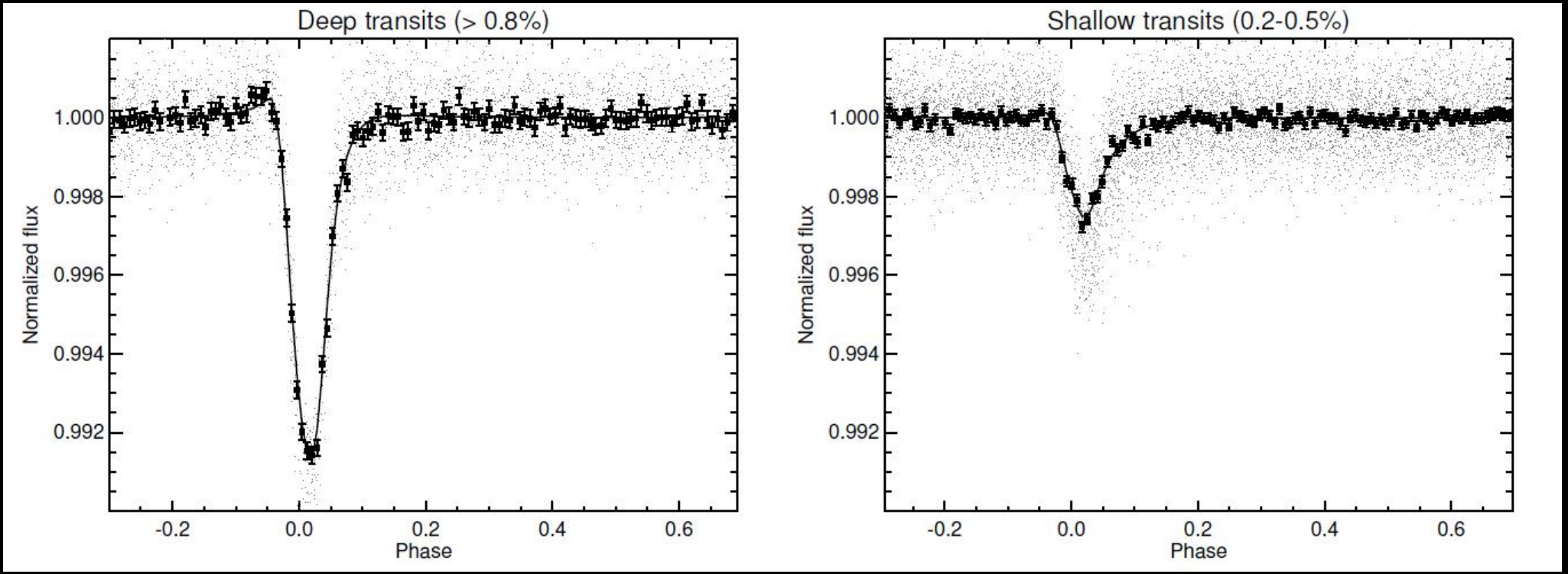


- 0.1 Earth mass transiting planet, 15.7 hour orbit around a KV star
- T = 2100 K, direct sublimation and/or explosive volcanism
- Large cloud of metal-rich vapour and entrained dust lost from planet

Rappaport et al 2012, ApJ, 752, 1

A disintegrating close-in rocky planet KIC 1255

- 0.1 Earth mass transiting planet, 15.7 hour orbit around a KV star
- T = 2100 K, direct sublimation and/or explosive volcanism
- Large cloud of metal-rich vapour and entrained dust lost from planet
- Limit cycle: dust forms, τ raised, surface cools, sublimation slows, less dust, τ decreases, surface heats, sublimation increases, dust forms, …



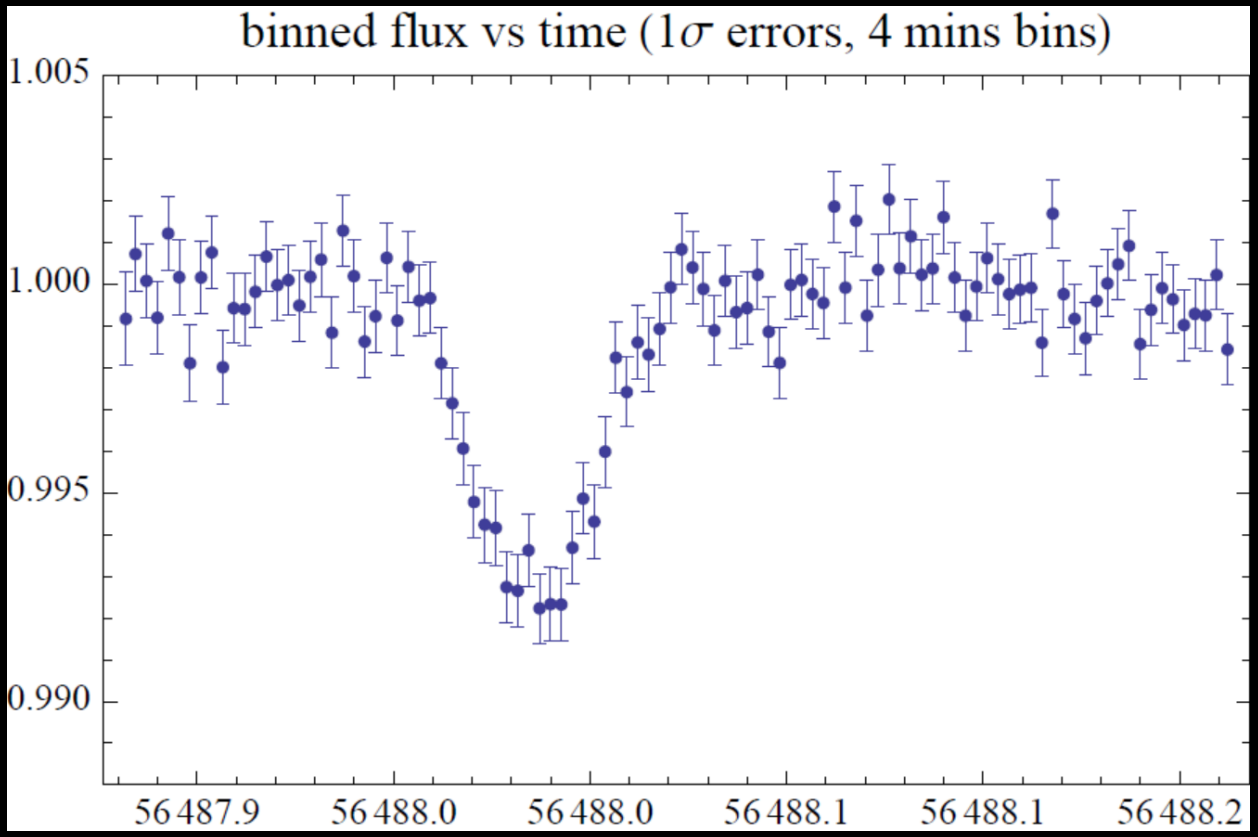
Brogi et al 2012 A&A 545, L5

Rappaport et al 2012, ApJ, 752, 1

A disintegrating close-in rocky planet KIC 1255

- WHT/ULTRACAM observations (now!)
  - High time-resolution simultaneous 3-colour optical photometry
  - constrain dust scattering function: grain size, composition
  - deep & shallow transits in u', g', z'; shallow transits in u', g', i'

Bochinski PhD thesis, supervisors Haswell & Kolb and informally Fossati



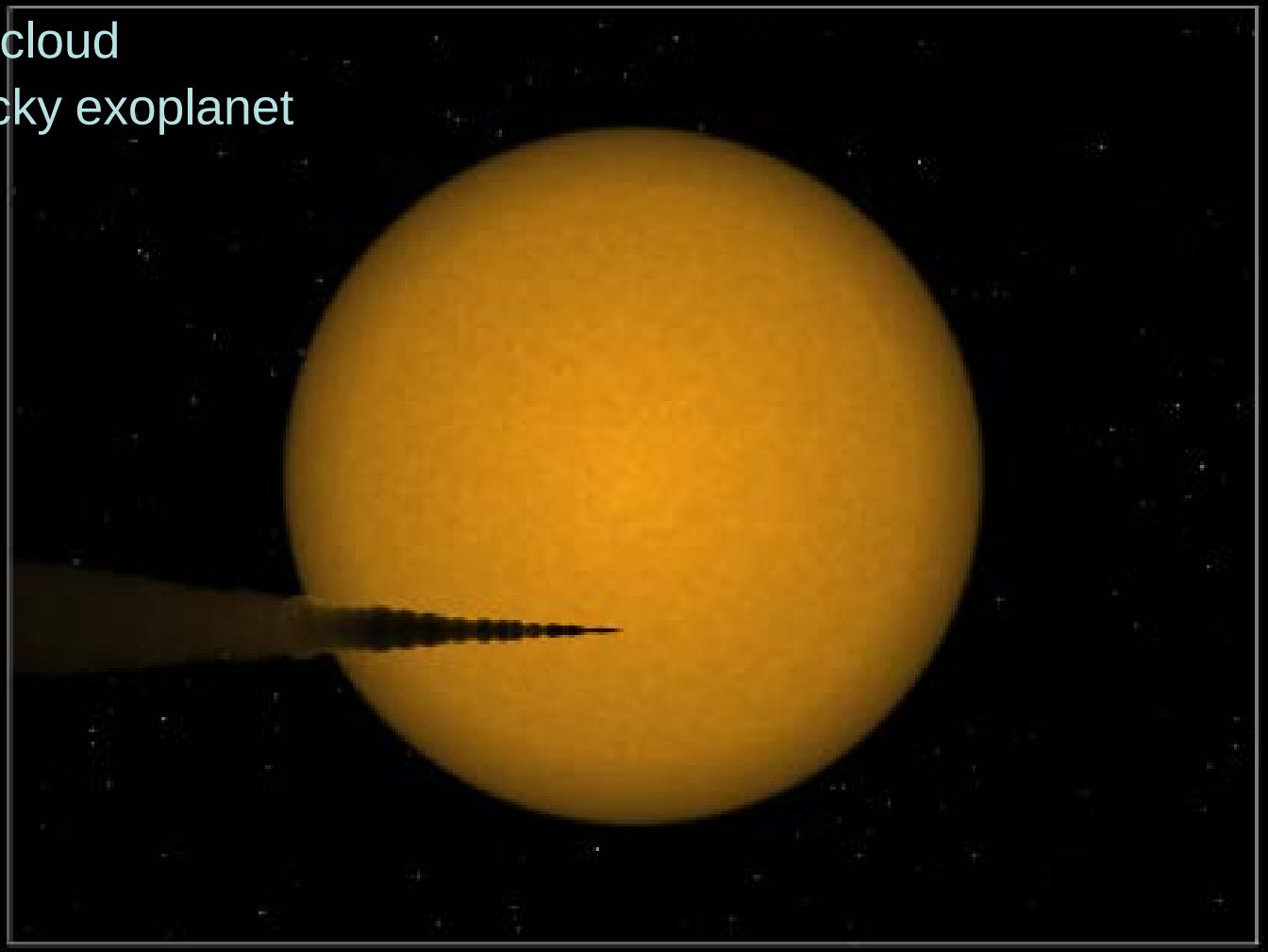
WHT/ULTRACAM data, July 2013

In collaboration with Marsh & Dhillon

A disintegrating close-in rocky planet KIC 1255

- CFHT/ESPaDoNS data in hand
  - High resolution optical spectra for transmission spectroscopy
  - Detect metal atoms/ions in cloud
  - Measure composition of rocky exoplanet

Bochinski PhD thesis, supervisors Haswell & Kolb and informally Fossati

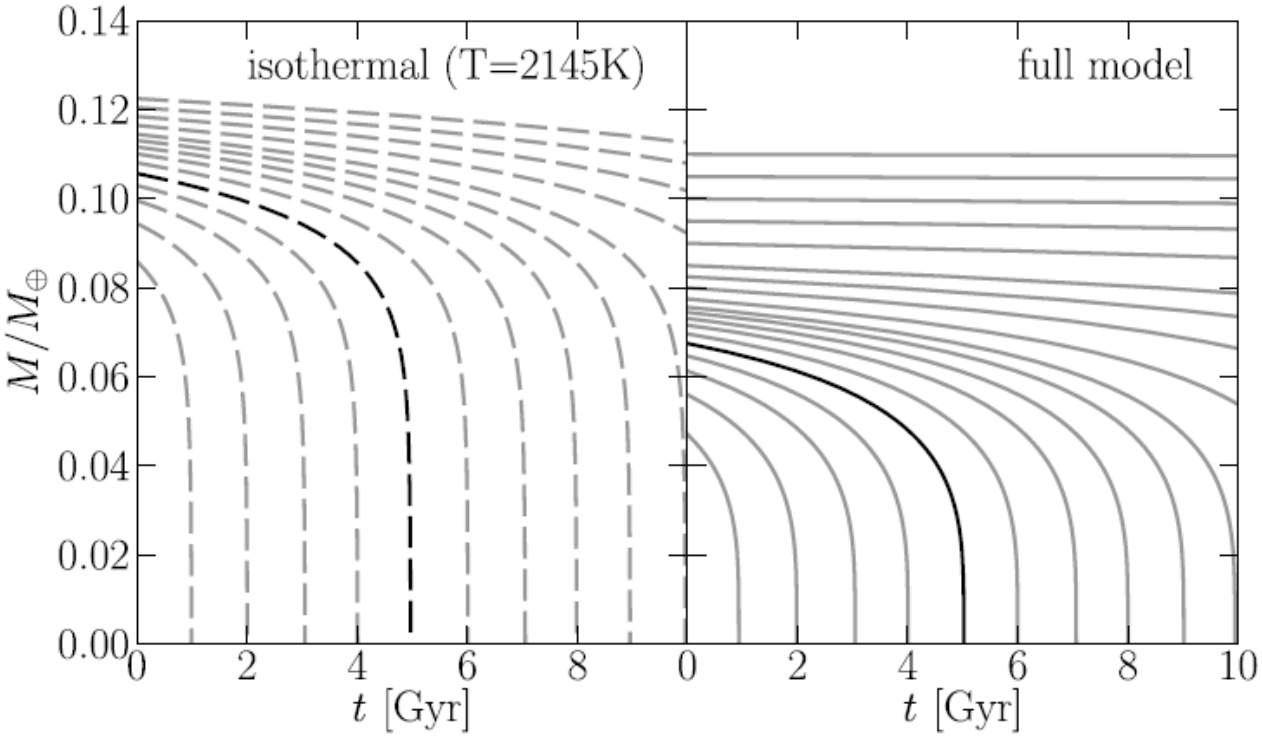


Artist's Impression of Disintegrating Exoplanet KIC 12557548 (Brogi et al. 2012)

Image credit: C.U.Keller (2012), Leiden Observatory, Leiden University, keller@strw.leidenuniv.nl

Catastrophic Evaporation of Rocky Exoplanets

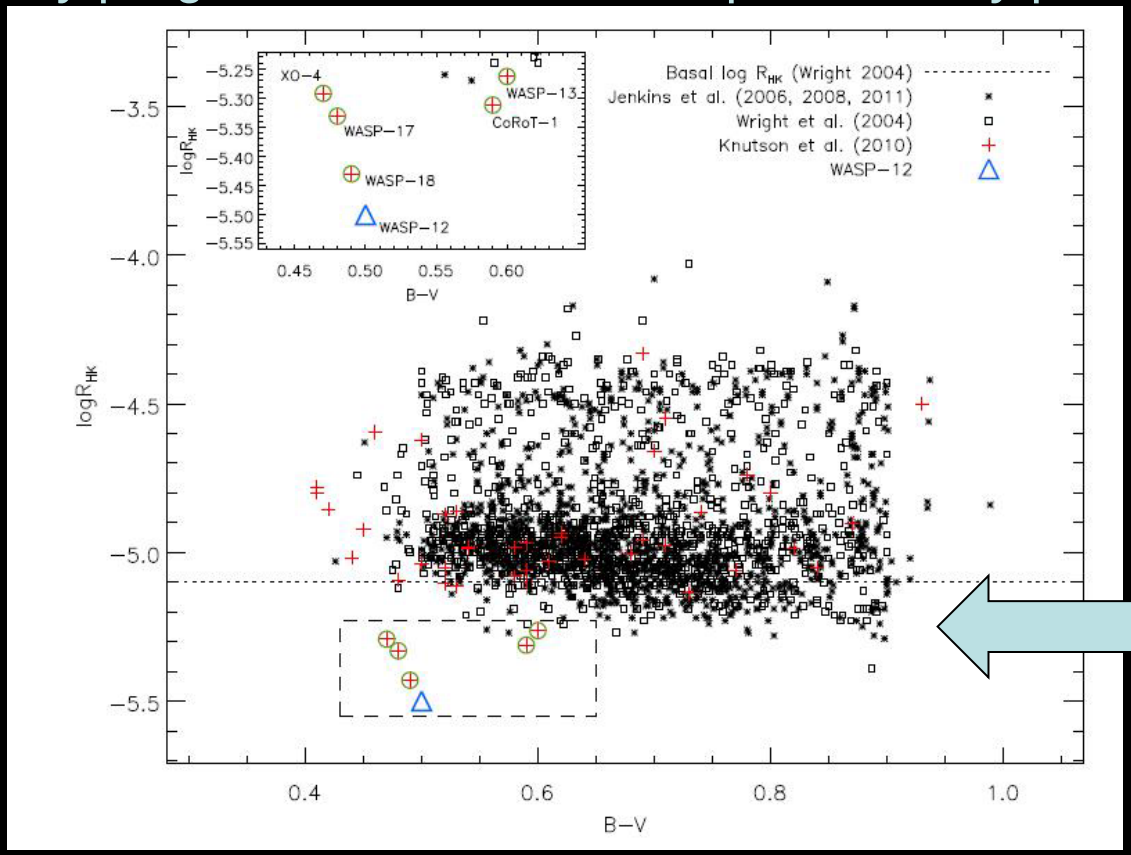
- T > 2000K : rock vaporizes, thermal wind driven.
- Radiative-hydrodynamic modelling with dust-gas energy exchange
- Small planets evaporate completely
- Mass loss rate depends strongly on planet mass
- KIC 1255 ~0.1 Earth mass, ~mass of moon
- KIC 1255 in final short-lived catastrophic phase, ~1% of planet life
- many progenitor low-mass short period rocky planets should exist.



(Perez-Becker & Chiang, 2013, arXiv:1302.2147 (ApJ),

Catastrophic Evaporation of Rocky Exoplanets

- T > 2000K : rock vaporizes, thermal wind driven.
- Radiative-hydrodynamic modelling with dust-gas energy exchange
- Small planets evaporate completely
- Mass loss rate depends strongly on planet mass
- KIC 1255 ~0.1 Earth mass, ~mass of moon
- KIC 1255 in final short-lived catastrophic phase, ~1% of planet life
- many progenitor low-mass short period rocky planets should exist.

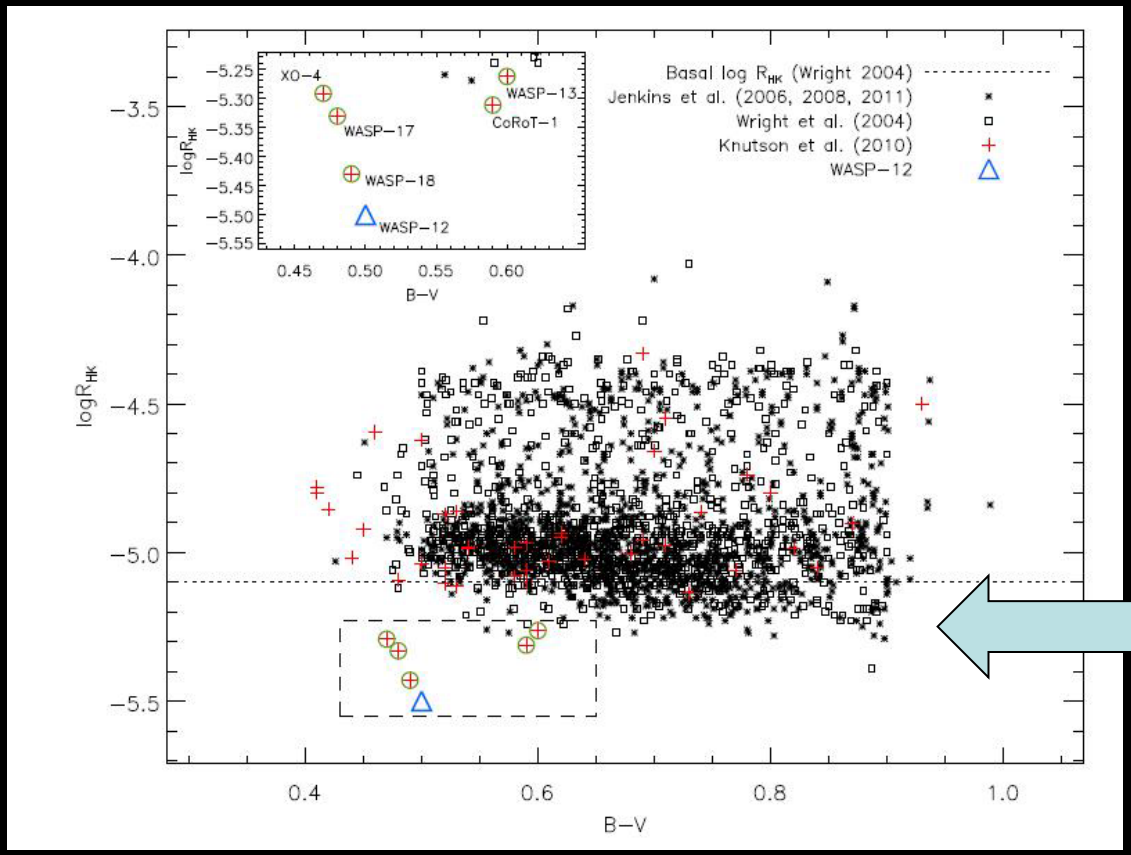


Fossati, Ayres, Haswell, Bohlender, Kochukhov, & Floer 2013, ApJLett, 766, 20

Hosts of mass-losing, low-mass, short period rocky planets?

Many low-mass short period rocky planets?

- Kepler-37: moon-sized
- KIC 1255: ~0.1 Earth mass, ~mass of moon, 16 hr orbit
- Kepler 78-b: Earth sized, 8.5 hour orbit
- KOI 1843: 0.6 R_Earth, 4.2 hour orbit



Fossati, Ayres, Haswell, Bohlender, Kochukhov, & Floer 2013, ApJLett, 766, 20

BRIGHT hosts of mass-losing, low-mass, short period rocky planets?

Staab PhD thesis

Conclusions

- WASP-12 system enshrouded in diffuse absorbing gas
- Other v. close-in hot Jupiters have anomalously depressed CaII H&K lines
- KIC 1255 in short-lived phase, producing copious metal-rich vapour
- There are several other small v. short-period Kepler planets
- Anomalous CaII H&K line cores indicate bright host stars of other extreme close-in planets?
- Possible opportunities to probe planet composition through transmission spectroscopy
- Targets for CHEOPS, PLATO & ECHO?