Observing small dusty planets with PLATO

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The PLATO mission conference – Warwick 2017

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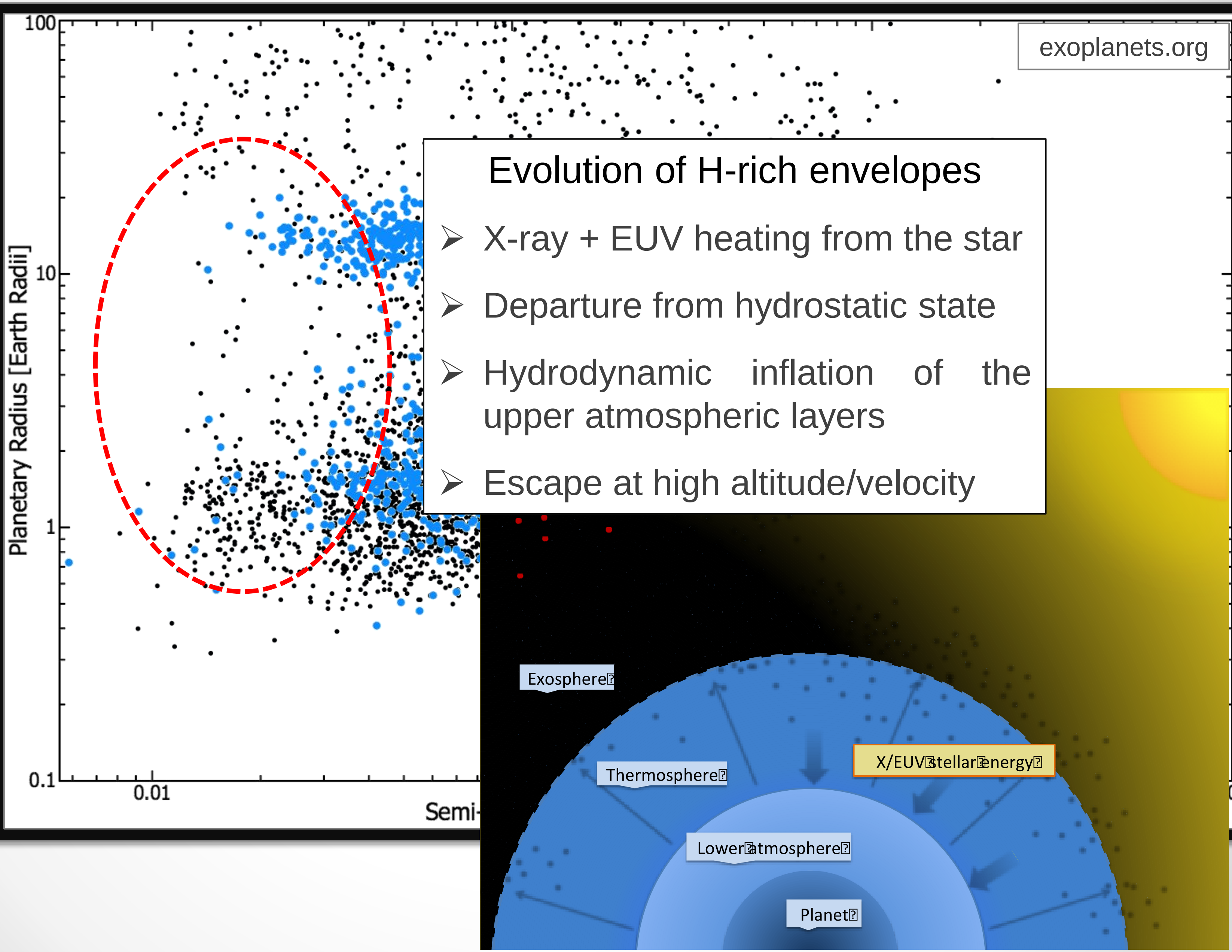
PlanetS

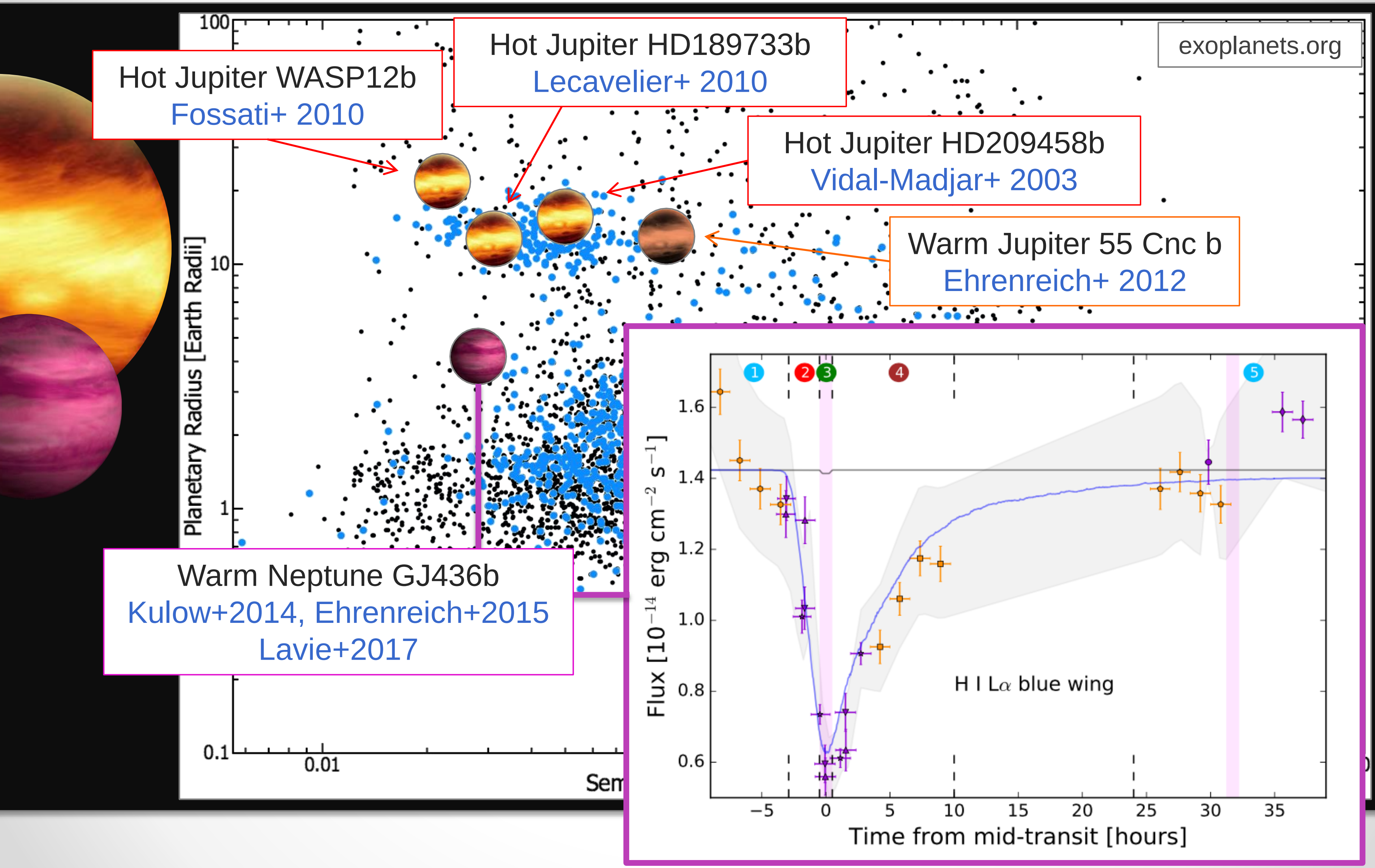
Stellar irradiation and close-in planets



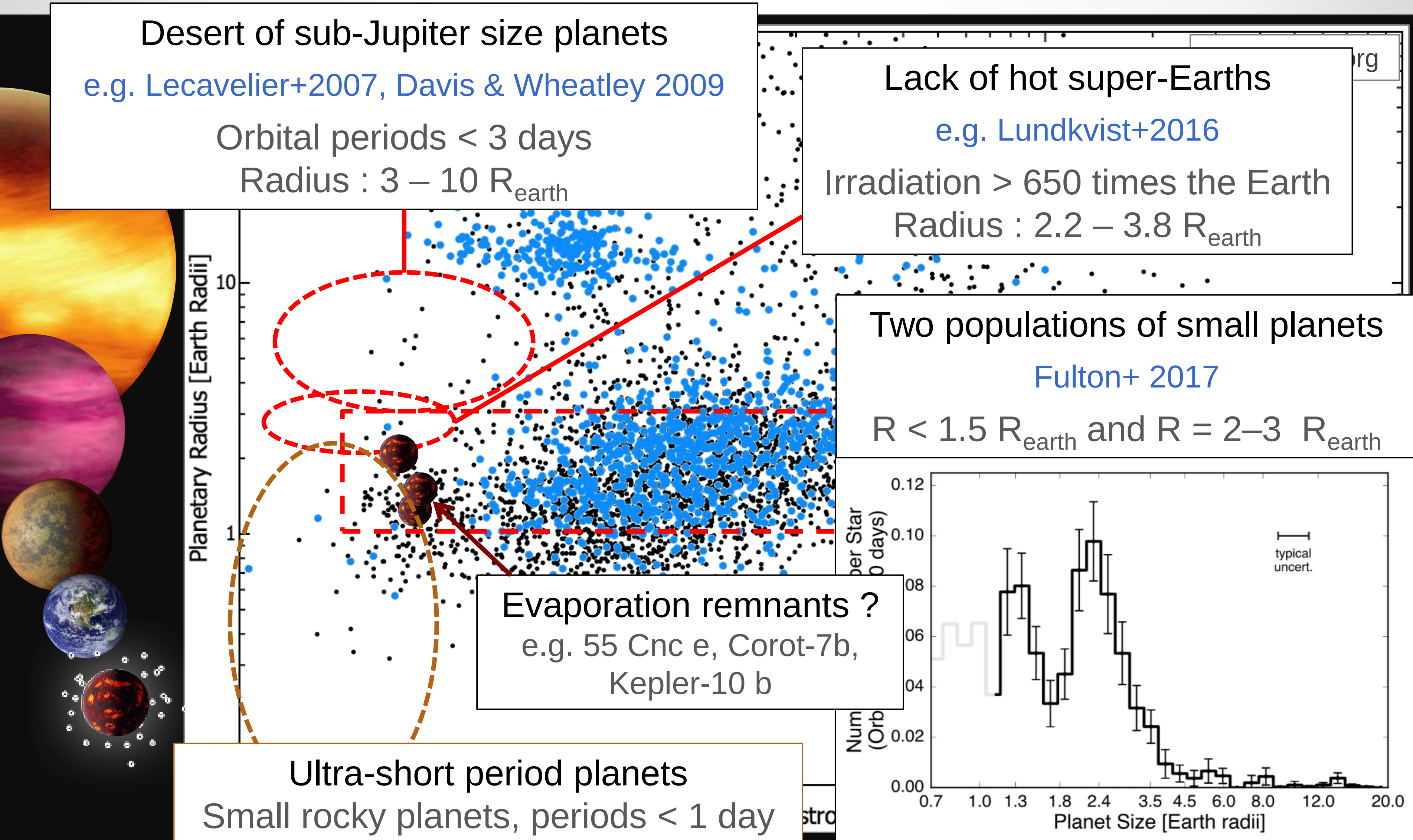
Evolution of H-rich envelopes

- X-ray + EUV heating from the star
- Departure from hydrostatic state
- Hydrodynamic inflation of the upper atmospheric layers
- Escape at high altitude/velocity

Stellar irradiation and close-in planets



Stellar irradiation and close-in planets



Role of evaporation supported by many theoretical studies

(eg Lopez et al. 2012, Jin et al. 2014, Kurokawa & Nakamoto 2014, Owen & Wu 2017)

Evolution of Ultra-Short Period (USP) planets

eg Rappaport+ 2012, 2014; Perez-Becker & Chiang 2013

- Strong bolometric irradiation from the close star
- Molten surface (T_{eq} > 1000 K), active volcanism, …
- Outgassing/sputtering of silicate and volatile elements, dust plumes, magma vapours, …
- Formation of a hot, dust & metal-rich atmosphere, sensitive to stellar activity

Grav-bound dust envelopes

- Earth and super-Earth size planets
- Envelope bound by gravity: no escape
- Variations in dust content and radius ?

Detectable through high-precision optical photometry

Disintegrating USP

- Small planets (< Mercury) & planetesimals
- Envelope expands through thermal wind
- Condensation of dust grains entrained by the gas flow
- Dust tails much larger than the body

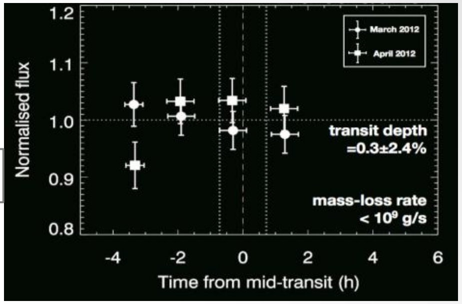
Detectable through high-precision optical photometry

USP Type I : The super-Earth 55 Cnc e

55 Cnc e in 2012 : Far-UV (Ehrenreich+2012)

- Search for evaporating oceans (Teq > 2000 K)
- Non-detection of hydrogen escape

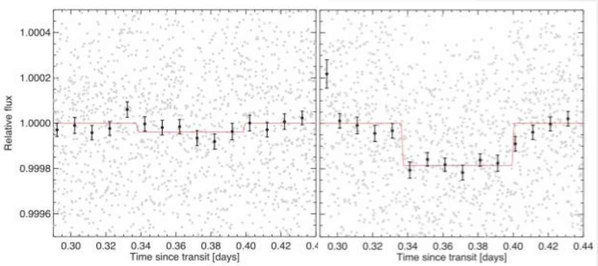
HST/STIS



Hinted at no volatile envelope

55 Cnc e in 2016 : IR (Demory+ 2016a, 2016b)

- Temporal variations in the IR transit and occultation depths
- Inefficient heat redistribution from the dayside to the nightside



Spitzer

Magma oceans with no atmosphere / Silicate-rich atmosphere

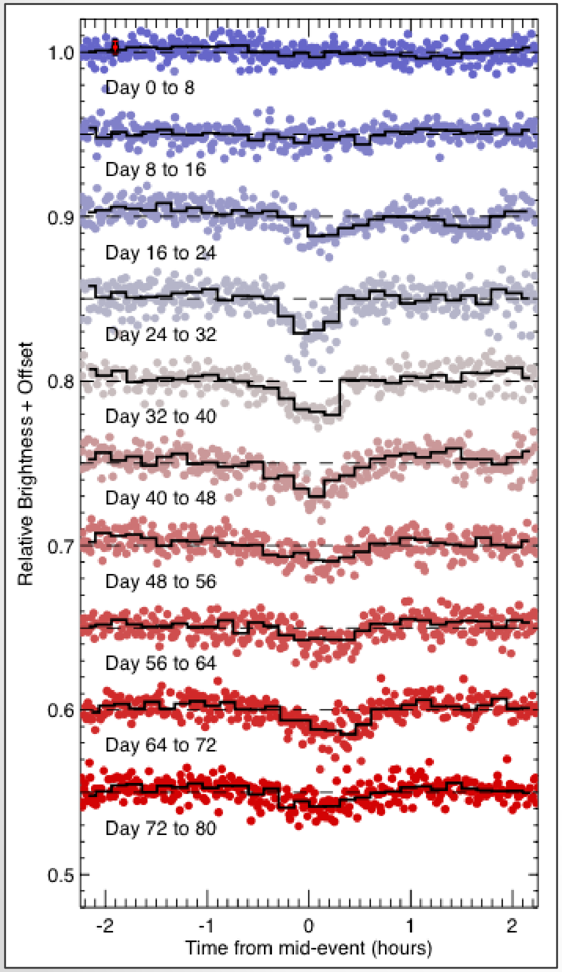
55 Cnc e in 2016 : Optical (Ridden-Harper+2016)

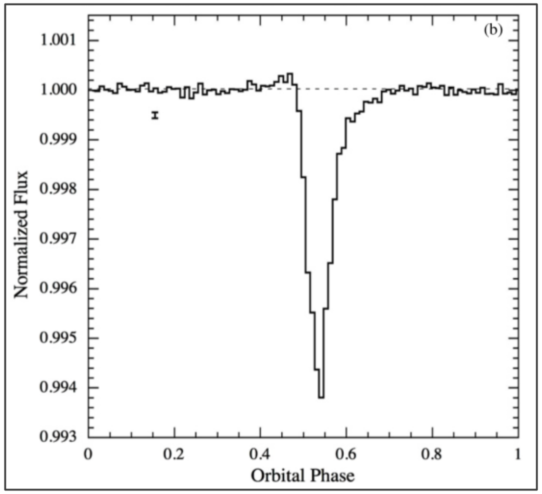
- Hints of Na and Ca+ absorption

If confirmed, extreme temporal variability

USP Type II : Disintegrating planet(esimal)s

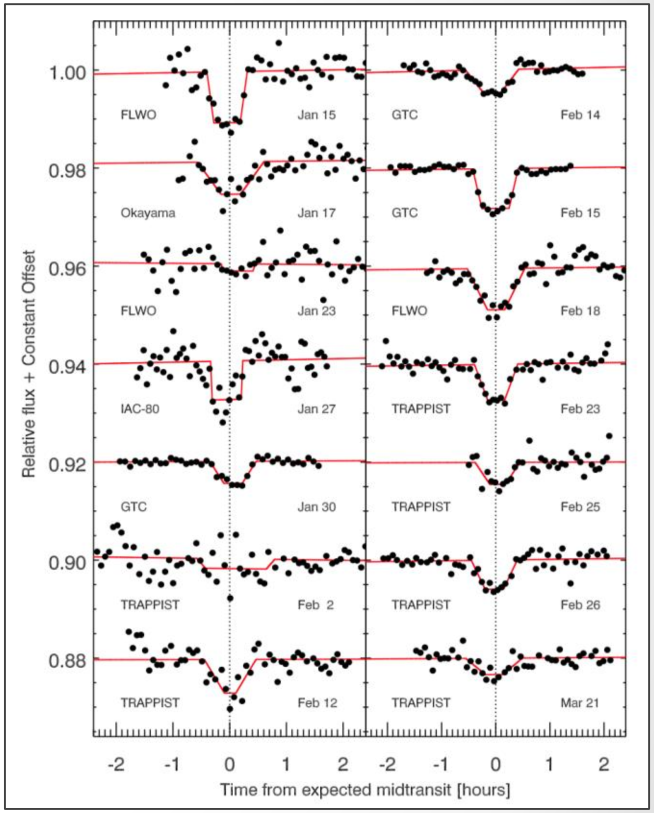
WD 1145+017 b
(Vanderburg+2015)
Absorption 10 – 60 %
White Dwarf (V = 17)

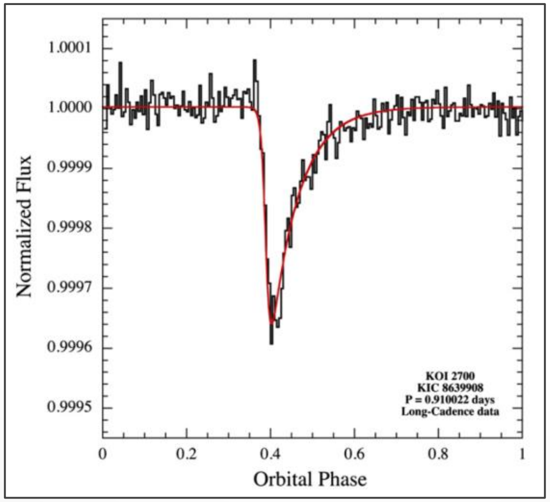




KIC 12557548 b
(Rappaport+2012)
Absorption 0 – 1.2%
K star (V = 16.7)

EPIC 201637175 b
(Sanchis-Ojeda+2015)
Absorption 0 – 1.3 %
M dwarf (V = 17)





KOI-2700 b (Rappaport+2014)
Absorption 0.05 %, K star (V = 15.4)

Space-borne photometric follow-up

Objectives:

- Characterize dust-induced radius variations of large USPs
- Characterize small disintegrating USPs

Facilities:

TESS:

- Global coverage of bright nearby stars
- Expected detection of ~40 large USPs in CHEOPS field (Sullivan+ 2015)
- Limited characterization if faint signals or temporal variability

CHEOPS:

- Selection of specific targets & observations at specific epochs
- Follow-up of TESS candidates (same SNR in 3 transits as TESS with full coverage)

PLATO:

- Launch 2026 + coverage of TESS fields & possible coverage of Kepler field
  -> study evolution of known USPs after 5 - 15 years
- Bright stars + long coverage: characterization of faint signals or short-term variations
  Simultaneous characterization of the host star (age, activity, …)
- Ground-based support

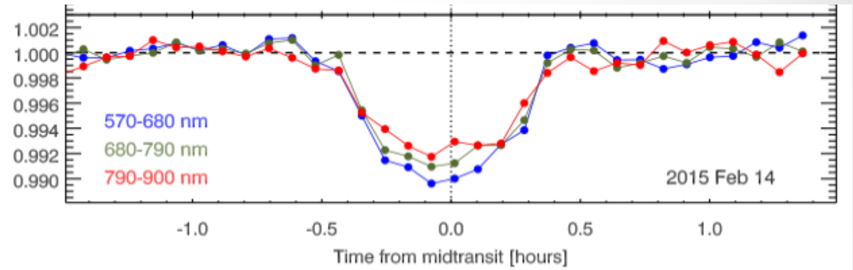
Ground-based chromatic follow-up

Measuring variations of absorption with wavelength (from UV to IR)

➡ dust composition (pyroxene, aluminum oxide …) + detection of volatiles species

- EPIC 201637175b (Sanchis-Ojeda+ 2015)

  large particles (~1 µm)



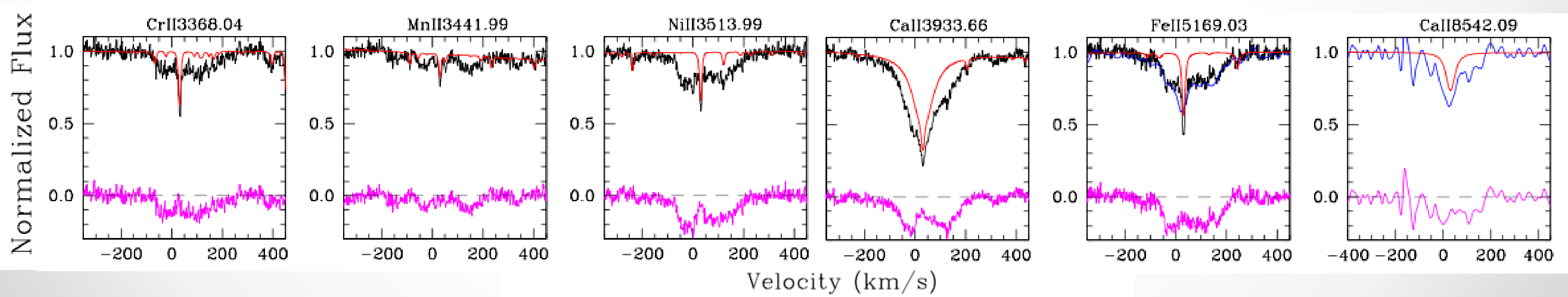
- KIC 12557548b (Bochinski+2015): variations in z' to g' bands (particles 0.25 to 1 µm)

  (Schlawin+2016): variations in r' & H bands (particles >0.2 or 0.5 µm)

- WD 1145+017b (Alonso+2016): gray transits in V band (grain size > 0.5 µm)

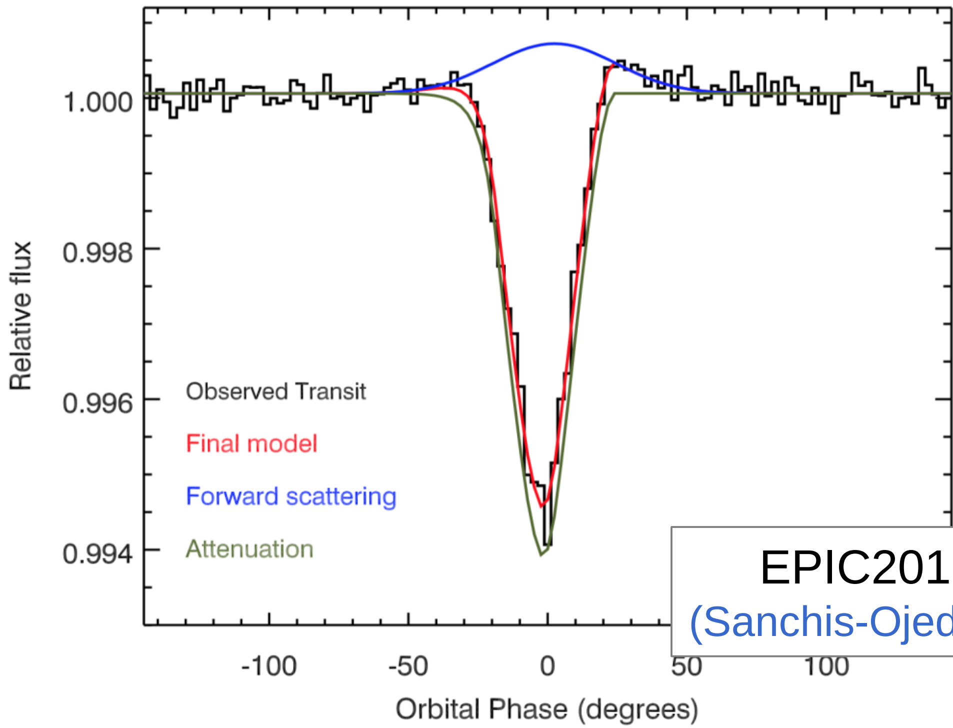
  (Zhou+2016): visible + infrared (particles > 0.8 µm)

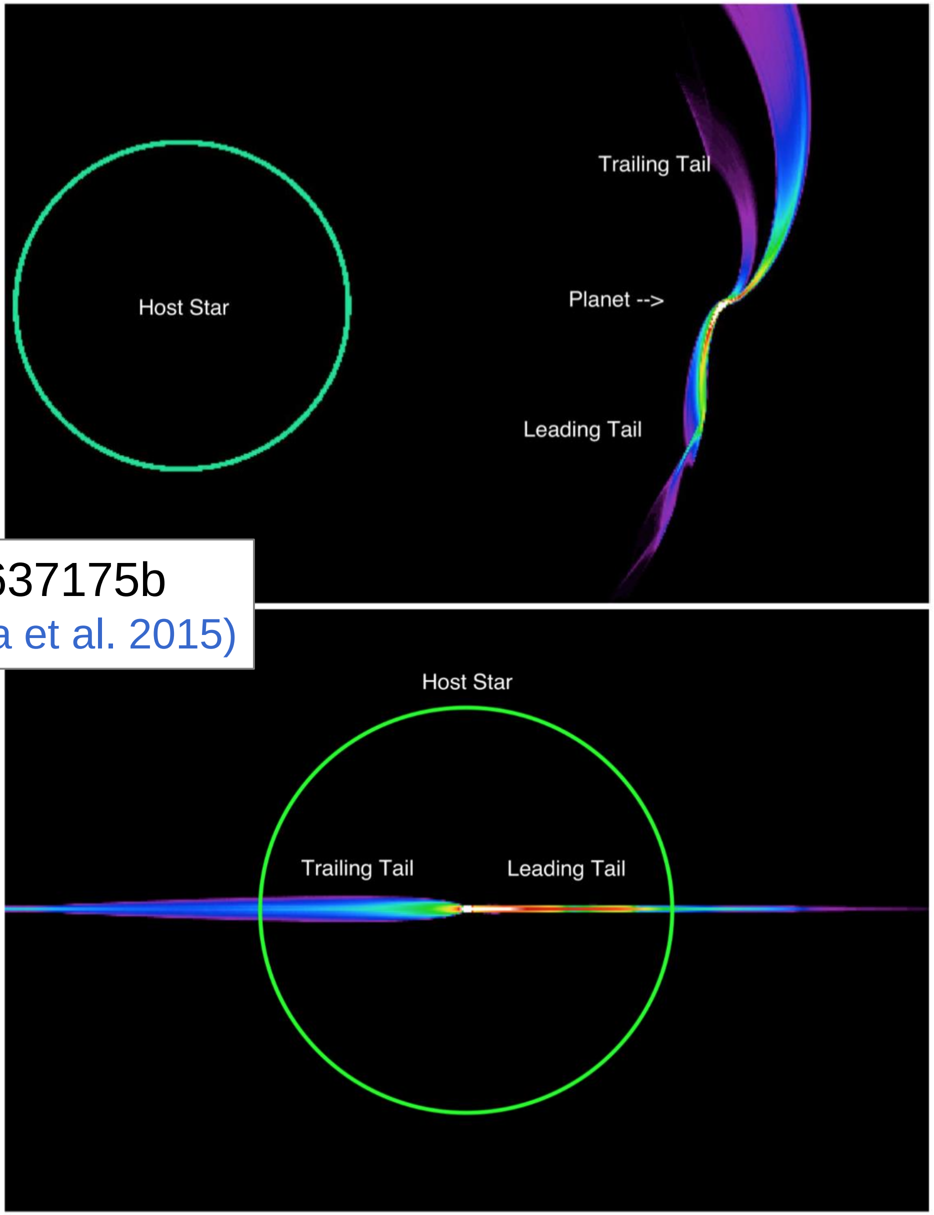
  (Xu+2015): resolved absorption lines in V to nIR (Mg, Ca, Fe, Ti, …)



Use of PLATO ground-based observations program

Interpreting observations of dust tails



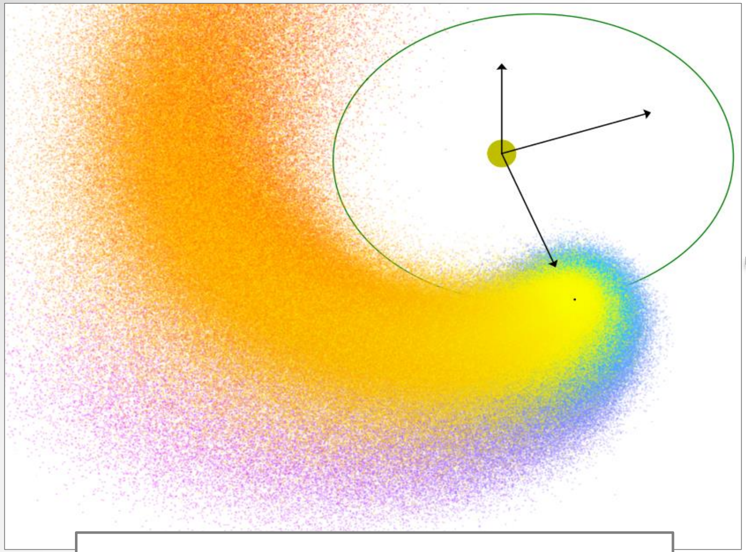


EPIC201637175b
(Sanchis-Ojeda et al. 2015)

Interests :

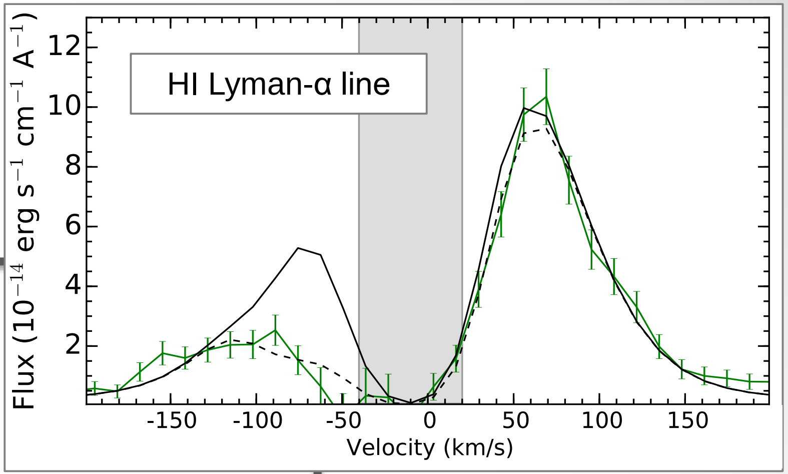
- Tail structure and composition
- Planet surface and interior
- Planet mass loss and evolution
- Kinship with larger progenitors
- …

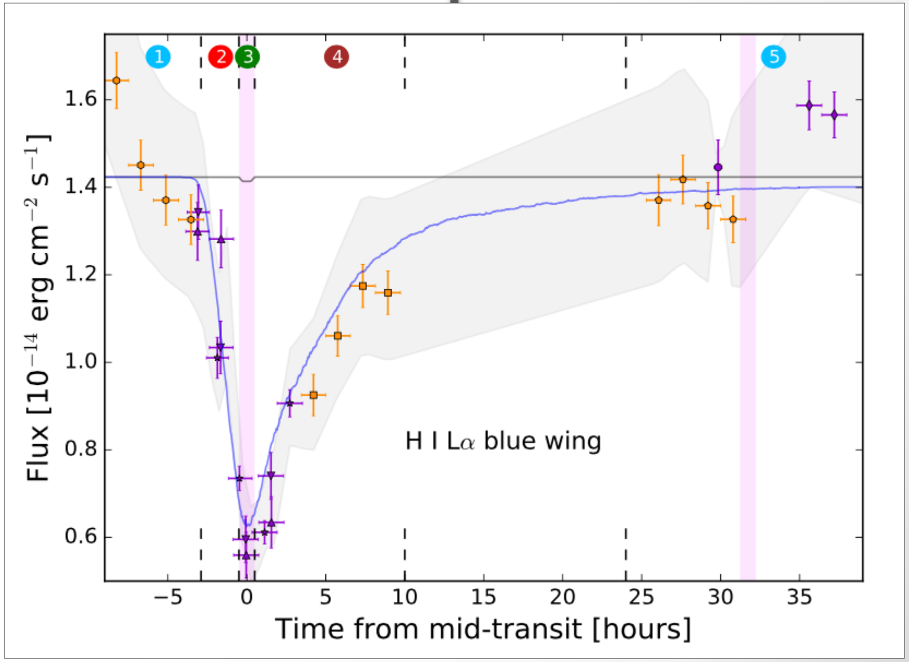
The EVE code : 3D simulations of gas tails



Warm Neptune GJ436b

Bourrier+2015b
Bourrier+2016a



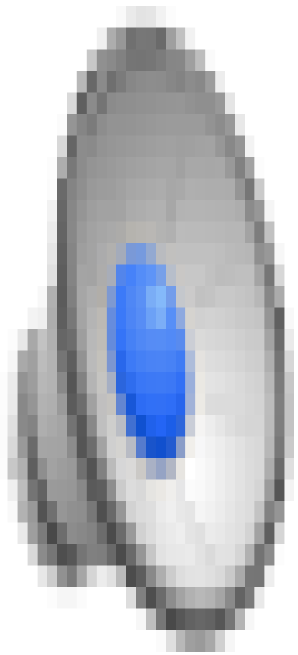


The EVaporating Exoplanets code

Bourrier & Lecavelier 2013
Bourrier+ 2014 a
Bourrier+ 2015 b

Kulow+2014, Ehrenreich+2015, Lavie+2017

The EVE^2 code : 3D simulations of dust & gas tails



Dust grains:

Pyroxene 0.5 µm

Pyroxene 0.05 µm

Conclusions

- We can learn a lot from the study of USPs
- This can be done by probing their dust envelopes with high-precision photometry
- Interest for a dedicated science program with PLATO & chromatic follow-up
  + development of a general dust & gas tail 3D model