

# SPECULOOS

On the Hunt for Habitable Planets well-suited for Atmospheric Characterization



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The SPECULOOS consortium

Bamberg – 12 Mar 2019

# SPECULOOS

Search for habitable Planets  
EClipsing ULtra-cOOl Stars



## What are « ultra-cool stars »?

**Ultracool dwarfs:**  $T_{\text{eff}} < 2700\text{K}$ ,

(Kirckpatrick et al. 1995).

Mix of **stars** + brown dwarfs



### Ultracool (dwarf) stars

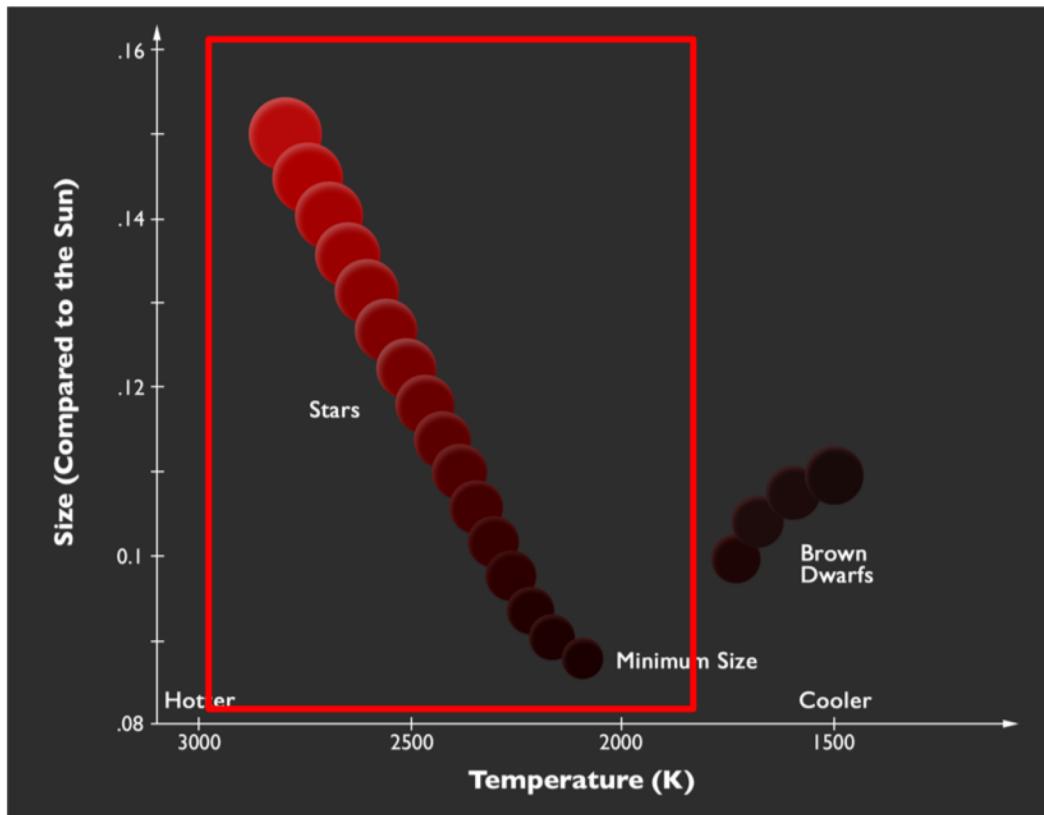
$T_{\text{eff}}$ : 2000 to 2700 K

**Mass:** 0.075 to  $0.1 M_{\odot}$

**Size:** 0.08 to  $0.15 R_{\odot}$

**Luminosity:** 0.01 to 0.1%  $L_{\odot}$

**Main-sequence lifetime:** >1000 Gyrs



Dieterich et al. (2014)

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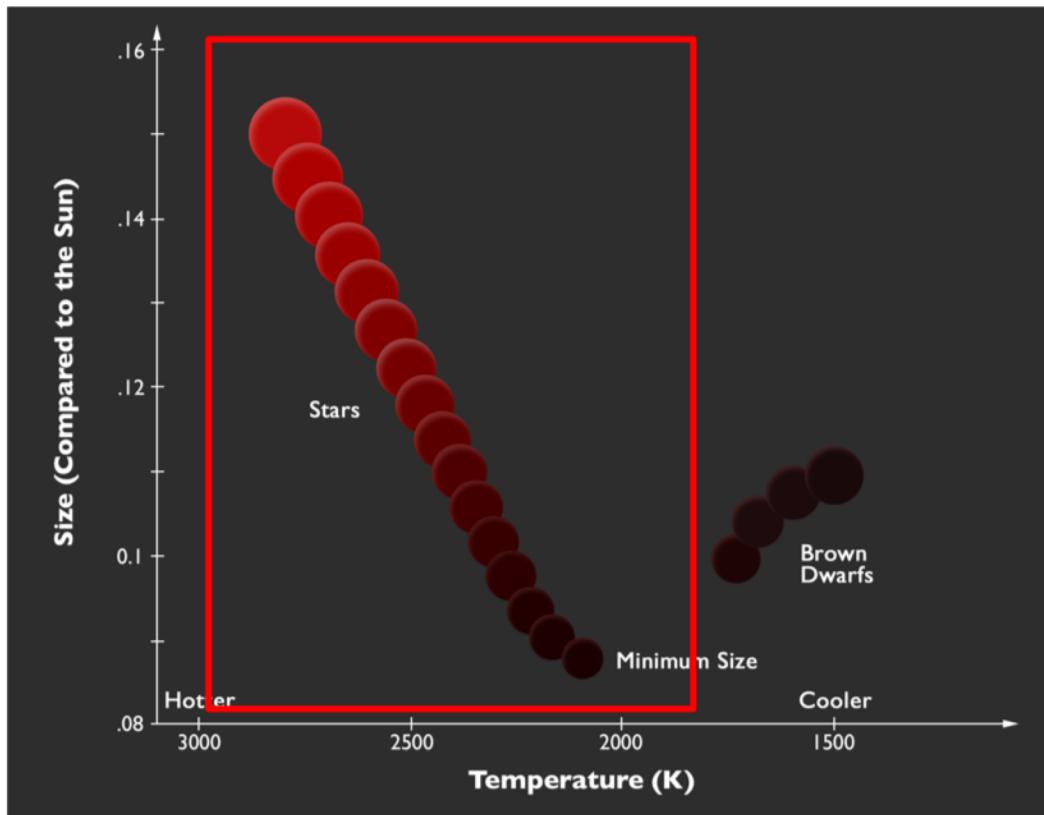
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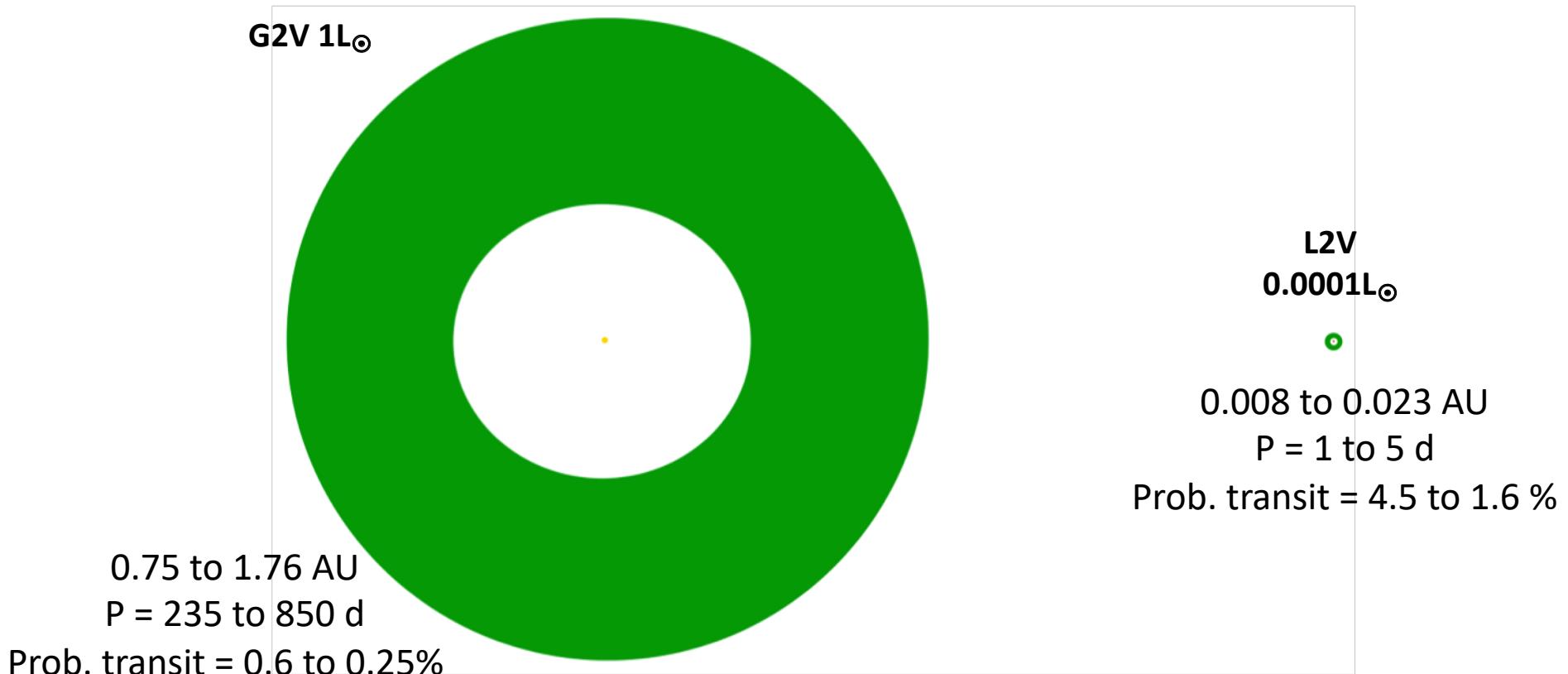
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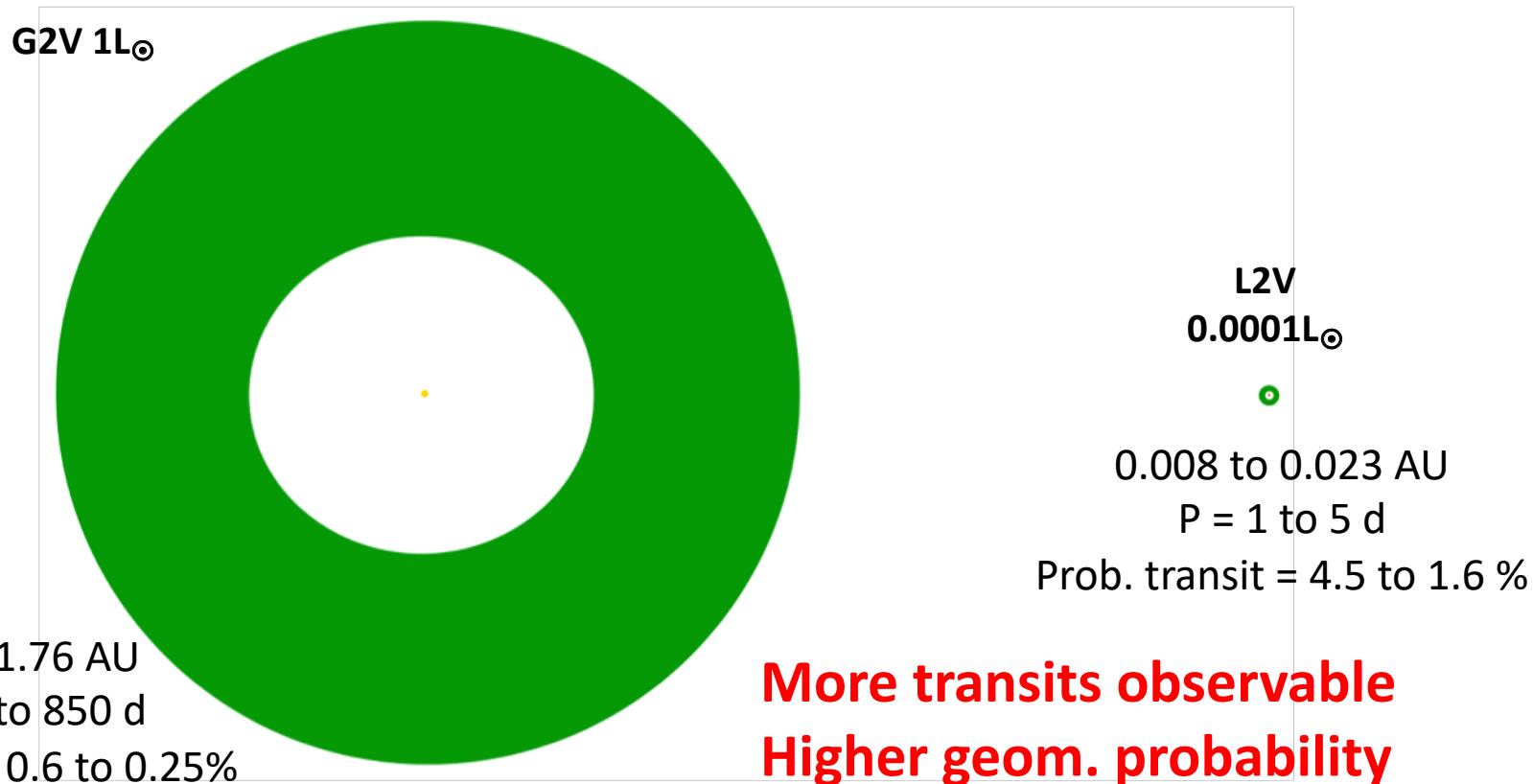
**Transit depth > 1% for earth size planets**

Habitable zone is VERY close to the star



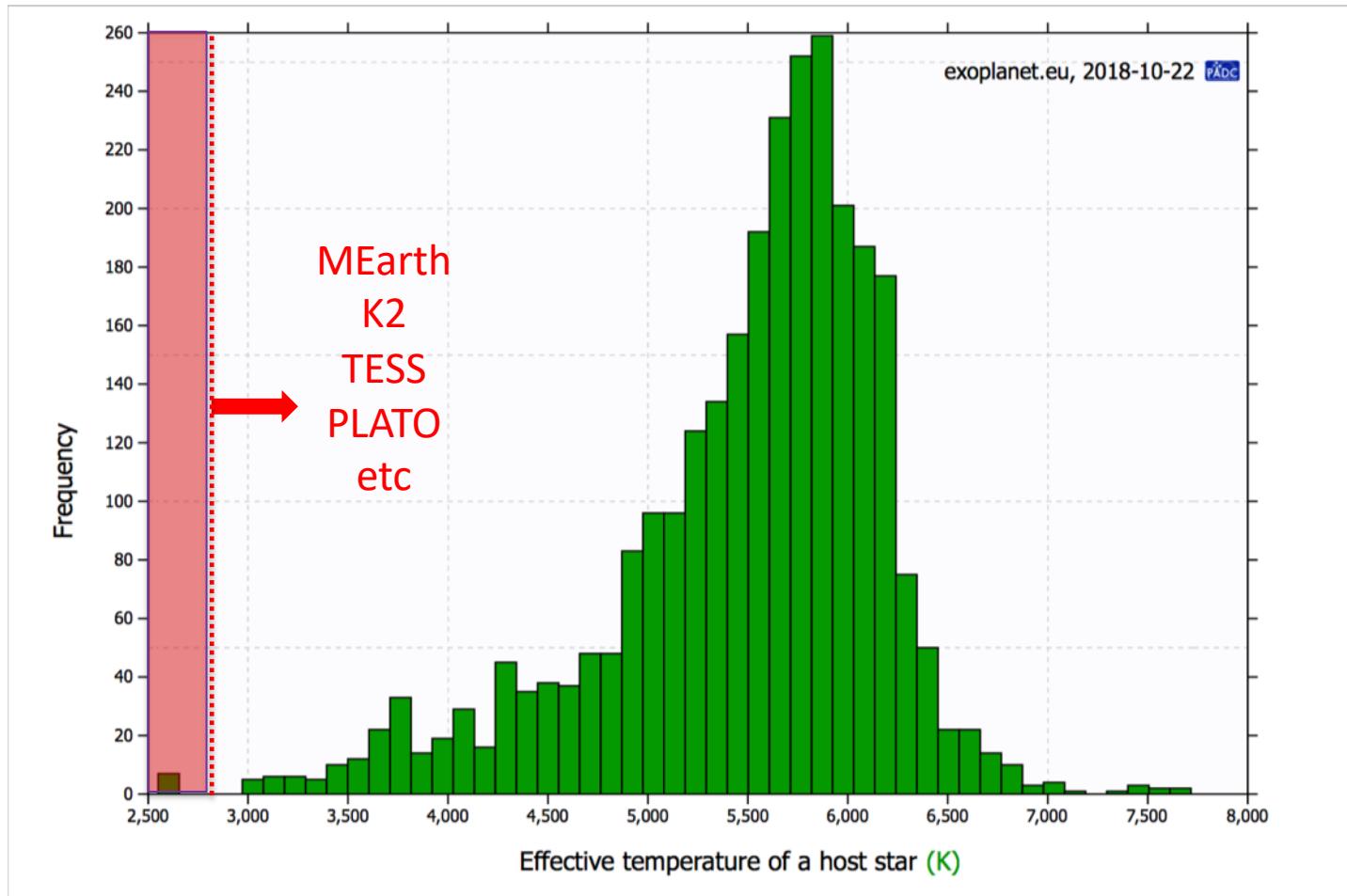
HZ limits from Kopparapu et al. (2013) – optimistic case

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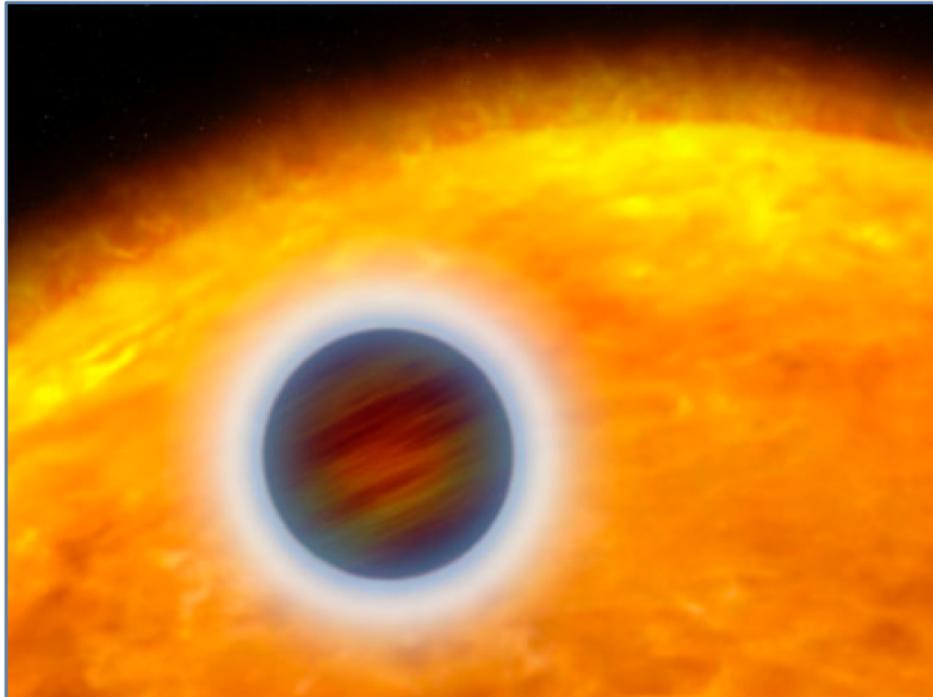


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## Territory uncharted by transit searches



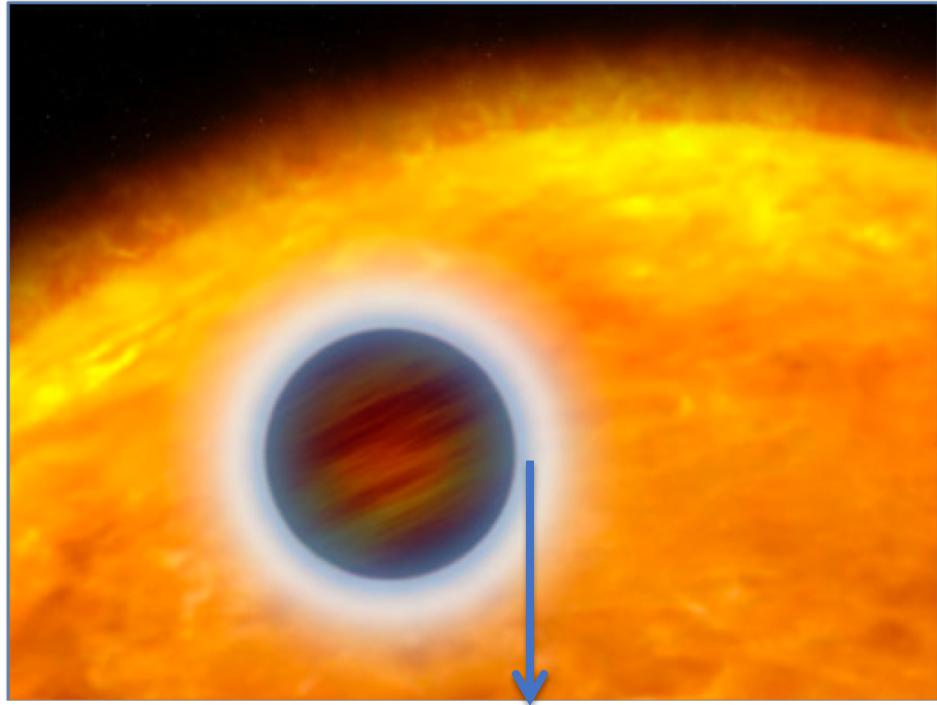
## Atmospheric study of Exoplanets?



**Transit  
transmission  
spectroscopy**

**expected Signal?**

## Atmospheric study of Exoplanets?



### Amplitude of the signal and SNR?

(e.g. Winn 2010)

$N_H$  = number of scale heights

$g_p$  = planet surface gravity

$R_p$  = planet radius

$\mu_p$  = atmo. mean molecular mass (amu)  
= 29 for Earth-like composition,

$T_p$  = planet equilibrium temperature

$R_*$  = star radius

$k_b$  = Boltzmann constant

C = constant

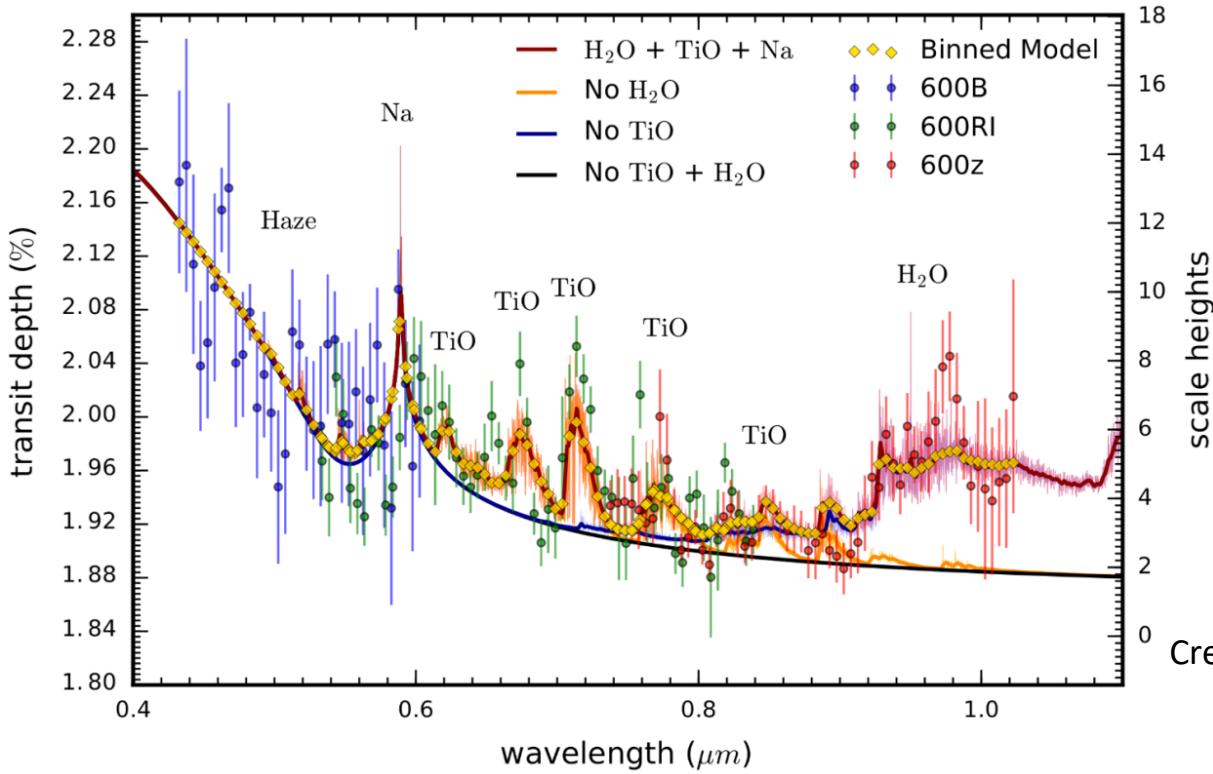
$W_{tr}$  = transit duration

$N_{tr}$  = number of transits

$$\Delta\delta = \frac{2N_H H_p R_p}{R_*^2}, \text{ where } H_p = \frac{k_b T_p}{\mu_p g_p}$$

$$SNR = C \times \Delta\delta \times \sqrt{10^{-K_*/2.5}} \times \sqrt{W_{tr} N_{tr}}$$

## Atmospheric study of Exoplanets?

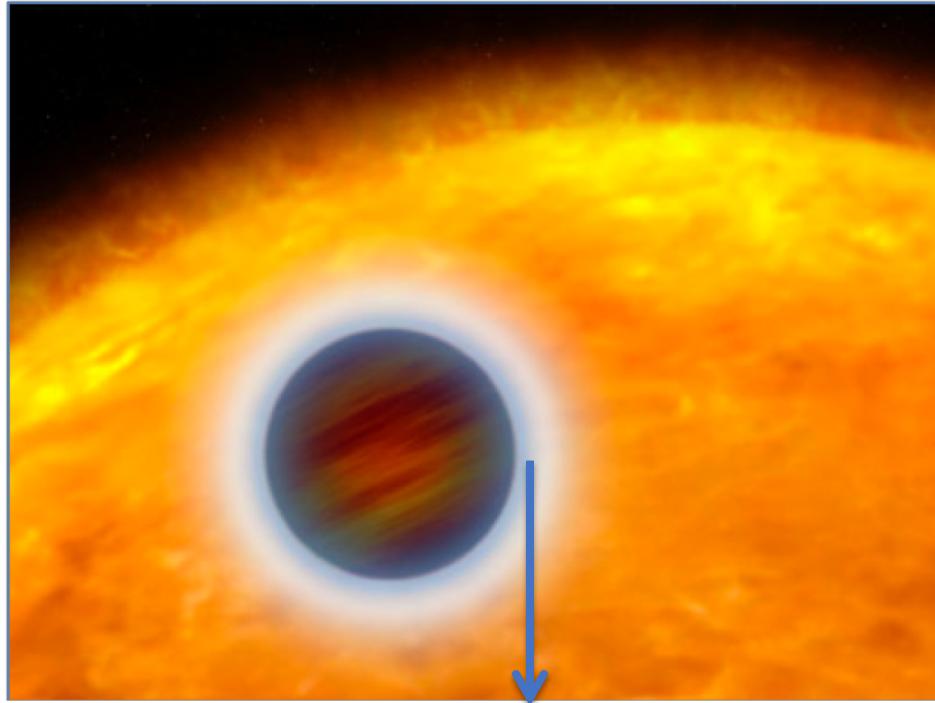


Extreme  
Hot Jupiter

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## Infrared transit transmission spectroscopy



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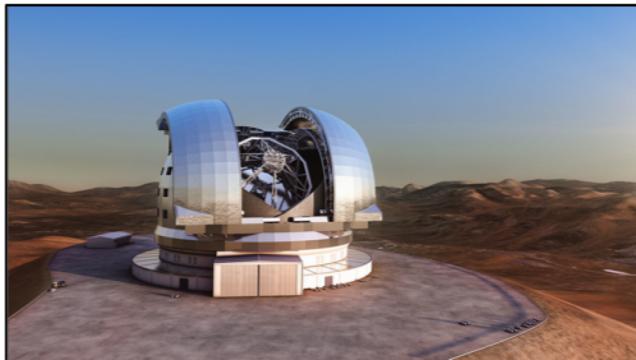
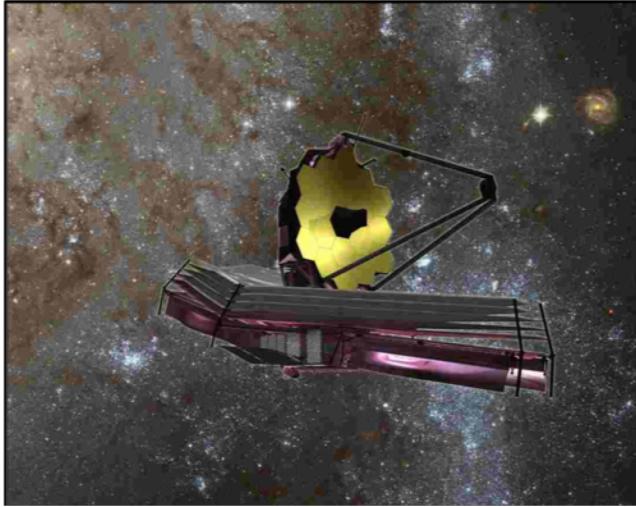
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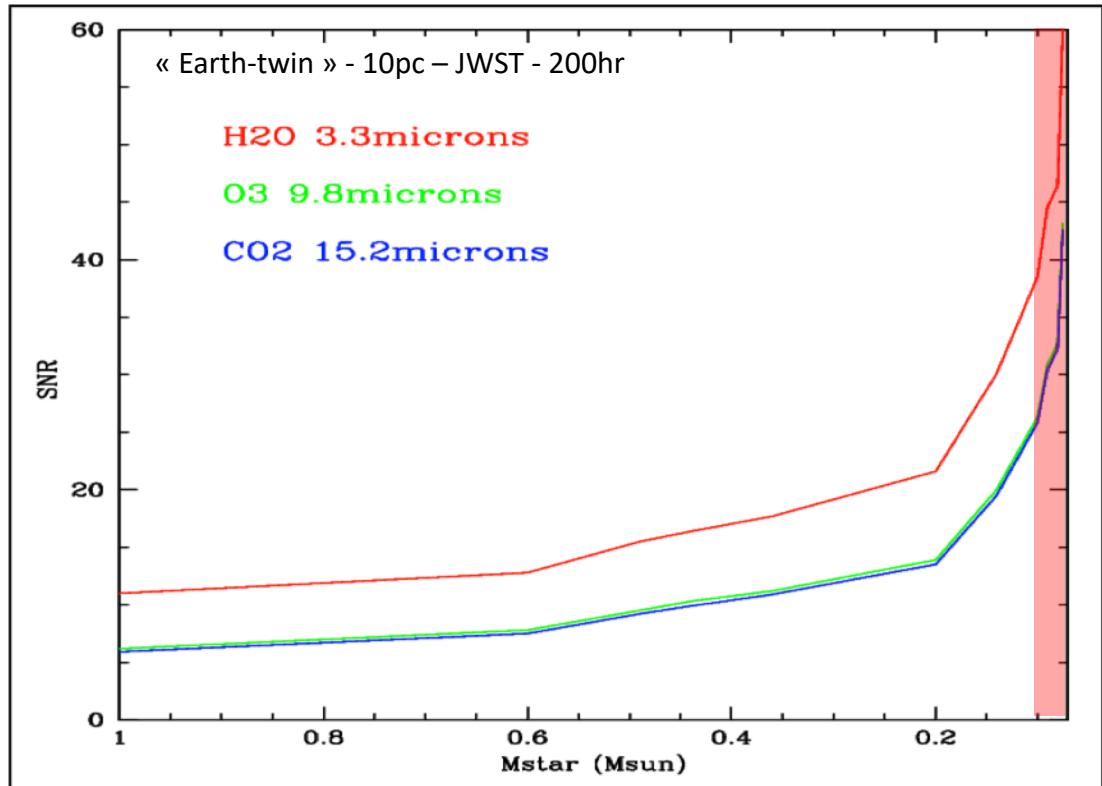
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## Atmospheric characterization of temperate Earth-sized planets

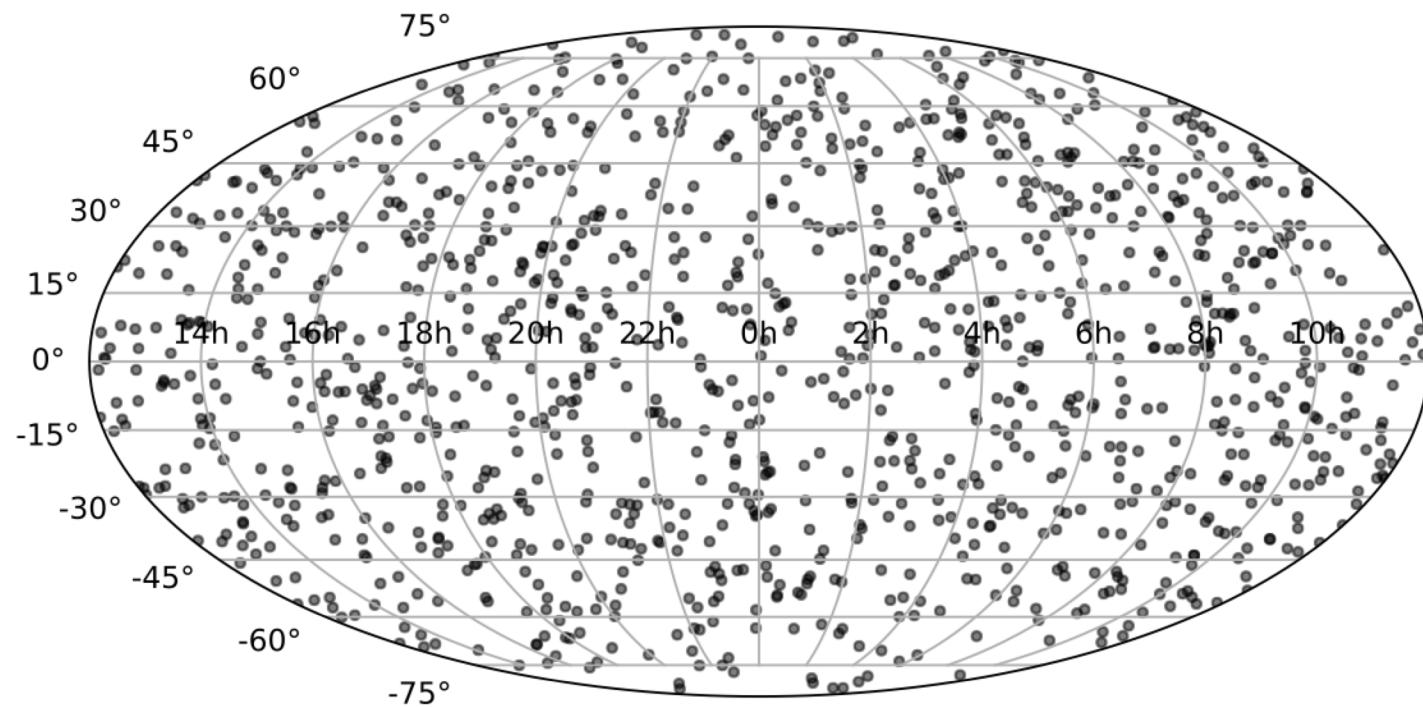


SNR of biomarkers:



From Kaltenegger & Traub (2009)

**Best targets: ~1000 ultra-cool stars with Kmag < 12.5**

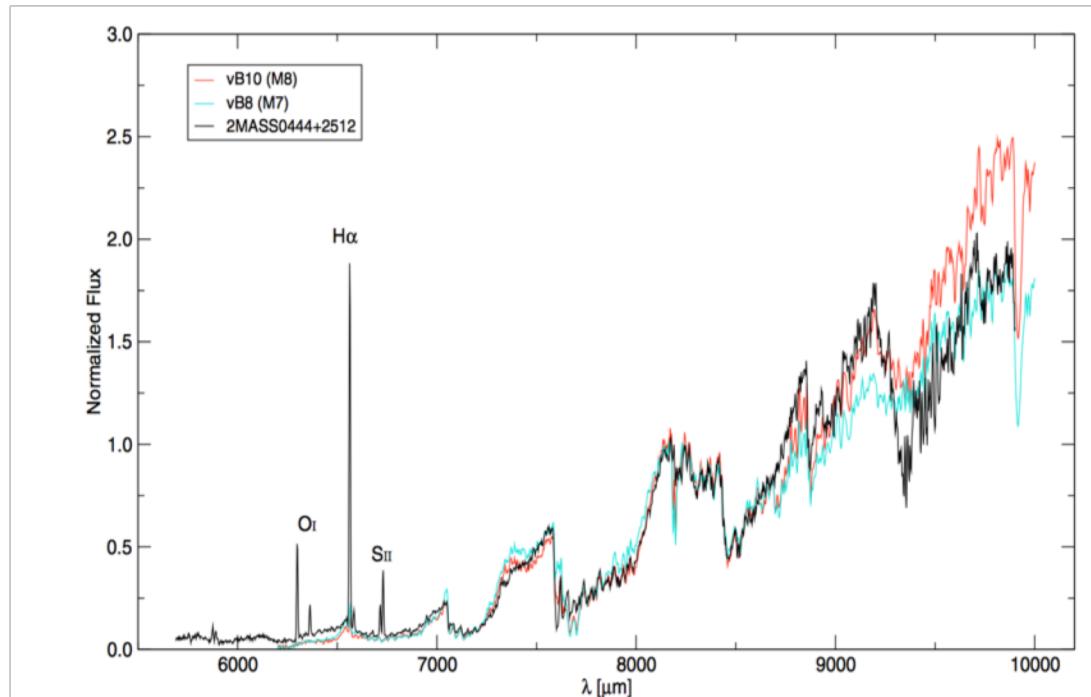
**SPECULOOS targets: spatial distribution (Aitoff projection)**

## SPECULOOS: basic concept

**Targets:** ~1000 ultra-cool dwarfs  
(Kmag < 12.5, 100 L-type brown dwarfs)

**Short transits:** down to 10 min

**Targets' emission peaks around 1.1  $\mu\text{m}$**



Bouy et al. (2008)

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Targeted survey  
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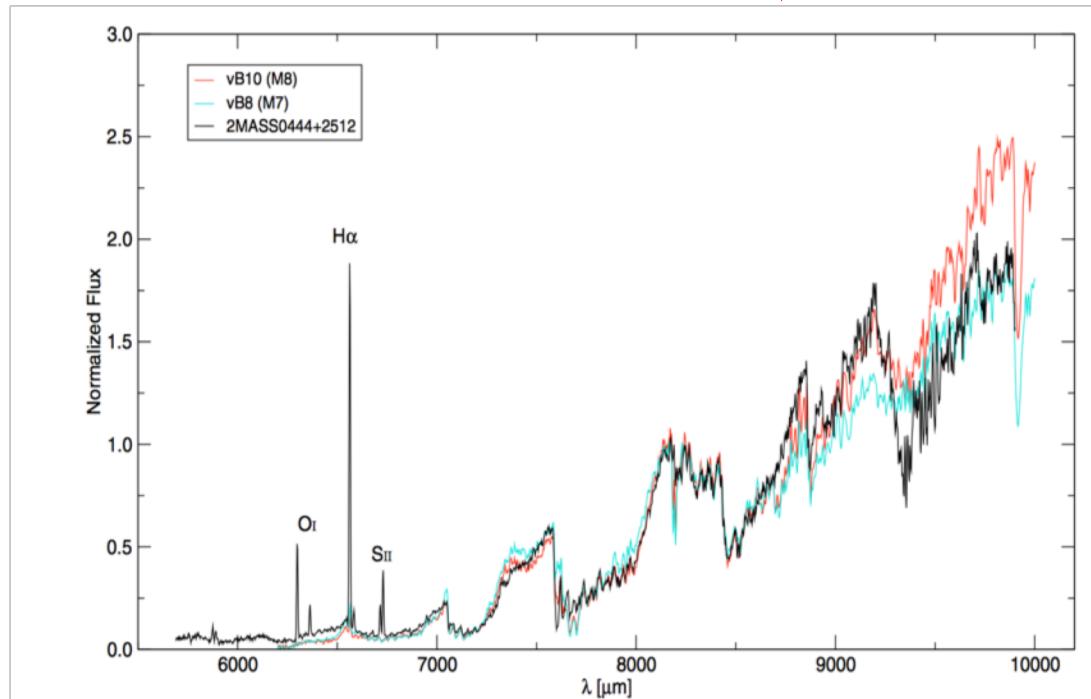


Continuous monitoring

**Targets' emission peaks around 1.1  $\mu$ m**



Near-IR optimized detectors



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Near-IR optimized detectors

**Excellent sites:** good transparency & seeing,  
low humidity



South: Chile  
North:  
Canary Islands/Mexico/Morocco

**Efficient exploration of the habitable zone**



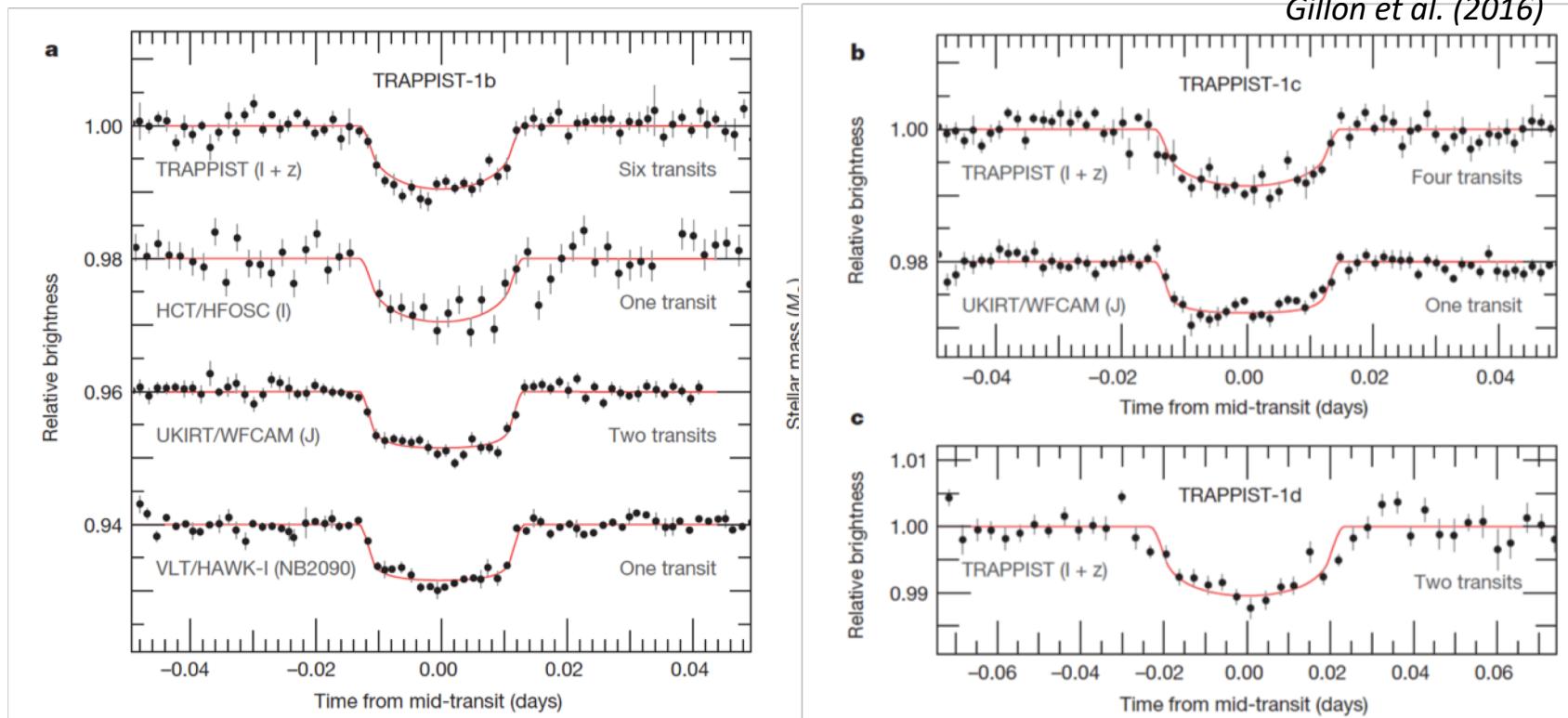
1 longitude is OK  
Monitoring duration optimized  
to each target

### Prototype Survey

- Since 2011, prototype survey with TRAPPIST 60cm robotic telescope at ESO La Silla
- Targets: 50 brightest southern ultra-cool dwarfs + 30 M6-type stars (e.g. Proxima)

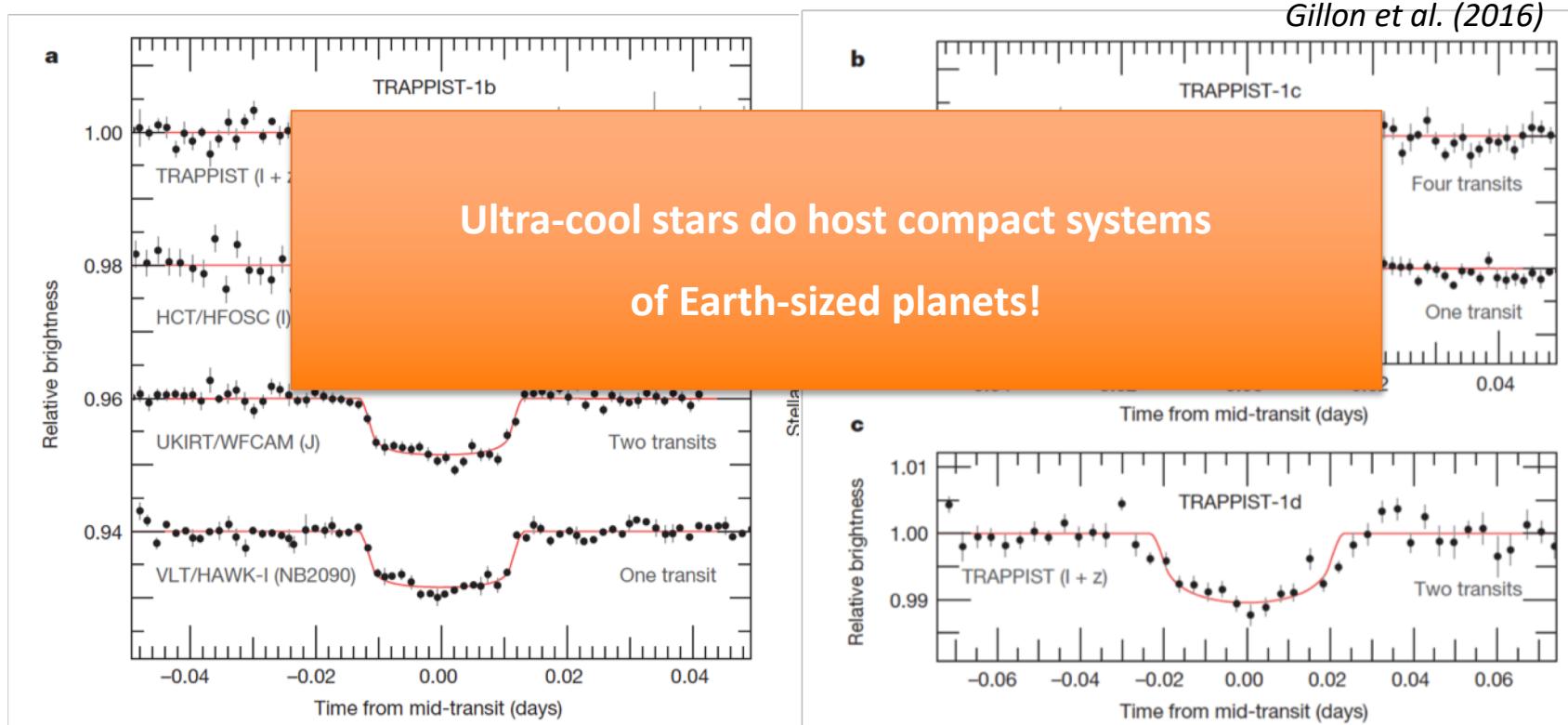
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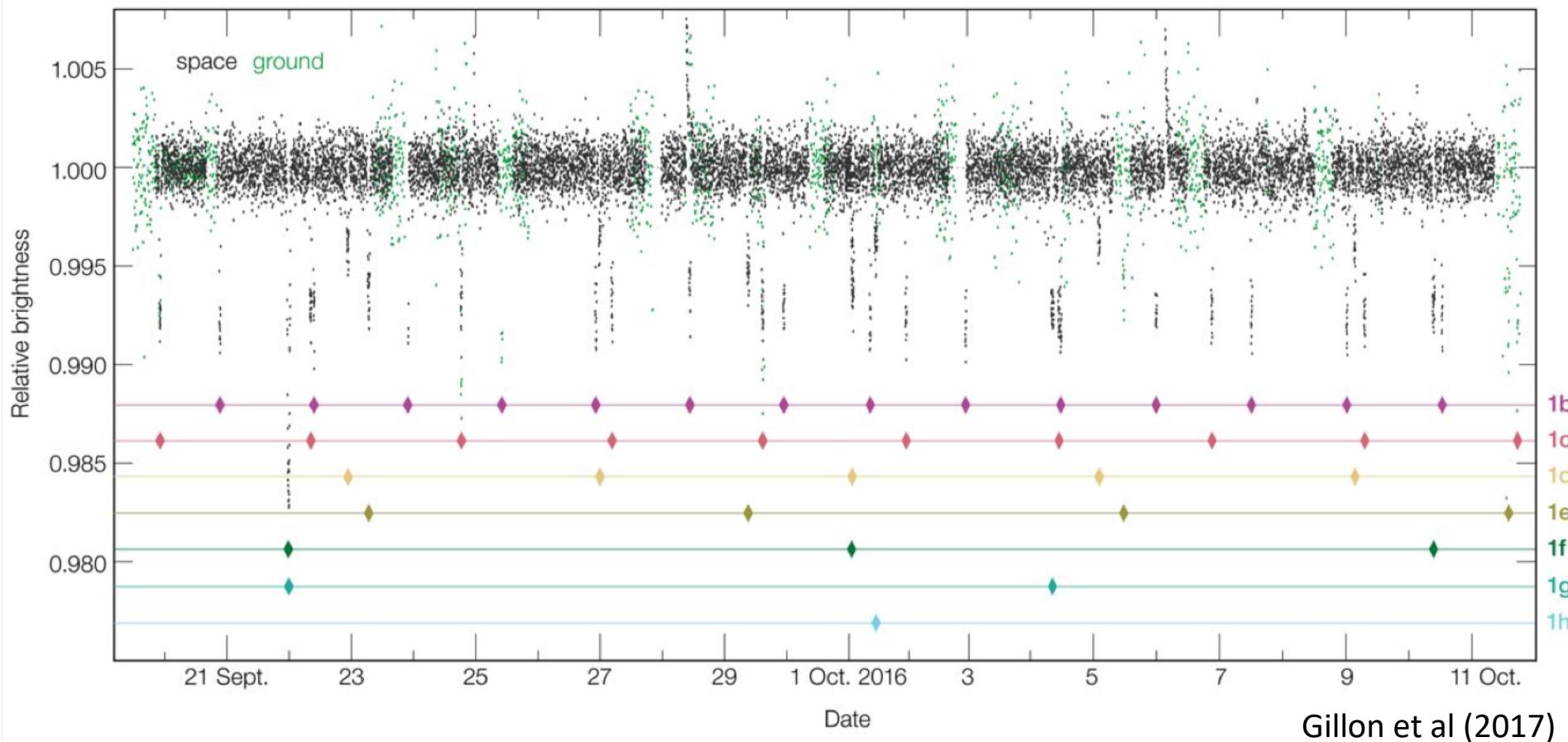
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Trappist 1 – Spitzer observations

20 days of observations - 34 transits – 7 planets!