TRAPPIST-UCSTS

A prototype search for terrestrial planets transiting the nearest ultra-cool stars

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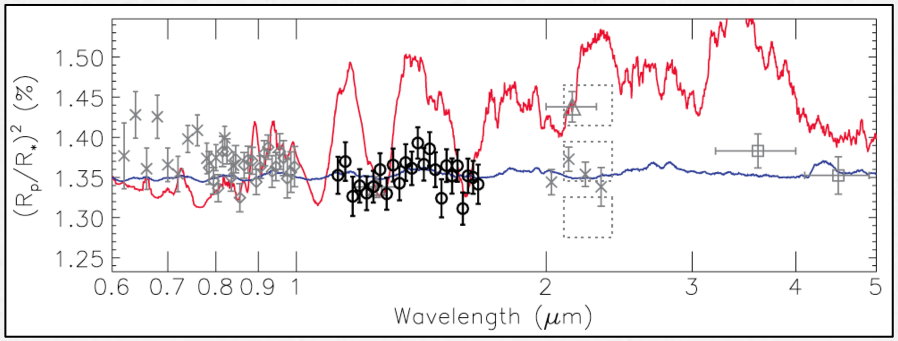
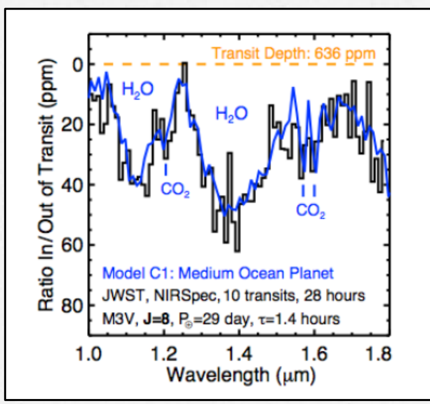
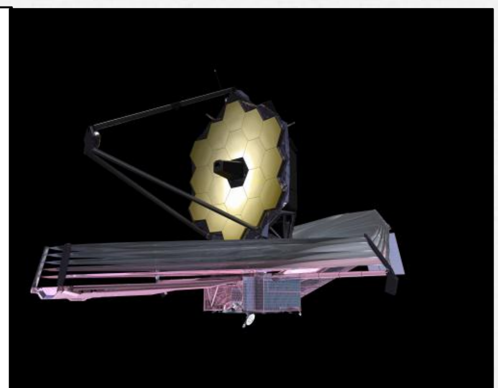
Atmospheric studies of transiting planets: now & tomorrow



Now: Spitzer, HST, VLT, …
Transmission spectrophotometry for GJ1214b, a gas-rich super-Earth transiting a nearby M4.5 dwarf





Tomorrow: JWST, E-ELT, EChO, FINESSE, …
Higher precision & resolution

Credits: Berta et al. (2012); Seager et al. (2009)

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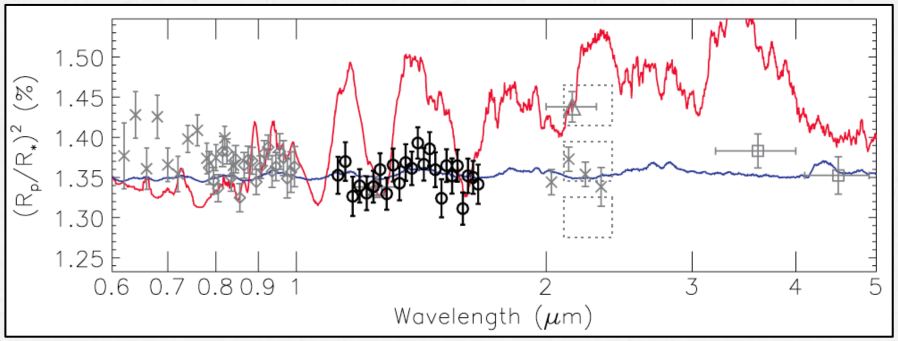

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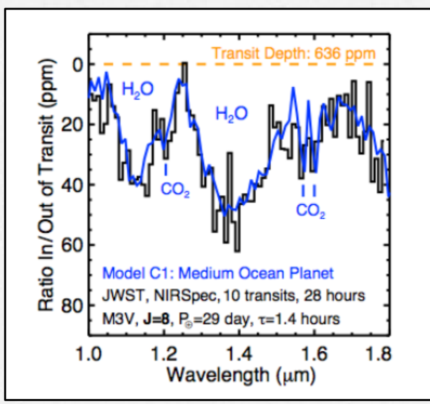

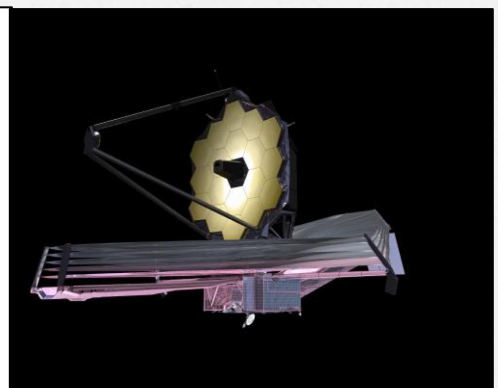

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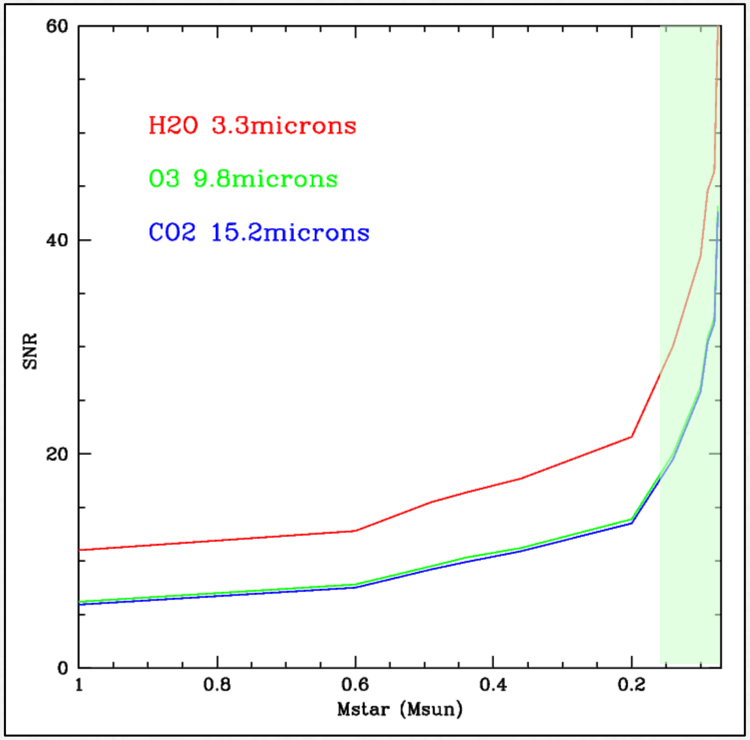
Will it be possible to study the atmosphere of actual terrestrial planets with JWST? And to search for biosignatures?

Credits: Berta et al. (2012); Seager et al. (2009)

JWST and biosignatures

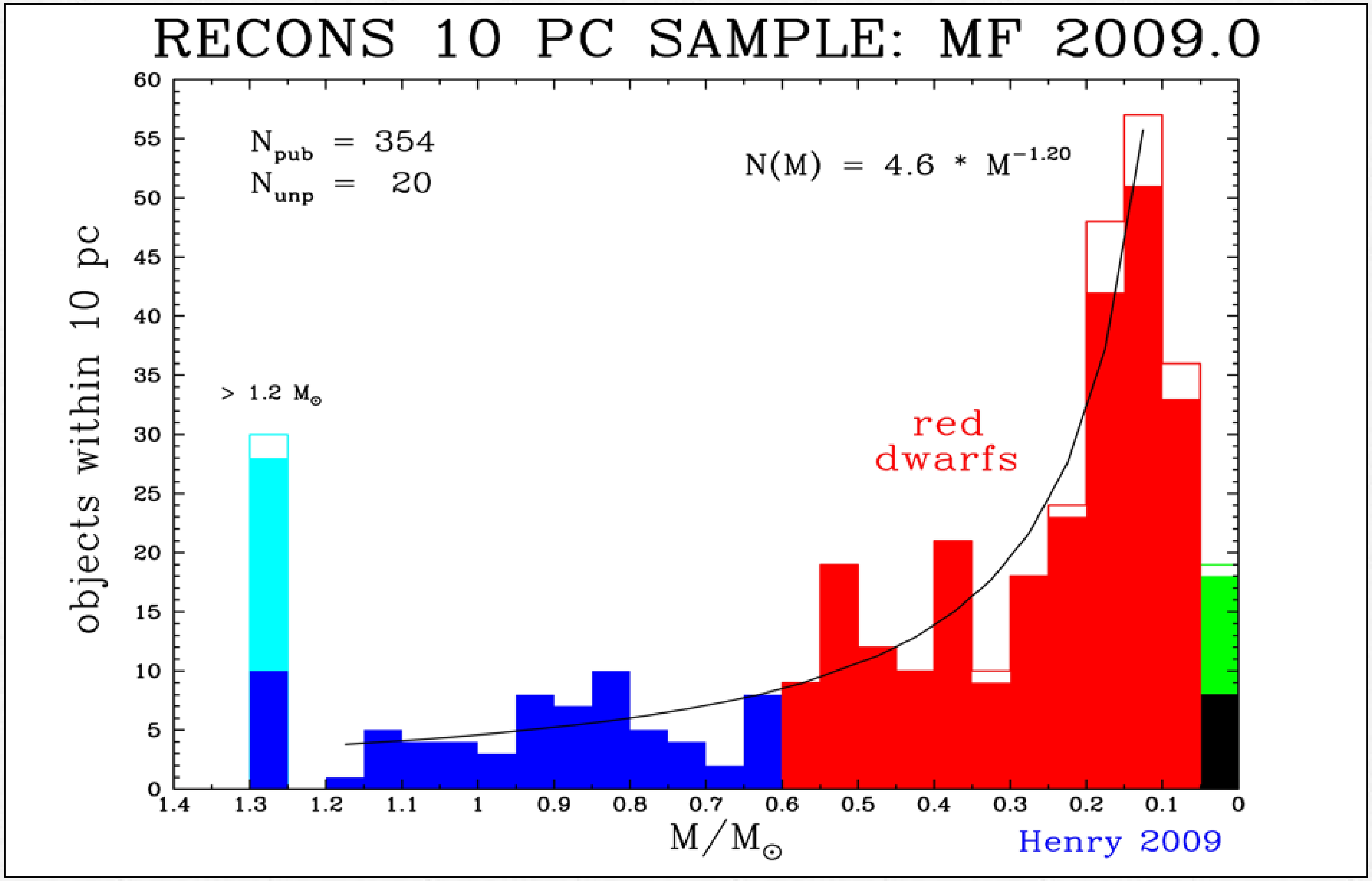
Inhabited Earth-twin - 10pc – JWST - 200hr



An opportunity with late M-dwarfs?

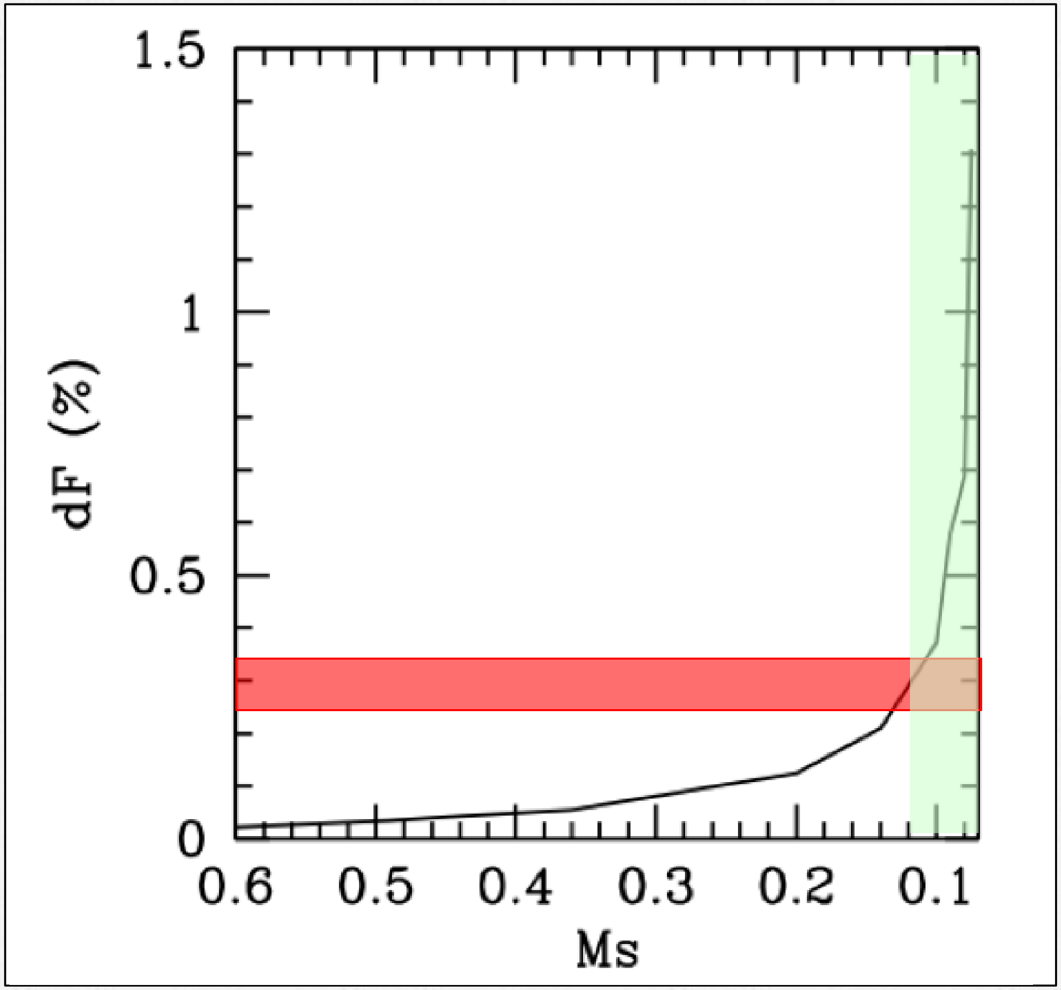
Credits: Kaltenegger & Traub (2009)

The solar neighborhood



Credits: recons.org

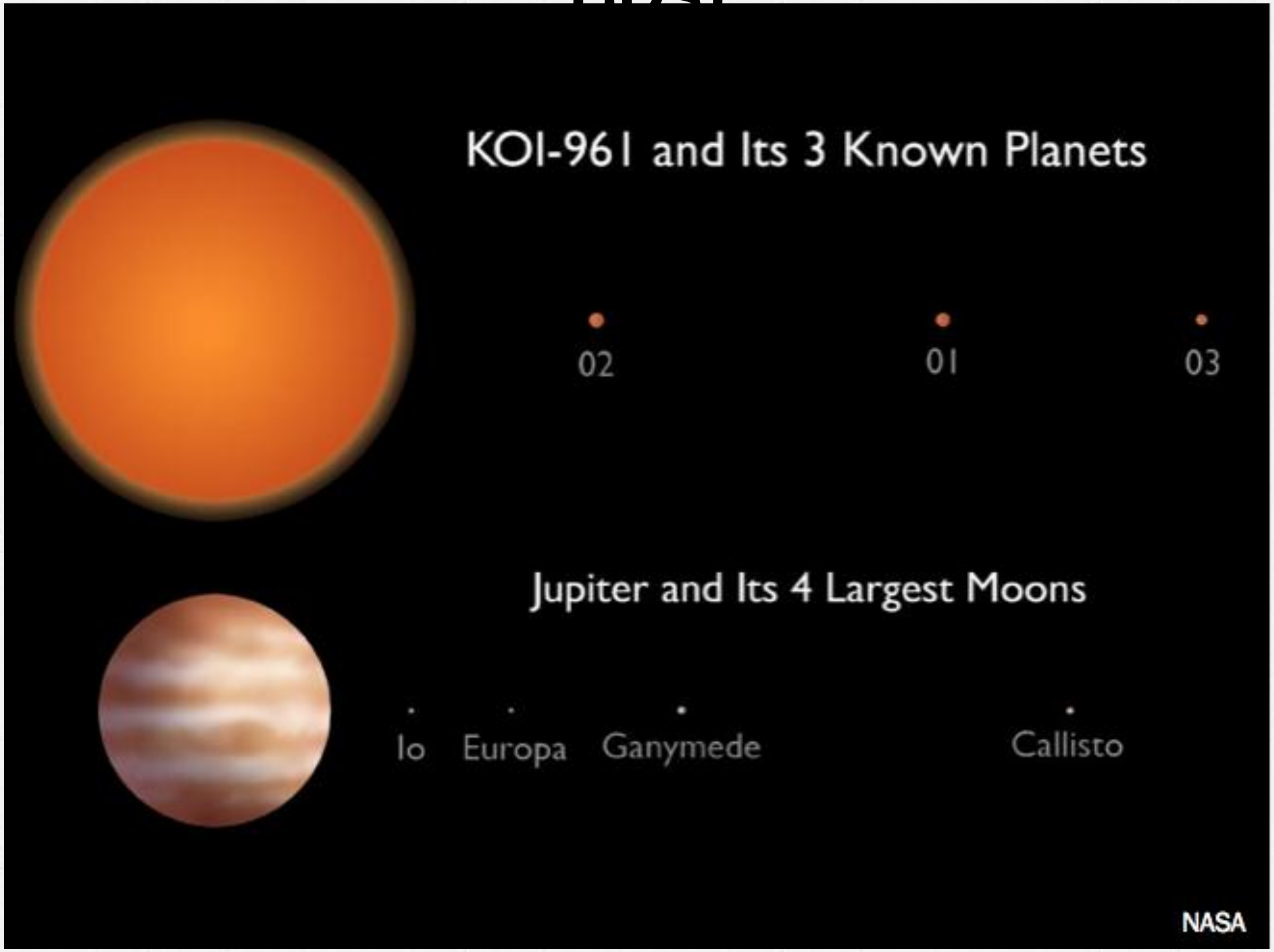
Earth-size planets from the ground?



Ultra-Cool Stars (UCS)

- Spectral type later than M5 (**$T_{eff} \leq 2700K$**).
- **Masses up to ~0.12 $M_{\odot}$**
- A few thousands known UCSs from wide-field surveys
- Many UCSs are **rapid rotator AND show little to no activity** (e.g. Tinney et al. 1998), suggesting a loss of efficiency in turbulent dynamo. Still, a significant fraction of M6-M7 are active flare stars (e.g. Proxima Centauri).
- For the coolest UCS, dust formation could lead to complex atmospheric dynamics (clouds) ➔ **photometric variability**

Between KOI-961 and Jupiter are UCS (and BDs)



UCS and planets

- **The fraction of young UCS with a disk is large** (Luhman et al. 2005, 2008). Their disks can have masses up to 12% of the UCS (Sholz et al. 2006).

- Models predict **the efficient formation of terrestrial planets** around UCS, and the inhibition of giant planets formation (Payne & Lodato 2007). Some models predict rocky Mars-size planets (Raymond et al. 2007), others predict larger ice-rich planets (Montgomery & Laughlin 2009).

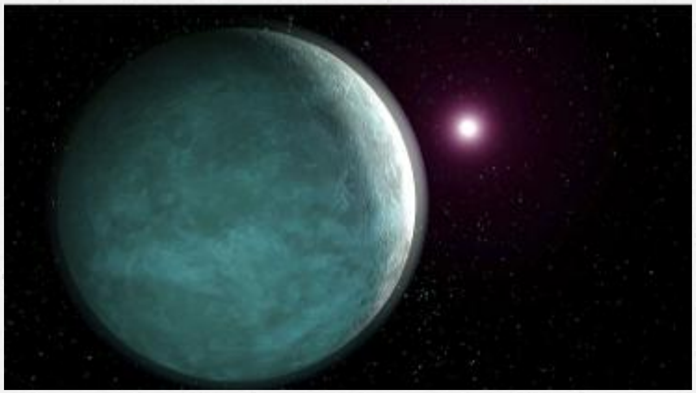
- Extrapolating to UCS the exoplanet results for early to mid M-dwarfs (e.g. Bonfils et al. 2011) that hint towards an efficient type I migration leads to **a large population of volatil-rich terrestrial planets orbiting < 0.1 AU**.

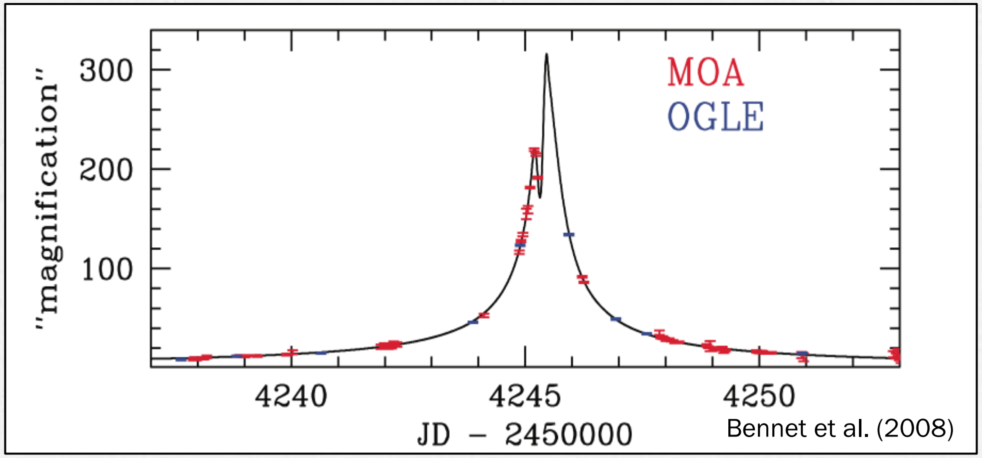
First planet detected around an UCS?

MOA-2007-BLG-192Lb

Detected by microlensing in 2007 (Bennet et al. 2008)

A few Earth-masses planet orbiting at ~0.7 AU from a ~0.085 $M_{\odot}$ UCS





Bennet et al. (2008)

UCS indeed form terrestrial planets!

Any chance for habitable planets transiting UCS and amenable for atmospheric studies with JWST?

- Scaling the SNRs from Kaltenegger & Traub (2009) and imposing SNR=10 as lower limit on the spectroscopic signatures leads to:

M6: J=12, d=26pc   M7: J=12.6, d=30pc   M8: J=13.3, d=34pc   M9: J=14.5, d=40pc

- From the UCS densities in the solar neighborhood (e.g. Reid et al. 2007), the derived number of potential targets for the whole sky is:

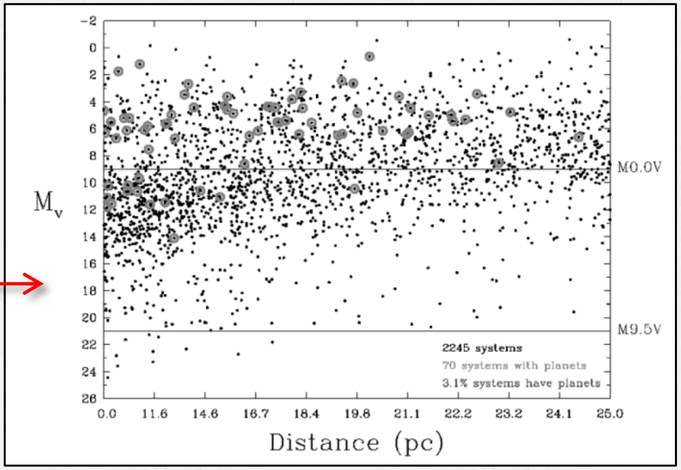
310 M6 + 270 M7 + 160 M8 + 260 M9 = 1000 UCS

- Mean transit probability close to HZ is 2.5%. Assuming one planet per UCS close to HZ leads to ~25 planets waiting to be caught in transit

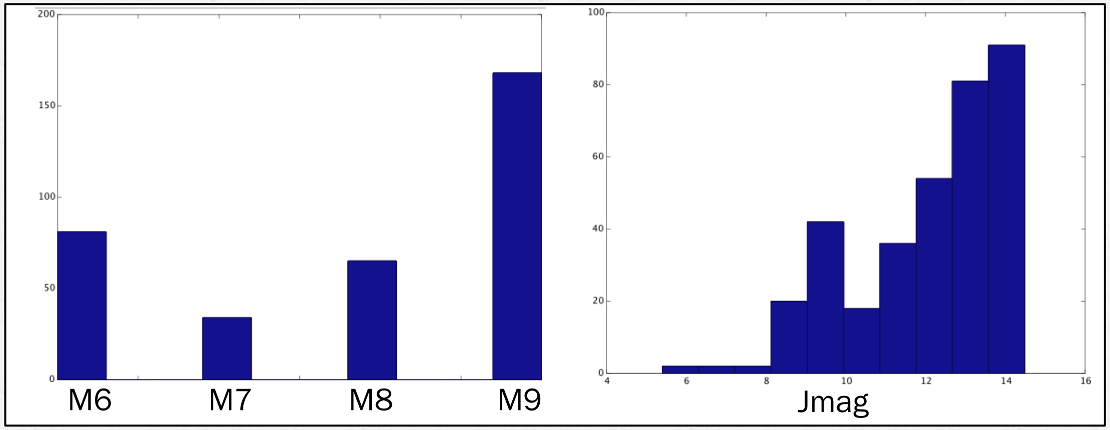
Are all the nearby UCS known?

No

e.g. the RECONS 25pc sample shows a clear paucity of M-dwarfs at « large » distance.



Catalogs search for the Southern sky: 350/500
Many from the BD-search programs



Credits:Hawleyet al. 1995; Henry et al. 2006;Faherty et al. 2009; Lépine & Gaidos 2011; Rojas-Ayala et al. (2012)

A dedicated nearby UCS transit survey using CCD detectors and modest-size telescopes?

<u>Test strategy</u>

- Using CCD detectors having the highest possible sensitivity in the red (back-illuminated, deep-depletion, fringe suppresion)
- Using all the near-IR part of the CCD QE curve ➔ I+z filter (idem MEarth).
- Observing from a very dry site to minimize the effects of water - OH absorption and emission bands shortward of 1 μm.

Phase 1. Prototype project for SNR + variability assesment

TRAPPIST

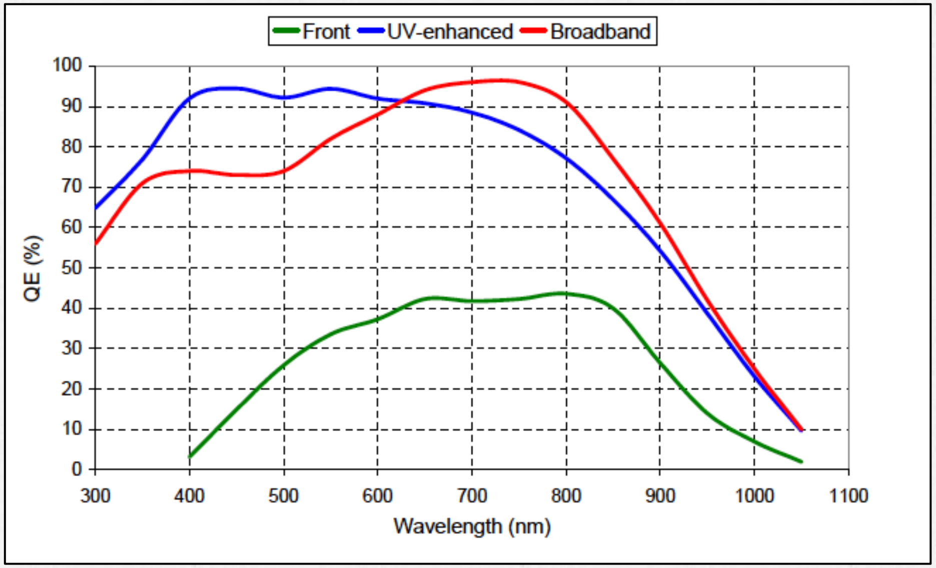
TRAnsiting **P**lanets and **P**lanetes**I**mals **S**mall **T**elescope

60cm robotic telescope

ESO La Silla Observatory, Chile

22’ x 22’ FOV

Back-illuminated Fairchild CCD optimised for the red



QE = 90% at 800nm
60% at 900nm
25% at 1000nm

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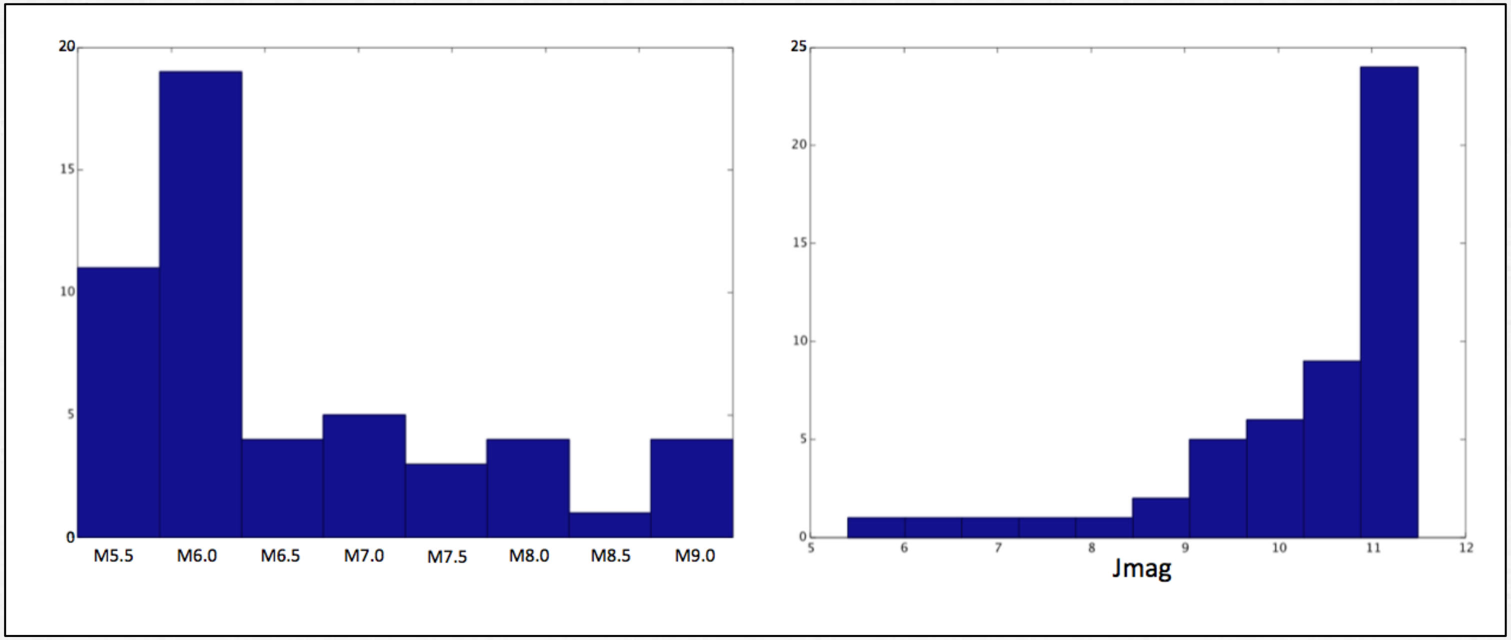
Monitoring of 50 UCSs brighter than J=11.5 visible from La Silla.

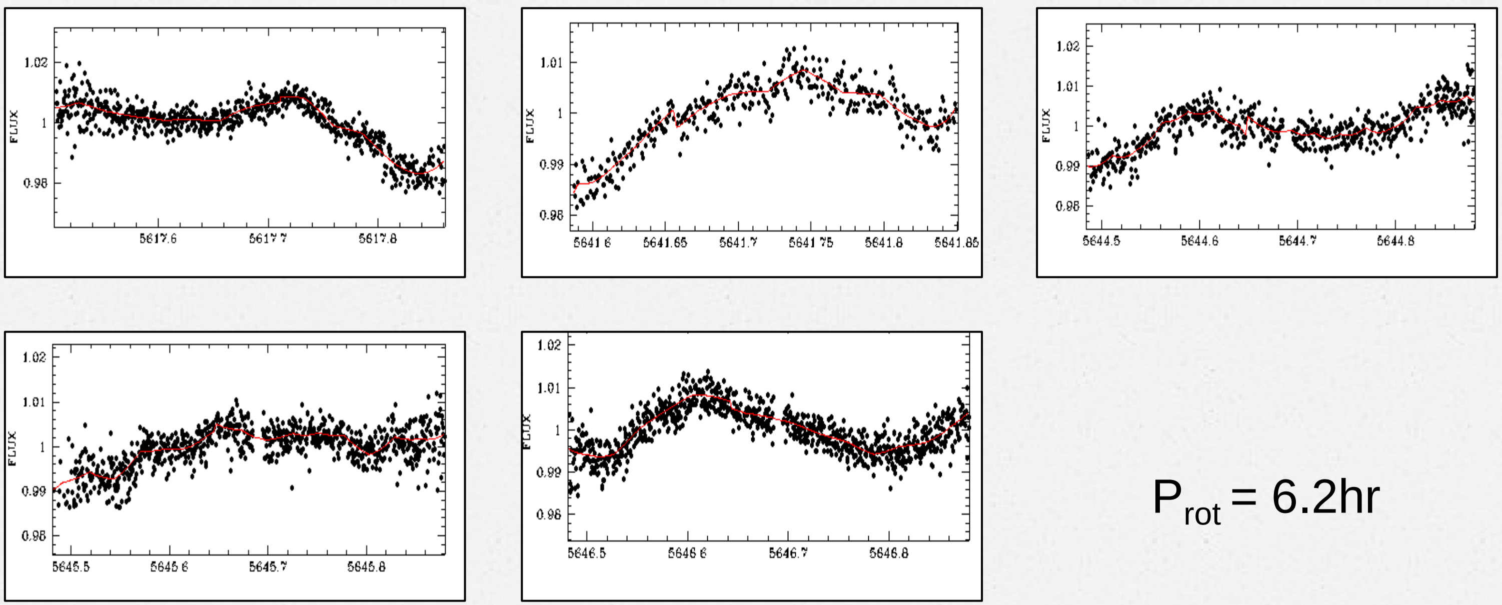
I+z filter. Several full nights.



TRAPPIST-UCSTS: a few results

M9V, J=9.5, 5 nights

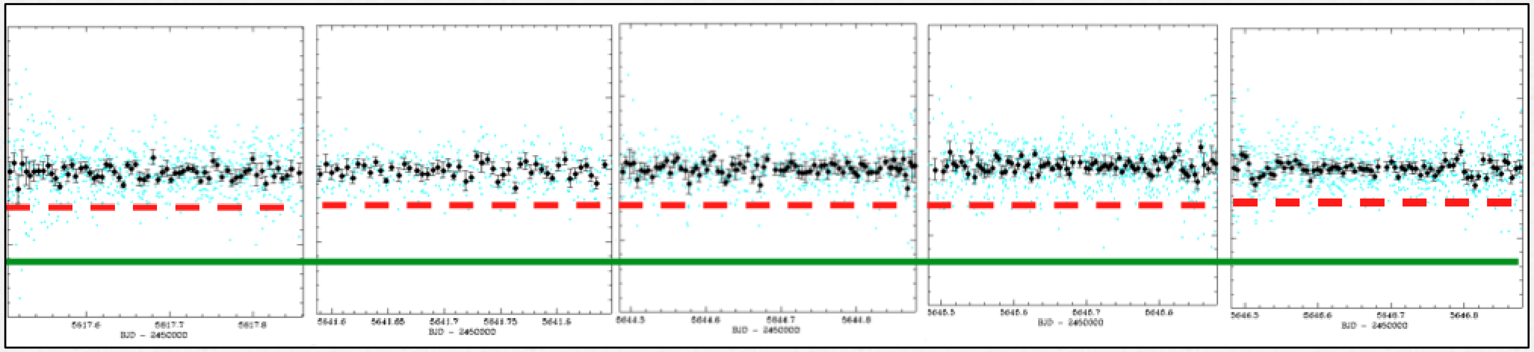
Model: rotating sliced sphere



P_{rot} = 6.2hr

TRAPPIST-UCSTS: a few results

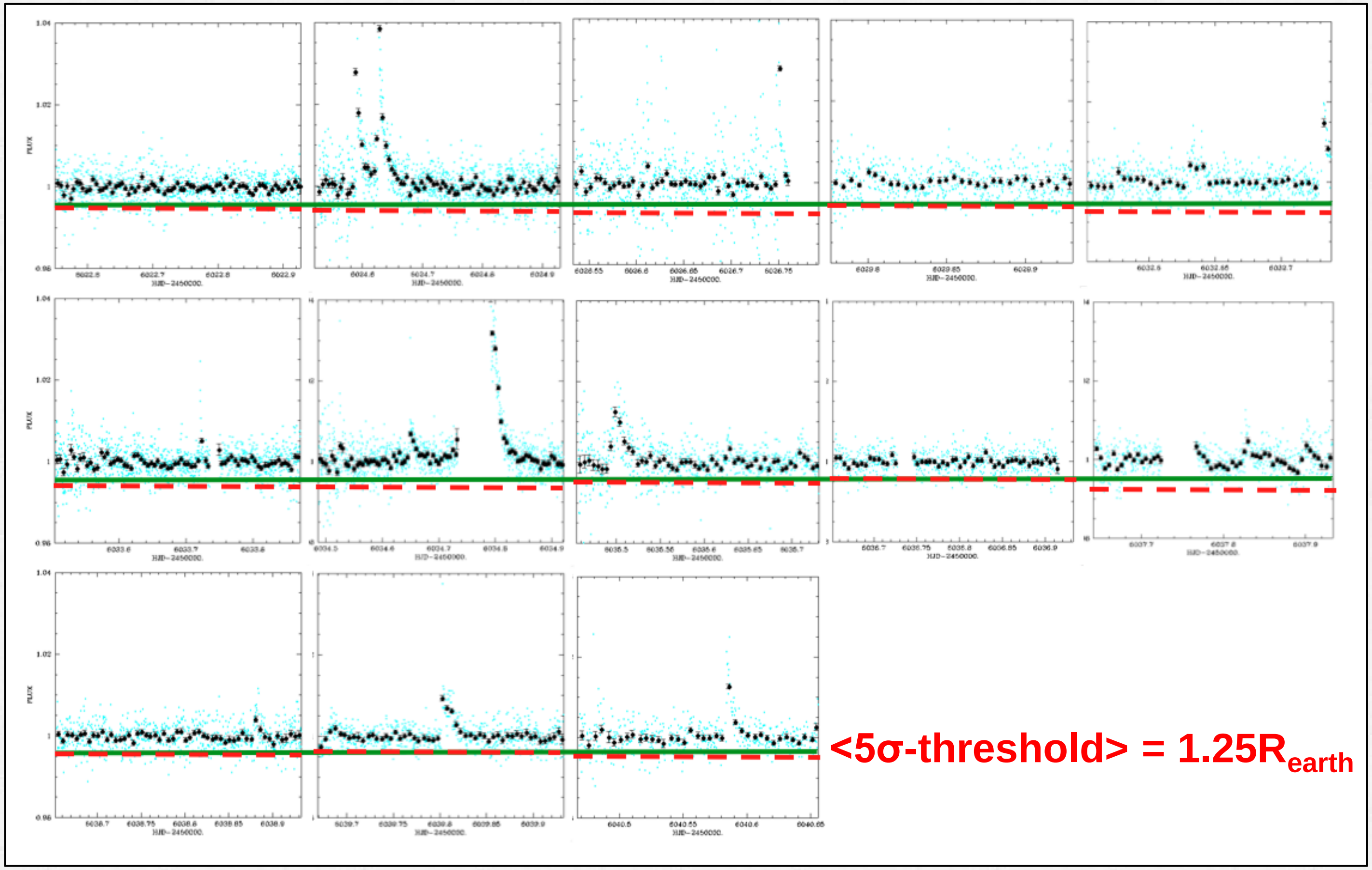
M9V, J=9.5, 5 nights



<5σ-threshold> = 0.6 R_{earth}

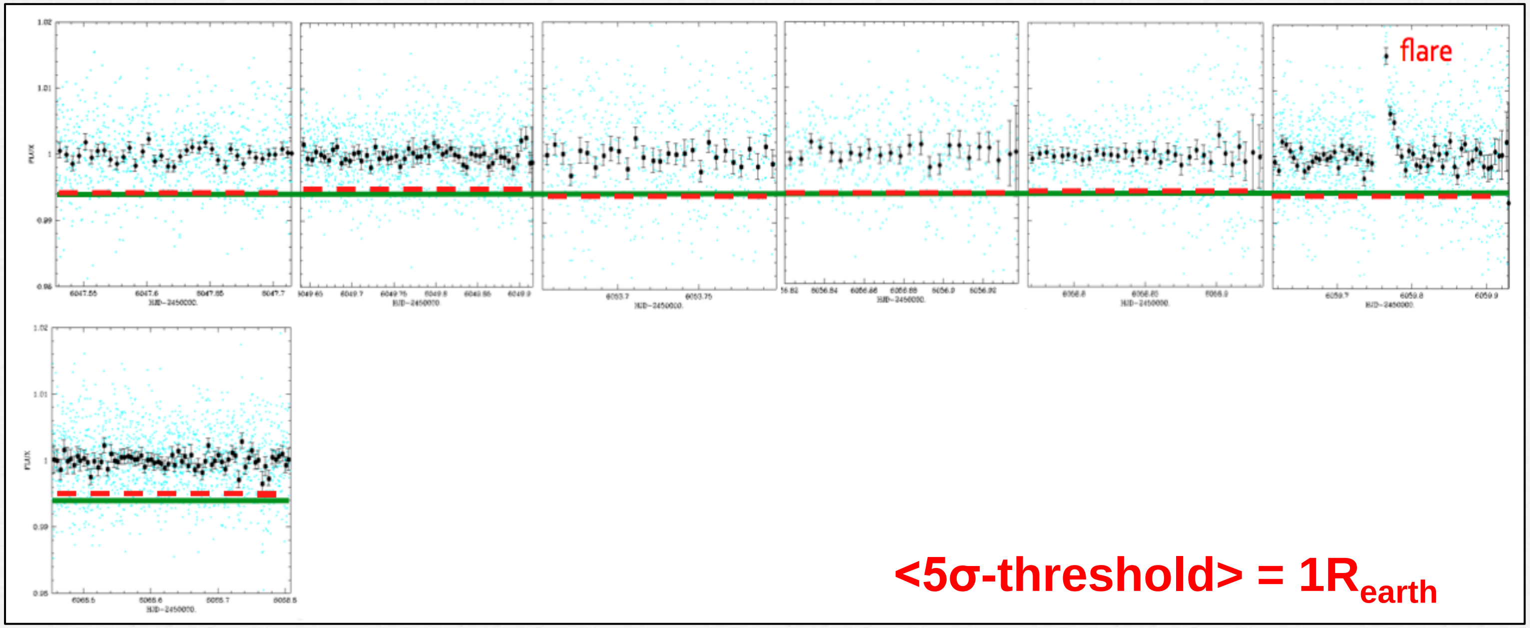
TRAPPIST-UCSTS: a few results

Proxima Centauri, M6V, J=5.4, 13 nights



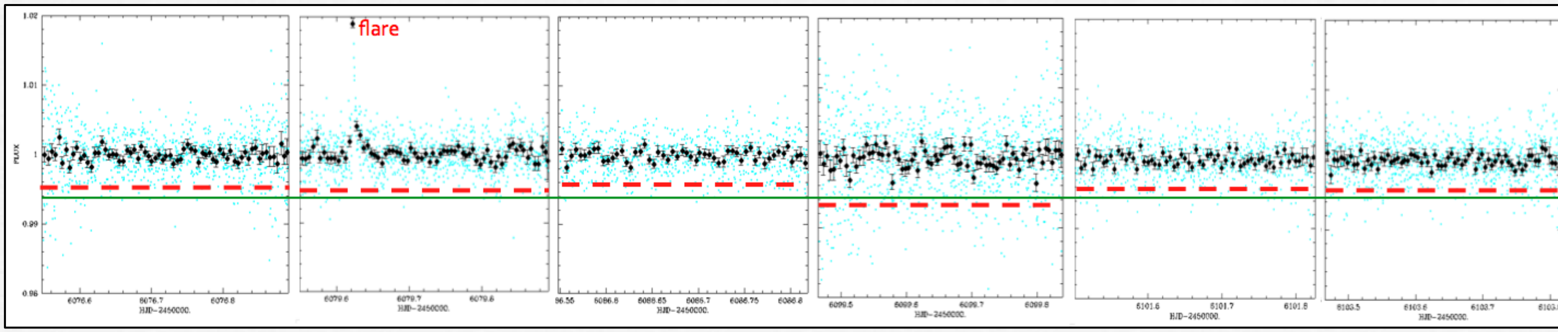
TRAPPIST-UCSTS: a few results

M7V, J=10.0, 7 nights



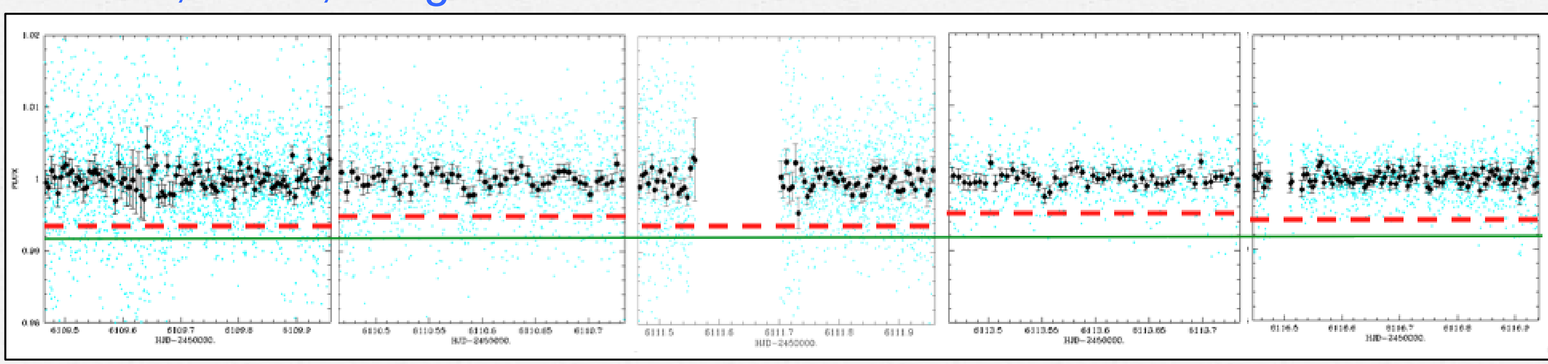
TRAPPIST-UCSTS: a few results

M7V, J=9.8, 6 nights



<5σ-threshold> = 0.9R_{earth}

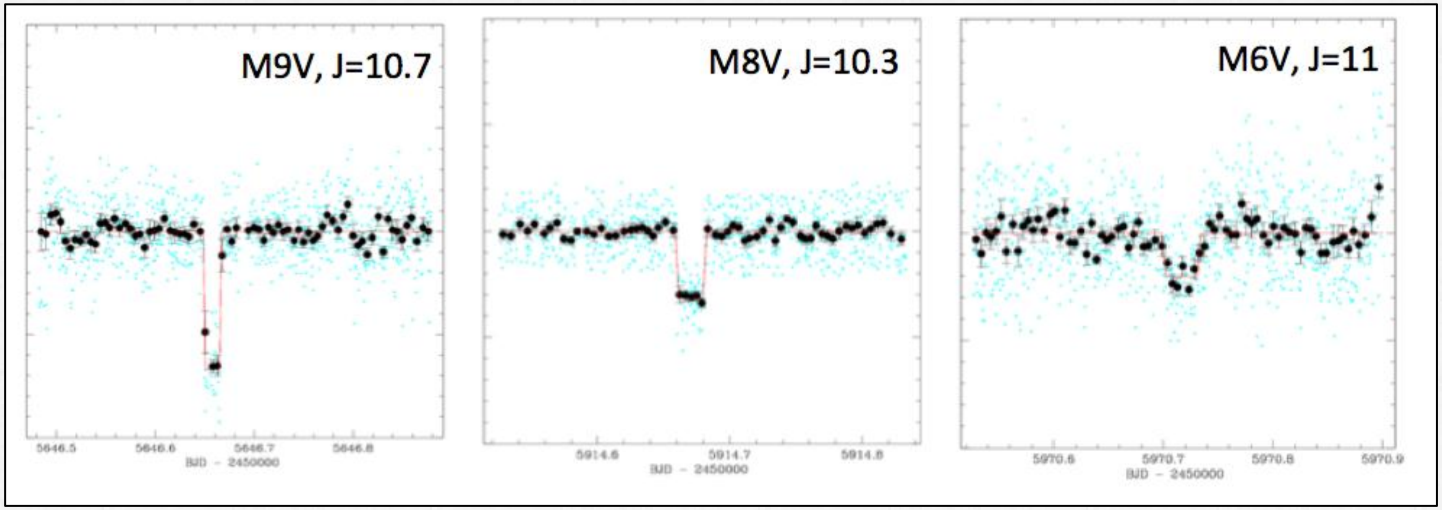
M8.5V, J=9.5, 5 nights



<5σ-threshold> = 0.8R_{earth}

TRAPPIST-UCSTS: detection threshold estimation

Injection of fake Earth-size planet transits and MCMC analysis



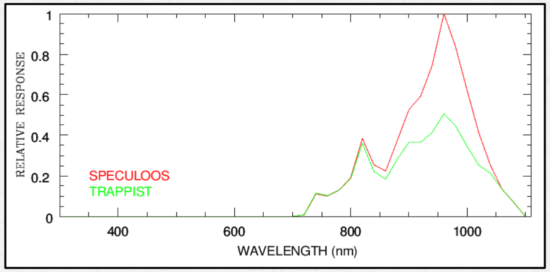
12-σ 7-σ 4-σ

TRAPPIST-UCSTS: main results so far

- 20 targets observed: 5 M6, 6 M7, 4 M8, 5 M9
- 8/20 = 40% variables:
  - 2 M6 and 3 M7 have flares
  - 3 rotational modulations (a few hours period)
  - The observed variability does not limit transit detection (except during flares)
- Photometric precision globally nominals, especially for dry nights
- Mean 5-σ detection tresholds:
  - M6: 1.1 R_{earth}
  - M7: 0.95 R_{earth}
  - M8: 0.93 R_{earth}
  - M9: 0.85 R_{earth}

SPECULOOS

Search for habitable Planets EClipsing Ultra-cOOl Stars



Near-IR optimized CCD

Paranal – synergy with NGTS

80cm telescopes + new-gen equatorial mount

Covering of >90% of the HZ for the 500 UCS suitable for JWST studies