Exoplanetas en el IAC

Enric Palle, et al

Instituto de Astrofísica de Canarias

Outline

Busqueda de planetas tierra
- XO, Superwasp, Mascara, QES, LCO
- MUSCAT2

Busqueda planetas espacio
- K2
- TESS
- PLATO

Caracterizacion de explanetas baja y alta res espectral
- HARPS(-N), CARMENES
- GTC
- MUSCAT2
- ESPRESSO
- NEREA
- HIRES
- ARIEL

Who we are? What we do?

EXOPLANETS &ASTROBIOLOGY

4 Staff (7)

7 PhD Students

6 postdocs

Investigadores involucrados

20 investigadores en el proyecto.


Roi Alonso Sobrino
EDP 2018: 0.5 EDP 2019: 0.5


Juan A. Belmonte Avilés
EDP 2018: 0.1 EDP 2019: 0.1


Carlos Cardona Guillén
EDP 2018: 0.0 EDP 2019: 0.5


Nuria Casasayas Barris
EDP 2018: 1.0 EDP 2019: 1.0


Patricia Chinchilla Gallego
EDP 2018: 0.2 EDP 2019: 0.2


Hans Deeg
EDP 2018: 0.5 EDP 2019: 0.5


Diego Hidalgo Soto
EDP 2018: 1.0 EDP 2019: 1.0


Peter Klagyivik
EDP 2018: 0.5 EDP 2019: 0.5


Javier A. Licandro Goldaracena
EDP 2018: 0.2 EDP 2019: 0.2


Nicolás Cedric Lodieu
EDP 2018: 0.2 EDP 2019: 0.2


Rafael Luque Ramírez
EDP 2018: 1.0 EDP 2019: 1.0


María P. Montañés Rodríguez
EDP 2018: 1.0 EDP 2019: 1.0


Felipe A. Murgas Alcaino
EDP 2018: 1.0 EDP 2019: 1.0


Lisa E. Nortmann
EDP 2018: 1.0 EDP 2019: 1.0


Grzegorz Nowak
EDP 2018: 1.0 EDP 2019: 1.0


Enric Pallé Bago
EDP 2018: 1.0 EDP 2019: 1.0


Hannu Parviainen
EDP 2018: 1.0 EDP 2019: 1.0


Jorge Prieto Arranz
EDP 2018: 1.0 EDP 2019: 1.0


Víctor J. Sánchez Bejar
EDP 2018: 0.5 EDP 2019: 0.3


Monika Beata Stangret
EDP 2018: 1.0 EDP 2019: 1.0

EDP total 2018: 13.7
EDP total 2019: 14.0

Estrellas de baja Masa, Enanas Marrones y Planetas Gigantes
IP: RAFAEL REBOLO

Sismología Solar y Estelar y Búsqueda de Exoplanetas
IP: FERNANDO PÉREZ

II. Busqueda de planetas desde tierra

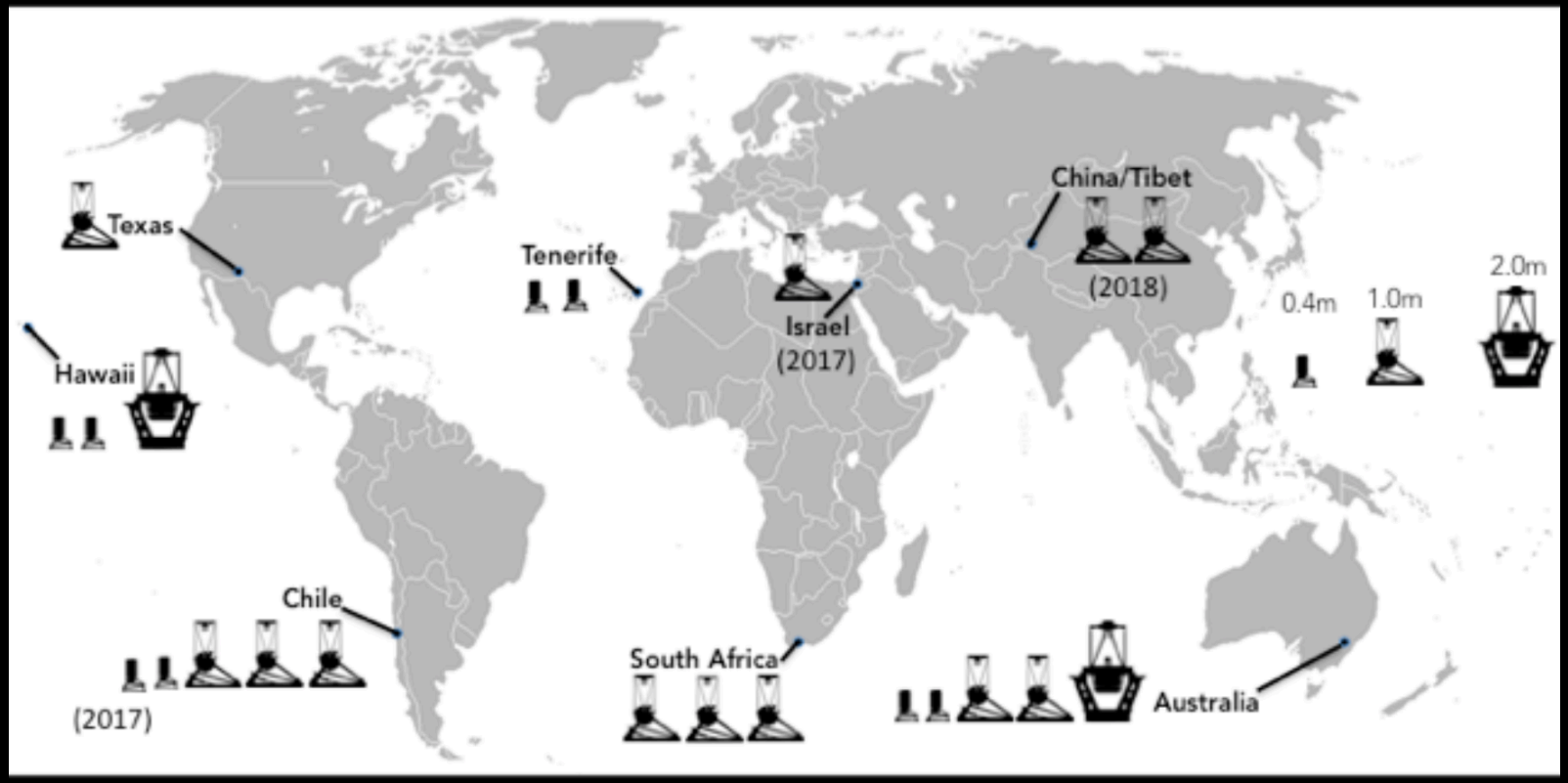
XO, Superwasp, Mascara, QES

En proceso de desaparición (explotación base de datos)

II. Busqueda de planetas desde tierra

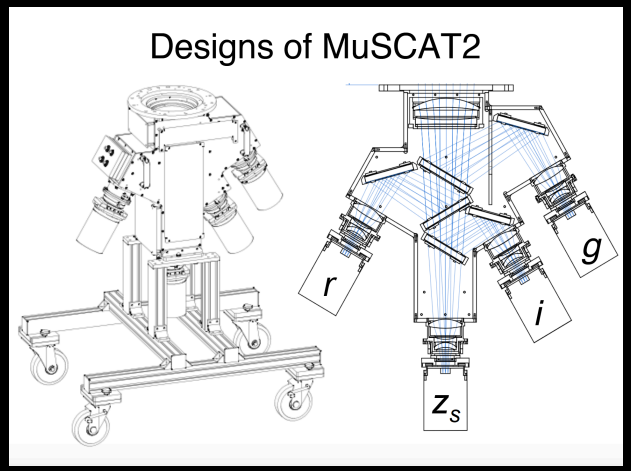
LCO Telescope network:

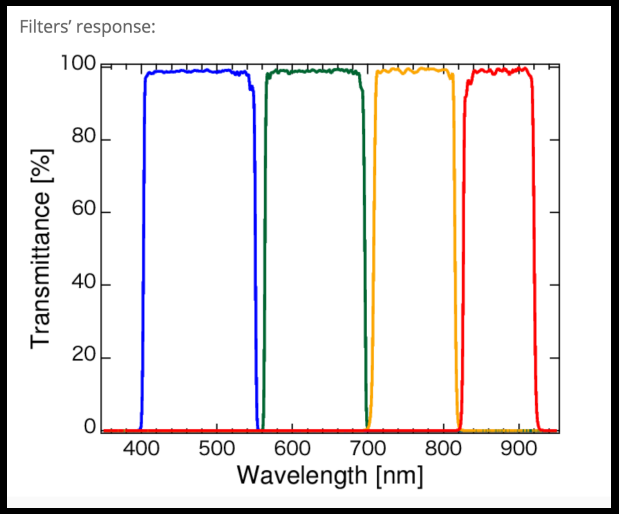
- One Node at Izaña 2 x 40cm telescopes, 2 x 1m telescope in 2019?
- IAC has some GTO time on the 0.4m network, and can apply to general TAC for LCO

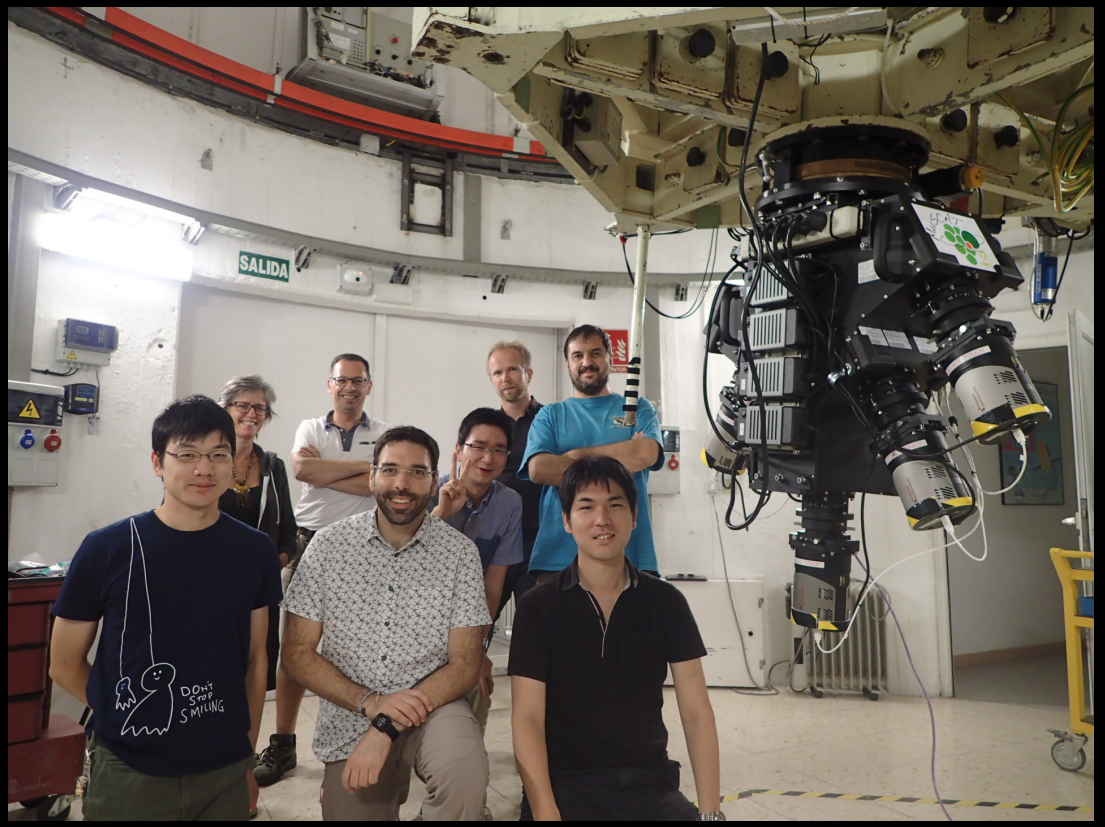


II. Busqueda de planetas desde tierra

MUSCAT2 @ TCS



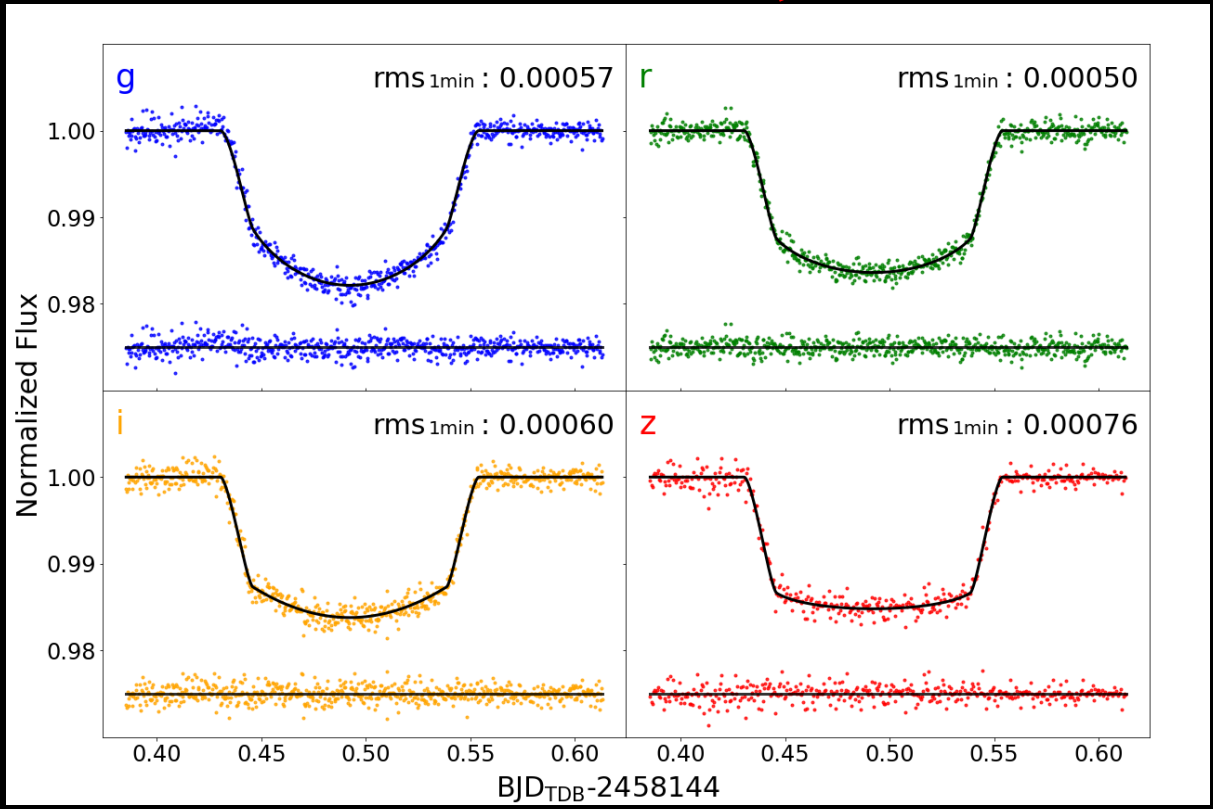




II. Busqueda de planetas desde tierra

Fotometria de muy alta precision
162 noches/año – 5 años --
2018: > 300 transitos, 265 noches
Mejoras en 2019 (camaras y difusores) [illegible] noches/año

TESS !!



II. Busqueda de planetas desde tierra

Velocidad Radial

1- Busquedas “a ciegas” por velocidad radial

- HARPS-N
- CARMENES
- ESPRESSO

2- Programa en RVs para confirmación de planetas que transitan

Space Missions

II. Busqueda de planetas desde el espacio

KEPLER: NASA Mission

K2: Extended misiion survey of ecliptic plane

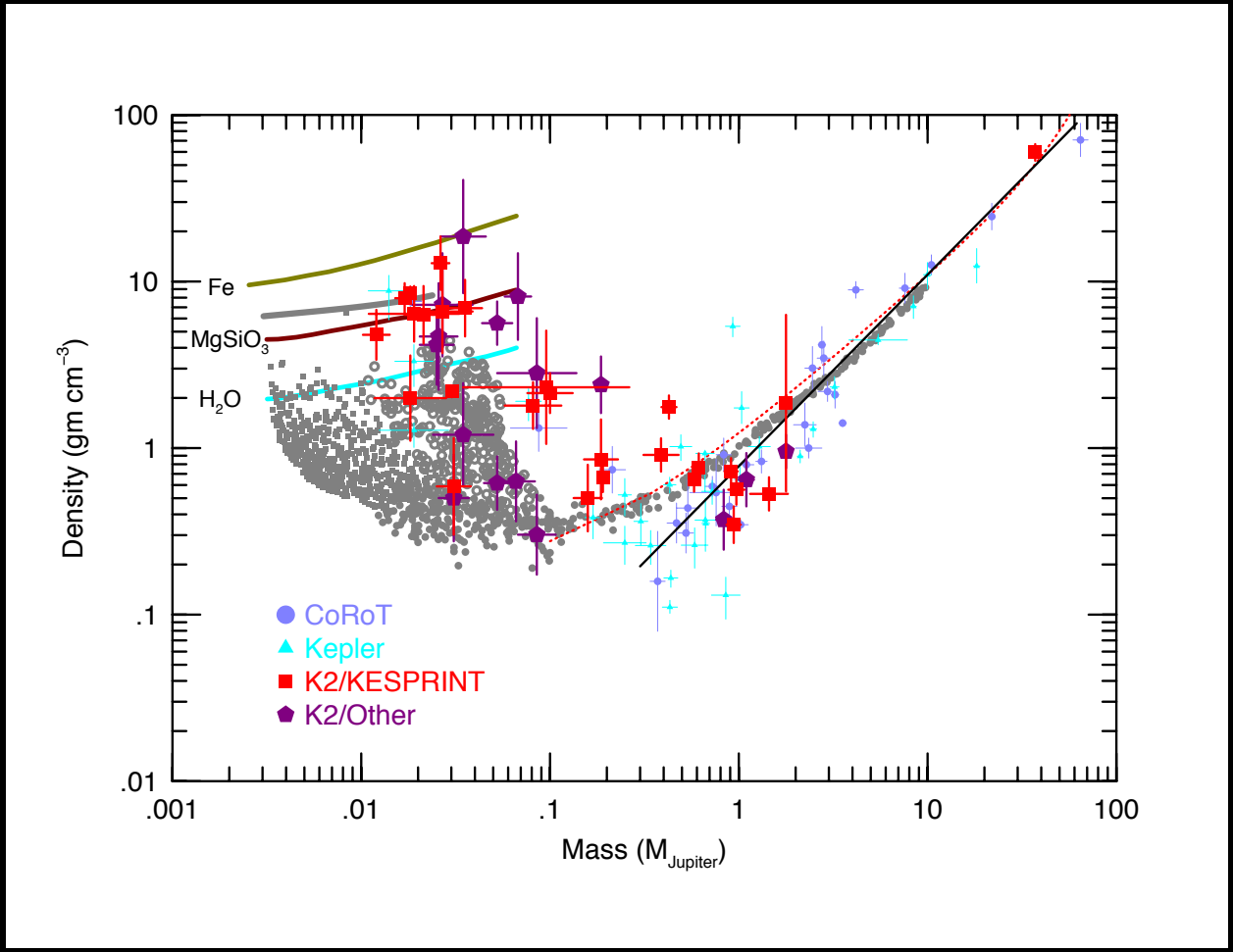
K2 followup: KESPRINT project

From detection to mass determination
Southern Hemisphere: HARPS
Northern Hemisphere: HARPS-N, CARMENES, FIES (+AO)

Collaboration among several institutions
No guaranteed time
And no vertical structure

K2 follow-up: KESPRINT project

KESPRINT > 45 Refereed publications



Grey points: Synthetic planets (Jin & Mordasini, 2017)

II. Busqueda de planetas desde el espacio

TESS: MIT & NASA Mission

E. Palle Invited International Collaborator

TESS is a magnificent opportunity for exoplanet science

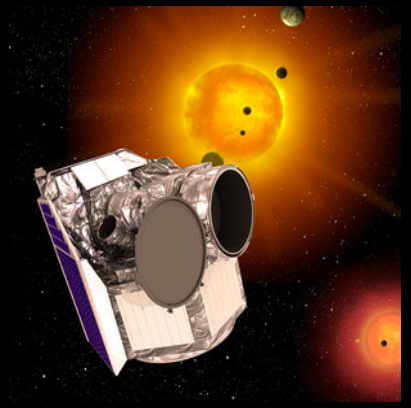
Started Science operation in August 2018 15-20 papers

Official follow-up TFOP free to anyone to participate

Scientific Activities:

- LCO photometric follow-up (Key project)
- MUSCAT2 (better in 2019-20)
- Large program HARPS for RVs
- Large program HARPS-N + FIES for RVs
- GTO ESPRESSO RVs and atmospheres
- GTO CARMENES for RVs for Mstar ONLY
- DDTs for atmospheric characterization, HARPS, ESPRESSO, etc..

II. Busqueda de planetas desde el espacio



CHEOPS: E.Palle, R. Alonso Board Members and Science Team

Main goal is to do extremely precise photometry of known transiting planets and search for transiting planets in systemes with RV planets

Majority of the time is for the consortium survey, but there will be open time through periodic call for proposals.

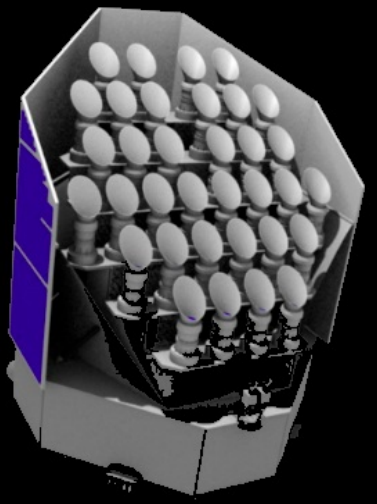
At IAC:

- Data reduction pipelines, bias, flatfielding, etc..
- Data analysis pipeline
- Ground-based preparation, mainly secondary eclipse measurements

Launch end of 2019

II. Busqueda de planetas desde el espa

PLATO: H. Deeg, R. Alonso, E.Palle



PLATO - 2025

Mission to search for planets via transits

IAC: Several working packages, not the main

Talk by Juan Carlos Suarez

Follow-up of the mission will be very similar to that of K2 and TESS, so we have a very large structure and experience in place.

II. Busqueda de planetas desde el espacio

ARIEL: I Ribas and E.Palle, Spanish Co-PIs

Large industrial investment and scheduler tasks done at ICE-CSIC, other packages at the UPM.

At IAC we are doing a small part of the TCS (EGSE), and coordinating some working packages

Low resolution atmospheric characterization of exoplanets, a statistical mission.

Still very long time before it flies, plenty of time to join.

Exoplanet Atmospheres

Exoplanet Atmospheres

1) At low resolution (spectro-photometry)
    1) Ground
    2) Space

2) At high spectral resolution
    1) Ground

3) Direct Imaging

Exoplanet Atmospheres

1) At low resolution (spectro-photometry)
    1) Ground (GTC)
    2) Space (HST, Spitzer)

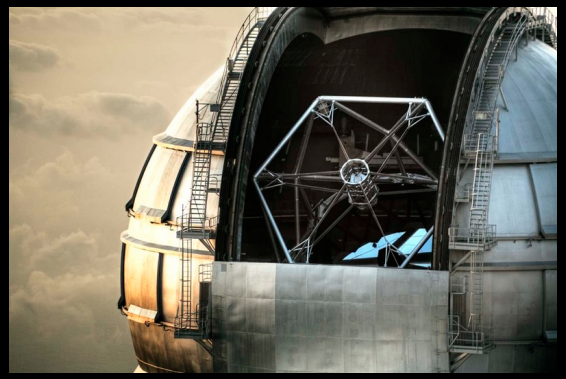
2) At high spectral resolution
    1) Ground (HARPS(-N), CARMENES, ESPRESSO)

3) Direct Imaging

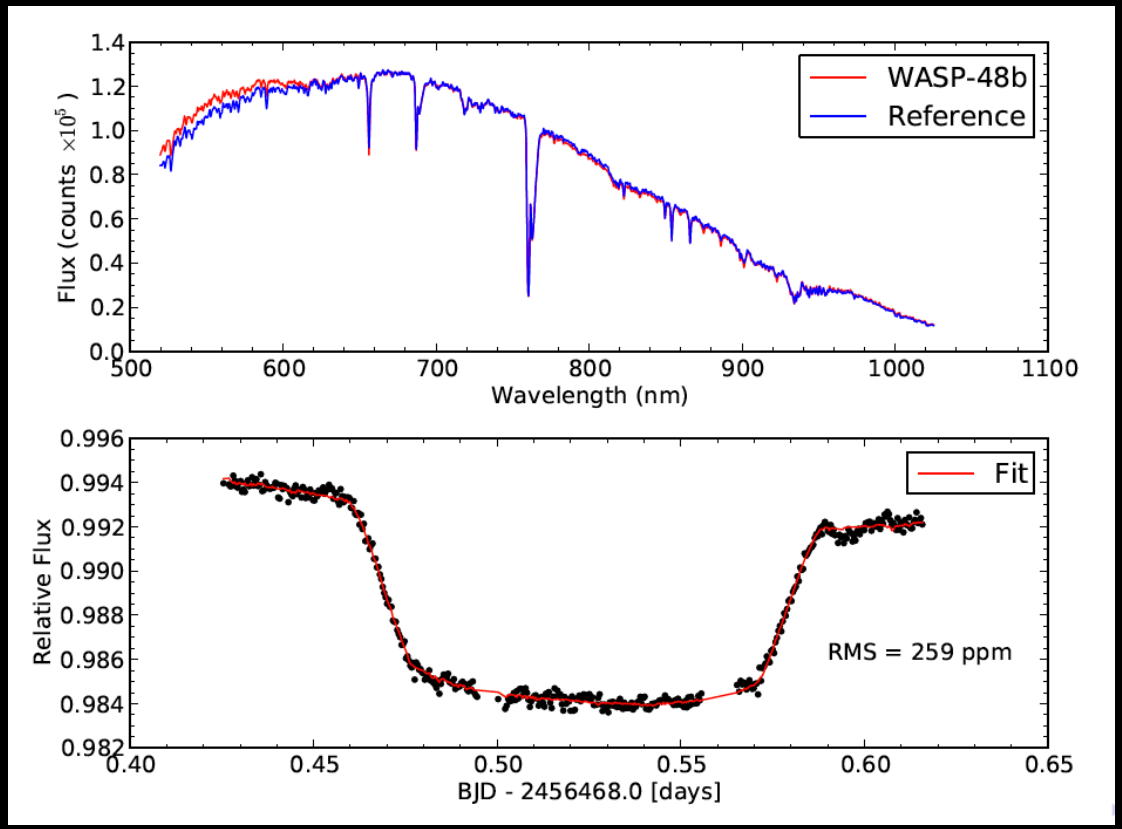
Exoplanet Atmospheres

Low spectral resolution

The Gran Telescopio Canarias

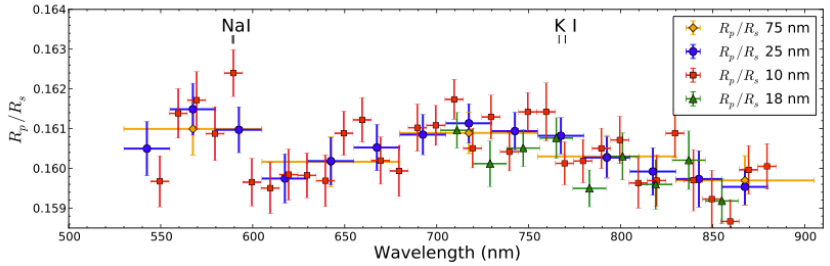


OSIRIS Long-slit spectroscopy

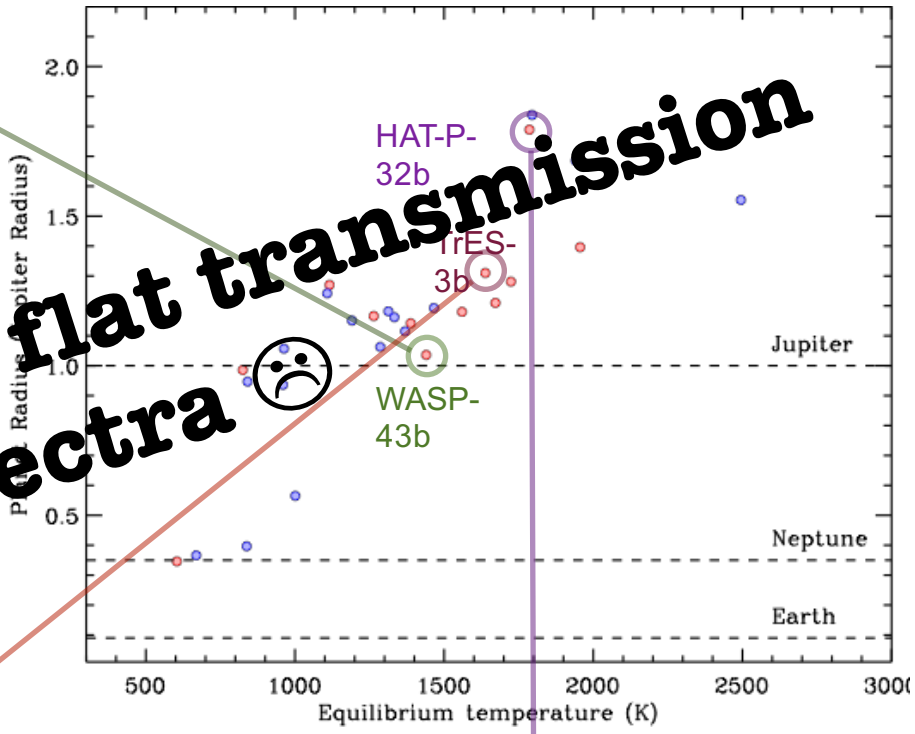


GUESS TARGETED EXOPLANETS

- **WASP-43b: tentative Na detection**
  - Murgas et al. (2014)

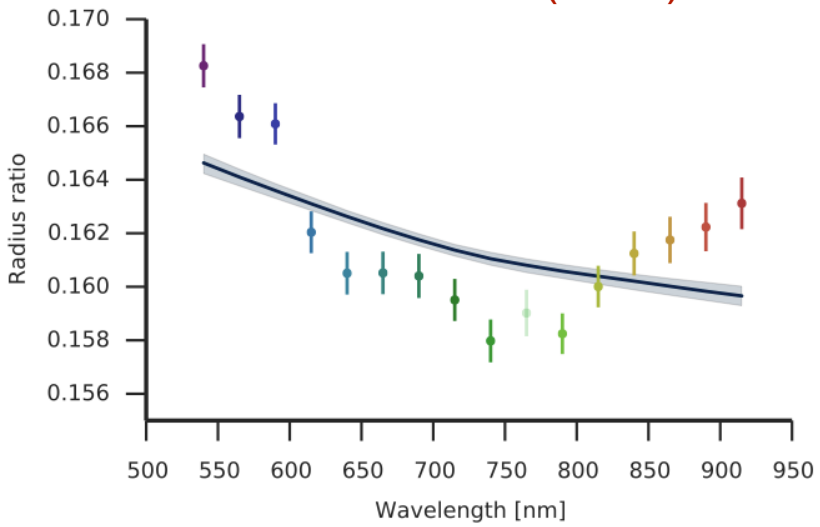


- **Planet radius v.s. Eq. temp.**

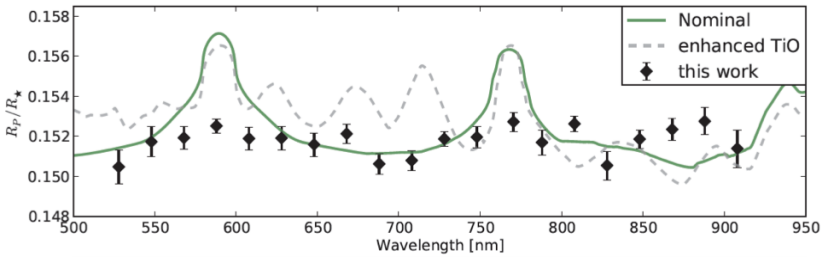


And .. Several flat transmission spectra ☹

- **TrES-3b: enhanced "Rayleigh-scattering"?**
  - Parviainen et al. (2016)

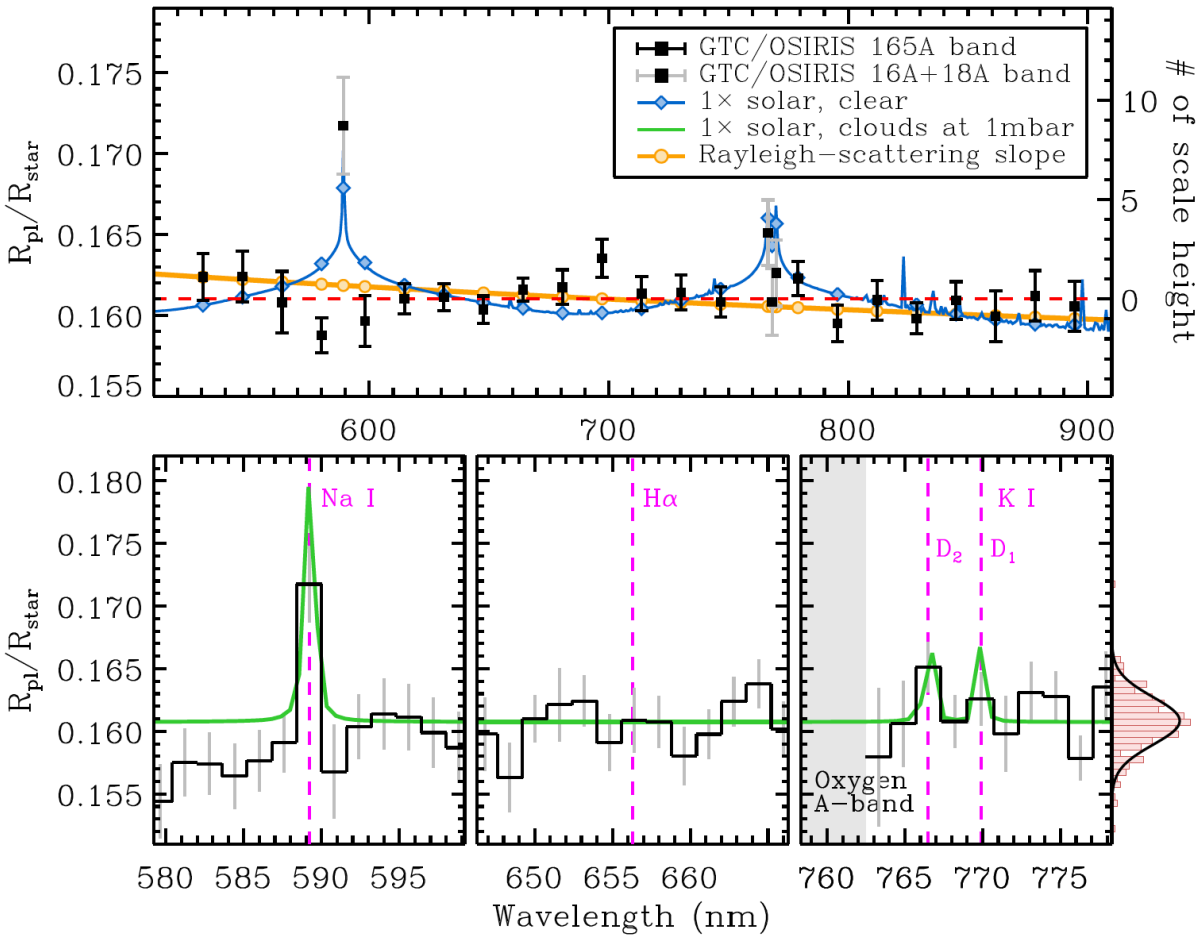


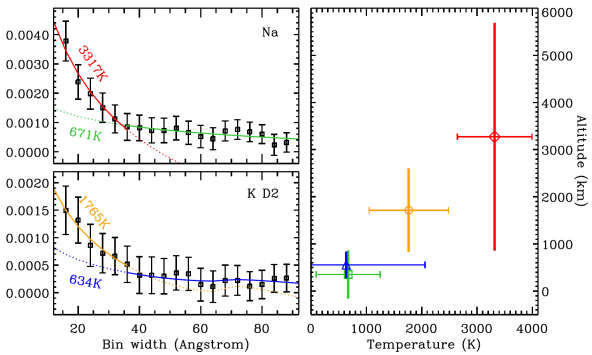
- **HAT-P-32Ab: flat and featureless**
  - Nortmann et al. (2016)



WASP-52b

WASP-52b's Facts		
V	12,2	mag
Mass	0,46	M_{Jup}
Radius	1,17	R_{Jup}
Gravity	6,5	m/s^2
T_{eq}	1264	K
H	703	km
$H/R\star$	0,00138	-

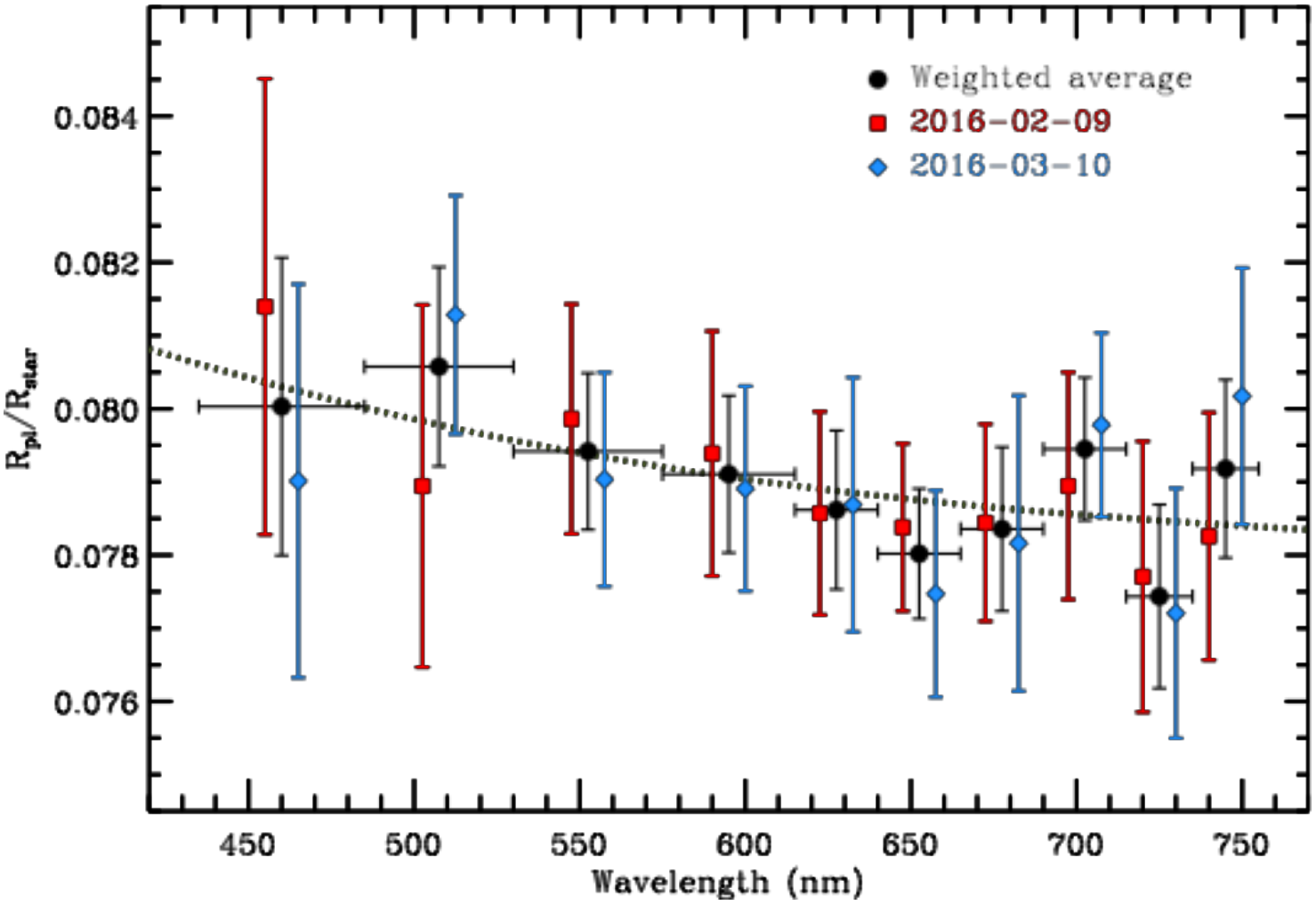




. 3. The *left panels* show the absorption depths integrated in different widths for Na (top) and K D_2 (bottom). The red/orange (green/blue) ves present the best-fitting isothermal models for the core (wing) re- n. The *right panel* shows the temperatures of these isothermal mod- at corresponding altitudes.

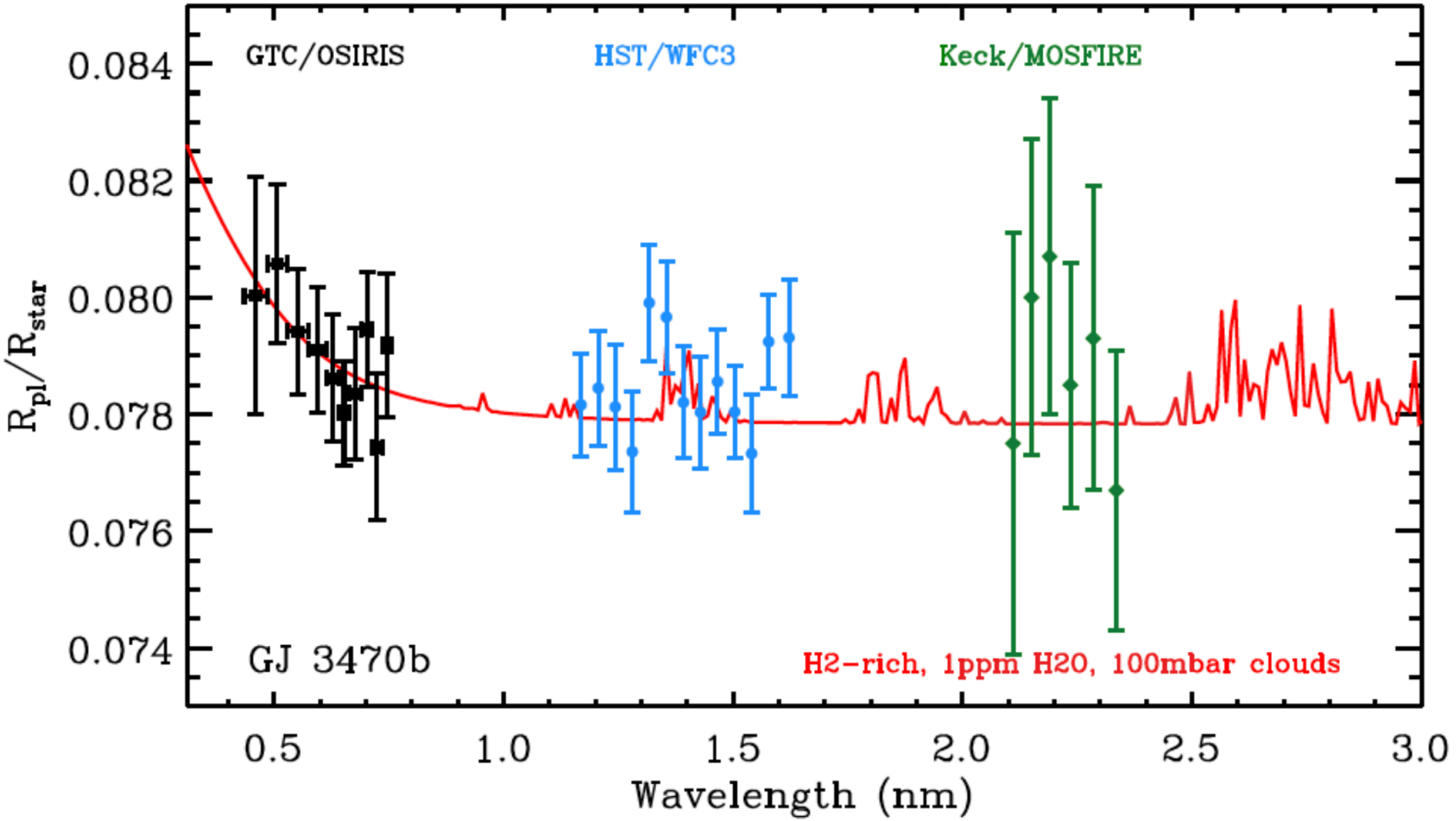
Chen et al, 2017a

GJ 3470b: a warm Uranus transiting a nearby M dwarf



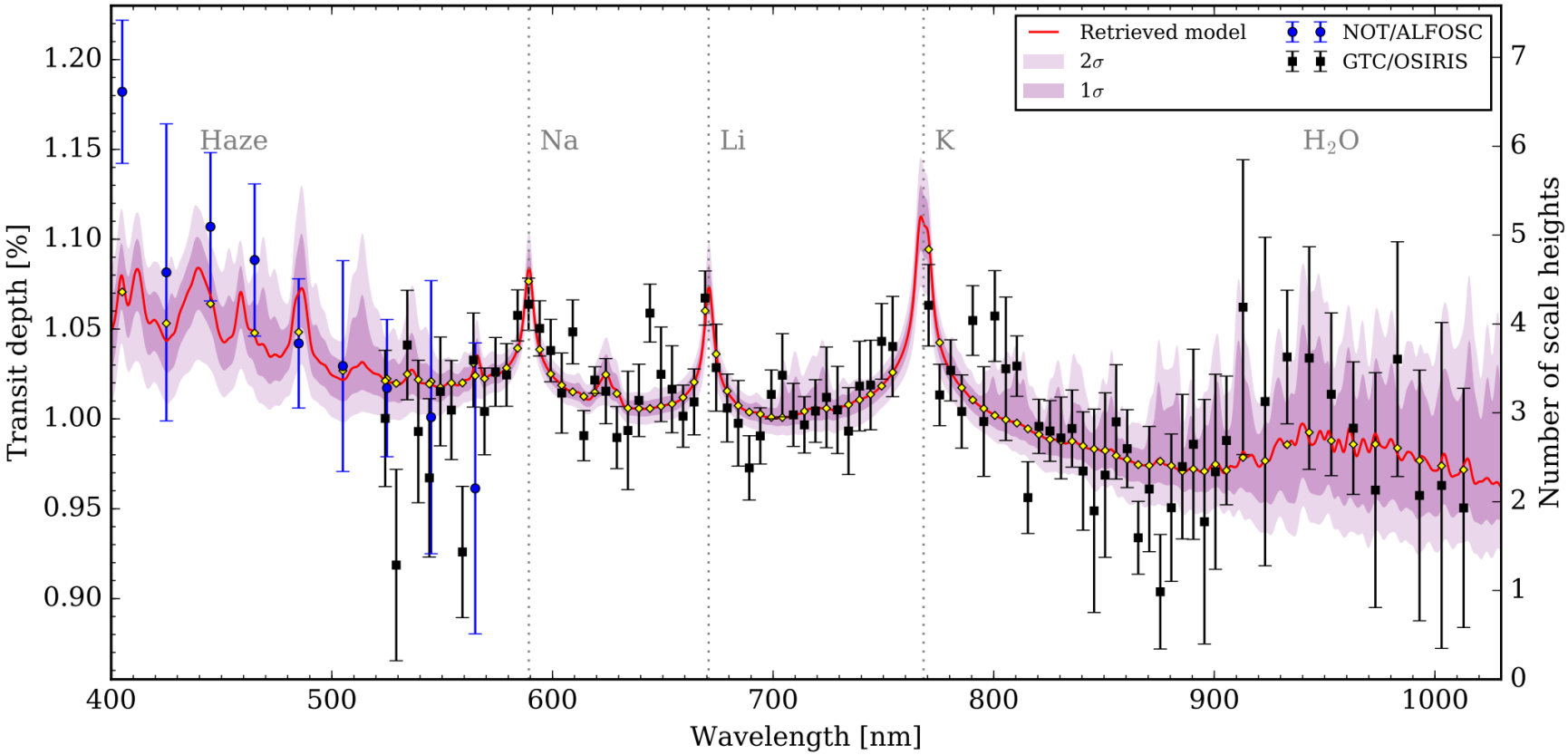
Chen et al, 2017b

GJ 3470b: a warm Uranus transiting a nearby M dwarf



Chen et al, 2017b

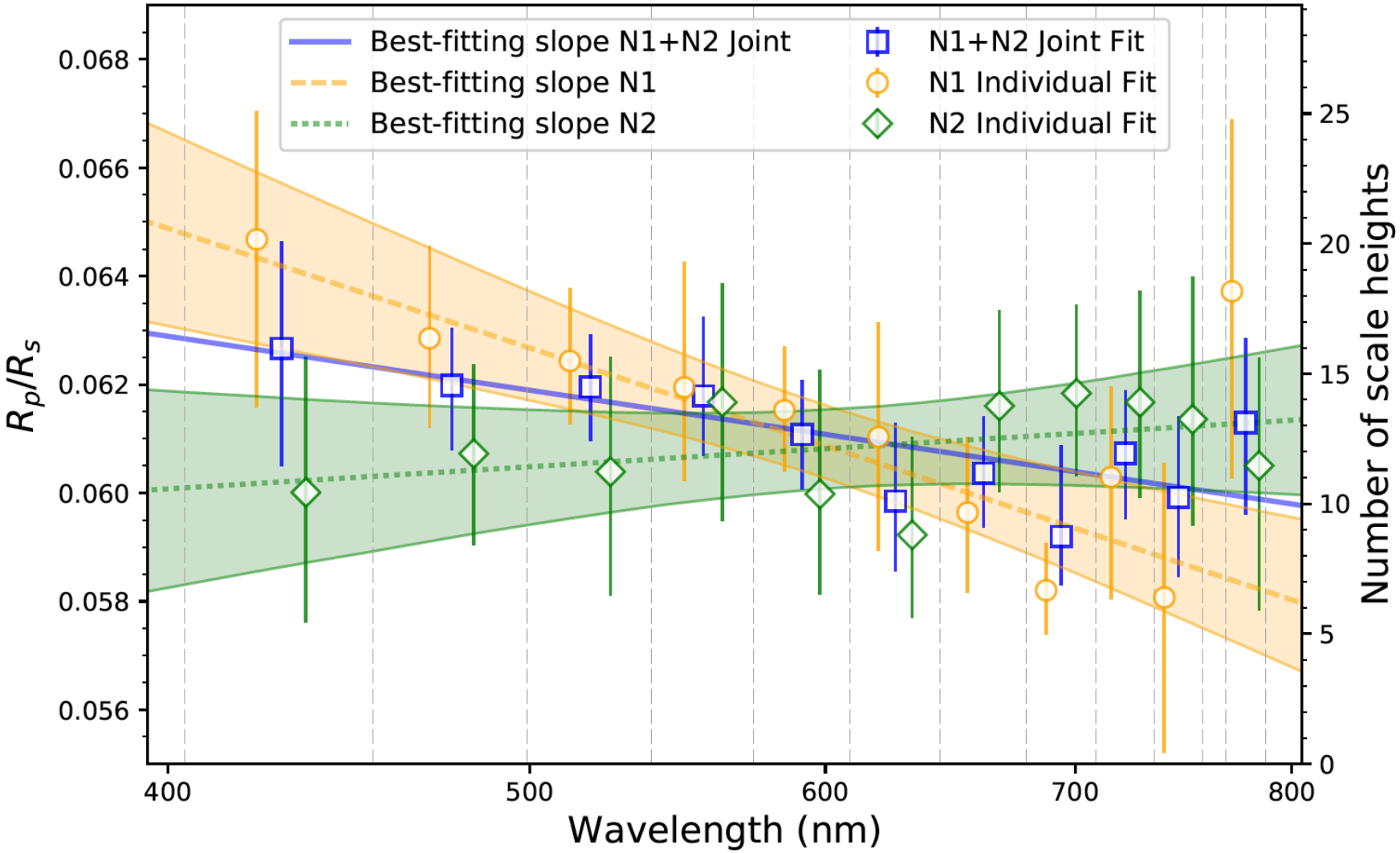
WASP-127b: the puffiest Neptune



Pressure-broadened absorption of Na, K and Li
Super-solar abundances
Presence of haze coverage around 52%
Hint of water absorption

Chen et al, 2018

HAT-P-11b: a planet around and active star



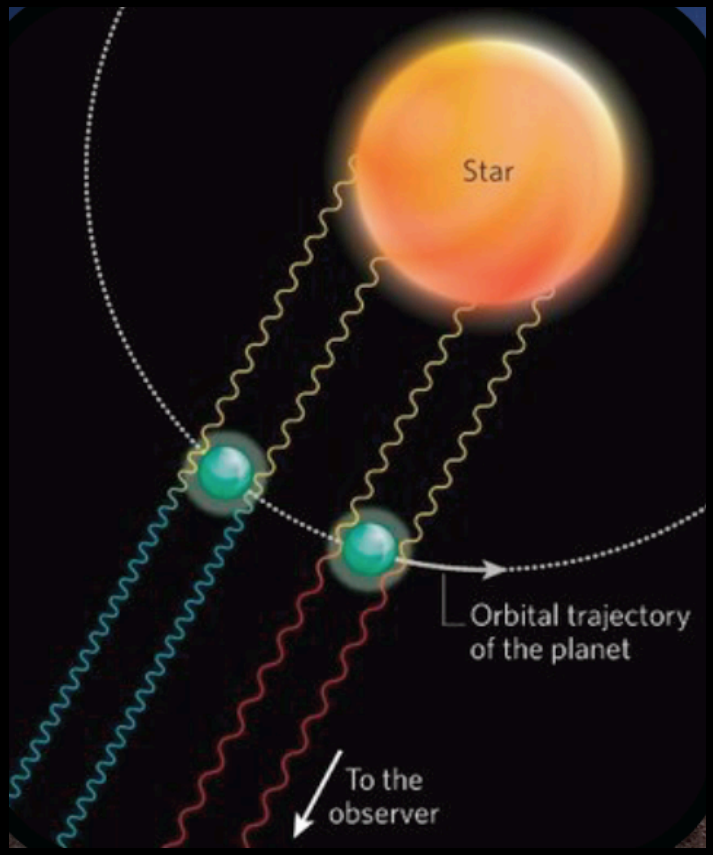
Murgas et al, 2019

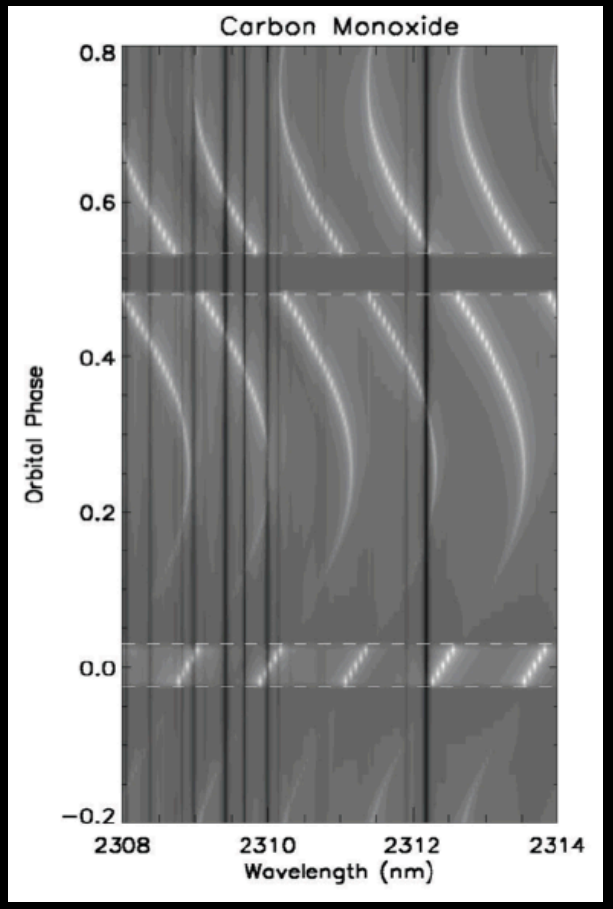
Exoplanet Atmospheres

High spectral resolution

High Resolution observation help us to get rid of the atmosphere:

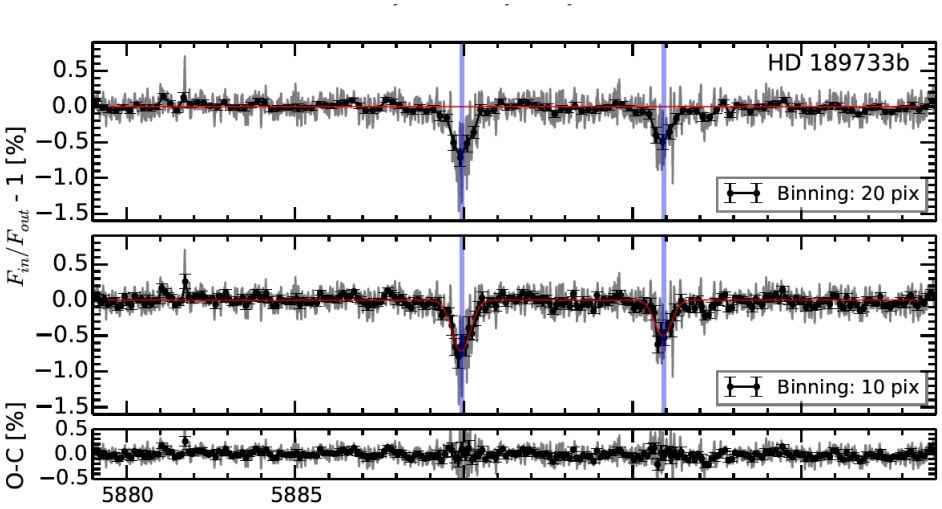
The planet moves at different speed than the star

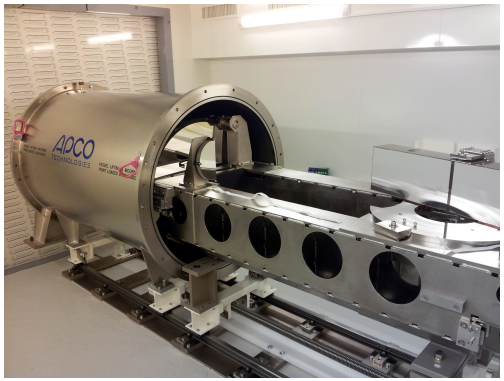




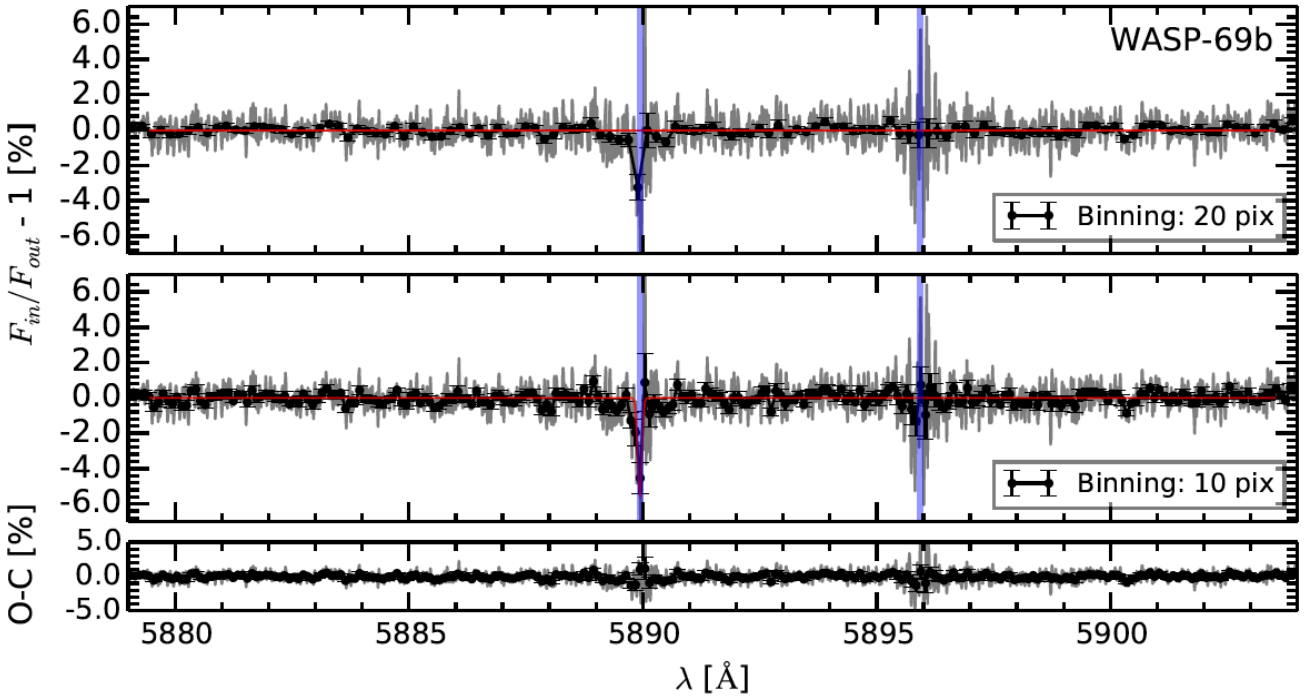
Snellen, 2010

Transmission spectroscopy Results

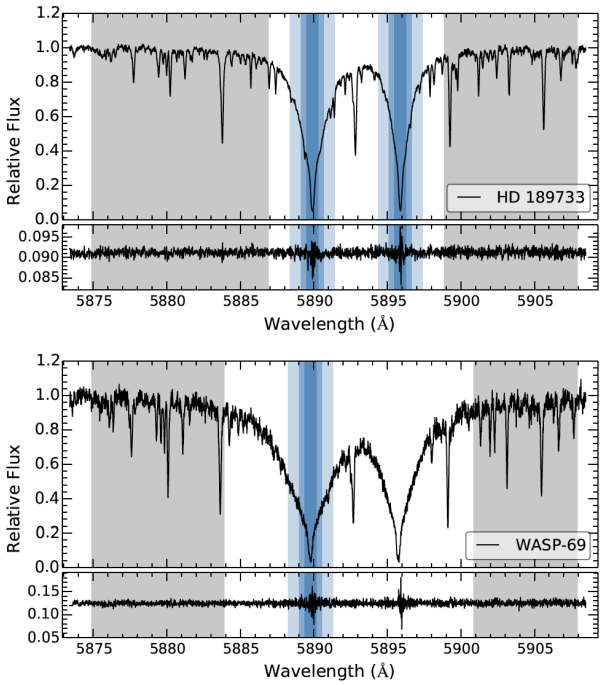


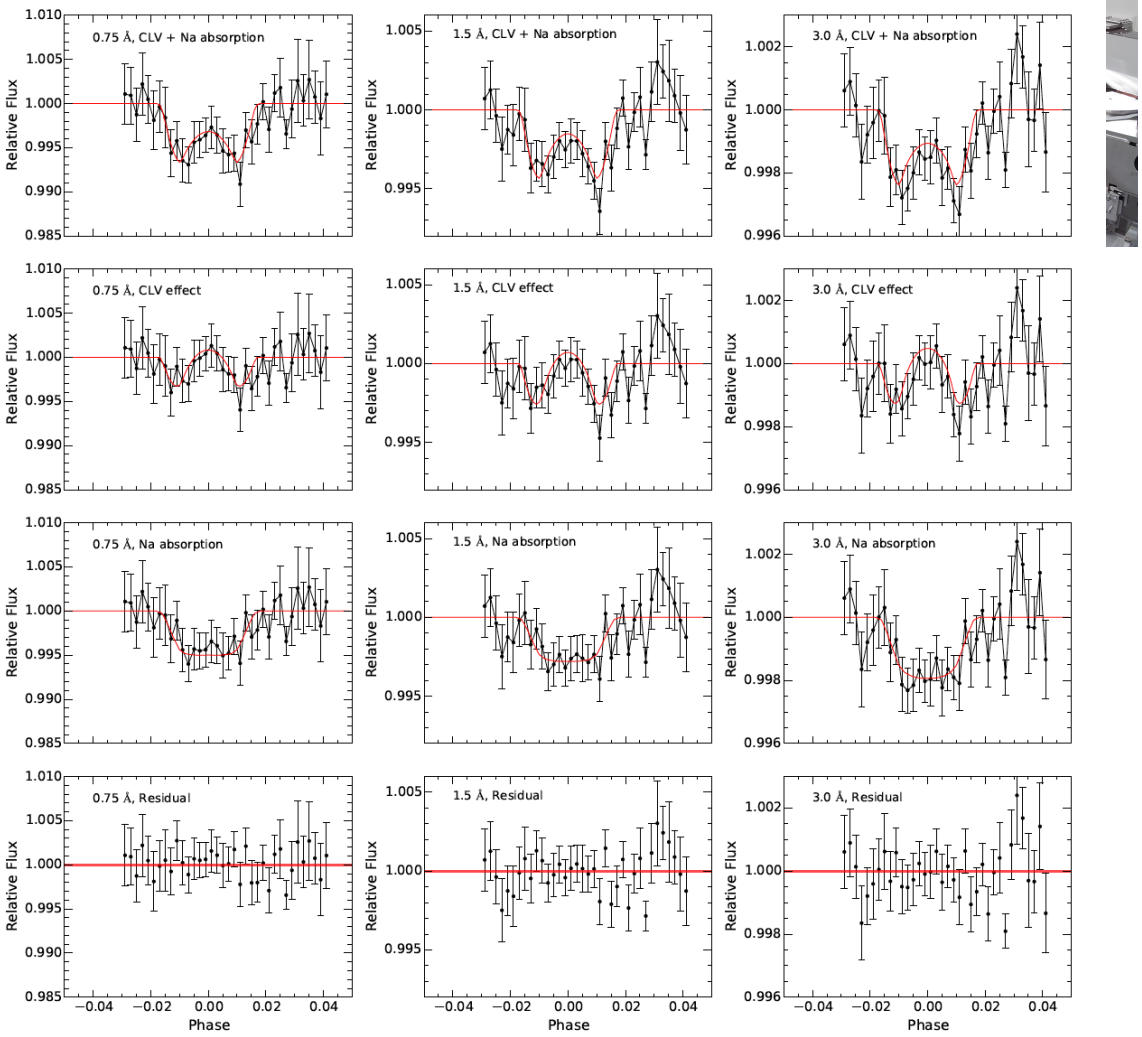


Casasayas et al, 2017



Transmission spectroscopy Results





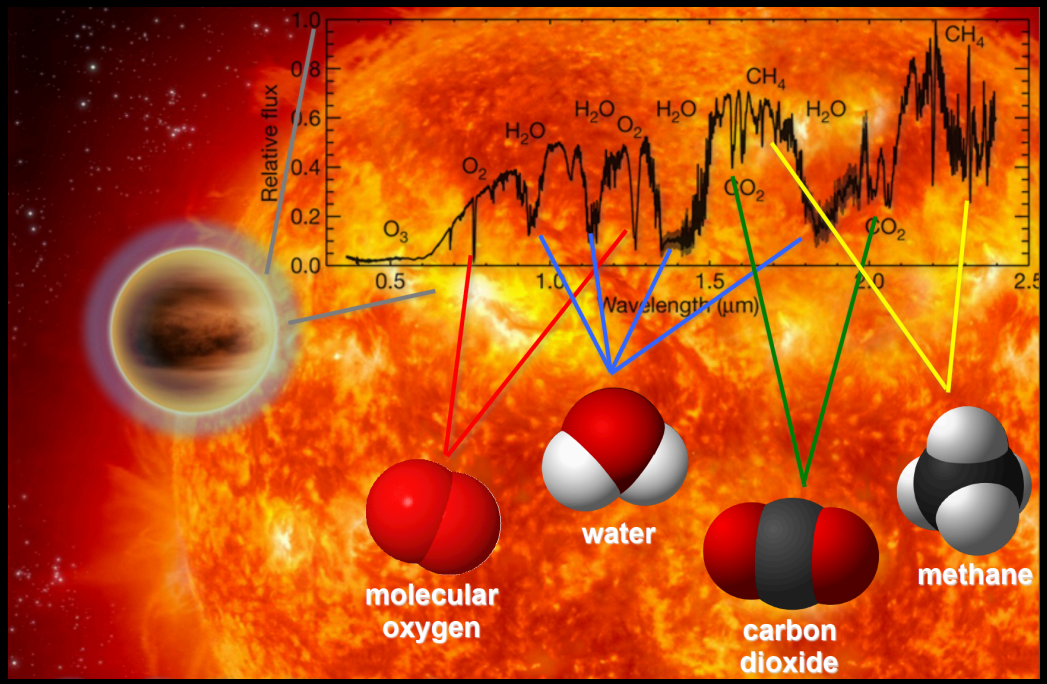
Casasayas et al, 2017

Transmission spectroscopy Results

CARMENES - Infrared

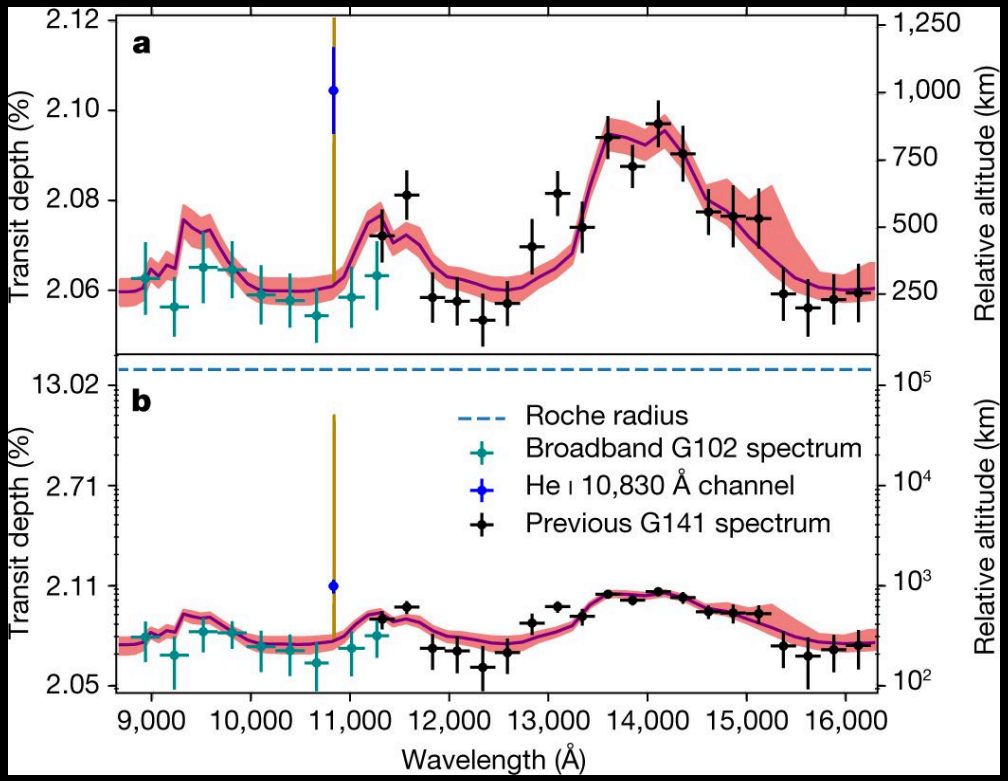
Access to further molecular species

- ***H_2O***
- CO_2
- CH_4



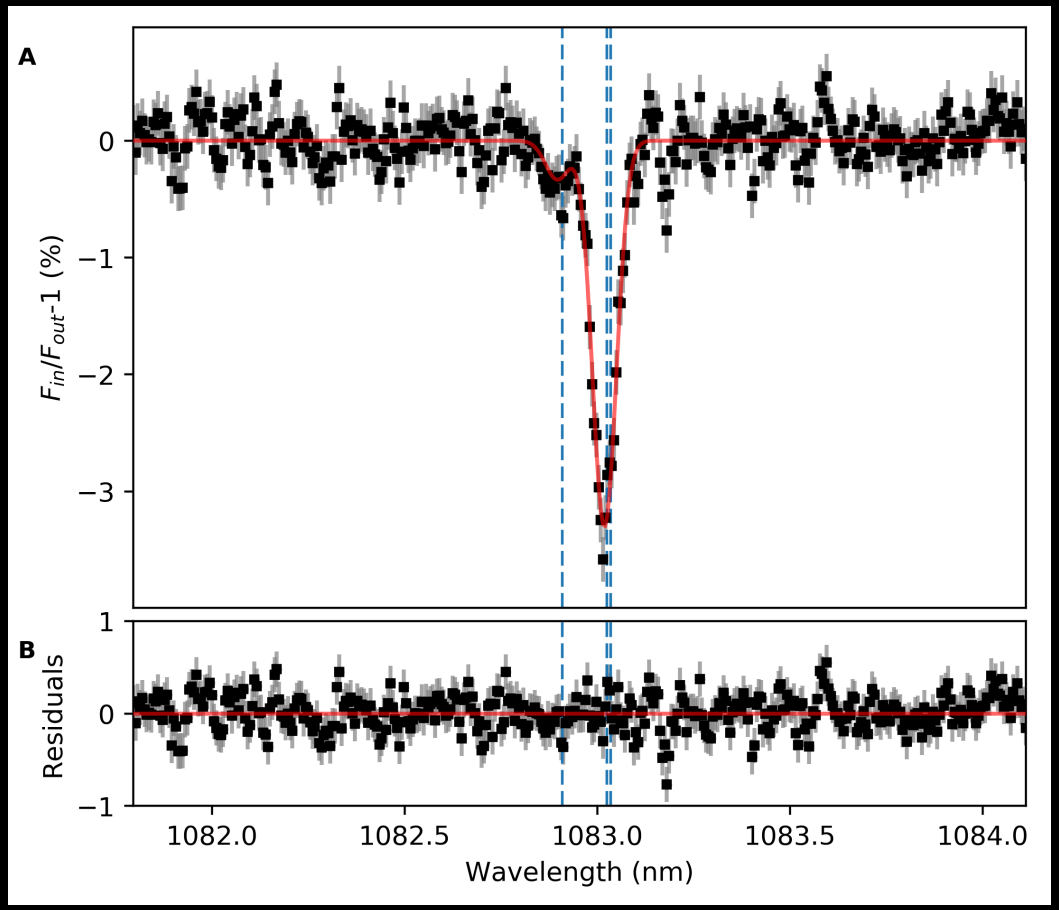
Transmission spectroscopy Results

CARMENES - Infrared



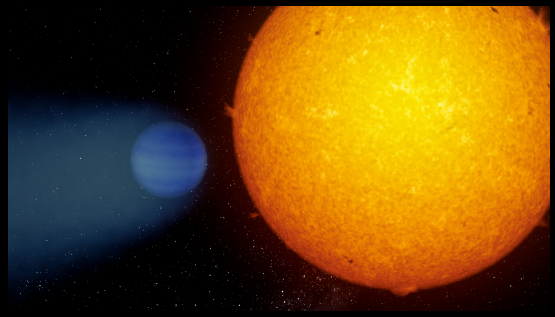
He I absorption
Spake et al, 2018

High spectral resolution has a lot to offer

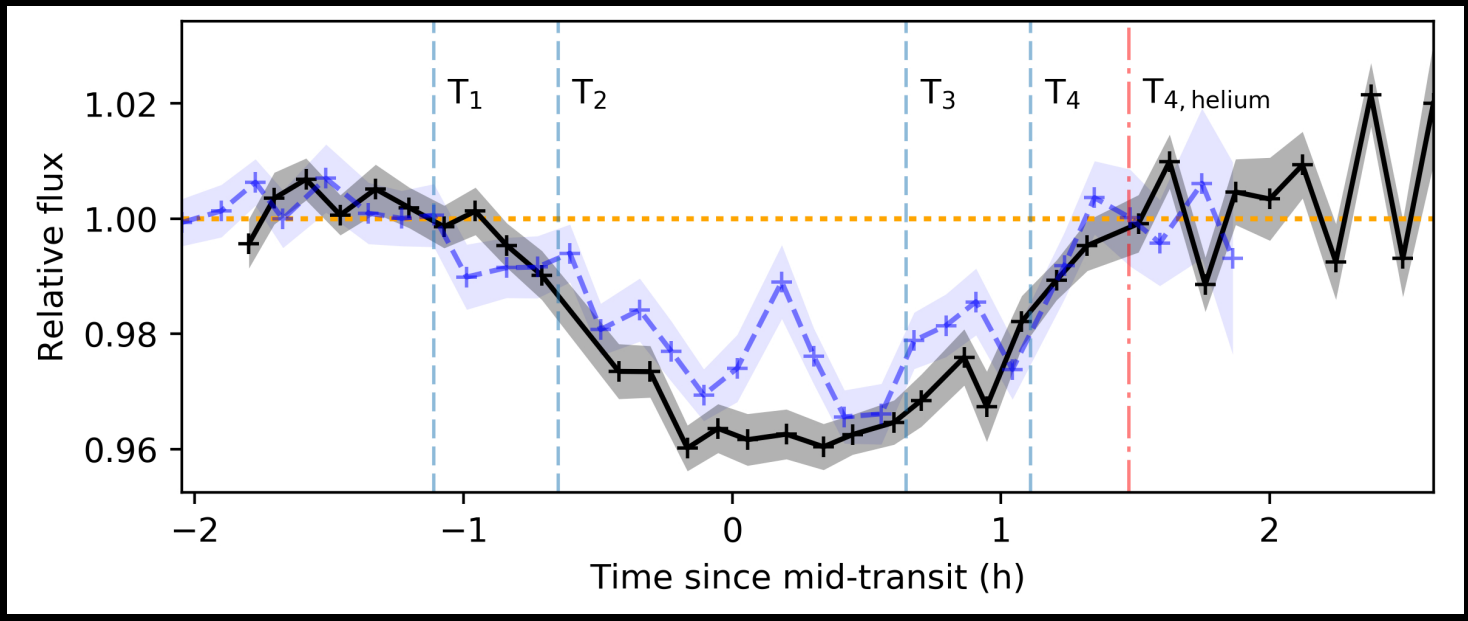


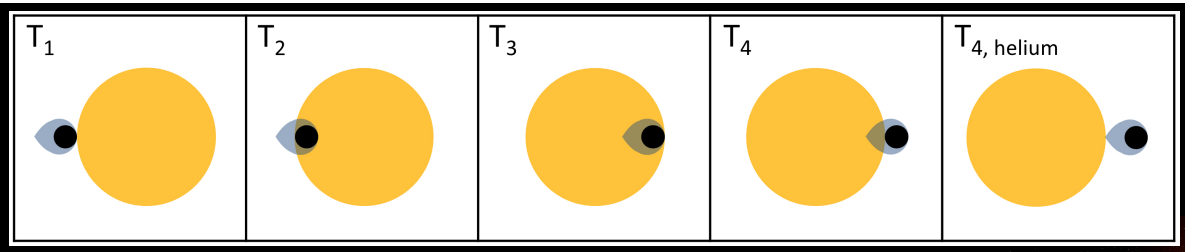
He I absorption
Nortmann et al, 2018

Line profiles
Escape velocities
Geometry

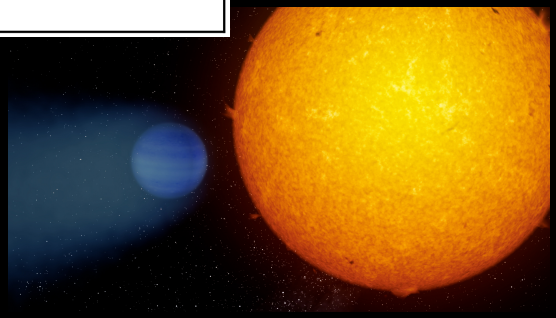


High spectral resolution has a lot to offer





Detection of Helium, Nortmann et al (2018)



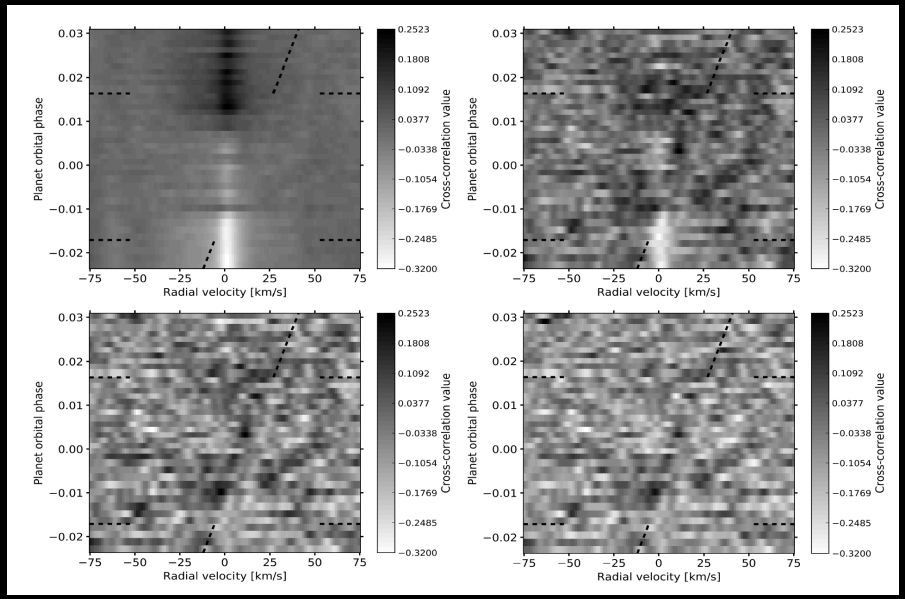
Transmission spectroscopy Results

CARMENES - Infrared

Water detected before GIANO-A

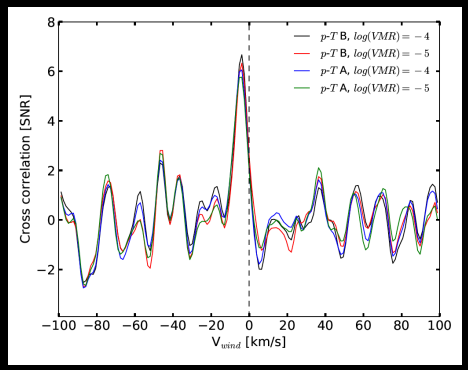
Now Water detection in several bands simultaneously

Alonso-Floriano et al 2018, Alex's work very soon

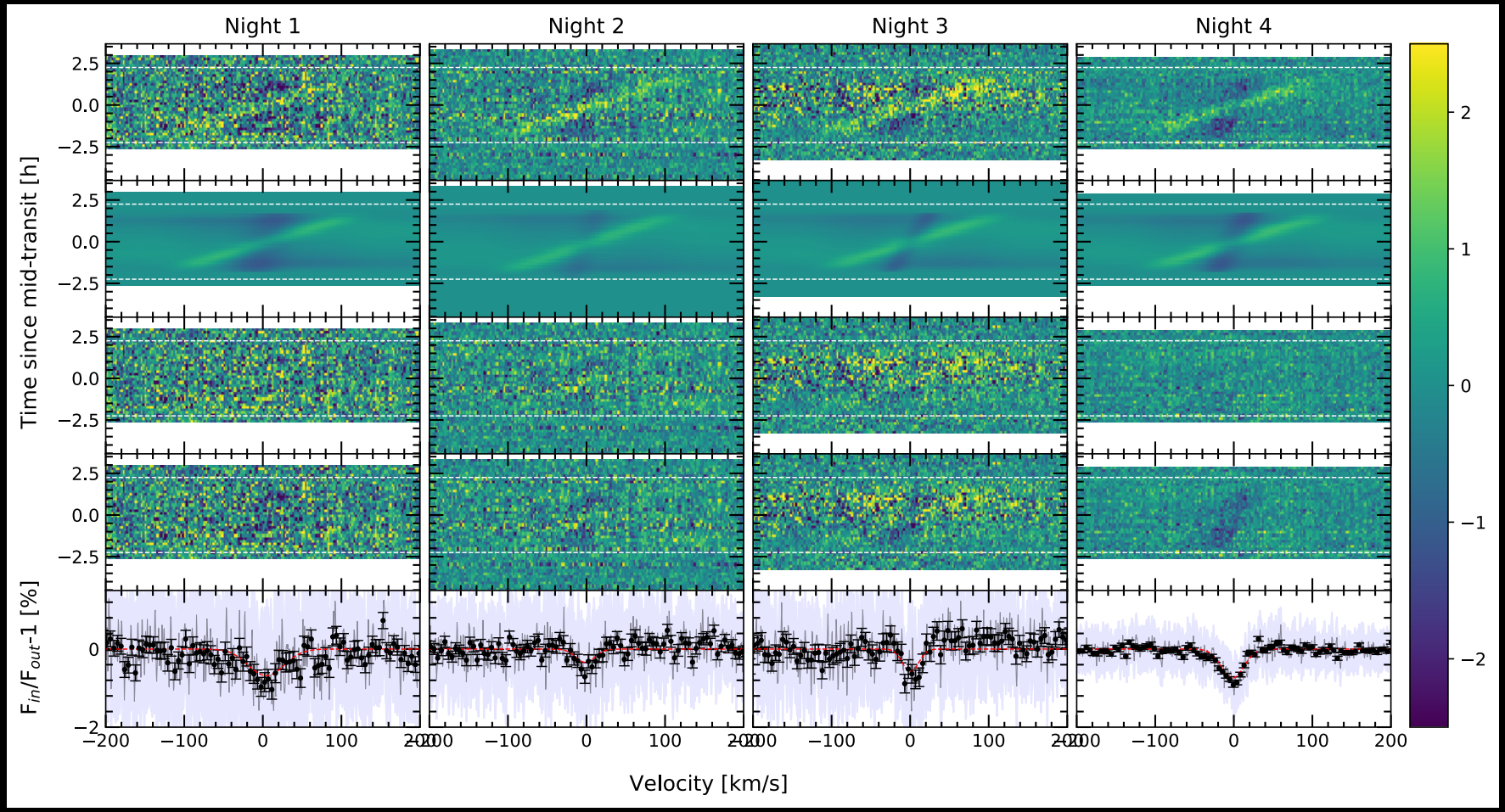


Our particular plan at IAC is to apply the technique to:

- CARMENES, GIANO, IRD and ESPRESO data in search of CH_4, CO_2 ….



State-of the-art (up to 1 month ago): Detection Balmer series



Casasayas et al. in prep

Exoplanet Atmospheres with ESPRESSO

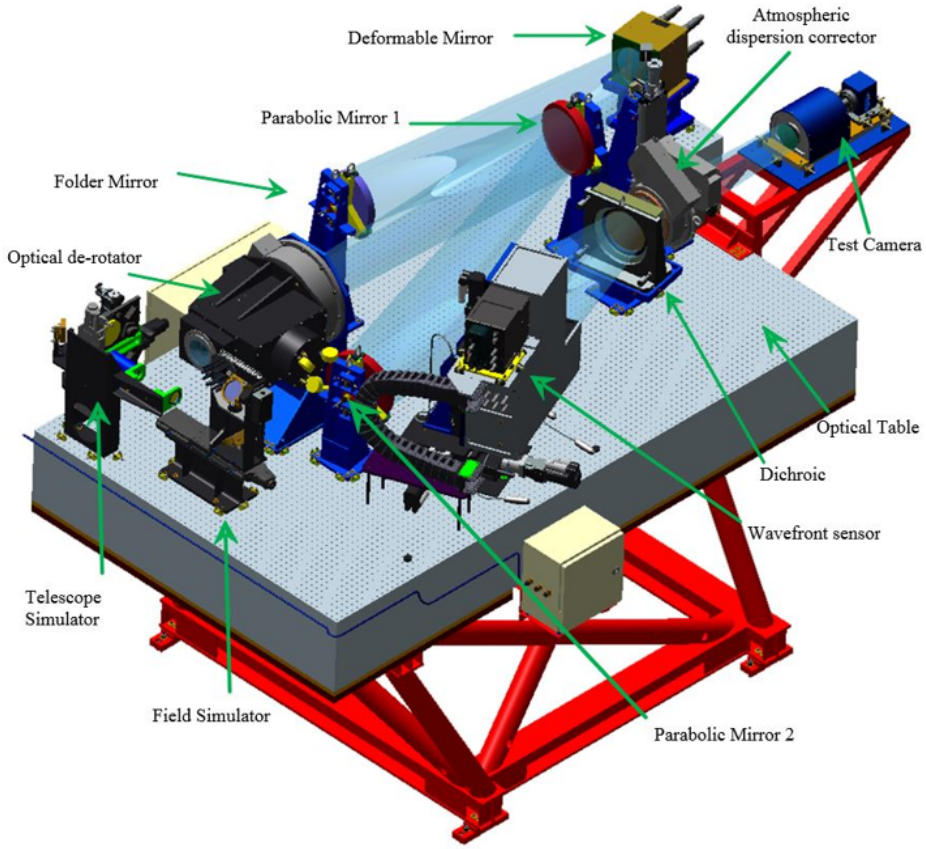
IAC is one of the ESPRESSO co-PI institutes

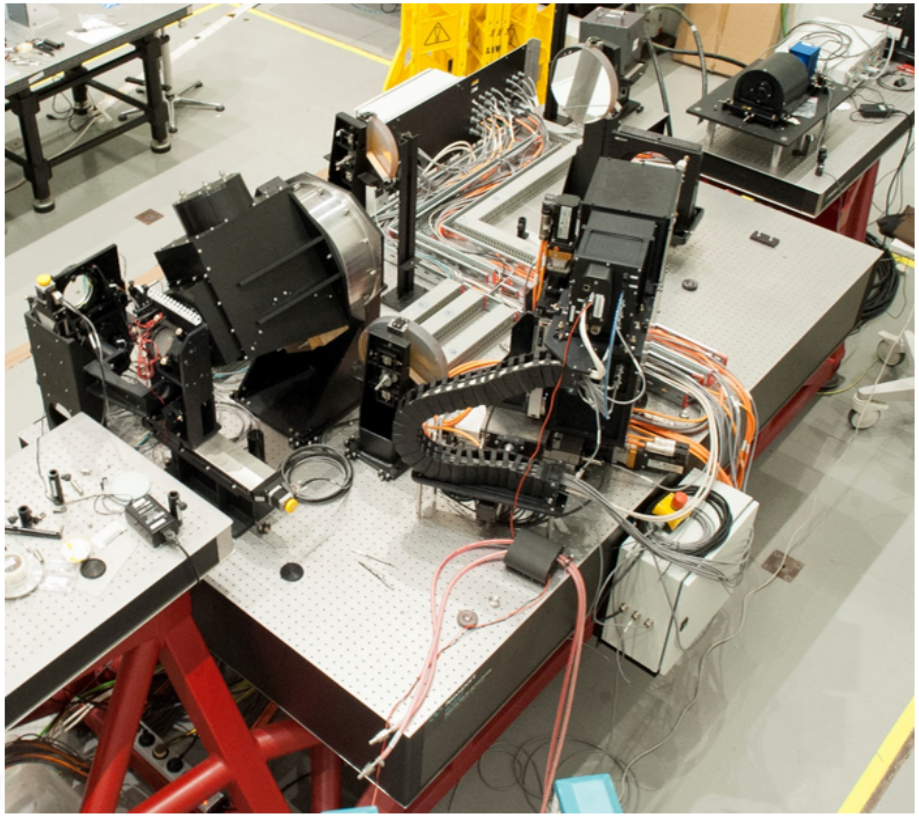
Early days, first transit data is being analyzed, need to be careful

See talk by Maria Rosa and Hugo

Call for new instrumentation for GTC

GTCAO Opto-mechanical design





- GTCAO Acceptance tests at lab (~ summer 2019)
- GTCAO LGS Preliminary Design Review (April 2019)

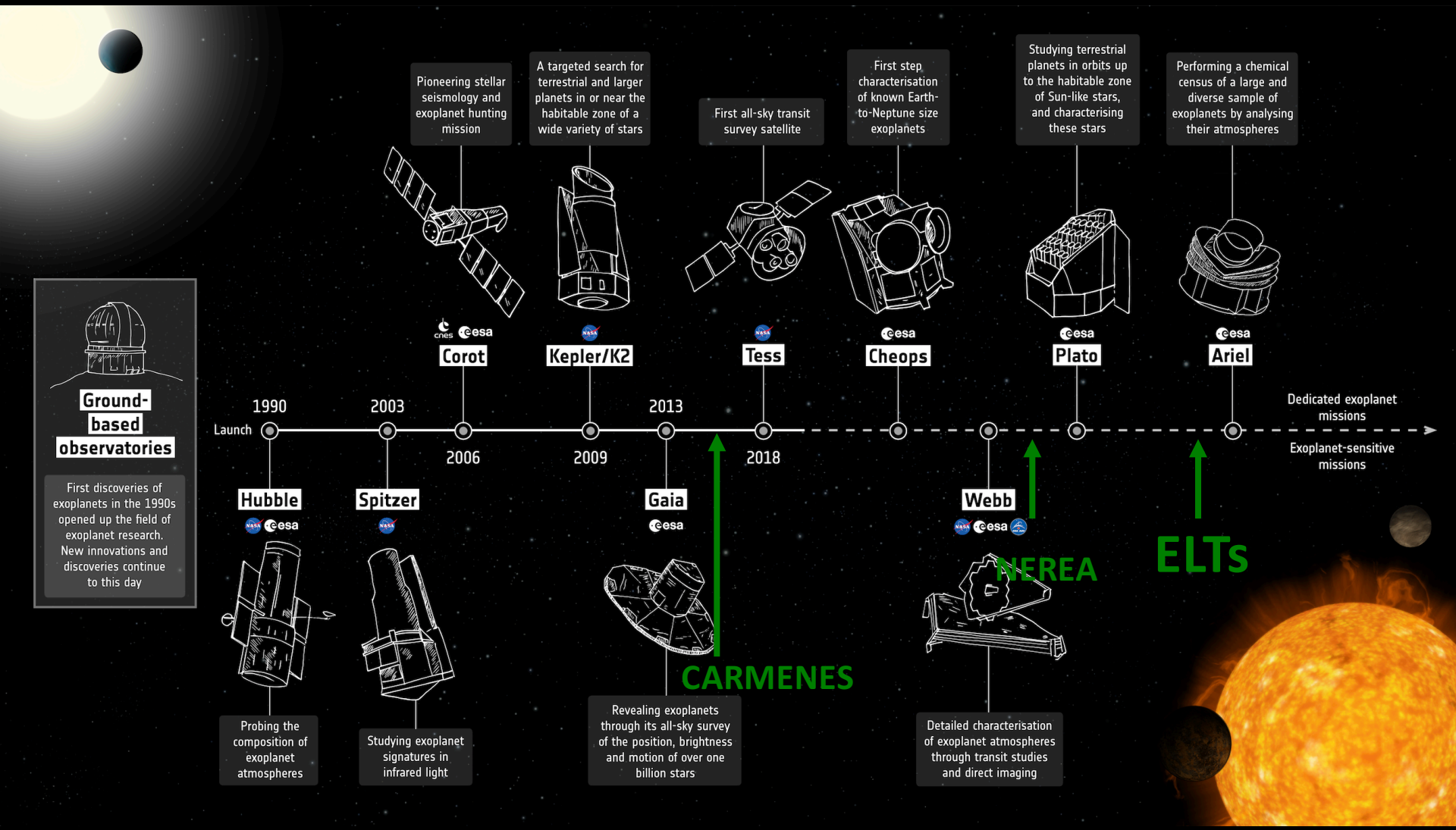
NEREA @ GTC

(Near EaRths and Exoplanet Atmospheres)

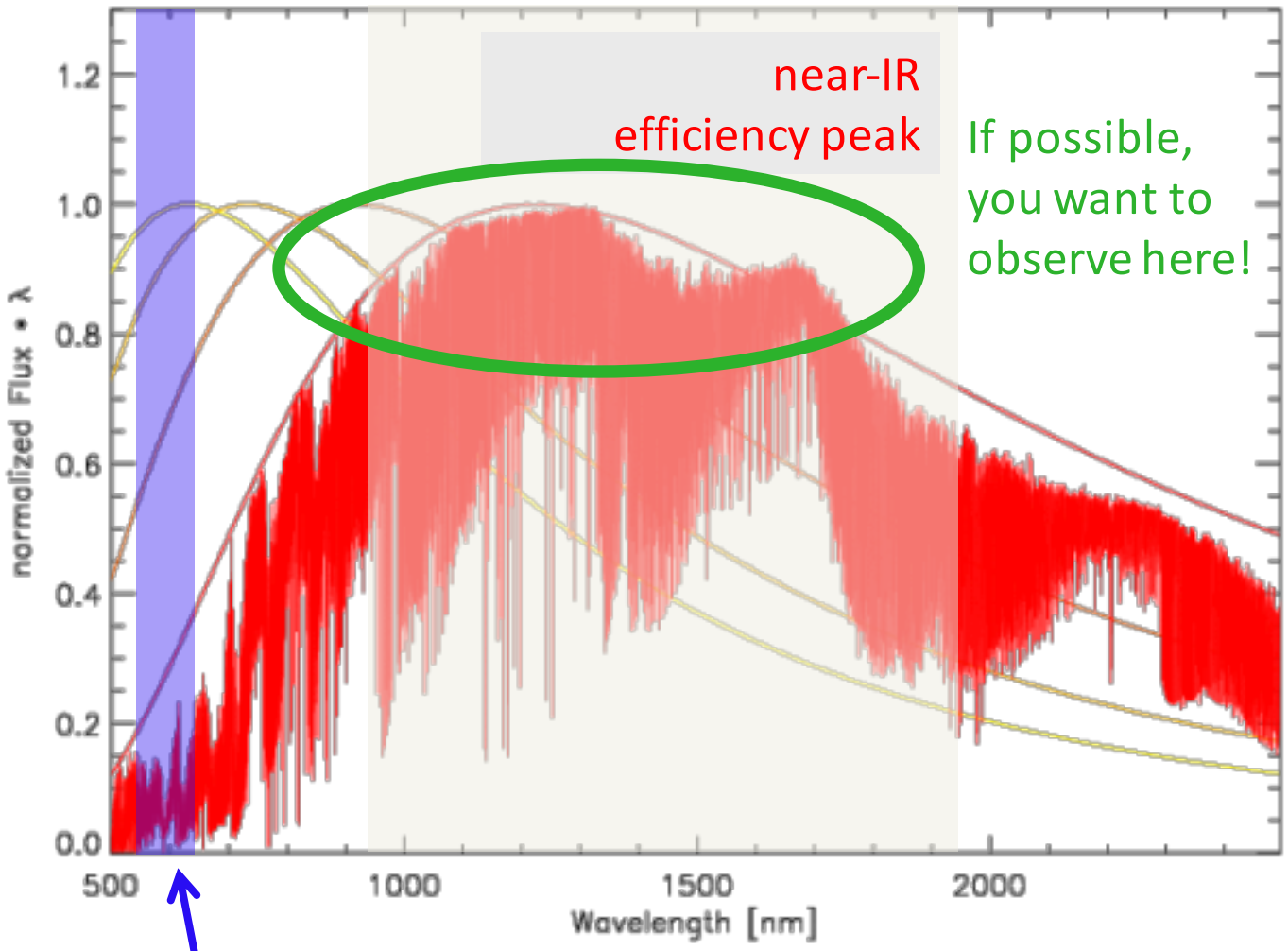
We propose an instrument concept based on a double science case for *exoplanets*

- Exploration of the nearest stars to Earth
- Characterization of atmospheres from Hot Jupiters to Super-earths

This spectrograph should become a common user instrument for a variety of science cases.


Ground-based observatories
First discoveries of exoplanets in the 1990s opened up the field of exoplanet research. New innovations and discoveries continue to this day
Launch
1990
2003
2006
2009
2013
2018
Dedicated exoplanet missions
Exoplanet-sensitive missions
Pioneering stellar seismology and exoplanet hunting mission
Corot
A targeted search for terrestrial and larger planets in or near the habitable zone of a wide variety of stars
Kepler/K2
First all-sky transit survey satellite
Tess
First step characterisation of known Earth-to-Neptune size exoplanets
Cheops
Studying terrestrial planets in orbits up to the habitable zone of Sun-like stars, and characterising these stars
Plato
Performing a chemical census of a large and diverse sample of exoplanets by analysing their atmospheres
Ariel
Hubble
Probing the composition of exoplanet atmospheres
Spitzer
Studying exoplanet signatures in infrared light
Gaia
Revealing exoplanets through its all-sky survey of the position, brightness and motion of over one billion stars
CARMENES
Webb
Detailed characterisation of exoplanet atmospheres through transit studies and direct imaging
NEREA
ELTs

The SED of M-Type Stars



"classical" *visible light* RV instruments

Proposed Instrument

Broad Spectral range 800 -1700 nm

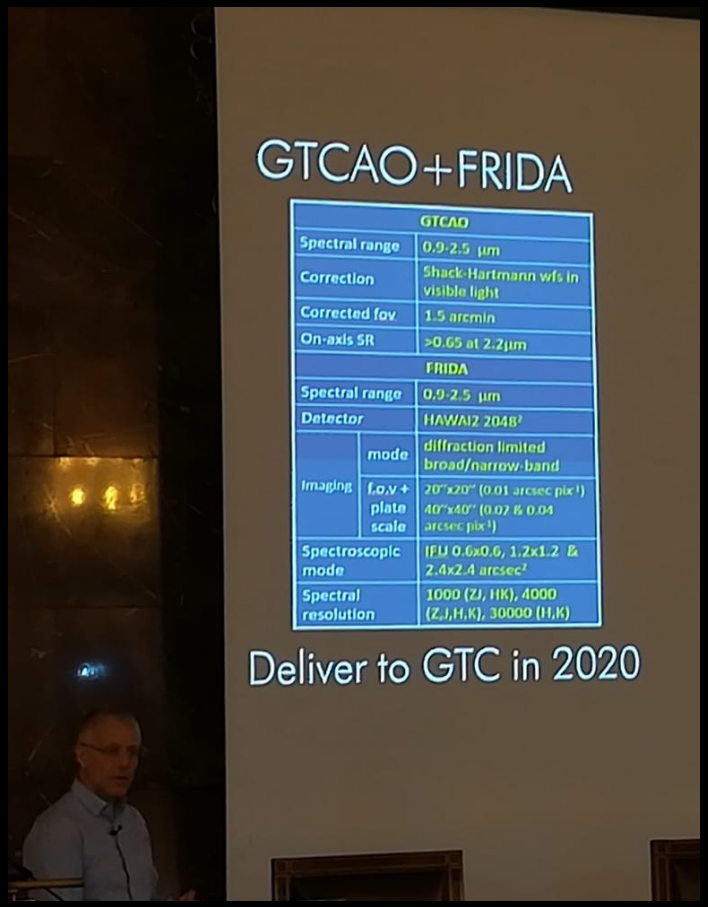
Spectral Resolution R > 70,000 up to 110,000

Stability 1 m/s

Compact design (behind AO system)

“Fast” construction and development

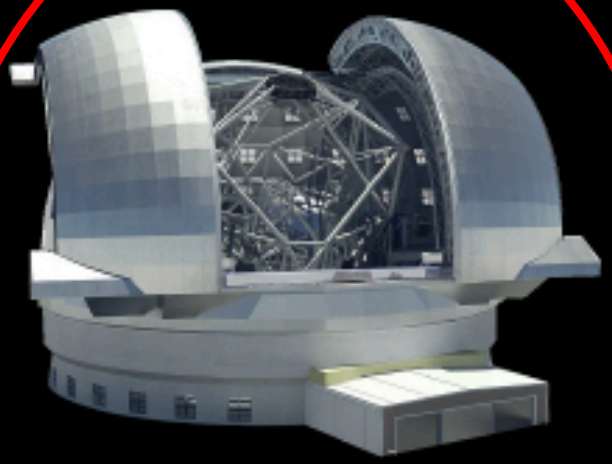
Common user instrument for a variety of science cases.



HIRES @ ELT

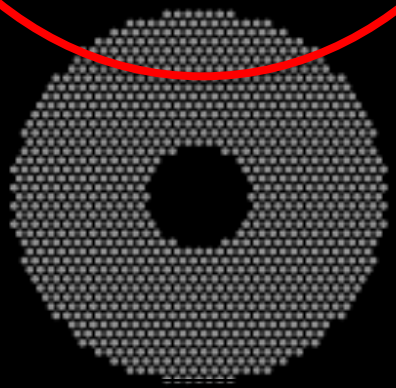
Atmospheric characterization via High-Res Spec (FOV, +AO) 2025-2030

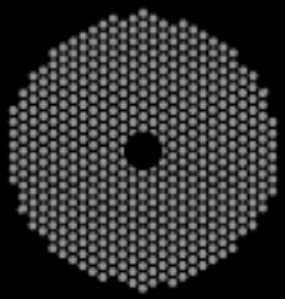
GIANT MAGELLAN TELESCOPE



EUROPEAN EXTREMELY LARGE TELESCOPE

THIRTY METER TELESCOPE





The HIgh-RESolution Spectrograph for ELT
HIRES

Consortium of 12 Countries (Italian PI) to build a high spectral resolution spectrograph:

- R = 100,000
- Spectral range 0.36-2.5 micron
- CODEX + SIMPLE Concept

España: Liderado por IAC (R. Rebolo) y E. Palle chair the exoplanet WG

SCIENCE CASES

- ***Exo-planet atmospheres and signatures of life***
- Planetary debris on the surface of white dwarfs
- Protoplanetary and proto-stellar disks
- Galactic archaeology to the Local Group and beyond
- Evolution of galaxies
- Stellar and AGN
- Chemical signatures during the epoch of re-ionization
- Fundamental physics
- ...

Exoplanet Atmospheres with ELTs

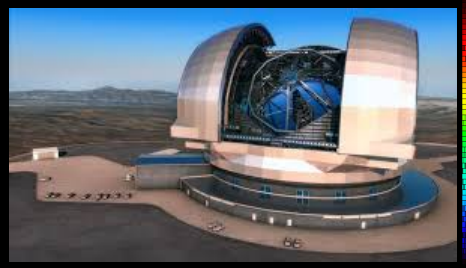
This science case involves ***two separate techniques***:

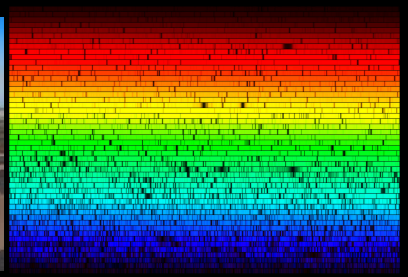
a) Transmission spectroscopy

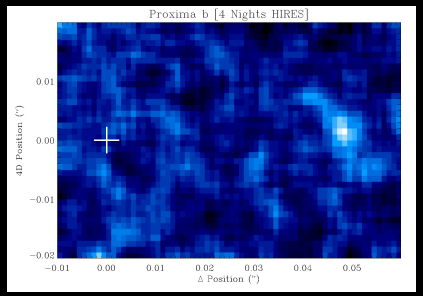
b) Direct detection of the planet's reflected light.

The TRLs defined for instruments such as HIRES enable both simultaneously, but it must be distinguished here than *only the former relies on the need of an AO system*.

Both cases involve high-resolution spectrographs (R>100,000) in the near-IR





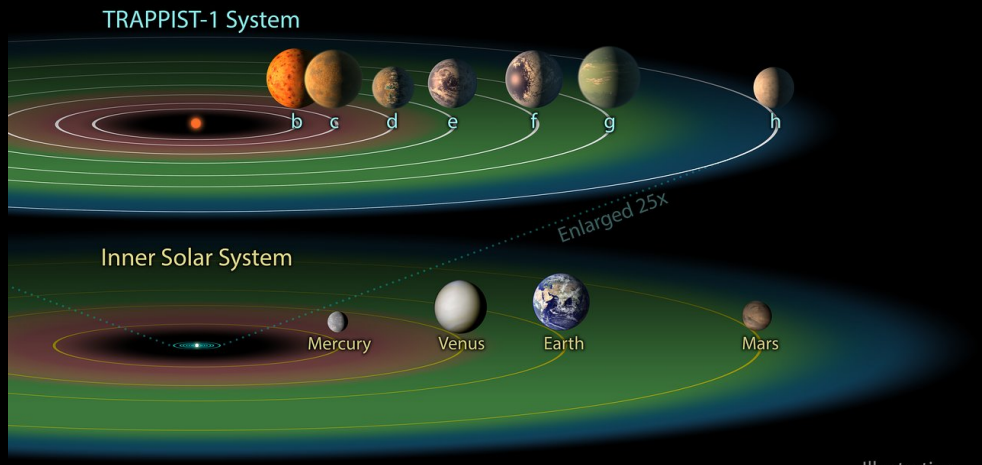


Exoplanet Atmospheres : transmission spectroscopy

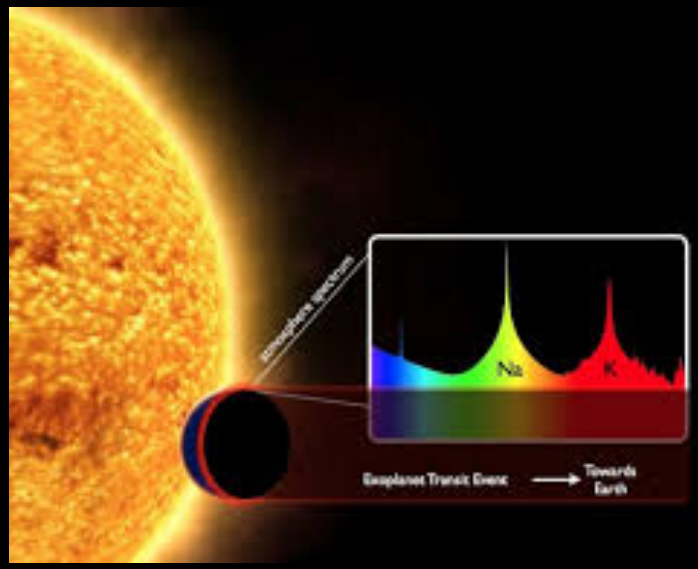
M dwarf Trappist 1 b & c:

- 1.3-1.7 um H_2O band at an SNR of 6 in two transits
- 0.9-1.1 um H_2O band in 4 transits
- CO_2 in 4 transits.
- molecular oxygen detected in 25 transits.

For these planets, the transit duration is less than 1 hour.



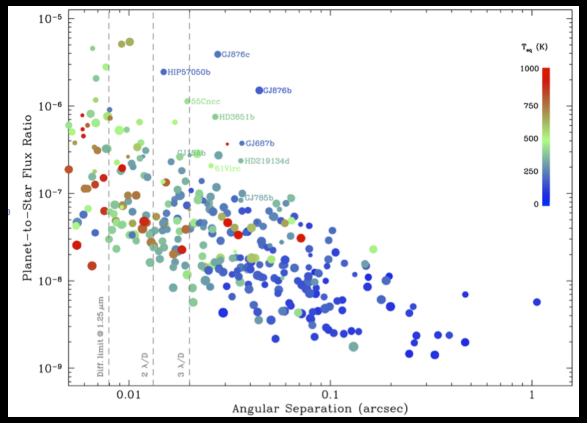
Illustration

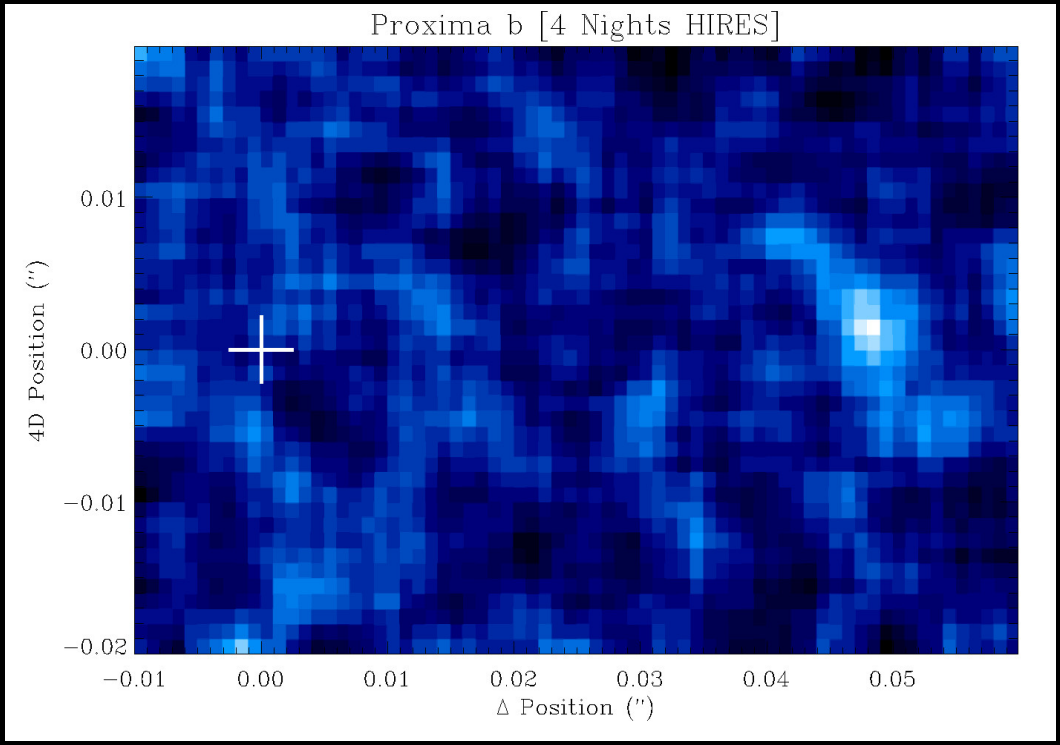


Exoplanet Atmospheres: Reflected light

HIRES: AO+ IFU

Simulated reflected light cross-correlation signal of the direct surroundings of Proxima, showing Proxima b at 48 mas in 4 nights, at the 8 sigma level



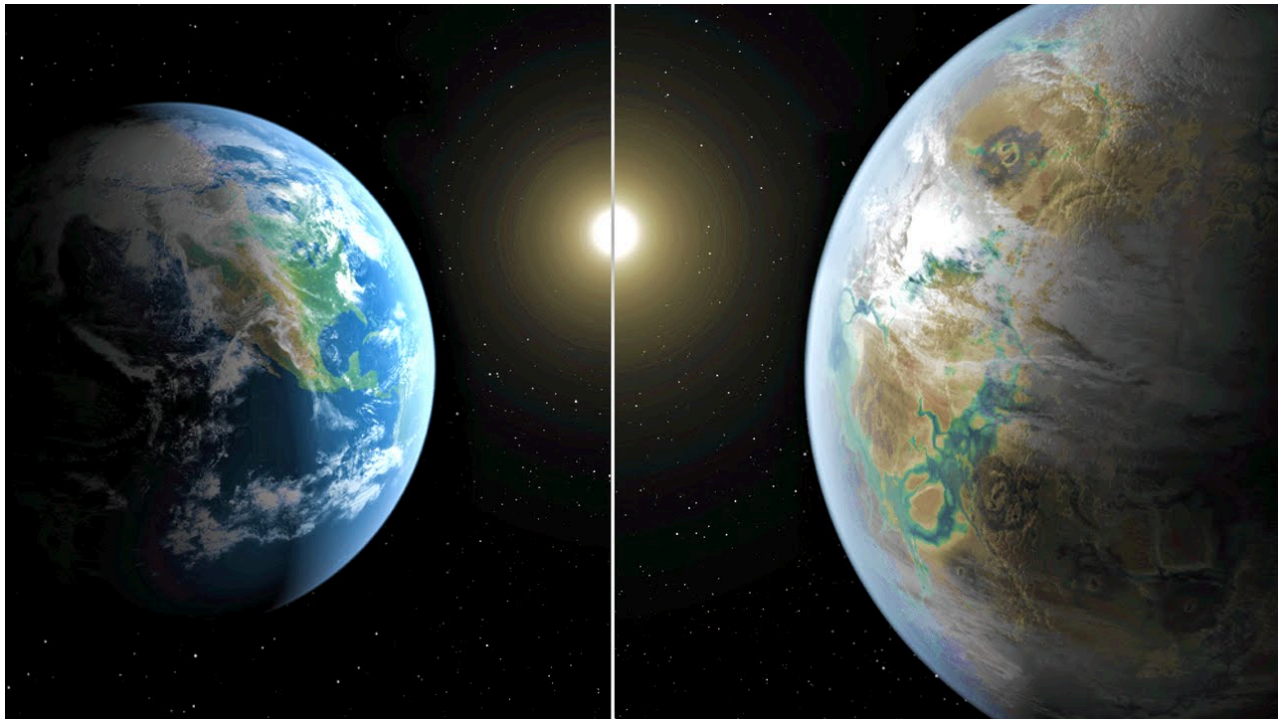


HIRES: The ExoEarths Characterizer Experiment?

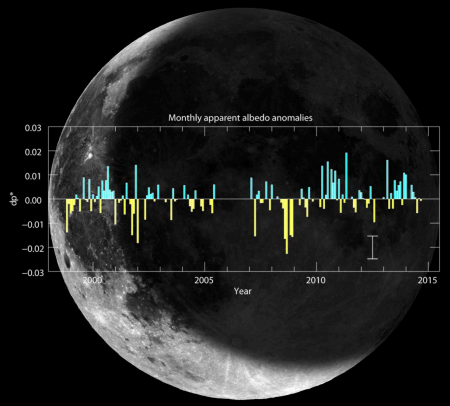
Given current knowledge and approaches, and with due caution:

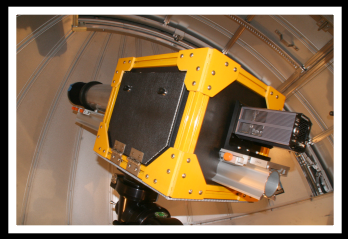
HIRES is the only instrument in design phase that is able to measure biomarker gaseous compositions in earth-like planets

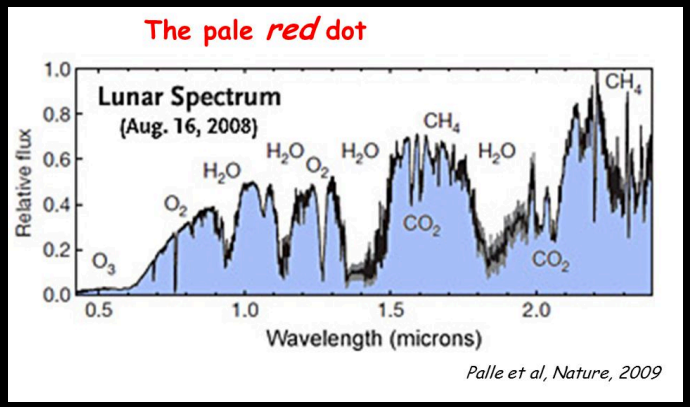
- JWST might come close with Trappist1-like systems
- Other ELTs might come short on photons?



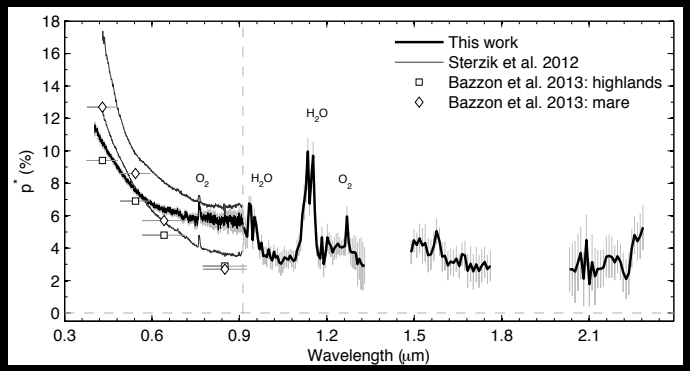
Astrobiologia

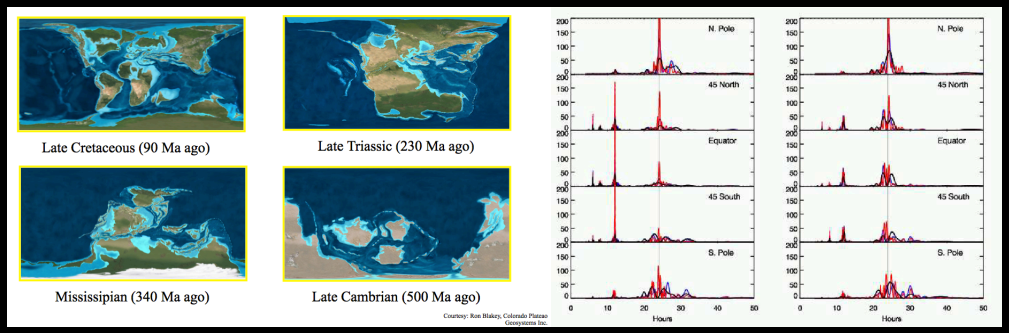


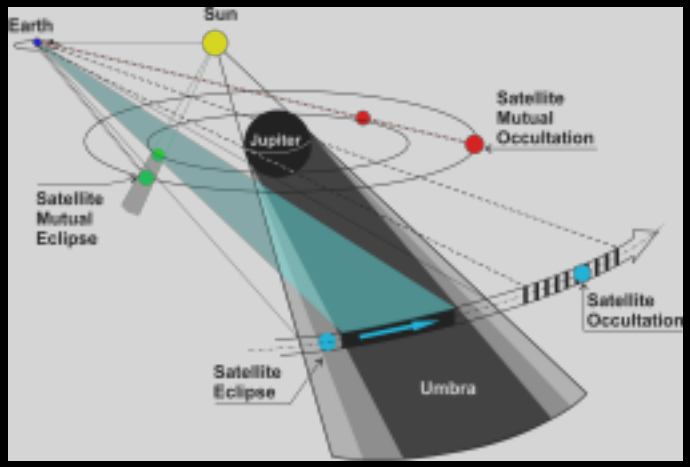


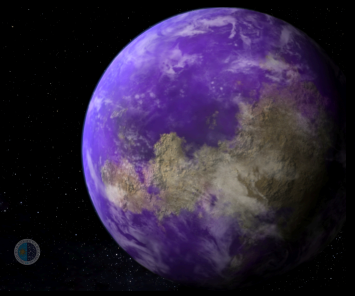


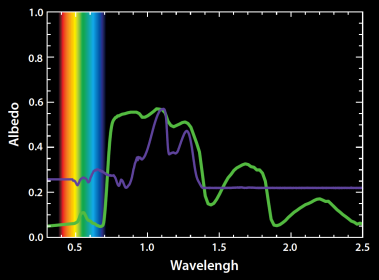
Palle et al, Nature, 2009

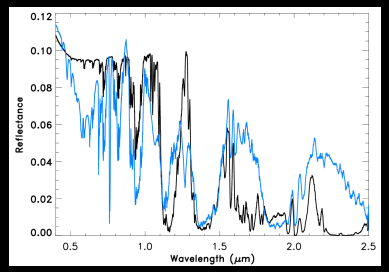













Thanks !!