Council of the
European Union

Brussels, 25 June 2024
(OR. en)

11541/24

ESPACE 64
INTER-REP 70

COVER NOTE

Subject:	SPECULOOS project and recent results from James Webb Space Telescope observations - Powerpoint presentation (Space WP meeting 25.06.2024)

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TRAPPIST-1 : the small star and the 7 earths

Emmanuël Jehin
STAR Institute (Université de Liège, FNRS)

LIÈGE université

Credits: NASA

Bruxelles 25/06/24

A long history with Space Sciences

LIÈGE université

belspo

ESO

AMOS

Raphael Liégeois

Other Liège specialties…

Liège

Waffles… and boulets !

Are we alone in the Universe ?

Our world… a planet among others

Is our Blue Planet unique ?

A rocky planet with water (70%)

Credits: NASA

… hosts a complex biosphere

Where are the Martians ?

Credits: NASA

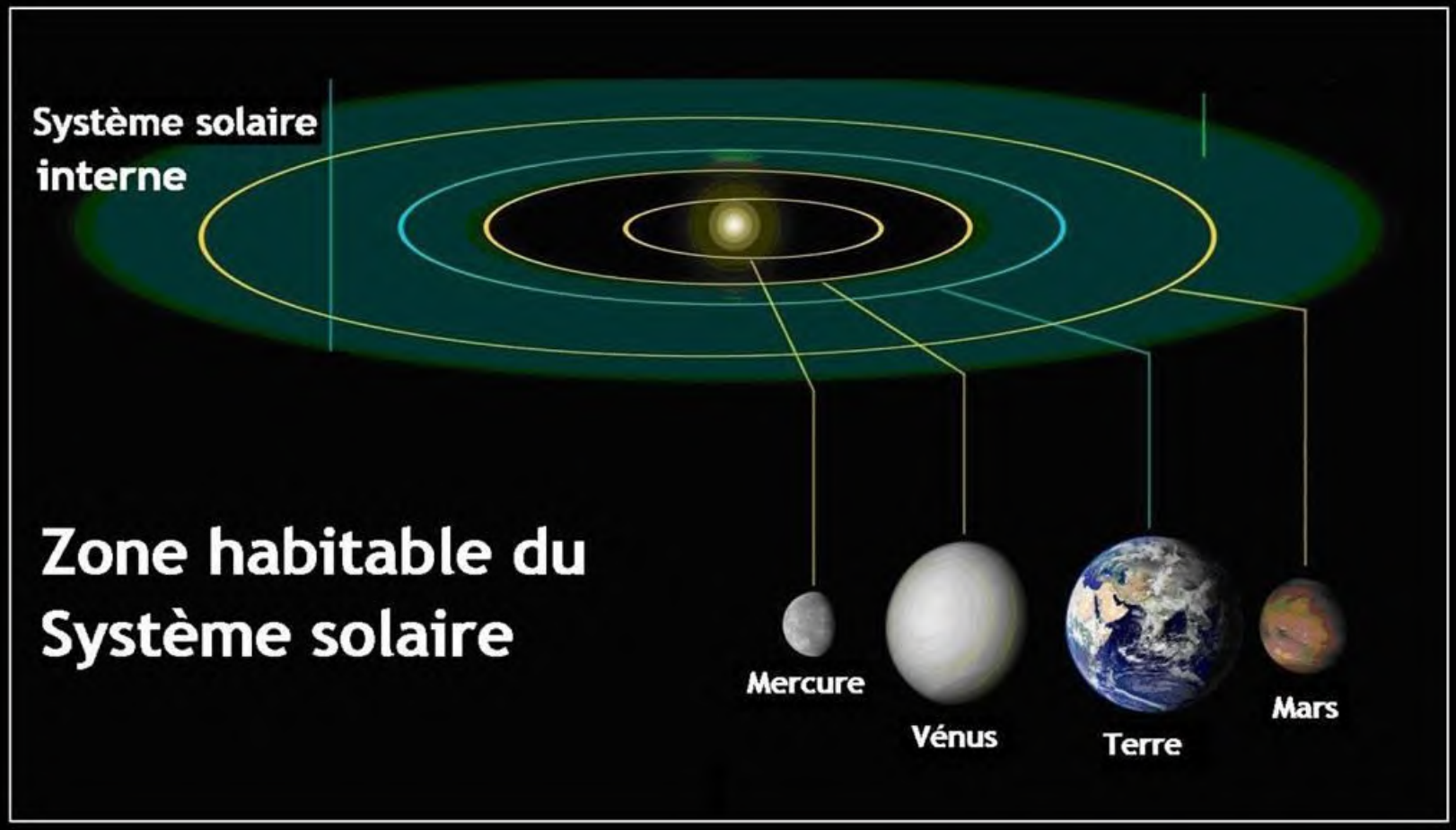
« Mars Attack » (Tim Burton, 1996)

Habitability conditions

for a planet ?

Astro-biology

« The habitable zone »



Aim to the stars...


The Milky Way… our Galaxy
~300 billion stars!

1995:The discovery of the first Exoplanet !

A Jupiter-mass companion to a solar-type star

Michel Mayor & Didier Queloz

Geneva Observatory, 51 Chemin des Maillettes, CH-1290 Sauverny, Switzerland

The presence of a Jupiter-mass companion to the star 51 Pegasi is inferred from observations of periodic variations in the star's radial velocity. The companion lies only about eight million kilometres from the star, which would be well inside the orbit of Mercury in our Solar System. This object might be a gas-giant planet that has migrated to this location through orbital evolution, or from the radiative stripping of a brown dwarf.

Didier Queloz and Michel Mayor
!! NOBEL PRIZE 2019 !!

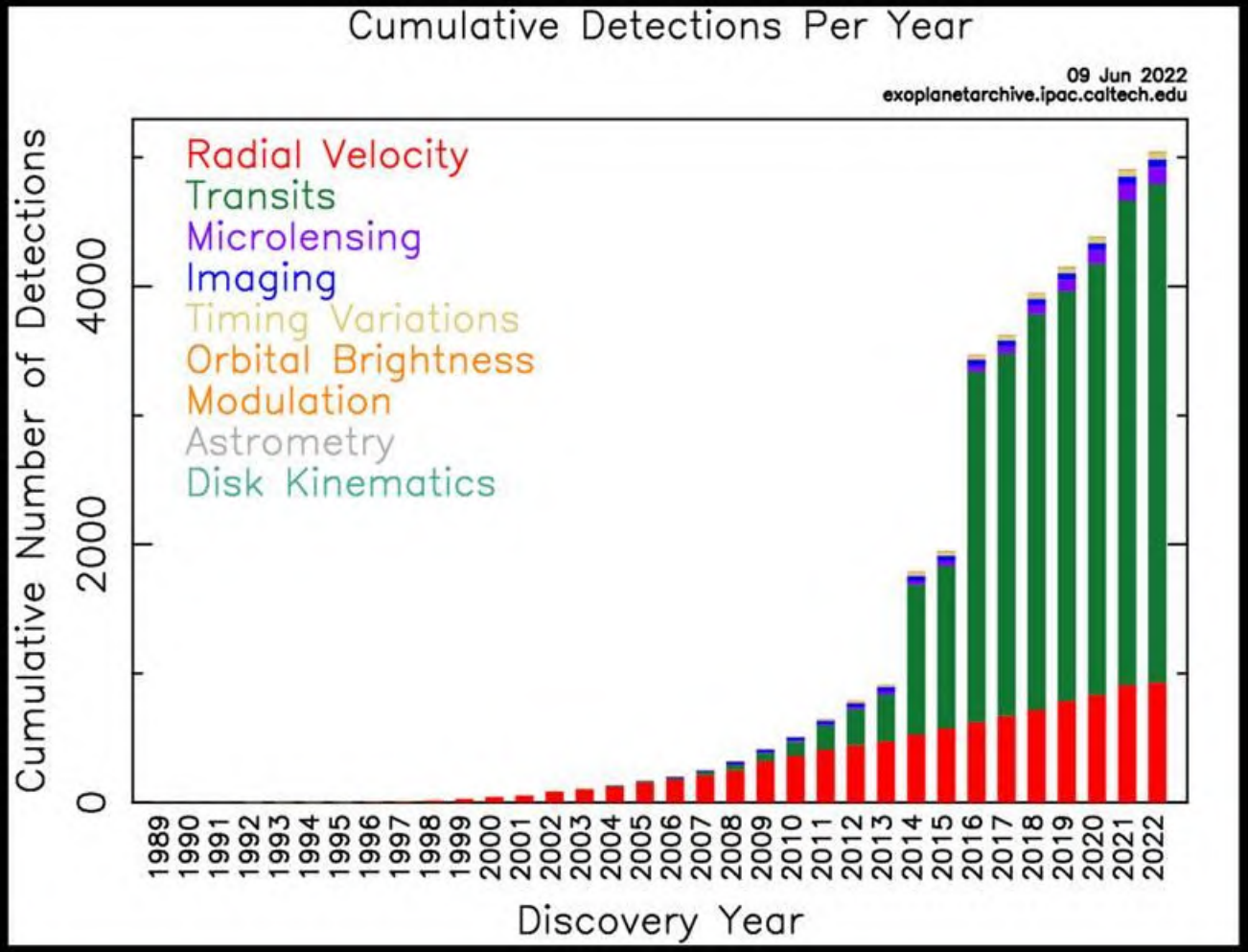
51 Peg : a hot jupiter close to its sun

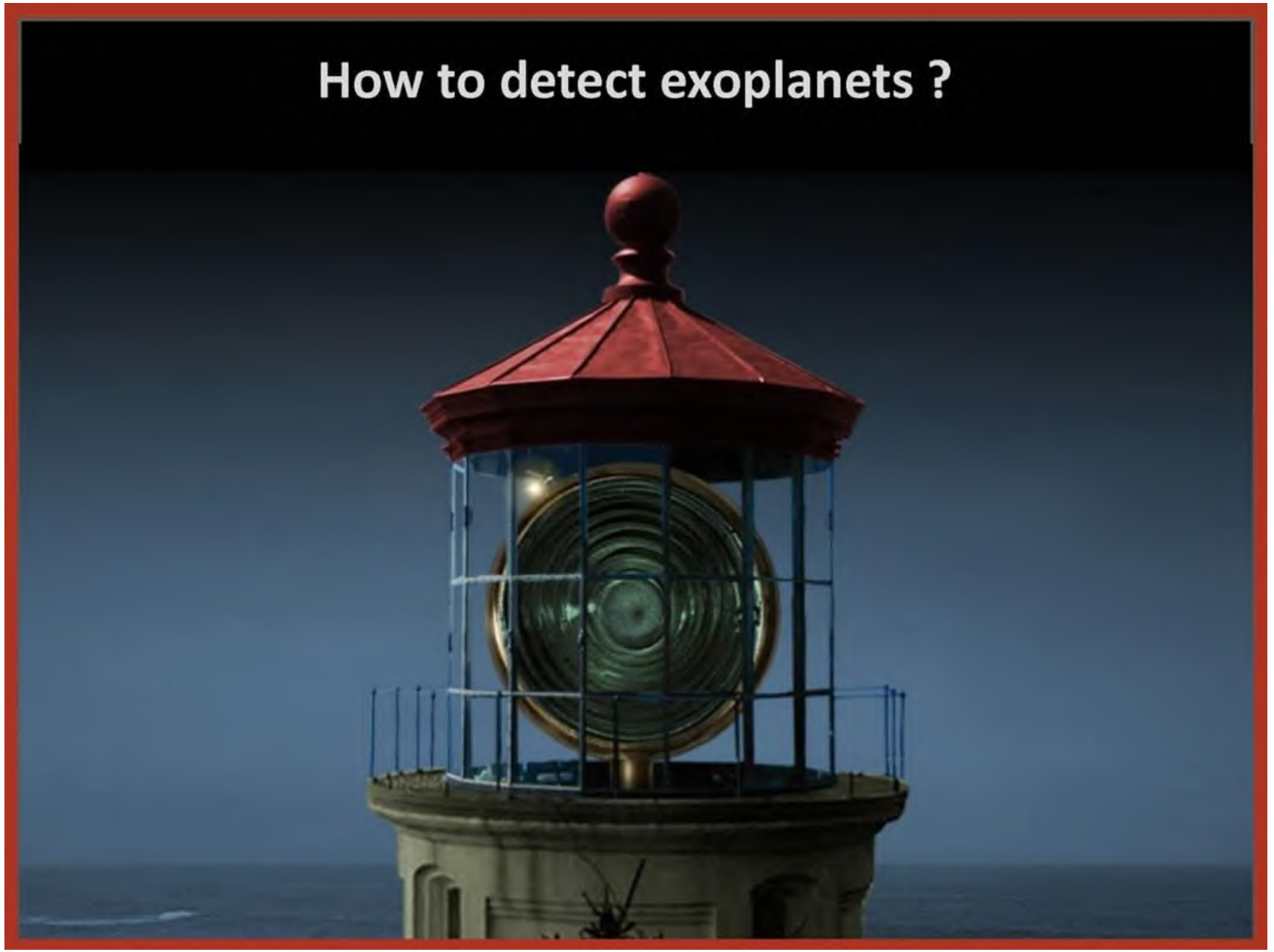
The hunt of exoplanets was open !

on the ground and in Space...

5339 exoplanets and 937 systems

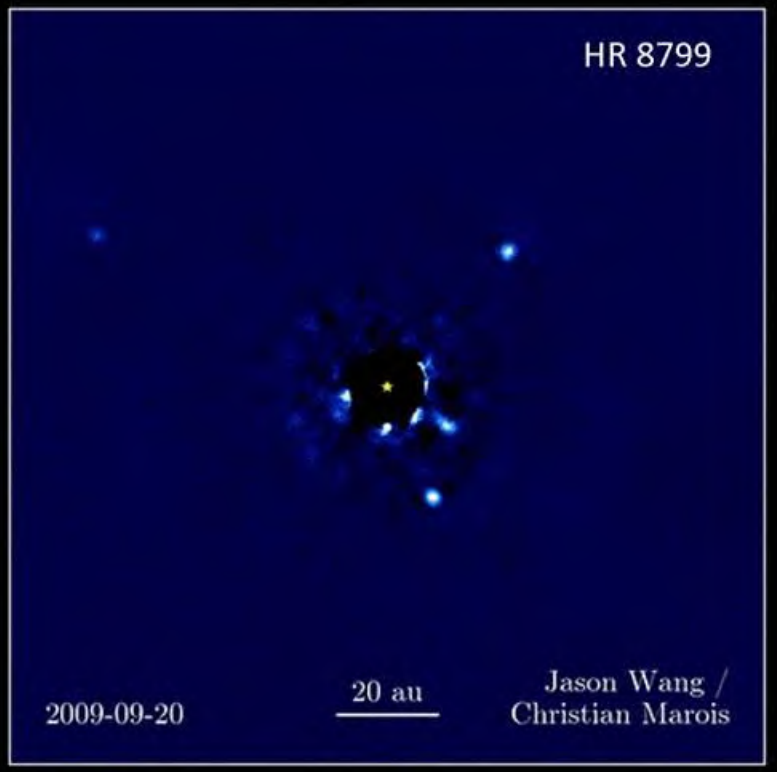
And this is only the beginning...



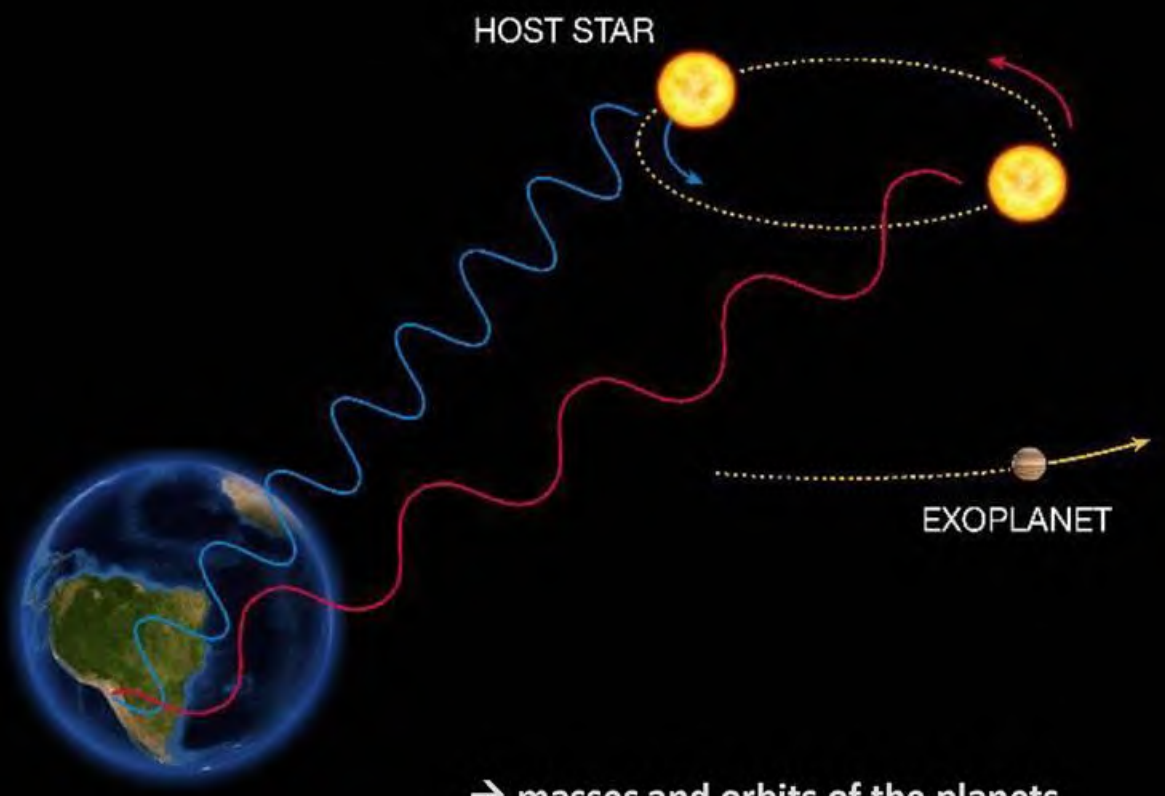

How to detect exoplanets ?


The exoplanet is lost in the star light!

Direct imaging

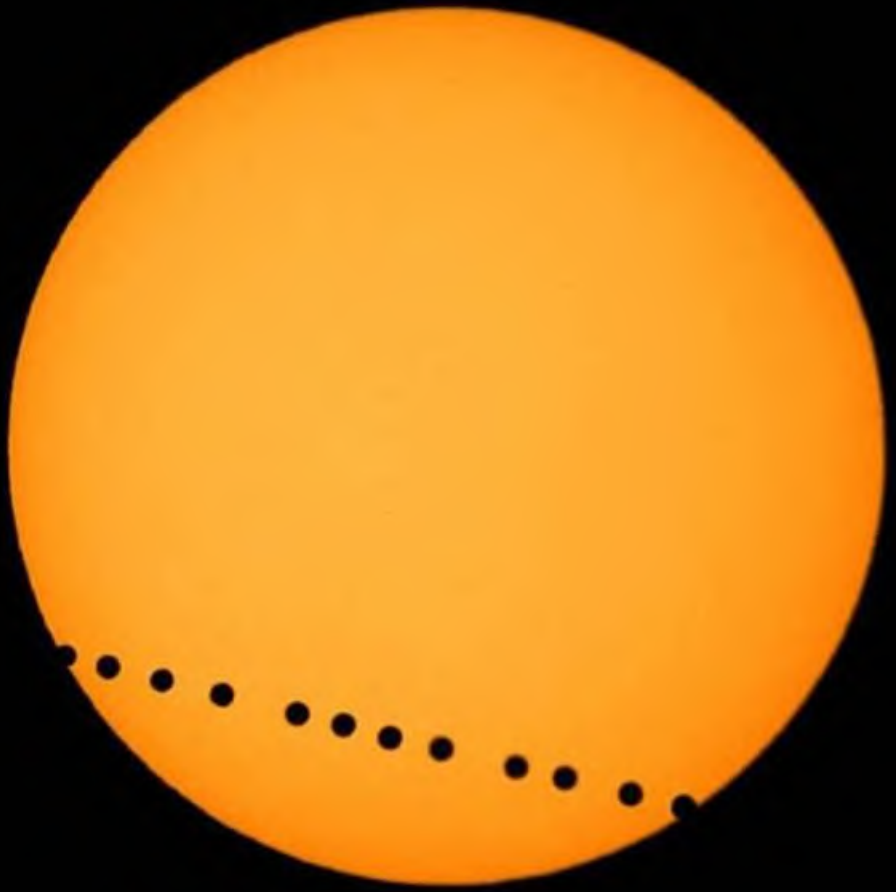


The radial velocity method

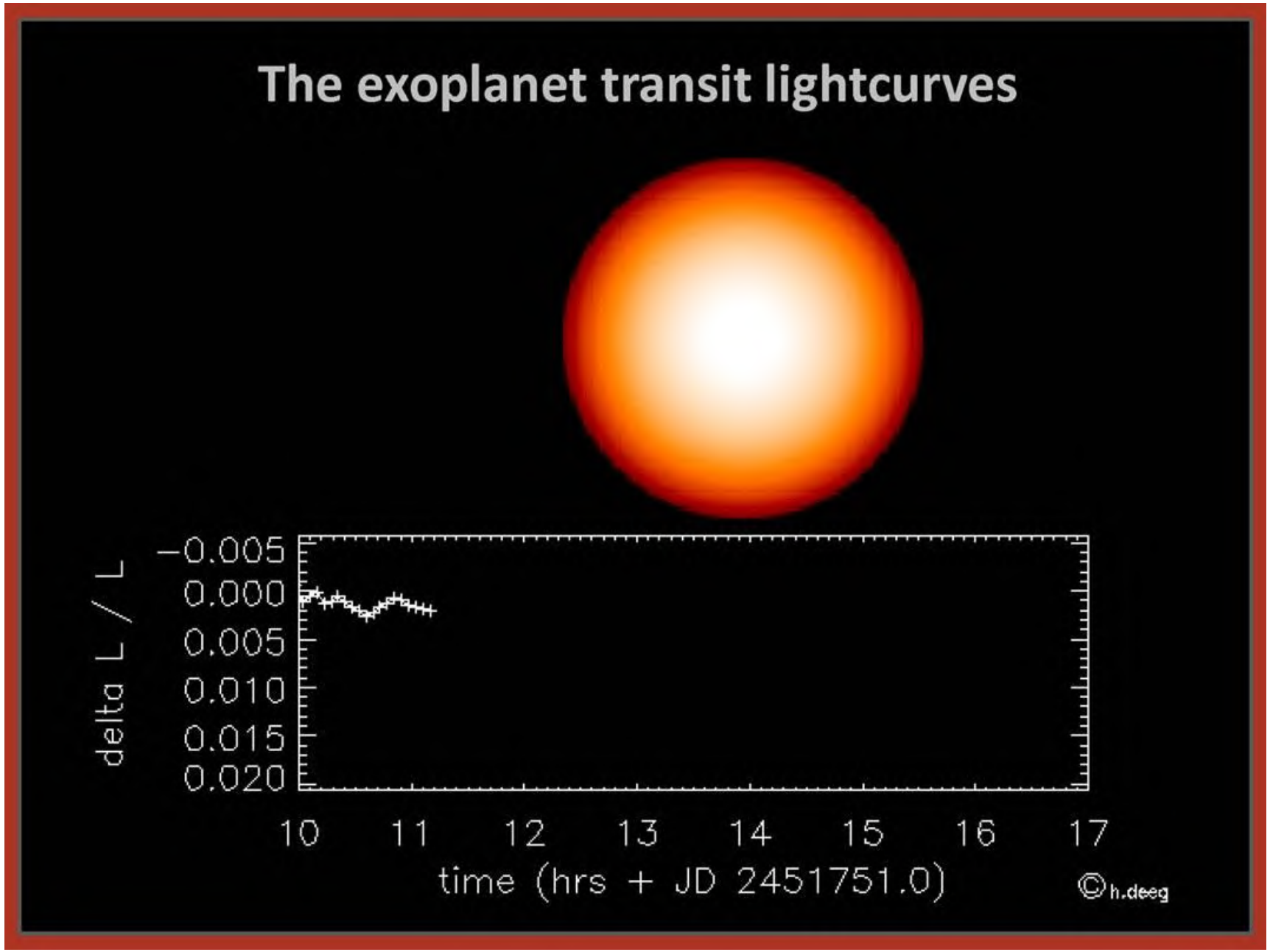


→ masses and orbits of the planets

The transit method



The transit of Vénus in front of the Sun (2012)


The exoplanet transit lightcurves
delta L / L
−0.005
0.000
0.005
0.010
0.015
0.020
10
11
12
13
14
15
16
17
time (hrs + JD 2451751.0)
©h.deeg

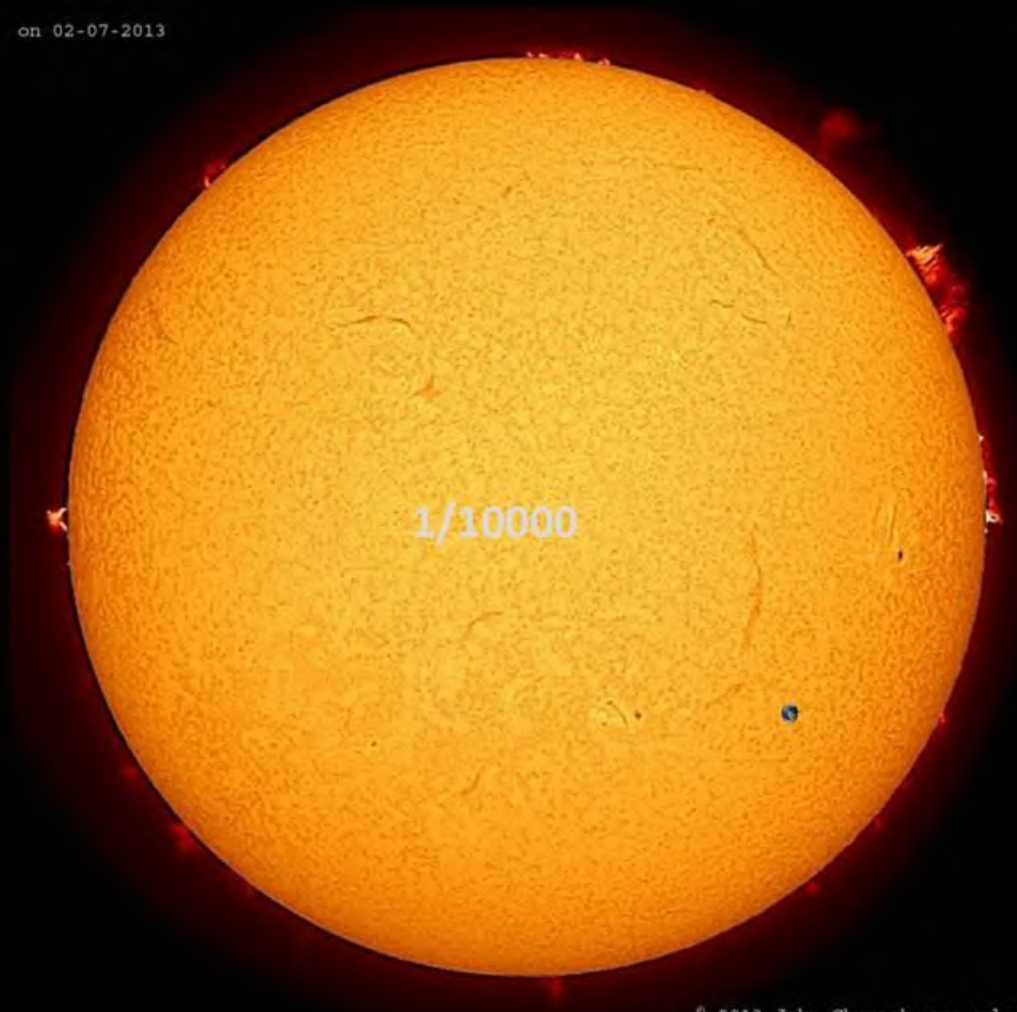
TRAPPIST : TRAnsiting Planets and PlanetesImals Small Telescope

Credits: E. Jehin


TRAPPIST-Sud at La Silla (ESO)
2010 (Chili)
ESO

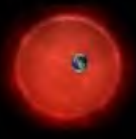
TRAPPIST-North 2015 (Morroco)

The ultracool red dwarfs

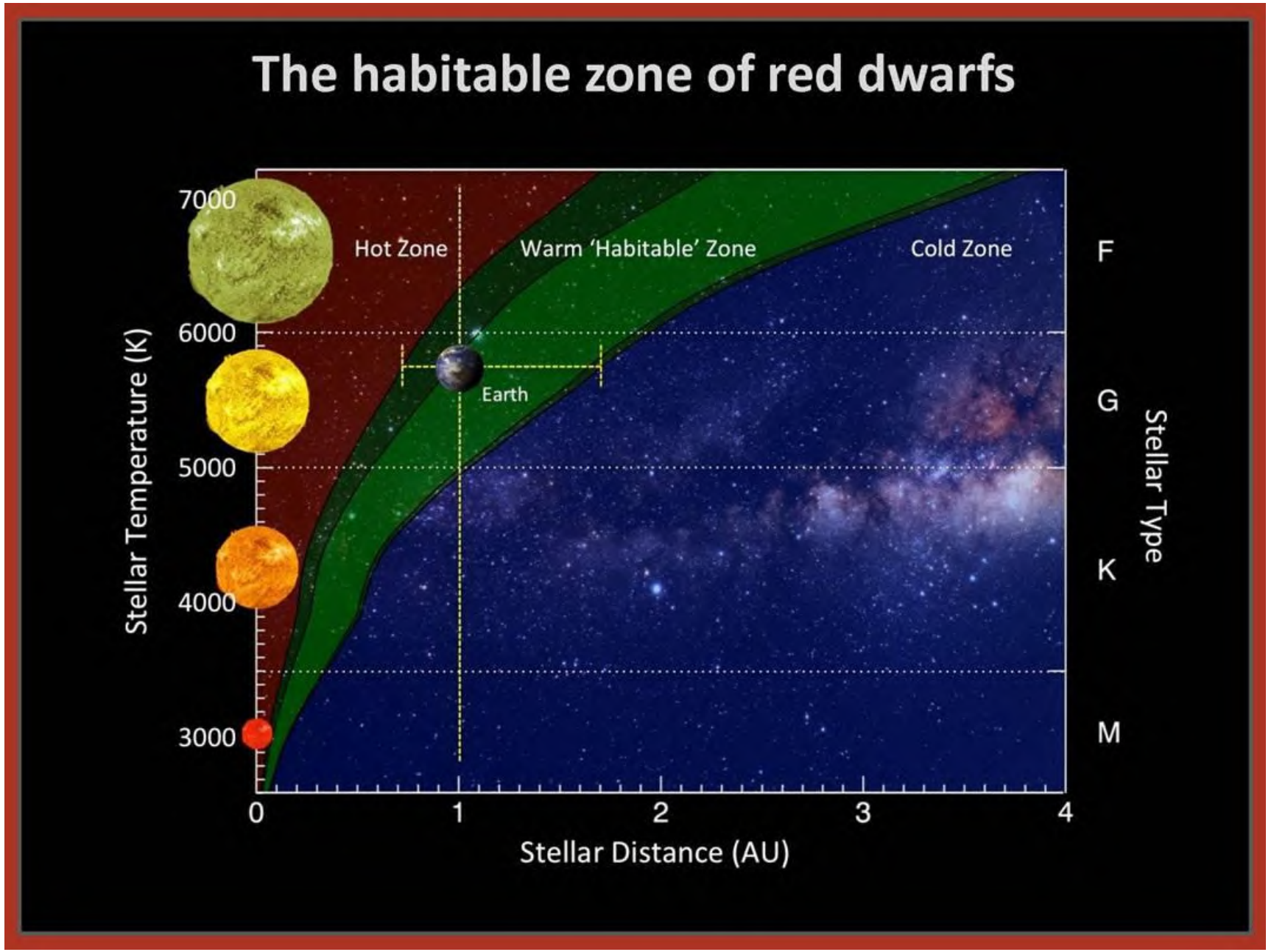


Michael Gillon

1/100



10x smaller

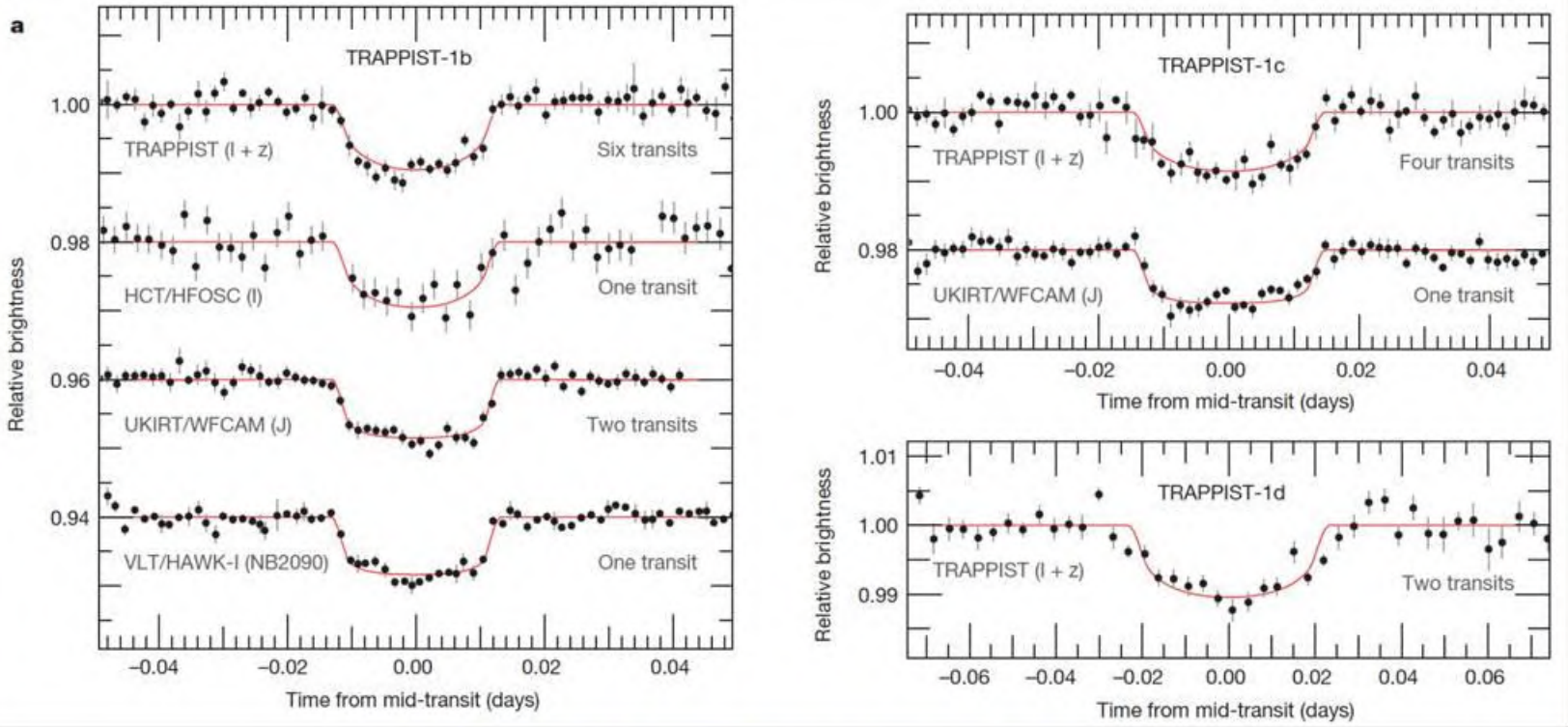

The habitable zone of red dwarfs
Hot Zone
Warm 'Habitable' Zone
Cold Zone
Earth
7000
6000
5000
4000
3000
Stellar Temperature (K)
0
1
2
3
4
Stellar Distance (AU)
F
G
K
M
Stellar Type

TRAPPIST-1: first transits

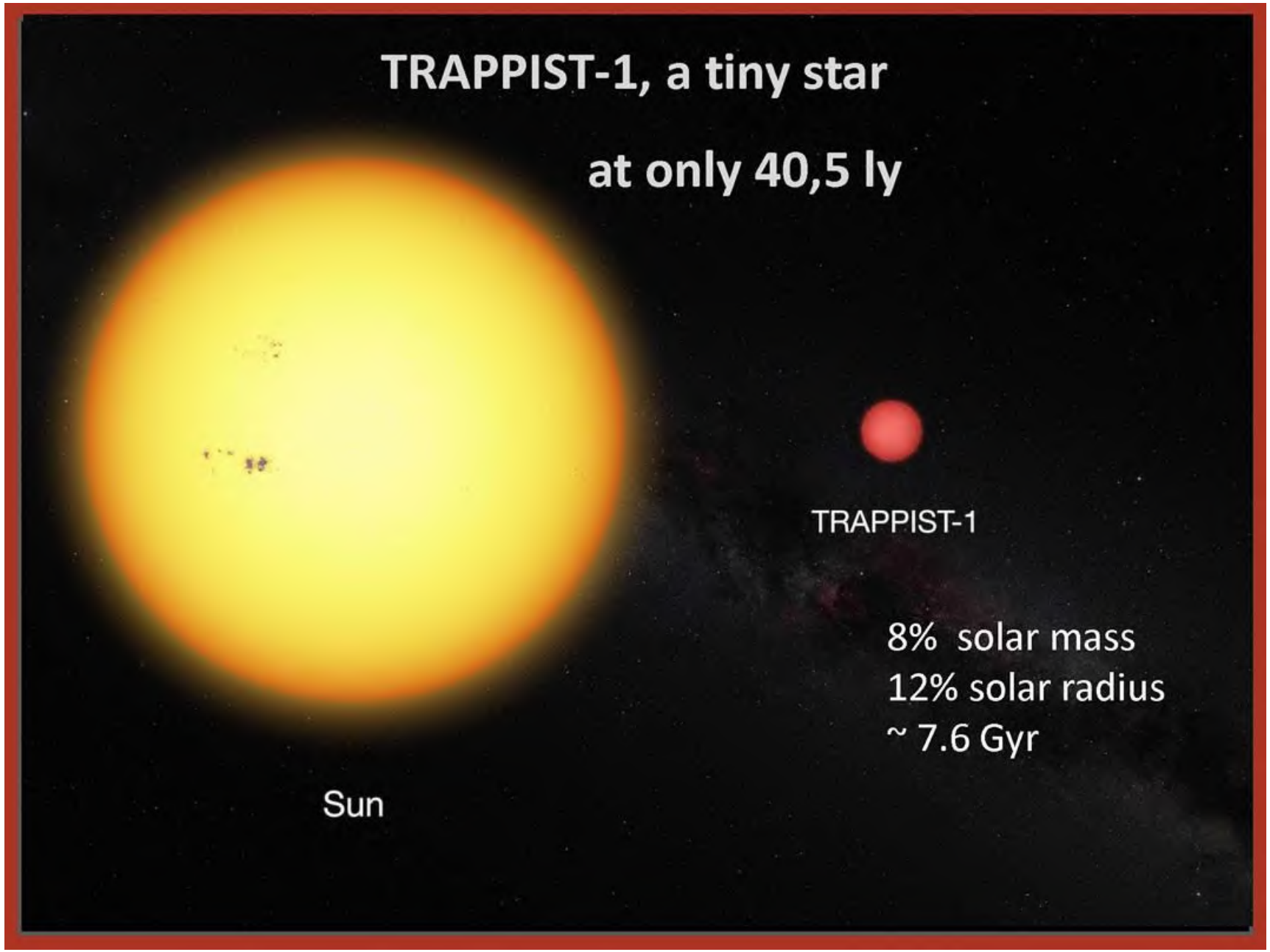
Three terrestrial planets with orbits of

1.5, 2.4 and ~18 days

Gillon et al. Nature May 2016



Ultracool dwarf stars host planets !


TRAPPIST-1, a tiny star
at only 40,5 ly
TRAPPIST-1
8% solar mass
12% solar radius
~ 7.6 Gyr
Sun

2016 :intensive observing campaign

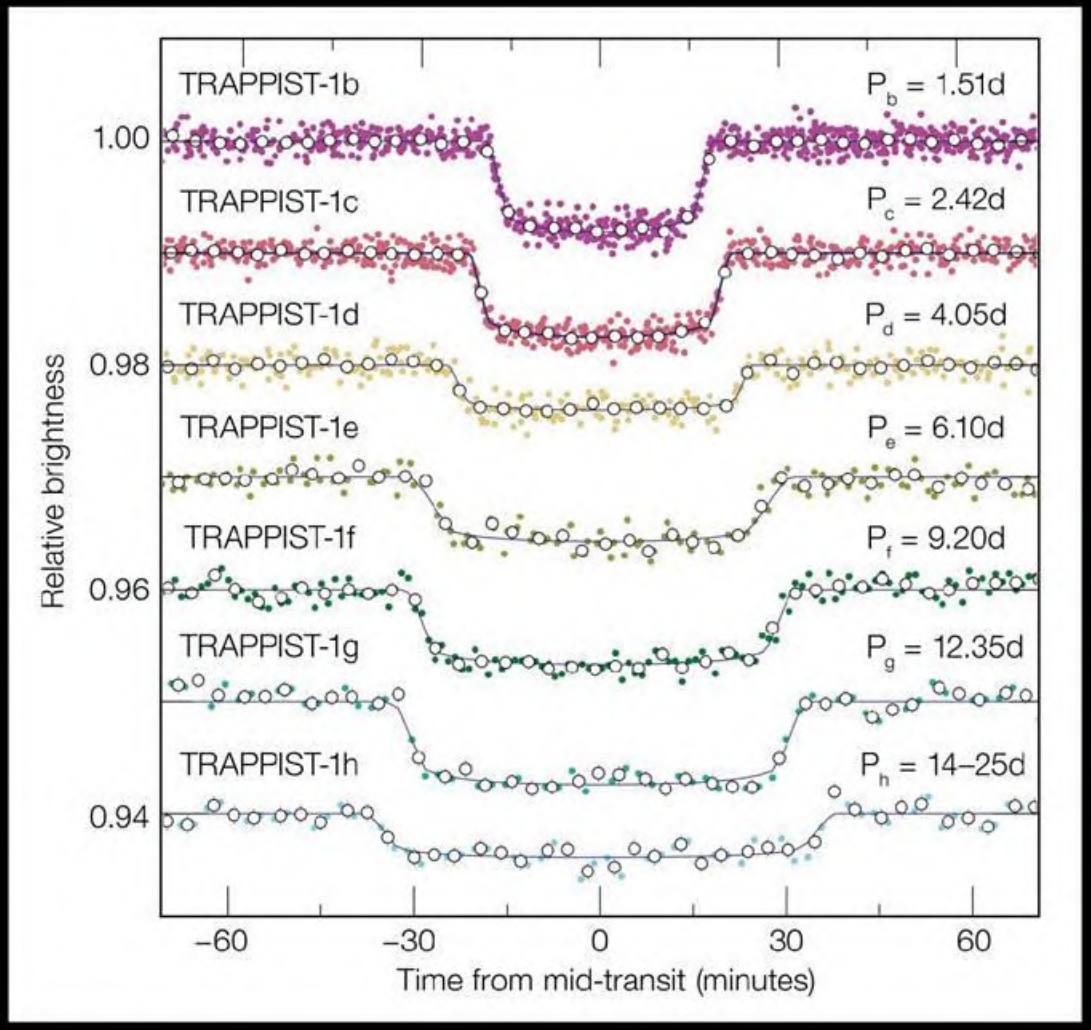
Détection of many new transits !



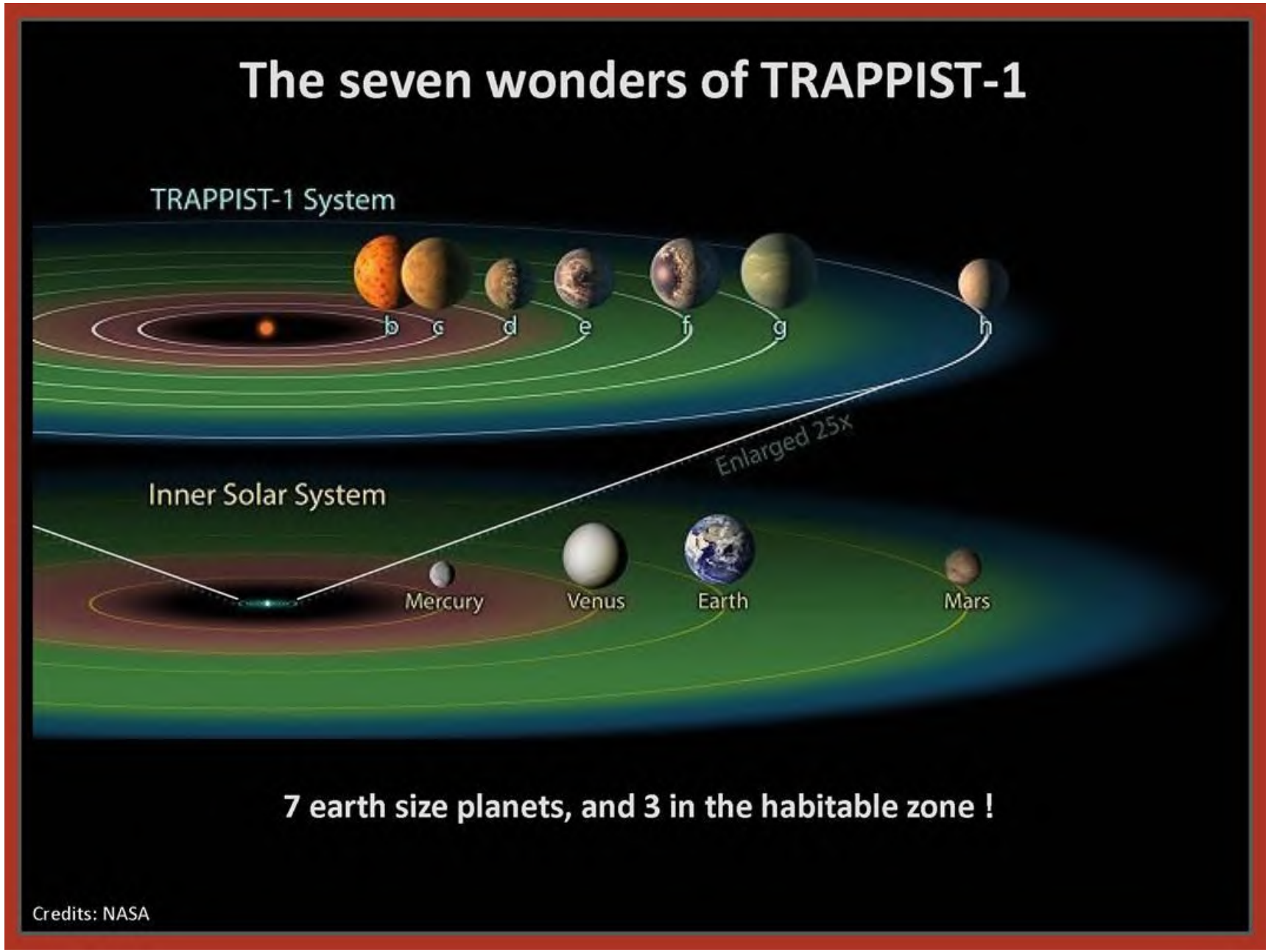





Seven Earth size rocky planets !



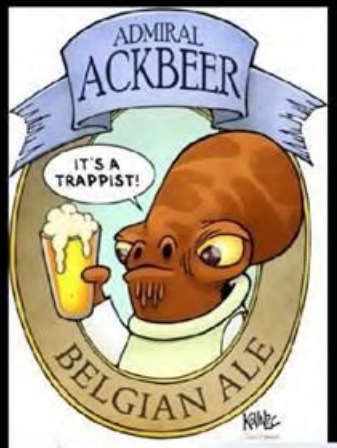
Gillon et al. Nature 2017
Gillon et al. Nature 2016

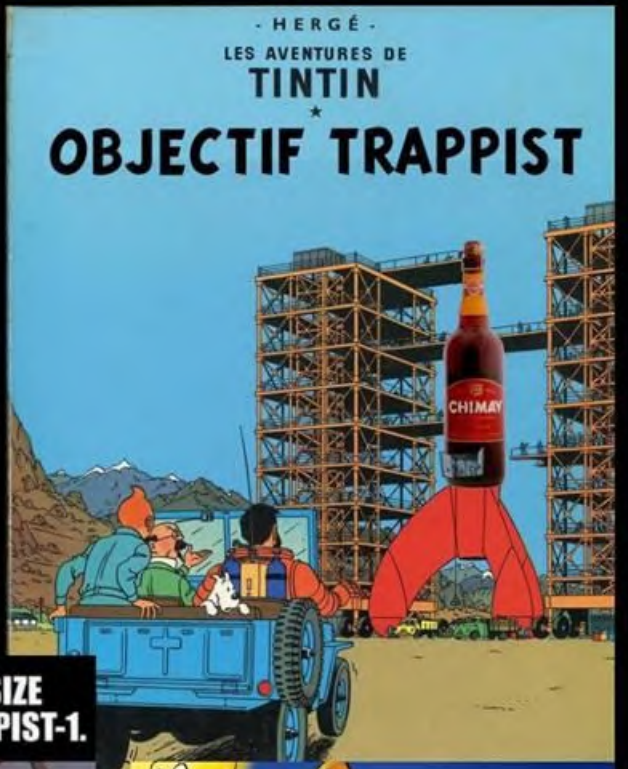

The seven wonders of TRAPPIST-1
TRAPPIST-1 System
b
c
d
e
f
g
h
Enlarged 25x
Inner Solar System
Mercury
Venus
Earth
Mars
7 earth size planets, and 3 in the habitable zone !
Credits: NASA

NASA press conference Washington DC

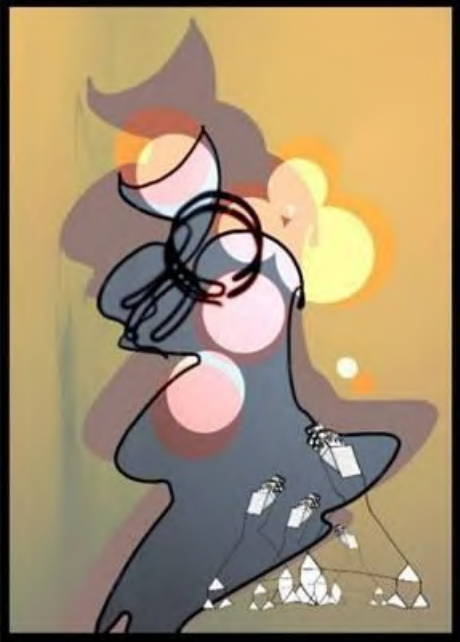
TRAPPIST-1 makes the headlines!

TRAPPIST-1 and its planets are a buzz!





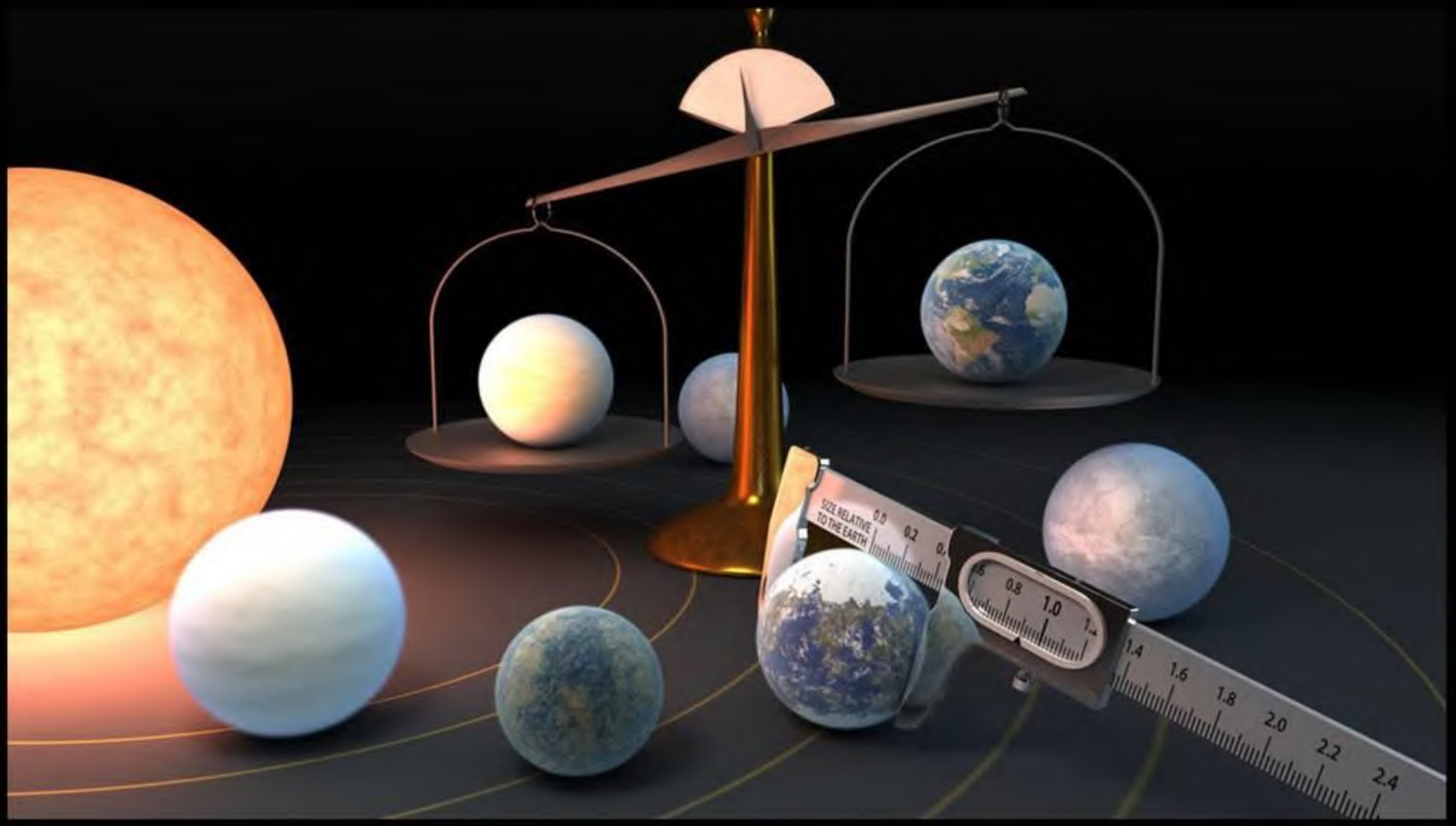
TRAPPIST-1 and arts



https://www.youtube.com/watch?v=9_5Yt1dp9yI
https://www.youtube.com/watch?v=GhqZhVeTud0

IN ISOLATION

New measurements



275 papers published and 1214 citations!

The TRAPPIST-1 planets portrait

Illustrations

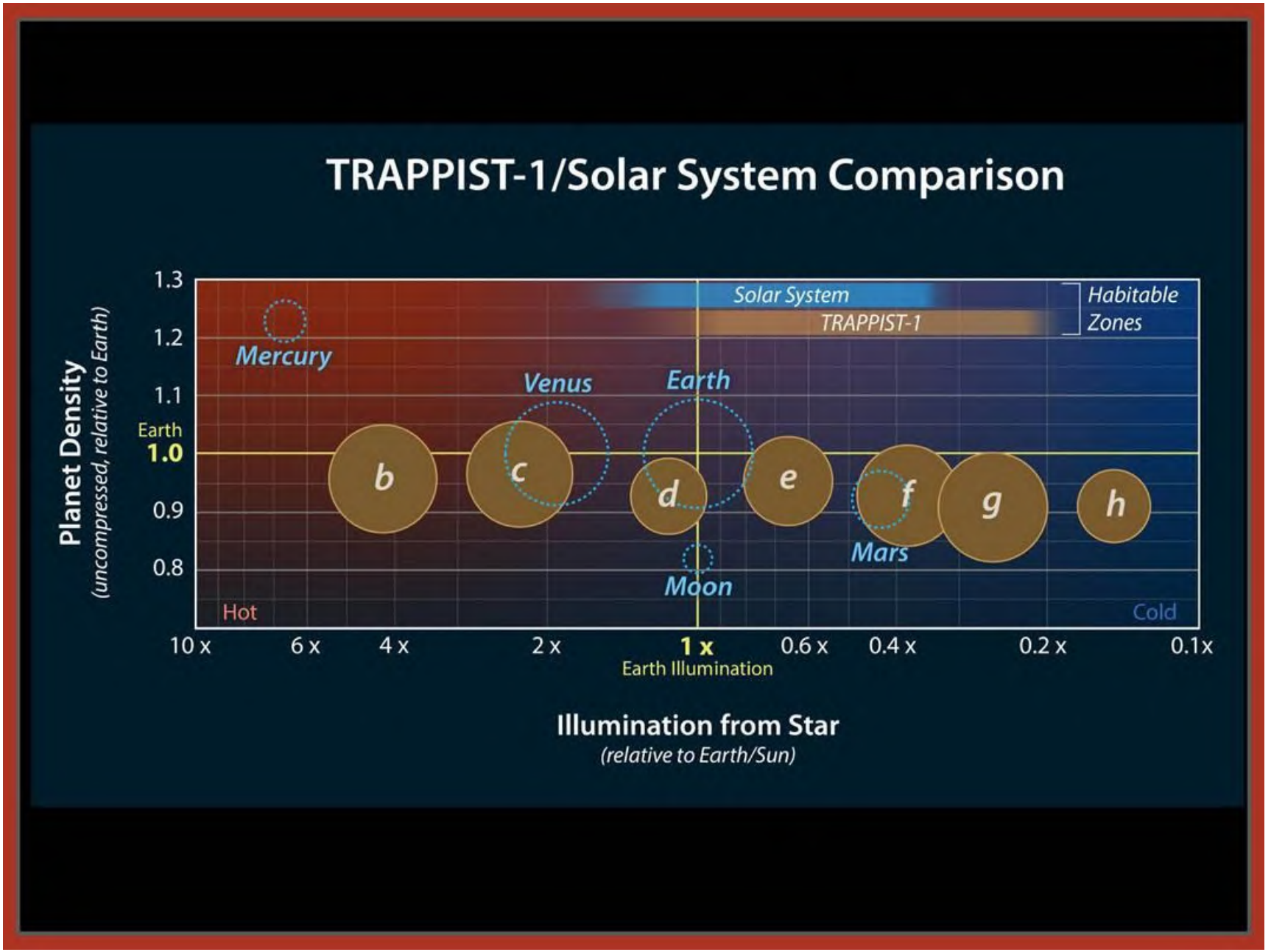
TRAPPIST-1 System
Feb. 2018

	b	c	d	e	f	g	h
Orbital Period	1.51 *days*	2.42 *days*	4.05 *days*	6.10 *days*	9.21 *days*	12.35 *days*	18.77 *days*
Distance to Star	0.0115 *AU*	0.0158 *AU*	0.0223 *AU*	0.0293 *AU*	0.0385 *AU*	0.0469 *AU*	0.0619 *AU*
Planet Radius	1.12 R_{earth}	1.10 R_{earth}	0.79 R_{earth}	0.92 R_{earth}	1.05 R_{earth}	1.13 R_{earth}	0.76 R_{earth}
Planet Mass	1.37 M_{earth}	1.31 M_{earth}	0.39 M_{earth}	0.69 M_{earth}	1.04 M_{earth}	1.32 M_{earth}	0.33 M_{earth}
Planet Density	0.99 ρ_{earth}	0.99 ρ_{earth}	0.79 ρ_{earth}	0.89 ρ_{earth}	0.91 ρ_{earth}	0.92 ρ_{earth}	0.75 ρ_{earth}
Surface Gravity	1.10 *g*	1.09 *g*	0.62 *g*	0.82 *g*	0.95 *g*	1.04 *g*	0.57 *g*

Solar System
Rocky Planets

	Mercury	Venus	Earth	Mars
Orbital Period	87.97 *days*	224.70 *days*	365.26 *days*	686.98 *days*
Distance to Star	0.387 *AU*	0.723 *AU*	1.000 *AU*	1.524 *AU*
Planet Radius	0.38 R_{earth}	0.95 R_{earth}	1.00 R_{earth}	0.53 R_{earth}
Planet Mass	0.06 M_{earth}	0.82 M_{earth}	1.00 M_{earth}	0.11 M_{earth}
Planet Density	0.98 ρ_{earth}	0.95 ρ_{earth}	1.00 ρ_{earth}	0.71 ρ_{earth}
Surface Gravity	0.38 *g*	0.90 *g*	1.00 *g*	0.38 *g*

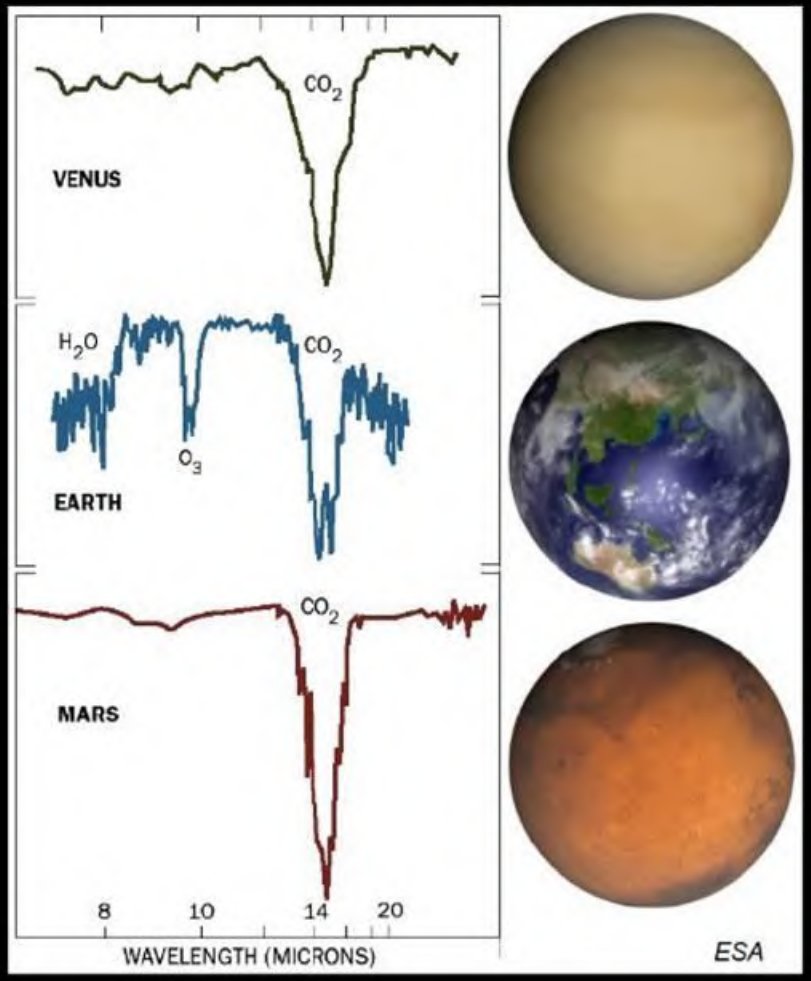
Agol et al. 2021

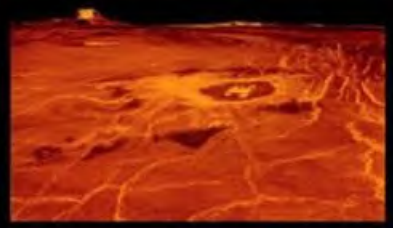

TRAPPIST-1/Solar System Comparison
Planet Density
(uncompressed, relative to Earth)
1.3
1.2
1.1
Earth
1.0
0.9
0.8
Solar System
TRAPPIST-1
Habitable
Zones
Mercury
Venus
Earth
b
c
d
e
f
g
h
Mars
Moon
Hot
Cold
10 x
6 x
4 x
2 x
1 x
Earth Illumination
0.6 x
0.4 x
0.2 x
0.1x
Illumination from Star
(relative to Earth/Sun)

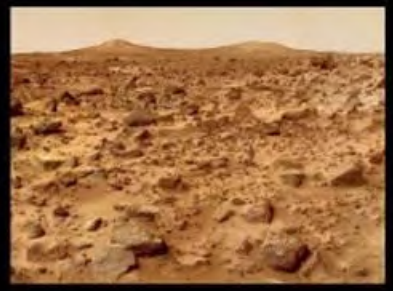
Red worlds…


Search of atmospheres with NASA IR-JWST
Credits: NASA

The search for « biosignatures »







SPECULOOS

Search for habitable Planets ECLipsing ULtra-cOOl Stars

http://www.speculoos.uliege.be

Observatory

LIÈGE université

cambridge exoplanet research centre

UNIVERSITY OF BIRMINGHAM

erc European Research Council

THE SIMONS FOUNDATION

ESO

The SPECULOOS-South/North Observatories

1000 red dwarfs

for the next 10 years

San Pedro (Mexico)

Teide (Tenerife)

Paranal (Chile)

SPECULOOS-2c and SPECULOOS-3b

Super Earth

(R=1.4$R_\oplus$, P=8.5d, d=105 ly)

Delrez et al. 2022

Hot earth size

(R=0.98$R_\oplus$, P=17h, d=55 ly)

Gillon et al. 2024


The European Extremely Large Telescope
2029
Credits: ESO

ESA Plato and Ariel space missions

PLAnetary **T**ransits and
Oscillations of stars
(2026)

Atmospheric **R**emote-sensing
Infrared **E**xoplanet
Large-survey (2029)

stay tuned !

Credits: ESA

Merci pour votre attention