# Perché cerchiamo e studiamo gli esopianeti?

# La Terra e il Sistema Solare sono unici?

*Gli esopianeti ad oggi conosciuti*

*sono così incredibilmente diversi*

*dai pianeti del Sistema Solare*

**Come era il nostro passato e come sarà il nostro futuro?**

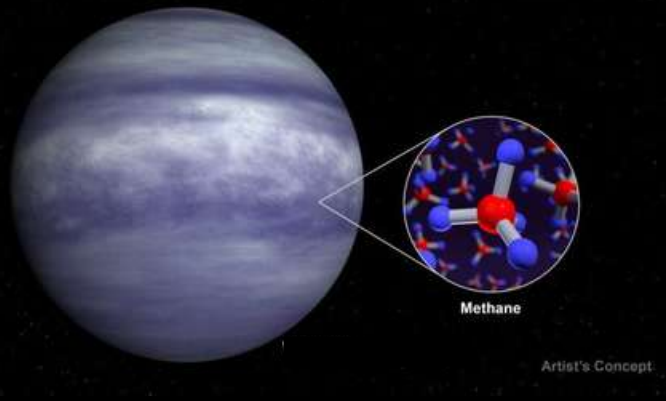
*Laformazione dei pianeti e*

*come questi evolvono*

**Siamo soli nell'universo?**
**Esistono altre forme di vita?**

Abitabilità di nuovi mondi

e ricerca di *biomarkers*



# Una scienza relativamente giovane

Rivista scientifica *Nature*, **Novembre 1995**

## A Jupiter-mass companion to a solar-type star

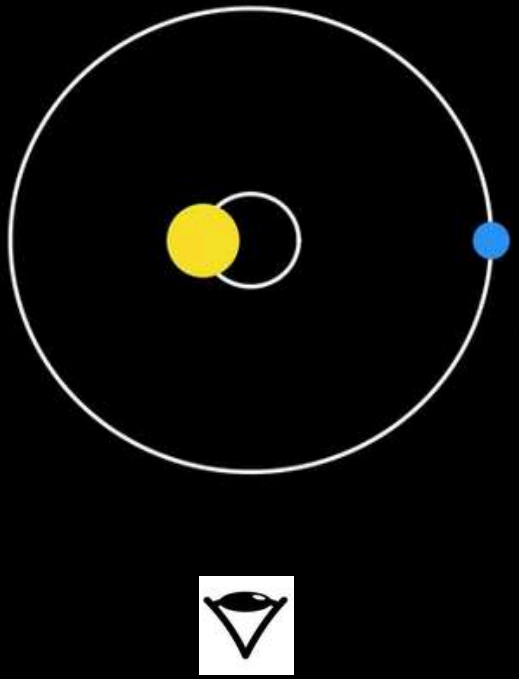
**Michel Mayor & Didier Queloz**

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

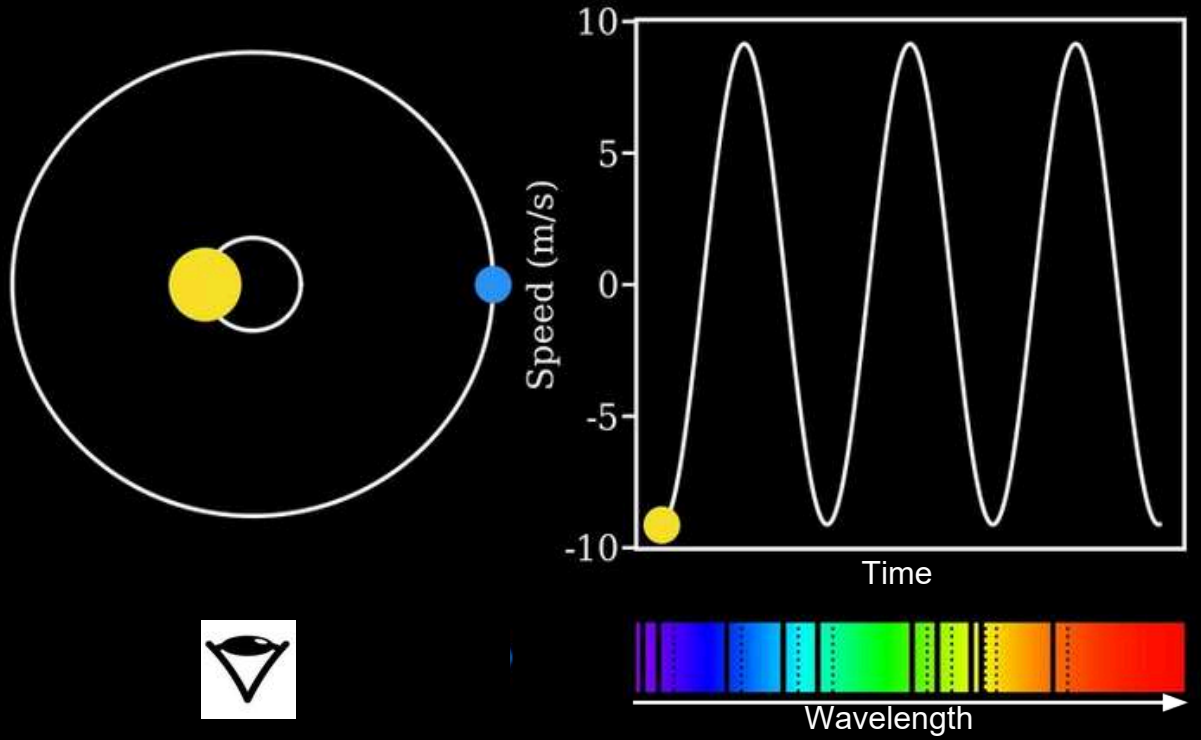
**The presence of a Jupiter-mass companion to the star 51 Pegasi is inferred from observations of periodic variations in the star's radial velocity. The companion lies only about eight million kilometres from the star, which would be well inside the orbit of Mercury in our Solar System. This object might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

Nobel per la fisica 2019

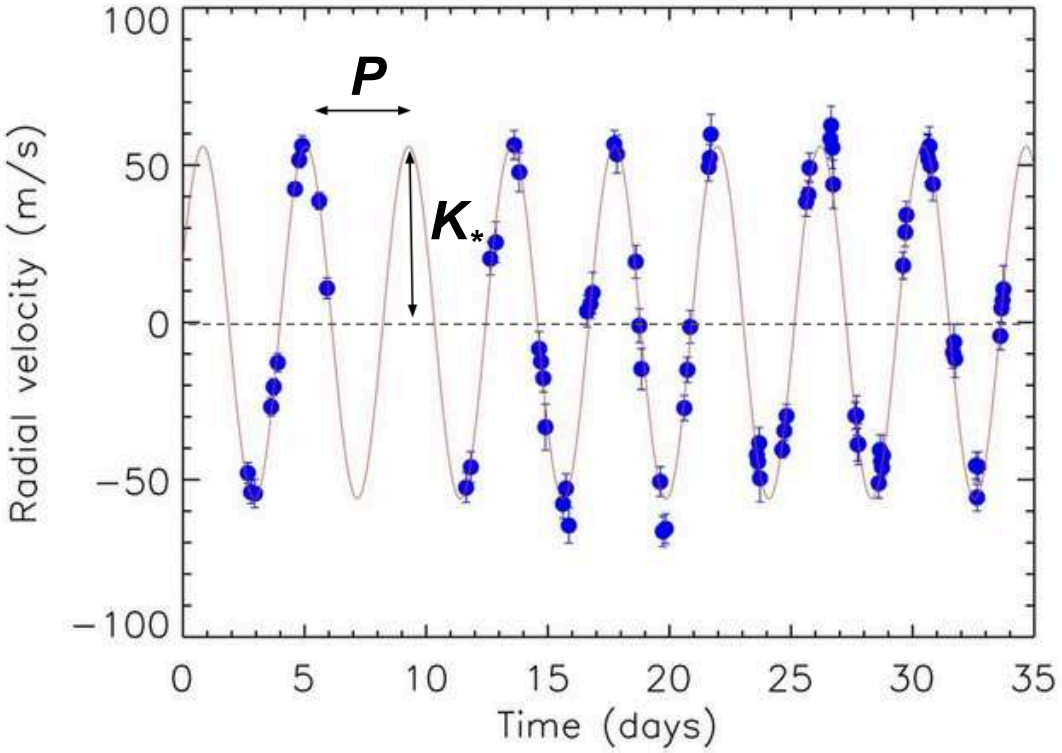
# Effetto Doppler e metodo delle velocità radiali



# Effetto Doppler e metodo delle velocità radiali



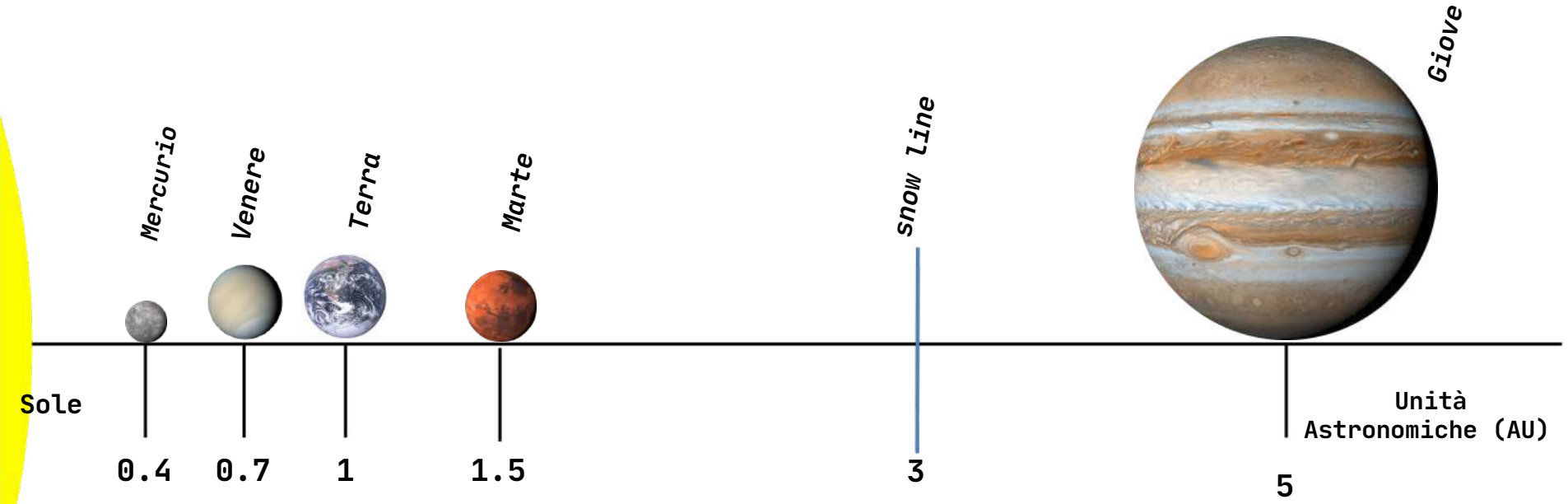
# Effetto Doppler e metodo delle velocità radiali




$$K_\star \approx \frac{M_p \sin i}{\sqrt[3]{P}}$$

$M_p$ :massa del pianeta
$i$ :inclinazione orbitale
$P$ :periodo orbitale

# Sistema solare (pianeti terrestri + Giove)




1 Unità Astronomica = $1.5 \times 10^{8}$ km (distanza media Terra-Sole)

Le dimensioni non sono in scala

# 51 Pegasi b è un “*gioviano caldo*”


Temperatura ≈ 1300 K
P ≈ 4.2 giorni
a ≈ 0.05 AU
Mp ≥ 0.5 Masse Gioviane

51 Peg

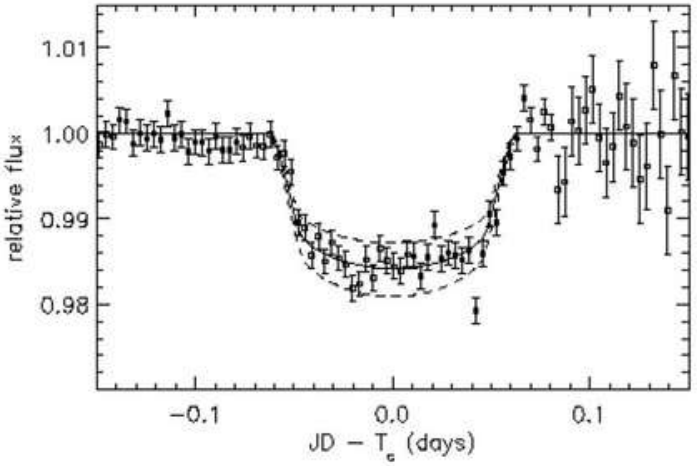
0.4 0.7 1 1.5 3 5

Unità Astronomiche (AU)

1 Unità Astronomica = $1.5 \times 10^{8}$ km (distanza media Terra-Sole)

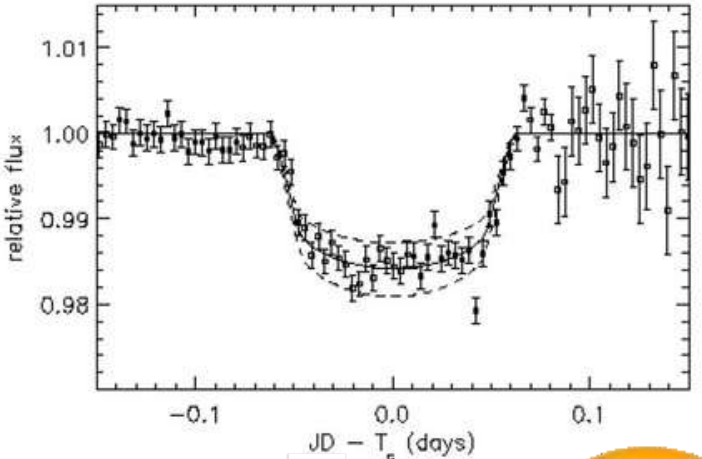
Le dimensioni non sono in scala

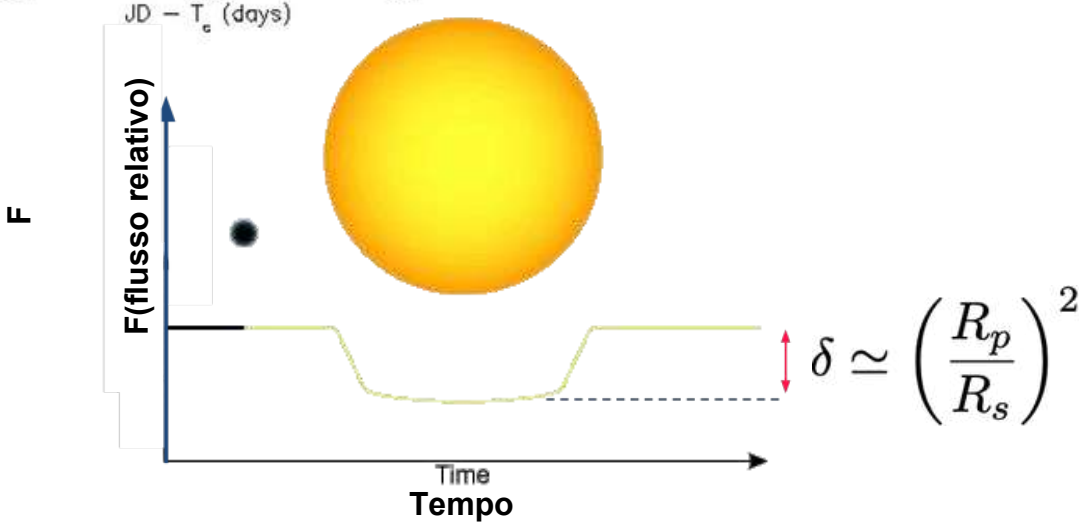
# 1999: il primo transito di un esopianeta




STARE Telescope
(Tim Brown)

# 1999: il primo transito di un esopianeta




STARE Telescope
(Tim Brown)

**HD 209458b**

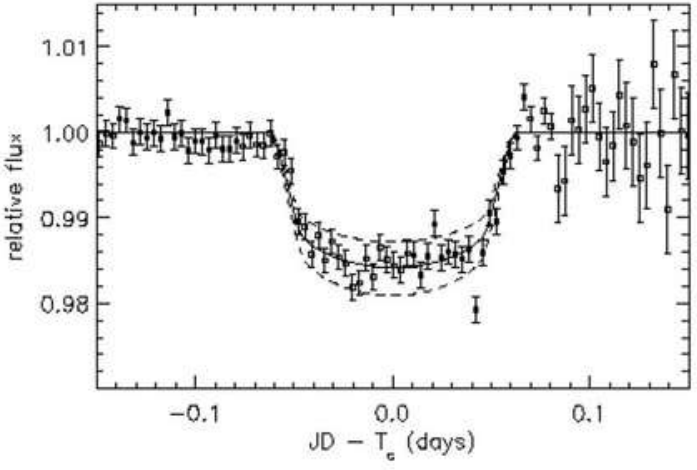
$P \simeq 3.5$ giorni

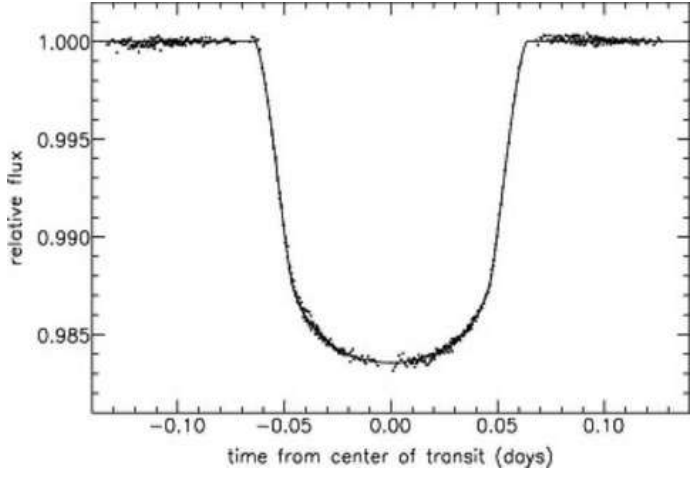
$R^p \simeq 1.4\ R_{Jup}$

$M^p \simeq 0.7\ M_{Jup}$

$\rho^p \simeq 0.3$ g/cm3

# 1999: il primo transito di un esopianeta




STARE Telescope
(Tim Brown)

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$P \simeq 3.5$ giorni

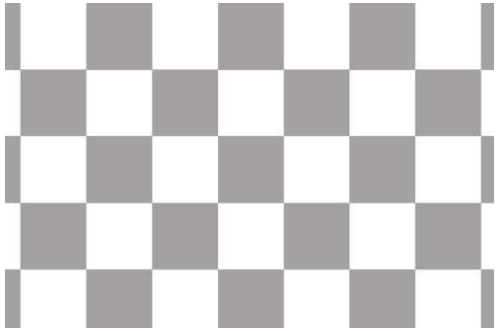
$R_p \simeq 1.4\ R_{Jup}$

$Mp \simeq 0.7$ MJup

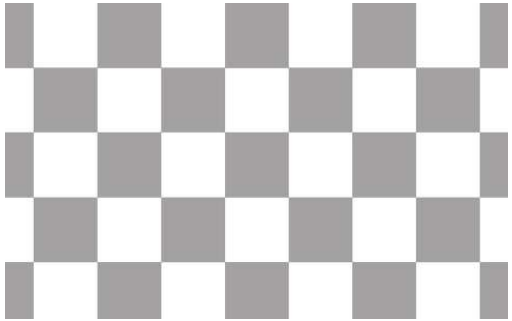
$\rho_p \simeq 0.3$ g/cm3

Hubble Space
Telescope

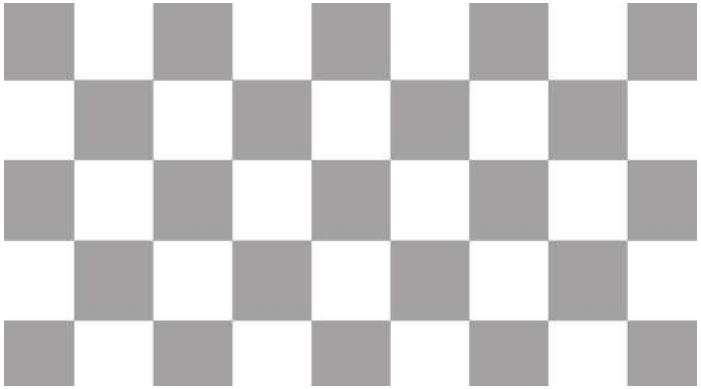
# Alcuni telescopi con spettrografi per la ricerca e lo studio di esopianeti



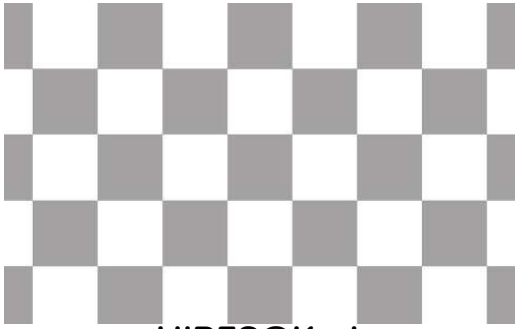
**HARPS-N@TNG**
Canary islands



**HARPS@ESO**
Chile

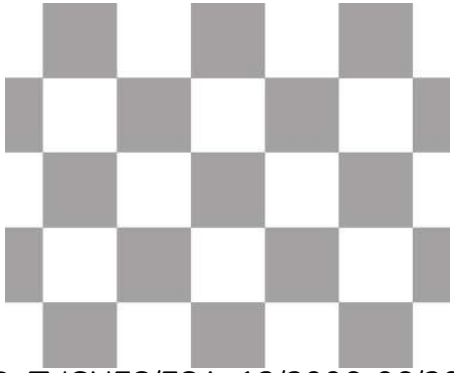


**ESPRESSO@VLT**
Chile

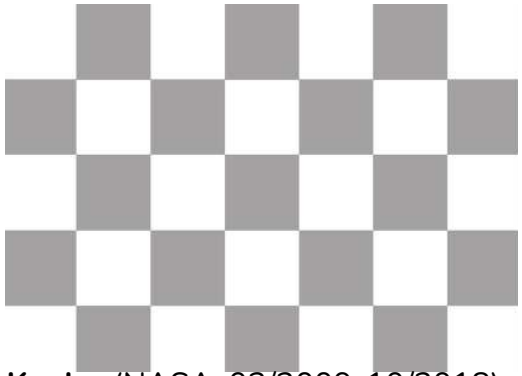


**HIRES@Keck**
Hawaii

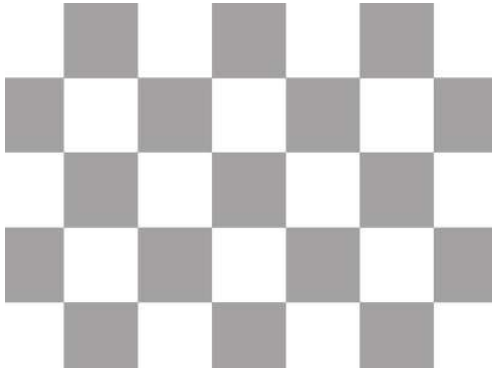
# Telescopi spaziali per la ricerca e lo studio di esopianeti



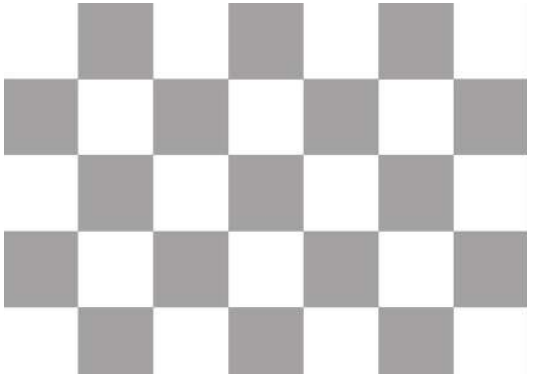
**CoRoT** (CNES/ESA; 12/2006-06/2014)
Ntel=1; D=30 cm



**Kepler** (NASA; 03/2009-10/2018)
Ntel=1; D=1 m

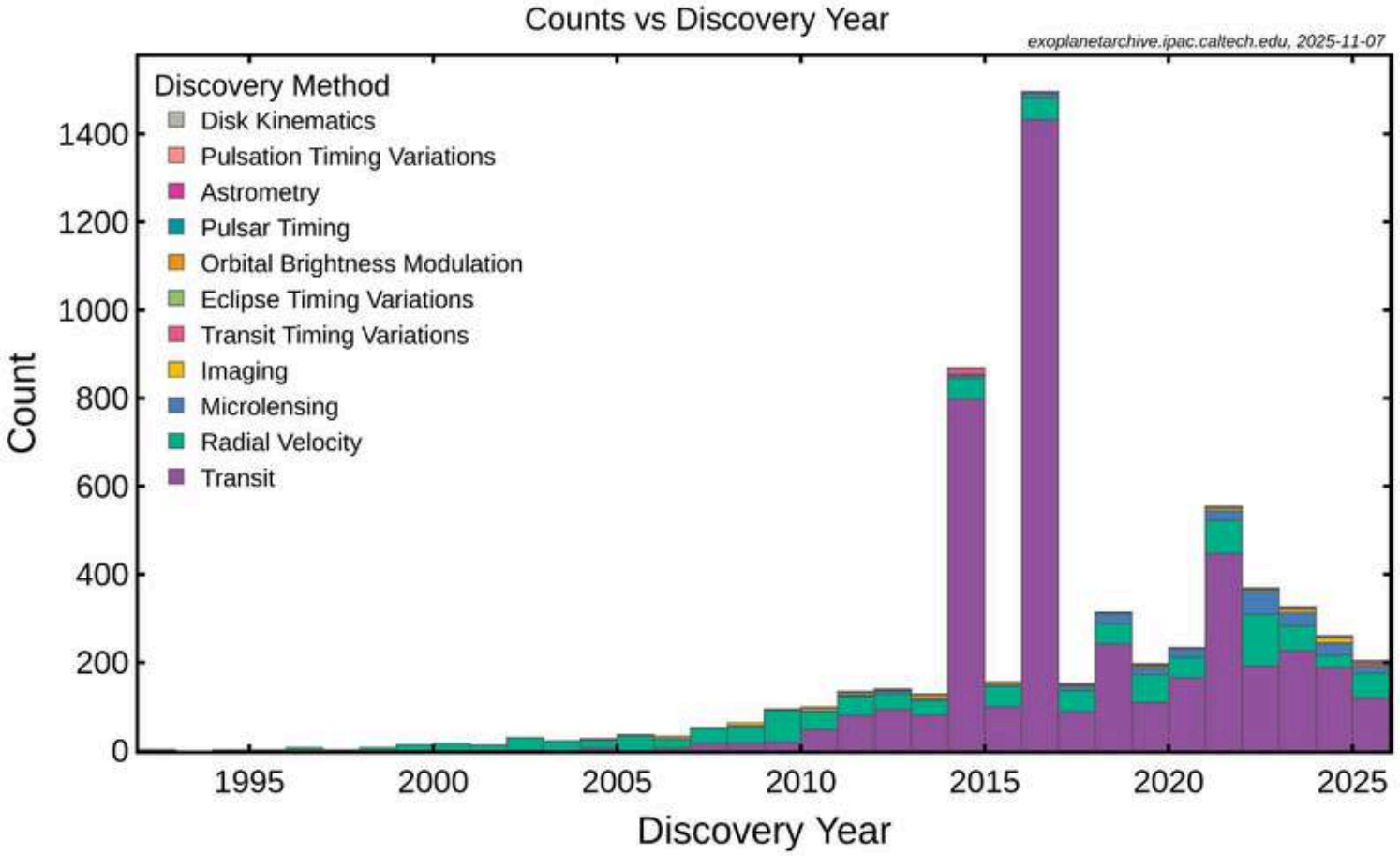


**CHEOPS** (ESA; 12/2019-)
Ntel=1; D=33 cm

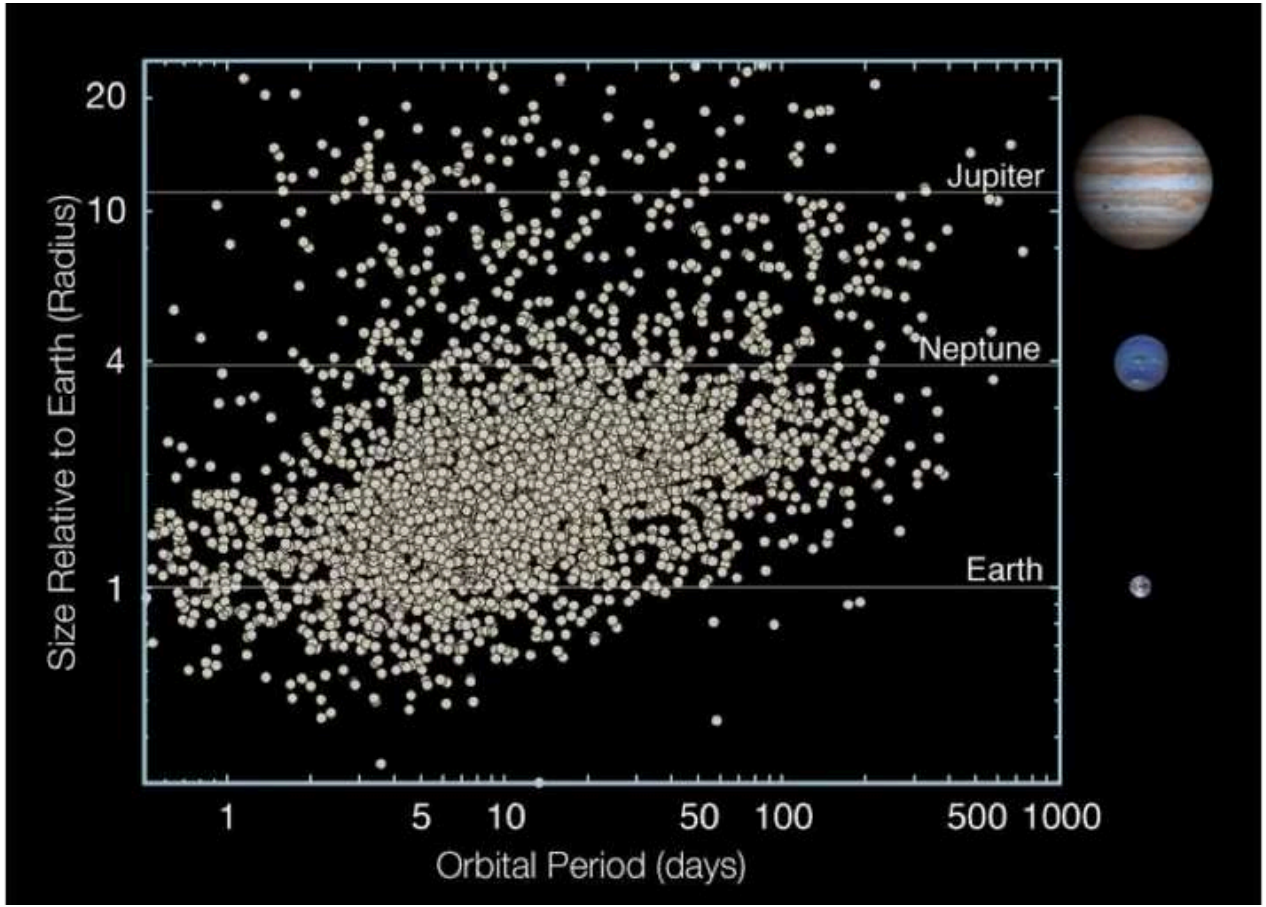


**TESS** (NASA; 04/2018-)
Ntel=4; D=10 cm

# La scoperta degli esopianeti



# Diagramma raggio-periodo (pianeti Kepler)

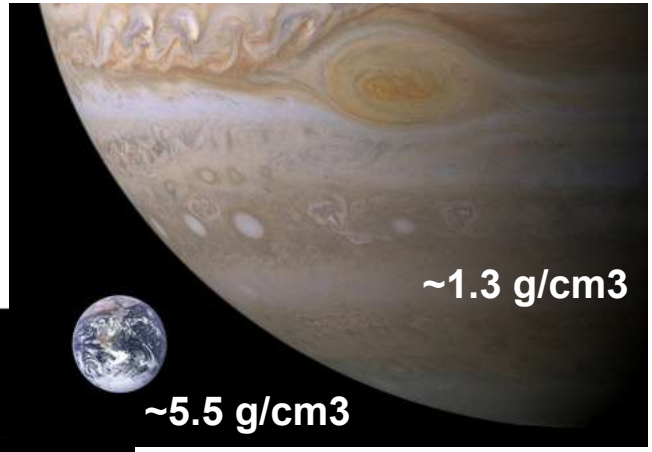


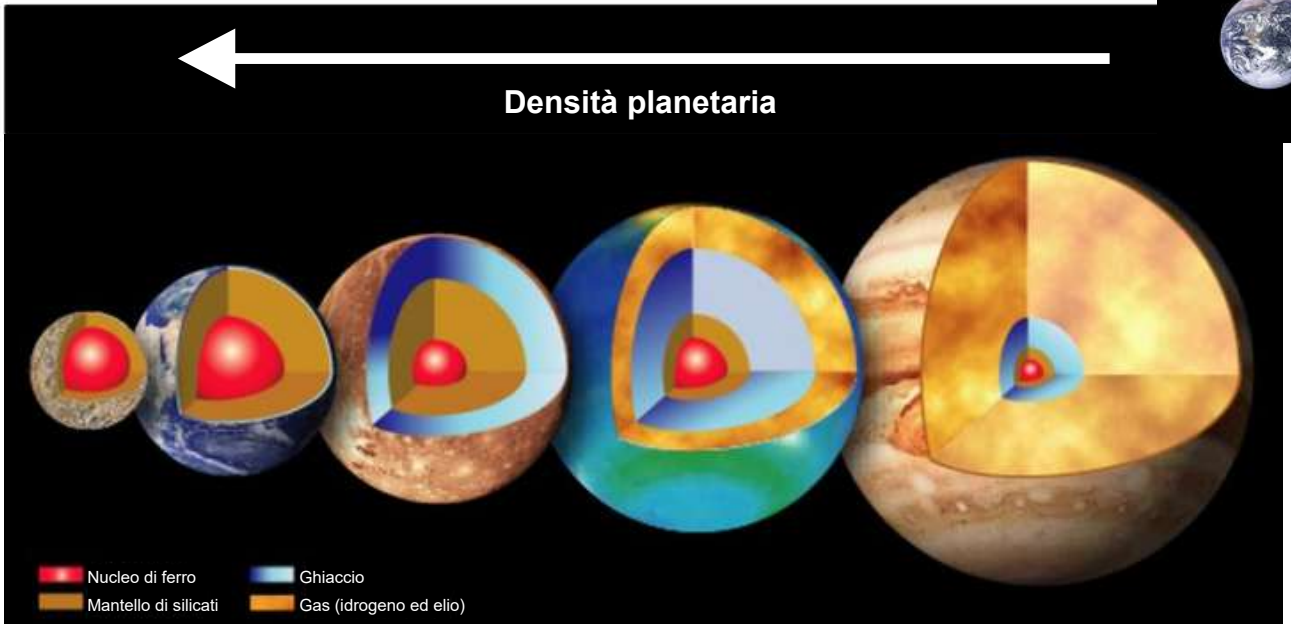

Sub-Nettuni
&
Super-Terre

# Densità media e composizione degli esopianeti

Velocità radiali ($M_p$) + Transiti( $Rp$)

$$\rho_p = \frac{M_p}{V_p} = \frac{M_p}{\frac{4}{3} \cdot \pi \cdot R_p^3}$$



Astronomy & Astrophysics

# TESS's first planet

## A super-Earth transiting the naked-eye star $\pi$ Mensae*

D. Gandolfi[1], O. Barragán[1], J. H. Livingston[2], M. Fridlund[3,4], A. B. Justesen[5], S. Redfield[6], L. Fossati[7], S. Mathur[8,9], S. Grziwa[10], J. Cabrera[11], R. A. García[12,13], C. M. Persson[3], V. Van Eylen[14], A. P. Hatzes[15], D. Hidalgo[8,9], S. Albrecht[5], L. Bugnet[12,13], W. D. Cochran[16], Sz. Csizmadia[11], H. Deeg[8,9], Ph. Eigmüller[11], M. Endl[16], A. Erikson[11], M. Esposito[15], E. Guenther[15], J. Korth[10], R. Luque[8,9], P. Montañes Rodríguez[8,9], D. Nespral[8,9], G. Nowak[8,9], M. Pätzold[10], and J. Prieto-Arranz[8,9]

*(Affiliations can be found after the references)*

Received 20 September 2018 / Accepted 28 September 2018

Ginevra, Mercoledì 5 Settembre 2018

Torino, Venerdì 14 Settembre 2018, ore 02:00 am: pianeta confermato!

Torino, Giovedì 20 Settembre 2018: invio dell'articolo alla rivista!

Torino, Venerdì 28 Settembre 2018: articolo accettato!

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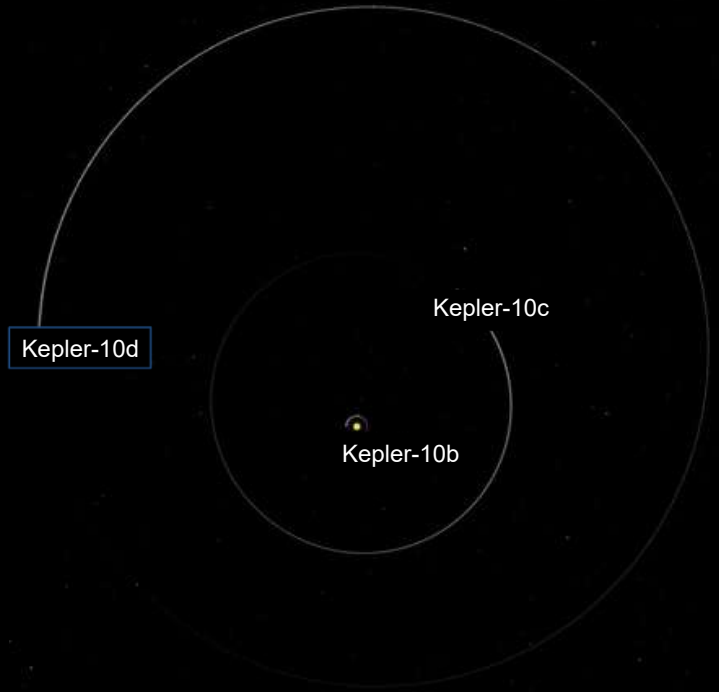
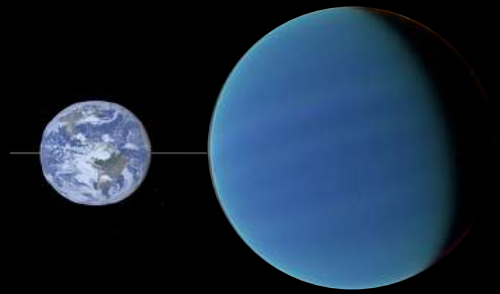
# The Kepler-10 exoplanet system




Kepler-10b

$P \simeq$ 20 ore; $R_p \simeq 1.5 R_\oplus$; $\rho_p \simeq$ 5.5 g/cm$^3$

Probabile mondo di lava



Kepler-10c

$P \simeq$ 45 giorni; $R_p \simeq 2.3 R_\oplus$; $\rho_p \simeq$ 4.7 g/cm$^3$

Probabile mondo di acqua

Più di 10 anni di osservazioni di velocità radiale con lo spettrografo HARPS-N al TNG per determinare in modo accurato e preciso i parametri dei pianeti Kepler-10c e d.

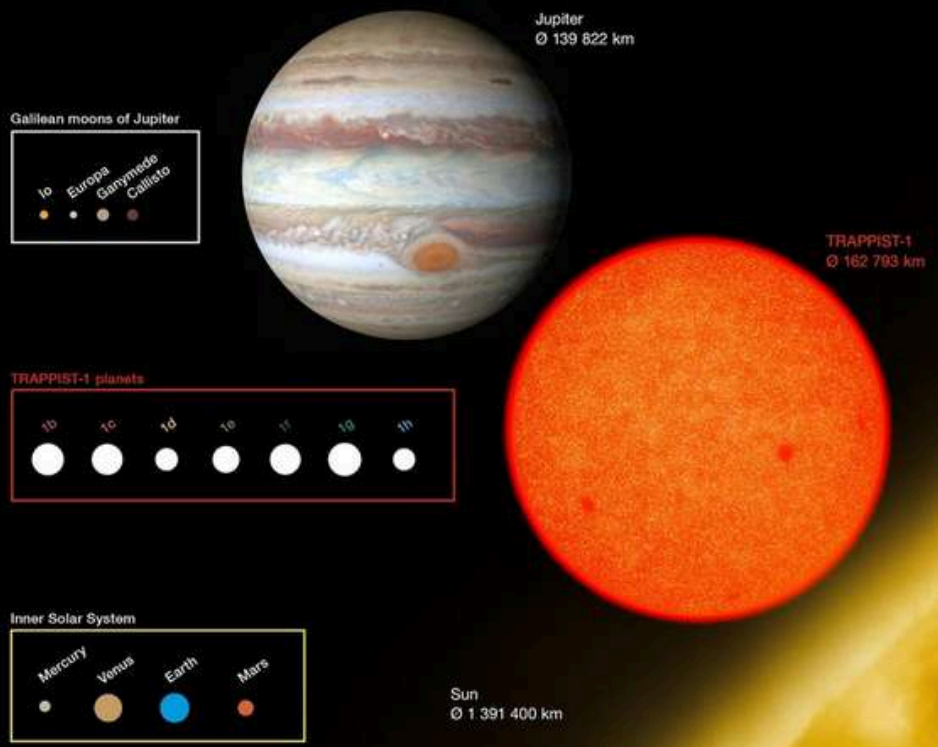
# Fascia di abitabilità

# La stella *TRAPPIST-1* e il suo sistema planetario

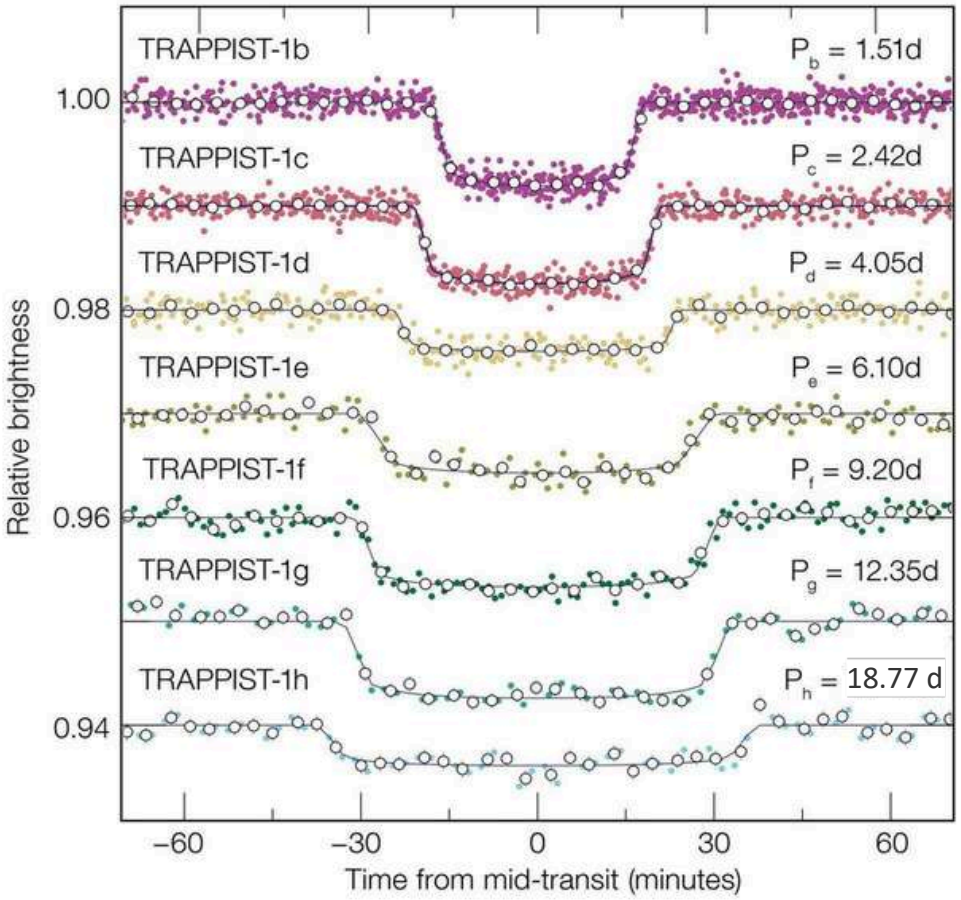
# La stella Trappist-1 ha un raggio 10 volte più piccolo di quello del Sole

# Size Comparison

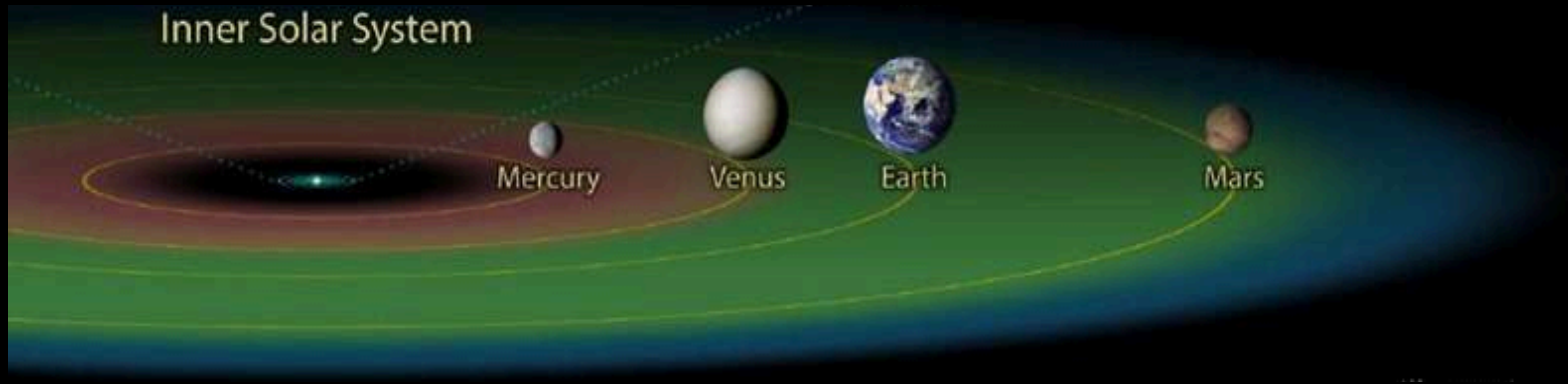
between **TRAPPIST-1** system, Galilean moons of Jupiter and the inner Solar System



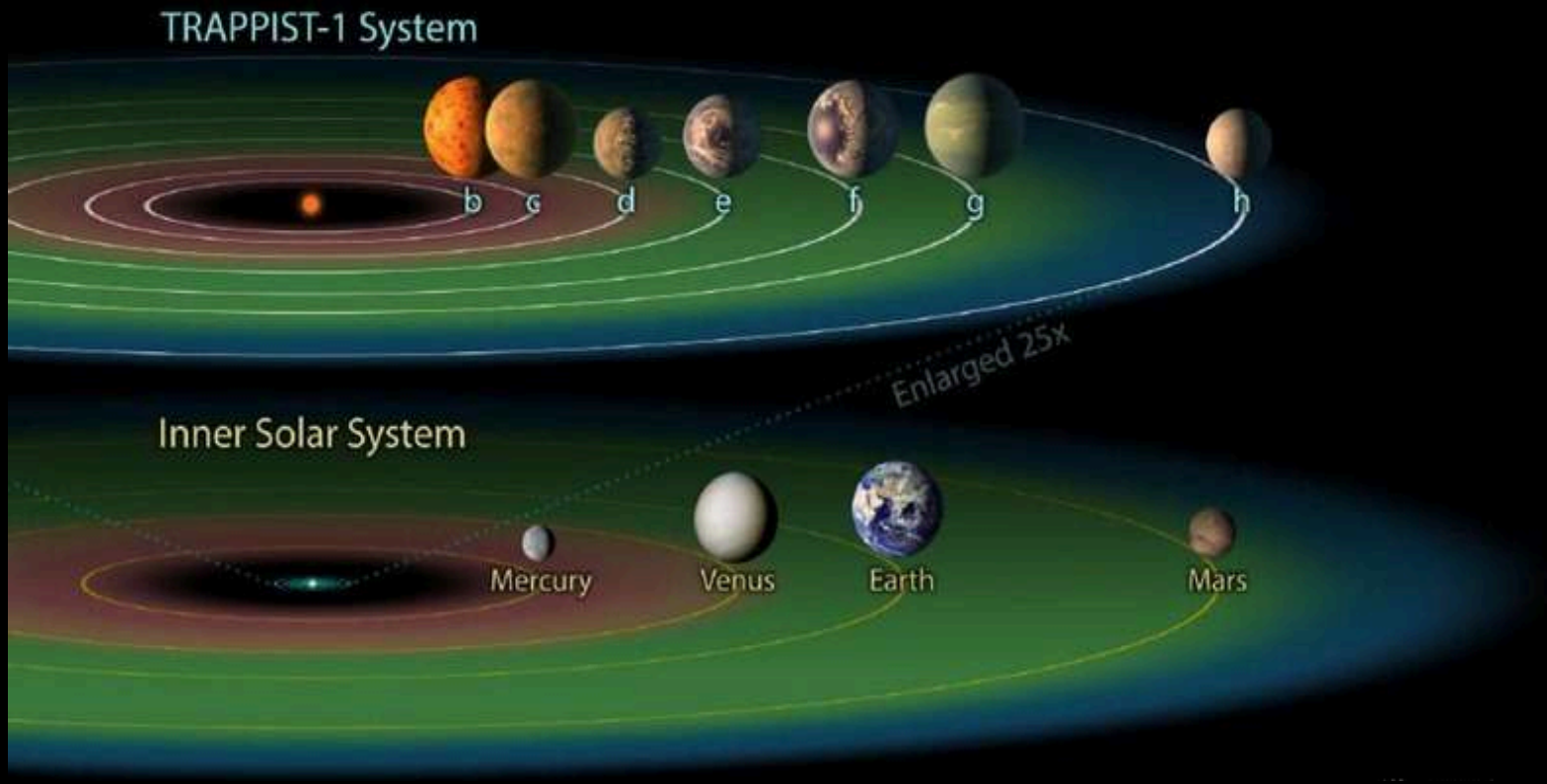
# *Trappist-1* – Transiti osservati dallo spazio



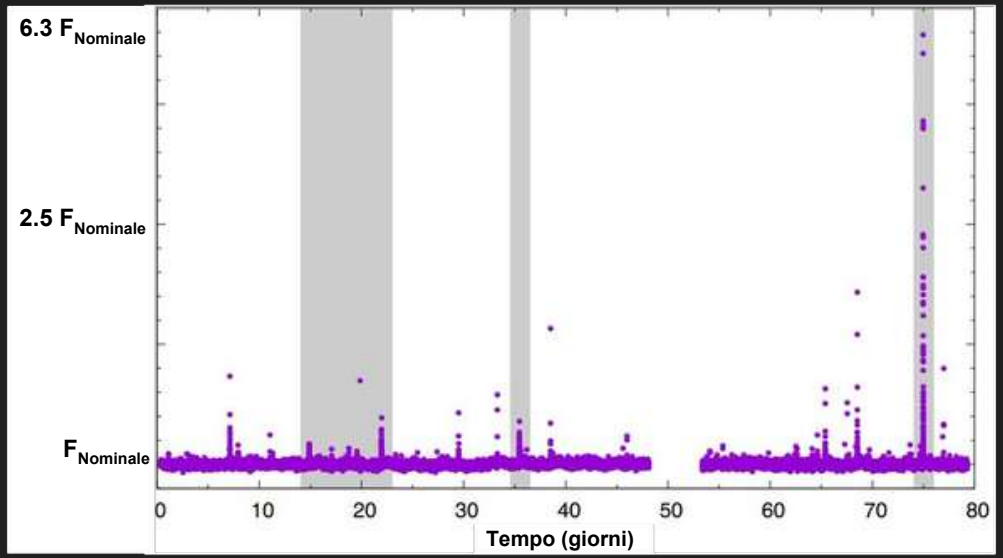
# Abitabilità dei pianeti *e, f, g*



# Abitabilità dei pianeti *e, f, g*



# Trappist-1 è una stella molto attiva




**Brillamenti 10-100 volte più intensi di quelli osservati sul Sole**

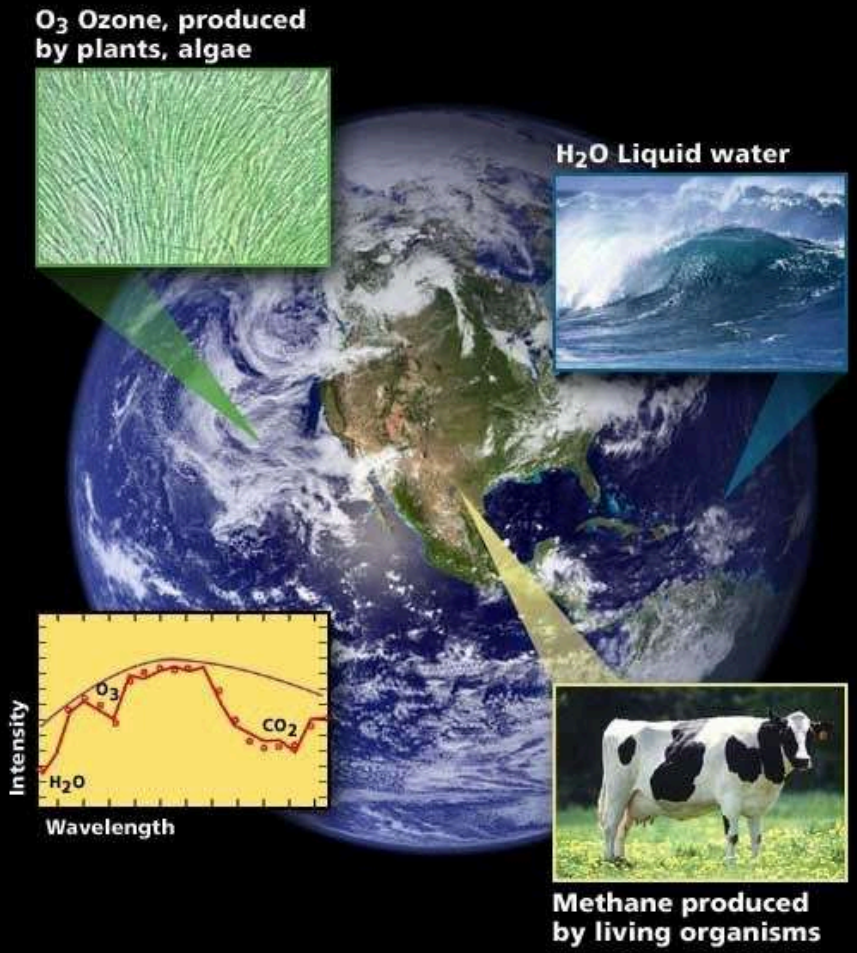
**Probabilmentenonsussistonolecondizioninecessarieallosviluppodiforme di vita (come le conosciamo noi)**

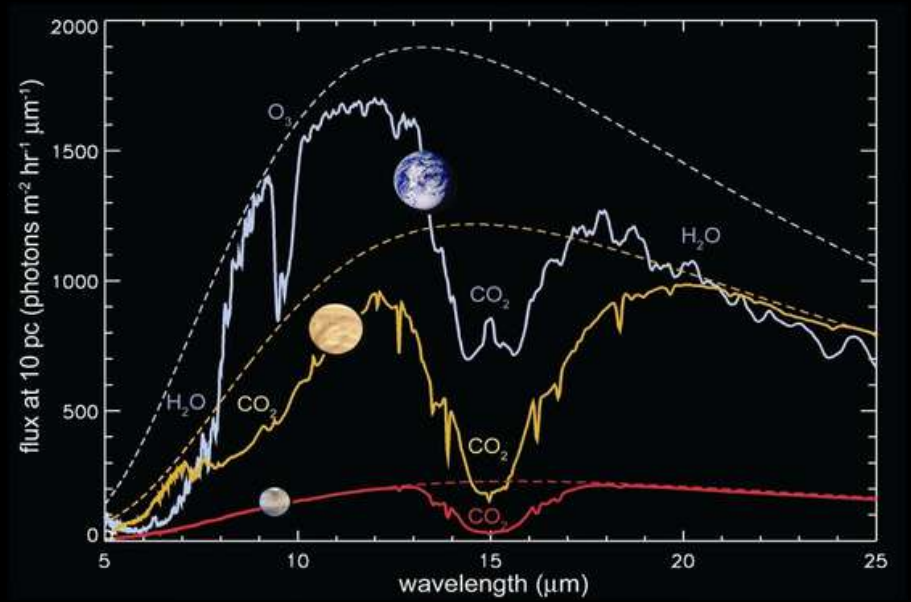
# Altre condizioni per l’abitabilità

- pianeta roccioso
- acqua liquida
- stabilità dinamica del sistema planetario
- atmosfera stabile
- campo magnetico
- presenza di un satellite naturale?

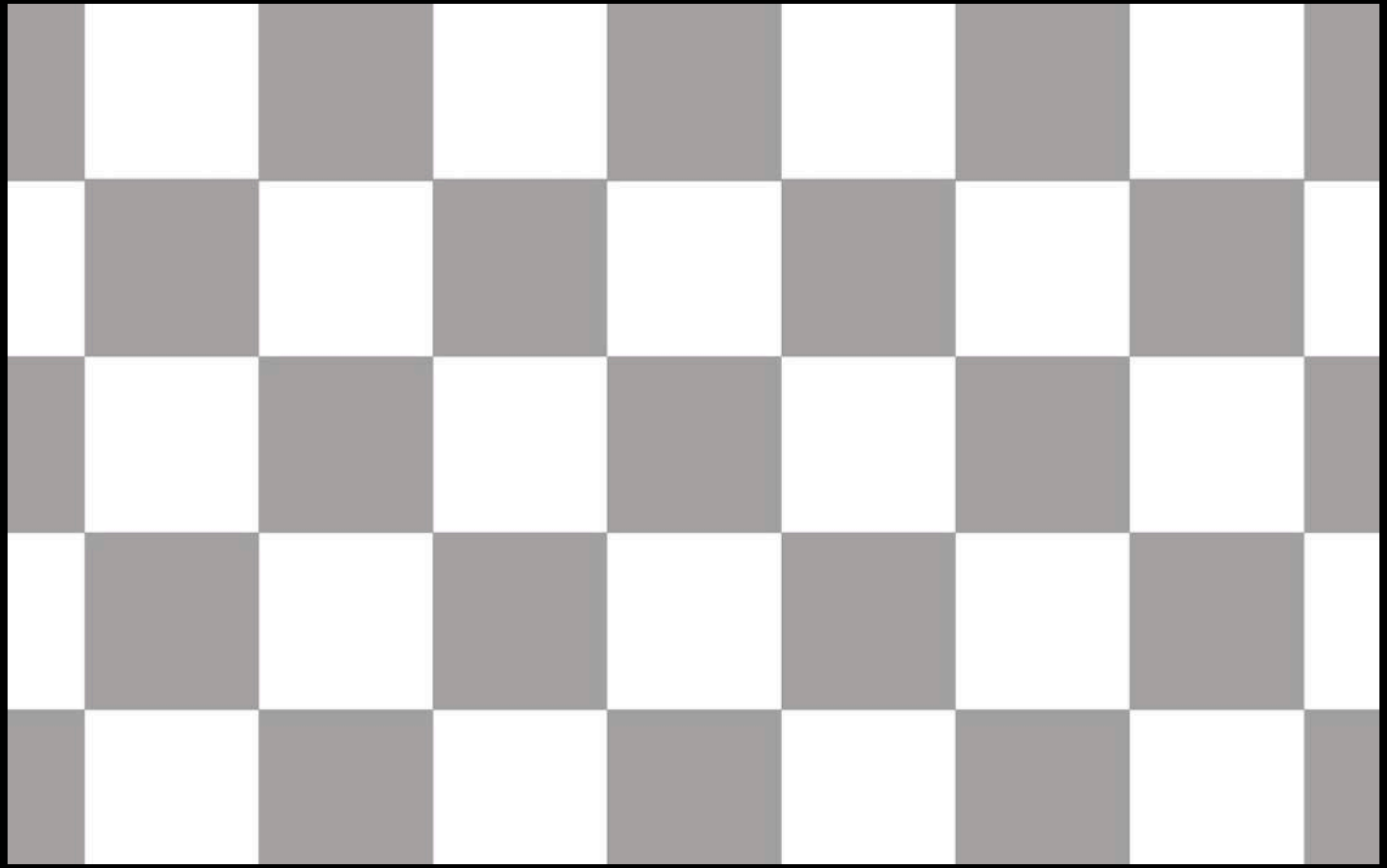
*Cascate del Niagara*

# Alla ricerca della vita nei “gemelli” della Terra



# Extremely Large Telescope (ESO), 2027



# Habitable Worlds Observatory (NASA+ESA?), 2040