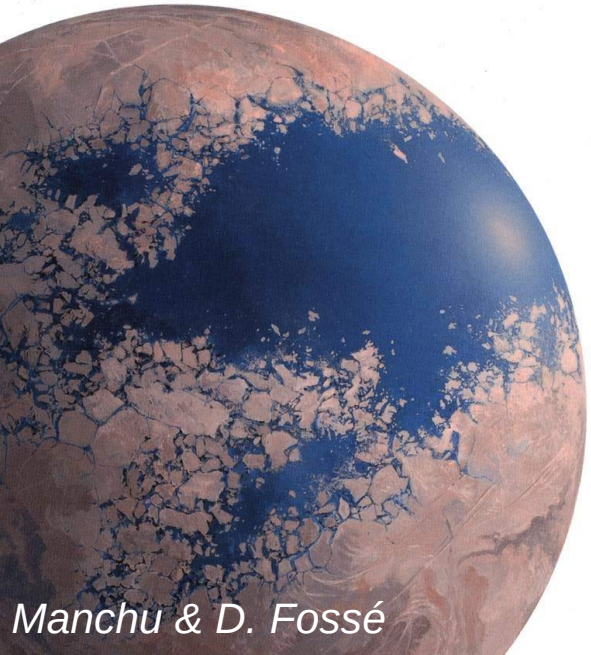
DE PLANETES EN EXOPLANETES



Manchu & D. Fossé

Martin Turbet

GRUBER FOUNDATION

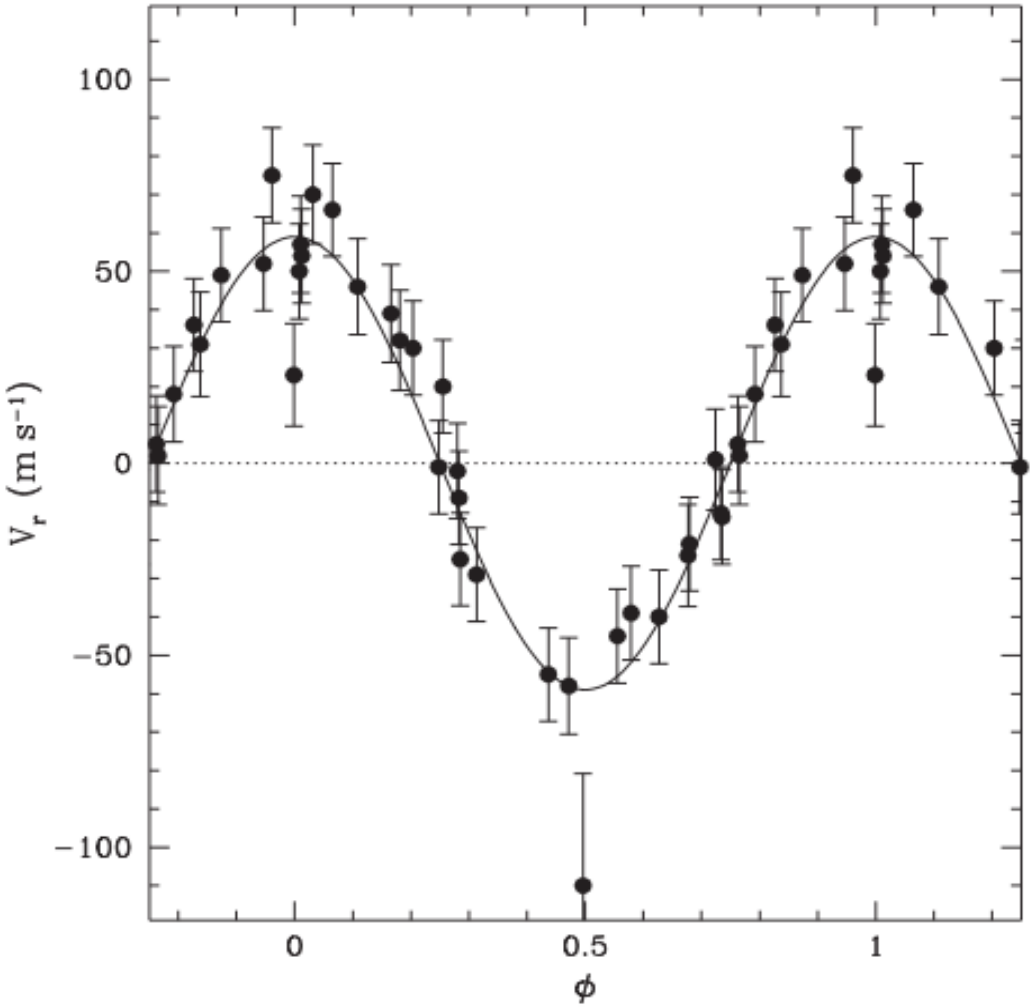
MARIE CURIE ACTIONS

OBSERVATOIRE DE GENÈVE FONDÉ EN 1772

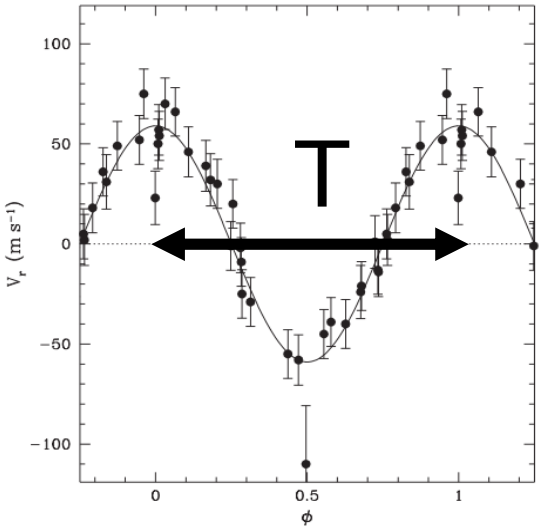
Marie Curie postdoctoral fellow
and TGF fellow
at the Geneva Observatory (CH)

Vue d’artiste de 51 Pegasi b, première exoplanète découverte en 1995 par deux astronomes suisses

NASA



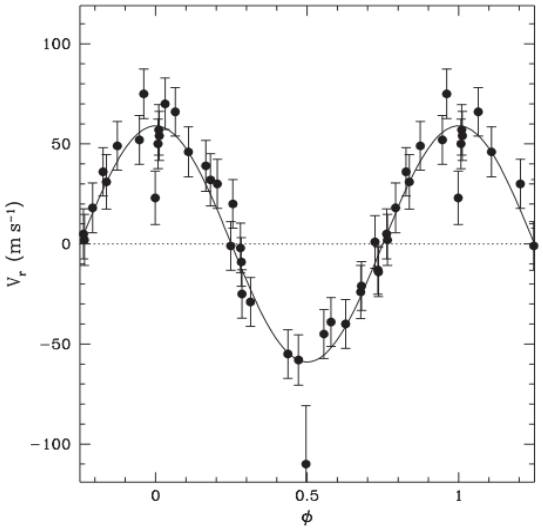
Mayor & Queloz 1995, Nature



CALCUL DE L'INSOLATION
grâce à la troisième loi de Kepler

$$\frac{T^2}{a^3} = \frac{4\pi^2}{GM} = \text{constante}$$

Lovis & Fischer 2010



A

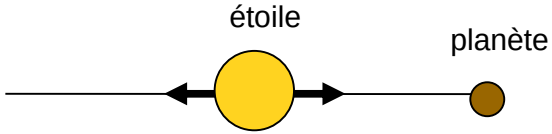
CALCUL DE LA MASSE MINIMALE

$$A = \sqrt{\frac{G}{(1-e^2)}}\, m_p \sin i\, (m_p + m_\star)^{-1/2}\, a^{-1/2}$$

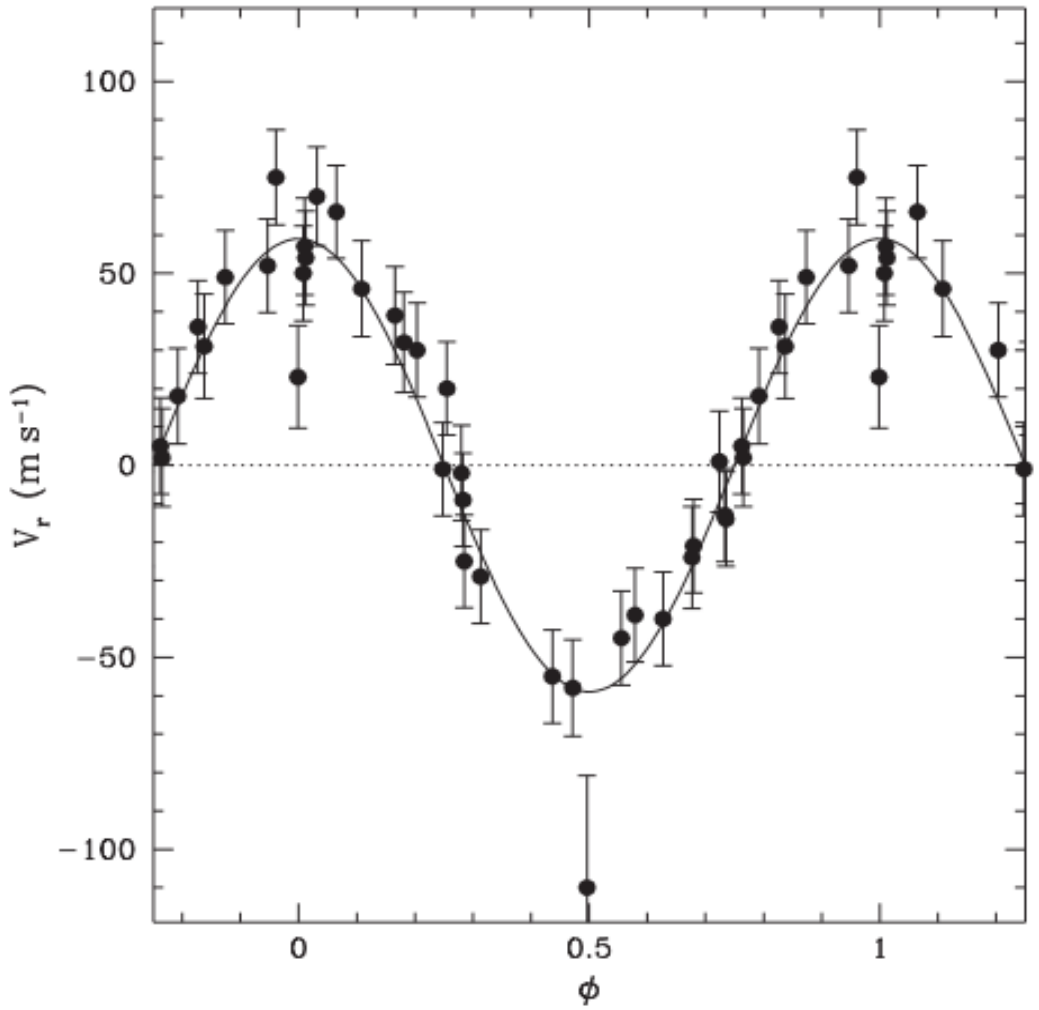
Lovis & Fischer 2010

CALCUL DE LA MASSE MINIMALE

CAS 1



51 PEGASI B



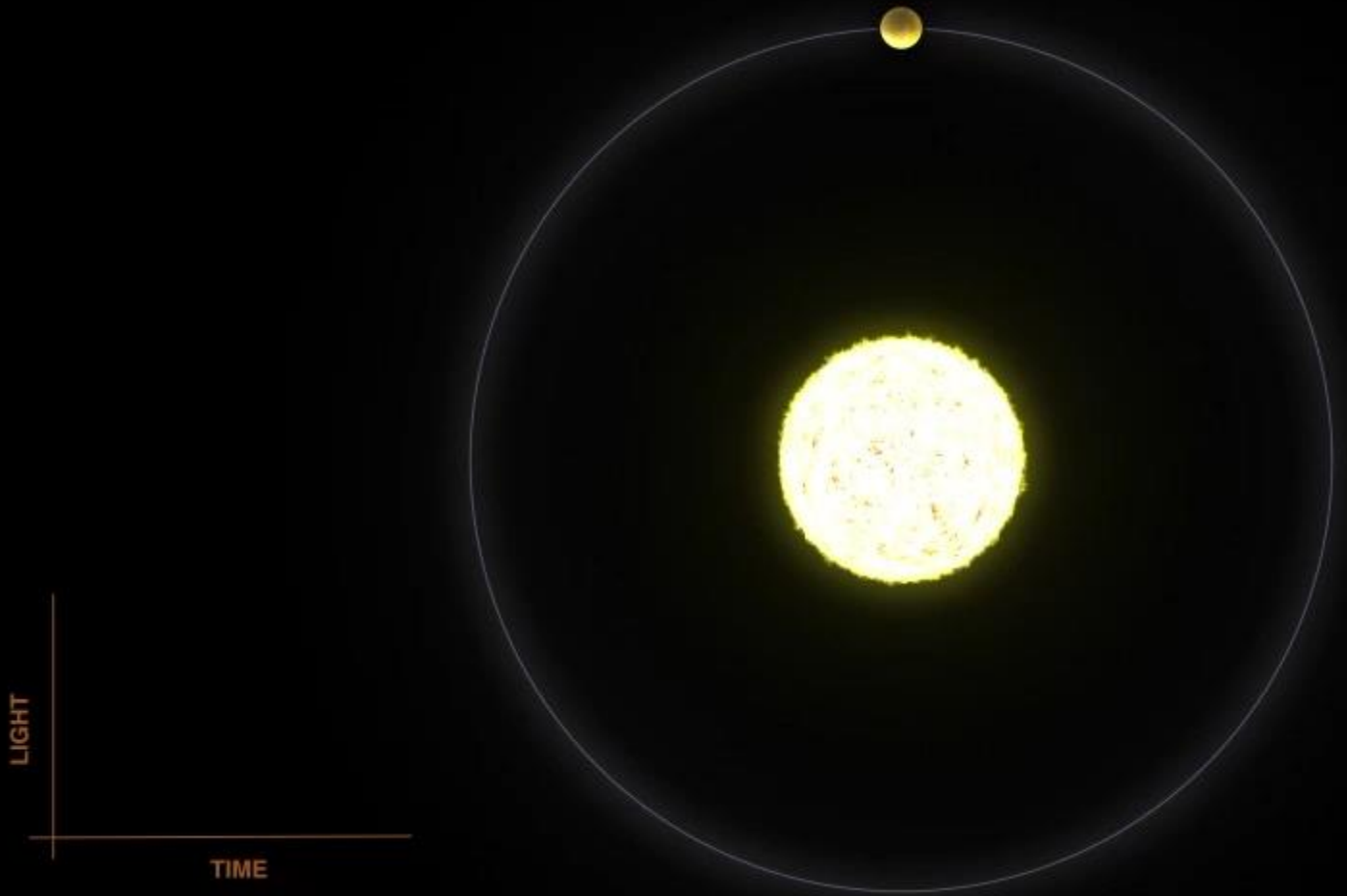
T=4.2 jours

Insolation 480 fois plus forte que celle de la Terre

Masse minimale 0.5 fois celle de Jupiter

Mayor & Queloz 1995, Nature

Vue d’artiste de 51 Pegasi b, première exoplanète découverte en 1995 par deux astronomes suisses



NASA

NASA

METHODE DES TRANSITS

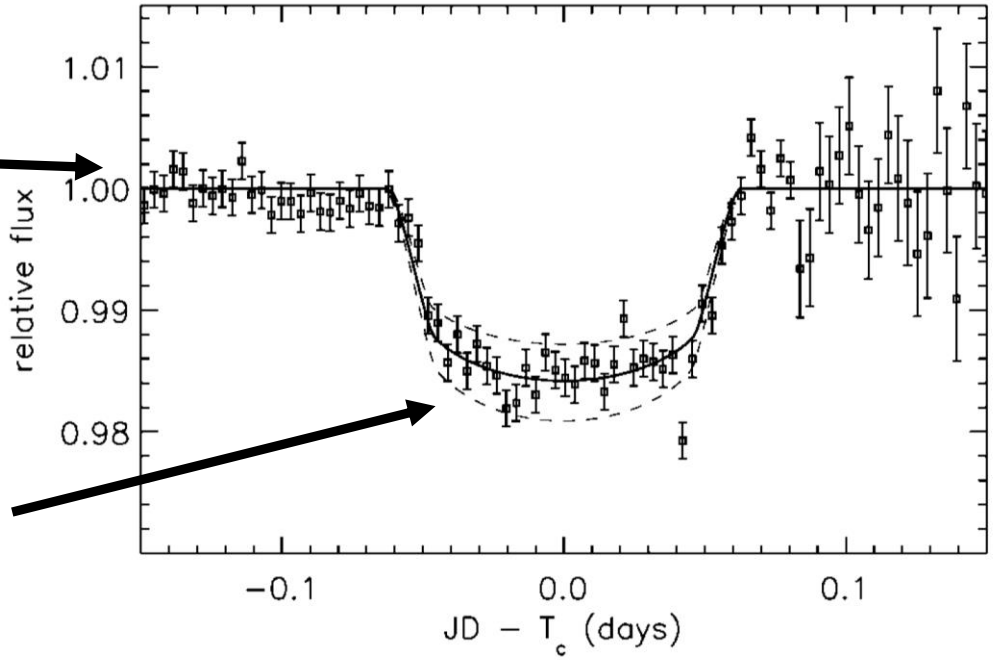
JUPITER CHAUD HD 209458 b

En dehors du transit :

$$F_{\text{ETOILE}}$$

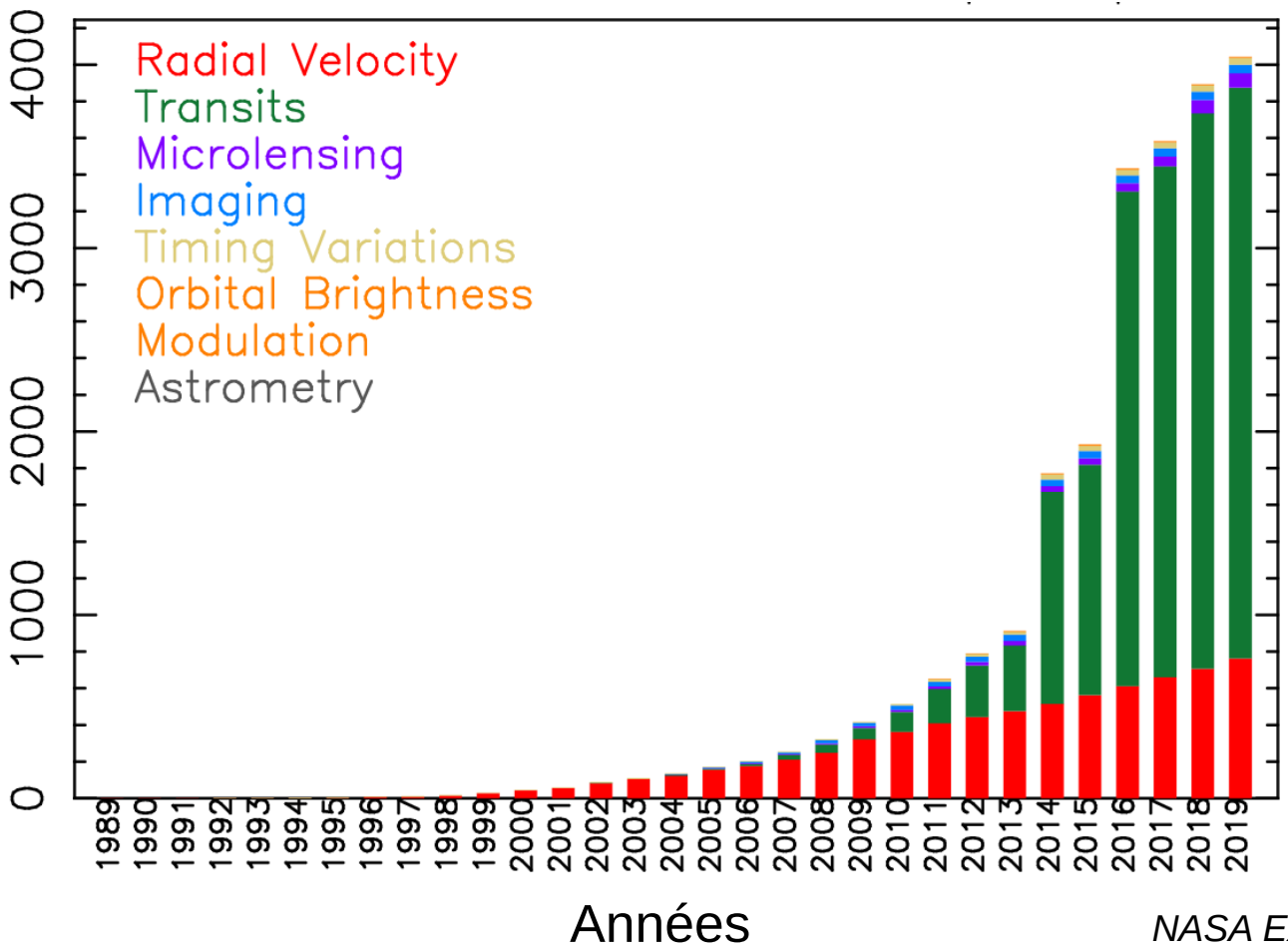
Pendant le transit :

$$F_{\text{ETOILE}} \times \frac{(\pi R^2_{ETOILE} - \pi R^2_{PLANETE})}{\pi R^2_{ETOILE}}$$



Charbonneau et al. 2000, ApJ

Nombre cumulé de détections d'exoplanètes par an

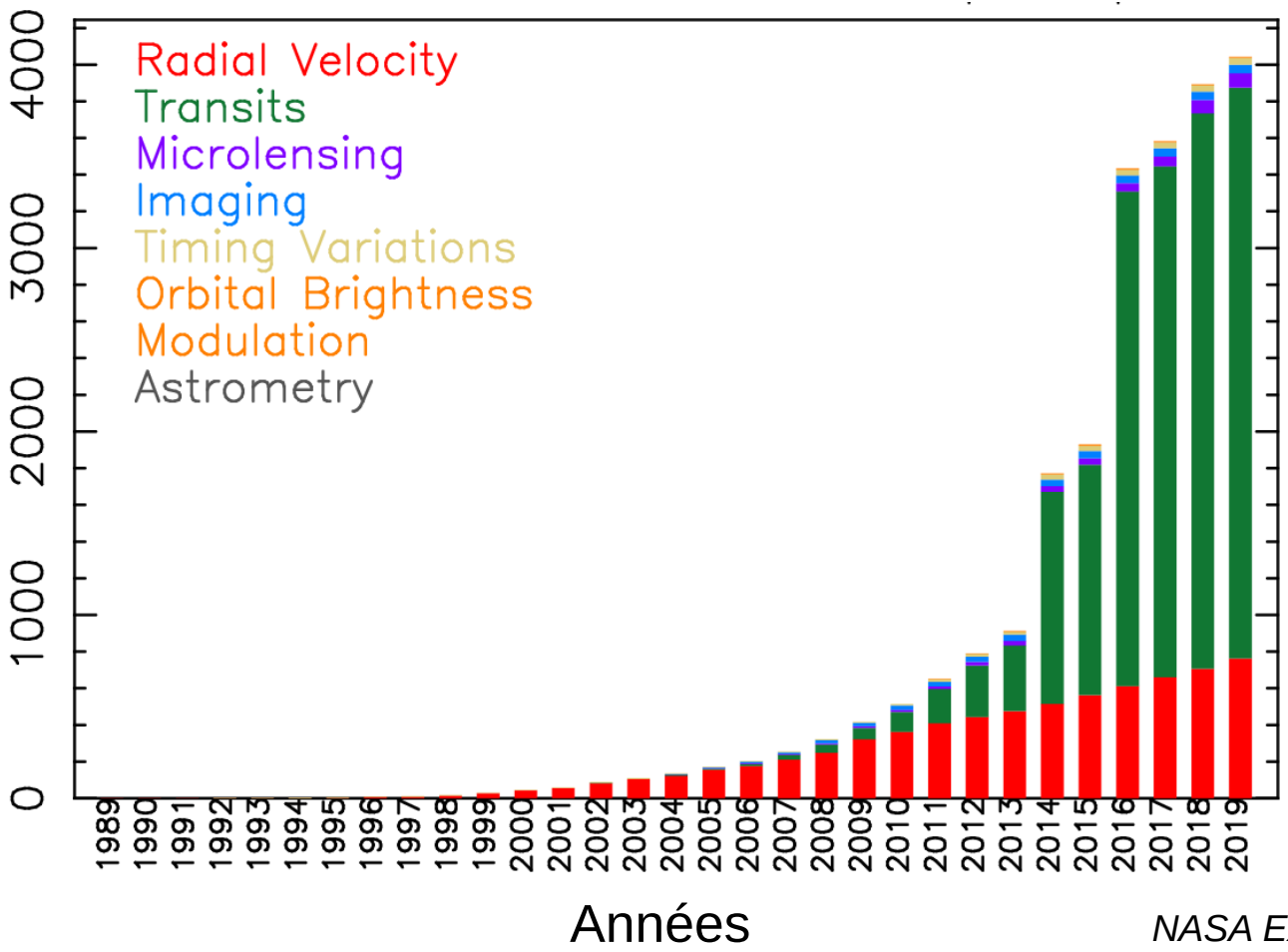


NASA Exoplanet archive

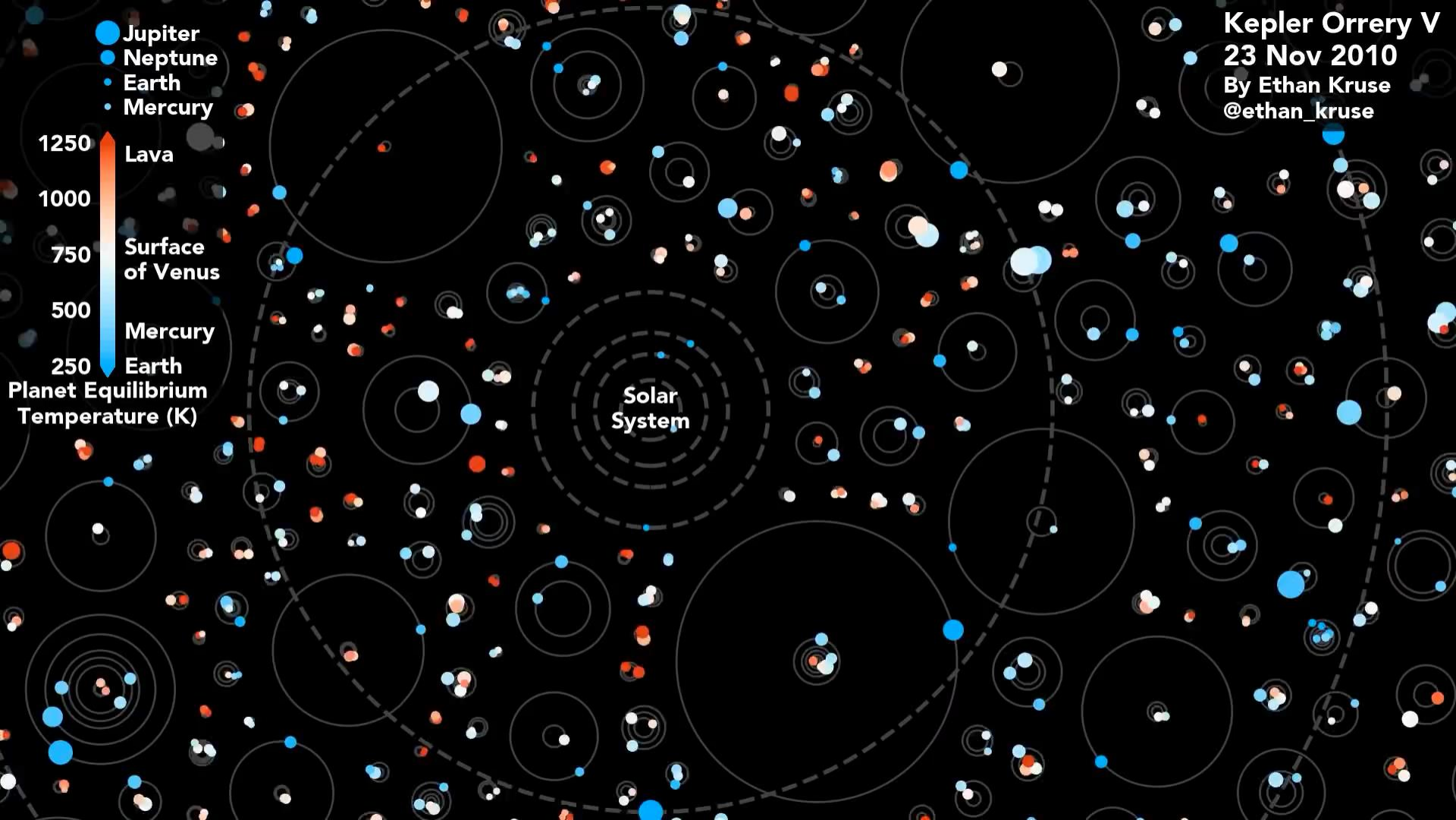
TELESCOPE SPATIAL KEPLER (2009-2018)

NASA

Nombre cumulé de détections d'exoplanètes par an



NASA Exoplanet archive


Jupiter
Neptune
Earth
Mercury
1250
Lava
1000
750
Surface of Venus
500
Mercury
250
Earth
Planet Equilibrium Temperature (K)
Solar System
Kepler Orrery V
23 Nov 2010
By Ethan Kruse
@ethan_kruse

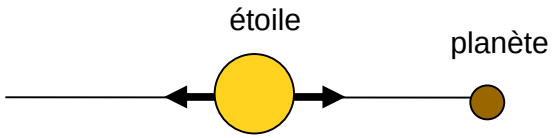
Vue d’artiste de Gliese 436b,
une Neptune chaude

Vue d’artiste de Corot 7b, une super-Terre en fusion (ESA/ESO)

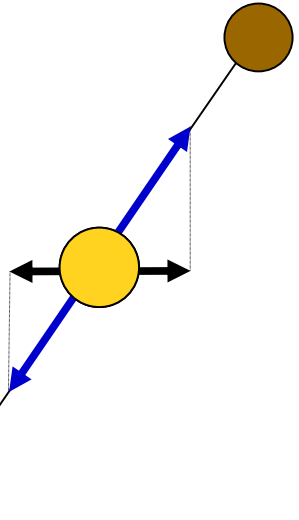
MESURES COMBINEES DE MASSES ET RAYONS

MESURES COMBINEES DE MASSES ET RAYONS

CAS 1



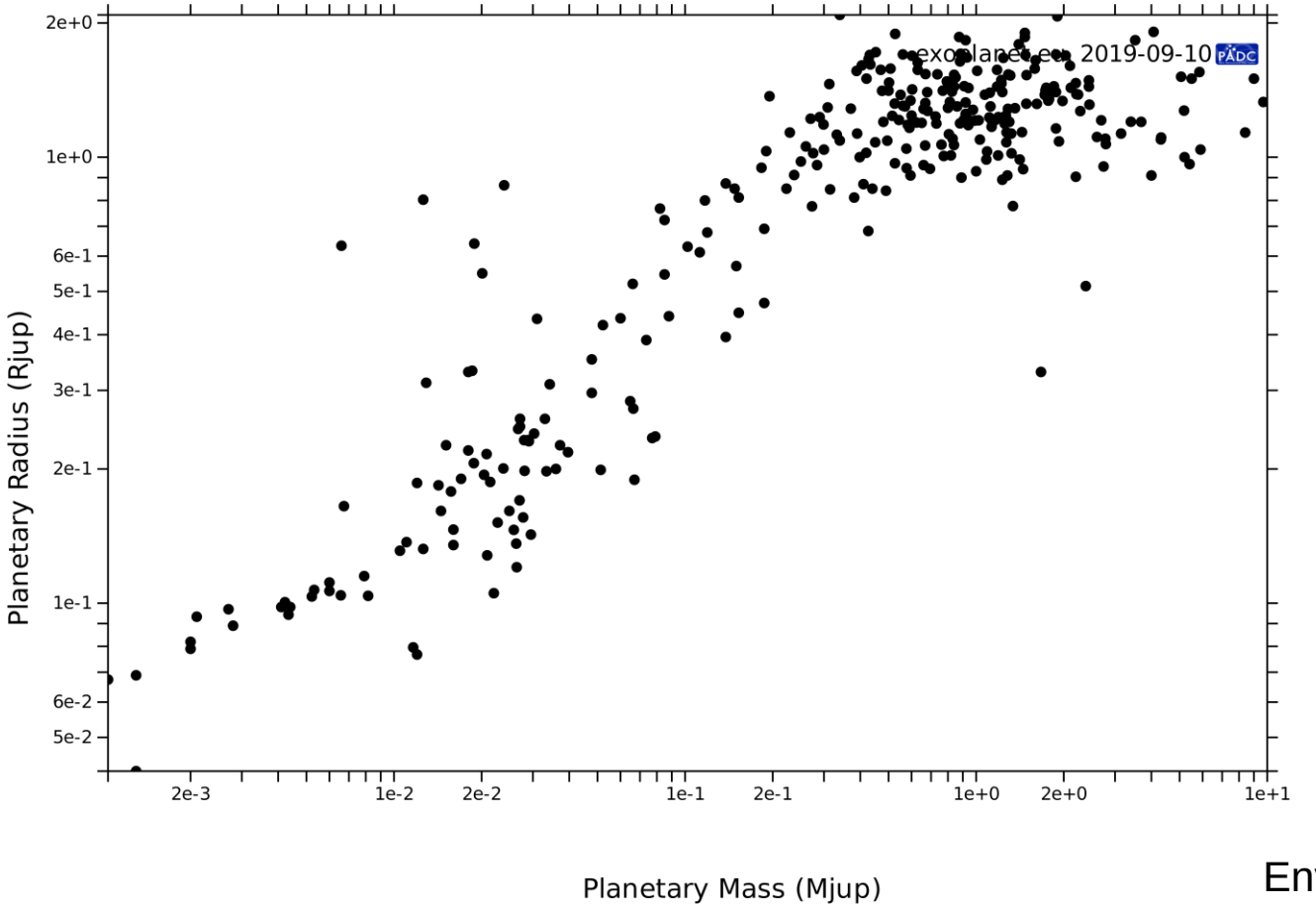
CAS 2



MESURES COMBINEES DE MASSES ET RAYONS

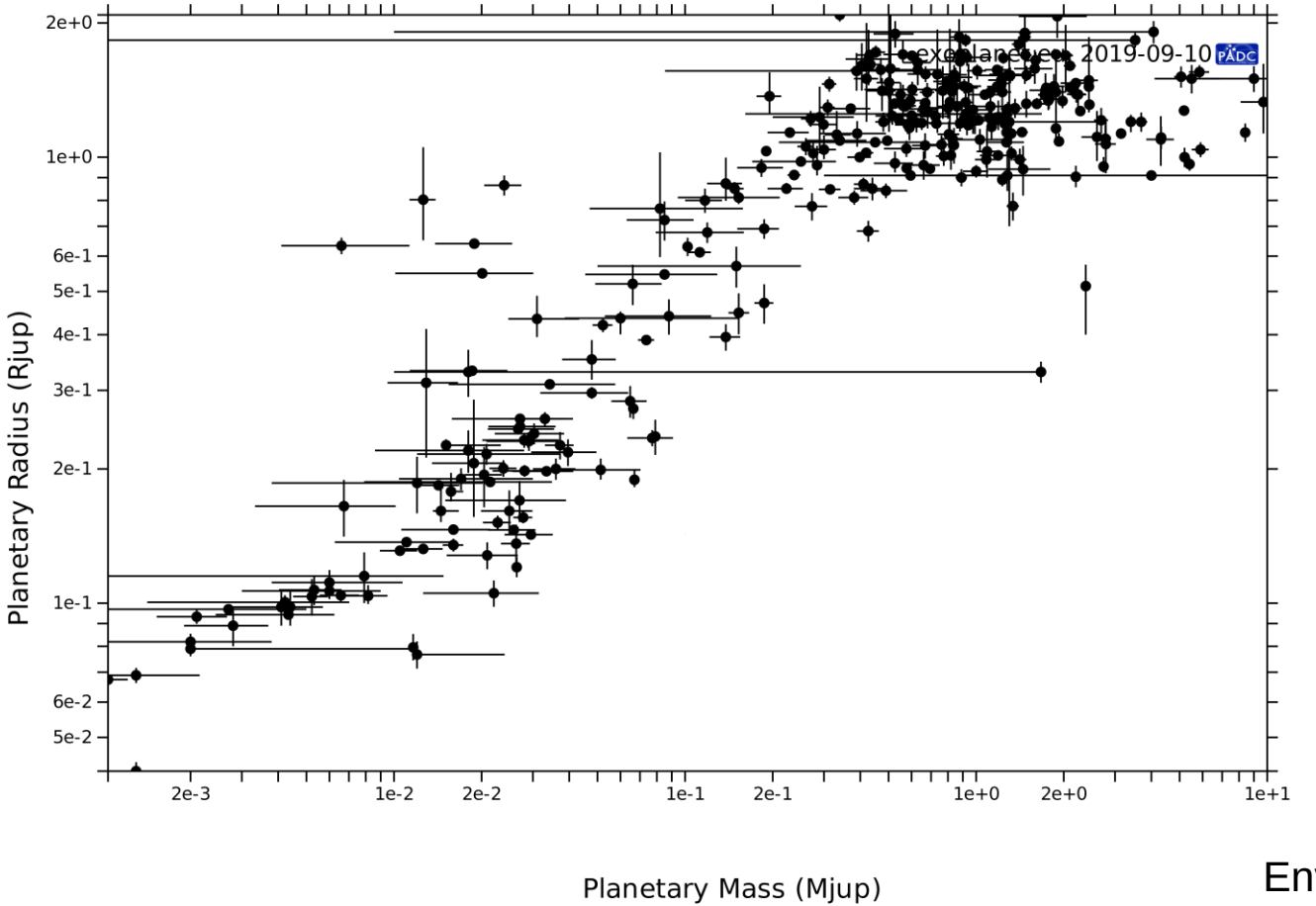
$$\rho = \frac{M_p}{\frac{4}{3}\pi\, Rp^3}$$

MESURES COMBINEES DE MASSES ET RAYONS



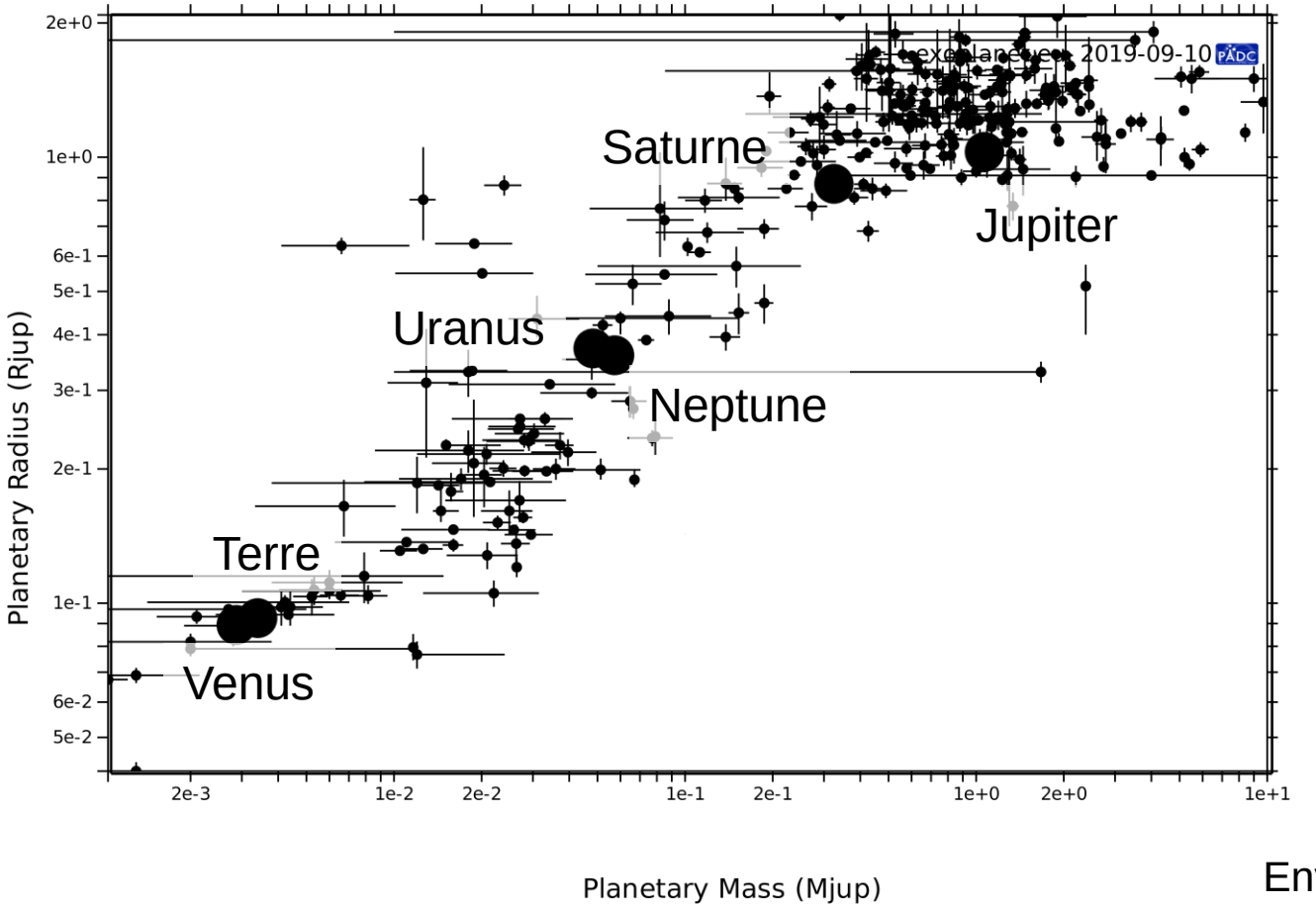
Environ 300 planètes

MESURES COMBINEES DE MASSES ET RAYONS



Environ 300 planètes

MESURES COMBINEES DE MASSES ET RAYONS



Environ 300 planètes

MESURES COMBINEES DE MASSES ET RAYONS

(1) Equilibre hydrostatique $dP + \rho g dr = 0$

MESURES COMBINEES DE MASSES ET RAYONS

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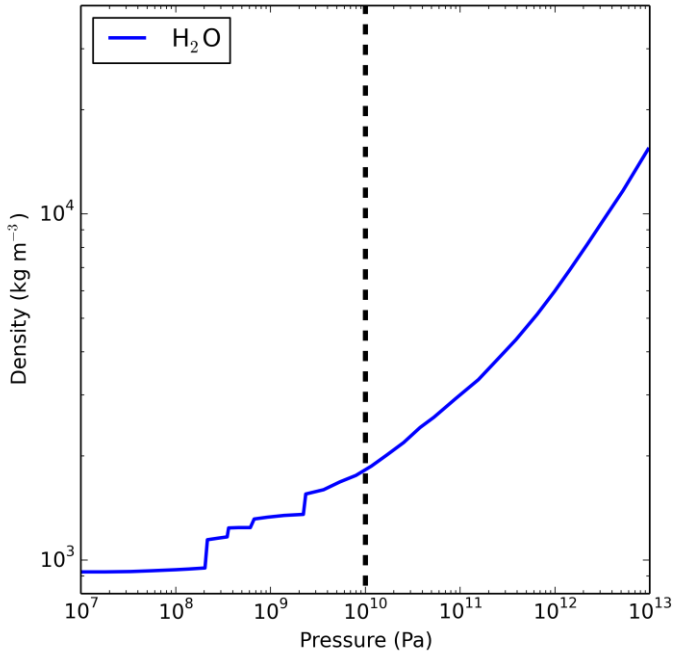
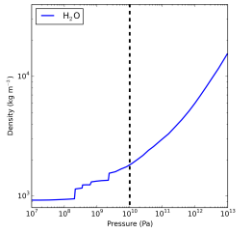
(2) Equations d'état



MESURES COMBINEES DE MASSES ET RAYONS

(1) Equilibre hydrostatique $$dP + \rho g dr = 0$$

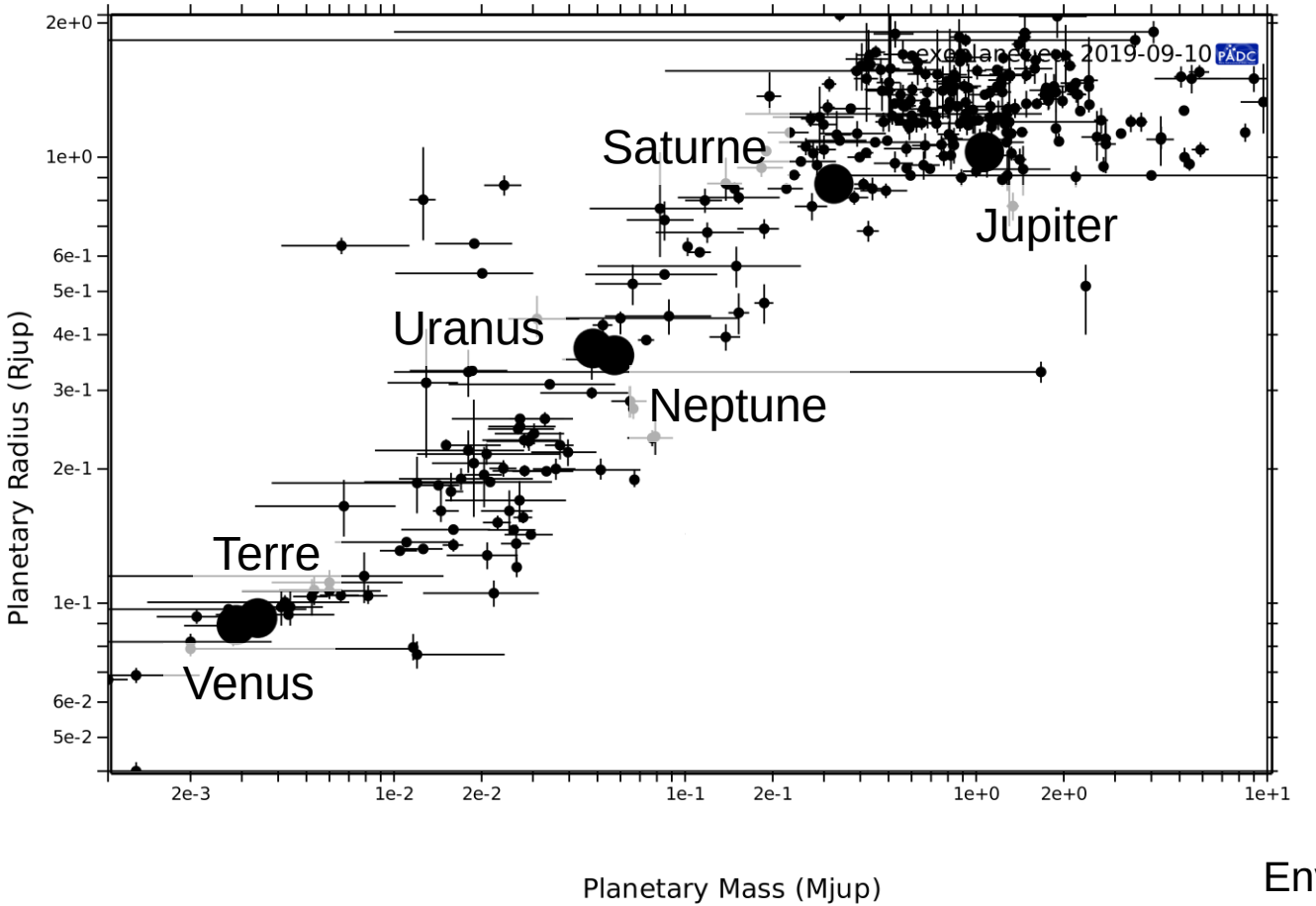
(2) Equations d'état



(3) Transport d'énergie (convectif ? conductif ?)

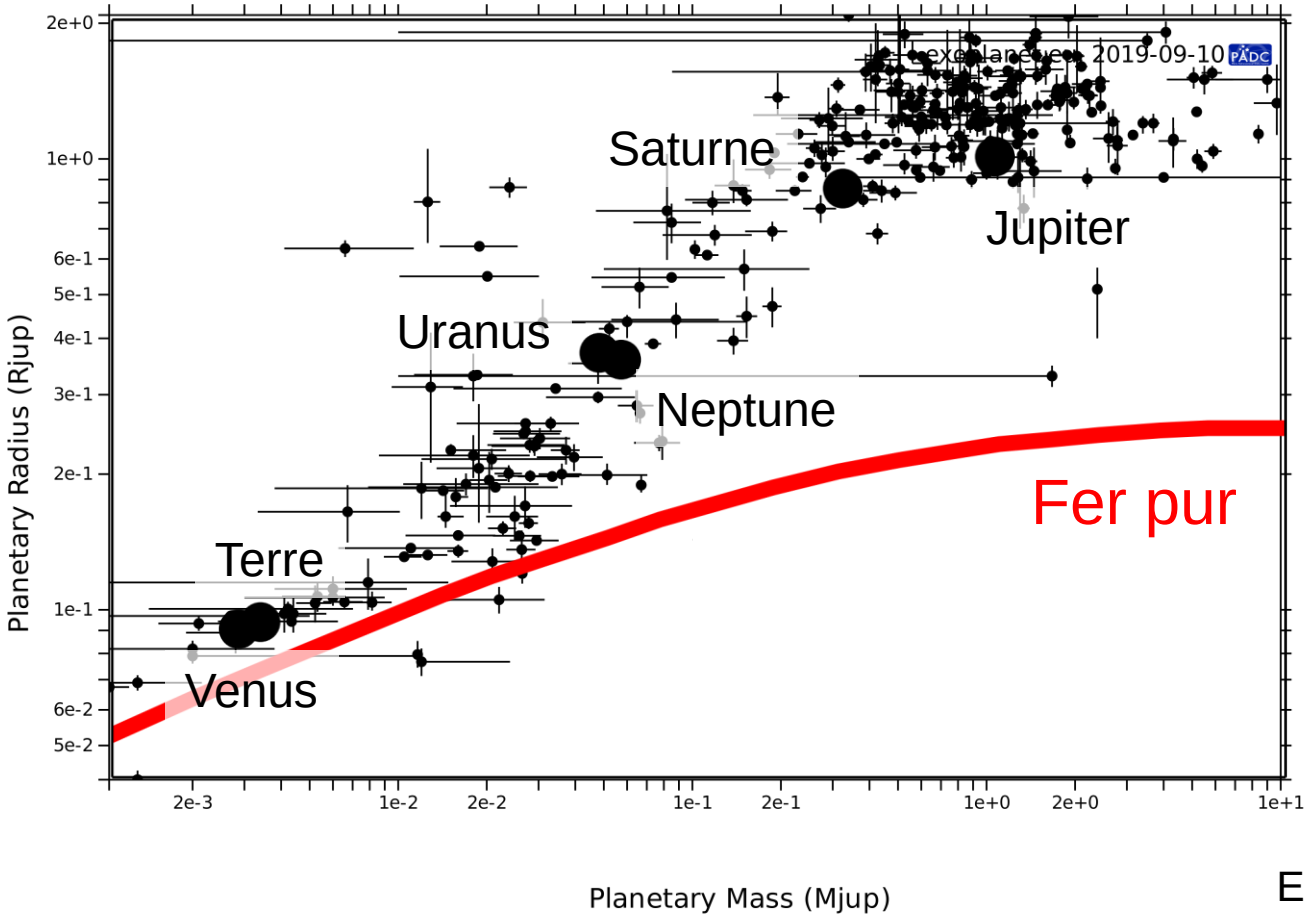
$$\frac{dT}{dr} = -K$$

MESURES COMBINEES DE MASSES ET RAYONS



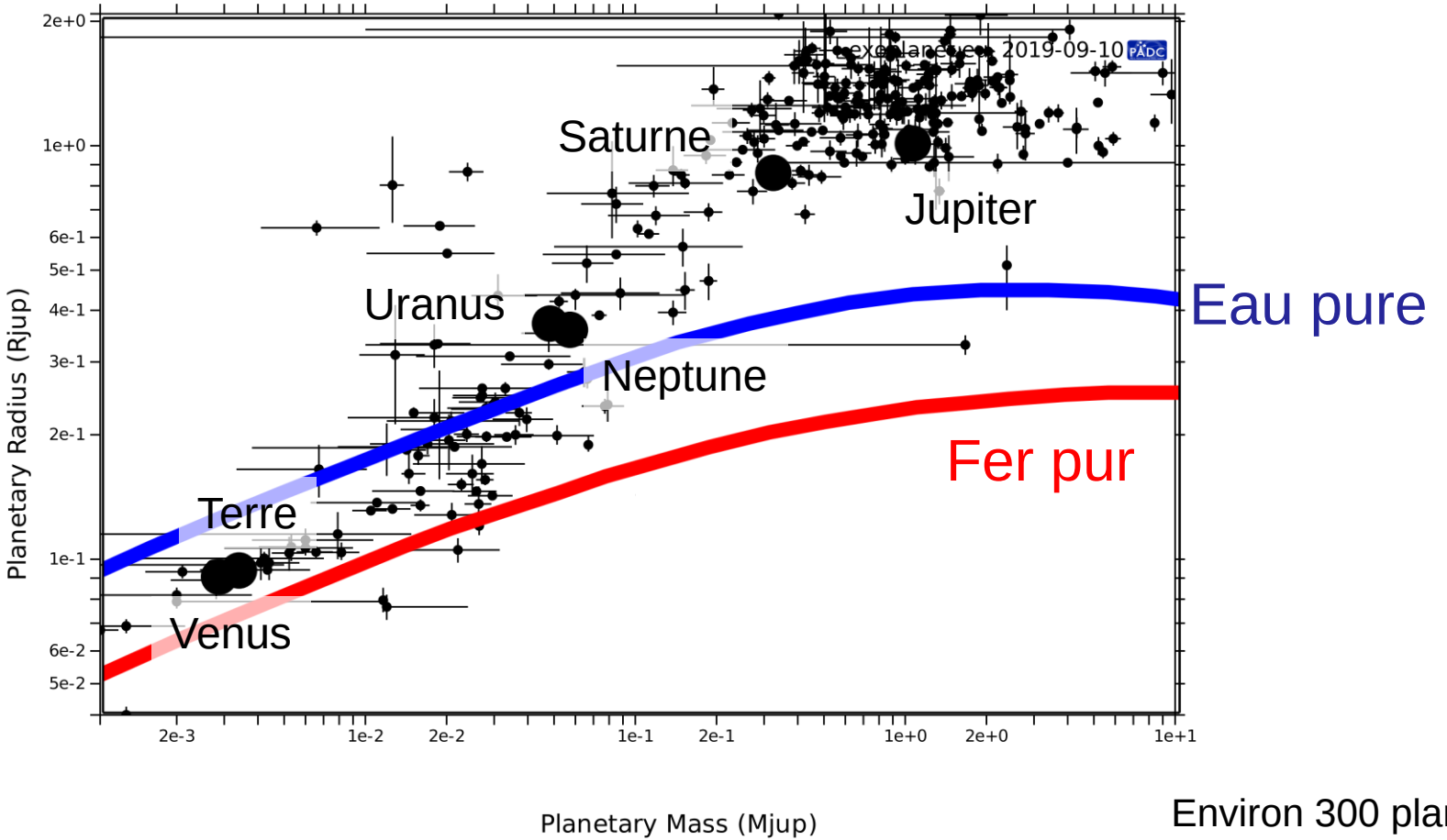
Environ 300 planètes

MESURES COMBINEES DE MASSES ET RAYONS



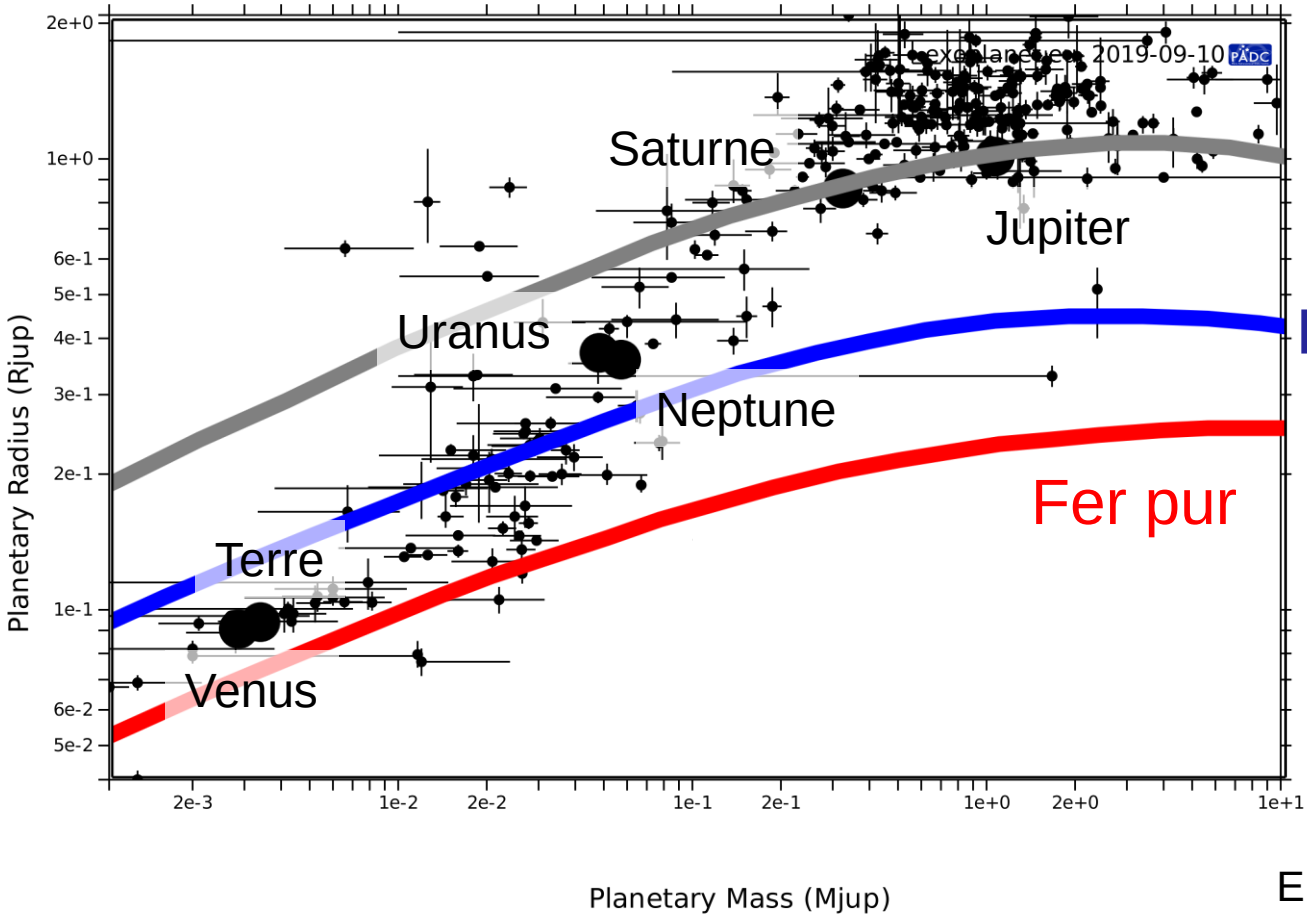
Environ 300 planètes

MESURES COMBINEES DE MASSES ET RAYONS



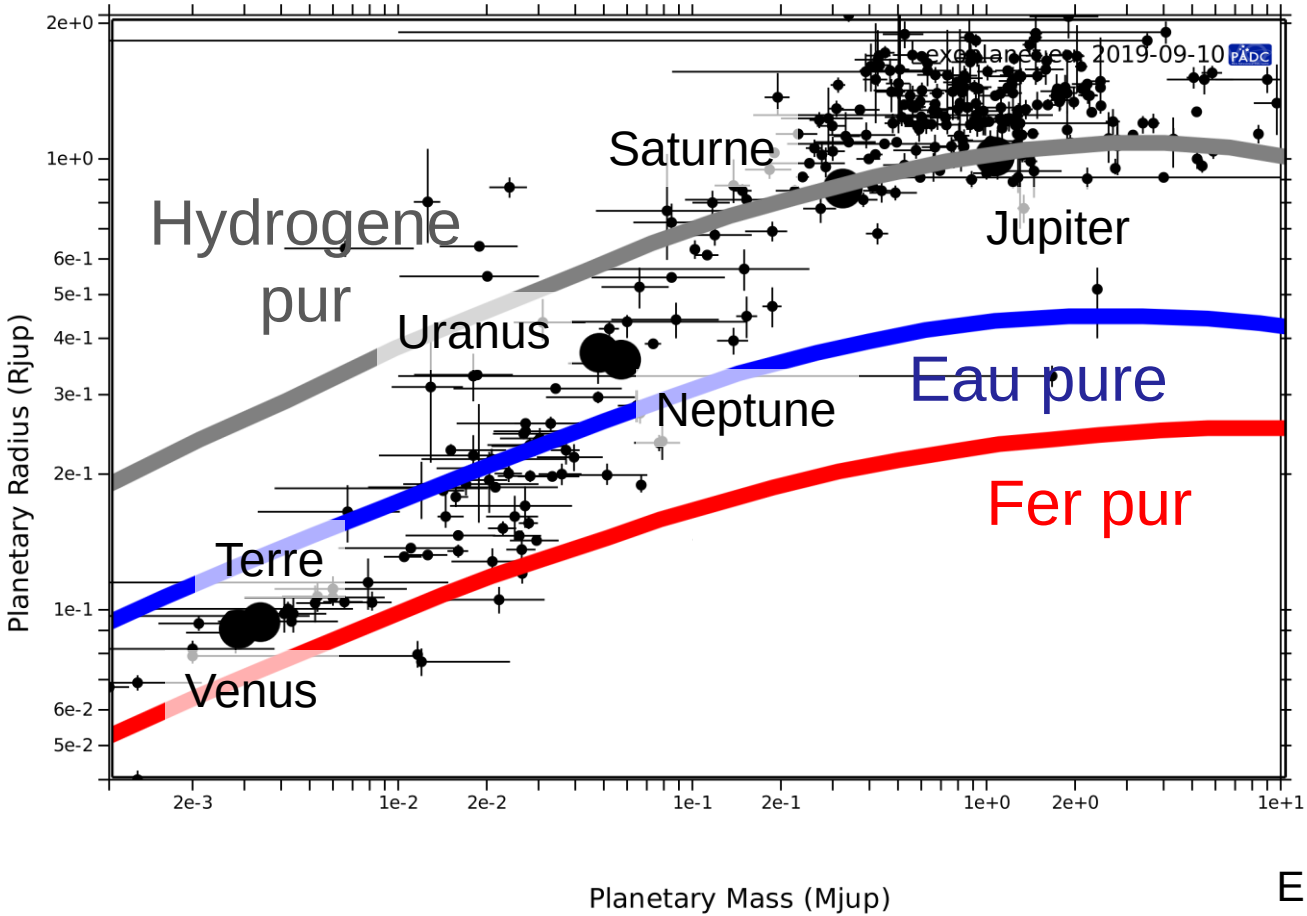
Environ 300 planètes

MESURES COMBINEES DE MASSES ET RAYONS



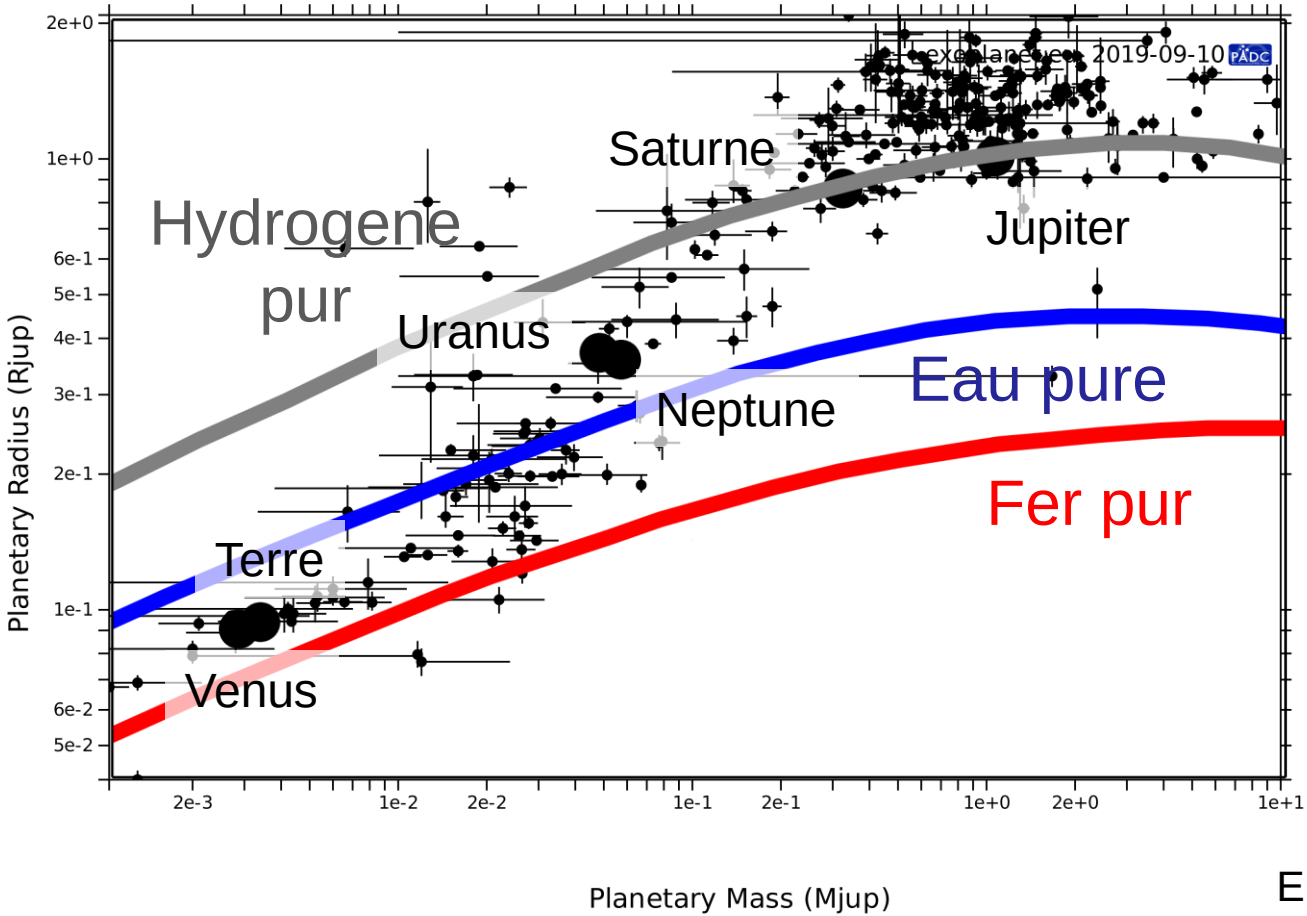
Environ 300 planètes

QUELQUES RESULTATS RASSURANTS



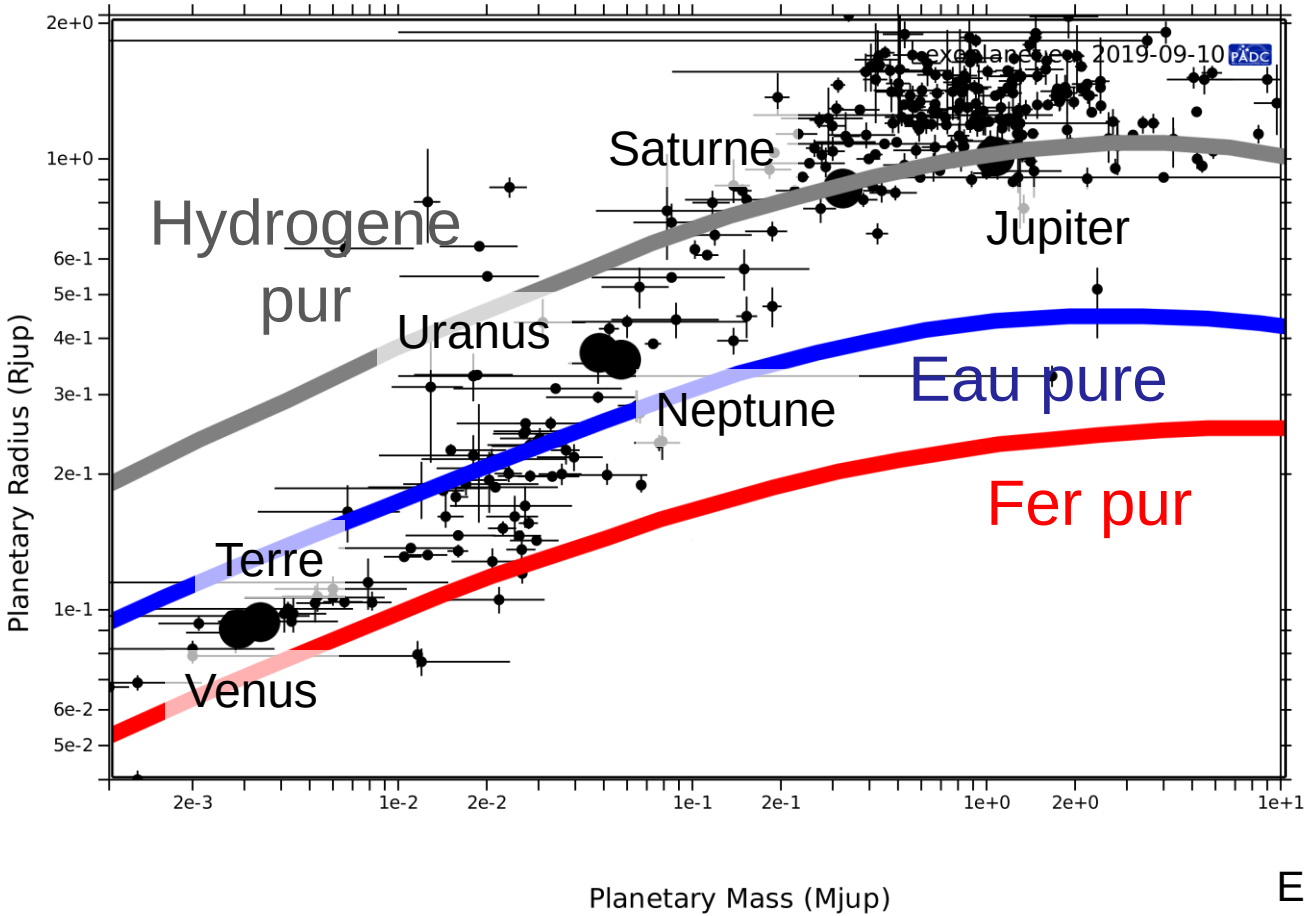
Environ 300 planètes

QUELQUES RESULTATS INTERESSANTS



Environ 300 planètes

QUELQUES RESULTATS INTRIGUANTS



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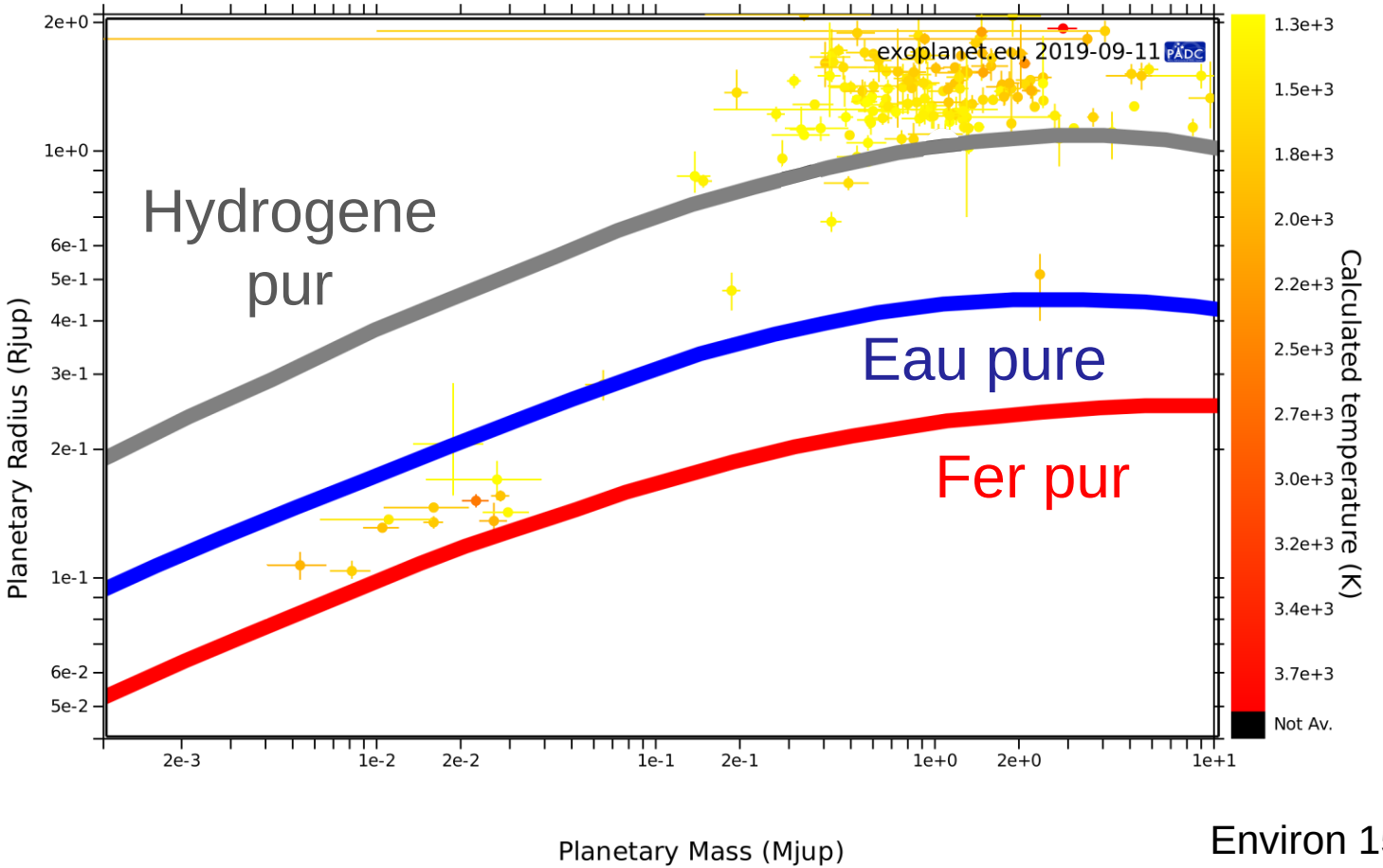
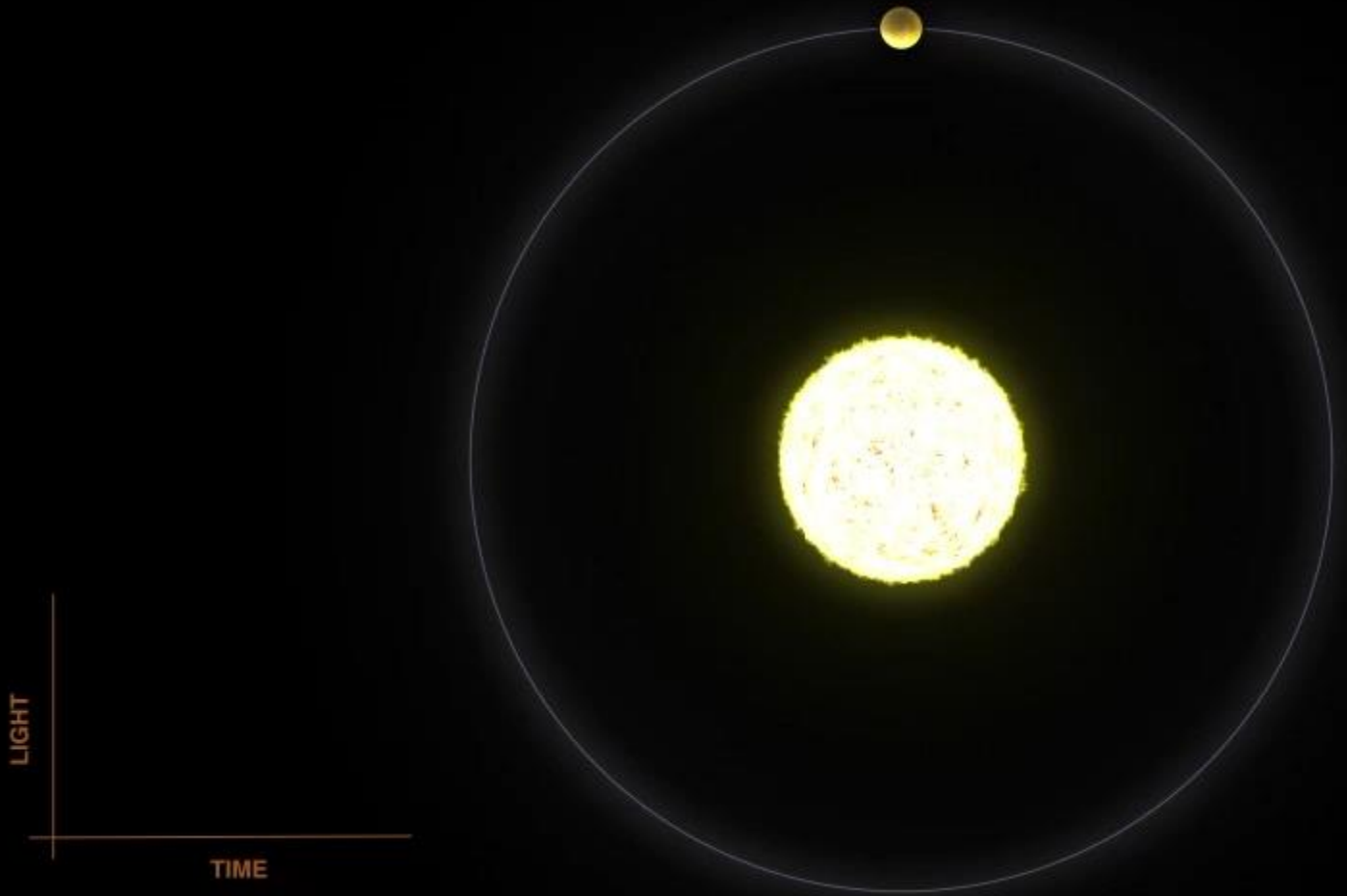
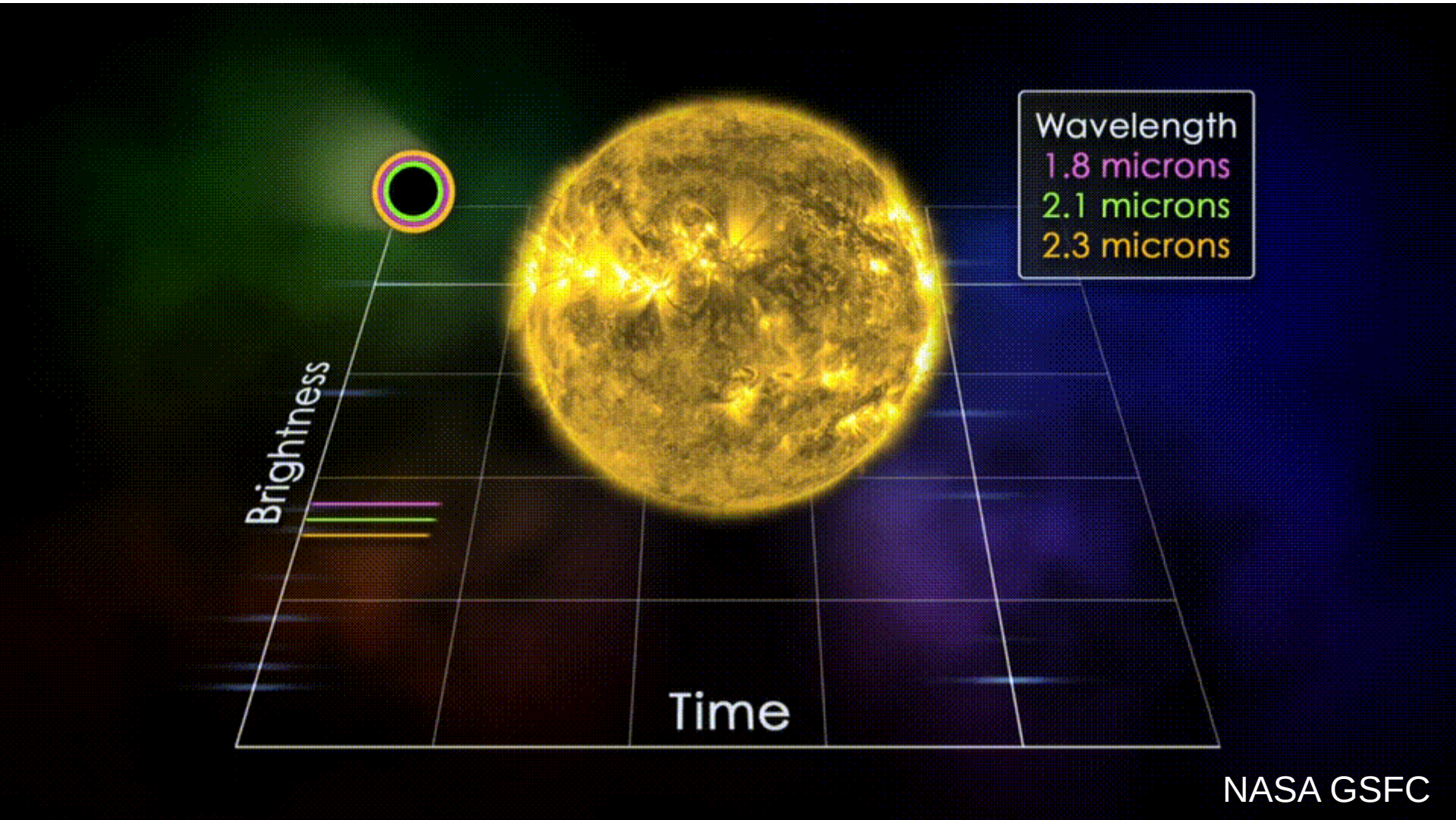


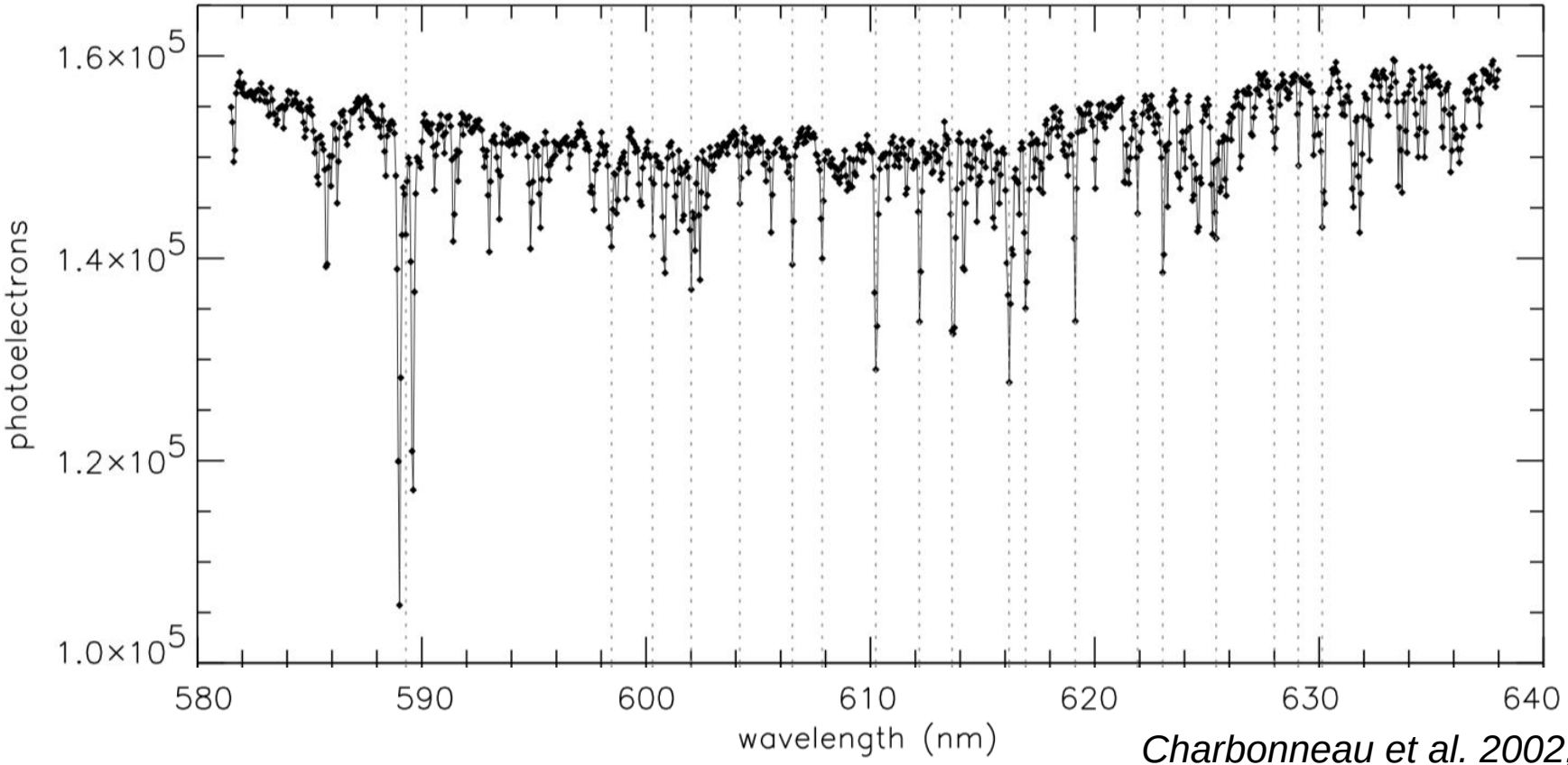
Environ 150 planètes



NASA

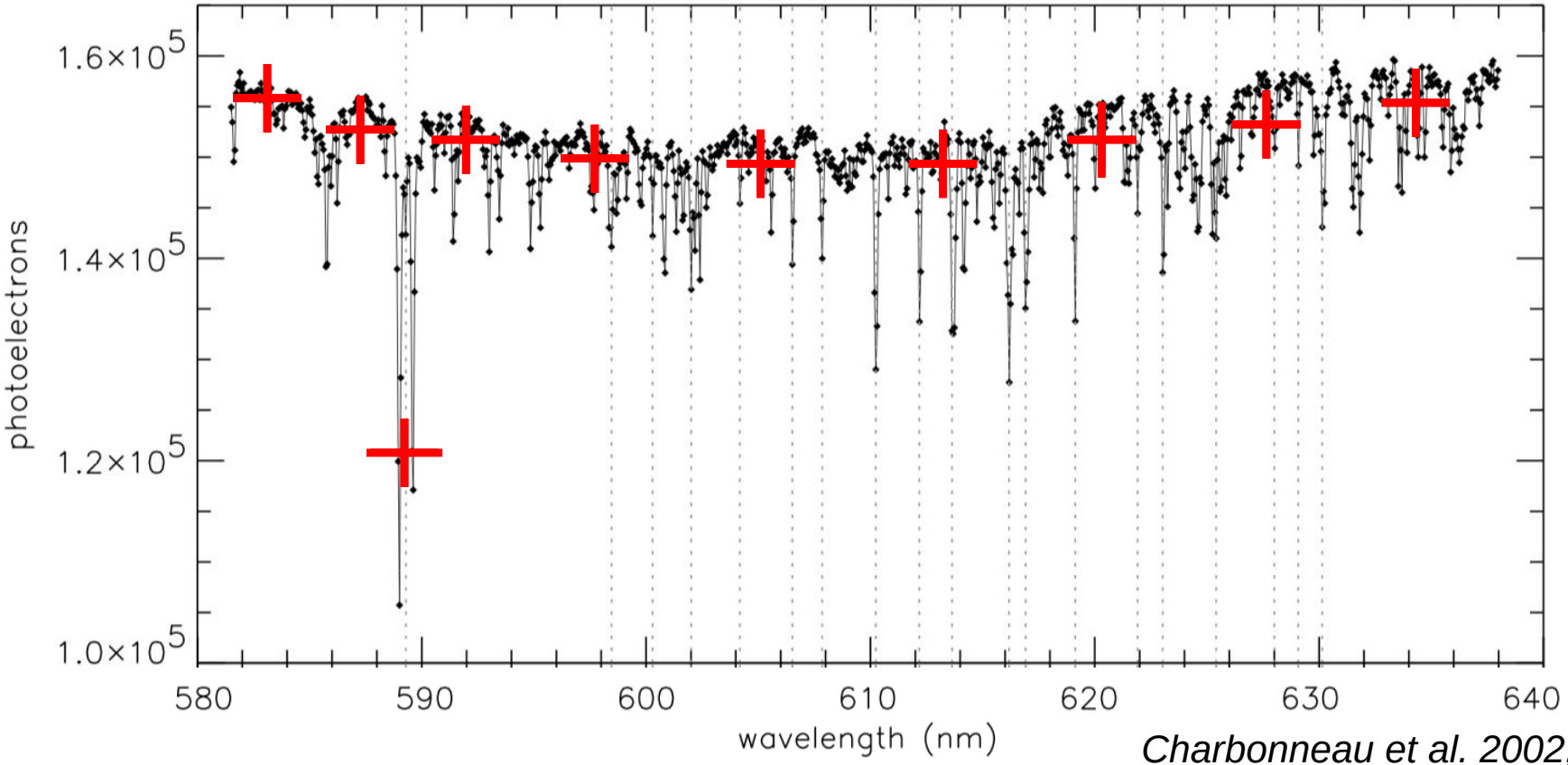

Wavelength
1.8 microns
2.1 microns
2.3 microns
Brightness
Time
NASA GSFC

PREMIER SPECTRE EN TRANSIT –
JUPITER CHAUD HD 209458 b



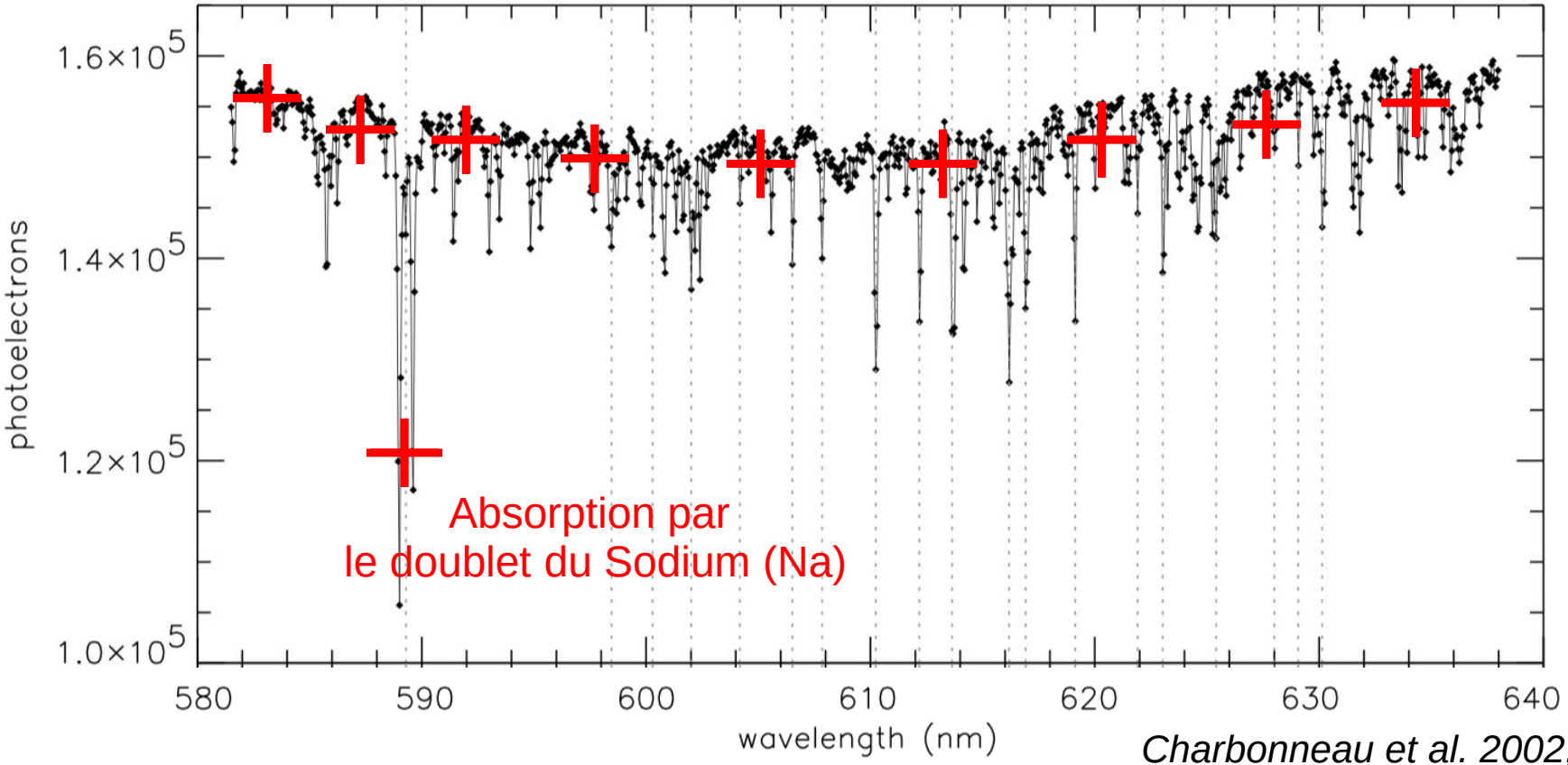
Charbonneau et al. 2002, ApJ

PREMIER SPECTRE EN TRANSIT –
JUPITER CHAUD HD 209458 b



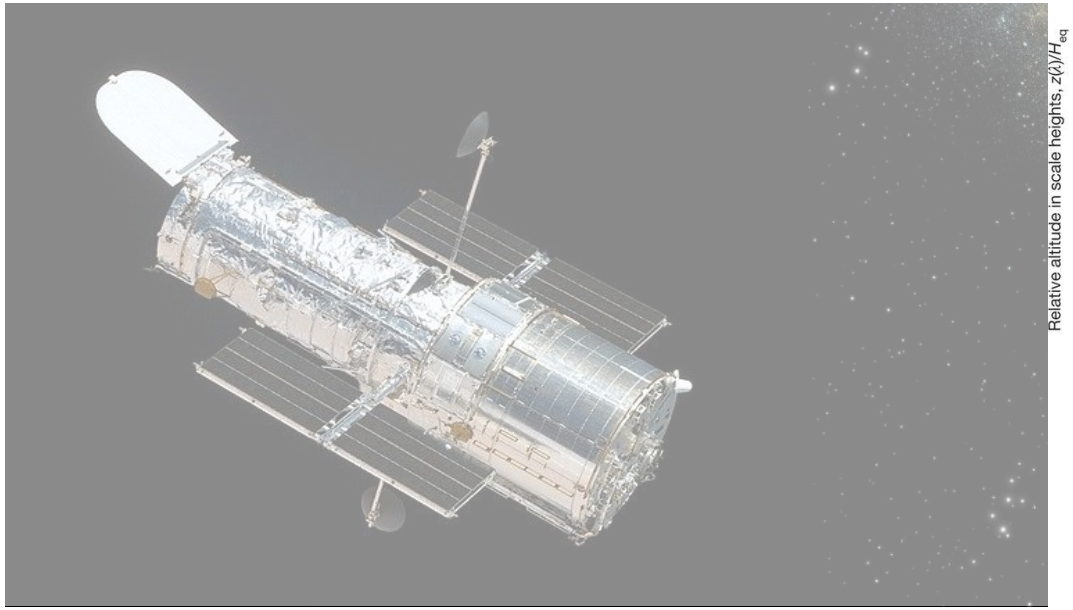
Charbonneau et al. 2002, ApJ

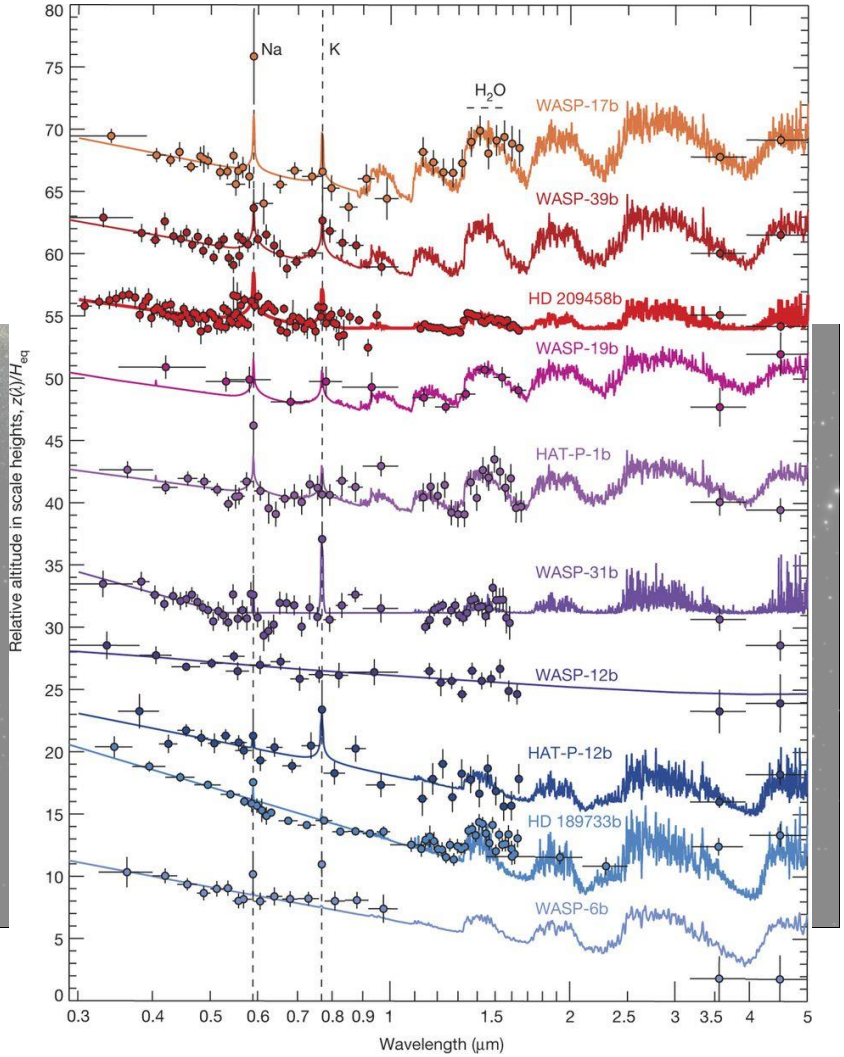
PREMIER SPECTRE EN TRANSIT –
JUPITER CHAUD HD 209458 b



Charbonneau et al. 2002, ApJ

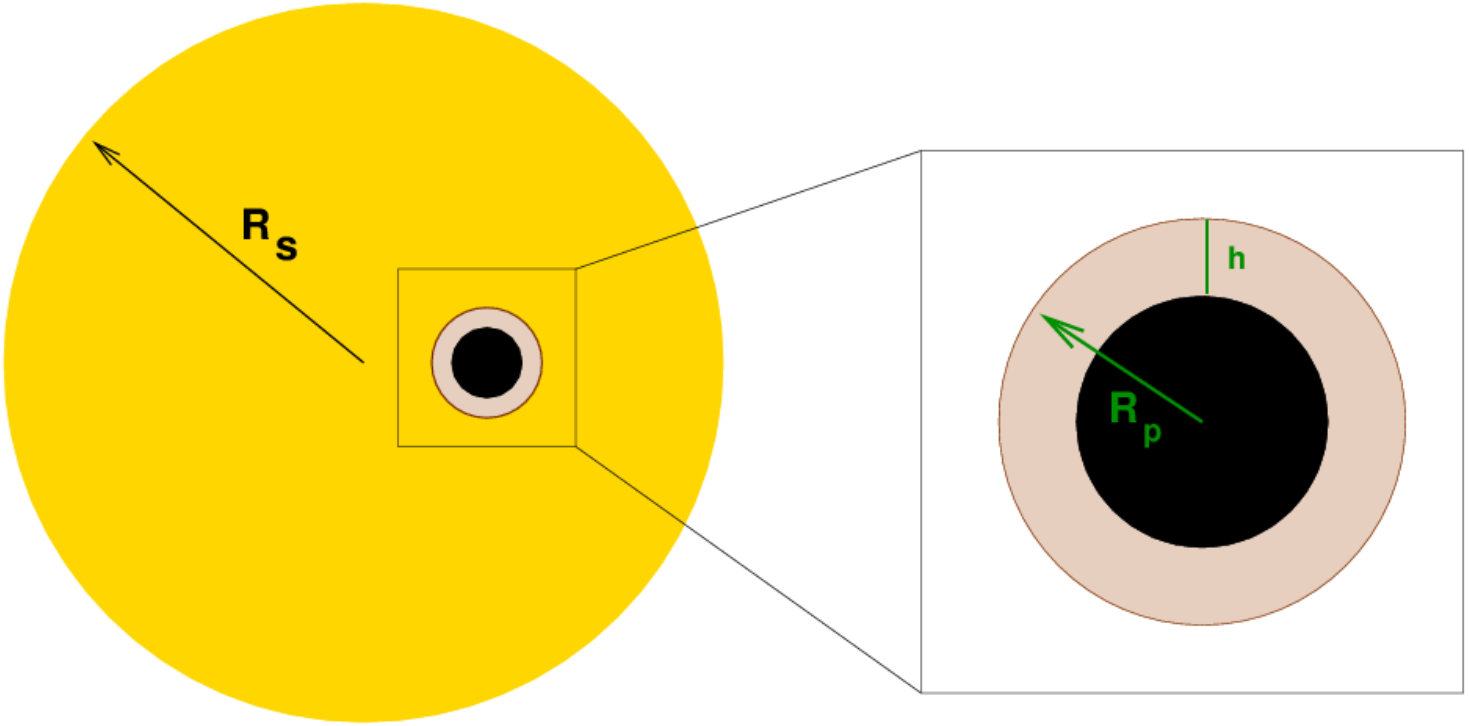
SPECTRES EN TRANSIT DE JUPITERS CHAUDS



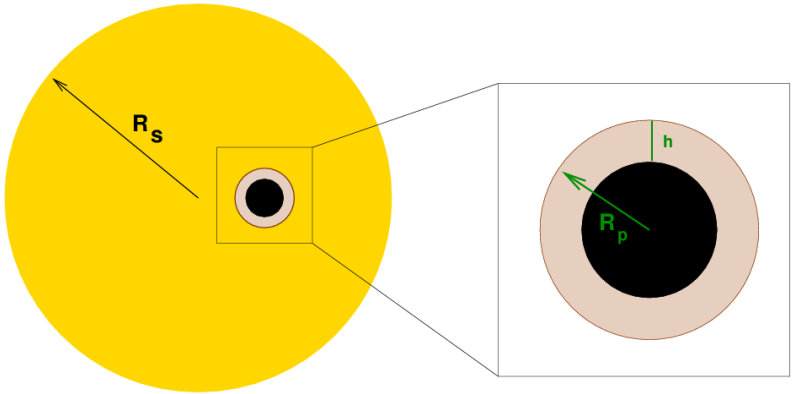


Sing et al. 2016, Nature

SPECTROSCOPIE DE TRANSIT



SPECTROSCOPIE DE TRANSIT



$$\text{SIGNAL} = \frac{R_p^2}{R_S^2} - \frac{(Rp-h)^2}{R_S^2}$$

$$= \frac{R_p^2}{R_S^2} - \frac{R_p^2}{R_S^2} \times \left(1 - \frac{h}{R_p}\right)^2$$

$$\sim \frac{2Rp \times h}{R_S^2}$$

ESTIMER LA TAILLE TYPIQUE D'UNE ATMOSPHERE

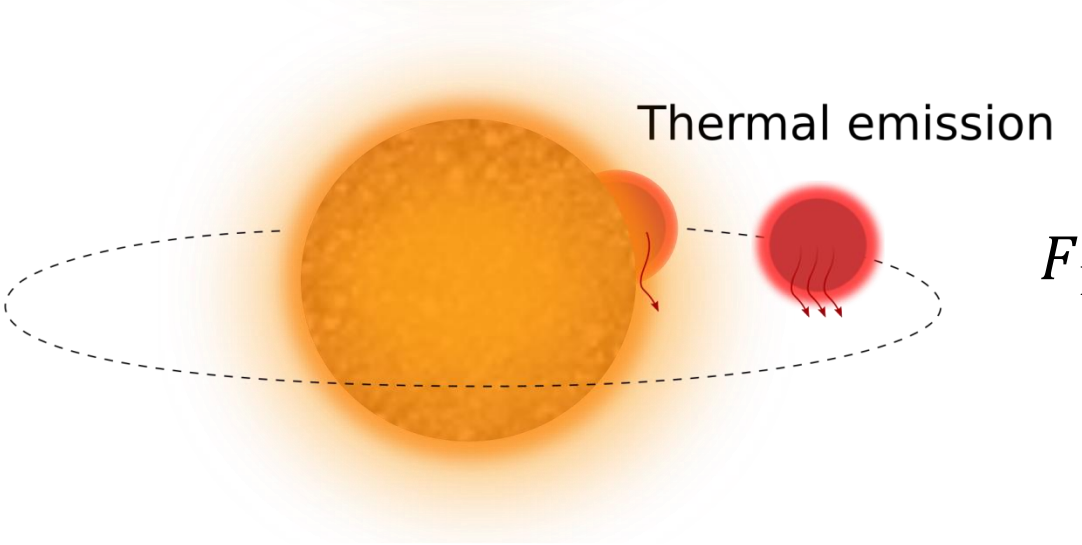
(1) Equilibre hydrostatique $dP + \rho g dr = 0$

(2) Equations d'état $P = \frac{\rho RT}{M}$ (GAZ PARFAIT)

$$dln(P) + \frac{Mg}{RT} dr = 0$$

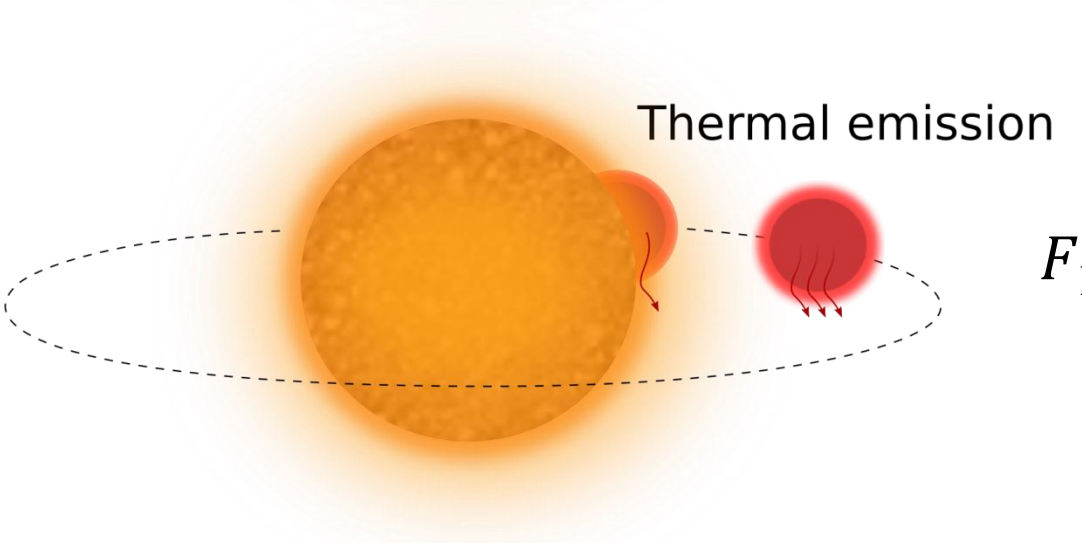
$$P \propto e^{(-\frac{r}{H})} \quad \text{avec} \quad H = \frac{RT}{Mg}$$

ECLIPSE SECONDAIRE



$$F_{\text{PLANETE}} = \pi\, Rp^2 \times \varepsilon\, \sigma\, T^4$$

ECLIPSE SECONDAIRE



$$F_{\text{PLANETE}} = \pi\, Rp^2 \times \varepsilon\, \sigma\, T^4$$

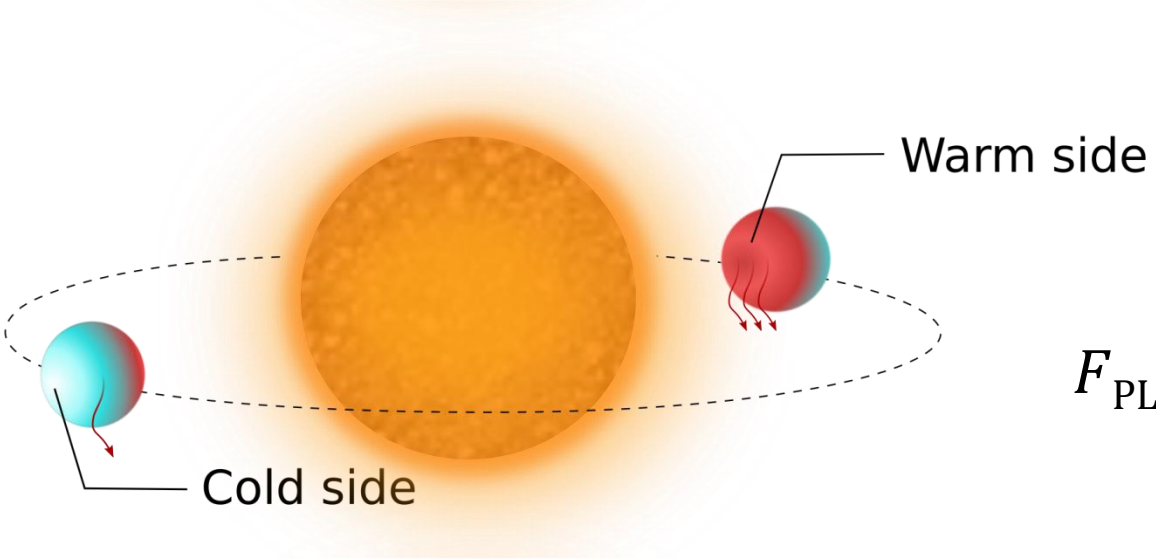
<u>En dehors de l'eclipse :</u>

$$F_{\text{ETOILE}} + F_{\text{PLANETE}}$$

<u>Pendant l'eclipse :</u>

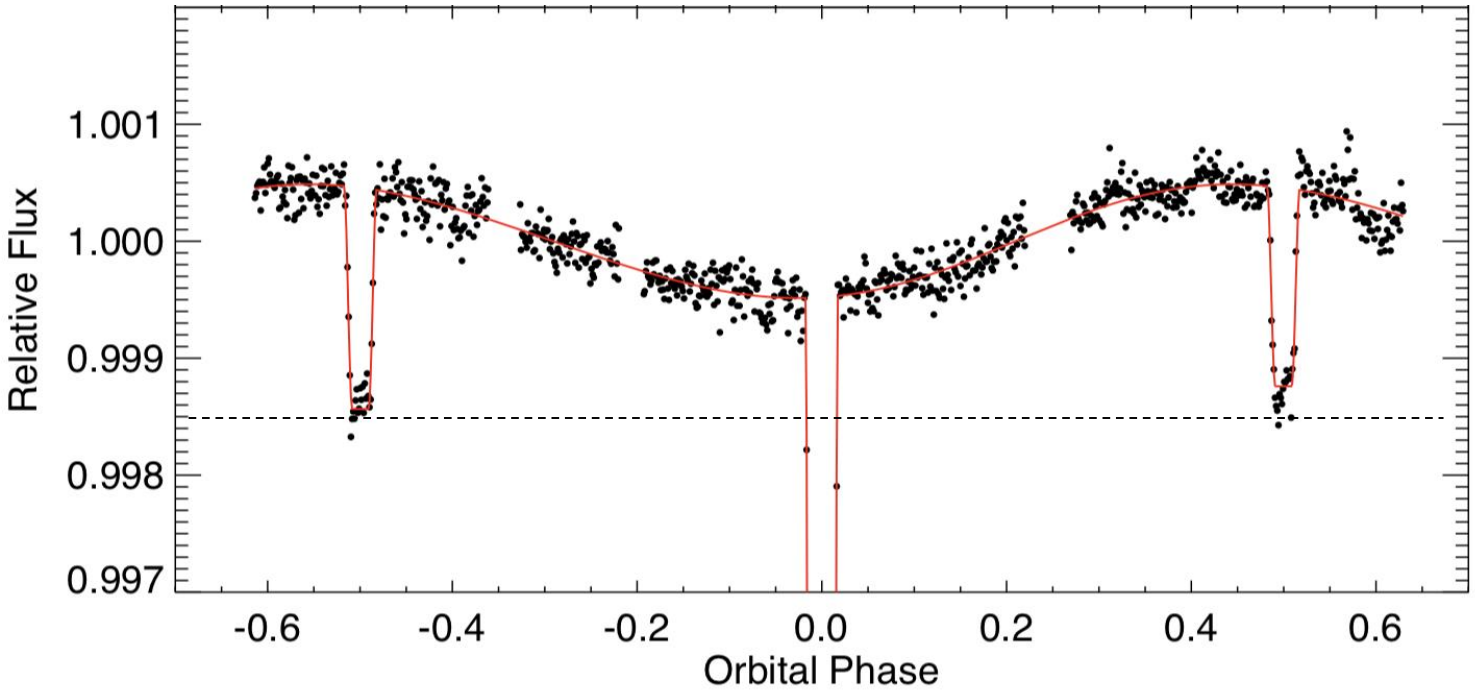
$$F_{\text{ETOILE}}$$

COURBE DE PHASE THERMIQUE



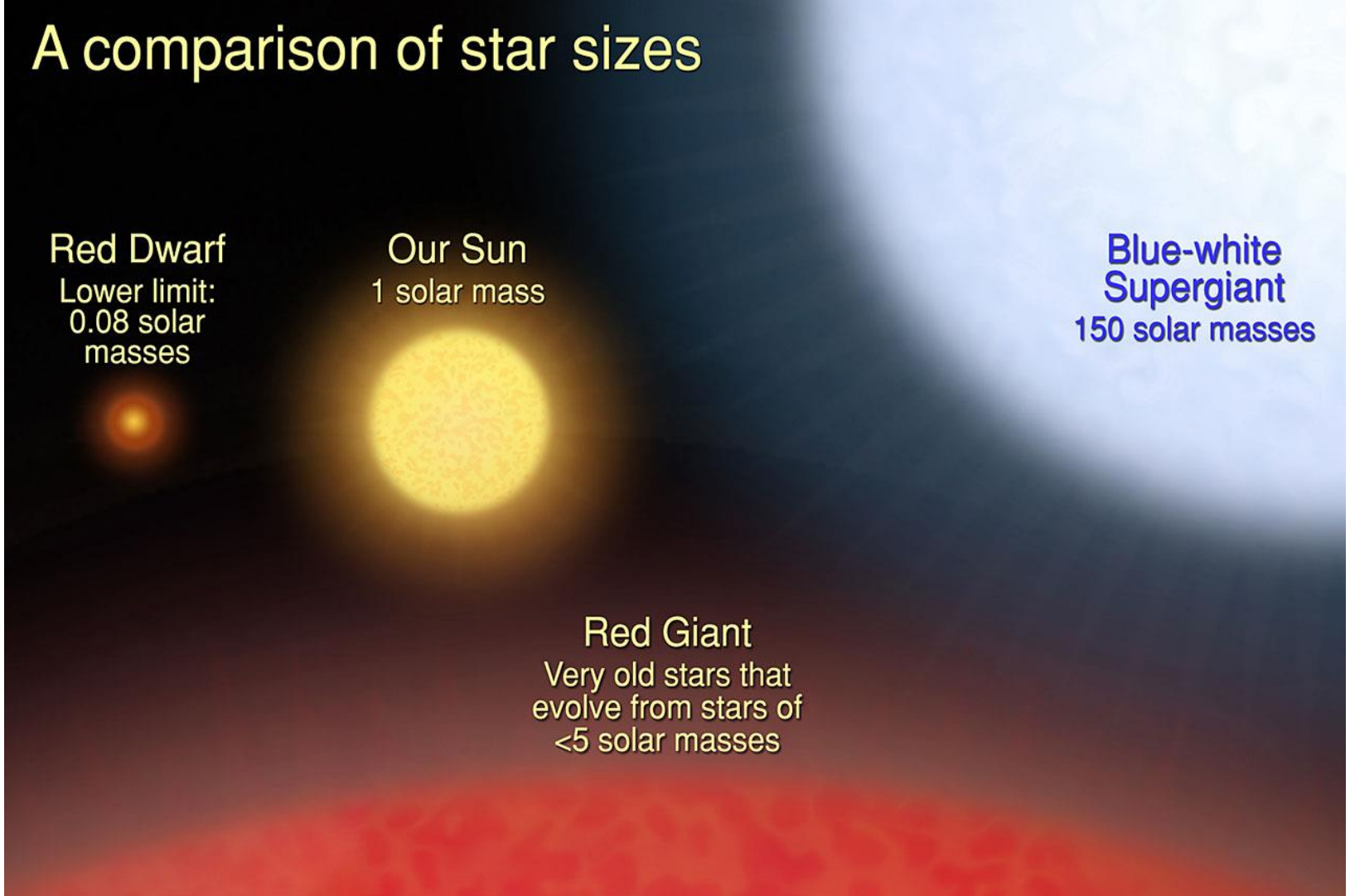
$$F_{\text{PLANETE}} = \pi\, Rp^2 \times \varepsilon\, \sigma\, T^4$$

COURBE DE PHASE THERMIQUE ET ECLIPSE SECONDAIRE DE HD 189733b

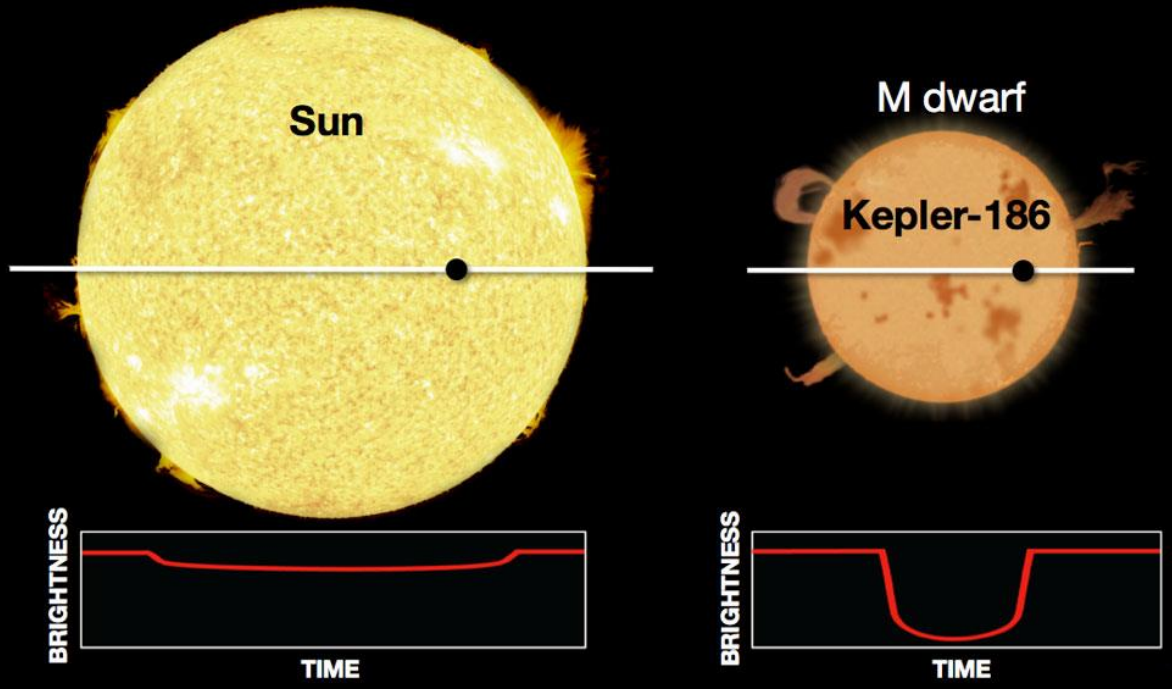


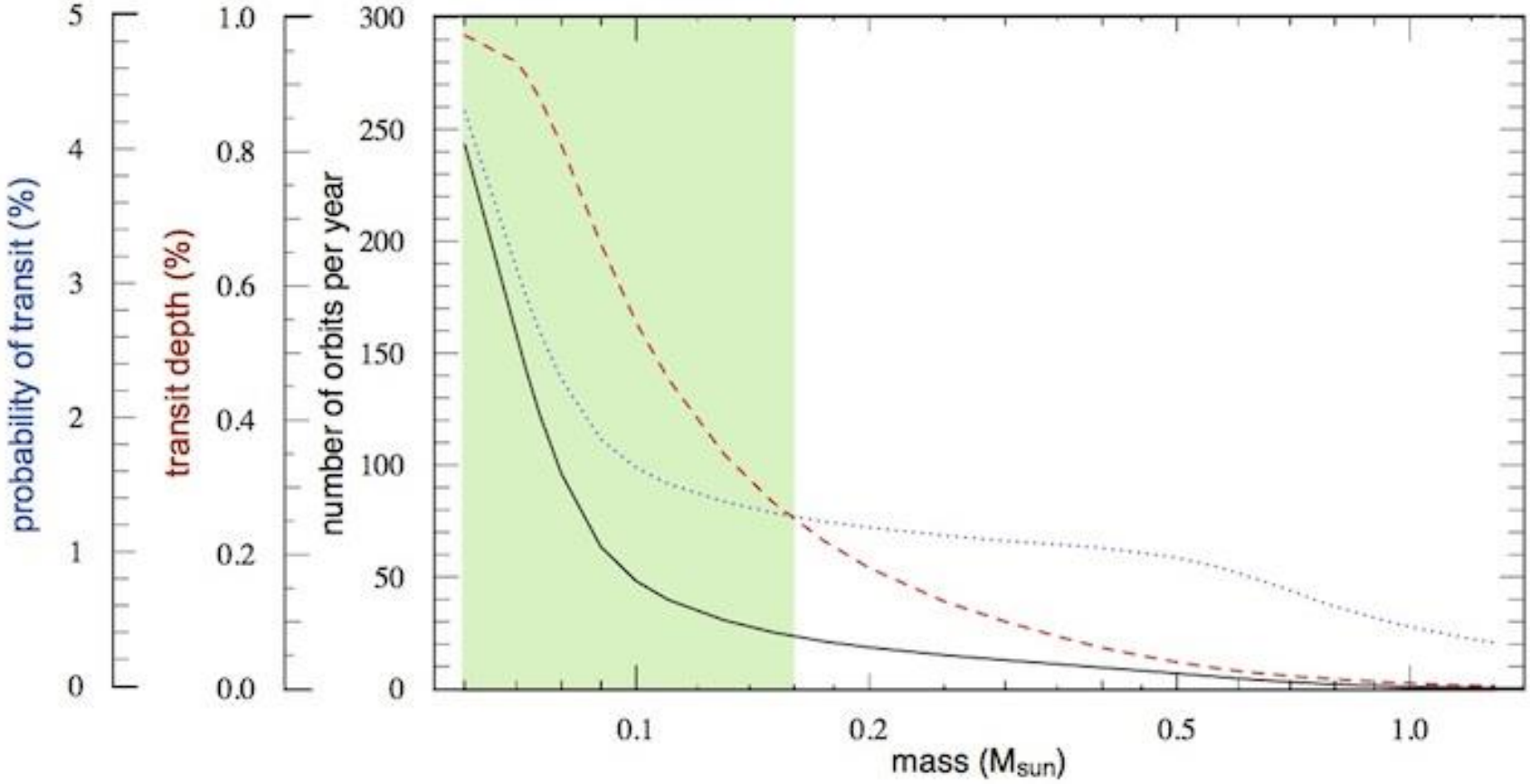
Knutson et al. 2012

L’opportunité des naines M


A comparison of star sizes
Red Dwarf
Lower limit:
0.08 solar
masses
Our Sun
1 solar mass
Blue-white
Supergiant
150 solar masses
Red Giant
Very old stars that
evolve from stars of
<5 solar masses

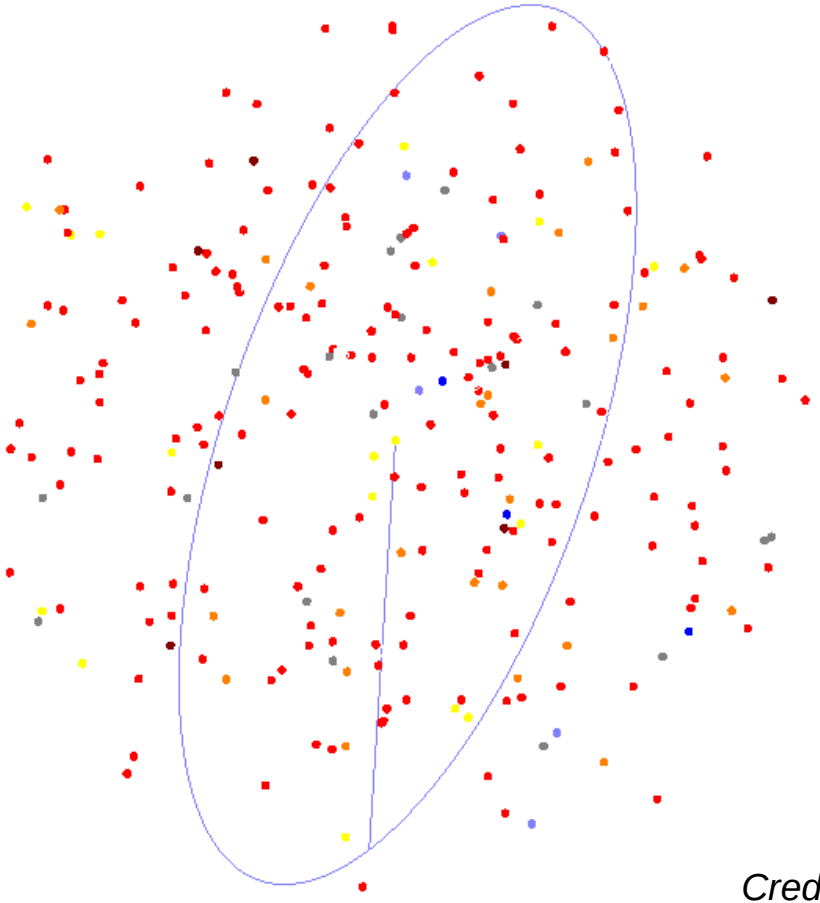
METHODE DES TRANSITS





Credit: SPECULOOS Project

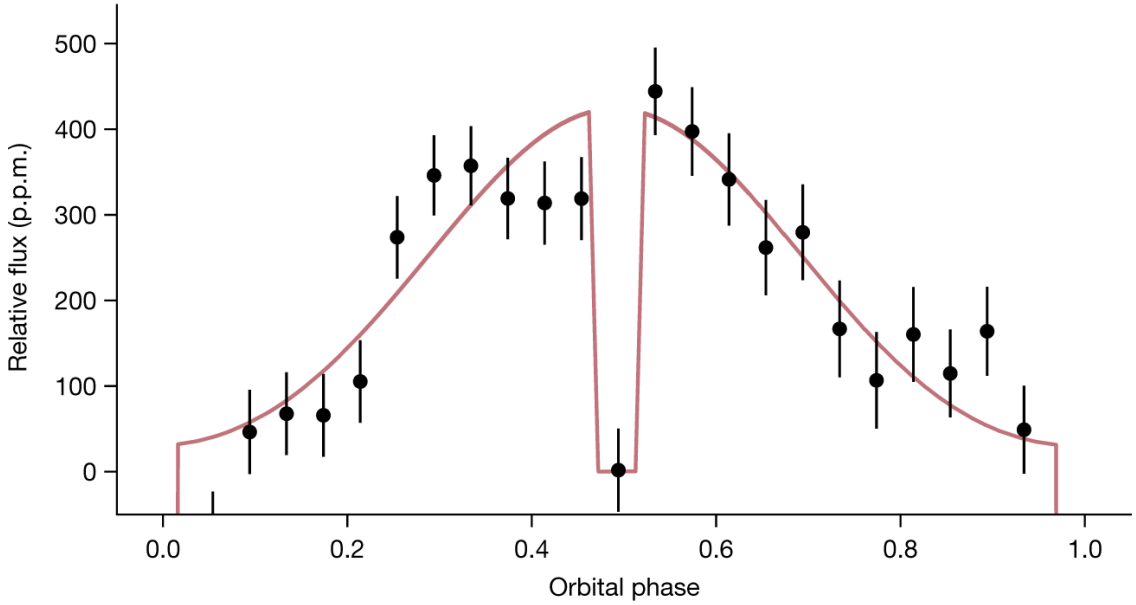
ETOILES SITUEES A MOINS DE 30 ANNEES LUMIERE

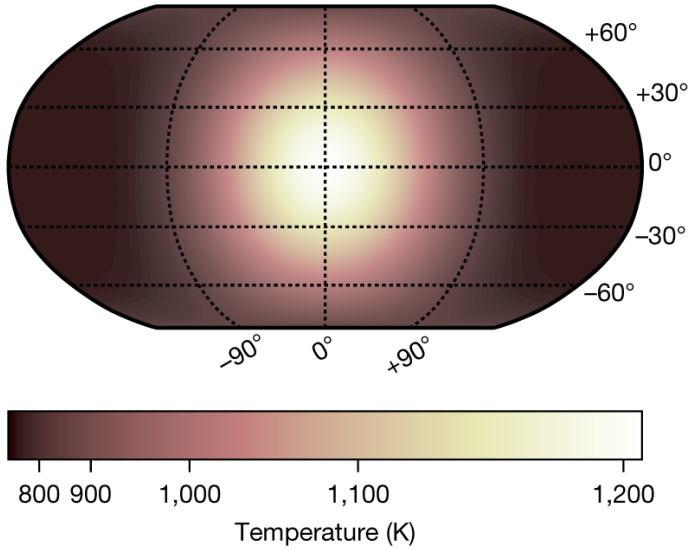


Credit: A. Riedel, T. Henry, and RECONS

ABSENCE D'ATMOSPHERE AUTOUR DE LA PLANETE ROCHEUSE LHS 3844b

1.3 R_p, 70x plus irradiée que la Terre





$$F_{\text{PLANETE}} = \pi\, Rp^2 \times \varepsilon\, \sigma\, T^4$$

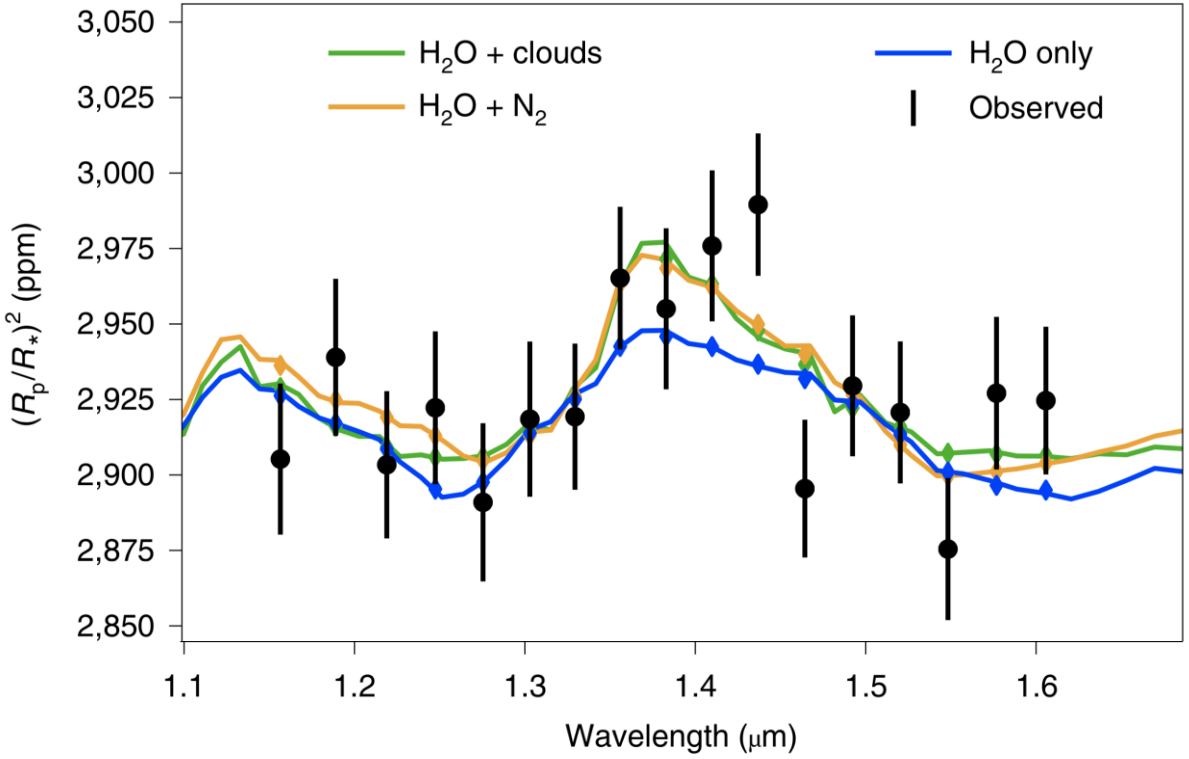
Kreidberg et al. 2019, Nature

DETECTION DE VAPEUR D'EAU SUR LA SUPER-TERRE TEMPEREE K2-18b

SIGNAL

$$\sim \frac{2Rp \times h}{R_s{}^2}$$

avec $h \propto \frac{RT}{Mg}$



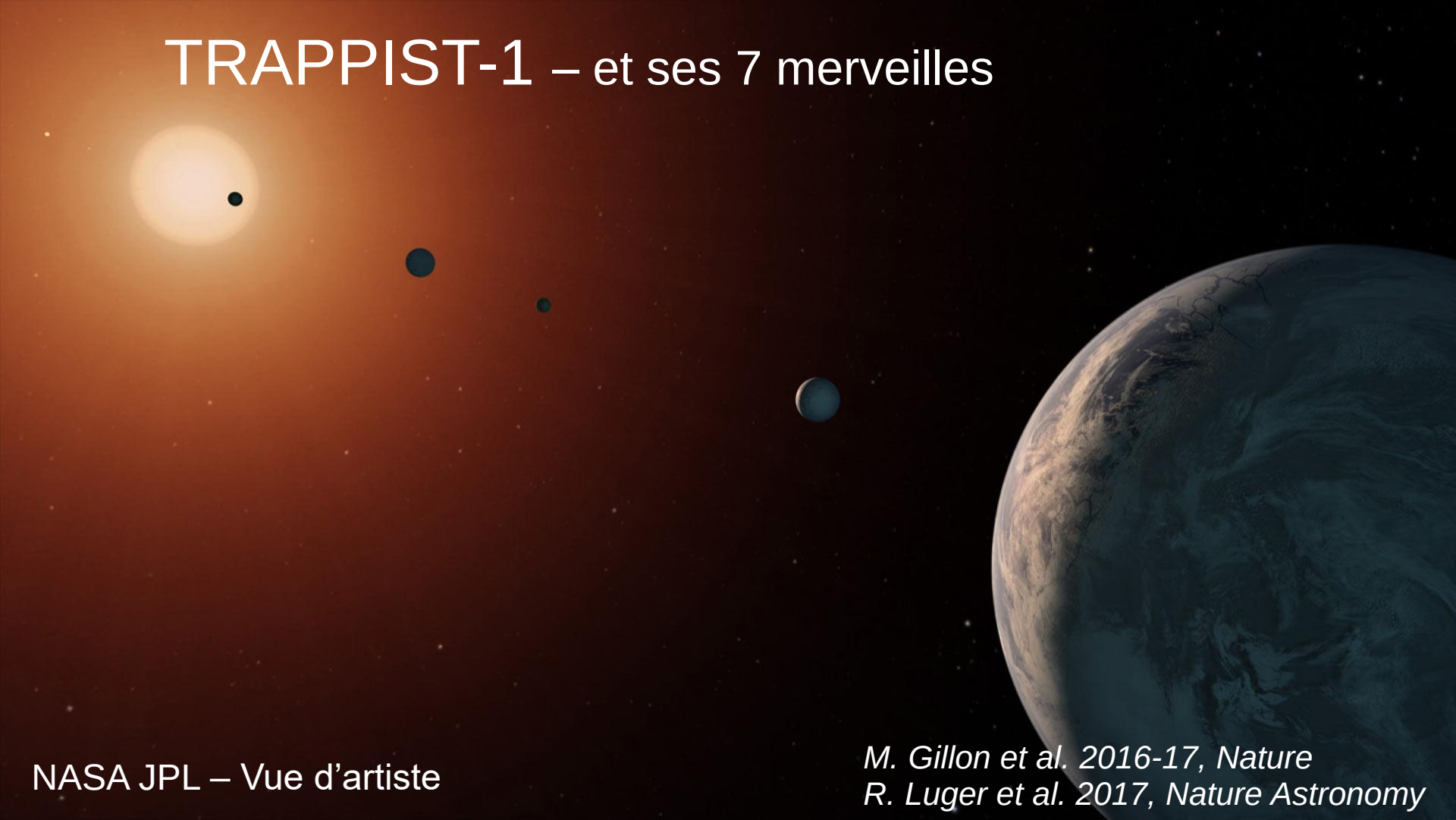
Tsiaras et al. 2019, Nature Astronomy

PROXIMA CENTAURI b – Notre plus proche voisine

ESO – Vue d'artiste

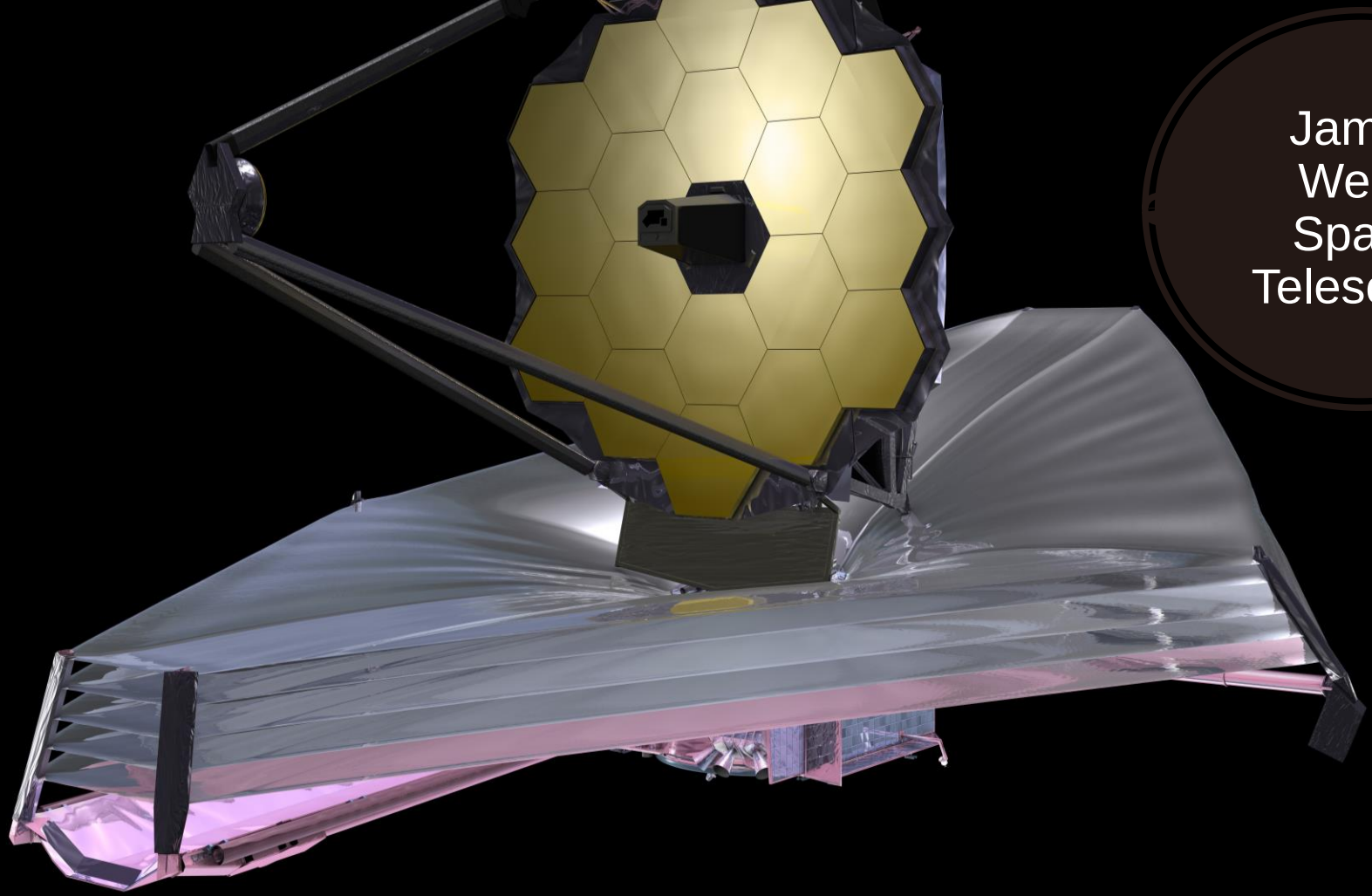
Anglada-Escudé et al. 2016, Nature

TRAPPIST-1 – et ses 7 merveilles



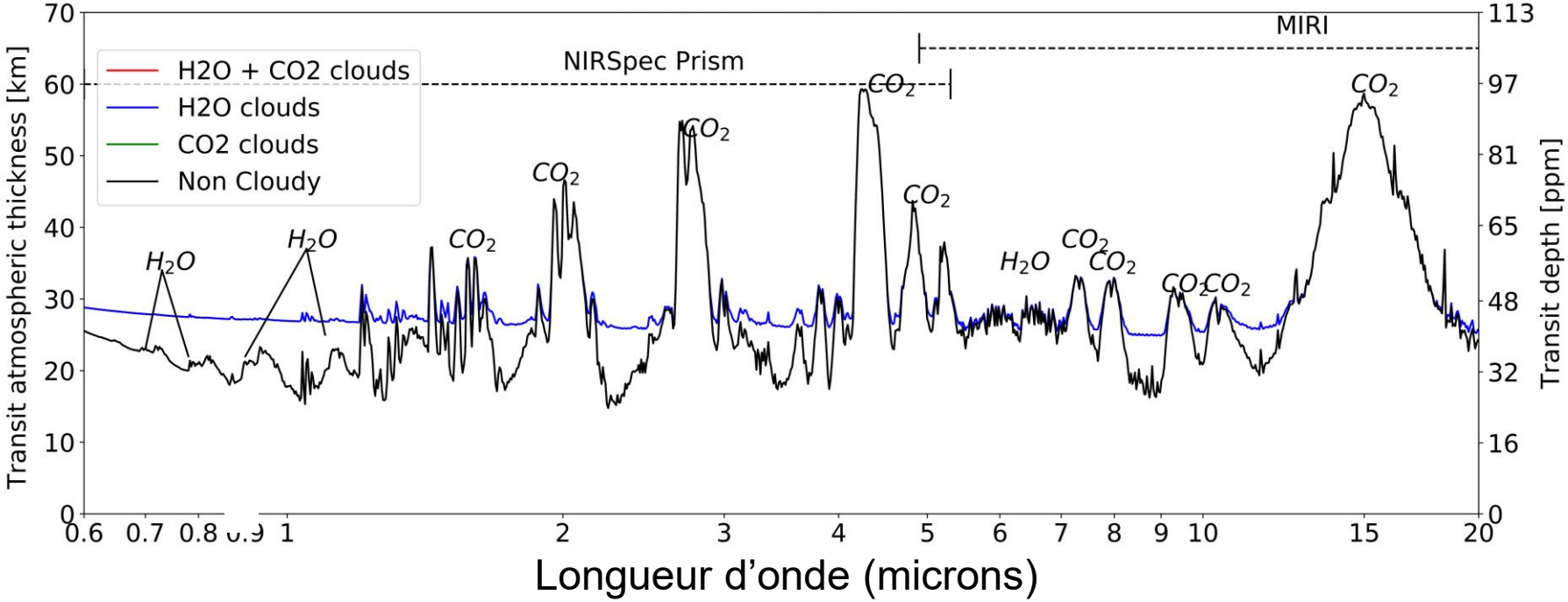
NASA JPL – Vue d'artiste

M. Gillon et al. 2016-17, Nature
R. Luger et al. 2017, Nature Astronomy



James Webb Space Telescope

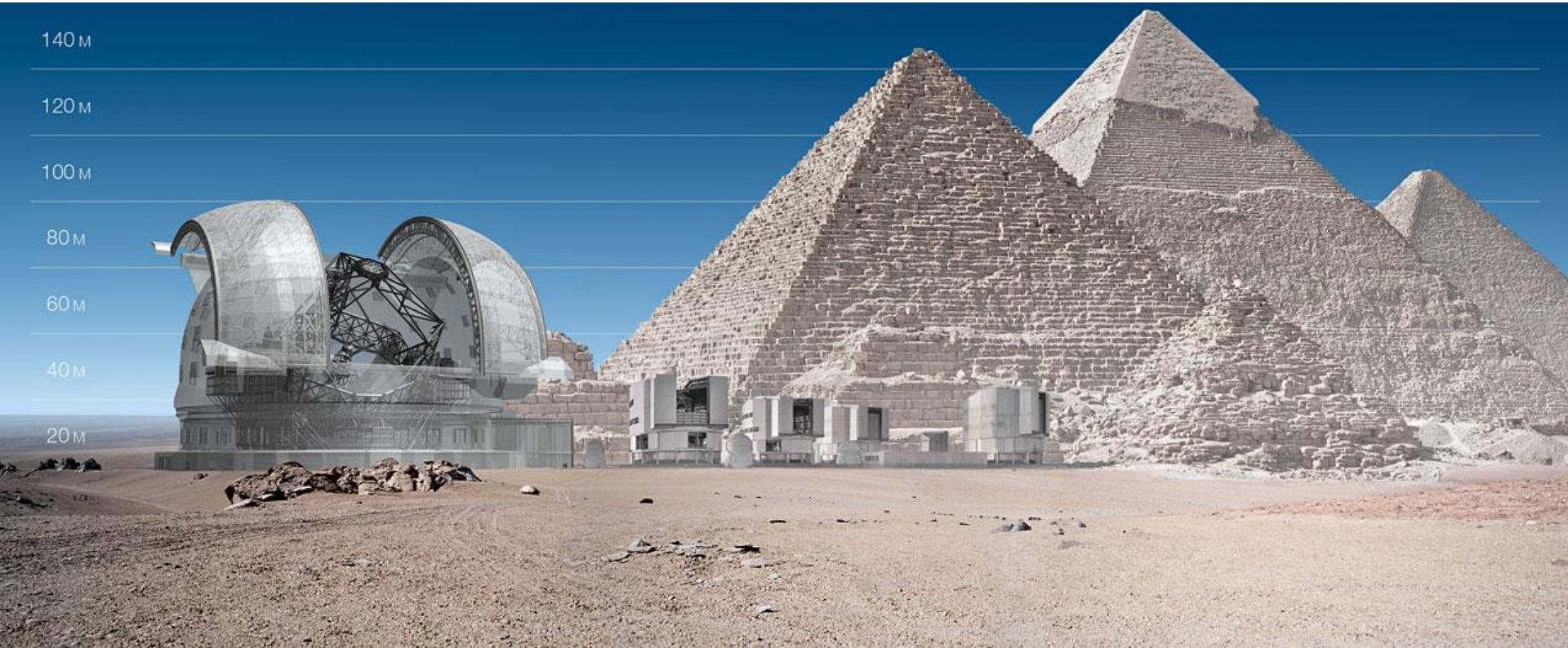
SPECTRE EN TRANSIT SIMULE POUR LA PLANETE TRAPPIST-1e

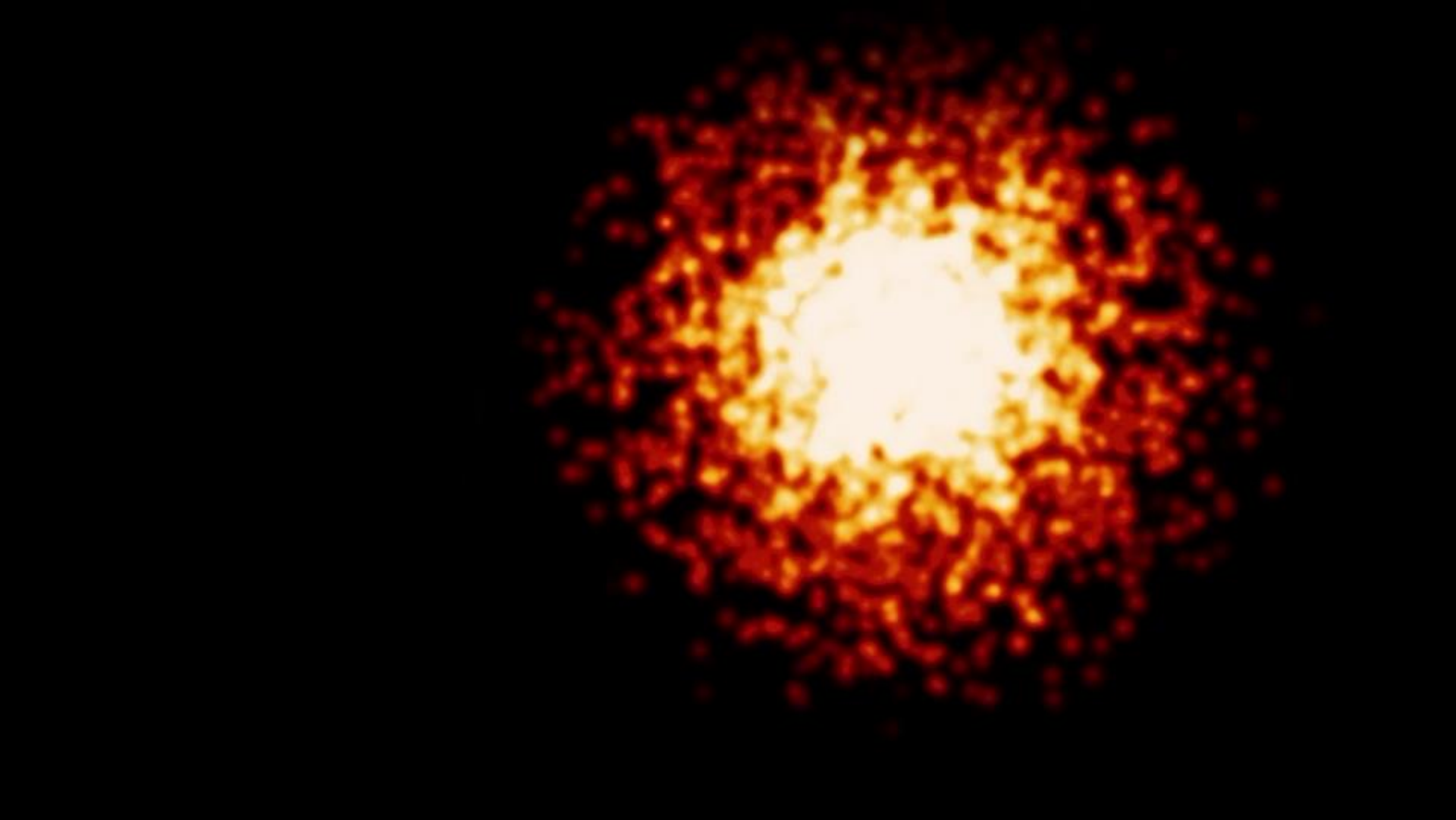


Fauchez et al. 2019

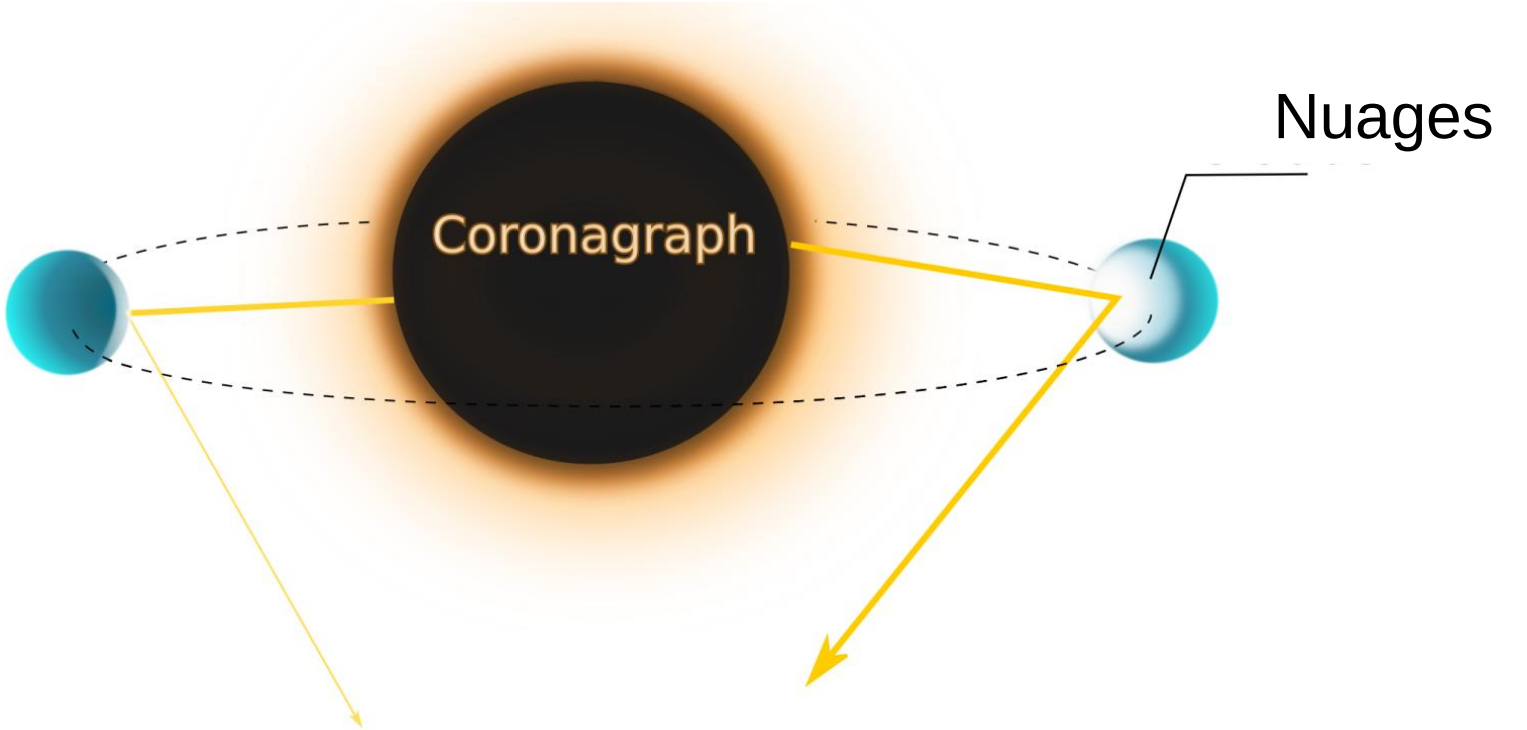
E-ELT- European Extremely Large Telescope

ESO / Pharaons

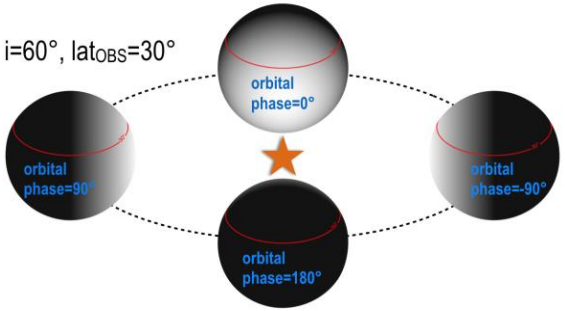


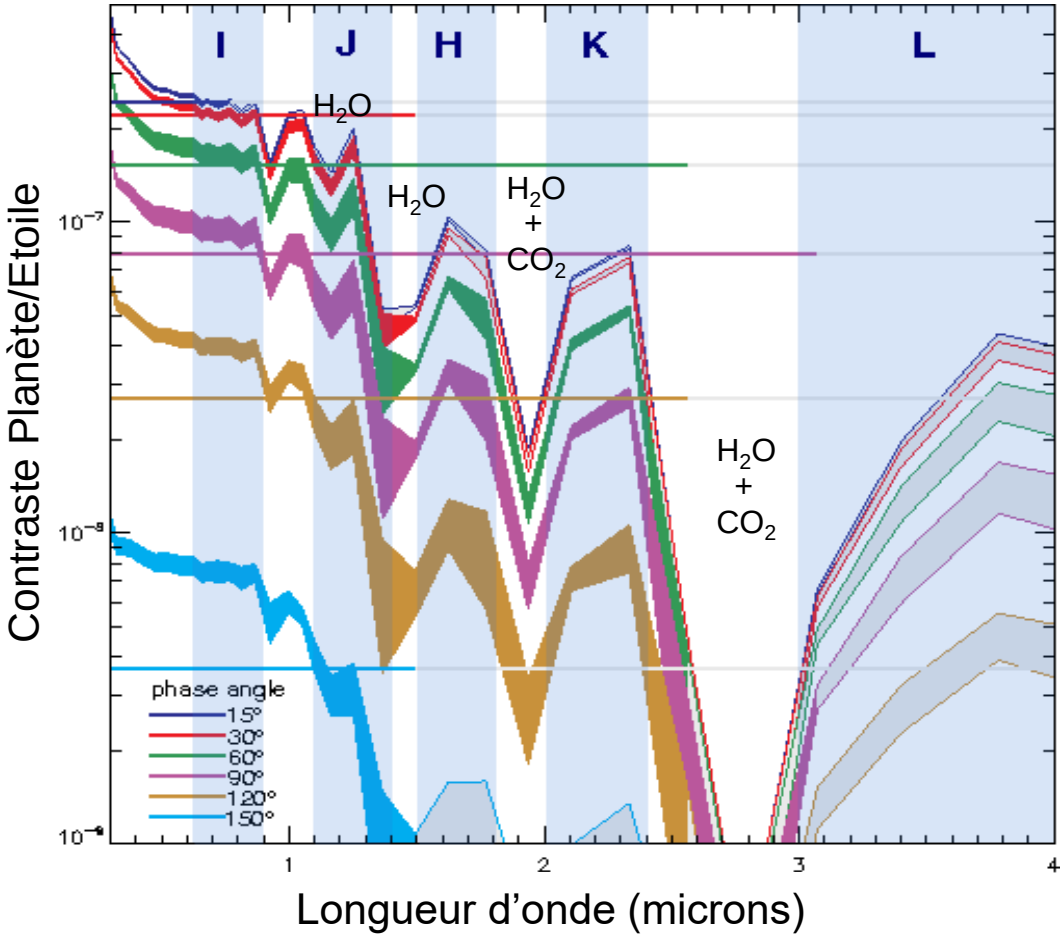


IMAGERIE DIRECTE
ET COURBE DE PHASE EN REFLEXION



SPECTRES SYNTHETIQUES POUR IMAGERIE DIRECTE AVEC L'ELT





Turbet et al. 2016, *A&A*

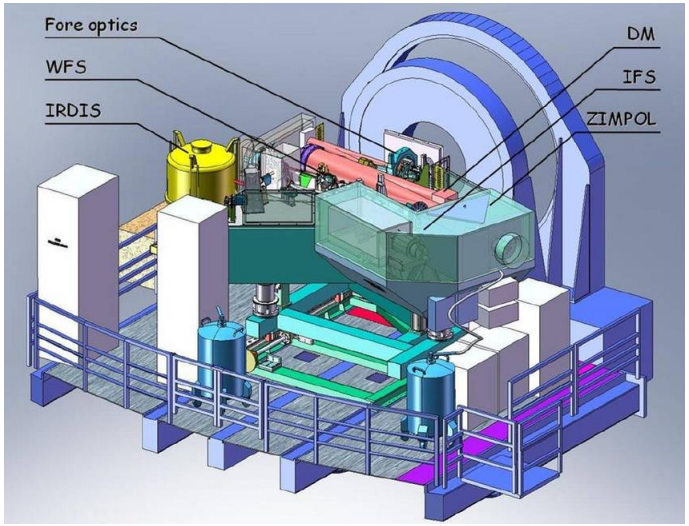
IMAGER DIRECTEMENT PROXIMA B AVEC LE VLT ?!

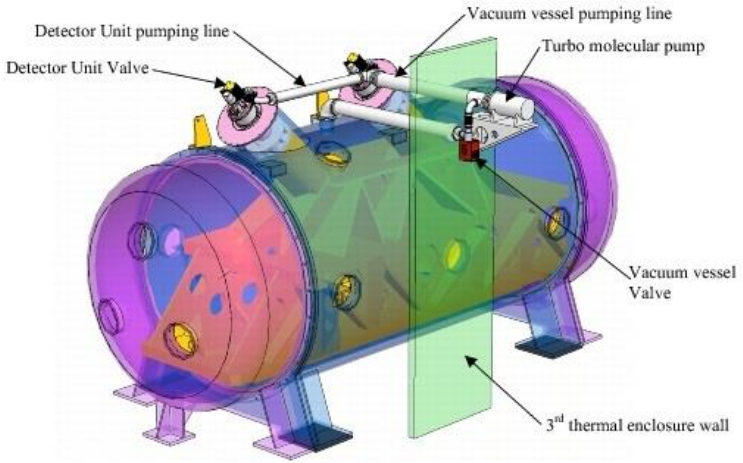
Lovis et al. 2017

SPHERE (imageur)

et

ESPRESSO
(spectrographe haute résolution)





Technique de haute résolution – haut contraste

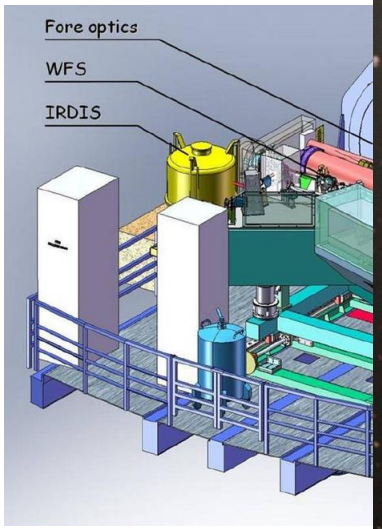
Snellen et al. 2015

IMAGER DIRECTEMENT PROXIMA B AVEC LE VLT ?!

Lovis et al. 2017

SPHERE (i

résolution)



T ste

Snellen et al. 2015

IMAGER DIRECTEMENT PROXIMA B AVEC LE VLT ?!

Lovis et al. 2017

SPHERE (imageur)

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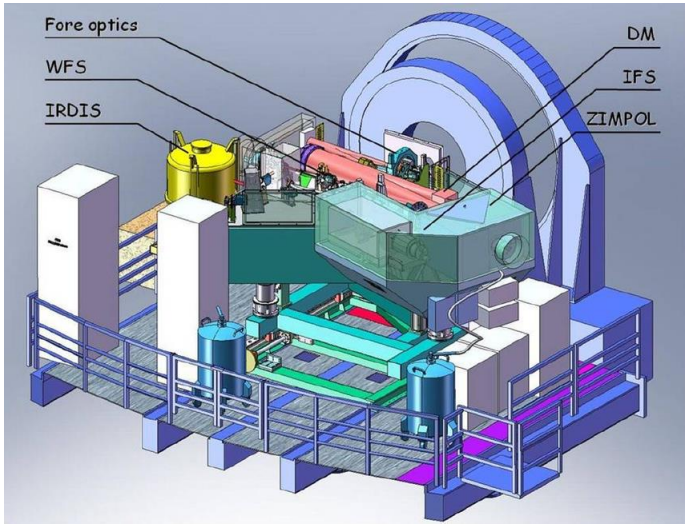
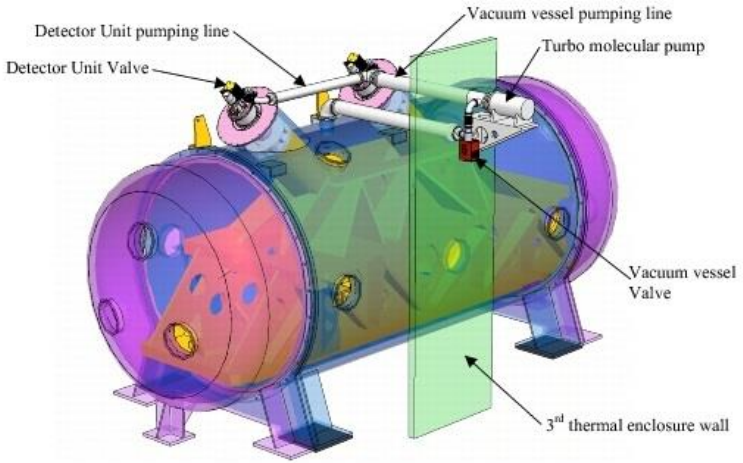


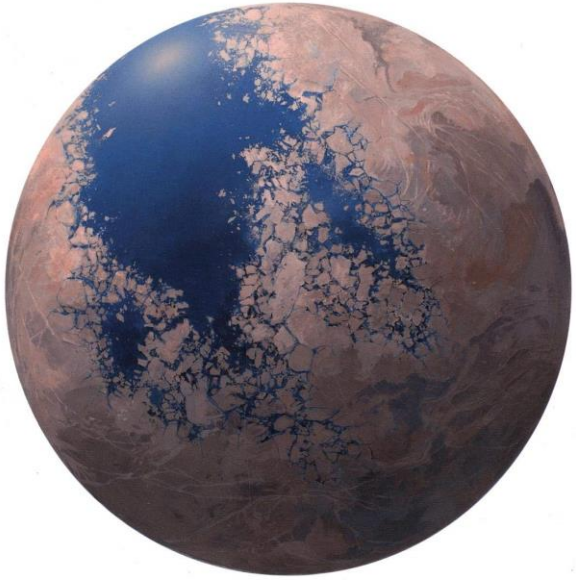


Technique de haute résolution – haut contraste

Snellen et al. 2015

David Fossé
Peintures de **Manchu**

exoplanètes



Belin

Enquête d'exoplanètes : la BD suisse d'initiation aux sciences

Un projet de la région de Banque Raiffeisen de Gimel

7'063 CHF

141% financé

8 jours

95 parrains

Parrainer maintenant

Devenir fan (29) Partager ce projet

https://www.lokalhelden.ch/salome

MERCI !

Des questions ?

(martin.turbet@unige.ch)