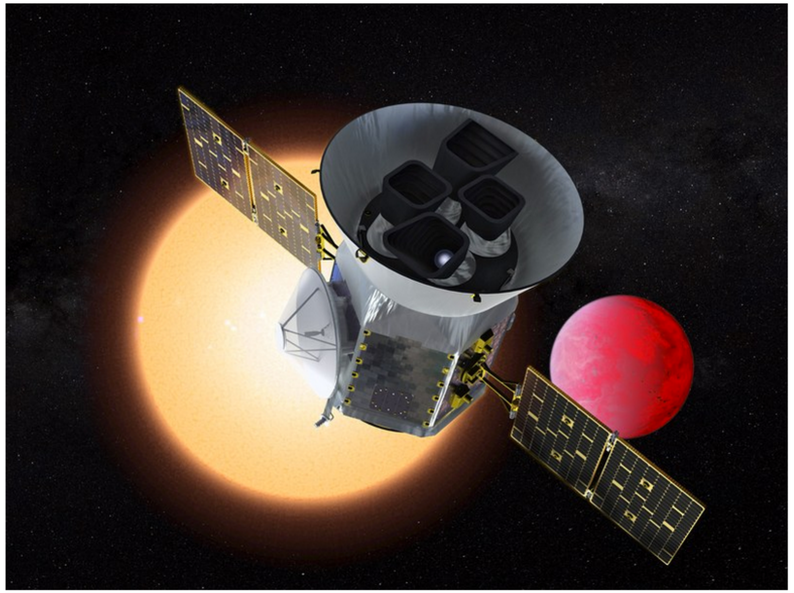
Can we search for life in the atmosphere of exoplanets?

Franck Selsis, Laboratoire d’astrophysique de Bordeaux, franck.selsis@u-bordeaux.fr

ROBBIE GONZALEZ SCIENCE 04.17.18 06:00 AM

NASA'S NEW EXOPLANET SATELLITE HAS A BETTER SHOT OF FINDING LIFE CLOSE TO HOME



TESS is designed to find and study the exoplanets closest to Earth.

NASA'S GODDARD SPACE FIGHT CENTER

Nasa TESS launch marks beginning of new quest to find alien planets and extraterrestrial life

Jasper Hamill Thursday 19 Apr 2018 9:21 am

15

The planet-hunting craft blasted off aboard a SpaceX Falcon 9 rocket (Photo: AP)

Nasa has launched a bold new mission which could finally answer the biggest question in the universe.

Biology
Biogeochemistry / geophysics
Atmospheric physics and (photo)chemistry
Earth and planetary science
Exoplanets / stars
Habitability
Atmosphere remote sensing / spectroscospy
Instruments and observation methods
Science history and epistemology
…

Can we search for life in the atmosphere of exoplanets?

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Entretiens sur la pluralité des mondes
Conversations on the Plurality of Worlds

FONTENELLE (1686)

Ensuite, c'est Mars qui se présente. Mars n'a rien de curieux que je sache; ses jours sont de plus d'une demi-heure plus longs que les nôtres, et ses années valent deux de nos années, à un mois et demi près. Il est cinq fois plus petit que la terre; il voit le soleil un peu moins grand et moins vif que nous ne le voyons; enfin, Mars ne vaut pas trop la peine qu'on s'y arrête.

Gravure (1791) de Jean-Baptiste Morret. (Musée Carnavalet, Paris)

COMPTES RENDUS

DES SÉANCES

DE L'ACADÉMIE DES SCIENCES.

SÉANCE PUBLIQUE ANNUELLE DU LUNDI 17 DÉCEMBRE 1900.

PRÉSIDÉE PAR M. MAURICE LEVY.

M. MAURICE LEVY prononce l'allocution suivante :

« MESSIEURS,

» Voici notre dernière séance solennelle d'un siècle où la Science aura tenu la plus grande place.

» C'est la première fois que le fait se produit. Mais aussi, nous sommes les premiers hommes que la Science, par une sorte de miracle, aura fait assister à deux existences terrestres : celle d'il y a soixante ans et celle d'aujourd'hui, infiniment plus dissemblables, à bien des égards, que si, en d'autres temps, elles avaient été séparées par des centaines, des milliers d'années, si bien que nous aurons vraiment vécu comme si nous étions nés deux fois à de longs siècles d'intervalle.

» Pourquoi cette rénovation de la vie s'est-elle produite juste à notre époque et pas avant? Est-ce un accident ou un commencement? Vivons-nous en un siècle fortuit ou est-il bien le premier d'une ère nouvelle et durable qui serait l'ère du Messianisme de la Science sur cette terre?

Ce prix, de la valeur de *deux mille francs*, sera décerné par l'Académie des Sciences, pour la première fois, dans sa séance publique de 1901.

PRIX PIERRE GUZMAN.

Mme *Clara Goguet*, veuve *Guzman*, a légué à l'Académie des Sciences une somme de *cent mille francs* pour la fondation d'un prix qui portera le nom de *prix Pierre Guzman*, en souvenir de son fils, et sera décerné à celui qui aura trouvé le moyen de communiquer avec un astre autre que la planète Mars.

Prévoyant que le prix de *cent mille francs* ne serait pas décerné tout de suite, la fondatrice a voulu, jusqu'à ce que ce prix soit gagné, que les intérêts du capital, cumulés pendant cinq années, formassent un prix, toujours sous le nom de *Pierre Guzman*, qui serait décerné à un savant français ou étranger, qui aurait fait faire un progrès important à l'Astronomie.

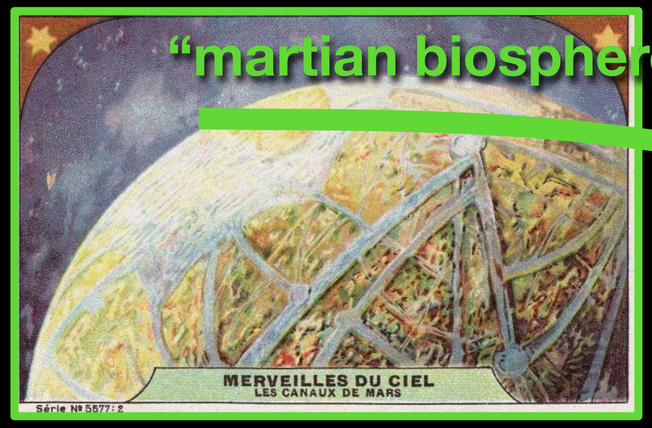
Le *prix quinquennal*, représenté par les intérêts du capital, sera décerné, s'il y a lieu, pour la première fois en 1905.

PRIX FONDÉ PAR Mme LA MARQUISE DE LAPLACE.

Ce prix, qui consiste dans la collection complète des Ouvrages de Laplace, est décerné, *chaque année*, au premier élève sortant de l'École Polytechnique.

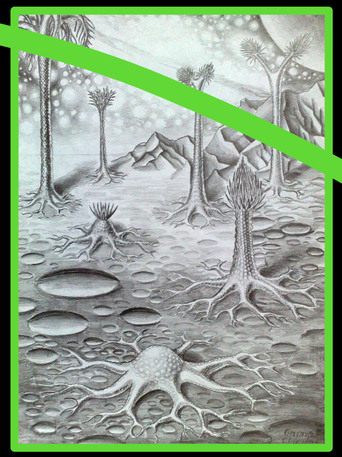
PRIX FONDÉ PAR M. FÉLIX RIVOT.

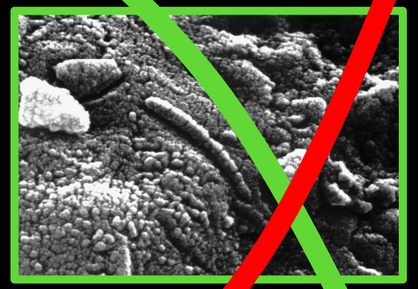
Ce *prix*, qui est *annuel* et dont la valeur est de *deux mille cinq cents francs*, sera partagé entre les quatre élèves sortant chaque année de l'École Polytechnique avec les nos 1 et 2 dans les corps des Mines et des Ponts et Chaussées.

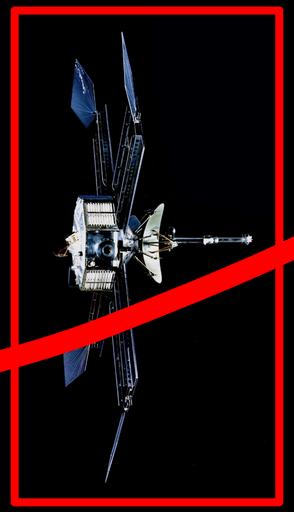


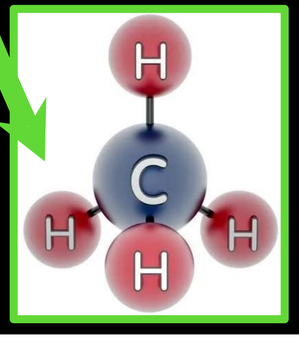
“martian biosphere”

observation power

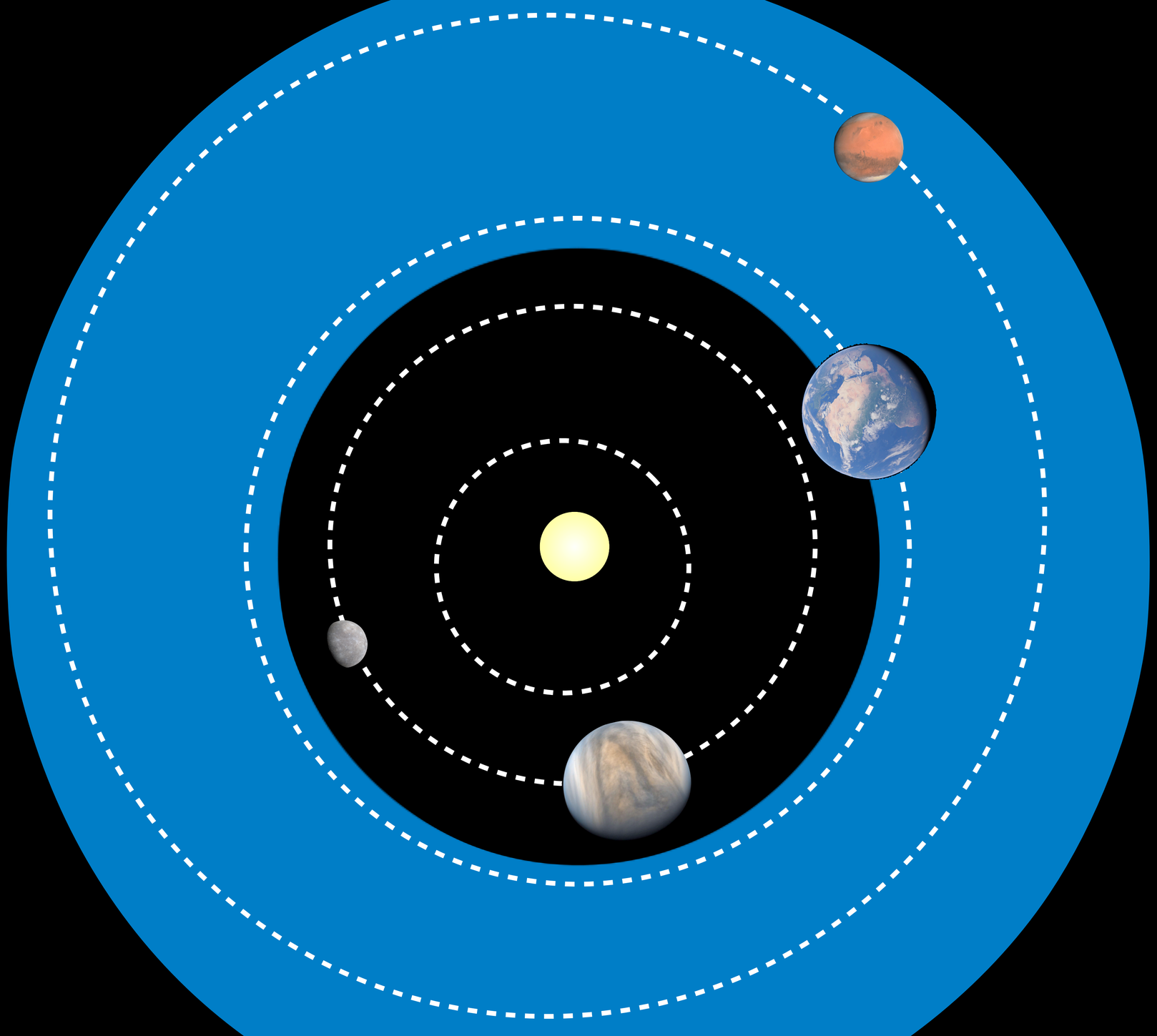


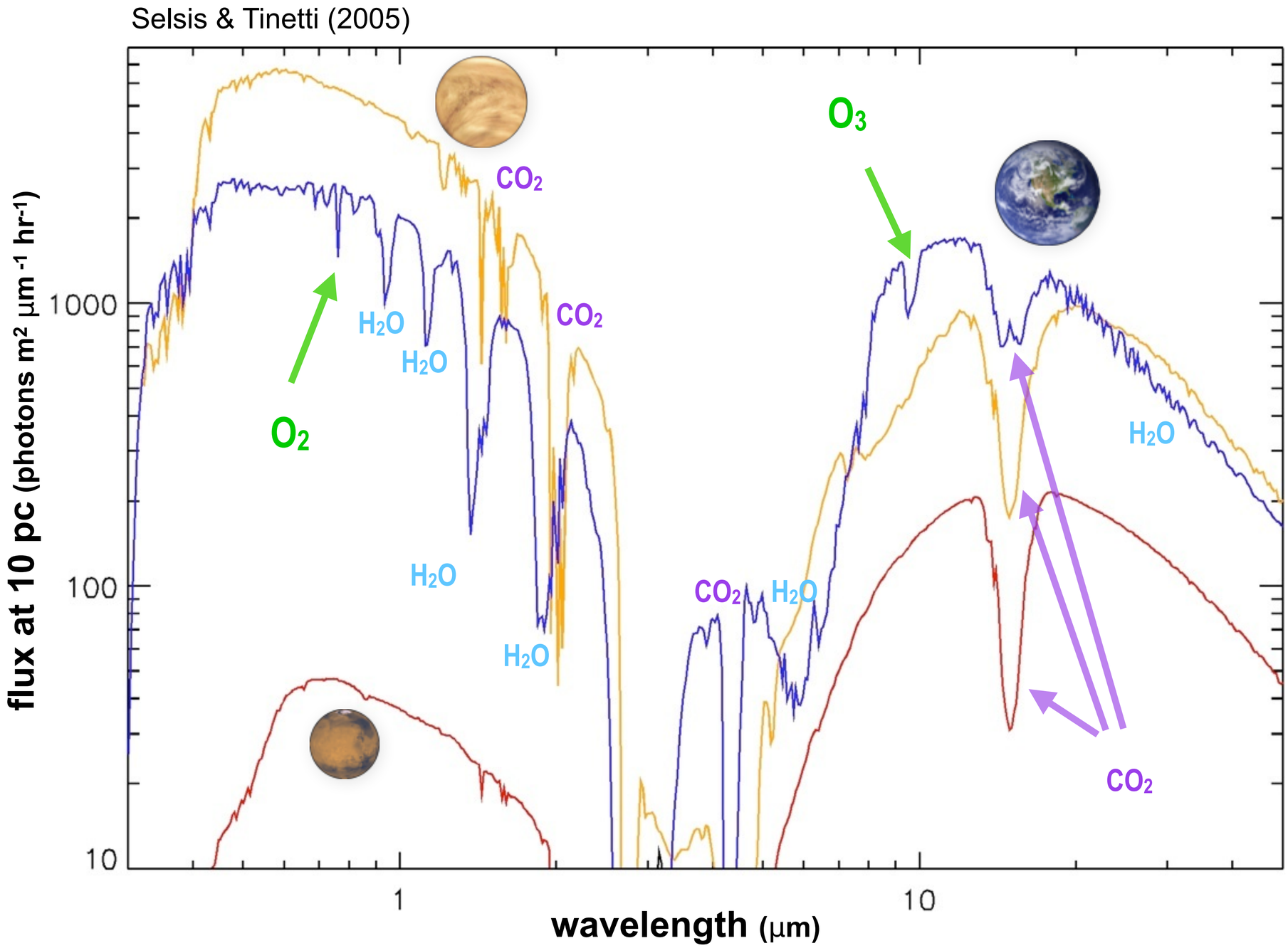


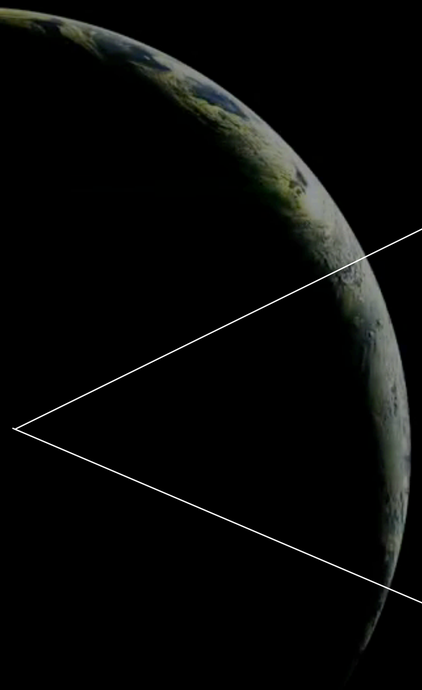




time




Selsis & Tinetti (2005)
flux at 10 pc (photons m² μm⁻¹ hr⁻¹)
1000
100
10
1
10
wavelength (μm)
CO2
CO2
CO2
H2O
H2O
H2O
H2O
O2
O3
CO2
H2O
H2O
CO2



zoom x 10^{12}

cyanobacteria

O_2 build-up
in the atmopshere

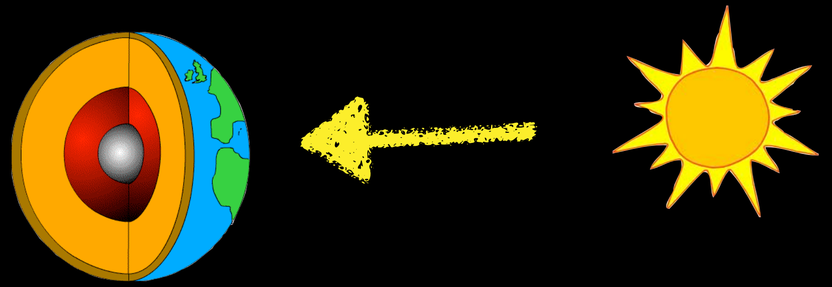
(light)

$2H_2O + CO_2 + h\nu$ —photosynthesis→ $CH_2O + O_2 + H_2O$

$CH_2O + O_2 + H_2O$ —respiration, oxidation→ $2H_2O + CO_2 + h\nu$

CH_2O
organic matter

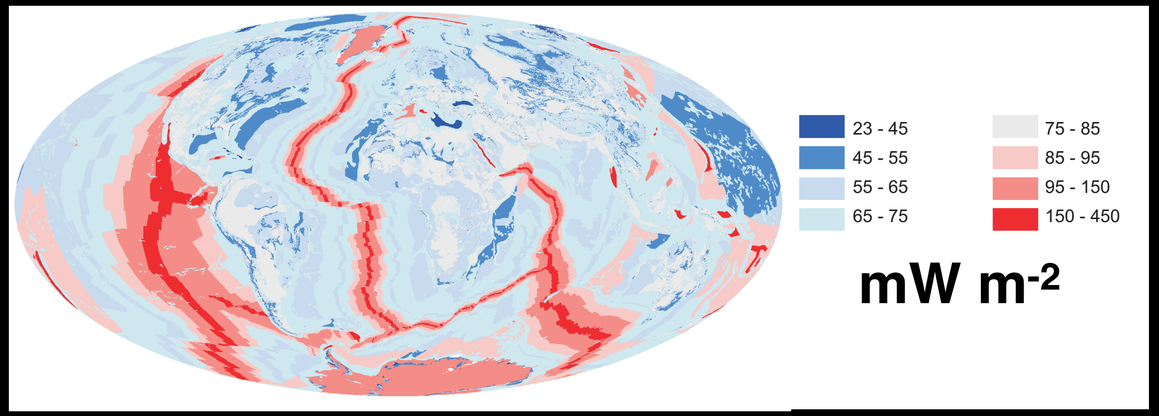
Burial of organic carbon



very low-entropy energy

- The average solar flux at Earth surface is 163 W/m^2
- 0.16% of that (0.268 W/m^2) is <u>directly</u> converted by photoautotrophic life into chemical energy.

200 gC/yr/m^2



< 50 gC/Myr/m^2

- The average internal heat flux of the Earth is 0.075 W/m^2
- Less than 10^{-6} of that is <u>indirectly</u> converted by life into chemical energy (Rosing et al., 2005, 2006)

very high-entropy energy

Although Chemoautotrophy is known since 1890, the Earth *deep biosphere* was unveiled only in the 1970s-80s

In a world with a purely chemoautotrophic primary production (= in the absence of photosynthesis), biology would cause no significant effect on the global carbon cycle
(Rosing et al., 2006)

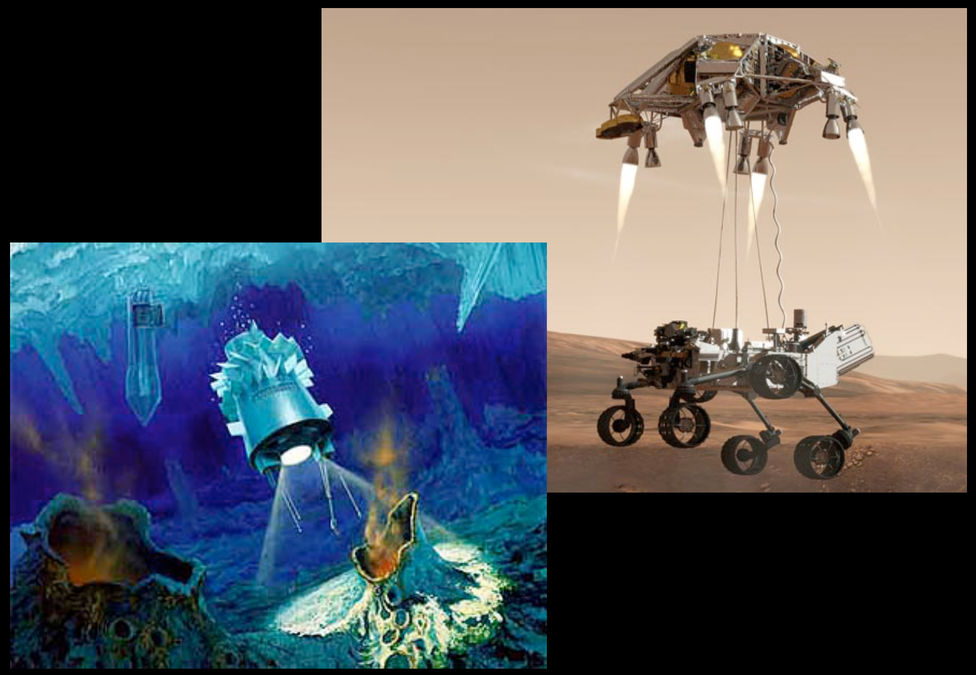
200 gC/yr/m²

< 50 gC/Myr/m²

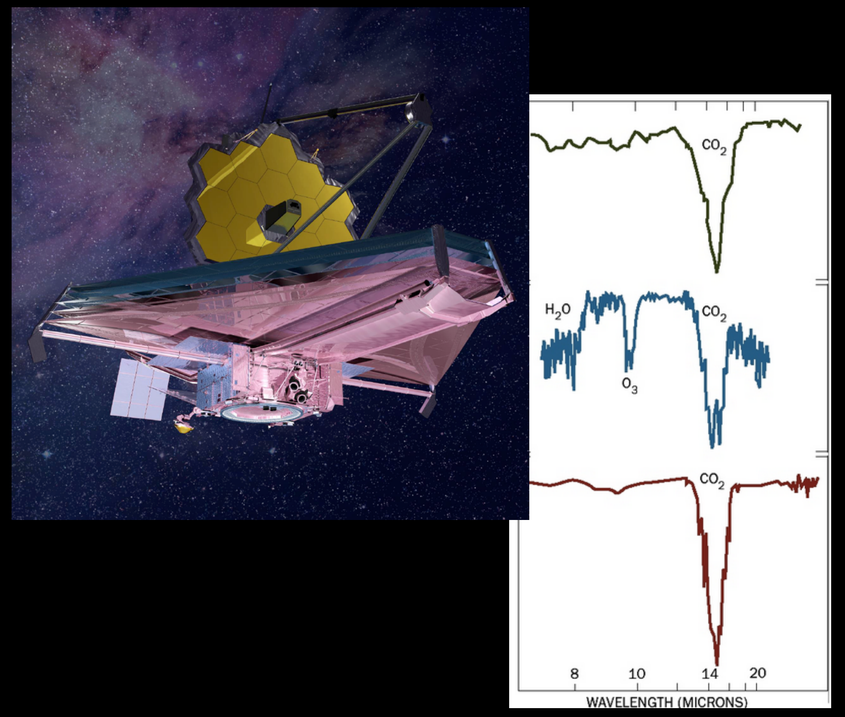
Habitability

Where can life exist or Where we can find life

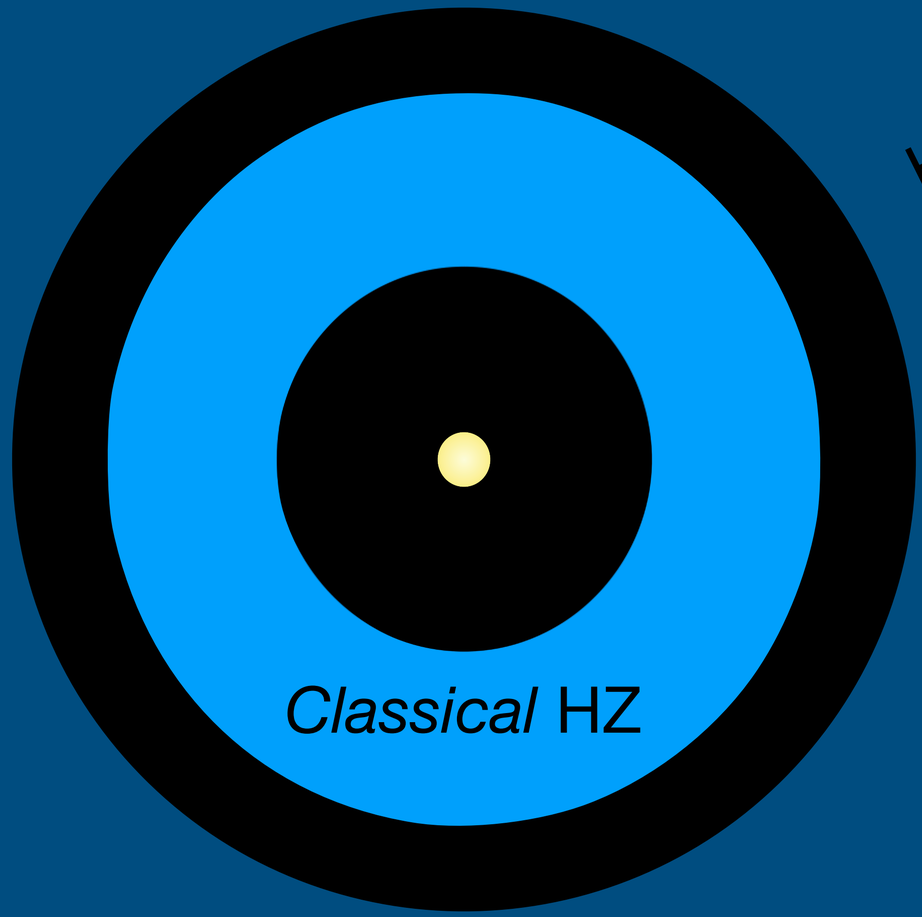
Solar System



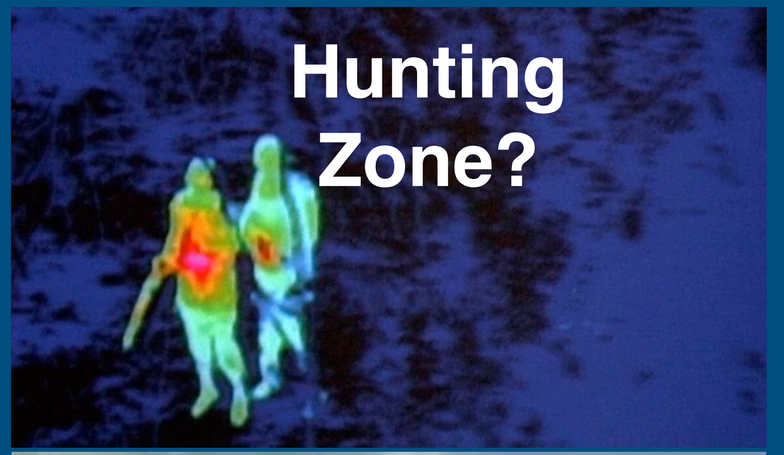
Extrasolar planets



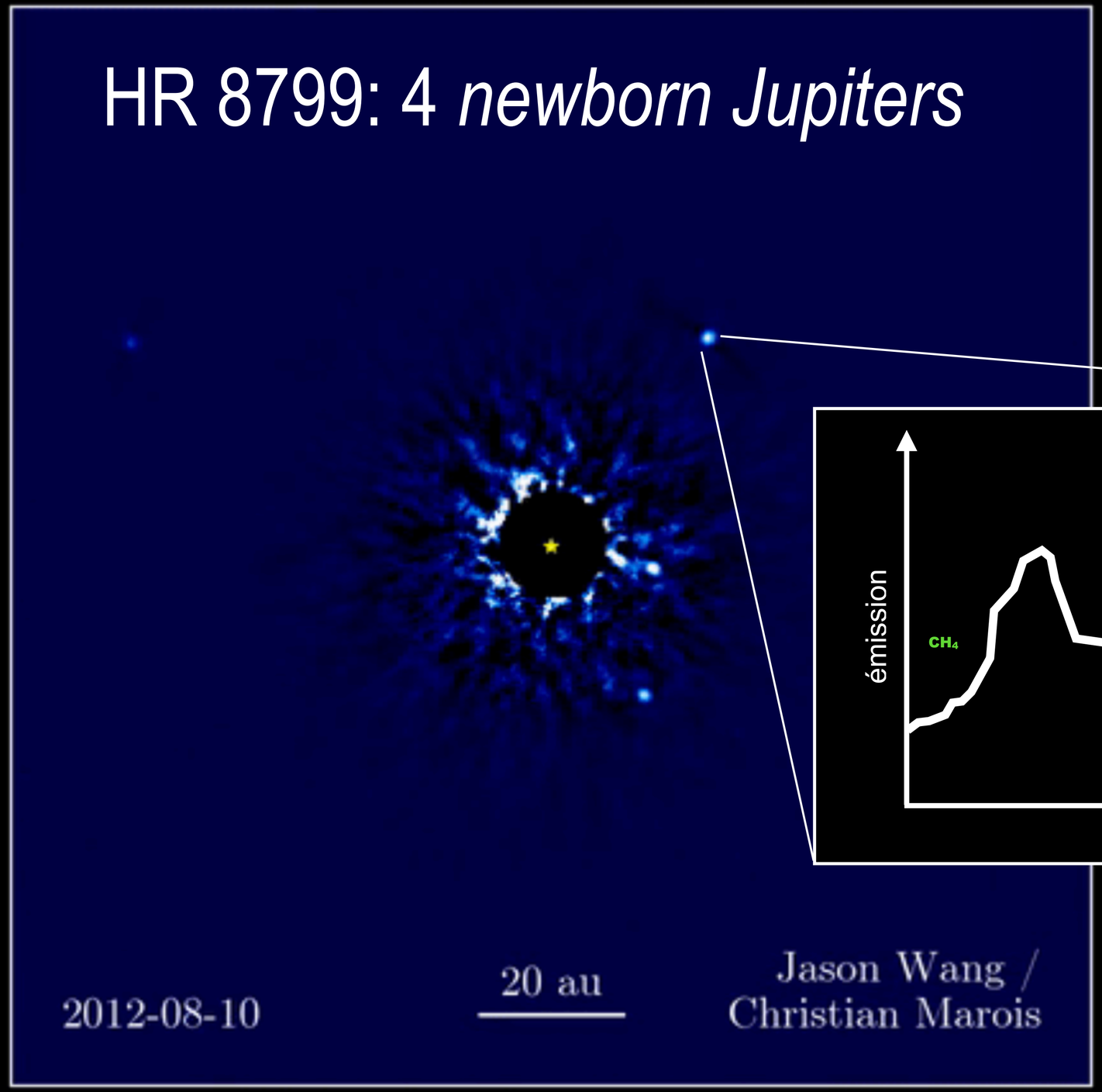

Classical HZ

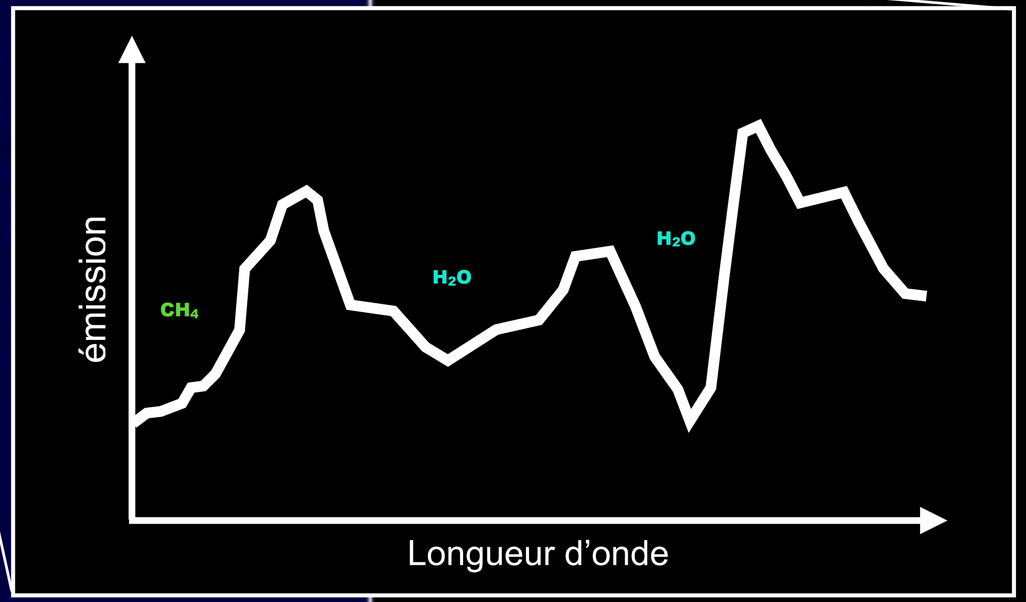


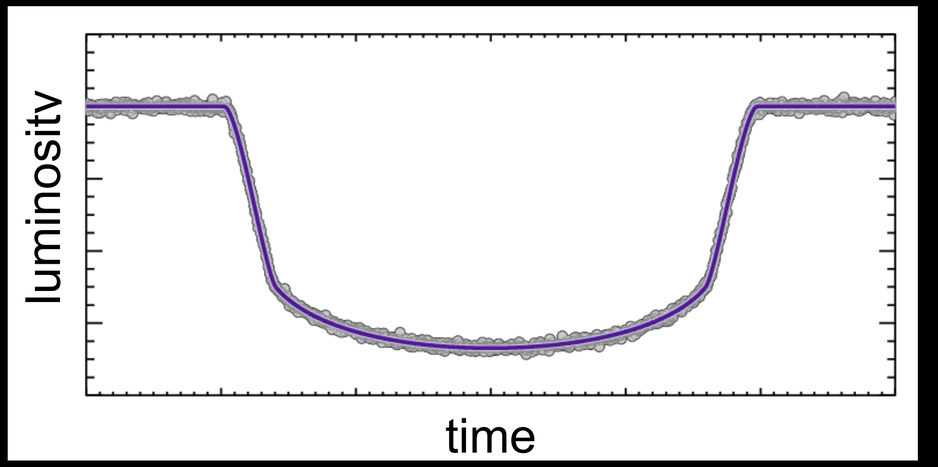
HZ for thick H_2 atmospheres

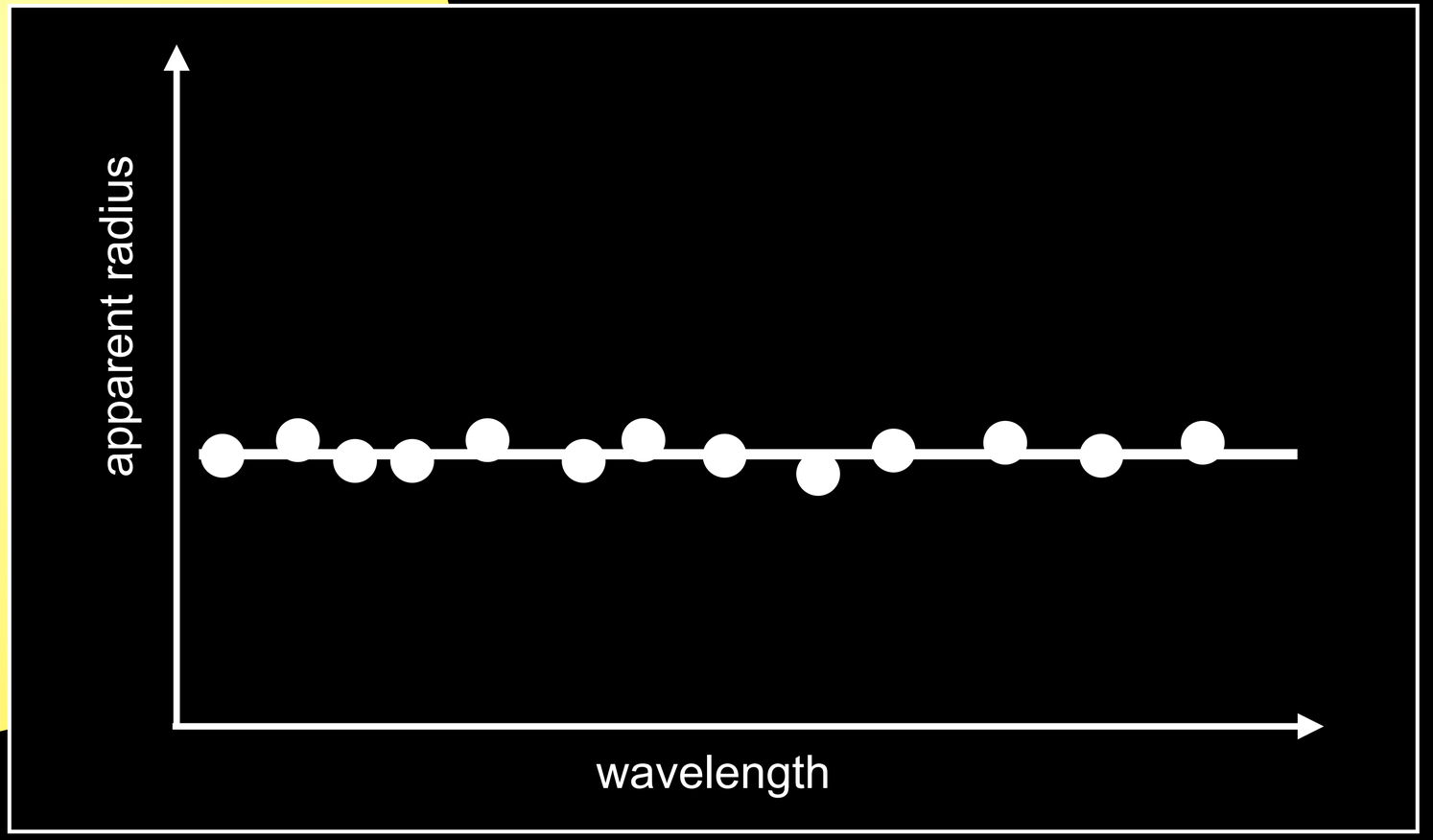


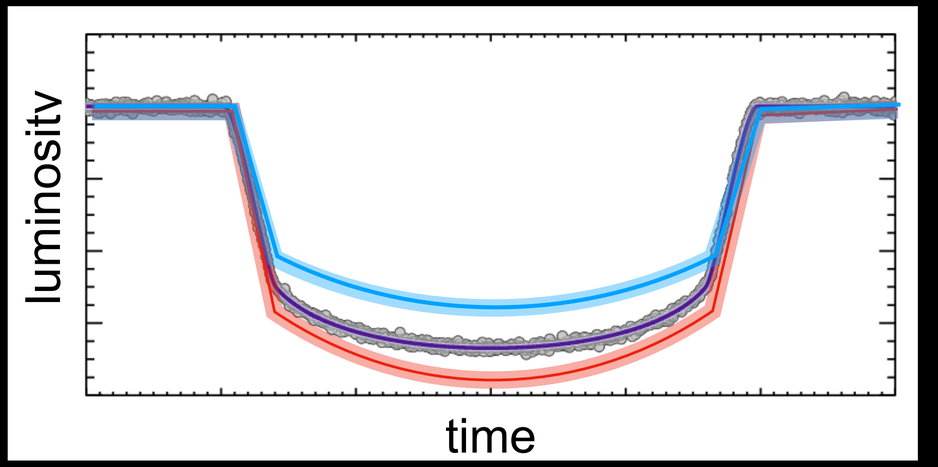
HR 8799: 4 *newborn Jupiters*

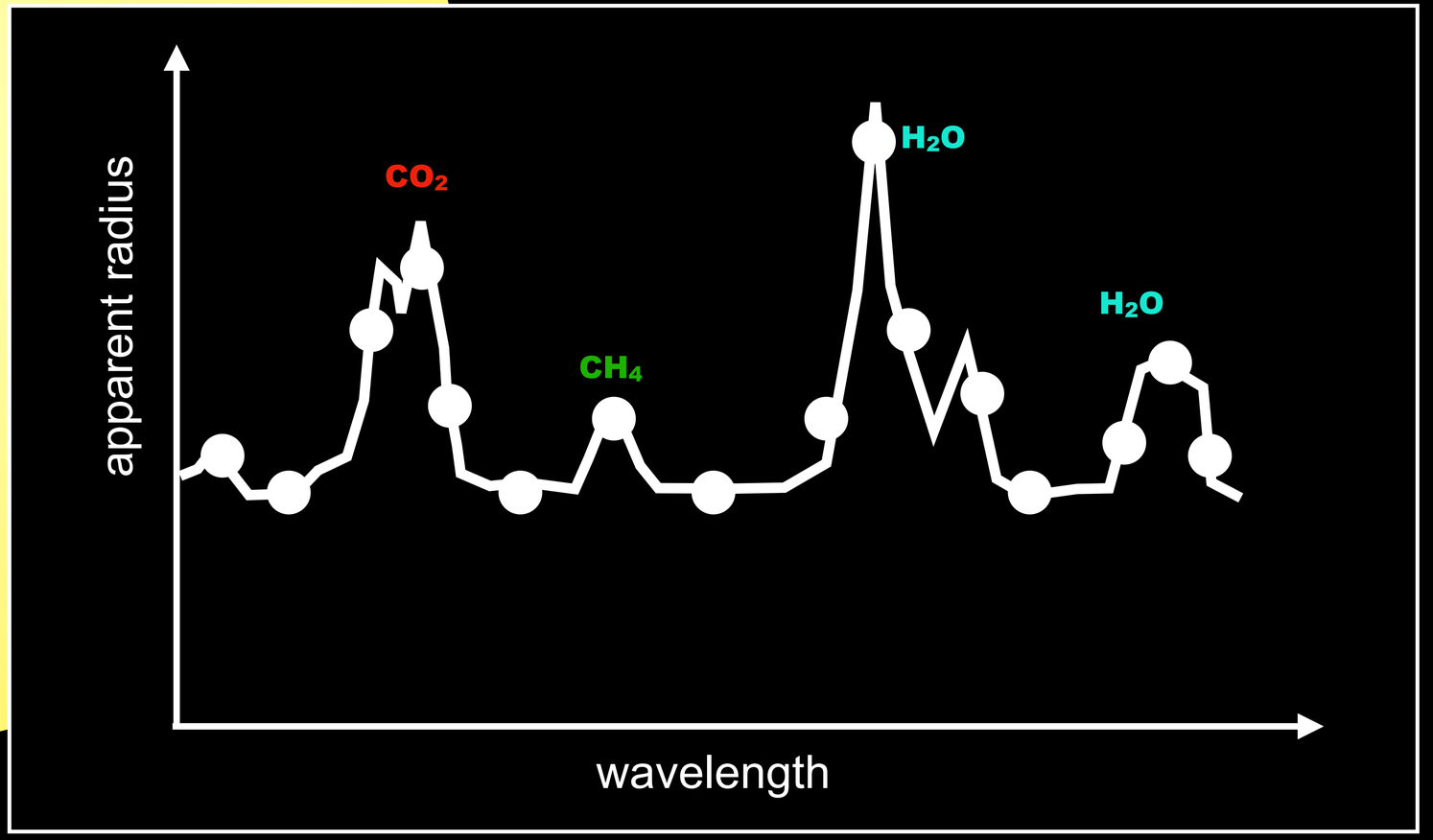





luminosity
time

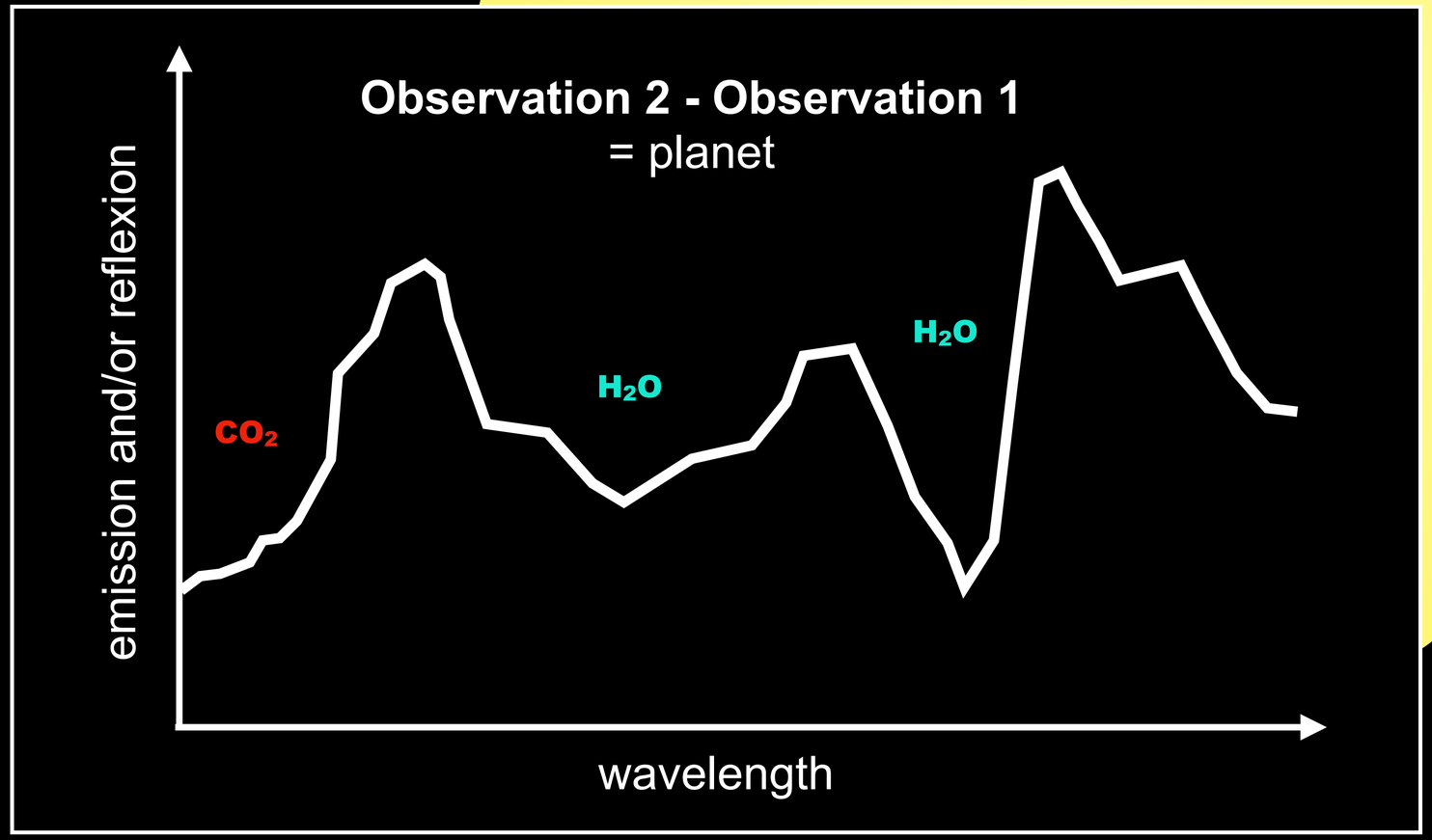

apparent radius
wavelength

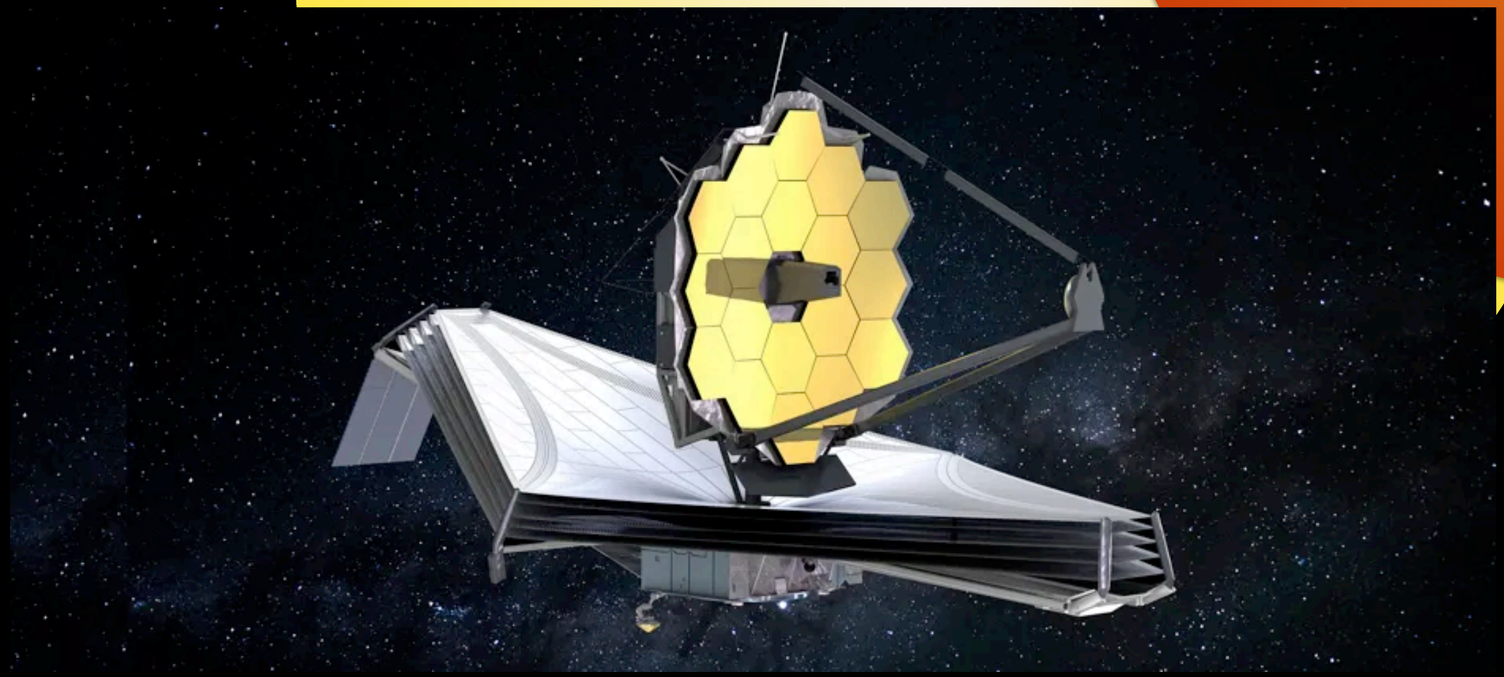

luminosity
time

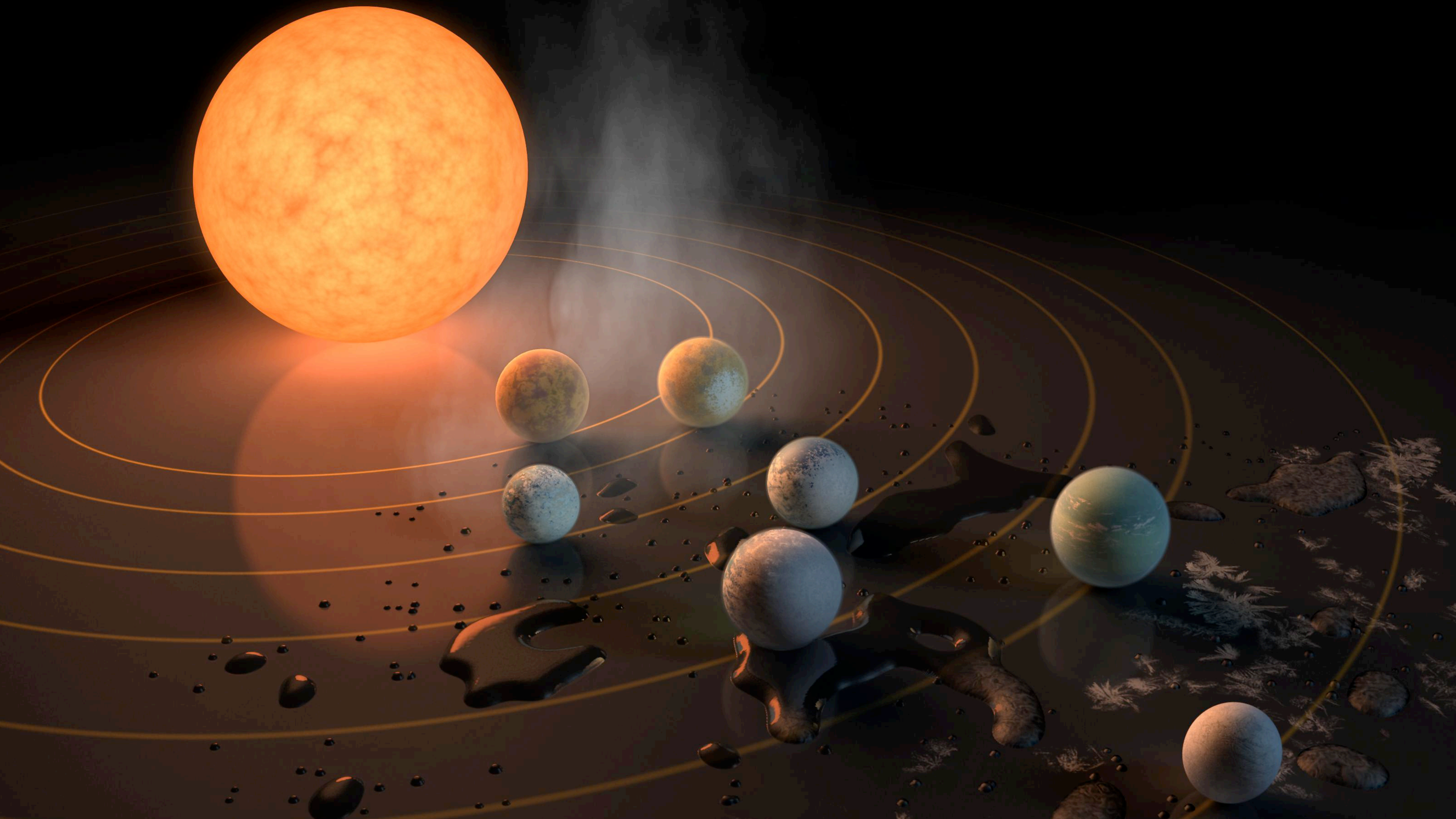

apparent radius
CO_2
CH_4
H_2O
H_2O
wavelength

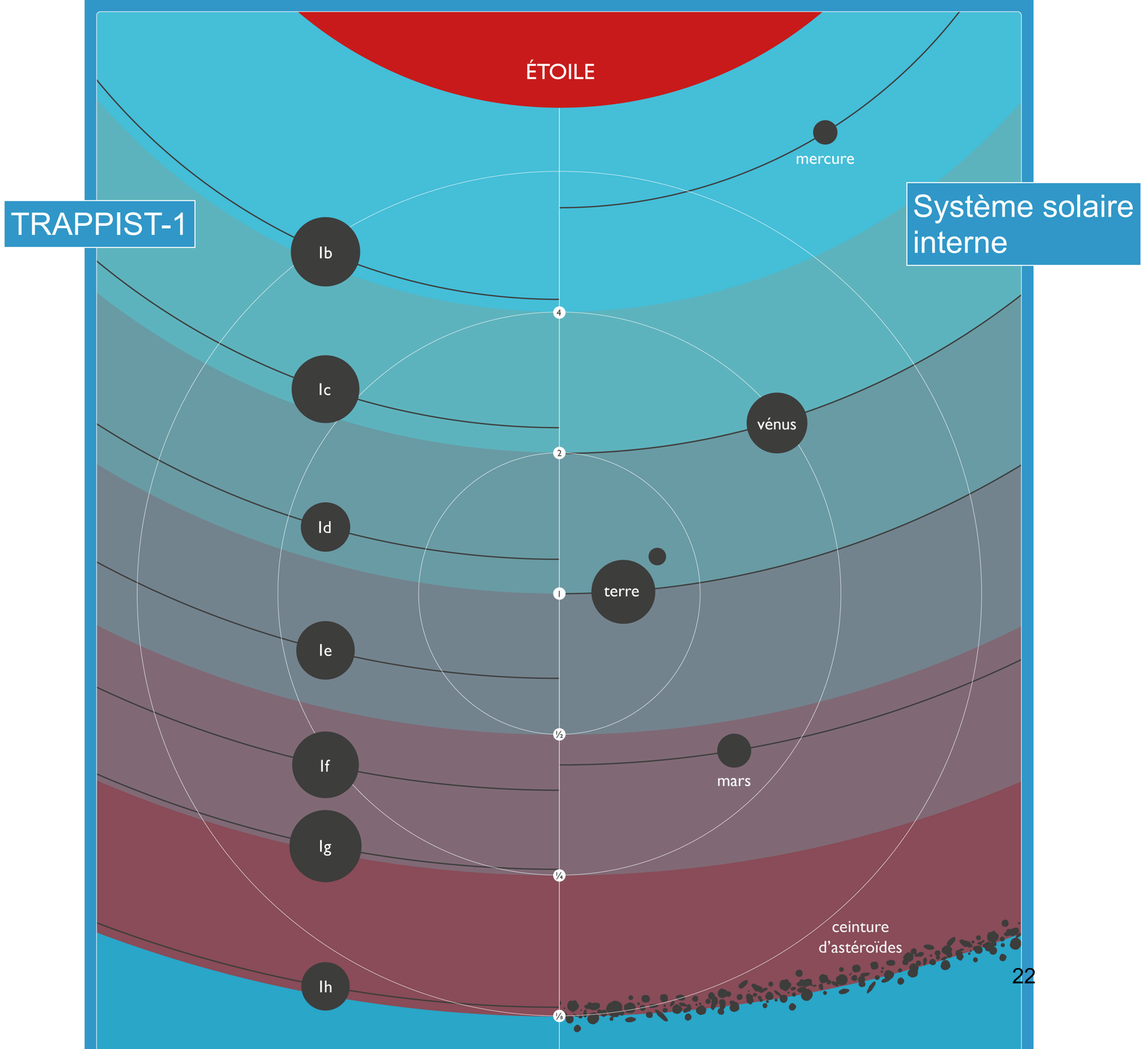
Observation 1
star +planet

Observation 2
star only








TRAPPIST-1
Système solaire interne
ÉTOILE
mercure
Ib
Ic
vénus
Id
terre
Ie
If
mars
Ig
ceinture d'astéroïdes
Ih
4
2
1
½
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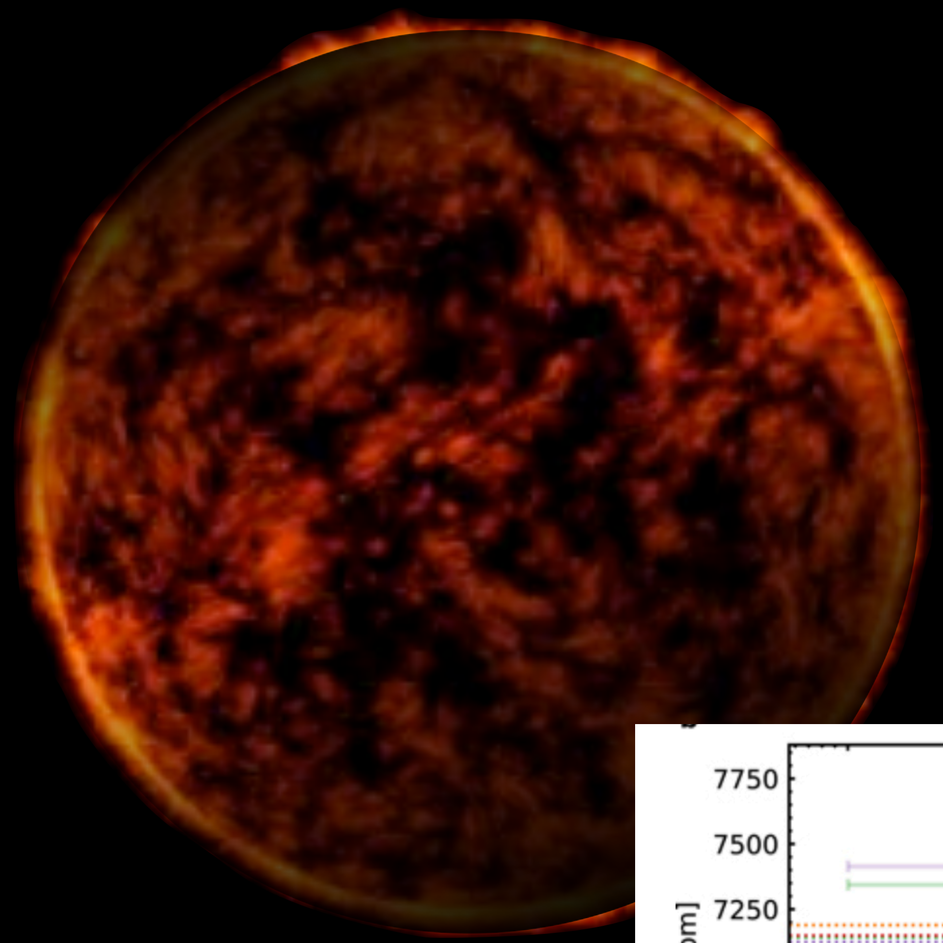
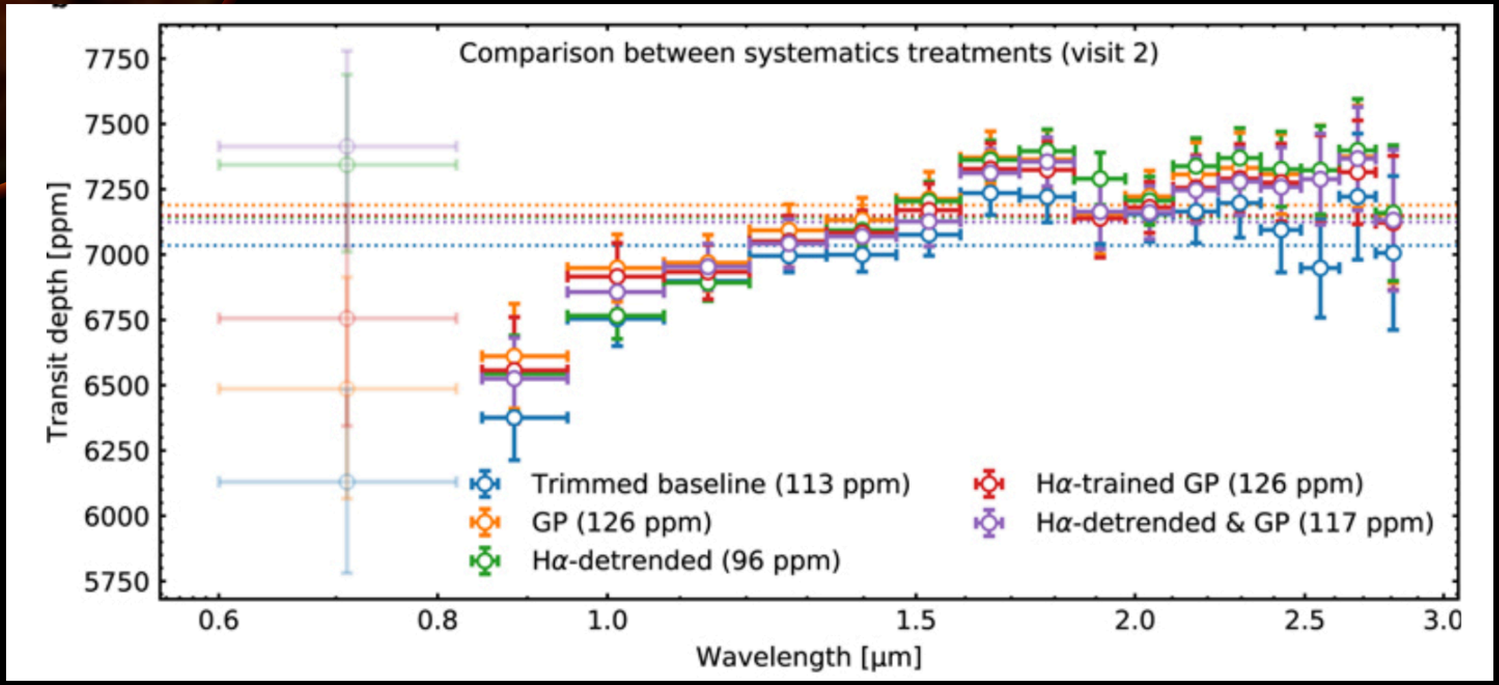
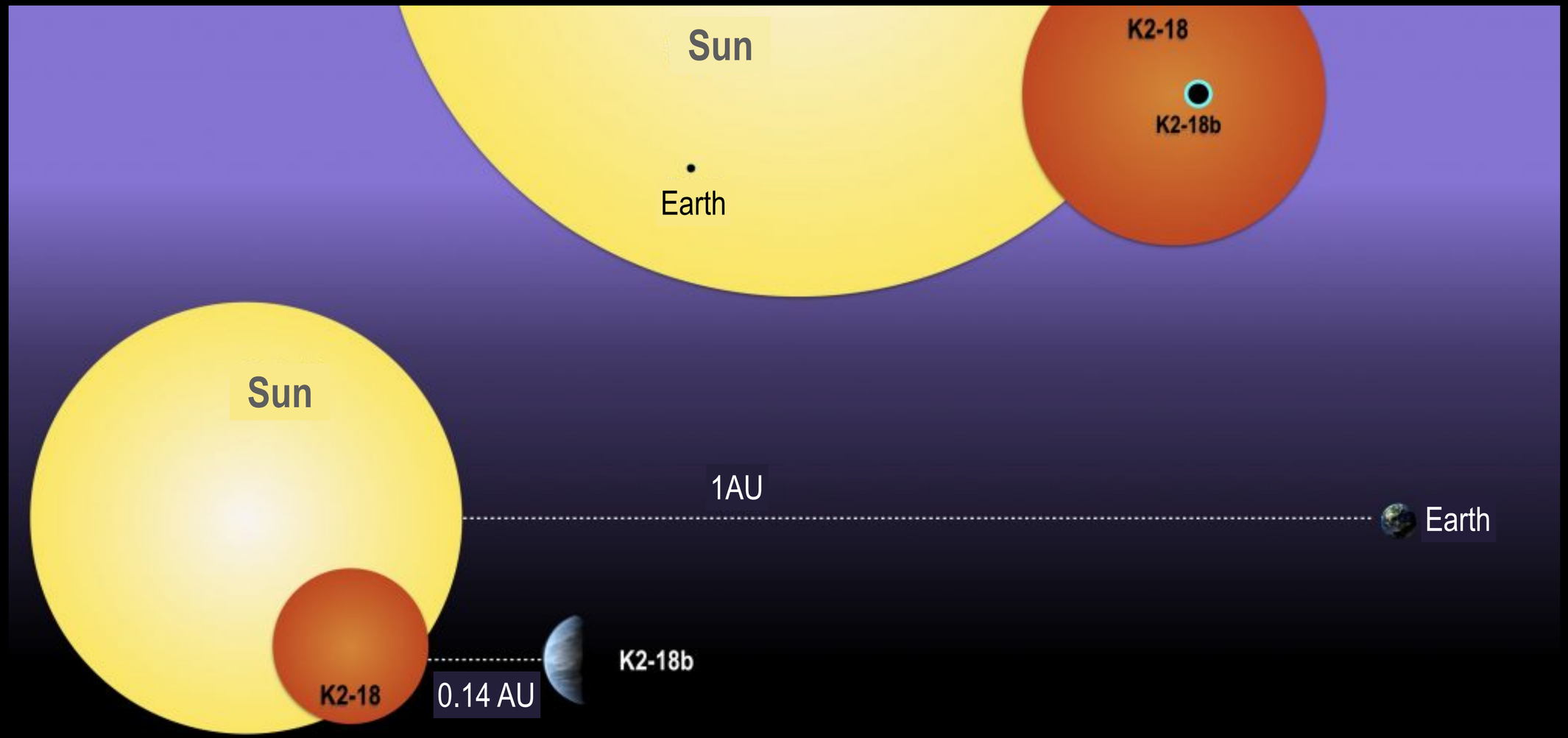
⅛



Lim+ 2023


Comparison between systematics treatments (visit 2)
Transit depth [ppm]
7750
7500
7250
7000
6750
6500
6250
6000
5750
0.6
0.8
1.0
1.5
2.0
2.5
3.0
Wavelength [μm]
Trimmed baseline (113 ppm)
GP (126 ppm)
Hα-detrended (96 ppm)
Hα-trained GP (126 ppm)
Hα-detrended & GP (117 ppm)


Sun
K2-18
K2-18b
Earth
Sun
1AU
Earth
K2-18b
K2-18
0.14 AU

The Astrophysical Journal Letters, 956:L13 (16pp), 2023 October 10 https://doi.org/10.3847/2041-8213/acf577

Carbon-bearing Molecules in a Possible Hycean Atmosphere

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[2] School of Physics and Astronomy, Cardiff University, The Parade, Cardiff CF24 3AA, UK
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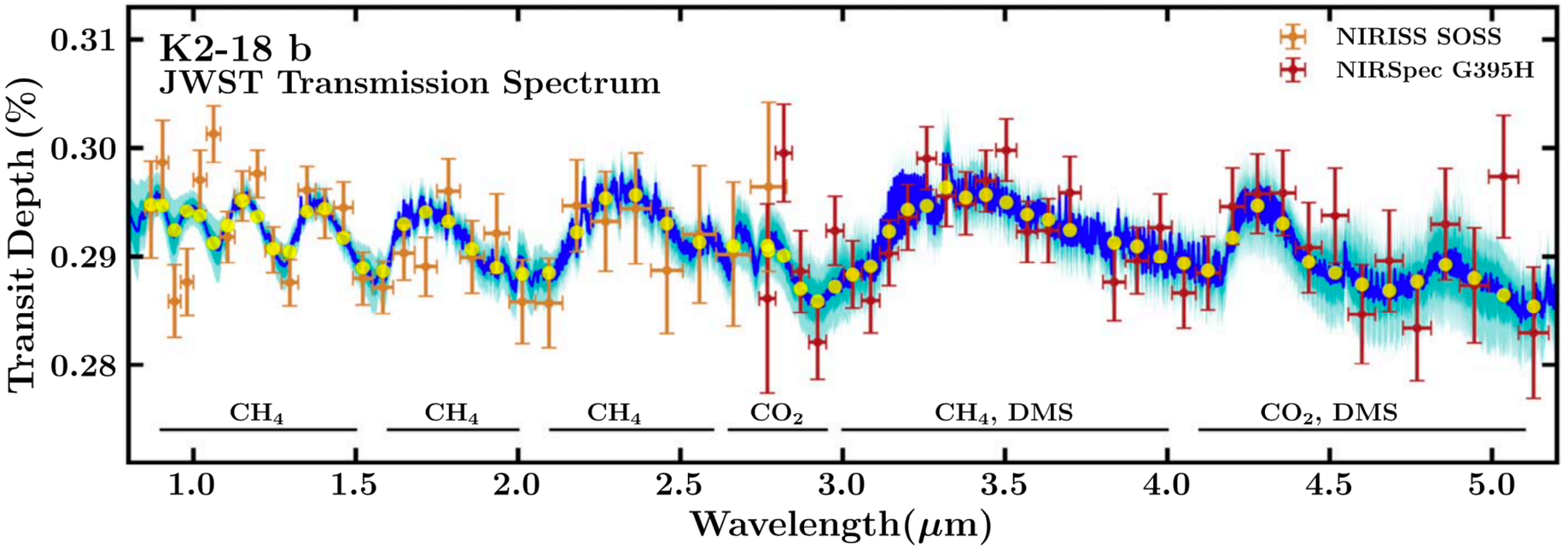
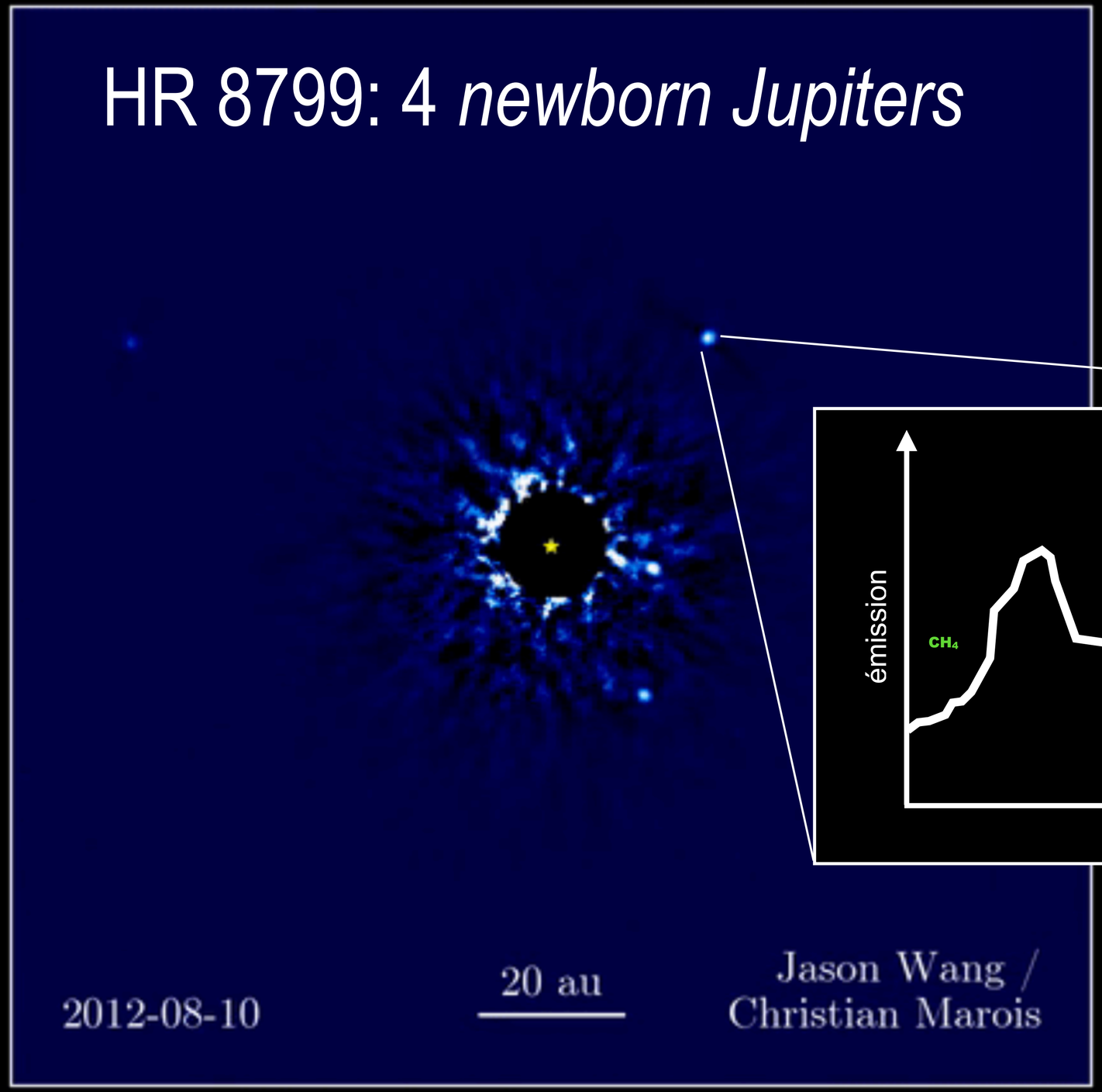
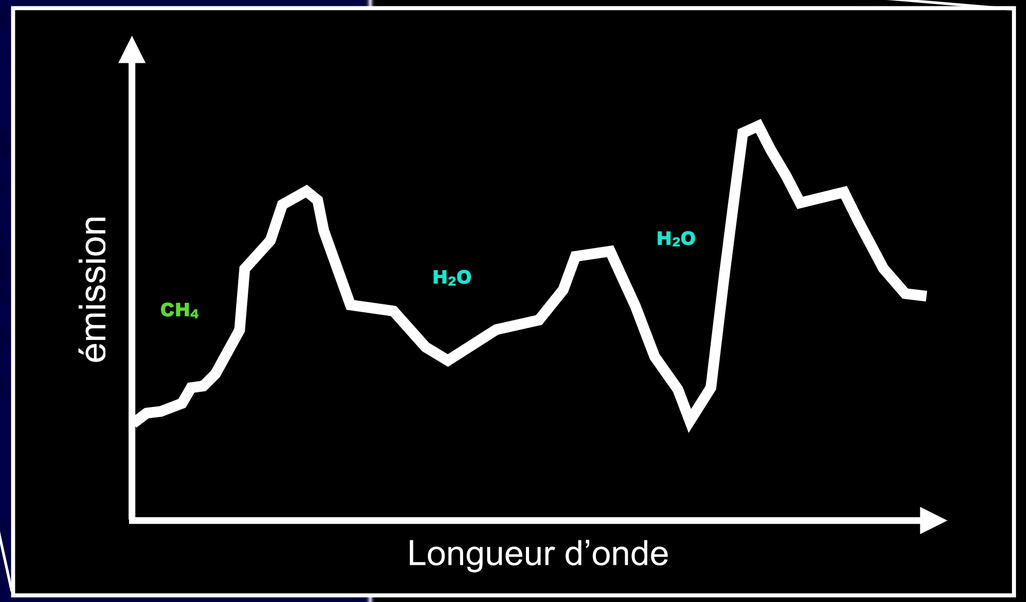
Abstract

The search for habitable environments and biomarkers in exoplanetary atmospheres is the holy grail of exoplanet science. The detection of atmospheric signatures of habitable Earth-like exoplanets is challenging owing to their small planet–star size contrast and thin atmospheres with high mean molecular weight. Recently, a new class of habitable exoplanets, called Hycean worlds, has been proposed, defined as temperate ocean-covered worlds with H_2-rich atmospheres. Their large sizes and extended atmospheres, compared to rocky planets of the same mass, make Hycean worlds significantly more accessible to atmospheric spectroscopy with JWST. Here we report a transmission spectrum of the candidate Hycean world K2-18 b, observed with the JWST NIRISS and NIRSpec instruments in the 0.9–5.2 μm range. The spectrum reveals strong detections of methane (CH_4) and carbon dioxide (CO_2) at 5σ and 3σ confidence, respectively, with high volume mixing ratios of $\sim$1% each in a H_2-rich atmosphere. The abundant CH_4 and CO_2, along with the nondetection of ammonia (NH_3), are consistent with chemical predictions for an ocean under a temperate H_2-rich atmosphere on K2-18 b. The spectrum also suggests potential signs of dimethyl sulfide (DMS), which has been predicted to be an observable biomarker in Hycean worlds, motivating considerations of possible biological activity on the planet. The detection of CH_4 resolves the long-standing missing methane problem for temperate exoplanets and the degeneracy in the atmospheric composition of K2-18 b from previous observations. We discuss possible implications of the findings, open questions, and future observations to explore this new regime in the search for life elsewhere.

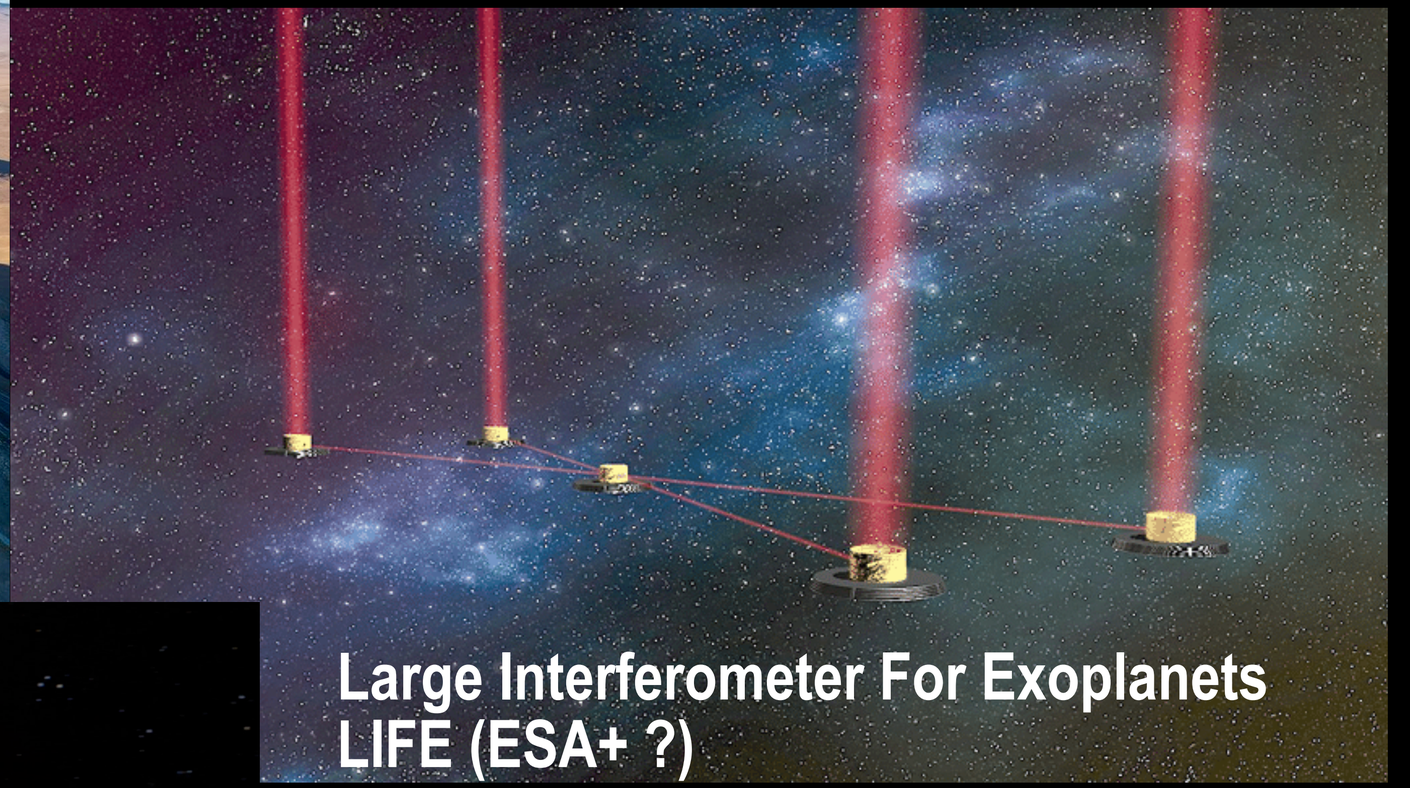


HR 8799: 4 *newborn Jupiters*

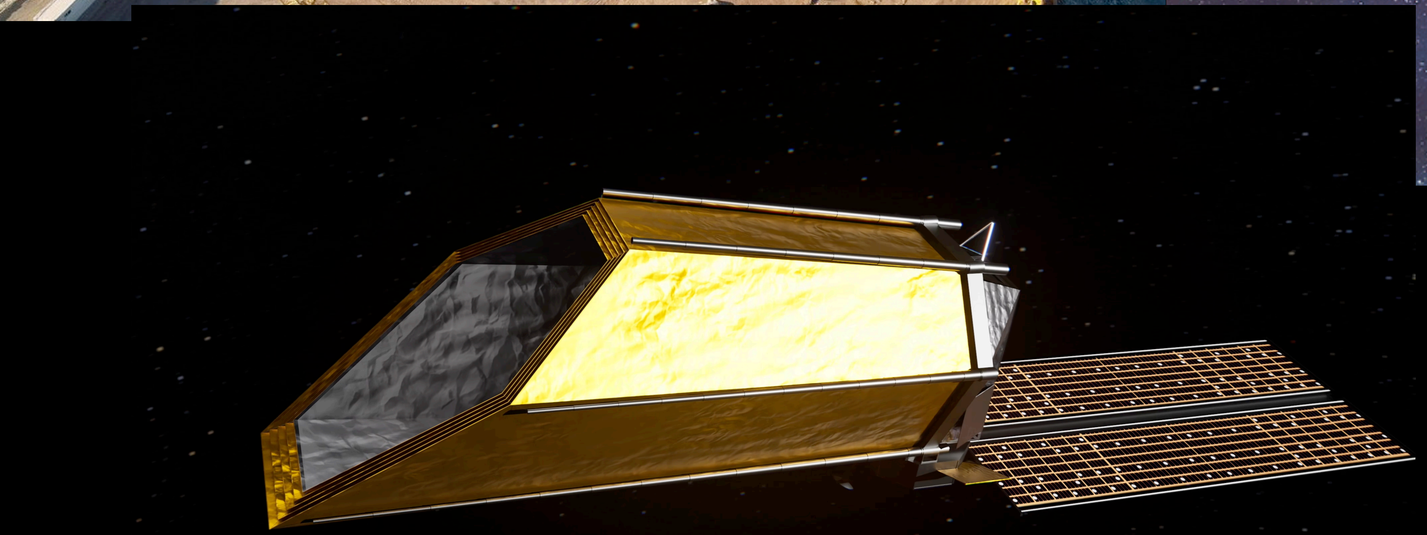




Extremely Large Telescope
E-ELT (ESO)



Large Interferometer For Exoplanets
LIFE (ESA+ ?)

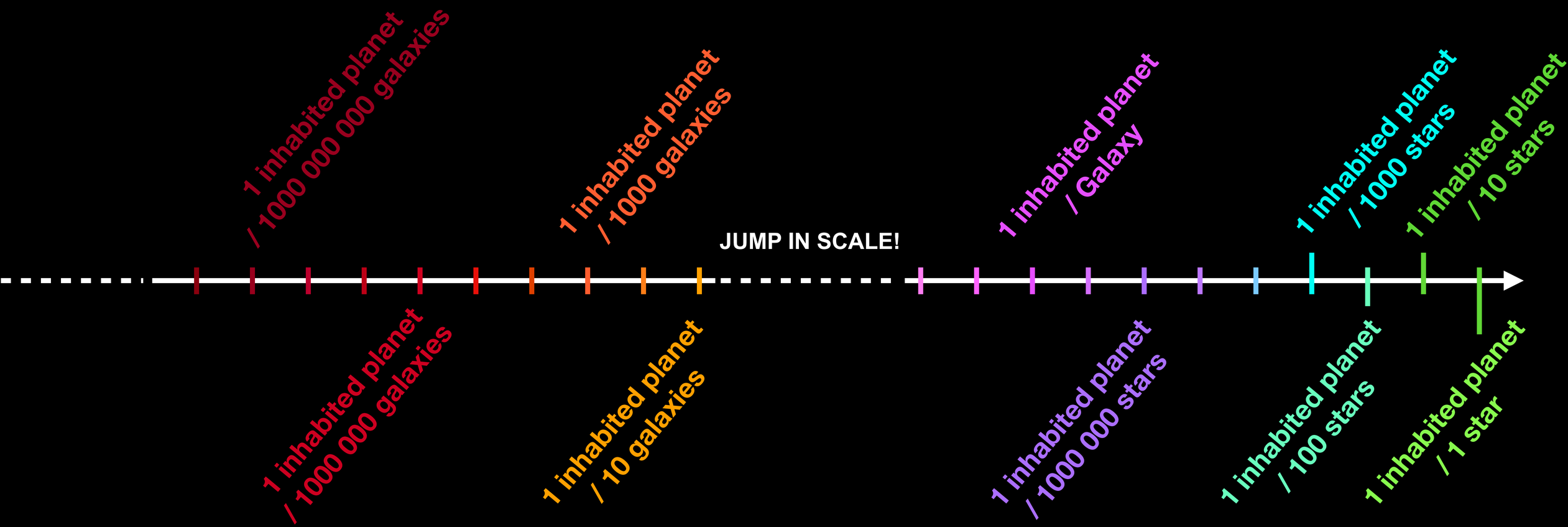


Habitable Worlds Observer
HWO (NASA+ ?)

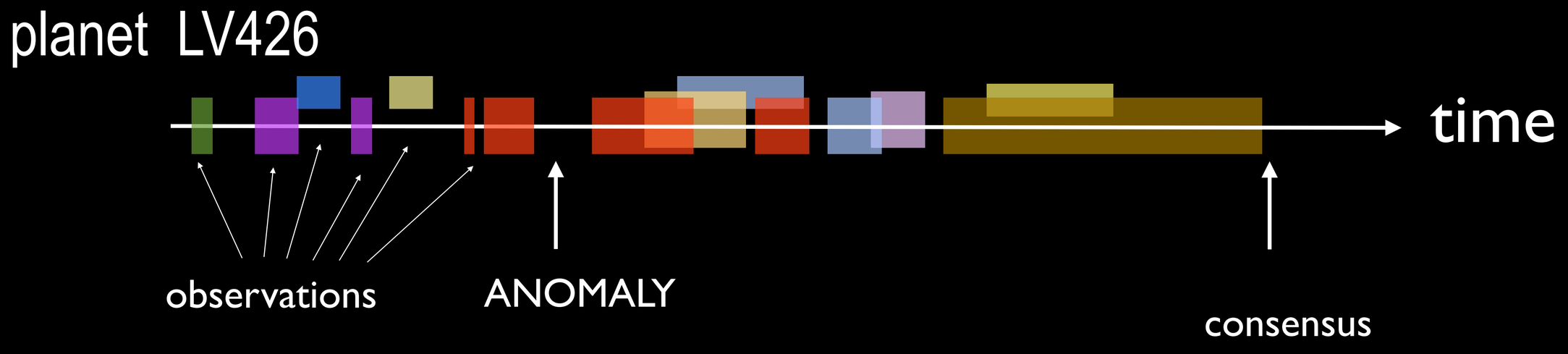
Are we alone?

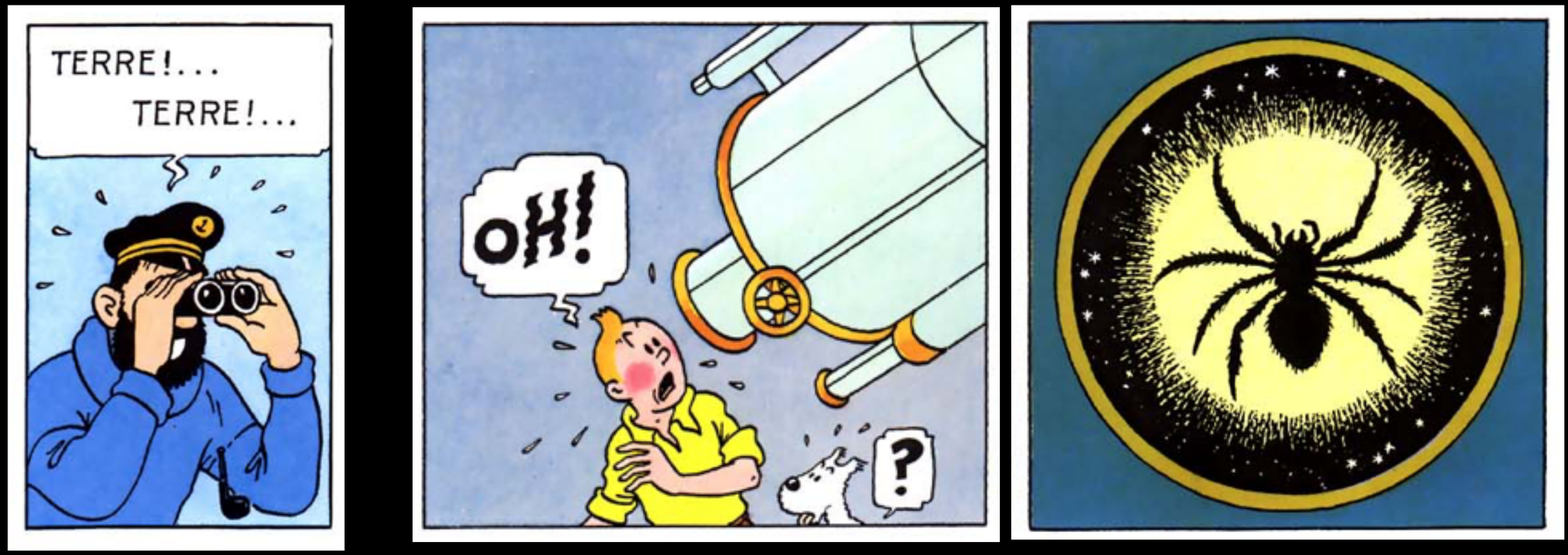
ou

Is there enough life life in the Universe to spot some nearby?




planet LV307
planet LV021
planet LV232
planet LV021
planet LV088
planet LV420
time
observations


planet LV426
time
observations
ANOMALY
consensus



L'étoile mystérieuse (*The sooting star*) Hergé 1946

- The search wil require several (many?) instruments not yet planned.
- It will require to observe/study many different planets to understand the processes controling their diversity.
- Finding *bio-like* signatures could happen early but certainly not their unambiguous confirmation/rejection as a biosignature.
- the unambiguous finding of life on an exoplanet is not imminent. It is unlikely to occur before decades even assuming that *observable life* is extremely common.