(Super-)Earths & Life
Best strategy with JWST

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(Super-)Earths & Life
Best strategy with JWST

Why it is hard
& we need to hijack time!

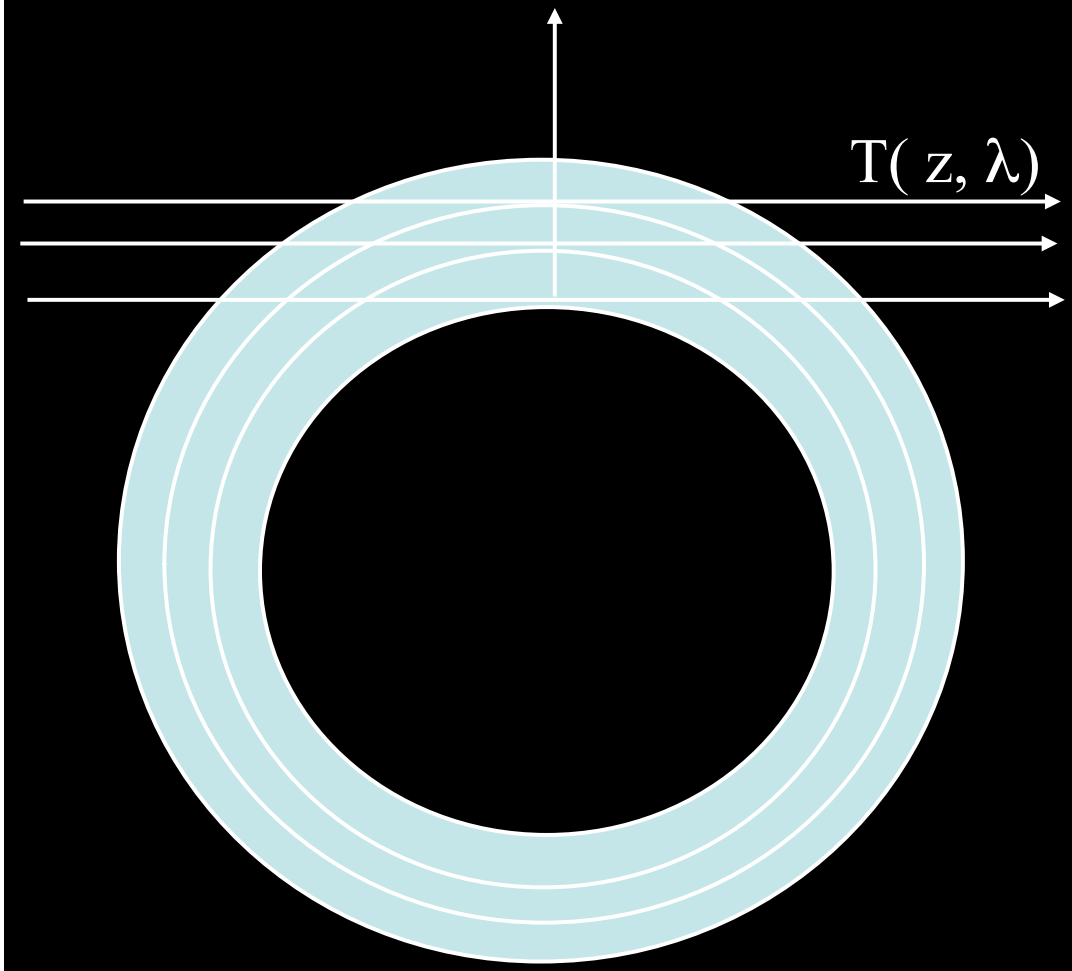
NASA/STS-125 Photo

Mini-Neptunes

8 - 15 M_E

Super-Earths

Transit Geometry



Atm. Absorption feature h proportional to scale height in the atmosphere H

$H \approx T/(g\,\mu)$

h is the effective height of an opaque atmosphere:

$h(\lambda) = \int (1-T)\, dz$

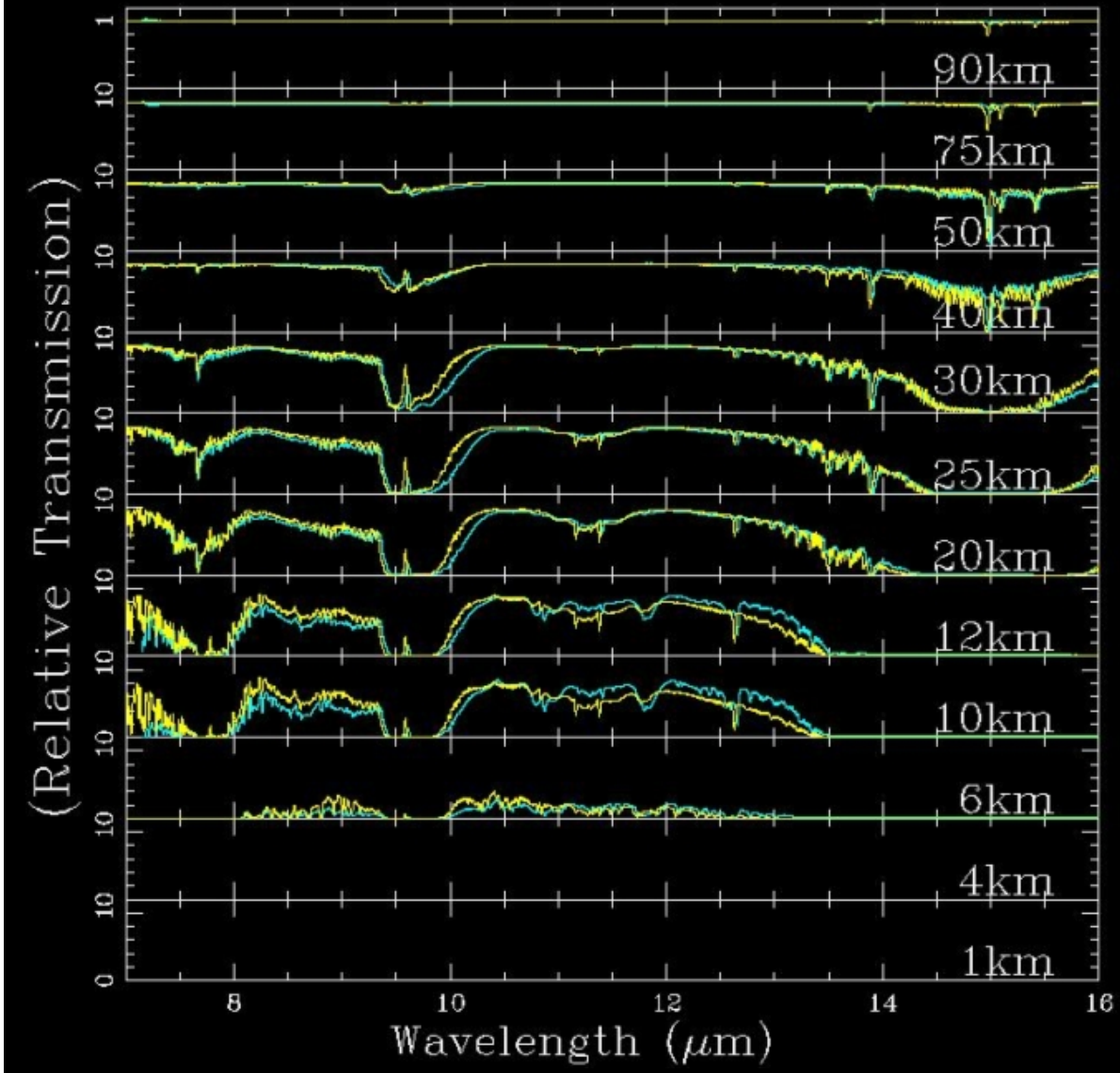
So

$R(\lambda) = R_0 + h(\lambda)$

$f_p(\lambda) = 2\pi R_p * h(\lambda) / \pi R_s^2$

$h_{EGP} = 10 - 100 \times h_{Earth}$

Earth: ATMOS-3:Transmission validation in far-IR



ATMOS-3 transmission of sunlight through Earth's atmosphere, measured with a fast FTS on Shuttle

yellow = model

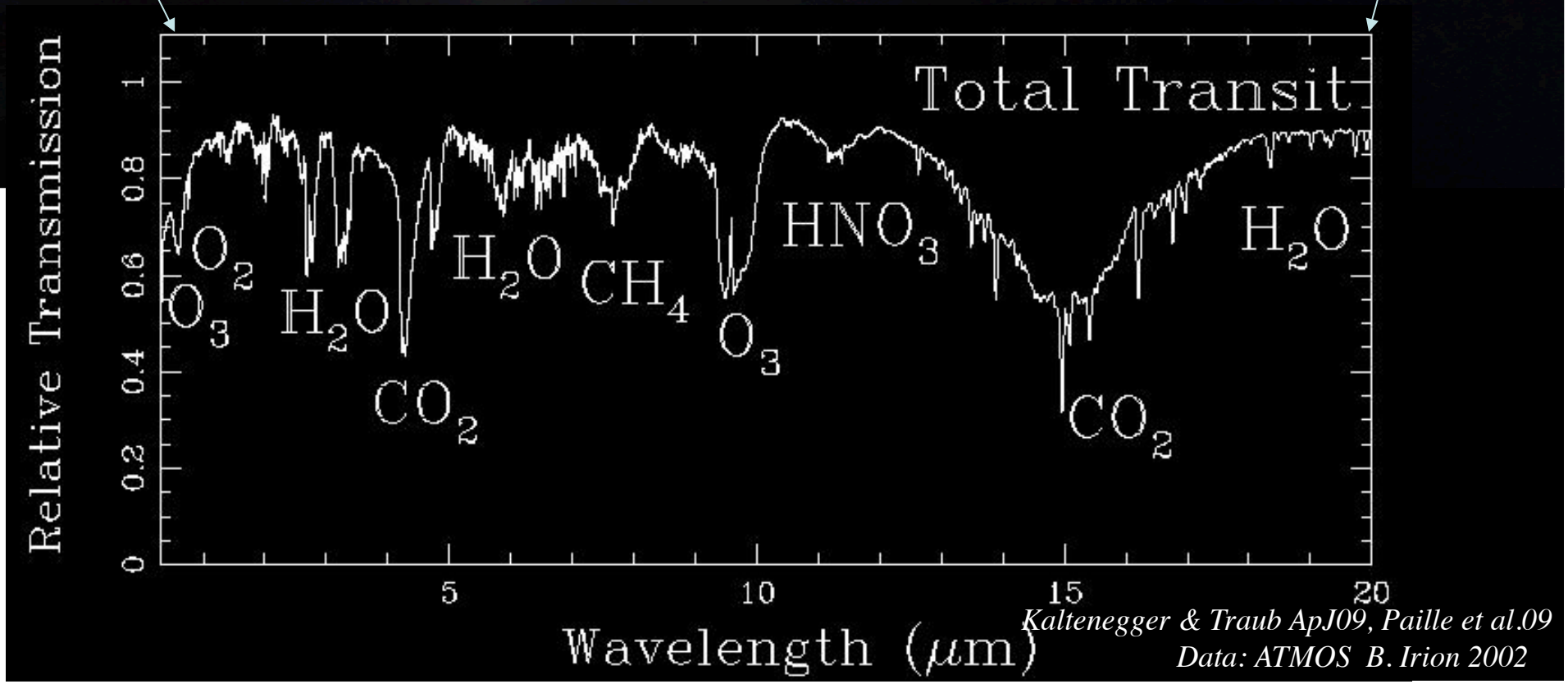
Fit is close, but line wings are not perfect, perhaps owing to line mixing effects in strong bands.

Note low transmission below 10

Kaltenegger & Traub ApJ 2009
Data: ATMOS B. Irion 2002

Data: Earth Transits transmitted starlight
(ATMOS3)

2002/201X+ ?



Kaltenegger & Traub ApJ09, Paille et al.09
Data: ATMOS B. Irion 2002

JWST Best Case: Closest Stars/Transit, e=0.3

Table 6: Major spectroscopic features and SNR of a transiting Earth for a single transit, for a 6.5-m space based telescope, for the closest stars per stellar subtype (see Table 5). For G2V, we use α centauri A, Gl 559 A at 1.34pc.

Feature	G2V	M0V	M1V	M2V	M3V	M4V	M5V	M6V	M7V	M8V	M9V
O_3	12.5	1.8	1.5	1.8	1.4	2.1	2.4	1.1	0.5	0.5	0.4
H_2O	3.5	1.0	0.9	1.2	1.0	1.8	2.7	1.5	0.8	0.9	0.9
CO_2	6.3	1.9	1.8	2.4	2.1	3.8	5.8	3.2	1.8	2.0	2.0
H_2O	8.1	2.5	2.4	3.2	2.8	5.1	7.8	4.4	2.5	2.8	2.7
CH_4	1.5	0.5	0.5	0.7	0.6	1.1	1.7	1.0	0.5	0.6	0.6
O_3	4.5	1.5	1.5	2.0	1.8	3.3	5.2	3.0	1.7	1.9	2.0
CO_2	4.3	1.4	1.4	2.0	1.7	3.2	5.0	2.9	1.7	1.9	1.9

Name	d(pc)	Sp Type
Gl 887	3.29	M0.5
Gl 15 A	3.56	M1
Gl 411	2.54	M2
Gl 729	2.97	M3.5
Gl 699	1.83	M4
Gl 551	1.30	M5.5
Gl 406	2.39	M6
Gl 473 B	4.39	M7
SCR1845-63A	3.85	M8.5
Denis1048	4.03	M9

6.5-m telescope			
Feature	λ(μm)	Δλ(μm)	H(λ),km
O_3	0.6	0.15	10
H_2O	1.9	0.2	5
CO_2	2.8	0.1	20
H_2O	3.3	0.25	20
CH_4	7.7	0.7	7
O_3	9.8	0.7	30
CO_2	15.2	3.0	25

Kaltenegger & Traub ApJ 2009

Table 3: Major spectroscopic features (col. 1) and SNR (col. 2-12) of a transiting Earth for a total co-added observation time of 200 hrs, for a 6.5-m space based telescope for the Sun and M stars

Table 4

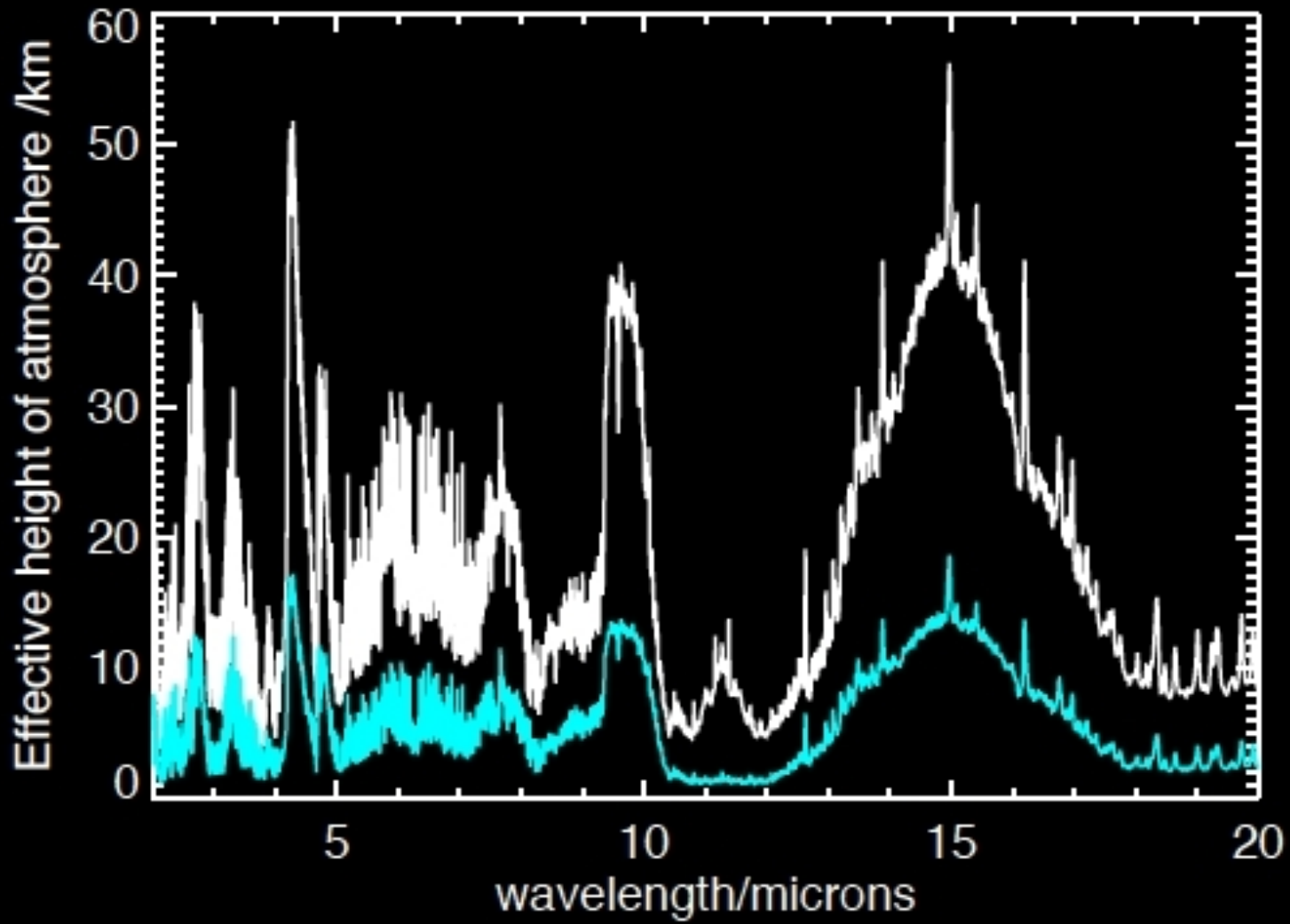
Transits of G2V and M Stars per Earth-Year (Column 1)[a]

SpTy Dwarf	[illegible]				200 hr (no. of years)
	a(HZ) (AU)	*P*(HZ) (hr)	Δ*T*(HZ) (hr)	Δ*I*/*I* (%)	
G2					15.4
M0	0.268	1571	5.37	0.022	6.7
M1	0.190	1039	3.96	0.035	6.0
M2	0.152	786	3.36	0.043	5.4
M3	0.123	633	2.96	0.055	4.9
M4	0.075	401	2.06	0.124	4.5
M5	0.047	238	1.50	0.209	3.6
M6	0.030	147	1.07	0.372	3.2
M7	0.022	98	0.78	0.582	3.0
M8	0.019	81	0.69	0.69	2.7
M9	0.013	46	0.43	1.31	2.5

Notes. [a] Number of transits to add up to 200 hr (Column 2), and number of years to accumulate 200 hr of transit observation time for an Earth-size planet in the HZ of its host star (Column 3).

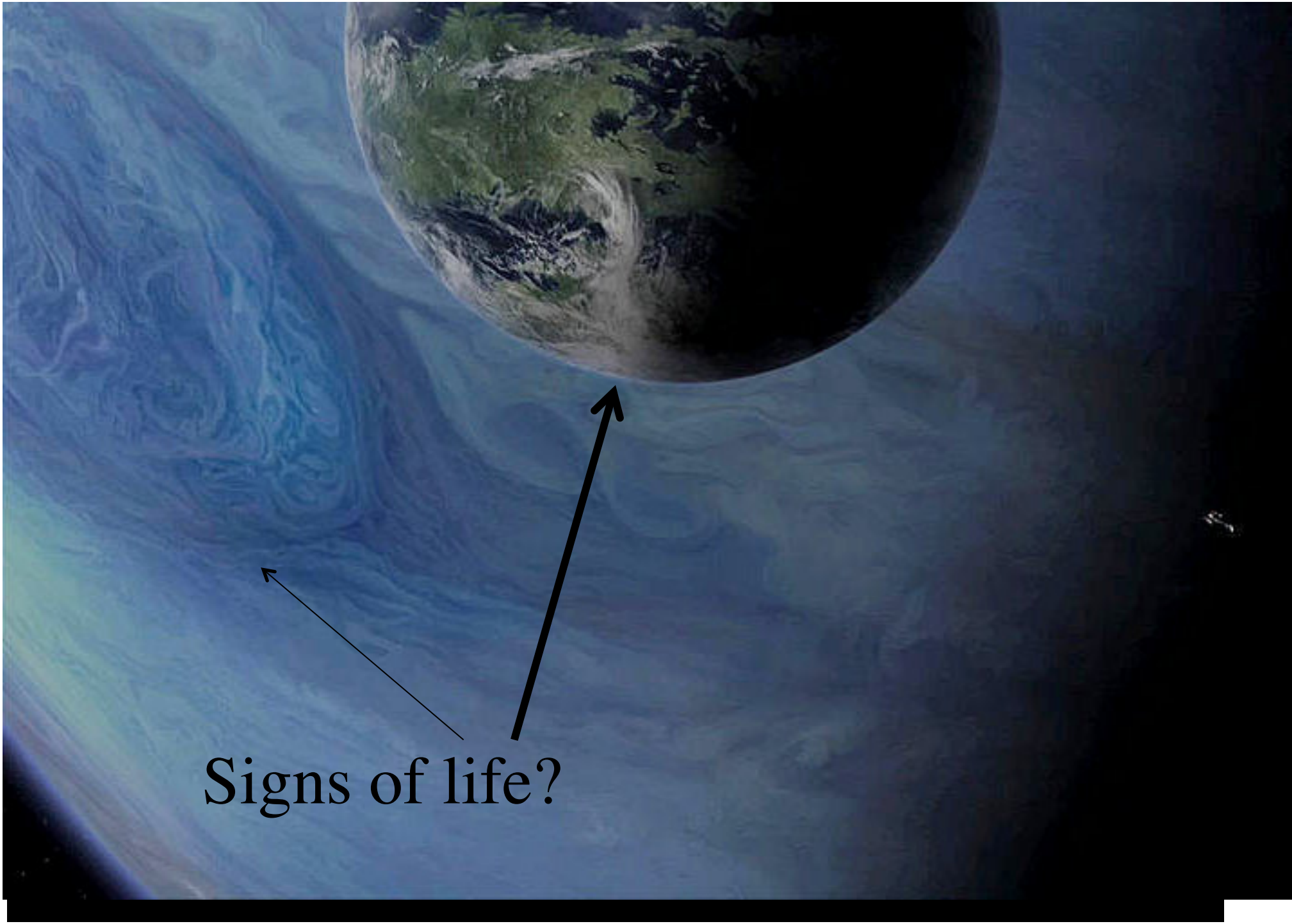
Kaltenegger & Traub ApJ 2009
Bouman, Kaltenegger & MIRI team (2011)

200hr intergation

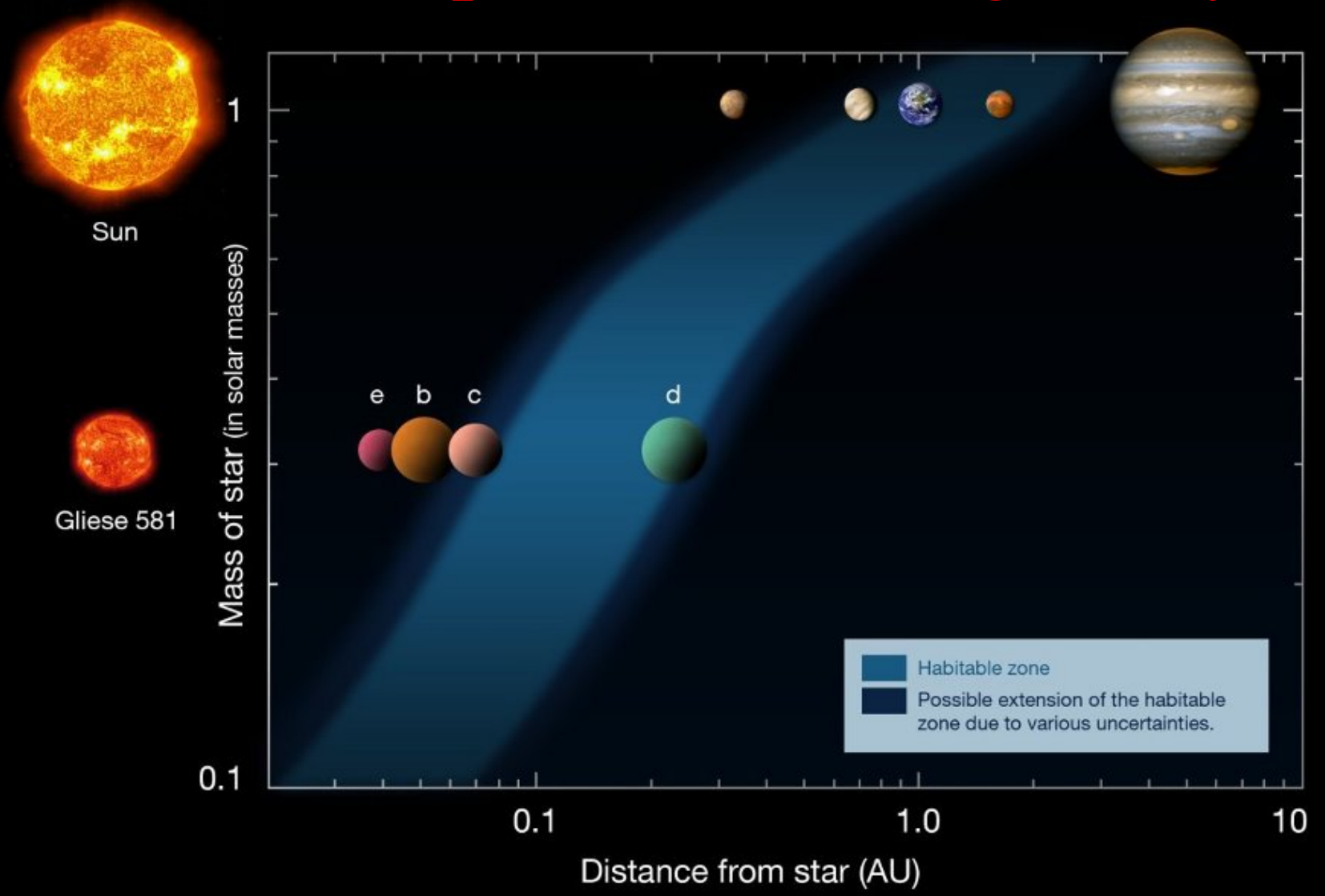


: heights: Earth and 3g super-Earth (red) around Sun.

Rauer et al A&A 2011

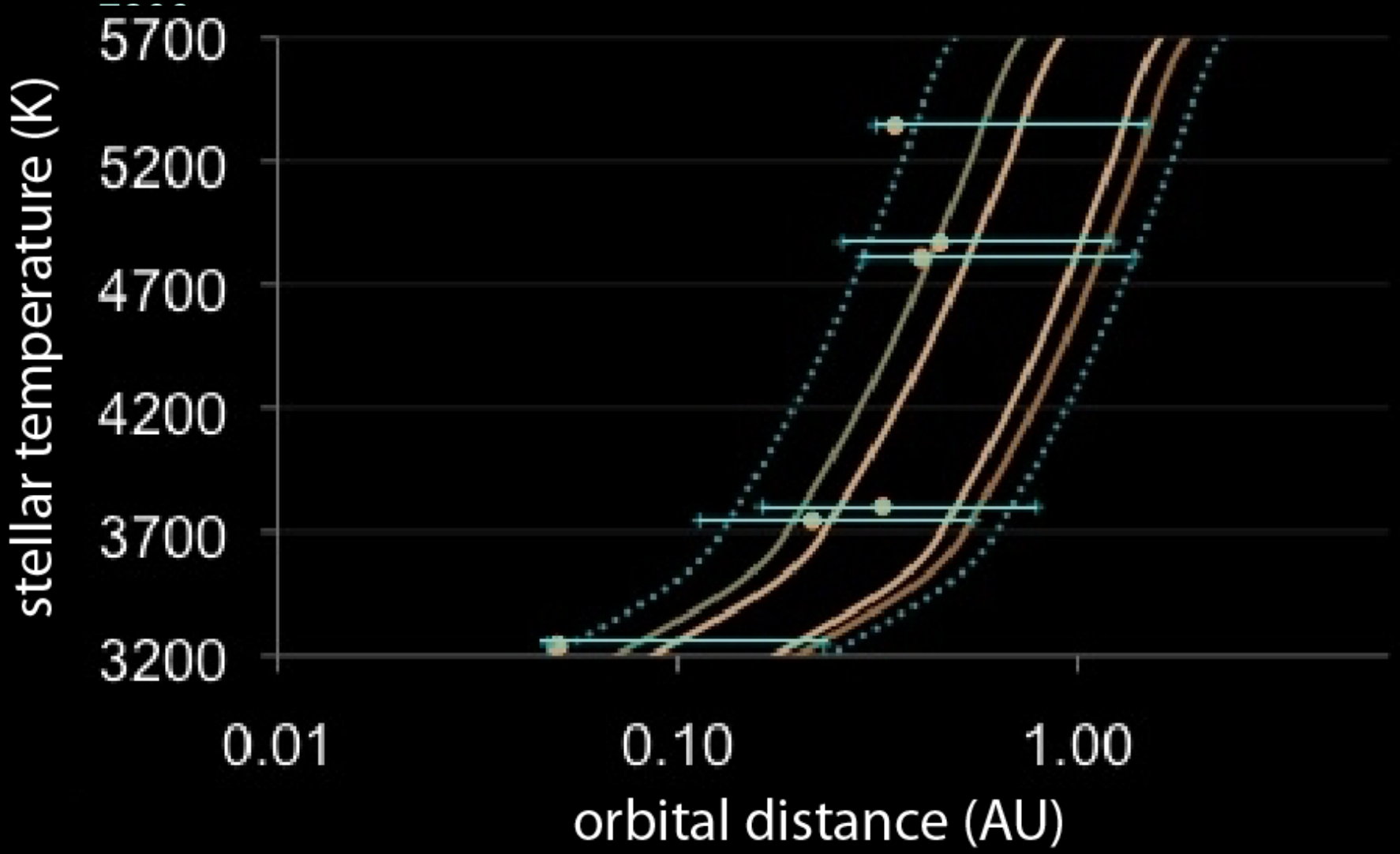

Signs of life?

Habitable Zone – water pot.liquid on surface of Earth-like planets (= incl. geol. cycles)



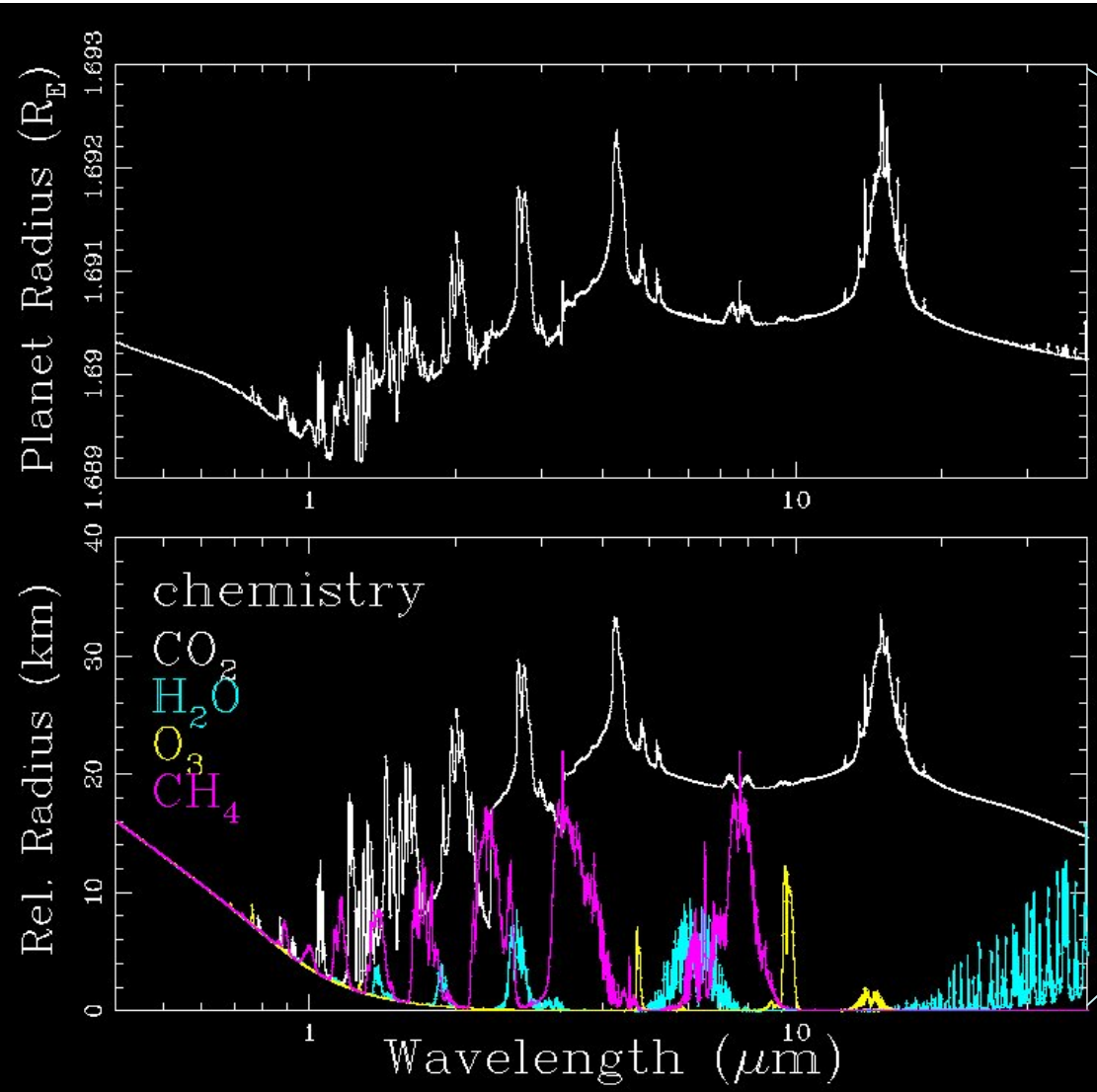
Selsis et al 2007, Kaltenegger et al 2011, von Paris et al 2010, Seager et al 2008, Miller-Ricci et al 2008,...

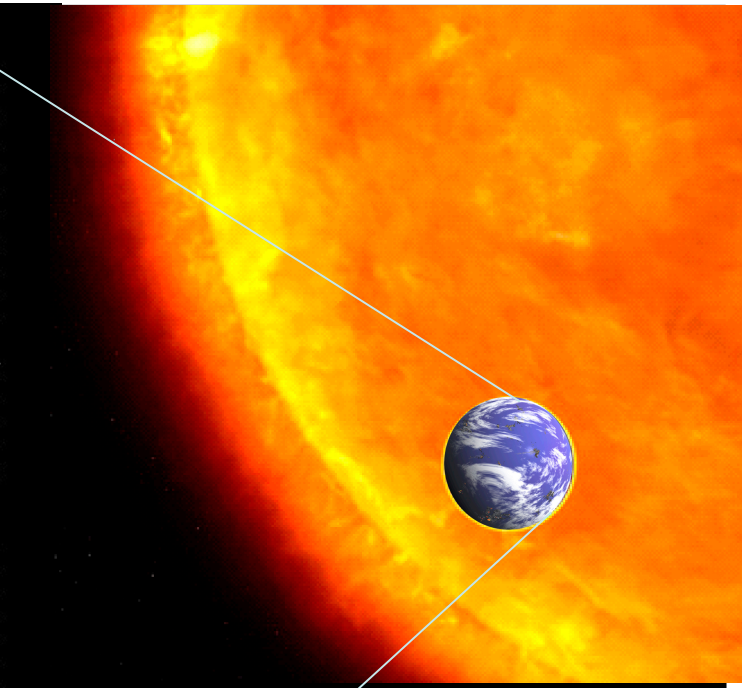
Habitable Zone: Kepler's pot. habitable planets explored



Planetary distance (AU)

Kaltenegger & Sasselov 2011 ApJL





Gl 581d Transit Spectra – to test HZ

in planetary radius

Kaltenegger, Mohanty & Segura ApJ 2011

Spectra (0.4 - 40 μm): Resolution 150

Science Case: E-ELT, JWST, SPITZER

FIND!!!! SMALL SPACE MISSIONS (e.g. TESS, ELEKTRA, ((ECHO, FINESS)) *Poster: O. Krause, M. Swain*

Not just FIND... (POS VIEW ☺ - 201X)

Characterize rocky exoplanets

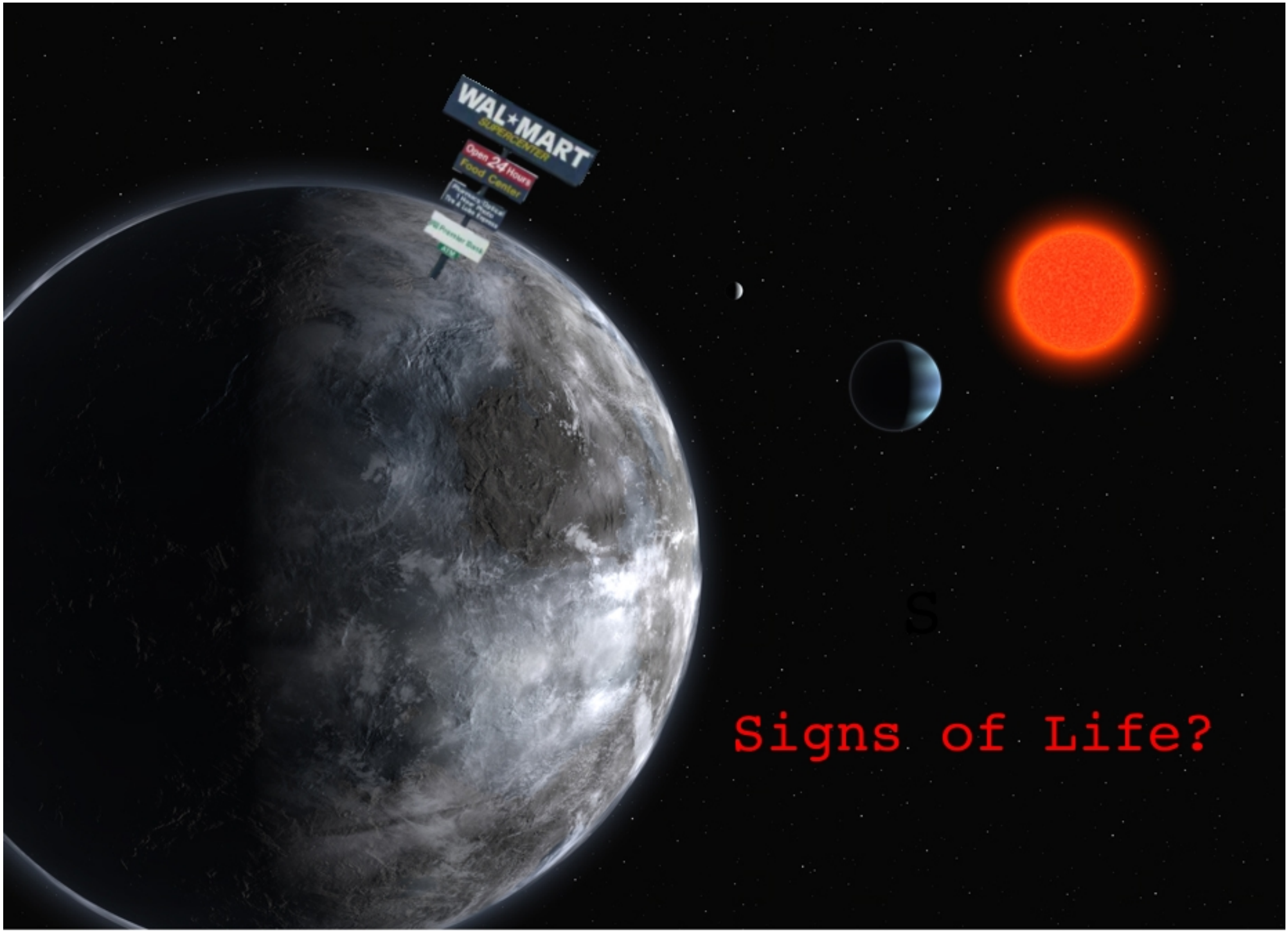
- composition	0 – 30+ years
- habitability	8+ – 30+ years
- HR Diagram of planets	8+ – 30+ years
-stage of evolution	8+ – 30+ years

- need TARGETS, TIME & CLOSE-BY & GOOD IDEAS

Are there other worlds like ours? Epicurius (c. 300 B.C)

2300 years and counting.... Let‘s find out

FIND **Earth-like** planets



The Planetary System in Gliese 581