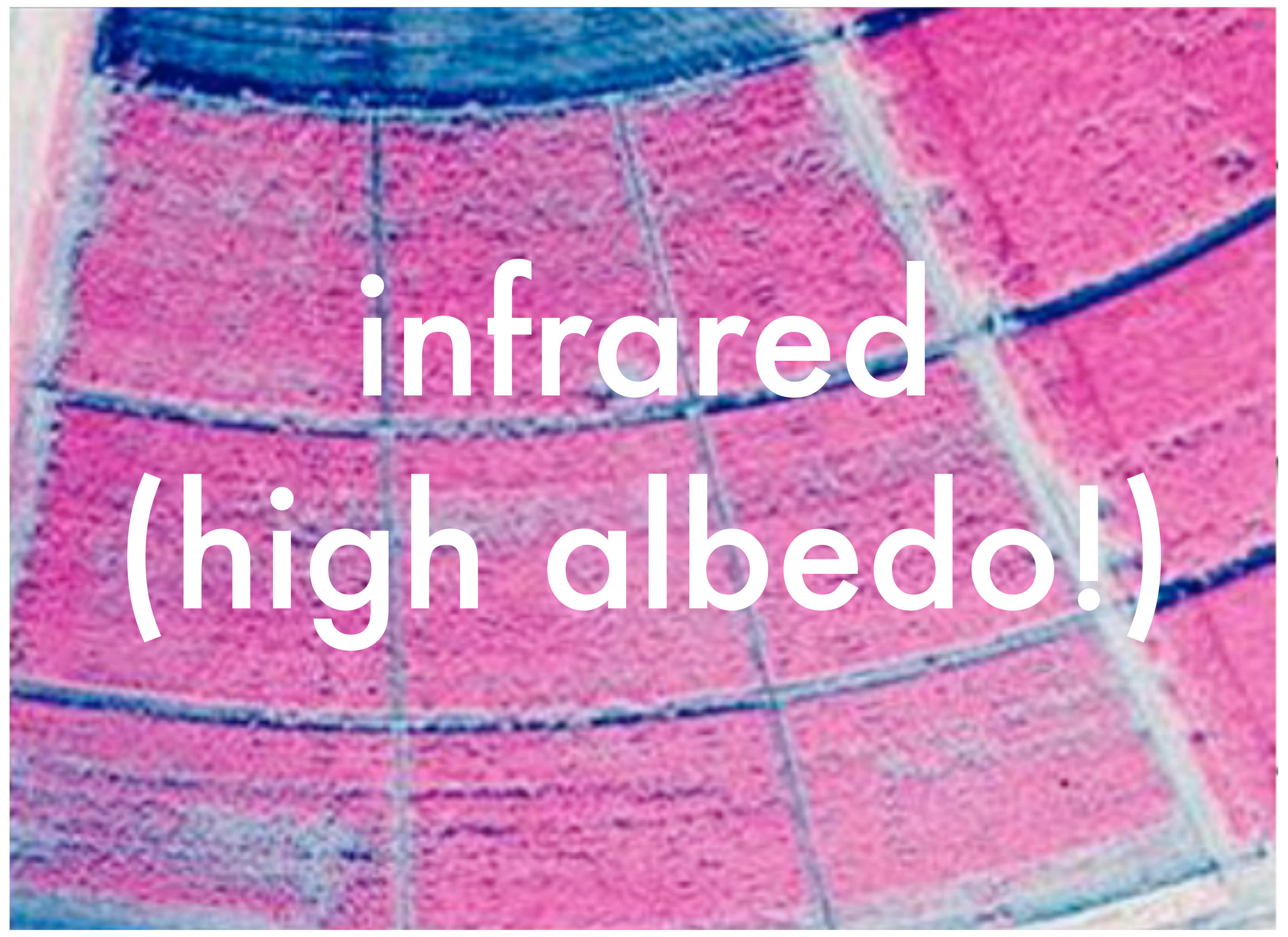
Pathways 2015 Pathways towards habitable planets, 13-17 July 2015, Bern, Switzerland

Absorption efficiencies of light-harvesting complexes in photosynthetic organisms exposed to the photoenvironment of exoplanets

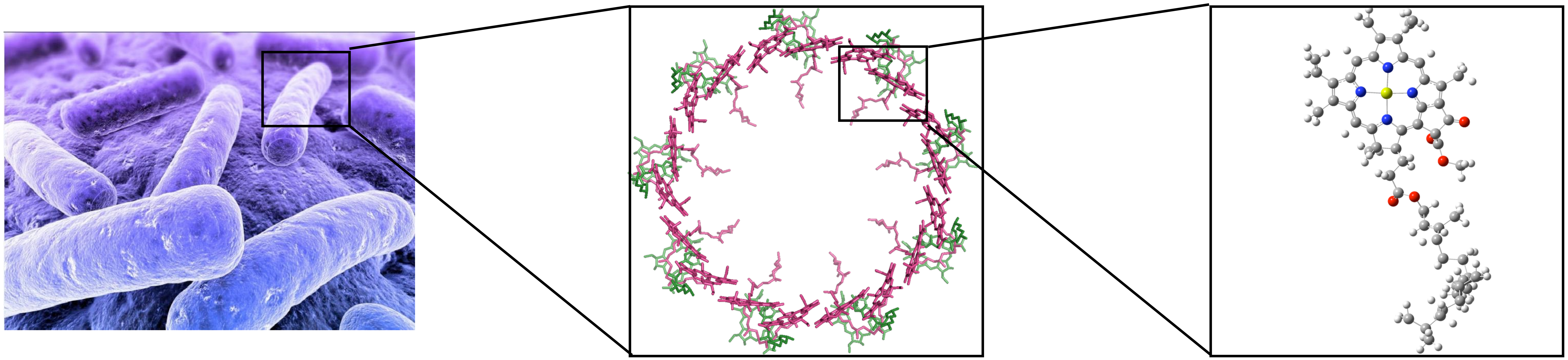
Y. Komatsu*, M. Umemura, M. Shoji, M. Kayanuma and Y. Shigeta
Center for Computational Sciences, University of Tsukuba, Japan



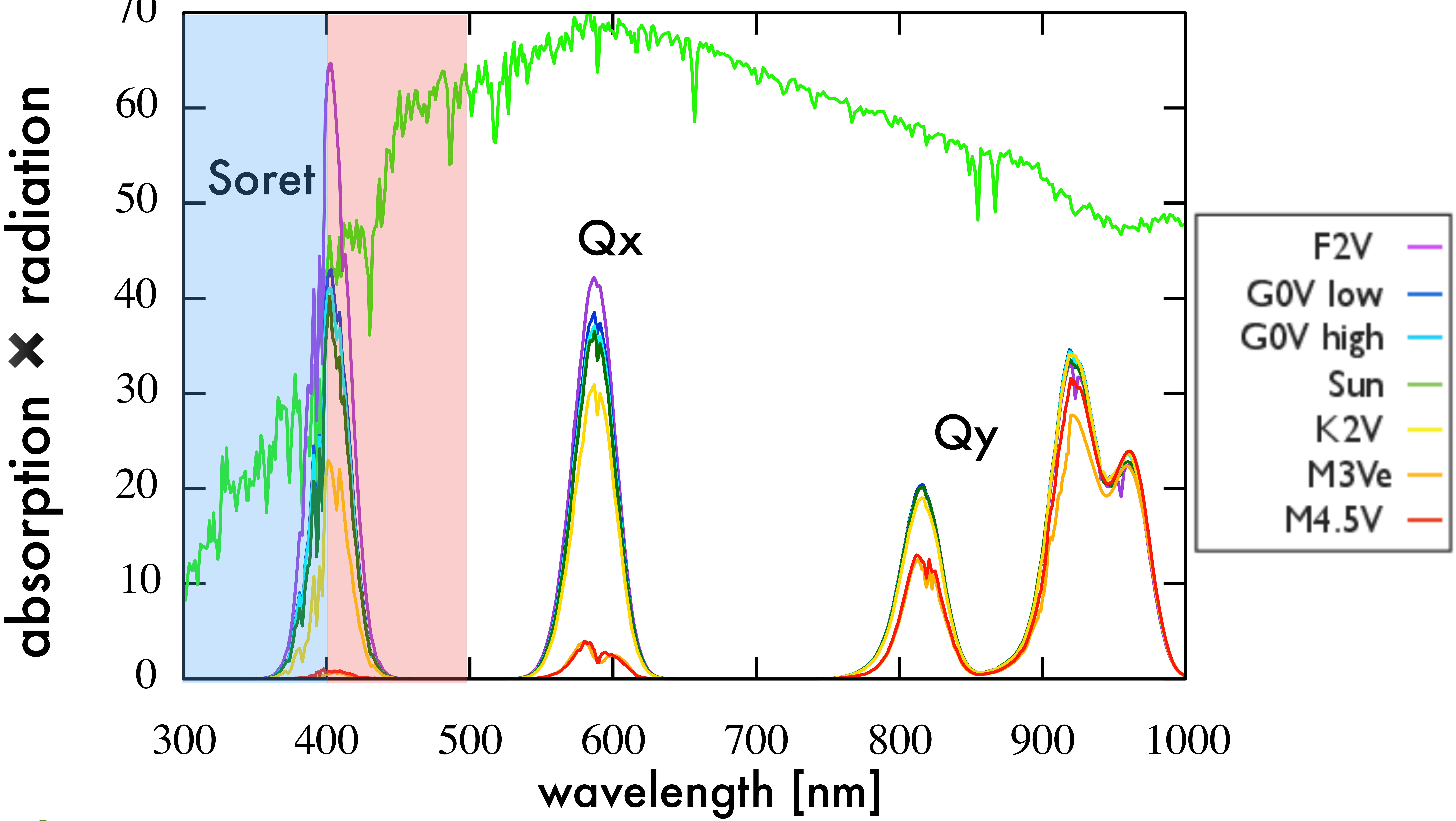
- vegetation has a unique spectral feature →how about planets orbiting F, G, K, M stars?

- purple bacteria absorb longer wavelength radiation than plants → M stars !

purple bacteria | antenna complex | photosynthetic pigment



- we investigated the light absorption ← quantum chemistry calculations top of planetary atmosphere



- FGK stars: Soret bands contribute to the efficiencies just around 4000 Å break (←heavy metals in stars).
- M stars: Qy bands contribute highly to the efficiencies.

Quiescent and Flaring Lyman-α Radiation of Host Stars and Effects on Exoplanet Atmospheres

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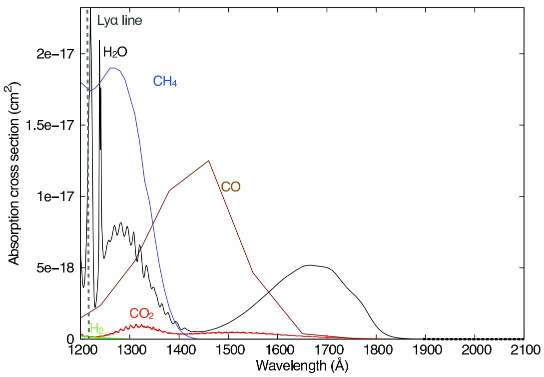
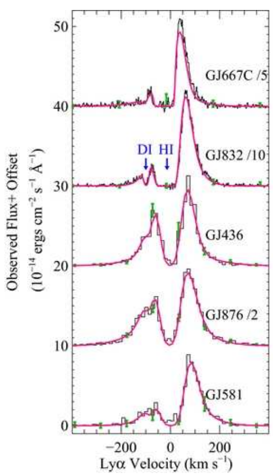
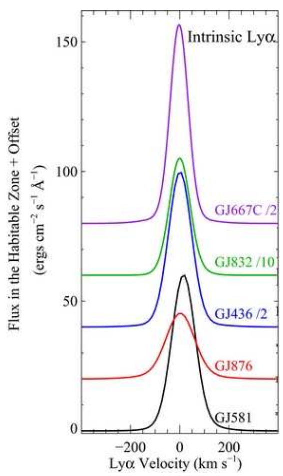
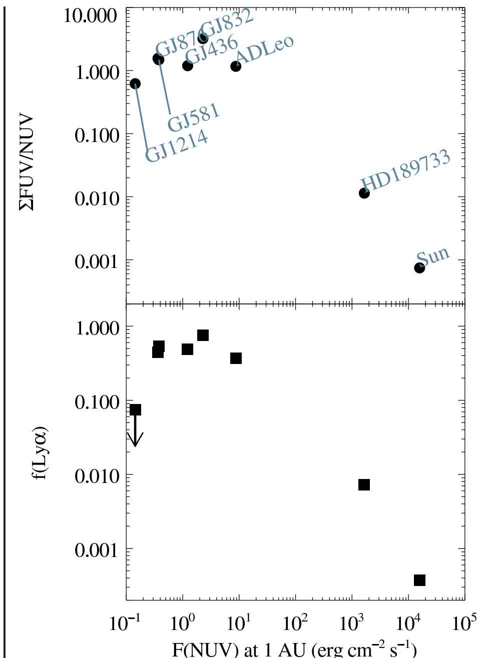
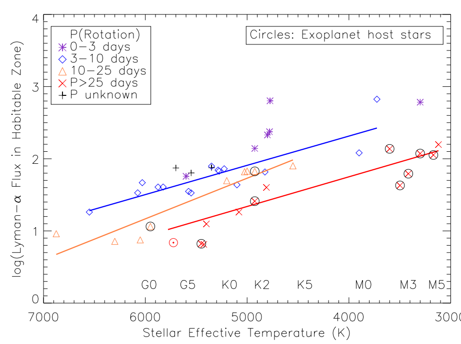
[5] Department of Astronomy, Cornell University, Cornell, NY

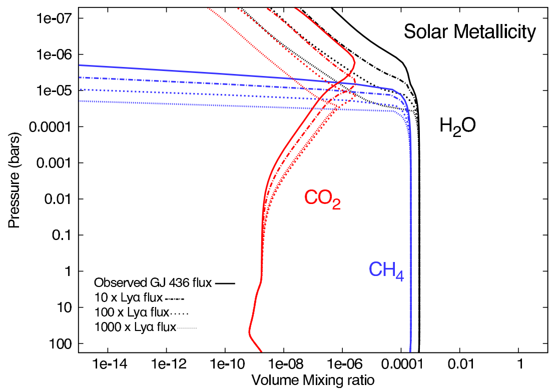


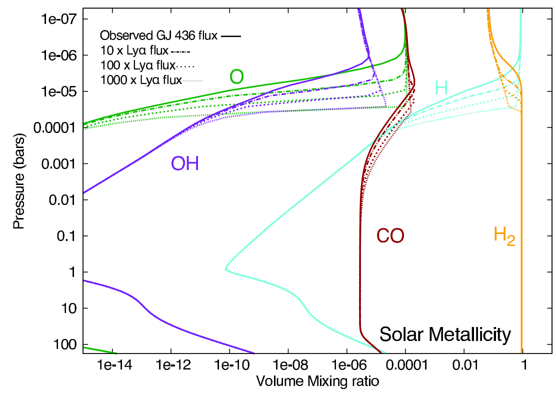









Solar Metallicity
H_2O
CO_2
CH_4
Pressure (bars)
Volume Mixing ratio
Observed GJ 436 flux
10 x Lyα flux
100 x Lyα flux
1000 x Lyα flux


Observed GJ 436 flux
10 x Lyα flux
100 x Lyα flux
1000 x Lyα flux
O
H
OH
CO
H_2
Solar Metallicity
Pressure (bars)
Volume Mixing ratio

Host's stars and habitability

Florian Gallet (Genève), Corinne Charbonnel (Genève/IRAP) and Louis Amard (Genève/LUMP)

UNIVERSITÉ DE GENÈVE

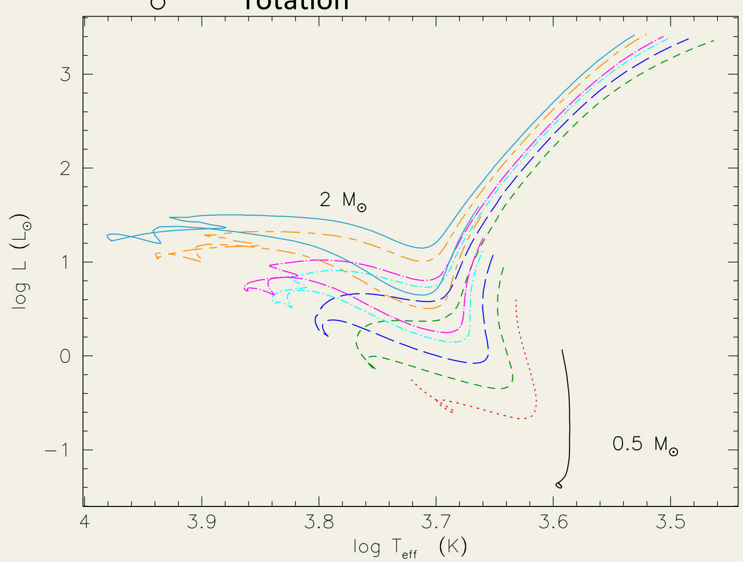
1) Introduction

- ✓ About **2000** exoplanets discovered within **different** configurations
- ✓ Thanks to **increase** of precision of modern techniques size and mass of detected planets have dramatically **decreased**
- ✓ **Earth like planets** => habitability?
  - **First** step : habitable zone (HZ) and continuously habitable zone (CHZ)
- ✓ We aim at:
  - highlighting the **impact** of stellar parameters on HZ and CHZ
  - add more **constraints** on HZ and CHZ location
  - link HZ location to stellar activity evolution

2) Reference grid of stellar models

STAREVOL

- mass range 0.5 – 2 $M_\odot$
- 4 metallicity values
- impact of rotation-induced mixing
- rotation



3) Model

- ✓ Habitable zone (Kopparapu et al. 2013,2014):

$$d=\left(\frac{L/L_\odot}{S_{eff}}\right)^{0.5} \qquad S_{eff}=\frac{F_{IR}}{F_{INC}}$$

⇨ 1-D radiative-convective climate model

$$Seff=S_{eff\odot}+aT_*+bT_*^2+cT_*^3+dT_*^4 \qquad T_*=T_{eff}-5780$$

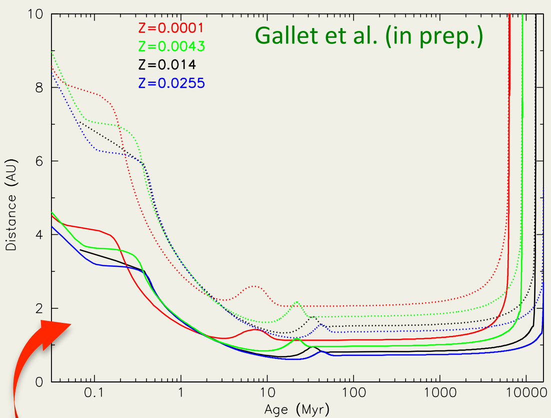
R_{in} = runaway greenhouse, net positive feedback of greenhouse effect

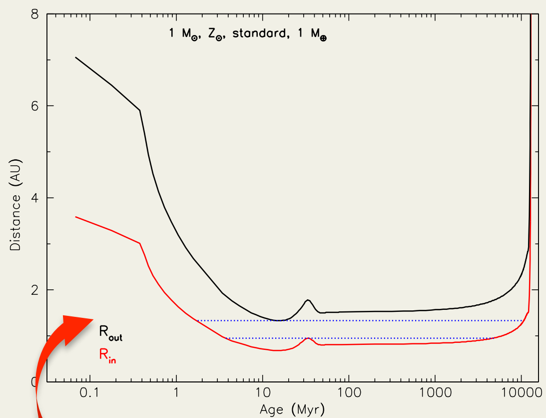
R_{out} = maximum greenhouse, Rayleigh scattering due to CO_2 reduce greenhouse effect

- ✓ Stellar **structure** evolution grid: Amard et al. (in prep.)

The authors acknowledge financial support from the Swiss National Science Foundation (FNS) and from the French Programme National National de Physique Stellaire PNPS of CNRS/INSU. This work results within the collaboration of the COST Action TD 1308

4) Key results

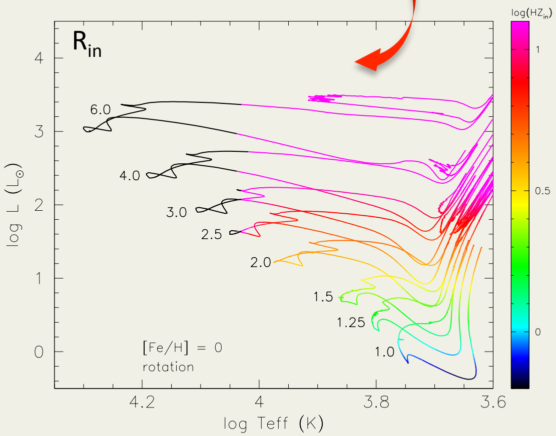




Metallicity and mass effect

CHZL and activity effect

$$Ro = \frac{P_{rot}}{\tau}$$



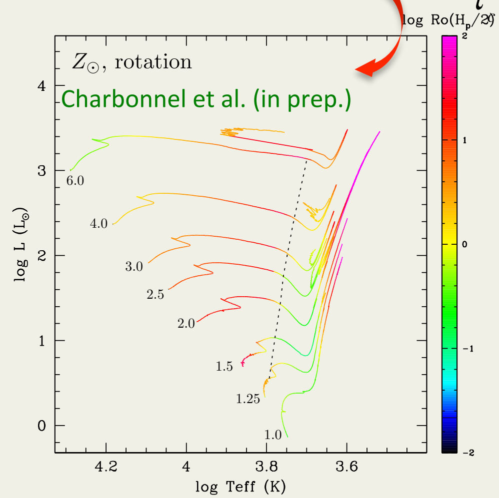


Table 1. Size of the HZ as a function of stellar mass.

ΔHZ	0.5 $M_\odot$	1 $M_\odot$	1.5 $M_\odot$	2 $M_\odot$
ΔHZ_{mean} (AU)	0.27	0.86	2.05	3.25
ΔHZ_{min} (AU)	0.2	0.65	1.2	1.85
ΔHZ_{max} (AU)	1.39	3.46	5.9	6.63

5) Conclusion

✓ **Systematic** study of HZ and CHZ
- grid available
- online tool scheduled

✓ **Strong** effect of mass and metallicity
- limits
- shapes

✓ **NO** rotation effect on HZL and CHZL

✓ **HZL** minimum when stellar activity at its **lowest**
- Impact on planetary formation?

→ Need to include
- star-planet tidal interaction (dissipation processes)
- magnetic interaction/protection
- …

Contact

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Habitable Planets and Dynamics in Stellar Binaries

Pathways 2015: Pathways towards habitable planets
13-17 July 2015
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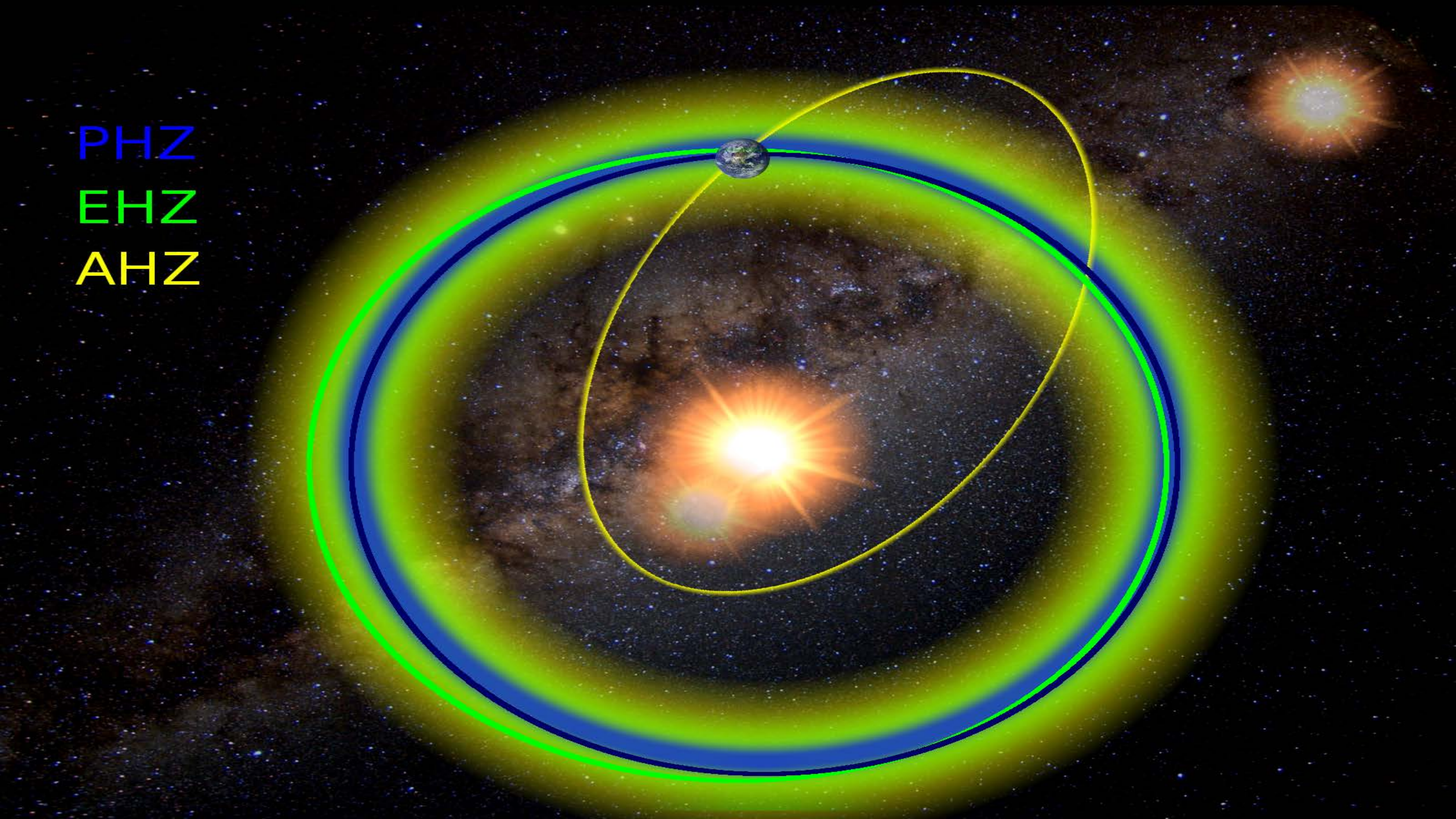

PHZ
EHZ
AHZ

Habitability of Exoplanets:

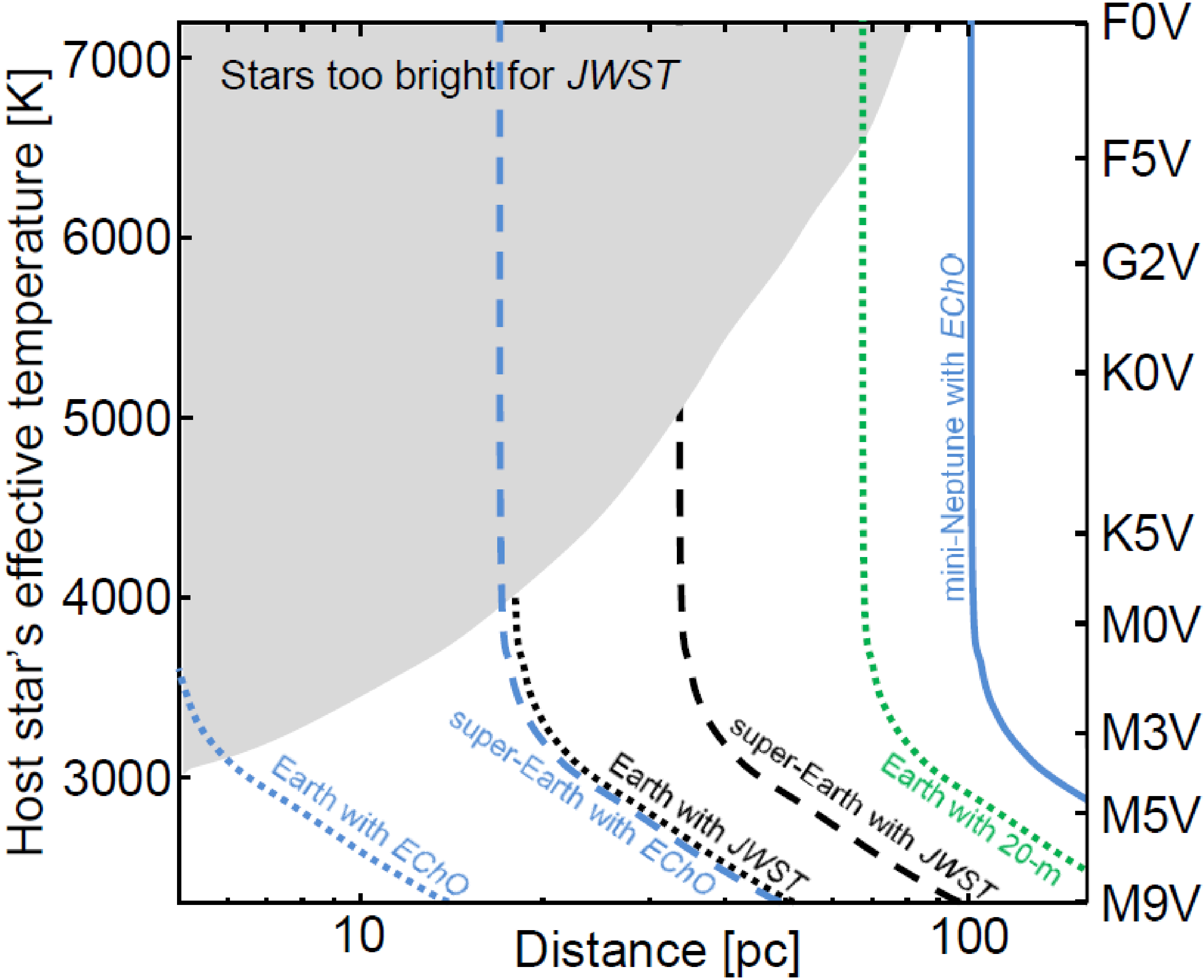
What can we learn in the next 10 years ?

– Julien de Wit –

Pathways 2015 – July 2015

Earth, Atmospheric and Planetary Sciences

MassSpec's potential

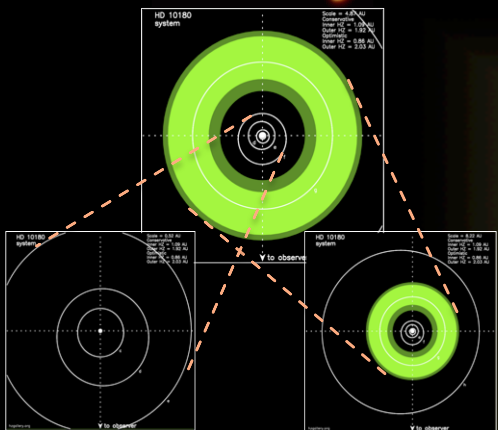


What Can the Habitable Zone Gallery Do for You?

Dawn M. Gelino[1] & Stephen R. Kane[2]

[1]NASA Exoplanet Science Institute, Caltech; [2]San Francisco State University

Gallery



✧ Includes up to 3 images for each system scaled for 1) Planets exterior to the HZ, 2) Planets in the HZ, 3) Planets interior to the HZ

✧ The light and dark green regions represent the conservative and optimistic HZ as given by Kopparapu et al. 2013, ApJ, 765, 131

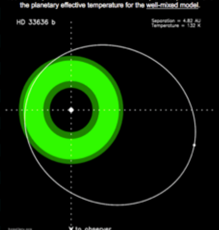
✧ The Gallery and Movies pages are *searchable*!!

Movies

Filter: Enter planet name to search

Planet	P (days)	Movie
11 Com b	326.0	avi | mpg | mp4
11 UMi b	516.2	avi | mpg | mp4
14 And b	185.8	avi | mpg | mp4
14 Her b	1773.4	avi | mpg | mp4
16 Cyg B b	798.5	avi | mpg | mp4
18 Del b	993.3	avi | mpg | mp4
24 Sex b	455.2	avi | mpg | mp4
24 Sex c	910.0	avi | mpg | mp4
30 Ari B b	335.1	avi | mpg | mp4
42 Dra b	479.1	avi | mpg | mp4
47 UMa b	1078.0	avi | mpg | mp4
47 UMa c	2391.0	avi | mpg | mp4
4 UMa b	269.3	avi | mpg | mp4
51 Peg b	4.2	avi | mpg | mp4
55 Cnc b	14.7	avi | mpg | mp4
55 Cnc c	44.4	avi | mpg | mp4
55 Cnc d	4909.0	avi | mpg | mp4
55 Cnc e	0.7	avi | mpg | mp4
55 Cnc f	261.2	avi | mpg | mp4
61 Vir b	4.2	avi | mpg | mp4
61 Vir c	38.0	avi | mpg | mp4
61 Vir d	123.0	avi | mpg | mp4
6 Lyn b	874.8	avi | mpg | mp4
70 Vir b	116.7	avi | mpg | mp4
75 Cet b	691.9	avi | mpg | mp4
7 CMa b	763.0	avi | mpg | mp4
81 Cet b	952.7	avi | mpg | mp4

This table contains links to movie files for each planet. The movies are available in AVI, MPEG-2, and MPEG-4 formats and are divided into 200 frames per orbit. The movies show the star-planet separation and the planetary effective temperature for the well-mixed model.



Above is a low-resolution version of how the animations look.

Circumbinary Planets: The below table provides special animations for the known circumbinary planetary systems. The main difference is the time dependent Habitable Zone due to the orbit of the binary. The solid lines are the Habitable Zone boundaries, the red dotted line is the orbital stability boundary, and the planet location is indicated by a pale blue dot. These are described in more detail in an article by Kane & Hinkel.

Planet	P (days)	Movie
Kepler-16 b	228.8	mpg | mp4
Kepler-34 b	288.8	mpg | mp4
Kepler-35 b	131.5	mpg | mp4

✧ Shows real-time predicted change in temp (well mixed model) and separation from star which is particularly useful for eccentric orbits

✧ Includes circumbinary planet movies!

Why Create the HZG?

- To provide an interactive method and table to visualize the orbits and Habitable Zones (HZs) and sort for planets which spend substantial time within the HZ
- To provide tools, graphics, and movies which can be easily imported into presentations to facilitate communication of these concepts in both public and scientific contexts
- To investigate the habitability of exoplanets and potential exomoons whose energy budget varies with a cyclic nature

Use Cases

- Using figures for talks/grants/papers
- Characterization of exoplanets and their moons
- Easy determination of and orbit visualization for known planets spend substantial time in their HZs
- Planetary environment studies
- Target selection, visual aids in a variety of contexts, and general demographic investigations
- See Kane & Gelino 2012, PASP, 124, 323 for more details

http://www.hzgallery.org

Table

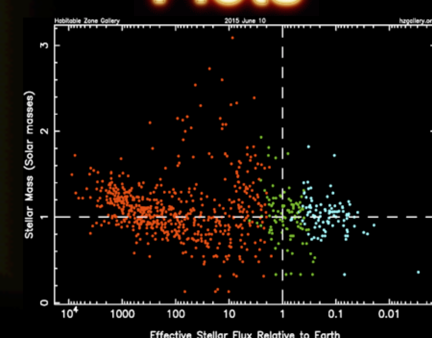
Click on planet name to bring up Gallery images

Click on table header to sort by that parameter

Planet	P (days)	e	ω (°)	t_{HZ}^{c} (%)	t_{HZ}^{o} (%)	T_{eff}^{a} (K)	T_{eff}^{b} (K)	T_{eff}^{c} (K)	T_{eff}^{d} (K)
11 Com b	326.0	0.231	94.8	0.0	0.0	1011	850	799	672
11 UMi b	516.2	0.080	117.6	0.0	0.0	1399	1177	1291	1086
14 And b	185.8	0.000	0.0	0.0	0.0	1026	863	1026	863
14 Her b	1773.4	0.369	22.6	0.0	0.0	217	182	147	124
16 Cyg B b	798.5	0.681	85.8	19.6	30.6	473	397	206	173
18 Del b	993.3	0.080	166.1	0.0	0.0	566	476	522	439
24 Sex b	455.2	0.184	227.0	0.0	0.0	536	451	445	374
24 Sex c	910.0	0.412	172.0	18.9	59.9	501	422	324	272
30 Ari B b	335.1	0.289	307.0	38.5	69.9	434	365	323	271
42 Dra b	479.1	0.380	218.7	0.0	0.0	1329	1118	891	749
47 UMa b	1078.0	0.032	334.0	0.0	57.1	250	210	242	204
47 UMa c	2391.0	0.098	295.0	0.0	0.0	199	167	180	152
4 UMa b	269.3	0.432	23.8	0.0	0.0	2110	1774	1329	1118
51 Peg b	4.2	0.013	58.0	0.0	0.0	1481	1245	1462	1229
55 Cnc b	14.7	0.004	110.0	0.0	0.0	861	724	858	721
55 Cnc c	44.4	0.070	356.0	0.0	0.0	616	518	574	483
55 Cnc d	4909.0	0.020	254.0	0.0	0.0	125	105	122	103
55 Cnc e	0.7	0.000	90.0	0.0	0.0	2328	1958	2328	1958
55 Cnc f	261.2	0.320	139.0	60.1	84.1	399	335	286	241
61 Vir b	4.2	0.120	105.0	0.0	0.0	1505	1266	1334	1122
61 Vir c	38.0	0.140	341.0	0.0	0.0	732	615	635	534
61 Vir d	123.0	0.350	314.0	0.0	0.0	569	478	395	332
6 Lyn b	874.8	0.059	314.9	0.0	0.0	467	392	440	370

✧ Sortable table of parameters for each planet including:
  - ✧ % of time spent in conservative HZ and optimistic HZ
  - ✧ temperatures for 2 different atmosphere models at 2 different locations: well mixed & hot dayside for periastron and apastron locations

Plots



✧ Dependence on the effective stellar flux received by the planet on stellar mass. Green = planets which spend > 50% of their orbital phase within the HZ. Red and blue = planets interior and exterior to the HZ respectively. The dashed crosshairs show the location of Earth.

✧ Other summary plots on the site include animated yearly depictions of the planet mass and orbital eccentricity versus the orbital period of exoplanets which enter their HZs.