Welcome to Centre for ExoLife Sciences

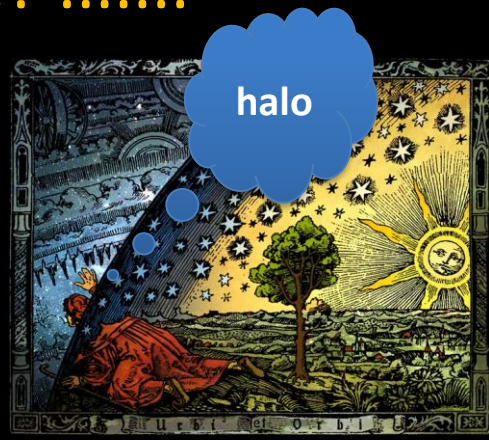
Start-up meeting at Scandic Hotel Copenhagen Sept.27/28,

novo nordisk fonden
Benefiting people and society

"Extraterrestrial life -- where and what is it?" …But meeting one another, ideas and projects, are the most important points of the meeting – to inspire one another toward understanding where the major questions are, and where progress may hide:

Can we contribute to defining what life is? Does it exist outside Earth or is it really something unique just here? *In a few years we will finally know*, and in a decade people will live on Mars – how do we contribute to make it possible? .....

…and plenty of continuing problems to address for many years beyond, including: Will we become a new species on Mars? Will we/they later colonize the whole Galaxy? Is the Universe becoming bio-friendly on a transition to a living universe? can we help it? --but for the moment let us concentrate on "the simpler questions"



Start-up welcome meeting at Centre for ExoLife Sciences, CELS (www.cels.nbi.ku.dk) at Scandic, Sept.27-28/2021

M1: Monday, 2021-09-27
08:30 – 09:00: Breakfast buffet
09:00 – 10:30: Uffe Gråe Jørgensen, Anders Priemé and Henrik Grum Kjærgaard about CELS
10:30 – 11:00: Coffee break

M2: Monday
11:00 – 12:30: Jan Härter, CELS cloud physics, Namiko Mitarai and Kim Sneppen about bio-complexity
Gisle Vestergaard about microbiology
12:30 – 14:00: Lunch break

M3: Monday
14:00 – 15:30: Intros from astrophys/planet.sci. Anders Johansen, Åke Nordlund, Maria Bergemann & Morten Bo Madsen
15:30 – 16:00: Coffee break

M4: Monday
16:00 – 17:00: Round-table group discussions

T1: Tuesday, 2021-09-28
08:30 – 09:15: Breakfast buffet
09:15 – 11:00: Student introductions by Kristian Holten Møller, Beatriz Campos Estrados, Miguel Zornoza, Casper Vindahl Jensen, Flavia Amadio, Miguel Garcia, and Marie-Luise Steinmeyer
11:00 – 11:30: Coffee break

T2: Tuesday
11:30 – 12:30: Round-table group discussions
12:30 – 14:00: Lunch break

T3: Tuesday
14:00 – 15:30: Student introductions by Nanna Falk Christensen, Eftychia Symeonidou, Emil Vogt, Azzura D'Allessandro, Jing Chen, and Nanna Bach-Møller
15:30 – 17:00: Round-table disc., coffee break & summary

18:00 – ca. 21:00: Dinner at rest. Babylon @ Søpavillonen

Hotel Scandic: Vester Søgade 6 (next to the Planetarium); Søpavillonen: Gyldenløvsgade 24 (between the two lakes)

Our 4-years CELS Novo Nordisk Synergy-project: Effects of bacteria on atmospheres of Earth, Mars, and exoplanets -

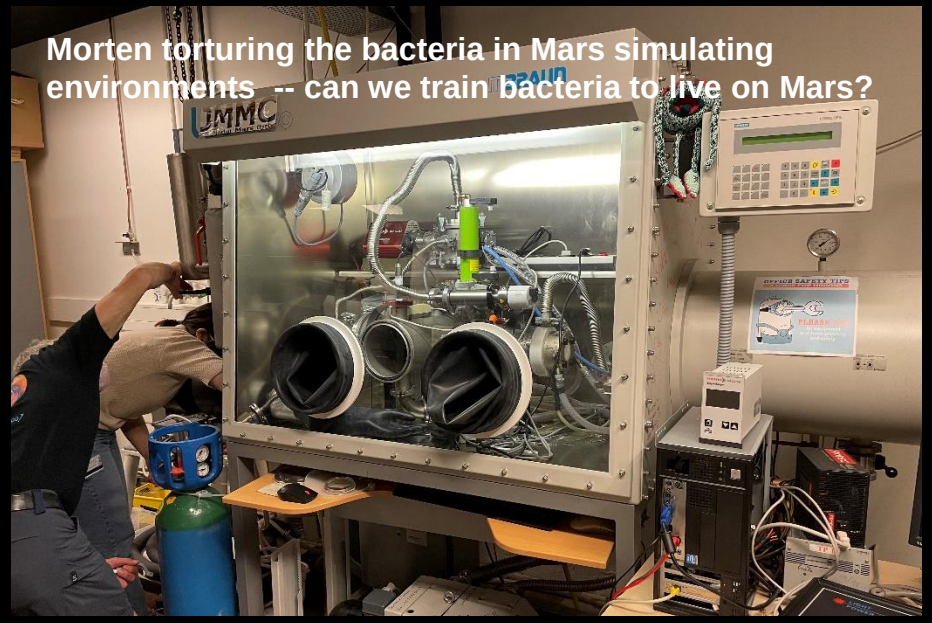
- adapting and identifying life in extraterrestrial environments

Several (very positive) statements from the international referee committee reminded us that it will not be trivial to reach our goals, and require lots of synergy and hard work – this is what we are here for!

Comments included reminders that the results will not be straight forward to interpret, and that the involved disciplines do not usually work together in classical academic environments ….but concludes that in spite of all this, they believe that we will be able to meet these huge challenges – that we will be able to deliver a deeper understanding of what life actually is, where and how to find it outside Earth, and that the PhD students at the centre will build a unique muliti expertise for their future career. Today is an important start-up milestone to prove that we can!

One of the referees also pointed at that even a smaller step along the way could be a great step towards the discovery of the first extraterrestrial life, such as for example our attempts to define and compute the role of biology in establishing an atmosphere out of chemical equilibrium.

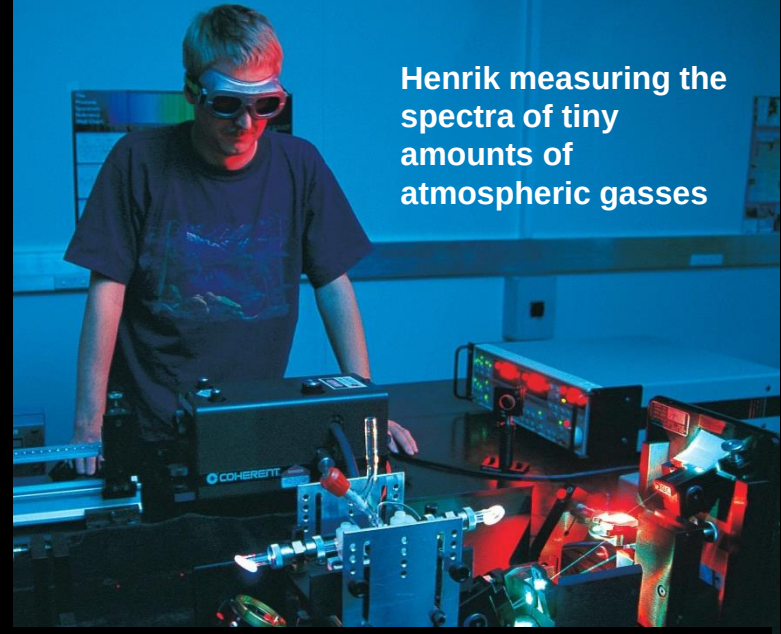
And finally the referees, maybe inspired by the names of 4 PI gentlemen on the application, reminded us that gender balance is good for scientific progress. We are happy to note that we now have an almost 50/50% gender balance among the total amount of people involved in the centre, and that today at our star-up meeting, we are 11 very bright women and 14 almost equally bright men, such that the total brain-power balance is completely sustainable and 50/50% gender neutral.



Morten torturing the bacteria in Mars simulating environments -- can we train bacteria to live on Mars?

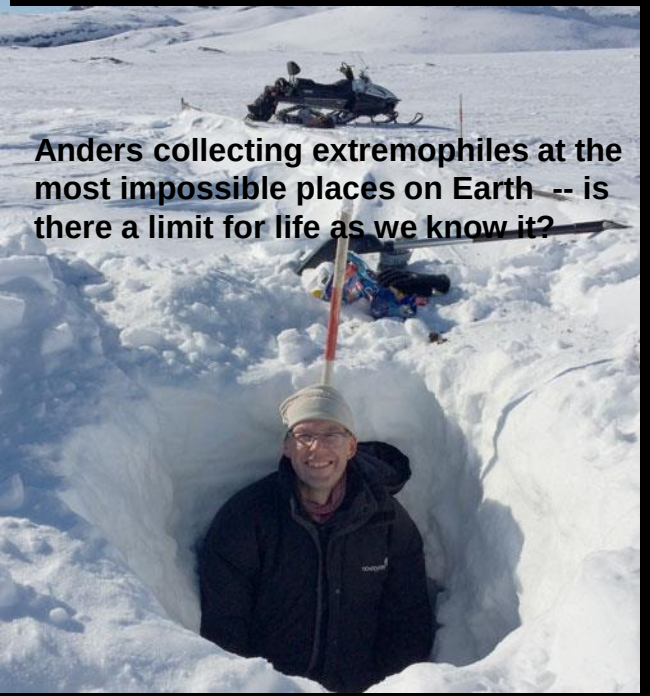
The idea and background of CELS

Combining astronomy, physics, chemistry and biology in the search for life beyond Earth.

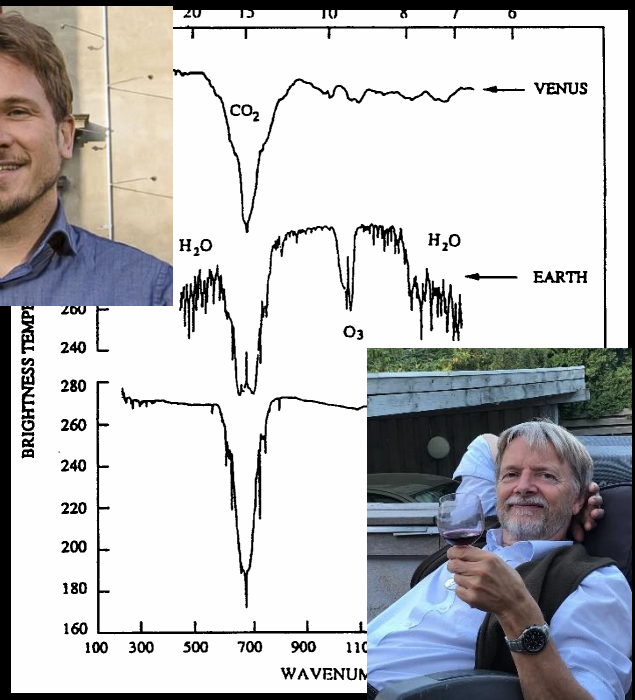


Henrik measuring the spectra of tiny amounts of atmospheric gasses

Centre for ExoLife Sciences (www.cels.nbi.ku.dk) --- how does it work?



Anders collecting extremophiles at the most impossible places on Earth -- is there a limit for life as we know it?



CELS -- the micro biology.

Micro-organisms are present (almost) everywhere on Earth, from Antarctica to Sahara, from 120 deg hot thermal vents to free-floating ice-clouds, from experiments outside the space station to the central parts of nuclear reactors.

Can they also originate there, and can they evolve there?
Does it mean that life can exist everywhere, and if so, why has it never established itself on Mars and Venus, and seemingly only once on Earth?

Is life really "a miracle"? and what does "life" actually mean?

Anders collecting bacteria under extreme conditions. Is there a limit?

"next step:"

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CELS -- the Mars chamber.

Morten and his students build the JMMC Mars chamber during several past years. One can change the atmospheric chemistry, radiation, temperature and pressure inside the chamber, to simulate conditions on Mars and on exoplanets.

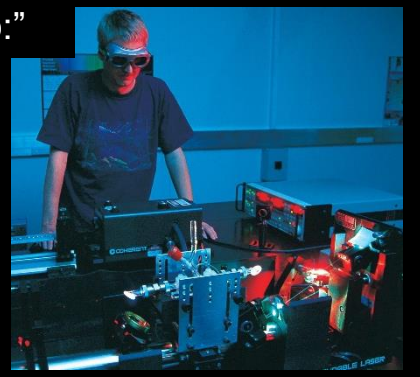
We expose the terrestrial extremophiles to even more harsh conditions. Is there a limit? How does the metabolism change under changing conditions, and after potential genetic engineering?

Can known bacteria from Earth be manipulated to live on Mars?

Can they help the colonisation?

Could something similar be habitating known exoplanets?

"next step:"



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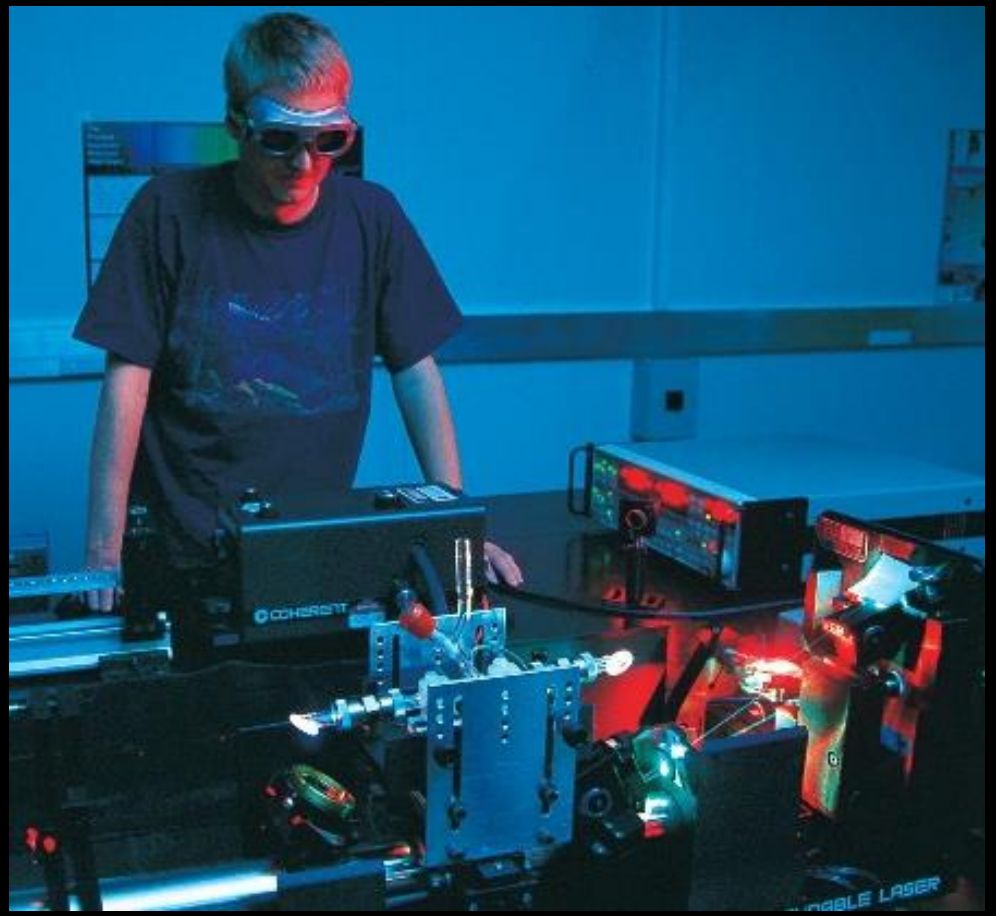


CELS -- the chemical spectra.

Henrik and his students has build sensitive spectroscopy equipment during several past years, including ring-down-cavity laser and infrared spectrographs.

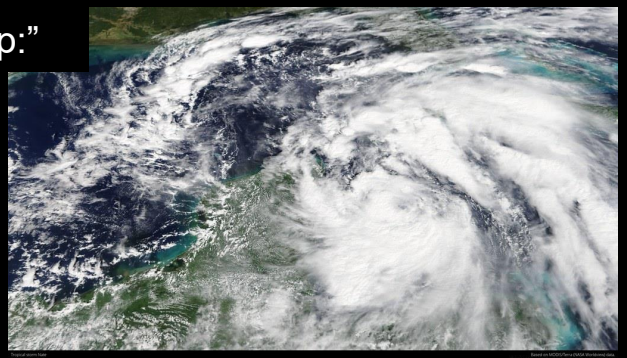
We will measure the spectra of gasses extracted from the bacterial experiments in the Mars chamber.

What does the spectrum of the bacterial exhaust gasses look like?

Can we identify what it is?

How will it affect the atmospheric chemistry?

“next step:”



Welcome to our Centre for ExoLife Sciences, https://cels.nbi.ku.dk/english/ start-up meeting 2021.

CELS -- the atmospheric effect, clouds.

Jan and his students are simulating the violent transitions that take place when clouds and strong precipitation appears in the atmosphere – it is crucial not only for Earth's atmosphere, but for our ability to interpret exoplanetary spectra too

Can bacteria serve as cloud nucleation seeds?

What is the difference between clouds nucleated on sand grains and on bacteria ?

How will it affect the atmospheric chemistry?

"next step:"

Welcome to our Centre for ExoLife Sciences, https://cels.nbi.ku.dk/english/ start-up meeting 2021.

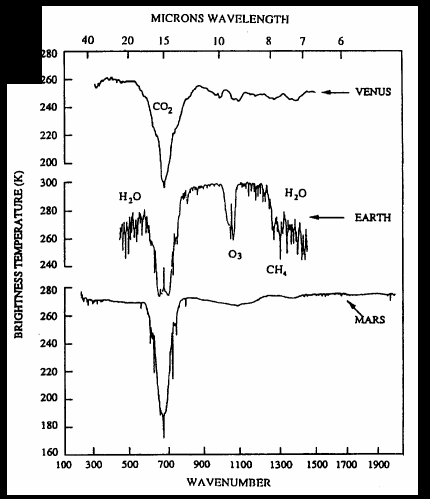
CELS -- the atmosphere of exoplanets.

The information about bacteria and their exhaust gasses that we obtained in the previous steps, will be included into our modelling of the chemical and physical structure of exoplanetary atmospheres, in order to compute their emerging spectra.

How will “our” bacteria affect the atmospheric structure and spectrum?

Can we identify “biological clouds” as a biomarker in spectra of exoplanets?

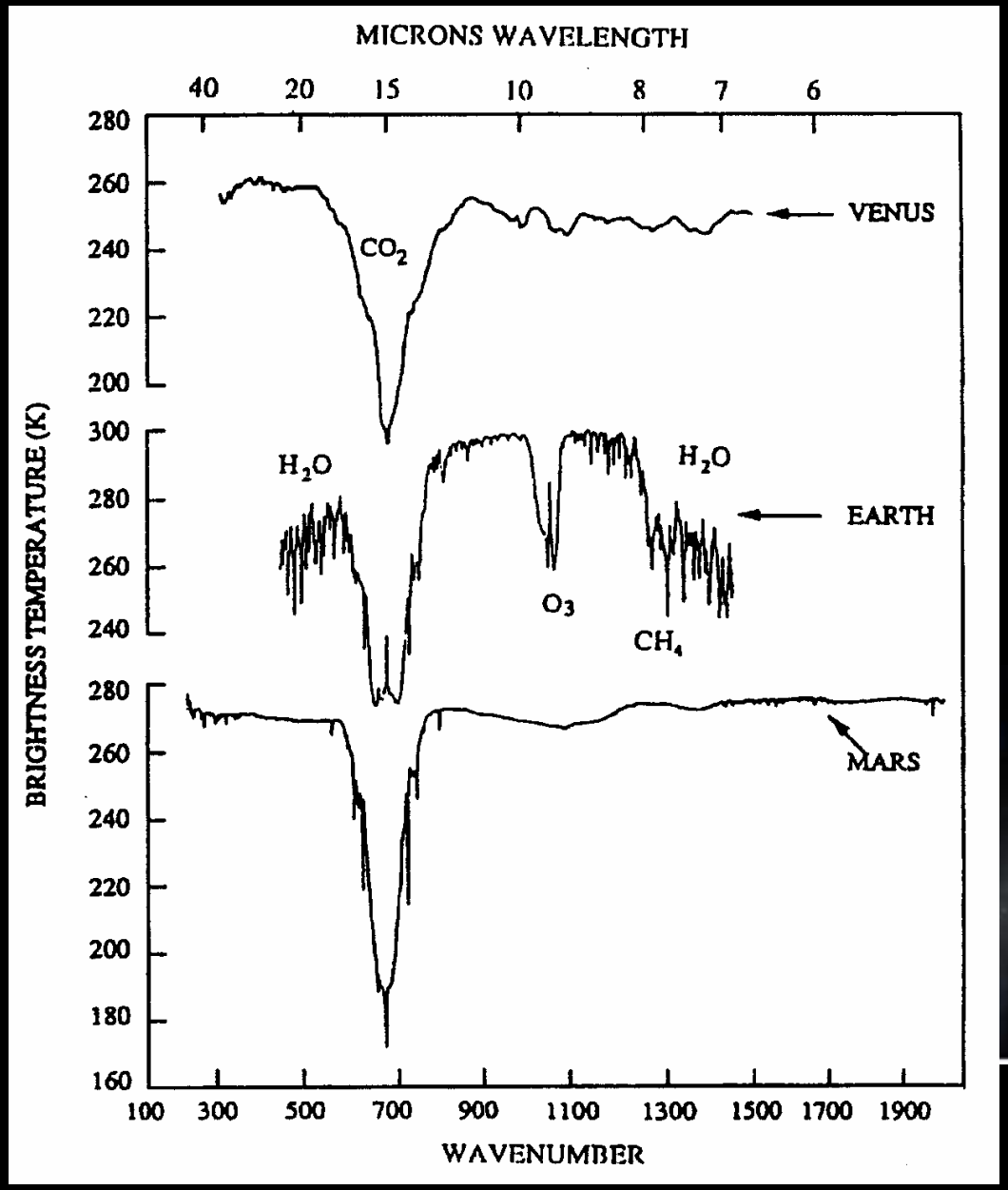
“next step:
Is anybody
out there?”



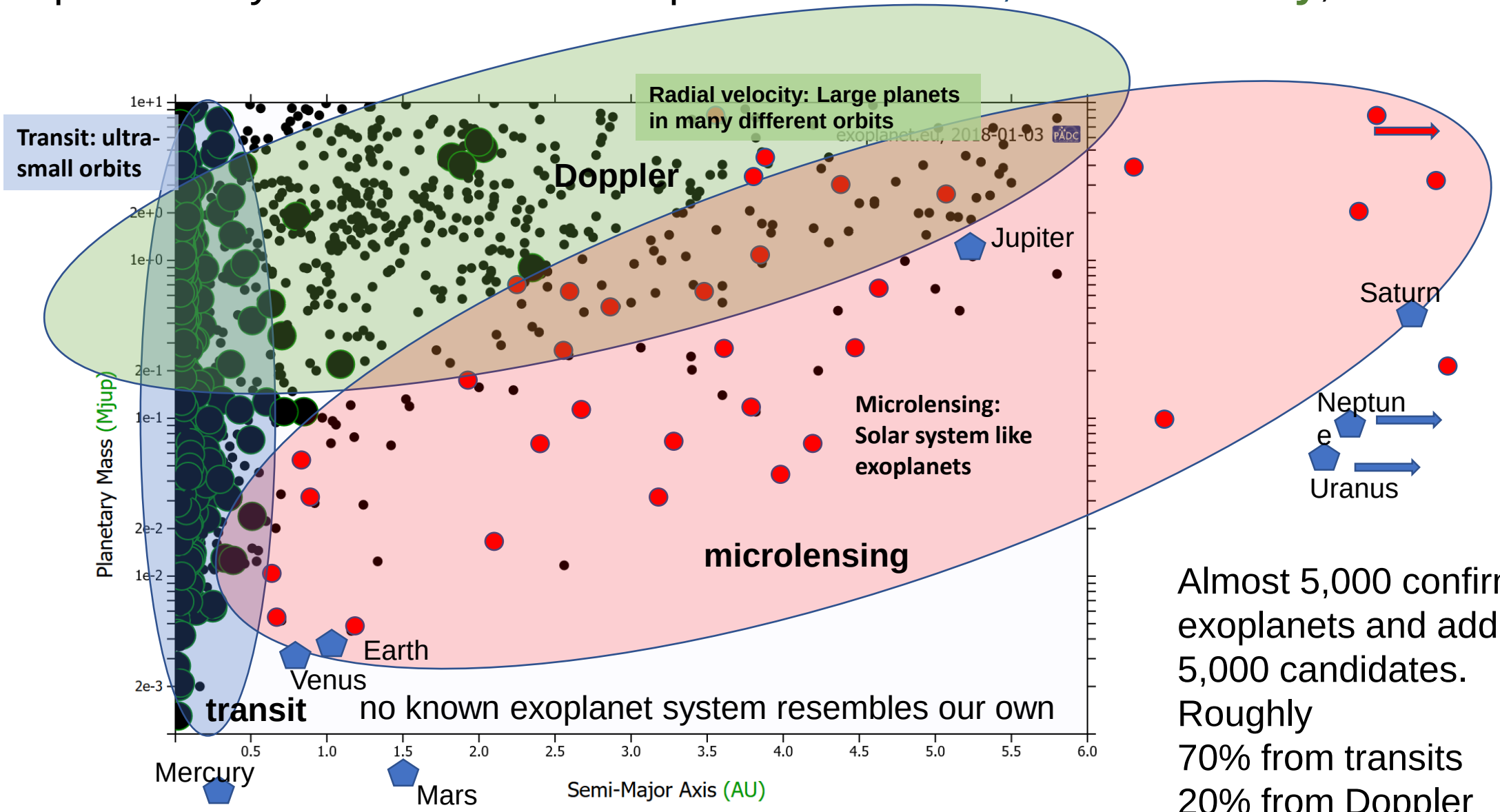
CELS -- the atmosphere of exoplanets.

If lifeforms affect the atmospheric composition and structure, as they do on Earth's atmosphere, we should be able to see it on many light years distance. If there is no such observable effect, there is no life on the planet -- probably.

How is life related to decreasing the entropy ?



3 complementary methods to find exoplanets -- transit, radial velocity, microlensing



Almost 5,000 confirmed exoplanets and additional 5,000 candidates.
Roughly
70% from transits
20% from Doppler
10% from other

75 years of exoplanet research (since Struve 1952) –
and still just scratching the surface of the fundamental questions

Transit, radial-velocity, and microlensing observations combined, points at 2.5 planets per star in our Galaxy – most of them are Earth-sized, very few are Jupiter-Saturn sized, and no known exoplanetary system resembles our own solar system – is that why we are here?

1/10 of all stars have a planet in the habitable zone, so:
There are 100 billion stars in our Galaxy =>
There are 10 billion exoplanets in the habitable zone

Nature generously made 10 billion Earth-sized planets in our Galaxy in the habitable zone – did it seed only one of them with life?

There are 15,000 stars within 100 light years from us
⇒There are more than 1,500 (Earth-sized) planets in the habitable zone of stars within 100 light years away --- where are all the inhabitants?

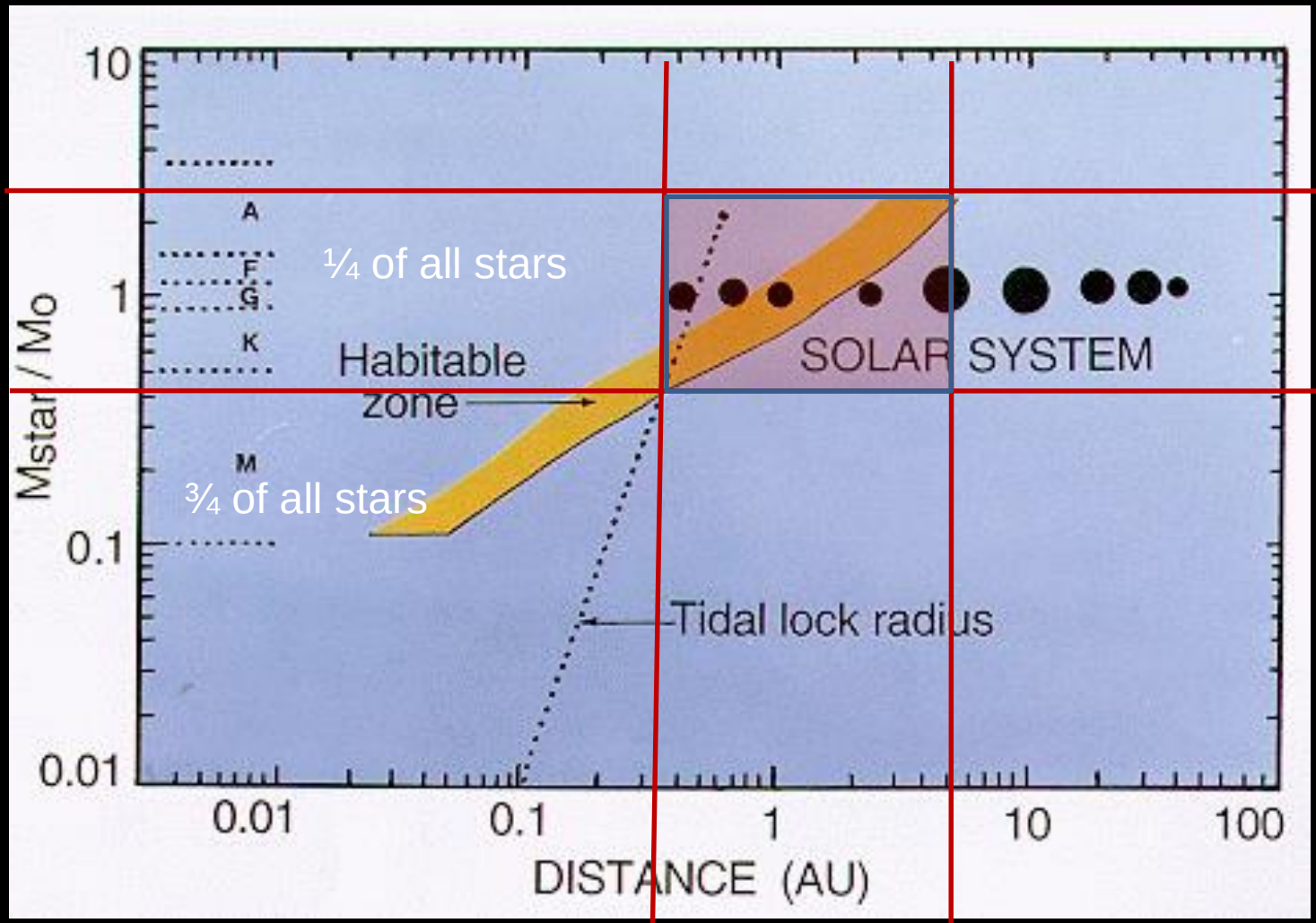
Are exoplanets in the habitable zone habitable?
Are habitable exoplanets habitated?

75% of exoplanets in the habitable zone will be tidally locked

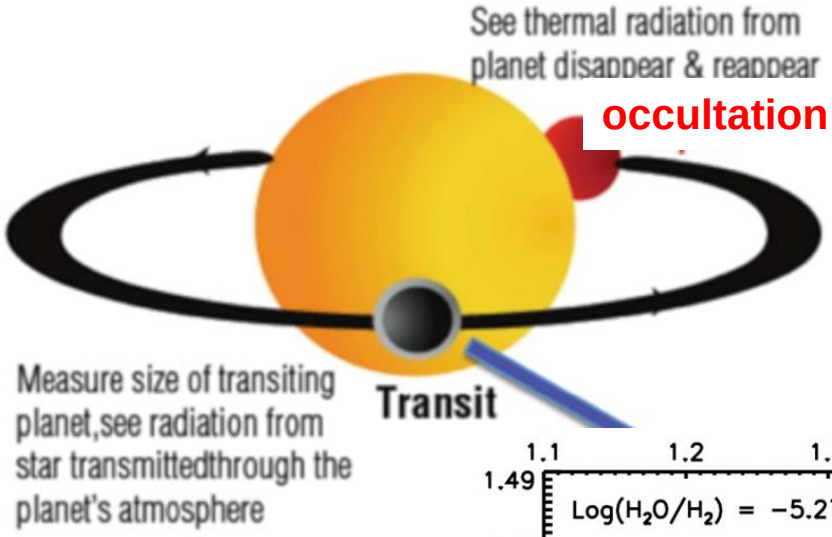
In our solar system only Venus has been continously in the habitable zone

GFK stars are ¼ of all stars

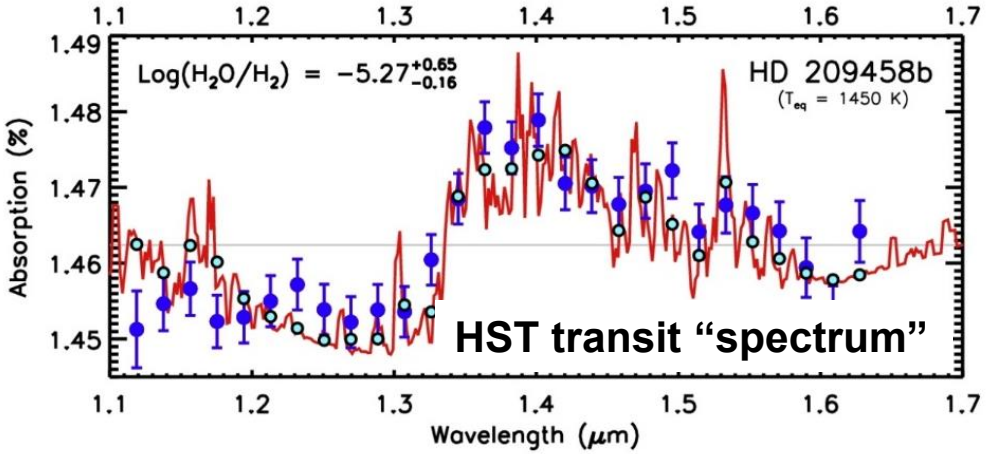
Can M (and A) stars, 3/4 of all stars, have habitable planets?

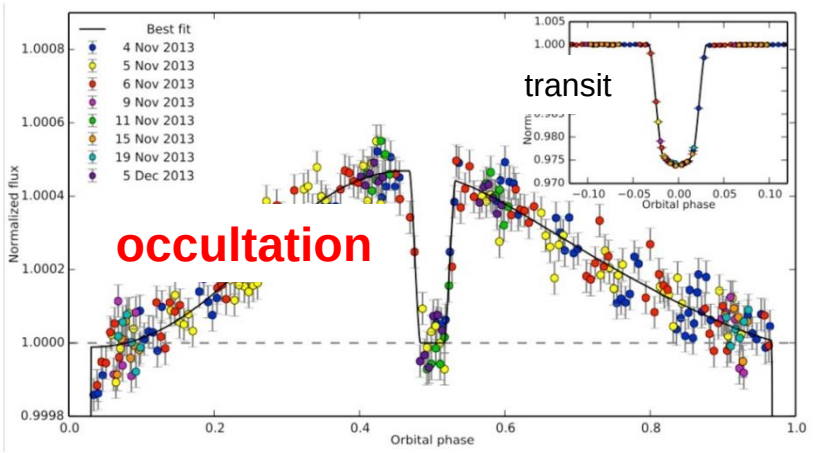


Without even seeing the planet, we can say something about its weather.

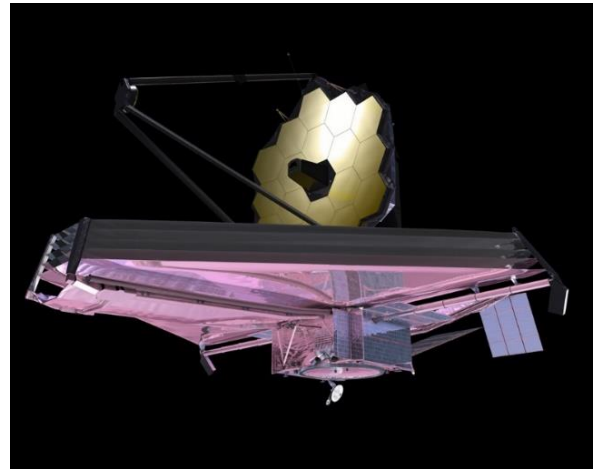


High quality transit observations will reveal components of the atmosphere (e.g. water) and day-night side temperature differences





The James Web telescope will give us transit "spectra" further into the infrared than HST did.



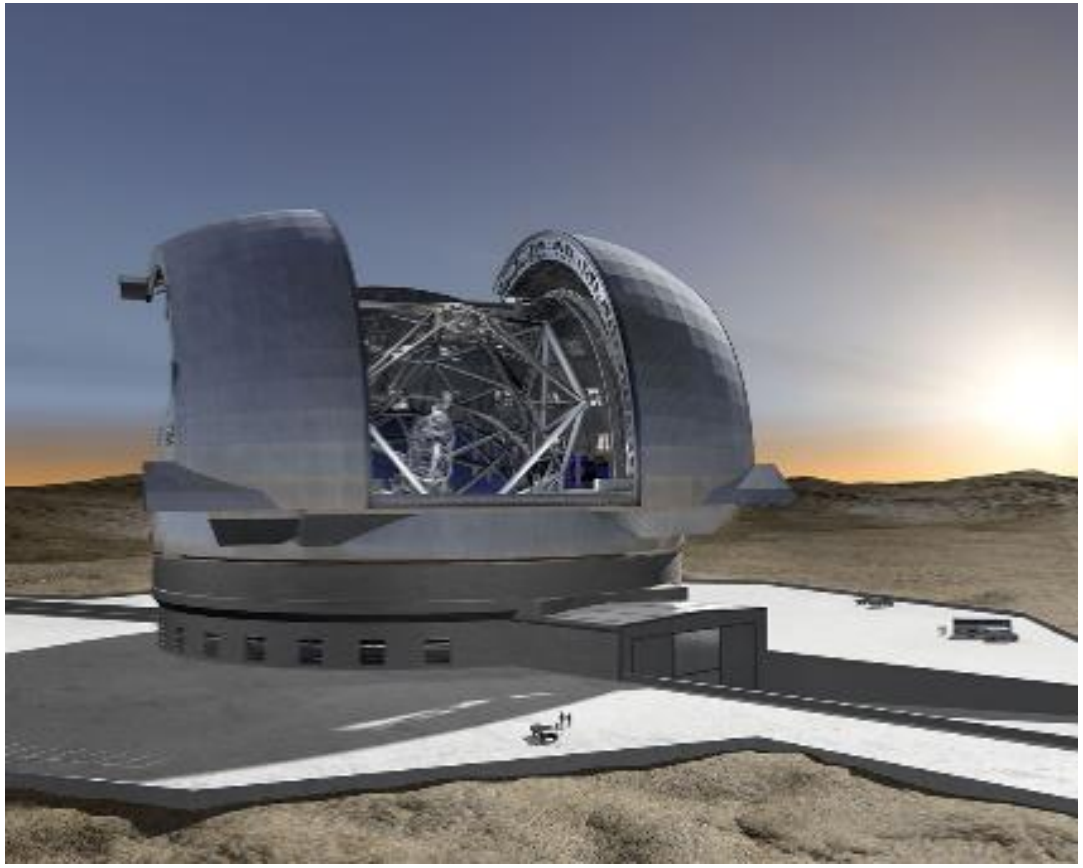
$$H = \frac{k_B T}{\mu_m g}$$

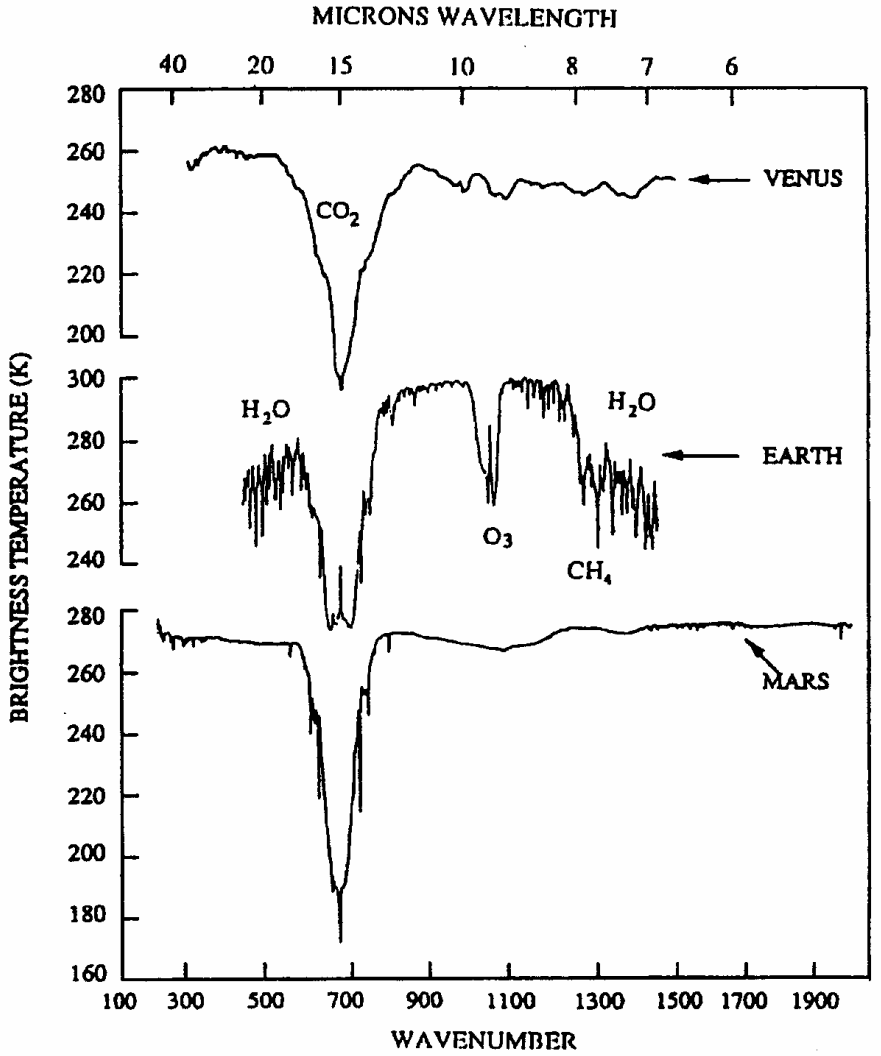
The chances of having a result that is clear […] are low, but….

where k_B is Boltzman's constant, μ_m is the mean molecular mass of the atmospheric gas (assumed to be constant), R is the molar gas constant, and g is the planetary surface gravitational acceleration. The scale height of the Earth's atmosphere is ~8.5 km and Jupiter's atmosphere is ~27 km.

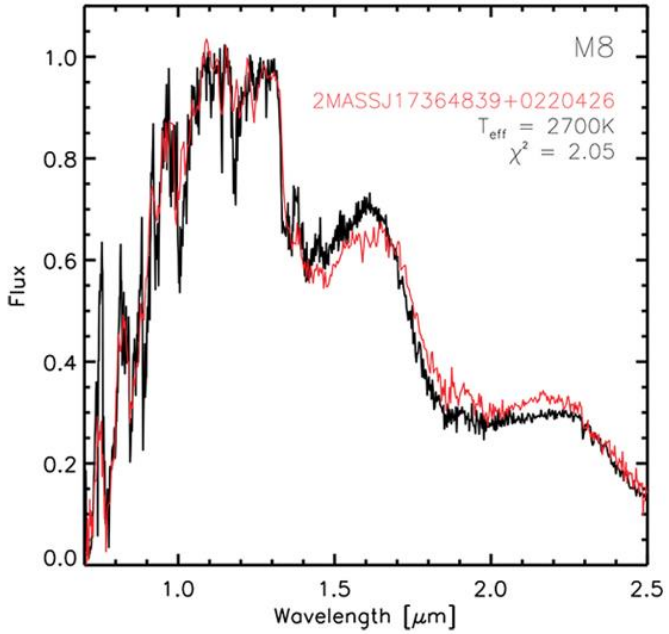
Are habitable exoplanets habitabitated?

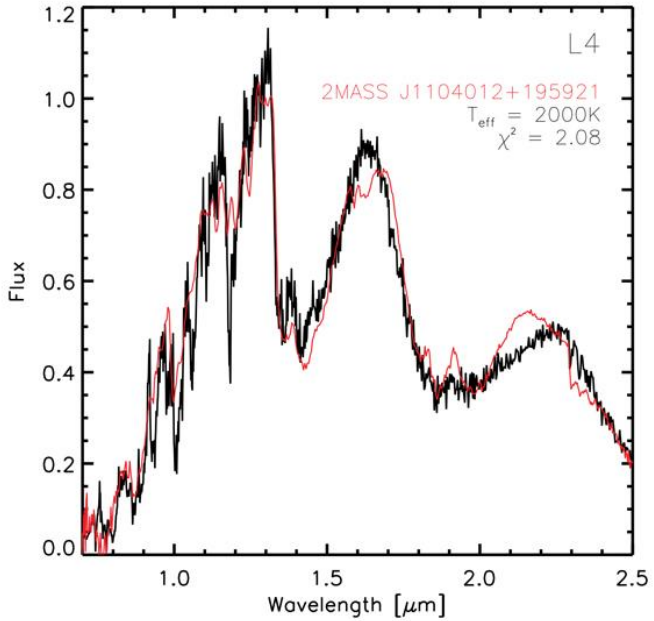
The ELT will during the mid-2020ies give us the first direct spectra of Earth-analogues orbiting Sun-like stars. Models will allow interpreting potential bio-signatures in their spectra.



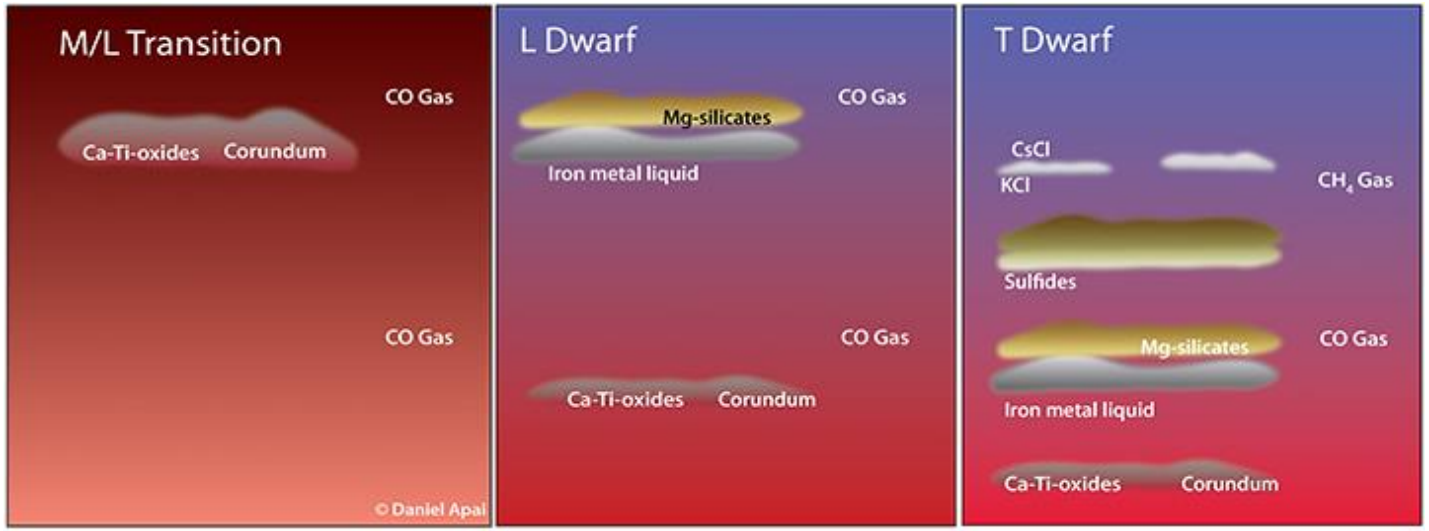


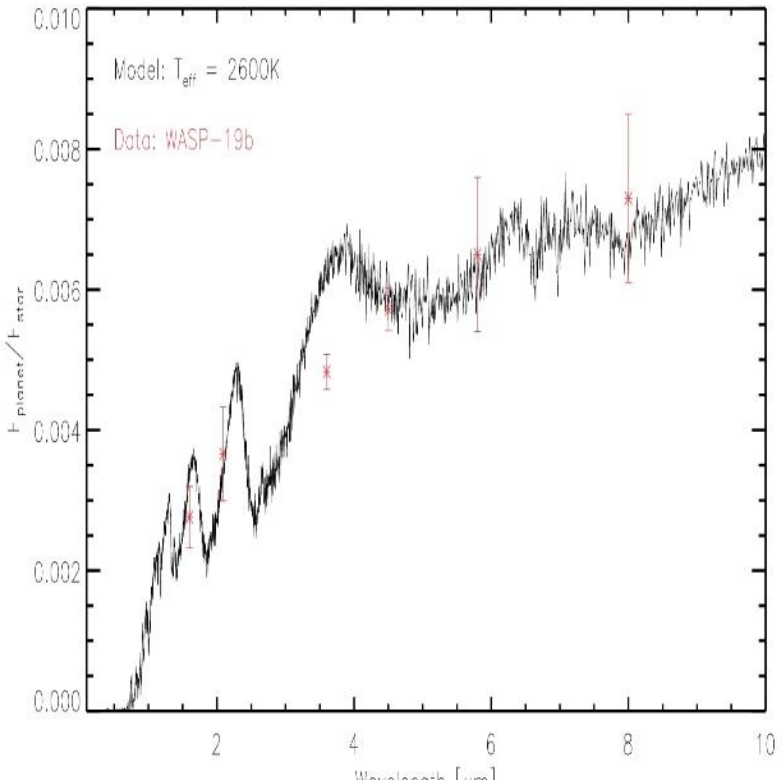
“If we could one day say that a temperate exoplanet is not in chemical equilibrium, it would be a great step towards the discovery of the first extraterrestrial life.”





Self-consistent DRIFT-MARCS fits to cool dwarfs, brown dwarfs, and hot exoplanets – computed (black) and transit (red) spectra from Juncher et al. A&A 2017





Clouds on exoplanets governs large part of the energy balance --- and they can be very different from clouds on Earth.

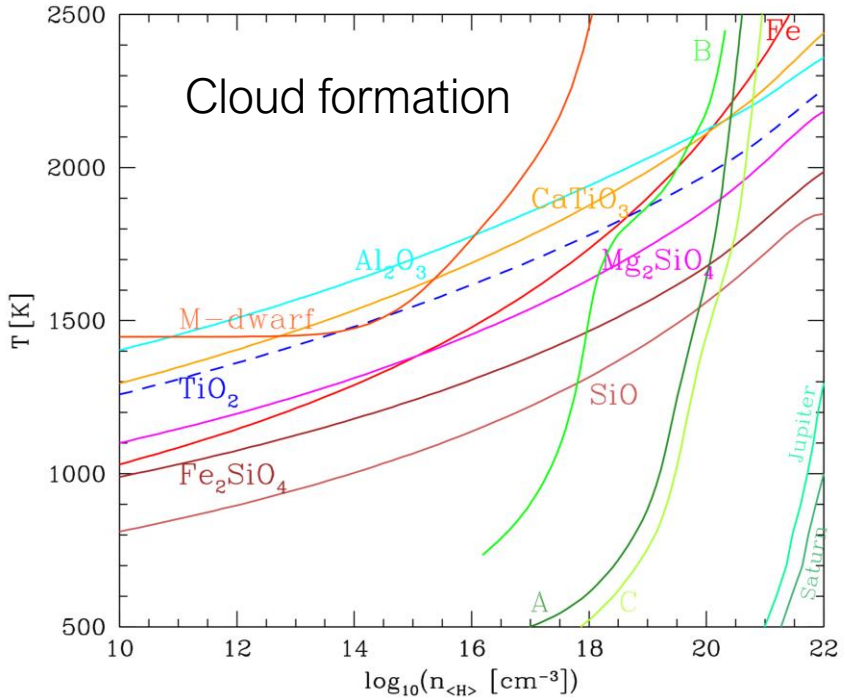
Earth:

- collections of droplets of liquid water or ice crystals
- form when humid air cools down enough for the
- water vapor to condensate

Clouds do usually not form as saturated vapour, but rather as nucleation followed by condensation onto the nuclei.
Can microorganisms form nucleation seeds?

Ultra cool dwarfs:

- very different conditions!
- composed of minerals such as rutile (TiO_2), olivine ($(Mg,Fe)_2SiO_4$) and corundrum (Al_2O_3)

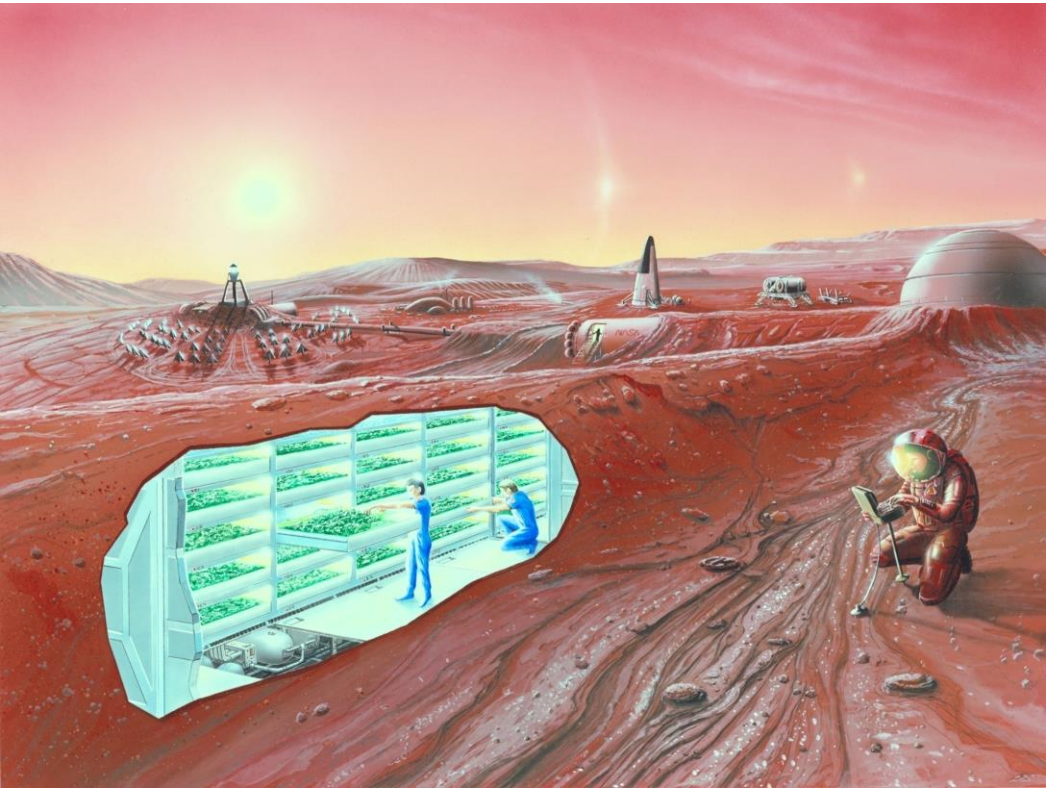


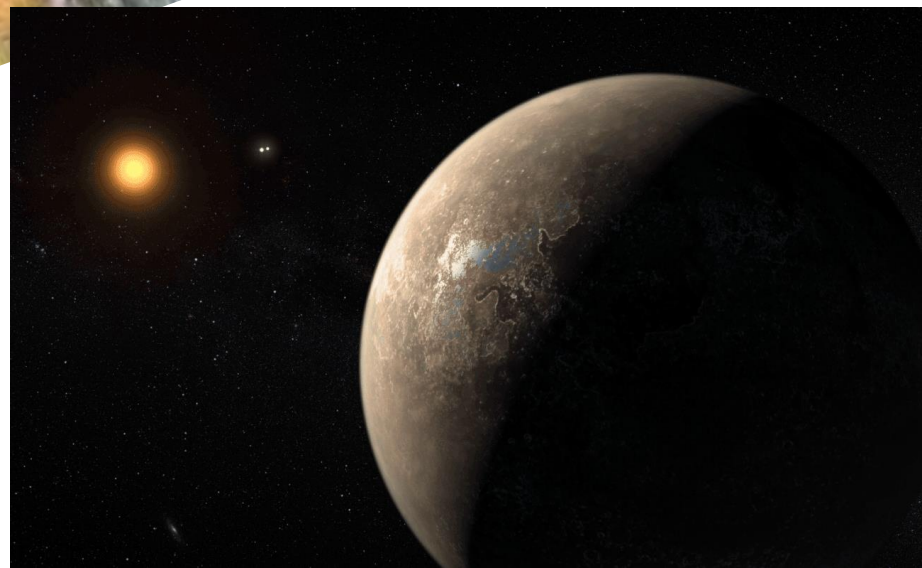
How do we get from the present and into the future?

Within our lifetime humanity will colonize Mars and send the first unmanned satellites to the nearest habitable or habitated exoplanets, --- and..

…we are part of it !

"…It will be a very rich environment for the PhD students who will build a multi expertise for their future…."





…thank you