

# Is there an Unhabitable Zone

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*Jérémy Leconte*



# The concept of «Habitable Zone»

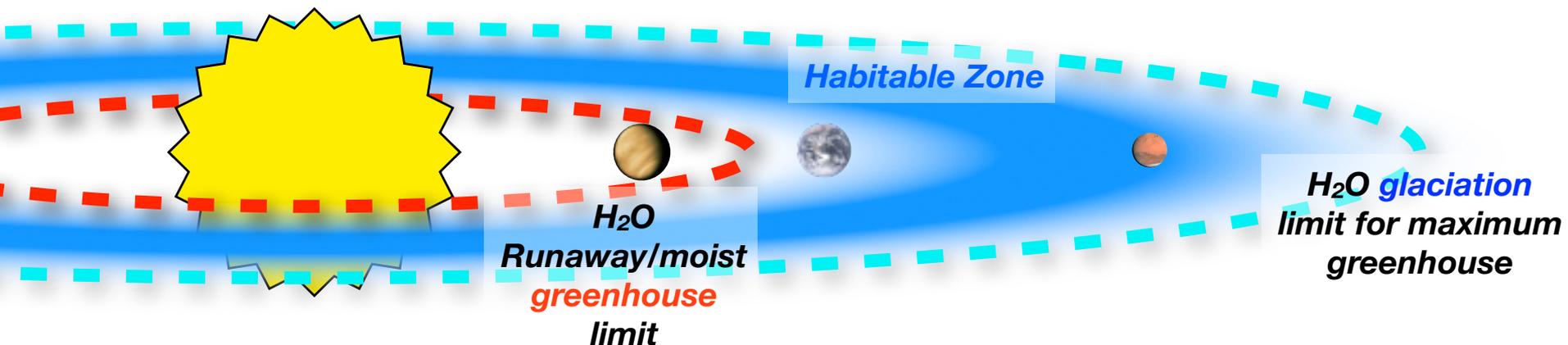
★ A working definition of the *Traditional* HZ:

«The region around a star where a  $N_2/CO_2/H_2O$  atmosphere can enable abundant long-lived liquid surface water»

★ not too arbitrary thanks to the carbonate-silicate cycle

★ Very misleading name!!!      **The non-non habitable zone**

★ A good place to start hunting (see talk by F. Selsis), but be careful not to get too focused



# *We must keep an open mind*

## A NECRO-BIOLOGICAL EXPLANATION FOR THE FERMI PARADOX

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### ABSTRACT

As we learn more about the frequency and size distribution of exoplanets, we are discovering that terrestrial planets are exceedingly common. The distribution of orbital periods in turn results in many of these planets being the occupants of the Habitable Zone of their host stars. Here we show that a conclusion of prevalent life in the universe presents a serious danger due to the risk of spreading Spontaneous Necro-Animation Psychosis (SNAP), or Zombie-ism. We quantify the extent of the danger posed to Earth through the use of the Zombie Drake Equation and show how this serves as a possible explanation for the Fermi Paradox. We demonstrate how to identify the resulting necro-signatures present in the atmospheres where a zombie apocalypse may have occurred so that the risk may be quantified. We further argue that it is a matter of planetary defense and security that we carefully monitor and catalog potential SNAP-contaminated planets in order to exclude contact with these worlds in a future space-faring era.

We have shown that there is a significantly non-zero probability that in the search for life in the universe we will also encounter large amounts of undeath. Any person who has been exposed to even a relatively benign

# The concept of «Habitable Zone»

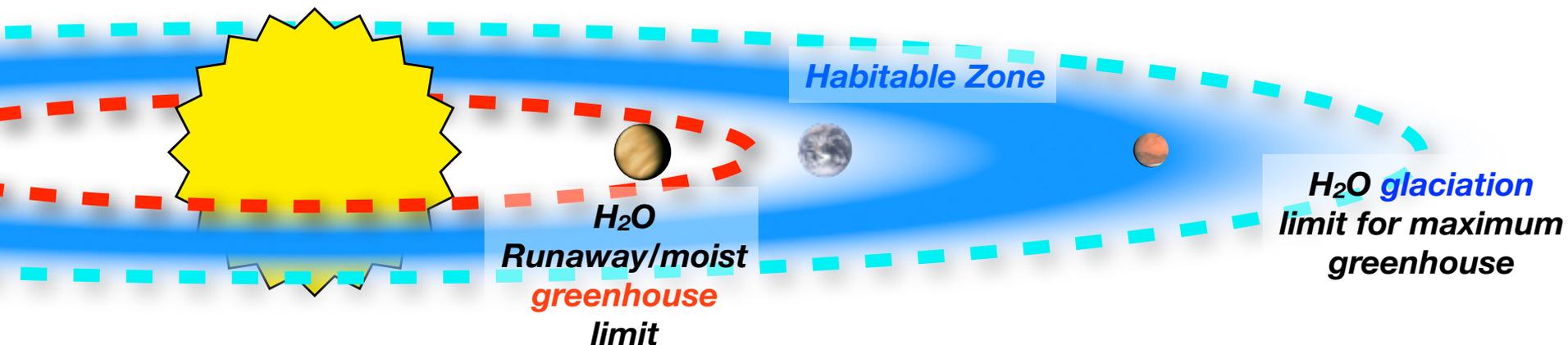
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***Can we extend this region?***

***Yes... if we relax some assumptions***

# Extending the «Habitable Zone»

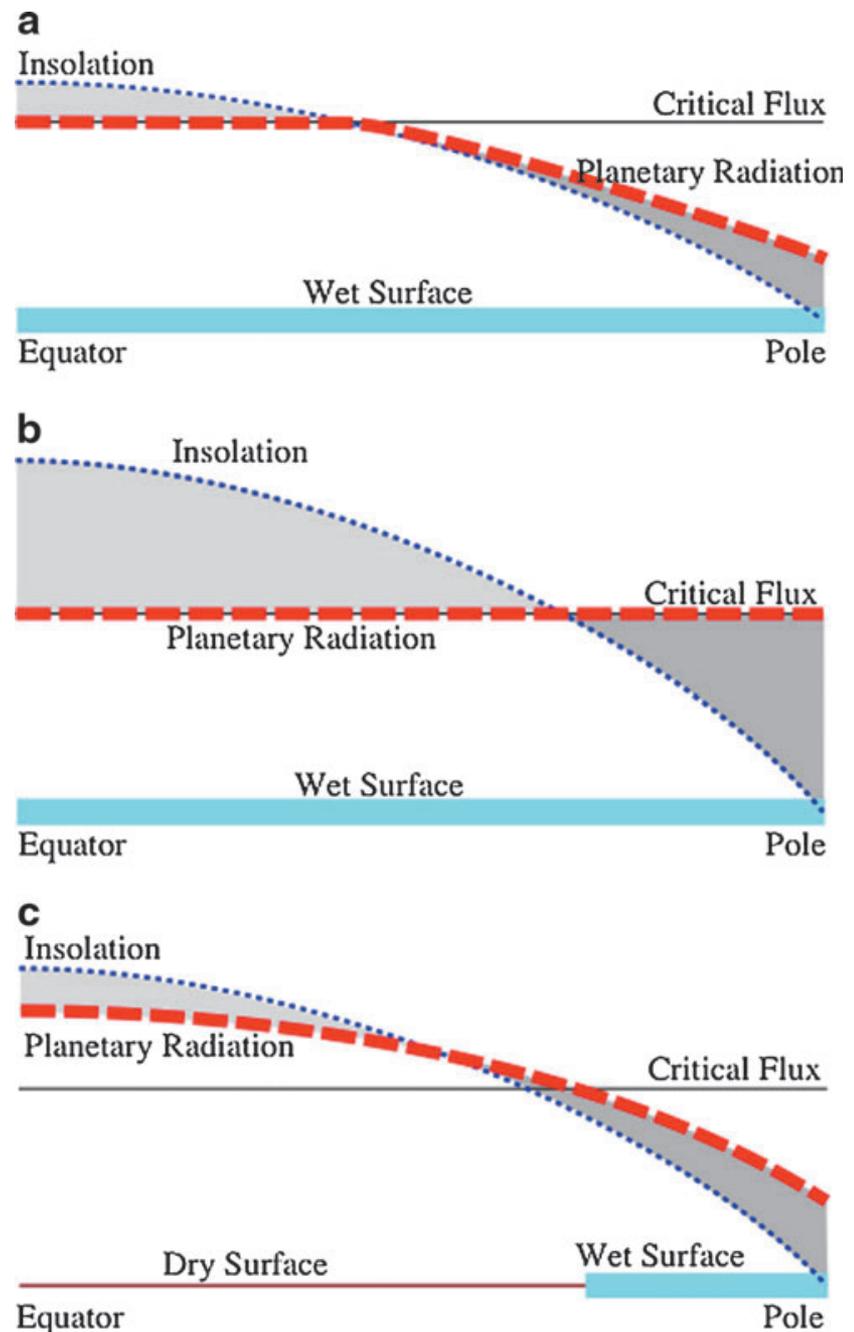
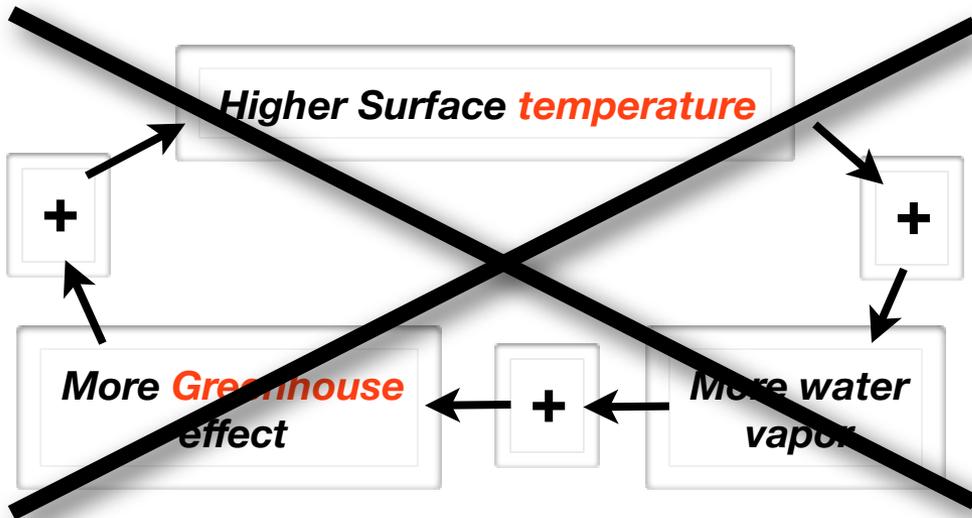
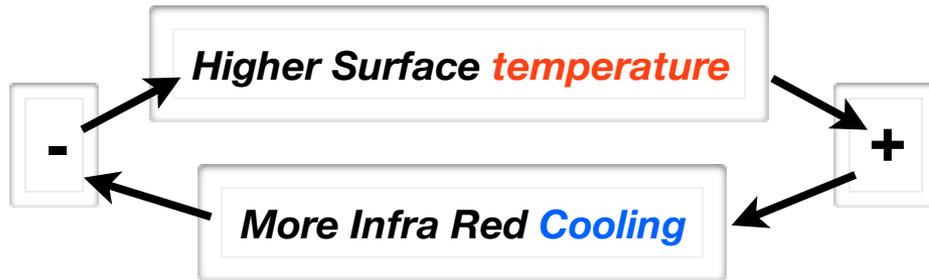
« *The region around a star where a  $N_2/CO_2/H_2O$  atmosphere can enable ~~abundant~~ long-lived liquid surface water* »

## ***The concept of dry/land planets***

*Abe, et al. (Astrobio, 2011)*

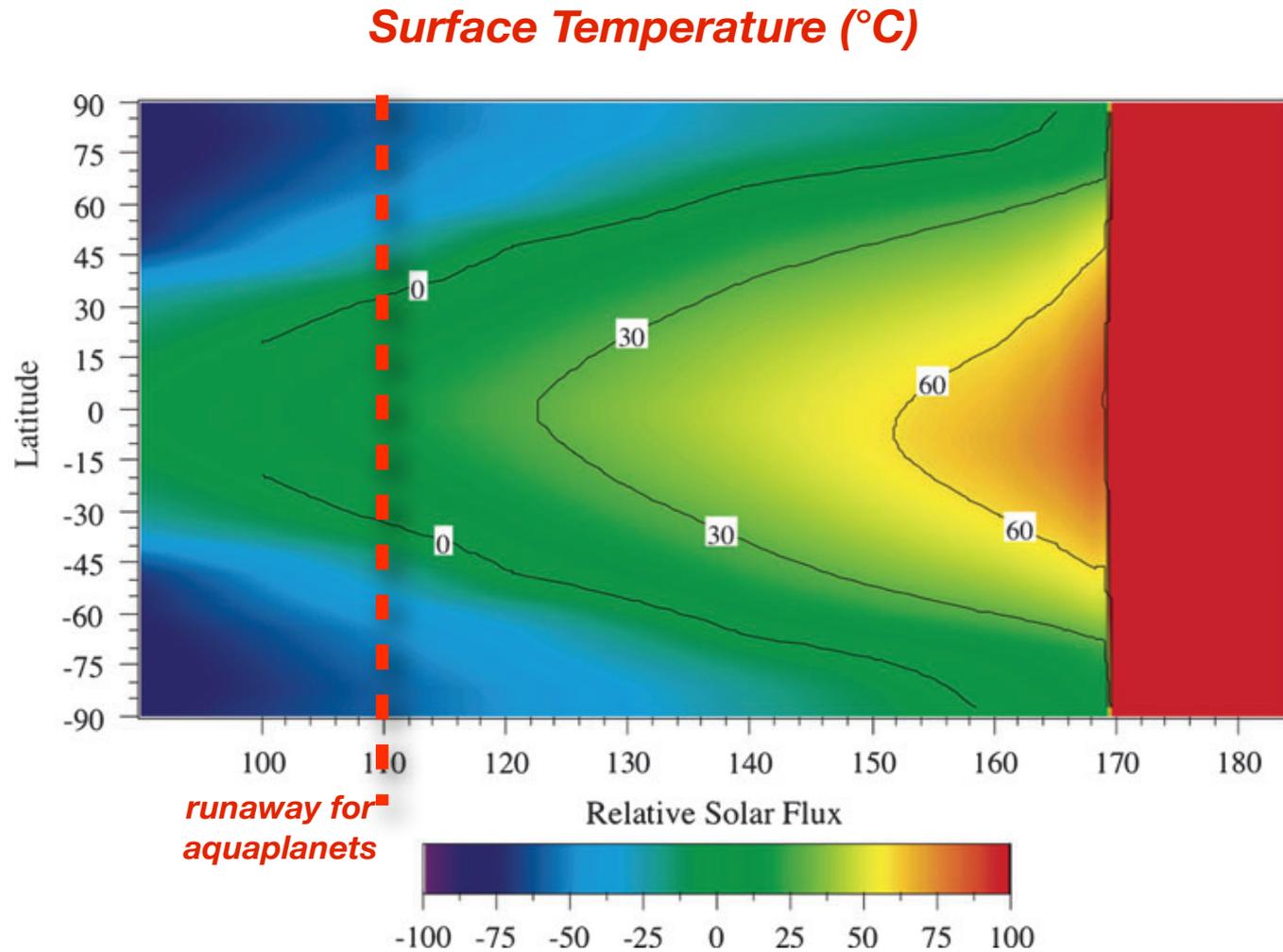


# Can we avoid the runaway greenhouse effect



Abe et al. (Astrobio, 2011)

# Extending the «Habitable Zone»: Dry planets



# Dry planets: what **not** to do!

★ **1D** models are **poorly suited** to address such questions!

★ The «trick» with landplanets is intrinsically linked to the interplay between the **humidity distribution / circulation**

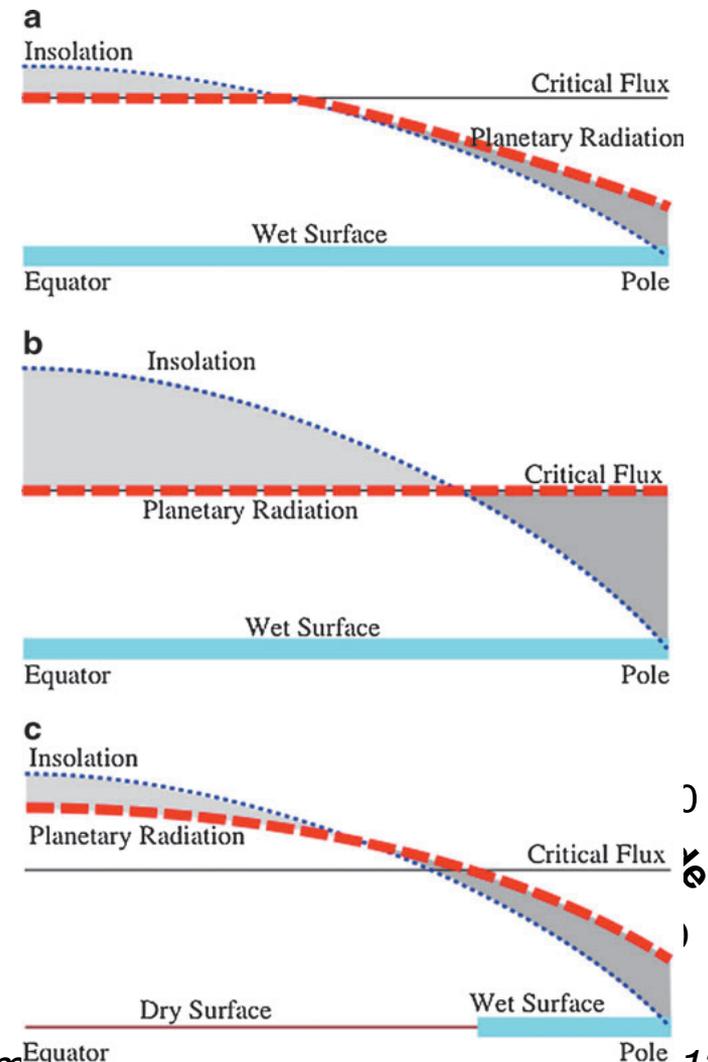
★ An averaged model does **not** give an averaged profile

➔ The average of 3D profiles  $\neq$  a 1D global profile

➔ especially for locked planets

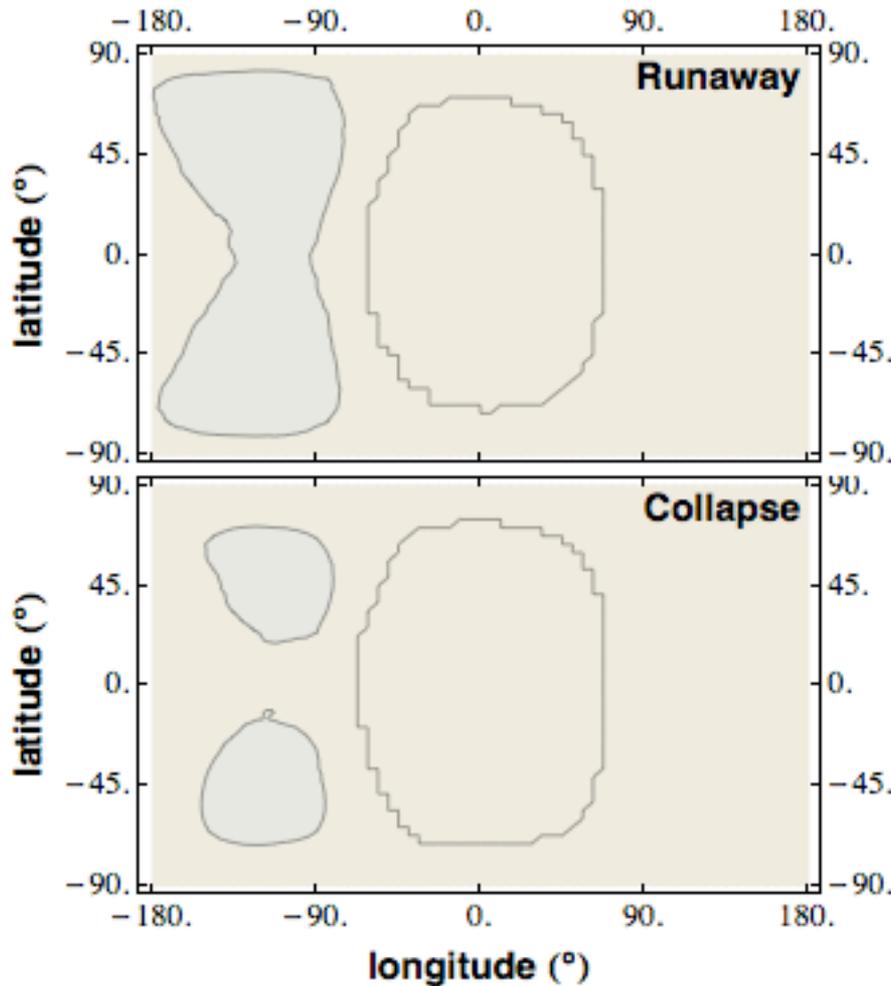
★ Humidity is **not** a parameter

➔ It is an output of the climate

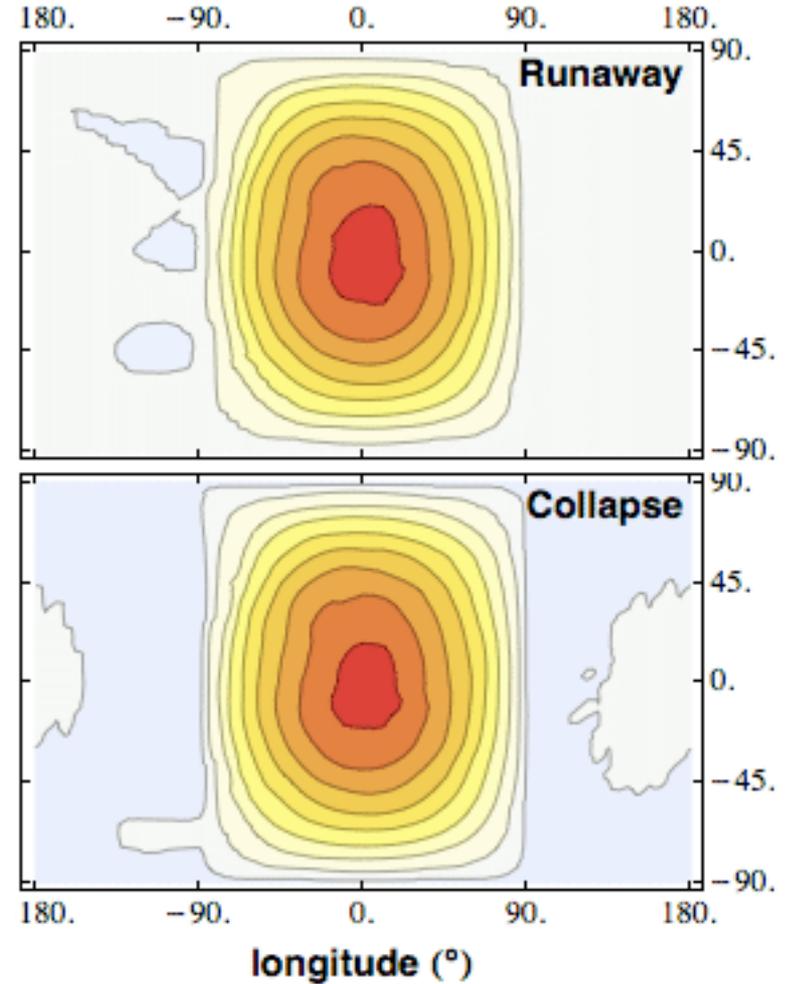


3D models from Lecigne et al. (2013)  
see also Wordsworth (2015)  
Abe et al. (Astroble, 2011)

# Water vapor positive feedback: existence of **climate bistability**

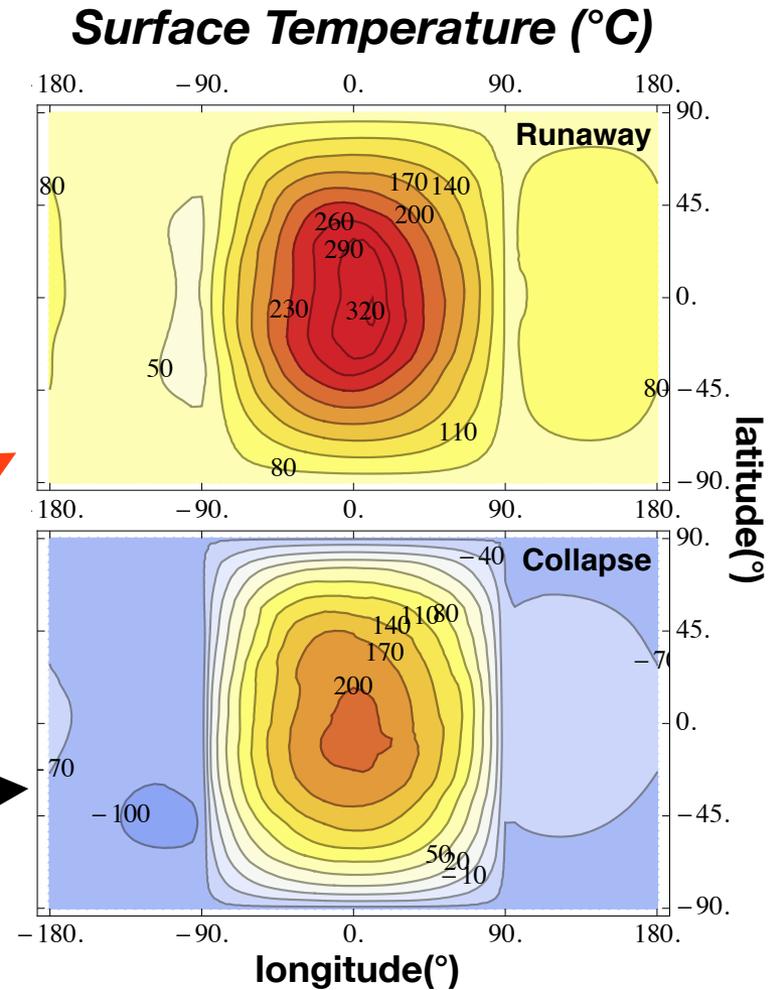
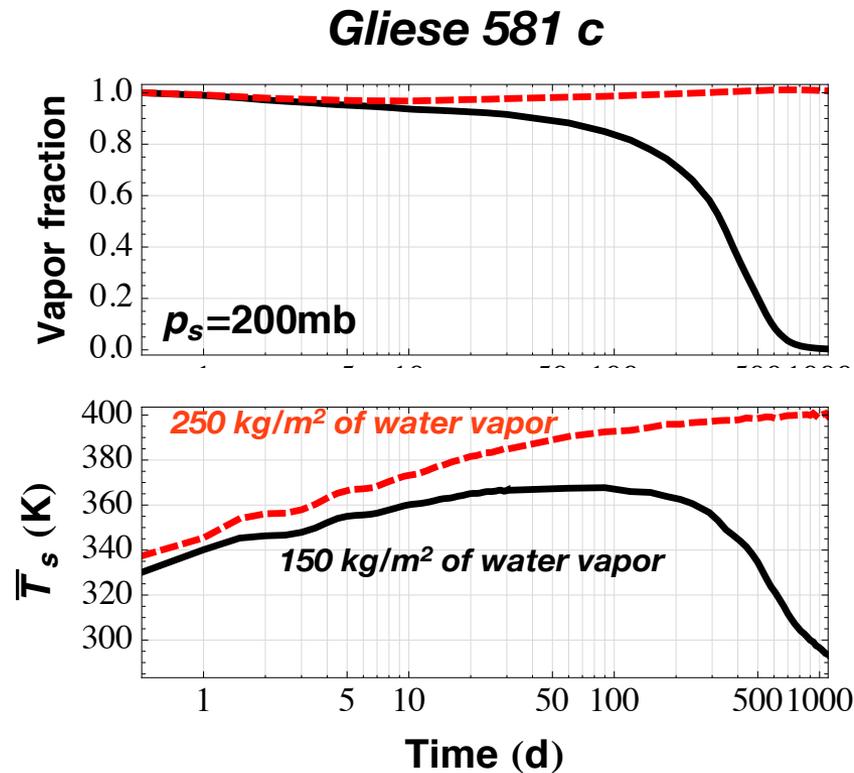


**Surface water (kg/m<sup>2</sup>)**

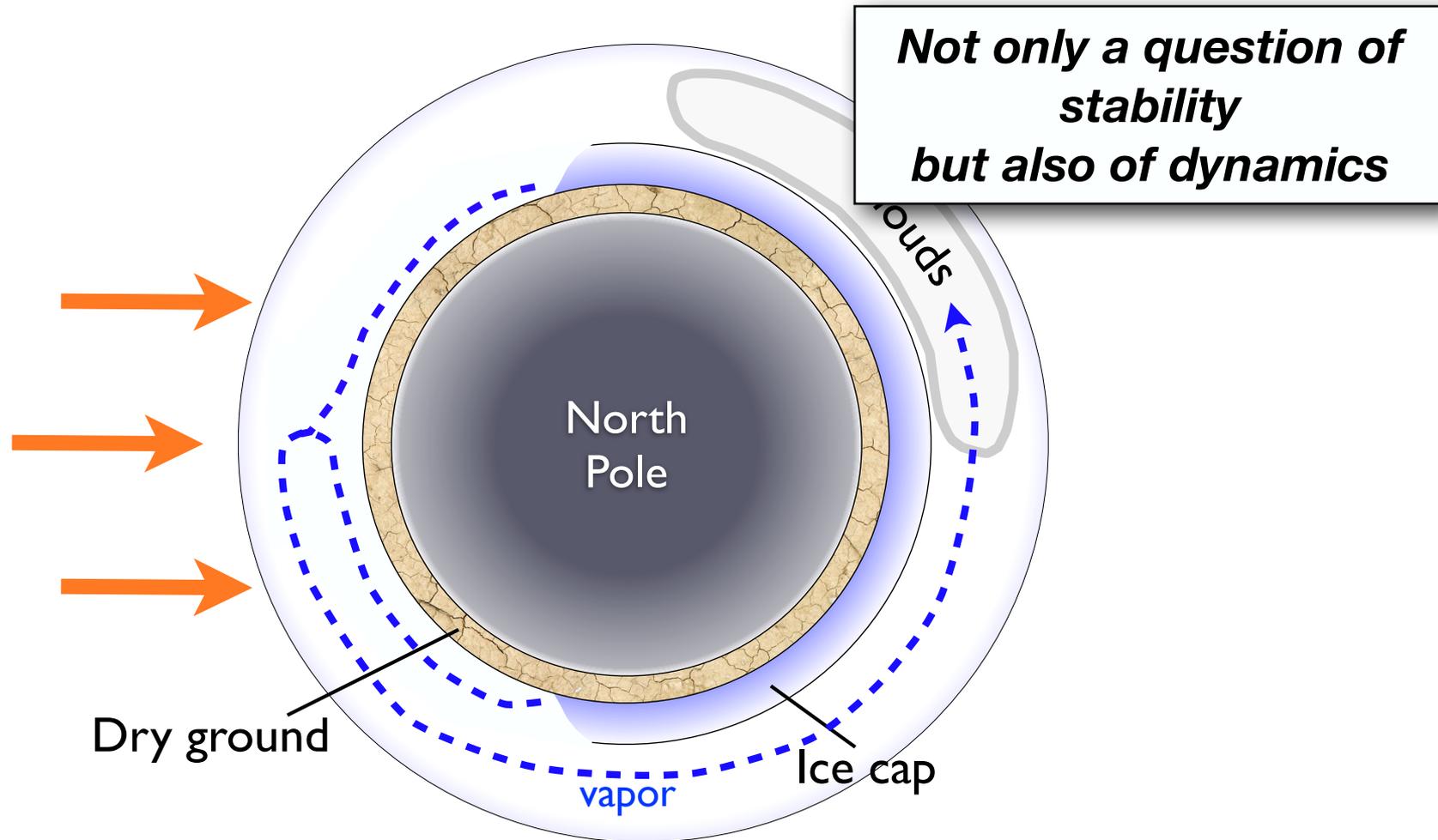


**Surface Temperature (°C)**

# Water vapor positive feedback: existence of **climate bistability**



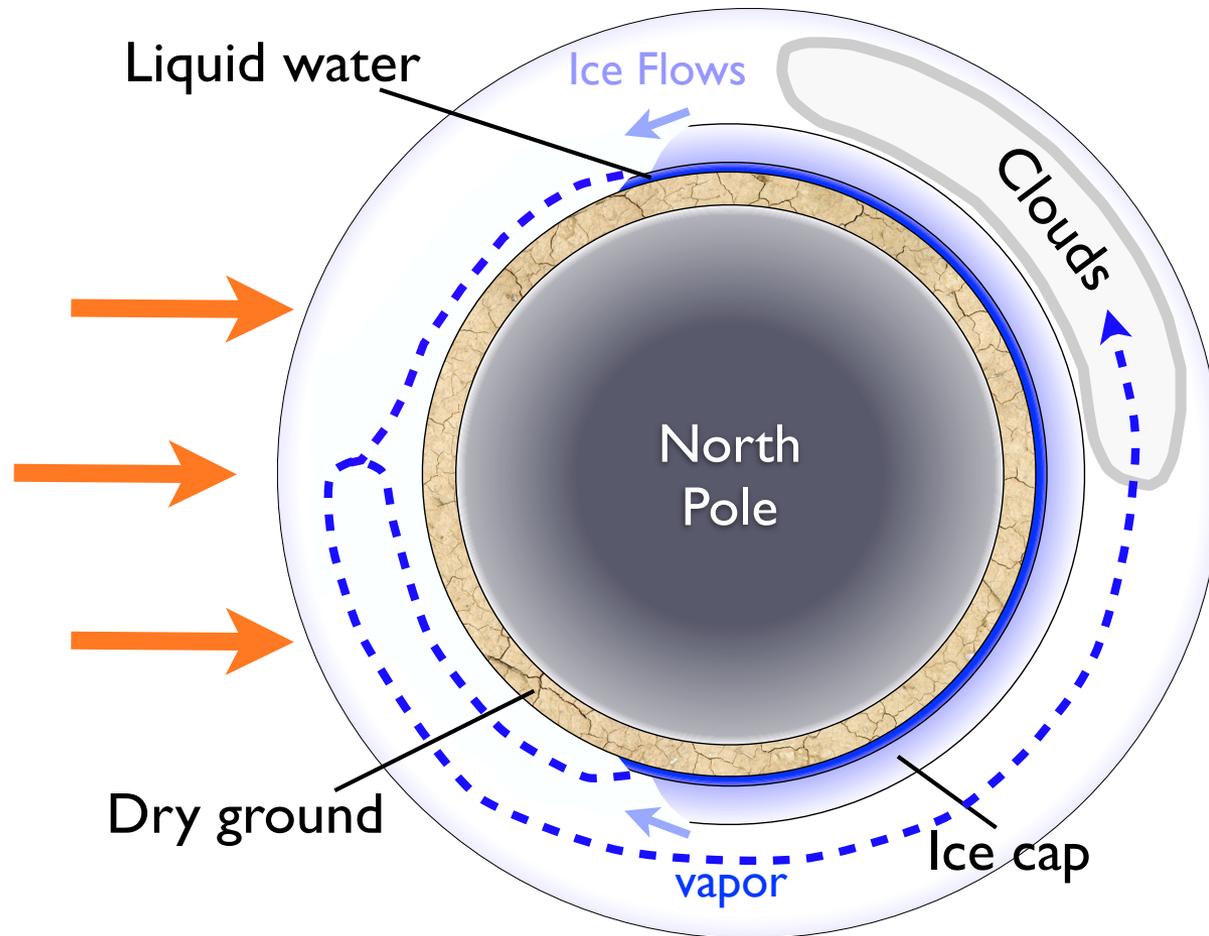
Can these objects bear **liquid** water?



*If no physical mechanisms to remove ice from cold traps*

*=> dry eyeball planet*

# Can these objects bear **liquid** water?

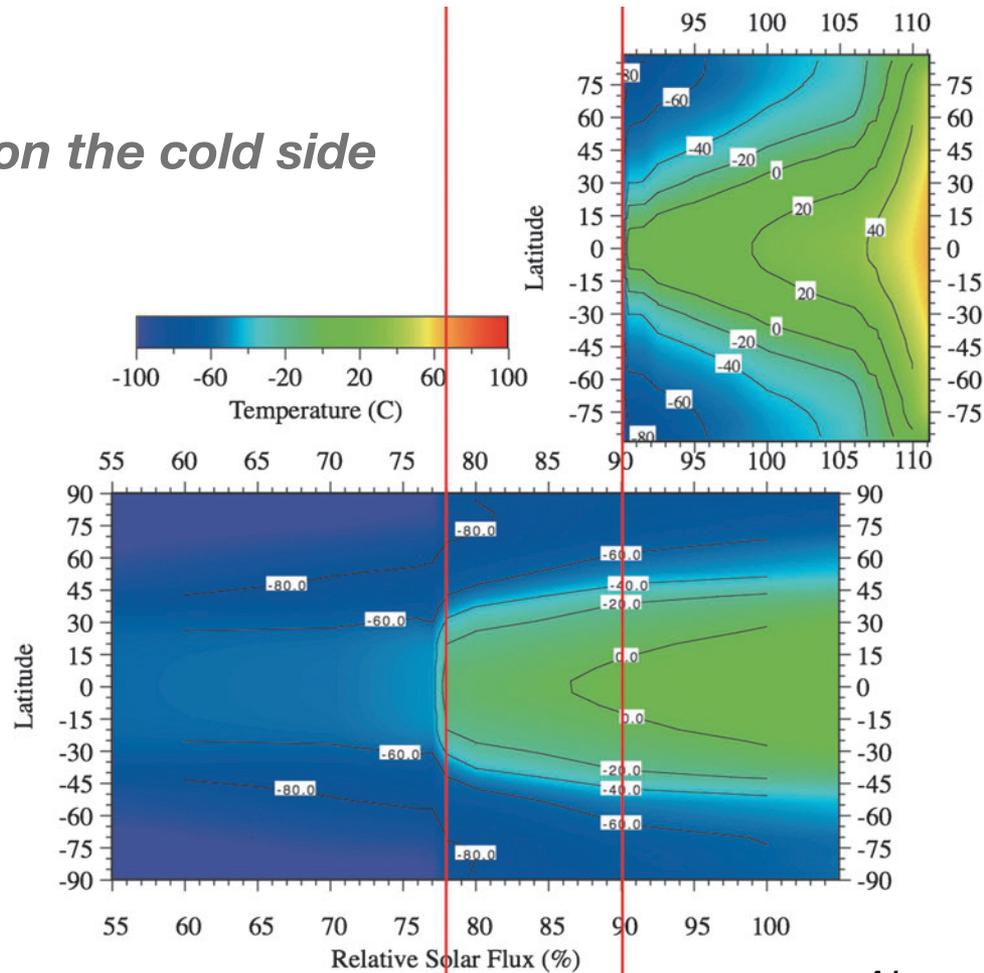


*Like on Earth, if a thick ice cap is present (a few km),  
Ice flows and subsurface water could exist.*

# Extending the «Habitable Zone»: Dry planets

«The region around a star where climate constraints enable ~~abundant~~ long-lived liquid surface water»

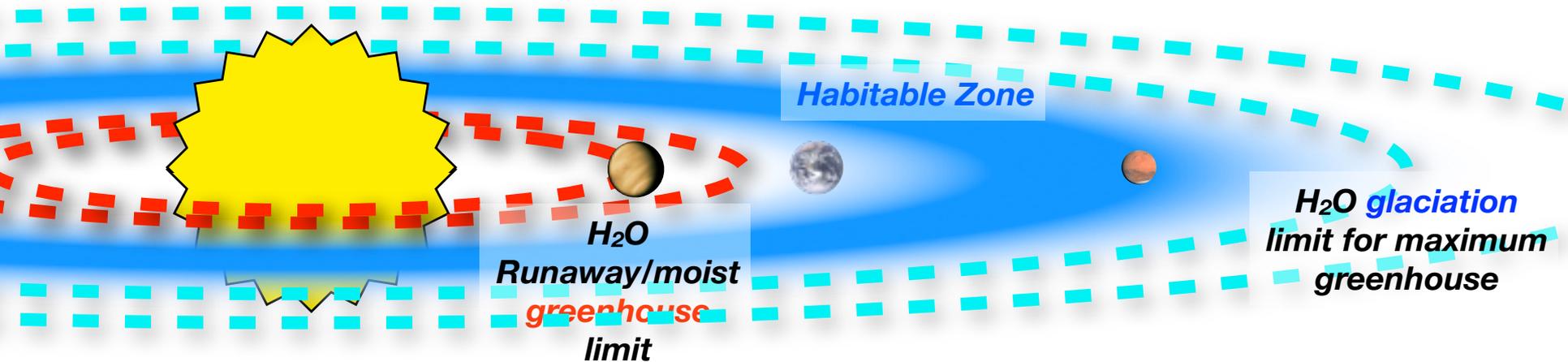
*works also on the cold side*



*Abe, et al. (Astrobio, 2011)*

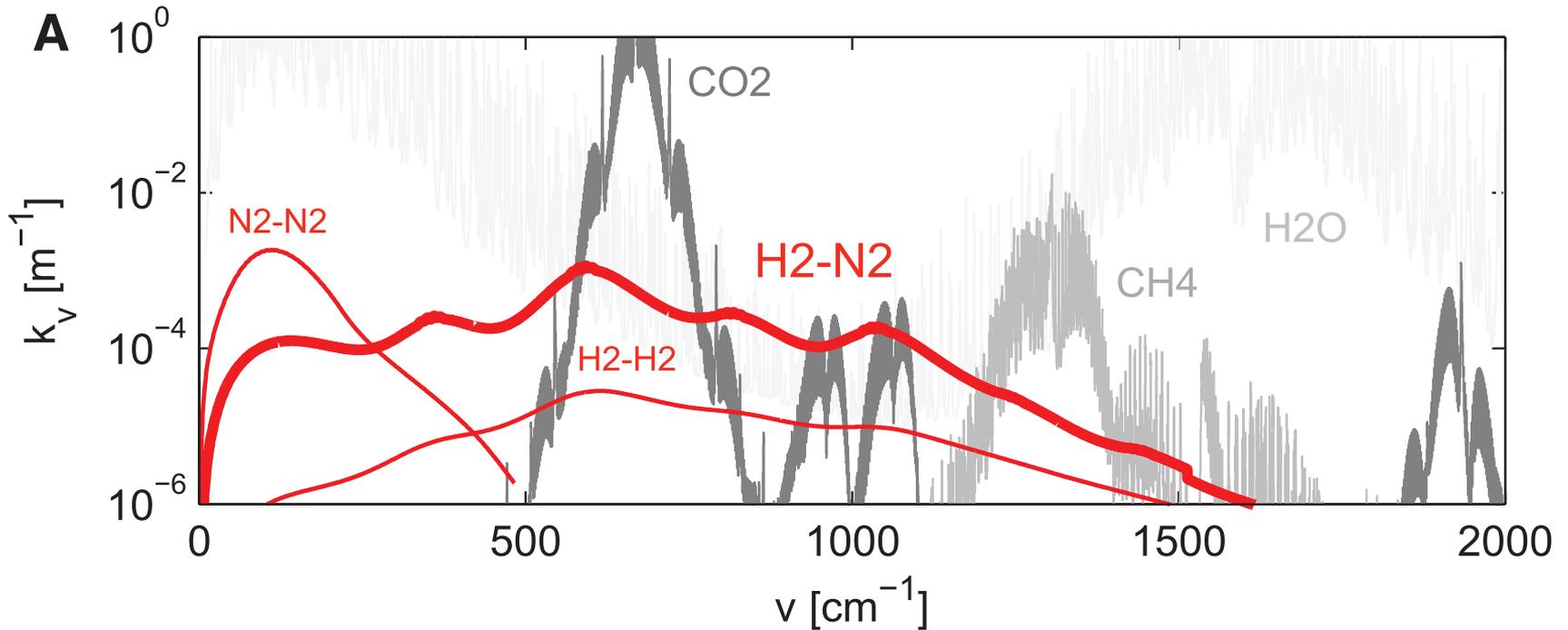
# Extending the «Habitable Zone»: Dry planets

« The region around a star where a  $N_2/CO_2/H_2O$  atmosphere can enable ~~abundant~~ long-lived liquid surface water »



# Extending the «Habitable Zone»

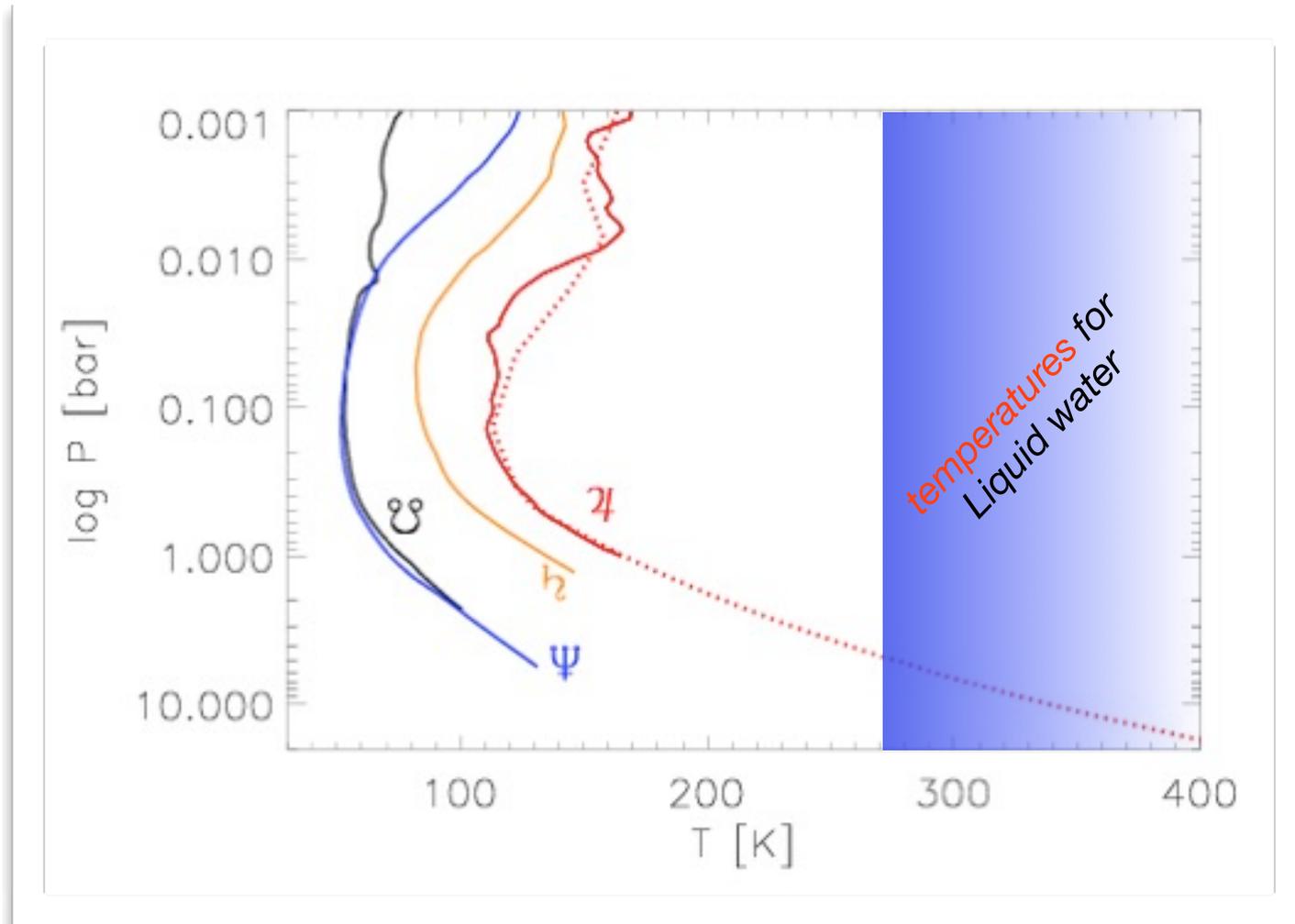
« The region around a star where a ~~N<sub>2</sub>/CO<sub>2</sub>/H<sub>2</sub>O~~ atmosphere can enable abundant long-lived liquid surface water »



Wordsworth & Pierrehumbert (2013)



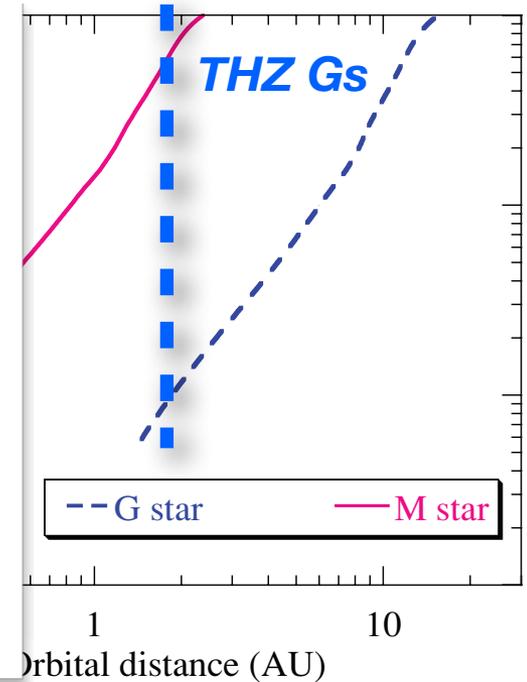
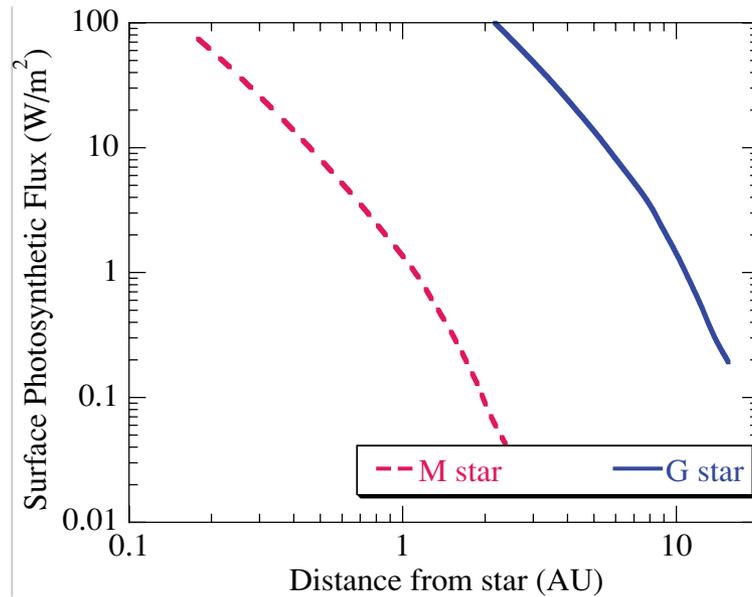
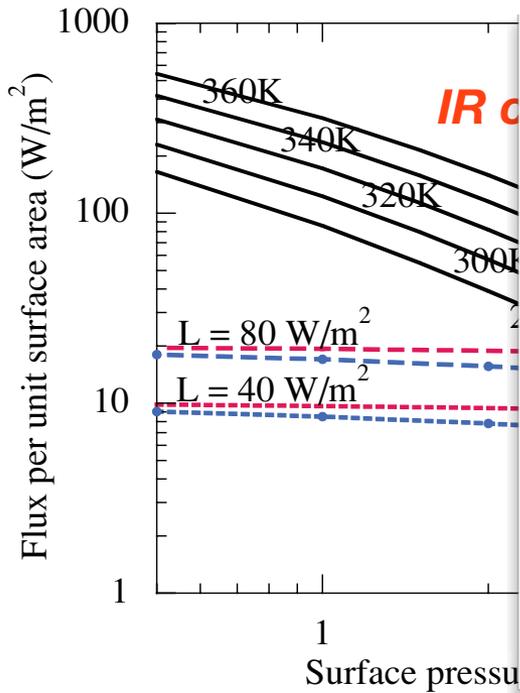
# Extending the «Habitable Zone»: Hydrogen atmospheres



*Lindal et al (1992)*  
*Seiff et al (1998)*

# Extending the «Habitable Zone»: Hydrogen atmospheres

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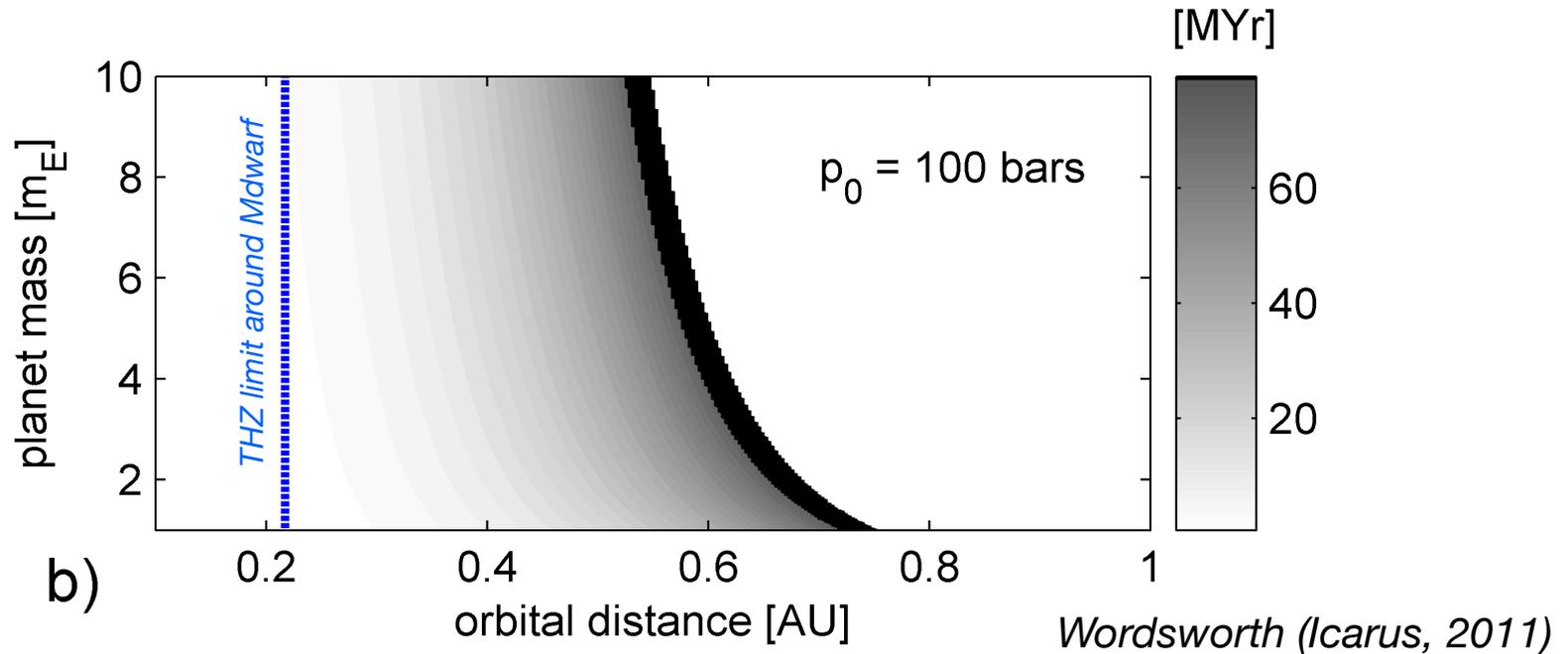
## ★ Caveats:

- ★ a lack of photosynthetic photons?
- ★ Need just the right amount...

Stevenson (Nature, 1999)  
Pierrehumbert & Gaidos (ApJ, 2011)  
Wordsworth (Icarus, 2011)

# Extending the «Habitable Zone»: Hydrogen atmospheres

« The region around a star where a ~~N<sub>2</sub>/CO<sub>2</sub>/H<sub>2</sub>O~~ atmosphere can enable abundant long lived liquid surface water »



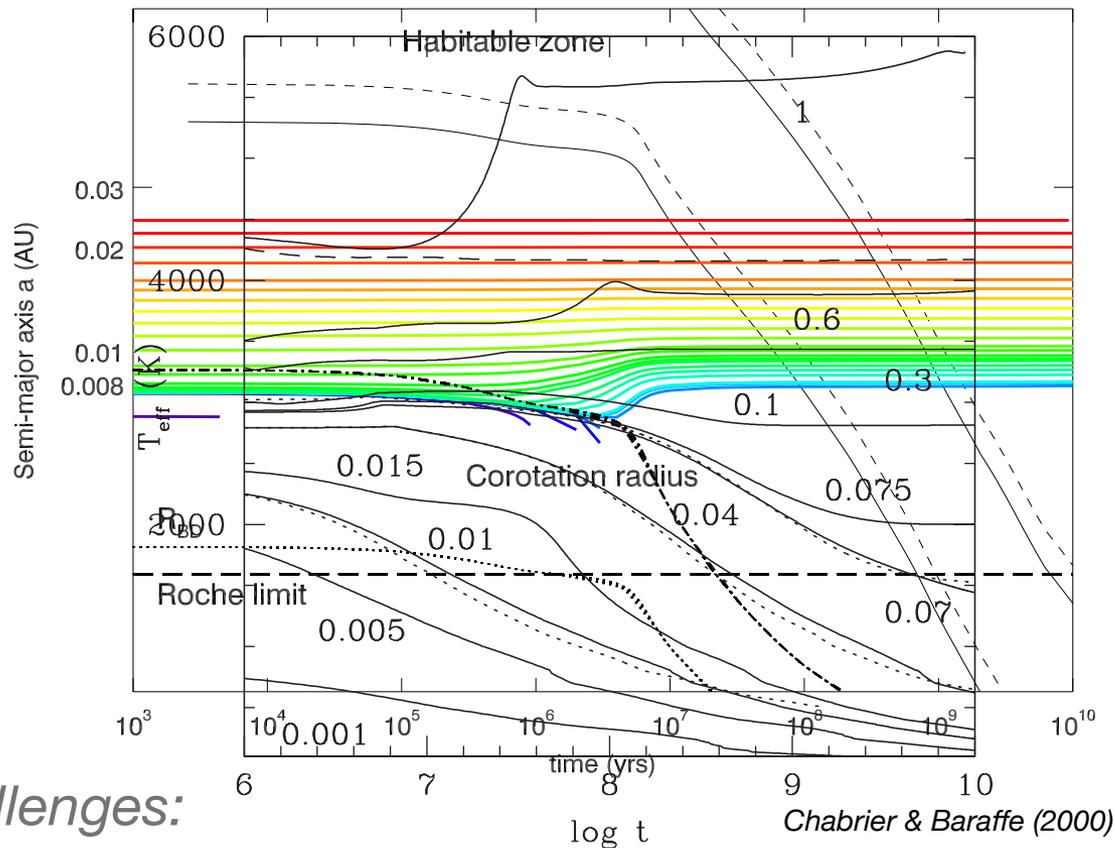
★ *Hydrogen escapes very easily*

➔ *always a period in the evolution where you get just the right conditions*

★ *same thing if the source is geothermal*

# Extending the «Habitable Zone»: substellar objects

« The region around a star where a ~~N<sub>2</sub>/CO<sub>2</sub>/H<sub>2</sub>O~~ atmosphere can enable abundant long lived liquid surface water »



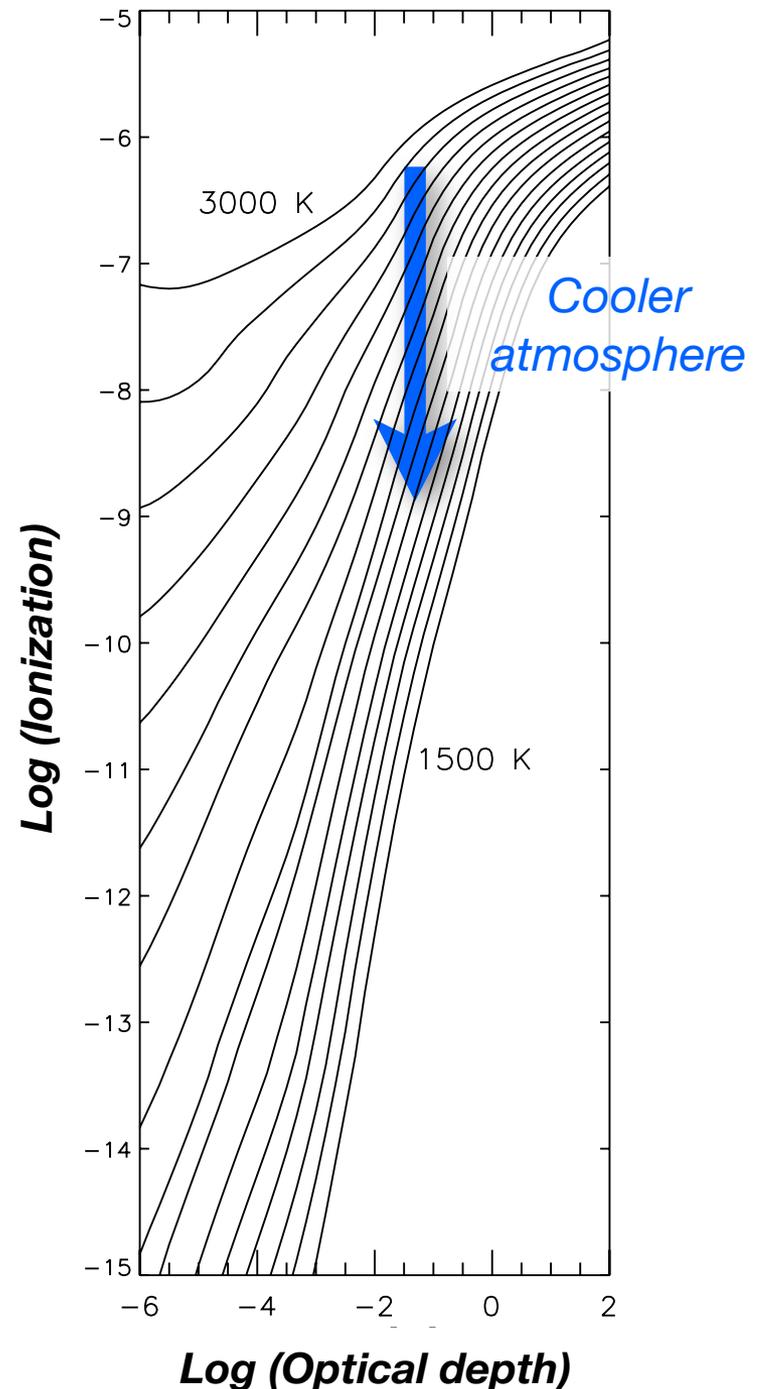
★ Lots of challenges:

- ★ did they loose their water?
- ★ What type of biomarkers?

Bolmont et al (A&A, 2011)  
Belu et al (ApJ, 2013)  
Talk by F. Selsis yesterday

# Late M stars/BDs and stellar Activity

- As the mass decrease
- Effective temperature decreases
  - Ionization decreases
- ➔ Decoupling of convection and magnetic field even at fast rotation
- reduced activity
- reduced spot coverage



***Life** could be  
pretty much **everywhere** out there*

***How can we go forward?***

The number of civilisations in our galaxy in which communication might be possible.

$$N = R^* \times f_p \times \eta_e \times f_l \times f_i \times f_c \times L$$

The fraction of stars with planets 

The fraction that can go on to support intelligent life.

Length of time such civilisations release detectable signs into space.

The average rate of star formation per year in our galaxy 

The average number of planets that can potentially support life (per star with planets.) 

The fraction that can go on to support life.

The fraction of civilisations that develop a technology detectable from space.



The Drake Equation.

# A time line of Exoplanet Facilities



CoRoT  
Kepler + K2



SWASP

HARPS-N  
HARPS  
SOPHIE

Now - 2014

VLT/Espresso  
2016



GAIA

2017



CHEOPS

TESS

"Warm"  
Spitzer  
HST



VLT  
CRIRES, FORS,  
FLAMES, K-MOS  
SPHERE



NGTS

(LCOGTN)

New IR spectrographs  
2015-2020



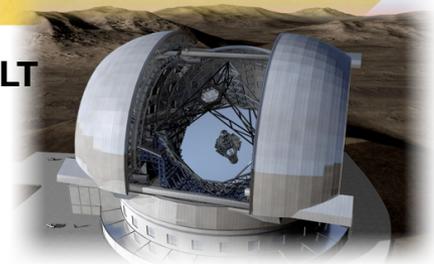
SKA

JWST

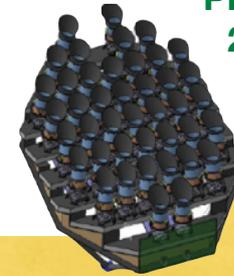


2020

E-ELT



PLATO  
2024



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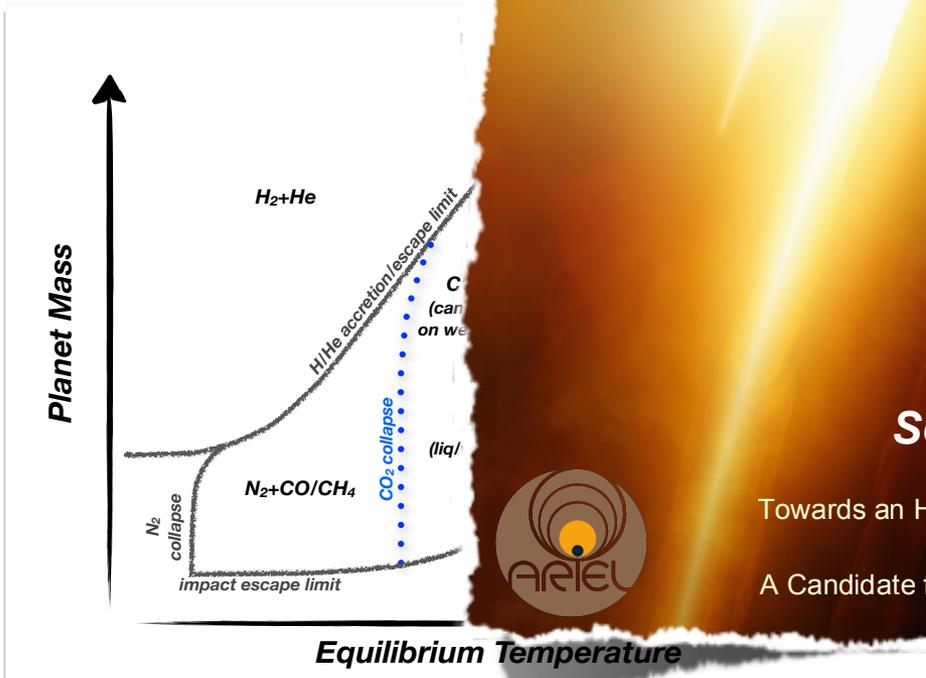


The Drake Equation.

# What type of atmosphere can we detect?

## ARIEL

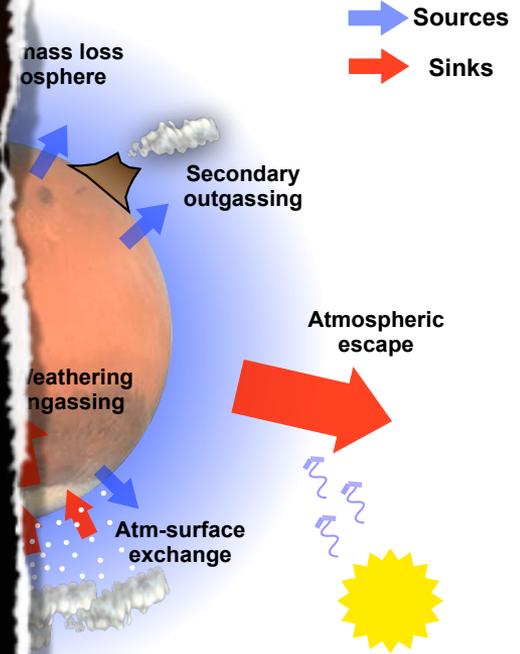
The Atmospheric Remote-Sensing Infrared Exoplanet Large-survey



See talk by G. Tinetti

Towards an H-R Diagram for Planets

A Candidate for the ESA M4 Mission



***Life*** could be  
***pretty much everywhere*** out there  
***(although some places look nicer than others)***

***The HZ*** is a nice place to look at...

***...but...***

***It should not be our starting point***

***and***

***It is gonna be far from the end***