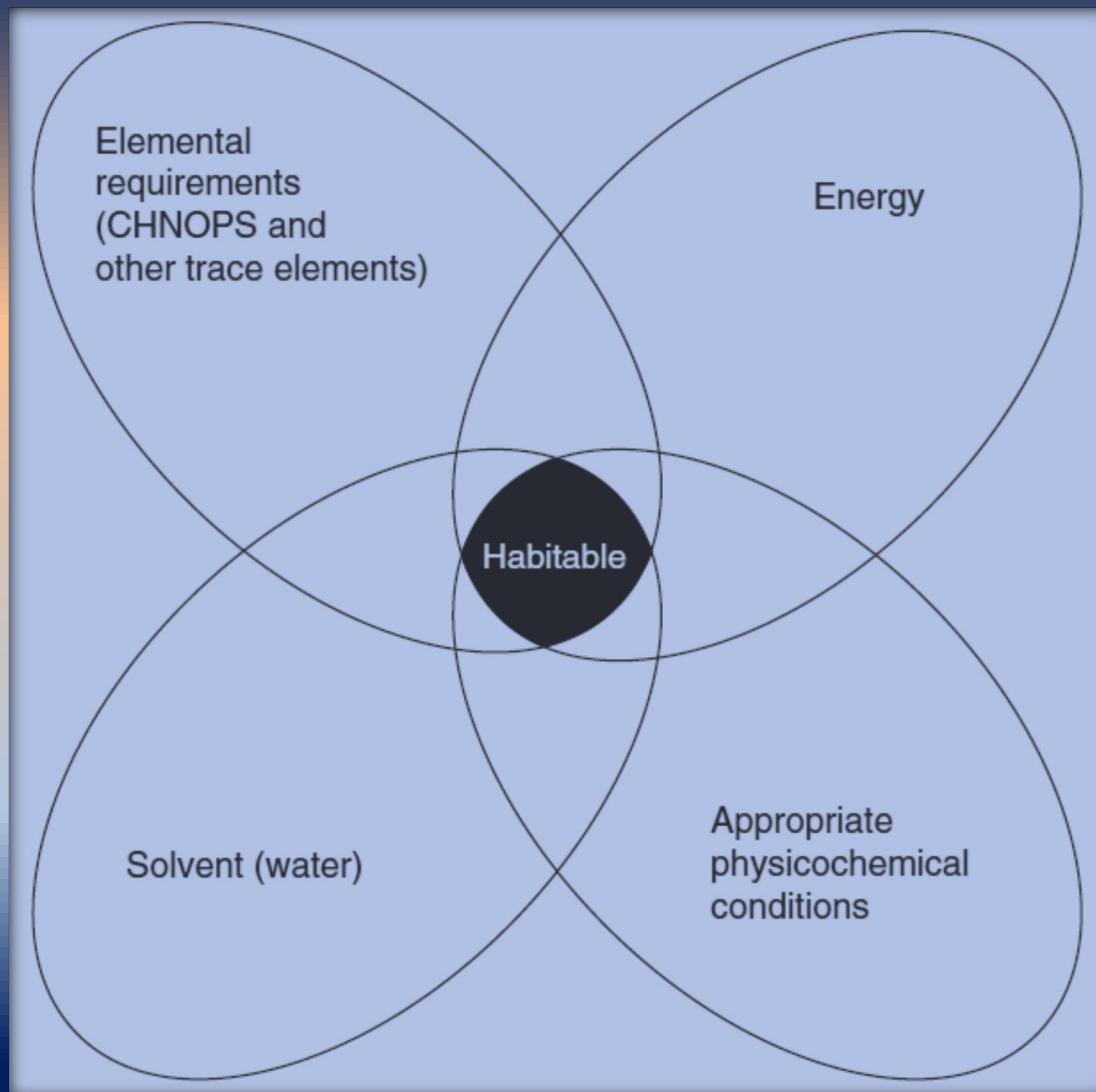


# **Terrestrial microorganisms from extreme environments as analogues to hypothetic microbial forms inhabiting Venus' clouds**

**Kotsyurbenko O.R.**

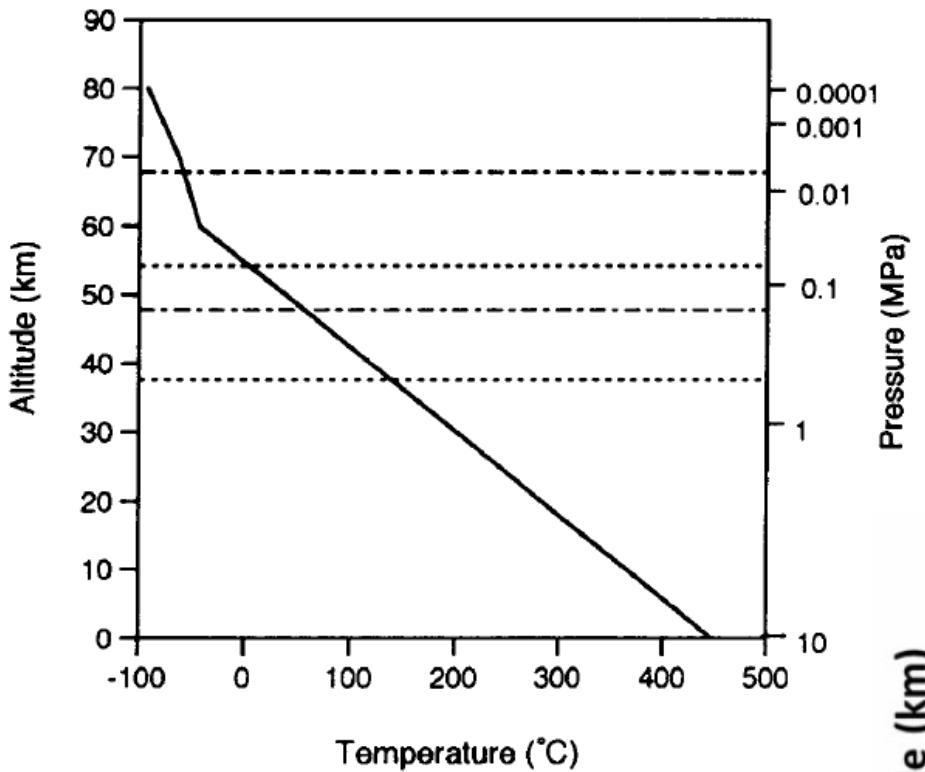
# Habitability concept



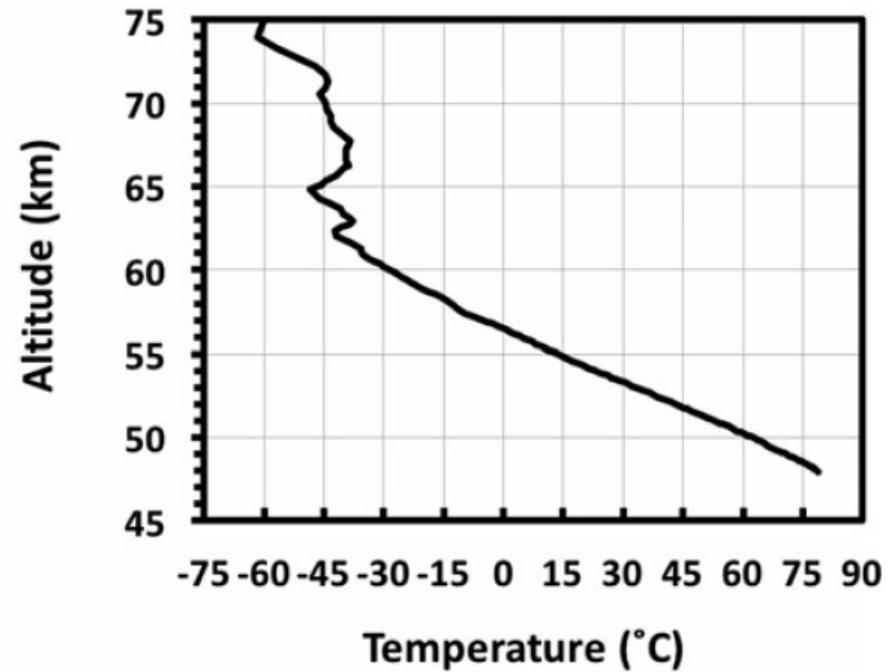
**A series of physicochemical requirements must come together at the spatial scale of an organism to allow that organism to be active in a given environment.**

*C.S. Cockell. Astrobiology. 2016*

# Temperature and pressure profiles in the Venusian clouds



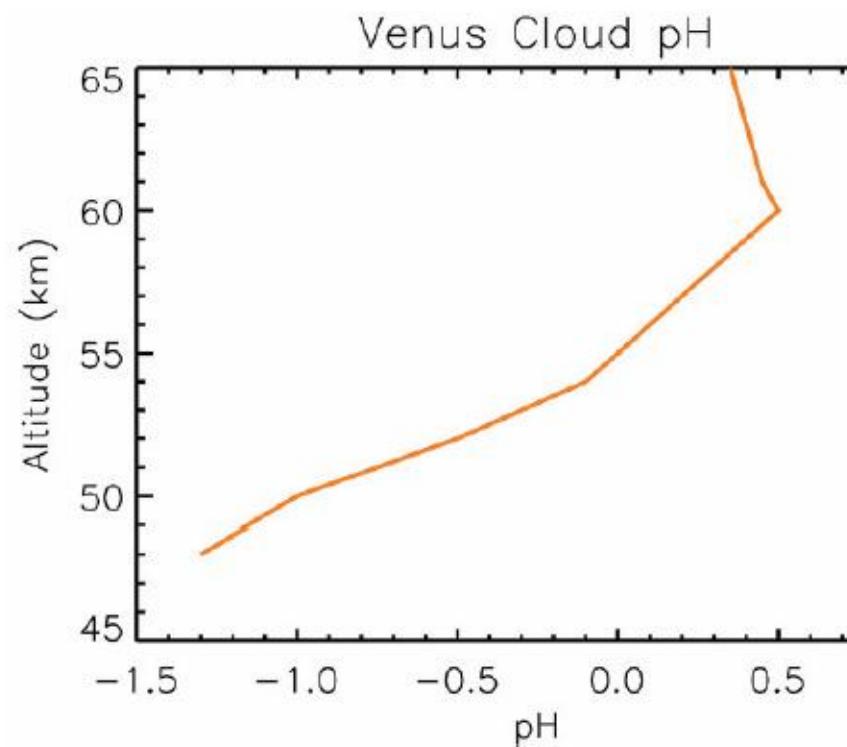
- Upper and lower bounds of the three Venusian cloud layers
- Region between  $0^{\circ}$  and  $150^{\circ}\text{C}$  which may be thermally biologically favorable.



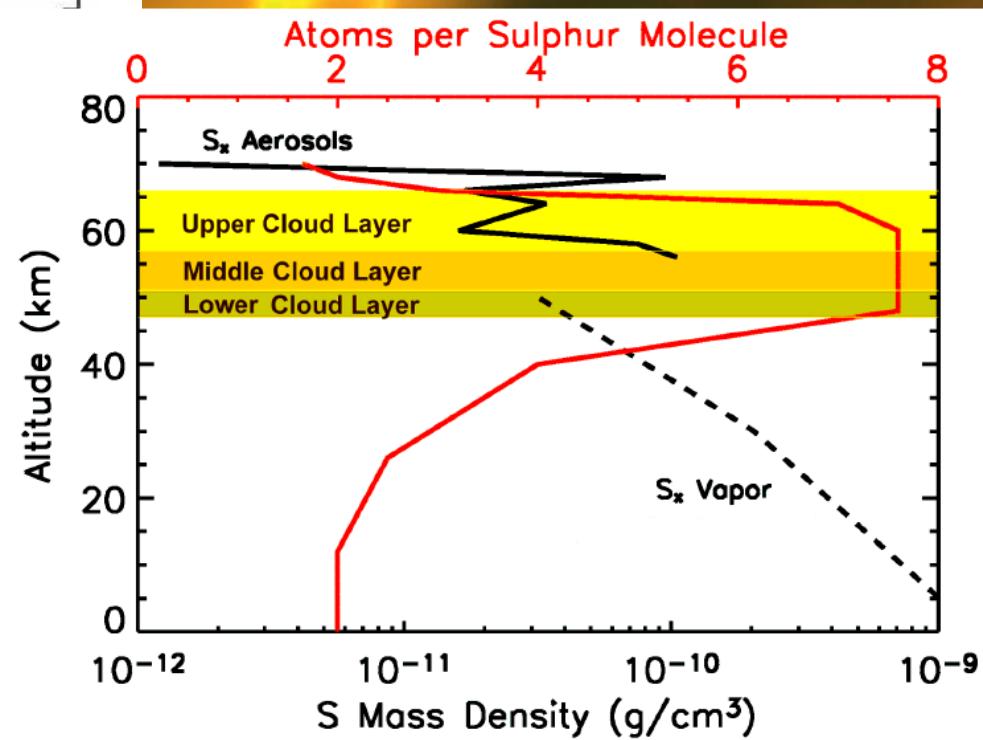
C.S. Cockell. Planetary and Space Science. 1999

Limaye et al. Astrobiology. 2018

# The pH of Venus' clouds as a function of altitude

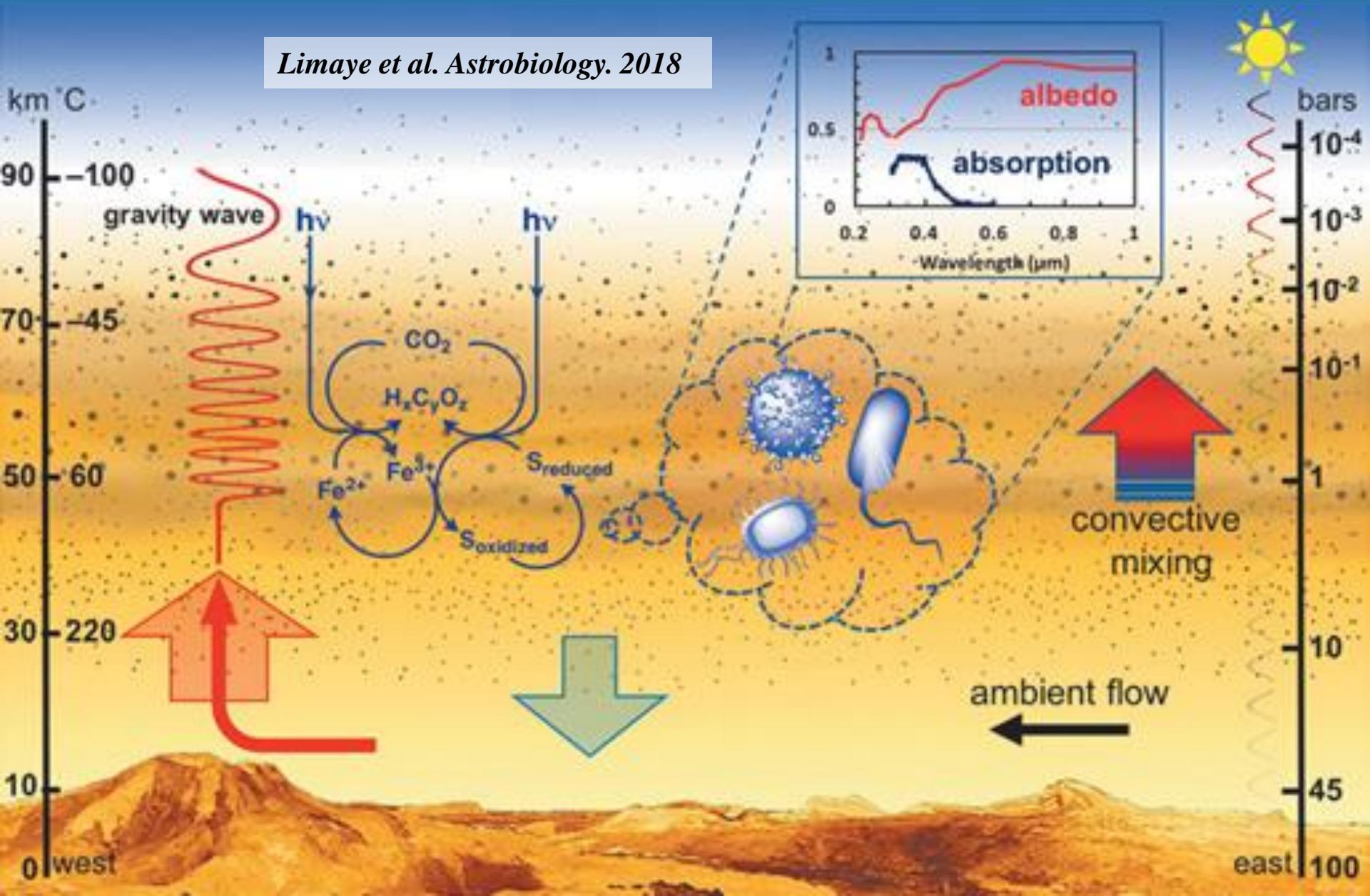


Schulze-Makuch et al. Astrobiology. 2004

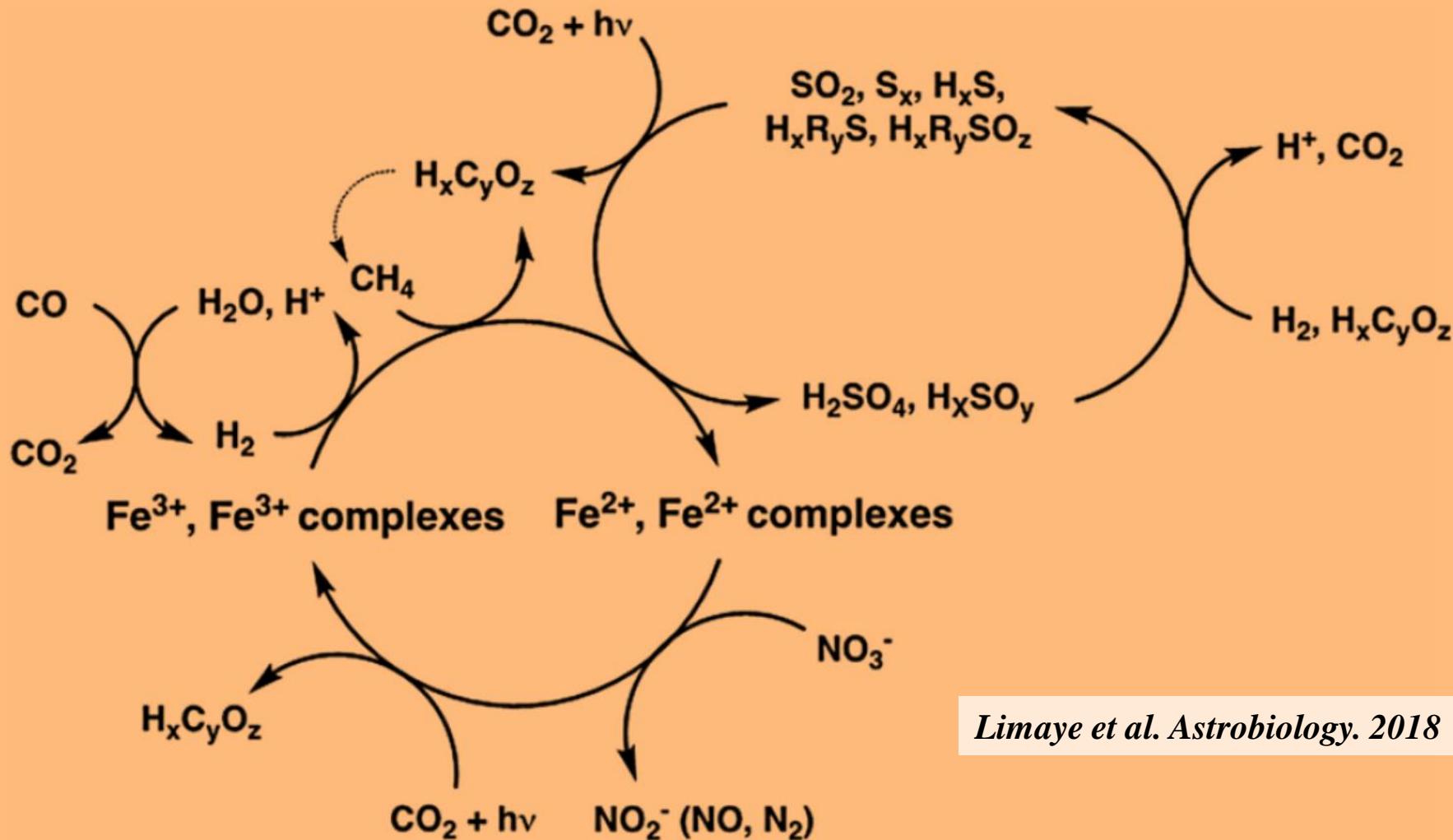


The spectral absorption by the unknown materials in the clouds of Venus can be an indication of presence of biological forms

*Limaye et al. Astrobiology. 2018*



# Diagram of possible redox cycles in the Venus' clouds



Putative Venusian microorganisms can survive by driving different metabolic processes based on redox cycles in Venus' clouds

# Habitability in the Venus' clouds

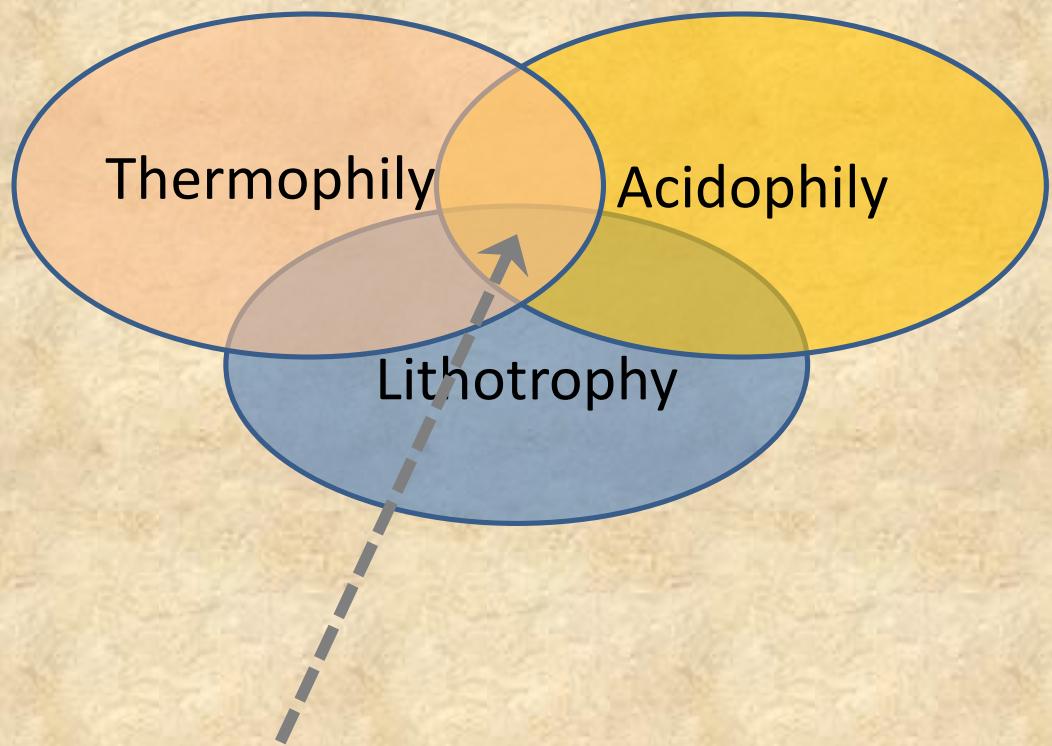
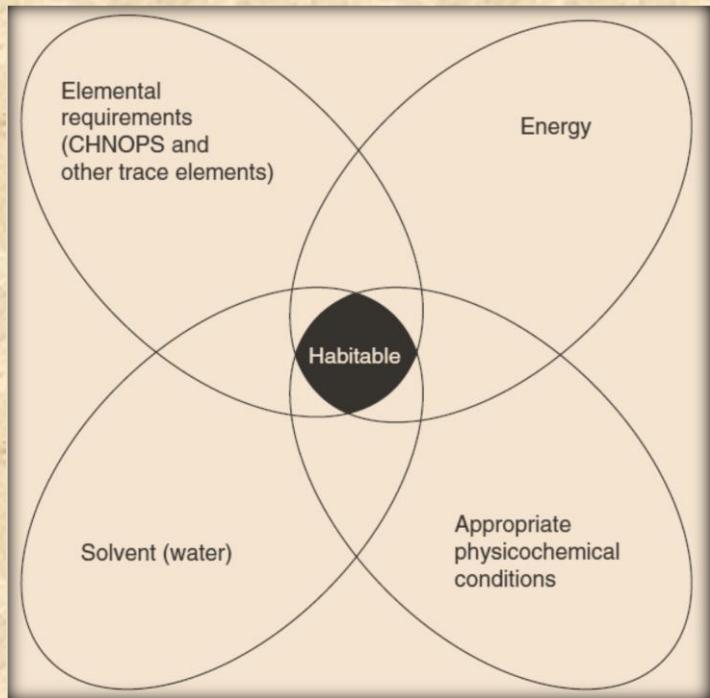
The conditions in the lower cloud layer of Venus (47.5–50.5 km):

*Temperature 50 – 60°C*

*Pressure 0,4 – 2 atm*

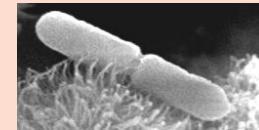
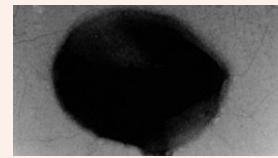
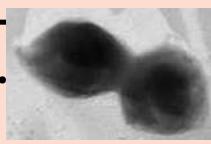
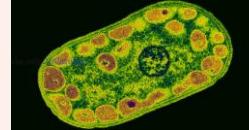
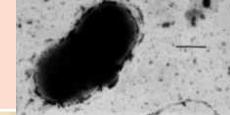
*pH ≤ 0,5*

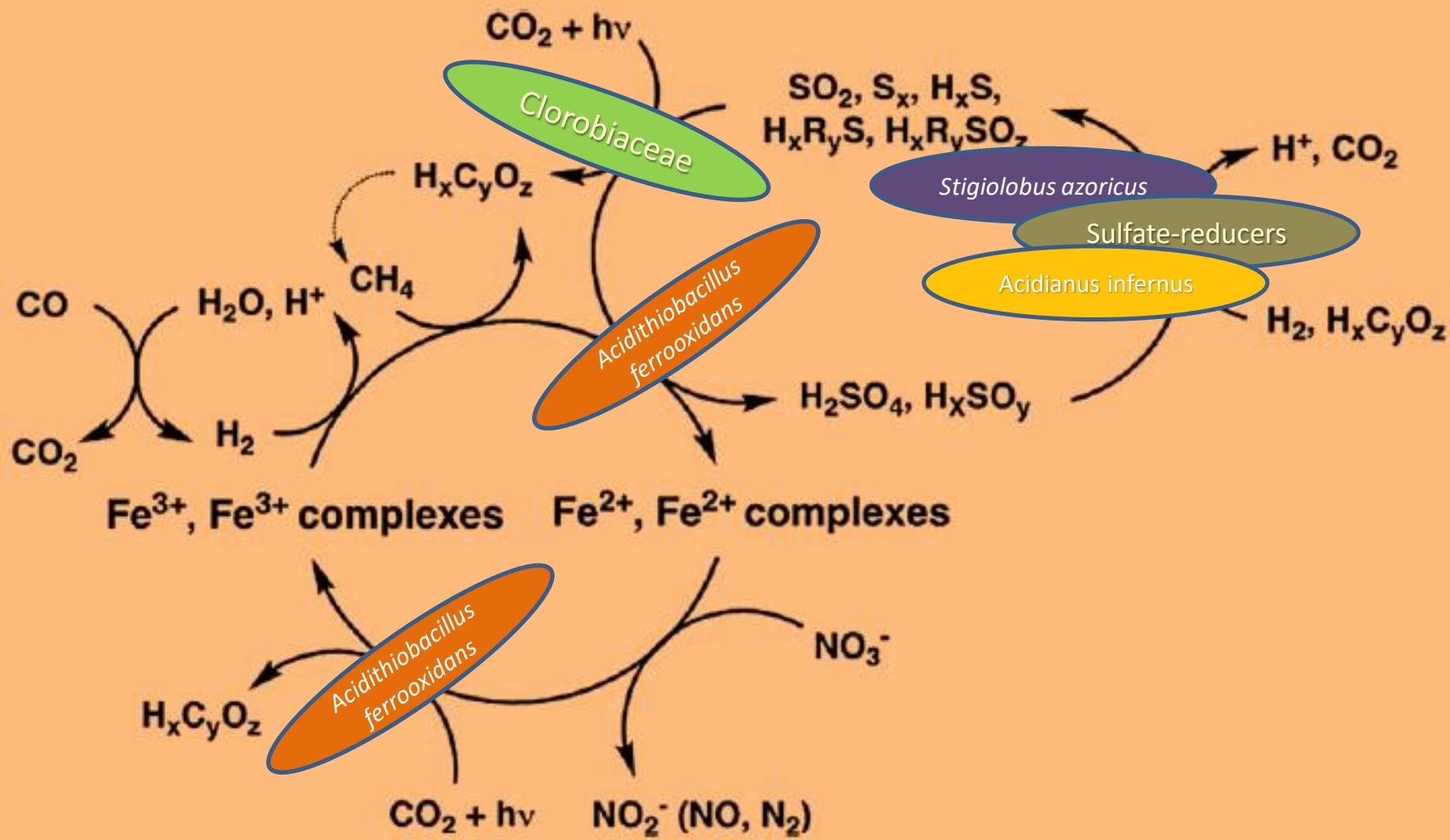
*Presence of sulfur and ferrous compounds and CO<sub>2</sub>,*



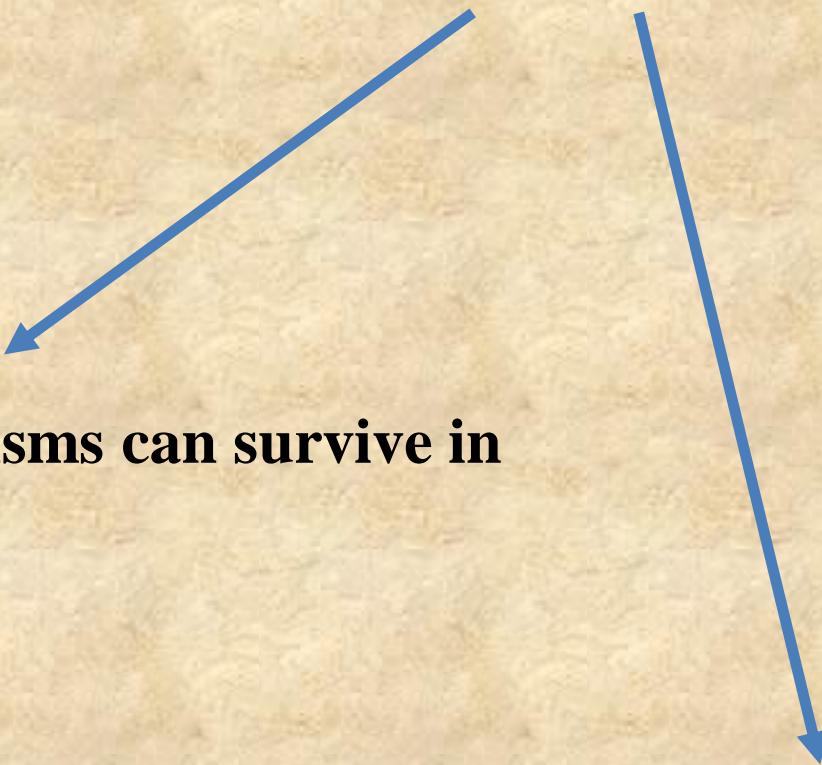
*Litho-Acido-Thermophyles*

# Extremophilic microorganisms able to withstand the conditions in Venus' clouds

Organism	T, C interval (Opt.)	pH Interval (Opt.)	Electron donors	Electron acceptors	Habitat, Picture	Reference
<i>Acidithiobacillus ferrooxidans.</i> <i>Proteobacteria, Bacteria</i>	(30) Survi- ve at 50-60	(1,5- 2,5)	H <sub>2</sub> , formate, ferrous ions or sulfur compounds	Fe <sup>2+</sup> →Fe <sup>3+</sup> S-comp → SO <sub>4</sub> <sup>2-</sup>	Geothermal springs 	Valdes et al., 2008
<i>Stygiolobus azoricus,</i> the order <i>Sulfolobales,</i> <i>Chrenarchaeota</i>	57-89 (80)	1-5,5 (2,5- 3,0)	H <sub>2</sub>	S <sup>0</sup> → S <sup>2-</sup>	Solfataras 	Segerer et al., 1991
<i>Acidianus infernus,</i> <i>Sulfolobaceae.</i> <i>Crenarchaeota</i>	65-96 (90)	1-5,5 (2)	H <sub>2</sub> , S <sup>0</sup>	S <sup>0</sup> → S <sup>2-</sup> S <sup>0</sup> → SO <sub>4</sub> <sup>2-</sup>	Solfataras, hydro-therm. syst. 	Segerer et al., 1986
Green sulfur bacteria <i>Chlorobiaceae fam</i>	differ.	differ.	sulfide ions, hydrogen, ferrous irons,sulfur	S <sup>-2</sup> → S <sup>0</sup> S <sup>0</sup> → SO <sub>4</sub> <sup>2-</sup> CO <sub>2</sub> reduct	Black sea 	
Sulfate-reducing bacteria	differ.	differ.	H <sub>2</sub> , org comp.	SO <sub>4</sub> <sup>2-</sup> → S <sup>2-</sup>		



## **Additional aspects of habitability in relation to Venus' clouds**



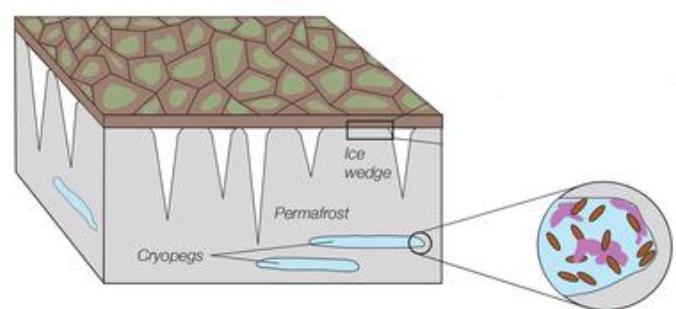
**Microorganisms can survive in microniches**

**Venusian organisms can have a combination of properties of different types of terrestrial microbes**

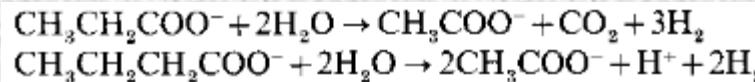
# Micronisches

Ecosystem	Environmental conditions	Specific conditions in microniches	Key factor
Permafrost	Low mineralization	Hypersalinity in cryopegs	Mineralization
Anaerobic synthrophic reactions	Thermodynamically unfavorable	Proper physical organization	Thermodynamics
Antarctic ice	Deeply cold	Microbial activity at - 45°C	Temperature

## Cryopegs



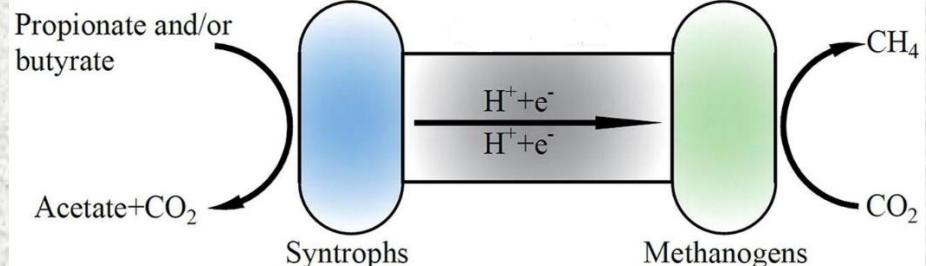
## Synthrophic reactions



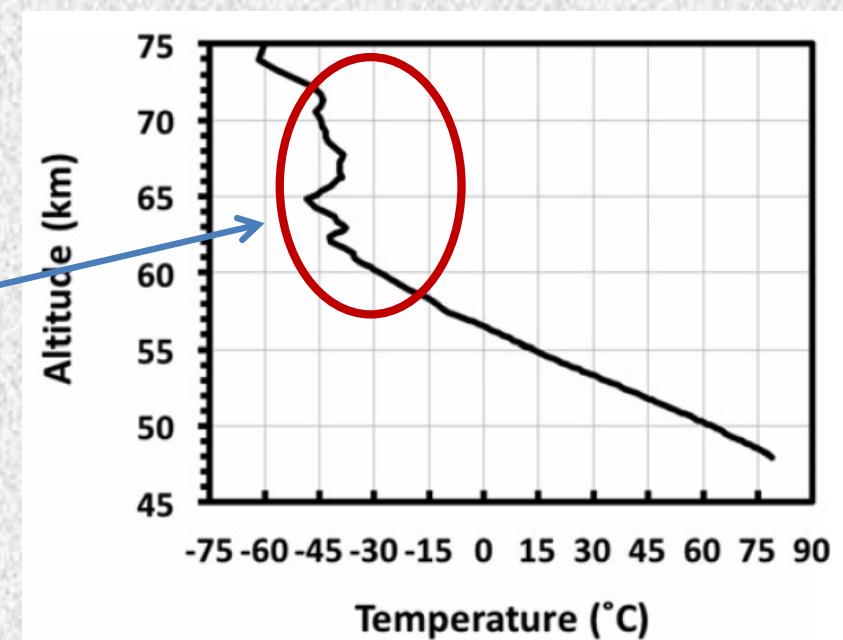
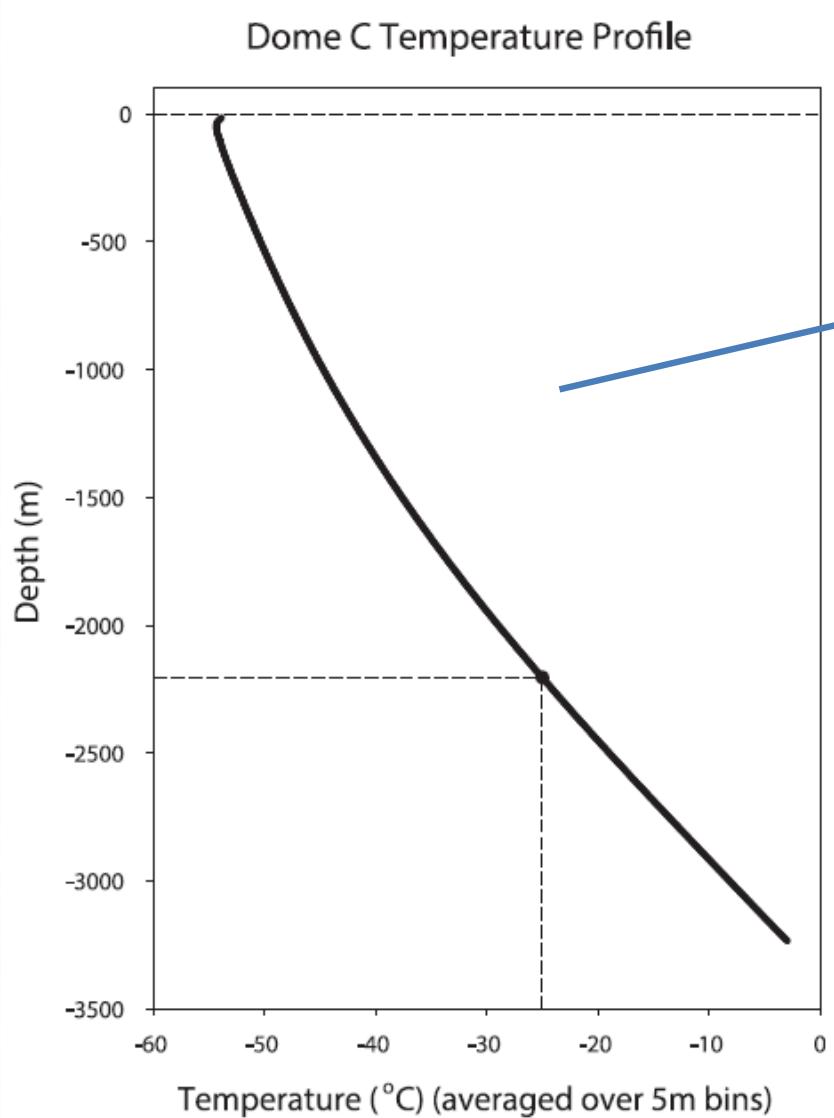
$\Delta G^\circ$   
(kJ/reaction)

71.7

48.3



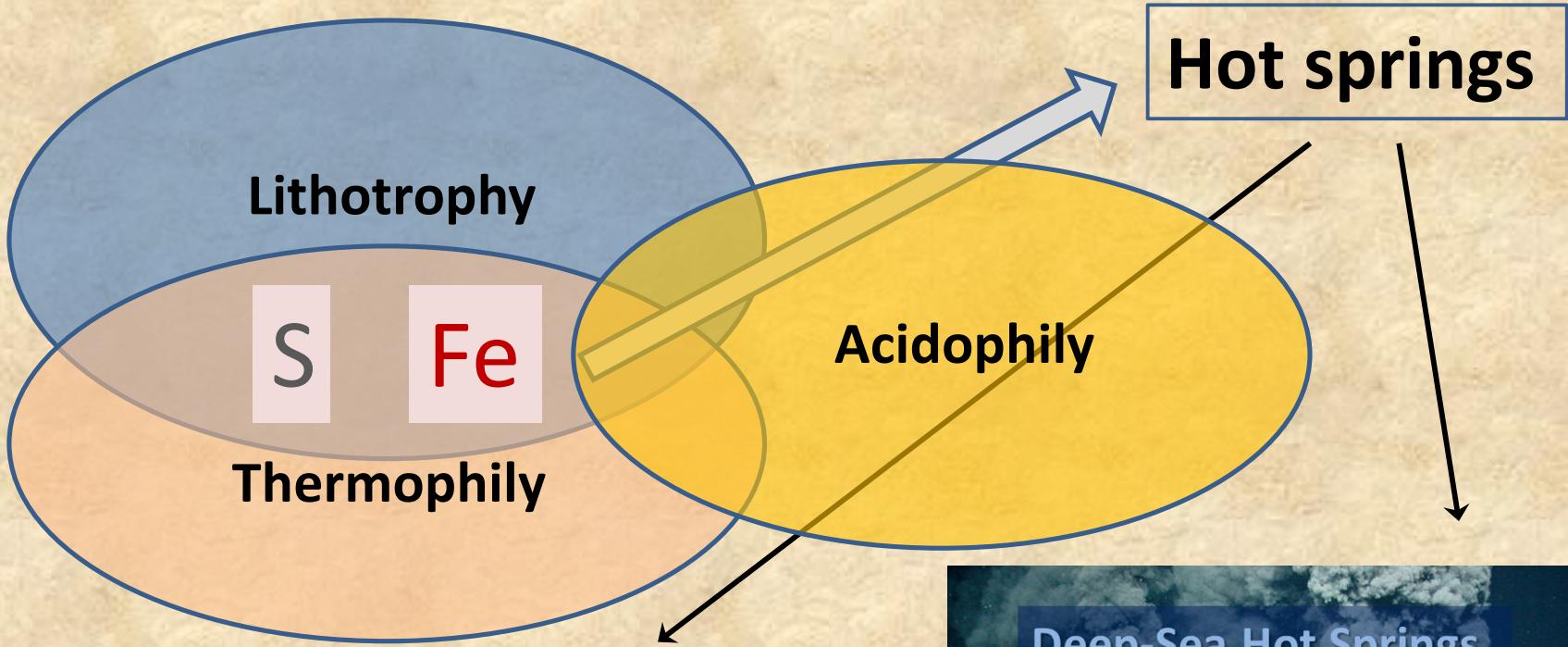
# Microbial activity in Antarctic ice



Temperature profile through an ice core in  
Antarctics

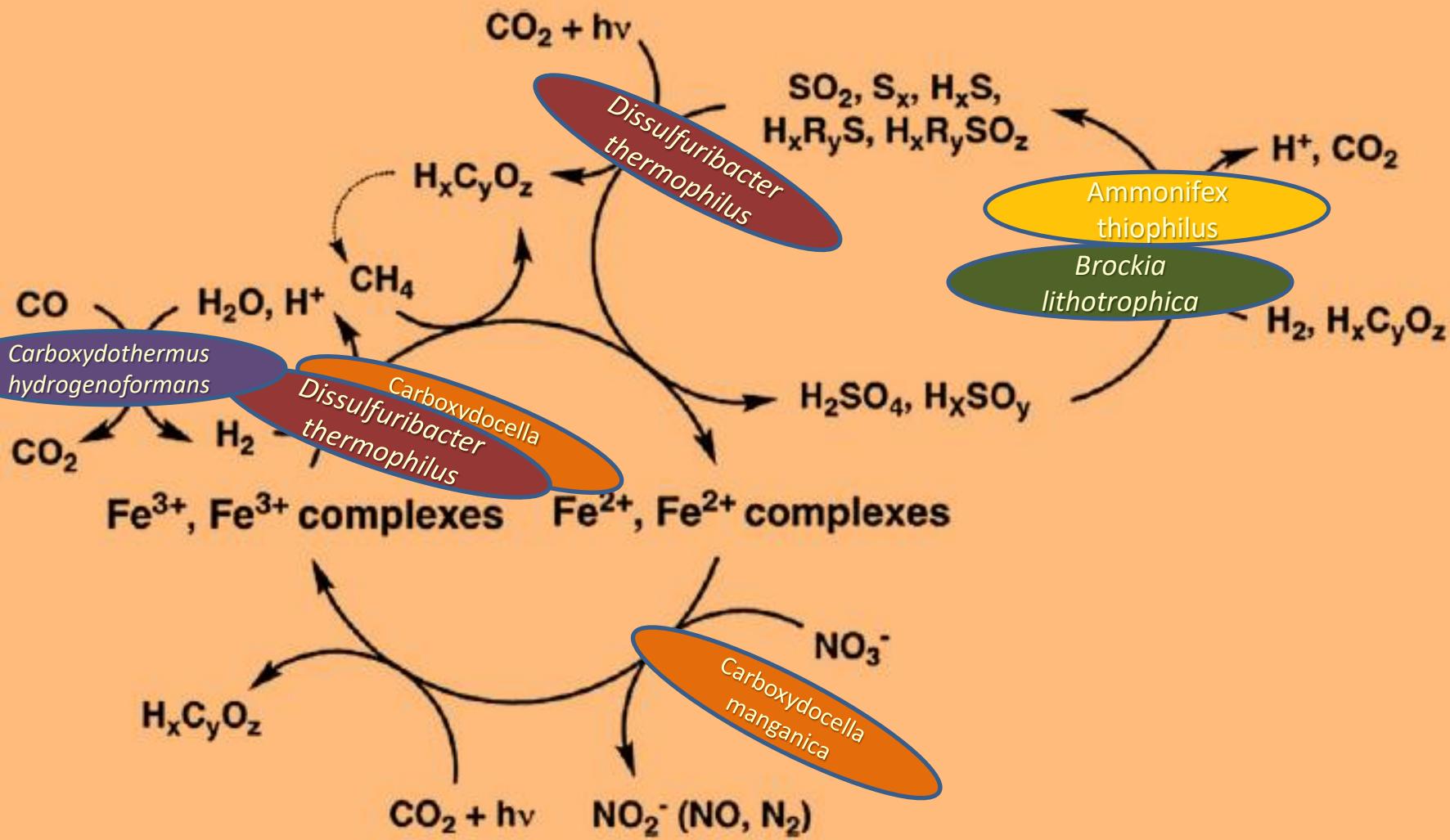
*The dotted lines show a putative threshold depth above which cells will be vitrified and hence not metabolising, and below which cells may be in a fluid state and able to metabolise, albeit slowly*

# Combination of properties



# Microorganisms isolated from hot springs

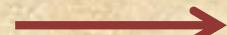
Organism	T, C interval (Opt.)	pH Interval (Opt.)	Electron donors	Electron acceptors	Habitat	Reference
<i>Ammonifex thiophilus</i>	60–82 (75)	6.0–7.5 (6.8)	H <sub>2</sub> , formate	S <sub>2</sub> O <sub>3</sub> <sup>2-</sup> → S <sup>2-</sup> SO <sub>4</sub> <sup>2-</sup> → S <sup>2-</sup> S <sup>0</sup> → S <sup>2-</sup>	Terrestrial hot spring (Kamchatka)	Miroslavchenko et al., 2008
<i>Carboxydocella manganica</i>	26–70 (58-60)	5.5–8.0 (6.5)	H <sub>2</sub> , organic compounds	Fe <sup>3+</sup> → Fe <sup>2+</sup> NO <sub>3</sub> <sup>-</sup> → NH <sub>4</sub> <sup>+</sup>	Terrestrial hot spring (Kamchatka)	Slobodkina et al., 2012
<i>Dissulfuribacter thermophilus</i>	28-70 (61)	5.6-7.9 (6,8)	Thiosulfate, sulfite, sulfur H <sub>2</sub>	SO <sub>4</sub> <sup>2-</sup> ← S <sub>2</sub> O <sub>3</sub> <sup>2-</sup> → S <sup>2-</sup> SO <sub>4</sub> <sup>2-</sup> ← SO <sub>3</sub> <sup>2-</sup> → S <sup>2-</sup> SO <sub>4</sub> <sup>2-</sup> ← S <sup>0</sup> → S <sup>2-</sup> Fe <sup>3+</sup> → Fe <sup>2+</sup>	Deep-sea hydrothermal vent of the Eastern Lau Spreading Center	Slobodkin et al., 2012
<i>Carboxydothermus hydrogenoformans</i>	70–72	7.0	CO	CO <sub>2</sub> ← CO → H <sub>2</sub>	Kunashir Island, Kurils Mud from hot swamp	Svetlichny et al., 1991
<i>Brockia lithotrophica</i>	46-78 (60-65)	5.5–8.5 (6,5)	H <sub>2</sub> , formate	S <sub>2</sub> O <sub>3</sub> <sup>2-</sup> → S <sup>2-</sup> SO <sub>4</sub> <sup>2-</sup> → S <sup>2-</sup> S <sup>0</sup> → S <sup>2-</sup>	Terrestrial hot spring (Kamchatka)	Perevalova et al., 2013



# **Contribution of microbiologists to the mission**

## **Studies**

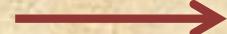
Selecting terrestrial ecosystems and microorganisms which could be analogs or have any key features relevant to the conditions in Venus' clouds



## **Outcomes**

Data base of terrestrial analogs

Study all specific (metabolic, biochemical, physiological etc) properties



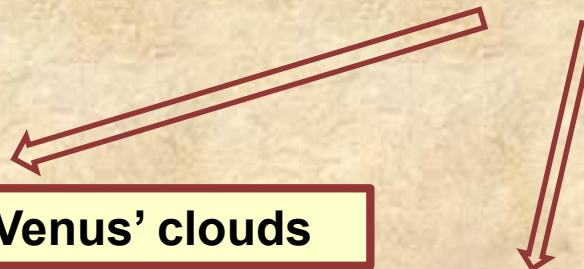
Biosignatures

Model/simulating experiments with selected microorganisms



Metabolic features, survival

Suggestions for astrobiology mission to Venus' clouds



Biotechnology applications