IS IT POSSIBLE TO NEGLECT THE EFFECTS OF LIFE WHEN CALCULATING THE BOUNDARIES OF HABITABILITY? J. I. Zuluaga[1], J. F. Salazar[2], Pablo A. Cuartas[1] and G. Poveda[3], [1]FACom - Instituto de Fisica - FCEN, Universidad de Antioquia, Calle 70 No. 52-21, Medellin, Colombia, [2]Escuela Ambiental, grupo GIGA, Facultad de Ingenieria Universidad de Antioquia, Calle 70 No. 52-21, Medellin, Colombia, [3]Departamento de Geociencias y Medio Ambiente, Universidad Nacional de Colombia, Medellin, Colombia.

Context: Habitability is normally defined as an abiotic prerequisite for life. The existence of suitable sources of energy and matter, mild temperatures and proper protection against the aggression of exogenous and endogenous effects, are among the factors considered when calculating the boundaries where life could arise and thrive [1].

But life itself is a major environmental force, as the study of the Earth System has taught us in the last couple of decades [2,3]. While we better know our planet and the complex interaction between the biota and its environment, we are more convinced that the Earth will be a different planet if uninhabited.

Aim: We develop here the novel hypothesis that life cannot be excluded when defining and calculating the physical boundaries of habitability. Habitability is an emergent property of a complex system involving the interacting of biotic and abiotic components. If our ultimate goal is to find inhabited planets we should stop disregarding the effect of life when defining for instance the limits of the Habitable Zone.

This hypothesis leaded us recently [4] to propose the definition of what we called the Habitable Zone of Inhabited Planets (InHZ for short). We review here this concept and the theoretical arguments and evidences supporting it. We also illustrate how this redefined region can be calculated in simple albeit powerful models.

Methods: We test our hypothesis using numerical simulations of biota-environment interaction in hypothetical inhabited worlds. We compare the results of these simulations with those obtained for uninhabited planets. Based on the idea that the equilibrium state of an inhabited planet could be a limit cycle instead of a fixed point, we simulate the environmental conditions in planets (inhabited or not) having oscillating properties that could favor the maintenance of habitable conditions even under supposedly deadly orbital and rotational configurations. We argue that this unconventional equilibrium states may naturally arise if life is included.

Results: We find that under general assumptions, inhabited planets support habitable environments under a wider range of conditions, as compared to similar planets lacking the power of biotic feedbacks. The position and extent of the Habitable Zone of those Inhabited Planets, depend on different assumptions made about the properties of their specific forms of life. For most of the assumed properties, the InHZ boundaries, however, are closer and further away than the traditional limits calculated without including biotic feedbacks.

We have found and simulated at least two environments locked in unconventional equilibrium states characterized by limit cycles. We find that planets where powerful regulatory mechanisms, such as those associated with life, can ensure the maintenance of those cycling states, may enjoy habitable conditions even under extreme stellar forcing.

References: [1] Kasting, J. F. Princeton University Press (2010). [2] Beerling, D., Annals of Botany, 96, 345–352, (2005). [3] Poschl, U., Martin, S., Sinha, B., Chen, Q., Gunthe, S., Huffman, J., Borrmann, S., Farmer, D., Garland, R., Helas, G., et al., Science, 329, 1513–1516 (2010). [4] Zuluaga, J.I., Salazar,J.F., Cuartas, P.A. & Poveda, G., BGD (2014).

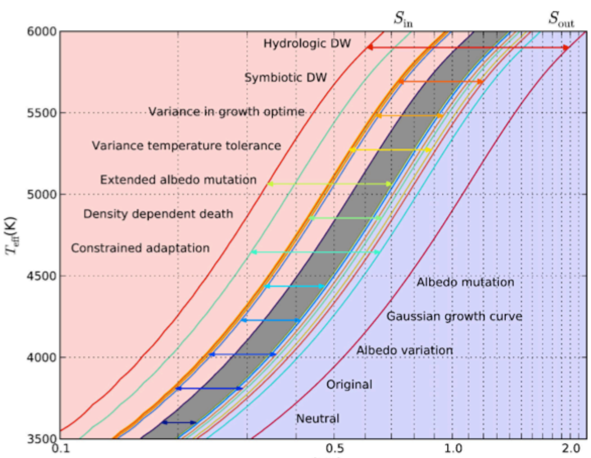

Figure caption: Boundaries of the InHZ as calculated with one of the simplified models of biota-environment interaction used in this work. Assuming different for life, change the limits of the Habitable Zone as shown by the colored continuous lines. In all cases the inclusion of life in the environmental dynamics, stretches the Habitable Zone beyond their traditional limits (dark gray band). This figure has been taken from Zuluaga et al. (2014) [4].