EPSC Abstracts
Vol. 5, EPSC2010-538, 2010
European Planetary Science Congress 2010

The extrasolar planet GL 581 d: A potentially habitable planet?

Ph. v. Paris (1), A.B.C. Patzer (2), M. Godolt (2), B. Stracke (1), P. Hedelt (3), S. Gebauer (2), L. Grenfell (2), D. Kitzmann (2) and H. Rauer (1,2)

(1) Institut für Planetenforschung, DLR, Berlin, (2) Technische Universität Berlin, (3) Laboratoire d'Astrophysique de Bordeaux, Univ. Bordeaux

Abstract

The planetary system around the M star Gliese 581 contains at least three close-in potentially low-mass planets, GL 581 c, d and e. In order to address the question of the habitability of GL 581 d, detailed atmospheric modeling studies for several planetary scenarios were performed. For four modelled high-pressure CO_2-rich scenarios (95% CO_2, 5, 10 and 20 bar surface pressure, and 5% CO_2 with 20 bar surface pressure), surface temperatures were above 273 K, indicating a potential habitability of the planet. For all other considered scenarios, calculated GL 581 d surface temperatures were below the freezing point of water, suggesting that GL 581 d is not habitable.

1. Introduction

In view of atmospheric modeling activities, the system Gliese 581 (GL 581) with four planets (Mayor et al. (2009)) is particularly interesting. It hosts at least three potentially low-mass, thus possibly terrestrial planets. The habitability of GL 581 c and d was investigated by Selsis et al. (2007) and v. Bloh et al. (2007), based on the first discovery data published by Udry et al. (2007). They concluded both that habitability of the inner planet GL 581 c is unlikely, whereas the outer planet, GL 581 d, might just be habitable. Based on the calculations by Selsis et al. (2007), Mayor et al. (2009) concluded that GL 581 d is in the habitable zone of its central star, based on a revised orbit where the planet receives more than 30 % more stellar energy than previously thought. In order to extend and complement these studies, a 1D radiative-convective model has been applied to the atmosphere of GL 581 d considering different planetary scenarios. By calculating atmospheric pressure, temperature and water profiles, a reasonable range of planetary surface conditions has been investigated in view of potential habitability.

2. Models and tools

A one-dimensional radiative-convective column model was used for the calculation of the atmospheric structure, i.e. the temperature and pressure profiles. The model is originally based on the model described by Kasting et al. (1984). The model version used in this work is based on v. Paris et al. (2008). Model atmospheres are restricted to be composed of the two most important greenhouse gases of the Earth's atmosphere (H_2O and CO_2), using N_2 as a background gas. Temperature profiles from the surface up to the mid mesosphere are calculated by solving the equation of radiative transfer and performing convective adjustment, if necessary. The convective lapse rate is assumed to be adiabatic.

The total surface pressure (1, 2, 5, 10, 20 bar) and CO_2 concentration (0.95, 0.05 and 355 ppm vmr, respectively) were varied. N_2 is assumed to act as a filling background gas. The range of surface pressures was chosen to represent scenarios adopted in the literature for early Earth and early Mars in terms of atmospheric column density. The values of CO_2 concentrations are chosen to represent modern Earth, early Earth and Mars conditions.

3. Summary

Detailed model calculations of possible atmospheres for the low-mass extrasolar planet GL 581 d have been presented. Using a radiative-convective column model, several key atmospheric parameters (e.g. surface pressure, atmospheric composition) were varied to investigate their influence on surface conditions. We confirm that GL 581 d is a potentially habitable planet, but only for massive CO_2 atmospheres (5 or more bar surface pressure with CO_2 concentrations of 95 %, 20 bar with 5 % CO_2), where surface temperatures exceeded 273 K, i.e. the freezing point of water. For these massive CO_2

atmospheres, surface temperatures could be as high as 357 K. For atmospheric scenarios with less CO_2, however, the planet was found to be uninhabitable.

Nevertheless, GL 581 d is the first extrasolar (potentially terrestrial) planet where habitable conditions are at least conceivable.

Acknowledgements

This research has been partly supported by the Helmholtz Gemeinschaft (HGF) through the HGF research alliance "Planetary Evolution and Life".

References

Kasting et al. (1984), Icarus, vol. 57, 335

Mayor et al. (2009), Astronomy&Astrophysics, vol. 507, 487

Selsis et al. (2007), Astronomy&Astrophysics, vol. 476, 1373

Udry et al. (2007), Astronomy&Astrophysics, vol. 469, L43

v. Bloh et al. (2007), Astronomy&Astrophysics, vol. 476, 1365

v. Paris et al. (2008), Plan. Space Sc., vol. 56, 1244