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A new approach to investigating star-planet-interaction based on UV transit observations of terrestrial planets around M-dwarfs

Eybl V. (1), Xiang-Grüß M. (2), Lammer H. (3), Antoniadis J. (4), Barentsen G. (5), Bjerkeli P. (6), Dorner B. (7), Dumitrache C. (8), Humberset B. (9), Jacimovic A. (10), Kuutmann A. (11), Moser H. (12), Rotter T. (13), Vinas Tió M. (14), and Ygouf M. (15)

(1) University of Vienna, Austria, (2) Christian-Albrechts-Universität zu Kiel, Germany, (3) Space Research Institute, Austrian Academy of Sciences, Austria, (4) Greece, (5) Armagh Observatory, UK, (6) Onsala Space Observatory, Sweden, (7) CRAL - Observatoire de Lyon, France, (8) University Politehnica of Bucharest, Romania, (9) University of Bergen, Norway, (10) University College Utrecht, Netherlands, (11) Sweden, (12) Luxembourg, (13) University of Graz, Austria, (14) Universitat Politècnica de Catalunya, Spain, (15) Laboratoire d'Astrophysique de Grenoble, France

Abstract

The detection and investigation of extended hydrogen atmospheres around extrasolar planets provides very promising insights into the interaction of the host star with the planet as well as the evolution of these planets and their atmospheres. There are different scenarios in the evolution of an Earth-like planet, during which hydrogen coronae can occur. Strong stellar activity influences the size of the planetary exosphere, producing highly energetic atoms (ENA). Measuring the size of the extended atmosphere and determining the velocities of hydrogen atoms, the influence of stellar wind on planetary atmospheres can be studied. We are considering M-type stars, because the majority of stars in our neighbourhood belongs to this type, and they exhibit strong stellar activity for very long time scales. Current detection methods are sufficient to be able to investigate hydrogen exospheres around small terrestrial planets orbiting low-mass stars.

1. Introduction

Exoplanets with expanded hydrogen atmospheres can be detected in the Lyman-alpha line at 121.567 nm. For ENAs to be produced there has to be a substantial amount of hydrogen extending outward a planet's magnetopause where interaction with stellar wind particles can take place. The determination of hydrogen velocities allows us to draw conclusions about the properties of the stellar wind at the location of the planet and the atmospheric hydrogen mass loss rate [1]. The presence of a hydrogen cloud around a terrestrial planet can be explained by several scenarios, depending on the composition of the atmosphere. Geochemical and biological processes may lead to the formation of an extended hydrogen atmosphere [2,4,5,6]. Stellar wind produces additional absorption features, making it possible to distinguish between hydrothermal and stellar-wind induced mass loss and to observe stellar wind conditions at the location of extrasolar planets [1]. Due to the large number of M-type stars in our neighbourhood, their comparably long periods of strong stellar activity and their size ratio favourable for the transit detection of low-mass planets, M-type stars represent the most promising candidates for the investigation of ENAs and the subsequent study of the interaction between the host star and the planets' atmosphere. Another important advantage of observing M-dwarfs is the fact, that their habitable zones are very close to the star [3], and therefore the transit probability for habitable planets is relatively high.

2. Method

We are using simple geometric relations to estimate the possibility of transit detection for terrestrial planets orbiting low-mass stars. The scale height of the planetary atmosphere scales reciprocally with the mass of the planet. This means, that a smaller planet will exhibit a larger extension of its hydrogen atmosphere. Therefore an Earth-analogue closely orbiting an M-dwarf can be expected to exhibit a hydrogen corona with a scale height of up to ten

Earth radii [9]. In the observation of the extrasolar giant planet HD 209458b the hydrogen thermosphere-exosphere of about 3 planetary radii resulted in a dip in the light curve of 15% [8]. HD209458 is a sun-like G0 star, but it is reasonable to assume that Lyman-α intensity can be similar for active M-stars [7]. Based on this assumption, we calculated estimations of transit signal depth for a range of M-type stars with Earth-like planets. The results suggest that it should be possible even with current generation instruments, to detect and investigate hydrogen exospheres of only a few Earth radii around planets orbiting stars as faint as spectral type M7.

6. Summary and Conclusions

Transit observations of M-type stars in the UV-range provide a unique opportunity to study the interaction of stellar activity and planetary atmospheres, as well as it sheds light into the evolutionary stage of these exoplanets and their atmospheres. M-dwarfs are especially suited for this type of research, as they represent the majority of stars in our neighbourhood, and exhibit strong stellar activity, including in the Lyman-α range for very long time scales. The star-to-planet radius ratio is also more favourable towards terrestrial planets with extended hydrogen coronae around M-stars, making them ideal targets for investigating the interaction between stellar wind and planetary atmospheres. Due to their habitable zones being very close to the host star and the higher transit probability for close-in exoplanets, M-type stars are also suited to study the influence of stellar wind on the atmospheres of habitable planets.

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