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The past rotation history of Kepler-11 revealed by the present atmospheres of its planets: advantages of the multi-planet approach

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Abstract

Planet atmospheric escape induced by high-energy stellar irradiation is a key phenomenon shaping the structure and evolution of planetary atmospheres. Therefore, the present-day properties of a planetary atmospheres are intimately connected with the amount of stellar flux received by a planet during its lifetime, thus with the evolutionary path of its host star.

Recently we developed the method, where using the analytic approximation based on hydrodynamic simulations for atmospheric escape rates, we track within a Bayesian framework the evolution of a planet as a function of stellar flux evolution history, constrained by the measured planetary radius [1]. We find that the ideal objects for this type of study are close-in sub-Neptune-like planets, as they are highly affected by atmospheric escape, and yet retain a significant fraction of their primordial hydrogen-dominated atmospheres. In [1] we tested the method for the wide range of parameters, finding the range of applicability, and then applied it to two real systems, each containing one planet appropriate for our analysis (in sense of its parameters and observational uncertainties).

Kepler-11 system hosts six closely packed planets of sizes between super-Earth and sub-Neptune orbiting the Sun-like star [2], [3]. At least five of them fall in the range of parameters which allows the use of our approach, except the outermost planet where only the upper limit for the mass is known. Using the multi-planet approach allows to better constrain the past rotational history of the star.

Given by initial studies [2], [3], the planets in system have an average densities between 0.6 and 1.7, what is very different to the planets in Solar system. The later work [4] reanalyses the properties of the star and arriving to higher planetary masses and densities, but yet much lower than planets in Solar system at the similar orbital distances.

All together, it makes Kepler-11 system particularly interesting for our study. We present the method and testing results, and results obtained for Kepler-11 system.

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