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Stellar winds and cosmic rays near terrestrial exoplanets

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Abstract

Stellar winds and cosmic rays are an important factor which determine the radiation Earth environment. Last years several terrestrial planet candidates were discovered and it seems to be essential to clarify radiation conditions near them too. We present estimations of stellar wind parameters based on the Parker model, possible fluxes and fluencies of cosmic rays based on the available data of stars' activity and magnetic field.

1. Introduction

The discoveries of terrestrial extrasolar planets candidates started the discussions of life conditions and possible conditions for habitable zone (see for ex. [1, 2, 3] and references within). Star winds and cosmic rays as a factor of space weather were almost omitted in consideration and took into account possibly by one group [4].

The influence of Galactic cosmic rays (GCR) on the planetary magnetic field was considered in different papers [5, 2]. For example in paper [3] atmospheric implications of cosmic rays near extrasolar Earth-like planets was studied and it was supposed that for such planets the GCR rays flux can be regarded as an isotropic and approximately constant as near the Earth. However stellar wind velocity and magnetic field as well as an activity of other stars (especially red dwarfs) might be considerably higher in comparison with solar values, the modulation of GCR might be much stronger.

Also it should be mentioned that the stellar cosmic rays, which are not detectable (or distinguishable) far away from their parent star may considered as an important factor of space weather in a habitable zone of star (see [6] and references therein). For our estimation of the cosmic rays level we use approach based on the first physical principles assuming solar-stellar analogies. We use simple equations, which have been proposed in the beginning of space era and may give the necessary answers with accuracy of factor 2–3. The main reason for using this approach is that our knowledge about stellar activities the same as the knowledge of the Sun environments in the beginning of space era in 1950th.

2. The model and methods

According to model developed by Parker [7] we may estimate a sound speed as a function of the coronal electron temperature $u_{cr} = \sqrt{2kT_e/m_p}$, a distance to the critical point $r_{cr} = GM/u_{cr}^2$ and stellar wind velocity $V_{SW} \approx u_{cr} \ln(r/r_{cr})$.

Using the velocity of stellar wind it is possible to estimate its density and derive a coronal temperature for which the critical point of stellar wind is at the coronal boundary

$$T = \frac{Gm_p M(\sqrt{3}-1)}{4kR_*},$$

i. e. the maximal temperature for a quite corona.

Using the stellar wind parameters we may estimate the radius of the astrosphere $R_{AS} = R_b(m_p n V^2/P_{ISM})^{1/2}$, where $P_{ISM} = 0.17$ eV cm^{-3} is the energy density of local interstellar medium.

In paper [8] was suggested that the modulation of GCR by solar wind occurs inside the solar wind shell, which extends uniformly and with spherical symmetry, from a solar distance $r = r_1$ out to $r = r_2$. Following Parker we may estimate how the steady state cosmic ray density $j_0(\eta)$ inside the modulation shell is related to the galactic density $j_\infty(\eta)$ outside. It seems to be clear that larger values of stellar wind velocity [1] and shell should lead to stronger effects of GCR modulation.

3. Summary and Conclusions

In paper we discussed the stellar winds and cosmic rays as an important factor of space weather which determine radiation environment near planets. We used the available parameters and made estimates for stellar winds , possible fluxes and fluencies of galactic and stellar cosmic rays.

We obtained that the simple models, which were derived for the Sun in 1950^{th}–1960^{th}, can give the reasonable results for the parameters and conditions on the orbit of exoplanets. Using the available data we showed the level of cosmic rays activity in the habitable zone and influences of the stellar winds on it.

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