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Inference of Magnetic Fields and Space Weather Hazards of Rocky Extrasolar Planets From a Dynamical Geophysical Model

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Abstract. In this paper we have inferred the magnetic shielding characteristics and space weather hazards of selected potentially habitable extrasolar planets using a dynamical geophysical model from calculations of internal heat, phases of volcanism and planetary magnetic moments. The space weather hazards on the extrasolar planet Kepler-452b orbiting around a Sun-like star are found to be a minimum which enhances the habitability probability of this planet.

Keywords. Extrasolar planets, Volcanism, Planetary magnetic fields, Space weather hazards

1. Introduction

The time variation of internal heat of planetary bodies causes changes in magnetic field of these planets. We suggest that the operations of the planetary dynamos are intimately connected to major geophysical transitions, mantle dynamics and volcanism. From our previous studies (Varnana *et al.* 2021a,b) we could develop a model in which we could find close associations between geological time evolution of internal heat, volcanism and magnetic fields in rocky planets in our solar system. These results are applied to infer magnetic shielding and space weather hazards of selected extrasolar planets with possible rocky composition.

2. Calculations and Results

Geological time evolution of internal heat flux S in a rocky planet is given by the relation

$$S(t) = So\exp(-\lambda t) \tag{2.1}$$

So is the internal heat flux during the planetary formation and $\lambda(1.5 \times 10^{-17}\ s^{-1})$ is radioactive decay constant applied to chondrites (Turcotte and Schubert 1982). We have

Table 1. Inference of the phase of volcanism, magnetic shielding characteristics and space weather hazards in selected extrasolar planets.

Extrasolar planet	**Spectral type and age of a host star**	**Phase of volcanism**	**Magnetic shielding possibility and moment (A-m)^2**	**Space weather hazard in the planet**
Trappist 1-g	M, 7.6 Gyrs	Post-cessation	**Low**, 1.52×10^{20}	High
GJ 667C-c	M, 2 Gyrs	Early ascending	**Low**, 9.9×10^{20}	High
Trappist 1-e	M, 7.6 Gyrs	Post-cessation	**Low**, 8.2×10^{20}	High
Kepler 452-b	G, 6 Gyrs	Late ascending	**High**, 2.7×10^{23}	Low
GJ 667C-f	M, 2 Gyrs	Early ascending	**Low**, 4.77×10^{20}	High

inferred the time evolution of $S(t)$ in extrasolar planets using (2.1). Peak volcanism and cessation of major volcanism in solar system rocky planets happens when S reaches certain critical values in our model. Applying this to rocky extrasolar planets we can find different phases of volcanism in these planets. The magnitude of magnetic fields is significant only during active phases of volcanism in these planets. The average magnetic moment of an extrasolar planet depends on its angular momentum. From the best available data of mass and radii of selected potentially habitable extrasolar planets we have studied its thermal evolution, cessation and peak ages of volcanism and planetary magnetic moments (Durand-Manterola 2009). The space weather hazard on the extrasolar planet depends on both host star activity conditions (this is related to age for G type stars and rotation for M type stars) and planetary magnetic field shielding characteristics which is dynamical in nature. The results of our calculations are given in Table 1.

The main results of our study are:

(i) Using a dynamical geophysical model applicable for rocky planets we have inferred phases of volcanism and magnetic field characteristics of selected potentially habitable extrasolar planets.
(ii) The space weather hazards on these extrasolar planets are also inferred based on the knowledge of stellar activity conditions in their host stars and planetary magnetism.
(iii) The space weather hazard on the extrasolar planet Kepler-452 b orbiting around a Sun-like star is found to be the lowest which enhances the habitability probability of this planet.

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