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Influence of Sudden Change of Solar Mass in the PN Stage on the Orbit of Earth-Like Planet

Yunfeng Zhu, Caijuan Pan*, Dasheng Pan, Hongqiang Huang & Zhi-Fu Chen

Department of Physics and Telecommunication Engineering of Baise University, Baise 533000, China.

**e-mail: pancaiiuan@163.com*

Abstract. Assuming that the terminated mass is confined within the range 0.4551–0.5813$M_\odot$ when the sun is going to evolve into a white dwarf, the velocity of the sun projecting the shell in the PN stage is much greater than the revolving velocity of the earth-like planet, therefore, we think that the solar mass change is instantaneous.

Key words. Sun—orbit—dwarf.

1. Enveloping model on solar projection in the PN stage

The total solar mass is $(M_c + M_{env})$, where M_c is the mass of core, and M_{env} is the projecting mass of the enveloping layer. The shells hit the companion stars according to their own speed. Based on the study of Villaver & Stanghellini (2005), we assume that the initial velocity of the projecting material of the solar enveloping layer $v_{env0} = 2 \times 10^4$ km s^{-1}, and the velocity of the enveloping layer decays according to the exponential form

$$v_{env}(r) = v_{env0}e^{-\frac{r}{r_J}}, \tag{1}$$

where r is the position of the planet, and r_J is the distance of Jupiter.

2. Orbital eccentricity of the planet

When v_{env} is big enough, the physical radius of the collision cross section is approximately equal to R, therefore, the planets accept the matter $M_{env}\pi R^2/4\pi r_0^2$ coming from the solar shell. These matter hits the planets at a velocity v_{env}, and produce a radial momentum of the planet with a radius R.

The radial velocity obtained by the planets is

$$v_r = \frac{M_{env}R^2}{4r_0^2}v_{env}e^{-\frac{r}{r_J}}. \tag{2}$$

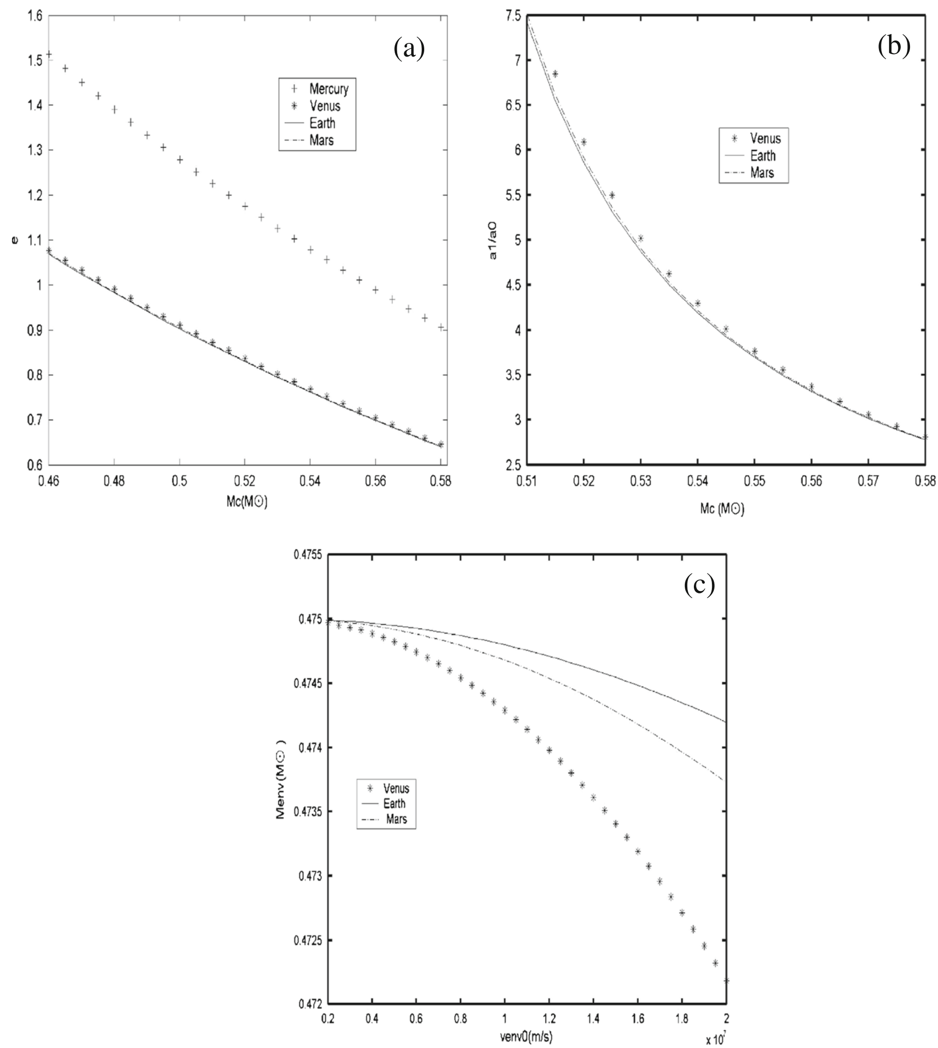

Figure 1. (**a**) The relation between the nuclear mass of the sun and the orbital eccentricity e of the earth-like planet. (**b**) The relation between the nuclear mass of the sun and the ratio of the semi-major axis of the elliptical orbit and the semi-major axis of the primary orbit of the earth-like planet. (**c**) The relation between the ejecting velocity of the solar shell and the shell mass when the earth-like planet moves along a parabolic path.

According to the relationship of the energy and eccentricity, we can obtain the planetary eccentricity due to the sudden change of solar mass as

$$e_1 = \frac{M_{\text{env}}}{M_{\text{c}}} \sqrt{1 + \frac{R^4}{16 m^2 r_0^3} \frac{(M_{\text{env}} + M_{\text{c}})}{G} v_{\text{env0}}^2 \mathrm{e}^{-\frac{r}{r_{\text{J}}}}}. \tag{3}$$

3. Orbital variation of earth-like planet

Considering the solar mass loss before the PN stage, the solar mass calculated in this paper is $0.95M_{\odot}$, the planetary distance increases 80% more than the present, and the initial projecting velocity of solar shell is 2×10^4 km s^{-1}.We take advantage of the results on stellar population in Han (1997). The final mass of a fixed star with mass $1M_{\odot}$ varies in the range 0.4551–$0.5813M_{\odot}$. We discuss the orbital variation of earth-like planetary. Under the model of the sun projecting the shell, the radial velocity of earth-like planet has the same order of magnitude as its revolving velocity. The orbital eccentricity of the earth-like planet varies in the range of 1.5457–0.6364, shown in Fig. 1.

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