Physics of Planetary Systems — Exercises

Astrophysikalisches Institut und Universitätssternwarte Jena
Thüringer Landessternwarte Tautenburg

Distributed: 2009-06-10; results due: 2009-06-17.

Set 7

Problem 7.1

Give three sources of "stellar noise" (i.e. radial velocity variability caused by the star and not by a planet) that limits one's ability to use radial velocity measurements to discover an exo-earth in a star's habitable zone. Also give the approximate time scales (approximate periods) and amplitudes of the noise sources. *(1 point)*

Problem 7.2

HD 4113b is a giant planet near the habitable zone of a G5 V star. The star has a radius of 1 $R_\odot$, a mass of 1 $M_\odot$, and a temperature of 5700 K. The planet has a period of 526.6 days and an eccentricity of 0.90. What is the equilibrium temperature of the planet at periastron (closest to the star) and apastron (farthest from the star) assuming an Earth-like albedo of 0.35? You can assume that the flux from the star is re-distributed across the planet surface. How habitable do you think this planet would be (or one of its satellites)? *(2 points)*

Problem 7.3

Instead of a 3-dimensional disk of planetesimals, consider a 2-dimensional one: all planetesimals are still spherical, but their centers all lie in one and the same plane. Following the 3D derivation given in the lecture, show that in such a flat disk the runaway growth is not possible. (Hint: systematically replace all 3D quantities in the formulas of runaway growth by their 2D counterparts.) *(3 extra points)*

Problem 7.4

Prove that the cross section for collision of a planetesimal with radius s and escape velocity at the surface $v_{\rm esc}$ with smaller "field" planetesimals, moving with velocities $v_{\rm rel}$, is $\sigma = \pi s^2 \left(1 + v_{\rm esc}^2/v_{\rm rel}^2\right)$. (Hint: a field planetesimal approaches the larger one in a hyperbolic trajectory with a certain impact parameter ("Stoßparameter") B and a speed $v_{\rm rel}$ at "local infinity". Derive a formula that relates B with the distance of closest approach and use it.) *(3 points)*

Problem 7.5

Assume the surface density of the planetesimal swarm in the early Solar System to be $\Sigma = 10$ g cm^{-2} at 1 AU and 3 g cm^{-2} at 5 AU. Estimate the mass and orbital separation of finished oligarchs at these distances.
(2 points)

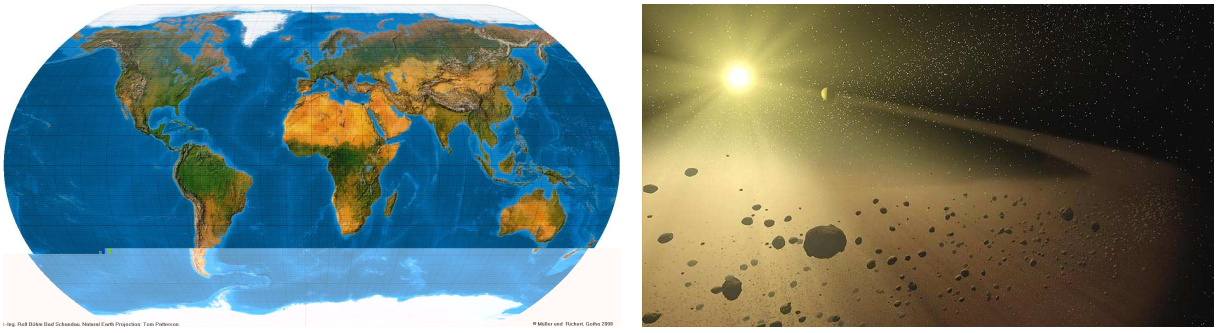

Figure 1: *(left)* "Color-coded" differential habitability on a known planet candidate…(© Müller und Richert, Gotha 2008). *(right)* An artist's impression of a planetesimal belt. (NASA/JPL-Caltech/T. Pyle, SSC)