# BUILDING STABLE STELLAR SYSTEMS WITH $\rho$ AS THE ONLY DATUM

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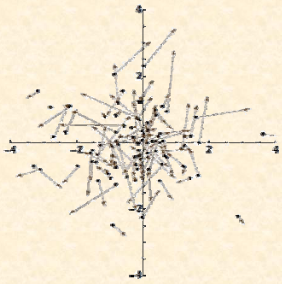
**Schwarzschild's method to set up a model galaxy is most useful when the distribution in velocity space is unknown. Nevertheless, one has to know beforehand beforehand which kind of orbits are spawned by the potential of the model. Moreover, although the system thus generated is in equilibrium, it isn't necessarily necessarily stable. Here we present a new method that allows to build up a stable stellar system without any previous knowledge of its distribution in velocity velocity space.**

## THE METHOD

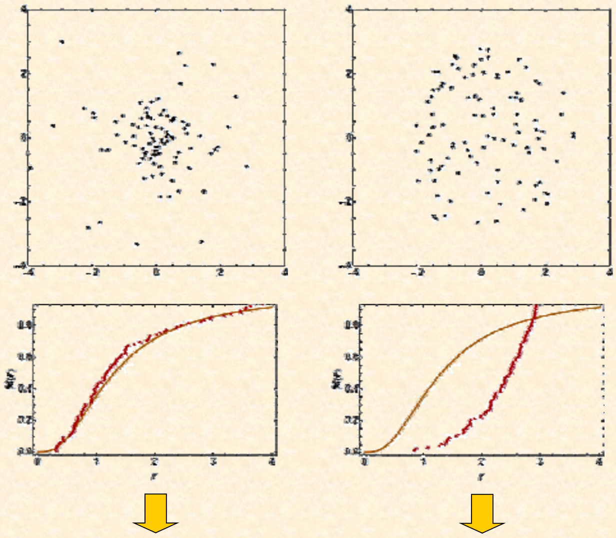
**Step 1:** Generate 100 stars following the density profile (in this example, a simple Plummer sphere).

**Step 2:** Give each particle a **random** velocity, i.e., no previous knowledge about the velocities is required. The moduli are chosen between 0 and $\sqrt{-2\Phi(r)}$.



**Step 3:** Advance each star in time by computing its orbit in the analytical (or eventually numerical) potential obtained from the density profile.

**Step 4:** Verify whether or not the final state of the previous integrations has kept the original density profile. If the answer is yes, the chosen velocities were right (left example below); otherwise the velocities were wrong (right example below).

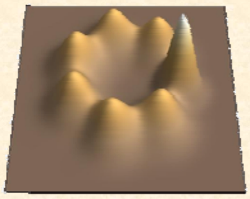


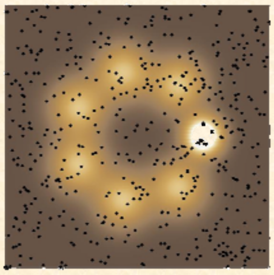
**Step 5:** Go to Step 1 and generate a new set of 100 stars to be added to the already built system.

**Step 5:** Choose *better* velocities (see next column), and go back to Step 3.

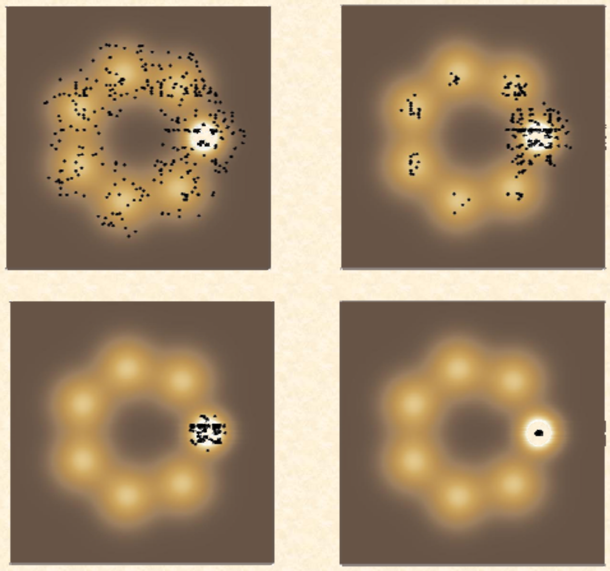
## THE ENGINE

How to choose better velocities? Using a **genetic algorithm**, i.e., an optimizer which searches for the maximum of some input function by combining (crossover) and changing (mutation) the digits of the values of the independent variables. Let's see it in action. Suppose we want to find the value of the maximum peak of the 7-peaked function depicted here:





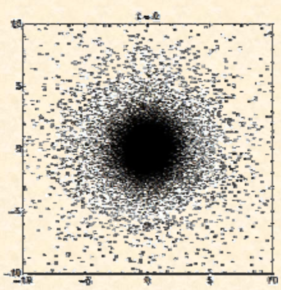
First, we fill the domain of the function with random values. Each point is an "individual" of the population. New points are generated by first selecting parents with a probability proportional to their fitness (in this case, the value of the function), then crossing their digits, and finally mutating some of those digits in order to allow the exploration of the entire domain. Thus, as new generations are bred, the population tends to better its overall fitness. Eventually, the fittest individual will lie at (or very close to) the maximum.



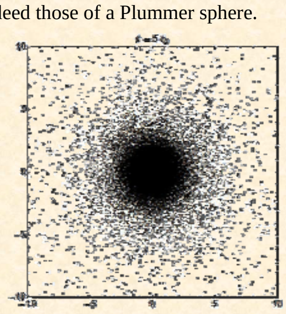
In our case, once the stars are advanced in time, we perform a Kolmogorov-Smirnov test over both the radii and the angles against the original density model. The resulting *L(z)* is the value of our fitting function.

## THE RESULT

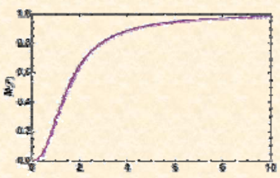
Here is a 50,000-particle Plummer sphere, with velocities generated as above.



After an evolution of 5 dynamical times, the system shows itself to be in equilibrium and stable, i.e., the original velocities are indeed those of a Plummer sphere.



The mass profile of the evolved system do correspond to a Plummer sphere: here are plotted the theoretical *and* the observed profiles.



The theoretical and observed profiles as a function of the energy (i.e., the defining function of a Plummer sphere) are also the same after 5 dynamical times. A Kolmogorov-Smirnov test gives *L(z)=0.76.*