

Double and Triple Stars

Solving the 3-Body Problem



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MICA (<http://www.mica-vw.org>)
Second Life, 2009-09-19

Stars in our galaxy are very far apart

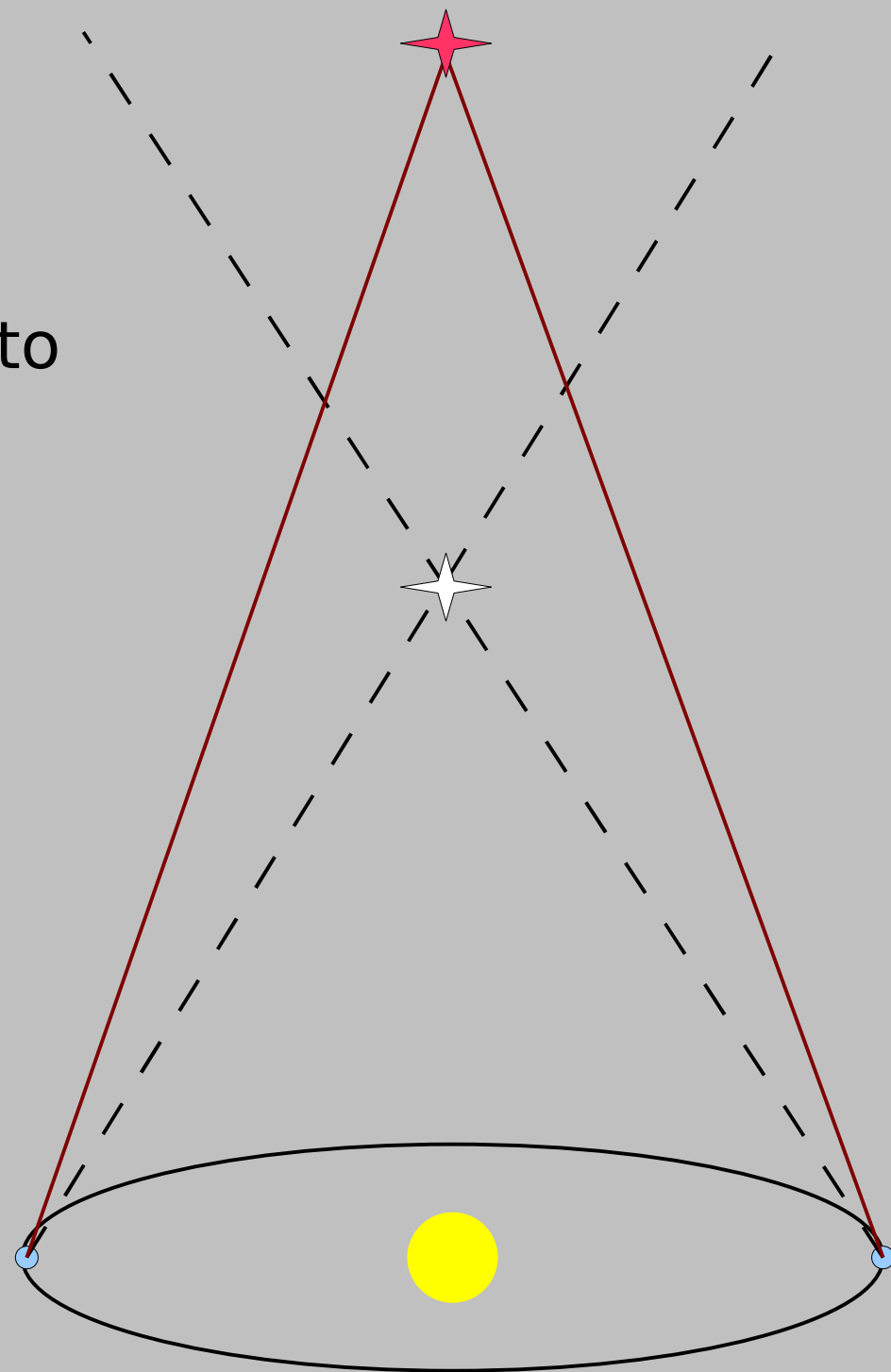
<u>Object</u>	<u>Scale model</u>	<u>Where</u>
Sun	Tennis Ball	Kansas City
Jupiter	Marble	35m away
Kuiper Belt	Sand	270m away
α Cent. A	Tennis Ball	New York

...so why do we care about star interactions?

William Herschel, 18th-19th Century

Tried to measure the distance to stars using *parallax*

“Double stars”, if chance alignments, would be an excellent source to observe to measure this.



Binary and Trinary Star Systems



61 Cygni

*(F. Ringwald,
CSU Fresno)*

Two K-stars in orbit
around each other
(period 660 years,
separation 80 AU),
~11 light-years
away.

Many (half of?) stars have at
least one companion. A
binary star system is a
system of two stars that
orbit around each other.



40 Eridani

2MASS 1.2 μ m Image

Globular Clusters



Achut Reddy/Flynn Haase/NOAO/AURA/NSF

Stellar densities at the core are high enough that stellar interactions can become significant.

The Physics of Star Orbits

As long as the stars don't get so close that they merge, or swap material, the physics of their orbits is governed entirely by gravity.

Newton's Law of Universal Gravitation

$$F = \frac{G M_1 M_2}{d^2}$$

F = Gravitational force between two objects

M_1, M_2 = mass of objects

d = distance between objects

G = Newton's Grav. constant

Newton's Second Law of Motion

$$F = m a$$

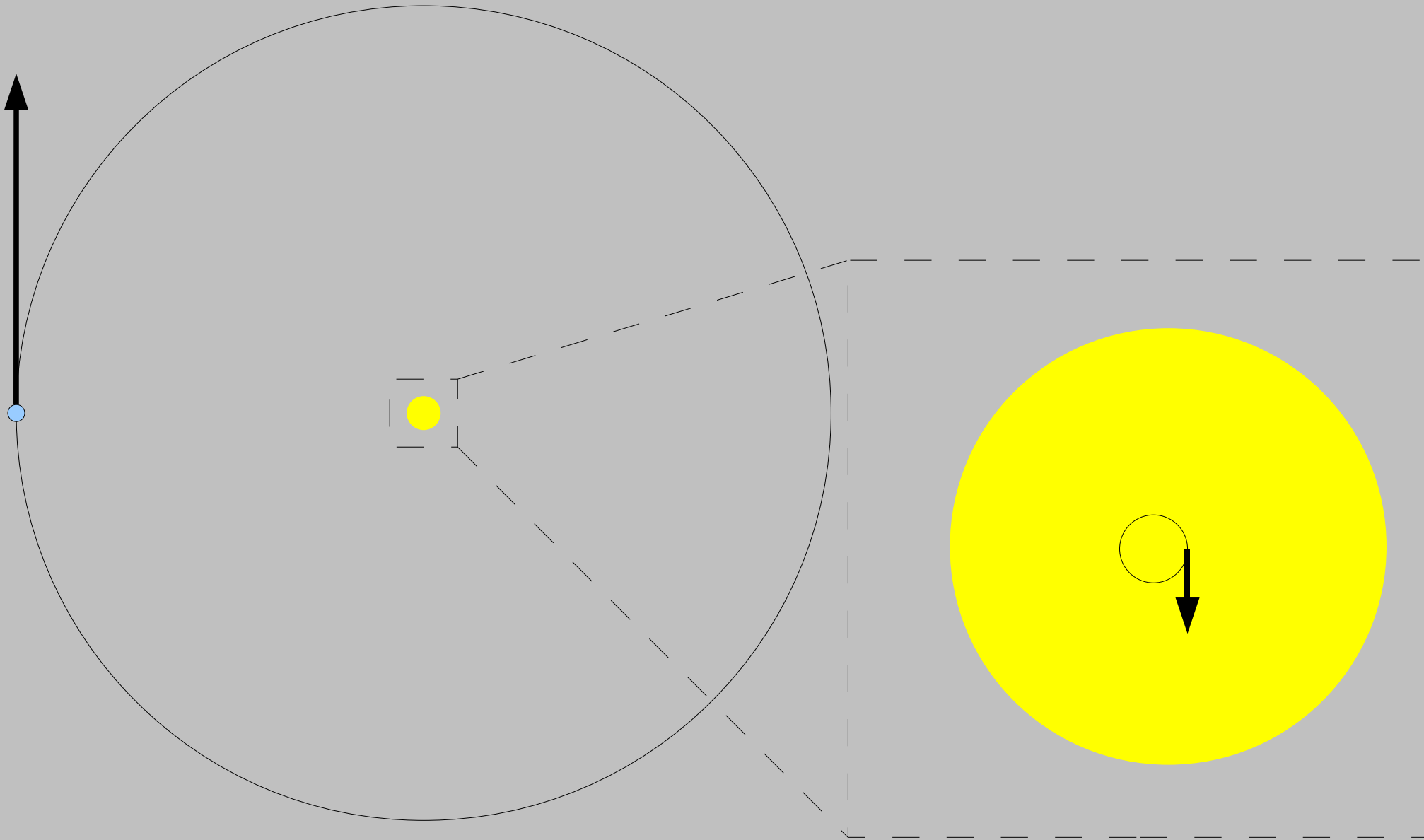
F = force on object

m = mass of object

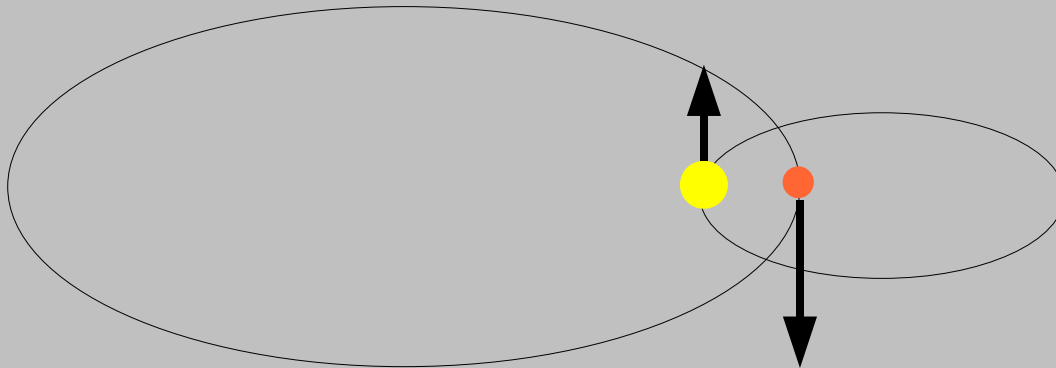
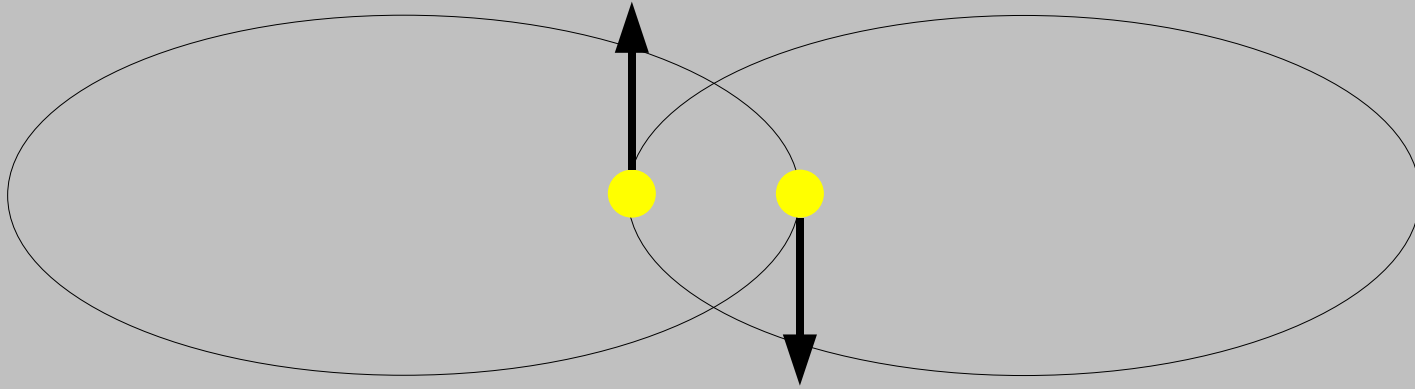
a = acceleration of object

The Two-Body Problem

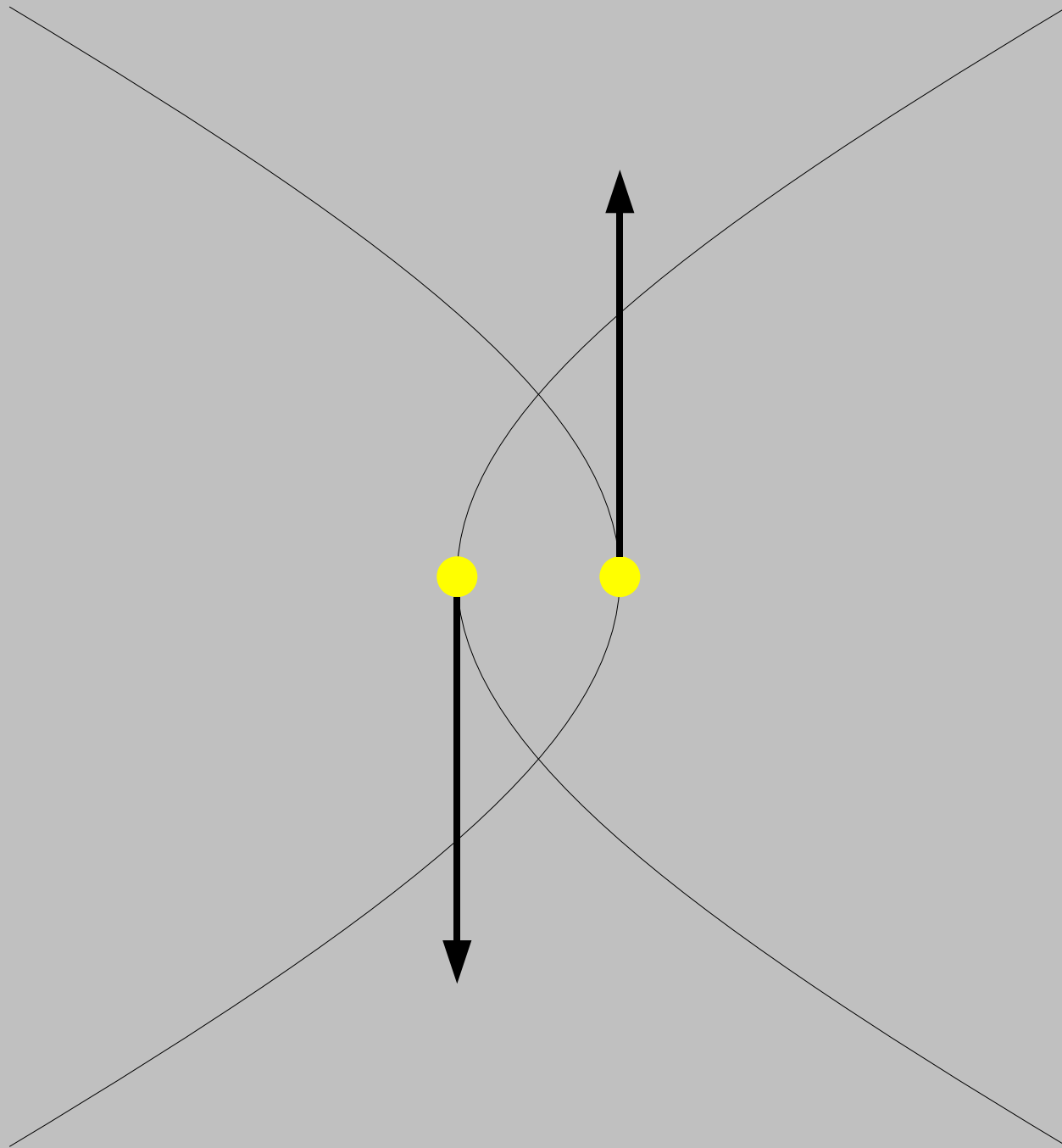
Only two objects = can be solved analytically



The Two-Body Problem

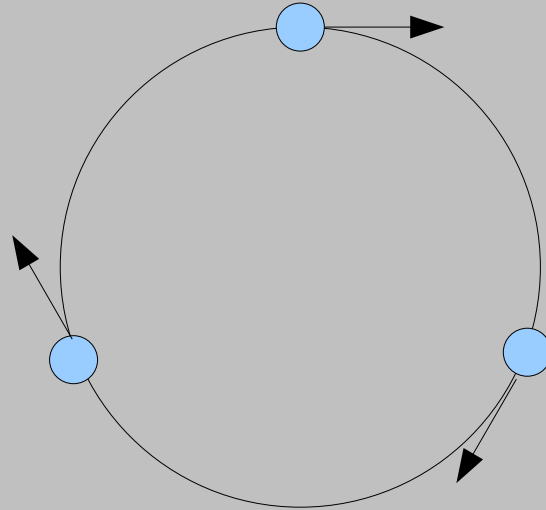


The Two-Body Problem



The Three Body Problem

You can write down an analytical solution for certain contrived situations, e.g.:



However, you cannot find an analytic function $x(t)$, $y(t)$, $z(t)$ that describes the motions of the three stars through space as you can with two bodies.

(The same applies for N bodies (where $N \geq 3$).)

Numerically Solving the Three Body Problem

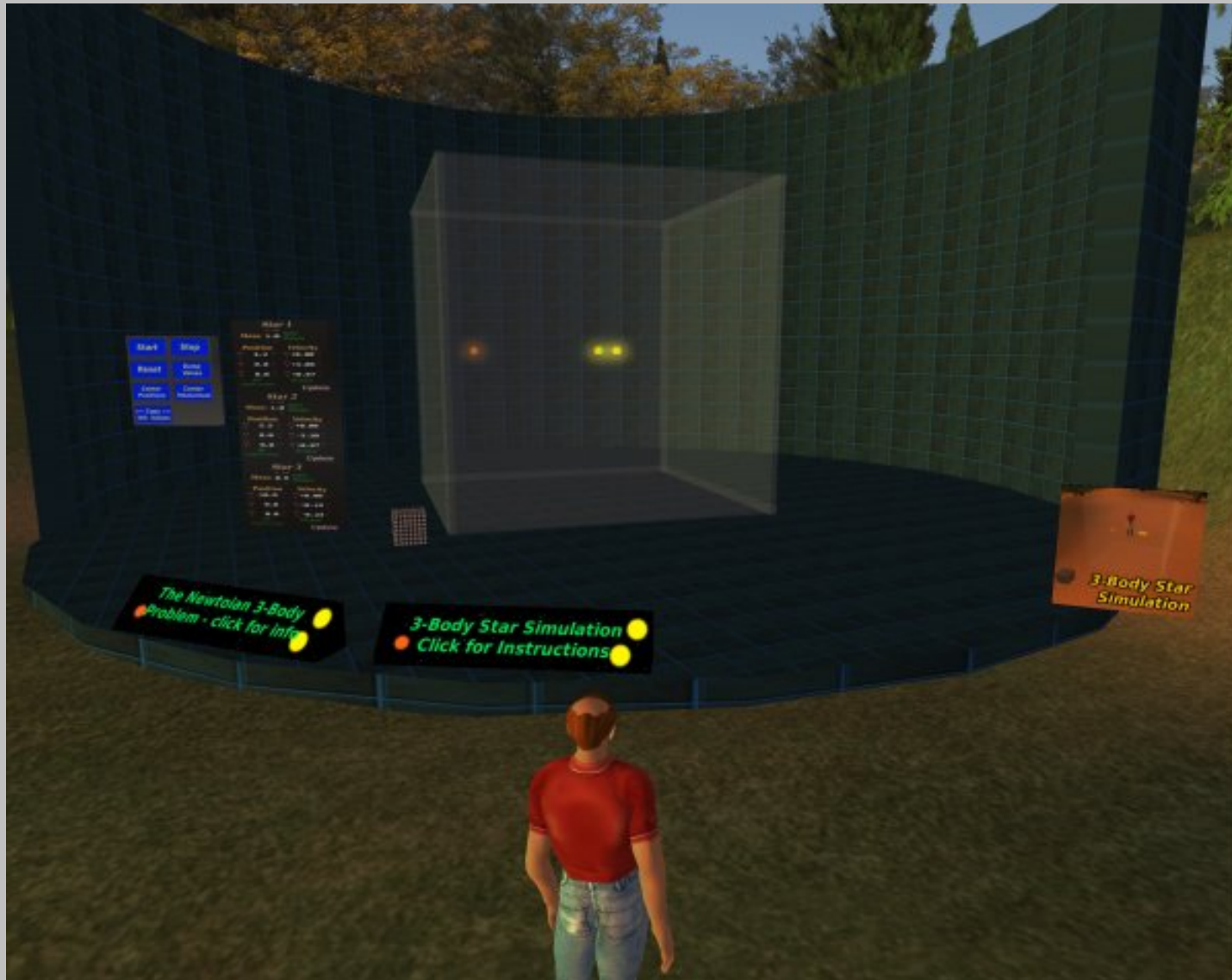
1. Start with an initial position $x(t=0)$ and velocity $v(t=0)$ for all stars.
2. Calculate the force (and thus acceleration) of all stars based on their given positions.
3. Update the velocity : $v(t+\Delta t) = v(t) + a\Delta t$
4. Update the position : $x(t+\Delta t) = x(t) + v\Delta t$
5. Repeat steps 2 through 4 over and over and over and over and over and over and....

This is a perfect solution only for $\Delta t \rightarrow 0$.

Thus, the smaller the Δt , the better.

You can use more sophisticated “integrators” (this is called the “Forward Euler” algorithm)

The MICA LSL 3-Body Simulator



StellaNova (211, 51, 26)

Epsilon Lyrae - the “double double”

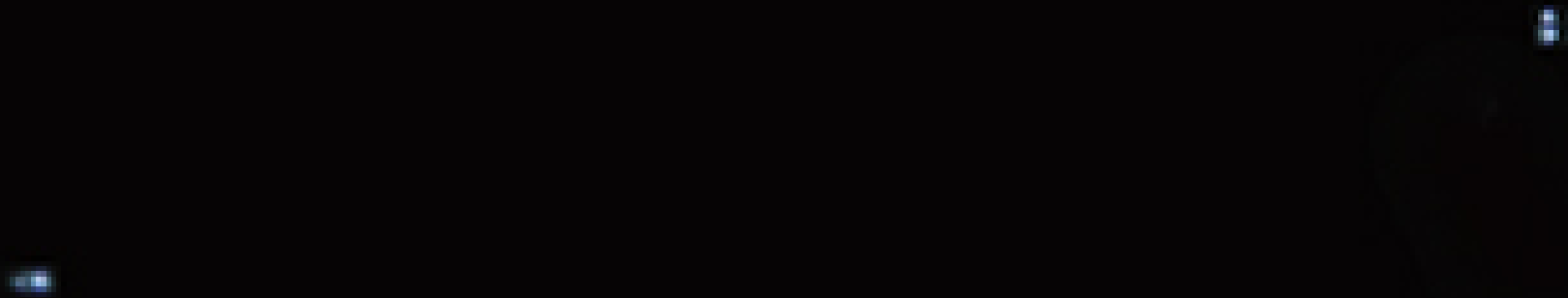


Image : <http://www.cosmicjourney.net/gallery.html>

3-Body Interactions

- Are chaotic; small changes in initial conditions can make big changes to the orbits later on.
- Require numerical solutions in general; only very special cases can be solved analytically.
- There are some (at least sort of) stable solutions, e.g. a star in a big orbit around a binary.
- When a single star collides with a binary:
 - ▶ One star is often ejected at high velocity
 - ▶ Two stars go off as a tighter binary
 - ▶ This can contribute to “core collapse” as well as flinging some stars to the outer part of Globbies.