gx - A program for simulating galaxy-collisions

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1 Introduction

This program supports a spatial modeling of galaxy interactions. It was developed because the forming of spiral arms is an interesting part of the *Galactic Astronomy*. The current version ($v1.2$) uses approximative equations of motion : The masses of the galaxies are unified in the centres of the disks and I use a number of test stars to indicate the individual stellar-motions in the halo. These stars indicate the formation of spiral arms after strong galaxy-interaction. There is no interaction between the test stars, so their equation of motion is equivalent with a restricted three body problem.

The integration of the equations of motion is very simple: see section 3.1 for more details.

The program supports many **UNIX** platforms: it was tested under *Linux, SunOS* and *Solaris*.

The program is able to present an animation in a window using the standard *X11R6* library. Optionally you can save pictures in *raw PBM* (or in *ascii PGM*) format.

2 Installing and running gx

The program is distributed in `tar.gz` format, you can untar it with:
`gzip -dc gx.tar.gz|tar xvf -`
Please read first the file COPYRIGHT. For compiling it, try simply: `make`. The program tries to find out under which platform will run. If an error occurs, edit Makefile. Probably you have to edit `config.h` for changing

some compile-time options. Its usage is very simple: you can set all the initial conditions of the galaxies by editing a file named `gx.in`. For running it, `cd` to the directory where `gx.in` is, and invoke the command: `./gxx`.

3 How it works

3.1 Equations of motion

The program uses the unit system of the celestial mechanics($\mathcal{M}_\odot$ for the mass, *mean solar day* for the time and *AU* for the distance).

The galaxies center's equations of motion are:
$\ddot{\mathbf{r}}_{1,2} = \mathbf{a}_{1,2}$, where $\mathbf{a}_1 = \frac{k^2\mathcal{M}_1}{|\mathbf{r}_2-\mathbf{r}_1|^3}(\mathbf{r}_2 - \mathbf{r}_1)$ and $\mathbf{a}_2 = \frac{k^2\mathcal{M}_2}{|\mathbf{r}_2-\mathbf{r}_1|^3}(\mathbf{r}_1 - \mathbf{r}_2)$.
Supposing that over small Δt time intervals $\mathbf{a}_{1,2}$ is constant, we obtain:

$$\mathbf{r}_{1,2}(t+\Delta t) = \mathbf{r}_{1,2}(t) + \mathbf{v}_{1,2}(t)\Delta t + \frac{\mathbf{a}_{1,2}(t)}{2}(\Delta t)^2,$$

where $\mathbf{v}_{1,2}$ is the velocity, and: $\mathbf{v}_{1,2}(t+\Delta t) = \mathbf{v}_{1,2}(t) + \mathbf{a}_{1,2}\Delta t$.
The test star's equations of motion are:
$\ddot{\mathbf{r}}_i = \mathbf{a}_i$, where $\mathbf{a}_i = \frac{k^2\mathcal{M}_1}{|\mathbf{r}_1-\mathbf{r}_i|^3}(\mathbf{r}_1 - \mathbf{r}_i) + \frac{k^2\mathcal{M}_2}{|\mathbf{r}_2-\mathbf{r}_i|^3}(\mathbf{r}_2 - \mathbf{r}_i)$.
Similarly:

$$\mathbf{r}_i(t+\Delta t) = \mathbf{r}_i(t) + \mathbf{v}_i(t)\Delta t + \frac{\mathbf{a}_i(t)}{2}(\Delta t)^2, \quad \mathbf{v}_i(t+\Delta t) = \mathbf{v}_i(t) + \mathbf{a}_i\Delta t.$$

3.2 Initial conditions

It uses an O_{xyz} mass-central reference frame . The initial conditions of the galaxies are:

$$\mathbf{r}_1(0) = \begin{bmatrix} 0 \\ -a \\ -b \end{bmatrix}, \mathbf{v}_1(0) = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix},$$

$$\mathbf{r}_2(0) = \begin{bmatrix} 0 \\ y_0 - a \\ \rho - b \end{bmatrix}, \mathbf{v}_2(0) = \begin{bmatrix} 0 \\ -v_\infty \\ 0 \end{bmatrix},$$

where $a = \frac{\mathcal{M}_2}{\mathcal{M}_1+\mathcal{M}_2}y_0$ and $b = \frac{\mathcal{M}_2}{\mathcal{M}_1+\mathcal{M}_2}\rho$.

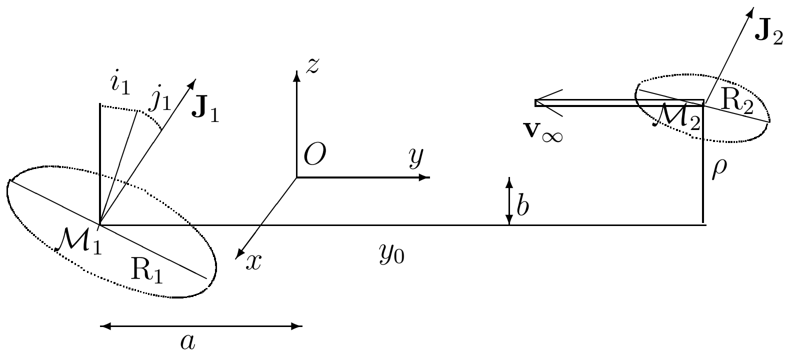

Figure 1: The galaxies and the O_{xyz} reference frame

There is a speciality in the initial conditions for the galaxies and the test stars:

$$(\frac{d\mathbf{J}_i}{dt})\Big|_{t=0} = \mathbf{0},$$

$$(\frac{d\mathbf{J}_{1,2}}{dt})\Big|_{t=0} = \mathbf{0} \Leftrightarrow \left((\frac{di_{1,2}}{dt})\Big|_{t=0} = 0 \ \& \ (\frac{dj_{1,2}}{dt})\Big|_{t=0} = 0 \ \& \ (\frac{d|\mathbf{J}_{1,2}|}{dt})\Big|_{t=0} = 0 \right),$$

where $\mathbf{J}$ is the angular momentum.

$\mathbf{J}$ is constant for the whole system, but not for the galaxies , for this reason $\mathbf{J}$ and the the symmetry-planes of the galaxies rotate $\Rightarrow$ the galactic longitude of the test stars change, $\Rightarrow$ the force acting on the test stars changes ($\Rightarrow$ the model is not exact...)

The initial conditions of the test stars are:

$$\mathbf{r}_i(0) = \mathbf{r}_{1,2}(0) + \mathcal{O}_{1,2}^{-1}(\mathbf{r}_i^{(1,2)}(0)).$$