6.S096 Lecture 9 – Visualization

OpenGL, Makefiles, Large Projects

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What is OpenGL?

The standard for most 2D/3D graphics rendering today.

`http://www.opengl.org/`

- Highly cross-platform (between OS, architecture, etc)
- Everything from decade-old computers to mobile devices today.
- An **abstract API** for drawing; bindings based in C
- Interface with the GPU graphics pipeline.

How do we get it?

There are a lot of really old (harmful!) tutorials out there.

These are good ones:

- Jason L. McKesson: `http://www.arcsynthesis.org/gltut/`
- opengl-tutorial: `http://www.opengl-tutorial.org/`
- WikiBooks

How will we use it?

I've written some wrappers for the initialization (both general GL and glut).

Let's look at the code (GlutWrapper.h)

OpenGL Display Function (jumping ahead)

```
glBindBuffer( GL_ARRAY_BUFFER, _positionBufferObject );
glBufferSubData( GL_ARRAY_BUFFER, 0,
                 sizeof( float ) * _bufSize, _buf );
glBindBuffer( GL_ARRAY_BUFFER, 0 );

glClearColor( 0.0f, 0.0f, 0.0f, 0.0f );
glClear( GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT );
```

OpenGL Display Function (jumping ahead)

```
glUseProgram( _program );
glBindBuffer( GL_ARRAY_BUFFER, _positionBufferObject );
glEnableVertexAttribArray( 0 );
glVertexAttribPointer( 0, 4, GL_FLOAT, GL_FALSE, 0, 0 );

glDrawArrays( GL_TRIANGLE_STRIP, 0, (GLsizei) _bufSize );

glDisableVertexAttribArray( 0 );
glUseProgram( 0 );

glutSwapBuffers();
glutPostRedisplay();
```

OpenGL Initialization

```
glutInit( &argc, argv );
uint32_t displayMode =  GLUT_DOUBLE
                      | GLUT_ALPHA
                      | GLUT_DEPTH
                      | GLUT_STENCIL;

glutInitDisplayMode( displayMode );
// We'll be using OpenGL 3.0
glutInitContextVersion( 3, 0 );
glutInitContextProfile( GLUT_CORE_PROFILE );
```

OpenGL: Buffer Objects

```
glGenBuffers( 1, &_positionBufferObject );
glBindBuffer( GL_ARRAY_BUFFER, _positionBufferObject );
//..etc
glBufferData( GL_ARRAY_BUFFER, 4 * bufSize,
              _buf, GL_STATIC_DRAW );
glBindBuffer( GL_ARRAY_BUFFER, 0 );
```

More in the code...

Let's look into the code...

Components

Requirements

25% **Physics Engine** - quality and extensibility of simulation code

25% **Visualization** - OpenGL; getting a good visualization working

15% **Unit testing** - gtest, quality and coverage of tests

15% **Software Process** - code reviews, overall integration of project

10% **Interactive** - user interactivity with simulation (keyboard, mouse, etc)

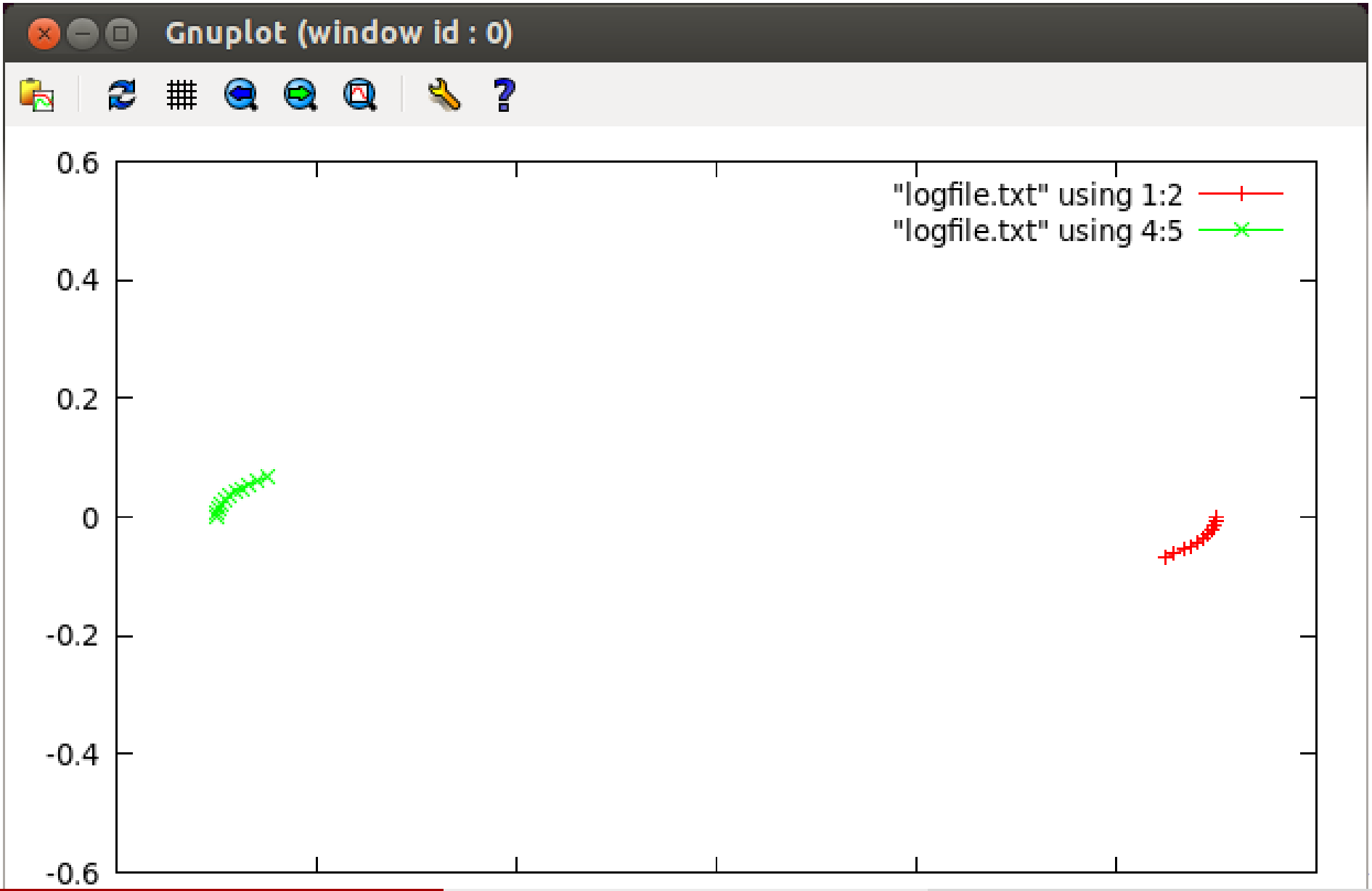
10% **Do something cool** - make it look cool, add a useful feature, do something interesting!

Extra 5% available in all areas for exceptional effort.

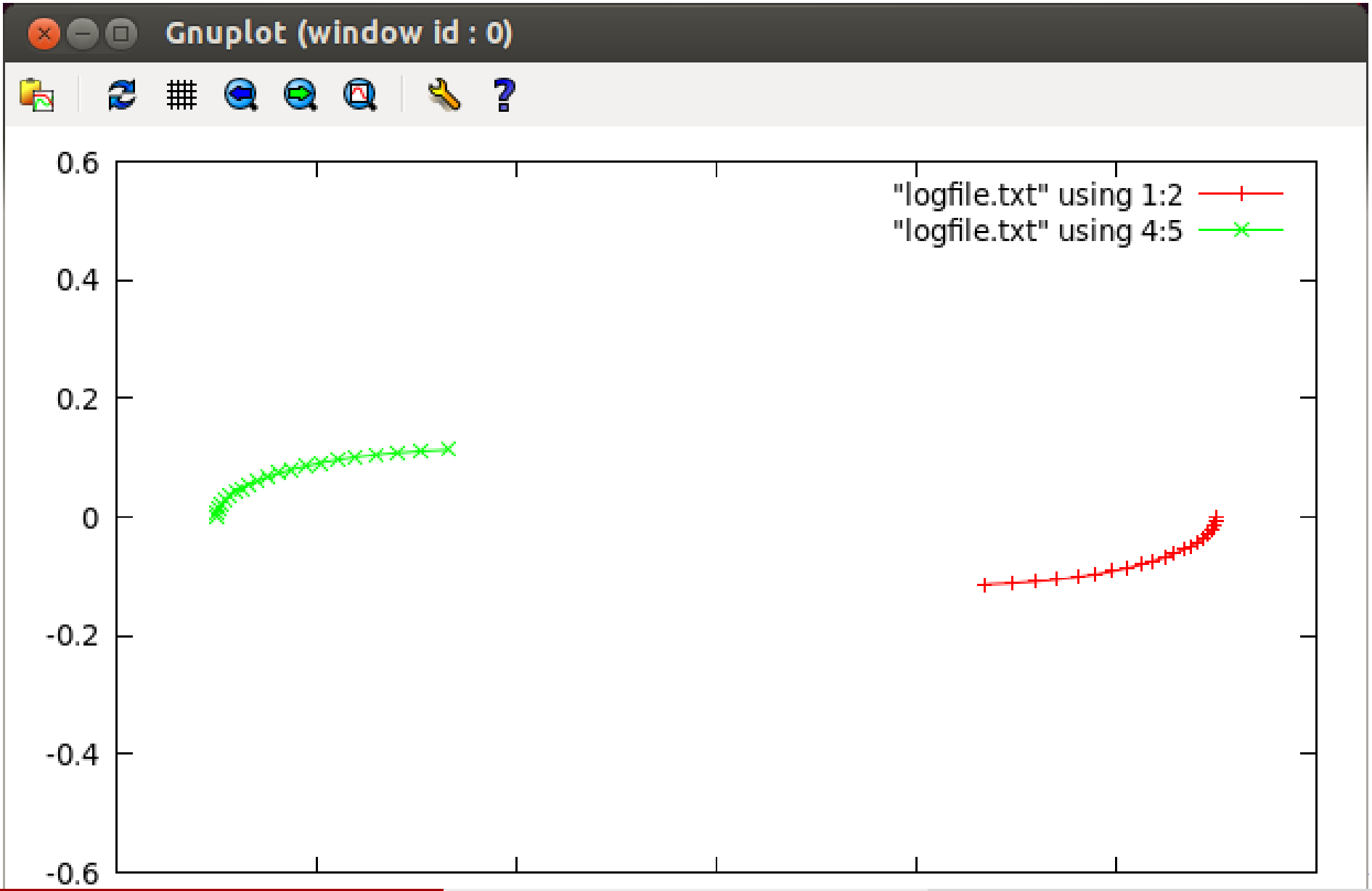
Physics Engine Inaccuracies

Your integrator should be improving on the basic; this is what the basic one does:

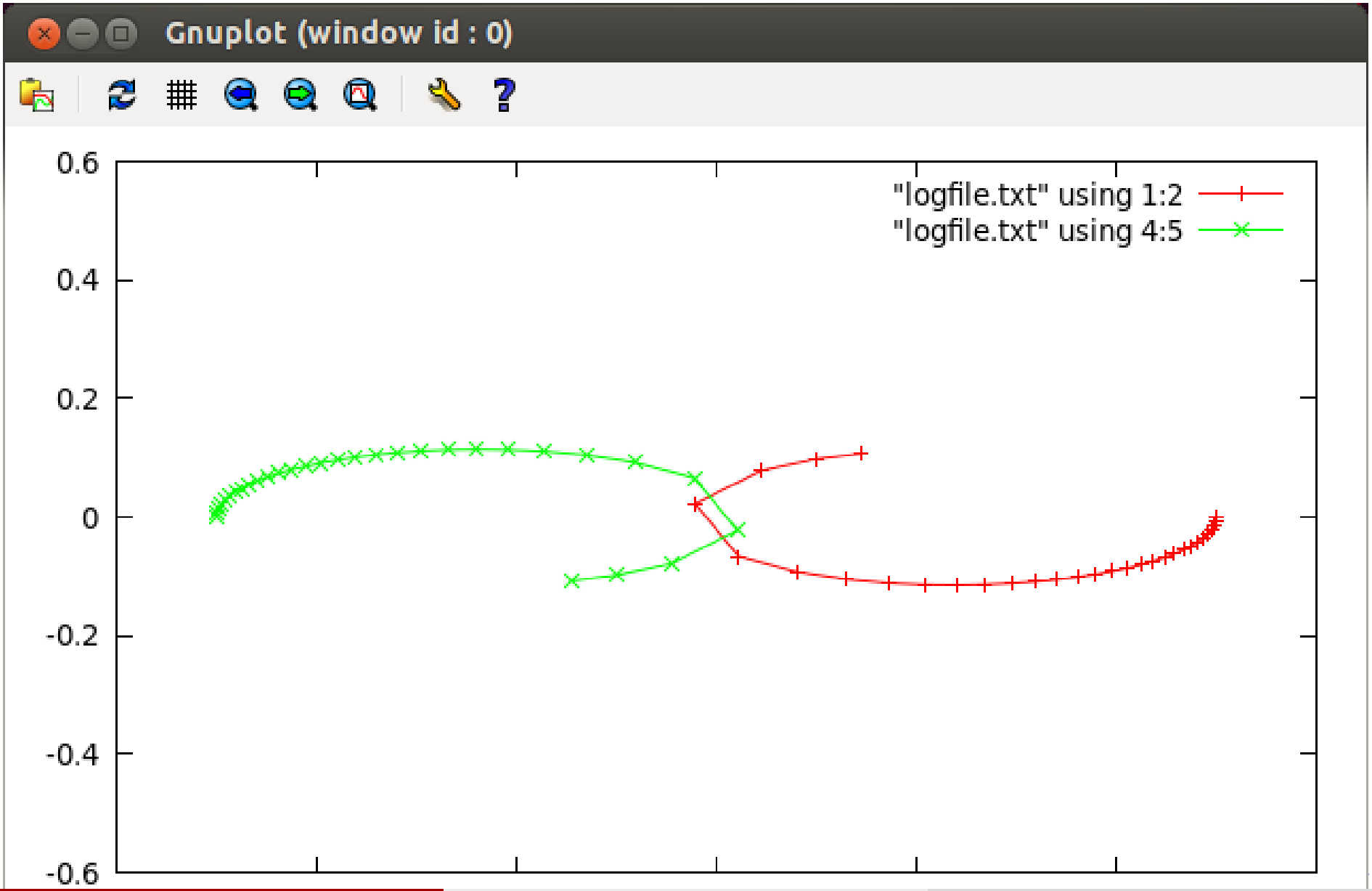
Binary Star System Example 1



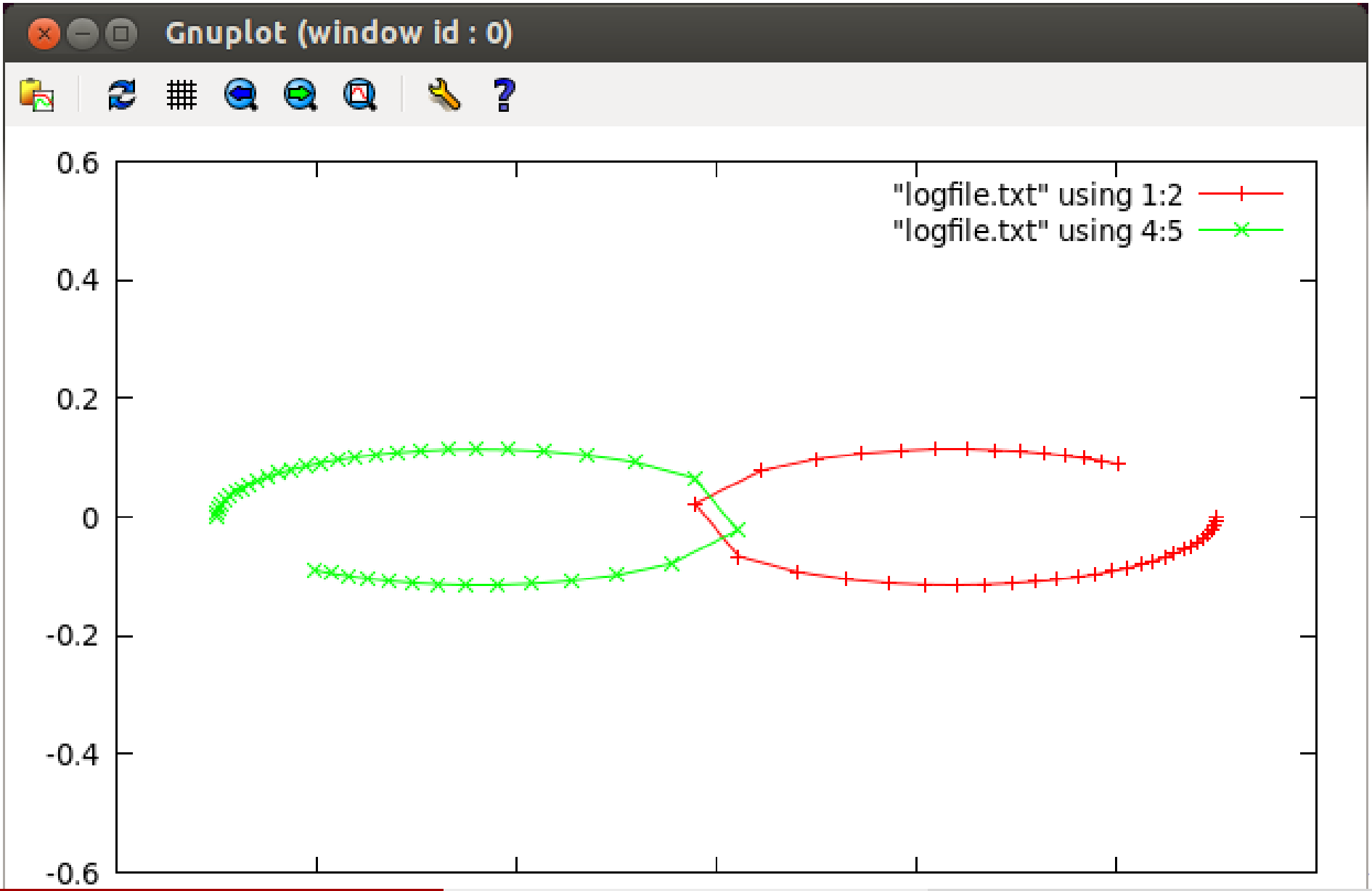
Binary Star System Example 2



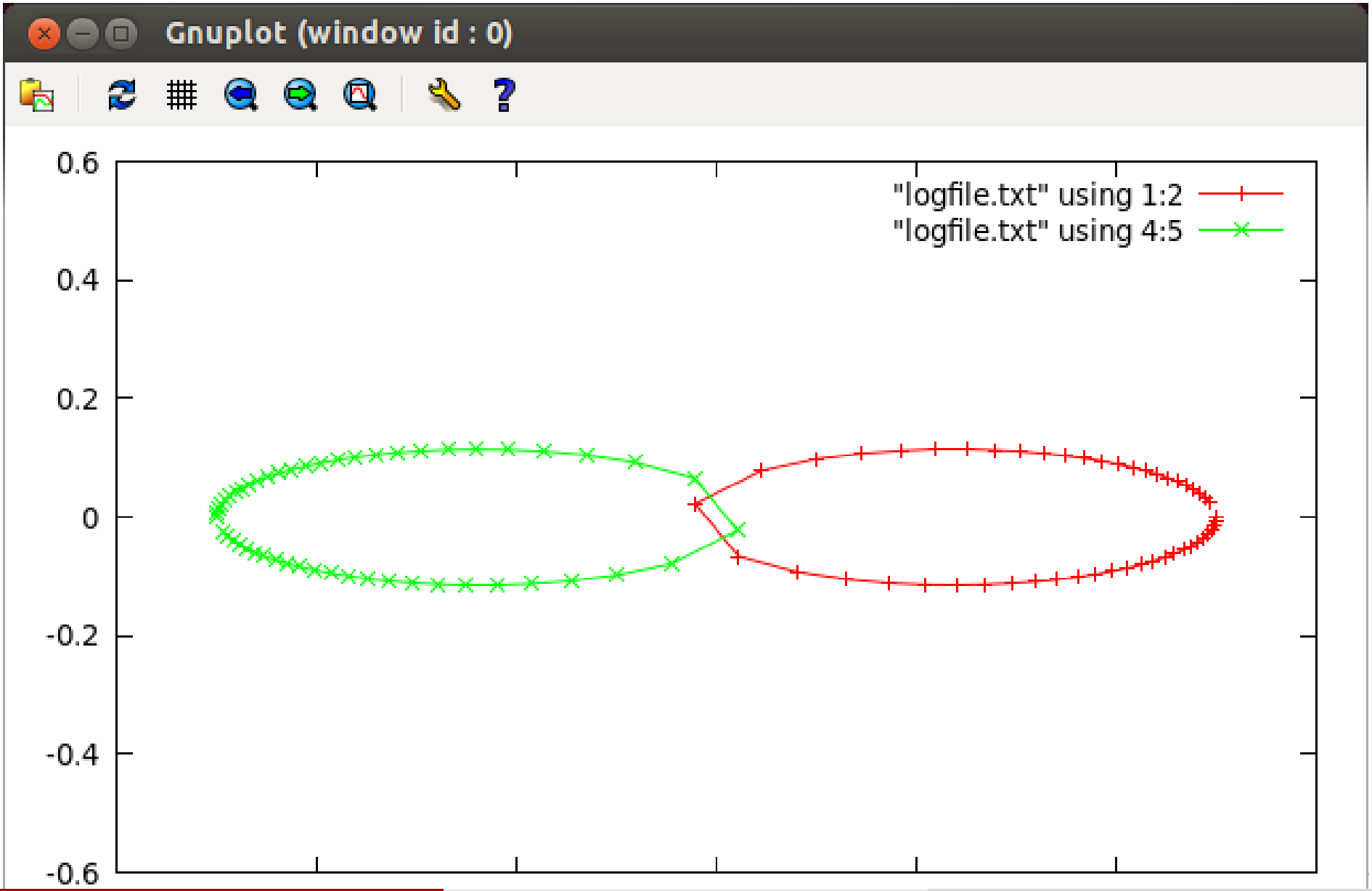
Binary Star System Example 3



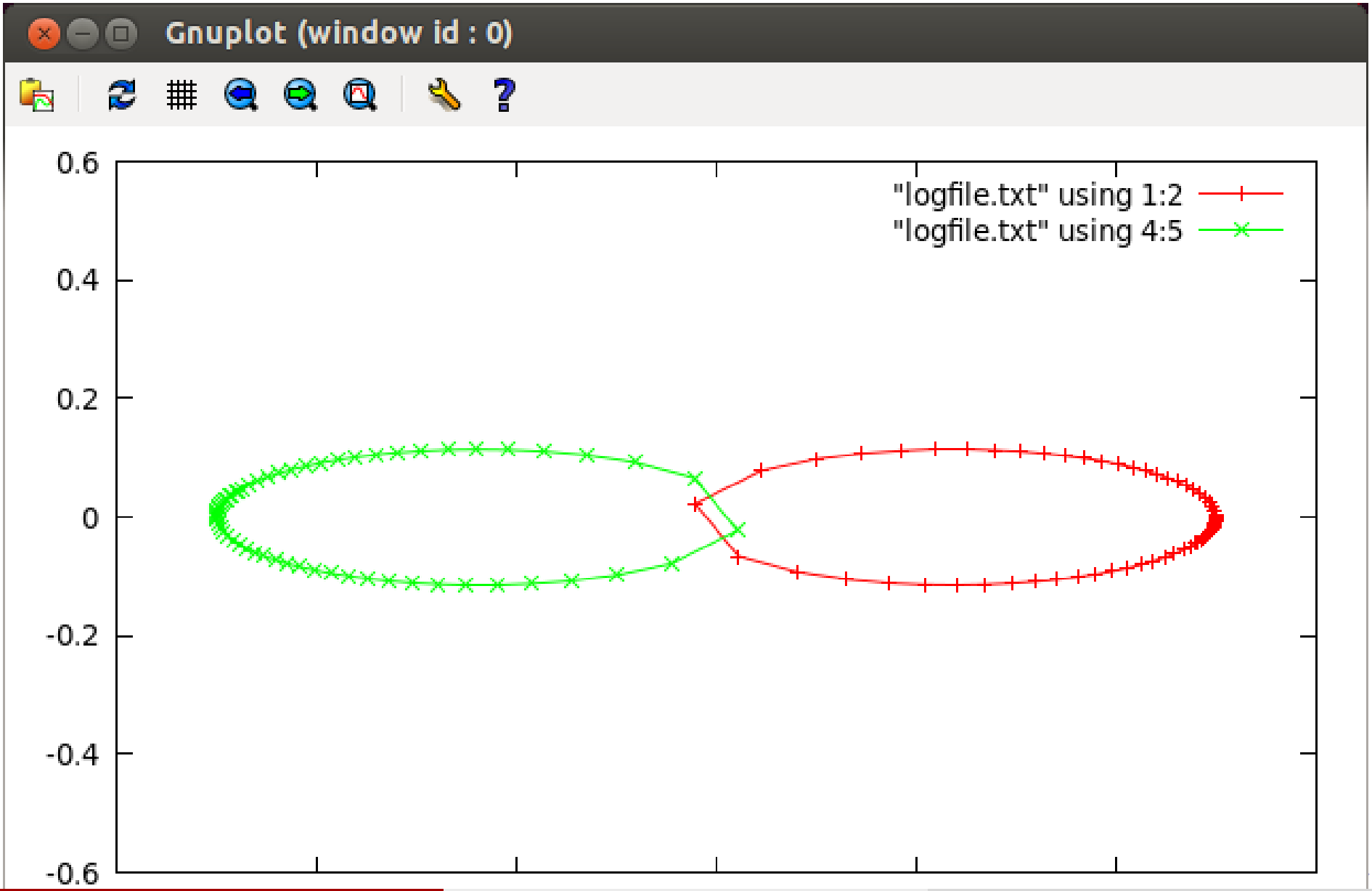
Binary Star System Example 4



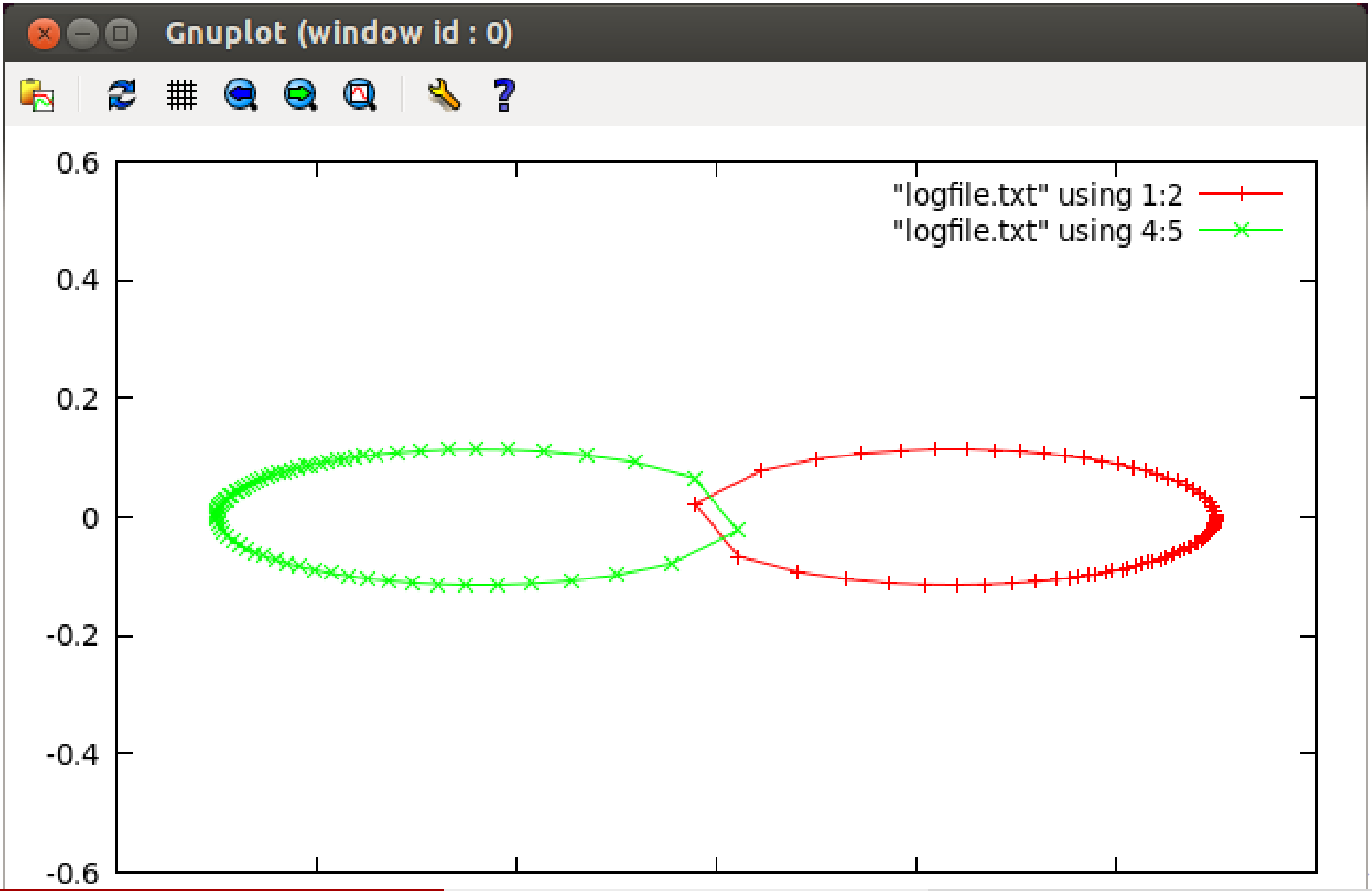
Binary Star System Example 5



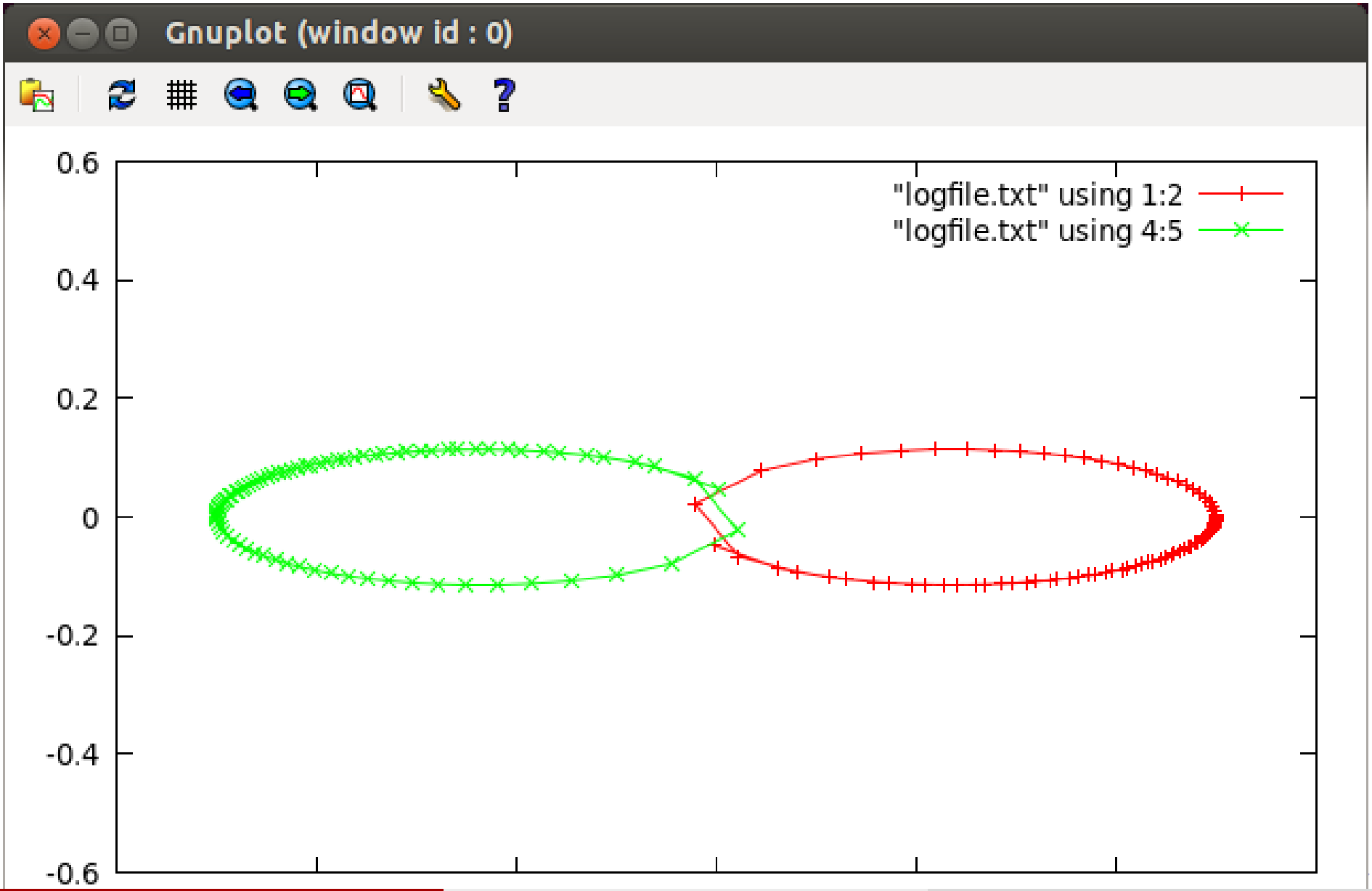
Binary Star System Example 6



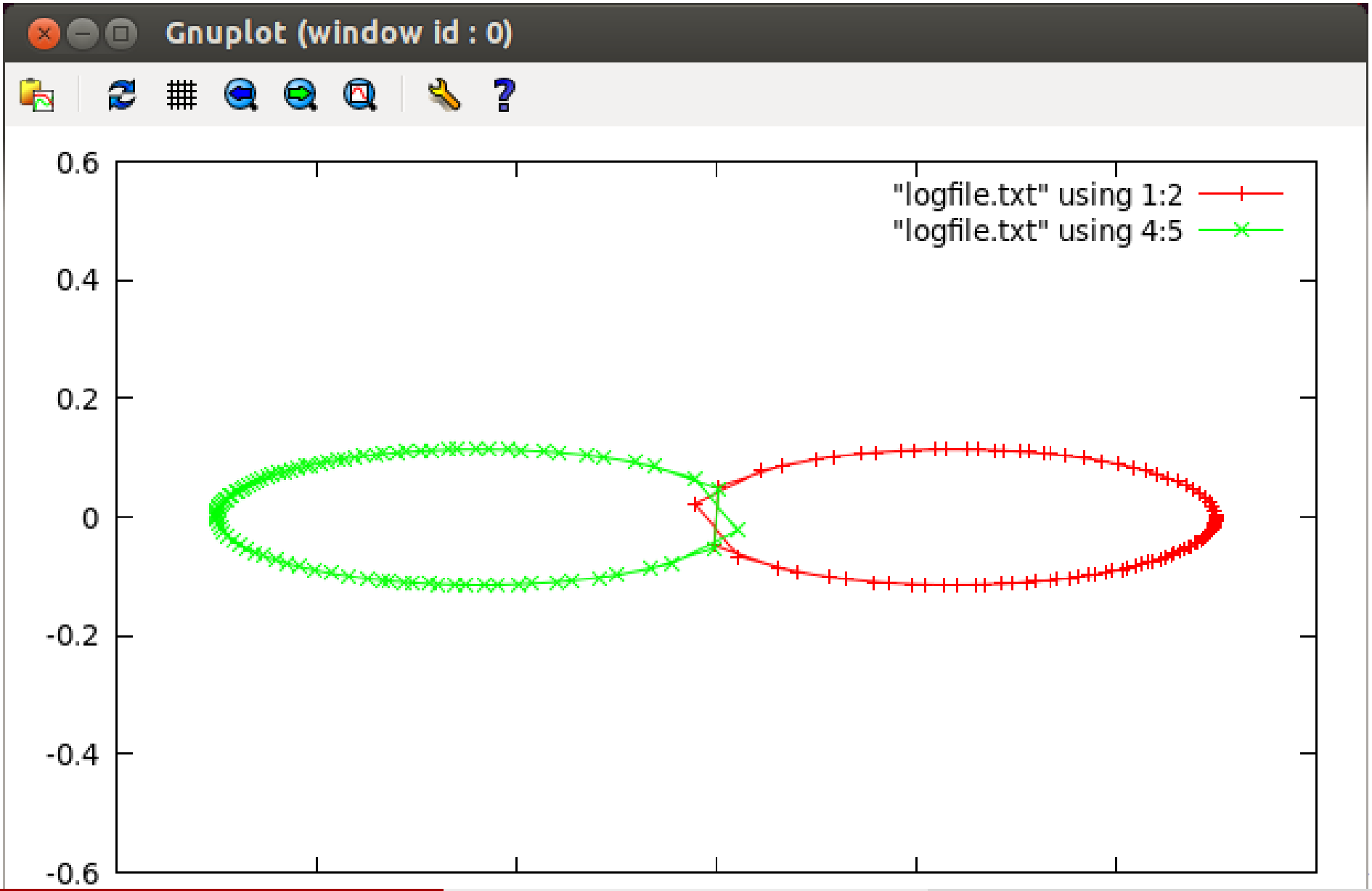
Binary Star System Example 7



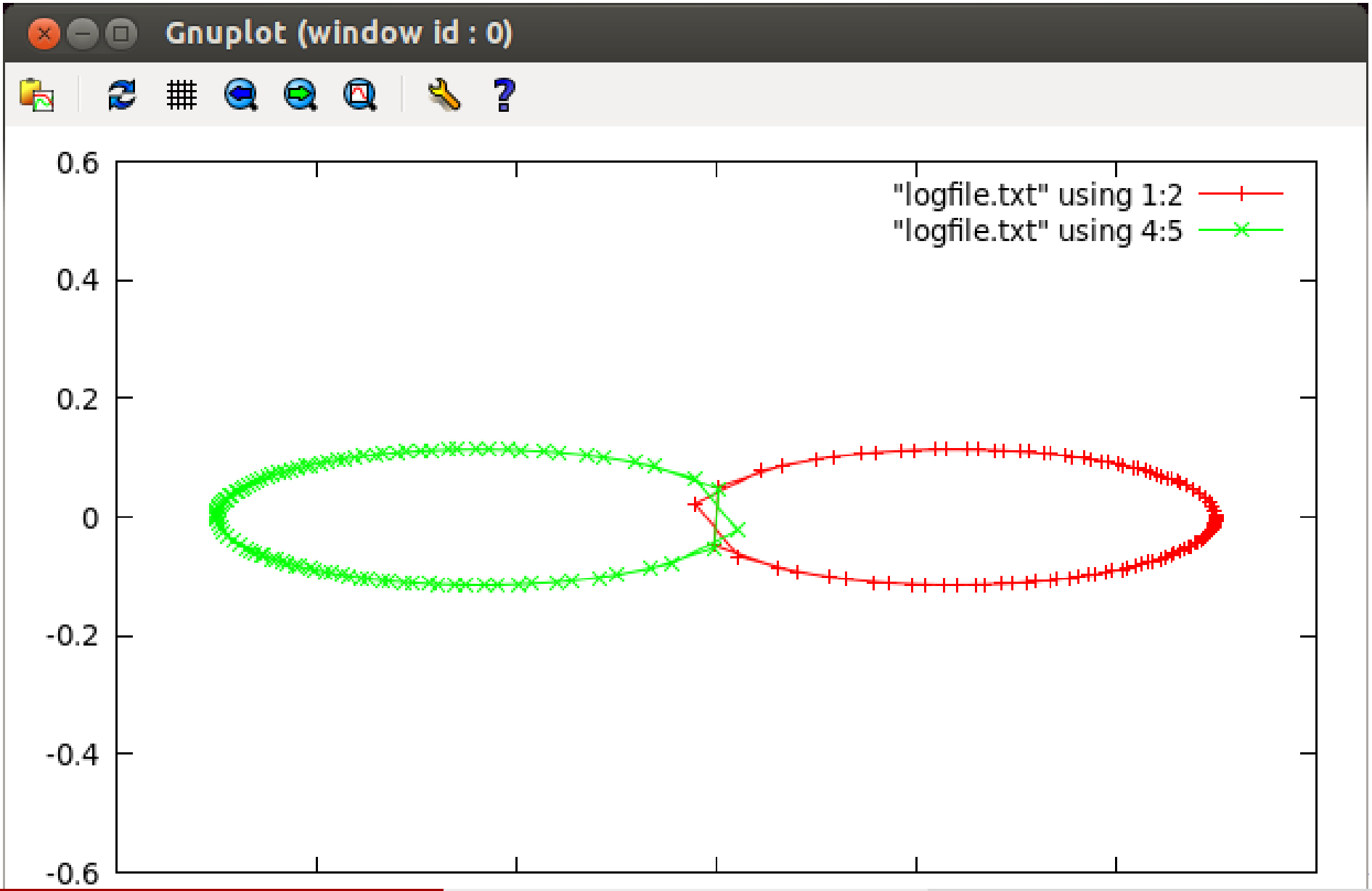
Binary Star System Example 8



Binary Star System Example 9



Binary Star System Example 10



Visualization

OpenGL!

Content Provided: Reminder

Vector3.h

So that you don't have to write (all) of your own vector math, feel free to use the header available at:
`http://web.mit.edu/6.s096/www/final/Vector3.h`.
It's a templated 3-d vector class that can be widely useful and is guaranteed fast ("plain old data type")

Content Provided - Vector3.h

```
template<typename T>
class Vector3 {
  T _x, _y, _z;
public:
  Vector3() : _x{}, _y{}, _z{} {}
  Vector3( T x_, T y_, T z_ ) :
    _x{x_}, _y{y_}, _z{z_} {}
  inline T x() const { return _x; }
  inline T y() const { return _y; }
  inline T z() const { return _z; }
  T norm() const;
  T normsq() const;
};
```

Reminder: the compilation process

1. **Preprocess**
2. **Compile**
3. **Link**

Code Reviews: what you send to me

- Your name and the name of the person whose code you are reviewing.
- The snippet of code you are reviewing: more than 30 lines, less than 100.
- Your comments interspersed in their code.
- A summary of main points relating to the review (what they did well, major areas for improvement, common issues, general observations).
- Send this to akessler@mit.edu, CC-ing the person being reviewed.

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You should choose a bite-sized chunk that will take you 45 mins to 1 hour to fully review.

Examples

Let's see some examples...

Wrap-up & Friday

Final project due Saturday 2/1 at 6pm.

Send me your code reviews tonight please!

Class on Fri. 1/29 is still in 34-101 at 2pm.

- Grab-bag: coding interviews, general perspective
- Bring all your C++ questions!

Questions?

- I'm available after class or on Piazza.
- Lab today in 32-044, 7-9pm
- We'll be covering more OpenGL and helping out with projects.