Using metaballs to model the pre-ringdown phase of the merger of Schwarzschild black holes

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Abstract

In this paper, Blinn's metaballs are used to model the pre-ringdown phase of the merger of Schwarzschild black holes.

1 Metaballs

Metaballs have been used in computer graphics ever since their discovery by Jim Blinn [1]. They were originally used to visualize electron density.

Where $G = c = \hbar = k = 1$, there is an analytical solution for the pre-ringdown phase of the merger of n metaballs (Schwarzschild black holes)

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travelling directly toward each other:

$$f(l) = \sum_{i=1}^{n} \frac{2M_i}{r_i}, \tag{1}$$

where M_i is the mass of the ith metaball, and

$$r_i = \sqrt{(l.x - v_i.x)^2 + (l.y - v_i.y)^2 + (l.z - v_i.z)^2}, \tag{2}$$

where l is the sample location, and v_i is the centre of the ith metaball. The isosurface (event horizon) is given by

$$f(l) = 1. \tag{3}$$

Included are figures of the pre-ringdown phase of a black hole merger. The isosurface was tessellated using the Marching Cubes algorithm [2]. Analogously, we seem to be visualizing graviton density.

The C++ code for this paper can be found at [3].

Another method for generating the isosurface is given in [4].

Figure 1: Two black holes of unit mass each, at a distance of 11.

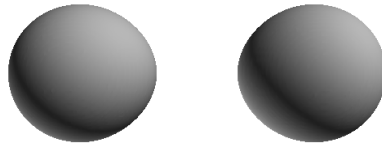Figure 2: Two black holes of unit mass each, at a distance of 10.

Figure 3: Two black holes of unit mass each, at a distance of 9.
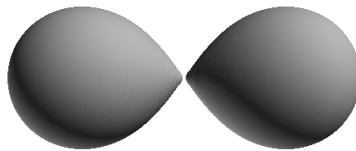

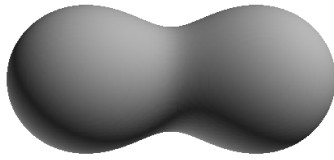Figure 4: Two black holes of unit mass each, at a distance of 8.

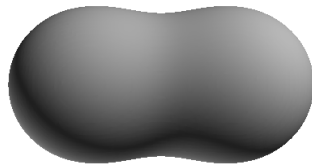Figure 5: Two black holes of unit mass each, at a distance of 7.

Figure 6: Two black holes of unit mass each, at a distance of 6.

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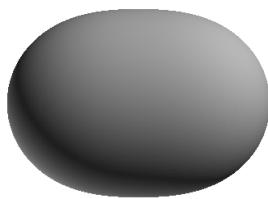Figure 7: Two black holes of unit mass each, at a distance of 5.

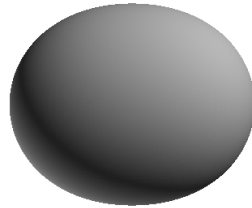Figure 8: Two black holes of unit mass each, at a distance of 4.

Figure 9: Two black holes of unit mass each, at a distance of 3.

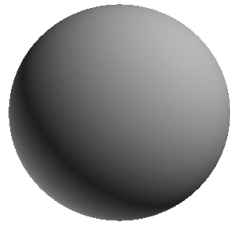Figure 10: Two black holes of unit mass each, at a distance of 2.

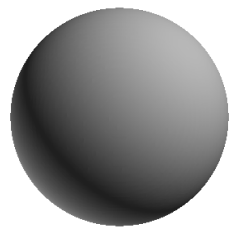Figure 11: Two black holes of unit mass each, at a distance of 1.

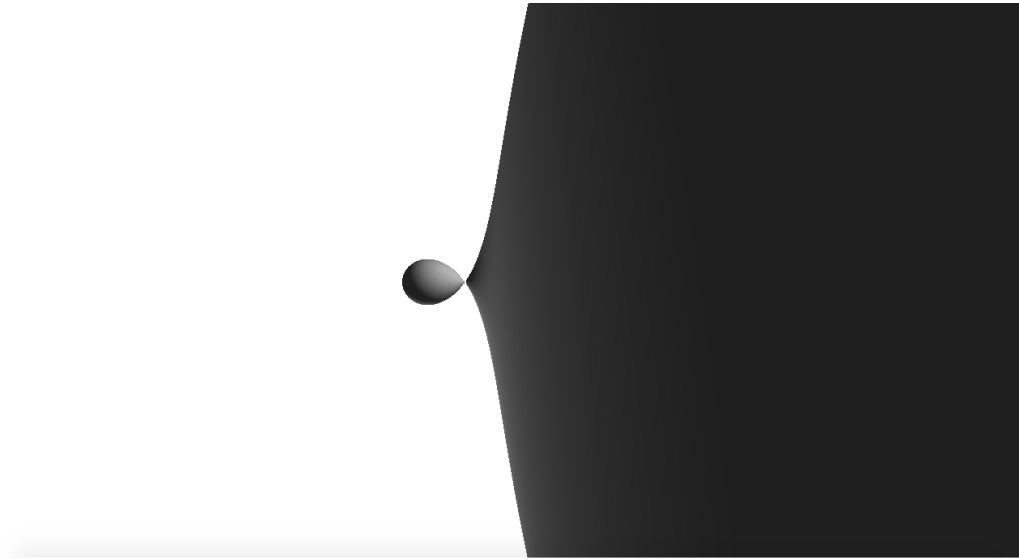Figure 12: *One* black hole of mass = 2.

Figure 13: A unit mass black hole merging with a black hole of mass = 1000.

References

[1] Blinn J. *A generalization of algebraic surface drawing* ACM Transactions on Graphics, Vol. 1, No. 3 (1982)

[2] Lorensen W, Cline H. *Marching Cubes: A high resolution 3D surface construction algorithm* Computer Graphics, Vol. 21, No. 4 (1987)

[3] Halayka, S. *C++ code* (2017) https://github.com/sjhalayka/bhmerger

[4] Emparan R, Martinez M. *Exact event horizon of a black hole merger* (2016) arXiv:1603.00712 [gr-qc]