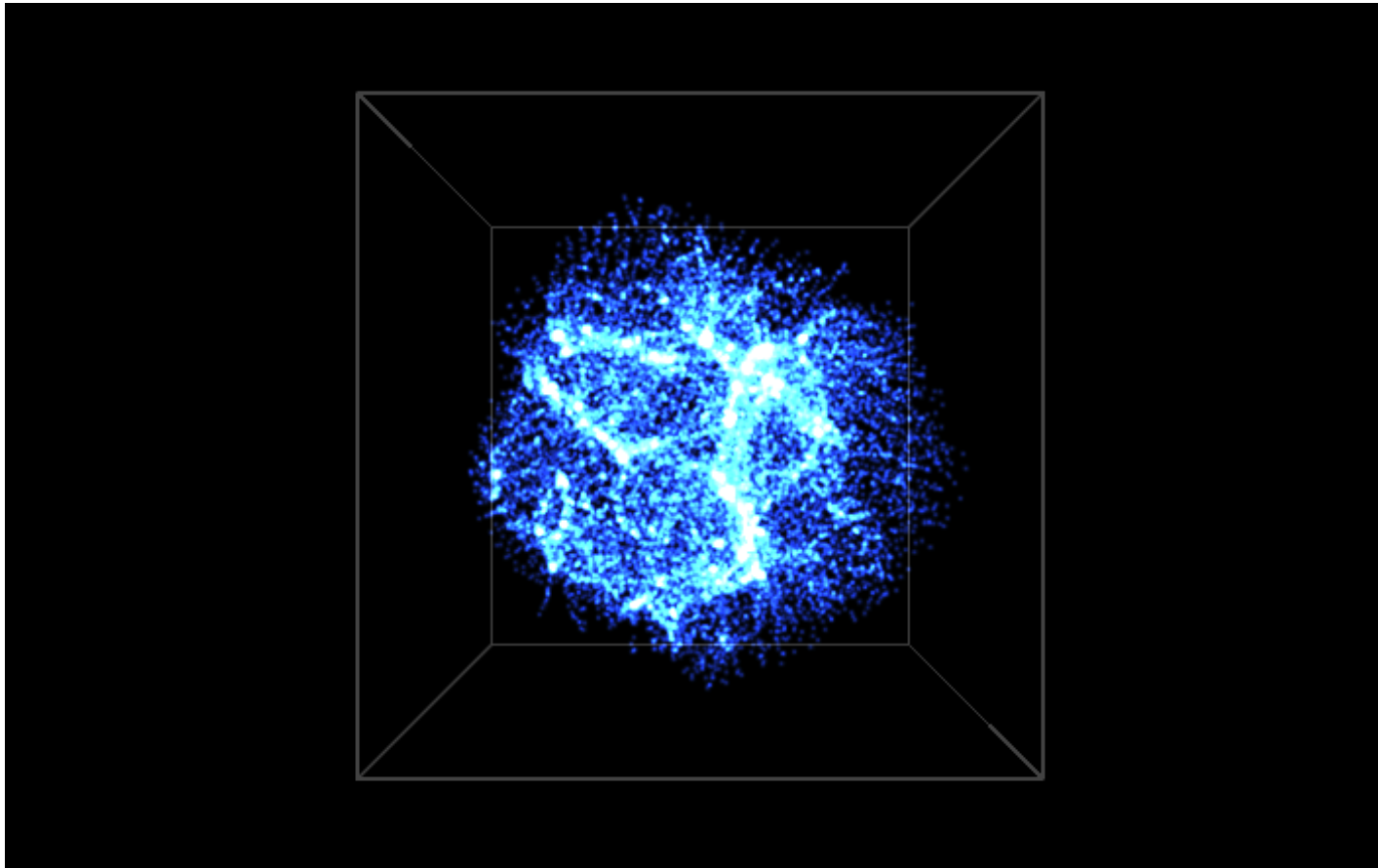


# Galaxy Formation



# 1 Description

## 1.1 Galaxy formation

This simulation models the formation of a spiral galaxy like the Milky Way. The simulation initially starts with gas and dark matter particles. Dark matter feels only the force of gravity, while the gas feels gravity plus pressure. As the gas density increases, it can be converted into stars. The simulation also includes stellar evolution, so that massive stars evolve and can become supernovae, returning their gas and metals back into the interstellar medium.

The simulation begins with a sphere of gas and dark matter that is expanding slightly with the general expansion of the Universe. However, the local gravitational attraction quickly reverses the expansion and the region begins to collapse. Local density enhancements are magnified and many small high density regions begin to start forming stars: these are protogalaxies. The dark matter forms filaments that connect the protogalaxies, which are gravitationally attracted to each other. Eventually most of the matter forms a central mass that will become a large spiral galaxy, surrounded by a swarm of satellite dwarf galaxies.

This simulation was prepared by Chris Brook (Brook et al. 2006, ApJ, 639, 126) using the code GCD+ (Kawata & Gibson, 2003, MNRAS, 340, 908) run on the Swinburne supercomputer.

This 3D PDF shows 4 snapshots in time from the simulation, and includes two views per snapshot: volume rendering and isodensity surfaces.

- Volume rendering is one way to represent the density of particles in 3D, whereby the colour scale represents the local density of particles. The lowest density regions in the simulation are shown in blue and the highest density regions at the cores of the protogalaxies and the central galaxy are shown in red.
- Isodensity surfaces are another way to represent the density information. Like contour lines on a standard map, isodensity surfaces contains all of the particles above a particular 3D space density level. Thus the isodensity surface represents a volume density cut. In this 3D PDF there are three levels of isodensity surfaces: low, medium, and high density. By toggling between these three isodensity levels, you can see into the density structure of the 3D volume. You can view progressively higher levels by hiding the lower isodensity surfaces. Start by hiding the low level (blue) surface, which will allow you to see the medium level (green) surface. Then hide the medium level surface to see the high level (brown) surface.

## 1.2 How to use this 3D PDF

The interactive 3D content appears on the next page of this document. You can interact with the 3D content in a variety of ways. Most of these can be found in the 3D toolbar (see below) that appears when you move the mouse cursor over the 3D figure.



To start, click and hold the left mouse button anywhere within the 3D figure. Then move the mouse around and see how the orientation changes. You can use the right mouse button in the same way to zoom in and out. Other interaction modes are also available. You can explore these by clicking on the drop-down menu of the left-most icon on the 3D toolbar.

Every 3D figure has a default view, which can be returned to by selecting View 1 from the toolbar Views menu. Some figures may also have other interesting views available for you to try.

There are some additional keyboard shortcuts for you to use. (Note that you must first left mouse click on the 3D figure to utilise these shortcuts.)

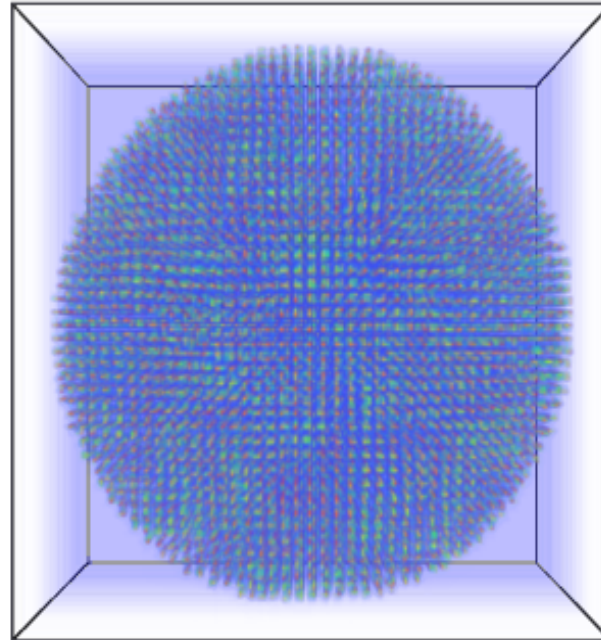
arrow keys (up, down, left, right)	rotate the object
+ , -	zoom in or out
a	autospin
* , /	increase, decrease the autospin speed
[ , ]	roll the object clockwise, anti-clockwise
h	return to the default view

Some 3D figures may also allow you to show or hide certain types of objects from view. If available, this option will appear as a text link below the 3D figure, e.g. [Click here to...](#)

*Note:* The free Adobe Reader (Version 8 or higher) is required for these 3D PDFs.

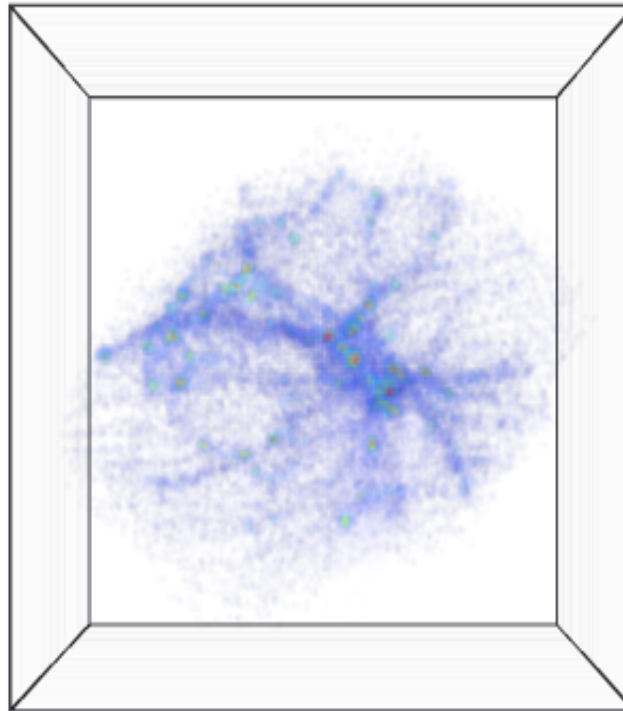
## 2 Time period 1

### 2.1 Volume rendering

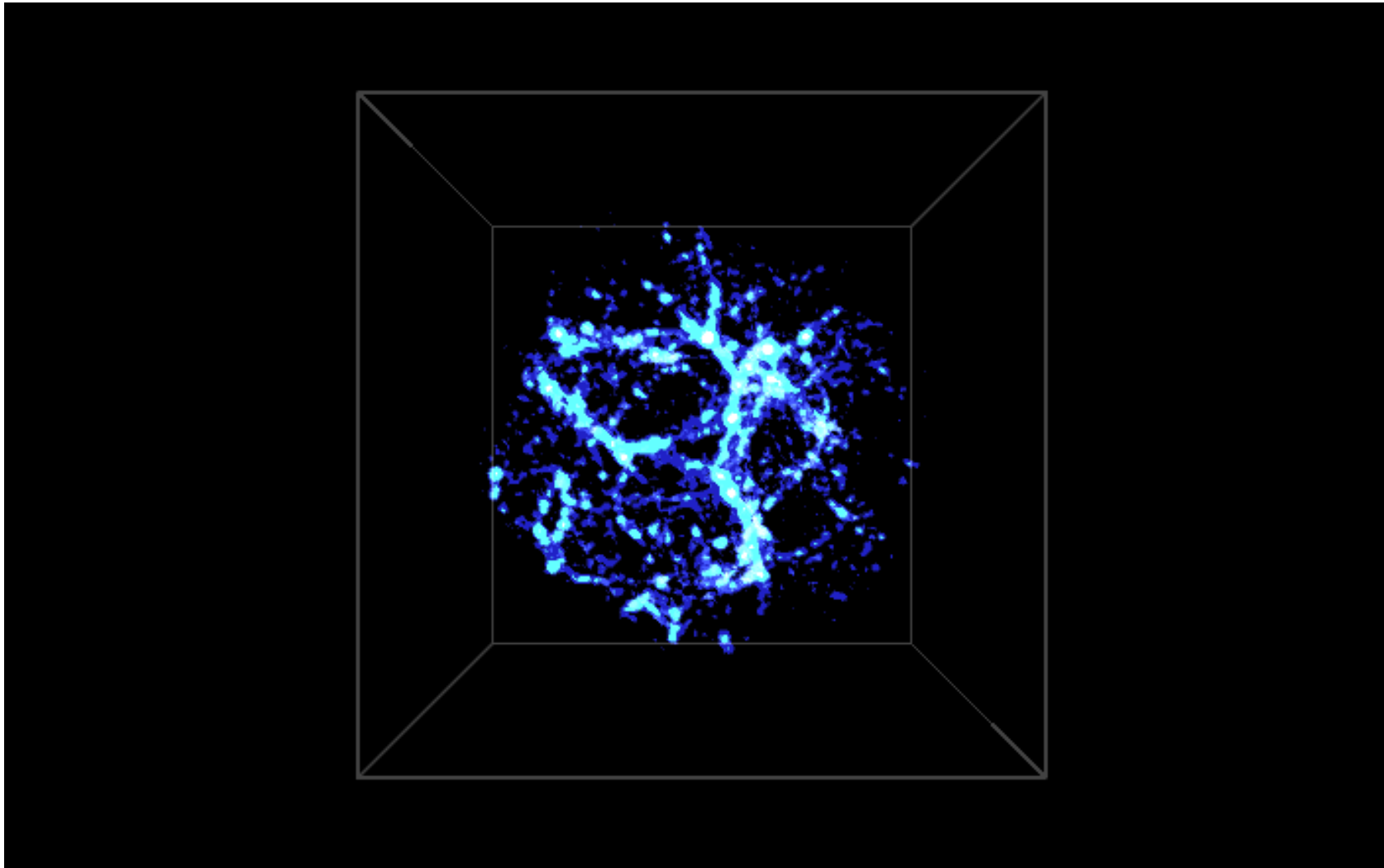


### 3 Time period 2

#### 3.1 Volume rendering



### 3.2 Isodensity surfaces

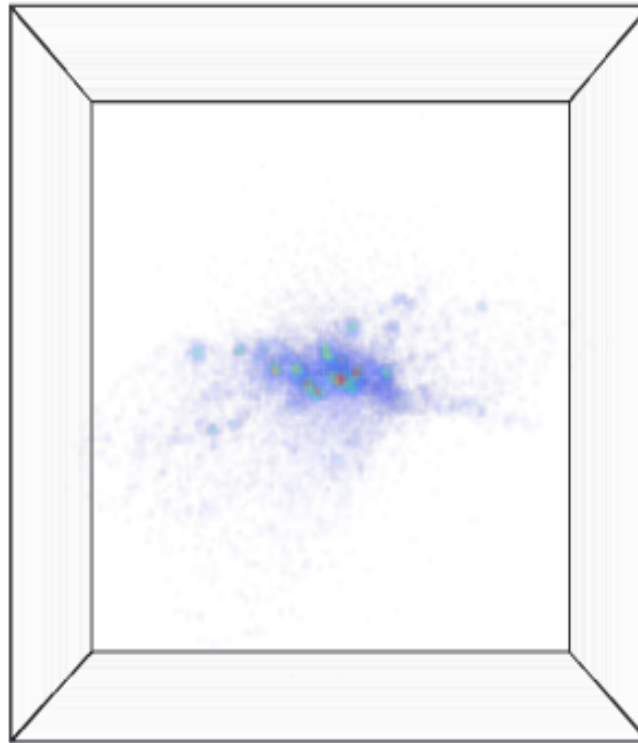


[Click here to hide/show the low level surface.](#)

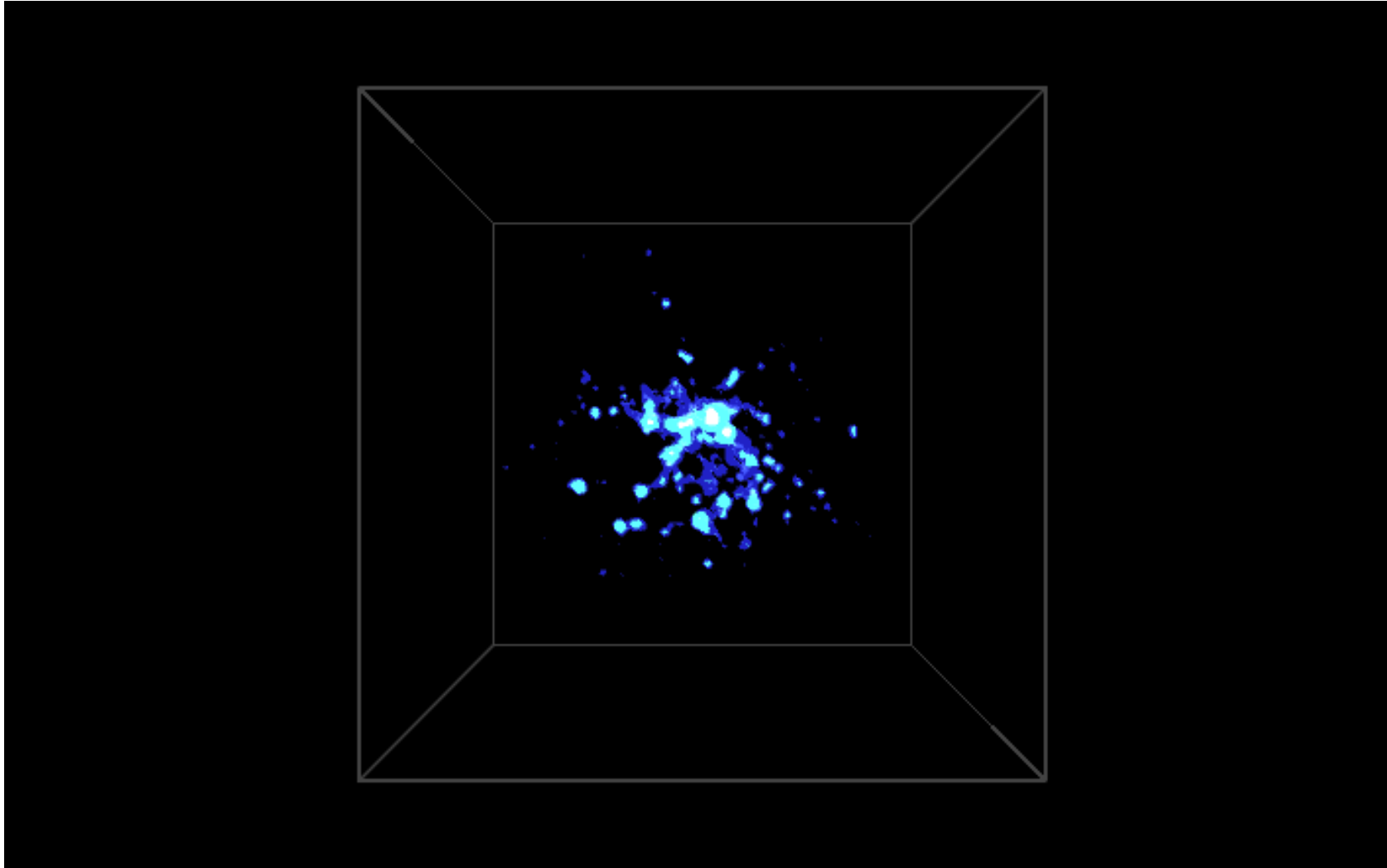
[Click here to hide/show the medium level surface.](#)

## 4 Time period 3

### 4.1 Volume rendering



## 4.2 Isodensity surfaces



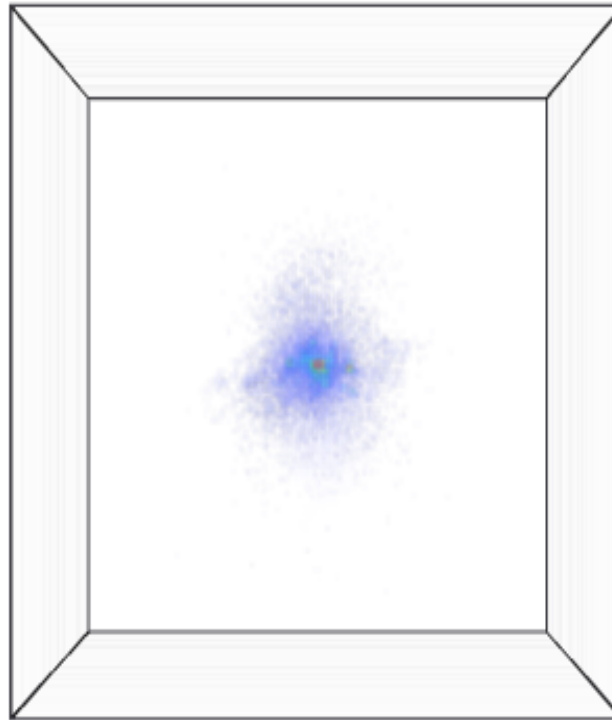
[Click here to hide/show the low level surface.](#)

[Click here to hide/show the medium level surface.](#)

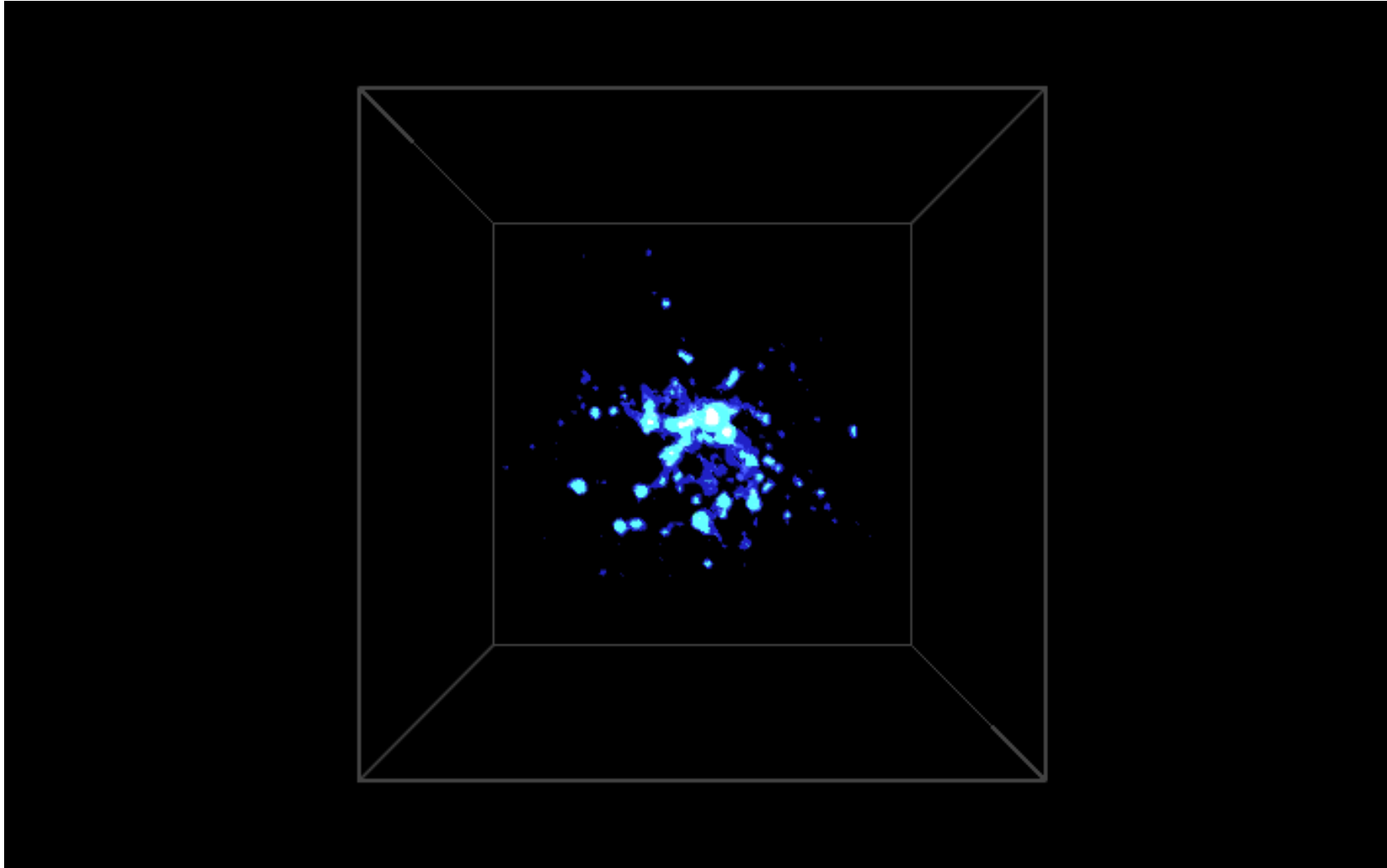


## 5 Time period 4

### 5.1 Volume rendering



## 5.2 Isodensity surfaces



[Click here to hide/show the low level surface.](#)

[Click here to hide/show the medium level surface.](#)

## 6 Credits

The data used for this PDF was provided courtesy of Chris Brook (Brook et al. 2006, ApJ, 639, 126). The simulation was run on the the Swinburne supercomputer using the GCD+ code (Kawata & Gibson, 2003, MNRAS, 340, 908).

The 3D content in this PDF document was prepared with S2PLOT (Barnes et al., 2006, PASA, 23, 82; Barnes & Fluke, 2008, New Astronomy, 13, 599).

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