Visualization of a High-Resolution Galaxy Formation Simulation

Ralf Kaehler
KIPAC/SLAC
2575 Sand Hill Road
Menlo Park
CA 94025, USA
kaehler@slac.stanford.edu

Tom Abel
KIPAC/SLAC
2575 Sand Hill Road
Menlo Park
CA 94025, USA
tabel@slac.stanford.edu

Ji-hoon Kim
University of California
1156 High Street
Santa Cruz
CA 95064, USA
mornkr@ucolick.org

ABSTRACT

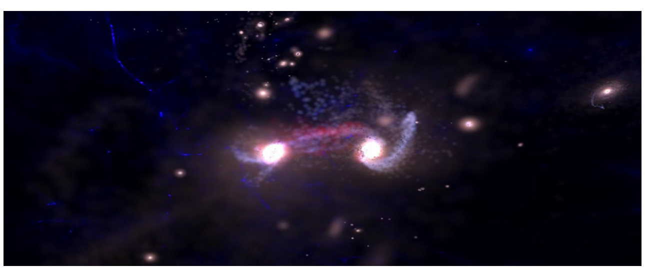
Due to increasing computational resources, three dimensional, time-dependent numerical simulations have become an important astrophysical method to study structure formation in the early Universe. Even the complicated nonlinear processes that drive the formation of the first galaxies can now be tackled using tailored numerical simulation codes that are run on large computational clusters. In this work we describe a 3D visualization of one of the most detailed galaxy formation simulations ever carried out in numerical astrophysics.

Categories and Subject Descriptors: B.X.X [Three-Dimensional Graphics and Realism]: Raytracing

General Terms: Algorithms.

Keywords: Scientific Visualization, Astrophysics.

1. NUMERICAL SIMULATION



This simulation shows the formation of large-scale structures and massive galaxies in the early Universe, less than 3 billion years after the Big Bang. The simulation models the complicated, non-linear interplay between the three main components of the galaxies. Dark matter, stars, the interstellar (and intergalactic) gas, see [1]. The computation was carried out on adaptive mesh refinement (AMR) grids with about 60 million cells and resolved the dark matter distribution and the stars within the galaxies with additional 40 million particles using about 40,000 time steps. The time span shown in this animation is 2 billion years and the region in the foreground has an extension of 50 million light years across. The simulation took about 200,000 CPU hours on a 768 core AMD cluster with 3TB of main memory.

SC'11 Companion, November 12–18, 2011, Seattle, Washington, USA.
ACM 978-1-4503-1030-7/11/11.

2. THE ANIMATION

The animation focusses on galaxy collisions and mergers in the foreground. The color-coding is based on the age of the stars. Red colors depict massive star forming regions, blue and white colors indicate young bright stars, whereas yellow and brown colors represent older stars. In this early epoch of the Universe merger events between the galaxies were very common and played an important role for their evolution, in particular by triggering the formation of new stars and driving gas to the centers of the galaxies feeding their central black holes. Some star formation is triggered in tidal arms seen as bright arcs connecting the colliding galaxies in the visualization. The blueish regions in the background represent the large-scale distribution of hydrogen gas on a scale of about 300 million light years.

3. GPU-ASSISTED RENDERING

The visualization was performed on programmable graphics hardware, employing massively parallel OpenGL shaders. The galaxies in the foreground were rendered using *geometry shaders*, that generated the polygons representing the star particles on-the-fly on the GPU, thereby avoiding the bottleneck between CPU and GPU memory. The volumetric data in the background was rendered by a GPU-assisted ray casting approach as described in [3, 2]. It computes the color-intensity for each pixel in separate instances of *fragment shaders* that sampled the grid-based AMR data and computed the light emission and absorption for each location in the computational domain.

4. ACKNOWLEDGMENTS

This work was partly support by the *National Science foundation* through award number AST- 0808398 and the LDRD program at the SLAC National Accelerator Laboratory as well as the Terman fellowship at Stanford University.

5. REFERENCES

[1] J. hoon Kim, J. H. Wise, M. A. Alvarez, and T. Abel. *The Astrophysical Journal*, 738(1):54, 2011.

[2] R. Kaehler, T. Abel, and H.-C. Hege. Simultaneous GPU-Assisted Raycasting of Unstructured Point Sets and Volumetric Grid Data . *Eurographics/IEEE VGTC Symposium on Volume Graphics*, 1:49–56, 2007.

[3] R. Kaehler, J. Wise, T. Abel, and H.-C. Hege. GPU-Assisted Raycasting for Cosmological Adaptive Mesh Refinement Simulations. In *International Workshop on Volume Graphics 2006*, pages 103–110, Boston, 2006. Eurographics / IEEE VGTC 2006.