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CINEMATIC SCIENTIFIC DATA VISUALIZATION FOR CADENS

Allocation: Illinois/175 Knh
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EXECUTIVE SUMMARY

The Advanced Visualization Lab (AVL) at the University of Illinois at Urbana–Champaign (Illinois) has continued to work on the National Science Foundation-funded CADENS project (Centrality of Advanced Digitally Enabled Science, ACI-1445176). The AVL coproduced and rendered visualization scenes for two full-dome planetarium shows, *Birth of Planet Earth* and *Imagine the Moon*. The research team has used Blue Waters for processing data as well as rendering scenes in 4K monoscopic, 4K stereoscopic, and full-dome formats. The researchers also rendered visualizations for the Earth's Call climate change event in Aspen, CO, U.S.A., May 17–19, 2019.

RESEARCH CHALLENGE

Drawing on data from scientists involved in high-performance computing-based research, the AVL creates visualizations in cinematic style intended for public outreach, through flat-screen science documentaries, films, and full-dome planetarium shows.

METHODS & CODES

The team's Blue Waters visualization work depends on several externally provided packages: Houdini, commercial visual effects software from SideFX; yt, the data analysis and visualization package (yt-project.org) for ingesting and regridding some types of data; VMD, the Visual Molecular Dynamics package from John Stone of the Theoretical Biophysics group at Illinois (www.ks.uiuc.edu); and Python with numpy and scipy for many sorts of data preprocessing from the forms provided by the scientists into forms usable by Houdini. The team has also developed their own software tools, including Ytini for yt-Houdini integration, and Blurend to organize the Houdini rendering workflow for Blue Waters' environment.

Visualizing energy harvesting in a photosynthetic purple bacterium [1] involved combining structural models from atomic, protein, organelle, and cell scales using multiple software tools [2]. The construction of structural models [3] was performed with VMD [2] and Mathematica, which was also used for the determination of relevant energy conversion steps [1]. Multiple copies of a static chromatophore model [3] were assembled in Houdini to emulate the interior of a low-light-adapted purple bacterial cell. Dynamic elements—photons, electronic excitations, protons, quinols/quinones, and ATP—were choreographed using Houdini to illustrate energy conversion processes for a lay viewer. Since the timescales for these conversion processes span almost 12 orders of magnitude (femtoseconds to milliseconds) [1], the animations deliberately represent a simplified visual narrative rather than the results of a specific simulation at one timescale. Some visual elements were rendered using Houdini, others with VMD.

In addition, the researchers relied on Blue Waters' capacity to create a high-quality visualization of Sarah T. Stewart's Moon-forming collision [4], as explained below.

RESULTS & IMPACT

Blue Waters enabled the research group to create and refine two data-driven cinematic animations for two full-dome planetarium shows released in 2019:

- Visualizing Energy Harvesting in a Photosynthetic Purple Bacterium[1–3]—*Birth of Planet Earth*
- Formation of the Moon [4]—*Imagine the Moon*

Full-dome shows have a lifespan of about 10 years, and though it has only been several months, *Birth of Planet Earth* has already received two awards and is being shown internationally. To suggest potential public impact for this work, it can be compared with another full-dome planetarium show in the CADENS series, *Solar Superstorms*, for which AVL also relied on Blue Waters for data visualization. Since its 2015 release, it has been booked by over 70 planetaria and science museums in 15 countries, and translated into at least 10 languages.

The research team also used Blue Waters to create data-driven graphics for the Earth's Call climate change event in 2019, which was viewed by more than one million people globally. The group visualized a total of 12 data sets for this event, five of which [5–9] were rendered using Blue Waters owing to the length of time required to render each frame.

WHY BLUE WATERS

Access to Blue Waters has allowed the team to iterate quickly and to meet deadlines. They were able over the course of a single weekend to render a Houdini scene involving a chromatophore model [3] and its surrounding environment that was made up of six separate render layers and totaled 20,870 image frames. The capability to render a large amount of images in a short period of time has allowed the team to make several iterations of the scene before finalizing a video shown during the International Planetary Society 2018 conference. This would not have been possible on the team's local cluster.

Furthermore, Blue Waters has made it possible to not sacrifice visual quality for render speed. One approximately 200-frame segment of the visualization of a planetary collision [4] was taking as many as 20 hours per frame to render. Blue Waters made it possible to render these images despite the long render time. Without Blue Waters, the team would have had to either change many render settings and significantly decrease the render quality, to change the camera position and lose the dramatic effect of having an arm of disk material pass closely overhead, or to spend many days trying to come up with a different data representation of the simulation to make the render more manageable on the local cluster.

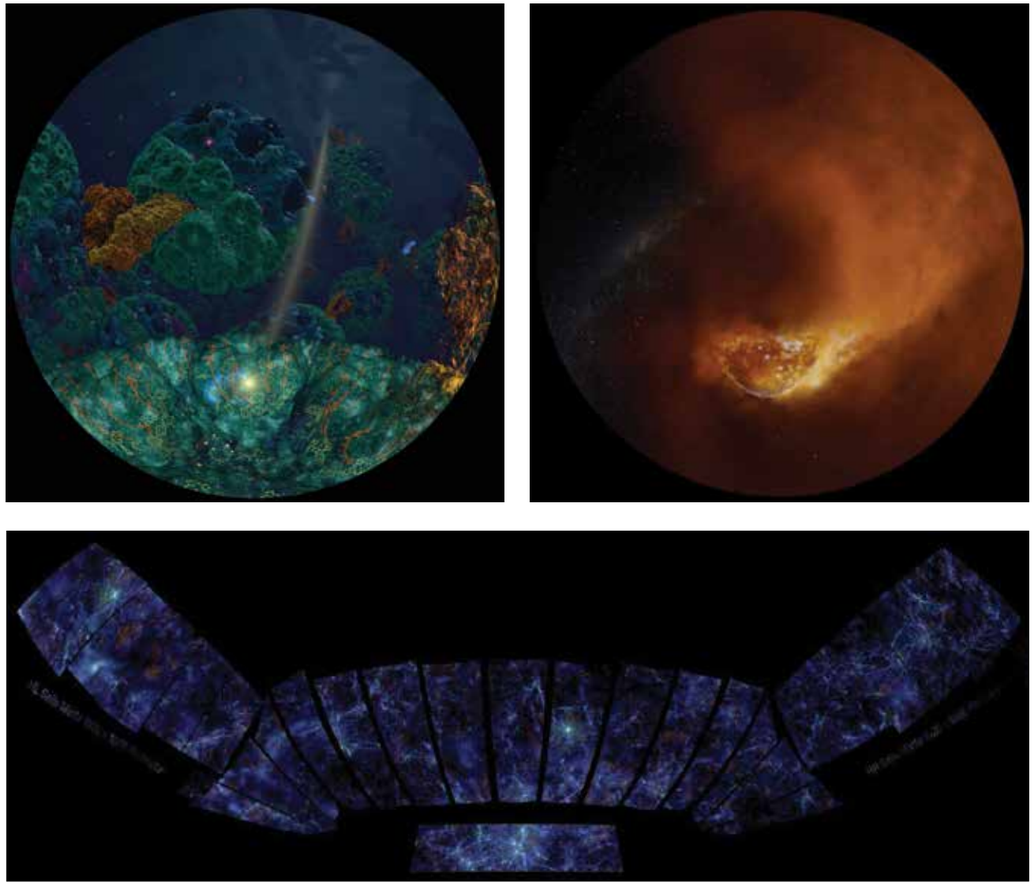

Figure 1: (top left) Photosynthetic energy harvesting in the purple bacterium *Rba. sphaeroides* [1]. Adapted from a visualization [2] of the structure [3] of chromatophores—photosynthetic vesicles—illustrating energy conversion steps from the capture of sunlight to the synthesis of ATP. (This segment is dedicated to Klaus Schulten. From the planetarium show, *Birth of Planet Earth*.) Figure 2: (top right) Visualizing the collision that formed Earth's Moon [4] as a Mars-sized body strikes the early Earth. Appears in *Imagine the Moon*. Figure 3: (bottom) Visualization of the large-scale structure of the early universe [5], projected onto a screen as well as front and side sails around the audience at the Earth's Call event in 2019.

PUBLICATIONS & DATA SETS

Birth of Planet Earth, full-dome planetarium show, directed by Thomas Lucas, distributed by Spitz, Inc., 2019.

Imagine the Moon, full-dome planetarium show at Adler Planetarium, Chicago, Illinois, U.S.A., 2019.

Earth's Call event, May 17–19, 2019, https://earthscall.org/.