

## 4-DIMENSIONAL DIGITAL UNIVERSE PROJECT

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### ABSTRACT

We have developed the four-dimensional digital universe theater at which we can visualize the observational data and theoretical models of astronomical objects stereoscopically. The astronomical objects cover all scales of the universe from the solar system to the large-scale structure of the universe. We have also produced the three-dimensional movies of various astronomical processes based on the results of computer simulations. We plan to distribute all the products of this project through the internet.

*Key words* : visualization — public outreach

### I. INTRODUCTION

The spatial and time scales of the universe is vastly large. The purpose of the 4-Dimensional Digital Universe (4D2U) project is to scientifically visualize such universe (4D2U also means “4-D to you”). We visualize the universe in 4-dimensions (3-D in space and 1-D in time) by using the stereo-projection system.

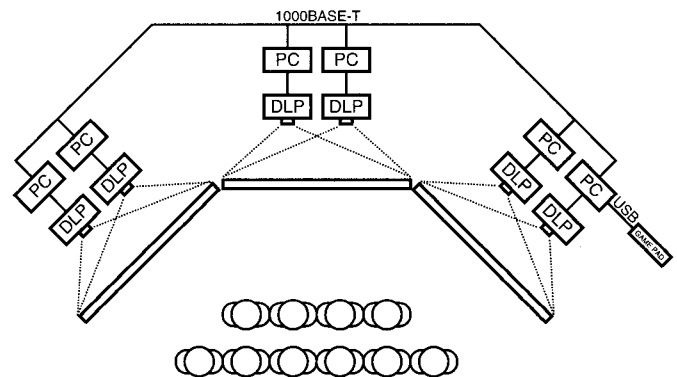
By using the 4D2U visualization, we aim to carry out two tasks. The first one is to provide general people with the latest results of astronomy in a scientifically correct and easily understandable way. We visualize the observational data from the world-class telescopes and the simulation data from the world-class supercomputers. The second one is to help astronomers intuitively understand their data by providing an interactive 3-D view of their data. Today the interactive 3-D view is necessary to understand the large-scale 3-D data.

In this project, astronomers create images and software by themselves. This is necessary to visualize the astronomical data in a scientifically correct way. In addition, it is also favorable to freely revise and distribute the products. All the core developers are astronomers in simulation astronomy.

We started the 4D2U project in the end of 2001. In the present paper, we report the outline of the present status of the 4D2U project.

### II. 4D2U THEATER HARDWARE

We developed the experimental 3-D projection system “4D2U theater” (Fig. 1). The theater consists of 3 1.8m×1.8m silver screens connected with angle 135°,



**Fig. 1.**— The schematic illustration of the 4D2U theater hardware.

which enables us to have the immersive and wide view.

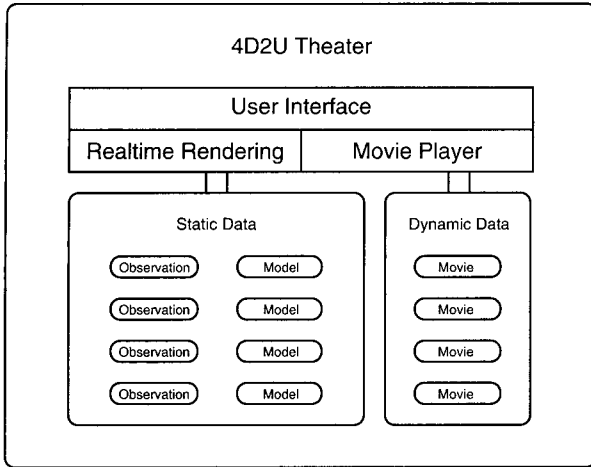
For the stereograph method, we adopted the circular polarization method. The two images for left and right eyes are projected by DLP projectors through the polarization filters to each screen. Then we can see the stereoscopic images with using polarization glasses. For each projector, a PC is connected. Total 6 PCs project the images synchronously by communicating via Gbit ethernet. For the PC-to-PC communication, we developed the original TCP/IP-based communication software, with which we can play the movie with 15-30fps. The theater is controllable by a game-pad connected to one of the PCs via USB.

About 20 people can enjoy the 3-D view at the theater.

### III. 4D2U THEATER SOFTWARE

The theater software consists of two major parts (Fig. 2): the static object data (observational data and

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**Fig. 2.**— The schematic illustration of the 4D2U theater software.

theoretical models) viewer “Mitaka” and the dynamic phenomena data (movies made from computer simulations).

#### (a) 4D2U Viewer: Mitaka

The structure of the universe is hierarchical. From small to large spatial scales, there are the Earth-Moon system, the Solar system, the stars in the Solar neighborhood, the Galaxy, the local group of galaxies, the cluster of galaxies, and the large-scale structure. Mitaka is a real-time interactive viewer of such astronomical objects. It can visualize all the scales of the universe seamlessly. It supports representative observational data of each hierarchical structure of the universe. If there are no observational data for some objects, we construct theoretical models. We constructed the models of the Galaxy and a globular cluster based on the latest observation and theory. With Mitaka, for example, we can voyage continuously from the Earth through the Galaxy to the end of the universe, seeing all the hierarchical structure of the universe. It can also play the simulation movies. Figure 3 shows examples of the object data visualized by Mitaka.

#### (b) Simulation Movie Library

The movie library is the collection of animations made from the results of computer simulations. The library covers simulations of many astronomical processes such as the formation of the Moon and the formation of the large-scale structure.

We use the results of large-scale simulations of many-body (particle) systems and fluid (grid-based) systems. We established the methods of the 3-D visualization of both systems. For particle data such as stars we developed the special rendering engine “Zindaiji”, which can perform fast 3-D rendering. Figure 4 shows examples of the simulation movies.

The list of the supported object data and the movie titles are summarized in Table 1. These are the elements of the 4D2U theater. By combining these elements, we make a program for a certain theme, e.g., “The Hierarchical Structure of the Universe”, “The Secret of the Milky-Way”, and “Voyage through the Solar System”.

The 4D2U system is constructed on WindowsXP. For GUI and movie play, we use DirectX library and for real-time 3-D rendering, we use OpenGL library.

## IV. SUMMARY AND FUTURE PROSPECTS

We have developed the 4D2U theater system and constructed the 4D2U data. The 4D2U data consists of the observational data, the theoretical models, and the simulation movies. We have established the basic methods for 3-D visualization of these data.

We have started the experimental monthly show to the public and met a good public response since 2002. We have also started providing the 4D2U data to museums, planetariums etc. Some of the data are also available on the project web page:

<http://4d2u.nao.ac.jp/>

As the second step, we plan to develop the dome-screen 4D2U theater. We challenge to build the world-first 3-D projection system for a dome-screen. We also plan to develop the portable system, mobile 4D2U theater. It is suitable for the use at classes and the exhibition at museums. We are also preparing to release the 4D2U data through the internet. For the information of the project, please check the above project web page.

## ACKNOWLEDGEMENTS

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TABLE 1.  
CURRENT NATIONAL VIRTUAL OBSERVATORY  
PROJECTS

Level	Object(Observation/Model)
	Movie(Simulation)
Solar System	Planets, Satellites, Asteroids, Comets, Kuiper Belt Objects
	Origin of the Moon, Birth of the Earth, Mars Exploration
Star	Nearby Stars
	Formation of a Binary, Jet from YSO
Galaxy	Globular Cluster, Our Galaxy
	HI Distribution,
	Gas Dynamics around a Massive BH, Dynamics of a Globular Cluster, Formation of a Spiral Galaxy
Cluster of Galaxies	Local Group, Clusters of Galaxies, Large-Scale Structure
	Formation of the Large-Scale Structure

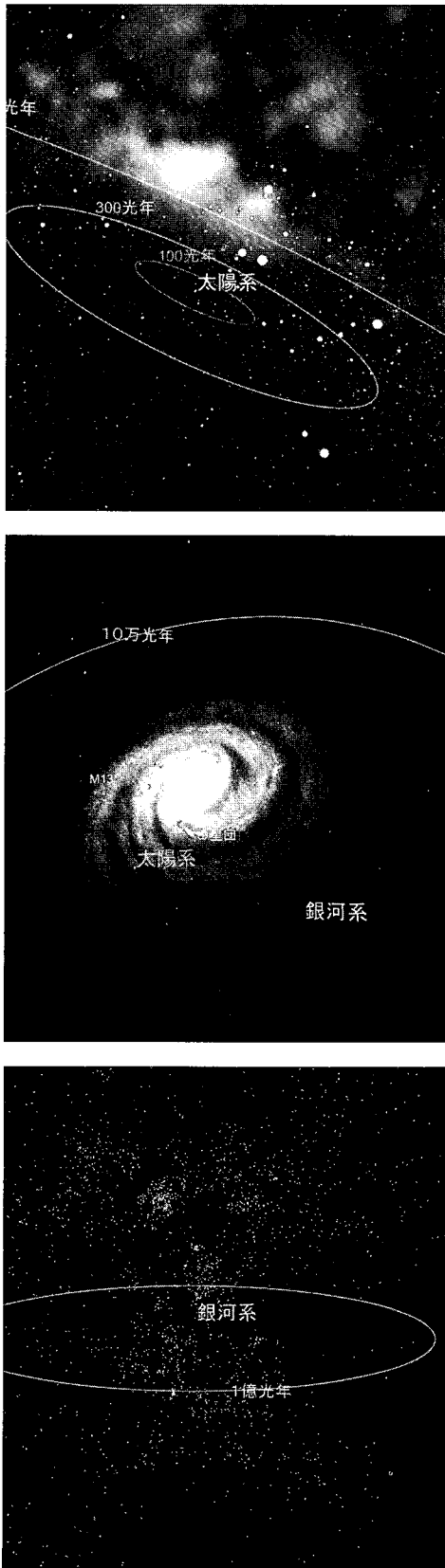


Fig. 3.— Examples of the visualization by Mitaka: the theoretical model of the Galaxy (middle), and the observational data of nearby stars (top) and galaxies (bottom).

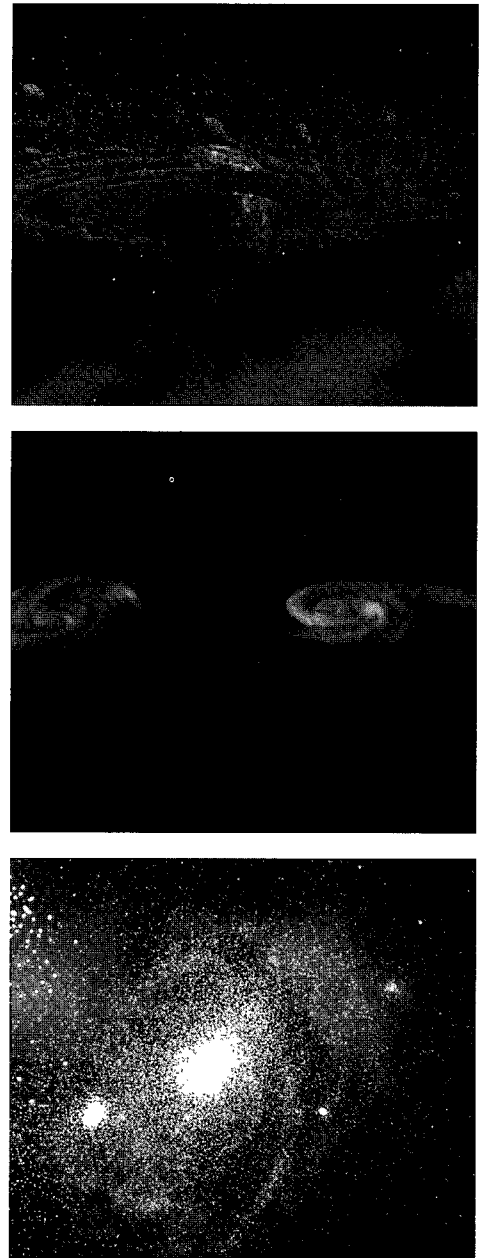


Fig. 4.— Examples of the movies made from computer simulation: “The Origin of the Moon” (top), “The Formation of a Binary”, and “The Formation of a Spiral Galaxy” (bottom).