

## Real-time data standards for the planetarium

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### Abstract

The American Museum of Natural History and the Hayden Planetarium have built the most accurate, comprehensive, 3-D atlas of the cosmos called the Digital Universe (DU)<sup>1</sup>. The DU enables one to journey from the mountains on Earth to the farthest quasars. The DU enjoys many distribution channels, including pre-rendered space-shows and news bulletins, live planetarium programmes, and a free version available on the internet. Recently, we have partnered with three planetarium vendors to bring the DU to planetariums around the world. These partnerships necessitate the adoption or creation of standards for three-dimensional data and associated metadata. Many standards exist in the current Virtual Observatory framework and additional standards are being proposed as part of the VAMP programme. We intend to identify additional standards necessary for 3-D, real-time rendering tools for fulldome and flat-screen environments.

### Introduction

The Digital Universe (Abbott et al., 2004b) is a scientifically accurate, interactive, 3-D atlas of the Universe created by the American Museum of Natural History (AMNH). The DU lies at the intersection of scientific knowledge and technology that exploits the power of visualisation. AMNH's strong academic partnerships ensure the continual growth and evolution of the DU for the future. By building various datasets into one self-consistent atlas, we provide a contextual environment in which to understand the Universe.

The DU enjoys many outlets for dissemination and distribution. Within AMNH, the atlas is showcased in our space-show productions, which in turn are distributed to dozens of institutions and seen by millions of visitors worldwide. The DU is also featured in AMNH's Science Bulletins news subscription service that reaches over three dozen institutions. In addition, we utilise the interactivity of the DU in Hayden Planetarium programmes, where we present the Universe with a live pilot and guide. And, of course, we offer the DU free on the web along with the open-source software Partiview (Levy, 2003; Abbott et al., 2004a).

In the past few years, we have focused on getting the DU into more planetariums. To that end, we co-developed Uniview via an internship programme with Linköping University in Sweden, from which SCISS, AB was formed to develop and distribute Uniview. We partnered with Sky-Skan, Inc.

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<sup>1</sup> <http://haydenplanetarium.org/universe/>

in 2005 to integrate the DU into their DigitalSky system, which is now installed in Sky-Skan domes around the world. And recently, we have signed an agreement with Evans & Sutherland to do the same, which we expect will dramatically increase the number of DU-enabled domes.

Now that we have four different software viewers for the same data, it is necessary to place more emphasis on data management and delivery. Producing multiple versions of one dataset is inefficient and unmanageable. Furthermore, multiple delivery methods create a development nightmare for software engineers and data processors. We are looking to the astronomical community in general and the EPO community specifically for strategies and experiences in data format and delivery standards.

### Existing standards

Currently, there are efforts underway to build standards for astrophysical data. They include the work of the International Virtual Observatory Alliance (IVOA), the Astronomy Visualization Metadata (AVM), and the Fulldome Standards Group. For the DU, we are in the process of choosing the best development path for us, whether we adopt existing standards, create our own standard, or find a middle-ground solution that involves using existing standards as our basis and creating a layer specific to our needs.

The most mature standards for astrophysical data today are those approved by the IVOA<sup>2</sup>. The IVOA was formed in 2002 and comprises Virtual Observatory (VO) projects from sixteen countries. The IVOA manages the development of standards for a range of data formats and access mechanisms. The most important recommendation for data formatting is the VOTable Format Definition (Ochsenbein et al., 2004), which was released in 2002 and revised in 2004. VOTable is an XML standard for the exchange of data represented as a set of tables and was derived from the FITS table format.

Another group (Hurt et al., 2007) is creating standards for the EPO community called the Astronomy Visualization Metadata (AVM)<sup>3</sup>. Their work involves developing metadata, or “tagging,” astronomical images making them accessible to software and on-line resources. Ultimately, these resources will be indexed in the Virtual Astronomy Multimedia Project (VAMP), which will provide a clearinghouse for EPO related metadata.

Even more specialised, the Fulldome Standards Group is developing guidelines for pre-rendered content for fulldome theatres. These include video and sound specifications, and image generation. While these may not seem related to DU standards, in the future we will need to be mindful of this work as pre-rendered and real-time content begin to blend together.

### Standardising the Digital Universe

The DU has unique issues that fall outside the current specifications of the IVOA or AVM standards. These include DU-generated data and metadata, three- and four-dimensional (time-evolving) data and environmental settings.

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<sup>2</sup> <http://www.ivoa.net/Documents/>

<sup>3</sup> <http://virtualastronomy.org/>

In order to maintain consistency between the various data in the DU, datasets are pre-processed then pass through a curatorial step before becoming part of the DU. This step may add data or metadata, thereby creating unique data attributes that differ from the original, published source. The most obvious example is the calculation of distance for our star catalogue, where source catalogues only publish a parallax value. An additional example is the 1.14 million 2MASS Redshift Catalogue, for which it was necessary to develop a density-based proximity factor so that we can see the denser regions (large-scale structure) through the field galaxies located in less dense regions. These added data are unique to the DU, and may not become part of the published dataset.

Beyond the pre-processing step, some data are not compatible with existing standards. Distance is the thorn in every astronomer's side; one object may have a dozen different distance values associated with it. Because distance is so difficult to determine, there has been little attention paid to including it in standards. Furthermore, the expression of distance in and of itself is challenging due to the vast scales in the Universe. We may want to use metres on one scale and megaparsecs on another.

Scale presents another unique data type for the DU. For each dataset, a scale specification is needed which, in turn, signals to the display software what scale to operate in. This is critical to the ability to explore a particular dataset effectively since it determines the flight speed.

Existing standards also do not address the problem of theoretical data. While the DU is mainly an atlas of observed data, theoretical and grid-based datasets will inevitably be utilised. These may include, but are not limited to, galaxy mergers, nebula evolution, stellar evolution, and cluster dynamics. While there are working groups for standardising theoretical datasets, these efforts have not yet produced an accepted standard.

## Data delivery and distribution

Beyond data formats, data delivery standards are critical to the efficient distribution of the DU. Will we deliver the DU in bulk to the client? Will we stream it over the internet? Currently, we believe a hybrid solution involving each of these will be most efficient.

Two standards exist for image survey data. These are the World Map Service (WMS) and the World Coordinate System (WCS). The WMS produces maps and metadata invoked by submitting requests in the form of a Uniform Resource Locator (URL). The WMS operation returns a map with well-defined geographic and dimensional parameters accompanied by metadata and information about particular features shown on the map.

The WCS are keywords in the header of a FITS file that describe the relationship between pixel coordinates on the image and coordinates in the sky. Many of the large-scale survey projects, including the Sloan Digital Sky Survey, are including this information in their data, making it easy to stream these data directly from the source.

## Appearance and presentation

Once we settle on a standard for data format and delivery, we will focus on the daunting task of standardising the appearance of the DU. Each of the four different software solutions render scenes differently. For example, the stars and Milky Way may appear too bright on one system and too dim on another. There are settings to accommodate these variations and, of course, this is also a function of the display system in each planetarium. However, companies who supply such systems typically have no more than a few standard systems for image generation.

Currently, we perform on-site quality control to ensure the atlas looks consistent and correct. This is time-consuming and expensive, but remains the most effective way to guarantee that the DU appears the same on all systems. In the future, it may be possible to build settings for each display system so that the quality control step is automated.

## Conclusions

The Digital Universe (DU) is an interactive atlas of the Universe that allows one to travel from the mountains on Earth to the most distant objects known. In an effort to bring the DU to a world-wide audience, we are working with three companies who build and install planetarium systems: SCISS, AB; Sky-Skan, Inc.; and Evans & Sutherland. Working with three different companies produces data management and delivery challenges that can only be solved by the creation or adoption of data standards.

We plan to develop standards that will automate the process of reading and updating data from the DU. These may be informed by the efforts of the International Virtual Observatory Alliance and the Astronomy Visualization Metadata, but currently they are both insufficient for our needs. We seek cooperation from these groups to make the necessary amendments and recommendations to these existing standards.

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