Seeing the sky through Hubble’s eye: The COSMOS SkyWalker

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ABSTRACT

Large, highresolution spacebased imaging surveys produce a volume of data that is difficult to present to the public in a comprehensible way. While megapixelsized images can still be printed out or downloaded via the World Wide Web, this is no longer feasible for images with $10^9$ pixels (e.g., the Hubble Space Telescope Advanced Camera for Surveys [ACS] images of the Galaxy Evolution from Morphology and SEDs [GEMS] project) or even $10^{10}$ pixels (for the ACS Cosmic Evolution Survey [COSMOS]). We present a Web-based utility called the COSMOS SkyWalker that allows viewing of the huge ACS image data set, even through slow Internet connections. Using standard HTML and JavaScript, the application successively loads only those portions of the image at a time that are currently being viewed on the screen. The user can move within the image by using the mouse or interacting with an overview image. Using an astrometrically registered image for the COSMOS SkyWalker allows the display of calibrated world coordinates for use in science. The SkyWalker “technique” can be applied to other data sets. This requires some customization, notably the slicing up of a data set into small (e.g., $256^2$ pixel) subimages. An advantage of the SkyWalker is the use of standard Web browser components; thus, it requires no installation of any software and can therefore be viewed by anyone across many operating systems.

Subject headings: miscellaneous — surveys — galaxies: general — galaxies: evolution — techniques: image processing

1. Introduction

In the last several years, a number of large, spacebased extragalactic imaging surveys have been conducted with the Hubble Space Telescope (HST) and its Advanced Camera for Surveys (ACS). Very prominent among these are contiguous areas covered by the Hubble Ultra Deep Field (UDF), the GOODS (Great Observatories Deep Origins Survey; Giavalisco et al. 2004) field, that of the GEMS (Galaxy Evolution from Morphologies and SEDs; Rix et al. 2004) and STAGES (Space Telescope A901/902 Galaxy Evolution Survey; M.

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Gray et al. 2006, in preparation) projects, or by COSMOS (‘Cosmic evolution survey’: Scoville et al. 2006a), here ordered by increasing sky coverage. While the UDF covers one ACS pointing, or about $3'' \times 3''$, GOODS consists of 15 pointings, GEMS 80, STAGES 81, and COSMOS 575, with a total area of 2 deg$^2$ for the latter. All of these images have in common that they are deep (the UDF is 1–1.5 mag deeper than the Hubble Deep Field; the other surveys collected at least one HST orbit per pointing), and they are very rich in galaxies: nearly 10,000 in the UDF, 40,000 in GEMS, and 2,000,000 in COSMOS.

These surveys all produced a very large number of data pixels, with up to $10^{10}$ pixels for COSMOS alone. The image areas are contiguous, and for parts of the surveys, they even exist as color images. So they are in principle excellent material not only for science, but also for presentation to the public. However, their size makes it almost impossible to show both size and detail at the same time. As an example, the UDF looks very nice printed at a size of, say, $1.5 \times 1.5$ m (corresponding to a resolution of $\sim 5$ pixels mm$^{-1}$), whereas the COSMOS ACS image would similarly require at least 35 m on a side for a print of the same resolution. At the same time it needs to be viewed from a distance of less than 1 m in order to appreciate all the details. This is not practically feasible.

The presentation of such data to the public via the Internet is similarly difficult. Even in a compressed JPEG format, the complete COSMOS ACS image cannot be transported in a sensible time, and even current 64 bit PCs have relevant size constraints for loading large images. In order to allow viewers from the public or science communities to browse through such available data sets, we have put together a World Wide Web-based application we call “SkyWalker”, which allows the user to, in principle, browse arbitrarily large images and to view any part of them on the screen. It builds on HTML and JavaScript only, which are by default integrated in any current image-capable Web browser. In this way, such images can be viewed not only without the installation of specialized software, but also by anyone with an Internet connection (even a slow one).

2. The SkyWalker technique

The goal of the SkyWalker is to allow browsing of large images without the requirement of downloading them as a whole. It should be possible with any graphical Web browser, and certainly for Firefox/Mozilla and Internet Explorer. The user should be able to pan around in the full image.

The main technical solution is that the full image is sliced up into smaller square images ("subimages") of $256 \times 256$ pixels, which are named with a prefix and a running number. At any time, $4 \times 4$ adjacent subimages are placed as background images in a grid of layers ("sublayers") in the framework of the JavaScript document object model (DOM; Wood et al. 1998). While a part of this region is visible through a mask ("viewport") of $\leq 768$ pixels on a side, the remainder lies outside the visible region (Fig. 1).
In order to select the region to be viewed, the user either moves a pointer around in a separate downscaled overview image that shows the location and size of the viewport, or else directly drags the displayed image itself in order to shift the position.

All the JavaScript code required for this is contained in the SkyWalker HTML page, which consists primarily of JavaScript and relies on the freely available DynAPI library of crossbrowser JavaScript functions. The library bundles a number of common JavaScript tasks, such as the creation, movement, and placement of layers, which are applications that are used for the SkyWalker. By using DynAPI library functions, a single syntax can be used for layer manipulations across different browsers, which would otherwise vary. All layer creation and manipulation tasks are handled via this library.

From the positioning inside the overview image, which is also contained in its own DOM layer, a JavaScript function computes several things: (1) the associated pixel position of the fullscale image, (2) from the pixel position the running numbers and thus the names of the 16 images to be displayed, and (3) the screen coordinates of the 16 sublayers. These are organized in four rows and four columns, and by always shifting them to identical coordinates and by identical offsets, they appear as a single, continuous image.

If the image is shifted to a position such that, e.g., a column comes to lie so far to the side that its contents are no longer visible in the viewport, its layer position is relocated from the right to the left side of the sublayer grid (or vice versa), and the image contents get exchanged to continue the contiguous image on that side. In this way, the same 16 layers are constantly defined and do not need to be destroyed and recreated again; just their location and content is changed.

For the astrometrically calibrated COSMOS SkyWalker (Fig. 2), three “zoom levels” are presented, consisting of sets of images of the COSMOS ACS F814W images (Scoville et al. 2006b; Koekemoer et al. 2006) at scale sizes of 1″0, 0″25, and 0″1 pixel−1. Other data sets are currently being incorporated, notably from the VLA COSMOS radio survey; in the future, these may potentially include data from other instruments (e.g., Xray and other optical images). We also added the option of displaying the sky coordinates of the central pixel in the viewport when activating a crosshair, computing R.A. and decl. from the pixel coordinates in tangential projection.

Other features are conceivable for the future; e.g., accessing a catalog by using information on individual galaxies and objects. Although the COSMOS SkyWalker is not able nor is it meant to replace applications such as Skycat, DS9, or other scientific data viewers, it can certainly be used for quick visual access to the ACS data and for presentation of the material to nonastronomers. The COSMOS SkyWalker is currently directly accessible at http://www.mpia.de/COSMOS/skywalker.

3. Future SkyWalking

Given the current state of the code, it is in principle possible for the SkyWalker application to present any contiguous data set that does not cover more than one hemisphere. In principle, it is possible to present any data set in a SkyWalker application. However, several steps need to be taken in order to do this. As a prerequisite, the full image needs to be sliced up into subimages, and a scaled down overview image needs to be prepared. Translation constants between the overview image and the full image have to be computed.

The SkyWalker code is open source licensed under the GNU General Public License (GPL) and is freely available from http://skywalker.sourceforge.net (the COSMOS SkyWalker described here represents ver. 4.0). At this site, we also maintain a list of different SkyWalker applications, which cur-

2The DynAPI 2 CrossBrowser JavaScript Library, Ver. 2.5.7, is available from http://dynapi.sourceforge.net under the GNU General Public License.

3 Here we have to note that the current version of the COSMOS SkyWalker works with images in gnomonic projection, which, like all zenithal perspective projections, will lead to field distortions at larger distances from the central point of the projection (Calabretta & Greisen 2002). If fields larger than a few degrees are to be shown, alternative projections should be used that are appropriate for the geometry of the data set. To accommodate the full celestial sphere, any projection can be used with nondiverging coordinates, the exact choice depending on whether the projection is supposed to be, e.g., equiareal or equidistant. The corresponding conversion from pixel to world coordinates then needs to be added to the code.
Fig. 2.— Screen shot of the COSMOS SkyWalker, showing the overview image (top left) with the position crosshair in the main viewport (right), the coordinates (bottom right) scale selection and image scale information (middle left). The crosshair shows the coordinate position center, and it can be turned on or off together with the coordinates.

We explicitly invite anyone to adapt current versions of the SkyWalker to their own data set and unique needs, or to add new features.

For the realization of the SkyWalkers, we would like to thank the COSMOS, GEMS, and UDF teams for their work, which generated these images. We also thank the developers of the DynAPI JavaScript library, which made programming easy, and to the developers of STIFF at Terapix, which facilitated the conversion of COSMOS ACS images from FITS to TIFF.

REFERENCES

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