Exploration of 3D spectroscopy data

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Abstract

Integral field spectroscopy (IFS) is a technique that is widely used by astrophysics. It allows the whole electromagnetic spectrum for each pixel of a telescope image to be captured, generating a large amount of information. Visualizing and exploring this information in a flexible and an intuitive way is a challenge. This paper presents an interactive method to explore IFS data.

Categories and Subject Descriptors (according to ACM CCS): I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques

1. Introduction

Integral field spectroscopy (also known as 3D spectroscopy) allows the whole electromagnetic spectrum for each pixel of a telescope image to be captured simultaneously [WEC*09]. It generates a large amount of information that can be used to analyze the composition, kinematic properties, and formation and evolution of galaxies.

Although the information collected is three-dimensional (representing the $I(x,y,\lambda)$ function), two dimensional tools are usually used to visualize the data. The information is often analyzed by generating 2D cuts or slices which show the spatial distribution of the intensity of a given wavelength. This reduces the amount of information and allows attention to be focused on the relevant part of the data set.

Nevertheless, the scientific community generally recognizes the need to use 3D visualization tools. One example is the Astronomical Medicine Project, which attempts to apply medical imaging and analysis techniques to three-dimensional astronomical data [BGH*07]. However, in spite of this need, very few exploration techniques have been proposed specifically for astrophysics.

This paper presents a novel method of exploration that combines volume rendering with a mechanism to select the visualized intervals of the spectrum.

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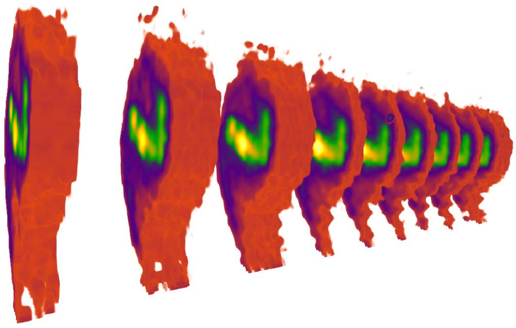

Figure 1: *Data cube rendered showing nine sectors.*

2. Proposed method

The information obtained using IFS (known as data cubes) can be represented as a 3D grid and rendered using volume visualization techniques [Joh08] [PvdH01]. Nevertheless, astrophysicists require more than images; they need to be able to explore this data.

Data cubes do not represent physical objects due to the fact that one of their dimensions is spectral. Moreover, they are very disproportionate; the spectral dimension is typically between twenty and forty times bigger than the other dimensions. The exploration must therefore be carried out using special purpose techniques.

We here propose a method of exploration based on the

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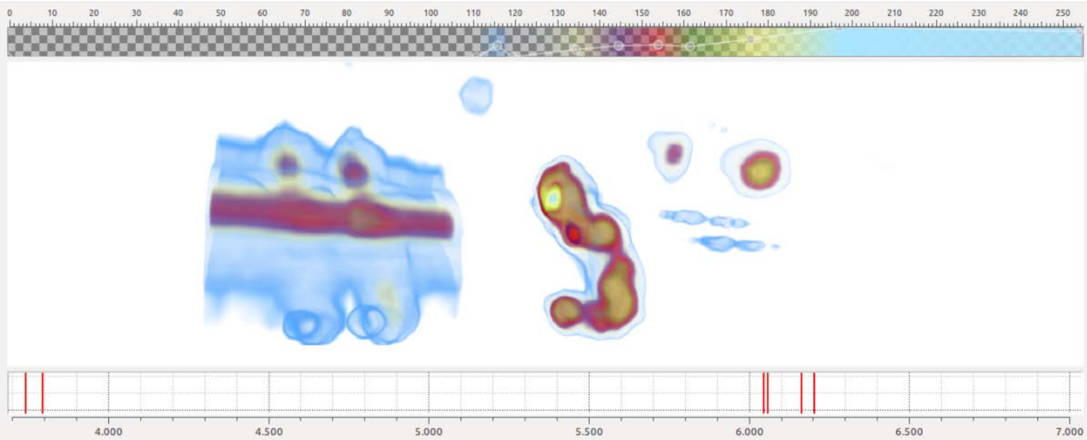

Figure 2: *Exploration tool.*

visualization of a subset of the volume determined by a sequence of wavelength intervals

$$[\lambda_0, \lambda_1], \ldots, [\lambda_{i-1}, \lambda_i], \ldots, [\lambda_{n-1}, \lambda_n] \qquad \lambda_i < \lambda_{i+1}$$

that are displayed with a fixed distance of separation (see Figure 1).

This method allows different zones of the model to be compared more easily and permits the user to focus on the relevant regions of the spectrum, supplying more information than a slice.

3. Implementation

To implement this method we have developed a volume ray casting algorithm and a widget for querying the definition of intervals (see Figure 2). The user can create, edit or remove intervals on the widget by moving the interval limits.

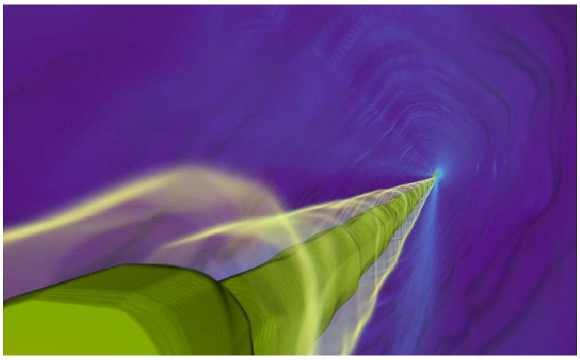

Figure 3: *Data cube visualization with the camera located inside it.*

The rendering process has been implemented by adapting a GPU three pass ray casting algorithm [Ngu07]. The first and second pass render the volume bounding box using the volume coordinates as texture coordinates, generating the ray entry and exit points for every pixel.In the third pass the ray equation is calculated and the pixel colour is composed by sampling the ray through the volume.

The algorithm used in our exploration method treats each sector as an independent volume, applying the previously described ray casting algorithm to each one. As every sector is rendered independently, it is necessary to combine the resulting images. Sectors are ordered according to distance from the observer. The ray casting algorithm is then run for each sector, starting with the one that is farthest away and using alpha blending to generate the combined image.

In order to allow the user to move the camera inside the volume, it is necessary to intersect the bounding box with the viewing frustum before drawing it at the first and second pass (see Figure 3).

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