

Three Tools to Aid Visualisation of FITS Files for Astronomy

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Abstract. Increasingly there is a need to develop astronomical visualisation and manipulations tools which allow viewers to interact with displayed data directly, in real time and across a range of platforms. In addition, increases in dynamic range available for astronomical images with next generation telescopes have led to a desire to develop enhanced visualisations capable of presenting information across a wide range of intensities. This paper describes three new tools for astronomical visualisation and image manipulation that are the result of a collaboration between software engineers and radio astronomers. The first tool, FITS3D, is a fast, interactive 3D data cube viewer designed to allow real-time interactive comparisons of multiple spectral line data cubes simultaneously. It features region specific selection manipulation including smoothing. The second tool, FITS2D, aids the visualisation and manipulation of 2D fits images. The tool supports the interactive creation of free-form masks which allow the user to extract any (potentially non-contiguous) subset of a fits image. It also supports annotations which can be placed without affecting the underlying data. The final tool is an R package for applying high dynamic range compression techniques to 2D fits images. This allows the full range of pixel brightness to be imaged in a single image, simultaneously showing the detail in bright sources while preserving the distinction of faint sources. Here we will present these three tools and demonstrate their capability using images from a range of astronomical images.

1. Introduction

As we move to larger and more data rich astronomical images there is a pressing need to develop fast, high quality interactive visualisation tools which can deal with the increased images sizes expected from next generation astronomical instruments. In particular, there is a lack of capability in interactive rendering of 3D FITS cubes, extraction tools for 2D FITS files and compression for high dynamic range astronomical images. Here we briefly present three such tools for the astronomical community.

2. 3D rendering: FITS3D

There are a number of tools which allow for viewing of 3D images (e.g. DS9; Joye & Mandel (2003) and Karma; Gooch (1996)). Historically, these tools are often slow or

cannot be used easily on a commodity laptop¹. Recently Hassan et al. (2011) described a system which can open a 26Gb FITS files viewed at 3 frames per second using a set of networked computers and AstroVis (Perkins et al. 2014) is able to render a 1.8Gb FITS file at 40 frames per second. However, even these newer systems are slow to load files² and often run at lower speeds (down to 1 frame per second) when the user zooms into an image. For the next generation of large telescopes such as the Square Kilometre Array, we need to be able to open images of many 10s of GBs, for at least preliminary viewing on a commodity laptop.

FITS3D³ has been created to allow for fast and interactive exploration of multiple 3D and 4D FITS files simultaneously. FITS3D reads in a FITS file with user controlled quality settings. At the lowest quality we are able to read in a 26Gb FITS file in 0.78 seconds, and then display it at approximately 280 frames per second⁴. In addition to standard imaging options such as real time histogram-based filtering, smoothing and rotations, FITS3D also allows rapid changes to quality settings for either the entire space, or only a user specified area (Figure 1). All of these mechanisms are optimised to both allow the clearest view of the data and ensure the best possible performance. As not all programs are able to load cubes of the same size as FITS3D, it is also able to export user selected cubes, which can then be used by other programs.

It is also possible to load in multiple cubes simultaneously using FITS3D. If these have the same coordinate systems, then the cubes will be overlaid using shared coordinates, so that two cubes can be looked at simultaneously and their intersections can be clearly (and correctly) seen. FITS3D also supports the exploration of 4D hypercubes, where the fourth dimension can be stepped through using a slider.

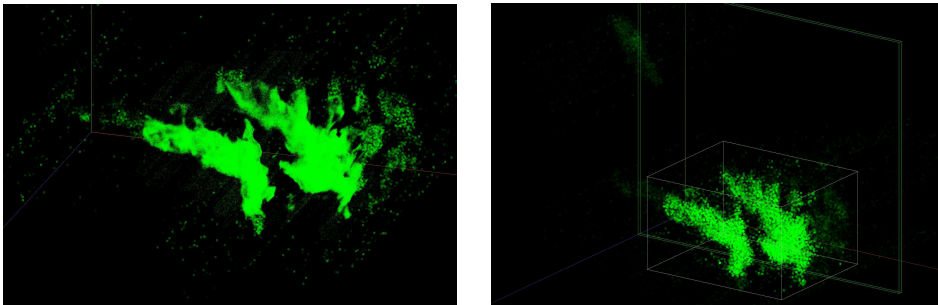


Figure 1. 3D cubes rendered using FITS 3D *Left*: An image with different quality for different regions. *Right*: User selection box.

2.1. Region Extraction & Annotation: FITS2D

The best current option for extracting region from a FITS file is the MIRIAD toolkit (Sault et al. 1995), which allows the user to extract a polygon with hand written coordinates.

¹For example, DS9 took 22 seconds to finish rendering a single frame of a 270Mb FITS file.

²AstroVis takes more than 5 minutes to load a comparatively small 272Mb FITS file.

³<https://github.com/chrishawkinsnz/Fits3D>

⁴Using a 2014 MacBook Pro.

Alternative tools such as the Fits Cutout web service (Haridas et al. 2005) are even more limited, only allowing the extraction of rectangular regions. However, astronomical objects are frequently complex shapes, often with occlusions or non-continuous parts which are hard to select cleanly this way. Additionally, region annotation with text and simple shapes like ellipses and rectangles is a feature that exists in a number of software packages such as kvis (Gooch 1996) and DS9, but the ability to create annotations of an arbitrary shape is lacking.

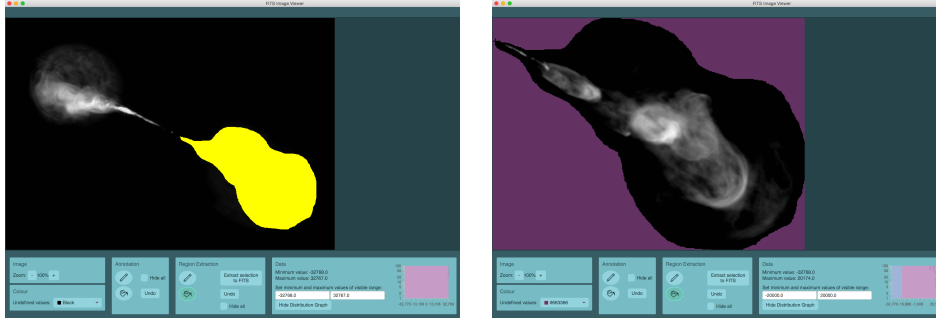


Figure 2. An example of region extraction using FITS2D *Left*: Object of interest being painted by the user *Right*: Object of interest now loaded as a separate file (note that pink represents blanked values).

FITS2D⁵ is a tool to support the existing collection of 2D FITS image viewing and manipulation tools. Its primary features are free form region extraction and annotation. Both extraction and annotation share a single mechanism based on standard image painting applications. A user is able to draw a freehand path using the paintbrush tool and may fill any closed shape using the paint bucket tool. Pixels selected either by the paintbrush or bucket tool may then be extracted as a new FITS file (see Figure 2). Since the FITS format expects are rectangular image, the generated image will be a rectangle larger than the selected area, but any non selected pixels will simply be exported as missing values. Annotations are the same, except that annotations can also be exported to a separate file (including their coordinates), and then reimported into any other files. The coordinates stored are used to ensure that the annotations appear in the same spatial location in all files.

2.2. High Dynamic Range Image Compression

High dynamic range (HDR) compression is the general problem of trying to show a large range of values when you only have a small number of output values. Gradient domain high dynamic range compression (Fattal et al. 2002) attempts to address this problem by compressing the derivative of the image, then reintegrating (numerically) in order to get back a compressed image. This technique has been applied extensively to photography, but is also applicable to astronomical FITS files. We explored the use

⁵<https://github.com/PragyaM/FITS2D>

of gradient domain high dynamic range compression on FITS images with the help of an R library⁶ and a C implementation⁷ of the algorithm.

Figure 3 shows there is some difference between the simple log scale and using the HDR compression. However, we find that the HDR compression is significantly slower (in large part due to the numerical integration required). We do note that there are other techniques for HDR compression that can be applied to astronomical images, and we hope to see more work done on this in future.

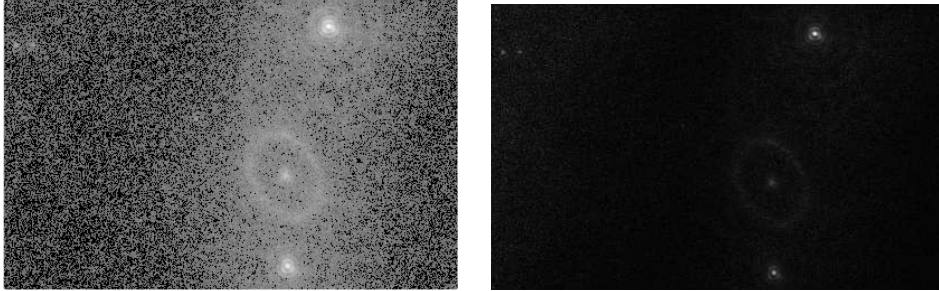


Figure 3. FITS test image from <http://www.cv.nrao.edu/fits/>. *Left*: Log scaled. *Right*: Using the HDR compression.

3. Conclusion

We have developed three new tools for exploration of astronomical data. Two of these tools, FITS3D and FITS2D, will be described in detail in future publications and all three packages are available for beta testing in the repositories given here.

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⁶<https://github.com/klapaukh/astror>

⁷http://ttic.uchicago.edu/~cotter/projects/hdr_tools/