3D visualisation of radio data in a scientific archive

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Abstract. New generation radiotelescopes will require that scientific archives are adapted to new technological challenges, being the SKA Observatory the most extreme case. SKA Regional Centres will provide data access, analysis tools and the computational environment for the data anlaysis or visualization. In this paper, we present the results on conducting research on how the new archives will provide added value services, like visualisation.

1. Introduction

Radio interferometry is a technique to make observations with more resolution and more sensitivity than with single-dish telescopes. Data produced with this method is multidimensional, files are commonly called datacubes. New instruments are going to create bigger and more complex data that will pose a great challenge for researchers and data centres.

The Square Kilometre Array Observatory (SKAO; SKA Organization 2021) will consist of two radio interferometres, one for low frequencies (50-350 MHz, SKA-Low) in Australia and another one for higher frequencies (350 MHz-15.4 GHz, SKA-Mid) in South Africa. SKAO is expected to produce around 700 PB of data per year that need to be stored, with files of several TB. The SKA Regional Centre Network (SRCNet; Garrido et al. 2023) will provide scientific support as well as access to the data, tools and resources for processing, analysis and visualisation.

Having access to 3D visualisation techniques that allow interacting with the models is very important to take full advantage of all the information contained in radio datacubes. There are many applications that deal with this subject; however, while the capabilities to visualise 2D images are very advanced, software for the representation of 3D Big Data is underdeveloped (Hassan & Fluke 2011). This is due to 3D rendering being computationally much more demanding than displaying 2D images.

In this project we address the issue of preparing for Big Data from SKAO regarding 3D visualisation. To accomplish this, we are developing a technique to create 3D models of astrophysical data in a remote server, and including it in a scientific archive. In section 2 we make a brief review of different tools, while how the 3D models are created is explained in section 3. The process to create remote visualisations and the scientific archive are described in section 4. Finally, conclusions are presented in section 5.

2. Exploration of 3D visualisation technologies

We have studied various tools from different fields, including but not limited to astrophysics, to study their strengths and limitations and to select the most convenient technology that scales up to astronomy Big Data requirements. We have made this exploration because other communities (e.g. the gaming community) have been developing advanced visualisation methods that could be useful for astrophysics. A short review of some tools is presented next, although others have been examined:

CARTA (Comrie et al. 2020) is being prepared for big observatories like SKAO or ngVLA. It uses a HDF5 schema to make it very efficient dealing with Big Data. However, it does not have the option of creating 3D models.

ViaLactea service (Vitello et al. 2018) is prepared for the analysis of multi-wavelength Big Data, with support for 2D images, cubes, catalogues and other data. It can create a 3D visualisation but its interactive options are very limited.

ParaView (Ahrens et al. 2005) is widely used in various fields like engineering, medical science or with sensor data, as it is a very versatile tool. It can have a client-server architecture and deal with big datasets. Yet, it is not very accessible, as creating 3D models and interacting with them is not straightforward if you are not familiar with the software.

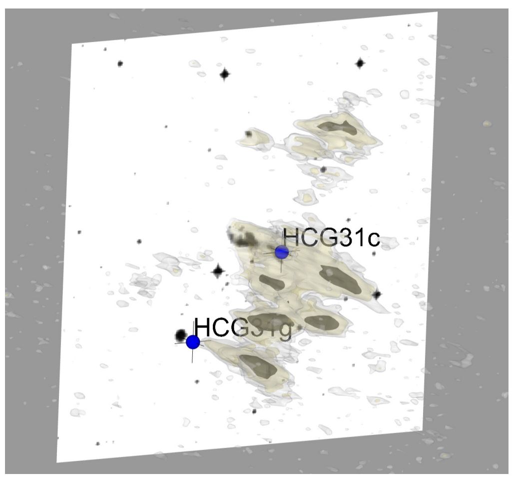

Figure 1. Visualisation of HI gas in the HCG31 group from VLA data (Verdes-Montenegro et al. 2005). Three iso-surfaces are shown along a DSS2 image of the same field of view and the positions of some galaxies from optical surveys. Each surface has a different colour.

3. 3D models

One of the products of radio interferometres are 3D datacubes, with two spatial axes and a spectral one. This type of data is very useful for the study of spectral lines like the 21 cm line, giving information about the structure and dynamics of galaxies and other objects. The 3D models that we create represent iso-surfaces, i.e. surfaces made by voxels of the same intensity, instead of the full cube. This approach loses information, but, if used correctly, the loss is non-important and it makes the files with the models much lighter, while reducing the amount of calculations needed for rendering.

From the exploration described in the previous section we have chosen X3D, an open standard for viewing and storing 3D data. With the addition of X3DOM, a JavaScript library, the models can be integrated into an HTML to make them interactive. The X3D-pathway (Vogt et al. 2016) is a method that implements X3D for astronomy visualisations, using the MayaVi python library to create the 3D models. We discovered that the way MayaVi stores the model is not efficient, therefore, we have explored an alternative method to produce X3D models, with a significant reduction in size.

We have produced a graphical interface based on HTML and JavaScript that provides the following capabilities: rotation and zoom (from X3DOM); hiding and showing surfaces and labels, changing the scale of the spectral axis, including a 2D optical image, changing the colour map and adding markers, among others. The X3D model is read by the HTML to display an interactive visualisation in a web page. Figure 1 shows the HI gas in a group of galaxies using this technique.

4. Remote visualisations in scientific archive

In order to create visualisations remotely and make them accessible, we have built a scientific archive using DaCHS (Demleitner et al. 2014). DaCHS is an open platform that implements IVOA standards and that can publish services sharing data like tables, images or spectra, following Open Science and FAIR principles. This service implements SIAP to make datacubes findable and allow queries, and Datalink to link complementary resources to the data. We use SODA* to provide access to a service able to transform datacubes into X3D models and provide a remote visualisation in the Spanish Regional Centre (Garrido et al. 2022). According to its recommendation, SODA is a low-level data access capability or server side data processing. We define SODA* as a server side data processing service (including custom parameters) because SODA is commonly used to make cutouts and we have presented a different use. A schema of the process used to create the remote visualisations is presented in Figure 2.

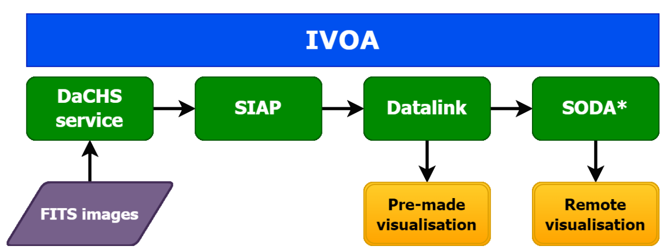

Figure 2. Flow diagram of the process to access and create 3D visualisations through a scientific archive from DaCHS.

5. Conclusions

SKAO will be a big challenge due to the unprecedented scale and complexity of the radio Big Data that it will produce. In order to make full use of the capabilities of the telescope, we need to prepare computational resources for storage, processing, analysis and visualisation. In the latter aspect, we have created a technique to transform radio datacubes into 3D models using X3D. To deal with big size cubes, this has been implemented in a scientific archive with DaCHS using IVOA standards like Datalink and SIAP, and SODA* to access our application, taking advantage of the espSRC to create the visualisations remotely.

Next steps include a thorough analysis of the scalability of our software, the implementation of other interactive options and the expansion to data from other instruments at other wavelengths.

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