

iDaVIE-v: Immersive Data Visualisation Interactive Explorer for Volumetric Rendering

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Abstract. We present the beta release of iDaVIE-v, a new Virtual Reality software for data cube exploration. The beta release of iDaVIE-v (immersive Data Visualisation Interactive Explorer for volumetric rendering) is planned for release in early 2021. iDaVIE-v has been developed through the Unity game engine using the SteamVR plugin and is compatible with all commercial headsets. It allows the visualization, exploration and interaction of data for scientific analysis. Originally developed to serve the Hi Radio Astronomy community for H_i source identification, the software has now completed the alpha testing phase and is already showing capabilities that will serve the broader astronomical community and more. iDaVIE-v has been developed at the *IDIA Visualisation Lab (IVL)* based at the University of Cape Town in collaboration with the *Italian National Institute for Astrophysics (INAF)* in Catania.

1. Introduction

Virtual reality (VR) tools are the best suited for 3D (or multi-dimensional) data exploration. They enable a unique and immersive perspective on the data and allow intuitive interactions with the data. They thus speed up both the data interrogation process and the scientific discoveries that arose from it. Nevertheless, even though VR is widely developed and exploited by the gaming industry, it is only in its early days for scientific exploitation and is mostly used for science education or communication.

The iDaVIE-v tool is part of the IVL¹ iDaVIE software suite and has been developed in collaboration with INAF-Catania. It is the first VR tool developed by a team of

¹<https://vislab.idia.ac.za>

developers and professional astronomers for scientific data analysis. *iDaVIE-v*'s primary scientific driver is the interrogation of Neutral Hydrogen (H_I) Radio Data Cubes, where it aims to enable a set of critical operations on the data that are best carried out in an immersive environment. These operations are, for example, H_I source detection, source identification, source characterisation and fast validation of (semi)automatic source extraction algorithms such as SoFIA². Even though it has been developed with these clear goals, its usage can be broader. The tool is flexible and can thus serve any science case that shares similar aims and uses similar data formats, such as the interrogation of medical and biological 3D datasets.

In this paper we illustrate the main capabilities of *iDaVIE-v* in the astronomical context. For more details on the technical software development and broader reach of *iDaVIE-v* and of the complete software suite *iDaVIE* we refer the reader to Sivitilli et al. (2019), Marchetti et al. (2019) and Jarrett et al. (2020).

2. *iDaVIE-v* hardware requirements

iDaVIE-v has been developed and tested to work with any commercial VR headsets currently available (e.g. Oculus Rift and Rift S, HTC Vive and Vive Pro or the Samsung Odyssey) and to (eventually) run on different operating systems (e.g. Microsoft Windows, Linux and MacOS). Nevertheless, the beta version presented here only runs on Microsoft Windows (Windows 10, version 1903 or newer). The minimum and recommended hardware requirements to run *iDaVIE-v* and avoid any efficiency issues are as follows:

- **Minimum requirements.** CPU: Quad core AMD Ryzen or Intel i5; Memory: 16 GB; Disk: SSD highly recommended; GPU: NVIDIA 1060 / NVIDIA 1650 Super / AMD Radeon RX 5500 XT or higher.
- **Recommended requirements.** CPU: AMD Ryzen R7 or Intel i9; Memory: 32 GB; Disk: NVMe SSD; GPU: NVIDIA 2070 / AMD Radeon RX 5700 XT or higher.

3. *iDaVIE-v* capabilities for H_I data cube studies

To ease the understanding of the tool, in this section we briefly summarise the operations and actions that are currently enabled in the *iDaVIE-v* beta release and that are thought to serve the Radio H_I astronomical community and its science needs. Any example reported hereafter will thus refer to this specific science case; for a more extensive description on the various scientific applications of the tool we refer the reader to Jarrett et al. (2020)

- **Data import: the desktop GUI.** The user can load the data in *iDaVIE-v* using an *ad-hoc* developed desktop GUI. This is because the most common desktop operations such as the search of files, scrolling of lists, click buttons and write text are best performed using a keyboard outside the VR environment. The typical

²<https://github.com/SoFiA-Admin/SoFiA>

set of data that needs to be imported for astronomical H_I science are the H_I data cube of interest (in `fits` format) and, if available (optional), a mask (aka a cube with the same size and format of the data cube, but that contains only the H_I source placeholders identified by a source finding algorithm like e.g. SoFIA) and a source catalogue (of any kind). The GUI (Fig. 1) allows to browse the local files, to load the mentioned data and to inspect them.

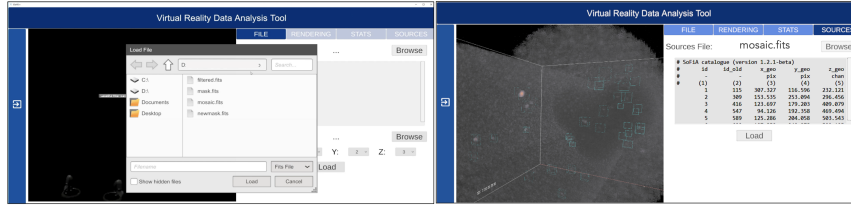


Figure 1. **iDaVIE-v Desktop GUI.** **Left:** the interface to load the data. **Right:** feedback after ingestion of all input files (cube, mask and data catalogue) is completed. In both images the "black" square on the left shows the VR view (aka what the user sees when wearing the VR headset), while the space on the right shows the files headers and allows some operations such as select the colour transform, change the data visualisations thresholds, visualise some basics statistics of the data. Most of these operations can also be performed in the VR environment.

- **Data interaction in the VR space.** Once the data are loaded the user puts on the headset and hand controllers for immersive scientific analysis. *iDaVie-v* is designed and developed with the user interactions foremost in mind. By design the hand controllers of most commercial VR systems have similar limitations when it comes to menu based operations, for this reason, in *iDaVie-v* most of the data interaction operations can be performed both through menus, and/or through voice-activated commands coupled with a series of simple gestures (such as moving the controllers up and down or left and right to e.g. change thresholds). In Fig. 2 we show some of *iDaVie-v* capabilities and visualisation modes. The most desired functionalities by the H_I astronomical community have been developed and implemented in the beta release. In a nutshell, the user can: **a)** visualise the entire data cube or select and visualise only a portion of it for better analysis; **b)** move/rotate the data in any direction (or simply walk through the data) and zoom in/zoom out on the data; **c)** change the colour transform to better highlight particular features in the data; **d)** overlay catalogues on the data cube; **e)** overlay a mask on the data cube; **f)** subtract the signal of the masked sources from the cube and explore the residuals; **g)** derive in real time, sky and source statistics, moment maps and other analytics that may be derived from the data and masks; **h)** edit the mask in real time by simply adding or subtracting voxels³ to it; **i)** take VR-view snapshots that saves jpeg files.
- **Data export.** Once an operation is completed the results can be exported and saved to disk. The outputs depend on the operations the user carried out on the data. There are several outputs that are originated by *iDaVie-v* such as plots, moment maps, screenshots, an amended mask and a new source catalogue.

³3D volumetric pixels

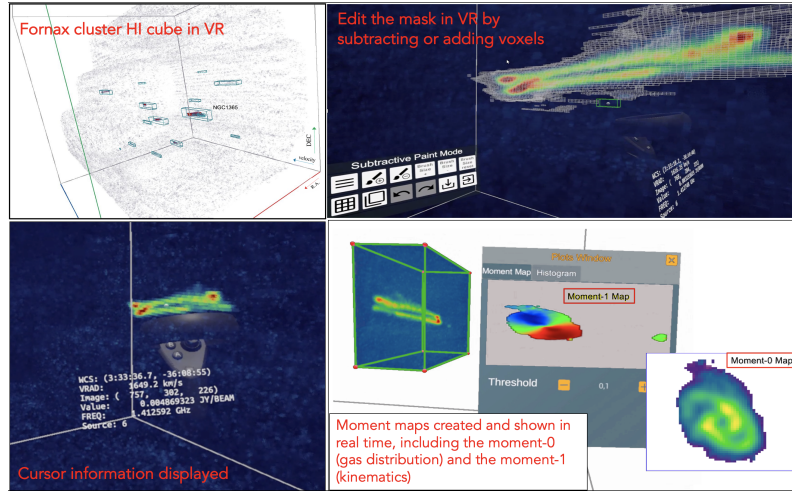


Figure 2. Some iDaVIE-v capabilities. **Top left:** iDaVIE-v VR environment view of the HI Australian Compact Telescope Array (ATCA) cube of the Fornax cluster (courtesy of P. Serra and collaborators, Serra et al. 2016). The sources are highlighted with cyan boxes. **Bottom left:** when the hand controller cursor intercepts an identified source in the cube, key source information extracted from the cube and mask (if any) are displayed to the user. **Top right:** illustration of iDaVIE-v in "edit mask" mode; in this case the user is deleting misidentified voxels from the mask shown as a grey voxels grid on the data. **Bottom right:** illustration of moment maps rendering of a selected source, NGC 1365, a large barred spiral in the Fornax Cluster

4. iDaVIE-v beta release & future development

The beta release of iDaVIE-v is expected for early 2021. The release will include the iDaVIE-v executable file and user instructions. The source code will be made publicly available only when the final release will be completed (late 2021). iDaVIE-v development will continue after the beta release in order to include other functionalities (such as the capability of importing and visualise multiple catalogues in one go) and will also rely on feed-backs from the user community for further improvement suggestions.

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