VRSMF: Visualizing the universe in 3D

User Manual of the VR software developed by Quasar Science Resources for the StarFormMapper project

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CHANGE LOG

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1. Introduction

The goal of this application is to provide an innovative science-driven tool to explore astronomical data using Virtual Reality headsets and Hand-Tracking devices for interaction. Virtual Reality brings an unprecedented level of immersion in a 3D virtual space which gives the possibility to better explore multi-dimensional data and build a virtual work environment that is more flexible and intuitive to use.

While the present common data analysis tools used in Astronomy rely on 2D visualisations, for the representation of data plots in 3D, native 3D visualisation that take advantage of the depth perception can lead to more precise selections, better clustering determinations, and overall quicker and more efficient interaction through tactile and haptic controllers. Also, interaction with time, as when propagating proper motions and radial velocities for source catalogues, can be better perceived by the astronomer having depth perception of the visualisations involved.

In the case of the VRSFM application, the 3D visualisation uses scientific data from the Gaia1 and Herschel2 ESA space missions as well as from results obtained within the “StarFormMapper (SFM) A Gaia and Herschel Study of the Density Distribution and Evolution of Young Massive Star Clusters” project.

Virtual Reality for the SFM project (VRSFM) has been developed by Quasar Science Resources S.L. in collaboration with the StarFormMapper Consortium. The main objective of the SFM project is to combine data from two of ESA’s major space missions, Gaia and Herschel, together with ground-based facilities, to constrain the mechanisms that underlie massive star and star cluster formation. This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 687528. Find out more at:

https://starformmapper.org/

https://www.starformmapper.es/

1http://sci.esa.int/gaia/
2http://sci.esa.int/herschel/
1.1. Scope

This document belongs to the deliverable D36. Outreach activities update for the EU H2020 (COMPET-5-2015 – Space) project “A Gaia and Herschel Study of the Density Distribution and Evolution of Young Massive Star Clusters” (Grant Agreement Number: 687528), with abbreviated code name StarFormMapper (SFM) project.

1.2. Acronyms

PC Personal computer
PM Proper Motion
QSR Quasar Science Resources S.L.
VRSFM Virtual Reality for the StarFormMapper project
2. VRSFM Application Installation

2.1. Current Version

The current version of the VRSFM Application is v1.0.

2.2. System Requirements

In order to run VRSFM a PC with the following features is necessary:

**Recommended Specifications**

- Graphics Card: NVIDIA GTX 1060 / AMD Radeon RX 480 or greater
- Alternative Graphics Card: NVIDIA GTX 970 / AMD Radeon R9 290 or greater
- CPU: Intel i5-4590 / AMD Ryzen 5 1500X or greater
- Memory: 8GB+ RAM
- Video Output: Compatible HDMI 1.3 video output
- USB Ports: 3x USB 3.0 ports plus 1x USB 2.0 port
- OS: Windows 10 operating system

**Minimum Specifications**

- Graphics Card: NVIDIA GTX 1050Ti / AMD Radeon RX 470 or greater
- Alternative Graphics Card: NVIDIA GTX 960 / AMD Radeon R9 290 or greater
- CPU: Intel i3-6100 / AMD Ryzen 3 1200, FX4350 or greater
- Memory: 8GB+ RAM
- Video Output: Compatible HDMI 1.3 video output
- USB Ports: 1x USB 3.0 port, plus 2x USB 2.0 ports
- OS: Windows 10 operating system

Also, in order to fully enjoy the 3D visualization, the Oculus Rift\(^3\) and the Leap Motion\(^4\) hand tracking sensors are required.

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\(^3\)https://www.oculus.com
\(^4\)https://www.leapmotion.com/
2.3. Downloading the Application

The most recent version of VRFM (v1.0) can be downloaded at the following address:

https://www.starformmapper.es/material-de-divulgacion/

The VRSFM.7z compressed file contains the executable file, VRSFM.exe, the star data files (data folder) as well as the rest of the files necessary to run the application (Figure 1). Decompress the file in any place you want to within your file system. To decompress the file, you can install the free and open source 7-zip tool.

![Figure 1: Contents of the VRSFM.7z file.](image)

2.4. Running the Software

Once uncompressed, double click on the VRSFM.exe icon to start the application.

![Figure 2: To run the VRSFM application, double click on VRSFM.](image)
An application configuration screen will open. We recommend to keep the options shown by default.

![VRSFM Configuration screen](image)

*Figure 3: VRSFM Configuration screen.*

To start the application, click the "Play!" button which will start the 3D visualization experience.

3. Interacting with the Application

In order to interact with the software, you will need the Oculus Rift and the Leap Motion devices. The Oculus Rift is a virtual reality headset that provides a virtual reality experience for the wearer. It can be purchased in several places, including the official Oculus site, [https://www.oculus.com/rift](https://www.oculus.com/rift).

![Oculus Rift device](image)

*Figure 4: Oculus Rift device.*

(Source: [https://www.oculus.com/rift](https://www.oculus.com/rift))

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The Leap Motion hand tracking sensor is a set of hardware and software that allows you to map gestures and actions of the hands to interact with the data in the virtual world\(^7\).

![Leap Motion hand tracking sensor](https://www.leapmotion.com/)

**Figure 5:** Leap Motion hand tracking sensor shown. The device is attached on the front of the Oculus Rift device. (Source: [https://www.leapmotion.com/](https://www.leapmotion.com/))

3.1. DataBlocks

Within the 3D VR, each of the preloaded Star Cluster is represented by a "DataBlock", a small cube that can be picked up with the virtual hand and moved to the desired visualisation location. Each cube is labelled “Picked me”. Once the DataBlock is dropped (open the hand), the data within is displayed and the interaction with the data within starts. A panel with further interactivity is also activated for each DataBlock.

![Open DataBlock menu](https://www.leapmotion.com/)

**Figure 6:** Open DataBlock menu.

\(^7\)[https://www.leapmotion.com/](https://www.leapmotion.com/)
3.2. Control Panel

To enable more complex interactions with the data, each block comes with a control panel with context-specific buttons. Buttons using hand tracking are not as straightforward as in 2D interfaces, they need to have an appropriate response to proximity and activation. This is displayed by making the buttons change colours depending on their current state. When a finger is nearby the border changes colour to notify the option to press it.

- (+), (-): Zoom in/out the area of interest.
- **Color:** The stars are coloured depending on the temperature of their surface. See Section 4.4.
- **Lum:** The size of each star depending on its luminosity. See Section 4.3
- **Mov:** The direction of movement of each star is displayed. See Section 4.2
- **HRD:** The Hertzsprung–Russell diagram is displayed. See Section 4.5
- **Play:** The movement of each star according to its direction is displayed.
- **Reset:** If after executing various tasks we want to return to the initial state, we can press the **Reset** button.
- **Cube:** Element used to rotate the area of interest.

![Control Panel with context-specific buttons.](image-url)
3.3. Scaling and Rotating

With the use of one hand we can rotate the plot just by grabbing and moving like we would a real physical object. The plot rotates around its fixed centre point. By grabbing the plot with two hands we can scale the object by moving apart or joining together both hands.

![Figure 8: You can scale and rotate the plots in the virtual world with your hands.](image)
4. Science Cases

Stars can concentrate in groups called stellar clusters. Clusters are families of stars all born at the same time and gravitationally bound together. There are two types of clusters: open clusters, which include hundreds to thousands of relatively young stars loosely gravitationally bound to each other, and globular clusters, which are tighter concentrations with up to hundreds of thousands of stars that are generally order.

VRSFM incorporates four science cases designed to give some insights into stars and star clusters. For this, we have chosen the Pleiades and the Beehive star clusters. The Pleiades, also known as the Seven Sisters and Messier 45, is an open star cluster containing middle-aged, hot B-type stars located in the constellation of Taurus\(^8\). The Beehive Cluster, also known as Praesepe M44, NGC 2632, or Cr 189, is an open cluster in the constellation Cancer. It is one of the nearest open clusters to Earth, containing a larger population of stars than other nearby bright open clusters\(^9\).

\(^8\)https://en.wikipedia.org/wiki/Pleiades
\(^9\)https://en.wikipedia.org/wiki/Beehive_Cluster
4.1. 3D Visualization of the Stars in the Cluster

The application allows the visualization of the stars in 3D and navigate amongst them. If the user clicks on the displayed play button, the stars will start moving in the 3D world according to their motion (see the next section). To reset the stars to their original positions, the user has to click on the Reset button in the control panel.

![3D visualization of the Pleiades](image)

*Figure 10: 3D visualization of the Pleiades. Before movement has been applied (top) and after movement has been applied (below).*
4.2. Movement of the Stars

Both isolated and clustered stars move through space. Their velocities can be measured with respect to different systems: the galaxy, the Sun or the centre of the cluster. The component of stellar motion towards or away from the Sun is known as radial velocity\(^{10}\). **Proper motion** (PM) is the astronomical measure of the observed changes in the apparent places of stars or other celestial objects in the sky when compared to the background of the more distant stars\(^ {11}\).

![Diagram of star movement](https://en.wikipedia.org/wiki/Proper_motion)

*Figure 11: Relation between proper motion and velocity components of an object.*
(Source: [https://en.wikipedia.org/wiki/Proper_motion](https://en.wikipedia.org/wiki/Proper_motion))

In order to display the movement of the stars, the **Mov** button has to be pressed. A line with origin in each star will appear on the screen (Figure 12) marking the direction of movement.

![Proper Motion of stars in the Pleiades cluster](https://en.wikipedia.org/wiki/Proper_motion)

*Figure 12: Proper Motion of the stars in the Pleiades cluster.*

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\(^{10}\) [https://en.wikipedia.org/wiki/Radial_velocity](https://en.wikipedia.org/wiki/Radial_velocity)

\(^{11}\) [https://en.wikipedia.org/wiki/Proper_motion](https://en.wikipedia.org/wiki/Proper_motion)
4.3. Star’s Luminosity

Luminosity is the total amount of energy emitted per unit of time by a star, galaxy, or other astronomical object. To see the luminosity of the stars in the cluster, click the Lum button in the control panel. The size of each star will increase according to its luminosity. More luminous stars appear bigger.

Figure 13: When the Lum button is clicked the luminosity of the stars is displayed.
4.4. Star’s Colour

Stars have different colours depending on the temperature of their surface. This allows the classification of the stars as listed in Table 1.

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<thead>
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<th>Temperature (kelvins)</th>
<th>Conventional color</th>
<th>Apparent color</th>
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<tr>
<td>O</td>
<td>≥ 33,000 K</td>
<td>blue</td>
<td>blue</td>
</tr>
<tr>
<td>B</td>
<td>10,000–30,000 K</td>
<td>blue to blue white</td>
<td>blue white</td>
</tr>
<tr>
<td>A</td>
<td>7,500–10,000 K</td>
<td>white</td>
<td>white to blue white</td>
</tr>
<tr>
<td>F</td>
<td>6,000–7,500 K</td>
<td>yellowish white</td>
<td>white</td>
</tr>
<tr>
<td>G</td>
<td>5,200–6,000 K</td>
<td>yellow</td>
<td>yellowish white</td>
</tr>
<tr>
<td>K</td>
<td>3,700–5,200 K</td>
<td>orange</td>
<td>yellow orange</td>
</tr>
<tr>
<td>M</td>
<td>≤ 3,700 K</td>
<td>red</td>
<td>orange red</td>
</tr>
</tbody>
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Table 1: Classification of the stars according to their color. (Source: https://oneminuteastronomer.com/708/star-colors-explained/)

Click the Color button in the control panel to assign colors to the stars according to their temperature.

Figure 14: Pleiades cluster stars classified according to their color.
4.5. Hertzsprung–Russell diagram

The Hertzsprung–Russell diagram, abbreviated as H–R diagram, HR diagram or HRD, is a scatter plot of stars showing the relationship between the stars’ absolute magnitudes or luminosities versus their stellar classifications or effective temperatures\(^{13}\).

Figure 15: Hertzsprung–Russell diagram identifying stellar luminosity as a function of temperature for many stars in our solar neighborhood. (Source: https://en.wikipedia.org/wiki/Luminosity)

This plot can be created by clicking the HRD button in the control panel.

Figure 16: HR diagram of the Pleiades cluster.

\(^{13}\)https://en.wikipedia.org/wiki/Hertzsprung%E2%80%93Russell_diagram