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## 3DMAP-VR, A PROJECT TO VISUALIZE 3-DIMENSIONAL MODELS OF ASTROPHYSICAL PHENOMENA IN VIRTUAL REALITY

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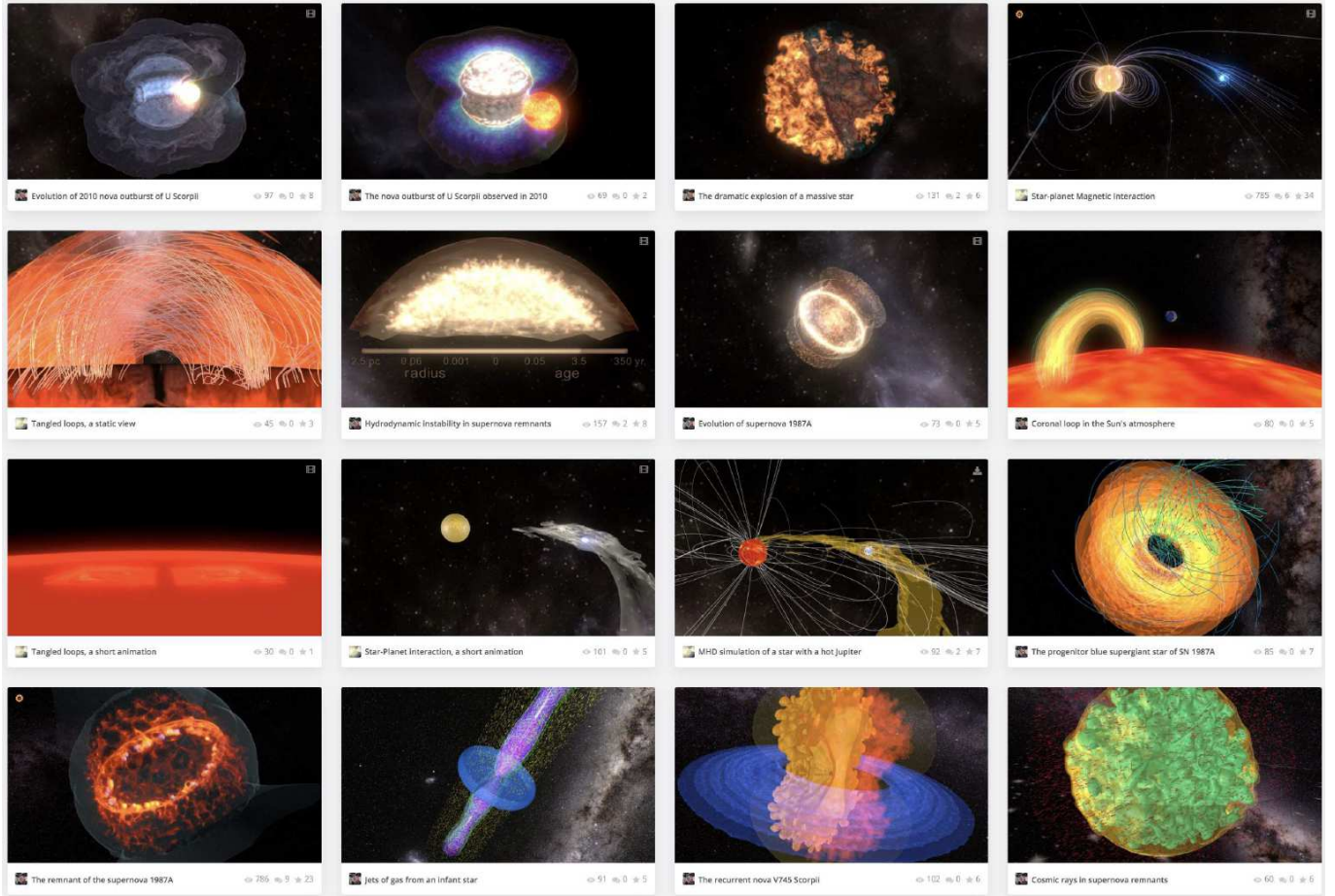
Fully 3D magnetohydrodynamic (MHD) simulations of astrophysical phenomena represent a challenge in standard data visualization for scientific purposes, for the amount of processed data and the wealth of scientific information they contain. Recently, the potential of virtual reality (VR) hardware and software began to be exploited for the purposes of scientific data analysis. Moreover, VR has also been adopted in different fields of public outreach and education with excellent outcome. To this end, YouTube and online multimedia digital stores host several VR titles with high visual impact in the categories of Astrophysics and Space Science. However, the routinely scientific use of the VR environment is still in its infancy and requires the development of ad-hoc techniques and methods.

In the first half of 2019, we launched **3DMAP-VR** (3-Dimensional Modeling of Astrophysical Phenomena in Virtual Reality), a project aimed at visualizing 3D MHD models of astrophysical simulations, using VR sets of equipment. The models account for all the relevant physical processes in astrophysical phenomena: gravity, magnetic-field-oriented thermal conduction, energy losses due to radiation, gas viscosity, deviations from proton-electron temperature equilibration, deviations from the ionization equilibrium, cosmic rays acceleration, etc. (e.g. [Orlando et al. 2011, 2015, 2016, 2017](#)).

The workflow to create VR visualizations of the models combines: 1) accurate 3D HD/MHD simulations performed for scientific purposes, using parallel numerical codes for astrophysical plasmas (e.g. the FLASH code, [Fryxell et al. 2000](#), or the PLUTO code, [Mignone et al. 2007](#)) on high performance computing facilities (e.g. CINECA, Bologna, Italy); 2) data analysis and visualization applications (e.g. [Interactive Data Language](#), [YT project](#), [ParaView](#), [Visit](#), [MeshLab](#), [MeshMixer](#)) to realize navigable 3D graphics of the astrophysical simulations and quickly have a VR representation of the models. The 3D representations are realized using a mixed technique consisting of multilayer isodensity surfaces with different opacities. Once the 3D graphics are ready, they are uploaded on [Sketchfab](#), one of the largest open access platforms to publish and share 3D virtual reality and augmented reality content. Our VR laboratory includes two Oculus Rift VR sets of equipment and dedicated computers with advanced graphics cards to visualize the models in VR. The laboratory is used to analyze the numerical results in an immersive fashion, integrating the traditional screen displays, and allows scientists to navigate and interact with their own MHD models. At the same time, we use the VR in educational and public outreach events in order to visualize invisible radiation, improve the learners sense of presence and, eventually, increase the content understanding and motivation to learn.

We realized an excellent synergy between our 3DMAP-VR project and Sketchfab to promote a wide dissemination of results for both scientific and public outreach purposes. We realized a Sketchfab gallery, “[Universe in hands](#)”, which gathers different models of astrophysical objects and phenomena developed by our team for scientific purposes and published in international scientific journals. More specifically these models describe (see Fig. 1): magnetic structures of the solar and stellar coronae (e.g. [Reale et al. 2016](#)); the interaction between a star and its planet (cf. [Pillitteri et al. 2015](#)); accretion phenomena in young stellar objects (e.g. [Orlando et al. 2011](#)); protostellar jets (e.g. [Ustamujic et al. 2016](#)); nova outbursts (e.g. [Drake & Orlando 2010](#)); the outcome of supernova explosions (e.g. [Orlando et al. 2016](#)); the interaction of supernova remnants with the inhomogeneous surrounding environment (e.g. [Orlando et al. 2015](#)); the effects of cosmic ray particle acceleration on the morphology of supernova remnants (e.g.

Orlando et al. 2012). In addition we created a second gallery, "The art of astrophysical phenomena", which collects artist's view of astrophysical phenomena for public outreach purposes. The two galleries are publically available and continuously updated to include new models.



**Figure 1.** Examples of 3D models uploaded in the Sketchfab gallery "Universe in hands".

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