“Planets in a room” a DIY low-cost kit
1st Year Report

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Introduction

Teaching planetary science using a spherical projector to show the sky and the planets’ surfaces is a very effective but usually very expensive idea. Whatsmore, it usually assumes the availability of a dedicated space and a trained user.

Planets in a room is a project made by the non-profit association **Speak Science** to build a low cost version of a small spherical projector and planetarium that teachers, museum, planetary scientists and other individuals can easily build and use on their own, to show and teach the planets and the stars.

Planets in a room was funded by the Europlanet Outreach Funding Scheme in September 2016 with half of the initial budget requested. The sum was considered to be enough to reach some of the main objectives in a rescheduled one year project and activities have begun in September 2016, to be considered KO of the project.

After one year of activity, Speak Science is releasing this document, “**Planets in a Room”, a DIY low-cost kit, 1st Year Report** with the results, together with a prototype of the hardware and software system, that has been presented at EPSC2017 Congress in Latvia.

Background and literature

The idea of developing a low-cost DIY spherical projector was first born as a spin-off of the educational activities that Speak Science has been organizing for the Italian schools in collaboration with research and educational institutions.

In the last years we experienced the very efficient use of a planetarium as an educational tool, collaborating with the Astrogarden Planetarium of the Roma Tre University (Dipartimento di Matematica e Fisica). A self-built full dome projector was built as a thesis by Tommaso Bosco (1) and used with a 7m inflatable dome in Italian schools to teach planetary science (2).

In the last 2 years we have also successfully collaborated with INAF-IAPS using a commercial >1m system for spherical projection built by 3Des (3) in a number of educational and public outreach activities. In the last year, with this system we have organized 10 lessons for schools at INAF-IAPS, in Rome and participated to different public events at Roma Tre University (like “Researchers Night” and "Eyes on Jupiter") for a total audience of thousands of visitors (4).


An image of the Astrogarden Planetarium of Roma Tre University and of 3Des sphere lesson during Researchers' night.

For both projects we produced original educational material (images, videos and storyboards) involving planetary scientists in the production, test and finalization of contents and working in close collaboration with teachers and educational experts.
We got to the conclusion that spherical projection (both on a sphere and in a dome) is a great tool to teach astronomy, planetary science and earth science in the spirit of hands-on education.
This conclusion, clearly stated in reference literature on the topic (5), has been applied and studied for a long time in the use of planetarium and navigation celestial software as educational tools (6).

We decided that a portable, cheap spherical projector that can easily be built and used by teachers, students, librarians, by anyone -not just experts- coupled with clear and effective educational content on planetary science could be a very good tool for planetary EPO.

The first step was to approach the topic from a physical point of view, finding as a good starting point the spherical projection theory proposed by Paul Bourke (7). All the existing configurations can be very easily deduced from the optical scheme explained by Bourke, with the use of two lenses, one of which a fisheye.

Next step of this project was to understand what already existed (on the market and freely distributed). There are many different commercial spherical projectors on the market: the first one is the one we have been using, Sfera Didattica XL by 3Des (3). Other good examples are Magic Planet, sold in the USA by GlobalImagination (8), and the bigger system for museums Science on a Sphere, developed by the NOAA, National Oceanic and Atmospheric Administration (9).

These products are commercial systems that require a budget of thousands of euros (see websites for pricing) that many schools cannot afford. Also, they are not studied to be transported easily (even if transportation is in some cases possible) and difficult to use for non-trained users. These systems

cannot be used to project on a dome as in a planetarium system. What smore, these systems are closed, meaning that final users will not play any part in the building and setting phases of the tool, nor in the production of educational contents.
Among open projects to build spherical projectors, we found the experience of a very small and cheap pico spherical projector, made using a laser projector and a single lens (10). This approach has been tested in our first test, but the approach seemed to be too tentative and not to produce the awaited professional results.

Wanting to develop a system that could project on a sphere but that could be also used as a planetarium full dome projection, we checked the experiences developed and distributed by amateur astronomers.

The projector built for the Astrogarden planetarium of the Roma Tre University was taken in account as a starting point (1) as well as other simple and open access systems, freely distributed online. The first one is the Lhoumeau Sky System Open project (11). Others, as Domebase, propose alternative building solutions, for example using photographic systems to optimize the system (12). All these projects distribute online plans to build different d.i.y. full dome projectors meant for amateur astronomers. They all use nonstandard auto-built pieces and lenses and materials not always easy to find on the market. They are made for a motivated and skilled target audience, such as amateur astronomers, and need to be optimized and simplified for a larger and less skilled audience (like teachers).

For what concerns the software interface, there is a vast community of programmers and users that are working on panorama, 360° images to be used and distributed with commercial and noncommercial virtual reality interfaces. A parallel effort is made by the community of amateur and professional to develop software to produce and modify images for free dome projection. The starting point for developing software for spherical projection is the dedicated wiki project where all kind of open source tools are being distributed (13) including the scripts that we used to work with images and videos. Among these, we acknowledge the rect2dome script distributed by Andrew Hazelden (14).

For the lessons and contents to be used with Planets in a room, we mainly produced original contents with the collaboration of researchers and scientists, using images and data distributed by NASA and ESA. But we must also acknowledge educational material for planetarium or spherical projectors freely produced and distributed by research institutions. Such as the planetarium free shows distributed by ESO (15) or the educational datasets developed by NOAA for the Science on a Sphere system and freely distributed (16). All these sources are extremely useful in producing educational material. They will also be a very powerful tool to involve the Planets in room community.

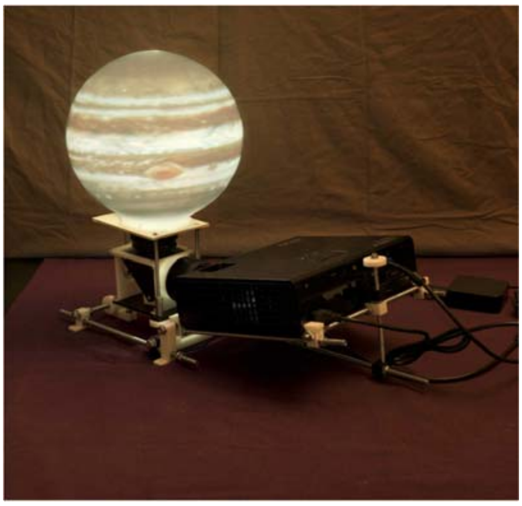
Also, the future implementation of free software usually used in a planetarium to navigate the sky, such as Stellarium (17), will be taken in account for future development of the Planets in a room project.

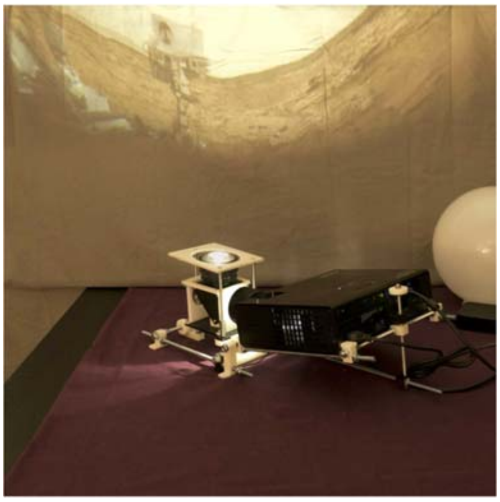
Results 1° year Project: Planets in a Room prototype at EPSC2017

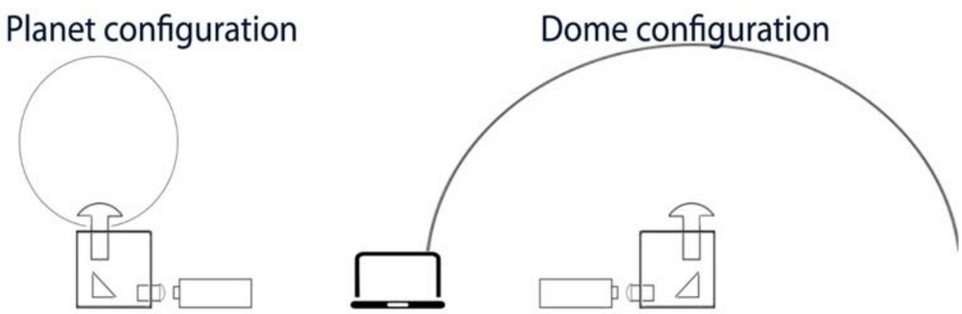
Two images of Planets in a Room presented at EPSC2017 in Latvia.

All these projects of spherical and dome projectors, both concerning hardware and software, were taken in account to build the hardware and software of **Planets in a Room-prototype** presented in September 2017 at EPSC (18).

In this first year of the project we have been developing a first prototype of the system building both hardware and software. This prototype has a very simple optical scheme studied to obtain a **good-resolution and clear** projection that covers **more than 90% of a sphere** and that can also be used in a **dome projection configuration** in a small planetarium. It is a **DIY kit** studied to be as low cost as possible, being complaint with a **<500euro limit** and using **external and not dedicated** PC and projectors.



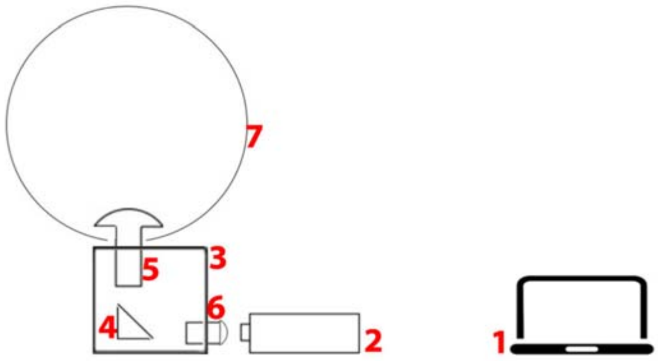




Planets in a room-prototype : In the photos above the kit working in planet configuration and in dome configuration. In the drawing below, a schematic representation of the two configurations of Planets in a room.

The building scheme of this first prototype can be seen in the diagram in next page. The system was studied to be easily reproduced by the final user, buying the requested pieces and following the instructions.

Planets in a room scheme



It uses external PC (1) and an external projector (2) that are not dedicated and that can be quickly removed from the system to be used elsewhere. The kit itself (3) is made from **3d printed pieces and off the shelf pieces bought in a hardware store**. It includes **2 lenses (5) and (6) and a diagonal (4)**.
In this configuration it projects on a **30cm plastic sphere** bought in a hardware store (7). For more details on the pieces, please see annex 1.

From an optical point of view, the two lenses that represent the best compromise are a standard F=50 mm F/D 1,4 working as image condenser and a Fisheye: F=8 mm F/D 3,5. The distance between the 2 lenses, being of about 84 mm.

The Planets in a room-prototype is also made of a software interface to be installed on the PC, with an **HTML interface** for the projection and navigation of the images that needs to be optimized for the final kit. In the prototype, the calibration procedure is manual and will be optimized including a **Script in python** in the final kit.

We have also been producing educational material to be used in Italian schools (from elementary to high school) in planetary lessons, working in the direction of defining a standard format that can be used by teachers in classroom. The materials produced until now are organized in lesson plans and storyboards to be internally used and need some additional work to be optimized, translated and widely distributed. We are delivering with Planets in a room- prototype a simplified first lesson called **Introduction to the Solar System** that was on display during EPSC2017.

The idea is to distribute Planets in a Room as a kit to a large, international community. This second phase of the project will be presented at EPSC2018

Bibliography

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(2) Astrogarden Planetarium webpage http://astrogarden.uniroma3.it/planetario/
(3) Sfera Didattica XL by 3Des http://www.3des.it
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(6) “Research on teaching astronomy in the planetarium”, Timothy F. Slater and Coty Tatge, Springer-Verlag; 1st ed. 2017
(7) Theory of spherical projection by Paul Bourke can be found at http://paulbourke.net/ (including Magic Planet http://paulbourke.net/dome/magicplanet/)
(8) Magic Planet http://globalimagination.com/
(9) Science on a Sphere https://sos.noaa.gov/What_is_SOS/
(10) http://eclecti.cc/computergraphics/snow-globe-part-one-cheap-diy-spherical-projection
(11) Lhoumeau Sky System Open project http://www.lss-planetariums.info/index.php
(12) Domebase http://www.domebase.org/building-the-mini-dome/fisheye-projection-lens
(13) http://wiki.panotools.org/Software
(14) http://www.andrewhazelden.com/blog/2014/01/dome2rect-updated/
(15) ESO Planetarium shows https://www.eso.org/public/products/planetariumshows/
(16) https://sos.noaa.gov/datasets/
(17) http://www.stellarium.org/
(18) “Planets in a room”, L.Giacomini, F.Aloisi, I. De Angelis, EPSC Abstracts Vol. 11, EPSC2017-280, 2017

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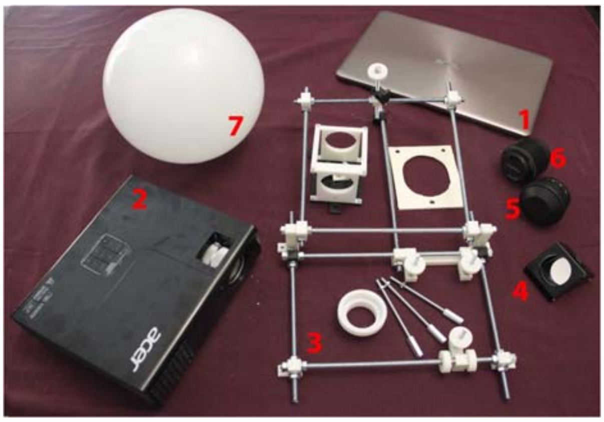
Annex 1: Manual of Planets in a Room -ver1 (10/09/2017)

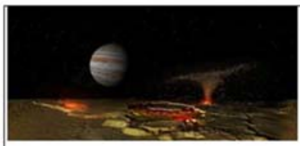


In the image a photo of all parts of the Planets in a room -ver 1 kit.

Piece	Material	Produced by	Cost (approx.)	Notes
1	Computer	ASUS (or other)	-	Not dedicated
2	Projector	ACER P1500 (or other)	-	Not dedicated
3	Kit (3d printed pieces, off the shelf pieces from a hardware store)	Speak Science	€ 130,00 (to build it on your own)	Easy to build. Plans and manual will be distributed in Objective 3, through website
4	Diagonal	Solomark (Model explorer)	€ 90,00	Can be bought on Amazon
5	Fisheye lens 8mm f3.5	Belomo	€ 216,7	Can be bought at peleng8.com
6	Lens 50mm f1.8	Yonguo	€ 48,42	Can be bought on Amazon
7	30 cm plastic sphere	leroy merlin (or other)	€ 13,9	It is the sphere of a street lamp
Total cost			**€ 499**	

Annex 2: Example of materials developed and tested with Planets in a room

In the following document we are attaching some pages of the storyboard of the lesson “Discovering Jupiter”. On the left column of the storyboard, you can see the images that are projected during the lesson on the sphere.

Slide	Oggetto	testo
	**Slide 0: Titolo**	Io sono……………………e sarò la vostra guida per questo viaggio alla scoperta del pianeta Giove realizzato grazie a “Pianeti in una stanza”. Pianeti in una stanza è un progetto dell’**Istituto di Astrofisica e Planetologia Spaziali dell’INAF**, con la collaborazione del **Dipartimento di Matematica e Fisica dell’Università Roma Tre** e dell’associazione **Speak Science** .
PREMI 0 PER VIDEO	**Video 0:** **Partenza dalla Terra** **Durata 1:11**	Lasciamo la Terra con Shuttle. Nel sistema solare ci sono 8 pianeti e tantissimi altri corpi come asteroidi e comete. Faremo un viaggio per studiare Giove, il piu grande dei pianeti del Sistema Solare. Ovviamente, faremo un viaggio di fantasia, perché su Giove come su gli altri pianeti, l’uomo non ha mai messo piede: ma come gli altri pianeti, Giove è stato guardato e studiato dalle nostre missioni spaziali e dai telescopi e molte delle immagini che vedrete in questo viaggio sono vere. **Viaggio di fantasia, ma alcune immagini vere**
	**Slide 1: Giove** **(immagine vera)**	Siamo a 600 milioni di Km dalla terra, distanza minima. Giove è un gigante gassoso, fatto di gas idrogeno e elio, proprio come il Sole. Non ha una superficie solida, è completamente fatto di gas. Andando verso l’interno, troviamo che Giove non possiede una crosta solida; il gas atmosferico diventa sempre più denso procedendo e si converte in liquido. **Giove gigante gas come sole, no crosta** **600 milioni di km dalla Terra**
	**Slide 13:** **panorama ricostruito sulla superficie di Io**	Immaginiamo Il panorama sulla superficie. Vediamo un po cosa vedremmo: vulcani che eruttano zolfo dappertutto. La maggior parte della superficie di Io è composta da ampie piane ricoperte di zolfo e anidride solforosa congelata. Il tutto a -180 gradi c perche siamo lontani dal Sole. NON è molto abitabile, vero? **Panorama: vulcani che eruttano zolfo. Piane di zolfo e anidride solforosa congelata a -180**
	**Slide 14:** **Europa** **(immagine vera)**	Ma fermiamoci un attimo a un’altra delle lune di Giove luna che si chiama Europa. La superficie di Europa è liscia bianca e coperta da fratture: si pensa sia fatta principalmente da ghiaccio. Al di sotto della superficie gli scienziati pensano possa esserci un oceano d'acqua liquida che sgorga dalle fratture e si ghiaccia appena arriva in superficie. **Europa superficie bianca liscia e con crepe, fatta di ghiaccio, Sotto: oceani?**
	**Slide 15** **panorama ricostruito sulla superficie di Europa**	La presenza di acqua liquida è molto, molto importante per la vita. Infatti Europa è stata identificata come una candidata per essere dimora per vita extraterrestre e per questo molto interessante da esplorare. Negli anni 2020 si prevedono missioni di esplorazione come l'europea Juice. **Acqua = vita. Missione juice 2020**