Planets in a room

Livia Giacomini, **Francesco Aloisi**, **Ilaria De Angelis**, **Stefano Capretti** and **Adriana Postiglione** describe an adaptable do-it-yourself planetary projector and the open and active user community forming around it.

Astronomy is an extraordinary tool for bringing people closer to science, and the most effective and engaging activities for a lay public are those that offer an active or emotional involvement of the participants (Freeman *et al.* 2014, Prince 2004, Hake 1998).

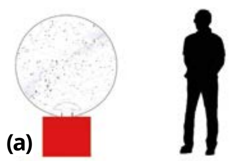
Spherical projection is very helpful in achieveing this, both to show the sky on the outside of a sphere for spectators to study, or to simulate the sky on the inside of a sphere, as in a planetarium (figure 1). Spherical projection improves our ability to visualize and understand celestial phenomena (Reynolds 1990, Chun 2005, Chun 2017, Petre 2015, Timothy & Coty 2017).

Planets in a Room (PIAR) is a do-it-yourself low-cost 3D-printable kit and online software interface that uses projection as an innovative step towards engaging the public. It uses two commercial lenses and a standard projector, and was developed by the scientific association Speak Science for use in schools, small museums, exhibits, planetariums and public events. It is also useful in scientific research contexts in order to show full-dome scientific images and planetary data on a spherical surface.

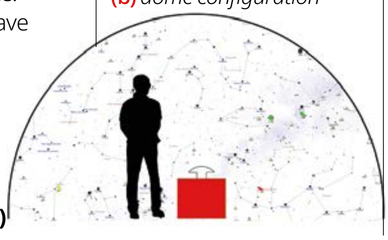
Over the years, several spherical projectors have been proposed for educational or commercial purposes. For systems based on dome configuration, the Lhoumeau Sky System Open project (Lhoumeau 2009) is an example of an open access system, freely distributed online. Domebase (Lower Eastside Girls Club 2013) first proposed alternative building solutions, for example using photographic systems. However, even though both projects distribute online plans to build different DIY full-dome projectors, they use nonstandard auto-built pieces and lenses and materials that are not always easy to find on the market. Consequently, they can only be used by particularly skilled and motivated users.

A further example is represented by the system built for the AstroGarden planetarium of Roma Tre University (Bosco 2014, AstroGarden 2017). This system, based on the fundamental theory of spherical projection proposed by Paul Bourke (Bourke 2017), is easier to use than the others, and adopts a standard projector and two lenses, one of which is a fisheye. But, as in the other examples, the system still needs specialist knowledge to construct.

There are also many commercial systems for projection on a sphere: the Italian Sfera Didattica XL by 3Des (3D Edu-sphere), Magic Planet, sold in the USA by Global Imagination (Global Imagination 2017), the bigger system for museums Science on a Sphere, developed by the National Oceanic and Atmospheric Administration (NOAA), or the spheres proposed by SSIDisplays (Screen Solutions International 2006), among others (Crespel *et al.* 2017). These products, although very useful and spectacular, require a



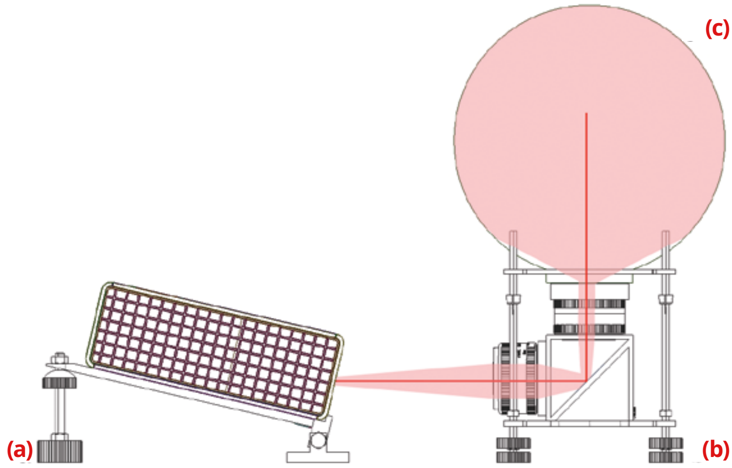
(a)



(b)

1 *The two modes of spherical projection useful in astronomy:* (a) *sphere configuration and* (b) *dome configuration*

Main image: Butuza Gabi/Unsplash



2 (above left) *Planets in room set up in sphere configuration, useful to show planetary data.*

3 (above right) *Planets in a room hardware configuration. The Projector system* **(a)** *is a support for the projector: its height and inclination can be modified to regulate the position of the light coming out of the projector. The Optical system* **(b)** *consists of a stand-alone system with 2 commercial lenses and a mirror. The first lens met by the beam of light is a standard F=50 mm with F/D between 1.4 and 1.8 that collects the light from the projector and focuses it on the mirror. The light beam is then reflected on a second lens, a circular fisheye with F≤8 mm and F/D 3.5. The plastic sphere was sold as a street light fitting.*

budget of thousands of euros that most educators or amateurs cannot afford. Moreover, they are not easy to transport and, again, are difficult to use for non-trained users. In addition, these systems cannot be used on a dome, as in a planetarium, but, most importantly, they are closed, i.e. the final users cannot play any role in the building and setting phases of the instrument, nor in the production of educational contents.

This is where the non-profit association Speak Science (Speak Science 2014) with the support of the Italian National Institute for Astrophysics (INAF) and Roma Tre University, began to think about building something to fill this void: a spherical projector cheap and easy enough to be used by educators, teachers or amateurs without particular skills, in order to reproduce images of planets and other celestial bodies – or even a starry sky if used in planetarium mode. We also wanted to leave enough room for users to customize the system, so that they could create their own educational and outreach contents and share them with other users.

Creating Planets in a Room

Our target for PIAR was to build a system:

- to project in sphere configuration with good resolution and clear projection on more than 90% of the surface of the sphere;
- to project in dome configuration on an inflatable small (5 m diameter) dome for planetarium use;
- to cost as little as possible (not more than €600);
- easy to transport, assemble, calibrate and use;
- compatible with different projectors and computers;
- to project the user's own, self-generated content.

The last point was particularly important to us. In fact, we wanted PIAR to be the catalyst to create a community of astronomers, educators or enthusiasts who could create, use and share their own content.

With these objectives in mind, we started preliminary work that led in 2016 to the submission of a proposal to the Europlanet Outreach Funding Scheme provided by Europlanet, the European-funded Research Infrastructure dedicated to planetary science (Europlanet Society). PIAR won the funding scheme and from that moment on, we began the development phase, consulting with scientists and teachers, our final users. Finally, in 2017 we were ready to present our first prototype (Giacomini *et al.* 2017).

Planets in a room is a DIY kit to build a small (20–40 cm diameter or more) spherical projector to display astronomical resources (figure 2). It is distributed through the website (www.planetsinaroom.net) in a form that allows any user to build it on their own, use it, develop new content, customize it and share it with an open community.

To become part of the project and to build and use PIAR, the user needs first to become a member of Speak Science association and subscribe to a yearly low-cost licence (less than €50 per year) that gives them access to the online platform to download all the technical information to build the system, use the calibration interface and access the educational content developed by the community.

There are different types of images that can be used with PIAR: real planetary maps that show the surfaces of the planets as seen by space missions or telescopes, scientific maps presenting relevant data about Earth or the planets (geological maps, elevation maps, temperature maps and other) and artistic impression images that use spherical visualization to emphasize scientific content. Animations and videos can also be projected on the sphere to show dynamic phenomena.

PIAR has also proved to be a useful tool for developing new educational projects with a hands-on approach, aimed at small groups of students. In fact, the need to calibrate and customize the system makes PIAR not a simple 'plug and play' tool, but instead an instrument that requires users to actively acquire some know-how and do some work to use the system itself. This constitutes an additional good educational opportunity; thanks to PIAR, it is possible to develop projects in which students are asked to become researchers themselves, learning how to use the system and using it to explain what they have learned about Earth and space.

Hardware and software

PIAR comprises the Projector system, Optical system and plastic sphere. To complete the system, the user will need two commercial lenses and an astronomical mirror to be mounted on the optical system (figure 3b), a computer and a projector. Both the optical and projector systems are made of pieces that can be 3D printed by the user and a set of additional standard pieces (bolts and screws) that can be bought in any hardware shop (figure 4). The system can be used with different, non-dedicated projectors and computers.

PIAR can project both in sphere mode, using a street lamp-style sphere bought in a hardware store or, by removing the sphere, in dome mode, on the internal surface of a small planetarium dome. With the standard brightness of a commercial projector, PIAR is best used with a plastic sphere with a diameter from 30 cm to 50 cm and in an inflatable dome with a diameter of less than 5 m.

This configuration with two different parts (projector and optical system) was chosen in order to leave as many free to move and flexible parameters as possible, in order for the kit to be moved and used

4 *The 3D printed components, left, and their assembly (right).*

with different projectors and in different conditions. With the help of the software interface, the projector and optical system can be adapted in the calibration phase and all the physical parameters of the system can be set up in the best configuration for each session. The chosen calibration can then be recorded and used until PIAR needs to be moved.

PIAR also includes a software interface accessible from an area of the website accessible only with a licence. The web-server application was developed starting from existing previous experiences, also taking in account the wiki project dedicated to software for spherical projection (PanoTools 2007), and the rect2dome scripts collection (Hazelden 2016).

To be automatically reprojected on the sphere by the software platform, the images need to be equirectangular projected maps. This projection was chosen because it is a standard for global dataset and globally used in panoramic photography to represent a spherical panoramic image.

The PIAR web-server application offers the user three different processes:

- **Calibration** In this first step, the software interface allows calibration of an image on the sphere, slightly modifying the projection depending on the hardware setup. The best configuration can then be saved and used for the session. A recalibration is needed every time the system is moved.
- **Presentation set-up** The software is used to build a presentation with a series of images chosen from an existing database or by uploading new ones.
- **Presentation projection** The software is used in the running mode to project the sequence of images on the sphere and navigate around and between them. This is the actual live 'show', in which the user can navigate through the images, but also navigate inside a single image, making it rotate on the sphere, tilting and moving it around to show a specific part of the image.

In the reserved area of the website, the licensed user will find a repository of images that are already optimized for the system, shared by the Speak Science team and the community. Following the instructions and a tutorial, the user will also be able to produce and upload their own images, in turn sharing them with the rest of the community.

Birth of PIAR community

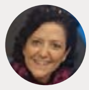
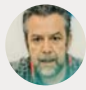
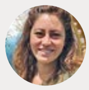
PIAR has gathered a rich community of active users. In the first, development phase, PIAR was tested in 10 different places in Europe, including universities, amateur observatories and planetaria. It was also presented at scientific Congresses: EPSC2017 in Latvia (Giacomini *et al.* 2017), EPSC2018 in Berlin (Giacomini *et al.* 2018), EPSC2019 in Geneva (Giacomini *et al.* 2019), EPSC2020 (Giacomini *et al.* 2020a) and EGU 2020 (Giacomini *et al.* 2020b) - and displayed at outreach events such as the Maker Faire in Rome and the European Researchers' Night in different locations.

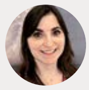
In 2020, the project entered a distribution phase in which universities, research centers, schools, associations and private users were invited to become part of the community, registering with Speak Science and building the system on their own, sharing their projects online.

The distribution of PIAR stopped in the 2020–22 period, because of the Covid-19 pandemic. In 2022 activities are restarting and PIAR was included in the Europlanet 2024RI project funded by the European Commission to distribute it widely in Europe and produce new educational content.

Speak Science is, in collaboration with the community of users, studying and implementing a number of improvements to the hardware, such as making a wooden version, and to the software platform, to include videos and real-time content. New contents and applications both for education and outreach are also in development. ●

AUTHORS



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ACKNOWLEDGMENTS

The authors would like to acknowledge Europlanet for funding this work: the project Europlanet 2024 RI has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871149. A special thanks goes to all the people who have experienced PIAR and helped us to optimize and improve it.

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