Progress toward a low-cost "Galileoscope" for the IYA2009

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Abstract

One of the IAU's Global Cornerstone Projects for the International Year of Astronomy 2009 is to develop, produce, and distribute huge numbers of very inexpensive, yet good-quality, small telescopes. This will enable millions of people around the world, especially children and others who can't afford a commercial telescope, to experience for themselves the thrill of scientific discovery that Galileo experienced when he turned his telescope skyward 400 years ago. We report progress toward realising the "Galileoscope" based on efforts by an IAU Task Group and an affiliated AAS working group as well as on discussions at the CAP2007 meeting in Athens.

The Galileoscope: An IAU IYA2009 Global Cornerstone Project

The IAU public brochure for IYA2009 asks: "*Who doesn't remember the first time they looked at the Moon through a telescope and were amazed by the details of the mountains and craters? The same is true for Jupiter's cloud belts and its fascinating Galilean moons, Saturn's rings, and a sparkling star cluster.*" This question has a simple and obvious answer: "Anyone who has never had the opportunity to look through a telescope!" Especially for those who can't afford to buy even a department-store telescope, a do-it-yourself Galileoscope could be the key to pursuing an interest in astronomy beyond IYA2009.

Accordingly, the IAU has made the development of an unprecedented inexpensive yet good-quality telescope one of its Global Cornerstone Projects for IYA2009. As the IYA2009 brochure goes on to say: "*Observing through a telescope for the first time is a unique experience that shapes our view of the sky and Universe.*" The IYA2009 programme wants to share this observational and personal experience with as many people as possible across the world and is collaborating with the US IYA2009 National Node to develop a simple, accessible, easy-to-assemble, and easy-to-use telescope that can be distributed by the millions. Ideally, every participant in an IYA2009 event should be able to take home one of these little telescopes. This simple telescope enables people to build and observe with a telescope that is similar to Galileo's. Sharing these observations and making people think about their importance is one of the main goals of IYA2009: "*Promote widespread access to new knowledge and observing experiences.*"

Parallel, coordinated efforts

At its March 2007 meeting in Garching, Germany, the IAU Executive Committee for IYA2009 appointed a Telescope Kit Task Group chaired by Rick Fienberg (S&T). Soon thereafter, the American Astronomical Society's IYA2009 Program Committee appointed a Telescope Kits & Optics Challenges Working Group chaired by Steve Pompea (NOAO), who is also a member of the IAU Task Group. Fienberg and Pompea have been coordinating their efforts ever since. While both groups are considering the Galileoscope's potential for improving public outreach as well as informal and formal science education, Fienberg's group is tilting toward outreach and Pompea's toward education.

Pompea's programme is an outgrowth of previous work on the development of educational telescope kits to increase science literacy (Pompea and Hawkins, 2004). It builds on experiences in the NSF-funded, informally oriented Hands-On Optics (HOO) project (Walker et al., 2007), a collaboration between SPIE — the International Society for Optical Engineering, the Optical Society of America, and NOAO. Module 3 of the HOO project is devoted to image formation using lenses and mirrors. As a culminating activity, participants build a small refracting telescope using the Learning Technologies Inc. (LTI) telescope kit originally developed for Project STAR at the Harvard-Smithsonian Center for Astrophysics. LTI builds and distributes the HOO kits, which were designed at NOAO.

NOAO has also developed an abbreviated telescope-education kit for the NSF-funded project Astronomy from the Ground Up, in collaboration with the Astronomical Society of the Pacific and the Association of Science-Technology Centers. This "Terrific Telescopes" mini-kit has been used in a number of workshops for science centre educators with considerable success.

Galileoscope project goals

The IAU and AAS groups share the following project goals:

- Design low-cost telescope kits that aid understanding of optical systems. (Note: Pre-assembled scopes may be OK for public outreach, but they are not suitable for education.)
- Find means of manufacturing and distributing these kits.
- Provide basic enquiry-based educational material on image formation and telescopes for more extended education programmes.
- Optimise kits for tradeoffs between magnification, field of view, optical quality, and ease of assembly and use.
- Don't reinvent the wheel; build on and/or adapt from existing telescope kits.
- Use Hands-On Optics Module 3 and Astronomy from the Ground Up's "Terrific Telescopes" module.
- Rely on existing networks for distribution (e.g., clubs, planetariums, science centres, teaching networks).
- Seek partners/underwriters to help minimise costs for design, manufacturing, and distribution.

As a first step, we canvassed the marketplace for existing low-cost telescope kits and pre-assembled telescopes, many of which are marketed primarily as toys. We found about a dozen different models from various suppliers and obtained samples of each for evaluation.

We need to develop something new

Current telescope kits are easy and fun to assemble, and there are some very inexpensive toy telescopes available. Despite this, and despite 20 years of success with the LTI telescope kit, which has great educational value, we nevertheless conclude that for the Galileoscope project we need to develop something new. Existing models exhibit a range of problems:

- If they produce correct images, they're of insufficient magnification for astronomical use (for example, 3x).
- If they offer enough magnification for astronomical use, the images are upside down, which makes aiming them difficult for novice users.
- They provide very narrow fields (< 1½°).
- They come without mounts to stabilise the view.
- Chromatic and other aberrations limit useful magnification.

From an educational perspective, the LTI kit remains the best of the bunch because of the way it enables students to experiment with image formation and telescope construction. But incorrect assembly by students can lead to degraded optical performance due to misplacement or tilting of the eyepiece lens, which is held in place by a soft foam insert. In general though, we want to build on the many positive aspects of these Project STAR telescopes while improving their optical performance as much as possible.

One size doesn't fit all

For IYA2009 we envision that two telescope kits may be necessary! One kit, the Galileoscope described by the IAU, would be optimised for looking at the Moon and the Galilean satellites of Jupiter — it might not show much else to advantage. The requirement for lowest possible cost will likely drive the Galileoscope's design.

Here are the draft specifications for the Galileoscope:

- Suitable for observing the Moon and Jupiter and its moons.
- Must be easy to build without supervision (since it may be distributed outside a formal or informal educational setting).
- Magnification can be moderate, e.g. 15x to 25x.
- Image quality can be modest; chromatism OK.
- Image should be right-side up.
- Field of view should be at least 2°.
- Stable mount is desirable; having a scheme for attaching the scope to something (e.g. a camera tripod) is essential.

A second kit, termed the Saturnscope, would be designed to reveal Saturn's rings; this would require higher magnification than that provided by the Galileoscope and would surely be more expensive too. If produced in bulk, though, we believe that both telescopes can be reasonably priced and give excellent value for money.

Here are the draft specifications for the Saturnscope:

- Suitable for observing the rings of Saturn. (Note, however, that during IYA2009 itself, Saturn's rings will be seen edge-on from Earth.)
- Needs magnification > 30x, ideally 50x to resolve the planet's disc and rings (20″ to 30″).
- Image quality must be very good; minimal false colour.
- Right-side up image is useful but not essential.
- Field may be narrow (but you need to be able to get Saturn into the eyepiece).
- A stable mount is absolutely essential.

New approaches and key collaborators

We are investigating a number of new approaches for these kits, including the use of aspheric surfaces, glass and plastic injection-moulded objectives, novel mounts, and simple methods of stray-light control (Pompea, 1995). We are also analysing a number of potential eyepiece designs. Our optical analysis partners include the Tucson companies Raytheon, Breault Research, and Photon Engineering, as well as Ceravolo Optics in Ottawa.

Key members of the AAS working group include a retired optical engineer from Lockheed Martin and a person with experience in telescope systems and manufacturability. We're also consulting with Dick Buchroeder, a legend among amateur astronomers for his optics expertise. Meade Instruments, the world's largest manufacturer of telescopes for backyard astronomers, has expressed serious interest in participating in the Galileoscope project; they offer deep capabilities in design, manufacturing, and distribution.

Additional progress made at CAP2007 in Athens

At the CAP2007 meeting in Athens, additional progress was made thanks to a presentation by Kaz Sekiguchi of the National Astronomical Observatory of Japan. He described two telescope kits used in classrooms and informal educational settings in Japan, and exhibited samples. Both use cemented doublet achromatic objectives and compound plastic eyepieces. These address one of the chief concerns raised at the CAP2007 meeting, namely, that we not distribute poor-quality optics that are more likely to turn kids off astronomy than to turn them on to it. The optical quality of the Japanese kits is as good as — or better than — that of many small commercial scopes.

The Spica kit employs nested cardboard tubes and is fairly complicated to assemble, requiring a little glue and a lot of patience. It provides a magnification of 35x with a standard eyepiece but can be supplied with 21x and/or 50x eyepieces too. The kit includes a tripod-mounting block and a "peep sight" finder and has a retail price of about $20, though it can be bought at somewhat

lower cost in bulk quantities. When looking at the assembled Spica telescope and considering its performance, it’s hard not to think of it as satisfying the requirements of our Saturnscope.

The Starbook kit uses similar lenses but a much simpler tube design involving plastic parts that simply snap together. The assembled scope provides 15x and a field of view of about 2½°. It also has a tripod socket; it’s aimed using “gun sight” tabs on the top of the plastic tube. If this telescope could be produced at lower cost, it could potentially serve as the IYA2009 Galileoscope.

Both of the Japanese kit telescopes provide an upside-down image, but because of their pointing aids and/or wide fields, this may not be a significant drawback. In any case, we plan to evaluate both kits further, and with Kaz Sekiguchi’s help (he’s now a member of the IAU Task Group), we’re in contact with the kits’ manufacturers to explore whether either or both kits might serve our purposes for IYA2009. Already the manufacturer of the Spica kit has expressed interest in the project and optimism that in sufficient quantities, his optics and other parts can be produced at costs that would make possible widespread distribution of the telescopes. We’re also discussing possible modifications to the design to improve its performance further as well as to simplify its assembly.

Conclusion

Great progress is being made in the design, optical analysis and testing of telescope kits. The next steps are to obtain a better understanding of the manufacturing and production issues, to work on reliable cost estimates, and to develop dissemination plans further. We are quite confident that this very important Cornerstone project of the IYA2009 will be successful — perhaps more successful than any of us dared to imagine!

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Photo by Craig Michael Utter, courtesy Sky & Telescope.

Figure 1 – The starting point for development of the IYA2009 Galileoscope is the Project STAR telescope kit from Learning Technologies . With simple acrylic lenses and cardboard tubes, it provides a relatively poor-quality image at a magnification of 16x.

Photo by Richard Tresch Fienberg, courtesy Sky & Telescope.

Figure 2 – Two inexpensive telescope kits from Japan offer very good performance thanks to their glass achromatic objectives and compound eyepieces. Either or both of these kits may prove adaptable to the Galileoscope project.