(1) Title of the grant:	**Kepler Education and Public Outreach (EPO)**
(2) Type of report:	**Final Report**
(3) Principal Investigator:	**Alan Gould**
(4) Period covered by report:	**15 November 2002 — 1 October 2012**
(5) Institution:	**University of California**
	Lawrence Hall of Science (LHS)
	Berkeley, CA 94720-5200
(6) Grant number:	**NAG2-6067**
PI's e-mail address:	**Alan Gould <agould@berkeley.edu>**

I am happy to report many successes of the Kepler EPO program in kindling public excitement and engagement for the NASA Kepler Mission as well as as a broad impact of educational efforts. Essential details for each project are described in this report (Table 1) with an overview of the projects illustrated in Figure 1. The projects served three major EPO audiences: formal education, informal education, and public outreach.

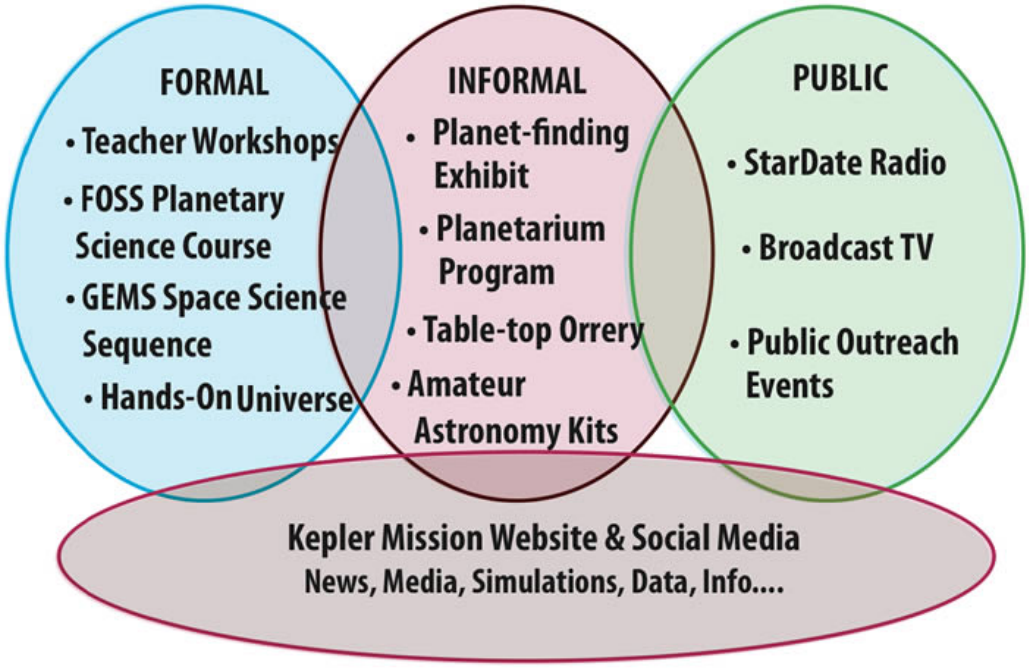


Figure 1. Overview of Kepler Mission EPO projects

Year by year details of Kepler Mission EPO accomplishments may be found in the series of annual reports on file for this mission (http://kepler.nasa.gov/education/resources/eval/). This Final Report treats the overall accomplishments and highlights.

Table 1. Summary of Accomplishments

Workscope Item	Workscope Description	Accomplishments
Coordination	•Organize and conduct coordination meetings overall and for each E/PO product. • Coordinate dissemination of all Kepler E/PO Products. • Represent Kepler E/PO at national meetings of NASA EPO Forums, AAS, NSTA.	LHS Kepler EPO staff provided coordination for all the projects described in this table for which LHS was lead institution. In addition, LHS staff provided key support for other Kepler EPO projects for which SETI Institute was the lead institution. In particular, LHS Kepler EPO staff: • posted StarDate Radio (produced by McDonald Observatory) broadcasts on the website kepler.nasa.gov • Kepler Names in Space: public submitted their names (and comments about the Kepler Mission) for inclusion on a DVD placed on the Kepler spacecraft before launch. Name collecting closed as of Thanksgiving 2008. Final count: 58,763.

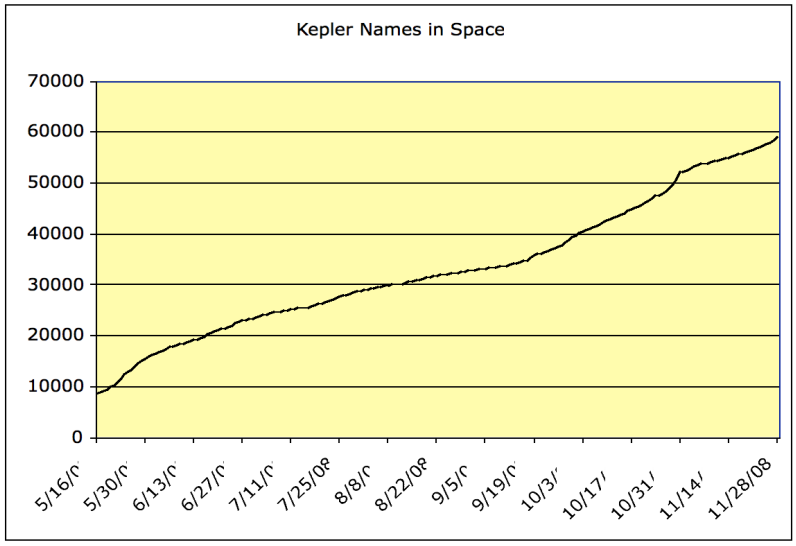


Figure 2. Record of number of people submitting names to the Kepler Names in Space program, for inclusion on the DVD affixed to the spacecraft.

• assisted Astronomical Society of the Pacific (ASP) and the Night Sky Network (NSN) in production *Shadows & Silhouettes* kit of activities for amateur astronomy clubs (Feb-Aug 2006).

Figure 3. NSN - Shadows and Silhouettes activity: Why isn't there an eclipse every month? From Dec 2006 through March 2007, NSN

club members reported 36 events using Kepler-funded Shadows and Silhouettes kit, serving 2,478 people total. 15 of the events serving over 1,200 people were about the lunar eclipse that occurred 2007 March 2. Comment from Night Sky Network March 2007 Newsletter: We received so many great reports about eclipse events! …Warren Rupp Observatory would not even let snow stop them. …so many visitors throughout the night that they gave the Shadows and Silhouettes eclipse presentation 5 times in a row. "The materials worked out very well and delighted audience members of all ages!"

Gould represented LHS Kepler EPO team at all Kepler Science Team meetings 2003–2012, responded to reporting requirements from NASA HQ regarding Kepler EPO program, for OEPM (Office of Education Program Management) reports, and represented Kepler at monthly telecon meetings of the NASA SMD Astrophysics Education Forum.

LHS Kepler EPO staff led teacher workshops about Kepler at every NSTA National Convention in the years 2004-2011 (7 years). LHS Kepler EPO staff also assisted in creating a poster that in January 2009 was inserted in the NSTA journals.

Figure 4. Two NSTA journals with articles and posters on Kepler Mission: ***Science Scope*** *(reaching ~ 18,000 middle school teachers with 2.5 "pass along" factor) and* ***The Science Teacher*** *((reaching ~ 28,500 high school teachers with 2.7 "pass along" factor)*

Gould presented numerous public workshops and school programs, such as
- speaker at Deer Valley High School Astronomy Day 2007 May 29
- speaker at rotary club in Richmond CA 2009 May 9
- classroom visits for Kepler mission at 4 schools in Boaz AL, 2009 Oct 27-29.
- Spacefest in Tucson May 2011 and 2012
- workshop sessions at Westlake Middle School in Oakland CA 2012 April 26
- Transit of Venus program at LHS serving 900 visitors, 2012 June 5

Figure 5. Kepler team scientists were in demand for public talks about Kepler Mission. The Kepler EPO team, especially Edna DeVore at SETI Institute, facilitated matching speakers with requests and venues, as well as giving many presentations themselves.

Figure 6. March 2009: Johannes Kepler (John McFarland) and Edna DeVore at NSTA National Convention.

Figure 7. 2008 Feb 28 Ethnic Media Roundtable at Lawrence Hall of Science. About 20 reporters from Bay area ethnic media (newspapers) attended. Alan Gould gave brief talk on Kepler, handed out Lithos, Fact Sheets, and Field of View Lithos as "press packet" then had Q & A, a very successful event.

FORMAL EDUCATION

Formal education engages students and teachers/professors in STEM (science, technology, engineering and mathematics) teaching and learning through schools, colleges and universities. Kepler EPO aimed to reach this audience nationally by employing existing, robust networks in formal education (GEMS, FOSS, and HOU) to leverage NASA's investment and reach diverse audiences, and promote.

GEMS

Create one GEMS Teacher Guide, Discovering Planets. Develop with formative evaluation in successive rounds of field testing followed by release and disseminate through commercial publisher.

In 2001, the US Department of Education's Mathematics and Science Education Expert Panel found GEMS to be a "Promising Science Program." GEMS supports best practices in teaching and learning, and is a recognized leader in the development of inquiry-based science education.

The original EPO plan morphed into a much larger project resulting in creation of two GEMS Space Science Sequences, one for grades 3–5 (SSS 3–5) and one for grades 6–8 (SSS 6–8). Activities were pilot tested at LHS, field tested at local schools, and nationally field tested at several schools. SSS 3–5 was completed and released in 2007 through GEMS commercial publisher, Carolina Biological and the well-established national network of more than 70 GEMS teacher training centers involving thousands of master teachers and hundreds of thousands of students. SSS 6-8 was released in 2008. Both SSS products combined are now in thousands of US classrooms—including those with under-served populations.

SSS 3–5	568
SSS 6–8	352
SSS Kit 3–5	646
SSS Kit 6–8	437

Table 2a. Space Science Sequence sales, 2007–2012. First 2 rows are instructors' books; rows 3–4 are kits. Each sale represents reaching between dozens to several hundred students per year, so overall SSS may be reaching tens of thousands to hundreds of thousands of students.

Both SSS were featured in the Carolina Biological exhibit booth at NSTA conventions from 2008 through 2012.

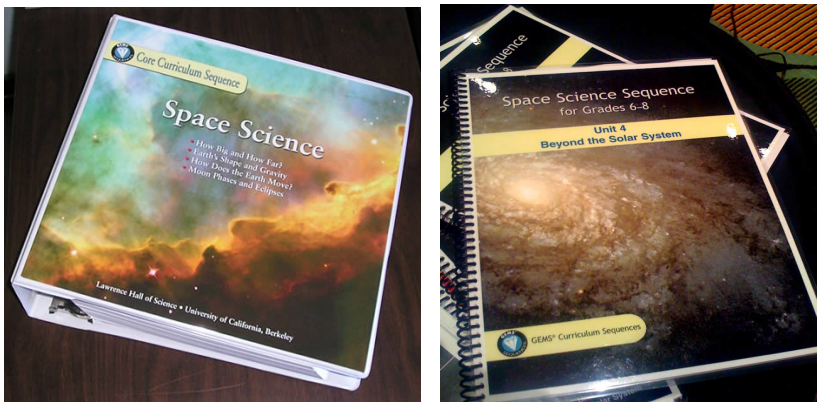


Figure 8. GEMS Space Science Sequence

Grades 3-5 *Grades 6–8*

GEMS Teacher Workshops about Space Science Sequences in NASA funded project AMANTISS (Advancing Mentor and Novice Teachers in Space Science):
Grade 3-5 Workshops:
Stockton, CA (June 2008) 27 participants
Fredonia, NY (March 2009) 14 participants

Pierre, SD (August 2009) 9 participants
Total: 50 participants; Average: 17 per site

Grades 6-8 Workshops:
Carson City, NV (June 2009) 30 participants
Mt. Pleasant, MI (June 2009) 23 participants
Southfield, MI (June 2009) 15 participants
Chicago, IL (August 2009) 17 participants
Albuquerque, NM (April 2010) 30 participants
Casper, WY (November 2010) 19 participants
Berkeley, CA (January 2011) 14 participants
Total: 140 participants; Average: 20 per site

Events at the 2008 National Science Teachers Association (NSTA) Convention in Boston, March, 27-30:

Mar 26 half-day short course on SSS 6-8. 12 participants.
Mar 27, GEMS workshop for grades 3-5 filled to capacity - over 50 teachers.
Mar 31, 11-1pm demos of Kepler materials at NASA booth. About 24 teachers.
Mar 31, 3:30 workshop "How to Find Alien Earths for about 12 teachers.

NSTA Regional Convention workshops held Oct 27–29 in Hartford CT; Nov 10-12 in New Orleans LA; Dec 7-10 in Seattle WA. Other GEMS teacher workshops featured SSS at GEMS sites and centers around the country

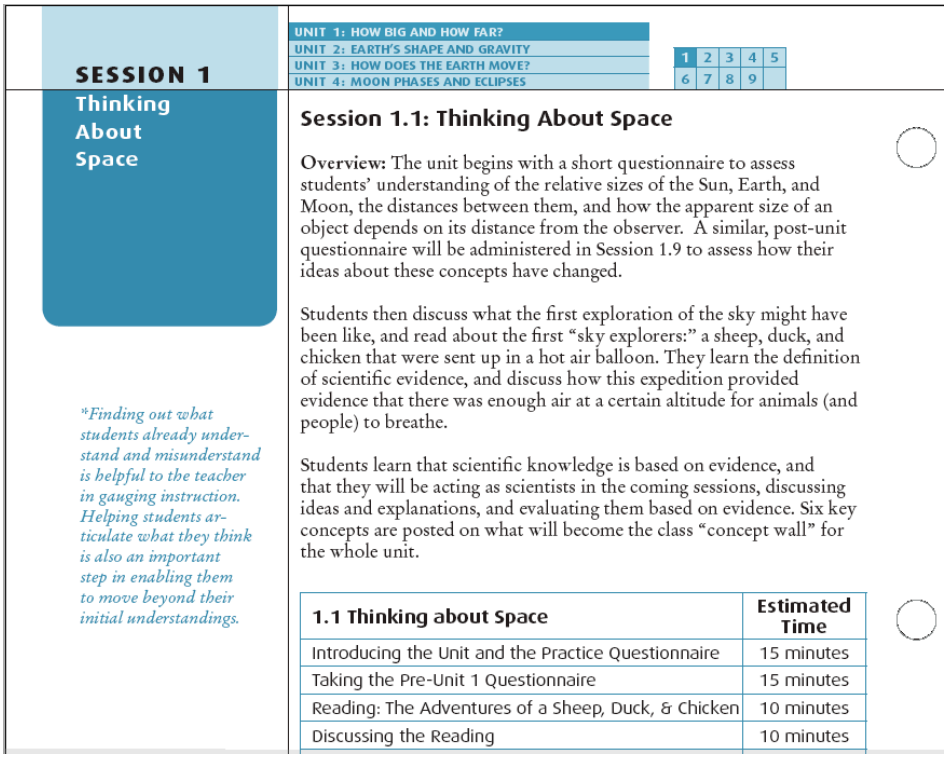
Figure 9. Teachers make "fist" angle measurements for Moon observations in a Space Science Sequence 3-5 workshop.

Figures 10 (above) and 11 (below).

Teachers at 2009 prelaunch workshops make transit models in the activity "Detecting Planet Transits" from Space Science Sequence 6-8.

Figure 12. GEMS workshop at NSTA 2006 Anaheim.

Figure 13. Teachers at a prelaunch workshop at JPL act out a 3D

		kinesthetic model (2 dimensions of space and one of time) of the inner solar system for the "Human Orrery" activity from Space Science Sequence 3–5. Orbits are laid out with ropes on the ground and tabs on the ropes are at 2-week time intervals for the planet-actors to step on every "two weeks" of model time. In Florida as study was done on effectiveness of SSS 3-5 as compared with traditional textbook teaching. The study was from 2007-2009 in 29 schools, grades 4-5 grade with 66 treatment teachers, 59 control teachers, 1418 treatment students and 1176 in control students. Treatment curriculum took 24 days class time. The findings were that student achievement on post-test for space science content, knowledge about models and evidence was positive and statistically significant. 5.5 months later, student achievement for content was no longer statistically significant, but modeling/evidence was. Higher socio-economic status students had (significantly) more success with models and evidence. Lower socio-economic status students would need extra support to get better achievement. An SSS 6-8 evaluation study noted that "Pre-test to post-test student learning gains were statistically significant for all units." See Table 2 for further evaluation information. In December 2010, John Ensworth of IGES NASA Review team notified us that SSS 6-8 had passed the NASA education review and we listed as a passed product in 2011.  UNIT 1: HOW BIG AND HOW FAR? UNIT 2: EARTH'S SHAPE AND GRAVITY UNIT 3: HOW DOES THE EARTH MOVE? UNIT 4: MOON PHASES AND ECLIPSES 1 2 3 4 5 6 7 8 9 SESSION 1 Thinking About Space Session 1.1: Thinking About Space **Overview:** The unit begins with a short questionnaire to assess students' understanding of the relative sizes of the Sun, Earth, and Moon, the distances between them, and how the apparent size of an object depends on its distance from the observer. A similar, post-unit questionnaire will be administered in Session 1.9 to assess how their ideas about these concepts have changed. Students then discuss what the first exploration of the sky might have been like, and read about the first "sky explorers:" a sheep, duck, and chicken that were sent up in a hot air balloon. They learn the definition of scientific evidence, and discuss how this expedition provided evidence that there was enough air at a certain altitude for animals (and people) to breathe. Students learn that scientific knowledge is based on evidence, and that they will be acting as scientists in the coming sessions, discussing ideas and explanations, and evaluating them based on evidence. Six key concepts are posted on what will become the class "concept wall" for the whole unit. **Finding out what students already understand and misunderstand is helpful to the teacher in gauging instruction. Helping students articulate what they think is also an important step in enabling them to move beyond their initial understandings.* 1.1 Thinking about Space | Estimated Time Introducing the Unit and the Practice Questionnaire | 15 minutes Taking the Pre-Unit 1 Questionnaire | 15 minutes Reading: The Adventures of a Sheep, Duck, & Chicken | 10 minutes Discussing the Reading | 10 minutes *Figure 14. Sample page from Space Science Sequence 3–5.*
Full Option Science System (FOSS)	Conduct 6 FOSS teacher workshops using Kepler Mission science, with the already developed FOSS Planetary Science course.	FOSS leadership approached Kepler EPO LHS staff for assistance in revising the Planetary Science course. The original plan was altered to allow for work in revising the course, in addition to the teacher workshops. The revised FOSS Planetary Science course for Middle School (2nd edition) incorporated many new elements about NASA missions and Kepler Mission in particular. The FOSS Planetary Science middle school module is a kit-based course, with hard-copy teacher guide, student materials, plus web-based resources. *Kepler* EPO infused *Kepler* science and discoveries in the newly revised Planetary

Science course which was released January 2012 by the publisher, Delta Education. FOSS is even more widely used in US classrooms than GEMS. FOSS curriculum is used in all fifty states by over 100,000 teachers and 2 million students; it is in about 16% of the nation's school districts. It is adopted in 50 of the 100 largest urban school districts where FOSS reaches large populations of under-served students. In many states, FOSS is on the curriculum adoption list for all schools.

8 FOSS teacher workshops were held at NSTA Regional Conventions:
2010 Oct 28 Kansas City KS, Nov 11 Baltimore MD, Dec 2 Nashville TN
2011 Oct 28 Hartford CT, Nov 11 New Orleans LA, Dec 9 Seattle WA
...and at NSTA National Conventions:
2011 Mar 11 San Francisco; 2012 Indianapolis IN.
Each had about 30 attendees.

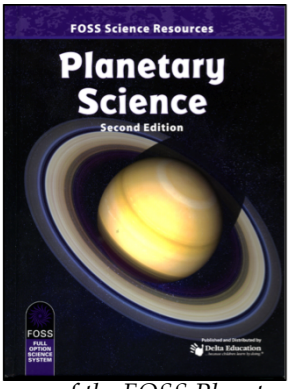


Figure 15. The cover of the FOSS Planetary Science course Resources (for student reading)

In addition FOSS held teacher professional development week-long workshops for 20 + middle school science teachers at Lawrence Hall of Science, UC Berkeley, 2011 June 28–July 1 and 2012 July 17-20. These events included public Symposiums featuring Kepler scientists (Bill Borucki, Gibor Basri, and Natalie Batalha in 2011; Bill Borucki, Gibor Basri, and Geoff Marcy in 2012) as well as Edna DeVore from SETI Institute.

Figure 16. 2012 Kepler Symposium Panelists (right to left): Gibor Basri, Geoff Marcy, Bill Borucki, and moderator Imke de Pater.

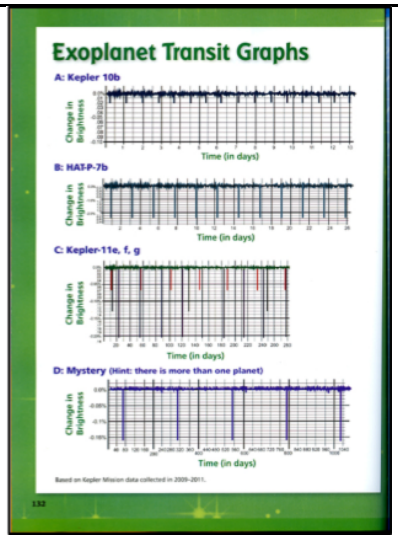


Figure 17. Light curves of Kepler planet discoveries created for students to analyze in Investigation 10 of the FOSS Planetary Science course.

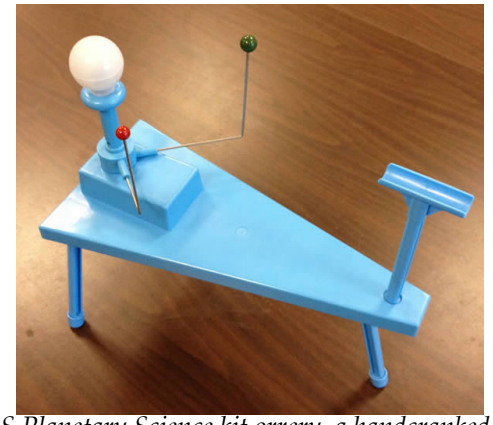


Figure 18. The FOSS Planetary Science kit orrery, a handcranked, two-planet model of a star-planet system, with holder for a light sensor (right). See also section on exhibits under Informal Education projects.

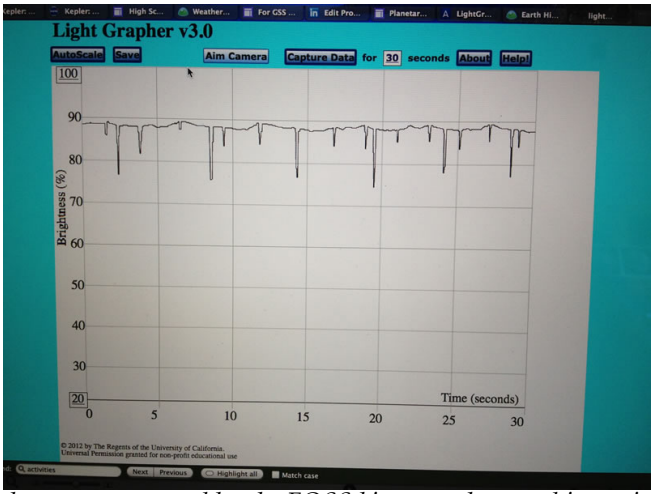
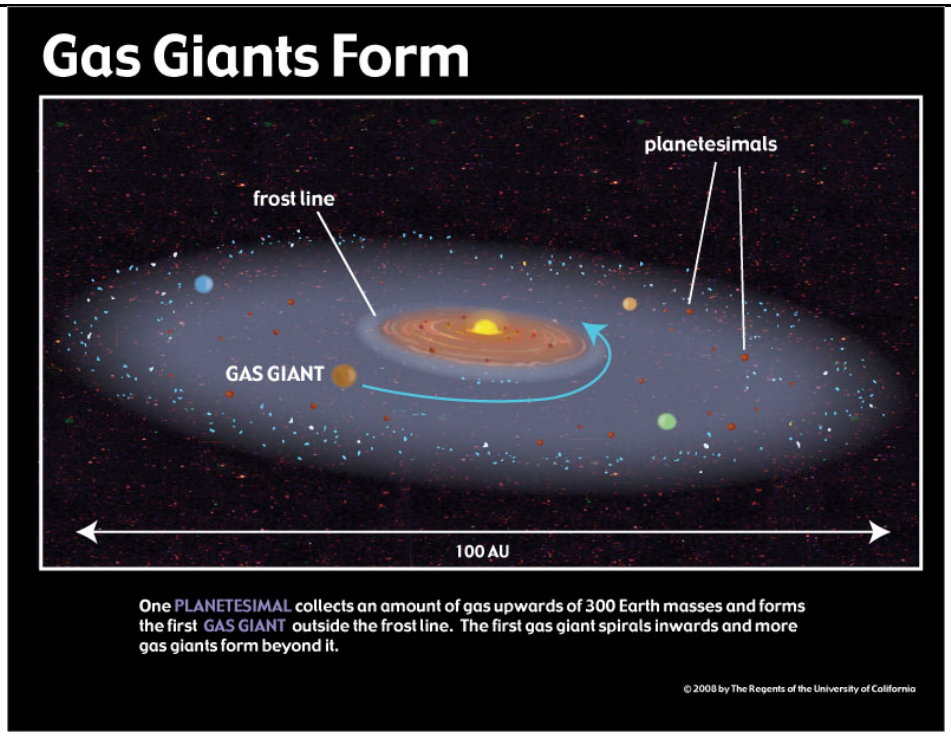


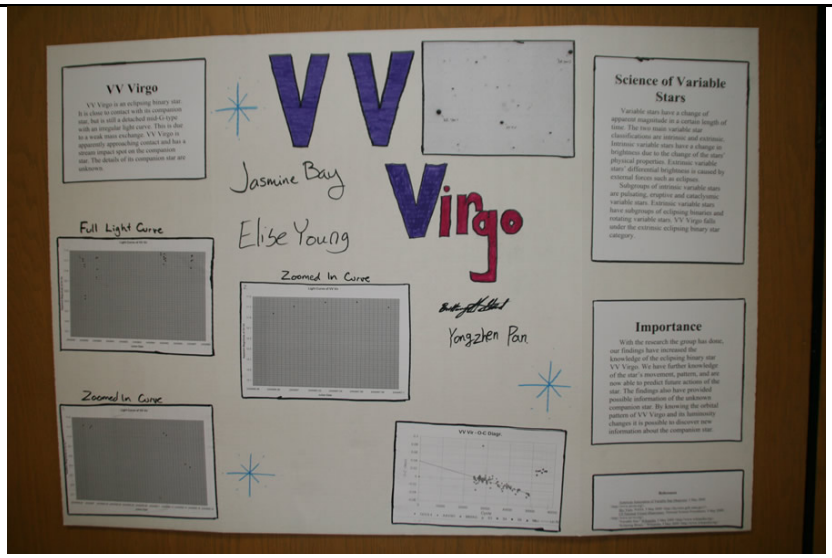
Figure 19. Light curve generated by the FOSS kit orrery but used in conjunction with the free Kepler EPO developed LightGrapher software that makes a webcam or laptop camera into a light sensor.

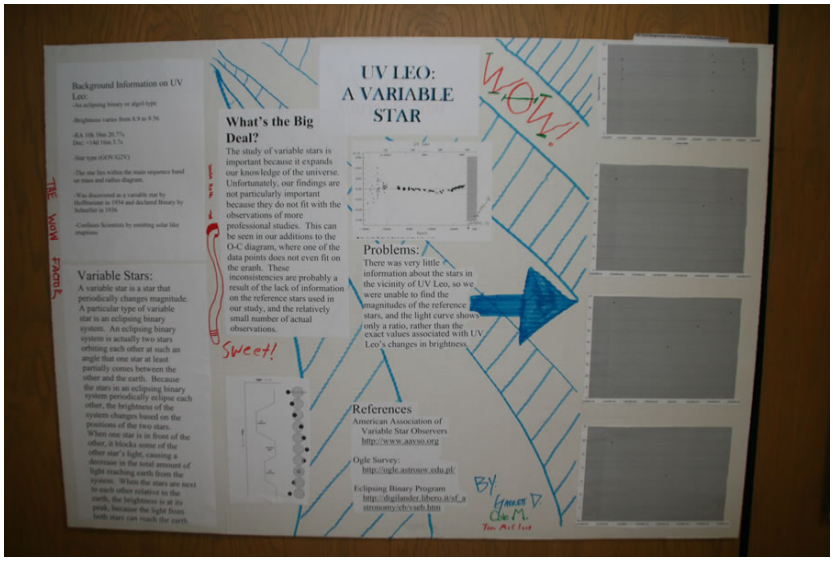
		 *Figure 20. One of 10 cards in the Origin of the Solar System activity, part of Investigation 8 in the FOSS Planetary Science course which also has activities on comparative planetology, NASA missions, and a Jupiter's moons activity which immediately precedes the the Exoplanet Discovery activity in Investgation 10.*

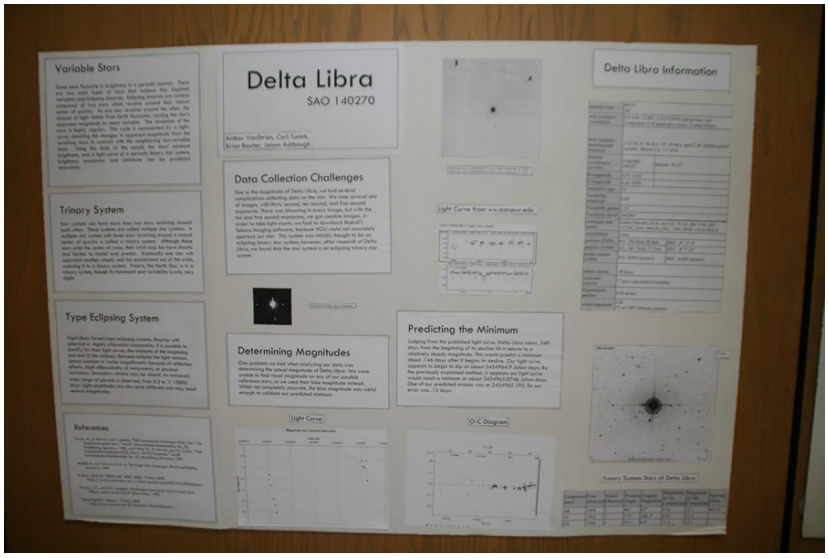
HOU	Develop "Discovering Planets" as supplement to the "Measuring Brightness" student book. Provides ongoing coordination for use of Kepler science in Hands-On Universe programs.	The Hands-On Universe (HOU) project, based at Lawrence Hall of Science at the University of California, Berkeley, provides materials for middle school and high school students that enable them to (a) use image processing software to analyze previously collected and prepared observations from the HOU telescope network and (b) participate in current student astronomy research projects, downloading requested observations via the Internet through a network of telescopes and analyze them with image processing software.
		
		During this Kepler EPO grant, the HOU Measuring Brightness book was incorporated into a new edition of HOU high school curriculum in a book entitles A Changing Cosmos, which is now available part of the Global Systems Science curriculum series (http://www.globalsystemsscience.org/) The Kepler HOU page has two sample investigations from A Changing Cosmos:
		
		• Tracking Jupiter's Moons
		  • Investigation - 260 kb PDF (PDF, 296 KB) — students use image processing software to analyze observatory images of Jupiter and its moons. Students determine the relationship of orbital radius and period, then use Newton's and Kepler's laws to compute the mass of Jupiter.
		• Exoplanet Transits
		  • Investigation Write-up (PDF, 620 KB) - Students use telescope images, image processing software, and data from the Internet to determine the size and orbital period of an exoplanet. It also includes ideas mining data on transits of short-period giant planets and eclipsing binary stars.

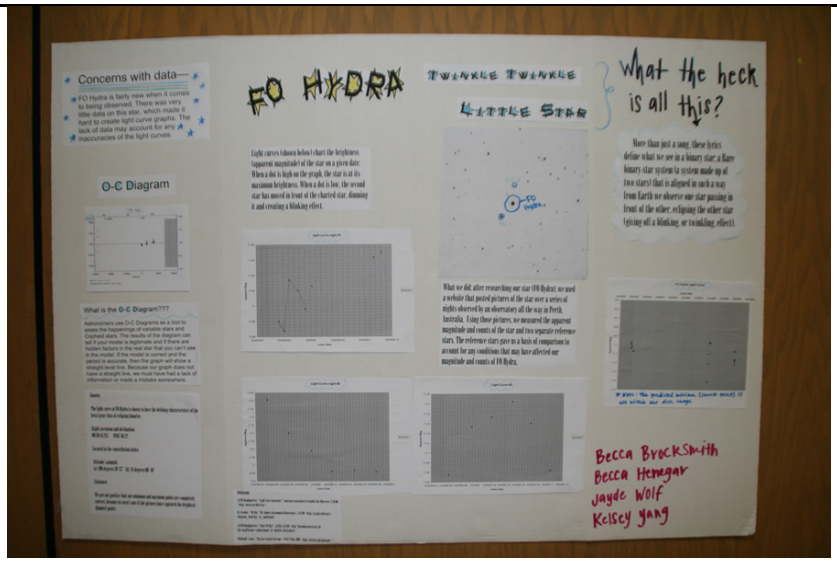
Figure 21. Presentations and development sessions were held at the HOU Conferences in the summers of 2003 through 2011 at Yerkes Observatory in Williams Bay WI. Above and below: the conference 2007 Jun 25-2.

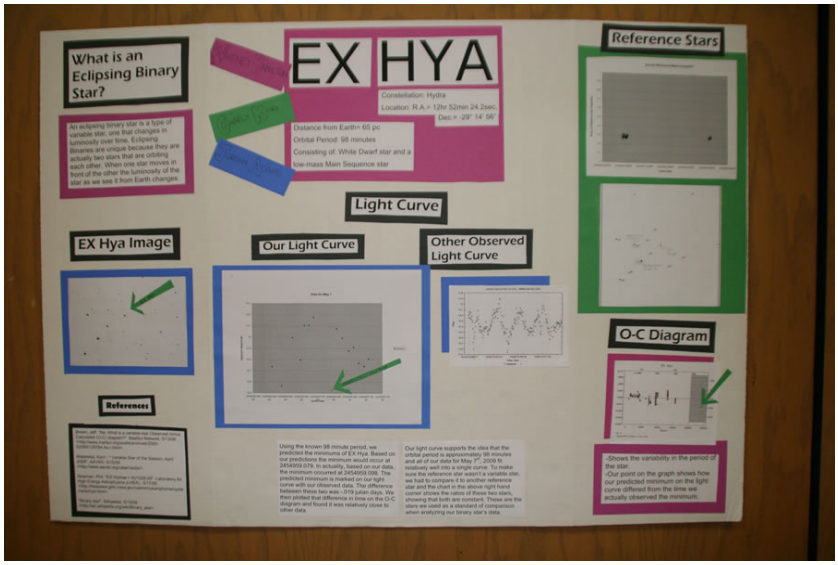
Figure 22. Below are 6 HOU student posters of work done on binary stars, including observations and light curves, in preparation for studies in exoplanet discovery.

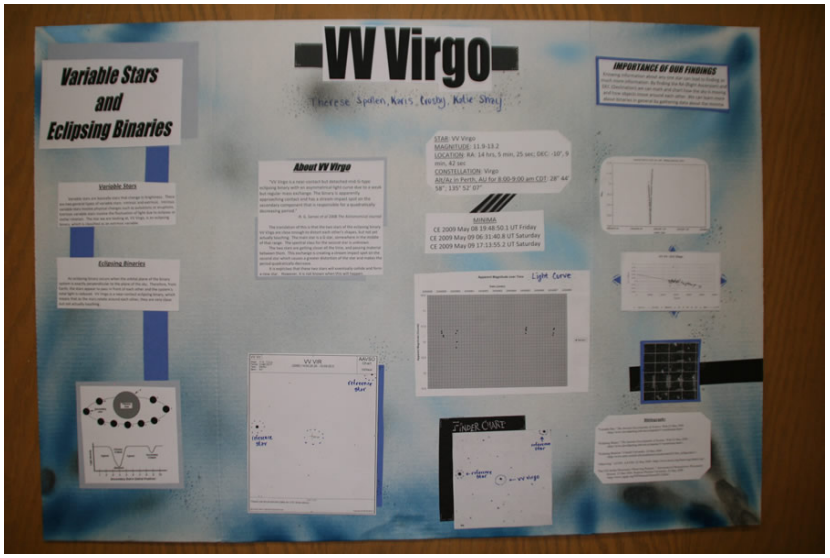

VV Virgo
VV Virgo is an eclipsing binary star. It is close to contact with its companion star, but is still a detached mid-G type with an irregular light curve. This is due to a weak mass exchange. VV Virgo is apparently approaching contact and has a stream impact spot on the companion star. The details of its companion star are unknown.
VV
Virgo
Jasmine Bay
Elise Young
Yongzhen Pan
Full Light Curve
Zoomed In Curve
Zoomed In Curve
Science of Variable Stars
Variable stars have a change of apparent magnitude in a certain length of time. The two main variable star classifications are intrinsic and extrinsic. Intrinsic variable stars have a change in brightness due to the change of the stars' physical properties. Extrinsic variable stars' differential brightness is caused by external forces such as eclipses.
Subgroups of intrinsic variable stars are pulsating, eruptive and cataclysmic variable stars. Extrinsic variable stars have subgroups of eclipsing binaries and rotating variable stars. VV Virgo falls under the extrinsic eclipsing binary star category.
Importance
With the research the group has done, our findings have increased the knowledge of the eclipsing binary star VV Virgo. We have further knowledge of the star's movement, pattern, and are now able to predict future actions of the star. The findings also have provided possible information of the unknown companion star. By knowing the orbital pattern of VV Virgo and its luminosity changes it is possible to discover new information about the companion star.
VV Vir -O-C Diagr.

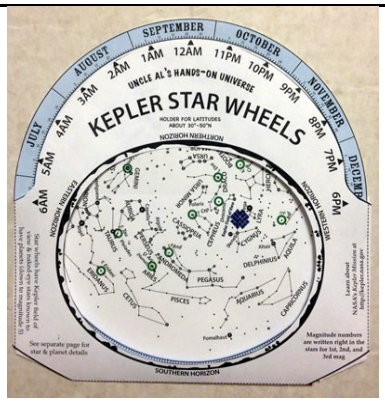

Background Information on UV Leo
-An eclipsing binary or algol-type
-Brightness varies from 8.9 to 9.56
-RA 10h 38m 20.77s
Dec: +14d 16m 3.7s
-Star type (GOV/G2V)
-The star lies within the main sequence band on mass and radius diagram.
-Was discovered as a variable star by Hoffmeister in 1934 and declared Binary by Schneller in 1936
-Confirm Scientists by emitting solar like eruptions
Variable Stars:
A variable star is a star that periodically changes magnitude. A particular type of variable star is an eclipsing binary system. An eclipsing binary system is actually two stars orbiting each other at such an angle that one star at least partially comes between the other and the earth. Because the stars in an eclipsing binary system periodically eclipse each other, the brightness of the system changes based on the positions of the two stars. When one star is in front of the other, it blocks some of the other star's light, causing a decrease in the total amount of light reaching earth from the system. When the stars are next to each other relative to the earth, the brightness is at its peak, because the light from both stars can reach the earth.
THE WOW FACTOR
What's the Big Deal?
The study of variable stars is important because it expands our knowledge of the universe. Unfortunately, our findings are not particularly important because they do not fit with the observations of more professional studies. This can be seen in our additions to the O-C diagram, where one of the data points does not even fit on the graph. These inconsistencies are probably a result of the lack of information on the reference stars used in our study, and the relatively small number of actual observations.
Sweet!
UV LEO: A VARIABLE STAR
WOW!
Problems:
There was very little information about the stars in the vicinity of UV Leo, so we were unable to find the magnitudes of the reference stars, and the light curve shows only a ratio, rather than the exact values associated with UV Leo's changes in brightness.
References
American Association of Variable Star Observers
http://www.aavso.org
Ogle Survey:
http://ogle.astrouw.edu.pl/
Eclipsing Binary Program
http://digilander.libero.it/sf_astronomy/ebcvseb.htm
BY


Variable Stars
Trinary System
Type Eclipsing System
References
Delta Libra
SAO 140270
Amber VanSlyke, Carl Tuinik, Brian Baxter, Jaison Ashbaugh
Data Collection Challenges
Determining Magnitudes
Light Curve
O-C Diagram
Predicting the Minimum
Delta Libra Information
Trinary System Stars of Delta Libra


Concerns with data
FO HYDRA
TWINKLE TWINKLE LITTLE STAR
What the heck is all this?
O-C Diagram
What is the O-C Diagram???
Becca BrockSmith
Becca Henegar
Jayde Wolf
Kelsey Yang


What is an Eclipsing Binary Star?
EX HYA
Constellation: Hydra
Location: R.A.= 12hr 52min 24.2sec
Dec.= -29° 14' 56"
Distance from Earth= 65 pc
Orbital Period: 98 minutes
Consisting of: White Dwarf star and a low-mass Main Sequence star
Reference Stars
Light Curve
EX Hya Image
Our Light Curve
Other Observed Light Curve
O-C Diagram
References


-VV Virgo-
Therese Spollen, Karis Crosby, Katie Stray
Variable Stars and Eclipsing Binaries
About VV Virgo
IMPORTANCE OF OUR FINDINGS
Light Curve
FINDER CHART

		 *Figure 23. Kepler Star Wheels. Another product of the LHS-HOU-Kepler EPO team was the adaptation of Uncle Al's HOU Starwheels to create a Kepler Starwheel, featuring stars with known exoplanets down to mag 5, now available through the Kepler website - http://kepler.nasa.gov/education/starwheel/ Many thousands of Kepler Starwheels have been handed out at workshops and public events.* On 2012 July 8 Alan Gould made a remote presentation to the Global Hands-On Universe Conference, Ifrane, Morocco about Kepler elements in the HOU high school curriculum, *A Changing Cosmos*, which continues distribution through LHS ((http://www.globalsystemsscience.org). From 2009–2012 it was a technology component with the Kendall/Hunt textbook, *Global Science*, by John Christensen.

INFORMAL EDUCATION

Informal education reaches people through museums, planetaria, and out-of-school organizations like Scouts. Kepler EPO informal education projects aimed to reach a national audience via existing, robust networks.

Small Dome Planetarium Program	Develop and disseminate an interactive planetarium program. Field test in a minimum of 8 planetariums, with formative evaluation Provide ongoing support for revisions and dissemination of interactive planetarium show. Revise planetarium show to reflect Kepler findings and discoveries.	The LHS Planetarium staff initially worked with the planetarium at the Pacific Science Center (Seattle WA) on a show called *Strange Planets* which included a section on the transit method of planet discovery. LHS has been a world-recognized leader in the development and distribution of audience participation planetarium programs since the 1970's. Field test kits for the show were sent to 6 planetariums and feedback was received from 4 of those planetariums. Summer of 2009, LHS planetarium presented the show daily and additional audience feedback collected via feedback forms. An article about Kepler and the Strange Planets show, *"Share the Hunt for Other Earths,"* was published in the March 2009 issue of the IPS journal *The Planetarian*. Also in summer of 2009 we finalized kit components and received requests from about 70 planetariums to receive show kits. They were delivered in September 2009. The *Strange Planets* planetarium show is now disseminated as part of the Planetarium Activities for Student Success (PASS) series and is available on the PASS website (http://www.planetarium-activities.org/). In the show there is a demonstration in which a light curve is generated in real time using a planet orrery, light sensor, and computer display projected on the dome. The audience learns what light curves are through the demonstration, and proceed to analyze particular light curves of planets discovered by Kepler.

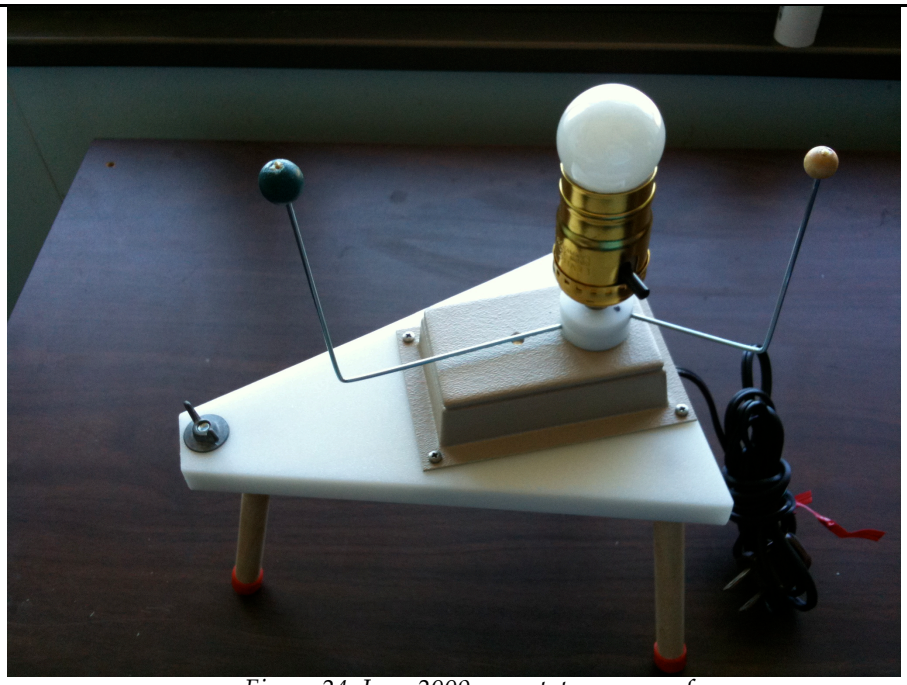


Figure 24. June 2009: a prototype orrery for Strange Planets planetarium show distribution.

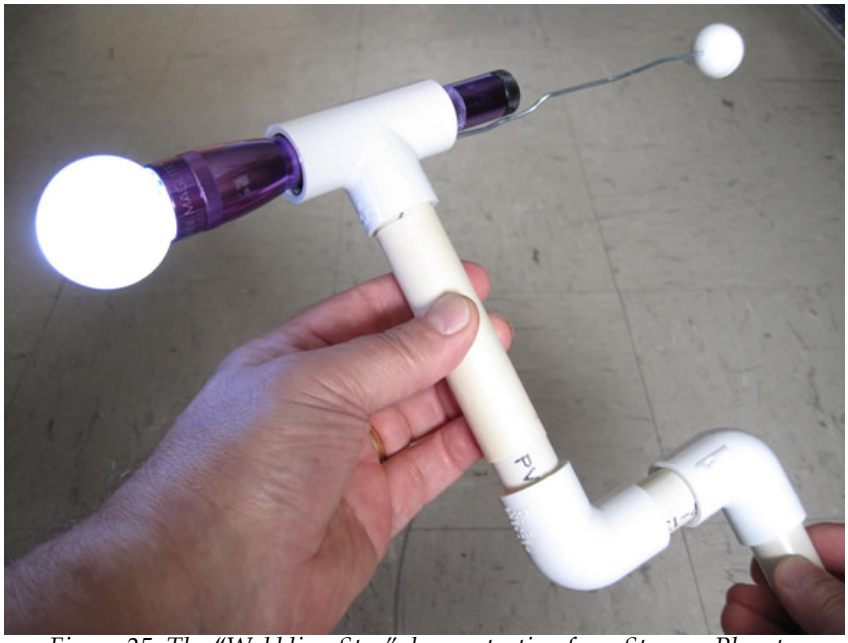


Figure 25. The "Wobbling Star" demonstration from Strange Planets Show, made with mag lite flashlight, PVC tubes, a ping pong ball and polystyrene ball. In a darkened planetarium, the lit ping pong ball (model star) appears to wobble as the presenter carries it around and turns the crank handle. Showed as public show at Lawrence Hall of Science June through Aug 13, 2009. Show kits distributed in September 2009 to 70 planetariums.

The Strange Planets show was updated in 2011 to reflect latest Kepler results.

On the Kepler website planetarium page (http://kepler.nasa.gov/education/planetariumProgramsAndVideo/), we link to programs developed by various planetarium show producers. These include:

		• Undiscovered Worlds: The Search Beyond Our Sun at the Boston Museum of Science • Extreme Planets by Clark Planetarium Productions is a 31 minute fulldome show about exoplanets, planet-finding, and concludes with a discussion of the Kepler mission. • A Planet for Goldilocks--The search for a world that is "just right"--a planetarium show from Goto Inc. "The amazing NASA Kepler mission results have already given us more than more than two thousand exoplanet candidates, some of which are in the Goldilocks Zone." See: http://www.goldilocks-zone.com/english.  *Figure 26. Advertising banner for A Planet for Goldilocks, from GOTO.*
Exhibit	Work with Space Science Institute (Boulder CO) to create the Planet Transit exhibit component for the traveling Alien Earths exhibit.. LHS runs a copy of the Kepler transit exhibit for the public.	The Alien Earths traveling exhibit was developed and completed by the end of 2004. Visitors operate a planet-star model (orrery) to watch transits of planets across the star (a light source) and see the drop in brightness on a photometer graphical display. Alien Earths exhibited at 11 museums during the US five year tour, and is now on permanent exhibit at the Virginia Air and Space Museum. LHS was the first venue where the exhibit debuted in February 2005. The itinerary of the exhibit was managed by Association of Science and Technology Centers (ASTC). The schedule kept at http://www.astc.org/exhibitions/alien/ialien.htm Feb 1 - Apr 30, 2005. Lawrence Hall of Science, Berkeley, CA Oct 1 - Dec 31, 2005. Science Museum of Western VA, Roanoke, VA Feb 1 - Apr 30, 2006. Louisville Science Center, Louisville, KY Jun 1 - Aug 31, 2006. Museum of Science and Technology, Syracuse, NY Oct 1, 2006 - Apr 30, 2007. Yale Peabody Museum of Natural History, New Haven, CT Jun 1 - Dec 31, 2007. Turtle Bay Exploration Park, Redding, CA Feb 1 - Apr 30, 2008. Virginia Museum of Natural History, Martinsville, VA Jun 1 - Aug 31, 2008. Cleveland Museum of Natural History, Cleveland, OH Oct 1 - Dec 31, 2008. Orlando Science Center, Orlando, FL Feb 1 - Apr 30, 2009. Buffalo Museum of Science, Buffalo, NY Jun 1 - Oct 31, 2009. Grey Roots Museum & Archives, Owen Sound, ON

Figure 27. Alien Earths transit exhibit at LHS grand opening, Feb 2005.

Figure 28. 2007: copy of Aliens Earths transit exhibit at LHS

A copy of the transit exhibit from Alien Earths was operational and used by the visiting public at LHS from Sept 2011 through June 2012. The transit exhibit continues to be used in the larger Alien Earths exhibit.

In addition to the heavy duty museum-grade transit exhibit for Alien Earths, the Kepler EPO team recognized a need for a light-weight tabletop exhibit/demo for use at conference workshops, booths, and classrooms.

Early prototypes for the tabletop Kepler orrery are shown in Figures 28–30.

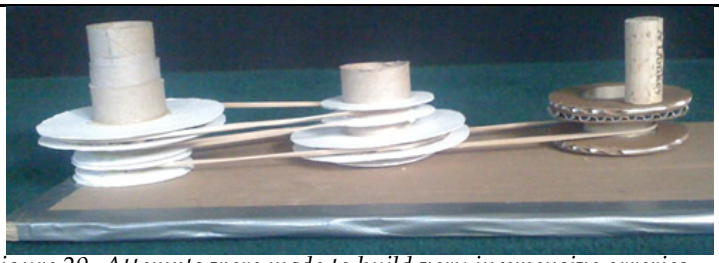


Figure 29. Attempts were made to build very inexpensive orreries from plastic, cardboard, and other easily obtained materials. This example is rubber band pulley idea that utterly failed.

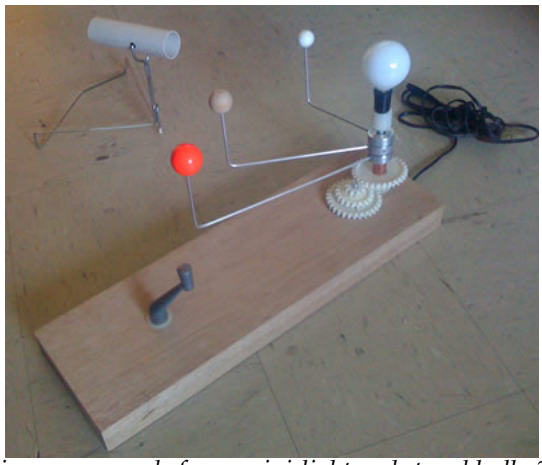


Figure 30. A working orrery made from mini-light socket and bulb, 3 planets on plastic gears from school supply company, and a casement window crank.

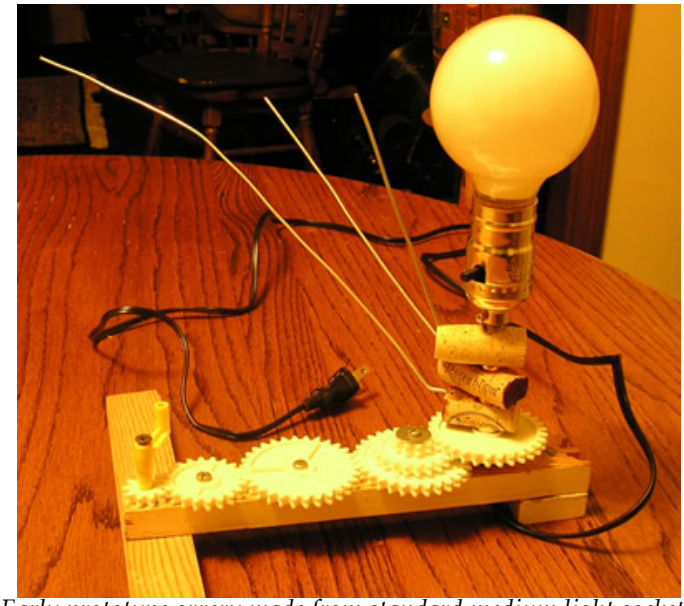


Figure 31. Early prototype orrery made from standard medium light socket, wine bottle corks to hold the planets to nested shafts driven by plastic gears from school supply company.

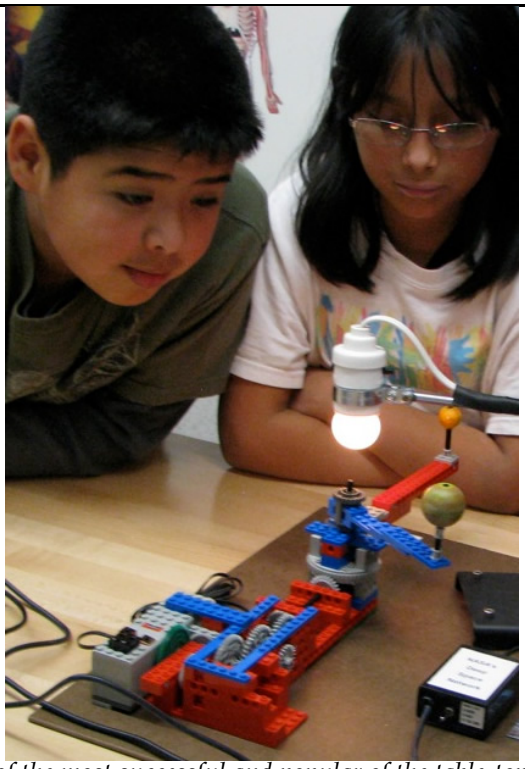


Figure 32. Some of the most successful and popular of the table-top orreries were the ones created using LEGO parts, as provided to teachers in some Kepler teacher workshops. The first of these was a 3-planet orrery made by Allan Ayres of the LHS Exhibit staff. Soon after, Kepler Deputy PI Dave Koch made a four-planet LEGO orrery that had a moon orbiting one of the planets. See http://kepler.nasa.gov/education/ModelsandSimulations/LegoOrrery/

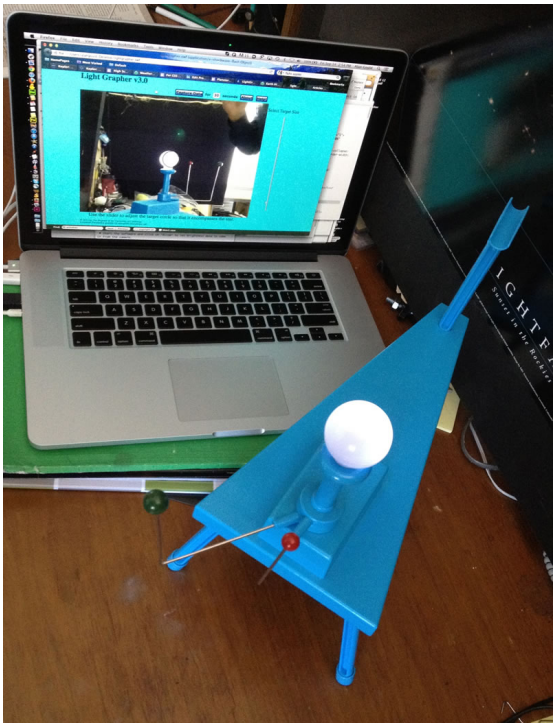
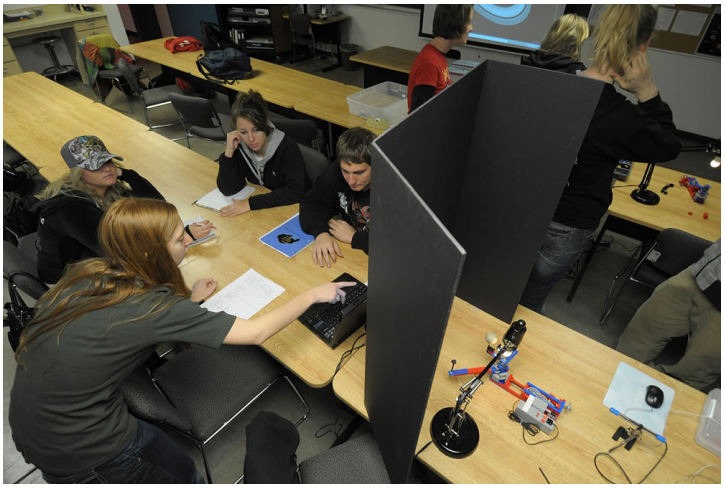


Figure 33. Recent (2012) tabletop orrery demo using the commercially available FOSS 2-planet orrery (http://www.deltaeducation.com/productdetail.aspx?PartNo=1401251) and Kepler's free LightGrapher software operating with a laptop camera (available on the Kepler website—

		http://kepler.nasa.gov/education/ModelsandSimulations/lightgrapher *(see also image of light curve in Figure 19)*  *Figure 34. LEGO transit model at JPL Open house May 2006.*  *Figure 35. Professor Doug Duncan at Univ of Colorado used Kepler-designed LEGO orreries in a c ollege exoplanet astronomy lab--students figure out characteristics of hidden planet system from light curve only. See article on the Kepler website* http://kepler.nasa.gov/education/ModelsandSimulations/LegoOrrery/dougduncan/

WEBSITE - PUBLIC OUTREACH

Web Page and Multimedia	Refine and update Kepler Website with latest ideas, news, and data.	Kepler website is fully functional and being used by the public. Updates are made regularly. The first Kepler site was created by Dave Koch prior to funding of the mission. In 2005 an LHS web designer rebuilt the site with a more aesthetic design. Then in 2009, The Navigator project team at JPL (now the Exoplanet Center) who had contracted the building of the award winning PlanetQuest site offered to help once again redesign the website, this time with a modern content management system (CMS) custom designed by a team from Raytheon.

Figure 36. In 2010, kepler.nasa.gov was nominated for a Webby award.

The site is rich with resources. Here are a few notable ones:

•News articles (http://kepler.nasa.gov/news/nasakeplernews/). Between 2008–2012, 120 articles were created to publicize key Kepler events and discoveries.

•Planet Discoveries Table (http://kepler.nasa.gov/Mission/discoveries/) and a discovery page created for each planet.

•Kepler Planet Candidate Data Explorer (interactive web page) http://planetquest.jpl.nasa.gov/kepler enables users to learn how *Kepler* finds planets, and invites visitors to dive into the *Kepler* exoplanet data by manipulating tables, graphing functions, and filtering tools.

•The Education section of the website has classroom activities, resources for amateur astronomers, planetarium show information, Kepler Starwheels, simulations, models, citizen science (Planet Hunters), and a "Just for Fun" area with music, art, sculpture, poetry, literature, opera, and drama.

•"Women of Kepler Mission" page. http://kepler.nasa.gov/news/nasakeplernews/index.cfm?FuseAction=ShowNews&NewsID=193

•Feature section on Johannes Kepler http://kepler.nasa.gov/Mission/JohannesKepler/

•Members of the Kepler Team - http://kepler.nasa.gov/Mission/team/

•Kepler Awards - http://kepler.nasa.gov/Mission/awards/

•Frequently Asked Questions - http://kepler.nasa.gov/Mission/faq/

•The First Kepler Science Conference, 2011 Dec 5-9. http://kepler.nasa.gov/Science/ForScientists/keplerconference/

•Solar system transits page http://kepler.nasa.gov/education/resources/SolarSystemTransits/

•Galleries of multimedia - http://kepler.nasa.gov/multimedia/ including artwork contributed by professional artists. http://kepler.nasa.gov/multimedia/artwork/proart/ These are largely a result of connections Alan Gould made at SpaceFest III in Tucson 2012 June 1.

•Presentation slide sets at http://kepler.nasa.gov/education/PowerpointFile/slides/ and http://kepler.nasa.gov/education/PowerpointFile/videos/

•Links "For Scientists" http://kepler.nasa.gov/Science/ForScientists/

•Links to Kepler Facebook and Twitter pages

•Paper model of Kepler. http://kepler.nasa.gov/education/ModelsandSimulations/papermodel/

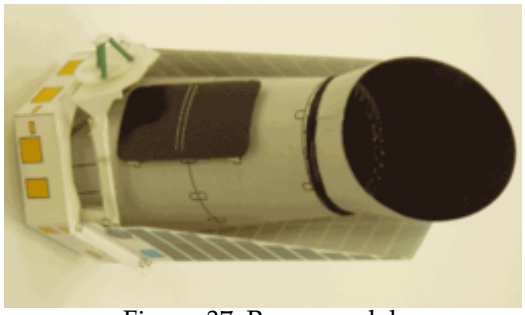


Figure 37. Paper model.

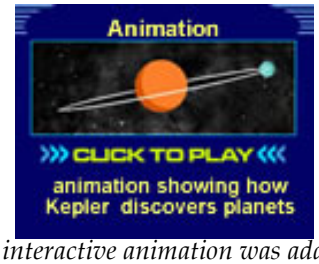


Figure 38. In 2005, a simple interactive animation was added to Kepler website. *http://kepler.nasa.gov/multimedia/Interactives/HowKeplerDiscoversPlanetsElementary/*

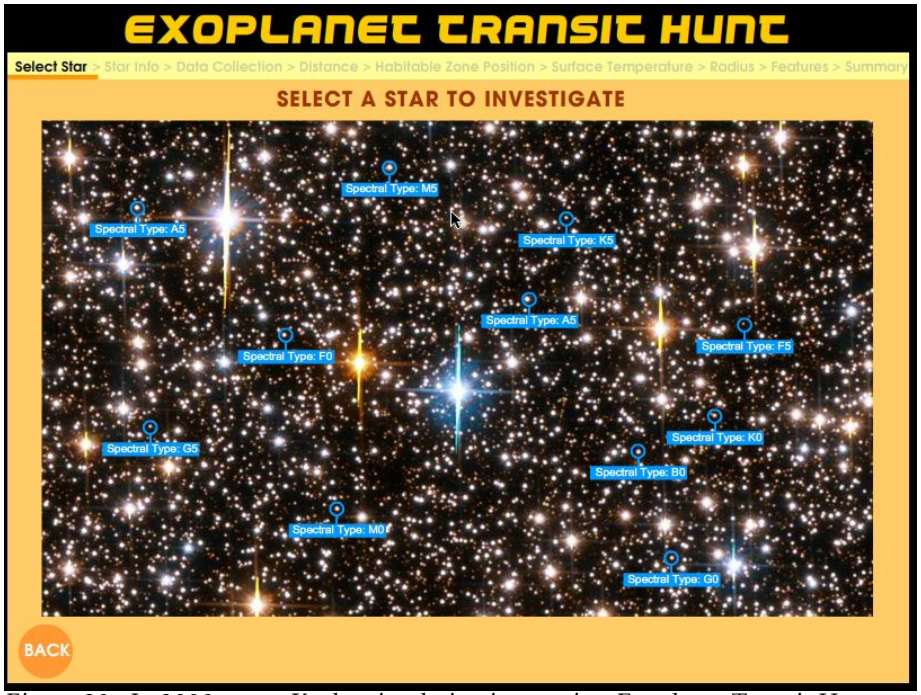


Figure 39. In 2008 a new Kepler simulation interactive, Exoplanet Transit Hunt, based on Dave Koch's original Hyperstudio simulation was put up at *http://kepler.nasa.gov/multimedia/Interactives/keplerFlashAdvDiscovery/* *- Users first pick a star to investigate and subsequent steps show how planets are discovered.*

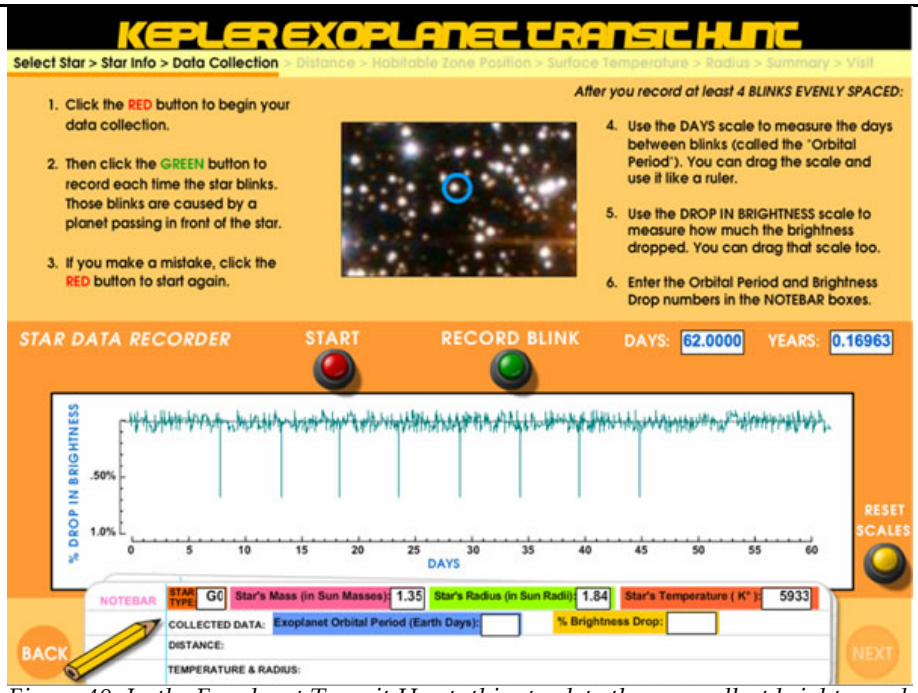


Figure 40. In the Exoplanet Transit Hunt, this step lets the user collect brightness data from the star they selected, and graphs the data in a light curve that they then use to measure period and depth of transit.

Figure 41. In the last step of Kepler Exoplanet Transit Hunt, users get to see an artist's depiction of the planet they discovered and see if it is Earth-like or not.

2012 Lawrence Hall of Science Activation Lab Simulations entitled *What Affects Whether a Planet Can Have Life?* were added to the Kepler website in July 2012, developed by the Research Group at the Lawrence Hall of Science. http://kepler.nasa.gov/multimedia/Interactives/activationlab

Evaluation	Help coordinate overall evaluation of Kepler E/PO. Prepare for summative evaluation	All Evaluation Reports are posted on: http://kepler.nasa.gov/education/resources/eval/ A summary of some of the key evaluation findings is in Table 2.

Table 2. Summary of EPO Effectiveness and Impact

EPO Element	Evaluation Summary/Effectiveness	Impact (/yr)
Transit Exhibit	• The LHS transit exhibit very inviting to visitors—87% of groups that came near stopped to use it—a high capture rate. Hold time also very high: 50 sec to 16 min with an average of 3.5 min. • The table-top LEGO Orrery model used in U. of Colo Astronomy Labs. • LEGO Orrery models were part of the kit for day-long TPD	> 100,000 visitors
Kit for NSN Astronomy Clubs	Shadows & Silhouettes Kit was used successfully and its activities well received at public events.	> 500 events >25,000 people
GEMS Space Science Sequence	Pre to post-test student learning gains were statistically significant for all units and grade levels. Grades 3–5 gain ranged from 12% to 20%. Grades 6–8 gains ranged from 11% to 17%. Results suggest consistent evidence of the effectiveness of the curriculum.	> 1500 teachers > 45,000 students
HOU HS Transit Investigation	Field test results indicate Transit Investigation successful & valuable. Students were able to understand the concepts better after the readings.	> 55 teachers > 3000 students
Strange Planets Planetarium Show	Survey results—very positive findings: visitors enjoyed the show; reported learning new info; could articulate themes/purpose of the show; liked hands-on parts; felt it is appropriate for a broad range of ages.	> 70 planetaria >30,000 visitors
Star Date Radio Broadcasts	StarDate broadcast on 278 stations & 572 time slots. Universo broadcast on 129 stations & 189 time slots. Survey respondents reported they were very likely to go outside to find the object discussed, or to go to the web site to learn more, but were not more likely to take a class or pursue a degree in science. Audience mainly men in their 50s and 60s	Millions of listeners Website visits: >250,000