A LIVELY ELECTRONIC COMPENDIUM OF RESEARCH, NEWS, RESOURCES, AND OPINION

Astronomy Education Review

Volume 7, Feb 2008 - Dec 2008
Issue 1

Astronomy@Home

by **George S. Mumford**
Emeritus, Tufts University
Received: 01/08/08, Posted: 03/03/08

The Astronomy Education Review, Issue 1, Volume 7:103-112, 2008

Abstract

In the field of distributed computing, thousands of people have computers running so-called screensaver or passive programs when their machines are not being used for other projects. These are not the screensavers normally thought of, but programs that are contributing to the growth of human knowledge. A lesser number are running active programs that require their interaction with the data provided them. As discussed in this article, these latter programs have far greater educational value than the former, and many are suitable for education at all levels, from middle school to college, and in informal and formal educational settings.

1. INTRODUCTION

What is your computer doing in its spare time? Maybe it's displaying fish swimming about the screen or an endless procession of clouds. Then it might be catching 40 winks. In place of these relatively useless activities, have you ever thought about turning it loose to compute cosmological models, or to search for intelligence in outer space, or to detect rotating neutron stars, or to investigate the distribution of dark matter within our home galaxy? You don't even have to be at the switch to run these projects, which are basically advanced forms of screensavers and examples of passive programs from the burgeoning field of distributed computing. This field includes experiences in climatology, biology, and many other areas in which your computer may be put to use for a scientific or other type of study from a single central server. Although understanding why and how the data behind these projects are collected and analyzed is educational, the ability to contribute by actually doing an analysis or making identifications (as in the following group) is even more so. And the equipment requirements are not so stringent. Select any of the following projects and you are in charge, whether it's to classify galaxies, investigate craters and other landforms on Mars or Eros, search for grains of interstellar dust, or join those seeking planetary systems around nearby stars. These are not technically distributed computing projects because your computer connects to a particular server or Web site to get the work that you do, but they are often referred to as active, as opposed to passive, projects in distributed computing.

2. ACTIVE (YOU-DO-IT) PROJECTS

These are presented in the order of the simplest (those that can be started with the least preparation—say, in middle school or maybe as an elementary school project) to the most complex (requiring considerable background for a full understanding at the college level).

2.1 Galaxy Zoo

Your students will be identifying galaxies from images of the Sloan Digital Sky Survey if you decide to have them join this undertaking. In participating, they will not only contribute to scientific research but also will be viewing parts of the Universe that few have seen before, while being introduced to the tremendous diversity among galaxies. According to a recent newsletter, the first phase of Galaxy Zoo has been completed: a million or more galaxies have been classified more than 30 individual times by volunteers from a cast of 100,000. The data are being processed, and scientific results will soon be published. A recent press release reports that volunteers have added some 480 overlapping galaxies (one galaxy appears projected on another) to the previously known 20. Your students will be involved in a real scientific enterprise. The second phase is scheduled to be up on site early in 2008. This will call for more detailed classifications and possibly a look beyond objects in the Sloan survey.

A computer program written to sort galaxies into various categories would do a reasonable job but would inevitably throw out weird or unusual objects. The human brain is much better at recognizing patterns and would likely recognize these interesting formations as something different from normal. Hence, individuals are needed.

A tutorial illustrates what you and your students will be doing. After a brief introduction to some differences between elliptical and spiral galaxies, a series of frames will test abilities to distinguish between these types of galaxies when viewed head-on or edge-on. Another series of frames gives practice in identifying merging galaxies, yet another series presents very faint objects, and a final set introduces objects to be ignored, such as stars, streaks, and irregular galaxies. Practice in determining whether a spiral galaxy is rotating clockwise or counterclockwise is also provided. On completion of the tutorial, a simple test assesses what has been learned. This involves viewing 15 images similar to the ones already viewed and identifying the objects by clicking on appropriate buttons. Don’t worry, a score of just over 50% (8 correct) will qualify one to move on to the Galaxy Analysis page. And the test can be repeated if necessary. Good luck!

About a decade ago, I was invited to teach a segment on astronomy to a group of seventh- and eighth-grade students at the school I once attended. This was the hardest job I have ever had. I really searched to find a Web-based project to whet their interest and to entertain them. At that time, I could find nothing comparable with Galaxy Zoo, which I would highly recommend for consideration to those of you doing a unit on astronomy with emphasis on galaxies in deep space in a middle school general science course.

2.2 Clickworkers

This began as an experiment in late 2000 to see if public volunteers, called clickworkers, could do some routine scientific analysis of a type normally handled by graduate students. All the original projects are up and running but have largely already served their purpose. Emphasis is now being shifted to the identification of Martian landforms from images taken with the HiRISE camera, an instrument on the Mars Reconnaissance Orbiter that has been returning images since 2006. The immediate task is for HiRISE Clickworkers to search for sand dunes, channels, gullies, boulders, patterned areas, and more, with a goal of locating interesting features. No tutorial is involved, so cataloging can be undertaken right away. The HiRISE images are huge. A single one, zoomed in all the way, is more than 10 computer screens in height and width. With enough volunteers, maybe inspection of the images at all scales will be possible.

Were I still actively involved in teaching, be it middle school or higher, one or more lab-type sessions would be spent on this topic. After a brief discussion of landforms, I would pair students with a computer and turn them loose to analyze images and debate about what they are seeing before certifying any results for transmission.

A second goal is to help find new sites on Mars for HiRISE to photograph. This involves searching through images made by Mars Global Surveyor's Mars Orbital Camera for landforms of interest to the HiRSE team. These are listed and described on the working page adjacent to the image produced by the camera.

During the fall of 2007, students were invited to participate in the HiRISE Image Targeting Challenge to help select a region of Mars that probably contained surface water in the past for HiRISE to image. One hopes that a similar challenge will be made in 2008 and years thereafter.

HiRISE provides a host of additional educational activities here, including a coloring book for Grades K–3 or above; activity books for Grades K–3, 4–8, and 9 and above; fact sheets; and tutorials.

Dawn Clickworkers are invited to develop their measuring and identification skills by studying craters on Eros and Mars in preparation for the critical examination of images of the asteroid Vesta and the dwarf planet Ceres. These images are anticipated from the Dawn spacecraft launched on September 27, 2007.

A tutorial that works with Internet Explorer 5.0, Netscape 6, or Firefox 1.07 must be completed before students are turned loose on a real field containing images from Eros or Mars obtained by the NEAR spacecraft. This tutorial asked me to identify seven craters in a given field and click on four points on the periphery of each. The ratings of the circle, drawn through the points to suggest the size of the crater, included such terms as "close," "pretty good," "good job," and "a little off." A bad result could be improved on. Then on to the real measures.

Mention is made of some related activities that may be of interest, such as how to make a football-stadium-sized crater some 10 or so stories deep in a comet, or an activity centered on locating impact craters on Earth. A couple of months could well be spent on the entire series of activities involved here, especially with some introduction to measuring Martian craters from the early stage of Clickworkers. Parts of this might make a reasonable activity for a museum or planetarium group; certainly there is material here for an introductory astronomy course. The landforms identification would seem to be an interesting activity for middle school students. NASA is to be commended for all these contributions to education.

2.3 Stardust@home

Pristine interstellar dust was returned to Earth in 2006 by the Stardust mission, launched February 7, 1999, that passed close to Comet P/Wild 2 some five years later. Details of the mission and trajectory may be found in the section on the mission timeline. This is the first such material ever collected in space, and scientists are eager to get their hands on samples, but first the particles have to be found. Stardust may have collected some 45 of these tiny-estimated one-micron dust grains that are embedded in an aerogel collector 1,000 square centimeters in area.

To find these particles, an automated scanning microscope was used to automatically collect digital images from the entire Stardust collector. These "stacks" of images, called focus movies, are available to view with a special virtual microscope that miraculously arrives in your computer when you sign up for the project.

The tutorial requires that you view 18 images. Adjacent to each is a series of horizontal bars on which the cursor can be moved up or down to change the focus of the virtual microscope. The images include samples of tracks from particles, regular dust, scratches, inclusions, and interstellar dust candidates. On completion of the tutorial—take your time—you may continue on to take the registration test. Another series of 10 focus movies is provided for you to view. You must respond correctly in eight cases before you can be certified to continue with the project. Most people, including yours truly, do not pass on the first try.

An incentive to view the real movies is that the discoverer of an interstellar dust particle will appear as a coauthor on scientific papers by the Stardust@home collaboration announcing the discovery of the particle. Further, the discoverer will have the privilege of naming the particle.

The team is serious about contributing to education. The Educator Page provides guides geared primarily toward comets for Grades K–12, as well as information on videos and workshops. Stardust@home in the Classroom contains additional information for students, lesson plans, and information on how teachers might use this project for professional development. This is also an ideal venue for informal education. The message board has a special section for teachers and students to share ideas about using Stardust@home. Trivia: When last visited, 2,854 users had posted 14,552 articles. When last visited, 2,813 users had posted 14,248 articles.

2.4 Systemic

This is the site where you can learn about one method of discovering extrasolar planets. A major thrust of this research collaboration is to improve our statistical understanding of the galactic planetary census through a large-scale simulation in which the public is invited to participate. Currently these materials are under development, so instead you can use radial velocity data sets compiled by the team (based mainly at the University of California Santa Cruz) to investigate nearby stars known to have planetary systems as a way to prepare for future simulations.

To become involved, download the systemic console that allows you to determine orbital parameters from radial velocity curves. In addition, Solar System and Alpha Centauri expansion packs are available for experienced users. These provide synthetic data sets for our Solar System and for a number of possible planetary systems associated with the two primary stars in the Alpha Centauri system.

Three tutorials explain how to use the console. In the first, radial velocity observations of the sunlike star HD 4208 are manipulated to derive orbital parameters of a potential planet; in the next, issues associated with Upsilon Andromedae lead to a more complex situation; and in the third tutorial, dynamical stability and planet–planet interactions that arise in crowded systems are introduced. Remember that this is a developing site, and changes are being made on a continuing basis. Hence, some of the information or illustrations that appear in a tutorial may not be similar to what appears on your computer screen. There is a considerable amount of information and procedures to be absorbed here. This is certainly the most complex of any of the projects described. Independent study at the college level strikes me as the ideal place to incorporate these materials.

Completed analyses may be uploaded to the systemic backend, described as a collaborative Web site where results can be compared with those of others. A learning project on extrasolar planets has been established at Wikiversity, a joint effort to create learning materials for classroom use or self-study. In addition to an introduction to the systemic console, there are links to other sources of material.

3. PASSIVE (They-Do-It) PROJECTS

David P. Anderson, who has directed SETI@home since 1998 and who developed the Berkeley Open Infrastructure for Computing (BOINC) in 2002, is primarily responsible for the evolution of distributed computing. To become involved in these programs, sometimes referred to as screensavers, virtually the first thing you do is download and install the appropriate version of BOINC. This will set up your computer to receive data from your choice of central server. Your computer processes these data when not involved with other concerns, like sending e-mail. Processed data are returned to the server, and more sent back to be analyzed. These programs do not affect how you computer performs. You can interrupt them at any time. Through setting various preferences, you can control the frequency with which your computer will be used. The projects are given here from the well established to those just starting up.

3.1 SETI@home

SETI (Search for Extraterrestrial Intelligence) has a goal of detecting intelligent life beyond our planet. This particular approach currently uses the large, fixed radio telescope at Arecibo, Puerto Rico, to detect narrow-bandwidth signals from space. The signals come not only from celestial sources and the receiver’s electronics, but also from TV stations, radar, and artificial satellites. Today’s radio SETI project analyzes these data digitally. The more computing power, the greater the frequency ranges that may be covered and the greater the sensitivity.

Because the Arecibo telescope is in a fixed position, it can only scan about a third of the sky that lies between declination 35 degrees north and the equator, with a beam 0.1 degree wide. If you join the program, your slice of data will represent 107 seconds of data collection while the beam slewed about 0.6 degree on the sky.

Previous radio SETI programs used special-purpose supercomputers located at a telescope to do the bulk of the data analysis. However, over a decade ago, in 1995, David Gedye proposed doing radio SETI using a virtual supercomputer composed of large numbers of Internet-connected computers. The SETI@home project was launched officially in 1999 to explore this idea.

The SETI@home screensaver has four elements. The first, the *Data Info* box, tells what region was searched to provide the data that your computer is processing; when and where the data were collected; and the base frequency of the data. The second element, *User Info*, includes your name; the number of units completed by your computer; and the total time your computer has been on this venture. The data supplied arrive as a signal that varies with time, which is turned into a set of frequency-based data using a mathematical operation called a fast Fourier transform. The result of this operation is the third element, the *graph*, which is produced in the lower frame of the screensaver. At the start of the operation, 15 of these transforms, each looking at the data with varying accuracy, are performed. These steps, plus other analyses, are noted in the fourth element, the *Data Analysis* pane, where you can follow what your computer is up to at any instant if you are so inclined. For additional details, visit the site referenced above.

Recently it has been announced that the SETI@home database will be researched for dying black holes.

Out of curiosity, I looked at some of the usage statistics that SETI@home has amassed. Among their top 20 participants, nine have been with the program since 1999, five since 2000, a pair from 2001, three from 2002, and one from 2006.

3.2 Einstein@home

Einstein suggested that we live in a Universe full of gravitational waves generated by exploding stars, colliding black holes, and other such events that alter space and time. The Laser Interferometer Gravitational Wave Observatory (LIGO) in the United States and GEO 600 in Germany are working together to find evidence for such gravitational waves. These experiments require enormous amounts of data to be processed, so the LIGO group created Einstein@home.

The analysis that your computer performs is on data obtained at a particular location on the sky. Your computer also receives a model of what it is thought a pulsar signal from that part of the sky should look like. A Fourier transform computes a model from the data received, which is compared with the one provided. The results are sent back to the central server. If the models match, the data are reanalyzed by two additional computers. If there is no match, one reanalysis of the data is made to ensure that there were no mistakes.

The Einstein@home screensaver appears as a rotating celestial sphere on which major stars of constellations and current zenith positions of the three gravity wave detectors are displayed. You may have trouble recognizing some of the constellations; they will appear backward from what you are accustomed to because they are being viewed from outside the celestial sphere.

L-shaped markers show zenith positions of each detector: blue for Ligo at Hanford, Washington; red for Ligo at Livingston, Louisiana; and red for GEO 600 of Hanover, Germany. Each detector is basically a very large Michelson interferometer, hence the shape.

Purple dots represent known pulsars. Note how they are clustered toward the plane and center of our galaxy. The two small concentrations in the celestial southern hemisphere indicate those located in the Magellanic Clouds. Dark red dots representing supernovae remnants are also clustered toward the galactic center. They are of particular interest for gravity wave hunters because some of these may have left behind a pulsar or spinning neutron star. An orange marker that looks like a gun-sight indicates the current search position. Its position is also noted in the lower right corner. The marker moves along as the search progresses.

Your name and data relating to your computer's involvement appear in the lower left. Search information appears to the right.

3.3 Cosmology@home

Developed in the Department of Astronomy at the University of Illinois at Urbana-Champaign, a central purpose of the Cosmology@home project is to enable participants to contribute to front-line cosmological research. Goals are to find the model that best describes our Universe and to find the range of models that agree with the available data. Participating computers will derive the observable predictions of millions of theoretical models using different combinations of parameters.

Each unit will simulate a Universe with a particular geometry, particle content, and "physics of the beginning." The predictions of the Universe prepared from this input will then be compared with such observed quantities as fluctuations in the cosmic microwave background; the large-scale distribution of galaxies and clusters of galaxies; measurements of the current expansion of the Universe; the acceleration of the Universe; primordial element abundances; and, in the long run, gravitational lensing data.

As an incentive to obtain participants, consideration is being given to offering the Cosmology@home Prize to the owner of the computer that calculated the model to best fit the data as of December 31, 2008.

There are three versions of a desktop background available for download, but no screensaver as yet.

3.4 MilkyWay@home

MilkyWay@home comes from the Computer Science Department at Rensselaer Polytechnic Institute and will rely on Internet-connected computers to model and determine the evolution of our home galaxy. Further, the developers hope to gain a better understanding of the power of volunteer computer resources.

Another goal of this undertaking is to investigate the distribution of dark matter within the Milky Way galaxy through studies of the debris arising from the merging of the Sagittarius Dwarf Ellipsoidal Galaxy into our system.

Here is an opportunity to become involved in the early stages of a project if you so desire. Some recent server problems have mainly been taken care of.

3.5 Orbit@home

Orbit@home, a BOINC-based project (likely listed as such soon) will use the *Orbit Reconstruction, Simulation and Analysis* (ORSA) framework to monitor the impact hazard posed by near-Earth objects. The work is in its very early stages, so you will find few details on the home page. More information is available at the ORSA Web site and in a poster by Pasquale Tricarico, Washington State University.

3.6 BRaTS@home

BRaTS@home is a startup that performs various calculations in Gravitational Wave Tracing. Based at the University of Missouri at St. Louis, BRaTS@home is currently accepting new volunteers by invitation only.

List of URLs in Order of Appearance

Other areas [distributed computing projects]:
http://en.wikipedia.org/wiki/List_of_distributed_computing_projects

Sloan Digital Sky Survey: http://www.sdss.org/

Galaxy Zoo: http://galaxyzoo.org/

Galaxy Zoo press release: http://galaxyzoo.org/pr_201207.aspx

Galaxy Zoo tutorial: http://galaxyzoo.org/Tutorial.aspx

Galaxy Analysis: http://galaxyzoo.org/GalaxyAnalysis.aspx

Clickworkers: http://clickworkers.arc.nasa.gov/top

HiRISE: http://marsoweb.nas.nasa.gov/HiRISE/

Mars Reconnaissance Orbiter: http://mars.jpl.nasa.gov/mro/

HiRISE Clickworkers: http://clickworkers.arc.nasa.gov/landforms?camera=hirise

Mars Global Surveyor: http://mars.jpl.nasa.gov/mgs/

Mars Orbital Camera: http://clickworkers.arc.nasa.gov/landforms?camera=moc

HiRISE Image Targeting Challenge: http://quest.arc.nasa.gov/challenges/hirise/

HiRISE educational activities: http://hirise.lpl.arizona.edu/epo/epo.php

Dawn Clickworkers: http://dawn.jpl.nasa.gov/clickworkers/

NEAR: http://near.jhuapl.edu/

Stardust mission: http://stardust.jpl.nasa.gov/overview/index.html

Stardust mission timeline: http://stardust.jpl.nasa.gov/mission/timeline.html

Stardust aerogel: http://stardust.jpl.nasa.gov/tech/aerogel.html

Stardust tutorial: http://stardustathome.ssl.berkeley.edu/ss_tutorial_start.php

Stardust@home: http://stardustathome.berkeley.edu/

Stardust educator page: http://stardust.jpl.nasa.gov/classroom/educators.html

Stardust@home in the classroom: http://stardustathome.ssl.berkeley.edu/classroom.php

Stardust informal education page: http://stardust.jpl.nasa.gov/classroom/informal.html

Stardust@home message board: http://stardustathome.ssl.berkeley.edu/forum/index.php

Systemic: http://www.oklo.org/

Systemic console: http://oklo.org/?page_id=86

Systemic backend: http://207.111.201.70/php/backend.php

Systemic Wikiversity: http://207.111.201.70/php/wiki.php?page=/Wikiversity

David P. Anderson: http://boinc.berkeley.edu/anderson/

Berkeley Open Infrastructure for Computing (BOINC) http://boinc.berkeley.edu/

SETI@home: http://setiathome.berkeley.edu/

SETI@home screensaver: http://setiathome.berkeley.edu/sah_graphics.php

SETI@home dying black holes:
http://www.planetary.org/html/UPDATES/seti/SETI@home/Update_110501.htm

SETI@home usage statistics: http://setiathome.berkeley.edu/stats.php

Einstein@home: http://www.einsteinathome.org/

Einstein@home data analysis: http://www.einsteinathome.org/about/data.html

Einstein@home screensaver: http://einsteinathome.org/about/screensaver.html

Cosmology@home: http://cosmologyathome.org/

Cosmology@home desktops: http://cosmologyathome.org//downloads.php

MilkyWay@home: http://milkyway.cs.rpi.edu/milkyway/

MilkyWay@home goal: http://milkyway.cs.rpi.edu/milkyway/forum_thread.php?id=13

Orbit@home: http://orbit.psi.edu/

Near-Earth objects: http://en.wikipedia.org/wiki/Near-Earth_object

ORSA: http://orsa.sourceforge.net/

ORSA poster: http://orsa.sourceforge.net/doc/presentations/DPS_2004/DPS_2004_poster_tricarico.pdf

BRaTS@home: http://maxwell.dhcp.umsl.edu/brats/

ÆR
103 - 112