Analyzing Online Data On Variable Stars: An Authentic Research Experience for Teachers

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Abstract This paper describes a project directed at training secondary school teachers in the techniques of astronomical research using powerful online resources with the end goal of helping students conduct authentic research.

1. Introduction and background

Amateur astronomers have led the way in conducting research by mining Internet data resources. Immense datasets, such as Stardial, already contain more data than can or will be inspected visually by the current cadre of professional astronomers. Taking advantage of this unique situation, astronomy educators are now adapting the computer-based techniques of amateurs for student use. Astronomy is an obvious choice for student-driven research projects in schools because nearly all of recent primary data and large amounts of secondary data (catalogues and technical publications) are in electronic form, easily accessible in the classroom using ordinary computer equipment.

The National Research Council National Science Education Standards and the American Association for the Advancement of Science Project 2061 Benchmarks clearly emphasize that students should learn science by doing science. In response, science education is slowly but steadily being transformed into a process-driven, inquiry-based area of study. As one avenue, inquiry-oriented science-fair-like research projects provide engaging opportunities for students to become personally and directly involved in scientific investigations. It is generally accepted that the field of astronomy easily captures many students' attention. Therefore, it is only natural that many students want to embark on astronomy-related science fair projects. Unfortunately a quick web-search provides only limited guidance for interested students in how to participate meaningfully in the enterprise of astronomy.

In a very short time, the amount of astronomical data freely available over the Internet has become substantial. More and more astronomical catalogues have been interlinked, search engines are becoming more and more sophisticated, and the research results from on-line data will likely be just as rich as that from "real" telescopes—and available almost instantaneously. Ventures such as the National Virtual Observatory (NVO) are actively trying to prepare for this data avalanche and the astronomy education community is beginning to gear up for how to bring this resource appropriately to students. We are exploring strategies to develop and evaluate various approaches to bringing non-science-major students and pre-service education majors into the astronomical enterprise in a meaningful way using Internet-based astronomy data.

2. The current project

Over the past decade, amateur astronomers have pioneered data-mining in astronomical databases. Amateurs have used online primary data to discover new variable stars and evaluate the current behavior of known variable stars (e.g. Wils 2003), to examine suspected variable stars (Bedient 2003), and to classify eclipsing binaries (Otero 2003). Still others have located solar system objects of interest such as Near-Earth Objects (NEOs) and Kuiper Belt Objects (KBOs) in online archival imagery, thus contributing to early refinement of their orbits soon after discovery (e.g. Matson *et al.* 2004). Change in brightness or change in motion provides an opportunity for careful observation and analysis of data—the essence of science. We intend to transfer some of the knowledge base of amateur astronomers to the science education classroom using data-mining techniques.

The current effort had its roots in the NSF-Funded Teacher Enhancement Project, "Towards Other Planetary Systems" (TOPS) (Meech *et al.* 2000) which ran from 1994 through 2003. TOPS provided training in basic astronomy to secondary school teachers, and provided opportunities to conduct research activities using small telescopes (Kadooka *et al.* 2003). The logistical requirements of providing the small telescopes and related instrumentation such as CCD and film cameras were very large, and obtaining personnel proficient in the use of such equipment and capable of training others can be difficult. Once the logistical problems were solved, there remained the problem of weather during the workshop observing sessions. P. R., a participant at TOPS 2001 through 2003, saw an opportunity to develop a similar teacher workshop, using a "virtual observatory" in the form of online archived images and data to investigate variable stars. Teachers trained in this manner can use the techniques learned in their classrooms, and encourage science-fair-type projects.

Variable stars provide an engaging opportunity for students to systematically study the behavior of astronomical objects that vary with time. The brightness changes of these stars can range from a few milli-magnitudes to as much as twenty magnitudes over periods of a few seconds to years, depending on the type of variable star. Over 30,000 variable stars are known and catalogued, and many more are suspected to be variable. The large number of un-catalogued and unclassified variable stars presents an exciting opportunity for students to be involved in the enterprise of scientific discovery.

In this project, we are developing a new summer workshop approach for participants focused on conducting research on variable stars using existing Internet datasets. The objectives are: (a) to learn to access Internet-databases; (b) to identify variable stars and determine their light curves; and (c) to develop strategies, written procedural guidelines, and resources needed to mentor students in variable star based science fair projects.

Students will use three primary resources: Stardial, an autonomous drift-scan camera on the web (McCullough and Thakkar 1997); the *All-Sky Automated Survey* (ASAS-3, Pojmański 2002); and the AAVSO International Database.

Stardial provides nightly images (weather permitting) of a band of sky between Declination 0° and −7°, sliced into Right Ascension chunks of 15 minutes. The red-sensitive KAF-400 CCD in the camera coupled with the RG-4 filter makes Stardial an ideal detector of red long-period variables. The one-time-per-night observation tempo makes it best for this type of variable star, though it has been used to detect novae, eclipsing binaries, bright asteroids, comets, and geosynchronous earth satellites. It provides primary data, that is, images that have not been processed or analyzed. Users need to learn basic photometry techniques in order to extract observations of individual objects. Students using Stardial must also apply knowledge of the celestial sphere to determine when an object might be visible in Stardial images.

The AAVSO International Database contains about 11.5 million variable star brightness estimates going back over ninety years. It is the largest and most comprehensive digital variable star database in the world. About 700 amateur observers from all over the world contribute over 400,000 new variable star brightness measurements to the database every year. The AAVSO is engaged in a NASA-funded effort to validate and place on-line most of the database. Once complete, the database will be available to anyone for instant retrieval online. [*Ed. note: The validation project is now complete.*]

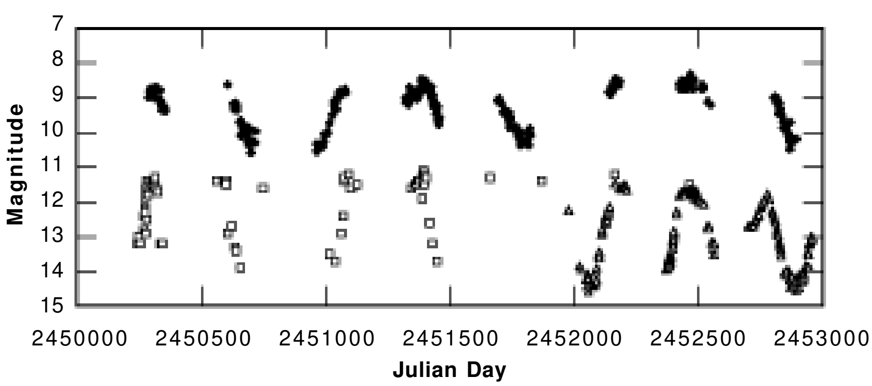

Figure 1. Observations of GX Aquilae developed from on-line resources demonstrates the potential of virtual observing. Diamond symbols represent Stardial data; squares, AAVSO data; and triangles, ASAS data.

Extracting and combining data from these three databases and others can result in a picture showing the behavior of a star over many years. The light curve of GX Aquilae shown in Figure 1 is an example.

Workshop participants learn astronomical data reduction techniques in extracting data, and statistical techniques in analysis and display of data. They are able to explore the behavior of known stars and describe and classify un-catalogued variable stars, conducting an original science research activity.

3. Online resources

Software for viewing and analyzing FITS-format images (FITSView, DS9, and IRIS) is available on the Web, as is software for advanced statistical analysis of light curves (AVE, ZAP, TS, and WWZ). The availability of the data and the tools to work with them make virtual astronomy a viable classroom project.

Workshop participants make extensive use of online databases and image servers to identify and validate their results. Chief among them are products of the Centre de Données Astronomiques de Strasbourg (CDS), the Set of Identifications, Measurements, and Bibliography for Astronomical Data (SIMBAD), the VizieR catalogue access tool, and the Aladin image and data viewer. SIMBAD is a database of 8,527, 819 cross-referenced identifiers of astronomical objects, providing accurate positions of known objects. VizieR provides access to nearly 4,000 catalogues of astronomical objects, searchable in many different ways. The most important to variable star hunters is searching by position; VizieR can query all its catalogues and provide information on objects located around a given Right Ascension and Declination. Important catalogues with VizieR used by researchers of long period variables are the Infrared Astronomical Satellite (IRAS) catalogues and the 2 Micron All-Sky Survey (2MASS). Aladin is an interactive online sky atlas allowing the user to visualize digitalized images of any part of the sky and superimpose entries from astronomical catalogs on the field. Aladin can access related data via SIMBAD, VizieR, and other archives for all known objects in the field. Aladin is particularly useful for multi-spectral cross-identifications of astronomical sources and checking new data sets by comparison with standard catalogues covering the same region of the sky.

The combination of all of these tools and techniques results in a true research experience for workshop participants and their students. They obtain their data, search for objects of interest in them, and then analyze the data to classify the star. They correlate their data with other information to determine some of the physical parameters for the star. The final product is as complete a picture of a specific star as can be determined, written in suitable presentation style. Data generated both by teacher participants, and by students later mentored by the teachers, are of publishable quality, with minimal help from the authors.

4. Evaluation and revision of materials

Five Teachers from Arizona participated in the initial summer evaluation of the manual created for the study of variable stars using internet databases. Technical problems that occurred most frequently involved the download of software, either because of inexperience with computer technology or regulations imposed on what can be placed on school-district owned computers.

In the introductory activities, teachers indicated that students would interact better with a picture of a tool button rather than a paragraph description in the instruction manual we created. They also suggested that an initial star-hopping activity be created to help students navigate in the image of the star field.

Teachers indicated several areas where students were likely to get frustrated or confused. An example was the need to add sample pictures that would not be suitable for photometry. Teachers felt that students needed concrete examples of what constituted an image unsuitable for photometry. A list of images for a given data set was also given so that the students could see the images that the investigator chose to keep for photometry.

Overall, the teachers felt that the detailed and revised manual was student-friendly, meaning that a student would be able to follow the instructions with little or no teacher input. This allows the teacher to simply help the student with any questions that might come up. This iteratively-revised manual now provides an excellent opportunity for students to do authentic, inquiry-based research.

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