Section 3: Initiatives in Astronomy Education

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Hands-On Astrophysics: Variable Stars for Astronomy Education and Development

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Abstract. Amateur astronomers, and students, can contribute to astronomical research by measuring the brightness of variable stars. *Hands-On Astrophysics* (HOA) is a project which uses the unique methods and the International Database of the American Association of Variable Star Observers (AAVSO) to develop and integrate a wide range of science, mathematical and computer skills, through the measurement and analysis of variable stars. It is very flexible and can be used at many levels, in many contexts — for classroom use from high school to university level, or for individual projects. In this paper we describe HOA, and how it can be used to promote international astronomy education and development, through research-based science education.

1. Introduction

In any part of the world, *practical (or laboratory) activities* can be an important part of science education at the school and university level, especially when they include a strong element of inquiry and discussion. Carefully-chosen *research projects* can also be used; they are almost obligatory at the graduate level, highly desirable at the undergraduate level, and quite possible at the senior high-school level — both because they contribute to effective learning of science processes and skills, and because they motivate students through the excitement of doing real science with real data. Research projects enable students to contribute to science; this is especially desirable in the developing countries, where the supply of trained research personnel is low.

All over the world, thousands of amateur astronomers and students are contributing to astronomical research by measuring the changing brightness of *variable stars*. The basic techniques are simple; the equipment required is inexpensive; and the demand for these measurements from the professional astronomical community has grown by a factor of 25 in the last three decades.

Variable stars are those which change in brightness. If measured sufficiently carefully, almost every star turns out to be variable. The variation may be due to geometrical processes, such as the eclipse of one star by a companion star,

or the rotation of a spotted star; or it may be due to physical processes such as pulsation, eruption, or explosion. Variable stars provide astronomers with important information about the properties, processes, nature, and evolution of the stars.

Many variable stars display changes in brightness that are large enough to be detected with the eye, using a small telescope, binoculars or (in the case of a few dozen bright variable stars) no optical aid at all. Amateur astronomers and students can make a useful contribution to astronomy by measuring these variable stars in a systematic way. The American Association of Variable Star Observers (AAVSO) was established in 1911. Its purpose is to co-ordinate variable-star observations made largely by dedicated "backyard" astronomers, evaluate the accuracy of these observations, compile, process, and publish them, and make them available to researchers and educators. The AAVSO now receives over 350,000 measurements a year, from 550 observers worldwide. The measurements are entered in the AAVSO electronic database, which contains close to 10 million measurements of several thousand stars. The demand for these measurements, from researchers and educators, has grown rapidly in the last three decades — partly as a result of major collaborations in space astronomy. To contact the AAVSO, write to: AAVSO, 25 Birch Street, Cambridge MA 02138, USA; e-mail: aavso@aavso.org; web site: **www.aavso.org**.

It occurred to us, several years ago, that the measurement and analysis of variable stars could help students to develop basic science and mathematics skills. Variable-star measurement and analysis is inherently simple; it can be done by any high-school or university student. The analysis and interpretation of the data involves a wide range of scientific and mathematical skills, some of which would be understood and appreciated by a beginning high-school student, and some of which would tax an expert in the field.

Both of us have a long-standing interest and involvement in variable stars and education. Together and with the help of many teachers (particularly Donna Young), the AAVSO Headquarters staff, and funds from the US National Science Foundation (NSF), we developed *Hands-On Astrophysics (HOA)*. It brings the excitement of astrophysical research and discovery to science, mathematics and computer classes through a flexible set of activities and projects on variable stars. It also helps to develop an understanding of basic astronomy concepts, to provide interdisciplinary connections, and to take students through the whole scientific process — while they have fun with real data!

HOA supports US National Standards for Science and Math Education — which are representative of standards in many other countries — by directly involving students in the scientific process. It uses 600,000 measurements of variable stars from the AAVSO International Database, and the techniques and materials that the AAVSO has developed and refined over nine decades. It includes an extensive teacher/student manual; computer software to analyze data and to create new data files; 45 star charts to make more observations; prints and slides for indoor activites; and a video-cassette with three short segments: the inspirational *Backyard Astronomy*, the informational *Variable Stars*, and the instructional *How to Observe Variable Stars*. It has an extensive website : **http://hoa.aavso.org** to provide ongoing support.

Students begin by using slides or prints of variable stars indoors, and by exploring the data through the software for graphing and analysis. They can then progress to making measurements of variable stars in the real sky or analyzing on-line archival data on variable stars. Some students may be able to access remote robotic telescopes to carry out their measuments. Students can take their own 35-mm slides of the night sky, for further indoor measurement or instruction. The *HOA* materials cover five northern constellations, but the *HOA* philosophy and process can be applied to other parts of the sky.

Students — especially those with a special interest in mathematics and computer science — can also enjoy variable star analysis indoors on the computer. *HOA* includes three PC software programs – a computer based tutorial HOAFUN, a data entry program HOAENTER, and a powerful data-analysis program VSTAR. VSTAR gives students a hands-on introduction to time series analysis — a technique which is now used in almost every branch of science, engineering and commerce.

There are many variable stars that are bright enough to be observed with small telescopes, or binoculars, or even with the unaided eye. Projects can involve assigning a star to each student, where they feel an "ownership" of the star and/or there can be a communal project where each student makes a few measurements of brightness each month or each several months. *HOA* can be especially successful when carried out by a group of students or amateur astronomers. The measurements can be combined for analysis and interpretation. These types of activities and projects develop and integrate a wide variety of skills, starting from background reading and planning; research judgement, strategy and problem solving; continuing with pattern recognition, interpolation and measurement; recognizing and understanding random and sytematic errors; computer programming and data management; processing and graphing of data; construction, analysis and interpretation of graphs; concepts of regularity and prediction; curve fitting and other statistical and numerical procedures; all the way to preparing oral and written reports.

HOA can be used in science, mathematics, and computer classes or for independent projects. It can be adapted to various levels, and can be used as a complete course of study or in parts. It can be used by any individual at any age to learn the art and science of variable-star astronomy. *HOA* materials are suitable for amateur astronomers who wish to learn more about the fascinating nature of variable stars. There is a wealth of information which can be utilized for science projects, for astronomy-club activities, and family learning. It is self-contained; no previous knowledge of astronomy, or variable stars is assumed. It is open-ended, and can lead to sophisticated research-based projects. It actively involves the students in the scientific process, and motivates them by enabling them to do real science with real data. Students can observe variable stars in the real sky, add their brightness measurements to the existing database in *HOA*, and analyze the data using the software provided. In addition, they can send their measurements to the AAVSO to be added to the International Database and to be used for further research projects by astronomers and educators worldwide.

2. Amateur Astronomers

An *amateur astronomer* is someone who loves astronomy, and cultivates it as a pastime or hobby. A more stringent definition might be that an amateur astronomer is someone who does astronomy with a high degree of skill, but not for pay (Williams 1988). Amateur astronomers make important contributions to astronomical research (Dunlop & Gerbaldi 1988) and education (Percy 1998a).

Given the fact that many science students in the astronomically-developing countries will go on to careers in engineering or business, amateur astronomy gives them a way to continue their interest in astronomy, and *HOA* gives them a way to continue to contribute to science. The Internet can also be a powerful tool for those who are "connected", since it provides access to large and sophisticated databases (such as the HIPPARCOS catalogue and epoch photometry –i.e. the individual photometric results contained in the catalogue) and instructions for analyzing and interpreting the data.

Astronomical research and education done by amateur astronomers is "democratic" in the sense that it enables anyone to do astronomy, whether they have formal credentials or institutional affiliations or not. It is "science for the citizens". That is certainly true of variable-star astronomy because, in the words of the song, "the stars belong to everyone".

3. Applications to Astronomically-Developing Countries

3.1. A Prelude to Research

Variable-star observing can be a prelude to more advanced astronomical activity. Wentzel (private communication, also 2001), for instance, has found *Hands-On Astrophysics* very useful in workshops with physics teachers in Vietnam, as part of the IAU's "Teaching for Astronomical Development" program. This is because students (and teachers) in many countries are not accustomed to working with real data — only with knowledge which appears in the textbook. Several developing countries have acquired (or are planning to acquire) small telescopes which will eventually be equipped with photoelectric photometers or CCD cameras. Is there a way to start doing real science, even before the telescope arrives and is operational? Yes! The solution is to begin doing serious visual measurements of variable stars, using binoculars or a very small telescope if one is available. The AAVSO, either through *Hands-On Astrophysics*, or by mail, by e-mail, or by its web site, can provide assistance in setting up an observing program. The measurements, so obtained, can then be contributed to the AAVSO International Database, to be used by researchers and educators (Mattei 1999).

The next step is photoelectric or CCD photometry with the newly-acquired telescope. These measurements are more precise than visual measurements, but the general principles of analysis are the same. The AAVSO has both a photoelectric program, and a CCD photometry program. Other international collaborative photometry programs are listed in Percy (1998b), who pointed out the value of beginning research as part of an international collaboration.

3.2. A Stepping Stone to other Databases

Databases from space astronomy missions are increasingly available on CD-ROM and/or the Internet, and they provide a practical way for astronomically-developing countries to begin research at very little cost — a PC with a CD-ROM drive and/or Internet connection. One example is the HIPPARCOS catalogue of astrometry and epoch photometry (Turon 1997, Perryman 1999). AAVSO observers provided crucial support for this mission (Turon 1997). In turn, the mission has provided dozens of new variables to be studied by photoelectric or CCD observers (Perryman 1999). It has also provided millions of photometric measurements of "unsolved" stars which require detailed analysis.

The HIPPARCOS mission has excellent research and education web pages (astro.estec.esa.nl/Hipparcos/hipparcos.html), with information on variable stars, interactive tutorials on variable star analysis, as well as data. Additional information on variable stars can be found on the AAVSO web site (**www.aavso.org**), along with user-friendly software for analyzing them (the TS11.ZIP program for time-series analysis, and the WWZ11.ZIP program for wavelet analysis), can be downloaded from **www.aavso.org/software.stm**. *Period98*, a powerful period-analysis package, can be downloaded from the web site **dsn.astro.univie.ac.at/period98** at the Institute of Astronomy, University of Vienna, along with an instruction manual.

For a continuation of this discussion, see the paper on "Simple Science, Quality Science", elsewhere in this volume (Percy 2001).

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Discussion

Melek enquired about the credit needed for this program. Mattei replied that it was designed either for one semester or two. Aguilar said that her experience was that research on variable stars, in particular observations of them, does help to stimulate interest in science and astronomy. She felt that this sort

of work with a small telescope provided the opportunity for people in developing countries to have access to scientific culture. Kozai asked for information on what was needed to participate in the project: what types of telescopes, photometers, star catalogues, etc. are necessary? The answer is that *Hands-On Astrophysics* includes star charts that can be used for visual observing with any available binoculars, small telescope, or the unaided eye. It also includes slides and prints for indoor activities, so it is not essential to observe the "real" sky in order to profit from the program.