THE EDUCATIONAL POTENTIAL OF THE HIPPARCOS DATA BASE

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ABSTRACT

Education is important to professional astronomy; astronomy is important to education. Since science education in schools and universities is most effective when students use *inquiry-based learning* with real scientific data and activities, the Hipparcos data base has significant educational potential. The astrometric data base can be used for activities and projects which illustrate important physical and astronomical concepts (as well as the role of random and systematic errors, selection effects etc.). The epoch photometric data base can also be used to develop and integrate a wide range of math and science skills, at the high school level and beyond. Many Hipparcos-based activities could be offered on-line, building on the success of the European Association for Astronomy Education's recent *Astronomy On-Line* project. There are, however, many schools and universities – especially in the developing countries – which do not have easy access to the Internet or to on-line data bases. I urge ESA to develop the educational potential of the Hipparcos data base, and to make it available, in appropriate form, to teachers and students worldwide.

Key words: developing countries; education.

1. INTRODUCTION

Education is important to astronomy, to attract and train the next generation of astronomers, and to increase the awareness, understanding, and appreciation of astronomy by the politicians and taxpayers who support us. Recall the comments of Professor Woltjer at the opening of this Symposium: he lamented the decreased funding of basic space science in Europe. Education and outreach would certainly help.

Astronomy is also important to education, above and beyond the needs of the astronomical profession. The practical and philosophical applications of astronomy have influenced history and culture. Astronomy has advanced mathematics and science in general, as well as being itself a dynamic science. Astronomy deals with our origins, and our place in time and space, and with our interactions with the extraterrestrial environment. It reveals a vast, varied, and beautiful universe, and harnesses curiosity, imagination, and a sense of shared exploration and discovery. In the classroom, it demonstrates the role of observation in the scientific method, and can be used to illustrate many concepts in physics, such as light, gravitation, and nuclear physics. It increases public interest in science, and attracts young people to study science, technology, and engineering. It is enjoyed as a hobby by millions of people around the world.

2. WHY ESA AND EUROPEAN ASTRONOMERS SHOULD BECOME INVOLVED IN ASTRONOMY EDUCATION

I am attending this Symposium as a variable star astronomer who is also very active in international astronomy education. I am President of the International Astronomical Union (IAU) Commission for the Teaching of Astronomy, whose purpose is 'to further the development and improvement of astronomy education at all levels, throughout the world'. I have a special interest in linking education and research, through student activities and projects using real data. One type of link between education and research is the contribution which skilled amateur astronomers make to astronomy – especially in the observation and analysis of variable stars. Amateur astronomers are 'lifelong learners' who learn astronomy by doing it. The contributions of amateur astronomers to the Hipparcos project are described elsewhere in this volume.

I believe that astronomers have an obligation to support education and outreach, both for their own benefit, and for the benefit of society. In the US, a 'science education initiative' has been developing since about 1980. Significant funding has been provided by agencies such as the National Science Foundation and the National Aeronautics and Space Administration (NASA). In a recent article, Rosendhal (1996) justified NASA's new interest in education by stating that 'it is a crucial element in (NASA) Office of Space Science's response to the need to make broader contributions to attaining the country's larger scientific and technical goals'. Scientists, their institutions, and the scientific community in general must acknowledge this responsibility to do more than their own scientific research in return for public funding. Scientists need to work in partnership with education professionals, and an infrastructure must be created which will facilitate such partnerships. Finally, ev-

Proceedings of the ESA Symposium 'Hipparcos - Venice '97', 13-16 May, Venice, Italy, ESA SP-402 (July 1997)

eryone must have realistic expectations, a long-term commitment, and patience (Rosendhal 1996). In this way, ESA, and European astronomers in general, will benefit from an 'education initiative', as will European education and culture.

But there is another consideration, with respect to Hipparcos and other space missions. Although there are significant differences between the European and the US systems of education (Wentzel 1990), educational research in many countries confirms that science teaching and learning are most effective when the *inquiry-based* or activity-based or 'hands-on' approach is used. The percentage of information retained by students ranges from 10 to 20 per cent in the standard lecture/textbook approach, through 30 to 50 per cent when using pictures, exhibits, and demonstrations, to 70 to 90 per cent when the students are actively involved in learning through discussions with each other, and through doing (or simulating) science activities. Hands-on approaches are especially effective when students can do real science, with real scientific data. This is most possible at the high school level and above. Students will experience special excitement and motivation when using data from a space mission such as Hipparcos.

For stellar astronomy, there may be an additional benefit. In North America (and probably elsewhere), stellar astronomy is not as popular with graduate students as extragalactic astronomy and cosmology. Perhaps, if undergraduate and graduate students could work with data from Hipparcos as part of their courses and programs, they would appreciate the importance, excitement, and challenge of stellar astronomy.

3. THE EDUCATIONAL POTENTIAL OF THE HIPPARCOS DATA BASE

The educational potential of the Hipparcos data base is broader than any one astronomer can imagine, but I will discuss only two aspects: the use of the astrometric data base to illustrate physical and astronomical concepts, and the use of the epoch photometry as an example of the special application of variable star observation and analysis in science and math education. A key aspect of these educational applications of the data base is the presence of random and systematic error, and selection effects – concepts which any user of the data base, and any young scientist, must understand.

3.1. Astrometric Projects

There are several topics, involving light, which are seldom taught (or taught well) in traditional high school and university physics courses: they include the inverse square law of brightness (the relation between absolute brightness, apparent brightness, and distance), the concepts of apparent size and motion, the (angular) units in which they are measured, and their relation to distance; and the measurement of distance by 'remote' techniques such as parallax, apparent size, motion, or brightness. All of these concepts could be well taught using practical activities and the Hipparcos data base. As an example of a practical activity: almost any student can demonstrate parallax by holding their finger at arm's length, and looking at it alternately with their right and left eye. The phenomenon of parallax is very obvious. If they then move their finger halfway to their nose, they will observe that the parallax increases. Other such activities are described by Percy (1995).

At the university level, there are several contexts in which the Hipparcos data base could be used. One is for practical activities in general astronomy courses – for non-science students and especially for science students. In the past, astronomers from Edinburgh UK have developed such activities, with some success (Brück & Tritton 1990). A second context is in the Practical Astronomy courses which are normally part of an Astronomy or Astronomy and Physics program at university. Here, the activities would be more extensive and open-ended. Finally, the data base could be used for research project courses, sometimes called 'undergraduate theses' (McNally 1990). Such courses normally occur in the last year of the BSc program though, at the University of Toronto, a 'research opportunity program' is available for students at the second-year level. I intend to use the Hipparcos data base extensively for such projects.

The data base could, of course, be used for MSc thesis work, especially at universities which do not have easy access to their own observational facilities. This is especially important in the astronomically developing countries.

3.2. Variable Star Projects

Variable star observation and analysis are especially well suited to science and math education, for several reasons. Students can develop and integrate a wide range of skills, including research planning and judgement, literature research, measurement (and random and systematic errors), data processing and analysis, statistics and curve fitting, concepts of periodicity and prediction, graphical analysis, and the preparation of written and oral reports. There are additional motivational factors: students can work on 'their own' star, and there is the possibility that their project could result in a publishable paper.

Projects can be adapted to a wide range of levels, from junior high school to graduate school. The American Association of Variable Star Observers (AAVSO) has developed a project *Hands-On Astrophysics* (directors Janet A. Mattei and John R. Percy) to use variable stars as a tool for science and math education in high school, and eventually introductory university (Mattei et al. 1996). It includes manuals, data and software, charts, slides, and instructional videos. Some of the software could be used to display and analyze Hipparcos/Tycho photometry; there is other existing software which could be used for this purpose; or new software could be developed. Certainly, manuals and activities appropriate to the Hipparcos/Tycho photometry should be developed.

At the university level, these activities and projects could become more sophisticated and open-ended. Various forms of period analysis, such as Fourier and autocorrelation techniques could be introduced. The significance of the results depends strongly on the signal/noise ratio of the data. Curve-fitting techniques such as Fourier decomposition could be applied to the light curves. Period changes could be investigated and interpreted.

There are a million stars in the Hipparcos/Tycho epoch photometry data base. Many of them are variable. Although other astronomers will squeeze some of the scientific results from this data base in the next few years, there will still be much to do. Many of the variable stars are non-periodic, and therefore appear in the 'unsolved' section of the Hipparcos variable star catalogue. Red giant, supergiant, Be, and RS CVn variables, for instance, are semi-regular or irregular. Students have the possibility of making new contributions to our understanding of these stars.

4. HOW SUCH EDUCATIONAL ACTIVITIES AND PROJECTS COULD BE DEVELOPED

Scientists and educators in the US have had extensive experience with the development of hands-on activities and projects, thanks to the funding which is available for this purpose. The key lessons which have been learned are: (i) the material should be developed by a *team* of scientists, curriculum experts, and teachers (i.e. potential users), (ii) the material should be extensively tested and evaluated before the final product is produced, and (iii) an effective means of producing, publicizing, and distributing the material must be in place. A key part of NASA's proposed 'ecosystem' for education and outreach is a system of 'brokers' who will facilitate the necessary processes and interactions. 'The process starts with the identification of an educational need, continues with the formation of a partnership between scientists and educators, and leads to the development of educational materials which are then catalogued and distributed by an archiver/disseminator to a wide variety of users' (NASA 1996). There is a new and active European Association for Astronomy Education (EAAE) which could play a key role in an analogous process in Europe. Among other things, the EAAE has organized *Astronomy On-Line*, a series of Internet-based activities linking scientists and schools across Europe (West & Madsen 1997). Since the Hipparcos data base will be available on-line, it could be a natural part of any future *Astronomy On-Line* program.

While it is not for me to determine how the development process might begin, one possibility would be for ESA and EAAE to convene a workshop of scientists and teachers to define the needs and opportunities, and the processes for addressing them. This could be done in individual countries, as well as in Europe as a whole. Since the Hipparcos data base is publicly available, the development could be done outside of Europe, but I hope that the European astronomy community will take pride in their data, and take the initiative themselves. I also hope that every future ESA mission has an education and outreach component built in.

5. THE NEEDS OF THE DEVELOPING COUNTRIES

While the activities and projects described above are suitable for schools and universities in Europe, North America, and other developed areas of the world, there are dozens of countries which are not yet astronomically developed, or in which the state of science and education are fragile. In most countries of the former Soviet Union, for instance, Internet access is difficult and/or prohibitively expensive. A CD-ROM data base which seems inexpensive to us, may be out of reach to them. We have a moral obligation to assist astronomers in such countries. They need understanding, opportunities to visit and work abroad, contacts with, and visits from other astronomers, access to appropriate books, journals, equipment, and data.

The International Astronomical Union (IAU) and other organizations have many programs for this purpose. The IAU has a Commission on the Teaching of Astronomy, many of whose programs are intended for astronomical development. The IAU also has a Working Group on the Worldwide Development of Astronomy. The UN and ESA have organized a series of annual Workshops on Basic Space Science, to integrate the developing countries into modern space science. The first five were held in: India (1991), Costa Rica, and Colombia (1992), Nigeria (1993), Egypt (1994), and Sri Lanka (1996). Another workshop is scheduled for Honduras in 1997 (on the topic of the use of small telescopes in basic space science and astronomy); another workshop is contemplated for Tunisia in 1998. The European astronomical community has been very helpful in supporting the development of astronomy in central America, and other areas, in the past. The Hipparcos data base would be an excellent tool for introducing basic space science. It gives astronomers and students, in these countries, one of the products of modern space astronomy, in a form which can be used at many levels. The data base is easy to produce: the cost of producing a few CD-ROM's is a few tens of dollars at most. One basic requirement would be a user-friendly 'tutorial' to introduce the inexperienced user (such as a student) to the data base. This might be accompanied by suitable software to display, explain, and manipulate the data. Another basic requirement, of course, is a computer.

I urge ESA to distribute free copies of the data base (including epoch photometry) to at least 20 to 30 institutions carefully selected by the IAU and the UN. These organizations, along with the host countries, would then be responsible for providing workshops and other instruction in the use of the data. Indeed, the IAU and COSPAR are considering a new program which would provide such workshops to young astronomers in the developing world.

6. CONCLUSIONS AND RECOMMENDATIONS

The Hipparcos data base – both astrometric and photometric – has significant potential for enhancing science education at the high school and university level. I urge ESA, the Hipparcos project team, and all other interested astronomers and educators to arrange for the development of this potential, in partnership with teachers and educational authorities, and to ensure the distribution of the materials developed. I also urge ESA to provide copies of the materials and the data base to key institutions in the developing world, selected in co-operation with the IAU and other organizations.

ACKNOWLEDGEMENTS

I thank the Natural Sciences and Engineering Research Council of Canada for research and travel support, and the organizers of this symposium for providing me with the opportunity to present this paper to those scientists who have been so deeply involved in the success of Hipparcos.

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