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# Pro-Am Collaboration and the AAVSO

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**Abstract.** Professionals need to be aware that there is a valuable resource available and waiting to be used - the amateur astronomy community. We give some examples of how pro-am collaborations have worked in the past, indicate the advantages and disadvantages of such collaborations, and suggest methods by which a professional can find and work effectively with amateur astronomers.

## 1. Introduction

There is a resource of which all professionals should be aware: the opportunity for professional-amateur (pro-am) collaboration. This can be as simple as working with a single, local amateur, or as complex as involving a large group on a project for a number of years.

There is a long history of pro-am interaction. In fact, the first professionals were hired by amateurs to maintain their observatories and help in observing and data reduction. An example of this is the Lowell Observatory (Flagstaff, Arizona), founded in 1894 by Percival Lowell, a rich Bostonian. He hired V. M. Slipher to maintain the observatory during those periods when Lowell was not in Flagstaff; Slipher of course used the 60cm Alvan Clark refractor plus a Brashear spectrograph to measure redshifts of galaxies.

It has only been in the past few decades that amateurs have stood in their own right. It is primarily due to the advent of cheap, high-quality instrumentation, plus the influx of technologically proficient observers. The traditional separation between the professional and the amateur is becoming blurred.

During the first half of the 20th century, most amateur observations were made visually, using small aperture telescopes. They concentrated on the long-period, high-amplitude variables, but lacking a strong connection to the professional community. The Space Age called many amateurs into duty to monitor artificial satellites during the Smithsonian Astrophysical Observatory's Moonwatch program. This program is described in Cornell (1975), and lasted for nearly 20 years with 400,000 observations of nearly 6,000 artificial satellites.

A major change after WWII was the release of the 1P21 photomultiplier tube. War surplus equipment plus a large base of militarily trained, electronically proficient, amateurs led to the development of highly precise photoelectic photometers. Wood (1963) wrote a book on photoelectric photometry (PEP) for amateurs, and PEP committees were formed in several of the larger amateur organizations. The photoelectric photometer gave amateurs the capability of making observations as precise as the professional, albeit on brighter objects.

In 1980, the International Amateur Professional Photoelectric Photometry (IAPPP) organization was founded by R. Genet and D. Hall. This was an active organization, promoting photoelectric astronomy and pro-am collaboration.

Several papers have been written about pro-am collaboration. Hearnshaw and Cottrell (1986) held an IAU colloquium on instrumentation and research programs for small telescopes. Henbest (1987) describes a joint meeting between the British Astronomical Association, an amateur group, and the Royal Astronomical Society, a professional organization, held in March of 1987. The summary indicated a desire on the part of professionals for closer collaboration on many projects, including monitoring Saturn for new cloud features, discovering comets, measuring the position of asteroids, and further photoelectric observations of just about everything. Percy et al. (1992) edited the proceedings of a meeting on International Cooperation and Coordination in Variable Star Research, attended by professionals and amateurs alike. Smith (1995) and others wrote papers for the Journal of the British Astronomical Association on the Centenary Meeting of the BAA variable star section, describing their experience in pro-am collaborations.. Millis (1996) organized a workshop at Lowell Observatory on the Role of Small Telescopes in Modern Astronomy, highlighting the critical role of small telescopes, often run by amateurs, in many areas of research. Percy and Wilson (2000) held a conference on amateur-professional partnerships in astronomy, highlighting many collaborative areas. The American Astronomical Society (AAS) recognized the importance of pro-am projects through the formation of the Working Group on Professional-Amateur Collaboration, a standing committee in the AAS with its own web site. Finally, Price (2005) discusses new areas of potential pro-am collaboration such as datamining.

Pro-am collaboration crosses the entire face of astronomy, from sunspots to gamma-ray afterglows. Talk to anyone working in astronomy and often an early interest in amateur astronomy will be found. To discuss this pro-am resource in the the specific context of variable-star research, the American Association of Variable Star Observers (AAVSO) will be used as an example.

## 2. The American Association of Variable Star Observers (AAVSO)

The AAVSO was established in 1911 by William Tyler Olcott, an avid amateur in the Boston area. The initial organization was closely associated with the Harvard College Observatory (HCO). In fact, the inital steps towards incorporation were taken at the request of E. C. Pickering, the Director of the HCO, who offered space and technical guidance. The first formal meeting of the AAVSO took place in 1917 and is shown in Fig. 1.

The AAVSO was originally affiliated with HCO, having an office on the Observatory grounds. Around 1954, it split off and became a private non-profit scientific organization. In 1986, the AAVSO purchased its current headquarters building in Cambridge, MA (Fig. 2), about 2km from the HCO. The AAVSO employs a permanent staff of 10, with several additional part-time and contract employees. The majority of the funding is through a private endowment, but the AAVSO does aggressively pursue funding via external research and education grants.

Figure 1. AAVSO Meeting, Harvard 1917

Figure 2. AAVSO Birch Street Headquarters building

The AAVSO is dedicated to the study of celestial objects that vary in optical brightness. They focus efforts in three directions: education, motivating and mediating professional-amateur astronomical collaborations, and data archiving. Variable-star astronomy is used to teach universal science concepts and get children and the public addicted to science. The AAVSO works to bring together amateur observers with professional astronomers who need data and need research assistance, allowing greater science to be done at a lower cost by more people. It also provides a single location where data from thousands of observers and observatories can be stored and searched, creating a virtual data clearing house for scientists the world over.

The AAVSO is one of the largest pro-am astronomy organizations in the world. It has 1200 members in 40 countries; about 20% are professionals. Another 2000 non-member observers and groups in 60 countries submit observations annually. Approximately 900,000 observations are archived annually, with a total International Database of 13 million observations, some dating back over 150 years. It maintains a permanent website at http://www.aavso.org where observations, charts, sequences, tutorials and other materials can be accessed.

The AAVSO is not the only amateur organization, though it is the largest such organization devoted to the study of variable stars. Others include: the Variable Star Observers League in Japan (VSOLJ; it grew from the Oriental Astronomical Association, founded 1920), the Association Francaise de Observateurs d'Etoiles Variables (AFOEV; founded 1921), and the Bundesdeutsche Arbeitsgemeinshaft für Veränderliche Sterne (BAV; founded 1950); and the variable star sections of many large amateur organizations such as the British Astronomical Association (BAA; founded 1890) and the Royal Astronomical Society of New Zealand (RASNZ; founded 1920). More information on any of these organizations can be found on the Web.

There are possible reasons to prefer working with a variable-star organization other than the AAVSO. Having amateurs physically nearby means that personal mentoring is possible, as well as visits to meetings to present research projects. Local amateurs will often become frequent collaborators. Nearby clubs will also speak a common native language, useful for communication. While English is becoming the de facto scientific language, not all amateurs can communicate effectively in it. Local clubs and affiliates of larger national organizations are also good sources of new observers, as most amateurs tend to join an astronomical organization as a stepping stone to more advanced observing.

## 3. Telescopes

One common assumption is that all amateur telescopes are small and not useful for scientific projects. While it is true that most amateurs do not have a 4m-class telescope in their backyards, many of the observatories are the equal of university facilities. Fig. 3a shows the 80cm telescope of M. Motta in Massachusetts; there are many amateurs with this class telescope. Even more common are amateurs associated with planetariums and public observatories. Fig. 3b shows the 90cm telescope of Georges Observatory, Ft. Bend, Texas; a facility that is used for public viewing on a few nights per year, but available to club members the rest of the time. The Faulkes 2m telescopes are also available to educational institutions; the educators are often associated with amateurs or are amateurs themselves.

Even if $0.3 - 0.5$m telescopes are considered, with modern CCDs these telescopes are fully capable of providing time-series photometry at moderately faint magnitudes. For spectroscopic support, these mesh well with 4m-class telescopes. The quality of modern telescopes is quite amazing, with small periodic error and mount hysteresis. With built-in autoguiding, long exposures and accu-

Figure 3. *Left:* Motta Observatory. *Right:* Georges Observatory.

rately registered long time series are possible. Field misidentification is a thing of the past. Most modern telescopes are GOTO, meaning a flexure map is in place and giving the telescope computer coordinates will position the telescope to within an arcmin or so. Software is available to fully automate a telescope plus camera system. There are far more fully robotic amateur systems today than exist in the professional world.

At the same time, many professional surveys are using smaller telescopes, such as the 10cm telescopes used by the TrES project (Alonso et al. 2004). For these systems, the amateur telescope may be the larger, followup observatory. This is another example of how the line between professional and amateur has been nearly erased.

## 4. Visual Observations

It is certainly true that visual observations formed the early history of amateur variable-star astronomy. Fig. 4a is of A. Jones, a prolific observer from New Zealand, who designed and built his 32cm reflector nearly 60 years ago. He has made an estimated half-million observations over his career. Fig. 4b is of G. Hanson, an Arizona amateur, who with his 45cm Dobsonian telescope has made over 50,000 observations. This is the traditional appearance of a visual amateur, much as the public's perception of a professional astronomer is like the photographs of Percival Lowell at the eyepiece of his 60cm Alvan Clark refractor.

For visual observers, the major change has been the availability of inexpensive, high quality telescopes. Hanson's Dobsonian is a large-aperture, easily positioned telescope that permits him to make more than a hundred estimates on any given night. Vendors such as Meade and Celestron are making Schmidt-Cassegrain telescopes with GOTO features for rapid acquisition of new fields. An ancillary change has been the creation of better finding charts, providing improved photometry for the comparison-star sequence. Better sequences enable the observer to reach his/her potential of about 0.1-0.2mag error per estimate.

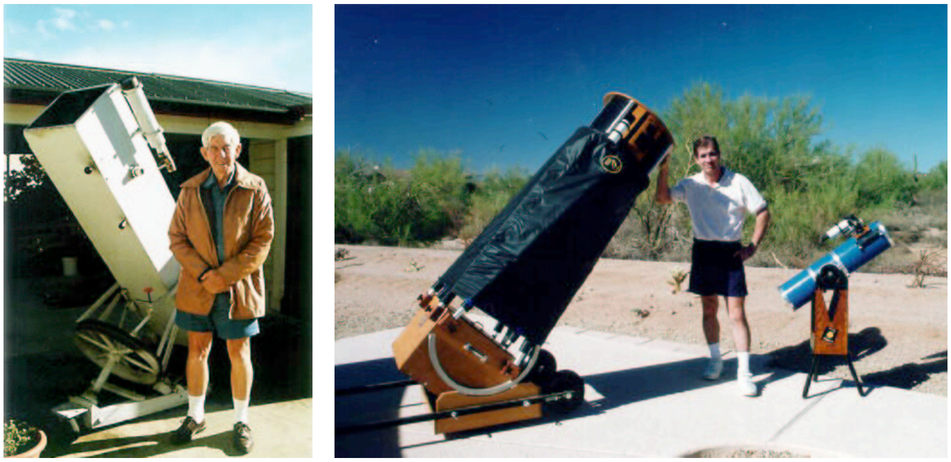

Figure 4. *Left:* Albert Jones. *Right:* Gene Hanson.

The advantage of visual observing is that, because minimal equipment is involved, the process has been ongoing for over a century. A typical light curve for Mira, the prototype long period variable, is shown in Fig. 5. This covers the period 1850 through 2000, showing the changing aspect of the light curve. Note that there are gaps in the data before about 1890; the AAVSO is searching for early datasets that have not been added to our database. Many early observers kept their data in personal logbooks, and often never submitting them to any formal organization. An example of this are the 250,000 observations taken during the early 20th century by A. W. Roberts, an observer in South Africa, that we have recently been able to find, digitize and add to our database.

The long monitoring data on many of the brighter variables, especially long-period variables, has been invaluable for many secular evolutionary studies. Wood and Zarro (1981) studied 3 Miras and compared the observed period changes with theoretical models. Templeton et al. (2005) used the hundreds of Mira variables in the AAVSO database to search for period changes. Bedding et al. (2002) studied the semiregular variable $L_2$ Puppis, showing that it has had a decade-long dimming event from dust. These are all studies that would be impossible without the long observational record from the visual observers.

Professionals also often complain about the precision of visual observers. True, each individual observation has an imprecision of 0.1-0.2mag for the better observers, but as long as the errors are random, averaging multiple observations can dramatically improve the light curve. Two examples of this are shown here. Fig. 6 shows the cepheid variable X Cyg, where the data from one visual observer, but from multiple pulsational cycles, is period-phased and phase-interval averaging is used. This visual curve is shown underneath the curve generated from published photoelectric data. Note that small bumps with height less than 0.1mag are readily apparent in both curves. This kind of averaging works well for stars that faithfully repeat their light variation from cycle to cycle.

For transient or non-repeating objects, the peculiar novae V838 Mon is given as an example. Fig. 7 shows the visual light curve for the variable using one-day means of the individual measures. There is a small zeropoint shift between the

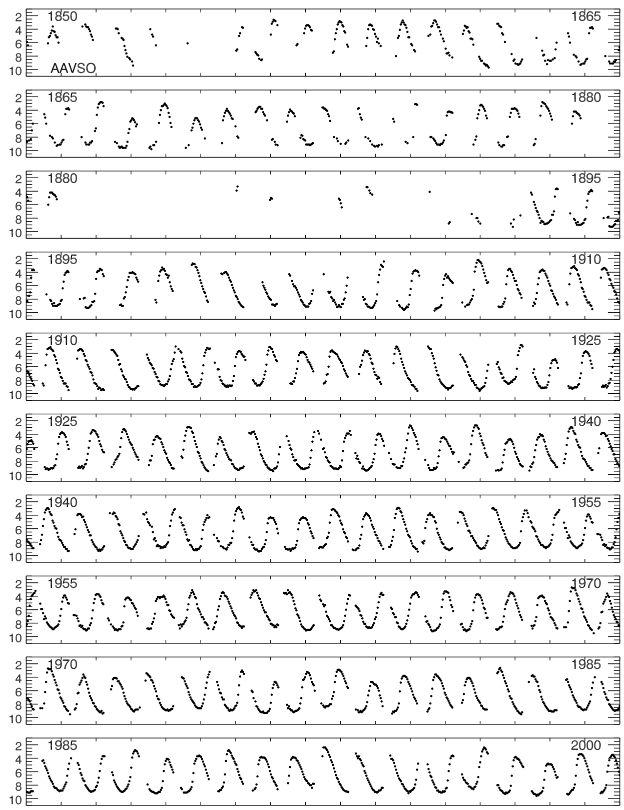


Figure 5. Light curve of Mira.

photoelectric and the visual data, due to the extreme red color of this nova. Such light-curve improvement is only possible when the object is well-observed, and data from many visual observers is combined.

Another modern use for visual data is for determining the start of an outburst for triggering Target of Opportunity observations at large ground-based telescopes and space-based missions. Fig. 8 is from Wheatley et al. (2003), showing a comparison between the AAVSO visual data and the simultaneous EUVE and RXTE satellite data for an outburst of the cataclysmic variable SS Cyg. The visual observers monitored the CV, and triggered the satellite observations when the start of an outburst was detected. The simultaneous observations show that the optical outburst preceded the EUV outburst by 0.6day and the X-ray outburst by 0.9-1.4day. The subsequent rise/fall pattern supports the view that both hot components arise in the boundary layer between the accretion disc and the white dwarf surface. The opposite case can also be of importance. A recent HST program on recently discovered CVs by Szkody et al. (2005) required that the CVs had to be in quiescence for instrument safety. Amateur monitoring confirmed the quiescent behavior in the hours prior to the HST observation.

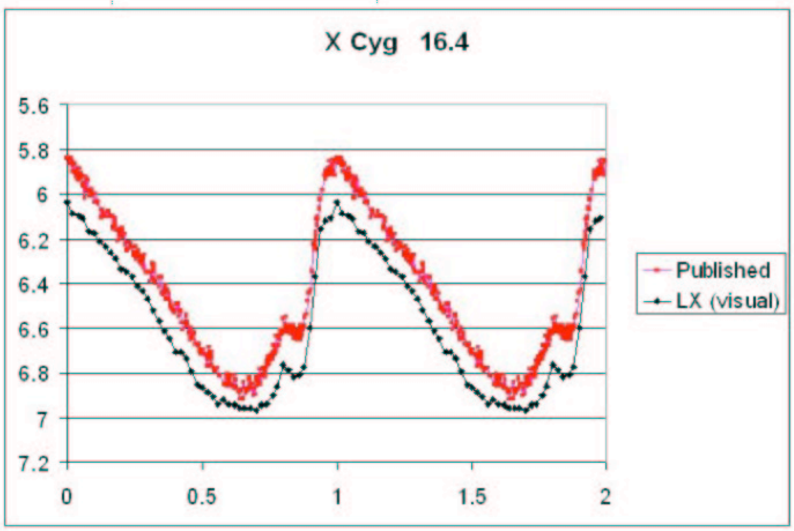


Figure 6. Light curve of X Cyg.

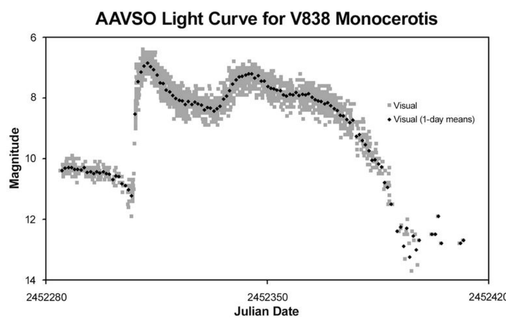


Figure 7. Visual light curve of V838 Mon.

## 5. Photographic Progress

While amateurs have always been interested in astronomical photography, little photometric work using photographic plates or film has been done by amateurs. The photographic process is inherently non-linear, making photometry difficult. Usually the results are not much better than visual techniques, though adequate for discovering and measuring high-amplitude variables. See Kaiser (1995) for a typical program. However, with modern 35mm cameras, imaging large areas of the sky looking for transient objects is still viable. Several novae surveys are underway in Japan and Chile using photographic techniques. An example is the survey by Liller (1999). The larger use of photography is actually archival searches of professional surveys, as described later.

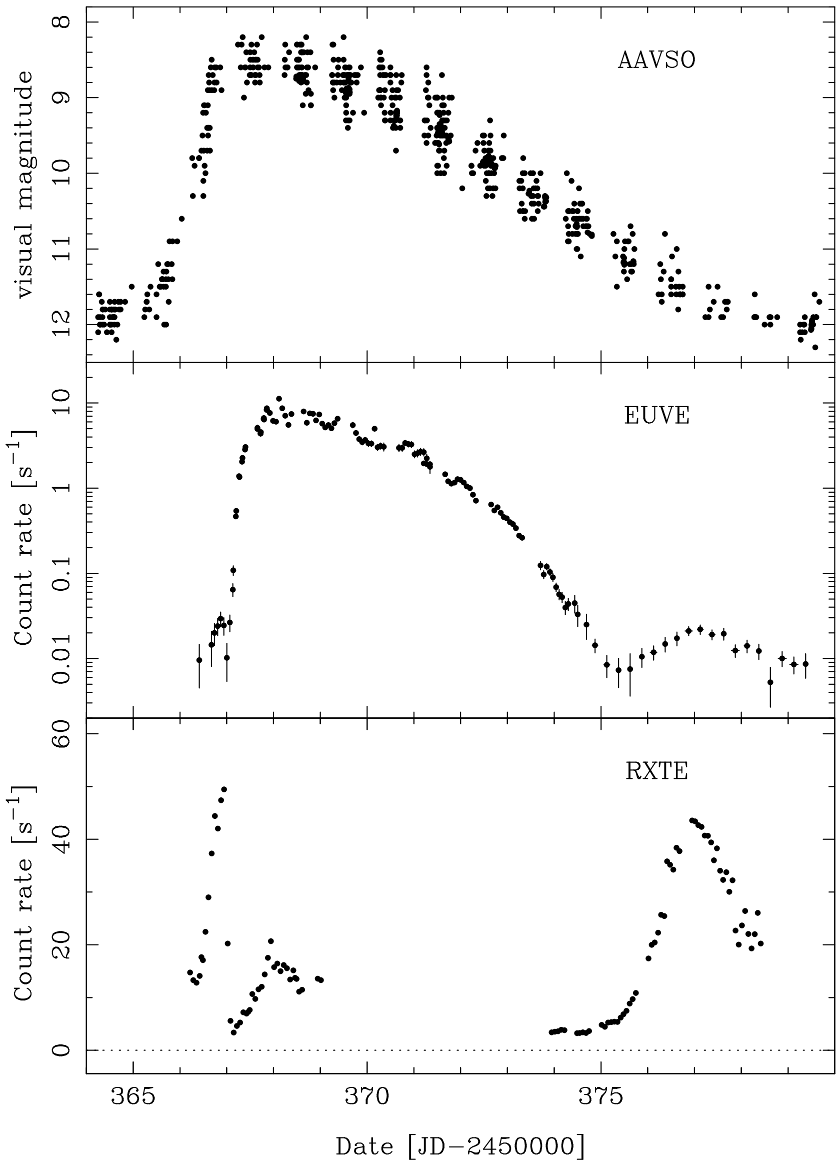


Figure 8. SS Cyg multiwavelength comparison. From Wheatley et al. (2003)

## 6. Modern Photometric Equipment

Not all amateurs are visual observers. Over half of those currently joining the AAVSO have some sort of CCD camera or electronic instrumentation. This fraction will only increase in the years ahead.

While some amateurs built their own single-channel photoelectric photometer after WWII, others purchased instruments available commercially in the 1970's and 1980's. In particular, the development of the solid state photometer such as the Optec SSP-3 brought many amateurs into the PEP fold. This was a simple, small instrument suitable for the back-end weight capacity of amateur telescopes, and required little instruction to make work effectively. It covered the entire silicon spectral response, with the two drawbacks that it was a manual instrument (viewing eyepiece, flip mirror, non-motorized filter slide) and that it was only effective on relatively bright stars. Still, there were hundreds of members in the IAPPP in its heyday, contributing valuable multifilter photometry to many scientific projects.

The real change occurred in the 1990's, when CCD technology advanced to the point that inexpensive cameras could be constructed. Berry et al. (1994) created the Cookbook CCD camera that was eventually used by over 2500 amateurs. Commercial cameras were available from Spectrosource, and eventually others such as Santa Barbara Instrument Group (SBIG) and Starlight Xpress. Once there was a sufficient market, sophisticated camera control and image processing software became available as well. The commercial market changes rapidly, so new CCDs from chip vendors are incorporated quickly, along with hardware improvements such as USB image download. In fact, many amateur cameras are more capable today than their professional counterparts.

The low-end market is developing even faster. The Meade DSI-Pro CCD camera is currently available on the commercial market for about USD$400. Other cameras have been announced in the under USD$1000 market, and they all show definite potential in providing accurate magnitude estimates. These lower-cost cameras are opening up the field to smaller telescopes and those in third world countries, often in an underrepresented geographical location.

Other innovations in the commercial market have been the tip/tilt low-order adaptive optics modules, spectrographs of varying resolution, and autoguiders. The SBIG spectrographs in particular are being used by many amateurs, obtaining spectra of the brighter stars and novae that are excellent. There are several groups building spectrographs as a team effort. Spectroscopy is not relegated to low resolution; some groups (such as Spectrashift) are working with bench-mounted spectrographs and obtainng 100m/s doppler measurements of exoplanetary systems. A book by Tonkin (2002) on amateur spectroscopy is available.

## 7. Archival Research

As mentioned earlier, amateurs can visit existing plate archives and examine old photographic plates, looking for times of minima, outbursting behavior or progenitors of unusual objects. An example of how such plate archives are used is given in Turner (2003). There are several large plate archives in existence. Perhaps the best known is the Harvard Plate Collection, currently maintained by A. Doane. This archive contains about a half-million plates taken in the early 20th century.

Plate archives seldom exist in the city where a professional lives who is working on a research project. Glass plates are rarely shipped anywhere due to their fragile nature. However, there are almost always amateurs near the archive, and in addition, amateurs that both know how to use the archive and that have permission to do so. Others are willing to travel to the appropriate city. This is especially true for the Harvard collection, since the AAVSO Fall meeting is always held near Harvard and amateur researchers often add a day or two to their travels to search the stacks.

Archival plate searches are often the only method by which progenitor activity can be studied for peculiar objects. Goranskij et al. (2004) inspected the archival plates at Sonneberg Obervatory and the Sternberg Astronomical Insitute for V838 Mon, finding that the B-type companion star seen in recent spectra dominated the precursor light for this unusual nova.

The professional community has seen the scientific value of the archival plates, and is taking steps to digitize entire collections. The United States Naval Observatory (USNO), for example, digitized most of the known large Schmidt telescope plates, such as those taken for the Palomar Observatory Sky Survey, and has made the digitized images available on the Web. A program is under way at Harvard to digitize their plates, but it will take a number of years to complete any such project. Until then, visiting the plate archives will be the only method of performing archival plate research.

There are other archival research methods. Datamining is an accepted practice today, now that so many catalogs and observations appear on the World Wide Web. There are many talented amateurs with excellent computer skills than can be utilized to find information. A datamining example is the paper by Otero (2004), showing how accessed data from the All Sky Automated Survey (ASAS, Pojmanski 2002) can be used to provide new elements for eclipsing binaries.

A final type of archival research is the use of the AAVSO database for studying long-term behavior of stars as mentioned earlier. A subset of this is when a professional has made a single-epoch observation of a variable, such as a spectra or infrared magnitude measurement. They often request a light curve of a variable covering the observational window to see where in the light curve cycle of the star the observation was made. The archival observations can also be used to predict future maxima or minima for scheduling observations.

## 8. Campaigns

Professional observers often find adequate coverage of a particular event is very hard to accomplish. For example, if HST is to obtain a 3-orbit exposure on a given date of a specific object, that date is often not known far in advance. Scheduling may be performed on a weekly basis, and the observer not told of the exact date and time until close to the actual observation. Finding time at a large ground-based observatory with little lead time is extremely difficult.

There are several ways in which ground-based support on a campaign can be accomplished. If the professional has at their disposal a locally-owned telescope, they can often do their own scheduling and insert an observation. Use of a national facility is harder, as a project may be granted time, but coordination is very difficult without disrupting the program of another observer. One can use a queue-scheduled robotic telescope such as the Faulkes Telescope or the Liverpool Telescope, but there are few of these available today and an agreement may not be in place. Finally, collaborators at other facilities may be able to obtain time on their telescopes.

Whether any of the above methods will work depends on many factors, not the least of which are when the space-based observation is to take place, what is the geographical location of the ground-based observatory, the instrument mounted on the available telescope, and the weather conditions. A long ground-based campaign can be even worse, in attempting to coordinate the times and efforts of many observatories to obtain nearly complete temporal coverage. Such techniques have been used with loose collaborations of professional sites, as with the Whole Earth Telescope (WET; Nather et al., 1990) and the Whole Earth Blazar Telescope (WEBT; Villata et al. 2002).

However, not all campaigns necessarily require large aperture telescopes. For a recent campaign on AE Aqr requested by Mauche (2005), for example, ground-based photometry was desired in support of an extreme multiwavelength campaign. AE Aqr is usually around visual magnitude 11.3, so is easy to reach with almost any amateur telescope. Flaring activity is possible with this highly magnetic cataclysmic variable, so careful ground-based monitoring was necessary to connect any activity seen in X-ray or gamma-ray regimes with those seen at radio wavelengths with the VLA. Because of the large number of amateurs available, 24-hour coverage over several days is easily possible for such campaigns, even taking into account geographical location and weather conditions.

Other campaigns require specific instrumentation or photometric passbands. Some professional observatories, for example, use infrared instruments during bright time and cannot do optical imaging on those nights.

Some professionals have formed their own campaign teams of amateurs, for specific programs. An example is the Center for Backyard Astrophysics (CBA), run by J. Patterson of Columbia University. It is a team of several dozen amateurs and small-college professors that monitor cataclysmic variables, obtaining detailed time-series coverage when important systems go into outburst.

One of the large advantages of working with an organization such as the AAVSO is that they can act as facilitators for campaigns. The professional presents a proposal to the AAVSO. The AAVSO advertises the campaign to their membership, usually including information on how to take observations to make them most useful to the requesting professional. As the data are uploaded to the AAVSO database, they are passed on to the professional. This is much like having a personal robotic telescope, without the maintenance and processing headaches!

## 9. Outside Expertise

Not all pro-am collaborations deal with observing. The usual definition of an amateur is one who does an activity for the love of it and is not paid, earning his/her living in some other field. This means that amateurs come from all walks of life, from social workers to CEOs of major corporations. Often there will be an amateur that has a particular expertise that is of value for a project. An example is someone who works full-time as a software database expert. If that person has an interest in astronomy, they obviously can be of great use in designing a new database to hold the results of a major campaign. Another amateur may be an electronics engineer, a statistician, a professional writer or an optician. Others may, in fact, be retired professional astronomers. All of these amateurs can be utilized if they can be identified. That is one of the values of a large organization such as the AAVSO - acting as a matchmaker since occupation information is often part of a membership application, or is known internally.

## 10. Data Quality

The AAVSO works diligently to improve the photometric quality of the observations submitted to its database. The new charts and sequences that are being produced eliminate that potential source of error, so that only the observer's estimation error remains. Workshops to demonstrate better techniques of visual observing have been held, with all lectures videotaped and in process of editing and incorporation into instructional DVDs. Workshops on CCD observing, along with manuals, have been given and produced. Email lists are available for observers to ask questions, with experts on call to give support. In other words, one of the roles of a formal amateur organization is training, improving the skills of the observers.

However, there are many amateurs now that have sufficient expertise to rival most professionals. One distinct advantage amateurs have is that they know their equipment very well, and have optimized their observing strategies to account for equipment features and sky conditions. An example of the quality of existing observations is from T. Vanmunster, whose twin 35cm telescopes are shown in Fig. 9 While Vanmunster concentrates on cataclysmic variables, he has also been active in the study of exoplanet transits. One of his light curves for the variable TrES-1 is shown in Fig. 10 This light curve has less than 5mmag error, showing the 20mmag transit clearly.

Figure 9. T. Vanmunster and Observatory.

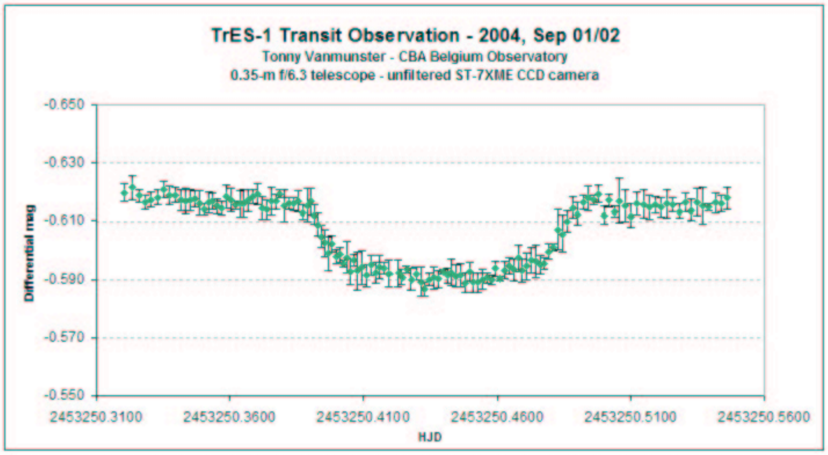


Figure 10. TrES-1 transit as observed by Vanmunster.

## 11. Summary

There are numerous advantages to working with amateurs in a pro-am collaboration. The distinction between professional and amateur has blurred, so that everyone should be treated as a valued collaborator and given equal footing. Amateurs are enthusiastic and have the sheer numbers to provide geographic and temporal coverage for many events. They tend to be competent, understanding their equipment better than most professionals visiting national facilities. They often have other useful skills such as database management. Many granting agencies require Broader Impact sections in proposals, showing how research will benefit the rest of the community. Including amateurs on your proposals often helps in satisfying this requirement.

At the same time, working with amateurs is not the same as working with professional colleagues. Not all amateurs are equally experienced, so training may be required. While some amateurs may live on isolated mountaintops, others are in severely polluted urban environments; the level of equipment and sites will vary greatly. Projects may need to be tailored to suit the abilities of the observers.

Communication is essential. Amateurs are curious and want to have the science behind the project explained in simple terms if possible. They want to see results and to see that their observations are not disappearing into a "black hole." Try to explain what you want from the amateurs. Their only rewards are appreciative comments from the professional, plus acknowledgements and inclusion as coauthors on papers.

Remember that amateur astronomers are not externally funded. Whenever possible, include upgrades to their equipment as part of your proposal.

Training, and finding amateurs for projects, are exactly what facilitators like the AAVSO are there to perform. Use their advice and work with them to create campaigns that utilize the amateur resource properly. Pro-am collaborations will further almost anyone's scientific goals, and can be a rewarding experience.

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