A Scientific Network of Small Telescopes

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Abstract

A network of small telescopes has been developed by the AAVSO. Used by amateurs and professionals alike, it provides access to quality photometric equipment and pristine sites for long-term monitoring and target-of-opportunity imaging. The system is described, along with presenting its unique features.

Introduction

The American Association of Variable Star Observers (AAVSO) has been in existence for 100 years. Its origins trace back to the last great survey era, when Harvard College Observatory was surveying the sky using photographic techniques. They were finding many "transient" objects, and needed amateur support for monitoring and follow-up. This was a similar era to what we are starting to encounter a century later with the upcoming LSST type surveys and modern amateur instrumentation.

Over the years, the AAVSO has expanded its role, and now provides training and mentoring of observers, collaborates with professional astronomers on joint campaigns to follow objects of interest (for example, ground-based photometry in support of a space-based project), archival and dissemination of variable-star photometry, and creating of observing software and tools of use to both the professional and amateur communities. In fact, many professionals are members of the AAVSO, as the organization is for anyone interested in variable-star astronomy. Our International Database currently holds 20 million variable-star estimates, obtained from thousands of worldwide observers.

Throughout its existence, the AAVSO headquarters and staff have played a passive role. That is, we've collected and given public access to observations made by others, but we've never corporately owned telescopes and the staff have not applied to national facilities to obtain our own observations in support of some campaign. That changed in 2005, when John Gross, Dirk Terrell and Walt Cooney asked if the AAVSO would be interested in joining their partnership that was running Sonoita Research Observatory (SRO; http://www.sonoitaresearchobservatory.org). This was a fully automated Celestron 14 (35cm) telescope on a Paramount ME, located in southern Arizona, as shown in Figure 1.

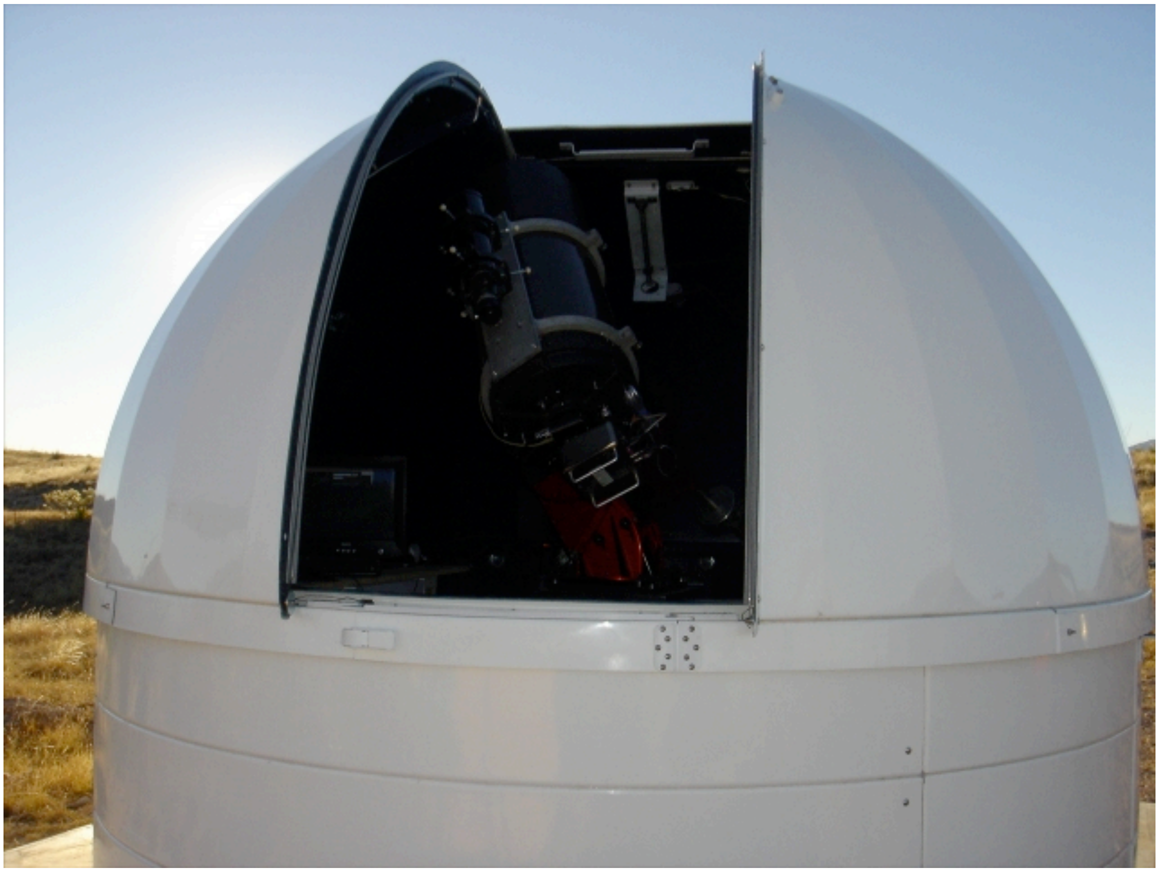

Figure 1. The original Sonoita Research Observatory dome in southern Arizona.

The AAVSO participated in SRO, acquiring hundreds of nights of all-sky calibration of variable-star fields, monitoring of important variables, and performing time-series photometry of campaign targets. We found this completely commercial-product system to perform admirably. We recently acquired the 1,000,000th image from SRO, all obtained through queue-scheduled observing.

This SRO telescope access was primarily for staff research and AAVSO projects. We had a sufficient backlog that we could initially make use of our entire allotted fraction of the time. However, after a couple of years, gaps were available in the program, and we offered telescope time to our membership. The primary requirements for use of SRO were that a formal proposal had to be written; the observations were made available 24-48hrs after their acquisition; and the proposer had to analyze the observations and publish the results within a reasonable length of time.

In 2008, however, Paul Wright, an AAVSO member in Minnesota, passed away. He left the AAVSO his two robotic telescopes that were located at Astrokolkhoz Observatory (AO; Cloudcroft, NM). We also formed a collaboration with Mt. John University Observatory (New Zealand) to refurbish their 61cm Optical Craftsman telescope. These new facilities formed the backbone of AAVSOnet, a new network of small, automated telescopes designed for variable-star photometry.

We don't have a large staff, and had no desire to support a wide variety of robotic telescope architectures. At the same time, we had zero funding for any kind of a network, and so could not go out and purchase a dozen identical telescopes. We therefore took an alternative approach: we used dissimilar hardware, but common software, for building the network. As new telescopes were acquired, or owners offered use of their existing systems to the AAVSO, we made sure that each used MaximDL for camera control, ACP/ACP scheduler for automation and scheduling, and the same ancillary scripts and file storage procedures.

AAVSO Network Goals

The goals of the AAVSO network (AAVSOnet) are:

1. Staff research and training. We have PhD scientists on staff, and the network enables their own research if it can be accomplished on small-aperture telescopes. For those staff members without a strong scientific background, performing the duty of a telescope advocate gives them a feel for how CCD observations are performed and lets them interact with the membership.
2. Membership access. We provide free access to the network for all members of the AAVSO, with the limitation that the member has to submit a formal request for telescope time that is then reviewed by a Telescope Allocation Committee. No "pretty pictures" are allowed, and the emphasis is on variable-star observing. Membership is extremely inexpensive considering this major benefit. AAVSOnet also gives members the opportunity to use high-end equipment (that is often beyond the financial means of the member) and usually located at a pristine site. For those without local CCD systems, it gives them the opportunity to learn about CCD observing without having to purchase a system first. We will also entertain proposals from non-AAVSO researchers for specific projects.
3. Long-term monitoring. The AAVSO has been around for 100 years, and our projects are often years or decades in duration. AAVSOnet is ideal for long-term monitoring of specific targets; ACP scheduler does beautifully on scheduling single observations per night of a target for as long as desired. We have stars that have been in the Sonoita queue for 6 years with no end in sight for their monitoring. Figure 2 shows a typical long-term light curve from SRO.
4. Rapid access to telescopes for targets of opportunity. Our queues are flexible, and if a new nova or transient object occurs, we can quickly add them with high priority. We also have full VOEvent capability, and have used the Sonoita telescope to acquire GRB afterglow observations within minutes of an alert.
5. No customized software. This is a strange goal, but very useful. We purposely have avoided writing our own software, other than a few control scripts. While some aspects of the system might be more efficient with

custom software, this avoidance criteria means that all software is maintained by the vendors and not by AAVSO staff.

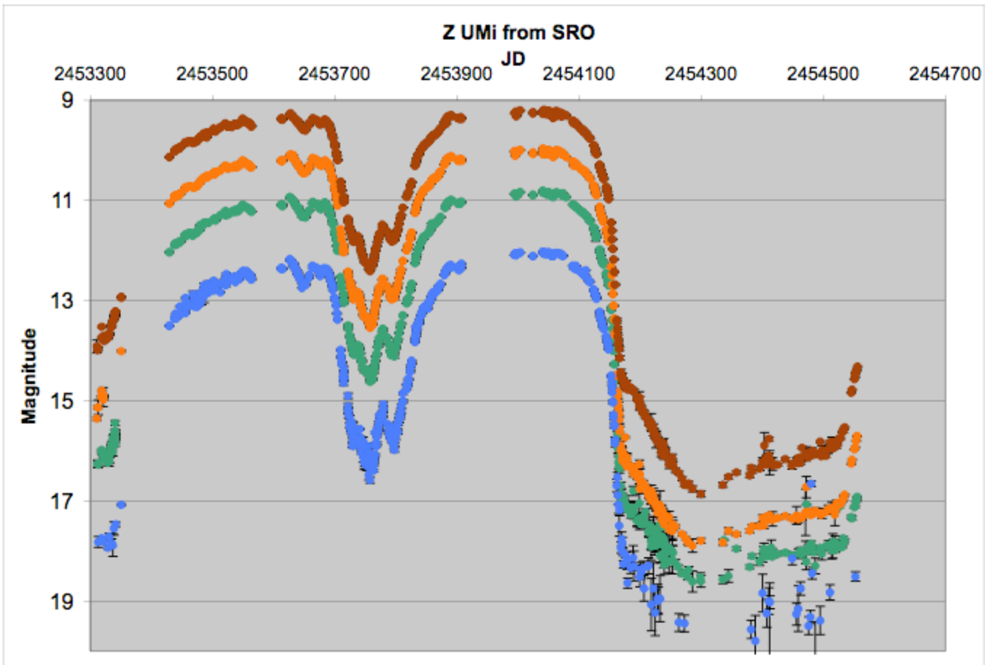

Figure 2. Three-year multi-filter light curve of an RCrB star from SRO.

Currently there are 8 active telescopes in the network; by the end of 2011, a total of 19 telescopes will be available. They range from 60mm astrographs for wide-field bright star photometry to 80cm telescopes used for both photometry and spectroscopy. Most of the systems are located in the United States, but telescopes are also sited in Chile, Argentina, Australia, and Israel, as shown in Figure 3.

Figure 3. Current and in-progress AAVSOnet sites (credit: Google).

AAVSOnet Unique Features

What sets AAVSOnet apart from other networks presented at this meeting?

1. The system is almost entirely volunteer run. Each site has a site manager who is typically an amateur astronomer who is offering space at his/her site for a robotic telescope. The site managers maintain the equipment, perform normal operational tasks like setting systems up for flatfielding, watching the weather, etc. The telescope advocates (those people who inspect images at the end of the night, pass on maintenance issues to the site managers, and interface with the researchers; very similar to normal Instrument Scientists) are currently AAVSO staff members, but we will be using volunteers for this effort very shortly.
2. Most of the funding is private, from bequests or individual donors. Most of the remaining equipment and software is donated by vendors.
3. We only accept proposals for scientific programs. We do not offer interactive control of the telescopes; everything is queue-scheduled and images are made available by the next business day.
4. The telescopes and sites are heterogeneous, but the software is homogeneous. All that changes for each system are the drivers for the specific hardware. Once you reach the image acquisition software level, every system looks virtually identical. All software is commercial. You could easily run 2-4m class telescopes in the same manner.

5. Because there are a variety of telescope sizes and capabilities, we can optimize the use of each one by selecting appropriate programs. Some have only Sloan filters; some have narrow-band filters along with continuum passbands. The larger apertures have multiple instruments, including imaging and spectroscopy.
6. The use of commercial software makes transient interrupts for any VOEvent notification particularly easy, since this feature is already built into the software. While the normal model is to provide images through a pipeline after local sunrise, we can access images earlier in the night for rare events.
7. Images are taken and calibrated (dark subtract, flat-field) before they are made available to the researcher. We feel that the site manager and telescope advocate have intimate knowledge of the system and know best how to calibrate the images.
8. We offer an integrated solution. The calibrated images can be sent directly to our Amazon Cloud server where the VPHOT image analysis package resides, enabling precision photometry without software purchase. VPHOT will also transform the raw photometry onto the standard system and produce output files in a standard format. That photometry can be sent to our International Database, where other software packages, such as VSTAR, can perform period searches and phase plotting.

A Typical System – The Bright Star Monitor (BSM)

BSM is highlighted here because it is an extremely inexpensive robotic system that performs well. The original BSM, shown in Figure 4, consisted of:

1. Takahashi FS-60C 60mm f/6 astrograph
2. SBIG ST-8XME CCD camera
3. SBIG CFW-9 filter wheel
4. Astrodon BVRIC filters
5. Celestron CGEM mount
6. MaximDL camera control software
7. ACP and ACP Scheduler automation software

The total expense, if everything was purchased new, is about $7500. More recent BSMs use the Astro-Tech AT-65EDQ astrograph to reduce costs while retaining image scale. Many private donors are willing to fund such systems.

Figure 4. Original BSM system near Cloudcroft, NM, with site manager Tom Krajci.

The primary emphasis with BSM is bright star photometry. The All-Sky Automated Survey (ASAS) is the only currently-active photometric survey, with systems in Chile and Hawaii. However, its exposures are optimized for stars in the 8-14mag range. BSM is optimized for stars in the 2-8mag range (such as Polaris and epsilon Aurigae). High throughput is not a requirement, so colored glass filters are perfect for BSM. The CGEM mount is the minimum mount for robotic control. We have made a couple of minor improvements to the mount, providing limit switches for safety, but otherwise it is a stock product. The image scale is 5arcsec/pixel, and the field of view is about 3 square degrees. This was chosen so that the majority of the bright targets would have comparison stars in the same field of view, with the maximum resolution possible to prevent blending in crowded fields. The original BSM acquired nearly 100,000 images during its first year of operation. As opposed to ASAS, the normal operation mode is point and shoot, moving between targets as the sky rotates them into good positions. Approximately 300 targets are covered per night, all in two or more filters. BSM can also perform time series observations. We have five such systems operational or nearly so, and this gives us considerable flexibility for scheduling.

Because this is bright star photometry, pristine skies are not a requirement. Urban conditions are just fine. What are requirements, however, are a good Internet connection and if possible, a maximum number of clear nights. Enclosures can be extremely primitive, from manual flip-top setups (only about 1 meter square footprint is needed) to inclusion in a roll-off enclosure with another telescope. While we have five of these systems coming on-line, we are always open to adding additional systems, especially if they are at useful longitudes.

Challenges for large telescope networks

As mentioned earlier, we have a mix of telescopes and sites. Most of the sites are private observatories, which makes operation and maintenance simple and inexpensive, but which adds the complexity of longevity. Operators can lose their day jobs, move, have illnesses, retire, have conflicts with the AAVSO. The one saving grace is that the telescopes in question are small. We can dismantle setups and move to another site if necessary. We recommend good contractual agreements with such sites to handle unforeseen circumstances.

Internet access is always a problem. If you pick a pristine site far from cities, internet access may be minimal. Major observatories such as CTIO have addressed this problem by large expenditures for infrastructure. We assume that a minimal 3G cellphone connection or low-bandwidth satellite link is available, sufficient for updating queue plans and checking system integrity. For primitive sites like this, we usually perform image calibration and star extraction with the local host computer. Star lists are then compressed and transmitted back to AAVSO headquarters. Images are stored on external USB hard drives. Every few months, an operator exchanges external hard drives and ships the old one to headquarters so that we have access to the original images. For all other systems, scripting compresses images as they are taken and then ftp transfers the images back to headquarters where they are processed on the next business day.

Right now, AAVSO headquarters is archiving all images taken through AAVSOnet. We have a large RAID5 file server that can handle the current volume of images, plus we archive images onto external hard drives for backup. We do not have the Internet capacity to serve the images other than to the original researcher; we may start using a Cloud Server to do this in the future. Estimates are that we are capable of taking about 1.5 million images per year with the 19-system AAVSOnet, so we will be expanding our file server capacity in the near future.

With telescopes moving to new fields hundreds of times during a night, and 100,000 images or more per year, maintenance is going to be an issue. The original Sonoita system has taken more than 1,000,000 images, approaching the MTBF for most components. With all robotic networks, allowance has to be made for replacement of components, both in cost and manpower. We do not guarantee sky access, so telescopes or computers may fail and be off-line for a few days before repairs are made. Commercial networks are far more conscious of this with paying customers, and may have to stockpile replacement parts and use overnight shipping to keep systems running.

As with private sites, use of volunteers as telescope advocates, as members of the Telescope Allocation Committee and for programming tasks is also a potential problem. Volunteers rarely stick around for extended periods of time, and so you need to build in training time as well as supervision time to ensure that their tasks are being executed properly.

Allocating time on a heterogenous network can be a challenge. If you have a 15th magnitude variable, it can be observed by some of the telescopes, but not all; they may not have the right filters, sufficient aperture, or may be geographically unsuited. The object list for a telescope that may be down for maintenance should be transferred to other systems. This can best be handled by a master supervisory scheduler; a concept on which we are currently working. In the meantime, such queue balancing is done by hand.

Non-imaging instruments are not well-handled by existing commercial software. There is no robotic spectroscopic software available; NIR instruments require their own special modes of operation; building in control of instrument selectors requires custom software. This is probably our biggest challenge for the future, and we are working with software vendors to solve such issues in a standard fashion.

Summary

Robotic systems need not be expensive. Not all research projects require big glass, and commercially available telescopes in the meter class are readily controlled by existing software packages. Everything from domes to focusers can be purchased at low cost and with high quality, so it is possible in today's market to purchase everything necessary off-the-shelf. We've demonstrated it; we encourage you to join the AAVSO and try the system yourself. Help us grow by donating telescope systems and volunteering your time!

Acknowledgements

Diffraction Ltd. has donated MaximDL for network use. DC3 Dreams provided site licenses for ACP and ACP Scheduler. SBIG has provided several CCD cameras for AAVSOnet. Software Bisque has upgraded the original SRO Paramount at their expense. Astrodon and other vendors have provided expert advice and discounts on their hardware. AAVSOnet would not be in existence without the dedicated help of volunteers like John Gross, Dirk Terrell, Tom Krajci, Peter Nelson, Jaime Garcia, Ido Bareket and others.