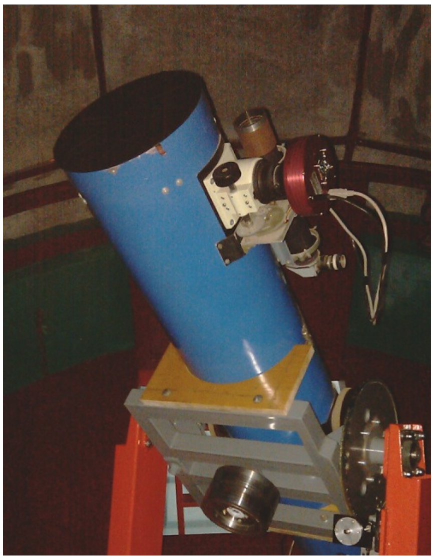
The "Heavenly Owl" observatory: Seeing above the Black Sea waterfront

Just two decades ago one had to put quite a lot of efforts to build a quality light curve for a variable star. It was required even more to discover a new one, dealing with lots of frames taken during a night, then printed and compared. Nowadays, variable stars observers are in a privileged situation: there many ways of making a discovering process easier and more fun. Sure, you need some devices, but the variety of choice and affordability is like never before. In this article Valery Tsehmeystrenko from Odessa is going to share his experience in variable stars observation and analysis.

There are two basic ways of studying variable stars in modern amateur astronomy. The first approach is classical observations of the real sky being equipped with modern hardware. Another way is a so-called data mining technique, when it is possible to use large photometric surveys' databases and obtain the data for further analysis via the Internet. In that case a one does not need a hardware and real clear sky above to make discoveries, as everything can be done by just using a software.



Data mining activity is a basis for the VS-COMPAS team. It's all about a searching for variable stars in the data of photometric surveys. Those surveys are conducted with the help of robotic telescope arrays continuously monitoring the sky every single clear night. The advantage of this approach is its physical independence of latitude: the whole telescope array can be installed on a mountain and controlled remotely.

But this article is dedicated to making your own “old-school” real observations of the sky. Not necessarily you are about to search for a new variable star – observations and light measurements of an existing variable as important as the discovery of a new star. In this article I'd like to share my experience in making variable stars observation in the private observatory called “Heavenly Owl” in Odessa, Ukraine: what hardware/software is used and how the photometry analysis can be done.

The main requirement and a driving force at the same time is a desire. Unfortunately, this is not enough for a true success :) In the world where every piece of iron can be controlled electronically, you need an advanced telescope setup as well. It depends on what program you are going to follow. For a visual observations a good binocular or telescope with an appropriate eyepiece is fine. The more faint object you are going to observe the larger aperture you need. But you would need a good training experience for a reliable brightness evaluation using comparison stars with the permanent [known] brightness. Accuracy of such measurements may be beyond the expectations. Thus, visual observations are losing their position to a modern electronic light detectors and CCD cameras.

CCD cameras have much better sensitivity, resolution and never get tired of sequences of measurements. Almost nobody uses films today, but there are still thousands and thousands unprocessed photographic frames with useful data from the past. For example, in Odessa, there is a collection of photographic frames of sky regions covering more than 40 years! Taking into consideration how important the coverage time frame in astronomy is, one could imagine the value of those collections.

Widely used handy amateur photo cameras are not so good in photometry gathering, since they use color sensors and not designed for a specific purposes, such as taking quality pictures at night. For a good photometry you would need a set of filters combined with cameras based on a black-and-white sensors designed for astronomers. Wheels of filters are useful for light measurement in different ranges. Combining a black-and-white CCD camera with filters is a good way to obtain a photometry with a scientific value.

The type and the size of a CCD sensor sets a restriction for a field of view available to a camera. A few more parameters that need to pay attention to when choosing a camera: the maximum sensitivity, the lowest dark current, the presence of anti-blooming and the cooling system on the matrix.

The telescope setup

In my observatory I use the following optical system:

- Newtonian telescope with a 200 mm primary mirror diameter and a focal length of 1256 mm. The relative aperture is 1:6.3.

- The Atik-314L + mono camera with a Sony icx285 chip (pixel size is 6.45 x 6.45 microns). The size of the matrix is 11mm. The Peltier element is used for active cooling.

- B and V photometric filters from Baader Planetarium (the R filter is still desirable though).

This configuration allows the field of view of 18'x24' with a resolution of about 1'' per pixel. Given the level of light pollution of the sky and its transparency, this equipment allows to reach the magnitude limit of up to 19m and do photometric measurements up to 16-17m confidently. Field of view is sufficient for comparison stars locating, but quite enough for most of observations.

In addition to the optical system , it is necessary to acquire more quality equatorial mount. This is perhaps the most complex and expensive component of the astronomical setup in amateur astronomy. Without a mount making precise and serious observations is extremely difficult. The mount must be equipped with hour angle drive to compensate for the daily rotation of the sky. Since the objects of observations are often quite dull, i.e. invisible to the naked eye, and can not be close enough to the bright star to guide, the visual guidance on such objects is virtually impossible. A general advise is to equip the mount with an automatic guiding system. Once the setup is calibrated by known bright stars, it will be easy to navigate the telescope to a target object via just a single mouse click.

The modern market offers a wide range of telescopes and mounts suitable for any purposes. But there people who using handmade custom mounts. And I am one of them. But before describing my own mount for the telescope, let's see what else a serious telescope must have.

No matter how accurate and quality the mount is, there are a sufficient number of factors that affects smooth mount motion. Even very small inaccuracies in mechanics or the polar axis alignment, atmosphere turbulence, etc. leads to an object “floating” in the telescope's field of view and tend to blur the image on a resulting frame. To prevent this, the telescope is equipped with a guiding system.

Optical guidance system is a system equipped with a single camera (or matrix) which is mechanically connected to the main telescope and purposely designed for automatic compensation of object's displacement in the telescope's field of view. Guidance can be off-axis or separate. In a case of off-axis guiding, a small prism in the eyepiece optics is installed, diverting part of the light guide to the camera . It is better to use a separate guiding optics. For that purpose a small refractor can be used, or camera with “fast” lenses with a focal length of 250-300 mm. It can be attached to the adjustment rings of the main telescope's tube along with the camera.

I use a self-made fork-type equatorial mount with a large capacity. GoTo mount is equipped with a system based on software created by a well-known amateur Mel Bartels. Guiding system is made of lenses with a focal length of 300 mm and a relative aperture of 1:4.5. In addition, the Phillips SPC900 camera adapted for long-term exposures is used. Camera's native matrix was replaced by a black-and-white Sony ICX618 camera. This increased the sensitivity of the camera significantly.

Software is the key

One more, and the last, thing that is needed to start the observations and study of variable stars is software. There are too much of software available to be able to discuss it all. Let's focus only on those samples which are widely used by the amateurs of astronomy for variable stars observations.

For autoguiding the ProGuider, Guidemaster, PHD Guiding, GuideDog or Maxim DL can be used. The latter is a true all-in-one processor, which does all the above programs do, and much more. For photometry measurements the IzmCCD, Maxim DL are primarily used. Don't forget about preparing the maps when you plan observations. This is essential if you are going to observe a set of targets during the night. You need a good time management skills to cover many targets in a short period of time.

On the AAVSO website there is a good chart plotter http://www.aavso.org/vsp. It can generate star maps with the desired coordinates and field of view. Also, there you can get a table with the parameters of the comparison stars, which are surrounded by the observed variable star.

Now we have prepared all the necessary equipment and got it snapped to the sky by known bright stars, focused and ready for observations. Take a test single shot. The duration of exposure depends on the characteristics of your camera and magnitude of stars that you want to measure. Start with 15-20 seconds. After receiving the first shot, make a conclusion about the need to increase or decrease the exposure. Supporting factor here is the signal-to-noise ratio. The SNR level of about 30 is considered sufficient, but sometimes it is possible to carry out photometry at smaller ratio.

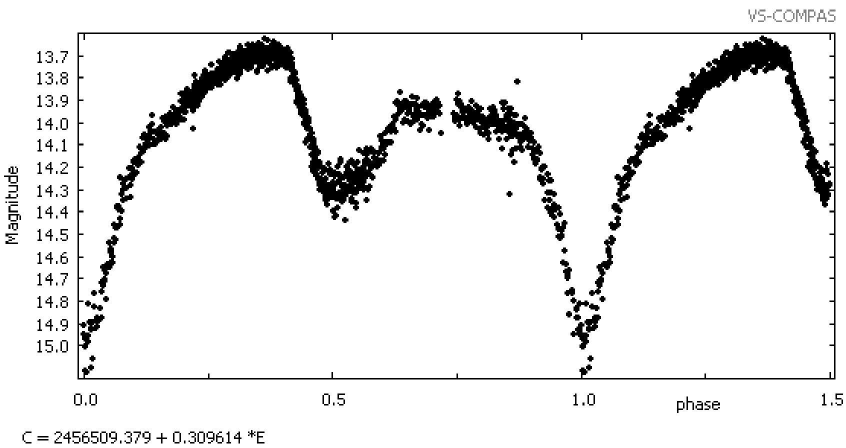
Compare the captured image with the map and make sure that the target object is located in the center of the field. Sometimes it is necessary to shift the telescope a little to cover the comparison star. Select the desired filter. The most used filter is V, since it's the closest one to the visual band. The process can be automated by using a motorized optical filters wheel. Before launching a series of pictures do a few more important manipulation - synchronize the time on the computer where the observation is conducted with the standard. While you can do that online or using other precise watches, previously amended, GPS receiver is the best choice.

When the setup is ready - start series of frames. The software allows you to specify any sequence, the automatic change of filters, exposure time, number of frames and more. The number of images and the intervals between them depend on the observed object, or rather of his period. The more frames you make, the more light measurements you can get for the object - the more accurate the resulting light curve will be.

For a short-period variable star the frames should be taken continuously or with minimal pauses. It is better to cover the whole period with one session, if the period is comparable to the duration of the night time and object visibility. For example, for intermediate polars, the observations of which, in particular, are held at the "Heavenly Owl" a continuous shooting is required at the minimum shutter speed. This is due to the presence of two periods, one of which can be from tens of seconds to 20 minutes.

As an example, I present (see the light curve below) the light curve of an interesting binary system in the constellation of Lyra. This is the result of observations made at the observatory "Heavenly Owl" during the summer of 2013. Measurements are done in visual band.

In the case of the long-period variable stars, there is no need for a large number of frames. Take several shots in each filter. At the end of the observations set, we still have to make the calibration frames. They can be of three types: Bias, Dark and Flat. Bias frames are frames with zero exposure. They are used to compensate for internal noise of the CCD camera itself. Dark files are taken with exposures equal to the basic shots exposure with the same temperature of the matrix. They allow you to remove artifacts such as hot and dead pixels of the matrix.



Flat files are used to compensate for the artifacts associated with the dust on the sensor, the optical surfaces and vignetting. To make Bias and Dark frames the telescope cover must be attached. Do the appropriate amount of shots with the same exposures. Making the Flat files is a little more complicated. Ideally, they are easy to get on evening or predawn twilight sky. You need to choose the exposure to get a ¼ - ½ of the value of complete saturation of the pixel. For example, full saturation for 16 bit camera is 65535. The value of a pixel in the Flat file should be in the range of 15.000 – 30.000. I use 20.000.

Another way of obtaining the Flat files is to use the so-called flat-box. I use a white screen which is attached to the dome. Am bringing him a telescope and the illuminating light bulb. For more scattered light, the telescope tube can be covered with a white cloth. Flat files must be taken separately for each filter. The number of calibration frames depends on a particular camera model. I usually make 15-20 frames of each type.

Once the calibration files are completed, the observational data can be processed. The first step is to calibrate frames containing the target object using the same calibration files. At this step we get a clear picture without any unnecessary noise content. The second step is photometry measurements. Don't forget to specify multiple comparison stars and their brightness in the range the data frames are.

With a series of photometric observations, we can build a light curve, find the period of a variable star, other parameters, depending on the variability type.

There are lots of software to make the analysis of the photometric data. A good example is a software package created by Andrey Prokopovich and Ivan Adamin (the VS-COMPAS project core team). There are desktop and web versions available. It is a powerful software that allows you to build the light curves, search for possible periods, combine data from a number of photometric surveys and more.

I would also like to mention another program called MCV created by professor Andronov. The program is unique in its kind and allows you to make a very accurate and detailed analysis of the photometric data.

Valery Tsehmeystrenko

The FU Orionis phenomenon: further reading (references) – see p.3 for the article

- Herbig, G. H., Eruptive phenomena in early stellar evolution, 1977, ApJ, 217, 693
- Herbig, G.H.; Bell, K.Robbin, Third Catalog of Emission-Line Stars of the Orion Population, 1988; Lick Observatory Bulletin, 1111, 90
- Vittone, A.A., Errico, L., FU Orionis systems, 2005, Mem. S.A.It. Vol. 76, 320
- Hartmann, L. & Kenyon, S. J., 1985; On the nature of FU Orionis objects, ApJ, 299, 462
- Hartmann, Lee; Kenyon, Scott J., 1996; Ann. Rev.of Astr. and Astroph., 34, 207
- Percy, J. R., 2007, "Understanding variable stars", Cambridge University Press, pp. 289-290
- Discovery of possible FU-Ori and UX-Ori type objects; online: http://crts.caltech.edu/CSS091110.html
- FU Orionis Stars; online: http://www.astro.umd.edu/~neal/fuori.html
- FU Orionis; online: http://www.nightskyinfo.com/archive/fu_orionis/
- The Herbig-Bell Catalog; online: http://www.stsci.edu/~welty/HBC/HBC.html
- The Furor over FUORs; online: http://www.universetoday.com/78796/the-furor-over-fuors/

The VS-COMPAS Project

The project was started in fall of 2011 by four amateur astronomers from Belarus. The main intention is to expand the International Variable Star Index (VSX) catalog with new variable stars, variable stars data analysis and research. Among the most significant achievements it is worth to mention more than 1200 variable stars discovered by combined efforts of seven active team members. All data about discovered stars is submitted to the VSX catalog running by the AAVSO. Another valuable goal the project has is increasing public interest to variable stars science.

More information about the team and discoveries can be found at http://vs-compas.belastro.net