The Value of Amateur Observations for Variable Star Research: Two examples

Albert Bruch

Laboratório Nacional de Astrofísica (LNA/MCTIC)

The increasing ease of access of dedicated amateur astronomers to sophisticated and competitive instrumentation in recent years enables them to collect large amounts of high quality data with great value for astronomical research. This holds true in particular for optical time series observations of variable stars. While more often than not they have either not the expertise or the time to extract the scientific content of the data, or are simply not interested in doing so, they make their data available to other interested parties by inserting them in publically accessible data bases. These data archives are valuable resources ready to be exploited for research. One of the largest and better known archive is the International Database of the American Association of Variable Star Observers (AAVSO). Here, I present results on two cataclysmic variables based exclusively on amateur data retrieved from the International Database.

V603 Aquilae:
Cyclic variations with twice the accretion disk precession period

Background

As all cataclysmic variables, the old nova V603 Aql is a binary system composed of a Roche-lobe filling late type secondary star which transfers matter via an accretion disk to a white dwarf. The orbital period is 3.32 h. A photometric modulation with a slightly longer period (3.49 h) termed superhump is thought to be caused by stresses induced by the periodic passage of the secondary star close to the extended part of the accretion disk which in this case is not circular but elliptically deformed. The superhump period is longer than the orbital period because the major axis of the elliptical disk precesses. An example of a light curve is shown in the upper frame of Fig. 1. The superhump modulations are readily seen, superposed by strong flickering, ubiquitous in cataclysmic variables.

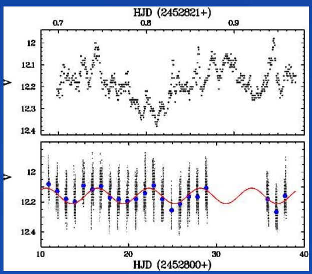

Fig. 1: .Example light curve (top) and combined light curves (bottom) of V603 Aql. For details, see text.

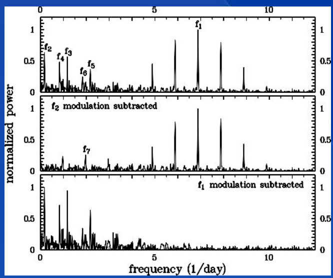

Fig. 2: .Power spectra of the combined light curves of V603 Aql (top) and after subtraction of signals f_2 (middle) and f_1 (bottom), respectively. For details, see text.

The data

An exceptionally dense, extended and homogeneous set of data of V603 Aql was found in the AAVSO International Database, consisting of 22 long (mostly >6 h) light curves, observed by amateur astronomer Lewis M. Cook, 19 of which were taken in subsequent nights. The time resolution was 35 sec throughout. All light curves are shown in the lower frame of Fig. 1, where the blue dots are nightly averages and the red curve is a least squares sine fit. No data set of similar extent and quality of this star exists.

Frequency analysis

The power spectrum of the entire data set is shown in the upper frame of Fig. 2. The high frequency range is dominated by the superhump frequency (f_1) and its aliases. At lower frequencies, several signals (f_2 … f_6) appear. Only f_2 is significant. The other signals are all caused by interactions between f_2 and the window function. This is confirmed in the central frame of Fig. 2 which contains the power spectrum after subtracting the best fit sine curve with the period fixed to $1/f_2$ from the original data.(f_7 and its aliases are side lobes of f_1). The lower frame contains the power spectrum after subtracting the best fit sine curve with the period fixed to $1/f_1$ from the data.

Discussion

The period corresponding to f_2 is 5.85 days which to a very high degree of precision is equal to *twice* the beat period between the orbital and the superhump period, i.e. the precession period of the elliptical accretion disk. This modulation is readily visible in the combined light curves, as evidenced by the solid sine curve drawn in the lower frame of Fig. 1. While in a small number of similar systems marginal evidence for variations on the disk precession period exists (but never nearly as clear as seen in the present case) there is no obvious mechanism to cause such light modulations. Geometrical effects can probably be ruled out because there is no correlation with the orbital inclination of the respective binaries. Variations on twice the precession period are even more mysterious.

The full details of this study are published in:
A. Bruch & L.M. Cook, 2018, New Astron, 63, 1

AT Cancri:
Coherent brightness variations in a dwarf novae: An intermediate polar?

Background

AT Cnc is a Z Cam type dwarf nova, i.e., a system where the normal dwarf nova outburst cycle is sometimes for an unpredictable time interrupted by a standstill between outburst and quiescent magnitudes. Apart from the long-term light curve not many details known about AT Cnc. A spectroscopic period of 4.83 h has been measured. Various claims for photometric periods on the time scale of hours have been published, but none of them was ever confirmed.

The data

37 light curves observed in irregular intervals by various amateur observers and with time resolutions between 35 and 99 sec have been retrieved from the AAVSO International Database. They all refer to two standstills in 2016 and 2018. The long term light curve of AT Cnc during this time interval is shown in Fig. 3, where the data used in this study are highlighted in red. Note that unfortunately no time resolved observations were taken during the 2017 standstill.

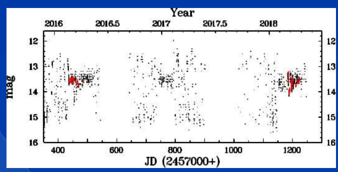

Fig. 3: Long term light curve of AT Cnc with the data used in this study highlighted in red.

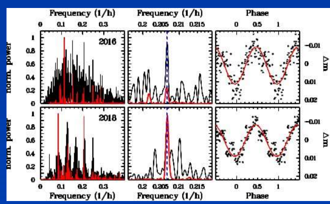

Fig. 4: Power spectra revealing orbital variations of AT Cnc, and folded light curves. For details, see text.

Orbital variations

The power spectra of the combined light curves of 2016 and 2018 are shown in Fig. 4 (left). The multitude of peaks are causes by the complicated window spectrum. Applying the CLEAN algorithm (red) simplifies the spectrum somewhat. Only one significant peak in common to both seasons remains (amplified in the central frames of the figure). The light curves folded on the corresponding period are shown in the right frames. The period is equal to the spectroscopic period within the errors of the latter and can thus safely be interpreted as a manifestation of the binary revolution. It permits to obtain a more precise value of orbital period of 4.83922 h (or its alias 4.83792, because of a slight cycle count ambiguity between 2016 and 2018).

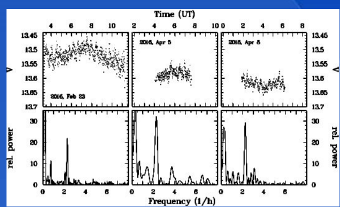

Fig. 4: Three light curves of AT Cnc and their power spectra, revealing a 26.7 min period.

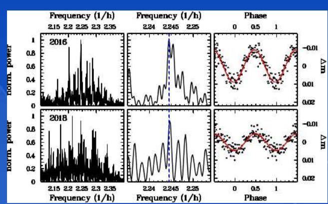

Fig. 6: Power spectra of the combined data set and folded light curves of the IP type variations of AT Cnc.

An intermediate polar?

The power spectra of many (albeit not all) individual light curves show a clear signal corresponding to a period of 26.7 min. Three examples are shows in Fig. 5. It persists in the combined seasonal light curves (Fig. 6; organized in the same was as Fig. 4), permitting to refine the period to 26.731 min. It can most straightforwardly be interpreted as the white dwarf rotation period within an intermediate polar (IP) model for AT Cnc, where the white dwarf has a magnetic field strong enough to control the accretion flow close to the central body. In this case, the ratio between the rotation and orbital periods is right in the centre of the corresponding distribution for all IPs. This is the ratio naturally assumed in a spin equilibrium condition. AT Cnc would be the first Z Cam star to be identified as an IP, conventional wisdom regarding these as non-magnetic

The full details of this study are published in:
A. Bruch et al., 2019, New Astron, 67, 22