SCALEGRAM ANALYSIS OF THE VARIABILITY OF THE POLAR AM HER

I.L. Andronov[1], S.V. Kolesnikov[1], N.M. Shakhovskoy[2]
[1] Astronomical Observatory, Odessa State University, Ukraine
[2] Crimean Astrophysical Observatory, Ukraine

ABSTRACT. The characteristics of the brightness variations of AM Her are studied at time scales from seconds to decades by using the scalegram method proposed by Andronov (1997, *As. Ap. Suppl.*, **125**, 207). The unbiased scatter estimate increases with the filter half-width according to a power law with an index 0.180 from 10^{-4} to 3000 days indicating a fractal nature of irregular variations with a low dimension of $D = 0.32$.

Key words: Stars: Cataclysmic: Polars: AM Her

AM Her exhibits a variability detected in a wide range (see e.g. Andronov, 1987ab for a review):

- seconds - accretion column oscillations; asymmetric boiling;
- tens of seconds - the "shot noise" caused by bombardment of the column by plasma inhomogeneties ("spaghetti");
- dozens of minutes - variations caused by clustering of small flares;
- 3 - hour wave and its harmonic - variations at the orbital period which is nearly equal to the spin period of the white dwarf with an arbitrary deviation $\leq 10^{-4}$;
- cycle–to–cycle and night–to–night variations of the light curve shape caused by physical variability of accretion structures;
- fast transitions between the high and low states with a minimum duration of ≈ 3 days;
- few year variability of the mean luminosity caused by either magnetic activity of the secondary, changing orientation of the magnetic axis of the white dwarf in respect to the secondary, minor variations of the orbital separation owed to a low-mass third body at an eccentric orbit.

This paper is based on our observations carried out at the 2.6m telescope of the Crimean Astrophysical Observatory with a typical time resolution of 4–5 seconds. During one of the nights (20.10.1993), the resolution was set to 1 sec, and we have used it for the study of flickering.

To study the long-term variability, we have used the observations from the AFOEV database. To avoid an additional noise caused by shifts of the instrumental systems of different observers, we have used the data obtained by only one observer - M.Verdenet (1997) from 1976 to 1997. After removing the "bad" and "fainter than" points, altogether 1313 points remained.

In Fig. 1 the photoelectric light curve with 1-sec resolution as well as the visual long–term light curve are shown with corresponding scalegrams. As the test functions, we have used σ_{O-C} ($= \sigma_1$ in the notation of Andronov (1997)), i.e. the unbiased estimate of the scatter of the data near the smoothing curve; the coefficient $R = N_{eff}^{-1/2} = \sigma[x_C]/\sigma_{O-C}$, the weighted r.m.s. accuracy estimate at the arguments of observations $\sigma[x_C]$ and the amplitude "signal/noise" ratio S/N=$\sigma_C/\sigma[x_C]$.

One may see the jumps between the two parts of the curves owed to different accuracy and exposure time. A prominent peak occurs at $\Delta t = 0\overset{\mathrm{d}}{.}025$ corresponding to a non-sinusoidal character of the orbital light curve. For the long–term data, the peak occurs at $\Delta t = 750^{\mathrm{d}}$ with a very weak peak at $\Delta t = 60^{\mathrm{d}}$.

However, the dependence of σ_{O-C} on Δt is remarkable straight in a double logarithmic scale within a very wide range from 10^{-4} to 3000 days. The best fit is the following:

$$\begin{array}{rcl} \lg \sigma_{O-C} & = & -0.796 + 0.1799 \cdot \lg \Delta t. \\ & & \pm\ \ 3 \quad\ \ \pm\ \ 13 \end{array} \qquad (1)$$

For smaller values of Δt, the uncorrelated photon noise becomes compatible with a contribution of flickering, thus the slope decreases. For larger values, the slope tends to zero because of finite length of the run.

To study night–to–night changes, we have computed the scalegram for all runs. The noise characteristic σ_{O-C} for 24 runs is shown in Fig. 2. One may note a remarkable gathering of the corresponding curves with a total width of $\approx 40\%$ with few outstanding curves corresponding to low level of flickering (bottom curves) or extra variations owed to bad weather conditions.

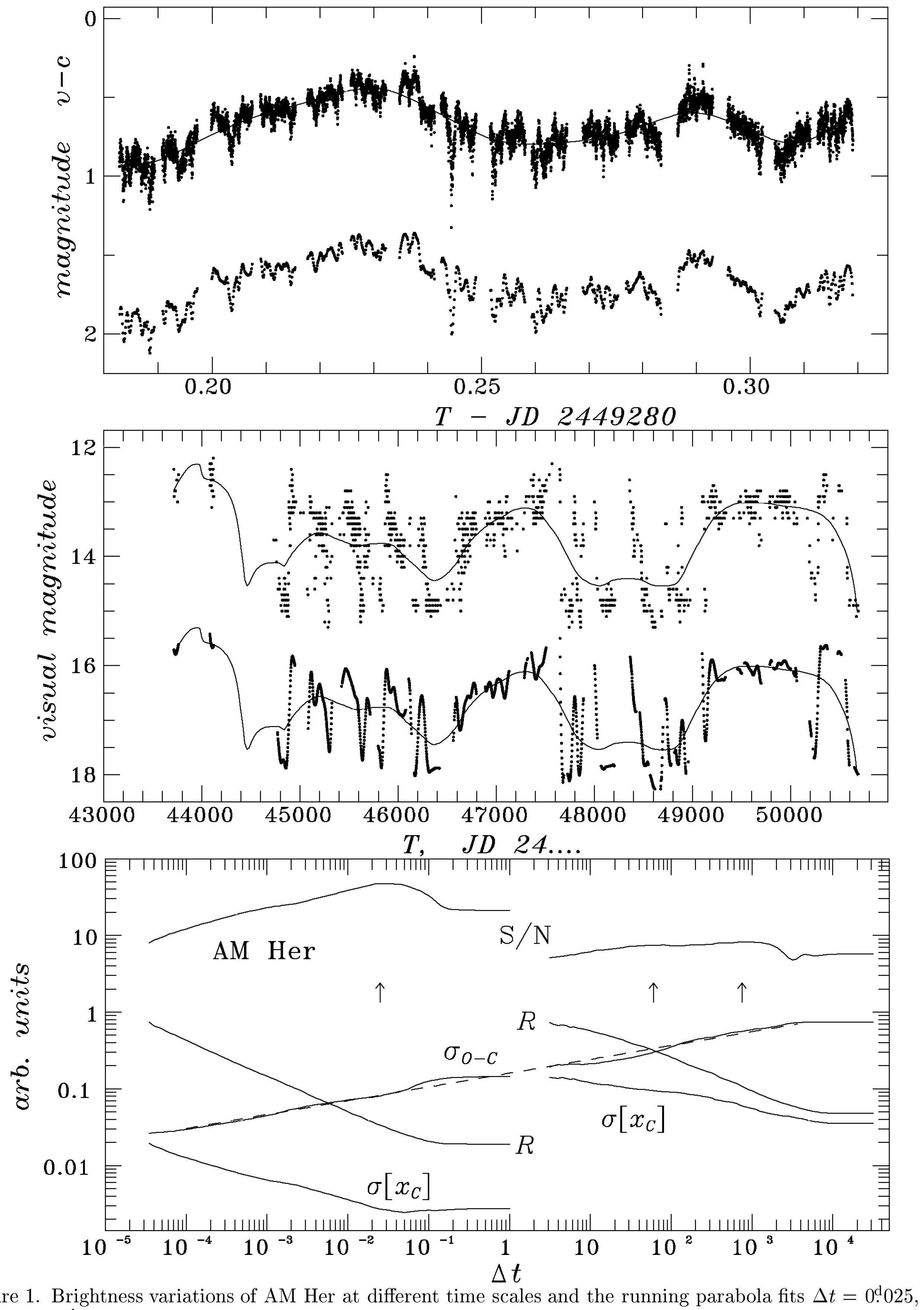

Figure 1. Brightness variations of AM Her at different time scales and the running parabola fits $\Delta t = 0\overset{d}{.}025$, 60^{d} and 750^{d} (up - photoelectric and middle - visual) and the scalegrams for both sets of data (bottom). The arrows mark the positions of the (local) maxima at the S/N test function.

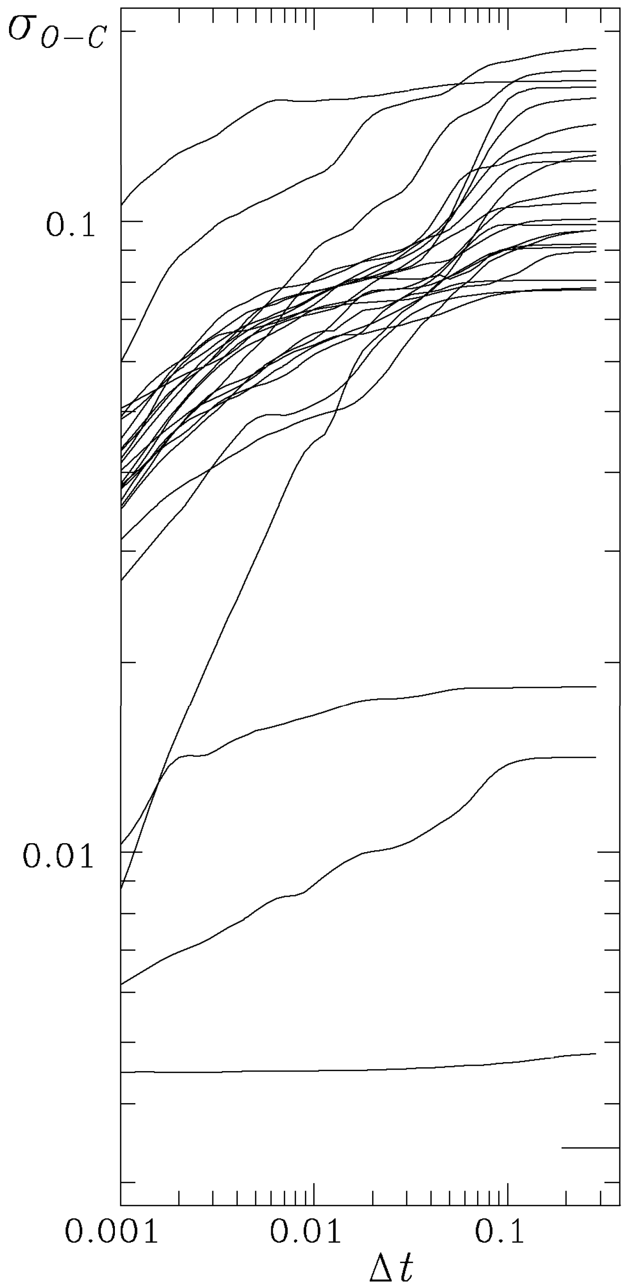

Figure 2. Test functions σ_{O-C} for 24 nights of 1-sec observations of AM Her obtained at 2.6m telescope.

The highest slope has the scalegram corresponding to the night 29.08.1992, when an unprecedented flare of the red dwarf was observed (Shakhovskoy et al., 1994). For the mean of all curves, the coefficients of the fit (1) are 0.67±0.05 and 0.172 ± 0.014. Thus the mean slope is equal to that of our 1-sec run within error estimates.

More careful study may allow to split the range into 3 parts. The first for the range -3.0...2.5 of $\lg \Delta t$ has a larger slope than from -2.5 to -1.5. For larger Δt, there is an increase caused by growing systematic differences between the fit and harmonic of the orbital light curve, and then followed by a standstill owed to finite length of the run.

From this point of view, one may recommend to use the value of $\Delta t \approx 0\overset{d}{.}035$ as the one best fitting the two-wave orbital variations.

Such linear shape of the dependence in the double logarithmic scale allows to propose some measures of the flickering, e.g. $I(\lg \Delta t) = \lg \sigma_{O-C}(\lg \Delta t)$ at some fixed values of $\lg \Delta t$, say, -3,-2.5 and -1.5. These values have been introduced for AM Her concretely, and may be changed for other objects. The slope may then be determined as $\gamma_\sigma = (I_2 - I_1)/\lg(\Delta t_2/\Delta t_1)$ and thus will be similar to the color index derived from a continuous spectrum. Detailed study of these parameters I will be done elsewhere.

As the value of σ^2_{O-C} characterizes the energy integrated from some effective limiting frequency $f = \alpha/\Delta t$, where α is a parameter depending on the basic functions used for the fit, one may assume that the power spectrum will obey a power law as well.An index $\gamma_S = 1 + 2\gamma_\sigma$. For our case, $\gamma_S \approx 1.36$, in an excellent agreement with our findings in previous years (cf. Shakhovskoy et al., 1992). Much larger slopes $\gamma_S \approx 1.8$ have been found for nonmagnetic cataclysmic variables, e.g. TT Ari (cf. Tremko et al., 1996).

One may note the same slopes γ_σ for fast and slow variability of AM Her producing the power law in a range of frequencies differing by 7.5 orders.

As the variations are fractal, there is no possibility to obtain some characteristic cycles from the σ_{O-C} test function. The S/N ratio is more sensible to detect possible quasi-periodic or cyclic variations. In Fig. 1 we show the fits corresponding to the maxima of the dependence of S/N on Δt, including the local one at $\Delta t = 60^d$. From the continuous approximation, the optimal value of $\Delta t \approx 0.545P$, where P is the period of a regular contribution.

The parameter $\gamma_S = 2(1 - D)$, where D is so-called fractal dimension (cf. Terebizh, 1992). Thus one may conclude that $D = 0.5 - \gamma_\sigma$ and, for AM Her, the fractal dimension $D = 0.32$.

References

Andronov I.L.: 1987a, *Ap. Space Sci.*, **131**, 557.
Andronov I.L.: 1987b, *Astron. Nachr.*, **308**, 229.
Andronov I.L.: 1997, *As. Ap. Suppl.*, **125**, 207.
Shakhovskoy N.M., Andronov I.L., Kolesnikov S.V.: 1994, *Odessa Astron. Publ.*, **7**, 40.
Shakhovskoy N.M., Kolesnikov S.V., Andronov I.L.: 1992, in: *"Stellar Magnetism"*, St.Petersburg, 148.
Terebizh V.Yu.: 1992, *Time Series in Astrophysics*, Moscow, Nauka.
Tremko J., Andronov I.L., Chinarova L.L., Kumsiashvili M.I., Luthardt R.,Pajdosz G., Patkos L., Roessiger S., Zola S.: 1996, *As. Ap.*, **312**, 121.
Verdenet M.: 1997, *ftp://cdsarc.u-strasbg.fr/pub/afoev/her/am*