GETTING BOUNDARY CONDITIONS FOR DWARF NOVA OUTBURST MODELS FROM AAVSO OBSERVATIONS

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Abstract

Described is a collaborative project to analyze the AAVSO's optical light curves of dwarf novae and to construct theoretical light curves of these stars in order to obtain a clearer picture of the events that occur in dwarf novae outbursts.

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1. Background

In cataclysmic variables, close interacting binary systems, the main source of optical radiation is the accretion disk that orbits the white dwarf primary component. In systems with orbital periods greater than four hours, the secondary component, a cool main sequence star, contributes significantly to the optical flux, but its contribution is most probably rather constant in time. Yet, regular as well as irregular photometric variations on timescales between (many) years and seconds are one of the characterizing features of cataclysmic variables. These features include outbursts, flares, flickering, and oscillations; orbital changes fall into a different category. In the case of dwarf novae all these variations are in some way ascribed to physical changes in the accretion disk, although their origin need not necessarily be in the disk itself. Thus, detailed analysis of optical photometric observations, in particular when they cover long time spans, should yield information on the stability and dynamics of accretion disks, or, more precisely, its outer, cool parts; the inner parts in the vicinity of the white dwarf emit radiation mostly in the ultraviolet.

One of the very noticeable features in dwarf novae are the semi-periodic outbursts. They clearly are closely related to dramatic physical changes in the accretion disk, and are apparently connected with strongly increased accretion onto the white dwarf. It is not clear, however, what the physical reason is for this instability. Two currently competing theoretical scenarios exist, both of which can account for some of the observed features but have problems in some other areas. One, the so-called **transfer instability model**, assumes that at semi-periodic intervals the atmosphere of the secondary star becomes unstable, and as a consequence, large amounts of material are dumped onto the accretion disk on a temporary basis, and from there are accreted onto the white dwarf. The other scenario, the so-called **disk instability model**, places the instability into the disk itself; the underlying physical reason for this instability is assumed to be a sudden jump in the internal friction (viscosity) of disk material due to ionization of hydrogen as soon as appropriate physical conditions are reached. Both theoretical models make some predictions about what features ought to be observable if this or that scenario would actually apply, but, in spite of considerable effort for several years, it has not yet been possible to decide convincingly in favor of one or the other.

Visual outburst light curves of dwarf novae have been observed by amateur astronomers all over the world for many decades, and the brighter objects in particular have been covered extremely well. These outburst light curves should contain a lot of rather detailed information on the accretion disks, particularly on their long-term behavior and stability. Also, from a careful analysis of the rise sections, it should be possible to distinguish between the two theoretical possibilities, or maybe even discard both.

2. The Problem

Although they have many features in common, the outburst light curves of different dwarf novae are distinctly different from each other as to the frequency and duration of the outbursts, and also the shapes of the outburst sections are rather different. Even within the same object, no two outbursts produce exactly the same observational pattern. Typically the outburst shapes for one object can be grouped in several classes, such as long or short duration, fast or slow rise, but each one has its idiosyncrasies. The multitude of features is disturbing, and it is by no means obvious which features are characteristic for which object, or which are characteristic for a larger number of dwarf novae or even for all of them. A detailed investigation of the observed light curves is necessary in order to provide the answers.

Once the phenomenology is clear, it is possible to create 'typical' light curves for individual objects or groups of objects, which contain all the frequently-recurring features together with the observed ranges of variation; fluctuations of secondary importance do not distract from the gross patterns. These 'typical' light curves then can be used as observational boundary conditions for numerical reproductions of outburst light curves. Assumptions about physical conditions in the disk and numerical input parameters to the models determine the resulting light curve. Thus, by carefully adjusting the models and trying to bring them into agreement with the observations it is possible to gain a clearer picture of what happens during the course of a dwarf nova outburst.

In order to reconstruct an outburst light curve theoretically, it is necessary first to form such a disk numerically so the basic physical structure becomes known, and then to follow its temporal development over several outburst cycles. In other words, in order to be able to compute outburst light curves it is essential to understand well the physics and dynamics of an accretion disk at any moment in time. To do this well is very demanding in terms of computing time required as well as storage capacity needed. In fact, the demand is so high that the limits of current technology in this area are continuously being pushed hard.

3. Our Project and First Results

The research problem as described above obviously consists of two essentially independent parts, that of analysing the observed light curves and that of theoretically constructing them. Our collaborative effort in fact began as these two independent projects, with each group initially unaware of the other's work.

The group in Tuebingen (F. Geyer, H. Ruder, and co-workers) is concerned with the theoretical aspects. A particle code was developed in which a multitude of "particles," corresponding to gas cells in an accretion disk, interact with each other in the computer, simulating the way in which we think particles interact in a disk. By means of mass overflow from the secondary star, a disk is first formed and its temporal development is then studied. In order for results to be comparable with observations, the electromagnetic emission from the entire disk is computed in certain wavelength bands at intervals of time, and a light curve is thus obtained.

This procedure is the one used, at least in principle; in practice many mostly computer-oriented problems still have to be solved, the most severe of which being how to cut down on the immense amounts of CPU time required. But first results clearly look very promising. They will be published elsewhere in due time.

On the observational side, J. Mattei and C. la Dous began by analysing the light curve of SS Cygni, the dwarf nova best monitored by AAVSO observers. For this investigation a presentation of the data on a magnitude scale turned out to be much more suitable than on an intensity scale, not only because scatter in the data was substantially reduced, but also because significant effects at the very beginning of the rise were much better resolved. On close inspection all rise and decline sections of the outbursts can be approximated satisfactorily by between one and three straight line segments. These fits, the resulting slopes of the segments, and their relation to minimum light are currently being investigated. From the results a "mean" light curve of SS Cygni, several cycles long and containing all the characteristic features, will be constructed. This "mean" light curve will then serve as observational boundary conditions for the models constructed in Tuebingen. Later the investigation will be expanded to other dwarf novae.

Progress reports on this collaborative project will be given as results are obtained.