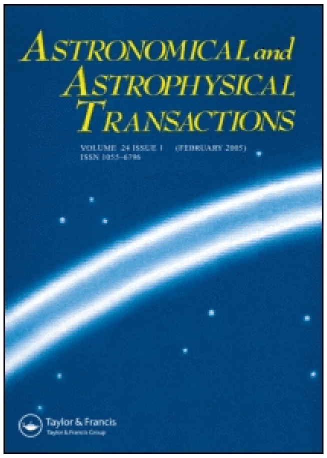

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Modelling of light and radial velocity curves in close binary systems: masses of stars and relativistic objects

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Online Publication Date: 01 February 2007
To cite this Article: Antokhina, E. A. (2007) 'Modelling of light and radial velocity curves in close binary systems: masses of stars and relativistic objects', Astronomical & Astrophysical Transactions, 26:1, 53 - 58
To link to this article: DOI: 10.1080/10556790701295159
URL: http://dx.doi.org/10.1080/10556790701295159

Astronomical and Astrophysical Transactions
Vol. 26, Nos. 1–3, February–June 2007, 53–58

Modelling of light and radial velocity curves in close binary systems: masses of stars and relativistic objects

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(Received 26 January 2007)

Synthesis methods for close binary systems allow the fundamental parameters of stars and relativistic objects to be reliably determined. The masses of massive hot stars and relativistic objects are of special interest in order to test stellar evolution theories. We present the results of light curve analysis, which allows us to determine stellar masses for two interesting massive binary systems containing early-type components and the results of X-ray light curves analysis of the unique object SS433 obtained by the INTEGRAL observatory. We also present the modelling of theoretical absorption line profiles and radial velocity curves of optical components in X-ray binary systems, which was carried out with our new computer code. Heating of the optical star by the incident X-ray radiation is taken into account using model atmosphere calculations. Comparing observed line profiles and radial velocity curves with the model data provides the possibility for correct determination of the masses of relativistic objects.

Keywords: Close binary systems; Relativistic objects; Models; Light curve; Radial velocity curve; Masses

1. Introduction

Synthesis methods were suggested in the 1970s by several researchers (see, for example, [1–3]). The methods most widely used nowadays are based on the Wilson–Devinney [2, 4] computer code.

We have our own set of computer codes for light and radial velocity synthesis for different binary models: the Roche model at an eccentric orbit, a model with a spheroidal accretion disc, a model with a precessing thick accretion disc, a model for X-ray binaries, etc. [5–8].

In the current paper, we present the results of light curve analysis for two interesting massive early-type binaries and a massive X-ray binary SS433 (section 2). Obtaining the masses of their components is important for developing the theory of stellar evolution.

The modelling of theoretical absorption line profiles and radial velocity curves for optical components in X-ray binaries and determination of the masses of relativistic objects was carried out by our new computer code which allows us to take into account correctly the X-ray irradiation of an optical star [9, 10] (section 3).

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Astronomical and Astrophysical Transactions
ISSN 1055-6796 print/ISSN 1476-3540 online
http://www.tandf.co.uk/journals
DOI: 10.1080/10556790701295159

2. Light curve analysis: three interesting massive binaries

2.1 *CPD-41°7742*

CPD-41°7742 is a spectroscopic binary (O9 + B1) with massive hot components on a slightly eccentric orbit. It is located in the young open cluster NGC 6231. XMM–Newton observations for this system shows clear phase-locked X-ray variability from wind–wind collision. Light curve analysis (figure 1) allows the absolute parameters of the system to be obtained [11].

2.2 *HD 93205*

A massive spectroscopic binary HD 93205 (O3V + O8V) contains one of the earliest known stars in a binary. It has a highly eccentric orbit ($e \approx 0.46$). A precise light curve with a very small amplitude (of magnitude abou 0.02) covering all orbital phases was obtained for the first time by our team at Cerro Tololo Inter-American Observatory (CTIO) and has an unusual form.

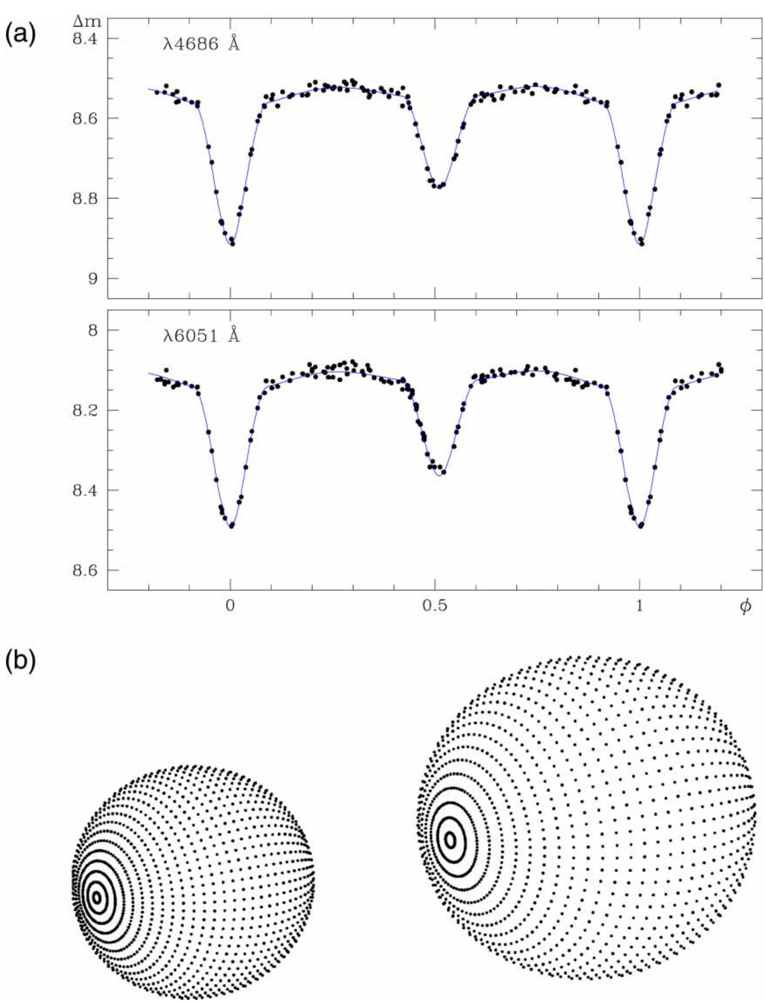

Figure 1. (a) The light curves and (b) the geometrical model of CPD-41°7742.

Table 1. Absolute parameters of CPD-41°7742 and HD 93205.

	Value for the following	
Parameter	CPD-41°7742	HD 93205
M_1 (units of $M_{\odot}$)	17.97	45.0
M_2 (units of $M_{\odot}$)	9.96	20.0
R_1 (units of $R_{\odot}$)	7.45	8.0
R_2 (units of $R_{\odot}$)	5.39	6.3
T_1 (K)	34000	49000
T_2 (K)	26260	36500
i (deg)	77.4	60
e	0.020	0.46
ω (deg)	33	17.4
P (days)	2.44	6.08

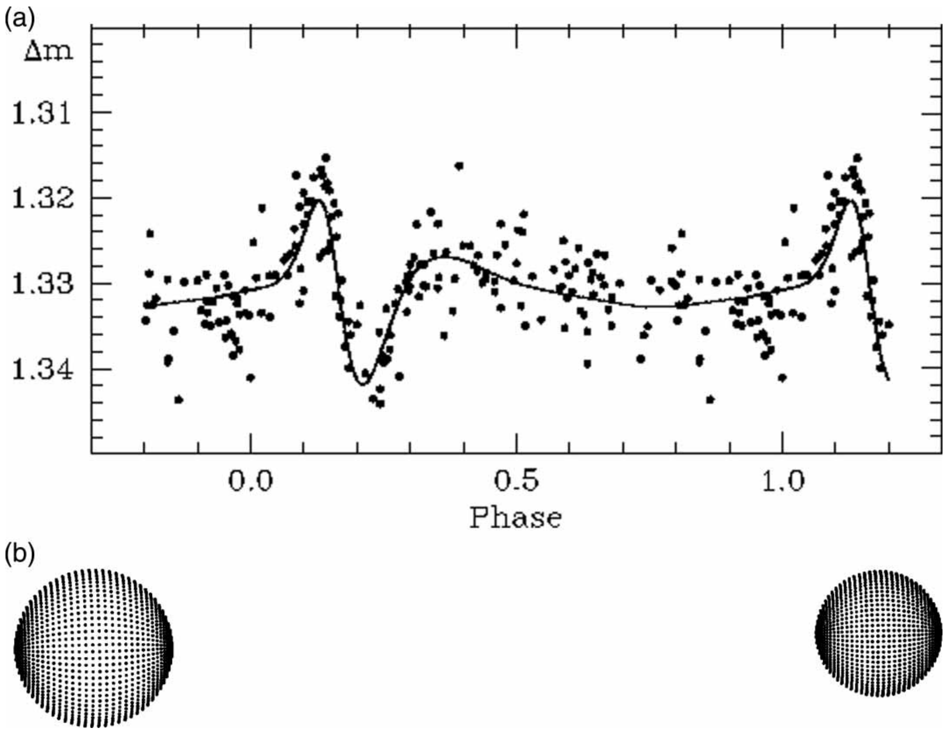

Figure 2. (a) The light curve and (b) the geometrical model of HD93205.

Our analysis by the synthesis method shows that the orbital inclination is about 60° and there are no eclipses. Light curve variability (figure 2) is caused only by small tidal deformation of stars during orbital motion [12].

2.3 *SS433*

SS433 is a massive eclipsing X-ray binary system, consisting of a massive donor star and a compact object, surrounded by a precessing accretion disc with relativistic jets. For the analysis of X-ray light curves (25–50 keV) of SS433, obtained by the INTEGRAL observatory we used our geometrical model of SS433 [8]. Orbital eclipses at the precessional phase 0.1 and

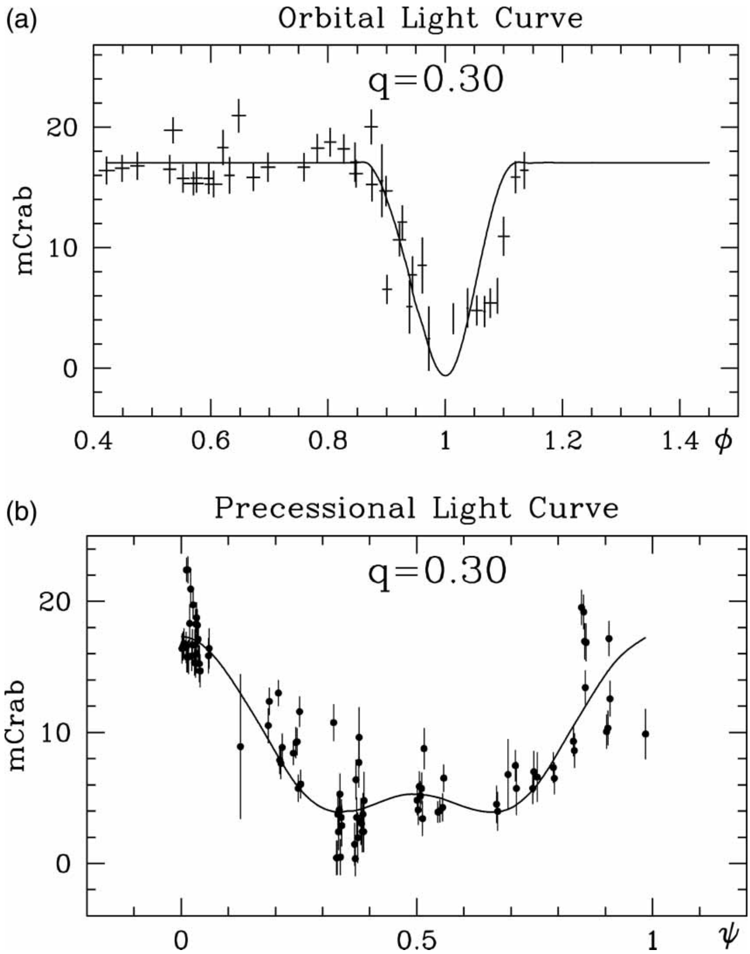

Figure 3. The modelling of (a) the orbital and (b) the precessional X-ray variability of SS433.

the precessional light curve were fitted simultaneously. In the framework of our geometrical model of the hard X-ray-emitting region in SS433 it turns out that the eclipse shape and the precessional amplitude are best reproduced by a wide oblate 'corona' above an optically thick accretion disc. Our analysis of both precessional and orbital variability allows us to constrain

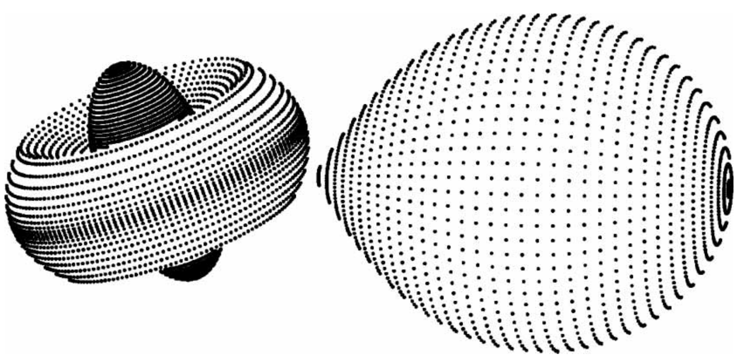

Figure 4. Sky-plane projection of the geometrical model of SS433.

the mass ratio $q = M_x/M_v = 0.3$–0.5. This implies that for the probable mass function $f_x(M) = (8 - 10)M_\odot$ the compact object mass $M_x = (4 - 12)M_\odot$ [13]. The best model X-ray light curves of SS433 and the schematic geometrical model are shown in figures 3, 4.

3. Line profiles and radial velocities synthesis for X-ray binaries

The standard method for analysing radial velocity curves of a binary is a point mass approach. However, stars in binaries can be very distorted. The synthesis method makes it possibile to

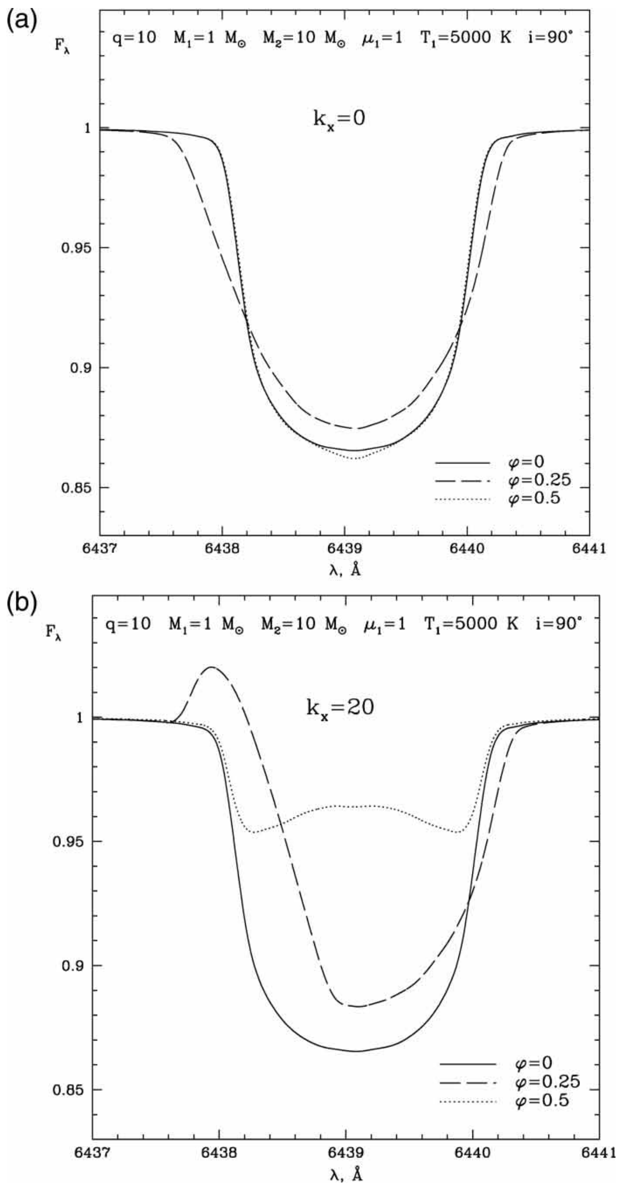

Figure 5. Orbital phase variations of the Ca I $\lambda = 6439$ Å line profiles in the spectrum of an X-ray-irradiated star for the heating parameters (a) $k_x = 0$ and (b) $k_x = 20$.

take into account the complicated shape of the components, to calculate physically the sound radial velocity curve and to obtain the correct masses of the components. This is especially important for X-ray binaries, in which an additional complication is high X-ray heating.

A new computer code for the synthesis of line profiles and radial velocities of optical stars in X-ray binary systems was suggested by Antokhina *et al.* [9, 10].

The model of the system is treated in the framework of Roche geometry. X-ray heating effects on the stellar surface (by incident radiation from the relativistic object) and absorption line profiles are calculated via solution of radiation transfer equations. Tidal deformation of the optical star and its X-ray heating lead to variations in the absorption line profiles with the orbital phase (figure 5). This variability can be used for an independent determination of the basic system parameters such as the mass ratio q of the components and the orbital inclination i.

Using this approach, we refined the mass of the black hole in the X-ray binary Cyg X-1 [14], the masses of neutron stars in the X-ray binaries Cen X-3, LMC X-4, SMC X-1, 4U 1538-52 and Vela X-1 [15] and the mass of the compact object in the low-mass binary 2S 0921-63 [16].

Acknowledgements

This work was supported by grant 05-02-17489 from the Russian Foundation for Basic Research and by grant Nsh-5218.2006.2 from the Programme for State Support of Leading Scientific Schools of the Russian Federation.

References

[1] G. Hill and J.B. Hutchings, Astrophys. J. **162** 265 (1970).
[2] R.E. Wilson and E.J. Devinney, Astrophys. J. **166** 605 (1971).
[3] D.B. Wood, Astron. J. **76** 701 (1971).
[4] R.E. Wilson, Astrophys. J. **234** 1034 (1979).
[5] E.A. Antokhina, Soviet Astron. **32** 608 (1988).
[6] E.A. Antokhina, Astron. Rep. **40** 483 (1996).
[7] E.A. Antokhina and A.M. Cherepashchuk, Soviet Astron. **31** 295 (1987).
[8] E.A. Antokhina, E.V. Seifina and A.M. Cherepashchuk, Soviet Astron. **36** 143 (1992).
[9] E.A. Antokhina, A.M. Cherepashchuk and V.V. Shimanskii, Izv. Russ. Akad. Nauk, Ser. Fiz. **67** 293 (2003).
[10] E.A. Antokhina, A.M. Cherepashchuk and V.V. Shimanskii, Astron. Rep. **49** 109 (2005).
[11] H. Sana, E. Antokhina, P. Royer *et al.*, Astron. Astrophys. **441** 213 (2005).
[12] E.A. Antokhina, A.F.J. Moffat, I.I Antokhin *et al.*, Astrophys. J. **529** 463 (2000).
[13] A.M. Cherepashchuk, R.A. Sunyaev, S.N. Fabrika *et al.*, Astron. Astrophys. **437** 561 (2005).
[14] M.K. Abubekerov, E.A. Antokhina and A.M. Cherepashchuk, Astron. Rep. **48** 550 (2004).
[15] M.K. Abubekerov, E.A. Antokhina and A.M. Cherepashchuk, Astron. Rep. **48** 89 (2004).
[16] M.K. Abubekerov, E.A. Antokhina, A.M. Cherepashchuk *et al.*, Astron. Rep. **50** 544 (2006).