







Orbital inclination change of eclipsing binaries

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Abstract

The binary stars are crucial for our knowledge about the universe. Especially, eclipsing binaries provide us a unique insight into the basic physical parameters of the stars, stellar clusters and galaxies.

Regular astronomical studies of eclipsing binaries allow us to discover a unique effect in the nature of eclipsing binaries.

One of them is the effect of nodal motion.

Eclipsing binaries with orbital inclination change (orbital precession)

- Nodal motion (orbital precession) is a change in the inclination of the orbit of binary stars.
- The effect of nodal motion (orbital precession) is determined by photometric analysis of the light curve of eclipsing binaries. We see that this effect the disappearance of both light minimums on the light curve of eclipsing binaries at the same time.
- There are several scientific ideas about the origin of this phenomenon. But still, the main reason for the occurrence of this phenomenon remains in a hypothetical state.



Conditions for orbital precession

The primary and secondary minimum depths must change • at the same time.



Conditions for orbital precession

• After the disappearance of the light minimum EB, we can get the radial velocity curve.



What new knowledge will give us the study of this effect?

- Researching of nodal motion effect helps us to determine the presence of **third body** around binary systems.
- Researching of the effect of nodal motion arises a new source of knowledge about **evolutionary theory** of binary systems.
- And it also helps us to determine invisible **black hole** near binary system. Thus, the phenomenon is very essential for further research.

Disappearance of light minima of SS Lac 10^{4} $0^{-1^{4}}$ 0^{-1

Dugan & Wright (1935), 1935AJ.....44..150D

SS Lac was discovered as an eclipsing binary star in 1935 by Dugan and Wright.

For the first time this phenomenon was observed in the nature of SS Lac, during the observation period of 1984-1985. M. Zakirov (1990) found the disappearance of the minima of the eclipsing binary SS Lac.

Eclipsing variable stars as a whole class are characterized by high stability of brightness variations, therefore, the termination of eclipses in SS Lac indicates serious changes in the system. And this is an interesting observational fact that requires a detailed study.

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However, in 24 SS Lac spectra obtained in 1997, at 8 orbital periods, orbital motion was detected along the spectral lines of both components (Tomasella, Munari, 1998). Tomasella and Munari, using these data, the parameter of the orbital elements was calculated,

(Min I = $2450716.32 (\pm 0.15) + 14.41638 (\pm 0.00010) * E$).



Tomasella and Munari (1998), 21998A+A...335..561T

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HS Hya a rapid change of inclination



During 45 years, HS Hya's orbital inclination changed to 14°. And the period of nodal motion about 631 years.

Year	Inclination [deg]	Reference
1964	88.9 ± 1.1	Strohmeier et al. (1965)
1972	85.30 ± 0.41	Gyldenkerne et al. (1975)
1991	79.83 ± 0.21	Perryman et al. (1997)
2002	76.13 ± 0.15	ASAS
2005	75.19 ± 0.28	ASAS
2008	74.60 ± 0.50	ASAS

P. Zasche1 and A. Paschke2 (2012), A&A 542, L23 (2012)

The first extragalactic eclipsing binary system with nodal motion MACHO 82.8043.71

The orbital inclination of this object changed to 14,4° during 20 years. And the period of nodal motion about 77 years.



P. Zasche and M. Wolf (2013), A&A 559, A41 (2013)

The VV Ori eclipsing binary star with nodal motion

In 1982 year, VV Ori's light curve turned out to be a total eclipse. After 30 years, the primary and secondary minimum has changed its depth and shape.

The left figure shows us that the base of the primary and secondary light curve minimums is not flat. This means that the eclipse has become partial.



John Southworth et.al. (2021), MNRAS 501, L65–L70 (2021)

List of eclipsing binaries with orbital precession (nodal motion)

System	type	RA hh:mm:ss	DEC deg:hh:ss	Vmag	EB period (day)	OP period (year)	Micro pulsation
RW Per	EA	04:20:16.76	+42:18:51.81	9.72	13.1989	?	
IU Aur	EB	05:27:52.40	+34:46:58.34	8.39	1.8115	330	
SV Gem	EA	06:00:41.01	+24:28:25.86	10.57	4.0061	?	
HS Hya	EA	10:24:36.76	-19:05:32.95	8.12	1.568	631	pulsation
V685 Cen	EA	11:24:26.61	-57:43:40.01	8.92	1.191	?	
AY Mus	EA	11:31:40.27	-65:16:16.46	10.28	3.22055	?	pulsation
V907 Sco	EA	17:56:55.56	-34:45:01.22	8.63	3.7763	68	pulsation
V699 Cyg	EA	20:17:00.33	+39:08:19.57	11.61	1.5515	?	pulsation
SS Lac	EA	22:04:41.55	+46:25:38.11	10.12	14.4162	600	
AH Cep	EB	22:47:52.94	+65:03:43.79	6.88	1.7747	?	
VV Ori	EB?	05 33 31.44	-01 09 21.85	5.34	1.48537	540	pulsation
MACHO 82.8043.171		05:29:46.19	-69:08:28.58	16.98	1.2565	77	

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We are currently researching eclipsing binaries with orbital precession. During 2019-2020 I have observed these eclipsing binaries:

- SS Lac
- HS Hya
- IU Aur
- RW Per
- SV Gem
- UZ Lyr
- V699 Cyg
- AH Cep

Now we are conducting photometric studies and studying their orbital precession.

• Light curves of some eclipsing binaries observed at Maidanak Obsevatory.



• Light curve of V699 Cyg from observations at Maidanak.



This light curve of some eclipsing binaries created basis of TESS data



0,9

0,85 0,8

1571,53

1572,03

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1819,37

1823,37

1825,37

1821,37

0,6

0,4

1817,37

6th MUM

1827,37

1572,53

Modeled light curve of eclipsing binary stars

We present results of new photometric study for the eclipsing binary star in the field of Hat-p-23b. This object identified the UCAC4 534-126251 = 2MASS 20243086+1646430) was discovered in the field of HAT-P-23. Taking into account the shape of the light curve, its period of P=0.66492 \pm 0.00012 day, amplitude of R≈0.18 mag, we classify this star as the eclipsing binary system of β Lyre (EB) type.



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Model, eclipsing binary, WD2015

 $i = 74,5 \pm 0,43 \ deg$ $T_1 = 6300 \pm 50,7 \ K$ $T_2 = 4350 \pm 22,6 \ K$ $q = 0,38123 \pm 0,0189$ Mean residual for input value = 0,113963884 Mean residual for predicted = 0,113008084 Determinant = 0,105934





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PHOTOMETRIC INVESTIGATION ECLIPSING BINARY SYSTEM IN HATP-23 b

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Abstract: We present results of new photometric study for the eclipsing binary star in the field of Hat-p-23b. (CzeV 1044 Del = USNO-B1.0 1067-0565390 = UCAC4 534-126251 = 2MASS 20243086+1646430) was discovered in the field of HAT-P-23. Taking into account the shape of the light curve, its period of P=0.6649281±0.0000027 day, amplitude of R≈0.18 mag, we classify this star as the eclipsing binary system of β Lyre (EB) type.

Key words: eclipsing binary, binary star system, astronomical observation, light curve, mathematical analysis

List of eclipsing binary stars with orbital precessions from KEPLER

In the article "Kepler eclipsing binary stars, vii, the catalog of eclipsing binaries found in the entire KEPLER DATA SET" gave a list of 43 eclipsing binary stars with changes in light minimum depth.

Thank you for your attention!