Data mining in astronomy: classification of eclipsing binaries.

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Plan

- Binary stars
- Eclipsing binary stars
- Modern catalogues and lists of eclipsing binary stars
- Classification of eclipsing binary stars
- Determination of fundamental stellar parameters and evolutionary status of close binary systems
- Astrophysical applications

Binary stars

Belgrade, Jul 1, 2010

Why study binaries?

- They are very common: perhaps 90% of stellar systems are binaries.
- There are still many puzzles to solve about their structure and evolution.
- They provide accurate data that are very difficult to determine for single stars such as masses and radii.

The direct determination of the mass of any astronomical object requires measurable gravitational interaction between at least two objects.

Gravitational interactions

- galaxy–galaxy interaction: the distances and separations are so large that no detectable motion on the plane of the sky is possible
- star–planet interaction: the objects contrast so greatly in brightness that (outside the solar system) only the highest possible precision can resolve the objects; in such cases only the star's motions are detectable, and the properties of that star must be assumed in order to deduce the properties of the planet

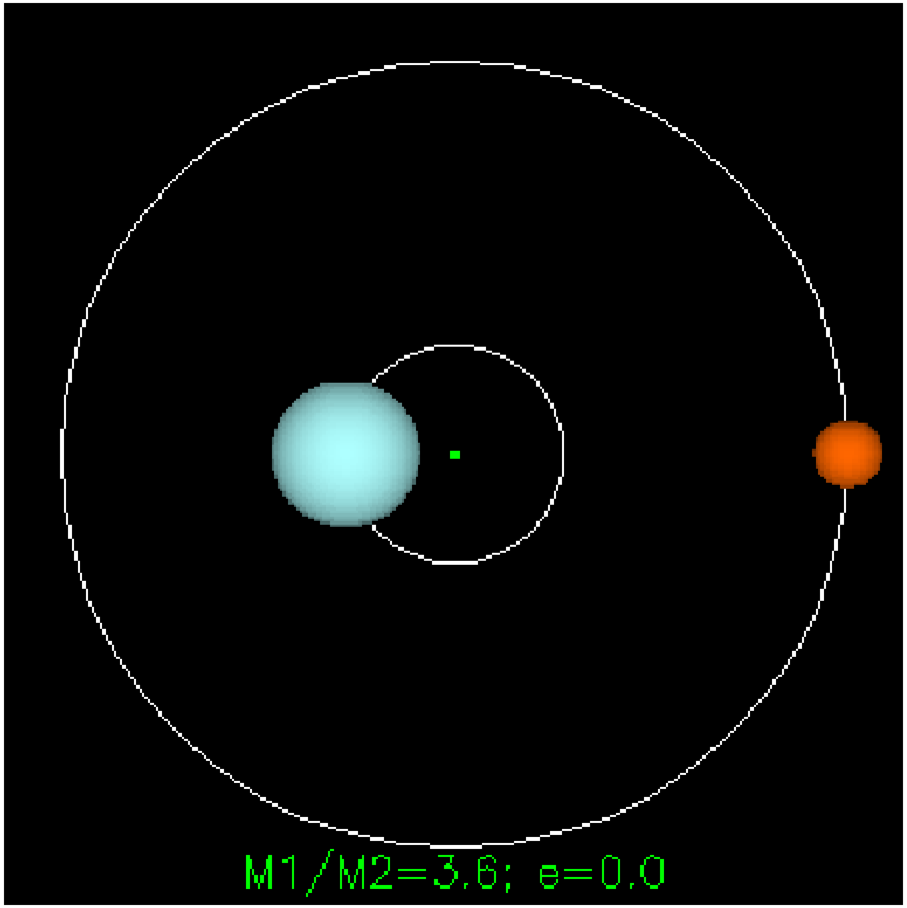
Gravitational interactions

- planet–satellite interaction: solar system only
- star–star interaction: the variations in position and velocity caused by orbital motion are detectable for a wide range of stellar separation and at least a factor of 5 in brightness (corresponds to a magnitude difference of about $1.^{m}75$)

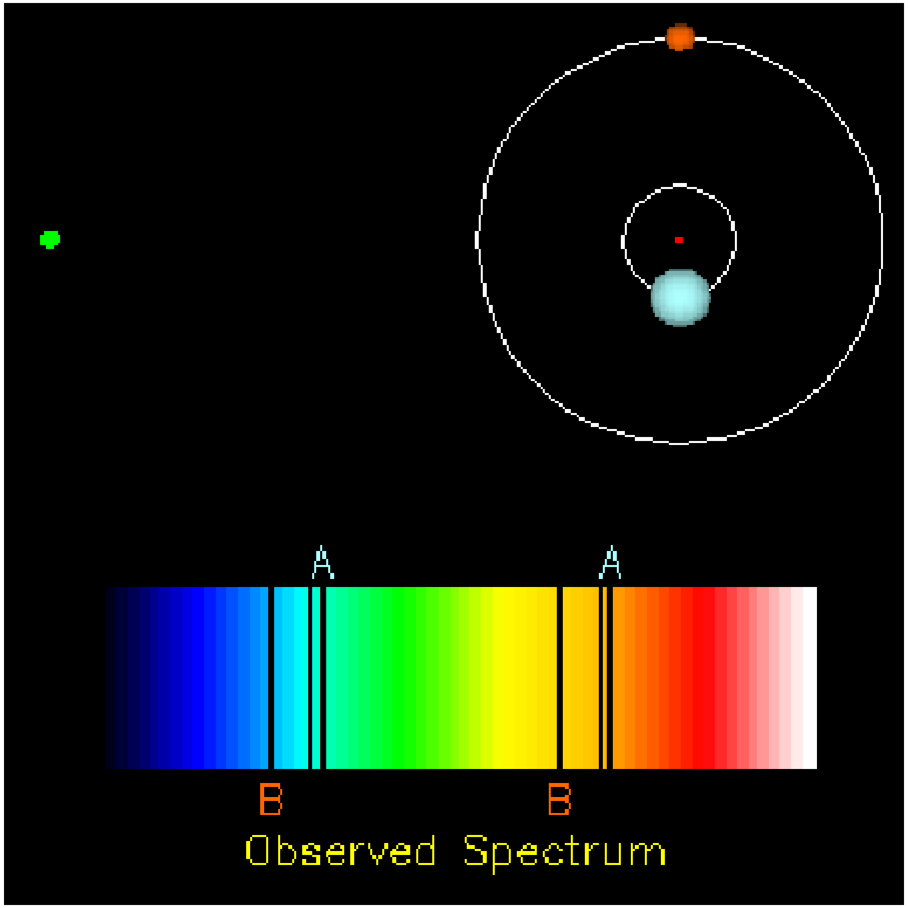
Types of binaries

- Described by the observational technique. A system is classified depending, mostly, on its semi-major axis and distance.

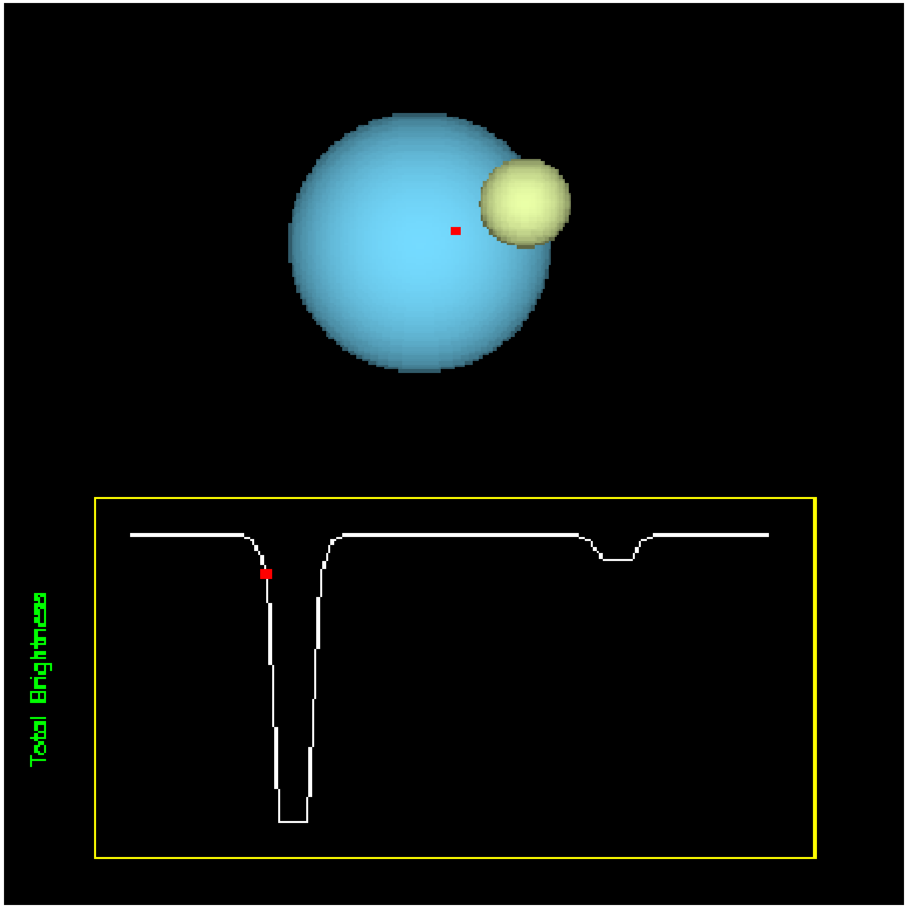
Visual binaries



Spectroscopic binaries



Eclipsing (photometric) binaries

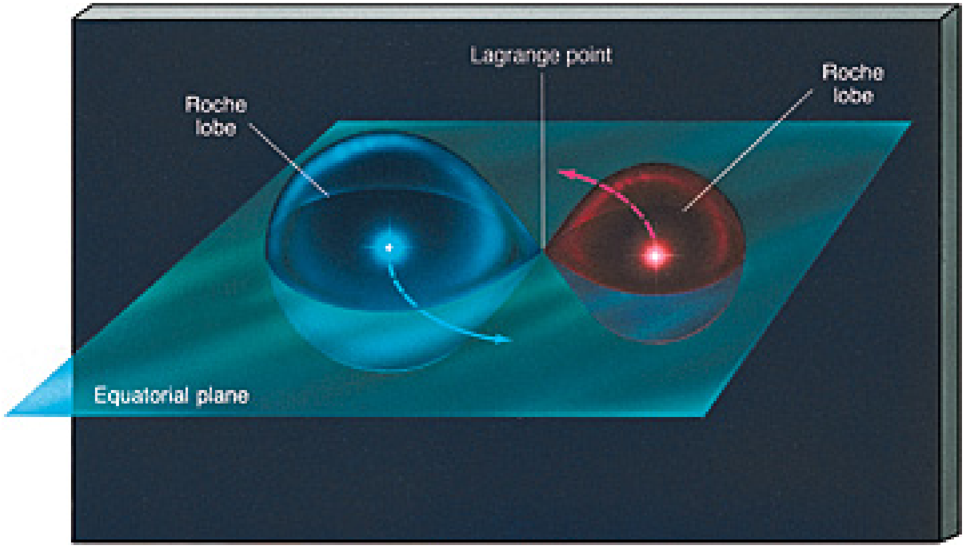


Types of binaries: Kopal scheme

- Descibed by stability within equipotential surfaces (Roche lobes).

Assumptions of the Standard Roche Model

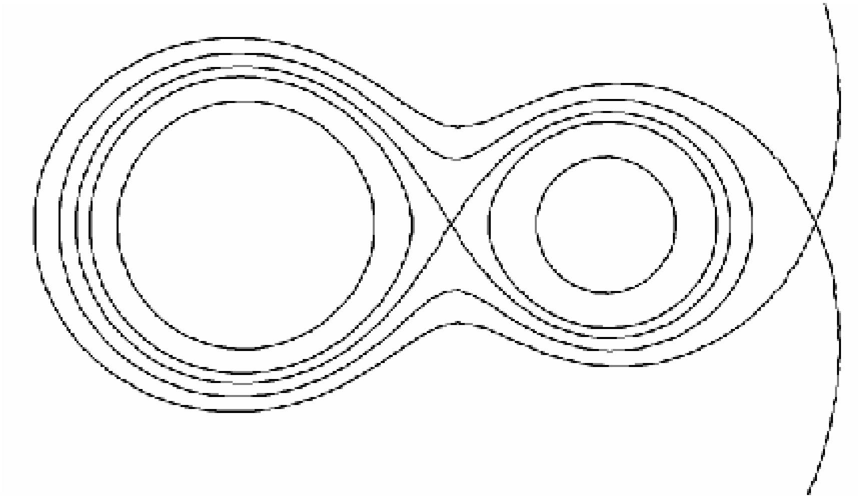
- Stars are point masses.
- Orbits are circular.
- Stars rotate synchronously.
- No radiation pressure effects.



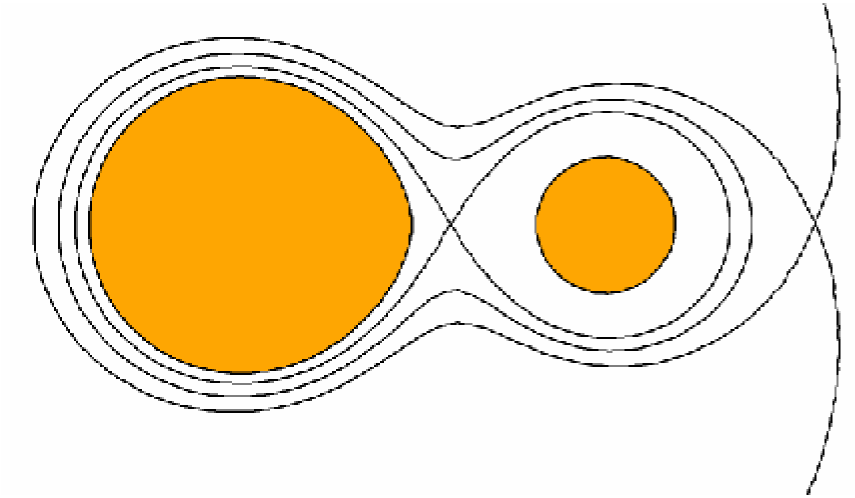
Tidal forces produce circular orbits and synchronous rotation in many interacting binaries.

Equipotentials are surfaces on which the sum of rotational and gravitational energy per unit mass is constant.

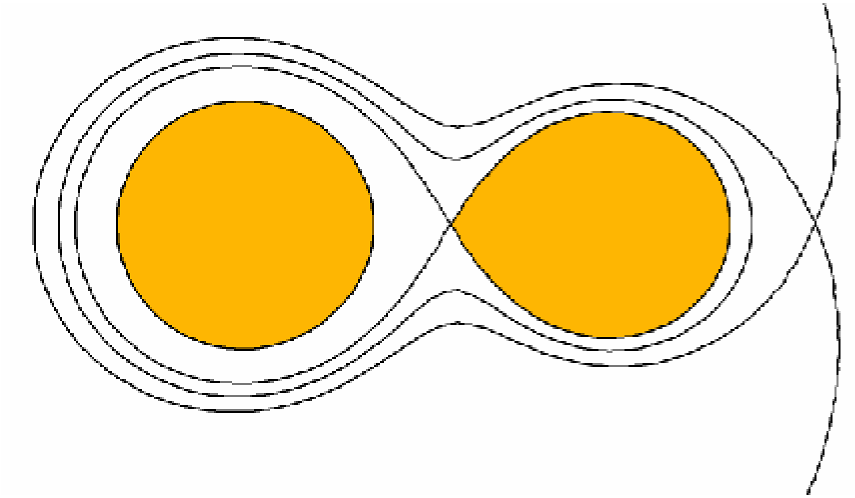
$r = f\,(a, m_1/m_2)$



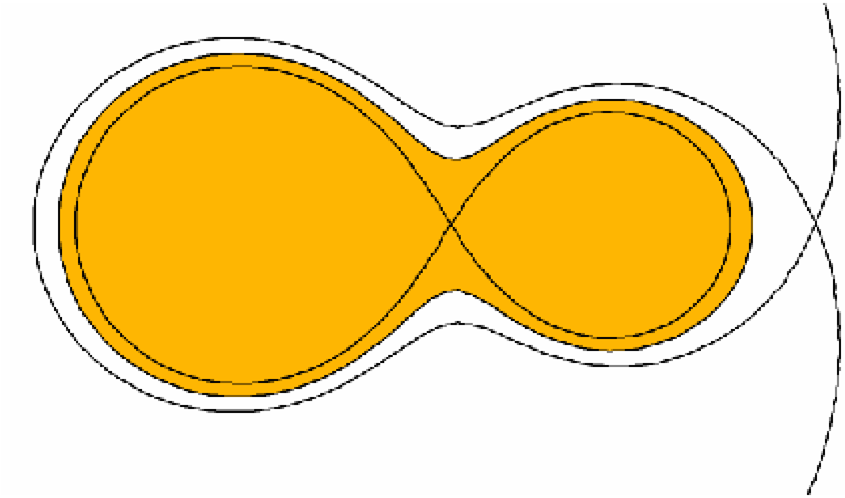
Detached (D): both components well within equipotentials



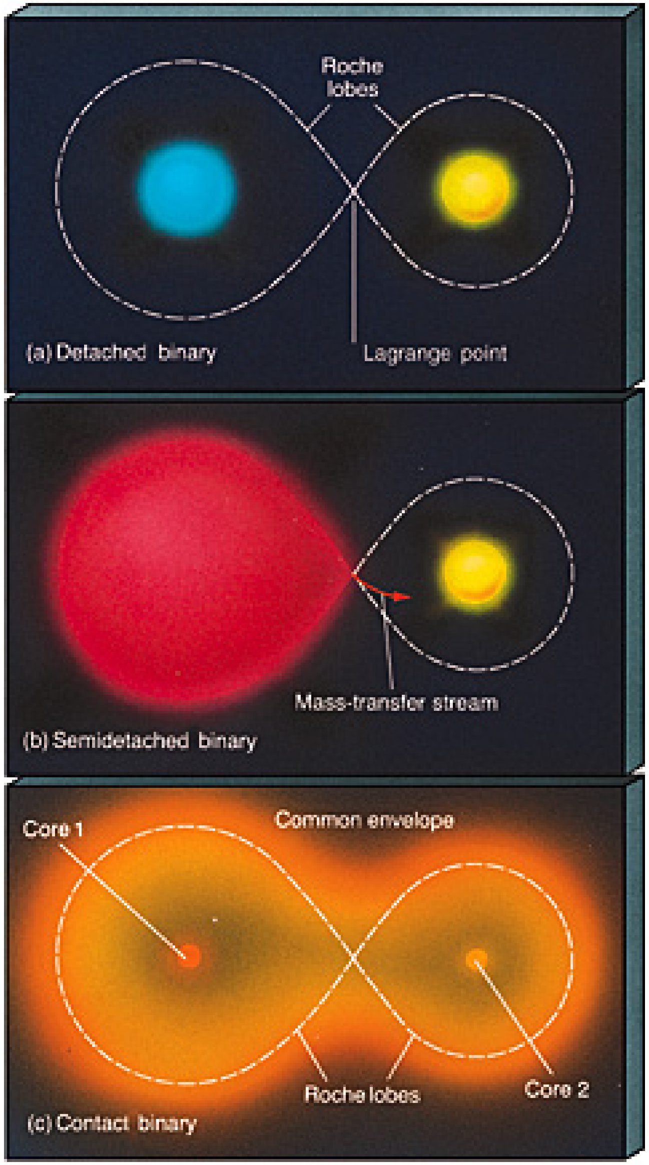
Semi-detached (SD): one component reaches equipotential



Contact (C): both components reach equipotentials

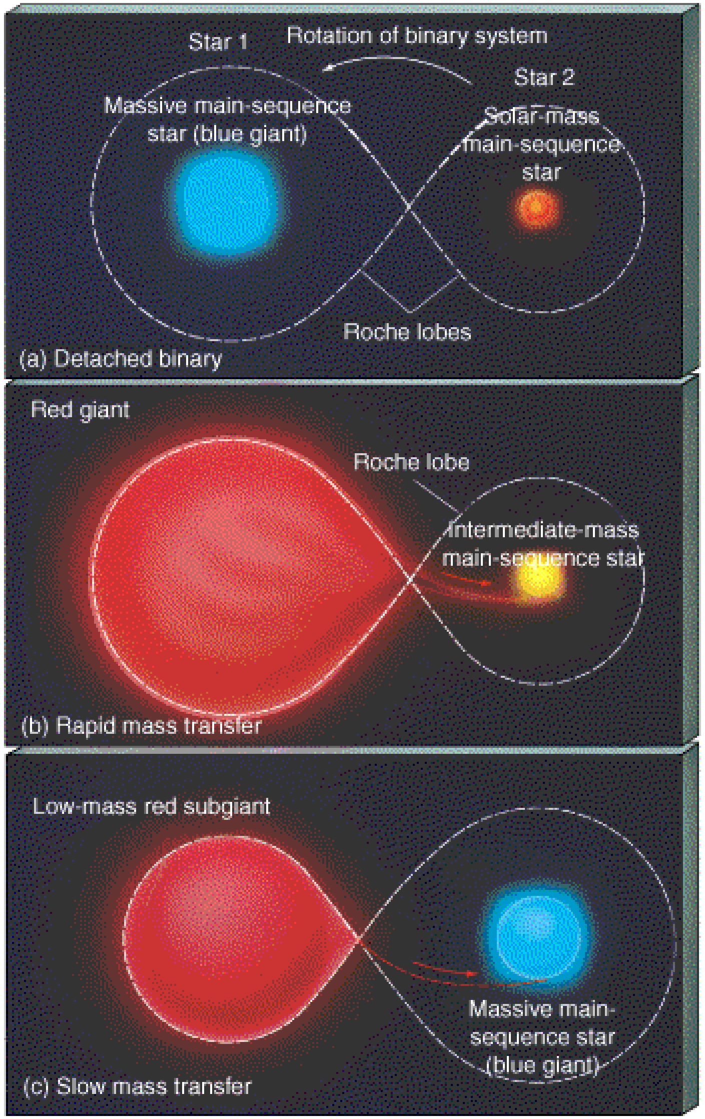


Types: resume



- In a detached binary, each star lies within its respective Roche lobe.
- In a semidetached binary, one of the stars fills its Roche lobe and transfers matter onto the other, which still lies within its own Roche lobe.
- In a contact or common-envelope binary, both stars have overflowed their Roche lobes, and a single star with two distinct nuclear-burning cores results.

The evolution of Algol


Star 1
Rotation of binary system
Star 2
Massive main-sequence star (blue giant)
Solar-mass main-sequence star
Roche lobes
(a) Detached binary
Red giant
Roche lobe
Intermediate-mass main-sequence star
(b) Rapid mass transfer
Low-mass red subgiant
Massive main-sequence star (blue giant)
(c) Slow mass transfer

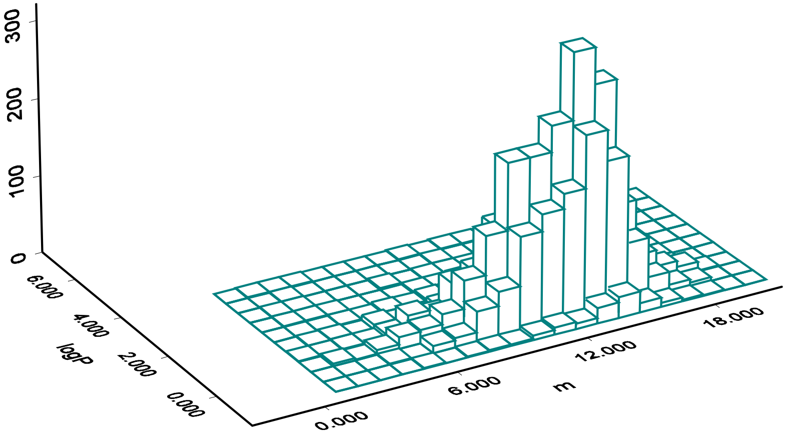
- Initially, Algol was probably a detached binary made up of two main-sequence stars —a relatively massive blue giant and a less massive companion similar to the Sun.
- As the more massive component (star 1) evolved off the main sequence it expanded to fill and eventually overflow its Roche lobe, transferring large amounts of matter onto its smaller companion (star 2).
- Today, star 2 is the more massive of the two, but it is on the main sequence. Star 1 is still in the subgiant phase and fills its Roche lobe, causing a steady stream of matter to pour onto its companion.

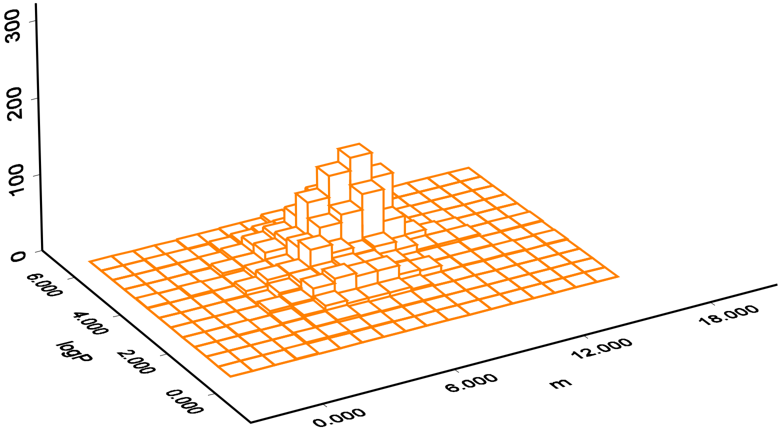
Eclipsing binary stars

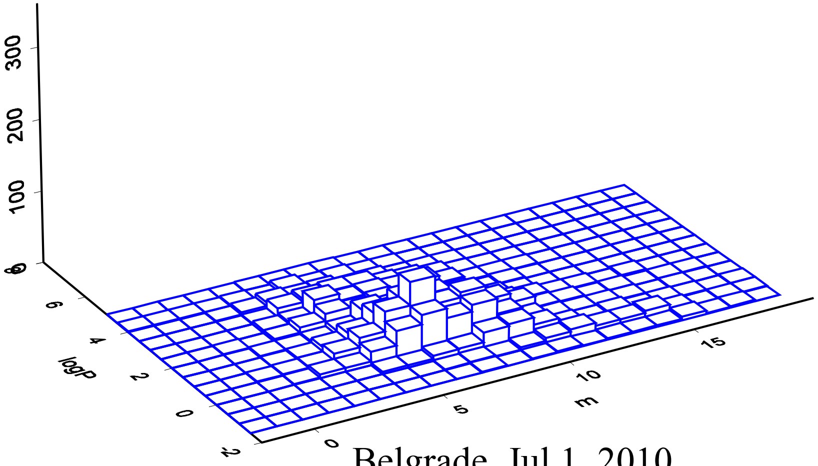
Eclipsing binaries

- Eclipsing binaries are very numerous.
- Independent stellar mass and luminosity determination is possible only for components of eclipsing binaries with the spectrum lines of the two components. However, they represent only some 5% of all known eclipsing binaries.
- So, for statistical investigations it is necessary to estimate at least approximate values of fundamental parameters (such as mass and radius) for eclipsing binaries with unknown spectroscopic elements.

Catalogued binaries: EB, VB (orbital), SB



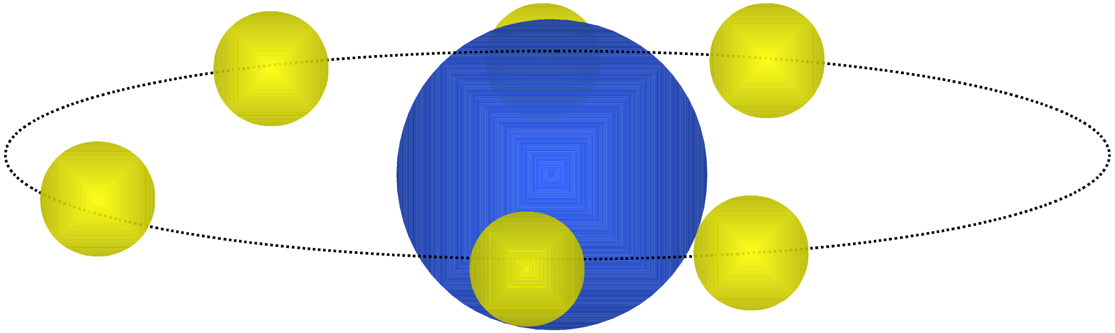


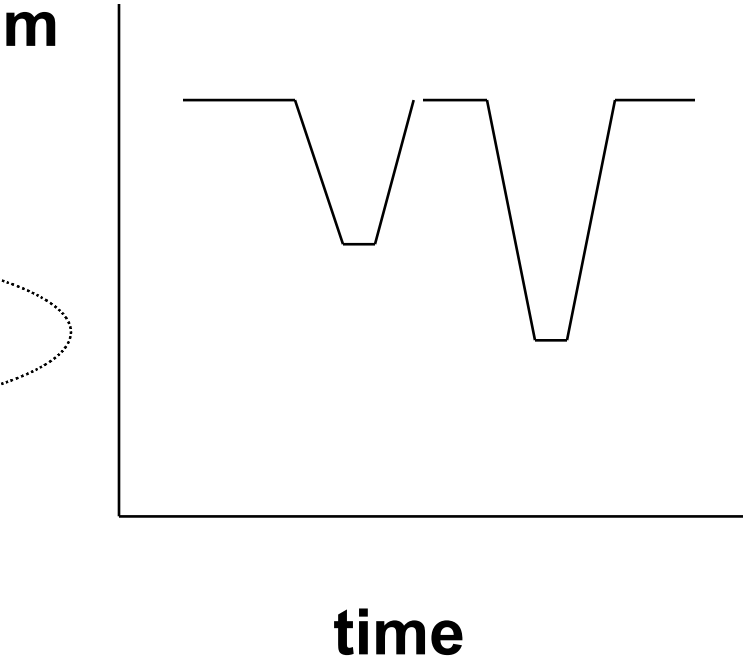


Eclipsing binaries

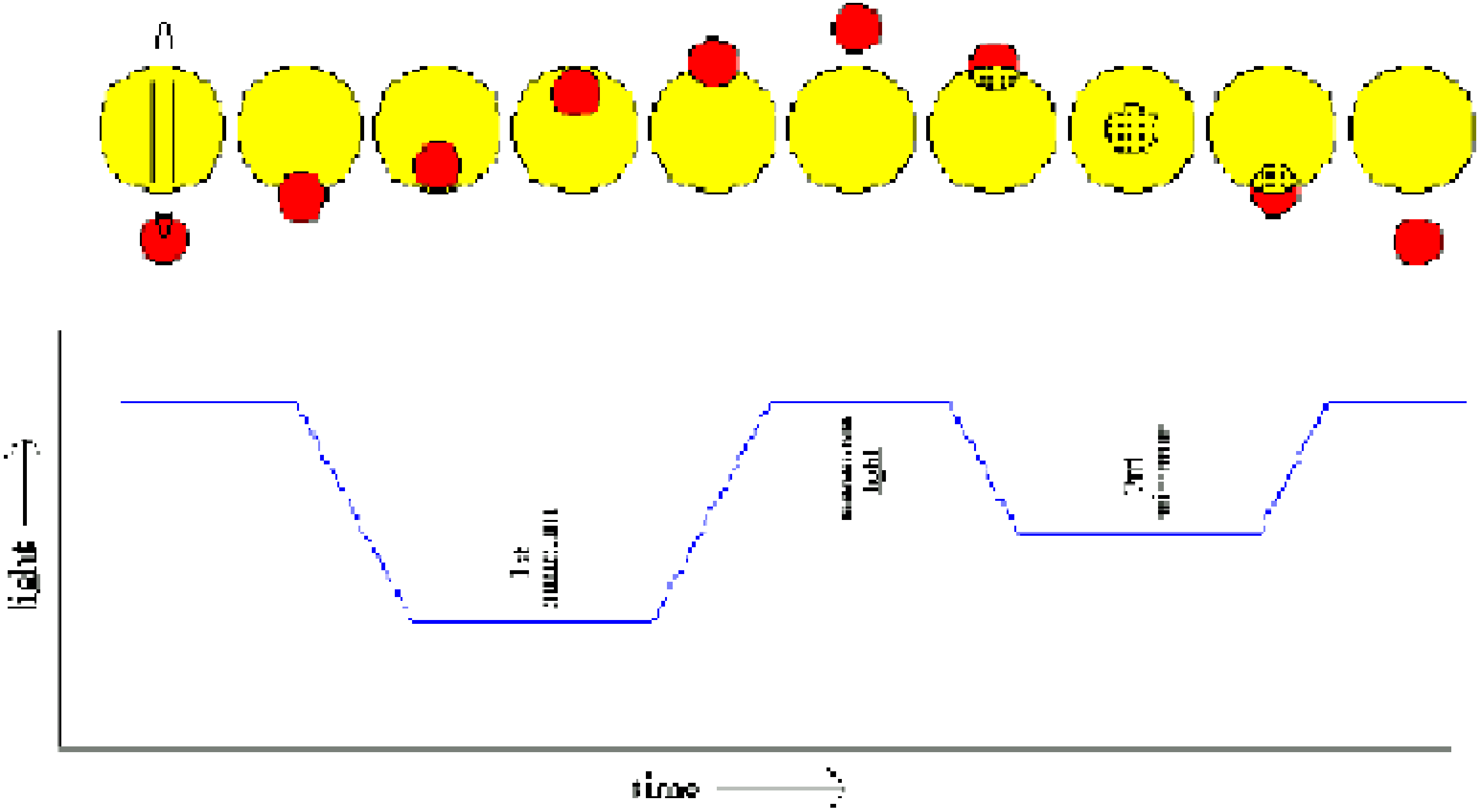
- Eclipsing (photometric) binaries are binary stars of which one at times eclipses the other, thus leading to alterations in the apparent total brightness of the combined stars. The eclipse occurs because the line of sight lies almost in the orbital plane of the stars.
- The component stars can not be observed singly, the fact that they are binary stars being shown only by the variation caused by the eclipse, i.e., by photometric methods.

Eclipsing binaries

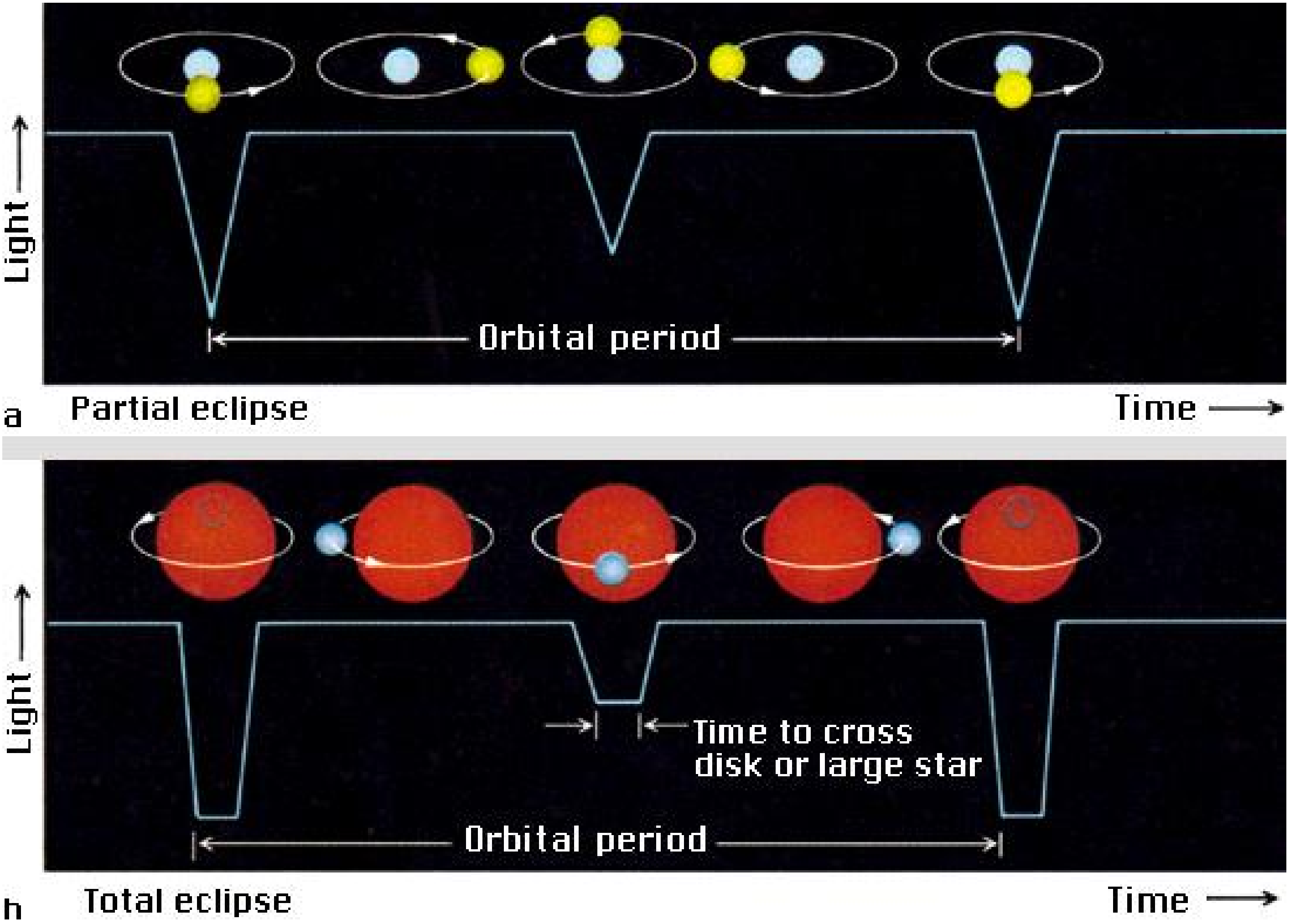




Light curve

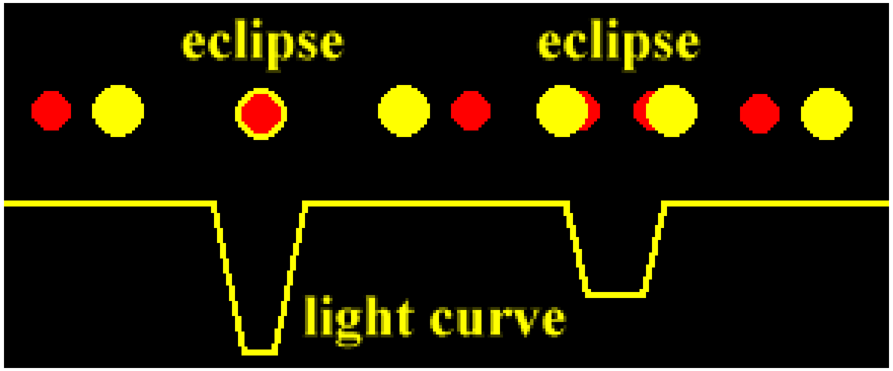


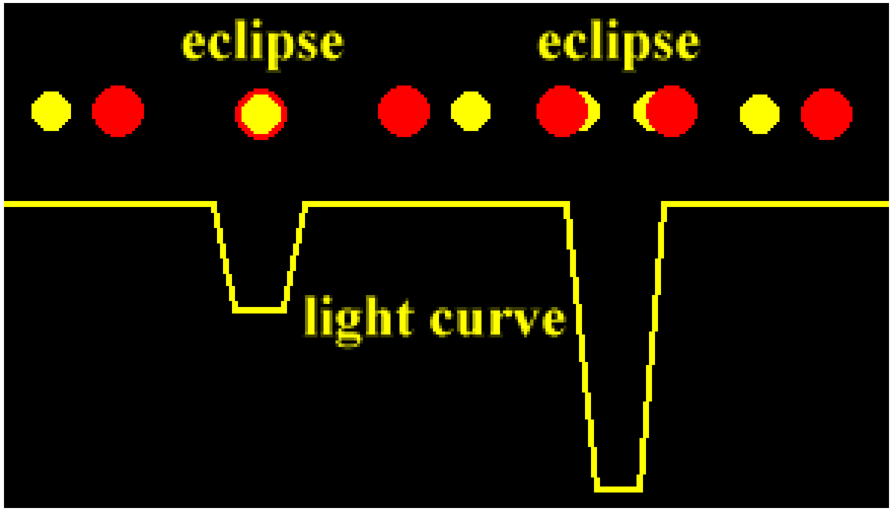
Total and partial eclipses



Eclipses and transits

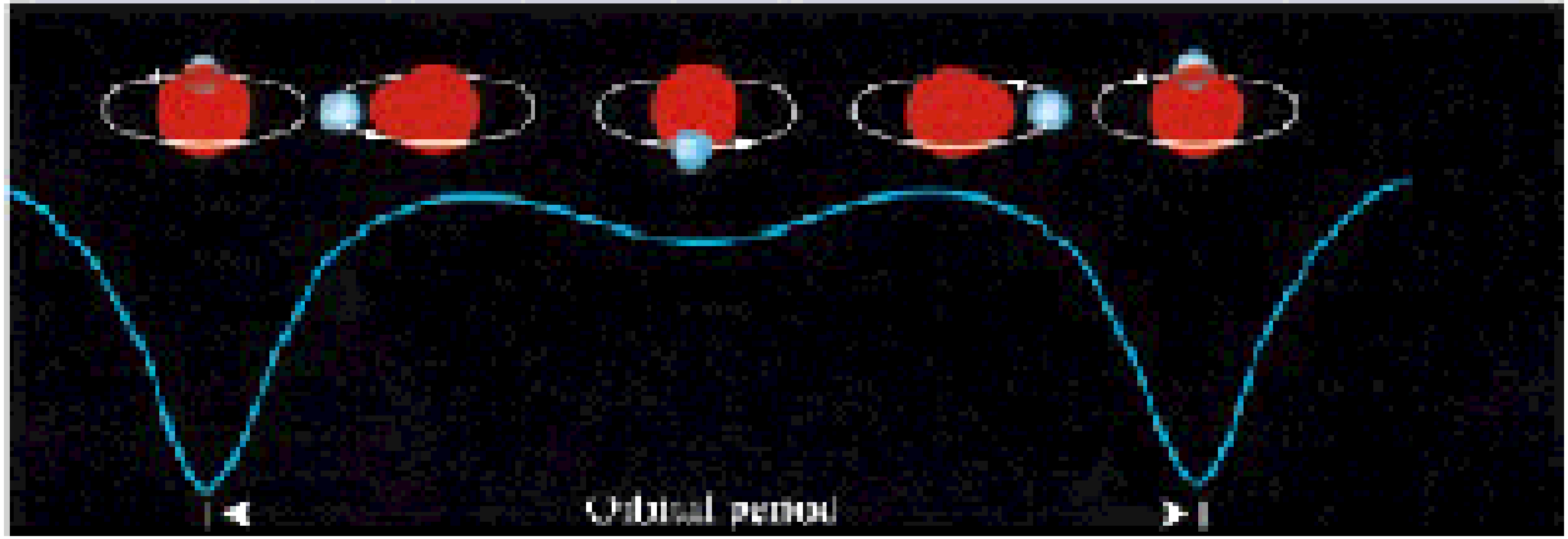
Larger component is the brighter one. Primary minimum is the transit.

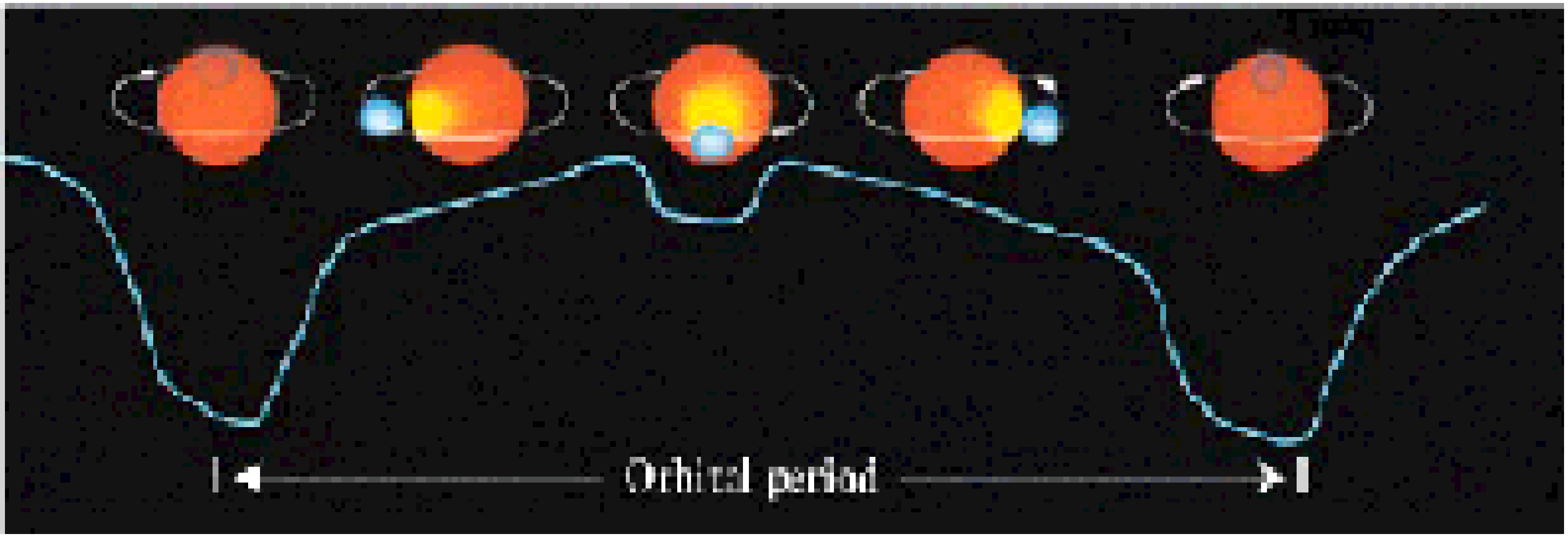




Larger component is the fainter one. Primary minimum is the eclipse.

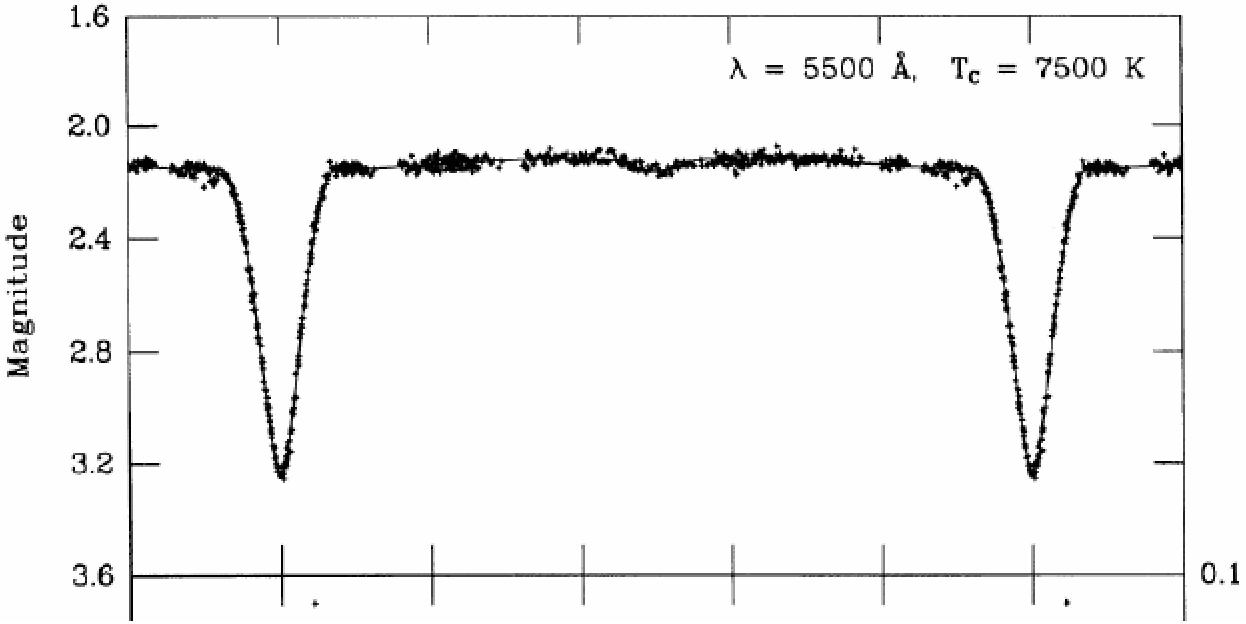
Effects of tidal distortion and reflection



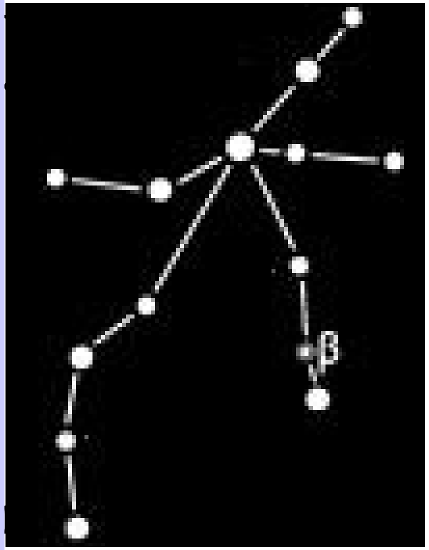


Classification based on the shape of the light curve: EA, EB, EW

- simple
- traditional
- suits the observers

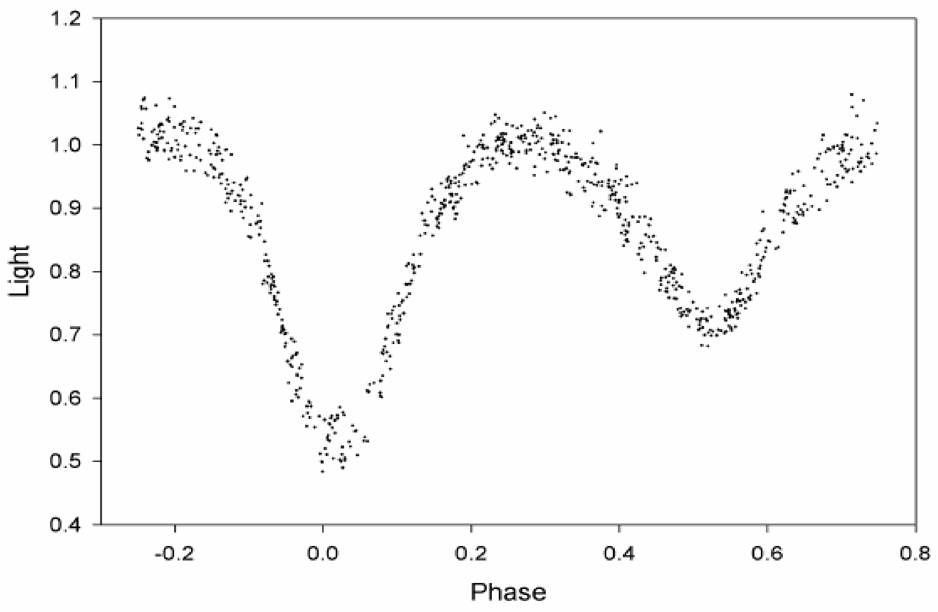


Algol



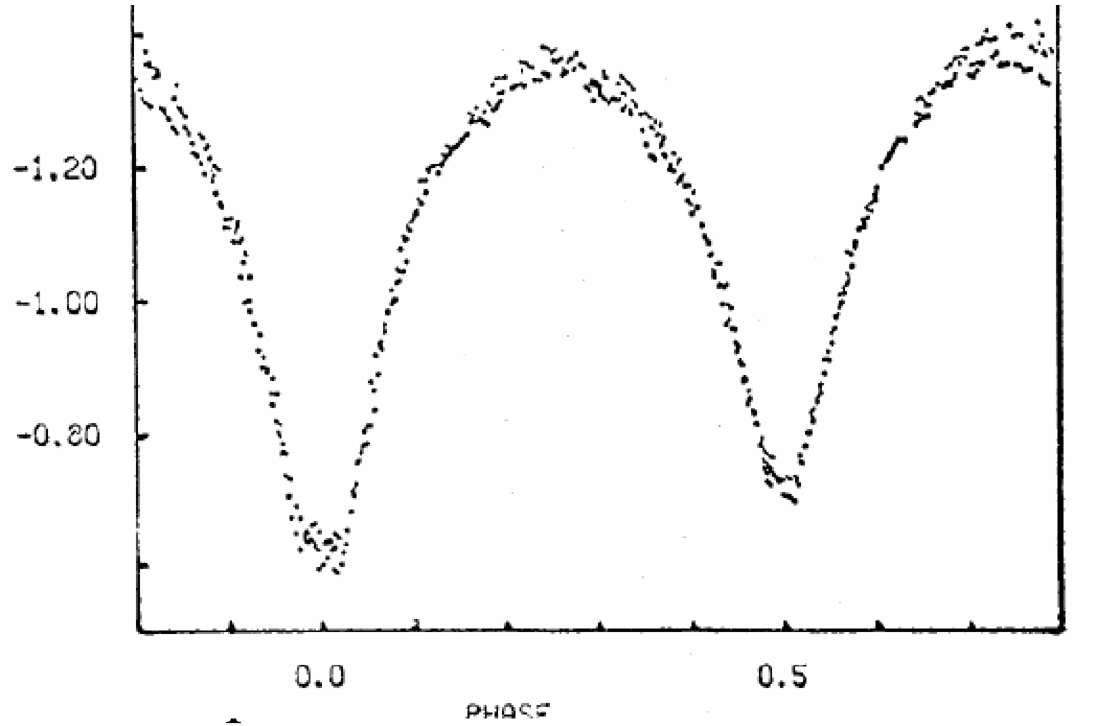
- It is possible to specify, for their light curves, the moments of the beginning and end of the eclipses.
- Between eclipses the light remains almost constant or varies insignificantly because of reflection effects, slight ellipsoidality of components, or physical variations.
- Secondary minima may be absent.
- An extremely wide range of periods is observed, $0.^{d}2 > P > 10000^{d}$.
- Light amplitudes are also quite different and may reach several magnitudes.

EB: β Lyrae – type eclipsing systems



- These are eclipsing systems
- It is impossible to specify, for their light curves, exact times of onset and end of eclipses because of a continuous change of a system's apparent combined brightness between eclipses
- Secondary minimum is observed in all cases, its depth usually being considerably smaller than that of the primary minimum
- Periods are mainly longer than 1 day.
- Light amplitudes are usually <2^m in V.
- The components generally belong to early spectral types (B-A).

EW: W Ursae Majoris – type eclipsing systems



- Systems consist of ellipso
- Systems have light curves for which it is impossible to specify the exact times of onset and end of eclipses.
- The depths of the primary and secondary minima are almost equal or differ insignificantly.
- Light amplitudes are usually $<0.^{m}8$.
- Periods are shorter than 1 day
- The components generally belong to spectral types F-G and later.

A light curve can provide relative quantities

- the relative radii of components (in units of a): $r_i=R_i/a$
- ratio of luminosities
- stellar figures
- center-to-limb variation of surface brightness (limb-darkening)
- third light (extra light of an optical or physical component)
- photometric mass ratio.

Modern catalogues and lists of eclipsing binary stars

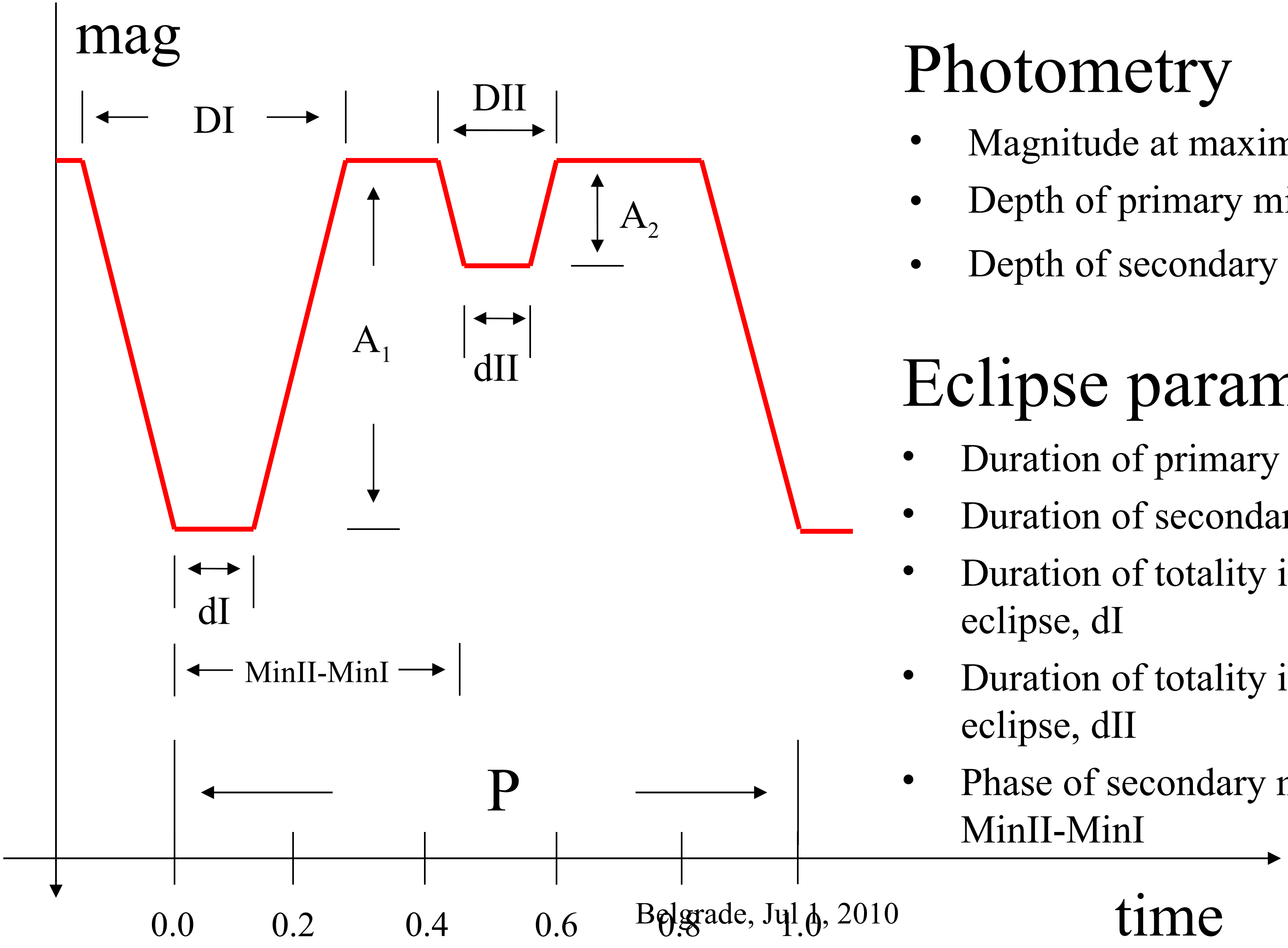
Belgrade, Jul 1, 2010

Catalogues of eclipsing variables (light-curve elements)

- General Catalogue of Variable Stars (GCVS)
- A Finding List for Observers of Interacting Binary Systems, 5th Edition
- Eclipsing variables in microlensing surveys

Light-curve elements

- Morphological type
- Epoch of primary minimum, T
- Period, P



Photometry

- Magnitude at maximum brightness
- Depth of primary minimum, A_1
- Depth of secondary minimum, A_2

Eclipse parameters

- Duration of primary eclipse, DI
- Duration of secondary eclipse, DII
- Duration of totality in primary eclipse, dI
- Duration of totality in secondary eclipse, dII
- Phase of secondary minimum, MinII-MinI

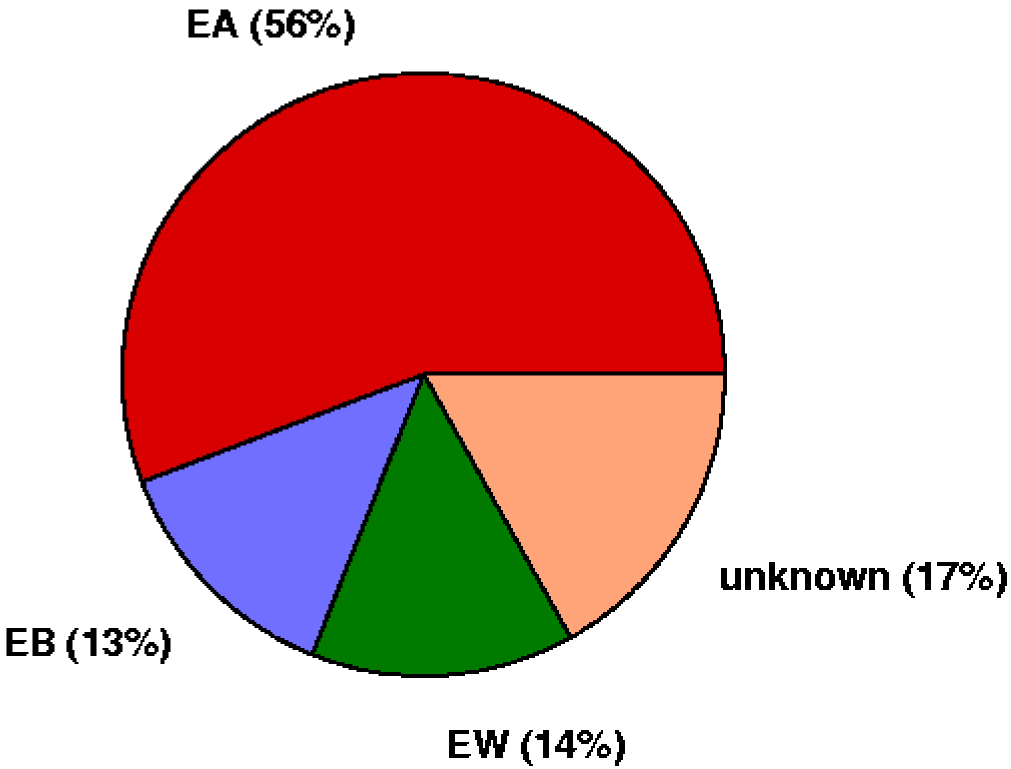
General Catalogue of Variable Stars (GCVS)

- Kholopov P.N., Samus N.N., Frolov M.S., et al.
- GCVS contains data for more than 35,000 individual variable objects discovered and named as variable stars and located mainly in the Milky Way galaxy.
- In addition to star name and position, it contains the variable type, maximum and minimum magnitude, the epoch of maximum light, period, spectral type, and references.
- All variables in the data set are arranged in the order of their names inside constellations.

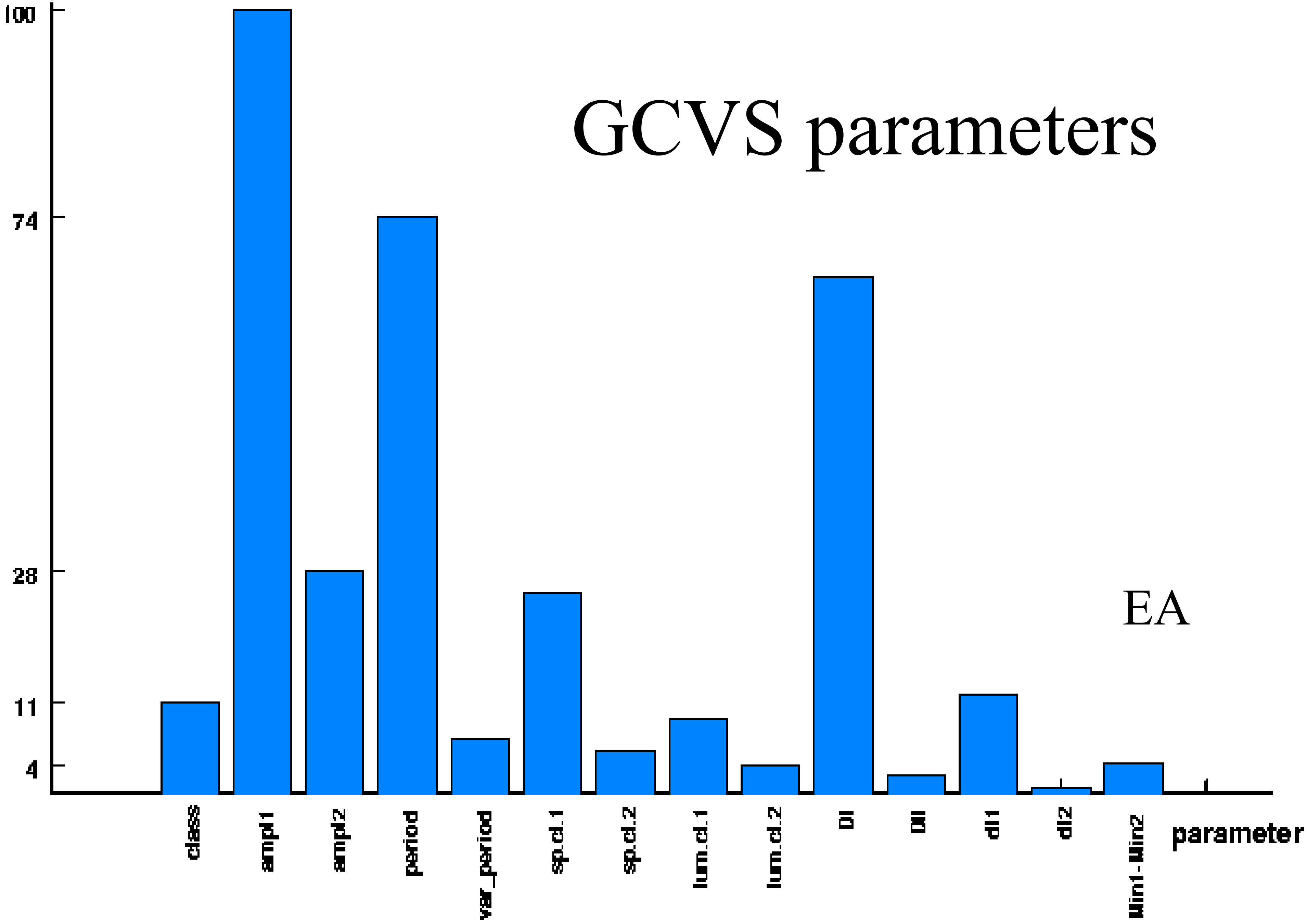
GCVS contains

- an extensive series of cross-identification tables to alternative designations
- data for variables in external galaxies (including the Magellanic Clouds) and for extragalactic supernovae
- some 6300 eclipsing variables – current edition

GCVS stars: morphological type

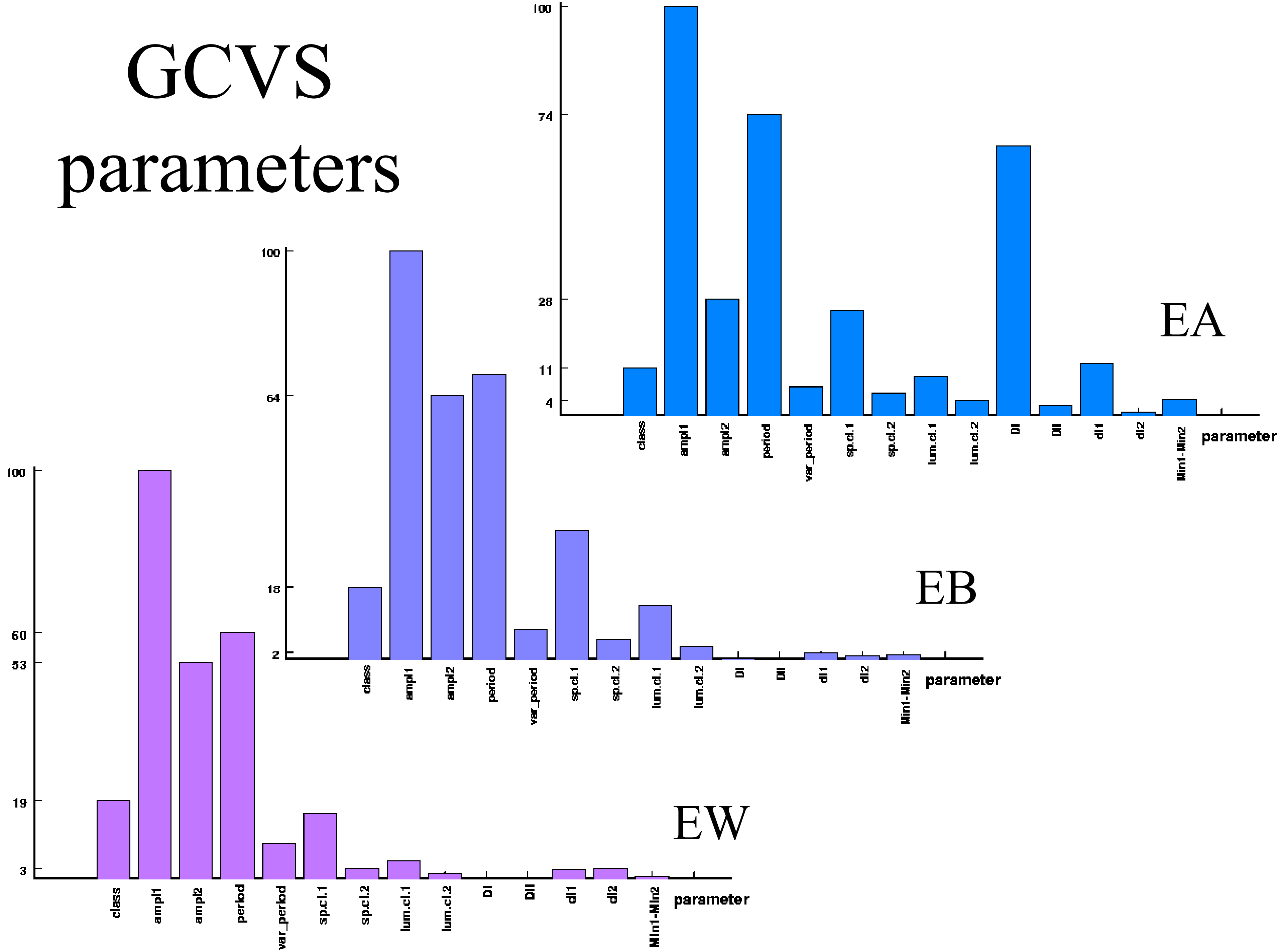


GCVS parameters



EA

GCVS parameters



A Finding List for Observers of Interacting Binary Systems, 5th Edition

- Wood F.B., Oliver J.P., Florkowski D.R., Koch R.H., 1980
- This catalogue is abstracted from the Card Catalog maintained at the University of Florida containing information on all published, and to the extent available, unpublished work on eclipsing binaries. The fifth edition differs from the previous ones in the extension of the magnitude limit at maximum light from 13^m to 15^m.
- The catalogue fields are: Finding List number; star name; position; magnitude at maximum light; depth of primary minimum; depth of secondary minimum; spectral class of star eclipsed at primary light; spectral class of star eclipsed at secondary light; epoch of primary minimum; orbital period; duration of primary minimum; duration of totality of primary minimum; BD, CoD, CPD, and HD number; alternate designations of system; codes indicating the nature of the system.
- The catalogue contains 3564 systems.

Eclipsing variables in microlensing surveys

- The nature of microlensing searches is that millions of stars are monitored for the rare occasions when the light of one is amplified by an intermediate mass along the line-of-sight.
- Since about one star in a thousand is variable, the harvest of variable stars is far greater than the harvest of massive compact halo objects.
- Number of found variable stars is well over 100,000 – several times the number in the General Catalogue of Variable Stars

Lists of eclipsing variables obtained as by-products of microlensing surveys

- The Optical Gravitational Lensing Experiment (OGLE)
- The MACHO Project (MAssive Compact Halo Objects)
- The All Sky Automated Survey (ASAS)
- Experience de Recherche d'Objets Sombres (EROS)
- Microlensing Observations in Astrophysics (MOA)

- Andromeda Galaxy Amplified Pixel Experiment (AGAPE)
- Disk Unseen Objects (DUO)
- Probing Lensing Anomalies NETwork (PLANET)

Eclipsing variables statistics

- Number of known eclipsing variables: about 6300 in GCVS (3564 in Wood–5) and about 13000 in microlensing surveys (half of them are in LMC and SMC)

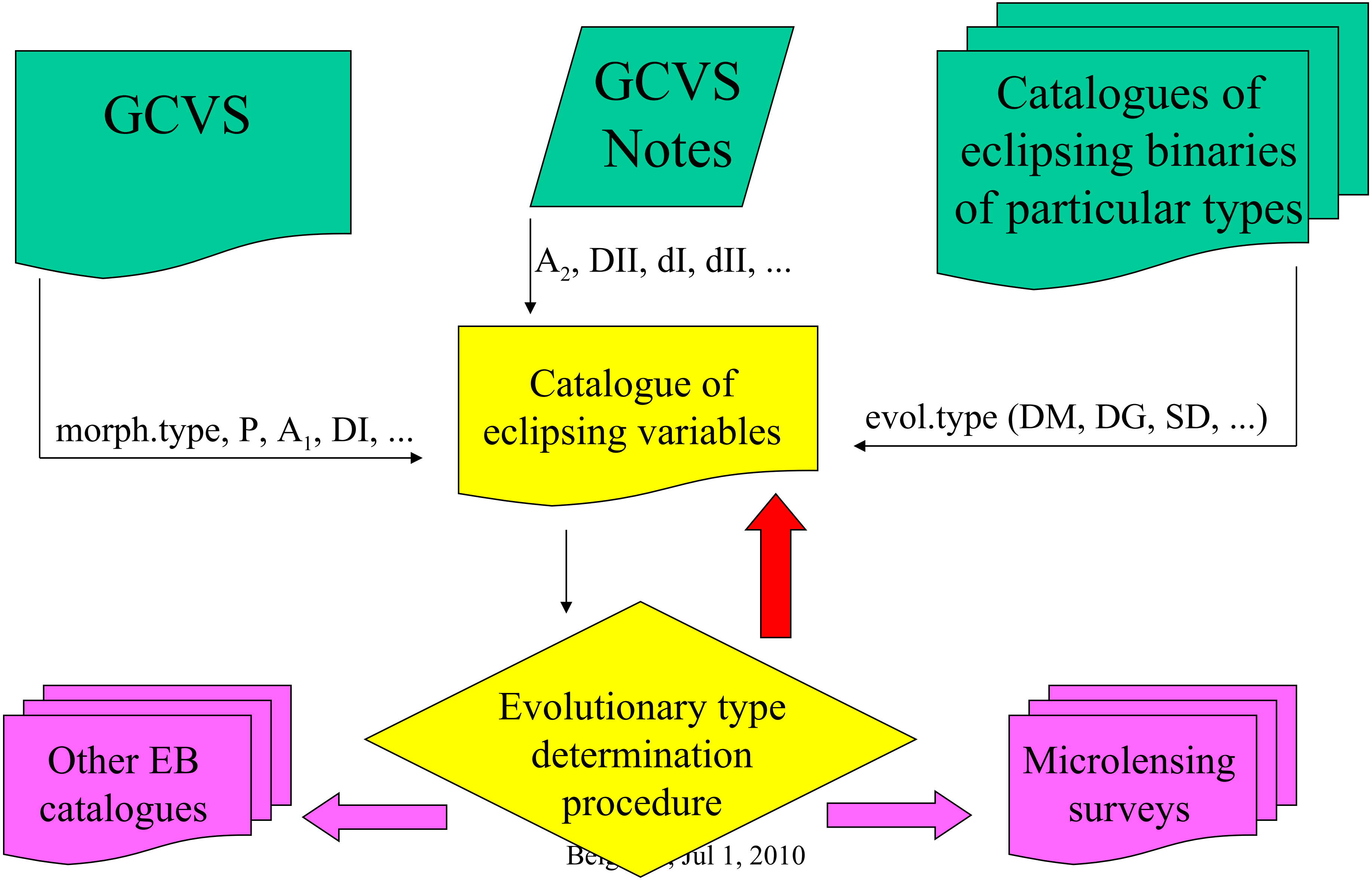
Goals

- Determination of fundamental parameters (mass, radius, temperature, luminosity etc.) of eclipsing binaries.
- Construction of fundamental relations (e.g., mass-luminosity relation) and the initial mass function.
- Specification of evolutionary state of different system types and development of a self-consistent and comprehensive evolutionary scheme for close binaries.
- Study of marginal systems.

How to do this?

- To compile a list of eclipsing variables, containing light-curve parameters and evolutionary type of systems.
- To construct a procedure for determination of system evolutionary type from observational data.
- To elaborate methods of determination of astrophysical parameters of eclipsing binary components from a limited set of observational data.
- To apply the methods to the list of eclipsing variables (with additional data on relative radii) and to construct a catalogue of fundamental parameters of eclipsing binaries.

Stage 1



GCVS

GCVS Notes

Catalogues of eclipsing binaries of particular types

A_2, DII, dI, dII, …

morph.type, P, A_1, DI, …

evol.type (DM, DG, SD, …)

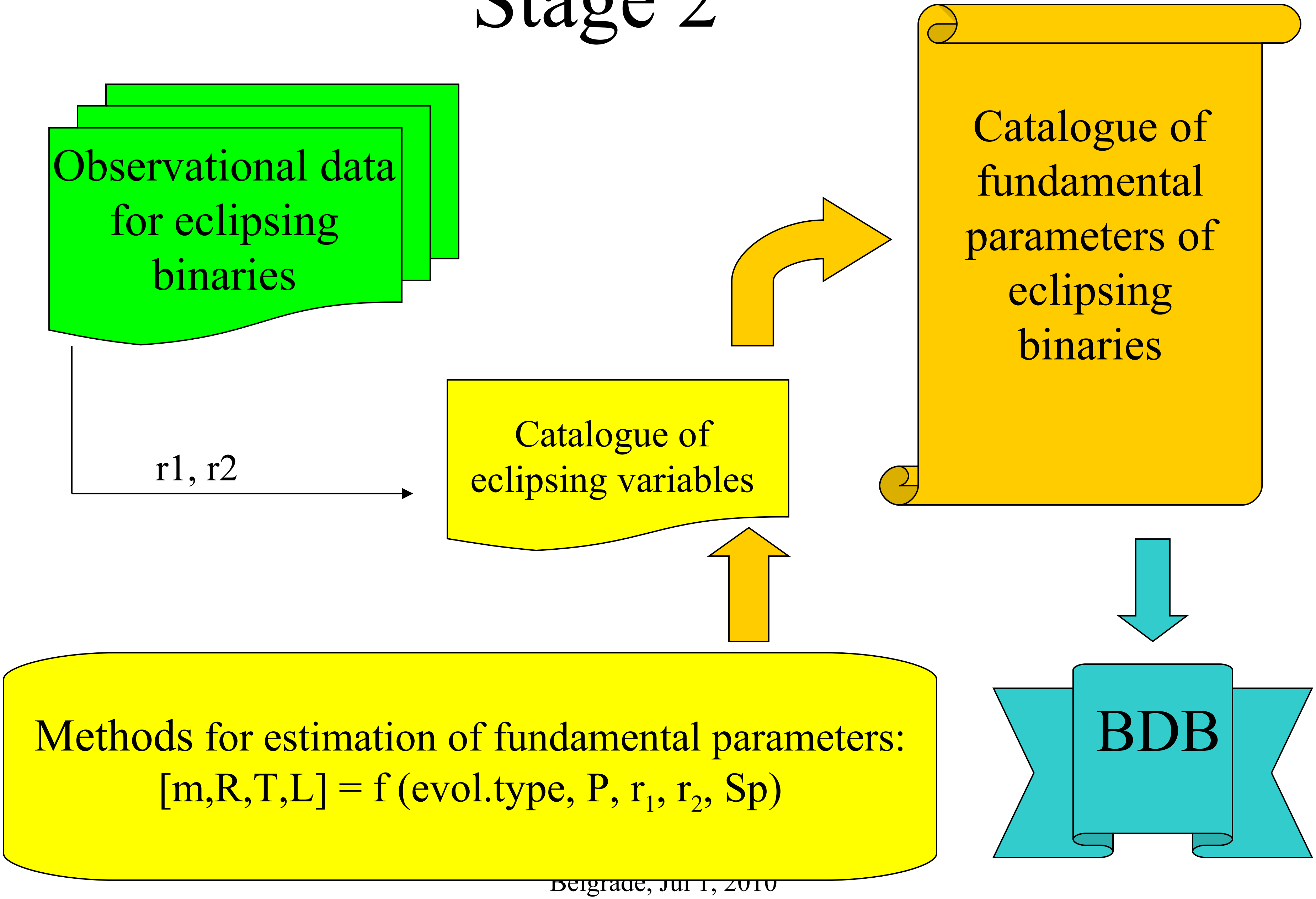
Catalogue of eclipsing variables

Evolutionary type determination procedure

Other EB catalogues

Microlensing surveys

Stage 2



Observational data for eclipsing binaries

r1, r2

Catalogue of eclipsing variables

Catalogue of fundamental parameters of eclipsing binaries

Methods for estimation of fundamental parameters:

$[m,R,T,L] = f\,(\text{evol.type}, P, r_1, r_2, Sp)$

BDB

Extraction of relevant data from GCVS and its Notes

- morphological type of the light curve (EA, EB or EW)
- maximum and minimum magnitudes
- the photometric system for magnitudes
- period of the variable
- duration of primary eclipse, DI
- spectra of components

Extraction of relevant data from GCVS and its Notes

- secondary minimum magnitude
- period variability indication
- duration of secondary eclipse, DII
- duration of totality in primary and in secondary eclipses, dI and dII
- phase of secondary eclipse, MinII-MinI

Specification of a classification scheme for eclipsing binaries

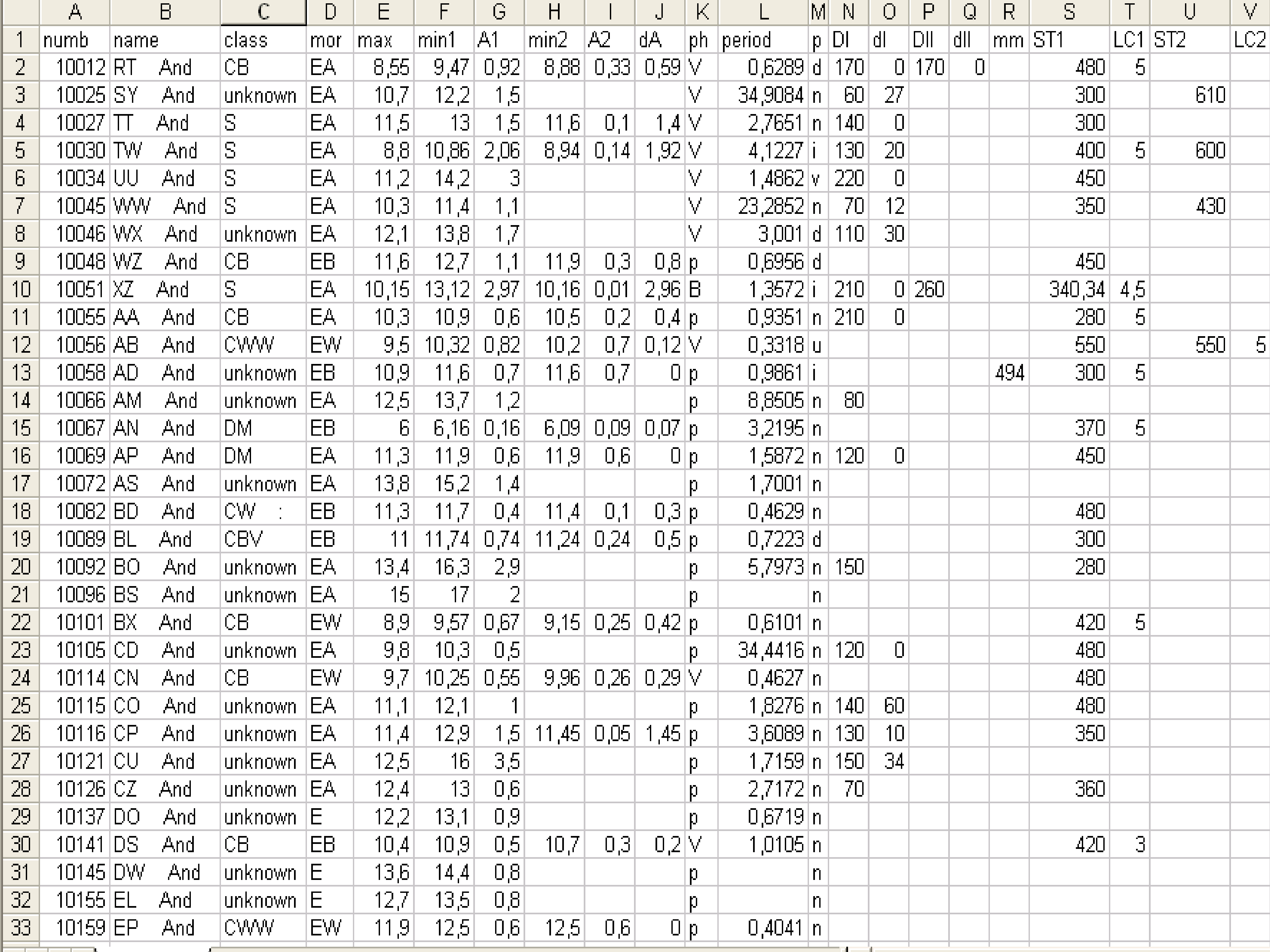
- DM: Detached main sequence systems
- DR: Detached subgiant system
- DG: Detached giant or supergiant system
- S: Semi-detached system
- C: Contact system of unknown sub-class
  - CB: Near-contact system of unknown sub-class
    - CBF: Near-contact F system
    - CBV: Near-contact V system
  - CE: Early-type contact system
  - CW: Late-type contact system of unknown sub-class
    - CWA: Late-type contact A system
    - CWW: Late-type contact W system

Preparation for use of Svechnikov et al's catalogues

- The catalogue of orbital elements, masses and luminosities of detached main-sequence eclipsing variable stars with known photometric and spectroscopic elements. M.A.Svechnikov, E.L.Perevozkina, 1999.
- The catalogue of orbital elements, masses and luminosities of detached main-sequence eclipsing variable stars with known elements of photometric orbit and unknown spectroscopic elements. E.L.Perevozkina, M.A.Svechnikov, 1999.
- The catalogue of photometric, geometrical and absolute elements of semidetached eclipsing binary systems with known spectroscopic orbits. L.P.Surkova, M.A.Svechnikov, 2005.
- The catalogue of photometric, geometrical and absolute elements of semidetached eclipsing binary systems with known photometric orbits and unknown spectroscopic orbits. L.P.Surkova, M.A.Svechnikov, 2005.
- The catalogue of orbital elements, masses and luminosities of short-period RS CVn systems. G.N.Dryomova, E.L.Perevozkina, M.A.Svechnikov, 2004.

Other catalogues of binaries – sources of independent classifiers

- Pribulla et al. (2003) – contact systems
- Budding et al. (2004) – semi-detached systems
- Shaw (1994) – near-contact systems
- Popper & Ulrich (1977) – subgiant detached systems
- Popper (1980), Malkov (1993) – various types

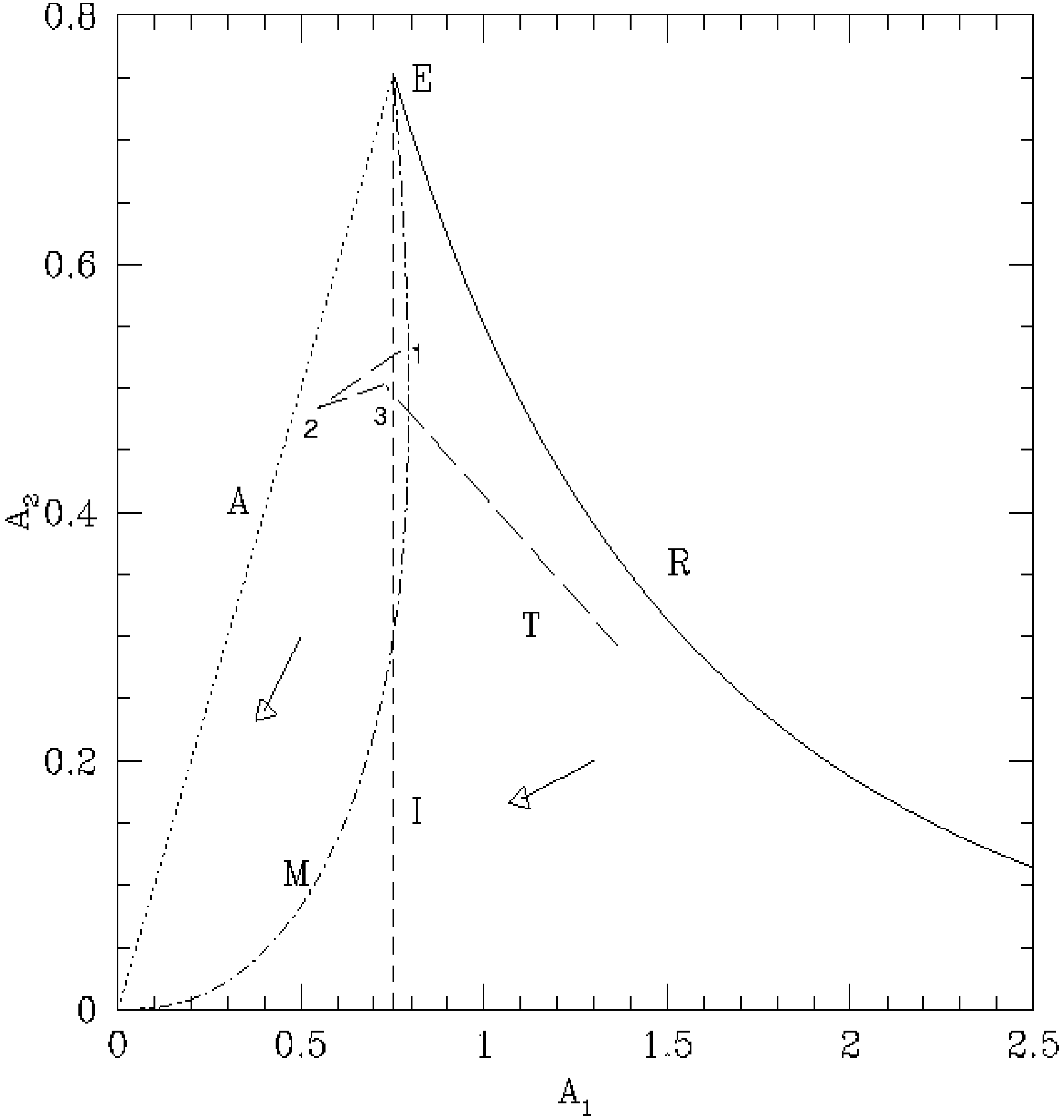


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	numb	name	class	mor	max	min1	A1	min2	A2	dA	ph	period	p	DI	dI	DII	dII	mm	ST1	LC1	ST2	LC2
2	10012	RT And	CB	EA	8,55	9,47	0,92	8,88	0,33	0,59	V	0,6289	d	170	0	170	0		480	5		
3	10025	SY And	unknown	EA	10,7	12,2	1,5				V	34,9084	n	60	27				300		610	
4	10027	TT And	S	EA	11,5	13	1,5	11,6	0,1	1,4	V	2,7651	n	140	0				300			
5	10030	TW And	S	EA	8,8	10,86	2,06	8,94	0,14	1,92	V	4,1227	i	130	20				400	5	600	
6	10034	UU And	S	EA	11,2	14,2	3				V	1,4862	v	220	0				450			
7	10045	WW And	S	EA	10,3	11,4	1,1				V	23,2852	n	70	12				350		430	
8	10046	WX And	unknown	EA	12,1	13,8	1,7				V	3,001	d	110	30							
9	10048	WZ And	CB	EB	11,6	12,7	1,1	11,9	0,3	0,8	p	0,6956	d						450			
10	10051	XZ And	S	EA	10,15	13,12	2,97	10,16	0,01	2,96	B	1,3572	i	210	0	260			340,34	4,5		
11	10055	AA And	CB	EA	10,3	10,9	0,6	10,5	0,2	0,4	p	0,9351	n	210	0				280	5		
12	10056	AB And	CWW	EW	9,5	10,32	0,82	10,2	0,7	0,12	V	0,3318	u						550		550	5
13	10058	AD And	unknown	EB	10,9	11,6	0,7	11,6	0,7	0	p	0,9861	i					494	300	5		
14	10066	AM And	unknown	EA	12,5	13,7	1,2				p	8,8505	n	80								
15	10067	AN And	DM	EB	6	6,16	0,16	6,09	0,09	0,07	p	3,2195	n						370	5		
16	10069	AP And	DM	EA	11,3	11,9	0,6	11,9	0,6	0	p	1,5872	n	120	0				450			
17	10072	AS And	unknown	EA	13,8	15,2	1,4				p	1,7001	n									
18	10082	BD And	CW :	EB	11,3	11,7	0,4	11,4	0,1	0,3	p	0,4629	n						480			
19	10089	BL And	CBV	EB	11	11,74	0,74	11,24	0,24	0,5	p	0,7223	d						300			
20	10092	BO And	unknown	EA	13,4	16,3	2,9				p	5,7973	n	150					280			
21	10096	BS And	unknown	EA	15	17	2				p		n									
22	10101	BX And	CB	EW	8,9	9,57	0,67	9,15	0,25	0,42	p	0,6101	n						420	5		
23	10105	CD And	unknown	EA	9,8	10,3	0,5				p	34,4416	n	120	0				480			
24	10114	CN And	CB	EW	9,7	10,25	0,55	9,96	0,26	0,29	V	0,4627	n						480			
25	10115	CO And	unknown	EA	11,1	12,1	1				p	1,8276	n	140	60				480			
26	10116	CP And	unknown	EA	11,4	12,9	1,5	11,45	0,05	1,45	p	3,6089	n	130	10				350			
27	10121	CU And	unknown	EA	12,5	16	3,5				p	1,7159	n	150	34							
28	10126	CZ And	unknown	EA	12,4	13	0,6				p	2,7172	n	70					360			
29	10137	DO And	unknown	E	12,2	13,1	0,9				p	0,6719	n									
30	10141	DS And	CB	EB	10,4	10,9	0,5	10,7	0,3	0,2	V	1,0105	n						420	3		
31	10145	DW And	unknown	E	13,6	14,4	0,8				p		n									
32	10155	EL And	unknown	E	12,7	13,5	0,8				p		n									
33	10159	EP And	CWW	EW	11,9	12,5	0,6	12,5	0,6	0	p	0,4041	n									

Construction of a new procedure: list of rules used for classification

- Light curve morphological type allowable values
- A_1-A_2 (depths of primary and secondary minima) relation for detached systems
- A_1-A_2 relation for detached MS systems
- $A_1.A_2$ and dA (=A_1–A_2) upper limits
- P (period) upper and lower limits
- P variation allowable values
- Duration of eclipses difference (DI-DII) ranges
- Phase of secondary minimum MinII-MinI ranges
- Primary and secondary spectral type (Sp_1, Sp_2) ranges
- Primary and secondary luminosity class (LC_1, LC_2) ranges

Theoretical location of detached systems with total eclipses in the A_1-A_2 plane



A: systems with A_1=A_2.

R: systems with components of equal radii, upper limit for detached systems.

I: left limit for systems, where brighter component is smaller.

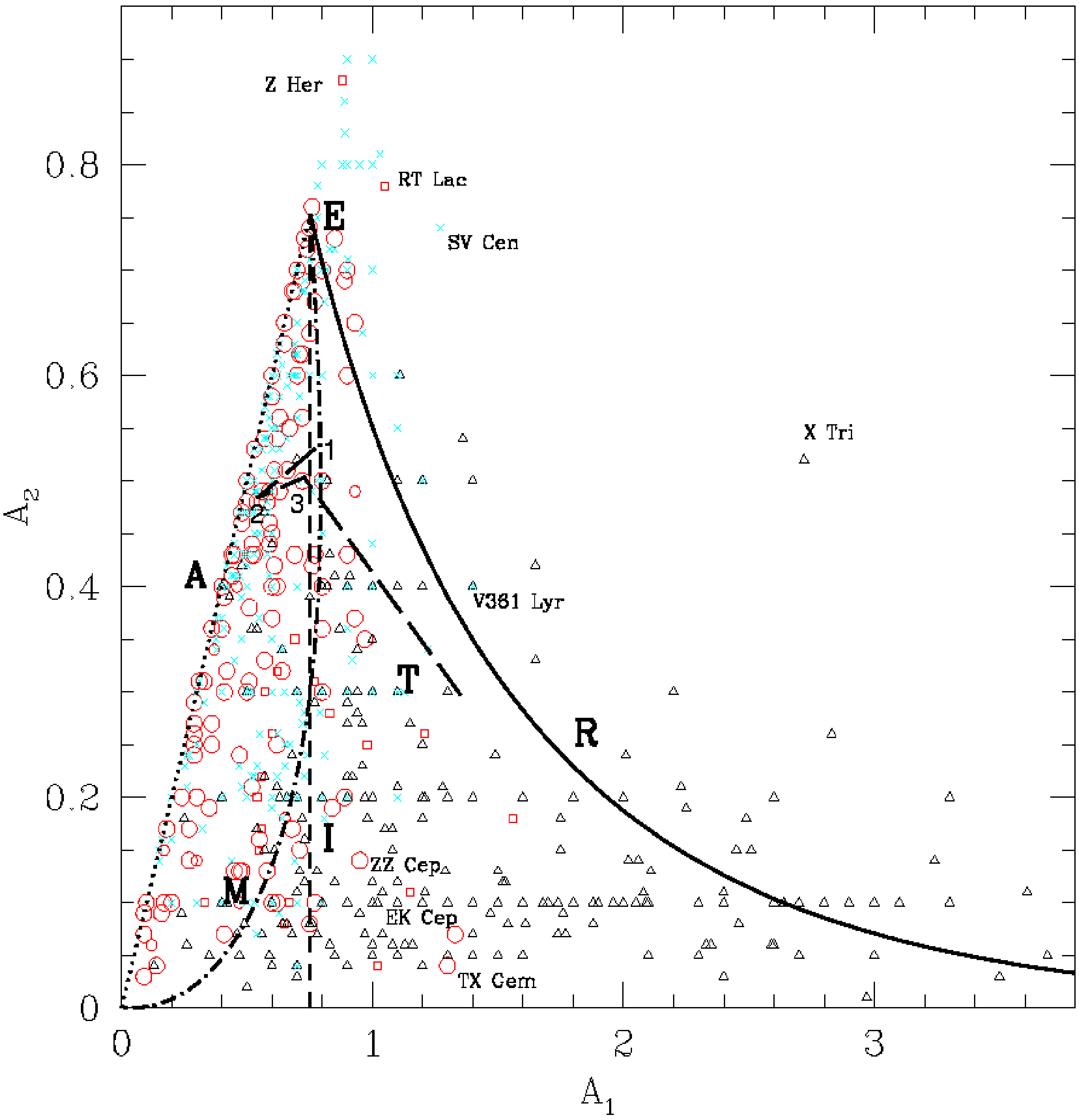
M: approximate relation for MS stars.

T: evolutionary track of a 2.8$m_{\odot}$ + 2.5$m_{\odot}$ system.

E: systems with identical components.

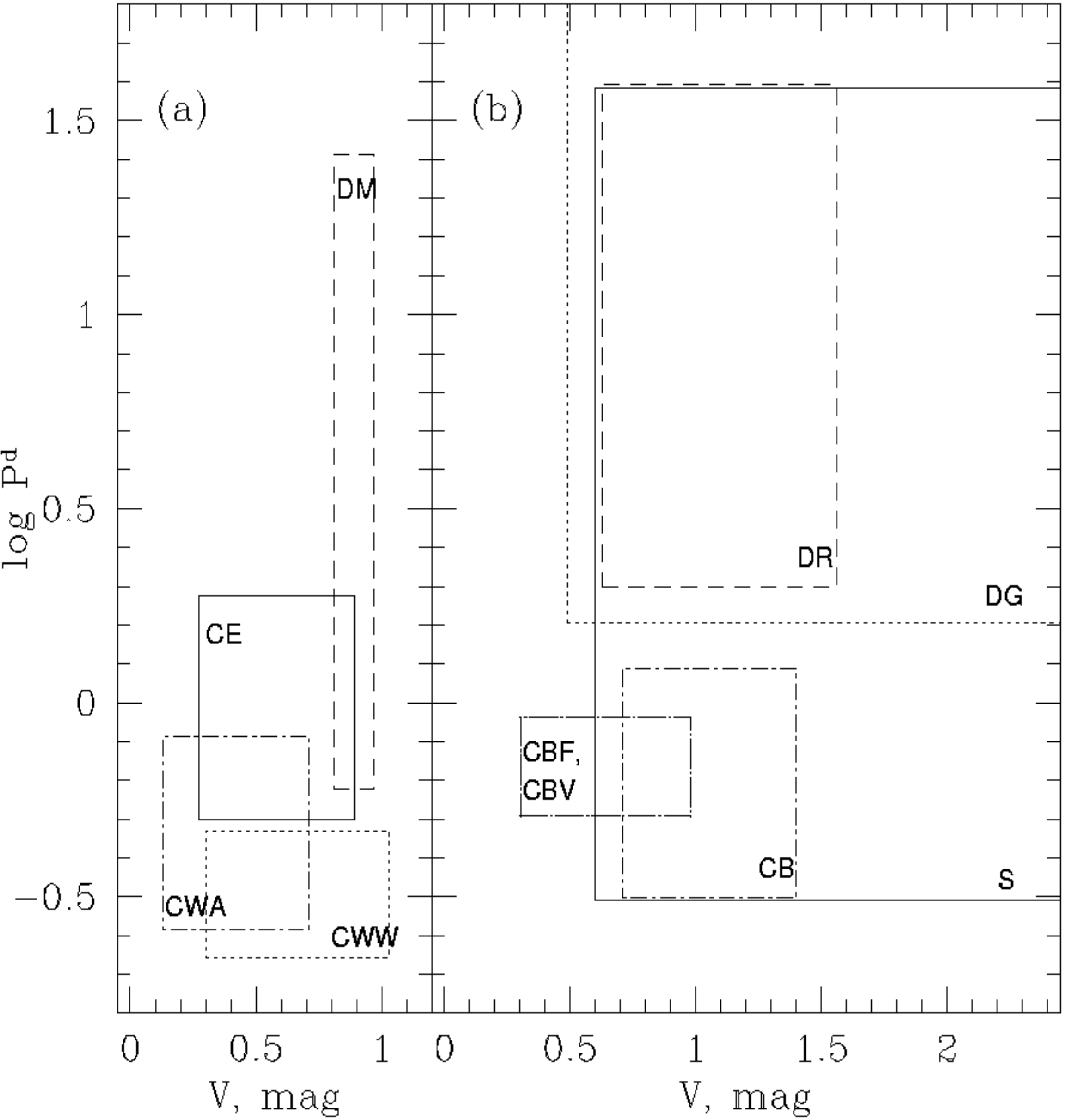
Arrows indicate direction of a system movement on the diagram if the eclipse becomes partial.

Catalogued systems in the A_1-A_2 plane



circles --- DM systems (larger), DR systems (smaller), squares --- DR systems, triangles --- S systems, crosses --- C systems.

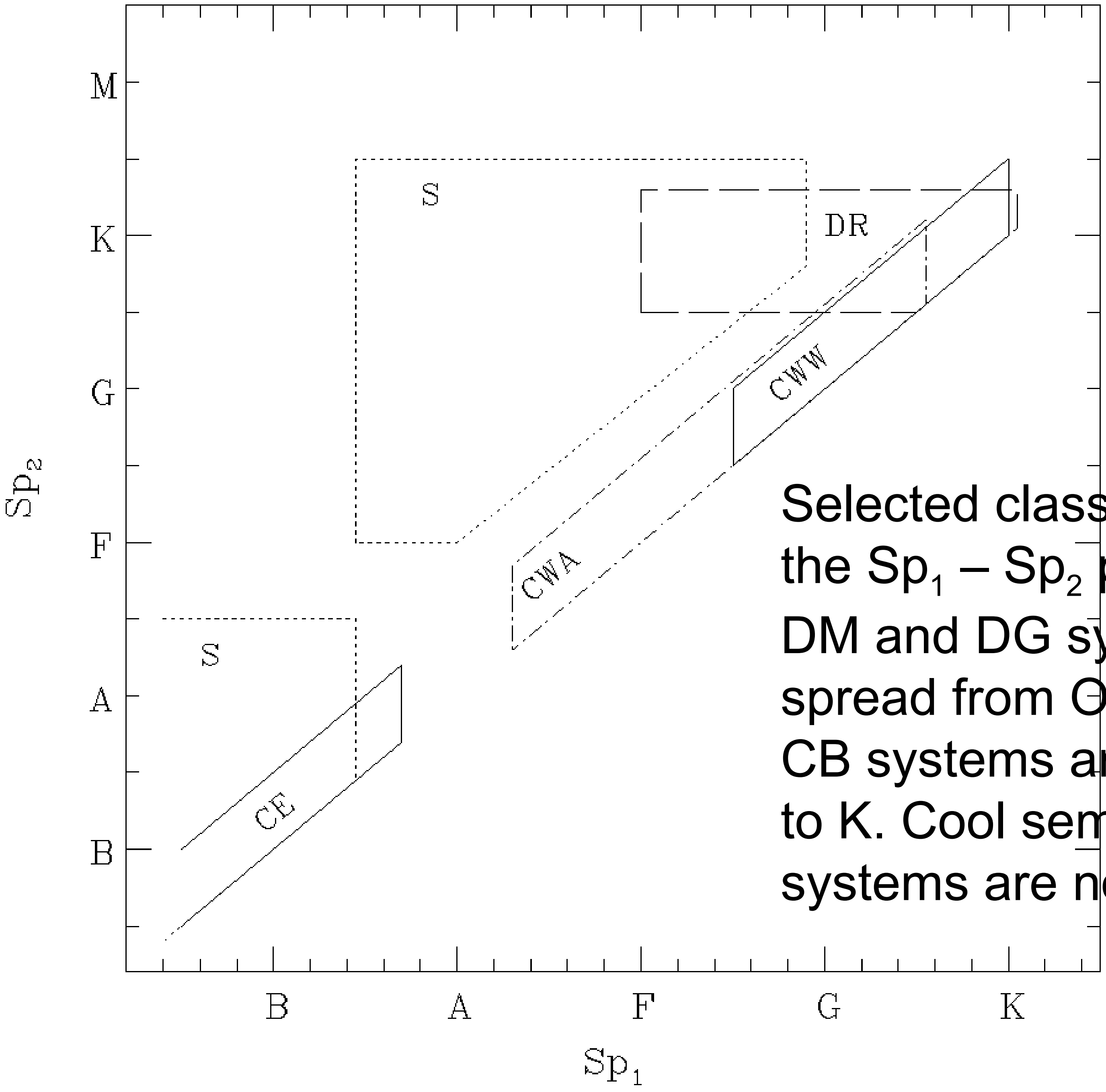
Limiting amplitudes and periods



Lower and upper borders of rectangles indicate minimum and maximum period for a given class, respectively.

Right border of rectangles indicates maximum value for the depth of primary minimum, A_1.

Left border of rectangles indicates maximum value for the depths difference, dA (for DM, CE and CW systems, panel (a) or maximum value for the depth of secondary minimum, A2 (for DR, DG, S and CB systems, panel (b).



Selected classes of systems in the Sp_1 – Sp_2 plane. Spectra of DM and DG systems are spread from O to M. Spectra of CB systems are spread from B to K. Cool semi-detached systems are not shown.

How the procedure works

- The procedure assigns an evolutionary class to a system, basing on its available observational parameters. One of the following classes can be assigned: D (detached system of unknown sub-class), DM, DR, DG, S, C, CB, CBV, CBF, CE, CW, CWA, CWW.
- If, according to the result of the classification, a system can belong to more than one of the listed classes, its class is considered to remain unknown. However, if a system could belong to both DM and DR, it was classified as D, etc.

Verification of the procedure, using 1029 stars with known classifier

- Altogether 475 systems (46%) were classified, class of others remains unknown.
- In 189 cases a less accurate classifier was assigned to a system (e.g., CWW –> CW).
- For 19 systems a classifier was made more accurate (e.g., CB –> CBV).
- In general
  - 113 of 194 (58%) D systems,
  - 79 of 437 (18%) S systems and
  - 283 of 398 (71%) C systems were classified correctly.

Classification of 5301 eclipsing variables with unknown classifier

- For 86 stars all classes are forbidden (remain unclassified)
- More than one class can be applied to 4225 (class remains unknown)
- 990 stars are successfully classified

Reasons for the failure of the classification process

- Star belongs to a marginal class: X-ray binary (V1341 Cyg), cataclysmic variable (RW Tri), polar (EF Eri), symbiotic star (V1329 Cyg)
- Star has constant light (NW Aur)
- Star has a period that is twice (or half) as much as catalogued one (RU Ind, AP Aps, HV TrA)
- Other errors in the GCVS

Statistics of 990 successfully classified stars

- 188 detached binaries, among them:
  - 58 detached MS systems
  - 1 detached subgiant system
  - 81 detached giant or supergiant systems
- 199 semidetached binaries
- 603 contact and near-contact binaries, among them:
  - 36 near-contact systems (3 of them are CBF)
  - 7 early type contact systems
  - 39 late type contact systems (24 of them are CWW)

Classification of EB from large catalogues

- Catalogue of eclipsing variables (Malkov et al. 2006): light curve morphological type, A_1, A_2, Sp_1, Sp_2, LC_1, LC_2, P, P variation information, DI, DII, MinII-MinI for 5301 stars
- Wood et al. (1980): A_1, A_2, Sp_1, Sp_2, LC_1, LC_2, P, DI, DII for 3564 stars

Classification of EB from large microlensing surveys

- OGLE-LMS and OGLE-SMC: light curve morphological type, A_1, A_2, P, MinII-MinI for 4085 stars
- MACHO: A_1, P, MinII-MinI for 6143 stars
- ASAS-3: A_1, P for 15481 stars

Large (more than thousand EB systems) surveys with at least two parameters are chosen

Results of classification.

Survey	No of stars	No of parameters	D	S	C
CEV	5301	13	188	199	603
Wood-5	3564	10	193	166	101
OGLE-LMC	2681	6	559	69	78
OGLE-SMC	1404	6	388	16	135
MACHO	6143	3	1125	24	25
ASAS-3	15481	2	536	73	811

For the majority of the classified stars more detailed classification is available

Current activity

- Improvement of the classification scheme
- Correction of the catalogue data
- Specification of rules for exotic (marginal) systems
- Use of other algorithms for classification: Bayes classifiers, decision trees etc.; in collaboration with Institute of Informatics Problems (IIP) RAS and Institute for Information Transmission (IITP) Problems RAS
- Development of methods of parameterisation
- Compilation of relevant catalogues

Data Mining as a Part of RVO Infrastructure

- Technical part of the work on eclipsing binaries classification is considered in the frame of the Russian Virtual Observatory.
- Well organised part of the RVO infrastructure is based on the AstroGrid system developed in UK and installed in Moscow at the Supercomputer Centre of the Russian Academy of Sciences and at the Institute of Informatics Problems of the Russian Academy of Sciences. These two installations are intended for problem solving by the Russian astronomers.
- RVO infrastructure is gradually extended with new instruments that should provide for solving of various problems of data analysis. In this connection an issue of incorporation into the RVO infrastructure of Data Mining tools is important.
- Eclipsing binaries classification problem played a catalyst role in this process.

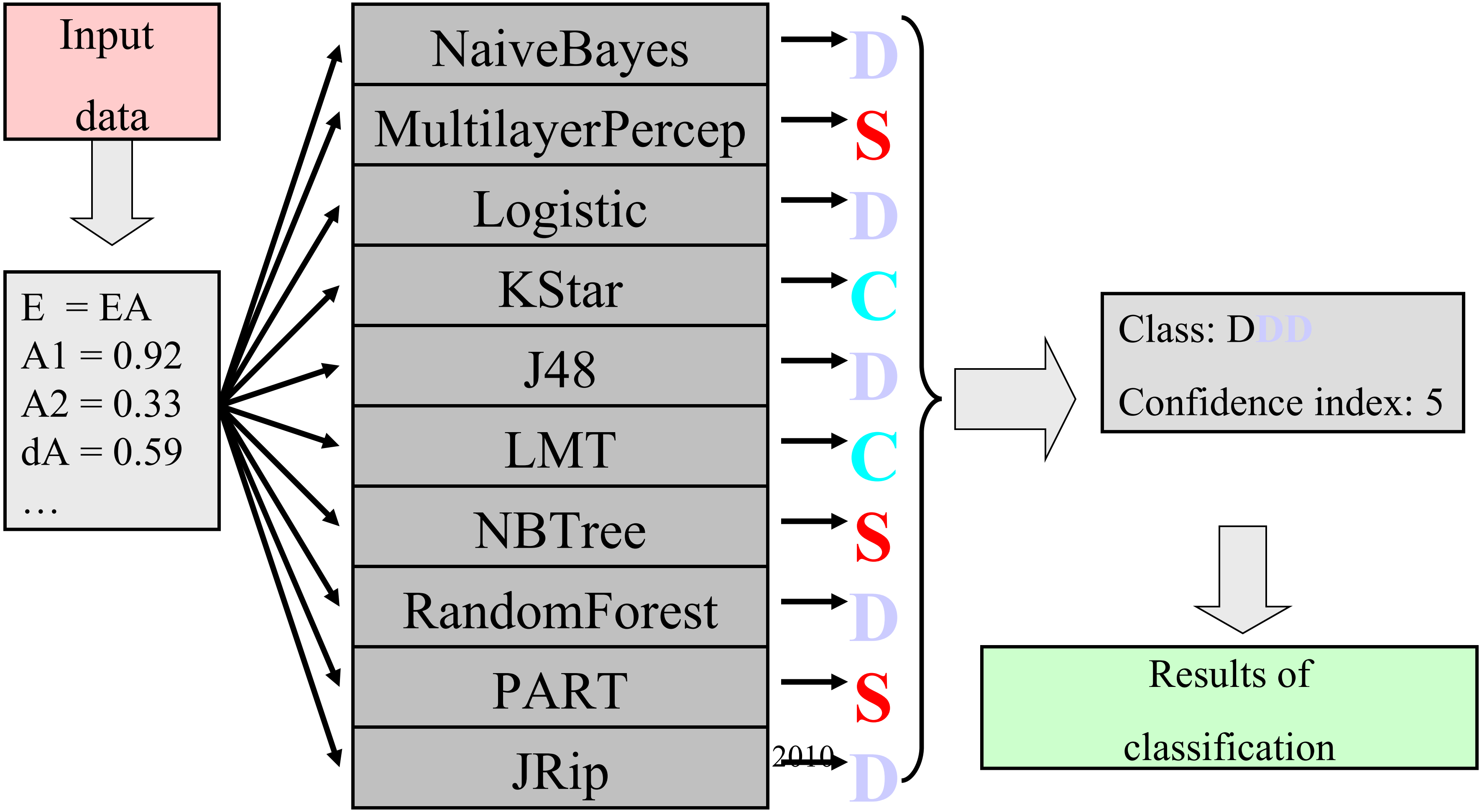
Weka and AstroWeka

- Existing Data mining instruments include: Java Data Mining, Oracle Data Mining, MATLAB, Weka.
- Weka has been chosen for this work as an open source implementing a large number of various Data Mining algorithms. It appeared also that Weka has been planned in the UK for incorporation into AstroGrid as AstroWeka
- AstroWeka is an extension of graphical interface of Weka providing for processing of data in the AstroGrid MySpace and for data exchange with other applications by means of the interface of PLASTIC (PLatform for AStronomical Tool InterConnection).
- AstroWeka is implemented as a separate application, not as an AstroGrid service.

Algorithms selected for EBs

- **Bayes Classifiers**
  - NaiveBayes
- **Functional Classifiers**
  - MultilayerPerceptron
  - Logistic
- **Pattern matching Classifiers**
  - KStar
- **Decision trees**
  - J48
  - LMT
  - NBTree
  - RandomForest
- **Decision rules**
  - PART
  - JRip

Schema of Ensemble Use for Classification



Input data

E = EA
A1 = 0.92
A2 = 0.33
dA = 0.59
…

NaiveBayes → D
MultilayerPercep → S
Logistic → D
KStar → C
J48 → D
LMT → C
NBTree → S
RandomForest → D
PART → S
JRip → D

Class: DDD
Confidence index: 5

Results of classification

2010

Result of classification

- Applying Ensemble Weka in AstroGrid 5514 binaries were classified providing the following star classes distribution:

- C - 852
    - CB - 89
        - CBF - 74
        - CBV - 149
    - CE - 15
    - CG - 1
    - CW - 84
        - CWA - 427
        - CWW - 331
- S - 547
    - S2C - 3
    - SA - 1902
    - SC - 1
    - SH - 13
- D - 553
    - DG - 41
    - DM - 422
    - DR – 10

As a threshold for the confidence index 7 has been chosen

Weka approach: conclusions

- Ensembled Weka installed at the AstroGrid installation of IPI RAS and published at the AstroGrid registries. Therefore, Ensembled Weka is ready for use.
- Ensembled Weka has been checked by solving of eclipsing binaries classification problem.
- It is planned to extend Ensembled Weka for solving clustering and regression kinds of Data Mining problems applying ensembles of algorithms.

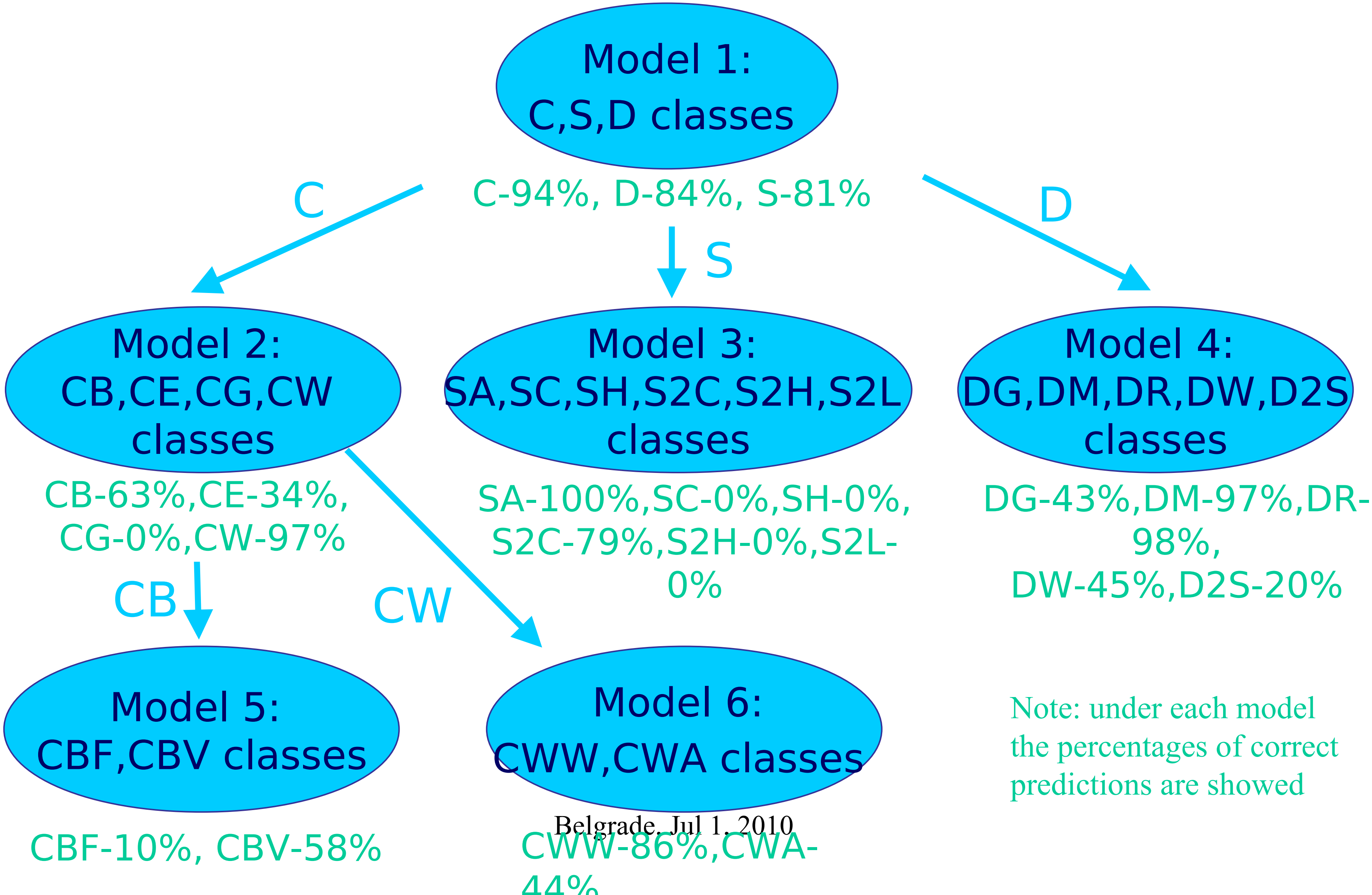
Oracle approach. 1

- Classification of eclipsing binaries was performed by the Support Vector Machine (SVM) algorithm. The SVM is a powerful machine learning method for the statistical classification of data used in various application domains. The main advantages of this method are high classification accuracy, robustness against overfiting and well-founded theory. Another reasons for the application of SVM for classification of eclipsing binaries are the large number of the eclipsing binaries parameters most of which are numerical.

Oracle approach. 2

- The training set that was used for building of the classification model consisted of 1162 binaries having the manually assigned classes. Due to existing hierarchy in the considered classification scheme of the eclipsing binaries we constructed six classification models by one on each node of the hierarchy classes tree. All classification models were built using the Oracle’s realization of the SVM algorithm that is part of the Oracle 10g Data Mining module.

Hierarchy of the classification models, testing results



Model 1:
C,S,D classes

C-94%, D-84%, S-81%

C

S

D

Model 2:
CB,CE,CG,CW classes

CB-63%,CE-34%,
CG-0%,CW-97%

Model 3:
SA,SC,SH,S2C,S2H,S2L classes

SA-100%,SC-0%,SH-0%,
S2C-79%,S2H-0%,S2L-0%

Model 4:
DG,DM,DR,DW,D2S classes

DG-43%,DM-97%,DR-98%,
DW-45%,D2S-20%

CB

CW

Model 5:
CBF,CBV classes

CBF-10%, CBV-58%

Model 6:
CWW,CWA classes

CWW-86%,CWA-44%

Note: under each model the percentages of correct predictions are showed

Oracle approach: conclusions

- The testing of the resulted classification models was accomplished by 10-fold cross validation approach. It was highest for the first hierarchy level of the classification scheme (contact system, semi-detached system and detached system) - about 90% - and less precise for other levels.

Astrophysical applications

- Fine structure of the MLR for intermediate masses. Evolution, metallicity, rotation effects.
- Subgiant (IV) sequence on HRD and interactive binaries population.
- Status of some types of EB (essentially contact and near-contact) in evolutionary scheme.
- Study of marginal systems.

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