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0521020247 - Light Curves of Variable Stars: A Pictorial Atlas

Edited by C. Sterken and C. Jaschek

Frontmatter

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This unique volume provides a complete reference on variable stars. It presents a wealth of typical light and colour curves (more than 200 in all) to allow identification, together with a detailed and up-to-date description of each subclass (giving the observational characteristics, historic background and current understanding of the astrophysical processes responsible for the variability).

The editors, together with seven other world experts, have created a unique pictorial atlas of variable stars. In the first chapter they give a clear introduction to the nomenclature and classification of the light curves of variable stars, and to photometric systems and photometric accuracy. In the remaining chapters they provide a detailed account of each subclass of variable star in turn from eruptive, pulsating, rotating and cataclysmic variables, through to eclipsing binary systems and X-ray binaries. Specific variable stars, types and classes of variables, together with key astrophysical terms can be quickly and easily located in the book by means of detailed object-name and subject indexes.

This comprehensive and up-to-date volume provides an essential reference for all those interested in variable stars – from researchers and graduate students through to dedicated amateurs.

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LIGHT CURVES OF VARIABLE STARS

A Pictorial Atlas

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In grateful appreciation for
meticulous bookkeeping and dissemination
of information on variable stars
for decades, in most difficult circumstances

we dedicate this book to

the Editors

P.P. Parenago,† B.V. Kukarkin,† P.N. Kholopov,† N.N. Samus'

and Authors

N.M. Artiukhina, O.V. Durlevich, Yu.I. Efremov, Yu.N. Efremov, V.P. Federovich,
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S.Yu. Shugarov, T.M. Tsvetkova

of the

General Catalogue of Variable Stars

and to

the Editors

L. Detre,† B. Szeidl, L. Szabados, K. Oláh

of the

Information Bulletin on Variable Stars

† deceased

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Preface

During the preparation of the observing programme of the TYCHO project on board the HIPPARCOS mission we started thinking about the large number of new variable stars that would be discovered. And since the TYCHO experiment yields only a scanty number of scattered measurements of each star during the life time of the satellite, it is immediately evident that one will encounter the problem of recognising the type or class of variability to which the variable star belongs. Such classification is – even with abundant data – not a trivial task, since many variable stars have light curves which, at first sight, look very similar. In addition, proper classification needs much more than a good-looking light curve, since luminosity and effective-temperature photometric indices also play a role, as well as miscellaneous data obtained with apparatus that are complementary to photometric instruments.

We thought to get some help by looking for standard light curves of typical variable stars that would be used as a template during the process of classification. We discovered then, with some surprise, that a compilation of typical photoelectric light curves of variable stars has never been published, nor does there exist a concise compendium of photometric properties of groups and classes of variables. What can be found, instead, is a large number of detailed morphological descriptions and numerous photometrically-incompatible photographic and visual light curves, scattered over many books and journals.

So, we decided to fill this gap and we started the compilation of typical light curves in a format that enables quick recognition of the pattern of variability. And we looked for a concise description explaining the physical processes that cause the observed variability, or an indication of which phenomena are not well understood. It was immediately obvious to us that no single person would be able to complete such a job, so the help of half a dozen experts was sought, and this book is the result of our joint efforts.

We first intended to present all data (light and colour curves) in one single

photometric system, and to represent the data with a single graphical software package. However, as the light curve data were coming in, we realised that it was just impossible to combine all photometric data into one single homogeneous data set. Moreover, we learned with dismay that for many light curves published less than a decade ago, the only remnant data are the graphs themselves, the original data having been lost forever – indeed a vivid demonstration that archiving of astronomical data is still in its infancy.

We have thus chosen the most representative photoelectric light and colour curves that could be found, and we have reproduced them, together with photographic light curves, where necessary. For some stars with large-amplitude light variations on very long time scales, we have illustrated the photoelectric light curve with a visual light curve, based mostly on data that were kindly supplied by the AAVSO. All these visual-magnitude graphs are displayed on approximately the same magnitude scale along the Y-axis.¹ The time axis, however, varies from one curve to another, and gives an expressive illustration of the monumental work achieved by the joint efforts of hundreds of amateur astronomers all over the world, almost throughout the entire 20th century, and equally to a most wonderful archiving task carried out by the AAVSO.

The book is organised into seven chapters. Chapter 1 provides a general introduction. Chapters 2 to 7 deal with the subclasses and light curve properties of each of the six main groups of variables as defined in the Fourth edition of the *General Catalogue of Variable Stars (GCVS)*. Each *GCVS* group is subdivided in several subclasses, and these subclasses are the topic of a separate Section. Each Section consists of a short description of the type of variability that is discussed, a representation of the historical background, and finally of a number of light and colour curves for several notorious stars member of the class. We deviate from the *GCVS* tradition of using only roman letters (like BCEP for the β Cep class) since that convention was made for no other reason than a practical one in the printing of the *GCVS* catalogues, and there is, today, no technical justification for preserving that convention.

We are convinced that this book will not only be useful during the analysis of TYCHO data, but also that other projects will profit from it. In particular, the growing number of Automatic Photometric Telescopes (APTs) being commissioned worldwide, the increasing number of serendipitous discoveries of variable stars in all kinds of CCD imaging projects, and the searches in data banks and archives continuously yield light curves to non-specialists. In addition to being a guide on how to read light curves, this book will also be a useful tool for the astronomy student and researcher, a textbook for astronomy

1. except for for light curves of supernovae, where the large magnitude range would yield graphs exceeding the technically available space on a single page

teachers and thesis supervisors, and also a guide for amateur astronomers. The search for specific variable stars, types and classes of variables, and astrophysical keywords, is made very easy through a most detailed name and subject index.

We also believe that this book comes at the right time. Variable-star research has been done so far using 'small' telescopes – that is, telescopes with apertures from about 150 cm down to 50 cm, and even below. Such research, for reasons of the photon budget, was mostly confined to our own galaxy. For some years, galactic work, in general, has become less popular and extra-galactic research is becoming the fashion. Variable-star work, in particular, is looked at with some disdain, and the 'small-telescope' tool is mentally associated with small science. Today it is mostly forgotten that the persistent study of variable stars has led us to answers on many questions on stellar structure and on stellar-atmosphere physics.

A very important task, carried out almost invisibly through nearly half a century, has been the bookkeeping and the classification of newly-discovered variables, along with the dissemination of information, both in catalogue form (*GCVS*) and in information bulletins (*IBVS*). Compilations that have taken man-centuries of labour in very difficult circumstances by dozens of colleagues, almost exclusively at the Sternberg Astronomical Institute in Moscow and at the Konkoly Observatory in Budapest, for no other return than the satisfaction in serving the whole astronomical community. It is for this reason that we dedicate this work to all those who have contributed and are still contributing to this task.

C. Sterken

C. Jaschek

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C.S. expresses his gratitude to the Belgian Fund for Scientific Research for supporting several research projects directly related with his contributions to this book.

Journal abbreviations

<i>Acta Astron.</i>	<i>Acta Astronomica</i>
<i>Ann. Tokyo Obs.</i>	<i>Annals of the Tokyo Observatory</i>
<i>Ann. Rev. Astr. Ap.</i>	<i>Annual Review of Astronomy and Astrophysics</i>
<i>Ap. J.</i>	<i>Astrophysical Journal</i>
<i>Ap. J. Lett.</i>	<i>Astrophysical Journal Letters</i>
<i>Ap. J. Suppl.</i>	<i>Astrophysical Journal Supplement Series</i>
<i>Ap. Sp. Sci.</i>	<i>Astrophysics and Space Science</i>
<i>Ark. f. astron.</i>	<i>Arkiv för Astronomi</i>
<i>Astr. Ap.</i>	<i>Astronomy and Astrophysics</i>
<i>Astr. Ap. Rev.</i>	<i>Astronomy and Astrophysics Reviews</i>
<i>Astr. Ap. Suppl.</i>	<i>Astronomy and Astrophysics Supplement Series</i>
<i>Astron. J.</i>	<i>Astronomical Journal</i>
<i>Astron. Nachr.</i>	<i>Astronomische Nachrichten</i>
<i>Astron. Soc. Pac. Conf. Ser.</i>	<i>Astronomical Society of the Pacific Conference Series</i>
<i>Bull. AAS</i>	<i>Bulletin of the American Astronomical Society</i>
<i>Bull. Astron. Inst. Czech.</i>	<i>Bulletin of the Astronomical Institutes of Czechoslovakia</i>
<i>Bull. Astron. Inst. Neth.</i>	<i>Bulletin of the Astronomical Institutes of the Netherlands</i>
<i>Bull. Astron. Inst. Neth. Suppl.</i>	<i>Bulletin of the Astronomical Institutes of the Netherlands Supplement Series</i>
<i>Bull. Crim. Astr. Obs.</i>	<i>Bulletin of the Crimean Astrophysical Observatory</i>
<i>Bull. Inf. CDS</i>	<i>Bulletin d'Information Centre de Données Stellaires</i>
<i>Cape Ann.</i>	<i>Annals of the Cape Observatory</i>
<i>GCVS</i>	<i>General Catalogue of Variable Stars, Fourth Edition</i>
<i>Fund. Cosmic Phys.</i>	<i>Fundamental Cosmic Physics</i>
<i>Harvard Bull.</i>	<i>Harvard Bulletin</i>
<i>Hvar Obs. Bull.</i>	<i>Hvar Observatory Bulletin</i>
<i>IAU Circ.</i>	<i>International Astronomical Union, Circular</i>

<i>IAPPP Comm.</i>	<i>International Amateur Professional Photoelectric Photometry Communications</i>
<i>Inf. Bull. Var. Stars (IBVS)</i>	<i>Information Bulletin on Variable Stars</i>
<i>JAAVSO</i>	<i>Journal of the American Association of Variable Star Observers</i>
<i>JAD</i>	<i>Journal of Astronomical Data</i>
<i>JRAS Canada</i>	<i>Journal of the Royal Astronomical Society of Canada</i>
<i>Lect. Notes Phys.</i>	<i>Lecture Notes in Physics</i>
<i>Lick Obs. Bull.</i>	<i>Lick Observatory Bulletin</i>
<i>Mem. R. Astron. Soc.</i>	<i>Memoirs of the Royal Astronomical Society</i>
<i>Mem. Soc. Astron. Ital.</i>	<i>Memorie della Societa Astronomica Italiana</i>
<i>Messenger</i>	<i>The Messenger</i>
<i>Mitt. Ver. Sterne Sonneberg</i>	<i>Mitteilungen über Veränderliche Sterne, Berlin-Babelsberg & Sonneberg</i>
<i>MNASSA</i>	<i>Monthly Notes of the Astronomical Society of Southern Africa</i>
<i>MNRAS</i>	<i>Monthly Notices of the Royal Astronomical Society</i>
<i>Observatory</i>	<i>The Observatory</i>
<i>Perem. Zvezdy</i>	<i>Peremennye Zvezdy</i>
<i>Proc. Astron. Soc. Aust.</i>	<i>Proceedings of the Astronomical Society of Australia</i>
<i>Proc. Amer. Acad. Arts Sci.</i>	<i>Proceedings of the American Academy of Arts and Sciences</i>
<i>Publ. Astron. Soc. Japan</i>	<i>Publications of the Astronomical Society of Japan</i>
<i>Publ. Astron. Soc. Pac.</i>	<i>Publications of the Astronomical Society of the Pacific</i>
<i>SAAO Circ.</i>	<i>South African Astronomical Observatory Circular</i>
<i>Sky Telesc.</i>	<i>Sky and Telescope</i>
<i>Space Sci. Rev.</i>	<i>Space Science Reviews</i>
<i>Trans. IAU</i>	<i>International Astronomical Union Transactions</i>
<i>Zeitschr. f. Astrophys.</i>	<i>Zeitschrift für Astrophysik</i>

Acronyms and abbreviations

AG	Astronomische Gesellschaft
AAVSO	American Association of Variable Stars Observers
AFOEV	Association Française des Observateurs d'Etoiles Variables
AGB	asymptotic giant branch
APT	Automatic Photometric Telescope
BAA	British Astronomical Association
<i>BCSVS</i>	<i>Bibliographic Catalogue of Suspected Variable Stars</i> , Roessiger & Braeuer (1993, 1994)
<i>BCVS</i>	<i>Bibliographic Catalogue of Variable Stars</i> , Roessiger & Braeuer (1994)
<i>BD</i>	<i>Bonner Durchmusterung</i>
CCD	charge coupled device
CDS	Centre de Données Stellaires, Observatoire de Strasbourg
CP	chemically peculiar
CV	cataclysmic variable
EROS	Expérience de Recherche d'Objets Sombres
ESO	European Southern Observatory
ESA	European Space Agency
<i>ftp</i>	file transfer protocol
<i>GCVS</i>	<i>General Catalogue of Variable Stars</i> 4th ed., Kholopov <i>et al.</i> (1985a)
He 3	Henize catalog number, <i>see</i> Section 1.2
HIPPARCOS	HIgh Precision PARallax COLlecting Satellite
HMXRB	high-mass X-ray binaries
H–R	Hertzsprung–Russell (diagram)
IAPP	International Amateur Professional Photoelectric Photometry
IAU	International Astronomical Union
<i>IBVS</i>	<i>Information Bulletin on Variable Stars</i>
IP	intermediate polars

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Acronyms and abbreviations

IUE	International Ultraviolet Explorer
LMXRB	low-mass X-ray binaries
LBV	Luminous Blue Variable
LPV	Long-Period Variable (Mira variable)
LMC	Large Magellanic Cloud
LTPV	Long-Term Photometry of Variables project
LTSV	Long-Term Spectroscopy of Variables project
MACHO	Massive Compact Halo Object
MLA	maximum light amplitude
<i>NSV</i>	<i>New Catalogue of Suspected Variable Stars</i> , Kukarkin <i>et al.</i> (1982)
OGLE	Optical Gravitational Lensing Experiment
OPAL	opacity code developed at Lawrence Livermore National Laboratory
PL	period–luminosity relation
PLC	period–luminosity–colour relation
PMS	pre-main sequence
PNNV	variable planetary nebula nuclei
R	Ratcliffe catalog number, <i>see</i> Section 1.2
RASNZ	Royal Astronomical Society of New Zealand
ROSAT	Röntgen Satellite
S	Henize catalog number, <i>see</i> Section 1.2
SAT	Strömgen Automatic Telescope
SIMBAD	Set of Identifications, Measurements and Bibliography of Astronomical Data
SMC	Small Magellanic Cloud
SPB	slowly-pulsating B stars
TYCHO	photometric instrument on board of HIPPARCOS
WD	white dwarf
WR	WR star, also WR catalog number, <i>see</i> Section 1.2