Montenbruck · Pfleger
Astronomy on the Personal Computer

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Astronomy on the Personal Computer

Translated by Storm Dunlop
With a Foreword by Richard M. West

Fourth, Completely Revised Edition
With 46 Figures and CD-Rom

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From the picture archive of Sterne und Weltraum; Photo: Thomas Helms.

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Foreword to the Fourth Edition

Astronomy is a venerable science with roots in the distant past. At the same time, it is one of the most modern and dynamic areas of basic research, involved in the study of truly basic questions that are of fundamental significance for mankind. From being a mainly observational-descriptive activity over the past millennia, it has recently evolved into a high-technology venture aimed at a profound understanding of our surroundings in space and, most importantly, our own place therein. It is obviously a very broad science with natural links in a great many directions, including physics and chemistry, as well as meteorology and mineralogy, from optics, mechanics and electronics to advanced mathematics and special computational techniques and, not least, philosophy.

Recent years have seen tremendous advances in this science, above all in observational and computational techniques. With larger telescopes and better instruments, professional observers are reaching for the unknown, beyond the current horizons. With faster and more reliable communication links, in particular the all-pervading world wide web, entirely new international research opportunities have materialized. What is no less impressive, however, is the enormous speed and determination with which amateur astronomers have reacted to the new possibilities. Thanks to improved and affordable observational facilities, in particular the wide availability of reasonably priced CCD cameras, they are now entering many fields that were until recently the exclusive domains of their professional colleagues with force.

The present book is another clear sign of this welcome development. Since the appearance of the first German edition, just 10 years ago, it has become a basic text for the serious amateur. The first English edition, published just one year later, made it accessible to a world wide community of astronomy fans, and one that has continued to grow ever since. It is no secret either that amateur astronomers are not the only ones to have profited from its clear and thoughtful presentation. Quite a few professionals – I am one of them – gladly admit that they have learned important details from its various informative chapters.

Why is it then that this book is so important and so basic in its field? Many answers may be given. Every reader will probably have his or her favourite reasons, be it the possibility to predict lunar phases and solar eclipses many years into the future, or the accurate computation of asteroid positions by means of astrometric standard stars in the observed field. However, I believe that there are other important, more general considerations.

The subjects covered and the methods described in this book constitute a very fundamental and absolutely indispensable part of astronomy. Without profound knowledge of the exact timings of celestial phenomena, without an understanding of the dynamics of the solar system and without the ability to calculate accurate positions of planets, comets and stars from any given place at any given time in the (near) future, there would be no observational astronomy as we know it today.

The readers will find here clear and detailed explanations about how such calculations are made, as well as the software means to do so with a high degree of accuracy. Of particular value is the possibility to read, to change and adapt the source codes to suit specific personal needs and preferences, now further facilitated by the use of the C++ language. This is a feature not offered by the increasingly popular 'planetarium-type' software packages that are directed towards a less demanding sector. The extensive object catalogues on CD-ROM provide a wonderful database for use with these programmes. The availability of a dedicated webpage with updates and related links is an added bonus.

Indeed, as the reader/user steps onto 'professional' territory by means of this book, he or she will find many new and exciting horizons opening. These encompass more than the valuable ability to serve the technical needs of astronomical observations – just consider the fun of working with well-conceived software on the home computer, and the satisfaction of better understanding the 'mechanics' of nature. Above all, however, it will help the serious amateur to achieve professional-quality results that will directly contribute to the advancement of astronomy.

The authors are to be congratulated for this fine service to the astronomical community. I have no doubt that this marvellous book will long continue to be a major reference source for all astronomy clubs and individuals who regularly observe the skies.

Garching
November 1999

Richard M. West (ESO)

Preface to the Fourth Edition

When we look back over the last ten years, it is largely reassuring that the astronomical and mathematical procedures in our book *Astronomy on the Personal Computer* have lost little of their validity and relevance at the end of this millennium. What is impressive, however, is the frenzied, or rather explosive, development of computer techniques, such that a computer has already won a firm place in many households alongside the telephone and the television set.

So it is not surprising then, that for this new edition we have concentrated on making a fundamental revision and modernization of all the programs. In view of the continuing decline in the use of the Pascal programming language, we have been happy to accede to the frequently expressed desire for our programs to be available in C++. If we exclude system-specific languages such as VisualBasic, then C and C++ constitute the most popular and widely used programming languages. As well as their availability for the most diverse computer systems, their significance also derives from their excellent support of applications close to the system level. This is particularly the case for C++, which, with its object-oriented programming techniques, is especially suitable for the development of graphical user interfaces.

In adapting the previous Pascal programs, we have not restricted ourselves to a simple port to the new language, but have instead undertaken a comprehensive, new implementation, taking the multiple possibilities offered by C++ into account. We hope that in this way the reader will be provided with an up-to-date and powerful suite of programs and libraries, without sacrificing the comprehensibility that had proved itself in the previous editions.

Changes in content result from (among other things) the consistent introduction of vector and matrix notation, which permits a compact and up-to-date representation of all coordinate transformations, and which is handled in the C++ programs through corresponding classes and operators. Wherever necessary, modifications were made to conform to current conventions and values. This involves both improved rotation elements for the major planets, and also the reckoning of geographical longitude on Earth. As in geography and satellite geodesy, this is now measured positively towards the east in astronomy. This has caused, for example, differences of sign in calculating local sidereal time or the station coefficients for stellar occultations. These are correspondingly incorporated into the individual algorithms and programs.

The chapter on the determination of orbits from three observations has been extended to include a description of the full Gaussian method of orbital deter-

mination, so that cases with multiple solutions may now be handled without any problems. An addition is the `Phases` program, which identifies possible solar or lunar eclipses, and which also calculates phases of the Moon. Many improvements have been introduced to make the programs more user-friendly. In calculating rise and set times, for example, it is now possible to choose between civil, nautical, and astronomical twilight. Similarly, in calculating stellar occultations, events that are difficult to observe are flagged, using a comprehensive set of criteria. Wherever necessary, input and output files may be specified in the command line for all programs.

With the accompanying CD-ROM, it has been possible, for the first time, to provide the executable programs for PCs running Windows and Linux in uncompressed form. Readers without a C++ compiler or programming experience are thus able to use the CD-ROM with its data and programs immediately for their own calculations. The addition of a compiler is necessary only for those readers who want to adapt or expand the programs for their own personal requirements. To this end, advice on the corresponding installation and implementation is given in the Appendix.

As an additional bonus, the CD-ROM contains the *Position und Proper Motion Catalogue* by S. Röser and U. Bastian (published by Spektrum Akademie Verlag), with detailed information on approximately 470 000 stars, as well as the *Asteroid Orbital Elements* database by E. Bowell with orbital information for more than 100 000 minor planets. The corresponding files were kindly made available by the Astronomische Rechen-Institut Heidelberg and the Lowell Observatory, to whom – as to the authors themselves – we must here express our grateful thanks. To simplify the use of these extremely comprehensive catalogues, various additional programs are included on the CD-ROM, which may be used to manipulate the data for entry into `Foto` and `Numint` programs.

We would also like to advise readers here about the newly established website `http://www.springeronline.com/3-540-67221-4/`, on which we, together with the publisher, provide useful information relating to the book. Here, for example, you will find the source code for the Pascal programs from the previous edition of *Astronomy on the Personal Computer*, and references to useful Internet resources. If necessary, corrections and software updates will also be posted here.

We wish to convey our particular thanks to Dr Ch. Caron, C.-D. Bachem, and B. Reichel-Mayer of Springer-Verlag in Heidelberg for their excellent cooperation and support during the preparation of this book. Similarly, we want to thank Dr L. Weidinger, whose support first made it possible to port our programs into a Linux environment.

December 2003 *O. Montenbruck and T. Pfleger*

Preface to the Second Edition

Since the publication of the first edition of *Astronomy on the Personal Computer*, we have received numerous comments and suggestions. Together with the publishers' interest in a new edition, this prompted us to revise the book and to incorporate a wide range of improvements to the text.

The first important addition is a chapter on the calculation of perturbations. This shows how gravitational perturbations by the major planets may be incorporated into the calculation of ephemerides for minor planets and comets. The `NUMINT` program described here enables more accurate positions to be calculated. This will be of considerable assistance in searching for what are often extremely faint objects. This tool for calculating perturbations complements the chapters on the calculation of ephemerides, the determination of orbits, and astrometry.

The second additional chapter discusses the calculation of physical ephemerides for the major planets and the Sun, and thus fills a gap in the earlier edition's coverage. Amateurs now have at their disposal the means of both predicting and subsequently reducing interesting planetary observations.

Other changes mainly concern the calculation of rising and setting times for the planets, and of the local circumstances that apply to solar eclipses.

Finally, there is now a single version of the program diskette that is supplied with the book. Since the firm of Application Systems Heidelberg have introduced their Pure Pascal compiler for Atari ST/TT computers that is compatible with Borland's Turbo Pascal, there is no need for a special Atari version of the program diskette. The enclosed diskette may, therefore, be used without modifications with Turbo Pascal on IBM-compatible machines or with Pure Pascal on Atari computers. Details about the appropriate installation procedures may be found in the `AAREADME.DOC` file on the diskette.

We should like to thank Springer-Verlag for their helpful co-operation, and also Application Systems Heidelberg for their technical support.

Munich, July 1994 *O. Montenbruck and T. Pfleger*

Preface to the First Edition

Nowadays anyone who deals with astronomical computations, either as a hobby or as part of their job, inevitably turns to using a computer. This is particularly true now that personal computers have become firmly established as ubiquitous aids to living. Calculations that could not even be contemplated a short time ago are now available to a whole range of users, and at no farther remove than their desks. Not only has the technical capacity of computers grown, but so has the need for powerful – i.e., fast and accurate – programs. So the wish to avoid conventional, astronomical yearbooks as much as possible is quite understandable. We were therefore delighted to take up our publisher's suggestion that we explain the fundamental principles of spherical astronomy, ephemeris calculations, and celestial mechanics in the form of this book.

Astronomy on the Personal Computer offers readers who develop their own programs a comprehensive library of Pascal procedures for solving a whole range of individual steps that frequently occur in problems. This includes routines for common coordinate transformations, for time and calendar calculations, and for handling the two-body problem. Specific procedures allow the exact positions of the Sun, the Moon, and the planets to be calculated, taking mutual perturbations into account. Thanks to the widespread use of Pascal as a computing language, and by avoiding computer-specific commands, the programs may be employed on a wide range of modern computers from the PC to the largest mainframes. The large number of routines discussed should at least mean that few readers will have to 're-invent the wheel', and that they will therefore be free to concentrate on their own particular interests.

Each chapter of this book deals with a fairly restricted theme and ends with a complete main program. From simple questions, such as the determination of rising and setting times or the calculation of the positions of the planets, more complex themes are developed, such as the calculation of solar eclipses and stellar occultations. The programs for the astrometric reduction of photographs of star fields and for orbit determination enable users to derive orbital elements of comets or minor planets for themselves. Even readers without programming experience will be able to use the appropriate applications.

Sufficient details are given of the astronomical and mathematical grounds on which solutions of specific problems are based for readers to understand the programs presented. This knowledge will enable them to adapt any of the programs to their individual needs. This close link between theory and practice also enables

us to explain what are sometimes quite complex aspects in a much easier fashion than the descriptions found in classical textbooks. To sum up, we hope that we have given readers a fundamental grounding in using computers for astronomy.

We should like to thank S. Dunlop for producing such an excellent translation and Dr. G. Wolschin and C.-D. Bachem of Springer-Verlag for their cordial co-operation and interest during the process of publishing this book. Our thanks are also due to all our friends and colleagues, who, with their ideas and advice, and their help in correcting the manuscript and in testing the programs, have played an important part in the success of this book.

Munich, August 1990 *O. Montenbruck and T. Pfleger*

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