

High Time Resolution Astronomy or High Speed Photometry

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Abstract

High Time Resolution Astronomy (HTRA) or High Speed Photometry offers opportunity to investigate phenomena that take place at timescales too fast for standard CCD imaging. Phenomena that occur within fractional-seconds to sub-millisecond timescales have been largely overlooked until recently due to technology limitations and/or research priorities in other areas. Discussed within the 1-second to millisecond range are flares, oscillations, quasi-periodic oscillations (QPOs), and lunar occultations. A Silicon Photomultiplier (SPM) detector with associated pulse amplifier and high-speed data acquisition system were used to capture stellar intensities at rates up to 1000 samples/sec on stars to 8 V-mag. Results on YY Gem flares, exploratory searches for oscillations on AW Uma, BM Ori, and X Per, and lunar occultations are discussed along with data reductions techniques. Opportunity for future study is also discussed.

1. Introduction

Our fascination with solar the system, star systems and their evolution, asteroid tracking, rotation, sizes, and composition as a few examples have led us to fainter and fainter objects, larger optics, and longer exposures. With longer exposures, events that take place in the fractional-second to millisecond timescale are averaged and lost.

Interest in this area opens up a whole new range of possible explorations. High speed photometry or high time resolution astronomy (HTRA) can fill an area of scientific exploration that complements conventional CCD imaging and offers unique insight into relatively unexplored areas. Richichi (2010) presents a good overview of how HTRA augments astronomical research. Figure 1 shows research areas versus timescale and the regions of study. Pulsars, oscillations, quasi-periodic oscillations (QPOs), and occultations push the millisecond and beyond range. These represent significant equipment challenges requiring very fast and sensitive photo detectors and larger aperture optics for 8-9 magnitude and beyond. In addition, with data rates in the kilohertz range there are challenges in coping with the storage and analysis of the data. With intensity sampling at 1000 samples/sec a two-hour data collection run generates 7.2 million data points for storage and subsequent analysis.

For the slower oscillations, transits, flares, and flicker events, data rates in the 10 to 100 Hz range still present the same equipment challenges but offer opportunity for the study of fainter objects. The previously cited Stellar Oscillation and Occultation arti-

cle presents numerous examples for study in these areas.

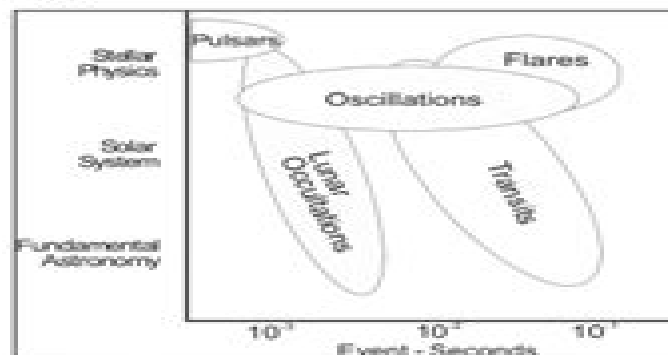


Figure 1. Research opportunities at various timescales, facsimile reproduced by permission from A. Richichi.

The trade-off between sampling rates and S/N is shown in Figure 2 for sampling rates of 10, 100, and 1000 samples/sec. This graph shows ideal conditions using a clear filter with minimal scintillation noise. The telescope has a 17-inch aperture and a silicon photomultiplier detector (SPM) with an internal gain in excess of 10^6 . At 1000 samples/sec the measurement limit is approximately 8th magnitude.

High Speed Astronomical Photometry

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High Speed Astronomical Photometry:

High Speed Astronomical Photometry Brian Warner, 1988 *High Time Resolution Astrophysics* Don Phelan, Oliver Ryan, Andrew Shearer, 2007-10-23 This is quite simply the first volume of its kind dedicated to the area of high time resolution astrophysics High time resolution astrophysics HTRA is an important new window on the universe and a vital tool in understanding a range of phenomena from diverse objects and radiative processes Underlining this science foundation technological developments in both instrumentation and detectors are described *An Introduction to Close Binary Stars* R. W. Hilditch, 2001-03-12 Binary systems of stars are as common as single stars They are of fundamental importance because they allow stellar masses radii and luminosities to be measured directly and explain a host of diverse and energetic phenomena including X ray binaries cataclysmic variables novae symbiotic stars and some types of supernovae This 2001 book was the first to provide a pedagogical and comprehensive introduction to binary stars It combines theory and observations at all wavelengths to develop a unified understanding of binaries of all categories It comprehensively reviews methods for calculating orbits the Roche model ideas about mass exchange and loss methods for analysing light curves the masses and dimensions of different binary systems and imaging the surfaces of stars and accretion structures This book provides a thorough introduction to the subject for advanced undergraduate and graduate students Researchers will also find this to be an authoritative reference **Compendium of Practical Astronomy** Günter D. Roth, 2012-12-06 It is a pleasure to present this work which has been well received in German speaking countries through four editions to the English speaking reader We feel that this is a unique publication in that it contains valuable material that cannot easily if at all be found elsewhere We are grateful to the authors for reading through the English version of the text and for responding promptly for the most part to our queries Several authors have supplied us on their own initiative or at our suggestion with revised and updated manuscripts and with supplementary English references We have striven to achieve a translation of Handbuch for Sternfreunde which accurately presents the qualitative and quantitative scientific principles contained within each chapter while maintaining the flavor of the original German text Where appropriate we have inserted footnotes to clarify material which may have a different meaning and or application in English speaking countries from that in Germany When the first English edition of this work Astronomy A Handbook translated by the late A Beer appeared in 1975 it contained 21 chapters This new edition is over twice the length and contains 28 authored chapters in three volumes At Springer's request we have devised a new title Compendium of Practical Astronomy to more accurately reflect the broad spectrum of topics and the vast body of information contained within these pages *Scientific and Technical Aerospace Reports*, 1995 *Handbook of CCD Astronomy* Steve B. Howell, 2006-03-02 Charge Coupled Devices CCDs are the state of the art detector in many fields of observational science Updated to include all of the latest developments in CCDs this second edition of the Handbook of CCD Astronomy is a concise and accessible reference on all practical aspects of using CCDs

Starting with their electronic workings it discusses their basic characteristics and then gives methods and examples of how to determine these values While the book focuses on the use of CCDs in professional observational astronomy advanced amateur astronomers and researchers in physics chemistry medical imaging and remote sensing will also find it very valuable Tables of useful and hard to find data key practical equations and new exercises round off the book and ensure that it provides an ideal introduction to the practical use of CCDs for graduate students and a handy reference for more experienced users

Optical, Infrared and Radio Astronomy Rosa Poggiani, 2016-12-05 This textbook presents the established sciences of optical infrared and radio astronomy as distinct research areas focusing on the science targets and the constraints that they place on instrumentation in the different domains It aims to bridge the gap between specialized books and practical texts presenting the state of the art in different techniques For each type of astronomy the discussion proceeds from the orders of magnitude for observable quantities that drive the building of instrumentation and the development of advanced techniques The specific telescopes and detectors are then presented together with the techniques used to measure fluxes and spectra Finally the instruments and their limits are discussed to assist readers in choice of setup planning and execution of observations and data reduction The volume also includes worked examples and problem sets to improve student understanding tables and figures in chapters summarize the state of the art of instrumentation and techniques

Celestial Shadows John Westfall, William Sheehan, 2014-11-19 Much of what is known about the universe came from the study of celestial shadows This book looks in detail at the way eclipses and other celestial shadows have given us amazing insights into the nature of the objects in our solar system and how they are even helping us discover and analyze planets that orbit stars other than our Sun A variety of eclipses transits and occultations of the moons of Jupiter and Saturn Pluto and its satellite Charon asteroids and stars have helped astronomers to work out their dimensions structures and shapes even the existence of atmospheres and structures of exoplanets Long before Columbus set out to reach the Far East by sailing West the curved shadow of the Earth on the Moon during a lunar eclipse revealed that we inhabit a round world a globe More recently comparisons of the sunlit and Earthlit parts of the Moon have been used to determine changes in the Earth's brightness as a way of monitoring possible effects in cloud coverage which may be related to global warming Shadows were used by the Greek mathematician Eratosthenes to work out the first estimate of the circumference of the Earth by Galileo to measure the heights of the lunar mountains and by eighteenth century astronomers to determine the scale of the Solar System itself Some of the rarest and most wonderful shadows of all are those cast onto Earth by the lovely Evening Star Venus as it goes between the Earth and the Sun These majestic transits of Venus occur at most two in a century after the 2012 transit there is not a chance to observe this phenomenon until 2117 while the more common sweep of a total solar eclipse creates one of the most dramatic and awe inspiring events of nature Though it may have once been a source of consternation or dread solar eclipses now lead thousands of amateur astronomers and eclipse chasers to travel the globe in

order to experience the dramatic view under totality These phenomena are among the most spectacular available to observers and are given their full due in Westfall and Sheehan s comprehensive study *Gamma-ray Astronomy* P. V. Ramana Murthy,A. W. Wolfendale,1993-04 The recent launch of NASA s Gamma Ray Observatory will increase interest in gamma ray astronomy This is a fully up dated new edition of the authors earlier volume published in 1986 and covers both the background science and the current state of the art in this field The emphasis is on the astronomy and astrophysics of known sources of cosmic gamma rays outside the solar system The authors discuss the mechanisms for the production and absorption of gamma rays The gamma ray line astronomy of the interstellar medium galactic centre and various discrete sources is then considered Gamma ray bursts are treated in considerable detail in chapter three and the final two chapters describe medium energy and ultra high energy gamma rays Relevant data from supernova SN1987A is also included in this edition The book includes comprehensive references to the primary literature together with many figures and tables The concentration on phenomenology makes this book a fine introduction to gamma ray astronomy *Astronomy and Astrophysics* S. Joardar,A. B. Bhattacharya,R. Bhattacharya,2008-04-15 This book is designed for upper division courses in astronomy and as a reference for science professionals The subject areas of astronomy and astrophysics have grown tremendously during the last few decades New developments in radio astronomy and recent data retrieved from NASAs Hubble Space Telescope have resulted in many discoveries and created new interest in the study of the universe Using four color throughout *Astronomy Astrophysics* describes the different techniques and instruments employed in the study of the universe and the results obtained with discussion on both theory and observation The book covers topics such as minor planets radio astronomy astronomical telescopes measurement of solar brightness distribution black holes and the Einstein effect A CD ROM with color figures and simulations accompanies the book **Vistas in Astronomy** Arthur Beer,2013-09-11 *Vistas in Astronomy* is a periodical compilation of different studies submitted by experts in the fields of astronomy astrophysics photometry celestial mechanics and nuclear cosmology The papers are published after thorough evaluation by the editors The following volume includes papers about papers in astronomy such as *Astronomy the People and the Governments* by Jean Claude Pecker and Gisele Ringard *Computer Simulations of Star Cluster Dynamics* by Sveere J Arseth *Velocity Fields in Stellar Atmospheres and the Concept of Microturbulence* by Gordon Worrall and Alistair B Wilson *Image Tubes in Astronomy* by J D McGee *High Speed Photometry* by R Edward Nather The text chiefly appeals to astronomers and astrophysicists especially those who wish to know the innovations discoveries and practices in the field of astronomy

Highlights of Astronomy, Volume 11A Johannes Andersen,1999-01-31 Since 1967 the main scientific events of the General Assemblies of the International Astronomical Union have been published in the separate series *Highlights of Astronomy* The present Volume 11 presents the major scientific presentations made at the XXIIIrd General Assembly August 18 30 1997 in Kyoto Japan The two volumes 11A B contain the text of the three Invited Discourses as well as the proceedings

or extended summaries of the 21 Joint Discussions and two Special Sessions held during the General Assembly The Observation and Analysis of Stellar Photospheres David F. Gray, 1992-06-04 Describes the equipment observational techniques and analysis used in the investigation of stellar photospheres **Optical Detectors For Astronomy II** Paola Amico, James W. Beletic, 2012-12-06 The 4 ESO CCO Workshop Optical Detectors for Astronomy was held during September 13-16 1999 at its usual location the headquarters of the European Southern Observatory in Garching Germany We prefer to remember this workshop as a meeting of friends who came to Garching to visit ESO and to present their work rather than a formal meeting Based on our experience with the 1996 ESO CCO workshop we deliberately put emphasis on creating an environment that encouraged the participants to stay together and informally exchange ideas These informal events began with a tour of the BMW auto factory and continued with a reception at SchloB Beletic the conference dinner at a real SchloB of the Bavarian International School where the participants enjoyed basket ball table soccer rock climbing and eventually dancing and concluded with a tour of the Paulaner Brewery and dinner at the Seehaus in the Englischer Garten The lunch Biergarten adjacent to the poster session area was a daily meeting point The result was a good mixture of excellent presentations and posters collected in these Proceedings and many occasions for people to get in touch and to have fun together as witnessed by the selection of workshop pictures that we randomly placed between papers This book contains a special contribution *RR Lyrae Stars* Horace A. Smith, 2004-09-16 Complete account of the applications of RR Lyrae stars in professional astronomy **Instrumentation for Ground-Based Optical Astronomy** Lloyd B. Robinson, 2012-12-06 Historically the discovery of tools or evidence that tools have been used has been taken as proof of human activity certainly the invention and spread of new tools has been a critical marker of human progress and has increased our ability to observe measure and understand the physical world In astronomy the tools are telescopes and the optical and electronic instruments that support them The use of the telescope by Galileo marked the beginning of a new and productive way to study and understand the universe in which we live The effects of this new tool on what we can see and how we see ourselves are well known However after almost four centuries of developing ever more sensitive and subtle instruments as tools for astronomy it might have been expected that only a few minor improvements would remain to be made or that possibly the law of diminishing returns would have taken effect On the contrary the new instruments and ideas for new instruments described in this book make it clear that the rate of progress has not diminished and that this subject is still as exciting and productive as ever Instrumentation for Ground Based Optical Astronomy was chosen as the theme for the Ninth Santa Cruz Summer Workshop in Astronomy and Astrophysics **Reports of Planetary Astronomy, 1985**, 1986 **A Dictionary of Astronomy** Ian Ridpath, 2018-04-26 Compiled with the help of over 20 expert contributors under the editorship of renowned author and broadcaster Ian Ridpath the third edition of A Dictionary of Astronomy covers everything from space exploration and the equipment involved to astrophysics cosmology and the concept of time in over 4 300 entries

The dictionary also includes biographical entries on eminent astronomers as well as worldwide coverage of observatories and telescopes. Supplementary material is included in the appendices such as tables of Apollo lunar landing missions, the constellations, planetary data, and numerous other tables and diagrams complement the entries. The entries have been fully revised and updated for this edition and more than 100 new entries have been added to reflect the recent developments within the field of astronomy, including Bennu, Euclid, Mars Orbiter Mission, and slowly pulsating B star A. A Dictionary of Astronomy is an invaluable reference source for students, professionals, amateur astronomers, and space enthusiasts.

Monthly Catalog of United States Government Publications, 1995-10 *Solar and Stellar Activity Cycles* Peter R. Wilson, 1994. A timely and authoritative synthesis of our understanding of activity cycles in the Sun and similar stars for graduate students and researchers.

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