

IAU Symposium

285

IAU Symposium

285

19–23 September 2011  
Oxford, United Kingdom

Proceedings of the International Astronomical Union

# New Horizons in Time-Domain Astronomy

New Horizons  
in Time-Domain  
Astronomy

*Edited by*

Griffin  
Hanisch  
Seaman

R. Elizabeth Griffin  
Robert J. Hanisch  
Robert L. Seaman

ISSN 1743-9213

International Astronomical Union



**CAMBRIDGE**  
UNIVERSITY PRESS



CAMBRIDGE

NEW HORIZONS IN TIME-DOMAIN ASTRONOMY

IAU SYMPOSIUM No. 285

*COVER ILLUSTRATION* by P. Marenfeld  
National Optical Astronomy Observatory (Tucson, AZ, USA)

The IAU Symposium 285 Scientific Organizing Committee dedicates this volume to  
Elizabeth Griffin in honour of her 70th birthday

IAU SYMPOSIUM PROCEEDINGS SERIES  
2011 EDITORIAL BOARD

*Chairman*

THIERRY MONTMERLE, IAU Assistant General Secretary  
*Institut d'Astrophysique de Paris,  
98bis, Bd Arago, 75014 Paris, France  
montmerle@iap.fr*

*Advisers*

IAN F. CORBETT, IAU General Secretary,  
*European Southern Observatory, Germany*

UTA GROTHKOPF, *European Southern Observatory, Germany*

CHRISTIANN STERKEN, *Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium*

*Proceedings Editors*

IAUS 278

Archaeoastronomy and Ethnoastronomy: Building Bridges Between Cultures  
C. L. N. RUGGLES, *University of Leicester, School of Archaeology and Ancient History,  
University Rd, Leicester LE1 7RH, United Kingdom*

IAUS 279

Death of Massive Stars: Supernovae and Gamma-Ray Bursts [*postponed to 2012*]  
P. ROMING, *Southwest Research Institute, Space Science & Engineering Division,  
P.O. Drawer 28510, San Antonio, TX 78228-0510, USA*

IAUS 280

The Molecular Universe

J. CERNICCHARO, *Depto. de Astrofísica, Centro de Astrobiología, Crta. Torrejón Km 4,  
28850 Torrejón de Ardoz, Madrid, Spain*

IAUS 281

Binary Paths to the Explosions of type Ia Supernovae

R. DI STEFANO, *Harvard-Smithsonian Center for Astrophysics, 60 Garden Street,  
Cambridge, MA 02138, USA*

IAUS 282

From Interacting Binaries to Exoplanets: Essential Modeling Tools

M. RICHARDS, *Pennsylvania State University, Dept. of Astronomy & Astrophysics,  
525 Davey Lab, University Park, PA 16802, USA*

IAUS 283

Planetary Nebulae: an Eye to the Future

A. MANCHADO, *Instituto de Astrofísica de Canarias, Calle Vía Láctea s/n,  
38200 La Laguna, Tenerife, Spain*

IAUS 284

The Spectral Energy Distribution of Galaxies (SED2011)

R. J. TUFFS, *MPI für Kernphysik, Astrophysics Dept, Saupfercheckweg 1, 69117 Heidelberg,  
Germany*

IAUS 285

New Horizons in Time-Domain Astronomy

R. E. M. GRIFFIN, *NRC Dominion Astrophysical Observatory, 5071 W Saanich Rd, Victoria,  
BC, V9E 2E7, Canada*

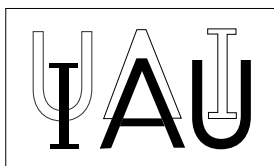
IAUS 286

Comparative Magnetic Minima: Characterizing Quiet Times in the Sun and Stars

C. MANDRINI, *Instituto de Astronomía y Física del Espacio, CC. 67 Suc. 28,  
1428 Buenos Aires, Argentina*

INTERNATIONAL ASTRONOMICAL UNION  
UNION ASTRONOMIQUE INTERNATIONALE

International Astronomical Union



# NEW HORIZONS IN TIME-DOMAIN ASTRONOMY

PROCEEDINGS OF THE 285th SYMPOSIUM OF THE  
INTERNATIONAL ASTRONOMICAL UNION  
HELD IN OXFORD, UNITED KINGDOM  
SEPTEMBER 19 – 23, 2011

Edited by

**R. ELIZABETH GRIFFIN**

*Dominion Astrophysical Observatory, Canada*

**ROBERT J. HANISCH**

*Space Telescope Science Institute and Virtual Astronomical Observatory, USA*

and

**ROBERT L. SEAMAN**

*National Optical Astronomical Observatory, Tucson AZ USA*



**CAMBRIDGE**  
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS

The Edinburgh Building, Cambridge CB2 2RU, United Kingdom  
32 Avenue of the Americas, New York, NY 10013-2473, USA  
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

© International Astronomical Union 2012

This book is in copyright. Subject to statutory exception  
and to the provisions of relevant collective licensing agreements,  
no reproduction of any part may take place without  
the written permission of the International Astronomical Union.

First published 2012

Printed in the United Kingdom at the University Press, Cambridge

Typeset in System L<sup>A</sup>T<sub>E</sub>X 2 $\epsilon$

*A catalogue record for this book is available from the British Library*

*Library of Congress Cataloguing in Publication data*

This journal issue has been printed on FSC-certified paper and cover board. FSC is an independent, non-governmental, not-for-profit organization established to promote the responsible management of the world's forests. Please see [www.fsc.org](http://www.fsc.org) for information.

ISBN 9781107019850 hardback  
ISSN 1743-9213

## Table of Contents

Introduction . . . . .	xiii
Foreword . . . . .	xvi
Acknowledgements . . . . .	xvii
Conference Photograph . . . . .	xviii
<b>Day 1: Can Our Data Meet the Challenges?</b>	
The Power of the Unexpected . . . . . <i>B. Warner</i>	3
Optical Transient Surveys . . . . . <i>B. Schmidt</i>	9
The Scientific Potential of LOFAR for Time-Domain Astronomy . . . . . <i>R. Fender, on behalf of the LOFAR Transients Key Science Project</i>	11
Kepler, CoRoT and MOST: Time-Series Photometry from Space . . . . . <i>H. Kjeldsen &amp; T. R. Bedding</i>	17
Long-term Monitoring with Small and Medium-sized Telescopes on the Ground and in Space . . . . . <i>P. A. Charles, M. M. Kotze, &amp; A. Rajoelimanana</i>	23
Opening the 100-Year Window for Time-Domain Astronomy . . . . . <i>J. Grindlay, S. Tang, E. Los, &amp; M. Servillat</i>	29
Spectroscopic Surveys . . . . . <i>F. Primas</i>	35
Time-Domain Astronomy with SWIFT, FERMI and LOBSTER . . . . . <i>N. Gehrels, S. D. Barthelmy, &amp; J. K. Cannizzo</i>	41
<b>Day 2: Explosive or Irreversible Changes</b>	
The Dynamic Radio Sky . . . . . <i>J. M. Cordes</i>	49
Cosmic Explosions (Optical) . . . . . <i>S. R. Kulkarni</i>	55
Systematically Bridging the Gap Between Novæ and Supernovæ . . . . . <i>M. M. Kasliwal (on behalf of the Palomar Transient Factory Collaboration)</i>	62
Supernovæ and Transients with EUCLID and the European ELT . . . . . <i>I. Hook</i>	63
Search for Electromagnetic Counterparts to LIGO-Virgo Candidates: Expanded Very Large Array Observations . . . . . <i>J. Lazio, K. Keating, F. A. Jenet, &amp; N. E. Kassim</i>	67
Explosions on a Variety of Scales . . . . . <i>L. Bildsten</i>	71

Transients with Pan-STARRS-1 . . . . .	71
<i>Stephen Smartt (and the PSI Science Consortium)</i>	
Light Echoes of Transients and Variables . . . . .	72
<i>A. Rest</i>	
A New Class of Relativistic Outbursts from the Nuclei of Distant Galaxies. . . . .	72
<i>S. B. Cenko, S. R. Kulkarni, D. A. Frail, &amp; J. S. Bloom</i>	
<b>Day 3: Things That Tick</b>	
Spectroscopic Binaries: Towards the 100-Year Time Domain. . . . .	75
<i>R. F. Griffin</i>	
On the Sensitivity of Period Searches. . . . .	81
<i>A. Schwarzenberg-Czerny</i>	
Sines, Steps and Droplets: Semi-parametric Bayesian Modelling of Arrival Time Series. . . . .	87
<i>T. J. Lored</i>	
Variable Stellar Object Detection and Light Curves from the Solar Mass Ejection Imager (SMEI) . . . . .	91
<i>R. A. Hounsell, M. F. Bode, M. J. Darnley, D. J. Harman, P. P. Hick, A. Buffington, B. V. Jackson, J. M. Clover, &amp; A. W. Shafter</i>	
Surveying the Bright Sky . . . . .	95
<i>A. A. Henden</i>	
High Time-Resolution Astronomy on the 10-m SALT . . . . .	99
<i>B. Welsh, D. Anderson, J. McPhate, J. Vallergera, O. H. W. Siegmund, D. Buckley, A. Gulbis, M. Kotze, &amp; S. Potter</i>	
Pulsars . . . . .	103
<i>B. W. Stappers</i>	
Charting the Transient Radio Sky on Sub-Second Time-Scales with LOFAR . . . . .	104
<i>J. W. T. Hessels (and the LOFAR Transients Key Science Project)</i>	
Probing the Physics of Planets and Stars with Transit Data. . . . .	105
<i>S. Aigrain</i>	
Asteroseismology . . . . .	105
<i>D. Kurtz</i>	
<b>Day 4: Irregular and Aperiodic Changes</b>	
Variability in Active Galactic Nuclei . . . . .	109
<i>E. W. Bonning</i>	
Variable Red Giants. . . . .	111
<i>F. Kerschbaum &amp; W. Nowotny</i>	

Polarimetric Variability . . . . .	117
<i>S. B. Potter</i>	
Gamma-Ray Waveband and Multi-Waveband Variability of Blazars . . . . .	121
<i>S. Ciprini</i>	
Two Centuries of Observing R Coronae Borealis . . . . .	125
<i>G. C. Clayton</i>	
On Rapid Interstellar Scintillation of Quasars: PKS 1257-326 Revisited . . . . .	129
<i>H. E. Bignall &amp; J. A. Hodgson</i>	
Sonification of Astronomical Data . . . . .	133
<i>W. L. Diaz-Merced, R. M. Candey, N. Brickhouse, M. Schneps, J. C. Mannone, S. Brewster, &amp; K. Kolenberg</i>	
Probing Magnetic Mysteries with Stellar Flares . . . . .	137
<i>R. A. Osten</i>	
Microscopy of the Interstellar Medium. . . . .	137
<i>M. Walker</i>	
Towards a New Generation of Multi-Dimensional Stellar Models: Can Our Models Meet the Challenges? . . . . .	138
<i>I. Baraffe, M. Vialler, &amp; R. Walder</i>	
Echo Mapping of AGNs. . . . .	138
<i>K. Horne</i>	
<b>Day 5: Preparing for the Future</b>	
Exploring the Time Domain with Synoptic Sky Surveys . . . . .	141
<i>S. G. Djorgovski, A. A. Mahabal, A. J. Drake, M. J. Graham, C. Donalek, &amp; R. Williams</i>	
Pulsars, SKA and Time-Domain Studies in the Future . . . . .	147
<i>M. Kramer</i>	
From HIPPARCOS to GAIA. . . . .	153
<i>L. Eyer, P. Dubath, S. Saesen, D. W. Evans, L. Wyrzykowski, S. Hodgkin, &amp; N. Mowlavi</i>	
The Future of the Time Domain with LSST . . . . .	158
<i>L. M. Walkowicz</i>	
Optimal Strategies for Transient Surveys with Wide-Field Radio Telescopes. . . . .	158
<i>J.-P. Macquart, N. Clarke, P. Hall &amp; T. Colegate</i>	
Next-Generation X-ray Astronomy. . . . .	159
<i>N. E. White</i>	
Technical and Observational Challenges for Future Time-Domain Surveys . . . . .	165
<i>J. S. Bloom</i>	
Summary: A Very Timely Conference . . . . .	171
<i>R. F. G. Wyse</i>	



**Workshop Reports**

The CoRoT and Kepler Revolution in Stellar Variability Studies . . . . .	177
<i>P. Degroote &amp; J. Debosscher</i>	
SWIFT: Opportunities, Capabilities and Data Handling . . . . .	183
<i>R. Starling</i>	
Optical & NIR Transient Surveys . . . . .	185
<i>N. J. G. Cross &amp; S. G. Djorgovski</i>	
Gravitational Waves and Time-Domain Astronomy . . . . .	191
<i>J. Centrella, S. Nissanke, &amp; R. Williams</i>	
The Future of X-ray Time-Domain Surveys . . . . .	199
<i>D. Haggard &amp; G. R. Sivakoff</i>	
Gravitational Microlensing . . . . .	207
<i>L. Wyrzykowski, M. Moniez, K. Horne, &amp; R. Street</i>	
Light Echoes . . . . .	215
<i>H. E. Bond, M. C. Bentz, G. C. Clayton, &amp; A. Rest</i>	
Using the VO to Study the Time Domain . . . . .	221
<i>R. Seaman, R. Williams, M. Graham, &amp; T. Murphy</i>	
Astrotopography . . . . .	227
<i>K. Horne, R. Baptista, M. C. Bentz, &amp; D. Steeghs</i>	
Small and Robotic Telescopes in the Era of Massive Time-Domain Surveys . . . .	235
<i>M. F. Bode &amp; W. T. Vestrand</i>	
Binarity and Stellar Evolution . . . . .	239
<i>R. E. M. Griffin &amp; Slavek Rucinski</i>	
Historical Time Domain: Data Archives, Processing, and Distribution . . . . .	243
<i>J. E. Grindlay &amp; R. E. M. Griffin</i>	
Data Management, Infrastructure and Archiving for Time-Domain Astronomy	249
<i>D. Schade</i>	
Amateur Community and “Citizen Science” . . . . .	255
<i>A. A. Henden</i>	
Stellar Tidal Disruption . . . . .	261
<i>G. R. Farrar</i>	
Workshop on Faint and Fast Transients . . . . .	269
<i>M. Kasliwal &amp; L. Bildsten</i>	
Workshop on Extreme Physics . . . . .	270
<i>C. Mundell &amp; M. Sullivan</i>	
Workshop on Algorithms for Time-Series Analysis . . . . .	271
<i>P. Protopapas</i>	
Workshop on Radio Transients . . . . .	272
<i>S. Croft &amp; B. Gaensler</i>	

**Poster Papers**

Cepheids in Galactic Open Clusters: An All-sky Census . . . . .	275
<i>R. I. Anderson, L. Eyer, &amp; N. Mowlavi</i>	
Investigating the Sources of Flickering and Superhumps in the Dwarf Nova V4140 Sgr . . . . .	278
<i>R. Baptista, B. Borges, &amp; A. Oliveira</i>	
AQUYE and IQUEYE, Very-High-Time-Resolution Photon-Counting Photometers <i>C. Barbieri, G. Naletto, L. Zampieri, E. Verroi, S. Gradari, S. Collins, &amp; A. Shearer</i>	280
The KEPLER Guest Observer Programme . . . . .	283
<i>T. Barclay</i>	
Modulated Light Curves of Multiperiodic Stars . . . . .	286
<i>J. M. Benkó, R. Szabó, &amp; M. Páparó</i>	
Time-Resolved Spectroscopy with SDSS . . . . .	289
<i>S. Bickerton, C. Badenes, T. Hettinger, T. Beers, &amp; S. Huang</i>	
Improved Time-Series Photometry and Calibration Method for Non-Crowded Fields: MMT Megacam and HAT-South Experiences . . . . .	291
<i>S.-W. Chang, Y.-I. Byun, &amp; D.-W. Kim</i>	
Fermi LAT Flare Advocate Activity. . . . .	294
<i>S. Ciprini, D. Gasparrini, &amp; D. Bastieri</i>	
Crab Pulsar: Enhanced Optical Emission During Giant Radio Pulses . . . . .	296
<i>S. Collins, A. Shearer, B. Stappers, C. Barbieri, G. Naletto, L. Zampieri, E. Verroi, &amp; S. Gradari</i>	
False-Alarm Probabilities in Period Searches: Can Extreme-Value Distributions be of Use? . . . . .	299
<i>J. Cuypers</i>	
Characterising the Dwarf Nova Population of the Catalina Real-time Transient Survey . . . . .	301
<i>D. de Budé, P. Woudt, &amp; B. Warner</i>	
Inverse Mapping of Pulsar Magnetospheres: Optical Emission Comes From 300 km Above the Surface . . . . .	303
<i>D. de Búrca, P. O'Connor, J. McDonald, &amp; A. Shearer</i>	
The Catalina Real-time Transient Survey . . . . .	306
<i>A. J. Drake, S. G. Djorgovski, A. Mahabal, J. L. Prieto, E. Beshore, M. J. Graham, M. Catalan, S. Larson, E. Christensen, C. Donalek, &amp; R. Williams</i>	
Searching for Periodic Variables in the EROS-2 Database . . . . .	309
<i>P. Dubath, I. Lecoœur, L. Rimoldini, M. Süveges, J. Blomme, M. López, L. M. Sarro, J. De Ridder, J. Cuypers, L. Guy, K. Nienartowicz, A. Jan, M. Beck, N. Mowlavi, D. Ordóñez-Blanco, J. B. Marquette, J. P. Beaulieu, P. Tisserand, É. Lesquoy, &amp; L. Eyer</i>	

Testing the Standard Model of Active Galactic Nuclei through Quasar Variability <i>A. Ederoclite, J. Polednikova, J. Cepa, J. Antonio de Diego Onsurbe, &amp; I. González-Serrano</i>	312
Time-Domain Studies of Gravitationally Lensed Quasars . . . . . <i>L. J. Goicoechea &amp; V. N. Shalyapin</i>	315
The VAO Transient Facility . . . . . <i>M. J. Graham, S. G. Djorgovski, A. Drake, A. Mahabal, R. Williams, &amp; R. Seaman</i>	318
Searching for Fast Optical Transients using a VERITAS Cherenkov Telescope . . . <i>S. C. Griffin</i>	321
La Silla-QUEST Variability Survey in the Southern Hemisphere . . . . . <i>E. Hadjijska, D. Rabinowitz, C. Baltay, N. Ellman, P. Nugent, R. Zinn, B. Horowitz, R. McKinnon, &amp; L. R. Miller</i>	324
Inferring Rotation Periods of Young Stars from Synoptic Observations . . . . . <i>P. Hartigan, C. M. Johns-Krull, &amp; P. Scowen</i>	327
Proposal for Multi-Messenger Observations of Radio Transients by Nasu and Ligo-Virgo . . . . . <i>K. Hayama, K. Niinuma &amp; T. Oyama</i>	331
Variability with WISE . . . . . <i>D. Hoffman, R. Cutri, J. Fowler, &amp; F. Masci</i>	334
Hottest Superfluid and Superconductor in the Universe: Lessons from the Cooling of the Cassiopeia A Neutron Star . . . . . <i>W. C. G. Ho, C. O. Heinke, D. J. Patnaude, P. S. Shternin, &amp; D. G. Yakovlev</i>	337
Fast Transient Detection as a Prototypical “Big Data” Problem. . . . . <i>D. L. Jones, K. Wagstaff, D. Thompson, L. D’Addario, R. Navarro, C. Mattmann, W. Majid, U. Rebbapragada, J. Lazio, &amp; R. Preston</i>	340
What To Do with Sparkers? . . . . . <i>E. F. Keane, B. W. Stappers, M. Kramer, &amp; A. G. Lyne</i>	342
A Refined QSO Selection Method Using Diagnostics . . . . . <i>D.-W. Kim, P. Protopapas, M. Trichas, M. Rowan-Robinson, R. Khardon, C. Alcock, &amp; Y.-I. Byun</i>	344
Interstellar Scintillation as a Cosmological Probe: Prospects and Challenges. . . . <i>J. Y. Koay, J.-P. Macquart, B. J. Rickett, H. E. Bignall, D. L. Jauncey, J. E. J. Lovell, C. Reynolds, T. Pursimo L. Kedziora-Chudczer, &amp; R. Ojha</i>	347
An Extremely Luminous Outburst from a Relativistic Tidal Disruption Event . . <i>A. J. Levan, on behalf of a larger collaboration</i>	349
Solar System Science with Robotic Telescopes . . . . . <i>T. A. Lister</i>	352
Real-Time Classification of Transient Events in Synoptic Sky Surveys. . . . . <i>A. A. Mahabal, C. Donalek, S. G. Djorgovski, A. J. Drake, M. J. Graham, R. Williams, Y. Chen, B. Moghaddam, &amp; M. Turmon</i>	355

Towards Improving the Prospects for Coordinated Gravitational-Wave and Electromagnetic Observations . . . . .	358
<i>I. Mandel, L. Z. Kelley, &amp; E. Ramirez-Ruiz</i>	
The NOAO Variable-Sky Project . . . . .	361
<i>T. Matheson, R. Blum, B. Jannuzi, T. Lauer, D. Norman, K. Olsen, S. Ridgway, A. Saha, R. Shaw, &amp; A. Walker</i>	
Statistics of Stellar Variability in Kepler Data with ARC Systematics Removal . . . . .	364
<i>A. McQuillan, S. Aigrain, &amp; S. Roberts</i>	
Variability Analysis based on POSS1/POSS2 Photometry. . . . .	366
<i>A. M. Mickaelian, A. Sarkissian, &amp; P. K. Sinamyan</i>	
Optical Pulsations from Isolated Neutron Stars . . . . .	369
<i>R. P. Mignani</i>	
LOFT: Large Observatory For X-ray Timing . . . . .	372
<i>R. P. Mignani, S. Zane, D. Walton, T. Kennedy, B. Winter, P. Smith, R. Cole, D. Kataria, &amp; A. Smith (for the LOFT team)</i>	
Search for Turbulent Gas through Interstellar Scintillation . . . . .	376
<i>M. Moniez, R. Ansari, F. Habibi, &amp; S. Rahvar</i>	
Optical Polarimetry of the Crab Nebula . . . . .	379
<i>P. Moran, A. Shearer, &amp; R. Mignani</i>	
Time Domain Astrophysics with SuperWASP . . . . .	382
<i>A. J. Norton and the SuperWASP Consortium</i>	
ARCONS: a Highly Multiplexed Superconducting UV-to-Near-IR Camera . . . . .	385
<i>K. O'Brien, B. Mazin, S. McHugh, S. Meeker, &amp; B. Bumble</i>	
Photographic Archives of Ukrainian Observatories: Digitizing a Heritage . . . . .	389
<i>L. Pakuliak, L. Kazantseva, N. Virun, &amp; V. Andruk</i>	
Towards a More General Method for Filling Gaps in Time Series. . . . .	392
<i>J. Pascual-Granado, R. Garrido, J. Gutierrez-Soto, &amp; S. Martín-Ruiz</i>	
The International Liquid Mirror Telescope (ILMT) as a Variability Time Machine . . . . .	394
<i>J. Poels, E. Borra, P. Hickson, R. Sagar, P. Bartczak, L. Delchambre, F. Finet, S. Habraken, J.-P. Swings, &amp; J. Surdej</i>	
Classification of ASKAP VAST Radio Light Curves. . . . .	397
<i>U. Rebbapragada, K. Lo, K. L. Wagstaff, C. Reed, T. Murphy, &amp; D. R. Thompson</i>	
The Importance of Timing Metadata. . . . .	400
<i>A. H. Rots</i>	
Using the Gregory-Loredo Algorithm for the Detection of Variability in the Chandra Source Catalog . . . . .	402
<i>A. H. Rots</i>	
On Our Multi-Wavelength Campaign of the 2011 Outburst of T Pyx . . . . .	404
<i>L. Schmidtbreick, A. Bayo, Y. Momany, V. Ivanov, D. Barria, Y. Beletsky, H. M. J. Boffin, G. Brammer, G. Carraro, W.-J. de Wit, J. Girard, G. Hau, M. Moerchen, D. Nuernberger, M. Pretorius, T. Rivinius, R. Sanchez-Janssen, F. Selman, S. Stefl, &amp; I. Yegorova</i>	

Multi-wave Monitoring of the Gravitational Lensed Quasar Q0957+561 . . . . .	406
<i>V. N. Shalyapin, L. J. Goicoechea, &amp; R. Gil-Merino</i>	
A Global Robotic Telescope Network for Time Domain Science . . . . .	408
<i>R. A. Street, T. A. Lister, Y. Tsapras, A. Shporer, F. B. Bianco, B. J. Fulton, D. A. Howell, B. Dilday, M. Graham, D. Sand, J. Parent, T. Brown, K. Horne, M. Dominik, P. Browne, C. Snodgrass, N. Kains, D. Bramich, N. Law, &amp; I. Steele</i>	
FRATs: Searching for Fast Radio Transients in Real Time with LOFAR. . . . .	411
<i>S. ter Veen, P. Schellart, &amp; H. Falcke, for the LOFAR Transients and Cosmic Ray Key Science Projects</i>	
Source Detection with Interferometric Datasets . . . . .	414
<i>C. M. Trott, R. B. Wayth, J.-P. R. Macquart, &amp; S. J. Tingay</i>	
Wide-Field Plate Database: Latest Results . . . . .	417
<i>M. Tsvetkov, &amp; K. Tsvetkova</i>	
Period Analyses of 100+ Years of RR Lyrae Data . . . . .	420
<i>E. N. Walker</i>	
The VLBA Fast Radio Transient Experiment: Progress and Early Results . . . . .	423
<i>R. B. Wayth, W. F. Brisken, A. T. Deller, W. A. Majid, D. R. Thompson, S. J. Tingay, &amp; K. L. Wagstaff</i>	
Around Gaia Alerts in 20 questions . . . . .	425
<i>L. Wyrzykowski &amp; S. Hodgkin</i>	
Poster Summaries. . . . .	429
Afterword . . . . .	454
Reflections on a Week in Oxford. . . . .	455
<i>T. Murphy</i>	
Author Index . . . . .	459

## Introduction

Studies of variability constitute prolific and profitable sources of information about how objects in the cosmos form, exist, and evolve. Variability can be periodic, aperiodic, spasmodic, or secular; it can involve times-scales from a millisecond to a century and beyond, and it can embrace the whole electromagnetic spectrum or just one portion of it. Studies of radial-velocity variables require well-tried techniques and only need dedication and persistence to yield new information; stellar pulsations and exoplanets are tough to identify and demand special observing techniques, while previously unknown cases of variability require new data-mining techniques applied to large data collections. Progress and innovation thus depend on fully-supported, open, and coherent database management systems plus appropriate data extraction and analysis tools. Discoveries and observations of variability can drive theory (e.g., supernovæ light-echoes or binary-star mergers), while theory can inspire searches for phenomena that would otherwise pass undetected (e.g., in asteroseismology).

Whereas it was once believed that variable stars were exceptional, every celestial object actually varies to some degree. Our plate stores proved essential for studies of spectroscopic and astrometric variability, and the AAVSO (operational since 1911) has likewise been invaluable for studies of photometric variability; both sources of historic data are in fact growing in value as their respective time-bases increase. At the same time, the substantial developments in theory and in observational techniques have enabled studies of group similarities to graduate to the finer details suggested by their differences. That progress owes as much to rapid access to digital data, to database mining techniques, and to tools developed by the Virtual Observatory, as to the increased power of telescopes and systems, improved detector sensitivity, innovative technology, and phenomenology-focused research.

But while modern ingenuity and proficiency have opened up new fields of study such as transients, blazars, gamma-ray bursts, active galactic nuclei and quasars, the puzzles posed by more traditional longer-term variability have not been laid to rest. On the contrary, objects with substantially long variability characteristics are now returning to the scene; some even reveal stellar evolution itself. At the same time, networks of observers are nowadays “hotwired” to alerts of new events rather than relying on telegraph or mail. Studies of variability are thus burgeoning in all respects, and the principle of free, open-access data is a core factor throughout.

On first detection all processes are mysterious, all objects unknown. As time-series data accumulate and archival cross-matching proceeds, empirical inferences emerge from the mist, and the first physical models are developed and debated. Available information on the plethora of variability types has now become overwhelming, to the point where whole symposia focus on just one type and its associated research community. But while specialist studies are undeniably important for refining theory, the significance of occurrences of similar phenomena in different objects may get overlooked, so key astrophysics can be missed.

This Symposium focused on the different manifestations of variability, and sought to shed light on new scientific insights which are not apparent when one type of object is studied in isolation. It therefore crossed previously recognized boundaries because the need is precisely to erase those boundaries, to think outside the box. Astrophysics transcends disciplines. Structures such as disks and jets, or processes such as pulsations and occultations, appear in different guises at different scales in different cosmic contexts.

The phenomenology of time-varying measurements that drives the empirical characterization of dramatically diverse astrophysical objects recurs time and again, but the cross-boundary links are less well aired. Phenomena of SNe, for example, were investigated for many years before it was realised that an apparently single class of object actually was composed of several very different celestial events. Recent digitizing of early plates of the Harvard collection has revealed objects that vary over periods of several tens of years with amplitudes of almost a magnitude. Can the cause(s) of those variations be linked to ones that manifest variations or pulsations of similar amplitudes but very much shorter period, and—if so—are there false constraints in current models? Similarly, can high-energy studies influence current concepts of stellar evolution and variability in the AGB zone? On the other hand, scientific progress in the phenomenology itself is still handicapped by very incomplete information regarding the frequency of events. How can observers make better use of tools, technologies and techniques in order to capture a greater percentage of transients, novæ, etc.?

The core question, “How can technology and collaboration be better harnessed to enhance the science requirements?” was fundamental to the Symposium’s planning. The full potential of new observing opportunities and techniques, new capabilities to revisit historic data, and new interpretative tools will not be realized unless the user community acquires the necessary skills to manage relevant data in diverse forms. “Showing and telling” are a vital element of the learning process, but are insufficient if performed only generically or are deemed to be the province of the specialist. Summarising the principles of applying the tools is inadequate without real examples. “What” and “when” are vital complementary ingredients of the banquet offered by variability, but achieve little without the all-important recipes for “how”. Neither database managers nor researchers can be maximally productive if working in isolation and without appropriate feedback. As well as highlighting what is actually new and what is promised, the Symposium included a strong didactic content in the form of topical workshops focusing on practical skills and knowledge.

The timing for a cross-discipline symposium in time-domain astronomy was highly favourable, and as at least one participant noted, this may be the last time that a Symposium of such broad scope will be feasible. Major new transient surveys are coming on-line as soon as the next year or two, and their data will drive the respective fields substantially forward at all wavelengths. On-line data from projects such as the Palomar Transient Factory, SkyMapper, Pan-STARRS, and LOFAR will revolutionize studies of (at least) supernovæ, novæ, AGNs (quasars/blazars), variable stars and pulsars. These projects (and many others) will lay the groundwork for even greater time-domain investigations over the next decade, including the truly massive Large Synoptic Survey. At the same time, high-speed digitizers to scan photographic plates are revealing the fascinating pervasiveness of even “more obvious” photometric and spectrum variability by harnessing the past to the present over long temporal baselines.

The Symposium was organized into daily themes:

- Monday: Can our data meet the challenges?
- Tuesday: Explosive or irreversible changes
- Wednesday: Things that tick
- Thursday: Irregular and aperiodic changes
- Friday: Preparing for the future

On each day we examined commonalities in the science as revealed by certain types of variability, crossing frequency and time-scale boundaries in the process, and including presentations from database experts on the present and projected status of analysis

tools. Talks from different sub-disciplines were intentionally interleaved in order to avoid specialist-level isolation, and speakers rose to the challenge and presented talks that were accessible to a broad audience. Some 110 poster papers were displayed in two multi-day sessions, leading to stimulating discussions over coffee and evening refreshments.

Afternoons were set aside for topical workshops, each organized by participants in the Symposium and structured as they saw fit for discussion of the challenges facing a particular subset of time-domain studies. Topics ran the gamut from Extreme Physics and Gravitational Waves to Stellar Variability, Astrotomography, Light Echoes, Historical Data, and Data Management.

An additional highlight of the Symposium was the Monday evening public lecture given by Professor Sir Martin Rees (Baron Rees of Ludlow), FRS and Astronomer Royal, entitled “From Microseconds to  $\text{\AA}$ ons—How Our Complex Cosmos Emerged.” Held in the auditorium of the Oxford University Museum of Natural History, the talk attracted a full house and was followed by a lively question-and-answer session.

Some in the community were concerned that a Symposium of such breadth, and structured as a hybrid between presentations of new research results, visions of the future, and a practicum of research tools, would not succeed on any of these fronts. In fact, comments from participants after the meeting were unanimous in their acclaim. More than anything else, perhaps, the meeting opened up lines of communication and collaboration that had not existed before. On the first day of the meeting a common comment was “I barely know 20% of the people here,” whereas by the end of the week people were saying “I’ve met at least three-quarters of the people, and have started new collaborations that would not have happened otherwise.” The welcoming environment of St. Catherine’s College, wherein nearly all participants of the conference were housed, encouraged many side discussions that often continued in the convivial pubs of Oxford.

While there may indeed not be another conference on time domain astronomy that casts such a broad net, this one certainly accomplished its goal of being integrative and enabling of cross-cutting research. The organizers thank the participants for their willingness to share their knowledge—and to appreciate the knowledge of others in different fields—as a means to understanding the many mysteries of the time domain.

*Robert Hanisch*

*Space Telescope Science Institute and Virtual Astronomical Observatory, USA*

*Elizabeth Griffin*

*Dominion Astrophysical Observatory, Canada*

*December 2011*



## Foreword

The divergences from convention which IAU S285 introduced affected not only the scheduling of each day's communications but also the layout of these Proceedings. In compiling them we have aimed to reflect the contents of the week's science in a manner that is both informative and useful as a research document. To that end, we laid emphasis on capturing not only the new but also the slightly speculative, welcoming opinions and ideas as well as journal-style research papers. Speakers were given the option of not submitting a full write-up if the content of a talk had been, or would be, published in its entirety elsewhere; 28% so chose, and for those we have reproduced here just an abstract, slightly modified into a summary.

The most severe divergence from a conventional schedule was the introduction of workshops (*a.k.a.* breakout sessions or focus discussions) on the three full afternoons. For each we have included here a report, written in whatever style its author(s) selected; some are statements condensed from the discussions which constituted the Workshop, some are brief scientific papers, while for just a few—those with a predominantly pedagogical element—we have reproduced instead the “paragraphs” which told visitors to our Wiki page what were a workshop's objectives and (possibly) an outline programme.

That daily schedule did not permit as many contributed talks as would have been the case in a more conventional programme—only 1 in 9 applicants could be thus accommodated; most of the rest prepared posters instead. We therefore offered all 110 poster presenters the opportunity to submit short write-ups of their posters. One-half accepted, while for the rest we have included their abstracts, once again modified into summaries.

While endeavouring to maintain fidelity between these Proceedings and what was communicated and discussed at IAU S285, we have tried hard to make the book *readable*. However, while the laurel of that achievement could be shared by the two closing papers of the Symposium (*q.v.*), we also recommend making time to heed the thought-provoking views in the after-dinner speech, which is reproduced intact on page 455. Without question, the pulse of change that is so clearly revealed by the perceptive and thought-provoking view of the younger generation will be incorporated into the way in which we conduct scientific research in the future.

As many remarked, ours was a star-studded cast, and—alas—the promised full-length write-up by the opening speaker of the first session could not be completed because its author was subsequently called to receive the Nobel Prize. The diversity of the topics which appeared to be touched by variability astonished even the organizers, and the capacity number of participants whom they attracted ran the whole gamut from senior academics and researchers to programmers and database experts and a blind graduate from an ethnic minority.

We thank the participants of IAU Symposium 285 for their contributions to this Proceedings, and for making the conference such a success.

## Acknowledgements

It is a real pleasure to thank the colleagues and organizations whose assistance, co-operation and advice contributed vitally towards the overall success of the Symposium:

- Mark Sullivan and Aris Karastergiou (co-Chairs of the LOC), who undertook the lion's share of the Website and Wiki management, handled all the housekeeping duties such as Registration and funding administration, and organized many invisible details with perfection,

- the LOC team recruited from Oxford Astrophysics: Vanessa Ferraro-Wood (Departmental Secretary) and graduate students Sarah Blake, Tom Evans, Ian Heywood, Kate Maguire, Amy McQuillan, Yen-Chen Pan and Kimon Zagkouris. Between them they coped efficiently with all the back-stage duties and manifold preparations and tasks, both before and during the event,

- Amy McQuillan, for managing the “Variability” mug,

- Pete Marenfeld, whose design of the Symposium poster captured cryptically and exquisitely the breadth and diversity of the meeting,

- Sehar Tahir, for providing invaluable technical support with Latex,

- the IAU, for generously sponsoring S285 through travel grants to 28 participants,

- the Royal Astronomical Society, for a grant to run the public lecture—and of course to Professor Rees for giving it,

- St. Catherine's College—so near the centre of this historic and vibrant University city, yet far enough away as to not be inconvenienced by its bustle—for accommodating the Symposium when we wanted it, and for being amazingly co-operative and flexible. The impressive organizational skills of their dining-room staff in serving an excellent lunch each day speedily yet graciously was a practical lesson in parallel processing,

- Oxford Astrophysics, for financial sponsorship and for lending us personnel,

- Oxford University Press and Springer Scientific Publications, for books to display,

- the Lord Mayor of Oxford (Cllr. Elise Benjamin), for opening the Symposium, and the City Council for laying on a reception, and

- most importantly of all, the participants, for donating time, energy, enthusiasm, ideas and good-will.

Elizabeth and Bob  
Co-Chairs, IAU S285

# CONFERENCE PHOTOGRAPH



Symposium participants, in the grounds of St. Catherine's College, Oxford