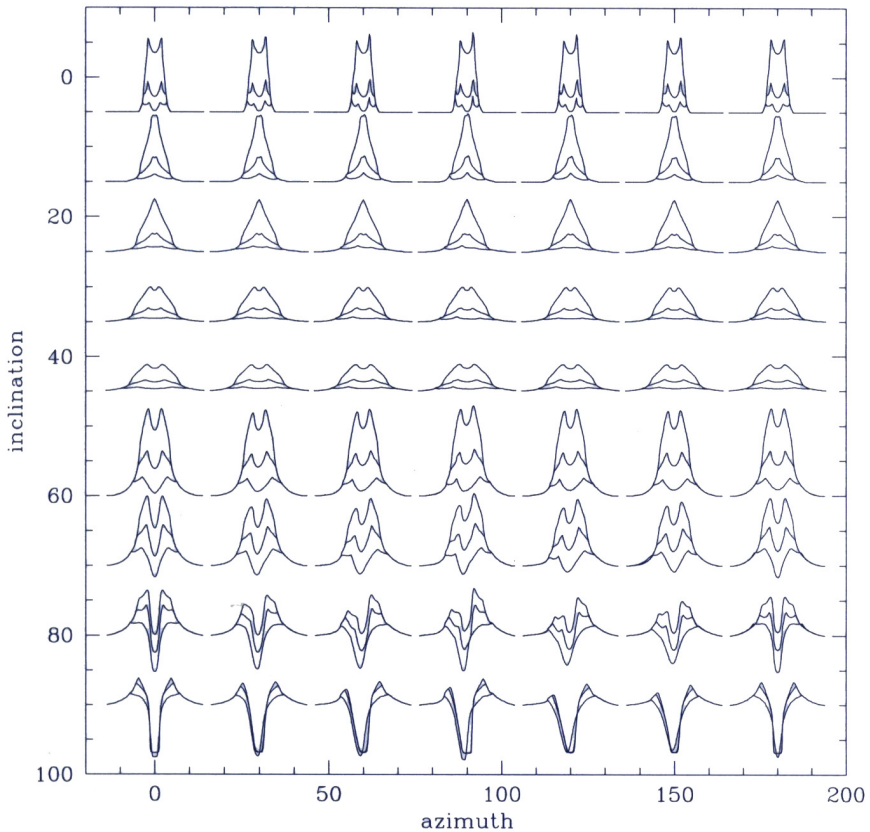




## THE Be PHENOMENON IN EARLY-TYPE STARS IAU Colloquium 175



**Edited by**  
**Myron A. Smith, Huib F. Henrichs**  
**and Juan Fabregat**

THE Be PHENOMENON IN EARLY-TYPE STARS  
IAU Colloquium 175

COVER ILLUSTRATION:

Theoretical  $H\alpha$  emission lines of non-axisymmetric Be star circumstellar disks as referenced in the current volume, W. Hummel, Fig. 7, p. 405.

**A SERIES OF BOOK ON RECENT DEVELOPMENT IN  
ASTRONOMY AND ASTROPHYSICS**

---

First Published 2000  
Copyright © 2000

**ASTRONOMICAL SOCIETY OF THE PACIFIC**  
390 Ashton Avenue, San Francisco, California, USA 94112-1722  
Phone: (415) 337-1100 Fax: (415) 337-5205  
E-Mail: [catalog@aspsky.org](mailto:catalog@aspsky.org) Web Site: [www.aspsky.org](http://www.aspsky.org)

All Rights Reserved

*No part of the material protected by this copyright notice may be reproduced or utilized in any form or by any means, electronic or mechanical including photocopying, recording or by any information storage and retrieval system, without written permission from the Astronomical Society of the Pacific.*

**ASP CONFERENCE SERIES - EDITORIAL STAFF**

Managing Editor: D. H. McNamara  
Associate Managing Editor: J. W. Moody  
LaTeX-Computer Consultant: T. J. Mahoney  
Production Manager: Enid L. Livingston  
Assistant Production Person: Krista Tobler

**Editorial Office:**

PO Box 24453, 211 KMB, Brigham Young University, Provo, Utah, 84602-4463  
Phone: (801) 378-2111 Fax: (801) 378-4049 E-Mail: [pasp@byu.edu](mailto:pasp@byu.edu)

**ASP CONFERENCE SERIES PUBLICATION COMMITTEE:**

Alexei V. Filippenko	Geoffrey Marcy
Ray Norris	Donald Terndrup
Frank X. Timmes	C. Megan Urry

**Printed by:**

Sheridan Books, Inc., 613 East Industrial Drive, Chelsea, Michigan 48118

Library of Congress Catalog Card Number: 00-106714  
ISBN: 1-58381-045-5

ASTRONOMICAL SOCIETY OF THE PACIFIC  
CONFERENCE SERIES



Volume 214

THE Be PHENOMENON IN EARLY-TYPE STARS  
IAU Colloquium 175

Proceedings of a meeting held in  
Alicante, Spain  
28 June - 2 July, 1999

Edited by

Myron A. Smith  
*Computer Sciences Corporation, Space Telescope Science Institute  
Baltimore, Maryland, USA*

Huib F. Henrichs  
*Astronomical Institute, University of Amsterdam, Amsterdam, Netherlands*

and

Juan Fabregat  
*Universidad de Valencia, Burjassot, Spain*

**A listing of all other ASP Conference Series Volumes and IAU Volumes  
published by the ASP is cited at the back of this volume**

# TABLE OF CONTENTS

The SOC and LOC .....	xiii
Preface .....	xiv
List of Participants .....	xvi
<b>1. OVERVIEW</b>	
<b>The Be Phenomenon<sup>1</sup></b>	
<i>L.A. Balona</i> .....	<b>1</b>
<b>Physical Properties and Evolutionary Stage of Be Stars</b>	
<i>P. Harmanec</i> .....	<b>13</b>
<b>The Connection with B[e] stars</b>	
<i>F. Zickgraf</i> .....	<b>26</b>
<b>The Be Phenomenon: Connections to B-supergiants</b>	
<i>A. Kaufer</i> .....	<b>37</b>
<b>A Spectropolarimetric Atlas of 61 Bright Northern Be Stars</b>	
<i>K.S. Bjorkman, M.R. Meade, B.L. Babler</i> .....	<b>48</b>
<b>On the Initial Mass Function of Be Stars and the Missing Be Stars of Late Spectral Types</b>	
<i>J. Zorec</i> .....	<b>51</b>
<b>The Visual Absolute Magnitude of the Central Objects in Be Stars</b>	
<i>A. Moujtahid, J. Zorec</i> .....	<b>55</b>
<b>Abundances of Be Stars in Very Young Open Clusters</b>	
<i>A. Marco, G. Bernabeu, J.M. Torréjon, J.J. Rodes, J. Fabregat</i> .....	<b>59</b>
<b>Be Star Surveys in Open Clusters with Balmer-line Photometry</b>	
<i>G. Capilla, J. Fabregat, D. Baines</i> .....	<b>63</b>
<b>Discovery of New Be Stars in the Galactic Open Cluster NGC7128</b>	
<i>Z. Balog, J. Vinkó, G. Fűrész et al.</i> .....	<b>67</b>
<b>Spectroscopic Investigations of the Main-Sequence B Stars in the Association Cas OB2 and the Open Cluster Platais 1 (C2128+488)</b>	
<i>I.A. Usenko, V.V. Koltjukh, S.M. Andrievsky et al.</i> .....	<b>71</b>
<b>Be Stars in the Magellanic Clouds</b>	
<i>S.C. Keller, M.S. Bessell, G.S. DaCosta</i> .....	<b>75</b>
<b>A Spectroscopic Study of Be stars in the SMC Cluster NGC 330</b>	
<i>W. Hummel, W. Gässler, B. Muschelok et al.</i> .....	<b>79</b>
<b>The B[e] Star MWC 84 (CI Cam)</b>	
<i>C. Jaschek, Y. Andriat</i> .....	<b>83</b>
<b>BCD Classification of Stars with the B[e] Phenomenon</b>	
<i>L. Cidale, J. Zorec, N. Morrell</i> .....	<b>87</b>

<sup>1</sup>Titles in boldface type refer to invited papers.

The Be Phenomenon in A-type Supergiants <i>E. Verdugo, A. Talavera, A.I. Gómez de Castro</i> .....	91
Rapid Variations of Discrete Absorption Components in the spectrum of P Cygni <i>G.L. Israelian</i> .....	96
The Nebula Surrounding the B[e] Supergiant R4 <i>A. Pasquali, A. Nota, N. Langer et al.</i> .....	100
The Connection between Classical Be Stars and Herbig Ae/Be Stars <i>T. Böhm, L.A. Balona</i> .....	103
Probing the Small Scale Structures around Herbig Be Stars using H $\alpha$ Spectropolarimetry <i>R.D. Oudmaijer, J.E. Drew, G. Busfield</i> .....	108
Modelling of Spherical Extended Atmospheres: Some New Results <i>A.C. Vázquez</i> .....	113
 <b>2. NEW MISSIONS</b>	
<b>Hipparcos Positions of B/Be Stars on the HR Diagram</b> <i>D. Briot, N. Robichon</i> .....	117
<b>Direct Optical Imaging of Be Disks</b> <i>P. Stee</i> .....	129
<b>The ST3 Mission, and its Capabilities for Be Star Observations</b> <i>R.P. Linfield</i> .....	141
<b>ISO Observations of Be Stars</b> <i>L.B.F.M. Waters, N. R. Trams, S. Hony et al.</i> .....	145
<b>X-ray Emission from Isolated Be Stars</b> <i>D.H. Cohen</i> .....	156
<b>Watching Binary Systems with Be Components with the GI2T-REGAIN Spectro-Interferometer</b> <i>N. Thureau, D. Bonneau, D. Mourard et al.</i> .....	170
<b>Interferometry and Stellar Magnetism</b> <i>O. Chesneau, K. Rousselet-Perraut, F. Vakili</i> .....	174
 <b>3. PERIODIC VARIATIONS</b>	
<b>Observed Periodic Phenomena</b> <i>D. Baade</i> .....	178
<b>Multimode Detections from Surveys</b> <i>C. Aerts</i> .....	192
<b>Optical Variability of the Be Star <math>\sigma</math> And during the Period 1975–1998: Rotational Modulation or Multimodal Pulsations?</b> <i>G. Guerrero, J.P. Sareyan, M. Álvarez et al.</i> .....	205
<b>Mid-term Photometric Periodic Variations in Be Stars HR 1960 and HR 2968</b> <i>F. Carrier, G. Burki</i> .....	208
<b>Long-Term Variability in the Winds of <math>\lambda</math> Eridani and 66 Ophiuchi</b> <i>G.J. Peters</i> .....	212
<b>A UV Spectrophotometric Technique for Measuring Temperatures of</b>	

Circumstellar Structures over B Stars <i>M.A. Smith</i> .....	216
Co-rotating Photospheric Clouds in $\mu$ Centauri <i>L.A. Balona, D. James, W.A. Lawson, R.R. Shobbrook</i> .....	220
The Multiperiodicity of $\mu$ Cen (B2IVe) <i>D. Baade, Th. Rivinius, S. Štefl</i> .....	224
Non-radial Pulsation Modeling of $\mu$ Centauri <i>Th. Rivinius</i> .....	228
Multiperiodic Variability and Outbursts of 28 Cygni <i>S. Tubbesing, Th. Rivinius et al.</i> .....	232
Short-period Variations of 28 CMa during 1998/9 <i>L.A. Balona, D. James</i> .....	236
Tracing the Transient Periods in the Be Star 28 $\omega$ CMa <i>S. Štefl, A. Budovičová, D. Baade et al.</i> .....	240
Non-radial Pulsation Modeling of $\omega$ (28) CMa <i>M. Mainz, Th. Rivinius, S. Tubbesing et al.</i> .....	244
Phase Variation and NRP Modes in Southern Be Stars <i>E. Janot-Pacheco, N.V. Leister, A.D. de Souza Jr. et al.</i> .....	248
NRP Modeling of the Line Profile Variations of $\lambda$ Eri in the 1994 Campaign <i>E. Kambe, R. Hirata, J. Fabregat</i> .....	252
Pulsations in 66 Oph: Multiperiodicity in He I 6678 <i>M. Floquet, C. Neiner, D. Briot et al.</i> .....	256
Short-term Periodicity in the Pole-on Be Star $\nu$ Cyg <i>M. Floquet, C. Neiner, A.M. Hubert, M. Floquet et al.</i> .....	260
Doppler Imaging of Non-radially Pulsating Stars <i>S. Jankov, E. Janot-Pacheco, N.V. Leister</i> .....	264
Mapping the Non-Radial Pulsations <i>S.V. Berdyugina, H. Korhonen, C. Schrijvers, J.H. Telting</i> .....	268
Line Profile Variability in the Be Star $\alpha$ Eridani <i>N.V. Leister, E. Janot-Pacheco, J. Leyton Z et al.</i> .....	272
Multi-frequency Variations in the Be star $\zeta$ Ophiuchi <i>A.D. de Souza Jr., E. Janot-Pacheco, N.V. Leister et al.</i> .....	276
Spectral and Light Variability of Be Star 60 Cygni <i>P. Koubský, P. Harmanec, A.M. Hubert et al.</i> .....	280
On the Excitation Mechanism for the Nonradial Pulsations in $\epsilon$ Persei <i>E. Kambe, H. Saio, U. Lee</i> .....	284
Trans-Photospheric Wave Leakage in Be Stars <i>R. Townsend</i> .....	288

#### 4. APERIODIC VARIATIONS

##### Recent Spectroscopic Evidence for Aperiodic Activity in Classical Be Stars

<i>M.A. Smith</i> .....	292
Physical Requirements for Flares in Stars <i>B. Haisch</i> .....	304
Can Magnetic Fields Be Detected in Be Stars? <i>G. Mathys, M.A. Smith</i> .....	316



<b>The Magnetic Field of <math>\beta</math> Cep and the Be Phenomenon</b>	
<i>H.F. Henrichs, J.A. de Jong, J.-F. Donati et al.</i> .....	324
<b>Light Curves of Be Stars due to Orbiting Arcs of Matter or Prominence-Like Structures</b>	
<i>J. Zorec, Y. Frémat, A.M. Hubert</i> .....	330
<b>Surface Magnetic Fields in Early-Type Stars</b>	
<i>V.S. Airapetian</i> .....	334
<b>The Rise of a Magnetic Flux Tube through the Radiative Envelope of a <math>9 M_{\odot}</math> Star</b>	
<i>J.P. Cassinelli, K.B. MacGregor</i> .....	337
<b>Be Phenomena in Young Early-type Stars: Various Forms of Interaction between the Star and the Circumstellar Gaseous Envelope</b>	
<i>M. Pogodin</i> .....	344
<b>Short-lived and Long-lived Outbursts in B and Be Stars from Hipparcos Photometry and Modelling</b>	
<i>A.M. Hubert, M. Floquet, J. Zorec</i> .....	348
<b>The Changing X-Ray Properties of <math>\gamma</math> Cas</b>	
<i>M.A. Smith, R.D. Robinson</i> .....	352
<b>5. CAMPAIGNS</b>	
<b>HEROS Be Star Campaigns</b>	
<i>S. Štefl, T. Rivinius</i> .....	356
<b>Chinese and Japanese Participation in B/Be Star Campaigns</b>	
<i>J. Hao</i> .....	364
<b>Results from MuSiCoS Campaigns on Be stars</b>	
<i>H.F. Henrichs, C. Neiner, A.M. Hubert et al.</i> .....	372
<b>Short-Term Wind and Photospheric Activity in Be Stars Deduced from Campaigns with the IUE Spacecraft</b>	
<i>G.J. Peters, D.R. Gies</i> .....	375
<b>6. DISKS</b>	
<b>Polarimetry as a Diagnostic of Circumstellar Envelopes</b>	
<i>K.S. Bjorkman</i> .....	384
<b>Line Profile Modeling of Disks</b>	
<i>W. Hummel</i> .....	396
<b>Theory of Global Disk Oscillations</b>	
<i>A.T. Okazaki</i> .....	409
<b>Long-term Variability in Be-Star disks</b>	
<i>J.H. Telting</i> .....	422
<b>The Formation and Structure of Circumstellar Disks</b>	
<i>J.E. Bjorkman</i> .....	435
<b>Spectrophotometric and Photometric Behaviours of Be Stars: the Circumstellar Envelope Formation Mechanisms</b>	
<i>J. Zorec, A.M. Hubert, A. Moujtahid</i> .....	448

Polarization from Be Disks with 1-Armed Density Waves <i>R. Ignace</i> .....	452
A Connection Between $V/R$ and Polarization in Be Stars <i>D. McDavid, K.S. Bjorkman, J.E. Bjorkman, A.T. Okazaki</i> .....	460
Reflections on Scattered Light: Monte Carlo Simulations of the Flux and Polarization Curves of $\beta$ Lyrae <i>J.L. Hoffman, B.A. Whitney, K.H. Nordsieck</i> .....	464
Near Infrared Spectroscopic Observations of Early-type Be Stars <i>N.M. Ashok, D.P.K. Banerjee</i> .....	468
Paschen and Brackett Lines in Be stars <i>L. Cidale, J. Zorec, J.P. Maillard, N. Morrell</i> .....	472
Mid-Infrared Spectra of Be Stars <i>S.A. Rinehart, J.R. Houck</i> .....	476
Fundamental Parameters of Be Stars Derived from Near-Infrared Spectra <i>L. Houziaux, Y. Frémat</i> .....	480
Far-infrared Excesses in Classical Be Stars <i>A.S. Miroshnichenko, K.S. Bjorkman</i> .....	484
Influence of the Plasma Opacity in the Calculations of IR Emission Due to Dielectronic Recombination of Mg II <i>A. Cruzado, A.E. Ringuélet</i> .....	488
On the Fe II Dielectronic Recombination in Stellar Envelopes <i>A. Cruzado, A.E. Ringuélet</i> .....	492
B-type Emission-line Stars with Warm Circumstellar Dust <i>T.A. Sheikina, A.S. Miroshnichenko, P. Corporon</i> .....	494
Optical and Near-Infrared Spectroscopy of the Emission Line Young Stellar Object Gy 2-18 (HHL 31) <i>P. Persi, V.F. Polcaro, J. Bohigas, M. Tapia</i> .....	498
Continuum Flux Excess in Be Stars Determined from Spectral Lines <i>J. Zorec, D. Ballereau, J. Chauville</i> .....	502
On the Characteristics of Circumstellar Envelopes in Be Stars near the Central Object <i>A. Moujtahid, J. Zorec, A.M. Hubert</i> .....	506
Physical Properties of Circumstellar Envelopes in Be Stars Derived from their Long-term Spectrophotometric Variations <i>A. Moujtahid, J. Zorec, A.M. Hubert</i> .....	510
Correlated Spectroscopic and Spectrophotometric Behaviours of Be Stars <i>A. Moujtahid, A.M. Hubert, J. Zorec et al.</i> .....	514
Shell Lines in Be Disks <i>R.W. Hanuschik</i> .....	518
Be Envelope Properties Determined from Fe II Emission Lines <i>J. Chauville, D. Ballereau, L. Cidale et al.</i> .....	523
Line Formation in Be Star Disks: Shell Absorption and Rotation Law <i>W. Hummel, M. Vrancken</i> .....	527
Interpretation of the Cyclic Balmer Progression Phenomenon <i>R. Hirata, A.T. Okazaki</i> .....	531
Long-term Variability of $\pi$ Aqr <i>K.S. Bjorkman, A.S. Miroshnichenko, D.A. McDavid et al.</i> .....	535
Discrete Structures in the CS Envelope of the Be star $\zeta$ Tau <i>D. Ballereau, J. Chauville, H. Cao et al.</i> .....	539

Variability of the H $\alpha$ Emission in the Be Star <i>o</i> Andromedae <i>E. Panko, A. E. Tarasov</i> .....	543
Semi-empirical Model of the Star V923 Aquilae <i>M.L. Arias, L.S. Cidale, A.E. Ringuélet</i> .....	547
Stellar and Circumstellar Activity in the Be Star EW Lac from the Multi-site 1993 Campaign <i>A.M. Hubert, M. Floquet, R. Hirata et al.</i> .....	550
A Spectroscopic and Photometric Study of the Shell Star EW Lac <i>H. Cao, Z. Li, L. Huang, Y. Guo</i> .....	554
The Be Phenomenon in Pleione <i>R. Hirata, M.R. Shimada, S. Masuda, J. Katahira</i> .....	558
The Emitting Envelope of Pleione between 1987 and 1998 <i>D. Ballereau, J. Chauville, J. Zorec, N. Morrell</i> .....	562
Spectral Changes of Pleione - Start of a New Cycle? <i>L. Iliev</i> .....	566
Spectral and Photometric Evolution of V725 Tau (1996-1999): Towards a Shell Phase? <i>A. Piccioni, C. Bartolini, S. Bernabei et al.</i> .....	569
IUE Spectra of Be Star CX Dra: Evidence for Winds <i>P. Škoda, P. Koubský</i> .....	573
The Circumstellar Structure of the Be Shell Star $\phi$ Per <i>W. Hummel, S. Štefl, Th. Rivinius</i> .....	577
59 Cygni: A Tilted $\phi$ Persei like System <i>Th. Rivinius, S. Štefl</i> .....	581
Photometry and Spectroscopy of X Per During the Years 1996-1999 <i>A. Piccioni, C. Bartolini, S. Bernabei et al.</i> .....	585
Multiwavelength Monitoring of the Be/X-ray Binary X Persei - Evidence for Multiple Disk Structures <i>P. Roche, A. E. Tarasov, V.M. Lyuty et al.</i> .....	589
X Per in 1996 - 1999: the Variability of Hydrogen and Helium Lines <i>I. Kolka, T. Eenmäe, A. Puss, L. Leedjärv</i> .....	593
Energy Balance in Circumstellar Envelopes <i>C.E. Millar, J.M. Marlborough, T.A.A. Sigut</i> .....	597
A Simple Spectropolarimetric Temperature Diagnostic for Circumstellar Disks <i>K.S. Bjorkman, J.E. Bjorkman, K. Wood</i> .....	603
Search for Evidence of Radiative Equilibrium Departures in Extended Atmospheres <i>R. Venero, L. Cidale, A. Ringuélet</i> .....	607
An MHD Model of Be Stars with Disks <i>A.E. Dudorov, D.E. Pudritz</i> .....	611
Be Star Discs: Inflow or Outflow? <i>J.M. Porter</i> .....	617
Effect of Instability-Generated Clumping on Wind Compressed Disk Inhibition <i>S.P. Owocki, D.H. Cohen</i> .....	621
Selfconsistent Models of Winds from Rotating Early-Type Stars - Application to B[e] star winds <i>P. Petrenz, J. Puls</i> .....	626
Ionization Structure and Mass Loss for Rapidly-Rotating Near	

Main-Sequence B Stars <i>J.E. Bjorkman, B.P. Abbott</i> .....	632
New Radiation Driven Wind Solutions Including Stellar Rotation: Applicability to Be stars <i>M. Curé</i> .....	636
He I Line Profiles Obtained From a Be Wind Model <i>R. Rohrmann</i> .....	640

## 7. INTERACTING BINARIES

Be Stars in Roche-Lobe Interacting Binaries <i>A.E. Tarasov</i> .....	644
Be stars in X-ray binary systems <i>M.J. Coe</i> .....	656
Glimpses of Be Binary Evolution <i>D.R. Gies</i> .....	668
Searching for New Be/X-ray Binaries in the SMC: the case of 1SAXJ0103–7209, XTEJ0055–724, RXJ0052–7319, XTEJ0111–7317 and 2E0050–7247 <i>S. Covino, G.L. Israel, V.F. Polcaro et al.</i> .....	681
Highly-Eccentric Be/X-ray Binaries: Evolution, Wind Rose Effect, Accretor-Propeller Luminosity Gap <i>N.V. Raguzova, V.M. Lipunov</i> .....	685
The Evolutionary Evidence for Be/Black Hole Binaries <i>N.V. Raguzova, V.M. Lipunov</i> .....	689
The Evolutionary Evidence for Most Be Stars Being Paired with Hot White Dwarfs <i>N.V. Raguzova</i> .....	693
Gas-Dynamical Modelling of Circumstellar Matter in $\beta$ Lyr A <i>V.V. Bisikalo, A.A. Boyarchuk, P. Harmanec et al.</i> .....	697
Origin of Circumstellar Matter in the Spectroscopic Binary CX Dra <i>H. Iwamatsu, R. Hirata, S. Masuda</i> .....	701
NLTE Model Atmospheres of Irradiated Stars in B Binaries <i>J. Kubát</i> .....	705
The Spectral Distribution of Be/X-ray Transients Implies Supernova Kicks <i>I. Negueruela</i> .....	709
The X-ray Outbursts of Be/X-ray Transients <i>I. Negueruela, A.T. Okazaki</i> .....	713
Global One-armed Oscillations in the Be/X-ray Binary LS I+61° 235/RX J0146.9+6121 <i>P. Reig, I. Negueruela, M.J. Coe et al.</i> .....	719
Evidence for Magnetic Field Decay in the Slowest Known Be/X-ray Pulsars X Per and RX J0146.9+5121 <i>X.-D. Li, Z.-R. Wang</i> .....	723
New <i>JHK</i> Photometry of LS I +61 303 <i>S. Martínez-Núñez, J. Fabregat</i> .....	727
Confirmation of a Moving Component in the H $\alpha$ Emission Line of	

LS I+61°303 <i>R.K. Zamanov, J. Martí</i> .....	731
Substantial Disc Loss in the Be/X-ray Binary System A0535+26 <i>N.J. Haigh, M.J. Coe, I.A. Steele, J. Fabregat</i> .....	735
Searching for New Be/X-ray Binaries in the Galactic Plane: the Case of GS 0834-43, 1WGA J1958.2+3232 and AX J1820.5-1434 <i>G.L. Israel, S. Covino, V.F. Polcaro et al.</i> .....	739
<b>8. SUMMARY</b>	
<b>Summary and Future Directions</b> <i>J.M. Marlborough</i> .....	<b>743</b>
Author Index .....	752
Objects Index .....	755
Subject Index .....	764