

B. Wolf O. Stahl A.W. Fullerton (Eds.)

# Variable and Non-spherical Stellar Winds in Luminous Hot Stars

Proceedings of the IAU Colloquium No. 169  
Held in Heidelberg, Germany, 15-19 June 1998



Springer

# Contents

## Session I Observations of Non-spherical Winds

chair: J.M. Marlborough and P. Williams

### Rotationally Modulated Winds of O Stars

Alex W. Fullerton . . . . .	3
-----------------------------	---

### Rotationally Modulated Winds of BA-Type Supergiants

Andreas Kaufer . . . . .	11
--------------------------	----

### Using Spectropolarimetry to Determine Envelope Geometry and Test Variability Models for Hot Star Circumstellar Envelopes

Karen S. Bjorkman . . . . .	19
-----------------------------	----

### Disks of Classical Be Stars

Stanislav Štefl . . . . .	24
---------------------------	----

### Evidence for Azimuthal Asymmetry in Be Star Winds

Geraldine J. Peters . . . . .	32
-------------------------------	----

### Short and Medium Term Variability of Emission Lines in Selected Southern Be Stars

Thomas Rivinius . . . . .	36
---------------------------	----

### Disk Winds of B[e] Supergiants

Franz-Josef Zickgraf . . . . .	40
--------------------------------	----

### Polarimetric Evidence of Non-spherical Winds

Antônio Mário Magalhães and Cláudia V. Rodrigues . . . . .	49
--	----

### Wolf-Rayet Wind Models: Photometric and Polarimetric Variability

Cláudia V. Rodrigues and Antônio Mário Magalhães . . . . .	57
--	----

<b>Anisotropic Outflows from LBVs and Ofpe/WN9 Stars</b>	62
Antonella Nota . . . . .	
<b>Non-isotropic Outflows in the Infrared: ISO Imaging of LBVs</b>	71
Norman R. Trams, C.I. van Tuyl, Robert H.M. Voors, Alex de Koter, Laurens B.F.M. Waters, and Patrick W. Morris . . . . .	
<b>Radio Evidence for Non-isotropic Outflows from Hot Stars</b>	80
Stephen White . . . . .	
<b>Optical Interferometry of Non-spherical Winds</b>	87
Farrokh Vakili, Denis Mourard, Philippe Stee, and Daniel Bonneau . . . . .	
<b>Direct Observational Evidence for Magnetic Fields in Hot Stars</b>	95
Gautier Mathys . . . . .	
<b>HST WFPCII Observations of the Inner HR Car Nebula</b>	103
Stephen Hulbert, Antonella Nota, Mark Clampin, Claus Leitherer, Anna Pasquali, Norbert Langer, and Regina Schulte-Ladbeck . . . . .	
<b>Observing Hot Stars in all Four Stokes Parameters</b>	107
Thomas Eversberg, Anthony F.J. Moffat, Michael Debruyne, John B. Rice, Nikolai Piskunov, Pierre Bastien, William H. Wehlau, and Olivier Chesneau . . . . .	
<b>Inverse Spectropolarimetric Modelling of Hot Star Wind Structure and Variability</b>	111
John C. Brown, Richard Ignace, and M. Piana . . . . .	
<b>Physics of Radiatively Driven Winds by High Angular Resolution Observations (HARO)</b>	115
Ph. Stee, D. Bonneau, D. Mourard, and F. Vakili . . . . .	
 <b>Session II Theory of Non-spherical Winds</b>	
chair: B. Baschek	
<b>Wind-Compressed Disks</b>	121
Jon E. Bjorkman . . . . .	
<b>Non-spherical Radiation-Driven Wind Models</b>	131
Joachim Puls, Peter Petrenz, and Stanley P. Owocki . . . . .	

<b>Radiation-Driven Disk Winds</b>	
Janet E. Drew, Daniel Proga, and René D. Oudmaijer . . . . .	140
<b>Radiative Fluxes and Forces in Non-spherical Winds</b>	
Rainer Wehrse and Guido Kanschat . . . . .	144
<b>Line-Driven Ablation by External Irradiation</b>	
Kenneth G. Gayley, Stanley P. Owocki, and Steven R. Cranmer . . .	151
<b>Extremely Luminous Atmospheres</b>	
Nir J. Shaviv . . . . .	155
<b>Disks formed by Rotation Induced Bi-stability</b>	
Henny J.G.L.M. Lamers, Jorick S. Vink, Alex de Koter, and Joseph P. Cassinelli . . . . .	159
<b>The Effects of Magnetic Fields on the Winds from Luminous Hot Stars</b>	
Joseph P. Cassinelli and Nathan A. Miller . . . . .	169
<b>Modeling Oblique Rotators: Magnetospheres and Winds</b>	
Steven N. Shore . . . . .	178
<b>X-Ray Emission from Magnetically Confined Winds</b>	
Jacques Babel . . . . .	187
 <b>Session III Variable Winds</b>	
chair: A.W. Fullerton, N. Markova and D. Massa	
<b>O-Star Wind Variability in the Ultraviolet and Optical Range</b>	
Lex Kaper . . . . .	193
<b>X-Ray Evidence for Wind Instabilities</b>	
Joseph J. MacFarlane, Joseph P. Cassinelli, and D.H. Cohen . . .	201
<b>X-Ray Variability of the O Star <math>\zeta</math> Puppis</b>	
Thomas W. Berghöfer . . . . .	203
<b>On the Variable Winds of BA Supergiants</b>	
Eugene Chentsov . . . . .	206

<b>UV Wind Variability in B Supergiants and its Implications for Wind Structures</b>	Derck Massa and Raman K. Prinja . . . . .	214
<b>Variability and Evidence of Non-spherical Stellar Winds in A-Type Supergiants</b>	Eva Verdugo, Antonio Talavera, and Ana I. Gómez de Castro . . . . .	218
<b>Variable Winds in Early-B Hypergiants</b>	Bernhard Wolf and Thomas Rivinius . . . . .	222
<b>Wind Variations of Wolf-Rayet Stars</b>	Anthony F.J. Moffat . . . . .	230
<b>Spectral Analyses of Wolf-Rayet Stars: The Impact of Clumping</b>	Wolf-Rainer Hamann and Lars Koesterke . . . . .	239
<b>The Long-Term Variability of Luminous Blue Variables</b>	Roberta M. Humphreys . . . . .	243
<b>Blitz Model for the Eruptions of Eta Carinae</b>	Nathan Smith, Joyce A. Guzik, Henny J.G.L.M. Lamers, Joseph P. Cassinelli, and Roberta M. Humphreys . . . . .	249
<b>Short-Term Variations of LBV's</b>	Otmar Stahl . . . . .	251
<b>Imaging Polarimetry of Eta Carinae with the Hubble Space Telescope</b>	Regina E. Schulte-Ladbeck, Anna Pasquali, Mark Clampin, Antonella Nota, John Hillier, and O.L. Lupie . . . . .	255
<b>Non-spherical Outflows in Massive Binary Systems: Circumbinary Disks?</b>	Gloria Koenigsberger, Edmundo Moreno, and Jorge Cantó . . . . .	260
<b>Long-Term Behaviour of the Variable Wind of P Cygni</b>	Indrek Kolka . . . . .	268
<b>High-Resolution Spectroscopy of Stellar Winds in Recently Recognized LBV Candidates</b>	Anatoly S. Miroshnichenko, Eugene L. Chentsov, and Valentina G. Klochkova . . . . .	272

<b>Evidence for Wind Anisotropies from Dust Formation by Wolf-Rayet Stars</b>	
Peredur M. Williams . . . . .	275
<b>ISO-SWS Spectroscopy of B[e] Stars</b>	
Robert H.M. Voors, Laurens B.F.M. Waters, and Patrick W. Morris . .	279
 <b>Session IV Theories of Wind Variations</b>	
chair: D. Massa	
<b>The Line-Driven Instability</b>	
Achim Feldmeier . . . . .	285
<b>Co-Rotating Interaction Regions in 2D Hot-Star Wind Models with Line-Driven Instability</b>	
Stanley P. Owocki . . . . .	294
 <b>Session V Pulsation</b>	
chair: A. Maeder	
<b>Pulsations in O Stars</b>	
Hubertus F. Henrichs . . . . .	305
<b>Non-radial Pulsations of BA Supergiants and Be Stars</b>	
Dietrich Baade . . . . .	312
<b>Theory of Pulsational Instabilities of Hot Stars</b>	
Alexei A. Pamyatnykh . . . . .	320
<b>Non-radially Pulsating Hot Stars: Non-radial Pulsations and Be Phenomenon</b>	
Yoji Osaki . . . . .	329
<b>Pulsation Hydrodynamics of Luminous Blue Variables and Pulsation-Driven Winds</b>	
Joyce A. Guzik, Arthur N. Cox, Kate M. Despain, and Michael S. Soukup	337
<b>Linear Strange Modes in Massive Stars</b>	
Wolfgang Glatzel . . . . .	345
<b>Instabilities in LBVs and WR Stars</b>	
Knut Jørgen Røed Ødegaard . . . . .	353

**Session VI Evolutionary Aspects**

chair: C. Sterken

**The Evolution of Non-spherical and Non-stationary Winds  
of Massive Stars**

- Norbert Langer . . . . . 359

**Rotation and Anisotropic Losses of Mass and Angular  
Momentum**

- André Maeder . . . . . 368

**Rotation and Wolf-Rayet Star Formation**

- Georges Meynet . . . . . 377

**Dusty LBV Nebulae: Tracing the Mass Loss History  
of the Most Massive Stars**

- Laurens B.F.M. Waters, Robert H.M. Voors, Patrick W. Morris,  
Norman R. Trams, Alex de Koter and Henny J.G.L.M. Lamers . . . . . 381

**Wolf-Rayet and LBV Nebulae as the Result of Variable  
and Non-spherical Stellar Winds**

- Mordecai-Mark Mac Low . . . . . 391

**Ring Nebulae Abundances: Probes of the Evolutionary  
History of Luminous Blue Variable Stars**

- Linda J. Smith, Antónella Nota, Anna Pasquali, Claus Leitherer,  
Mark Clampin, and Paul A. Crowther . . . . . 400

**The Wind Momentum – Luminosity Relationship  
of Blue Supergiants**

- Rolf-Peter Kudritzki . . . . . 405

**Conference Summary: The Demise of Spherical  
and Stationary Winds**

- Immo Appenzeller . . . . . 416

- Object Index** . . . . . 423