Preface

The idea for this book originated in the La Silla observatory where two of the editors were doing phase-resolved spectroscopy of some cataclysmic variable stars using the NTT. We realized that although indirect imaging techniques such as eclipse mapping and Doppler tomography had been around for more than a decade and had provided some of the most interesting discoveries, no book existed which covered these techniques. Moreover, no colloquium had ever been organized specifically on these topics. The implementation of tomographic methods in astrophysics, in order to probe structures on angular scales of micro-arcseconds, started about 15 years ago with the development of the eclipse mapping method. This method is able to reconstruct light distributions in eclipsing binaries by exploiting the regular obscuration of the light source by one of the binary components. A similar approach to regularised data fitting lead to a variety of related methods in order to resolve light distributions of the accretion flows in binaries, the surface structures of stars and the inner regions of active galaxies. The scientific output of these methods is considerable and they are increasingly becoming versatile tools for a wide community of researchers.

A specialised workshop seemed highly desirable, so we decided to organise the first international workshop on astrotomography. The idea of the meeting, which took place in Brussels in early July 2000, was to bring together researchers sharing an interest in applying indirect imaging methods in astronomy, and to compare the methods used in different fields. During the meeting, a large amount of time was devoted to extensive reviews of the various reconstruction techniques. In conjunction with the reviews, short contributed talks highlighted recent results and developments. Due to the small number of participants, 60, there was plenty of opportunity for discussion and interaction. Moreover, we wanted that the proceedings of this meeting could be used as a handbook on these methods. The reviewers were therefore asked to provide extensive accounts of their field. The proceedings thus consist of 13 reviews of about 25 pages each as well as 15 contributed talks of 6∼8 pages. A wide range of topics are discussed, mostly on the properties of accretion flows in semi-detached binary systems containing a compact stellar remnant. Other topics include the surface and magnetic field structure of single stars, the shock waves of Mira stars, the accretion flows around black holes in binaries and active galactic nuclei and the structure of Algol systems. The large variety of subjects covered is a clear illustration of the importance that indirect imaging techniques have gained in astrophysics. A new

generation of optical telescopes and spectrographs is coming on-line which will push the possibilities of indirect imaging even further. In conjunction with that, specialised instruments and projects on existing telescopes will deliver data sets with high time and wavelength resolutions tailored for accurate mapping experiments. We hope that these proceedings will provide a helpful overview for any researcher interested in such techniques. With the same spirit of producing more than just proceedings, we also include a list of some useful resources on the Internet. We also hope that the web page of the workshop will be kept alive and become a useful reference on astrotomography.

We would like to thank all the participants for making this workshop a success, and in particular all the contributing review authors for having generously agreed to come to the meeting at their own expense, and for their efforts in providing a balanced set of review papers. Many thanks to all the members of the local organising committee for the hard work before, during and after the workshop. The Brussels Planetarium is thanked for providing us with a meeting venue and excellent support. We also wish to thank the Director of the Royal Observatory of Belgium, Prof. Paul Pâquet, for his efforts. Rob Hynes provided us with a superb 'scientific impression' of an interacting binary that featured on the workshop poster and various other locations. Finally, we are grateful for financial support from project G.0265.97 of the Research Programme of the Fund for Scientific Research – Flanders (F.W.O. – Vlaanderen).

Brussels, Southampton,
November 2000

Henri Boffin,
Danny Steeghs,
Jan Cuypers

Workshop webpage: `http://www.astro.oma.be/DopplerWorkshop/`

List of Contributors

Timothy M.C. Abbott
Nordic Optical Telescope
Apartado 474
38700 Santa Cruz de La Palma
Canary Islands, Spain
tabbot@not.iac.es

Rodrigo Alvarez
Institut d'Astronomie et
d'Astrophysique
Université Libre de Bruxelles
C.P. 226, Boulevard du Triomphe
1050 Brussels, Belgium
Rodrigo.Alvarez@oma.be

Raymundo Baptista
Departemento de Física, UFSC
Campus Trinidade
88040-9000 Florianópolis, Brazil
bap@fsc.ufsc.br

John R. Barnes
Centro de Astrofisica
da Universidade do Porto
Rua das Estrelas
4150 Porto, Portugal
jrb@astro.up.pt

Henri M.J. Boffin
Royal Observatory of Belgium
3 av. Circulaire
1180 Brussels, Belgium
Henri.Boffin@oma.be

David A.H. Buckley
South African Astronomical
Observatory
PO Box 9, Observatory 7935
Cape Town, South Africa
dibnob@saao.ac.za

Elsa Bertino
South African Astronomical
Observatory
PO Box 9, Observatory 7935
Cape Town, South Africa
eb@saao.ac.za

Kim B. Bruce
Mullard Space Science Laboratory
University College London
Holmbury St Mary, Dorking, UK
kbb@mssl.ucl.ac.uk

Andrew Collier Cameron
School of Physics and Astronomy
University of St Andrews
Scotland KY16 9SS, UK
acc4@st-andrews.ac.uk

Jorge Casares
Instituto de Astrofisica de Canarias
38200 La Laguna
Tenerife, Spain
jcv@ll.iac.es

Craig Chambers
Mullard Space Science Laboratory
University College London
Holmbury St Mary, Dorking, UK
cch@mssl.ucl.ac.uk

Philip A. Charles
Department of Physics and Astronomy
University of Southampton
Southampton, SO17 1BJ, UK
pac@astro.soton.ac.uk

Mark Cropper
Mullard Space Science Laboratory
University College London
Holmbury St Mary, Dorking, UK
msc@mssl.ucl.ac.uk

Vik S. Dhillon
Department of Physics and Astronomy
University of Sheffield
Sheffield S3 7RH, UK
vik.dhillon@sheffield.ac.uk

Jean-François Donati
Observatoire Midi-Pyrénées
14 Avenue E. Belin
31400 Toulouse, France
jean-francois.donati@obs-mip.fr

André Fokin
Institute for Astronomy of the Russia Academy of Sciences
48 Pjatnitskaja
109017 Moscow, Russia
fokin@inasan.rssi.ru

Hidekazu Fujiwara
Department of Earth and Planetary Sciences, Kobe University
Nada-ku
Kobe 657-8501, Japan
fujiwara@jet.planet.sci.kobe-u.ac.jp

Denis Gillet
Observatoire de Haute-Provence
04870 Saint-Michel l'Observatoire, France
gillet@obs-hp.fr

Petr Hadrava
Astronomical Institute of the Academy of Sciences of the Czech Republic, 251 65 Ondřejov,
Czech Republic
had@sunstel.asu.cas.cz

Pasi Hakala
Observatory and Astrophysics Laboratory
FIN-00014, University of Helsinki
Finland
Pasi.Hakala@astro.utu.fi

Reinhard Hanuschik
ESO
Karl-Schwarzschild-Str. 2
85748 Garching, Germany
rhanusch@eso.org

Emilios T. Harlaftis
Institute of Astronomy and Astrophysics
National Observatory of Athens
P.O. Box 20048, Thession
Athens - 11810, Greece
ehh@astro.noa.gr

Carole A. Haswell
Department of Physics and Astronomy
The Open University
Walton Hall, Milton Keynes
MK7 6AA, UK
C.A.Haswell@open.ac.uk

Herman Hensberge
Royal Observatory of Belgium
Ringlaan 3
1180 Brussel, Belgium
Herman.Hensberge@oma.be

Keith Horne
University of St Andrews
Scotland KY16 9SS, UK
kdh1@st-andrews.ac.uk

Robert I. Hynes
Department of Physics and Astronomy
University of Southampton
Southampton, SO17 1BJ, UK
rih@astro.soton.ac.uk

S. Ilijiïc
Faculty of Geodesy
University of Zagreb
Kačiïceva 26
10000 Zagreb, Croatia
silijic@geodet.geof.hr

Alain Jorissen
Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles,
C.P. 226, Boulevard du Triomphe,
1050 Brussels, Belgium
ajorisse@astro.ulb.ac.be

Oleg Kochukhov
Uppsala Astronomical Observatory
Box 515No.
75120 Uppsala, Sweden
Oleg.Kochukhov@astro.uu.se

U. Kolb
Department of Physics and Astronomy, The Open University
Walton Hall, Milton Keynes
MK7 6AA, UK
U.C.Kolb@open.ac.uk

Jens Kube
Universitäts-Sternwarte Göttingen
Geismar Landstrasse 11
37073 Göttingen, Germany
jkube@uni-goettingen.de

J.D. Landstreet
Physics and Astronomy Department
The University of Western Ontario
London, Ontario
Canada N6A 3K7
jlandstr@uwo.ca

Makoto Makita
Department of Astronomy, Kyoto University
Sakyo-ku
Kyoto 606-8502, Japan
makita@jet.planet.sci.kobe-u.ac.jp

Tom R. Marsh
Dpt of Physics and Astronomy
Southampton University
Highfield, Southampton SO17 1BJ
trm@astro.soton.ac.uk

Takuya Matsuda
Department of Earth and Planetary Sciences, Kobe University
Nada-ku
Kobe 657-8501, Japan
matsuda@jet.planet.sci.kobe-u.ac.jp

Luisa Morales-Rueda
Dpt of Physics and Astronomy
Southampton University
Highfield, Southampton SO17 1BJ
lmr@astro.soton.ac.uk

Chris K. J. Moran
Dpt of Physics and Astronomy
Southampton University
Highfield, Southampton SO17 1BJ
ckjm@astro.soton.ac.uk

Rachel C. North
Dpt of Physics and Astronomy
Southampton University
Highfield, Southampton SO17 1BJ
rcn@astro.soton.ac.uk

Kieran O'Brien
University of St Andrews
Scotland KY16 9SS, UK
kso@st-and.ac.uk

J.M. Oliveira
ESA Space Science Department
SCI-SO/ESTEC, PB 299
2200 AG Noordwijk, The Netherlands
joliveir@estec.esa.nl

K. Pavlovski
Department of Physics
University of Zagreb
Bijenička 32
10000 Zagreb, Croatia
kpavlovski@geodet.geof.hr

Pascal Petit
Laboratoire d'Astrophysique
Observatoire Midi-Pyrénées
14 avenue Edouard Belin
31400 Toulouse, France
petit@ast.obs-mip.fr

Nikolai Piskunov
Uppsala Astronomical Observatory
Box 515No.
75120 Uppsala, Sweden
piskunov@astro.uu.se

Bertrand Plez
GRAAL,Université Montpellier II,
cc072
34095 Montpellier cedex 05, France
plez@graal.univ-montp2.fr

Stephen Potter
South African Astronomical
Observatory
P.O. Box 9, Observatory 7935
Cape Town, South Africa
sbp@sirius.saao.ac.za

Mercedes T. Richards
Department of Astronomy
University of Virginia
P.O. Box 3818, Charlottesville
VA 22903-0818, USA
mrichards@virginia.edu

Daniel J. Rolfe
Dpt of Physics and Astronomy
The Open University
Walton Hall
Milton Keynes, MK7 6AA
d.j.rolfe@open.ac.uk

Encarni Romero-Colmenero
South African Astronomical
Observatory
P.O. Box 9, Observatory 7935
Cape Town, South Africa
erc@saao.ac.za

Axel Schwope
Astrophysikalisches Institut Potsdam
An der Sternwarte 16
Potsdam 14482, Germany
aschwope@aip.de

S.L.S. Shorlin
Physics and Astronomy Department
The University of Western Ontario
London, Ontario
Canada N6A 3K7
sshorlin@astro.uwo.ca

T.A.A. Sigut
Physics and Astronomy Department
The University of Western Ontario
London, Ontario
Canada N6A 3K7
asigut@astro.uwo.ca

R.C. Smith
University of Sussex
Astronomy Centre
Brighton, BN1 9QJ, UK
rcs@star.cpes.susx.ac.uk

Danny Steeghs
Dpt of Physics and Astronomy
Southampton University
Southampton, SO17 1BJ, UK
ds@astro.soton.ac.uk

Rudi Stehle
University of Leicester
Astronomy Group
University Road, Leicester, LE1 7RH
rst@star.le.ac.uk

Claus Tappert
Dipartimento di Astronomia
Vicolo dell Ósservatorio 5
I-35122 Padova, Italy
claus1@sole.pd.astro.it

Sonja Vrielmann
Dept. of Astronomy
University of Cape Town
Rondebosch 7700, South Africa
sonja@pinguin.ast.uct.ac.za

G.A. Wade
Département de Physique
Université de Montréal
C.P.6128, Succ. Centre Ville
Montréal H3C 3J7, Canada
wade@astro.umontreal.ca

Christopher A. Watson
Dpt of Physics and Astronomy
University of Sheffield
Sheffield S3 7RH, UK
c.watson@sheffield.ac.uk

Graham Wynn
Dpt of Physics and Astronomy
University of Leicester
Leicester LE1 7RH, UK
gwy@star.le.ac.uk

Cristina Zurita
Instituto de Astrofisica de Canarias
38200 La Laguna
Tenerife, Spain
czurita@ll.iac.es

List of Participants

- **Raymundo Baptista** UFSC Trindade, Brazil
- **John Barnes** Universidade de Porto, Portugal
- **Henri Boffin** Royal Observatory of Belgium
- **Jan Cuypers** Royal Observatory of Belgium
- **Andrew Collier Cameron** University of St Andrews, UK
- **Jean-Pierre De Cuyper** Royal Observatory of Belgium
- **Vik Dhillon** University of Sheffield, UK
- **Jean-Francois Donati** Observatoire Midi Pyrenees, France
- **Lars Freyhammer** Royal Observatory of Belgium
- **Michael Goad** University of Leicester, UK
- **Paul Groot** Harvard Smithsonian CfA, USA
- **Petr Hadrava** Academy of Sciences of the Czech Republic
- **Pasi Hakala** Tuorla Observatory, Finland
- **Emilios Harlaftis** National Observatory of Athens, Greece
- **Herman Hensberge** Royal Observatory of Belgium
- **Frederic V. Hessman** Universitaets-Sternwarte Goettingen, Germany
- **Donald W. Hoard** Cerro Tololo Inter-American Observatory, Chile
- **Keith Horne** University of St Andrews, UK
- **Gaitee Hussain** University of St Andrews, UK
- **Robert Hynes** University of Southampton, UK
- **Sasa Ilijic** Zagreb University, Croatia
- **Alain Jorissen** Universite Libre de Bruxelles, Belgium
- **Pavel Koubsky** Ondrejov Observatory, Czech Repulic
- **Akiko Koyama** Kobe University, Japan
- **Jens Kube** Universitaets-Sternwarte Goettingen, Germany
- **Markus Kuster** Tuebingen, Germany
- **Patricia Lampens** Royal Observatory of Belgium
- **Stuart Littlefair** University of Sheffield, UK
- **Makoto Makita** Kobe University, Japan
- **Tom Marsh** Southampton University, UK
- **Takuya Matsuda** Kobe University, Japan
- **Ronald Mennickent** Universidad de Concepcion, Chile
- **Luisa Morales-Rueda** University of Southampton, UK
- **Vitaly Neustroev** Udmurt State University, Russia
- **Rachel North** University of Southampton, UK
- **Kieran O'Brien** University of St Andrews, UK
- **Manuel A. Perez-Torres** University College Cork, Ireland
- **Pascal Petit** Observatoire Midi-Pyrenees, France
- **Nikolai Piskunov** Uppsala Astronomical Observatory, Sweden
- **Stephen Potter** South African Astronomical Observatory
- **Gavin Ramsay** Mullard Space Science Lab, UK
- **Mercedes Richards** University of Virginia, USA
- **Pablo Rodriguez-Gil** IAC Tenerife, Spain
- **Daniel Rolfe** The Open University, UK

- **Robert Schwarz** Astrophysical Institute Potsdam, Germany
- **Axel Schwope** Astrophysical Institute Potsdam, Germany
- **Warren Skidmore** University of St Andrews, UK
- **Vallery Stanichev** Bulgarian Academy of Sciences
- **Danny Steeghs** University of Southampton, UK
- **Claus Tappert** Universita di Padova, Italy
- **Gaghik Tovmassian** IA UNAM, USA
- **Eduardo Unda** University of Southampton, UK
- **Sonja Vrielmann** University of Cape Town, SA
- **Christopher Watson** University of Sheffield, UK
- **Graham Wynn** University of Leicester, UK
- **Cristina Zurita** IAC, Spain

Some Useful Resources on the Internet

- `http://www.astro.oma.be/DopplerWorkshop`
  The web page of the workshop in which updated information will be available as well as useful links to astrotomography resources.

- `http://www.astro.soton.ac.uk/~trm/software.html`
  Software from Tom Marsh, including *doppler*, for doppler imaging of accretion discs, *molly* for 1D spectrum analysis, and *pamela*, for reduction from 2D to 1D astronomical spectra.

- `http://ibm-2.MPA-Garching.MPG.DE/~henk/`
  Henk Spruit preliminary web page, containing his fast Doppler mapping program.

- `http://star-www.st-and.ac.uk/~kdh1/`
  The minimalist web page of Keith Horne.
  In `http://star-www.st-and.ac.uk/schedar/kdh1/doptom/doptom.html`, a paper about Doppler Tomography can be found as well as the source code.

- `http://sunkl.asu.cas.cz/~had/korel.html`
  KOREL is a code for spectra disentangling using Fourier transforms, available from P. Hadrava.

- `http://www.astro.soton.ac.uk/~trm/doppler_table.html`
  Up-to-date list of publications using Doppler Tomography, maintained by Tom Marsh.

- `http://www.astro.univie.ac.at/~kgs/research.html`
  Home page of the stellar activity working group of the Institute for Astronomy at the University of Vienna. Includes an impressive collection of Doppler images of stars.

- `http://www.shef.ac.uk/~phys/people/vdhillon/`
  Home page of Vik Dhillon with some online presentations, including the one he gave in Brussels.

- `http://www.astro.virginia.edu/people/faculty/mtr8r/index.html`
  The web page of Mercedes T. Richards with information about doppler tomography of Algols and hydrodynamic simulations of mass transfer.

- `http://star-www.st-and.ac.uk/~acc4/coolpages/imaging.html`
  Mapping starspots of A. Collier Cameron with the slides of his presentation in Brussels and some eclipsing binaries star mapping movies.

- http://webast.ast.obs-mip.fr/people/donati/
  The animated homepage of J.-F. Donati.

- http://www.shef.ac.uk/~phys/people/vdhillon/ultracam/
  ULTRACAM is an ultra-fast, triple-beam CCD camera which has been designed to study one of the few remaining unexplored regions of observational parameter space – high temporal resolution. The camera, which has recently been funded in full (292 k) by PPARC, will see first light during 2001 and will be used on 2-m, 4-m and 8-m class telescopes in Australia, the Canary Islands, Chile, Greece, South Africa and Spain to study astrophysics on the fastest timescales. ULTRACAM is a project of V. Dhillon and T. Marsh.

- http://astro.esa.int/SA-general/Research/Detectors_and_optics/detectors_scam.html
  S-Cam is the prototype of a cryogenic camera for ground-based astronomy, based around a 6x6 array of Ta–Al superconducting tunnel junction (STJ) devices, photon-counting array detectors with intrinsic energy resolution. The detector presently provides individual photon arrival time accuracy to about 5 μs, and a wavelength resolution of about 60 nm at 500 nm, with each array element capable of counting up to $\sim$5000 photons s^{-1}.

- http://www.astro.soton.ac.uk/~rih/binsim.html
  Rob Hynes's binary star visualisation.