Planetary Nebulae Beyond the Milky Way

Proceedings of the ESO Workshop held at Garching, Germany, 19-21 May, 2004
In the last decade extra-galactic planetary nebulae (PNe) have gained increasing importance. Improved observational capabilities have allowed fainter and fainter PNe to be studied in galaxies well beyond the Milky Way. Planetary nebulae, characterized by their emission line spectrum, in particular the strong [O III] 5007Å line, can be detected to at least 30 Mpc. They are found in galaxies of all types and also between the galaxies in nearby galaxy clusters. They are valuable as probes, for providing both the velocity of their host stars and also the evolutionary status and relation to the stellar population from which they formed.

Whilst there had been a 1-day meeting devoted to extra-galactic PNe at the IAU General Assembly in the Hague in 1994, it was apparent to us that the topic had expanded to the extent that a full conference was well justified. The last day of the IAU Symposia on Planetary Nebulae had typically been allocated to extra-galactic PNe, but it was clear that it could not do full justice to the developments in the field. The resulting workshop was held at ESO Headquarters from 19 to 21 May 2004 and was devoted to exploring the potential for PN in the extra-galactic context.

The Scientific Organizing Committee (SOC) was formed to include scientists covering all the major areas of extra-galactic PN research, from stellar evolution to extra-galactic distance scale to dynamical studies. The SOC consisted of Magda Arnaboldi (Italy), Robin Ciardullo (USA), Nigel Douglas (The Netherlands), Ken Freeman (Australia), George Jacoby (USA), Roberto Mendez (USA), Richard Shaw (USA), Grażyna Stasińska (France) and was co-chaired by two of us (Stanghellini and Walsh).

About 65 scientists from around the world participated in the workshop which consisted of a mix of invited and contributed talks and a display of posters. The authors of poster papers presented their work during a short oral presentation. There were also two discussion sessions: one on “Observational Challenges,” chaired by Quentin Parker, and another on “Future Challenges,” chaired by Richard Shaw. Alan Moorwood gave the welcoming address and Holland Ford summarized the workshop with some witty collages of speakers slides and digital photographs taken at the conference. During the busy 3 days in Garching, we found that many scientific collaborations, and new friendships, were born, and old ones renewed.
During the preparations for the conference a German amateur astronomer, Gunther Cibis, asked us if we were going to tackle the nomenclature for extragalactic PNe. None of us had thought carefully about this and we were forced to admit that this was now becoming important with the burgeoning number of PNe being discovered in nearby galaxies. Much of one of the discussion sessions was devoted to this subject and Agnes Acker and Quentin Parker contributed a proceedings article. Whilst no clear consensus emerged, we hope that the subject will be considered at the next IAU meeting on PNe in Hawaii in 2006.

Even though one of the days of the conference was scheduled on a Bavarian holiday, the local organization went flawlessly, thanks primarily to Christina Stoffer. Britt Sjoeborg also helped out during the conference. Marina Rejkuba provided the mainstay of the Local Organizing Committee, Nausicaa Delmotte helped with the web pages, and Ed Janssen designed the conference poster. Pamela Bristow very ably prepared the proceedings for publication.

This meeting was the first full-scale conference devoted to the subject of planetary nebulae beyond the Milky Way. It is apparent from these proceedings that the field is maturing rapidly and is multi-faceted enough that, within a few years, a sequel to this meeting can be considered.

Tucson, Garching, Groningen

January 2005

Letizia Stanghellini
Jeremy Walsh
Nigel Douglas
## Contents

### Part I  Historical Overview

Planetary Nebulae Beyond the Milky Way – Historical Overview
*Michael J. Barlow* .................................................. 3

### Part II  Planetary Nebula Surveys

Surveys for Planetary Nebulae in the Magellanic Clouds
*George H. Jacoby* .................................................. 17

H-alpha Stacked Images Reveal Large Numbers of PNe in the LMC
*Warren Reid, Quentin Parker* ........................................ 30

The Census of Planetary Nebulae in the Local Group
*Romano L.M. Corradi, Laura Magrini* ............................. 36

Planetary Nebulae in the Outer Disk and Halo of M31
*Alexei Kniazev, Eva K. Grebel, Dan Zucker, Eric Bell, Hugh Harris* ...... 46

Deep PN Surveys Beyond the Local Group
*Roberto H. Méndez* .................................................. 49

Planetary Nebulae in NGC 5128 (Centaurus A)
*Eric W. Peng, Holland C. Ford, Kenneth C. Freeman* .................. 59

Extragalactic Planetary Nebula:
Methods of Discovery Using Infrared Photometry
*Pedro García-Lario, Amelia Bayo, Carlos Alfageme* .................. 67

Proposed Nomenclature for Extragalactic Planetary Nebulae
*Quentin A. Parker, Agnes Acker* ..................................... 72

### Part III  The Planetary Nebula Luminosity Function

The Planetary Nebula Luminosity Function
*Robin Ciardullo* .................................................. 79
The PNLF Distance to the Sculptor Group Galaxy NGC 55  
G.C. Van de Steene, G.H. Jacoby, C. Praet, R. Ciardullo, H. Dejonghe . . . 91

### Part IV PN Stellar Progenitors

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass Loss at the Tip of the AGB: Essentials for Population Synthesis</td>
<td>Lee Anne Willson</td>
</tr>
<tr>
<td>AGB Stars in the Local Group, and Beyond</td>
<td>M.A.T. Groenewegen</td>
</tr>
<tr>
<td>Abundance Gradients in Local Group Galaxies</td>
<td>Maria-Rosa Cioni</td>
</tr>
<tr>
<td>Red Giant Stars in NGC 5128</td>
<td>Marina Rejkuba</td>
</tr>
<tr>
<td>Molecules in the AGB Stars of Nearby Galaxies</td>
<td>M. Matsura, A.A. Zijlstra, J.Th. van Loon, I. Yamamura</td>
</tr>
<tr>
<td>Clues on Post-Asymptotic Giant Branch Evolution and Planetary Nebulae</td>
<td>Letizia Stanghellini</td>
</tr>
<tr>
<td>Central Stars of Planetary Nebulae in the Magellanic Clouds</td>
<td>Eva Villaver</td>
</tr>
<tr>
<td>Stellar Winds of Central Stars of the LMC PNe</td>
<td>Anabel Arrieta, Letizia Stanghellini</td>
</tr>
<tr>
<td>Parameters of PNe: Constant Density versus Density Distribution</td>
<td>Michaela Kraus</td>
</tr>
</tbody>
</table>

### Part V Physical Conditions of PNe

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma Diagnostics and Elemental Abundance Determinations for PNe – Current Status</td>
<td>Xiao-wei Liu</td>
</tr>
<tr>
<td>Probing Nebular Physical Conditions Using the Hydrogen Recombination Spectrum</td>
<td>Y. Zhang, X.-W. Liu, R. Wesson, P.J. Storey, Y. Liu, I.J. Danziger . . . 183</td>
</tr>
</tbody>
</table>
## Contents

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probing the Nebular Thermal Structure Using the He\textsuperscript{+} Recombination Spectrum and Evidence Against Temperature Fluctuations and Density Inhomogeneities</td>
<td>Y. Zhang, X.-W. Liu, Y. Liu</td>
<td>190</td>
</tr>
<tr>
<td>Chemically Inhomogeneous Photoionization Modelling of the Planetary Nebula SMC N87</td>
<td>Yiannis G. Tsamis, Daniel Péquignot</td>
<td>192</td>
</tr>
<tr>
<td>MOCASSIN: 3D Photoionisation and Dust Radiative Transfer Modelling of PNe</td>
<td>Barbara Ercolano, M.J. Barlow, P.J. Storey, X.-W. Liu</td>
<td>196</td>
</tr>
<tr>
<td>C III\textsuperscript{+} Imagery of Planetary Nebulae and Extragalactic H II Regions</td>
<td>R.J. Dufour, R.B.C. Henry, K.B. Kwitter, B.A. Buckalew, B.D. Moore, J. Bohigas, C. Esteban</td>
<td>199</td>
</tr>
<tr>
<td>CRIRES and VISIR, ESO’s Latest Tools for Infrared Studies of PNe beyond the Milky Way</td>
<td>Hans Ulrich Käufl</td>
<td>201</td>
</tr>
</tbody>
</table>

### Part VI  PNe as Chemical Probes of Galaxies

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planetary Nebulae in the Sagittarius Dwarf Spheroidal Galaxy</td>
<td>Albert A. Zijlstra, Krzysztof Gesicki, Jeremy Walsh, Daniel Péquignot</td>
<td>215</td>
</tr>
<tr>
<td>What PNe Could Tell About Extinction Inside External Galaxies</td>
<td>Joachim Köppen</td>
<td>217</td>
</tr>
</tbody>
</table>
A Study of Chemical Abundances of Planetary Nebulae in M33
Mario Perinotto, Laura Magrini, Antonio Mampaso,
Romano L.M. Corradi .................................................. 232

The Inner Abundance Gradient of M33 from Bright Planetary Nebulae
Grażyna Stasińska, José M. Vílchez, Enrique Pérez,
Rosa M. Gonzalez Delgado, Romano L.M. Corradi, Antonio Mampaso,
Laura Magrini .......................................................... 234

Crowded Field 3D Spectrophotometry of Extragalactic Planetary Nebulae
Martin M. Roth, Thomas Becker, Petra Böhm, Detlef Schönberner,
Matthias Steffen, Katrina Exter ...................................... 239

Extragalactic PNe Observed with 3D Spectroscopy
Katrina Exter, Petra Böhm, Thomas Becker, Martin Roth ............. 244

Spectroscopy of Planetary Nebulae in Sextans A and Sextans B
Laura Magrini, Pierre Leisy, Romano L.M. Corradi, Mario Perinotto,
Antonio Mampaso, José Vílchez ..................................... 247

Local Group Census: The Dwarf Irregular Galaxy NGC 6822
P. Leisy, L. Magrini, R.L.M. Corradi, A. Mampaso .................. 252

Spectroscopy of PNe in Sextans A, Sextans B, NGC 3109 and Fornax
Alexei Y. Kniazev, Eva K. Grebel, Alexander G. Pramskij,
Simon A. Pustilnik .................................................... 257

Planetary Nebula Abundances in NGC 5128 with VLT FORS
J.R. Walsh, G. Jacoby, R. Peletier, N.A. Walton ....................... 262

Part VII PNe as Kinematic Probes of Galaxies

Galaxy Dynamics and the PNe Population
Nigel G. Douglas ....................................................... 269

Mapping the Stellar Dynamics of M31
Helen Merrett, M. Merrifield, K. Kuijken, A. Romanowsky, N. Douglas,
N. Napolitano, M. Arnaboldi, M. Capaccioli, K. Freeman, O. Gerhard,
D. Carter, N.W. Evans, M. Wilkinson, C. Halliday, T. Bridges ........ 281

A Keck/Deimos Survey of Red Giant Branch Stars in the Outskirts of M31
Annette M.N. Ferguson, Scott Chapman, Rodrigo Ibata, Mike Irwin,
Geraint Lewis, Alan McConnachie ................................... 286
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planetary Nebulae in NGC 5128 with VLT FLAMES</strong></td>
<td>292</td>
</tr>
<tr>
<td>Marina Rejkuba, Jeremy R. Walsh</td>
<td></td>
</tr>
<tr>
<td><strong>Probing Halos with PNe: Mass and Angular Momentum</strong> in Early-Type Galaxies</td>
<td>294</td>
</tr>
<tr>
<td>Aaron J. Romanowsky</td>
<td></td>
</tr>
<tr>
<td><strong>Modelling Kinematics and Dark Matter: The Halos of Elliptical Galaxies</strong></td>
<td>299</td>
</tr>
<tr>
<td>Ortwin Gerhard</td>
<td></td>
</tr>
<tr>
<td><strong>Dynamics of Rotating Elliptical Galaxies</strong></td>
<td>311</td>
</tr>
<tr>
<td>Flavio De Lorenzi, Victor P. Debattista, Ortwin E. Gerhard</td>
<td></td>
</tr>
<tr>
<td><strong>Dynamics of the NGC 4636 Globular Cluster System</strong></td>
<td>316</td>
</tr>
<tr>
<td>Ylva Schuberth, Tom Richtler, Boris Dirsch, Michael Hilker, Leopoldo Infante, Søren Larsen, Markus Kissler-Patig</td>
<td></td>
</tr>
<tr>
<td><strong>Dynamics of Elliptical Galaxy NGC 4697 from Integrated Light and PNe</strong></td>
<td>318</td>
</tr>
<tr>
<td>Niranj Sambhus, Flavio De Lorenzi, Ortwin Gerhard</td>
<td></td>
</tr>
<tr>
<td><strong>Planetary Nebulae as Dynamical Tracers: Mass-to-Light Ratio Gradients in Early-Type Galaxies</strong></td>
<td>324</td>
</tr>
<tr>
<td><strong>Part VIII PNe in the Intracluster Environment</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Intracluster Planetary Nebulae as Probes of Intracluster Starlight</strong></td>
<td>331</td>
</tr>
<tr>
<td>John Feldmeier</td>
<td></td>
</tr>
<tr>
<td><strong>Planetary Nebulae as Tracers of Galaxy Clusters</strong></td>
<td>343</td>
</tr>
<tr>
<td>Magda Arnabold</td>
<td></td>
</tr>
<tr>
<td><strong>Planetary Nebulae as Tracers of the Intergalactic Stellar Background: A Population Synthesis Theoretical Approach</strong></td>
<td>355</td>
</tr>
<tr>
<td>Alberto Buzzoni, Magda Arnabold</td>
<td></td>
</tr>
<tr>
<td><strong>The Survival of Planetary Nebulae in the Intracluster Medium</strong></td>
<td>361</td>
</tr>
<tr>
<td>Eva Villaver, Letizia Stanghellini</td>
<td></td>
</tr>
</tbody>
</table>
Part IX  Prospects

Extragalactic Planetary Nebulae: Observational Challenges and Future Prospects
Quentin A. Parker, Richard Shaw ........................................ 365

Author Index ................................................................. 369
List of Participants

ARNABOLDI, Magda
INAF, Obs. of Turin
arnaboldi@to.astro.it

ARRIETA, Anabel
Univ. Iberoamericana,
Física y Matemáticas, Mexico
anabel.arrieta@uia.mx

BARLOW, Michael
University College London
mjb@star.ucl.ac.uk

BUZZONI, Alberto
INAF - Oss. Astronomico di Bologna
buzzoni@bo.astro.it

CHITA, Sabina
MPI for Radioastronomy, Bonn
schita@mpifr-bonn.mpg.de

CIARDULLO, Robin
The Pennsylvania State University
rbc@astro.psu.edu

CIONI, Maria-Rosa
ESO-Garching
mcioni@eso.org

CORRADI, Romano
Isaac Newton Group
S. Cruz de la Palma
rcorradi@ing.iac.es

DE LORENZI, Flavio
University of Basel
Astronomical Institute
lorenzi@astro.unibas.ch

DOUGLAS, Nigel
Kapteyn Astronomical Institute
Groningen
ndouglas@astro.rug.nl

DUFOUR, Reginald
Rice University, Physics & Astronomy
rjd@rice.edu

ERCOLANO, Barbara
University College London
be@star.ucl.ac.uk

EXTER, Katrina
Instituto de Astrofísica de Canarias
katrina@ill.iac.es

FIELDMEIER, John
Case Western Reserve Univ.
johnf@bottom.astr.cwru.edu

FERGUSON, Annette
MPI for Astrophysics, Garching
ferguson@mpa-garching.mpg.de

FORD, Holland
Johns Hopkins University
ford@pha.jhu.edu

GARCIA-LARIO, Pedro
ESA/ISO Data Centre
Pedro.Garcia.Lario@esa.int

GERHARD, Ortwin
University of Basel
Astronomical Institute
gerhard@astro.unibas.ch
GIRARDI, Leo  
Osservatorio Astronomico di Trieste  
lgirardi@ts.astro.it

GROENEWEGEN, Martin  
Instituut voor Sterrenkunde, Leuven  
groen@ster.kuleuven.ac.be

JACOBY, George  
WIYN Observatory, Tucson  
jacoby@wiyn.org

KÄUFL, Hans Ulrich  
ESO-Garching  
hukauf@eso.org

Kniazev, Alexei  
MPI for Astronomy, Heidelberg  
kniazev@mpia.de

KÖPPEN, Joachim  
Observatoire de Strasbourg  
koppen@astro.u-strasbg.fr

KRAUS, Michaela  
Astronomical Institute  
Utrecht University  
M.Kraus@phys.uu.nl

KUNTSCHNER, Harald  
ST-ECF, Garching  
hkuntsch@eso.org

KWOK, Sun  
Inst. of Astronomy & Astrophysics  
Acad. Sinica, Taipei  
kwok@asiaa.sinica.edu.tw

LEE, Henry  
University of Minnesota  
hlee@astro.umn.edu

LEISY, Pierre  
Isaac Newton Group  
S. Cruz de la Palma  
pleisy@ing.iac.es

LIU, Xiao-wei  
Peking University  
liuxw@vega.bac.pku.edu.cn

MACIEL, Walter  
IAG/Univ. of São Paulo  
maciel@astro.iag.usp.br

MAGRINI, Laura  
Dept. of Astronomy, Florence  
laura@arcetri.astro.it

MANCHADO, Arturo  
Instituto de Astrofisica de Canarias  
amt@iac.es

MATSUURA, Mikako  
Department of Physics, UMIST  
m.matsuura@umist.ac.uk

MENDEZ, Roberto  
Institute for Astronomy  
University of Hawaii  
mendez@ifa.hawaii.edu

MERRETT, Helen  
University of Nottingham  
ppxhm@nottingham.ac.uk

NAPOLITANO, Nicola Rosario  
Kapteyn Astronomical Institute  
Groningen  
nicola@astro.rug.nl

NICKELER, Dieter  
Astronomical Institute  
Utrecht University  
D.H.Nickeler@phys.uu.nl

PARKER, Quentin  
Macquarie Univ., Sydney/  
Anglo-Australian Obs.  
qap@ics.mq.edu.au

PATRIARCHI, Patrizio  
Istituto di Radioastronomia - CNR  
Florence  
pat@arcetri.astro.it
PEÑA, Miriam  
Instituto de Astronomia, UNAM  
Mexico  
miriam@astrososcu.unam.mx

PENG, Eric  
Rutgers University  
ericpeng@physics.rutgers.edu

PERINOTTO, Mario  
Dept. of Astronomy, Florence  
mariop@arcetri.astro.it

REID, Warren  
Macquarie University, Sydney  
warren@ics.mq.edu.au

REJKUBA, Marina  
ESO-Garching  
mrejkuba@eso.org

RICHER, Michael  
Instituto de Astronomia, UNAM  
Mexico  
richer@astrosen.unam.mx

ROMANOWSY, Aaron  
University of Nottingham  
aaron.romanowsky  
@nottingham.ac.uk

ROTH, Martin  
Astrophysikalisches Institut Potsdam  
mroth@aip.de

SAMBHUS, Niranjan  
University of Basel  
Astronomical Institute  
sambhus@astro.unibas.ch

SCHOENBERNER, Detlef  
Astrophysikalisches Institut Potsdam  
deschoenberner@aip.de

SCHUBERTH, Ylva  
Sternwarte der Universität Bonn  
ylva@astro.uni-bonn.de

SHAW, Richard  
NOAO, Tucson  
shaw@noao.edu

STANGHELLINI, Letizia  
NOAO, Tucson  
letizia@noao.edu

STASINSKA, Grazyna  
LUTH, Observatoire de Paris-Meudon  
grazyna.stasinska@obspm.fr

TSAMIS, Yiannis  
LUTH, Observatoire de Paris-Meudon  
Yiannis.Tsamis@obspm.fr

VAN DE STEENE, Griet C.  
Royal Observatory of Belgium  
Brussels  
gsteene@oma.be

VILLAVER, Eva  
Space Telescope Science Institute  
villaver@stsci.edu

WALSH, Jeremy  
ST-ECF, Garching  
jwalsh@eso.org

WANG, Wei  
Peking University  
Department of Astronomy  
bwaw@vega.bac.pku.edu.cn

WILLSON, Lee Anne  
Iowa State University  
lwillson@iastate.edu

ZHANG, Yong  
Peking University  
Department of Astronomy  
zhangy@bac.pku.edu.cn

ZIJLSTRA, Albert  
Department of Physics, UMIST  
a.zijlstra@umist.ac.uk