WORKPLANS: Workshop on Planetary Nebula Observations

Isabel Aleman [1],*,[†], **Jeronimo Bernard-Salas** [2],[†], **Joel H. Kastner** [3],[†], **Toshiya Ueta** [4],[†] **and Eva Villaver** [5],[†]

1   Instituto de Física e Química, Universidade Federal de Itajubá, Av. BPS 1303, Pinheirinho, Itajubá 37500-903, Brazil
2   ACRI-ST, 260 Route du Pin Montard, 06904 Sophia-Antipolis, France; jeronimo.bernard-salas@acri-st.fr
3   Center for Imaging Science, School of Physics and Astronomy, and Laboratory for Multiwavelength Astrophysics, Rochester Institute of Technology, 54 Lomb Memorial Drive, Rochester, NY 14623, USA; jhk@cis.rit.edu
4   Department of Physics & Astronomy, University of Denver, 2112 E. Wesley Ave., Denver, CO 80208, USA; Toshiya.Ueta@du.edu
5   Departamento de Física Teórica, Universidad Autónoma de Madrid, 28049 Madrid, Spain; eva.villaver@uam.es
*   Correspondence: bebel.aleman@gmail.com
†   Workshop scientific organizers. These authors contributed equally to this work.

Abstract: This workshop is the second of the WORKPLANS series, which we started in 2016. The main goal of WORKPLANS is to build up a network of planetary nebulae (PNe) experts to address the main open questions in the field of PNe research. The specific aims of the WORKPLANS workshop series are (**i**) to discuss and prioritize the most important topics to be investigated by the PN community in the following years; (**ii**) to establish a network of excellent researchers with complementary expertise; (**iii**) to formulate ambitious observing proposals for the most advanced telescopes and instrumentation presently available (ALMA, SOFIA, VLT, GTC, HST, etc.), addressing those topics; and (**iv**) to develop strategies for major proposals to future observatories (JWST, ELT, SPICA, Athena, etc.). To achieve these goals, WORKPLANS II brought together experts in all key sub-areas of the PNe research field, namely: analysis and interpretation of PNe observational data; theoretical modeling of gas and dust emission; evolution from Asymptotic Giant Branch stars (PNe progenitors) to PNe; and the instrumentation and technical characteristics of the relevant observatories.

1. Introduction

Planetary nebulae (PNe) are formed by the ejection of the outer layers of evolved low and intermediate mass stars ($\sim$1–8 M$_\odot$). These objects have important roles in stellar evolution, in the enrichment of the interstellar medium (ISM) and in the evolution of galaxies. PNe are unique astrophysical laboratories in which we can investigate a wide variety of physical conditions from highly-ionized plasma to low-temperature dusty molecular regions in a spatially resolved manner. The findings from PNe research are applicable not only within the field, but also to a broad range of astrophysical objects with similar characteristics. Solving the open issues in the field of PN would therefore have a great impact not only for the PN research community, but also for the astronomical community as a whole.

The IAU PN Working Group discusses several open problems in the field of PN in the white paper entitled "*The present and future of planetary nebula research*" [1]. According to the paper, the main problems to be investigated by the community are:

- uncover PNe that cannot be identified in the optical spectral range
- improve central star evolutionary models
- improve our knowledge of the atmospheres and winds of central stars
- investigate the role of binary central stars in the evolution/formation of PNe
- understand the history and mechanisms of mass-loss and structure formation in the circumstellar nebulae
- improve techniques to derive chemical abundances
- understand the abundance discrepancies measured from collisional and recombination lines
- understand the formation mechanisms and survival of dust and molecules in PNe

The IAU PN working group white paper [1] also makes clear the need of further multi-wavelength observations in the PN research field and serves as a motivation for this workshop series. As in any topic in Astronomy, research on PNe is strongly driven by observations. New facilities built in the last few decades have improved the instruments and opened new spectral windows. Other new and forthcoming facilities, like ALMA and future telescopes such as JWST, will play a key role on the state-of-art astronomy research in the next years. Multiwavelength studies have become possible and, since different wavelength ranges probe different realms of chemistry and physics, the multiwavelength approach has already greatly improved our understanding of a wide range of astronomical objects, including PNe. This provides strong motivation for bringing together researchers with expertise in different wavelength ranges but with a common goal, namely, to understand the formation and evolution of PNe.

To fully explore the possibilities of the current and future instruments for the study of PNe, it is essential to aggregate different expertise—and the formation of an international network of scientists is then a natural step. Such a network provides a framework for the more efficient use of astronomical data and helps the PN community compete for time on the main telescopes, where a strong worldwide presence is an important factor.

The aim of the WORKPLANS series of workshops is to build a network of PN observers whose expertise in observations or theoretical analysis is spread across different sub-fields and spectral domains. The participants are organized in groups to formulate and draft proposal concepts for future observations maximizing the scientific output. During the workshop, we overview the key questions in the field, review the capabilities of observational facilities for (current and future) PN research, discuss which observations are best suited to solving the open problems in the field, and discuss the corresponding necessary analysis (in terms of tools and expertise).

Workshops with similar purposes have been organized with great success by the Asymptotic Giant Branch stars (AGB) research community, which has regular meetings strategically scheduled before each ALMA observing cycle. These meetings generated successful proposals that were granted observing time by this highly competitive observatory. The PNe community is relatively small, with a history of successful collaborations, as exemplified by the *ChanPlaNS* and *HerPlaNS* collaborations, both of which have produced significant results (e.g., [2–8]). These surveys were conceived during the Planetary Nebulae Workshop held in Rochester, NY, USA, in 2009 [9], with follow up at the Planetary Nebulae Workshop in Miraflores de la Sierra, Madrid, Spain in 2013; both meetings were organized with goals similar to those of WORKPLANS.

2. WORKPLANS I

In the first WORKPLANS (25–29 January 2016), 51 researchers gathered in the Lorentz Center[1], Leiden, Netherlands, for what was a very fruitful week. We started the meeting with a broad review

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1　https://www.lorentzcenter.nl/

of potential relevant topics to be investigated in the next years in the PNe field (with talks mainly on Monday). From Tuesday to Thursday, we focused on the scientific and technical aspects of specific wavelength ranges. In the mornings, we reviewed the capabilities of the main telescopes and instruments from each spectral range. The afternoons of these three days were dedicated to group discussions, networking and drafting observing proposals. Brief summaries of those discussion and proposal were given at the end of the day. On Friday, a summary was given by the group leaders, together with the current status of the draft. At least eight proposals were drafted and submitted soon after the workshop.

3. WORKPLANS II

The format and goals of WORKPLANS II were similar to its previous edition. The main change was to reduce the time for the "X-ray observations" session, based on experience from WORKPLANS I and the increasing limitations of current facilities. The "X-rays" session was merged into the optical/ultraviolet session, which was made independent from the "infrared observations" session. These changes better balanced the current interests of the PN community and the facilities presently available and under construction. We also made small changes to the program in comparison to WORKPLANS I to add a little more time for plenary discussions. The workshop program is compiled in Table 1.

We organized the workshop to occur with ample time before deadlines for submission of observing proposals for various major facilities (in particular the JWST Cycle 1 proposal deadline), while attempting to avoid periods with classes in universities, to maximize attendance. The workshop was held during the week of 16–20 December 2019, in the Lorentz Center, the Netherlands.

Table 1. WORKPLANS II program.

Time	Talk	Lecturer/Chair
Monday 16 December		
09:30–10:00	Arrival, office assignment, coffee and tea	
10:00–10:10	Welcome	Lorentz Center Staff
10:10–10:20	Goals and Structure of the Meeting	Isabel Aleman
10:20–10:40	Talk In Honour to Prof. S. Pottasch	Jeronimo Bernard-Salas
Session 1: Open Problems and Possible Solutions I		Chair: Letizia Stanghellini
10:40–11:05	Uncertainties in Abundances	Monica Rodriguez
11:05–11:30	The Abundance Discrepancy Problem	Roger Wesson
11:30–12:00	Plenary Discussions	
12:00–13:30	Lunch and Informal Discussions	
Session 2: Open Problems and Possible Solutions II		Chair: Jorge Garcia-Rojas
13:30–13:55	S-Process Elements in PNe	Nick Sterling
13:55–14:20	PAHs in PNe	Els Peeters
14:20–14:45	Dust budget in galaxies	Mikako Matsuura
14:45–15:10	Challenges of multi-wavelength PN surveys	Quentin Parker
15:10–15:40	Plenary Discussions	
15:40–16:00	Coffee and Tea Break	
Session 3: Open Problems and Possible Solutions III		Chair: Eva Villaver
16:00–16:25	Shaping of Planetary Nebulae	Noam Soker
16:25–16:50	Binaries in Planetary Nebula	David Jones
16:50–17:30	Plenary Discussions	
17:30–18:00	Posters–flash presentations	
18:00	Wine and Cheese welcoming party with poster session	

Table 1. *Cont.*

Time	Talk	Lecturer/Chair
Tuesday 17 December		
Session 4: Infrared I		Chair: Jan Cami
09:00–09:30	IR Observatories	Eric Lagadec
09:30–09:50	Observations of Planetary Nebulae with Herschel and AKARI	Toshiya Ueta
09:50–10:10	Observations of Planetary Nebulae with JWST	Raghvendra Sahai
10:10–10:30	Observations of PNe/Evolved Stars with SPICA/Origins Space Telescope	Elvire De Beck
10:30–11:00	Coffee and tea break	
11:00–12:00	Plenary Discussions–Which infrared data do we need to solve the open questions?	
12:00–13:30	Lunch and Informal Discussions	
Session 5: Infrared II		Chair: Griet Van de Steene
13:30–14:30	Defining Strategic Plan–Defining Projects and Groups	
14:30–18:00	Hands-on Sessions–Groups discuss and draft proposals	
Wednesday 18 December		
Session 4: Optical, UV, X-Rays I		Chair: Denise Gonçalves
09:00–09:30	Optical/UV Observatories I	Romano Corradi
09:30–09:50	Optical/UV Observatories II	Henri Boffin
09:50–10:10	What MUSE can do for PNe	Jeremy Walsh
10:10–10:30	X-Rays Observatories and the Observation of PNe	Martin Guerrero
10:30–11:00	Coffee and tea break	
11:00–12:00	Plenary Discussions–Which Optical/UV/X-rays data do we need to solve the open questions?	
12:00–13:30	Lunch and Informal Discussions	
Session 5: Optical, UV, X-Rays II		Chair: Joel Kastner
13:30–14:30	Defining Strategic Plan–Defining Projects and Groups	
14:30–18:00	Hands-on Sessions–Groups discuss and draft proposals	
Thursday 19 December		
Session 6: Radio to Submillimetre I		Chair: Valentin Bujarrabal
09:00–09:30	Radio I	Wouter Vlemmings
09:30–10:00	Radio II	Carmen Sanches-Contreras
10:00–10:30	Polarization and Magnetic Fields in PNe	Laurence Sabin
10:30–11:00	Coffee and tea break	
11:00–12:00	Plenary Discussions–Which radio/Sub/mm data do we need to solve the open questions?	
12:00–13:30	Lunch and Informal Discussions	
Session 7: Radio to Submillimetre II		Chair: Albert Zijlstra
13:30–14:30	Defining Strategic Plan–Defining Projects and Groups	
14:30–18:00	Hands-on Sessions–Groups discuss and draft proposals	
Friday 20 December		
Session 10: Wrap Up		Chair: Quentin Parker
09:00–09:30	Workshop Summary	Quentin Parker
09:30–11:20	Summary of the prepared proposals	Group Leaders
11:20–12:00	Closing Remarks	Organizers

WORKPLANS II had short-term and long-term practical goals. In the short term, we intended to reinforce the previously formed network, inviting at least some of the discussion leaders who emerged during the last workshop while expanding the network by inviting new participants. During the workshop, we formed task forces to address the topics previously mentioned. The task forces focused on a specific spectral realm to strategize proposals designed to use the current forefront facilities that can complement extant data. We invited experts in observations to cover the whole radiative spectrum, from X-rays to radio. Teams were assembled that also included specialists with deep knowledge of the fundamental physics of PNe and hence were prepared to analyze and model the observed objects.

We also discussed preparations for the use of future instruments, in particular JWST, to be launched in 2022. This represents one of our key long-term goals. Another long-term goal is to keep WORKPLANS as a regular and productive tradition in the PNe community.

Fifty-five participants from all around the world, covering a wide range of expertise, gathered for WORKPLANS II. To maximize the workshop science output, in addition to having a wide range of expertise, in the preparation of our participants list and the program, we also considered the balance of gender, career stage, and geographical representation. The list of participants is compiled in Table 2, and the group picture appears in Figure 1.

Table 2. WORKPLANS II participants list.

Name	Affiliation	Country
Organizers		
Isabel Aleman	Universidade Federal de Itajubá	Brazil
Jeronimo Bernard-Salas	ACRI-ST	France
Joel Kastner	RIT	USA
Toshiya Ueta	University of Denver	USA
Eva Villaver	Universidad Autónoma de Madrid	Spain
Lecturers and Participants		
Stavros Akras	University of Rio Grande	Brazil
Karla Ziboney Arellano-Córdova	IAC	Spain
Mike Barlow	UCL	UK
Henri Boffin	ESO	Germany
Panos Boumis	National Observatory of Athens	Greece
Jesse Bublitz	RIT & IPAG	USA, France
Valentin Bujarrabal	OAN	Spain
Jan Cami	University of Western Ontario	Canada
	SETI Institute	USA
Alessandra Candian	University of Amsterdam	Netherlands
Alexandros Chiotellis	National Observatory of Athens	Greece
Romano Corradi	GTC - IAC	Spain
Elvire De Beck	Chalmers University of Technology, Onsala Space Observatory	Sweden
Jorge Garcia-Rojas	IAC	Spain
Veronica Gomez-Llanos	UNAM	Mexico
Denise Gonçalves	Valongo Observatory	Brazil
Martin Guerrero	IAA-CSIC	Spain
Harm Habing	Leiden University	Netherlands
David Jones	IAC	Spain
Eric Lagadec	Nice Observatory	France
Foteini (Claire) Lykou	The University of Hong Kong	China
Arturo Manchado	IAC	Spain
M. Belén Mari	Valongo Observatory	Brazil
Mikako Matsuura	Cardiff University	UK
Rodolfo Montez	Harvard-Smithsonian Center for Astrophysics	USA
Masaaki Otsuka	Kyoto University	Japan
Quentin Parker	The University of Hong Kong	Hong Kong, China
Els Peeters	University of Western Ontario	Canada
	SETI Institute	USA
Andrés Felipe Perez-Sanchez	Leiden University	Netherlands
Guillermo Quintana-lacaci	IFF-CSIC	Spain
Matthew Redman	NUI Galway	Ireland
Nicole Reindl	University of Potsdam	Germany
Andreas Ritter	The University of Hong Kong	Hong Kong, China
Mónica Rodríguez	INAOE	Mexico
Laurence Sabin	University of Guadalajara	Mexico
Raghvendra Sahai	NASA/JPL	USA
Carmen Sanches-Contreras	CSIC	Spain
Noam Soker	Technion	Israel
Letizia Stanghellini	NSF's OIR Lab	USA
Nicholas Sterling	University of West Georgia	USA
Jesus Toalá	UNAM	Mexico
Griet Van de Steene	Royal Observatory	Belgium
Wouter Vlemmings	Onsala Space Observatory	Sweden
Jeremy Walsh	ESO	Germany
Roger Wesson	UCL	UK
Albert Zijlstra	The University of Manchester	UK

A good measure of the success of WORKPLANS II was that, by the end of the workshop, the participants were already talking about a third installment.

Figure 1. Participants of WORKPLANS II.

4. Honoring Prof. Stuart Pottasch

The workshop paid tribute to the life and research of Stuart R. Pottasch and his extensive contribution to Planetary Nebulae research. Stuart was born in 1932 in New York city, and passed away on 4 April 2018 in Groningen. He married Anne Maria de Groot in Leiden with whom he had three children. After she passed away, he then married Greet Mientjes. Besides his passion for Planetary Nebulae, he was also well known for having a large collection of cactuses and parrots. He became one of the youngest professors (if not the youngest) at Groningen University, when he was appointed professor at the Kapteyn Astronomical Institute in 1963 by Adriaan Blaauw. His research legacy includes over 400 papers, of which 93 are first author (43 on PNe), and over 20 Ph.D. students, with his first student being Harm Habing.

While he is known for his research in PNe, Stuart's research is very vast and diverse and includes bright rims, nova outbursts, solar corona, ISM, H II regions, and more. In fact, his two most cited papers are on the interpretation of the Solar UV emission line spectrum. His focus on PNe started with the launch of the Astronomical Netherlands Satellite (ANS) in 1974, and he went on to exploit facilities such as the IUE, IRAS, ISO, Spitzer, and later Herschel to better understand this fascinating stage of stellar evolution. His research in PNe is equally vast, and encompasses nearly all areas of PN research: studies of the central star, nucleosynthesis, nebular physical conditions and chemical composition, dust, PN distances and distribution, and PNe in the galactic context. In 1984, he published a fascinating and very comprehensive book on the subject "Planetary Nebulae: A study of late stages of stellar evolution". During the last two decades, he became very interested in the use of IR lines to derive the nebular chemical composition and their enrichment to the ISM.

While gone, Stuart's research will have a long lasting impact in the study of PNe for many years to come, and a current and new generation of PN scientist will keep benefitting from his tremendous and productive career.

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Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AGB	Asymptotic Giant Branch
ALMA	Atacama Large Millimeter/submillimeter Array
ChanPlaNS	Chandra Planetary Nebula Survey
CSIC	Consejo Superior de Investigaciones Científicas
ELT	Extremely Large Telescope
ESO	European Southern Observatory
GTC	Gran Telescopio Canarias
HerPlaNS	Herschel Planetary Nebula Survey
HST	Hubble Space Telescope
IAA	Instituto Astrofísica Andalucía
IAC	Instituto de Astrofísica de Canarias
IAU	International Astronomical Union
IFF	Instituto de Física Fundamental
INAOE	Instituto Nacional de Astrofísica, Óptica y Electrónica
IPAG	Institut de Planétologie et d'Astrophysique de Grenoble
ISM	Interstellar Medium
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope
NASA	National Aeronautics and Space Administration
NSF	National Science Foundation
NUI	National University of Ireland
OAN	Observatorio Astronómico Nacional
OIR Lab	National Optical-Infrared Astronomy Research Laboratory
PN	Planetary Nebula
RIT	Rochester Institute of Technology
SETI	Search for Extraterrestrial Intelligence
SOFIA	Stratospheric Observatory for Infrared Astronomy
SPICA	Space Infrared Telescope for Cosmology and Astrophysics
UCL	University College London
UNAM	Universidad Nacional Autónoma de Mexico
VLT	Very Large Telescope
WORKPLANS	Workshop on Planetary Nebula Observations

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