

GALAXY EVOLUTION AND FEEDBACK ACROSS
DIFFERENT ENVIRONMENTS

IAU SYMPOSIUM 359

COVER ILLUSTRATION:

Background: Gas column density in the cosmic web, $z=2$, comoving 15 Mpc side (credit: Rainer Weinberger, IllustrisTNG Collaboration). From this cosmic web, galaxies and clusters have been formed, as shown with the foreground images, revealing different forms of feedback.

Top left: Jellyfish galaxy JO201 (credit: GASP collaboration, 2019) suffering feedback within a galaxy cluster.

Top right: Composite image of galaxy cluster MS0735.6 + 7421 showing feedback effects in the X-ray gas (Credit: X-ray: NASA/CXC/Univ. Waterloo/B.McNamara; Optical: NASA/ESA/STScI/Univ. Waterloo/B.McNamara; Radio: NRAO/Ohio Univ./L.Birzan et al., 2006, revised 2018).

Bottom left: HST [OIII] narrow-band image of the QSO J135251 + 654113 showing the ionized gas extending by 30 kpc (orange) overlaid on a continuum-band image of the host galaxy (grey) (Credit: Storchi-Bergmann et al. 2018, ApJ 868, 14; figure by Fausto Barbosa), revealing Supermassive Black Hole feedback beyond the host galaxy.

Bottom right: Composite image of the Starburst galaxy M82 showing feedback from star formation (Credit: X-ray: NASA/CXC/JHU/D. Strickland; Optical: NASA/ESA/STScI/AURA/The Hubble Heritage Team; Infrared: NASA/JPL-Caltech/Univ. of Arizona/C. Engelbracht).

IAU SYMPOSIUM PROCEEDINGS SERIES

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International Astronomical Union



**GALAXY EVOLUTION AND
FEEDBACK ACROSS DIFFERENT
ENVIRONMENTS**

**PROCEEDINGS OF THE 359th SYMPOSIUM OF
THE INTERNATIONAL ASTRONOMICAL UNION
HELD IN BENTO GONÇALVES, BRAZIL
2–6 MARCH, 2020**

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**CAMBRIDGE
UNIVERSITY PRESS**

Cambridge University Press

978-1-108-49068-9 — Galaxy Evolution and Feedback across Different Environments (IAU S359)

Edited by T. S. Bergmann , W. Foreman , R. Overzier , R. Riffel

Frontmatter

[More Information](#)

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314-321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi - 110025, India

103 Penang Road, #05-06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org

Information on this title: www.cambridge.org/9781108490689

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First published 2021

A catalogue record for this publication is available from the British Library

ISBN 978-1-108-49068-9 Hardback

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Preface

The history of IAU Symposium 359 – Galaxy Evolution and Feedback across Different Environments, GALFEED for short, began with a meeting, by the end of 2014, between two of us at the Harvard/Smithsonian CfA: William and Thaisa, who was visiting the CfA. Due to our common interest in Active Galactic Nuclei (AGN) feedback, at that opportunity, we decided to create the IAU Commission X1 – Supermassive Black Holes, Feedback and Galaxy Evolution. And shortly afterwards, we began to discuss the promotion of an IAU Symposium on this topic in the south of Brazil. But these Symposia are very competitive, and the first proposal, focusing on feedback from AGN, did not succeed. There had been too many recent Symposia on this topic. Discussing this fact with our young colleagues from the astronomy group at the Instituto de Física, UFRGS (Universidade Federal do Rio Grande do Sul), Porto Alegre, Brazil, and with their support, we changed the proposal to include the broader topic of galaxy evolution and a strong community outreach component, that led to its selection by the IAU.

Our goal with this Symposium was, thus, to bring together the AGN and galaxy evolution science communities, that usually propose separate Symposia. However, we now know that AGN is a phase occurring in most galaxies that critically influences their evolution. Thus it is important to study the two processes together and to enable researchers, in both topics, to learn from each other. Key questions we have discussed during the Symposium include: How do galaxies acquire their gas and how efficiently is it transformed into stars? How is the SMBH in the galaxy center fuelled to become an AGN? What is the main physical mechanism that quenches star formation? How powerful are the stellar and AGN feedback processes in regulating galaxy evolution? What is the role of the environment on galaxy evolution and AGN triggering?

During our Symposium, the above questions have been discussed in 118 scientific contributions, grouped in six sessions:

(1) The first session addresses the formation and early evolution of galaxies and supermassive black holes via models, simulations and observations, targeting massive galaxies, starburst galaxies and QSOs;

(2) The second session focuses on the epoch of Cosmic Noon, addressing black hole masses, galaxy mergers, star-forming galaxies, distant quasar host galaxies, including the claim that there is no quenching of star formation in quasars;

(3) In the third session we discuss high density environments, from protoclusters, through the effect of black hole outbursts on galaxy clusters, to the effect of the environment on starburst and AGN activity;

(4) The fourth session addresses feedback associated with secular evolution, including the effect of AGN jets and outflows on galaxies, via models and observations, and a discussion of the important role of the adopted gas density on the calculation of outflow power from ionised gas kinematics;

(5) The fifth session concentrates on the fueling of star formation and nuclear activity, including the observation of gas flows with ALMA down to the inner few parsecs around the supermassive black hole and models of the flows in the innermost parsec;

(6) In the sixth session, the primary topic is the state of the present day Universe, via the study of resolved stellar populations of galaxies to derive their star formation history and the investigation of resolved excitation and kinematics of the gas in individual nearby active and non-active galaxies.

The seventh and last session comprises a compilation of 25 specific questions proposed by the participants and discussed on the last day of the Symposium together with the proposed answers given both at the conference or afterwards by the participants.

Cambridge University Press

978-1-108-49068-9 — Galaxy Evolution and Feedback across Different Environments (IAU S359)

Edited by T. S. Bergmann, W. Forman, R. Overzier, R. Riffel

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Preface

It was a pleasure to receive the approximately 200 colleagues and students who came to the Symposium in Bento Gonçalves during the week of March 2 to 6 of 2020, making the meeting a success, just before the cancelation of all similar meetings due to the COVID-19 pandemic. We were pleased, in particular, by the enthusiastic participation of Brazilian students and post-docs who helped with the reception of our foreign colleagues as well as with the outreach activities that engaged about 2000 people during the 5 days of the Symposium.



The SOC, from left to right: William Forman, Françoise Combes, Thaisa Storchi-Bergmann, Richard Davies, Roderik Overzier and Keiichi Wada. Missing from the picture: Raffaella Morganti and Sebastian Sanchez.



Welcome address by the Chair.



The audience of the Symposium.

Thaisa Storchi-Bergmann, *Editor and Chair of the SOC*

William Forman, *Co-editor and Co-chair*

Roderik Overzier, *Co-editor and Co-chair*

Rogério Riffel, *Co-editor and Chair of the LOC*

Dedication

We dedicate this volume to the memory of Dr. João Evangelista Steiner, who prematurely passed away on September 10, 2020, by the time we were finishing these Proceedings. As co-chair Roderik Overzier posed, “the great oak of Brazilian Astronomy has fallen, and we will be lost without its shadow”.



Left: João Steiner. **Right - From left to right:** Daniel May, Roberto Menezes, Patricia da Silva, João Steiner, Tiago Ricci, Catarina Aydar, Pedro H. Cezar

João was a Professor of Astrophysics at IAG-USP (Instituto de Astronomia, Geofísica e Ciências Atmosféricas - Universidade de São Paulo) and a member of the Brazilian Academy of Sciences. He was an active astrophysicist who made important scientific contributions in the area of compact stars (in particular cataclysmic variables) and Active Galactic Nuclei. A 1983 paper by him and Jules Halpern, written when both were at the Harvard-Smithsonian Center for Astrophysics, Cambridge, US, is an important reference to this date on the nature of LINER galactic nuclei.

Besides being a productive researcher, and having advised more than 20 students and post-docs, João was restless to promote scientific research not only in astrophysics but also in other areas of knowledge, having been secretary general of the Brazilian Society for the Progress of Science (SBPC), Secretary for the Coordination of Research Units of the Ministry of Science, Technology and Innovation (MCTI), directed the Institute for Advanced Studies of University of São Paulo (IES/USP) and was also director of INPE (Instituto Nacional de Pesquisas Espaciais). João was particularly concerned that Brazilian astrophysics had the necessary infrastructure to be at the forefront of astrophysical research. He coordinated the efforts of modernization of the Pico dos Dias Observatory, the establishment of the National Astrophysics Laboratory (LNA) and played a fundamental role in the Brazilian participation in the Gemini and SOAR observatories consortia. More recently, he had been the lead scientist coordinating the Brazilian participation in the GMT (Giant Magellan Telescope).

João came with his 6 students and post-docs (see figure above) to participate in the Symposium, happily reporting on the results of their recent survey of nearby southern galaxies with the Gemini Multi-Object Integral Field Spectrograph called “Diving 3D”, described along 9 contributions to the present volume. His contributions, guidance and leadership will be missed.

Thaisa Storchi-Bergmann, William Forman, Roderik Overzier and Rogério Riffel
The Editors

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Members of the LOC - from left to right Rodrigo Flores, Tiago Ricci, Hekatelyne Carpes, Cristina Furlanetto, Juliana Motter, Ana L. Chies-Santos, Eduardo Brock, Marina Trevisan and Jaderson Schimoia (not in the picture: Allan Schnorr-Müller, Rogério Riffel and Rogemar Riffel).

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Acknowledgements

IAU 359 was a very special and successful meeting because of the remarkable efforts of many people. First, it gathered a superb cast of scientists from around the world for a superb set of talks. Second, it provided a showcase for South American postdocs and students to present their exciting work. The posters and the flash talks were dramatic and interesting – too many to absorb in too short a time – but the symposium proceedings are now before you! Read, enjoy, and reflect. Third, our public outreach event was the highlight of the season for the young and old of Bento Gonçalves and surrounding towns that packed the lecture hall until it overflowed and waited for over an hour after the public lecture in order to ask questions and have their photos taken with the speakers. It was inspiring to experience the enthusiasm of this audience for astrophysics!

We would like to thank the support from the IAU, SAB (Sociedade Astronômica Brasileira), Instituto Serrapilheira and FAPERGS (RS foundation for research support). We thank also the SOC for the guidance; the LOC for the logistic support, the creation of the “Universe at your feet” sandals, bags and notebooks; the astronomy students from our Physics Institute of Universidade Federal do Rio Grande do Sul (IF-UFRGS) and from other institutes for the support during the sessions and outreach activities; our University UFRGS for its support and the provost of research Rafael Roisler, for his speech in the opening ceremony; our partner Universities Universidade Federal da Fronteira Sul and Universidade Federal de Santa Maria for their support and the town of Bento Gonçalves, represented in the opening ceremony by the Secretary of Tourism, Rodrigo Parisotto, who welcomed the participants.



Thanks to the students, for their support throughout all activities.

The partnership with the town administration allowed us to use the space Casa das Artes, adjacent to the hotel, to develop our many educational and outreach activities, under the leadership of the director of the UFRGS Planetarium Daniela Pavani. We thank

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her and her team for the promoted activities for young school students during the days, and for the general public and high school students during the nights.



Kids waiting for the Planetarium session.



Audience of the nighttime outreach talks.



About 2,000 people attended these activities that included shows in an inflatable Planetarium, nighttime observations and talks by renowned international participants of the Symposium.

A word from Henrique Roberto Schmitt, Thaisa's first PhD student

In the name of Thaisa's students, I would like to point out that this symposium also marks a major point in Dr. Thaisa Storchi-Bergmann's career. After a long tenure as a professor at the Astronomy Department at UFRGS, Thaisa is retiring from teaching and administrative duties, which will allow her to dedicate more time to research and other interests. We would like to congratulate her on this major achievement, as well as on her highly accomplished professional career, spanning more than three decades, with seminal contributions to several areas of extragalactic astrophysics. Furthermore, her current and

former students and post-docs would like to thank her for the guidance, friendship and encouragement that she provided through the different stages of their careers. Thanks to her energetic and gregarious nature, they were brought into a vibrant group, pursuing leading edge research in her many areas of interest. By incorporating these students into the daily activities of the group, not only were they taught the basics of the field, and guided on how to navigate the arduous and sometimes convoluted process of obtaining a degree, they were also encouraged to pursue their own interests and explore their own ideas. This independence was essential, not only for the professional development of the students and their future careers, but also for the overall success of the group, keeping it in the forefront of the field, with collaborations throughout the globe.



Special thanks to (from left to right): Daniela Pavani for coordinating the outreach activities; Grazyna Stasinska, Christopher Harrison and Christine Jones, for giving the nighttime talks.



Thaisa's present and former students and post-docs. **Left:** top, from left to right, Bruna Arajo, Natalie Schreiber, Henrique Schmitt, Jaderson Shimoia, [Thaisa], Gabriel Roier, Cristina Furlanetto, Julio Cesar, Hekatelyne Carpes, Daniel Ruschel Dutra, Oli Dors Jr.. Bottom: Edwin David, Bruno Dall'Agnol de Oliveira, Guilherme Couto. **Right:** Thaisa with former student Rodrigo Nemmen

A word from the Chair

Being in a phase of my career when I am retiring from teaching and administrative duties at the University, I would like to use this opportunity to thank all the participants and in particular my students, post-docs, my PhD advisor, Miriani Pastoriza, my colleagues

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and collaborators, from whom I learned so much during the years we worked together. Special thanks go to my former students Henrique Schmitt and Rodrigo Nemmen for their kind words during the Symposium. I also use this opportunity to pay tribute to Astronomy and the Universe with the following poem. My cousin Roberto Niederauer has composed a melody to go with it and played it at the Symposium. The song is available on Youtube:

<https://www.youtube.com/watch?v=I-5j6Nb-3mg>.

The Universe Song

*When you look far, you see our Universe's past
Took shape at the Big Bang,
Then the first atoms began to circulate, away
And where they stayed, galaxies they created
Inside all galaxies, stars took form and Black Holes were born
Inside the stars, new heavier elements were forged
Then Supernovae and Black Holes
Spread the elements around the Universe
And where they stayed, new stars they created
And from star dust, this rich star dust, planets formed around
And in one planet, a little blue planet we were born,
We were finally born.*



Roberto Niederauer and Thaisa: the authors of the Universe song

Thaisa Storchi-Bergmann
Chair of the SOC

CONFERENCE PHOTOGRAPH

