Bonn/Bochum-Graduiertenkolleg Workshop

The Magellanic Clouds and Other Dwarf Galaxies

Physikzentrum Bad Honnef, Germany
19th – 22nd January 1998

Edited by
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Sternwarte der Universität Bonn, Auf dem Hügel 71,
D–53121 Bonn, Federal Republic of Germany

Shaker Verlag

October 1998
Foreword by the Spokesman of the Graduiertenkolleg

It is a great pleasure that the 25th meeting of our Graduate Working Group, which is being supported now in its 6th year by the Deutsche Forschungsgemeinschaft, could become a significant international event. It is also gratifying to see this workshop as a harvest after 5 years of intensive work. The Graduate Working Group has seen a host of guest scientists who have visited in the framework of close collaboration, or gave lectures and seminars during the many previous meetings. This gathering of experts on galaxies, and particularly dwarf galaxies, represents a small milestone in the recent past of galaxy research at the Universities of Bonn and Bochum.

Until the late 70’s, the investigation of dwarf galaxies was restricted to a few small groups. Although the Magellanic Clouds had been studied extensively due to their proximity, it took a while until the term dwarf galaxy became fashionable among astrophysicists. There are several reasons why dwarf galaxy research is one of today’s fastest growing branches of modern astrophysics. First, the Magellanic Clouds have always been appreciated as the ideal astrophysical laboratory in which one can study all kinds of processes without being hampered by distance and line-of-sight problems. Second, since it was known early on that dwarf galaxies are so little evolved, their relevance to cosmology was recognized. Third, by virtue of their low mass, the evolution of their ISM and stellar populations can be studied in the absence of internal large-scale triggers like stellar bars or density waves. It is therefore not surprising that the past two decades have seen a rapidly increasing rate of related research projects and publications, accompanied by an ever increasing number of conferences dedicated to this subject, one of which is being reported in these proceedings.

While to the non-expert it might at first glance look as if dwarf galaxy research is a rather specialized field, a quick look at contemporary reviews on galaxy research demonstrates that understanding low-mass galaxies is of utter importance to also comprehend what is going on in more massive and, in particular, more distant ones. A prime example is the understanding of the faint blue galaxy population at redshift 0.4 to 1.0, which has experienced a further boom with the scrutiny of distant objects in the Hubble Deep Field. It is obvious that in order to understand stellar systems at large distances, it is all the more important (also for the cosmologists) to understand those just outside our doorstep!

Research on the Magellanic Clouds and other dwarf galaxies had been going on at the Universities at Bonn and Bochum for some time prior to the Bonn/Bochum Graduate Working Group. It was therefore quite natural to combine the experience gained in two small research groups in order to intensify this research, while at the same time establishing an educational programme in which graduate students could benefit for their own career, and contribute to the progress in a very proliferous field of research.

We are grateful to the Deutsche Forschungsgemeinschaft for financing this Graduate Working Group, thus rendering possible this intensive educational and research programme in a very prolific and fascinating field of research. I would like to take this opportunity to thank Christian Brüns for his invaluable help in organizing this workshop. It has been (and still is) a great pleasure to work with the students in the Graduate Working Group. It is their enthusiasm and diligence that, besides my natural endeavour in this field of research, ensures permanent motivation!

Uli Klein
Bonn, April 1998
Foreword of the Editors

After having completed the present edition of the proceedings of our workshop on “The Magellanic Clouds and Other Dwarf Galaxies” we wish to express our gratitude to all contributors. The concept of our “Graduiertenkolleg” is meant to provide an efficient framework for graduate education and research and to foster not only the relations between students and supervisors but also between students and distinguished representatives of the community of our field of research. In this sense the graduate school can be seen as an attempt to realize the old (and often forgotten) idea of unifying teaching and research at universities. This edition is a handy manifestation.

We remember quite well that, when we tried to expand our scientific ambitions centered on the Magellanic Clouds, the extension “... and Other Dwarf Galaxies” sounded meaningless to many ears. Looking at the entire collection of reviews, talks and posters addressing such a large variety of astrophysical issues, it now seems to us that no better headline for merging the various interests within our graduate school could have been found.

We hope that it is of interest for many researchers to have a look at the extensive key word and object lists (see the appendices “Subject Index” and “List of Objects” on page 337 and 331 respectively) to quickly find specific information among the wealth of topics and objects, which appear in contributed talks and posters. We also hope that the attractive cover (designed by Michael Hilker and Sven Kohle) strengthens the wish of a potential reader to know what is in the book.

We wish to thank the Shaker Verlag, namely Dr. Shaker, for giving us the permission to make the proceedings available in free electronic form on our webserver (see also the next preface about “Electronic Publishing”) and all the participants (see the “List of Participants” on page 313) for their help in creating a fascinating workshop, for their contributions, and of course for further supporting the electronic version with updates and new links. We very much appreciate the contribution by Joachim Köppen, who fell sick shortly before the workshop and could not participate.

Considering the statistics of incoming contributions (see electronic version, at the URL: http://www.astro.uni-bonn.de/~webgk/ws98/technfa.html#subm), it is noteworthy that the first contribution was a review, and so was the last. The distribution of time of the arrival of the reviews was nearly homogeneous, whereas the one for the talks and especially for the posters was peaking at our deadline.

Many thanks go to the Deutsche Forschungsgemeinschaft as the funding institution of the Graduiertenkolleg and also for supporting this workshop.

Tom Richtler & Jochen M. Braun
Bonn, October 1998
Electronic Publishing

In the last few years sciences have improved by new electronic means, not only to create huge data bases and providing tools for data reduction, but also in electronic publishing (EP) and information exchange.

One of the most powerful aids apart from E-Mail and FTP (File Transfer Protocol) is the World Wide Web (WWW or W3), which has developed from the “toy” status to a very fast publication means, useful for announcing meetings, presenting institutes and working groups, providing the latest data about equipment, and nowadays also for publishing. Right from the start WWW was intended as a scientific tool developed at CERN, but soon was adopted by the whole society, at least in some countries with appropriate and cheap telecommunication infrastructure. Thus in addition to the tools (like browsers) developed by scientists, commercial products arose and the language of the Web, HyperText Markup Language - HTML, came into Babylonian trouble. To create future standards and secure the general accessibility, the WWW Consortium (W3C) formed, which has created the current (but still unsupported) standards HTML 4.0 and CSS 2.0, and is developing further scientifically relevant techniques, namely XML, XSL, and DOM.

To focus on astrophysics, literature search in the good old libraries was supported by electronic search engines, literature data bases, and preprint servers, e.g. ADS, CDS, and XXX, and publishing in printed journals including the well-tried referee process was extended by electronic versions, in different quality and accessibility. That EP is of enhanced importance today can be seen e.g. by the controversial panel discussion at the “AG Tagung” in Innsbruck 1997 after the talk “Electronic publishing in its context and in a professional perspective” by André Heck (1998, Reviews in Modern Astronomy 11, 337).

Let me stress a few aspects which, from my personal point of view are import in future:

- We need an international referee process decoupled from journals or publishers and revised international copyright laws doing justice to sciences.
- Scientists have to stay involved in modern techniques, i.e. knowing the basics of TEx, HTML etc., and every institution needs scientists especially trained in these subjects.
- Continent based mirror servers should be erected providing certified scientific information easily and freely accessible for the whole international community.

As a small step in this respect we present these proceedings in two different versions. One is the classical book (constructed with the typesetting system TEx & LATEX), which is published and distributed by the Shaker Verlag, the second is the electronic version (written in HTML) on the WWW server of the Astronomical Institutes of the University of Bonn. The latter can be visited via the following Uniform Resource Locator (URL):

\url{http://www.astro.uni-bonn.de/~webgk/ws98/cover.html}

and should provide the full information including updates after the day of printing (noted in the “Erratum”, an appendix of the electronic version) and related URLs. As technical modifications are possible - and even probable, people using the HTML version may also visit the appendix “Technical Information” (e.g. giving recommended browsers).

I hope that the electronic version will be a fruitful and frequently visited supplement to the printed version.

Jochen M. Braun
Bonn, October 1998
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EV – only part of the electronic version available at the WWW URL:
http://www.astro.uni-bonn.de/~webgk/ws98/cover.html

page numbers refer to the printed version published by
Shaker Verlag, Aachen, ISBN 3-8265-4457-9
Conference Summary

Evan D. Skillman

University of Minnesota

This is not formally a conference summary. Foremost, the hosts are thanked and congratulated. I then share a few impressions and a gedanken experiment is proposed.

1. Mandatory Laudatory Comments
It has been my great pleasure to be a participant in this workshop. The Bad Honnef conference center is certainly an exceptional facility which is conducive to interaction. The conference organizers have done a superb job in arrangements so that we haven’t had to worry about anything (with the possible exception of the participants who still haven’t made it back from Köln yet), and the result has been a wealth of exchange of ideas. I especially appreciated the poster review sessions, which helped to act as an introduction to the many exciting results presented as posters.

This meeting represents a solid endorsement of the Graduiertenkolleg (GK), in both its choice of science themes and its organization. When I was a first year graduate student, Bart Bok visited the University of Washington, and repeated over and over, “If you want to study star formation, study the Magellanic Clouds”. At the time he was bemoaning the lack of a millimeter observing facility in the southern hemisphere - something which has been rectified. The expansion of the theme from the Magellanic Clouds to dwarf galaxies in general has allowed the work at Bonn and Bochum to reach an even larger audience.

Having attended an earlier meeting of the GK, I should state that my impressions are all very positive. The benefits of forming a concentration of studies shared between two university departments are obvious and impressive. The students have access to numerous first class facilities, faculty, and many other resources. In fact, one can say that the students have enhanced access to numerous facilities since the resources available through the GK help to make them more competitive for observing time.

When I attended the GK meeting in the Fall of 1995, I was impressed with the many ideas for new projects that students were then forming. Many of those projects have been completed and were presented at this meeting. Good science is being done. The GK experience has become an excellent platform from which to launch a career in astrophysics.

2. Some Impressions
Some of the most successful conference summaries that I have witnessed were, in fact, not summaries at all. Thus, I will not attempt to summarize the whole conference, but rather to present some of my impressions gained during the workshop. Of course, the overall impression is that by concentrating on the nearest galaxies one can gain insights unafforded in any other context. Sometimes we may feel that this is lost in the rush to high redshift, but it certainly is not lost on the participants of this workshop. Again and again we were treated to stunning views of the Magellanic Clouds in wavelength after wavelength. There is a lot still to be learned from the Magellanic Clouds and even more to be learned by pushing for comparable studies of other nearby galaxies.
Simply because of my recent research activities, many of my impressions are grouped under the category of stellar populations. First among them is that the HST is an instrument ideally suited for stellar population studies. The leaps forward afforded by the vast improvement over ground based resolution has revolutionized our view of galaxies.

Nowhere is this more true than for the dwarf spheroidal galaxies. In the last decade, our views of these “simple” systems has changed enormously. The variety of star formation histories is still begging for a simple explanation. The kinematic studies of literally hundreds of stars (many now with multiple epochs) in most of the dSphs have continued to bear out Aaronson’s bold claim that these are dark matter dominated systems. As spectra of individual stars provide detailed abundance analyses, we may still be in for more surprises.

I was very impressed by the degree of sophistication in treatment of color-magnitude-diagrams (CMDs) and the general agreement between independent groups. For example, the presentations by Aparicio and Gallart showed how the different features in the CMDs could be used in concert to place strong constraints on star formation histories reaching back to the earliests epochs. Tolstoy and Hopp independently studied HST data on VII Zw 403 and (1) came to very similar conclusions about basic properties and (2) agreed on the features in the CMD which were most difficult to fit with a range of reasonable models.

There was a great deal of attention paid to the detailed structure in the ISM and its origins. I will never again confuse the terms “bubbles”, “super-bubbles”, and “supergiant shells”.

In the detailed H I imaging of the Magellanic Clouds, we are confronted with the problem of how best to deal with the high degree of complexity. Does it make sense to divide everything into categories of “holes” and “concentrations”? Perhaps it is pertinent to reflect back on the work that Hodge conducted for many decades, providing H II region luminosity functions (which also required making decisions about whether to divide features into components or combine features into single entities). We have seen that Oey has taken these H II region luminosity functions and used them to distinguish between “saturated” and “unsaturated” IMFs. While the analogy is not sound on a physical basis, I wonder that we may not see a similar understanding of the H I holes and concentrations in the future.

Concerning ISM structure, it is evident that x-ray observations are rapidly playing an increasing role in our understanding of the phase structure of the ISM. The x-ray images available today remind me of the H I images that were available a few decades ago. As the spatial and spectral resolution and sensitivity increase, important new insights are bound to come from this waveband.

Also, concerning the bubbles, I was disappointed that after presenting a detailed star formation history of the Sextans A dwarf, no one asked about the connection between the stellar population and the H I hole. I tried to check on this in preparing for this summary talk, but the limited field of view of the HST WFPC2 observations didn’t allow for a clear answer. Recently, van Dyk has shown evidence from ground based data for a radial gradient in stellar ages that supports a wind blown bubble model for the central H I deficit.

Moving to galaxy scales, the numerical calculations presented by Mac Low were very impressive. There has been endless speculation concerning the effects of star formation on the ISM of dwarf galaxies, and, in particular, the ability of a galaxy to blow away all of its ISM. These new calculations appear to present a more realistic impression of what is possible and what is not.

This leads to the connected question of what is the H I that is frequently found in the vicinity of dwarf galaxies. I refer to this H I which is usually at similar velocity but disconnected from the normal velocity fields, as “floppy disks”. Two alternative origins immediately come to mind. It could be that this material is tidal debris, left over from an interaction or a merger. Alternatively, this could be material which is primordial in nature and has not yet been incorporated into the galaxy. Within the limitations of available observing facilities, it is difficult to design an observational test which distinguishes these two possibilities. It is, however, a very important question.
Table 1. A Summary of Impressions

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|---|---|
| 1) | DH TR DE ES |
| 2) | MM P BO BIP |
| 3) | ET UH FSP |
| 4) | NO AA SA |
| 5) | XR HY |
| 6) | HST BF SPS |
| 7) | IBVC BSS |
| 8) | DS EBKS |
| 9) | A H&C LHR |
| 10) | NN RFP |
| 11) | FD TR PG |

Finally, I have to admit that one of the most remarkable things that I heard during the entire workshop was the story of Hunter’s graduate school foreign language exam. To pass the exam, she was required to translate a scientific article written in German. In fact, she translated the article into Spanish. I was impressed not only with the demonstration of language skills, but the display of stubborn independence found in astronomers everywhere.

This presentation of my impressions was accompanied by a visual aid. Uli Klein asked me to reproduce it in my conference summary, so it appears here as Table 1.

3. A Gedanken Experiment

Finally, knowing that most of the workshop participants would be spending one more night at Bad Honnef, I proposed an exercise to be carried out after dinner. At the time I called it an exercise, but since this is Germany, it is probably better referred to as a gedanken experiment.

The conference participants were treated to a trip to Köln, the highlight of which was a tour of the Dom. The Dom had recently experienced some refurbishing work, as evidenced by the many ton scaffold that was still hanging in the top of the church.

The following exercise occurred to me. What if that scaffold had fallen and crushed some of the workshop participants?

For this exercise, I assume the following cosmology: (1) there is a heaven, (2) there is a single deity, (3) when good people go to heaven the deity answers their questions, and (4) all astronomers are good. The purpose of the exercise is not to quibble with my assumed cosmology, but, rather, to imagine the questions of the deceased workshop participants as they enter heaven.

To kick off the proposed exercise, I tackled the question what if all of the invited review speakers were done in?

I started with Jay Gallagher. (The main reason for this was because I wasn’t sure how this would go over and Jay had already left for Munich.) Jay’s talk highlighted the degree of the interconnections between different studies and how observations of dwarf galaxies had impact on literally every major question in astronomy today. Actually, I think that Jay’s question was very easy. He would ask “What are the answers to everyone else’s questions?”

Mario Mateo’s talk emphasized the sophistication of the measurements of the dark matter associated with dSphs and their complicated star formation histories. I imagine that he would be able to negotiate a second question and the two together would be “What is dark matter, really?” and “Concerning dwarf spheroidals, where did the gas go?”

Elias Brinks has always been fascinated with detailed images of the distribution of neutral hydrogen in galaxies. On one hand, the energetics of the holes can be explained by the presence of stellar clusters. On the other hand, few of the known holes have identifiable stellar populations in their interiors. Elias would ask “How are these holes formed?”
Deidre Hunter presented detailed observations of star formation on different scales. In one case, she pointed to a sequence of two generations of star formation and proposed that a third might be ready to occur. A theory of star formation should have predictive power, and thus, Deidre might ask “Is there going to be a third generation of star formation?”

You-Hua Chu presented detailed comparisons of the x-ray distributions and the gas kinematics in the Magellanic Clouds. She questioned the assumptions of pressure equilibrium. You-Hua would simply demand a complete picture of the multi-phase ISM in the Large Magellanic Cloud.

Jan Palous showed us, through numerical simulations, how ISM bubbles evolve. The calculations are simplified by taking advantage of certain symmetries. He would like to know if 2-dimensional simulations give the correct insight into a three dimensional world.

Trinh Thuan presented observations of SBS 0335 − 052, which he proposes is a young galaxy which is just forming now. He would like to know if it is possible for galaxies to be forming in the current epoch.

In summary, I would like to thank the organizers one last time for a truly enjoyable workshop. I congratulate them on their 25th GK meeting and I look forward to the 50th!
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