

HUNTING FOR THE DARK: THE HIDDEN SIDE OF GALAXY FORMATION

To learn more about AIP Conference Proceedings,
including the Conference Proceedings Series, please visit the webpage
<http://proceedings.aip.org/proceedings>

HUNTING FOR THE DARK: THE HIDDEN SIDE OF GALAXY FORMATION

Proceedings of the International Conference

Qawra, Malta 19 – 23 October 2009

EDITORS

Victor P. Debattista
Cristina C. Popescu

University of Central Lancashire, UK

SPONSORING ORGANIZATIONS

Malta Council for Science & Technology (MCST)
Royal Astronomical Society
University of Malta
University of Central Lancashire
Heritage Malta
Toyota, Michael Debono Limited
Air Malta
Farsons

AIP
American Institute
of Physics

Melville, New York, 2010

AIP CONFERENCE PROCEEDINGS 1240

Editors

Victor P. Debattista
Cristina C. Popescu
Jeremiah Horrocks Institute
University of Central Lancashire
PR1 2HE Preston, UK

E-mail: vpdebattista@uclan.ac.uk
cpopescu@uclan.ac.uk

Authorization to photocopy items for internal or personal use, beyond the free copying permitted under the 1978 U.S. Copyright Law (see statement below), is granted by the American Institute of Physics for users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of \$25.00 per copy is paid directly to CCC, 222 Rosewood Drive, Danvers, MA 01923, USA. For those organizations that have been granted a photocopy license by CCC, a separate system of payment has been arranged. The fee code for users of the Transactional Reporting Services is: 978-0-7354-0786-2/10/\$30.00

© 2010 American Institute of Physics

Permission is granted to quote from the AIP Conference Proceedings with the customary acknowledgment of the source. Republication of an article or portions thereof (e.g., extensive excerpts, figures, tables, etc.) in original form or in translation, as well as other types of reuse (e.g., in course packs) require formal permission from AIP and may be subject to fees. As a courtesy, the author of the original proceedings article should be informed of any request for republication/reuse. Permission may be obtained online using Rightslink. Locate the article online at <http://proceedings.aip.org>, then simply click on the Rightslink icon/"Permission for Reuse" link found in the article abstract. You may also address requests to: AIP Office of Rights and Permissions, Suite 1N01, 2 Huntington Quadrangle, Melville, NY 11747-4502, USA; Fax: 516-576-2450; Tel.: 516-576-2268; E-mail: rights@aip.org.

L.C. Catalog Card No. 2010904056

ISBN 978-0-7354-0786-2

ISSN 0094-243X

CONTENTS

Preface	xi
Acknowledgments	xii
Welcome Address	xiii
G. Bromage	

INTRODUCTION

The Dark and Light Side of Galaxy Formation: Is an End in Sight?	3
B. Moore	
Baryons and Their Halos	13
S. McGaugh	
The Decade of Galaxy Formation: Pitfalls in the Path Ahead	17
S. P. Driver	
The Dark and Dusty Side of Galaxy Evolution	29
S. Serjeant	

SESSION 1: DUST, STAR FORMATION AND AGN

The Evolution of Galaxies: An Infrared Perspective	35
C. C. Popescu and R. J. Tuffs	
The AKARI Extragalactic Large Area Survey: Towards the North Ecliptic Pole	47
T. Takagi, Y. Ohya, H. Matsuhara, T. Wada, S. Oyabu, T. Goto, H. Hanami, C. P. Pearson, S. Serjeant, M. Negrello, G. J. White, H. M. Lee, M. Im, and M. Malkan	
Dust and Stars: Galaxies in the AKARI Deep Field South (ADF-S)	51
A. Pollo, K. Malek, T. T. Takeuchi, P. Bienias, M. Shirahata, S. Matsuura, and M. Kawada	
Cosmic Star Formation History Revealed by the AKARI	55
T. Goto, M. Yagi, C. Yamauchi, and the AKARI NEPD Team	
The Star Formation Rate Functions at $z=0-1$: The Latter Half of the History of Visible and Hidden Star Formation in the Universe	59
T. T. Takeuchi, V. Buat, D. Burgarella, E. Giovannoli, K. L. Murata, J. Iglesias-Páramo, and J. Hernández-Fernández	
Spitzer's Mid-Infrared View on Dusty Galaxy Evolution	63
E. Sturm	
Luminous Buried AGNs in Ultraluminous Infrared Galaxies	72
M. Imanishi	
Mid-Infrared Spectral Diagnostics of Luminous Infrared Galaxies	76
A. Petric and the GOALS Collaboration	
Starburst or AGN Dominance in Submillimetre-Luminous Candidate AGN?	80
K. Coppin, A. Pope, K. Menéndez-Delmestre, D. M. Alexander, and J. Dunlop	
Molecular Gas in Violent Phases of Galaxy Evolution	82
P. Guillard, F. Boulanger, N. P. H. Nesvadba, M. E. Cluver, P. N. Appleton, P. Ogle, and G. Pineau des Forêts	
Dust Emission from Stephan's Quintet	85
G. Natale, R. J. Tuffs, J. Fischera, N. Lu, C. C. Popescu, C. K. Xu, P. Appleton, F. Boulanger, M. Dopita, P. Duc, Y. Gao, P. Ogle, G. Pineau des Forêts, W. Reach, J. Sulentic, and M. Yun	
Infrared Properties of the Halo, Bulge and Disk of the Edge-on Galaxy NGC 7814	87
E. Simmat, R. J. Tuffs, and C. C. Popescu	
Observing Cold Dust with Herschel/SPIRE	89
B. Schulz and the SPIRE Consortium	

Infrared SED Model for Young Galaxies: Effect of SN Reverse Shock and Shattering on Dust Grains . . .	91
T. T. Takeuchi, T. T. Ishii, H. Hirashita, T. Nozawa, and T. Kozasa	

SESSION 2: GAS AND STAR FORMATION

HI and Star Formation Properties of Massive Galaxies: First Results from the GALEX Arecibo SDSS Survey	95
B. Catinella, D. Schiminovich, and G. Kauffmann	
The Episodic Star Formation History of Low Surface Brightness Galaxies	99
J. H. Kim and S. S. McGaugh	
The GALEX Extended Mission: Surveying UV Tracers of the Hidden Side of Galaxy Evolution	103
D. C. Martin and the GALEX Science Team	
On the Kennicutt-Schmidt Relation of Low-Metallicity High-Redshift Galaxies	115
N. Y. Gnedin and A. V. Kravtsov	
The Evolution of Luminous Compact Blue Galaxies: Disks or Spheroids?	119
D. J. Pisano, C. A. Garland, K. Rabidoux, S. Wolfe, R. Guzmán, J. Pérez-Gallego, and F. J. Castander	
Chemodynamical Simulations with Variable IMF	123
C. Kobayashi	
Post-Starburst Galaxies: Why Aren't They Forming Stars?	127
S. De Rijcke, P. Buyle, D. J. Pisano, K. Freeman, and H. Dejonghe	
The Circum-Galactic Gas around Cosmologically Simulated Disks	131
S. Courty, B. K. Gibson, and R. Teyssier	
Gas Circulation and Galaxy Evolution	135
F. Fraternali	
Hot Gas Halos in Galaxies	146
J. S. Mulchaey and T. E. Jeltema	
Modeling a High Velocity LMC: The Formation of the Magellanic Stream	150
C. Mastropietro	
Are Galactic Coronae Thermally Unstable?	154
C. Nipoti	
The Environments of Distant Radio Galaxies	158
J. Bryant	
Semi-Analytic Models on the Molecular and Neutral Gas in Galaxies	160
J. Fu, Q. Guo, and G. Kauffmann	
What We Can Learn from the HI Properties of Galaxies—Galaxies Appear Simpler than Expected? . .	162
D. A. Garcia-Appadoo, A. A. West, J. J. Dalcanton, and M. J. Disney	
The WSRT HALOGAS Survey	164
G. Heald, G. I. G. Józsa, P. Serra, T. A. Oosterloo, R. Sancisi, F. Fraternali, R. J. Rand, R. A. M. Walterbos, E. Jütte, and G. Gentile	
Galactic Fountains and Gas Accretion	166
F. Marinacci, J. Binney, F. Fraternali, C. Nipoti, L. Ciotti, and P. Londrillo	
The VIMOS-VLT Deep Survey: History of the Galaxy Clustering in the Universe	169
A. Pollo and the VVDS Team	
Hot Halo Gas in Galaxy Mergers	171
M. Sinha and K. Holley-Bockelmann	
Metallicity of the Polar Disk in NGC4650A: Constraints for Cold Accretion Scenario	173
M. Spavone, E. Iodice, M. Arnaboldi, O. Gerhard, R. Saglia, and G. Longo	
Galaxy Formation through Winds, Infall and Merger: Learning from Galactic Archaeology	175
T. Tsujimoto	
The Relation between Gas Accretion and Resolved Star Formation in Galaxies	177
J. Wang, G. Kauffmann, and R. Overzier	

SESSION 3: BULGES, NUCLEI AND SUPERMASSIVE BLACK HOLES

Formation of Supermassive Black Hole Binaries and Massive Seed SMBHs in Gas-Rich Merger	181
L. Mayer	
Bulges of Nearby Galaxies—What Are the Structures We See in the Centers of Disk Galaxies?	195
N. Drory, D. B. Fisher, and M. H. Fabricius	
High-Redshift Clumpy Discs in Cosmological AMR Simulations	199
D. Ceverino	
Why Outflows Have Low Angular Momentum	203
C. Brook, F. Governato, R. Roškar, A. Brooks, L. Mayer, T. Quinn, and J. Wadsley	
Black Hole-Bulge Relations of Megamaser Galaxies	207
J. E. Greene, C. Y. Peng, C.-Y. Kuo, and J. A. Braatz	
Testing Mass Determinations of Supermassive Black Holes via Stellar Kinematics	211
M. Cappellari, R. M. McDermid, R. Bacon, R. L. Davies, P. T. de Zeeuw, E. Emsellem, J. Falcón-Barroso, D. Krajnović, H. Kuntschner, R. F. Peletier, M. Sarzi, R. C. E. van den Bosch, and G. van de Ven	
Measuring the Low Mass End of the M_{\bullet}-σ Relation	215
D. Krajnović, R. M. McDermid, M. Cappellari, and R. L. Davies	
A New Estimation of SMBH Mass Function in the Local Universe	219
M. Vika and S. P. Driver	
Do Nuclear Star Clusters and Supermassive Black Holes Follow the Same Host-Galaxy Correlations? . . .	223
P. Erwin and D. Gadotti	
Nuclear Star Clusters and Black Holes	227
A. Seth, M. Cappellari, N. Neumayer, N. Caldwell, N. Bastian, K. Olsen, R. Blum, V. P. Debattista, R. McDermid, T. Puzia, and A. Stephens	
Black Hole Binary Mergers within Gas Discs	231
J. Cuadra	
Supermassive Black Hole Formation inside Primordial Black Hole Clusters	235
V. I. Dokuchaev, Yu. N. Eroshenko, and R. G. Rubin	
A Minor-Merger Origin for Inner Disks and Rings in Early-Type Galaxies	237
M. C. Eliche-Moral, A. C. González-García, M. Balcells, J. A. L. Aguerri, J. Gallego, and J. Zamorano	
Velocity Dispersions across Bulge Types	239
M. Fabricius, R. Saglia, N. Drory, D. Fisher, R. Bender, and U. Hopp	
Mapping Star Forming and AGN Galaxies	241
J. Gerssen, D. Wilman, and L. Christensen	
Structural and Kinematical Constraints on the Formation of Stellar Nuclear Clusters	243
M. Hartmann, V. P. Debattista, A. Seth, M. Cappellari, and T. Quinn	
Intermediate Mass Black Holes in Galactic Globular Clusters	245
B. Jalali, M. Kissler-Patig, K. Gebhardt, E. Noyola, and N. Neumayer	
Exploring Galaxy Formation and Evolution via Structural Decomposition	247
L. Kelvin, S. Driver, A. Robotham, D. Hill, and E. Cameron	
Large Scale Environments of Nearby Quasars	249
H. Lietzen, P. Heinämäki, P. Nurmi, L. J. Liivamägi, E. Saar, E. Tago, E. Tempel, M. Einasto, J. Einasto, M. Gramann, and L. O. Takalo	
Inner Polar Disks and Rings: How Do They Form?	251
A. Moiseev, O. Sil'chenko, and I. Katkov	
The Role of Bars on Bulge Formation: Stellar Line-Strength Indices of Bulges	253
I. Pérez and P. Sánchez-Blázquez	
Star-Forming Ring Relics in the Centers of Early-Type Galaxies	255
O. Sil'chenko	

SESSION 4: FAINT COMPONENTS

Outer Disks: Radial Migration and Misaligned Gas Infall	259
R. Roškar, V. P. Debattista, T. R. Quinn, and F. Governato	
Stellar Disk Truncations: HI Density and Dynamics	263
I. Trujillo and J. Bakos	

Galaxy Formation from the Edge: Science Enabled by Large-Scale Stellar Surveys	267
K. V. Johnston	
Studying the Kinematics of Faint Stellar Populations with the Planetary Nebula Spectrograph	279
M. R. Merrifield and the PN. S Consortium	
Probing the Merger History of Red Early-Type Galaxies with Their Faint Stellar Substructures	283
L. Michel-Dansac, M. Martig, F. Bournaud, E. Emsellem, P. A. Duc, and F. Combes	
Multi-Wavelength Characterization of the Outskirts of Spiral Galaxies	287
J. Bakos and I. Trujillo	
Revealing S0 Galaxies' Formation Histories Using the Stellar Kinematics of the Faint Outer Disks . . .	289
A. Cortesi, M. R. Merrifield, E. Nordermeer, L. Coccatto, S. Bamford, N. R. Napolitano, M. Arnaboldi, O. Gerhard, A. J. Romanowsky, P. Das, N. G. Douglas, K. Kuijken, K. C. Freeman, and M. Capaccioli	
Searching for Tidal Remnants in the Milky Way: Photometric Survey of Globular Clusters	291
J. A. Carballo-Bello, D. Martínez-Delgado, and A. Sollima	
Galactic Stellar Haloes in the CDM Model	293
A. P. Cooper, S. Cole, C. S. Frenk, S. D. M. White, G. De Lucia, A. Helmi, A. J. Benson, A. Jenkins, J. Navarro, V. Springel, and J. Wang	
A Super-Deep Study of the Outskirts of Haro 11	295
G. Micheva, E. Zackrisson, G. Östlin, and N. Bergvall	
Tidal Structures around Nearby 'Isolated' AGNs	297
A. A. Smirnova, A. V. Moiseev, and V. L. Afanasiev	
Direct Detection of Galaxy Stellar Halos: NGC 3957 as a Test Case	299
M. Tafelmeyer	
Wandering Stars: An Origin of Escaped Populations	301
M. Teyssier, K. V. Johnston, and M. Shara	
Testing Galaxy Evolution in Group Environment. The NGC 6962 Group	303
J. Vennik	
Red Halos Revealed by Surface Photometry	305
E. Zackrisson, N. Bergvall, and G. Micheva	

SESSION 5: DARK MATTER

Dark Matter from the Observational Perspective	309
K. C. Freeman	
Dark Matter Tested with Satellites	319
F. Combes and O. Tirit	
A Multiscale Approach to Environment	323
D. Wilman, S. Zibetti, and T. Budavári	
The Many Manifestations of Downsizing: Hierarchical Models Confront Observations	327
F. Fontanot	
Scaling Relations for Early-Type (Red-Sequence) Galaxies in the Virgo and Fornax Clusters	331
P. Côté	
The ATLAS^{3D} Project: A Paradigm Shift for Early-Type Galaxies	335
E. Emsellem, K. Alatalo, L. Blitz, M. Bois, F. Bournaud, M. Bureau, M. Cappellari, R. L. Davies, T. A. Davis, P. T. de Zeeuw, S. Khochfar, D. Krajnović, H. Kuntschner, P.-Y. Lablanche, R. M. McDermid, R. Morganti, T. Naab, T. Oosterloo, M. Sarzi, N. Scott, P. Serra, A. Weijmans, and L. M. Young	
Probing the 2-D Kinematic Structure of Early-Type Galaxies Out to 3 Effective Radii	339
R. N. Proctor, D. A. Forbes, A. J. Romanowsky, J. P. Brodie, J. Strader, M. Spolaor, J. T. Mendel, and L. Spitler	
Superdense and Normal Early-Type Galaxies at $1 < z < 2$	343
P. Saracco, M. Longhetti, and A. Gargiulo	
The Star Formation Histories of Red-Sequence Galaxies	347
M. J. Hudson, S. P. Allanson, R. J. Smith, and J. R. Lucey	
Digging for Formational Clues in the Halos of Early-Type Galaxies	351
A. J. Romanowsky	
Milky Way Satellite Properties in a ΛCDM Universe	355
A. V. Macciò	

The Dark Matter Content of Early-Type Galaxies	359
I. Ferreras	
Biases in Mass Estimates of dSph Galaxies	363
E. L. Lokas, S. Kazantzidis, J. Klimentowski, and L. Mayer	
Testing Galaxy Formation Scenarios with a New Mass Estimator	367
J. Wolf	
Kinematic Mass Measurements of Inner and Outer Spiral Disks	371
K. A. Herrmann and R. Ciardullo	
Are Stellar Over-Densities in Dwarf Galaxies the “Smoking Gun” of Triaxial Dark Matter Haloes? ...	375
J. Peñarrubia, M. G. Walker, and G. Gilmore	
Polar Disk Galaxies as New Way to Study Galaxy Formation: The Case of NGC4650A	379
E. Iodice	
Measuring Dark Matter by Modeling Interacting Galaxies	383
H. P. Petsch, A. Ružička, and Ch. Theis	
HI Velocity Dispersions and Flaring: Disk Masses and the Shape of Dark Matter Halos	387
P. C. van der Kruit, also on behalf of J. C. O’Brien and K. C. Freeman	
A Dark Matter Disc in the Milky Way	391
J. I. Read, T. Bruch, L. Baudis, V. P. Debattista, O. Agertz, L. Mayer, A. M. Brooks, F. Governato, A. H. G. Peter, and G. Lake	
New Tools for Probing the Phase Space Structure of Dark Matter Halos	395
M. Valluri, V. P. Debattista, T. Quinn, and B. Moore	
Dark Satellites of the Milky Way	399
T. Okamoto	
Spin Flips: Variation in the Orientation of Dark Matter Halos over Their Merger Histories	403
P. E. Bett	
Formation of Slowly Rotating Elliptical Galaxies in Major Mergers: A Resolution Study	405
M. Bois, F. Bournaud, E. Emsellem, K. Alatalo, L. Blitz, M. Bureau, M. Cappellari, R. L. Davies, T. A. Davis, P. T. de Zeeuw, J. Falcón-Barroso, S. Khochfar, D. Krajnović, H. Kuntschner, P.-Y. Lablanche, R. M. McDermid, R. Morganti, T. Naab, M. Sarzi, N. Scott, P. Serra, R. C. E. Van den Bosch, G. Van de Ven, A. Weijmans, and L. M. Young	
Origin and Evolution of Galactic Spin from Looking at Galaxy Pairs	407
B. Cervantes-Sodi, X. Hernandez, and C. Park	
Analytical Predictions for the Fundamental Parameters of Disk Galaxies	409
L. Darriba and J. M. Solanes	
Measuring the Local Dark Matter Density	411
S. Garbari, G. Lake, and J. Read	
Disk Heating: Comparing the Milky Way with Cosmological Simulations	413
E. L. House, C. B. Brook, and B. K. Gibson	
Determining Orbits for the Milky Way’s Dwarfs	415
H. Lux, J. I. Read, and G. Lake	
Wide Field Views of M31’s dE Satellites: NGC 147 and NGC 185	417
N. E. D. Noël, A. M. N. Ferguson, and M. J. Irwin	
Normalized Hubble Diagrams for Simulated Galaxy Groups	419
P. Nurmi, P. Heinämäki, P. Teerikorpi, and A. Chernin	
The Origin of the Diversity of Dwarf Spheroidal Galaxies	421
Y. Revaz and P. Jablonka	
Galaxy Disk Heating as a Result of Minor Mergers	423
M. T. Tapia, M. Balcells, and M. C. Eliche-Moral	
Hundreds of Milky Way Satellites and a Fundamental Curve Connecting Dark Matter Halos to Galaxies	425
E. J. Tollerud	
Tidal Stripping of Dwarf Spheroidal Galaxies	427
S. Valcke, S. De Rijcke, and H. Dejonghe	
Galaxy Physics via the Disk Stellar Velocity Ellipsoid	429
K. B. Westfall, M. A. Bershady, M. A. W. Verheijen, T. P. K. Martinsson, D. R. Andersen, and R. A. Swaters	

Dark Matter and the Tully-Fisher Relations of Spiral and S0 Galaxies	431
M. J. Williams, M. Bureau, and M. Cappellari	
List of Participants	433
Photo Gallery	439
Author Index	453

PREFACE

The international conference "Hunting for the Dark: The Hidden Side of Galaxy Formation" was held in Malta 19-23 October 2009 at the Dolmen Hotel situated on picturesque Qawra Bay. The meeting was organised by the University of Central Lancashire and the University of Malta, providing a forum for 140 scientists from 22 countries. The scientific programme included 13 invited talks, 62 contributed talks and over 50 poster presentations.

The meeting was born from the wish to bring together diverse communities of researchers working on unravelling the complicated processes by which galaxies form. Many of the components and processes that play an important role in the formation of galaxies are either dark, obscured or faint. Testing theories and models is therefore a challenging task; it was this challenge that the conference sought to address. The topics addressed by the meeting included the properties of dark matter halos in disk, elliptical and dwarf galaxies, supermassive black hole formation and growth, the scaling relations of supermassive black holes, nuclear star clusters and bulges, stellar halos and tidal debris, disk outskirts, dust enshrouded star formation, the effect of dust on spectral energy distributions, hot and cold accretion onto galaxies, hot gas halos and gas circulation.

A significant number of new theoretical and observational results were presented and discussed at the workshop. Theorists presented models spanning a large range of scales and complicated physics, while observers, not to be outdone, spanned the entire spectral range from radio, through to infra-red, optical, UV and X-rays. Judging from this we feel that we have achieved our goal of bringing together many of the diverse communities working on galaxy formation.

We would like to thank all the participants for making the meeting as stimulating and exciting.

Victor P. Debattista
Cristina C. Popescu
Jeremiah Horrocks Institute
University of Central Lancashire

ACKNOWLEDGEMENTS

This meeting would not have been possible without the help of a large number of people. Much valuable advice on the science content of the meeting was provided by the Scientific Organizing Committee which was comprised of Andi Burkert (University of Munich, Germany), James Bullock (University of California at Irvine, USA), Francoise Combes (Observatoire de Paris, France), Victor Debattista (chair, University of Central Lancashire, UK), Michael Dopita (Australian National University, Australia), Simon Driver (University of St. Andrews, UK), Annette Ferguson (University of Edinburgh, UK), Ken Freeman (Australian National University, Australia), Karl Gebhardt (University of Texas at Austin, USA), Ben Moore (University of Zurich, Switzerland), Cristina Popescu (chair, University of Central Lancashire, UK) and Richard Tuffs (Max Planck Institut für Kernphysik, Germany). Their input was instrumental in bringing together such an exciting mix of diverse communities.

We were very fortunate to have had a Local Organizing Committee that was always able to solve any logistical problem we encountered. At the University of Malta, Pierre-Sandre Farrugia deserves particular mention for his indefatigable work to ensure a successful, and enjoyable, meeting. Thanks to him, a host of Boojums that may have plagued the conference never materialized. At the University of Central Lancashire, the conference secretary, Emma Kelly, worked tirelessly to insure the smooth running of the conference. Additional help was provided by the remainder of the LOC: Edward Mallia, Joseph Caruana (who designed the conference poster), Pauline Galea, Matthew Agius and Ray Pace. Additional volunteers during the conference included Monica Micallef, David Grech, Jackson Said, Yury Kulakov, and Alessio Magro. Assistance with the editing of these proceedings by Bogdan Păstrăv, Dmitrij Semionov and Marina Debattista is gratefully acknowledged.

The assistance of Patricia Camilleri through the Communication Office of the University of Malta is also gratefully acknowledged. Our thanks also go to Professor Anthony Bonanno, chair of the Department of Archaeology of the University of Malta for his delightful lecture on the Maltese Neolithic.

We would also like to acknowledge the University of Malta, in particular the Chair of the Physics Department and Dean of Science, Professor Charles Sammut, for the considerable support, both financial and human. The support we received from the University of Central Lancashire, and most especially the encouragement from the Head of the Jeremiah Horrocks Institute, Professor Gordon Bromage, allowed us to focus our energies on the main issues.

We are also very grateful for the sponsorships we received. The Malta Council of Science and Technology, headed by Nicholas Sammut, was an early and generous supporter of the meeting. The sponsorship from Heritage Malta allowed the conference attendees to experience a small part of the rich cultural heritage that Malta has to offer. A sponsorship from the Royal Astronomical Society allowed a number of students to attend the conference; for many of these attendance was a significant step in their careers. Further sponsorships were provided by Toyota, Farsons, Air Malta, the St. Paul's Bay town council, and the Malta Tourism Authority.

Welcome Address

Gordon Bromage

Jeremiah Horrocks Institute, University of Central Lancashire, UK

Good morning, ladies and gentlemen. Welcome to this international conference entitled "Hunting for the Dark – the Hidden Side of Galaxy Formation", in this splendid location on the beautiful island of Malta.

I have great pleasure in welcoming you here, on behalf of the Vice-Chancellor of the University of Central Lancashire and all the astronomy staff of the Jeremiah Horrocks Institute at UCLan, and on behalf of the conference's organising committees. Welcome to this Hunt: for the Dusty; for the Elusive; for the Faint; for the Invisible; for the Obscured; for the Undetected Dark. It is certainly a challenging yet exciting task.

If you read Lewis Carroll's surreal rhymes in his "Hunting of the Snark", you may, like me, recognise quite a few parallels with our own Hunt, and take some amusement from this, as the conference organisers realised some time ago. You might be a pessimist and even entertain a notion – "a faint but wildly possible notion" – that at the end of this Hunt we may be unfortunate enough to catch a Boojumino for our Dark Matter Particle, and then "softly and suddenly vanish away". Let us sincerely hope that we are infinitely more successful than that.

To guide us, let us first look back in time along our hunting trail. We can trace it back seventy or eighty years to two crucial revelations in the history of astrophysics. First, we remember Trümper's famous demonstration in 1930 of the importance of interstellar dust, from observations of open star clusters in the Milky Way. Secondly, there were Babcock's and Oort's studies of the mass-to-light ratios in the outer regions of disks of nearby galaxies such as M31. In a retrospectively famous section of Oort's talk at the dedication of the McDonald Observatory in Texas in 1939, he said (and I extract from his words here, for reasons of brevity): "The distribution of mass ... appears to bear almost no relation to that of the light. ... In the outer parts of the nebula, the ratio of mass density to light density is found to be very high, and this conclusion holds for whatever dynamical model we consider..."

So the trail of Dark and Hidden Matter could be said to start in earnest at least 70 years ago. It has followed a winding path to the present day, with many twists and turns. Well, after 70 years, do we like those on the Snark Hunt, "shudder to think that the chase might fail"? No – absolutely not, of course, because we are eternal optimists: we are astronomers and astrophysicists, after all, and moreover great progress has been made in recent years towards our goal. I am reminded here of a recent article, a leading article in the UK's Guardian newspaper last July, written (obviously, but please note) by a non-astronomer, and entitled "In Praise of... Astronomers". I would like to quote

some extracts here: and you may want to find this article, frame it and put it on your office wall, for those bad days when things seem to be going wrong in your hunt for the truth. "They usually work alone, and in dark places, but they have lit up our universe. Skywatchers began as guardians of clock and calendar, compiled our tide tables and pioneered modern navigation. They devised instruments, invented the science of optics, and minted the mathematics to explain the phenomena they observed. From Eratosthenes of Alexandria... 2200 years ago [to today], astronomers are part of an epic story of wide-eyed discovery... Astronomers around the world compete, co-operate and confer; they are a global community, in the richest sense of the term, and we owe them our understanding of space and time, and light, and mass, and gravity: in a word, everything." (from The Guardian, Editorial, Saturday 25 July 2009).

We who are Hunting for the Dark certainly comprise a truly global community: I am very impressed and pleased to note that there are delegates here from no fewer than 22 different countries! And we are here to compete, co-operate and confer on the Hidden Side of Galaxy Formation.

Now I would like to briefly allude to a most remarkable young role-model astronomer from one short period in the 2200-year-long history of our science, this very long history referred to by the Guardian leader-writer. There may well be some delegates here who are unfamiliar with the work of Jeremiah Horrocks, after whom we named our Astrophysics Institute at UCLan. He was on a quite different hunt from the present one, but I believe he provides much valuable inspiration for us on our hunt for the Dark. Horrocks lived and worked in Lancashire nearly 400 years ago. He performed his most famous observations and calculations in 1638-9 just a few kilometres from our Institute in Preston. His story is a quite fantastic one, providing an inspiration especially to students and young astronomers. Since some of you may be unaware of the story, let me tell you some of the highlights. A poor scholar working as a tutor in rural Lancashire, he performed his key work between the ages of 18 and 22. He died suddenly in Liverpool at the age of only 22 or 23, but it is no exaggeration to state that he inaugurated English research astronomy, just a few years after the famous work of Kepler and Galileo. He was the first to correctly determine the lunar orbit as an ellipse, based on his own observations, at age 20. He was the first to successfully predict and observe a transit of Venus across the face of the Sun – a phenomenon crucial for determining the size-scale of the universe – in deepest rural Lancashire with amateur equipment, observing the Sun in the middle of a northern-English cloudy winter, and where Kepler and everyone else had failed. Newton sang his praises in the "Principia". Allan Chapman, distinguished historian of astronomy at Oxford, has said that Horrocks provided a linch-pin in the development and understanding of gravity (very relevant to our present Hunt this week, of course) between Kepler and Newton.

But now let us come back swiftly to 2009. We should take inspiration, then, from many past hunts in astronomy, and keep hunting with all the resources at our disposal. After the conference this week, let us hope that we are able to say of our quarry (with apologies again to Lewis Carroll): "We sought it with Surveys, we sought it with care;/ We pursued it with Halos and hope;/ We threatened its life with a Baryonic Pair;/ We charmed it with Spitzer and ... Initial Mass Functions and Star Formation Histories".

I wish you a most successful and enjoyable conference here in Malta.