

16-20/9/2019



PROGRAMME & ABSTRACTS

KICCO





Cosmology: the end of the beginning. Future prospects in cosmology, large scale structure and galaxy formation

Astronomy involves some of the biggest questions in science: Where did the Universe come from? How big is it? When will it end? For most of human history, answers to these questions were based on lore, tradition and mythology. It is only in our lifetimes that we have had the tools to tackle these problems scientifically. This meeting is, in part, a celebration of 10 years of the Kavli Institute for Cosmology, Cambridge. This anniversary is certainly worth celebrating, but the meeting also comes at an interesting time in the development of cosmology. The results from the Planck satellite (a key research focus in the first decade of the Kavli Institute) together with theoretical developments and results from many other projects, have established a 'standard model' of cosmology. We have now measured with great precision things that we don't understand. We do not know what the dark matter and dark energy really are. Inflation, although a very attractive idea, is an incomplete theory and raises many fundamental questions including how to describe an eternally inflating multiverse. We still lack a full understanding of the subsequent evolution of cosmic structures and the key physical processes regulating the formation and evolution of galaxies. Despite the immense progress of recent years we are a long way from answering the 'big questions'. It is for this reason that we have subtitled the meeting 'the end of the beginning', borrowing from Winston Churchill's famous wartime quote. We have a standard model, but now what? A key goal of the meeting is to explore ways developing cosmology over the next decade. We cannot be sure where the next breakthrough might come: whether it be from galaxy evolution, the physics of the intergalactic medium, large-scale structure, gravitational waves, the cosmic microwave background, or miraculous developments in theoretical physics. There is all to play for!

The organisers are committed to conducting meetings that are productive and enjoyable for everyone.

This meeting is a place for the open exchange of scientific ideas. Harassment of participants in any form will not be tolerated. Thank you for helping make this a welcoming, respectful space for all.

The European Astronomical Society Council (EAS)

Ethics Statement and Guidelines for Good Practice will apply during the conference. Participants are encouraged to read the document and follow its recommendations.

https://eas.unige.ch/documents/EAS_Ethics_Statement.pdf

Any participant who wishes to report any inappropriate behaviour is encouraged to speak, in confidence, to the LOC
E-mail **kiccl0th@ast.cam.ac.uk**

Scientific Organising Committee:

Debora Sijacki • KICC, University of Cambridge, UK (Chair)
Anthony Challinor • KICC, University of Cambridge, UK
George Efstathiou • KICC, University of Cambridge, UK
Martin Haehnelt • KICC, University of Cambridge, UK
Anthony Lasenby • Cavendish Laboratory, Uni. of Cambridge, UK
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Amanda Smith • IoA, University of Cambridge, UK
Cora Uhlemann • DAMTP, University of Cambridge, UK
Lewis Weinberger • IoA, University of Cambridge, UK

Contents

5	Sessions Overview
6	Participants: A - B
7	B - H
8	H - O
9	P - Z
10	Programme: Monday
11	Tuesday
12	Wednesday
13	Thursday
14	Friday
15	Abstracts (Talks)
91	Abstracts (Posters)
111	Local Information
112	Site Map
113	Hoyle Ground Floor Plan
114	Kavli Ground Floor Plan
115	Fitzwilliam College Map
116	Cambridge City Map
117	Eco-friendly Notice

Sessions Overview

Monday 16 September - Registration from 08:30 to 09:00 in the Hoyle building foyer.

Monday	Tuesday	Wednesday	Thursday	Friday
CMB, Early Universe & Precision Cosmology	LSS & Precision Cosmology	Reionization & IGM	Galaxies & SMBHs	Galaxies & SMBHs
09:00 Introduction Roberto Maiolino & George Efstathiou 09:15 Marc Kamionkowski 16 09:45 Andrei Linde 17 10:15 Mustafa Amin 18	09:00 Will Percival 32 09:30 Hiranya Peiris 33 10:00 Ian McCarthy 34 10:15 Cora Uhlemann 35	09:00 Richard Ellis 51 09:30 Piero Madau 52 10:00 Michael Shull 53 10:15 Anson D'Aloisio 54	09:00 Simon White 68 09:30 Reinhard Genzel 69 10:00 Renske Smit 70 10:15 Harley Katz 71	09:00 Manuella Campanelli 85 09:30 Samaya Nissanke 86 10:00 Michalis Agathos 87 10:15 Peter Johansson 88

COFFEE BREAK - HOYLE RECEPTION FOYER

11:00 Enrico Pajer 19 11:15 Clem Pryke 20 11:30 George Efstathiou 21 12:00 Benjamin Joachimi 22 12:15 Poster Session 91	11:00 Risa Wechsler 36 11:30 Uros Seljak 37 12:00 Simone Ferraro 38 12:15 Ewald Puchwein 39	11:00 Matteo Viel 55 11:20 Laura Keating 56 11:40 Masami Ouchi 57 12:00 Charlotte Mason 58 12:15 Nicolas Laporte 59	11:00 Volker Springel 72 11:30 Andrey Kravtsov 73 11:50 Benedikt Diemer 74 12:05 Avishai Dekel 75	11:00 Martin Bourne 89 11:15 Asa Bluck 90 11:30 Conference Summary 12:30 Lunch & Conference End
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LUNCH

14:00 David Spergel 23 14:30 Eric Linder 24 14:45 Daniel Holz 25 15:05 Antonella Palmese 26 15:20 Ryan Cooke 27	14:00 Vid Irsic 40 14:15 Sunny Vagnozzi 41 14:30 Rachel Mandelbaum 42 15:00 Elisa Chisari 43 15:20 Hendrik Hildebrandt 44	14:00 Andrea Pallottini 60 14:15 Avery Meiksin 61 14:30 Romain Meyer 62 14:45 Yi-Kuan Chiang 63 15:00 Poster Session 91	14:00 Alice Shapley 76 14:30 Stefanie Walch 77 14:50 Vadim Semenov 78 15:05 Matthew Smith 79	
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TEA BREAK - HOYLE RECEPTION FOYER

16:00 Jo Dunkley 28 16:30 Eric Baxter 29 16:50 Stefania Amodeo 30 17:05 Guilhem Lavaux 31 18:00 Welcome Reception	16:00 Shahab Joudaki 45 16:15 Giulia Despali 46 16:30 Steven Allen 47 16:50 Sebastian Bocquet 48 17:05 David Barnes 49 19:00 Public Talk 50	16:00 Jacqueline Hewitt 64 16:30 Anastasia Fialkov 65 17:00 Celine Peroux 66 17:20 Peter Sims 67 18:45 Drinks 19:30 Dinner	15:50 Alberto Sesana 80 16:20 Xiaohui Fan 81 16:40 Sarah Bosman 82 16:55 Lucio Mayer 83 17:10 Kirsten Hall 84	
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18:00
Welcome Reception in the IoA reception foyer (Hoyle building)

19:00-20:00
Public Talk at Lady Mitchell Hall Sidgwick Avenue Cambridge CB3 9DD

18:45
Pre-dinner drinks served in the Fellows' garden, Clare College. (Dress code for evening receptions and conference banquet is smart/casual)

19:30
Conference dinner in the Great Hall

* Please note: all information is subject to change; any updates will be announced via the Hoyle and Kavli reception monitors.



Participants A-Z

Professor Tom Abel Stanford/KIPAC

Mr Alberto Acuto Astrophysics Research Institute Liverpool John Moores University *P.g. 92* ❶

Michalis Agathos KICC/DAMTP, University of Cambridge *P.g. 87*

Miss Fruzsina Agocs Cavendish Laboratory, University of Cambridge *P.g. 92* ❷

Professor Steven Allen Stanford University *P.g. 47*

Professor Mustafa Amin Rice University *P.g. 18*

Dr Stefania Amodeo Cornell University *P.g. 30*

Dr Tobias Baldauf DAMTP, University of Cambridge

Anton Baleato Lizancos KICC, University of Cambridge *P.g. 92 & 93* ❸

Mr William Barker Cavendish Laboratory/KICC, University of Cambridge *P.g. 93* ❹

Dr David Barnes MIT *P.g. 49*

Mr Eric Baxter KICC, University of Cambridge *P.g. 29*

Professor John Barrow DAMTP, University of Cambridge

Mr Adrian Bayer UC Berkeley *P.g. 93* ❺

Mr Jake Bennett IoA, University of Cambridge *P.g. 94* ❻

Professor Roger Blandford KIPAC Stanford *P.g. 50*

Dr Asa Bluck KICC, University of Cambridge *P.g. 90*

Dr Sebastian Bocquet LMU Munich *P.g. 48*

Dr Sarah Bosman University College London *P.g. 82*

Dr Martin Bourne IoA/KICC, University of Cambridge *P.g. 89*
 Mr Steven Brereton KICC, University of Cambridge
 Dr Luke Butcher University of Edinburgh *P.g. 94* 7
 Dr Yan-Chuan Cai University of Edinburgh *P.g. 95* 8
 Erminia Calabrese Cardiff University
 Professor Manuela Campanelli Rochester Institute of Technology *P.g. 85*
 Professor Bob Carswell IoA, University of Cambridge
 Professor Anthony Challinor KICC, University of Cambridge
 Dr Ricardo Chávez Murillo Institute of Radio Astronomy and Astrophysics *P.g. 95* 9
 Dr Ke-Jung (Ken) Chen Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) *P.g. 95* 10
 Dr Yi-Kuan Chiang Johns Hopkins University *P.g. 63*
 Dr Elisa Chisari University of Oxford *P.g. 43*
 Dr Ryan Cooke Durham University *P.g. 27*
 Dr William Coulton University of Cambridge *P.g. 96* 11
 Dr Mirko Curti KICC, University of Cambridge *P.g. 96* 12
 Professor Anson D'Aloisio University of California, Riverside *P.g. 54*
 Dr Colin DeGraf IoA/KICC, University of Cambridge *P.g. 97* 13
 Professor Avishai Dekel The Hebrew University of Jerusalem *P.g. 75*
 Dr Giulia Despali MPA Garching *P.g. 46*
 Dr Carolyn Devereux University of Hertfordshire *P.g. 97* 14
 Dr Benedikt Diemer Harvard *P.g. 74*
 Mrs Philippa Downing KICC, University of Cambridge
 Professor Simon Driver University of Western Australia
 Professor Jo Dunkley Princeton University *P.g. 28*
 Professor George Efstathiou KICC, University of Cambridge *P.g. 21*
 Professor Richard Ellis University College London *P.g. 51*
 Ms Ana Esteban IAC *P.g. 97* 15
 Ms Martina Fagioli ETH Zurich *P.g. 98* 16
 Professor Michael Fall STSci
 Professor Xiaohui Fan University of Arizona *P.g. 81*
 Simone Ferraro LBNL Berkeley *P.g. 38*
 Dr Anastasia Fialkov Sussex University *P.g. 65*
 Professor Carlos Frenk Durham University
 Dr Oliver Friedrich KICC, University of Cambridge *P.g. 98* 17
 Professor Reinhard Genzel Max Planck Institute for Extraterrestrial Physics *P.g. 69*
 Dr Iulia Georgescu Nature Research
 Dr Donald Goldsmith Berkeley
 Dr Steven Gratton KICC, University of Cambridge
 Professor Martin Haehnelt University of Cambridge
 Dr Steffan Hagstotz Stockholm University
 Ms Kirsten Hall John Hopkins University *P.g. 84*
 Dr Alex Hall University of Edinburgh *P.g. 98* 18
 Dr Will Handley KICC, University of Cambridge *P.g. 99* 19
 Mr Lukas Hergt Cavendish Laboratories, University of Cambridge *P.g. 99* 20

Professor **Jacqueline Hewitt** Massachusetts Institute of Technology *P.g. 64*
 Professor **Hendrik Hildebrandt** Ruhr-University Bochum *P.g. 44*
 Professor **Colin Hill** Columbia University / Flatiron Institute
 Professor **Henk Hoekstra** Leiden University
 Professor **Daniel Holz** University of Chicago *P.g. 25*
 Mr **Derek Inman** New York University *P.g. 99* 21
 Dr **Vid Irsic** Department of Astronomy, University of Washington, IoA *P.g. 40*
 Mr **Sadra Jazayeri** DAMTP, University of Cambridge
 Dr **Benjamin Joachimi** University College London *P.g. 22*
 Professor **Peter Johansson** University of Helsinki *P.g. 88*
 Dr **Gareth Jones** KICC, University of Cambridge *P.g. 100* 22
 Dr **Shahab Joudaki** University of Oxford *P.g. 45*
 Mr **Marios Kalomenopoulos** University of Edinburgh, Royal Observatory *P.g. 100* 23
 Professor **Marc Kamionkowski** Johns Hopkins University *P.g. 16*
 Dr **Marios Karouzos** Nature Astronomy
 Dr **Harley Katz** University of Oxford *P.g. 71*
 Dr **Laura Keating** CITA *P.g. 56*
 Ms **Sophie Koudmani** IoA, University of Cambridge *P.g. 100 & 101* 24
 Professor **Andrey Kravtsov** The University of Chicago *P.g. 73*
 Dr **Girish Kulkarni** Tate Institute of Fundamental Research
 Dr **Nimisha Kumari** University of Cambridge *P.g. 101* 25
 Mr **Joseph Kuruvilla** Argelander Institute for Astronomy, University of Bonn *P.g. 101* 26
 Professor **Ofer Lahav** University College London
 Dr **Nicolas Laporte** University College London *P.g. 59*
 Professor **Anthony Lasenby** KICC, University of Cambridge
 Dr **Guilhem Lavaux** Institut d'Astrophysique de Paris / CNRS *P.g. 31*
 Dr **Pablo Lemos** University College London
 Professor **Andrei Linde** Stanford University *P.g. 17*
 Professor **Eric Linder** UC Berkeley *P.g. 24*
 Dr **Kaloian Lozanov** Max Planck Institute for Astrophysics
 Dr **Xiangcheng Ma** University of California, Berkeley *P.g. 102* 27
 Professor **Piero Madau** University of California Santa Cruz *P.g. 52*
 Professor **Roberto Maiolino** KICC, University of Cambridge
 Professor **Rachel Mandelbaum** Carnegie Mellon University *P.g. 42*
 Dr **Nir Mandelker** Yale University *P.g. 102* 28
 Dr **Yewei Mao** GuangZhou University *P.g. 102 & 103* 29
 Dr **Charlotte Mason** Center for Astrophysics, Harvard and Smithsonian *P.g. 58*
 Professor **Lucio Mayer** University of Zurich *P.g. 83*
 Dr **Ian McCarthy** Liverpool JMU *P.g. 34*
 Professor **Avery Meiksin** Institute of Astronomy, University of Edinburgh *P.g. 61*
 Mr **Romain Meyer** University College London *P.g. 62*
 Professor **Joseph Mohr** LMU-Munich *P.g. 103* 30
 Dr **Toshiya Namikawa** DAMTP, University of Cambridge *P.g. 104* 31
 Professor **Samaya Nisanke** University of Amsterdam
 Dr **Masami Ouchi** The University of Tokyo *P.g. 57*

Dr Enrico Pajer DAMTP, University of Cambridge *Pg. 19*

Dr Andrea Pallottini Centro Fermi/Scuola Normale Superiore *Pg. 60*

Dr Antonella Palmese Fermilab *Pg. 26*

Professor Hiranya Peiris UCL/Stockholm *Pg. 33*

Professor Will Percival University of Waterloo/Perimeter Institute *Pg. 32*

Dr Celine Peroux European Southern Observatory *Pg. 66*

Professor Max Pettini IoA, University of Cambridge

Dr Andrew Pontzen University College London

Ms Ana-Roxana Pop Harvard University *Pg. 104* 32

Professor Clem Pryke University of Minnesota *Pg. 20*

Dr Ewald Puchwein Leibniz Institute for Astrophysics Potsdam (AIP) *Pg. 39*

Professor Martin Rees IoA, University of Cambridge *Pg. 50*

Mr Andreas Salcedo The Ohio State University *Pg. 104 & 105* 33

Professor Uros Seljak UC Berkeley/LBNL *Pg. 37*

Mr Vadim Semenov University of Chicago *Pg. 78*

Professor Alberto Sesana Università di Milano Bicocca *Pg. 80*

Professor Alice Shapley UCLA *Pg. 76*

Professor Paul Shellard DAMTP, University of Cambridge

Dr Blake Sherwin DAMTP, University of Cambridge

Professor Michael Shull University of Colorado *Pg. 53*

Dr Debora Sijacki IoA/KICC, University of Cambridge

Dr Peter Sims Brown University *Pg. 67*

Dr Renske Smit KICC, University of Cambridge *Pg. 70*

Dr Matthew Smith CCA, Flatiron Institute *Pg. 79*

Ms Amanda Smith IoA, University of Cambridge

Professor David Spergel Princeton University *Pg. 23 & Pg. 50*

Dr Ulrich Sperhake University of Cambridge

Professor Volker Springel Max-Planck-Institute for Astrophysics *Pg. 72*

Dr Alessio Spurio Mancini KICC, University of Cambridge *Pg. 105* 34

Mr Sam Stafford Astrophysics Research Institute Liverpool John Moores University *Pg. 106* 35

Miss Rosie Talbot IoA, University of Cambridge *Pg. 106 & 107* 36

Mr Konstantinos Tanidis University of Turin *Pg. 107* 37

Mr Luca Tortorelli ETH Zurich *Pg. 108* 38

Dr Cora Uhlemann DAMTP, University of Cambridge *Pg. 35*

Dr Sunny Vagnozzi Stockholm University *Pg. 41*

Professor Matteo Viel SISSA *Pg. 55*

Mr Jan-Albert Viljoen University of Western Cape *Pg. 108* 39

Dr Francisco Villaescusa-Navarro Flatiron Institute *Pg. 41*

Professor Stefanie Walch I.Physics Institute, University of Cologne *Pg. 77*

Professor Risa Wechsler KIPAC *Pg. 36*

Mr Lewis Weinberger IoA, University of Cambridge *Pg. 109* 40

Professor Simon White Max Planck Institute for Astrophysics *Pg. 68*

Dr Radoslaw Wojtak University of Copenhagen *Pg. 109* 41

Mr Chenxiao Zeng The Ohio State University *Pg. 110* 42

Mr Inigo Zubeldia IoA, University of Cambridge *Pg. 110* 43

Monday 16th September • CMB, Early Universe & Precision Cosmology

- 09:00-09:15** Introduction by Roberto Maiolino & George Efstathiou
- 09:15-09:45** *Can Λ CDM survive another decade:* Marc Kamionkowski (R) **Pg. 16**
- 09:45-10:15** *What is the future of inflationary theory:* Andrei Linde (R) **Pg. 17**
- 10:15-10:30** *Nonlinear dynamics of cosmological fields:* Mustafa Amin (C) **Pg. 18**
- 10:30-11:00** Coffee break
- 11:00-11:15** *All possible symmetries of cosmological correlators:* Enrico Pajer (C) **Pg. 19**
- 11:15-11:30** *The search for inflationary B-modes: latest results from BICEP/Keck:*
Clem Pryke (C) **Pg. 20**
- 11:30-12:00** *Tensions with Λ CDM:* George Efstathiou (R) **Pg. 21**
- 12:00-12:15** *The Inconsistent Universe: problems with KiDS, or with Λ CDM?:*
Benjamin Joachimi (C) **Pg. 22**
- 12:15-12:45** Poster Session **Pg. 91**
- 12:45-14:00** Lunch
- 14:00-14:30** *Fundamental physics from CMB: next steps:* David Spergel (R) **Pg. 23**
- 14:30-14:45** *Cosmic growth, gravitational waves, and CMB:* Eric Linder (C) **Pg. 24**
- 14:45-15:05** *Update on standard siren science:* Daniel Holz (H) **Pg. 25**
- 15:05-15:20** *Measuring the Hubble constant with a gravitational wave black-hole merger and the Dark Energy Survey:* Antonella Palmese (C) **Pg. 26**
- 15:20-15:35** *Towards a direct measurement of cosmic dynamics:* Ryan Cooke (C) **Pg. 27**
- 15:35-16:00** Tea break
- 16:00-16:30** *Synergy between next generation CMB and LSS probes of cosmology:*
Jo Dunkley (R) **Pg. 28**
- 16:30-16:50** *Pushing to small scales with galaxy and CMB survey cross-correlations:* Eric Baxter (H) **Pg. 29**
- 16:50-17:05** *Baryonic processes from thermal and kinetic SZ:* Stefania Amodeo (C) **Pg. 30**
- 17:05-17:20** *Correlating the CMB to observations of the low z universe with a full forward model: a robust probabilistic analysis based on BOSS and Planck dataset:*
Guilhem Lavaux (C) **Pg. 31**
- 18:00-20:00** Welcome Reception

Tuesday 17th September • LSS & Precision Cosmology

- 09:00-09:30** *Future of galaxy surveys:* Will Percival (R) **Pg. 32**
- 09:30-10:00** *Emulating the Universe:* Hiranya Peiris (R) **Pg. 33**
- 10:00-10:15** *The BAHAMAS project: emulating the observable Universe:* Ian McCarthy (C) **Pg. 34**
- 10:15-10:30** *Probing cosmology and fundamental physics with counts-in cells:*
Cora Uhlemann (C) **Pg. 35**
- 10:30-11:00** Coffee break
- 11:00-11:30** *Relating galaxies to mass distribution: methods, issues and challenges:*
Risa Wechsler (R) **Pg. 36**
- 11:30-12:00** *From cosmological data analysis to fast Bayesian methods and machine learning:* Uros Seljak (R) **Pg. 37**
- 12:00-12:15** *Inflation and dark energy from high redshift surveys:* Simone Ferraro (C) **Pg. 38**
- 12:15-12:30** *Relics of cosmic reionization in the high redshift Lyman-alpha forest and their impact on dark matter constraints:* Ewald Puchwein (C) **Pg. 39**
- 12:30-14:00** Lunch
- 14:00-14:15** *Fuzzy dark matter from intergalactic medium:* Vid Irsic (C) **Pg. 40**
- 14:15-14:30** *Massive neutrinos and scale-dependent galaxy bias:* Sunny Vagnozzi (C) **Pg. 41**
- 14:30-15:00** *Weak lensing: state-of-the-art and future prospects:* Rachel Mandelbaum (R) **Pg. 42**
- 15:00-15:20** *Cosmology with weak gravitational lensing: challenges and opportunities:*
Elisa Chisari (H) **Pg. 43**
- 15:20-15:35** *KiDS-VIKING-450: Cosmic shear tomography with optical+infrared data:*
Hendrik Hildebrandt (C) **Pg. 44**
- 15:35-16:00** Tea break
- 16:00-16:15** *Cosmological parameter constraints from weak gravitational lensing tomography and overlapping redshift-space galaxy clustering:* Shahab Joudaki (C) **Pg. 45**
- 16:15-16:30** *Constraining dark matter models with strong gravitational lensing:*
Guilia Despali (C) **Pg. 46**
- 16:30-16:50** *The landscape of galaxy cluster cosmology:* Steven Allen (H) **Pg. 47**
- 16:50-17:05** *Multiwavelength galaxy cluster cosmology with the South Pole Telescope and the Dark Energy Survey:* Sebastian Bocquet (C) **Pg. 48**
- 17:05-17:20** *Quantitatively defining consistent relaxed galaxy cluster samples for precision cosmology with impending surveys:* David Barnes (C) **Pg. 49**
- 19:00-20:00** Public talk: Martin Rees, Roger Blandford and David Spergel **Pg. 50**

Wednesday 18th September • Reionization & IGM

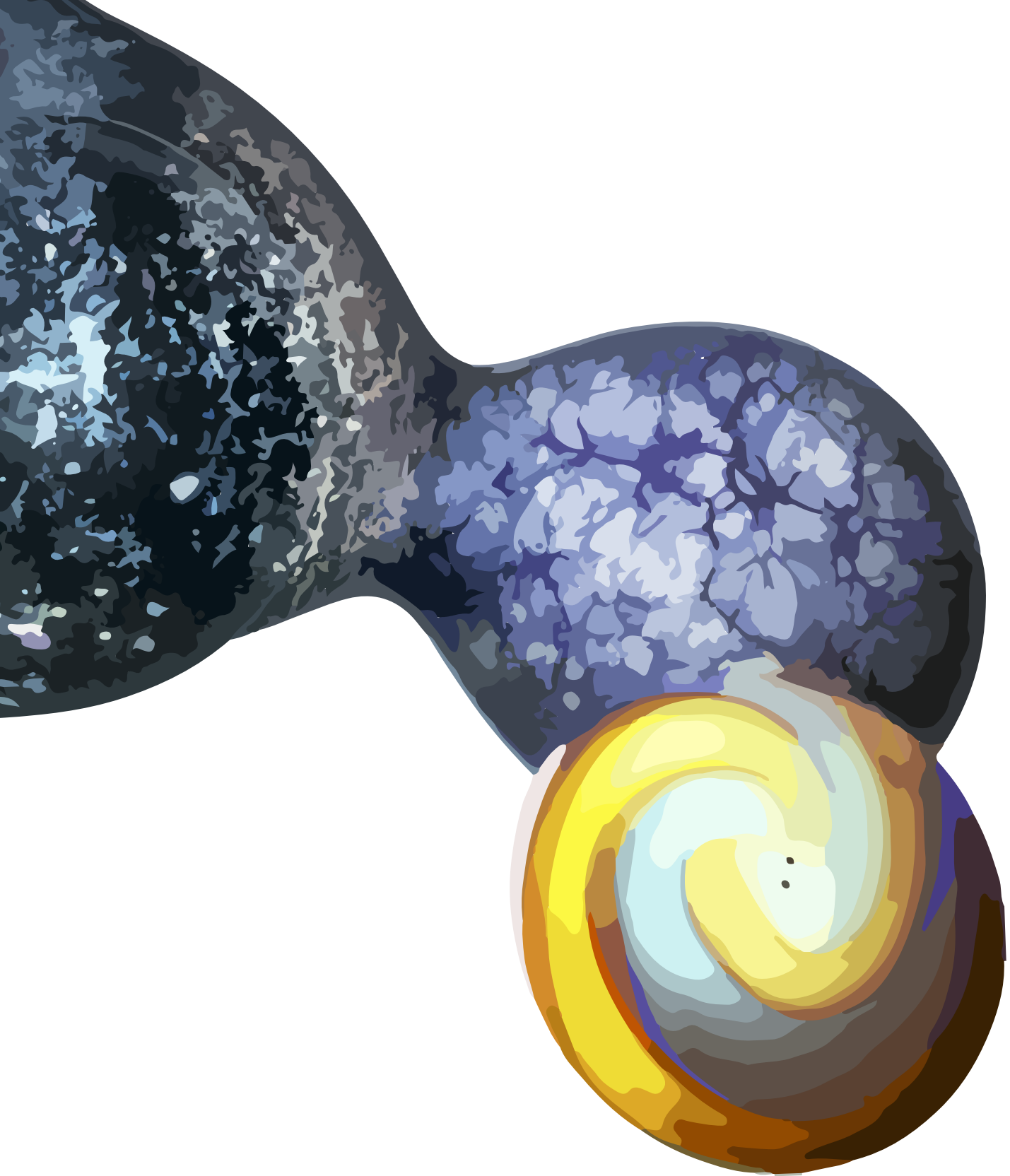
- 09:00-09:30** *The quest for cosmic dawn:* Richard Ellis (R) **Pg. 51**
- 09:30-10:00** *Sources of reionization and the changing neutrality of the intergalactic medium:* Piero Madau (R) **Pg. 52**
- 10:00-10:15** *Reionization sources of Lyman continuum photons from quasars and O-stars:* Michael Shull (C) **Pg. 53**
- 10:15-10:30** *Reionization and the thermal history of the IGM:* Anson D'Aloisio (C) **Pg. 54**
- 10:30-11:00** Coffee break
- 11:00-11:20** *The intergalactic medium as a cosmological probe:* Matteo Viel (H) **Pg. 55**
- 11:20-11:40** *Islands of neutral hydrogen below redshift 5.5:* Laura Keating (H) **Pg. 56**
- 11:40-12:00** *Exploring early galaxies and cosmic structures with Subaru, HST, and ALMA:* Masami Ouchi (H) **Pg. 57**
- 12:00-12:15** *What can galaxies tell us about reionisation?:* Charlotte Mason (C) **Pg. 58**
- 12:15-12:30** *Probing Cosmic Dawn: determining the age of the most distant galaxies:* Nicolas Laporte (C) **Pg. 59**
- 12:30-14:00** Lunch
- 14:00-14:15** *The gas structure and radiation field of the first galaxies:* Andrea Pallottini (C) **Pg. 60**
- 14:15-14:30** *Gaseous cosmological structures and metagalactic ultra-violet background:* Avery Meiksin (C) **Pg. 61**
- 14:30-14:45** *Probing the epoch of reionisation with cross-correlations of high-redshift galaxies and the IGM transmission:* Romain Meyer (C) **Pg. 62**
- 14:45-15:00** *Intensity mapping tomography; method and application to data:* Yi-Kuan Chiang (C) **Pg. 63**
- 15:00-15:30** Poster Session **Pg. 91**
- 15:30-16:00** Tea break
- 16:00-16:30** *Progress in 21cm hydrogen line measurements of the epoch of reionization and the cosmic dawn:* Jacqueline Hewitt (R) **Pg. 64**
- 16:30-17:00** *Unveiling cosmic dawn:* Anastasia Fialkov (R) **Pg. 65**
- 17:00-17:20** *Cosmic evolution of metals and baryons:* Celine Peroux (H) **Pg. 66**
- 17:20-17:35** *A Bayesian approach to recovering the power spectrum of the epoch of reionization with HERA:* Peter Sims (C) **Pg. 67**
- 18:45** Drinks followed by Conference dinner at 19:30

Thursday 19th September • Galaxies & SMBHs

- 09:00-09:30** *Outstanding problems in galaxy formation: Simon White (R) Pg. 68*
- 09:30-10:00** *Evolution of galaxies from $z = 2$ to $z = 0$ from an observational perspective: Reinhard Genzel (R) Pg. 69*
- 10:00-10:15** *An ALMA view of galaxies in the epoch of reionisation: Renske Smit (C) Pg. 70*
- 10:15-10:30** *Simulating the properties of the first galaxies: insights for Hubble, ALMA, and JWST: Harley Katz (C) Pg. 71*
- 10:30-11:00** Coffee break
- 11:00-11:30** *Future prospects for galaxy formation simulations: Volker Springel (R) Pg. 72*
- 11:30-11:50** *The three causes of low-mass halo assembly bias: Andrey Kravtsov (H) Pg. 73*
- 11:50-12:05** *The splashback radius as a physical halo boundary: Benedikt Diemer (C) Pg. 74*
- 12:05-12:25** *The origin of the golden mass of galaxies and black holes: Avishai Dekel (H) Pg. 75*
- 12:25-14:00** Lunch
- 14:00-14:30** *Key open questions within the landscape of current and future galaxy spectroscopic surveys at high redshift: Alice Shapley (R) Pg. 76*
- 14:30-14:50** *Star formation and feedback in the multi-phase ISM: Stefanie Walch (H) Pg. 77*
- 14:50-15:05** *The connection between local and global star formation in galaxies: Vadim Semenov (C) Pg. 78*
- 15:05-15:20** *Detailed modelling of star formation in a galactic context and its impact on the efficiency of stellar feedback: Matthew Smith (C) Pg. 79*
- 15:20-15:50** Tea break
- 15:50-16:20** *The long term vision of gravitational wave astrophysics: Alberto Sesana (R) Pg. 80*
- 16:20-16:40** *The most distant quasars: Xiaohui Fan (H) Pg. 81*
- 16:40-16:55** *Evidence for quasar evolution in the first billion years: Sarah Bosman (C) Pg. 82*
- 16:55-17:10** *The tale of angular momentum transport in self-gravitating disks: new insights on protogalaxies, massive black hole seeds and super-Eddington accretion: Lucio Mayer (C) Pg. 83*
- 17:10-17:25** *Downsizing of star formation: weighing dark matter haloes hosting clustered infrared background sources: Kirsten Hall (C) Pg. 84*

Friday 20th September • Galaxies & SMBHs

- 09:00-09:30** *Accretion dynamics of binary black holes approaching merger:*
Manuella Campanelli (R) **Pg. 85**
- 09:30-10:00** *New perspectives onto the Universe in the era of multi-messenger astronomy: present status and challenges:* Samaya Nissanke (R) **Pg. 86**
- 10:00-10:15** *Gravitational Waves from Neutron-Star Mergers: Implications for Nuclear Physics and Cosmology:* Michalis Agathos (C) **Pg. 87**
- 10:15-10:30** *Post-Newtonian dynamical modelling of super-massive black holes in global large-scale simulations:* Peter Johansson (C) **Pg. 88**
- 10:30-11:00** Coffee break
- 11:00-11:15** *AGN jet feedback in realistic cluster environments:* Martin Bourne (C) **Pg. 89**
- 11:15-11:30** *Is star formation quenching governed by global, environmental, or local phenomena?:* Asa Bluck (C) **Pg. 90**
- 11:30-12:30** Conference Summary:
Chair: Roger Blandford; co-chairs: Jo Dunkley, Alice Shapley,
Ofer Lahav, Carlos Frenk
- 12:30-14:00** Lunch & End of the Symposium



Abstracts
(Talks)

Can Λ CDM survive another decade?

Marc Kamionkowski • Johns Hopkins University

I was asked to give a talk with this title. I think the answer is yes. A more interesting question, though, is whether Λ CDM will survive another century, and I think the answer to that question is definitely not: There are just too many ad hoc ingredients, kludges, and coincidences. Λ CDM is a phenomenological model analogous to the Bohr-Sommerfeld models of quantum mechanics that preceded the full development of quantum mechanics in the 1920s. I don't know what will replace Λ CDM, but I will speculate about some of the possible ingredients and features of a deeper model.

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What is the future of inflationary theory?

Andrei Linde • Stanford University

I will describe the present status and future prospects of inflationary cosmology, concentrating on the development of new classes of inflationary models, the possibility of their testing by cosmological observations, and the problem of initial conditions for inflation.

NOTES:

Nonlinear dynamics of cosmological fields

Mustafa Amin • Rice University

I will discuss the formation, gravitational clustering and interactions of non-topological solitons (oscillons) in self-interacting, cosmological scalar fields. The results are relevant for the dynamics of the inflation field at the end of inflation, for axion-like dark matter and other cosmological fields with attractive self-interactions. I will touch upon potential observational implications of such solitons including small-scale structure formation, black-hole formation and generation of gravitational waves. Time permitting, I will provide results regarding the equation-of-state of spatially inhomogeneous, nonlinear cosmological scalar fields and their implications.

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All possible symmetries of cosmological correlators

Enrico Pajer • DAMTP, University of Cambridge

The primary observable in cosmology are averages of perturbations, a.k.a. correlators. Primordial correlators are the initial conditions for all observed correlators, for example of the Cosmic Microwave Background or of Large Scale Structures. Primordial correlators display an astonishing amount of symmetry: statistical homogeneity, isotropy and scale invariance. I will present a complete classification of all possible additional symmetries that might leave primordial correlators invariant, the prospects of observationally detecting these symmetries and their implications for the physics of the very early universe.

NOTES:

The search for inflationary B-modes: latest results from BICEP/Keck

Clem Pryke • University of Minnesota

The BICEP/Keck series of experiments are small aperture refracting telescopes designed to measure the polarization pattern of the Cosmic Microwave Background at degree angular scales. The latest BK15 results use measurements at 95, 150 and 220GHz, in conjunction with additional bands from WMAP and Planck, to constrain the foreground signal and set the limit $r < 0.07$ (95% confidence). I will describe the current instruments, data and analysis, and also the major BICEP Array upgrade which is projected to reach sensitivity of $\sigma(r) \sim 0.003$ within the next five years.

NOTES:

The Inconsistent Universe: problems with KiDS, or with Λ CDM?

Benjamin Joachimi • UCL

Recent measurements of the cosmic microwave background by Planck and by galaxy weak lensing surveys at low redshift have resulted in a marginal, yet intriguing discrepancy in the amplitude of matter density fluctuations, one of the fundamental parameters of the cosmological concordance model. Building on the most recent results of cosmological weak lensing analysis from the ESO Kilo-Degree Survey (KiDS), I will discuss the consistency of these results with other weak lensing surveys and with complementary probes of large-scale structure. Moreover, I will present new approaches to asserting the consistency of correlated datasets and demonstrate that there is no evidence for internal tension in KiDS weak lensing data.

NOTES:

Fundamental physics from CMB: next steps

David Spergel • Princeton University & CCA, Flatiron Institute

Measurements of CMB fluctuations have already provided important measurements of the composition of the universe and the amplitude of primordial fluctuations. I will review the results from the precision results from Planck, discuss the status of results from the Atacama Cosmology Telescope, the South Pole Telescope and the BICEP experiment, and look forward to upcoming measurements from the Simons Observatory and CMB-S4. I will also discuss the potential contributions of future precision measurements of the CMB spectrum.

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Cosmic growth, gravitational waves, and CMB

Eric Linder • UC Berkeley

Cosmic growth of structure is an incisive probe of dark energy and gravity. Recently, we have recognized new connections with gravitational wave observatories, and the synergy between them. Cosmic structure surveys also can work with CMB lensing and polarization experiments to constrain further the nature of cosmic acceleration and gravity.

NOTES:

Update on standard siren science

Daniel Holz • University of Chicago

We review the present and future of gravitational-wave standard siren constraints. We discuss existing measurements from GW170817 and GW170814, focusing on both counterpart and statistical standard siren approaches. For counterpart standard sirens, we capitalize on the identification of an electromagnetic transient to independently determine the redshift to the source. The counterpart GW170817 standard siren constrains the Hubble constant to $\sim 15\%$. For statistical standard sirens, we combine standard siren measurements for a sample of galaxies within the three-dimensional gravitational-wave localization volume, considering every galaxy as a potential host. This method is of particular utility for dark sirens such as binary black holes, which are not expected to be associated with an electromagnetic counterpart. We make projections for upcoming gravitational-wave detector networks, showing that future standard sirens are expected to measure the Hubble constant to 2% within five years.

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Measuring the Hubble constant with a gravitational wave black-hole merger and the Dark Energy Survey

Antonella Palmese • Fermilab

In this talk I will present the first measurement of the Hubble constant using a binary black hole gravitational wave detection from LIGO/Virgo (GW170814) and the Dark Energy Survey (DES) galaxy catalog. The DES collaboration has a dedicated effort to follow up gravitational wave events, and it led to the discovery of the kilonova associated to GW170817. Our team has also followed up GW170814, but found no compelling evidence for an electromagnetic counterpart. In order to use GW170814 as a standard siren and measure the Hubble constant in the absence of a host galaxy redshift, we applied a statistical method that takes into account all the potential host galaxies observed with DES. The uncertainty on the Hubble constant from a single event of this kind is close to 50%, but we anticipate a multifold increase on the LIGO/Virgo event detection rate in the coming years. The synergy between gravitational wave detections with and without an associated electromagnetic counterpart, and large galaxy surveys will allow precision cosmology studies in the very near future.

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Towards a direct measurement of cosmic dynamics

Ryan Cooke • Durham University

The discovery of the accelerated expansion of the Universe is perhaps the most surprising result that has come from the recent surge of cosmological discoveries. All evidence that currently supports the accelerated expansion is based on either indirect probes and/or depends on an assumed cosmological model; cosmic acceleration has not yet been directly detected. In this talk, I will discuss the possibility of directly measuring cosmic acceleration with a spectroscopic monitoring campaign of cosmological sources using either current or future facilities, and how we might overcome the current level of instrument systematics. I will also present the current bounds on cosmic acceleration, based on 20 years of high resolution spectroscopy with the 8-10m class telescopes.

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Synergy between next generation CMB and LSS probes of cosmology

Jo Dunkley • Princeton University

I will talk about how upcoming CMB and large-scale structure probes will work together to constrain our cosmological model. By combining gravitational lensing, clustering, and galaxy cluster measurements, seen via both microwave and optical data, we will improve our ability to measure the total mass of neutrino particles, constrain the evolution of dark energy, and look for unexpected physics. I will give particular examples of the expected synergy between the Simons Observatory (combined with Planck satellite), and the LSST and DESI surveys.

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Pushing to small scales with galaxy and CMB survey cross-correlations

Eric Baxter • KICC, University of Cambridge

Cross-correlations between galaxy and CMB surveys can be used to probe interesting physics at the scales of galaxy groups and clusters. In particular, these cross-correlations are sensitive to the mass and gas profiles of halos, providing insight into the masses of these objects, features at halo boundaries, and constraints on baryonic processes occurring within the halos. In this talk, I will present recent measurements of halo profiles using data from several galaxy and CMB surveys (SDSS, DES, SPT, ACT, and Planck), and will comment on potential improvements with future data.

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Baryonic processes from thermal and kinetic SZ

Stefania Amodeo • Cornell University

The thermal and kinetic Sunyaev-Zel'dovich effects (tSZ, kSZ) probe the thermodynamic properties of the circumgalactic medium (CGM) and the intracluster medium (ICM) of galaxy groups and clusters, since they are proportional, respectively, to the integrated electron pressure and momentum along the line-of-sight. A combination of the two effects is a powerful tool to study the average gas pressure and density profiles of a given cluster sample, thus allowing to quantify the departure from the predicted dark matter profile and constrain baryonic processes like star formation, AGN feedback and non-thermal pressure support (Battaglia et al. 2017). While the tSZ has been extensively measured in clusters (and for a wide range of halo masses), kSZ detections (around $4\text{-}\sigma$) are relatively new. We will describe how the tSZ and kSZ signals can be measured by combining observations of the cosmic microwave background (CMB) with large scale structure data from spectroscopic and photometric optical galaxy surveys. Building on the approach used in Schaan et al. 2016, we use CMB data from the Atacama Cosmology Telescope (ACT), cross correlated with individual velocity estimates for galaxies in the Baryon Oscillation Spectroscopic Survey (BOSS), that provide new and more significant detections of the kSZ signal. We derive parametric constraints on the radial density profile and on baryonic processes such as the energy injected through feedback and the non-thermal pressure support. We will discuss the implications of the baryonic effects in theoretical modelling of the matter power spectrum which need to be accounted for in cosmological surveys that aim to probe the non-linear regime. Finally, we will discuss forecasts for future high-resolution CMB experiments, like AdvACT, SPT-3G, the Simons Observatory, and CMB-S4.

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Correlating the CMB to observations of the low z universe with a full forward model: a robust probabilistic analysis based on BOSS and Planck dataset

Guilhem Lavaux • Institut d'Astrophysique de Paris

Cosmological datasets, such as galaxy surveys and Cosmic Microwave Background observations, are complex to use owed to the limits imposed by the instrumentation and unwanted systematic effects induced by our environment (e.g. fibre collisions, atmosphere, dust reddening, stars). Even if cross correlating the two above observations lower the sensibility to both individual source of errors, the interpretation of the results is still largely limited by systematic effects (e.g. gravitational lensing, Sunyaev-Zel'dovich effects). New methods, based on full forward modelling of these surveys, are becoming available which are able to address the challenge. I will notably show two new results. The first is obtained by the application of the BORG (Bayesian Origin Reconstruction from Galaxies, Jasche & Wandelt 2013, Lavaux & Jasche 2016, Jasche & Lavaux 2019) inference framework to the SDSS3-DR12 BOSS datasets (Alam et al. 2015), which gives for the first time an unbiased view of the formation of large scale structure from redshift $z = 0.2$ to $z = 0.7$. I will show the new features of the model that we have recently developed, notably the different steps to render the inference robust, that is to remove the effects of both known and unknown systematic effects in the galaxy survey dataset (Jache & Lavaux 2017, Porqueres et al. 2019). I will give an assessment of the quality of the inferred dynamical history of that same volume. The second result comes from the cross-correlation of density and potential fields obtained with that method with the lensing and temperature maps derived from the Planck CMB observations. I will notably focus on the CMB gravitational lensing map, the Integrated Sachs-Wolf effect. I will discuss the challenges in obtaining those maps and the new hope in the development of accurate/precise probes of cosmology with this kind of end-to-end modelling tools.

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Future of galaxy surveys

Will Percival • University of Waterloo & Perimeter Institute

Analyses of galaxy clustering in redshift surveys such as the Baryon Oscillation Spectroscopic Survey (BOSS), have provided robust cosmological measurements through the BAO and RSD techniques and are now considered as one of the pillars of modern observational cosmology. The future of galaxy surveys for cosmology lies both in new surveys covering larger volumes of the Universe and in the development of new techniques. I will quickly review the standard techniques used to extract cosmological information from galaxy surveys, and then spend more time considering new cosmological probes. In particular I will show how voids can be used as standard shapes and present results from a recent analysis of BOSS. Future surveys including the Dark Energy Spectroscopic Instrument (DESI), the Euclid satellite mission and the MaunaKea Spectroscopic Explorer, will provide an order of magnitude more information than BOSS and I will introduce these surveys and discuss predictions for the expected measurements.

NOTES:

Synergy between next generation CMB and LSS probes of cosmology

Hiranya Peiris • UCL & Stockholm University

Answering the “big questions” in cosmology requires significant innovation in forward-modelling the Universe, particularly in cases where models are time-consuming to compute, complex and/or non-linear. I will review the utility of emulator-based approaches to forward modelling. I will describe two case studies: (a) machine-learning-based emulators in regimes where the size of available training sets is either small or large, illustrated respectively with models of Lyman- α forest data and models of galaxy SEDs from stellar population synthesis codes; and (b) laboratory analogues of early universe physics, which emulate false vacuum decay in ultra cold atom experiments.

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The BAHAMAS project: emulating the observable Universe

Ian McCarthy • Liverpool JMU

The standard model of cosmology is remarkably successful at explaining a wide range of observations of our Universe. However, it is now being subjected to much more stringent tests than ever before, and recent large-scale structure (LSS) measurements appear to be in (mild) tension with its predictions. Is this tension signalling that new physics is required? For example, time-varying dark energy, or perhaps a modified theory of gravity? A contribution from massive neutrinos? Before coming to such bold conclusions we must be certain that all of the important systematic errors in the LSS tests have been accounted for. Presently, the largest source of systematic uncertainty is from the modelling of complicated astrophysical phenomena associated with galaxy formation. In particular, energetic feedback processes associated with star formation and black hole growth can heat and expel gas from collapsed structures and modify the large-scale distribution of matter. Furthermore, the LSS field is presently separated into many sub-fields (each using different models, that usually neglect feedback), preventing a coherent analysis. Cosmological hydrodynamical simulations (are the only method which) can follow all the relevant matter components and self-consistently capture the effects of feedback. In this talk, I will present preliminary results from a new ERC-funded project to develop an unprecedentedly large suite of cosmological simulations designed specifically for LSS cosmology applications, with the effects of feedback realistically accounted for and that allow us to unite the different LSS tests. We use advanced emulation techniques to make predictions for LSS over a wide cosmological landscape in observable space. I will present what we have learned to date from comparisons to a large variety of observations.

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Probing cosmology and fundamental physics with counts-in cells

Cora Uhlemann • DAMTP, University of Cambridge

Counts-in-cells statistics capture essential non-Gaussian properties of the cosmic web, including peculiar regions of high and low density. I will show that those statistics not only provide information complementary to common two-point statistics, but also allow for accurate theoretical predictions. I will explain how matter counts-in-cells statistics and their dependence on cosmological parameters can be predicted from first principles. I will show how those predictions can be extended to describe biased tracers and weak lensing observables. Finally, I will give an outlook on the future potential of those statistics to constrain fundamental physics and cosmology using upcoming galaxy surveys.

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Connecting galaxies and dark matter halos: methods, insights, and challenges

Risa Wechsler • KIPAC, Stanford University

In our modern understanding of galaxy formation, every galaxy forms within a dark matter halo and the formation and growth of galaxies over time is connected to the growth of the halos in which they form. The advent of large galaxy surveys as well as high-resolution cosmological simulations has provided a new window into the statistical relationship between galaxies and halos and its evolution over time. This galaxy-halo connection provides a key test of physical galaxy-formation models; it also plays an essential role in constraints of cosmological models using galaxy surveys and in elucidating the properties of dark matter using galaxies. I will review techniques for predicting the galaxy-halo connection, for inferring it from large galaxy surveys, and the insights that have arisen from these approaches, and will highlight the biggest challenges in bringing these approaches to the next level of precision.

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From cosmological data analysis to fast Bayesian methods and machine learning

Uros Seljak • UC Berkeley & LBNL

I will present some recent methods developed for optimal data analysis of cosmological observations, in the presence of incomplete and noisy data, nonlinear evolution and biasing. These methods highlight the sophisticated nature of modern data analysis approaches in cosmology, including marginals, probability distributions, and optimization in billions of dimensions, as well as computational developments such as fast N-body simulations and backpropagation through them. The need to solve difficult problems in cosmology lead us to develop methods that have broader applications. As an example I will present a fast Bayesian posterior and evidence calculation method that can be orders of magnitude faster than standard sampling methods. I will also present novel supervised and unsupervised machine learning methods inspired by these cosmology analyses.

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Inflation and dark energy from high redshift surveys

Simone Ferraro • LBNL Berkeley

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Relics of cosmic reionization in the high redshift Lyman- α forest and their impact on dark matter constraints

Ewald Puchwein • Leibniz Institute for Astrophysics Potsdam

We present a new suite of cosmological hydrodynamical simulations that is combined with radiative transfer calculations of cosmic reionization to explore relic signatures of a recently completed patchy reionization in the high-redshift Lyman- α forest. We discuss spatial fluctuations in reionization redshift, ionizing radiation field, IGM temperature and pressure smoothing, as well as how they affect cosmological constraints based on high-redshift Lyman- α forest data, in particular on the free streaming of dark matter.

NOTES:

Fuzzy dark matter from intergalactic medium

Vid Irsic • University of Washington & KICC, University of Cambridge

Extremely light bosons with a De Broglie wavelength of ~ 1 kpc have been suggested as dark matter candidates that may resolve some of the current small scale problems of the cold dark matter model. Due to the small-scale nature of the theoretical prediction, the parameter space of such a model can be effectively probed by the clustering of the intergalactic medium. I will present results of such an analysis performed using hydrodynamical simulations to model the Lyman- α flux power spectrum in these models, and compare with the observed flux power spectrum from two different data sets: the XQ-100 and HIRES/MIKE quasar spectra samples.

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Massive neutrinos and scale-dependent galaxy bias

Sunny Vagnozzi • Stockholm University & KICC, University of Cambridge

A robust detection of neutrino masses is avowedly among the key goals of several upcoming Large-Scale Structure (LSS) surveys. To fully harness the constraining power of the LSS, a careful treatment of galaxy bias is crucial. In cosmologies with massive neutrinos, defining the galaxy bias with respect to the total matter field leads to a scale-dependence in the bias on large, linear scales. This scale-dependence has, to date, almost always been neglected, with the bias assumed to be a constant. In this talk, I will argue that neglecting this scale-dependence will lead to important shifts in the recovered cosmological parameters, such as the sum of neutrino masses, the scalar spectral index, or the dark matter physical energy density. I encourage future analyses of galaxy surveys to correctly account for this effect.

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Weak lensing: state-of-the-art and future prospects

Rachel Mandelbaum • Carnegie Mellon University

Weak gravitational lensing is one of the most sensitive probes of the growth of structure in the Universe, and is therefore a key part of the cosmological community's program for understanding the nature of dark energy. It is also a powerful probe of the connection between the visible components of galaxies and galaxy clusters, and their dark matter halos. The past few years have seen advances in weak lensing measurements with ongoing surveys such as the Dark Energy Survey (DES), the Kilo-Degree Survey (KIDS), and the Hyper-SuprimeCam (HSC) Survey. In this review talk I will summarize the current state of the field, including key recent results, synergies with other observations, and challenges that must be overcome in order to realize the scientific potential of even more powerful upcoming surveys (Euclid, LSST, and WFIRST).

NOTES:

Cosmology with weak gravitational lensing: challenges and opportunities

Elisa Chisari • University of Oxford

68% of the energy density of the Universe today is in the form of a mysterious "dark energy" component which seems to be driving its accelerated expansion. To elucidate the nature of this component, and to assess whether it is compatible with General Relativity, a next generation of experiments is at our doorstep. These experiments use weak distortions of galaxy shapes ("gravitational lensing") as one of their main probes, and will soon reach an unprecedented high-precision regime. In such a regime, accurate modelling of the large-scale structure of the Universe becomes crucial to realize the goal of obtaining unbiased constraints on the cosmological model. I will describe efforts to build and test models of the large-scale structure using a combination of analytical theory, cosmological simulations and existing observational data sets. In particular, I will demonstrate that the incidence of galaxy formation on our interpretation of gravitational lensing observables is significant. Effects such as the impact of Active Galactic Nuclei feedback on the distribution of matter, or tidal correlations between the shapes of galaxies, are starting to play a role in our efforts to constrain cosmology. At the same time, I will show that these effects can also open up new windows into the Universe.

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KiDS-VIKING-450: Cosmic shear tomography with optical+infrared data

Hendrik Hildebrandt • Ruhr-University Bochum

In this talk I will present cosmic shear results based on the combined KiDS optical and VIKING infrared data over an area of 450 square degrees. I will show how the crucial redshift calibration benefits from the extended wavelength coverage and how this leads to more robust cosmological conclusions. The results will be put into context and compared to findings from the two other big cosmic shear experiments (HSC and DES) and other cosmological probes. Furthermore, I will show brand-new results from a machine-learning-based calibration of the KiDS+VIKING photometric redshifts and how this alternative method influences the cosmological results.

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Cosmological parameter constraints from weak gravitational lensing tomography and overlapping redshift-space galaxy clustering

Shahab Joudaki • University of Oxford

I will discuss the combined analysis of weak lensing tomography and overlapping redshift-space galaxy clustering from KiDS and the spectroscopic surveys of 2dFLenS and BOSS, with a focus on improvements to systematics mitigation, parameter constraints in standard and extended cosmologies, and possible discordance with the Planck measurements of CMB anisotropies.

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Constraining dark matter models with strong gravitational lensing

Guilia Despali • Max Planck Institute for Astrophysics

Strong gravitational lensing is one of the most accurate methods to measure the mass of galaxies and haloes and one of the most promising to investigate the nature of dark matter. Given that the abundance of small-mass and dark clumps is very different in cold and warm dark matter model, this kind of observations can put important constraints on the nature of dark matter; through the detection of small-scale perturbations of the surface brightness distribution of lensed arcs. In order to meaningfully interpret observational results, we derived detailed predictions for the detection expectations in different dark matter scenarios, using theoretical models and numerical simulations. In particular, I will present predictions for future observations, quantifying how many lenses and which resolution we would need to put stringent constraints on the nature of dark matter and discriminate CDM from WDM, considering both substructures and haloes along the line-of-sight as sources of perturbation. Moreover, I will present results coming from high resolution hydrodynamical simulations run with sterile neutrino warm dark matter and self-interacting dark matter, showing what is the effect of each of these models on the properties of the lens galaxies, the lensing signal and the abundance of low-mass (sub)haloes.

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The landscape of galaxy cluster cosmology

Steven Allen • Stanford University

I will briefly summarize the latest results on cosmology from cluster studies. The prospects for progress over the coming decade are outstanding with new catalogs, hundreds of times larger, being constructed across a variety of wavelengths. Extracting the full cosmological information from these catalogs will require a coordinated approach, combining multi-wavelength survey data, targeted follow-up observations and tailored simulations. I will highlight a few of the more significant considerations in this regard.

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Multiwavelength galaxy cluster cosmology with the South Pole Telescope and the Dark Energy Survey

Sebastian Bocquet • LMU Munich

The galaxy cluster sample selected by the South Pole Telescope (SPT) via the thermal Sunyaev-Zel'dovich effect is about to be increased by a factor of 2 to 2.5, with a total number of clusters of order 103. Compared to the latest SPT cluster cosmology work (Bocquet et al., 2018), the new catalog benefits from a wider survey footprint and deeper cluster extraction (Bleem et al., in prep.; Klein et al., in prep). We complement this cluster survey with its well-defined selection with mass calibration from optical weak-lensing data from the Dark Energy Survey (DES). Over the overlapping survey footprint, the DES provides high-SNR mass calibration up to redshift ~ 1 . Combining the SPT cluster sample with DES weak-lensing therefore yields one of the most powerful datasets for cluster cosmology to date, and sets the stage for multi-wavelength cluster cosmology from large surveys. In my talk, we will discuss the cluster cosmology framework and the most important systematic uncertainties that need to be controlled. I will show the latest progress and results from SPT clusters with DES weak-lensing calibration.

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Quantitatively defining consistent relaxed galaxy cluster samples for precision cosmology with impending surveys

David Barnes • MIT

Impending surveys from facilities such as e-Rosita, SPT-3G and Euclid will revolutionize cluster cosmology by yielding samples with $>10^5$ galaxy clusters, producing an exquisitely detailed 10 Gyr picture of cluster formation. In this new era of precision cluster cosmology dynamically relaxed clusters occupy a special role, enabling a reliable deprojection of ICM properties and reduced systematics associated with mass estimation. However, defining a relaxed cluster is non-trivial. Visual classification, based on a regular morphology and strong central emission, has an inherent lack of objectivity and presents a daunting challenge given the scale of future surveys. In contrast, classifying clusters by measurable image features produces an objective and reproducible method, but is fundamentally a thresholding exercise with arbitrary cut-off values depending on the study. In this talk, we will use mock X-ray observations of the IllustrisTNG, C-Eagle, BAHAMAS and MACSIS simulations to produce a quantitative definition of a relaxed galaxy cluster based on minimizing the scatter in estimated masses. We will examine the high-dimensional relaxation criteria space to explore if the common 3D aperture theoretical and 2D aperture X-ray observable relaxation criteria thresholds can be aligned to yield a consistent sample of relaxed clusters and how this evolves with sensitivity, redshift, numerical resolution and subgrid modelling. Finally, we will assess the impact of a quantitative definition of relaxed clusters on estimated cluster masses, scaling relations and the covariance of cluster observables.

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KICC 10th Anniversary Symposium • Public Talk

Lady Mitchell Hall • Tuesday Sept 17, 2019 at 7pm

<https://www.kicc.cam.ac.uk/events/kicc-10th-anniversary-symposium-1/social-events>

Some of the greatest minds in astrophysics address the big questions:

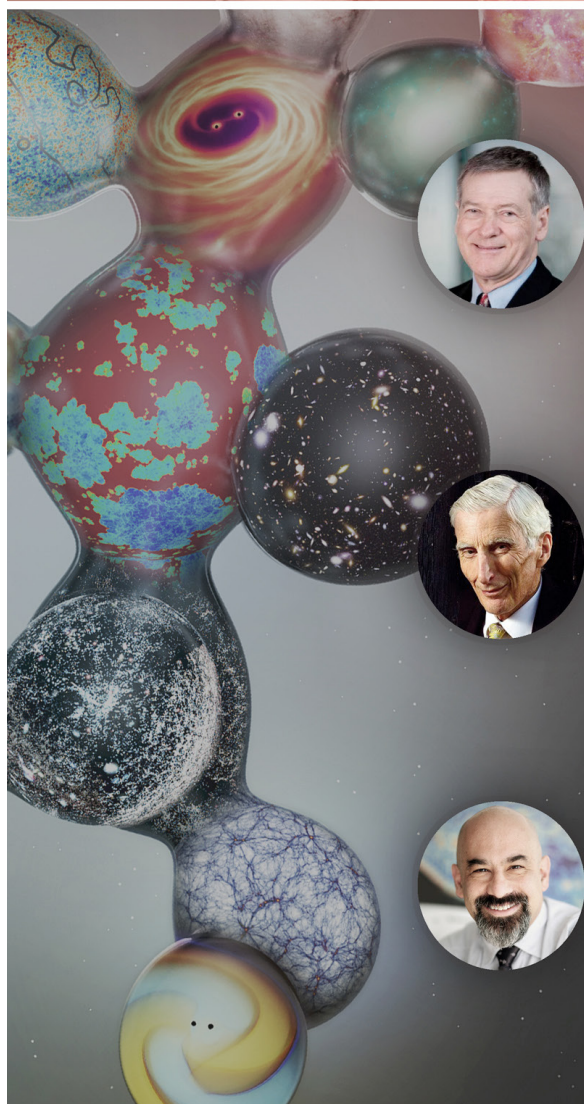
How did the Universe begin?

What is its fate?

IS THERE LIFE OUT THERE?

What are black holes and gravitational waves?

Do we need new physics?



Roger Blandford took his BA, MA and PhD. degrees at Cambridge University. Following postdoctoral research at Cambridge, Princeton and Berkeley he took up a faculty position at Caltech in 1976 where he was appointed as the Richard Chace Tolman Professor of Theoretical Astrophysics in 1989. In 2003 he moved to Stanford University to become the first Director of the Kavli Institute for Particle Astrophysics and Cosmology and the Luke Blossom Chair in the School of Humanities and Science. His research interests include black hole astrophysics, cosmology, gravitational lensing, cosmic ray physics and compact stars. He is a Fellow of the Royal Society, the American Academy of Arts and Sciences, the American Physical Society and a Member of the National Academy of Sciences. In 2008-2010, he chaired a two year National Academy of Sciences Decadal Survey of Astronomy and Astrophysics. He shared the 2016 Crafoord Prize for Astronomy.

Martin Rees's research interests include galaxy formation, high energy astrophysics, black holes, and cosmology. He is a Fellow (and Former Master) of Trinity College and the UK's Astronomer. After various posts in the UK and the USA, he became a Professor at Cambridge and served 10 years as Director of the Institute of Astronomy. In 2005 he was appointed to the House of Lords, and he was President of the Royal Society for the period 2005-10. He is a foreign member of the US National Academy of Sciences, Russian Academy of Sciences, the Pontifical Academy, the Japan Academy and several other foreign academies. His awards include the Balzan Prize, the Bower Award for Science of the Franklin Institute, the Gruber Prize, the Crafoord Prize and the Templeton Prize. In addition to his research publications, he has written extensively for a general readership. His ten books include 'Before the Beginning', 'Just Six Numbers', 'Our Cosmic Habitat', 'Gravity's Fatal Attraction' and the recently-published, 'On the Future: Prospects for Humanity'.

David Spergel is the Director of the Center for Computational Astrophysics at the Flatiron Institute and is the Charles Young Professor of Astronomy, Emeritus at Princeton University. Using microwave background observations from the Wilkinson Microwave Anisotropy Probe (WMAP) and the Atacama Cosmology Telescope, Spergel and his colleagues have measured the age, shape and composition of the universe. These observations have played a significant role in establishing the standard model of cosmology. Spergel is currently co-chair of the Wide Field Infrared Survey Telescope (WFIRST) science team. WFIRST will study the nature of dark energy, complete the demographic survey of extrasolar planets, characterize the atmospheres of nearby planets and survey the universe with more than 100 times the field of view of the Hubble Space Telescope.

Sources of reionization and the changing neutrality of the intergalactic medium

Piero Madau • UC Santa Cruz

The transformation of cold neutral intergalactic hydrogen into a highly ionized warm plasma marks the end of the cosmic dark ages and the beginning of the age of galaxies. A combination of cosmic microwave background data and quasar absorption line spectra shows that this transition must have begun in earnest around redshift 10, and that the Universe was nearly fully reionized some 0.9 Gyr after the Big Bang. While a broad consensus on the epoch and duration of the reionization process may be emerging from a variety of astrophysical probes, many key aspects, such as the very nature of the first astrophysical sources of radiation and heating, how they interacted with their environment, and the early thermodynamics of primordial baryonic gas remain uncertain despite a considerable community effort over the last two decades. In this talk I will survey the key aspects of reionization-era phenomenology, describe the diverse range of techniques and theoretical tools currently available, and review some recent challenges in our understanding of the cosmic dawn.

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Reionization sources of Lyman continuum photons from quasars and O-stars

Michael Shull • University of Colorado

I will discuss recent calculations of the probable sources of cosmological ionization from hot (O-type) stars and active galactic nuclei (AGN) based on current models of stellar evolutionary tracks and non-LTE line-blanketed atmospheres and HST/COS observations of the rest-frame Lyman continuum spectra of quasars down to 350 Å. Current observations suggest that cosmological reionization occurs starting at redshifts $z = 20$ -30 and is mostly complete by $z = 7$. A fully ionized intergalactic medium with primordial He abundance $Y_p = 0.2477$ ($y = \text{He}/\text{H} = 0.0823$ by number) in a flat Λ CDM cosmology with $\Omega_m (1+z)^3 \gg 1$ produces a CMB optical depth $\tau(z_{\text{rei}}) = (0.0521)[(1+z_{\text{rei}})/8]^{3/2}$ scaled to $z_{\text{rei}} = 7$, independent of h to lowest order (Shull et al. 2012, ApJ, 747, 100). With Planck 2018 parameters, $\Omega_m = 0.315$ and $\Omega_b h^2 = 0.0224$, and $\tau = 0.054 \pm 0.007$, this constraint is consistent with reionization complete by $z = 7$. The co-moving star formation density to maintain full ionization at $z = 7$ is estimated to be $(0.012 \text{ M}_\odot/\text{yr}/\text{Mpc}^3)[(1+z)/8]^3 [C_H / 3 / f_{\text{esc}} / 0.2] (T_4)^{-0.845}$ for standard values of gas clumping factor ($C_H = 3$), escape fraction ($f_{\text{esc}} = 0.2$), electron temperature (10^4 K), and LyC photon production efficiency of $10^{53.2}$ photons/s per ($\text{M}_\odot/\text{yr}$) of star formation. However, this LyC efficiency depends on the stellar IMF, metallicity, and rotation rate as well as close-binary evolution.

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Reionization and the thermal history of the IGM

Anson D'Aloisio • UC Riverside

During reionization, the intergalactic medium is heated to temperatures between 20-30,000 K. I will discuss the parameter space of this heating and the dynamical response of the IGM to it. I will also discuss implications for $z > 5$ Lyman- α forest observations, which potentially include sightlines through patches of the Universe that are still undergoing reionization.

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The intergalactic medium as a cosmological probe

Matteo Viel • SISSA

I will review what fundamental physics questions can be addressed by investigating the intergalactic medium.

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Islands of neutral hydrogen below redshift 5.5

Laura Keating • CITA

Above redshift 5, the opacity of the Lyman- α forest shows fluctuations across large spatial scales. The most extreme example of this is a sightline that shows no detectable Lyman- α transmission for 110 cMpc/h , extending down to redshift 5.5. In this talk, I will present results from high-resolution cosmological radiative transfer simulations in large volumes. I will show that all of these observations can be reproduced in a scenario where reionization ends later than previously thought. In this case, the most opaque sightlines are due to residual islands of neutral hydrogen in the IGM.

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Exploring early galaxies and cosmic structures with Subaru, HST, and ALMA

Masami Ouchi • University of Tokyo

I will review our recent and on-going observational studies of early galaxies and cosmic reionization with Subaru, HST, and ALMA, highlighting our large-area deep optical imaging survey conducted with Subaru Hyper Suprime-Cam. I will introduce the forthcoming massive optical/near-infrared spectroscopic survey with Subaru Prime Focus Spectrograph (PFS) and show forecast-study results for high- z galaxies with PFS.

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What can galaxies tell us about reionization?

Charlotte Mason • CfA Harvard & Smithsonian Observatory

The timeline and topology of reionization are currently uncertain but if they are accurately measured they can unveil properties of 'first light' sources and provide insight into the nature of early structure formation. I will describe how we can use galaxies at our current observational frontiers to learn about reionization. In particular, Lyman- α emission from galaxies can probe the intergalactic medium at high redshift but requires modelling physics from pc to Gpc scales. I will present current constraints on reionization from observations of galaxies, focusing on Lyman- α observations at $z > 6$ using a multi-scale forward-modelling approach, and describe future prospects.

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Probing Cosmic Dawn: determining the age of the most distant galaxies

Nicolas Laporte • University College London

Determining the period when the first galaxies emerged from a dark intergalactic medium represents a fundamental milestone in assembling a coherent picture of cosmic history. But the so-called 'Cosmic Dawn' period is not accessible yet directly by current ground-based and space telescopes, but it can be constrained following two different methods : simulations of the first population of galaxies or by measuring the age of the most distant galaxies. For the later, a multi-wavelength approach combining photometric and spectroscopic data from the NIR to sub-mm is crucial. This technique allows to estimate the age of very high-redshift galaxies from either the shape of the $4000\text{\AA}$ break or the amount of dust formed. Our group is conducting deep NIR spectroscopic surveys using X-Shooter/VLT and MOSFIRE/Keck combined with deep ALMA observations to probe the nature and properties (including age, nature, stellar mass, and SFR) of $z > 7$ HST selected galaxies. In this talk, I will describe the latest constraints we obtained on several of the most distant galaxies as well as what we can expect from future facilities.

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The gas structure and radiation field of the first galaxies

Andrea Pallottini • Centro Fermi & Scuola Normale Superiore

The discovery and characterization of primeval galaxies is a key question of modern observational and theoretical cosmology. Optical/near infrared surveys are exquisite tools to search for galaxies in the Epoch of Reionization (EoR). The interstellar medium of such a system can be characterized via spectroscopic data, in particular, the far infrared lines obtained by exploiting the unprecedented capabilities of the Atacama Large Millimeter Array (ALMA). The most remote systems in the Universe are mapped by these experiments, and this can be combined with detailed galaxy simulations to achieve a solid theoretical understanding. I will present high-resolution (10 pc), cosmological, zoom-in, simulations of Lyman Break Galaxies (LBG). With our models we can follow the hydrodynamical, chemical, and radiative evolution of these systems, thus allowing us to characterize the properties of both the interstellar medium and radiation field of LBGs in the EoR. By carefully computing line and continuum emission, we compare our models to the most recent observations. This is crucial in guiding the interpretations of ALMA observations and -- at the same time -- allows us to draw novel conclusions on formation and evolution of Lyman- α emitters/LBGs in the EoR.

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Gaseous cosmological structures and metagalactic ultra-violet background

Avery Meiksin • Institute of Astronomy, University of Edinburgh

Measurements and predictions for the structure of the Intergalactic Medium (IGM) have achieved unprecedented levels of precision. A principle remaining uncertainty in models of the IGM is the origin of the metagalactic ultra-violet background (UVBG) that photoionizes the gas, including its relation to cosmic reionization. This talk discusses how fluctuations in the UVBG depend on several key properties of galaxies and Quasi-Stellar Objects, the most plausible candidate sources for the UVBG: their bias factors, evolution and number counts. It will be shown how these factors may be measured using current and future surveys that probe the large-scale structure of the IGM, such as e-BOSS and DESI. It will also be shown how the UVBG fluctuations themselves may in turn influence the spatial power-spectrum of the sources.

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Probing the epoch of reionisation with cross-correlations of high-redshift galaxies and the IGM transmission

Romain Meyer • UCL

The intergalactic medium (IGM) underwent its last cosmic phase transition as hydrogen was reionised by early galaxies in the first billion years. The timing of this cosmic hydrogen reionisation has been extensively constrained by multiple probes. However, capturing the patchy and stochastic nature of reionisation has proved a challenge for all existing models, because the nature and the properties of the sources of reionisation are still unknown. Characterising the properties and the relative contributions of the sources of reionisation is thus crucial to complete our picture of cosmic history and galaxy evolution. Unfortunately, the numerous faint galaxies beyond the reach of current capabilities are thought to make a major contribution to the reionisation photon budget. In this talk, I will show how the correlation of tracers of the faint population with the IGM transmission in the post-overlap phase of reionisation can address this issue. We have assembled a large sample of Lyman-Break Galaxies, Lyman- α Emitters and metals absorbers in the field of several $z \sim 6$ quasars. We report the detection of a statistical HI proximity effect in the Lyman- α forest of $z \sim 6$ quasars which we attribute to the faint population clustered around our bright tracers. Analytical modelling of this proximity effect allows us to constrain the contribution of the clustered faint objects to reionisation. We find that $z \sim 6$ $M_{UV} < -18$ galaxies have, on average, a higher escape fraction and/or increased ionising efficiencies, and therefore are able to drive reionisation. I will discuss the use of various IGM transmission statistics for the cross-correlation as well as potential differences in the environment of LBGs, LAEs and metals in the early Universe. This refreshing approach provides a promising measurement of the ensemble-averaged contribution of faint galaxies to reionisation. Our results represent a significant step in our understanding of cosmic reionisation and the physical properties of early galaxies.

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Intensity mapping tomography; methods and application to data

Yi-Kuan Chiang • Johns Hopkins University

The targets of intensity mapping do not need to be limited to strong emission lines in the extragalactic background. I will introduce a cross-correlation-based formalism to recover previously collapsed redshift information for cosmic photons in intensity maps of arbitrary bandwidths. This enables a tomography not only in line-of-sight distance (or cosmic time) but also in frequency space as the photons get redshifted by the cosmic expansion. I will demonstrate this method with data by probing the continuum, Lyman- α line, and Lyman break in the cosmic UV background up to $z \sim 2$ using GALEX All Sky and Medium Imaging Surveys. This allows us to perform spectral diagnostics for the entire body of the UV background and provide insights on cosmic star formation, black hole accretion, and potential emission from the diffuse intergalactic medium. We expect this method to be generically applicable for a rich set of existing and upcoming wide-field datasets in probing the cosmic background over a wide range of wavebands up to cosmic high noon.

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Progress in 21 cm hydrogen line measurements of the epoch of reionization and the cosmic dawn

Jacqueline Hewitt • MIT

The 21 cm hydrogen line has been recognized for some time to be a potential tracer of large-scale structure, star formation, and the state of the intergalactic medium during the epoch of reionization and the cosmic dawn. The measurements are challenging, requiring detection and characterization of a weak signal in the presence of strong foreground emission. Several recently completed low frequency radio experiments — EDGES, LOFAR, MWA, PAPER, GMRT — have provided first results. These results include upper limits of increasing sensitivity, and through EDGES a possible detection of the effects of the very first stars on the intergalactic medium. A next generation instrument, HERA (Hydrogen Epoch of Reionization Array) is under construction. HERA will be significantly more capable, addressing ambitious scientific goals and exploring new technologies for the future.

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Unveiling cosmic dawn

Anastasia Fialkov • University of Sussex

Cosmic dawn - the era of primordial star and black hole formation - is one of the least-explored epochs in the history of the Universe. One of the potentially powerful probes of cosmic dawn is the predicted 21 cm signal of neutral intergalactic hydrogen. The 21 cm signal is tied to the intensity of radiation generated by the first sources of light, and, thus, can be used to constrain the process of primordial star and black hole formation as well as reionization. First claimed detection of the signal from redshift $z \sim 17$ by the EDGES Low Band instrument (announced in February 2018) is very controversial and disagrees with standard astrophysics and cosmology. In my talk I will review the status of 21 cm cosmology. I will discuss astrophysical implications of the existing upper limits from $z \sim 6-14$, the status of the EDGES Low detection, and methods to verify 21 cm observations in the future.

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Cosmic evolution of metals and baryons

Celine Peroux • European Southern Observatory

Spectacular measurements of the Cosmic Microwave Background provide an understanding of the basic constituents of the present Universe. Surprisingly, only a minority of the normal matter can be probed by observations of starlight from galaxies. The remaining 90% of the baryons are traced by the intergalactic gas. We will present new results on the metal budget of the Universe and its evolution with cosmic times, including this phase of the baryons. As a corollary, we will introduce the first measure of dust content of the Universe up to $z = 5$ inferred from absorption systems. We will then focus on the cold gas, which is at the heart of the physical processes through which baryons convert into stars. We will show how global accretion is required to interpret the cosmic evolution of the condensed matter. Collectively, these results provide a modern census of the observed baryons in the Universe. Finally, we will postulate on the next breakthroughs in the field of galaxy evolution and the growth of structure.

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A Bayesian approach to recovering the power spectrum of the epoch of reionization with HERA

Peter Sims • Brown University

Observations of redshifted 21 cm emission from Cosmic Dawn (CD) and the Epoch of Reionization (EoR) promise to provide a direct, multiscale probe of the temperature, density and ionisation state of the intergalactic medium during early cosmic history. However, detecting the cosmological signal free from contamination by bright astrophysical foregrounds necessitates an extremely careful analysis of the data. In this talk I will present a Bayesian framework for the joint modeling of the instrument, astrophysical foregrounds and the power spectrum of redshifted 21 cm emission from CD and the EoR. I will provide a brief overview of this technique and highlight its advantages relative to existing approaches. I will conclude with an update on our progress towards using this technique to derive constraints on the power spectrum of the EoR from the most recent season of HERA data.

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Evolution of galaxies from $z = 2$ to $z = 0$ from an observational perspective

Reinhard Genzel • Max Planck Institute for Extraterrestrial Physics

I will summarize what we have learned over the last two decades about the formation and evolution of massive galaxies from the epoch of maximum star/galaxy formation activity 10 Gyrs ago, to the present. Deep, multi-wavelength imaging surveys and follow-up spectroscopic observations find that most galaxies start as clumpy, turbulent rotating disks embedded in dark matter halos and grow in an equilibrium, baryonic cycle, consistent with state of the art numerical simulations. Galaxy growth due to internal star formation in the disks is predominantly driven by baryonic gas accretion from the cosmic web and minor mergers. Outflows of gas due to supernovae, massive stars and active galactic nuclei remove gas and metals back out into the circum-galactic medium, resulting in a fairly low efficiency baryonic condensation. At all redshifts this equilibrium growth comes to an end when the galaxies reach the Schechter mass, $M_{\star} \sim 8 \times 10^{10} M_{\odot}$, and galaxies transition to the 'red sequence' of the galaxy population. The baryonic gas cooling efficiency in the halo, environmental effects and AGN outflows all may play a role in this 'quenching' of the star formation activity.

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An ALMA view of galaxies in the epoch of reionisation

Renske Smit • University of Cambridge

In the past decade hundreds of galaxies have been identified in the Epoch of Reionisation (EoR), selected from their rest-frame UV light. Only a handful of these sources, however, have spectroscopic redshift determinations and we have limited understanding of their properties. ALMA is currently transforming this field by identifying massive ISM reservoirs at $z > 6.5$ from their bright [CII] line emission. I will present new spectroscopic confirmations from ALMA of galaxies in the EoR, where Lyman- α is typically undetected due to the intervening neutral IGM. These bright [CII] lines can be used to start probing the low-resolution kinematics of these systems, showing clear velocity gradients that indicate either rotation or ongoing merger activity. I will present high resolution ALMA follow-up in one of these sources: the most detailed view of the kinematics in a typical star-forming galaxy at $z \sim 7$ to date. Curiously, the [CII] emission in this source is dominated by an extended, 4 kpc rotating disk structure, demonstrating the power of ALMA to push the frontier of dynamical studies.

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Simulating the properties of the first galaxies: insights for Hubble, ALMA, and JWST

Harley Katz • University of Oxford

Characterizing the properties of the first generations of stars, galaxies, and black holes remains on the frontier of observational astronomy. HST and ALMA have revealed numerous interesting properties of high-redshift galaxies that are in stark contrast with the observational characteristics of low-redshift systems. Numerical simulations of early galaxy formation have provided an invaluable tool for interpreting these observations. State-of-the-art simulations now include much of the relevant physics (e.g. coupled radiative transfer) and reach required resolutions (e.g. parsec scales), that such galaxies can be modelled in detailed in a full cosmological context. Combined with novel post-processing methods (e.g. from machine learning), simulations are beginning to provide a more complete picture of the expected physics that governs early galaxy formation. In this talk, I will discuss how state-of-the-art simulations are allowing us to better understand galaxy formation in the early Universe both deep in the ISM and on the largest scales of cosmic filaments.

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Future prospects for galaxy formation simulations

Volker Springel • Max Planck Institute for Astrophysics

Simulations of cosmic structure formation have come a long way. Nowadays, they are not only accurately predicting the dark matter backbone of the cosmic web and the internal structure of halos and their satellites far into the non-linear regime, but are also following the baryonic sector with rapidly improving physical fidelity. In my talk, I will review the methodology and selected successes of recent hydrodynamical galaxy formation simulations. According to these calculations, the role played by strong, scale-dependent feedback processes from supernovae and supermassive black holes could hardly be overstated. I will critically discuss some of the primary uncertainties in modelling these processes, and consider a number of challenges lying ahead in this field in the coming years.

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The three causes of low-mass halo assembly bias

Andrey Kravtsov • University of Chicago

After a brief review of the overall concept of halo assembly bias (the dependence of halo clustering on proxies of halo formation time), its relevance for cosmological inference from galaxy surveys, and previous works on the subject, I will present a detailed analysis of the physical processes that cause halo assembly bias. I will particularly focus on the origin of assembly bias in the mass range corresponding to the hosts of typical galaxies. I will show that haloes located within the splashback shells of larger halos are responsible for approximately two thirds of the assembly bias signal in the galaxy regime, but do not account for the entire effect. The remaining assembly bias signal is due to a relatively small fraction ($\leq 10\%$) of haloes in dense regions. I will present tests of a number of additional physical processes thought to contribute to assembly bias and demonstrate that the two key processes are the slowing of mass growth by large-scale tidal fields and by the high velocities of ambient matter in sheets and filaments. I will thus argue that there are three processes that contribute to assembly bias of low-mass halos: large-scale tidal fields, gravitational heating due to the collapse of large-scale structures, and splashback subhaloes located outside the virial radius.

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The splashback radius as a physical halo boundary

Benedikt Diemer • Harvard University

The size, mass, and evolution of dark matter halos impact our understanding of virtually all areas of structure and galaxy formation. These properties are conventionally defined using somewhat arbitrary spherical overdensity radii, largely because halo profiles are thought not to have a well-defined edge. In this talk, I will show that halos do have such an edge: the splashback radius, or rather, a non-spherical splashback boundary. Redefining halo properties based on this boundary has profound consequences for the assignment of satellites, assembly bias, halo mass functions, and the galaxy-halo connection. The splashback feature has recently been detected in a number of galaxy surveys, opening the intriguing possibility of constraining cosmology and the nature of dark matter from future observations of the halo outskirts.

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The origin of the golden mass of galaxies and black holes

Avishai Dekel • Hebrew University of Jerusalem

This talk will address the preferred mass and time for galaxy formation in dark-matter haloes similar to the one that hosts the Milky Way but when the Universe was only a few Gigayears old. It is proposed that this magic scale arises from the interplay between supernova explosions in low-mass galaxies and feedback from supermassive black holes in massive galaxies, associated with shock heating of the circum-galactic gas which suppresses cold gas supply for star formation in massive galaxies. Cosmological simulations reveal that the same mechanisms are responsible for a robust sequence of events in the history of typical galaxies, where galaxies undergo a dramatic gaseous compaction, sometimes caused by galaxy mergers, into a compact star-forming phase, termed “blue nugget”. This process triggers inside-out quenching of star formation, which is maintained by a hot massive halo aided by black hole feedback, leading to today's passive elliptical galaxies. The blue-nugget phase is responsible for drastic transitions in the main structural, kinematic and compositional properties of galaxies. In particular, the growth of the black hole in the galaxy center, first suppressed by supernova feedback when below the critical mass, is boosted by the compaction event and keeps growing once the halo is massive enough to lock the supernova ejecta by its deep potential well and the hot halo. These events all occur near the same characteristic halo mass, giving rise to the highest efficiency of galaxy formation and black hole growth at this magic mass and time.

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Key Open Questions within the Landscape of Current and Future Galaxy Spectroscopic Surveys at High Redshift

Alice Shapley • UCLA

The past decade has featured tremendous progress in our understanding of key physical processes in galaxies during the first few billion years of cosmic time. We have gained new insights into the properties of massive stars, gas and dust in distant galaxies, and the factors driving the rise and fall of galaxy star-formation histories and structural transformations. At the same time, many key open questions remain. Much of the recent progress has been driven by new optical and near-infrared spectroscopic measurements with large ground-based telescopes and HST in space. I will review the current landscape of large galaxy spectroscopic surveys at high redshift, and the prospects offered by the next generation of observing facilities from the ground and in space.

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Star formation and feedback in the multi-phase ISM

Stefanie Walch • University of Cologne

Star formation takes place in the densest and coldest parts of the interstellar medium (ISM), in dark molecular clouds. These are swept up by multiple supernova explosions on scales of several hundred parsec. While condensing out of the warm ISM, the clouds are continuously fed with fresh gas. Thus, the turbulent substructure and magnetic field properties are imprinted during cloud formation. The formation of dense clouds from the multi-phase ISM, the onset of star formation, and the evolution of the molecular clouds under the impact of stellar feedback from newly born massive stars is studied in high-resolution simulations within the SILCC-Zoom project.

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The connection between local and global star formation in galaxies

Vadim Semenov • University of Chicago

Observed star-forming galaxies convert their gas into stars surprisingly inefficiently. Available gas in galaxies is depleted on the timescale of several Gyr which is orders of magnitude longer than any physical timescale relevant for star formation. The origin of long gas depletion times is a long-standing puzzle. Many galaxy simulations can reproduce observed long depletion times but the physical mechanism controlling their values is not well understood. In addition, some of the simulations show a rather counter-intuitive behavior: global depletion times appear to be almost insensitive to the assumptions about local star formation in individual star-forming regions, a phenomenon described as "self-regulation." Yet another part of the puzzle is the observed tight and near-linear correlation between star formation rates and the amount of molecular gas on kiloparsec and larger scales. A linear correlation implies that depletion time of molecular gas is almost independent of molecular gas density on $>$ kiloparsec scales, while popular models of star formation in galaxies predict a strong dependence. I will present results from a suite of isolated disk galaxy simulations in which we systematically explored the behavior of depletion times. Using insights from these simulations we formulated a physical model that explains both the origin of long gas depletion times in observed galaxies and the results of galaxy formation simulations. This model and our simulation results also provide major insights into the origin of the observed linear correlation between star formation rates and molecular gas.

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Detailed modelling of star formation in a galactic context and its impact on the efficiency of stellar feedback

Matthew Smith • CCA, Flatiron Institute

When considering the impact of stellar feedback on a galaxy’s evolution, it is not sufficient to consider the sources of feedback in isolation without correctly modelling the process of star formation from which they originate. The manner in which star formation proceeds in a galaxy (its efficiency on both local and global scales, its clustering in both space and time) directly determines the feedback budget available and controls where, when and at what rate it is deposited. As one example, strongly clustered star formation leads to proportionally clustered supernovae (SNe), which in turn determines whether expanding SN remnants are able to overlap, break out from a disc and launch galactic outflows. In Smith+2019, we demonstrated that the ability of SN feedback to regulate properties of dwarfs in cosmological simulations is non-trivially dependent on the SF prescription adopted. In recent years, the development of analytic models of cloud-scale star formation (regulated, for example, by turbulence and/or feedback), coupled with the availability of observations of molecular gas with high spatial resolution (e.g. ALMA), provide the impetus to develop a new generation of physically motivated “subgrid” models of star formation within galaxy-scale simulations. As part of the larger SMAUG (Simulating Multiscale Astrophysics to Understand Galaxies) collaboration, we present novel techniques to model star formation in high resolution simulations of galaxy formation and its interplay with stellar feedback. We study methods for extracting input parameters for analytic star formation models (virial parameters, turbulent Mach numbers, dense gas fraction etc.) at the resolution scale of the simulation. We investigate the impact of the choice of analytic model on galactic star formation and we examine the resulting coupling to overall galaxy and outflow properties via stellar feedback, looking particularly for observational signatures that can provide constraints on both star formation and stellar feedback theories, complementary to cloud scale observations. We also deploy these techniques in a cosmological context to study the impact of the SF law on low mass haloes (via its impact on the burstiness of feedback and therefore quenching and core production).

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The long term vision of gravitational wave astrophysics

Alberto Sesana • Università di Milano-Bicocca

Following detection by advance LIGO, gravitational wave (GW) stocks are on the rise. Despite their enormous impact, ground based detectors are only sensitive to GW sources in the audio band, and still too low redshift. I will describe a long-term vision of GW astronomy, introducing science with third generation ground based detectors and then shifting to the still unexplored low frequency regime, probed by future space-borne interferometers such as LISA and ongoing and future pulsar timing arrays (PTAs). I will discuss the main sources of 3G, LISA and PTAs, detection prospects, synergies with electromagnetic detectors and implication for astrophysics and fundamental physics.

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The most distant quasars

Xiaohui Fan • University of Arizona

I will review the progress on surveys of the highest redshift luminous quasars, and the efforts of using them to constrain early supermassive black hole growth and cosmic reionization. The discovery of luminous quasars at redshifts up to 7.5 demonstrates the existence of several billion $M_{\odot}$ supermassive black holes less than a billion years after the Big Bang. They are accompanied by intense star formation in their host galaxies, pinpointing sites of massive galaxy assembly in the early universe, while their absorption spectra reveal an increasing neutral intergalactic medium at the epoch of reionization. Extrapolating from the rapid evolution of the quasar density at $z = 5-7$, we expect that there is only one luminous quasar powered by a billion $M_{\odot}$ black hole in the entire observable universe at $z \sim 9$, marking the epoch when the first luminous quasars emerged in the universe.

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Evidence for quasar evolution in the first billion years

Sarah Bosman • University College London

The number of discovered quasars in the first billion years is undergoing a dramatic expansion, with now 42 observed quasars at $z > 6.5$ - an increase by a factor of more than 4 in the last 3 years. With increased sample size, studies of early quasars can now move from anecdotal to statistical. The increased blueshift of the broad CIV emission line (CIV BEL) was the first reported sign of quasar evolution of high redshift. However measurements have so far focussed on a small number of objects, and have used a variety of definitions of the CIV blueshift, as well as a variety of (model-dependent) means of measuring the velocity shift. No consensus yet exists on the presence and magnitude of the effect. To settle this issue, we have analysed 5 quasar samples over $1.5 < z < 7.5$, carefully selected to be matched in UV luminosity. We design a model-independent method to extract the relative emission line shifts of 6 BELs, including CIV, in a way which does not rely on the source's systemic redshift. We find that the low-ionisation BELs (OI, CII, MgII) show no relative shift from each other at any redshift. However, the velocity blueshift of CIV increases by a factor ~ 2.5 at $z > 6$ compared to $1.5 < z < 6.0$, over which it remains constant at ~ 940 km/s. This result is independent from the choice of line of reference, instrument, and resolution of the observations. We present two toy models to explain the CIV shift. The first is based on a selection bias towards face-on quasars and ongoing SMBH growth, without invoking any change in emission physics. The second interpretation attempts to explain the effect via increased torus obscuration, an effect which has been predicted by some simulations of quasar assembly in immature host galaxies. Our results represent a significant step in the study of early quasars, afforded to us by the incredible increase of data from photometric surveys, and offer a glimpse of the future science accessible in the JWST and Euclid era.

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The tale of angular momentum transport in self-gravitating disks: new insights on protogalaxies, massive black hole seeds and super-Eddington accretion

Lucio Mayer • University of Zurich

Angular momentum transport in disks is key to understand galaxy formation as well as the origin and growth of massive, gravitationally bound objects in astrophysical disks, from stellar objects and gas giant planets to massive black holes and nuclear star clusters. We focus on the results of new multi-scale simulations of protogalactic disks as well as of massive galaxies at $z > 6$, for the first time studying the coupling between gravitational instability and MHD phenomena. Drawing from our recent work on self-gravitating magnetized protoplanetary disks we show that, even for protogalaxies, a new regime where a powerful magnetic dynamo is driven by the distinctive 3D flow dynamics triggered by spiral density waves may lead to a new paradigm of how galactic nuclei evolve at high redshift.

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Downsizing of star formation: weighing dark matter haloes hosting clustered infrared background sources

Kirsten Hall • Johns Hopkins University

Powerful quasars can be seen out to large distances. As they reside in massive dark matter haloes, they provide a useful tracer of the large scale structure. We stack Herschel-SPIRE images at 250, 350 and 500 microns at the location of 11,235 quasars in ten redshift bins spanning $0.5 \leq z \leq 3.5$. The unresolved dust emission by a quasar and its host galaxy dominate on instrumental beam scales, while extended emission is spatially resolved on physical scales of order a megaparsec. This emission is due to dusty star-forming galaxies clustered around the dark matter haloes hosting quasars. We measure radial surface brightness profiles of the stacked images to compute the angular correlation function of dusty star-forming galaxies correlated with quasars. We then model the profiles to determine large scale clustering properties of quasars and dusty star-forming galaxies as a function of redshift. We adopt a halo model and parameterize it by the most effective halo mass at hosting star-forming galaxies, finding $\log(M_{\text{eff}}/M_{\odot}) = 13.8 \pm 0.1$ at $z = 2.21 - 2.32$, and, at $z = 0.5 - 0.81$, the mass is $\log(M_{\text{eff}}/M_{\odot}) = 10.7_{-0.2}^{+0.1}$. Our results indicate a downsizing of dark matter haloes hosting dusty star-forming galaxies between $0.5 \leq z \leq 2.9$. The derived dark matter halo masses are consistent with other measurements of star-forming and sub-millimeter galaxies. The physical properties of dusty star-forming galaxies inferred from the halo model depend on the details of the quasar halo occupation distribution in ways that we explore at $z > 2.5$, where the quasar HOD parameters are not well constrained.

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Accretion dynamics of binary black holes approaching merger

Manuela Campanelli • Rochester Institute of Technology

Supermassive black holes at the centers of galaxies power some of the most energetic phenomena in the Universe. Their observations have numerous exciting consequences for our understanding of galactic evolution, black hole demographics, plasma dynamics in strong-field gravity, and general relativity. When they collide, they produce intense bursts of gravitational and electromagnetic energy and launch powerful relativistic jets. Understanding these systems requires solving the highly-nonlinear and highly-coupled field equations of General Relativity and Relativistic Magnetohydrodynamics. It is only with the use of sophisticated numerical techniques for simulations, data extraction and visualization, and running on petascale supercomputers of ten to hundreds of thousands of CPUs simultaneously that this problem is tractable. This talk will review some of the new developments in the field of numerical relativity, and relativistic astrophysics that allow us to successfully simulate and visualize the innermost workings of these violent astrophysical phenomena.

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New perspectives onto the Universe in the era of multi-messenger astronomy: present status and challenges

Samaya Nissanke • University of Amsterdam

The discovery of both gravitational wave (GW) and electromagnetic (EM) radiation from the binary neutron star merger, GW170817, has opened up a new era of multi-messenger astronomy. Although only a single event, the follow-up and joint GW+EM characterization have offered us a new perspective on the Universe enabling critical insights into diverse fields from gravity, high-energy astrophysics, nuclear physics, to cosmology. In this talk, I will give a brief overview of the GW discovery and EM follow-up of this event, and then discuss how to place compact object mergers in their full astrophysical and cosmological context using joint GW+EM measurements. I will conclude by discussing the lessons that we are learning from this one event and the remarkable opportunities and challenges that have emerged in this new observationally-driven field as we move from the discovery era to one of precision astrophysics in the next decade.

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Gravitational Waves from Neutron-Star Mergers: Implications for Nuclear Physics and Cosmology

Michalis Agathos • KICC/DAMTP, University of Cambridge

The first detection of a gravitational-wave signal from a binary neutron star coalescence, known as GW170817, by the LIGO and Virgo observatories, signifies the beginning of a new era in astrophysics. By analysing gravitational wave signals from neutron star binaries and by adequately modelling of matter effects, we can constrain the barotropic equation of state (EoS) of cold matter at supranuclear densities found in the neutron-star interior. In this talk I will summarise the analyses performed on GW170817, that put tight constraints on the stars' tidal parameters, radii and EoS. I will then discuss the prospects of extracting additional information by modelling and analysing the post-merger part of such events. The last part of the talk will discuss how combining information from the multiple detections expected in the coming years, from gravitational-wave or multi-messenger observations, will further tighten the constraints on the EoS and also provide a new independent way of measuring the Hubble parameter.

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Post-Newtonian dynamical modelling of supermassive black holes in global large-scale simulations

Peter Johansson • University of Helsinki

We will present our new code KETJU, which is an extension of the widely used smoothed particle hydrodynamics simulation code GADGET-3. The key feature of the code is the inclusion of algorithmically regularized regions around every supermassive black hole (SMBH). This allows for simultaneously following global galactic-scale dynamical and astrophysical processes, while solving accurately the dynamics of SMBHs at sub-parsec scales. The KETJU code includes post-Newtonian terms in the equations of motion of the SMBHs, which enables a new SMBH merger criterion based on the gravitational wave coalescence timescale, pushing the merger separation of SMBHs down to ~ 0.005 pc in a galactic-scale simulation. Using KETJU we are able to study the formation of the largest stellar cores in massive early-type galaxies, as we are able to resolve the core scouring process by SMBH binaries in detail from the binary formation until the SMBH merger driven by gravitational wave emission. Using KETJU we can also directly calculate the expected gravitational wave signal from the motion of the resolved SMBH binary in mergers of massive gas-poor galaxies. Finally, we will discuss the future prospects of KETJU, which allows for a straightforward inclusion of gas physics in the simulations. This is particularly relevant, as the upcoming ESA LISA mission is expected to be most sensitive for detecting gravitational waves from SMBHs with masses in the range $\sim 10^6$ - 10^7 $M_{\odot}$, which are expected to reside in gas-rich late-type galaxies.

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AGN jet feedback in realistic cluster environments

Martin Bourne • IoA & KICC, University of Cambridge

Feedback in the form of powerful jets plays an important role in galaxy cluster evolution, where the large lobes of relativistic plasma they inflate are critical in regulating the heating and cooling of the intracluster medium (ICM). However, the modus operandi of communicating the mechanical energy of the jets isotropically to the ICM remains an open question. Given the large dynamic range in the processes governing AGN feedback and its interaction with the ICM, attempting to simulate all of the relevant scales presents a formidable task. I will discuss our state of the art galaxy cluster simulations using novel prescriptions for jet feedback implemented within the moving-mesh code AREPO. The method relies upon a super-Lagrangian refinement technique that provides vastly improved resolution near the SMBH while allowing coarser resolution on larger scales. The technique means we can inject jets on relatively small scales and capture their propagation and evolution to large distances (~ 100 kpc). I will present results from our most recent works in which we investigate jet evolution in realistic cluster environments. Using our novel method we launch very high-resolution jets into fully cosmologically evolved zoom simulations of galaxy clusters at both high- and low-redshifts, for a range of jet powers. I will discuss how and where the feedback energy is deposited in the ICM, turbulence driving (or lack thereof), as well as the role ICM weather has on distributing the energy. Additionally, I will present mock X-ray observations in order to compare with real systems, including comparisons to Hitomi observations of the Perseus cluster.

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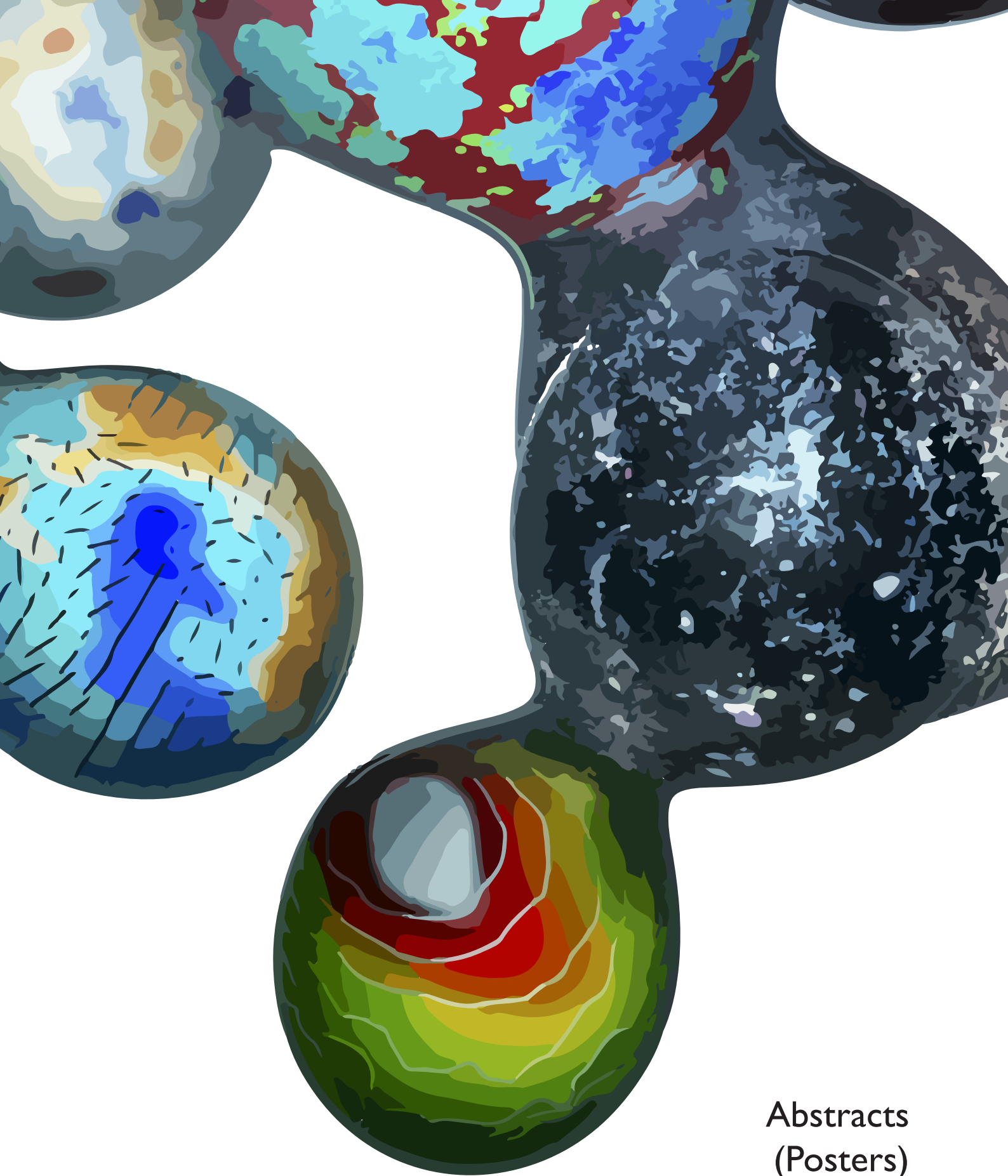
This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Is star formation quenching governed by global, environmental, or local phenomena?

Asa Bluck • KICC, University of Cambridge

I will present new results from analyzing spatially resolved star formation in ~ 4500 galaxies taken from the MaNGA DR15 public data release, incorporating information from over 10 million spectra. First, we demonstrate that studies of (s)SFR profiles in galaxies which are restricted to detections in emission lines are highly biased. We correct for this effect by estimating star formation rate densities for all spaxels, using the strong empirical sSFR – D4000 relationship. From this, we show how the often quoted ‘inside-out’ quenching result is largely an artefact of selection bias. Using the full sample of spaxels, we construct a sophisticated machine learning technique utilizing artificial neural networks which demonstrates that the probability of a given spaxel being quenched is much more strongly connected with global parameters (e.g. stellar mass, central density and central velocity dispersion) than local spatially resolved parameters (e.g. stellar mass density, metallicity and location within the galaxy). Thus, whilst star formation is a local process (as evidenced by the existence of the resolved main sequence), galaxy quenching is fundamentally a global process. Finally, I will demonstrate that for central galaxies, the mass of the central black hole is the most constraining single parameter which governs quenching, consistent with contemporary AGN-feedback quenching models. For satellite galaxies, the dependence of quenching on environment is more important than for centrals, but ultimately all parameters are significantly less predictive of quenching, which is indicative of a more complex evolutionary history.

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Abstracts
(Posters)

Using cosmological hydro simulations to improve the halo model with an eye to large-scale structure emulators

1

Alberto Acuto • Liverpool JMU

Upcoming surveys (such as LSST, Euclid, eROSITA, CMB-S4 etc.) will require robust and accurate theoretical predictions for the distribution of matter on large scales, so that these surveys can constrain the standard model of cosmology and to test its possible extensions. Cosmological hydrodynamical simulations can, at least in principle, provide such predictions, but the task is too computationally demanding at present to simulate the full cosmological landscape. The halo model formalism is an attractive alternative, given the speed at which the predictions can be generated. In fact, the halo model formalism makes use of simple mass-redshift dependent functions (that strongly depends on the chosen cosmology) to trace several LSS observables without running various simulations. However, it suffers from well-known issues in the non-linear regime and the handling of the complex physics of galaxy formation. Here we present some interesting results from a project that aims to characterise and improve the performance of the halo model by making detailed comparisons to the BAHAMAS suite of cosmological hydrodynamical simulations and real observations (Planck, SPT, ACT, DES etc). We explore how well the halo model performs at recovering several cosmological probes like the true Sunyaev-Zel'dovich, weak lensing, and X-ray auto- and cross-correlation functions and make physical adjustments to the halo model to better reproduce the simulations.

oscode: fast solutions of oscillatory ODEs in cosmology

2

Fruzsina Agocs • KICC, University of Cambridge

Bayesian analysis of the cosmic microwave background (CMB) allows us to constrain cosmological parameters and infer the physics of the early universe. The forward modelling phase of Bayesian inference involves calculation of the likelihood function of the model parameters, which requires one to numerically solve linear, ordinary differential equations with oscillatory solutions efficiently. We present a novel numerical routine, *oscode*, with a C++ and Python interface, for such purposes. The method makes use of the Wentzel-Kramers-Brillouin approximation used in quantum mechanics to rapidly traverse highly oscillatory regions of the solution, giving a significant speedup compared to Runge-Kutta-like methods. Its efficiency is demonstrated on physical examples of the Schrödinger equation and the Mukhanov-Sasaki equation; the latter is solved to generate primordial power spectra of curvature perturbations in different cosmological scenarios.

CMB B-mode delensing: prospects and challenges for the next generation of experiments

3

Anton Baleato Lizancos • KICC, University of Cambridge

Lensing-induced B-mode polarisation of the cosmic microwave background is a source of noise in searches for a primary signal associated with primordial gravitational waves. To the extent that the distribution of matter responsible for lensing deflections can be mapped, the lensing B-mode can be estimated and subtracted off in a procedure called “delensing”. For the Simons Observatory, this will involve internal reconstruction using quadratic estimators combined with external tracers of the large-scale structure, most notably the cosmic infrared background (CIB). Here, we explore possible biases affecting this procedure. The first bias we consider appears

Anton Baleato Lizancos • KICC, University of Cambridge

whenever there is an overlap in modes between the field to be delensed and that from which the reconstruction is derived — as in the case of an EB quadratic estimator reconstruction — the delensed power spectrum is artificially suppressed. From an analytic model and simulations, we show that this bias inevitably results in a loss of constraining power and must be avoided by masking overlapping modes. In addition to this, we characterise and suggest methods to mitigate the bias due to residual galactic dust present in CIB maps used for the purpose of B-mode delensing.

Habitable Tordion Worlds

William Barker • University of Cambridge (Cavendish Astrophysics, Kavli Institute)

Recent computational work has identified the 33 unique power-counting renormalizable (PCR) Poincaré gauge theories (PGTs) of gravity, which are parity-preserving and contain neither tachyons nor ghosts. Several of these admit spin-parity $2+$ massless particles (long-range forces and gravity waves?) and $0-$ massive particles (dark matter?), though these are all tordions rather than gravitons. Motivated by these findings, we use a classical approach to systematically categorize parity-preserving PGTs according to their cosmological implications. The 33 PCR theories span 16 distinct cosmologies, whose actions mostly do not contain an Einstein-Hilbert term. The theories with the most favorable particle content belong to cosmologies which amazingly imitate Einstein's general relativity, with the usual Friedmann equations emerging from complex torsion interactions. Furthermore, these theories are 'k-screened', in that the spatial curvature does not play a role in cosmology, in the same way that the topology of the universe is unconstrained by cosmology according to GR. We anticipate significant torsion effects in the early universe which may play a role in matter-antimatter asymmetry, radiation dominance and even inflation. Late universe effects may have implications for the origins and evolution of the cosmological constant.

Look Elsewhere

Adrian Bayer • UC Berkeley

During this age of data science, physicists are taking advantage of scanning vast parameter spaces in search of signals supporting exotic new theories. But if one scans too large a parameter space, the probability of finding a spurious signal becomes substantial. This is dubbed the "look-elsewhere effect": if you keep looking elsewhere in parameter space you'll eventually find a seemingly significant signal, when really it's just noise. Quantifying this effect is a pressing problem, which until now has been tackled from a frequentist perspective. In our work, We present a Bayesian approach for calculating a look-elsewhere corrected significance for these searches. We apply the concept of a maximum posterior mass (MPM) estimator, which maximises the posterior density times the posterior volume. This gives the solution with the highest Bayes factor and can be used for approximate Bayesian evidence and hypothesis testing. We apply our method to topics ranging from non-Gaussian models of inflation to finding new particles in high energy physics experiments.

Resolving shock heating, turbulence and the baryon cycle in high redshift massive galaxies

6

Jake Bennett • IoA, University of Cambridge

Recent cosmological galaxy formation simulations have found that potentially copious amounts of gas do not shock heat in the circumgalactic medium and virialise, but instead deliver cold gas from the cosmic web directly onto galaxies. This significantly changes how galaxies are built up, leading to high central mass deposition rates and hence requiring strong feedback to prevent excessive star formation. However, these simulations typically do not focus their numerical resolution on resolving structure accretion shocks, potentially leading to so-called 'in-shock cooling'. Using novel computational methods within the moving mesh code Arepo, we can now target numerical resolution to more accurately resolve accretion shocks on-the-fly. This allows us to run full cosmological simulations of high redshift massive galaxy assembly, with a reduced impact from 'in-shock cooling', to investigate how gas is cooled and heated as it streams from cosmic filaments onto the forming galaxies. Furthermore, high resolution at accretion shocks will allow us to more robustly capture the generation of vorticity in the wake of curved shocks to estimate how much of the gas energy budget is stored in turbulent motions. The predictions of this work will be directly relevant for future observations by JWST and SKA. This method can also be further generalised to target increases in the spatial resolution within the circumgalactic medium of galaxies, hence allowing not only cosmic inflow but also galaxy outflow multi-phase structure and clumpiness to be captured accurately. This can then be compared against future ALMA and MUSE observations.

Cosmic acceleration from holographic information capacity

7

Luke Butcher • University of Edinburgh

I will describe a new explanation for late-time cosmic acceleration that does not require dark energy or modified gravity [arXiv:1810.08616]. The theory is based on a generic quantum phenomenon: whenever the information capacity of a system can change, there will be a quantum correction to its average motion. I examine how this effect alters the expansion of an FRW universe, with information capacity set by the Holographic Principle. The result is a pair of semiclassical Friedmann equations (and their solutions) in which cosmic acceleration occurs "for free", a natural consequence of treating the universe as a quantum system. The new theory is falsifiable, introduces a single free parameter, and appears to be consistent with current observations. At late times, cosmic acceleration resembles that of phantom dark energy, with the potential to resolve the current tension in H_0 .

Combining cosmological probes around density peaks and troughs

8

Yan-Chuan Cai • University of Edinburgh

Combining cosmological probes from weak gravitational lensing (WL) and redshift-space distortions (RSD) over the same sky is appealing for cosmology. It allows us to optimally extract cosmological information from galaxy surveys by mitigating systematics and cancelling cosmic variance. However, modelling the two observables has been a major challenge. I will demonstrate a method to model the non-linear RSD signal around spherical peak and trough regions with their density profiles measured from WL. The method therefore allows us to extract cosmological information from combining WL and RSD. I will show that this method provides unique constraints for Ω_m , Ω_Λ and the gravitational slip parameter. I will show that it has the potential to break degeneracies among cosmological parameters when combined with other probes such as the CMB and supernovae.

HII Galaxies as Cosmic Laboratories

9

Ricardo Chávez Murillo • Institute of Radio Astronomy and Astrophysics

H II galaxies are precious laboratories to study the physical mechanisms driving and regulating star formation through cosmic time, since they can be easily observed from the local universe to the highest redshifts. In particular, mapping their emission lines provide invaluable information on their gas content and kinematics, their chemical abundances and gradients, as well as their ionisation fields and star formation rates. These properties provide key constraints on the local conditions for star formation and feedback mechanisms, the role of galaxy interactions and gas inflows and outflows, and their impact in the mass assembly and chemical evolution. Thus, through the study of HII galaxies it is possible to draw a detailed picture of the several interlinked physical processes driving star formation and chemical evolution in galaxies from low to high redshifts.

How the First Supernovae Regulated Star Formation in the First Galaxies

10

Ke-Jung (Ken) Chen • Academia Sinica Institute of Astronomy and Astrophysics (ASIAA)

Metals from Population III (Pop III) supernovae led to the formation of less massive Pop II stars in the early universe, altering the course of evolution of primeval galaxies and cosmological reionization. There are a variety of scenarios in which heavy elements from the first supernovae were taken up into second-generation stars, but cosmological simulations only model them on the largest scales. Here, we present small-scale, high-resolution simulations of the chemical enrichment of a primordial halo by a nearby supernova after partial evaporation by the progenitor star. We find that ejecta from the explosion crash into and mix violently with ablative flows driven off the halo by the star, creating dense, enriched clumps capable of collapsing into Pop II stars. Metals may mix less efficiently with the partially exposed core of the halo, so it might form either Pop III or Pop II stars. Both Pop II and III stars may thus form after the collision if the ejecta do not strip all the gas from the halo. The partial evaporation of the halo prior to the explosion is crucial to its later enrichment by the supernova.

William Coulton • KICC, University of Cambridge

As weak lensing surveys provide increasingly precise measurements we become increasingly sensitive to non-Gaussianities in the data. These non-Gaussianities can be probed with higher order statistics and they contain a wealth of cosmological information that is not accessible to two-point statistics. I will describe how higher point statistics, such as extrema counts and bispectra, can be used to significantly increase our constraints on cosmological parameters. Specifically, I will show that for an LSST like experiment, higher point statistics can tighten constraints on neutrino mass by 30-60%.

A “KLEVER” probe of the ISM in high redshift galaxies with multi-band KMOS observations

Mirko Curti • KICC, University of Cambridge

We will present KLEVER, an ESO Large Programme aimed at investigating dynamics, gas excitation properties and chemical abundances in high redshift galaxies, by means of near-IR spatially resolved spectroscopy. Exploiting KMOS multi-IFU observations in the J, H and K bands we aim to map multiple optical rest-frame emission lines (from [O II]3727 to [S III]9530) in a sample of ~ 100 galaxies between $1.2 < z < 2.5$. The survey targets both gravitationally lensed galaxies in Frontier Fields clusters and non-lensed galaxies in the COSMOS and GOODS fields. Our observing strategy allows us to obtain a detailed characterisation of the properties of the ISM in these sources on spatially resolved basis, thanks to the wealth of nebular diagnostics provided. We investigate the physical drivers responsible for the evolution in the emission line ratios at these redshifts, as clearly seen e.g. in the BPT diagrams, by assessing whether the offsets from the relations observed in the local Universe correlate with different quantities like electron density, ionization parameter and nitrogen abundance. We also derive full metallicity maps, exploiting different calibrators and evaluate presence and evolution of metallicity gradients. Although the bulk of the analysed galaxies are characterised by flat gradients, suggesting that efficient feedback and gas mixing processes are in place at these epochs, the irregular and non-axisymmetric patterns often seen in the full 2D metallicity maps suggests to move beyond the classical “radial-averages” approach to get meaningful constraints on galaxy evolution models and allow for a fair comparison with prescriptions of high resolution simulations.

Multi-messenger observations of supermassive black hole mergers: GW detection rates and host galaxy morphologies

13

Colin DeGraf • Institute of Astronomy and KICC, Cambridge

Analogous to the LIGO detections of stellar-mass black hole mergers, upcoming surveys such as LISA and PTAs are expected to detect mergers of supermassive black holes. Prior to these measurements, it is important to understand how these mergers correlate with their host galaxies, and what we can expect from multi-messenger observations. Using cosmological simulations, I will show the predicted GW detection rates at several mass scales, how these mergers correlate with their host galaxy properties, and the implications for electromagnetic follow ups, focusing on morphological evidence that the host galaxy has undergone a recent merger. Finally, I will show that although the inspiral/hardening timescales have a relatively weak impact on the GW detection rate, they significantly affect the detectability of merger signatures in host galaxy morphologies.

Measuring the environment of radio loud galaxies using Cosmic Microwave Background lensing from the latest Planck data release

14

Carolyn Devereux • University of Hertfordshire

Understanding how galaxies trace the large scale structure of the Universe can give us insight into galaxy evolution and cosmology. A particular area of interest is the environments of radio loud active galactic nuclei (RLAGN), since RLAGN play an important role in regulating the growth of massive galaxies. Traditionally, measurements of halo mass have relied on galaxy-galaxy n-point auto or cross-correlations. A promising alternative technique is that of measuring the cross-power spectrum of galaxy density fields with weak lensing maps of the cosmic microwave background (CMB) offering a clean measurement, using the CMB as a $z = 1100$ backlight. We use the CMB lensing map from the latest release by Planck (2018) to measure the linear bias and typical halo mass of RLAGN at $z \sim 0.3$. The results confirm that RLAGN typically inhabit halos of masses comparable to that of rich galaxy groups and clusters. The implications of these results will be discussed.

Peculiar velocities of lens galaxies from microlensing

15

Ana Esteban • Institute of Astrophysics of the Canary Islands (IAC)

We use the counting of caustic crossing events to estimate the peculiar velocity of lens galaxies. We simulate the motion of the stars in the lens galaxy instead of considering an effective contribution of the stellar velocity field. To do that, we infer the PDF of the peculiar velocity using dynamical microlensing magnification maps.

Martina Fagioli • ETH Zurich

In the era of big cosmological surveys, it is important to be able to combine information coming from different datasets. This includes information and constraints which are coming from imaging and spectroscopic surveys. We present here an innovative technique for modelling spectroscopic surveys using an Approximate Bayesian Computation (ABC) framework. By relying on high-fidelity image simulations generated using UFig, we are able to carefully account for complex selection effects. These targets are then used to generate synthetic spectra using USpec (Fagioli+ 2018, JCAP, 11, 015). Embedding these simulations into the ABC framework, we can measure key parameters of the luminosity functions of blue and red galaxies as well as galaxy physical properties (such as stellar population parameters and emission line properties, respectively for the red and the blue galaxy populations). We can apply our method to the existing surveys BOSS and eBOSS to test the performance of our novel galaxy population models.

Finding primordial non-Gaussianity in the tails of the density PDF

17

Oliver Friedrich • KICC, University of Cambridge

We present a method to derive the full set of cumulants of the evolved density field from any set of primordial cumulants. This way we can constrain the amplitude of different primordial Bispectrum shapes in a unified framework that studies the tails of the local density PDF as a function of smoothing scale.

The influence of our local environment on cosmological statistics

18

Alex Hall • University of Edinburgh

Measurements of galaxy clustering and weak lensing will be central to constraining extensions to the current cosmological paradigm, and will be vital in uncovering the nature of dark energy. All such measurements are made from an atypical place in the Universe, namely from within our local overdensity, a fact which is not usually accounted for when modelling the observed signals. As the precision of lensing and clustering statistics increases with the upcoming Euclid and LSST surveys, it is timely to ask what influence, if any, our local environment has on quantities like the weak lensing power spectrum due to large-scale correlations in the cosmic density field. I will demonstrate how conditional two-point statistics can be derived using the Edgeworth expansion, and show how the leading-order scale dependence may be computed with low-order perturbation theory, quantifying the implications for parameter inference.

Will Handley • KICC, University of Cambridge

The paradox of observed fine-tuned spatial flatness is traditionally resolved by invoking inflation as a mechanism for flattening the universe. Given this, we cannot assume a-priori that the universe flat during inflation. This is in contrast to nearly all analyses and treatments, which usually assume a flat universe for expositional simplicity. Here I will discuss the interaction of inflation curvature, the theoretical implications for eternal inflation, observational implications for low- ℓ features and tensions, and present constraints on inflationary models in this regime.

Constraining the kinetically dominated Universe

20

Lukas Hergt • Cavendish Laboratories, University of Cambridge

The cosmic microwave background (CMB) has provided us with a wealth of information about the early Universe and is one of the cornerstones of the Big Bang cosmological model. The Λ CDM model of cosmology manages to fit the power spectrum of the CMB remarkably well. Nonetheless, the data also revealed features in the CMB angular power spectrum hinting at potential additional physics. These features include a lack of power at low-multipoles and a small dip at multipoles of approximately 20-30. One major candidate to cause such features is the primordial power spectrum (PPS) of curvature perturbations generated during a period of cosmic inflation. It typically enters into the Λ CDM model in form of a simple power-law. I will illustrate why we classically expect an inflation field to have been kinetically dominated when going back in time and I will show how this causes oscillations and a cutoff towards large scales in the PPS, which could potentially explain those features. To that end I use MCMC parameter estimations and Bayesian model comparisons using data from the Planck satellite.

Early Structure Formation in LPBH Cosmologies

21

Derek Inman • New York University

Primordial black holes (PBH) comprising some fraction of the Universe's dark matter is a potentially interesting alternative to the more standard particle based dark matter. If the fraction is large, PBHs can significantly alter how and when nonlinear structures develop. If it is small, they could provide potentially interesting constraints on WIMPs and/or seed the supermassive black holes known to exist by redshift ~ 7 . We have run LPBH cosmological simulations of structure formation starting from deep in the radiation era and ending at $z = 100$. We analyze the clustering, structure and mass function of halos in the simulation, as well as typical PBH velocities relevant for CMB constraints. Future use cases include tidal perturbations on primordial PBH binaries and whether the formation of stars differs in this scenario.

Gareth Jones • University of Cambridge

The past century has seen massive improvements in the study of galaxy kinematics. Early work focused on single nearby galaxies, while current studies probe the kinematics of many objects or single objects in greater detail. With the continued use of modern IFUs and interferometers (e.g., SINFONI, ALMA), we may now study the dynamics of galaxies at high redshift. However, the sample of galaxy observations at $z > 4$ that featured the sensitivity and resolution for rotational analysis or resolved dynamical characterization has been small. Even with this limitation, multiple ongoing mergers have been detected at $z > 5$, and slight evidence for ordered rotation is present for some main sequence and starburst galaxies. The ALMA Large Program to INvestigate CII at Early Times (ALPINE) targeted 118 LBGs at $z = 4-6$, representing a vast increase in the sample size of possibly dynamically interesting sources. Initial analysis of this dataset has revealed multiple merging systems, and evidence for rotation in both targeted and serendipitous field galaxies. Current work focuses on simulated observations of model galaxies, in order to test whether intrinsic properties can be extracted from low resolution and low sensitivity observations. The characterization of both dynamically disturbed mergers and relaxed, rotating disks in the epoch between the end of reionization and cosmic noon will be useful for models of galactic evolution.

Cosmological gravitational waves propagation with numerical simulations

Marios Kalomenopoulos • University of Edinburgh, Royal Observatory

The detection of GWs some years ago, opened a new window to the Universe. Using GWs signals we can study various aspects of fundamental cosmology and test GR in unexplored phenomena. During this project, we study the effects of large scale structures in the universe to the waveforms of propagating GWs, both analytically and by using state-of-the-art cosmological simulations. This can result in a better understanding of our detected signals, but potentially also give us useful information about the matter anisotropies in the universe.

The impact of AGN-driven outflows on simulated dwarf galaxies

Sophie Koudmani • IoA, University of Cambridge

The systematic analysis of optical large-scale surveys has revealed a population of dwarf galaxies hosting active galactic nuclei (AGN), which have been confirmed by X-ray follow-up observations. Recently, the MaNGA survey identified six dwarf galaxies that appear to have an AGN that is preventing on-going star formation. This discovery challenges the canonical picture of quenching mechanisms where it is assumed that stellar feedback channels are solely responsible for regulating star formation in low-mass galaxies. It is therefore timely to study the physical properties of dwarf galaxies, in particular whether the presence of an AGN can affect their evolution. Using the moving mesh code AREPO, I have investigated different models of AGN activity, ranging from simple energy-driven spherical winds to collimated, mass-loaded, bipolar outflows in high resolution isolated simulations of dwarf galaxies hosting an active black hole. The simulations also include a novel implementation of star formation and mechanical supernova feedback. Here I will present the results from these simulations,

Sophie Koudmani • IoA, University of Cambridge

focussing on the impact of AGN activity on star formation and outflow properties, and I will compare the outflow kinematics to observations from MaNGA. I will also present some first results from high resolution self-consistent cosmological zoom-in simulations of dwarf galaxies with an AGN. I will discuss whether AGN activity as a new ingredient might help explain some of the apparent discrepancies between dwarf galaxy observations and predictions from the Λ CDM model, e.g. the cusp vs. core problem, and whether AGN activity could regulate the baryon cycle in dwarf galaxies by hindering cosmic gas inflows.

Chemical properties of Blue Compact Dwarf Galaxies: Local Analogues of High Redshift Galaxies

25

Nimisha Kumari • University of Cambridge

Blue compact dwarf galaxies (BCDs) are low-metallicity star-forming galaxies found in the nearby Universe, as such they are thought to be excellent local analogues/proxies of high redshift galaxies. By studying the properties of the interstellar medium of these less-evolved local systems, we can probe and predict the properties of the primordial faint galaxies, which are not readily accessible using present technology. This is one of the reasons why BCDs have been the focus of many imaging, spectroscopic and integral field spectroscopic (IFS) studies for over two decades. IFS is the best available technique to study these galaxies hosting star-forming regions, because it not only allows us to access information encoded in the emission lines from the star-forming regions, but also enables us to map their distribution and varying properties throughout each system. I use IFS observations from the Gemini North Multi-Object Spectrograph (GMOS-N) to study the H II regions in a sample of BCDs, combine them with large samples of star-forming galaxies from previous studies including BCDs, green peas and low-mass SDSS galaxies, and further explore the observed properties with chemical evolution models. Such studies are imperative to enhance our understanding of the chemical abundance patterns not only in the local Universe but also in the distant Universe; and hence elucidate several secrets of the chemical evolution of the Universe.

Three-point Gaussian streaming model for redshift-space distortions

26

Joseph Kuruvilla • Argelander Institute for Astronomy, University of Bonn

Peculiar velocities affects the redshifts of distant galaxies and introduces distortions in all statistical measures of the reconstructed large-scale structure. These distortions can be used to constrain the gravitational theory through clustering statistics. Here we introduce the three-point streaming model to describe the redshift-space three-point correlation function (RS-3PCF). We showcase the linear theory predictions for three-point velocity statistics and the fidelity of these predictions against N-body simulations. We introduce the three-point Gaussian streaming model which is able to reproduce the RS-3PCF with high fidelity on linear scales. With the phenomenological model we have introduced, it paves a way in which the higher order redshift-space correlation function could be utilised to precisely test theories of gravity and interacting dark-energy models for future galaxy surveys like EUCLID and LSST.

Globular cluster formation in early galaxies; implications for cosmology

27

Xiangcheng Ma • University of California, Berkeley

I will present a suite of high-resolution, cosmological zoom-in simulations of galaxies at the reionization epoch from the Feedback In Realistic Environments (FIRE) project. By explicitly resolving star cluster formation self-consistently for the first time in cosmological simulations, I will show that a large fraction of stars formed in proto-globular clusters ubiquitously in high-redshift galaxies over a broad range of mass. These clusters formed in overpressurized clouds compressed by feedback-driven winds and/or collision of gas streams in a highly gas-rich, turbulent environment. Our results suggest that cluster formation is the main mode of star formation in high-redshift galaxies. Given that these clusters are luminous and small in size, I will show that they preferentially stand out in current surface-brightness-limited surveys. This effect will likely bias the measurement of faint-end galaxy UV luminosity functions at $z > 6$ from the Hubble Frontier Fields.

Evolution of Cold Accretion Streams in the CGM of Massive Galaxies at High- z

28

Nir Mandelker • Yale University

Massive galaxies at high redshift are thought to be fed by cold gas streams from the cosmic web, which are able to penetrate the hot halos surrounding the galaxies. However, the evolution of these cold streams as they interact with the hot CGM is poorly understood, and cannot be reliably studied using cosmological simulations due to insufficient resolution in the streams and outer halo. I will present results of a detailed study of this interaction, focusing on the Kelvin Helmholtz Instability (KHI) in a dense supersonic cylinder in 3D, using analytic models and idealized high resolution simulations. We find that streams narrower than 0.5-5 per cent of the halo virial radius can disintegrate prior to reaching the central galaxy, with the threshold radius decreasing with increasing stream density and velocity. Stream disruption generates a turbulent mixing zone around the stream with velocities at the level of ~ 20 per cent of the initial stream velocity. KHI also causes significant stream deceleration and energy dissipation. For typical streams, 10-50 per cent of the gravitational energy gained by inflow down the dark matter halo potential can be dissipated, capable of powering Lyman- α blobs if most of it is radiated. I will also discuss how these results are affected by the self-gravity of the stream and by radiative cooling, both of which can prevent stream disruption but have little affect on stream deceleration and energy dissipation.

Star Formation History of Holmberg IX

29

Yewei Mao • GuangZhou University

The dwarf irregular galaxy, Holmberg IX, is considered to be generated by tidal interaction between M81 and M82. This poster will present a spatially resolved investigation of Holmberg IX on the basis of multi-wavelength imaging data, aimed at understanding the formation and evolution of this galaxy. SED-fitting has been performed

Yewei Mao • GuangZhou University

to derive stellar population age and star formation timescale for individual pixels in images from best-fit parameters. As a consequence, 2-D maps of stellar population properties for Holmberg IX have been obtained. The results of this work manifest that, Holmberg IX is an entirely young system but with no current star formation; it appears to be born from a single and short-term star formation event about 100 Myr ago. In view that Holmberg IX is located in a gas-rich environment, the reason why star formation was quenched recently seems to be a conundrum. More analyses are still ongoing at present to find an interpretation.

Constraining Feedback Processes with Well-Calibrated Cluster and Group Samples

Joseph Mohr • LMU Munich

Selecting galaxy cluster candidates using intracluster medium (ICM) signatures in the SZE or X-ray and then confirming with optical imaging have produced large, low contamination cluster samples that are well suited for cosmological study. These (typically) weak lensing informed analyses produce validated cluster samples whose contamination, selection effects and-- crucially-- masses are well understood. As an example, with the SPT-SZ sample we can currently estimate single cluster masses with 20% statistical scatter and 15% systematic uncertainty. Accurate masses enable clusters of differing mass and redshift to be studied over similar portions of the cluster virial and infall regions. We employ the validated SPT-SZ cluster sample (extending to $z \sim 1.7$) to study the impact of (AGN) feedback on clusters with mass scales $M_{500} > 3 \times 10^{14} M_{\odot}$ in SPT-SZ (Chiu+18, Bulbul+19) and now we push to $M_{500} > 1.5 \times 10^{14} M_{\odot}$ with the new SPTpol sample. Baryonic scaling relations (L_x , ICM mass) for this sample show mass trends steeper than self-similar; an indication that feedback is important in determining the ICM structure on these mass scales. Redshift trends are statistically consistent with self-similar evolution, indicating that any ongoing feedback must be insignificant or balanced by ongoing ICM radiative losses. Detailed comparisons of these results to existing numerical simulations allow us to constrain feedback processes, reducing theory uncertainties on the matter power spectrum (needed for cosmic shear studies). Future eROSITA group samples will enable improved constraints. We study feedback more directly using the cluster radio AGN population and its dependence on cluster mass and redshift in 10^3 X-ray and 10^4 optically selected clusters. The radio AGN are centrally concentrated and exhibit strong number density increases with cluster mass and redshift. Using published estimates for the relation between mechanical feedback and radio luminosity, we estimate the average, ongoing mechanical feedback into the cluster core, finding it to be a strong, increasing function of cluster mass and redshift. We compare this feedback to core radiative X-ray losses ($r < 0.1 R_{500}$) constrained as a function of mass and redshift using the SPT-SZ sample. For cluster masses $M_{500} > 3 \times 10^{14} M_{\odot}$ the radio feedback is in rough balance with core radiative losses out to $z \sim 1$. At lower masses radio AGN feedback dominates losses by a factor of a few (Gupta+19).

Measuring weak lensing and cosmic birefringence with high precision CMB B-mode polarization

31

Toshiya Namikawa • University of Cambridge

One of the promising cosmological probes in the next decades is the CMB polarization. While CMB temperature anisotropies have been already measured very precisely, CMB polarization, in particular a twisting pattern in the polarization map (B mode) is still dominated by the statistical noise. The precise measurements of B mode will enable us to explore not only the primordial gravitational waves but also to measure gravitational lensing, and cosmic birefringence. I will present my recent work on data analysis using high precision B-mode data, including the reconstruction of lensing, cosmic birefringence by the BICEP2/Keck Array collaborations, and CMB-galaxy lensing cross-correlation by Subaru HSC and POLARBEAR.

X-ray and SZ scaling relations from galaxies to clusters with the IllustrisTNG simulations

32

Ana-Roxana Pop • Harvard University

The observable thermodynamical properties of the intracluster medium reflect the complex interplay between astrophysical processes such as AGN feedback and the gravitational collapse of the host halo. Using the IllustrisTNG simulations, we measure the X-ray emission and the impact of the gas on CMB through the Sunyaev-Zel'dovich effect over a wide range of mass scales: from galaxies and groups, all the way to the most massive clusters ($M_{500, \text{crit}} > 10^{15} M_{\odot}$). We calculate the X-ray properties of our simulated haloes using methods that are consistent with observational techniques, which account for the bias and scatter introduced by estimating halo masses. Thus, we infer the scaling relations between X-ray measurements such as the soft-band luminosity and the spectroscopic temperature, hot gas content and Sunyaev-Zel'dovich properties, and we find reasonable agreement between IllustrisTNG and the observed relations. Our work helps to better understand the role played by AGN feedback from cluster to galaxy scales, informing future subgrid BH feedback models. Moreover, our results highlight the scatter and bias introduced by estimated masses, and thus the importance of converting simulated ICM properties to the observable space when comparing simulations to current X-ray observations. Finally, we will provide important predictions for future X-ray missions such as eROSITA, Athena and Lynx regarding the redshift evolution of the X-ray and SZ scaling relations.

Cosmological Forecasts from a Combination of Cluster Weak Lensing, and Cluster-Galaxy and Galaxy-Galaxy Projected Correlation Functions

33

Andreas Salcedo • The Ohio State University

Cluster weak lensing is one of the most sensitive probes of cosmology, particularly the amplitude of matter clustering σ_8 and matter density parameter Ω_m . The main nuisance parameter in a cluster weak lensing

Andreas Salcedo • The Ohio State University

cosmological analysis is the scatter between the true halo mass and the relevant cluster observable, denoted $\sigma_{\ln M_c}$. We show that combining cluster weak lensing $\Delta\Sigma$ with the projected cluster-galaxy cross-correlation function $w_{p,cg}$ and galaxy-galaxy auto-correlation function $w_{p,gg}$ can be used to break the σ_8 - $\sigma_{\ln M_c}$ degeneracy and produce tight, percent-level constraints on σ_8 . Using a grid of cosmological N-body simulations, we compute derivatives of $\Delta\Sigma$, $w_{p,cg}$, and $w_{p,gg}$ with respect to halo occupation distribution (HOD) parameters, cosmological parameters σ_8 and Ω_m and the cluster mass-observable scatter $\sigma_{\ln M_c}$. We also compute covariance matrices motivated by the properties of the DES cluster and weak lensing survey and the BOSS CMASS galaxy redshift survey. For our fiducial scenario combining $\Delta\Sigma$, $w_{p,cg}$, and $w_{p,gg}$ measured over 0.3-30.0 Mpc/h we forecast a 2.2% constraint on σ_8 while marginalizing over Ω_m . We further investigate the contributions to this constraint from different combinations of our observables at large ($r_p > 3.0$ Mpc/h) and small ($r_p < 3.0$ Mpc/h) scales and find that all scales of each observable contribute significantly to the tightness of the constraint. Given accurate modeling, percent level constraints on σ_8 are achievable with currently available datasets such as those from the Dark Energy Survey.

Constraints on dark energy and modified gravity from combined large-scale structure probes

Alessio Spurio Mancini • KICC, University of Cambridge

The main goal of current and future cosmological surveys is to use multiple probes to investigate the true nature of cosmic acceleration. These joint multi-probe analyses promise to tighten considerably the constraints achievable on dark energy and modified gravity models that could be responsible for cosmic acceleration. However, the vast amount of existing models poses serious computational and statistical challenges to the analysis of cosmological surveys. In my poster I will show how combinations of different cosmological datasets can be used to place constraints on a large number of theoretical options with reduced computational effort. I will present cosmological constraints obtained from a combined analysis of weak gravitational lensing, galaxy-galaxy lensing and galaxy clustering from the Kilo-Degree Survey (KiDS) and the Galaxy And Mass Assembly (GAMA) survey, including all the cross-correlations between the different probes. This analysis places constraints on the Horndeski class of dark energy and modified gravity models, which includes the majority of extensions to Λ CDM. Analysing the KiDS and GAMA datasets in Horndeski gravity rather than in Λ CDM significantly reduces the long-standing tension between the cosmological model favoured by these large-scale structure surveys and the best-fitting parameters from Planck measurements of the Cosmic Microwave Background (CMB). I will conclude with a look at how constraints on the large Horndeski class of dark energy and modified gravity models can be improved and maximised with future Stage IV cosmological surveys.

Investigating the Effects a Running Scalar Spectral Index has on Large Scale Structure

35

Sam Stafford • Astrophysics Research Institute Liverpool John Moores University

The standard 6 free-parameters of the Λ CDM model have been measured with unprecedented precision with the recent culmination of the Planck mission. However, this does not mean that extensions/modifications to this model are ruled out, with there being current ongoing research into the likes of warm dark matter, modified gravity, massive neutrinos and dynamical dark energy. This presentation will focus on another extension to this model, in the form of a running scalar spectral index. The scalar spectral index of the primordial matter power spectrum n_s is currently measured to be 1 at greater than 5σ accuracy, a result directly predicted by the theory of inflation. However, in the Λ CDM model, the value for n_s is held fixed across all k scales, whereas inflation predicts that n_s should vary with scale. This variation with scale is contained in the parameter α_s which would be an addition to the current 6 free-parameters of the standard model, with the magnitude of this parameter dependent on the model of inflation. This presentation will focus on the effects a cosmology with α_s as a free parameter has on the large-scale structure seen in the Universe today, alongside its effects on certain dark matter halo properties. This has been investigated using the BAHAMAS suite of large-volume hydrodynamical simulations, with a running spectral index imprinted into the initial conditions of the simulations. Furthermore, these simulations allow us to test the combination and separability of the effects of feedback and α_s on large-scale structure.

Blandford-Znajek jets in galaxy formation simulations: A new sub-grid model for AGN feedback

36

Rosie Talbot • IoA, University of Cambridge

X-ray observations indicate that a significant fraction of galaxy clusters have short central cooling times. The degree of star formation and amount of cold gas that should then be present is not observed, however, implying that heating mechanisms are at work. Feedback from the central AGN, in the form of relativistic jets, is expected to play a dominant role here, however the relative importance of mechanisms through which the feedback energy couples to the ICM is still an open question. The complex nature of the interactions between the physical processes manifest in these clusters makes analytic models intractable. This puts galaxy formation simulations in a unique position as they provide insight into how heating and cooling are regulated by AGN jet feedback in a realistic environment. The scales on which the relevant processes act, however, span many orders

Blandford-Znajek jets in galaxy formation simulations: A new sub-grid model for AGN feedback *continued...*

36

Rosie Talbot • IoA, University of Cambridge

of magnitude. Jets are launched close to the BH horizon and propagate to large distances. Gas is funnelled in from the ICM where, ultimately, it is micro-scale processes in the accretion disc that determine the rate at which this gas feeds the BH. The dynamic range required to simulate this from first-principles is therefore computationally unfeasible making it necessary to invoke so-called "sub-grid" models. In our recent work (Fiacconi et. al. (2018)) we have incorporated a new AGN accretion model into the moving-mesh code AREPO whereby super-Lagrangian refinement techniques allow mass and angular momentum flows to be followed all the way from galaxy scales down to the outer edge of the accretion disc. The BH mass and spin are then able to be tracked self-consistently by coupling this with a sub-grid thin α -disc. We have further developed an AGN jet model (Bourne et. al. (2017, 2019)) which also utilises super-Lagrangian refinement, here enabling the injection of the jet on parsec scales and its subsequent evolution to be followed to hundreds of kiloparsecs. We now use these models as a framework to couple the jet to the BH spin, taking advantage of the Blandford-Znajek mechanism to self-consistently predict its power. So, for the first time, we are in a position to investigate how feedback from a BZ jet affects structure on cluster scales. Here I present our first results in which we tested this novel AGN jet feedback model in a circumnuclear disc, accurately following the evolution of the sub-grid accretion disc, the BH mass and spin as well as the propagation of the jet.

Developing a unified pipeline for large-scale structure data analysis with angular power spectra: the importance of redshift-space distortions for galaxy number counts

37

Konstantinos Tanidis • University of Turin

We develop a cosmological parameter estimation code for (tomographic) angular power spectra analyses of galaxy number counts, for which we include, for the first time, redshift-space distortions (RSD) in the Limber approximation. This allows for a speed-up in computation time, and we emphasise that only angular scales where the Limber approximation is valid are included in our analysis. Our main result shows that a correct modelling of RSD is crucial not to bias cosmological parameter estimation. This happens not only for spectroscopy-detected galaxies, but even in the case of galaxy surveys with photometric redshift estimates. Moreover, a correct implementation of RSD is especially valuable in alleviating the degeneracy between the amplitude of the underlying matter power spectrum and the galaxy bias. We argue that our findings are particularly relevant for present and planned observational campaigns, such as the Euclid satellite or the Square Kilometre Array, which aim at studying the cosmic large-scale structure and trace its growth over a wide range of redshifts and scales.

Luca Tortorelli • ETH Zurich

The galaxy Luminosity Function (LF) is a key observable not only for galaxy formation and evolution studies, but it has a dominant role for cosmology too, since it holds fundamental information about the power spectrum of primordial density fluctuations. Here, we propose an innovative technique to forward model wide-field broad and narrow-band galaxy surveys, using our fast image simulator (UFig, Berge+13) and consequently measure the LF of galaxies. Relying on the method described in Herbel+ 2017, we use Approximate Bayesian Computation (ABC) to adjust the galaxy population model parameters of the simulations to match the observations from a range of imaging and spectroscopic surveys such as CFHTLS, Subaru-HSC and PAUS (Tortorelli+ 2018, JCAP 11, 035). By minimizing the distance between the datasets based on a Random Forest Classifier, we can obtain constraints on the LF of blue and red galaxies as a function of redshift, as well as other galaxy physical properties, without the limitations coming from e.g., the determination of individual galaxies photometric redshifts. Furthermore, to validate our results and test the goodness of the cosmological applications, we compared the redshift distributions for real data and for posterior sample simulations. We forward modeled the VVDS Wide and Deep surveys and we then compared the family of $n(z)$ from our ABC posterior samples with those from the official VVDS catalogues, finding very good agreement of the redshift distributions.

Future constraints on modified gravity from redshift space distortions

Jan-Albert Viljoen • University of Western Cape

Different gravitational theories can be compared by looking at the growth rate of large-scale structure formation, as measured via redshift space distortions. Next-generation spectroscopic galaxy surveys over huge volumes of the Universe (such as Euclid, SKA and DESI), are expected to deliver high-precision measurements of the growth index. We forecast these constraints, using the galaxy angular power spectrum. This allows us to fully exploit the spectroscopic accuracy by using very thin redshift bins. We further study binning strategies to maximize the constraining power of the surveys. In addition, the angular power spectrum naturally includes wide- angle and cross-bin correlations, and does not require Alcock-Paczynski corrections. We also discuss possible improvements from combining overlapping surveys via the multi-tracer method.

Lewis Weinberger • IoA, University of Cambridge

The evolution of Lyman- α emitters (LAEs) is an excellent probe of the progress of cosmic reionization, allowing us to constrain the neutral fraction of the IGM. Observations of this type of emission line galaxies at high redshifts can be analysed statistically, calculating properties such as luminosity functions and clustering, that can then be compared with theoretical models to understand how this final phase transition of the universe is proceeding. In order to disentangle the attenuation of the IGM, models must be calibrated to match the variety of observational datasets available at lower redshifts $z < 6$. In this poster I will discuss the construction of models which are calibrated at $z = 5.7$ to be consistent with the observed luminosity function, EW distribution and clustering. This calibration alone suggests a duty-cycle of the UV output for high- z galaxies. Having calibrated such models we can then impose a reionization history and calculate how this will affect the visibility of LAEs beyond $z > 6$. Amongst other results I will also discuss the role that a partially-neutral CGM can play in complicating Lyman- α attenuation.

Cosmological constraints from observations of extragalactic background light γ -ray attenuation

Radoslaw Wojtak • University of Copenhagen

γ -ray photons emitted from extragalactic sources can annihilate with photons of extragalactic background light. The effect can be measured as an energy-dependent attenuation of γ -ray flux and it is now well determined from Fermi-LAT and ground-based Cherenkov telescope observations of blazars in a wide range of redshifts. Since γ -ray attenuation scales with distance to the source, the measurements convey information on cosmological model through the standard distance-redshift relations. I will present and discuss the first constraints on the Hubble constant and the matter density parameter from the current measurements of γ -ray attenuation. The obtained cosmological parameters are in overall agreement with the Planck flat Λ CDM cosmological model. However, the constraints -- currently limited primarily by systematic errors -- are not strong enough to provide a significant argument which could corroborate or question the tension between the Hubble constant inferred from the Planck observations and its low-redshift counterpart derived from type-Ia supernovae observations with distance calibrations employing Cepheids. I will discuss perspectives for the future development and the potential of using the measurements to shed more light on the tension between low- and high-redshift determinations of the Hubble constant. The results are reported in preprint arXiv:1903.12097.

Temperature evolution of the IGM species with interactions during the Epoch of Reionization

42

Chenxiao Zeng • The Ohio State University

The epoch of reionization (EOR) marks the end of the cosmic dawn and the beginning of structure formation in the universe. The impulsive ionization fronts heat and ionize the gas within the reionization bubbles. The temperature during this transition is a key yet uncertain ingredient in the current models. Here we present a new model of the temperature evolution for the ionization front by adding non-equilibrium effects. Particularly, we include the interactions of the major species (e^- , H I, H II, He I, and He II) in pairs. For a better step-size control when solving the stiff equations describing the energy transfer rate between different species, we implement a semi-implicit integration method and construct the corresponding energy transfer rate matrix.

Cosmology with galaxy clusters and CMB lensing: cosmological constraints from Planck galaxy clusters with CMB lensing mass bias calibration

43

Inigo Zubeldia • IoA, University of Cambridge

Planck galaxy clusters with CMB lensing mass bias calibration as demonstrated by Planck, galaxy clusters detected via the Sunyaev–Zel'dovich (SZ) effect offer a powerful way to constrain cosmological parameters such as Ω_m and σ_8 . Determining the absolute cluster mass scale is, however, difficult, and some recent calibrations have yielded cosmological constraints in apparent tension with constraints in the Λ CDM model derived from the power spectra of the primary CMB anisotropies. As demonstrated by Planck, galaxy clusters detected via the Sunyaev–Zel'dovich (SZ) effect offer a powerful way to constrain cosmological parameters such as Ω_m and σ_8 . Determining the absolute cluster mass scale is, however, difficult, and some recent calibrations have yielded cosmological constraints in apparent tension with constraints in the Λ CDM model derived from the power spectra of the primary CMB anisotropies. In this poster I will present a new cosmological analysis of the galaxy clusters in the Planck MMF3 cosmology sample with a CMB lensing calibration of the cluster masses (Zubeldia & Challinor, in prep.). In this analysis we find $\Omega_m = 0.33 \pm 0.02$, $\sigma_8 = 0.76 \pm 0.04$, and $1 - b_{SZ} = 0.71 \pm 0.10$, where the mass bias factor $1 - b_{SZ}$ relates cluster mass to the SZ mass that appears in the X-ray-calibrated cluster scaling relations, thus finding no evidence for tension with the Planck primary CMB constraints on Λ CDM model parameters.

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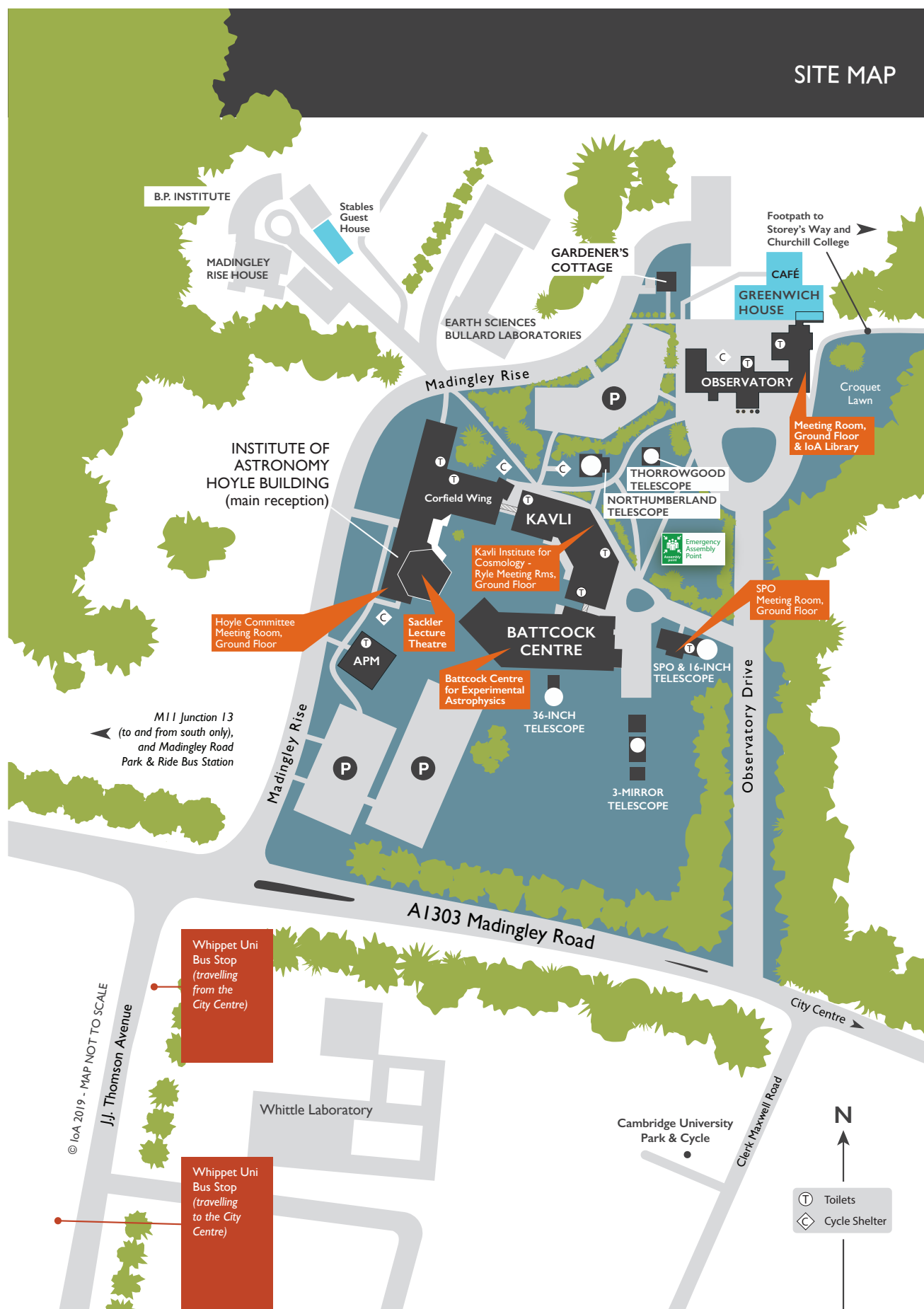
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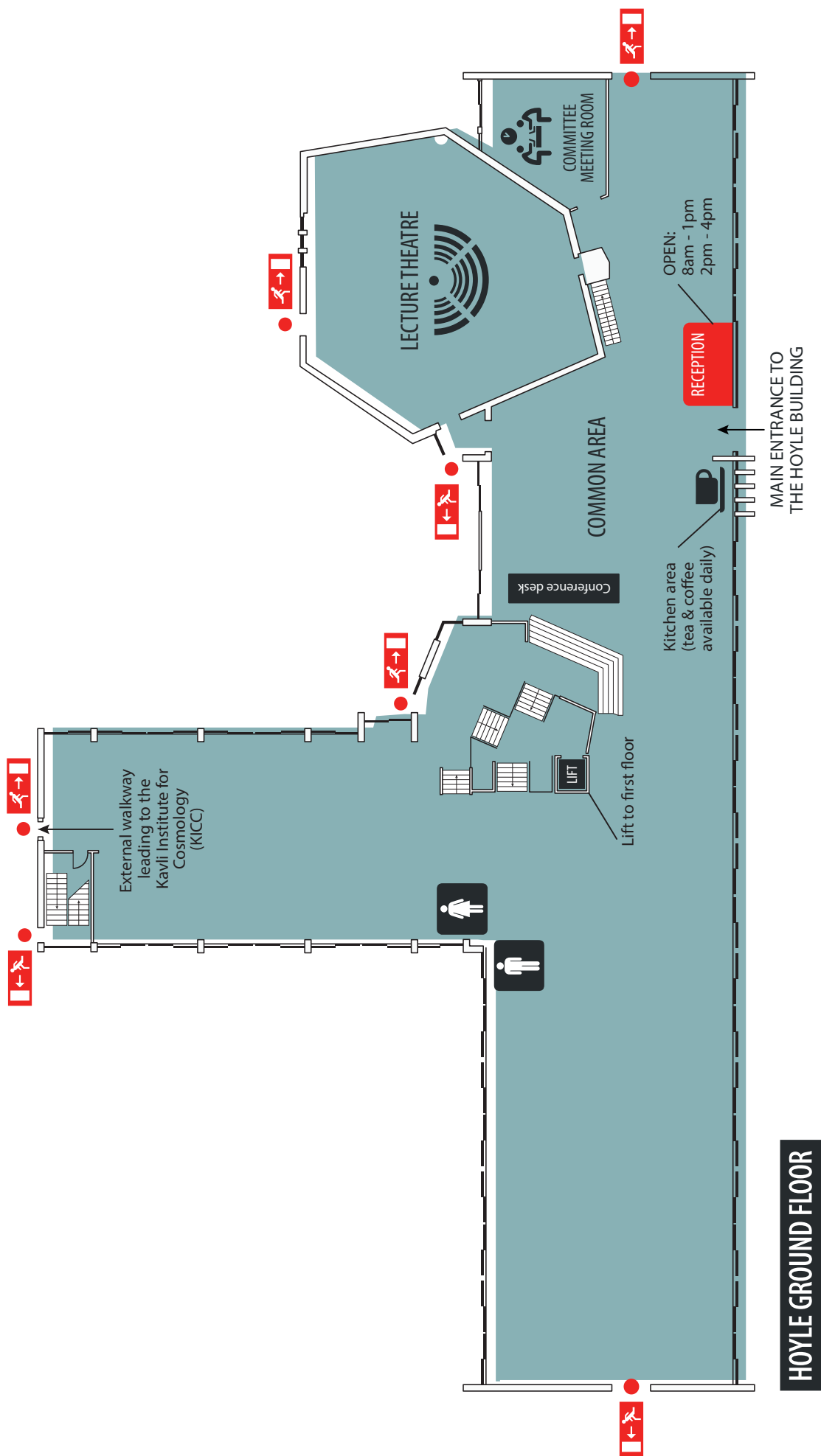
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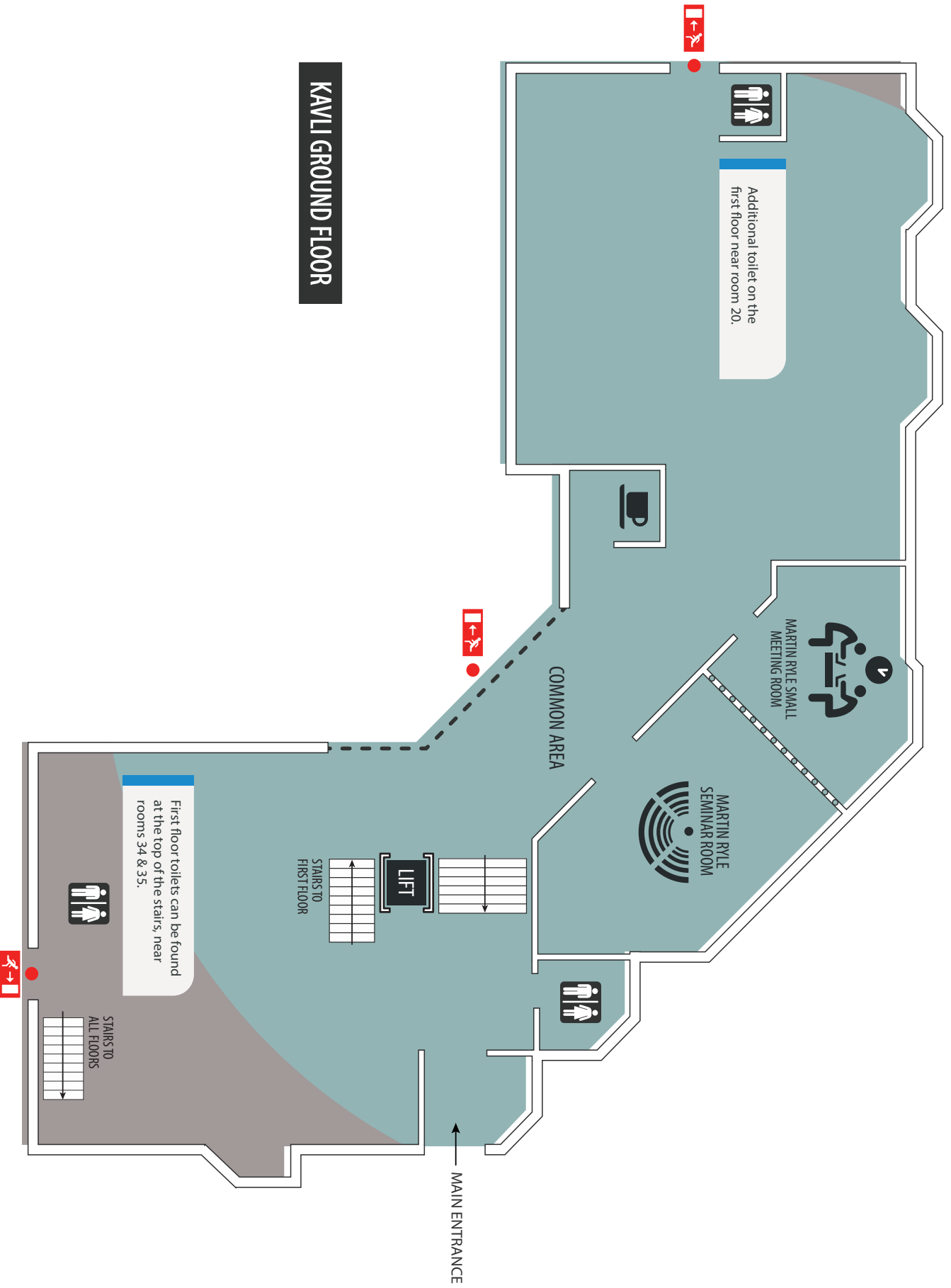
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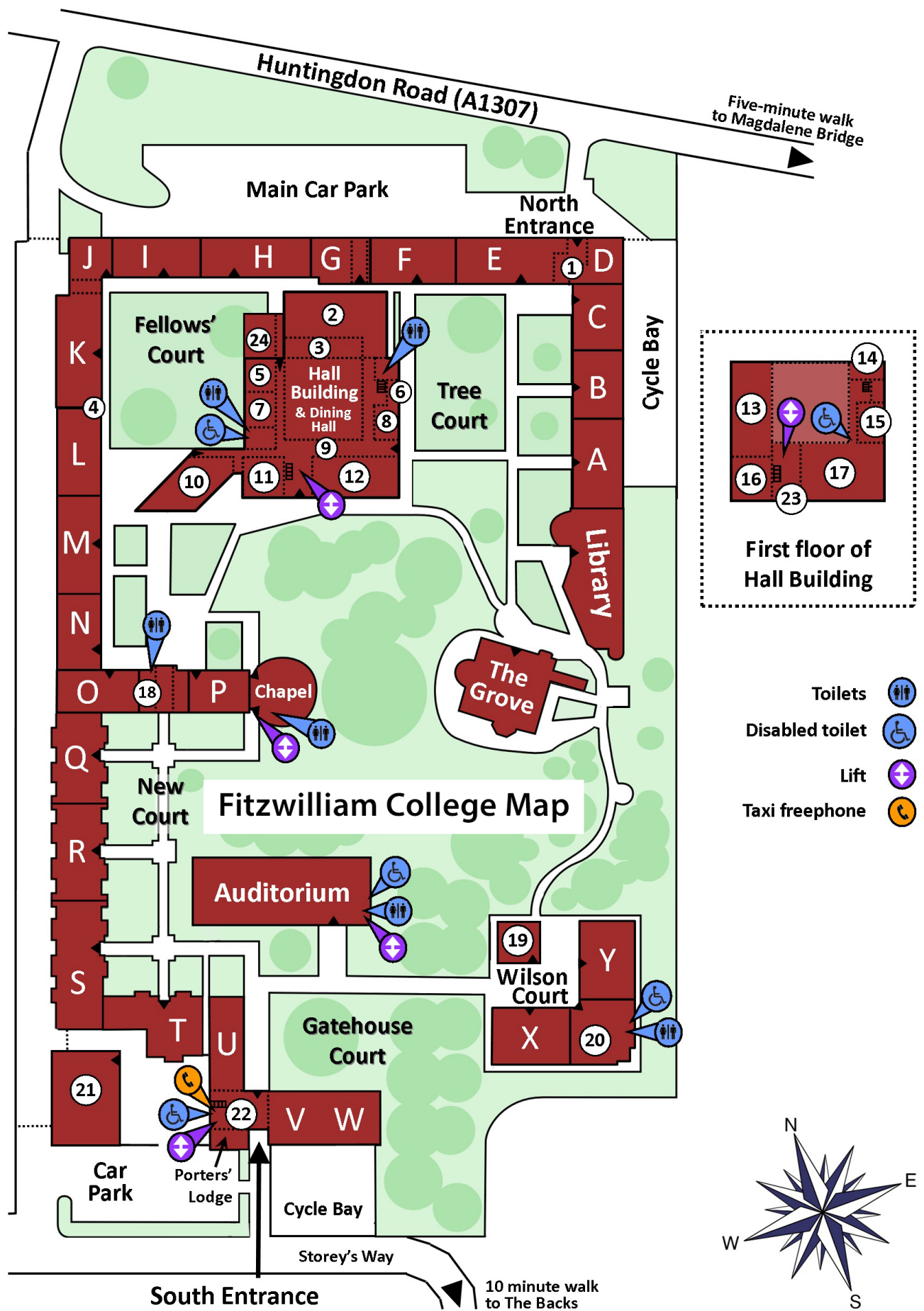
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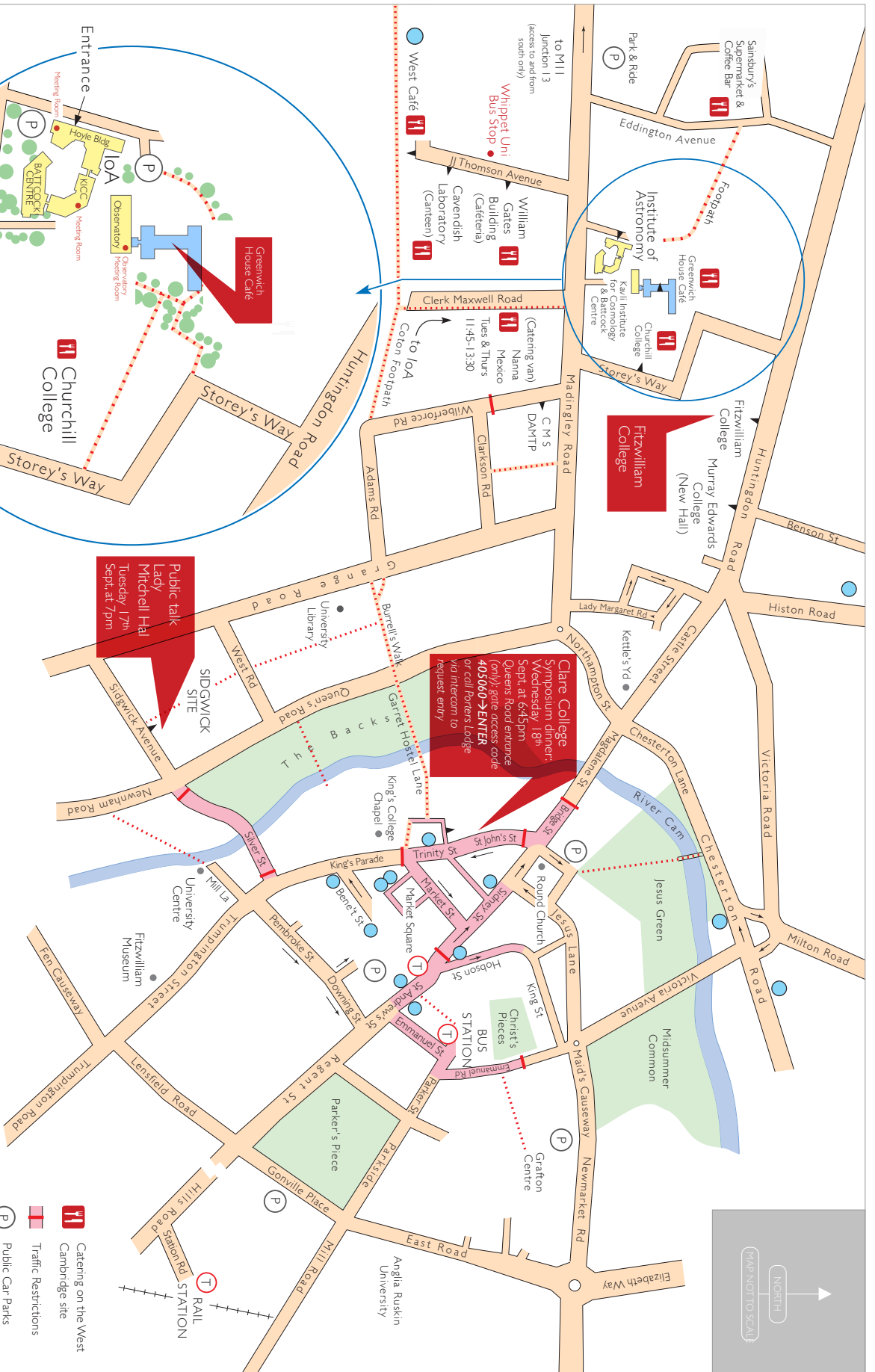




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