Ben Hoyle

Personal Information
Nationality: British
DOB: 12/12/1979

http://icc.ub.edu/~hoyleb/

Contact Details
+34 697 400 785
Fernandez Duro 30
Barcelona, 08014, Spain
benhoyle1212@gmail.com

Education & Qualifications

- **The University of Barcelona** — Barcelona, Spain.
  Post Doctoral Research Associate — *Oct 2009 - present*
  - Galaxy and galaxy cluster research. Comparing data with theory and simulations.
- **The University of Portsmouth** — Portsmouth, U.K.
  Galaxy Zoo & Google Research Associate — *Jan 2009 - Oct 2009*
  - Exploit existing Google Maps API and Earth technologies with Galaxy Zoo I & II data.
- **The University of Portsmouth** — Portsmouth, U.K.
  PhD Cosmology and Astrophysics — *Oct. 2005 - June 2009*
  - PhD Thesis: Constraining Cosmological Parameters using Clusters of Galaxies.
- **The University of Exeter** — Exeter, U.K.
  MPhys Theoretical Physics with North American Study 2:1 — *Oct 1998 - Jun 2002*
  - Master Thesis: Chaotic ferning patterns in glycoaminoglycans: Their structure and form.
- **University of New Mexico** — Albuquerque, N.M., U.S.A.
  Year abroad studying Theoretical Physics — *Aug 2000 - May 2001*
- **North Devon College** — Barnstaple, Devon, U.K.
  Advanced levels — *Aug 1996 - June 1998*
  - Mathematics, Further Mathematics, Physics, [ABB].

Teaching Experience

University of Barcelona — Barcelona, Spain
IDL & MySQL course lecturer — *June 2010*
- Prepared and presented introductory courses to IDL and web-based MySQL data retrieval.

Intercultura — Heredia, Costa Rica
Free lance English teacher — *Sept. - Dec. 2004*
- Substitute English teacher, while studying Spanish.

Akademie fuer Fremdsprache — Berlin, Germany
Free lance English teacher — *Sept. 2002 - May 2004*
- Teaching general and technical English at levels from beginner to advanced with varying group sizes for adults.

The Oxford College — Barcelona, Spain
English teaching qualification and experience — *August 2002*
- Trinity Cert. TESOL qualification.

Skills & Relevant Experience

Seven years of cosmology and astrophysics research experience including:

Expert IDL programmer.
Coding theoretical predictions.
Manipulating and cross correlating massive data sets.
Regular SDSS Casjobs, VESPA, Millennium Simulation user.
Experienced CAMB user.
Active member of the XMM Cluster Survey.
In collaboration with Bootes HST.

Web design experience using:
PhP, MySQL, JavaScript, CSS & HTML.
Public outreach.
LoC member for the ICG '*Modified Gravity on Cosmological Scales*' workshop.
Observing experience at NOAO Kitt Peak, A.Z
Proficient in German and Spanish.

First Author & Notable Publications

'The fraction of early-type galaxies in low redshift groups and clusters of galaxies ' Ben Hoyle, Robert C. Nichol, Karen. L. Masters, Raul Jimenez, Steven P Bamford. Submitted to MNRAS/ arXiv:1110.6320

'A critical analysis of high-redshift, massive, X-ray selected galaxy clusters: I.' Ben Hoyle, Raul Jimenez, Licia Verde, Shaun Hotchkiss. Submitted to JCAP/ arXiv:1108.5458

'Implications of multiple high-redshift galaxy clusters.' Ben Hoyle, Raul Jimenez, Licia Verde accepted in PRD/arXiv:1009.3884. Citation count 23

'The XCS Active Galactic Nuclei and Starburst Galaxies in XMMXCS J2215.9-1738 at z=1.46.' Matt Hilton, Ed Lloyd-Davies, S.Adam Stanford, John P. Stott, Chris A. Collins, A.Kathy Romer, Mark Hosmer, **Ben Hoyle**, Scott T. Kay, Andrew R. Liddle, Nicola Mehrtens, Christopher J. Miller, Martin Sahlen, Pedro T.P. Viana. Accepted in ApJ/arXiv:1005.4692. Citation count 26

'Early assembly of the most massive galaxies' Chris A. Collins (LJMU), John P. Stott, Matt Hilton, Scott T. Kay, S. Adam Stanford, Michael Davidson, Mark Hosmer, **Ben Hoyle**, Andrew Liddle, Ed Lloyd-Davies, Robert G. Mann, Nicola Mehrtens, Christopher J. Miller, Robert C. Nichol, A. Kathy Romer, Martin Sahlen, Pedro T. P. Viana, Michael J. West. Accepted in Nature/arXiv:0904.0006. Citation count 35

'Galaxy Morphologies and the Color-Magnitude Relation in XMMXCS J2215.9-1738 at z=1.46' Matt Hilton, S. Adam Stanford, John P. Stott, Chris A. Collins, **Ben Hoyle**, Michael Davidson, Mark Hosmer, Scott T. Kay, Andrew R. Liddle, Ed Lloyd-Davies, Robert G. Mann, Nicola Mehrtens, Christopher J. Miller, Robert C. Nichol, A. Kathy Romer, Kivanc Sabirli, Martin Sahlen, Pedro T. P. Viana, Michael J. West, Kyle Barbary, Kyle S. Dawson, Joshua Meyers, Saul Perlmutter, David Rubin, Nao Suzuki. Accepted in ApJ/arXiv:0903.1731. Citation count 24

'Galaxy Zoo: Bar Lengths in Nearby Disk Galaxies.' Ben Hoyle, Karen.L. Masters, Robert C. Nichol, Edward M. Edmondson, Arfon M. Smith, Chris Lintott, Ryan Scranton, Steven Bamford, Kevin Schawinski, Daniel Thomas. Accepted in MNRAS/arXiv:1104.5394. Citation count 8

'Does stellar mass assembly history vary with environment?' Ben Hoyle, Raul Jimenez, Licia Verde. Accepted in MNRAS/arXiv:1101.5532. Citation count 1

'Will Multiple Probes of Dark Energy find Modified Gravity?' Charles Shapiro , Scott Dodelson, **Ben Hoyle**, Lado Samushia, Brenna Flaugher. Accepted in PRD/arXiv:1004.4810. Citation count 8

Selected Talks

'Removing biases in the analysis of high z galaxy clusters' The University of Stockholm
Stockholm, Sweden *Sept 13th 2011*

'Cosmology and biases with high redshift galaxy clusters' The University of Cape Town
Cape Town, South Africa *August 28th 2011*

'High redshift clusters and statistical bias' SZ clusters
Santander, Spain *June 28th 2011*

'Non-Gaussianity and high redshift clusters' PONT
Avingnon, France *March 21st 2011*

'High redshift galaxy clusters' U.K. National Astronomical Meeting.
Llandudno, Wales *March 18th 2011*

'Non-Gaussianity to explain high-redshift, massive galaxy clusters'
University of Helsinki *March 12th 2011*

'Non-Gaussianity and high-redshift, massive galaxy clusters'
University of Geneva *March 5th 2011*

'Implementing Google technologies with Galaxy Zoo' Galaxy Zoo team meeting
The Royal Greenwich Observatory, U.K *Aug 17th 2009*

'The XMM Cluster Survey' U.K. National Astronomical Meeting
Queens Uni Belfast, Ireland *March 3rd 2008*

Public Outreach

Sept. 2009 Wrote and directed GoogleEarth tours of Galaxy Zoo galaxies and clusters, for the general public and a galaxy-alphabet learning tool for young children.

Aug. 2009 Tutored a 17y old work experience student at the ICG. We examined the latest results of classifications from GalaxyZoo2.

June 2009 Tutored a 15y old work experience student at the ICG. We used Google Earth as a medium to examine developments in exoplanet research.

July 2008 Tutored a 17y old work experience student at the ICG. We looked at cluster mass reconstruction using strongly lensed images.

July 2007 Tutored a 16y old work experience student at the ICG. Project examined the need for dark matter and energy to explain observations.

Feb. 2007 Talk at a local secondary school about life as a physicist.

Dec. 2006 Two day demonstration in the Institute of Physics 'Lab in a Lorry'. Explaining physical processes to groups of school children.

Research Interests

Cosmological constraints from clusters.
Galaxy properties with evolution/environment
Cross correlating massive data sets.
Tests of Modified Gravity.
Mass measurements of galaxy clusters.
Gravitational lensing.
Cosmological parameter estimation.
Statistics in Cosmology.

References

Prof. Licia Verde
liciaverde@icc.ub.edu
The ICC,
University of Barcelona,
Barcelona,
08028
Spain

Prof. Bob Nichol
bob.nichol@port.ac.uk
The ICG,
University of Portsmouth,
Portsmouth,
PO1 2EG
UK

Prof. Raul Jimenez
raul.jimenez@icc.ub.edu
The ICC,
University of Barcelona,
Barcelona,
08028
Spain

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Personal Information
Nationality: British
DOB: 12/12/1979

http://icc.ub.edu/~hoyleb/

Contact Details
+34 697 400 785
Fernandez Duro 30
Barcelona, 08014, Spain
benhoyle1212@gmail.com

Research Statement

Clusters of Galaxies

The cluster mass function measures the number of clusters per unit mass, per unit solid angle as a function of redshift, and is not only dependent on cosmological parameters (Press & Schechter, 1974; Sheth & Tormen, 1999) but also on the theory of gravity (Schäfer & Koyama, 2008; Song & Koyama, 2009; Kobayashi & Tashiro, 2009). To use clusters for such analysis, one needs massive data sets with precisely measured masses over a broad redshift range with well understood completeness. My PhD thesis was dedicated to measuring optically derived mass proxies of optically and X-ray selected clusters using the weak lensing magnification bias and X-ray astrophysics, and building a mass function to test cosmological models (e.g., Shapiro et al., 2010)

Since then my attention has turned to high redshift ($z > 1.0$) galaxy clusters (Hoyle et al., 2011), which appeared to be causing tension with ΛCDM assuming WMAP5 priors on cosmological parameters, of which we examined the effect of non-Gaussianities of the initial density perturbations as a possible explanation. This work spurred a fury of ongoing activity within the community (e.g., Mortonson et al., 2011; Enqvist et al., 2011; Baldi & Pettorino, 2011; Hotchkiss, 2011; Hoyle et al., 2011; Harrison & Coles, 2011; Chongchitnan & Silk, 2011).

It turns out that the analysis which had been performed by many groups (including myself) was biased, because fair comparisons with simulations had not been made. These biases were addressed in these papers, Hotchkiss (2011); Hoyle et al. (2011). However, these biases could only be removed by assuming some form for the unknown, and very complicated, selection function of the high redshift surveys. I am currently developing a technique which allows more realistic assumptions about the survey geometry to be imposed, while still providing information about cosmological parameters (Hoyle et al, in prep). Inferring information about cosmological parameters for surveys with unknown selection functions, will become increasingly important in the near future, e.g., with the launch of eROSITA and at the highest redshifts for future optical surveys where completeness may be difficult to model, e.g., DES, Pan-Starrs. I would like to continue to refine these robust statistical techniques developed in Hoyle et al. (2011) and apply them to current and future data.

Weak lensing magnification bias of SDSS galaxies and quasars

The weak lensing magnification bias distorts the number density of distant (background) galaxies, through the gravitational lensing by lower redshift (foreground) galaxies, groups, and clusters of galaxies. Unlike gravitational shear, which distorts the shapes of background galaxies, the magnification bias is typically measured using point sources, such as high redshift quasars. The effect is two fold, the number density of background galaxies become diluted due the stretching of the solid angle around the foreground galaxies, but conversely, the background galaxy flux becomes magnified which can increase the number density because lower flux objects can be observed. Whether the net effect for any particular quasar is positive or negative depends on the shape of the averaged background quasar luminosity function.

This signal was convincingly detected at a signal-to-noise of 8 sigma by Scranton (2005) who used galaxy positions and colors from the Sloan Digital Sky Survey (York et al., 2000, hereafter SDSS) Data Release 3 (Abazajian, 2005, DR3), which imaged approximately 3800 sq. deg. of the northern sky. Subsequent

analysis has been performed on the same data set utilising the high signal-to-noise of this method, e.g., (Menard et al., 2009) who constrained the amount of interstellar dust. Amazingly however, Scranton (2005) did not fit a cosmological model or parameters to the signal. More recently, Hildebrandt et al. (2009) used high redshift lyman break galaxies identified in CFHTLS imagining (Erben et al., 2009), to also detect the magnification bias signal, but also have not performed fits to cosmological parameters.

Extending this analysis to the SDSS DR7 (Abazajian et al., 2009) and SDSS3 which covers $\sim 14,000$ sq. deg. of the sky, will increase the available area by a factor of 4, which will increase the signal-to-noise of this measurement by a factor of ~ 2. I would like to extend the results of Scranton (2005) by fitting the signal for cosmological parameters (the signal is sensitive to the parameters; bias, σ_8 , Ω_m). With such a large signal-to-noise, it should be possible to divide the high redshift quasar sources into bins of redshift, which will allow me to measure the evolution of geometry. Furthermore, by dividing the low redshift galaxy lenses into volume limited samples of low redshift galaxies (e.g., Ross et al., 2010), we will be able to measure the growth of structure through the evolution of the bias between galaxies and dark matter. This independent measurement of both growth and geometry is a test of theories of modified gravity (e.g., see Song & Koyama, 2009). Additionally, by calculating the auto correlation function of the foreground galaxies (similar to Ross et al., 2010), we will be able to independently constrain galaxy bias, allowing us to break degeneracies between cosmological parameters.

Bar structures in disk galaxies.

As part of a Google funded position at the ICG in 2009, I created a website to quantify the size and shape of galactic bars in low redshift galaxies, first identified as containing a bar by the Galaxy Zoo II (Lintott et al. in prep.), project. The site dynamically linked GoogleMaps images of SDSS galaxies, with purpose built JavaScript tools to measure the lengths and widths of galactic bars (see `http://www.icg.port.ac.uk/~hoyleb/bars/` for a working example). The result of the project was that each galaxy had bar lengths and widths measurements by at least six independent observers. This constituted the largest sample of bar length measurements by two orders of magnitude at that time, and is still the largest sample.

Realistic simulations of barred galaxies, are computationally expensive to perform due to the resolution needed to obtain a bar, instabilities and the effects of gas cooling flows and feedback processes, e.g., see Scannapieco et al. (2010) for a sample of 5 barred galaxy simulations. We compared these high resolution simulations, and other simulations (e.g., Athanassoula, 2003; Athanassoula et al., 2009), with the findings using the above observational project in Hoyle et al. (2010).

This work still remains the state of the art, and I would like to continue to examine the effects of bars on the host galaxy's properties. For example, we found that red galaxies host longer bars than blue galaxies, and that the bars are more red in colour than the disk. Is the colour metamorphism a gradual process, starting from the centre of the bar, or a process which affects the entire bar simultaneously? These questions can be answered by examining the variation of the bar colour across the length and width of the bar, as a function of galaxy colour, disk colour and other bar properties. Such an analysis may lead to an understanding of the mechanism which affects global galaxy colour. Currently, high redshift Hubble Space Telescope images of galaxies are being examined by the Galaxy Zoo project. A marriage of high and low redshift samples of barred galaxies will allow us to examine correlations of bars and environment (e.g., Masters et al., 2011; Skibba et al., 2011) over the history of the Universe.

Ben Hoyle, November 2011

References

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Ben Hoyle

Personal Information
Nationality: British
DOB: 12/12/1979

http://icc.ub.edu/~hoyleb/

Contact Details
+34 697 400 785
Fernandez Duro 30
Barcelona, 08014, Spain
benhoyle1212@googlemail.com

Full List of Publications

'Galaxy Zoo: The Environmental Dependence of Bars and Bulges in Disc Galaxies Ramin A. Skibba, Karen L. Masters, Robert C. Nichol, Idit Zehavi, **Ben Hoyle**, Edward M. Edmondson, Steven P. Bamford, Carolin N. Cardamone, William C. Keel, Chris Lintott, Kevin Schawinski, Michael J. Williams Submitted to MNRAS/arXiv:1111.0969

'The fraction of early-type galaxies in low redshift groups and clusters of galaxies ' Ben Hoyle, Robert C. Nichol, Karen. L. Masters, Raul Jimenez, Steven P Bamford. Submitted to MNRAS/ arXiv:1110.6320

'The similar stellar populations of quiescent spiral and elliptical galaxies' Aday R. Robaina, **Ben Hoyle**, Anna Gallazzi, Raul Jimenez, Arjen van der Wel, Licia Verde. Submitted to MNRAS/ arXiv:1109.5352

'The XCS: Predicted overlap with the Planck Cluster Catalogue' Pedro T. P. Viana, Antnio da Silva, Elsa P. R. G. Ramos, Andrew R. Liddle, E. J. Lloyd-Davies, A. Kathy Romer, Scott T. Kay, Chris A. Collins, Matt Hilton, Mark Hosmer, **Ben Hoyle**, Nicola Mehrtens, Christopher J. Miller, Martin Sahln, S. Adam Stanford, John P. Stott. Submitted to MNRAS/ arXiv:1109.1828

'A critical analysis of high-redshift, massive, X-ray selected galaxy clusters: I.' Ben Hoyle, Raul Jimenez, Licia Verde, Shaun Hotchkiss. Submitted to JCAP/ arXiv:1108.5458

'The XMM Cluster Survey: Optical analysis methodology and the first data release.' Nicola Mehrtens, A.Kathy Romer, E.J. Lloyd-Davies, Matt Hilton, Christopher J. Miller, S.A. Stanford, Mark Hosmer, **Ben Hoyle**, Chris A. Collins, Andrew R. Liddle, Pedro T.P. Viana, Robert C. Nichol, John P. Stott, E.Naomi Dubois, Scott T. Kay, Martin Sahlen, Owain Young, C.J. Short, L. Christodoulou, William A. Watson, Michael Davidson, Craig D. Harrison, Leon Baruah, Mathew Smith, Claire Burke, Paul-James Deadman, Philip J. Rooney, Edward M. Edmondson, Michael West, Heather C. Campbell, Alastair C. Edge, Robert G. Mann, David Wake, Christophe Benoist, Luiz da Costa, Marcio A.G. Maia, Ricardo Ogando, submitted to MNRAS/arXiv:1106.3056

'Galaxy Zoo: Bar Lengths in Nearby Disk Galaxies.' Ben Hoyle, Karen.L. Masters, Robert C. Nichol, Edward M. Edmondson, Arfon M. Smith, Chris Lintott, Ryan Scranton, Steven Bamford, Kevin Schawinski, Daniel Thomas. Accepted in MNRAS/arXiv:1104.5394

'Does stellar mass assembly history vary with environment?' Ben Hoyle, Raul Jimenez, Licia Verde. Accepted in MNRAS/arXiv:1101.5532

'The XCS: X-ray analysis methodology.' E.J. Lloyd-Davies, A.Kathy Romer, Mark Hosmer, Nicola Mehrtens, Michael Davidson, Kivanc Sabirli, Robert G. Mann, Matt Hilton, Andrew R. Liddle, Pedro T.P. Viana, Heather C. Campbell, Chris A. Collins, E.Naomi Dubois, Peter Freeman, **Ben Hoyle**, Scott T. Kay, Emma Kuwertz, Christopher J. Miller, Robert C. Nichol, Martin Sahlen, S.Adam Stanford, John P. Stott. Accepted in MNRAS/arXiv:1010.0677

'Implications of multiple high-redshift galaxy clusters.' Ben Hoyle, Raul Jimenez, Licia Verde accepted in PRD/arXiv:1009.3884

'The XCS Active Galactic Nuclei and Starburst Galaxies in XMMXCS J2215.9-1738 at z=1.46.' Matt Hilton, Ed Lloyd-Davies, S.Adam Stanford, John P. Stott, Chris A. Collins, A.Kathy Romer, Mark Hosmer, **Ben Hoyle**, Scott T. Kay, Andrew R. Liddle, Nicola Mehrtens, Christopher J. Miller, Martin Sahlen, Pedro T.P. Viana. Accepted in ApJ/arXiv:1005.4692

''The XCS: The build up of stellar mass in Brightest Cluster Galaxies at high redshift.' J.P. Stott, C.A. Collins, M. Sahlen, M. Hilton, E. Lloyd-Davies, D. Capozzi, M. Hosmer, A.R. Liddle, N. Mehrtens, C.J. Miller, A.K. Romer, S.A. Stanford, P.T.P. Viana, M. Davidson, **Ben Hoyle**, S.T. Kay, R.C. Nichol. Accepted in ApJ/arXiv:1005.4692

'Will Multiple Probes of Dark Energy find Modified Gravity?' Charles Shapiro , Scott Dodelson, **Ben Hoyle**, Lado Samushia, Brenna Flaugher. Accepted in PRD/arXiv:1004.4810

'Galaxy Zoo: Bars in Disk Galaxies.' Karen L. Masters, Robert C. Nichol, **Ben Hoyle**, Chris Lintott, Steven Bamford, Edward M. Edmondson, Lucy Fortson, William C. Keel, Kevin Schawinski, Arfon Smith, Daniel Thomas. Accepted in MNRAS/arXiv:1003.0449

'Radio Weak Gravitational Lensing with VLA and MERLIN' P. Patel, D. J. Bacon, R. J. Beswick, T. W. B. Muxlow, **Ben Hoyle**. Accepted in MNRAS/arXiv:0907.5156

'Delensing Gravitational Wave Standard Sirens with Shear and Flexion Maps' Charles Shapiro, David Bacon, Martin Hendry, **Ben Hoyle**. Accepted in MNRAS/arXiv:0907.3635

'Early assembly of the most massive galaxies' Chris A. Collins (LJMU), John P. Stott, Matt Hilton, Scott T. Kay, S. Adam Stanford, Michael Davidson, Mark Hosmer, **Ben Hoyle**, Andrew Liddle, Ed Lloyd-Davies, Robert G. Mann, Nicola Mehrtens, Christopher J. Miller, Robert C. Nichol, A. Kathy Romer, Martin Sahlen, Pedro T. P. Viana, Michael J. West. Accepted in Nature/arXiv:0904.0006

'Galaxy Morphologies and the Color-Magnitude Relation in XMMXCS J2215.9-1738 at z=1.46' Matt Hilton, S. Adam Stanford, John P. Stott, Chris A. Collins, **Ben Hoyle**, Michael Davidson, Mark Hosmer, Scott T. Kay, Andrew R. Liddle, Ed Lloyd-Davies, Robert G. Mann, Nicola Mehrtens, Christopher J. Miller, Robert C. Nichol, A. Kathy Romer, Kivanc Sabirli, Martin Sahlen, Pedro T. P. Viana, Michael J. West, Kyle Barbary, Kyle S. Dawson, Joshua Meyers, Saul Perlmutter, David Rubin, Nao Suzuki. Accepted in ApJ/arXiv:0903.1731

'The XCS: Forecasting cosmological and cluster scaling-relation parameter constraints' Martin Sahln, Pedro T. P. Viana, Andrew R. Liddle, A. Kathy Romer, Michael Davidson, Kivanc Sabirli, Ed Lloyd-Davies, Mark Hosmer, Chris A. Collins, Peter E. Freeman, Matt Hilton, **Ben Hoyle**, Scott T. Kay, Robert G. Mann, Nicola Mehrtens, Christopher J. Miller, Robert C. Nichol, S. Adam Stanford, Michael J. West. Accepted in MNRAS/arXiv:0802.4462