List of science papers – #2

full list of scientific papers based on ASTRODEEP results

UEDIN for the Astrodeep project

ASTRODEEP

"Unveiling the power of the deepest images of the Universe"

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ABSTRACT

In this document we present the publications obtained within ASTRODEEP during the period 01/01/2014 – 31/12/2014.
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Approved by: AEC
Date: 22/01/2015

Summary of Science Papers

During 2014 a substantial number of science results have been produced with the support of the ASTRODEEP project. Here we provide the title, authorship, journal reference and abstract for each paper published or submitted in 2014 that contains an explicit acknowledgement of ASTRODEEP support. These papers all present significant scientific advances based on early versions of catalogues within the key survey fields that are the focus of the ASTRODEEP project. In several cases the analysis undertaken en route to science results has revealed both the strengths and deficiencies of existing catalogues, reaffirming the central premise of ASTRODEEP that high-quality data products can only be produced and validated in conjunction with cutting-edge research.

We list first those papers that have been published in peer-reviewed journals, followed by the papers that are in press or have been submitted for publication. In total we list 29 papers. The final two papers in this list are more specifically technical in nature, reporting new outputs from ASTRODEEP that we expect to be exploited in science papers in 2015 and beyond.

Abstracts of papers published in peer-reviewed journals

A new method for classifying galaxy SEDs from multiwavelength photometry
Wild, Vivienne; Almaini, Omar; Cirasuolo, Michele; Dunlop, Jim; McLure, Ross; Bowler, Rebecca; Ferreira, Joao; Bradshaw, Emma; Chuter, Robert; Hartley, Will.
2014, MNRAS, 440, 1880
We present a new method to classify the broad-band optical–near-infrared spectral energy distributions (SEDs) of galaxies using three shape parameters (super-colours) based on a principal component analysis of model SEDs. As well as providing a compact representation of the wide variety of SED shapes, the method allows for easy visualization of information loss and biases caused by the incomplete sampling of the rest-frame SED as a function of redshift. We apply the method to galaxies in the United Kingdom Infrared Telescope Infrared Deep Sky Survey Ultra Deep Survey with $0.9 < z < 1.2$, and confirm our classifications by stacking rest-frame optical spectra for a fraction of objects in each class. As well as cleanly separating a tight red sequence from star-forming galaxies, three unusual populations are identifiable by their unique colours: very dusty star-forming galaxies with high metallicity and old mean stellar age; post-starburst galaxies which have formed $\gtrsim$10 per cent of their mass in a recent unsustained starburst event; and metal-poor quiescent dwarf galaxies. We find that quiescent galaxies account for 45 per cent of galaxies with $\log M^*/\mathrm{M}_\odot > 11$,

declining steadily to 13 per cent at $\log M^*/M_\odot = 10$. The properties and mass function of the post-starburst galaxies are consistent with a scenario in which gas-rich mergers contribute to the growth of the low- and intermediate-mass range of the red sequence.

The bright end of the galaxy luminosity function at z~7: before the onset of mass quenching?

Bowler, R. A. A.; Dunlop, J. S.; McLure, R. J.; Rogers, A. B.; McCracken, H. J.; Milvang-Jensen, B.; Furusawa, H.; Fynbo, J. P. U.; Taniguchi, Y.; Afonso, J.; Bremer ,M.,N.; Le Fevre, O.

2014, MNRAS, 440, 2810

We present the results of a new search for bright star-forming galaxies at redshift $z \simeq 7$ within the UltraVISTA second data release (DR2) and UKIDSS (UKIRT Infrared Deep Sky Survey) UDS (Ultra Deep Survey) DR10 data, which together provide 1.65 deg^2 of near-infrared imaging with overlapping optical and *Spitzer* data. Using a full photometric redshift analysis, to identify high-redshift galaxies and reject contaminants, we have selected a sample of 34 luminous ($-22.7<M\mathrm{UV}<-21.2$) galaxies with $6.5 < z < 7.5$. Crucially, the deeper imaging provided by UltraVISTA DR2 confirms all of the robust objects previously uncovered by Bowler et al., validating our selection technique. Our new expanded galaxy sample includes the most massive galaxies known at $z \simeq 7$, with $M_* \simeq 10^{10}\,\mathrm{M}_\odot$, and the majority are resolved, consistent with larger sizes ($r_{1/2} \simeq 1$–1.5 kpc) than displayed by less massive galaxies. From our final robust sample, we determine the form of the bright end of the rest-frame UV galaxy luminosity function (LF) at $z \simeq 7$, providing strong evidence that it does not decline as steeply as predicted by the Schechter-function fit to fainter data. We exclude the possibility that this is due to either gravitational lensing, or significant contamination of our galaxy sample by active galactic nuclei (AGN). Rather, our results favour a double power-law form for the galaxy LF at high redshift, or, more interestingly, an LF which simply follows the form of the dark matter halo mass function at bright magnitudes. This suggests that the physical mechanism which inhibits star formation activity in massive galaxies (i.e. AGN feedback or some other form of 'mass quenching') has yet to impact on the observable galaxy LF at $z \simeq 7$, a conclusion supported by the estimated masses of our brightest galaxies which have only just reached a mass comparable to the critical 'quenching mass' of $M_* \simeq 10^{10.2}\,\mathrm{M}_\odot$ derived from studies of the mass function of star-forming galaxies at lower redshift.

The evolution of the dust temperatures of galaxies in the SFR-M$_*$ plane up to z ~ 2

Magnelli, B.; Lutz, D.; Saintonge, A.; Berta, S.; Santini, P.; Symeonidis, M.; Altieri, B.; Andreani, P.; Aussel, H.; Béthermin, M.; and 31 coauthors.

2014, A&A, 561, 86

We study the evolution of the dust temperature of galaxies in the SFR- M_* plane up to z ~ 2 using far-infrared and submillimetre observations from the Herschel Space Observatory taken as part of the PACS Evolutionary Probe (PEP) and Herschel Multi-tiered Extragalactic Survey (HerMES) guaranteed time key programmes. Starting from a sample of galaxies with reliable star-formation rates (SFRs), stellar masses (M_*) and redshift estimates, we grid the SFR-M_*parameter space in several redshift ranges and estimate the mean dust temperature (T_{dust}) of each SFR-M_* - z bin. Dust temperatures are inferred using the stacked far-infrared flux densities (100-500 mum) of our SFR-M_* - z bins. At all redshifts, the dust temperature of galaxies smoothly increases with rest-frame infrared luminosities (L_{IR}), specific SFRs (SSFR; i.e., SFR/M_*), and distances with respect to the main sequence (MS) of the SFR- M_* plane (i.e., Deltalog $(SSFR)_{MS}$ = log [SSFR(galaxy)/$SSFR_{MS}(M_*,z)$]). The T_{dust} - SSFR and T_{dust} - Deltalog $(SSFR)_{MS}$ correlations are statistically much more significant than the T_{dust} - L_{IR} one. While the slopes of these three correlations are redshift-independent, their normalisations evolve smoothly from z = 0 and z ~ 2. We convert these results into a recipe to derive T_{dust} from SFR, M_* and z, valid out to z ~ 2 and for the stellar mass and SFR range covered by our stacking analysis. The existence of a strong T_{dust} - Deltalog $(SSFR)_{MS}$ correlation provides us with several pieces of information on the dust and gas content of galaxies. Firstly, the slope of the T_{dust} - Deltalog $(SSFR)_{MS}$ correlation can be explained by the increase in the star-formation efficiency (SFE; SFR/M_{gas}) with Deltalog $(SSFR)_{MS}$ as found locally by molecular gas studies. Secondly, at fixed Deltalog $(SSFR)_{MS}$, the constant dust temperature observed in galaxies probing wide ranges in SFR and M_* can be explained by an increase or decrease in the number of star-forming regions with comparable SFE enclosed in them. And thirdly, at high redshift, the normalisation towards hotter dust temperature of the T_{dust} - Deltalog $(SSFR)_{MS}$ correlation can be explained by the decrease in the metallicities of galaxies or by the increase in the SFE of MS galaxies. All these results support the hypothesis that the conditions prevailing in the star-forming regions of MS and far-above-MS galaxies are different. MS galaxies have star-forming regions with low SFEs and thus cold dust, while galaxies situated far above the MS seem to be in a starbursting phase characterised by star-forming regions with high SFEs and thus hot dust.

Constraints on the star-formation rate of z ~ 3 LBGs with measured metallicity in the CANDELS GOODS-South field

Castellano, M.; Sommariva, V.; Fontana, A.; Pentericci, L.; Santini, P.; Grazian, A.; Amorin, R.; Donley, J. L.; Dunlop, J. S.; Ferguson, H. C.; and 12 coauthors.

2014, A&A, 566, 19

Aims: We aim to constrain the assembly history of high-redshift galaxies and the reliability of UV-based estimates of their physical parameters from an accurate analysis of a unique sample of z ~ 3 Lyman-break galaxies (LBGs).

Methods: We analyse 14 LBGs at z ∼ 2.8-3.8 constituting the only sample where both a spectroscopic measurement of their metallicity and deep IR observations (CANDELS+HUGS survey) are available. Fixing the metallicity of population synthesis models to the observed values, we determine best-fit physical parameters under different assumptions about the star-formation history (SFH) and also consider the effect of nebular emission. For comparison, we determine the UV slope of the objects, and use it to estimate their SFR_{UV99} by correcting the UV luminosity.
Results: A comparison between star-formation rate (SFR) obtained through SED-fitting (SFR_{fit}) and the SFR_{UV99} shows that the latter are underestimated by a factor of 2-10, regardless of the assumed SFH. Other SFR indicators (radio, far-IR, X-ray, recombination lines) coherently indicate SFRs a factor of 2-4 larger than SFR_{UV99} and in closer agreement with SFR_{fit}. This discrepancy is due to the solar metallicity implied by the usual beta - A_{1600} conversion factor. We propose a refined relation, appropriate for subsolar metallicity LBGs: A_{1600} = 5.32 + 1.99 * beta. This relation reconciles the dust-corrected UV with the SED-fitting and the other SFR indicators. We show that the fact that z ∼ 3 galaxies have subsolar metallicity implies an upward revision by a factor of ∼1.5-2 of the global SFRD, depending on the assumptions about the age of the stellar populations. We find very young best-fit ages (10-500 Myr) for all our objects. From a careful examination of the uncertainties in the fit and the amplitude of the Balmer break we conclude that there is little evidence of the presence of old stellar population in at least half of the LBGs in our sample, suggesting that these objects are probably caught during a huge star-formation burst, rather than being the result of a smooth evolution.

The colour distribution of galaxies at redshift five

Rogers, A. B.; McLure, R. J.; Dunlop, J. S.; Bowler, R. A. A.; Curtis-Lake, E. F.; Dayal, P.; Faber, S. M.; Ferguson, H. C.; Finkelstein, S. L.; Grogin, N. A.; and 4 coauthors.

2014, MNRAS, 440, 3714

We present the results of a study investigating the rest-frame ultraviolet (UV) spectral slopes of redshift $z \approx 5$ Lyman-break galaxies (LBGs). By combining deep *Hubble Space Telescope* imaging of the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey and *Hubble* Ultra-Deep Field with ground-based imaging from the UKIRT Infrared Deep Sky Survey Ultra Deep Survey, we have produced a large sample of $z \approx 5$ LBGs spanning an unprecedented factor of >100 in UV luminosity. Based on this sample we find a clear colour–magnitude relation (CMR) at $z \approx 5$, such that the rest-frame UV slopes (β) of brighter galaxies are notably redder than their fainter counterparts. We determine that the $z \approx 5$ CMR is well described by a linear relationship of the form: $d\beta = (-0.12 \pm 0.02)dM_{UV}$, with no clear evidence for a change in CMR slope at faint magnitudes (i.e. $M_{UV} \geq -18.9$). Using the results of detailed simulations we are able, for the first time, to infer the intrinsic (i.e. free from noise) variation

of galaxy colours around the CMR at $z \approx 5$. We find significant (12σ) evidence for intrinsic colour variation in the sample as a whole. Our results also demonstrate that the width of the intrinsic UV slope distribution of $z \approx 5$ galaxies increases from $\Delta\beta \simeq 0.1$ at $M_{\rm UV} = -18$ to $\Delta\beta \simeq 0.4$ at $M_{\rm UV} = -21$. We suggest that the increasing width of the intrinsic galaxy colour distribution and the CMR itself are both plausibly explained by a luminosity-independent lower limit of $\beta \approx -2.1$, combined with an increase in the fraction of red galaxies in brighter UV-luminosity bins.

A Submillimeter Galaxy Illuminating its Circumgalactic Medium: Lyman alpha Scattering in a Cold, Clumpy Outflow

Geach, J. E.; Bower, R. G.; Alexander, D. M.; Blain, A. W.; Bremer, M. N.; Chapin, E. L.; Chapman, S. C.; Clements, D. L.; Coppin, K. E. K.; Dunlop, J. S.; and 10 coauthors.

2014, ApJ, 793, 22

We report the detection at 850 microns of the central source in SSA22-LAB1, the archetypal "Lyman-alpha Blob" (LAB), a 100 kpc scale radio-quiet emission-line nebula at z = 3.1. The flux density of the source, $S_{850} = 4.6 \pm 1.1$ mJy, implies the presence of a galaxy or group of galaxies with a total luminosity of $L_{IR} \approx 10^{12} L_{sun;}$. The position of an active source at the center of a ~50 kpc radius ring of linearly polarized Ly-alpha emission detected by Hayes et al. suggests that the central source is leaking Lyalpha photons preferentially in the plane of the sky, which undergo scattering in H I clouds at a large galactocentric radius. The Ly-alpha morphology around the submillimeter detection is reminiscent of a biconical outflow, and the average Ly-alpha line profiles of the two "lobes" are dominated by a red peak, which is expected for a resonant line emerging from a medium with a bulk velocity gradient that is outflowing relative to the line center. Taken together, these observations provide compelling evidence that the central active galaxy (or galaxies) is responsible for a large fraction of the extended Ly-alpha emission and morphology. Less clear is the history of the cold gas in the circumgalactic medium being traced by Ly-alpha: is it mainly pristine material accreting into the halo that has not yet been processed through an interstellar medium (ISM), now being blown back as it encounters an outflow, or does it mainly comprise gas that has been swept-up within the ISM and expelled from the galaxy?

The Hawk-I UDS and GOODS Survey (HUGS): Survey design and deep K-band number counts

Fontana, A.; Dunlop, J. S.; Paris, D.; Targett, T. A.; Boutsia, K.; Castellano, M.; Galametz, A.; Grazian, A.; McLure, R.; Merlin, E.; and 33 coauthors.

2014, A&A, 570, 11

We present the results of a new, ultra-deep, near-infrared imaging survey executed with the Hawk-I imager at the ESO VLT, of which we make all the data (images and catalog) public. This survey, named HUGS (Hawk-I UDS and GOODS

Survey), provides deep, high-quality imaging in the K and Y bands over the portions of the UKIDSS UDS and GOODS-South fields covered by the CANDELS HST WFC3/IR survey. In this paper we describe the survey strategy, the observational campaign, the data reduction process, and the data quality. We show that, thanks to exquisite image quality and extremely long exposure times, HUGS delivers the deepest K-band images ever collected over areas of cosmological interest, and in general ideally complements the CANDELS data set in terms of image quality and depth. In the GOODS-S field, the K-band observations cover the whole CANDELS area with a complex geometry made of 6 different, partly overlapping pointings, in order to best match the deep and wide areas of CANDELS imaging. In the deepest region (which includes most of the Hubble Ultra Deep Field) exposure times exceed 80 hours of integration, yielding a 1 - sigma magnitude limit per square arcsec of ∼28.0 AB mag. The seeing is exceptional and homogeneous across the various pointings, confined to the range 0.38-0.43 arcsec. In the UDS field the survey is about one magnitude shallower (to match the correspondingly shallower depth of the CANDELS images) but includes also Y-band band imaging (which, in the UDS, was not provided by the CANDELS WFC3/IR imaging). In the K-band, with an average exposure time of 13 hours, and seeing in the range 0.37-0.43 arcsec, the 1 - sigma limit per square arcsec in the UDS imaging is ∼27.3 AB mag. In the Y-band, with an average exposure time ∼8 h, and seeing in the range 0.45-0.5 arcsec, the imaging yields a 1 - sigma limit per square arcsec of ∼28.3 AB mag. We show that the HUGS observations are well matched to the depth of the CANDELS WFC3/IR data, since the majority of even the faintest galaxies detected in the CANDELS H-band images are also detected in HUGS. Finally we present the K-band galaxy number counts produced by combining the HUGS data from the two fields. We show that the slope of the number counts depends sensitively on the assumed distribution of galaxy sizes, with potential impact on the estimated extra-galactic background light.

The Progenitors of Local Ultra-massive Galaxies Across Cosmic Time: From Dusty Star-bursting to Quiescent Stellar Populations

Marchesini, Danilo; Muzzin, Adam; Stefanon, Mauro; Franx, Marijn; Brammer, Gabriel G.; Marsan, Cemile Z.; Vulcani, Benedetta; Fynbo, J. P. U.; Milvang-Jensen, Bo; Dunlop, James S.; Buitrago, Fernando.

2014, ApJ, 794, 65

Using the UltraVISTA catalogs, we investigate the evolution in the 11.4∼Gyr since z=3 of the progenitors of local ultra-massive galaxies (log(Mstar/$M\odot$)≈11.8; UMGs), providing a complete and consistent picture of how the most massive galaxies at z=0 have assembled. By selecting the progenitors with a semi-empirical approach using abundance matching, we infer a growth in stellar mass of 0.56+0.35−0.25 dex, 0.45+0.16−0.20∼dex, and 0.27+0.08−0.12 dex from z=3, z=2, and z=1, respectively, to z=0. At z<1, the

progenitors of UMGs constitute a homogeneous population of only quiescent galaxies with old stellar populations. At $z>1$, the contribution from star-forming galaxies progressively increases, with the progenitors at $2<z<3$ being dominated by massive (Mstar$\approx 2\times10^{11}$M$\odot$), dusty (AV$\sim$1-2.2 mag), star-forming (SFR$\sim$100-400$\sim$M$\odot$ yr-1) galaxies with a large range in stellar ages. At $z=2.75$, $\sim$15% of the progenitors are quiescent, with properties typical of post-starburst galaxies with little dust extinction and strong Balmer break, and showing a large scatter in color. Our findings indicate that at least half of the stellar content of local UMGs was assembled at $z>1$, whereas the remaining was assembled via merging from $z\sim1$ to the present. Most of the quenching of the star-forming progenitors happened between $z=2.75$ and $z=1.25$, in good agreement with the typical formation redshift and scatter in age of $z=0$ UMGs as derived from their fossil records. The progenitors of local UMGs, including the star-forming ones, never lived on the blue cloud since $z=3$. We propose an alternative path for the formation of local UMGs that refines previously proposed pictures and that is fully consistent with our findings.

A reassessment of the redshift distribution and physical properties of luminous (sub-)millimetre galaxies

Koprowski, M. P.; Dunlop, J. S.; Michalowski, M. J.; Cirasuolo, M.; Bowler, R. A. A.

2014, MNRAS, 444, 117

Motivated by the current controversy over the redshift distribution and physical properties of luminous (sub-)mm sources, we have undertaken a new study of the brightest sample of unlensed (sub-)mm sources with pre-Atacama Large Millimeter/submillimeter Array (ALMA) interferometric follow-up in the Cosmological Evolution Survey field. Exploiting the very latest multifrequency supporting data, we find that this sample displays a redshift distribution indistinguishable from that of the lensed sources uncovered with the South Pole Telescope, with $z_{\rm median} \simeq 3.5$. We also find that, over the redshift range $z \simeq 2$–6, the median stellar mass of the most luminous (sub-) mm sources is $M_* \simeq 3 \times 10^{11}\,{\rm M}_\odot$, yielding a typical specific star formation rate sSFR $\simeq 3\,{\rm Gyr}^{-1}$. Consistent with recent ALMA and the Submillimeter Array studies, we confirm that source blending is *not* a serious issue in the study of luminous (sub-) mm sources uncovered by ground-based, single-dish surveys; only $\simeq$10–15 per cent of bright ($S_{850} \simeq 5$–10 mJy) (sub-) mm sources arise from significant (i.e. >20 per cent) blends, and so our conclusions are largely unaffected by whether we adopt the original single-dish mm/sub-mm flux densities/positions or the interferometric data. Our results suggest that apparent disagreements over the redshift distribution of (sub-)mm sources are a result of 'down-sizing' in dust-enshrouded star formation, consistent with existing knowledge of the star formation histories of massive galaxies. They also indicate that extreme star-forming galaxies at high redshift are, on average, subject to the same star formation rate-limiting processes as less luminous objects, and lie on the 'main

sequence' of star-forming galaxies at $z > 3$.

The bulge-disc decomposed evolution of massive galaxies at 1 < z < 3 in CANDELS

Bruce, V. A.; Dunlop, J. S.; McLure, R. J.; Cirasuolo, M.; Buitrago, F.; Bowler, R. A. A.; Targett, T. A.; Bell, E. F.; McIntosh, D. H.; Dekel, A.; and 8 coauthors

2014, MNRAS, 444, 1001

We present the results of a new and improved study of the morphological and spectral evolution of massive galaxies over the redshift range $1 < z < 3$. Our analysis is based on a bulge–disc decomposition of 396 galaxies with $M_* > 10^{11}\,M_\odot$ uncovered from the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS) Wide Field Camera 3 (WFC3)/IR imaging within the Cosmological Evolution Survey (COSMOS) and UKIRT Infrared Deep Sky Survey (UKIDSS) UDS survey fields. We find that, by modelling the H_{160} image of each galaxy with a combination of a de Vaucouleurs bulge (Sérsic index $n = 4$) and an exponential disc ($n = 1$), we can then lock all derived morphological parameters for the bulge and disc components, and successfully reproduce the shorter-wavelength J_{125}, i_{814}, v_{606} *HST* images simply by floating the magnitudes of the two components. This then yields sub-divided four-band *HST* photometry for the bulge and disc components which, with no additional priors, is well described by spectrophotometric models of galaxy evolution. Armed with this information, we are able to properly determine the masses and star formation rates for the bulge and disc components, and find that: (i) from $z = 3$ to 1 the galaxies move from disc dominated to increasingly bulge dominated, but very few galaxies are pure bulges/ellipticals by $z = 1$; (ii) while most passive galaxies are bulge dominated, and most star-forming galaxies disc dominated, 18 ± 5 per cent of passive galaxies are disc dominated, and 11 ± 3 per cent of star-forming galaxies are bulge dominated, a result which needs to be explained by any model purporting to connect star formation quenching with morphological transformations; (iii) there exists a small but significant population of pure passive discs, which are generally flatter than their star-forming counterparts (whose axial ratio distribution peaks at $b/a \simeq 0.7$); (iv) flatter/larger discs re-emerge at the highest star formation rates, consistent with recent studies of sub-mm galaxies, and with the concept of a maximum surface density for star formation activity.

The decomposed bulge and disc size-mass relations of massive galaxies at 1 < z < 3 in CANDELS

Bruce, V. A.; Dunlop, J. S.; McLure, R. J.; Cirasuolo, M.; Buitrago, F.; Bowler, R. A. A.; Targett, T. A.; Bell, E. F.; McIntosh, D. H.; Dekel, A.; and 8 coauthors.

2014, MNRAS, 444, 1660

We have constructed a mass-selected sample of $M_* > 10^{11}\,M_\odot$ galaxies at $1 < z < 3$ in the CANDELS UKIDSS UDS and COSMOS fields and have decomposed these

systems into their separate bulge and disc components according to their H_{160}-band morphologies. By extending this analysis to multiple bands, we have been able to conduct individual bulge and disc component SED fitting that has provided us with stellar-mass and star formation rate estimates for the separate bulge and disc components. Having utilized the new decomposed stellar-mass estimates, we confirm that the bulge components display a stronger size evolution than the discs. The median sizes of the bulge components is 3.09 ± 0.20 times smaller than similarly massive local galaxies over the full $1 < z < 3$ redshift range; for the discs, the corresponding factor is 1.77 ± 0.10. Moreover, by splitting our sample into the passive and star-forming bulge and disc sub-populations and examining their sizes as a fraction of their present-day counter-parts, we find that the star-forming and passive bulges are equally compact, star-forming discs are larger, while the passive discs have intermediate sizes. This trend is not evident when classifying galaxy morphology on the basis of single-Sérsic fits and adopting the overall star formation rates. Finally, by evolving the star formation histories of the passive discs back to the redshifts when the passive discs were last active, we show that the passive and star-forming discs have consistent sizes at the relevant epoch. These trends need to be reproduced by any mechanisms that attempt to explain the morphological evolution of galaxies.

Colour matters: the effects of lensing on the positional offsets between optical and submillimetre galaxies in Herschel-ATLAS

Bourne, N.; Maddox, S. J.; Dunne, L.; Dye, S.; Eales, S.; Hoyos, C.; González-Nuevo, J.; Smith, D. J. B.; Valiante, E.; de Zotti, G.; and 2 coauthors

2014, MNRAS, 444, 1884

We report an unexpected variation in the positional offset distributions between *Herschel*-Astrophysical Terahertz Large Area Survey (H-ATLAS) submillimetre (submm) sources and their optical associations, depending on both 250-μm signal-to-noise ratio and 250/350-μm colour. We show that redder and brighter submm sources have optical associations with a broader distribution of positional offsets than would be expected if these offsets were due to random positional errors in the source extraction. The observation can be explained by two possible effects: either red submm sources trace a more clustered population than blue ones, and their positional errors are increased by confusion, or red submm sources are generally at high redshifts and are frequently associated with low-redshift lensing structures which are identified as false counterparts. We perform various analyses of the data, including the multiplicity of optical associations, the redshift and magnitude distributions in H-ATLAS in comparison to HerMES, and simulations of weak lensing, and we conclude that the effects are most likely to be explained by widespread weak lensing of *Herschel*-SPIRE sources by foreground structures. This has important consequences for counterpart identification and derived redshift distributions

and luminosity functions of submm surveys.

Determining the stellar masses of submillimetre galaxies: the critical importance of star formation histories
Michalowski, Michal J.; Hayward, Christopher C.; Dunlop, James S.; Bruce, Victoria A.; Cirasuolo, Michele; Cullen, Fergus; Hernquist, Lars
2014, A&A, 571, 75
Submillimetre (submm) galaxies are among the most rapidly star-forming and most massive high-redshift galaxies; thus, their properties provide important constraints on galaxy evolution models. However, there is still a debate about their stellar masses and their nature in the context of the general galaxy population. To test the reliability of their stellar mass determinations, we used a sample of simulated submm galaxies for which we created synthetic photometry. The photometry were used to derived their stellar masses via spectral energy distribution (SED) modelling, as is generally done with real observations. We used various SED codes (Grasil, Magphys, Hyperz, and LePhare) and various alternative assumed star formation histories (SFHs). We found that the assumption of SFHs with two independent components enables the SED modelling codes to most accurately recover the true stellar masses of the simulated submm galaxies. Exponentially declining SFHs (tau models) lead to lower masses (albeit still formally consistent with the true stellar masses), while the assumption of single-burst SFHs results in a significant underestimation of the stellar masses. Thus, we conclude that studies based on the higher masses inferred from fitting the SEDs of real submm galaxies with double SFHs are most likely to be correct, implying that submm galaxies lie on the high-mass end of the main sequence of star-forming galaxies. This conclusion appears robust to assumptions of whether submm galaxies are driven by major mergers, since the suite of simulated galaxies modelled here contains examples of both merging and isolated galaxies. We identified discrepancies between the true and inferred stellar ages (rather than the dust attenuation) as the primary determinant of the success or failure of the mass recovery. Regardless of the choice of SFH, the SED-derived stellar masses exhibit a factor of ~2 scatter around the true value, and this scatter is an inherent limitation of the SED modelling due to simplified assumptions (regarding, e.g., the SFH, detailed galaxy geometry and wavelength dependence of the dust attenuation). Finally, we found that the contribution of active galactic nuclei (<60% at the K-band in these simulations) does not have any significant impact on the derived stellar masses.

Discovering extremely compact and metal-poor, star-forming dwarf galaxies out to z ~ 0.9 in the VIMOS Ultra-Deep Survey
Amorín, R.; Sommariva, V.; Castellano, M.; Grazian, A.; Tasca, L. A. M.; Fontana, A.; Pentericci, L.; Cassata, P.; Garilli, B.; Le Brun, V.; and 35 coauthors
2014, A&A, 568, 8

We report the discovery of 31 low-luminosity ($-14.5 \gtrsim M_{AB}(B) \gtrsim -18.8$), extreme emission line galaxies (EELGs) at $0.2 \lesssim z \lesssim 0.9$ identified by their unusually high rest-frame equivalent widths ($100 \leq EW[O\ iii] \leq 1700$ Å) as part of the VIMOS Ultra Deep Survey (VUDS). VIMOS optical spectra of unprecedented sensitivity ($I_{AB} \sim 25$ mag) along with multiwavelength photometry and HST imaging are used to investigate spectrophotometric properties of this unique sample and to explore, for the first time, the very low stellar mass end ($M_\star \lesssim 10^8 M_\odot$) of the luminosity-metallicity (LZR) and mass-metallicity (MZR) relations at $z < 1$. Characterized by their extreme compactness ($R_{50} < 1$ kpc), low stellar mass and enhanced specific star formation rates ($sSFR = SFR/M_\star \sim 10^{-9}$-$10^{-7}$ yr^{-1}), the VUDS EELGs are blue dwarf galaxies likely experiencing the first stages of a vigorous galaxy-wide starburst. Using T_e-sensitive direct and strong-line methods, we find that VUDS EELGs are low-metallicity ($7.5 \lesssim 12 + \log(O/H) \lesssim 8.3$) galaxies with high ionization conditions ($\log(q_{ion}) \gtrsim 8$ cm s^{-1}), including at least three EELGs showing Heiiλ 4686 Å emission and four extremely metal-poor (≲10% solar) galaxies. The LZR and MZR followed by VUDS EELGs show relatively large scatter, being broadly consistent with the extrapolation toward low luminosity and mass from previous studies at similar redshift. However, we find evidence that galaxies with younger and more vigorous star formation - as characterized by their larger EWs, ionization and sSFR - tend to be more metal poor at a given stellar mass.

Evidence of Very Low Metallicity and High Ionization State in a Strongly Lensed, Star-forming Dwarf Galaxy at z= 3.417

Amorín, R.; Grazian, A.; Castellano, M.; Pentericci, L.; Fontana, A.; Sommariva, V.; van der Wel, A.; Maseda, M.; Merlin, E.

2014, ApJ, 788, 4

We investigate the gas-phase metallicity and Lyman continuum (LyC) escape fraction of a strongly gravitationally lensed, extreme emission-line galaxy at z = 3.417, J1000+0221S, recently discovered by the CANDELS team. We derive ionization- and metallicity-sensitive emission-line ratios from H+K band Large Binocular Telescope (LBT)/LUCI medium resolution spectroscopy. J1000+0221S shows high ionization conditions, as evidenced by its enhanced [O III]/[O II] and [O III]/Hβ ratios. Strong-line methods based on the available line ratios suggest that J1000+0221S is an extremely metal-poor galaxy, with a metallicity of 12+log (O/H) < 7.44 (Z < 0.05 Z $_\odot$), placing it among the most metal-poor star-forming galaxies at z gsim 3 discovered so far. In combination with its low stellar mass (2×10^8 M $_\odot$) and high star formation rate (5 M $_\odot$ yr^{-1}), the metallicity of J1000+0221S is consistent with the extrapolation of the mass-metallicity relation traced by Lyman-break galaxies at z gsim 3 to low masses, but it is 0.55 dex lower than predicted by the fundamental metallicity relation at z lsim 2.5. These observations suggest a rapidly growing galaxy, possibly fed by massive accretion of pristine gas. Additionally, deep LBT/LBC photometry in the UGR

bands are used to derive a limit to the LyC escape fraction, thus allowing us to explore for the first time the regime of sub-L* galaxies at z > 3. We find a 1σ upper limit to the escape fraction of 23%, which adds a new observational constraint to recent theoretical models predicting that sub-L* galaxies at high-z have high escape fractions and thus are the responsible for the reionization of the universe.

A mass threshold in the number density of passive galaxies at z ~ 2
Sommariva, V.; Fontana, A.; Lamastra, A.; Santini, P.; Dunlop, J. S.; Nonino, M.; Castellano, M.; Ferguson, H.; McLure, R. J.; Galametz, A.; and 10 coauthors
2014, A&A, 571, 99.
The process that quenched star formation in galaxies at intermediate and high redshifts is still the subject of considerable debate. One way to investigate this puzzling issue is to study the number density of quiescent galaxies at z ~= 2 and its dependence on mass. Here we present the results of a new study based on very deep K_s-band imaging (with the HAWK-I instrument on the VLT) of two HST CANDELS fields (the UKIDSS Ultra-deep survey (UDS) field and GOODS-South). The new HAWK-I data (taken as part of the HUGS VLT Large Program) reach detection limits of K_s> 26 (AB mag). We have combined this imaging with the other ground-based and HST data in the CANDELS fields to select a sample of passively-evolving galaxies in the redshift range 1.4 <z< 2.5 (via the pBzK color-based selection criterion). Thanks to the depth and wide area coverage of our imaging, we have been able to extend the selection of quiescent galaxies to a magnitude fainter than previous analyses. Through extensive simulations we demonstrate, for the first time, that the observed turnover in the number of quiescent galaxies at K >= 22 is not due to incompleteness, but is real. This has enabled us to establish unambiguously that the number counts of quiescent galaxies at z ~ 2 flatten and slightly decline at magnitudes fainter than K_s ~ 22 (AB mag.), in contrast to the number density of star-forming galaxies, which continues to rise to fainter magnitudes. We show that this trend corresponds to a stellar mass threshold $M_* \sim= 10^{10.8} M_{sun;}$ below which the mechanism that halts the star formation in high-redshift galaxies seems to be inefficient. We also show that, while pBzK galaxies at K< 23 are in the redshift range 1.4 < z < 2.5, as expected, at K> 23 a higher redshift population of z ~ 3pBzK galaxies is detected and dominates the counts at the faintest magnitudes. Finally, we compare the observed pBzK number counts with those of quiescent galaxies extracted from four different semi-analytic models. We find that only two of these models reproduce the observed trend in the number counts, even qualitatively, and that none of the models provides a statistically acceptable description of the number density of quiescent galaxies at these redshifts. We conclude that the mass function of quiescent galaxies as a function of redshift continues to present a key and demanding challenge for proposed models of galaxy formation and evolution.

Accounting for Cosmic Variance in Studies of Gravitationally Lensed High-redshift Galaxies in the Hubble Frontier Field Clusters

Robertson, Brant E.; Ellis, Richard S.; Dunlop, James S.; McLure, Ross J.; Stark, Dan P.; McLeod, Derek.

2014, ApJ, 796, L27

Strong gravitational lensing provides a powerful means for studying faint galaxies in the distant universe. By magnifying the apparent brightness of background sources, massive clusters enable the detection of galaxies fainter than the usual sensitivity limit for blank fields. However, this gain in effective sensitivity comes at the cost of a reduced survey volume and, in this Letter, we demonstrate that there is an associated increase in the cosmic variance uncertainty. As an example, we show that the cosmic variance uncertainty of the high-redshift population viewed through the Hubble Space Telescope Frontier Field cluster Abell 2744 increases from ~35% at redshift z ~ 7 to >~ 65% at z ~ 10. Previous studies of high-redshift galaxies identified in the Frontier Fields have underestimated the cosmic variance uncertainty that will affect the ultimate constraints on both the faint-end slope of the high-redshift luminosity function and the cosmic star formation rate density, key goals of the Frontier Field program.

The temperature dependence of the far-infrared-radio correlation in the Herschel-ATLAS

Smith, D. J. B.; Jarvis, M. J.; Hardcastle, M. J.; Vaccari, M.; Bourne, N.; Dunne, L.; Ibar, E.; Maddox, N.; Prescott, M.; Vlahakis, C.; and 5 coauthors.

2014, MNRAS, 445, 2232

We use 10 387 galaxies from the *Herschel* Astrophysical TeraHertz Large Area Survey (*H*-ATLAS) to probe the far-infrared radio correlation (FIRC) of star-forming galaxies as a function of redshift, wavelength, and effective dust temperature. All of the sources in our 250 μm-selected sample have spectroscopic redshifts, as well as 1.4 GHz flux density estimates measured from the Faint Images of the Radio Sky at Twenty centimetres (FIRST) survey. This enables us to study not only individual sources, but also the average properties of the 250 μm-selected population using median stacking techniques. We find that individual sources detected at ≥5σ in both the *H*-ATLAS and FIRST data have logarithmic flux ratios (i.e. FIRC q_λ parameters) consistent with previous studies of the FIRC. In contrast, the stacked values show larger q_λ, suggesting excess far-IR flux density/luminosity in 250 μm-selected sources above what has been seen in previous analyses. In addition, we find evidence that 250 μm sources with warm dust spectral energy distributions have a larger 1.4 GHz luminosity than the cooler sources in our sample. Though we find no evidence for redshift evolution of the monochromatic FIRC, our analysis reveals significant temperature dependence. Whilst the FIRC is reasonably constant

with temperature at 100 μm, we find increasing inverse correlation with temperature as we probe longer PACS and SPIRE wavelengths. These results may have important implications for the use of monochromatic dust luminosity as a star formation rate indicator in star-forming galaxies, and in the future, for using radio data to determine galaxy star formation rates.

Essential physics of early galaxy formation
Dayal, Pratika; Ferrara, Andrea; Dunlop, James S.; Pacucci, Fabio.
2014, MNRAS, 445, 2545
We present a theoretical model embedding the essential physics of early galaxy formation ($z \simeq 5$–12) based on the single premise that any galaxy can form stars with a maximal limiting efficiency that provides enough energy to expel all the remaining gas, quenching further star formation. This simple idea is implemented into a merger-tree-based semi-analytical model that utilizes two mass and redshift-independent parameters to capture the key physics of supernova feedback in ejecting gas from low-mass haloes, and tracks the resulting impact on the subsequent growth of more massive systems via halo mergers and gas accretion. Our model shows that: (i) the smallest haloes (halo mass $M_{\rm h} \leq 10^{10}\,{\rm M}_{\odot}$) build up their gas mass by accretion from the intergalactic medium; (ii) the bulk of the gas powering star formation in larger haloes ($M_{\rm h} \geq 10^{11.5}\,{\rm M}_{\odot}$) is brought in by merging progenitors; (iii) the faint-end UV luminosity function slope evolves according to $\alpha = -1.75 \log z - 0.52$. In addition, (iv) the stellar mass-to-light ratio is well fitted by the functional form $\log M_{*} = -0.38 M_{\rm UV} - 0.13\,z + 2.4$, which we use to build the evolving stellar mass function to compare to observations. We end with a census of the cosmic stellar mass density (SMD) across galaxies with UV magnitudes over the range $-23 \leq M_{\rm UV} \leq -11$ spanning redshifts $5 < z < 12$; (v) while currently detected LBGs contain ≈50 per cent (10 per cent) of the total SMD at $z = 5$ (8), the *James Webb Space Telescope* will detect up to 25 per cent of the SMD at $z \simeq 9.5$.

The SCUBA-2 Cosmology Legacy Survey: ALMA Resolves the Rest-frame Far-infrared Emission of Sub-millimeter Galaxies
Simpson, J. M.; Smail, Ian; Swinbank, A. M.; Almaini, O.; Blain, A. W.; Bremer, M. N.; Chapman, S. C.; Chen, Chian-Chou; Conselice, C.; Coppin, K. E. K.; and 19 coauthors.
2015, ApJ, 799, 81
We present high-resolution (0.''3) Atacama Large Millimeter Array 870 mum imaging of 52 sub-millimeter galaxies (SMGs) in the Ultra Deep Survey field to investigate the size and morphology of the sub-millimeter (sub-mm) emission on 2-10 kpc scales. We derive a median intrinsic angular size of FWHM = 0.''30 ± 0.''04 for the 23 SMGs in the sample detected at a signal-to-noise ratio (S/N) >10. Using the photometric redshifts of the SMGs we show that this corresponds to a median physical half-light diameter of 2.4 ± 0.2 kpc. A stacking analysis of the SMGs detected at S/N <10 shows they have sizes consistent with the 870 mum

bright SMGs in the sample. We compare our results to the sizes of SMGs derived from other multi-wavelength studies, and show that the rest-frame ~250 mum sizes of SMGs are consistent with studies of resolved ^{12}CO (J = 3-2 to 7-6) emission lines, but that sizes derived from 1.4 GHz imaging appear to be approximately two times larger on average, which we attribute to cosmic ray diffusion. The rest-frame optical sizes of SMGs are around four times larger than the sub-millimeter sizes, indicating that the star formation in these galaxies is compact relative to the pre-existing stellar distribution. The size of the starburst region in SMGs is consistent with the majority of the star formation occurring in a central region, a few kiloparsecs in extent, with a median star formation rate surface density of 90 ± 30 $M_{\odot}$ yr^{-1} kpc^{-2}, which may suggest that we are witnessing an intense period of bulge growth in these galaxies.

The SCUBA-2 Cosmology Legacy Survey: the submillimetre properties of Lyman-break galaxies at z = 3-5

Coppin, K. E. K.; Geach, J. E.; Almaini, O.; Arumugam, V.; Dunlop, J. S.; Hartley, W. G.; Ivison, R. J.; Simpson, C. J.; Smith, D. J. B.; Swinbank, A. M.; and 21 coauthors.

2015, MNRAS, 446, 1293

We present detections at 850 mum of the Lyman-break galaxy (LBG) population at z ≈ 3, 4, and 5 using data from the Submillimetre Common User Bolometer Array 2 Cosmology Legacy Survey in the United Kingdom Infrared Deep Sky Survey `Ultra Deep Survey' field. We employ stacking to probe beneath the survey limit, measuring the average 850 mum flux density of LBGs at z ≈ 3, 4, and 5 with typical ultraviolet luminosities of $L_{1700} \approx 10^{29}$ erg s^{-1} Hz^{-1}. We measure 850 micron flux densities of (0.25 ± 0.03), (0.41 ± 0.06), and (0.88 ± 0.23) mJy, respectively, finding that they contribute at most 20 per cent to the cosmic far-infrared (IR) background at 850 microns. Fitting an appropriate range of spectral energy distributions to the z ~ 3, 4, and 5 LBG stacked 24-850 micron fluxes, we derive IR luminosities of $L_{8\text{-}1000\ mum} \approx 3.2, 5.5$, and 11.0×10^{11} $L_{sun;}$ [and star formation rates (SFRs) of ≈50-200 $M_{sun;}$ yr^{-1}], respectively. We find that the evolution in the IR luminosity density of LBGs is broadly consistent with model predictions for the expected contribution of luminous-to-ultraluminous IR galaxies at these epochs. We observe a positive correlation between stellar mass and IR luminosity and confirm that, for a fixed mass, the reddest LBGs (UV slope beta > 0) are redder due to dust extinction, with SFR(IR)/SFR(UV) increasing by about an order of magnitude over -2 < beta < 0 with SFR(IR)/SFR(UV) ~ 20 for the reddest LBGs. Furthermore, the most massive LBGs tend to have higher obscured-to-unobscured ratios, hinting at a variation in the obscuration properties across the mass range.

Abstracts of papers submitted for publication or in press

GOODS-HERSCHEL: star formation, dust attenuation and the FIR-radio correlation on the Main Sequence of star-forming galaxies up to z~4

Pannella, Maurilio; Elbaz, David; Daddi, Emanuele; Dickinson, Mark E.; Hwang, Ho Seong; Schreiber, Corentin; Strazzullo, Veronica; Aussel, Herve; Bethermin, Matthieu; Buat, Veronique; and 18 coauthors

2014, arXiv:1407.5072

We use the deep panchromatic dataset available in the GOODS-N field, spanning all the way from GALEX ultra-violet to VLA radio continuum data, to select a star-forming galaxy sample at z~[0.5-4] and robustly measure galaxy photometric redshifts, star formation rates, stellar masses and UV rest-frame properties. We quantitatively explore, using mass-complete samples, the evolution of the star formation activity and dust attenuation properties of star-forming galaxies up to z~4. Our main results can be summarized as follows: i) we find that the slope of the SFR-M correlation is consistent with being constant, and equal to ~0.8 at least up to z~1.5, while the normalization keeps increasing to the highest redshift, z~4, we are able to explore; ii) for the first time in this work, we are able to explore the FIR-radio correlation for a mass-selected sample of star-forming galaxies: the correlation does not evolve up to z~4; iii) we confirm that galaxy stellar mass is a robust proxy for UV dust attenuation in star-forming galaxies, with more massive galaxies being more dust attenuated; iv) strikingly, we find that this attenuation relation evolves very weakly with redshift, the amount of dust attenuation increasing by less than 0.3 magnitudes over the redshift range [0.5-4] for a fixed stellar mass, as opposed to a tenfold increase of star formation rate; v) this finding explains the evolution of the SFR-Auv relation reported in literature: the same amount of star formation is less attenuated at higher redshift because it is hosted in less massive, and less metal rich, galaxies; vi) the correlation between dust attenuation and the UV spectral slope evolves in redshift, with the median UV spectral slope of star-forming galaxies becoming bluer with redshift. By z~3, typical UV slopes are inconsistent, given the measured dust attenuation, with the predictions of commonly used empirical laws...

No evidence for evolution in the typical rest-frame UV sizes or morphologies of L* galaxies at 4<z<8

Curtis-Lake, E.; McLure, R. J.; Dunlop, J. S.; Rogers, A. B.; Targett, T.; Dekel, A.; Ellis, R. S.; Faber, S. M.; Ferguson, H. C.; Grogin, N. A.; and 5 coauthors.

2014, arXiv:1409.1832.

We present the results of a study investigating the sizes and morphologies of redshift 4<z<8 galaxies in the CANDELS GOODS-S, HUDF and HUDF parallel fields. Based on non-parametric measurements and incorporating a careful

treatment of measurement biases, we quantify the typical size of galaxies at each redshift as the peak of the log-normal size distribution, rather than the arithmetic mean size. Parameterizing the evolution of galaxy half-light radius as r50\propto(1+z)^n, we find n=-0.34\pm0.29 at bright UV-luminosities (0.3L*(z=3)<L<L*) and n=-0.57\pm0.76 at faint luminosities (0.12L*<L<0.3L*). In a given luminosity range, these measurements are consistent with no evolution in typical galaxy size with redshift. Moreover, simulations based on artificially redshifting our z~4 galaxy sample also confirm that we cannot reject the null hypothesis of no size evolution. This result is caused by the systematic under-estimation of the largest galaxy sizes, such that the build-up in the tail of the log-normal size distribution seen at z~4-5 cannot be distinguished from a scenario where the large, low surface-brightness, galaxies at higher redshifts have their sizes systematically underestimated. To explore the evolution of galaxy morphology we first compare asymmetry measurements to those from a large sample of simulated single Sersic profiles, in order to robustly categorise galaxies as either `smooth' or `disturbed'. Comparing the disturbed fraction amongst bright (MUV<-20) galaxies at each redshift to that obtained by artificially redshifting our z~4 galaxy sample, we find no clear evidence for evolution in galaxy morphology over the redshift interval 4<z<8. Therefore, based on our results, a bright (MUV<-20) galaxy at z~6 is no more likely to be measured as `disturbed' than a comparable galaxy at z~4. (abr.)

The Herschel view of the dominant mode of galaxy growth from z=4 to the present day

Schreiber, Corentin; Pannella, Maurilio; Elbaz, David; Béthermin, Matthieu; Inami, Hanae; Dickinson, Mark E.; Magnelli, Benjamin; Wang, Tao; Aussel, Hervé; Daddi, Emanuele; and 13 coauthors.

2014, arXiv:1409.5433

We present an analysis of the deepest Herschel images in four major extragalactic fields GOODS-North, GOODS-South, UDS and COSMOS obtained within the GOODS-Herschel and CANDELS-Herschel key programs. The picture provided by 10497 individual far-infrared detections is supplemented by the stacking analysis of a mass-complete sample of 62361 star-forming galaxies from the CANDELS-HST H band-selected catalogs and from two deep ground-based Ks band-selected catalogs in the GOODS-North and the COSMOS-wide fields, in order to obtain one of the most accurate and unbiased understanding to date of the stellar mass growth over the cosmic history. We show, for the first time, that stacking also provides a powerful tool to determine the dispersion of a physical correlation and describe our method called "scatter stacking" that may be easily generalized to other experiments. We demonstrate that galaxies of all masses from z=4 to 0 follow a universal scaling law, the so-called main sequence of star-forming galaxies. We find a universal close-to-linear slope of the logSFR-logM* relation with evidence for a flattening of the main sequence at high

masses (log(M*/Msun) > 10.5) that becomes less prominent with increasing redshift and almost vanishes by z~2. This flattening may be due to the parallel stellar growth of quiescent bulges in star-forming galaxies. Within the main sequence, we measure a non varying SFR dispersion of 0.3 dex. The specific SFR (sSFR=SFR/M*) of star-forming galaxies is found to continuously increase from z=0 to 4. Finally we discuss the implications of our findings on the cosmic SFR history and show that more than 2/3 of present-day stars must have formed in a regime dominated by the main sequence mode. As a consequence we conclude that, although omnipresent in the distant Universe, galaxy mergers had little impact in shaping the global star formation history over the last 12.5 Gyr.

The galaxy luminosity function at z ~ 6 and evidence for rapid evolution in the bright end from z ~ 7 to 5

Bowler, R. A . A.; Dunlop, J. S.; McLure, R. J.; McCracken, H. J.; Furusawa, H.; Taniguchi, Y.; Fynbo, J. P. U.; Milvang-Jensen, B.; Le Fevre, O.

2014, arXiv:1411.2976

We present a sample of 266 bright (-22.7 < M_UV < -20.5) Lyman-break galaxies at 5.5 < z < 6.5 found within a total of 1.65 square degrees of imaging in the UltraVISTA/COSMOS and UKIDSS UDS/SXDS fields. The deep near-infrared imaging available in the two independent fields, in addition to deep optical (including z'-band) data, enables the sample of z ~ 6 star-forming galaxies to be securely detected long-ward of the break (in contrast to several previous studies). By simulating the potential contamination of our sample by cool galactic brown dwarfs, we find that the expected contamination rate of our initial sample is < 3 percent and that dwarf stars can be effectively removed by fitting dwarf star spectral templates to the photometry. At z ~ 6 the galaxy surface density in the UltraVISTA field exceeds that in the UDS by a factor of ~ 1.8, indicating strong cosmic variance even between degree-scale fields at z > 5. We calculate the bright end of the rest-frame Ultra-Violet (UV) luminosity function (LF) at z ~ 6. The galaxy number counts are a factor of 2 lower than predicted by the recent LF determination by Bouwens et al.. In comparison to other smaller area studies, we find an evolution in the characteristic magnitude between z ~ 5 and z ~ 7 of dM* ~ 0.4 mag, and show that a double power-law or a Schechter function can equally well describe the LF at z = 6. Furthermore, the bright-end of the LF appears to steepen from z ~ 7 to z ~ 5, which could indicate the onset of mass quenching or the rise of dust obscuration, a conclusion supported by comparing the observed LFs to a range of theoretical model predictions.

Probing the galaxy-halo connection in UltraVISTA to z ~ 2

McCracken, H. J.; Wolk, M.; Colombi, S.; Kilbinger, M.; Ilbert, O.; Peirani, S.; Coupon, J.; Dunlop, J.; Milvang-Jensen, B.; Caputi, K.; and 3 coauthors.

2014, arXiv:1411.4983

We use percent-level precision photometric redshifts in the UltraVISTA-DR1 near-infrared survey to investigate the changing relationship between galaxy stellar mass and the dark matter haloes hosting them to z ~ 2. We achieve this by measuring the clustering properties and abundances of a series of volume-limited galaxy samples selected by stellar mass and star-formation activity. We interpret these results in the framework of a phenomenological halo model and numerical simulations. Our measurements span a uniquely large range in stellar mass and redshift and reach below the characteristic stellar mass to z ~ 2. Our results are: 1. At fixed redshift and scale, clustering amplitude depends monotonically on sample stellar mass threshold; 2. At fixed angular scale, the projected clustering amplitude decreases with redshift but the co-moving correlation length remains constant; 3. Characteristic halo masses and galaxy bias increase with increasing median stellar mass of the sample; 4. The slope of these relationships is modified in lower mass haloes; 5. Concerning the passive galaxy population, characteristic halo masses are consistent with a simply less-abundant version of the full galaxy sample, but at lower redshifts the fraction of satellite galaxies in the passive population is very different from the full galaxy sample; 6. Finally we find that the ratio between the characteristic halo mass and median stellar mass at each redshift bin reaches a peak at log(M_h/M_sun) ~ 12.2 and the position of this peak remains constant out to z ~ 2. The behaviour of the full and passively evolving galaxy samples can be understood qualitatively by considering the slow evolution of the characteristic stellar mass in the redshift range probed by our survey.

The galaxy stellar mass function at 3.5<z<7.5 in the CANDELS/UDS, GOODS-South, and HUDF fields

Grazian, A.; Fontana, A.; Santini, P.; Dunlop, J. S.; Ferguson, H. C.; Castellano, M.; Amorin, R.; Ashby, M. L. N.; Barro, G.; Behroozi, P.; and 31 coauthors.

2014, arXiv:1412.0532

The galaxy stellar mass function (GSMF) at high-z provides key information on star-formation history and mass assembly in the young Universe. We aimed to use the unique combination of deep optical/NIR/MIR imaging provided by HST, Spitzer and the VLT in the CANDELS-UDS, GOODS-South, and HUDF fields to determine the GSMF over the redshift range 3.5<z<7.5. We utilised the HST WFC3/IR NIR imaging from CANDELS and HUDF09, reaching H~27-28.5 over a total area of 369 arcmin^2, in combination with associated deep HST ACS optical data, deep Spitzer IRAC imaging from the SEDS programme, and deep Y and K-band VLT Hawk-I images from the HUGS programme, to select a galaxy sample with high-quality photometric redshifts. These have been calibrated with more than 150 spectroscopic redshifts in the range 3.5<z<7.5, resulting in an overall precision of sigma_z/(1+z)~0.037. We have determined the low-mass end of the high-z GSMF with unprecedented precision, reaching down to masses as low as M*~10^9 M_{sun} at z=4 and ~6x10^9 M_{sun} at z=7. We find that the GSMF at 3.5<z<7.5

depends only slightly on the recipes adopted to measure the stellar masses, namely the photo-z, the SFHs, the nebular contribution or the presence of AGN on the parent sample. The low-mass end of the GSMF is steeper than has been found at lower redshifts, but appears to be unchanged over the redshift range probed here. Our results are very different from previous GSMF estimates based on converting UV galaxy luminosity functions into mass functions via tight M/L relations. Integrating our evolving GSMF over mass, we find that the growth of stellar mass density is barely consistent with the time-integral of the SFR density over cosmic time at z>4. These results confirm the unique synergy of the CANDELS+HUDF, HUGS, and SEDS surveys for the discovery and study of moderate/low-mass galaxies at high redshifts.

New redshift z ~ 9 galaxies in the Hubble Frontier Fields: Implications for early evolution of the UV luminosity density

McLeod, Derek J.; McLure, Ross J.; Dunlop, James S.; Robertson, Brant E.; Ellis, Richard S.; Targett, Thomas T.

2014, arXiv:1412.1472

We present the results of a new search for galaxies at redshift z ~ 9 in the first two Hubble Frontier Fields with completed HST WFC3/IR and ACS imaging. To ensure robust photometric redshift solutions, and to minimize incompleteness, we confine our search to objects with H_{160} < 28.6 (AB mag), consider only image regions with an rms noise sigma_{160} > 30 mag (within a 0.5-arcsec diameter aperture), and insist on detections in both H_{160} and J_{140}. The result is a survey covering an effective area (after accounting for magnification) of 10.9 sq. arcmin, which yields 12 galaxies at 8.4 < z < 9.5. Within the Abell-2744 cluster and parallel fields we confirm the three brightest objects reported by Ishigaki et al. (2014), but recover only one of the four z > 8.4 sources reported by Zheng et al. (2014). In the MACSJ0416.1-240 cluster field we report five objects, and explain why each of these eluded detection or classification as z ~ 9 galaxies in the published searches of the shallower CLASH data. Finally, we uncover four z ~ 9 galaxies from the previously unsearched MACSJ0416.1-240 parallel field. Based on the published magnification maps we find that only one of these 12 galaxies is likely boosted by more than a factor of two by gravitational lensing. Consequently we are able to perform a fairly straightforward reanalysis of the normalization of the z ~ 9 UV galaxy luminosity function as explored previously in the HUDF12 programme. We conclude that the new data strengthen the evidence for a continued smooth decline in UV luminosity density (and hence star-formation rate density) from z ~ 8 to z ~ 9, contrary to recent reports of a marked drop-off at these redshifts. This provides further support for the scenario in which early galaxy evolution is sufficiently extended to explain cosmic reionization.

Stellar masses from the CANDELS survey: the GOODS-South and UDS fields

Santini, P.; Ferguson, H. C.; Fontana, A.; Mobasher, B.; Barro, G.; Castellano, M.; Finkelstein, S. L.; Grazian, A.; Hsu, L. T.; Lee, B.; and 28 coauthors.

2014, arXiv:1412.5180

We present the public release of the stellar mass catalogs for the GOODS-S and UDS fields obtained using some of the deepest near-IR images available, achieved as part of the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS) project. We combine the effort from ten different teams, who computed the stellar masses using the same photometry and the same redshifts. Each team adopted their preferred fitting code, assumptions, priors, and parameter grid. The combination of results using the same underlying stellar isochrones reduces the systematics associated with the fitting code and other choices. Thanks to the availability of different estimates, we can test the effect of some specific parameters and assumptions on the stellar mass estimate. The choice of the stellar isochrone library turns out to have the largest effect on the galaxy stellar mass estimates, resulting in the largest distributions around the median value (with a semi interquartile range larger than 0.1 dex). On the other hand, for most galaxies, the stellar mass estimates are relatively insensitive to the different parameterizations of the star formation history. The inclusion of nebular emission in the model spectra does not have a significant impact for the majority of galaxies (less than a factor of 2 for ~80% of the sample). Nevertheless, the stellar mass for the subsample of young galaxies (age < 100 Myr), especially in particular redshift ranges (e.g., $2.2 < z < 2.4$, $3.2 < z < 3.6$, and $5.5 < z < 6.5$), can be seriously overestimated (by up to a factor of 10 for < 20 Myr sources) if nebular contribution is ignored.

Abstracts of technical ASP publications

Improving resolution and depth of astronomical observations via modern mathematical methods for image analysis

Marco Castellano, Daniele Ottaviani, Adriano Fontana, Emiliano Merlin, Stefano Pilo, Maurizio Falcone

2014, ASP Conf Series, in press.

In the past years modern mathematical methods for image analysis have led to a revolution in many fields, from computer vision to scientific imaging. However, some recently developed image processing techniques successfully exploited by other sectors have been rarely, if ever, experimented on astronomical observations. We present here tests of two classes of variational image enhancement techniques: ”structure-texture decomposition” and ”super-resolution” showing that they are effective in improving the quality of observations. Structure-texture decomposition allows one to recover faint sources previously hidden by the background noise, effectively increasing the depth of available observations. Super-resolution yields a higher-resolution and

a better sampled image out of a set of low resolution frames, thus mitigating problems in data analysis arising from the difference in resolution/sampling between different instruments, as in the case of EUCLID VIS and NIR imagers.

T-PHOT: Advanced techniques of precision photometry for present and future multiwavelength surveys

E. Merlin and the astrodeep consortium

2014, ASP Conf Series, in press.

The blending of extragalactic sources in low-resolution images is a major complication to the photometric analysis of infrared or ground based data. To cope with this issue, one can use the information from a high-resolution image as spatial and morphological prior, obtaining precision photometric measurements on lower resolution images of the same field. We present T-PHOT, new software developed to this aim in the context of the AstroDEEP project. T-PHOT is fast, robust and versatile, and it largely improves on similar codes being used in the community.