The VISTA Deep Extragalactic Observations (VIDEO) Survey

Matt J. Jarvis[1,2]
Boris Häußler[1,3]
Kim McAlpine[2]

[1] Astrophysics, Department of Physics, Oxford, United Kingdom
[2] Physics Department, University of the Western Cape, Bellville, South Africa
[3] Centre for Astrophysics, Science & Technology Research Institute, University of Hertfordshire, Hatfield, United Kingdom

The VIDEO survey is designed to answer key questions regarding the formation and evolution of galaxies, in particular the role of accretion onto black holes and how galaxy evolution may vary depending on environment. VIDEO undertakes deep near-infrared imaging over three well-observed extragalactic fields allowing in-depth study of galaxy evolution over $1 < z < 4$, linking the shallower VST and VISTA surveys with the UltraVISTA survey. The area and depth of the VIDEO survey enables the detection of the bulk of the luminosity density arising from galaxies over 90% of the history of the Universe, as well as the most massive galaxies at all epochs and any associated accretion activity. A few scientific highlights from the early VIDEO data are provided.

How and when were massive galaxies formed?
When did they assemble the bulk of their stellar mass and how?
Where does this mass assembly occur?
These are the crucial questions that VIDEO is designed to answer.

VIDEO enables us to perform an in-depth study of the Universe over the redshift range $1 < z < 4$, linking the shallower surveys such as the VISTA Hemisphere Survey (VHS) and the VISTA Kilo-Degree Survey (VIKING; see de Jong et al. p. 44) with the deeper UltraVISTA survey (McCracken et al. p. 29). The depths of the VIDEO survey have been chosen to detect all "typical" elliptical galaxies out to redshifts of $z \sim 4$, and much fainter galaxies at around a tenth of the luminosity of a typical elliptical galaxy at $z \sim 1$, thereby enabling us to detect the bulk of the luminosity density arising from galaxies over 90% of the history of the Universe, and the most massive galaxies at the highest redshifts.

Thus we are able to investigate in exquisite detail which galaxies are in place first, and address the issue of downsizing in the mass function of forming galaxies, where the massive early-type galaxies appear to be in place before the less massive galaxies.

The epoch for which VIDEO is aimed is also a crucial one in the history of the Universe, as this is when the bulk of the star formation and accretion activity took place. VIDEO is therefore the ideal survey with which to investigate the effects that star formation and accretion activity have on galaxy evolution in general.

Moreover, the intrinsic rarity of the most luminous active, starburst and elliptical galaxies means that it is important to survey a large enough area, from which the luminosity function and clustering of particular galaxy populations can be measured. VIDEO covers 12 square degrees, improving on previous area-limited surveys that have measured the clustering of various galaxy populations to scales of < 0.5 degrees. Crucially, VIDEO will have sufficient area to carry out these investigations as a function of both redshift and environment.

VIDEO not only can detect the galaxies which contribute the bulk of the luminosity density at these redshifts, but the five near-infrared (NIR) filters, along with ancillary data from visible-wavelength surveys and the Spitzer Space

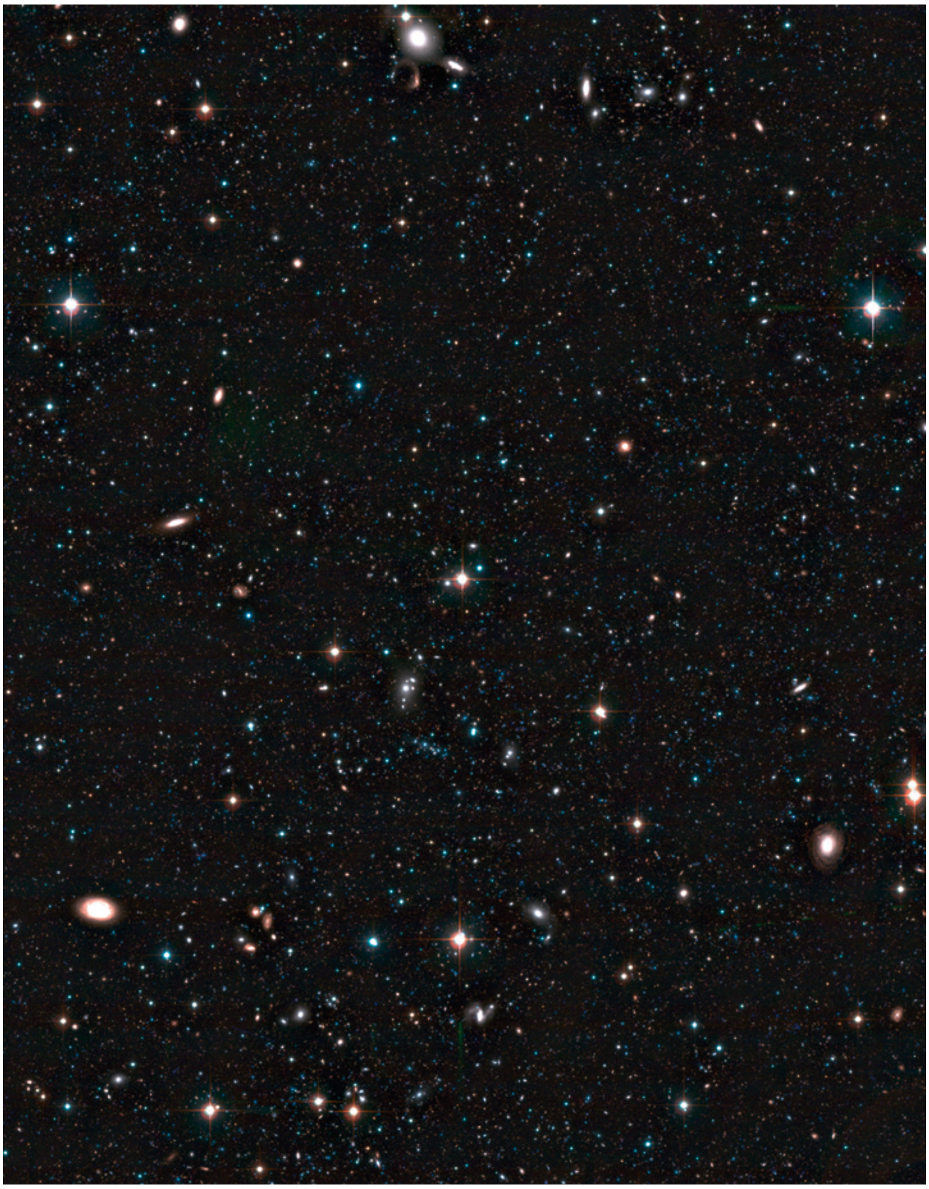


Figure 1. Colour image containing around 1/100 of the total 12 square degree area of the VIDEO field, centred on a region within the XMM-LSS field.

Telescope, will provide photometric redshifts for galaxies all the way out to $z \sim 6$ for the most massive galaxies.

Survey fields

The VIDEO survey is being carried out over three of the most widely observed high Galactic latitude fields: these are two VISTA tiles (3 square degrees) in the ELAIS-S1 field; three VISTA tiles (4.5 square degrees) in the XMM-Newton Large Scale Structure (XMM-LSS) field; and another three tiles in the extended Chandra Deep Field South. The total area covered is ~ 12 square degrees. A small fraction of the VIDEO survey data is shown in Figure 1. The three fields have a wealth of data from the X-ray through to the radio waveband, and are, along with COSMOS/UltraVISTA, the primary fields for observation with future facilities in the southern hemisphere.

Figure 1 in Jarvis et al. (2013) shows the footprint of the VIDEO observations in each of these three fields. The design of these positions was driven by the need to cover the wealth of ancillary data available in these fields, including Spitzer (e.g., Mauduit et al., 2012) and Herschel (Oliver et al., 2012), in addition to future ground-based optical data from both the VST and the Dark Energy Survey. Further in the future these areas will also be targeted with the deepest radio observations by the Square Kilometre Array precursor telescope MeerKAT (Jarvis, 2012) and also form part of the Large Synoptic Survey Telescope (LSST) deep drilling fields.

Photometric redshift accuracy

One of the key elements of the VIDEO survey is to provide the NIR data needed to obtain accurate photometric redshifts over all cosmic epochs, but particularly at $z > 1$, where the spectral break at 4000 Å is redshifted beyond the visible wavelength window. These photometric redshifts underpin much of the science that is and will continue to be carried out with the VIDEO survey data. To show the accuracy to which we can measure photometric redshifts with VIDEO, we cross-match the publically released deep-imaging data in the VIDEO-XMM3 field with the latest release of the VIMOS-VLT Deep Survey (VVDS) spectroscopic survey (Le Fevre et al., 2013) over the same region of sky. We select all of those spectroscopic sources with very secure spectroscopic redshifts and compare them with their photometric redshifts derived from the VIDEO photometry, combined with optical data from the Canada France Hawaii Telescope (CFHT), resulting in 1403 galaxies at $0 < z < 3.5$. By only using those sources that were classified as galaxies by the Le Phare photometric redshift code (Ilbert et al., 2006) we find that the normalised median absolute deviation of $(z_{spec} - z_{phot})/(1 + z_{spec})$ is 0.014 and the catastrophic outlier fraction, defined as $|z_{spec} - z_{phot}|/(1 + z_{spec}) > 0.15$, is just 0.65%. In Figure 2 we show the spectroscopic redshifts from the VVDS against the photometric redshifts from VIDEO.

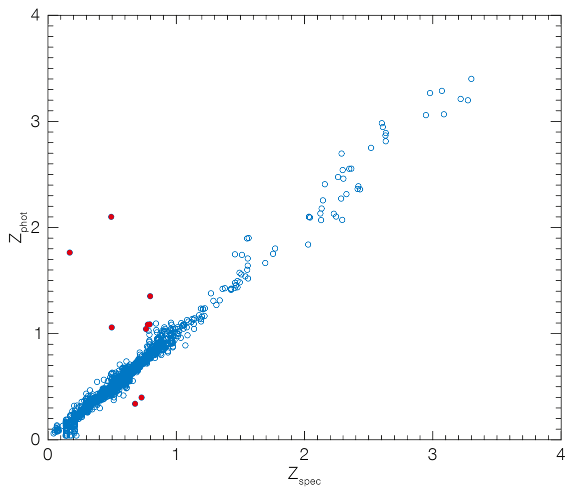


Figure 2. Photometric redshifts from VIDEO+CFHT data (z_{phot}) are plotted versus high-reliability spectroscopic redshifts (z_{spec}) from the VVDS spectroscopic survey. Filled red circles denote the nine sources classified as catastrophic outliers.

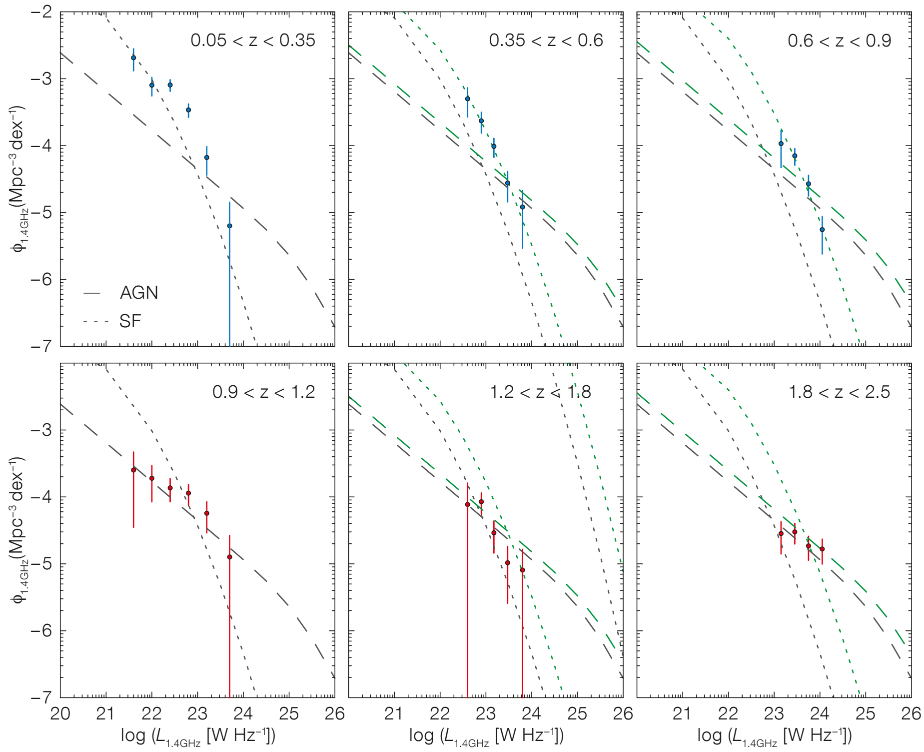


Figure 3. The star-forming (top panel — blue points) and active galactic nuclei (AGN; bottom panel — red points) radio luminosity function (RLF) in three redshift bins. Star-forming galaxies are identified as objects fitted by blue templates in the photometric redshift fitting procedure. The local luminosity function for star-forming galaxies and AGN from Mauch & Sadler (2007) are plotted as black dotted and dashed lines respectively. The green dotted line is the evolved RLF of star-forming galaxies and the green dashed line is the evolved RLF of AGN assuming the evolution parameters from McAlpine et al. (2013).

Disentangling low luminosity radio AGN from star-forming galaxies to $z \sim 2$

Over the past decade it has become clear that active galactic nuclei (AGN) may provide a critical feedback process that truncates star formation in massive galaxies. In particular, radio-loud AGN may provide an additional form of feedback via the mechanical deposition of energy resulting from jets. The predominantly low luminosity AGN, which are thought to be responsible for the bulk of mechanical feedback at $z < 1$, and are believed to be powered by inefficient accretion of hot gas, appear to inhabit gas-poor, quiescent massive galaxies. On the other hand the higher luminosity sources that are efficiently accreting cold gas tend to reside in similarly massive galaxies, but with indications of recent star formation activity. However, decoupling the low luminosity AGN activity from star formation activity at radio wavelengths can be challenging, due to the large overlap in radio luminosity between the lowest luminosity AGN and moderately star-forming galaxies. However, with deep optical imaging coupled with the NIR imaging provided by VIDEO, we may have an efficient method of tracing the evolution of these different populations.

McAlpine, Jarvis & Bonfield (2013) used a combination of visible imaging, NIR imaging from VIDEO and deep radio data from the Jansky Very Large Array to decouple the evolution of star-forming galaxies and AGN traced by radio emission. In Figure 3 we show the radio luminosity function in three redshift bins for galaxies classified as a) star-forming, and b) quiescent, based on their optical–NIR spectral energy distributions. We can see that this split is consistent with the differential evolution of both populations with redshift, showing that it is possible to use multi-colour imaging data to categorise AGN and star-forming galaxies. Given the rarity of AGN and the most luminous star-forming galaxies, with the full VIDEO survey area we will have a unique dataset with which to answer the key questions on AGN evolution and its impact on galaxy evolution.

Additionally the area coverage of VIDEO allows us to study the environments of such AGN. In Karouzos, Jarvis & Bonfield (2013) we find that such radio sources tend to reside in environments of increased density with respect to a stellar-mass matched sample of elliptical galaxies. This in turn implies that the fuelling source for low luminosity radio sources may indeed come from the hot intracluster medium.

The high-redshift Universe

VIDEO is uniquely placed to quantify the density and spatial clustering of the most massive galaxies at the earliest epochs. Initial work on this topic by Willott et al. (2013) used VIDEO data to show that the bright end of the galaxy luminosity function at $z \sim 6$ follows an exponential decline and that these massive galaxies appear to be both larger and dustier than their fainter counterparts discovered in deep Hubble Space Telescope (HST) imaging. VIDEO data will be crucial in helping to pin down the luminosity function of high-redshift ($z > 6$) galaxies. Although much shallower than the very deep NIR surveys conducted with the HST Wide Field Camera 3 (WFC3), the area is such that we can measure the shape of the bright end of the galaxy luminosity function within the epoch of reionisation and gain a full picture of the galaxy population at these high redshifts.

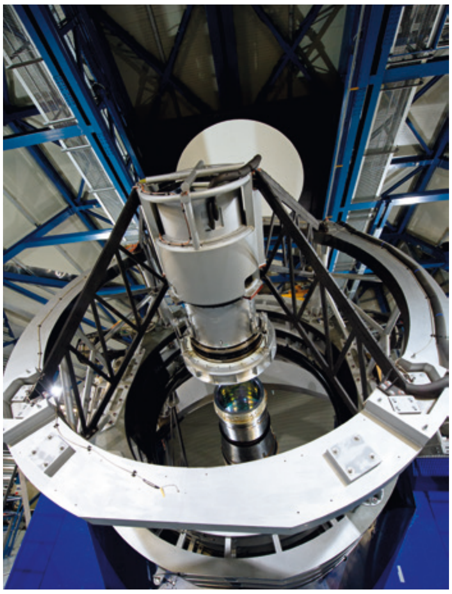
With the full VIDEO survey area we will be able carry out the first statistically significant clustering analysis of massive galaxies towards the epoch of reionisation, providing a direct link between the underlying dark matter distribution and galaxy populations and how this evolves up to the highest redshifts. The VIDEO survey will detect a factor of ~ 10 more $M > 10^{11} M_{\odot}$ galaxies than UltraVISTA at $z \sim 6$, as the limiting factor is area rather than depth.

Acknowledgements

We would like to thank David Bonfield for the tremendous amount of work that he put in for the first few years of the VIDEO survey.

References

Ilbert, O. et al. 2006, A&A, 457, 841
Jarvis, M. J. 2012, African Skies, 16, 44
Jarvis, M. J. et al. 2013, MNRAS, 428, 1281
Karouzos, M., Jarvis, M. J. & Bonfield, D. G. 2013, MNRAS, submitted
Le Fèvre, O. et al. 2013, A&A, 55, 14
Mauch, T. & Sadler, E. M. 2007, MNRAS, 375, 931
Mauduit, J.-C. et al. 2012, PASP, 124, 714
McAlpine, K., Jarvis, M. J. & Bonfield, D. G. 2013, MNRAS, 436, 1084
Oliver, S. et al. 2012, MNRAS, 424, 1614
Willott, C. J. et al. 2013, AJ, 145, 4



ESO/C. Malin

A view from the top of the VISTA telescope showing the secondary mirror assembly and the primary mirror. The dome screen for flat field illumination is seen at the rear.