Decrypting the Universe

Large Surveys for Cosmology

Joint Royal Observatory Edinburgh/JSPS
Core-to-Core Program Workshop

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Talk abstracts

Contents

1 The state of the Universe

Prof. David Spergel

"The state of the Universe"

We are at a remarkable moment in cosmology. We have a simple model with a handful of parameters that fits a host of astronomical data. Yet, we do not understand the basic ingredients of this model: dark energy, dark matter, and the physics of inflation. I will review the current observational situation with an emphasis on results from microwave background experiments and discuss some future observational prospects.

Dr. Alexander Murphy

"The direct detection of Dark Matter"

The goal of being the first to directly detect dark matter is one of the most competitive topics of modern science. Strongly motivated by astronomical evidence and by theories of particle physics beyond the standard model, it is believed that our galaxy is immersed within a halo of weakly interacting massive particles. This talk will review the methods and status of the leading groups endeavouring to make this detection.

2 Dark Energy

Prof. Ed Copeland

"Dark Energy theory"

I briefly review attempts that have been made to model dark energy. These include models of a cosmological constant, dynamical models where a scalar field may be responsible for the observed late time acceleration through to the possibility that we are not fully in control of the gravity sector and the acceleration may be some manifestation of modified gravity. In all cases we will see some degree of fine tuning is required with the current models.

Prof. Takahiko Matsubara

"Anisotropic clustering of galaxies in high-z Universe as a probe of Dark Energy"

The anisotropic clustering of galaxies are considered as a powerful probe of dark energy. The BAO encoded in galaxy clustering provides a useful scale for this purpose. I will review a method of constraining the dark energy using the anisotropic clustering of galaxies in high-z universe. Our original method using the correlation function in high-z space will be presented. Prospects for accurately modelling the BAO in galaxy clustering will be discussed.

Dr. David Parkinson

"Optimisation of large surveys to probe the dark energy"

The next generation of large-scale structure surveys will provide a number of complimentary methods to determine the dark energy properties (e.g. weak lensing, cluster number counts, baryon acoustic oscillations and supernovae). These surveys have been estimated to make a measurement of some parameterisation of the dark energy (e.g. $\Omega_{\rm DE}$, w_0, w_a) to some accuracy by a Fisher Matrix approach, defined by the DETF as a Figure of Merit. The design of the particular details of a survey will change from initial concept to final plan, and can be optimised using such a Figure of Merit. This talk discuss how this is done for BAO and Weak Lensing surveys.

Dr. Alexandre Refregier

"DUNE: The Dark UNiverse Explorer"

DUNE is a wide-field space mission for the high-precision study of dark matter and dark energy. DUNE will also provide unique all-sky legacy surveys in the visible and NIR for various fields in Astronomy, I will describe the main science drivers, mission baseline and current status of the mission.

3 Science with Subaru

Prof. Toru Yamada

"Wide field surveys with Subaru telescope"

In this talk, I will review the wide-field surveys and achieved scientific results from Subaru in order to introduce the idea about current and future performance and feasibility of the Subaru telescope for the discussions at the rest of the workshop. This includes introductions and science highlights of Subaru Deep Field, Subaru XMM-Newton Deep Surveys, COSMOS, Subaru/UKIDSS DXS 10-deg Survey (SCDXT), and wide-field narrow-band surveys (especially for SSA22-NB Survey), many of which I've been involved, although not all. In the context, I would like to briefly talk about our new results in the widest-field ($>$ a few deg^2) and deep surveys, namely SCDXT and SSA22-NB surveys.

Dr. Satoshi Miyazaki

"Hyper Suprime-Cam"

Hyper Suprime-Cam (HSC) is a next generation wide field camera proposed for 8.2 m Subaru Telescope. The planned field of view is 1.5 degree in diameter, nearly 10 time improvement over the existing prime focus camera (Suprime-Cam). We will have image quality ($D80 \lesssim 0.28\,\mathrm{arcsec}$) in $600 < \lambda < 1100\,\mathrm{nm}$ everywhere on the field which is equivalent with that of Suprime-Cam. The number of CCDs required to fill the entire field (about 60 cm in diameter) is about 100 when we adopt 2k4k (15 micron pixel). Fully depleted CCDs developed by Hamamatsu will be adopted. We have been discussing with Gemini Telescope whether it is feasible to coordinate the WFMOS instrument (3000 fiber spectrograph with 1.5 degree diameter field) project with HSC. In this talk, we will update the status of the HSC project.

Dr. Masami Ouchi

"Constraining galaxy formation and reionization by deep and wide-field surveys "

In the first half of my talk, I present recent results from our deep and wide-field surveys of Lyα emitters (LAEs) at z=3.1-6.6 in the Subaru/XMM Deep Field (SXDF). Our deep and wide-field SXDF data allow us not only to measure clustering of LAEs, but also to obtain accurate luminosity function that is unprecedentedly robust to statistical errors and field variance. Lyα Luminosity function (LF) of LAEs shows no evolution within a factor of 2-3 from z=3.1 to 5.7 in the apparent Lyα luminosity or number density. On the other hand, UV LF of LAEs increases in the past, while that of dropout galaxies decreases in this redshift range. It indicates the emergence of Lyα emitting population at $z \sim 6$. We find that clustering of LAEs does not significantly change from $z = 5.7$ to 6.6 based on preliminary data of our on-going $z = 6.6$ LAE survey. This clustering evolution places constraints on the neutral fraction and the size of ionized bubbles, which are consistent with recent measurements from GRBs and luminosity function of LAEs. The second half of my talk focuses on showing our prospects of next-generation deep and wide-field surveys with Subaru/HSC and WFMOS. I introduce recent discussions of two programs, ultra-deep and deep-wide surveys, for high-z galaxies with Subaru/HSC and spectroscopic follow-up studies with WFMOS.

4 Large scale structure with photo-z surveys

Prof. Yannick Mellier

"Review on weak lensing and large scale structure"

Prof. Ofer Lahav

"Photometric redshift surveys"

The talk will discuss the methodology for deriving accurate photometric redshifts from imaging surveys and a recent application to a sample of one million SDSS Luminous Red Galaxies. Future planned large imaging surveys such the "Dark Energy Survey" and the DUNE space mission will be presented, with implications for understanding the nature of Dark Energy from a variety of cosmological probes.

Dr. Stefanie Phleps

"Investigating large-scale structure with Pan-STARRS: Activities at MPE"

Pan-STARRS, the Panoramic Survey Telescope & Rapid Response System, will survey 3/4 of the sky in five filters over a period of 3.5 years. After completion, the catalogue will contain photometric redshifts with an accuracy of $\sigma_z/(1+z) = 0.02$ for about 10 million luminous red galaxies up to a redshift of $z = 1.5$. This unique data set can be used for all sorts of cosmological and extragalactic analyses. I will introduce the survey and present planned investigations of galaxy evolution and galaxy clustering, especially in respect to the measurement of the equation of state parameter w of the dark energy from BAOs.

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5 Baryonic acoustic oscillations

Dr. Will Percival

"Baryon Acoustic Oscillations in the 2dFGRS and SDSS"

In this talk I will present Baryon Acoustic Oscillation (BAO) distance measurements from galaxy samples drawn from the SDSS and 2dFGRS. I will demonstrate how BAO can be used to provide distance-scale measurements, and discuss some advantages of using BAO rather than smooth features in the power spectrum as standard rulers. Recent observations of BAO will be presented from the combined 2dFGRS and SDSS main galaxy samples, the SDSS luminous red galaxies, and the combined SDSS sample. The observed scale of the BAO gives constraints $r_s/D_V = 0.1980 \pm 0.0058$ at $z = 0.2$, and $r_s/D_V = 0.1094 \pm 0.0033$ at $z = 0.35$ (1-sigma errors), with correlation coefficient of 0.39. Here r_s is the comoving sound horizon scale at recombination, and $D_V(z) = [(1+z)^2 D_A^2 cz/H(z)]^{1/3}$. Matching the BAO to have the same measured scale at all redshifts then gives $D_V(0.35)/D_V(0.2) = 1.812 \pm 0.060$. These distance constraints will be compared with other cosmological data.

Prof. Tom Shanks

"Photo-z versus spectroscopic routes to baryon acoustic oscillations"

We present large-scale galaxy clustering results for SDSS LRGs out to $z = 0.9$. We investigate how these photo-z results compare to results from redshift surveys in their sensitivity to detecting baryonic acoustic oscillations (BAO). We discuss future prospects for detecting BAO from photo-z surveys such as VST ATLAS+ VISTA Hemisphere Survey and from spectroscopic redshift surveys using instruments such as AAOmega and WFMOS.

Prof. Raul Jimenez

"The PAU Baryonic Acoustic Oscillations Experiment"

I will describe a new funded initiative to observe a quarter of the sky with a precision of $0.002(1+z)$ up to redshift $z \sim 1$. I will show the expected precision on dark energy parameters and the ancillary science that we expect to obtain beyond BAO physics.

Dr. Nikhil Padmanabhan

"BOSS : The Baryon Oscillation Spectroscopic Survey"

I will introduce BOSS, a proposed low redshift baryon oscillation survey using the SDSS 2.5m telescope. The survey plans on surveying 10000 sq. deg of the sky, and measuring the redshifts to 1.5 million luminous red galaxies to a redshift of 0.8. It also will target 160,000 quasars between $z = 2.0$ and 3.0, attempting a first measurement of BAO with the Lyman-α forest. I will discuss the forecasts for this survey, as well as discuss some new techniques for analyzing the next generation of BAO surveys.

Dr. Tomonori Totani

"FastSound: A near-infrared BAO survey by Subaru/FMOS"

FMOS is the new multifiber near-infrared spectrograph of Subaru telescope, whose engineering first light would be January 2008. I will report the status of this instrument, and talk on the FastSound project, which is a proposed BAO survey for about 500,000 Hα emitting galaxies at $z \sim 1$.

6 Galaxy formation and clustering

Prof. Shaun Cole

"Galaxy formation theory and modelling"

This talk presents a brief overview of the physical processes that it is necessary to model in order to build a complete model of galaxy formation. I review several significant improvements that have been made in various components of such models. These include the modelling of the structure of dark matter haloes, dynamical friction, AGN feedback and other topics, but I concentrate on improvements in modelling dark matter halo merger trees. Finally, I review the recent paper , Harker, Cole & Jenkins (2007), as an illustration the potential of combining galaxy formation modelling with large scale structure observations.

Dr. Jon Loveday

"Galaxy clustering in UKIDSS Large Area Survey"

I will discuss the clustering of galaxies selected from the UKIDSS Large Area Survey, with particular emphasis on the potential of using photometric redshifts to determine the very large-scale clustering of galaxies.

Dr. Nelson Padilla

"Statistics of high redshift galaxies from MUSYC"

In this talk, I will review recent results on the correlation and luminosity function of galaxies in the MUSYC survey, which covers 1sq degree of the sky from the X-ray to the Radio wavelength range, which allows accurate photometric redshifts and several intrinsic galaxy properties to be obtained. In particular I will focus on the general population of galaxies down to redshifts $z \sim 2$ and on Ly-α emitters at $z = 3.1$.

Dr. Avery Meiksin

"Photoionization impact of galaxies and QSOs on the IGM"

Numerical simulations of reionization of the IGM by galaxies and QSO sources are used to solve for the temperature evolution of the IGM. It is shown that reionization dominated by a. galactic sources, b. QSO sources, and c. a combination of galactic and QSO sources each produces broadly different characteristic IGM temperature distributions. A model in which galaxies dominated the ionization of the IGM down to $z = 3$ followed by QSOs at $z < 3$ produces temperatures best matching IGM measurements. This, along with other evidence, suggests the escape fraction of ionizing radiation from galaxies was higher in the past.

7 Nearby cosmology

Dr. Amina Helmi

"Nearby cosmology review"

Many of today's observables within the Milky Way and nearby galaxies relate to events occurring at high redshift, during and soon after the era of reionization. In this sense, galaxies in the Local Group provide a crucial diagnostic link to the early universe, as well as some of the most stringent tests of modern cosmological models. In this review, I will discuss recent results from large wide field surveys and focus on their impact on our understanding of the dynamics, chemical histories and assembly of the Milky Way and its satellites.

Prof. Gerry Gilmore

"The dSph satellites of the Milky way as Dark Matter tests"

The dSph are key probes of Dark Matter on small scales. Their number, astrophysical status and mass profiles are all determined by the properties of Dark Matter. I provide an update of recent SDSS-based luminosity function determinations, and kinematic studies of the actual DM mass profiles on small scales.

Dr. Masashi Chiba

"Near-field cosmology: structure and dynamics of the old galactic components"

We present here the recent progress in our understanding of the old stellar components of the Milky Way and Andromeda as fossil records of galaxy formation. Special attention will be paid to if the Cold Dark Matter (CDM) theory as a current theoretical paradigm is able to reproduce recently accumulated data sets of fossil stars as provided by several surveys with Subaru and SDSS/SEGUE. We show our recent studies in this regard, including structure and dynamics of Galactic metal-poor stars provided by SDSS/SEGUE, stellar populations of the M31 halo provided by Subaru, and simulation studies for the formation of thin- and thick-disk components. A detailed comparison with the CDM predictions has been made and key issues are addressed for understanding the formation of disk galaxies.

Dr. Andreea Font

"Reconstructing the formation histories of the Milky Way and Andromeda galaxies "

In hierarchical cosmologies, large galaxies like the Milky Way and Andromeda (M31) form through the accretion and tidal disruption of smaller (satellite) galaxies. Evidence of these processes remains imprinted in the observed stellar properties of the galactic halo and debris from tidally-disrupted satellites. I will show how combining information about the age, chemical abundance, and phase-space distribution of these stars can be used to reconstruct the formation histories of the Milky Way and M31. I will illustrate this approach using a suite of high resolution N-body models of Milky Way- and M31-like galaxies formed in a hierarchical Lambda CDM Universe. Finally, I will compare these theoretical results with recent observations from state-of-the-art wide field surveys of these galaxies.

8 Supernovae

Prof. Mamoru Doi

"Type Ia supernova and dust extinction"

Type Ia Supernova (SNIa) is one of the best standard candles, and has been used for cosmological expansion measurements. To improve accuracy as a standard candle further, we have to deal with dust extinction of host galaxies as well as intrinsic dispersions of SNIa color/brightness. We show recent results of our re-analysis of nearby SNeIa and discuss color distributions of SNIa. Also we show recent activities of measuring cosmological expansions with SNeIa on elliptical hosts.

Prof. Richard Ellis

"Verifying the utility of distant supernovae as precision cosmology probes"

I will report on a now completed Keck survey of high signal to noise rest-frame UV spectroscopy of intermediate redshift CFHT SNLS Type Ia supernovae that illustrate the challenges remaining in utilizing these events as precision cosmology probes with future ground and space-based missions.

Dr. Mark Sullivan

"The Supernova Legacy Survey"

The CFHT Supernova Legacy Survey (SNLS) is a 2003-2008 programme using around 500 high-redshift ($0.2 < z < 1.0$) Type Ia Supernovae (SNe Ia) to constrain the average equation-of-state parameter of dark energy, w. We will present results from the first 3.5 years of the survey, including the latest analyses of the cosmological constraints derived from around 300 SNe Ia segregated according to their host galaxy environment. These tests, and others enabled by the SNLS dataset, provide a powerful test of systematics, such as dust extinction and evolution, that can affect the use of SNe Ia as precision cosmological probes. Finally, we briefly discuss the prospects for SN cosmology surveys planned over the next 5 years in the context of science learned from SNLS.

Dr. Isobel Hook

"Cosmology with the European Extremely Large Telescope"

The European ELT has now entered the detailed design phase with the aim of starting operation well before the end of the next decade. The baseline reference design is a 42m telescope with adaptive optics built in. I briefly describe the project and the dramatic advances that such a telescope will produce for observational cosmology. I will focus on the future constraints on Dark Energy, such as can be expected from a Type Ia supernova survey reaching redshifts up to 4, and observing the dynamical expansion of the Universe in "real time" via a high-precision survey of QSO absorption lines.

9 Modified gravity and more BAOs

Prof. Roy Maartens

"Modified gravity models"

The observed late-time acceleration of the universe is usually interpreted as due to a dark energy field in the framework of General Relativity. But it is also possible that the acceleration is due to an intrinsic weakening of gravity itself on large scales - in other words, a modification of General Relativity on large scales. There are two key challenges for modified gravity theories before they are even applied to cosmology: Firstly the theoretical challenge of internal consistency and regularity. Secondly the challenge of solar system observations, which force modified gravity to closely mimic General Relativity in the solar system. For those modified gravity theories that pass these two challenges, the task is to compute the luminosity distance and perturbations, and then use cosmological observations to place further constraints on the theories. Unfortunately there is currently no guidance from fundamental theory as to which modified gravity model, if any, should be favoured. This leads us to a more general objective - how to develop observational tests that could provide a signature of modified gravity in general, i.e., a signature of the breakdown of General Relativity on cosmological scales. Since it is possible to construct a GR dark energy model to reproduce any given expansion history $H(z)$, we need to look at structure formation to find such signatures of modified gravity.

Dr. Kazuhiro Yamamoto

"Observational test of modified gravity models with future imaging survey of galaxies"

We consider the extent to which future imaging surveys of galaxies can distinguish between dark energy and modified gravity models for the origin of the cosmic acceleration. We parameterize the cosmic expansion by the two parameters, w_0 and w_a, and the linear growth rate of density fluctuations by Linder's γ, independently. We perform the Fisher matrix analysis for a weak lensing survey such as the on-going Hyper Suprime-Cam (HSC) project.

Dr. Atsushi Taruya

"A closure theory for non-linear evolution of power spectrum"

The next-generation galaxy redshift survey will achieve a high-precision measurement of cosmic matter power spectrum and it would provide a valuable information on the formation of large-scale structure and the expansion history of the universe. In particular, acoustic signature of the primeval baryon-photon fluid imprinted in the observed galaxy power spectrum, known as the baryon acoustic oscillations (BAOs), can be used as the cosmic standard ruler to accurately probe the expansion history of the universe and to clarify the nature of dark energy. For a few percent accuracy on the determination of equation of state for dark energy, more precise theoretical predictions for matter power spectrum are required. In this talk, I discuss the theoretical issues on the non-linear power spectrum and present a non-linear statistical method to predict the time evolution of matter power spectrum. Based on this, prospects for accurate prediction of BAO scales and some related problem are addressed.

Dr. Shun Saito

"The impact of non-linear evolution of cosmological matter power-spectrum on the measurement of neutrino masses"

Next-generation galaxy redshift surveys will achieve an accurate measurement of cosmological matter power spectrum with precision of percent level, particularly focusing on the baryon acoustic oscillations (BAOs). Since the characteristic scale of BAOs is comparable to the free-streaming scale of massive neutrinos, it will offer an exciting opportunity for precision determinations of neutrino masses. Here, we discuss the prospects for measuring the neutrino masses, including properly the non-linear gravitational evolution of matter power spectrum for a mixed dark matter model (neutrinos plus cold dark matter) for the first time. Based on the perturbation theory, the effect of non-linearity is quantified and the impact on the neutrino mass determination is clarified.

Mr. Raul Angulo

"The detectability of baryonic acoustic oscillations in future galaxy surveys"

We assess the detectability of baryonic acoustic oscillations (BAO) in the power spectrum of galaxies using ultra large volume N-body simulations of the hierarchical clustering of dark matter and semi-analytical modelling of galaxy formation. A step-by-step illustration is given of the various effects (nonlinear fluctuation growth, peculiar motions, nonlinear and scale dependent bias) which systematically change the form of the galaxy power spectrum on large scales from the simple prediction of linear perturbation theory. Using a new method to extract the scale of the oscillations, we find that the BAO approach gives an unbiased estimate of the sound horizon scale. We use our results to forecast the accuracy with which forthcoming surveys (Pan-STARRS, WFMOS, SPACE) will be able to measure the sound horizon scale, and hence the dark energy equation of state parameter.

Dr. Gary J. Hill

"The Hobby-Eberly Telescope Dark Energy Experiment (HETDEX)"

HETDEX will outfit the 10 m Hobby-Eberly telescope with a new wide field and an array of 145 integral-field spectrographs (VIRUS) to survey a 350 sq. degree area in the north galactic cap. Each fiber-coupled spectrograph will cover 350-590 nm, simultaneously at 5 A resolution, providing $\sim 40,000$ spectra per exposure. This instrument, called VIRUS, will open up large area surveys of the emission-line universe for the first time, and in particular will be used to detect ~ 1 million Lyman-α emitting (LAE) galaxies with $1.9 < z < 3.8$ in the survey area. The 3-D map of these galaxies, filling 7.5 cubic Gpc, will be used to detect baryon acoustic oscillations and to constrain the expansion history of the Universe at this early epoch. The measurement will provide a unique opportunity to constrain evolution of dark energy and will provide the most accurate constraint on the curvature of the Universe.
The prototype of the VIRUS unit spectrograph is currently in use for a pilot survey to better measure the properties of LAE galaxies in support of HETDEX. The HETDEX dataset will also contain ~ 2 million $z < 0.5$ star-forming galaxies, and many other objects selected spectroscopically, such as metal poor stars. HETDEX is estimated to cost $34M, of which $20M has been raised. Following the successful Science Requirements Review in June 2007, and the Preliminary design review in early 2008, contracts will be let for the HET wide field upgrade in early 2008. We plan to deploy the upgrade and VIRUS in 2010, and complete observations for HETDEX in 2013.

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10 Surveys at other wavelengths

Mr. Joshua Younger

"Evidence for a population of high-redshift submillimeter galaxies from interferometric imaging"

We have used the Submillimeter Array to image a flux limited sample of seven submillimeter galaxies, selected by the AzTEC camera on the JCMT at 1.1 mm, in the COSMOS field at $890\,\mu$m with $\sim 2\,$arcsec resolution. All of the sources – two radio–bright and five radio–dim – are detected as single point–sources at high significance ($> 6\sigma$), with positions accurate to $\sim 0.2\,$arcsec that enable counterpart identification at other wavelengths observed with similarly high angular resolution. As compared to the two radio-bright sources in the sample, and those in previous studies, the five radio-dim sources in the sample (1) have systematically higher submillimeter-to-radio flux ratios, (2) have lower IRAC $3.6-8.0\,\mu$m fluxes, and (3) are not detected at $24\,\mu$m. These properties, combined with size constraints at $890\,\mu$m ($\theta \sim 1.2\,$arcsec), suggest that the radio–dim submillimeter galaxies represent a population of very dusty starbursts, with physical scales similar to local ultraluminous infrared galaxies, with an average redshift higher than radio–bright sources.

Dr. Eelco van Kampen

"Surveys of high-z galaxies and galaxy clusters with Herschel and SCUBA-2"

I'll present the case for surveying high-z galaxies at long wavelength, especially in and around overdense regions like galaxy clusters. Presented will be predictions for such surveys with SCUBA-2 and Herschel, to be done over the next two to three years.

Dr. Philip Best

"Decrypting the Universe with future radio surveys"

The LOFAR radio telescope, currently under construction in the Netherlands and across Europe, offers great prospects for improving our understanding of cosmology and galaxy formation. I will summarise the overall capabilities of LOFAR, concentrating particularly on the "extra-galactic surveys" key science project. I will then focus on one particular aspect: using LOFAR to determine how the role of radio AGN feedback evolves with cosmic time.

Prof. Steve Rawlings

"The Square Kilometre Array (SKA)"

The Square Kilometre Array (SKA) is a machine that has the potential to make definitive studies of the large-scale structure of the Universe, and hence strongly constrain the 'dark sector' of the Universe in which we live. I will focus both on 'first-light' experiments with the SKA and a possible ten-year survey programme.

11 Synergy of methods

Dr. Masahiro Takada

"The non-Gaussian signatures in cosmic shear fields"

The cosmic shearing effects on distant galaxy images offer a unique way for measuring the total matter distribution of large-scale structure weighted by angular diameter distance combinations. However, most of useful cosmological information arise from the small angular scales where mass distribution is in the non-linear regimes. Therefore the non-Gaussian errors induced by the non-linear gravitational clustering need to be properly taken into account for the high-precision cosmic shear measurement. I will describe how the non-Gaussian errors influence cosmic shear measurements particularly with a future survey in mind and could lead to degradation in parameter constraints. If time is allowed, I will also describe a possibility of combining cosmic shear and cluster counts, both available from a single imaging survey, to improve dark energy constraints.

Dr. Jochen Weller

"Complementarity of future Dark Energy probes"

We discuss in a "parameter free" fashion the ability of future surveys to constrain dark energy. We pay particular attention how different types of surveys, such as weak lensing, cluster counts, supernovae and baryon acoustic oscillation measurements, are sensitive to different redshift ranges and how complementary they are. This will be mainly discussed in the context of the Dark Energy Survey, but we will also show results for other proposed surveys.