'Weak Lensing in the Era of Stage-IV Surveys (WeakLens)' Abstracts

Talks

Investigating the imprint of quintessence in cosmic magnification beyond weak Lensing

Authors

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Abstract

We study cosmic magnification beyond lensing in a late-time universe dominated by quintessence and cold dark matter. The cosmic magnification angular power spectrum, especially going beyond the well-known lensing effect, provides an independent avenue for investigating the properties of quintessence, and hence, dark energy. By analysing the magnification power spectrum at different redshifts, it is possible to extract new information about the large-scale imprint of dark energy, including whether we are able to disentangle different models from one another. Using three well-known quintessence models, we analyse the cosmic magnification angular power spectrum while taking relativistic corrections into account. We found that it will be difficult to distinguish between quintessence models, and quintessence from the cosmological constant, in lensing magnification angular power spectrum on large scales, at redshifts $z \leq 1$; whereas, when relativistic corrections are incorporated, the total magnification angular power spectrum holds the potential to distinguish between the models, at the given z. At $z \geq 3$, the lensing magnification angular power spectrum can be a reasonable approximation of the total magnification angular power spectrum. We also found that both the total relativistic and the Doppler magnification signals, respectively, surpass cosmic variance at $z \leq 0.5$: hence the effect may be detectable at the given z. On the other hand, the ISW and the time-delay magnification signals, respectively, are surpassed by cosmic variance on all scales, at epochs up to $z = 4.5$, with the gravitational-potential magnification signal being zero.

Modelling and Mitigation of Electronic systematics for weak lensing analysis

Authors

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Abstract

The Euclid galaxy survey aims to measure the shapes of 1.5 billion galaxies with unprecedented accuracy to map the matter density of the Universe via weak gravitational lensing. With Euclid we enter a new era of precision constraints on dark matter and dark energy parameters. However, to fully realise Euclid's potential, it is crucial to understand and mitigate limitations from detector-induced systematics in the Visible instrument (VIS). In particular, charge transfer inefficiency (CTI) and an oscillatory electronic effect in the readout register known as pixel bounce, degrade image quality and bias shape measurements. If left uncorrected, these effects can lead to shear calibration biases, adversely impacting weak lensing analyses.

Cosmology with the line-of-sight shear of strong gravitational lenses

Authors

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Abstract

Stage-IV photometric galaxy surveys are designed to measure the position and shapes of billions of galaxies. Their aim is to characterise the large-scale distribution of matter in the Universe using galaxy clustering and weak gravitational lensing. As a by-product, stage-IV surveys are expected to detect more than a hundred thousand strong gravitational lenses. In this talk, I will describe how the weak-lensing perturbations to strong lenses, specifically their line-of-sight (LOS) shear, can be used as a cosmological probe. This new observable allows us to define three new correlation functions: the LOS shear with itself, with galaxy positions, and with galaxy shapes, thereby promoting the standard 3×2pt correlation method to a 6×2pt scheme. I will present the estimators for these new correlation functions as well as the full covariance matrix of the 6x2pt scheme, demonstrating that for a Euclid-like survey, the cosmological information carried by the LOS shear of strong lenses will be detectable with a very high signal-to-noise ratio, even in the most pessimistic of cases. I will further show the forecast constraints obtainable on sigma_8 and Omega_m with the new 6x2pt correlation functions.

Cosmology from the cross-correlation of CMB lensing from ACT-DR6 and galaxy shear from DES-Y3

Authors

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Abstract

We cross-correlate measurements of lensing from two sources: the Cosmic Microwave Background (CMB) from the Atacama Cosmology Telescope (ACT)'s DR6, and galaxy weak lensing from the Dark Energy Survey (DES) Y3. This presents the highest signal-to-noise measurement of its kind to date with a value of ~17.5, marking a significant improvement from the previous value of 7.1 made using ACT-DR4. This combination is most sensitive to the amount of matter clustering in the Universe, $S_8 = \sigma_8(\Omega_m/0.3)^{0.5}$, providing a 4.8% measurement. Future CMB cross-correlations with Stage IV lensing surveys will be a powerful tool for studying structure evolution across a different redshift range to each probe individually, as well as constraining various astrophysical and systematic effects which affect each survey. Here we also constrain baryonic feedback, an important astrophysical effect that impacts the distribution of matter surrounding galaxies, through the one-parameter effective model A_{mod}. The galaxy systematics we calibrate include the multiplicative shear bias, photometric redshift uncertainty, and intrinsic galaxy alignments. We also develop and implement our analysis within the Simons Observatory Likelihood and Theories framework (SOLikeT), in order to prepare for future analyses both with DES-Y6 and Stage IV surveys (e.g. combining SO with Rubin/LSST).

Looking for a twist: probing modified gravity via weak lensing–kSZ cross-correlations

Authors

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Abstract

In General Relativity (GR), the rotational component of the momentum field of matter sources a vector gravitomagnetic (frame-dragging) field, which induces a relativistic correction to the weak-lensing convergence field. At the same time, the momentum field sources the kinetic Sunyaev–Zel'dovich (kSZ) effect. The common origin of these two effects allows the gravitomagnetic signal to be extracted via their cross-correlation, and forecasts using N-body simulations have shown that a significant detection is within reach of Stage-IV lensing surveys such as Euclid and Rubin/LSST in combination with next-generation CMB experiments such as the Simons Observatory. Modified gravity theories, including Hu-Sawicki f(R) gravity and the normal branch of the Dvali–Gabadadze–Porrati (nDGP) model, generically predict an enhancement of the gravitomagnetic potential relative to GR, making the weak lensing–kSZ cross-correlation a promising probe of deviations from ΛCDM. In this work, we extend the weak lensing–kSZ cross-correlation framework to these modified gravity models using N-body simulation data from the FORGE project. We compute the cross angular power spectrum of the lensing convergence and the kSZ effect in both f(R) and nDGP cosmologies and quantify the expected signal-to-noise ratio for upcoming weak lensing surveys and CMB experiments, finding that the gravitomagnetic cross-correlation may provide a new and independent observational test of modified gravity.

Scalable Bayesian Model Comparison for Stage-IV Weak Lensing via Automatic Laplace Collapsed Sampling

Authors

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Abstract

Rigorous analysis of Stage-IV weak-lensing data requires the proper handling of a growing list of nuisance parameters; marginalising the uncertainty from intrinsic alignments, errors, and biases in a Bayesian framework must be done in order to get unbiased cosmology posteriors from the vast amount of incoming data. Systematic modeling also introduces its own uncertainty: the functional form of baryonic feedback, intrinsic alignments, and photo-z distributions are all uncertain, so weighing competing models is as necessary as constraining parameters. This necessitates methods which are capable of robust model comparison, scale to high dimensions (where per-bin per-survey nuisance parameters can reach hundreds of dimensions), and can be run fast enough to perform comparisons across a grid of cosmological, baryonic, and systematic models.
This is a tall order; nested sampling, the standard tool for Bayesian model comparison, scales cubically with dimension, becoming intractable above ~50 parameters.
We present a JAX-native GPU pipeline for weak lensing inference, combining vectorised nested slice sampling with neural emulators, further accelerated with Automatic Laplace Collapsed Sampling (ALCS). ALCS reduces the sampling dimensionality to just the core cosmological parameters: at each likelihood call, nuisance parameters are optimised to their conditional Maximum A Posteriori (MAP) value, and the curvature of the likelihood at that MAP (computed via automatic differentiation) provides the volume contribution of the marginalised parameters. For a joint 3x2pt analysis across Euclid, Rubin/LSST and Roman, where each survey has its own per-bin nuisance parameters, this reduces the sampling dimensionality from hundreds down to fewer than ten, making multi-survey model comparison tractable on a single GPU.
We previously demonstrated GPU nested sampling for a ΛCDM vs w_0w_aCDM shear model comparison in just two days on a single A100 GPU. Collapsed sampling extends this into the high-nuisance regime, providing the computational efficiency to analyse across many competing models. This allows us to honestly marginalise out our modeling uncertainty, and present cosmological posteriors that properly account for what we do not know about astrophysical systematics.
We present performance, validation, and forecast results on simulated Stage-IV datasets, and showcase a diagnostic for the quality of the curvature approximation across cosmological parameter space.