DOWNLOAD PDF NON-LINEAR COSMOLOGICAL POWER SPECTRA IN REAL AND REDSHIFT SPACE

Chapter 1 : Large Scale Structure Observations - Will J. Percival

We have extended this analysis into redshift space and found a solution for the non-linear, anisotropic redshift-space power spectrum in the limit of plane-parallel redshifl distortions. The quadrupole-to-monopole ratio is calculated for the case of power-law initial spectra.

Advanced Search Abstract The galaxy power spectrum is now a well-known tool of precision cosmology. In addition to the overall shape, baryon oscillations and the small-scale suppression of power by massive neutrinos capture complementary information on cosmological parameters when compared with the angular power spectrum of cosmic microwave background anisotropies. We study both the real-space and redshift-space galaxy power spectra in the context of non-linear effects, and model them based on the halo approach to large-scale structure clustering. We consider potential systematics in the cosmological parameter determination when non-linear effects are ignored and the galaxy power spectrum is described with the linear power spectrum scaled by a constant bias factor. We suggest that significant improvements can be made when non-linear effects are taken into account as a power-law contribution with two additional parameters to be determined from the data. In addition to cosmological parameters through galaxy clustering, such an approach allows a determination of useful information related to astrophysics on how galaxies occupy dark matter haloes. In addition to information related to the primordial power spectrum, characterized by a slope and a normalization, through a turnover at , the overall shape of the galaxy power spectrum captures cosmological information related to the horizon at the matterâ€"radiation equality. In addition to the overall shape, additional features in the galaxy power spectrum allow improved measurements of several cosmological parameters. Similar to the oscillatory features in the cosmic microwave background CMB anisotropy power spectrum, the matter power spectrum is expected to exhibit the presence of baryons through oscillations. Unlike well-known oscillatory features in the angular power spectrum of CMB anisotropies, baryon-related oscillations in the matter power spectrum of the large-scale structure are highly suppressed due to the low baryon to dark matter ratio. While the ideal way to detect baryon oscillations is to measure the three-dimensional dark matter power spectrum directly, unfortunately, there are no useful probes of this quantity. Effects such as weak gravitational lensing that trace matter fluctuations only provide information related to the projected power spectrum over a broad window function in redshift space e. This leads to an averaging of small features such as baryon oscillations such that they remain undetectable even considering the most favourable scenarios. Galaxy redshift surveys, on the other hand, allow a measurement of the three-dimensional power spectrum of the galaxy distribution. Since galaxies are expected to trace matter fluctuations, at least in large and linear scales, the galaxy power spectrum has been pursued for an observational detection of baryon oscillations. While expectations for precision parameter measurements are generally high, these have been tested to some extent with measured power spectra from redshift surveys such as the 2dF Galaxy Redshift Survey 2dFGRS; Colless et al. The same surveys have allowed first attempts to detect baryon oscillations, though there is still no significant evidence for them e. In addition to galaxy redshift surveys, a number of additional observational efforts are either under way or planned to image the large-scale structure out to a redshift of a few. These wide-field surveys typically cover tens to thousands of square degrees on the sky and include weak gravitational lensing shear observations with instruments such as the Supernova Acceleration Probe SNAP; Massey et al. These surveys are expected to produce catalogues of dark matter haloes, which in the case of lensing and SZ surveys are expected to be essentially mass-selected Holder et al. In particular, similar to the approach in galaxy redshift surveys, one can measure the power spectrum of clustering associated with these haloes, as a whole, and use that power spectrum for cosmological studies. In addition to the shape, cosmological information comes from the redshift evolution of rulers that can be calibrated through CMB data Cooray et al. The cosmological studies based on the galaxy power spectrum and related halo clustering information, unfortunately, is affected by non-linearities. While sources are expected to trace inhomogeneities in mass due to the non-linear evolution of gravitational perturbations at late times, the galaxy power spectrum at small scales departs significantly from the linear description corrected for source bias. In the case of current measurements, the cosmological interpretation is restricted only for large scales where clustering is expected to be linear. The standard approach to describe the galaxy power spectrum involves the linear power spectrum scaled by a constant bias factor e. Additionally, by restricting cosmological interpretation to specific range of wavenumbers, it is likely that we have only extracted limited information from current data. For example, in the case of the 2dFGRS, analyses have only been considered out to a wavenumber of 0. It is clear that further studies are needed on galaxy clustering well into the non-linear regime, and to understand what information can be extracted from the non-linear regime of clustering or, at least, from the transition regime where non-linearities become important. The purpose of this paper is to understand the onset of non-linearities in the galaxy power spectrum. We study how cosmological parameter measurements can be improved by extracting information from mildly non-linear scales that are currently ignored. In particular, we pay attention to systematics that are introduced to cosmological parameter measurements when the galaxy power spectrum is modelled simply with a scaled version of the linear power spectrum. We show that parameter estimates are biased away from the true values and that these departures can be significantly reduced when the non-linear contribution, at least near the regime of transition from linear to non-linear clustering, is modelled as a power law. Since parameters related to this description are determined from data simultaneously with cosmological parameter estimates, this approach leads to a slight degradation of errors associated with cosmological parameters alone. The main advantage is that these estimates, however, remain either unbiased or biased at a level that is negligible. The suggested approach also avoids an arbitrary distinction as to what scales correspond to the linear regime of clustering while also allowing the maximum extraction of cosmological information from data. The paper is organized as follows. In the next section, we outline the main considerations related to the halo approach to galaxy clustering. We make use of the Fisher matrix approach to quantify biases and expected errors on parameter measurements in Section 3. In Section 4 , we conclude with a summary. Under this description, the galaxy spectrum takes the form of 1.

Chapter 2 : Cosmological Calculations

Some exact solutions are found for power-law initial spectra. We have extended this analysis into red-shift space and found a solution for the non-linear, anisotropic redshift-space power spectrum in the limit of plane-parallel redshift distortions.

In fact, a lot of the information from galaxy surveys does not come directly from the comoving power, but from effects that distort the observed signal away from this ideal. We now outline three of these effects, showing how they can be used to retrieve cosmological information. Projection and the Alcock-Paczynski effect The physics described above is encoded into the comoving galaxy power spectrum. However, we do not measure clustering directly in comoving space, but we instead measure galaxy redshifts and angles and infer distances from these. If we use the wrong cosmological model to do this conversion, then the distances we infer will be wrong and the comoving clustering will contain detectable distortions. In the angular direction the distortions depend on the angular diameter distance DA z. Adjusting the cosmological model to ensure that angular and radial clustering match constrains H z DA z , and was first proposed as a cosmological test the AP test by Alcock and Paczynski If we instead consider averaging clustering in 3D over all directions, then, to first order, matching the scale of clustering measurements to the comoving clustering expected is sensitive to 33 Although this projection applies to all of the clustering signal, BAO provide the most robust and strongest source for the comparison between observed and expected clustering, providing a distinct feature on sufficiently large scales that it is difficult to alter with non-linear physics. In order to extract this information, we need to parametrize over nuisance broad-band features, extracting just the BAO signal. This is usually achieved by means of a smooth function, commonly a polynomial or spline with a set of free parameters, with sufficient flexibility to match the broad-band shape of all of the cosmological models to be tested, but not the BAO signal. If a fiducial cosmological model is used to convert redshifts to distances, then departures between the expected BAO position, and the observed one are commonly quantified by dilation scales. For an anisotropic fit, we can define two dilation scales, perpendicular and parallel to the line-of-sight 34 where rd sets the comoving BAO scale see Section 2. For a single fit to the BAO in an isotropically averaged clustering measurement, the combined dilation scale is 35 Estimates of the BAO scale can be made based on either r or P k , but they include the noise from small scales and shot noise differently. A review of current BAO measurements was provided in the introduction of Anderson et al. Since then, the DR9 data set has been analysed splitting into measurements along and across the line-of-sight Anderson et al. Redshift-space distortions The second observational effect that we will consider results from the fact that our estimates of galaxy distances are made from redshifts. These redshifts are caused by both the Hubble expansion and from any additional motion within a comoving frame, called the peculiar velocity. We can write 36 where s is the redshift-space i. The distortions in the field that result from the peculiar-velocity dependent shifts are called Redshift-Space Distortions RSD. Locally, galaxies act as test particles in the flow of matter. If galaxies fully sampled the velocity field, the peculiar velocity distribution of galaxies would match that of the mass. We should be aware that galaxies are expected to be at special locations in the density field, potentially giving rise to a small bias in their velocity distribution compared to that of the mass. As discussed in Section 3. On large-scales this growth is the dominant source of RSD. Consider a galaxy on the near-edge of a strong over-density: A galaxy at the far-edge of an over-density will appear closer, and we therefore see that clusters will appear "squashed" along the line-of-sight in redshift-space. By a similar argument, under-dense regions appear "stretched" along the line-of-sight. This is shown in Fig. Explanatory diagram showing how real-space structures top row look in redshift-space bottom row. If we assume that the patch of the Universe from which clustering is measured is sufficiently far away that the line-of-sight is approximately constant across the patch, this effect causes an increase in the measured power that can be easily modelled. The random velocities attained by such galaxies smear the collapsed object along the line of sight in redshift space, leading to the existence of linear structures pointing towards the observer in redshift-space. These apparent structures are known as "Fingers-of-God" FoG and reduce information on small scales. However this model is not guaranteed to work in the quasi-linear regime, although the damping term can model some of the quasi-linear signal if p is treated as a free parameter Percival and White An alternative to modelling the FoG is to try to correct data by using phase information to "collapse clusters" along the line of sight e. This method has similarities with "reconstruction" used to recover BAO information. Standard measurements of the RSD signal are intrinsically limited by the number of radial modes present, which provide the sample variance limit. McDonald and Seljak showed that, with two samples of galaxies covering the same region, it is possible to measure ratios of power spectra independent of cosmic variance - provided that the two samples both have different linear deterministic biases. These combine to give measurements of f 8 that are limited by the total number of modes within a survey, rather than just those in the radial direction - potentially a strong source of further information. The picture for RSD measurements presented in this section relies on a number of assumptions, particularly the combination of linear theory with a simple damping model, and the assumption that we are only interested in pairs of galaxies for which the line-of-sights are approximately parallel. These assumptions have been tested and shown to be adequate for current RSD growth rate measurements Samushia et al. Many RSD-based measurements of the growth rate have been made from a number of spectroscopic surveys, with a recent compilation provided in Reid et al. For current surveys, this separation can only be achieved on large-scales, where RSD can be modelled with perturbation theory, leading to joint RSD and AP measurements e. The power of the large-scale AP test was shown in Samushia et al. Primordial non-Gaussianity As discussed in Section 2 , determining the amount of primordial non-Gaussianity in the matter over-density field provides a key way of distinguishing between inflationary models. Observations of the large-scale clustering of galaxies have the potential to measure this, as we will now demonstrate. One of the simplest way to parameterise non-Gaussianity is to assume that the potential has a local quadratic term 41 Although many other forms of non-Gaussianity are possible, any detection of non-Gaussianity would be interesting, and it is therefore instructive to consider how this simple model can be constrained by galaxy clustering measurements Dalal et al. We can see this by reconsidering the peak-background split model - in Section 3. If we decompose the potential in Eq. Unfortunately, the large-scale clustering signal is one of the most difficult to measure, not just because large volumes are required to reduce sample variance. In fact, observational systematics can strongly affect the clustering on large-scales. For the SDSS, variations in stellar density and seeing for imaging data can lead to target density fluctuations giving rise to large-scale power in spectroscopic galaxy samples that is degenerate with the fNL signature Ross et al. Summary A summary of the physics encoded within the linear galaxy power spectrum is presented in Fig. This provides a simple model for the power spectrum, showing the measurements that can be made from each component. Summary of the physics encoded in the observed large-scale galaxy clustering signal, as described by the linear power spectrum.

Chapter 3 : Non-linear cosmological power spectra in real and redshift space (pdf) | Paperity

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Chapter 5 : [astro-ph/v1] Nonlinear Cosmological Power Spectra in Real and Redshift--Space

We have extended this analysis into red-shift space and found a solution for the non-linear, anisotropic redshift-space power spectrum in the limit of plane-parallel redshift distortions. The quadrupole-to-monopole ratio is calculated for the case of power-law initial spectra.

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