***GRE workshop 2019 programme***

**Monday morning**

**Session chair: Jaiyul Yoo**

**(talks 9:30 --- 11:00, discussion 11:15 --- 12:30)**

Julian Adamek (London Queen Mary)

**Relativistic effects in N-body simulations of cosmic large-scale structure**

As our advanced telescopes produce ever larger and deeper maps of our Universe we need to consider that observations are taken on our past light cone and on a spacetime geometry that is pervaded by small distortions. A precise understanding of the weak-field regime of General Relativity allows one to model these aspects consistently within N-body simulations of cosmic structure formation. The subtle relativistic effects in cosmic structure can tell us how gravity operates on the largest scales that we observe and may hold the key to unraveling the mystery of dark energy.

Francesca Lepori (Geneva)

**Weak-lensing observables from relativistic N-body simulations**

Modelling the weak-lensing observables in the non-linear regime is a crucial task for future Large Scale Structure probes. The standard weak-lensing map modelling is based on the following ingredients: Newtonian N-body simulations and ray tracing techniques, where the convergence field is usually computed for lensing distortions over the unperturbed photons path, i.e. assuming the so-called Born approximation. In this seminar, I will discuss how the two approximations outlined above can be released by using relativistic N-body simulations and a non-perturbative framework for the geodesic light propagation in the inhomogeneous Universe.

Michel-Andrès Breton (Paris LUTH)

**Relativistic effects on galaxy clustering asymmetry**

On the largest cosmic scales we assume the statistical isotropy and homogeneity of the matter density field. However our knowledge comes mostly from observing the universe via messengers like photons which can be disturbed during their propagation, resulting in a distortion in our perception of the Universe. For redshift-space distortions in particular only peculiar velocities are usually accounted for, however with the increasing quality of data it will become possible to measure more subtle effects. We will see in particular the impact of relativistic effects on the galaxy correlation-function asymmetry using large N-body simulations and sophisticated ray-tracing techniques to reconstruct the perturbed light-cone.

**Monday afternoon**

**Session chair: Ruth Durrer**

**(talks 14:00 --- 15:00, discussion 15:15 --- 16:00, general discussion 16:00—16:30)**

Farbod Hassani (Geneva)

**The importance of non-linearities in dark energy models.**

In the last decades, a large number of dark energy models are developed in Cosmology to explain the observed accelerated expansion of the universe. We have studied the k-essence model as a viable dark energy model and have developed a relativistic N-body code, k-evolution (based on gevolution), in which we solve non-linear equations of motion for matter and k-essence scalar field. I'm going to introduce k-evolution code, then I'll show that for some choice of parameters the k-essence non-linearities suffer from a new instability and blowup in finite time.

Ermis Mitsou (Zurich)

**The dynamics of General Relativity in the observational coordinates**

The observational coordinates are a family of spherical coordinate systems in which the angles are constant along the light-like geodesics forming the observer light-cones. They are therefore particularly suited for cosmology and simplify dramatically the expressions of cosmological observables. Nevertheless, the time-evolution of information from the initial condition hypersurface to our light-cone is currently performed in the more standard coordinate systems. This therefore requires a tedious coordinate transformation, which is usually of the same degree of complexity as the observables themselves in the usual coordinates. Taking full advantage of the general covariance of General Relativity, one can by-pass this inconvenience and compute time-evolution in the observational coordinates directly. This is achieved by performing a 2+1+1 decomposition of the equations of motion and appropriately fixing the shift vector. I will present this construction as well as the linearization of the equations around the homogeneous and isotropic solution.

**Boat trip in Lake Zürich (17:30)**

**Tuesday morning**

**Session chair: Giovanni Marozzi**

**(talks 9:30 --- 11:00, discussion 11:15 --- 12:30)**

Giovanni Cabass (Garching MPA)

**CMB Spectral Distortions: a Robust Probe of Primordial non-Gaussianity**

Deviations of the CMB spectrum from a black-body are a powerful probe of the three-point function of curvature perturbations. Dissipation of acoustic waves in the photonelectron-baryon fluid heats the plasma: the heating is not balanced by an appropriate change in photon number, and a Bose-Einstein spectrum is formed. A non-zero three-point function of curvature perturbations makes the heating rate spatially dependent, so that the observed chemical potential in the sky will be anisotropic and correlated with large-scale temperature fluctuations. In this talk I discuss how the angular correlation of temperature anisotropies and spectral distortions is insensitive to contamination from late-time projection effects (unlike other observables like the CMB temperature bispectrum), making it an excellent, albeit futuristic, probe of primordial nonGaussianity.

Giovanni Marozzi (Pisa)

**The rotation of the polarisation direction: is there a new effect in CMB lensing?**

In this talk I will consider the rotation of CMB photon polarisation direction by foreground lensing, showing how this is a true physical effect which has to be taken into account at second order in perturbation theory. To conclude, focusing on B-mode power spectrum, I will show the magnitude of this effect and discuss the reason because this has to be taken in consideration in future CMB survey, that aim to measure a tensor-to-scalar ratio of the order of 10^{-3}.

Jaiyul Yoo (Zurich)

**T¯: A new cosmological parameter?**

The background photon temperature T¯ is one of the fundamental cosmological parameters. Despite its significance, T¯ has never been allowed to vary in the data analysis, owing to the precise measurement of the comic microwave background (CMB) temperature by COBE FIRAS. However, even in future CMB experiments, T¯ will remain unknown due to the unknown monopole contribution Θ0 at our position to the observed (angle-averaged) temperature ⟨T⟩obs. By fixing T¯≡⟨T⟩obs, the standard analysis underestimates the error bars on cosmological parameters, and the best-fit parameters obtained in the analysis are biased in proportion to the unknown amplitude of Θ0. Using the Fisher formalism, we find that these systematic errors are smaller than the error bars from the Planck satellite. However, with T¯≡⟨T⟩obs, these systematic errors will always be present and irreducible, and future cosmological surveys might misinterpret the measurements.

**Tuesday afternoon**

**Session chair: Martin Kunz**

**(talks 14:00 --- 15:00, discussion 15:15 --- 16:30, general discussion 16:30—17:00)**

Pierre Fleury (Geneva)

**Testing the equivalence principle on cosmological scales**

The equivalence principle is the main pillar of the general theory of relativity. Albeit exquisitely well constrained on Earth and in the Solar System, its validity remains to be proved on cosmic scales, especially when the unknown dark matter is concerned. In this talk, I will show that relativistic effects in galaxy surveys offer the possibility to directly test the equivalence principle. Order ten-percent constraints can be put with future extremely large surveys like the Square Kilometer Array.

Basundhara Ghosh (Geneva)

**The observable E\_g statistics**

Recently it has been shown that the E\_g statistics, useful to test theories of modified gravity, is plagued by additional scale and bias dependent lensing contributions. In this work we develop and illustrate a method to remove these lensing terms by using in addition to the galaxy clustering data also shear data and the correlations of shear and galaxy clustering. I will be talking about this particular statistics, and our proposition about making it truly observable. I will also discuss what results this method gives for the Dark Energy Survey and Euclid.

**Dinner at Rigiblick Gourmet Restaurant (18:30)**

**Wednesday morning**

**Session chair: Camille Bonvin (?)**

**(talks 9:30 --- 11:00, discussion 11:15 --- 12:30)**

Enea Di Dio (Berkeley)

**The relativistic dipole and gravitational redshift on LSS**

In this talk I will discuss the impact of gravitational redshift on the measurement of the dipole of the correlation function. Even though at linear order the Euler equation leads to a cancellation between the gravitational potential and the acceleration of galaxy motion, beyond linear order the measurement of the dipole will depend on the gravitational redshift.   
Motivated by recent claims of gravitational redshift detection on LSS scales, I will show how to generalise relativistic perturbation theory to third order, to compute the dipole of the correlation function at 1-loop. I will discuss how these results complicate the interpretation of the dipole in terms of gravitational redshift due to the presence of other relativistic effects.

Giuseppe Fanizza (Pisa)

**H0 measurement from higher redshift surveys**

In this talk, I will discuss the expected corrections due to relativistic effects to the measurements of H0 from higher redshift LSS surveys. I will then consider how much these corrections might be important in order to understand better the tension between H0 local and H0 CMB.

Felipe Oliveira Franco (Geneva)

**A null test to probe the scale-invariance of the growth of structure**

One specific property of the LCDM model is that the way structures are growing as a function of time is scale-independent. In this talk, I will show how to construct a null test to probe this   
property in a model-independent way. For this, I will combine different observables, namely the quadrupole and hexadecapole of the galaxy number counts, and the Doppler magnification dipole. This last observable is obtained by cross-correlating galaxy number counts with the cosmic convergence. I will show that deviations in the scale-independence of a few percents can be detected with a survey like SKA.