PROJECT NUMBER	235759
TITLE	AGILE: Perturbative Approaches to Gravitational Instability and Lensing in Cosmology
CALL IDENTIFIER	FP7-PEOPLE-IEF-2008
PRINCIPAL INVESTIGATOR	Emiliano Sefusatti
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ORGANIZATION	CEA-Saclay, France

THE AGILE PROJECT: SUMMARY REPORT

The project has as main goal the development and testing of analytical predictions for the statistical properties of the matter and galaxy distributions at large scales in the observable Universe, typically described in terms of their spatial correlation functions. Such broad topic is at the center of current cosmological investigations, since measurements of the galaxy and weak lensing power spectrum or two-point correlation functions in future surveys is expected to provide valuable information on the mechanism responsible for the current accelerated expansion of the Universe, as well as on the initial conditions and on the physics of the early Universe.

In this context, the AGILE project presents three characterizing aspects. In the first place, it focuses on *analytical* predictions in nonlinear perturbation theory (PT), with a specific attention to the lastest developments of Renormalized PT (Crocce & Scoccimarro, 2006; Bernardeau *et al.*, 2008) and the Time-RG approach (Pietroni, 2008). Second, it extends the predictions and analysis for two-point correlation functions to higher-order correlators, a direct result of the nonlinear evolution and therefore a fundamental test of our theoretical models. In the third place, a specific goal of the project is to assess possible observable consequences of departures from the standard cosmological model, with the cases of primordial non-Gaussianity and quintessence models as primary examples.

A key aspect of the investigations of the AGILE project consists, in fact, in showing that nonlinear corrections in LSS observables should indeed be seen as an opportunity to test physics beyond the standard model, rather than a problem in the reconstruction of the underlying linear theory quantities.

Effect of primordial non-Gaussianity on matter correlators

A couple of papers published during the first year of the project dealt with the problem of the effects of primordial non-Gaussianity on matter correlators on intermediate scales. [2] provides a detailed comparison of the matter bispectrum measured in N-body simulations with both Gaussian and non-Gaussian initial conditions with predictions in Eulerian PT. Such comparison involves all measurable configurations down to the mildly nonlinear regime from redshift $z = 0$ to $z = 2$ and shows a representative choice of triangular configurations sets. The theoretical predictions include up to 1-loop corrections in PT, as derived in [3] The agreement between the numerical and theoretical resutls is remarkable even at intermediate scales and low redshift. The effect of local non-Gaussian initial conditions on nonlinear corrections is remarkable, particularly for squeezed configurations. The non-Gaussian correction for generic triangles is expected to lead to interesting limits on non-Gaussian parameters from weak lensing observations.

Following the next step in the project proposal, [7] present a complete study of the effects of primordial non-Gaussianity on the power spectrum and bispectrum of biased populations. This work has direct relevance for the interpretation of large-scales redshfit surveys observations. By comparing with full measurements of the halo power spectrum and bispectrum in N-body simulations with non-Gaussian initial conditions it shown that a reasonable agreement is provided by a model characterized by several, distinct and non-trivial corrections both to the underlying matter correlators and to halo bispectrum. In particular it highlights the significant potentiality of higher-order correlation functions to test the initial conditions of the Universe.

[3] extends previous results in Renormalized PT (RPT) to the case of non-Gaussian initial conditions, by showing that the reordering scheme of the perturbative corrections based on multipoint propagators retain its validity when higher-order initial correlators are non-vanishing. As for the Gaussian case, it is possible to derive an explicit expression for the high-momentum limit of the propagators, still characterized by an exponential cut-off. We find the correction to the large-k limit of the propagator due to non-Gaussianity to be independent of the initial bispectrum with a dependence, instead, on the kurtosis of the one-dimensional initial displacement field.

[5] studies some novel corrections due non-Gaussian initial conditions to weak lensing observables. Estimators for weak lensing observables such as shear and convergence generally have nonlinear corrections, which, in principle, make weak lensing power spectra sensitive to primordial non-Gaussianity. These contributions for weak lensing autocorrelation and cross-correlation power spectra, are quantitatively evaluated.

In addition, at the beginning of the project, an invited review by the principal investigator has benn published on the broad topic of primordial non-Gaussianity and higher-order correlation functions ([1]).

Clustering quintessence and gravitational instability

[4] studies structure formation in the presence of a quintessence compo- nent with zero speed of sound in the framework of Eulerian PT. It is shown that for such dark energy model quintessence and dark matter can be studied as a unique fluid in terms of the total energy density contrast and the common velocity. The clustering of quintessence is responsible for a rapid evolution of the growth rate at low redshifts, and modifies the standard relation between the velocity divergence and the growth factor. For the total fluid, exact solutions are derived for the linear growth function in integral forms as in the ΛCDM case. Also studied are second oreder solution in PT and the corresponding tree-level bispectra. The reduced bispectrum, in particular, receives sensible modifications only in the clustering case and can potentially be used to detect or rule out the model.

As a further development of these first results, [6] extends the recently proposed Time-RG method to provide accurate predictions for the density power spectrum in models of clustering quintessence. It is shown that quintessence perturbations induce small corrections to the nonlinear evolution of power spectrum contrasting with the large effect of a vanishing speed of sound on the linear growth function at low redshift. For this reason, models with the same normalization of the linear density power spectrum can present significantly different nonlinear corrections depending on the value of the sound speed. The relation between [7] linear and non-linear growth of structures should be properly taken into account in constraining models with inhomogeneous dark energy.

OTHER ACTIVITIES

Organization of the *PTchat* workshop on resummation methods in cosmological perturbation theory at the Institut de Physique Théorique of CEA/Saclay September 20-22, 2011.
Website: `http://ipht.cea.fr/Meetings/PTCHAT2011/index.php`.

Organization of the workshop *The Almost Gaussian Universe*, on the observable effects of primordial non-Gaussianity held at the Institut de Physique Théorique of CEA/Saclay June 9-11, 2010.
Website: `http://ipht.cea.fr/Meetings/GaussUniverse2010/index.php`.

From February 2011, Dr. Sefusatti is a member of the Theory Working Group in the EUCLID mission collaboration, one of the most promising large-volume galaxy survey recently approved by European Space Agency. The results of the project will in fact be relevant in the preparation for the mission and for the full exploitation of potentiality of these observations.

In the period April-July, 2011, Dr. Sefusatti has been a research tutor (*directeur de stage de recherche*) together with F. Vernizzi, of Nicolas Bonne, a first year master student at Ecole Politecnique, Palaiseau. The project consisted in the calculation of the one-loop correction in perturbation theory to the total density power spectrum in models of quintessence with vanishing sound speed.

CONFERENCES & MEETINGS

- *EUCLID France* meeting, Paris, December 2, 2011.
- *D-Day 29 Nov (Journee Energie Noire)*, LAL, Orsay, November 29, 2011.
- *PTchat workshop*, IPhT, CEA-Saclay, September 20-22, 2011.
- *Euclid Mission Meeting 2011*, Bologna, September 7-8, 2011.
- *Cosmo 2011*, University of Porto, August 22-26, 2011.
- *DEUS: Current and Future Challenges of the Dark and Early Universes*, DARK center, University of Copenhagen, August 8-12, 2011.
- *String Theory and Precision Cosmology*, Cornell University, Ithaca (NY), July 25-29, 2011.
- *Cosmological non-Gaussianity: Theory confronts Observations*, University of Michigan, Ann Arbor (MI), May 13-14, 2011.
- *PONT 2011: Progress on Old and New Themes in cosmology*, Avignon, April 18-22, 2011.
- *Cosmo/CosPA 2010*, University of Tokyo, September 27-October 1, 2010.
- *Modern Cosmology: Early Universe, CMB and LSS*, conference, Centro de Ciencias de Benasque Pedro Pasqual, Spain, August 1-20, 2010.
- *The Almost Gaussian Universe*, ESF Exploratory Workshop, IPhT, CEA/Saclay, June 9-11, 2010.
- *CosmoZsurvey* Workshop, LAM, Marseille, France, April 27-30, 2010.

Relevant Refereed Publications

[7]   Sefusatti, E., Crocce, M. & Desjacques, V.
        The halo bispectrum in N-body simulations with non-Gaussian initial conditions
        accepted for publication in *Mon. Not. R. Astron. Soc.*
        e-Print: arXiv:1111.6966 [astro-ph.CO].

[6]   D'Amico, G. & Sefusatti, E.
        The nonlinear power spectrum in clustering quintessence cosmologies
        J. Cosmol. Astropart. Phys. **11**, 013 (2011)
        e-Print: arXiv:1106.0314 [astro-ph.CO]

[5]   Jeong, D., Schmidt, F. & Sefusatti, E.
        Primordial Non-Gaussianity and the Statistics of Weak Lensing and other Projected Density Fields
        Phys. Rev. D **83**, 123005 (2011)
        e-Print: arXiv:1104.0926 [astro-ph.CO]

[4]   Sefusatti, E. & Vernizzi, F.
        Cosmological structure formation with clustering quintessence
        J. Cosmol. Astropart. Phys. **03**, 047 (2011)
        e-Print: arXiv:1101.1026 [astro-ph.CO]

[3]   Bernardeau, F., Crocce, M. & Sefusatti, E.
        Multi-point propagators for non-Gaussian initial conditions
        Phys. Rev. D **82**, 083507 (2010)
        e-Print: arXiv:1006.4656 [astro-ph.CO]

[2]   Sefusatti, E., Crocce, M. & Desjacques, V.
        The matter bispectrum in N-body simulations with non-Gaussian initial conditions
        Mon. Not. R. Astron. Soc. **402**, 1014 (2010)
        e-Print: arXiv:1003.0007 [astro-ph.CO]

[1]   Liguori, M., Sefusatti, E., Fergusson, J. & Shellard, E.P.S.
        Primordial non-Gaussianity and Bispectrum Measurements in the Cosmic Microwave Background and the Large-Scale Structure
        review article in "Testing the Gaussianity and Statistical Isotropy of the Universe"
        Advances in Astronomy, Volume 2010 (2010), Article ID 980523, 64pp
        e-Print: arXiv:1001.4707 [astro-ph.CO]

SEMINARS & TALKS

- "Nonlinear Structure Formation beyond the Standard Cosmological Model", seminar, APC, Paris, December 20, 2011.

- Presentation of the Theory Working Group at the EUCLID France meeting, Paris, December 2, 2011.

- "Testing the initial conditions with the large-scale structure", invited seminar, DAMTP, Cambridge University, November 18, 2011.

- "Non-linear Evolution of Structures with Clustering Dark Energy", invited seminar, ITP, University of Heidelberg, September 28, 2011.

- "Nonlinear non-Gaussianities", *PTchat* workshop, IPhT, CEA-Saclay, September 22, 2011.

- "Testing the initial conditions with the large-scale structure", *Cosmo 2011* conference, University of Porto, August 25, 2011.

- "Non-linear Evolution of Structures with Clustering Dark Energy", seminar, *DEUS* workshop, DARK, University of Copenhagen, August 10, 2011.

- "Testing the initial conditions with the large-scale structure", invited seminar, *String Theory and Precision Cosmology* conference, Cornell University, Ithaca, July 25, 2011.

- "Primordial Non-Gaussianity & the Galaxy Bispectrum", invited talk, *Cosmological non-Gaussianity* workshop, University of Michigan, Ann Arbor, May 15, 2011.

- "Non-Gaussianities", invited review talk, *PONT 2011* conference, Avignon, April 20th, 2011.

- "Testing the initial conditions of the Universe with the Large-Scale Structure", seminar, University of Helsinki, April 11, 2011.

- "Nonlinearities & non-Gaussianities in the Large-Scale Structure: from Inflation to Dark Energy", seminar, IAP, Paris, January 10, 2011.

- "Testing the initial conditions with the large-scale structure", seminar, *Cosmo2010* conference, University of Tokyo, Tokyo, September 30, 2010.

- "Toward a model for the galaxy bispectrum with generic initial conditions", seminar, *Modern Cosmology* workshop, Centro de Ciencias Pedro Pasqual, Benasque, August 5, 2010.

- "Primordial non-Gaussianity and higher-order correlations", invited seminar, *CosmoZsurvey* workshop, LAM, Marseille, April 28, 2010.

- "Primordial non-Gaussianity in the Large Scale Structure", invited seminar, CERN, Theory Division, Geneva, April 14, 2010.

- "Primordial (and non-primordial) non-Gaussianity in the Large Scale Structure", invited seminar, LUTH, Observatoire de Meudon, Meudon, February 26, 2010.

References

Bernardeau, F., Crocce, M., & Sefusatti, E. 2010, Phys. Rev. D , 82, 083507

D'Amico, G., & Sefusatti, E. 2011, J. Cosmol. Astropart. Phys., 11, 13

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Sefusatti, E. 2009, Phys. Rev. D , 80, 123002

Sefusatti, E., Crocce, M., & Desjacques, V. 2010, Mon. Not. R. Astron. Soc. , 721

—. 2011, ArXiv: 1111.6966 [astro-ph.CO]

Sefusatti, E., & Vernizzi, F. 2011, J. Cosmol. Astropart. Phys., 3, 47