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Toward a full-shape analysis of the galaxy anisotropic 3-point correlation function at the BAO scale

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With the present and upcoming Stage IV spectroscopic surveys, soon we will have data of more than a billion galaxies. This enables us to move beyond traditional two-point statistics to explore higher-order correlations. In particular, the three-point correlation function (3PCF) offers many advantages –it can probe non-Gaussianity, break degeneracies between cosmological parameters, and improve their constraints. Furthermore, a new model of anisotropic 3PCF enables the separation of the signal contributions from redshift-space distortions and the Alcock-Paczyński effect, which is crucial as all the surveys are in redshift space.

The bottleneck of this promising 3PCF model is its computation costs –matter 3PCF takes 24 CPU hours, and galaxy 3PCF takes more than 100 CPU hours for a single cosmological model. Consequently, it would take several years to constrain cosmological parameters with methods such as Markov chain Monte Carlo (MCMC). Therefore, to speed up the computation, we applied a neural network algorithm to create an emulator, which can compute one cosmological model in less than a second on a laptop.

The emulator allows variation of the following parameters: matter density Ω_m, scalar amplitude of primordial density fluctuations A_s and dimensionless Hubble parameter h. It accelerates the computation of one model by more than 10 million times, while maintaining competitive sub-percent accuracy. It will enable the use of the galaxy anisotropic 3PCF on upcoming datasets from, for example, Euclid or DESI.

Additionally, we found that including the anisotropic component in the cosmological parameter constraints yields significant improvements over the isotropic component. If the squeezed triangle configurations are included in the analysis (r_{min} = 20 $h^{-1}Mpc$), we obtain an improvement of over 25%. If the squeezed triangles are excluded, the improvement is negligible.

Author: NAGAINIS, Kristers (University of Latvia Institute of Astronomy)

Co-authors: Dr VERAPOLUMBO, Alfonso (INAF - Osservatorio Astronomico di Brera); FARINA, Antonio (Istituto Nazionale di Astrofisica (INAF)); GUIDI, Massimo (University of Bologna); MORESCO, Michele Ennio Maria (Istituto Nazionale di Astrofisica (INAF))

Presenter: NAGAINIS, Kristers (University of Latvia Institute of Astronomy)

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