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Shear and rotation in massive galaxy clusters

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Massive galaxy clusters, being at the high mass end of the mass function are becoming a common tool in cosmology. Their
abundance is a strong indicator of non-linear structure formation and it depends on the value of important cosmological
parameters, such as the matter density parameter $\Omega_{\rm m}$, the mater power spectrum normalization σ_8
and the dark energy equation of state $w_{\rm de}$. A precise determination of the mass function is a current goal of both theoretical and observational studies, due to the wealth of implications related to it.

From a theoretical point of view, the mass function is related to the function $\delta_{\rm c}$, that, in the framework
of the spherical collapse model, represents the density above which structures can form. In the standard approach,
perturbations are assumed to be spherical and non rotating, but in an era of precision cosmology it is necessary to
relax this assumption. Shear and rotation can be added naturally into this formalism as shown recently by (Del Popolo et al.
2013; Pace et al. 2014) and their combination is parametrized via the parameter α. This
extension of the simple spherically symmetric model makes such that $\delta_{\rm c}$ is now a function of both mass and redshift, contrary to the standard case where it only depends on time. This implies that the mass function and hence
the total number of objects that can be observed will strongly depend on the evolution with mass of the parameter
α. Since theory, so far, does not constrain it, in this work we choose a particularly simple form:
$\alpha=-\beta\log_{10}\frac{M}{M_s}$, where β is the slope of the logarithmic relation and
$M_s=8\times10^{15}\,h^{-1}\,M_\odot$ is a normalization mass. When $M=M_s$, deviation from sphericity are null and we recover the standard case.

The combined effect of shear and rotation, due to the dominance of the latter, implies a decreased number of objects
with respect to the spherically symmetric case since structure formation is slowed down.

Using data on massive clusters by (Campanelli et al. 2012) we constrain the value of the slope β and we infer its
consequences on the number of massive objects. In our analysis we find $\Omega_{\rm m}=0.284\pm0.0064$,
$h=0.678\pm0.017$ and $\beta=0.0019^{+0.0008}_{-0.0015}$ at $1-\sigma$ level, when keeping $\sigma_8=0.818$ fixed and
restricting our analysis to a flat ΛCDM model.

Summary

A precise determination of the mass function is an important tool to verify cosmological predictions of the ΛCDM model and to infer more precisely the better model describing the evolution of the Universe. Galaxy clusters have been currently used to infer cosmological parameters, in particular the matter density parameter $\Omega_{\rm m}$, the matter power spectrum normalization σ_8 and the equation of state parameter $w_{\rm de}$
of the dark energy fluid.
In this work, using data on massive galaxy clusters ($M>8\times10^{14}\,h^{-1}\,M_\odot$) in the redshift range
$0.05<z<0.83$ we put constraints on the parameter α introduced within the formalism of the
extended spherical collapse model to quantify deviations from sphericity due to shear and rotation.

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