

# Orientation of galaxy spins relative to filaments of the large-scale structure of the Universe



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The theory of galaxy formation posits a clear correlation between the spin of galaxies and the directions on the elements of the large-scale structure of the Universe, in particular on filaments. A substantial number of observational and modelling studies have been conducted with the objective of identifying the dependence of the spin position on the elements of the large-scale structure. However, the results of these studies are contradictory. This paper presents a study of the orientation of the spins of 4513 galaxies with respect to 3494 filaments of the large-scale structure of the Universe. In our sample, all galaxies have an inclination angle to the observer greater than 85 degrees, which allows us to unambiguously determine the direction of the spin axis of the galaxy in space, as they are seen almost they are seen very close from the edge. The results demonstrate a tendency for galaxy spins to align along the filament axes of the large-scale structure, with a statistically significant outcome. This work was carried out with the financial support of the Russian science foundation (project No. 24-72-10084 «Edge-on galaxies: a laboratory for exploring the Universe»).

## Introduction

A large number of papers have been published on the orientation of galaxy spins relative to filaments, including works based on observational data. In [1], it was found that bright spiral galaxies have predominantly co-directed galaxy spins with filaments, while elliptical galaxies have a perpendicular spin direction. The authors of [2] found predominantly perpendicular orientation spins of galaxies in denser environments. But some authors did not find any relation, e.g., [3,4]. Such differences in the results may be related to the difficulty in determining the galaxy spin positions, to the identification of the filaments themselves, and to the limited statistics.

## Edge-on galaxy sample

The uncertainty in the spin position of galaxies can be circumvented by using edge-on galaxies. We use the largest catalogue of edge-on galaxies EGPS [5] to date, containing 16551 galaxies. Filaments were determined from the catalogue [6], which is based on a sample of 499 340 galaxies with redshift  $0.009 < z < 0.155$  in the cosmic microwave background (CMB) system; it contains 15421 filaments. After cross-identification galaxies from the EGPS catalogue with galaxies from the filament catalogue [6], we formed a sample of 3494 filaments and 4513 edge-on galaxies.

## Search for correlation

The probability density distribution of angle cosine between the edge-on galaxy spin and the filament direction in three dimensional space is shown in Fig. 1. It is clear from this distribution that the spins of most galaxies tend to be parallel with respect to the filament axis. Using linear regression, we obtain a tangent of inclination angle of 0.15 with confidence intervals from 0.047 to 0.25 and a vertical intersection equal to 0.93 with confidence intervals from 0.87 to 0.98. The confidence intervals are given for 95% level of significance. The p-value for slope is: 0.006. The p-value tests the null hypothesis that the coefficients are equal to zero. A low value ( $< 0.05$ ) indicates that we can reject the null hypothesis. Thus, the coefficients determined by the approximation are significant, and the distribution does show that the spins of most galaxies tend to be parallel with respect to the filament axes.

Also we tested how the null-hypothesis significance of this correlation depends on the sample size. A certain number of galaxies were randomly selected 100 times from the main sample and their  $\cos(\theta)$  distribution was approximated by a straight line. This procedure was carried out for a random sample size between 200 and 4500 galaxies in steps of 200. For each selected number of galaxies, the obtained p-values were averaged. The dependence of the p-value on the number of galaxies in the sample is shown in Fig. 2. It follows from the dependence that in order to find the relation between the galaxy spin and the filament axis, we need a sample of more than 3000 galaxies (which corresponds to  $p\text{-value} \approx 0.05$ ).

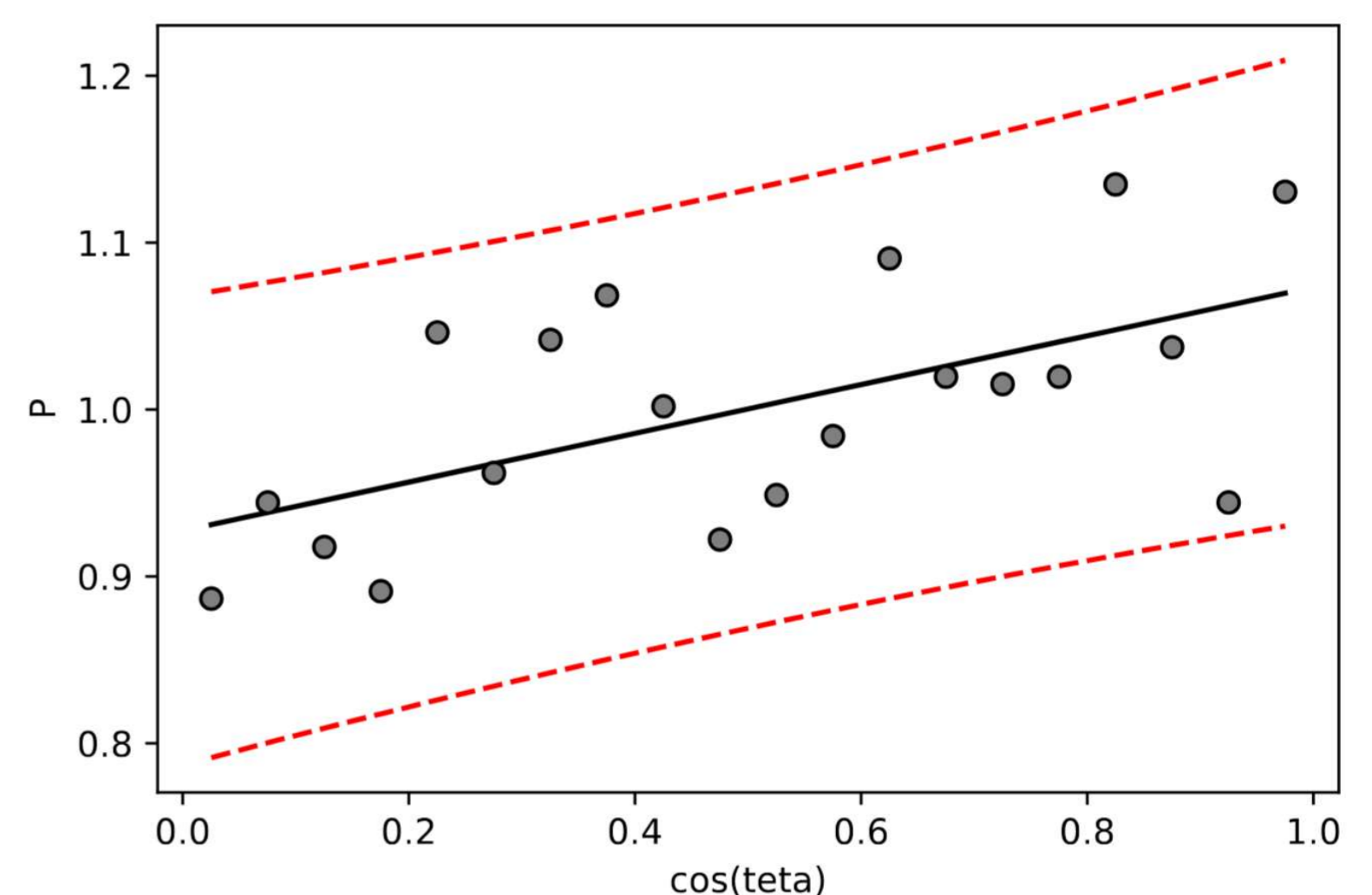


Fig.1. Probability density distribution of the mutual orientation of the spins of galaxies and filaments in three-dimensional space. The distribution is based on a sample of 3494 galaxies visible from an edge-on view from the EGPS catalogue [5] and 4513 filaments from the catalogue [6]. The black solid line is the approximation straight line. The red dashed lines show the confidence interval.

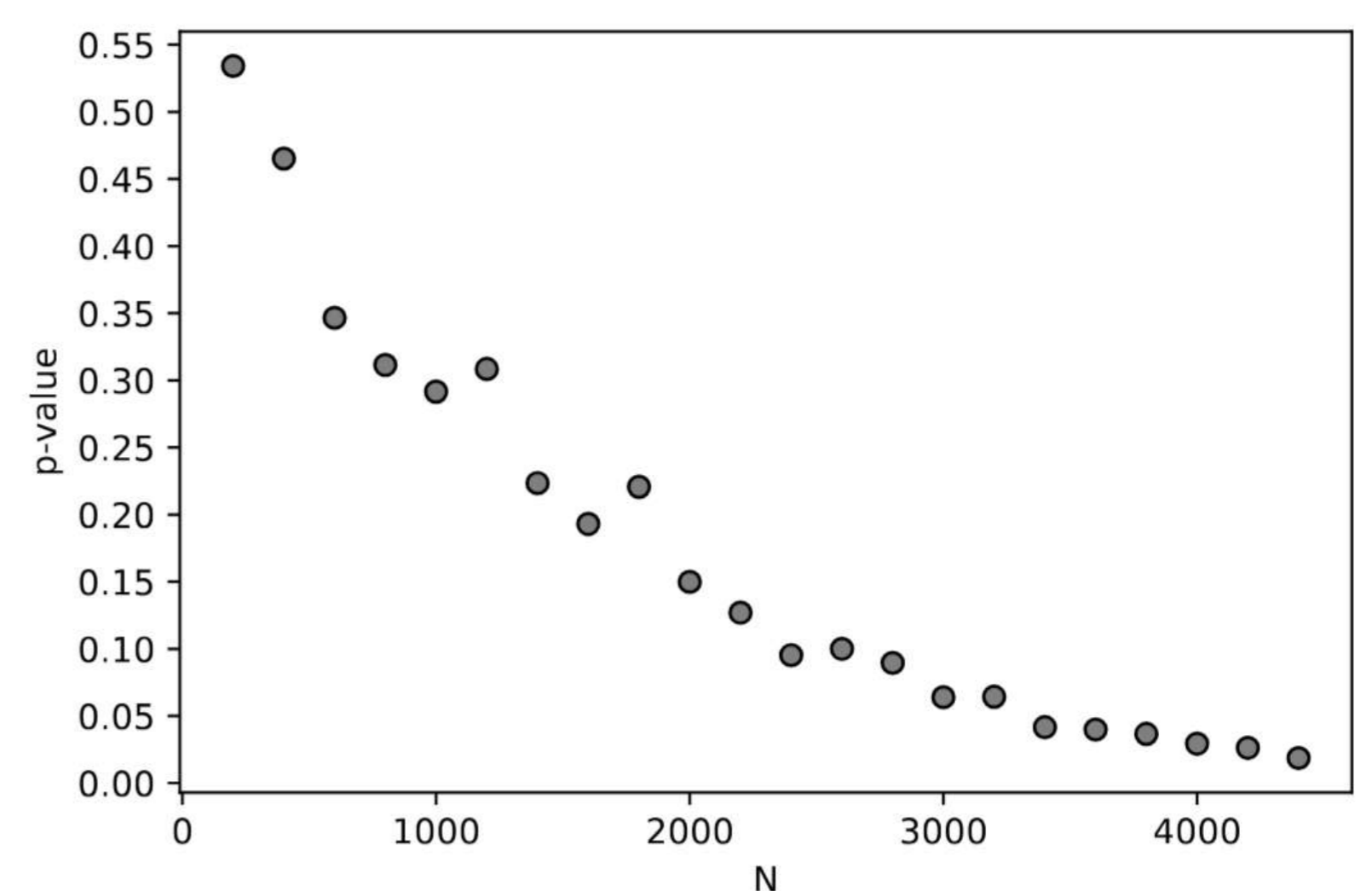


Fig 2. Dependence of the p-value of the slope angle of the approximation line on the sample size .

## Literature

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