Orientation of the spins of the edge-on galaxies relative to the filaments

Antipova A., Makarov D.

Special astrophysical observatory of the Russian academy of sciences (SAO RUS)

We analyze the spin orientation of edge-on galaxies relative to the filaments of the large-scale structure of the Universe. We use the Revised Flat Galaxy Catalog, which contains 4236 flat galaxies with an axes ratio a/b>7. This simple criterion selects mostly late-type galaxies (Sc, Sd) oriented edge-on to a line of sight. The edge-on galaxies allows us to determine a spin orientation with high accuracy. We found very weak indication of an alighment of the spins with respect to the filaments on the 2-sigma level. We tested different dependancies of the alignment from galaxy properties, including the galaxy brightness, the distance from a filament, the redshift and the axes ratio a/b. The effect is most pronounced for the nearby (z < 0.03) and the most thin galaxies (a/b > 10).

Introduction

The question of influence of environment on the formation and evolution of galaxies in the large scale structure is crucial for modern cosmology. The orientation of galaxy spins relative the large scale structures helps us to understand how galaxies get their angular momentum. The theory of tidal torques predicts the formation of the spin under influence of the tidal field on collapsing proto-halos (Hoyle 1949; Peebles 1969; Efstathiou & Jones 1979; White 1984; Porciani et al. 2002) This imply correlation between the galaxy spins and the tidal field. However, there are not so many reliable observational proofs of this correlation. Tempel & Libeskind (2013) show that the spins of bright spirals have weak tendency to align with filaments of the large scale structure.

The measurement of the inclination angle of galaxies is one of the main difficulties for estimation of the orientation of the spin that prevent us to detect the correlation. One of the way to solve the problem is to use a refind sample of the edge-on galaxies. In that case the spin is oriented in the plane of the sky and we can determine it with high precision. Unfortunately, this restriction significantly limits the sample of galaxies for the analysis. This work is based on the Revised Flat Galaxy Catalog (RFGC, Karachentsev et al. 1999) and the catalog of filaments in Sloan Digital Sky Survey (SDSS) (Tempel et al. 2014).

Sample

FGC contains 4236 flat galaxies over all sky with an axes ratio a/b>7 and a>0.6 arcmin. These objects have a number of advantages for observations. Thanks to selection criterion RFGC galaxies belong to the narrow range of late morphological types Sc-Sd. Since the flat galaxies are observed almost edge-on, that allows us to measure position angle and orientation of the spin with precision better than 5 deg. The late type galaxies show more uniform spatial distribution than galaxies of early types. RFGC catalog contains significant number (817) of ultra-flat galaxies with a/b>10. It is expected that such disks can not survive in case of intense amount of merger events during hierarchical clustering, and thus they are more sensitive to the influence of an environment. The catalog of filaments (Tempel et al. 2014) is based on data of SDSS dr8 using marked point process methodology, which allow one to make a simultaneous morphological and statistical characterization of the filamentary pattern. This catalog associates the sample of 499340 galaxies with 0.009<z<0.155 in cosmic microwave background (CMB) rest frame in 15421 filaments.

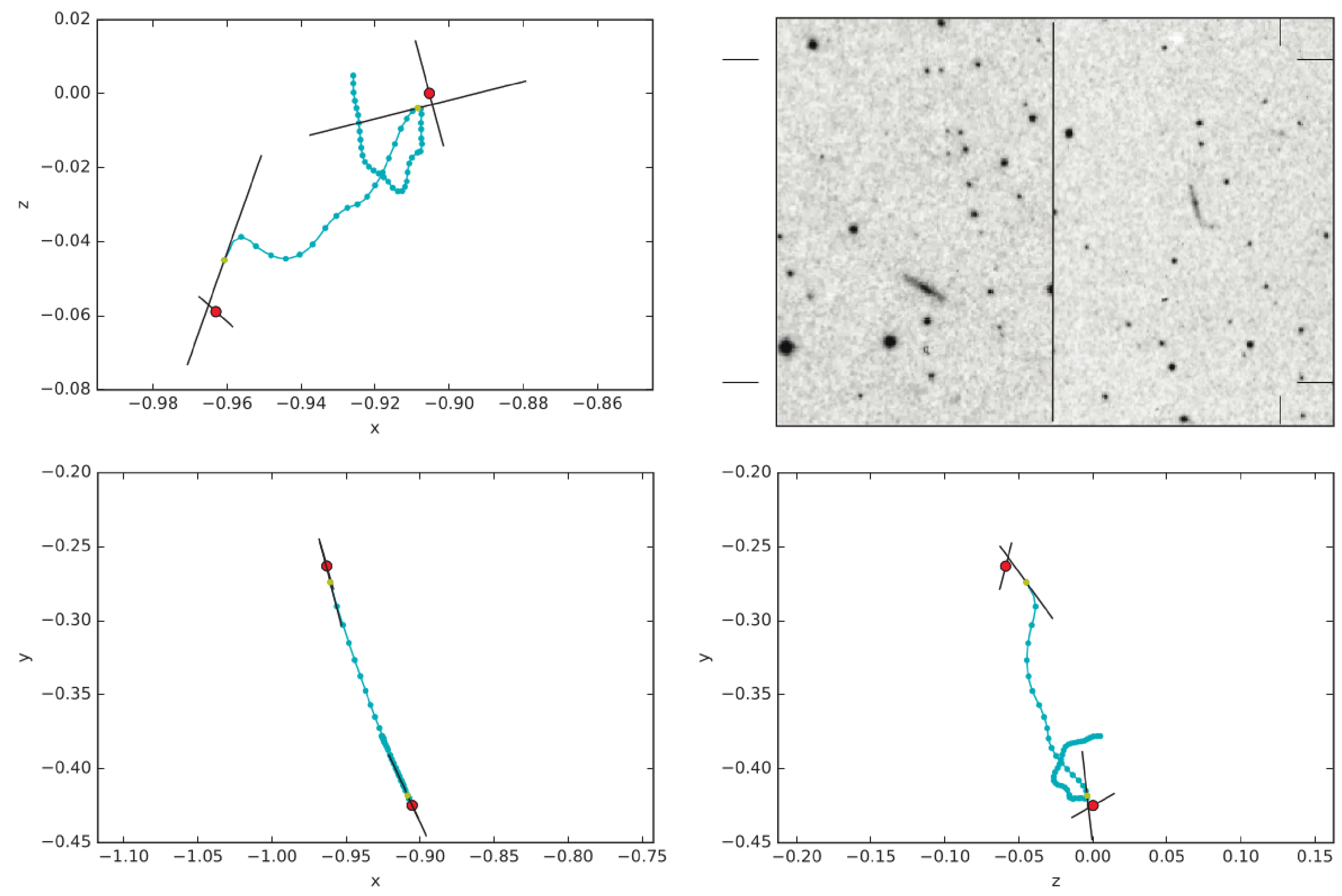

Fig. 1. The figure shows the projections of filament (No 227) and galaxies (RFGC2625, RFGC2437) in the Cartesian coordinate system and images of galaxies. cyan points - filament points; cyan solid line - spline interpolation of filament points; red circles - galaxies; yellow points - closest to the galaxies filament points; black solid line — tangent to filament or spin of the galaxy.

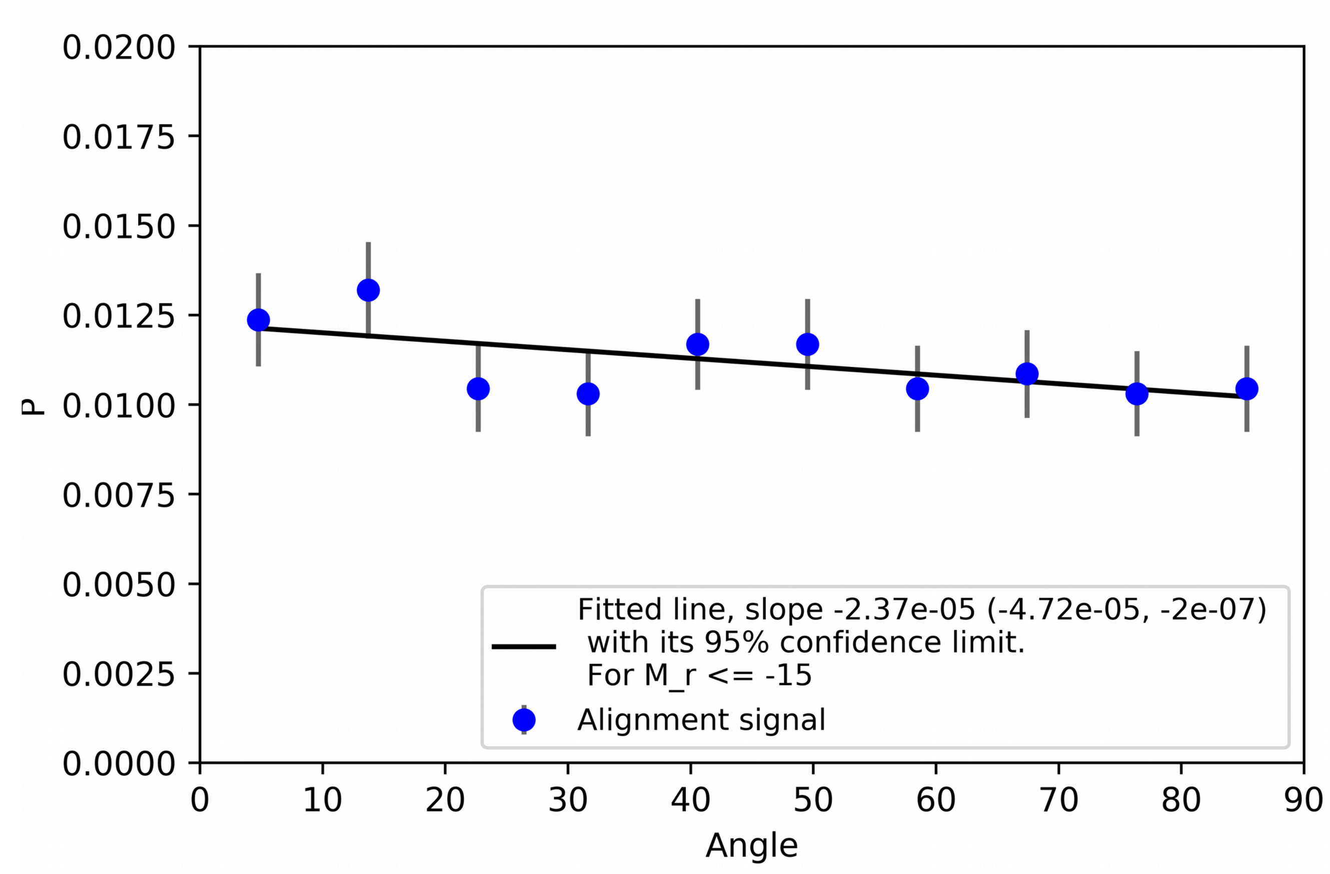

Fig. 2. The figure shows the orientation probability distribution between a galaxy spin and a filament in 3D distribution. The distribution is based on a sample of 813 edge-on galaxies from the RFGC (Karachentsev et al 1999) and 706 filemants from the catalog by Tempel et al. (2014). We find very weak correlation at ±2σ level between the galaxy spin and the filament they belong to. We find that the spin of galaxies has a weak tendency to be aligned with the filament axis.

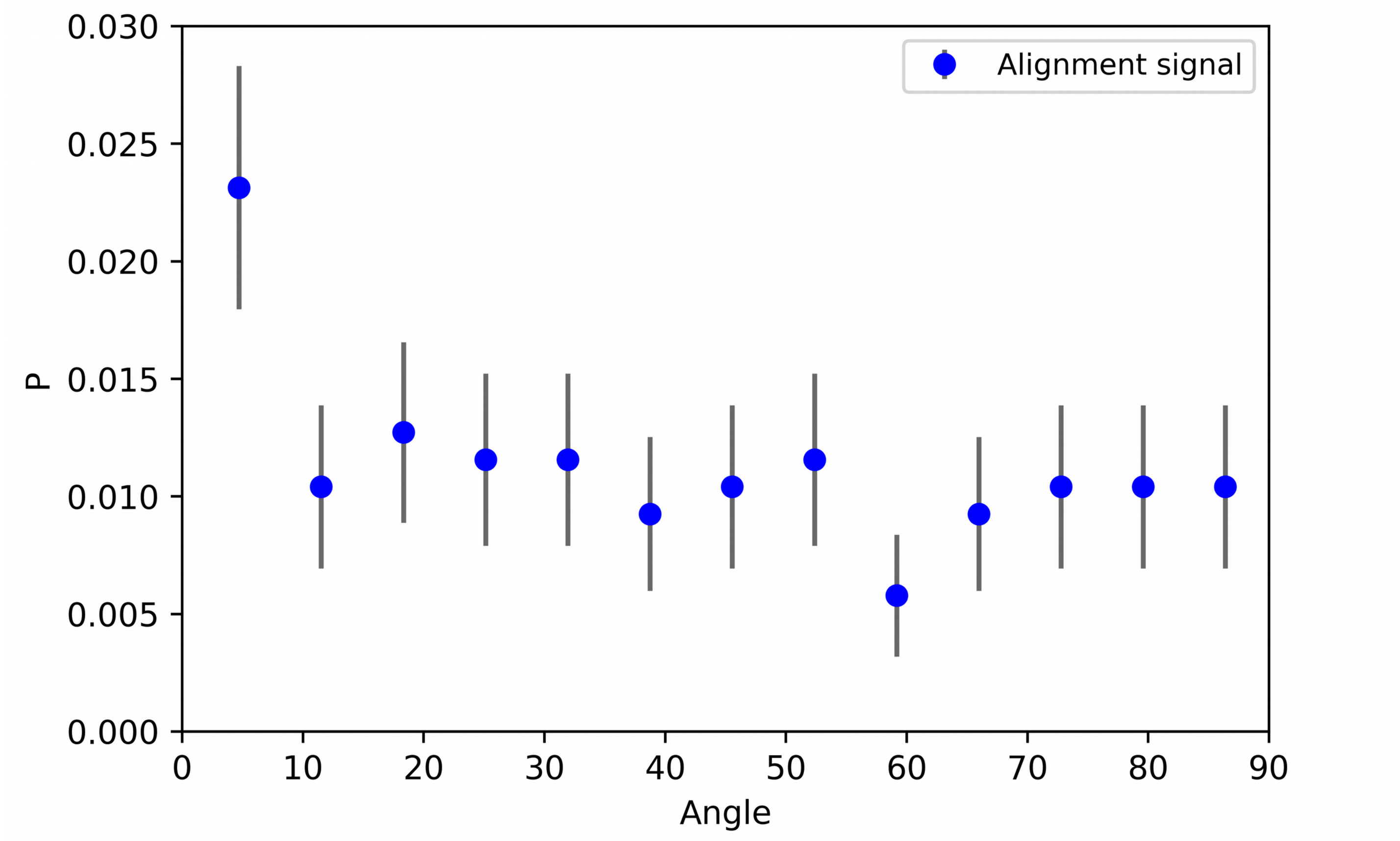

Fig. 3. The figure shows the orientation probability distribution between a galaxy spin and a filament in 3D distribution. The edge-on galaxies and filemants are the same as on the Fig. 2, but for galaxies with an axis ratio a/b>10 and redshift z<0.03. For this sample of galaxies, we find that the spin of galaxies are predominantly oriented parallel to the axis of the filaments. This effect is noticeable at ±2.4σ

Discussion and conclusions

We find that the spins of thin galaxies prefer to be oriented parallel to the axis of the host filament. This correlation is noticeable at a level of ± 2σ. To find a stronger leveling effect, we conduct a series of tests. In these tests, we search the characteristics of galaxies for which a stronger correlation is observed. We consider the correlation depending on the brightness of galaxies, the distance from the filament axis, redshift, and the ratio of the a / b axes.

The selection of galaxies by brightness, distance from the axis of the filament does not give significant results. Our result can be explained by the fact that this selection gives a weak effect, invisible in small samples. In the range 0.2–0.5 h^{-1} Mpc from the filament axis, we have 124 galaxies and 68 galaxies brighter than M_r < - 20.5 mag. Although according to Lee (2004), the correlation is stronger for bright galaxies (M_r < - 20.5 mag). The work of Tempel & Libeskind (2013) confirms the result of Lee (2004), and also claims that the alignment is much stronger for spiral galaxies that are slightly further from the filament axis (in the range 0.2 - 0.5 h^{-1} Mpc).

According to numerical simulations, massive galaxies typically have a spin oriented perpendicular to the axis of the filament, while low-mass galaxies have a spin direction (Bailin & Steinmetz 2005; Aragón-Calvo et al. 2007; Codis et al. 2012; Trowland, Lewis & Bland-Hawthorn 2013 ; Aragon-Calvo & Yang 2014). This transition occurs at a mass of about 5×10^{12} $M_\odot$ at zero redshift for the halo (Codis et al. 2012). Ultrathin galaxies are located in areas of low density, so it is difficult to estimate their mass from satellites. However, Karachentsev et al. (2016) estimated orbital mass for 30 ultrathin galaxies. It was found that the characteristic total mass of ultrathin galaxies is about 5×10^{11} $M_\odot$. We find that galaxies at z <0.03 tend to align the spin with the axis of the filament, the slope of the approximating straight line is -4.23×10^{-5} (-8.33×10^{-5}, -1.25×10^{-6}). We observe the same effect for galaxies with the axis ratio a/b> 10, the slope of the approximating straight line is -7.13×10^{-5} (-1.41×10^{-4}, -9.93×10^{-7}). A stronger effect (at the level of 2.4 σ) is observed when galaxies are selected according to the last two criteria (z < 0.03 & a/b > 10).

Acknowledgements

This study is supported by the Russian Science Foundation (grant 19-12-00145).

References

Aragón-Calvo M. A., van de Weygaert R., Jones B. J. T., van der Hulst J. M., 2007
Aragon-Calvo M. A., Yang L. F., 2014, MNRAS, 440, L46
Bailin J., Steinmetz M., 2005, ApJ, 627, 647
Codis S., Pichon C., Devriendt J., Slyz A., Pogosyan D., Dubois Y., Sousbie T., 2012, MNRAS, 427, 3320
Efstathiou, G., & Jones, B. J. T. 1979, MNRAS, 186, 133
Hoyle, F. 1949, MNRAS, 109, 365
Karachentsev, I. D., Karachentseva, V. E., Kudrya, Yu. N., et all. 1999,AISAO,47,3
Karachentsev I.D., Karachentseva V.E., Kudrya Y.N., 2016, AstBu, 71, 129
Lee, J. 2004, ApJL, 614, L1
Peebles, P. J. E. 1969, ApJ, 155, 393
Porciani, C., Dekel, A., & Hoffman, Y. 2002, MNRAS, 332, 325
Tempel, E. & Libeskind, N. I. 2013,ApJL, 775, 42
Tempel, E., Stoica, R. S., Martínez, V. J., et al. 2014,MNRAS,438,3465
Trowland H. E., Lewis G. F., Bland-Hawthorn J., 2013, ApJ, 762, 72
White, S. D. M. 1984, ApJ, 286, 38

«Diversity of the Local Universe» 30.09-4.10.2019, Russia, Karachai-Cherkessian Republic, Nizhnij Arkhyz, Special Astrophysical Observatory.