

HARNACK INEQUALITIES FOR FUNCTIONAL SDES DRIVEN BY SUBORDINATE MULTIFRACTIONAL BROWNIAN MOTION

ZHI LI, LITAN YAN AND LIPING XU*

Abstract. Being base on the Girsanov theorem for multifractional Brownian motion, which can be constructed by the multifractional derivative operator, we establish the Harnack inequalities for a class of stochastic functional differential equations driven by subordinate multifractional Brownian motion by an approximation technique.

Mathematics subject classification (2020): 60H15, 60G15, 60H05.

Keywords and phrases: Harnack inequality, multifractional Brownian motion, subordinator, coupling.

REFERENCES

- [1] A. AYACHE, S. COHEN AND J. L. VEHEL, *The covariance structure of multifractional Brownian motion, with application to long range dependence*, Acoustics, Speech, and Signal Processing., 10.1109/ICASSP.2000.860233.
- [2] J. H. BAO, F. Y. WANG AND C. G. YUAN, *Bismut formulae and applications for functional SPDEs*, Bull. Sci. Math., **137**, (2013), 509–522.
- [3] J. H. BAO, F. Y. WANG AND C. G. YUAN, *Asymptotic Log-Harnack inequality and applications for stochastic systems of infinite memory*, Stochastic Processes and their Applications., **129**, 11 (2019), 4576–4596.
- [4] R. F. BASS AND D. A. LEVIN, *Harnack inequalities for jump processes*, Potential Analysis., **17**, (2002), 375–388.
- [5] A. BENASSI, S. JAFFARD AND D. ROUX, *Elliptic gaussian random processes*, Revista Matematica Iberoamericana., **13**, 1, (1997), 19–90.
- [6] S. BOUDRAHEM AND P. R. ROUGIER, *Relation between postural control assessment with eyes open and centre of pressure visual feed back effects in healthy individuals*, Exp. Brain Res., **195**, (2009), 145–152.
- [7] B. BOUFOUSSI, M. DOZZI AND R. GUERBAZ, *Sample path properties of the local time of multifractional Brownian motion*, Bernoulli., **13**, 3, (2007), 849–867.
- [8] F. COMTE AND E. RENAULT, *Long memory continuous time models*, J. Econometrics., **73**, 1, (1996), 101–149.
- [9] I. CSISZÁR AND J. KÖRNE, *Information Theory: Coding Theorems for Discrete Memory-less Systems*, Academic Press, New York, 1981.
- [10] F. DE LA, A. L. PEREZ-SAMARTIN, L. MATNEZ, M. A. GARCIA AND A. VERA-LOPEN, *Long-range correlations in rabbit brain neural activity*, Ann. Biomed. Eng. February., **34**, 2, (2006), 295–299.
- [11] C. S. DENG AND X. HUANG, *Harnack inequalities for functional SDEs driven by subordinate Brownian motions*, Potential Analysis., <https://doi.org/10.1007/s11118-020-09882-0>.
- [12] C. S. DENG AND R. SCHILLING, *Harnack inequalities for SDEs driven by time-changed fractional Brownian motions*, Electron. J. Probab., **22**, (2017), 1–23.
- [13] C. S. DENG, *Harnack inequalities for SDEs driven by subordinate Brownian motions*, J. Math. Anal. Appl., **417**, (2014), 970–978.
- [14] X. L. FAN, *Harnack inequality and derivative formula for SDE driven by fractional Brownian motion*, Sci. China Ser. A., **561**, (2013), 515–524.

- [15] X. L. FAN, *Harnack-type inequalities and applications for SDE driven by fractional Brownian motion*, Stoch. Anal. Appl., **32**, (2014), 602–618.
- [16] F. GONG AND F. Y. WANG, *Heat kernel estimates with application to compactness of manifolds*, Q. J. Math., **52**, (2001), 171–180.
- [17] F. A. HARANG, T. NILSSEN AND F. N. PROSKE, *Girarov theorem for multifractional Brownian processes*, arXiv:1706.07387v1, (2017).
- [18] X. HUANG AND S. Q. ZHANG, *Mild solutions and Harnack inequality for functional stochastic partial differential equations with Dini drift*, J. Theoret. Probab., **32**, (2019), 303–329.
- [19] Z. LI, *Shift Harnack inequality and integration by parts formula for functional SDEs driven by fractional Brownian motion*, Proceedings of the American Mathematical Society., **144**, (2016), 2651–2659.
- [20] M. LI, S. C. LIM, B. J. HU AND H. FENG, *Towards describing multi-fractality of trafficusing local Hurst function*, in: Lecture Notes in Computer Science., **4488**, (2007), 1012–1020.
- [21] Z. LI AND L. T. YAN, *Harnack inequalities for SDEs driven by subordinator fractional Brownian motion*, Statistics and Probability Letters., **134**, (2018), 45–53.
- [22] S. C. LIM, *Fractional Brownian motion and multifractional Brownian motion of Riemann-Liouville type*, Journal of Physics A General Physics., **34**, (2001), 1301–1310.
- [23] A. MIMICA AND P. KIM, *Harnack inequalities for subordinate Brownian motions*, Electronic Journal of Probability., **17**, (2012), 1–23.
- [24] S. V. MUNIANDY AND S. C. LIM, *Modeling of locally self-similar processes using multifractional Brownian motion of Riemann-Liouville type*, Phys. Rev. E., **63**, 4, (2001), 046104.
- [25] M. NIU AND B. XIE, *Wang’s Harnack inequalities for space-time white noises driven SPDEs with two reflecting walls and their applications*, J. Math. Anal. Appl., **469**, (2019), 568–593.
- [26] R. F. PELTIER AND J. L. VÉHEL, *Multifractional Brownian motion: definition and preliminary results*, inria-00074045 (1995).
- [27] K. V. RAL’CHENKO AND G. M. SHEVCHENKO, *Path properties of multifractal Brownian motion*, Theor. Probability and Math. Statist., **80**, (2010), 119–130.
- [28] M. RAO, R. SONG AND Z. VONDRAČEK, *Green function estimates and Harnack inequality for subordinate Brownian motions*, Potential Analysis., **25**, (2006), 1–27.
- [29] M. RÖCKNER AND F. Y. WANG, *Harnack and functional inequalities for generalized Mehler semigroups*, J. Funct. Anal., **203**, (2003), 237–261.
- [30] M. RÖCKNER AND F. Y. WANG, *Supercontractivity and ultracontractivity for (non-symmetric) diffusion semigroups on manifolds*, Forum Math., **15**, (2003), 893–921.
- [31] M. RÖCKNER AND F. Y. WANG, *Log-Harnack inequality for stochastic differential equations in Hilbert spaces and its consequences*, Inf. Dim. Anal. Quantum Probab. Rel. Top., **13**, (2010), 27–37.
- [32] M. RYPDAL AND K. RYPDAL, *Testing hypotheses about sun-climate complexity linking*, Phys Rev Lett., **104**, 12, (2010), 128–151.
- [33] S. G. SAMKO, *Fractional Integration of Variable Order*, 1995.
- [34] J. SHAO, *Harnack inequalities and heat kernel estimates for SDEs with singular drifts*, Bull. Sci. Math., **137**, (2013), 589–601.
- [35] J. SHAO, F. Y. WANG AND C. YUAN, *Harnack inequalities for stochastic (functional) differential equations with non-Lipschitzian coefficients*, Electron. J. Probab., **17**, (2012), 1–18.
- [36] I. SIMONSEN, *Measuring anti-correlations in the nordic electricity spot market by wavelets*, Physica A., **322**, 1, (2003), 597–606.
- [37] F. Y. WANG, *Logarithmic Sobolev inequalities on noncompact Riemannian manifolds*, Probab. Theory Related Fields., **109**, (1997), 417–424.
- [38] F. Y. WANG, *Harnack inequalities for log-Sobolev functions and estimates of log-Sobolev constants*, Ann. Probab., **27**, (1999), 653–663.
- [39] F. Y. WANG AND J. WANG, *Harnack inequalities for stochastic equations driven by Lévy noise*, J. Math. Anal. Appl., **410**, (2014), 513–523.
- [40] W. WANG, *Harnack inequality, heat kernel bounds and eigenvalue estimates under integral Ricci curvature bounds*, Journal of Differential Equations., **269**, 2, (2020), 1243–1277.
- [41] F. Y. WANG AND Y. C. YUAN, *Harnack inequalities for functional SDEs with multiplicative noise and applications*, Stochastic Processes and their Applications., **121**, 11, (2011), 2692–2710.

- [42] W. WANG AND P. ZHANG, *Some gradient estimates and Harnack inequalities for nonlinear parabolic equations on riemannian manifolds*, *Mathematische Nachrichten.*, **290**, 11–12, (2017), 1905–1917.
- [43] L. WANG AND X. ZHANG, *Harnack inequalities for SDEs driven by cylindrical α -stable processes*, *Potential Anal.*, **42**, (2015), 657–669.
- [44] W. WILLINGER, W. LELAND, M. TAQQU AND D. WILSON, *On self-similar nature of ethernet traffic*, *IEEE/ACM Trans Networking.*, **2**, 1, (1994), 1–15.
- [45] L. T. YAN AND X. W. YIN, *Harnack inequality and derivative formula for stochastic heat equation with fractional noise*, *Electron. Comm. Probab.*, **23**, 35, (2018), 1–11.
- [46] L. T. YAN AND X. W. YIN, *Bismut formula for a stochastic heat equation with fractional noise*, *Statist. Probab. Lett.*, **137**, (2018), 165–172.
- [47] X. W. YIN, G. J. SHEN AND Z. L. GAO, *Harnack inequality for stochastic heat equation driven by fractional noise with Hurst index $H > 1/2$* , *Journal of Mathematical Inequalities.*, **14**, 4, (2020), 1113–1122.
- [48] X. C. ZHANG, *Derivative formulas and gradient estimates for SDEs driven by α -stable processes*, *Stochastic Processes and their Applications.*, **123**, (2013), 1213–1228.