Bibliography on stable distributions, processes and related topics

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The following sections are a start on organizing references on stable distributions by topic. It is far from complete. Starting on page 29 there is an extensive list of papers on stable distributions, many of which are not included in the first section. Some of the papers there do not directly refer to stable distributions. Someday I may have the time to edit those out, but for now please ignore those references. This list includes a bibliography file provided years ago by Gena Samorodnitsky from Cornell University.

I would like to keep this list correct and up-to-date. If you have corrections or additions, please e-mail them to me at the above address, and suggest where to place your references in one of the sections below. A sentence or two summarizing the content would be useful. Please provide all references in BibTeX form, especially if you have more than one or two additions. (See http://en.wikipedia.org/wiki/BibTeX for basic information on BibTeX.) Please send a copy of your papers along.
Contents

1 Univariate stable distributions ........................................ 4
  1.1 General references .................................................. 4
  1.2 Computations of stable densities, cdf, simulation, etc. ....... 4
  1.3 Generalized Central Limit Theorem and Domains of Attraction 4
  1.4 Statistical estimation, diagnostics, assessing fit, hypothesis testing 5
  1.5 Miscellaneous univariate stable .................................... 6

2 Application areas ....................................................... 6
  2.1 Engineering .......................................................... 6
    2.1.1 Radar processing .............................................. 8
    2.1.2 Image processing ............................................ 8
    2.1.3 Telecommunications .......................................... 8
    2.1.4 Acoustics (including sonar and ultrasound) .............. 8
    2.1.5 Network modeling ........................................... 8
    2.1.6 Queueing theory ............................................. 9
    2.1.7 ICA/blind source separation and PCA ..................... 9
    2.1.8 Vibration noise ............................................. 9
    2.1.9 Miscellaneous engineering applications .................. 9
  2.2 Finance, Economics, Value at Risk, Real Estate, Insurance .... 9
    2.2.1 Modeling asset returns ..................................... 10
    2.2.2 Option pricing ............................................... 10
    2.2.3 Value at risk ................................................ 11
    2.2.4 Foreign exchange/parallel market/cryptocurrencies .. 11
    2.2.5 Real estate .................................................. 11
    2.2.6 Insurance ................................................... 11
    2.2.7 Commodity price modeling .................................. 11
    2.2.8 Miscellaneous econ/finance ................................ 11
  2.3 Extreme value theory .............................................. 12
  2.4 Computer science ................................................ 12
  2.5 Random walks .................................................... 12
  2.6 Branching processes ............................................. 13
  2.7 Fractional/anomalous diffusions and turbulence .............. 13
  2.8 Dynamical systems, ergodic theory, stochastic recurrence equations 14
  2.9 Physics, astronomy and chemistry ................................ 14
  2.10 Survival analysis, frailty, reliability ........................ 15
  2.11 Embedding of Banach spaces ................................... 15
  2.12 Geology and Geophysics ........................................ 15
  2.13 Medicine, biology, genetics .................................... 15
  2.14 Random trees ................................................... 16
  2.15 Rainfall, hydrology, climatology .............................. 16
  2.16 Miscellaneous ................................................... 16
  2.17 Long tails in business, political science, etc. ............. 17
1 Univariate stable distributions

1.1 General references


1.2 Computations of stable densities, cdf, simulation, etc.


The standard method for simulating univariate stable terms is Chambers et al. (1976); the formula is stated in the introductory chapter mentioned in Section 1.1. The original paper does not give a proof of the method, but focuses on the computational steps, and uses the $0$-parameterization (the $M$ parameterization of Zolotarev).


1.3 Generalized Central Limit Theorem and Domains of Attraction


Central pre-limit theorem: Klebanov et al. (1999), Klebanov et al. (2000), Klebanov et al. (2006).

Fuchs et al. (2001) state a different criteria for being in the domain of attraction of a positive stable distribution ($\alpha < 1$, $\beta = 1$).


1.4 Statistical estimation, diagnostics, assessing fit, hypothesis testing


Empirical process model with estimated parameters: Section 4.2 of del Barrio et al. (2007).


Wavelet based: Antoniadis et al. (2006).

Estimation of concentration data: Benson et al. (2001), Rishmawi (2005), Chakraborty et al. (2009).


1.5 Miscellaneous univariate stable


Functions of stable random variables: Otiniano et al. (2013), Rathie et al. (2016), Davis et al. (2018).


2 Application areas

2.1 Engineering

The standard models of signal processing are based on Gaussian noise. While this works well in many problems, this assumption is not accurate in some
situations where there is impulsive, heavy-tailed noise. In such situations, linear Gaussian filters perform poorly. Using methods based on stable models gives robust nonlinear signal processing methods.


Filtering Cauchy noise: Kim et al. (2020)


Generalizations of the Kalman filter: Stuck (1978), Balakrishna and Hareesh (2009), Le Breton and Musiel (1993), Sornette and Ile (2001), Gordon et al. (2003), Tzagarakis and Tsakalides (2009), Idan and Speyer (2010), Idan and Speyer (2012a), Idan and Speyer (2013)

Particle filters: Gençäga et al. (2008), Kittichotpanich (2008), Li et al. (2017), Cortés-Aburto et al. (2018), McCulloch (2020)


Time delay estimation and direction of arrival: Georgiou et al. (1999), Penn et al. (2020), Ollivnyk and Lukin (2020), Ollivnyk et al. (2021), Zha and Qiu (2007), Asghari et al. (2022)

Wind power: Gaidai et al. (2020), Simiu et al. (2001), Xu, Wu, Yang, Wang, and Wang (Xu et al.)

2.1.1 Radar processing

2.1.2 Image processing

2.1.3 Telecommunications

Vehicle-to-vehicle communication Bazzi et al. (2019)
Robust receiver design Clavier et al. (2021)

2.1.4 Acoustics (including sonar and ultrasound)


2.1.5 Network modeling
2.1.6 Queueing theory


2.1.7 ICA/blind source separation and PCA


2.1.8 Vibration noise


2.1.9 Miscellaneous engineering applications


Structural analysis of airplanes del Rosario et al. (2021).

2.2 Finance, Economics, Value at Risk, Real Estate, Insurance

The main motivation for considering stable laws in finance is that empirical returns have heavier tails than the normal/Gaussian model predicts. And stable laws allow one to model cumulative returns using the stability of sums: if $X_1, X_2, \ldots, X_n$ are returns over one period with an $\alpha$-stable distribution, then the cumulative return over $n$ time periods $X_1 + X_2 + \cdots + X_n$ also has an
α-stable distribution. This is true if the terms are independent or dependent stable, but is not true for other models of returns.

### 2.2.1 Modeling asset returns


Morningstar Encorr Analyzer now includes the ability to model returns with a stable distribution.


Jama (2009) looks at returns on the South African exchange. The works by Cont and Tankov (2004), Tankov (2007), Kallsen and Tankov (2006) use Lévy processes to model returns, arguing that jumps are an important part of the behavior of actual returns that cannot be captured by a Gaussian model. A probability book with an emphasis on computational issues and finance, which includes a chapter on stable distributions, is Paolella (2007).

stable GARCH: Bonato (2011), Broda et al. (2013)
CDOs: Scherer and Prange (2009)
Energy markets: Pantalone et al. (2016)
Predicting crashes: Belinskyski et al. (2019)

### 2.2.2 Option pricing

McCulloch (1996a), Carr and Wu (2003), Cartea and Howison (2003), Cartea
2.2.3 Value at risk

2.2.4 Foreign exchange/parallel market/cryptocurrencies
Basterfield et al. (2003), Basterfield et al. (2005a), Basterfield et al. (2005b), Fofack and Nolan (2001), Lan and Tan (2007), Zhao and Wu (2009), Majoros and Zemplén (2018), Andria (2021)

2.2.5 Real estate
King and Young (1994), Young and Graff (1995), Graff et al. (1997), Brown (2000), Brown (2004), Brown (2005), Young et al. (2006), Young (2008). The first paper above argues that because of the non-normality of real estate prices, diversification is not a good idea (unless you have a huge portfolio); careful management of property is more important.

2.2.6 Insurance
Asmussen et al. (1997), Embrechts et al. (1997), Duczkowski (2021)

2.2.7 Commodity price modeling

2.2.8 Miscellaneous econ/finance
Li and Ma (2013) discuss a stable Cox-Ingersoll-Ross model for interest rates.
2.3 Extreme value theory


2.4 Computer science


Feature modeling: Fiche et al. (2013).


Modeling sparse graphs: Caron and Fox (2017).


Differential privacy: Ito et al. (2021).

Consensus formation: Katoh and Shioda (2021).

2.5 Random walks


There have been several papers using Lévy flights to describe foraging behavior for different animals, see Viswanathan et al. (1996) and Viswanathan et al. (1999). Reynolds and Frye (2007). However, more recent work points out some errors in the data used in these papers and questions the relevancy of heavy tailed models for foraging, see Edwards et al. (2007) and Travis (2007).

Lévy swimmers under confinement Zhou et al. (2021)
Scaling laws in human travel [Brockmann et al. (2006), Raichlen et al. (2013)].
Statistical issues in Kawai and Petrovskii (2012).


2.6 Branching processes


2.7 Fractional/anomalous diffusions and turbulence


Stable first passage times through random fracture networks, Hyman et al. (2019).


2.8 Dynamical systems, ergodic theory, stochastic recurrence equations


Stochastic recurrence equations: Kesten (1973), Mikosch et al. (2012).

2.9 Physics, astronomy and chemistry


Cosmic ray modeling: Phan et al. (2021)

Fluctuation flux for plasma in a controlled fusion experiment are modeled by a stable law in Jha et al. (2003), Steinbrecher and Weyssow (2004), and Yanushkevichienė and Saenko (2013).


Laser cooling of atoms: Bardou et al. (2002)


Lévy glass: Barthelemy et al. (2008), Janzen et al. (2010) and Janzen et al. (2010).

The Landau distribution is used in physics to describe the fluctuations in the energy loss of a charged particle passing through a thin layer of matter. This distribution is a special case of the stable distribution with parameters $\alpha = 1$, and $\beta = 1$. It was originally discussed in Landau (1944), more information is in Leo (1994).


Out-of-equilibrium systems: Campi and Bianconi (2019)


Superconductivity: Angello et al. (2010) and Valenti et al. (2014) give a computational analysis of the phase dynamics of short and long Josephson junctions in the presence of non-Gaussian (Lévy) noise sources (Resonant Activation, Noise Enhanced Stability and Soliton dynamics). Guarcello et al. (2016) analyze phase dynamics, i.e., focus on solitons, in long Josephson junctions, as a Lévy noise source is taken into account. Guarcello et al. (2017) study the effects of the Lévy noise on the switching currents of graphene-based Josephson
junctions. See also Gattenlöhner et al. (2016) and Briskot et al. (2014).

Dattoli et al. (2014) use stable laws to describe photoluminescence decay of silicon nanocrystals.


Solar flares: Lei et al. (2020)

2.10 Survival analysis, frailty, reliability


Reliability testing: Gaver et al. (2004).

2.11 Embedding of Banach spaces


2.12 Geology and Geophysics


Magnetotelluric data: Chave (2014), Chave (2017).

2.13 Medicine, biology, genetics


Sorace (2012) describes a long-tailed distribution of disease combinations in the U.S. Medicare system. In this setting, the idea it more of sparsity: rather than prominent clusters of combinations of diseases, there are many, many combinations of different illnesses that occur. This argues that the costs of medical care cannot be significantly lessened by focusing on a few common clusters of diseases.


Forest fires: Malamud et al. (1998).
Nanopore modeling: Kotulska (2007).
Genetic regulatory networks: Ding et al. (2019).

Like a Lévy flight, epidemics may spread locally and then take a large jump to a different country: Brockmann and Hufnagel (2007), Linder et al. (2008), Boto and Stollenwerk (2009), Machado and Lopes (2020).

Long range dispersal: Smith and Weissman (2020).
Cerebral cortex: Stringer et al. (2019), Liu et al. (2021).

2.14 Random trees

2.15 Rainfall, hydrology, climatology
Climatology: Lavallée and Beltrami (2004).

2.16 Miscellaneous
Heinrich (1987) considers sums of ψ-mixing random variables and a connection with continued fractions. See also Hensley (2000), Finch (2007) and Heinrich et al. (2004), where a connection to rounding errors is made.

Farsad et al. (2016), Farsad et al. (2015), Farsad et al. (2018) use stable laws to model time synchronization in molecular timing channels.

Quality control: Naseri et al. (2020)

2.17 Long tails in business, political science, etc.
These references are about extreme events, generally not situations where there is a numeric value that is being measured. There is not a direct probability distribution involved, but the idea of unusual/atypical occurrences can be important.

Anderson (2006) discusses the “Long Tail” occurring in sales, where many low volume items can account for significant revenue. The best known example of this is Amazon.com, where the lack of brick-and-mortar stores make it feasible to sell low volume goods on a large scale. Brynjolfsson et al. (2006) also discuss this.

King and Zeng (2001) discuss measuring rare events in international relations. The first author has a webpage on rare events at http://gking.harvard.edu/category/research-interests/methods/rare-events.

Bremmer and Keat (2009) write about the fat tail in political and economic events. They do not measure a quantitative variable, rather they write about typical events that cluster around some center and occasionally there is an extreme event, like the 1998 financial crisis in Russia or the September 11, 2001 terrorists attacks on the U.S. These are bulges/bumps far from the normal events that happen. They argue that one should be thinking about these possible risky events.

3 Multivariate stable distributions

3.1 General references

Existence of spectral measures: Feldheim (1937), Lévy (1954), Courrège (1964)

Representation in $L^\alpha$: Schreiber (1972), Bretagnolle et al. (1966)

3.2 Multivariate stable densities, cdf, simulation, etc.
For exact simulation, see [Modarres and Nolan (1994)] for discrete spectral measures. Can also simulate radially symmetric and elliptically contoured using sub-Gaussianity, this is used in [Nolan (2005)]. Sub-stable vectors can be simulated in the same way. And sums of any of the above are stable.


### 3.3 Multivariate estimation


U-statistics: [Teimouri et al. (2017)].

### 3.4 Conditional distributions and moments


### 3.5 Dependence measures


General tests for independence using the empirical distribution function: [Hoefding (1948)], [Blum et al. (1961)]. Tests using the characteristic function: [Csörgő (1985)], [Székely et al. (2007)], [Székely and Rizzo (2009)].

### 3.6 Approximation and metrics

3.7 Miscellaneous multivariate stable

Substable: Misiewicz and Takenaka (2002)

Sums of dependent heavy tailed random variables: Basrak et al. (2011), Bartkiewicz et al. (2011), Tyran-Kaminska (2010a,b,c).


4 Regression


Vector autoregression: Hannsgen (2008) discusses whether there are heavy tailed distributions involved in structural VAR used for policy analysis. The presence of infinite variance makes the use of structural VAR questionable. A revision of this paper is available in Hannsgen (2012).

5 Time series


6 Stable processes

6.1 General references

Samorodnitsky and Taqqu (1994b), Janicki and Weron (1994)
6.2 Stochastic integrals, series, minimal representations


6.3 Path properties


6.4 Prediction


6.5 Miscellaneous topics in stable processes


Connections between continuous and discrete processes: Lee (2009).

7 Stable measures on vector spaces and groups


8 Related distributions and processes, extensions of the notion of stability


Laplace distributions: Kotz et al. (2001).

Operator stable laws: if the scaling term $a_n$ in the definition of joint stability is replaced by a matrix $A_n$, then a larger class of multivariate distributions results. One simple case is if the matrix is diagonal, say $A_n = \text{diag}(n^{-1/\alpha_1}, n^{-1/\alpha_2}, \ldots, n^{-1/\alpha_d})$ with all independent components with the $j$-th coordinate being an $\alpha_j$-stable r.v. These are called marginally stable laws. The general case is more complicated, see Jurek and Mason (1993), Cambanis and Taraporevala (1995), Meerschaert and Scheffler (2001a). Two dimensional case: Michaliček (1972a), Michaliček (1972b). Also Scheffler et al. (2020).


$\alpha$-symmetric multivariate distributions of Cambanis et al. (1983), see Fang et al. (1990).

Tsilevich and Vershik (1999) consider $\alpha = 0$.

Davydov et al. (2007) and Davydov et al. (2008) have defined a general notion of stability on a cone $K$ with some operation $+$, that generalizes sum stability and includes max-stability, min-stability, and more.
α-symmetric distributions: Cambanis et al. (1983), Chapter 7 of Fang et al. (1990).

9 References

References


Avram, F. and M. S. Taqqu (1986a). Different scaling for finite i.i.d. arrays. Preprint.


29


Buriticá, G. and P. Naveau (2021). Stable sums to infer high return levels of multivariate rainfall time series. 10.48550/ARXIV.2112.02878.


Champagnat, N., M. Deaconu, A. Lejay, N. Navet, and S. Boukherouaa (2013). An empirical analysis of heavy-tails behavior of financial data: The case for power laws. hal-00851429 https://hal.inria.fr/hal-00851429.


54


Cormode, G. (2003). Stable distributions for stream computations: it’s as easy as 0,1,2. In *Workshop on Management and Processing of Massive Data Streams at FCRC*.


Davydov, Y. and A. Nagaev (2004). On the role played by extreme summands when a sum of i.i.d. random vectors is asymptotically α-stable.


Drew, L. (2020). The nervous systems of foraging and predatory animals may prompt them to move along a special kind of random path called a lévy walk to find food efficiently when no clues are available. *Quanta*. https://www.quantamagazine.org/random-search-wired-into-animals-may-help-them-hunt-20200611/.


Frain, J. C. (2007b). Small sample power of tests of normality when the alternative is an $\alpha$-stable distribution. Trinity Economics Papers TEP-0207, Trinity College Dublin, Department of Economics.

Frain, J. C. (2008). Value at Risk (VaR) and the $\alpha$-stable distribution. Trinity Economics Papers TEP-0308, Trinity College Dublin, Department of Economics.


behaviour in time series. Journal of Statistical Mechanics: Theory and Ex-
periment 2016(12), 123205.


Gouëzel, S. (2007). Statistical properties of a skew product with a curve of

Gouriéroux, C. and J.-M. Zakoïan (2017). Local explosion modelling by non-
causal process. Journal of the Royal Statistical Society: Series B (Statistical
Methodology) 79(3), 737 – 756.

tempered stable distributions on the real line with applications to finance.


Grabchak, M. (2015a). Inversions of Lévy measures and the relation between
long and short time behavior of Lévy processes. Journal of Theoretical Prob-
ability 28(1), 184–197.

and other self-decomposable processes. Statistical Inference for Stochastic
Processes, 1–22.

Grabchak, M. (2021, 01). On the transition laws of p-tempered

\[ \alpha \]


Grabchak, M. and G. Samorodnitsky (2010). Do financial returns have finite or
infinite variance? A paradox and an explanation. Quantitative Finance 10(8),
883–893.

Academic Press.


correlations, Volume 26 of Lecture Notes in Statistics. Springer: New York:

Grafakos, L. and G. Teschl (2013). On Fourier transforms of radial functions


92


Haralick, R. M. (2xxx). The kernel trick. posted online.


Humphries, N. E., Queiroz, J. R. M. Dyer, N. G. Pade, M. K. Musyl, K. M.
Schaefer, D. W. Fuller, J. M. Brumschweiler, T. K. Doyle, J. D. R. Houghton,
G. C. Hays, C. S. Jones, L. R. Noble, V. J. Wearmouth, E. J. Southall, and
D. W. Sims (2010). Environmental context explains Lévy and Brownian

Humphries, N. E., H. Weimerskirch, N. Queiroz, E. J. Southall, and D. W. Sims
of the National Academy of Sciences* 109(19), 7169–7174.

Hung, T. L. and P. T. Kien (2019). On the rates of convergence to symmetric
stable laws for distributions of normalized geometric random sums. *Filo-
mat* 33(10), 3073 – 3084.

http://dx.doi.org/10.1063/1.531044.

gineers* 116, 770–808.

151–213.

American Society of Civil Engineers* 116, 770–808.

of the Institution of Civil Engineers, Part I* 5, 519–577.


Huser, R. and A. C. Davison (2013, 02). Composite likelihood estimation for

Huskova, M., S. G. Meintanis, and C. Pretorius (2021). Tests for het-

in transformation models. *Stat Papers*. https://doi.org/10.1007/s00362-021-
01267-8.

of stable laws for first passage times in three-dimensional random fracture

Ibragimov, I. (1982). Hitting probability of a Gaussian vector with values in a


102


108


111


124


Li, P., W. Chen, H. Ge, and M. K. Ng (2020). $\ell_1 - \alpha \ell_2$ minimization methods for signal and image reconstruction with impulsive noise removal. *Inverse Problems* **36**(5).


Mandelbrot, B. and J. Van Ness (1968). Fractional Brownian motions, fractional

*Water Resources Research* 4, 909–918.

Mandelbrot, B. and J. Wallis (1969a). Computer experiments with fractional

Mandelbrot, B. and J. Wallis (1969b). Robustness of the rescaled range r/s in
the measurement of noncyclic long-run statistical dependence. *Water Resour.
Res. 5*, 967–988.


Mandelbrot, B. B. (1976). Intermittent turbulence and fractal dimension: kur-
tosis and the spectral exponent 5/3 + b. In R. Teman (Ed.), *Turbulence and
Notes in Mathematics, Volume 565.

W.H. Freeman and Co.

In C. H. Scholz and B. B. Mandelbrot (Eds.), *Fractals in Geophysics*, Pure
and Applied Geophysics, pp. 5–42. Birkhauser Basel.

Manneville, P. (1980). Intermittency, self-similarity and 1/f spectrum in dissipa-
tive dynamical systems. *Le Journal de Physique* 41, 1235–1242.

PARIS UNIVERSITÉ, Paris.

viscosity and the electrical polarizability of arbitrarily shaped objects. *Phys.
Rev. E* 64, 061401.


Mantegna, R. N. (1994). Fast, accurate algorithm for numerical simulation of

Mao, Z., S. Chen, and J. Shen (2016). Efficient and accurate spectral method us-

Marchal, P. (2005). Measure concentration for stable laws with index close to


Nagaev, A. and A. Zaigraev (2003). New large deviation local theorem for sums of i.i.d. random vectors when the limit distribution is $\alpha$-stable.


Nolan, J. P. (2015b). *SimplicialCubature: Integration of Functions Over Simplices*. CRAN. R package, online at [https://cran.r-project.org/web/packages/SimplicialCubature/](https://cran.r-project.org/web/packages/SimplicialCubature/).


171


Proceedings of the Seminar on Stability Problems for Stochastic Models, Part
II (Naleczow, 1999), Volume 106, pp. 2747–2751.

Soltani, A. R. and A. Shirvani (2010). Truncated stable random variables:

Sorace, J. (2012, 13 November). Humans are not electrons: Characterization of
the medicare disease probability distribution. Seminar, NIH.


Springer.

174.

decision metrics for coded orthogonal signaling in symmetric alpha-stable

model for ad hoc DS/CDMA packet radio networks with variable coherent

distribuições estáveis. Phd thesis, Universidade de Brasília, Departamento de
Estatística do Instituto de Ciências Exatas.

for estimating ARMA models with GARCH/APARCH innovations following
GEV and stable distributions. Preprint.

time-series models. Research Paper 87-07, Institute of Statistics and Decision
Sciences, Duke University, Dunham, NC.

505.

Spanos, A. (1993). On modeling speculative prices: Student’s t autoregres-
sive model with dynamic heteroskedasticity. Technical report, University of
Cyprus.

Company.

188


Xu, S., W. Wu, Y. Yang, B. Wang, and X. Wang. Analytical solution of stochastic real-time dispatch incorporating wind power uncertainty characterized by Cauchy distribution. IET Renewable Power Generation n/a(n/a).


Yin, C. and X. Sha (2018). A new class of symmetric distributions including the elliptically symmetric logistic.


210


Zhelezov, O. I. (2018). One modification which increases performance of n-
dimensional rotation matrix generation algorithm. *International Journal of
Chemistry Mathematics and Physics* 2(2), 13–18.

interference arising from random spatial fields of interferers utilizing multiple
subcarriers. *J Wireless Com Network* 27. https://doi.org/10.1186/s13638-
022-02110-w.

Zhidkov, S. (2018a). Replication data for: Statistical characterization and mod-
eling of noise effects in near-ultrasound aerial acoustic communications.

Zhidkov, S. V. (2018b). Statistical characterization and modeling of noise ef-
effects in near-ultrasound aerial acoustic communications. *The Journal of the
Acoustical Society of America* 144(4), 2605–2612.

Codes for Additive White Symmetric Alpha-Stable Noise Channels. *arXiv

Chance, long tails, and inference in a non-Gaussian, Bayesian theory of
vocal learning in songbirds. *Proceedings of the National Academy of Sci-
eses* 115(36), E8538–E8546.

Zhou, J., P. Haygarth, P. Withers, C. Macleod, P. Falloom, K. Beven, M. Ock-
enden, K. Forber, M. Hollaway, R. Evans, A. Collins, K. Hiscock, C. Wearing,
R. Kahana, and M. Villamizar (2016, 04). Lattice Boltzmann method for the

Zhou, T., Z. Peng, M. Gulian, and J. F. Brady (2021, jun). Distribution and
pressure of active lévy swimmers under confinement. *Journal of Physics A:
Mathematical and Theoretical* 54(27), 275002.

sensing. *ArXiv e-prints*.

Zhu, Q., J. Shen, and J. Ji (2020). Internal signal stochastic resonance of a
two-component gene regulatory network under Lévy noise. *Nonlinear Dy-


Zieliński, R. (2000a). A median-unbiased estimator of the characteristic expen-

Zieliński, R. (2000b). A reparametrization of the symmetric α-stable distribu-
tions and their dispersive ordering. *Teor. Veroyatnost. i Primenen.* 45(2),
410–411.


