UNIVERSITÀ DEGLI STUDI DI PADOVA

Dipartimento di Fisica e Astronomia Galileo Galilei

Beyond Brownian Diffusion

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Physics diversity network (DIPHER24)

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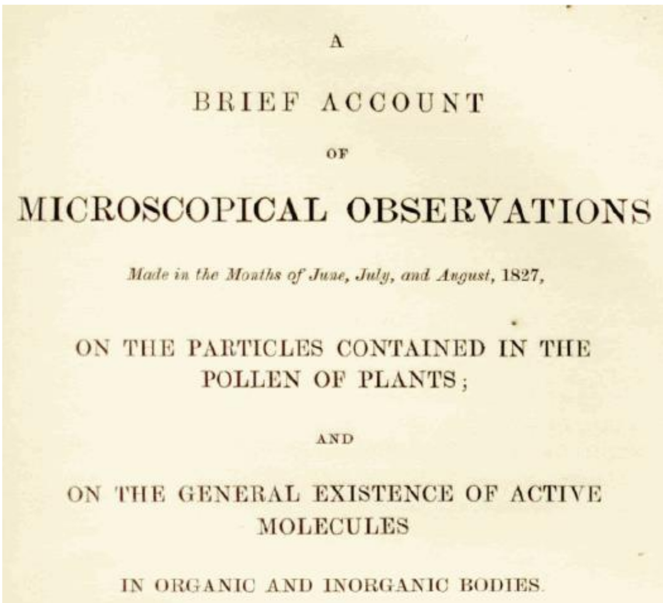
Università degli Studi di Padova

PADOVA

OUTLINE

- Introduction to diffusion and its anomalies
- Experimental evidence of Brownian yet not Gaussian Diffusion
- Diffusing Diffusivity models
- Effects of non-gaussianity on targeting problems
- Individual experience with gender and diversity and at Padova University

The random motion of particles suspended in a medium is called Brownian Motion


A

BRIEF ACCOUNT

OF

MICROSCOPICAL OBSERVATIONS

Made in the Months of June, July, and August, 1827,

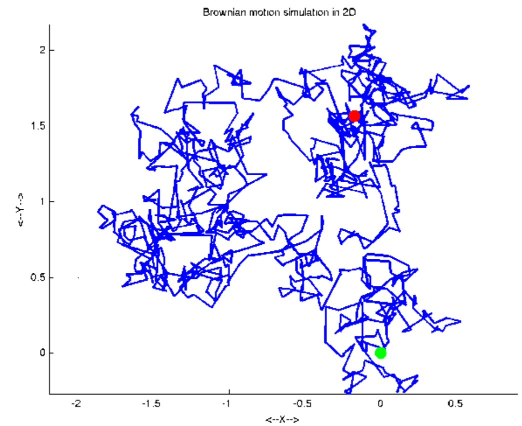
ON THE PARTICLES CONTAINED IN THE POLLEN OF PLANTS;

AND

ON THE GENERAL EXISTENCE OF ACTIVE MOLECULES

IN ORGANIC AND INORGANIC BODIES.

What Robert Brown saw in his microscope ?



- very rapid
- highly irregular
- zigzag motion

"Vital Force" (?)

- **living pollen**
- **dead pollen**
- **fine inorganic particles**

Particles of Egyptian sphinx

Display identical motion having a physical origin (but which ???)

This motion is not caused by currents (flows) in the liquid, nor by convection, nor by evaporation of the solvent

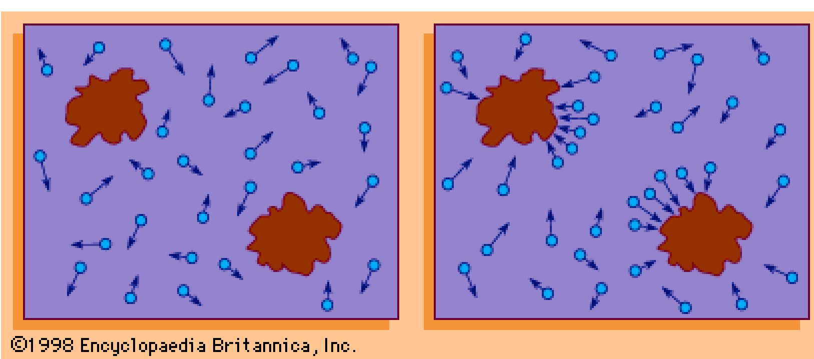
Explanation of Brownian motion – Einstein and Smoluchowksy

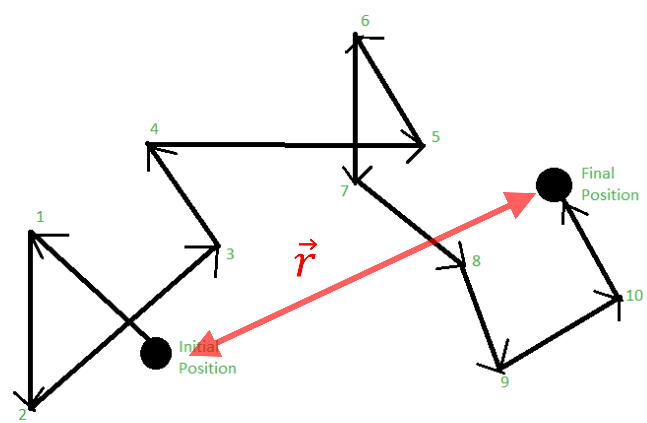
- Movement of Brownian particles are caused by *collisions* with molecules of the solvent

- These *molecules move erratically* in display of their thermal energy, of which the temperature is a certain measure

- Molecules of the solvent are too *little* to be observed directly

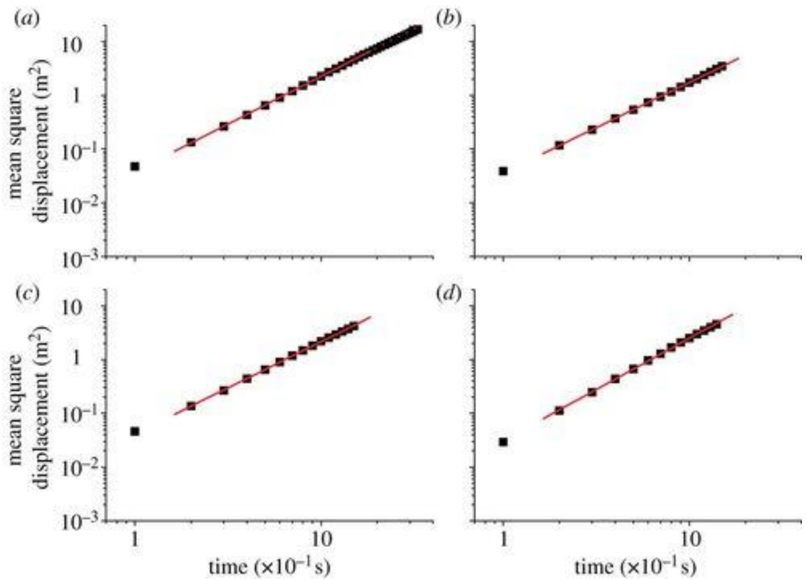
- Particlers of the suspension, even though they are tiny from a human point of view, are *true giants* in comparison withe molecules of the solvent , and can be observed directly





$\overline{\vec{r}^2}$ $P(\vec{r})$

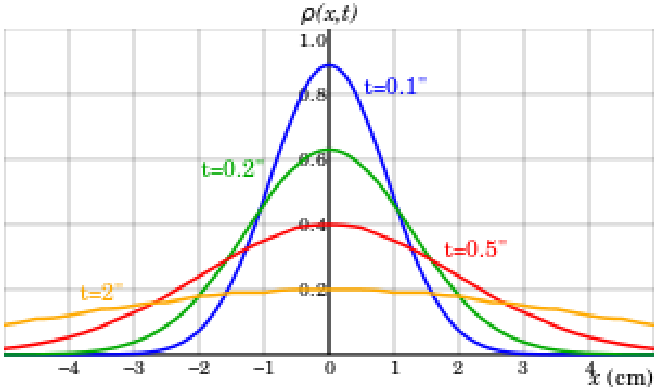
Normal diffusion is BROWNIAN and GAUSSIAN:



BROWNIAN:

$$\lambda_r = \sqrt{\overline{\vec{r}^2}} = \sqrt{6Dt}$$

$$D \sim k_B T$$

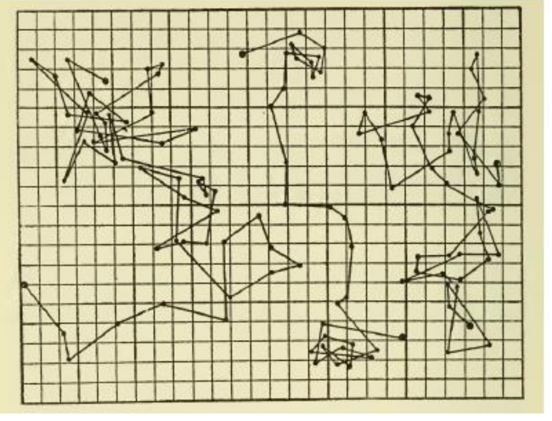


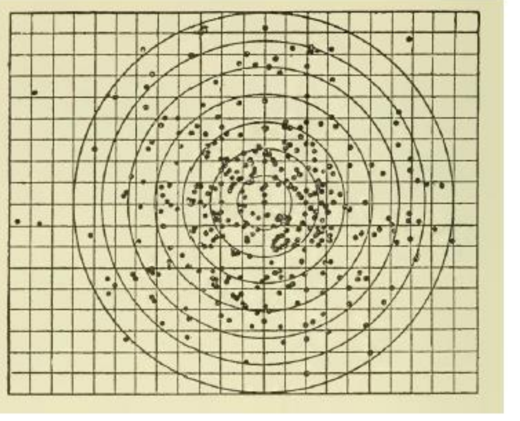
GAUSSIAN:

$$P(x,t) = \frac{1}{\sqrt{4\pi D}} \frac{e^{-\frac{x^2}{4Dt}}}{\sqrt{t}}$$

UBIQUITOUS phenomenon that play a SIGNIFICANT ROLE in virtually ALL MOLECULAR PROCESSES

J. B. Perrin (1909): experimental work to test and verify Einstein – Smoluchowski's theory of Brownian motion



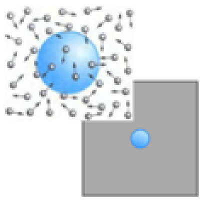


J. Perrin, Brownian Movement and Molecular Reality. London, Taylor and Francis (1910)
http://web.mit.edu/swangroup/footer/perrin_bm.pdf

Perrin wrote that his results "cannot leave any doubt of the rigorous exactitude of the formula proposed by Einstein," and his work later earned him his own Nobel Prize in Physics, in 1926.

Langevin approach

Newton's 2° law of motion: $ma(t) = F(t)$



$$\cancel{m\frac{d^2}{dt^2}}\,x(t) = -\gamma\frac{d}{dt}\,x(t) + \sqrt{2\sigma}\,\xi(t) \;\Rightarrow\; \frac{d}{dt}\,x(t) = \sqrt{2D}\,\xi(t)$$

Particle position at time t

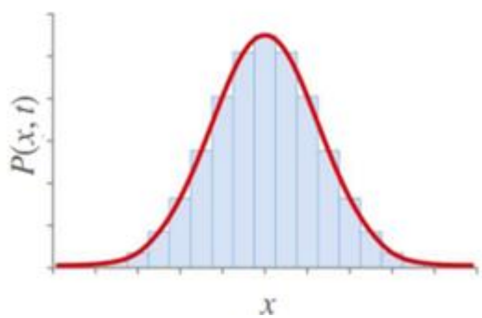
Viscous drag

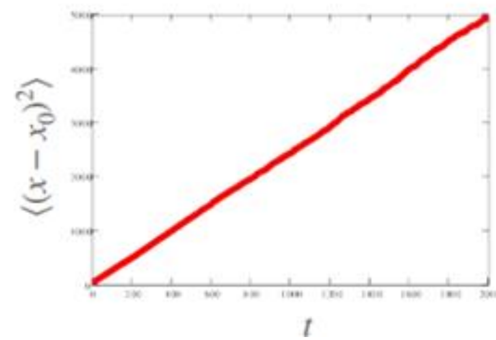
Stochastic force

Diffusion coefficient

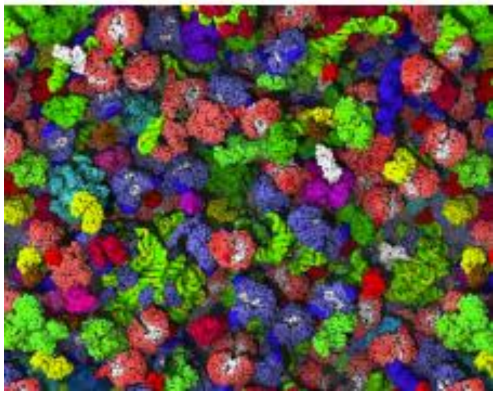
$\langle\xi(t)\rangle=0$

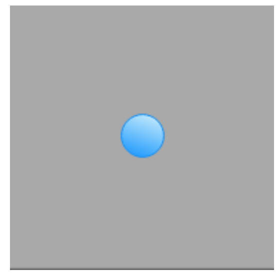
$\langle\xi(t)\xi(t')\rangle=\delta(t-t')$

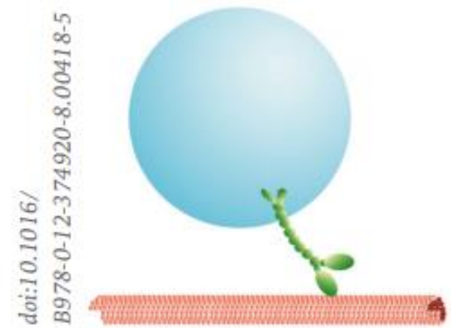




Beyond Gaussian Diffusion







Confined motion

Free Motion

Active Motion

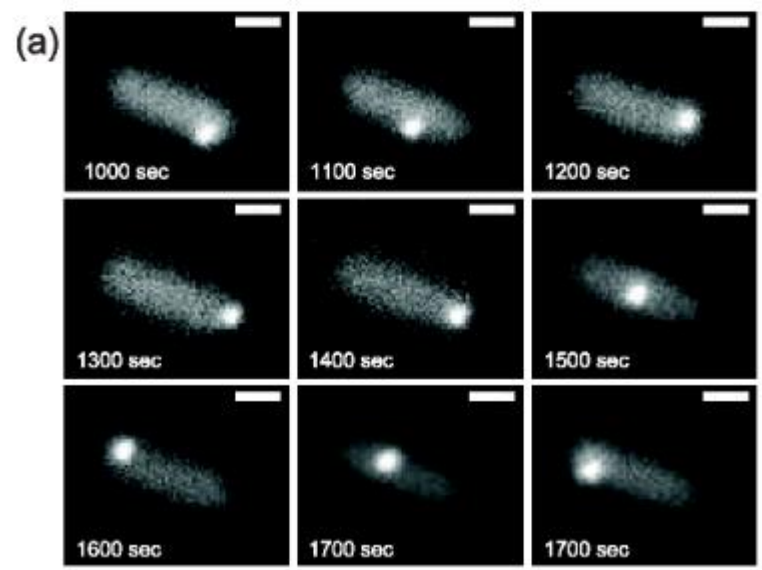
Single particle tracking experiments are rising new challenges

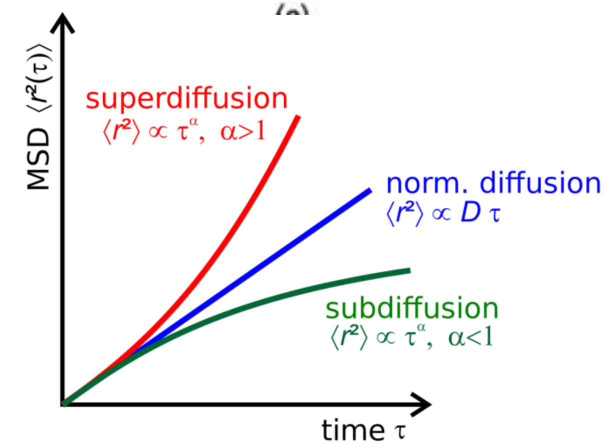
(powerful immaging techniques such single molecule spectroscopy)

Rep. Prog. Phys. **76** (2013) 046602 F Höfling and T Franosch

Table 2. Overview of *in vivo* experiments on crowded cellular fluids as a guide to the discussion in section 5.1.1.

Cell type	Probe (size)	Experimental technique	Temporal and spatial scales investigated	Subdiffusion exponent α or diffusion constant D	Year	Ref.
S. pombe	Lipid granules (300 nm)	Laser tracking, video microscopy	50 μs–1 ms, 40 ms–3 min	0.70–0.74	2004	[231]
		Laser tracking	0.1–10 ms (PSD)	0.81 (interphase), 0.84 (cell division)	2009	[232]
		Video microscopy	10 ms–10 s	0.4 (time average)	2010	[233]
		Video microscopy, laser tracking	$>$10 ms, 0.1 ms–1 s	0.8, normal for $t \lesssim 3$ ms, then $\beta = 1-\alpha \approx 0.2$	2011	[234]
E. coli	mRNA (100 nm)	Video microscopy	1–30 s, 10^{-3}–1 Hz (PSD)	0.70 ± 0.07, 0.77 ± 0.03	2006	[235]
		Video microscopy	1–10^3 s	0.71 ± 0.10	2010	[236]
E. coli, *C. crescentus*	Chromosomal loci (GFP labelled)	Video microscopy	1–10^3 s	0.39 ± 0.04 (ensemble and time averages coincide)	2010	[236]
Human ostero-sarcoma cells (nucleus)	Telomeres (GFP labelled)	Video microscopy	10 ms–1 h	Subdiffusion with α varying with lag time, $\alpha(t)$: $0.32 \to 0.51 \to 1$.	2009	[237]
SV-80 cells	PS beads (3 μm)	Video microscopy	40 ms–50 s	0.5–1 for $t > 10$ s, 3/2 for $t < 3$ s (motor proteins)	2002	[238]
Mammalian and plant cells	Rhodamine dye	FCS	$0.1\text{ ms} < \tau_{1/2} < 1\text{ s}$	0.6, or 2 components: $D_1 = D_{aq}/5$, $D_1/D_2 = 40$	1999	[239]
COS-7 and AT-1 cells	EGFP proteins	FCS	$\tau_{1/2} \approx 1$ ms	0.7–1, or 2 components: $D_1 = D_{aq}/5$, $D_1/D_2 = 10$	2000	[240]
HeLa cells	FITC-dextran (1.8–14.4 nm)	FCS	$0.4\text{ ms} < \tau_{1/2} < 16\text{ ms}$	0.71–0.84 (depending on tracer size)	2004	[241]
HeLa and liver cells	Gold beads (5 nm)	FCS	10 μs–1 s, $\tau_{1/2} \approx 0.3$ ms	0.53, with sucrose added: 0.66	2007	[242]
Mammalian cells	Gold beads (5 nm)	FCS	$0.1\text{ ms} < \tau_{1/2} < 0.9\text{ ms}$	0.52 (cytoplasm), 0.58 (nucleoplasm)	2007	[243]





$$\langle r^2 \rangle \cong t^\alpha$$

$$\alpha \neq 1$$

Hofling F and Franosch T

Anomalous transport in the crowded world of biological cells

Rep. Progr. Phys. 76 046602 (2013)

Different sources of anomaly

Long jumps $\xrightarrow{\text{super}}$ Lévy flights / Levy walks in space

Long waiting times as arising from random potential models $\xrightarrow{\text{sub}}$ Lévy flights in time

Long temporal correlations $\xrightarrow{\text{super \& sub}}$ fractional motions

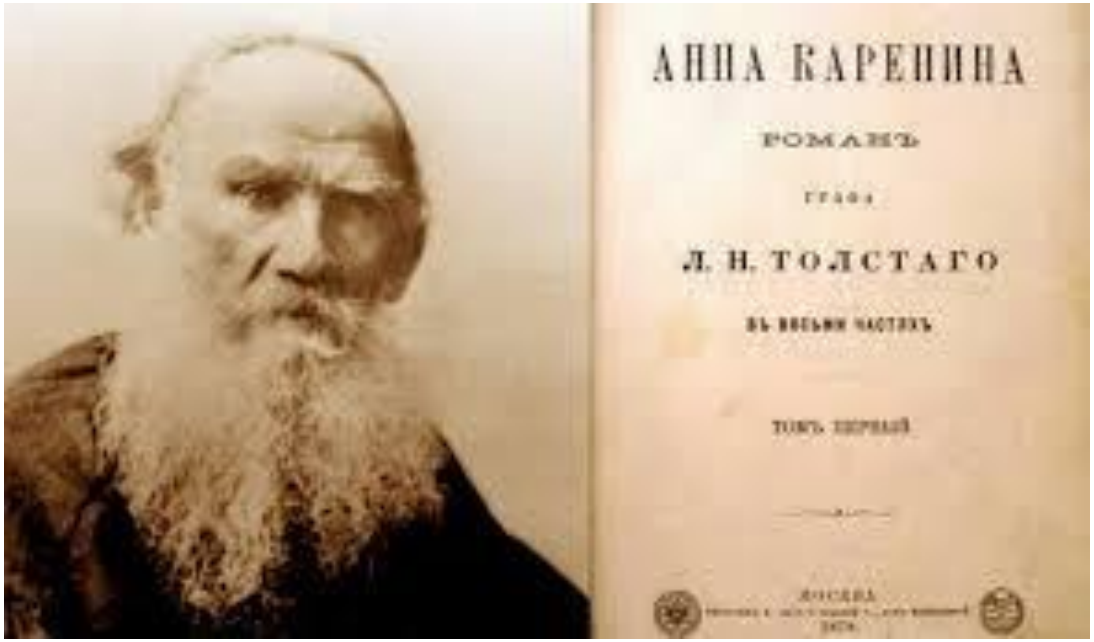
Geometrical constraints $\xrightarrow{\text{sub}}$ Diffusion on fractal structures and in crowded environment

...

Inhomogeneous and/or non-stationary environment $\xrightarrow{\text{super \& sub}}$ Scaled Brownian motion, heterogeneous diffusion processes

Normal diffusions are all alike; every anomalous diffusion is anomalous in its own way

L. Tolstoi , Anna Karenina (slightly modified)



Anomalous yet Brownian

Bo Wang[a], Stephen M. Anthony[b], Sung Chul Bae[a], and Steve Granick[a,b,c,d,1]

15160–15164 | PNAS | September 8, 2009 | vol. 106 | no. 36

When Brownian diffusion is not Gaussian

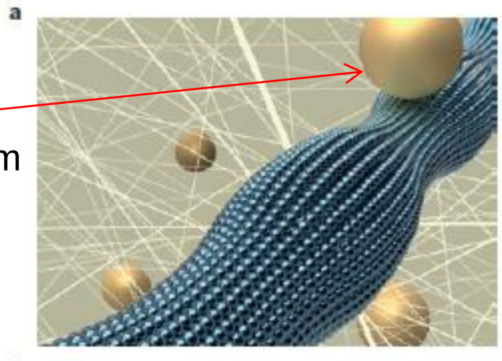
Bo Wang, James Kuo, Sung Chul Bae and Steve Granick

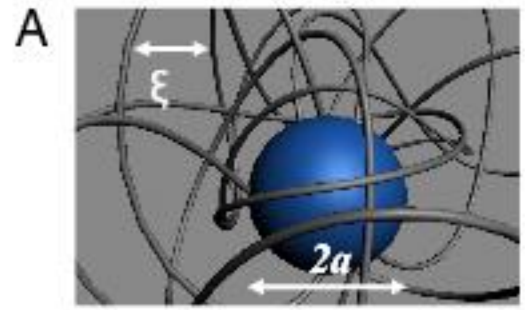
NATURE MATERIALS | VOL 11 | JUNE 2012 | www.nature.com/naturematerials

Diffusion of colloids on phospholipid tubes

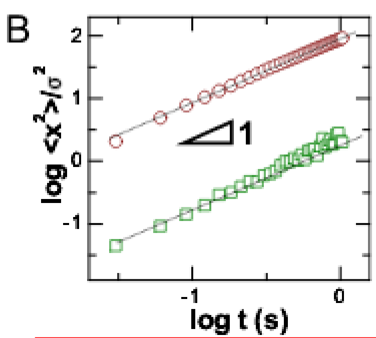
Colloidal beads in entangled actin suspensions

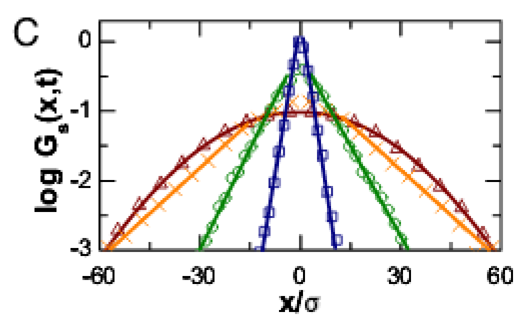
Diameter 100 nm

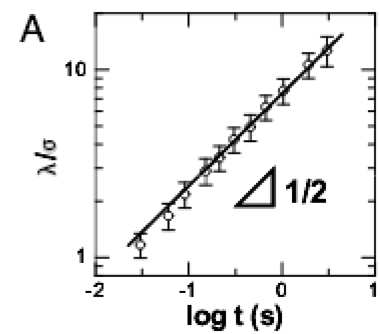




a=25-250 nm



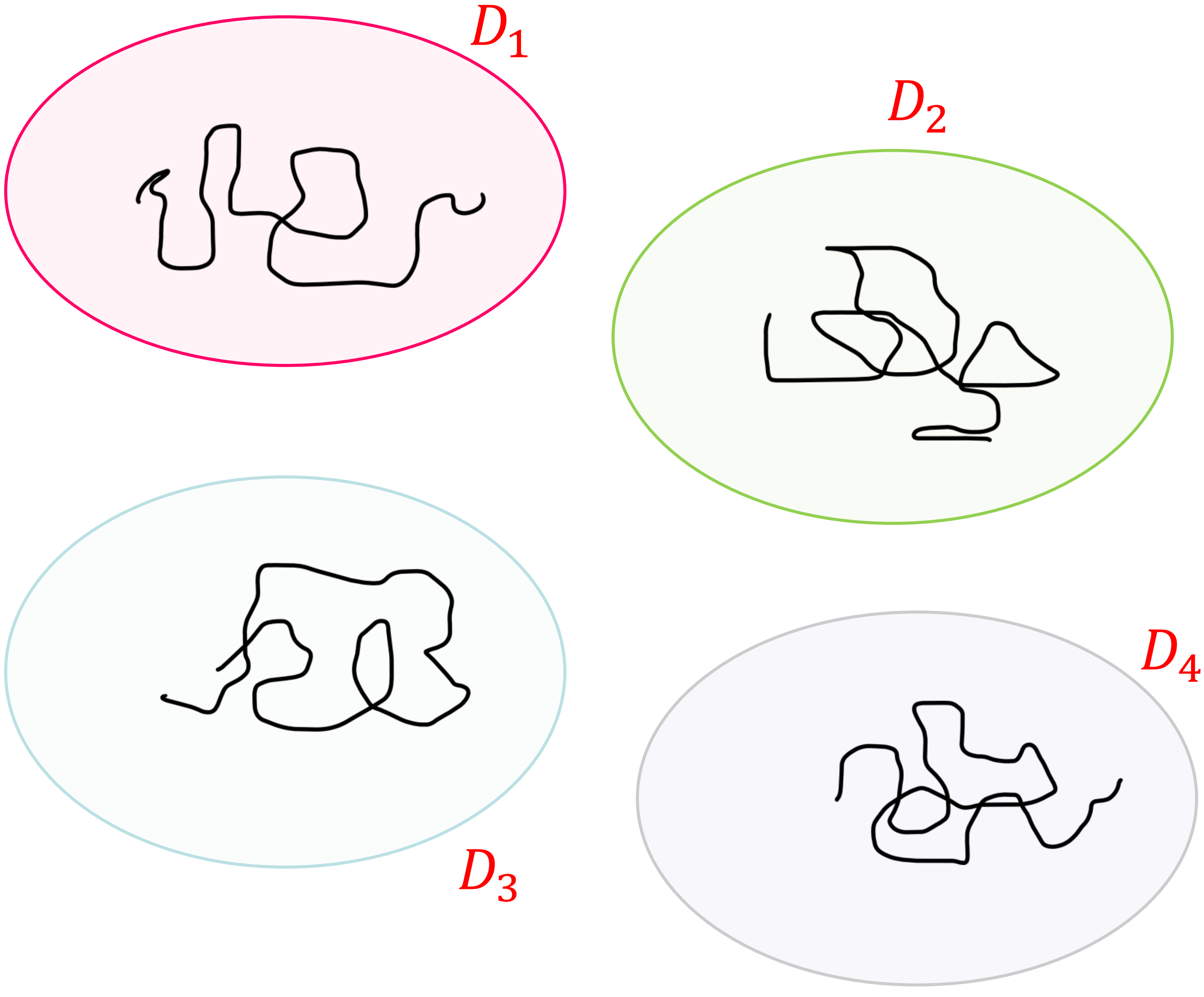




$$\left\langle x^2(t) \right\rangle = \int_{-\infty}^{\infty} x^2 f(x,t)\,dx = 2Dt$$

$$f(x,t) = \frac{1}{2\lambda(t)} e^{\left(-\frac{|x|}{\lambda(t)}\right)} \quad , \quad \lambda = \sqrt{Dt}$$

Brownian yet not Gaussian dynamics !!!

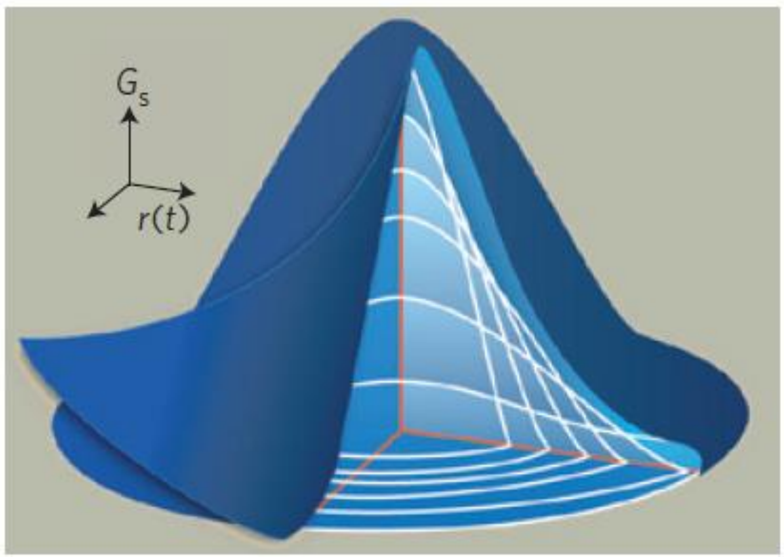

D_1
D_2
D_3
D_4

ENSEMBLE BEHAVIOUR IN TERMS OF DISTRIBUTIONS OF DIFFUSIVITIES OF INDIVIDUAL TRACER PARTICLES (SUPERSTATISTICAL APPROACH)

$$\boxed{p(D) = \frac{1}{D_*} exp\left(-\frac{D}{D_*}\right)}$$

$$G(r,t) = \frac{1}{\sqrt[d]{4\pi D t}} e^{-r^2/4Dt}$$

b



$$\boxed{f(r,t) = \int_0^\infty G(r,t) p(D) dD}$$

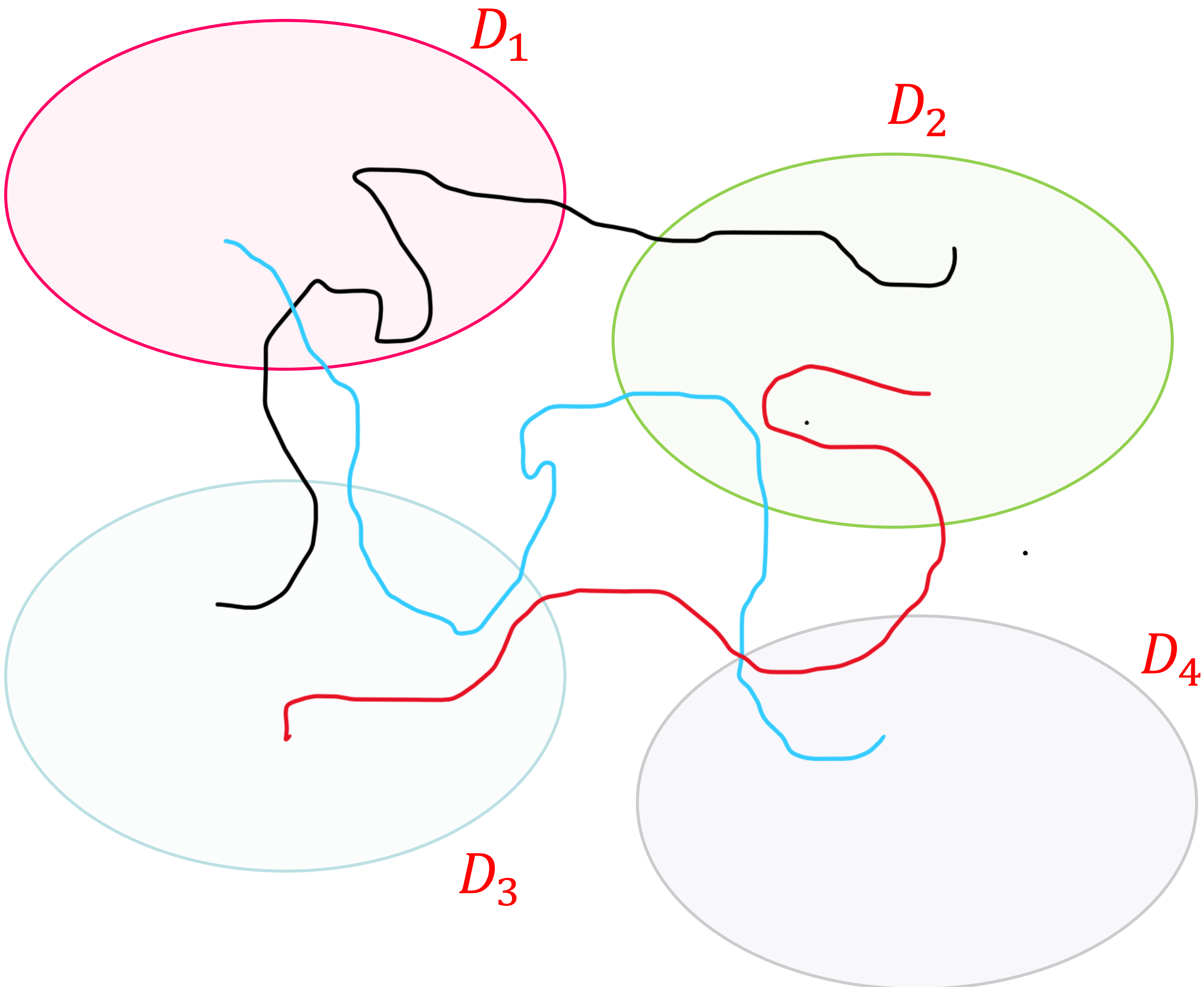
$$\boxed{f(x,t) = \frac{1}{2\sqrt{D_* t}} exp\left(-\frac{|x|}{\sqrt{D_* t}}\right)}$$

OK

$$\boxed{\langle x^2(t)\rangle = \frac{\sqrt{\pi}}{4} D_* t}$$

OK

No crossover to the gaussian behaviour!


D_1
D_2
D_3
D_4

Minimal Langevin Model for Diffusing Diffusivity

NON INTERACTING PARTICLES DIFFUSE IN ONE DIMENSION:
EACH ONE WITH ITS OWN INSTANTANEOUS DIFFUSION COEFFICIENT THAT VARIES WITH TIME

$$\boxed{\frac{d}{dt}x(t) = \sqrt{2D(t)}\,\xi(t)}$$

OVERDAMPED LANGEVIN EQUATION

$$\langle \xi(t) \rangle = \langle \eta(t) \rangle = 0$$
$$\langle \xi(t)\xi(t') \rangle = \langle \eta(t)\eta(t') \rangle = \delta(t\text{-}t')$$

$$D(t) = y^2(t) \quad \longleftarrow \quad \textbf{GUARANTEES POSITIVITY}$$

$$\frac{dy(t)}{dt} = -y(t) + \eta(t) \quad \longleftarrow \quad \textbf{LINEAR RESTORING TERM (Ornstein-Uhlenbeck)}$$

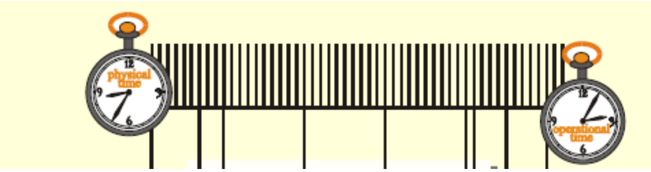
It guarantees stationary dynamics with finite correlation time
Distribution of probability is exponential

Minimal Langevin model for diffusing diffusivities

$$\frac{d}{dt}x(t) = \sqrt{2D(t)}\xi(t)$$

$$\boxed{\frac{d\tau}{dt} = D(t)}$$

Subordination approach (Bochner, 1949) (financial mathematics)



A subordinator associates a random time increment with the number of steps of the subordinated process

$$\tau(t) = \int_0^t dt' D(t') = \int_0^t dt' y^2(t')$$

$$\boxed{\frac{\partial}{\partial t}p(x,t) = D(t)\frac{\partial^2}{\partial x^2}p(x,t)}$$

$$\frac{dx(\tau)}{d\tau} = \sqrt{2}\xi(\tau)$$

Integral formula for subordination (Feller, vol.II)

$$\boxed{p(x,t) = \int_0^\infty d\tau\, G(x,\tau)T(\tau,t)}$$

$$G(x,\tau) = \frac{1}{\sqrt{4\pi\tau}}\exp\left(-\frac{x^2}{4\tau}\right)$$

$T(\tau,t)$ is the PDF of the process $\tau(t)$

$$\boxed{\hat{p}(k,t) = \int_0^\infty d\tau\, \hat{G}(k,\tau)T(\tau,t) = \int_0^\infty d\tau\, e^{-k^2\tau}T(\tau,t) = \tilde{T}(k^2,t)}$$

The Fourier transform of $p(x,t)$ is the Laplace transform of the density function $T(\tau,t)$

$\tau(t)$ is the integrated square of the Ornstein-Uhlenbeck process

THOUGH PROBLEM....BUT

SIAM J. APPL. MATH.
Vol. 51, No. 2, pp. 568-574, April 1991

014

ON THE DISTRIBUTION OF THE INTEGRATED SQUARE OF THE ORNSTEIN-UHLENBECK PROCESS*

THAD DANKEL, JR.†

NOW 16!

Abstract. Using functional integral methods, the Laplace transform of the square of the Ornstein-Uhlenbeck process $X(t)$ integrated over $0 \leq t \leq T$ is calculated. Via the complex inversion integral, the asymptotic behavior as $T \to \infty$ of the density and distribution functions, as well as these functions conditioned on the event $X(T)=0$, are studied. It is found that the approximation by an inverse Gaussian distribution, introduced earlier by Grenander, Pollak, and Slepian, is asymptotically correct (to within a constant factor) in the conditional case, but not in the unconditional case.

Key words. Ornstein-Uhlenbeck process, functional integrals, asymptotic distributions, Laplace transforms, inverse Gaussian distribution

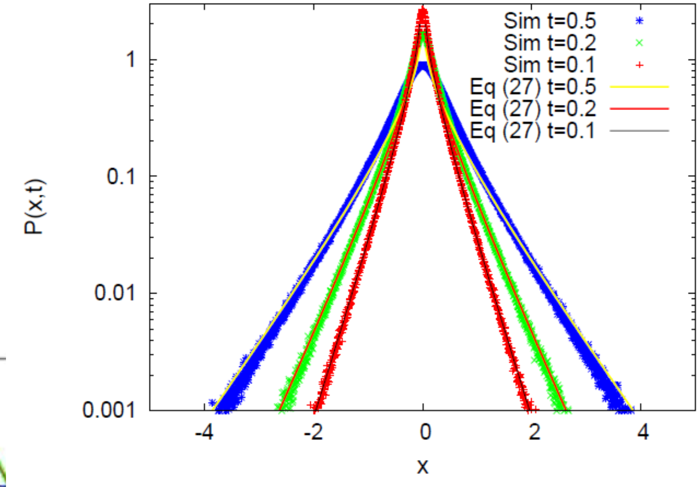
AMS(MOS) subject classifications. 60G10, 60G15, 60J25, 41A60, 28C20

$$\tilde{T}(s,t) = \frac{e^{t/2}}{\left[\frac{1}{2}\left(\sqrt{1+2s}+\frac{1}{\sqrt{1+2s}}\right)\sinh\left(t\sqrt{1+2s}\right)+\cosh\left(t\sqrt{1+2s}\right)\right]^{1/2}}$$

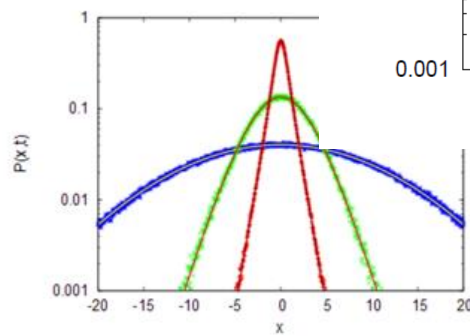
Exact solution of the diffusing diffusivity model

- **Short times, t << 1**

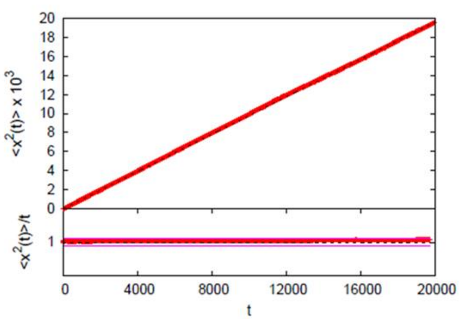
$$p(x,t) = \frac{1}{\pi\sqrt{t}}\int_0^{\infty} dk \frac{\cos(kx)}{\left(k^2+\frac{1}{t}\right)^{1/2}} = \frac{1}{\pi\sqrt{t}} K_0\left(\frac{|x|}{\sqrt{t}}\right)$$



- **Long times**

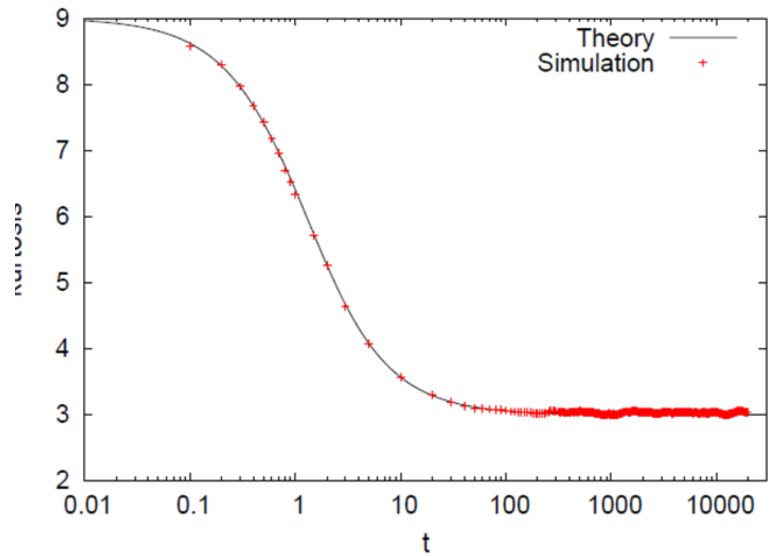


$$\boxed{p(x,t) = \frac{1}{\sqrt{4\pi\langle D\rangle_{st}\, t}}\exp\left(-\frac{x^2}{4\langle D\rangle_{st}\, t}\right)}$$



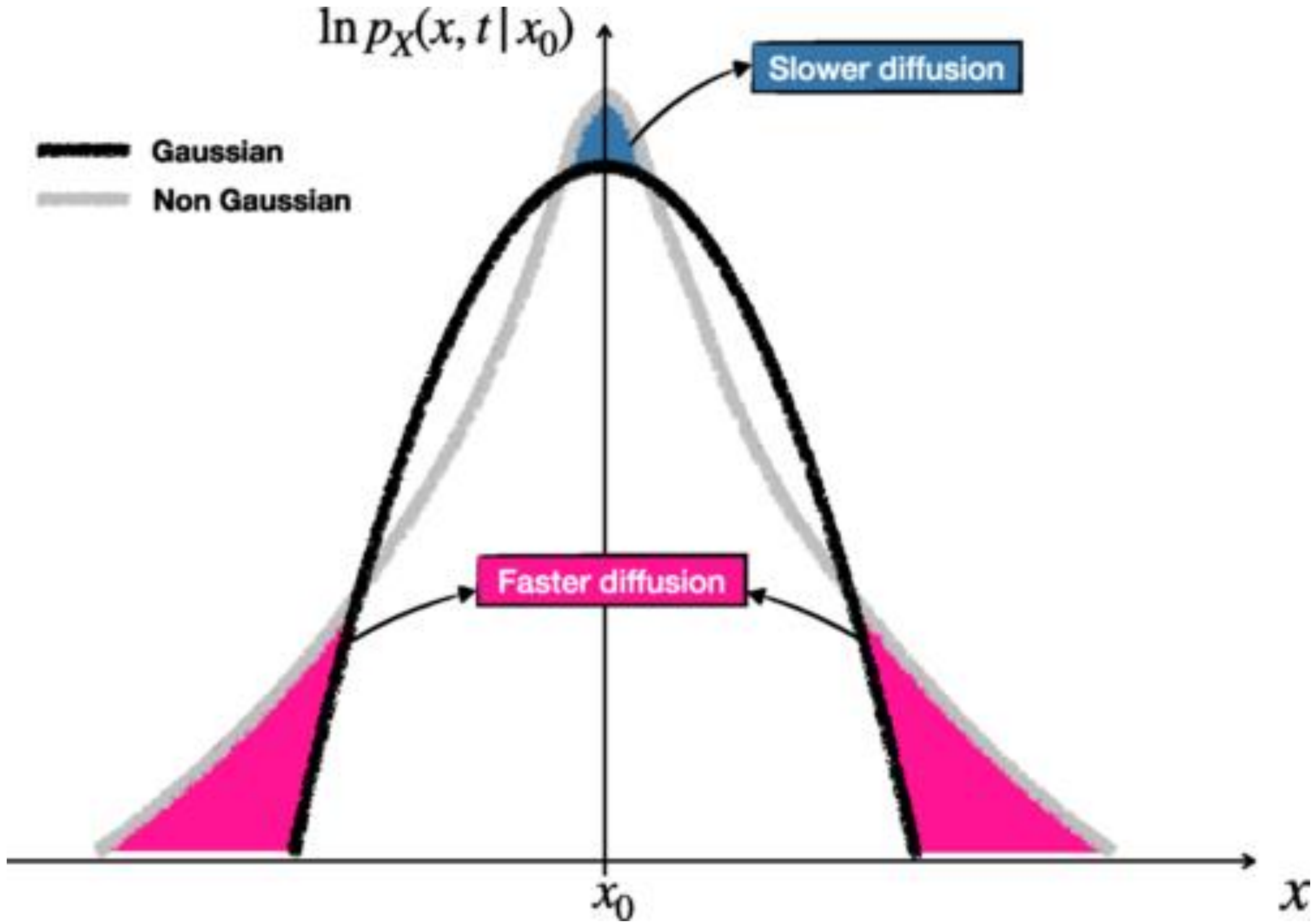
Kurtosis

$$\boxed{K = \frac{\langle x^4(t)\rangle}{\langle x^2(t)\rangle^2}}$$



From a practical viewpoint:

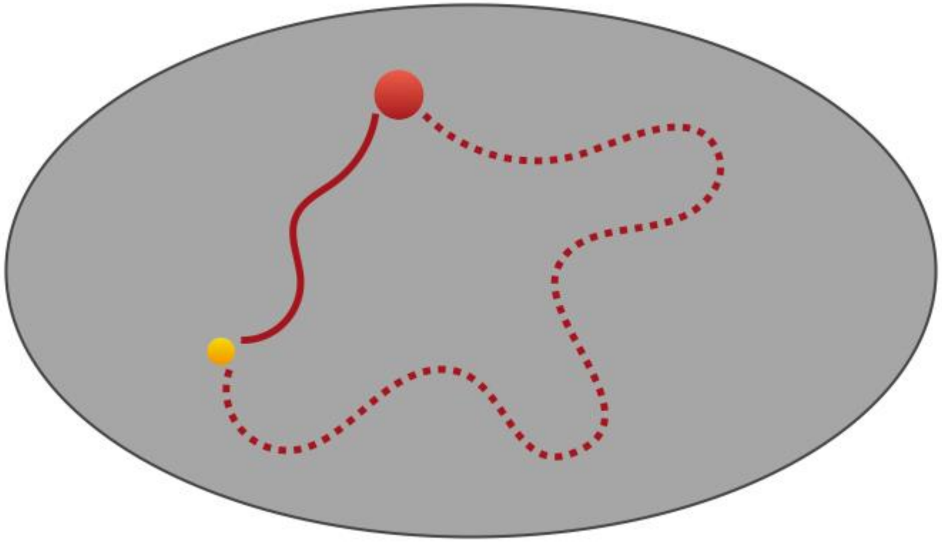
Why all this matters ? As the non-Gaussian character mostly appears in the tails of the distribution, and thus with low probability…



WHICH OF THESE EFFECT IS DOMINANT WHEN CONSIDERING TARGETING PROCESSES?

TARGETING PROCESSES

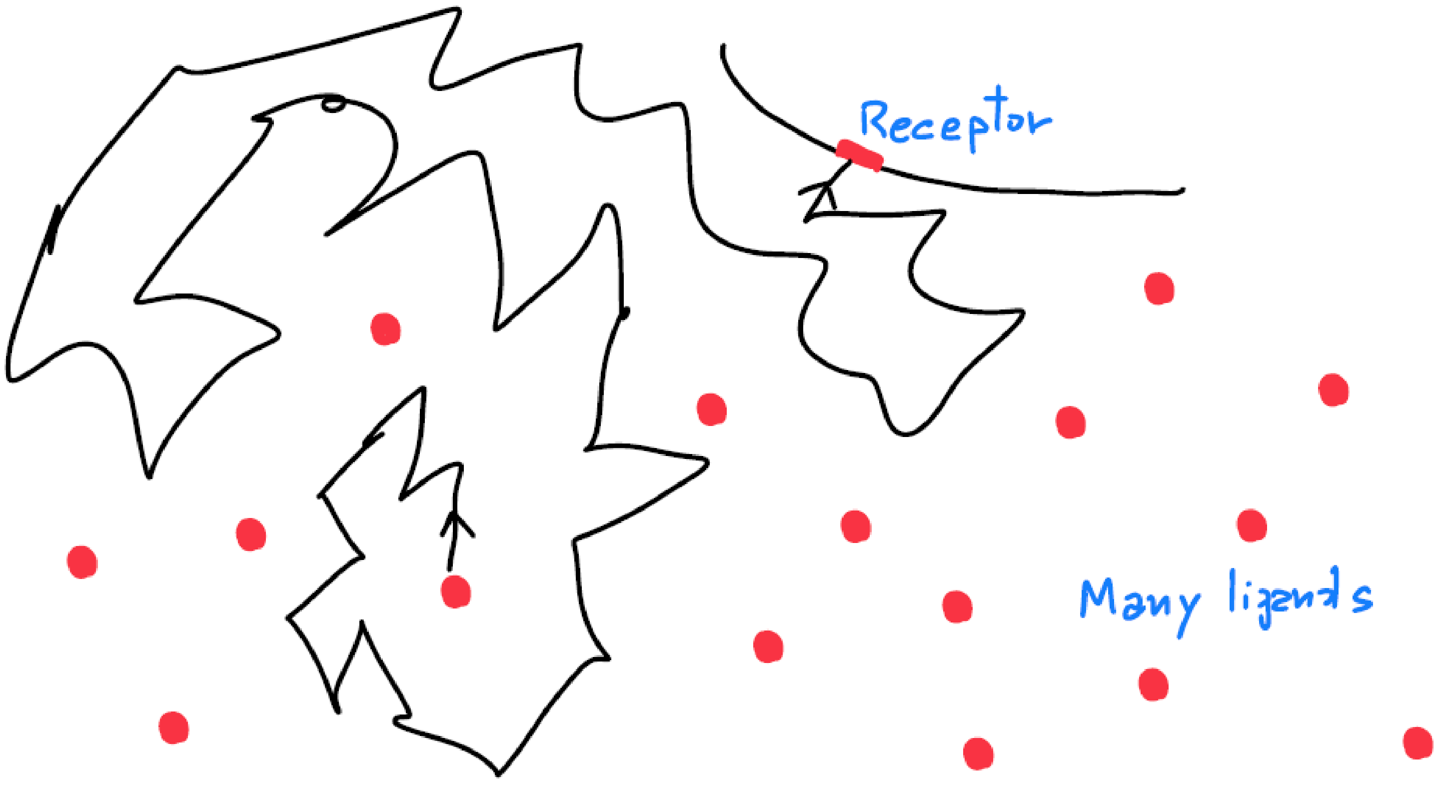
- Fluorescence quenching
- Integrate and fire neurons
- Execution of buy/sell orders when a stock price firt reach a threshold
- **Biology**:
- Transcriptor factors
- Drug binding
- Chemical signalling



Searcher that moves according to a specific diffusive model

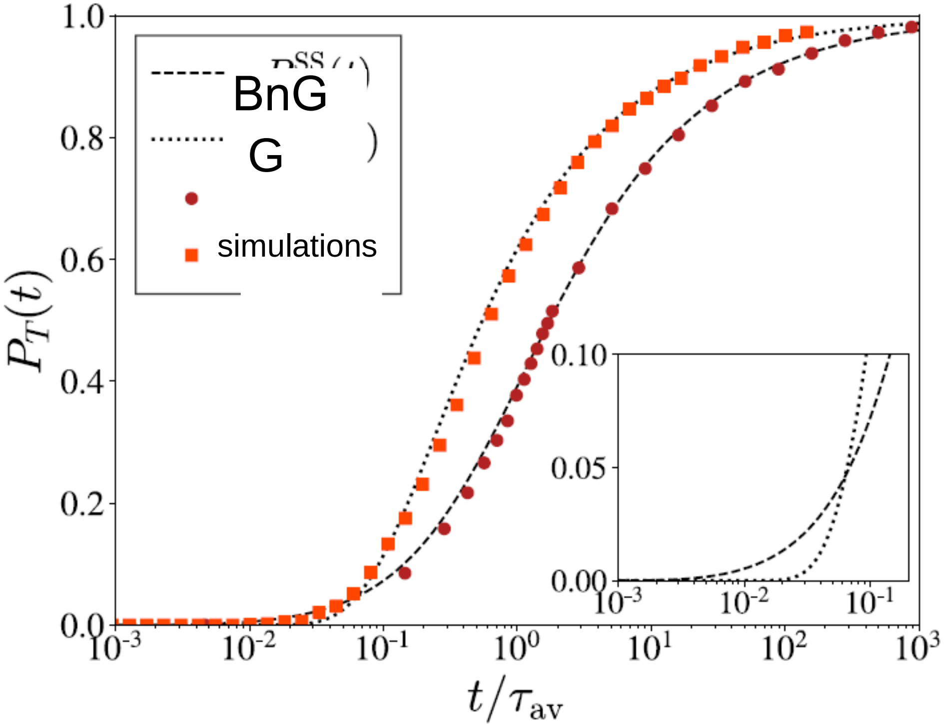
Perfectly absorbing target

MEAN FIRST PASSAGE TIME



In manu cases activation is triggered when many searches reach the target (robustness), e.g. QUORUM SENSING

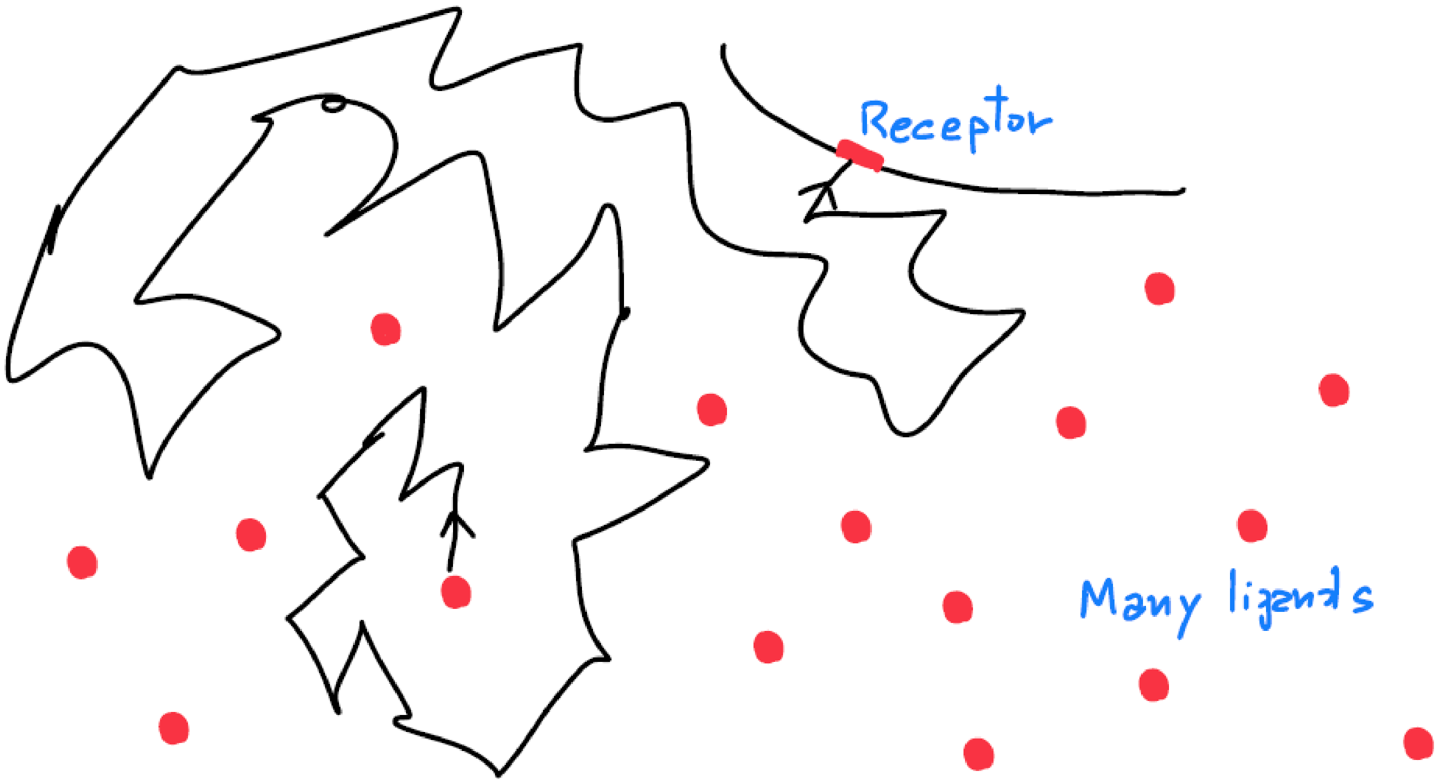
Text book on stochastic processes: $P_T(x_0, t, D) = 1 - \int P_X(x, t|x_{0,} D)$



$\tau_T^{BnG}(x_0) > \tau_T^G(x_0, D_{av})$

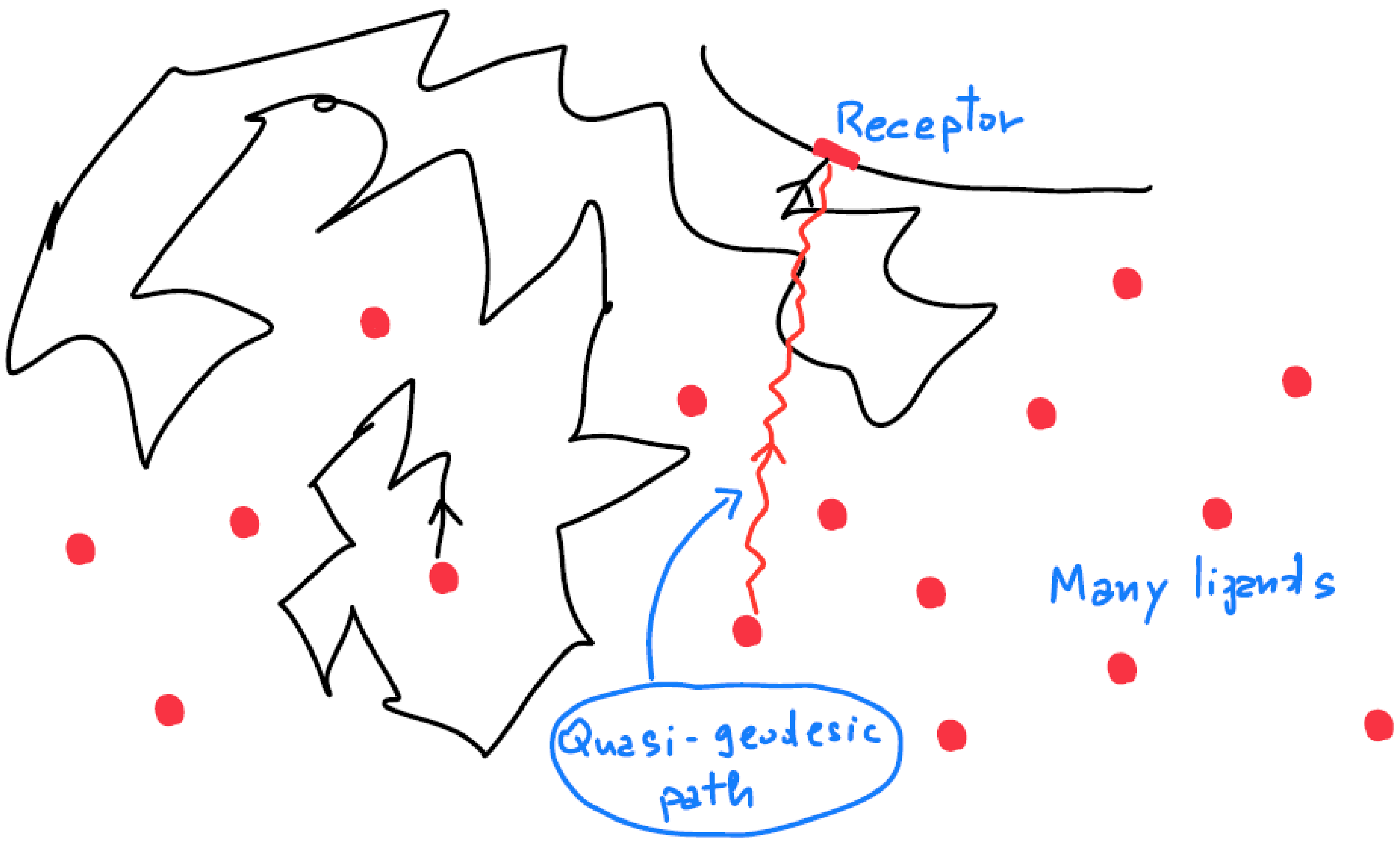
The characteristic time to target of a single searcher for subordinated non-Gaussian diffusion processes is larger than in ordinary Gaussian diffusion!

EXTREME FIRST PASSAGE TIME



In other cases activation is triggered when the first searcher reach the target (a paradigmatic example is human reproduction, in which a single sperm cell out of M ~ 10^8 finds and fertilizes the egg.)

Extreme FPT is governed by rare trajectories which are the few among the many to follow a quasi-geodesic path to the target



The tail effect non-Gaussianity adds to these rare events the possibility for the searcher to diffuse faster

EXTREME FIRST PASSAGE TIME

$M \gg 1$ ***INDIPENDENT SEARCHERS WITH ARRIVAL TIME*** τ_i

$$T_M = \min_i [\{\tau_1, \tau_2, \ldots\ldots, \tau_M\}]$$

$Heterogeneity\ for\ diffusing\ particles\ with\ \ p_D(D_n)\ \ (n = 1,2\ , \ldots .)\Longrightarrow D_{av}$

$$P(T_M > t) = \prod_{i=1}^{M} P(\tau_i > t) = \prod_n \left[\mathcal{S}_{D_n}(t)\right]^{M_n}$$

$M_n\ number\ of\ searcher\ with\ diffusion\ coeeficient\ D_n$

$S_{D_n}(t)\ Survival\ probability\ not\ easy\ to\ compute$

$M \gg 1$ suggests that the computation of $P(T_M > t)$ can be approximated by the short time behaviour when $S_{D_n}(t) \approx 1$

EXTREME FIRST PASSAGE TIME

$$\tau_{\rm av} \equiv \frac{\ell^2}{2D_{\rm av}} ,$$

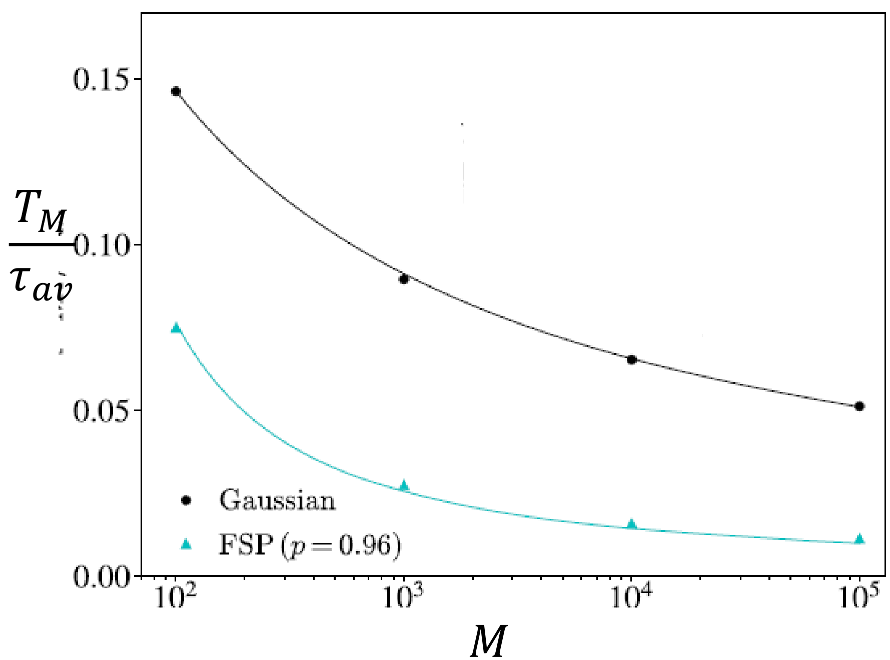
Average time to cover a distance ℓ

Gaussian case, only one D

$$\frac{T_M}{\tau_{av}} \approx \frac{1}{2\,ln\,M} \qquad M \gg 1$$

Non Gaussian case, distribution of D

$$\frac{T_M}{\tau_{av}} \approx \frac{1}{(\ln M)^2} \qquad M \gg 1$$

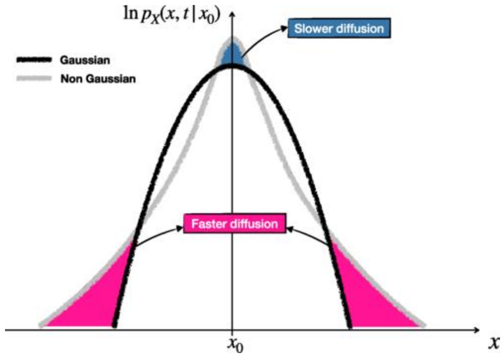


CONCLUSIONS

- We considered processes in which the origin of **non-Gaussianity** is ascribed to **heterogeneity of the ensembles of diffusers and/or of the environment**
- Such heterogeneity implies both an **excess of probability in the central part and in the tails** of the displacements distribution, when compared with the Gaussian one in diverse searchers strongly enhances the fast targetting of the first few instances
- In particular we have shown that **a higher probability for few, faster diffusers**, pointing out that a redundant information stored **(tail effect) influences extreme searches**

Non-Gaussianity is both disvantageous and advantageous:

- It is **disvantageous** when dealing with systems in which **a large percentage of searchers need to reach the target.**
- It is **advantegeous** when only a **few searchers**, among many, **are required to reach the target**



PHYSICAL REVIEW E **109**, 034120 (2024)

Being heterogeneous is disadvantageous: Brownian non-Gaussian searches

Vittoria Sposini,[1,*] Sankaran Nampoothiri,[2,†] Aleksei Chechkin,[3,4,5,‡] Enzo Orlandini,[6,§]
Flavio Seno,[6,‖] and Fulvio Baldovin[6,¶]

PHYSICAL REVIEW LETTERS **132**, 117101 (2024)

Being Heterogeneous Is Advantageous: Extreme Brownian Non-Gaussian Searches

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OXFORD (1096)

Scientific Bias: much easier to pubblish with the right preprint cover

The most snobbish and exclusive community in the world are Oxford Catholics

1222 • 2022

800

ANNI

UNIVERSITÀ DEGLI STUDI DI PADOVA

UNIVERSITY (1222)

Università degli Studi di Padova

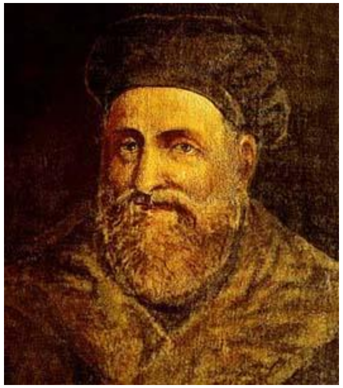
ALUMNI

Janus Pannonius

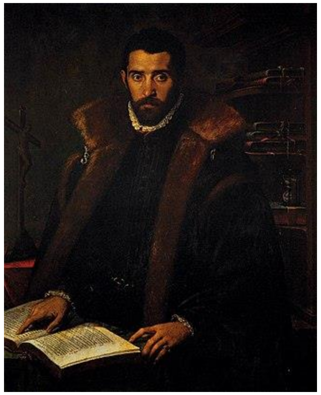
Galileo Galilei
1592-1610

William Harvey

Vesalius



Falloppio



Torquato Tasso

Elena Lucrezia Cornaro
25 June 1678

Tullio Levi Civita

GENDER UMBALANCE

FIRST FEMALE FULL PROFESSOR

MASSIMILA BALDO CEOLIN (1963)

Università degli Studi di Padova

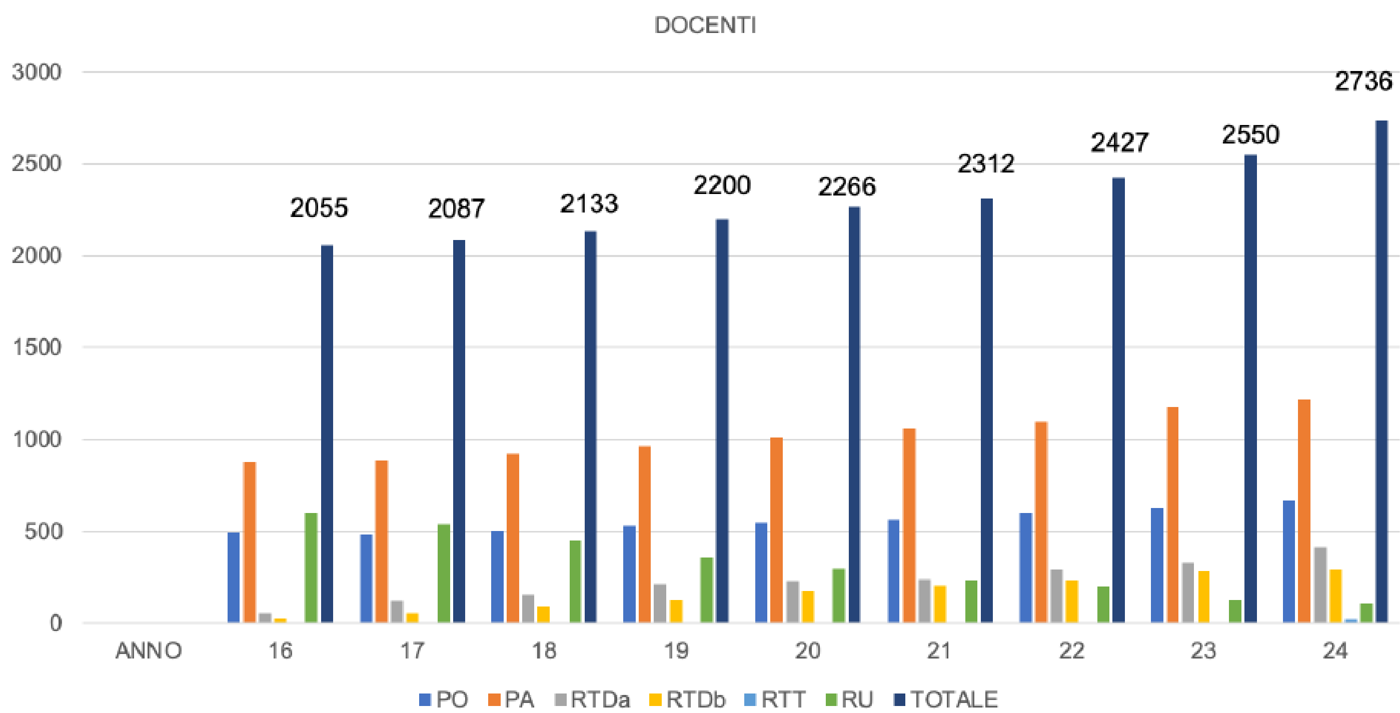
GENDER UMBALANCE

FIRST FEMALE RECTOR

DANIELA MAPELLI (2019)

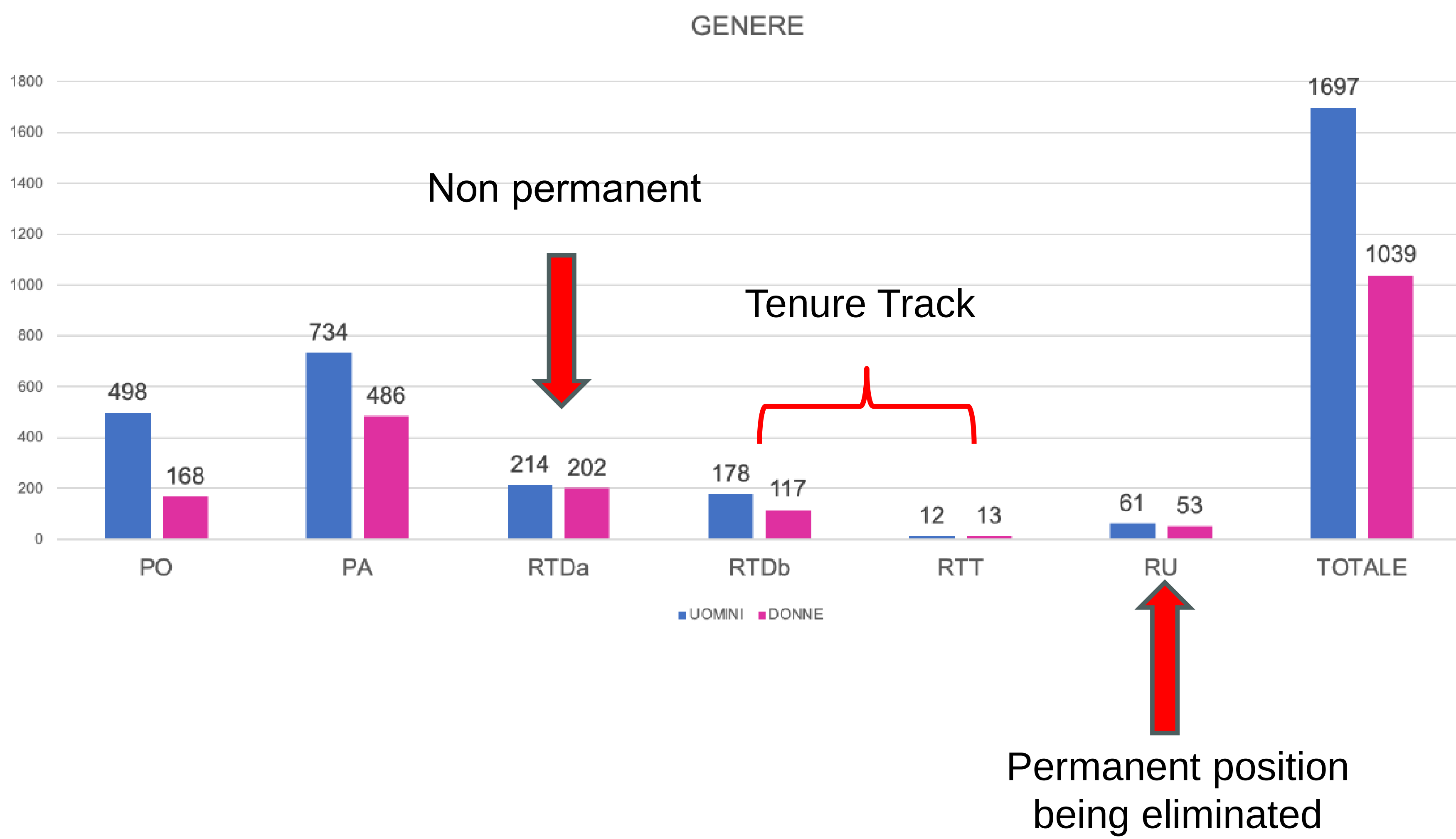
UNIVERSITÀ DEGLI STUDI DI PADOVA

L'ateneo in cifre
DOCENTI



Whoever has will be given more,
and they will have an abundance.
Whoever does not have,
even what they have will be taken from them

Matthew **13**, 12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117
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53
1697
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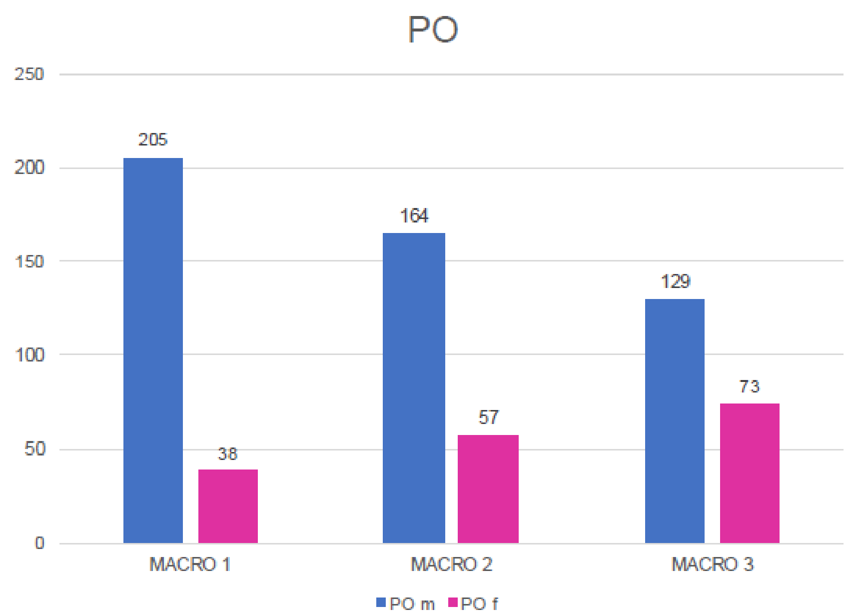
RTT
RU
TOTALE
UOMINI
DONNE
Non permanent
Tenure Track
Permanent position being eliminated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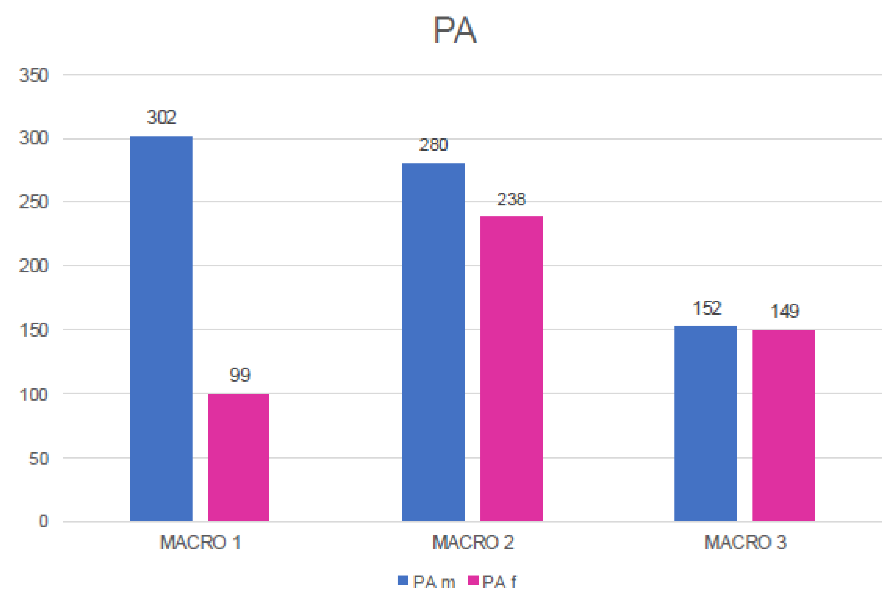
73
MACRO 1
MACRO 2
MACRO 3
PO m
PO f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99
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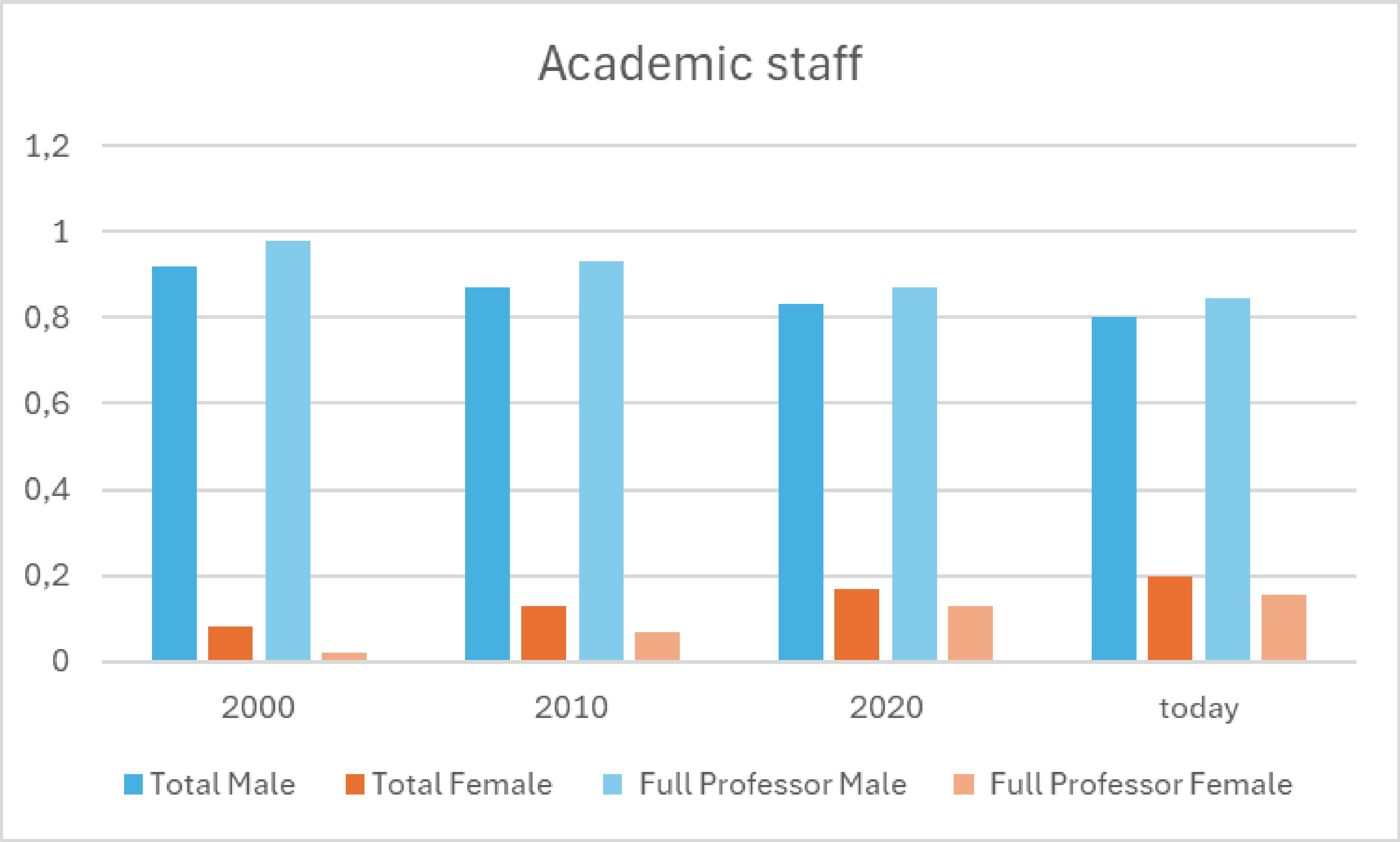
238
152
149
MACRO 1
MACRO 2
MACRO 3
PA m
PA f

PE LS SH

Department of Physics and Astronomy

78 Administrative and technical staff
99 Postdocs
150 Ph.D. students



Academic staff
1,2
1
0,8
0,6
0,4
0,2
0
2000
2010
2020
today
Total Male
Total Female
Full Professor Male
Full Professor Female


1222·2022
800
ANNI
UNIVERSITÀ
DEGLI STUDI
DI PADOVA
AVLA FEDERICO GVELLA
Contro la violenza
il diritto alla libertà,
il diritto di vivere senza paura

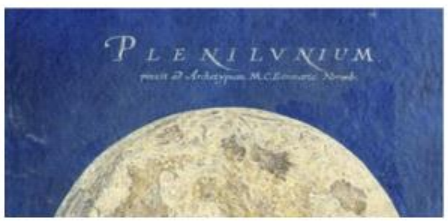
UNIVERSITÀ DEGLI STUDI DI PADOVA

Activities

Video project "International Day of Women and Girls in Science"

Le Sorelle del Cielo

di e con Grazia Dentoni e Simonetta Marcello



The sisters of heaven. Theatrical journey of narration, gesture and sound

The play offers a view on 20th century physics through the eyes of four female scientists who were its protagonists, including Prof. Milla Baldo Ceolin.

Diversity that makes science better
With Francesca Vidotto

Gewalt an Frauen

Dienstag, 21. November 2023

Immer mehr Details zum Mord an Giulia: Mit Klebeband zum Schweigen gebracht

Nur 50 Meter von ihrem Zuhause entfernt könnte Filippo Turetta zum ersten Mal mit dem Messer auf Giulia Cecchettin eingestochen haben: Die Carabinieri rekonstruieren anhand von Spuren den Angriff, der sich am 11. November gegen 23.30 Uhr im Industriegebiet von Fossò bei Venedig ereignet hat.

A+ A-

Università degli Studi di Padova

The Department of Physics and Astronomy has established the Inclusion and Diversity Commission, dedicated to fostering a climate of welcome, respect and appreciation of differences within our community, technical and administrative staff, the student population and teachers and researchers. The objectives are Research and monitoring, Training and Awareness.

1. **Questionnaire:** Identify current obstacles (gender, mobbing), conducting and making available an analysis of harassment/bullying to possibly identify areas of intervention to improve inclusion.

2. **Short sessions** during department council meetings to address issues of inclusion and diversity, improving awareness and understanding of the challenges and opportunities for a more equitable academic environment.

Università degli Studi di Padova

QUESTIONNAIRE COMPLETION PERCENTAGE

DFA/INAF/INFN	PARTECIPANTI	%*
STUDENTS	362	**15**
PHD	57	**41**
POST DOC	30	**30**
PROFESSORS	91	**79**
RTDA/RTDB	36	**78**
TECHNICAL AND ADMINISTRATIVE STAFF	78	**100**

UniPD online course "Equity and inclusion"

The online course "Equity and inclusion" is an initiative promoted by the Gender Equality Plan and is part of the equal training, culture and science interventions and, at the same time, intends to promote awareness of the different forms of harassment, violence and discrimination and knowledge of the services available in the University for those who suffer them.

Università degli Studi di Padova

November 25, 2024

QUESTIONI DI GENERE:
VIOLENZA E FEMMINICIDIO

UNO, NESSUNA, CENTOMILA

scheda approfondita [LINK]

LETTURA DUE ATTORI

TEMI AFFRONTATI

- La violenza come problema universale
- L'importanza di affrontare il tema della violenza
- L'importanza della sensibilizzazione continua
- Il ruolo delle donne nella lotta contro la violenza

SINOSSI

La lettura affronta il tema universale della violenza, esplorandone le diverse forme, alcune delle quali possono sembrare sottili o comiche, mentre altre generano rabbia e indignazione.

Tuttavia, l'opera promuove la **necessità di parlare apertamente della violenza**, sottolineando che il silenzio non è la soluzione e che solo attraverso il **dialogo aperto** possiamo sperare di provocare un cambiamento.

Nel suo potente epilogo, viene offerto un messaggio di speranza che evidenzia il **ruolo fondamentale delle donne nella lotta contro la violenza** e ci ricorda che questa discussione cruciale non deve essere limitata a occasioni specifiche, ma deve diventare una parte costante del nostro tessuto sociale.

Dai testi di Lella Costa, Franca Rame, Serena Dandini
Con Evarossella Biolo e Marco Artusi

Play: Uno, Nessuna, Centomila

Flash mob: TOYS? by Anna Piratti

MUSEO GIOVANNI POLENI

Science from the Islamic World to Today's Europe

A DFA and Giovanni Poleni Museum project

Science from the Islamic World to Today's Europe
Cross-Fertilisation between Past and Future

Proposed by the Department of Physics and Astronomy with the collaboration of various partners, the project is funded by the University of Padua. It aims at presenting to the public various aspects of the development of science from the Islamic contributions up to cutting-edge physics and astronomy, shedding light on the exchanges and cross-fertilisation between various countries and cultures.

Inclusion and the active participation of the local community are two of the main features of the project, which is actually based on the co-creation of knowledge by the public. In this sense, mixed working groups will be formed, composed of members of the local Islamic communities and other foreign communities, and PhD students from the University of Padua; these groups will work in synergy, in a continuous exchange of ideas and knowledge, using the rich collection of scientific instruments of the Giovanni Poleni Museum. For the PhD students, the participation in the project is part of a Soft Skills PhD course. The working groups will have several training meetings, from October 2022 to March 2023. Each group will then develop a new science communication project, which will be presented to the public in Padua in April-May 2023.


Panasoni
4clima.com
BEDESCHI
GHOSTS
PADOVA

The Abdus Salam International Centre for Theoretical Physics

Dipartimento di Fisica e Astronomia Galileo Galilei

United Nations Educational, Scientific and Cultural Organization

ICTP - East African Institute for Fundamental Research under the auspices of UNESCO

University of Rwanda

International Union of Pure and Applied Physics

Stellenbosch University Iyunivesithi Universiteit

Donostia International Physics Center

StatPhys in Kigali

July 5-6 (School on complex systems/Organized Tour)
July 7-10 (Workshop), 2025

Kigali, College of Sciences and Technology, University of Rwanda

Satellite meeting of

THANK YOU FOR YOUR ATTENTION…