SENSOR WEB:
NEW CHALLENGES FOR COMPLEX SYSTEMS PHYSICS AT THE NANOSCALES *in particular noise challenges *

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NEW CHALLENGES in Complex System Physics:

Disaster forecasting,crisis modelling and sustainable development

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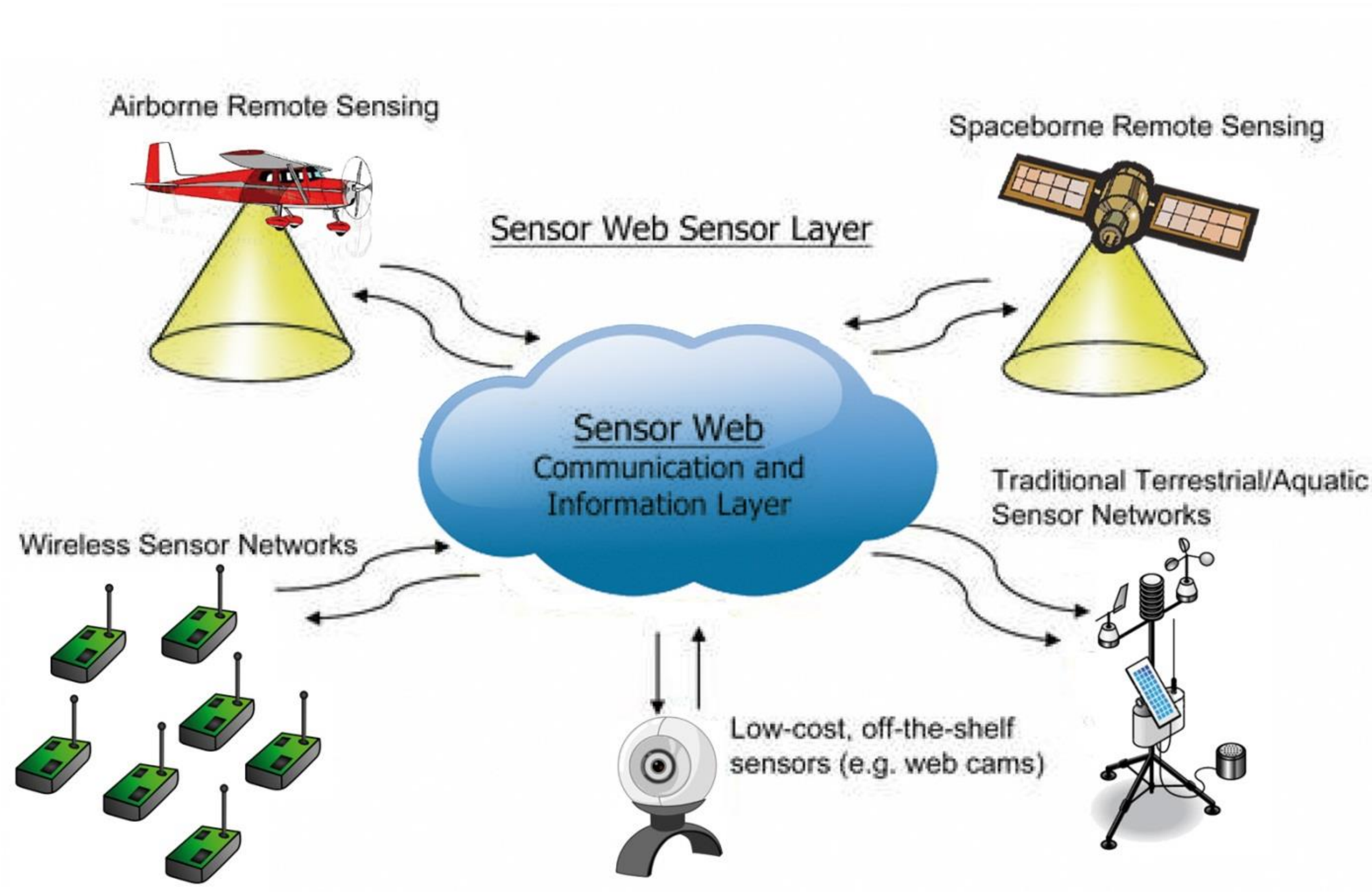
Sensor Web

A Sensor Web contains a group of distributed and heterogeneous sensors interconnected by a communication center (internet) and sharing data and information through interoperable inter-faces. Users are able to access and control the sensors via World Wide Web (WWW).

Sensor Web



Airborne Remote Sensing
Spaceborne Remote Sensing
Sensor Web Sensor Layer
Sensor Web
Communication and
Information Layer
Traditional Terrestrial/Aquatic
Sensor Networks
Wireless Sensor Networks
Low-cost, off-the-shelf
sensors (e.g. web cams)

Sensor Web

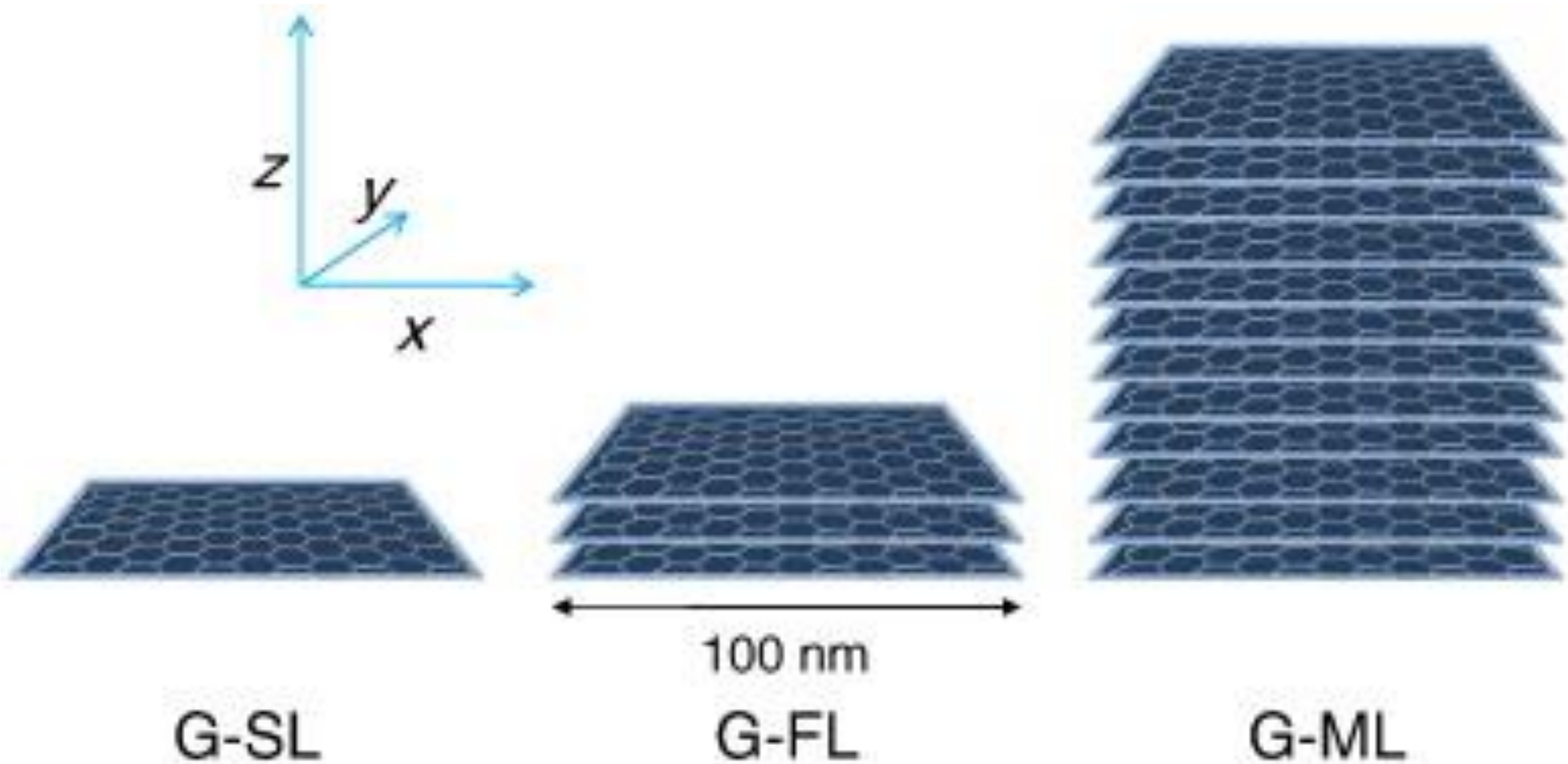
The sensor web is a fast developing technology , relying on:

1. Fast, cheap, reliable, responsive and sensitive (i.e. high signal-to-noise ratio) sensors temperature, pressure).
2. Information theoretical approaches able to extract information from noisy data sequence (e.g. Shannon measures)

Understanding noise is a central issue for the development of any new technology underlying the Sensor Web.

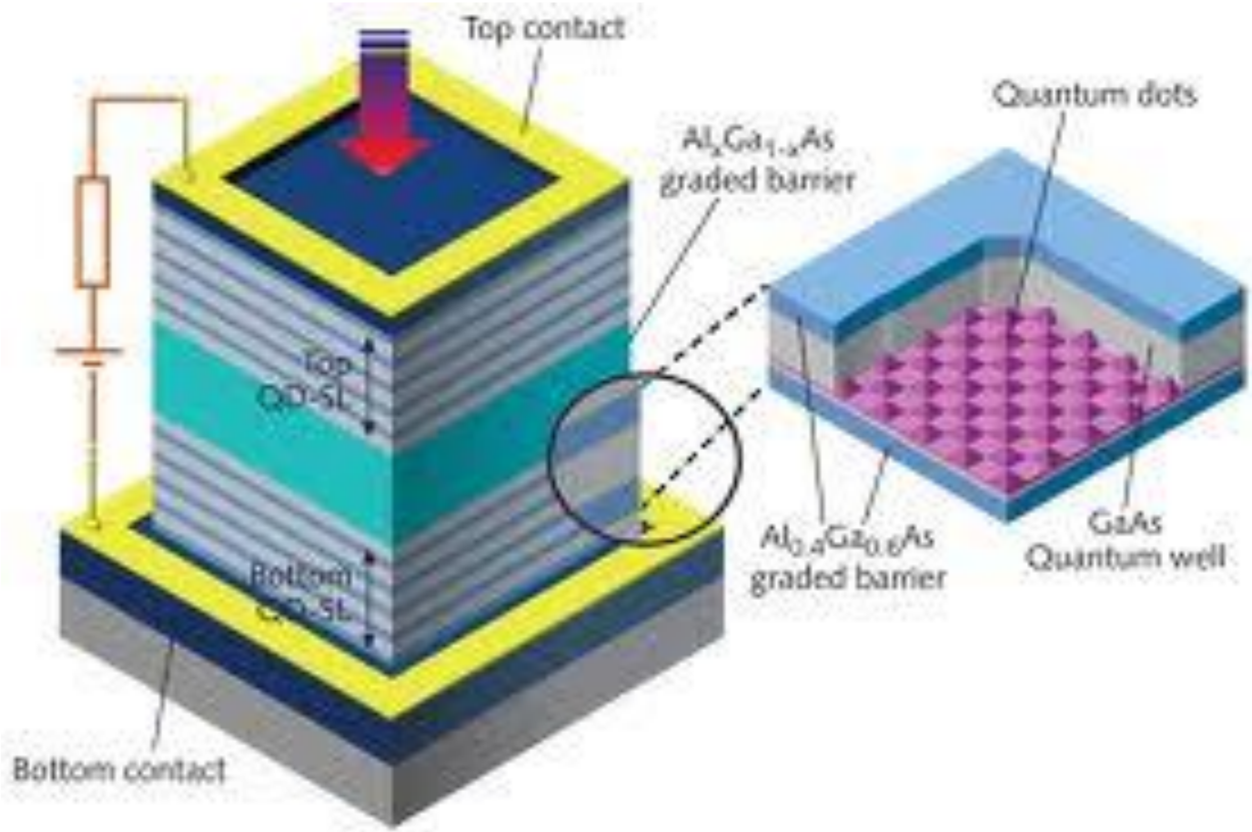
Additionally, it represents a tool for early detection of deviations from the correct operation conditions ('disaster prediction') .

Graphene layered structures



SINGLE LAYER FEW LAYERS MULTI LAYERS

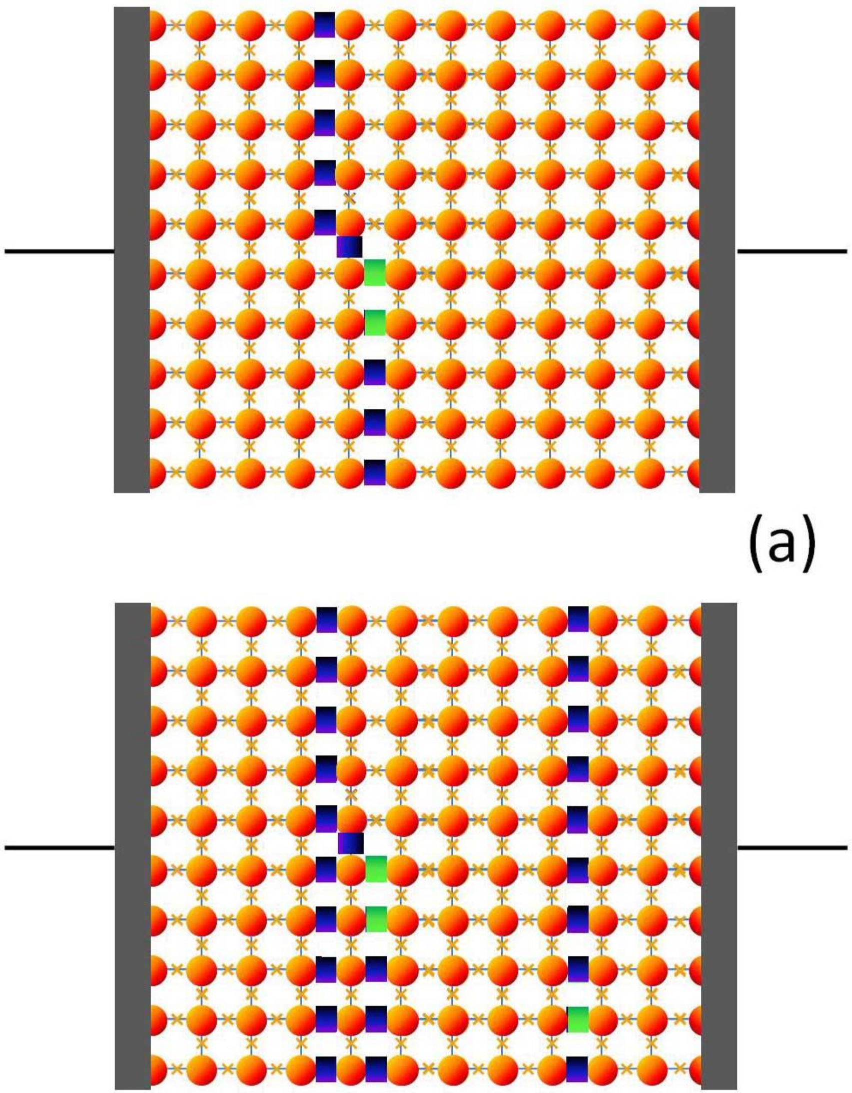
Quantum Well/Dots Layered Structures



Large arrays of QW/QD structures are the basic unit for airborne/satellite infrared observations (for example earth observations, global warming monitoring, …)

Josephson Junction Arrays (weak-links)

- Temperature increases
- Layers are formed when a JJ weak-link achieves the resistive state (intermediate, green, first, and, then, normal green)
- Grains (network nodes) remain in the superconductive state (orange)

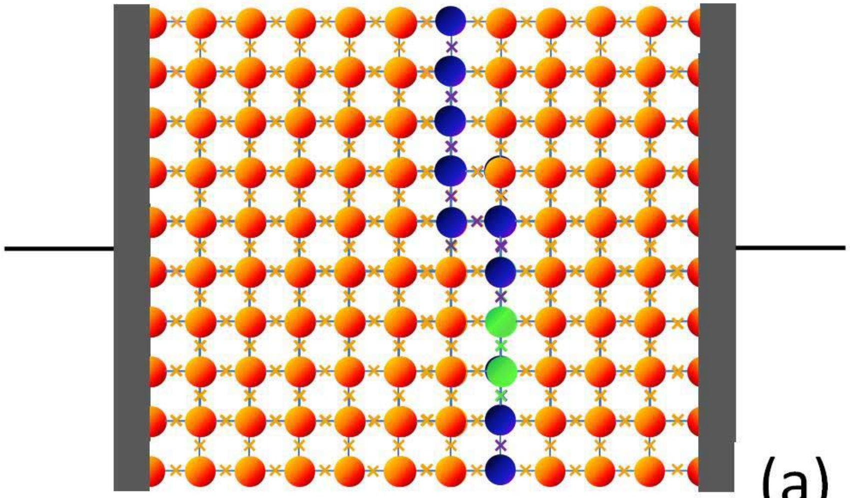


(a)

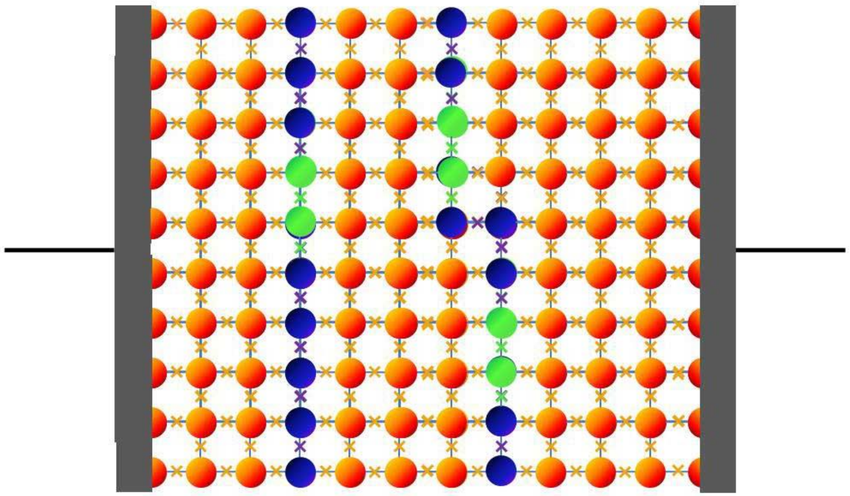
(b)

Josephson Junction Arrays (strong-links)

- Temperature increases
- Layers are formed when each grain achieves the resistive state (intermediate, green, first, and, then, normal green)

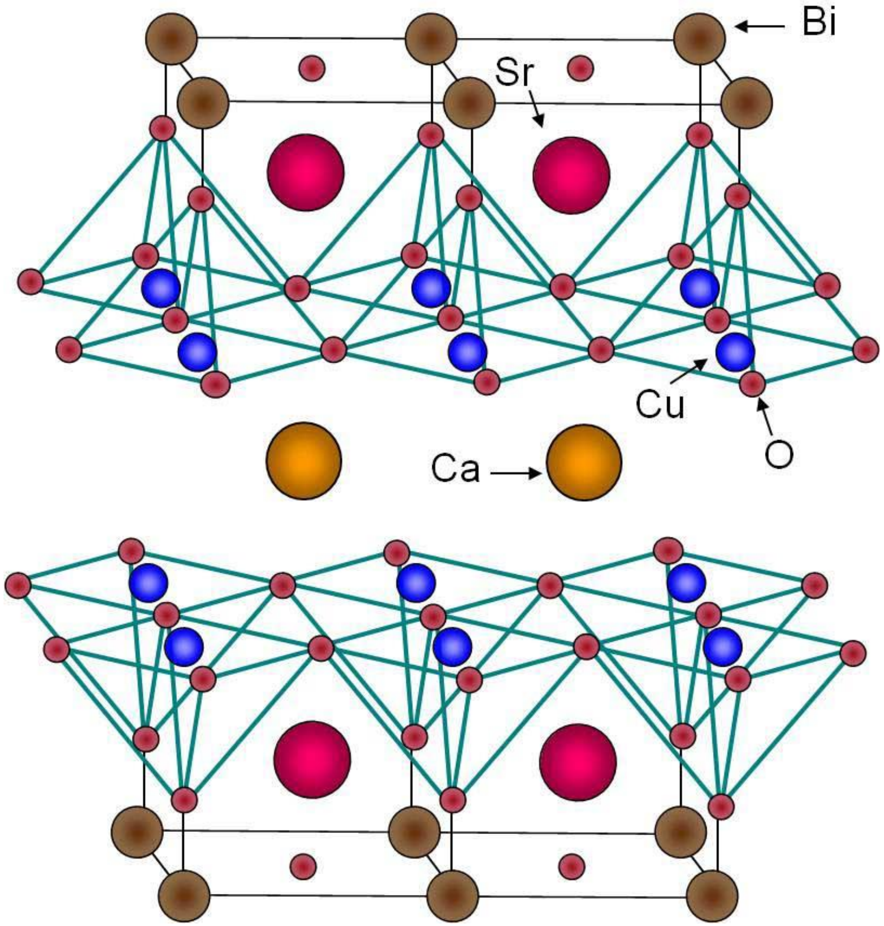


(a)



(b)

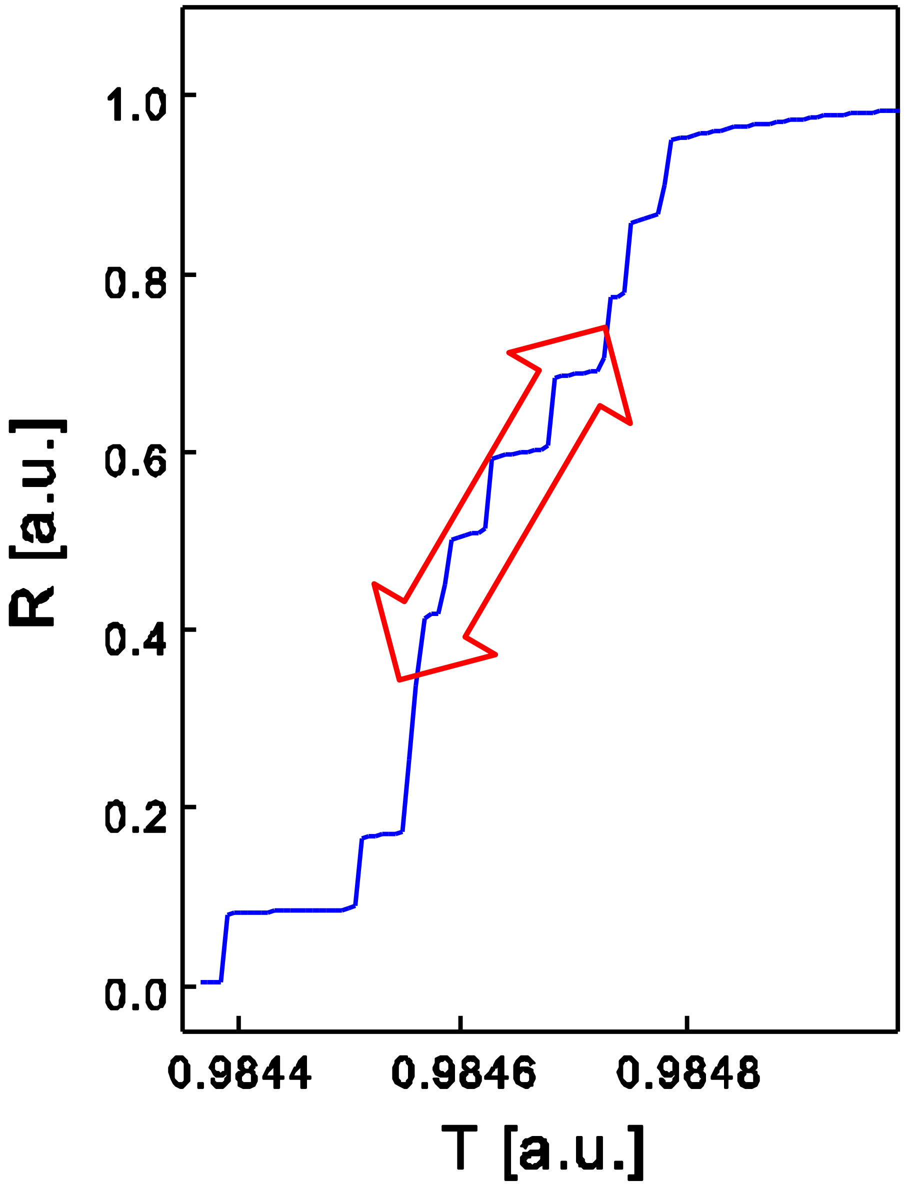
High Tc Superconductors



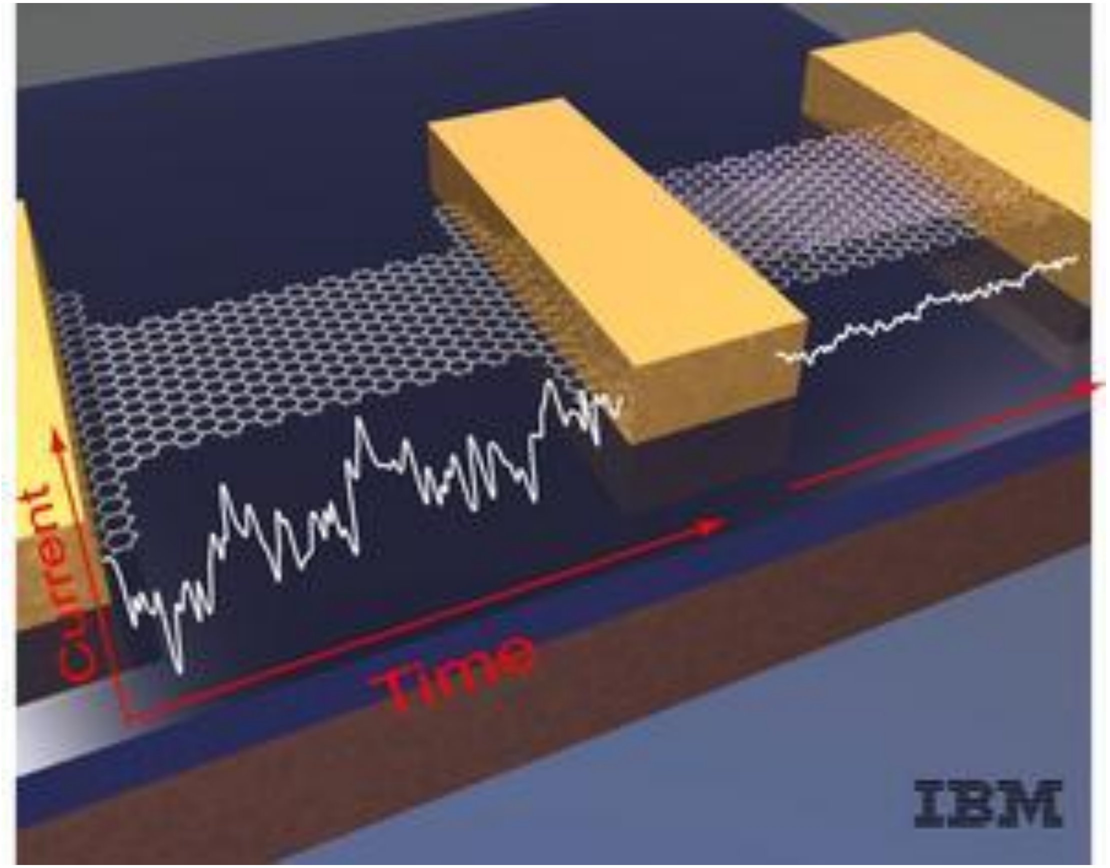
Cuprate superconductors have a layered structure with the superconductivity taking place mostly at the Cu_2O planes.

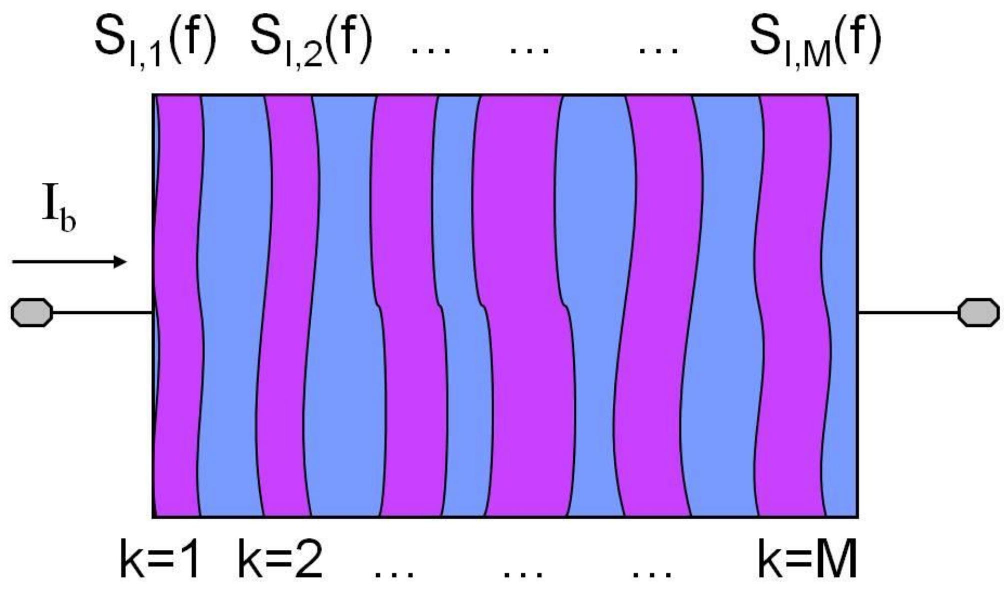
The other layers act as charge reservoir.

Transition Edge Sensors



What about noise in a layered structure?





$$V = \left(R_1 + R_2 + \ldots R_M\right) I$$

$$\Delta V = \left(\Delta R_1 + \Delta R_2 + \ldots \Delta R_M\right) I$$

$$\Delta V^2 = \left(\Delta R_1^2 + \Delta R_2^2 + \ldots \Delta R_M^2\right) I$$

$$\Delta V^2 = M \cdot \Delta R^2 \cdot I$$

How to model the nonuniformity of the charge distribution across the layers ?

$$\frac{dn}{dt} = \beta n_{\omega} - Rn^2$$

First of all , let us consider the quasiparticle continuity equation, which describes the generation of two quasiparticles upon breaking a Cooper pair by a thermal phonon and their annihilation, when they form a Cooper pair and emit a phonon..

$$\frac{dn_{\omega}}{dt} = \frac{Rn^2}{2} - \frac{\beta n_{\omega}}{2} - \gamma_{es}\left(n_{\omega} - n_{\omega,o}\right)$$

A. Rothwarf and B.N. Taylor, Phys. Rev. Lett. **19**, 27 (1967).

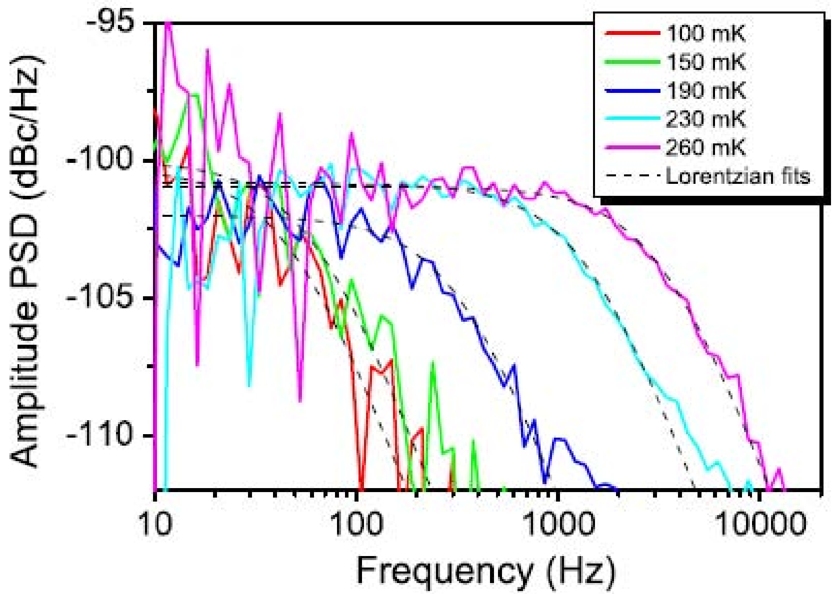
Quasiparticles generation/recombination fluctuations

$$\frac{d\Delta n}{dt} = \frac{2\Delta n}{\tau_r} + \beta \Delta n_\omega + \partial(t)$$

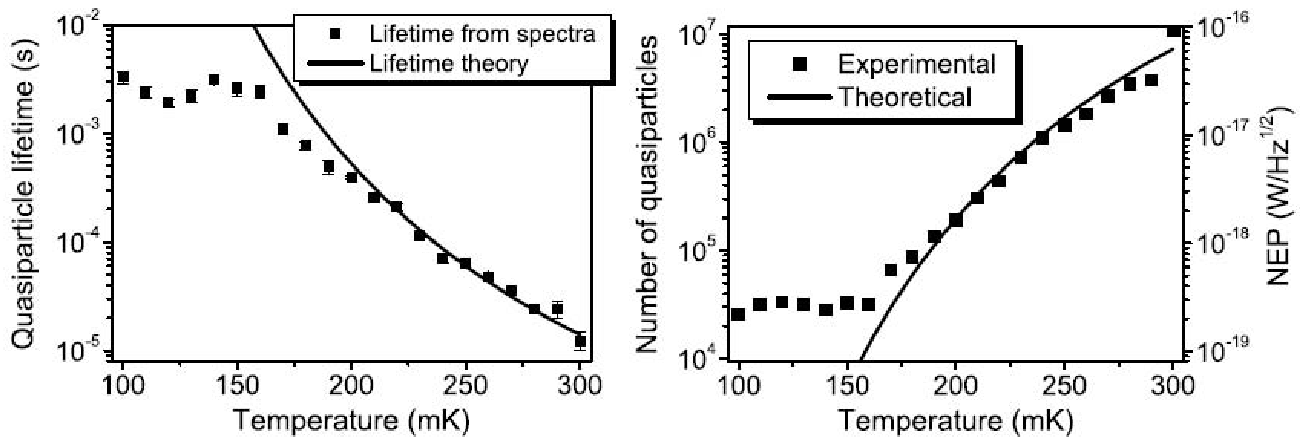
negligible

$$S_n(\omega) = 4\left\langle \Delta n^2 \right\rangle \frac{\tau_r}{1+\omega^2 \tau_r^2}$$

Quasi particles fluctuations in low Tc superconductors



Aluminium



P.J. de Visser, J.J.A. Baselmans, P. Diener, S.J.C. Yates, A. Endo, T.M. Klapwijk, Phys. Rev. Lett. **106**, 167004 (2011)

Quasiparticles fluctuations in high Tc superconductors !

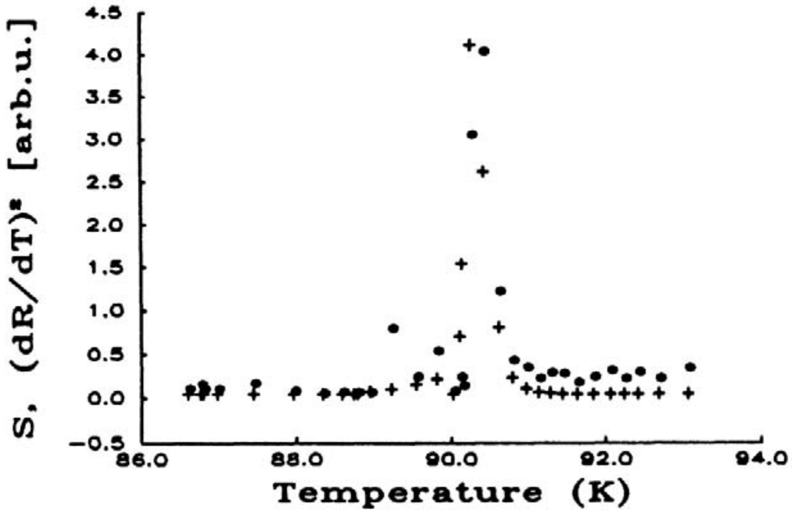


FIG. 1. Excess noise power at 6 Hz (●) and square of the resistance derivative (+) near T_c in $Y_1Ba_2Cu_3O_{7-\delta}$, plotted with arbitrary units.

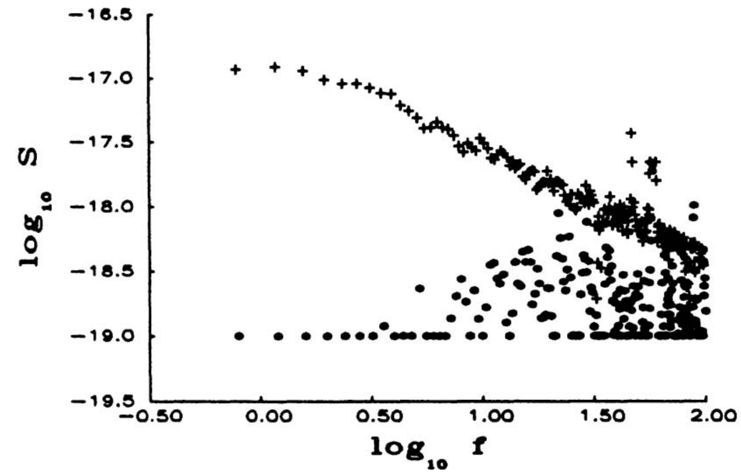


FIG. 2. Noise-power spectra of $Er_1Ba_2Cu_3O_{7-\delta}$ in the superconducting (●) and normal (+) states. These spectra were measured at 83.5 and 148.7 K, respectively. −19 is the max-

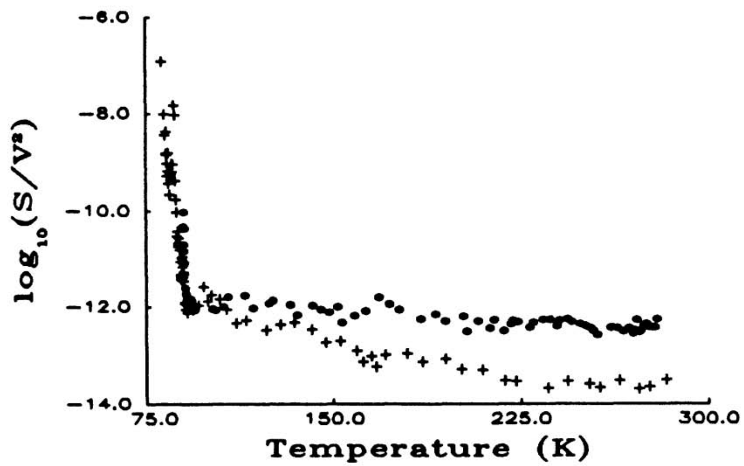
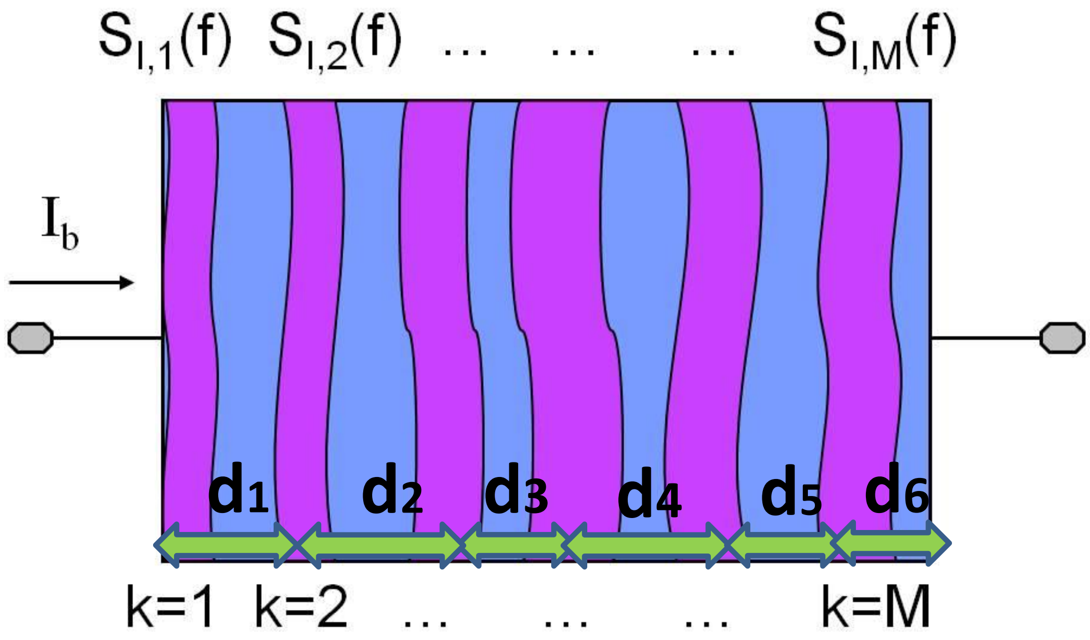


FIG. 3. Typical temperature dependence of the normalized noise spectra S/V^2 at 6 Hz in $Y_1Ba_2Cu_3O_{7-\delta}$ (●) and $Er_1Ba_2Cu_3O_{7-\delta}$ (+).

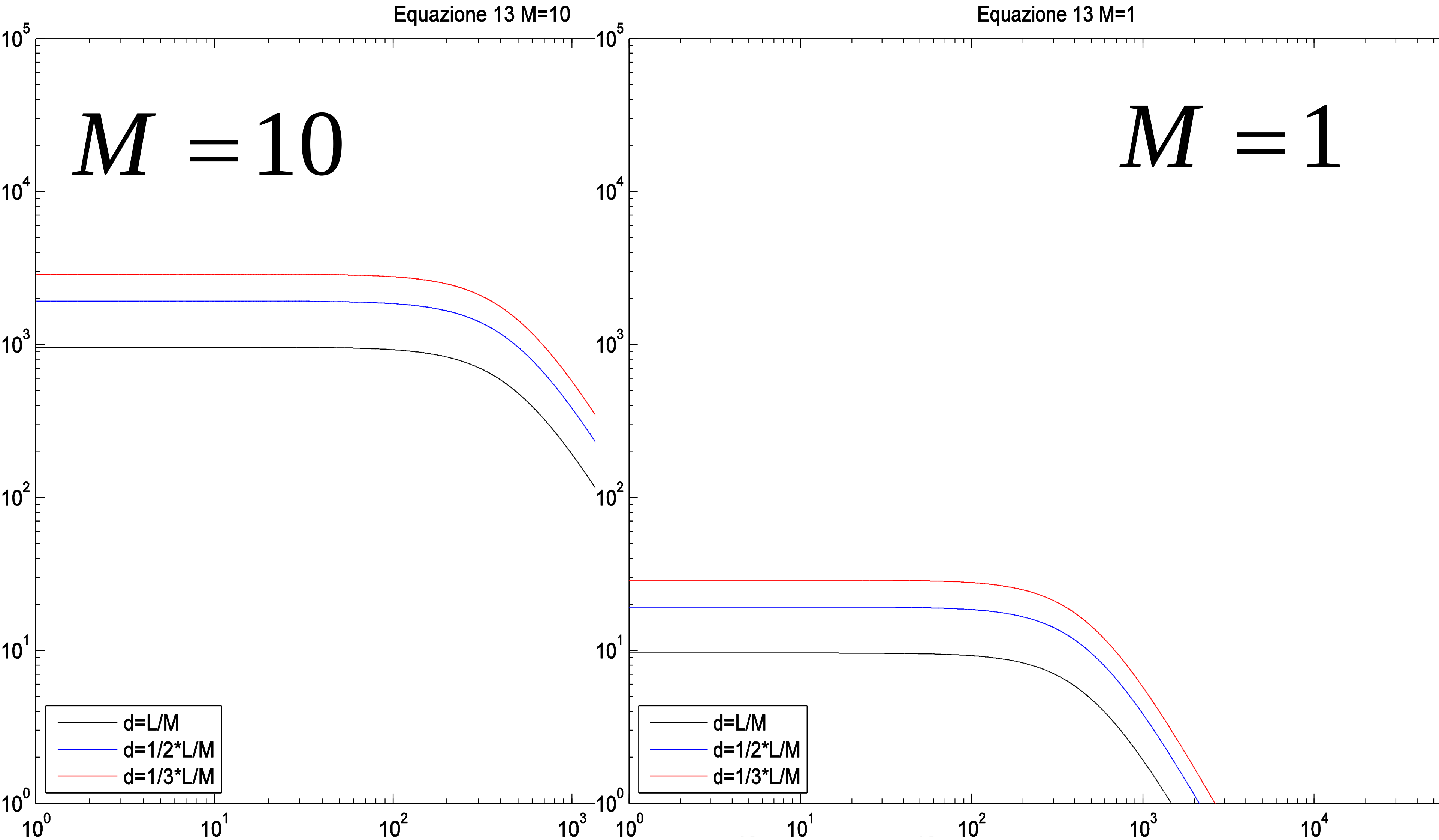


$$\frac{\partial \Delta n}{\partial t} + v_t \frac{\partial \Delta n}{\partial x} = -\frac{\Delta n}{\tau_r} + \partial(t)\partial(x - x')$$

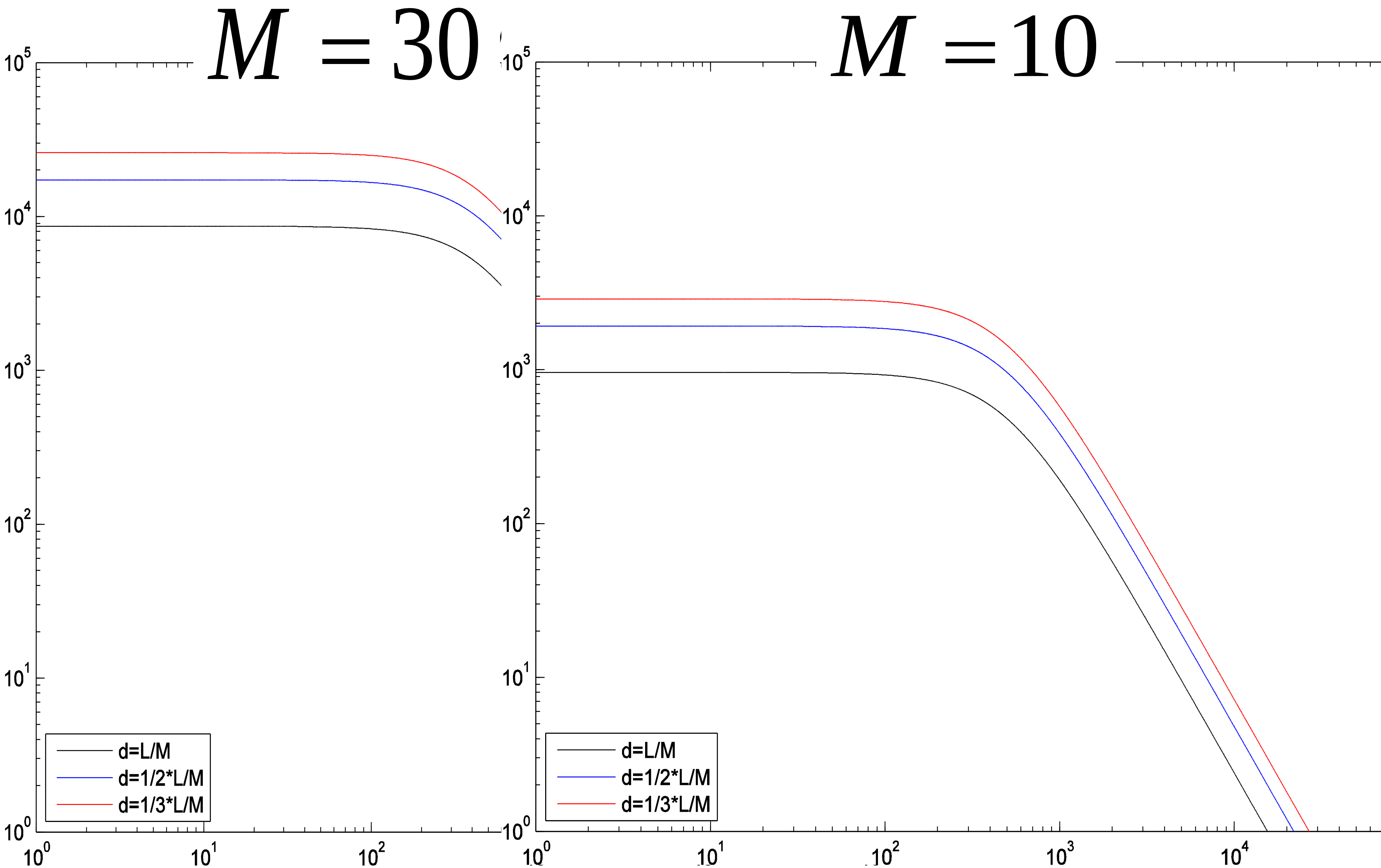
In order to account for the discreteness of the generation-recombination sources (i.e. to take into consideration that the g-r processes are localized in a few layers) the ***x'*** variable is taken as discrete.
In particular, one can write that ***x'* varies from d to Md**, with **d** being the distance between the layers nad the sum is performed over **k ranging from d to Md**

$$S_n(\omega) = \frac{4\left\langle \Delta n^2 \right\rangle}{L} Re\left\{ -\frac{1}{\beta} \cdot \exp\left(-\beta L\right) \cdot \left(\frac{1-\exp\left(-\beta d\right)^{M+1}}{1-\exp\left(-\beta d\right)} \right) + \frac{M}{\beta} \right\}$$

$$\frac{1}{\beta} = \frac{\tau_r}{1+j\omega\tau_r}$$



Equazione 13 M=10
Equazione 13 M=1
$M = 10$
$M = 1$
d=L/M
d=1/2*L/M
d=1/3*L/M
d=L/M
d=1/2*L/M
d=1/3*L/M
10^0
10^1
10^2
10^3
10^4
10^5



$M = 30$
$M = 10$
d=L/M
d=1/2*L/M
d=1/3*L/M
d=L/M
d=1/2*L/M
d=1/3*L/M

Conclusions

A generation/recombination noise model has been put forward for multilayered systems, where the generation/recombination processes occur at separate discrete layers.

The model has been applied to model quasiparticle fluctuations by using a continuity equation modified to consider the discreteness of the recombination centers .

The approach is general and can be deployed for different layered systems with transport processes occurring via sources and sinks of carriers.

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Thanks for your attention!