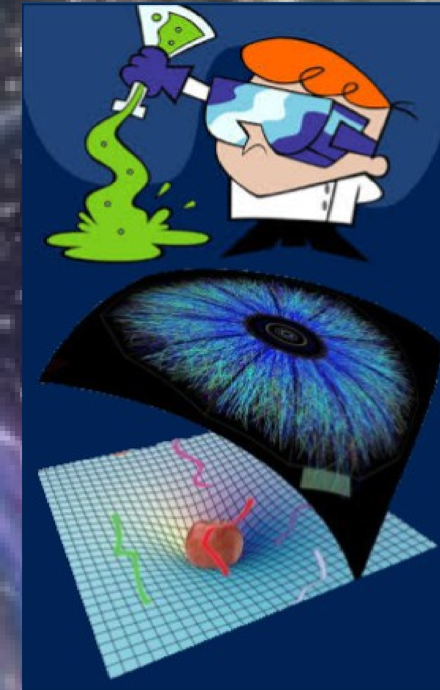
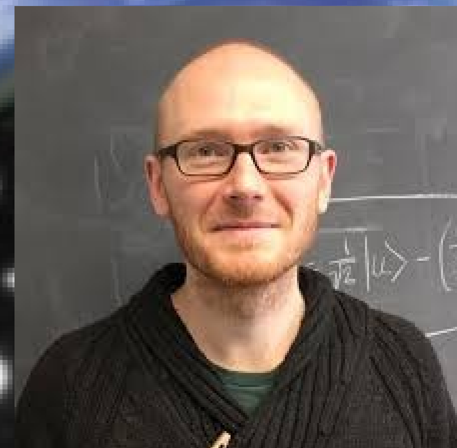


Discussion about applications of holography

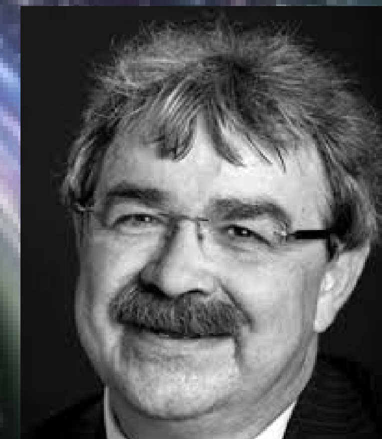
Matteo Baggioli (HoloTube Creator)

Our panelists

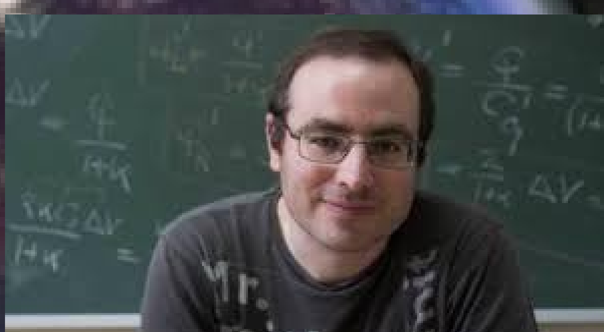
Koenraad Schalm
(Leiden)



Blaise Gouteraux
(Paris)



Jan Zaanen
(Leiden)



Carlos Hoyos
(Oviedo)

Saso Grozdanov
(MIT)

Luca Delacretaz
(Chicago)

BOUNDS AND UNIVERSALITY

CONDENSED MATTER

HYDRODYNAMICS AND BEYOND

- If you want to intervene live during the panel use the <u>raise hand button</u> please

- At the end of every theme, each participant can ask a question or make a comment

Write your question in the Chat and I will make It for you

Unmute yourself and speak up

(only if we dont see you)

STUDENTS SPEAK UP !

THE MAN WHO ASKS
A QUESTION IS A FOOL
FOR A MINUTE.

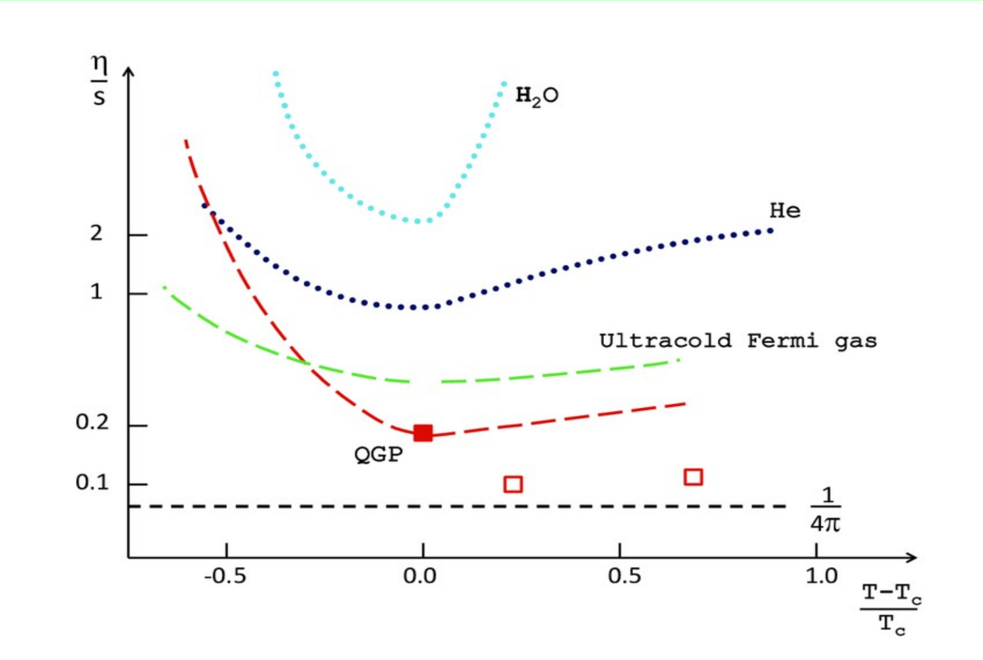
THE MAN WHO
DOES NOT ASK, IS
A FOOL FOR LIFE.

CONFUCIUS

Theme 1

Universality, scalings and bounds

UNIVERSALITY AND BOUNDS



Plenty of violations:

1) breaking translations
2) breaking isotropy
3) magnetic field
4) SYK
5) viscoelastic fermi liquids
6) ….

1) Is it the correct quantity to bound ? Can experiments detect the violations and what they are actually measuring (momentum diffusion ?)

2) Generalizations ? Similar bounds (sound speed, entropy production, ...) ?

3) What is the meaning of those violations (faster than Planckian ?) ?

$$D \geq v^2 \tau$$

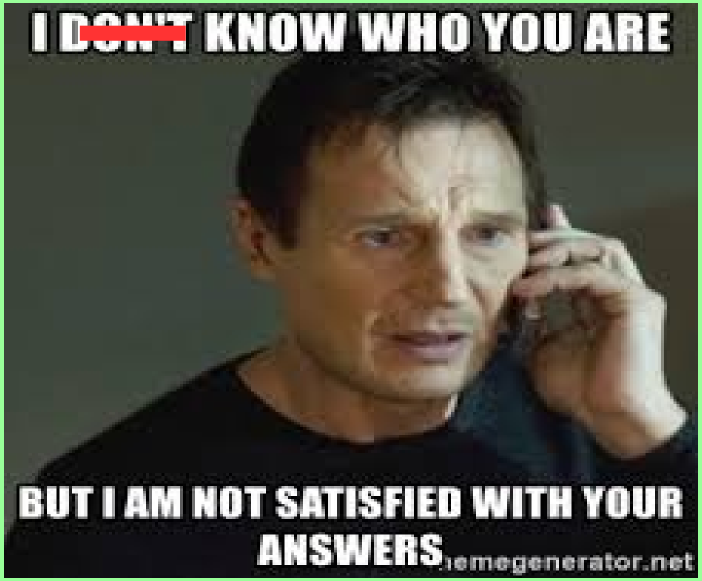
IS THIS BETTER?

1) Who is <u>v</u> ? Mike told us is v_B (and it works) but why ?
What about v= v_sound ?

2) How to put that together with: $D \leq v^2_{\text{lightcone}} \tau_{eq}$

3) Does it work only for energy diffusion and why?
Does it need an incoherent regime or not?

4) Where does the bound come from actually?
Can we "prove it" ?



τ_{pl} the Planckian time

1) Are we satisfied with its definition using the uncertainty principle ?

2) Why does it appear at large temperature where the physics is classic ? And is it linked to other bounds (e.g. speed of sound) ?

arXiv:2001.03805 [pdf, other] cond-mat.str-el hep-th doi 10.1073/pnas.1910131116

Thermalization and Possible Signatures of Quantum Chaos in Complex Crystalline Materials

Authors: Jiecheng Zhang, Erik D. Kountz, Kamran Behnia, Aharon Kapitulnik

arXiv:1905.03551 [pdf, other] cond-mat.mtrl-sci cond-mat.stat-mech doi 10.1088/1361-648X/ab2db6

A lower bound to the thermal diffusivity of insulators

Authors: Kamran Behnia, Aharon Kapitulnik

arXiv:1908.04792 [pdf, other] cond-mat.mtrl-sci cond-mat.stat-mech

On the Planckian bound for heat diffusion in insulators

Authors: Connie H. Mousatov, Sean A. Hartnoll

ASK A QUESTION

MAKE A COMMENT

RAISE A DOUBT

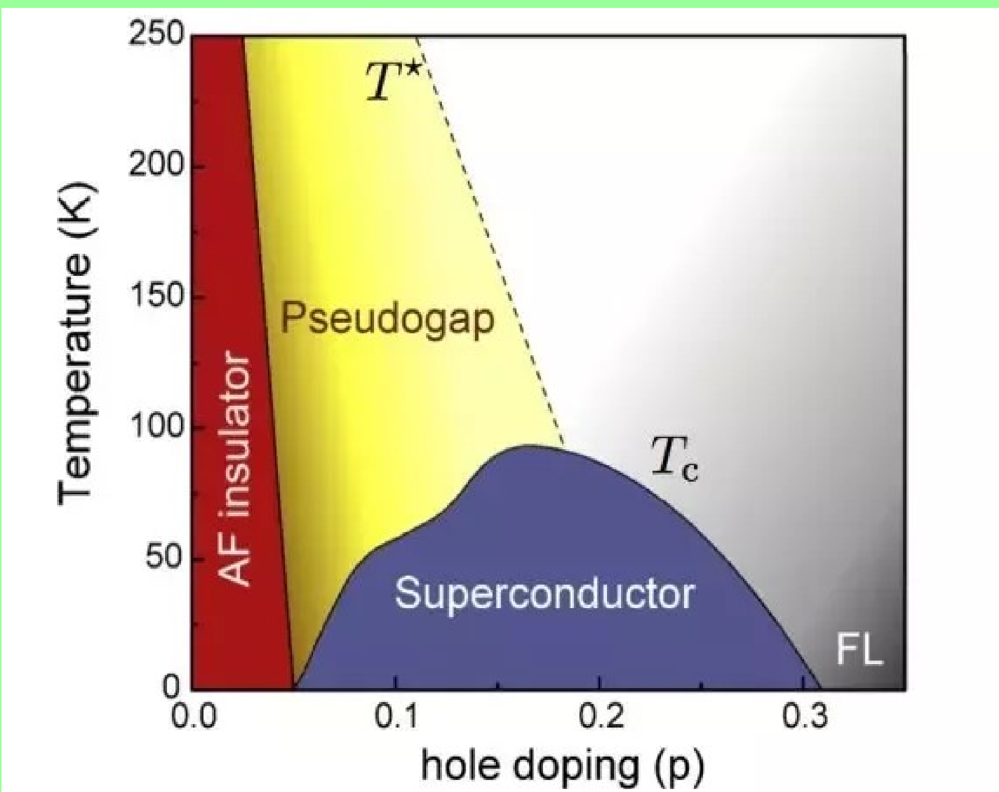
MAKE US THINK

Don't be Shy.

Theme 2

Applications to

- Condensed Matter (**cond-mat** new, recent, search)



a.k.a. we put this picture in every talk but what did we learn about it from holography ?

physicsworld

Magazine | Late

everyday science

EVERYDAY SCIENCE | BLOG

What do strange metals and black holes have in common?

23 Jun 2015 Hamish Johnston

Physics Today **65**, 6, 68 (2012); https://doi.org/10.1063/PT.3.1616

quick study

From black holes to strange metals

Hong Liu

String theory relates gravity to the physics of a novel phase of matter observed above the superconducting transition temperature.

Hong Liu is an associate professor of physics at the Massachusetts Institute of Technology in Cambridge.

Ever since the end of the Stone Age, metals have fascinated humankind and have been vital in the development of civilization. More recently, physicists have been fascinated by a new class of "strange" metals, discovered two decades ago, whose exotic properties challenge fundamental notions of

tures than ordinary metals—as high as 165 K. Theorists have proposed many ingenious ways to understand the physical origin of superconductivity in cuprates and their high transition temperatures, but no consensus has been reached and many mysteries remain.

One of the most significant mysteries is the nature of a phase just above the transition temperature. It has thermodynamic and transport properties significantly different from those of an ordinary metal, prompting the name "strange metal" (see panel a of the figure). Strange metals conduct electricity and heat, as ordinary metals do, but photoemission experiments fail to reveal any particle-like excitations. Electronic interactions in the strange metal are so strong that if you add an electron to the system, it will be devoured before it can propagate far enough to show its particle-like properties. In other words, the electrons that make up a strange metal appear to lose their individuality

Quanta magazine

Physics | Mathematics | Biology | Computer Science | All Articles

Natalie Wolchover

Senior Writer/Editor

July 1, 2013

STRING THEORY

Signs of a Stranger, Deeper Side to Nature's Building Blocks

New findings suggest that beneath the surface of quantum theory lies a vibrant string theory world where some matter corresponds to black holes in higher dimensions.

Home / Physics / General Physics

MARCH 2, 2011

Black holes: a model for superconductors?

by University of Illinois College of Engineering

Home / Physics / Superconductivity

Home / Physics / Quantum Physics

AUGUST 26, 2019 FEATURE

New theory draws connections between Planckian metals and black holes

by Ingrid Fadelli , Phys.org

STRANGE METALS

$$R \sim T \text{ and } \cot \Theta_H \sim T^2$$

→ arXiv:1406.1659 [pdf, other] hep-th cond-mat.str-el doi

Quantum Critical Transport and the Hall Angle

Authors: Mike Blake, Aristomenis Donos

Nice idea of the two scales (à la Anderson) by Aristos and Mike but never realized ...

→ arXiv:1812.01040 [pdf, other] hep-th cond-mat.str-el gr-qc doi 10.1103/Phys

Anomalous scalings of the cuprate strange metals from nonlinear electrodynamics

Authors: Sera Cremonini, Anthony Hoover, Li Li, Steven Waskie

Only model working that I know (and only probe limit...)

1) We dont have a single satisfactory model able to reproduce the scalings of strange metals ! (do we?)

2) Is just showing linear in T enough ? And is it really Holography the only way to get it ?

3) Did holography really help for strange metals scalings and how / where?

4) Holographic superconductors... and then what ?

5) What is the next step ?

Most promising ideas *(my opinion)*

Strong Momentum dissipation →

arXiv:1405.3651 [pdf, other] cond-mat.str-el hep-th doi

Theory of universal incoherent metallic transport

Authors: Sean A. Hartnoll

Weak Momentum dissipation →

arXiv:1612.04381 [pdf, other] cond-mat.str-el hep-th doi 10.21468/SciPost

Bad Metals from Fluctuating Density Waves

Authors: Luca V. Delacrétaz, Blaise Goutéraux, Sean A. Hartnoll, Anna Karlsson

Contact with the Lab ! →

arXiv:1909.07991 [pdf, other] cond-mat.str-el hep-th

A hydrodynamical description for magneto-transport in the strange metal phase of cuprates

Authors: Andrea Amoretti, Martina Meinero, Daniel K. Brattan, Federico Caglieris, Enrico Giannini, Marco Affronte, Christian Hess, Bernd Buechner, Nicodemo Magnoli, Marina Putti

1) Diffusion bound in the charge sector can be violated, so can it be the responsible of linear in T (à la Hartnoll) ?

2) The pinning proposal is interesting but how natural/finetuned is it? What is the key ingredient ? (phase relaxation ?)

(Planckian again : w_peak = T, what about holography ?)

3) What is the status of the hydro/strange metals connection ?

1) Are the homogeneous lattices useful ?
And for what ?

2) What is the difference between hardcore numerical lattices and the homogeneous ones (commensurability?)? Which are the limits of the two?

3) What is the role/meaning of the global symmetries if any? And what is the mysterious phase relaxation?

4) Are the homogeneous lattices problematic ?
Instability/meta-stability ?
(I dont know a single model with SSB which is stable both thermodynamically and dynamically)

ASK A QUESTION

MAKE A COMMENT

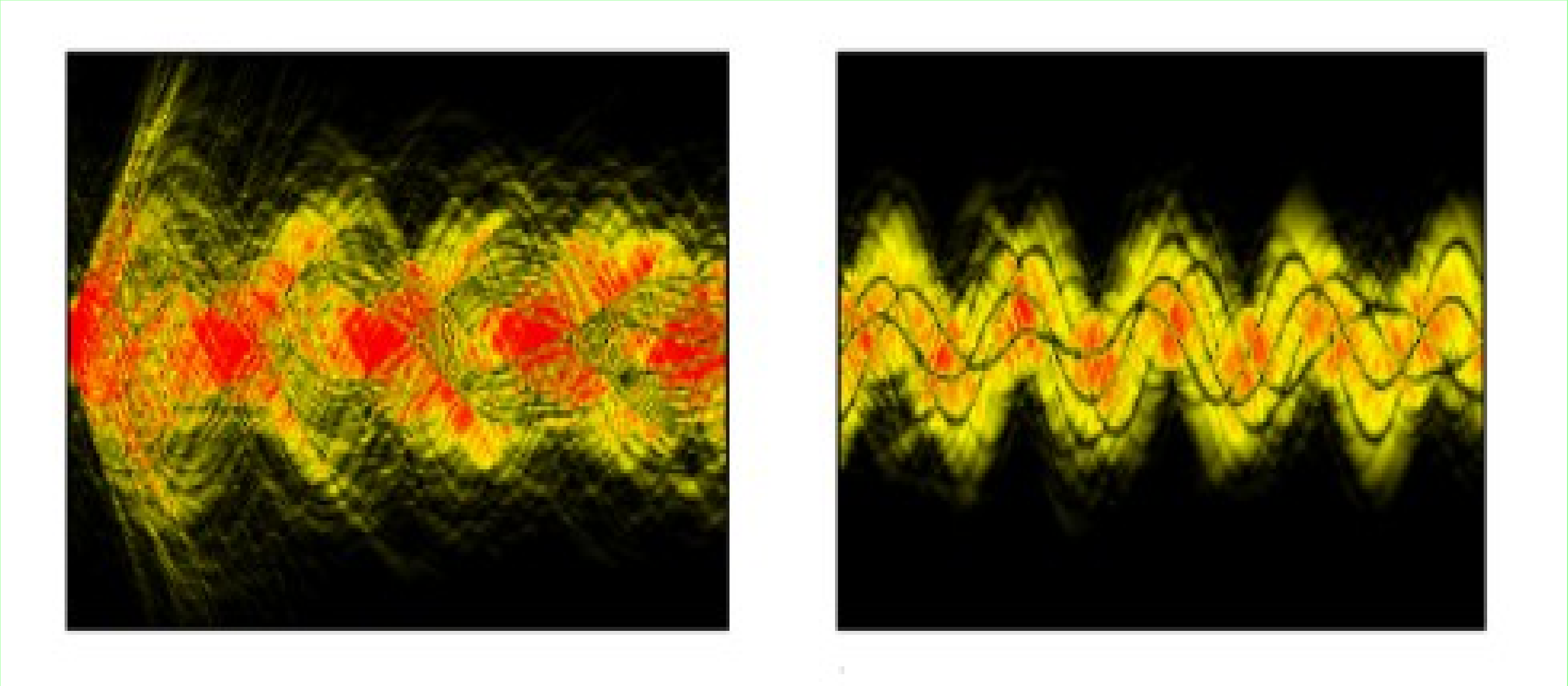
RAISE A DOUBT

MAKE US THINK

Don't be Shy.

Theme 3

Hydrodynamics, Chaos and Out-of-equilibrium physics



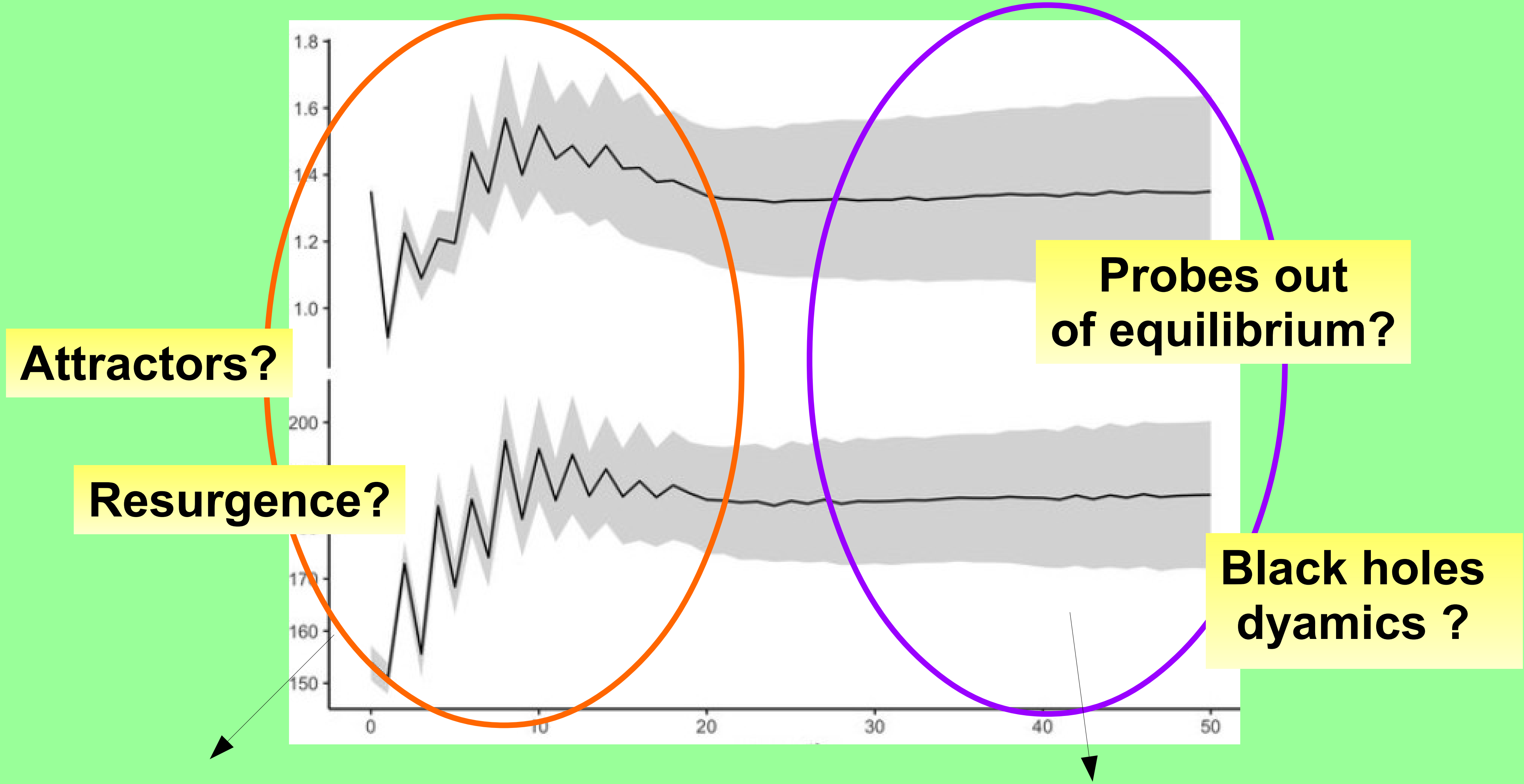
HYDRO and CHAOS (it is really a chaos)

1) Why we can get "quantum chaos" with hydro ?
   Clash of time scales! Chaos (early time) vs hydro (late time) !
   Is that really quantum chaos (cf. level statistics etc)?

2) Is there anything in electron hydrodynamics which is theoretically fundamental ? (the theory was from the 60's)
   Is it just an experimental and materials science development or is there anything new? How holography can help?

3) Pole skipping is widely observed but what is the meaning of those points ? Why is it so general ?

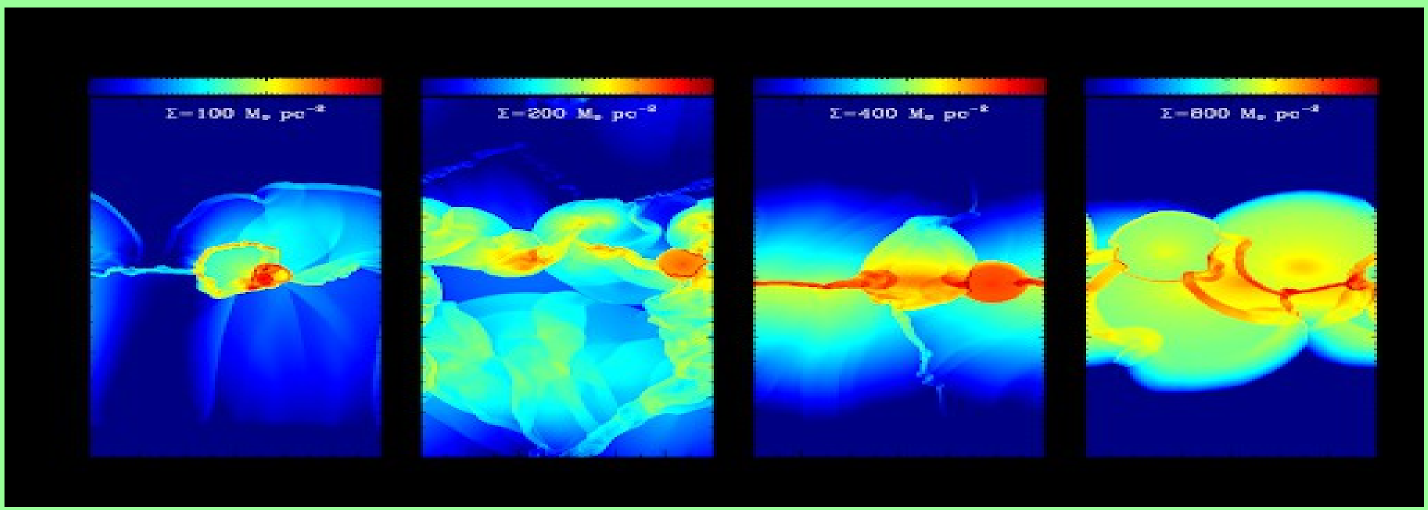
OUT OF EQUILIBRIUM
MY (biased) SUMMARY



I am super power with the numerics,
Fancy plots but …. i dont understand anything

Late time goes like the QNMs...
Didnt I know it already ?

1) What do we learn from these out-of-equilibrium setups?
(the only thing I hear every time is that the relaxation time is very fast...)



2) Anything interesting/universal before late times ?

3) Can we understand why it is “too” fast
(people even say instantaneous) ?

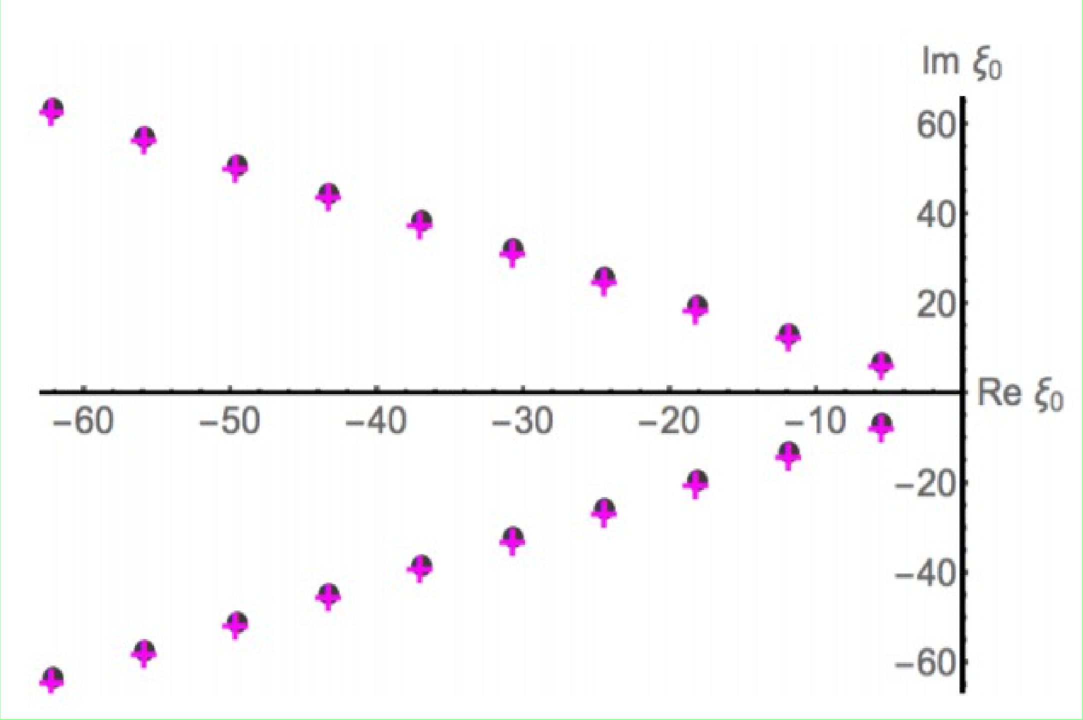
HYDRODYNAMICS

1) Standard answer: "asymptotic series with zero radius of convergence"

VS

Saso-Pavel-Andrei-Petar "you need to use some complex analysis"

2) Resummation of hydro: we resum it and we can obtain all higher QNMs and even instabilities etc...
What does that mean? Does hydro know too much ?



BEYOND HYDRODYNAMICS

1) Holography for open quantum systems ?

arXiv:2004.02888 [pdf, other] hep-th cond-mat.stat-mech gr-qc quant-ph

Open quantum systems and Schwinger-Keldysh holograms

Authors: Chandan Jana, R. Loganayagam, Mukund Rangamani

2) Anomalies and topologies in hydro... where we at?

Universality beyond hydro ?

arXiv:2005.02850 [pdf, other] hep-th cond-mat.other

Topological hydrodynamic modes and holography

Authors: Yan Liu, Ya-Wen Sun

BIG QUESTIONS

1) What is the most important open question for holography ?

2) What do you expect to be the next big result of holography ?

ASK A QUESTION

MAKE A COMMENT

RAISE A DOUBT

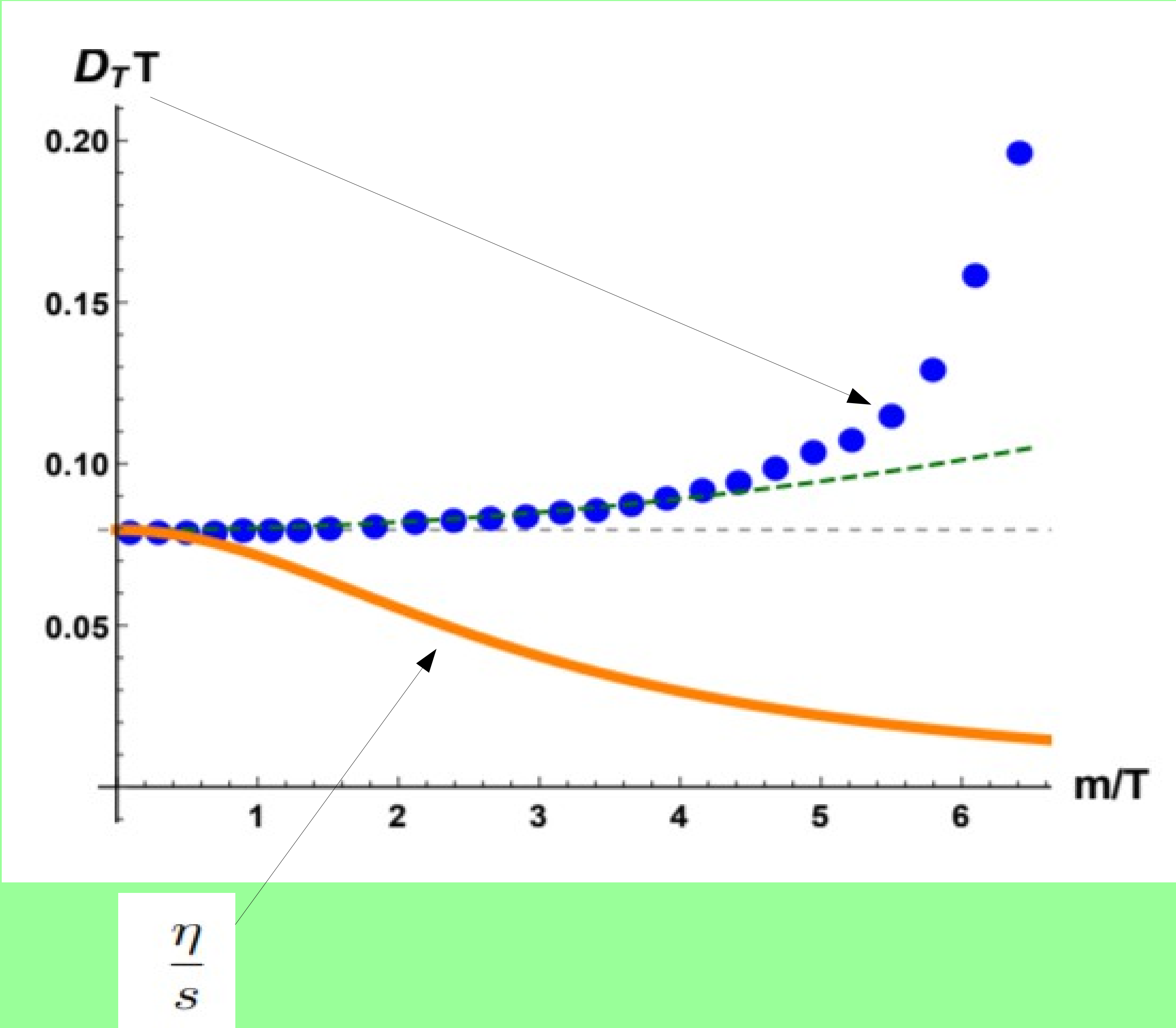
MAKE US THINK

Don't be Shy.

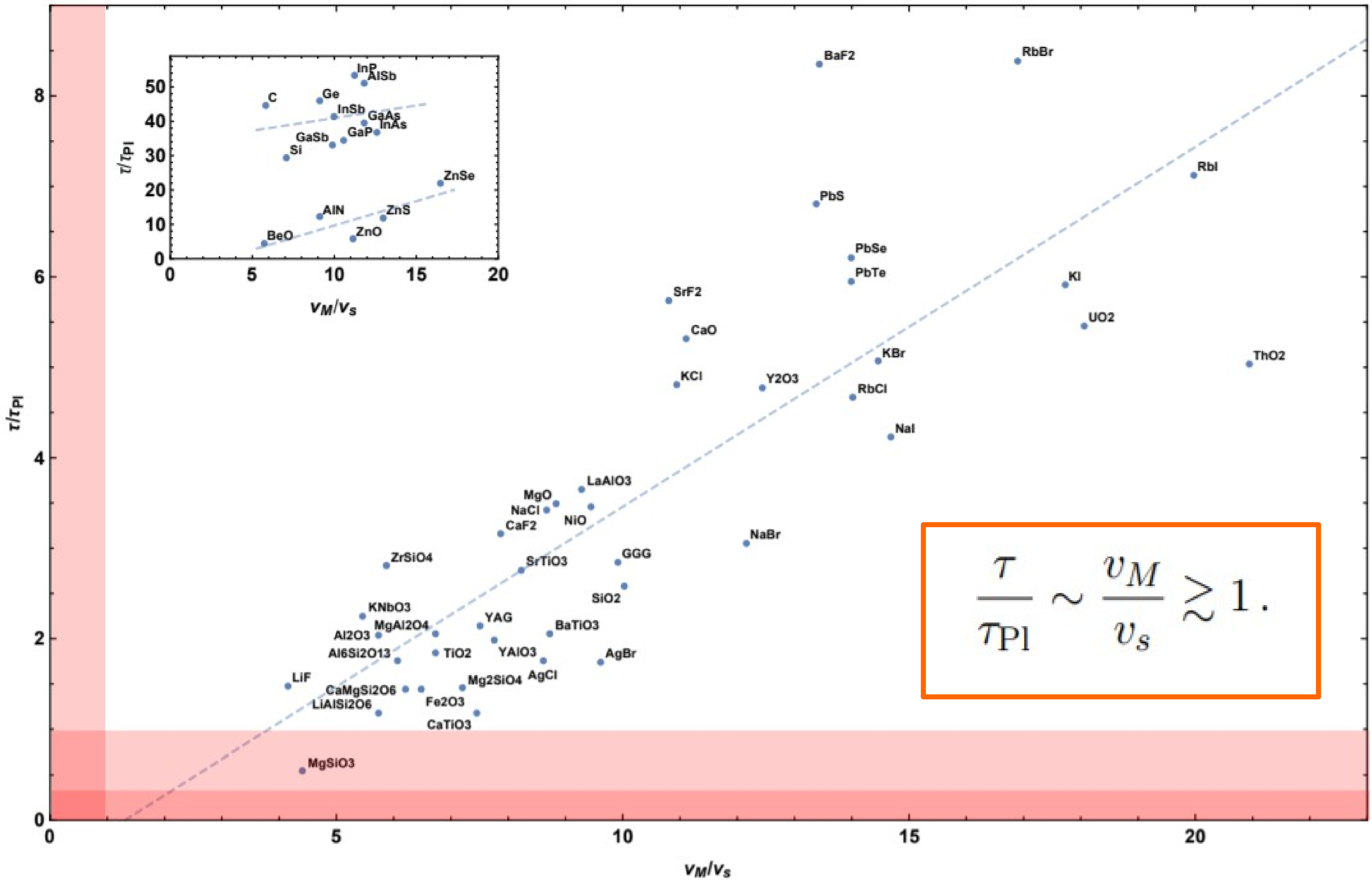
Thanks to our panelists and to all of you !

Let us know if you liked this format and you want it again

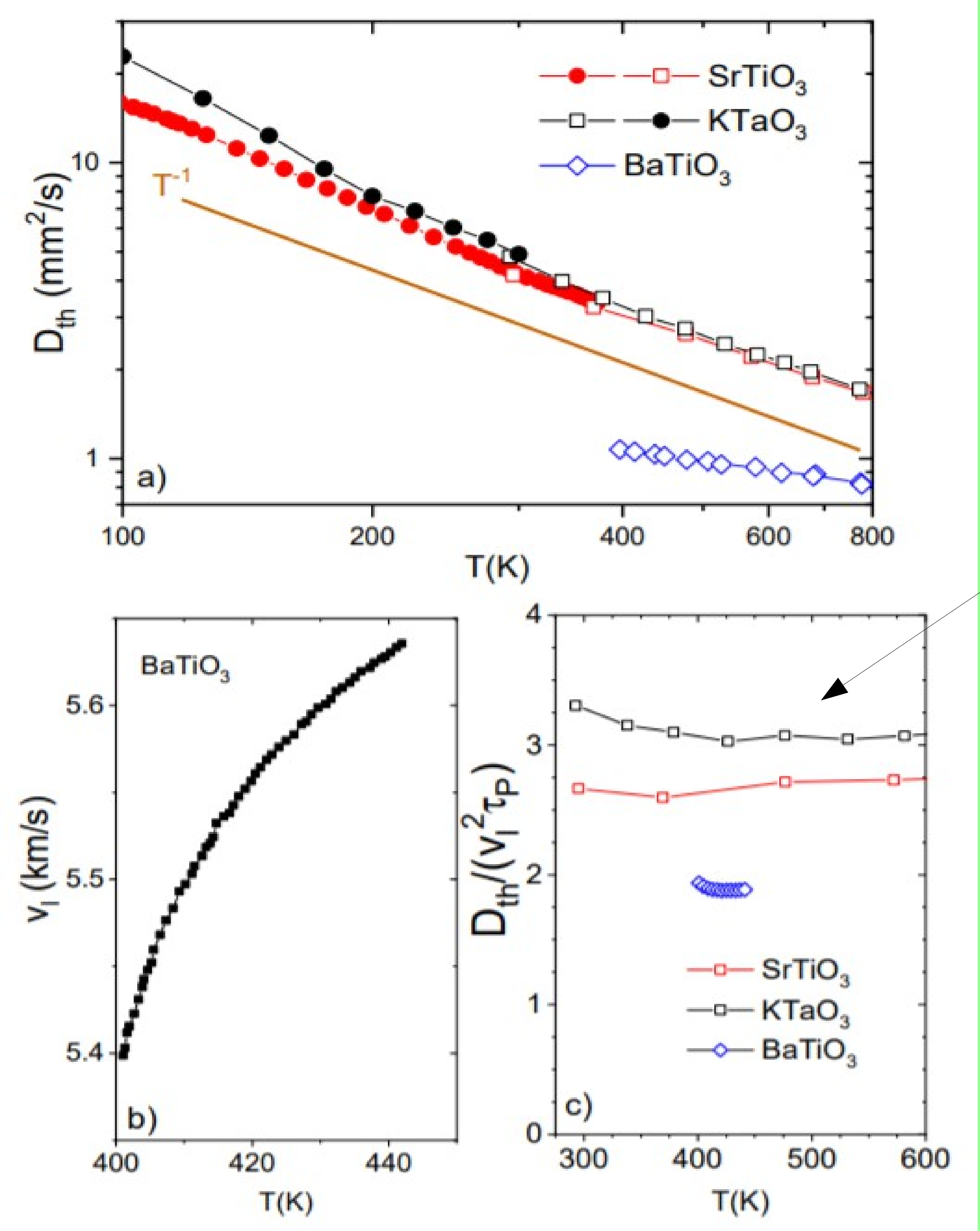
(contactholotube@gmail.com)



$D_T T$
0.20
0.15
0.10
0.05
1
2
3
4
5
6
m/T
$\frac{\eta}{s}$



$$\frac{\tau}{\tau_{Pl}} \sim \frac{v_M}{v_s} \gtrsim 1\,.$$


SrTiO3
KTaO3
BaTiO3
T-1
Dth (mm2/s)
10
1
a)
100
200
400
600
800
T(K)
BaTiO3
vl (km/s)
5.6
5.5
5.4
b)
400
420
440
T(K)
Dth/(vl2τP)
4
3
2
1
0
SrTiO3
KTaO3
BaTiO3
c)
300
400
500
600
T(K)

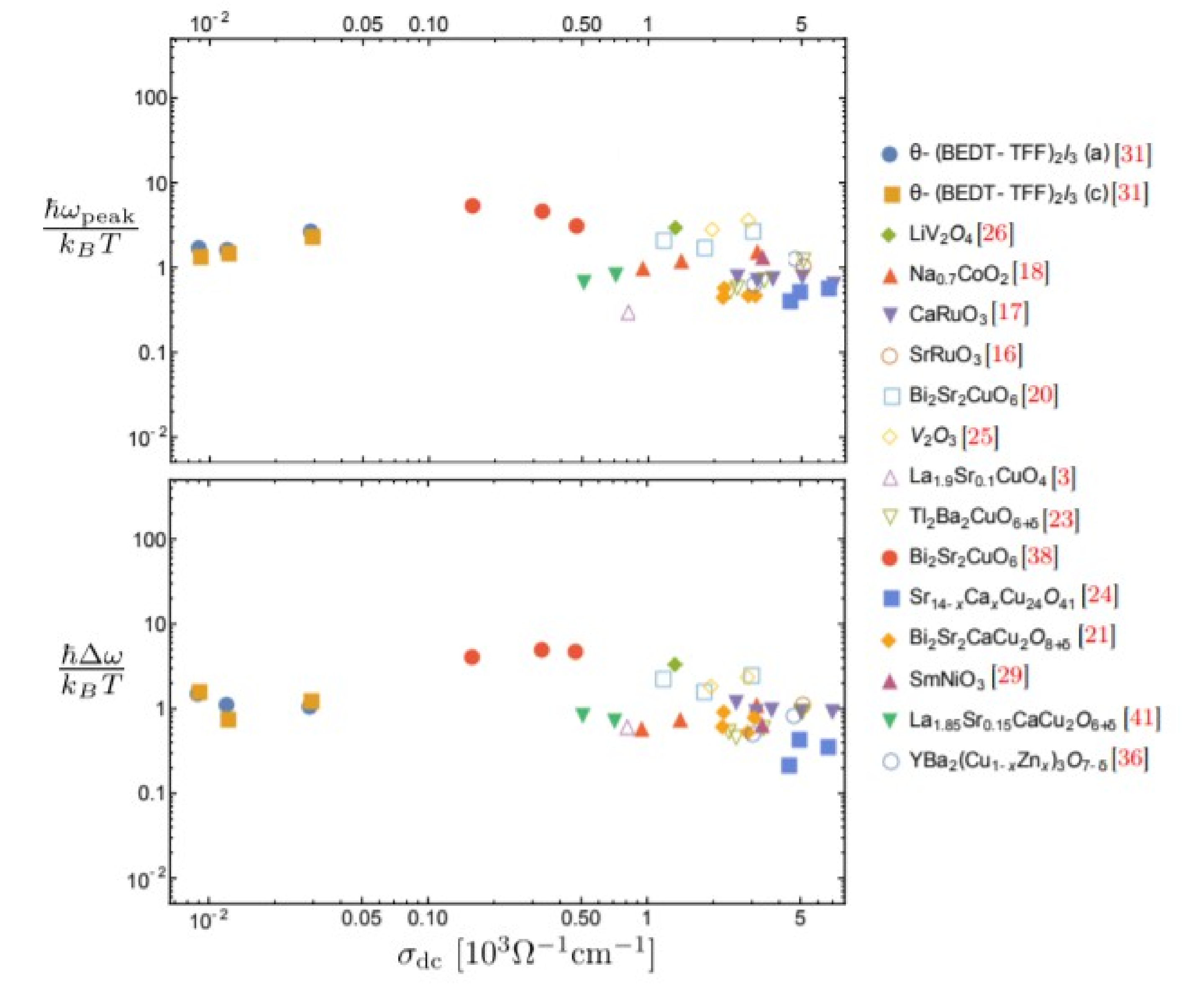
$$\sigma_{DC} = \sigma_{ccs} + \sigma_{diss}$$

$$\theta_H \sim \frac{B}{Q}\sigma_{diss}$$

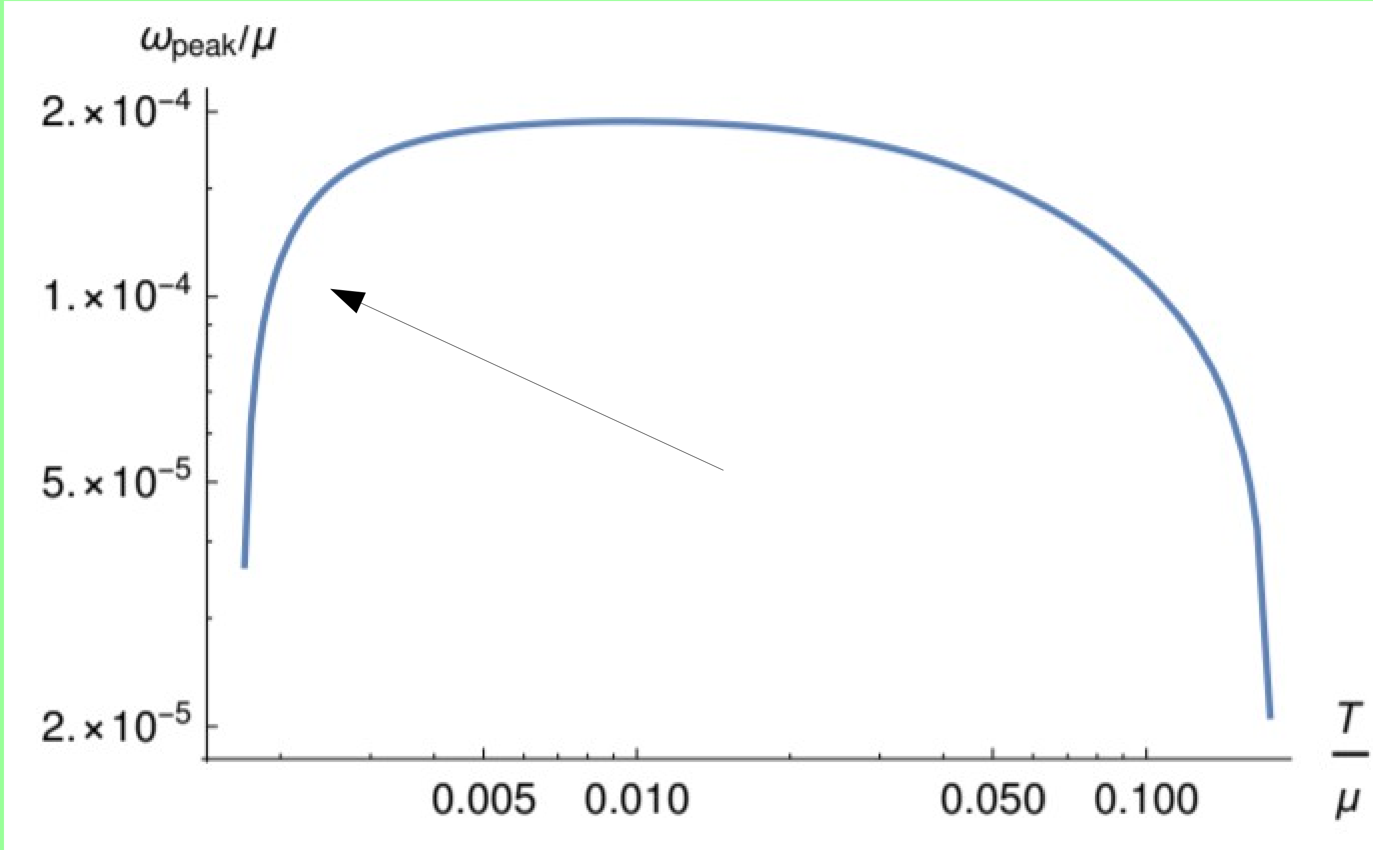
$$S = \int d^4x\sqrt{-g}\,\left[\mathcal{L}_{\rm Bath} + \mathcal{L}_{\rm U(1)}\right], \qquad (1)$$

with a bath sector $\mathcal{L}_{\rm Bath}$ supported, for example, by a neutral scalar ϕ and axionic scalars, and a charge sector $\mathcal{L}_{\rm U(1)}$ describing the dynamics of a $U(1)$ gauge field A_μ. In particular, since we are interested in capturing generic nonlinear electrodynamics effects, the latter will be encoded in the Lagrangian term $\mathcal{L}_{\rm U(1)} = \mathcal{L}(s, p, \phi)$, which is a generic function of the two combinations

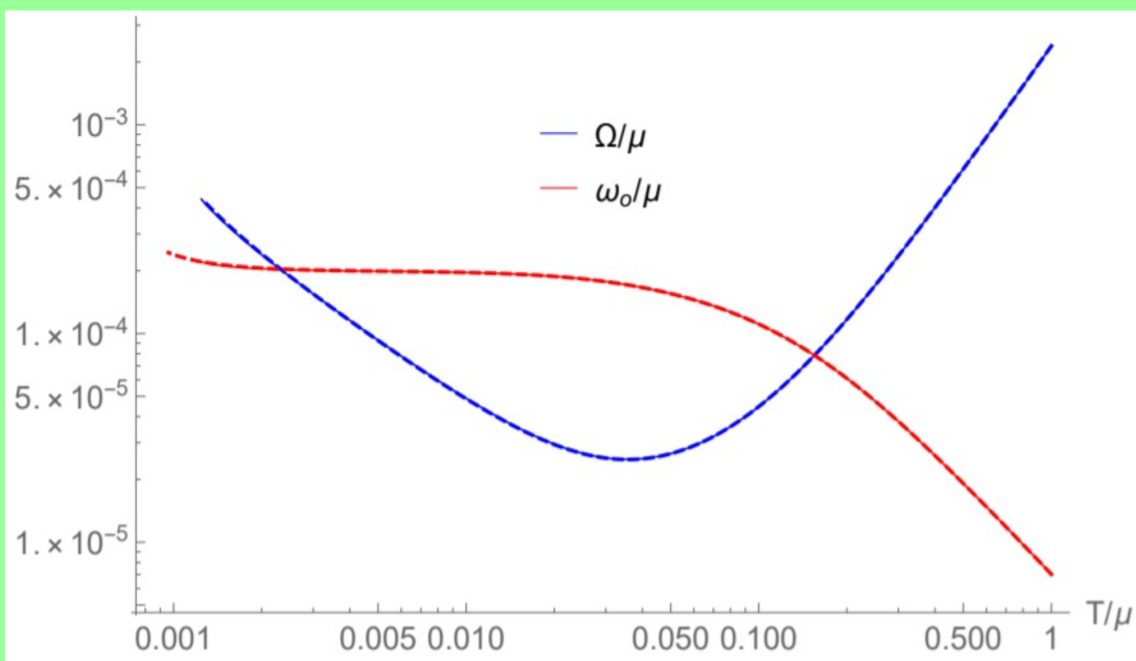
$$s = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu}\,, \qquad p = -\frac{1}{8}\epsilon_{\mu\nu\rho\sigma}F^{\mu\nu}F^{\rho\sigma}\,, \qquad (2)$$



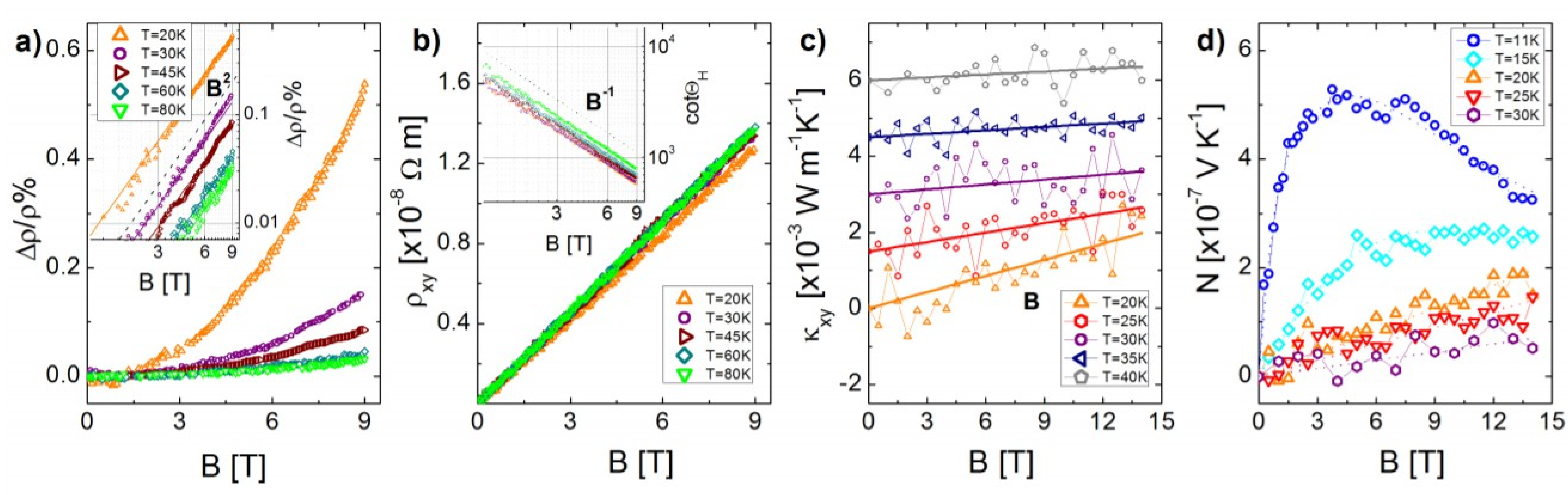
$$\sigma(\omega) = \sigma_o + \frac{\rho^2}{\chi_{\pi\pi}} \frac{\Omega - i\omega}{(\Omega - i\omega)(\Gamma - i\omega) + \omega_o^2} .$$



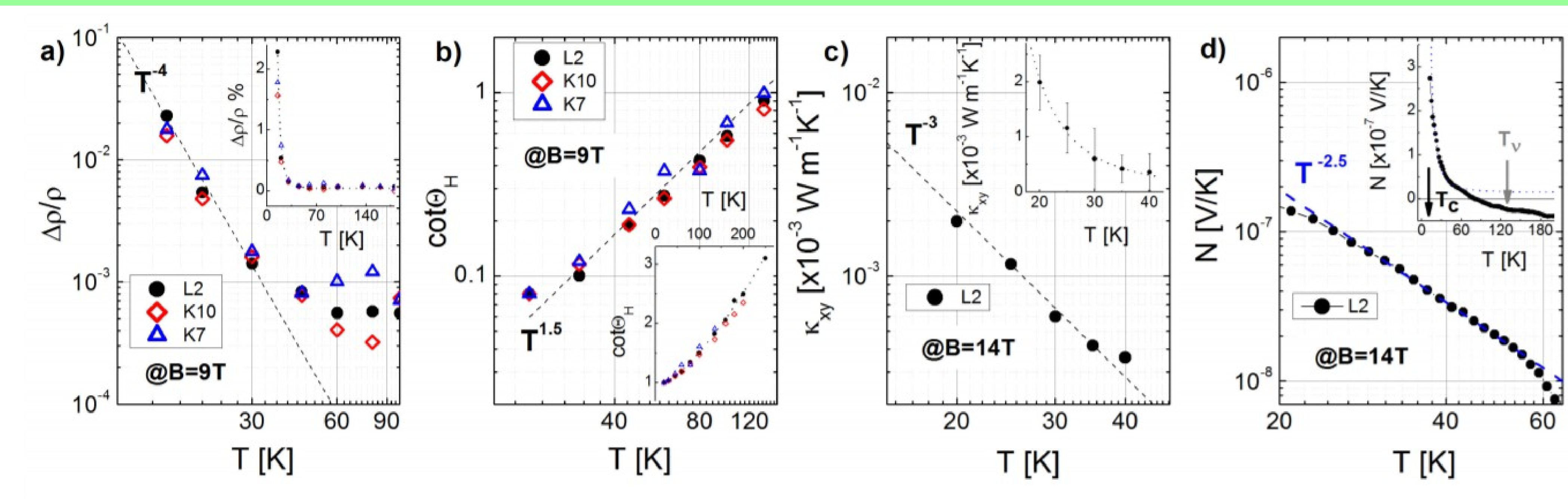
ω_{peak}/μ
$2.\times10^{-4}$
$1.\times10^{-4}$
$5.\times10^{-5}$
$2.\times10^{-5}$
0.005
0.010
0.050
0.100
$\frac{T}{\mu}$



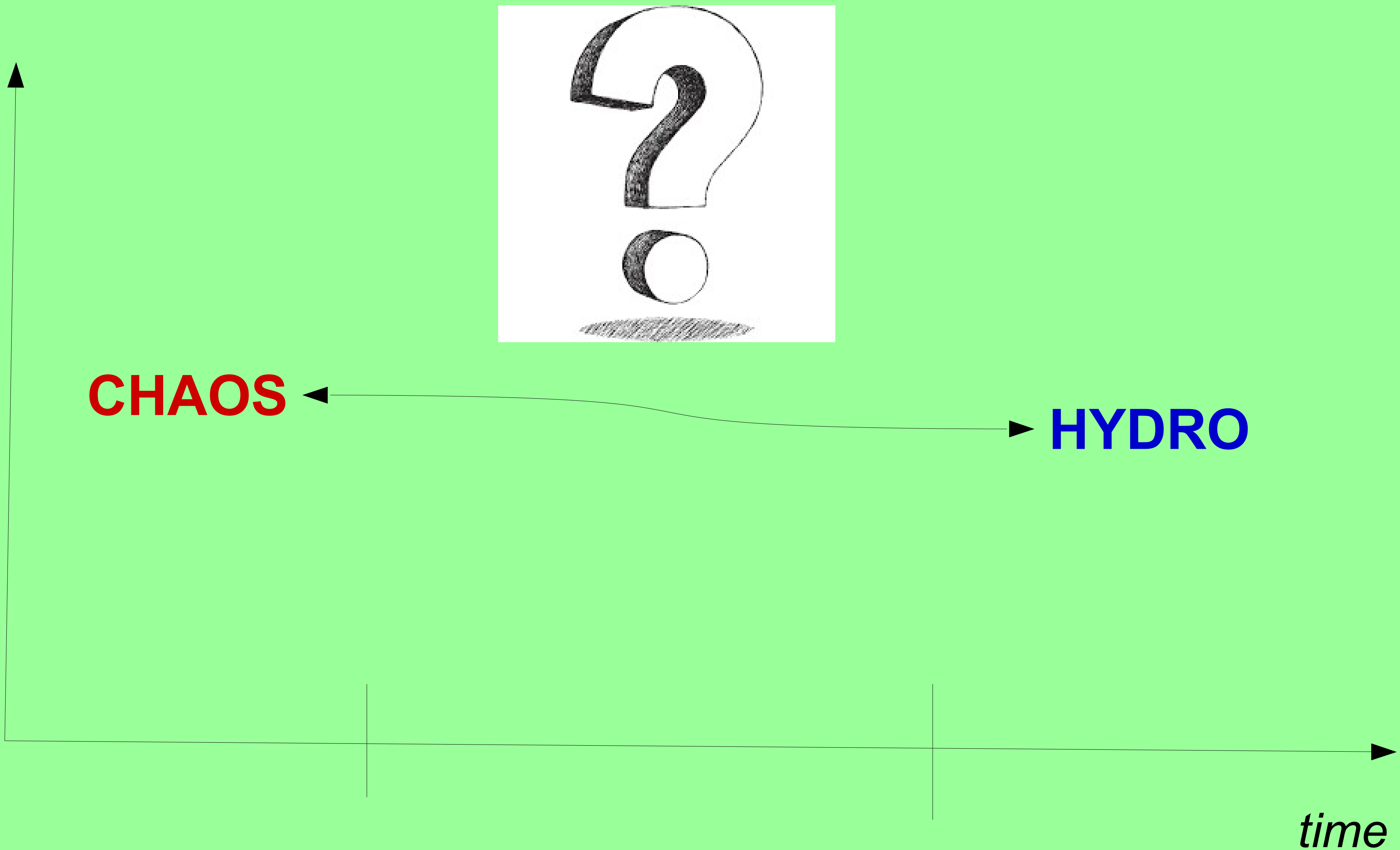
Ω/μ
ω_o/μ
10^{-3}
$5.\times10^{-4}$
$1.\times10^{-4}$
$5.\times10^{-5}$
$1.\times10^{-5}$
0.001
0.005 0.010
0.050 0.100
0.500
1
T/μ



a)
b)
c)
d)
Δρ/ρ%
B [T]
T=20K
T=30K
T=45K
T=60K
T=80K
B²
ρxy [x10⁻⁸ Ω m]
B⁻¹
cotΘH
κxy [x10⁻³ W m⁻¹K⁻¹]
T=25K
T=35K
T=40K
N [x10⁻⁷ V K⁻¹]
T=11K
T=15K



a)
b)
c)
d)
Δρ/ρ
T⁻⁴
Δρ/ρ %
T [K]
L2
K10
K7
@B=9T
cotΘH
T¹·⁵
κxy [x10⁻³ W m⁻¹K⁻¹]
T⁻³
@B=14T
N [V/K]
T⁻²·⁵
N [x10⁻⁷ V/K]
Tν
Tc

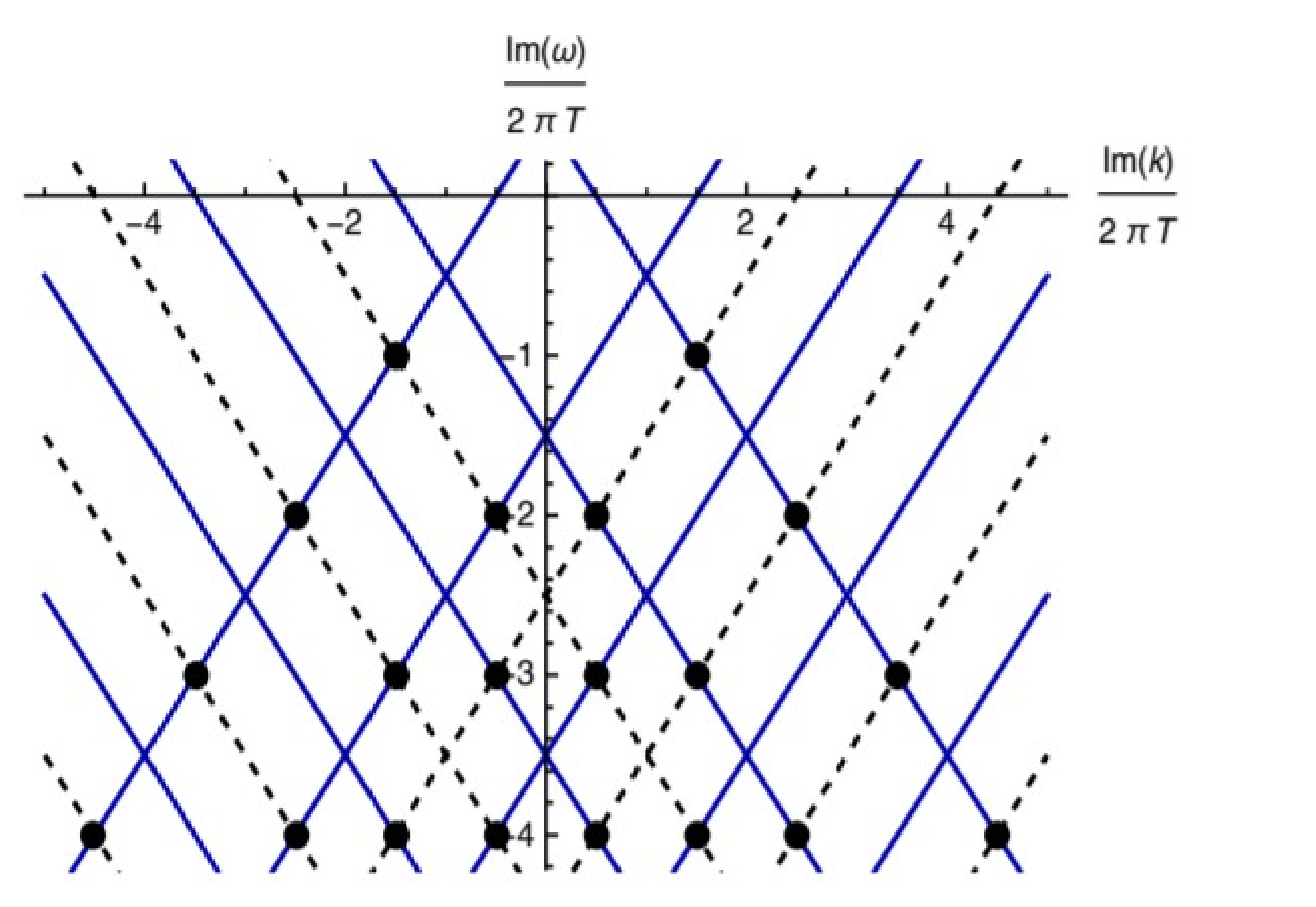

CHAOS
HYDRO
time

MINIMUM OF RESISTANCE IN IMPURITY-FREE CONDUCTORS

R. N. GURZHI

Submitted to JETP editor December 21, 1962

J. Exptl. Theoret. Phys. (U.S.S.R.) **44**, 771-772 (February, 1963)



$\frac{\mathrm{Im}(\omega)}{2\pi T}$
$\frac{\mathrm{Im}(k)}{2\pi T}$
−4
−2
2
4
−1
−2
−3
−4