LONG BASELINE MOLECULAR INTERFEROMETRY

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Very Long Baseline Atom Interferometry Workshop
CERN / March 2023

DLR

Very Long Baseline Molecular Interferometry

Why even try?

TOPICAL REVIEW

Gravitational decoherence

Angelo Bassi[1,2], André Großardt[3,4] and Hendrik Ulbricht[5]

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Classical and Quantum Gravity, Volume 34, Number 19
Citation Angelo Bassi *et al* 2017 *Class. Quantum Grav.* 34 193002
DOI 10.1088/1361-6382/aa864f

Article PDF

Figures References

+ Article information

Abstract

We discuss effects of loss of coherence in low energy quantum systems caused by or related to gravitation, referred to as gravitational decoherence. These effects, resulting from random metric fluctuations, for instance, promise to be accessible by relatively inexpensive table-top experiments, way before the scales where true quantum gravity effects become important. Therefore, they can provide a first experimental view on gravity in the quantum regime. We will survey models of decoherence induced both by classical and quantum gravitational fluctuations; it will be manifest that a clear understanding of gravitational decoherence is still lacking. Next we will review models where quantum theory is modified, under the assumption that gravity causes the collapse of the wave functions, when systems are large enough. These models challenge the quantum-gravity interplay, and can be tested experimentally. In the last part we have a look at the state of the art of experimental research. We will review efforts aiming at more and more accurate measurements of gravity (*G* and *g*) and ideas for measuring conventional and unconventional gravity effects on nonrelativistic quantum systems.

Collapse Models: Main Properties and the State of Art of the Experimental Tests

Matteo Carlesso & Sandro Donadi

Conference paper | First Online: 02 November 2019

Part of the Springer Proceedings in Physics book series (SPPHY,volume 237)

Abstract

Collapse models represent one of the possible solutions to the measurement problem. These models modify the Schrödinger dynamics with nonlinear and stochastic terms, which guarantee the localization in space of the wave function avoiding macroscopic superpositions, like that described in Schrödinger's cat paradox. The Ghirardi–Rimini–Weber (GRW) and the Continuous Spontaneous Localization (CSL) models are the most studied among the collapse models. Here, we briefly summarize the main features of these models and the advances in their experimental investigation.

Collapse Models

1986 Ghirardi, Rimini, and Weber (GRW)
Adler (2007)

1990 Continous Spontaneous Localization (CSL) Model

1996 Diosi-Penrose (PD) Model

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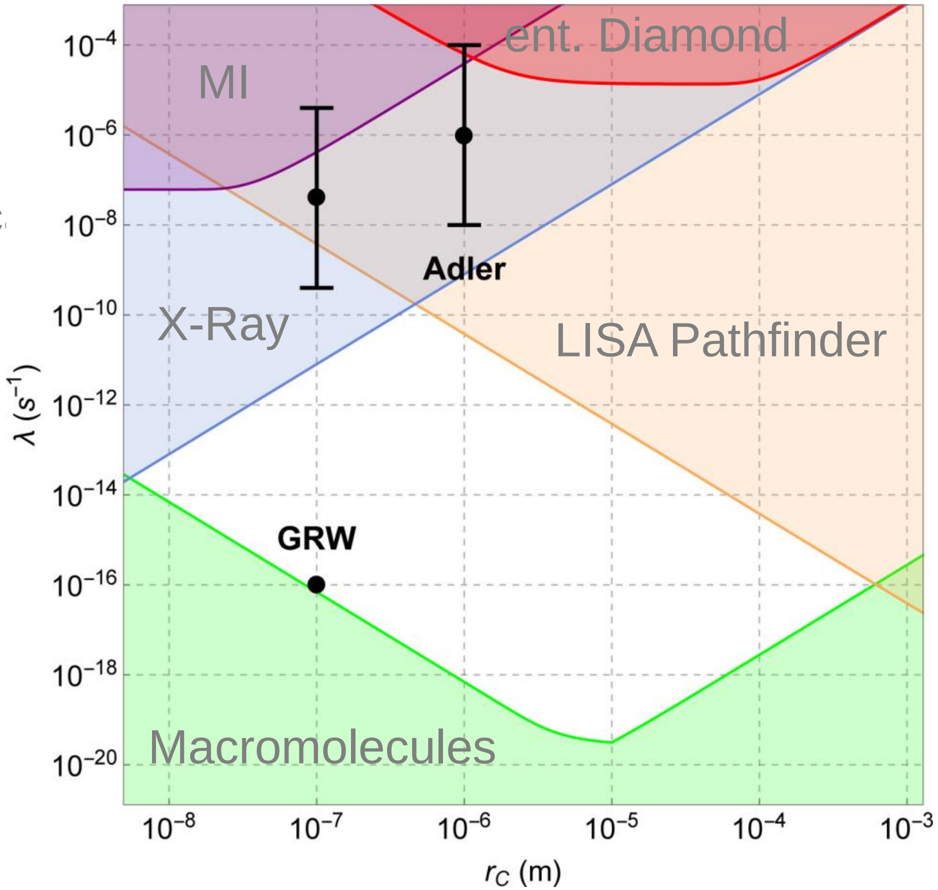


[Picture taken from A. Belenchia et al., Physics Reports 951, 1-70 (2022)]

Very Long Baseline Molecular Interferometry

Experimental Tests

Very Long Baseline Molecular Interferometry

Experimental Tests

Letter | Published: 23 September 2019

Quantum superposition of molecules beyond 25 kDa

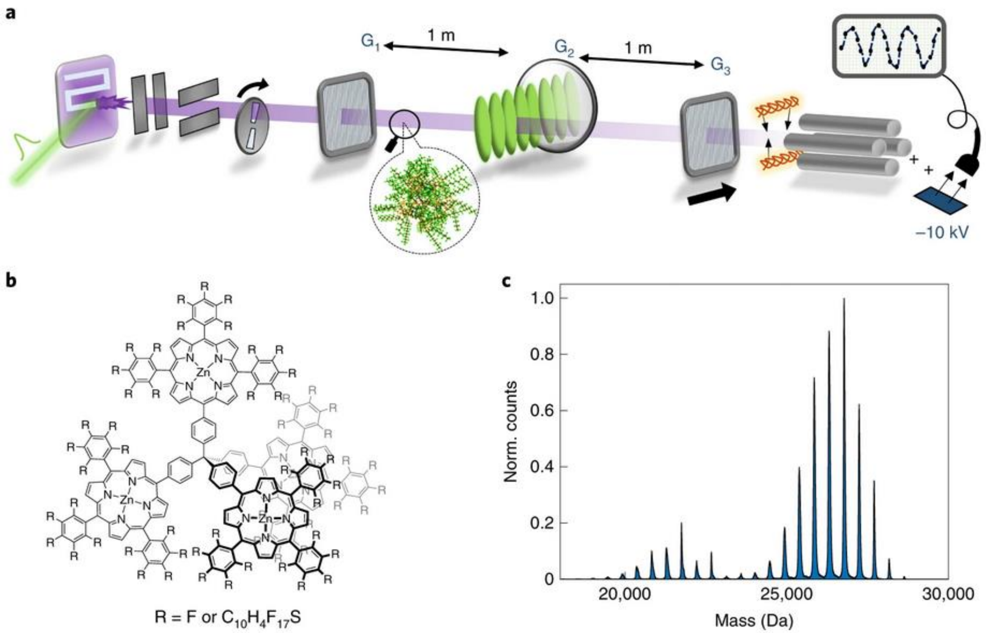
Yaakov Y. Fein, Philipp Geyer, Patrick Zwick, Filip Kiałka, Sebastian Pedalino, Marcel Mayor, Stefan Gerlich & Markus Arndt

Nature Physics 15, 1242–1245 (2019) | Cite this article

Abstract

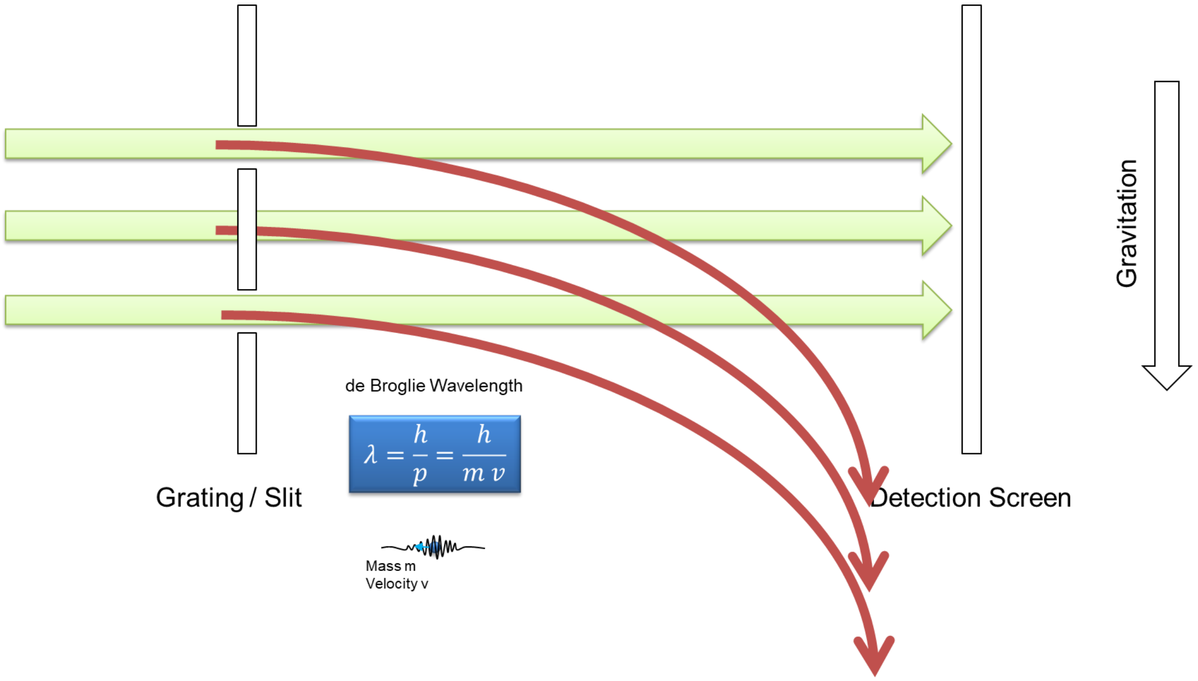
Matter-wave interference experiments provide a direct confirmation of the quantum superposition principle, a hallmark of quantum theory, and thereby constrain possible modifications to quantum mechanics[1]. By increasing the mass of the interfering particles and the macroscopicity of the superposition[2], more stringent bounds can be placed on modified quantum theories such as objective collapse models[3]. Here, we report interference of a molecular library of functionalized oligoporphyrins[4] with masses beyond 25,000 Da and consisting of up to 2,000 atoms, by far the heaviest objects shown to exhibit matter-wave interference to date. We demonstrate quantum superposition of these massive particles by measuring interference fringes in a new 2-m-long Talbot–Lau interferometer that permits access to a wide range of particle masses with a large variety of internal states. The molecules in our study have de Broglie wavelengths down to 53 fm, five orders of magnitude smaller than the diameter of the molecules themselves. Our results show excellent agreement with quantum theory and cannot be explained classically. The interference fringes reach more than 90% of the expected visibility and the resulting macroscopicity value of 14.1 represents an order of magnitude increase over previous experiments[2].

‚Long Baseline Universal Matter Wave Interferometer‘ (LUMI)



Very Long Baseline Molecular Interferometry

Experimental Tests



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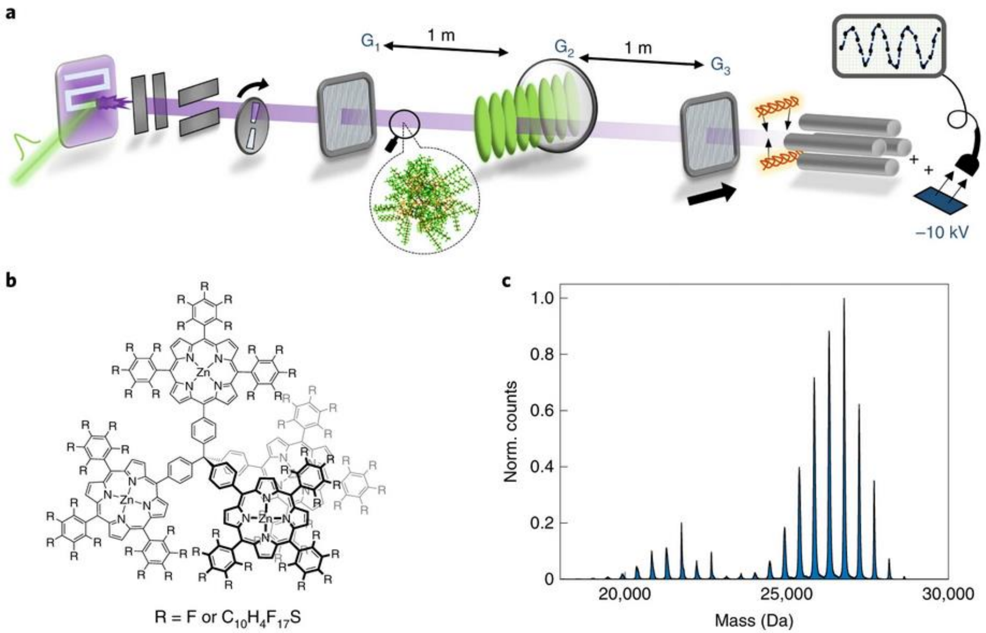

Very Long Baseline Molecular Interferometry

Microgravity

R. Kaltenbaeck et al.
https://arxiv.org/abs/1503.02640

Very Long Baseline Molecular Interferometry

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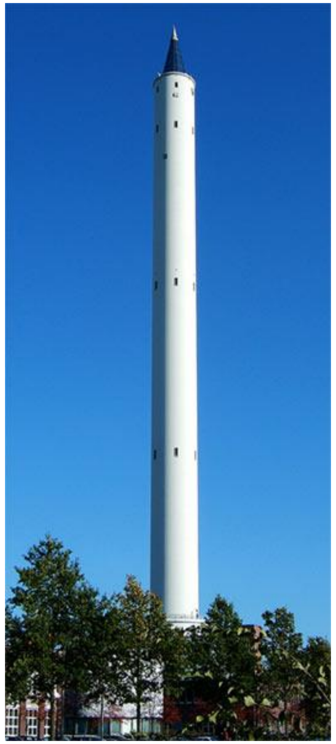

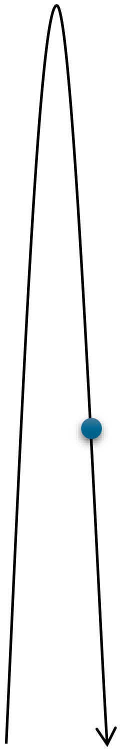

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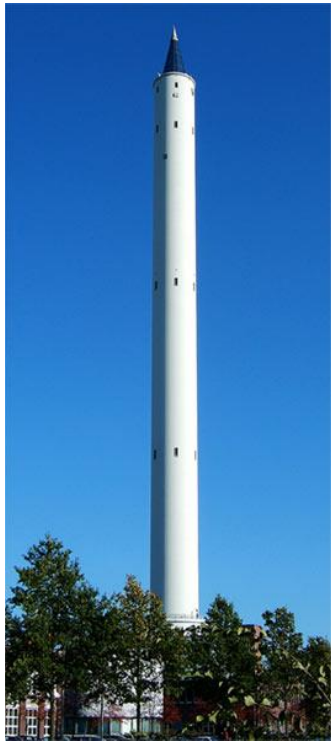

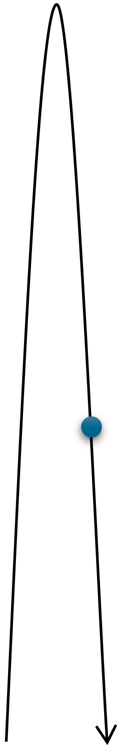

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- Drop Time
  - Free Falling: 4,74s
  - Catapult: 9,3s

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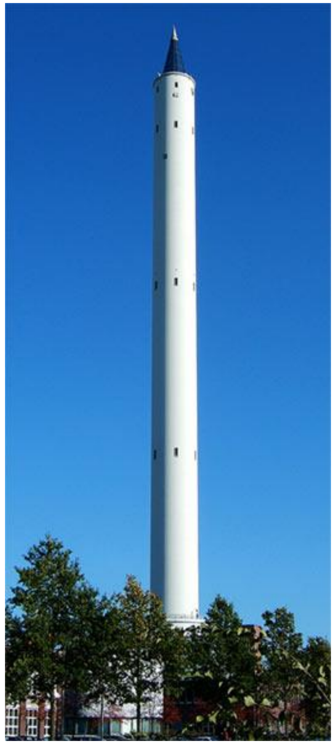

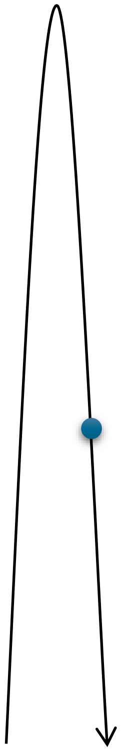

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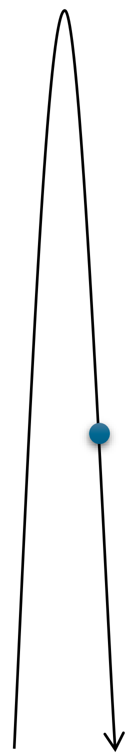
Very Long Baseline Molecular Interferometry

Molecular Fountain



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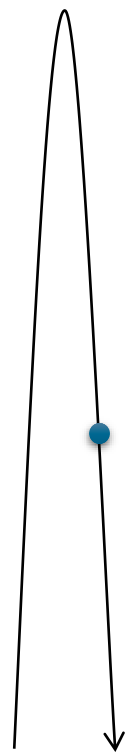

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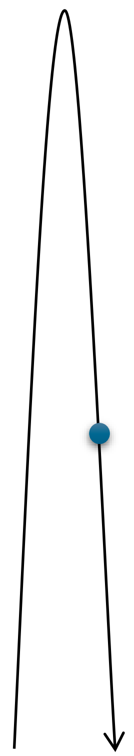

Very Long Baseline Molecular Interferometry

Molecular Fountain

Building @ DLR – QT Ulm

- Drop Tower
- Height: 25 m
- Free – Falling Time : 3,2s

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Published: 10 February 2013

A universal matter-wave interferometer with optical ionization gratings in the time domain

Philipp Haslinger, Nadine Dörre, Philipp Geyer, Jonas Rodewald, Stefan Nimmrichter & Markus Arndt

Nature Physics **9**, 144–148 (2013) | Cite this article

Abstract

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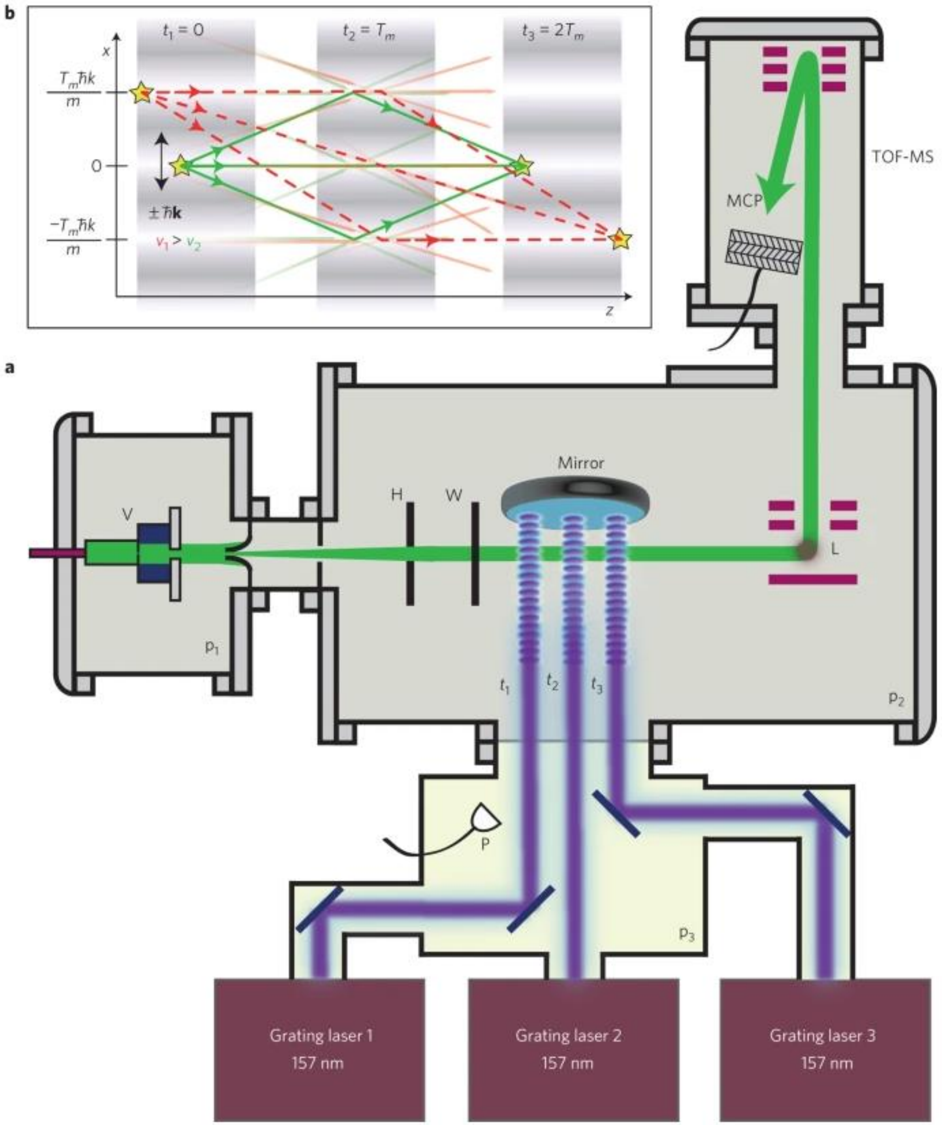

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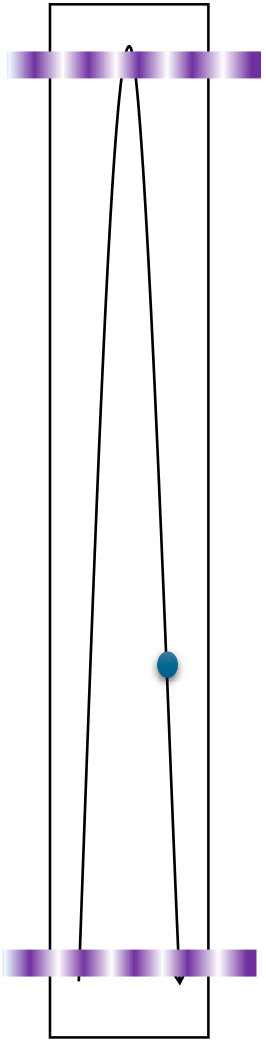

Achievable Mass m = 2 10^8 amu

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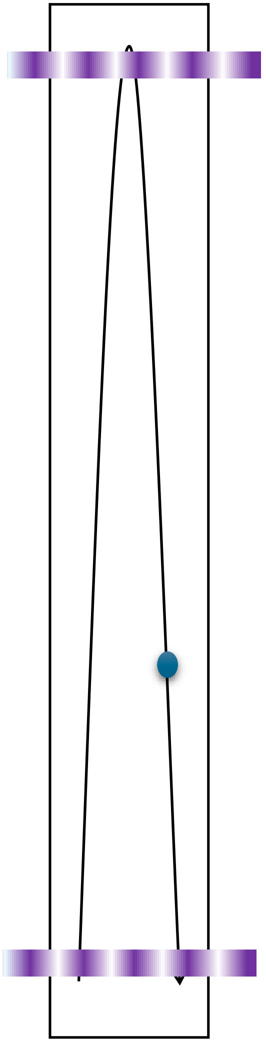

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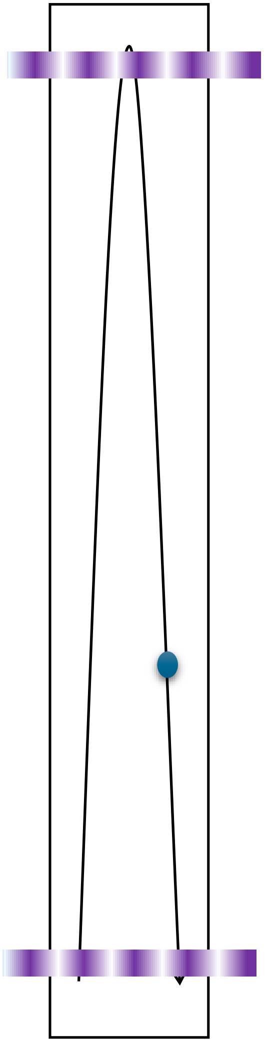

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Challenges

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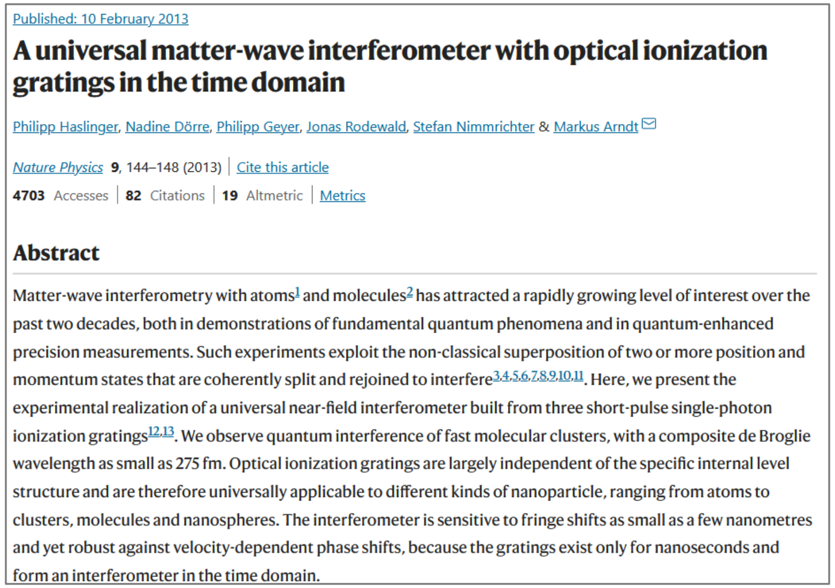

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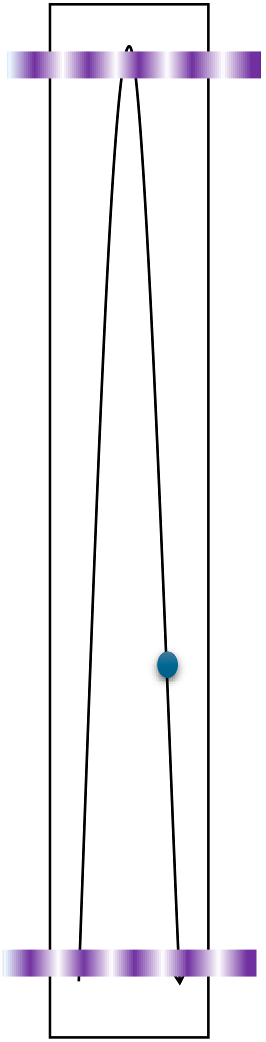

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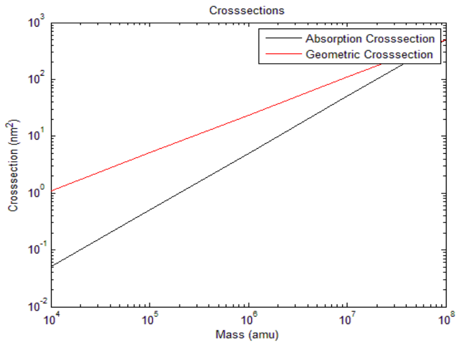

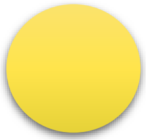

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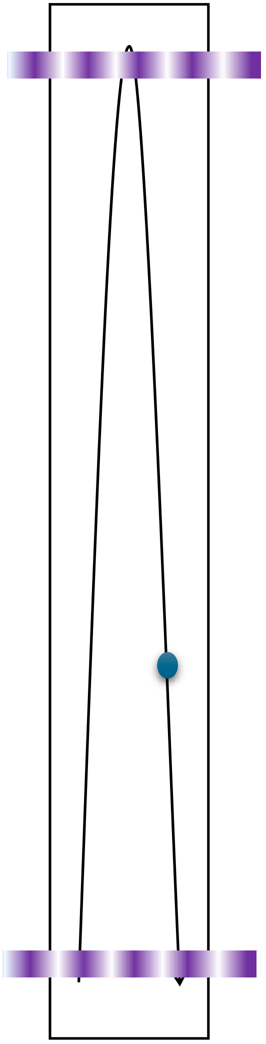

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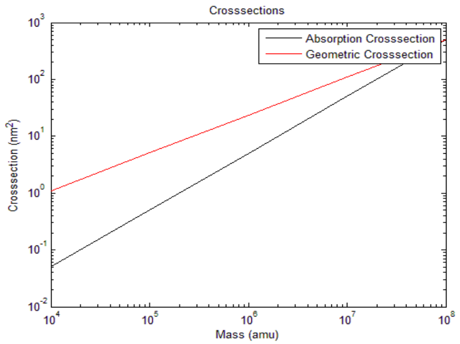

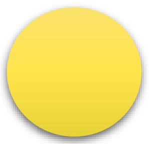

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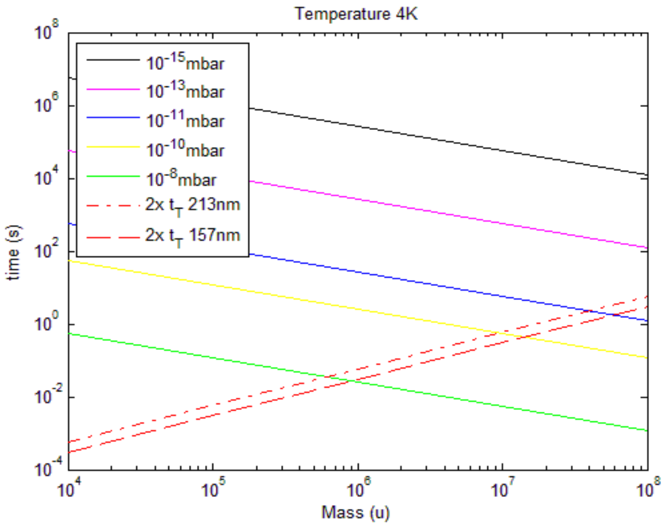

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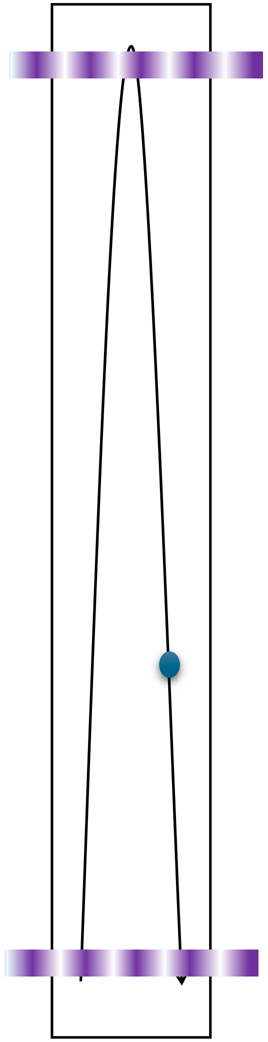

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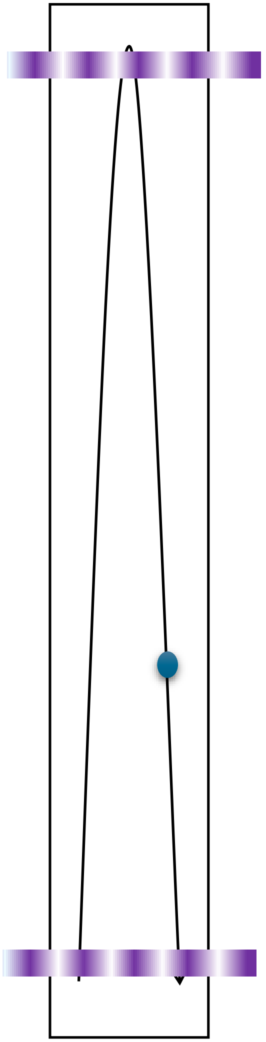

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- Thermal & Structural Tower Integrity
- Vacuum Quality
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Published: 10 February 2013

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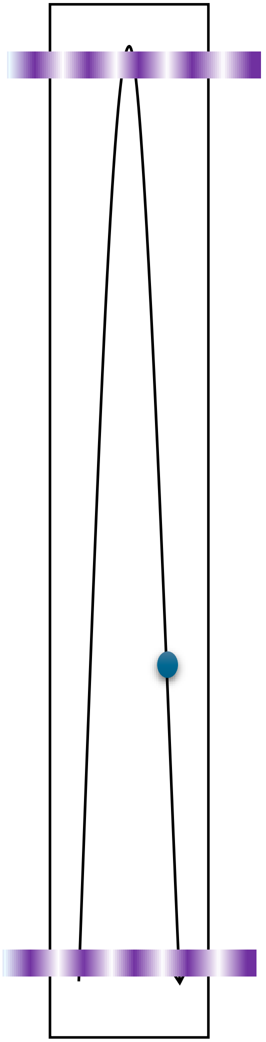

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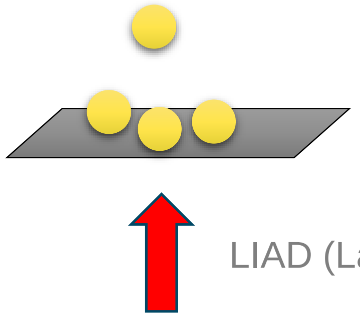

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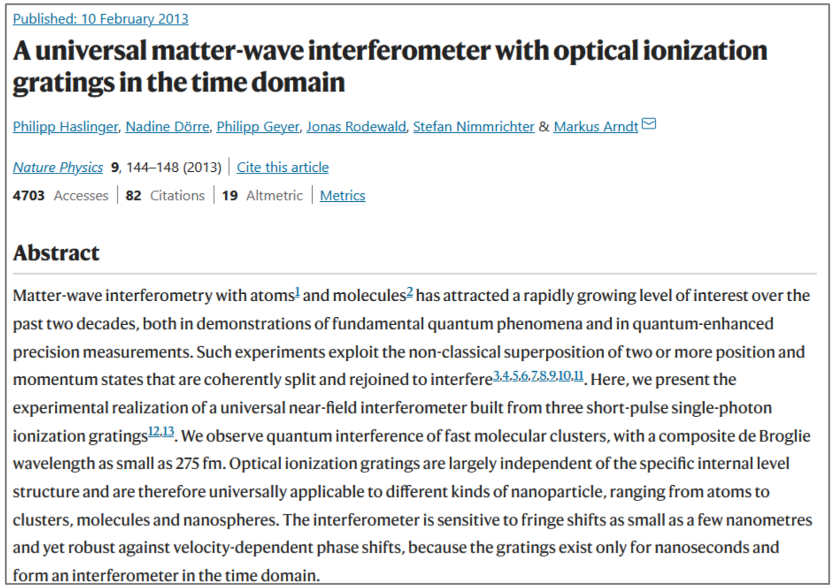

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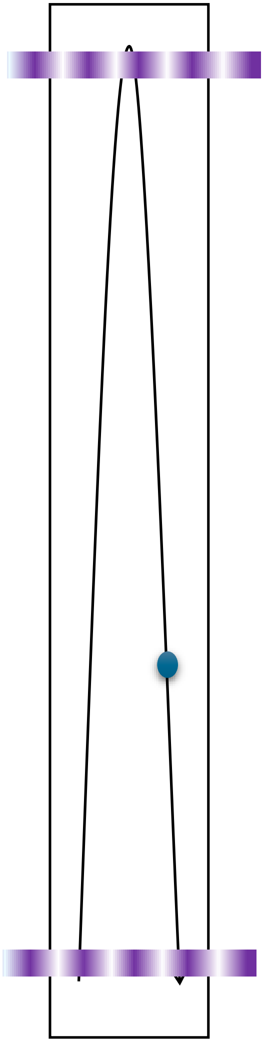

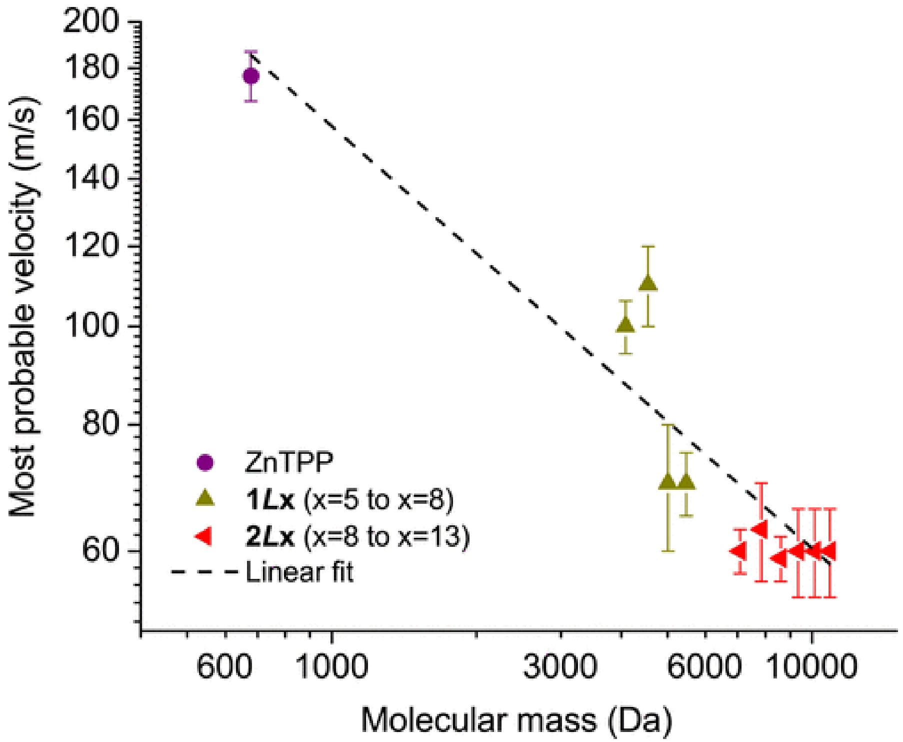

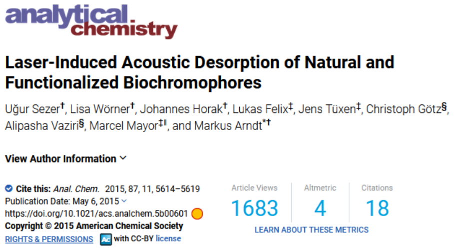

analytical chemistry

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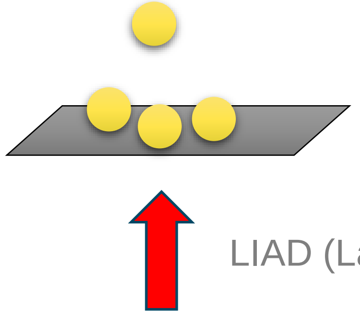

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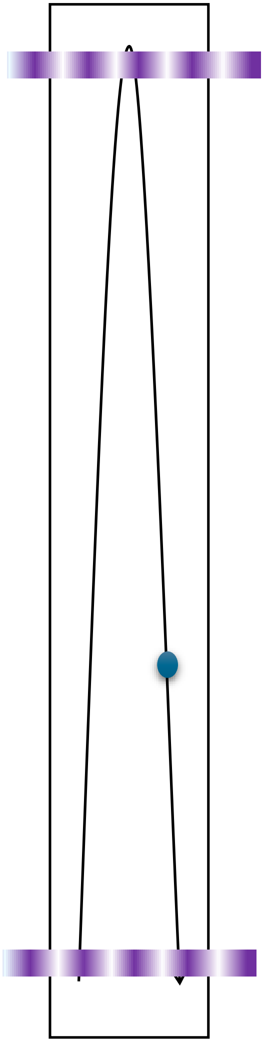

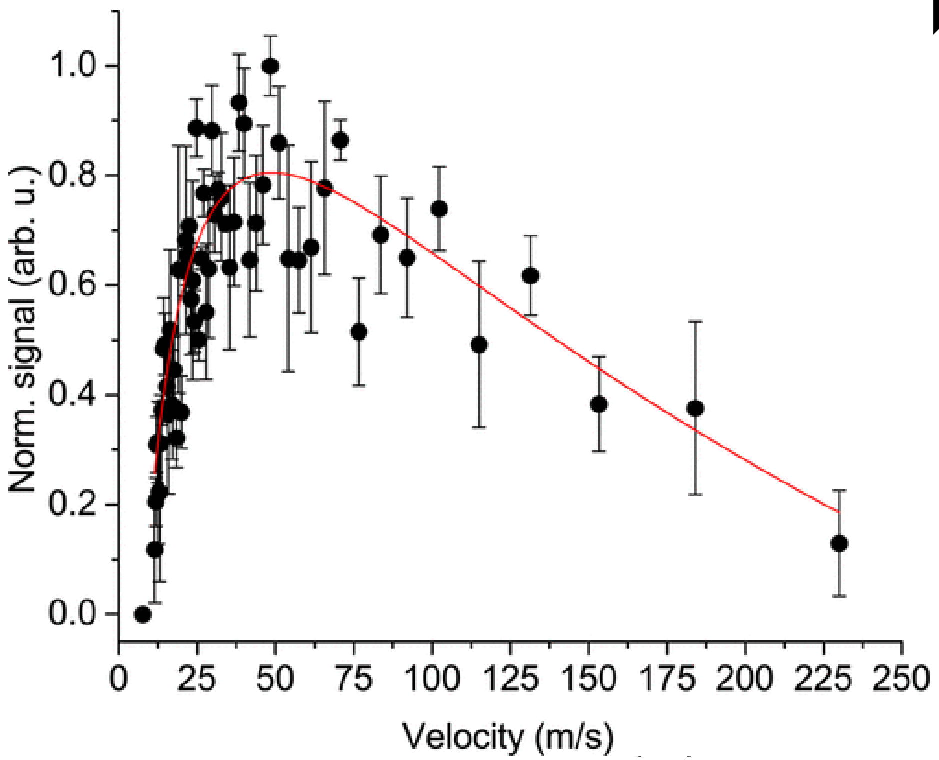

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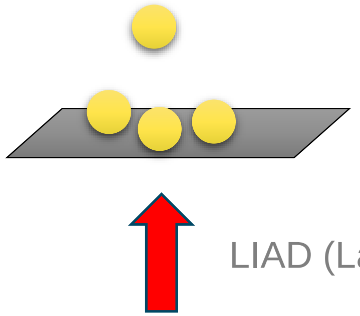

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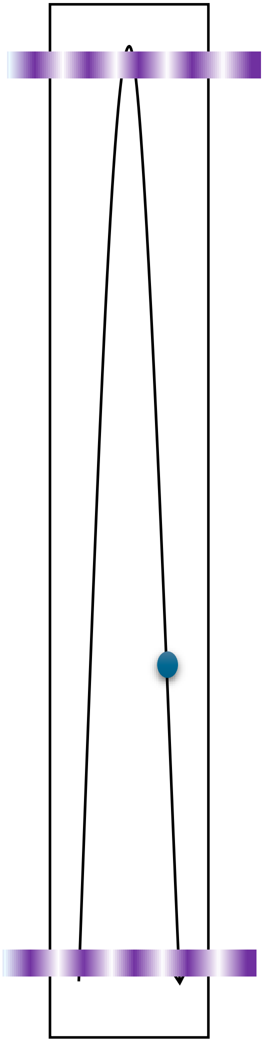

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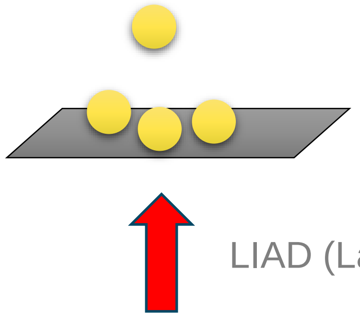

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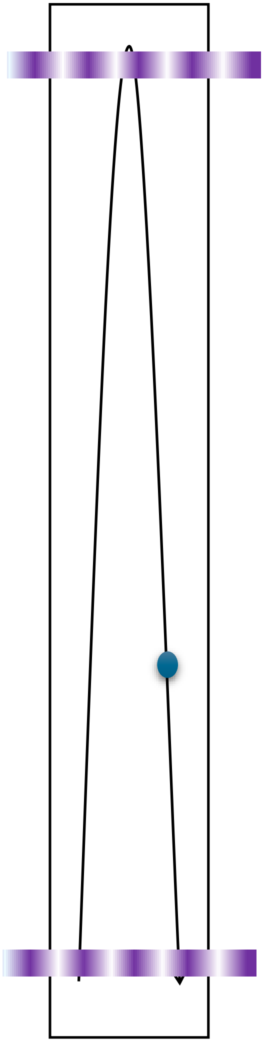

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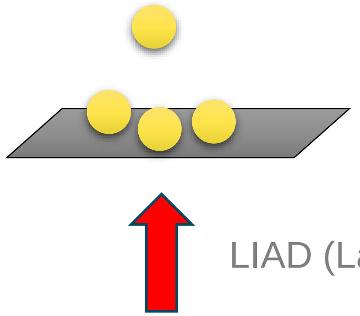

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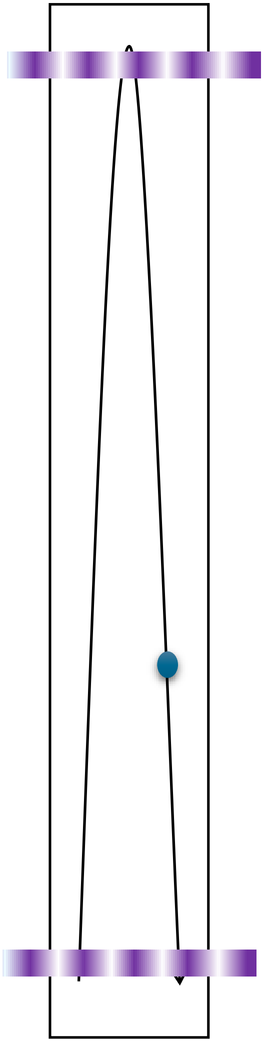

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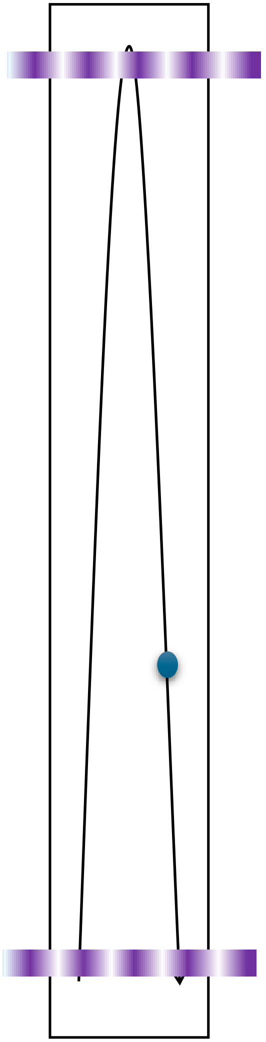

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LONG BASELINE MOLECULAR INTERFEROMETRY

Dr. Lisa Wörner

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CERN / March 2023

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