ROOM TEMPERATURE SPIN FILTERING IN A METALLOPEPTIDE

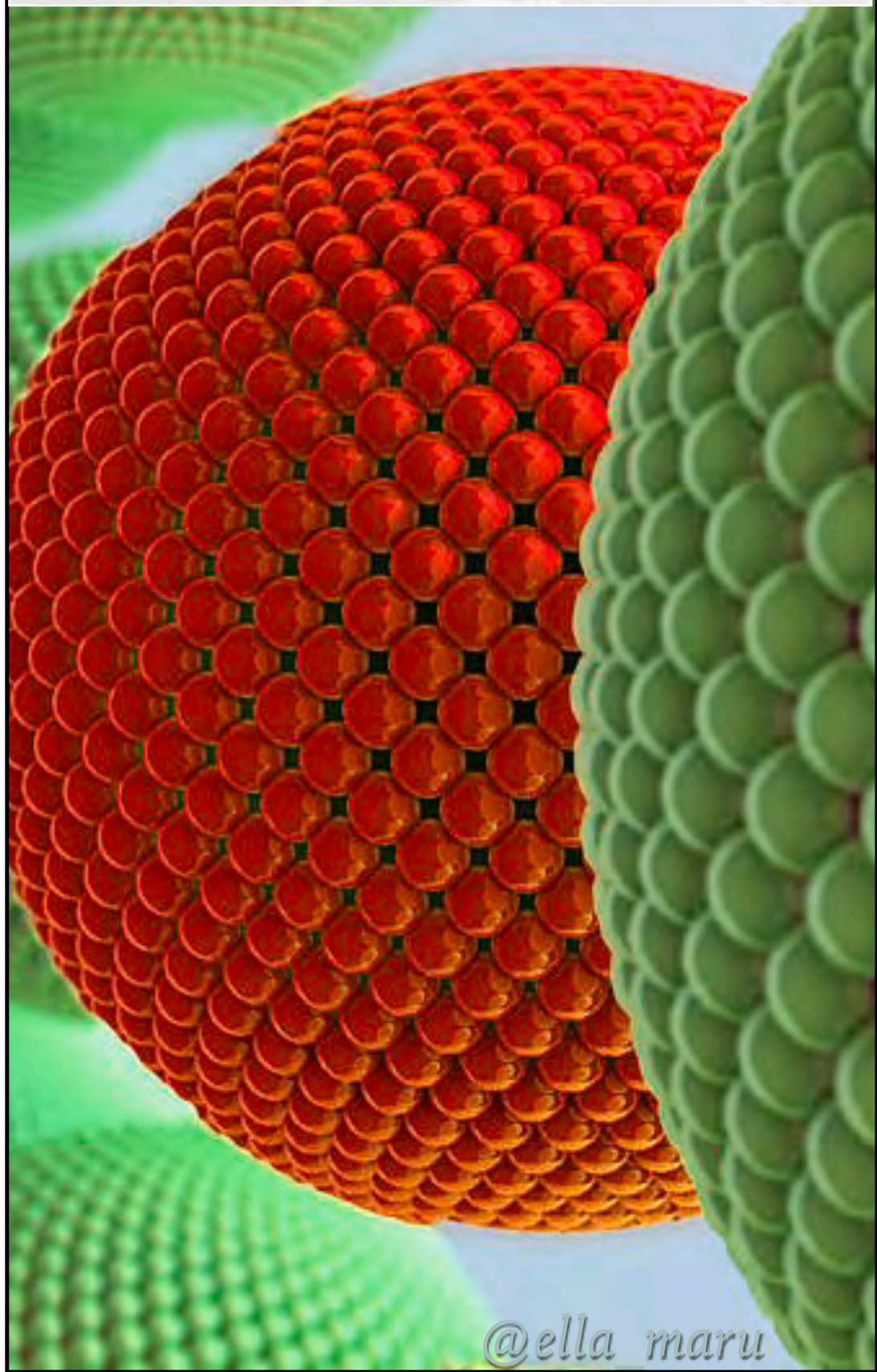
TOWARDS MOLECULAR MEMRISTIVITY?

Salvador Cardona-Serra, ICMol

SPICE WORKSHOP 2019, Mainz, 18/10/2019

@salvajcardona

SPIN PHENOMENA
INTERDISCIPLINARY CENTER



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Alejandro Gaita
Luis Escalera
Silvia Giménez
Jose Jaime Baldoví
Lorena Rosaleny

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Vibronic Coupling

2006

BACHELOR

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Institut de Ciència Molecular

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Vibronic Coupling

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DFT & Magnetism

2007-2008

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CRANN

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Spintronics *2014-2018* — *POSTDOC*

Memristor *2019* — *NANOMEM*

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TECHNOLOGICAL REVOLUTION TIMELINE

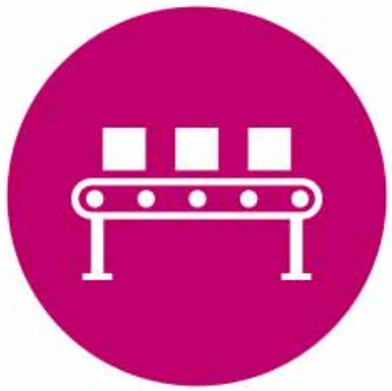
Four Industrial Revolutions

1765

1st revolution

MECHANIZATION

led by the steam engine



1870

2nd revolution

MASS PRODUCTION

driven by electricity and oil-based power

1969

3rd revolution

AUTOMATED PRODUCTION

supported by electronics and information technologies

Today

4th revolution

NEW TECHNOLOGIES

Internet of Things (IoT), Artificial Intelligence (AI); Big Data, Cloud, Cyber-Physical Systems...

BIG DATA AND PATTERN RECOGNITION

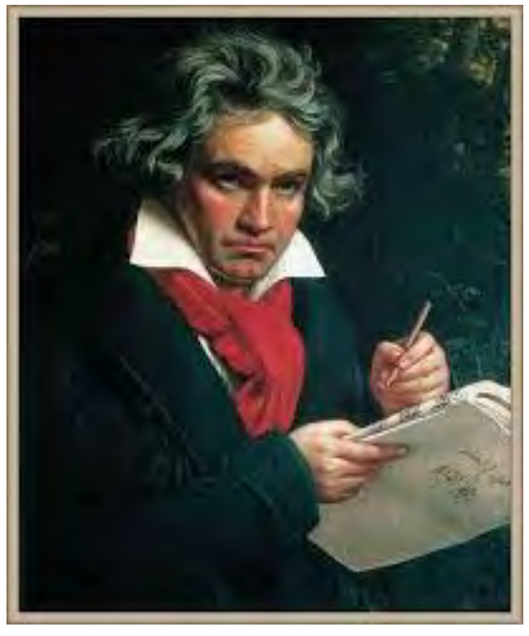
BIG DATA AND PATTERN RECOGNITION

INTERNET OF THINGS

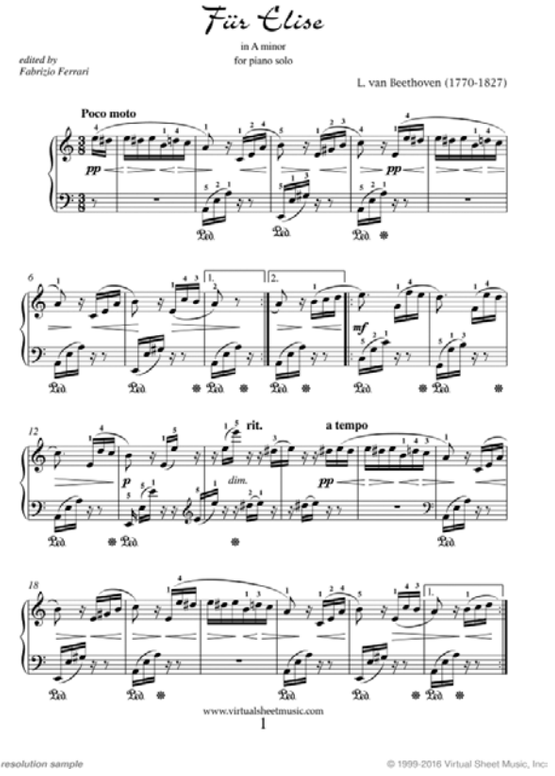
VON NEUMANN BOTTLENECK

MOST ENERGY/TIME CONSUMING PROCESS

VON NEUMANN BOTTLENECK



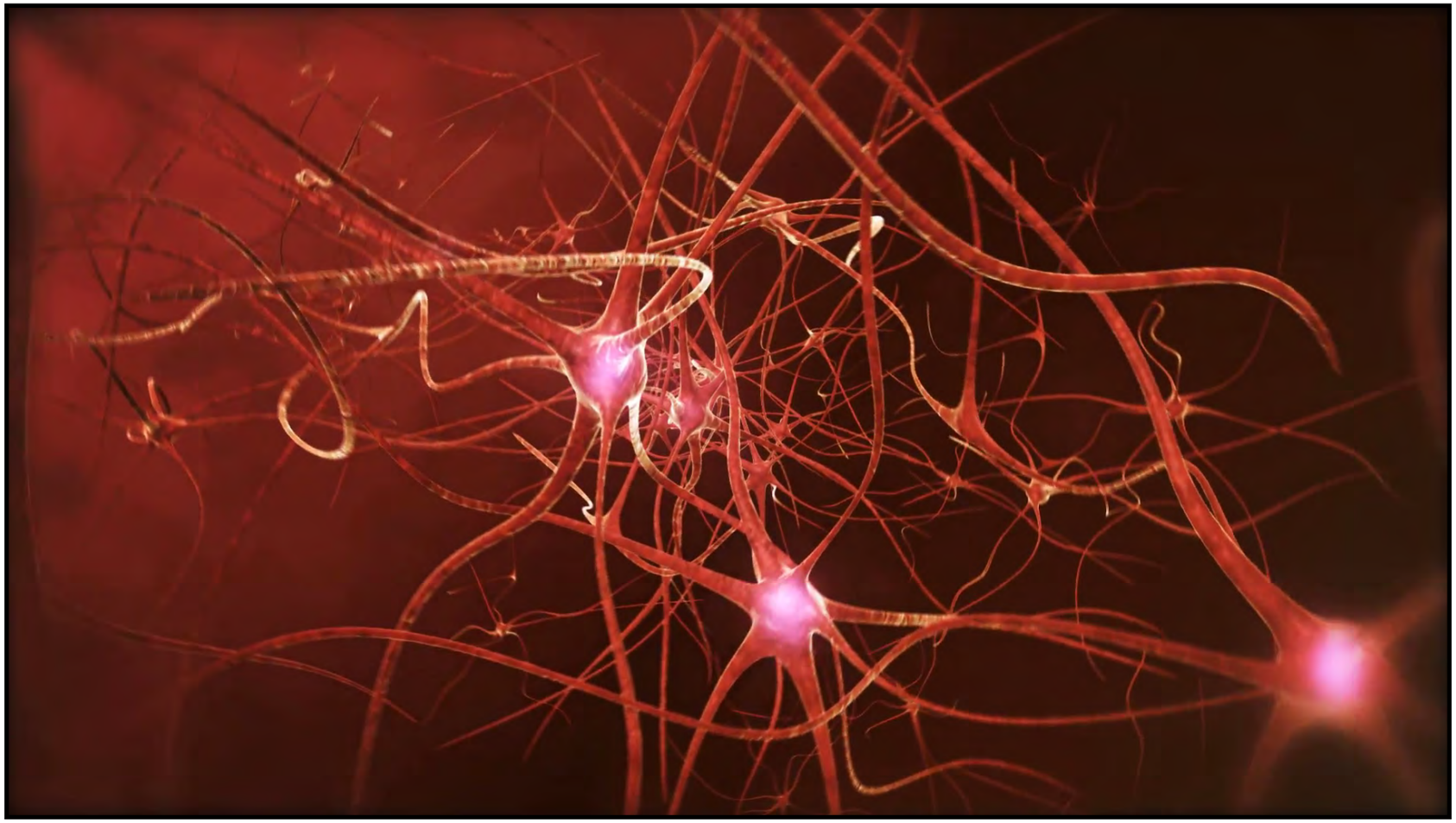
100 m



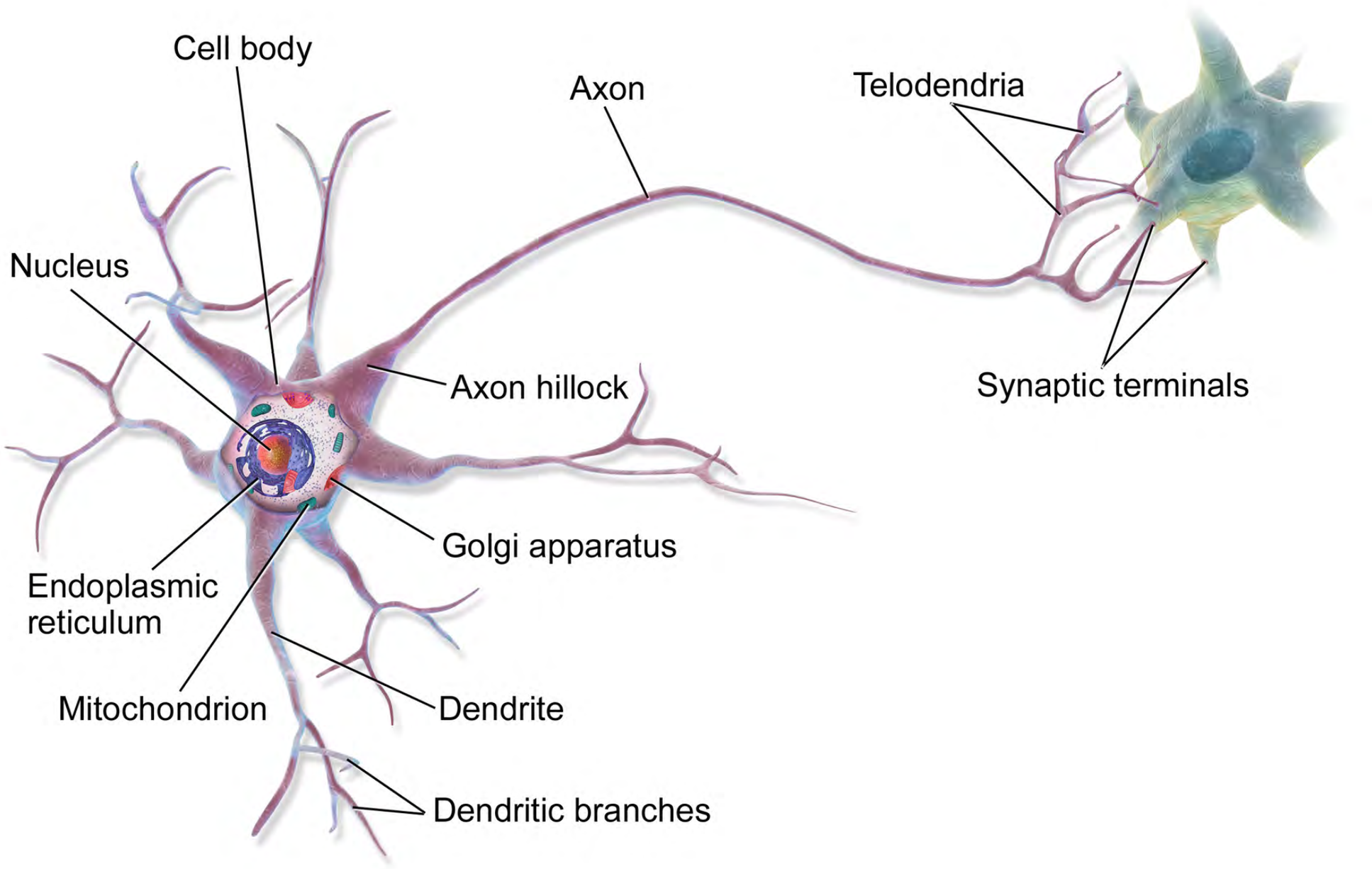
MOST ENERGY/TIME CONSUMING PROCESS

NEUROMORPHIC COMPUTING

BEYOND VON NEUMANN



HOW DOES A NEURON WORKS?



HOW DOES A NEURON WORKS?

HOW DOES A NEURON WORKS?

HOW DOES AN ARTIFICIAL NEURON WORKS?

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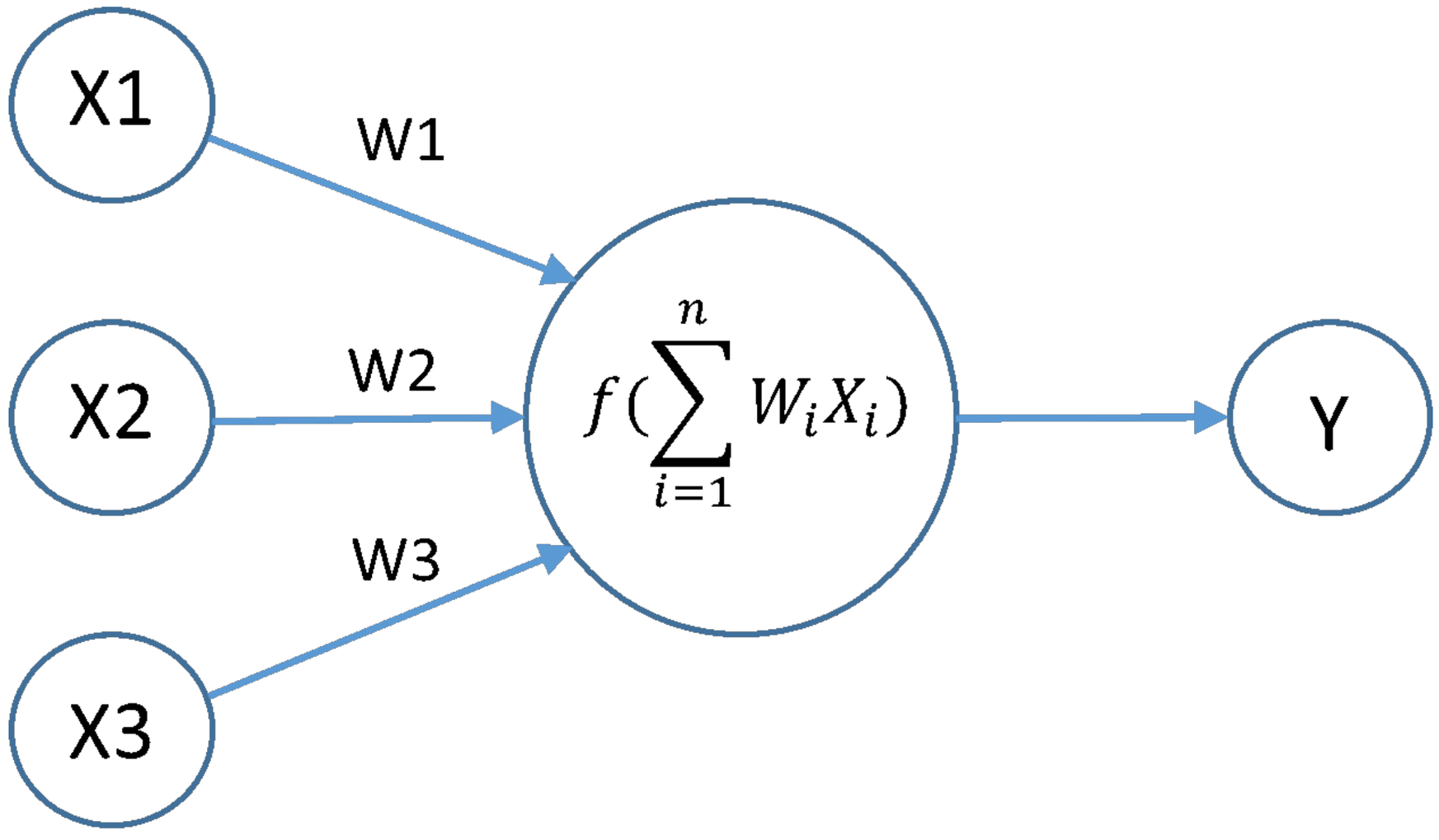

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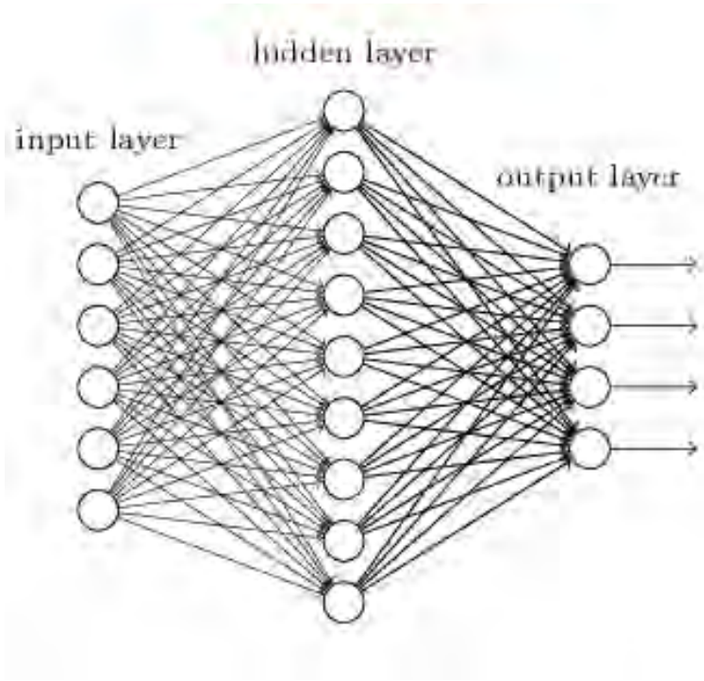
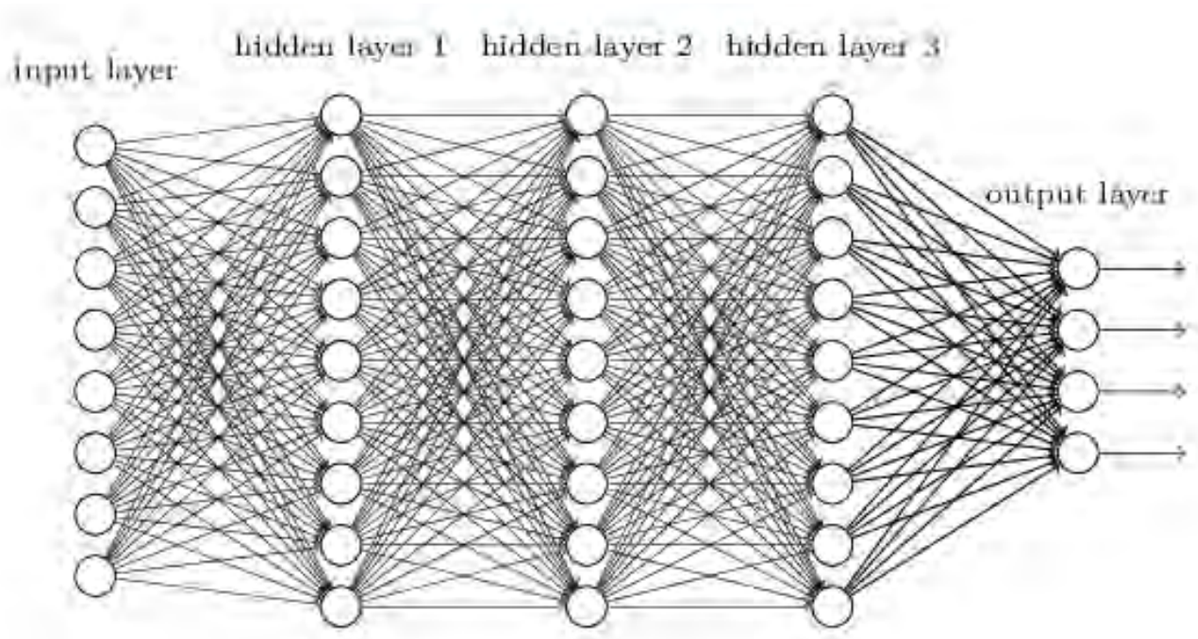
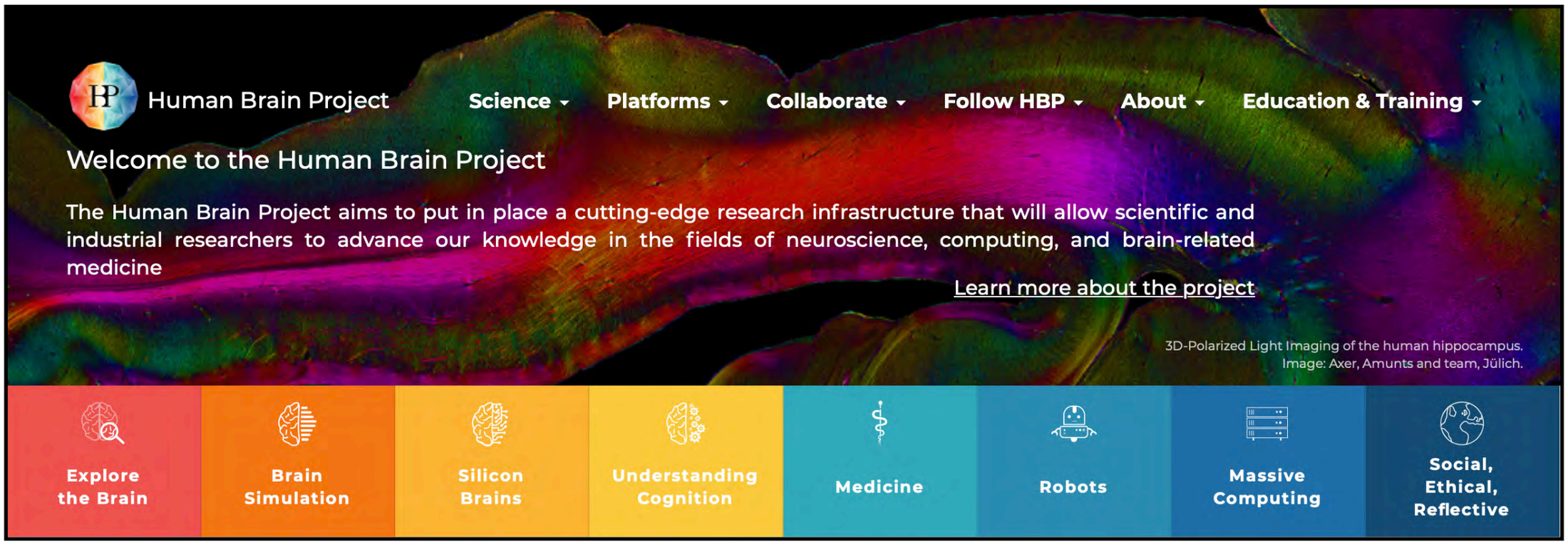




EU FLAGSHIP + ERC PROJECTS



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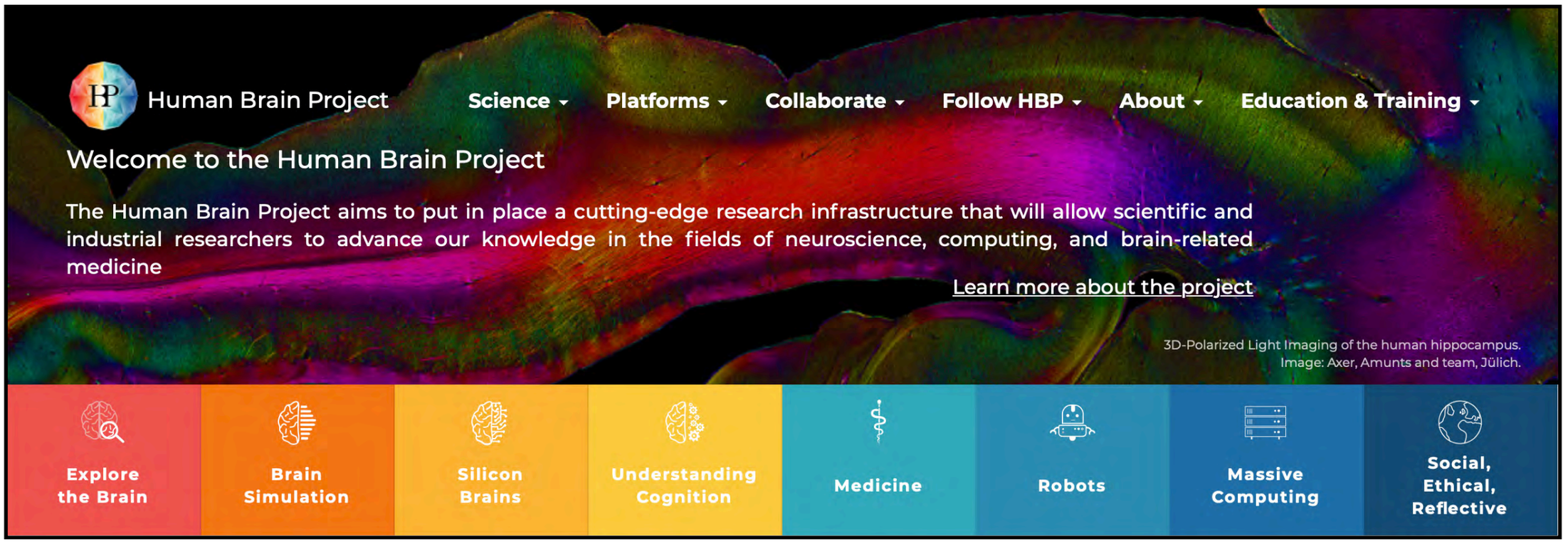

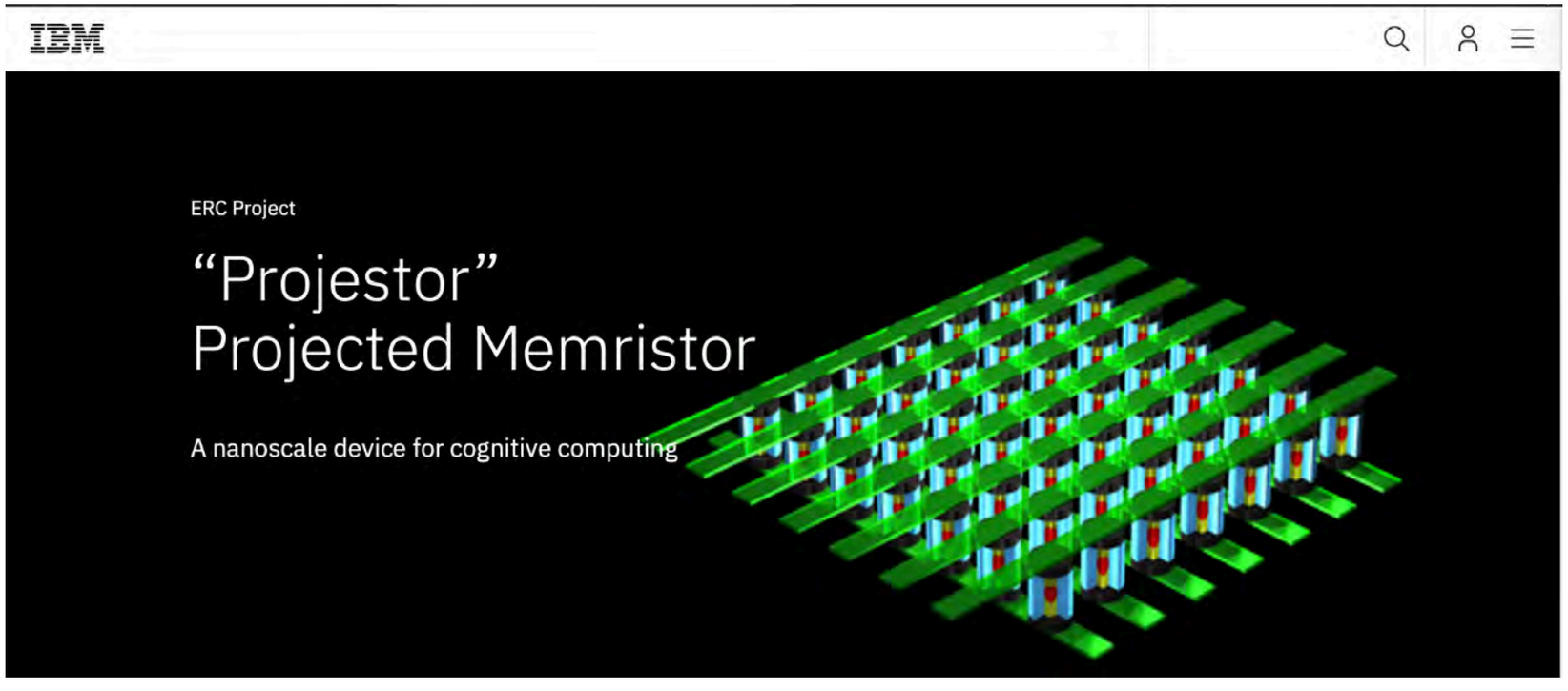

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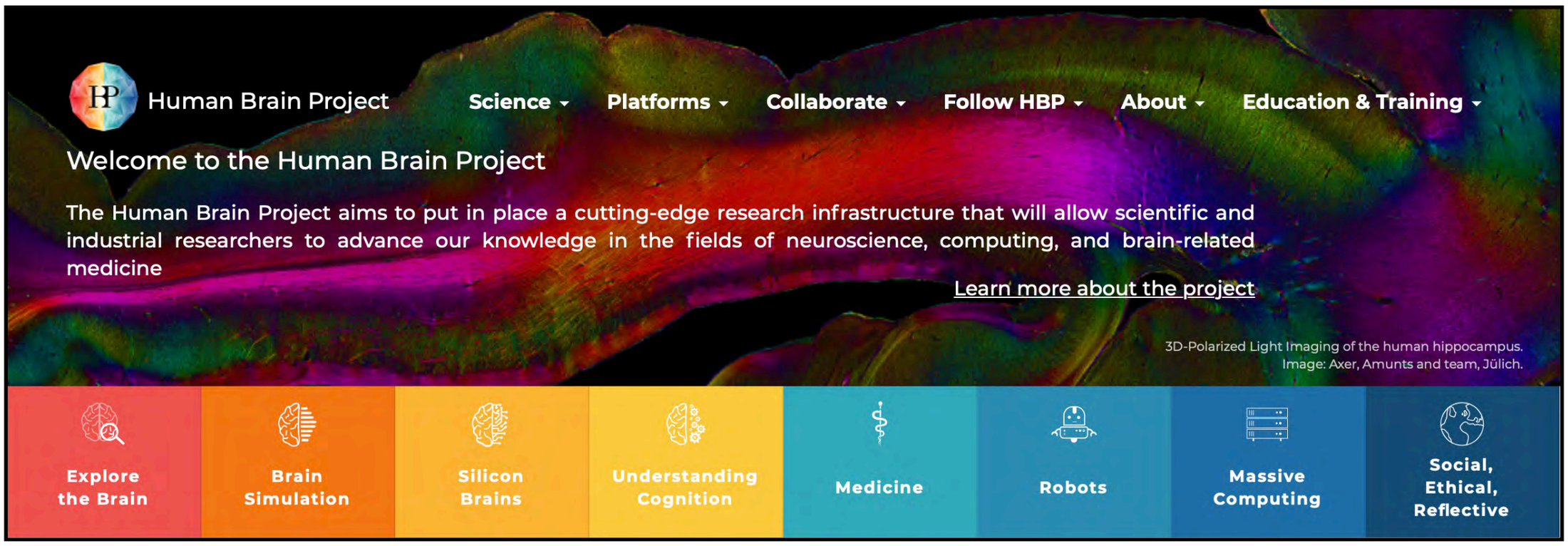


Damien Querlioz Research

NANOINFER ERC project

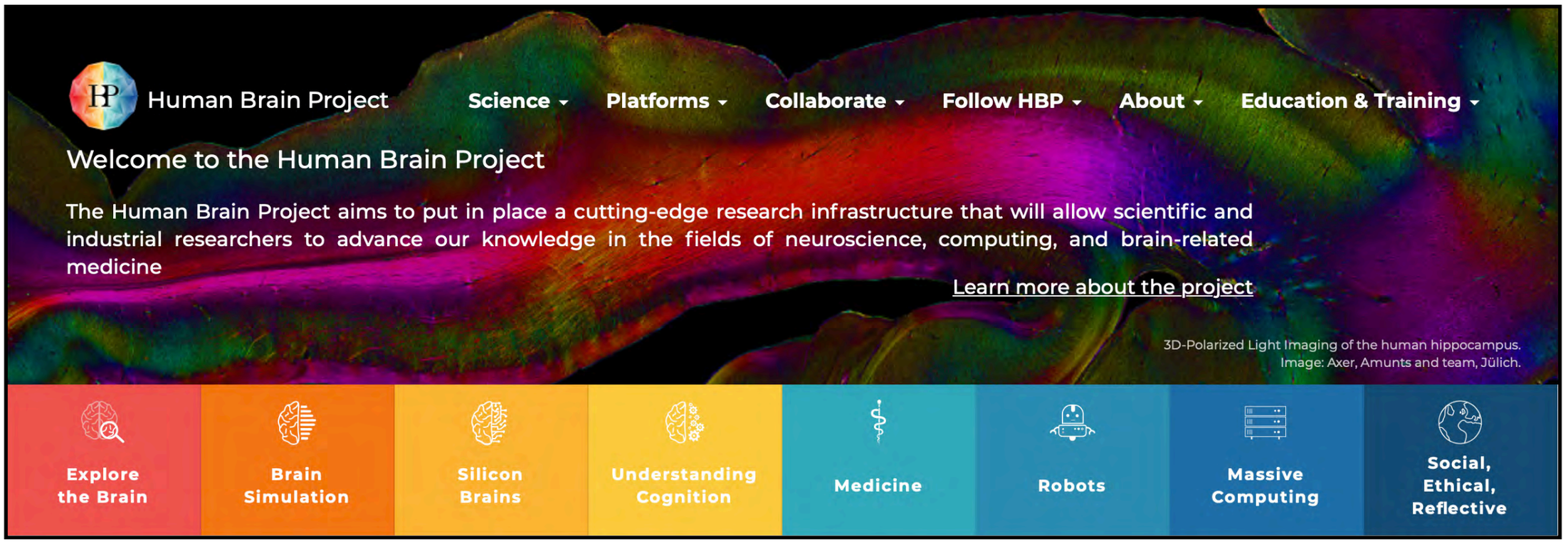
The Project

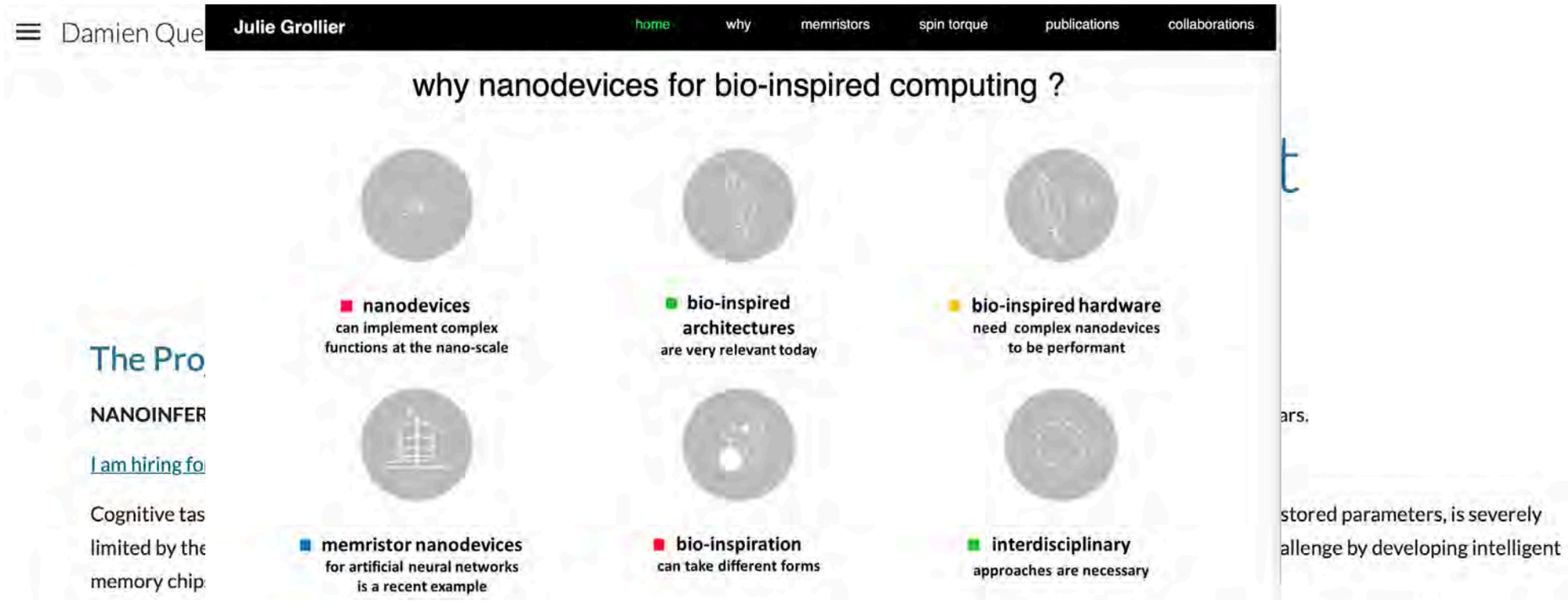
NANOINFER is my newest project! It started in 2017 and is funded by a European Research Council Starting Grant for a duration of 5 years.

I am hiring for this exciting project

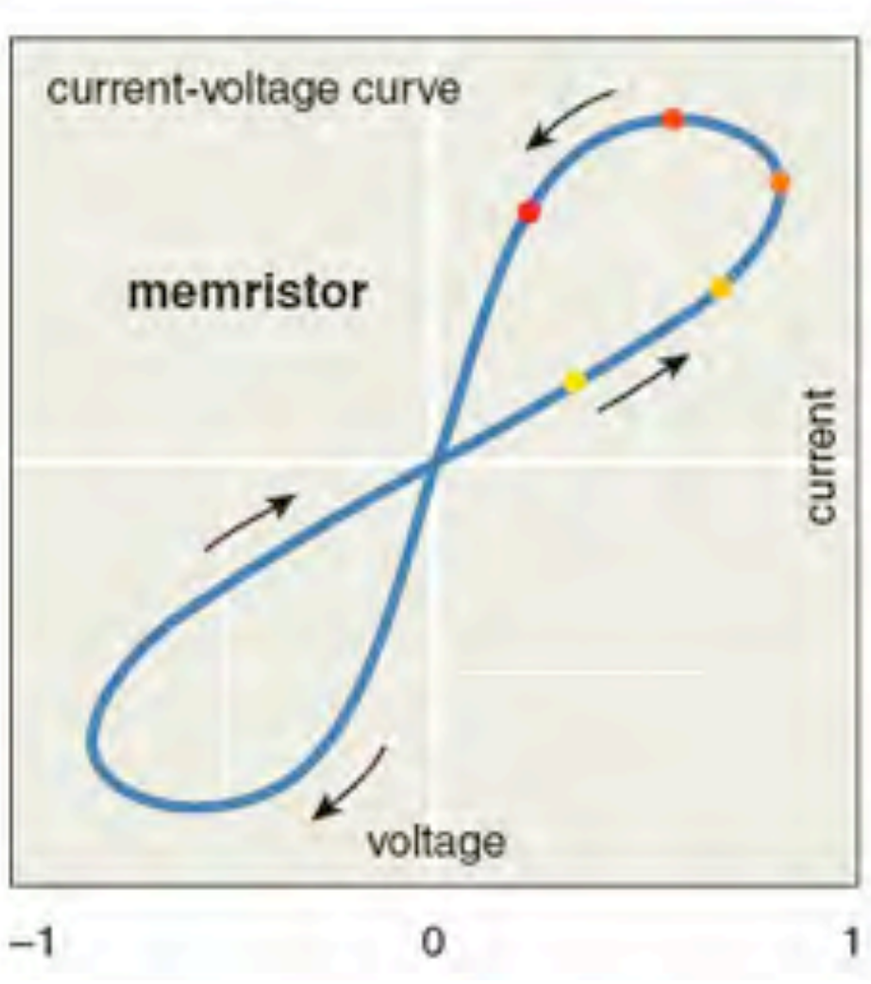
Cognitive tasks are increasingly necessary in modern electronics. The energy efficiency of associated algorithms, which rely on abundant stored parameters, is severely limited by the separation of computation and memory elements in conventional computers. In NANOINFER, I will directly address this challenge by developing intelligent memory chips that **natively perform both memory and computing functions**, using CMOS and emerging nanodevices.

EU FLAGSHIP + ERC PROJECTS



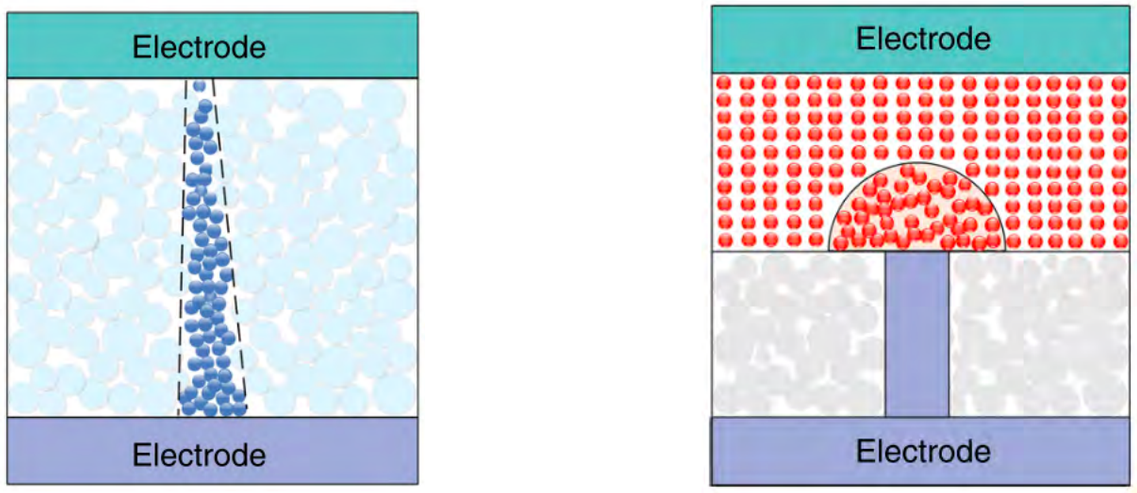


HOW?
(MOLECULAR) MEMRISTORS

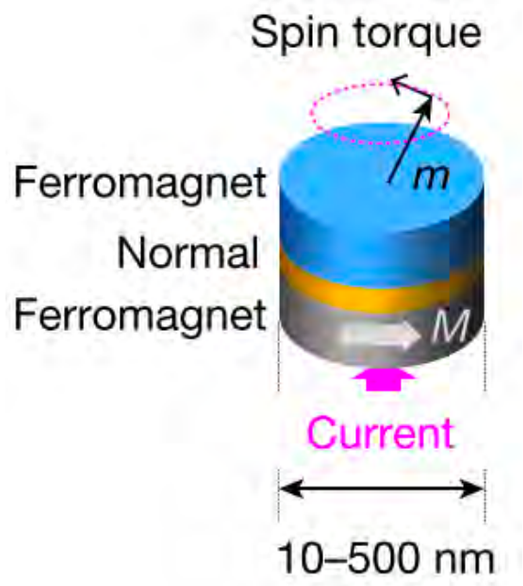


MEMRISTIVITY MECHANISMS

Solid-State



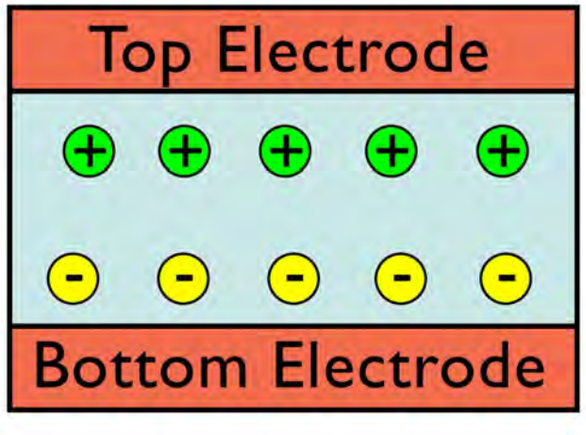
Yang et al. Nat. Comm. 2019



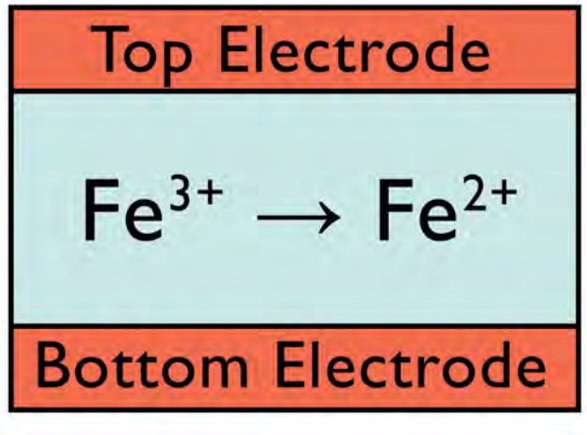
Grollier et al. Nature. 2017

Molecular

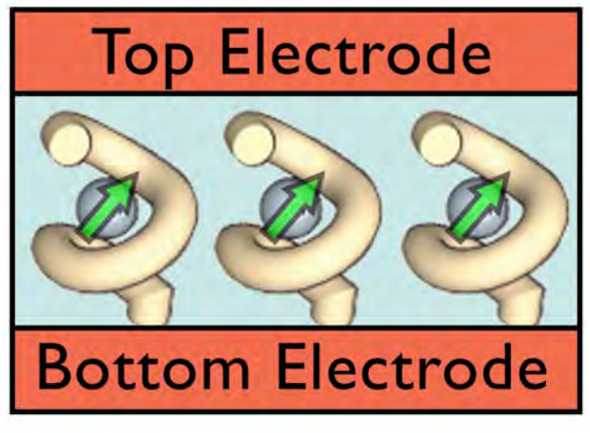
Ion Migration



Redox-active



Magnetism



CISS EFFECT

nature COMMUNICATIONS

Article | OPEN | Published: 06 August 2013

A chiral-based magnetic memory device without a permanent magnet

Oren Ben Dor, Shira Yochelis, Shinto P. Mathew, Ron Naaman & Yossi Paltiel

nature COMMUNICATIONS

Article | OPEN | Published: 23 February 2017

Magnetization switching in ferromagnets by adsorbed chiral molecules without current or external magnetic field

Oren Ben Dor, Shira Yochelis, Anna Radko, Kiran Vankayala, Eyal Capua, Amir Capua, See-Hun Yang, Lech Tomasz Baczewski, Stuart Stephen Papworth Parkin, Ron Naaman & Yossi Paltiel

COMMUNICATION

Molecular Spintronics

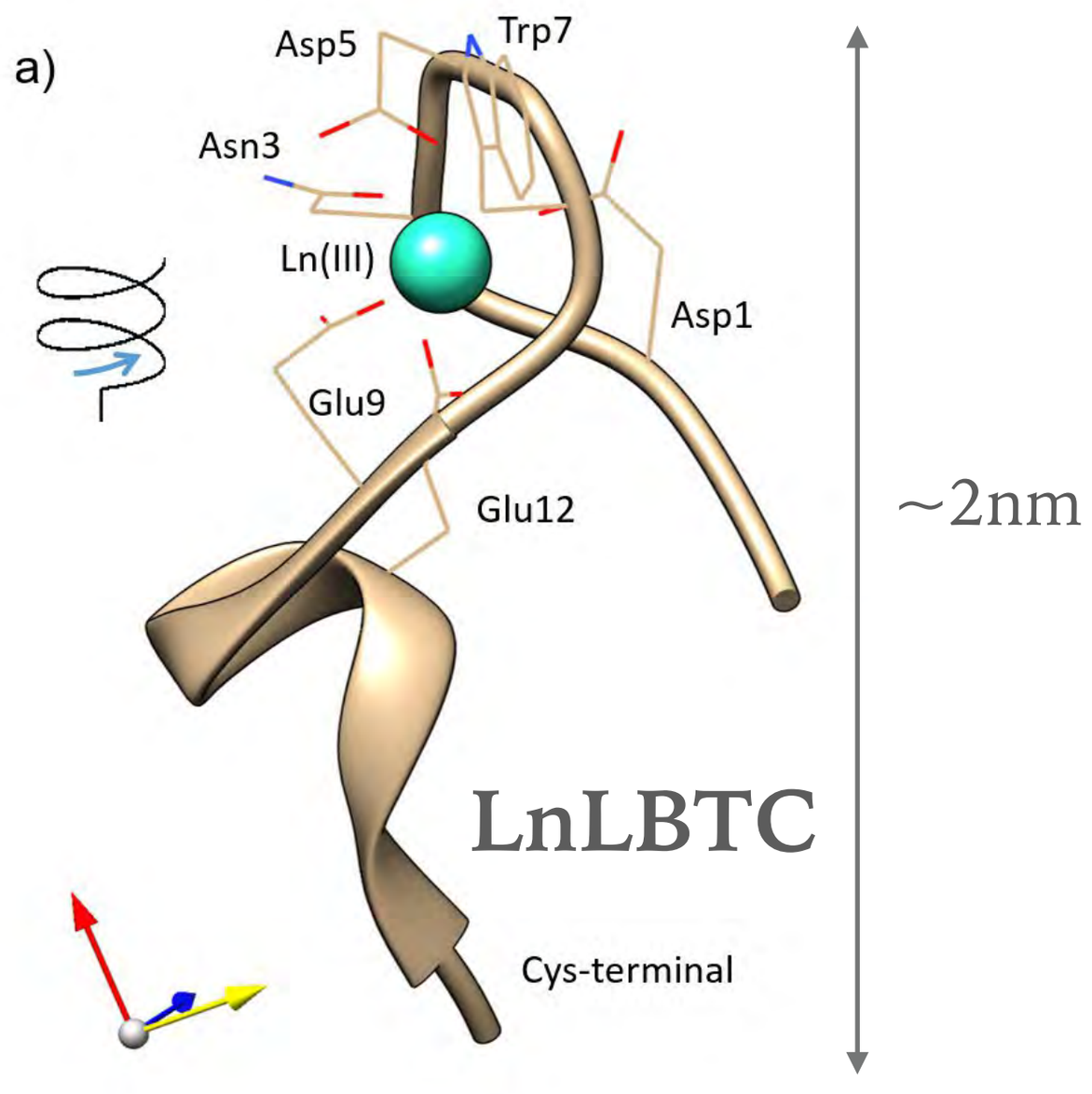
NANO · MICRO small

www.small-journal.com

Single Nanoparticle Magnetic Spin Memristor

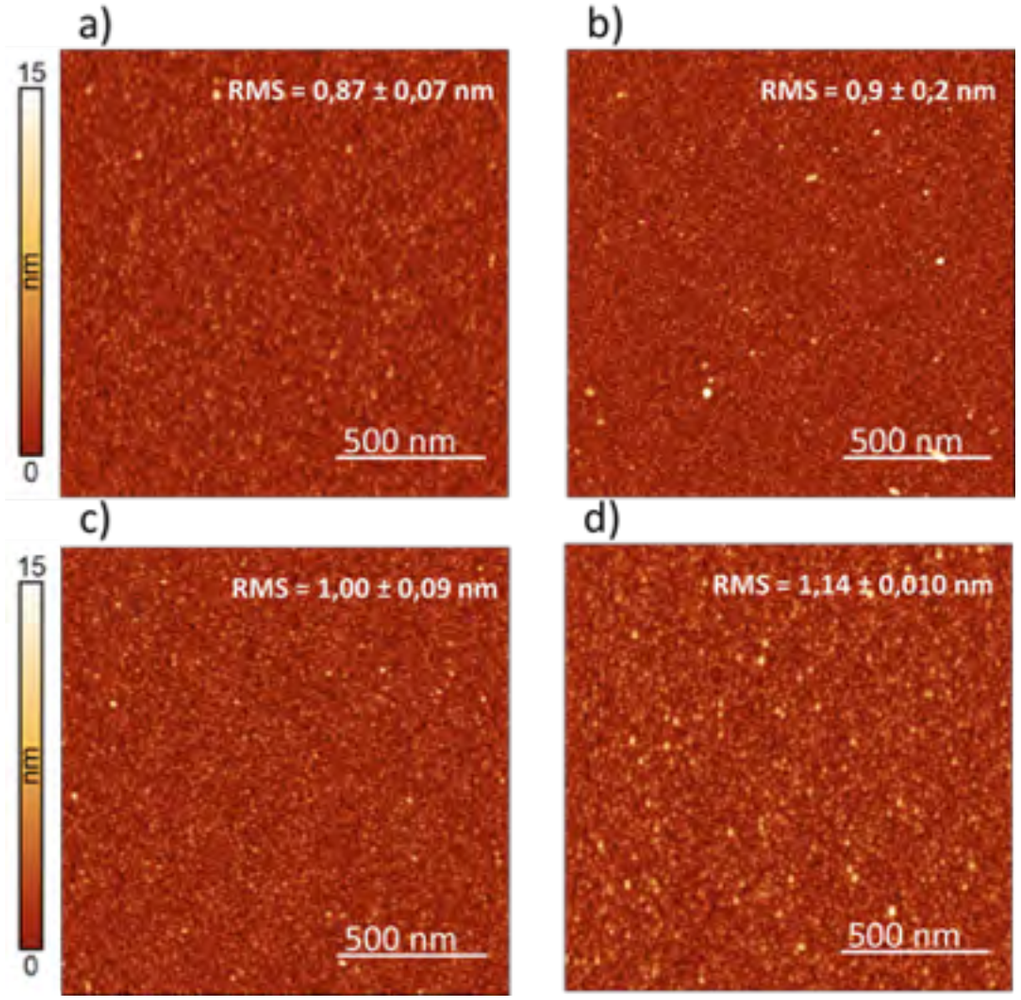
*Hammam Al-Bustami, Guy Koplovitz, Darinka Primc, Shira Yochelis, Eyal Capua, Danny Porath, Ron Naaman, and Yossi Paltiel**

CISS EFFECT + PARAMAGNETIC ION = MAGNETORESISTANCE?

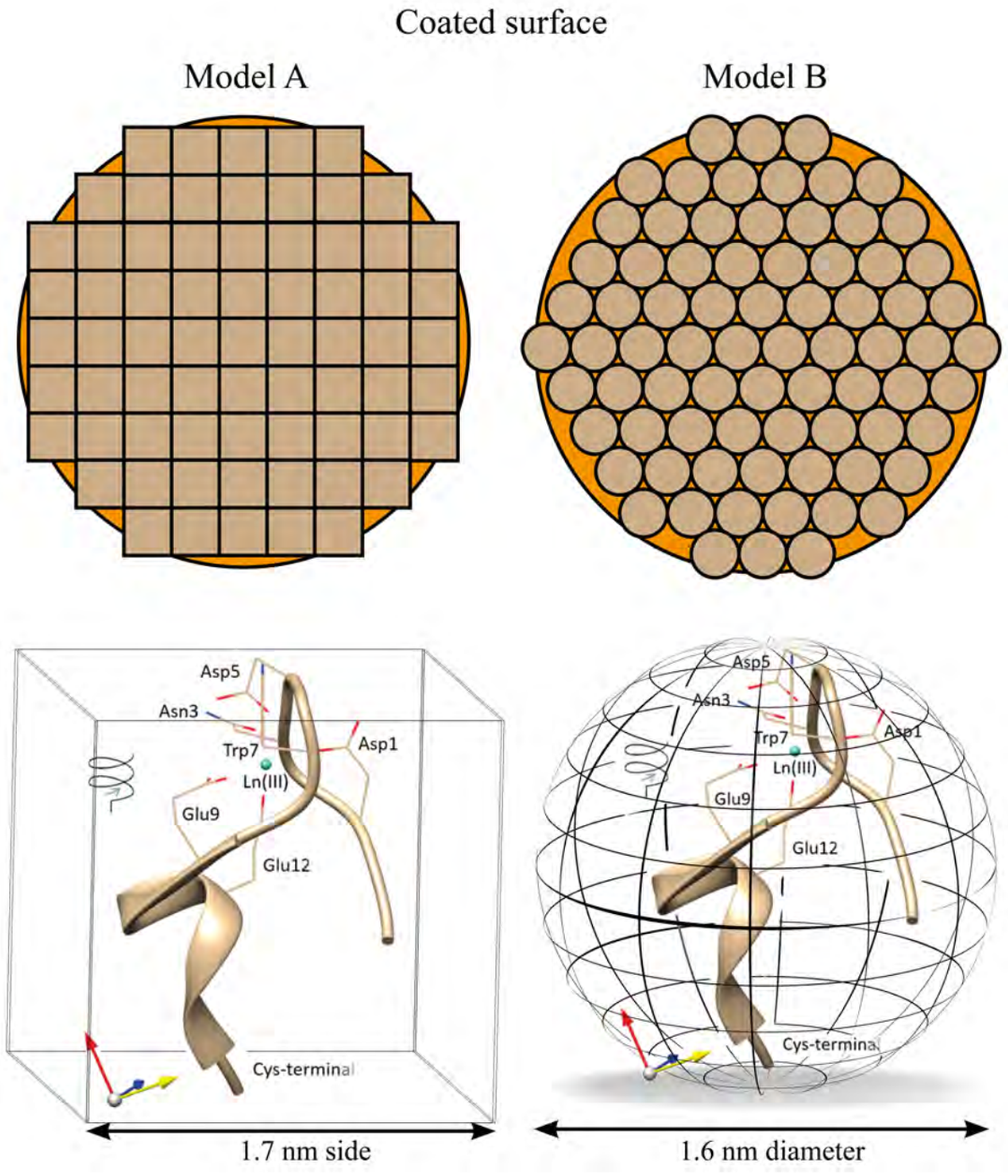


SAMs ASSEMBLY

Coverage >90%

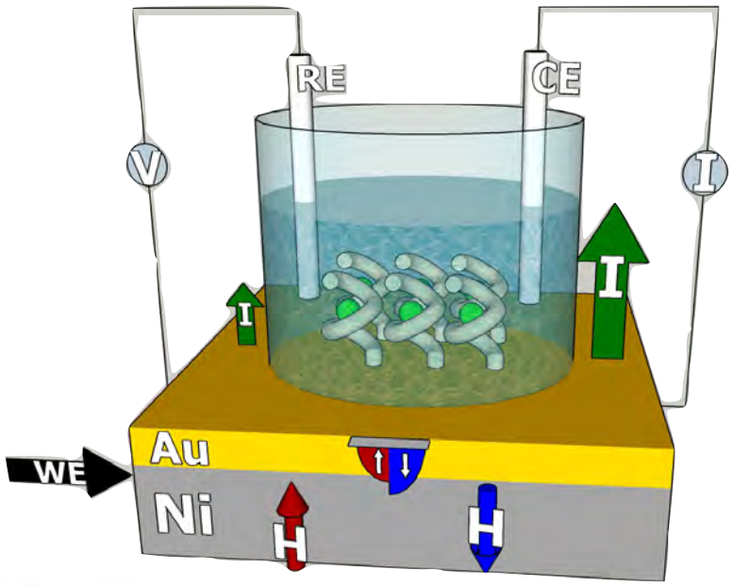


(a-d) Atomic force microscopy images of a Ni@Au surfaces incubated overnight in buffer solution



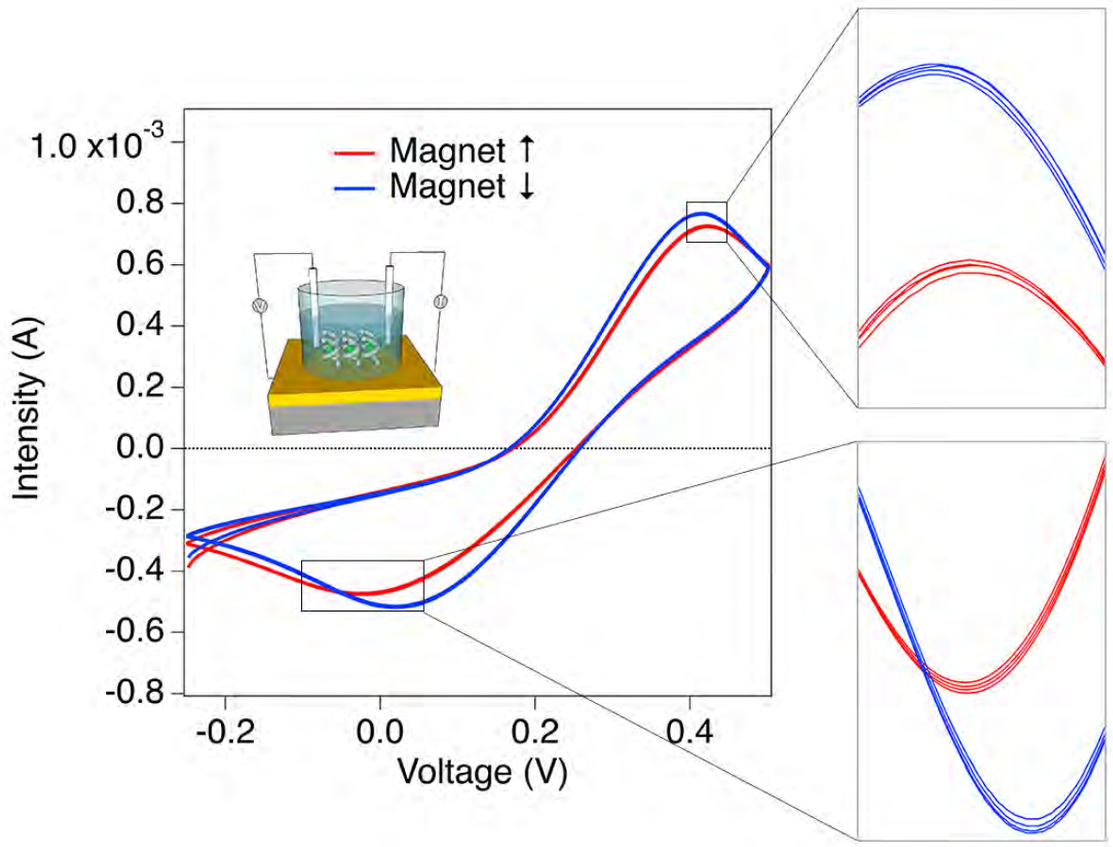
Torres-Cavanillas, R. et al. preprint:arXiv:1905.09225v1, **2019**, *Submitted*.

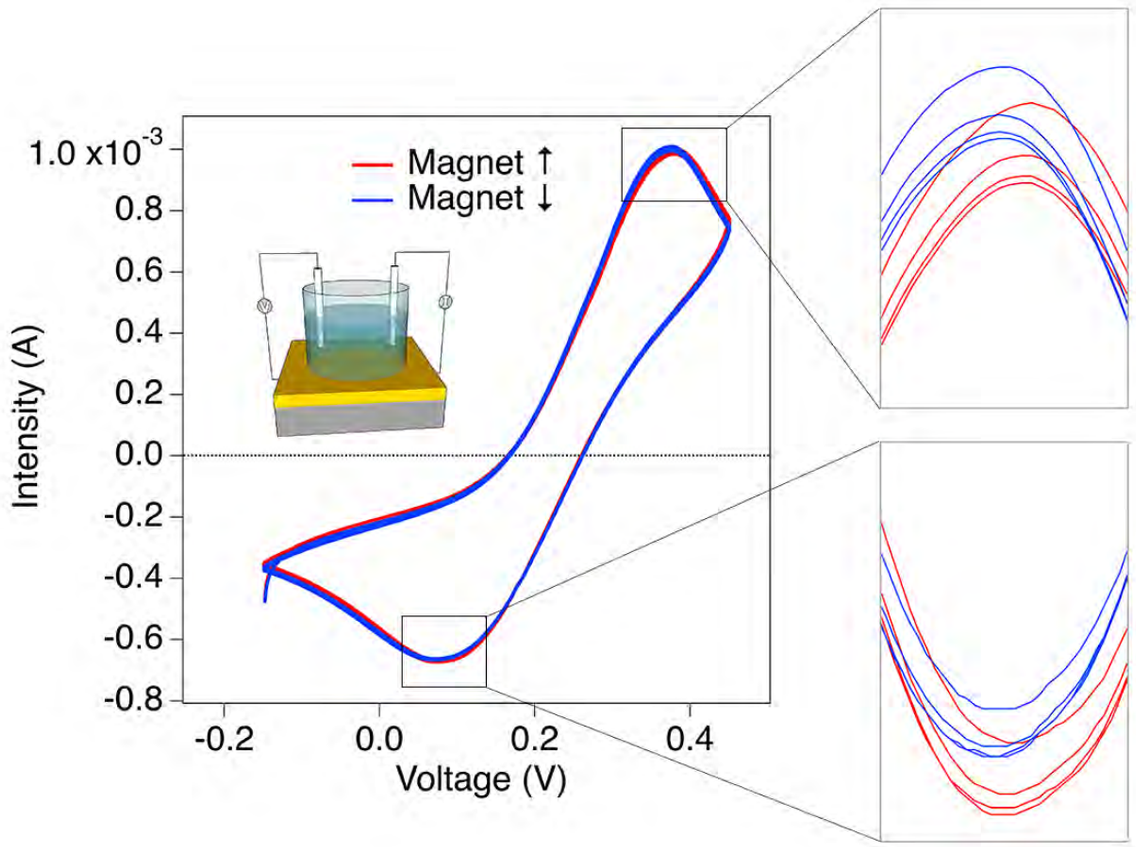
ELECTROCHEMISTRY



Obtained Spin Polarization

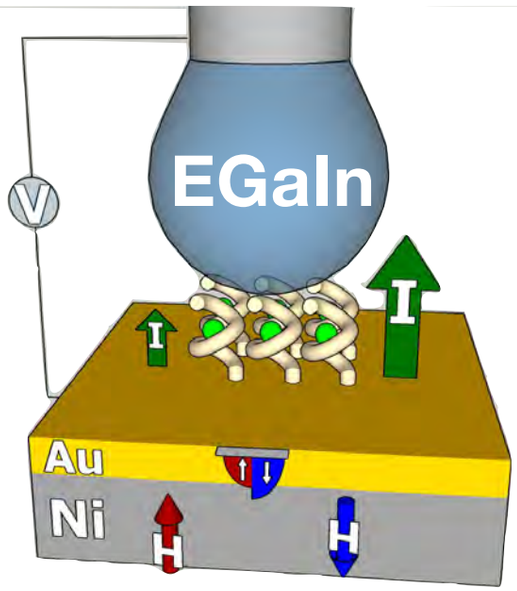
(TbLBTC)SP ~5%





Torres-Cavanillas, R. et al. preprint:arXiv:1905.09225v1, **2019**, *Submitted*.

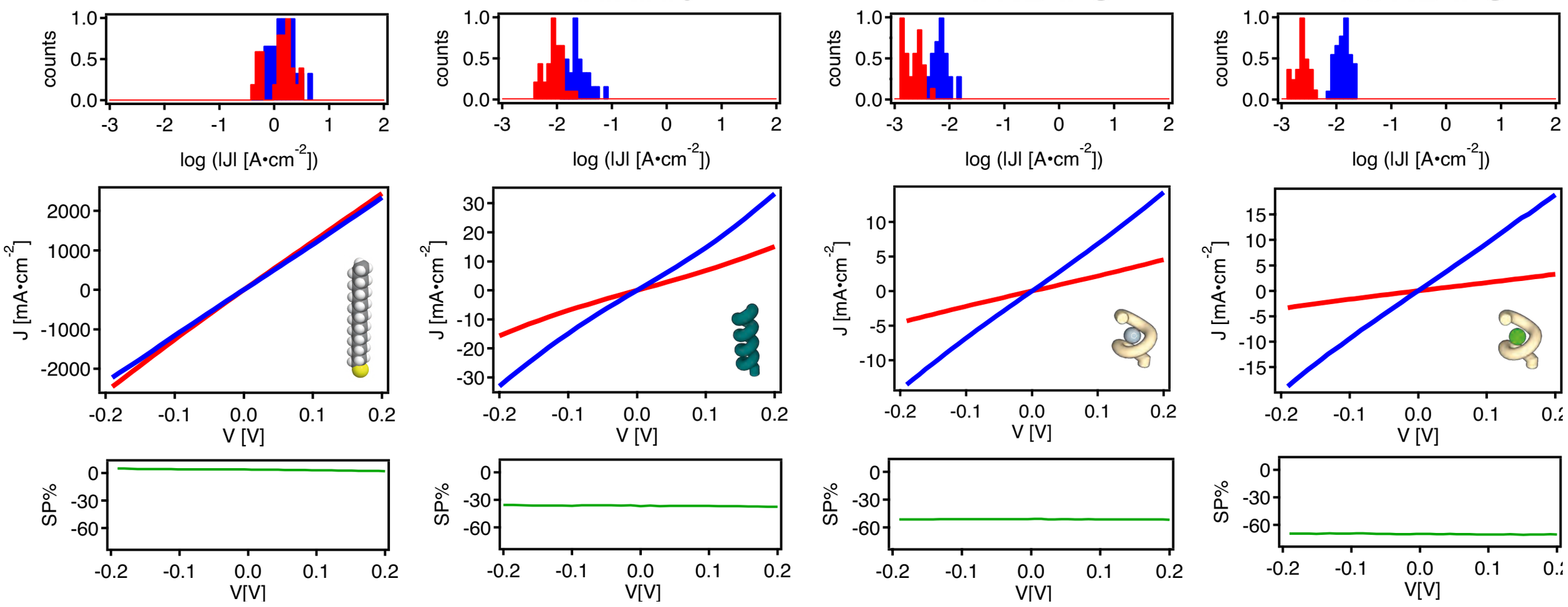
EGaIn SPIN POLARIZATION



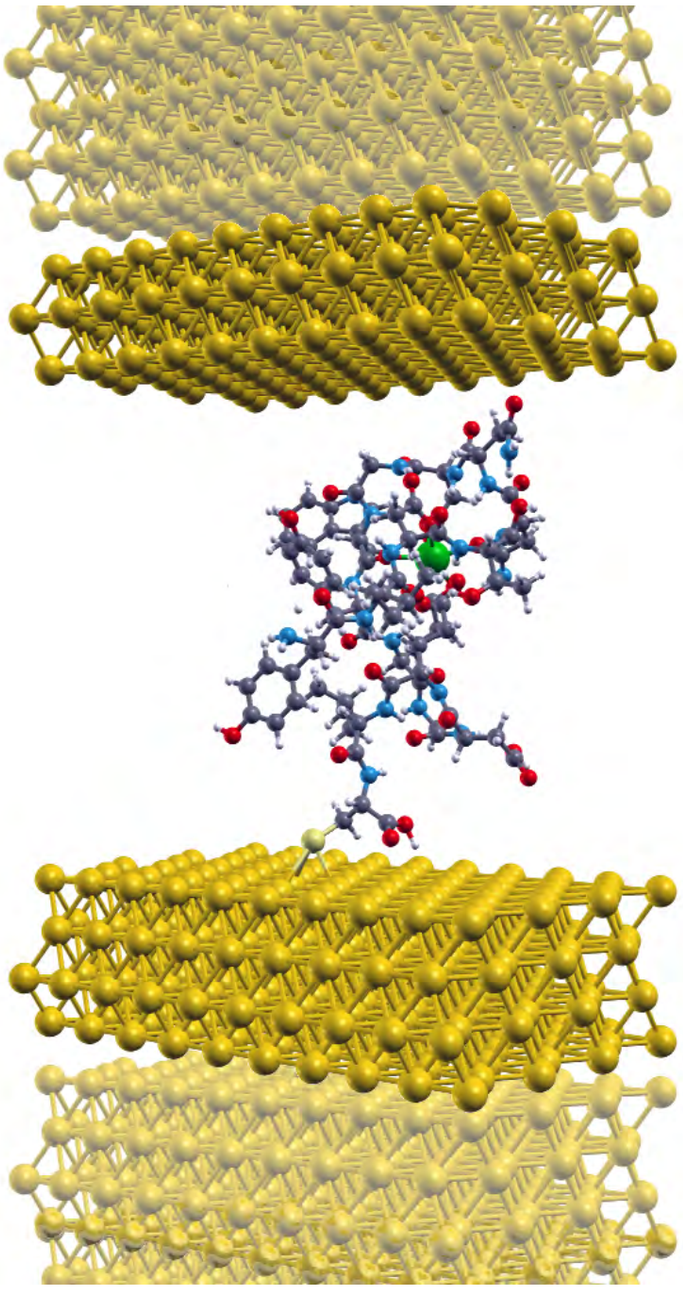
Obtained Spin Polarization

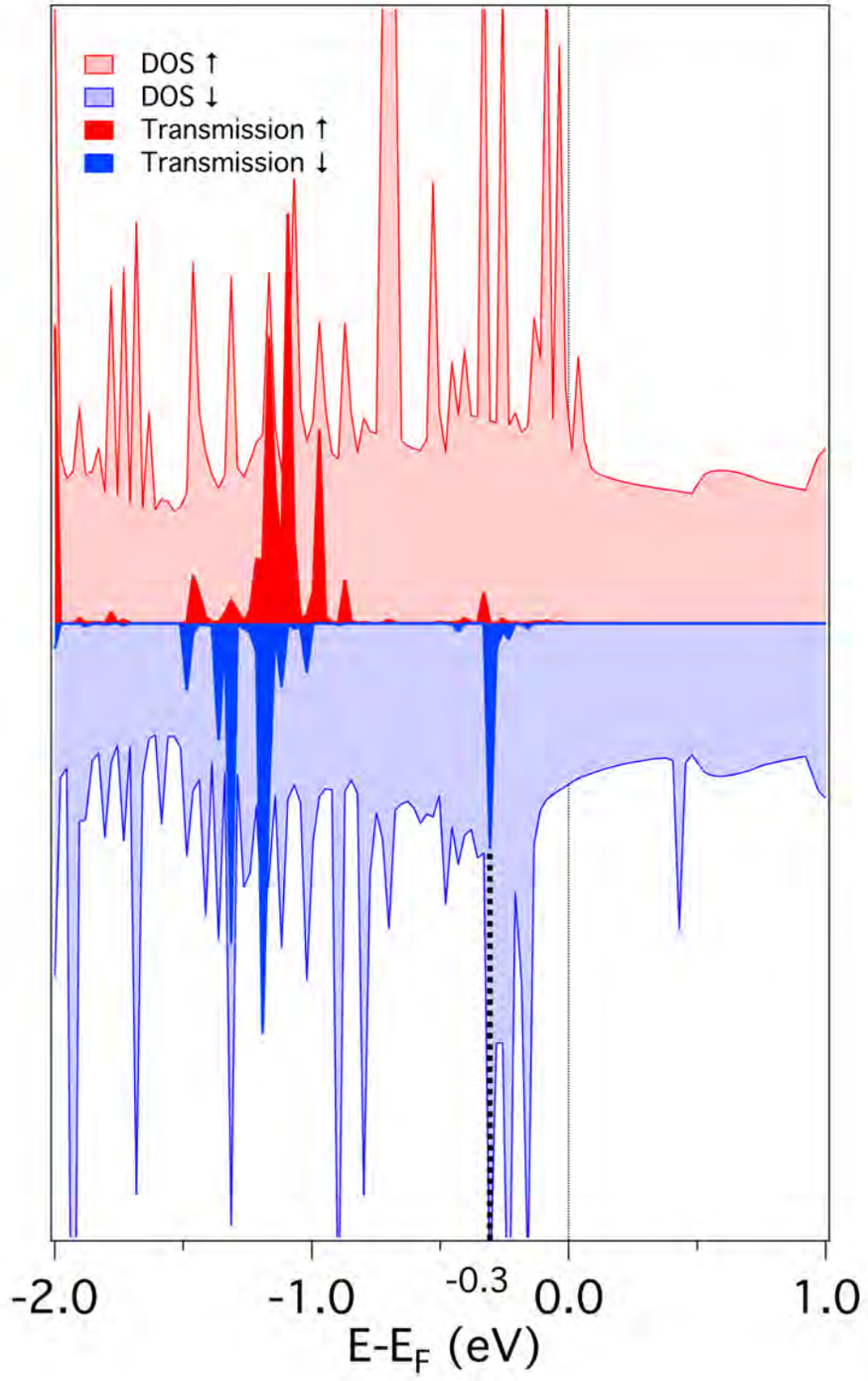
(TbLBTC)SP ~70%

a) C18 b) ALA8 c) YLBTC d) TbLBTC

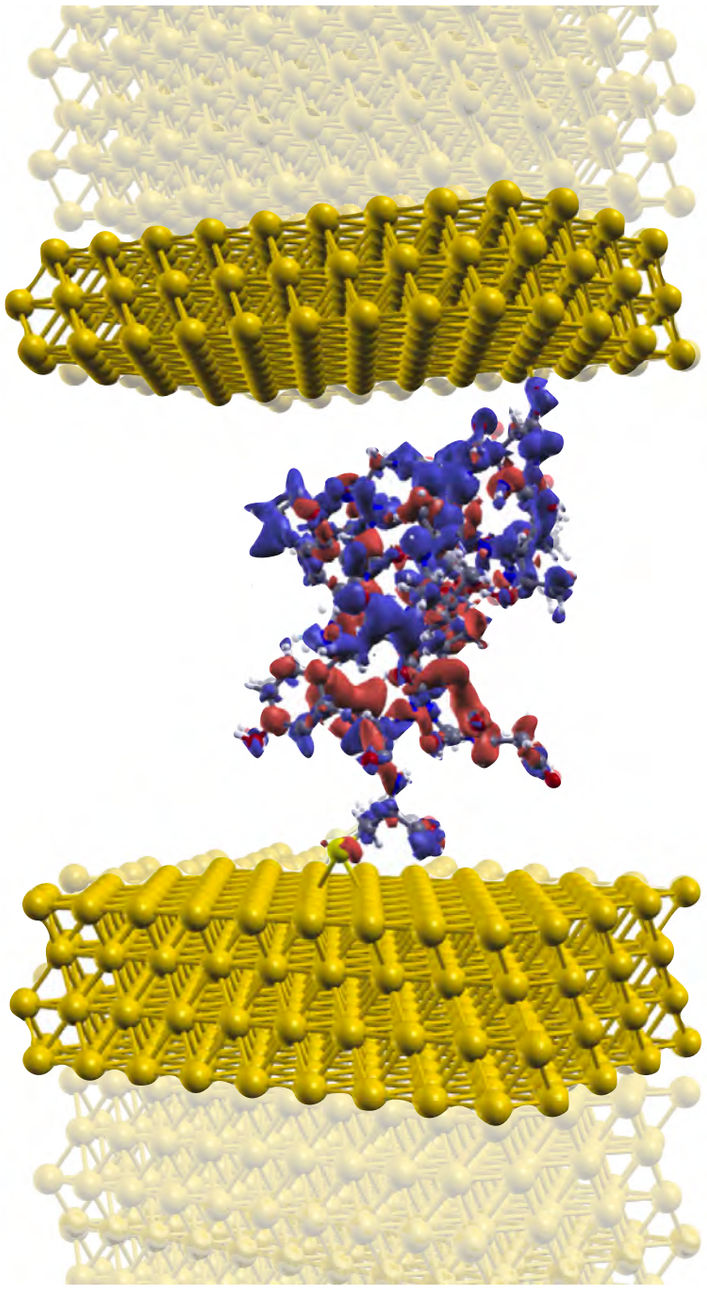


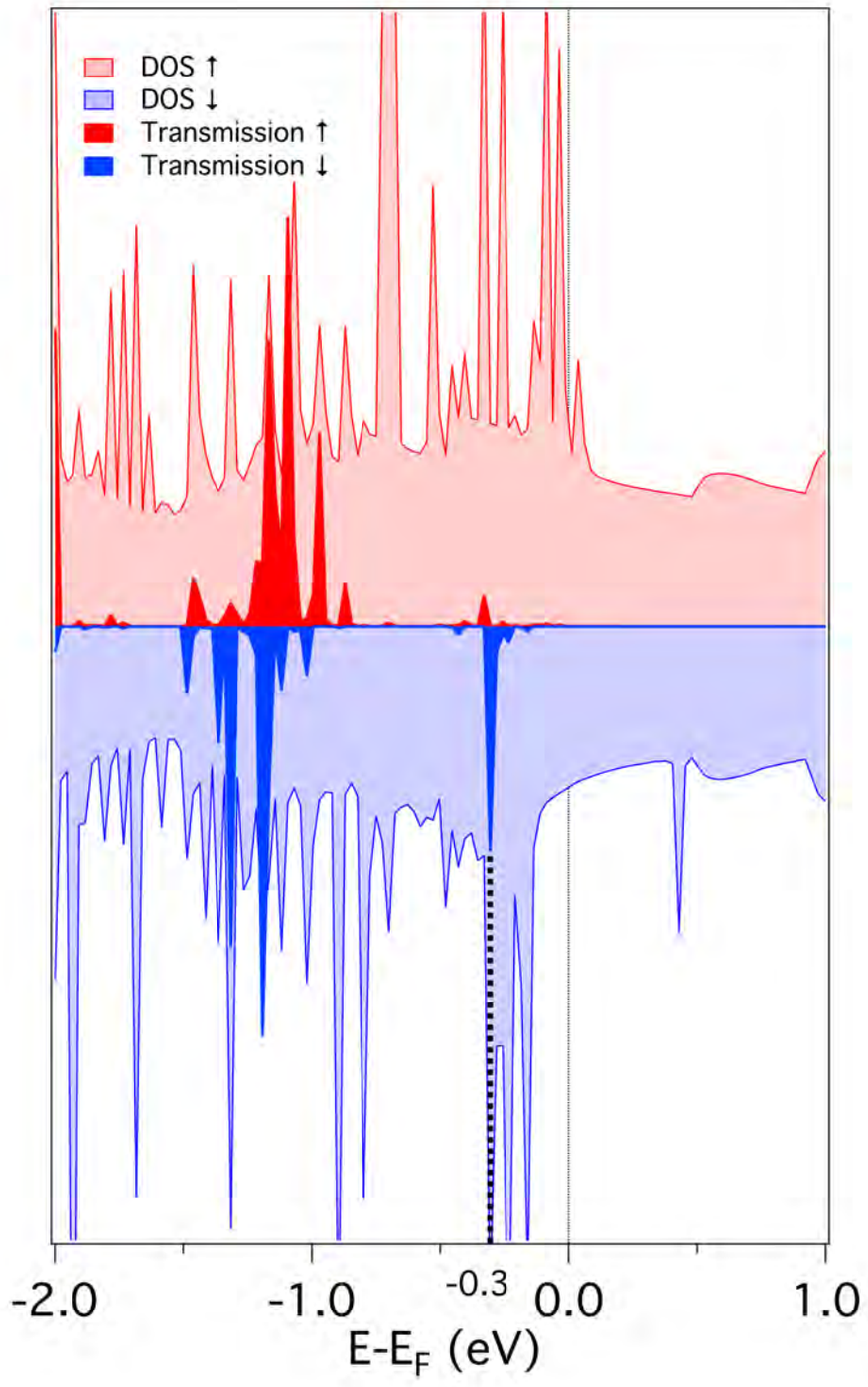
TRANSPORT PROPERTIES





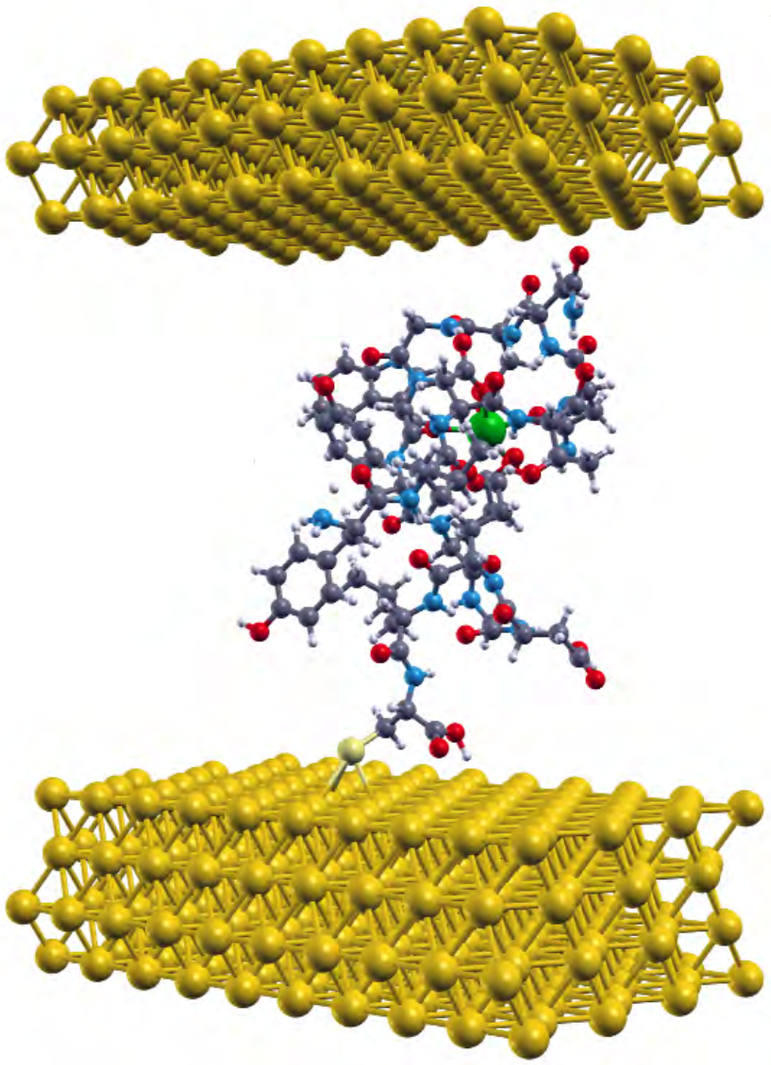
TRANSPORT PROPERTIES



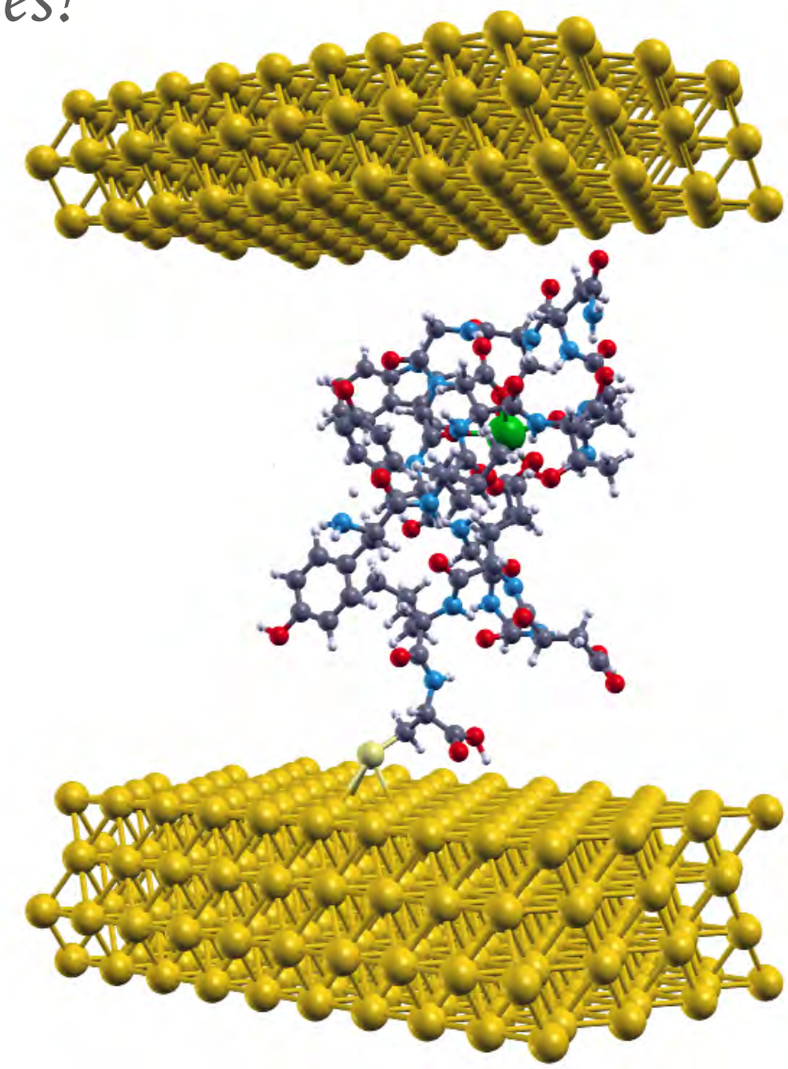


CAN THIS BE RELATED WITH MEMRISTIVE BEHAVIOR?

Think about time scales!



Slow pulsed measurements



Fast pulsed measurements

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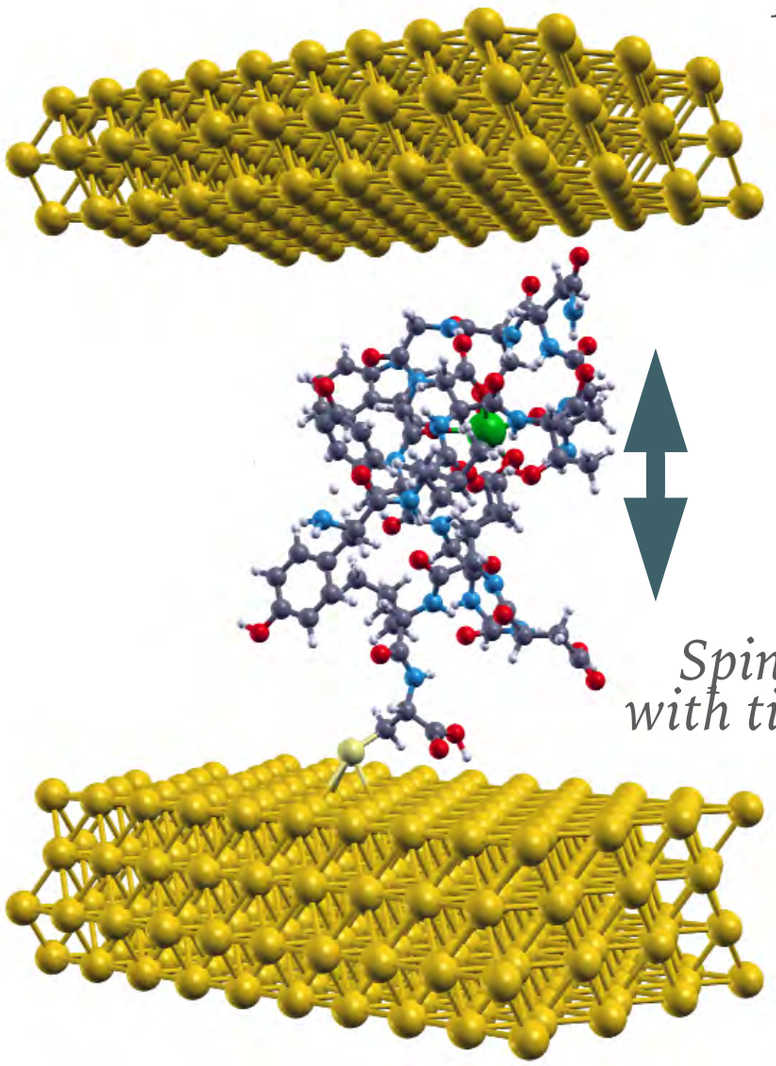
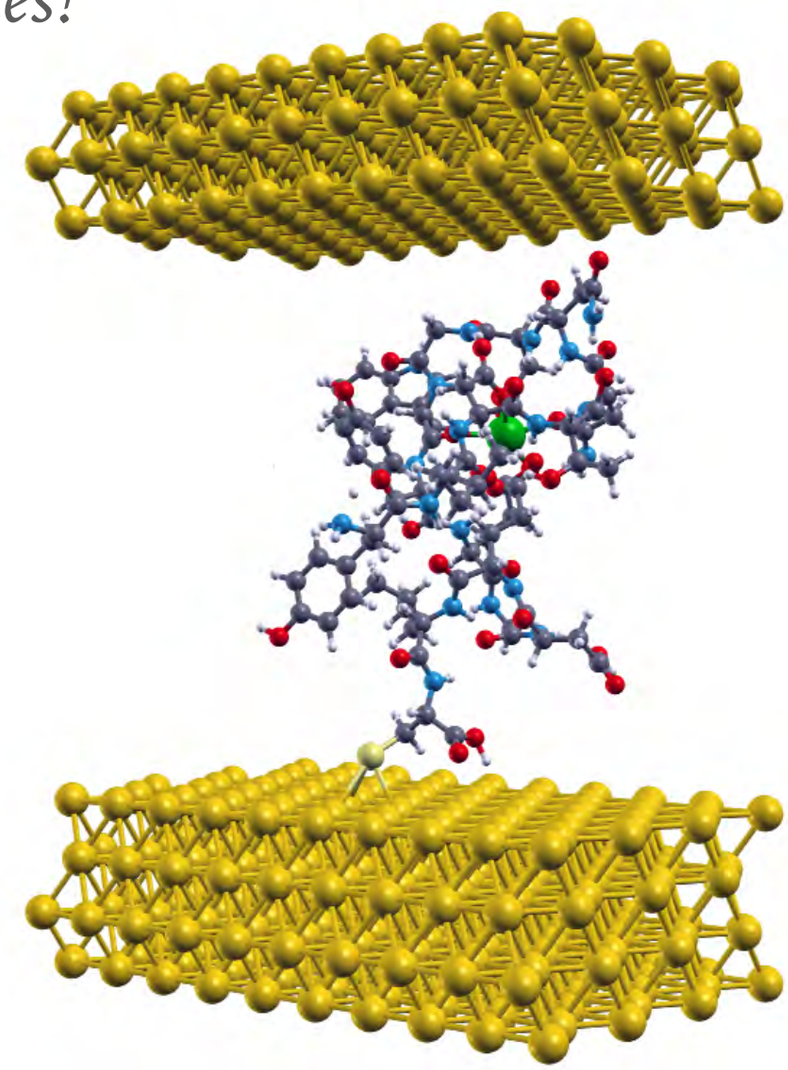


Spin is oriented by current with time enough to follow AC

Slow pulsed measurements



Fast pulsed measurements

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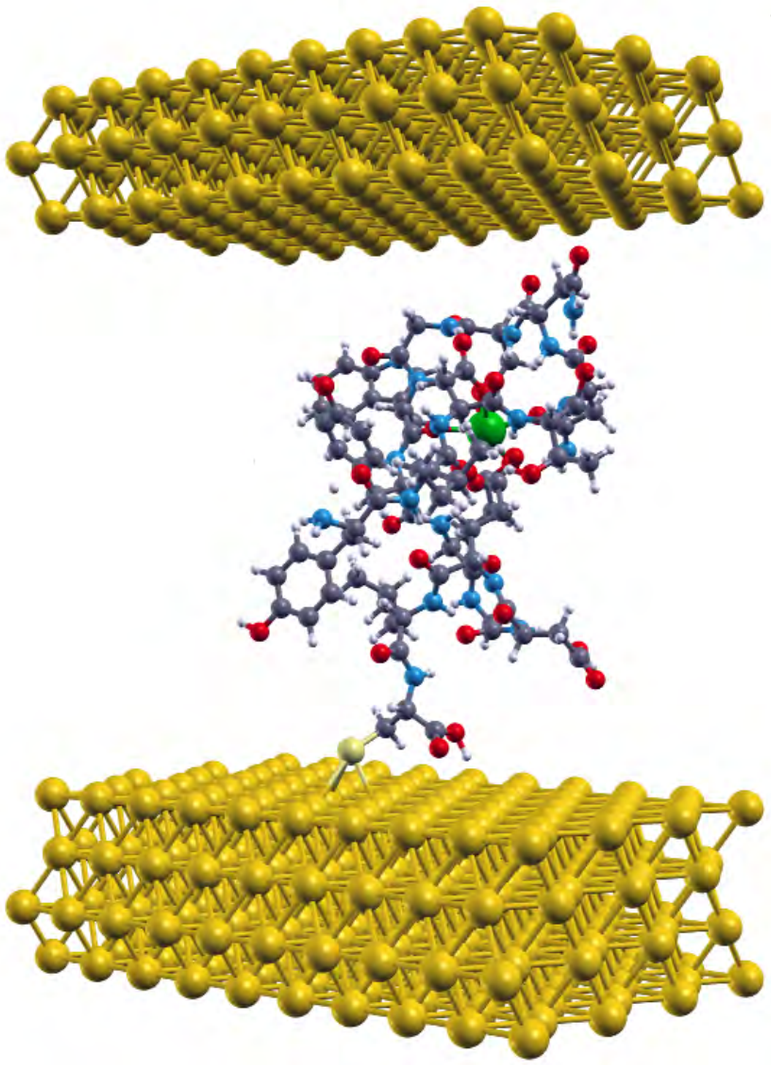
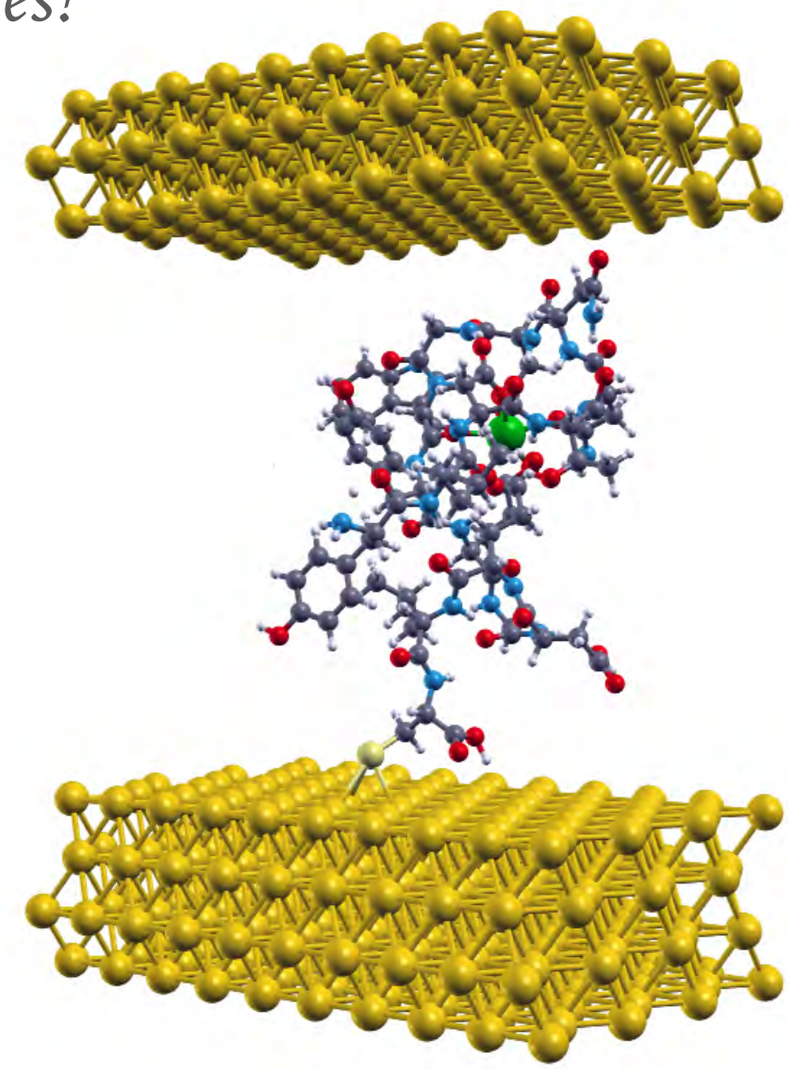


Slow pulsed measurements



Fast pulsed measurements

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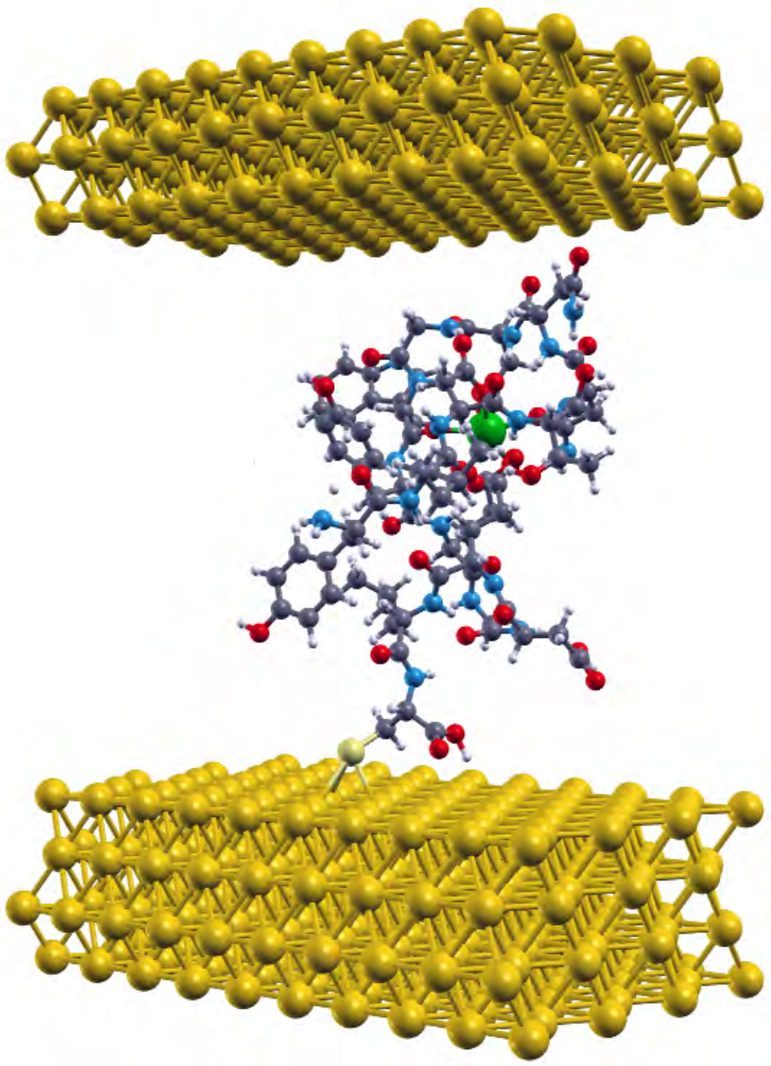
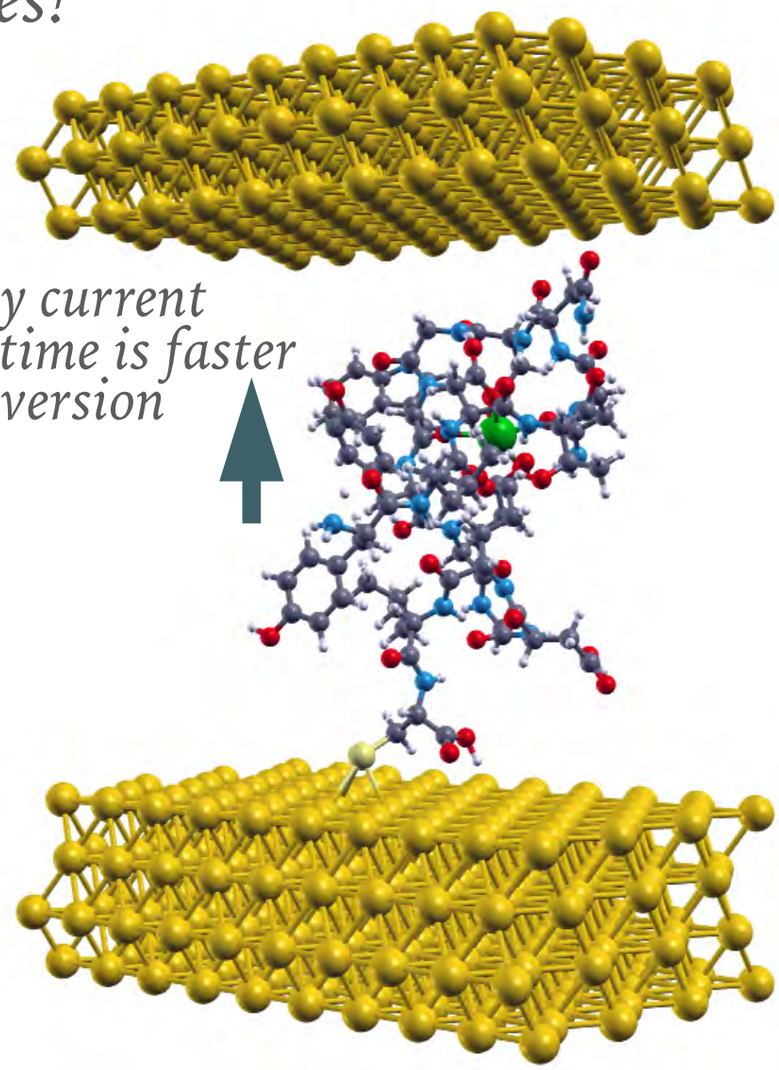


Slow pulsed measurements

Spin is oriented by current but the measurement time is faster than the spin inversion



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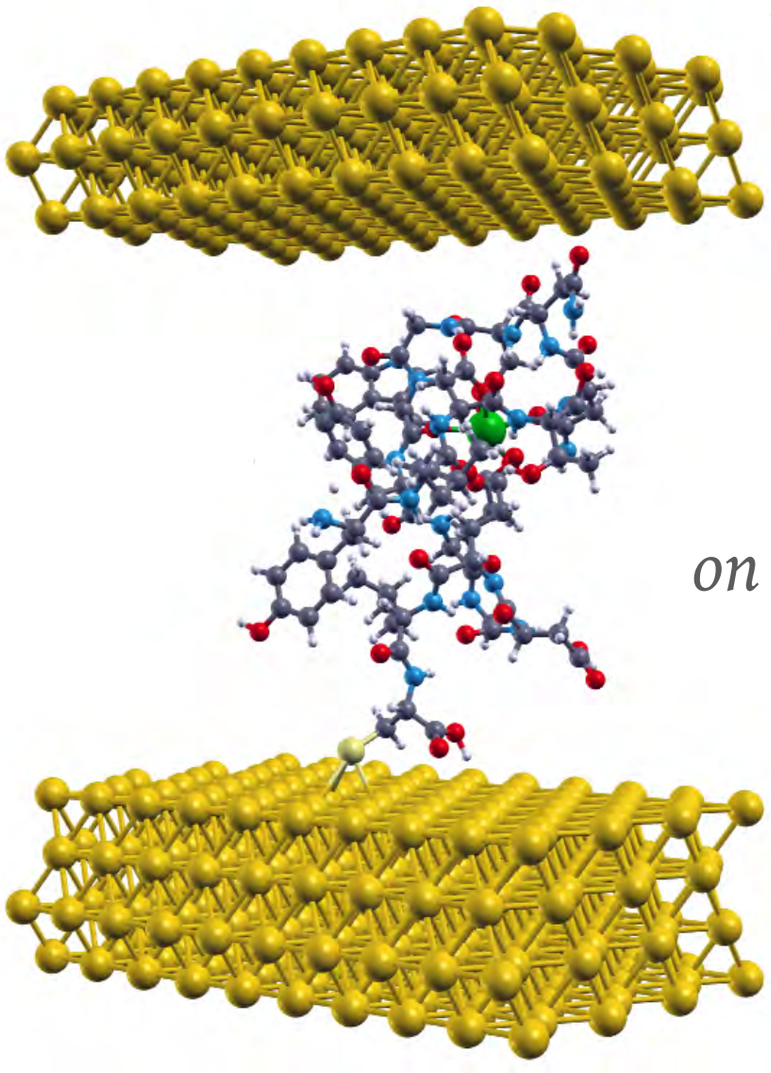
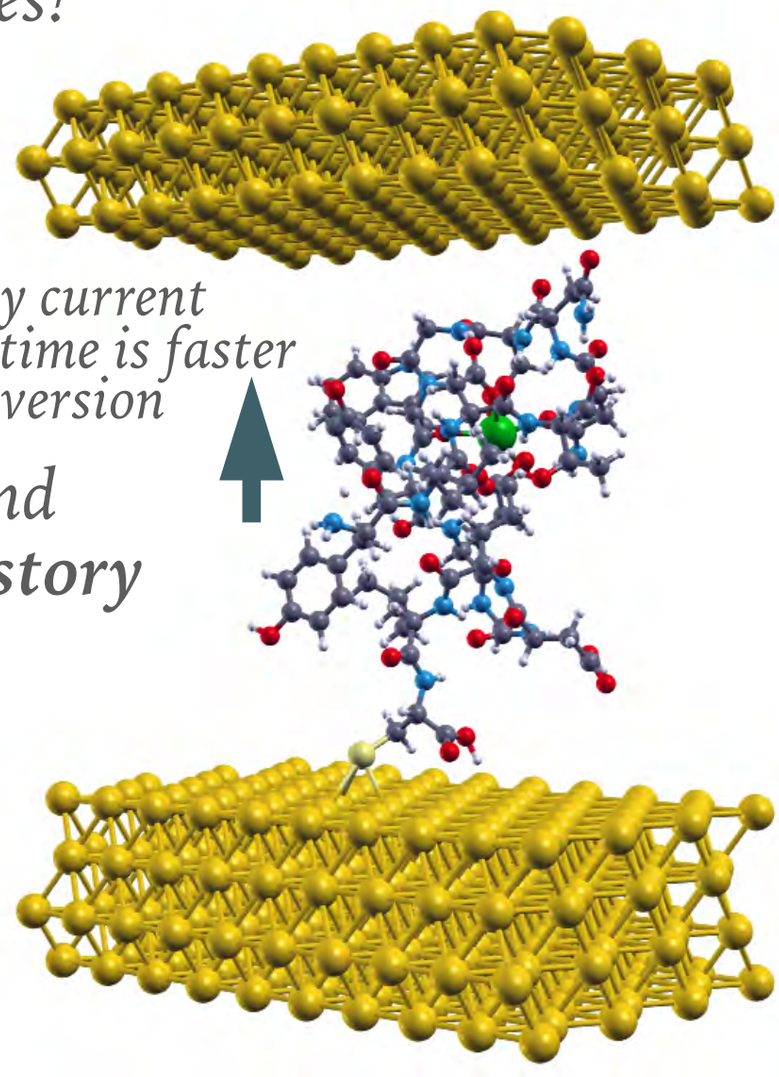


Slow pulsed measurements

Spin is oriented by current but the measurement time is faster than the spin inversion

*Intensity would depend on **previous voltage history***



Fast pulsed measurements

Torres-Cavanillas, R. et al. preprint:arXiv:1905.09225v1, **2019**, *Submitted*.

TAKE HOME MESSAGE

Spin-dependent transport calculations confirmed an **interaction** between the magnetic polarizations of the **current** and the **lanthanide** ion.

Since the sign of the magnetic polarization affects the total resistance, the **conductance** of the device effectively **depends on the applied voltage history**.

Next step: Performing elaborate measurements to **confirm memristive behavior** in our Ln-biomolecule.

ACKNOWLEDGEMENTS

Eugenio Coronado

Alejandro Gaita-Ariño

Alicia Forment-Aliaga

Silvia Giménez-Santamarina

Lorena E. Rosaleny

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Institut de Ciència Molecular

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EXCELENCIA MARÍA DE MAEZTU