# ANDREA KOUTA DAGNINO

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## EDUCATION

**The Open University**                                                         2017-Present
*BSc (Honours) in Mathematics*

· Predicted degree classification: 1st class
· Relevant modules: Mathematical models and modelling (88%), Quantum mechanics (95%), Electromagnetism (100%), Fluid dynamics and mathematical methods, Deterministic and stochastic dynamics, Final year project.
· Will have completed 30 ECTS credits more than required from degree regulations.

**Deledda International School**                                                *2015-2021*
MYP, IB DP1 Chemistry SL, IB DP1 Theory of Knowledge

## RESEARCH/OUTREACH EXPERIENCE

**Final year project**                                                Starting in February 2022
*Research student*

· Topic to be confirmed, but main focus on quantum entanglement/quantum information.

**Topological quantum systems simulation ⍥**                          November 2022- present
*Independent*

· Computed properties such as the Berry connection, Chern number and band structure of quantum systems in Python, and applied it to study toy models such as the Haldane model.
· Analytically and numerically analyzed properties of chiral edge states in finite Chern insulators with varying boundary conditions.
· Bench marked my results against the existing literature with excellent agreement.
· Currently writing an expository essay on the Berry phase and its connection to the Quantum Hall effect (QHE) and Topological insulators, which includes plots made with my code.

**Summer research project ⍥**                                      May 2021 - September 2021
*Research student*

· Employed the QuSpin Python library to simulate finite quantum systems on lattices using both exact and approximate diagonalization techniques (e.g. block-diagonalization and Lanczos).
· Investigated the phase properties of extended Bose Hubbard models (EBHM) in one dimension.
· Identified two EBHMs which exhibit signatures of weak ergodicity breaking, and performed both numerical and analytical tests to probe for the presence of rare states in their spectrum.
· Operated the computing cluster at the School of Physical Sciences to perform intensive computational tasks.
· Authored a 50-page research report summarizing novel results from the project.

**Undergraduate research project (extension of summer project)**        October 2021 - present
*Research student*

· Further investigated the two-chain model introduced in my summer project, looking more closely at characterising the identified rare states.
· Currently planning on performing a perturbative analysis.

**Fisika lectures ▶**                                                    July 2020 - present
*Content creator*

· Produced more than 20 lecture videos on Linear algebra, Statistical mechanics and Special relativity.
· Total: 9.2k views

## WRITTEN WORKS AND PROJECTS

### Simulating Extended Hubbard Models &#x1F4C4;
*Research report*      May 2021 - September 2021

· Presented an ab-initio derivation of the Extended Hubbard model (EBHM) from the Born-Oppenheimer approximation, an overview of the Eigenstate Thermalization Hypothesis and its relation to random matrix theory.
· Showed that in the attractive Hubbard potential regime the 1D EBHM presents atypical states which can be readily observed by looking at the time averaged eigenstate expectation values of certain operators. When viewed from a post-quench perspective however these states rapidly fall into the continuum.
· Developed a model of two disconnected EBH chains interacting through an intersite potential which presents a band of rare states with null correlations $n_{i,A}n_{i,B}$. These states are disconnected from the rest of the spectrum and exhibit supra-thermal $n_i^2$, $n_i n_{i+1}$ and $c_i^\dagger c_i$ correlators. This characterizes them as states with most states on one chain, where double occupation on some sites allows for in-chain hopping to occur, thus explaining the large Hubbard and hopping correlators.

### Berry phase, the Quantum Hall effect and Topological order &#x1F4C4;
*Expository essay*      November 2021 - present

· Derived the Adiabatic theorem and used it to motivate a geometrical interpretation of the Berry phase. The concept of Berry curvature as a magnetic field in phase space is developed, leading to the introduction of the first Chern number as a topological invariant.
· Discussed the integer quantization of the Hall conductance and related it to the TKNN invariant. This then led to the question of how one could achieve a non-trivial Chern numbers in band theories without external magnetic fields.
· Introduced the Qi-Wu-Zhang model and Haldane models as elementary examples of Chern insulators. The resulting emergence of chiral edge states is discussed.
· Numerically investigated the geometrical/topological properties of several toy models and produced corresponding topological phase diagrams.

### Observer-dependent Quantum Entanglement &#x1F4C4;
*Expository essay*      October 2021 - November 2021

· Summarized some important results in Quantum field theory and General relativity.
· Derived the Unruh temperature using two different approaches: an analytic continuation argument and a direct integral calculation.
· Used the mixed density matrix resulting from the Unruh radiation to predict the entanglement degradation measured by accelerating observers.

### The Undergraduate Companion to Theoretical Physics &#x1F4C4;
*Lecture notes*      September 2020 - present

· Typeset a series of lecture notes on foundational courses in physics:

1. Classical physics (60 pages)
2. Electromagnetism (140 pages)
3. Quantum mechanics (350 pages)
4. Thermal and statistical physics (160 pages)
5. Modern physics (100 pages)
6. Mathematical methods (530 pages)

### Deriving laws of Statistical, Analytical and Fluid mechanics &#x1F4C4;
*MYP Personal Project*      June 2019 - September 2019

· Produced an 80-page literature review discussing the physics behind several day-to-day phenomena such as blackbody radiation, capillary action, Navier-Stokes equation, spin-stabilised motion.
· Created over 20 figures using Adobe illustrator to convey mathematical arguments through a visual medium.
· Numerically solved for the trajectories of spin-stabilised disks using fourth order Range-Kutta methods.

## TECHNICAL SKILLS &#x1F517;

**LaTeX, Python, Maxima, Adobe Illustrator**

## CONFERENCES ATTENDED

**SQP Autumn School 2021**
**GSSI Statistical and Quantum Mechanics 2021**