

# Horan Tsui

STUDENT

Sichuan University, Chengdu, Sichuan Province, China

□(+86) 157-5648-7821 | ☐ L1919159@Gmail.com | ↗ brooktsui.github.io/

*"WHAT is this unseen flame of darkness whose sparks are the stars?"*

## Summary

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I'm an undergraduate student majoring in physics from China, enjoy both mathematics and physics for their beauty and power.

The ongoing investigation of the ineffable world is exciting, which appeals to me to participate in this thrilling parade and to wish to contribute a verse.

Research interests:

**Physics beyond the standard model (Neutrino, Dark Matter), Black Hole Physics, Gravity/Gauge Duality, Quantum Entanglement.**

## Education

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### Physics, Sichuan University

Chengdu, China

MAJOR GPA(LAST 2 YEARS): 3.65(3.85)/4.0

Sep. 2018 - Present

- Changed the major from mechanical engineering to physics in 2020
- Advanced courses with average score **90+/100**:  
String Theory and CFT, Quantum Field Theory, General Relativity, Scattering Theory, Group Theory, Electrodynamics, Quantum Mechanics, Thermodynamics and Statistical Physics, Theoretical Mechanics, etc.
- **LaTeX**, Mathematica

## Experience

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### Black Hole Thermodynamics

Sichuan University, China

PROF. HAI-TANG YANG

Dec. 2020 - Jun.2021

- Learning: black hole thermodynamics, negative temperature, black hole phase transition, black hole/string transition, AdS/CFT.
- **Did background research** about the negative T system and BH thermodynamics.
- **Posited a general model**, the energy-bounded S. H. O., to study the negative T system. And bridged it with nuclear-spin systems and LASER systems.
- **Independently proved a recurrence relation of restricted integer partition functions** for studying the negative T system, and learned some number theory.
- **Reproduced the negative T behavior in exotic BTZ-BHs**. Although I did not continue it since I felt skeptical about some assumptions.
- **Attempted to use AdS/CFT correspondence** to construct a negative T BH out of the energy-bounded S. H. O. at the boundary. However, the pandemic began to spread. Being quarantined at home, I did not continue the previous work due to the lack of communication with the mentor.
- **Made a report** about works I had done until then.
- **Studied the chaotic behavior of black holes** for interest, especially the reaction of null and time-like geodesics of a point-like particle under the phase transition in RN-AdS spacetime, and found the free energies undergo a discontinuous change.
- Due to the pandemic and some family issues, I quit the group in Jun. 2021.

### Non-Commutative Spacetime and Pauli Exclusion Principle Violation

Sichuan University, China

PROF. SHIN-TED LIN

Apr. 2022 - Present

- Learning: non-commutative spacetime theory and phenomenology,  $\theta$ -Poincare model, Hopf algebra, Drinfel'd twist.
- **Being the research assistant (RA)**, I am **responsible for all the theoretical parts** of the project in collaboration with an experimentalist from China Jinping Underground Lab.
- **Did background research** about the non-commutative spacetime and the phenomenology, Pauli Exclusion Principle Violation (PEPV).
- **Developed a new formalism** of the model proposed by Balachandran *et al* based on the twisted permutation algebra, and **extrapolated it into many-body systems by Hopf algebra**.
- **Corrected a mistake** made by previous works in the phase structure of states in non-commutative spacetime by the new formalism.
- **Generalized the Pauli Exclusion Principle** into non-commutative spacetime based on the new phase structure, and then clarified the target of the experiments.
- **Help to design the experiments**, selecting the atoms to be used, the channels to be observed ( $2P \rightarrow 1S$ ), and the region of interest.
- **Made two reports** about my theoretical works to professors from Turkey.
- **The paper is in writing now**. We anticipate publishing it in Phys. Rev. Lett. or Phys. Rev. D at the end of the year.

## Bound on Primordial Black Holes being Dark Matter

University of Notre Dame, USA

PROF. YUHSIN TSAI

July 2022 - Present

- Learning: curved spacetime QFT, Hawking emission rate, primordial black holes, GUP, Axions, and numerical methods.
- **Did background research** of the topic, and **made a report** in the meeting.
- **Posited the correction of GUP**, the generalized uncertainty principle which I came to during this period. The correction could yield the most results as before but more naturally. I also found it consistent with the Black Hole/string transition. It was collated as a short paper and shared with Prof. Tsai. I will elaborate on it later on.
- **Analyze the behavior of quantum fields in BH spacetime** in a semi-analytical way **by ODE tools**, including the Frobenius method and Wronskian.
- **Spotted a gap** that the widely used code, BlackHawk, for producing the Hawking emission spectra lacks the consideration of particles' mass, and **reproduced the Hawking emission spectra by MMA** for massive and massless particles.
- To be continued.

## Sterile/Active Neutrino, Dark Photon/Photon Oscillation

Institute of Theoretical Physics,  
Chinese Academy of Sciences, China

PROF. JIANG-HAO YU

Aug. 2022 - Present

- Learning: electroweak theory, neutrino physics, MSW effect, quantum kinematic equation(QKE), dark photon
- **Simulated the solar neutrino evolution** in a simplified model by MMA in the scheme of neutrino pendulum and Landau-Zener approximation respectively.
- **Simulated the sterile/active neutrino maxing** by QKE and Boltzmann equations.
- **Have been studying the dark photon/photon oscillation by the density-matrix method** which has yet to be discussed. The similarity between dark photon/photon and active/sterile neutrino impressed me.
- **Constructed the collision terms from QFT** for DP/P oscillation.
- To be continued.

## Publication

### The Paper about the PEPV

FIRST CO-AUTHOR

*potentially at the end of the year*

- The paper is in writing, and the theoretical part for which I am responsible has finished.

### Several Notes

WRITER

*Past - Future*

- GUP
- Black Hole Thermodynamics
- String Theory and CFT in Chinese
- T-Duality
- Majorana Fermions
- QED. The note I wrote for teaching my roommate for his Ph.D. study in quantum optics
- ...

## Presentation

### Black Hole Thermodynamics and Negative Temperature

Physics Hall  
Sichuan University

SPEAKER

May, 2021

- Introduced the evolution of the black hole thermodynamics and recent results.
- The negative temperature and its appearance in the exotic-BTZ black holes.

### Non-commutative Spacetime and Pauli Exclusion Principle Violation

*Online*

SPEAKER

Jun, 2022

- Introduced the non-commutative spacetime and one of the phenomena, PEPV.
- My work about the generalization and the discussion about the model.

### Curved Spacetime QFT and Hawking Emission.

*Online*

SPEAKER

Aug, 2022

- Introduced the curved spacetime QFT and explained the quantum origin of Hawking radiation.
- Discussed the possible way of calculating the emission rate.
- The perspectives for the field.

# Exotic Atomic Transition

Online

## SPEAKER

- New theorems and conclusions from the corrected frame.
- Elaboration on the atomic model and experiments.

Oct, 2022

## Honors & Awards

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### ACADEMIC

2021	<b>Silver Prize</b> , National Students Mathematics Competition	Chengdu, China
2021	<b>Premier Specialized Prize</b> , Scholarship	
2021	<b>University Innovation Program Award</b> , Accolade	
2022	<b>Premier Specialized Prize</b> , Scholarship	
2022	<b>Outstanding Student</b> , Accolade	

### EXTRACURRICULAR

2020	<b>Gold Prize</b> , National Students Art Festival: Recitation	Chengdu, China
2020	<b>Silver Prize</b> , National Students Art Festival: Drama	Chengdu, China
2021	<b>Club President Leadership</b> , Accolade	

## Extracurricular Activity

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### Drama Group (High-Level Art Group of the University)

Sichuan University, China

#### PRESIDENT

- Led the group to win a silver prize in drama and a gold prize in recitation in the highest-level national competition.
- Participated the public performance on the campus of original dramas twice.

Feb. 2020 - Jun.2022

### Archery Association

Sichuan University, China

#### MEMBER

Sep. 2018 - Oct. 2019