Haojie Hu (胡豪杰)
Postdoc Position: JSPS Fellow
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Experience & Education

- **Postdoc: University of Tsukuba (JSPS Fellow)** — *Aug. 2024 - Now*
  Research: Astrophysics — JSPS Host: Prof. Ken Ohsuga
- **Ph.D.: Peking University** — *Sep. 2018 - Jun. 2024*
  Major: Astrophysics — Ph.D Supervisor: Prof. Kohei Inayoshi
- **Teaching Assistant: Peking University** — *Sep. 2020 - Jun. 2023*
  Stellar Formation and Evolution & Fluid Dynamics in Astrophsyics
- **Summer School: Peking University** — *Jul. 2022*
  "Chinese Space Station Telescope" Summer School
- **B.S.: East China University of Science and Technology** — *Sep. 2014 - Jun. 2018*
  Major: Applied Physics — Advisor: Prof. Wei Liao

Research Keywords & Interests

Black Hole (BH) Accretion, Outflows/Winds/Jets, Supermassive Black Holes (SMBHs), Super-Eddington Accretion, Co-evolution between SMBHs & Host Galaxies, Feedback, James Webb Space Telescope, XRISM, etc.

Publication list

(5 refereed paper: 4 first author + 1 collaboration; 2 papers in prep.)

1. **HuH**., Inayoshi K., Haiman Z., Ho L. C., Ohsuga K., The Convergence of Heavy and Light Seeds to Overmassive Black Holes at Cosmic Dawn. 2025, The ApJ Letter, 983, L37 (2025).

2. **Hu**, **H**., Inayoshi, K., Haiman, Z., Quataert, E. & Kuiper, R. Long-term Evolution of Supercritical Black Hole Accretion with Outflows: A Subgrid Feedback Model for Cosmological Simulations. The ApJ. 934, 132 (2022).

3. **Hu**, **H**., Inayoshi, K., Haiman, Z., Quataert, E. Li, W., & Kuiper, R. Supercritical Growth Pathway to Overmassive Black Holes at Cosmic Dawn: Coevolution with Massive Quasar Hosts. The ApJ. 935, 140 (2022).

4. **Hu**, **H**., Qiu, Y., Gendron-Marsolais, M., Bogdanović, T., Hlavacek-Larrondo, J., Ho, L. C., Inayoshi, K., & McNamara, B. R. Signature of Supersonic Turbulence in Galaxy Clusters Revealed by AGN-driven Hα Filaments. The ApJ Letter, 929, L30 (2022).

5. Qiu, Y., **Hu**, **H**., Inayoshi, K., Ho, L. C., Bogdanović, T., & McNamara, B. R. Dynamics and Morphology of Cold Gas in Fast, Radiatively Cooling Outflows: Constraining AGN Energetics with Horseshoes. The ApJ Letter, 917, L7 (2021).

6$\sim$. **Hu**, **H**., et al. in prep. $\times$ 2

Academic Service

Referee: Publications of the Astronomical Society of Japan.
Membership: Astronomical Society of China.

Technical Skills and Abilities

Languages: English & Chinese
Programming Languages: c/c++, Python & Fortran
Soft Skills: basic Linux, LaTeX, VisIt, Cloudy, Matlab, galight decomposition and etc
Courses: Accretion power in astrophysics, The first galaxies in the Universe, Cosmology, Galaxy structure and evolution, Galactic dynamics, Physics of the Interstellar And Intergalactic medium.
Simulation Codes: PLUTO, Enzo, INAZUMA/UWABAMI, Athena++; Radiation transfer: M1 closure+ Variable Eddington Tensor + Ray Tracing + Flux Limited Diffusion

Involved Projects

•Project 1: The cosmic evolution of seed BHs: from DM halo mergers to super-Eddington accretion.

Method: Two-dimensional radiative hydrodynamical simulations (with PLUTO) & semi-analytical modeling (not finishing).

- Code: PLUTO + Flux Limited Diffusion (for radiation transfer)
- Publications: Three papers are published in this project (Paper 1, 2, & 3).
- Major Results: (a) I performed long-term simulations to model the BH accretion structures in the super-Eddington regime. The simulations reveal that the inflow rate decreases toward the BH following a universal power-law profile, consistent with radiatively inefficient accretion scenarios; (b) By incorporating merger histories of high-redshift dark matter halos, I developed a semi-analytical model that leverages the derived BH accretion framework to explain the existence of high-redshift SMBHs. Using this model, I provided predictions for JWST observations, distinguishing observable signatures of light and heavy seed BH populations at redshifts $z > 10$; (c) Within the framework of this semi-analytical model, I explored various growth pathways for seed BHs embedded in different host galaxies. I demonstrated that rapid accretion onto seed BHs can lead to the formation of overmassive SMBHs. Furthermore, the eventual BH-to-galaxy mass ratio is primarily determined by the strength of feedback processes at later evolutionary stages. I established clear criteria differentiating between accelerated and decelerated seed BH growth scenarios.

•Project 2: AGN-driven outflow in Perseus A : its morphological evolution and dynamical structures

Method: Three-dimensional radiative hydrodynamical simulations (in ENZO with AMR) & semi-analytical modeling (finished).

- Code: ENZO + AMR + Ray-tracing
- Publications: Two papers are published in this project (Paper 4 & 5)
- Major Results: (a) The origin of cold gas filaments in Perseus A remains unclear. (b) Based on the premise that these cold gas filaments form through cooling of hot outflows, we employ 3D radiation-hydrodynamic (RHD) simulations to investigate the cooling evolution of AGN-driven hot outflows. (c) Our simulations successfully reproduce various observed morphologies and dynamical structures of these cold filaments. (d) Our modeling provides insight into the origin of cold gas filaments and enhances our understanding of AGN feedback through hot outflows.

•Project 3 (on-going): Outflow regulated super-Eddington accretion: resolving Bondi & bulge scales

Two-dimensional radiative hydrodynamical simulations (in PLUTO).

- Code: PLUTO + FLD + Ray-tracing (Multi-frequency radiative transfer) + Nonequilibrium thermochemistry
- Results (in preparation): We successfully reproduce the transition to mildly super-Eddington accretion onto seed black holes (BHs), explicitly accounting for accretion-driven outflows. These outflows significantly impact the dense accretion disk, disrupting its structure through colliding shocks. However, when the viscous timescale is properly considered, the disruptive effects of outflows are minimized, allowing the dense accretion disk to remain largely intact. This outflow-regulated rapid growth of BHs naturally leads to their co-evolution with stellar bulges, consistent with observed local scaling relations.

•Project 4 (on-going): Formation & Evolution of Clumpy Outflows from Super-Eddington Accretion

Three-dimensional general relativistic radiative hydrodynamical simulations (in INAZUMA).

- Code: INAZUMA + GR + M1 closure (for radiation transfer)
- Results (in preparation): The high-resolution capability of XRISM has revealed the presence of clumpy outflows in the vicinity of black holes (BHs), significantly advancing our understanding of outflow structures. Motivated by this discovery, we employ 3D general relativistic radiation-hydrodynamic (GR-RHD) simulations to investigate the formation mechanisms and subsequent evolution of clumpy outflows driven by super-Eddington accretion.

Senimar talks & Contributed Talks

- – BH accretion workshop 2025, Nagoya City University (5-7, May 2025)
  – Probing the Genesis of Supermassive Black Holes: Emerging Perspectives from JWST and Expectation toward New Wide-Field Survey Observations Kavli IPMU (18-21, Nov. 2024)
  – First Star VI in NYC (20-23, May 2024)
  – COSPAR in Busan (13-21, Jul. 2024)
  – Galaxy formation in Hangzhou: Observation and Physics of AGN, China, Oct. 2023
  – East Asian AGN workshop at Kagoshima, Japan, Sep. 2023
  – Astrophysical BHs: A Rapidly Moving Field at Hong Kong, China, Jun. 2023
  – Galaxy-IGM workshop 2022 at Japan, Aug. 2022
  – 2021 The first KIAA forum on gas in galaxies for early career scientist, Nov. 2021
  – East-Asia AGN workshop in Chongqing University, China, Oct. 2021

- – Semina talk @ Zhejiang University, May 2023
  – Semina talk @ Shanghai Astronomical Observatory, CAS, Shanghai, China, May 2023
  – Semina talk @ Tsung-Dao Lee Institute, Shanghai Jiao Tong University, Shanghai, May 2023
  – Semina talk @ Tsinghua University, Beijing, China, Mar. 2023
  – Semina talk @ University of Duisburg-Essen, Oct. 2022
  – Semina talk @ Kavli IPMU, Jun. 2022