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Shivan Khullar

Education

2019-Present **University of Toronto**, *Toronto, Canada*
Ph.D. (Direct-Entry) Astronomy and Astrophysics
Advisors: Prof. Norman Murray and Prof. Chris Matzner

2014-2019 **BITS Pilani University**, *Goa, India*
M.Sc. (Hons.) Physics & **B.E. (Hons.) Electronics and Instrumentation**

Research Interests

I'm interested in simulating the universe. My research focuses around the role of turbulence, magnetic fields and stellar feedback in the star formation process. I'm interested in questions related to star formation - from star formation in the nearby universe to the formation of the first stars in the universe. I use numerical simulations as a tool to understand systems that are too complicated to study analytically. I use some of the world's largest supercomputers to run these simulations and analyze the data.

Keywords: Star formation, ISM, stellar feedback, molecular clouds, simulations

Publications

Summary: 3 first author publications, 1 n-th author publication

- 'The density structure of supersonic self-gravitating turbulence', **Shivan Khullar**, Christoph Federrath, Mark R. Krumholz, Christopher D. Matzner, 2021, MNRAS ADS Link arXiv Link
- 'Probing the high-z IGM with the hyperfine transition of ^{3}He+', **Shivan Khullar**, Qingbo Ma, Philipp Busch, Benedetta Ciardi, Marius B. Eide and Koki Kakiichi, 2020, MNRAS ADS Link arXiv Link
- 'Determining star formation thresholds from observations', **Shivan Khullar**, Mark R. Krumholz, Christoph Federrath, Andrew J. Cunningham, 2019, MNRAS ADS Link arXiv Link
- 'The Single-Cloud Star Formation Relation', Riwaj Pokhrel, Robert A. Gutermuth, Mark R. Krumholz, Christoph Federrath, Mark Heyer, **Shivan Khullar**, S. Thomas Megeath, Philip C. Myers, Stella S. R. Offner, Judith L. Pipher, William J. Fischer, Thomas Henning, Joseph L. Hora, 2021, APJ Letters ADS Link arXiv Link

Honors & Awards

2019 - 2021 **Department of Astronomy and Astrophysics International Entrance Award**, *Department of Astronomy and Astrophysics, University of Toronto*
Award amount: $10,000

2020 **International Graduate Student Fellowship for Excellence in Doctoral Studies**, *Department of Astronomy and Astrophysics, University of Toronto*
Award amount: $3,000

2021 **Mary and Ron Martin International Graduate Fellowship**, *University of Toronto*
Award amount: ∼$9,000

2021 **International Graduate Student Fellowship for Excellence in Doctoral Studies**, *Department of Astronomy and Astrophysics, University of Toronto*
Award amount: $3,000

2022 **Mary and Ron Martin International Graduate Fellowship**, *University of Toronto*
Award amount: ∼$9,000

2022 **International Graduate Student Fellowship for Excellence in Doctoral Studies**, *Department of Astronomy and Astrophysics, University of Toronto*
Award amount: $3,000

Talks and Conferences

Invited Talks

November 2022 **Journal club seminar, McMaster University**, *Virtual*
Title: Playing with FIRE: Molecular clouds and star formation in a galactic feedback-halting experiment

October 2021 **Star Formation/ISM Rendezvous, Princeton University**, *Virtual*
Title: Star formation thresholds and the density PDF

February 2019 **International Max Planck Research School on Astrophysics at the Ludwig Maximilians University, Munich**, *Garching, Germany*, Star Formation Thresholds: Real and Illusory

Contributed Talks

July 2023 **The Physics of Star Formation: From Stellar Cores to Galactic Scales**, *Lyon, France*
Title: Playing with FIRE: Molecular clouds and star formation in a galactic feedback-halting experiment

July 2022 **A Holistic View of Stellar Feedback and Galaxy Evolution**, *Ascona, Switzerland*
Title: Playing with FIRE: Molecular clouds and star formation in a galactic feedback-halting experiment

Posters/Lightning Talks

June 2022 **International High Performance Computing Summer School**, *Athens, Greece*
Title: Combining multiple scales in star formation simulations

May 2022 **Canadian Astronomical Society (CASCA), Annual Meeting**, *Virtual*
Title: GMCs on FIRE: The impact of feedback on star formation rates, efficiencies, and laws

May 2021 **Canadian Astronomical Society (CASCA), Annual Meeting**, *Virtual*
Title: The density structure of supersonic self-gravitating turbulence

May 2020 **Canadian Astronomical Society (CASCA), Annual Meeting**, *Virtual*
Title: Star Formation Thresholds: Real or Illusory?

Teaching Experience

Teaching Assistant

Fall 2023 **AST 221: Stars and Planets**, *University of Toronto*

Summer 2023 **AST 201: Stars and Galaxies**, *University of Toronto*

Fall 2022 **AST 101: The Sun and Its Neighbours**, *University of Toronto*

Summer 2022 **AST 201: Stars and Galaxies**, *University of Toronto*

Winter 2022 **AST 320: Intro to Astrophysics**, *University of Toronto*

Fall 2021 **AST 325/326: Intro to Practical Astronomy**, *University of Toronto*

Summer 2021 **AST 201: Stars and Galaxies**, *University of Toronto*

Winter 2021 **AST 201: Stars and Galaxies**, *University of Toronto*

Fall 2020 **AST 101: The Sun and Its Neighbours**, *University of Toronto*

Winter 2020 **AST 201: Stars and Galaxies**, *University of Toronto*

Fall 2019 **AST 101: The Sun and Its Neighbours**, *University of Toronto*

Spring 2018 **Mathematical Methods for Physics**, *BITS Pilani, Goa*

Fall 2017 **Electro-Magnetic Theory I**, *BITS Pilani, Goa*

Duties include:

- Leading tutorials, planetarium shows, observing nights, marking projects and exams (AST 101/201, University of Toronto)
- Designing and leading tutorials, grading assignments (AST 221, University of Toronto)
- Designing and leading tutorials, grading lab reports (AST 325/326, University of Toronto)
- Making assignment solutions, holding office hours and grading assignments (AST 320, University of Toronto)
- Designing lecture slides, marking quizzes (BITS Pilani, Goa)

Service

Mentorship

- Phil Van-Lane, graduate student at University of Toronto
- Kanah Smith, undergraduate student at University of Toronto, now PhD student at IST Austria
- Ethen Sun, graduate student at University of Toronto
- Isaac Rosenberg, undergraduate student at University of Toronto

Outreach

- Planetarium shows at UofT GASA's AstroTours

- Various exhibits and refreshments coordination at UofT GASA's AstroTours

Organizational

- Formed and organized a star-formation/ISM focus group at University of Toronto.

Technical Skills and Coursework

Technical skills

- Languages - Python, C, C++, R, Mathematica; English, Hindi, Punjabi, Bengali
- High Performance Computing - MPI/OpenMP, Used Gadi/Raijin supercomputer at NCI Australia, Niagara supercomputer at SciNet, Compute Canada.

Relevant Coursework

- **Graduate:** Stars, Cosmology, Radiation, Astrophysical Fluid Dynamics, Scientific Computing for Physicists, Quantitative Data Science, Neural Network Programming
- **Undergraduate:**
  - **Theory:** Mechanics, Oscillations and Waves; Thermodynamics, Vector Calculus, Linear Algebra and Complex Analysis, Probability and Statistics, Ordinary Differential Equations, Electromagnetic Theory I, Introduction to Astronomy and Astrophysics, Theory of Relativity, Optics, Classical Mechanics, General Theory of Relativity and Cosmology, Electromagnetic Theory II, Quantum Mechanics I, Mathematical Methods of Physics, Quantum Mechanics II, Statistical Mechanics, Group Theory and Applications, Non-linear Dynamics and Chaos, Atomic and Molecular Physics, Nuclear and Particle Physics, Solid State Physics, Quantum Field Theory, Particle Physics.
  - **Lab:** Computational Physics, Physics Laboratory I, Electricity Magnetism and Optics Laboratory, Modern Physics Laboratory, Advanced Physics Lab, Computer Programming

Undergraduate Research Experience

August 2018 - Dec 2018 **Determining Star Formation Thresholds from Observations**, *RSAA, Australian National University, Canberra, Australia*

Supervisors - Prof. Mark Krumholz and Prof. Christoph Federrath

We created mock observations from simulations of star formation and wrote a pipeline to anaylze these mock observations. Using these mock observations, we found that the interpretation of a star formation threshold from certain observational data is misleading and presented a method to find such a threshold (if it exists) from observations.

Jan 2019 - June 2019 **Gravitational Decoherence**, *Raman Research Institute, Bangalore, India*

Supervisor - Prof. Joseph Samuel

I studied the Aharonov-Bohm effect, theory of quantum decoherence, quantum field theory in curved space time, the Unruh effect, and the phenomenon of gravitational decoherence following Samuel (2018). Wrote a Mathematica code to calculate the form factor for a given path configuration of a quantum particle in the double slit experiment.

June 2018 - July 2018 **The ^{3}He+ hyperfine transition line signal at high redshifts**, *Max Planck Institute for Astrophysics, Garching, Germany*

Supervisor - Prof. Benedetta Ciardi

We used simulations of cosmic reionization and a high-z QSO environment to calculate the differential brightness temperature of the ^{3}He+ 3.46 cm line from these simulations. If detectable, the ^{3}He+ signal could be used to probe the high redshift universe. We analysed whether the ^{3}He+ signal could be found using current or future radio telescopes.

May - June 2017 **Determining the size distribution of H II regions during Reionization using granulometry**, *NCRA-TIFR, Pune, India*

Supervisor - Prof. Tirthankar Roy Choudhury

I wrote a code in Python to implement the granulometry technique on image data from hydro-dynamical simulations of HII bubble growth based on excursion set models. These simulations violated photon number conservation and the granulometry technique would help in pin-pointing the reason for this violation by giving information on the size distribution of HII regions.

May - July 2016 **Mass Modelling of galaxies using HI 21-cm line observations**, *IUCAA, Pune, India*

Supervisor - Dr. Neeraj Gupta

Using observational data from NED, we created moment maps in CASA and then plotted rotation curves of galaxies. The rotation curves were then fitted to the velocity curves obtained using the gas, stellar and dark matter contributions and the dark matter distribution (densities) were obtained.