EXPLORE

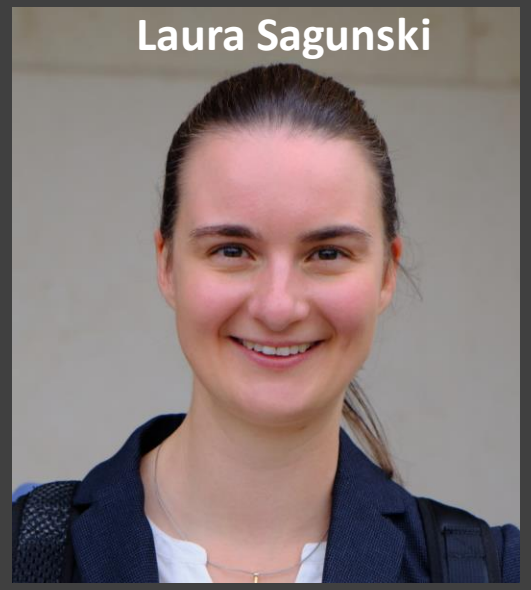
EXPeriential **L**earning **O**pportunity through **R**esearch and **E**xchange

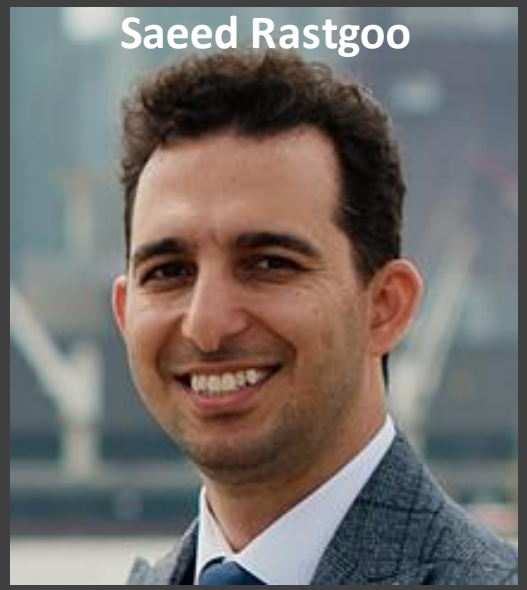
GOETHE UNIVERSITÄT FRANKFURT AM MAIN

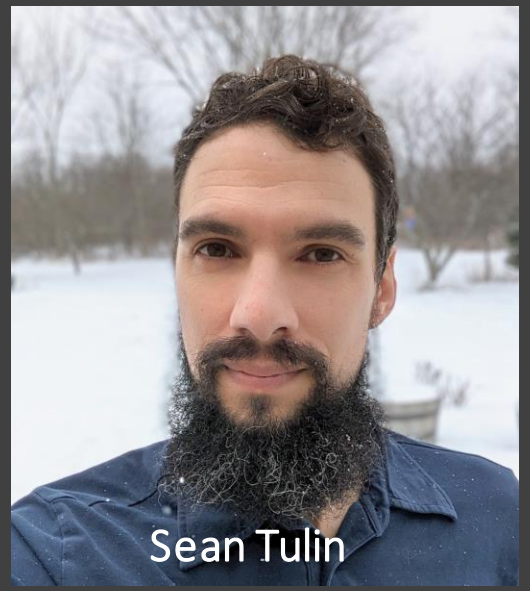
CRC-TR 211

YORK UNIVERSITÉ UNIVERSITY

Who we are:
Mentors of EXPLORE







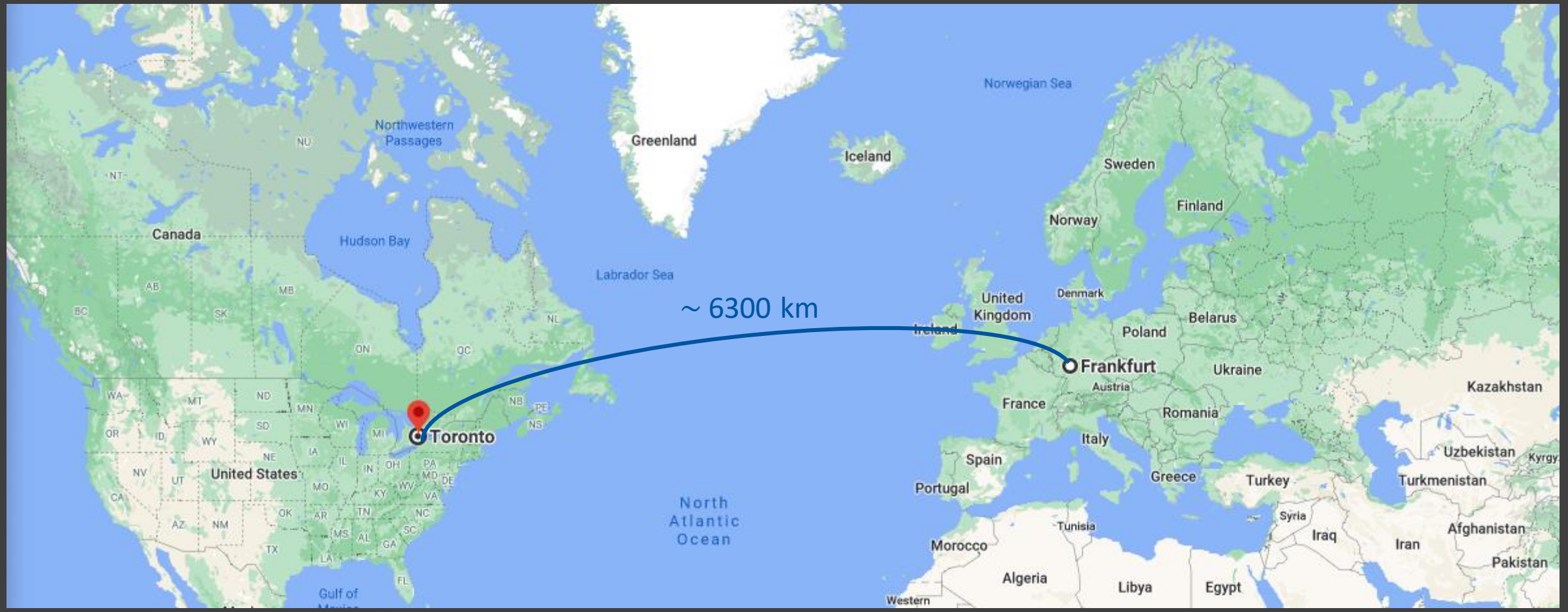
Who you are

Undergraduate students who want to:

- Join international research team
- Do research in theoretical physics and solve mysteries of the universe
- Learn Python

No experience needed, but must be eager to learn!

Where we are


~ 6300 km
Toronto
Frankfurt
Canada
United States
Greenland
Iceland
Norwegian Sea
Sweden
Finland
Norway
Hudson Bay
Northwestern Passages
Labrador Sea
North Atlantic Ocean
United Kingdom
Ireland
Denmark
Poland
Belarus
Ukraine
Austria
France
Romania
Italy
Spain
Portugal
Greece
Turkey
Kazakhstan
Uzbekistan
Turkmenistan
Syria
Iraq
Iran
Afghanistan
Pakistan
Tunisia
Morocco
Algeria
Libya
Egypt
Western
Gulf of

Where we are

Goethe University

York University

What is EXPLORE?

- Students from GU, York & possibly other universities work together on real research projects
- International, diverse research teams
- Theoretical and computational aspects of astroparticle and gravitational physics
- Upcoming research theme: "Astrophysical Probes of Fundamental Physics"

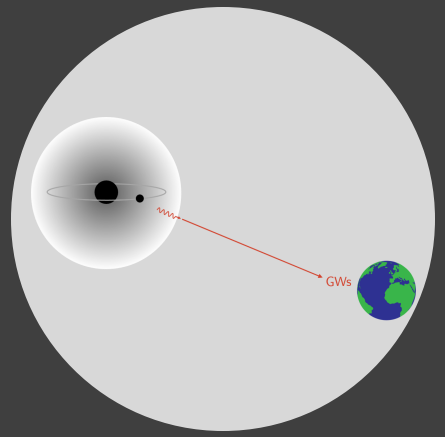
History of EXPLORE

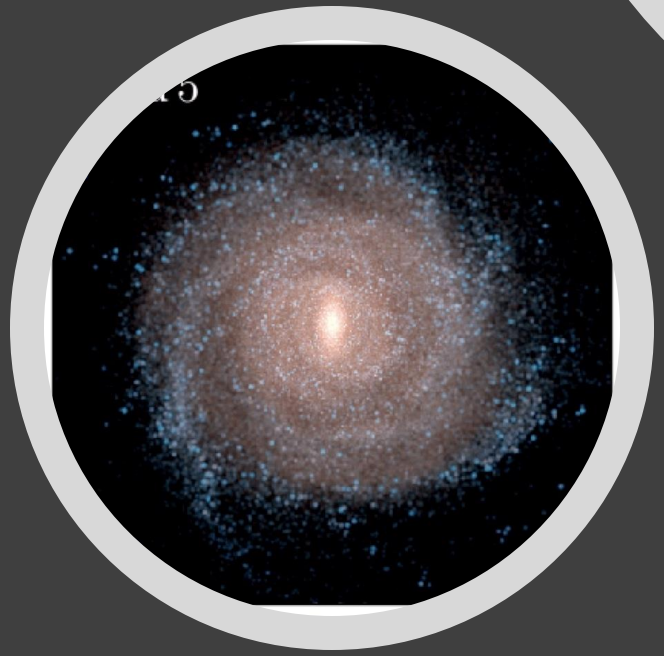
EXPLORE I - Summer 2021:

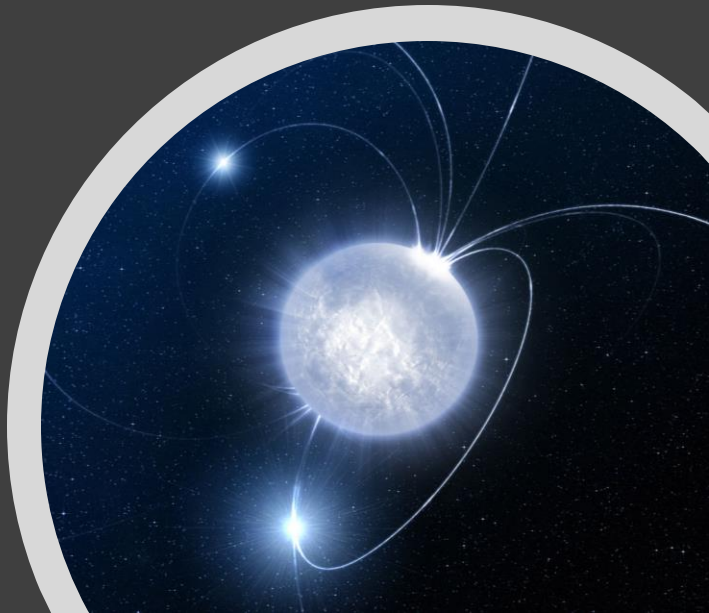
- 17 EXPLORE students; 5 faculty mentors + 5 junior mentors
- 4 research teams (1-2 faculty mentors, 1-2 junior mentors + students)
- Projects involved analytical & numerical computations, data analysis, simulations, coding, ...
- Students could choose/apply for which project to join
- Similar structure in EXPLORE II in Winter 2022

Research projects EXPLORE I

- Dark matter stars
- Probing dark matter with gravitational waves
- The Galactic distribution of dark matter from simulations
- The Life and Death of Dark Matter Halos





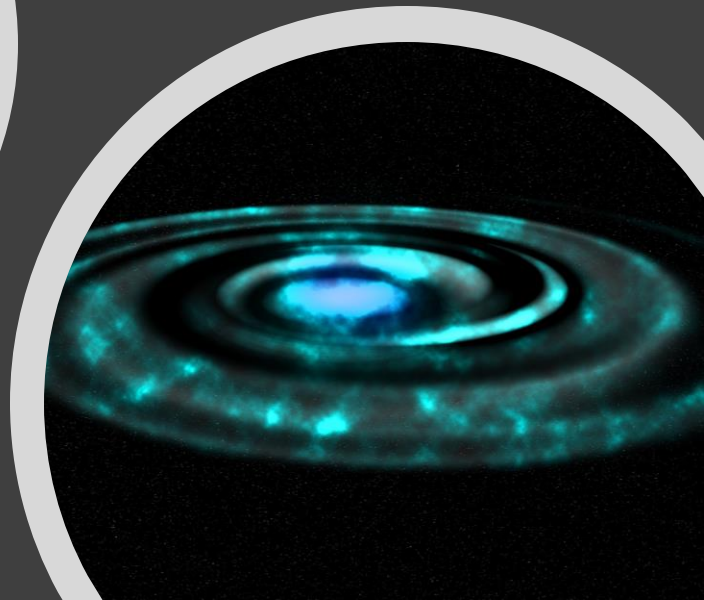


Activities EXPLORE II

- Python tutorials
- EXPLORE lectures
- Weekly research meetings
- Online workshop (end of March):
  Student teams can present their results
- Sponsored trip to Germany (Feb 21-25, during reading week):
  team research, lecture by experts, cultural activities, and more!

Research projects EXPLORE II

- Black holes
- Neutron stars
- Gravitational waves
- Self-interacting dark matter
- Dark matter distribution in galaxies
- Dark matter stars



Join us in Winter 2022

- If interested to join EXPLORE, please send an application consisting of:
  - Cover letter
  - CV
  - Transcript (unofficial)

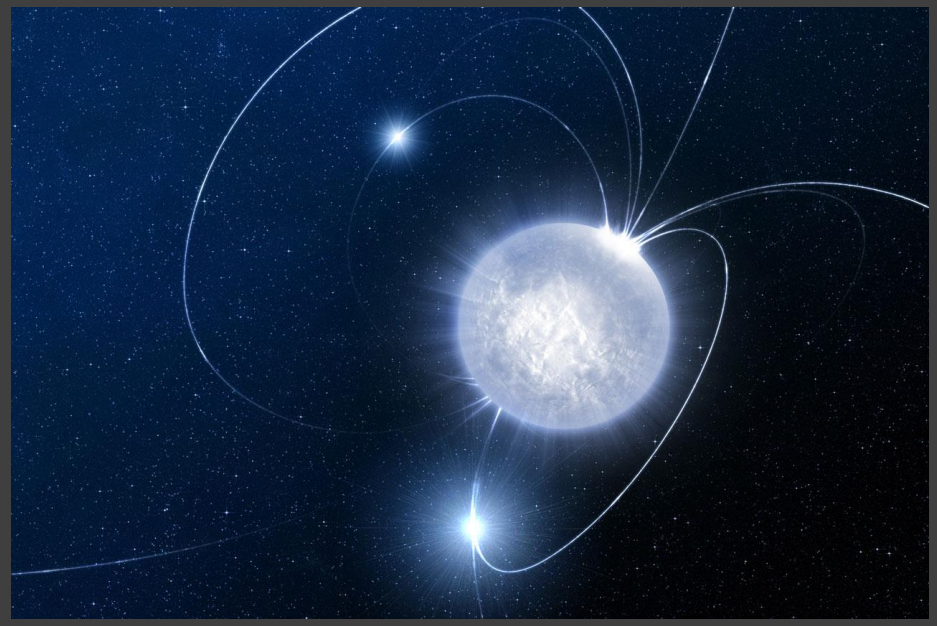
  to nassimb@yorku.ca before **November 1, 2021**.
- Enroll in PHYS 4310 in Winter 2022.
- **Prerequisites:** None. All students are welcome to apply, though preference may be given to students who have completed their second year.

https://astro.uni-frankfurt.de/innovative-teaching/

Any Questions?

Dark stars (Jürgen)

- Study properties of dark stars made of dark matter with a dark charge (dark photon)
- Explore features of neutron stars filled with dark matter in form of bosons (see Ellis et al. PRD 97 (2018) 123007)
- Solve the Tolman-Oppenheimer-Volkoff equations and derive mass-radius relations
- Set limits from causality in semi-analytic calculations



Credit: ESO/L.Calçada

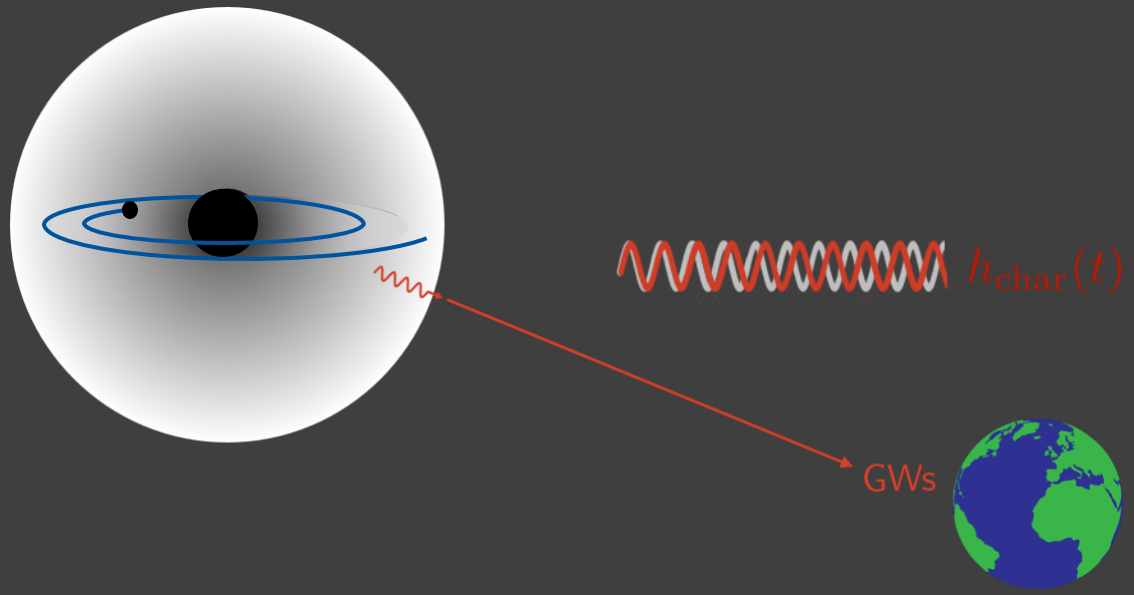
Probing dark matter with gravitational waves (Saeed, Laura)

- Black hole with dark matter halo
- Creates dark matter spike with extremely high density

  → Violent environment
- Binary merger dynamics drastically affected

  → Different GW signal!

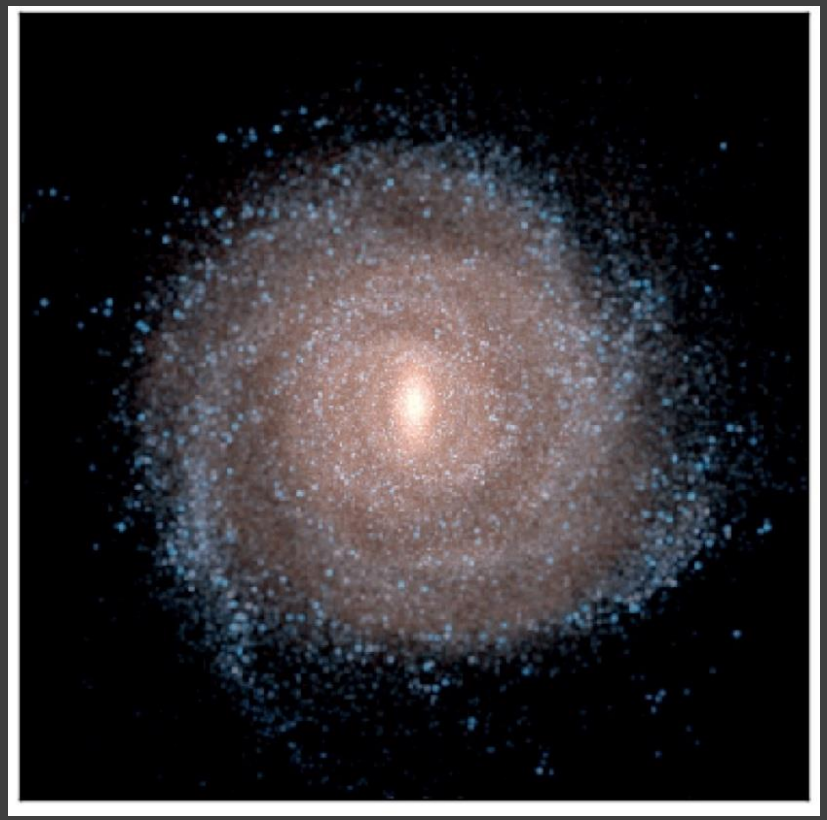
  → Probe DM with GWs!



[Eda et al.: https://arxiv.org/abs/1408.3534,
Alvarez et al.: https://arxiv.org/abs/2012.15050]

The Galactic distribution of dark matter from simulations (Nassim)

- Dark matter self-interactions can change the dark matter density and velocity distribution in our Galaxy.
- Important for the interpretation of results from dark matter direct & indirect searches.
- Study the dark matter distribution of Milky Way-like galaxies in self-interacting dark matter simulations.



Simulated Milky Way-like galaxy

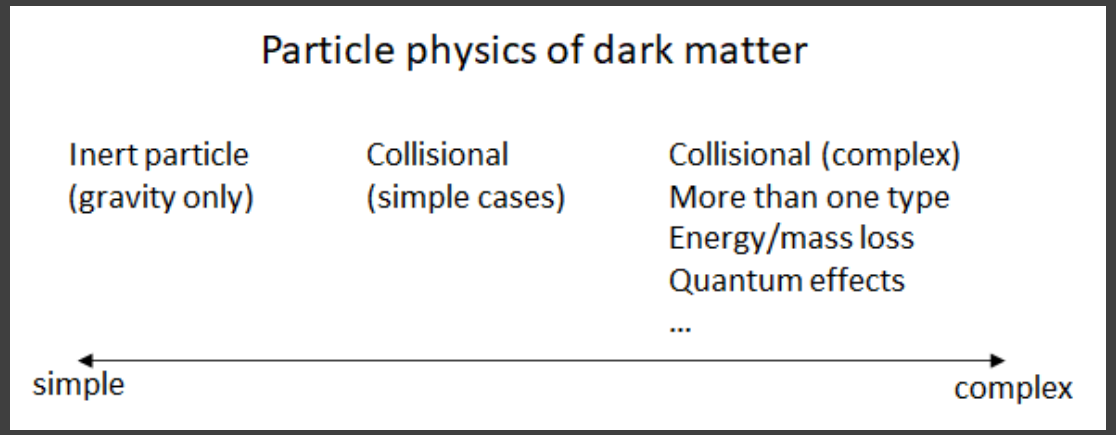
The Life and Death of Dark Matter Halos

(Sean)

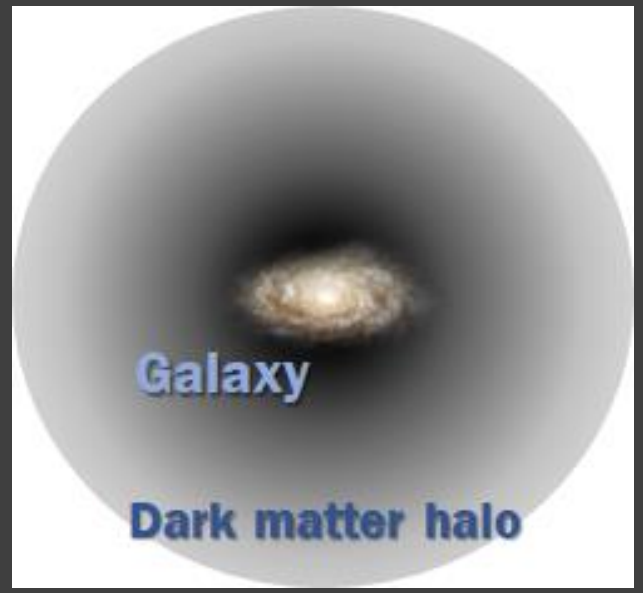
Goals:

•New method for simulating time evolution of dark of halos (simplified Smoothed Particle Hydrodynamics)

•Explore the zoo of dark matter models and make predictions connecting models to astronomical observations



•Example: Formation of first stars seeded by dark matter mini-halos



You:

•Part of a team working on a common simulation package

•Learn and do analytical work bridging particle physics, computational fluid dynamics, astronomical observations

•Run simulations on Compute Canada