Meera Patel

PhD Application to Prof. Sijing Shen's Extragalactic Astrophysics group at University of Oslo

Dear Prof. Shen,

I am writing to apply for the PhD position in extragalactic astrophysics within your group at the University of Oslo, working on numerical galaxy formation in the context of the ESA ARRAKIHS mission. I am currently completing my Master's in Physics and Astronomy at the University of Amsterdam, with a thesis at Nikhef on detector R&D for dark matter direct detection under Dr. Tina Pollmann. My background combines detector R&D with strong computational skills across multiple languages and HPC environments. My coursework at the University of Amsterdam has also been primarily computational and theoretical, including machine learning, C++ programming, and cosmology.

My interest in dark matter models and their observational signatures developed through coursework and a scientific writing course with Prof. Gianfranco Bertone at the University of Amsterdam, where I conducted a literature review on Fuzzy Dark Matter, covering its theoretical foundations, predicted suppression of small-scale structure, and current observational prospects including gravitational wave signatures. This background made your group's recent work on interference in FDM filaments (Zimmermann et al. 2025) particularly striking to me: the finding that interference fringes provide a non-suppressive signature in the matter power spectrum that could break the FDM-WDM degeneracy is the kind of observable prediction that ARRAKIHS could eventually help test through its measurements of faint substructures. I am also aware that correctly interpreting such observations requires understanding how baryonic processes reshape dark matter profiles, something your earlier work on feedback-driven core formation in CDM halos (Governato et al. 2012) addresses directly, and which the PhD position's focus on modeling star formation, feedback, and gas accretion would let me engage with hands-on. The prospect of working at this intersection, where I can run simulations that incorporate both dark matter physics and baryonic processes, then comparing predictions with real multiwavelength observations from a space mission, is what draws me most to this position.

My strongest technical preparation for this position is computational. As a personal project, I am developing a Kerr black hole ray tracing visualizer in Fortran, implementing a fourth-order Runge-Kutta integrator for geodesic equations. This is not a hydrodynamical simulation, but it demonstrates my ability to write physics simulations from scratch, work with numerical ODE solvers, and generate and post-process large simulation output. During my undergraduate at Boston University, I worked on the Fermilab g-2 experiment, developing particle extrapolation algorithms in C++ using particle tracking libraries. This was work that gave me a solid foundation in the analysis tools and collaborative workflows of large physics experiments. I have worked on computing clusters at Fermilab, Nikhef, and the national Snellius supercomputer, and am comfortable with batch job submission and large-scale computational workflows. In my thesis work, I have refactored data processing pipelines and implemented signal processing techniques such as matched filtering, and I have experience with PyTorch from ML coursework that may be useful for ML-augmented analysis of simulation data. I enjoy the collaborative side of research also; I regularly help officemates with CAD, programming, and the occasional integral check. I have learned I work best when given independence within a collaborative group and I look forward to continuing that balance in a PhD.

The opportunity to design simulations, develop models for baryonic processes and dark matter physics, and compare predictions with multi-wavelength ARRAKIHS observations is the kind of work I want to build my research career around. Working at the intersection of simulation and observation is a direction I want to explore seriously. I would bring an intuition for how measurement uncertainties propagate, which could strengthen the observational comparison component of the project. When comparing simulation predictions to ARRAKIHS photometry of faint substructures, the question of what's a real feature versus what's a systematic artifact is the kind of problem my laboratory experience has trained me to think about.

Thank you for considering my application. I would welcome the opportunity to discuss how my skills and background could contribute to your group's work.

Sincerely,
Meera Patel