Meera Patel

PhD Application to Dr. Siching 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 liquid noble gas TPCs under Dr. Tina Pollmann. My background combines detector R&D with strong computational skills across multiple languages and HPC environments. While I have not yet worked with hydrodynamical simulations, the position's goal of connecting simulations to ARRAKIHS observational data is where I see my experimental perspective as useful, as understanding noise, systematics, and calibration is central to meaningful comparison between simulated and observed data.

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 CERN's GEANE package and ROOT. 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. My thesis work has also shown me that I do my best work when I can take initiative on my own, designing hardware upgrades and rethinking analysis, while contributing to the group by supervising a bachelor's student and helping officemates with programming, integrals, and CAD.

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 where I see my long-term future. My experimental background, like understanding noise, systematics, calibration, and what real data looks like, is something I would bring to the observational comparison side of this project that a purely computational applicant might not. 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 exactly the kind of problem my laboratory experience has trained me to think about. I would welcome the opportunity to discuss how my skills and background could contribute to your group's work.

Sincerely,
Meera Patel