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**Thesis Abstract:**


In this dissertation I focus on predictions that can be made using cosmological N-body dark matter only simulations through the analysis of simulation substructure properties.

Chapter 1 contains an introduction to the concordance cosmological framework and an overview of proposed alternatives to models of this framework.

Chapter 2 contains an introduction to observational signatures relied on in my research.

Chapter 3 contains and introduction to the numerical methodologies relied on in my research. In Chapters 1-3 no equations are written with the intent of making the introductory material accessible to the non-specialist. The next three chapters comprise my standalone academic publications with self-contained introductions to my three areas of research.

In Chapter 4, I focus on metal-poor globular clusters (MPGCs) as a unique probe of the early universe, in particular the reionization era. A popular hypothesis is that the observed truncation of MPGC formation is due to reionization. Under this hypothesis, constraining the formation epoch of MPGCs provides a complementary constraint on the epoch of reionization. I provide a self-consistent dark matter only zoom cosmological simulation in the ΛCDM model using the RAMSES code (Teyssier, 2002) to perform an analysis of the Virgo cluster globular cluster system by identifying the present-day globular cluster system with early, rare dark matter peaks. By analyzing both the line-of-sight velocity dispersion and the surface density profile of the present- day distribution, I am able to constrain the redshift and mass of the dark matter peaks. Although found to be degenerate, I quantify a dependence on the chosen line of sight of these quantities, whose strength varies with redshift. Coupled with star formation efficiency arguments, I find a best-fitting formation mass and redshift of $\simeq 5 \times 108 M_\odot$ and $z \simeq 9$. I predict $\simeq 300$ intracluster MPGCs in the Virgo cluster. My results confirm the techniques pioneered by Moore et al. when applied to the Virgo cluster and extend and justify the analytic results of Spitler et al. numerically.

In Chapter 5 , I consider an alternative explanation of the late-time accelerated expansion of the universe to that of the positive cosmological constant, a Hu-Sawicki f(R) gravity model. I explore observational consequences that could be used to differentiate this model from ΛCDM via a suite of high resolution zoom simulations using the ECOSMOG code Li et al. (2012) to examine the effect of f(R) gravity on the properties of a halo that is analogous to the Virgo cluster. I show that the velocity dispersion profiles can potentially discriminate between f(R) models and ΛCDM, and provide complementary analysis of lensing signal profiles to explore the possibility to further distinguish the different f(R) models. My results confirm the techniques explored by Cabr ́e et al. (2012) to quantify the effect of environment in the behavior of f(R) gravity, and I extend them to study halo satellites at various redshifts. I find that the modified gravity effects in our models are best observable at low redshifts, and that effects are generally stronger for satellites far from the center of the main halo. I show that the screening properties of halo satellites trace very well the physical properties of the dark matter particles, this agreement means that low-resolution simulations in which subhalos are not very well resolved can in principle be used to study satellite properties. I discuss observables, particularly for halo satellites, that can potentially be used to constrain the observational viability of f(R) gravity.

In Chapter 6, given that my research critically relies upon halo finder properties, I examine how robust physical predictions from a given subhalo finder are by comparing a range of subhalo finders. In this chapter, I detail my role in the co-authored work which was to propose and to evaluate criteria for halo finder comparison. I deploy the criterion that was most functional to develop and package an algorithm that could use this merit function to produce a "counterpart halo catalogue", that is a halo catalogue where each halo corresponded to the same halo found by different halo finders in a given simulation. This algorithm was relied on by my co-authors the rest of the paper analysis, to allow comparison of different substructure finders and quantify their robustness. I show a merit function proposed by (Klimentowski et al. , 2010; Libeskind et al. , 2010) to be the ideal merit function of those considered to identify the same halo found by two different halo finders. I develop a technique to identify the same halo found by N different halo finders, enabling the construction of a "counterpart catalogue". Using the "counterpart catalogue" I constructed, my co-authors show the phase-space halo finder ROCKSTAR to be suitable where detailed satellite and substructure properties are required.

In Chapter 7, I summarize the scientific contributions I made within this dissertation and a prospective for future work.