University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

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BSc (Sharif University of Technology, 2011)

"The Local Group and its dwarf galaxy members in the standard model of cosmology"

Department of Physics and Astronomy

August 2, 2017
3:00 P.M.
David Turpin Building
Room A144

Supervisory Committee:
Dr. Julio Navarro, Department of Physics and Astronomy, University of Victoria (Supervisor)
Dr. Alan McConnachie, Department of Physics and Astronomy, UVic (Member)
Dr. Marcelo Laca, Department of Mathematics and Statistics, UVic (Outside Member)

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Dr. Oleg Gnedin, Department of Astronomy, University of Michigan

Chair of Oral Examination:
Dr. Christopher Nelson, Department of Biochemistry and Microbiology, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

According to the current cosmological paradigm, \Lambda Cold Dark Matter" (ƛCDM), only ~20% of the gravitating matter in the universe is made up of ordinary (i.e. baryonic) matter, while the rest consists of invisible dark matter (DM) particles, which existence can be inferred from their gravitational inuence on baryonic matter and light. Despite the large success of the ƛCDM model in explaining the large scale structure of the Universe and the conditions of the early Universe, there has been debate on whether this model can fully explain the observations of low mass (dwarf) galaxies. The Local Group (LG), which hosts most of the known dwarf galaxies, is a unique laboratory to test the predictions of the ƛCDM model on small scales.

I analyze the kinematics of LG members, including the Milky Way-Andromeda (MW-M31) pair and dwarf galaxies, in order to constrain the mass of the LG. I construct samples of LG analogs from large cosmological N-body simulations, according to the following kinematics constraints: (a) the separation and relative velocity of the MW-M31 pair; (b) the receding velocity of dwarf galaxies in the outskirts of the LG. I find that these constraints yield a median total mass of 2 x $10^{12} M_{\odot}$ for the MW and M31, but with a large uncertainty. Based on the mass and the kinematics constraints, I select twelve LG candidates for the APOSTLE simulations project. The APOSTLE project consists of high-resolution cosmological hydrodynamical simulations of the LG candidates, using the EAGLE galaxy formation model. I show that dwarf satellites of MW and M31 analogs in APOSTLE are in good agreement with observations, in terms of number, luminosity and kinematics.

There have been tensions between the observed masses of LG dwarf spheroidals and the predictions of N-body simulations within the _CDM framework; simulations tend to over-predict the mass of dwarfs. This problem is known as the \too-big-tofail" problem. I find that the enclosed mass within the half-light radii of Galactic classical dwarf spheroidals, is in excellent agreement with the simulated satellites in APOSTLE, and that there is no too-big-to-fail problem in APOSTLE simulations. A few factors contribute in solving the problem: (a) the mass of haloes in hydrodynamical simulations are lower compared to their N-body counterparts; (b) stellar mass-halo mass relation in APOSTLE is different than the ones used to argue for the too-big-to-fail problem; (c) number of massive satellites correlates with the virial mass of the host, i.e. MW analogs with virial masses above ~ 3 x $10^{12} M_{\odot}$ would have faced too-big-to-fail problems; (d) uncertainties in observations were underestimated in previous works.

Stellar mass-halo mass relation in APOSTLE predicts that all isolated dwarf galaxies should live in haloes with maximum circular velocity (V_{max}) above 20km s^{-1}. Satellite galaxies, however, can inhabit lower mass haloes due to tidal stripping which removes mass from the inner regions of satellites as they orbit their hosts. I examine all satellites of the MW and M31, and find that many of them live in haloes less massive than V_{max} = 20 km s^{-1}. I additionally show that the low mass population is following a different trend in stellar mass-size relation compared to the rest of the satellites or field dwarfs. I use stellar mass-halo mass relation of APOSTLE field galaxies, along with tidal stripping trajectories derived in Penarrubia et al., in order to predict the properties of the progenitors of the LG satellites. According to this prediction, some satellites have lost a significant amount of dark matter as well as stellar mass. Cra II, And XIX, XXI, and XXV have lost 99 per-cent of their stellar mass in the past.

I show that the mass discrepancy-acceleration relation of dwarf galaxies in the LG is at odds with MOdified Newtonian Dynamics (MOND) predictions, whereas tidal stripping can explain the observations very well. I compare observed velocity dispersion of LG satellites with the predicted values by MOND. The observations and MOND predictions are inconsistent, in particular in the regime of ultra faint dwarf galaxies.