



**University
of Victoria**

Graduate Studies

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

of

KYLE OMAN

MSc (University of Waterloo, 2013)

BSc (University of Waterloo, 2011)

**“An Explanation for the Unexpected Diversity of Dwarf Galaxy
Rotation Curves”**

Department of Physics and Astronomy

Monday, July 31, 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. Falk Herwig, Department of Physics and Astronomy, UVic (Member)

Dr. Florin Diacu, Department of Mathematics and Statistics, UVic (Outside Member)

External Examiner:

Dr. Justin Read, Department of Physics, University of Surrey

Chair of Oral Examination:

Dr. Dennis Hore, Department of Chemistry, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

The cosmological constant + cold dark matter (Λ CDM) theory is the 'standard model' of cosmology. Encoded in it are extremely accurate descriptions of the large scale structure of the Universe, despite a very limited number of degrees of freedom. The model struggles, however, to explain some measurements on galactic and smaller scales. The shape of the dark matter distribution toward the centres of galaxies is predicted to be steeply increasing in density ('cuspy') by the theory, yet observations of the rotation curves of some galaxies suggest that it instead reaches a central density plateau (a 'core'). This discrepancy is termed the 'cusp-core problem'.

I propose a new way of quantifying this problem as a diversity in the central mass content of galaxies. This characterization does not distinguish between dark and ordinary ('baryonic') matter, but the apparent problem is so severe that the signature of the cusp-core discrepancy is still obvious. By formulating the problem in this way, several uncertain modelling steps are effectively removed from the discussion, allowing for a more narrowly focussed examination of remaining steps in the analysis. My subsequent comparison of recent results from galaxy formation simulations and observed galaxies in the space of the baryonic Tully-Fisher relation (BTFR) reveals some galaxies with an apparent anomalously low dark matter content not only in the centre, but out to the largest measurable radii. These objects are very difficult to explain within the Λ CDM framework; the most plausible interpretation which emerges is that the effect of systematic uncertainties in modelling the kinematics in these galaxies - particularly in the estimate of their inclinations - has been substantially underestimated. This motivates a re-examination of rotation curve measurement methods.

I use a collection of simulated galaxies to demonstrate that, when these are synthetically 'observed' and modelled analogously to real galaxies, non-circular motions present in the gas discs give the appearance of cores, even though all of the simulated galaxies have central cusps. The errors are large enough to reproduce the full width of the observed scatter in rotation curve shapes. Provided the simulations produce sufficiently faithful models of real galaxies, these modelling errors could constitute a solution to the cusp-core problem within the Λ CDM paradigm. Regardless, the kinematic models must be better understood before drawing any strong cosmological conclusions.