The General Assembly of Galaxy Halos: Structure, Origin and Evolution
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Halo formation and evolution: unification of structure and physical properties

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Abstract. The assembly of matter in the universe proliferates a wide variety of halo structures, often with enigmatic consequences. Giant spiral galaxies, for example, contain both dark matter and hot gas, while dwarf spheroidal galaxies, with weaker gravity, contain much larger fractions of dark matter, but little gas. Globular clusters, superficially resembling these dwarf spheroidals, have little or no dark matter. Halo temperatures are also puzzling: hot cluster halos contain cooler galaxy halos; dwarf galaxies have no hot gas at all despite their similar internal processes. Another mystery is the origin of the gas that galaxies require to maintain their measured star formation rates (SFRs). We outline how gravitational quantum theory solves these problems, and enables baryons to function as weakly-interacting-massive-particles (WIMPs) in Lambda Cold Dark Matter (LCDM) theory. Significantly, these dark-baryon ensembles may also be consistent with primordial nucleosynthesis (BBN) and cosmic microwave background (CMB) anisotropies.

Keywords. halo formation and evolution, dark matter, gravitational quantum theory

1. Introduction

The application of quantum mechanics to gravity and its experimental verification is now well established (Jenke *et al.* 2011). Using this approach, Ernest (2009) has shown that quantum theory predicts the existence of vast numbers of extremely long lived, well-bound, stable and electromagnetically invisible Rydberg-type gravitational eigenstates in large-scale deep gravity wells like those of galactic halos. Baryons with wavefunction ensembles containing large fractions of these dark states will exhibit WIMP-like behavior. Furthermore, the larger a gravitational well is, the greater its "percentage" of well-bound dark states. Quantum statistical analysis also shows that these dark baryons are more highly favored on approach to equilibrium (Ernest & Collins 2014): larger, deeper wells with more relaxed halos contain the largest fractions of dark baryons.

2. Aligning halo structure and properties in the quantum approach

It can be shown (Ernest, 2006) that baryons could have rapidly formed dark-baryonic-ensemble halos in the wells of super-massive primordial black holes (SMPBHs) formed by direct collapse (Carr, 1975) at the last phase transition (e^+/e^-), very early in universal history. These dark-eigenspectral-ensemble baryons made up the dark fraction (∼4/5) of matter in the universe, the remaining, more-strongly-interacting ensembles forming the traditional baryonic component. Importantly, because they behave like WIMPS in most other ways, dark-state baryons can potentially be consistent with BBN and CMB anisotropies. (Dark-ensemble baryons have different BBN cross sections to lab-based, localized-particles and will not strongly participate in baryon-photon oscillation.) Examples of unifying structure with properties using the quantum approach are given below.

(1) *Dark matter-hot gas ratio correlated with halo type and evolutionary path*: Dwarf elliptical galaxies and globular clusters seem like very different objects but in the quantum scenario they are the un-merged descendants of the original primordial dark-eigenspectral-ensemble halos, whose structural differences relate to their evolutionary paths. Since quasi-equilibrium favors dark states, an un-merged, relaxing halo will have its non-coalesced dark-baryon fraction grow larger with time. Dwarf spheroidal galaxies are examples of these relaxed systems. Their eigenstate equivalent kinetic energies ($\propto$ total mass to radius ratio M_0/R_0) are $<< 1$ eV, so that their eigenspectrally-visible baryonic component does not emit X-rays, and their large dark matter component is actually due their large reservoir of dark-ensemble baryonic gas. Globular clusters are initially similar structures but have their visible-eigenspectral baryon fraction stripped by passage through the denser galactic medium. Particle-particle interactions (expected from theory to be stronger than electromagnetic ones) act to equilibrate the dark-visible imbalance, eventually resulting in stripping the dark component as well, leaving globular clusters with observationally little gas or dark matter. Massive spiral and elliptical galaxies, formed from merging, have halos which also gradually darken, as any remaining un-coalesced baryons shift to statistically-favored dark eigenspectral ensembles. Hence, left undisturbed, active galaxies eventually become quiescent ellipticals. The dark eigenspectral ensembles can function as hidden repositories of baryons however, and quiescent ellipticals with baryons in these reservoirs can be reborn as active galaxies on merging or disruption. Merging shifts particle eigenspectra away from the dark eigenspectral repository, and provides a fresh supply of coalescent-compliant baryons that increase SFRs.

(2) *Correlation of halo gas temperature with effective quantum state kinetic energy*: The quantum approach predicts a clear correlation of halo gas temperature T with eigenspectral equivalent kinetic energy. For clusters of galaxies, $M_0/R_0 \sim 2 \times 10^{22}$ kg/m, implying $T_{theor.} \sim 5\times10^3$ eV, while $T_{obs.} \sim 3-10\times10^3$ eV. There is equally good correlation for massive spirals: 2×10^2 eV (*theor.*), $1 - 2.5 \times 10^2$ eV (*obs.*); and ellipticals: 8×10^2 eV (*theor.*), $1 - 10 \times 10^2$ eV (*obs.*). Dwarf ellipticals show no sign of hot gas ($T_{theor.} \sim 0.03$ eV), yet the same hot-gas production mechanisms occur in these dwarf galaxies as in larger galaxies, and its observational absence strengthens the voracity of the quantum approach. Lastly, the Sun's hot corona surrounding its relatively cool photosphere is also explained: in the quantum approach the corona's high storage temperature is predicted from the average of its longer-lived eigenstate kinetic energies ($T_{theor.} \sim 350$ eV).

3. Summary

If one accepts the universal truth of quantum theory, then it is clear that it both predicts and requires un-coalesced baryons to be dark on large scales. In this context it is difficult to see how a quantum approach does *not* provide the solution to the dark matter problem. A universe having WIMPs as baryons in a dark disguise adds a new dimension to understanding galaxy evolution and other astrophysical problems by providing opportunity for dark and visible matter inter-conversion throughout cosmic history.

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