Energy Density Driven Galactic Formation and Evolution

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This letter is inspired by the findings of M. Rabinowitz in his recent publication, “Why Observable Space Is Solely Three Dimensional” (Rabinowitz 2014). His paper provides coherent reasoning why our physical universe can only have one time and three spatial dimensions. He also states that “flux,” i.e., electrostatics and by analogy, gravitation, must remain consistent with three-dimensional space with forces obeying the inverse-square law.

This proposal considers flux behavior under highly relativistic conditions as occurred during the era matter creation and initial star and galaxy formation. With expansion of the universe, energy density diminished with force law transforming from $1/r$ to $1/r^2$ over the course of cosmic time. Galaxies formed under relativistic conditions in the early-universe were subject to increasingly Keplerian dynamics as they evolved. Angular momentum in this changing dynamic was conserved through mass distribution and disruption of previously stable orbits, especially at the periphery. This selective mass ‘refining’ is responsible for the broad conformity to the Baryonic Tully-Fisher Relationship.

Galaxies being massive energy storage devices are subject to inertial effects including time lag between a change in force and the galactic response. This stored energy is responsible for today’s unresolved galactic phenomena including flat circular velocity profiles and unresolved “non-Newtonian” dynamics.

INTRODUCTION

Why do we inhabit a three dimensional universe? Recent works have offered physical reasons why this *must* be so. An earlier paper investigated the implications of varying dimensions on physical processes. The author concluded that from a theoretical perspective, three spatial and a single time dimension is the one unique combination that permits atom formation and physical structure (Tegmark 1997). Tegmark recommended a more thorough analysis of binding energy stability criterion to further confirm his findings. Recently, Rabinowitz analyzed the orbital stability for several spatial/time dimensions and arrived at a similar conclusion. Both bodies of work demonstrated no stable orbits are possible in four or more spatial dimensions (or more than one time dimension).

Rabinowitz showed that for two spatial dimensions, binding energy is negatively divergent ($E2 \rightarrow -\infty$) which Rabinowitz deemed “unphysical.” With regard to flux dynamics, he concluded “Although traditionally treated the same mathematically, n dimensions in a higher dimensional space are not the same as strictly n-space because flux can’t be confined to just the given n dimensions in a higher space.” It will be argued that this conclusion is true for particles (atoms) in the sub-relativistic regime. Although this situation describes our late-stage universe with peculiar velocities rarely exceeding 0.01c, this conclusion may not be directly applicable in the early universe when matter was highly relativistic. This letter explores this inference not as it relates to general dimensionality, but to the special condition of flux dynamics for relativistic moving particles.

THEORETICAL CONSIDERATIONS

Rabinowitz states atoms or other stable gravitationally bound matter can only form in a three dimensional universe due to a stable binding energy condition. We can expand this concept by considering the same in a relativistic context. Motion (or energy imparted) to a particle is subject to time dilation and length contraction. Flux dynamics are also impacted through a modification of effective force law. Theoretical work related to this phenomenon (dimensional reduction under high energy conditions) is consistent with this proposal. Physical experiments have been proposed to measure this effect in high energy cosmic ray trajectories (Ashford 2014) (Stojkovic 2014).

PHYSICAL CONSIDERATIONS

Experiments have been performed investigating the spatial and temporal electrostatic potential of relativistic electron “nano-pulses” with the inference that these results could be applied to gravitational effects as well (Calcaterra 2012). These experiments measured the voltage at various locations and distances along the pulsed electron beam path traveling at >0.99c. This is analogous to relativistically moving particles in the early universe.

Two interesting results were revealed; the electrostatic charge and its associated voltage are rigidly held to the electron, or in other words, the charge field travels with the particle. Perhaps more interesting is that the voltage potential behaved logarithmically in the direction perpendicular to motion. The strength of the electric charge is maintained, but is directed or confined in the form of a logarithmic potential. It is this form of the relativistic potential that is associated with 1/r force law (not the 3-D isotropic $1/r^2$ rest’ form).

Rabinowitz’ result ($E2 \rightarrow -\infty$) being unphysical describes a special case where pure logarithmic and divergent potentials exist. Nature prevents this unphysical condition by limiting all massive particles (electrons, atoms, stars, or galaxies) to velocities <c. Pure divergent flux never fully develops thus precluding this unphysical result. These experiments infer it is not the relative motion between the sensor (observer) and the moving electron pulse (particle) creating this phenomena, but absolute velocity (high energy density) that modifies its flux behavior. High energy particle interactions are quite different than particles interacting at “rest.”

CONCEPTUAL COSMOLOGICAL PROCESS

Based on physical and theoretical considerations above, a novel cosmological process is described that links past galaxy formation to unresolved dynamics observed today. In the proposed scenario, matter in the very early universe was subject to highly relativistic conditions which induced flux “confinement,” similar to the experiment above. All forces were subject to relativistic conditions. First to bind into three dimensional shapes were the strong, shorter range nuclear and electric forces. Gravity being many magnitudes weaker continues to bind mass over huge cosmological distances.

This binding process has left traces in galactic morphology and kinematics. In this scenario, early-era galaxies formed under “stronger” 1/r force law were imparted with high angular momentum, much greater than what is observed today. In this evolving environment, gravitationally-bound galaxies conserve momentum through mass redistribution and loss. This relic momentum is responsible for pseudo-logarithmic disk potentials and flat rotation profiles.

SUPPORTING OBSERVATIONS

Unlike some models that require flat galactic rotation well beyond the stellar disk, this proposal directly attributes "non-Newtonian" dynamics to matter distribution and angular momentum. This is indeed the case, with observations showing the Milky Way exhibiting flat rotation to ~40 kpc followed by Keplerian decline (Moffat 2014). Similar rotation curve behavior has been recently discovered for gas components of the Milky Way as well (Gadazutdinov 2015) (Gnacinski 2015). These two recent discoveries are at odds with the existence of extended virial halos or baryonically divorced gravitational dynamics.

This proposal provides the physics support for the Baryonic Tully-Fisher Relationship. For example, in the early universe, a myriad of galaxy structures were created. Over cosmological time all were subject to conform in accordance to the baryonic mass-circular velocity relationship. It is interesting to note that this empirical relationship cannot be derived through the use of Keplerian dynamics or 'dark' particle corrections (McGaugh 2012). Both of these approaches are static and neither accounts for a currently active, evolving cosmology still influencing galactic structure and dynamics.

Relativistic transformational force law is consistent with latest research into star and galaxy formation and evolution. Immediately after creation, matter governed by 1/r force law experienced extreme and intensive interaction. This intense burst accounts for rapid stellar and galactic physical structure creation inside the first billion years. As the energy density (and velocity component) sharply diminished with expansion, previously peaked star formation slowed as the force law became progressively Keplerian.

Evidence of this early burst of star formation has been observed in footprint of the Milky Way's thick disk (Snaith 2014). This research discovered intense star formation starting over 12 billion years ago and lasting roughly 3 billion years. This was followed by a continuous quiescent level of thin disk star formation that is still active today. For this scenario to make physical sense, the authors concluded that the raw materials for galactic formation had already been in place prior to star formation in this early epoch in order to be support with the thick disk's radial chemical profile. This is in stark contrast to the standard model of prolonged 'dark' accretion and associated baryonic inflow.

Transitional force law impacts all galactic types in the same manner. In order to conserve angular momentum as force law evolves, stellar and gas components are destabilized, redistributed and 'shed' into extragalactic space. This 'shedding' of stars preferentially affects outer orbits first, resulting in favored mass retention in the inner regions compared to the periphery. This shedding scenario has been considered to explain the unique linear relationship between dynamical mass density of inner galactic disk and central baryonic density. In a recent paper, it was concluded; *"…galaxies must progressively lose more and more baryons during their formation with decreasing mass (as suggested by the BFTR), but the fraction of baryons in the inner regions should remain higher than the cosmic value and almost constant in any type of galaxy…"* (Lelli 2014). The Baryonic Tully-Fisher is a natural outcome of this refining process (dynamically selective mass loss) over cosmological time.

Another recent study consisting of observationally backed simulations has revealed compact massive galaxies, once abundant, have decreased their numbers since 10 billion years ago. Additionally, these compact galaxies have had very little mass growth while becoming increasingly dense (Stringer 2015). Based on these observations, Stringer conjectured, *"lesser mass growth tending to lead to a more concentrated final structure, and mass loss even more so."* Stringer's analysis also leans toward mass loss as a physical process explaining this observation, similar to Lelli.

On the flip-side, if a significant number of stars were 'released' from galaxies in earlier epochs, there should be evidence of a large population inhabiting space. This contingent has recently been discovered in a survey of the near-infrared background light, where the authors concluded, *"Our results indicate that a substantial fraction of the EBL (Extragalactic Background Light) at optical and near-infrared wavelengths originates from stars outside of galaxies (with boundaries as traditionally defined). This in turn adds to the cosmic energy budget and, depending on the mass characteristics and spectrum of the population responsible, could help alleviate the "photon underproduction crisis" and the "missing baryon problem." (Paraphrased for clarity)* (Zemcov 2014). This discovery is entirely consistent with predicted loss of stars during early galactic formation and evolution.

CONCLUSION

Non-Newtonian behavior observed for rotationally supported galaxies is a manifestation of stored angular momentum. Just as a flywheel tends to remain in motion after torque is removed, galactic disks conserve imparted angular momentum through mass redistribution. Since this redistribution takes time, disk behavior will not be consistent with expectations based on the current sub-relativistic, Keplerian universe. This disconnect is at the heart of unresolved galactic phenomena.

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