A fluid mechanical explanation of dark matter

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Abstract. Matter in the universe has become “dark” or “missing” through misconceptions about the fluid mechanics of gravitational structure formation. The linear Jeans (1902, 1929) theory gives vast overestimates (by factors of trillions or more) for the initial condensation mass of baryonic matter, and vast underestimates (by factors of trillions or more) for the initial condensation mass of the non-baryonic matter. Gravitational condensation occurs on non-acoustic density nuclei at the largest Schwarz length scale $L_{ST}, L_{SV}, L_{SM}, L_{SD}$ permitted by turbulence, viscous, or magnetic forces, or by the fluid diffusivity. Non-baryonic fluids have diffusivities larger (by factors of trillions or more) than baryonic (ordinary) fluids, and cannot condense to nucleate baryonic galaxy formation as is usually assumed. Baryonic fluids begin to condense in the plasma epoch at about 13,000 years after the big bang to form proto-supercusters, and form proto-galaxies by 300,000 years when the cooling plasma becomes neutral gas. Condensation occurs at small planetary masses to form “primordial fog particles” from nearly all of the primordial gas by the new theory, Gibson (1996), supporting the Schild (1996) conclusion from quasar Q0957+651A,B microlensing observations that the mass of the lens galaxy is dominated by “rogue planets ... likely to be the missing mass”. Non-baryonic dark matter condenses on superclusters at scale $L_{SD}$ to form massive super-halos.

1. Introduction

Gravitational structure formation is intrinsically non-linear. As matter is pulled toward a density maximum by gravity to form a condensate and pulled away by gravity from a density minimum to form a void, both gravitational forces are increased by the resulting redistribution of mass so that the mass flow rates are accelerated. This is a classical positive feedback process. Linear theories are notoriously misleading when applied to non-linear processes. Fluid mechanics provides a familiar example, where steady laminar solutions for the momentum equations with non-linear terms neglected are vastly different from the random turbulent motions actually observed when the Reynolds number (the ratio of inertial to viscous forces) is large.

Jeans [1, 2] applied a linear perturbation stability analysis to the problem of gravitational structure formation in a motionless gas with uniform properties. Neglecting non-linear terms of the momentum and density conservation equations reduces the problem to one of acoustics.
Sound wave-crests provide density maxima that can nucleate gravitational condensation only if a wave-length $\lambda$ propagation time $\tau_\lambda = \lambda/V_S$ is greater than the “free fall” gravitational time scale $\tau_G = (\rho G)^{-1/2}$, where $V_S$ is the speed of sound in the gas, $\rho$ is the gas density and $G$ is Newton’s gravitational constant $6.7 \times 10^{-11}$ m$^3$kg$^{-1}$s$^{-2}$. Thus, acoustic density perturbations with sizes $L \geq L_J = V_S/\rho G$ can grow, but those smaller cannot. This Jeans criterion for gravitational instability has been universally adopted in astrophysics and cosmology, with modifications to take into account effects of general relativity and the rapid expansion rate of the early universe when the first structures formed [3, 4]. However, the Jeans criterion is unreliable. Its widespread application is responsible for the present dark matter paradox.

Jeans asserted that acoustic density maxima with $\lambda \geq L_J$ remain acoustic with velocity $V_S$ after condensation begins. This is one of many misconceptions in [2], including the claim that cores of galaxies consist of hot gas and not stars, and are sources of matter flowing from other Universes. Actually, acoustic density nuclei must rapidly stop moving with sound speed $V_S$ as they accumulate zero momentum from the motionless ambient fluid. Gibson [5] shows that non-acoustic density nuclei are absolutely unstable to gravitational structure formation in a motionless fluid. Most density maxima and minima are produced by turbulent mixing of density. They move approximately with the fluid velocity and have a characteristic length scale $L_B = (D/\gamma)^{1/2}$ termed the Batchelor scale, where $D$ is the molecular diffusivity of the density and $\gamma$ is the rate-of-strain of the turbulence [3]. Gravitational condensation on non-acoustic density maxima and void formation from non-acoustic density minima are limited either by the dominant fluid force or by molecular diffusivity to length scales larger than the largest “Schwarz” length scale $L_{SX}$. Schwarz scales are derived in the following Section by comparing dispersive forces with the force of gravity, and the diffusion velocity with the gravitational velocity. The subscript “X” may be $T, V, M, D$ referring to either turbulent, viscous, magnetic or diffusive limitations to gravitational condensation.

2. Theory

A density nucleus with scale $L \ll L_J$ and mass excess $M'$ in a large body of motionless, homogeneous gas is gravitationally unstable and will form a condensate, just as the same sized density nucleus with mass deficit $-M'$ is gravitationally unstable and will form a void. Both cases contradict Jeans’ theory. If the gas is not motionless, gravitational forces $F_G \approx \rho^2 GL^4$ on scale $L$ must be larger than turbulence forces $F_T \approx \varepsilon^{2/3}L^{8/3}$, viscous forces $F_V \approx \rho \nu \gamma L^2$, or magnetic forces $F_M \approx (H^2/\rho)L^2$, where $\varepsilon$ is the viscous dissipation rate, $\nu$ is the kinematic viscosity, $H$ is the magnetic field, and $H^2/\rho$ is the magnetic pressure. Equality occurs at the turbulent Schwarz scale $L_{ST} = \varepsilon^{1/2}/(\rho G)^{3/4}$, the viscous Schwarz scale $L_{SV} = (\nu \gamma/\rho G)^{1/2}$, and the magnetic Schwarz scale $L_{SM} = [(H^2/\rho)/\rho G]^{1/2} = (\chi H/\varepsilon^{1/3})/\rho^2 G^{2/3}$, where $\chi H$ is the diffusive dissipation rate of the magnetic field variance. From turbulent mixing theory, density fluctuations on scale $L$ diffuse with velocity $D/L$ [3]. Equating this to gravitational velocities $L/\tau_G$ gives the Schwarz diffusive scale $L_{SD} = (D^2/\rho G)^{1/4}$. Condensation of non-baryonic fluids on galactic scales is impossible because $L_{SD} \gg L_{\text{galaxy}}$ [3].
3. Application of the theory

By the new theory [3], gravitational decelerations to form proto-superclusters and protogalaxies begin in the plasma epoch at 13,000 years after the big bang, limited by viscous forces at scale $L_{SV}$. The initial conditions of the primordial hydrogen and helium gas are constrained by the COBE satellite observation that $\delta T/T \approx 10^{-5}$. Turbulence levels were thus extremely weak, with maximum rates-of-strain only slightly larger than that of the expanding universe $\gamma = 1/t = 10^{-13}s^{-1}$. The viscosity $\nu$ and diffusivity $D$ of the mixture were about $10^{13} m^2s^{-1}$, giving the condensation mass $M_{SV} = L_{SX \max}^3 \rho = L_{SV}^3 \rho = 10^{23-24} kg$. The entire universe of primordial gas condensed to form small planetary mass objects (Mercury to Mars) termed “primordial fog particles”, or PFPs.

4. Observations

Schild [7] concludes that his lensing galaxy consists mostly of small planetary objects “likely to be the missing mass”, based on continuous month-period fluctuations between quasar image Q0957+651A,B light curves with a 1.1 year time delay. Three observatories confirm the same time delay and the same fluctuating (microlensed) signals [8]. MACHO and EROS collaborations exclude Galactic planetary masses as the halo dark matter assuming homogeneous spatial distributions of the objects [9]. However, large clumping corrections to star microlensing mass exclusion diagrams are required for $10^{-7} M_\odot$ objects because such small objects develop extreme spatial intermittency during their 15 billion years of nonlinear gravitational accretion. Such corrections could resolve the apparent observational inconsistency between quasar-microlensing [7] and star-microlensing [9] studies of small planetary mass objects as galaxy dark matter.

5. Conclusions

The Jeans criterion for gravitational instability is unreliable, and is replaced by a new criterion that density fluctuations in a gas will experience gravitational condensation and void formation on length scales larger than the maximum Schwarz scale; that is, $L \geq L_{SX \max}$. The baryonic “missing mass” or “dark matter” consists of those PFPs that have not aggregated to form stars. Because non-baryonic dark matter has $L_{SD}$ scales larger than galactic scales it is a negligible part of the galactic dark matter, but dominates supercluster dark matter as super-halos [5].

References

[1] J. H. Jeans, Phil. Trans. R. Soc. Lond. A 199 (1902) 1.
[2] J. H. Jeans, Astronomy and Cosmology, Cambridge Univ. Press, 1929.
[3] P. J. E. Peebles, Principles of Phys. Cosmology, Princeton Univ. Press, Princeton, NJ, 1993.
[4] E. W. Kolb and M. S. Turner, The Early Universe, Addison-Wesley Pub. Co., 1994.
[5] C. H. Gibson, Appl. Mech. Rev. 49 (1996) 299.
[6] C. H. Gibson 1968, Phys. Fluids, 11 (1968) 2305.
[7] R. E. Schild Astrophysical Journal 464 (1996) 125.
[8] C. H. Gibson and R. E. Schild Astrophysical Journal, submitted (see webpage).
[9] C. Alcock and others Astrophysical Journal 486 (1997) 697.
[10] (this article is) Gibson C. H., in "Sources and detection of dark matter in the universe", D. B. Cline Ed., Elsevier, North-Holland, 1998, 409-411.