Fossils of turbulence and non-turbulence in the primordial universe: the fluid mechanics of dark matter

Carl H. Gibson

Departments of Mechanical and Aerospace Engineering
and Scripps Institution of Oceanography
University of California at San Diego, La Jolla, CA 92093-0411, USA
Contact e-mail: cgibson@ucsd.edu, http://www-acs.ucsd.edu/~ir118

1 Introduction

Was the primordial universe turbulent or non-turbulent soon after the Big Bang? How did the hydrodynamic state of the early universe affect the formation of structure from gravitational forces, and how did the formation of structure by gravity affect the hydrodynamic state of the flow? What can be said about the dark matter that comprises 99.9% of the mass of the universe according to most cosmological models? Space telescope measurements show answers to these questions persist literally frozen as fossils of the primordial turbulence and nonturbulence that controlled structure formation, contrary to standard cosmology which relies on the erroneous Jeans 1902 linear-inviscid-acoustic theory and a variety of associated misconceptions (e.g., cold dark matter). When effects of viscosity, turbulence, and diffusion are included, vastly different structure scenarios and a clear explanation for the dark matter emerge [1]. From Gibson's 1996 theory the baryonic (ordinary) dark matter is comprised of proto-globular-star-cluster (PGC) clumps of hydrogenous planetoids termed “primordial fog particles” (PFPs), observed by Schild 1996 as “rogue planets ... likely to be the missing mass” of a quasar lensing galaxy [2]. The weakly collisional non-baryonic dark matter diffuses to form outer halos of galaxies and galaxy clusters [3].

2 Fluid mechanics of structure formation

Before the 1989 Cosmic Microwave Background Experiment (COBE) satellite, it was generally assumed that the fluid universe produced by the hot Big Bang singularity must be enormously turbulent, and that galaxies were nucleated by density perturbations produced by this primordial turbulence. George Gamov 1954 suggested galaxies were a form of “fossil turbulence”, thus coining a very useful terminology for the description of turbulence remnants in the stratified
ocean and atmosphere, Gibson 1980—1999. Other galaxy models based on turbulence were proposed by von Weizsacker 1951, Chandrasekhar 1952, Ozerov and colleagues in 1968—1971, Oort 1970, and Silk and Ames 1972. All such theories were rendered moot by COBE measurements showing temperature fluctuation values $\delta T/T$ of only $10^{-5}$ at 300,000 years compared to at least $10^{-2}$ for the plasma if it were turbulent. At this time, the opaque plasma of hydrogen and helium had cooled to 3,000 K and become a transparent neutral gas, revealing a remarkable photograph of the universe as it existed at $10^{13}$ s, with spectral redshift $z$ of 1100 due to straining of space at rate $\gamma \approx 1/t$.

Why was the primordial plasma before 300,000 years not turbulent? Steady inviscid flows are absolutely unstable. Turbulence always forms in flows with Reynolds number $Re = \delta v L/\nu$ exceeding $Re_{cr} \approx 100$, where $\nu$ is the kinematic viscosity of a fluid with velocity differences $\delta v$ on scale $L$, Landau-Lifshitz 1959. Thus either $\nu$ at $10^{13}$ s had an unimaginably large value of $9 \times 10^{27}$ m$^2$ s$^{-1}$ at horizon scales $L_H = ct$ with light speed velocity differences $c$, or else gravitational structures formed in the plasma at earlier times and viscosity plus buoyancy forces of the structures prevented strong turbulence.

### 3 Fossils of first structure (proto-supervoids)

The power spectrum of temperature fluctuations $\delta T$ measured by COBE peaks at a length $3 \times 10^{20}$ m which is only 1/10 the horizon scale $ct$, suggesting the first structure formed earlier at $10^{12}$ s (30,000 years). The photon viscosity of the plasma $\nu = c/n\sigma_T$ was $4 \times 10^{26}$ m$^2$ s$^{-1}$ then, with free electron number density $n = 10^{10}$ m$^{-3}$ and $\sigma_T$ the Thomson cross section for Compton scattering. The baryon density $\rho$ was $3 \times 10^{-17}$ kg m$^{-3}$, which matches the density of present globular-star-clusters as a fossil of the weak turbulence at this time of first structure. The fragmentation mass $\rho(ct)^3$ of $10^{46}$ kg matches the observed mass of superclusters of galaxies, the largest structures of the universe. Because $Re \approx Re_{crit}$, the horizon scale $ct = 3 \times 10^{20}$ m matches the Schwarz viscous scale $L_{SV} = (\gamma \nu / \rho G)^{1/2}$ at which viscous forces $F_V = \rho \gamma L^2$ equal gravitational forces $F_G = \rho^2 GL^4$, and also the Schwarz turbulence scale $L_{ST} = \varepsilon^{1/2} / (\rho G)^{3/4}$ at which inertial-vortex forces $F_I = \rho \varepsilon^{2/3} L^{8/3}$ equal $F_G$, where $\varepsilon$ is the viscous dissipation rate. Further fragmentation to proto-galaxy scales is predicted in this scenario, with the nonbaryonic dark matter diffusing to fill the voids between constant density proto-supercluster to proto-galaxy structures for scales smaller than the diffusive Schwarz scale $L_{SD} = (D^2 / \rho G)^{1/4}$, where $D$ is the diffusivity of the nonbaryonic dark matter. Fragmentation of the nonbaryonic material to form superhalos implies $D = 10^{28}$ m$^2$ s$^{-1}$, from observation of present superhalo sizes $L_{SD}$ and densities $\rho$, trillions of times larger than $D$ for H-He gas with the same $\rho$. 


4  Fossils of the first condensation (as “fog”)

Photon decoupling dramatically reduced viscosity values to $\nu = 3 \times 10^{12}$ m$^2$ s$^{-1}$ in the primordial gas of the nonturbulent $10^{20}$ m size proto-galaxies, with $\gamma = 10^{-13}$ s$^{-1}$ and $\rho = 10^{-17}$ kg m$^{-3}$, giving a PFP fragmentation mass range $M_{SV} \approx M_{ST} \approx 10^{23} - 10^{25}$ kg, the mass of a small planet. Pressure decreases in voids during fragmentation as the density decreases, to maintain constant temperature from the perfect gas law $T = p/\rho R$, where $R$ is the gas constant, for scales smaller than the acoustic scale $L_J = V_S/(\rho G)^{1/2}$ of Jeans 1902, where $V_S$ is the sound speed. However, the pressure cannot propagate fast enough in voids larger than $L_J$ so they cool. Hence radiation from the warmer surroundings can heat such large voids, increasing their pressure and accelerating the void formation, causing a fragmentation within proto-galaxies at the Jeans mass of $10^{35}$ kg, the mass of globular-star-clusters. These proto-globular-cluster (PGC) clumps of PFPs provide the materials of construction for everything else to follow, from stars to people. Leftover PGCs and PFPs thus comprise present galactic dark matter inner halos which typically have expanded to about $10^{21}$ m (30 kpc) of the core and exceed the luminous (star) mass by factors of $10^{-30}$.

5  Observations

Observations of quasar image twinkling frequencies reveal that the point mass objects which dominate the mass of the lens galaxy are not stars, but “rogue planets... likely to be the missing mass”, Schild 1996, independently confirming this prediction of Gibson 1996. Other evidence of the predicted primordial fog particles (PFPs) is shown in Hubble Space Telescope photographs, such as thousands of $10^{25}$ kg “cometary globules” in the halo of the Helix planetary nebula and possibly like numbers in the Eskimo planetary nebula halo. These dying stars are very hot ($100,000$ K versus $6,000$ K normal) so that many PFPs nearby can be brought out of cold storage by evaporation to produce the $10^{13}$ m protective cocoons that make them visible to the HST at $10^{19}$ m distances.

6  Summary and conclusions

The Figure summarizes the evolution of structure and turbulence in the early universe, as inferred from the present nonlinear fluid mechanical theory. It is very different, very early, and very gentle compared to the standard model, where structure formation in baryonic matter is forbidden in the plasma epoch because $L_J$ is larger than $L_H = ct$ and galaxies collapse at 140 million years (redshift $z=20$) producing $10^{46}$ kg Population III superstars that explode and re-ionize the universe to explain the missing gas (sequestered in PFPs). No such stars, no galaxy collapse, and no re-ionization occurs in the present theory. To produce the structure observed today, the concept “cold dark matter” (CDM)
was invented; that is, a hypothetical non-baryonic fluid of “cold” (low speed) collisionless particles with adjustable $L_J$ small enough to produce gravitational potential wells to drive galaxy collapse. Cold dark matter is unnecessary in the present theory. Even if it exists it would not behave as required by the standard model. Its necessarily small collision cross section requires $L_{SD} \gg L_J$ so it would diffuse out of its own well, without fragmentation if $L_{SD} \gg L_H$. The immediate formation of “primordial fog particles” from all the neutral gas of the universe emerging from the plasma epoch permits their gradual accretion to form the observed small ancient stars in dense globular-star-clusters known to be only slightly younger than the universe. These could never form in the intense turbulence of galaxy collapse in the standard model because $L_{ST}$ scales would be too large.

**Fluid Mechanical Theory of Structure Formation**  
**During the First Three Million Years**

![Diagram showing the evolution of structure and turbulence in the early universe]

**Figure 1:** Evolution of structure and turbulence in the early universe

**References**

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