GRAVITATIONAL HYDRODYNAMICS VS OBSERVATIONS OF VOIDS, JEANS CLUSTERS AND MACHO DARK MATTER

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Gravitational hydrodynamics acknowledges that hydrodynamics is essentially nonlinear and viscous. In the plasma, at \( z = 5100 \), the viscous length enters the horizon and causes fragmentation into plasma clumps surrounded by voids. The latter have expanded to 38 Mpc now, explaining the cosmic void scale \( 30/h = 42 \) Mpc. After the decoupling the Jeans mechanism fragments all matter in clumps of ca 40,000 solar masses. Each of them fragments due to viscosity in milli-brown dwarfs of earth weight, so each Jeans cluster contains billions of them. The Jeans clusters act as ideal gas particles in the isothermal model, explaining the flattening of rotation curves. The first stars in old globular clusters are formed by aggregation of milli-brown dwarfs, without dark period. Star formation also happens when Jeans clusters come close to each other and agitate and heat up the cooled milli brown dwarfs, which then expand and coalesce to form new stars. This explains the Tully-Fischer and Jackson-Faber relations, and the formation of young globular clusters in galaxy mergers. Thousand of milli brown dwarfs have been observed in quasar microlensing and some 40,000 in the Helix planetary nebula.

While the milli brown dwarfs, i.e., dark baryons, constitute the galactic dark matter, cluster dark matter consists probably of 1.5 eV neutrinos, free streaming at the decoupling. These two types of dark matter explain a wealth of observations.

\textit{Keywords:} Hydrodynamics, cosmic voids, Jeans cluster, milli brown dwarf, neutrinos

1. Introduction

It is generally understood that hydrodynamics is in principle important in the early Universe, but its role is small in practice. There is a great impetus from quantum field theory, inflation of a mysterious scalar field explains the structure in the CMB. In this approach, hydrodynamics is linearized before the decoupling of photons and matter. It was Gibson 1996 who questioned this assumption\textsuperscript{1} The conclusion is astonishing: \textit{There is a viscous instability in the plasma, so the concordance approach cannot be correct. Hydrodynamics can explain structure formation without cold dark matter trigger.} Here we summarize our recent work, Ref.\textsuperscript{2}

2. Hydrodynamics

The Navier-Stokes eqn expresses conservation of the specific momentum in a fluid,

\[
\frac{\partial \vec{q}}{\partial t} = \nabla B + \vec{v} \times \vec{\omega} + \vec{F}_{\text{viscous}} + \vec{F}_{\text{other}},
\]

averaged over system control volumes exceeding the momentum collision length scale. \( B = p/\rho + \frac{1}{2}v^2 + lw \) is the Bernoulli group of mechanical energy terms. For adiabatic flows the “lost work” term \( lw \) due to frictional losses is negligible so the
enthalpy $p/\rho$ decreases or increases to compensate for changes in the kinetic energy per unit mass $\frac{1}{2}v^2$. The viscous force is $\vec{F}_{\text{viscous}} = \nu_\ast \nabla^2 \vec{v} + (\frac{1}{2} \nu_s + \nu_b) \nabla \cdot (\nabla \cdot \vec{v})$, with kinematic shear viscosity $\nu_\ast = \eta/\rho$ and bulk viscosity $\nu_b = \zeta/\rho$, while other fluid forces may arise. The inertial-vortex force per unit mass $\vec{v} \times \vec{\omega}$, with $\vec{\omega} = \nabla \times \vec{v}$, produces turbulence if it dominates the other forces; for example, $|\vec{v} \times \vec{\omega}|/|\vec{F}_{\text{viscous}}|$ is the Reynolds number. A large viscosity corresponds to a small Reynolds number, with universal critical value $\sim 25 - 100$.

Jeans considers a gas clump of density $\rho_B$, typical size $L$ and mass $\rho_B L^3$. Its gravitational force has magnitude $G(\rho_B L^3)^2/L^2$. Equating this to the $\vec{v} \times \vec{\omega}$ force $(\rho_B L^3)v^2/L$ with $v$ the sound speed, yields the Jeans length $L_J = v/\sqrt{G\rho_B}$. A fluid will collapse on scales of $L_J$ into mass clumps $\rho_B L_J^3$. It is generally believed that only this scale is relevant, but Gibson considers the case where viscosity yields the dominant force. Applying the balance of gravitation and viscous force $\sim (\rho_B L^3)\nu v/L^2$ brings the Schwarzschild viscous scale $L_{SV} = (\nu v/G\rho_B)^{1/3}$. It appears that merely these two scales suffice to explain the major properties of cosmic structure formation.

We consider a flat cosmology and $h = 0.744$ so that neutrino dark matter has $\Omega_{\nu} = 0.111/h^3/2 = 0.173$, while no cold dark matter is assumed to exist. For baryons we take $\Omega_B = 0.02265/h^2 = 0.0409$ (WMAP5) and $\Omega_\Lambda = 0.786$ assures a flat space.

3. Viscous instability in the plasma

Silk damping involves a photon mean free path of $10^{-5}$ pc at decoupling, while the acoustic horizon is $d_H^A = 128$ kpc, so it is no surprise that the viscous length $L_{SV} = 76$ kpc is smaller already. Indeed, the shear viscosity increases in time as $1/T^2$, and before decoupling the plasma becomes too viscous to follow the cosmic expansion. A viscous instability occurs at $z = 5120$ when $L_{SV}$ enters the horizon $d_H^H$. It tears the plasma apart at density minima, and creates voids, next to condensations with baryonic clustering mass $\pi \rho_B L^3/6 = 1.7 \cdot 10^{14} M_\odot$, fat galaxy clusters. The initial void scale $d_H^c = 7.3$ kpc expands by a factor $1 + z$ to become $38$ Mpc now, a typical void size, $30/h$ Mpc = $40$ Mpc. ACDM predicts such voids formed last and full of debris, rather than first and empty as observed. At decoupling the neutrino hot dark matter is still free streaming and homogeneous. At $z \sim 7$ the neutrinos condense on e.g. hot galaxy clusters so the baryonic voids, still filled with neutrinos, become completely empty. Thus till $z \sim 7$ the metric is quite uniform.

4. Fragmentations in the gas at the Jeans and viscous scales

At last scattering, the plasma turns into a neutral gas and further baryonic structures form. For H with 24% weight of He, the sound speed is $v = 5.68$ km/s. The gas fragments at the Jeans scale into clumps of mass $M_J = \pi \rho_B L_J^3/6 = 38,000 M_\odot$.

At decoupling the viscosity decreases to the $10^{13}$ times smaller hot-gas value. The viscous scale $L_{SV} = 0.14$ pc m implies a further condensation of Jeans clumps into masses of order $\pi \rho_B L_{SV}^3/6 = 4 \cdot 10^{-5} M_\odot = 13 M_\odot$. We call these objects milli brown dwarfs (mBDs), each Jeans cluster contains billions of them.
5. Comparison to observations

In some of the Jeans clusters (JCs) collision processes quickly lead to star formation, basically without a dark period, thus transforming them into globular clusters and ordinary stars. In the major part of the JCs the mBDs cool and they still persist without stars. These JCs are in mainly in isothermal equilibrium and act as ideal gas particles that constitute the galactic dark matter. Their physical presence explains why the isothermal model describes flattening of the rotation curves, while the Tully-Fischer and Faber-Jackson relations follow from JC-JC interactions.

The matrix of dark JCs is revealed by new star formation (young globular clusters) as seen in photographs of galaxy mergers such as Tadpole, Mice and Antennae. From the GHD scenario following decoupling, the first stars form gently by a frictional binary accretion of still warm mBDs to form larger planet pairs and finally small stars as observed in old globular clusters. Thereby they create an Oort cavity as clearly exposed in e.g. the Helix planetary nebula.

At decoupling the entire baryonic universe thus turns to a fog of mBDs. Quasar microlensing observations confirm that galactic dark matter is composed from such objects. Indeed, thousands of crossings events have been observed, of mostly earth mass objects and some Jupiters. Due to the cosmic expansion the mBDs cool and the freezing temperature of H and He occurs at redshift $z \approx 8$, producing the cool dark baryonic mBDs in clumps predicted as the galaxy dark matter.

Cluster dark matter is the “true” dark matter, probably composed of 1.5 eV neutrinos. They condense at $z \sim 7$ on galaxy clusters, causing the extra-galactic mBDs to reionize into hot X-ray gas. Since then the voids are fully empty and the universe is strongly inhomogeneous.

When cooled, the mBDs are too small to dim light, even from remote sources, but they can account for dimming when they are heated. Warm atmosphere diameters are $\approx 10^{13}$ m, the size of the solar system out to Pluto, bringing them out of the dark. The separation distance between mBDs is $\approx 10^{14}$ m, as expected if the JC density of mBDs is the primordial density $\rho_0 = 2 \times 10^{-17}$ kg m$^{-3}$. In planetary nebula such as the nearby Helix, dark mBDs at the boundary of the $3 \times 10^{15}$ m Oort cavity are evaporated. HST optical images of Helix show $\approx 10^3$ “cometary knots”, gaseous planet-atmospheres $\approx 10^{13}$ m which we identify as mBDs with metallicity, and Spitzer shows 40,000 of them in the infrared from the $10^3 M_\odot$ available. Similar behavior is observed in other planetaries.

The large density contrast between plasma clumps and voids does not prevent a $10^{-5}$ CMB temperature contrast, since temperature is mainly set by the expansion.

References

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