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"Is the nonbaryonic dark matter Theo-neutrinos", Carl H. Gibson commentary.

The quark-gluon plasma has a very LARGE viscosity compared to that of the big bang turbulent combustion fluid, which is what constrains the big bang event. Reynolds numbers become SMALL.

Neutrino mass and signature from the dark matter in A1689

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The baryonic dark matter is clearly Earth mass hydrogen planets in clumps of a trillion from HGD cosmology, Gibson (1996) and Schild (1996). CHG

PACS 98.65.-r – Galaxy groups, clusters, and superclusters; large scale structure of the Universe
PACS 14.60.St – Non-standard-model neutrinos, right-handed neutrinos, etc.

Abstract – The dark matter in the galaxy cluster Abell 1689 is modelled by isothermal neutrinos. New data on the $2d$ mass density allow an accurate description of its core and halo. There is no "missing baryon problem" and the baryons occur at the cosmic mass fraction beyond 2.1 Mpc. Combining cluster and cosmic data leads to a solution of the dark matter riddle by left and right handed neutrinos with mass $(1.861 \pm 0.016)h_{70}^{-2}\mathrm{eV}/c^2$. Absence of neutrinoless double beta decay points to Dirac neutrinos: chargeless electrons with different flavor and mass eigenbases, as for quarks. Though the cosmic microwave background spectrum is matched up to some 10% accuracy only, the case is not ruled out because the plasma phase of the early Universe may be turbulent.

What is this in kilograms?

Old turbulence or New turbulence?

Yes.

Mythical!

No.

Introduction. – Nothing matters more than dark matter (DM), but its current status is paradoxical. While the cosmic microwave background (CMB) [1,2] and baryon acoustic oscillations [3] bring strong support for a WIMP (weakly interacting massive particle), the axion or perhaps a sterile neutrino, three decades of (in)direct searches have consistently left the researchers empty handed. Recent experiments include LUX [4], an underground Xe experiment, the Large Hadron Collider (LHC) in its 2012-2014 run at 7-8 GeV [5], the Alpha Magnetic Spectrometer at the International Space Station measuring electrons, positrons and (anti)protons [6,7], and the Fermi X-ray telescope [8–10]. None of them yielded a decisive clue. Hopes are now set on the 13 TeV run at the LHC, the next one of Lux and the first of Xenon1T.

But are we perhaps barking up the wrong tree? Various tensions with Λ cold dark matter (ΛCDM) cosmology are known [11–14]. The most natural source of DM is neutrinos. In ΛCDM they cannot make up the DM due to free streaming: structure formation is hindered when the total mass in the neutrino families exceeds a bound that is maximally 0.72 eV/c^2 [2]. This corresponds to a cosmic mass fraction $\Omega_\nu < 1.6\%$, far below the cosmic dark matter fraction $\Omega_c = 24.2 \pm 0.2\%$ [1]. However, there is an argument against this *linear* structure formation: The plasma may well be turbulent and produce nonlinear structures like galaxy clusters [15–17]. Indeed, the quark-gluon plasma has a low viscosity, which leads to a Reynolds number Re $\sim 10^{19}$ for a patch of acoustic horizon size [18, 19]. Since this horizon is larger than the causal horizon, turbulence can not develop – at this scale. But *turbulence can develop on subhorizon scale* – and hence it should. The plasma remains turbulent till the recombination [18, 19], hence, lacking further study, the option that neutrinos make up the dark matter, is not ruled out. This scenario explains many perplexing observations [16, 17]. We shall not dwell further into this, but rather test whether the case is indeed worth the effort.

Neutrino oscillations yield small m^2 differences, so if they are heavy, they have nearly the same mass. The upper limit of the electron antineutrino mass is 2.0 eV/c^2 [20], and for the 3 families (ν_e, $\bar\nu_e$; ν_μ, $\bar\nu_\mu$; ν_τ, $\bar\nu_\tau$) the thermal densities add up to $\Omega_\nu = \rho_\nu/\rho_c \le 0.13$, less than Ω_c. Hence if ν's are the source of DM, also right-handed ones (sterile ν's, not involved in weak processes) must exist. Reactor experiments favor them too [21–23].

Cosmology offers further evidence. While the CMB has achieved "precision cosmology", gravitational lensing can reach this status too. Indeed, the quite relaxed galaxy cluster Abell 1689 offers a test. There are well constrained data for the $2d$ mass density $\Sigma(r)$, primarily from strong lensing (SL), that is to say, from background galaxies lensed into several ($\le$ 5) pieces of an arc, up to some

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[1] We adopt the cosmology $H_0 = h_{70}70$ km/s Mpc, $h_{70} = 1$, $\Omega_m = 0.30$ and $\Omega_\Lambda = 0.70$, so that $1' = 184.5$ kpc at $\bar z = 0.183$ of A1689.

Neutrinos are the only known form of nonbaryonic dark matter.

200 kpc off the cluster centre. Further out, weak lensing (WL) occurs, that is, light from a randomly oriented background galaxy gets a systematic tangential shear $g_t(r)$ towards a circle around the cluster centre [24]. The effect can be deduced by averaging over the galaxies within a suitably defined field. The cluster galaxies can of course be observed easily. Finally, X-ray observations provide the electron density profile $n_e(r)$ and thus the mass density of the X-ray gas. These inputs provide a unique basis for an accurate reconstruction of the mass profile.

An initiating WL study of A1689 was performed in [25]. Ref. [26] reports a SL analysis yielding Σ for radii up to 270 kpc. Ref. [27] employs an entropy-regularized maximum likelihood analysis of the lens magnification and the distortion of red background galaxies detected with Subaru. Ref. [28] unveils the $3d$ structure of galaxy clusters such as A1689 and resolves the discrepancy between X-ray and lensing masses. Ref. [29] fits the NFW profile of cold dark matter [30] with the concentration parameter $c_{200} = 8-9$ [29]. However, it is known that modelling only the central data $r < 300$ kpc leads to smaller values, $4-5$. An NFW fit of the combined data leads to $c_{200} = 4.5$ [31]. Nowadays the focus is on the trixiality of A1689 [28,29,32]. However, the spherical approximation will serve our goals, since most matter is dark and more spherical than the gas.

Most authors focus on the NFW profile, so that no information about the mass of the DM particle is obtained. Still, some groups consider isothermal fermions. Cowsik & McClelland [33] model the DM of the Coma cluster as an isothermal sphere of neutrinos, which leads to a mass[2] of $\simeq 2$ eV. Treumann et al. study 2 eV thermal neutrinos next to thermal CDM and X-ray gas for clusters like Coma [34]. We apply an isothermal fermion model for a single type of dark matter, for the galaxies and the X-ray gas; a fit to lensing data of the Abell 1689 cluster works well and yields as best case the neutrino with mass ~ 1.5 eV [35]. This approach has been followed up whenever new data became available. In [36] we apply the model to SL data by [37] and X-ray data by [38], confirming the result. In [31] we adopt the galactic matter profile of [39], to find that neutrinos perform better ($\chi^2/\nu \sim 0.7$) than the NFW profile ($\chi^2/\nu \sim 2.2$).

Data sets to be employed. Recently, Umetsu et al. perform a WL analysis combined with some magnification properties [29], which provides important information as we shall discuss below. The authors provide 14 data points Σ^i_{wl} at $124 < r_i < 2970$ kpc and the correlation matrix C^{wl}_{ij}. The latter needs no regularisation, because each bin has $S/N > 1$. The methods for combining the WL shear and magnification effects to derive the radial mass density profiles are explained in [32,40]. Between 124 and 270 kpc the data overlap with those of [26].

We take additional data for $\Sigma(r)$ from SL analysis by Limousin et al [26]. For description of the analysis we also refer to [31]. There result 12 data points (r_i, Σ^i_{sl}) for $3 < r_i < 270$ kpc and their covariance matrix C^{sl}_{ij}, which has eigenvalues between $0.03\Sigma_c^2$ and $1.4\,10^{-8}\Sigma_c^2$. To account for information due to (implicitly assumed) priors and for further scatter, we add a constant σ^2_{sl} to the diagonal elements, so that the role of the small eigenvalues is suppressed. This leads to the modified covariance matrix $\overline{C}_{sl} = \sigma^2_{sl} I + C_{sl}$. A model for $\Sigma(r)$ then involves $\chi^2_{sl}(\Sigma) = \sum_{i,j=1}^{12}[\Sigma(r_i) - \Sigma^i_{sl}](\overline{C}^{-1}_{sl})_{ij}[\Sigma(r_j) - \Sigma^j_{sl}]$. We choose σ_{sl} on an empirical basis. In order not to erase the information coded in C_{sl}, one needs $\sigma^2_{sl} \ll 0.03\Sigma_c^2$. In [31] we take the average of the diagonal elements, now we even allow half of it: $\bar\sigma^2_{sl} = \mathrm{tr}\, C_{sl}/24 = (0.0375\Sigma_c)^2$.

We also employ the 13 data points for g_t between 200 kpc and 3 Mpc from the WL study [29]. While based on better statistics, they overlap with the data of [27].

The data for n_e we take from Morandi et al [38], who analyze Chandra X-ray observations. The density profile is recovered in a non-parametric way by rebinning the surface brightness into circular annuli via spherical deprojection [41], see also the discussion in [31].

Modelling the baryons. In a galaxy cluster there are three components: Galaxies, X-ray gas and dark matter. The galaxy mass density is dominated by the brightest cluster galaxy (BCG, "central galaxy" *cg*). An adequate profile with mass M_G, core size R^i_G and scale R^o_G is [39]

$$\rho_G(r) = \frac{M_G(R^i_G + R^o_G)}{2\pi^2(r^2 + R^{i\,2}_G)(r^2 + R^{o\,2}_G)}. \tag{1}$$

If $R^i_G \ll R^o_G$ it is a cored, truncated isothermal sphere.

The mass density of the X-ray gas follows [38] as $\rho_g(r) = 1.167\, m_N n_e(r)$ for a typical $Z = 0.3$ solar metallicity [35]. The 56 data points for n_e with the maximum of the upper and lower errors fit well to a cored Sérsic profile

$$n_e(r) = n^0_e \exp\left[k_g - k_g(1 + r^2/R_g^2)^{1/2n_g}\right]. \tag{2}$$

The best fit parameters are

$$\begin{aligned} n^0_e &= 0.0670 \pm 0.0028\,\mathrm{cm}^{-3}, \qquad k_g = 1.98 \pm 0.25, \\ R_g &= 21.6 \pm 2.7\,\mathrm{kpc}, \qquad n_g = 2.97 \pm 0.14. \end{aligned} \tag{3}$$

The $\chi^2(n_e)/\nu = 1.71$ with $\nu = 52$ implies the marginally acceptable q-value 0.0010 for our spherical approximation.

Towards data fits. SL data yield the $2d$ mass density

$$\Sigma(r) = \int_{-\infty}^{\infty} \mathrm{d}z \rho\left(\sqrt{r^2 + z^2}\right). \tag{4}$$

Within a disc of radius r it has the average $\overline{\Sigma}(r) = 2r^{-2}\int_0^r \mathrm{d}r'\, r'\Sigma(r')$. In weak lensing one determines the transversal shear, which is related to $\overline{\Sigma}$ and Σ as

$$g_t(r) = \frac{\overline{\Sigma}(r) - \Sigma(r)}{\Sigma_c - \Sigma(r)}. \tag{5}$$

[2]In the text we employ the short hand eV for eV/c^2.

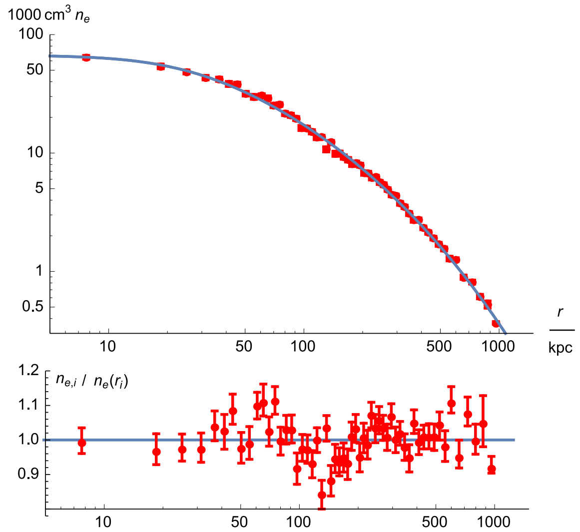

Fig. 1: Electron density as function of radius. Data from [38], full line: cored Sérsic profile (2). Lower pane: relative values.

The data of [29] involve $\Sigma_c = 0.682\, h_{70}\, \mathrm{gr\, cm}^{-2}$.

We fit our parameters by minimizing $\chi^2(\Sigma, g_t, n_e) = \chi^2(\Sigma, g_t) + \chi^2(n_e)$, where the lensing errors add up to

$$\chi^2(\Sigma, g_t) = \chi^2_{sl}(\Sigma) + \chi^2_{wl}(\Sigma) + \chi^2_{wl}(g_t). \qquad (6)$$

NFW fitting. Minimising only $\chi^2_{wl}(\Sigma) + \chi^2_{wl}(g_t)$ leads to $\nu = 27 - 2$ and $\chi^2/\nu = 1.25$, implying the good q-value 0.18, in support of a recent Bayesian analysis [29]. However, the SL data put stress on this. Ref. [31] reports $[\chi^2_{sl}(\Sigma)+\chi^2_{wl}(g_t)]/\nu = 2.2$ for its regulator $\sigma_{sl} = \sqrt{2}\bar\sigma_{sl}$ and $\nu = 20$ so that $q = 1.5\, 10^{-3}$, marginally acceptable; this case now yields $\chi^2(\Sigma, g_t)/\nu = 2.21$ for $\nu = 37$ with a bad q-value $3.3\, 10^{-5}$. Our present $\bar\sigma_{sl}$ yields $\chi^2(\Sigma, g_t)/\nu = 2.98$ with $\nu = 37$ and $q = 3.3\, 10^{-9}$, very bad. All by all, NFW fits are less satisfactory for the combined SL and WL data.

Neutrino model. For the DM we now consider g identical, nonrelativistic thermal fermion modes, denoted by ν, with mass m_ν and chemical potential $m_\nu \mu$, at temperature $T_\nu = m_\nu \sigma_\nu^2$. With potential energy $m_\nu \varphi(r)$ due to all gravitating matter, its mass density reads

$$\rho_\nu(r) = \int \frac{\mathrm{d}^3 p}{(2\pi\hbar)^3} \frac{g m_\nu}{\exp\{[p^2/2m_\nu^2 + \varphi(r) - \mu]/\sigma_\nu^2\} + 1}. \qquad (7)$$

Because positive energy particles escape from the cluster and $\varphi(\infty) \equiv 0$, the integral is restricted to $p^2/2m_\nu + m_\nu\varphi(r) < 0$. The gravitational potential φ is solved from the Poisson equation $\varphi'' + 2\varphi'/r = 4\pi G\rho$, $\rho = \rho_G + \rho_g + \rho_\nu$.

The data in fig. 2 expose that Σ does not decay fast for $r > 300$ kpc. Hence our previous fits [31, 35, 36] with a large chemical potential μ and fast decay of $\rho_\nu(r)$ do not apply. But this turns out to be a blessing: isothermal fermions can produce a good fit to the data *including the tails.* Then, when plotting the baryon fraction $f_b = M_b/(M_\nu + M_b)$, with $M_b = M_G + M_g$, as function of r, we notice around $r_{ms} = 2250$ kpc a quadratic maximum $f_b(r_{ms}) = 0.16 \pm 0.01$, overlapping with the cosmic value $f_b^c = 0.1580 \pm 0.0014$ [2]. The absence of a "missing baryon problem" around r_{ms} allows to eliminate it completely: we take the gas density from the observations and continue its fit (2) beyond 1 Mpc, solve ρ_ν from the Poisson equation up to some *mass separation radius* r_{ms} and impose beyond r_{ms} the cosmic ratio $\rho_\nu(r) = (1/f_b^c - 1)\rho_g(r)$, so that it holds there that $M_\nu(r) = (1/f_b^c - 1)M_b(r)$ and $f_b(r) = f_b^c$ (see Fig. 3). To achieve the matching, we set $f_b^c = \bar f_b^c \pm \delta f_b^c$ and add to $\chi^2(\Sigma, g_t, n_e)$ the combination

$$\chi^2_{ms}(r_{ms}) = \frac{1}{\delta f_b^{c2}} \left(\frac{M_b}{M} - \bar f_b^c\right)^2 + \frac{1}{\delta f_b^{c2}} \left(\frac{\rho_b}{\rho} - \bar f_b^c\right)^2, \qquad (8)$$

with $M_b = f_G^b M_G + M_g$, $M = M_\nu + M_b$, all taken at r_{ms}, and likewise for the ρ's. f_G^b is the baryon fraction of the BCG, which we take as 1, though $f_b^G = \bar f_b^c$ would hardly change the fit. The best minimum yields $\chi^2(\Sigma, g_t, n_e) + \chi^2_{ms}(r_{ms}) = 131.9$ for $\nu = 97 - 11$ d.o.f., so that its $q = 0.0011$ slightly improves the gas-only value. The $\chi^2_{sl}(\Sigma) = 5.63$, $\chi^2_{wl}(\Sigma) = 8.33$, $\chi^2_{wl}(g_t) = 28.8$ add up to $\chi^2(\Sigma, g_t) = 42.7$. Their $\nu = 39 - 6$ d.o.f. imply $\chi^2(\Sigma, g_t)/\nu = 1.29$ and the good lensing-alone q-value 0.12. The fits for Σ and g_t are represented in figs. 2 and 3, respectively.

Accounting for the variation of r_{ms} causes conservative error bars. The BCG has mass and inner and outer radius

$$M_G = 3.2 \pm 1.0\, 10^{13} M_\odot, \qquad (9)$$
$$R_G^i = 7.2 \pm 1.4\,\mathrm{kpc}, \qquad R_G^o = 129 \pm 40\,\mathrm{kpc}.$$

The gas fit (3) is not altered by combining with the lensing data. The velocity dispersion and chemical potential read

$$\sigma_\nu = 1330 \pm 40\,\frac{\mathrm{km}}{\mathrm{s}}, \quad \mu - \varphi(0) = 5.0 \pm 0.9\ 10^6 \frac{\mathrm{km}^2}{\mathrm{s}^2}. \qquad (10)$$

Finally, the fermion mass comes out as

$$\left(\frac{g}{12}\right)^{1/4} m_\nu = 1.92^{+0.13}_{-0.16}\, \frac{\mathrm{eV}}{c^2}. \qquad (11)$$

This exceeds the 1.45 ± 0.03 of [35], the 1.55 ± 0.04 of [36] and the 1.51 ± 0.04 eV of [31]. However, an additional type of dark matter is assumed in the model of Ref. [31].

The depth of the potential well $\varphi(0) = -19.4 \pm 0.4\ 10^6$ $\mathrm{km}^2/\mathrm{s}^2$ has also a systematic error from the extrapolation of the gas data beyond 1 Mpc with the Sérsic profile (2).

At $r_{200} = 2.37$ Mpc the cluster has overdensity 200 with $M_{200} = (18.1 \pm 0.8) 10^{14} M_\odot$, to be compared with the $(1.32 \pm 0.09)/h\, 10^{15} M_\odot = (18.9 \pm 1.3)\ 10^{14} M_\odot$ of [29].

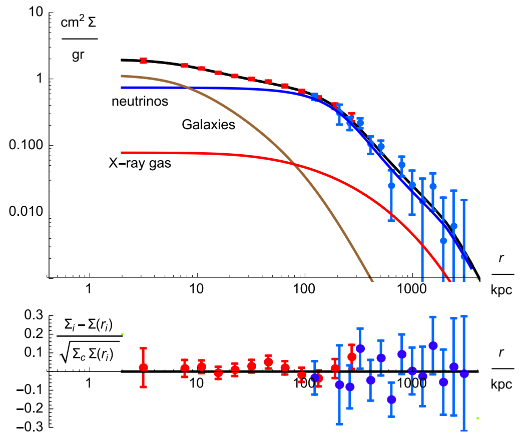

Fig. 2: $2d$ mass density Σ and the contributions from its components as function of r. Left data from [26] with error bars $(\overline{C}_{ii}^{sl})^{1/2}$. Right data from [29] with error bars $(C_{ii}^{wl})^{1/2}$. Black line: best fit to our model. The kink in the slope at $r_{ms} = 2.05$ Mpc reflects the mass separation: below r_{ms} the neutrinos deplete towards the interior. Lower pane: Relative deviations.

At $r_{ms} = 2.05 \pm 0.39$ Mpc the Newton acceleration

$$\frac{GM(r_{ms})}{r_{ms}^2} = 5.4\,10^{-11}\frac{\mathrm{m}}{\mathrm{s}^2} = 0.92\frac{cH_0(\bar{z})}{4\pi}, \qquad (12)$$

with $M(r_{ms}) = (16.4 \pm 0.7)10^{14}M_\odot$, leads to a consistent picture: Beyond r_{ms} the cosmic acceleration dominates the attraction to the cluster, preventing mass separation. Hence, unlike r_{200}, r_{ms} has a clear physical meaning.

The cosmic budget. The mass (11) depends on the degeneracy factor g: In the cluster a smaller DM particle mass can be compensated by a larger degeneracy, at fixed $g^{1/4}m$. At the cosmic scale gm gets fixed, lifting the degeneracy. Each active (anti)neutrino has a number density of 56.0 cm^{-3}, and we assume that sterile ν's are also thermal. Supposing there are $N_f = 3 + \Delta N_f$ neutrino families with $g = 2N_f$ degrees of freedom, all having basically a mass of 1.92 eV, the cosmic budget comes out as $\Omega_\nu = (N_f/6)^{3/4}(0.251 \pm 0.019)h_{70}^{-3/2}$, where we reinserted Hubble's constant [35]. The physical density parameter thus reads $\Omega_\nu h^2 = (N_f/6)^{3/4}(0.123 \pm 0.009)h_{70}^{1/2}$. The Planck cold dark matter fraction is $\Omega_c h^2 = 0.1188 \pm 0.0010$ [2]. Neutrinos can exactly account for this in case $N_f = 6$, $g = 12$, which amounts to the 3 active and 3 sterile ones (3+3 model), all having nearly the same mass. That case for $\Delta N_f = 2$ needs $m_\nu = 2.14$ eV which is ruled out [20].

In general it is not required that the masses are equal, and neither the chemical potentials nor the velocity dispersions. While neutrino oscillations have shown small mass differences between the active neutrinos, reactor experiments expose hints for one, two or possibly 3 sterile neutrinos with eV mass differences; at least two sterile species

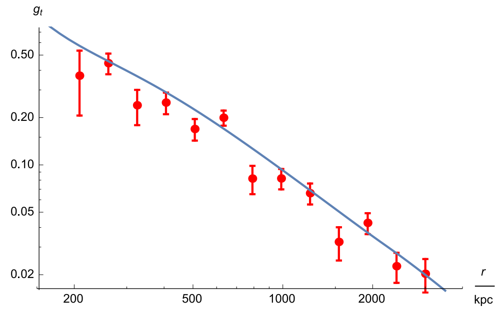

Fig. 3: Weak lensing shear g_t as function of r. Data from Umetsu et al. [29]; full line: best fit to the model.

are needed to explain CP violation [21–23]. Neutrinoless double beta decay ($0\nu\beta\beta$) implies for the known mixing angles [20] a sharpest lower bound $m_{\beta\beta}^{0\nu} \geq 0.33 m_\nu = 0.64 \pm 0.05$ eV when both Majorana phases are equal to π. Upper bounds for $m_{\beta\beta}^{0\nu}$ are 0.45 eV by EXO-200, 0.28 eV by KamLAND-Zen [42] and 0.4 eV by GERDA [43], respectively. Hence Majorana neutrinos are disfavored and we arrive at Dirac neutrinos: chargeless electrons with different flavor and mass eigenbases, like quarks. Detection of $0\nu\beta\beta$, though, would lead to a smaller mass of the active ν's and a higher mass(es) of the sterile ν's.

We considered only neutrinos bound to the cluster. Accounting, as in our earlier works, also for the unbound ones, yields a mass and other parameters compatible within the error bounds. We noticed the overlap of our Ω_ν with the Ω_c from the CMB. The smaller error bar of the latter [2] offers a sharper prediction for the 3+3 Dirac mass: $m_\nu = (1.861 \pm 0.016)h_{70}^{-2}\mathrm{eV}/c^2$.

The Dirac nature implies that the $\Delta m^2 \sim 1\,\mathrm{eV}^2$ effects seen so far at 2σ–3σ evidence in neutrino oscillations must be statistical flukes. Much effort will be needed to test this prediction and establish its Dirac mass differences $\Delta m_{12} = 1.1\,10^{-5}m_\nu$ and $|\Delta m_{13}| = 3.5\,10^{-4}m_\nu = 1.3\,10^{-9}m_e$.

It is generally expected that active neutrinos have sub-eV masses, implying that they hardly contribute to the cosmic mass budget. Within our approach this case leads to 5 or 6 sterile neutrino families (3+5, 3+6 models). These extra modes are massless during big bang nucleosynthesis, so they put stress on observations of ^{4}He and D, though they may help to soften the ^{7}Li problem [44].

Massive neutrinos are known not to describe the CMB correctly. Our 3+3 Dirac model with $m_\nu = 1.86\,/h_{70}^2$ eV can be fit to the Planck CMB data [2]. With the CLASS-code [45] we find that the parameter set $\Omega_b h^2 = 0.0245$, $h = 0.725$, $\tau_{\rm reio} = 0.175$, $A_s = 2.19\,10^{-9}$, $n_s = 1.33$ and $Y_{\rm He} = 0.25$ achieves to have the peaks at the right positions with amplitude at 70% of the first acoustic TT peak and within some relative 10% below or above the other TT, TE and EE peaks. It remains to be seen whether this can be repaired by the effects of turbulence.

Summary. The dark matter of the galaxy cluster A1689 is modelled by isothermal neutrinos. The fit works well

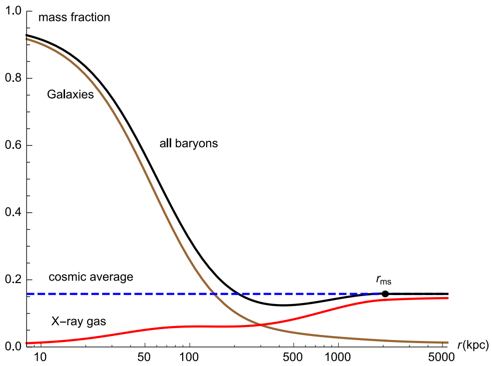

Fig. 4: Baryonic mass fractions as function of r. In the centre the brightest cluster galaxy dominates. The depletion beyond 300 kpc is standard. Beyond 700 kpc the neutrinos are relatively depleted, allowing the baryons to reach the cosmic fraction 0.158 at the mass separation radius $r_{ms} = 2.05$ Mpc. From there on baryons and neutrinos occur at cosmic ratios.

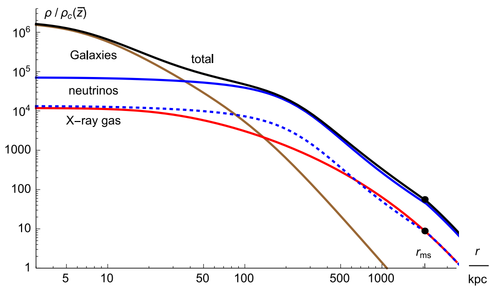

Fig. 5: Mass densities of Galaxies, X-ray gas and neutrinos in A1689, normalised to the critical density $\rho_c(\bar{z})$, as function of r. The dotted line presents the gas density if it had the cosmic fraction of the neutrino dark matter density. Its overlap beyond r_{ms} is a principle of our model; its near-overlap at the origin a surprise. The surplus from 20 to 650 kpc and the depletion from 650 to $r_{ms} = 2050$ kpc show that the neutrinos are cored.

and is remarkably consistent, without "missing baryons". Beyond $r_{ms} = 2.1$ Mpc the baryon fraction is cosmic, consistent observations [46]; the Newton force is weaker than the cosmic acceleration $cH_0/4\pi$ and hence unable to achieve mass separation. When for $r < r_{ms}$ the would-be cosmic mass ratio between the ν dark matter and the X-ray gas is compared to the its actual density, the "excess mass" of the ν-core is compensated in the outskirts [46] by an ν under-concentration between 0.7 and 2.1 Mpc, rather than a baryon over-concentration [47].

The rotation around the cluster centre has a maximum of 2330 km/s at $r = 430$ kpc due to the neutrino core (Fig. 6), a further test for the model. The central X-ray gas density appears to be near the cosmic baryon ratio w.r.t. the local neutrino dark matter density (Fig. 5).

It is desirable to have gas data beyond 1 Mpc, so that the extrapolation is better constrained. Likewise, a new strong lensing analysis may update the 2007 Limousin et al result [26], which is central for fixing our parameters.

Our cluster results stem with the cosmic ones if there exist 3 Dirac neutrino families with mass of approximately 1.86 eV. This is not ruled out by free streaming because the plasma may have been turbulent. Perhaps the ^{7}Li problem [44] can be solved by turbulence. Support for the neutrino picture may come from the "cosmic train wreck" galaxy cluster Abell 520, where a central clump with huge mass-to-light ratio $800 M_\odot/L_{R\odot}$ exhibits DM separated from the galaxies [48–50]. This is a puzzle for ΛCDM, but colliding cores of degenerate neutrinos may partly end up in the center due to the exclusion principle. Likewise, such cores may hinder each other and cause an offset between baryonic and dark mass as in Abell 3827 [51], where it is larger than ΛCDM can explain [52].

Neutrinos of mass 1.86 eV$/c^2$ become non relativistic at redshift 7900, so near the recombination they behave like cold dark matter and explain most of the CMB data, up to some 10% accuracy. However, the employed theory of linear fluctuations does not account for turbulence effects, so that a match may still arise. The KATRIN experiment searches the neutrino mass down to 0.2 eV$/c^2$. Most likely they are Dirac particles with mass in the $\bar{\nu}_e$ itself, so that the detection or rejection of our prediction will be easy.

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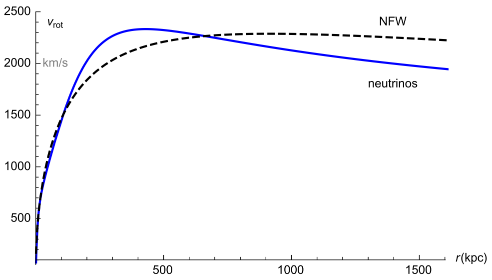

Fig. 6: Full line: Circular rotation velocity of galaxies as function of r; the bump around 430 kpc is caused by the neutrino core. Dashed: NFW prediction.

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This interesting paper attacks the key outstanding problems of cosmology: 1. What is the nonbaryonic dark matter? 2. What is the role of turbulence in cosmic structure formation? Observations discussed in the Journal of Cosmology clearly show that the standard model LCDMHC is spectacularly inadequate and misleading. There is NO dark energy. There is NO cold dark matter. The assumption of collisionless fluid mechanics MUST be abandoned. The assumption that turbulence cascades from large scales to small is just as wrong, backwards and misleading as LCDMHC cosmology and must also be abandoned. Standard models of collisional fluid mechanics using the Gibson turbulence definition based on the inertial vortex force and the three Kolmogorov universal similarity laws serve as the physical basis of hydro-gravitational-dynamics (HGD) cosmology. The easiest prediction of HGD cosmology is that a fog of earth-mass hydrogen planets in Jeans-mass clumps of a trillion will form at the plasma to gas transition at 10^13 seconds. This Gibson (1996) prediction was independently observed by Schild (1996), where these dark matter planets were termed "primordial fog particles" by Gibson and "rogue planets" by Schild. The Jeans mass clumps of planets are metastable with the mass of globular star clusters (10^36 kg) and are the source of all star formation. No stars form from gas and dust. No stars are much more massive than the sun. Collisional fluid mechanics works with Planck particles and Planck antiparticles at the time of the hot big bang, when "Old turbulence" was impossible because there were no length scales larger than 10^-35 meters. The Reynolds number of big bang turbulence was about 10^6 when gluon viscous forces and quarks of the strong force damped it out. No turbulence was possible until 10^12 seconds when proto-galaxies served as fluid particles and turbulent boundary layers formed on expanding supervoids, forming superclusters such as the A1689 object discussed by Dr. Nieuwenhuizen. The Reynolds number of the fluid of protogalaxies was ~ 10^3, not 10^19.