WHAT DOES THE DYNAMICAL ANALSIS OF CLUSTERS OF GALAXIES TELL US ABOUT MASSIVE NEUTRINOS?

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It is often claimed that massive neutrinos (ν's) can solve the "missing mass" problem, but it is not so clear in the particular case of clusters of galaxies (C.O.G.). Let us assume that the unseen matter is composed by massive ν's only. If they are cosmological, the ν's should obey Fermi-Dirac statistics with a density of $\sim$ 100 ν/cm^3/species. But if "relic," the ν's would be so slow (1) that they cannot exist in this form (because of the previous Jeans instability or because they are trapped in wells generated by baryonic matter). Since the time when the ν's decoupled from the primeval mixture (T $\sim$ 3-1 MeV), the ν's can be considered as a "gravitational plasma," so that violent relaxation occurs in inhomogeneous systems, leading to a Lynden-Bell distribution defined by three parameters: η_ν (numerical density), V_ν (r.m.s. velocity) and the ν-mass, m_ν, all unknown. All three of these parameters are, in fact, necessary to define a state of ν-matter.

Dynamical analyses of C.O.G. with a single baryonic component model lead, for the mass defect ratio (Virial mass/luminous mass), to values running from 3 (2) to 20.

Two interpretations are possible: 1. Galaxies have dynamical masses 3 to 20 times their luminous ones and ν's are located in massive haloes; then $m_\nu \gtrsim$ 22 eV (4) and V_ν of the same order as the star velocity ($\sim$ 100 km/s). The total ν-mass is then 3 to 20 times the visible one. This solution is very simple, but it has been argued that if galaxies are too massive, the two-body relaxation time (too small) is in contradiction with the nonrelaxation state observed in the C.O.G. (3). Moreover, the "questionable" dependence of M/L on scale cannot be explained.

2. The ν's have the same density profile as the galaxies, and the virial masses of galaxies are equal to their luminous ones. This occurs if $V_\nu \equiv V_{gal}$, and suggesta that $n_\nu \propto n$(baryonic) everywhere. From the dynamical value M/L we then obtain:

$$m_\nu \simeq \frac{(M/L)}{30} h_{50} \qquad \begin{array}{l} m_\nu = 1.5 - 9 \text{ eV } (H = 50); \\ m_\nu = 3 - 18 \text{ eV } (H = 100). \end{array}$$

These values have to be compared with the result $m_\nu \gtrsim$ 4 eV of Tremaine and Gunn (4). Once again this explanation cannot elucidate the dependence of M/L on the scale of the system.

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In fact, the previous considerations are obtained from one-component analysis. If massive ν's are present, they are dynamically influential and a two-component analysis is necessary. It then turns out that the predominance is governed by the ratio V_ν/V_{gal} (6 and references therein). a) In the very hot case ($V_\nu >> V_{gal}$), a baryonic cluster is located in the center of the ν-cluster. The gravitational potential is smooth (except at the center) and the modeling of the baryonic cluster is then not affected by the ν-cluster; the usual analysis and the missing mass problem are unaffected! b) There is, in principle, a possibility of detecting tepid ν's: i) If they exist, the asymptotic slope of the density profile of galaxies depends only on the properties of neutrinos (6). ii) If they do not exist, the galaxy density profile depends on the velocity dispersion profile of galaxies.

In the "cold" case, two possibilities exist: a) $V_\nu \lesssim V_*$ (100 km/s): ν's are confined in the galaxies of the cluster so that it is equivalent to the first case discussed. b) $100 \lesssim V_\nu \lesssim 500$ km/s (500 is the velocity of the most massive galaxies): Cold ν's are then located at the center of the cluster, deepening the potential so that a central enhancement must appear in the density profile. What is the real situation? Quintana (5) has noted such an enhancement in the center of the Coma cluster. We confirm that result by comparison of small- and large-scale maps of the Coma cluster (2). Are neutrinos then really detected in the Coma cluster? Unfortunately, other physical explanations are possible. For instance, the previously noticed existence of massive binary systems of galaxies (7) may also deepen the potential, as well as taking into account the anisotropy of the dispersion velocity tensor.

In conclusion: Although neutrinos are exciting from a cosmological point of view, they do not solve the missing mass problem so easily, at least for clusters of galaxies. From dynamical considerations, it seems to us that if massive ν's (or other inos) exist, they are probably located in galaxy haloes and then are distributed by mising in the centers of rich clusters, leading to possible observational effects.

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Discussion

Schallwich: I should mention that we have detached diffuse optical emission in a cluster of galaxies (A1146) which could provide as much mass as there is in the galaxies of the cluster.

Dressler: As you pointed out, observations of clusters of galaxies rule out a large two-body relaxation, which in turn implies that the missing mass is not associated with individual galaxies. This has not been considered a problem, however, since calculations such as those done by Richstone predict that the halos would be tidally stripped in rich clusters.