NATURE OF 'UNSEEN' GALACTIC ENVELOPES

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It is suggested that unseen matter in a galactic envelope or in a group of galaxies may consist of substellar bodies originating as the first permanent 'stars' in the formation of a very massive galaxy according to a model previously proposed by the author.

The writer has described a model for galaxy-formation (McCrea 1979, 1982). It is on the basis of simple big-bang cosmology: since this includes no means for initiating condensations, some additional assumption is unavoidable: we assume that after the epoch of decoupling the material of the cosmos splits into clouds of all sizes. The universe continues expanding, but neighbouring clouds may fall together under mutual gravitation. In an encounter of interest the relative motion is supersonic; it produces a layer of shocked material which breaks up into primary condensations. Each first collapses on itself forming short-lived supermassive stars which end in outbursts that (a) produce the *first heavy elements*, (b) induce in the rest of the condensation the formation of the *first normal stars*. These disperse or remain as a *globular cluster*, the aggregate of all such stars and clusters forming the *halo of a galaxy* composed of the material involved in the encounter. Any left after forming the halo goes to produce a nucleus or disk stars which mainly determine the optical appearance; here we are concerned with the halo population which on the model contains most of the mass. For a galaxy of mass about that of our Galaxy $M_G \simeq 10^{11}\mathcal{M}_\odot$ the model correctly predicts a mass $m_G \simeq 10^6\mathcal{M}_\odot$ for a globular cluster. At present it does not predict the mean mass $\mathcal{M}_{*G}$ of a star formed as in (b); so we shall adopt (c) $\mathcal{M}_{*G} \simeq 0.5\mathcal{M}_\odot$ as an estimated mean mass of halo stars in the Galaxy.

For a galaxy of mass M formed according to the model, if m is the mass of a primary condensation and ρ its mean density when formed, we have $m \propto M^{-1/3}$ and $\rho \propto M^{2/3}$. When the first stars of average mass $\mathcal{M}_*$ are formed, the mean density ρ_* is different, but it is natural to assume $\rho_* \propto \rho \propto M^{2/3}$. When stars are formed in material of density ρ_*, according to almost any theory of a critical mass, we have $\mathcal{M}_* \propto \rho_*^{-1/2}$. Combining these results $\mathcal{M}_* \propto M^{-1/3}$, or writing $M = \mathcal{M} M_G$ and using (c) we have $\mathcal{M}_* \simeq 0.5\mathcal{M}^{-1/3}\mathcal{M}_\odot$. Also we see that $m/\mathcal{M}_*$ is independent of M i.e on

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the model the number of stars in a globular cluster is about the same for all galaxies. Finally, the halo has diameter $\propto M^{1/3}$. Taken literally we have inferred that the halo of a 'galaxy' say 100 times as massive as our Galaxy would be composed of stars of average mass about $0.1\mathcal{M}_\odot$, which are about the faintest stars observed; the diameter would be about 5 times that of our Galaxy. Presumably this halo would be undetectable by direct observation since it would be out-shone by the rest of the galaxy. Again, a galaxy about 1000 times as massive as our Galaxy would have a halo of 10 times the diameter that would be composed of bodies of about $0.05\mathcal{M}_\odot$. According to usual estimates, nuclear burning would not be ignited in these, so we should have an enormous completely dark envelope.

Well-known reasons show that surrounding certain actual galaxies there is an amount of dark matter much exceeding the visible parts in mass; also in some groups of galaxies there is evidence of much dark matter. Such matter must be the dominant constituent of the system concerned. Here I consider the hypothesis that it is *baryonic*, i.e. neither neutrinos nor black holes. Because of cosmic abundances it must then be mainly hydrogen and helium, but not gas which would be too impermanent. The only known permanent state is in bodies between about $0.1\mathcal{M}_\odot$ and $0.001\mathcal{M}_\odot$; more massive bodies would not be dark and less massive would probably evaporate. Thus we want extensive 'galaxies' that are composed of such *substellar bodies* and relatively little else. The only way to provide such a structure is to have the bodies made throughout the required region; once they have been formed and are moving under the gravitation of the system itself the state is long-lasting. These requirements regarding actual dark matter appear to be met in a rather convincing manner by the halos of very massive galaxies predicted by our model. Thus our purpose is to propose the hypothesis:

> Unseen galactic envelopes and unseen matter in groups of galaxies consist of substellar bodies formed as the first permanent 'stars' in very massive galaxies.

The problem of unseen matter is so formidable that a drastic solution is demanded. Therefore a suggestion that some galaxies possess masses large enough to furnish them, according to the model, with halos composed of bodies of mass not exceeding about $0.1\mathcal{M}_\odot$ may be not too fantastic. On the other hand, our numerical examples show that the hypothesis becomes of interest for masses exceeding about 100 times the mass of our Galaxy, which are normally considered more applicable to groups of galaxies. In the case of such a mass it may therefore be better to regard the model as applying to the first stage in forming a whole group rather than as necessarily leading to the production of a single enormous galaxy. This possibility of a unified treatment of dark matter in both cases would be an additional recommendation. The suggestion that dark matter consists of faint stars is not novel, but its derivation from a model for galaxy formation that offers even tentative predictions about numbers and masses appears to be new.

REFERENCES

McCrea, W.H.: 1979, Irish Astr. Jl. 14pp. 41-49.
McCrea. W.H.: 1982, *Progress in Cosmology* (A.W. Wolfendale, ed.) D. Reidel Publ. Co., Dordrecht, Holland, pp. 239-257.

Discussion

Rees: I would just like to emphasize that your proposed correlation between the masses of stars and the scale of the bound system they belong to is expected only if the stars form at a relatively "recent" epoch. If Population III objects condensed at $Z \gtrsim 100$ (as is envisaged in models where their luminosity gives rise to distortions in the microwave background), they would not at that stage "know" what scale of bound system they are destined to be in.

McCrea: I should have done better not to mention Population III objects! The halo "stars" -- or "jupiters" if the mass is small enough -- about which I spoke are not the Population III stars of other models. On the present model the halo objects are formed when a galaxy as a whole (or possibly a group of galaxies as a whole) is formed. So they "know" from the outset the scale of the bound system to which they belong; there is no paradox in their mean mass being dependent upon that system's total mass.

In giving a brief oral description of the model, I referred to Population III stars because other speakers had mentioned them; in the written version I refer to "short-lived supermassive stars" and in my spoken account I said that these may resemble Population III stars of certain other models. But in my model such stars are a (temporary) part of the galaxy being formed; so they are not pre-galactic in the sense of those other models. In that sense, as Professor Rees says, my processes may be somewhat more "recent" than postulated pre-galactic processes. However, as stated in the cited references, I contemplated an epoch $z \simeq 100$, which may not be a lot more recent, but I appeal to no similar pre-galactic happenings.

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