PoS PROCEEDINGS OF SCIENCE

# The Baryonic Mass vs. Dark Halo Mass Relationship in Galaxies. The imprint of large energy feedbacks and of the inefficiency of the cosmological star formation.

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We derive the Baryonic Mass Function of galactic structures from their inner kinematics and prove its cosmological importance by showing its universal nature, its substantial independency of the method with which is derived. The present day amount of baryons estimated from the BMF is in good agreement with that obtained by integrating the star formation occurred in the Universe over the whole Hubble time.

From the BMF and the theoretical Halos Mass Function of virialized objects, we obtain the relationship between the baryonic mass of a galaxy and its virial (total, dark) mass. We find that this relation clearly bears the effect of baryonic feedbacks occurred during the galaxy formation process, i.e. the supernovae explosions and the quasar activity, that have coupled the dark and ordinary matter in galaxies.

*Baryons in Dark Matter Halos*
*5-9 October 2004*
*Novigrad, Croatia*

*Speaker.

## 1. Introduction

The formation of stars, in galaxies of various Hubble Type, from $z \sim 6$ down to the present time, has assembled luminous baryons in a quantity $\Omega_{b,lum} \simeq (2-4)\times 10^{-3}$ ([8, 2]). On the other hand the density of baryons associated to detectable emissions falls short respect to $\Omega_b = 0.044 \pm 0.004$), very precisely determined both through the Cosmic Background Radiation (CMB) anisotropy and measurements of the primordial abundance of light elements [13].

The circumstance that $\Omega_b$ is a factor of about 10 larger than $\Omega_{b,lum}$ put forth two problems: the first is how to detect these 'missing' baryons and second is to explain why so a few baryons are presently in gas and stars inside galaxies.

## 2. The baryonic mass as cosmological label of Galaxies.

In order to derive the mass density of baryons associated to galaxies $\Omega_b^g$, one has to make the very reasonable assumption that the starlight and the photons emitted by various radiative processes occurring in the interstellar gas are good tracers of the baryons distribution in galaxies. Thus, the baryon cosmological density associated to stars and gas in galaxies is derived through the galaxy Luminosity Function $\Phi(L)$:

$$\Omega_b^g = \sum \Omega_b^{E,S} = \frac{1}{\rho_c} \sum \int_{L_{min}}^{L_{max}} \left(\frac{M_b}{L}\right)^{E,S} \Phi^{E,S}(L)\, LdL\ ,$$

yields the value

$$\Omega_b^g(KIN) = (3.3 \pm 0.4)\times 10^{-3}, \tag{2.1}$$

where the label KIN indicates that the baryonic mass is estimated from its effects on the galaxy's kinematics.

By comparing with the *cosmological* value $f_{cosm} = 6 \pm 1.2$ we realize that, contrariwise to what occurs in galaxy clusters, the baryons detected today in galaxies, are only a small fraction (less than 10%!) of those which galaxies have started with.

## 3. The present-day baryonic content in galaxies matches the cosmological star formation history

The density of star formation per unit time as a function of redshift $\dot{\rho}_\star(z)$ can be estimated from observations of the associated IR and UV fluxes. Using a Salpeter IMF and the data by [7] we find, integrating over cosmic time and taking into account dark remnants,

$$\Omega_\star^g \simeq 4.0 \times 10^{-3}. \tag{3.1}$$

The excellent agreement of the above values with $\Omega_b^g(KIN)$ lends additional substance to the claim that we properly weigh the baryons in galaxies.

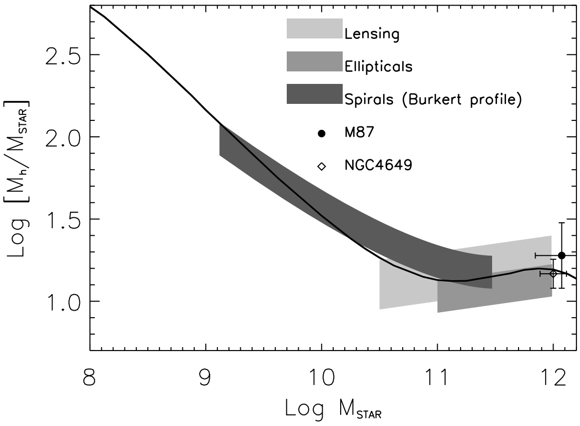


**Figure 1:** The derived Dark-to-Stellar mass relationship as a function of stellar mass in galaxies

## 4. The virial-to-stellar mass relationship

We derive the cosmological Galaxy Baryonic Mass Function (**GBMF**) by adding to the GBMF of disk systems [10] the contribution due to ellipticals/spheroids estimated using the $(M/L)_{r^\star}$ given by [1]. The resulting **GBMF** is well fitted by a Schechter Function plus a power law term:

$$\mathbf{BMF}(M_b)dM_b = \left(1.72\times 10^{-3}\tilde{M}_b^{-1.215}e^{-\tilde{M}_b/2.9} + 4\times 10^{-7}\,\tilde{M}_b^{-2.6}\right)\frac{dM_b}{10^{11}M_\odot} \tag{4.1}$$

where $\tilde{M}_b \equiv M_b/(10^{11}\,M_\odot)$.

For cosmological virialized halos, the statistics of halos containing one galaxy is given by the Galaxy Halo Mass Function (**GHMF**) which we obtain a) adding the sub-halos [14], i.e. galactic halos in groups and clusters and in the largest galaxy halos and b) subtracting the halo group-cluster mass function as determined by [6] from the 2dF Group Luminosity Function.

By solving the integral equation

$$\int_{\bar{M}_{star}}^{\infty} GBMF(M_{star})dM_{star} = \int_{\bar{M}_h}^{\infty} GHMF(M_h)dM_h \tag{4.2}$$

we get the relation between the star component in a galaxy and its dark matter halo mass (Figure 1).

We argue that the fast rise below $10^{11}M_\odot$ of the DM fraction is due to the increasing efficiency of supernovae (SN) feedback in removing gas in the cold phase. The more powerful active galactic nuclei (AGN) kinetic feedback ([4]) is instead able to remove most of the gas even in the massive spheroids.

Using the SMBH mass function derived in [12] and following again Eq 4.2 we get the SMBH masses linked with each halo. The relation we find matches the one obtained by SAM modelling ([4]) which include SN and AGN feedbacks.

## 5. Results and Conclusions

These results are in very good agreement with the values of $M_{vir}/M_{STAR}$ obtained by

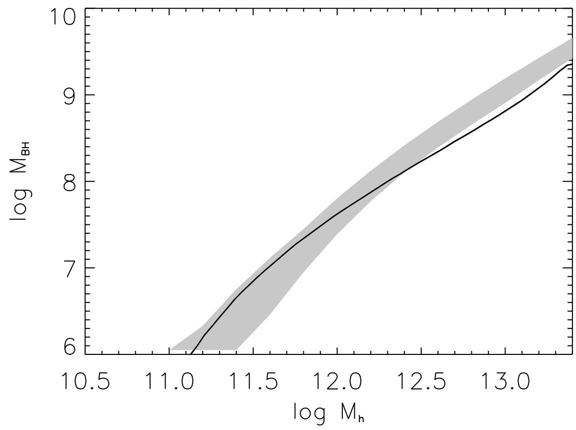


**Figure 2:** The derived relation SMBH-Halo mass relationship compared with the the feedback-constrained theoretical relation by [4] which includes both supernova and active galactic nuclei feedbacks

- extrapolating to virial radius the inner mass models of a number of giant ellipticals [3] and that underlying the Universal Rotation Curve of spirals ([9, 11]).
- accurate X-ray -based mass models of giant ellipticals in which the gravitational potential is known for a relevant fraction of the virial radius
- the weak-lensing investigations that provide the shear field around an average galaxy of luminosity $L$ from which it is possible to infer the virial mass that can be compared with its stellar mass after we assume a typical mass to light ratio for this latter component ([5]).

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