# COSMOLOGICAL PARAMETERS: FASHION AND FACTS

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We are at a specific period of modern cosmology, during which the large increase of the amount of data relevant to cosmology, as well as their increasing accuracy, leads to the idea that the determination of cosmological parameters has been achieved with a rather good precision, may be of the order of 10%. There is a large consensus around the so-called concordance model. Indeed this model does fit an impressive set of independent data, the most impressive been: CMB $C_l$ curve, most current matter density estimations, Hubble constant estimation from HST, apparent acceleration of the Universe, good matching of the power spectrum of matter fluctuations. However, the necessary introduction of a non zero cosmological constant is an extraordinary new mystery for physics, or more exactly the come back of one of the ghost of modern physics since its introduction by Einstein. Here, I would like to emphasize that some results are established beyond reasonable doubt, like the (nearly) flatness of the universe and the existence of a dark non-baryonic component of the Universe. But also that the evidence for a cosmological constant may not be as strong as needed to be considered as established beyond doubt. In this respect, I will argue that an Einstein-De Sitter universe might still be a viable option. Some observations do not fit the concordance picture, but they are generally considered as not to be taken into account. I discuss several of the claimed observational evidences supporting the concordance model, and will focus more specifically on the observational properties of clusters which offer powerful constraints on various quantities of cosmological interest. They are particularly interesting in constraining the cosmological density parameter, nicely complementing the CMB result and the supernova probe. While early estimations were based on the of the $M/L$ ratio, i.e. a local indirect measure of the mean density which needs an extrapolation over several orders of magnitude, new tests have been proposed during the last ten years which are global in nature. Here, I will briefly discuss three of them: 1) the evolution of the abundance of clusters with redshift 2) the baryon fraction measured in local clusters 3) apparent evolution of the baryon fraction with redshift. I will show that these three independent tests lead to high matter density for the Universe in the range $0.6 - 1.$. I therefore conclude that the dominance of vacuum to the various density contributions to the Universe is presently an interesting and fascinating possibility, but it is still premature to consider it as an established scientific fact.

## 1. Introduction: the contents of the Universe

Cosmology is a rather young field still undergoing a very fast evolution. Twenty years ago the nature of the microwave background was still a matter of debate, although it was generally believed that the origin was mainly from the Big Bang, the exact shape of the spectrum was still uncertain. The measurement of the spectrum by COBE, which was concomitant to the Gush et al. measurement (1990), showing that the spectrum was a nearly perfect blackbody has been a fundamental result in modern cosmology, by establishing in a definitive way one of the most critical prediction of the standard hot Big Bang picture. The determination of cosmological parameters is a central question in modern cosmology and it has become more central after the next fundamental result established by COBE: the first robust detection of the CMB fluctuations, nearly thirty years after the prediction of their presence (Sachs and Wolf, 1967). This detection has opened a new area with the perspective of reaching high "precision cosmology". However, it is also important to mention the fact that the Inflation paradigm (Guth, 1981) has represented an enormous attraction for theorist towards the field of cosmology, opening the perspective of properly testing high energy physics from cosmological data, while such a physics will probably remain largely unaccessible from laboratory experiment. Even if the data from the CMB fluctuations were not taken at face values as a proof of inflation the need for new physics appear very strongly (it is interesting to mention that the origin of the asymmetry between matter and antimatter was a fundamental problem which solution involves physics of the very early universe).

Moreover, the presence for non-baryonic dark matter can be now considered as a well established fact of modern physics. This was far from being obvious twenty years ago. By present days the abundances of light elements is well constrained by observations, consistent with a restricted range of baryon abundance (O'Meara et al., 2001):

$$\Omega_{baryons} = 0.02h^{-2} \pm 0.002 \tag{1}$$

where $h$ is the Hubble constant in unit of 100 km/s/Mpc. The above baryon abundance is in full agreement with what can be inferred from CMB (Le Dour et al., 2000; Benoît et al., 2002b). There are differences in matter density estimations, but nearly all of them lead to a cosmological density parameter in the range [0.2–1.], and therefore those estimates imply the presence of a non-baryonic component of the density of the universe. An other implication is that most baryons are dark: the amount of baryons seen in the Universe is mainly in form of stars:

$$\Omega_{\rm stars} = 0.003 - 0.010 \qquad (2)$$

much less than predicted by primordial nucleosynthesis. This picture, the presence of two dark components in the Universe, has gained considerable strength in the last twenty years, first of all because the above numbers have gained in robustness. However, it is now believed that a third dark constituent has been discovered: the dark energy.

## 2. Observions and cosmological parameters

### 2.1. *What the CMB does actually tell us?*

#### 2.1.1. *The curvature of space*

The detection of fluctuations on small angular scale, mainly by the Saskatoon experiment (Netterfield et al, 1995) more than 7 years ago provided a first convincing piece of evidence for a nearly flat universe (Linewaever et al., 1997; Hancock et al., 1998; Lineweaver and Barbosa, 1998), or more precisely evidence against open models which were currently favored at that time. This conclusion is now firmly established thanks to high precision recent measurements including those of Boomerang, Maxima and DASI (de Bernardis et al;, 2000; Hanany et al., 2000; Halverson et al., 2002): open models are now entirely ruled out: $\Omega_t > 0.92$ at 99% C.L., it should be noticed that upper limit on $\Omega_t$ are less stringent, $\Omega_t < 1.5$ at 99% C.L., unless one add some prior, for instance on the Hubble constant.

The most recent measurements of CMB anisotropies, including those obtained after this conference by Archeops (Benoît et al., 2002a), provide a remarkable success of the theory: the detailed shape of the angular power spectrum of the fluctuations, the theoretical predictions of the $C_l$ curve, is in excellent agreement with the observational data. This success gives confidence in the robustness of conclusions drawn from such analyzes, while alternative theories, like cosmological defects (Durrer et al, 2002) are almost entirely ruled out as a possible primary source of the fluctuations in the C.M.B. This gives strong support for theories of structures formation based the gravitational growth of initial passive fluctuations, the gravitational instability scenario, a picture sketched nearly seventy years ago by G. Lemaître (1933). At the same time this implies that conclusions on cosmological parameters from CMB have to be considered as robust: the

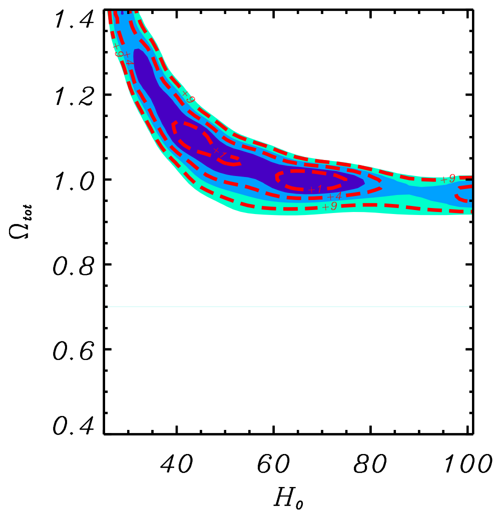


Figure 1. On this picture the likelihood contours from the CMB constraints are given: dashed lines, when projected provide the 68%, 95%, 99% confidence intervals, while shade area correspond to the contours on two parameters. The likelihood is maximized on the other parameters. This diagram illustrates several aspects of constraints that can be obtained from CMB: flatness of the universe follows from the fact that $\Omega_t > 0.92$ at 99% C.L., but $H_0$ is very poorly constrained. Indeed CMB allows to severely tighten the model parameters space, but can leave us with indetermination on specific individual parameter because of degeneracies. See Douspis et al., (2000) for further details.

spectacular conclusion that the universe is nearly flat space[a] is a major scientific result of modern science which is certainly robust and is very likely to remain as one of the greatest advance of modern Cosmology.

### 2.1.2. *A strong test of General Relativity*

Contrarily to a common conception, General Relativity (GR) is weakly tested on cosmological scales: the expansion of the Universe can be described in a Newtonian approach, while departure from the linear Hubble diagram are weak, and therefore does not provide strong test of GR. Ac-

[a]It is sometimes believed that a space cannot be "nearly" flat, because mathematically space is flat or not. This is not true in Cosmology where there is a natural scale which is $c/H_0$. Stating that the Universe is nearly flat means that its curvature radius $R_c$ is much larger than this scale.

tually the observed Hubble diagram is used to fit the amplitude of the cosmological constant, i.e. ones assumes (a non-standard version of!) GR and fits one of the parameter, therefore this does not constitute a test of the theory. However, the $C_l$ curve of CMB fluctuations provides an interesting test of GR on such scales: the angular distance to the CMB accordingly to RG is such that:

$$D_{\rm ang} \sim \frac{1.}{300} c(t_0 - t_{\rm lss}) \tag{3}$$

($t_0$ being the present age of the universe, and $t_{\rm lss}$ the age of the universe at the last scattering surface (lss) from where the $C - l$ curve is produced). This means that the angular distance to the CMB is of the same order than the one to the Virgo cluster! Therefore the $C_l$ curve can be obtained only within a theory where photons trajectories are essentially those predicted by GR.

### 2.2. *Is the Universe accelerating ?*

It is often mentioned that the present day data on the CMB excluded a model without a cosmological constant. Given the present-day quality of the data, and the anticipated accuracy one can hope from satellite experiments, this is a crucial issue. Actually, what's happen is that an Einstein-de Sitter is at the boarder of the $3 - \sigma$ contour in likelihood analysis. But this is not sufficient to claim that the model is excluded at $3 - \sigma$! Actually, a model without a cosmological constant provides a very acceptable fit to the data in term of a goodness of fit. Therefore, *CMB data do not request a non-zero cosmological constant.*

The possible detection of a cosmological constant from distant supernovae has brought the essential piece of evidence largely comforting the so-called concordance model: the apparent luminosity of distant supernovae now appears fainter, i.e. at larger distance, than expected in any decelerating universe (Riess et al, 1998; Perlmutter et al., 1999) and can therefore be explained only within an accelerating universe (under the assumption of standard candle). Indeed a CDM model in a flat universe dominated by a cosmological constant is in impressive agreement with most of existing data: such a model is consistent with the HST measurement of the Hubble constant, the age of the Universe, the power spectrum and the amplitude of matter fluctuations as measured by clusters abundance and weak lensing on large scale, as well as most current measurements of the mass content on small scales obtained by various technics. The concordance model offers

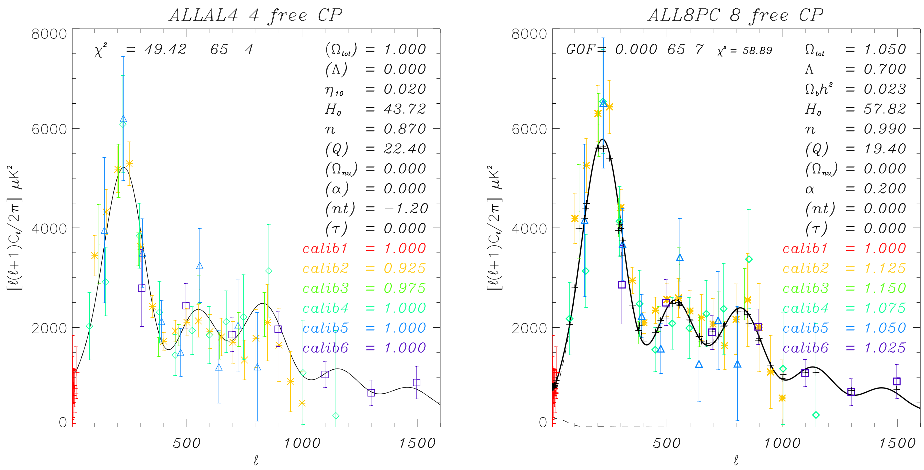


Figure 2. An example of an acceptable model to the CMB data without inclusion of a cosmological constant (left) The Hubble constant has been taken to a low value of 44 km/s/Mpc. An exemple of optimal model is shown, corresponding to the concordance model. Both provide an acceptable fit in term of goodness of fit. Courtesy of M. Douspis.

therefore a remarkable success for the CDM theory, but at the expense of the introduction of a non-zero cosmological constant.

### 2.3. *Some reasons for caution*

Despite the above impressive set of agreements cited above, one should keep an open mind. The question of the age of the Universe is not an issue: models fitting adequately the $C_l$ curve leads to similar ages, consistent with existing constraint. For instance, the model drawn on figure 2 (left side) has an age of 15 Gyr, well consistent with age estimates (actually a model with $t_0 \sim 10$ Gyr should probably not be securely rejected on this basis). Identically the amplitude of matter fluctuations on small scales is sometimes claimed to be inconsistent with a high density universe, while there is actually a degeneracy between this amplitude and the matter density parameter $\Omega_m$. Very often, authors implicitly refer to the standard CDM scenario ($\Omega_m = 1$, $h \sim 0.5$, $n = 1$). Actually this simplest CDM model is known to be ruled out from several different arguments, but there exists also different way one can imagine the spectrum to be modified in order to match the data (an example is a possible contribution of hot dark matter of the order of 20%).

A high density universe is actually inconsistent (because of the age problem) with value of the Hubble constant as high as those found by the HST. However, the HST measurement of the Hubble constant has been questioned (Arp, 2002). In order to illustrate the argument I show the figure given by Arp, which is claimed to represent the Hubble diagram from the HST data. Clearly, a firm conclusion on the Hubble constant from this data seems difficult and actually Arp claims that data can favor $H_0 \sim 55$ km/s/Mpc. An other doubt on the Hubble constant comes from the Sunyaev-Zeldovich measurements: in a recent review Carlstrom et al. (2002) found that the best value slightly depends on the cosmology, but that in an Einstein-de Sitter model one finds an average values of $H_0 \sim 55$ km/s/Mpc, furthermore given that such determination suffers from possible clumping of the gas (Mathiesen et al., 1999; see below), the actual value could be 25% less!

Let us now examine observational direct evidences for or against a nonzero cosmological constant. Distant SNIa are observed to be fainter than expected (in a non-accelerating universe) given their redshift, indicating very directly that the universe is accelerating should they be standard candles. The signal is of the order of 0.3 magnitude (compared to an Einstein–de Sitter universe). It is important to realize that several astrophysical effects of the same order are already existing, and that their actual amplitude might be difficult to properly evaluated. Rowan-Robinson (2002) argued for instance that the dust correction might have been underestimated in high redshift SNIa, while such a correction is of the same order of the signal. Identically, the K-correction that has to be applied to high redshift supernovae is large (in the range 0.5–1. mag) and is estimated from zero redshift spectral templates; one can therefore worry whether some shift in the zero-point would not remain from the actual spectrum, with an amplitude larger than the assumed uncertainty (2%). Identically, the progenitor population at redshift 0.5 is likely to be physically different from the progenitors of local SNIa (age, mass, metalicity). Consequence on luminosity are largely unknown.

Finally it is worth noticing that the first 7 distant SNIa which were analyzed conducted to conclude to the rejection of a value of $\lambda$ as large as 0.7: $\lambda < 0.51$ (95%) (Perlmutter et al., 1997). Several arguments have been used in the past or recently to set upper limit on a dominant contribution of $\lambda$ (Maoz et al., 1993; Kochanek, 1996; Boughn et al., 2002). There is therefore a number of arguments for caution:

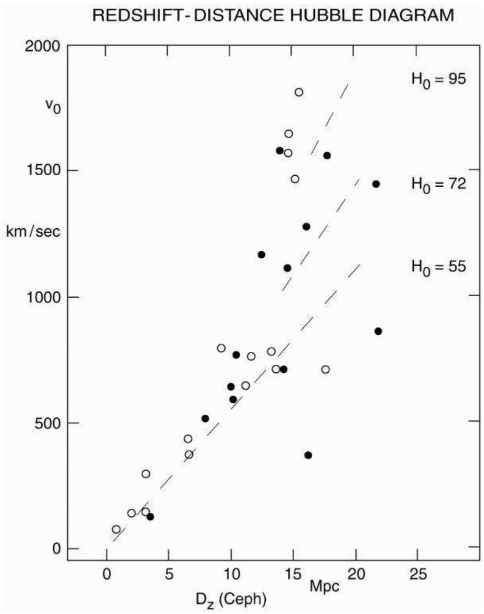


Figure 3. Hubble diagram from HST cepheids according to Arp (2002). Clearly the derivation of a value from this data set is uncertain. But a value of 55 km/s/Mpc seems as least as adequate as the HST finding (72 km/s/Mpc).

1) SNIa measurements provide the **single** direct evidence for a cosmological constant,
2) most measurements of $\Omega_m$ are local in nature (mostly inferred from clusters),
3) some upper limits have been published on $\lambda$ which do not agrre with recent measurements ,
4) a non-zero cosmological constant is an extraordinary new result in physics and therefore deserves extraordinary piece of evidence.

Before the existence of the cosmological constant can be considered as scientifically established, it is probably necessary to reinforce evidence for the convergence model by obtaining further direct evidence for a cosmological constant. Because there exist degeneracies in parameters determination with the CMB, even the Planck experiment will not allow to break these degeneracies. It is therefore necessary to use tests which provide complementary information. The data provided by the distant SNIa satisfies well this requirement. As it is difficult to think of a new test measuring directly the presence of a cosmological constant, the best approach is probably still to try to have reliable estimates of the matter density from global technics. In this respect, clusters are probably the most powerful tool, as they provide several major roads to measure the density matter of the Universe and which exploration is still in its infancy. Here I will concentrate on this perspective.

## 3. The mean density of the Universe from Clusters

The classical way to use clusters to constraint the average matter density in to try to obtain a direct measurement of the local density. This is the principle of $M/L$ test. Because the matter content of the universe is essentially in a dark form, we do not have direct measurement of the mass content even at the local level. This is the reason why in practice we rely on a two-steps procedure: first the average luminosity density of the universe is estimated from galaxy samples, this quantity is now relatively well known thanks to the large redshift surveys like the SLOAN or the 2dF (although difference of the order of 50% might still exist); the second ingredient is the value of the $M/L$ ratio obtained from data on clusters (total luminosity and mass estimations). There might be a factor of two of uncertainty in this quantity. For instance Roussel et al. (2000) found that the average $M/L$ could be as large as $750h$ when the mass–temperature relation for clusters is normalized from numerical simulations of Bryan and Norman (1998), while values twice smaller are currently obtained by other technics. The basic principle for estimating the average density of the Universe is then to write:

$$\rho_m = \rho_l \times M/L$$

However, it should be realized that the volume occupied by clusters is a tiny fraction of the total volume of universe, of the order of $10^{-5}$. The application of the $M/L$ relies therefore on an extrapolation over $10^5$ in volume!

## 4. New global tests

In order to have a reliable estimation of the mass density of the universe, it is vital to have the possibility to use global tests rather than local ones.

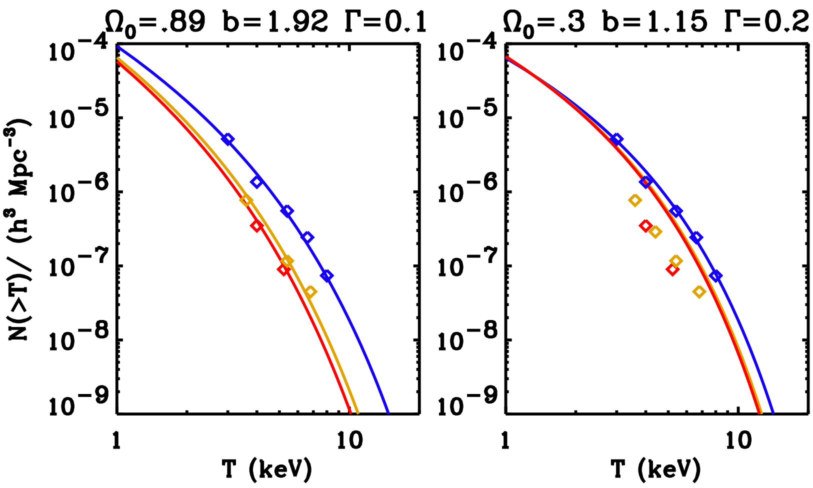


Figure 4. These plots illustrate the power of the cosmological test of the evolution of the abundance of X-ray clusters: the TDF (temperature distribution function) has been normalized to present day abundance (blue – dark grey – lines). The abundance of local clusters is given by the blue (dark grey) symbols (Blanchard et al., 2000). Present abundance allows one to set the normalization and the slope of the spectrum of primordial fluctuations on clusters scale (which is $\Omega_m$ dependant). The evolution with redshift is much faster in a high matter density universe (left panel, $\Omega_m = 0.89$) than in a low density universe (right panel, $\Omega_m = 0.3$): $z = 0.33$ (yellow – light) the difference is already of the order of 3 or larger. It is relatively insensitive to the cosmological constant. We also give our estimate of the local TDF (blue symbols) derived by Blanchard et al. (2000), as well as our estimate of the TDF at $z = 0.33$ (yellow symbols– light grey). Also are given for comparison data (Henry 2000) and models predictions at $z = 0.38$ (red – dark grey – symbols and lines). On the left panel, the best model is obtained by fitting simultaneously local clusters and clusters at $z = 0.33$ leading to a best value of $\Omega_m$ of 0.89 (flat universe). The right panel illustrates the fact that an flat low density universe $\Omega_m = 0.3$ which fits well local data does not fit the high redshift data properly at all.

### 4.1. *The evolution of the abundance of clusters*

The abundance of clusters at high redshift has been used as a cosmological constraint more than ten years ago (Peebles et al., 1989; Evrard, 1989). Ten years ago, Oukbir and Blanchard (1992) emphasized that the evolution of the abundance of clusters with redshift was rather different in low and high density universe, offering a possible new cosmological test. The interest of this test is that it is global, not local, and therefore allows to actually constraint directly $\Omega_m$. It is relatively insensitive to the cosmological constant. In principle, this test is relatively easy to apply, because the abundance at redshift $\sim 1.$ is more than an order of magnitude less in a critical universe, while it is almost constant in a low density universe. Therefore the measurement of the temperature distribution function (TDF) even at $z \sim 0.5$ should provide a robust answer. In recent years, this test has received considerable attention (Borgani et al, 1999; Eke et al., 1998; Henry, 1997; Henry, 2000; Viana and Liddle, 1999, among others). The first practical application was by Donahue (1996) who emphasized that the properties of MS0451, with a temperature of around 10 keV at a redshift of 0.55, was already a serious piece of evidence in favor of a low density universe. This argument has been comforted by the discovery of a high temperature cluster at redshift $z \sim 0.8$, MS1054, which has a measured temperature of $\sim 12$ keV (Donahue et al, 2000). In the mean time, however, the redshift distribution of EMSS clusters was found to be well fitted by a high density universe under the assumption of a non evolving luminosity-temperature relation (Oukbir and Blanchard, 1997; Reichert et al., 1999), as seems to follow from the properties of distant X-ray clusters (Mushotsky, R.F. and Sharf, 1997; Sadat et al., 1998).

Application of this test is the purpose of the XMM $\Omega$ program during the guaranty time phase (Bartlett et al., 2001). In principle, this test can also be applied by using other mass estimates, like velocity dispersion (Carlberg et al, 1997), Sunyaev-Zeldovich (Barbosa et al, 1996), or weak lensing. However, mass estimations based on X-ray temperatures is up to now the only method which can be applied at low and high redshift with relatively low systematic uncertainty. For instance, if velocity dispersions at high redshift ($\sim 0.5$) are overestimated by 30%, the difference between low and high density universe is canceled. Weak lensing and SZ surveys of clusters to allow this test remain to be done.

### 4.2. *The local temperature distribution function*

In order to estimate the amount of evolution in the number of clusters, one obviously needs a reliable estimate of the number of clusters at $z \sim 0$. This already is not so easy and is a serious limitation. The estimation of the local temperature distribution function of X-ray clusters can be achieved from a sample of X-ray selected clusters for which the selection function is known, and for which temperatures are available. Until recently, the standard reference sample was the Henry and Arnaud sample (1991), based on 25 clusters selected in the 2. – 10. keV band. The ROSAT satellite has since provided better quality samples of X-ray clusters, like the RASS and the BCS sample, containing several hundred of clusters. Temperature information is still lacking for most of clusters in these samples and therefore such clusters samples do not allow yet to improve estimations of the TDF in practice. We have therefore constructed a sample of X-ray clusters, by selecting all X-ray clusters with a flux above $2.210^{-11}$ erg/s/cm$^2$ with $|b| > 20$. Most of the clusters come from the Abell XBACS sample, to which some non-Abell clusters were added. The completeness was estimated by comparison with the RASS and the BCS and found to be of the order of 85%. This sample comprises 50 clusters, which makes it the largest one available for measuring the TDF at the time it was published. The inferred TDF is in very good agreement with the TDF derived from the BCS luminosity function or from more recent comprehensive survey (Reiprich and Böhringer, 2002) (with $\sim 65$ clusters). The abundance of clusters is higher than derived from the Henry and Arnaud sample as given by Eke et al. (1998) for instance. It is in good agreement with Markevitch (1998) for clusters with $T > 4$ keV, but is slightly higher for clusters with $T \sim 3$ keV. The power spectrum of fluctuations can be normalized from the abundance of clusters, leading to $\sigma_8 = \sigma_c = 0.6$ (using PS formula) for $\Omega_m = 1$ and to $\sigma_c = 0.7$ for $\Omega_m = 0.35$ corresponding to $\sigma_8 = 0.96$ for a $n = -1.5$ power spectrum index (contrary to a common mistake the cluster abundance does not provide an unique normalization for $\sigma_8$ in low density models, but on a scale $\sim \sqrt[3]{\Omega_m} 8h^{-1}$Mpc), consistent with recent estimates based on optical analysis of galaxy clusters (Girardi et al., 1998) and weak lensing measurements (Van Waerbeke et al., 2002).

### 4.3. *Application to the determination of $\Omega_m$*

The abundance of X-ray clusters at $z = 0.33$ can be determined from Henry sample (1997) containing 9 clusters. Despite the limited number of clusters and the limited range of redshift for which the above cosmological test can be applied, interesting answer can already be obtained, demonstrating the power of this test. Comparison of the local TDF and the high redshift TDF clearly show that there is a significant evolution in the abundance of X-ray clusters (see figure 1), such an evolution is unambiguously detected in our analysis. This evolution is consistent with the recent study of Donahue et al. (2000). We have performed a likelihood analysis to estimate the mean density of the universe from the detected evolution between $z = 0.05$ and $z = 0.33$. The likelihood function is written in term of all the parameters entering in the problem: the power spectrum index and the amplitude of the fluctuations. The best parameters are estimated as those which maximize the likelihood function. The results show that for the open and flat cases, one obtains high values for the preferred $\Omega_m$ with a rather low error bar :

$$\Omega_m = 0.92^{+0.26}_{-0.22} \quad \text{(open case)} \tag{4}$$

$$\Omega_m = 0.86^{+0.35}_{-0.25} \quad \text{(flat case)} \tag{5}$$

(Blanchard et al., 2000). Interestingly, the best fitting model also reproduces the abundance of clusters (with $T \sim 6$ keV) at $z = 0.55$ as found by Donahue and Voit (2000).

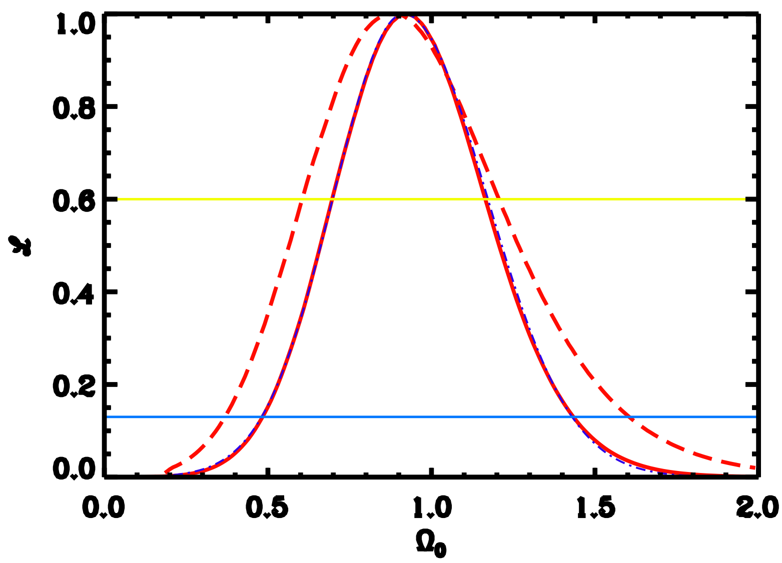


Figure 5. Likelihoods from the measured abundance of EMSS clusters in the redshift range (0.3,0.4) based on the Henry's sample (1997). The dashed line is for a flat universe while the continuous line is for an open cosmology.

### 4.4. *Systematic uncertainties in the determination of* $\Omega_m$

The above values differ sensitively from several recent analyzes on the same test and using the same high redshift sample. It is therefore important to identify the possible source of systematic uncertainty that may explain these differences. The test is based on the evolution of the mass function (Blanchard and Bartlett, 1998). The mass function has to be related to the primordial fluctuations. The Press and Schechter formalism is generally used for this, and this is what used in deriving the above numbers. However, this may be slightly uncertain. Using the more recent form proposed by Governato et al. (1999) we found a value for $\Omega_m$ slightly higher (a different mass function was used in Figure 1). A second problem lies in the mass temperature relation which is necessary to go from the mass function to the temperature distribution function. The mass can be estimated either from the hydrostatic equation or from numerical simulations. In general hydrostatic equation leads to mass smaller than those found in numerical simulations (Roussel et al., 2000; Markevitch, 1998; Reiprich and Böhringer, 2002; Seljak, 2002). Using the two most extreme mass–temperature relations inferred from numerical simulations, we found a 10% difference. We concluded that such uncertainties are not critical.

An other serious issue is the local sample used: using HA sample we found a value smaller by 40%. Identically, if we postulated that the high redshift abundance has been underestimated by a factor of two, $\Omega_m$ is reduced by 40%. The determination of the selection function of EMSS is therefore critical. An evolution in the morphology of clusters with redshift would result in a dramatic change in the inferred abundance (Adami et al., 2001). This is the most serious possible uncertainty in this analysis. However, the growing evidences for the scaling of observed properties of distant clusters (Neumann and Arnaud, 2001), rather disfavor such possibility.

### 4.5. *An other global test : the baryon fraction in local clusters*

This is a very interesting test proposed by White et al. (1993) which in principle offer a rather direct way to measure $\Omega_m$. It relies on one side on the fact that one should be able to measure the total mass of clusters, as well as their baryon content and on the other side that the primordial abundance of baryons can be well constrained from the predictions of primordial nucleosynthesis and the observed abundances of light elements. Furthermore, the CMB is providing interesting constraints on the baryon density of the universe, that are essentially consistent with values inferred from nucleosynthesis (Eq. 1). X-ray observations of clusters allow to measure their gas mass which represents the dominant component of their (visible) baryonic content (the stellar component represents around 1% of the total mass). In this way one can measure the baryon fraction $f_b$ and infer $\Omega_m$:

$$\Omega_m = \gamma^{-1}\frac{\Omega_{bbn}}{f_b}$$

where $\gamma$ represents a correction factor between the actual baryon fraction and the naive value $\Omega_{bbn}/\Omega_m$; typically, $\gamma \sim 0.9$. This method has been used quite often (Evrard, 1997; Roussel et al., 2000). There are some differences between measurements, mainly due to the mass estimators used. One key point is that the baryon fraction has to be estimated in the outer part of clusters as close as possible to the virial radius. However, the outer profile of the X-ray gas has been shown by Vikhlinin et al. (1999) not to follow the classical $\beta$ profile, usually assumed, but being actually steeper; consequently derived gas masses are somewhat lower than from usual analysis. Recently, several consequences of this work were derived on the baryon fraction (Sadat and Blanchard, 2000):

- the scaled baryon fraction flattens in the outer part of clusters.
- the global shape of the baryon fraction from the inner part to the outer part follows rather closely the shape found in numerical simulations from the Santa Barbara cluster project (Frenk et al, 1999).
- when mass estimates are taken from numerical simulations the baryon fraction, corrected from the –rather uncertain– clumping factor (Mathiesen et al, 1999) could be as low as 10% ($h = 0.5$).

The consequence of this is that a value of $\Omega_m$ as high as 0.8 can be acceptable. Large systematic uncertainties are still possible, and value twice lower can certainly not be rejected on the basis of this argument, but similarly a value $\Omega_m \sim 1$ can not be securely rejected.

### 4.6. *The baryon fraction in high redshift clusters*

A reasonable assumption is that the baryon fraction in clusters should remain more or less constant with redshift, as there is no motivation for introducing a variation with time of this quantity. When one infers the baryon fraction from X-ray observations of clusters at cosmological distances, the background cosmology is coming in the inferred value, through angular and luminosity distances. Therefore for a given observed cluster, the inferred

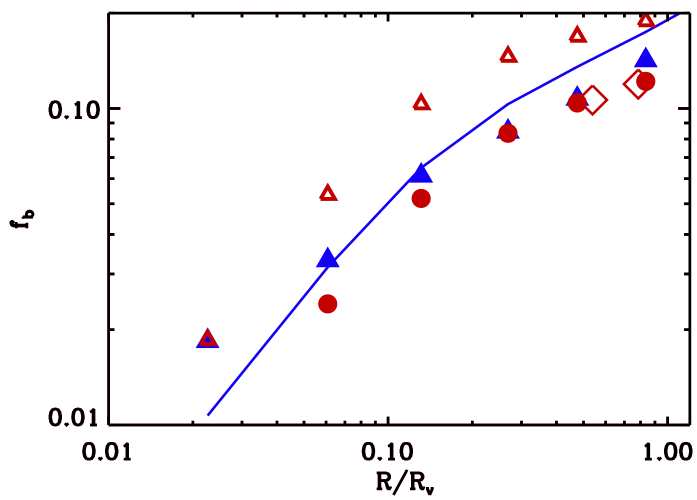


Figure 6. From the observed X-ray surface brightness of the distant cluster RXJ1120 (Arnaud et al., 2002) the gas fraction density profile (red filled circles) is compared to the results from the local clusters derived by Roussel et al. (2000) (blue open triangles) and those found in the outer regions by Sadat and Blanchard (2000) (red rhombuses). The profile shape is very close to those of local clusters. The amplitude is right for an $\Omega_m = 1.$ model, while a lambda model (open red triangles) is in strong disagreement with the data.

gas fraction would vary accordingly to the cosmology. This opens a way to constraint the cosmology, if one assumes that the apparent baryon fraction has to be constant (Sasaki, 1996; Pen, 1997), or equivalently that the emissivity profiles of clusters has to be identical when scaling laws are taken into account (Neumann and Arnaud, 2001). Application of this test probably needs a large statistical sample, but a preliminary application can be done on a distant cluster observed by XMM: RXJ1120.

This distant cluster is a perfect candidate for the application of this test: the X-ray emission has been detected up to a distance close to the virial radius (Arnaud et al., 2001), the cluster is a $\sim 6$ keV cluster, with a relaxed configuration. The gas profile can be derived up to a radius of the order of the virial radius without extrapolation. The inferred radial gas profile possesses two remarkable properties: i) the shape of the gas profile in this distant cluster is in very good agreement with the shape of the profile inferred from local clusters by Sadat and Blanchard (2000), giving an interesting further piece of evidence in favor of this shape ii) the amplitude matches the amplitude of the local sample only for a high matter density universe, while an universe dominated by a cosmological constant is strongly disfavored.

## 5. Conclusion

In this paper I have presented a personal point of view on the observational determination of cosmological parameters and especially on question of the possible non-zero value of the cosmological constant. Although, the concordance model provides a nice agreement with several observational data sets, I have argued that i) the only direct case foran accelerating universe, implying the domination of the vacuum density over the other type of dark matter already assumed to be present in the Universe (baryonic dark matter, non-baryonic dark matter), is coming from the distant SNIa and is not sufficient to be considered as robustly established. ii) some evidences against the concordance model are systematically rejected, because they are judged as insufficiently robust. The global picture drawn by the concordance model might be right after all! But I still consider that the case for a cosmological constant is oversold. It would be crucial in order to strength the case to have independent evidence either direct or indirect. A possible way for this would be to achieve a reliable measurement of the matter density of the Universe, which in conjunction with the CMB evidence for flatness, would allow an estimate of the cosmological constant. I have argued that clusters are in several ways the best tool to achieve such a measurement. Again contrary to a common prejudice I have illustrated that there are different values obtained by such methods, *some corresponding to high matter density* consistent with an Einstein-de Sitter model.

Summarizing results on clusters, I have shown an up-to-date local temperature distribution function obtained from a flux limited ROSAT sample comprising fifty clusters. When compared to Henry's sample at $z = 0.33$, obtained from the EMSS, this sample clearly indicates that the TDF is evolving. This evolution is consistent with the evolution detected up to redshift $z = 0.55$ by Donahue et al. (1999). This indicates converging evidences for a high density universe, with a value of $\Omega_m$ consistent with what Sadat et al. (1998) inferred previously from the full EMSS sample taking into account the observed evolution in the $L_x - T_x$ relation (which was found moderately positive and consistent with no evolution). From such analyzes, low density universes with $\Omega_m \leq 0.35$ are excluded at the two-sigma level.

This conflicts with some of the previous analyzes on the same high redshift sample. Actually, lower values obtained from statistical analysis of X-ray samples were primarily affected by the biases introduced by the local reference sample, which lead to a lower local abundance and a flatter spectrum for primordial fluctuations (Henry, 1997, 2000; Eke et al., 1998; Donahue and Voit, 1999). Our result is consistent with the conclusion of Viana and Liddle (1999), Reichert et al. (1999) and Sadat et al (1988). The possible existence of high temperature clusters at high redshift, MS0451 (10 keV) and MS1054 (12 keV), cannot however be made consistent with this picture of a high density universe, unless their temperatures are overestimated by a large factor or the primordial fluctuations are not gaussian. The baryon fraction in clusters is an other global test of $\Omega_m$, provided that a reliable value for $\Omega_b$ is obtained. However, it seems that the mean baryon fraction could have been overestimated in previous analysis, possibly being closer to 10% rather than to 15%-25%. This is again consistent with a high density universe. Finally, we have seen in one case that the apparent evolution of the baryon fraction in clusters could also be consistent with a high density universe.

In conclusion, I pretend that the determination of cosmological parameters and especially the evidence for a non-zero cosmological constant is still an open question which needs to be comforted and that the exclusion of an Einstein de Sitter model is over-emphasized.

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