© M.S.Shulman (shulman@dol.ru) and G. Raffel, 2010

On galaxies angular size evolution

(August 2, of 2010. Updated September 10, of 2010)

Abstract

We analyze a model of galaxy angular size evolution in the Universe depending on redshift. This model is an alternative to the standard cosmological model and allows us to obtain agreement with the observational data if the transverse galaxy size evolves according to the same law as the radial distance from the galaxy.

1. Introduction

As is well known, galaxy angular size dependence on redshift is considered to be an important test for any cosmological model. The author of the recent publication **[Lopez-Corredoira, 2010]** investigates this dependence using large statistics on galaxies with the same luminosities across a wide range of red shifts. The revealed data are compared with the predictions of five different cosmological models. As the author writes, the real galaxy angular size is *inversely proportional* to the redshift (Fig. 1 red curve) which is inconsistent with the prediction of the standard cosmological model (SCM) (the blue curve).

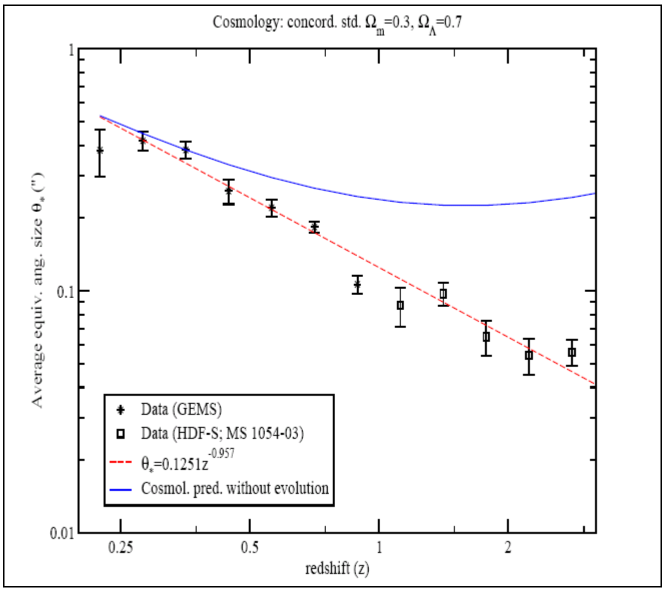

Figure 1 (**[Lopez-Corredoira, 2010]**).

The predicted (SCM) and observed averaged galaxy angular size dependence on redshift.

Below we show that the observed data do correspond to another cosmological model **[Shulman, 2007a]** that has been developed since 1993, called the Spherical Expanding Universe Theory (SEUT).

2. Distances and angles in the cosmology

For the expanding Universe, one can introduce different types of distances. Let us consider a 2D analogue of the Universe, like the surface of a balloon, that is covered by a coordinate grid (e.g. parallels and meridians). During the expansion of this 2D surface, as the distances between coordinate lines increase, the grid itself corresponds to some dimensionless coordinate frame. For example, if the balloon surface contains 10 meridians, then they divide the equator onto 10 similar parts at any radius value. A length measured by these parts is called "the comoving distance coordinate" L_{comov}. On the other hand, any actual length physically expands with the balloon as its radius increases, which determines a metric (physical) distance L_{metr}. These different distances are connected with the scale factor a(t) by the relation:

$$L_{metr} = a(t)\, L_{comov}$$

In our epoch, we set $a(t_0)=1$, and at earlier times t of the Universe evolution $0<a(t)<1$.

In order to take into account an object's angular size we must consider at least two circumstances. Firstly, we observe the photons emitted from a distant object not as it is now, but as it was at the moment of the photon emission. Secondly, the photon propagation depends on the type of spatial geometry that characterizes the Universe.

Let us consider the second case first. In the SEUT, one postulates that the Universe has a spherical type of metric (i.e. a closed geometry model) as depicted in Fig. 2. The circumference in Fig. 2 with radius R and the center at the point O represents a simplified picture of the spherical Universe. An observer is located at the point A, and a galaxy is located at the point D. Here BD=r is the radius of a small circumference. The angle Ω corresponds to the (transverse) galaxy size $d=CE\approx\Omega*BD=\Omega*r$, where the interval CE is *perpendicular* to the page plane and to the radial commoving distance AD.

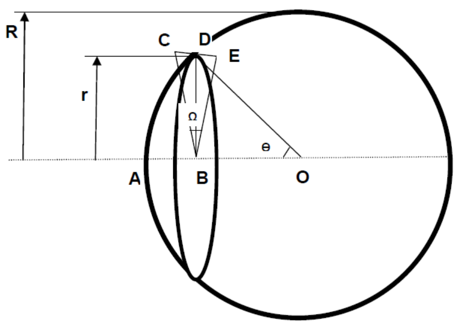

Figure 2. Connection between angles and distances on the spherical surface

Thus, for any surface having this kind of spherical geometry, the relation between the transverse galaxy size d and its angular size for an observer at the point A is

$$d \approx a\, R \sin(r/R)\, \Omega = R \sin(r/R)\, \Omega \,/\, (1+z)$$

In Fig. 1, the angle ϴ (for which sin ϴ=r/R) corresponds to the radial commoving distance between a galaxy and an observer. It is important to note that *this angle is also a function of redshift z*.

Now we can complete take into account the first case, namely the evolution of the size of the Universe between the time of the photon emission and its observation. We incorporate the *radial* metric distance expansion by introducing the scale factor a(z) into the *right* part of the above relation. It remains to take into account the dependence $\Theta(z)$ to determine an evolution law of the *transverse* galaxy size d on the left side. It is reasonable to consider two possibilities:

- The transverse galaxy size remains constant, and only the radial distance between galaxies increases (i.e., the Universe expansion is specified only for large scales and does not affect the galaxy size evolution).
- The transverse galaxy size increases like the radial distances between galaxies (i.e., the Universe expansion is specified for all scales).

3. SEUT's prediction

First let us note that there is a simple relation between the angle Θ (that corresponds to the radial commoving distance between a galactic and observer) and the redshift z (see **[Shulman and Raffel, 2008]**):

$$\Theta(z) = \ln(1+z)$$

Because of that, we find for the model with *constant* transverse galaxy size:

$$\Omega_{const}(z) \approx d/[a(z)\ R \sin \Theta(z)] = (1+z)\ d\ /\ R \sin[\ln(1+z)]$$

So, we have at small z

$$\Omega_{const}(z) \approx (1+z)*d/[R \sin(z)] \approx (1+z)d/(Rz) = const * (1+z)/z.$$

On the other hand, for the model with transverse size that *evolve*s like the radial distance, the factor a = 1/(z+1) appears before *both* of these quantities, so we have:

$$\Omega_{var}(z) \approx a(z)\ d\ /\ [a(z)\ R \sin \Theta(z)] = d\ /\ R \sin[\ln(1+z)]$$

Then at small z:

$$\Omega_{var}(z) \approx d/[R \sin(z)] \approx d/(Rz) = const\ /\ z.$$

The second case seems to be more natural. In this case, for small z, the SEUT predictions offer qualitative agreement with the observational data from **[Lopez-Corredoira, 2010]**.

Fig.3 shows the results of the precise calculations including approximate dependence $\Omega(z) \sim 1/z$ (green curve). The red curve (for the model with constant metric galaxy size) diverges from the green curve already at z ~ 1. On the other hand, the blue curve is nearer to the green one, quantitatively as well as qualitatively. It starts to increase slowly only after z>4.

4. Conclusion

Thus, the SEUT gives a satisfactory description of the galaxy angular size dependence on redshift. Such a conclusion, however, is strongly associated with the hypothesis that the transverse galaxy size expands in the same way as the radial distance.

One can see in the literature two different positions on the transverse size evolution of an astrophysical object. For example, **[Lee, 2009]** argues that the size of galaxies may expand with the Universe if dark matter is in the form of a Bose-Einstein condensate. Also, **[Longair, 2008]** writes in Section 5.4:

> Proper distances perpendicular to the line of sight must also change by a factor *a* between the epochs t and t_0 because of the isotropy and homogeneity of the world model…

However, in Section 7.4.4 Longair assumes galaxies are like rigid rods and gives the formulas for the angular size diameter determination using just such the suggestion.

The authors of the popular science paper **[Lineweaver and Davis, 2005]** consider this question, and argue for constant galaxy size, i.e. when any distance inside a galaxy (or another local object) is changing, then the gravitational equilibrium is disturbed, so a tendency appears to restore the initial distance. This seems reasonable for SCM, because the SCM gravitational force between any two masses m_1 and m_2 is proportional to R^{-2}, where R is the distance between them. However, this is *not true* for the SEUT, because each mass in SEUT is also increasing with time proportionally to R, so ultimately the attraction force $F = Gm_1m_2/R^2$ remains constant, and the gravitational equilibrium *is not disturbed*.

Note, in the point 15.2 of the famous monograph **[Weinberg, 1972]** its author writes that if we accept the “deceleration parameter” and Hubble constant values from the observation data, than we should believe that the Universe density is near $2\rho_{cr}$. But the SEUT leads just to this relation ($\rho = 2\rho_{cr}$) between the actual density and critical one!

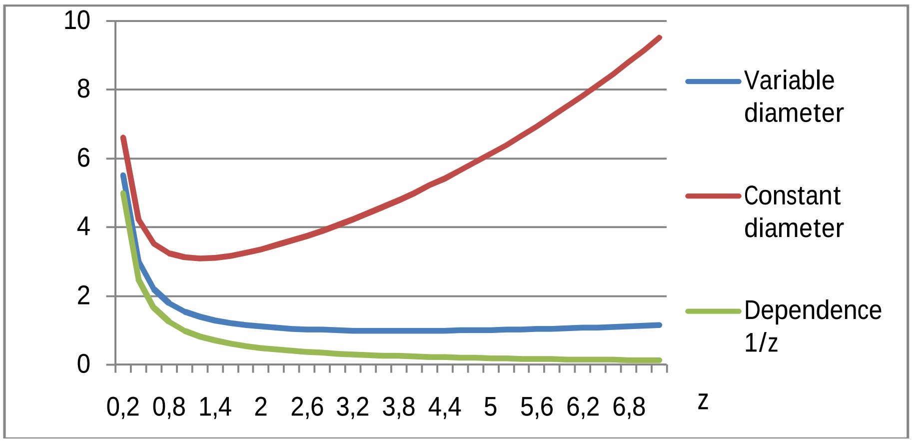

Figure 3
Approximate (green curve) and calculated angular galaxy size dependences on redshift z for the SEUT’s models having constant size (red curve) and variable one (blue curve).

Let us add that the SEUT provides a number of other astrophysical predictions that are confirmed by the observed data as well as, and often better than, predictions of the SCM (**[Shulman, 2007a, 2007b]**, **[Shulman and Raffel, 2008]**, **[Raffel and Shulman, 2010]**).

References:

[Lee, 2009] Jae-Weon Lee. Are galaxies extending? arXiv:0805.2877v4 [astro-ph] 1 Oct 2009.

[Lopez-Corredoira, 2010] Lopez-Corredoira M. Angular size test on the expansion of the Universe. arXiv:1002.0525v1 [astro-ph.CO] 2 Feb 2010.

[Longair, 2008] Malcolm S. Longair. Galaxy Formation. Second Edition. 2008. Springer-Verlag.
[Lineweaver and Davis, 2005] Ch. Lineweaver and T. Davis. The paradoxes of Big Bang. "V mire nauki", Moscow, 2005 (in Russian).
[Raffel and Shulman, 2010] G.A. Raffel, M.H. Shulman. On the galaxy distribution depending on redshift. 2010. Available at:
http://timeorigin21.narod.ru/eng_time/Galaxy_distr_eng.pdf
[Shulman, 2007a] M.H. Shulman. Cosmology: a New Approach. Available at:
http://www.timeorigin21.narod.ru/eng_time/Cosmology.pdf
[Shulman, 2007b] M.H. Shulman. On the supernovae low luminosity problem. 2007. Available at: http://www.timeorigin21.narod.ru/eng_time/On_supernovae.pdf
[Shulman and Raffel, 2008] M.H. Shulman, G.A. Raffel. On the Oldest Photons Phenomenon. Available at:
http://www.timeorigin21.narod.ru/eng_time/Oldest_photons_eng.pdf
[Weinberg, 1972] Weinberg S., Gravitation and Cosmology: Principles and applications of the General Theory of Relativity, John Wiley and Sons, Inc., 1972.