A&A 529, A26 (2011)
DOI: 10.1051/0004-6361/201016057

Astronomy
&
Astrophysics

A conventional approach to the dark-energy concept

K. Kleidis[1] and N. K. Spyrou[2]

[1] Department of Mechanical Engineering, Technological Education Institute of Serres, 621.24 Serres, Greece
e-mail: `kleidis@teiser.gr`
[2] Department of Astronomy, Aristoteleion University of Thessaloniki, 541.24 Thessaloniki, Greece
e-mail: `spyrou@astro.auth.gr`

Received 3 November 2010 / Accepted 14 January 2011

ABSTRACT

Motivated by results implying that the constituents of dark matter (DM) might be collisional, we consider a cosmological (toy-) model, in which the DM itself possesses some sort of thermodynamic properties. In this case, not only can the matter content of the Universe (the baryonic component, which is tightly gravitationally-bounded to the dark one, also being included) be treated as a classical gravitating fluid of positive pressure, but, together with all its other physical characteristics, the energy of this fluid's internal motions should be taken into account as a source of the universal gravitational field. In principle, this form of energy can compensate for the extra (dark) energy, needed to compromise spatial flatness, while the post-recombination Universe remains ever-decelerating. What is more interesting, is that, at the same time (i.e., in the context of the collisional-DM approach), the theoretical curve representing the distance modulus as a function of the cosmological redshift, $\mu(z)$, fits the Hubble diagram of a multi-used sample of supernova Ia events quite accurately. A cosmological model filled with collisional DM could accommodate the majority of the currently-available observational data (including, also, those from baryon acoustic oscillations), without the need for either any dark energy (DE) or the cosmological constant. However, as we demonstrate, this is not the case for someone who, although living in a Universe filled with self-interacting DM, insists on adopting the traditional, collisionless-DM approach. From the point of view of this observer, the cosmologically-distant light-emitting sources seem to lie farther (i.e., they appear to be dimmer) than expected, while the Universe appears to be either accelerating or decelerating, depending on the value of the cosmological redshift. This picture, which, nowadays, represents the common perception in observational cosmology, acquires a more conventional interpretation within the context of the collisional-DM approach.

Key words. dark matter – dark energy

1. Introduction

The beginning of the 21st century was one of the most exciting epochs for cosmology as a science. According to observational data on the temperature variations in the cosmic microwave background (CMB) that became in public at that epoch (de Bernardis et al. 2000; Jaffe et al. 2001; Padin et al. 2001; Stompor et al. 2001; Netterfield et al. 2002), now, we are quite confident that the Universe can be adequately described by a spatially flat Robertson-Walker (RW) cosmological model.

As a consequence, the total energy density, ε, of the Universe matter-energy content, in units of the energy density $\varepsilon_c = \rho_c c^2$ (equivalent to the critical rest-mass density, $\rho_c = \frac{3H_0^2}{8\pi G}$, where H_0 is the Hubble parameter at the present epoch, c is the velocity of light, and G is Newton's universal constant of gravitation), should be very close to unity, $\Omega = \frac{\varepsilon}{\varepsilon_c} \simeq 1$, i.e., much larger than the measured quantity, $\Omega_M = \frac{\rho}{\rho_c} \simeq 0.3$ (Komatsu et al. 2009).

At the same time, high-precision distance measurements, performed with the aid of the supernovae Ia (SNe Ia) standard candles, indicated that, in any cosmological model with vanishing cosmological constant, Λ, the far-off light-emitting sources appear to be dimmer than expected (Riess et al. 1998; Perlmutter et al. 1999).

The observational data then seemed to favour a Universe of collisionless content (i.e., filled with matter in the form of dust) and $\Lambda \neq 0$, in which $\Omega_M \simeq 0.3$ and $\Omega_\Lambda = \frac{\Lambda c^2}{3H_0^2} \simeq 0.7$ (Riess et al. 2001, 2004). Since a non-vanishing cosmological constant (necessarily) involves a repulsive (gravitational) force (see, e.g., Sahni 2004), the apparent dimming of the distant light-emitting sources was attributed to a relatively recent phase of accelerated expansion (see, e.g., Linder 2008).

The onset of the dimming of the cosmologically distant indicators used (hence, the associated transition from acceleration to deceleration), takes place at a relatively low value of the cosmological redshift, z, the so-called transition redshift, z_t, which, nowadays, is being (observationally) set at $z_t = 0.46 \pm 0.13$ (Riess et al. 2004, 2007). In this case, the cosmological constant can be determined observationally, since, on theoretical grounds, $z_t = \left(2\frac{\Omega_\Lambda}{\Omega_M}\right)^{1/3} - 1$ (see, e.g., Perivolaropoulos 2007, Eq. (21)), i.e., the transition redshift depends on the value of Λ. The particle-physics vacuum does contribute an effective cosmological constant, which could serve (also) as compensation to the extra energy needed to flatten the Universe (Sahni & Starobinsky 2000). Unfortunately, the energy-density attributed to such a source is 10^{123} times larger than what is observed (see, e.g., Padmanabhan 2003; Sahni 2004).

Hence, it became evident that, for the above-mentioned observational results to be reconciled within a unified theoretical framework, a different approach (i.e., other than the cosmological constant) was needed.