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Ю. Кудря, канд. физ.-мат. наук, ст. науч. сотр.
Астрономическая обсерватория
Киевского национального университета имени Тараса Шевченко

БАРИОННАЯ ЗАВИСИМОСТЬ ТАЛЛИ – ФИШЕРА ДЛЯ ГАЛАКТИК ИЗ КАТАЛОГА 2MFGC

Представлены барионные и звездные (массовые) зависимости Талли – Фишера (ТФ), прокалиброванные на выборках галактик из каталога 2MFGC, имеющих оценки водородных масс. Прокалиброваны зависимости как для исходной выборки галактик объемом N=2988, сформированной по данным HyperLEDA и каталога 2MFGC, так и зависимости на основе определенным образом почищенных подвыборок. Двухпараметрическая барионная ТФ-зависимость для почищенной выборки объемом N=2831 и соответствующая ей звездная зависимость для почищенной выборки объемом N=2790 характеризуются стандартными отклонениями $\sigma_{BTF} = 0.196$ *и* $\sigma_{STF} = 0.207$, *соответственно. По аналогии с "обычными" инфракрасными зависимостями Талли – Фишера (то есть зависимостями абсолютных звездных величин от ширины радиолинии 21 см или от скорости вращения галактик) мы пробуем улучшить зависимости введением четырех дополнительных регрессоров (поверхностную яркость, индекс концентрации, цвет и отношение осей). Оказалось, что введение дополнительных регрессоров в барионную и звездную зависимости ТФ для исходной выборки N=2988 улучшает* σ_{BTF} *на 11 % и* σ_{STR} *на 17.5 %. Оказалось также, что шестипараметрические барионная и звездная зависимости ТФ характеризуются теми же значениями* σ_{BTF} *и* σ_{STF}, *что и двухпараметрические регрессии при несколько больших объемах почищенных выборок, то есть многопараметрические зависимости дают возможность оценивать барионные и звездные массы для несколько бóльшего числа галактик на том же уровне точности. В данной работе на наших выборках ми подтверждаем известный факт, что барионные зависимости имеют меньший разброс по сравнению с соответствующими звездными зависимостями. Двухпараметрическая барионная зависимость на почищенной выборке оказалась совместной с зависимостью для сверхтонких дисковых галактик.*

Yu. Kudrya, Ph.D., senior researcher
Astronomical Observatory of National Taras Shevchenko University of Kyiv

BARYON TULLY-FISHER RELATION FOR GALAXIES FROM THE 2MFGC CATALOG

Baryon and stellar (mass) Tully-Fisher (TF) relations calibrated on samples of galaxies from the 2MFGC catalog, having hydrogen mass estimates, are presented. The relations have been calibrated for both the initial sample of galaxies with the size N = 2988, formed from data of HyperLEDA and the 2MFGC catalog, and the relations based on subsamples cleaned in certain way. The two-parameter baryon TF relation for the cleaned sample with size N = 2831 and the corresponding stellar relation for the cleaned sample of size N = 2790 are characterized by standard deviations $\sigma_{BTF} = 0.196$ *and* $\sigma_{STF} = 0.207$, *respectively. By analogy with the "usual" infrared Tully-Fisher relations (that is, relations of absolute stellar magnitudes on the width of the 21-cm radio-line or on the rotation velocity of galaxies), we try to improve the relations by introducing four additional regressors (surface brightness, concentration index, color and axes ratio). It appeared that the introduction of additional regressors into the baryon and stellar TF relations for the initial sample N = 2988 improves* σ_{BTF} *by 11 % and* σ_{STR} *by 17.5 %, respectively. It also appeared that the six-parameter baryon and stellar TF relations are characterized by the same values* σ_{BTF} *and* σ_{STR} *as the two-parameter regressions for somewhat larger sizes of cleaned samples, that is, the multiparameter relations make it possible to estimate the baryon and stellar masses for a somewhat larger number of galaxies at the same level of accuracy. In this paper, on our samples, we confirm the known fact that baryon TF relations have a smaller scatter in comparison with the corresponding stellar relations. The two-parameter baryon NF relation on the cleaned sample appeared to be consistent with the relation for hyperfine disk galaxies.*

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V. Zhdanov, Dr. Sci., Prof., S. Dylda, stud. phys. fac.
Taras Shevchenko National University of Kyiv

HYDRODYNAMIC COSMOLOGICAL MODEL AND THE "COSMIC DOOMSDAY"

We discuss the well-known "Big Rip" cosmological solutions in connection with a correspondence between hydrodynamic (H) and scalar field (SF) models of the dynamical dark energy. Namely, we compare a minimally coupled self-interacting SF and the H-model with a barotropic equation of state in the homogeneous isotropic Universe. In general case these models are not fully equivalent, though for some SF potentials and some regimes of expansion they yield the same evolution of the energy density and the scale factor as functions of time. We consider examples of the SF potentials, that provide such a restricted equivalence in case of linear H-model equations of state; however, we show that in case of the canonical SF Lagrangians (with the standard kinetic term) there is no room for the Big Rip.

Introduction. In 2003 Caldwell et al [1] described an example of a cosmological evolution dubbed Big Rip, when the energy density diverges in finite time. The reason for such a divergence owes to special equation of state (EOS) $p = p(e) = we$ with the EOS parameter $w < -1$. More generally, this is related with the existence of the phantom line in the EOS corresponding to $p + e = 0$. The interest to this situation has recently grown in view of the results of PLANK [2] that show some tendency to confirm such inequality, though the Standard model value $w = -1$ is also within the error limits (see also [3]). The occurrence of divergences has been discussed elsewhere (see, e.g. [4-6] for a review). Usually singularities may indicate some incompleteness of the theory and they can be removed, e.g., by some change of EOS. For example, among possible types of qualitative cosmological behavior [6,7] one can find models with a more complicated EOS, which describe a transition from one phantom state to the other. Moreover, the hydrodynamic (H) model is an oversimplification of the real physical picture, and it is desirable to relate it to a more consistent field theory.

Below we consider relations of the hydrodynamic description with the scalar field (SF) theory, which is widely used, e.g., to discuss inflationary scenarios of the early Universe and dynamical dark energy [8–10]. There are different approaches to the problem of correspondence between H and SF models [8] dealing with general SF Lagrangians. In this paper we consider a canonical minimally coupled SF with a self-interaction potential which fills the homogeneous isotropic Universe. In accordance with observational data the space-time metric is assumed to be spatially flat. We consider barotropic EOS as in many papers on homogeneous isotropic cosmology[1]. The requirement that the SF Lagrangian has the canonical form imposes strong restriction on the possibility to relate H and SF models.

Basic relations. The Friedmann-Lemaitre-Robertson-Walker space-time metric of isotropic homogeneous cosmology can be written as

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu = dt^2 - a^2(t)\left[d\chi^2 + \chi^2 dO^2\right], \tag{1}$$

leading to the Friedmann equations (the spatially flat case)

$$\frac{d^2a}{dt^2} = -\frac{4\pi}{3} a(e + 3p), \tag{2}$$

$$H^2 = \frac{8\pi}{3} e, \quad H = \frac{1}{a}\frac{da}{dt}, \tag{3}$$

here $G = c = 1$.

Equations of the relativistic hydrodynamics (H-model) follow from the energy-momentum tensor of ideal fluid

$$T^{(h)}_{\mu\nu} = h\, u_\mu u_\nu - g_{\mu\nu} p., \tag{4}$$

where $h = e + p$ is the specific enthalpy, in case of the barotropic EOS the pressure $p = p(e)$ is a function of the invariant energy density e.

Now we consider a correspondence between the H-model and the model dealing with a minimally coupled scalar field the Universe. The SF Lagrangian is assumed in the form

$$L_{(f)} = \frac{s}{2} \varphi_{,\alpha} \varphi^{,\alpha} - V(\varphi),$$

where we introduce parameter $s = 1$ in case of the canonical scalar field model, and $s = -1$ corresponds to the "phantom" case. The corresponding energy-momentum tensor

$$T^{(f)}_{\mu\nu} = s\, \varphi_{,\mu} \varphi_{,\nu} - g_{\mu\nu} L_{(f)} \tag{5}$$

The SF-equations are

$$\ddot\varphi + 3H\dot\varphi + sV'(\varphi) = 0. \tag{6}$$

Comparison of SF and H models. Due to conditions of isotropy and homogeneity the only non-zero components of (4) and (5) take on the similar form with $T^{(h)}_{00} = e$, $T^{(h)}_{ij} = -g_{ij} p$, ($i, j = 1,2,3$) if and only if

$$e = \frac{s}{2}\dot\varphi^2 + V(\varphi), \quad p = \frac{s}{2}\dot\varphi^2 - V(\varphi), \quad \dot\varphi \equiv d\varphi/dt. \tag{7}$$

However, the SF and H models have different number of degrees of freedom. If we choose some EOS $p = p(e)$ or, equivalently, a dependence of specific enthalpy $h = e + p = h(e)$ on the energy density, equations (7) yield

$$\dot\varphi^2 = s\, h(e), \quad e = \frac{s}{2}\dot\varphi^2 + V(\varphi). \tag{8}$$

This is an additional constraint on the initial values for the second order equations (6), which in the SF model must be arbitrary. That is, there cannot be a complete equivalence of the SF and H models. If we suppose that the initial conditions of the SF-model satisfy equations (8) at $t = t_0$. The question is, what are the restrictions for $V(\varphi)$ so as to preserve (8) for all $t > t_0$? With this aim we introduce a function $\Theta(V)$, which is implicitly defined as a solution of the equation

$$\vartheta = s \cdot h\left(\frac{s}{2}\vartheta + V\right), \tag{9}$$

with respect to ϑ; then from (8) we have $\dot\varphi^2 = \Theta(V) > 0$. In view of (3), it must be $e > 0$. We denote $E(V) = s\,\Theta(V)/2 + V$. For $E(V)$ we have

[1] We note that in case of inhomogeneous cosmology the barotropic EOS with negative w cannot be applied, and some modification is needed [11, 12].

$$E-\frac{1}{2}h\left(E\right)=V \tag{10}$$

In order to provide the uniqueness of the solution of (10) with respect to E and (9) with respect to ϑ it is sufficient that

$$h'\le 2-\varepsilon\,, \tag{11}$$

where $\varepsilon>0$ can be arbitrarily small. This corresponds to $dp/de\le 1-\varepsilon$.

Derivative of (8) upon the time on account of (6) yields (assuming $\dot\varphi\ne 0$)

$$2s\frac{dV}{d\varphi}=-\mathrm{sign}(\dot\varphi)\left[2-h'(E(V))\right]\sqrt{24\pi E(V)\Theta(V)}\,, \tag{12}$$

We have an equation for potential $V(\varphi)$, which is different for different signs of $\dot\varphi$.

Note that sometimes it is convenient to work with the equation

$$\left(\frac{dV}{d\varphi}\right)^2=6\pi E(V)\Theta(V)\left[2-h'(E(V))\right]^2, \tag{13}$$

and then, when a solution of (13) is found, to check signs according to (12).

Linear equation of state. Now we consider examples with concrete equations of state. The simplest case deals with the linear EOS:

$$h(e)=\xi(e-e_0)+h_0=\xi e-\eta,\quad \eta=\xi e_0-h_0\,. \tag{14}$$

Let us suppose $\xi<2$, which corresponds to $dp/de<1$.

In this case $\Theta=\dfrac{2s(\xi V-\eta)}{2-\xi},\quad E(V)=\dfrac{2V-\eta}{2-\xi}$, and equation (12) now takes on the form

$$\frac{dV}{d\varphi}=-s\cdot\mathrm{sign}(\dot\varphi)\sqrt{24\pi s\,\xi\left[\left(V-\frac{2+\xi}{4\xi}\eta\right)^2-\left(\frac{2-\xi}{4\xi}\eta\right)^2\right]}\,. \tag{15}$$

For $s\xi>0$ the solution of this equation is

$$V(\varphi)=\frac{\eta}{4\xi}\left\{2+\xi+(2-\xi)\cosh\left[\alpha(\varphi-\varphi_0)\right]\right\},\quad \alpha=\sqrt{24\pi s\,\xi}\,.$$

This is the necessary condition for H and SF models to describe the same evolution under additional condition

$$\mathrm{sign}[\eta(2-\xi)\dot\varphi(\varphi-\varphi_0)]=-1\,.$$

In this case the H-model and SF-model describe the same solution for the scale factor. For example, in case of the slow-roll regime of the inflation theory this is fulfilled, but this is violated near the minimum of the potential where one may have an oscillatory behavior.

For $h_0=0$, $s\xi>0$ we have

$$V(\varphi)=\frac{e_0}{4}\left\{2+\xi+(2-\xi)\cosh\left[\alpha(\varphi-\varphi_0)\right]\right\};$$

and the additional condition is $\mathrm{sign}\left\{(2-\xi)\dot\varphi(\varphi-\varphi_0)\right\}=-s$.

In particular, for $s\xi<0$ the expression in square brackets in the radicand of (15) must be negative, whence the potential must be a bounded function. Then, there is no real non-trivial solution for the potential, if $s\xi<0$ and $(2-\xi)\eta=0$.

For $s\xi<0$

$$V(\varphi)=\frac{\eta}{4\xi}\left\{2+\xi+(2-\xi)\cos\left[\alpha(\varphi-\varphi_0)\right]\right\},\quad s\xi<0,\quad \alpha=\sqrt{-24\pi s\,\xi}$$

The additional condition is $\mathrm{sign}[\eta(2-\xi)\dot\varphi\sin(\varphi-\varphi_0)]=-1$.

For $h_0=0$ $V(\varphi)=\dfrac{e_0}{4}\left\{2+\xi+(2-\xi)\cos\left[\alpha(\varphi-\varphi_0)\right]\right\},\quad \alpha=\sqrt{-24\pi s\,\xi}$; the additional condition is $\mathrm{sign}[\xi(2-\xi)\dot\varphi\sin(\varphi-\varphi_0)]=-1$.

At last, consider the case $\eta=0$. It is easy to see that (15) can be fulfilled only if $s\xi>0$. This means that the case with $\xi<0$ (yielding the"Big Rip" [1]) has no canonical scalar field counterpart. In the phantom case ($s=-1$) such a counterpart is possible.

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В. Жданов, д-р фіз.-мат. наук, проф.,
С. Дилда, студ. фіз. ф-ту,
Київський національний університет імені Тараса Шевченка, Київ

ГІДРОДИНАМІЧНА КОСМОЛОГІЧНА МОДЕЛЬ І "КОСМІЧНИЙ КІНЕЦЬ СВІТУ"

Обговорено відомі космологічні розв'язки типу "Великого розриву "у зв'язку з відповідністю гідродинамічної (H) і скалярно-польової (SF) моделей динамічної темної енергії. Порівняно мінімально зв'язану SF-модель із самодією та H-модель із баротропним рівнянням стану в однорідному ізотропному Всесвіті. Загалом ці моделі не повністю еквівалентні, хоча для деяких потенціалів скалярного поля й деяких режимів розширення вони дають таку саму еволюцію густини енергії та масштабного фактора з часом. Розглянуто приклади потенціалів SF, які забезпечують обмежену еквівалентність у випадку лінійних рівнянь стану H-моделі; однак, показуємо, що у випадку канонічних лагранжианів скалярного поля (зі стандартним кінетичним членом) Великий розрив не виникає.

В. Жданов, д-р. физ.-мат. наук, проф., С. Дылда, студ. физ. ф-та,
Киевский национальный университет имени Тараса Шевченко, Киев

ГИДРОДИНАМИЧЕСКАЯ КОСМОЛОГИЧЕСКАЯ МОДЕЛЬ И "КОСМИЧЕСКИЙ КОНЕЦ СВЕТА"

Обсуждаем хорошо известные космологические решения типа "Большого разрыва" в связи с соответствием гидродинамической (H) и скалярно-полевой (SF) моделей динамической темной энергии. А именно, сравниваем минимально связанную SF-модель с самодействием и H-модель с баротропным уравнением состояния в однородной изотропной Вселенной. В общем случае эти модели не полностью эквивалентны, хотя для некоторых потенциалов скалярного поля и некоторых режимов расширения они дают такую же эволюцию плотности энергии и масштабного фактора со временем. Мы рассматриваем примеры SF-потенциалов, которые обеспечивают ограниченную эквивалентность в случае линейных уравнений состояния H-модели; однако, мы показываем, что в случае канонических лагранжианов скалярного поля (со стандартным кинетическим членом) Большой разрыв не возникает.

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E. Fedorova, Ph.D
Taras Shevchenko National University of Kiev, Astronomical Observatory

DETERMINING THE UPPER LIMIT ON THE BLACK HOLE MASS FROM NGC 4748 X-RAY PHOTOMETRY

In this paper, we analyze all the available X-ray photometrical data of the narrow-line Seyfert 1 galaxy NGC 4748, namely XMM-Newton (EPIC and OM), INTEGRAL (ISGRI and JEM-X) as well as SWIFT (BAT and XRT) to estimate, if it's possible, the mass of the central black hole from the variability of the lightcurves. In the XMM/EPIC composite lightcurve, we found fast quasiperiodic variations of the 0.5-10.0 keV flux on a timescales of 10^3 seconds. These variations were interpreted as the result of the emission of a dense hot clump of matter orbiting the central black hole near the innermost stable trajectory. The structure function analysis of this lightcurve allowed us to put an upper limit to the mass of the central BH, as 6.23 * $10^7 M_\odot$.
Key words: active galactic nucleus, X-rays, black hole mass.

1. Introduction. NGC 4748 is nearby narrow-line type 1 Seyfert (NLS1) galaxy in Corvus constellation at the redshift z=0.01463 [10]. NGC 4748 is a barred spiral galaxy, interacting with the other slightly smaller spiral galaxy [7, 11], with radio-quiet active nucleus (1.4 Ghz flux of 14.0±0.6 mJy, following [2]). There is present subnuclear starburst activity, but the object is nonetheless AGN-dominated [13]. The mass of the black hole in the nucleus of NGC 4748 was determined by Hao et al. [4] basing on the stellar vs. BH mass correlation, as 5.5*$10^6 M_\odot$. Higher value of the BH mass was obtained by Wang & Lu [12] using the correlation of the mass of BH and the velocity dispersion within the narrow line region, indicated by the [OIII] line width, i.e. 4.2*$10^7 M_\odot$. Later, the core of NGC 4748 was investigated in details by means of the reverberation mapping method to HST/WFC3 data [3], and the black hole mass was re-calculated [1] to be $2.55^{+0.74}_{-0.88}\ 10^6 M_\odot$. Here we try to determine the upper limit on the central black hole mass value, applying the autocorrelation function and FFT analyses to variable X-ray lightcurves of this object.

Following the results by Pal et al. [8] based on ROSAT/HRI data, NGC 4748 have quite steep photon-index Γ=2.50±0.17. Similar result was obtained by Landi et al. [5], Γ=2.20±0.11, for the SWIFT/XRT spectrum of NGC 4748. For wide-band X-ray spectrum, Panessa et al. [9] obtained a photon index of Γ=2.01±0.13 and no cut-off at high energies, no Fe-K emission lines and no reflection components in the composite SWIFT/XRT + INTEGRAL/ISGRI spectrum. They also founded the hardness ratio between 0.1-2.0 keV and 2-10 keV band slightly higher than 1.

Here we use the X-ray observational data available by January 2017, namely, the data obtained by INTEGRAL, XMM-Newton and Swift missions. This allowed us to analyze both a flux variability and wide-band 0.5-195 keV X-ray spectrum. The paper is organized as follows. In the Section 1 we describe the data used and it's reduction. In Section 2 we analyze the flux variability on different timescales. Finally, in Section 4 we discuss our results, and in the Section 5 we draw out our conclusions.