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Lifting the tension of HST and JWST data with conventional cosmology by PBHs

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It is argued that observations of well developed galaxies and quasars in the very young universe can be explained by their seeding with massive primordial black holes (PBHs). The model of creation of such PBHs is presented. The suggested mechanism predicts, as a by-product, possible existence of antimatter in the Galaxy

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[*] Speaker

1. Crisis in cosmology, is it real?

Dense population of the early universe, noticeably younger than one billion years at redshifts $z \gtrsim 10$, discovered by Hubble Space Telescope (HST) and James Webb Space Telescope (JWST), was taken as a strong blow to the conventional ΛCDM cosmology. However, the resolution of the crisis by primordial black holes (PBH) was suggested in refs. [1, 2] long before these problems arose. Namely it was suggested that the galaxy formation is *seeded* by supermassive primordial black holes (PBH) both in the early and in the present day universe. These idea was rediscovered and gaining increasing support in recent publications under the pressure of HST and JWST data.

The validity of the mechanism of PBH formation suggested in papers [1, 2] is supported by the following ”experimental" data:

- The predicted log-normal mass spectrum of PBH perfectly well agrees with the observational data in wide mass interval.
- Noticeable antimatter population of the Galaxy is predicted and confirmed by registration of positrons, antinuclei, and antistars in the Milky Way.
- The early and contemporary universe are full of massive black holes, presumably primordial.

In papers [1, 2] inverted mechanism of galaxy formation is proposed, that allows to resolve all inconsistencies between the conventional ΛCDM cosmology and astronomical observations.. Namely it has been suggested that firstly primordial supermassive black holes during prestelar cosmological epoch was formed and later on they seeded galaxy formation. Usually it is assumed that supermassive BHs (SMBHs), observed in centres of all large galaxies, are created by matter accretion to the density excess in the galactic centre, but the estimated necessary time is much larger than the universe age, even for the contemporary universe, with the age about 15 billion years, to say nothing of the 20 times younger universe at $z \sim 10$. The earlier observed problems in contemporary and young universe are reviewed in ref. [3].

2. HST, JWST, and ALMA observations

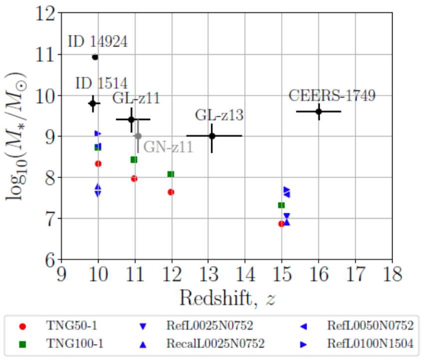
2.1 JWST data and the ΛCDM cosmology

In Fig. 1 some published data on masses and redshifts of the measured by JWST at large redshifts. In the left panel several galaxies with redshifts from 11 to 16 are presented as black crosses. The expectations of ΛCDM model are depicted by coloured points. Since the scale is logarithmic, the inconsistency is huge.

2.2 Early galaxies, spectroscopic confirmation

A registration of a very young galaxy is presented by a different instrument, ALMA (Atacama Large Millimeter Array) [4] implies a spectroscopic redshift of $z = 12.117 \pm 0.001$. According to the determination of ALMA the cosmic age of a distant JWST-identified galaxy, GHZ2/GLASS-z12, is 367 million years after the Big Bang. It is determined through ionised Oxygen observation and confirms that the JWST is able to look out to record distances. That heralds a leap in our ability to understand the formation of the earliest galaxies in the Universe.

Moritz Haslbauer et al, Has JWST already falsified dark-matter-driven galaxy formation? arXiv:2210.14915



Comparison of the size of the most massive galaxies, obtained in models of formation and growth of galaxies based on LCDM (colored dots) with JWST observations (black dots with errors) depending on the redshift of the observed galaxies.

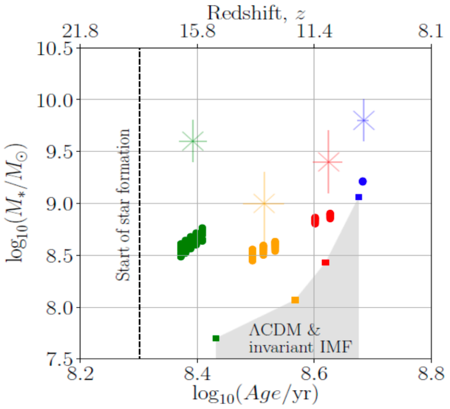


Figure 1: Comparison of the JWST data with the predictions of the conventional ΛCDM cosmology

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3. Impossible galaxies

A striking discovery is announced in ref. [5]. Six candidate massive galaxies (stellar mass $> 10^{10}$ solar masses) are observed at $7.4 \lesssim z \lesssim 9.1$, 500–700 Myr after the Big Bang, including one galaxy with a possible stellar mass of $\sim 10^{11} M_\odot$, too massive to be created in so early universe. According to the 'science' it is impossible to create so well developed galaxies. NB: "May be they are supermassive black holes of the kind never seen before. That might mean a revision of usual understanding of black holes." This discovery very well agrees with our predictions of PBHs.

4. Problems prior to JWSP data

Similar serious problems are known already for many years. The Hubble space telescope (HST) discovered that the early universe, at $z = 6 - 7$ is too densely populated with quasars, alias SMBH, supernovae, gamma-bursters and it is very dusty.

No understanding how all these creature were given birth in such a short time is found in conventional cosmology. Moreover great lots of phenomena in the present day universe are also in strong tension with canonical cosmological expectations, see review [3].

"Hubble" sees the universe up to $z = 6 - 7$, but accidentally a galaxy at $z \approx 12$ has been discovered for which both Hubble and Webb are in good agreement. Still only after publications of

JWST data astronomy establishment became seriously worried. All the problems are neatly solved if the universe is populated by primordial black holes (PBH) and the astrophysically large bubbles with very high baryonic density, according to the model of refs. [1, 2].

5. BH types by formation mechanisms

• 1. Astrophysical black holes, created by the collapse of a star which exhausted its nuclear fuel. The expected masses should start immediately above the neutron star mass, i.e. about $3M_\odot$, but noticeably below $100M_\odot$.
Recently LIGO/Virgo discovered BHs with masses close to $100M_\odot$. Their astrophysical origin was considered impossible due to huge mass loss in the process of collapse. Now some, quite exotic, formation mechanisms are suggested.
• 2. BH formed by accretion on the mass excess in the galactic center.
In any large galaxy there exists a supermassive BH (SMBH) at the center, with masses varying from a few millions $M_\odot$ (e,g, Milky Way) up to almost hundred billions $M_\odot$. However, the conventional accretion mechanisms are not efficient enough to create such monsters during the universe life-time, $t_U \approx 14.6$ Gyr. At least 10-fold longer time is necessary, to say nothing about SMBH in 10 times younger universe.
• 3. Primordial black holes (PBH) created during pre-stellar epoch
The idea of the primordial black hole (PBH) i.e. of black holes which could be created in the early universe prior to star formation was first put forward by Zeldovich and Novikov [6]. According to their idea, the density contrast in the early universe inside a bubble with radius equal to the cosmological horizon might accidentally happen to be large, $\delta\rho/\rho \approx 1$, then that piece of volume would be inside its gravitational radius i.e. it became a PBH. This mechanism was elaborated later in by S. Hawking [7] and B.Carr and S.Hawking [8].

6. Problems of the contemporary universe. Summary. Reviewed in [3].

•1. SMBH in all large galaxies. Too short time for their formation through the usual accretion mechanism.
•2. SMBH in small galaxies and even in (almost) empty space. No material for their creation. Pushed out of large galaxies? Wandering BHs? Or PBH!
A striking example: discovery by the Hobby-Eberly Telescope at Texas's McDonald Observatory of a SMBH with $M_{BH} \approx 1.7 \cdot 10^{10} M_\odot$ i.e. 14% of the stellar mass of the galaxy. observed due to the motions of the stars near the center of the galaxy. Usually the mass of the central BH is about 0.1 % of the galaxy mass.
•3. Strange stars in the Galaxy, too fast and with unusual chemistry.
•4. Too old stars, older than the Galaxy and maybe older than the universe?
•5. MACHOs, non-luminous objects with masses about $0.5M_\odot$ observed via microlensing; origin unknown.
• 6. Problems with the BH mass spectrum in the Galaxy, masses are concentrated in the narrow interval $(7.8 \pm 1.2)M_\odot$.
•7. Origin and properties of the sources of the observed gravitational waves.

•8. IMBH, with $M \sim (10^3 - 10^5) M_\odot$, in dwarfs and globular clusters, unexpectedly discovered, despite being predicted in ref. [9].
•9. Antimatter in the Milky Way, including positrons, anti-nuclei, and antistars.

7. Seeding of galaxy formation by PBH

The hypothesis proposed in refs [1, 2] that primordial SMBH seed galaxy formation, allows to understand the presence of SMBH in all large and several small galaxies accessible to observation in the present day universe. This mechanism explains also how the galaxies observed by HST/JWST in the very young universe might be created. The idea has been rediscovered in several recent works.

For example in ref. [10] is noted that recent observations with JWST have identified several bright galaxy candidates at $z \gtrsim 10$, some of which appear unusually massive (up to $\sim 10^{11}$ M$_\odot$). Such early formation of massive galaxies is difficult to reconcile with standard ΛCDM predictions. The observed massive galaxy candidates can be explained, with lower star formation efficiency than required in ΛCDM, if structure formation is accelerated by massive ($\gtrsim 10^9$ M$_\odot$) PBHs that enhance primordial density fluctuations. This exactly our suggestion of 1993 [1].

In ref. [11], see also[12] is stated that observational data on high-redshift quasars reveal that many supermassive black holes were in place less than 700 Million years after the Big Bang. The detection of an X-ray-luminous quasar in a gravitationally-lensed galaxy, identified by JWST at $z \approx 10.3$, powered by SMBH with the mass $\sim 4 \times 10^7 M_\odot$ in the galaxy is reported. This mass is comparable to the inferred stellar mass of its host galaxy, in contrast to the usual examples from the local universe where mostly the BH mass is $\sim 0.1\%$ of the host galaxy's stellar mass. The combination of such a high BH mass and large BH-to-galaxy stellar mass ratio $\sim$ 500 Myrs after the Big Bang is consistent with a picture wherein that early supermassive black holes originated from heavy seeds. However, the origin of the first parent black holes remains a mystery. Seeds of the first BHs are postulated that could be either light i.e., $(10 - 100) M_\odot$ remnants of the first stars or heavy i.e., $(10^4 - 10^5) M_\odot$, created by direct collapse of gas clouds, according to the authors.

Much simpler and easier if the seeds are primordial BHs, as predicted by DS [1] and DKK [2], but at least the idea of seeding seems to be accepted by the community.

8. BHs in dwarf galaxies and globular clusters

It was suggested in ref. [13] in 2017 that globular clusters and dwarf galaxies are seeded by primordial black holes with intermediate mass (IMBH) of the order of a few thousand solar mass. Otherwise formation of these ”tiny" objects was mysterious. In the last several years quite a few such IMBH inside globular clusters are observed confirming the prediction. Similar seeding features are predicted for dwarf galaxies.

Recently, already when the Conference was over, a new publication indicating existence of active galactic nucleus, inside the Galactic globular cluster 47, was published [14]. According to the authors the most plausible explanations are that the source is an undiscovered millisecond pulsar or a weakly accreting black hole. The black hole activity suggests a black hole mass of $\sim (54 - 6000) M_\odot$, indicating an intermediate-mass black hole or a heavy stellar-mass black hole.

The seeding of dwarfs by intermediate mass BHs seems to be confirmed by the recent data [15] as well. For the first time, astronomers have spotted evidence of a pair of dwarf galaxies featuring giant black holes. In fact, they haven't just found just one pair – they've found two.

Analogously the predicted an intermediate-mass black hole is observed in a dwarf galaxy SDSS J090613.77+561015.2 [16]. Discovery of an intermediate-mass black hole (IMBH) with a mass of $M_{BH} = 3.6^{+5.9}_{-2.3} \times 10^5 M_\odot$, that surely cannot be created by accretion but, other way around, might seed the dwarf formation, as advocated in ref. [13].

9. PBH, inflation, and a few words about the model

In earlier works the predicted masses of PBH were quite low. Inflation allows for formation of PBH with very large masses. Inflationary mechanism was first applied to PBH production in paper [1], a year later in [17], and soon after in [18]. Presently inflationary mechanisms of PBH production are commonly used. It allows to create PBH with very high masses, but the predicted spectra are multi-parameter and quite complicated. The only exception is the log-normal spectrum of DS and DKK as calculated in refs. [1, 2] and tested by observations. Another new feature of the DS/DKK mechanism is an application of the Affleck-Dine [19] baryogenesis scenario to PBH formation, repeated now in many works.

The log-normal mass spectrum has the following form:

$$\frac{dN}{dM} = \mu^2 \exp\left[-\gamma \ln^2 (M/M_0)\right], \tag{1}$$

where μ is an unknown parameter with dimension of mass, γ is dimensionless and is not determined by the model but is naturally expected to be of order unity. The central mass M_0 is theoretically predicted [20] to be close to $M_0 \approx 10 M_\odot$, where $M_\odot \approx 2 \times 10^{33}$ gram is the solar mass. According to the theory M_0 should be close to the mass inside the cosmological horizon at the QCD phase transition (p.t.) from quarks to hadrons. The horizon mass at the QCD p.t. is $10 M_\odot$, for $\mu = 0$. At larger chemical potential the T_{pt} could be somewhat smaller and M_{hor} would be larger.

The model of refs. [1, 2] is based on the formation of astrophysically large bubbles, with masses up to $10^4 M_\odot$ or even higher, with baryon-to-photon ratio of order unity. The number of bubbles and antibubbles would be approximately the same. They would mostly form primordial black holes and at the tail of their distribution, if mass is too small or/and if the size is too large, they would turn into stellar-like objects or clouds of (anti)matter. All that would take place at the QCD phase transition, after massless quarks turned into massive baryons.

10. Gravitational waves from BH binaries

Gravitational wave (GW) discovery by LIGO strongly indicates that the sources of GW are primordial black holes, see e.g. ref. [21]. The following three problems are simpler resolved in the case of PBH sources:

• 1. Origin of heavy BHs with ($M \sim 30 M_\odot$). Such BHs are believed be created by massive star collapse, though a convincing theory is still lacking. There appeared much more striking problem of BH with $M \sim 100 M_\odot$. • 2. Formation of BH binaries from the original stellar binaries.

• 3. Low spins of the coalescing BHs .

Returning to a large mass problem of the LIGO sources, to form so heavy BHs, the progenitors should have $M > 100M_\odot$. i.e. two orders of magnitude higher than the solar mass and a low metal abundance to avoid too much mass loss during the evolution. Such heavy stars might be present in young star-forming galaxies but they are not observed in the necessary amount. On the opposite, PBHs with the observed by LIGO masses may be easily created with sufficient density.

11. Chirp mass distribution

Two rotating gravitationally bound massive bodies are known to emit gravitational waves. In quasi-stationary inspiral regime, the radius of the orbit and the rotation frequency are approximately constant and the GW frequency is twice the rotation frequency.

The luminosity of the GW radiation during this regime is:

$$L = \frac{32}{5} m_{Pl}^2 \left(\frac{M_c\, \omega_{orb}}{m_{Pl}^2} \right)^{10/3} , \tag{2}$$

where M_1, M_2 are the masses of two bodies in the binary system and M_c is the so called chirp mass:

$$M_c = \frac{(M_1\, M_2)^{3/5}}{(M_1 + M_2)^{1/5}} , \tag{3}$$

and

$$\omega_{orb}^2 = \frac{M_1 + M_2}{m_{Pl}^2 R^3} . \tag{4}$$

The available data on the chirp mass distribution of the black holes in the coalescing binaries in O1-O3 LIGO/Virgo runs are analysed and compared with theoretical expectations based on the hypothesis that these black holes are primordial with log-normal mass spectrum [22].

The inferred best-fit mass spectrum parameters, $M_0 = 17M_\odot$ and $\gamma = 0.9$, fall within the theoretically expected range and shows excellent agreement with observations.

Model distribution $F_{PBH}(< M)$ with parameters $M_0 \approx 17M_\odot$ and $\gamma \sim 1$ for two best Kolmogorov-Smirnov tests is presented in Fig. 4, where EDF= empirical distribution function. Similar value of the parameters are obtained in [23, 24], see also [25].

On the opposite, binary black hole formation based on massive binary star evolution require additional adjustments to reproduce the observed chirp mass distribution, see Fig. 5.

Thus we conclude that PBHs with log-normal mass spectrum perfectly fit the data. Astrophysical BHs seem to be disfavoured.

12. Black Dark Matter (BDM)

The first suggestion PBH might be dark matter "particles" was made by S. Hawking in 1971 [26] and later by G. Chapline in 1975 [27] who noticed that low mass PBHs might be abundant in the present-day universe with the density comparable to the density of dark matter. He assumed scale independent spectrum of cosmological perturbations and thus flat mass spectrum in log interval:

$$dN = N_0(dM/M)$$

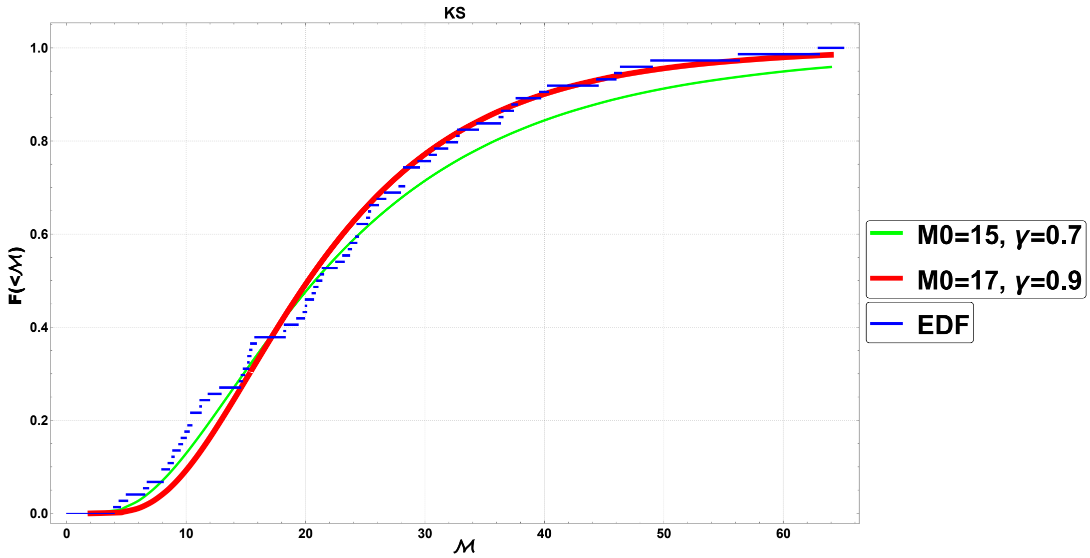

Figure 2: Chirp mass distribution according to LIGO/Virgo data, compared to that obtained from log-normal mass spectrum.

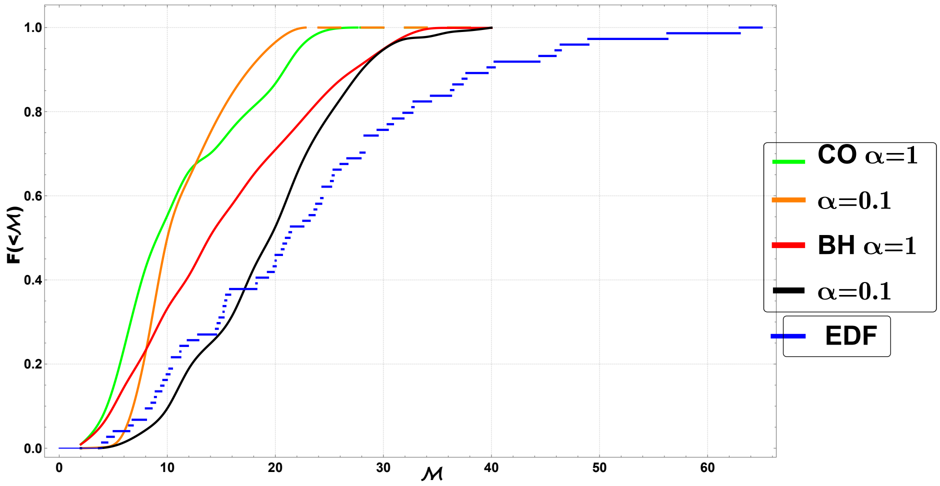

Figure 3: Cumulative distributions $F(<M)$ for several astrophysical models of binary BH coalescences.

with maximum mass $M_{max} \lesssim 10^{22}$ g, which hits the allowed mass range, see below.

In the next paper by Dolgov and Silk, 1992 [1], realistic much high masses were allowed to be created, around $\sim 10 M_\odot$ up $10^6 M_\odot$, and even higher. The log-normal normal mass spectrum was predicted.

Constraints on the mass fraction of PBHs have been analysed by B.Carr and F. Kuhnel [28, 28] under assumption of monochromatic mass spectrum of PBHs. According to the author the bounds should be taken with caution being model-dependent. The limits are presented in Fig. 6.

In the paper by S.G. Rubin and collaborators [30] it was argued that PBHs could be formed

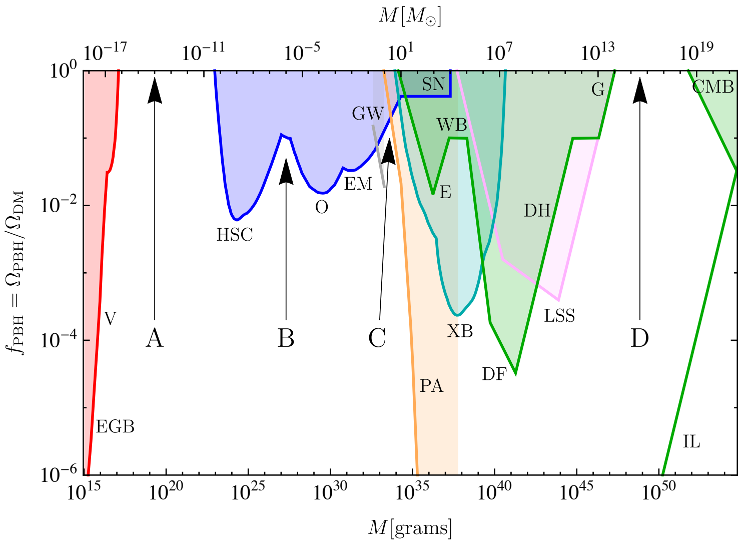

Figure 4: Constraints on $f(M)$ for a monochromatic mass function, from evaporations (red), lensing (blue), gravitational waves (GW) (gray), dynamical effects (green), accretion (light blue), CMB distortions (orange) and large-scale structure (purple). Evaporation limits from the extragalactic gamma-ray background (EGB), the Voyager positron flux (V) and annihilation-line radiation from the Galactic centre (GC). Lensing limits from microlensing of supernovae (SN) and of stars in M31 by Subaru (HSC), the Magellanic Clouds by EROS and MACHO (EM) and the Galactic bulge by OGLE (O). Dynamical limits from wide binaries (WB), star clusters in Eridanus II (E), halo dynamical friction (DF), galaxy tidal distortions (G), heating of stars in the Galactic disk (DH) and the CMB dipole (CMB). Large scale structure constraints(LSS). Accretion limits from X-ray binaries (XB) and Planck measurements of CMB distortions (PA). The incredulity limits (IL) correspond to one PBH per relevant environment (galaxy, cluster, Universe). There are four mass windows (A, B, C, D) in which PBHs could have an appreciable density.

in clusters. Dynamical interactions in PBH clusters offers additional channel for the orbital energy dissipation thus increasing the merging rate of PBH binaries. As a result the constraints on f_{PBH} could be weaker.

A recent analysis performed in ref. [31], based on the PBH formation model of papers [32, 33], shows that even $f_{PBH} = 0.1 - 1$ is not excluded.

13. Antimatter history

The first search for antimatter in the Milky Way, anti-comets, has been performed by B.P. Konstantinov and collaborators [34, 35]. Such activity was strongly criticised by Ya.B. Zeldovich, despite their very friendly relations. For a long time nobody believed that there could be antimatter objects of any kind in the Galaxy, despite rather weak observational bounds [42–44]. This negative attitude was justified by an absence of any reasonable model of creation of subdominant but noticeable anti-population in the Galaxy. The first scenario of creation of antimatter in the Galaxy was proposed in refs. [1, 2], but nevertheless it was taken with great reluctance to say the least. Now the attitude is slowly changing under the weight of observations of galactic positrons, antinuclei, and (sic!) antistars.

Antimatter in the universe at cosmological scales was taken much more favourably due to reasonable models of C(CP) violation of different signs at cosmologically large distances. Possible mechanisms of C(CP)-violation in cosmology is reviewed in ref. [36]. The study of antimatter in cosmology was initiated by Floyd Stecker with collaborators! [37, 38]. The summary of the situation presented at 2002 was done in two keynote lectures [39, 40].

Of course the father of antimatter is justly considered Paul Dirac, who said in his Nobel lecture "Theory of electrons and positrons", December 12, 1933: "It is quite possible that... these stars being built up mainly of positrons and negative protons. In fact, there may be half the stars of each kind. The two kinds of stars would both show exactly the same spectra, and there would be no way of distinguishing them by present astronomical methods."

At the present days we know how one can distinguish stars from an antistars by observations from the Earth [41], at least in principle. The spectra of light are not exactly the same, even if CPT is unbroken and the polarisation of radiation from weak decays could be a good indicator or the type of emitted neutrinos/antineutrinos from supernovae.

14. Antimatter in the Galaxy

Based on the conventional approach to cosmological antimatter creation, no antimatter object is expected to be in the Galaxy. However, it was predicted in 1993 and elaborated in 2009 that noticeable amount of antimatter, even antistars might be in the Galaxy and in its halo [1, 2]. The bounds on the density of galactic antistars are rather loose, because the annihilation proceeds only on the surface of antistars that are objects with short mean free path of protons, as analysed in papers [42–44].

14.1 Anti-evidence: cosmic positrons

The observation of intense 0.511 line is a proof of abundant positron population in the Galaxy. In the central region of the Galaxy electron–positron annihilation proceeds at a surprisingly high rate, creating the flux:

$$\Phi_{511\ \mathrm{keV}} = 1.07 \pm 0.03 \cdot 10^{-3}\ \mathrm{photons\ cm^{-2}\,s^{-1}}. \tag{5}$$

The width of the line is about 3 keV. Emission mostly goes from the Galactic bulge and at much lower level from the disk [45–47] and references to earlier works therein.

Until recently the commonly accepted explanation was that e^+ are created in the strong magnetic fields of pulsars but the recent results of AMS probably exclude this mechanism, since the spectrum of $\bar{p}$ and e^+ at high energies are identical as is presented at L'Aquila Joint Astroparticle Colloquium, 10th November, 2021 by S. Ting.

14.2 Anti-evidence: cosmic antinuclei

Very high fluxes of antinuclei are continuosly registered at AMS. In 2018 AMS-02 announced possible observation of six $\overline{He}^3$ and two $\overline{He}^4$ [48]. Recent registration of more events are reported at [49]: 7 $\overline{D}$ ($\lesssim$ 15 GeV) and 9 $\overline{He}$ with energies ($E \sim 50$ GeV). The fraction $\overline{He}/He \sim 10^{-9}$, is too high compared to the flux that could be created by the secondary production of anitinuclej in cosmic ray collision.

Moreover, it is not excluded that the flux of anti-helium is even much higher because low energy $\overline{He}$ may escape registration in AMS.

14.2.1 Deuterium/Helium problem

The canonical big bang nucleosynthesis (BBN) gives 25% of ^4He, much smaller fraction of deuterium, $\sim (10^{-5} - 10^{-4})$, and about the same fraction of ^3He.

There is a huge discrepancy of these results with the large observed fraction of $\overline{D}$ with respect to $\overline{He}$, and, what's more, with the observed $\overline{He^3} > \overline{He^4}$. In the case of the standard BBN this ratio should be much smaller than unity, but the observed ratio of antinuclei is practically the same.

It is assumed that the abundances of $\overline{D}$ and $\overline{He}$ are determined by (anti)BBN with large β (or η) in our bubbles with high baryonic number density, see sec. 9. However if $\beta \sim 1$, practically no primordial deuterium could be created at BBN. On the other hand in our scenario formation of primordial elements takes place inside non-expanding compact stellar-like objects with fixed temperature. If the temperature is sufficiently high, this so called BBN may stop before abundant He formation with almost equal abundances of D and He. One can see that looking at abundances of light elements as a function of temperature. Is it is so, antistars may have equal amount of $\overline{D}$ and $\overline{He}$!!!

14.3 Anti-evidence: antistars in the Galaxy

In ref. [50] a striking discovery is announced, namely the authors identified in the Fermi Large Area Telescope gamma-ray source catalog 14 antistar candidates not associated with any objects belonging to established gamma-ray source classes and with a spectrum compatible with baryon-antibaryon annihilation.

14.4 X-ray signatures of antistars

An additional method to search for antistars is proposed in ref. [51]. In astrophysically plausible cases of the interaction of neutral atmospheres or winds from antistars with ionised interstellar gas, the hadronic annihilation will be preceded by the formation of excited $p\bar{p}$ and $He\bar{p}$ atoms. These atoms rapidly cascade down to low levels prior to annihilation giving rise to a series of narrow lines which can be associated with the hadronic annihilation gamma-ray emission. The most significant are L (3p-2p) 1.73 keV line (yield more than 90%) from $p\bar{p}$ atoms, and M (4-3) 4.86 keV (yield $\sim$ 60%) and L (3-2) 11.13 keV (yield about 25%) lines from $He^4\bar{p}$ atoms. These lines can be probed in dedicated observations by forthcoming sensitive X-ray spectroscopic missions XRISM and Athena and in wide-field X-ray surveys like SRG/eROSITA all-sky survey.

14.5 Antihelium and antistars

A possibility that antinuclei can be emitted from a population of antistats in the Galaxy is suggested in ref. [52]. A minor population of antistars in galaxies has been predicted by some of non-standard models of baryogenesis and nucleosynthesis in the early Universe, and their presence is not yet excluded by the currently available observations. Detection of an unusually high abundance of antinuclei in cosmic rays can probe the baryogenesis scenarios in the early Universe.

Recent report of the AMS-02 collaboration on the tentative detection of a few antihelium nuclei in GeV cosmic rays provided a great hope on the progress in this issue. Possible sources of antinuclei

in cosmic rays from antistars which are predicted in a modified Affleck-Dine baryogenesis scenario by DS [1] are discussed. The expected fluxes and isotopic content of antinuclei in the GeV cosmic rays produced in scenarios involving antistars are estimated.
It is shown that the flux of antihelium cosmic rays reported by the AMS-02 experiment can be explained by Galactic anti-nova outbursts, thermonuclear anti-SN Ia explosions, a collection of flaring antistars, or an extragalactic source with abundances not violating existing gamma-ray and microlensing constraints on the antistar population.

15. Summary of the results

• 1. Then idea of seeding of galaxies and supermassive black holes is getting more and more support. Especially puzzling are black hoes in the early and contemporary universe inside very small galaxies. A large number of such black holes is observed by JWST and it is much more natural that the seed are presented by primordial black holes.
• 2. Our prediction of seeding galaxy clusters and dwarf galaxies is confirmed by recent discoveries of IMBH inside GS and dwarfs.
• 3. The theoretically calculated log-normal mass spectrum ob PNBHs very well agrees with the chirp mass distribution of of LIOG/Virgo/Carga events.
• 4. The prediction of antimatter population of the Milky Way is confirmed by observations of positron annihilation line, observation of antinuclei, and possible discovery of antistars in the Galaxy.

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