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Dark Stars: Supermassive and Ultramassive Dark Macroobjects

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Abstract

R. Genzel and A. Ghez were awarded the 2020 Nobel Prize in Physics for their discovery that Sgr A* is a **supermassive compact object**, for which Supermassive Black Hole (SBH) was the only accepted explanation. In 2013, we proposed a principally different explanation of supermassive compact objects: "*Macroobjects of the World have cores made up of the discussed DM particles. Other particles, including DM and baryonic matter, form shells surrounding the cores*" [1]. According to the developed Hypersphere World-Universe Model (WUM), the World consists of Dark Matter (about 92.8% of the total Matter) and Ordinary matter (about 7.2%). It means that Dark Matter (DM) should play the main role in any Cosmological model. It is the case in WUM, and Ordinary matter is a byproduct of Dark Matter Particles (DMPs) self-annihilation. In present paper, we discuss Dark Stars, Supermassive and Ultramassive Dark Macroobjects in frames of WUM.

Keywords

World-Universe Model, Dark Stars, Superclusters, Multicomponent Dark Matter, Explosive Volcanic Rotational Fission, Angular Momentum, JWST Discoveries

1. Introduction

John Michell (1724-1793) was an English natural philosopher and clergyman who provided pioneering insights into a wide range of scientific fields including astronomy, geology, optics, and gravitation. Considered "*one of the greatest unsung scientists of all time*", he is the first person known to have proposed the existence of "**Dark Stars**" and the first to have suggested that earthquakes travelled in (seismic) waves. The American Physical Society described Michell as being "*so far ahead of his scientific contemporaries that his ideas languished in ob-*

scurity, until they were re-invented more than a century later". The Society stated that while "*he was one of the most brilliant and original scientists of his time, Michell remains virtually unknown today, in part because he did little to develop and promote his own path-breaking ideas*" [2].

In a paper for the Philosophical Transactions of the Royal Society of London, read on 27 November 1783 [3], Michell was the first to propose the existence of "dark stars". Michell suggested that there might be many "dark stars" in the universe and proposed that astronomers could detect "dark stars" by looking for star systems which behaved gravitationally like two stars, but where only one star could be seen. Michell argued that this would show the presence of a "dark star". It was an extraordinarily accurate prediction of binary systems, in which a "dark star" and a normal star orbit around their center of mass. In the Milky Way (MW) galaxy, there are a dozen such binary systems emitting X-rays [2].

The first known binary system was Cyg X-1 identified independently by several researchers in 1971. It remains among the most studied astronomical objects in its class. The compact object is now estimated to have a mass $\sim 21.2 M_{\odot}$. Cyg X-1 is about 5 million years old [4]. Though highly and erratically variable, Cyg X-1 is typically the brightest persistent source of hard X-rays with energies up to 60 keV [5].

Cyg X-1 was the subject of a friendly scientific wager between physicists S. Hawking and K. Thorne in 1975, with Hawking, hoping to lose, betting that it was not a Black Hole (BH). He conceded the bet in 1990 after observational data had strengthened the case that there was indeed BH in the system. **This hypothesis lacks direct empirical evidence but has generally been accepted from indirect evidence** [4].

Observational works on nearby galaxies in the last 25 years have revealed that Supermassive Compact Objects, for which SBHs was the only accepted explanation, in a mass range $M_{SBH} \sim 10^{6}$ - $10^{10} M_{\odot}$ reside at centers of all massive elliptical galaxies and massive bulges of disk galaxies. Large-core spheroids are extremely massive $M_{*} \gtrsim 10^{12} M_{\odot}$ and tend to host Ultramassive Black Holes (UBHs) with mass $M_{UBH} \gtrsim 10^{10} M_{\odot}$ [6].

2. Dark Stars

The history of Dark Stars can be traced back to at least the end of 18th century:

- In 1783, Michell was the first to propose the existence of dark stars [3];
- In 1844, F. Bessel argued that the observed proper motion of the stars Sirius and Procyon could only be explained by the presence of faint companion stars influencing the observed stars through their gravitational pull: *If we were to regard Procyon and Sirius as double stars, their change of motion would not surprise us. The existence of numberless visible stars can prove nothing against the evidence of numberless invisible ones* [7];
- In 1904, Lord Kelvin wrote: *Many of our stars, perhaps a great majority of them, may be dark bodies* [7];

- In 2005, E. Ripamonti and T. Abel discussed the role of cold DM in the formation of Primordial Luminous Objects [8]. A mechanism whereby DM in protostellar halos plays a role in the formation of the first stars is discussed by D. Spolyar, K. Freese, and P. Gondolo [9]. Heat from neutralino DM annihilation is shown to overwhelm any cooling mechanism, consequently impeding the star formation process. A **dark star** powered by DM annihilation instead of nuclear fusion may result [9]. Dark stars are in hydrostatic and thermal equilibrium, but with an unusual power source [10].

3. Explosive Volcanic Rotational Fission Model [11]

3.1. Multicomponent Dark Matter

Two-component DM systems consisting of bosonic and fermionic components are proposed for the explanation of emission lines from the bulge of Milky Way galaxy. C. Boehm, P. Fayet, and J. Silk analyze the possibility of two coannihilating neutral and stable DMPs: a heavy fermion for example, like the lightest neutralino (>100 GeV) and the other one a possibly light spin-0 particle (~100 MeV) [12].

WUM proposes multicomponent DM system consisting of two couples of co-annihilating DMPs: a heavy Dark Matter Fermion (DMF)—DMF1 (1.3 TeV) and a light spin-0 boson—DIRAC (70 MeV) that is a dipole of Dirac's monopoles with charge $\mu = e/2\alpha$ (e is an elementary charge and α is a dimensionless Rydberg constant); a heavy fermion—DMF2 (9.6 GeV) and a light spin-0 boson—ELOP (340 keV) that is a dipole of preons with electrical charge $e/3$; self-annihilating fermions DMF3 (3.7 keV), DMF4 (0.2 eV), and boson XION (10.6 μeV). XION is an analog of Axion discussed in literature. In our view, XIONs are responsible for the Le Sage's push mechanism of gravitation [13].

The reason for this multicomponent DM system was to explain:

- The diversity of Very High Energy gamma-ray sources in the World;
- The diversity of DM Cores of Macroobjects of the World (Superclusters, Galaxies, and Extrasolar Systems (ESS)), which are Fermion Compact Objects and DM Reactors in WUM [13].

WUM postulates that rest energies of DMFs and bosons are proportional to a basic energy unit: $E_0 = hc/a$ (h is the Planck constant, c is a gravitodynamic constant, and a is a basic size unit) multiplied by different exponents of α and can be expressed with following formulae:

DMF1 (fermion): $E_{DMF1} = \alpha^{-2} E_0 = 1.3149950$ TeV

DMF2 (fermion): $E_{DMF2} = \alpha^{-1} E_0 = 9.5959823$ GeV

DIRAC (boson): $E_{DIRAC} = \alpha^{0} E_0 = 70.025267$ MeV

ELOP (boson): $E_{ELOP} = 2/3\,\alpha^{1} E_0 = 340.66606$ keV

DMF3 (fermion): $E_{DMF3} = \alpha^{2} E_0 = 3.7289402$ keV

DMF4 (fermion): $E_{DMF4} = \alpha^{4} E_0 = 0.19857111$ eV

XION (boson) $E_{XION} = \alpha^{6} E_0 = 10.574179$ μeV

DMPs do not possess an electric charge. Their masses cannot be directly measured by mass spectrometry. Hence, they can be observed only indirectly due to their self-annihilation and irradiation of gamma-quants.

According to the Big Bang (BB) model:

- Formation and evolution of galaxies can be explained only in terms of gravitation within an inflation + DM + dark energy scenario. What is the origin of Cold DM? Where did it come from?
- The standard explanation used for the abundance of deuterium is that the universe does not consist mostly of baryons, but that non-baryonic DM makes up most of the mass of the universe. Where did non-baryonic DM come from?

ESA. Science & Exploration. Space Science in the paper "Did black holes form immediately after the Big Bang?" asked: "*How did supermassive black holes form*? *What is dark matter*?" wrote: "*In an alternative model for how the Universe came to be*, *as compared to the* '*textbook*' *history of the Universe*, *a team of astronomers* [14] *propose that both of these cosmic mysteries could be explained by so-called* '*primordial black holes*'. *Black holes could themselves be the as-of-yet unexplained dark matter* [15].

In **WUM**, the Universe is the Creator of DM in the World. There are no BHs in the World. Instead, there are DM Cores (Dark Stars) inside of all Macroobjects (Superclusters, Galaxies, Stars, Planets, and Moons).

3.2. Macroobject Shell Model

In WUM, Macrostructures of the World (Superclusters, Galaxies, Extrasolar systems) have Nuclei made up of DMFs, which are surrounded by Shells composed of DM and Baryonic Matter. The shells envelope one another, like a Russian doll. The lighter a particle, the greater the radius and the mass of its shell. Innermost shells are the smallest and are made up of heaviest particles; outer shells are larger and consist of lighter particles. A proposed Weak Interaction of DMPs provides integrity of all shells. Table 1 describes parameters of MOs' Cores, which are 3D fluid balls with a very high viscosity and function as solid-state objects.

The calculated parameters of the shells show that:

Table 1. Parameters of MOs' cores made up of different fermions in present epoch.

Fermion	Fermion Mass m_f, MeV	Macroobject Mass M_{max}, kg	Macroobject Radius R_{min}, m	Macroobject Density ρ_{max}, kg·m^{-3}
DMF1	1.3×10^{6}	1.9×10^{30}	8.6×10^{3}	7.2×10^{17}
DMF2	9.6×10^{3}	1.9×10^{30}	8.6×10^{3}	7.2×10^{17}
Electron-Positron	0.51	6.6×10^{36}	2.9×10^{10}	6.3×10^{4}
DMF3	3.7×10^{-3}	1.2×10^{41}	5.4×10^{14}	1.8×10^{-4}
DMF4	2×10^{-7}	4.2×10^{49}	1.9×10^{23}	1.5×10^{-21}

- Nuclei made up of DMF1 and/or DMF2 compose Cores of dark stars in Galaxies and normal stars in Extrasolar Systems (ESS);
- Shells of DMF3 and/or Electron-Positron plasma around Nuclei made up of DMF1 and/or DMF2 make up Cores of Galaxies;
- Nuclei made up of DMF1 and/or DMF2 surrounded by shells of DMF3 and DMF4 compose Cores of Superclusters.

It is worth noting that A. Einstein was the first who proposed to explain very massive and compact astrophysical objects in terms of shells. He proposed that the final state of continued gravitational collapse was a tiny and compact shell of matter in his manuscript [16]. This approach has recently been rediscovered by C. Vaz in the article [17]. This point is stressed in the manuscripts of Prof. C. Corda [18] [19].

3.3. Angular Momentum

Angular Momentum problem is one of the most critical problems in Standard model that must be solved. To the best of our knowledge, the developed WUM is the only one cosmological model in existence that is consistent with the Law of Conservation of Angular Momentum. To be consistent with this Law, any theory of evolution of Universe must answer the following questions:

- How did Galaxies and ESS get their substantial orbital and rotational angular momenta;
- How did MW give birth to different ESS in different times;
- The age of MW is about the Age of the World. What is the origin of MW huge orbital and rotational angular momenta? We must discuss the Beginning of MW;
- The oldest star in MW (named Methuselah) is nearly as old as the universe itself. How did it happen?
- The beginning of Solar System (SS) was 4.57 Byr ago. What is the origin of SS rotational and orbital angular momenta? We must discuss the Beginning of SS.

In our opinion, there is only one mechanism that can provide angular momenta to MOs—**Rotational Fission** of overspinning (surface speed at equator exceeding escape velocity) Prime Objects. From the point of view of Fission model, the Prime object is transferring some of its rotational angular momentum to orbital and rotational momenta of satellites. It follows that **rotational momenta of prime objects should exceed orbital momenta of their satellites** [20].

In frames of WUM, Prime Objects are DM Cores of Superclusters, which must accumulate tremendous angular momenta before the Birth of the Luminous World. It follows that a long enough time period must elapse. We named this period "Dark Epoch" and developed a New Cosmology of the World [20]:

- WUM introduces Dark Epoch (spanning from the Beginning of the World 14.22 Byr ago for 0.45 Byr) when only DM MOs existed, and Luminous

Epoch (ever since for 13.77 Byr for Laniakea Supercluster) when Luminous MOs emerged due to the Explosive Volcanic Rotational Fission of Superclusters' DM Cores and self-annihilation of DMPs;

- Main players of the World are Superclusters' DM Cores that accumulated tremendous rotational angular momenta during Dark Epoch and transferred it to DM Cores of Galaxies during their Rotational Fission;
- The experimental observations of galaxies in the World show that most of them are disk galaxies. These results speak in favor of the developed Rotational Fission mechanism;
- MW's DM Core was born 13.77 Byr ago as the result of Rotational Fission of Virgo Supercluster's DM Core;
- DM Cores of ESS, planets and moons were born as the result of the repeating Rotational Fissions of Galaxy's DM Cores in different times (4.57 Byr ago for SS in MW);
- MOs of the World form from the top (superclusters) down to galaxies, ESS, planets, and moons.

3.4. Formation of Macrostructures [21]

In WUM, Cores of all MOs possess the following properties:

- Their Nuclei are made up of DMFs and contain other particles, including DM and Baryonic matter, in shells surrounding the Nuclei;
- DMPs are continuously absorbed by Cores of all MOs. Ordinary Matter (about 7.2% of a total Matter) is a byproduct of DMPs self-annihilation. It is re-emitted by Cores of MOs continuously. MOs' cores are essentially DM Reactors fueled by DMPs. All chemical elements, compositions, radiations are produced by MOs themselves as the result of DMPs self-annihilation in their DM cores;
- Nuclei and shells are growing in time: size $\propto \tau^{1/2}$; mass $\propto \tau^{3/2}$; and rotational angular momentum $\propto \tau^{2}$ (τ is an absolute cosmological time), until they reach the critical point of their stability, at which they detonate. Satellite's cores and their orbital L_{orb} and rotational L_{rot} angular momenta released during detonation are produced by Overspinning DM Cores (ODMCs). The detonation process does not destroy ODMCs; it is rather gravitational hyper-flares;
- Size, mass, composition, L_{orb} and L_{rot} of satellite DM cores depend on local density fluctuations at the edge of ODMC and cohesion of the outer shell. Consequently, the diversity of satellite DM cores has a clear explanation. Satellite DM cores are given off by "**Volcanoes**" on prime DM Cores erupting repeatedly;
- WUM refers to ODMC detonation process as Gravitational Burst (GB), analogous to the Gamma Ray Burst.

In frames of **WUM**, the repeating GBs can be explained the following way:

- As the result of GBs, ODMCs lose a small fraction of their mass and a large part of their rotational angular momentum;

- After GBs, DM Cores of Prime Objects (superclusters and galaxies) absorb new DMPs. Their masses increase $\propto \tau^{3/2}$, and their angular momenta L_{rot} increase much faster $\propto \tau^2$, until they detonate again at the next critical point of their stability. That is why DM cores of Satellites (galaxies and ESS) are rotating around their own axes and DM Cores of Prime Objects;
- Afterglow of GBs is a result of processes developing in the Nuclei and shells after detonation;
- In case of ESS, a star wind is the afterglow of star detonation: star's DM Core absorbs new DMPs, increases its mass $\propto \tau^{3/2}$ and gets rid of extra L_{rot} by star wind particles;
- Solar wind is the afterglow of Solar Core detonation 4.57 Byr ago. It creates the SS bubble continuously;
- In case of Galaxies, a galactic wind is the afterglow of repeating galactic DM Core detonations. In MW it continuously creates two DM Fermi Bubbles [11];

In frames of the developed Rotational Fission model, the following discoveries can be explained:

- Gravitational Birst of ODMC of Virgo Supercluster 13.77 Byr ago gave birth to Sgr A*, the Core of MW;
- Gravitational Birst of ODMC of MW 13.77 Byr ago gave birth to the core of the Methuselah star;
- Gravitational Birst of ODMC of MW 5 Myr ago gave birth to the binary system Cyg X-1 at the same time, moreover dark star is the rotating DM core made of DMF1 and DMF2 with the surface speed at equator less than the escape velocity. Both stars have Halos made of DMF3 particles emitting X-rays as the result of their self-annihilation.

3.5. Decisive Role of Gravitational Parameter *G* in Cosmology

WUM is based on Gravitomagnetism. The explanation of the galactic rotation curve made by G. O. Ludwig: *The effects attributed to dark matter can be simply explained by the gravitomagnetic field produced by the mass currents* [22] is in good agreement with the approach of WUM. Thanks to the revealed by WUM Inter-Connectivity of Primary Cosmological Parameters, we show that Gravitational parameter G that can be measured directly makes measurable all Cosmological parameters, which cannot be measured directly.

It is worth noting that in WUM, parameter G is proportional to the energy density of the Medium of the World ρ_M that is inversely proportional to the cosmological time: $\rho_M \propto \tau^{-1}$. Therefore, parameter $G \propto \tau^{-1}$, as it was proposed by P. Dirac in 1937. Introduced by WUM, Cosmological time marches on at constant pace since the Beginning of the World until the present Epoch and defines the Absolute Age of the World: $A_\tau = \tau$. The Hubble's parameter H (which is, in fact, the wave resistance of the Medium), equals to: $H = \tau^{-1}$ and should be measured using Cosmic Microwave Background Radiation data only.

We emphasize that in frames of WUM, there is no need to invent new Physical Laws for describing early stages of the World observed by JWST. We can use the well-known equations considering a time-varying G.

4. Supermassive Dark Macroobjects

Distances to remote objects, other than those in nearby galaxies, are nearly always inferred by measuring the cosmological redshift of their light. An important distinction is whether the distance is determined via spectroscopy or using a photometric redshift technique. The spectroscopic redshift is conventionally regarded as being necessary for an object's distance to be considered definitely known, whereas photometrically determined redshifts identify "candidate" distant sources. For comparisons with the light travel distance of the astronomical objects listed below, the age of the universe since BB is currently estimated as 13.787 ± 0.020 Byr [23].

4.1. Most Distant Objects

Below we discuss Macroobjects with $z > 10$ (see **Table 2** and **Table 3**, adapted from [23]):

Table 2. Most distant galaxies with spectroscopic redshift determinations.

Name	Redshift	Light travel distance, Gly
HD1	$z = 13.27$	13.579; 13.599; 13.477; 13.476
JADES-GS-z13-0	$z = 13.20^{+0.24}_{-0.07}$	13.576; 13.596; 13.474; 13.473
JADES-GS-z12-0	$z = 12.63^{+0.24}_{-0.08}$	13.556; 13.576; 13.454; 13.453
GLASS-z12	$z = 12.117^{+0.01}_{-0.01}$	13.536; 13.556; 13.434; 13.433
JADES-GS-z11-0	$z = 11.58^{+0.05}_{-0.05}$	13.512; 13.532; 13.410; 13.409
GN-z11	$z = 10.957^{+0.001}_{-0.001}$	13.481; 13.501; 13.380; 13.379
UDFj-39546284	$z = 10.38^{+0.07}_{-0.06}$	13.449; 13.469; 13.348; 13.347

Table 3. Notable candidates for most distant galaxies.

Name	Redshift	Light travel distance, Gly
F200DB-045	$z = 20.4^{+0.3}_{-0.3}$	13.725; 13.745; 13.623; 13.621
CEERS-93316	$z = 16.39^{+0.32}_{-0.22}$	13.661; 13.681; 13.559; 13.558
F200DB-175	$z = 16.2^{+0.3}_{-0.0}$	13.657; 13.677; 13.555; 13.554
S5-z17-1	$z = 16.0089^{+0.0004}_{-0.0004}$	13.653; 13.673; 13.551; 13.550
F150DB-041	$z = 16.0^{+0.2}_{-0.2}$	13.653; 13.673; 13.551; 13.549
SMACS-z16a	$z = 15.92^{+0.17}_{-0.12}$	13.651; 13.671; 13.549; 13.548
F200DB-015	$z = 15.8^{+3.4}_{-0.1}$	13.648; 13.668; 13.546; 13.545

- HD1 is one of the earliest and most distant known galaxies yet identified in the observable universe. HD1's unusually high brightness has been an open question for its discoverers; it has a significantly more luminous ultraviolet emission than similar galaxies at its redshift range [24];
- F200DB-045 is a candidate high-redshift galaxy, with an estimated redshift of approximately z = 20.4, corresponding to 168 Myr after BB. If confirmed, it would be one of the earliest and most distant known galaxies observed. F200DB-045 would have a light-travel distance (lookback time) of 13.7 Byr;
- C. Ilie, J. Paulin, and K. Freese in the article "Supermassive Dark Star candidates seen by JWST?" wrote [25]:

The first generation of stars in the Universe is yet to be observed. There are two leading theories for those objects that mark the beginning of the cosmic dawn: hydrogen burning Population III stars and Dark Stars, made of hydrogen and helium but powered by Dark Matter heating. The latter can grow to become supermassive ($M_* \sim 10^6 M_\odot$ *) and extremely bright (* $L \sim 10^9 L_\odot$ *). We show that each of the following three objects: JADES-GS-z13-0, JADES-GS-z12-0, and JADES-GS-z11-0 (at redshifts* $z \in [11,14]$ *) are consistent with a Supermassive Dark Star interpretation, thus identifying, for the first time, Dark Star candidates.*

It is worth noting that in 2013 we proposed a principally different explanation of supermassive compact objects: "*Macroobjects of the World have cores made up of the discussed DM particles. Other particles, including DM and baryonic matter, form shells surrounding the cores. The first phase of stellar evolution in the history of the World may be dark stars, powered by Dark Matter heating rather than fusion. Neutralinos and WIMPs, which are their own antiparticles, can annihilate and provide an important heat source for the stars and planets in the World*" [1].

Detailed analysis of observations of the first batch of $z \approx 11$ - 20 Candidate Objects revealed by JWST is done by H. Yan, *et al.* in [26].

4.2. Observations of SBHs

The size of SBHs can be estimated by their mass, and most massive ones are typically found at the centers of large galaxies. The very large number of SBHs have their mass values from $4.3 \times 10^6 M_\odot$ (Sagittarius A* at the center of MW) to $1 \times 10^{10} M_\odot$ (NGC 1281, compact elliptical galaxy) [27]. Below we will discuss the most interesting ones.

Distant quasars are unique tracers to study the formation of the earliest SBHs and the history of cosmic reionization. Despite extensive efforts, up to now only four quasars have been found at $z \geq 7.5$:

- J. Yang, *et al.* report a discovery of a luminous quasar, J1007+2115 at z = 7.515 [28]. The quasar is powered by $(1.5 \pm 0.2) \times 10^9 M_\odot$ SBH that is twice as massive as that in quasar J1342+0928 at z = 7.54. At this redshift, the age of the universe is 690 Myr [29];
- F. Wang, *et al.* report a discovery of a luminous quasar J0313-1806 at z =

7.642. Deep spectroscopic observations reveal SBH with a mass of $(1.6 \pm 0.4) \times 10^9 M_\odot$ in it. The existence of such a massive SBH just ~670 Myr after BB challenges significantly theoretical models of SBH growth [30];

- R. L. Larson, *et al.* report the discovery of SBH at $z = 8.679$, in CEERS 1019 galaxy that has the stellar mass $M_\circledast \approx 10^{9.5 \pm 0.3} M_\odot$. SBH has the mass of $M_{SBH} \approx 10^{6.95 \pm 0.37} M_\odot$ and existed at 570 Myr after BB [31].

4.3. Galaxy without SBH in Center

A2261-BCG (short for Abell 2261 Brightest Cluster Galaxy) is a huge elliptical galaxy in the cluster Abell 2261. One of the largest galaxies known, A2261-BCG is estimated to have a diameter of a million light-years. It is the brightest and the most massive galaxy in the cluster and has one of the largest galactic cores ever observed, spanning more than 10 kly. Yet, unusually, its center does not contain SBH [32].

A2261-BCG, located at least 3 Bly from Earth, is also well known as a radio source. Its core is highly populated by a dense number of old stars, but is mysteriously diffuse, giving it a large core. In 2012, using Hubble Space Telescope, scientists realized there was no SBH with expected mass $\sim 10^{10} M_\odot$ present in its center. A central mass density of the core is $< 0.1 M_\odot \text{pc}^{-3}$, which is extremely diffuse in comparison to the denser cores of less luminous galaxies [33].

K. Gultekin, *et al.* use Chandra X-ray observations to look for evidence of a recoiling BH from A2261-BCG because of its large, flat stellar core, revealed by Hubble Space Telescope observations [34]. They found no X-ray emission arising from a point source in excess of the cluster gas and can place limits on the accretion of any BH in the central region to a 2 - 7 keV flux below a bolometric Eddington fraction of about 10^{-6}. Thus there is either no $\sim 10^{10} M_\odot$ BH in the core of A2261-BCG, or it is accreting at a very low level [34].

4.4. Runaway SBH

In 2023, P. van Dokkum, *et al.* report the serendipitous discovery of an extremely narrow linear feature in HST/ACS images that may be an example of such a wake (see **Figure 1**). The feature extends 62 kpc from a nucleus of a compact star-forming galaxy at $z = 0.964$. The stellar continuum colors vary along the feature and are well-fit by a simple model that has a monotonically increasing age with distance from the tip. The line ratios, colors, and the overall morphology are consistent with an ejected SBH moving through the circumgalactic medium (CGM) at high speed while triggering star formation. The best-fit time since ejection is ~39 Myr and an implied velocity is $v \sim 1600$ km/s. The expected SBH mass is $M_{BH} \sim 2 \times 10^7 M_\odot$ [36].

The feature is not perfectly straight in the HST images, and they show that the amplitude of the observed spatial variations is consistent with the runaway SBH interpretation. The interaction of a runaway SBH with CGM can lead to the formation of a wake of shocked gas and young stars behind it. Opposite the

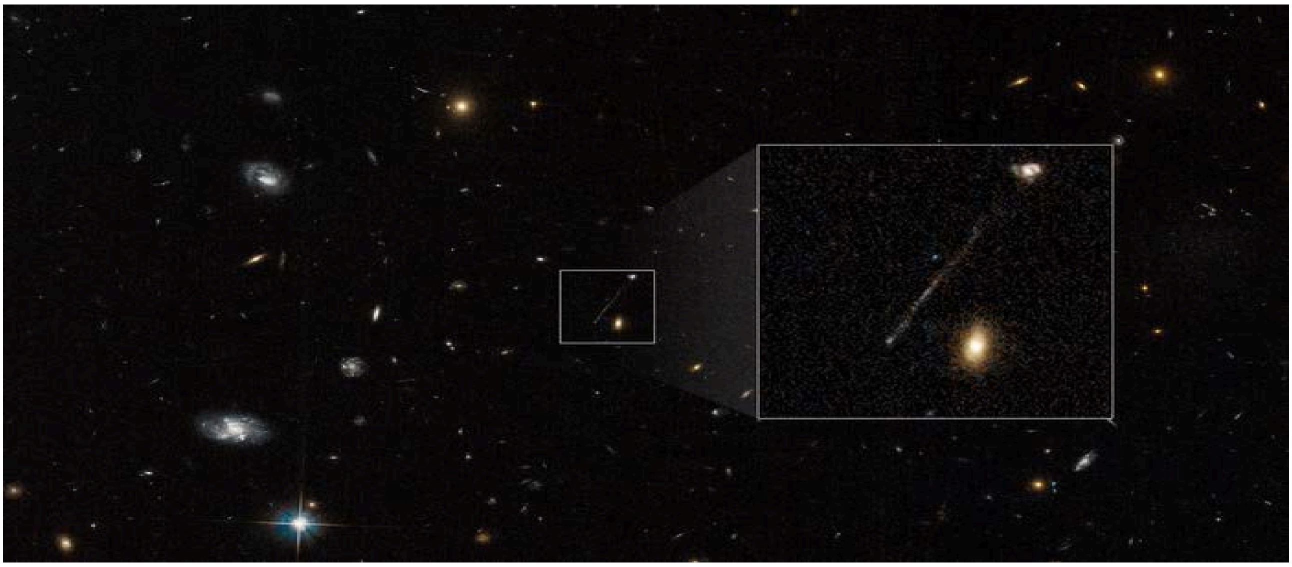

Figure 1. Runaway Black Hole near dwarf galaxy RCP 28. This Hubble Space Telescope archival photo captures a curious linear feature that is so unusual it was first dismissed as an imaging artifact from Hubble's cameras. But follow-up spectroscopic observations reveal it is a 200,000-light-year-long chain of young blue stars. A supermassive black hole lies at the tip of the bridge at lower left. The black hole was ejected from the galaxy at upper right. It compressed gas in its wake to leave a long trail of young blue stars. Nothing like this has ever been seen before in the universe. This unusual event happened when the universe was approximately half its current age. Adapted from [35].

primary wake is a fainter and shorter feature, marginally detected in [OIII] and the rest-frame far-ultraviolet. This feature may be shocked gas behind a **binary SBH** that was ejected at the same time as the SBH that produced the primary wake. The host galaxy is compact and somewhat irregular. The authors find the half-light radius of the galaxy $r_e \approx 1.2\ \text{kpc}$ [36].

P. van Dokkum, *et al.* propose the following runaway SBH scenario:

- A merger leads to the formation of a long-lived binary SBH;
- A third galaxy comes in binary SBH. Its SBH sinks to the center of the new merger remnant, and this leads to a three-body interaction. It can be about 1 Byr between these two events;
- One black hole (usually the lightest) becomes unbound from the other two and receives a large velocity kick. Conservation of linear momentum implies that the remaining binary gets a smaller velocity kick in the opposite direction. If the kicks are large enough all SBHs can leave the galaxy. This event happened ~40 Myr before the epoch of observation.

In frames of **WUM**, the runaway galaxy can be explained the following way:

- Original host galaxy had a spinning DM Core with a surface speed at equator less than the escape velocity;
- During about 1 Byr the DM Core has got an additional rotational angular momentum $\propto \tau^2$ up to the critical point when the surface speed at equator achieved the escape velocity ~39 Myr ago;
- As the result of the Explosive Volcanic Rotational Fission of DM Core of the host galaxy, DM core of the runaway galaxy with the mass $\sim 2\times10^7 M_\odot$ was

kicked away with the velocity ~1600 km/s;

- DM Core of the host galaxy, having a mass $> 2\times10^{7} M_{\odot}$, was kicked away in the opposite direction with the smaller velocity;
- DM core of the runaway galaxy started to create DM cores of stars with velocities ≪ 1600 km/s;
- Summing of these two velocities leads to the formation of the primary wake of DM cores of young stars behind DM core of the runaway galaxy;
- Opposite the primary wake is a fainter and shorter feature that is the young stars created by DM Core of the residual DM Core of the host galaxy;
- Due to the self-annihilation of DMPs of the DM cores of the young stars, ordinary matter created on their surfaces and stars become visible.

4.4. Formation Models

These discoveries pose the most stringent constraints on masses of seed BHs. How SBHs initially formed is one of the biggest problems in the study of galaxy evolution today. SBHs have been observed as early as 570 Myr after BB, and how they could grow so quickly remains unexplained. The fact that a galaxy so massive existed so soon after first stars started to form is a challenge to current theoretical models of the formation of galaxies.

In astrophysics and particle physics, Self-Interacting Dark Matter (SIDM) is an alternative class of DMPs which have strong interactions, in contrast to the standard cold dark matter (CDM). SIDM was postulated in 1999 [37]. On galactic scales, DM self-interaction leads to energy and momentum exchange between DMPs. SIDM has also been postulated as an explanation for the DAMA annual modulation signal. Moreover, it is shown that it can serve the seed of SBHs at high redshift [38].

S. Balberg and S. L. Shapiro demonstrate that the formation of a central BH is the natural and inevitable consequence of the gravothermal catastrophe in SIDM halo. Through gravothermal evolution driven by collisional relaxation, SIDM halo will form a massive inner core whose density and velocity dispersion will increase secularly in time. Eventually, the inner core arrives at a relativistic radial instability and undergoes dynamical collapse to BH. According to the authors, forming SBHs by core collapse in SIDM halos requires no baryons, no prior epoch of star formation and no other mechanism of forming BHs seeds [39].

J. Pollack, D. N. Spergel, and P. J. Steinhardt consider the cosmological consequences if a small fraction of the DM is ultra-strongly self-interacting. This possibility evades all current constraints that assume that the self-interacting component makes up the majority of DM. Nevertheless, even a small fraction of ultra-strongly SIDM can have observable consequences on astrophysical scales. It can undergo gravothermal collapse and form seed BHs in the center of a halo [40].

W. X. Feng, *et al.* propose a scenario where a SIDM halo experiences gravothermal instability and its central region collapses into a seed BH. According to the authors, the presence of baryons in protogalaxies could significantly accelerate the gravothermal evolution of the halo and shorten collapse timescales [41].

In 2021, C. R. Argüelles, *et al.* propose a novel mechanism for the creation of SBHs from DM without requiring prior star formation or needing to invoke seed BHs with unrealistic accretion rates. The authors investigate the potential existence of stable galactic cores made of fermionic DM, and surrounded by a diluted DM halo, finding that the centers of these structures could become so concentrated that they could also collapse into SBHs once a critical threshold is reached. They analyzed this mechanism with DM haloes mass up to $5.9\times10^{10}M_{\odot}$ [42].

5. Ultramassive Dark Macroobjects

The most massive BHs discovered so far are [6] [43]:

- **NGC 6166** is a supermassive galaxy, with several smaller galaxies within its envelope, in the Abell 2199 cluster. It lies 490 million light years away in the constellation Hercules. The primary galaxy in the cluster is one of the most luminous galaxies known in terms of X-ray emissions. NGC 6166 has a large number of globular clusters (around 39,000) suggesting also that the halo of this galaxy blends smoothly with the intra-cluster medium. Because of that, the galaxy has the richest globular cluster system known. Also, a peculiar thing about NGC 6166 is that **it shows a blueshift *i.e.* it is moving towards us**. The galaxy harbors UBH at its center with a mass of nearly 30 billion solar mass;
- **H1821+643** is an extraordinarily luminous, radio-quiet quasar in the constellation of Draco. Identified in 2014, back then it was considered the most supermassive BH at a distance of over 10.4 Bly. The mass of this supergiant is more than 30 billion solar masses;
- **Abel 1201**. Outside the local Universe, measurements of M_{BH} are usually only possible for SBHs in an active state: limiting sample size and introducing selection biases. Gravitational lensing makes it possible to measure the mass of non-active SBHs. Using multi-band Hubble Space Telescope imaging and the lens modeling software PyAutoLens, J. W. Nightingale, *et al.* present models of a $z = 0.169$ galaxy-scale strong lens Abell 1201 and find $M_{UBH}=(3.27\pm2.12)\times10^{10}M_{\odot}$ [44];
- **S5 0014+81** has a mass of $\sim4\times10^{10}M_{\odot}$. It is actually a blazar. Blazars are the most energetic of all sub classes of quasars. It is one of the most luminous quasars with total output power of 10^{41} W;
- **Holm 15A** is the brightest cluster galaxy of the galaxy cluster Abell 85 in the constellation Cetus, about 700 Mly from Earth. K. Mehrgan, *et al.* find UBH with a mass of $(4.0\pm0.80)\times10^{10}M_{\odot}$. This is the most massive BH with direct dynamical detection in the local universe [45];
- **IC 1101** is a supergiant galaxy at the center of the Abell 2029 galaxy cluster and located 1.15 Bly from the Earth. It possesses a diffuse core which is the largest known core of any galaxy to date, and also hosts UBH that is a bright

radio source and has a mass of $(4 - 10)\times 10^{10} M_{\odot}$;

- **TON 618** is a hyperluminous, broad-absorption line, radio-loud quasar, located in the constellation Canes Venatici. It contains the most massive known BH, with a mass of 66 billion solar masses. It is one of the brightest objects in the known Universe that shines with a luminosity of 4×10^{10} W;
- **SLAB**. B. Carr, F. Kühnel, and L. Visinelli *consider the observational constraints on stupendously large black holes* (*SLABs*) *in the mass range* $M > 10^{11} M_{\odot}$. *These have attracted little attention hitherto, and we are aware of no published constraints on a SLAB population in the range* $(10^{12} - 10^{18}) M_{\odot}$. *However, there is already evidence for black holes of up to nearly* $10^{11} M_{\odot}$ *in galactic nuclei* [46], *so it is conceivable that SLABs exist, and they may even have been seeded by primordial black holes* [47]. They consider constraints on primordial BHs in the mass range $(10^{-18} - 10^{15}) M_{\odot}$ in case of DM comprised of WIMPs, which form halos around them and generate γ-rays by annihilations [48].

It is worth noting that the theoretical limit $M_{BH} = 5\times 10^{10} M_{\odot}$ is the maximum mass of BH that models predict, at least for luminous accreting SBHs. At around $10^{10} M_{\odot}$, both effects of intense radiation and star formation in the accretion disc slows down BH growth. Given the age of the universe and the composition of available matter, there is simply not enough time to grow BHs larger than this mass [44].

6. Superclusters

A supercluster is a large group of smaller galaxy clusters or galaxy groups. They are among the largest known structures in the universe. MW is part of the Local Group galaxy group (which contains more than 54 galaxies), which in turn is part of the Virgo Supercluster, which is part of the Laniakea Supercluster. The most interesting superclusters discovered so far are:

- **Laniakea Supercluster** (LSC) is a galaxy supercluster that is home to MW and approximately 10^5 other nearby galaxies (see **Figure 2**). It is known as one of the largest superclusters with estimated by L. Bliss, *et al.* binding mass $10^{17} M_{\odot}$ [50]. The neighboring superclusters to LSC are the Shapley Supercluster, Hercules Supercluster, Coma Supercluster, and Perseus-Pisces Supercluster (see **Figure 3**). Distance from the Earth to the Centre of LSC is 250 Mly. The mass-to-light ratio of Virgo Supercluster is about 300 times larger than that of the Solar ratio. Similar ratios are obtained for other superclusters [51]. These ratios are one of the main arguments in favor of presence of large amounts of Dark Matter in the World and validate the developed Model of Superclusters' Macrostructure.

We emphasize that $\sim 10^5$ nearby galaxies are moving around Centre of LSC. All these galaxies did not start their movement from "Initial Singularity". The neighboring superclusters have the same structures. It means that the World is a Patchwork Quilt of different Luminous Superclusters ($\gtrsim 10^3$).

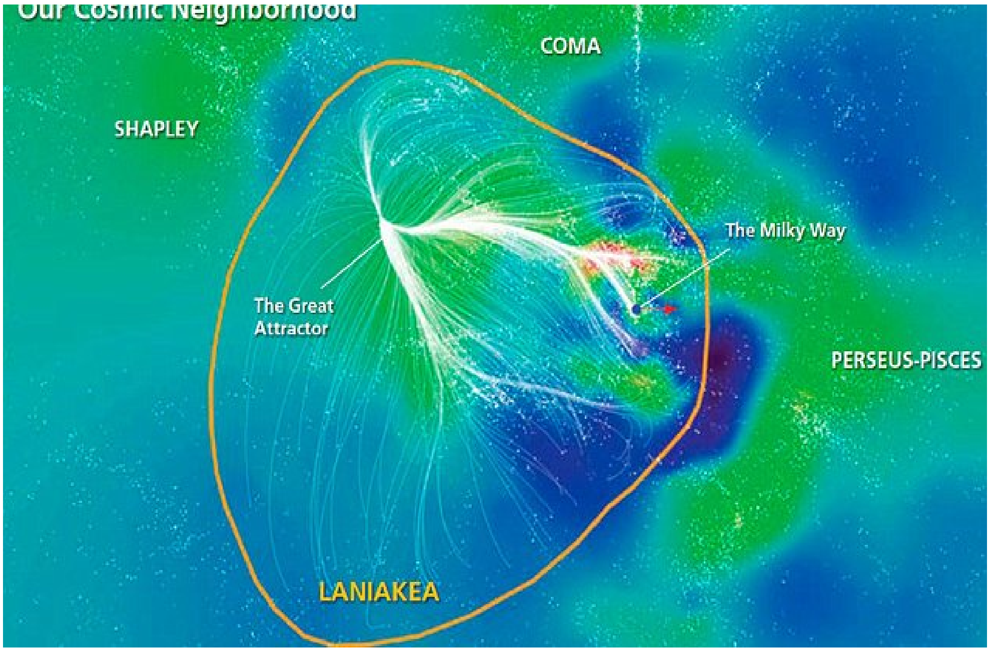

Figure 2. Laniakea Supercluster. Adapted from [49].

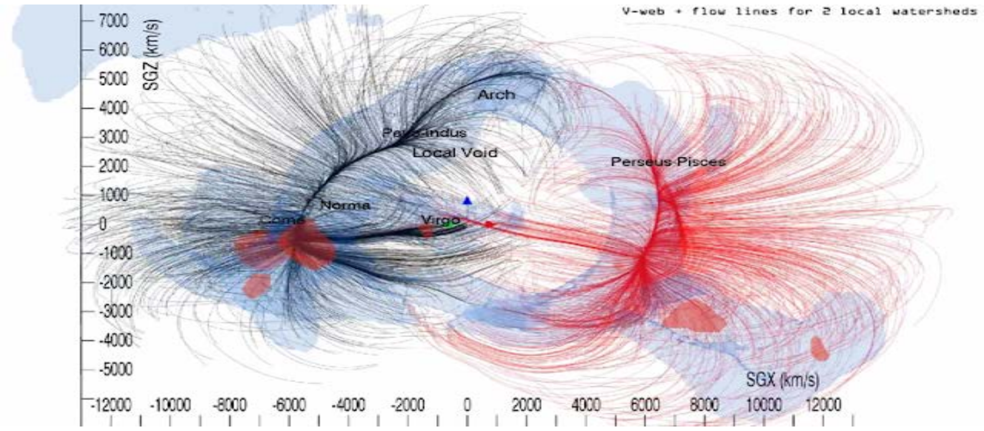

Figure 3. A representation of structure and flows due to mass within 6000 km·s^{-1} (~80 Mpc). Surfaces of red and blue respectively represent outer contours of clusters and filaments as defined by the local eigenvalues of the velocity shear tensor determined from the Wiener Filter analysis. Flow threads originating in our basin of attraction that terminate near Norma Cluster are in black and adjacent flow threads that terminate at the relative attractor near Perseus Cluster are in red. Arch and extended Antlia Wall structures bridge between the two attraction basins. Adapted from [49].

According to R. B. Tully, *et al*., "*Galaxies congregate in clusters and along filaments, and are missing from large regions referred to as voids. These structures are seen in maps derived from spectroscopic surveys that reveal networks of structure that are interconnected with no clear boundaries. Extended regions with a high concentration of galaxies are called* '*superclusters*', *although this term is not precise*" [49].

- **Phoenix A**. The Phoenix Cluster is a massive, Abell class type I galaxy cluster. It is one of the most massive galaxy clusters known, with the binding mass $(1.26 - 2.5)\times 10^{15} M_{\odot}$ and is the most luminous X-ray cluster discovered. It is located at a distance of 8.57 Bly from Earth. About 42 member galaxies were identified and currently listed in the SIMBAD Astronomical Database, though the real number may be as high as 10^3. Estimated mass of UBH is about $10^{11} M_{\odot}$ [46].

7. Large-Scale Structures

The organization of structure arguably begins at the stellar level, though most cosmologists rarely address astrophysics on that scale. Stars are organized into galaxies, which in turn form galaxy groups, galaxy clusters, superclusters, sheets, walls and filaments, which are separated by immense voids, creating a vast foam-like structure sometimes called the "cosmic web" [52].

P. Wang, *et al.* made a great discovery: "*Most cosmological structures in the universe spin. Although structures in the universe form on a wide variety of scales from small dwarf galaxies to large super clusters, the* ***generation of angular momentum across these scales is poorly understood****. We have investigated the possibility that filaments of galaxies—cylindrical tendrils of matter hundreds of millions of light-years across, are themselves spinning. By stacking thousands of filaments together and examining the velocity of galaxies perpendicular to the filament's axis* (*via their red and blue shift*), *we have found that these objects too display motion consistent with rotation making them the largest objects known to have angular momentum.* ***These results signify that angular momentum can be generated on unprecedented scales***" [53].

In 2021, A. Lopez reported about the discovery of "*a giant, almost symmetrical arc of galaxies—the Giant Arc—spanning* 3.3 *billion light years at a distance of more than* 9.2 *billion light years away that is* ***difficult to explain in current models of the Universe****. This new discovery of the Giant Arc adds to an* ***accumulating set of* (*cautious*) *challenges to the Cosmological Principle***" [54].

8. JWST Discoveries [20]

The problem of ancient galaxies formation is a long-standing problem. The age of the Universe is 13.77 ± 0.06 Byr, based on the cosmic microwave background data. Astronomers believe that our own MW galaxy is approximately 13.6 Byr old. MW is one of the two largest spiral galaxies in the Local Group (other being Andromeda Galaxy). Massive mature disk galaxies like MW cannot form so soon for 0.17 Byr only.

The summary of the JWST discoveries in the Early World:

- The most secure oldest galaxy is GLASS-z13 ($z \approx 13$, light-travel distance of 13.4572 Byr) that has already built up $\sim 10^9 M_{\odot}$ in stars;
- A search of 88 candidate galaxies at $z > 11$ shows that some of them could be at redshifts as high as 20. Some of those distant galaxies are strikingly massive;
- Most of the early galaxies are nicely shaped, disklike galaxies;
- It could be that some of these very distant, highly red-shifted galaxies are just

very dusty. They may contaminate searches for ultra-high-redshift galaxy candidates from JWST observations;
- A new redshift record obtained for galaxy candidate CEERS-93316 at $z = 16.7$ (light-travel distance of 13.5512 Byr) with a stellar mass $M^* \sim 10^9 M_\odot$;
- Seven galaxies with $M^* > 10^{10} M_\odot$ and $7 < z < 11$ were found in the survey area, including two galaxies with $M^* \sim 10^{11} M_\odot$. The stellar mass density in massive galaxies is much higher than anticipated from previous studies: a factor of 10 - 30 at z~8 and more than three orders of magnitude at z~10;
- Extremely Compact Bright Galaxies were found at z ~ 12 - 17 with effective radii $r_e \sim 200 - 300$ pc. One bright galaxy GL-z12-1 at z~12 has an extremely compact size with $r_e = 61 \pm 11$ pc;
- Super-early, massive, evolved galaxies with blue spectra, and very small dust attenuation.

9. WUM Explanations

These latest observations of the World can be explained in frames of the developed WUM only [55]:
- "*Galaxies **do not** congregate in clusters and along filaments*". On the contrary, Cosmic Web that is "*networks of structure that are interconnected with no clear boundaries*" is the result of the Rotational Fission of DM Cores of neighbor Superclusters;
- *"Generation of angular momentum across these scales*" provide DM Cores of Superclusters through the Rotational Fission mechanism;
- *"Spinning cylindrical tendrils of matter hundreds of millions of light-years across*" are the result of spiral jets of galaxies generated by DM Cores of Superclusters with internal rotation;
- The Giant Arc is the result of the intersection of the Galaxies' jets generated by the neighbor DM Cores of Superclusters;
- The calculated maximum mass of the supercluster DM Core of 2.1×10^{19} solar mass (see **Table 1**) is in good agreement with the values discussed by L. Bliss [50] and B. Carr, F. Kühnel and L. Visinelli [47]. In the future, these stupendously large compact objects can give rise to new Luminous Superclusters as the result of their DM Cores' rotational fission and DMPs self-annihilation;
- 13.77 Byr ago, when the Laniakea Supercluster emerged, the estimated number of DM Supercluster Cores in the World was around $\gtrsim 10^3$. It is unlikely that all of them gave birth to Luminous Superclusters at the same cosmological time being far away from each other. The 3D Finite Boundless World presents a Patchwork Quilt of different Luminous Superclusters, which emerged in various places of the World at different Cosmological times;
- The distribution of MOs in the World is spatially Inhomogeneous and Anisotropic and temporally Non-simultaneous. Cosmological principal is valid for the Homogeneous and Isotropic Medium of the World consisting of ele-

mentary particles with 2/3 of the total Matter. The distribution of MOs with 1/3 of the total Matter is Inhomogeneous and Anisotropic, and therefore, the Cosmological Principal is not viable;

- The mechanism of X-ray emission (self-annihilation of DMF3 particles) is valid for the galaxy NGC 6166, the Phoenix Cluster, Fermi Bubbles, the Solar and Planetary Coronas, and many other X-ray sources;
- In article [11], we discuss the intense radio source known as Sgr A* in Centre of MW considering the shell of electron-positron plasma around Nuclei made up of DMF1 responsible for the radio emission. In our opinion, the same mechanism of radio emission is valid for the bright radio source IC 1101, the radio-loud quasar TON 618, the radio source A2261-BCG and many other radio-active sources;
- According to WUM, Cores of Galaxies are DM Compact Objects made up of DMF1 and/or DMF2 with shell of DMF3 with the calculated maximum mass of $6\times10^{10}M_{\odot}$ (see **Table 1**). This value is in good agreement with the experimentally obtained value of the most massive BH ever found, with a mass of $6.6\times10^{10}M_{\odot}$ at the center of TON 618 [43]. It is worth noting that there are no black holes in WUM;
- The main conjecture of BBM: "*Projecting galaxy trajectories backwards in time means that they converge to the Initial Singularity at* $t = 0$ *that is an infinite energy density state*" is wrong because all Galaxies are gravitationally bound with their Superclusters (see **Figure 2** and **Figure 3**). BB never happened.

WUM explains JWST discoveries the following way [55]:

- **It is a question of time!** The Beginning of the World was 14.22 Byr ago! WUM introduces Dark Epoch (spanning for LSC from the Beginning of the World for 0.45 Byr) when only DM Macroobjects existed, and Luminous Epoch (ever since, 13.77 Byr). Transition from Dark Epoch to Luminous Epoch is due to an Explosive Volcanic Rotational Fission of Overspinning DM Supercluster's Cores and self-annihilation of DMPs. Ordinary Matter is a byproduct of DMPs self-annihilation;
- Macroobjects form from the top (Superclusters) down to Galaxies and Extrasolar systems in parallel around different Cores made up of different DMPs;
- Early-galaxies formed in near present configuration. There are no protogalaxies in the World. That is why JWST did not see their images;
- Compact Disc Galaxies emerged as the result of the Rotational Fission of the overspinning DM Core of Superclusters. Each of them has one DM Core. There are no frequent mergers at the early epoch;
- Massive mature disk galaxies with mass up to $M^* \sim 10^{11}M_{\odot}$ cannot form so soon because it takes billions of years to form them, and so should not be there at all at the "beginning";
- The presence of very dusty highly red-shifted galaxies should be proved by discussing a mechanism of dust creation. According to Herschel Space Observatory, *dust is formed in stars and is then blown off in a slow wind or a*

massive star explosion. The dust is then 'recycled' in the clouds of gas between stars and some of it is consumed when the next generation of stars begins to form. Dust formed in stellar wind or by Supernova Shockwave [56]. The dust could have been efficiently ejected during the very first phases of galaxy build-up as A. Ferrara, A. Pallottini, P. Dayal speculated;

- We hope that oldest galaxies with high-redshifts $z > 20.4$ (light-travel distance >13.7 Byr) will be confirmed. It depends on the physical parameters of JWST.

10. Conclusion

Astronomers have great achievements in investigations of the Solar System that became an Experimental laboratory for astrophysicists to check their theories. We are at the Beginning of a New Era of Astronomy, Cosmology, and Astrophysics! Young physicists should be a part of it. They should concentrate their efforts on the development of a New Cosmology and Classical Physics. I am very excited about the Future of Physics!

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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