Pramana–J. Phys. () :
DOI

A Theory of Dark Matter

JAIDEV B. PARMAR

Abstract. A model of the Universe is constructed and a number of problems in Contemporary physics like Baryon Asymmetry, Dark Matter, Proton Decay, Galaxy Rotation Curve, Quasars, SMBH, Relativistic Astrophysical Jets, Coronal Heating, Solar Cycle, Supernovae mechanism, Magnetar magnetic field, Cosmological Lithium problem, Solar neutrino problem and Existence of Black holes are discussed in the light of the Hypothetical Universe. It is proposed that there exists stable neutrons and antineutrons that could explain the Dark matter and the missing antimatter of the Universe.

1. Introduction

Imagine that there is an immortal planetary sized being made up of epiphenomenal ectoplasm, we name Galactus, who does not interact gravitationally with matter, moves around the space at will and perceives the entire human year the same as how we humans perceive a minute. Suppose he visits the Earth and observes us, to him we humans would seem like indistinguishable dots, assuming that his senses are not keen enough to distinguish between man, woman, young, old, fertile or infertile qualities of humans. Galactus would observe that one dot splits to two dots (a woman giving birth to a baby) and thus concludes that all Human dots have the property of splitting into two Human dots. But his conclusion is obviously wrong because humans are in reality more complex entities than just simple dots. There is not only internal differentiation between sexes but also only under special circumstances do some special humans - Females give birth. But this differentiation is not apparant to Galactus.

Let us replace Galactus by a human scientist, and a human dot from previous paragraph by a neutron. The scientist observes that one free neutron undergoes β-decay and is converted to a proton and an electron and thus he concludes that all free neutrons have the property that they undergo β-decay.

The question is what if the human scientist has made the same mistake that Galactus has supposedly made for the humans? Neutrons are not elementary particles, they are infact composite particles, internally made up of quarks and gluons and hence there is a possibility that there could be different types of neutrons having slightly different properties but indistingushible to our probes. Our aim is to take this idea forward and look at a few unsolved problems in contemporary Physics and try to view them through the light of the above idea, the problems that will be discussed are:

1. Baryon Asymmetry [1]
2. Dark Matter [2]
3. Proton Decay[3]
4. Galaxy Rotation Curve [4]
5. Quasars and Super massive black holes (SMBH) [5]
6. Relativistic Astrophysical Jets [6]
7. Coronal Heating
8. Solar Cycle [7]
9. Supernovae mechanism
10. Origin of magnetar magnetic field
11. Cosmological Lithium [8]

We would also revisit the problem below:

1. Solar neutrino problem
2. Can Black Holes other than SMBH exist?

2. Assumptions

Suppose we are able model the real Universe and call the model the Hypothetical Universe (HU). The HU will have properties that are quite similar to the known properties of the real Universe namely the strong, weak, electromagnetic and gravitational. In addition, we have the freedom to change any property of HU model as per our will. Assuming that we have at our disposal a hypothetical powerful computer which has very high precision and we are able to run, control and observe the HU simulation in arbitrary accelerated time. Further we choose to give the following initial conditions to the HU simulation:

1. Matter-Antimatter symmetric state. Lets assume that the baryonic matter and anti-matter is in the form of a neutral particle soup of Protons, Antiprotons, Electrons, Positrons, Neutrons and Antineutrons randomly but isotropically distributed in the HU.

2. The mass is stationery. i.e., the particles do not have appreciable bulk velocities in any particular direction

3. From the Standard Model (SM) of particle physics [9], we take the following for the particles of HU:

   - Neutrons are made up of two d type quarks having of charge $(-\frac{1}{3})$ and one u type quark of charge $(+\frac{2}{3})$
   - Each quark has a unique color charge and is one of the 3 kinds of different color charges, the colors are red, green or blue making the overall neutron color neutral
   - Antineutrons are made up of two $\bar{d}$ type antiquarks of charge $(+\frac{1}{3})$ and one $\bar{u}$ type antiquark of charge $(-\frac{2}{3})$
   - Each antiquark again has a unique color and is one of the 3 kinds of different color charges, the colors are ant-red, anti-green and anti-blue making the overall antineutron also color neutral

Suppose we distinguish nucleons based on the unique quark color, thus as depicted in Fig 2..1, since the type u quark is unique inside a neutron, then depending on the color charge of the u quark, the neutrons are named as the red n_r, green n_g and blue n_b type neutrons. It is assumed that of the total number of neutrons, each type will consist of a third of the total number of neutrons N. Thus the number of any specific color species of the neutrons is $N_i = \frac{1}{3}N$, where $i \in \{r, g, b\}$.

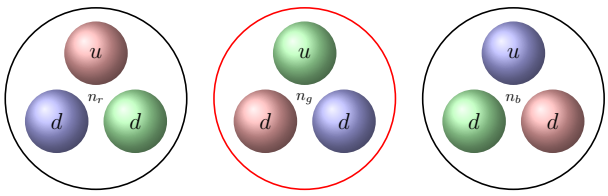

Figure 2..1. The three types of neutrons

The antineutrons as depicted in Fig 2..2, can similarly be named from the $\bar{u}$ antiquark as the anti-red $\bar{n}_{\bar{r}}$, anti-green $\bar{n}_{\bar{g}}$ and anti-blue $\bar{n}_{\bar{b}}$ antineutrons. The total number of antineutrons is also N. Thus there are total of $2N$ particles at the start of the HU simulation.

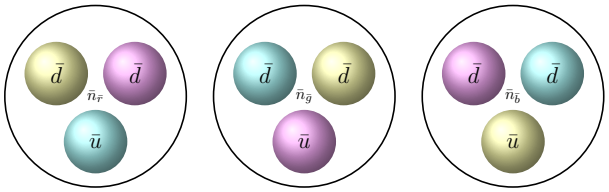

Figure 2..2. The three types of antineutrons

3. Additional Properties

Apart from the normal rules of the Universe, we impose additional rules below for the HU:

1. In the nucleon, the quarks retain their individual color charge.

2. In the nucleon, the green quark has a special property that it induces one of the other quarks to become of the same type as itself via weak interaction. A nucleon is stable if the type of the green quark and the type of one of other quark is the same.

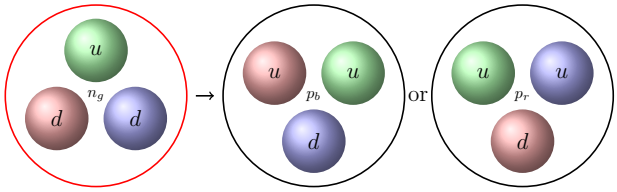

Figure 3..1. Neutron to Proton transformation

4. Simulation Run

Based upon the above assumptions and rules, upon running simulation model inside the computer, we expect to see the following evolution of the HU. Most of the electrically charged pairs will undergo mutual annihilation reaction leaving behind the electrically neutral particles in the form of Neutrons and Antineutrons. There will be a creation of a huge amount of γ-rays due to the annihilation reaction and a portion of the γ-rays produced will keep on undergoing pair production and annihilation until the formation of Neutron-Antineutron pairs, this being the final freezout of the annihilation reaction. As for the neutrons, from the additional property (2), since the n_r and n_b have the green quark that already has the same type of d quark inside the neutron and hence these are stable. A n_g neutron does not have a u quark of the same type and hence will induce the β-decay in one of the of the d quarks as in Fig 3..1 and in a few hours of the simulation time, bulk of the n_g

neutrons will get converted to either p_r or p_b i.e., red or blue colored protons based on their color of the unique d quark, all other species of neutrons and antineutrons viz $n_r, n_b, \bar{n}_{\bar{r}}, \bar{n}_{\bar{g}}$ and $\bar{n}_{\bar{b}}$ are stable and will not transform to the respective protons and antiprotons. The generated electrons from the β-decay of the n_g neutron will interact with the γ-rays produced during the initial annihilation reactions and will be the source of the Cosmic Microwave Background (CMB) Radiation and the energy in for form for radiation will initiate turbulence in the neutral plasma. The turbulence will lead to bulk circular motion inside the plasma, this will feedback to the DM that will also start circulating along with normal matter that is in Plasma form.

Thus at a certain point after a few hours, we will have the Proton:Neutron:Antineutron ratio of 1:2:3. Thus the ratio of the neutrons that will undergo β-decay from the total is $\frac{1}{3}N/2N = \frac{1}{6} = 0.167 = 16.7\%$. There will be five times more mass in the form of stable neutrons and antineutrons than the unstable n_g neutrons. The Hydrogen formed after the β-decay of n_g neutron will make up 16.7% of the overall starting mass of the HU. The rest will be in the form of electrically neutral particles, composed of stable neutrons and antineutrons that will make up the Dark Matter (hereafter refereed to as DM).

4.0.1 *Quasars* There will be random fluctuations due to turbulent circular motion of the fluid mass in the HU, the central location of the circulating eddies will be stationary. At the centers of these eddies, mass would start to come together due to the mutual gravitational attraction. They will collapse together and this will initiate mutual annihilation between the neutrons and antineutrons. The γ-rays created in these annihilation will start the phase of re-ionization of the HU and the radiation will scatter the electrons and protons away from the central core location but would not affect the DM. The DM would keep falling into the core location and make it progressively bigger. The nature of these cores will be antimatter type since the ratio of neutrons to antineutrons is 2:3. For every 2 neutrons annihilated, one anti-neutron will accrue into the core. This core in time will evolve into a Quasar. These Quasars will be extremely bright as the matter-antimatter annihilation would happen on the surface of these Quasars. After a point of time, these Quasars will turn into the Super Massive Black Holes (SMBH). Once this stage is reached the energy that was previously liberated in all directions in the form of light will be collimated into the Astrophysical Jets ejected from the rotational axis of the SMBHs.

4.0.2 *Relativistic Astrophysical Jets* The rotating SMBH would be in the form of a torus, the DM that falls into the SMBH undergoes annihilation reaction between the neutrons and antineutrons. The photons created would increase the angular velocity of the SMBH and consequently increase the radius of the torus, at a certain point, the gravitational pull at the center of the torus would be low enough that the high energy photons will be able to escape through the polar axes. The photons that come out along the polar axes would undergo pair production and the particles created would be accelerated to relativistic speeds. Again what comes out of the Astrophysical Jets is the Proton:Neutron:Antineutron matter in 1:2:3 ratio. Thus the SMBHs act as the recyclers of the HU. Once the high energy light of the Quasars is collimated in an SMBH, the normal matter in the form of scattered Plasma starts to lose energy and collapse into clouds of molecular Hydrogen, this would start the phase of Recombination. The molecular hydrogen clouds would start to migrate back to the galactic centers pulled by the gravity of the SMBHs, they will form accretion disks around their SMBHs and further collapse to form the initial matter stars and together with the central SMBHs form the primordial Galaxies. The DM is depleted near the SMBHs but the concentration gets higher as the radial distance increases away from the SMBH. Thus it would seem the Galaxies are surrounded by a DM halo.

4.0.3 *Coronal Heating* The DM at the location of the Accretion disc of the Galaxies is rarefied but not lost. The DM rains down on stars, the antineutrons in the DM annihilate at the stellar atmospheres leading to the high temperature stellar coronae. The neutrons in the DM migrate to the stellar cores and become available to participate in the nuclear reactions inside the stellar core. The $p-p$ chain reactions is not the primary reaction in the stellar core, the primary reaction that powers the stars are:

$$ {}^{1}_{1}p + {}^{1}_{0}n \longrightarrow {}^{2}_{1}D \tag{4..1} $$

$$ 2^{2}_{1}D \longrightarrow {}^{4}_{2}He \tag{4..2} $$

Overall reaction:

$$ 2^{1}_{1}p + 2^{1}_{0}n \longrightarrow {}^{4}_{2}He + 28.3MeV \tag{4..3} $$

The above reactions also create Helium as their final product but without the production of any positrons and neutrinos. Thus in the stars, it is not required that the stellar cores be so hot that $p-p$ chain reactions to proceed at an appreciable level.

4.0.4 *Stellar Cycles* There will be clouds of neutrons floating inside the stellar core. At the steady state, the neutron clouds wold coalesce into a central neutron cloud with the center of gravity coinciding with the center of gravity of the matter star. As the star revolves around the galactic center, it passes through the interstellar medium, and depending upon the resistance offered by the intervening medium due to the density of the intervening medium, there could be a small change in the velocity of the star. The neutron cloud inside the stellar core are not directly affected by the velocity change and would continue to move with their original velocity and thus there will be desynchronization between the Center of gravity (CG) of the star and the CG of neutron cloud. The neutron cloud would now start to move chaotically around the center of gravity of the star in the attempt to again coincide with the CG of the star as it will be acted upon by the gravity of the material inside the sphere with radius equal to the difference in the CGs of the star and the neutron cloud. This chaotic motion of the neutron cloud around the stellar core would result in uneven production of energy depending on the location of the neutron cloud inside the stellar core. The apparent cyclicity of the chaotic motion of the neutron cloud creates the stellar cycles.

In HU, the Deuterium, Helium and Lithium-7 production can be explained due to presence of free neutrons inside the stellar cores.

$$^{2}_{1}D +^{1}_{0} n \longrightarrow ^{3}_{1}T \tag{4..4}$$

$$^{4}_{2}He +^{3}_{1} T \longrightarrow ^{7}_{3}Li \tag{4..5}$$

With the overall reaction:

$$^{2}_{1}D +^{4}_{2} He +^{1}_{0} n \longrightarrow ^{7}_{3}Li \tag{4..6}$$

Once the Hydrogen is depleted from the stellar core, the neutron consumption will cease. The incessant raining of neutrons from the DM would increase the concentration of the neutron clouds and they would start to accrue and stabilize at the stellar core and start to form an extremely dense neutron core held together by its own gravitational pull. The core would be surrounded by a Helium shell and the star would enter the CNO cycle and become a red giant or supergiant. Further evolution of the star would happen and it happens in the real Universe. For a sufficiently large star, the neutron core will be surrounded by an iron core.

4.0.5 *Supernova* The neutron core is already formed long before the star explodes into a supernova. Upon the cessation of all the nuclear reactions, the star would start to collapse around the neutron core, the energy of the collapse would heat up the star and create an implosion. The implosion would create the heavier elements due to high temperatures and pressures near and around the neutron core but the implosion would rebound from the super dense neutron core, the shock-wave created would transform from implosion into an explosion. All the layers of the star including the innermost iron shell surrounding the neutron core are expelled by the shock-wave leaving only the already existing solid neutron core behind and thus a neutron star is born.

The supernova would seed the galaxy with metals and lead to next generation stars that are not as massive but the same processes that powered the original stars would power the new stars.

All the astrophysical objects like the stars, planets and moons have neutron cores inside them.

5. Discussion

5.1 *Baryon Asymmetry*

There is no Baryon Asymmetry in HU. The asymmetry has been shifted to the Green Quark, which enables us to create the required DM in the from of stable neutrons and antineutrons.

5.2 *Dark Matter*

The DM from the previous section has the following properties:

- It is composed of $n_r, n_b, \bar{n}_{\bar{r}}, \bar{n}_{\bar{g}}$ and $\bar{n}_{\bar{b}}$, that is the non-green neutrons and the antineutrons that are stable with energy equal to the normal neutron of around 1GeV
- It is electrically neutral, it does not interact electromagnetically and interacts only gravitationally
- It forms the halo around the Galaxies
- It has the required density to account for the relic density
- A stable neutron and antineutron could annihilate each other if they are incident on each other with the formation of γ-rays and thus the DM undergoes self annihilation

From the experimental evidence, the amount of visible matter in the real Universe is estimated to be 4.9% and the Dark Matter is 26.8% [10], this provides a basis

of comparison of the number obtained and the experimental ratio of $4.9/(4.9 + 26.8) = 0.154 = 15.4\%$. Thus the experimental figure of 15.4% is quite close to the figure of 16.7% obtained when the proposed one species of the neutrons n_g undergoes the β-decay in the HU model.

5.3 *Proton Decay*

The Protons generated from the β-decay of the n_g type neutrons are stable. If p_g type protons existed initially or are created during pair production inside Astrophysical Jets then they would be unstable and each one would decay into a stable neutron with the emission of a positron and a neutrino.

5.4 *Galaxy Rotation Curve*

From the HU simulation, the Galaxies are indeed surrounded by a halo of DM and that provides explanation of the Galaxy rotation curve observed.

5.5 *Quasars and Super massive black holes*

5.5.1 *What is the origin of the M-sigma relation between supermassive black hole mass and galaxy velocity dispersion?* The M-sigma relation where $M, M_\odot$ and σ are the Mass of the SMBH, Solar mass and velocity dispersion respectively is:

$$\frac{M}{10^8 M_\odot} \approx 3.1 \left(\frac{\sigma}{200.km.s^{-1}}\right)^4$$

Comparing it with Kolmogorov's second hypothesis from his turbulence theory of 1941 where η is the Kolmogorov length scale, ν is the kinematic viscosity and ξ is the energy dissipation [11]

$$\eta = \left(\frac{\nu^3}{\xi}\right)^{\frac{1}{4}}$$

Rearranging the Kolmogorov's equation

$$\xi = \frac{\eta^4}{\nu^3}$$

Thus the energy dissipation ξ can be related to the Mass of the SMBH and η the Kolmogorov length scale to the velocity dispersion, ν the kinematic viscosity of the material in space would act as the proportional constant. The M-sigma relation can thus be apparently related to the theory of Turbulence. If this is true then the Universe is finite and having a boundary through which energy is dissipated out.

5.5.2 *How did the most distant quasars grow their supermassive black holes up to* 10^{10} *solar masses so early in the history of the HU?* Explained in 4.0.1.

5.6 *Relativistic Astrophysical Jets*

5.6.1 *Why do the accretion discs surrounding certain astronomical objects, such as the nuclei of active galaxies, emit relativistic jets along their polar axes?* Explained in 4.0.2.

5.7 *Coronal Heating*

5.7.1 *Why is the Sun's corona (atmosphere layer) so much hotter than the Sun's surface?* Explained in 4.0.3.

5.8 *Solar Cycle*

5.8.1 *How does the Sun generate its periodically reversing large-scale magnetic field?* Explained in 4.0.4.

5.8.2 *How do other solar-like stars generate their magnetic fields, and what are the similarities and differences between stellar activity cycles and that of the Sun?* The Magneto-Hydro-dynamic (MHD) flows inside the plasma of the stars would be formed such that they oppose the disturbance created when the neutron cloud is offset from the stellar center. The MHD flow that is created will generate the magnetic fields of the star.

5.8.3 *What caused the Maunder Minimum and other grand minima, and how does the solar cycle recover from a minima state?* It is possible that the Sun went though a period when the interstellar medium did not cause any disturbance to the velocity of the Sun and thus the neutron cloud inside was undisturbed and stayed at the Sun's center. This led to a stable Sun with no Sun spots and that period would be similar to the Maunder Minimum observed.

5.9 *Supernovae mechanism*

5.9.1 *What is the exact mechanism by which an implosion of a dying star becomes an explosion?* The Supernova mechanism is explained here 4.0.5.

It has to be noted that the implosion is not strong enough to create neutrons by squeezing together electrons and nuclei. The neutron core was already present inside the star.

5.10 *Origin of magnetar magnetic field:*

5.10.1 *What is the origin of magnetar magnetic field?* In the HU, it is possible that after a supernova explosion, the neutron star formed has parts of the iron shell

left behind on the star surface in a highly ionized state. The iron nuclei stripped of all electrons is positively charged and the rotation of the neutron star would create the extreme magnetic field of the magnetar. The extreme magnetic field will not allow the electrons from space to flow back to the neutron star and neutralize the iron nuclei for a long time.

5.11 *Cosmological Lithium*

5.11.1 *Why is there a discrepancy between the amount of lithium-7 predicted to be produced in Big Bang nucleosynthesis and the amount observed in very old stars?*

As explained in the previous section, the HU has alternate pathways to create Lithium-7 by the reaction 4..6 inside the stellar cores.

5.12 *Solar neutrino problem:*

5.12.1 *The solar neutrino problem concerns a large discrepancy between the flux of solar neutrinos as predicted from the Sun's luminosity and measured directly.* In the HU, the primary energy production reaction 4..3 that produces Helium, does not produce neutrinos and hence the Solar neutrino problem is resolved.

5.13 *Can Black Holes other than SMBH exist?*

In the HU the matter black holes will in time be annihilated after a while by the DM that has more amount of antimatter than matter as it rains upon the black holes. It is also expected that the black holes display Astrophysical jets due to annihilation reactions happening inside like in SMBH since we do not observe these, their existence is doubtful.

6. Evidence

It is impossible to provide any direct evidence for the proposed DM as it is not possible to artifically capture the proposed DM due to the difficulty in capturing electrically neutral neutrons and antineutrons. But there is a plethora of indirect evidence that the author believs provides a strong support for proposed DM.

6.1 ^{14}C - *Carbon-14*

Suppose that a cosmic ray made up of proton is moving at 99% of the speed of light. Suppose also that there is a intergalactic medium through which this particle is travelling towards us and the Magnetic Field strength of this IGM is uniformly $0.1nT$ and is perpendicular to the direction of motion of the ray. The IGM induces a curve in the motion of any charged particle and the radius of the orbit of proton due to the magnetic field is will be:

$$\rho = \frac{m_0 v}{qB\sqrt{1-\left(\frac{v}{c}\right)^2}} \tag{6..1}$$

Thus substituting the standard values of the charge and mass of the proton and along with the Lorentz factor for 99% of the speed of light, the radius of the orbit for the proton will be 5193.77 light years. Thus the the proton will be captured and start rotating in a circular orbit of a few thousand light years much before it has a chance to reach our Milkyway Galaxy let alone reach the solar system and the Earth that have higher Magnetic field strengths. Thus the Cosmic Rays that reach the Earth and originate from outside the Milkyway, cannot be composed of charges particles, they have to be composed of electrically neutral particles.

The Cosmic Rays that are incident on Nitrogen nucleus in the upper atmosphere of the Earth, converts it into the unstable isotope of Carbon-14 with a half life of around 5730 years. Carbon-14 is produced in the upper layers of the troposphere and the stratosphere by thermal neutrons absorbed by nitrogen atoms in the following reaction:

$$^{1}_{0}n + {}^{14}_{7}N \longrightarrow {}^{1}_{6}C + {}^{1}_{1}p \tag{6..2}$$

Since the unstable Carbon-14 is observed in Nature, it provides the evidence that the Neutrons needed for the reaction come from outer space in Cosmic Rays and thus free neutrons exist in Nature.

6.2 *Earth's Geomagnetic Field*

It has been proposed that the Earth's magnetic field is generated by electrically conducting iron liquid surrounding the solid inner iron core by a dynamo mechanism. But this is analogous to creating a perpetual machine with no source of energy to run the dynamo that has been running for billions of years.

The Neutron has an intrinsic magnetic diopole moment $\mu_n = -9.6623647e^{-27}JT^{-1}$ and hence behaves like a tiny permanent magnet. If a number of neutrons align, then their individual magnetic moments would sum up and create a magnet with a large field strength. Thus if the Earth's core in part is made up of of free magnetically aligned Neutons, then there is no need for induced dissipative electric currents and dynamo mechanism to generate the Geomagnetic field. Additionally the Neutron core will not be affected by Curie temperature that affects iron since the magnetic moment of the Neutron is it's inherent Quantum Mechanical property. The hot iron core infact will act like an induced magnet rather than a permanent magnet.

7. Limitations of the model

The HU has the following limitations:

1. Arbitrary Initial conditions
2. It does not say anything about the Big-Bang and Cosmic Inflation and Hubble expansion
3. It is silent on the Dark Energy that accounts for 70% of the mass budget

8. Conclusion

From the model of the hypothetical Universe, we can conclude that the HU is symmetric with regards to matter and antimatter, the DM is baryonic, namely composed of a combination of the stable neutrons and the missing antimatter in the form of stable antineutrons. The DM passes all the tests required of a DM candidate and has the needed relic density without invoking any new physics. We have thus put forth a theory that accounts for all that is needed to explain the nature of DM and account for the missing antimatter and have provided a mechanism through which the DM can be explained with the the Standard Model of particle physics with a small extension that there are three neutron species, two of them are stable and one is unstable and that makes up all the visible matter of the HU.

A number of problems in Contemporary physics as listed in Section 1. are discussed.

The author acknowledges that there are severe limitations in the model and it does not address many issues like the Big-Bang, Inflation and Dark Energy. But even with the limitations, the model seems to provide explanations for a number of problems in contemporary Physics. The model invokes no new Physics nor modification to gravity. Even after selecting arbitrary initial conditions the model asymptotically evolves to something that is analogous to observable universe today.

References

[1] Laurent Canetti, Marco Drewes, and Mikhail Shaposhnikov. Matter and antimatter in the universe. *New Journal of Physics*, 14(9):095012, sep 2012.

[2] Katherine Garrett and Gintaras Duda. Dark matter: A primer. *Advances in Astronomy*, 2011:1–22, 2011.

[3] Pran Nath and Pavel Fileviez Pérez. Proton stability in grand unified theories, in strings and in branes. *Physics Reports*, 441(5-6):191–317, apr 2007.

[4] Vera C. Rubin and Jr. Ford W. Kent. Rotation of the andromeda nebula from a spectroscopic survey of emission regions. *The Astrophysical Journal*, 159:379, feb 1970.

[5] Laura Ferrarese and David Merritt. A fundamental relation between supermassive black holes and their host galaxies. *The Astrophysical Journal*, 539(1):L9–L12, aug 2000.

[6] R. A. Laing and A. H. Bridle. Systematic properties of decelerating relativistic jets in low-luminosity radio galaxies. *Monthly Notices of the Royal Astronomical Society*, 437(4):3405–3441, dec 2013.

[7] Michael J. Thompson. Grand challenges in the physics of the sun and sun-like stars. *Frontiers in Astronomy and Space Sciences*, 1, jun 2014.

[8] Brian D. Fields. The primordial lithium problem. *Annual Review of Nuclear and Particle Science*, 61(1):47–68, nov 2011.

[9] S. F. Novaes. Standard model: An introduction.

[10] Planck Collaboration, P. A. R. Ade, and et al. Planck 2013 results. i. overview of products and scientific results. *Astronomy & Astrophysics*, 571:A1, oct 2014.

[11] A. N. Kolmogorov. The local structure of turbulence in incompressible viscous fluid for very large reynolds numbers. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 434(1890):9–13, jul 1991.