Scientific Voyage
Vol. 1 No. 2
Page 1-12 (2020)

SCIENTIFIC VOYAGE
ISSN: 2395-5546

GCECT
Publication
Apr.-Jun.

Cosmoparticle physics: The enlightening voyage to the Dark Universe

M.Yu. Khlopov[1,2,3]
[1] *National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), 115409 Moscow, Russia*
[2] *Institute of Physics, Southern Federal University Stachki 194, Rostov on Don 344090, Russia*
[3] *Universit de Paris, CNRS, Astroparticule et Cosmologie, F-75013 Paris, France*
E-mail: khlopov@apc.univ-paris7.fr

Abstract: Physics of the dominant part of the energy-density of the modern Universe - dark matter and dark energy - lies beyond the Standard model (BSM) of elementary particles. The now standard cosmological model involves BSM physics to describe the cornerstones of the structure and evolution of the Universe: inflation, baryosynthesis and dark matter/energy. It makes Dark the whole story of the Universe: from the origin of its basic initial conditions to the modern structure and evolution. It implies existence of BSM physics, which still finds no experimental evidence, since search for it at the LHC only tightens constraints on its effects. We show that the challenge to shed light on the physics of the Dark Universe can be related to development of cosmoparticle physics, studying fundamental relationship of micro- and macro worlds in cross disciplinary studies of its physical, cosmological and astrophysical signatures.

Keywords: Cosmology; Particle physics; Cosmoparticle physics; inflation; baryosynthesis; Dark matter; Beyond the Standard models

1. Introduction

The paradox of the current situation in cosmology and particle physics can be characterized as *conspiracy* of physics and cosmology beyond the corresponding Standard models [1,2]. Except for the nonzero mass of neutrino there is no experimental evidence for effects of physics Beyond the Standard model (BSM) of elementary particles. Search for such effects at the LHC only tightens the constraints on deviations from the predictions of the standard model (SM) of elementary particles. On the other hand BSM physics is not only needed to solve the internal theoretical problems of the SM like divergence of Higgs boson mass in the electroweak theory or CP violation in QCD, but becomes necessary theoretical basis for the now standard model of the structure and evolution of the Universe - inflationary cosmology with baryosynthesis and dark matter/energy. Astronomical data of the precision cosmology confirm this standard cosmological model, putting more and more stringent constraints on possible deviations from its predictions.

The standards of the modern cosmology mean that the we live in Dark Universe not only because it is dominated now by dark matter and dark energy, but also because its basic parameters are determined by the mechanisms of inflation and baryosynthesis related to the dark (unknown) part of the fundamental physics.

Mutual relationship of cosmology and particle physics is developed in the cosmoparticle physics, studying this relationship in the cross disciplinary search for its physical, astrophysical and cosmological signatures. Here we briefly discuss the

motivation for genesis and basic principles of cosmoparticle physics and pay special attention to the reflection of the BSM physics of the modern cosmology in the nonstandard features in astrophysical and cosmological phenomena. The evidences for such features will enlighten the true history of the Universe and the laws of new physics, which governed it.

2. Unification of the frontiers of the fundamental knowledge

The modern picture of the so called Standard model of elementary particle physics finds strong support in the experiments at particle accelerators and colliders. The last missed element in the set of fundamental particles of the Standard model (SM), the Higgs boson was discovered at the Large Hadron Collider (LHC) in 2012.

However it is not the end of discoveries in particle physics, since the wide field of physics Beyond the Standard model is badly needed and waits for its exploration.

Theoretical and practical need to extend the SM follows from its internal problems, some of which can be solved by supersymmetry symmetry between bosons and fermions. Since we do not observe supersymmetry in the mass spectra of known fermions and bosons, then it must be broken, and the search for supersymmetric partners heavier than the corresponding particles was one of the greatest challenges for the Large Hadron Collider and/or the next generation of accelerators. The idea of unifying all the fundamental forces of Nature is the aesthetically appealing reason for the extension of the SM. The similarity of the description of the fundamental particle interactions (electromagnetism, strong and weak interactions), achieved in the SM, is embedded deeply in a grand unified theory (GUT), which extends the fundamental symmetry of elementary particles.

By placing the set of known particles in such theory, we see that there remain white spots which should be occupied to complete it.

The wider the theory, the larger is the number of additional particles and fields, corresponding to the total symmetry. These particles and fields correspond to the hidden sector of the relevant theory, since they are hidden from direct experimental verification or because of their large mass, or because of the extremely weak interaction with the known particles.

In both cases, the (super-weak interaction, or very super-large mass) verification of the predictions requires the use of indirect methods. That is why the expanding Universe, as a possible source of information about elementary particles, attracts the most attention of people involved in elementary particle physics.

Modern cosmology is based on two observational facts. On the fact that the Universe is expanding, and that the modern Universe is filled with the thermal background of electromagnetic radiation. Combining these facts leads to the ideas of Big Bang expanding Universe. Big Bang theory leads to very high temperatures at the very early stages of expansion. We can never build an accelerator of elementary particles to energies of the GUT which are naturally realized in the early stages of cosmological evolution. Thus, the internal development of particle physics leads to the theory of a hot expanding Universe, called Big Bang Universe, as a natural landfill of its fundamental ideas.

However, to resolve the quantitative inconsistencies, which at a deeper examination became more pronounced, it has been necessary to add new fundamental elements to the basics of its theoretical constructions. The theory of the Big

Bang Universe is now supplemented by at least four additional elements inflation, baryosynthesis, non-baryonic dark matter and dark energy, based on physical laws predicted by the theory of elementary particles which, however, have not been experimentally verified.

The inflation gives the principal answer for the questions why is the Universe expanding? Why the expansion makes the Universe so homogeneous and isotropic? and Why the evolution in causally disconnected regions is identical? It suggests that in the past there was a phase of superluminal (in the simplest case of exponential) expansion in the early Universe. This stage could not form if matter, radiation or relativistic plasma was dominant but it could, under certain conditions, form under the effect of various cosmological implications of the theory of elementary particles,

The question: Why does the Universe not contain an equal amount of matter and antimatter? finds its answer in the process of baryosynthesis, linking this observed baryon asymmetry of the Universe with the physical mechanism of generation of an excess of baryons and leptons over their antiparticles in the early Universe.

To explain the difference in the amount of baryonic matter and the total amount of matter in the Universe the dark matter is needed, the physical basis of which relates to the hidden sector of particle physics.

There are many different physical mechanisms pretending to describe inflation and baryosynthesis. There are also many different candidates for the role of dark matter particles. Unfortunately, the early Universe, when there were inflation and baryosynthesis as well as dark matter was created, cannot be observed directly by astronomical means. It is therefore necessary to develop a system of indirect methods of correct choices of variants associated with different cosmological scenarios and models of elementary particles on which they are based. The set of elementary particles and quanta of their interaction represent the Lego of the Universe for different sets we come to different pictures of the Universe, its evolution and structure [3].

Thus the internal development of elementary particle physics requires cosmological verification of the principles of particle physics. On the other hand, this approach which lies in the area inaccessible by direct modern experimental methods, was used to construct the physical principles of modern cosmology. The natural result of this internal development of the frontiers of our knowledge at the largest and smallest physical scales was their unification in the framework of cosmoparticle physics, studying fundamental relationship of micro- and macro world.

3. Cosmophenomenology of very early Universe: from BSM physics to BSM cosmology

The now standard cosmological model reproduces the main features of the observed Universe - its global homogeneity, isotropy, baryon asymmetry, accelerated expansion, formation of the large scale structure from small density fluctuations, reflected in the observed anisotropy of the cosmic microwave background radiation (CMB). In this picture BSM physics, supporting its necessary elements, can lead to specific, model dependent features and one of such possibilities is related with strong primordial inhomogeneities.

3.1. Primordial Black holes

The standard model of cosmology assumes homogeneous and isotropic Universe, in which the observed structure of inhomogeneities arises from growth of small primordial density fluctuations. It makes strong primordial inhomogeneities a prominent tracer of BSM physics of very early Universe. Primordial Black Holes (PBH) are the most popular example of this kind (see e.g. [4,5] for review and references).

To form a black hole in the homogeneously expanding Universe the expansion should stop in some region. It corresponds to a very strong inhomogeneity of the cosmological expansion [6–8]. In the universe with equation of state

$$p = \gamma\epsilon, \tag{1}$$

where the numerical factor γ is in the range

$$0 \leq \gamma \leq 1, \tag{2}$$

the probability to form a black hole is given by [9]

$$W_{PBH} \propto \exp\left(-\frac{\gamma^2}{2\left\langle\delta^2\right\rangle}\right), \tag{3}$$

where $\left\langle\delta^2\right\rangle \ll 1$ is the amplitude of density fluctuations.

For relativistic equation of state ($\gamma = 1/3$) the probability (3) is exponentially small. It can be enhanced, if in the early Universe the amplitude of density fluctuations was much larger, than in the period of galaxy formation. Another possibility corresponds to much softer equation of state, corresponding to matter dominated stage with $\gamma = 0$.

Therefore PBH origin represents strong deviation from the Standard cosmological scenario. It may be related with early matter dominated stages, phase transitions in the early Universe or non-flat features in the spectrum of primordial density fluctuations. All these phenomena can be originated from BSM physics.

PBHs with mass $M \leq 10^{15}$ g evaporate by the mechanism of Hawking [12,13]. This process is the universal process of production of any type of particles with mass

$$m \leq T_{evap} \approx 10^{13}\,\mathrm{GeV}\frac{1\,\mathrm{g}}{M}.$$

It can be the source of superweakly interacting particles, like gravitino [14] as well as of fluxes of particles with energy much larger, than the thermal energy of particles in the surrounding medium. It causes non equilibrium processes in the hot Big Bang Universe, nonequilibrium cosmological nucleosynthesis [15], in particular.

PBHs with mass $M \geq 10^{15}$ g should survive to the present time and represent a specific form of dark matter. The existing constraints on PBH contribution into the total density [17] seem to exclude PBH dominance in the dark matter density. However, as it was noticed in [16], PBH formation in clusters can strongly influence these constraints and even the possibility of PBH dominant dark matter is not excluded. It would make primordial nonhomogeneities in the form of PBHs the dominant matter content of the modern nonhomogeneities.

Mechanism of PBH cluster formation can be illustrated with the use of the axion-like model, in which the first step of symmetry breaking at scale f takes place on the inflationary stage [10,5]. Then at the second stage of the symmetry breaking at $T \sim \Lambda$ closed massive walls are formed so that the larger wall is accompanied by a set of smaller walls. Their collapse form a PBH cluster, in which the range of PBH masses M is determined by the model parameters f and Λ [10,11]

$$f(\frac{m_{pl}}{\Lambda})^2 \leq M \leq \frac{m_{pl}}{f} m_{pl} (\frac{m_{pl}}{\Lambda})^2. \quad (4)$$

Here the minimal mass is determined by the condition that the width of wall doesn't exceed its gravitational radius, while the upper limit comes from the condition that the wall enters horizon, before it starts to dominate within it [11]. At $\Lambda < 100\,\mathrm{MeV}(m_{pl}/f)^{1/2}$ the maximal mass exceeds $100 M_{odot}$. Collapse of massive walls to such black holes takes place at [10]

$$t > \frac{m_{pl}}{f} \frac{m_{pl}}{\Lambda^2}. \quad (5)$$

At $\Lambda < 1\,\mathrm{GeV}$ and $f = 10^{14}\,\mathrm{GeV}$ it happens at $t > 0.1\,\mathrm{s}$, what can lead to interesting observable consequences.

Closed wall collapse leads to primordial gravitational wave (GW) spectrum, estimated as peaked at [1,2,10]

$$\nu_0 = 3 \times 10^{11} (\Lambda/f)\mathrm{Hz}. \quad (6)$$

Their predicted contribution to the total density can reach

$$\Omega_{GW} \approx 10^{-4} (f/m_{pl}), \quad (7)$$

being at $f \sim 10^{14}$ GeV $\Omega_{GW} \approx 10^{-9}$. For $1 < \Lambda < 10^8\,\mathrm{GeV}$ the maximum of the spectrum corresponds to

$$3 \times 10^{-3} < \nu_0 < 3 \times 10^5\,\mathrm{Hz}, \quad (8)$$

being in the range from tens to thousands of Hz a challenge for LIGO/VIRGO grvitational wave searches and at smaller frequencies for future eLISA experiment.

Predictions for Gravitational wave signals from PBH coalescence in cluster involve study of cluster evolution, which appears to be a rather nontrivial problem [16] and strongly depends on the period, when cluster separates from the general expansion. If such separation takes place on the RD stage, cluster evolution can lead to rapid coalescence of PBHs within the cluster, accompanied with evaporation of some of PBHs. Separation of cluster on MD stage would lead to much slower evolution of the gravitationally bound system of PBHs, in which formation of binaries of BH (BBH) and their coalescence would lead to observable effects in gravitational wave (GW) detectors.

Being in cluster, PBHs with the masses of tens $M_\odot$ form binaries much easier, than in the case of their random distribution, as well as formation of such PBHs in collapse of first stars is rather problematic. In this aspect detection of signals from binary BH coalescence in the gravitational wave experiments [18–22] may be considered as a positive evidence for this scenario [1,2,10]. Repeatedly detected signals localized in the same place would provide successive support in its favor

or exclusion [1,2,10,16,23]. The existing statistics is evidently not sufficient to make any definite conclusion on this possibility. However, repeating detection of four GW signals in the August of 2017 noted in GWTC catalog [24] may be an interesting hint to such a possibility [1,2,10].

Primordial black holes reflect strong inhomogeneity of the energy density in very early Universe. Their production is not a necessary consequence of all the models of very early Universe and this model dependence provides a very sensitive probe for BSM physics. On the other hand, the confirmation of PBH existence will not only tighten the class of possible realistic BSM physics models, but will be an inevitable evidence for BSM cosmology.

The same is true for the existence of antimatter objects in baryon asymmetric Universe, which can reflect strong nonhomogeneity of the baryosynthesis.

3.2. Antimatter and Baryon Asymmetry

The baryon asymmetry of the Universe reflects the evident dominance of matter over antimatter in the visible part of the Universe. The set of astrophysical data exclude completely equal amounts of matter and antimatter, however large is the separation of matter and antimatter domains within the observed part of the Universe. Indeed, at the border of such domains annihilation of nuclei and antinuclei should lead to gamma radiation, which is severely constrained by the observed gamma ray background.

However, these constraints still don't exclude completely the existence of antimatter objects, which can be formed in antimatter domains in baryon asymmetric Universe originated from the strongly nonhomogeneous baryosynthesis [25–31] (see [11,4,30] for review and references).

If created, antimatter domains should survive in the surrounding matter to the present time. It puts a lower limit on its size being in terms of its mass about $10^3 M_{odot}$ [27–29] that corresponds to a minimal mass of globular clusters. If antimatter object is formed in our Galaxy, it should be the source of cosmic ray antinuclei.

There are two principal possibilities for an antimatter object in our Galaxy.

The approach of [26,30–32] predicts compact dense objects with exotic properties, being dominantly the source of heavy antinuclei.

In the approach of [27–29] antimatter forms an antimatter globular cluster, whose structure and evolution is similar to the globular cluster of matter stars.

However exotic, the hypothesis on antimatter globular cluster in our Galaxy [27] doesn't contradict observations, if the mass of the cluster doesn't exceed the limit

$$M \leq 10^5 M_{odot}. \tag{9}$$

Indeed, globular clusters belong to an old population of the Galaxy. They are dominantly situated in halo, where matter gas density is low. Their gravitational potentials are not sufficient to hold matter, lost by stars by stellar winds or supernova explosions.

In the case of antimatter cluster, it means that there is no antimatter gas within it and matter gas that enters the cluster annihilates only on the surface of antimatter stars. Taking into account low density of matter gas in halo and relatively small surface on which it can annihilate, one can find with surprise that

antimatter globular cluster should be a rather faint gamma ray source. The upper limit (9) follows from the condition that the antimatter lost by antimatter stars and polluting the Galaxy doesn't cause overproduction of gamma ray background from annihilation with the matter gas [27–29].

It was noted in [27–29] that cosmic antihelium flux may be a profound signature for an antimatter globular cluster in our Galaxy. Symmetry in physics of matter and antimatter would make antihelium-4 the second by abundance element of antimatter. In addition to antihelium lost by antimatter stars its cosmic fluxes can increase due to destruction of heavier antinuclei in their annihilation with matter. Rough estimation of the expected antihelium flux as simply proportional to the ratio of the mass of antimatter cluster to the total mass of the Galaxy predicts that it should be within the reach by AMS02 experiment to 2024.

This prospect makes necessary to specify the predictions for the cosmic antihelium flux in more details and such analysis can be based on our knowledge of properties of globular clusters. The nontrivial problem, which arises in this case, is the prediction for the spectrum of cosmic ray flux originated from a single (antimatter GC) source, as well as proper treatment of formation of this flux and of its propagation in the Galaxy.

There is some evidence for possible detection of cosmic antihelium-3 nuclei as well as for some detected events that may correspond to antihelium-4 in AMS02 experiment. Such events can hardly find natural astrophysical explanation [33] and their confirmation would provide a strong evidence for existence of macroscopic forms of antimatter in our Galaxy.

4. From WIMP miracle to Dark Matter reality

4.1 WIMP miracle and beyond

According to the now standard cosmological model, the dark matter, corresponding to $\sim 25\%$ of the total cosmological density, is a new stable form of nonbaryonic matter (see, e.g. Refs. [34–39] for review and reference). To support development of gravitational instability from small initial density fluctuations, dark matter should decouple from plasma and radiation at least before the beginning of matter dominated stage. To satisfy these conditions, one can assume some neutral sufficiently weakly interacting form of nonrelativistic matter. Here sufficiently weak interaction should be considered in the cosmological sense. It should provide decoupling of dark matter and in the conditions of a low density cosmological plasma even nuclear strong interaction cannot prevent decoupling from plasma and radiation.

During the last three decades Weakly Interacting Massive Particle (WIMP, see for details, e.g. Refs. [34,35,39]) were most popular dark matter candidate owing to its *miraculous* feature: if the mass of this particle is in the 100 GeV - 1 TeV range, freezing out of primordial gas of these particles in early Universe naturally leads to prediction of their modern density, explaining the dark matter.

The WIMP miracle was accompanied by the expectations of new physics phenomena to be found at the LHC in this energy range. Such expectations were dominantly related with necessity to explain the origin of the electroweak symmetry breaking scale and to solve the problem of divergence of the Higgs boson mass. Supersymmetry (SUSY) with the scale about 100 GeV - 1 could naturally provide

solution for these problems and predicted existence of supersymmetric partners of known particles with the mass, corresponding to this scale. accessible for their search at the LHC. The lightest SUSY particle could be stable,neutral and have the interaction cross section, typical for WIMPs.

SUSY WIMPs should penetrate the terrestrial matter and scatter on nuclei in underground detectors. The strategy of direct WIMP searches implies detection of recoil nuclei from this scattering (see for review e.g. [40]).

Production of WIMPS in collisions of ordinary particles should lead to effects of missing mass and energy-momentum, being the challenge for experimental search for production of dark matter candidates at accelerators, e.g. at the LHC. WIMPs of the supersymmetric origin were expected to be associated with the Lightest Supersymmetric particle (LSP) and their production at the LHC should have been accompanied by discovery of the supersymmetric partners of ordinary particles.

However, in the lack of positive evidence for SUSY at the LHC and controversial results of WIMP searches in the underground detectors a particle physics solution for the dark matter problem can involve much wider class of models.

The list of dark matter candidates in these models extends to both strongly and superweakly interacting particles with masses ranging from super low to super high energy scales. Their list involves: axions and axion-like particles, sterile neutrinos, new stable hadrons, mirror particles and many other examples of new forms of matter, whose stability is supported by extension of SM symmetry (see, e.g. [39] for review and references). Dark matter candidates can be macroscopic, like PBH dark matter [16]. These candidates are elusive for direct or indirect methods of WIMP searches. It implies more nontrivial methods to study their properties, which involve all the possible aspects of dark matter physics.

In the case of SUSY scale, which is too high for direct experimental search, its cosmological impact provides important indirect probes, in which effects of supersymmetric partner of graviton, gravitino, are of special interest [41]. Gravitinos are expected to be present in all local supersymmetric models. If gravitino is not LSS, it is *metastable* and at the mass of few TeV decays after nucleosynthesis. It leads to important modifications of the nucleosynthesis paradigm. High energy products of gravitino decays interact with nuclei of the primordial plasma and give rise to cascades of nonequilibrium nuclear processes. In particular, the antiprotons produced by the fragmentation of gluons emitted by decaying gravitinos are a source of nonequilibrium light nuclei resulting from collisions of those antiprotons on equilibrium nuclei [42–45, 15]. Then, ^{6}Li, ^{7}Li and ^{7}Be nuclei are produced by the interactions of the non-equilibrium nuclear flux with ^{4}He equilibrium nuclei. To compare these predictions with the observational data on the light element abundance the precise information on the particle and nuclear interactions with nuclei is needed. Therefore this approach, supported by its successive development [46, 47], reveals the importance of obtaining these nuclear data as the completion of the missed link in the logical chain, by which cosmological consequences of particle theory are related to their astrophysical probes.

In the extreme case Supersymmetry energy scale may be very high and superweakly interacting superheavy gravitino can become a viable candidate for dark matter (see, e.g. [4] for review and references). The corresponding Supergavity can provide physical framework for unification of all the four fundamental forces of Nature, including gravity, as well as the physical basis for Starobinsky inflation, but in this case the supersymmetry loses a possibility to solve the problems of

divergence of Higgs boson mass and of the origin of the electroweak symmetry breaking scale.

4.2 Cosmoparticle physics of composite dark matter

Direct searches for dark matter give puzzling results. The dark matter signal detected by DAMA collaboration at high significance level is not confirmed by other experiments that differ by strategy of searches and the content of detectors. A review of the current experimental situation may be found in [48]. This apparent contradiction comes from the analysis of the data in the terms of WIMPs and under the assumption that nuclear recoils are the source of the signal in DAMA detector.

Starting from 2006 it was proposed [39,40,49–51] that the signal may be due to a different source: if dark matter can bind to normal matter, the observations could come from radiative capture of thermalized dark matter, and could depend on the detector composition and temperature. This scenario naturally comes from the consideration of composite dark matter. Indeed, one can imagine that dark matter is the result of the existence of heavy negatively charged particles that bind to primordial nuclei.

New particles with electric charge and/or strong interaction can form anomalous atoms and be present in the ordinary matter as anomalous isotopes. Therefore, stringent upper limits on anomalous isotopes, especially, on anomalous hydrogen put severe constraints on the existence of new stable charged particles. In order to avoid anomalous isotopes overproduction, stable particles with charge ± 1 (and corresponding antiparticles), as well as with the odd charge $\pm(2n-1)$ (where n is integer) should be absent, so that stable negatively charged particles should have even charge $-2n$ only.

Indeed, positively charged particles form atoms of anomalous isotopes with ordinary electrons, while negatively charged particles with even charge $-(2n-1)$ can capture n nuclei of primordial helium after Big Bang Nucleosynthesis and form $+1$ charged ion. Particles with even negative charge $-2n$, created in excess over their antiparticles, bind with n nuclei of primordial helium in neutral strongly interacting dark atoms.

Elementary particle frames for heavy stable $-2n$ charged species are provided by several models (see e.g. [39] for review and references). There are principally two types of such species:

(a) They have no QCD interaction, i.e. are lepton like particles with no fixed absolute value of the charge, which is constrained only by the condition of the absence of anomalies [1,10,39,40,50].
(b) They are $\bar{\Delta}$ like $(\bar{U}\bar{U}\bar{U})$ clusters of new stable heavy $\bar{U}$ (anti)quarks with strongly suppressed hadronic interaction [39,40,49,51].

In the models (a) any value of $-2n$ charge is possible, while only double charged O^{--} are predicted in models (b).

The models (a) draw special attention due to their possible relationship with composite Higgs models, proposed as the solutions for the SM problems of divergence of Higgs boson mass and origin of electroweak symmetry breaking scale. In such models, like in Walking Technicolor model (see, e.g. [1,10,50], the constituents of composite Higgs are linked existence of exotic multiple-charged particles and in

the context of dark atom model search for such particles acquires the meaning of experimental probe for physics of Dark Universe.

Just after Big Bang Nucleosynthesis, when primordial helium is produced, these particles are bound with helium nuclei. In the case (a) at $n > 1$ particles with charge $-2n$ bind with n helium nuclei in X-helium Thompson-like atoms. In the case (b) all the O^{--} are bound with helium nuclei in a Bohr atom-like O-helium state, in which heavy lepton-like negatively charged core is surrounded by a nuclear interacting helium shell.

Dark atoms can play the role of dark matter and explain the observed dark matter density. Specifics of their nuclear interaction can explain positive results of DAMA/NaI and DAMA/LIBRA experiments and negative results of other groups [1,10]. Collisions of dark atoms in the center of Galaxy can lead to their excitation with successive de-excitation by emission of electron-positron pairs. It can explain the observed excess in positronium annihilation line in the galactic bulge [1,57]. Such explanation is possible only for a limited range of mass of dark atom constituents. In the case of O^{--} this mass is in a narrow window around 1.3 TeV, challenging verification of this hypothesis in searches for stable double charged particles at the LHC.

O-helium, being an α-particle with screened electric charge, can catalyze nuclear transformations, which can influence primordial light element abundance and cause primordial heavy element formation. It is especially important for quantitative estimation of role of dark atoms in Big Bang Nucleosynthesis and in stellar evolution. Their constituents can form exotic isotopes and components of cosmic rays. These effects need a special detailed and complicated study of dark atom nuclear physics [10,58].

Combination of physical, astrophysical and cosmological effects of dark atoms illustrates methods of cosmoparticle physics of Dark Universe.

4. Conclusion

The convergence of the frontiers of our knowledge in micro- and macro worlds leads to the following wrong circle of problems: *The theory of the Universe is based on the predictions of particle theory, that need cosmology for their test.* Cosmoparticle physics [34,35,59,60] offers the way out of this wrong circle. It studies the fundamental basis and mutual relationship between micro-and macro-worlds in the proper combination of physical, astrophysical and cosmological signatures.

The important aspects of this relationship arise in the problem of physics of Dark Universe, which involves BSM particle models and is inevitably associated with observable features, beyond the now standard cosmological paradigm.

Here we have concentrated on the extension of the SM of electroweak and strong interactions of elementary particles. However, BSM physics can hardly avoid modification of the general relativistic description of gravity. Such modifications may be related with extra dimensions of space-time or additional types of space-time symmetries, leading to new types of gravitational phenomena, reflected in astrophysical objects (see [61–66]).

To conclude, even a brief sketch of possible links of cosmology and particle physics shows how large may be the field of such studies. Our voyage to the physics and cosmology of Dark Universe involved nontrivial features of new physics like Primordial black holes, antimatter stars or dark atoms. It was aimed to give some

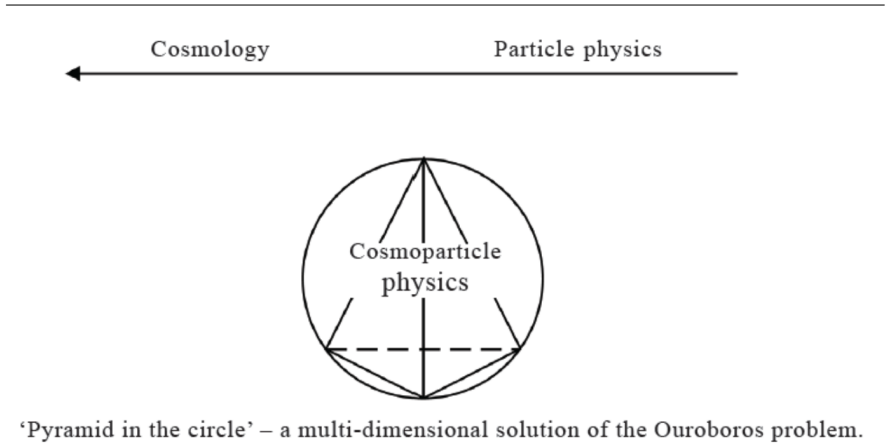


Fig. 1 Cosmoparticle physics provides nontrivial solution for the Ouroboros puzzle

flavor of methods of cosmoparticle physics, appealing to extensive and through investigation of nontrivial aspects of the links that follow from fundamental relationship of micro- and macro-worlds.

Acknowledgments

The work was supported by grant of the Russian Science Foundation (Project No-18-12-00213).

References

1. M.Yu. Khlopov, *Int. J. Mod. Phys. D* **28** (2) (019) 1941012.
2. M. Khlopov, *Bled Workshops in Physics* **20** (2) (019) 21.
3. M. Khlopov, *Res. Rev.: J. Pure and Appl. Phys.* **3** (2015) 9.
4. S. Ketov and M.Yu. Khlopov, *Symmetry* **11** (2019) 511 .
5. M.Y. Khlopov, *Res. Astron. Astrophys* **10** (2010) 495.
6. Y.B. Zeldovich and I.D. Novikov, *Sov. Astron.* **10** (1967) 602.
7. S.W. Hawking, *Mon. Not. R. Astron. Soc.* **152** (1971) 75.
8. B.J. Carr and S.W. Hawking, *Mon. Not. R. Astron. Soc.* **168** (1974) 399.
9. B.J. Carr, *Astroph. J.* **201** (1975) 1.
10. M. Khlopov, *EPJ Web of Conferences* **222** (2019) 01006.
11. M.Y. Khlopov and S.G. Rubin, *Cosmological Pattern of Microphysics in Inflationary Universe* (Springer Science Business Media: Kluwer, Dordrecht, The Netherlands, 2004).
12. S.W. Hawking, *Comm. Math. Phys.* **43** (1975) 199.
13. S.W. Hawking, *Nature* **248** (1974) 30.
14. M.Y. Khlopov, A. Barrau and J. Grain, *Class. Quantum Gravit.* **23** (2006) 1875.
15. E.V. Sedel'nikov, S.S. Filippov and M.Y. Khlopov, *Phys. Atom. Nucl.* **58** (1995) 235.
16. K.M. Belotsky, V.I. Dokuchaev, Yu.N. Eroshenko, E.A. Esipova, M.Yu. Khlopov, L.A. Khromykh, A.A. Kirillov, V.V. Nikulin, S.G. Rubin and I.V. Svadkovsky, *Eur. Phys. J. C* **79** (2019) 246.
17. B. Carr, F. Kuehnel and M. Sandstad, *Phys. Rev. D* **94** (2016) 083504.
18. B.P. Abbott et al., *Phys. Rev. Lett.* **116** (2016) 061102.
19. B.P. Abbott et al., *Phys. Rev. Lett.* **116** (2016) 241103.

20. B.P. Abbott et al., *Phys. Rev. Lett.* **118** (2017) 221101.
21. B.P. Abbott et al., *Phys. Rev. Lett.* **119** (2017) 141101.
22. B.P. Abbott et al., *Astrophys. J. Lett.* **851** (2017) L35.
23. T. Bringmann, P.F. Depta, V. Domcke and K. Schmidt-Hoberg, *Phys. Rev. D* **99** (2019) 063532.
24. The LIGO Scientific Collaboration (The Virgo Collaboration), B.P. Abbott et al., arXiv:1811.12907 (2018).
25. V.M. Chechetkin, M.Y. Khlopov, M.G. Sapozhnikov and Y.B. Zeldovich, *Phys. Lett. B* **118** (1982) 329.
26. A. Dolgov and J. Silk, *Phys. Rev. D* **47** (1993) 4244.
27. M.Y. Khlopov, *Gravit. Cosmol.* **4** (1998) 69.
28. K.M. Belotsky, Y.A. Golubkov, M.Y. Khlopov, R.V. Konoplich and A.S. Sakharov, *Phys. Atom. Nucl.* **63** (2000) 233.
29. M.Y. Khlopov, S.G. Rubin and A.S. Sakharov, *Phys. Rev. D* **62** (2000) 083505.
30. A.D. Dolgov, *Nucl. Phys. Proc. Suppl.* **113** (2002) 40.
31. A.D. Dolgov, M. Kawasaki and N. Kevlishvili, *Nucl. Phys. B* **807** (2009) 229.
32. S.I. Blinnikov, A.D. Dolgov and K.A. Postnov, *Phys. Rev. D* **92** (2015) 023516.
33. V. Poulin, P. Salati, I. Cholis, M. Kamionkowski and J. Silk, *Phys. Rev. D* **99** (2019) 023016.
34. M. Yu. Khlopov, *Cosmoparticle physics* (World Scientific, New York-London-Hong Kong-Singapore, 1999)
35. M. Khlopov, *Fundamentals of Cosmic Particle physics* (CISP-SPRINGER, Cambridge 2012).
36. G. Bertone, *Particle dark matter: Observations, models and searches* (Cambridge Univ. Pr., UK, 2010)
37. E. Aprile and S. Profumo, *New J. of Phys.* **11** (2) (009) 105002.
38. J.L. Feng, *Ann. Rev. Astron. Astrophys.* **48** (2) (010) 495.
39. M.Yu. Khlopov, *Int. J. Mod. Phys. A* **28** (2) (013) 1330042.
40. M.Yu. Khlopov, *Int. J. Mod. Phys. A* **29** (2) (014) 1443002.
41. M.Yu. Khlopov, *Symmetry* **7** (2015) 815.
42. M.Yu. Khlopov and A.D. Linde, *Phys. Lett. B* **138** (1984) 265.
43. F. Balestra, G. Piragino, D.B. Pontecorvo, M.G. Sapozhnikov, I.V. Falomkin and M.Yu. Khlopov, *Sov. J. Nucl. Phys.* **39** (1984) 626.
44. Yu.L. Levitan, I.M. Sobol, M.Yu. Khlopov and V.M. Chechetkin, *Sov. J. Nucl. Phys.* **47** (1988) 109.
45. M.Yu. Khlopov, Yu.L. Levitan, E.V. Sedelnikov and I.M. Sobol, *Phys. Atom. Nucl.* **57** (1994) 1393.
46. K. Jedamzik, *Phys. Rev. D* **70** (2004) 063524.
47. M. Kawasaki, K. Kohri and T. Moroi, *Phys. Lett. B* **625** (2005) 7.
48. R. Bernabei, *Bled Workshops in Physics* **15** (2) (014) 10.
49. M.Yu. Khlopov, *JETP Lett.* **83** (2) (006) 1.
50. M.Y. Khlopov and C. Kouvaris, *Phys. Rev. D* **77** (2) (008) 065002.
51. D. Fargion, M. Khlopov and C.A. Stephan, *Class. Quantum Grav.* **23** (2) (006) 7305.
52. K.M. Belotsky et al., *Gravitation and Cosmology* **11** (2) (005) 3.
53. K. Belotsky, M. Khlopov and K. Shibaev, arXiv:astro-ph/0602261.
54. K. Belotsky, M. Khlopov and K. Shibaev, *Gravitation and Cosmology* **12** (2) (006) 1.
55. K. Belotsky, M.Yu. Khlopov, K.I. Shibaev, Stable quarks of the 4th family? in Eds. N.L. Watson and T.M. Grant: "The Physics of Quarks: New Research." (Horizons in World Physics, Vol. 265), NOVA Publishers, Hauppauge NY, 2009, PP. 19-47; arXiv:0806.1067 [astro-ph].
56. M.Y. Khlopov and C. Kouvaris, *Phys. Rev. D* **78** (2) (008) 065040.
57. J.-R. Cudell, M.Yu. Khlopov and Q. Wallemacq, *Adv. High Energy Phys.* **2014** (2014) 869425.
58. J.-R. Cudell, M.Yu. Khlopov and Q. Wallemacq, *Bled Workshops in Physics* **13** (2) (012) 10.
59. A.D. Sakharov, *Vestnik AN SSSR* **4** (1989) 39.
60. M.Yu. Khlopov, *Vest. Russ. Acad. Sci.* **71** (2001) 1133.
61. G. Abbas, M. Zubair, and G. Mustafa, *Astrophys. Space Sci.* **358** (2015) 26.
62. G. Abbas, A. Kanwal, and M. Zubair, *Astrophys. Space Sci.* **357** (2015) 109.
63. G. Abbas, S. Nazeer and M.A. Meraj, *Astrophys. Space Sci.* **354** (2014) 449.
64. G. Abbas, D. Momeni, M.A. Ali, R. Myrzakulov and S. Qaisar, *Astrophys. Space Sci.* **357** (2015) 158.
65. D. Deb, S. Ghosh, S.K. Maurya, M. Khlopov and S. Ray, *Tech Vistas* **1** (2018) 1.
66. A. Das, S. Ghosh, D. Deb, F. Rahaman and S. Ray, *Nucl. Phys. B* **954** (2020) 114986.
67. S. Nojiri and S.D. Odintsov, *Phys. Lett. B* **631** (2005) 1.

Scientific Voyage
Vol. 1 No. 2
Page 13-27 (2020)

SCIENTIFIC VOYAGE
ISSN: 2395-5546

GCECT
Publication
Apr.-Jun

Indian connections to Nobel Prizes

Safiqul Islam[1]
[1] *Department of Mathematics, St. Theresa International College, Ongkarak, Nakhonnayok - 26120, Thailand; E-mail: sofiqul001@yahoo.co.in*

Abstract: This research is an attempt to find out the possible reasons why some great Indian scientists missed the Nobel Prize. There are many great scientists worldwide who have made significant contributions pertaining to science but not received any recognition yet. Human being are always scientifically curious which should never fade away. We should pay due homage to their efforts and success which have helped us to lead a meaningful life.

Keywords: Nobel prize; Science and society; Indian scientists

1. Introduction

The prizes for outstanding accomplishments in physics, chemistry, physiology or medicine, literature and peace which were instituted by Alfred Nobel in 1895 and later on for economics are regarded as a recognition of the highest order achievement [1]. Nobel prize winners have a special status as it include great minds like Albert Einstein, Max Planck, Neils Bohr, Paul Adrien Maurice Dirac, Werner Karl Heisenberg, Erwin Schrödinger, C. V. Raman and Richard Feynman. We attempt at understanding the secret of getting a Nobel by way of knowledge from journalistic pieces and book form (even from former Nobel Laureates).

We should first give up the colonial mindset that everything trend-setting in science comes only from the West. Governments should set up an autonomous Research Excellence Council to exclusively cater to promoting research excellence, with a size-able fund to put this into practice.

A brief outline of the originator of the Nobel and his Will would be appropriate before I come to the topic proper. It will afford a glimpse into his personality, what his Will stresses and what the Nobel stands for and, therefore, what motivates the Nobel Committee to select the one from many potentially worthy recipients.

Fig. 1 Alfred Nobel (1883-1896)

Alfred Nobel [2], in whose name this prize has been instituted, was an interesting and complex personality. He was a bachelor with literary interests, had great energy, ascetic habits, proneness to depressive bouts; he was a pacifist with a pessimistic outlook towards mankind (Frängsmyr, 1966) [3]. Nobel's complex personality puzzled his contemporaries. He had a deep interest in literature and wrote plays, novels, and poems, almost all of which remained unpublished. Among his contemporaries, he had the reputation of a liberal or even a socialist, but he actually distrusted democracy. Though Nobel was essentially a pacifist and hoped that the destructive powers of his inventions would help bring an end to war, his view of mankind and nations was pessimistic. He was, further, a benevolent misanthrope but at the same time a super idealist.

He once wrote: 'I am a misanthrope and yet utterly benevolent, have more than one screw loose yet I am a super-idealist who digests philosophy more efficiently than food'. It was the idealist in him that drove Nobel to bequeath his fortune to those who had benefited humanity through science, literature and efforts to promote peace (Frängsmyr, 1966). It is worthwhile noting here the contents of his will connected with the Nobel Prize: The whole of my remaining realizable estate shall be dealt with in the following way: The whole of my capital, invested in safe securities by my executors, shall constitute a fund, the interest on which shall be annually distributed in the form of prizes to those who, during the preceding year, shall have conferred the greatest benefit to mankind. The said interest shall be divided into five equal parts, which shall be apportioned as follows: one part to the person who shall have made the most important discovery or invention within the field of physics; one part to the person who shall have made the most important chemical discovery or improvement; one part to the person who shall have made the most important discovery within the domain of physiology or medicine; one part to the person who shall have produced in the field of literature the most outstanding work in an ideal direction; and one part to the person who shall have done the most or the best work for fraternity between nations, for the abolition or reduction of standing armies and for the holding and promotion of peace congresses. The prizes for physics and chemistry shall be awarded by the Swedish Academy of Sciences; that for physiological or medical work by the Caroline Institute in Stockholm; that for literature by the Academy in Stockholm, and that for champions of peace by a committee of five persons to be elected by the Norwegian Storting. It is my express wish that in awarding the prizes no consideration whatever shall be given to the nationality of the candidates, but that the most worthy shall receive the prize, whether he be a Scandinavian or not".

2. Great Indian scientists

Out of 10 Nobel prizes connected with India, only 6 have gone to Indian citizens: Rabindranath Tagore in 1913 for literature, C.V Raman in 1930 for physics, Mother Teresa in 1979 for peace, Amartya Sen in 1998 for economic sciences and Kailash Satyarthi in 2014 for Peace [4]. Sixty-year-old Kailash Satyarthi [5] today became the fifth Indian citizen to win the Nobel Prize joining the likes of Rabindranath Tagore, C. V. Raman, Mother Teresa and Amartya Sen in the elite club. The child rights crusader, shared the Nobel Peace prize for 2014 with Pakistani teenager Malala Yousafzai for "their struggle against the suppression of children and young people and for the right of all children to education". He is

Fig. 2 Sir Ronald Ross (1857-1932)

Fig. 3 Sir Jagadish Chandra Bose (1858-1937)

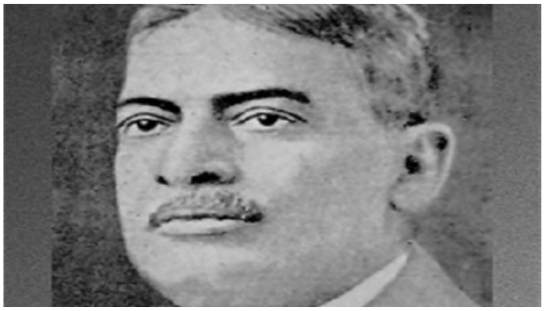


Fig. 4 Sir Upendranath Brahmachari (1873-1946)

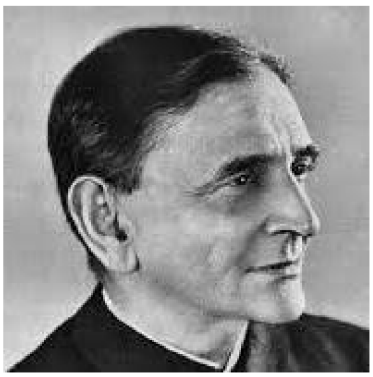


Fig. 5 Debendra Mohan Bose (1885-1975)

Fig. 6 C. V. Raman (1888-1970)

Fig. 7 Meghnad Saha (1893-1956)

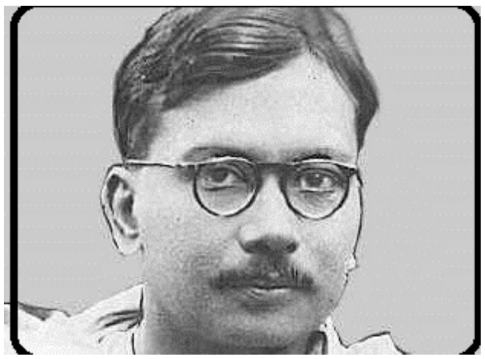


Fig. 8 Jnan Chandra Ghosh (1894-1959)

Fig. 9 Satyendra Nath Bose (1894-1974)

Fig. 10 Subrahmanyan Chandrasekhar (1910-1995)

Fig. 11 Har Gobind Khorana (1922-2011)

the first India-born activist to win the Peace Nobel. Sir Ronald Ross, born in Almora, India, North West of Nepal, was a British medical doctor who received the Nobel Prize for Physiology or Medicine in 1902 for his work on the transmission of malaria. He is the first Indian Nobel lauteate in medical science. One can debatably add R. K. Pachauri, who was Chair of the Intergovernmental Panel on Climate Change, which got the Peace prize in 2007. If one think of Nobel Laureates of Indian origin or settlement, one could add Subrahmanyan Chandrasekhar for Physics in 1983, Har Gobind Khorana (an American of Indian origin) for Physiology or Medicine in 1968 and Abhijit Vinayak Banerjee in economic sciences in 2019. One could debatably also add V. S. Naipaul's Nobel for Literature in 2001, since his forefathers came from India.

Ten Nobel prizes, having a near or distant connection with India and eight Nobel prizes, having a near or distant connection with psychiatry. It is heartening that the number has gone up by 1 for India and 3 for psychiatry-allied branches in 2014. Is it not intriguing, however, that the number of Nobel that India has produced as an area and psychiatry and allied branches have produced as a discipline is much the same? And if we were to see how many mainstream psychiatrists have got the Nobel, it is just two: Wagner-Jauregg way back in 1927, and Kandel in 2000, and if we were to see how many Indian citizens working from India have got the Nobel in Medicine, it is none.

C. V. Raman won the Nobel Prize in Physics in 1930 for the discovery of the Raman effect. He once said that although scientists are claimed as nationals by one or another of many different countries, yet in the truest sense, they belong to the whole world". Raman studied physics in India and got his degrees from the University of Madras. He did not follow the usual route of Indian scholars and go to Britain to get a PhD degree. He worked in a government office and in 1917 accepted a physics professorship at the University of Calcutta. He and his associate, K. S. Krishnan, observed a phenomenon of light scattering, first with their naked eyes, later with some optical instruments. They communicated the discovery in 1928. Legend has it that as soon as Raman had submitted the manuscript on the new effect for publication, he booked his passage to Stockholm from Calcutta for the following December. This is believable to the extent that

Raman was known to be self-confident and that his Nobel recognition followed his discovery with unusual speed. Raman was Indian and India could rightly claim him. Many of the Nobel laureates, however, migrated from their native lands, often changing countries more than once. This migration comes naturally to scientists, even under the most peaceful and ordinary conditions. Since the Second World War, too, The Nobel Prize and national politics there has been a steady migration of scientists responding to the pull of better research and economic opportunities afforded primarily in the United States and Western Europe.

It sometimes happens that nationalism, however benevolent, creeps into a nomination. In an unsuccessful nomination for the Nobel Prize in Chemistry for 1939, N. R. Dhar of Allahabad, then in India, sent a letter to the Nobel Committee proposing the Frenchman Georges Urbain for his excellent researches on rare earth chemistry. Following a description of Urbain's achievements in chemistry, Dhar notes that Urbain is the doyen of French chemistry and a real gentleman. In Dhar's time his expressions raised fewer eyebrows than they would today. Frederick Sanger is the only person to have received two Nobel Prizes in chemistry, in 1958 and 1980. A few years before, the American Chemical Society's Chemical C Engineering News conducted a poll for its 75th anniversary to establish an international list of 75 people who, during the past 75 years, had contributed most to chemical enterprise. Curiously, the British Sanger did not make that list of 75, even though the poll targeted chemists only.

It is a delicate question whether the authorities in any country are willing to actively help their scientists receive a Nobel Prize. Lobbying may be done with taste and honest means, though nobody is eager to go on record about what activities may be carried out in this respect. Recently, a noted science historian in Budapest was invited to prepare a report on whether it was feasible to facilitate creating another Nobel laureate in Hungary.

A large number of great Indians who did not receive the Nobel Prize include the names of Jagdish Chandra Bose, Sir Upendranath Brahmachari, Debendra Mohan Bose, Sir Jnan Chandra Ghosh, Satyendra Nath Bose, Meghnad Saha, G. N. Ramachandran and E. C. G. Sudarshan. Apart from them in medical science [11], Mahendralal Sarkar, Gopal Ray, Nilratan Sarkar, Gopal Chandra Chattopadhyay are some notable names.

Jagdish Chandra Bose was born on 30.11.1858 at Mymensinghin (now in Bangladesh) located in the Bengal Province of British India and was fortunate enough to have education at Cambridge (B.A.) and London(B. Sc.) and received the exposure to science which was fast altering the face of western civilization even though British colonial power had no interest in nurturing science in India. Bose having the heritage of ancient Indian civilization with its multi faceted accomplishments could easily absorb the spirit of science and pursued it at Presidency college, Calcutta after returning to India. Initially he faced some discrimination but his exceptional talent as a teacher and scientist was too overwhelming and was eventually given due recognition.

Bose's research works are mainly in two areas: (i) electromagnetic waves, their transmission and reception and (ii) nature of life process present in plants. His pioneering breakthroughs in both these are outstanding. However, in this article will confine ourselves to the former. Over the years, fortunately, the scientific community seems to have got the historical records right. In 1998 IEEE (institution of Electrical and Electronics Engineers) accepted that it was J. C. Bose who invented

the mercury drop coherer which was used by Marconi. Maxwell's equations had predicted electromagnetic waves and their generation in different frequencies and application was a hot priority area of work. As far as Bose's work is concerned, the following facts are known: In 1895 at Presidency college Bose ignited gun powder and rang a bell kept at a reasonably large distance using the electromagnetic wave signaling and thus demonstrated for the first time that communication could be sent through electro-magnetic waves. He was vehemently against making money out of his researches and had no hesitation in generously sharing the path breaking works that he did. He introduced the best research attitude to his generation of Indians. For them, he represented the spirit of old selfless rishis of India whose teachings and insights are open to all willing to accept it. Unlike Marconi who sought commercialize his work on radio waves, Bose was interested in all his researches purely as a scientific endeavor in quest of nature. In 1899 he announced his invention of iron-mercury-iron coherer (transmitter) in a paper submitted to Royal Society. Bose's demonstration of wireless signaling has priority over that of Marconi. The period 1894-1900 was very productive years for Bose. He performed pioneering research in radio transmission and mm range microwaves. He designed equipment for radio wave transmission and reception and also studied the wave properties of reflection, refraction and polarization. Based on his experiments with galena he developed a type of semi conductor diode useful for detection of cm range electromagnetic waves. In spite of these, it was Guglielmo Marconi and Carl Ferdinand Braun who were awarded 1909 Nobel prize in physics for their contributions for the development of wireless telegraphy. It may be noted that in 1896 both Bose and Marconi were in London and had interactions. Over the years, fortunately, the scientific community seems to have got the historical records right. In 1998 IEEE (Institution of Electrical and Electronics Engineers) accepted that it was J. C. Bose who invented the mercury drop coherer which was used by Marconi. Bose also holds the first patent for the solid state detector based on galena crystal and was the first to use a semiconducting junction to detect mm length microwaves. His pioneering work on microwaves was acknowledged by great physicists like Lord Kelvin and Lord Rayleigh. In a book by O. E Dunlop Jr. titled "Marconi-the Man and His Wireless" and edited by Marconi himself, full one and a half page was devoted in tribute to Sir Jagdish Chandra Bose for providing crucial support to Marconi at the critical juncture when Marconi needed it most [6]. Many of the instruments designed by Bose are still on display at Bose Institute, Kolkata and largely in usable condition. They include antennas, polarizers and wave guides. Neville Francis Mott, who received Nobel Prize in 1977 for his work on solid state electronics remarked that "J C Bose was at least 60 years ahead of his time ... In fact he had anticipated the existence of P-type and N-type semiconductors".

J. C. Bose [7] was an example of the best in Indias spiritual tradition. He was vehemently against making money out of his researches and had no hesitation in generously sharing the path breaking works that he did. Reflecting on his works on life in plants he felt that he experimentally substantiated the Hindu belief that whole universe was an aspect of the Eternal One. He introduced the best research attitude to his generation of Indians. For them, he represented the spirit of old selfless rishis of India whose teachings and insights are open to all willing to accept it. Unlike Marconi who sought commercialize his work on radio waves, Bose was interested in all his researches purely as a scientific endeavor in quest of nature. Satyendra Nath Bose (1894-1974) was a Kolkata born physicist and he and the

other great Bengali physicist M. N. Saha studied together at Calcutta university and respectively ranked first and second in their M.Sc. examination. Both were students of Jagdish Chandra Bose and it is like one lighted a candle triggering the lighting of other candles. Both Bose and Saha were highly motivated young men who were excited by the revolution taking place in physics triggered by In sharp contrast to the attitude of Drona, Einstein immediately realized that Boses paper was an important step forward in understanding the general quantum behavior of particles . He himself translated it into German and got it published in the famous German research journal Zeitschrift für Physik (Vol 26, 178-181, 1924) and elaborated the ideas further to formulate what is now known as Bose Einstein statistics relativity and quantum hypothesis. In fact the first English translation of Einstein's relativity papers were by Bose and Saha. After serving some years at Calcutta university, in 1921 Bose joined Dacca university (now in Bangladesh) as a lecturer. At that time Planck's quantum hypothesis was well accepted but quantum mechanics was yet to emerge. It was the era of old quantum theory. While studying the black body radiation as photon gas, Bose used a counting procedure (statistics) for the gas constituents (photons) different from the then well known Maxwell-Bolizmann statistics which to his surprise and excitement gave the correct radiation intensity distribution discovered by Planck. He had difficulty in getting this new derivation published and hence decided to request the great Einstein for help in its publication. Like Ekalavya of Mahabharata who considered Drona as his guru, Bose was considering himself as a humble disciple of the 'revered master' that Einstein was. But the irony of it all is that in spite of this revolutionary work, Bose is not a Nobel Laureate even though he was nominated for it! Einstein immediately realized that Bose's paper was an important step forward in understanding the general quantum behavior of particles. He himself translated it into German and got it published in Abraham Pais who has written an authoritative biography of Einstein considers Bose's paper as the fourth and last revolutionary papers of old quantum theory. The other three are by Planck, Einstein and Bohr. Thus Bose belongs to the exalted group of Bose, Einstein, Fermi and Dirac on one hand and equally formidable company of Planck, Einstein and Bohr. But the irony of it all is that in spite of this revolutionary work, Bose is not a Nobel Laureate even though he was nominated for it! [German research journal Zeitschrift für Physik (Vol. 26, 178-181, 1924)]. His ideas formulated now what is now known as Bose-Einstein statistics. In fact this work is the origin of quantum statistics dealing with Bose-Einstein statistics for bosons integer spin, i.e., 0, 1 ,..spin particles) and Fermi-Dirac statistics for fermions (half integer spin , i.e., 1/2.3/2,.. spin particles). Astrophysicist J. V. Narlikar considers this as an achievement in the Nobel Prize class. Abraham Pais who has written an authoritative biography of Einstein considers Bose's paper as per of old quantum theory. The other three are by Planck, Einstein and Bohr. Thus Bose belongs to the exalted group of Bose, Einstein, Fermi and Dirac on one hand and equally formidable company of Planck, Einstein and Bohr. But the irony of it all is that in spite of this revolutionary work, Bose is not a Nobel Laureate even though he was nominated for it! Bose Einstein statistics has a crucial role in the governing principle of lasers, superfluid quantum systems, superonductivity and Bose-Einstein condensates. In fact more than one Nobel prizes were awarded for research related to the concept of Boson and the latest one was in 2001 for the discovery of Bose-Einstein condensates. Boses work stands out as one of the corner stones of the way we understand the micro world

and quantum phenomena. Every student of physics learns about bosons which is the most lasting honor for his memory and achievements.

Rai Bahadur Sir Upendranath Brahmachari [8] was an Indian scientist and a leading medical practitioner of his time. In 1909 he developed a scientific method to estimate the amount of haemoglobin in the resistant corpuscles. He discovered pentavalent antimonials, Urea Stibamine (carbostibamide) in 1922 and determined that it was an effective substitute for the other antimony-containing compounds in the treatment of Kala-azar (Visceral leishmaniasis) which is caused by a protozoon, Leishmania donovani. The drug effectively countered the epidemic of kala-azar which was prevalent during the late twentieth century in the vast track of the Gangetic plain and the Brahmaputra valley. He was rightly nominated for the Fellowship of the Royal Society of London, as well as Nobel Prize. He never received international support and even within India, his nominators were only from Calcutta, as a result he could not receive the Nobel prize in medicine.

D. M. Bose [9] was an undoubtedly an exceptional physicist and contemporary scientists who shared comparable international and national reputation in his lifetime. His life and works are less discussed and known to people today. He has made well-known contributions in the field of cosmic rays, artificial radioactivity and neutron physics. During his work in England and Germany, he came in contact with many reputed physicists of that time like Max Planck, Albert Einstein, Peter Debye, Walther Nernst, Heinrich Hertz and Max Born. Much less is known about the work of D. M. Bose and his colleague Bibha Choudhuri, who missed the Nobel Prize for discovering the mu-meson, due to lack of access to modern scientific tools. Nobel prize in 1950 went to C. F. Powell for his development of the photographic method of studying nuclear processes and his discoveries regarding mesons made with modern technology. In his book "The Study of Elementary Particles by the Photographic Method", Powell has rightly acknowledged that the method developed by Bose and Choudhuri in 1941 on distinguishing between tracks of proton and meson in an emulsion was inevitably the first attempt and commented that "the physical basis of their method was correct and their work represent the first approach to the scattering method of determining momenta of charged particles by observation of their tracks in emulsion".

Sir Jnan Chandra Ghosh [10] can be rightly considered as one who tried to make the country a better place to live in through his dedicated services in science and technology. He is remembered for his research on the theory on strong electrolytes which was proposed in 1918. He also made significant contributions in kinetics, fluorescence, catalysis, auto-oxidation and other allied branches. He also made pioneering investigations in areas like the Fischer-Tropsch synthesis for obtaining liquid fuel from carbon monoxide and hydrogen and step-wise mechanism of ammonia synthesis from its elements, nitrogen and hydrogen. Ghosh played a very important role in shaping science and engineering education in the country and should have deserved the Nobel prize in chemistry.

Satyendra Nath Bose citef4 pointed out that Planck's formula for the distribution of energy in the radiation from a black body was the starting point of the quantum theory, which has been prevalent during the last 20 years and has fruitful in every domain of physics. Bose's early scientific interest had been aroused by reading Einstein's papers on relativity. When he arrived in Berlin, Einstein had already published his research on a unified field theory. Einstein later extended Bose's method to establish the quantum theory of a monoatomic ideal gas. He

developed the theory in three communications to the Prussian Academy in Berlin on 10 July 1924, 8 January 1925 and 29 January 1925, respectively. Einstein also extended Bose's method of treating light-quanta to material particles. At Dacca University Bose kept up an interest in experimental physics, especially the studies of thermoluminescence and crystal structure.

Meghnad Saha [12] was born on the 6th October 1893 in a village named near Dhaka. He belonged to very poor backward community and had to struggle before he could come to eminence. Fortunate circumstances helped him to get good education and he was a class fellow of S. N. Bose at Presidency college. Before shifting to Allahabad university in 1923 he was working in Calcutta. There in 1920 he formulated the famous theory of ionization and equation bearing his name which is a major achievement crucial in understanding stellar structure and evolution. That both S. N. Bose and M. N. Saha could incorporate correct quantum mechanical concepts in their theories even before the formal advent of quantum mechanics speaks highly of their physical insight. Saha's theory deals with high temperature ionization of elements and its application to stellar atmosphere. His theory and subsequent developments led to detailed study of stellar spectra and knowledge of pressure and temperature distribution in stellar atmosphere. In his book Theoretical Astrophysics (Oxford University Press 1939) Professor S. Rosseland writes: "The impetus given to astrophysics by Saha's work can scarcely be overestimated, as nearly all later progress in this field has been influenced by it and much of the subsequent work has the character of refinement of Saha's idea". Narlikar considers that Saha's work belongs to Nobel class. Saha is equally well known for his sustained efforts in nurturing research in physics. During his leadership the physics department at Allahabad became well known for its academic excellence. He was the leading light in organizing scientific societies like National Academy of Sciences, Allahabad, Indian Physical Society, and Indian Association for Cultivation of Science. He continued to diversify his areas of interest and has trained or inspired a large number of physicists. His greatest contribution to the cause of Indian Science is the establishment of Institute of Nuclear Physics at Kolkota in 1943 presently known as Saha Institute of Nuclear Physics run by the Department of Atomic Energy and has evolved as a prominent center of physics research in India. He was an architect of river planning and played a critical role in reforming the traditional Indian calender. He was a social activist and was a member of Indian Parliament. He died when he was 63 but fully active in his multifarious academic and social activities till the end Saha's theory deals with high temperature ionization of elements and its application to stellar atmosphere. His theory and subsequent developments led to detailed study of stellar spectra and knowledge of pressure and temperature distribution in stellar atmosphere.

Gopalasamudram Narayanan Ramachandran [13] was born on 8.10.1922 at Ernakulam, Kerala and studied for his B.Sc. at St Joseph's college, Tiruchi. In 1942 he moved to Indian Institute of Science, Bangalore to study electrical engineering. Sir C. V. Raman spotted the research. It is said that he told the chairman of the department of electrical engineering that I am admitting Ramachandran into my department as he is a bit too bright to be in yours". Ramachandran is perhaps the most distinguished of Raman's students. He obtained his D.Sc. from IISc also later a Ph.D. from Cambridge. Soon the then famous Vice-Chancellor of Madras university spotted Ramachandran's potential and appointed him as professor and head of physics department when he was just 30. World renowned works of Ra-

Fig. 12 Gopalasamudram Narayanan Ramachandran (1922-2001)

machandran were accomplished at Madras. At IISc Ramachandran had become an expert in X-ray diffraction techniques and this was being applied at that time to a wide variety of bio-molecules. Ramachandran's works bring together the fields of molecular biophysics, X-ray crystallography, peptide synthesis, NMR and other optical studies. He (along with his students) is most widely known for discovering triple helix structure of collagen-most abundant protein of connective tissues in 1955 and his analysis of allowed conformations of proteins through the use of what are known as 'Ramachandran plots' was published in the Journal of Molecular Biology in 1963. These rank among the most outstanding works on structural biology along with the other two famous works namely alpha helix structure folded polypeptides discovered by Linus Pauling and double helix structure of DNA discovered by Watson and Crick. It is remarkable that Ramachandran's works were carried out in India facing all the problems associated with Indian science. In this sense, he is a true successor to C. V. Raman's legacy. Ramachandran was clearly a Nobel class' scientist who did not get entry into this class. His works are text book material in the area of structural biology and molecular biophysics. However, in 1999 the international scientific community made some amends to this omission. The Edwald Prize (1999) of the International Union of Crystallography was awarded to G. N. Ramachandran for his outstanding contribution in the field of crystallography, in the area of anomalous scattering and its use in the solution of the phase problem, in the analysis of fibres, collagen in particular and foremost for his fundamental work on the macromolecular conformation and the validation of macromolecular structures by means of Ramachandran Plot" which even today remains the most useful validation tool'. Ramachandran returned from Madras (Chennai) to IISc in 1971 and led a new department which has evolved as a important center for research in structural biology. During his last years he suffered from Parkinsonisim and died on 7.4.2001 at the age of 78.

Ennakkal Chandy George Sudarshan [14] was born on 16.9.1931 at Pollam, Kottayam district of Kerala. He did his M.Sc. from Madras university (1952) and Ph.D. from University of Rochester, New York in 1958. His academic career is mostly in USA and he is at the University of Texas at Austin since 1969. Sudarshan is undoubtedly the most accomplished and renowned living theoretical physicists of Indian origin and has prodigious creative output. His research interests span the fields of particle physics, quantum optics, quantum field theory,

Fig. 13 Ennakkal Chandy George Sudarshan (1931-2018)

quantum information theory, gauge theories, and classical mechanics. He has deep interest in Vedanta philosophy and spirituality worked as Director of Institute of Mathematical Sciences at Chennai for over five years during 1980's. No doubt, he is the most accomplished and renowned living theoretical physicists of Indian origin and has prodigious creative output. His research interests span the fields of particle physics, quantum optics, quantum field theory, quantum information theory, gauge theories, and classical mechanics. He has deep interest in Vedanta philosophy and spirituality. He was nominated to Nobel prize several times but the coveted honor has eluded him so far. He together with Robert Marshaks, invented in 1957 of what is known as the V-A theory of weak interaction. Around the same time Gell-Mann and Feynman also published similar work. In fact, Sudarshan and Marshak narrowly missed the full credit for this important work which clearly belongs to Nobel class because of some delay in the publication of their work in a regular research journal. This theory eventually evolved as electro weak theory of weak interactions developed by Sheldon Glashow, Abdus Salam and Steven Weinberg. They were honored with Nobel prize in 1979.

In 1960's Sudarshan put forward the theory of tachyons-conjectured particles which have speeds larger than the speed of light in vacuum. Most of the journals were initially reluctant to publish novel idea but eventually it got the attention of a number of physicists and much work was done. However tachyons have remained elusive experimentally. If and when they get discovered it will completely change our conception and understanding of the universe and can also have several potential applications. The idea of tachyon was a revolutionary concept within the framework of special theory of relativity. He developed the quantum representation of coherent light which is being referred to in literature as Sudarshan-Glauber representation. It is said that original idea of coherent representation of light beams is due to Glauber However, the diagonal representation' discovered by Sudarshan is a far reaching result which showed the general equivalence of classical and quantal descriptions of all states of light field and is of wider validity. The mathematical equivalence is now referred as the Optical Equivalence Theorem' and is a very fundamental result in modern optics. In fact Sudarshan's diagonal representation forms the starting point of later developments in quantum optics.

Sudarshan developed formalism called dynamical maps which is a fundamental work in the theory of open quantum systems. In collaboration with B. Mishra

he has proposed in 1977 what is known as quantum zeno effect. It predicts an interesting result that an unstable particle, if subjected to continuous observation, will never decay. Quantum zeno effect corresponds to the limiting behavior of an unstable quantum system when subjected to infinitely strong coupling to environment. In 1989 there was a report of the experimental confirmation of quantum zeno effect by W. Itano and collaborators. The 2005 Nobel Prize given to Glauber for the contribution to the quantum theory of optical coherence ignoring the seminal contributions of Sudarshan has caused much anguish among physicists who are admirers of Sudarshan's contributions to physics in general and quantum optics in particular. A number of physicists from India and abroad have expressed their concern and dismay to the Nobel committee regarding this. Sudarshan himself has put forward his forthright opinion to the Nobel committee in a letter. A section of the letter (taken from Frontline Vol 22, Issue 24 Nov 19-Dec 02, 2005) reads: "It is my belief that the Royal Swedish Academy was impartial and that to assure the proper priorities it has a Committee in Physics, with members competent to examine and understand the published work. It was also my belief that the members of the Committee did their work diligently and with care. I am therefore genuinely surprised and disappointed by this year's choice. It would distress many others and me if extra scientific considerations were responsible for this decision. It is my hope that these glaring injustices would be noted by the Academy and modify the citations. Give unto Glauber only what is his. Sincerely yours E. C. G. Sudarshan".

5. Concluding remarks

Undoubtedly the eight cases discussed above concern Indian scientists who carried out outstanding work deserving Nobel Prize. The researches of all of them except Sudarshan were carried out in India. The works of Jagdish Chandra Bose, Sir Upendranath Brahmachari, Debendra Mohan Bose, Sir Jnan Chandra Ghosh, Satyendra Nath Bose and Meghnad Saha were done during colonial period and lack of resources and modern facilities during that time.

One may suspect that Nobel prizes which epitomize the achievement of excellence as per the vision and norms of western civilization are hard to win by scientists from other nations, particularly from third world countries, in spite of the fact according to "Nobel's will" in awarding the prizes no consideration be given to the nationality of the candidate. There would have been numerous deserving Nobel Laureates if the entire history of India is taken into consideration. It is generally believed that to be worthy of the prize, scientists from India have to stand out distinctly much above his western counterpart. But such a view is perhaps too simplistic. Even in the western world there have been a number of cases where Nobel prizes were not awarded to very deserving cases. Confining only to physics, some of the glaring omissions (not in any particular order) are: Thomas Alva Edison (Inventor of many gadgets including telegraph, movies,electric bulb etc), Thomas Tesla (Electromagnetism), Lise Meitner (nuclear fission), Chien-Shiung Wu (Parity non-conservation), Yuval Ne'eman (Particle physics), George Zweig (quark composition of particles), Fred Hoyle (Astrophysics), Jocelyn Bell Burnell (Radio pulsars), George Gamow (Theory of Cosmic Microwave Background radiation), Freeman Dyson (quantum field theory), Robert Oppenheimer (Theoretical physics), Sidney R. Coleman (Particle physics).

The debate as to why most Indian Scientists missed the Nobel is left open to all audiences and Indians at large. Let's hope for a better world where scientist's shall be properly judged as they spent most of their times for the welfare of people and always try for a better improvement and quality of life.

Acknowledgments

The author is very much grateful to the editor Dr. Saibal Ray for illuminating discussions and pertinent suggestions that have significantly improved the work in terms of research quality and presentation. Author is thankful to his mother Mst. Momena Begum, who has always been a source of his inspiration. The paper is compiled during the hard time when mankind is facing a great challenge to COVID-19. Let's all hope that science succeeds over religion and politics at large.

References

1. Google and Science Magazines.
2. https://en.wikipedia.org /wiki /**Alfred Nobel**.
3. T. Frängsmyr, *The Royal Swedish Academy of Sciences*, **Alfred Nobel-Life and Philosophy** (1996) [http://www.nobelprize.org/alfred nobel/biographical/articles/frangsmyr/].
4. Science India: **The National Science Magazine**.
5. https://en.wikipedia.org/wiki/Kailash Satyarthi.
6. P. N. Tandon, *Indian Journal of History of Science*, **54.2** (2019) 173.
7. https://en.wikipedia.org/wiki/**Jagadish Chandra Bose**.
8. R. Singh and S. Roy, Indian Journal of History of Science **54.1** (2019) 3.
9. Science and Culture **76** (2010) 491.
10. S. Mahanti, *Dream 2047* **10** (2008) 32.
11. S. Ray, *Bangalir Bigyan Gobeshona Ebong Odhora Nobel*, Bangla o Malatkahini **1** (2012) 38.
12. https://en.wikipedia.org/wiki/**Meghnad Saha**.
13. https://en.wikipedia.org/wiki/**G.N. Ramachandran**.
14. https://en.wikipedia.org/wiki/**E.C.G. Sudarshan**.

Scientific Voyage
Vol. 1 No. 2
Page 28-32 (2020)

SCIENTIFIC VOYAGE
ISSN: 2395-5546

GCECT
Publication
Apr.-Jun

A novel theoretical proposition on the field emission of electrons under the action of centrifugal force

Somenath Chakrabarty[1]
[1]*Department of Physics, Visva-Bharati, Santiniketan 731 235, West Bengal India*
E-mail: somenath.chakrabarty@visva-bharati.ac.in

Abstract: In this article we have suggested a novel idea of electron emission process from the surface of a metallic hollow sphere under the action of centrifugal force. The surface is assumed to be of a single layer metallic atoms. Therefore all the electrons are at the same radial distance from the centre of the sphere. The metallic sphere is assumed to be rotating about one of its symmetry axes with a uniform angular velocity. It may therefore be treated as a non-inertial frame. We have started with classical non-relativistic form of Hamiltonian for the electrons in such a uniformly rotating non-inertial frame and later make some quantum correction. In this theoretical study the conduction electrons in the metallic surface are assumed to be free classical gas. It has been noticed that in the Hamiltonian the single particle centrifugal potential, which is negative in nature is minimum at the equator. As a consequence free electrons will be accumulated inside the centrifugal potential well. We have proposed a mechanism to get electron emission from the equatorial zone under the action of centrifugal force. In the quantum picture it is of course tunneling from the potential well.

Keywords: Electrons; Field emission; Centrifugal force

1. Introduction

In the present article we have proposed a new mechanism of field emission of electrons (see [1–3] for the conventional model and also see [4,5] for field emission associated with magnetar). We have considered a hollow metallic sphere of extremely thin surface width, almost like a single layer of atoms. Therefore all the electrons are at a constant radial distance, say R from centre of the sphere. Then we can say that exactly like the celestial sphere, used in theoretical astronomy, the position of an electron is assigned by θ and ϕ the polar and the azimuthal coordinates. It has further been assumed that the free electrons on the metallic surface behave like a classical gas. The hollow sphere has a spinning motion about one of the symmetry axes. Since it is a metallic sphere, there are a lot of free electrons. These delocalized electrons can have mass motion during the rotation of the sphere. Whereas, the positively charged ions are rigidly attached in the spherical shape ionic lattice. Therefore they are at rest. The flow of electrons will be towards the negative centrifugal potential near the equator. The depth of the potential increases with the increase in angular velocity of the rotating sphere. The free electrons from rest of the places will be accumulated at the equator. It has been observed that in the steady state the free electrons will be accumulated near the equatorial zone within the angular width $\theta = 69^0$ to $\theta = 120^0$. This is also the range of the potential and is independent of the angular velocity of the sphere. Classically, outside this region is totally void. Not a single electron can be there in the void zone [7].

In this article, our investigation is purely theoretical in nature. We strongly believe that this theoretical proposition can be verified experimentally. It should

further be noted that to the best of our knowledge, this problem has not been reported earlier.

We have arranged the article in the following manner: In the next section we have developed the basic formalism and in Sec. 3, a mechanism for the emission of electrons under the action of centrifugal force has been introduced and finally in Sec. 4, we have given the conclusion and discussed the importance of quantum correction.

2. Basic formalism

It is well known that a rotating sphere is equivalent to a non-inertial frame [8]. In the classical form of Hamiltonian for an electron, the potential has a minimum near the equator. The electrons should therefore be accumulated near the equatorial zone. To get some quantitative estimate, we follow Landau and Lifshitz [8]. We can write down the Lagrangian of a free electron in the following form:

$$L = \frac{1}{2}mv^2 + m\mathbf{v}.(\mathbf{\Omega} \times \mathbf{r}) + \frac{1}{2}(\mathbf{\Omega} \times \mathbf{r})^2 - U(\mathbf{r}), \tag{1}$$

where m and $\mathbf{v}$ are respectively the mass and the velocity of the electron, $\mathbf{\Omega}$ is the uniform angular velocity of the sphere and $U(\mathbf{r})$ is some background potential experienced by the electrons. Since the surface thickness of the hollow sphere is assumed to be extremely thin, almost like single atomic layer, the radial distances of all the free electrons from the centre are same. Hence we can write $\mid \mathbf{r} \mid = R$, the radius of the sphere. The background potential $U(R)$ is therefore a constant.

We have further assumed that the electron distribution is symmetric with respect to the azimuthal coordinate ϕ. Then the surface distribution of electrons depend only on the polar coordinate θ. Hence following the standard definition, the single particle Hamiltonian is given by

$$H = \mathbf{p}.\mathbf{v}(\mathbf{p}) - L. \tag{2}$$

Then with some little algebra it can very easily be shown that the Hamiltonian for an electron is given by

$$H = \frac{p^2}{2m} - \frac{1}{2}m\Omega^2R^2\sin^2\theta + U(R), \tag{3}$$

which may be re-expressed as

$$H = \frac{p^2}{2m} + V(\theta) + U(R), \tag{4}$$

where $V(\theta)$ is the well known centrifugal potential. Since only the free electrons can have mass motion and the metallic ions are immovable because they are tightly fixed in the ionic lattice by some rigidity force and also they are quite massive, we can write down the Poison's equation satisfied by the electron in the following form:

$$\nabla^2 V(\mathbf{r}) = 4\pi m G n_e. \tag{5}$$

Here $V(\mathbf{r})$ is equivalent to a gravitational potential arising from the centrifugal force experienced by the electrons on the rotating surface. Since the surface thickness is infinitesimally thin, the radius vector is a constant and from the rotational

symmetry, the centrifugal potential is independent of the azimuthal coordinate. Then we can re-write the above equation in the form:

$$\frac{1}{R^2}\frac{1}{\sin^2\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial V(\theta)}{\partial\theta}\right) = 4\pi G m n_e. \tag{6}$$

This is the relevant part of Poisson's equation. Substituting for $V(\theta)$, we have after some little algebra

$$4\pi G m n_e = m\Omega^2(1 - 3\cos^2\theta) = m\Omega^2 x. \tag{7}$$

Since the left hand side is positive definite, the quantity $x = 1 - 3\cos^2\theta$ must also be ≥ 0 and this gives $|\cos\theta| \leq 1/3^{1/2}$. Therefore within the range of θ between 60^0 and 120^0, the values of n_e are non-zero, with maximum at $\theta = 90^0$. Beyond this range of θ, the electron density n_e becomes negative, which is unphysical. In Fig. 1 we have shown the variation of the quantity x with θ, where θ is from 0^0 to 180^0. It is quite obvious that x is non-zero positive definite for $60^0 \leq \theta \leq 120^0$. The result is independent of the azimuthal angle ϕ. The peak at $\theta = 90^0$ is because of the minimum. In Fig. 2 we have plotted the variation of $x(\theta, \phi)$ in three-dimension. Since the quantity $x(\theta, \phi)$ is independent of ϕ coordinate, we got a closely spaced repetition of the curve shown in Fig. 1.

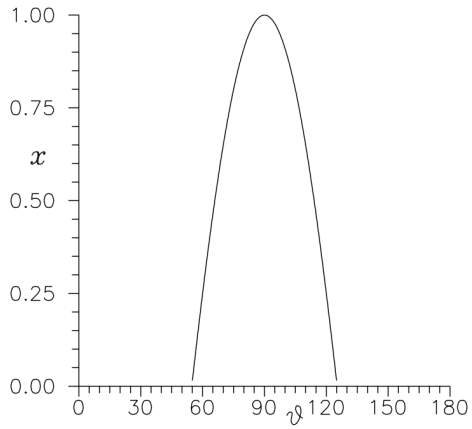


Fig. 1 Variation of x (introduced in the text) with θ

3. A possible new mechanism of electron emission

In this section we have introduced a new mechanism of field electron emission from the surface of the rotating metallic hollow sphere under the action of centrifugal force. To get electron emission, we propose the following changes near the equator. A large number of extremely thin needles with very sharp edges and made up of the same conducting material are put along the equator. These needles are projected radially outward with erected sharp edges. Another addition is a metallic belt along

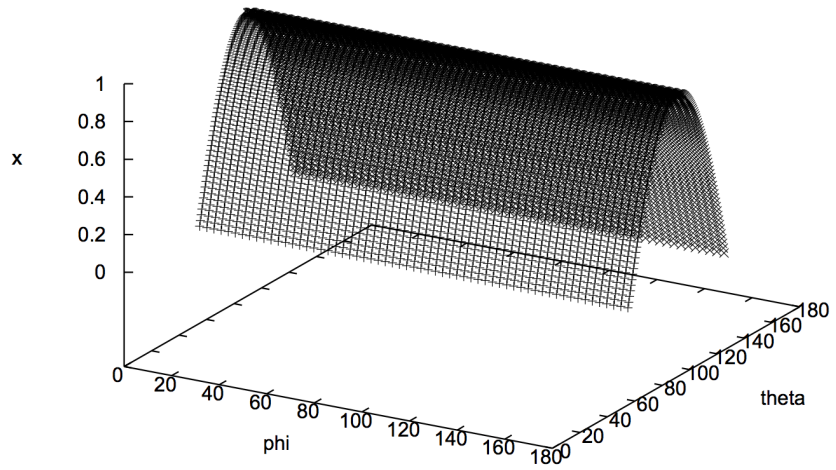


Fig. 2 Variation of x (introduced in the text) with θ and ϕ

the equator, but slightly above the sharp edges of the needles. It is like the zodiac belt of the celestial sphere, but not on the surface of the sphere at the equator. The angular width of the belt is less than 60^0. The negative potential region near the equatorial zone is now connected with the negative pole of a battery using silver-graphite brush connector. The belt is connected with the positive pole of the same battery. In the rotating condition, the circuit is completed along with a current measuring device. Since the needles are metallic, electrons will travel towards the edges and because of the sharp nature of the edges, following the mechanism of lightning arrester, electrons which are repelling each other at the sharp edges will go to the space and will move towards the positively charged metallic belt, which behaves like a positively charged cloud. As a consequence the circuit will show the flow of electric current. The current measuring device will show zero current when the sphere is at rest. As soon as it starts rotating some current will be seen in the measuring instrument. The intensity of current may not be quite high, but will be finite in magnitude (may be $\sim \mu$ amp) and measurable.

In this classical model, strength of field current is independent of the magnitude of angular velocity of the sphere. This can not be not be correct. But it is the limitation of the classical idea. In the conclusion we have shown that the strength of current will increase with the increase in $|\ \boldsymbol{\Omega}\ |$.

4. Conclusion

In this article we have proposed a mechanism of electron field emission. If it is found to be correct, then it will be a new mechanism of electron emission.

Finally we would like to mention, that from the classical point of view the strength of field current is independent of the magnitude of angular velocity of the sphere. This is not correct. The strength of current should increase with the rotational speed of the sphere. Of course this physical phenomenon can only be explained by quantum mechanics. For the proper explanation, one has to incorporate quantum correction. From Eq. (4) it is obvious that the depth of potential

well is $\propto \Omega^2$. Now it is well known that the number of energy levels will increase with the depth of quantum mechanical potential well. Therefore when Ω is small enough, the potential well will be shallow, which in turn gives very few energy levels and as a consequence the number of electrons at the equatorial region will be low enough. The strength of field current may therefore be immeasurable for low Ω.

Because of the increase in the number of energy levels inside the potential well, which also gives enormous number of electrons, the strength of field current will increase with the increase in angular velocity of the sphere. With the increase in the magnitude of angular velocity, the continuum to bound transition probability will also increase. In the extreme case, when the angular velocity is large enough, the number of energy levels inside the potential well be so large and so closely spaced that they are almost like continuum and as a result in such situation, the transition will be like continuum to continuum. We expect a saturation of field current with the increase in angular velocity.

Therefore our final remark is that, the mechanism of field emission under the action of centrifugal force has not been discussed before.

References

1. R.H. Fowler and L. Nordheim, *Proc. Roy. Soc. (London)* **119** (1928) 173.
2. R.G. Forbes and J.H.B. Deane, *Proc. Roy. Soc. (London)* **463** (2007) 2907.
3. S.-D. Liang and L. Chen, *Phys. Rev. Lett.* **101** (2008) 027602.
4. A. Ghosh and S. Chakrabarty, *Eur. Phys. J. A* **47** (2011) 56.
5. A. Ghosh and S. Chakrabarty, *Mon. Not. R. Astron. Soc.* **425** (2012) 239.
6. A. Ghosh and S. Chakrabarty, *Astrophys. Astronomy* **32** (2011) 377.
7. S. Das, S. Ghosh and S. Chakrabarty, *Mod. Phys. Lett.* **32** (2017) 1750180.
8. L.D. Landau and E.M. Lifshitz, *Classical Mechanics* (Butterworth-Heimenann, Oxford, 1975).

Scientific Voyage
Vol. 1 No. 2
Page 33-38 (2020)

SCIENTIFIC VOYAGE
ISSN: 2395-5546

GCECT
Publication
Apr.-Jun.

Sintering and Properties of Calcia as a Refractory Material

T. K. Bhattacharya[1]

[1] *Department of Ceramic Technology, Government College of Engineering and Ceramic Technology, Kolkata 700010, West Bengal, India*
E-mail: tkb_ceramics@yahoo.co.in

Abstract: The investigation is focused on the sintering of calcia in single stage and double stage process from natural source limestone and evaluation of its properties like bulk density, apparent porosity, hydration resistance and microstructure in relation with sintering temperature. The result showed that bulk density increases and apparent porosity decreases with sintering temperature in both single and double stage process. In single stage process, maximum densification was 79.4 percent whereas it maximised to 90.74 percent in double stage process at 1650^0C. Hydration resistance of sintered calcia increases with densification as well as increase of grain size. With increasing apparent porosity hydration gain increases due to enhancement of water movement through the interconnected space followed by adsorption and chemical reaction. Double stage sintering process develops dense microstructure as compared single stage sintering process.

Keyword: Calcia; Limestone; Sintering; Hydration

1. Introduction

Calcia is considered as an attractive basic oxide refractory material in new generation due to its excellent properties like high melting point (~ 2570^0C), high hot properties, excellent slag resistance and its worldwide abundance of its raw material limestone [1-4]. The thermodynamic stability of calcia, being more stable than magnesia even in contact of carbon and relatively low vapour pressure at elevated temperature, makes it suitable for steel making process using vacuum technology [5-7]. The harmful property of this material is its susceptibility to hydration, which could not be stopped even in presence of atmospheric moisture. This detrimental property can precisely be controlled by sintering of cacia to a large extent to form highly dense with large grain size [8-10]. The thermodynamically stable cubic crystal structure of CaO does not permit any polymorphic transformation and not to be dead burnt. Various attempt were made to develop highly dense with anti hydration properties of calcia by using different sintering aids, e.g. CuO, Fe_2O_3, Al_2O_3, La_2O_3, CeO_2 and other additive compounds [11]. The additives like La_2O_3 , CeO_2 and Y_2O_3 have enhance solid state sintering but CuO, Fe_2O_3, Al_2O_3 through liquid state sintering of lime. Limestone contain various impurities like SiO_2, Al_2O_3 and Fe_2O_3, play an important role in sintering by the formation of liquid coating on the CaO grains, improved hydration resistance [12]. Calcia derived from hydroxide precursor is more dense and hydration resistant than derived from carbonate [13 –14].

The aim of this investigation is to study the sintering of calcia in both single and double stage process and evaluation the properties like densification and hydration resistance in relation with apparent porosity and microstructure of sinter. The performance in relation with material properties and to find out the best sintering process to develop high dense calcia sinter with improved hydration resistance.

2. Experimental

2.1 Materials

The purer variety limestone sample from Madhyapradesh region of India was selected as a basic carbonate source in this study. The lump size was crushed into ¾ to 1 inch size, properly washed and dried. The dried limestone sample was ground with a fineness of -300 BS mesh size. The hydroxide powder was prepared by calcinations of limestone first at about 900^0C followed by slaking of oxide by large excess water to form calcium hydroxide. The single stage sintering was carried out from carbonate source and double stage sintering was from carbonate derived hydroxide source. Sintered calcia were abbreviated as "SSP" and "DSP" respectively for distinguishing the single and double stage process.

2.2 Materials fabrication and Sintering

Batches for "SSP" and "DSP" were prepared from limestone and limestone derived hydroxide powder respectively. The green briquette of 3.8 mm height and 12.9 mm diameter was prepared by applying uniaxial pressing with a pressure of 100 MPa with 2 minutes dwell time. The 6 weight percent water was used as a binding agent. The green briquette was dried at 110°C for 24 hours and then subjected to sintering at 1500°C to 1650°C with 2 hours soaking at peak temperature in a program controlled electrically heated muffle furnace.

2.3 Material Characterization

The densification behaviour of sintered calcia was characterized in terms of bulk density and apparent porosity by liquid displacement method in xylene under vacuum using Archimedes principle according to ASTM C-373-88. The percent densification was measured on the basis of specific gravity of pure CaO (3.35). The hydration resistance was measured by subjecting 50 gm. of -5 + 10 BS mesh sinters to 50^0C and 95 percent relative humidity in a steam humidity cabinate for 3 hours as per ASTM C110-15. The microstructure of the polished surface was observed by reflected light microscopy after thermal etching at about 800^0C for 45 minutes. The average grain size of the sintered lime was measured by linear intercept method as per ASTM-E112-13.

3. Results and Discussions

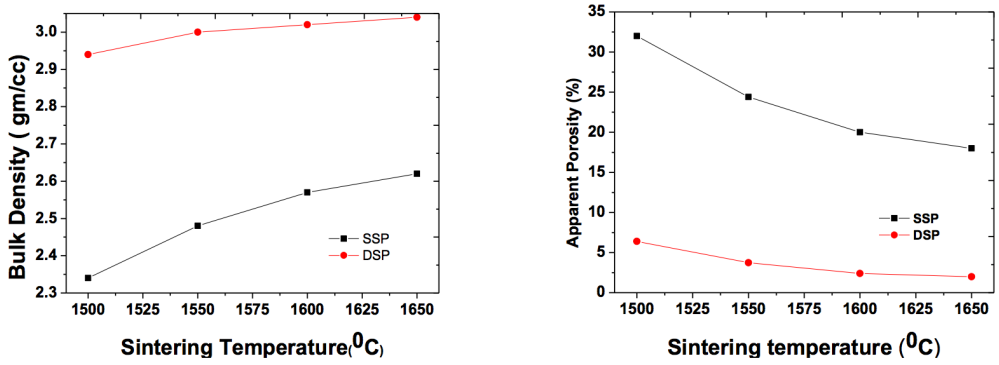
Limestone as a carbonate sources is collected from Madhyapradesh region of India. It is relatively pure with a very low amount of impurities around 2 weight percent. The physico-chemical properties of raw limestone is shown in Table-1 and it is already reported in my previous publication [15].

Sintering of characteristics of calcia in terms of bulk density and apparent porosity is shown in fig.1. It is seen that bulk density of calcia derived from double stage sintering process is quite high than single stage sintering process. The relative bulk density of all sintered materials increases and apparent porosity decreases with increasing sintering temperature. Bulk density in single stage sintering process at 1550^0C is 2.48 gm/cc with a 24.4 % apparent porosity. With increasing sintering temperature from 1550^0C to 1650^0C in single stage sintering process, densification improved to 2.62 gm/cc. Double stage sintering process yield maximum density of 3.04 gm/cc with 2% apparent porosity at 1650^0C.

Table-1: Physico-chemical properties of raw limestone

Chemical Analysis of raw limestone (wt.%)							
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	LOI
1.48	0.20	0.11	54.56	Trace	0.11	0.33	42.88

Physical Properties of Limestone	
DTA (endo peak, ^0C)	: 914
Specific gravity	: 1.58
Specific surface area (m^2/gm) of carbonate derived CaO	: 7
Specific surface area(m^2/gm) of hydroxide derived CaO	: 24



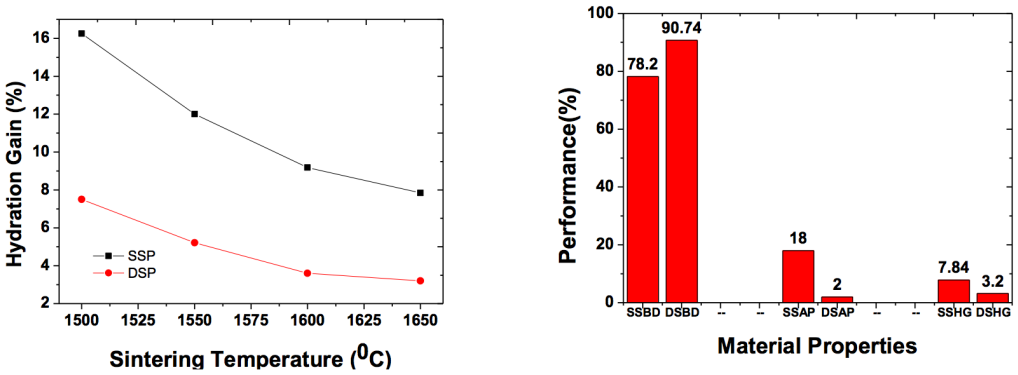
(a) (b)

Fig. 1: (a) Bulk Density of sintered Calcia at different sintering temperature, (b) Apparent porosity (%) of sintered Calcia at different sintering temperature

Oxide formation from $Ca(OH)_2$ or $CaCO_3$ form excess vacancies into lime lattice which appreciably increases the rate of material transport and greatly reduce activation energy of densification. These vacancies disappear at an appreciable rate above 1100^0C [16]. Dehydration of hydroxide occur at 550^0C, relatively lower temperature than decarbonation of carbonate. The early born oxide from hydroxide has an enormous surface area and free energy than those of carbonate derived oxide. These early born oxides undergo plastic flow and show significant sinterability at relatively low temperature. It is found that at 870^0C the rate of sintering of hydroxide derived oxide should be equal to that of carbonate derived oxide at 1400^0C [16,17]. Moreover, the water vapour evolves from hydroxide enhances the sintering by lowering the equilibrium value of dihedral angle between oxide grains and pores [16-18]. The inter particle space is also moistened by it and a capillary suction is generated which brings the particle together for neck growth at an early stage [19].

The most unwanted unique hydration property of calcia refractory is called hydration, the chemical combination calcia with water to form calcium hydroxide. The structural openness of CaO lattice facilate to hydrate even at atmospheric moisture. The affinity towards hydration can be minimised by increasing bulk density, grain size of sintered as well as formation of protective layer on the surface of calcia grain. This is achieved by sintering at higher temperature. The percent hydration gain decreases with increasing sintering temperature both in single and double stage process and shown in Fig. 2(a). Caicia derived from single stage

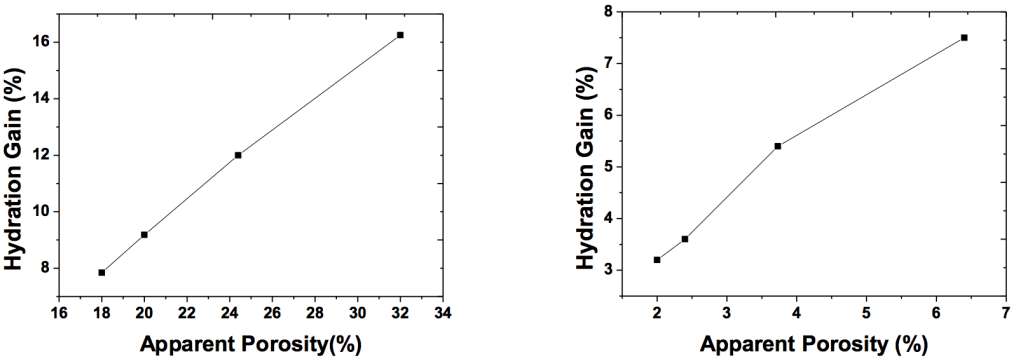
sintering process from carbonate precursor shows lower hydration resistance than derived from hydroxide. Hydration gain of sintered calcia from carbonate precursor at 1650^{0}C is 7.84 percent and that for hydroxide derived calcia, the hydration gain reduced to 3.20 percent. The higher hydration resistance in double stage sintering process is due to develop of dense sinter with higher grain size of calcia from hydroxide precursor[11,15]. The relative material performance of sintered calcia is also shown in fig. 2b.



(a) (b)

Fig. 2: (a) Hydration Gain (%) of sintered Calcia at different sintering temperature, (b) Comparative performance of Single stage & Double stage sintering process (SSBD = Highest Bulk density of Calcia in single stage process, DSBD = Highest Bulk density of Calcia in double stage process, SSAP = Lowest Apparent Porosity of Calcia in single stage process, DSAP = Lowest Apparent Porosity of Calcia in double stage process, SSHY = Highest hydration resistance of Calcia in single stage process, DSHY = Highest hydration resistance of Calcia in double stage process).

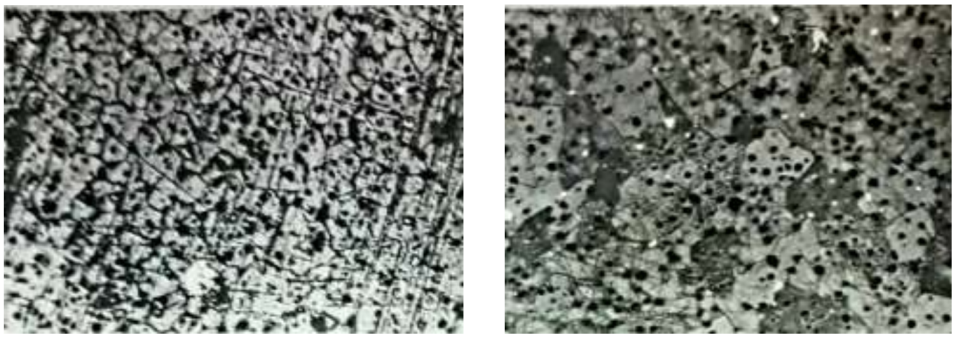
Apparent porosity part play an important role on hydration process as its presence favours the movement of water through the interconnected space followed by adsorption chemical reaction. The hydration gain in both single and double stage process increases with increasing apparent porosity and shown in Fig. 3. With increasing apparent porosity, the exposed surface area of sintered calcia increases, enhanced the formation of calcium hydroxide [15,16,18].



(a) (b)

Fig. 3: (a) Hydration Gain (%) of sintered Calcia with apparent porosity (%) in single stage sintering process, (b) Hydration Gain (%) of sintered Calcia with apparent porosity (%) in double stage sintering process.

The micro structural evaluation of calcia is very much significance with densification and hydration resistance of sintered product. The optical micrograph of calcia sinter in both single and double stage sintering process are shown in Fig. 4. Carbonate derived calcia in single stage sintering process does not show significant grain growth whereas hydroxide derived calcia in double stage sintering process develop grains of irregular shape with a significant extent. The inter and intra granular pores are present in all microstructure. The microstructure of calcia in single stage sintering process is too much porous due to insignificant densification. The average grain size of sintered calcia in single stage sintering process is 10 μm whereas in double stage sintering process is 32 μm.



(a) **25μm** **(b)** **25μm**

Fig. 4: Microstructure of sintered Calcia at 1600^0C for (a) in single stage sintering process and (b) in double stage sintering process

4. Conclusion

The calcia sintered derived from double stage sintering process showed better performance towards densification and hydration resistance. The maximum densification in double stage process was 90.74 percent with 3.2 percent hydration gain. Hydration gain increases with apparent porosity of sintered calcia both in single and double stage process. Double stage sintering process develops dense microstructure with an average grain size of 32 μm. The intra and inter granular pores are present in both calcia microstructure derived from single and double stage sintering process.

References :

1. F. Nadachowski, *Interceram* **1** (1975) 42.
2. B. Brenzny, *J. Am. Ceram. Soc.* **59** (1976) 529.
3. D. Carr and L.F. Rooney, Limestone and Dolomite in Industrial Rocks and Minerals, American Institute of Mining.
4. R.S. Boynton, *Chemistry and Technology of Lime and Limestone*, pp. 18-21 (John Wiley and Sons, New York, 1980).
5. G.V. Samsonv, *The Oxide hand book*, pp. 178-206 (Plenum Press, New York, 1973).
6. A. Ghosh, T.K. Bhattacharya, B. Mukherjee and S.K. Das, *Ceram. Int.* **27** (2001) 201.
7. L.L. Wong and R.C. Bradt, *J. Am. Ceram. Soc.* **78** (1975) 1611.
8. A.V. Gropyanov, *Refract. Indust. Ceram.* **44** (2003) 32.
9. A. Miskufova, T. Kuffa, T. Havlik and J. Trpcevska, *Mater. Struct.* **8** (2001) 33.
10. C.S. Morgan, L.L. Hall and C.S. Yust, *J. Am. Ceram. Soc*. **41** (1963) 55.
11. A. Ghosh, T.K. Bhattacharya, B. Mukherjee and S.K. Das, *Ceram. Silik*. **47** (2003) 70.

12. T.K. Bhattacharya, A. Ghosh, H.S. Tripathi and S.K. Das, *Bull. Mater. Sci.* **26** (2003) 703.
13. J.H. Xue, M.F. Han and Q.Y. Wang, *Eng. Mater*. **2552** (2007) 336.
14. S. Jurecka, P. Sutta, A. Miskufova and T. Havlik, *J. Ceram. Soc. Japan* **110** (2002) 512.
15. T.K. Bhattacharya, A. Ghosh and S.K. Das, *Ceram. Int.* **27** (2001) 455.
16. W.L. Dekyser, R. Wollast and P.H. Duvigneaud, *J. Mater. Sci.* **4** (1969) 989.
17. D.A. Jerebtsov and G.G. Mikhailov, *Ceram. Int.* **27** (2001) 25.
18. A. Miskufova, T. Havlik, B. Bitschnau, A. Kielski and H. Pomadowski, *Ceram. Silik.* **59** (2015) 115.
19. W.-N. Zhang, X.-T. Wang and Z. Wang, *Solid State Pheno*. **281** (2017) 156.

Scientific Voyage
Vol. 1 No. 2
Page 39-48 (2020)

SCIENTIFIC VOYAGE
ISSN: 2395-5546

GCECT
Publication
Apr.-Jun.

Real-time invoice generation using Raspberry Pi on android platform

Aniruddha Sarkar[1] and Arkadip Ray[2]

[1]*Department of Computer Science and Engineering, Government College of Engineering & Ceramic Technology, Kolkata 700010, WB, India*
Email: sarkar4540@gmail.com

[2]*Department of Information Technology, Government College of Engineering & Ceramic Technology, Kolkata 700010, WB, India*
Email: arka1dip2ray3@gmail.com

***Abstract*:** Human operator based retail invoicing systems have put data accumulation, bill printing and real-time data processing into practice in retail outlets and supermarkets. These systems provide real-time centralised billing and provide invoicing facility; however can seldom be implemented in small and medium scale shops, due to size and implementation cost. The primary objective is to design a system, suitable for small and medium scale shop owners, which will allow the basic invoicing process – invoice generation, invoice printing and enlisting of invoices for further usage. In addition, the application will provide a fast and simple user experience, removing the requirement of a skilled operator.
Keywords: Android application; Socket protocol, MySQL database, Middleware server, Raspberry Pi

1. Introduction

Digital invoice generation, printing and storage systems are one of reliable and consistent systems used to keep track of the sales of a retail outlet or a store. It is relatively hassle-free and easy to use than maintaining pen-and-paper book of records for billing and invoices.

However, the available digital invoicing systems are designed for large-scale retail outlets and usually requires dedicated skilled operators at the terminals for data entry. Also, these systems come with significantly large price tag, due to hardware. Thus, for addressing these problems, the solution must be able to perform the following:

(i) Create invoices and provide real-time calculations, (ii) Provide user experience for faster checkouts, such that the storekeeper himself can operate the system in small and medium scale stores, (iii) Store invoices and enlist them later, (iv) Allow to export the collected data, (vi) Provide invoices in a digital printable document format, such as Portable Document Format (PDF) and (vii) Uses cost-effective hardware solutions.

In this paper, we have created one such digital invoicing system, which is usable in small and medium scale retail outlets and stores, and is able to perform the aforementioned. We have leveraged the Android platform in the system, as it is one of the major smartphone platforms around the world and has already reached millions, which include shopkeepers and retail outlet cashiers. This eliminates the possibility of buying costly hardware, thus reduces the cost of implementation. An Android Application is developed to provide the interface to use the system. The application is straightforward and can be used to create, store, enlist and print invoices. For faster checkouts, the application allows entry of items using barcode scanning and retrieval of information of previously added items. It communicates to a Middleware Server, to store, fetch and print invoices. The Server is integrated with MySQL database for storing and retrieving data. MySQL database provides additional functionalities for exporting data and connecting to other systems, which enables further analysis of the data. The Server, along with MySQL database and other components, is deployed on Raspberry Pi running Rasbian Operating System, which is connected to an Android smartphone using a Wi-Fi network. The server uses CUPS Printing Server to connect a printer with Raspberry Pi. The server stores the printed invoices in PDF format for digitally sending the documents to customers.

2. Related research works

This section provides the literature review of existing systems related to this research topic. Sung[1] presents the major players and analysis of global smartphone market. The paper also describes that smartphone market growth is overall constant and has already reached billions. Husni et al.[2] proposes Shopping Application System that uses NFC and RFID technology to allow the customers to have cashless billing using their Android smartphones. Samal et al. [4]

recommends a Shopping Application for customers to generate improved billing and cart management. Sainath et al. [3], suggests 1D-barcode scanning in a shopping cart and Sancheti et al. [5] uses 2D-barcode scanning in a shopping cart, to automate the billing process of a supermarket. Krishnamoorthy et al. [6] purports IoT technology to automate the shopping experience. These systems, due to their heavy customer interaction, are error-prone.

Sachdeva et al. [7] presents a review paper on Raspberry Pi, which discusses its benefits and usage. Dhage et al. [8], proposes Raspberry Pi as a Bluetooth enabled printer adapter. Krishnamoorthy et al. [9] introduced automated shopping experience based on embedded sensors using Raspberry Pi with ultrasonic sensor. Pangasa et al. [10] analysed the main components of automation in billing systemlike scanning system, microcontroller and transmission medium. Megalingam et al. [11] introduced automatic billing of products using an RFID reader.

3. Proposed system

This section describes the peripherals used, overall architecture of the system and the components of the proposed system, namely – Android Application, Socket Protocol, MySQL Database, Middleware Server and CUPS Print Server. Configuration of Raspberry Pi is also discussed here.

3.1 Materials

The peripherals required to build the proposed system are – Raspberry Pi, Android smartphone and Printer.

3.1.1 Rasberry Pi 3 B+

Every embedded system requires a Computing Unit, which is a Central Server or a specially designed Computer, for storing data, running various algorithms on the collected data and printing the data. The computing unit used in this system is Raspberry Pi3 B+. It is a fully-fledged computer with HDMI, USB, Ethernet, Wi-Fi and many other features packed into one business card-sized board. It is powered through a micro-USB port, using 5V 2A adapter. It contains an ARM-based SOC whichstores data in an 8GB microSD card and runs on Raspbian OS which is a Linux distribution containing X11 server and package management.

3.1.2 Printer

The proposed system requires a printer, for printing invoices or bills for customer. The printer used in this system is HP LaserJet Pro P1108. It is a monochrome Laser printer and is connected using USB technology.

3.1.3 Android smartphone

As of 2019, over 24,000 various types of Android smartphones are available in the market. These phones appear in various sizes as well as shapes, and comes with variety of hardware. These are usually equipped with touch screen. The benefit of an Android smartphone comes with the Android platform, which allows applications targeted for the platform to run on almost all of these devices. The Android smartphone we have used is Asus Max Pro M1.

3.2 Overall architecture

The android application has been used as an interface to control the system. It provides options to the user, based on the selection of which, the application sends data to the Middleware Server using the Socket Protocol. The Middleware Server communicates with the Android Application to receive data from the user, which is stored in the MySQL database and is sent to the printer. Fig 1 describes the overall architecture of the proposed system.A MicroSD card, with capacity of 8 GB has been used to store the Raspbian Operating System, Middleware Server, MySQL database, the Shell Scripts and CUPS server. The MicroSD card is inserted into the relevant slot in Raspberry Pi and powered on. An android phone is connected, using Wi-Fi, to the Access Point created by configuring the Raspberry Pi, thus enabling Socket Connection between the Android Application and the Middleware Server. The Printer is connected to the Raspberry Pi using a USB cable.

3.3 Android application

Android Platform supports a multitude of devices, and targeting the platform to build application allows us to target these devices. Applications targeted for the platform can be created using the Android Software Development Kit

or SDK. The SDK contains all toolchains required to create an Android Application. Android Studio is an Integrated Development Environment which provides various GUI features to control the Android SDK and allows rapid development. Fig 2 describes the flowchart of the Application. The application allows the shopkeeper or, the salesperson to create, save, view and print invoices. The application also allows fast retrieval of information regarding previously entered products using serial numbers. The serial numbers can be encoded in 1D as well as 2D barcodes. The application uses Zxing library to decode barcodes captured using the device's camera.

3.4 Socket protocol

Socket Protocol is based on the Transmission Control Protocol, and used to communicate between different applications. Socket allows communication between applications using IP addresses and port numbers. Socket follows the Server-Client model of communication, where one server can respond to multiple clients. The clients initiate the requests and the server responds.In this system, we have used the Java Standard Library's Socket Server and Socket classes to allow communication between Android Application and Middleware Server.

3.5 MySQL database

In this system, MySQL Database server has been used to store the data of customers, invoices and products. MySQL database is an open-source Relational Database which allows operations using Structured Query Language. A database is created in the MySQL server and two tables are created in it – Bill and Product. MySQL server exposes its API in multiple languages, thus one can use the APIs to perform further data analysis and operations on the collected data. The table schema used for creating Bill and Product table are shown in Figs. 3 and 4, respectively.

3.6 Middleware server

The Middleware server, which connects to the Android Application, MySQL server and Print Server, controls the flow of data among these components. The server has been written in Java language. Java provides a huge Standard Library, of which we have primarily used the Java Socket API and the Java Printing API. The Server creates a Socket Server instance and waits for the Android Application to make a connection. On every new connection, its input stream is read for data and command. If the command is known, the Middleware Server performs the respective operation and writes to the output stream of the connection. The operations allowed by the server are – saving and printing bill, enlisting previous bills and getting product description by serial. In Fig. 5, the flowchart describes the operations performed by the Middleware Server.

To save a bill, the server reads the customer and product details from the Socket. It then connects to MySQL server using Java Database Connection (JDBC) library and stores data into tables. To print a bill, the server reads the customer and product details from the Socket and translates it to Hyper Text Markup Language (HTML). It then uses the Flying Saucer Library's PDF printing to convert the translated data to a Portable Document Format (PDF) file. Finally, using the Java Printing API, the PDF file is sent to the CUPS print server.To enlist previous bills, the server queries the MySQL database using JDBC library and fetches the previous bills. It then writes the data queried, to the output stream of the Socket.To get product description by serial, the server reads the serial from the Socket's input stream and queries the MySQL database using JDBC library, whether the serial exists or not. If the serial exists, the product description is written to the Socket's output stream.After every operation, an acknowledgement containing the success or failure of the operation is prompted to the Socket's output stream.

3.7 Common Unix printing system (CUPS)

CUPS or Common UNIX Printing System is an Internet Printing Protocol based server, which receives print requests from other processes and sends them to the respective printer. CUPS server is required for the Java Printing API to work. Along with CUPS, the respective driver, which can control the printer, must also be supplied. The CUPS is configured for HP LaserJet Pro P1108, by editing the configuration file for the CUPS server.

3.8 Configuration of RASPBIAN operating system

Raspbian OS is the official Operating System for Raspberry Pi and is shipped as a disk image file with an .img extension. It is supplied with X11 Server, which enables Graphical User Interface by connecting a monitor. One can write this image to a microSD card and use the same to run the Raspbian OS in Raspberry Pi.Java Runtime Environment 8, MySQL Community Server 8.0 and CUPS Server, all compiled for ARM 64-bit architecture, is installed

within the OS. The compiled Middleware Server is then copied into the system. MySQL server is configured and the configuration to use the internal Wi-Fi module as a Access Point is written. The Access Point is configured to be password-protected using WPA2-PSK.

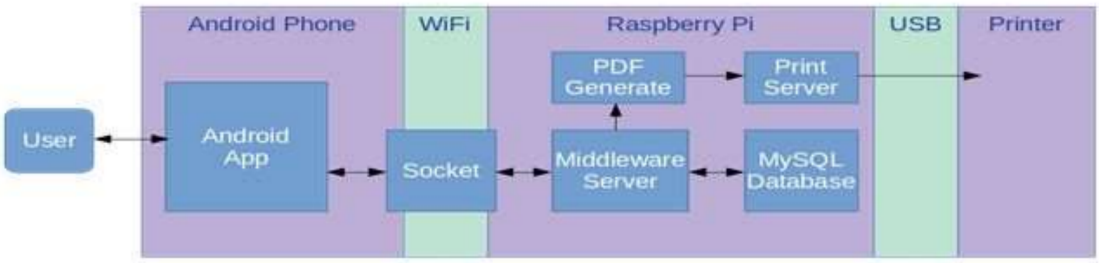


Fig. 1: Overall architecture of proposed system

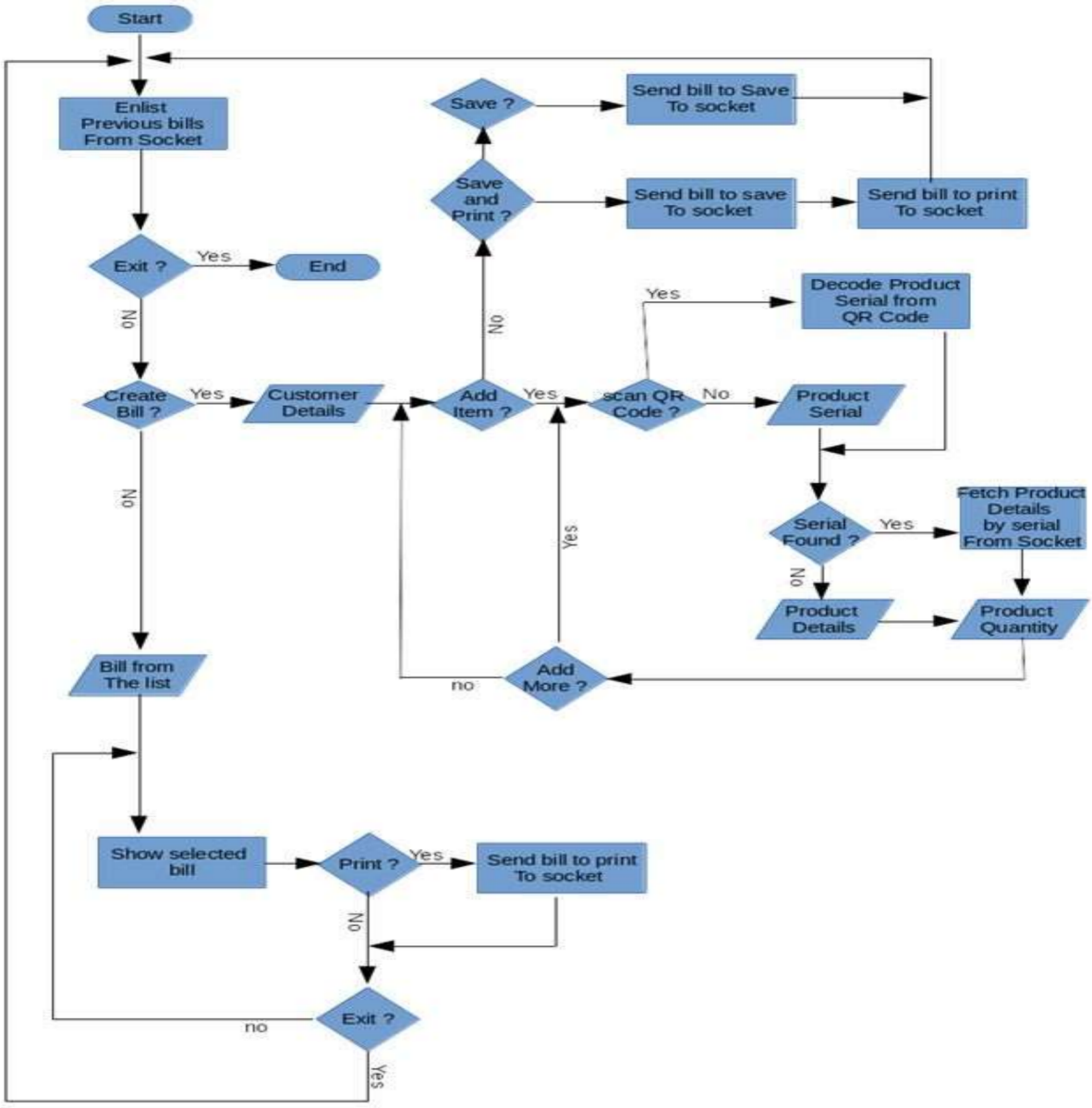


Fig. 2: Flowchart of android application

Field	Type	Null	Key	Default	Extra
id	int(6)	NO	PRI	NULL	auto_increment
cust_name	text	YES		NULL	
cust_phone	text	YES		NULL	
cust_address	text	YES		NULL	
billing_datetime	timestamp	NO		CURRENT_TIMESTAMP	on update CURRENT_TIMESTAMP

Fig. 3: Table schema for bill table

Field	Type	Null	Key	Default	Extra
id	int(6)	NO	PRI	NULL	auto_increment
name	text	YES		NULL	
serial	varchar(32)	YES		NULL	
quantity	int(6)	YES		NULL	
rate	text	YES		NULL	
bid	int(6)	YES		NULL	

Fig. 4: Table schema for product table

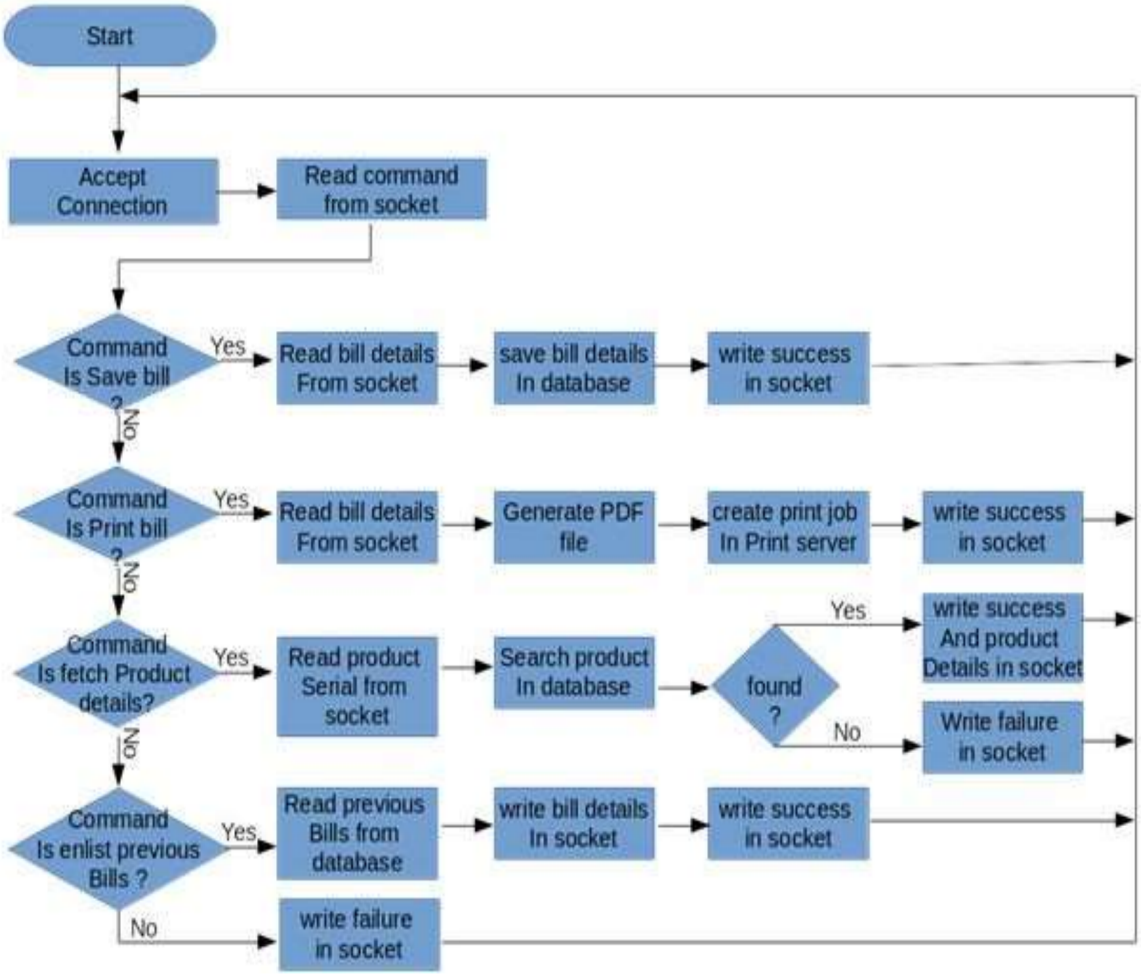


Fig. 5: Flowchart of middleware server

4. Analysis of testing results

This section describes the analysis of testing performed on the proposed system. The system is tested using a single smartphone, however, multiple smartphones can be simultaneously connected to the system.

4.1 Expense calculation and invoice creation

For creating invoices, the application asks for the customer details. Then for adding item, the item details can be either fetched by using serial number or can be provided directly in the input fields. After adding items, the quantity of an item can be adjusted accordingly, or can be made zero to remove the item. The total price of items in the cart is automatically calculated upon selection of items. An invoiceis generated by clicking the "Create Bill" button. Fig. 6(a) shows the application home window without any previously added invoices. Fig. 6(b) shows entry of data regarding invoice and cart expense calculation.

4.2 Storing invoices

The application sends the collected data to the Middleware server, which then updates the relevant table values in the MySQL database. One can store the created bill by clicking on the "Save" button. One can view the existing invoices by clicking on a previous bill entry in the home window of the application. Fig. 6(c) shows the response after clicking on "Save" button. Fig. 7 shows the MySQL database entries created after addition of an invoice. Fig. 8(a) shows the application home window after addition of an invoice. Fig. 8(b) shows a previously added invoice.

4.3 Printing invoices

The application sends the collected data to the Middleware server, which then generates a PDF document and sends the file to the CUPS server to initiate a Print Job. One can print the created bill by clicking on "Save and Print" button, or can print an existing bill by opening the bill and clicking on "Print" button as shown in Fig. 8(c). Fig. 9 shows the document sent for printing.

4.4 Faster checkout using barcode scanning

Barcode scanning has been implemented in the application using Zxing Library, which support 1D as well as 2D barcodes. The barcode is scanned to get a serial number. If an item with the same serial number is previously entered, then the latest details are fetched from the Database and shown to the user. This helps to make the checkout faster by preventing the user to enter the name and price of the item every time. Fig. 10 shows the fetching of a previously entered product detail using QR code scanning.

5. Implementation of proposed system

The designed system provides facilities for creating, storing and printing bills anddeliversa simple and faster user experience. In contrast to the pen-and-paper method of invoicing, this system is reliable and relatively error-free to many human errors. As minimum as one operator can implement the system who usually is the storekeeper himself. The employment of barcode scanning enhances the efficiency of the system by decreasing the time required to add an item in an invoice. Thus, the system is suitable for implementation in small and medium scale stores.

Fig. 6(a)

Fig. 6(b)

Fig. 6(c)

Fig. 6(a) Application home window without previous bills, (b) Creation of bill, (c) Response after saving bill

```
mysql> select * from product;
+----+-------------------+---------------+----------+------+------+
| id | name              | serial        | quantity | rate | bid  |
+----+-------------------+---------------+----------+------+------+
|  4 | Aactaril Soap 75g | 8901138834500 |        2 | 270  |    7 |
+----+-------------------+---------------+----------+------+------+
1 row in set (0.00 sec)

mysql> select * from bill;
+----+-----------------+---------------+--------------+---------------------+
| id | cust_name       | cust_phone    | cust_address | billing_datetime    |
+----+-----------------+---------------+--------------+---------------------+
|  7 | Aniruddha Sarkar | +917548950804 | Kolkata -10  | 2019-05-20 13:17:11 |
+----+-----------------+---------------+--------------+---------------------+
1 row in set (0.00 sec)
```

Fig. 7: Entries in MySQL database after saving bill

Fig. 8(a)

Fig. 8(b)

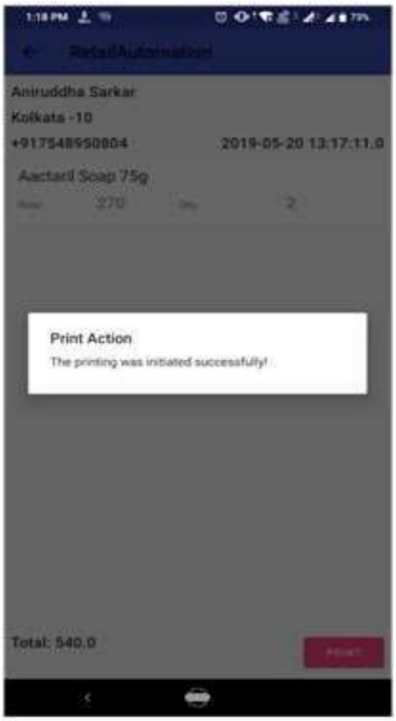


Fig. 8(c)

Fig. 8: (a) Application home window with saved bill, (b) Previous bills, (c) Response after printing

ABC Stores

Tel: +91-75400-0000, Address:73, Kolkata - 700010

2019-05-20 13:17:11.0

Customer Name: **Aniruddha Sarkar**

Customer Phone: **+917548950804**

Customer Address: **Kolkata -10**

Serial	Item	Quantity	Rate	Amount
1	Aactaril Soap 75g	2	270.0	540.0

Total: 540.0

For ABC Stores

This is a computer generated invoice. Not valid without authorized signatory.

Fig. 9: Invoice for printing

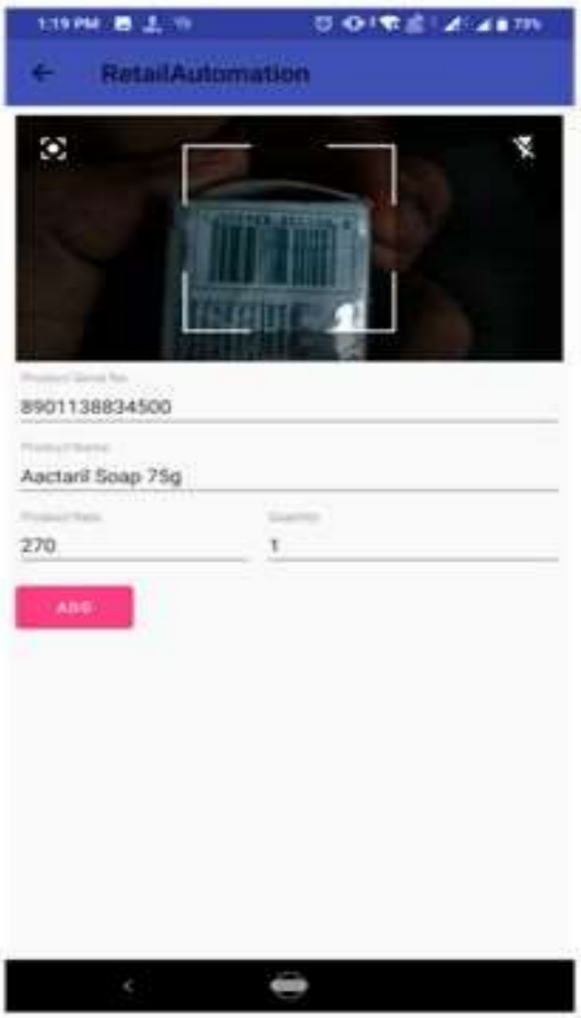


Fig. 10: QR code scanning for previously added products

6. Future works and conclusion

This work shows a successful demonstration of an invoicing system for small and medium scale stores, using which the basic billing process – creating, storing and printing bills can be done. The system is suitable for small and medium scale shops, but not suitable for large scale stores or supermarkets due to the lack of user management.

We can introduce more features into the application, including but not limited to – customer profile consisting of the products he/she buys, selling recommendations to help the shopkeeper, giving insights of the shop, recommendations for restocking of products, advertisement of products using SMS and sending bills via SMS service.Also, inventory management system, sending emails to customers containing the bills, and credit management for customer can be devised on the proposed system asadditional attributes. We can also include a payment gateway to allow cashless transaction.User management can be implemented in the system for keeping track of salespersons and improving security.

Acknowledgement:

We are indebted to Dr. Saibal Ray, Associate Professor (Physics), Government College of Engineering and Ceramic Technology, Kolkata for his guidance and constant encouragement in completing our research work.

References:

[1] H.C. Song, H.C., *Analysis of the global smartphone market and the strategies of its major players*, Hanyang University, University of Texas at Dallas (2010).

[2] E. Husni and S.P. Purwantoro, *Shopping application system with Near Field Communication (NFC) based on Android*, IEEE International Conference on System Engineering and Technology (ICSET), Bandung, Indonesia, Date of Conference: 11-12 September 2012.

[3] S. Sainath, K. Surender and V.V. Arvind, *Int. J. Comp. Appl.* **0975** (2014) 8887.

[4] S. Samal and S.P. Jena, 2014, *Int. J. Adv. Comp. Res.* **4** (2014) 236.

[5] K.K. Sancheti, P.G. Bhor and V.P. Patil, Int. J. Sci. Tech. Manag. Res. **3** (2018) 13.

[6] A. Krishnamoorthy, V. Vijayaranjan and R. Sapthagiri, Advances in Intelligent Systems and Computing **862** (2019), DOI https://doi.org/10.1007/978-981-13-3329-3_20.

[7] N.N. Dhage and S.D. Markande, *Bluetooth enabled printer adapter using raspberry pi,* IEEE International Conference on Pervasive Computing (ICPC), 8-10 Jan. 2015, Pune, India.

[8] P. Sachdeva and S. Katchii, *Int. J. Cur. Engg. Tech.* **4** (2014) 3818.

[9] A. Krishnamoorthy, V. Vijayarajan and R. Sapthagiri, R. (2019), *Automated Shopping Experience Using Real-Time IoT*, In: Satapathy S., Bhateja V., Somanah R., Yang XS., Senkerik R. (eds) Information Systems Design and Intelligent Applications. Advances in Intelligent Systems and Computing, Vol. 862, Springer, Singapore (2019).

[10] H. Pangasa and S. Aggarwal, *An Analysis of Li-Fi based Prevalent Automated Billing Systems in Shopping Malls*, 3rd International Conference on Computing Methodologies and Communication (ICCMC), IEEE, August 2019.

[11] R.K. Megalingam, S. Vishnu, S. Sekhar, V. Sasikumar, S. Sreekumar and T.R. Nair, *Design and Implementation of an Android Application for Smart Shopping,* International Conference on Communication and Signal Processing (ICCSP), pp. 0470-0474, IEEE (2019).

Scientific Voyage
Vol. 1 No. 2
Page 49-53 (2020)

SCIENTIFIC VOYAGE
ISSN: 2395-5546

GCECT
Publication
Apr.-Jun.

Helping stick for blind people

Anal Mandal[1] and Koustabh Sengupta[2]

[1]*Department of Electronics & Communication Engineering,*
Techno Engineering College, Banipur, Habra 743233, WB, India
E-mail: mandalanal@gmail.com

[2]*Department of Electronics & Communication Engineering,*
Techno Engineering College, Banipur, Habra 743233, WB, India
E-mail: koustabhsengupta97@gmail.com

Abstract: In India, as it is true for all developing countries, a considerable number of people, especially from the lower state of society, suffer from visual disabilities. Visual impairment or vision less may cause people difficulties with daily activities such as walking, driving, or socializing, to lead a life very dependent on others. Hence, there are millions of visually impaired or blind people in this world who are always in need of helping hands. For many years, these have become a well-known attribute to blind person's navigation and later efforts have been made to improve the cane by adding remote sensor. Blind people have problem when they walk on the street or stairs using white cane, but they have sharp haptic sensitivity. The electronic walking stick will help the blind person by providing a much more convenient means of life. The main aim of this project is to contribute our knowledge and services to the people who are visually challenged. In addition, it will help in automated driving. If this feature is installed in vehicles, then it will help to prevent accidental collisions.

*Keywords:*Obstacle detection; Voice commands; Handicapped aids; Navigation system

1. Introduction

No one cares about beggars, and in case of blind ones, they are just being neglected everywhere [1]. In India,also, the picture is same; sometimes they are killed in road while begging. Hence, in India we have to make some technology for them. Being an engineer, it is our duty to do so. Hence, we have tried to design a blind people's helping stick [2,3]. The circuit we have made can be installed in a stick for blind people. So that they can easily get notifications about the incoming obstacles in front of them [4,5].

Another thing is that the number of road accidents are rapidly increasing. To stop this, we can use the same technology to introduce "Vehicle Collision Protection System (VCPS)".

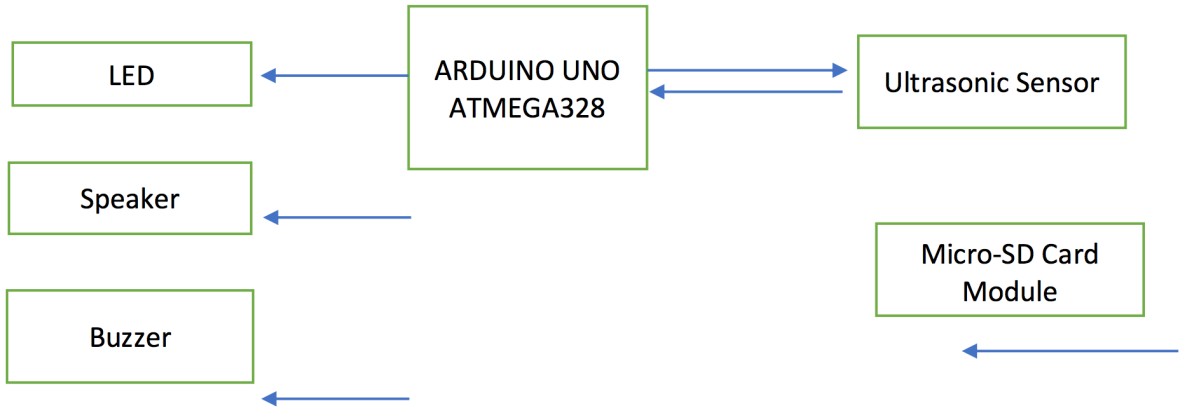
Keeping in mind both cases, we have tried to develop an obstacle detection system with voice alert. This project uses Ultrasonic Sensor to detect any obstacle in the given range [6,7]. If some obstacle detected then it sends the information to the Arduino and Arduino warns the user about an obstacle in the given range to prevent collision.

2. Working principle

The system consists of an Arduino UNO microcontroller, Ultrasonic Sensor, Micro-SD card adapter module, Buzzer, LED and Speakers. In figure, the block diagram of circuit and the circuit diagram is given below.

The obstacle detection part of the system contains two ultrasonic transmitters-receivers. It uses a 40KHz ultrasonic signal to acquire information and can detect the presence of any obstacle within the specified measurement range of approximately 0.03 to 4 meters.

It operates by sending out a pulse of ultrasound. Eventually the pulse is reflected from a solid object in the path of the pulse. The time between the outgoing pulse being transmitted and its echo being received corresponds to the distance between the transmitter and the object or the obstacle.



Block Diagram

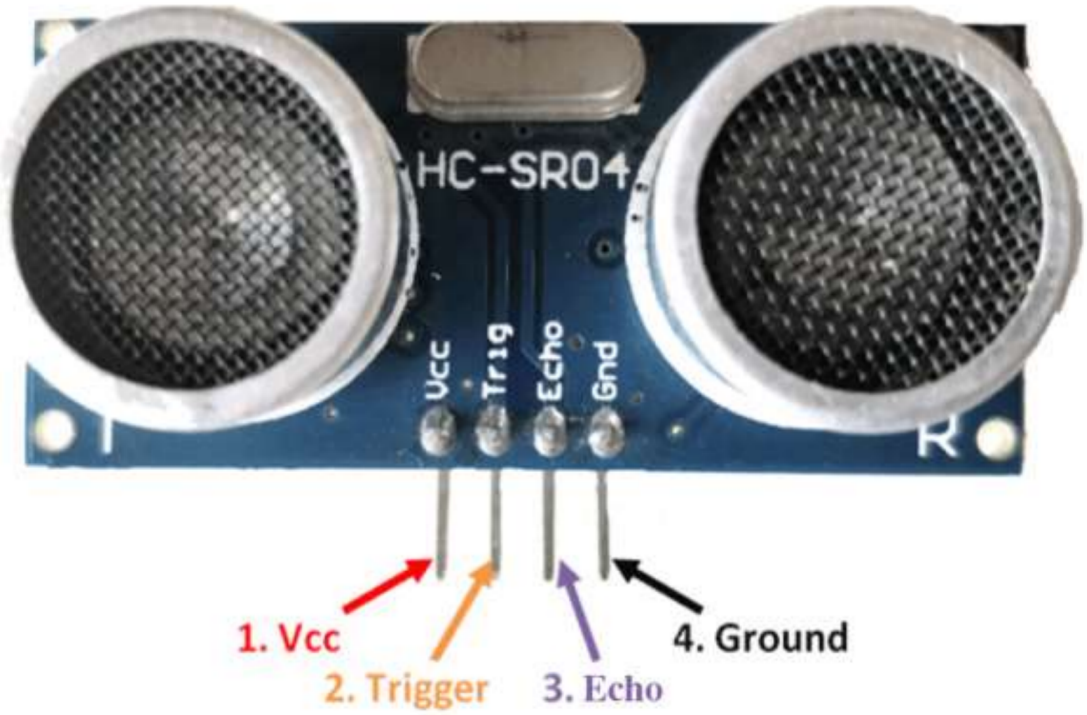
3. Technical specification

3.1 ARDUINO UNO

3.2 Specification of ARDUINO UNO

Feature	Specification
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage(recommended)	7-12V
Input Voltage(limits)	6-20V
Digital I/O Pins	14(of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40mA
DC Current for 3.3V Pin	50mA
Flash Memory	32KB of which 0.5KB used by bootloader
Serial Read Only Memory (SRAM)	2KB(ATmega328)
(EEPROM)	1KB(ATmega328)

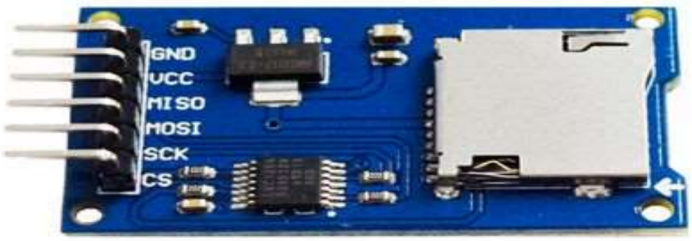
3.3 Ultrasonic sensor



3.4 Specification of ultrasonic sensor

Electrical Parameters	HC-SR04 Ultrasonic Module
Operating Voltage	DC-5V
Operating Current	15mA
Operating Frequency	40KHZ
Farthest Range	4m
Nearest Range	2cm
Measuring Angle	15 Degree
Input Trigger Signal	10us TTL pulse
Output Echo Signal	Output TTL level signal, proportional with range
Dimensions	45*20*15mm

3.5 Micro SD card adapter module



4. Photographs of working project

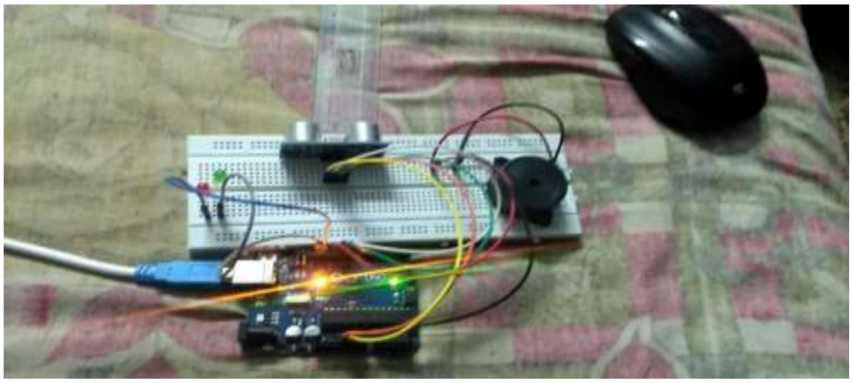


Fig 1 – Circuit with Obstacle

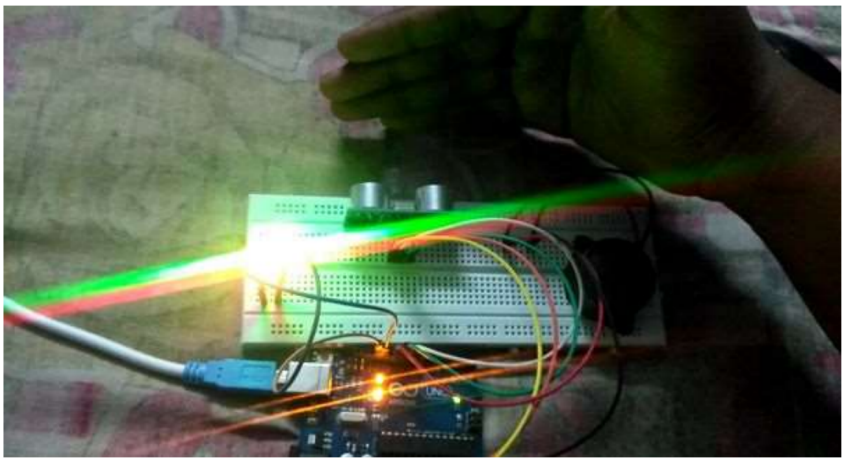


Fig 2 – Circuit without Obstacle

5. Future scope for improvement and conclusion

In case of the Blind Stick (Helping Hand) we can further improve by using a camera that will detect the type of obstacle in front of the user by image processing technique.

This device can be installed on vehicles to prevent road accident. With this device, we only can detect obstacle within its range and give a warning to its user until now. However, if we can detect the speed of an incoming object towards us and the speed of our own, then we can assume the time of collision. First, the device will warn the user to stop until the vehicle is inside the safety distance, and then it will pull an emergency safety break to stop the vehicle when it has crossed the safety distance limit. However, to prevent the collision, both the vehicles has to be equipped with this VCPS (Vehicle Collision Protection System) device. This will help our country to reduce the number of road accidents. This will give vehicles a step closer towards automated driving. In addition, after installing this we can call our vehicles as an Artificially Intelligent Vehicle.

Acknowledgement:

We express our gratitude towards Mr. Arkadip Ray, Mr. Dipanjan Sar and Dr. Maloy Kr. Chandra, Principal of Techno Engineering College, Banipur for providing us the insight and guidance in completing this project.

References:

[1] S. Udgirkar et al., *Int. J. Innovat. Res. Comp. Commun. Engg.* **4** (2016) 15918.

[2] M. Surve et al., *Int. J. Elect. Electron. Comp. Sys.* **4** (2016) 4.

[3] M. Bousbia-Salah et al., *An Ultrasonic Navigation System for Blind People*, IEEE International Conference on Signal Processing and Communications, Dubai, 1003 (2007).

[4] S. Chaurasia and K.V.N. Kavitha, *An electronic walking stick for blinds*, International Conference on Information Communication & Embedded Systems, Chennai (2014).

[5] R. Mohanapriya et al., *Int. J. Adv. Res. Electron. Commun. Engg.* **5** (2016) 2014.

[6] M. Pawar et al., *Int. J. Engg. Develop. Res.* **4** (2016) 144.

[7] V.S.S. Kaushalya et al., *Int. J. Sci. Res. Pub.* **6** (2016) 579.