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Centre for Theoretical Physics
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CENTRE FOR THEORETICAL PHYSICS (CTP) AT JAMIA MILLIA ISLAMIA: VISION AND PROSPECTS

The idea for the newly established Centre for Theoretical Physics (CTP) at JMI has grown out gradually from the deep concerns about theoretical physics in North India. In Indian universities there is large number of young and talented students and research scholars; the students require inspiration from scientists working on the fore fronts and the young researchers need encouragements, adequate facilities and interaction with experts. These are largely absent in the university sector in India. This situation can be altered by providing platform for interaction among different research groups and individuals in the universities with the leading experts in the field within the country and abroad. In fact, the Inter-university Centre in Astronomy and Astrophysics (IUCAA) was created with a mission to support astrophysics research in the university sector; we need more such Centres. The Centre for theoretical physics is deeply inspired by the philosophy of IUCAA.

In the year 1987, Professor Dadhich made several visits to Jamia in connections with his meeting at UGC related to IUCAA. Professor Q. N. Usmani was delighted to see the first proposal for IUCAA in the form of a small booklet; he was inspired by the idea of IUCAA. He then started writing a proposal for a Centre of Theoretical Physics at Jamia Millia without realizing that one needs a charismatic personality like J.V. Narlikar to achieve the goal. And the idea for CTP remained a dream for several years. In the years 2001 and 2002, Jamia Physics department organised two successful meeting on Astro-particle physics with an active support of IUCAA. In 2002, M. Sami was invited to IUCAA as a visiting fellow for a period of three years. Apart from his research, he participated in the other activities of the Centre and closely monitored the dynamics of this institution. Its committed, dynamic faculty, strong visitors program and their interaction with the young postdoctoral fellows and students in a friendly environment are key points for the success of IUCAA. Prof. Usmani and M. Sami were once again convinced to have CTP at Jamia; they have now seen a successful Centre functioning. Prof. Q. N. Usmani prepared a proposal for CTP around the same time which was submitted to UGC in 2005. However, it was a difficult task to get the proposal through. Then a miracle happened few months later, our Vice-Chancellor, Prof Mushirul Hasan succeeded in attracting financial support for various research centres including the CTP in the year 2006. Thus the CTP is a result of untiring efforts of Professor Hasan. It is now the duty of Jamia faculty to respond to the challenging work, the newly established Centres require.

The CTP at Jamia Millia is committed to frontline research in selected areas of theoretical physics and it would act as a hub of interaction among scientists in these areas.

The Centre for Theoretical Physics was formally inogurated by Prof. J. V. Narlikar and N. Prof Dadhich in November 2006. In the past two years or so, the CTP create an adequate infrastructure to support. Its small faculty, students and visitors.

The Research Focus of CTP

The research focus of the centre is high energy physics and cosmology. The work in cosmology is related to Cosmological Inflation and Dark Energy. The observations on Cosmic Microwave Background (CMB) confirm the predictions of *inflation*; the recent Nobel Prize to COBE team is great encouragement to all cosmologists. In spite of the striking features of inflation, its implementation yet remains adhoc. It is important to support the paradigm from a fundamental theory and the needle of hope points towards string theory, a consistent quantum theory of all interactions around Planck scale. It is quite possible that the early universe physics would also provide answer to the dark energy puzzle. A very active work now is going on at the interface of High Energy Physics and Cosmology. A close interaction of cosmologists and high energy physicists is needed to carry out this work. Within Indian context, the two communities are by and large hesitant to talk to each other. In view of the active work on the interface of cosmology and high energy physics, it would be important that we focus on this theme in the near future. The other important aspects of astrophysics (astrophysical processes, solar physics) and other branches of theoretical physics can be supported through visitors programs to begin with. In the second phase (next five years), we can actively turn to these areas also.

Thrust Research Areas

In view of the active themes in cosmology, we will focus on the following topics. We, however, do not undermine the importance of other topics in Astrophysics. We understand that issues of structure formation are of great importance and require immediate attention. We also appreciate that Solar Physics deals with important problems and it is not a narrow area of astrophysics as one might think. We plan to carry out work on astrophysical processes and solar physics through our visitors program in the first phase which would then allow us to bring these themes in the thrust areas of CTP in the next five years.

Cosmology

- Particle physics models of inflation and constraints from CMB observations.
- Construction of particle physics models of dark energy.
- Cosmological perturbations.
- Modified Gravity Theories and their implications for late time Cosmology.

High energy physics and its interface with cosmology

Modern Cosmology witnessed the first revolution in 1980 with the invent of *Inflation*. The paradigm has stood the test of theoretical and observational challenges in the last two decades. In spite of its successes, it still remains a paradigm in search of a viable model. Its realization is ad hoc and it lacks strong support from a fundamental theory. Many models can meet the observational constraints. Future precision experiments can help narrow the class of models. It is therefore not surprising that efforts are being made to derive inflationary models from string theory, a consistent quantum theory around the Planck's scale.

The high redshift supernovae observations in 1998 have thrown yet one more challenge to theoretical and observational cosmology. Universe seems to be in the phase of accelerated expansion at present. Cosmic speed up is either a result of dark energy, an exotic form of matter, which 70% of the total energy content of the universe or the modification of geometry itself. A host of models are under active investigations at present. Again, observations it many different schemes and it is hoped the the future precision experiments in the next decade would pin point a model or a class of models that can account for late time acceleration.

In view of the large amount of data related to supernovae, CMB, large scale structure and lensing, it is important to investigate the constraints on the model building. On the theoretical side, it is important to derive models of inflation and dark energy from fundamental theories of particle physics. String inspired models in cosmology have been under active consideration for past few years; Gauss-Bonnet gravity inspired by low-energy effective string action can lead to Dark Energy effects. String theory has a very rich structure of non-probative objects like D-branes; their dynamics might contain crucial information about dark energy. As for the string theory, the problem lies with the compactification process necessary to bring it down from 10(11)-dimensions to 4-dimensions we live in. The process is not unique. For instance, in the flux compactification scheme, there is a possibility of more than 10^{100} vacua and we should believe that we live in one of them. It is easier to believe in *God* than these vacua. String theory can never be verified directly, the required energies existed in the early universe and if string theory is correct, it might have left imprints on the cosmic evolution. String theorists are therefore hoping to get indirect evidence of their theory in cosmology. On the other hand cosmologists are looking for the justification of inflation and dark energy in a fundamental theory. This justifies the need to work on the interface of cosmology and high energy physics.

The Weinberg-Salam theory of electro weak interactions is based upon Higgs Mechanism of spontaneous symmetry breaking which gives masses to Z(W) bosons. The predictions of this theory are verified to great precision including various couplings of the theory. The irony is that Higgs particle is not yet discovered; its mass from few GeV (in the beginning) is pushed to few hundred GeV. If the Higgs sector is not strongly coupled, its discovery is around the corner. The other important issue is related to the hunting of super symmetric particles without which the string theory is in trouble; cosmology also badly needs them. In the next two years, these objects should be detected in super colliders. Thus the aforesaid areas are important. On the other hand, the issues related to strong coupling regime require large numerics, Lattice gauge theory has been very successful to tackle the non-perturbative problems of the field theory. In high energy physics, our focus will be on the following themes.

- D-brane dynamics.
- Phenomenology of unified and grand unified theories.
- Supersymmetry and super gravity and their phenomenological implications.
- Neutrino Physics

RESEARCH ACTIVITIES

Research interests of the Centre for Theoretical Physics include a variety of topics in theoretical physics, especially gravitation, cosmology and the interface between cosmology and particle physics, nuclear physics. This is an especially exciting time for this kind of science; a flood of data and surprising observational results are revolutionizing cosmology and advances in string theory have brought it into closer contact with low-energy physics and gravitation.

A. Universe: Its past, present and future

Accelerated expansion seems to have played an important role in the dynamical history of our universe. There is a firm belief that it has passed through inflationary phase at early times and there have been growing evidences that it is accelerating at present. The recent measurement of the Wilkinson Microwave Anisotropy Probe (WMAP) in the Cosmic Microwave Background (CMB) made it clear that (i) the current state of the universe is very close to a critical density and that (ii) primordial density perturbations that seeded large-scale structure in the universe are nearly scale-invariant and Gaussian, which are consistent with the inflationary paradigm. The five years WMAP data puts the inflationary models under Pressure. For instance, the steep brane world inflation, $\lamda \phy^4$ and hybrid models are nearly ruled out. The future Planck data may put tough constraints on the original model of Linde. This situation calls for the study of other models of inflation. Typically all the D-brane models lead to a very small ratio

Of tensor to scalar perturbations. Unfortunately, they are plagued with several problems apart from the reheating issues after inflation. Recently, a delicate model of D-brane inflation was studied by Klebanov and coauthors. The deep investigation of the model by M. Sami with collaborators S. Panda and S. Tsijikawa demonstrated that the model can not meet all the observational requirements. Further refinements of the scenario are needed. It is also important to revisit the original geometrical model of inflation due to A. Starobinsky. The reheating in this model needs fresh investigations. M. Sami is looking into this problem with S. Tsujikawa.

As for the current accelerating of universe, it is supported by observations of high redshift type Ia supernovae treated as standardized candles and, more indirectly, by observations of the cosmic microwave background ,galaxy clustering, baryon oscillations and weak lansing. The study of large scale structure reveals that around 30 percent of the total cosmic budget is contributed by dark matter. In view of the universe being critical, there is a deficit of almost 70 percent; the supernovae observations tell us that the missing component is an exotic form of energy with large negative pressure dubbed *dark energy*. The recent observations on baryon oscillations provides yet another independent support to dark energy. The idea that universe is in the state of acceleration is slowly establishing in modern cosmology.

The dynamics of our universe is described by Einstein equations in which the contribution of energy content of universe is represented by energy momentum tensor appearing on RHS of these equations. The LHS represents pure geometry given by the curvature of space time. Einstein equations in their original form with energy momentum tensor of normal matter can not lead to acceleration. There are then two ways to obtain accelerated expansion, either by supplementing energy momentum tensor by dark energy component or by modifying the geometry itself. In the frame work of DGP, the extra dimensional effects can lead to late time acceleration. The other alternative which is largely motivated by phenomenological considerations is related to the introduction of inverse powers of Ricci scalar to Einstein Hilbert action; the string corrections to gravity can also lead to dark energy like effects. The third intriguing possibility is provided by Bakinstein relativistic theory of modified gravity which apart from spin two field contains a vector and a scalar field. This heory can lead to Lorentz violation effects. M. Sami With V. Rubakov , M. Libanov and Tsujikawa studied a similar Lorentz violating model of dark energy. The work is followed by others. This model satisfies observational constraints and can lead to phantom dark energy.

Due to the simplicity of mechanism, most of the work in cosmology related late time acceleration is attributed to the assumption that within the framework of general relativity, cosmic acceleration is sourced by an energy-momentum tensor which has a large negative pressure. The simplest candidate of dark, yet most difficult from field theoretic point of view, is provided by cosmological constant. Due it non evolving nature it is plagued with fine tuning problem which can be alleviate in dynamically evolving scalar fields. A variety of scalar field models have been conjectured for this purpose including quintessence , K-essence and recently tachyonic scalar fields.

Apart from the dark energy problem, cosmological constant has other important implications, in particular, in relation to the age problem. In any cosmological model with normal form of matter, the age of universe falls short as compared to the age of some well known old objects found in the universe. Remarkably, the presence of L can resolve the age problem. Historically L was introduced by Einstein to achieve a static solution which turned out to be unstable. However, after the Hubble's redshift discovery in 1929, the motivation for having L was lost and it was dropped. Since then the cosmological constant was introduced time and again to remove the discrepancies between theory and observations and withdrawn when these discrepancies were resolved. It had come and gone several times making its come back finally, seemingly for ever!, in 1998 through supernova Ia observations. Recently much efforts have gone in understanding L in the frame work of quantum fields and string theory. It should be noted that the constant L enters into the equation naturally. It was introduced by Einstein in an ad-hoc manner to have a physically acceptable static model of the Universe and was subsequently withdrawn when Friedmann found the non-static model with acceptable physical properties. In classical physics, the cosmological constant is a free parameter of the theory and its numerical value should be determined from observations.

Cosmological constant can be associated with vacuum fluctuations in the quantum field theoretic context. Though the arguments are still at the level of numerology but may have far reaching consequences. Unlike the classical theory the cosmological constant L in this scheme is no longer a free. Unfortunately, the scale predicted by quantum field theory is far apart from the observed value of the cosmological constant *i* the *the famous cosmological constant problem*. Tremendous efforts have recently been made in finding out de-Sitter solutions in supergravity and string theory. Using flux compactification, KKLT formulated a procedure to construct de-Sitter vacua of type IIB string theory. They demonstrated that the life time of the vacua is larger that the age of universe and hence these solutions can be considered as stable for practical purposes. Although a fine-tuning problem of *£* still remains in this scenario, it is interesting that string theory gives rise to a stable de-Sitter vacua with all moduli fixed. We note that a vast number of different choices of fluxes leads to a complicated landscape.

In spite of the fact that introduction of L does not require an adhoc assumption and it is also not ruled out by observation as a candidate of dark energy. As mentioned above, the scenario base upon L is faced with the worst type of fine tuning problem. The numerical value of L at early epochs should be tuned to a fantastic accuracy so as not to disturb today's physics. As mentioned above the fine tuning problem can alleviated scalar field models of dark energy.

The scalar field aiming to describe dark energy is often imagined to be a relic of early universe physics. Depending upon the model, the scalar field energy density may be larger or smaller than the background (radiation/matter) energy density . In case it is larger than the back ground density, the density should scale faster than allowing radiation domination to commence which requires a steep scalar field potential. In this case the field energy density overshoots the background and becomes sub dominant to it. This leads to the locking regime for the scalar field. The field unlocks the moment its energy density becomes comparable to the background. Its further course of evolution crucially depend upon the form of field potential. In order to obtain viable dark energy models, we require that the energy density of the scalar field remains unimportant during radiation and matter dominant eras and emerges only at late times to give rise to the current acceleration of universe. It is then important to investigate cosmological scenarios in which the energy density of the scalar field mimics the background energy density. The cosmological solutions which satisfy this condition is called *scaling solutions*.

The exponential potentials can give rise to scaling solutions for a minimally coupled scalar field, allowing the field energy density to mimic the background being sub-dominant during radiation and matter dominant eras. In this case, for any generic initial conditions, the field would sooner or later Nucleosynthesis puts stringent restriction on any additional degree of freedom which translates into a constraint on the slope of the exponential potential. M. Sami with S. Tsujikawa investigated the Gauss-Bonnet corrected gravity and showed that it can lead to transit from scaling regime to dark energy at late times. Unfortunately, the model is under pressure from Nucleosynthesis constraint. The Gauss-Bonnet coupling also gets large at late times and can not be justified within the perturbative regime the Gauss-Bonnet correction is computed in string theory. M. Sami with collaborators, S. Nojiri, S. Odintsov, S. Jhingan and I. Thangkool investigated the higher order string curvature corrections and obtained de-Sitter solution. They also studied the non-locally corrected gravity and demonstrated that it can lead to phantom and non-phantom dark energy.

As mentioned above, the string inspired models have been under active considerations in cosmology for past few years. String theory, as well as the string inspired brane-world models such as the Randall-Sundrum one, suggest a modification of Newton's law of gravitation at small distance scales. Search for modifications of standard gravity is an active field of research in this context. It is well known that short range corrections to gravity would violate the Newton-Birkhoff theorem. M. Sami with collaborators, M. Azam, C. S. Uniikrishnan and and T. Shiromizu have recently proposed a torsion balance based experiment to search for the effects of violation of this celebrated theorem valid in Newtonian gravity as well as the general theory of relativity. They explained the main principle behind the experiment and provide detailed calculations suggesting optimum values of the parameters of the experiment. According to his work, the projected sensitivity is sufficient to probe the Randall-Sundrum parameter up to 10 microns. An experiment to measure this effect is being planned at TIFR in the group of Unikrishnan.

B. Aspects of Dark Energy

Last one year, we have been engaged in studying dierent observational as well theoretical aspects of dark energy.

In one of our papers, we examine flat models containing a dark matter component and an arbitrary dark energy component, subject only to the constraint that the dark energy satisfies the weak energy condition. We determine the constraints that these conditions place on the evolution of the Hubble parameter with redshift, $H(z)$, and on the scaling of the coordinate distance with redshift, $r(z)$. Observational constraints on $H(z)$ are used to derive an upper bound on the current matter density. We demonstrate how the weak energy condition constrains fitting functions for $r(z)$.

Most parametrizations for dark energy involve the equation of state w of the dark energy. In another work, we choose the pressure of the dark energy to parametrize. As p = constant essentially gives a cosmological constant, we use the Taylor expansion around this behavior p = .p0+(1.a)p1+... to study the small deviations from the cosmological constant. In our model, the departure from the cosmological constant behavior has been modeled by the presence of extra K-essence fields while keeping the cosmological constant term untouched. The model is similar to assisted inflation scenario in a sense that for any higher order deviation in terms of Taylor series expansion, one needs multiple K-essence fields. We have also tested our model with the recent observational data coming from Supernova type Ia measurements, the baryon oscillations peak (BAO) and the gas mass fraction of the galaxy clusters inferred from X-ray observations and obtain constraints for our model parameters.

The thawing quintessence model with a nearly flat potential provides a natural mechanism to produce an equation of state parameter, w, close to .1 today. We have examined the behavior of such models for the case in which the potential satisfies the slow roll conditions: [(1/V)(dV/d)]2 ≤ 1 and (1/V)(d2V/d2) ≤ 1, and we have derived the analog of the slow-roll approximation for the case in which both matter and a scalar field contribute to the density. We have shown that in this limit, all such models converge to a unique relation between 1 + w, , and the initial value of (1/V)(dV/d). We have derived this relation, and used it to determine the corresponding expression for w(a), which depends only on the present-day values for w and . For a variety of potentials, our limiting expression for w(a) is typically accurate to within w ≤ - 0.005 for w ≤ .0.9. For redshift z ≤ - 1, w(a) is well-fit by the Chevallier-Polarski-Linder parametrization, in which w(a) is a linear function of a.

We have also reconstructed the interaction rate of the holographic dark energy model recently proposed by Zimdahl and Pav´on in the redshift interval 0 < z < 1.8 with observational data from supernovae type Ia, baryon acoustic oscillations, gas mass fraction in galaxy clusters, and the growth factor. It shows a reasonable behavior in the sense that it increases with expansion from a small or vanishing value in the long past but starts decreasing at recent times. The later feature suggests that the equation of state parameter of dark energy does not cross the phantom divide.

Modifying the Einstein's gravity at large distance scales is one of the interesting proposals to explain the late time acceleration of the universe. In one of investigations, we have analysed the scaling solutions in modified gravity models where the universe is sourced by a background matter fluid together with a tachyon type scalar field. We have described a general prescription to calculate the scaling potential in such models. Later on we have considered specific examples of the modfications and have appleied our method to calculate the scaling potential and the scale factor. Our method can be applied to any modified gravity model, in the presence of tachyon field.

C. Modified Gravity Models

Although dark energy is the most straightforwad and popular choice, there have been other ideas to explain the late time acceleration of the universe. One interesting idea is to modify the gravity on large cosmological scales in such a way so that the universe starts accelerating at late times. One option is to modify the Einstein-Hilbert (EH) action by adding terms that blows up as the scalar curvature goes to zero. Although most of these models are in conflict with tests of GR in solar systems as they contain additional degress of freedom, there are certain models based on inverse power of more general curvature invariants which have been shown to agree with the solar system tests. The search for viable models that pass different observational bounds are still ongoing and this promising field is one of our future research interests.

We investigated the possibility of a dark energy universe emerging from an action with higher-order string loop corrections to Einstein gravity in the presence of a massless dilaton. These curvature corrections (up to R^4 order) are different depending upon the type of (super)string model which is considered. We find in fact that Type II, heterotic, and bosonic strings respond differently to dark energy. A dark energy solution was shown to exist in the case of the bosonic string, while the other two theories do not lead to realistic dark energy universes. Detailed analysis of the dynamical stability of the de-Sitter solution was also presented for the case of a bosonic string. A general prescription for the construction of a de-Sitter solution for the low-energy (super)string effective action was also indicated. Beyond the low-energy (super)string effective action, when the higher-curvature correction coefficients depend on the dilaton, the reconstruction of the theory from the universe expansion history can be done with a corresponding prescription for the scalar potentials.

D. Inhomegeneous Universe and Acceleration of the Universe

In the context of unmodified standard Einstein gravity, it can be possible to explain the current acceleration of the universe without adding extra dark energy component, but by invoking the effect of the backreaction of the inhomgeneity on the background expansion. One interesting aspcet of this line of investigation is to relate the epoch of structure formation to the onset of the acceleration which is still unexplained. Our future research goal is to calculate exactly the magnitudes of these backreaction and compare them with the observations. The idea of explaining the late time acceleration of the universe without invoking dark energy is very interesting and is certainly worthy of investigation.

E. Topological defects and Dark Energy

The exact nature of dark energy has been a subject of intense theoretical investigation. Although most promising and widely studied candidates are cosmological constant as well as so called quintessence and k-essence, one interesting possibility is the solid dark energy originally proposed by Bucher and Spergel (astro-ph/9812022) where the dark energy possesses resistances to pure shear deformations, resulting stability with respcet to small perturbations. Two possible candidates for this type of dark energy are the fraustrated network of cosmic strings and domain walls. The fact that these types of topological defects inevitably appear in models of spontaneous symmetry breaking make them more interesting. Despite this, the idea of topological defect network playing the role of dark energy and its subsequent cosmological tests has not been thoroughly investigated and this is one of our future research goals.

F. Spehrical Collapse and Dark Energy

One of the outstanding issues in dark energy studies is to find whether the dark energy is cosmological constant or is it dynamical. One of the important probes for this study is the evolution of inhomogeniety in the universe and for this it is essential we understand correctly how the presence of inhomogeneity affects the evolution of overdensities. One fundamental tool for this is the spherical collapse formalism. It decribes how small spherical overdensity decouples from the background evolution, slows down, and eventually turns around and collapse. It is generally assumed that the collapse is not complete so the system does not reach the singularity, instead it eventually virializes and stabilizes to a finite size. There are numerous studies of the generalization of spherical collpase formalism to include both homogeneous and inhomogeneous dark energy. But in most of the studies the dark energy component has been modelled as a perfect fluid with constant equation of state or as quintessence, i.e a minimally coupled scalar field with cannonical kinetic energy. Although K-essence models with non-cannonical kinetic energy is a promising idea for dark energy, till now it has not been studied for spherical collapse formalism. Spherical collapse formalism has not also been studied for modified gravity models. Our future research plan is to do a thorough investigation on spherical collapse formalism with k-essence as well as with modified gravity models.

G. High Energy Physics

In High Energy Physics we are presently working in the area of Neutrino Physics. Our work is also concerned with some beyond Standard Models of Particle Physics where candidates for dark matter may exist.

The currently available experimental data on neutrino oscillation indicate that the mass squared differences of neutrinos are quite small. Although the mass-squared differences and mixing angles (except q_{13}) are known from neutrino oscillation experiments, the absolute values of the neutrino masses still remain unknown. Depending on the scale, the pattern of neutrino masses may be hierarchical or quasi-degenerate in nature. In particular, if one assume that relic neutrinos constitute the hot dark matter of the universe, then the scale of neutrino masses are expected to be somewhat higher than their differences, and neutrinos are expected to be quasi-degenerate. Quasi-degeneracy of neutrinos has also been suggested in a number of theoretical models proposed in the literature. For example, considering neutrino masses as degenerate at some seesaw scale, various authors have shown that large mixing angles for solar as well as atmospheric neutrinos can be obtained after extrapolating masses and mixing to the weak scale using renormalization group equations.

Among the neutrino oscillation parameters, the values of two mass-squared differences and two mixing angles, viz. q_{12} and q_{23}, are already known to a reasonable degree from the solar and atmospheric neutrino data. However, quantities still unknown are the mixing angle q_{13}, mass scale *m* of the neutrinos and the *CP* violating phase l in the neutrino mixing matrix.

Recently, we have studied the interplay among the unknown quantities, namely, *m* -the neutrino mass scale, elements of the perturbation matrix which leads to quasi-degeneracy and q_{13} - one of the mixing angle for neutrinos, assuming that neutrinos are of Majorana nature and the masses are quasi-degenerate. We have taken into account the solar and the atmospheric data as well as neutrino less double beta decay constraint in our analysis. The maximum allowed value of q_{13} and the cosmological upper limit on the overall neutrino mass scale actually restrict the parameter space of the perturbation matrix lifting the degeneracy. This also enables us to constrain various theoretical models of the neutrino mass matrix, like say a simple model of neutrino mass using a leptonic Higgs doublet and three right-handed singlet fermions at TeV energy scale or below with discrete A_4 symmetry or model of degenerate neutrino mass with abelian family symmetry. This in turn determine the way degeneracy is lifted. We find that, corresponding to different values of *m,* there exist upper bounds on q_{13}, so that a precise determination of the latter in future may put upper limit on the former, and vice versa. One can also find a possible correlation between *m* and lower bound of q_{13}, depending on the relative strength of the unperturbed degenerate mass matrix and the perturbation. This work has been published in Physical Review D,76:073003,2007.

In principle the Dirac CP violating phase present in the simplest three neutrino model could be observed in neutrino oscillation experiments. Unless q_{13} is too small the oscillation experiments are most promising way to probe the Dirac CP phase in neutrino mixing matrix directly particularly in baseline experiments. The simplest measure of this violation would be the difference of oscillation probabilities of neutrinos of one flavor alpha to another flavor beta and that of oscillation probabilities of anti-neutrinos from alpha to beta.

However, there are other difficulties in probing this phase – as there are possible degenerate solutions of neutrino mixing parameters leading to equal probability of oscillation. Also in baseline experiments although neutrinos travel enough distance and oscillate but it also interact with earth's matter. Apart from standard interactions there could also be important non-standard interactions of neutrinos with matter. Works are in progress to find out ways to probe CP violating phase in presence of possible non-standard interactions.

Minimal extension of Standard Model with addition of second scalar doublet OR in minimal supersymmetric model with additional U(1) symmetry it might be possible to get a suitable candidate for cold dark matter. However, it is challenging to satisfy various cosmological constraints as well as various phenomenological constraints of Particle physics for such dark matters. Works in this direction are also in progress.

We hope to enhance research activities at our Centre through fruitful discussion among cosmologists, high energy physicists as well as nuclear physicists at the national and international level.

D. Gravitational Waves

A super-massive blackhole at the centre of a galaxy and a stellar blackhole orbiting around it is an ideal source for detection of gravitational radiation. In the last years of inspiral we expect the radiation reaction to be the dominant force driving the orbit closer to central black hole. This expectation is popularly summarized in literature by the statement that "the system is clean". However, such sources are by definition part of some galaxy and within the central parsec the mass of the disk is comparable to the mass of central black hole. This being so, another crucial question that arises is, can we neglect the tidal interactions of such sources with the disk in comparison with the radiation reaction force? Even bolder assertion would be to seek information about the disk from the gravitational waveforms.

In this project which is developed by Sanjay Jhingan, Takahiro Tanaka (Yukawa Institute, Kyoto) and Kimitake Hayasaki (Kyoto University) we are analyzing relationship in the parameters such as eccentricity, inclination, transition radius and the mass ratio of sources with the geometry of the disk such that the system can be treated as clean, i.e., incorporating the radiation reaction force is sufficient to give us accurate waveforms.

Having a clearer astrophysical perspective on the nature of our sources, we expect to be able to provide bounds in the initial parameter space for which templates needs to be constructed. Moreover, we also expect to extend this study to have better estimates on the number of such sources we expect to observe.

E. Gravitational Collapse

Due to growing evidence of naked singularity formation in spherically symmetric models, recently considerable attention is being devoted to explore collapse with different symmetries. Most of the work in non-spherical collapse is with cylindrical models. Thorne's seminal analysis of cylindrical collapse led him to formulate the **hoop conjecture**, which essentially states that horizons form when and only when the gravitational mass of the system is confined to a maximum "radius" in every direction. In no model so far the hoop conjecture is refuted, even though there is a growing family of counter examples to cosmic-censorship conjecture.

The source term in most of these examples with cylindrical symmetry, as also the ones earlier, is either purely dust collapse or is usually motivated from counter-rotating particles, without rotation which would manifest kinematically, i.e. in the form of the metric. The solution we present differs from these solutions in this aspect, which is crucial for our theme of studying rotation represented in initial data.

A precise characterization of the statement, weather Cauchy evolution leads to naked singularities or not, without reference to any model or symmetry would need a better understanding of the initial data profiles, especially from the physical angle. As a first step in this direction, we have attempted to include a physical parameter other than the usual ones, i.e., density or pressure gradients. We have chosen to present a model where one retains the essential features like regularity of data but has the feature of rotation naturally incorporated in it as initial data. Although cylindrical symmetry is assumed, it simplifies the calculations to bring out the role played by rotation.

In this work we (Sanjay Jhingan, Sukratu Barve and A. Prasanna) have provided a dynamical background for studying collapse with rotation leading to curvature singularities, analyzing the geodesics to incorporate the effect of inertial frame dragging consistently. We find that when the system is axially free, and there is no initial acceleration, both naked and covered singularities are formed depending upon the rotation supplied initially. Positive acceleration towards the center prevents any geodesics from emerging an effect is insensitive to rotation. Further, if the initial acceleration is away from the center or if axial freedom itself is relaxed, the singularity does not form in this model.

E. A Renormalization Group approach to solve Einstein equations

The Einstein equations form a highly nonlinear system, and in most of the cases their non-solvability is the key hindrance in analysing relativistic systems. The technique of renormalization group was applied to solving partial differential equations by Bricmont and Kupiainen. We have adapted this technique to analyse Einstein equations. In a recent paper (Sanjay Jhingan and Jesus Ibanez) we revisited the problem of generalized cosmology using renormalization group approach. A complete analysis of these cosmologies, where specific models appear as asymptotic fixed-points is provided. We showed that in modified cosmology, which imply modification of Friedman equation in the scaling regime, there is a "anomalous dimension" parameter which decides if we have either power-law or exponential potential in the scaling regime.

VISITS OF FACULTY MEMBERS

- Dr. Sanjay Jhingan has visited Department of Theoretical Physics, University of Basque Country, Bilbao Spain and Department of Fundamental Physics, University of Barcelona, Spain during 15 March 2007 - 14 April 2007.
- M. Sami has visitred Gunma Technical University & Nagoya University, Japan.
- Sanjay Jhingan has visited IUCAA & TIFR.
- Rathin Adhikari visited Harish-Chandra Research Institute, Allahabad during 25th May - 16th June, 2007 for scientific collaboration.
- Anjan Ananda Sen has visited Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italay in July 2007 for a month.
- Anjan Ananda Sen has visited Statistical Physics Group, University of Autonoma, Barcelona, Spain in November 2007 for a month.
- Rathin Adhikari visited Deptt. of Physics, University of Calcutta during 26th December - 5th January, 2008.
- Anjan Ananda Sen has attended the workshop on "Brane Cosmolgy" at IIT Kharagpur and delivered a invited lecture on "Inflation in Brane Models" in February 2008.
- Rathin Adhikari attended workshop "Nu-Horizons" held at HRI, Allahabad during 13-15 February, 2008.

PH.D. PROGRAM

Two semester course was offered to the students who joined Centre for Theoretical Physics for Ph.D. program.

Broad areas convered during the course work:

1st Semester	*2nd Semester*
1. Mathematical Physics - I	1. Mathematical Physics - II
2. Quantum Field Theory	2. Particle Physics
3. Gravitation / Nuclear Physics I	3. Cosmology/Nuclear Physics II/Particle Phenomenology
	4. Structure and evolution of scientific thoughts.

INTERACTION WITH DEPARTMENT OF PHYSICS, JAMIA MILLIA ISLAMIA

The very idea for a Centre for Theoretical physics was conceived by some members of the Department of Physics and therefore it is very natural to have a close collaboration with the department of Physics.

CTP and department of physics enjoy a good working relationship. The head of the Physics department is a member of our board of studies. There is participation by members of the respective departments in the activities of common scientific interest.

MSc. and PhD students of the department of physics benefit from the seminar organised at the centre.

Members of CTP are involved with the academic activities (teaching) at the department of physics. There will be 2 to 3 courses taught by the CTP members at the department in the academic session 2008-2009. MSc. students are doing projects with the faculty members of the CTP.

ACADEMIC CALENDER OF CTP (2008 - 2009)

May 2008	:	Graduate School Ends
August 2008	:	New Session of Graduate School begins
September 2008	:	One-day science outreach program activity for Jamia school children and graduate students of science faculty
October 2008	:	Series of lectures on gravitation and cosmology by Prof. Jayant Narlikar, Prof. Naresh Dadhich & Prof. Pankaj Joshi
December 2008	:	Workshop on Dark Energy and its Alternatives
December 2008	:	First semester of Graduate School ends
January 2009	:	Second semester of Graduate School begins
February 2009	:	13th Regional Meeting on Mathematical Physics: High Energy Physics, Gravitation and Cosmology
April 2009	:	Graduate School ends

PUBLICATIONS

1. String-inspired cosmology: Late time transition from scaling matter era to dark energy universe caused by a Gauss-Bonnet coupling.
   Shinji Tsujikawa and M. Sami
   JCAP 0701:006, 2007

2. A Note on the Viability of Gauss-Bonnet Cosmology
   R. Chingangbam, M. Sami, P.V. Tretyakov and A.V. Toporensky
   Phys. Lett B 66: 162, 2008

3. Prospects of inflation in delicate D-brane cosmology
   Sudhakar Panda, M. Sami and Shinji Tsujikawa
   Phys.Rev.D76: 103512, 2007

4. UV stable, Lorentz-violating dark energy with transient phantom era.
   Mazim Libanov, Eleftherios Papantonopoulos, Valery Rubakov, M. Sami and Shinji Tsujikawa
   JCAP 0708: 010, 2007

5. String-inspired cosmology: Late time transition from scaling matter era to dark energy universe caused by a Gauss-Bonnet coupling.
   Shinji Tsujikawa and M. Sami.
   JCAP01, 006(2007)

6. Models of Dark Energy
   M. Sami
   The Invisible Universe: Dark Matter and Dark Energy, edited by Lefteris Papantonopoulos. Lecture Notes in Physics #720, Springer, New York, NY USA, 2007

7. Dark energy generated from a (super) string effective action with higher order curvature corrections and a dynamical dilaton
   E. Elizalde, S. Jhingan, S. Nojiri, S.D. Odintsov, M. Sami and I. Thongkool
   Eur.Phys.J.C53:447-457, 2008

8. Lepton flavour violation in the little Higgs model.
   S.Rai Choudhury, A.S. Cornell, A. Deandrea, Naveen Gaur and Ashok Goyal
   Phys.Rev.D75:055011, 2007

9. Renormalization Group Approach to Generalized Cosmological Models
   J. Ibanez and S. Jhingan
   Int.J.Theor.Phys.46:2313-2325, 2007

10. Neutrino mass scale and the mixing angle q_{13} for quasidegenerate Majorana neutrinos.
    R. Adhikari, A. Datta and B. Mukhopadhayaya
    Phys. Rev D76, 073003, 2007

11. Bulk antisymmetric tensor fields in a Randall-Sundrun Model
    B. Mukhopadhyaya, S. Sen and S. Sen Gupta
    Phys.Rev.D. 76:121501, 2007

12. The Weak Energy Condition and the Expansion History of the Universe.
    A.A. Sen and Robert J. Scherrer
    Phys. Lett. B659: 457, 2008

13. Deviation From LambdaCDM: Pressure Parametrization
    A.A. Sen
    Phys.Rev.D77:043508,2008

14. Thawing Quintessence with a nearly flat potential
    Robert J. Scherrer and A.A. Sen
    Phys.Rev.D77:083515, 2008

15. Reconstructing the interaction rate in holograhic models of dark energy
    A.A. Sen and D. Pavon
    Phys.Lett.B.664:7, 2008

VISITORS PROGRAM

Visitors program is one of the integral parts of CTP. The Centre wants to support visitors which would include experts in the thrust areas plus the long term visitors in allied areas from universities and colleges. CTP should provide a platform for their interaction with the faculty and the visiting experts. The Centre has provision to support visiting fellows, visiting professors and a sizable number of short term visitors from India and abroad.

The duration of short-term visits may be ranging from 2 weeks to 2 months. Centre will provide TA/DA to such short-term visitors. In general CTP highly encourages academic people to visit the Centre.

VISITORS DURING ACADEMIC YEAR APRIL 2007 – APRIL 2008

- Prof. Ashok Goyal (Delhi University)
- Prof. Amit Roy (Director, Inter University Accelerator Center, Delhi)
- Prof. A.N. Mitra
- Prof. Ajit Kembhavi, IUCAA, Pune
- Prof. Bikash Sinha, Director, SINP, Kolkata
- Dr. B. Ananthanarayan, Centre for High Energy Physics, IISc, Bangalore
- Prof. Ernest Ma, Physics & Astronomy Deptt., University of California, Riverside, USA
- Dr. Gianluca Clacagni (Astronomy Centre, University of Sussex, UK)
- Dr. Ishwaree Neupane, University of Canterbury, New Zealand
- Prof. J. Maharana, Institute of Physics, Bhubaneswar
- Dr. Jaydeep Majumder, Helsinki University Finland
- Prof. Martin Rivas, University of The Basque Country, Bilbao, Spain
- Prof. M. Mofazzal, BARC, Mumbai
- Prof. Naresh Dadhich (Director, IUCAA, Pune)
- Prof. N. V. Mitskievich, Deptt. of Theoretical Physics, Peoples Fellowship University, Moscow
- Prof. N. D. Hari Dass, DAE-Ramanna Fellow, IISc Bangalore
- Prof. Q.N. Usmani
- Prof. Ram Gopal Vishwakarma, Universidad Autónoma de Zacatecas, Zacatecas, ZAC (MEXICO)
- Dr. Shrirang Deshingkar, HRI, Allahabad
- Prof. Sudhakar Panda (Harish Chandra Research Institute, Allahabad)
- Dr. Shinji Tsujikawa (Gunma Technical University, Japan)
- Prof. Sirajul Hasan, Director, Indian Institute of Astrophysics, Bangalore
- Prof. S. Wadia, TIFR, Mumbai
- Dr. Sergio Palomares - Ruiz, University of Durham, United Kingdom

EXPECTED VISITORS DURING THE YEAR APRIL 2008 – APRIL 2009

Indian Visitors

- Arti Deshmukhiya, Silchar University
- Jayant Narlikar, IUCAA, Pune
- Pankaj Joshi, TIFR, Mumbai
- Spenda Wadia, TIFR, Mumai
- T. Padmanabhan, IUCAA, Pune
- G.W. Deshkar
- Naresh Dadhich, IUCAA, Pune
- Shirang Desingkar, IUCAA, Pune
- Sushant Ghosh, BITS, Dubai Campus
- Varun Sahni, IUCAA, Pune

Foregn Visitors

- A. Toporansky, Moscow, Russia
- D. Polarski, Université de Tours, France
- L. Perivolaropoulos, University of Ioannina, Greece
- M. Zalaletnikov, Tashkent University
- Murtaza Ghulam Husain
- Nino Flachi, Yukawa Institute, Kyoto, Japan
- Reza Tavakol, Queen Marry College, London
- S. Tsujikawa, Tokyo Science University, Japan
- S. Nojori, Nagoya University, Japan
- T. Shiromizu, Tokyo Institute of Technology, Japan
- Takahiro Tanaka, Yukawa Institute, Kyoto, Japan

SEMINAR BY VISITORS

1. **String Cosmology**
   Prof. J. Maharana, Institute of Physics, Bhubaneswar

2. **Slow-fast-slow role transitions during inflation and their signatures in the power spectrum.**
   Dr. P. Chinganbam

3. **Gravity: A 100 years after Einstein's happiest thought**
   Prof. S. Wadia, TIFR, Mumbai

4. **From Newton's Laws to Feqnman's Dream**
   A.N. Mitra

5. **Gravity and Higher Dimensions**
   N. Dadhich, IUCAA, Pune

6. **Probing New Physics at the International Linear Collider With Polarized Beams**
   Dr. B. Ananthanarayan, Centre for High Energy Physics, IISc, Bangalore

7. **Kinematical formalism of elementary spinning particles**
Prof. Martin Rivas, Department of Theoretical Physics, University of The Basque Country, Spain

8. **Can we see naked singularities?**
Dr. Shrirang Deshingkar, HRI, Allahabad

9. **Einstein's Gravity Under Pressure**
Prof. Ram Gopal Vishwakarma, Universidad Autónoma de ZacatecasZAC (MEXICO)

10. **"Accelerating Universes and String Theory"**
Prof. Ishwaree Neupane, University of Canterbury, New Zealand

11. **Inflationary Universe & String Theory**
Dr. Jaydeep Majumder, Helsinki Institute of Physics, University of Helsinki, Finland

12. **Supermassive Black Holes**
Prof. Ajit Kembhavi, IUCAA, Pune

13. **Core Nucleus Dynamics in Ù - Hypernuclei**
Prof. Q.N. Usmani

14. **Testing Dark Matter with Neutrino**
Dr. Sergio Palomares - Ruiz, University of Durham, United Kingdom

15. **Utility of a Special Second Scalar Doublet**
Prof. Ernest Ma, Physics & Astronomy Deptt., University of California, Riverside, USA

16. **A_4 Symmetry and Neutrinos**
Prof. Ernest Ma, Physics & Astronomy Deptt., University of California, Riverside, USA

17. **The Large Hadron Collider - New Challenges in a New Era**
Prof. Biswarup Mukhopadhyaya, Harish-Chandra Research Institute, Allahabad

18. **"The Culture of Non-Commutativity in Mathematics and Physics"**
Prof. Tulsi Dass, ISI, Delhi

Students and Visitors during a seminar at CTP

PUBLIC OUTREACH PROGRAM

One of the important activities at Centre for Theoretical Physics is its public out reach program. Though our primary concern is doing theoretical research in some of the fundamental issues of nature, we are mindful of the fact that science whether it is theoretical or experimental is done with public money.

The science outreach program has two primary goals:

1) To organise public lectures which can reach a wide audience in all disciplines?

2) To organise popular science activities for Jamia school children and undergraduate students.

The first popular lecture was delivered by Padma Shree Prof. T Padmanabhan, on History of the Calendar.

Now we are planning to organise a workshop for Jamia school children and undergraduate students. It will be one day workshop. In the pre lunch session we plan to have

1) General introduction to astronomy

2) Hands on activity like:
   i) making sundial,
   ii) make a hand held spectroscope

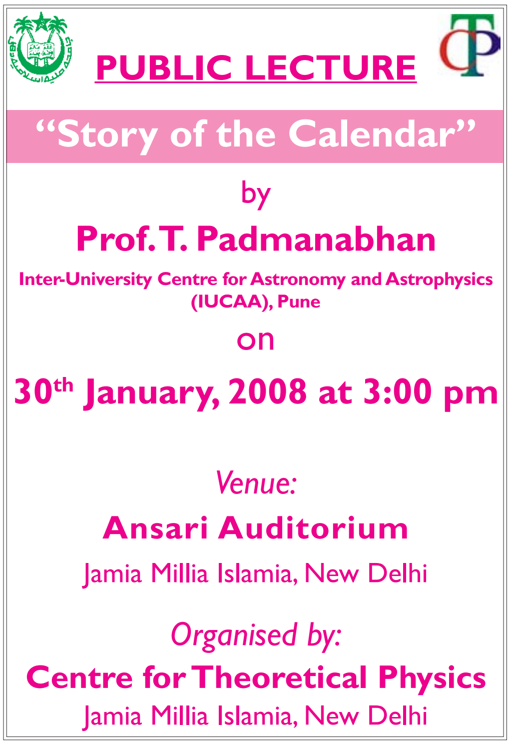
3) Making planetary model.

In the post lunch session we will have

4 Introduction to astronomical telescope

5 Making an astronomical telescope.

Dr. Arvind Pranjape of Inter-University Centre for Astronomy and Astrophysics has agreed to come to Jamia and conduct this activity. There will be a state of the art planetarium for display. The working telescopes which students will assemble will be given to Jamia School and the Department of Physics.



ONE-DAY MEETING ON PERSPECTIVES IN HIGH ENERGY PHYSICS & COSMOLOGY

One-day meeting on Perspectives in High Energy Physics & Cosmology was held on 17th September, 2007. The meeting was held on the occasion of opening of Graduate School of the Centre for Theoretical Physics. The experts in High Energy Physics and Cosmology gave broad overview of research activities in their areas. List of speakers:

- Prof. S. Wadia
- Prof. N. Dadhich
- Prof. A.N. Mitra

Prof. Spenta Wadia

TWO-DAYS MEETING ON PROSPECTS AND PROBLEMS IN GRAVITATION AND COSMOLOGY

Two-days meeting on Prospects and Problems in Gravitation and Cosmology was held during 29-30 January, 2008. The lecture detail is as follows:

1. **Felicitation Session:** Presentation of memento and introduction by M Sami
2. **T. Padmanabhan:** A career in Physics: Physicist as an Artist
3. **T. R Seshadri:** CMB polarization from cosmic magnetic field
4. **G. Y. Mahajan:** Particle creation & classicality in quantum field theory
5. **J. S. Bagla:** Gravitational Clustering in the Non-Linear Regime: Challenges and Insights
6. **S. Sarkar:** Subleading contribution to blackhole entropy in Brick-Wall approach
7. **L. Sriramkumar:** Cooling and reheating the universe
8. **C. S. Unnikrishnan:** Physics in the once-given Universe: Cosmic Relativity and dynamics"
9. **M. Azam:** Proposal for an experiment to search for Randal Sundrum type corrections to the Newton's Law of gravitation.
10. **H. K. Jassal:** Dark Energy : Theoretical and Observational Issues
11. **D. A. Kothawala:** Quantum Gravitational corrections to thestress-energy tensor around the BTZ black hole

Prof. T. Padmanabhan delivery lecture during the meeting

WORKSHOP (HEPCOS - 2008)
High Energy Physics & COSmology

With the aim of more discussions among high energy physicists and cosmologists in the country, Centre for Theoretical Physics at Jamia Millia Islamia organized a 2-day workshop entitled - 'HEPCOS-2008' on March 11-12, 2008. It was inaugurated by eminent scientist Prof. A. N. Mitra. About 15 scientists from 7 research institutes and 4 universities/institutes delivered lectures . Faculty members, Ph.D students and M.Sc students from Delhi University, J N University and Jamia Millia Islamia participated in this workshop. Prof. Amitava Raychaudhuri, Director of Harish-chandra Research Institute, Allahabad talked about the current development in neutrino physics. Prof. N. K. Mondal, Spokesperson of Indian Neutrino Observatory told about the present status of the observatory which is going to be one of the biggest laboratory in the area of Nuclear and High energy Physics in the country. Some of the topics widely covered in this workshop are Neutrinos, Dark matter, Searches of Supersymmetric particles & Higgs particle at Large Hadron Collider, CMB spectrum, Black holes and String theory. At the end of workshop, in his speach Prof. Raychaudhuri appreciated the developments of Centre for Theoretical Physics. List of speakers, their affiliation and the topic of their lectures are given below :

1) Pijushpani Bhattacharya, SINP, Kolkata
   Dark matter in Milky way

2) Sourov Roy, IACS, Kolkata
   Implication of non-universal gaugino masses on the dark matter and higgs searches

3) Amitava Datta, IISER, Kolkata
   Dark Matter and SUSY searches at LHC

4) Anindya Datta, Physics Deptt., Univ. of Calcutta
   Footprints of Supersymmetry on ice-(cube) ?

5) K. Narayan, CMI, Chennai
   Cosmologies with Big Bang singularities and their gauge theory duals.

6) V. Ravindran, HRI, Allahabad
   Higgs production at LHC

7) Syed Afsar Abbas, CTP, JMI, Delhi
   On confinement and deconfinement in QCD

8) N.D. Hari Dass, CHEP, IISc., Bangalore
   On Direct Detection of Cosmic Neutrino Background

9) Amitava Raychaudhuri, HRI, Allahabad
   Neutrino Physics and INO

10) N.K. Mondal, TIFR, Mumbai
   Status of INO

11) P.K. Tripathy, IIT, Madras
   Non-supersymmetric attractors in string theory and their stability

FELICITATION OF PROF. MUSHIRUL HASAN, VICE CHANCELLOR, JAMIA MILLIA ISLAMIA

The Centre for Theoretical Physics (CTP) organised a program to felicitate Prof. Mushirul Hasan, Vice Chancellor, Jamia Millia Islamia on his being awarded the **"Padamashree"**. This program was held on the evening of 18th January, 2008.

The Vice Chancellor was greated by the members of the CTP and various Head of Departments, and Directors of the Research Centres of Jamia Millia Islamia.

Prof. Mushirul Hasan also spoke on the occasion. He highlighted some of the important developments and changes Jamia Millia Islamia has undergone in past few years. He also motivated the younger generations to come forward and take active participation in building Jamia Millia Islamia.

LECTURE COURSES

1. LECTURE COURSE ON "KINEMATICAL FORMALISM OF ELEMENTARY SPINNING PARTICLES"

A lecture course for graduate students and young researchers was organized at the Centre from 7th to 13th November. Prof. Martin Rivas from Department of Theoretical Physics, Basque University, Spain, in a set of 3 lectures reviewed Kinematical formalism of elementary spinning particles.

Course Contents:

1. General formalism
2. Examples of relativistic and non-relativistic spinning particles
3. Quantization of the models
4. Dirac particle
5. Some spin features and predictions of the formalism

2. TOPICAL COURSE IN GRAVITATION

A lecture course for graduate students and young researchers was organized at the Centre from 2nd week of October, 2007 until 12th December, 2007. Prof. N.V. Mitskievich from Department of Physics,Peoples Friendship University, Moscow, in this course reviewed basics of Gravitation, Blackhole Physics and Cosmology.

CENTRE'S WEBSITE & ONLINE LIBRARY

The Centre has hosted its independent website with domain name "http://www.ctp-jamia.res.in" in the month of February, 2008. Now the website is fully functional and various informations & activities of the Centre are posted on the website time-to-time.

The process of digitilization of Library has also been started. Now the catelogue of books are available online on the University Intranet. It is still under the development stage. Both website design & maintenance and library software development work is being done by our computer staff Khalid Raza.

PROJECTS

Ongoing Projects

- **JSPS-DST Project (2007 - 2009)**

This is a project under Indo-Japanese Cooperative Science Programme. The duration of the project is two years. In the first year of the project, Indian investigator Prof. S. Panda visited Nagoya University and Gunma Technical Institute, Japan. From the Japanese side Prof. Nojiri and Dr. S. Mizuno visited Centre for Theoretical Physics, Jamia Millia Islamia.

The key points of scientific results obtained during the first year are as follows:

1. The D-brane inflation was investigated. In this paper, it was shown that the inflation is highly constrained by observational data and requires heavy fined tuning. Ideas relating to the final solution of the problem are given in this paper (Phys.Rev.D76: 103512, 2007)

2. We investigated string curvature corrected gravity and applied it to dark energy problem. It was shown that the model provides a viable solution. The stability of the solutions was also investigated. Future prospects in this direction were highlighted (Elizalde et.al Eur.Phys.J.C53:447-457,2008)

3. In collaboration with T. Shiromizu from Tokyo Technical Institute, we have made a proposal to major correction to Newtons Law of Gravitation. The experimental setup is seriously considered as present at TIFR, Mumbai (Accepted for publications in Physical Review Letters.).

- **UGC Project on observational Cosmology (2008 - 2011)**

A UGC Major Research project entitled "Accelerating Universe and its observational signatures" has been awarded to Dr. Anjan Ananda Sen of our center. The duration of the project is of three years from April 2008. Ms. N Chandrachani Devi has joined in this project has a Project Fellow.

The main objective of this project is two fold. Firstly it is aimed to study the inflationary in string theory, mainly in terms of Brane-Inflation, and look for distinctive stringy signatures that can be detected in current and future observational cosmology. The impact of the structure of the higher dimensional bulk on the CMB predictions e.g the spectral index as well as the Non-Gaussianities will be studied.

Secondly lots of effort will be focused in studying the nature of dark energy and it observational signatures. In this regar, particular emphasis will be given on the models of Modified Einstein's gravity on large distance scales. Also one of the main aims of this project will be to study the evolution of the overdensities in the accelerating universe through spherical collapse model.

Submitted Projects

- **DST Project on Theoretical Cosmology**

This is a joint research propsal with Delhi university (Dr. Deepak Jain and Dr. Abha Dev)

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