NUCLEAR ASTROPHYSICS pdf

1: Nuclear Physics â€“ Physics & Astronomy

Nuclear astrophysics is an interdisciplinary branch of physics involving close collaboration among researchers in various subfields of nuclear physics and astrophysics: notably stellar modeling; measurement and theoretical estimation of nuclear reaction rates; physical cosmology and cosmochemistry; gamma ray, optical and X-ray astronomy; and extending our knowledge about nuclear lifetimes and masses.

This process, called nucleosynthesis, occurs at extreme stellar temperatures and pressures, making it difficult to simulate in the laboratory. The conditions produced by NIF experiments, however, are well matched to the conditions that exist in stars in several phases of their evolution. As a result, NIF is a powerful tool for exploring nuclear physics. NIF can more realistically replicate the hot, dense stellar plasma where both processes occur in nature than is possible in other laboratory experiments. Livermore physicists are currently studying the slow nucleosynthesis process, or s-process. This reaction has a relatively large cross-section, or production probability, at stellar temperatures and densities, so it has been studied to high accuracy in laboratory experiments using low-energy accelerators. Stellar plasma Two important reactions occur in the s-process. In neutron capture, the mass of the nucleus increases by one unit, while the charge stays constant. In beta decay, the charge of the nucleus increases of decreases, and the mass remains unchanged. Accelerator experiments have measured the rates for neutron capture and beta decay, called cross sections, for most stable nuclei. Measuring cross sections of unstable short-lived nuclei has been impossible, however, in part because such studies would require unsafe quantities of radioactive material. Another complication is that nuclei in a stellar plasma often exist in excited states that modify capture probability. NIF holds advantages over accelerators. Laser experiments require a much smaller quantity of radioactive material than accelerators, allowing the experiments to be safely performed. Radioactive or short-lived elements can also be directly created at NIF, but not in accelerators. With NIF, scientists can produce stellar conditions with much higher quantities of neutrons. In addition, the laser energy compresses the target, reducing its area by a factor of 1,, boosting the density of nuclei, and increasing the probability of a neutron hitting a nucleus. Because of the additional neutrons and the extremely dense target material, an astonishing 2, years of stellar neutron capture occurs in every NIF shot. Even for short-lived nuclei, multiple reactions are possible in a single shot, potentially advancing scientific understanding of nucleosynthesis far more rapidly than accelerator-based experiments. Low-energy neutrons The gamma reaction history diagnostic, a tool developed for ignition experiments, is ideal for rapidly detecting and measuring important low-energy neutrons before the more energetic neutrons have a chance to muddy the signal. The diagnostic is one of more than 60 such instruments available for experimenters.

2: Nuclear Astrophysics

Nuclear Astrophysics is a field at the intersection of nuclear physics and astrophysics that seeks to understand how nuclear processes shape the cosmos. In essence we look for the connection between properties of atomic nuclei and the properties of planets, stars, and galaxies.

Everything that is visible in the night sky is powered by nuclear reactions. We asked a few questions to find out. Nuclear Astrophysics is a field at the intersection of nuclear physics and astrophysics that seeks to understand how nuclear processes shape the cosmos. In essence we look for the connection between properties of atomic nuclei and the properties of planets, stars, and galaxies. One fascinating aspect of this field is its interdisciplinarity and diversity. Work in nuclear astrophysics includes astronomical observations using telescopes, gravitational wave detectors, and neutrino detectors; accelerator laboratory experiments using beams of stable nuclei, radioactive nuclei, neutrons, and gamma-rays; laboratory analysis of interstellar grains; large scale computer simulations of stellar explosions and nuclei; and theoretical work in nuclear physics and astrophysics. We created very neutron rich nuclei that make up the crust of neutron stars but are unstable on earth to figure out how these nuclei can react to cool neutron stars. We also took advantage of a new capability at NSCL to generate so called reaccelerated radioactive beams. We collided the nuclei in these beams with a newly developed helium gas jet target at the same energies that these collisions happen inside an X-ray burst â€” a thermonuclear explosion that frequently occurs on the surface of neutron stars. We are part of a large collaboration that builds a new recoil separator called SECAR, which will enable us to dramatically increase the sensitivity to measure the nuclear reactions that happen in such collisions. What are the key open problems in the field? Current key open questions include the question of the origin of the elements heavier than about germanium, in particular the elements from germanium to palladium who seem to have a much more complex origin than anticipated. Another open question is how we can use neutron stars as laboratories to learn about what happens with ordinary matter when its compressed to very high densities. This ties into observations with X-ray observatories, radio telescopes, and the possible detection of gravitational waves from neutron star systems. Schematic overview of the nuclear processes in the Universe on the chart of nuclides. The Joint Institute for Nuclear Astrophysics JINA-CEE and other interdisciplinary centers focusing on nuclear astrophysics around the world continue to change the way nuclear astrophysics is done by facilitating close collaboration, coordination, as well exchange of ideas, people, and data between nuclear physics and astrophysics. This will enable researchers to take full advantage of technical advances that will address long standing challenges in the field. One such challenge is the study of astrophysical nuclear processes in the laboratory. In stars, reactions involve stable nuclei that are easily accelerated to astrophysical energies, but the reactions are so slow that they cannot be measured in most cases. In stellar explosions reactions are fast, but involve unstable nuclei that are difficult to produce in accelerator laboratories. Both challenges will be addressed with new facilities and instruments around the world, including a new generation of radioactive beam accelerator facilities such as FRIB in the US, underground accelerator facilities, and the use of recoil separators to enhance sensitivity to slow reactions. Together with advances in astronomy, such as new stellar spectroscopy surveys, new x-ray observatories, and gravitational wave detectors, and advances in computational capabilities this will create tremendous opportunities to answer long standing questions in the field. Can you give any advice to young scientists who want a career in nuclear astrophysics? One of the great things about nuclear astrophysics is the breadth of the field. There are many pathways to become a nuclear astrophysicist, through nuclear physics, astronomy, or chemistry and once one works in the field there are many different directions one can develop into based on ones interest. To take full advantage of these opportunities it is important to be open minded and take advantage of cross-disciplinary education opportunities â€” in nuclear astrophysics its important for astronomers to know some nuclear physics, and for nuclear physicists to know some astronomy. Its also important to not worry too much about crossing field boundaries, its actually a necessity in an interdisciplinary field like nuclear astrophysics. I am always amazed to see how much progress and new insights can come from someone crossing fields and provide a fresh perspective. For me, the best thing about being a physicist is to be part of an international community of researchers that transcends cultural and political boundaries and is driven by a genuine interest of finding out how nature works. Read the full paper Trends in nuclear astrophysics Hendrik Schatz J.

3: JINA-CEE, Joint Institute for Nuclear Astrophysics - Center for the Evolution of the Elements

Particle physics evolved out of nuclear physics and the two fields are typically taught in close association. Nuclear astrophysics, the application of nuclear physics to astrophysics, is crucial in explaining the inner workings of stars and the origin of the chemical elements.

The top photo shows the nuclear process on a neutron star. The bottom picture is an artist rendering of novae. Astrophysics Nuclear physics and astronomy are inextricably intertwined. The detailed properties of atomic nuclei, , times smaller than atoms, determine the chemical composition of the universe and the nature of stars. Many of the critical nuclei are short-lived rare isotopes, which decay within fractions of seconds. They are created briefly in stellar explosions serving as stepping stones for reactions creating new elements, and they also make up the crust of neutron stars where the extreme dense environment inhibits their decay. At NSCL some of these very same nuclei can be studied, and the signatures of their properties can then be found in the composition of our solar system and in stellar explosions observed with X-ray, gamma-ray, optical, neutrino- and, possibly in the near future, gravitational-wave observatories. By combining nuclear experiment, nuclear theory, astrophysical models, and observations we address open questions concerning the origin of the elements, the engines of stars and stellar explosions, and the nature of dense matter. Research on the origin of the elements in nature focuses on astrophysical processes with rare isotopes that have created many of the elements found on earth and in stars. We produce these very neutron rich, or very neutron deficient rare isotopes in the laboratory, determine their properties and decays, and have them undergo the same reactions that occur in stellar environments. The data are then used in computer simulations of stellar explosions to understand the buildup of new elements. Researchers in these areas are: Novae and X-ray bursts research focuses on measuring the nuclear reactions that power these stellar explosions in the laboratory using fast, stopped, and reaccelerated beams. Nuclear theory is developed to predict reaction rates and to interpret nuclear reaction measurements. X-ray burst and nova computer models are used to link results to observations and to guide future experiments. Supernova research includes experiments with charge exchange reactions. The data guide work in nuclear theory to better predict these interactions. Massive star core collapse and thermonuclear supernova computer models identify critical nuclear physics, determine its impact on astronomical observations, and seek to identify the still unknown explosion mechanism. Nuclear Processes in Stars are not well known because reactions are too slow to be measured directly. Research includes calculations of helium fusion at low temperatures, and studies of how our lack of knowledge of nuclear reaction rates affects the lives of stars and elements created.

4: Renovations lead to big improvement at Nuclear Astrophysics lab

Particle and Nuclear Astrophysics probes questions of fundamental importance, but still takes place in relatively small collaborations. It is a wonderful research opportunity for both undergraduate and graduate students, who are involved in both hardware development and data analysis.

Henri Becquerel Since s cloud chambers played an important role of particle detectors and eventually lead to the discovery of positron , muon and kaon. The history of nuclear physics as a discipline distinct from atomic physics starts with the discovery of radioactivity by Henri Becquerel in , [2] while investigating phosphorescence in uranium salts. Thomson [4] a year later was an indication that the atom had internal structure. At the beginning of the 20th century the accepted model of the atom was J. In the years that followed, radioactivity was extensively investigated, notably by Marie and Pierre Curie as well as by Ernest Rutherford and his collaborators. By the turn of the century physicists had also discovered three types of radiation emanating from atoms, which they named alpha , beta , and gamma radiation. Experiments by Otto Hahn in and by James Chadwick in discovered that the beta decay spectrum was continuous rather than discrete. That is, electrons were ejected from the atom with a continuous range of energies, rather than the discrete amounts of energy that were observed in gamma and alpha decays. This was a problem for nuclear physics at the time, because it seemed to indicate that energy was not conserved in these decays. The Nobel Prize in Physics was awarded jointly to Becquerel for his discovery and to Marie and Pierre Curie for their subsequent research into radioactivity. Rutherford was awarded the Nobel Prize in Chemistry in for his "investigations into the disintegration of the elements and the chemistry of radioactive substances". In Albert Einstein formulated the idea of massâ€”energy equivalence. While the work on radioactivity by Becquerel and Marie Curie predates this, an explanation of the source of the energy of radioactivity would have to wait for the discovery that the nucleus itself was composed of smaller constituents, the nucleons. More work was published in by Geiger and Ernest Marsden , [7] and further greatly expanded work was published in by Geiger. The key experiment behind this announcement was performed in at the University of Manchester: The plum pudding model had predicted that the alpha particles should come out of the foil with their trajectories being at most slightly bent. But Rutherford instructed his team to look for something that shocked him to observe: He likened it to firing a bullet at tissue paper and having it bounce off. As an example, in this model which is not the modern one nitrogen consisted of a nucleus with 14 protons and 7 electrons 21 total particles and the nucleus was surrounded by 7 more orbiting electrons. Around , Arthur Eddington anticipated the discovery and mechanism of nuclear fusion processes in stars , in his paper The Internal Constitution of the Stars. This was a particularly remarkable development since at that time fusion and thermonuclear energy, and even that stars are largely composed of hydrogen see metallicity , had not yet been discovered. The Rutherford model worked quite well until studies of nuclear spin were carried out by Franco Rasetti at the California Institute of Technology in Rasetti discovered, however, that nitrogen had a spin of 1. James Chadwick discovers the neutron[edit] Main article: With the discovery of the neutron, scientists could at last calculate what fraction of binding energy each nucleus had, by comparing the nuclear mass with that of the protons and neutrons which composed it. Differences between nuclear masses were calculated in this way. In the Yukawa interaction a virtual particle , later called a meson , mediated a force between all nucleons, including protons and neutrons. This force explained why nuclei did not disintegrate under the influence of proton repulsion, and it also gave an explanation of why the attractive strong force had a more limited range than the electromagnetic repulsion between protons. The center of the atom contains a tight ball of neutrons and protons, which is held together by the strong nuclear force, unless it is too large. Unstable nuclei may undergo alpha decay, in which they emit an energetic helium nucleus, or beta decay, in which they eject an electron or positron. After one of these decays the resultant nucleus may be left in an excited state, and in this case it decays to its ground state by emitting high energy photons gamma decay. This research became the science of particle physics , the crown jewel of which is the standard model of particle physics which describes the strong, weak, and electromagnetic forces. Modern nuclear physics[edit] Main articles: Liquid-drop model , Nuclear shell model , and Nuclear structure A heavy nucleus can contain hundreds of nucleons. This means that with some approximation it can be treated as a classical system , rather than a quantum-mechanical one. In the resulting liquid-drop model , [19] the nucleus has an energy which arises partly from surface tension and partly from electrical repulsion of the protons. The liquid-drop model is able to reproduce many features of nuclei, including the general trend of binding energy with respect to mass number, as well as the phenomenon of nuclear fission. Superimposed on this classical picture, however, are quantum-mechanical effects, which can be described using the nuclear shell model , developed in large part by Maria Goeppert Mayer [20] and J. Other more complicated models for the nucleus have also been proposed, such as the interacting boson model , in which pairs of neutrons and protons interact as bosons , analogously to Cooper pairs of electrons. Ab initio methods try to solve the nuclear many-body problem from the ground up, starting from the nucleons and their interactions. Nuclei may also have extreme shapes similar to that of Rugby balls or even pears or extreme neutron-to-proton ratios. Experimenters can create such nuclei using artificially induced fusion or nucleon transfer reactions, employing ion beams from an accelerator. Beams with even higher energies can be used to create nuclei at very high temperatures, and there are signs that these experiments have produced a phase transition from normal nuclear matter to a new state, the quarkâ€”gluon plasma , in which the quarks mingle with one another, rather than being segregated in triplets as they are in neutrons and protons. Radioactivity and Valley of stability Eighty elements have at least one stable isotope which is never observed to decay, amounting to a total of about stable isotopes. However, thousands of isotopes have been characterized as unstable. These "radioisotopes" decay over time scales ranging from fractions of a second to trillions of years. Plotted on a chart as a function of atomic and neutron numbers, the binding energy of the nuclides forms what is known as the valley of stability. Stable nuclides lie along the bottom of this energy valley, while increasingly unstable nuclides lie up the valley walls, that is, have weaker binding energy. The most stable nuclei fall within certain ranges or balances of composition of neutrons and protons: For example, in beta decay a nitrogen atom 7 protons, 9 neutrons is converted to an oxygen atom 8 protons, 8 neutrons [23] within a few seconds of being created. In this decay a neutron in the nitrogen nucleus is converted by the weak interaction into a proton, an electron and an antineutrino. The element is transmuted to another element, with a different number of protons. In alpha decay which typically occurs in the heaviest nuclei the radioactive element decays by emitting a helium nucleus 2 protons and 2 neutrons , giving another element, plus helium In many cases this process continues through several steps of this kind, including other types of decays usually beta decay until a stable element is formed. In gamma decay , a nucleus decays from an excited state into a lower energy state, by emitting a gamma ray. The element is not changed to another element in the process no nuclear transmutation is involved. Other more exotic decays are possible see the first main article. For example, in internal conversion decay, the energy from an excited nucleus may eject one of the inner orbital electrons from the atom, in a process which produces high speed electrons, but is not beta decay , and unlike beta decay does not transmute one element to another. Nuclear fusion[edit] In nuclear fusion , two low mass nuclei come into very close contact with each other, so that the strong force fuses them. It requires a large amount of energy for the strong or nuclear forces to overcome the electrical repulsion between the nuclei in order to fuse them; therefore nuclear fusion can only take place at very high temperatures or high pressures. When nuclei fuse, a very large amount of energy is released and the combined nucleus assumes a lower energy level. The binding energy per nucleon increases with mass number up to nickel Stars like the Sun are powered by the fusion of four protons into a helium nucleus, two positrons , and two neutrinos. The uncontrolled fusion of hydrogen into helium is known as thermonuclear runaway. A frontier in current research at various institutions, for example the Joint European Torus JET and ITER , is the development of an economically viable method of using energy from a controlled fusion reaction. Nuclear fusion is the origin of the energy including in the form of light and other electromagnetic radiation produced by the core of all stars including our own Sun. Nuclear fission[edit] Nuclear fission is the reverse process to fusion. For nuclei heavier than nickel the binding energy per nucleon decreases with the mass number. It is therefore possible for energy to be released if a heavy nucleus breaks apart into two lighter ones. The process of alpha decay is in essence a special type of spontaneous nuclear fission. It is a highly asymmetrical fission because the four particles which make up the alpha particle are especially tightly bound to each other, making production of this nucleus in fission particularly likely. From certain of the heaviest nuclei whose fission produces free neutrons, and which also easily absorb neutrons to initiate fission, a self-igniting type of neutron-initiated fission can be obtained, in a chain reaction. Chain reactions were known in chemistry before physics, and in fact many familiar processes like fires and chemical explosions are chemical chain reactions. The fission or "nuclear" chain-reaction , using fission-produced neutrons, is the source of energy for nuclear power plants and fission type nuclear bombs, such as those detonated in Hiroshima and Nagasaki , Japan, at the end of World War II. Heavy nuclei such as uranium and thorium may also undergo spontaneous fission , but they are much more likely to undergo decay by alpha decay. For a neutron-initiated chain reaction to occur, there must be a critical mass of the relevant isotope present in a certain space under certain conditions. The conditions for the smallest critical mass require the conservation of the emitted neutrons and also their slowing or moderation so that there is a greater cross-section or probability of them initiating another fission. In two regions of Oklo , Gabon, Africa, natural nuclear fission reactors were active over 1. However, it is not known if any of this results from fission chain reactions. The most common particles created in the Big Bang which are still easily observable to us today were protons and electrons in equal numbers. The protons would eventually form hydrogen atoms. Almost all the neutrons created in the Big Bang were absorbed into helium-4 in the first three minutes after the Big Bang, and this helium accounts for most of the helium in the universe today see Big Bang nucleosynthesis. Some relatively small quantities of elements beyond helium lithium, beryllium, and perhaps some boron were created in the Big Bang, as the protons and neutrons collided with each other, but all of the "heavier elements" carbon, element number 6, and elements of greater atomic number that we see today, were created inside stars during a series of fusion stages, such as the proton-proton chain , the CNO cycle and the triple-alpha process. Progressively heavier elements are created during the evolution of a star. Since the binding energy per nucleon peaks around iron 56 nucleons , energy is only released in fusion processes involving smaller atoms than that. Since the creation of heavier nuclei by fusion requires energy, nature resorts to the process of neutron capture. Neutrons due to their lack of charge are readily absorbed by a nucleus. The heavy elements are created by either a slow neutron capture process the so-called s process or the rapid, or r process. The s process occurs in thermally pulsing stars called AGB, or asymptotic giant branch stars and takes hundreds to thousands of years to reach the heaviest elements of lead and bismuth. The r process is thought to occur in supernova explosions which provide the necessary conditions of high temperature, high neutron flux and ejected matter. These stellar conditions make the successive neutron captures very fast, involving very neutron-rich species which then beta-decay to heavier elements, especially at the so-called waiting points that correspond to more stable nuclides with closed neutron shells magic numbers.

5: MIT Department of Physics

We are closely integrated into the Joint Institute for Nuclear Astrophysics Center for the Evolution of the Elements (JINA-CEE) that offers unique opportunities for young scientists to network across subfields with experimentalists at other laboratories around the world, nuclear theorists, computational astrophysicists, and astronomical observers.

In recent years, cosmology has changed from being a highly speculative area of theoretical physics into a field where precise experimental data and deep theoretical considerations interact to form an increasingly clear picture of the early history and future fate of the universe. Recent high-precision results from the WMAP satellite, from supernova studies, and from other extragalactic observations seem to confirm the inflationary model of the universe developed by Alan Guth. Inflation can explain why the universe is so large, so uniform, and so close to geometric flatness. Inflation also helps to cement the link between particle physics and cosmology by proposing that the ripples that we measure today in the cosmic background radiation originated as quantum fluctuations perhaps only seconds after the instant of the big bang. The recent observational results also show that the rate of expansion of the universe is accelerating, due to a nonvanishing cosmological constant or something similar. These new results raise profound theoretical questions which drive one of the most exciting fields of physics in this decade. A number of experimentalists in the astrophysics and particle experiment groups are working on research relevant to cosmology. String theorists Hong Liu and Washington Taylor are also currently working on problems related to cosmology. However, they also drive major environmental problems. The prospect of global warming and climate change driven by greenhouse gas emissions from fossil fuel combustion presents a particularly difficult challenge. Considerable science and technology development are needed, as well as policies that enable widespread and timely global deployment of key energy technologies. Ernest Moniz , in collaboration with faculty colleagues across the Institute, is examining the linked technology and policy pathways to mitigating greenhouse gas emissions on a large scale. Recent and current work focuses on nuclear power, photovoltaics, and coal utilization with carbon dioxide geological sequestration. In addition, evolution of the electricity transmission system is under study. Many of the basic structural features of quantum field theory were developed by physicists at the CTP ; the work of Jeffrey Goldstone on Goldstone bosons, Roman Jackiw on anomalies, and Frank Wilczek on asymptotic freedom, form an integral part of our current understanding of field theory, and are featured prominently in all textbooks on the subject. Roman Jackiw is studying possible mechanisms and signatures of CPT violation. Edward Farhi and Robert Jaffe are studying the role that quantum fluctuations may play in stabilizing extended field configurations such as solitons in gauge theories like the Standard Model. Jaffe is also applying field theory methods to the study of the Casimir effect in nanoscopic systems. Iain Stewart has developed new types of effective field theory suited for studying phenomena in gauge theories like QCD. Finally, Frank Wilczek retains a keen interest in applications of field theory to condensed matter systems, including the description of anyons, a subject he pioneered. There is a close connection between quantum field theory and statistical physics; in addition to work on field theory in the CTP , related research is done in the Condensed Matter Theory Group. For example, it allows a clean separation between QCD and electroweak physics in the description of B meson decays. This means that some processes, in which the electroweak physics is understood, can be used to study hadron structure, whereas other processes, in which the QCD physics is understood, can be used to look for deviations from the standard model, such as in its description of CP violation. Iain Stewart works on developing new effective theories and on applications of known effective field theories. He co-invented the soft-collinear effective theory which allows these techniques to be applied to processes with energetic jets or energetic hadrons. In jet physics, these techniques allow one to derive factorization theorems which make it possible to use high energy collisions to investigate short distance physics. Iain Stewart and Jesse Thaler are using effective theories to improve our understanding of jet properties and jet substructure. This is particularly relevant for the Large Hadron Collider LHC , where jet production is often the dominant background for potential signals of new physics. For all its intellectual depth and empirical success, the standard model of fundamental interactions including QCD, electroweak gauge theory, and minimally coupled gravity has significant conceptual and esthetic shortcomings. There are also several observed phenomena that the standard model does not address, e. An important branch of theoretical physics is concerned with addressing these shortcomings by suggesting ways to augment the standard model. Phenomenological beyond-the-standard-model physics focuses specifically on questions that are sufficiently concrete and well posed that they will receive experimental illumination in the near future. An outstanding example is the possibility of weakly broken supersymmetry at the LHC ; this is suggested by quantitative aspects of theories that unify the interactions, and if correct would lead to a rich and informative flow of new discoveries, that will both call for and reward insight. Other examples are axion physics, many aspects of neutrino physics, and attempts to understand the patterns of quark and lepton masses and mixings. Beyond-the-standard-model physics takes inspiration from cosmology, quantum field theory, symmetry, and string theory as well as from experiment and observation. Many relevant CTP activities are mentioned in the separate descriptions of those areas. Frank Wilczek studies unified supersymmetric models and axion physics. Jesse Thaler studies the theoretical frameworks and LHC signatures for a variety of beyond the standard model scenarios, hoping to gain insight into the origin of mass, the nature of dark matter, the apparent weakness of gravity, and the symmetry structure of our universe. Robert Jaffe and his collaborators developed the MIT bag model of confinement, still one of the favorite models of quark dynamics, and applied it to the spectrum and structure of hadrons. Professor Jaffe is also one of the leaders in the quest to use new experiments to elucidate the spin structure of the nucleon. John Negele uses lattice field theory to solve QCD ab initio and thereby understand from first principles how QCD gives rise to the observed quark and gluon structure of protons, neutrons, and other hadrons. The combination of numerical computation and analytic techniques enables one to make fundamental progress in solving complex problems in QCD that are not amenable to either technique alone. Current lattice studies range from calculating the contributions of quarks and gluons to the spatial, momentum, and spin structure of nucleons measured by MIT experimentalists Stanley Kowalski and Richard Milner to understanding the role of diquarks and instantons in hadron structure. Professor Negele is one of the founders of a national initiative to develop Terascale computers optimized for lattice QCD and is leading a collaboration to exploit them to understand hadron structure. As part of this initiative, a dedicated 5. Understanding QCD in extreme conditions requires linking usually disparate strands of theoretical physics, including particle and nuclear physics, cosmology, astrophysics and condensed matter physics. Krishna Rajagopal and Frank Wilczek study the properties of the cold dense quark matter that may lie at the centers of neutron stars. This stuff is the QCD analogue of a superconductor. However, if probed with ordinary light it looks like a transparent insulator and not like an electric conductor, as previously assumed. The properties of sufficiently dense quark matter have now been understood from first principles, but many interesting questions remain to be answered at lower densities. Progress requires coupled advances in theory, astrophysical observation, and experiments on analogue systems made of ultracold fermionic atoms. Robert Jaffe and Edward Farhi did the first work on quark matter in astrophysics. This work makes contact with research in Xray astronomy, condensed matter theory and ultracold cold atoms carried out elsewhere in our department. For example, they study how a high energy quark plowing through this liquid loses energy and under what conditions a pair of heavy quarks moving through this fluid can bind into a meson. Bolek Wyslouch and Gunther Roland are leading the related experimental effort at the Large Hadron Collider, where definitive measurements are anticipated. Rajagopal has also analyzed the critical point in the QCD phase diagram and has proposed signatures for its experimental detection, making it possible for experimentalists at RHIC to do a definitive search for the critical point in a large region of the phase diagram. Their work has focused on designing quantum algorithms, that is, finding ways to use quantum mechanics to achieve algorithmic speedup for certain computationally difficult problems. The quantum computing group in the Center for Theoretical Physics is responsible for the quantum adiabatic evolution algorithm and the idea of quantum walk algorithms both of which are continuous time Hamiltonian based approaches to quantum computing. This group showed that a quantum computer can determine who wins a game faster than any classical computer. The method involving scattering theory and demonstrates how ideas from physics can be used in the design of quantum algorithms. The quantum computing group in the Center for Theoretical

Physics has ties to many other researchers and centers at MIT. For example Professors Farhi and Goldstone are members of the W. He showed that a quantum computer can factor faster than a classical computer, which ignited the field. MIT is a main center of research in string theory, with six faculty members and numerous postdocs and graduate students working in this area. Work on string theory at MIT is currently focused in several different directions. Washington Taylor is working on nonperturbative formulations of string theory and on relating the space of string vacua to observable physics. Barton Zwiebach is working on tachyon condensation and string field theory, and he has recently written an undergraduate textbook on string theory. The string group in the CTP interacts broadly with the other groups within the CTP , and with the astrophysics group in the physics department. Faculty in other departments working in string-related areas include Isadore Singer math. In addition to the regular MIT faculty, Ashoke Sen spends two months each year with the group as the Morningstar visiting professor.

6: An Introduction to Nuclear Astrophysics, Boyd

r-processâ€”has not been reached yet, progress in nuclear physics and astrophysics has been made in the past decade toward unraveling the origin of the r-process elements.

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7: astrophysics - How does gravity cause nuclear fusion in stars? - Physics Stack Exchange

The Physics Frontier Center JINA (Joint Institute for Nuclear Astrophysics) provides an intellectual center with the goal to enable swift communication and stimulating collaborations across field boundaries and at the same time provide a focus point in a rapidly growing and diversifying field.

8: Nuclear Astrophysics | Global Events |USA| Europe | Middle East | Asia Pacific

Nuclear astrophysics A few years ago the Astrophysics Group, along with colleagues at the Goddard Space Flight Center of NASA, were the first to identify an object with the strongest magnetic field yet found in the Universe, this object recognized as a kind of neutron star called a magnetar.

9: Institute for Structure and Nuclear Astrophysics // University of Notre Dame

Abstract: Heavy-ion storage rings can be employed for nuclear astrophysics studies. Over the last two decades the experimental storage ring ESR at GSI has played a central role for such investigations.

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