Lecture 1. Stars and interstellar medium.

In astronomy, the interstellar medium (ISM) is the matter and radiation that exists in the space between the star systems in a galaxy. This matter includes gas in ionic, atomic, and molecular form, as well as dust and cosmic rays. It fills interstellar spaceand blends smoothly into the surrounding intergalactic space. The energy that occupies the same volume, in the form of electromagnetic radiation, is the interstellar radiation field.

The interstellar medium is composed of multiple phases, distinguished by whether matter is ionic, atomic, or molecular, and the temperature and density of the matter. The interstellar medium is composed primarily of hydrogen followed by helium with trace amounts of carbon, oxygen, and nitrogen comparatively to hydrogen.[1] The thermal pressures of these phases are in rough equilibrium with one another. Magnetic fields and turbulent motions also provide pressure in the ISM, and are typically more important dynamically than the thermal pressure is.

In all phases, the interstellar medium is extremely tenuous by terrestrial standards. In cool, dense regions of the ISM, matter is primarily in molecular form, and reaches number densities of 10^6 molecules per cm^3 (1 million molecules per cm^3). In hot, diffuse regions of the ISM, matter is primarily ionized, and the density may be as low as 10^{-4} ions per cm^3. Compare this with a number density of roughly 10^{19} molecules per cm^3 for air at sea level, and 10^{10} molecules per cm^3 (10 billion molecules per cm^3) for a laboratory high-vacuum chamber. By mass, 99% of the ISM is gas in any form, and 1% is dust.[2] Of the gas in the ISM, by number 91% of atoms are hydrogen and 9% are helium, with 0.1% being atoms of elements heavier than hydrogen or helium,[3] known as "metals" in astronomical parlance. By mass this amounts to 70% hydrogen, 28% helium, and 1.5% heavier elements. The hydrogen and helium are primarily a result of primordial nucleosynthesis, while the heavier elements in the ISM are mostly a result of enrichment in the process of stellar evolution.

Lecture 2. Galaxies and quasars.

Active galaxies are galaxies that have a small core of emission embedded at the center of an otherwise typical galaxy. This core is typically highly variable and very bright compared to the rest of the galaxy.

For normal galaxies, we think of the total energy they emit as the sum of the emission from each of the stars found in the galaxy, but in active galaxies, this is not true. There is a great deal more emitted energy in active galaxies than there should be and this excess energy is found in the infrared, radio, UV, and X-ray regions of the electromagnetic spectrum. The energy emitted by an active galaxy, AGN for short, is anything but normal. So what is happening in these galaxies to produce such an energetic output?

Most, if not all, normal galaxies have a supermassive black hole at their center. In an active galaxy, its supermassive black hole is accreting material from the galaxy's dense central region. As the material falls in toward the black hole, angular momentum will cause it to spiral in and form into a disk. This disk, called an accretion disk, heats up due to the gravitational and frictional forces at work.

Lecture 3. Basic physical laws.

article is about the philosophy of scientific laws. For the scientific and mathematical aspects, see Laws of science.

A physical law or scientific law is a theoretical statement "inferred from particular facts, applicable to a defined group or class of phenomena, and expressible by the statement that a particular phenomenon always occurs if certain conditions be present."[1] Physical laws are typically conclusions based on repeated scientific experiments and observations over many years and which have become accepted universally within the scientific community. The production of a summary description of our environment in the form of such laws is a fundamental aim of science. These terms are not used the same way by all authors.

The distinction between natural law in the political-legal sense and law of nature or physical law in the scientific sense is a modern one, both concepts being equally derived from physis, the Greek word (translated into Latin as natura) for nature.

Lecture 4. Sources of stellar energy.

This is a presentation of research into the inductive solution to the problem on the internal constitution of stars. The solution is given in terms of the analytic study of regularities in observational astrophysics. Conditions under which matter exists in stars are not the subject of a priori suppositions, they are the objects of research. In the first part of this research we consider two main correlations derived from observations: “mass-luminosity” and “period — average density of Cepheids”. Results we have obtained from the analysis of the correlations are different to the standard theoretical reasoning about the internal constitution of stars. The main results are: (1) in any stars, including even super-giants, the radiant pressure plays no essential part — it is negligible in comparison to the gaseous pressure; (2) inner regions of stars are filled mainly by hydrogen (the average molecular weight is close to 1/2); (3) absorption of light is derived from Thomson dispersion in free electrons; (4) stars have an internal constitution close to polytropic structures of the class 3/2. The results obtained, taken altogether, permit calculation of the physical conditions in the internal constitution of stars, proceeding from their observational characteristics L, M, and R. For instance, the temperature obtained for the centre of the Sun is about 6 million degrees. This is not enough for nuclear reactions. In the second part, the Russell-Hertzsprung diagram, transformed according to physical conditions inside stars shows: the energy output inside stars is a simple function of the physical conditions. Instead of the transection line given by the heat output surface and the heat radiation surface, stars fill an area in the plane of density and temperature. The surfaces coincide, being proof of the fact that there is only one condition — the radiation condition. Hence stars generate their energy not in any reactions. Stars are machines, directly generating radiations. The observed diagram of the heat radiation, the relation “mass-luminosity-radius”, cannot be explained by standard physical laws. Stars exist in just those conditions where classical laws are broken, and a special mechanism for the generation of energy becomes possible. Those conditions are determined by the main direction on the diagram and the main point located in the direction. Physical coordinates of the main point have been found using observational data. The constants (physical coordinates) should be included in the theory of the internal constitution of stars which pretend to adequately account for observational data. There in detail manifests the inconsistency of the explanations of stellar energy as given by nuclear reactions, and also calculations as to the percentage of hydrogen and helium in stars.

Lecture 5. Interaction of radiation with matter.

X-ray photons are created by the interaction of energetic electrons with matter at the atomic level. Photons (x-ray and gamma) end their lives by transferring their energy to electrons contained in matter. X-ray interactions are important in diagnostic examinations for many reasons. For example, the selective interaction of x-ray photons with the structure of the human body produces the image; the interaction of photons with the receptor converts an x-ray or gamma image into one that can be viewed or recorded. This chapter considers the basic interactions between x-ray and gamma photons and matter.

Lecture 6. Radiative transfer equation and it's simple solutions.

Radiative transfer is the physical phenomenon of energy transfer in the form of electromagnetic radiation. The propagation of radiation through a medium is affected by absorption, emission, and scattering processes. The equation of radiative transfer describes these interactions mathematically. Equations of radiative transfer have application in a wide variety of subjects including optics, astrophysics, atmospheric science, and remote sensing. Analytic solutions to the radiative transfer equation (RTE) exist for simple cases but for more realistic media, with complex multiple scattering effects, numerical methods are required. The present article is largely focused on the condition of radiative equilibrium.

Lecture 7. Physical processes in celestial sources of radiation.

Astrophysical X-ray sources are astronomical objects with physical properties which result in the emission of X-rays.

There are a number of types of astrophysical objects which emit X-rays, from galaxy clusters, through black holes in active galactic nuclei (AGN) to galactic objects such as supernova remnants, stars, and binary starscontaining a white dwarf (cataclysmic variable stars and super soft X-ray sources), neutron star or black hole (X-ray binaries). Some solar system bodies emit X-rays, the most notable being the Moon, although most of the X-ray brightness of the Moon arises from reflected solar X-rays. A combination of many unresolved X-ray sources is thought to produce the observed X-ray background. The X-ray continuum can arise from bremsstrahlung, either magnetic or ordinary Coulomb, black-body radiation, synchrotron radiation, inverse Compton scattering of lower-energy photons by relativistic electrons, knock-on collisions of fast protons with atomic electrons, and atomic recombination, with or without additional electron transitions.

Lecture 8. The theory of interactions.

Theory of Interaction aims to provide a foundational framework for computation and interaction. It proposes four fundamental principles that characterize the common features of all models of computation and interaction. These principles suffice to support a model independent treatment of the two most important relationships in computer science, the equality between processes and the relative expressiveness between models. Based on the two relationships the theory of equality, the theory of expressiveness and the theory of completeness are developed.

Lecture 9. Energy and mechanisms of nuclear fission.

In nuclear physics and nuclear chemistry, nuclear fission is either a nuclear reaction or a radioactive decay process in which the nucleus of an atom splits into smaller parts (lighter nuclei). The fission process often produces free neutrons and gamma photons, and releases a very large amount of energy even by the energetic standards of radioactive decay.

Nuclear fission of heavy elements was discovered on December 17, 1938 by German Otto Hahn and his assistant Fritz Strassmann, and explained theoretically in January 1939 by Lise Meitner and her nephew Otto Robert Frisch. Frisch named the process by analogy with biological fission of living cells. It is an exothermic reaction which can release large amounts of energy both as electromagnetic radiation and as kinetic energy of the fragments (heating the bulk material where fission takes place). In order for fission to produce energy, the total binding energy of the resulting elements must be less negative (higher energy) than that of the starting element.

Fission is a form of nuclear transmutation because the resulting fragments are not the same element as the original atom. The two nuclei produced are most often of comparable but slightly different sizes, typically with a mass ratio of products of about 3 to 2, for common fissileisotopes.[1][2] Most fissions are binary fissions (producing two charged fragments), but occasionally (2 to 4 times per 1000 events), threepositively charged fragments are produced, in a ternary fission. The smallest of these fragments in ternary processes ranges in size from a proton to an argon nucleus.

Lecture 10. The luminosity of stars and their mass.

The mass/luminosity relation is important because it can be used to find the distance to binary systems which are too far for normal parallax measurements, using a technique called "dynamical parallax".[5] In this technique, the masses of the two stars in a binary system are estimated, usually as being the mass of the Sun. Then, using Kepler's laws of celestial mechanics, the distance between the stars is calculated. Once this distance is found, the distance away can be found via the arc subtended in the sky, giving a preliminary distance measurement. From this measurement and the apparent magnitudes of both stars, the luminosities can be found, and by using the mass–luminosity relationship, the masses of each star. These masses are used to re-calculate the separation distance, and the process is repeated. The process is iterated many times, and accuracies as high as 5% can be achieved.[5] The mass/luminosity relationship can also be used to determine the lifetime of stars by noting that lifetime is approximately proportional to M/L. One finds that more massive stars live shorter. A more sophisticated calculation factors in a star's loss of mass over time.

Lecture 11. Modern theoretical ideas about the nature of stars and their systems.

Perhaps the most convincing line of evidence supporting this theory are observations of the same process currently happening elsewhere in our Galaxy. It would be strange if our Solar System formed in a different way to every other system in the Galaxy, since physics is supposed to work the same way everywhere. We see stars forming in the depths of giant clouds of gas and dust, and we even see young stars with disks of debris around them, which look just like the debris disk we think the planets formed from.

Other lines of evidence come from simulations of the process. Many astronomers spend most of their time constructing detailed simulations of physical processes in computers. You can put into the simulation details of how the physics should happen and then run it to see what the result is. Current simulations of the formation of a solar system from a cloud of gas work quite well.

Observations of the solar system itself support the theory too. In fact it was these observations which lead to the proposal of the theory in the first place.

1. All the planets orbit the Sun in the same direction. Most of their moons also orbit in that direction, and the planets (and the Sun) rotate in the same direction. This would be expected if they all formed from a disk of debris around the proto-Sun.

2. The planets also have the right characteristics to have formed from a disk of mainly hydrogen around a young, hot Sun. Those planets near the Sun have very little hydrogen in them as the disk would have been too hot for it to condense when they formed. Planets further out are mostly hydrogen, (since that was what was mostly in the disk), and are much more massive because there was so much more material they could be made from.

Finally in this model the Sun is mostly composed of hydrogen. This can also be tested. Observations of the Sun agree incredibly well with what would be expected of a giant ball of mostly hydrogen generating heat by nuclear fusion in the core. The composition can also be measured using helioseismology (the study of 'Sunquakes') and agrees with the theory.

Lecture 12. Physical methods of research of space objects.

Space exploration

From Wikipedia, the free encyclopedia

Saturn V rocket, used for the American manned lunar landing missions

The Moon as seen in a digitally processed image from data collected during a spacecraft flyby

Space exploration is the ongoing discovery and exploration of celestial structures in outer space by means of continuously evolving and growing space technology. While the study of space is carried out mainly by astronomers with telescopes, the physical exploration of space is conducted both by unmanned robotic space probes and human spaceflight.

While the observation of objects in space, known as astronomy, predates reliable recorded history, it was the development of large and relatively efficient rockets during the mid-twentieth century that allowed physical space exploration to become a reality. Common rationales for exploring space include advancing scientific research, national prestige, uniting different nations, ensuring the future survival of humanity, and developing military and strategic advantages against other countries.[1]

Space exploration has often been used as a proxy competition for geopolitical rivalries such as the Cold War. The early era of space exploration was driven by a "Space Race" between the Soviet Union and the United States.

The launch of the first human-made object to orbit Earth, the Soviet Union's Sputnik 1, on 4 October 1957, and the first Moon landing by the American Apollo 11 mission on 20 July 1969 are often taken as landmarks for this initial period. The Soviet Space Program achieved many of the first milestones, including the first living being in orbit in 1957, the first human spaceflight (Yuri Gagarin aboard Vostok 1) in 1961, the first spacewalk (by Aleksei Leonov) on 18 March 1965, the first automatic landing on another celestial body in 1966, and the launch of the first space station (Salyut 1) in 1971.[2]

After the first 20 years of exploration, focus shifted from one-off flights to renewable hardware, such as the Space Shuttle program, and from competition to cooperation as with the International Space Station (ISS).

Lecture 13. Current problems in astrophysics.

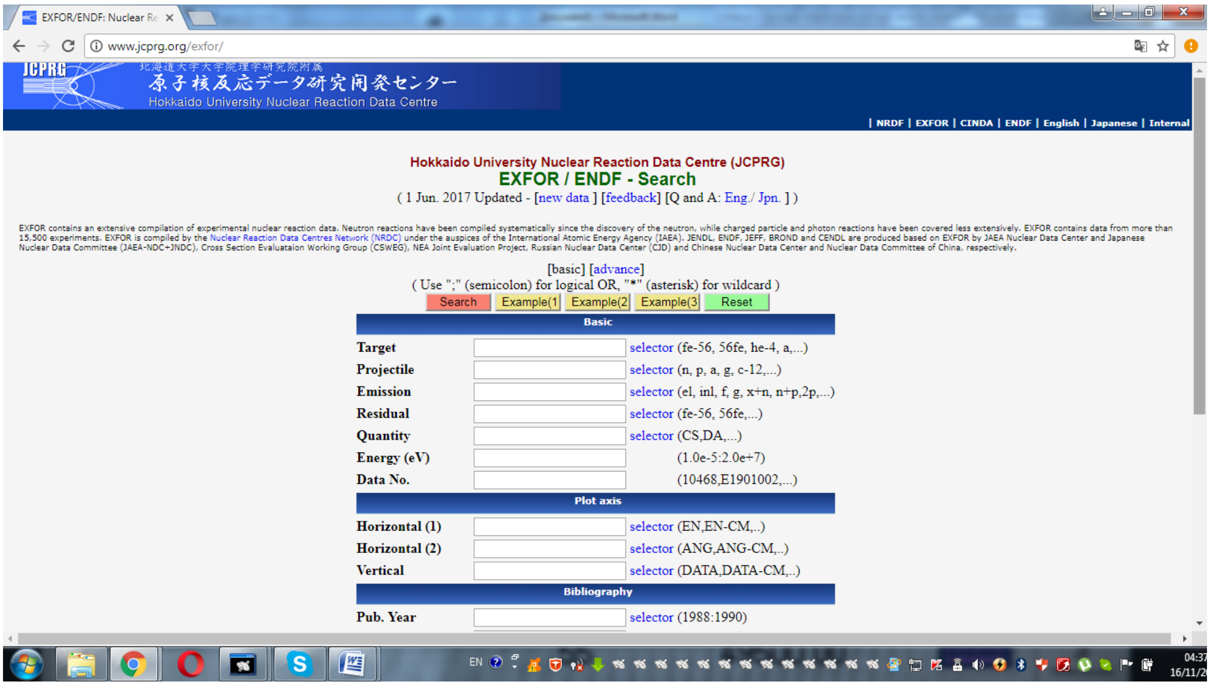
Some of the major unsolved problems in physics are theoretical, meaning that existing theories seem incapable of explaining a certain observed phenomenon or experimental result. The others are experimental, meaning that there is a difficulty in creating an experiment to test a proposed theory or investigate a phenomenon in greater detail.

There are still some deficiencies in the Standard Model of physics, such as the origin of mass, the strong CP problem, neutrino oscillations, matter–antimatter asymmetry, and the nature of dark matter and dark energy.[1][2] Another problem lies within the mathematical framework of the Standard Model itself—the Standard Model is inconsistent with that of general relativity, to the point that one or both theories break down under certain conditions (for example within known spacetime singularities like the Big Bang and the centers of black holes beyond the event horizon).

Lecture 14. Nuclear reactions in astrophysical objects.

Nuclear astrophysics is that branch of astrophysics which helps understanding the Universe, or at least some of its many faces, through the knowledge of the microcosm of the atomic nucleus. It attempts to find as many nuclear physics imprints as possible in the macrocosm, and to decipher what those messages are telling us about the varied constituent objects in the Universe at present and in the past. In the last decades much advance has been made in nuclear astrophysics thanks to the sometimes spectacular progress made in the modelling of the structure and evolution of the stars, in the quality and diversity of the astronomical observations, as well as in the experimental and theoretical understanding of the atomic nucleus and of its spontaneous or induced transformations. Developments in other sub-fields of physics and chemistry have also contributed to that advance. Notwithstanding the accomplishment, many longstanding problems remain to be solved, and the theoretical understanding of a large variety of observational facts needs to be put on safer grounds. In addition, new questions are continuously emerging, and new facts endangering old ideas. This review shows that astrophysics has been, and still is, highly demanding to nuclear physics in both its experimental and theoretical components. On top of the fact that large varieties of nuclei have to be dealt with, these nuclei are immersed in highly unusual environments which may have a significant impact on their static properties, the diversity of their transmutation modes, and on the probabilities of these modes. In order to have a chance of solving some of the problems nuclear astrophysics is facing, the astrophysicists and nuclear physicists are obviously bound to put their competence in common, and have sometimes to benefit from the help of other fields of physics, like particle physics, plasma physics or solid-state physics. Given the highly varied and complex aspects, we pick here some specific nuclear physics topics which largely pervade nuclear astrophysics.

Lecture 15. Databases on nuclear reactions.



Hokkaido University Nuclear Reaction Data Centre (JCPRG)

EXFOR / ENDF - Search

(1 Jun. 2017 Updated - [new data] [feedback] [Q and A: Eng./ Jpn.])

EXFOR contains an extensive compilation of experimental nuclear reaction data. Neutron reactions have been compiled systematically since the discovery of the neutron, while charged particle and photon reactions have been covered less extensively. EXFOR contains data from more than 15,500 experiments. EXFOR is compiled by the Nuclear Reaction Data Centres Network (NRDC) under the auspices of the International Atomic Energy Agency (IAEA). JENDL, ENDF, JEFF, BROND and CENDL are produced based on EXFOR by JAEA Nuclear Data Center and Japanese Nuclear Data Committee (JAEA-NDC+JNDC), Cross Section Evaluataion Working Group (CSWEG), NEA Joint Evaluation Project, Russian Nuclear Data Center (CJD) and Chinese Nuclear Data Center and Nuclear Data Committee of China, respectively.

[basic] [advance]

(Use ";" (semicolon) for logical OR, "*" (asterisk) for wildcard)

Basic		
Target		selector (fe-56, 56fe, he-4, a,...)
Projectile		selector (n, p, a, g, c-12,...)
Emission		selector (el, inl, f, g, x+n, n+p,2p,...)
Residual		selector (fe-56, 56fe,...)
Quantity		selector (CS,DA,...)
Energy (eV)		(1.0e-5:2.0e+7)
Data No.		(10468,E1901002,...)
Plot axis		
Horizontal (1)		selector (EN,EN-CM,..)
Horizontal (2)		selector (ANG,ANG-CM,..)
Vertical		selector (DATA,DATA-CM,..)
Bibliography		
Pub. Year		selector (1988:1990)