Nuclear astrophysics.

Lecture 1.

In astronomy, the interstellar medium (ISM) is the matter 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 space and 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. 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. 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, 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.

The interstellar medium begins where the interplanetary medium of the Solar System ends. The solar wind slows tosubsonic velocities at the termination shock, 90—100 astronomical units from the Sun. In the region beyond the termination shock, called the heliosheath, interstellar matter interacts with the solar wind.

Before modern electromagnetic theory, early physicists postulated that an invisible luminiferous aetherexisted as a medium to carry lightwaves. It was assumed that this aether extended into interstellar space, asPatterson (1862) wrote, "this efflux occasions a thrill, or vibratory motion, in the ether which fills the interstellar spaces."

Lecture 2.

Quasars or **quasi-stellar radio sources** are the most energetic and distant members of a class of objects called active galactic nuclei (AGN). Quasars are extremely luminous and were first identified as being high redshift sources ofelectromagnetic energy, including radio waves and visible light, that appeared to be similar to stars, rather than extended sources similar to galaxies. Their spectra contain very broad emission lines, unlike any known from stars, hence the name "quasi-stellar." Their luminosity can be 100 times greater than that of the Milky Way. Most quasars were formed approximately 12 billion years ago, and they are normally caused by collisions of galaxies, with the galaxies' central black holes merging to form either a supermassive black hole or a binary black hole system.

Although the true nature of these objects was controversial until the early 1980s, there is now a scientific consensus that a quasar is a compact region in the center of a massive galaxy surrounding a central supermassive black hole. Its size is 10–10,000 times the Schwarzschild radius of the enclosed black hole. The energy emitted by a quasar derives from mass falling onto the accretion disc around the black hole.

A **galaxy** is a gravitationally bound system of stars, stellar remnants, interstellar gas, dust, and dark matter. The word galaxy is derived from the Greek *galaxias,* literally "milky", a reference to the Milky Way. Galaxies range in size from dwarfs with just a few thousand (10^3) stars to giants with one hundred trillion (10^{14}) stars, each orbiting its galaxy'scenter of mass. Galaxies are categorized according to their visual morphology as elliptical, spiral and irregular. Many galaxies are thought to have black holes at their active centers. The Milky Way's central black hole, known as Sagittarius A*, has a mass four million times greater than the Sun. As of July 2015, EGSY8p7 was the oldest and most distant observed galaxy with a light travel distance of 13.2 billion light-years from Earth, and observed as it existed 570 million years after the Big Bang. Previously, as of May 2015, EGS-zs8-1 was the most distant known galaxy, estimated to have a light travel distance of 13.1 billion light-years away and to have 15% of the mass of the Milky Way. Approximately 170 billion (1.7×10^{11}) to 200 billion (2.0×10^{11}) galaxies exist in the observable universe. Most of the galaxies are 1,000 to 100,000 parsecs in diameter and usually separated by distances on the order of millions of parsecs. The space between galaxies is filled with a tenuous gas having an average density of less than one atom per cubic meter. The majority of galaxies are gravitationally organized into associations known as galaxy groups, clusters, and superclusters. At the largest scale, these associations are generally arranged into sheets and filaments surrounded by immense voids.

Lecture 3.

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." Physical laws are typically conclusions based on repeated scientific experiments and observationsover 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*.

Several general properties of physical laws have been identified. Physical laws are:

- True, at least within their regime of validity. By definition, there have never been repeatable contradicting observations.
- Universal. They appear to apply everywhere in the universe.
- Simple. They are typically expressed in terms of a single mathematical equation.
- Absolute. Nothing in the universe appears to affect them.
- Stable. Unchanged since first discovered (although they may have been shown to be approximations of more accurate laws—see "Laws as approximations" below),
- Omnipotent. Everything in the universe apparently must comply with them (according to observations).
- Often expressions of existing homogeneities (symmetries) of space and time.
- Typically theoretically reversible in time (if non-quantum), although time itself is irreversible.

Physical laws are distinguished from scientific theories by their simplicity. Scientific theories are generally more complex than laws; they have many component parts, and are more likely to be changed as the body of available experimental data and analysis develops. This is because a physical law is a summary observation of strictly empirical matters, whereas a theory is a model that accounts for the observation, explains it, relates it to other observations, and makes testable predictions based upon it. Simply stated, while alaw notes that something happens, a theory explains why and how something happens.

Lecture 4.

The most obvious feature of the stars is that they glow, rather, are self-luminous bodies. Due to what they are covered by the energy loss? This question arose as soon as was formulated the law of conservation of energy, but to find a comprehensive answer to it managed only a century later.

Usually people think that the main difficulty of the problem - in a huge release of energy in the power of the sun and stars. In fact, it is not in this. Specific pace of energy from the Sun and the stars more than modest. Thus, based on one gram of the substance sun every second its allocated only 2 ergs. In ordinary earthly standards is quite negligible pace of energy - in a pile of rotting autumn leaves. In the human body rate of energy release on the order of four (!) Than in the sun. However, to maintain this level of energy production, we need to eat three times a day. And the sun (and the stars) shine for billions of years without eating.

Thus, the real problem lies in the fact that the stars shine very long time. During this time they really manage to highlight the enormous amount of energy. Whence it is drawn?

As already mentioned, the question was raised in the 40-ies of the XIX century, with the discovery of the law of conservation of energy. Immediately it became clear that the source of energy, in principle, can be gravity. So, Robert Meyer, one of the fathers of the law of conservation of energy, thought that the sun shines at the expense of the kinetic energy of the drop-down on his meteoric material. It is interesting that for decades was considered the hypothesis of Meyer's almost ridiculous, and was mentioned only as a historical curiosity. However, we now know that a modernized version of Meyer mechanism - accretion - plays an important role in the world of stars.

Lecture 5.

Interaction of radiation with matter - is reduced to a set of elementary scattering (elastic and inelastic), absorption and generation of e-magnet. radiation. The following analysis focuses on the processes that lead to the weakening of the radiation. The radiation flux with the frequency v, passes through the layer of material is reduced due to absorption, elastic scattering side and because of inelastic scattering. In the case of optical instruments. radiation is called attenuation. extinction.

Interaction (as separate elementary processes, as well as any combination thereof) of a photon with a scattering or absorbing particle is characterized by an effective cross section (ECS) s. It can be defined as the ratio of the probability of interaction per unit path dp / dx to the concentration of N particles with the k-eq interact:

$$\sigma = \frac{1}{N} \cdot \frac{d\Pi}{dx}$$

ECS depends on the state of photons and particles before and after reaction. There are differential EPS determines the probability of such an interaction, with a rum-photon and particle from the fixed initial state of transition in certain end-state, and complete, or integral, ECS - the result of the integration of the differential ECS over all final states. Full ECS has the dimension of area (cm2).

Lecture 6.

Let us turn to the description of the propagation of radiation in the environment, which interacts radiation. Interaction of radiation and matter can be viewed on different physical levels. For our purposes it is sufficient to introduce makroscopy emissivity and absorption of light, although the calculation of the coefficients themselves physical as the frequency of the photon and the physical characteristics of the environment carried out by classical and quantum electrodynamics methods.

If the medium is able to both emit and absorb light, then, setting coefficients of emission j_ν and absorption α_ν known coordinates and time functions depending on the physical state of matter stationary case, we can write $\frac{dI_\nu}{ds} = -\alpha_\nu I_\nu + j_\nu$.

Lecture 7.

The main distinguishing feature of receiving information in astronomy - the inability to put the "experiment" in the usual sense of the word Physics. Special way is impossible to "prepare" the object under study or even to influence it. Due to the finite speed of light, studying the signal from any source, we study the physical processes taking place in it many hundreds, thousands or even billions of years ago. Therefore, it is more accurate to speak of the astronomical observations, that is, a passive reception of information from the source. Thus, reception and study of the temporal and spectral characteristics of the signal from astronomical sources is the main way to study their physical condition and evolution. To get a clear physical Karina on the mentioned class of objects (such as stars or galaxies) need to observe as much as possible more of them at different stages of their evolution.

The main information channel in astronomy still involves the study of electromagnetic radiation. The whole space is permeated by radiation of starlight, interstellar gas and dust, hot intergalactic gas, the relic microwave radiation. Therefore there is a problem (A) separated positions on the celestial sphere sources from each other and (b) select a signal from among a separate source of natural noise.

Lecture 8.

At that time, all scientists were convinced of the existence of the ether, but the experience of Michelson as if proved otherwise, as noted the absence of the ether wind. Now let's look at the existence of the ether from the other side. The ether wind should be observed when moving particles or bodies in space. Note the following observations, that challenge, I think, no one will.

1. When a charged particle in a magnetic field space, or radiation, if a particle is accelerated.

2. When moving neutral particles in space there are de Broglie waves, the characteristics of which depend on the mass of the particle and its speed.

Now to the waves and see whether and when distributing any effects, and immediately see the presence of the red shift in the spectra of distant stars and galaxies.

So, we have considered both the particles and radiation: in both cases, we see the effects resulting from their displacement in space. The conclusion can be made so. Ether exists. Why it was not detected in Michelson's experiment? The answer is. At those sizes in which the experiment was conducted, the air surrounding the Earth and moving along with it, so the difference in speed of propagation of electromagnetic waves in different directions in the vicinity of the earth and was not revealed.

If we take for granted the existence of the ether, it naturally raises the question of its structure and properties. One thing we already know the property - this is the observed polarization of the vacuum. The second property suggests static air - it is present everywhere. However, the third property requires air to be dynamic and capable exchange electromagnetic waves and gravitational interactions. Synthesis ether latter two properties, combined with the specified information in the first paragraph, leads to a structure in the form of polar ether (consisting of two oppositely part of charge) particles in a stationary position and transmitting rotation via interaction. Further development of these views you can find out by visiting the general theory of interactions. I note that there is described a new deuterium gravitation, new theory of the structure of elementary particles, atoms and molecules, the new theory of chemical bonding and so much more new. It is said that no assumptions other than given in this communication, the author no longer does, however, all of these theories fit into the structure of the physical vacuum presented here.

Due to the fact that the theories claiming to describe anything and everything a lot in this forum I have them counted three, I want to add that the general theory of interactions is a subject that is not used by the virtual and uncertainty concepts, and her main principle is continuity, which implies the principle of causality.

Lecture 9.

Nuclear fission - the process of splitting the atomic nucleus into two (rarely three) core with similar masses, called fission fragments. As a result of the division may be other reaction products: light nuclei (mainly alpha particles), neutrons and gamma rays. The division is spontaneous (spontaneous) and internally (as a result of interaction with other particles, especially with neutrons). Dividing heavy nuclei - exothermic process, whereby a large amount of energy is released as kinetic energy of the reaction products, as well as radiation. Nuclear fission is the source of energy in nuclear reactors and nuclear weapons.

The process of division can occur only when the potential energy of the initial state of the fission nucleus exceeds the sum of the masses of the fission fragments. Since the specific energy of heavy nuclei decreases with increasing mass, this condition is satisfied for almost all nuclei with mass number.

However, experience shows that even the heaviest nuclei are divided spontaneously with a very low probability. This means that there is an energy barrier (barrier dividing) preventing division. For a description of the fission process, including the calculation of the fission barrier is used several models, but none of them can explain the process thoroughly.

Lecture10.

The term "supernova" were named stars that flashed far (orders of magnitude) more so-called "new stars". In fact, neither one nor the other new physically are not: break out the existing stars. But in several historical instances flashed those stars that were previously in the sky is almost completely visible or not, this phenomenon and create the effect of the appearance of a new star.

Supernovae - stars whose brightness increases at the outbreak on tens star quantities for several days. The maximum supernova star shine brightest from across the galaxy in which it broke out, and may even exceed it. For example, the luminosity of the supernova SN 1972E in ~ 13 times the integrated luminosity of their home galaxy NGC 5253 [1]. Therefore supernova can record of very distant galaxies up to red shift the z ~ 1 (~ 1000 Mpc), and even more. In the energy is released during the supernova explosion about 1050 - 1051 erg.

On the discovery of a supernova is reported to the Central Bureau for Astronomical telegram International Astronomical Union, where a circular sent to the name given to a supernova. The name is made up of SN label, which put year after opening, the end of the one- or two-letter designation. The first 26 supernovae of the year get one-letter designations, in the end of the name, in capital letters from A to Z. The remaining supernovae receive two-letter designation of lowercase letters: aa, ab, and so on. Thus, for example, a supernova named SN 2003C was opened a third in 2003.

Lecture 11.

The universe as a concept and object of knowledge. Planets, stars, galaxies and their structures. Classification of the stars, their basic characteristics: mass, luminosity, size, chemical composition, temperature. The relationship between the parameters of the stellar, stellar evolution.

By the end of the XVII century, astronomers finally abandoned the geocentric system of the world and began to study the universe, taking as a basis the physical laws discovered by Newton. However, despite the fact that the structure of the solar system had already formed a more or less accurate representation, much still remains unclear - openaxiom.ru. Astronomers can only assume that the stars - countless and they are at a great distance from the Earth, from the solar system and from each other. However, the distance was not possible, although attempts in this direction were made permanent.

Lecture 12.

By analyzing the properties of the radiation emitted by space objects, determine the physical properties of celestial bodies. According to the observed radiation are primarily determined by the position of the source in the sky, and its shape. At a certain distance to a celestial body in its radiation can also be found the body size and the total amount of energy radiated for a given period of time. This information is usually not sufficient to determine the physical condition of the body, and especially to determine the nature of the explosion incident thereon. For information about the physical condition of the heavenly bodies is obtained by examining the radiation in the individual, the narrow wavelength intervals. To understand the methods of such studies should be familiar with the processes that contribute to the radiation of bodies. Since the vast majority of the celestial bodies is made up of gas, and having a high temperature, we confine ourselves to the description of the heated gas emission processes.

Gas, like all the other bodies, is composed of atoms that constitute the system of charged particles. Around having a positive charge of the nucleus of the atom, electrons move, the charge of which is negative. If the charge of the nucleus is equal to the total charge of the electrons, the atom is called a neutral, and in the case where this condition is not fulfilled - ion. The simplest of all is the hydrogen atom, which has just one electron. The nucleus of the hydrogen atom is called a proton. In following the complexity of the atom - helium - core, four times better than the mass of the hydrogen atom nucleus consists of two protons and two particles called neutrons, deprived of charge and are very close in mass to the proton. The electrons in an atom of helium and two. The energy of the electron motion in the nuclear field can not be arbitrary. For each atom there is a set (a set of) the permissible values of the electron energy - the energy states of the atom. About the causes of this characteristic structure of atoms, to tell here is not possible, since the corresponding theory is too complicated. We note only that this fact is confirmed by a huge number of physics experiments.

Lecture 13.

The subject of astrophysics, is the study of physical processes in the universe. The main source of information about distant cosmic objects, with a few exceptions of the moon, planets, and some of the small bodies of the solar system, available direct study of modern astronautics funds is coming from their electromagnetic radiation. Therefore, the task of astrophysics is to build a model that would explain the appearance of radiation of various space objects with observed characteristics:.. Intensity, spectrum, polarization, time profile, etc. To solve this problem, astrophysics researchers come from the well-known picture of the physical processes and laws in the conditions, depending on the temperature and density of matter, the presence of the magnetic field and its value from the possible influence of gravitational forces.

Modern Astrophysics was formed after World War II. From the point of view of observing its main feature - the extension of the spectral range of the test radiation. Antebellum only Astrophysics used the astronomical observations in visible light - a relatively narrow band of the electromagnetic spectrum. It is clear that in this case the focus is first of all the objects in the universe, which emit mainly visible light - stars, nebulae, galaxies. The theory of radiation has been constructed on the basis of the knowledge obtained in terrestrial laboratories. Currently used in astronomy almost all ranges - from radio waves to gamma rays. The transformation of astronomy all-wave enriched the knowledge of the known sites and led to the discovery of new objects, allowed to register radiation from these areas, where matter (matter and radiation) is in the so-called extreme (extreme) conditions such that it is practically impossible to implement in laboratories on the ground. This high density of matter that exist in the early stages of the universe, in the interior of neutron stars and black holes in the immediate vicinity; strong magnetic fields of white dwarfs and neutron stars. Under these conditions the fabric often acquires new physical properties. It is in those areas where implemented certain extreme conditions, and focus the main problems of modern astrophysics.

Lecture 14.

Nuclear astrophysics, astrophysics division, closely associated with the nuclear physics and the theory of elementary particle interactions. It overlaps with the physics of cosmic rays and neutrino astrophysics. It is <a. It uses to achieve lab. and theoretical. nuclear physics to explain the sources of energy asters. objects of chemical origin. elements for cosmic chronology. In turn, observations to impose restrictions on the number of parameters of the theory of elementary particle interactions with accuracy which can not be achieved in the laboratory. experiments (especially for weakly interacting particles,. of the neutrino).

The first successful application of nuclear physics to explain the energy source of stars were the work of X. A. Bethe (N. A. Bethe), C. Critchfield (C. Critchfield) and K. von Weizsäcker (S. vonWeizsacker) by the reactions of hydrogen and carbon-cycle the nitrogen cycle (con. 30-ies.). These reactions determine the evolution of stars at the stage of hydrogen burning in the center (m. N. Ch stars. Sequences, in particular the Sun). In the later stages of evolution occur reaction of helium burning, carbon, oxygen, neon, silicon, and so on. <P. (See. The evolution of the stars). These reactions are the result of the strong, of e-mag., As well as the weak interactions of particles (the latter is particularly important in neutron reactions substances).

Lecture 15.

The problem of development and improvement of information technology - the total for the various areas of human activity. Scientific research in general (nuclear physics, in particular), only one of them. The state of affairs in this area in recent years, characterized by a rapid increase in the volume received, analyzed and used information while increasing the requirements for accuracy and reliability. This directly links the effectiveness of scientific research with the progress in information technology.

Organization of various kinds of electronic libraries, databases and data banks, development and improvement of the data processing and the use of methods, not only when analyzing the results of the experiments, but also in the planning and preparation of new ones, as well as - in the simulation experiments that, for whatever reasons, can not it is implemented - all this creates the basis for carrying out both fundamental and applied research to a new level.

In many cases, modern information processing technology, especially developed database allows to obtain new scientific results to decide in some cases, unique challenges, which in the absence of such databases could not only be solved (in view of the huge effort or in principle) but also supplied. This report focuses on the description of the experience of using databases of nuclear physics data, previously created in the Center Photonuclear experimental data (Centre's) SINP to address some of the original nuclear physics research tasks. The rapid development in recent years, a variety of network technologies, especially the Internet, the most direct way closer databases created in specialized organizations, with a particular user and it creates the conditions for the implementation of many previously unavailable features.