ANNOTATION

of dissertation for the Philosophy Doctor (PhD) degree on «6D061100 – Physics and Astronomy»

Agishev Aldiyar

Chaotic regularities of characteristics of gas-dust stars and clusters of galaxies

General description of work

This work is devoted to the study of chaotic patterns in astrophysical processes and objects. A new methodology for calculating information entropy and its normalization for quasiregular, chaotic and stochastic processes was proposed and approbate. The proposed method quantitatively classifies stars with gas-dust shells and molecular clouds by their degree of order and chaos. Algorithms for processing the results of observations based on information-entropy criteria that used to describe open systems of various natures are constructed. From the catalogs of observational data, the fractal properties in the distribution of galaxies are determined. A fractal model for describing the observed distributions of galaxies in an expanding Universe is proposed.

Relevance of the topic

In the Milky Way, gas and dust are organized hierarchically and self-similarly, which should be the result of turbulent processes that generate similar structures on scales from 0.1 to 100 pc, respectively, from dense cores to giant molecular clouds. Star formation also shows fractal structures, typically observed in areas with a spatial hierarchy ranging from a few parsecs to several kilo parsecs. This complexity can be determined by various methods. Some general methods, such as estimating the mass or size distributions of certain types of objects (clouds, cores, and clusters), are not always accurate, since they also depend on other criteria for determining objects and their boundaries. In a strictly hierarchical scenario, have no characteristic spatial scale that can be used to determine any particular structure.

The study of the mechanism of clustering in the distributions of young stars of a molecular gas and individual regions in giant molecular clouds are one of the key tasks of modern astrophysics. Considering each of these structures as accurate as possible, we can compare the properties of different clusters as a function of the measurement scale for each of them. This approach allows us to compare similar objects in different regions and in different physical conditions.

Generally we consider that the fractal dimension observed in the interstellar medium has an almost universal value of the fractal dimension around $D = 2.3 \pm 0.3$. Such observational universality indicates either that the interstellar structure is controlled by the same physical mechanisms everywhere, or that different physical mechanisms tend to generate essentially the same types of structures. Part of the problem lies in the wide range of physical processes that lead to establishing various structures, such as protostellar jets and outflows of protostellar winds,

ionizing radiation, expansion of ionized hydrogen regions HII, supernova explosions, collisions and cloud merging, interaction of galaxies and gravitational instabilities. With such studies, we have a number of problems that are still relevant. One of them is classification problem: distinguishing the observed characteristics of a certain class of objects or processes.

Application of new methods can solve some of this problems associated with the classification by spectra. One of such ways in modern astrophysics is application methods of the dynamic chaos theory. As quantitative characteristics of chaos, information entropy and the fractal dimension of sets of physical quantities are usually used. These characteristics are used to describe the properties of hierarchical and self-similar systems.

However, the information-entropy approach has not been implemented to describe and evaluate turbulence level in molecular clouds and protostellar nebulae. It can be assumed that the assessment of informational entropy of objects will contribute to the determination of areas, where motion is of self-organized. In turn, such regions can be characterized by the presence, for example, of accretion fluxes leading to primary star formation.

The fractal dimension, which quantifies the spatial uniformity of the distribution, can be calculated both for the distribution of gas, dust, and for whole complexes of star formation regions. The universal form of the cosmic "anti-gravity" force, repeated at different scales of the group, clusters of galaxies and their clusters resemble a hierarchically embedded system. The dynamics created by the repulsion of individual groups seems nested, and it is similar for large scales, up to the size of the clusters. The same similarity is the definition of fractal objects, when parts have qualitatively similar properties, like the whole. These properties are also called scale invariance.

Well-known studies indicate the complexity of classifying objects such as Be and B[e] type stars. This is primarily due to the lack of high-resolution spectroscopic studies for each of the individual stars. Despite the large amount of data set for Be stars, the search, determination, and extraction of such stars is still an urgent task. Moreover, the quantitative spectral classification should be used along with the qualitative classification and is necessary for the study of star radiation. At the same time, we consider it possible to use information-entropy analysis, since the stellar radiation of these types of stars is a kind of a chaotic signal. This method will be based on informational-entropic criteria of self-organization, established by Z.Zh. Zhanabaev. The advantage of this approach is that the criteria for distinguishing classes of chaotic and stochastic objects are based on fundamental theoretical conclusions.

The aim of the work a qualitative and quantitative assessment of the patterns of observed structures in gas and dust stars, molecular clouds and clusters of galaxies using information-entropy and fractal methods from the observed spectra and images.

Research objectives

1. Define normalized information-entropy criteria for normalization quasiregular, chaotic, stochastic processes.

2. Collecting observational material and conducting radio astronomy spectral observations of the Orion A complex and stars with gas and dust shells.

3. Based on the analysis of spectral data of star formation regions in the Orion A molecular cloud and stars with gas and dust shells, conduct a quantitative classification of these objects by the information-entropy method.

4. Determine the fractal dimension of the distribution of galaxies in the Local Group and whole observable Universe, the distances to which are determined by the redshifts in their spectra.

5. To develop a model for the expansion of the Universe based on the concept of a nonlinear fractal measure which including a fractal dimension defined by the theory and catalogs of galaxies.

Research objects: optical and radio spectra of molecular clouds, stars, and catalogs of galaxies.

Research subject: regularities of phenomena occurring in molecular clouds, stars and galaxies, as a result of the scale invariance (fractality) properties and universal information-entropy criteria.

Method of investigation

For the analysis of astrophysical spectra by the theory of dynamic chaos, fractal, information-entropy methods of processing registered radiation spectra and galaxy distribution catalogs are used. Computer analysis and data processing are carried out in MatLab, Class, IRAF.

Main provisions to be protected

1. The self-similar values of the informational entropy of quasiregular, chaotic, stochastic signals are normalized, respectively, by the sum of entropies of the individual components as discrete one-dimensional, two-dimensional, three-dimensional processes.

2. The informational and entropy criteria for fractal, chaotic, stochastic signals quantitatively distinguish stars with gas-dust shells, molecular, protostellar cores and galaxy clusters from the observed spectra.

3. Around galactic formations in a space with zero gravity, galaxies move randomly, their positions on a global scale form a fractal set with dimension $D = 2.465$, which is determined theoretically and from observations.

4. Astrophysical observations of the accelerated expansion of the Universe described by a scale-invariant, nonlinear fractal model with the accuracy of determining the Hubble constant interrelated with the accuracy of determining the coordinates of the galaxy from the uncertainty relation for wave processes.

The scientific novelties of work are:

1. A method for normalizing the information entropy of quasiregular, chaotic, stochastic signals by the sum of entropies of one-dimensional, two-dimensional, three-dimensional signals respectively is proposed on the example of chaotic mappings of various dimensions.

2. The information-entropy method developed in the work carried out a qualitative and quantitative classification according to the criteria of types of molecular clouds, protostellar cores, and stars with a gas-dust shell by the data obtained with the GBT, IRAM, NSRT, SPM and CFHT telescopes.

3. The fractal dimension D = 2.465 of galaxy clusters was determined globally by a theoretical model and catalogs of galaxies.

4. A fractal model for describing the observed expansion of the Universe through a scaling factor (the difference between fractal and topological dimensions) $\gamma = D - d = 0.465$ and the radius of zero gravity specified as a free parameter, which is not included in the final result corresponding to the saturation of global expansion is proposed.

Theoretical and practical significance of the work

The results obtained in the work can be used to normalize the information entropy of processes of various natures and degrees of complexity. The methods of normalizing information entropy proposed in the work allow us to quantitatively determine the state of certainty of the characteristics of the process and the object, for example, the signal-to-noise ratio.

The practical benefits of obtained results in the thesis consists in the possibility of evaluating the internal order in chaotic, stochastic signals received from optical, radio telescopes, from a database of astronomical observations. The methods and algorithms proposed in the work and results of a physical analysis of the considered processes can be used to study phenomena of various nature: registration of gravitational waves, search for black holes, Earth's seismic activity and etc.

Researches are based on the original scientific works listed in references.

Personal contribution of the author

Radio astronomical observations were obtained by the author during a research internship at the Xinjiang Astronomical Observatory (XAO), Chinese Academy of Sciences - Urumqi, China) on the NSRT instrument.

The results of digital signal analysis, theoretical models were obtained directly by the applicant. The task setting and discussion of the results were carried out jointly with scientific consultants.

The reliability of the results

The results and conclusions obtained during the study reflect the content of all sections and are confirmed by the publication of the main scientific results in peer-reviewed international and domestic scientific journals. The reliability of the scientific conclusions of the work is confirmed by consistency with the results of independent researchers and conclusions obtained by other authors.

Approbation of work

Based on the materials of thesis 16 printed works were published:

Articles with a high impact-factor according to the database of Thomson Reuters or in the publications included in the international scientific database Scopus:

1. Wu G. … Agishev A.T. … et al. A kinematic study of the integral shaped filament: what roles do filaments play in forming young stellar clusters? //Research in Astronomy and Astrophysics. – 2018. – Т. 18. – №. 7. – С. 077.

2. Khokhlov S. A. … Agishev A.T. … et al. Toward Understanding the B [e] Phenomenon. VII. AS 386, a Single-lined Binary with a Candidate Black Hole Component //The Astrophysical Journal. – 2018. – Т. 856. – №. 2. – С. 158.

Articles in publications recommended by CCSA of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan:

1. Бейсебаева А.С., Алдынгурова А.К., Агишев А.Т., Хохлов А.А. Энтропийный анализ пространственного распределения галактик // Журнал проблем эволюции открытых систем. – 2016. – Т.1. – №. 18. – С. 136 – 140.

2. Жанабаев З.Ж., Хохлов С.А., Агишев А.Т. Нормированная энтропия горячих звезд // Журнал проблем эволюции открытых систем. – 2017. – Т.1. – №. 19. – С. 13 – 17.

3. Zhanabaev Z.Zh., Kozhagulov Y.T., Khokhlov S.A., Agishev A.T., Zhexebay D.M. Informational and entropic criteria of self-similarity of fractals and chaotic signals // International Journal of Mathematics and Physics. – 2018. – Vol. 90. – №. 1. – P.90-96.

4. Omar A., Amantayeva A., Bissekenova A., Agishev A.T., Khokhlov S. Information entropy spectra of hot stars // Вестник КазНИТУ. – 2018. – Т.127. – №.3. – С. 465 - 469.

Publications in collections of theses of reports:

1. Кожагулов Е.Т., Агишев А.Т. Закономерности информационно-энтропийного анализа для иерархических структур // Материалы международной научной конференции студентов и молодых ученых «Фараби әлемі». – Алматы, 2015. – С.418.

2. Хохлов С.А., Агишев А.Т. Анализ радиоизлучения солнца методом клеточной энтропии // Материалы международной научной конференции студентов и молодых ученых «Фараби әлемі». – Алматы, 2015. – С.500.

3. Жанабаев З.Ж., Хохлов С.А., Агишев А.Т. Фрактально - геометрическое описание диаграммы «расстояние – скорость» для антигравитирующих галактик // III International workshop «Nuclear physics and astrophysics». – Almaty, 2016. – pp. 41-42.

4. Жанабаев З.Ж., Хохлов С.А., Агишев А.Т. Фрактальная топология галактических скоплений // Материалы международной научной конференции СДФФФО-9 "Современные достижения физики и фундаментальное физическое образование". – Алматы, 2016. – С.190-192.

5. Агишев А.Т., Хохлов А.А. Классификация горячих звезд типа В // Материалы международной научной конференции студентов и молодых ученых «Фараби әлемі». – Алматы, 2016. – С.408.

6. Жанабаев З.Ж., Бейсебаева А.С., Хохлов С.А., Агишев А.Т. Классификация горячих звезд на основе информационно – энтропийного анализа // Материалы 10-ой международной научной конференции «Хаос и структуры в нелинейных системах. Теория и эксперимент». – Алматы, 2017. – С.40-43.

7. Жанабаев З.Ж., Хохлов С.А., Агишев А.Т. Бифуркационные режимы эволюции нелинейной фрактальной меры // Материалы 10-ой международной научной конференции «Хаос и структуры в нелинейных системах. Теория и эксперимент». – Алматы, 2017. – С.44-47.

8. Алимбетова Д.А., Агишев А.Т. Информационная энтропия основного хребта нити интегральной формы скорость-температура в облаке Ориона // Материалы международной научной конференции студентов и молодых ученых «Фараби әлемі». – Алматы, 2019. – С.243.

In foreign international conferences:

1. Zhanabaev Z., Agishev A.T., Zhexebay D.M. Gravitational-wave nature of accelerated extension of the universe // International conference of students and young Scientists in theoretical and experimental physics HEUREKA-2018. – Ukraine, 2018. – pp. G1.

2. Жанабаев З.Ж., Агишев А.Т., Жексебай Д.М. Гравитационно-волновая природа ускоренного расширения Вселенной // Международная научная конференция «Астрономическая школа молодых ученных». – Украина, 2018. – С.27.

Relationship of the thesis topic with the plans of scientific works

The methods developed in the dissertation are used in the implementation of the order of the Ministry of Education and Science of the Republic of Kazakhstan “Financing for scientific and (or) scientific and technical projects for 2018-2020” on the topic: “Information-entropy technologies of multichannel telecommunication systems and their application”, in accordance with the plans of scientific research work.

Structure and volume of the thesis

The thesis consists of an introduction, three sections, the conclusion, a list of used sources and contains one appendix. The work is presented in 111 pages of typewritten text, illustrated by 44 figures, 35 formulas are given, 2 tables, the list of used sources contains 279 items.