NATIONAL SCIENCE FUND
Ministry of Education and Science

PROJECT

Evolutionary processes in astrophysics: synergy of observations with theory

NATIONAL SCIENCE FUND
Ministry of Education and Science

Application forms – Part 2

„COMPETITION FOR FINANCIAL SUPPORT FOR RESEARCH PROJECTS– 2017”

Scientific description of the project

Competition:
Competition for financial support of research projects – 2017
Main research/thematic area, of the project:
Physical sciences
Additional research/thematic area – for interdisciplinary projects:
Project title:
Evolutionary processes in astrophysics: synergy of observations with theory
Type of the planned research (fundamental or applied):
Fundamental
Applying organization:
Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences
Partner organizations:
Coordinator of the research team (academic position and degree, name):
Prof. Dr. Tanyu Rusinov Bonev

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1. Analysis of the current state of research on the problem area

1.1. Timeliness and relevance of scientific problems addressed by the project

The subject of this project is compliant with the contemporary trends in the development of astronomy and astrophysics. A fast look over the scientific programs of the European Space Agency (ESA, http://www.esa.int/ESA), and of the European Southern Observatory (ESO, http://www.eso.org/sci.html) shows that they are based on the close link between the collection of new observational data and their interpretation with the help of new theories about the formation and evolution of astronomical objects. For that purpose new observational technologies are designed, space missions are running and planned, innovative unique telescopes and instruments are build. Subject of these studies is a diversity of astronomical objects, comprising a huge range of space and time scales, starting with the early Universe, going through a variety of galaxies and different types of stars, and reaching the Sun and the bodies in our planetary system. Following the trend of comprehensive approach and interdisciplinarity, this project is dealing with contemporary and significant studies of the processes and phenomena relevant to the early Universe, to galaxies, to early stages in the stellar evolution, main sequence stars, symbiotic and cataclysmic stars, to the Sun and small bodies in the Solar System.

As a result of the vast amount of observational data and theoretical investigations during the last decades the contemporary Cosmological Model was constructed and the basic characteristics of the Universe were determined with high precision. The evolutionary character of the Universe as a whole was established: the Universe dynamics changes, its constituents, physical processes and structure evolve. However, at present there remain still unsolved several important problems concerning Universe characteristics and processes, which have played considerable role at different stages of Universe evolution, as for example: the nature of the dark matter, the dark energy and the dark radiation, the exact baryogenesis model, the eventual leptogenesis model, the physical nature of the inflaton and the concrete inflation model, etc.

One of the key elements of the modern theory of galaxy evolution is secular evolution (SE). Driving mechanisms of SE could be internal (e.g., bars) or external (like interaction with another galaxy). Regarding disk galaxies, an important aspect of SE is the formation of pseudo-bulges. They do not follow the "central black hole mass – bulge mass" relation, established for the classical bulges. This implies different evolution scenarios of the central black hole and bulge for the two types. SE has indirect influence on the activity in the galactic nuclei via gas inflow.

Flux variability is among the main characteristics of active galactic nuclei (AGNs). Most extreme are blazars – their flux variability is related either to fluctuations caused by shock waves in the jet, or to geometrical effects. Detailed multi-band light curves allow search for the inter-band time delay, as well as building the spectral energy distribution (SED) and following its evolution. This

allows us to make conclusions about the processes generating flux variability and about the mechanisms driving the evolution of the energy distribution of the relativistic particles in jets.
mechanisms driving the evolution of the energy distribution of the relativistic particles in jets.

The star formation is a continuous process, both in our galaxy and in other galactic systems. The formation of stars from interstellar clouds of gas and dust is a typical example of the evolution of space objects. Recently formed stars begin to emit in the visible region of the spectrum due to gravitational contraction and reaching a high enough temperature and pressure in the cores of stars, there begin the process of nuclear fusion. In this way, the elements heavier than hydrogen and helium are formed, and dispersed in the Galaxy by the outbursts of Nova and Supernova stars. The current evidences from observations indicate that mass accumulation does not stop with the formation of the star, but continues by accretion from the circumstellar disk on the stellar surface. In such circumstellar discs at a later stage of evolution begins the formation of planetary systems. By studying the processes of star formation, we get information about a substantial part of the evolution of the entire universe, the galactic systems, the star clusters and the individual stars.

There are two theories in modern astrophysics, which without any doubt are nova days among the most successful scientific achievements. First is the theory of stellar evolution, and the second is concerned with stellar atmospheres structure. We completely owe them our capacity to predict all fundamental physical characteristics of a star with given mass and age, and to determine the abundances of dozens of chemical elements in stellar atmospheres with an accuracy better than five percent. One sentence expression of stellar evolution looks like this - gravitational collapse of the proto-stellar molecular cloud, ignition of the thermonuclear fusion in the core parts, depletion of the nuclear fuel, then series of collapses that lead to the formation of a white dwarf, a neutron star, or a black hole. Throughout the evolution, electromagnetic radiation has been transferred to the atmosphere, and outward. Once registered by the observer, this radiation becomes the only source of information about evolutionary processes, and the atmospheric structure; it serves as an observational background of both theories. From the observational point of view, the initial and final stages of stellar evolution are much more interesting; this fact is mainly due to the dynamics of the ongoing processes. From the evolutionary point of view, however, the stage of hydrogen burning in the central parts of stars is considerably longer.

Massive stars, i.e. stars with initial masses larger than about 9 solar masses , play a key role in the evolution of galaxies and of our Universe. The very first generation of these objects (very massive stars, Population III) might have been responsible for the re-ionization of the early Univers. In the present cosmos, massive stars provide most of the metals and the energy. In the distant Universe they dominate the UV light from the young galaxies. At the endpoint of their evolution, massive stars suffer a gravitational collapse and explode as supernova (of type II or Ib,c). Eventually a Gamma-Ray-Burst emerges, the most energetic cosmic flash. Thus, our knowledge about massive stars and their evolution is crucial for our understanding of the Universe as a whole.

Eclipsing binary systems (EBS) play an important role in the process of improving our knowledge of the stellar physics (Kallrath & Milone 2009). The primary use of detached EBs is as checks on the success of theoretical predictions (e.g. Pols et al. 1997) or to investigate the physical processes included in the models, such as mixing length (Ludwig et al. 1999), convective core overshooting (Claret et al. 2007), the chemical enrichment law (Ribas et al. 2000) and limb darkening coefficients from model atmospheres (Claret et al. 2008). The study of detached eclipsing binaries offers us a unique method of determining the physical parameters of stars and to compare these measurements to the predictions from stellar models.

Symbiotic stars are long-period interacting binaries consisting of a cool giant of III-II luminosity type or Mira and a compact object, most often a white dwarf, accreting mass from the atmosphere of the cool component. Their photometric and spectral variability is determined on one hand from the orbital motion, eclipses and heating/reflection effects, and on the other one – from the outburst events of the compact object, which are in a number of cases accompanied by intensive loss of mass in the form of optically thick shells, stellar wind and bipolar collimated jets. According to the theory the compact object undergoes an outburst generated by burning of hydrogen in a shell source at its surface. Symbiotic stars provide the best possibilities to investigate the evolution of accreting white dwarfs in binary systems which is among the topical tasks of modern astrophysics – theoretical and observational ones.

Another contemporary field in the investigations of stellar evolution is the analysis of the short timescale variability of cataclysmic stars (flickering). Flickering is the term for stochastic photometric variations on timescales of a few minutes with amplitude of a few times 0.1 magnitudes. The flickering is a variability typical for the accreting white dwarfs in cataclysmic variables and recurrent novae (Warner, B. 1995, "Catclysmic Variable Stars", Camb. Astrophys. Ser., Vol. 28 Cambridge University Press), however among symbiotic stars only 10 % display flickering (Sokoloski, Bildsten & Ho 2001, MNRAS 326, 553). The importance of the investigations of the flickering is dictated by the circumstance that the character of the processes causing this phenomenon are not clarified yet.

Significant part of the contemporary knowledge of star formation and evolution comes from investigations of the processes and phenomena on our Sun. Special role in this respect plays the analysis of solar eruptive phenomena. Coronal mass ejections (CMEs) observed as bright transient features in white-light coronagraph observations are very frequently accompanied by eruptive or dynamical phenomena low in the solar atmosphere: solar flares and filament (prominence) eruptions and occasionally jets, magnetic reconfiguration, extreme ultraviolet lines (EUV) waves, coronal dimmings or brightenings, or post-flare loop arcades (Webb & Howard, 2012). Eruptive prominences (EP), CMEs and solar flares are the most powerful solar eruptive events that are the basic factors, which influence space weather (SW) in the heliosphere. Thus, the study of solar eruptive phenomena is important for a better understanding of the physical processes leading to their emergence and evolution as well as for the development of more plausible theories (Chen, 2011) and more accurate predictions of the changes in SW caused by them (Schwenn, 2006).

The proposed work is important and timely, as it will contribute significantly to advancing research on the topic of early-stage solar eruption evolution and its acceleration. By making the needed connection between observational parameters of EPs and CMEs, it will enhance our capability to understand their nature better and to forecast solar eruptions. The project is innovative, as it seeks to establish definitively the link between EPs, flares and CMEs. Identification of observable coronal eruption parameters will allow the development of predictive tools that will improve the current state of solar event forecasting. This new knowledge determines the importance of the investigations in the field of solar eruptive phenomena.

The small bodies in the Solar System, asteroids and comets, are a rich source of information about the physical state and chemical constitution of the protoplanetary cloud from which the Sun and the planets have been formed about 4.5 billion years ago. Therefore their investigation is a modern topic in astrophysics, the number of scientific publications on the subject is continuously growing, and the targets of a great number of previous, running and planned space missions are asteroids and comets. Additional motivation and illustration of the state-of-the-art of the field is the circumstance that some of these bodies are crossing the Earth's orbit and therefore are considered as potentially hazardous.

1.2. Current state of the research on the problem area

The detailed study of the "central black hole mass – bulge mass" relation shows that the growth of the central black holes is decoupled from the growth of their pseudo-bulge hosts, as in the case of classical bulges (Saglia et al., 2016, ApJ, 818, 47). Moreover, the structure and kinematics of the broad line region of AGNs is related to bulge evolution (Ho & Kim, 2014, ApJ, 789, 17). In this context, the precise bulge classification and the reliable determination of its parameters using photometric decomposition is essential.

Blazar variability on various time scales is well described by the so-called shock-in-jet model, related to the evolution of the energy distribution of the relativistic particles, as well as by the geometric model. The synergy between the observational data and the models applied (e.g., the observed "bluer-when-brighter" bahaviour is reasonably explained within the shock-in-jet model) results in reliable conclusions about the ongoing processes. Contemporary studies do not favour a particular model to explain the observed variations in blazar SEDs (e.g., Bachev, 2015, MNRAS, 451, L21; Gaur et al., 2015, MNRAS, 452, 4263, Larionov et al., 2016, MNRAS, 461, 3047).

A baryogenesis model with scalar field condensate (Kirilova & Panayotova, AdvAstron, 2015, 2015, id.425342), compatible with inflation and low reheating temperature, was proposed and studied. Similar models of nonhomogeneous baryogenesis propose a principal solution of the problem of the generation of super-structures and the massive black holes. Cosmological constraints on different characteristics of particles and processes in the early Universe were obtained on the basis of Big Bang Nucleosynthesis theory and the observational data on light elements abundances and the baryonic density of the Universe (Kirilova & Frere, NewAR, 2012, 56, 169).

The main questions which the theory of the early stages of stellar evolution has to answer are: how are the stars and stars participating in double and multiple systems formed, what is the ratio of newly formed stars with large and small masses, how star clusters and associations are formed, what is the mass at initial star formation and the accumulated mass of the later stages of stellar evolution. Over the last few decades several theories have been proposed explaining star formation processes, which require the accumulation of new observational data. Based on the comparison of the observations of the pre-main sequence stars, the theoretical models of the stellar evolution can be corrected.

Over the past two decades, a growing body of theoretical and observational evidence has been assembled indicating that rotation, binarity and possibly magnetic fields are as important a factor for massive star evolution as mass-loss. Consequently, several grids of evolutionary models for massive single stars, accounting for rotation in addition to mass loss, have been computed and made available to the international community (see, e.g., Ekstroem et al 2012, Brott et al. 2011, Chieffi and Limongy 2013). While the models make detailed predictions of the surface properties of massive stars as a function of mass, initial chemical composition and initial rotational rate, it is not in advance clear if and to what extent the physical processes included in the evolutionary calculations are comprehensive and describe adequately the real nature of the stars.

Stellar models succeed in predicting the mass-radius relation to an accuracy of a few percent for main-sequence stars with $1M_\odot < M_\star < 5M_\odot$ (e.g. Andersen 1991). Systematic discrepancies between model and observation in the mass-radius relation for a given age have been associated with the amount of convective core over-shoot (mass transfer) by Clausen et al. (2010). Low-mass stars with $M_\star < M_\odot$ are the most common stars in the solar neighborhood, but only a very limited number of these are well-characterized (Torres 2013). For these stars, stellar models also show systematic discrepancies in the observed mass-radius relations, but on a larger scale. Some investigations (e.g. Keppens et al. 2000) established the influence of angular momentum evolution for binary systems of different types (components at different evolutionary stages), e.g. whereas the usually small changes in orbital parameters on the main sequence are caused by angular momentum loss through the wind(s) of the stars and spin-orbit coupling, on the giant branch the much larger changes of the semi-major axis are due to the expansion of the stellar envelope(s) and spin-orbit coupling.

Symbiotic stars undergo optical outbursts with duration from about one year to several decades. During outburst their continuum increases by a factor of 10-20, the energy flux of the lines of high ionization degree decreases strongly and Balmer profiles get multicomponent ones containing in some cases several indications of loss of mass. The bolometric luminosity of the outbursting compact object increases many times and reaches ~10^4 Lsun.

According to the modern theory the observed phenomenon is interpreted with evolutionary processes of a white dwarf, accreting matter rich of hydrogen. The accretion rate of the compact companion in classical symbiotic stars is supposed to be in a narrow range where it is equal to the burning rate of hydrogen. In this case so called regime of steady state burning realizes at the surface of the companion. The increase of the rate above the upper limit of this range produces the optical outburst when a shell of hydrogen rich matter not included in the burning process forms onto the white dwarf. Such an object can acquire size of a red giant. Since, according to the theory, the burning rate does not change, it should evolve at a constant bolometric luminosity and the growth of the optical brightness of the system to be due only to continuum energy redistribution resulted from his expansion.

If the accretion rate falls below the lower limit of the range, the accreted material gradually decreases and the burning stops. Unceased accretion, however, gives rise to a new shell where the gravitation of the compact object causes a growth of the temperature and pressure and after some time the hydrogen burning begins again. This regime is related to the behaviour of symbiotic novae and recurrent novae. The evolution of the white dwarf acquires a cyclic pattern and every cicle contains three stages: accretion – burning – explosion. According to the theory, for a white dwarf with a mass of 0.6 Msun the stage of accretion lasts 10^5 yr, and the explosion elapses for hundreds of days. The evolution of the white dwarf during the explosion (optical outburst) has two stages: an increase of the bolometric luminosity at a constant radius (heating) and an expansion at a constant bolometric luminosity.

The observations, however, show that in a number of cases the photometric and spectral characteristics of the outbursting classical symbiotic stars do not follow the theoretical prediction. Some systems do not evolve at a constant bolometric luminosity, but the luminosity increases and, moreover, the expansion of the outbursting compact object is accompanied by a spectral indication of loss of mass, which means, that it is due not to accumulation of mass resulted from an increase of the accretion rate, but rather to mass outflow. Moreover, some more recent hydrodynamic simulations of accretion of solar material onto white dwarfs show that steady burning regime does not occur. All these show that although the modern theory to give an opportunity for explanation of some basic characteristics of the behaviour of the symbiotic stars, a number of other characteristics of these stars remain unexplained. To formulate the theory, high quality observational data allowing precise determination of some basic parameters, for example the bolometric luminosity and mass-loss rate of the outbursting compact object, are needed. Some of the parameters of the donor of mass-the cool component, are of the first importance too, as in a number of cases it initiates the outburst.

What causes the flickering in cataclysmic stars is still an open question, and subject of discussions. Different sites for the origin of the flickering have been discussed. They are all related to the accretion process: (1) the bright spot (the region of impact of the stream of transferred matter from the mass donor star on the accretion disk); (2) the boundary layer (between the innermost accretion disk and the white dwarf surface); (3) inside the accretion disk itself.

Despite many observational and theoretical studies in recent decades, the origin of solar eruptions and exact relationships between them remain a matter of debate. During last decade two space missions were started, which afford unique opportunities of observing the activity events in solar atmosphere. The first one is Solar Terrestrial Relations Observatory (STEREO) mission (Kaiser et al. 2008) that was launched in 2006. This mission is composed of STEREO Behind (B) and Ahead (A) spacecraft. Two spacecraft separated and entered heliospheric orbits in opposite directions, STEREO-A leading in east direction and STEREO-B trailing in west direction around the Sun, increasing their separation by $\approx 45^\circ$ per year, but maintaining their average distance of ≈ 1.0 AU from the Sun all the time. Each of the two identical spacecraft contains the Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) suite (Howard et al., 2008), which includes the Extreme Ultra-Violet Imager EUVI (1–1.7 solar radii (Rs)) (Wülser et al., 2004), the coronagraph COR-I for 1.4 – 4.0 Rs, and the coronagraph COR-II for 2 – 15 Rs. Second mission is Solar Dynamic Observatory (SDO) that was launched in 2010 (Pesnell et al., 2012) and orbiting along a circular geosynchronous orbit. The SDO mission includes three scientific investigations: the Atmospheric Imaging Assembly (AIA), Extreme Ultraviolet Variability Experiment (EVE), and Helioseismic and Magnetic Imager (HMI).

During the last several decades instruments onboard dedicated spacecrafts perform *in situ* measurements for determination of the parameters of the gas and dust constituents of cometary nuclei. The most recent example in that respect is the Rosetta mission, successfully completed in

2016. The mission lasted 12 years and contributed with a huge amount of data for the understanding of the formation of cometary nuclei. These unique results were presented in June this year, in Sofia, during the meeting "COMETS WORKSHOP 2017: Comet formation paradigm after Rosetta. What is the hallmark of cometary nuclei formation in protoplanetary discs inherited from Rosetta?", http://www.astro.bas.bg/comets2017/. Nevertheless observations from ground-based observatories, equipped with special instruments for cometary research, continue to play important role. They obtain the spatial distribution of the surface brightness at larger distances from the nucleus, which bears important information on the characteristics of the material released from its surface and on the interaction of that material with the solar radiation and the solar wind and the frozen in interplanetary magnetic field.
The asymmetric interaction between solar radiation and the surface of asteroids is important for the understanding of the evolution of their orbits and the derivation of their rotational parameters (axis orientation, period of rotation, precession). . Because of the asymmetric shape of most of the asteroids, the derivation of these parameters requires long series of photometric observations (Kryszczy´nska et al.., 2012, A&A 546, A72; Apostolovska et al., 2014, Serb.Ast.J., 189, 79).

1.3. Focus of proposed research in line with the objectives of the National Research Strategy and with regional, national and European research priorities

The proposed research project meets the requirements and objectives of the National Research Strategy: to reform scientific organizations, to enhance the efficiency of research development, to develop the National roadmap for research infrastructure as part of "The European Research Area Roadmap"; accessibility of activities and research results. During the peer review of the national system "Science-Innovation" by the instrument "Policy Support Facility" in 2015 it was pointed out that the funding of basic research should be carried out on project basis through the national scientific funds. The proposed project is also compliant with regional, national and European research priorities.Development of observational astronomy is one of the European priorities in the field of research. With the national funding of the European countries was built and developed European Southern Observatory (ESO) in Chile, where currently the largest telescope in the world is under construction, with a total diameter of the mirror 39 meters. In summary, the proposed project supports the execution of the National Research Strategy as well as the European research priorities, as far as it focuses to accumulation of new knowledge and aims for excellence in scientific investigation.

Important: The information necessary for scientific evaluation of the project proposal according to the criteria and sub-criteria included in the Form for scientific evaluation of the project proposal (published as part of the Guidelines for Applicants for the competition) should be provided in the sections of the scientific description of the project.

2. Project objectives, hypotheses and approaches for accomplishment of project objectives

2.1. Project objectives and hypotheses

We will study the "central black hole mass – bulge mass" relation, as well as the indications of the SE influence on the gas inflow for selected active galaxies.
Flux variability and SED evolution on different time scales and for different brightness states will be studied for selected blazars.
One of our objectives is to gain physical knowledge concerning the evolution of the physical characteristics of the Universe and to obtain cosmological constraints on the characteristics of the considered particles and processes.

The investigations of the pre-main sequence stars aims the studying of physical processes of star formation, the presence of circumstellar disk, and the accumulation of a mass of stars as a result of accretion from the circumstellar disk. We will compare the data from the accretion rates and the light curves at the observed objects in order to determine the processes causing the accretion and the evolutionary stage of the objects. Our main objective is to present a classification of the studied pre-main sequence stars, which exhibit photometric variability, as a function of photometric properties and their physical parameters: age, mass, evolutionary status, etc.

Stars spend more than ninety percent of its lifetime inside the Main Sequence strip on the Hertzprung-Russell diagram. Exactly here we notice the greatest success of both theories - the evolution of a single isolated star with an atmosphere for which flat-parallel approximation is valid. This is the reason that studying the influence of processes and events external to the Main sequence stars, such as stellar winds in the hottest objects, and slow selective accretion of circumstellar matter onto the stellar atmosphere in the cooler objects, is very important. Here we can also add the impact of close component in binary stars, which causes non-radial pulsations and/or subsequent transfer of matter via the inner Lagrangian point. Therefore, the main goal of our research in the frame of the project is to obtain new observational facts, and to put new limitations to the existing theories concerning Main sequence stars.

The goal in the investigation of massive OB stars is to compare their observed parameters with predicted properties in order to identify and constrain uncertain physical features and processes in stellar evolution and atmosphere models. To this end we will use own data derived using optical spectroscopy and applying the model atmosphere code FASTWIND as well as literature data obtained following methods and approaches similar to ours. The properties of the stars will be compared to published predictions based on two grids of single massive star evolution models which include rotationally induced mixing: that of Ekstroem et al 2012 and Brott et al. 2011. In this comparison we will try to put constrain on all important parameters that may influence stellar evolution, such as e.g. mass, age, binarity, metallicity and magnetic fields.

The main objective in the investigation of eclipsing binary systems is the derivation of stellar parameters of a large number of stars, member of these systems in which the spectra of both components are observable.

About symbiotic stars the basic aim is to obtain estimates of the mass-loss rate and luminosity of the outbursting compact object at different states of the light of the systems BF Cyg, Z And and AG Peg which are in active phase or immediately after it.

The investigation of the flickering in cataclysmic stars has following objectives: (1) to obtain the unreddened colours of the flickering source - depending on the data we will calculate one or more of the following (U-B)_0, (B-V)_0, (V-R)_0, (V-I)_0 colours, (2) to derive the physical parameters of the flickering source - temperature, size, position, and (3) to find how the above parameters change when the objects becomes brighter and fainter.

The research on solar eruptive phenomena has following scientific goals: (1) Identification and quantification of observational plasma parameters (rotation, down-flow motions, velocities, brightness changes) in the EP body and legs during the early stages of its evolution. The goal is quantifying the eruption precursors, (2) Identification and quantification of observational plasma parameters (rotation, upward motions, direction, changes in brightness) during the eruptive phase. The aim is to determine the type of EP, the physical mechanisms leading to an eruptive instability and parameters of the eruption, which can be used as CME precursors, and (3) Examination of the evolution of two-ribbon flares that usually accompanied solar eruptive phenomena. Such evolution is believed to provide a signature of the reconnection process in the corona. The aim is to probe the trigger mechanism of the eruption process.

The aim in the investigations of comets is to characterize the dust component of the periodic and new comets which will be visible in the period 2018-2020. In order to accomplish this aim we will use the hypothesis that the observed features of the brightness distribution around the nucleus is caused by its heterogeneity. In asteroids, the aim is to follow up the evolution of their orbits as a result of collisions and of the asymmetric interaction between the solar radiation and their surfaces. This will require the determination of the shape and rotational parameters of selected asteroids, with accent on objects which are passing close to the Earth. Asteroids which will be discovered by GAIA will be included in the observation plans (the team participates in the international network GAIA-FUN-SSO, https://gaiafunsso.imcce.fr/).

2.2. Approaches for accomplishment of the research goals including interdisciplinarity of the project

For a reliable bulge classification and for the study of relations between the bulge parameters and the black hole a suitable selection of galaxies will be made.
Blazars with high intra-night duty-cycle were selected so that the brightness variability and SED evolution could be studied.
Approaches for accomplishment of the research goals include: investigation of the physical content at different stages of the early Universe evolution; numerical modelling of the epochs of baryogenesis and nucleosynthesis in the early Universe; study of the processes influencing baryogenesis and Big Bang Nucleosynthesis epochs; study of the effect of additional particles on Universe dynamics and their direct interactions with the constituents of the high temperature plasma of the early Universe at different stages of its evolution.

During the stage of formation and in the early stages of evolution, the young stellar objects show strong photometric and spectral variability. Periodic or non-periodic variability with amplitudes reaching up to 2-3 stellar magnitudes, short or long-term bursts, diminishing in brightness as a result of obscurations by clouds of gas and dust are observed. We aim to obtain new observational data and compare existing data on the young stellar objects in the fields of star formation, determination of their age, interaction with the interstellar medium, accretion from the circumstellar disk or manifestations of stellar activity. We will examine the light curves of the observed objects in order to determine the processes causing changes in the brightness at the current evolutionary stage.

The benchmark of the current astronomical epoch is the great advance in digital spectroscopy, chiefly through the use of modern echelle spectrographs and CCD detectors, coupled with the advances in numerical stellar atmospheres models. The Institute of Astronomy and National Astronomical Observatory 'Rozhen' (IA-NAO) follows this tendency what helps us since 2011 to start a project aimed to investigate physical properties of many EBS. About 50 objects were selected from the photometric data-base of STEREO mission (NASA). The selection was prepared inspecting light curves of many hundreds objects appropriate to be observed with the NAO Rozhen facilities. The project relies on obtaining and analyzing of high resolution spectra taken with Coude and the new Echelle Spectrograph Rozhen (ESpeRo; Bonev, Tomov, Markov et al., 2017) both fed by the 2-m telescope of the NAO and ARCES the échelle spectrograph fed by the 3.5m telescope of the Apache Point Observatory (New Mexico, USA). ESpeRo is a bench mounted with temperature and humidity controlled environment instrument. It is able to provide in one hour exposure a high resolution spectrum, R=40000, with singnal-to-noise ratio 80-100 for 9-th magnitude star. The uncertainties of radial velocities derived at proper and rich in absorption features regions are well bellow 1km/s. Up to now there were derived more than 1000 spectra and deriving new spectral observations continues. All available spectra are reduced with IRAF and are ready to be analyzed. For thirty systems with ten and more observed phases were constructed RV curves. Seven of these systems are with more than 30 observed phases what satisfies requirement for reliable stellar masses derivation (Southworth 2012). All these ensure spectral data with sufficient resolution and S/N ratio for which accurate velocities can be derived and analysed with sophisticated mathematical techniques. Two-dimensional cross-correlation techniques (Zucker & Mazeh 1994) and the broadening function technique (Rucinski 1992) are applied for RV curves derivation. To obtain physical parameters of individual stars in eclipsing system, we use to apply 'disentangling' technique originally implemented by Simon & Sturm 1994 and recently developed as KOREL by Hadrava 2004, Hadrava 2009. We like to point on the disentangling method which takes advantage of the fact that a set of spectra distributed over the orbital cycle of a double-lined binary displays the same two spectra, only shifted by different relative velocities. Best-estimate values for the two spectra and the orbital elements are then extracted from the observations by a statistical analysis technique. The individual spectra can then be further analyzed by available stellar atmosphere models - standard single-star procedures to derive effective temperatures and chemical compositions of eclipsing binary components (e.g. Spectroscopy Made Easy, Valenty & Piskunov 1996, last revised at 2016-Jul-15; Spectrum, Gray 1992).

About symbiotic stars we will analyse the continuum energy distribution from multicolour photometry in a broad spectral range to obtain the basic parameters of the system's components, the profiles of the spectral lines to investigate the structure of the gasflow in the system and we will also perform modeling of the geometrical structure of the outbursting compact object with use of both the light curve and spectral data.

The approach of characterization the flickering of cataclysmic variables is based on 5-colour (UBVRI) photometric observational data.

To accomplish the objectives of the solar eruptive phenomena investigations we will use data from AIA and HMI of SDO and EUVI, COR1 and COR2 of STEREO A and B. The data that we plan to analyze include observations in the EUV lines, covering the 0.1 to 20 MK temperature range. We intend to use also line-of-sight magnetograms taken by the HMI/SDO in order to examine the pre-eruptive magnetic evolution (Scherrer et al. 2012). The data in H-alpha line from groundbased observatories will be also used to study the pre-eruptive changes in the chromosphere. Data processing will be performed by the SolarSoft system.

For the cometary investigation we will obtain images of the near nucleus coma with narrow-band filters, centered at typical cometary emissions and continuum windows. Polarimetric imaging will be performed by using a Wollaston prism in combination with a half-wave retarder. For comets brighter than 8 magnitude spectropolarimetric data will be obtained. The characterization of the selected astroids will be done by means of long series of photometric observations.

3. Methods, research equipment and techniques

3.1. Research methodology and techniques

In order to reach the goals of the project, two main groups of methods will be used, classical (spectroscopy and photometry) and relatively new, innovative methods, emerged in the last several decades (polarimetry, spectropolarimetry, use of data from space missions, data mining the archive collections). **There is link, connecting the observational methods with the research techniques; this is the one-, two-, and three-dimensional image processing.** The research techniques, which will be used in this project, are characterized by their variety which is a natural consequence of the great number of different astronomical objects, this project aims to study

The methods which will be used for reaching the goals of the projects can be divided into two groups: classical (spectroscopy and photometry) and relatively innovative (polarimetry, spectropolarimetry, use of data obtained by space missions, use of archive observations, data mining). The unifying link between the different research methods and approaches is the processing of one-, two, and three-dimensional images. The research techniques are characterized by a wide variety, which is a direct consequence of the large set of different astronomical objects of interest, included in the project.
The “central black hole mass – bulge mass” relation study, as well as the search for indications of gas inflow, will be based on data from the 2-m telescope of Rozhen NAO as well as on archival data. The bulge parameters will be determined using two-dimensional photometric decomposition.
The blazar variability will be studied by means of intra-night monitoring with the 2-m and 50/70-cm telescopes of Rozhen NAO and the 60-cm telescope of Belogradchik Observatory. The light curves will be analyzed via cross-correlation and structural functions. The well-manifested

outbursts will be modeled (e.g., using the helical-jet model). The SEDs built will be approximated with models of synchrotron emission, so that the parameters characterizing the energy distribution and evolution of the relativistic particles could be obtained.
The investigation includes analysis of astronomical and astrophysical observational data from terrestrial and cosmic missions and experimental data, numerical modelling of the evolution of the early Universe, the evolution of its baryon charge, its chemical content, etc. comparative analysis of observational data with the results of the numerical modelling.
The investigation of pre-main sequence objects will be based on combined analysis of spectral and photometric observations of variable stars of following types: T Tau, FU Ori, EX Lup, UV Cet, UX Ori and others.

To reveal the physical parameters of individual stars in binary systems we use the light curves and spectra of many EBS. A variety of codes exists to analyse the light curves of EB and derive the orbital parameters (i, e, and ω) and stellar radii in units of the orbital semi-axis. The most frequent obstacle to an accurate radius determination from such codes, notably in partially eclipsing systems, is the fact that a wide range of combinations of stellar radii, orbit inclination, eccentricity, and ω, may yield light curves that are essentially indistinguishable. The widely-used Wilson-Devinney code (Wilson 1998), allow one to input together light curves as well as the radial velocity observations, and return a single set of results for the stellar and orbital parameters. From a physical point of view this is clearly the preferable procedure, providing single sets of masses, radii, etc. which as a rule have relatively small formal errors. The most critical requirement for obtaining accurate masses is an accurate determination of the orbital velocities from the observed double-lined spectra, both for eclipsing and non-eclipsing binaries, because the derived masses are proportional to the third power of these velocities. As we described above the available observing material up to now satisfies the requirements of good spectral resolution spectra and S/N ratio.

In order to achieve the goals of the investigation of symbiotic stars we will apply the methods of classical spectroscopy to obtain line profiles, radial velocities and equivalent widths. We will use data of simultaneous photometry to obtain energy fluxes in spectral lines and continuum. We will use also a good set of time resolved spectral data to trace the evolution of the profiles.

For the analysis of the flickering we are performing simultaneous multicolour observations in five optical bands - UBVRI. For these observations following telescopes will be used: the 2.0 m RCC telescope and the 50/70 cm Schmidt camera of NAO Rozhen, the 60 cm telescope of the Belogradchick Astronomical Observatory, the 30 cm astrograph of IRIDA observatory, and the automated 41 cm Schmidt-Cassegrain telescope of the University of Jaen, Spain.

The analysis of the solar eruptive phenomena includes following phases: (1) Data processing and analysis of EP and working with databases; (2) Quantitative estimates of the height, horizontal displacement and kinematic parameters of the EP; (3) EP association with the CME and / or solar flares; (4) Determination of changes in the helical structure of the EP, as a sign of development of kink or torus instability and EP type qualification; (5) Quantitative estimation of the increase in brightness in and around the EP body as a sign of magnetic reconnection; (6) Interdisciplinary studies for determination of the physical or statistical connection between solar eruptions, geophysical and atmospheric parameters.

The investigation of comets will be based on construction of 2D maps of the surface brightness, color, and polarization, and their interpretation based on Monte-Carlo modeling. Retrieval of the shape and rotational characteristics of asteroids (period, spin axis orientation, etc.) from long-term light curves.

3.2. Previous accomplishments and competencies of the research team in the research area of the project

In order to give an illustration of previous research and competences, we present here only a small subset of papers published by members of the project team: Bachev, 2015, MNRAS, 451, L21; Slavcheva-Mihova & Mihov, 2011, A&A, 526, A43; Kirilova & Panayotova, 2015, AdvAstron, 2015, id.425342; Koleva, K., Madjarska, M. S., Duchlev, P., Schrijver, C. J., Vial, J.-C., Buchlin, E., Dechev, M. : 2012,. A&A 540A, 127; Duchlev, P., Koleva, K., Madjarska, M. S., Dechev, M., 2016, New Astronomy 48, 66.

The senior scientists in the project team are experienced in planning and obtaining observations, analyzing them and giving relevant interpretation on the results concerning the early Universe, galaxies, different types of stars, the Sun and the bodies in the Solar System. On most of the topics work is running for decades and hundreds of original results are published in papers with impact factor or impact rang. The competencies of the project team are relevant to the proposed scientific investigations.

Good illustration for the accomplishments and competencies of the project members can be found in their CVs, and in the lists of publications, included therein.

The project leader and the leaders of the separated work-packages are habilitated scientists with rich publication lists in the relevant topics. One characteristic of the project is the well balanced ratio between primary investigators, internationally recognized, with great experience and skills, and young, perspective scientists. This is one of the guarantees for the sustainable continuation of the research topics, included in this project, after its completion.

CVs of team members should be added after the scientific description of the project following the attached form. The CVs should not be provided in separate files.

3.3. Capacity of the applying and partner organizations to conduct the proposed research

The Institute of Astronomy and National Astronomical Observatory (IA and NAO), Bulgarian Academy of Sciences is the largest scientific organization dealing with astronomy in Bulgaria. Primary mission of the institute is to conduct fundamental research in astronomy and astrophysics. Institute works closely with two universities (Sofia and Shumen) who only have their own telescopes for astronomical observations and where only train students in astronomy. IA and

NAO has two professional astronomical observatories: NAO Rozhen and Astronomical Observatory in Belogradchik. The project team will use primary data obtained with telescopes of NAO Rozhen, but provided observations with telescopes in Greece and France, as well as using data from space satellites, NASA and ESA.

NAO Rozhen is the largest astronomical complex in south-eastern Europe and a major training center for undergraduate and graduate students in astronomy in the region. NAO Rozhen has three telescopes for optical observations of comets, asteroids, stars, star clusters and galaxies and a telescope for observations of the sun. The largest telescope in NAO Rozhen is manufactured by Carl Zeiss factory in Jena two-meter telescope system Ritchey-Chretien-Coude. The telescope is equipped with two focal reducer spectrograph eshelen, coude spectrograph, four CCD cameras for different tricks, sets shirokoivichni and tesnoivichni filters. The telescope will be used for spectral and photometric observations of objects included in the program of the project. Over the past 37 years since the telescope was included in operation, the host equipment is continually updated in order to maintain the effectiveness of its work. The control system of the telescope, was also completely renovated 8 years ago with funds from NSF. In 2017 the system was updated and recoating of the main mirror of the telescope is planed also for 2017.

NAO Rozhen has two smaller telescopes: the 50/70 cm Schmidt telescope and the 60 cm Cassegrain telescope. Both telescopes are equipped with modern CCD cameras for observation and will be used primarily to obtain photometric data. The presence of three professional telescope in NAO Rozhen allows for synchronous monitor the sen- such as observations of the same object simultaneously in two or more optical fields or simultaneous spectral and photometric observations.

Since the project's funds are limited to 20% of direct costs, the maximum amount of equipment (22,080 BNG) is not sufficient to purchase the astronomical instruments and equipment for observation. Provided project funds could only be used for equipment and supplies supporting the operation of the telescopes. For example: computers control the telescope and CCD camera, backup and storage of the data received for processing and ananaliz results; new filters or optical elements for correction of workers telescopes.

After completion of the contract purchased by the project equipment will remain to work at NAO Rozhen, which provides free access to all Bulgarian astronomers and astronomers from abroad who have agreements for scientific cooperation with us.

4. Research plan and tasks to be executed by the research team

The scientific research work planned under this project proposal is divided into five work packages (WP). The packages are defined according to the object type and specificity of physical processes that will be studied as described in the project exposure. Each WP has its leader and for the packages involving more than one tasks laid down additional scientist in charge. WP leaders and scientists in charge are well known in the specifics scientific field with extensive experience in the organization and management of research and observational campaigns with broad international participation. Their main function would be to organize the work on the implementation of specific scientific tasks and to ensure the timely achievement of project objectives. Research groups members, the leaders of the WP and the specific activities are provided in the tables (chapter 7 of the project proposal). The list of the WPs is given below.

WP1: Evolutionary processes in galaxies and in the early Universe - synergy between observations and theory (Assoc. Prof. Dr. B. Mihov)

WP2: Early stages of stellar evolution - synergy of observations with theory (Prof. Dr. E. Semkov)

WP3: Evolution of the main sequence stars - synergy of observations with theory (Prof. DSc. I. Iliev)

WP4: Evolution of symbiotic and cataclysmic stars- synergy of observations with theory (Assoc. Prof DSc. N. Tomov)

WP5: Evolution of the Sun and the Solar system bodies - synergy of observations with theory (Prof. Dr. T. Bonev)

4.1. Description of the project's outline and work break down structure

For each of the WPs, there are three specific activities:

- **Project activities 1.1, 2.1, 3.1, 4.1, 5.1 – Performing astronomical observations** and provision of planned research with observational data. The main part of the observation material will be obtained with a 2-m RCC telescope and 50/70 cm Schmidt telescope of NAO Rozhen and with the equipment available. In most cases observational programs aim accumulation of homogeneous set of photometric, spectral and spektropolarimertic data covering relatively long time scale. So observation activity will take place between 4th and 33rd month of the project. Primary reduction and processing the observational material will be performed. For some tasks, the original observations of the NAO will be complemented by observation of astronomical data archives, virtual databases and data sets obtained by project participants in astronomical observatories abroad. The main result of this activity are received and processed up to the state of ready for analysis astrophysical data. The role of the WP leader is to identify observers and with them to select the research targets, to organize the preparation and submission of observational proposals and initial data reduction.

- **Project activities 1.2, 2.2, 3.2 , 4.2, 5.2 - Analysis of observational material.** This is basic research activity and will be carried out by working groups in their respective field. The specific working tasks in each group will be duty of the scientist in charge whose main aim will be to maximize the efficient use of observational data and the capacity of each group member according to the individual competences and training. The main objectivities are: charts, tables, figures, conclusions about studied astrophysical phenomena and objects and relationships between them. It will serve for preparation of scientific publications. These activities will be held between 7th and 30th month of the project.
- **Project activities 1.3, 2.3, 3.3, 3.4, 3.5** - Publication of the research results. Within this activity scientific publications and presentations at scientific conference and symposiums, and small announcements at the web-site of IA with NAO and popular scientific publications will be prepared. Lectures and presentations on the planned project workshop and conference will be also prepared. Since this activity is directly dependent of the result of the activities described in the preceding two paragraphs, its implementation will take place between tth and 36th month of the project. Also it is possible, publication activity to continue after the expiry of the planned project duration. The results of the publishing activity are: submitted and/or accepted publications in scientific journals with impact factor or impact rank, presentations and posters of conferences, lectures etc. It is planned minimum of 36 publications in well known astronomical journals.

4.2. Schedule

Gantt diagram

WP/month	01-03	04-06	07-09	09-12	13-15	16-18	19-21	22-24	25-27	27-30	31-33	34-36
WP 1	■	■	■	■	■	■	■	■	■	■	■	■
Activity 1.1		■	■	■	■	■	■	■	■	■	■	
Activity 1.2			■	■	■	■	■	■	■	■		
Activity 1.3			■	■	■	■	■	■	■	■	■	■
WP 2	■	■	■	■	■	■	■	■	■	■	■	■
Activity 2.1		■	■	■	■	■	■	■	■	■	■	
Activity 2.2			■	■	■	■	■	■	■	■		
Activity 2.3			■	■	■	■	■	■	■	■	■	■
WP 3	■	■	■	■	■	■	■	■	■	■	■	■
Activity 3.1		■	■	■	■	■	■	■	■	■	■	
Activity 3.2			■	■	■	■	■	■	■	■		
Activity 3.3			■	■	■	■	■	■	■	■	■	■
WP 4	■	■	■	■	■	■	■	■	■	■	■	■
Activity 4.1		■	■	■	■	■	■	■	■	■	■	
Activity 4.2			■	■	■	■	■	■	■	■		
Activity 4.3			■	■	■	■	■	■	■	■	■	■
WP 5	■	■	■	■	■	■	■	■	■	■	■	■
Activity 5.1		■	■	■	■	■	■	■	■	■	■	
Activity 5.2			■	■	■	■	■	■	■	■		
Activity 5.3			■	■	■	■	■	■	■	■	■	■

4.3. Project management plan

In order to ensure successful project implementation and to establish comprehensive and effective control - administrative, financial and technical, the following structure and tools for project management has been provided:

The project is managed by a Steering Committee (SC) consisting of Project leader, Coordinator and Work packages leaders, as presented in the description of the research plan. Each participant in the SC has specific duties and responsibilities and any overlapping of activities will be avoided. The project leader is responsible for the overall implementation of the project. His primary responsibility is to ensure proper and timely implementation of the work program and planned activities for their timely and accurate reporting and to resolve all issues related to the financial part of the project and links with NSF. Specifically, he is responsible for:

- Making emergency management decisions
- Relations to the Research commissions of NSF
- Financial Project Coordination
- Leading the conceptual, functional and reporting project meetings
- Periodic management of the reports for project implementation
- Preparation and submission of annual reports to the NSF

The project leader, Prof. Dr. T. Bonev, has extensive scientific and administrative experience with NSF -funded projects, participation in contracts for bilateral international cooperation projects, participation in projects funded by external organizations. In IA with NAO he is a head of internal institutional project and director of the institute.

The project coordinator is responsible for the technical coordination of project activities. He has responsibility for coordinating the activities on the work program together with the heads of the work packages. Responsibility is focused on the overall project, while the role of the heads of the work packages is limited to the particular work package. The project coordinator should have administrative experience as a technical coordinator and project manager with NSF and projects funded by external organizations and participation in international agreements on bilateral cooperation.

The tasks of the SC are: making effective decisions; useful and effective internal communication; Control of project implementation (technical and administrative). SC focuses on overseeing the implementation of the project and the management of activities. WP leaders are responsible for the implementation and reporting of all activities provided in the respective work package. They organize and ensure good internal communication between the participants in the package as well as the maintenance of effective liaison between participants and members of the SC. WP leaders have the necessary administrative experience in the implementation and management of research projects.

The Project leader manages the SC, which has overall responsibility for the coordination, planning and control of the project. SC advice the Project Leader in case of need for taking a decision or current issues related to the implementation of the work program. The project coordinator organizes project meetings (incl. also remote) of the SC and meeting minutes. The first meeting shall be held within 10 days after the start of the project. At least two meetings of the SC for reporting progress in implementation of the project and discussing the financial and organizational issues will be held.

Instruments for project management are the decisions of the Project leader and the SC, reflected in the documentation and project reports. Project documentation contains all documents related to the project management and development, in particular: correspondence with NSF, minutes of all meetings of the SC, technical reports, financial documents for the project.

Reports on the implementation of the project: There will be an intermediate report (at the end of the first stage of the project) and the final report to the NSF. The intermediate report summarizes the work progress, new results, and deviations from the work plan appropriate corrective measures and work plan for the next period. The final report reflects the overall project implementation and compliance with the preliminary plans. The reports are divided on activities and directions in the work packages. Each participant in the project presents his personal report (intermediate and final) for the work to corresponding scientist in charge and to the WP leader. The WP leaders prepared the report for the WP and the project manager prepares intermediate and final report of the project. Working time on the project will be reported in the personal reports of each participant and will include time for the implementation of observational programs, for data reduction and analysis and for preparation of publications. The project leader, the coordinator and the WP leaders take into account the time to complete the management activities of the project.

All current issues and changes arising from the implementation of the work program will be decided locally (i.e. within the work packages) by the WP leaders. As a last resort, a meeting will be held with the presence of the Project Leader and the SC. In case of deviation from the technical circumstances of the project, the project leader in cooperation with the SC is responsible to take management and technical solutions and to promptly notify the NSF.

Decisions related mainly to the work defined in the description of the WP will be taken by the WP leader, with agreement with the SC and the coordinator. The project leader will be informed for all matters by the WP leaders, including through management reports on the work packages.

Decisions concerning the allocation and use of resources for each individual participant that do not affect budgets schemes or results, or changes in technical approaches in the general plan will be made by the project leader and the SC

5. Expected results from the project

The expected results from the project are entirely of fundamental nature and will be implemented as: scientific publications, mostly in the journals with impact factor and impact rank, talks at international conferences, seminars and presentations of young scientists, PhD students and post-doctors, training of students, assistance in defense of master's degrees, qualification of participants in the project and obtaining new academic positions for some of them. We expect also to increase the number of citations of the project participants, as well as to enhance their individual h-index. Students will be able to be co-authors in scientific publications for the first time.

5.1. Description of the results related to acquiring new knowledge, potential for practical application or solving social problems

The scientists involved in the project team shall hold significant experience from working in IA and NAO and they are qualified in the field of fundamental research. Obtaining new knowledge about objects that are included in our study will the basic aim of the team. We plan to study astronomical objects that are not yet classified, that have not been well studied or show variable properties and also new object that will be discovered in the process of the project. In astronomy there is a wide field for research, since there are millions of stars, planets and galaxies that we are about to study. The main role of the project results will be enriching our knowledge on a wide range astronomical objects that show transmission mass and angular momentum. Based on statistical analysis, after accumulating enough observational data, it can be changed or modified the theoretical ideas about the origin and evolution of cosmical objects.

At the same time astronomy is a science that influences strongly the personal and public notion and perception for life, nature and Universe. Astronomical knowledge is the basis of modern science and it is in use by a number of other sciences, such as theoretical physics, geophysics, meteorology, aerospace, philosophy and more. Discoveries in astronomy are followed with interest by the public, discussed in the media, stimulate interest in science in general. A better understanding of the processes as in the nearby universe and the extragalactic distance allows us to evaluate our place as civilization.

5.2. Increasing the research capacity of the applying and/or partner organizations, as well as improving team members qualification

Work on the project will allow to increase the number of scientific papers authored by IA and NAO. The recommendation to the project participants is to focus their efforts on publishing in journals with impact factor and impact rank. This will be increased and the evaluation of the scientific effectiveness of the institute, after the application of the Regulations to Law for the Development of the Academic Staff in Bulgaria. On the other hand, the visibility of our articles in the journals with impact factor and impact ranking will increase the number of our citations and the possibility of new collaborations with scientists from other countries.

The criteria for acquiring the academic positions in IA and NAO are among the highest in comparison with other scientific organizations and universities with similar activity. Additional scientific articles that the participants in the project will be published and the citations of them, will ensure the availability some of the scientists to qualify for higher academic positions. Duration of the project allows the four Ph.D students in IA and NAO involved in the project to advance significantly in the work to complete the thesis. The new results obtained during this project may accelerate the training of PhD students and help to defense of their dissertations.

Work in the project team will help the participants to develop their skills in obtaining quality astronomical data, processing and analysis. They will also enable them to expand their knowledge of the physical properties and evolution of cosmic objects. We plan to train young scientists and students in the methodology of writing scientific papers and the presentation of the results on scientific forums. The very participation in international conferences will help to establish new collaborations with colleagues from abroad. The additional opportunities to work on this and similar research projects will stimulate MS and PhD students to remain in IA and NAO and after completion of their studies.

6. Plan for realization and dissemination of the results from the project

As the research project have completely fundamental character, the realization of the study will consist mainly from research papers and reports on scientific conferences. To maximize the visibility of our scientific results they will be published mainly in journals with impact factor and impact ranking, which are regularly monitored by the astronomical community and are refereed in secondary sources. The most commonly used by Bulgarian authors journals are: Astronomy and Astrophysics (A@A) with impact factor 5.185 and the Monthly Notices of the Royal Astronomical Society (MNRAS) with impact factor 4.952. Bulgaria, by IA with NAO is a member of the board of directors of A@A, which provides free access and free publishing articles in the journal. A@A is one of the most authoritative astronomical journals created as a union of several national European journals. MNRAS is a British journal, with free publication and with sufficient authority in the astronomical community also.

If there are enough funds we can publish our papers in journals with paid access, such as the American Astronomical Journal, Astrophysical Journal, Publications of the Astronomical Society of the Pacific and others. with impact factor between 4 and 6. However, the funds that we expect to receive from the project will not be enough for a great number of paid publications. For this reason, some intermediate results could be published in journals with impact factor from 1 to 3 and free for publication as: Publications of the Astronomical Society of Australia, Research In Astronomy and Astrophysics, Astrophysics and Space Science, Astronomische Nachrichten and others. A significant advantage of the project team is that the issue of IA and NAO - Bulgarian Astronomical Journal is included in the database for referring of SCOPUS and already has a certain impact rank. This allows the young scientists and students to publish their original papers in prestigious peer-reviewed journal and to gain the relevant experience for preparation of articles for publishing in the most prestigious astronomical journals.

Another option for disseminating the results from the project is the presentation of tolks and posters at international conferences. Priority will be given to our participation in Symposia of the International Astronomical Union and in the European Weeks of Astronomy and Space Science. These are the scientific forums that gathered astronomers from around the world who are leading scientists on the topics of relevant scientific forums. The proccidings of these conferences as a rule are referred in the scientific databases Web of Science or SCOPUS. For PhD students and young scientists would be helpful to participate in training schools in a variety of areas of astronomy where they can acquire practical skills for processing and analysis of the results of observations, but also to share their research results with colleagues at the same age.

The annual conferences of the Union of astronomers in Bulgaria also allow the presentation of our results from this project. At them the young scientists and students acquire practical skills to present their results to the competent audience, to answer questions on the substance of their work and to participate in discussions on scientific topics. For scientists with established scientific topics is useful to become familiar with the work of their colleagues working in other areas of astronomy. To exchange ideas for joint research and new methods for observation and processing the results.

We plan also to present results of the project and the media and the wider community in the country. Scientists from IA and NAO are subject to ongoing interest by press and electronic media.

In these interviews we will also share information about the results from our research obtained in the frame of this project. The objectives we set for the realization are at the forefront of astronomy and will help in the promotion of Bulgarian science. On the other hand NAO Rozhen is visited annually by 15,000 - 20,000 guests that acquainted with our work at the place, look at the telescopes and the scientific instruments used for observations it the observatory and learn about the scientific achievements of the institute. After implementation of the objectives of the project the results will also become a part of the lectures, which are exported to visitors of NAO Rozhen and thus reach a wide range of active population in the country.