BULGARIAN ACADEMY OF SCIENCES
INSTITUTE OF ASTRONOMY

NATIONAL ASTRONOMICAL OBSERVATORY - ROZHEN
AND
ASTRONOMICAL OBSERVATORY - BELOGRADCHIK

A short history of astronomy in the Bulgarian Academy of Sciences

1952 - A Department of Astronomy (DA) at the Physical Institute of BAS was created.

1957 - The first satellite tracking station in Bulgaria was created in DA.

1958 - DA became a self-dependent branch of BAS.

1967 - The Bulgarian government took a decision for the construction of National Astronomical Observatory (NAO).

1970 - A contract for the supply of a 2-meter universal reflector in the optical system Ritchey-Chrétien-Coudé was concluded with VEB Carl Zeiss, Jena.

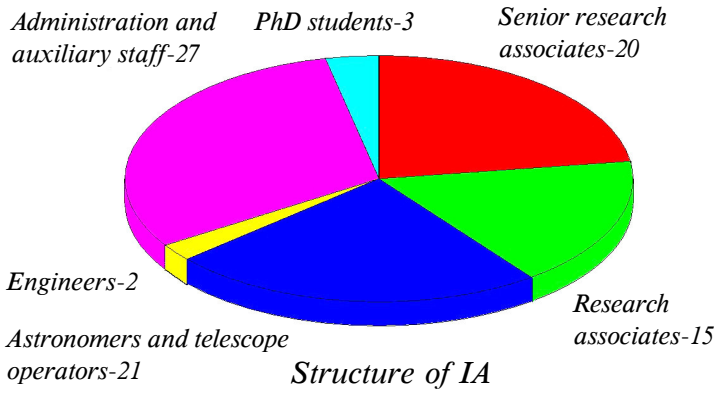
1976 - The Astronomical Observatory Belogradchik became an observational base of DA BAS.

1980 - The regular observations with the 2 m telescope of NAO - Rozhen started.

1981 - Official opening of NAO - Rozhen.

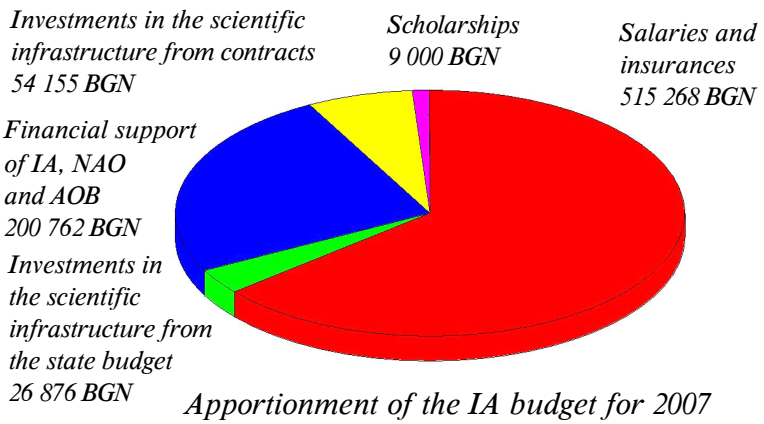
1995 - The Institute of Astronomy (IA) was created as a successor of DA BAS.

Structure and scientific activity of IA



Structure of IA

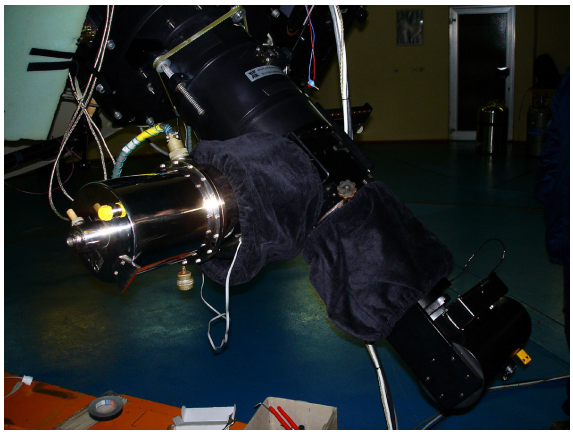
IA carries out fundamental research in observational astronomy, as well as theoretical investigations on the origin and evolution of cosmic objects. Another important activity of IA is education of M.S. and PhD students in the field of astronomy. IA has two observatories for optical astronomical observations — NAO - Rozhen and AO - Belogradchik, as well as the infrastructure needed for them. The structure and equipment of IA is used for the organization of national and international astronomical schools and conferences. The staff of IA is 85 persons, including scientific, technical, auxiliary and administration staff, and 3 PhD students. The scientific activity of IA is distributed among seven departments: Sun, Solar System, Nonstationary stars, Stellar atmospheres and envelopes, Chemically peculiar stars, Stellar clusters, and Galaxies. In 2007 44 scientific projects were developed in IA, including 17 projects of the institute, 5 projects with the National Scientific Foundation and 20 international projects.



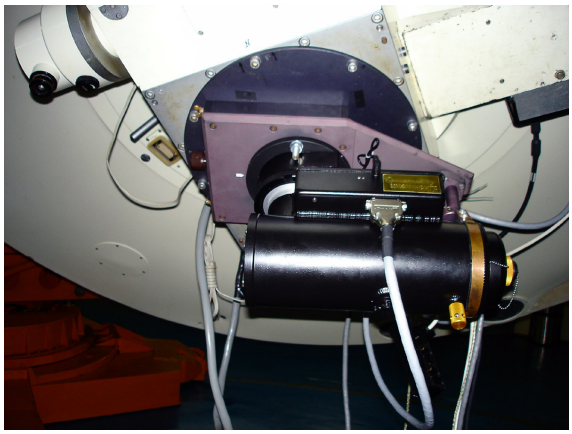
Apportionment of the IA budget for 2007

International relations and publications of IA

A traditional publication of IA is “The Astronomical Calendar”. Its 54th regular edition was published last year. The publishing of a scientific journal of IA was restored in 2007. The two new volumes of Bulgarian Astronomical Journal (extension of “Известия на ССА” and “Astrophysical



The two-chanel focal reducer, mounted on the 2 m telescope of NAO - Rozhen



CCD camera VersArray, mounted in the RC focus of the 2 m telescope

Investigations") have been already published. IA has scientific relations and cooperation on scientific projects with many astronomical institutes and observatories from European countries like: Germany, France, Poland, Romania, Ukraine, Russia, Slovakia, Finland, Czech Republic, Greece, Hungary, Great Britain, Belgium, Macedonia, and with USA. The results from the scientific activity of the Institute of Astronomy during 2007 were published in 104 papers.

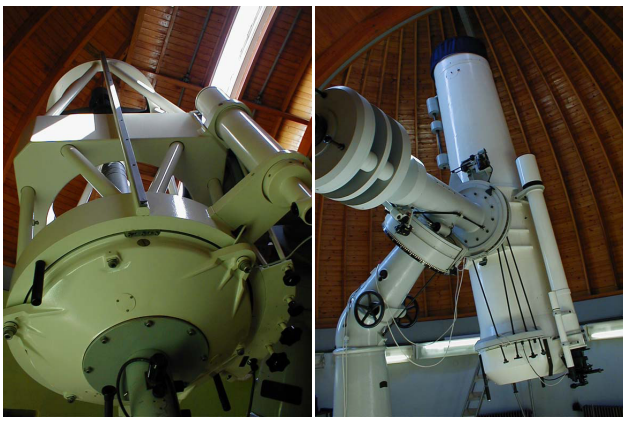
NAO - Rozhen

Participants in the international school of spectroscopy, organized in NAO - Rozhen (October 2007)

NAO - Rozhen is situated in the Rhodope Mountains at 1750 m altitude and coordinates: longitude $1^h\ 38^m\ 58^s$ and latitude 41° 41′ 48″. The astronomical observatory is the biggest one-time Bulgarian investment in scientific infrastructure and a leading astronomical center in the South-East Europe. The 2-m telescope of Rozhen observatory is equipped with two modern CCD cameras with nitrogen cooling — VersArray and Photometrics, a two-channel focal reducer, broad band and interference set of filters. The direct observations from the RC focus of the telescope are used for photometric investigations of comets and asteroids from the Solar system, stars and stellar clusters, galaxies, quasi stellar sources, etc. The Coudé-spectrograph of the 2-m telescope at NAO - Rozhen is a powerful instrument that allows us to obtain stellar spectra with a high resolution and "signal-to-noise" ratio of about 1000, and to measure velocities in space with an accuracy of 500 m/s. The chemical composition of stars, the parameters of stellar wind, stellar envelopes, etc. are studied using spectral observations from NAO - Rozhen.

The domes of the 50/70 cm Schmidt and the 60 cm Cassegrain telescopes

The Solar dome built in 1994 and the 15 cm coronagraph, constructed in IA



The 60 cm and the 50/70 cm Schmidt telescopes of NAO

From the beginning NAO - Rozhen has at its disposal also two small telescopes for optical observations: 50/70 cm Schmidt telescope and 60 cm Cassegrain telescope. Both telescopes are equipped at present with CCD cameras with thermo-electric cooling. The relatively big field of observation makes the telescopes suitable for photometry of variable and fast moving objects, as well as of nearby galaxies. From 2005 NAO - Rozhen has also a 15 cm Lyot-coronagraph with Hα filter, designed for observations of quiescent, eruptive, and active prominences in the low solar corona, and a solar refractor, which is in preparation for observations in white-light and Hα line (the solar activity in the photosphere and chromosphere). A center for visitors, equipped with a 18 cm telescope, conference room and small museum, are situated in NAO - Rozhen, too.

Astronomical Observatory Belogradchik

The construction of the Astronomical Observatory Belogradchik (AOB) began in 1961 and till 1974 the observatory was used as a satellite tracking station. AOB was built near the Belogradchik citadel at 610 m altitude and coordinates: longitude $1^h\ 30^m\ 41^s$, latitude $43°\ 37'\ 22''$. In 1965 a 60 cm telescope for professional research in astrophysics was ordered in Carl Zeiss Jena. For a decade this was the largest professional telescope in Bulgaria. Many international meetings and schools of astronomy were organized in AOB. In 1994 the observatory was equipped with a 36 cm Celestron telescope of Schmidt-Cassegrain type. Currently two main modes of astronomical observations are carried out at Belogradchik observatory: electrophotometric observations with a single channel photometer, and with SBIG ST8 CCD camera. The photometer is fully computer controlled. Observations carried out at AOB, cover research in fields as astrometry, astrophysics of special types of variable stars, and extragalactic objects. The observatory is open for organized visits of student and tourist groups.

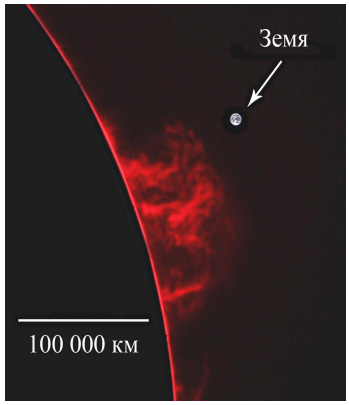
The main building of AOB and the domes of both telescopes

The 60 cm telescope of AOB

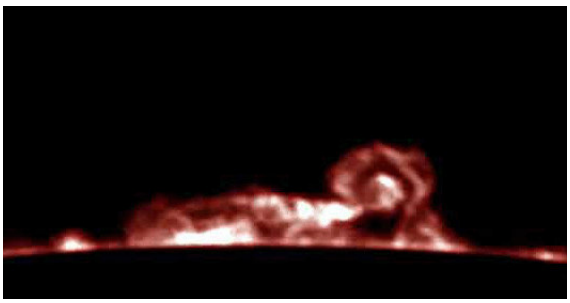
Investigations of the Sun

The study of the Sun is essentially significant for the fundamental aspects of astrophysics, as well as for the applied scientific branches, such as nuclear physics, plasma physics and magnetohydrodynamics.**The solar activity** (sunspots, prominences, flares, etc.) is a basic topic of solar researches in IA. It is the basic mechanism that drives the space weather and its influence on the Earth's atmosphere.

The quiescent and eruptive prominences are basic objects of observation and study in IA. They are a natural laboratory for the physics of non-totally ionized plasma and its interaction with magnetic fields. The studies of the structure and dynamics of the quiescent prominences allowed the determination of oscillations in some of them, as well as the possible mechanisms leading to such destabilizations. The kinematic patterns of eruptive prominences, as well as their associations



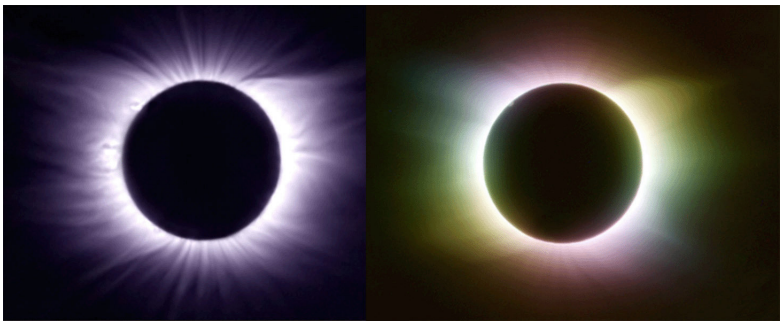
Quiescent prominences, September 27 2005



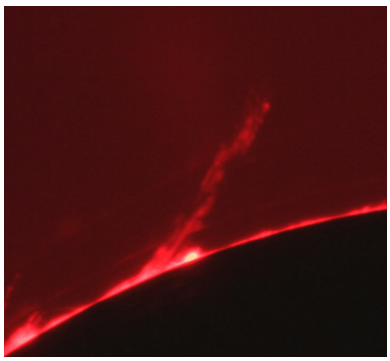
An active prominence, November 15 2005

with coronal mass ejections (CMEs) and/or solar flares were determined. The eruptive prominences, coronal mass ejections and flares are the most important solar events, as far as space weather effects are concerned, linking solar eruptions, major interplanetary disturbances, and geomagnetic storms. Their significance as a driving mechanism for the space weather is an important topic in solar physics.

The observations of the **total solar eclipses** are an important task in the observational program of IA. They are rare and valuable opportunities to study the structure and physical properties of the solar corona, which have not yet been approached with different space-borne and ground-based instruments used outside eclipses. Two big campaigns for observation of total eclipses on August 11 1999 and March 29 2006 were carried out. Rich observational material for the solar corona and prominences was obtained.



White-light and polarized solar corona during the March 29, 2006 total solar eclipse, Side, Turkey

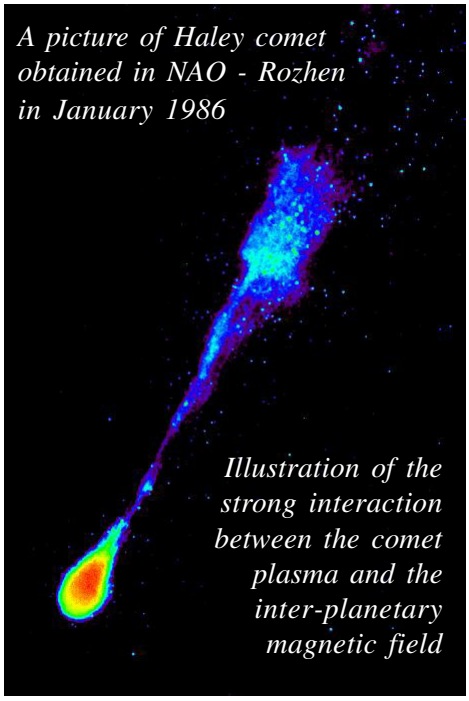


An eruptive prominence, August 22 2006

Investigations of the Solar system objects

The small bodies (**asteroids** and **comets**) are remains from primordial material of the Solar system formation and their investigation gives the answers like: how the Solar system is created? What were the conditions in the proto-planetary cloud, which led to planet formations? What are the parameters of inter-planetary environment nowadays? What is the role of the Sun? Are the comets connected with the origin of life on our planet? Which objects endanger the Earth and what is the probability for an impact? On the other hand, these objects are future source of row materials for the Earth technologies. The investigations of the Solar system became especially topical after the discovery of extrasolar planets and planetary systems.

The study of the orbital motion and rotational properties of the small bodies contributes to the improvement of the dynamical theories and the clarifying of the structure of the asteroid belt. In connection with the motion of the artificial satellites, investigations of the gravitational influence of the Earth's potential and atmosphere on their orbits are made. Positional observations of small bodies have been carried out in the National observatory since it is in operation and dozens of new **small planets** were discovered. The first one was named after the computer inventor — John Atanasoff. Very active was the participation of NAO-Rozhen in the first international survey (INAS) searching for asteroids which can impact the Earth, and in its frame the potential by hazardous asteroid (4486 Mithra) was discovered. Monthly, the positions of hazardous small bodies, observed from NAO - Rozhen,



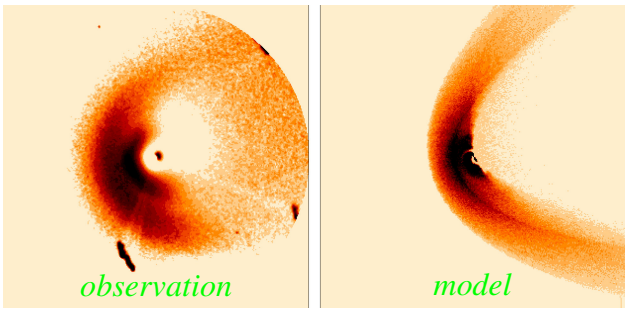
A picture of Haley comet obtained in NAO - Rozhen in January 1986

Illustration of the strong interaction between the comet plasma and the inter-planetary magnetic field

are sent to the Minor Planet Center (MPC) at the Smithsonian Astrophysical Observatory, USA, and are used for making more precise their orbits and evaluation of the impact risk.

The successful participation in the world-wide campaign **International Halley Watch** initiated investigations of the dust, neutral and ion components in the cometary atmospheres, and the influence of the Sun over them, continuing nowadays. Most interesting results are: the first image of the **comet Haley** from Europe; unique sequence of images of the first appearance of the tail at this passing by, being the first observation of a tail when a comet and the Sun are in opposition in respect to the Earth. Nowadays the cometary studies continue with the modeling of the processes in their atmospheres. The comparison of the observations with the models gives the parameters of cometary nuclei.

Investigations using photometric observations of different types of small planets (comets and asteroids, including: near-earth asteroids, objects from the Main belt, Trojans, Trans-Neptunian Objects) are made for better understanding of the nature and genetic relations between them and complete clarifying of the scenario of the Solar system formation.



Structures in the coma of comet C/NEAT (2001 Q4) and its shaping

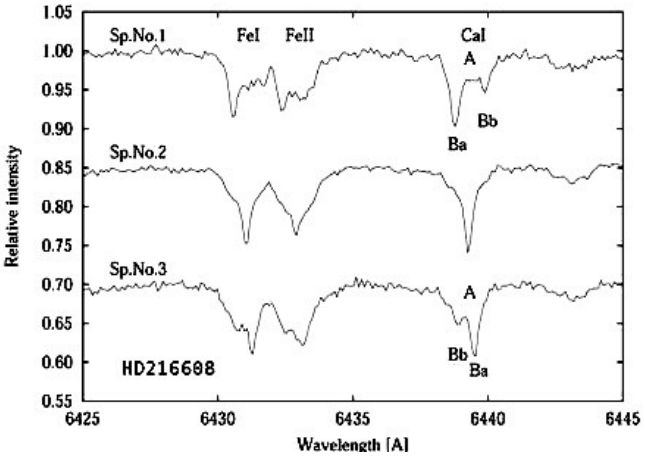
Measurements and investigations of the total content of **ozone** (TCO) in the Bulgarian atmosphere are carried out. In the period 1979 — 1992 they show negative trend (decreasing of the ozone), while during the last decades there is no statistically significant trend in ozone changes, i.e. no decreasing of TCO in Bulgaria.

Investigations of stars and stellar systems

The reflection nebula M42, a region of active starformation

Main goal of our studies is the complex study of the atmospheres of **chemically peculiar stars**. More than one-sixth of the stars with temperatures between 7000 and 17000 K have atmospheres whose chemical composition differs significantly from what we observe in our Sun. Most typical are the excesses in the elemental abundances of iron-peak and rare-earth elements, while some of the light elements are deficient. **Metallic-line stars** (Am-stars) are the most numerous sub-group of chemically peculiar stars. In the atmospheres of stars in binary systems we observe tides similar to those we have in the oceans. As a result of spectroscopic observations carried out at NAO - Rozhen, for the first time we reached the conclusion that stars with higher tides in the atmospheres exhibit smaller excess of heavy elements. The chemical composition of the stellar atmospheres of metal-rich stars was derived by using the spectral synthesis method. Half a dozen new spectroscopic binary stars with metal-enriched atmospheres have been discovered.

Metal-weak atmospheres of other type of stars named **Lambda Bootis** are thought to be resulting in an interaction between stars and interstellar clouds of dust and gas when the stars fly through the clouds. Orbital parameters of two new spectroscopic binaries of type Lambda Bootis have been determined for the first time. Our data strongly support the idea that those

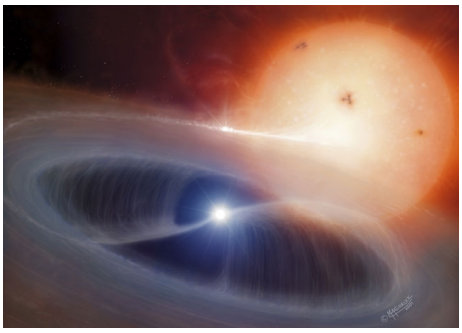


Spectra of HD216508, a spectral double star, discovered in NAO - Rozhen

stars belong to the young Galactic disk population and their basic astrophysical characteristics are not very much different from those of "normal" A-stars. A correlation between the age and the chemical peculiarities strength is not found out.

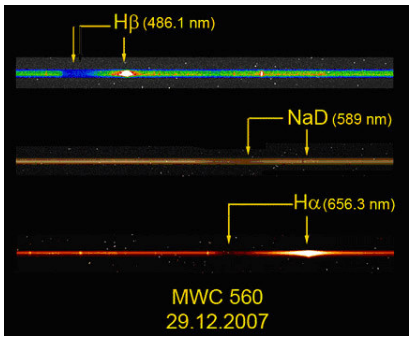
The key limiting assumptions incorporated within current **OB stars** model atmospheres include a globally stationary and spherically symmetric stellar wind with a smooth density stratification. However, recent observational results indicate that hot stars winds are certainly not smooth and stationary. In particular, long-term monitoring campaign of OB stars performed at NAO - Rozhen in collaboration with other observatories revealed the presence of large-scale wind structures, such as high density spirals, disks etc. Evidence of small-scale structures (clumps/blobs) are also found. Stellar pulsations and magnetic fields might equally be responsible for the appearance of large-scale wind features, while intrinsic wind instabilities might lead to the formation of clumps and blobs.

Coudé-spectrograph of the 2 m telescope in NAO - Rozhen



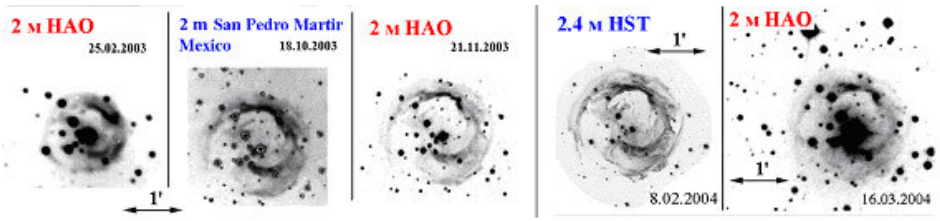
A model of a symbiotic star

The symbiotic stars are interacting double systems, consisting of a red cool giant and a compact object (white dwarf), which accretes mass from the stellar wind of the giant and undergoes episodic outbursts. An ejection of an optically thick shell exceeding by a factor of 40 the size of the compact object, as well as two velocity mass outflow regimes, including outflow with a high velocity of 500 km/s and another one with low velocities close to 60 km/s, were observed during the 2000 — 2002 outburst of the symbiotic system **Z And**. The hydrogen line Hα in the spectrum of the symbiotic recurrent nova **RS Oph** has a strongly variable broad emission component indicating radial velocities up to 2300 km/s. The white dwarf has a strong enough magnetic field which works as a propeller: the fast rotating magnetosphere ejects discrete components (blobs) from the innermost part of the disk, which blobs give rise to the different components of the broad emission line. The typical mass of one average blob was calculated to be 10^{-9}—10^{-7} $M_{\odot}$. In 1990 an ejection with an enormous velocity of up to 7000 km/s from the symbiotic star **MWC 560** was observed in NAO-Rozhen. Nowadays, almost two decades after the observation of that impressive phenomenon, the mass outflow with a high velocity of up to 2000 km/s from the accretion disk, surrounding the white dwarf in this binary system, continues.



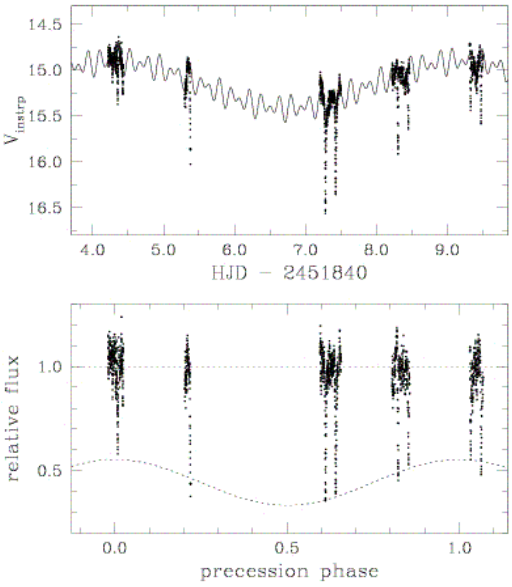
Spectra of MWC560, taken at the end of 2007

As a result of the unique outburst of the object **V838 Mon** an expanding light echo appeared, which was observed for several years. The light echo is a very luminous source in the space and an exceptionally rare natural phenomenon. The distance, from its side, provides a possibility to obtain the luminosity, which is of fundamental importance to understand the nature of the phenomenon. The data show that very probably the distance to V838 Mon is 10 kpc. In this case it should be the most luminous source in our Galaxy, observed up to the present time, having luminosity of more than 10^{6} $L_{\odot}$ in its light maximum.



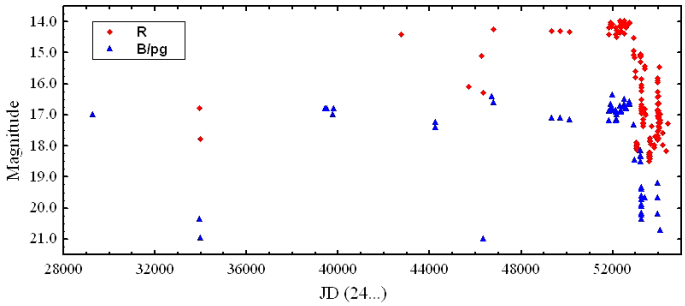
Evolution of the light echo after the outburst of the star V 838 Mon, observed at NAO - Rozhen and at other observatories

Photometric and spectral observations of the VY Scl and SW Sex type **cataclysmic variables (TT Ari, KR Aur, PX And, DW UMa, MV Lyr)** are carried out in order to study the behavior of accretion structures and develop models of the selected stars. The periodogram analysis of the light curves of the SW Sex novalike **PX And** reveals the presence of "negative superhumps" and the corresponding retrograde precession period of the accretion disk. The analysis suggests that the eclipse depth is modulated with the precession period. The phenomenon is observed for the first time. The CCD photometric observations of the eclipsing novalike cataclysmic variable **DW UMa** reveal that the star presents eclipses with very different depth: ~3.2 mag in intermediate state and ~1.2 mag in the high state. Eclipse mapping reveals that this difference is almost entirely due to the appreciable changes in the accretion disc radius in the different states. The phenomenon is observed for the first time in a novalike star.



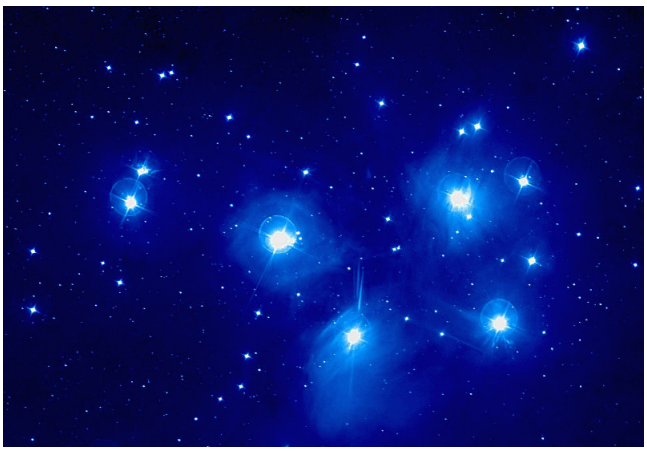
PX And light curves showing the modulation of the out-of-eclipse magnitude and eclipse depths with the detected periods

Young nonstationary stars: T Tau, FU Ori, EX Lup, UX Ori, etc. The photometric and spectral variability, flares, rotational variability of the brightness, interaction with circumstellar disks, and variable accretion were studied. Long-term variability of spotted stars in stellar clusters and associations on archival photographic plates giving possibility to increase the time interval, is investigated. The multi-color light curves of stars V 1184 Tau, V 350 Cep, V 391 Cep, and V 718 Per were obtained. Optical observations of some **gamma-ray burst** sources: GRB 030226, GRB 030329, GRB 060218, were made.



Light curves in blue and red for 70 years period of the star V 1184 Tau (constructed from archival photographic observations and from new observations made in NAO - Rozhen)

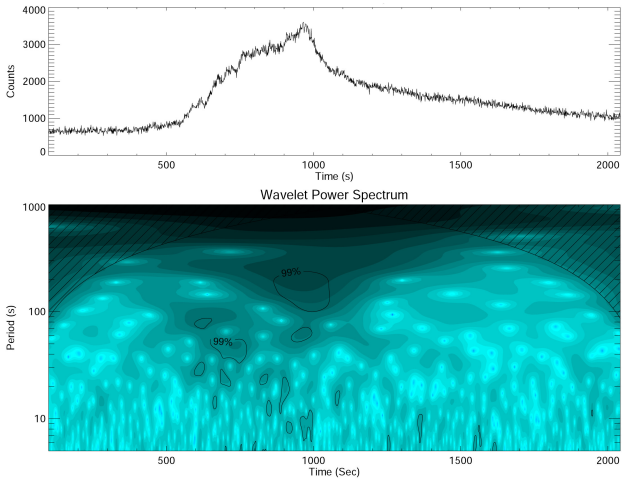
Active processes in stars of late spectral class. Modulation of brightness in presence of spots is being studied, rotation periods and parameters of spots are determined, models of light curves are built and long term cycles of activity are being studied. Photometric study of the active giant **FK Com** disproved the presence of flip-flop events (alternative switch over of stellar activity between two opposite longitudes on the star), proposed by other authors. An oscillating process with 5.8 years period has been found overlaid with sudden phase jumps. The main process of oscillation — cycle of activity — is due to migration of the main stable spot around the pole. In a similar study of the active giant **HD 199178** a 4.2 year cycle of activity has been found. Studies of double systems with ellipsoidal or δ Scuti components, components of Wolf-Rayet type gave new data for stellar parameters and parameters of the systems (**33 Tau, WR 140, CT Her**). The photometric study of WR 140 at NAO Rozhen in the period 1991 — 2001 showed for the first time the existence of eclipses in the system during periastron — 1993 and 2001. The eclipses are a consequence of the formation of carbon dust clouds as a result of collision of the stellar wind from the two components.



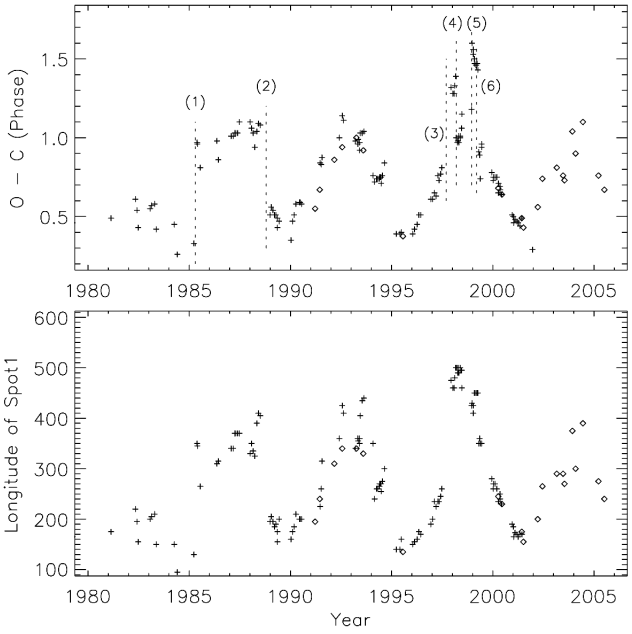
The open stellar cluster Pleiades — one of the youngest in our Galaxy

A colorimetric study of the active star EV Lac during flare state is performed by means of multicolor high-speed simultaneous observations carried out at 6 telescopes in Bulgaria and abroad. An analysis of the colors behavior and the high-frequency oscillations detected during the flare is done.

Studying chemically peculiar stars in such clusters gives important information about the structure and the history of the Milky Way. Observations with the 2-m telescope at NAO led to the discovery of **twenty new stars** with peculiar abundances in seven open stellar clusters. Quite recently we came to know that such stars exist in the Magellanic Clouds — nearby satellite galaxies of our own galaxy, the Milky Way.

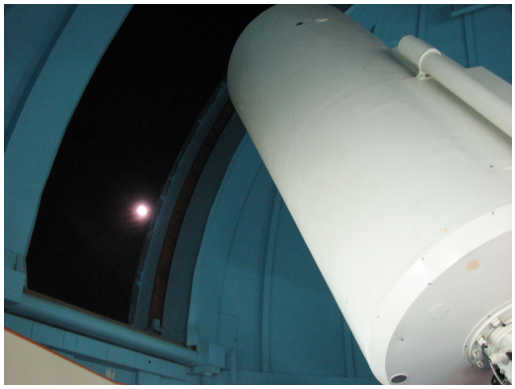


Wavelet analysis and lightcurve of the star AD Leo during a flare, detected on March 8, 2007



A O-C diagram of the minima of brightness for the star FK Com (above) and changes of the longitude of the main spot (down)

Broadband photometric investigations were carried out for several Galactic Globular Clusters (GGC): Pal 1, Pal 13, M5 and NGC 6229. New features of the stellar distribution along the color-magnitude diagram for stars with double burning source were established — bimodal for NGC6229 and three-modal for M5. It was found that Pal1 and Pal13 are younger than the bulk of GGCs of about 2 billion years. Long-term observations were taken to reveal the variable stars in some globular clusters. New RR Lyr variables were detected in M13, M92, M56, M75 and NGC6229. Light curves for RR Lyr and W Vir in GCCs M13 and M56 were published. Thorough analysis of the spatial orientations of some GGCs revealed a flattened form like their counterparts in the neighbor galaxies — Magellanic Clouds.



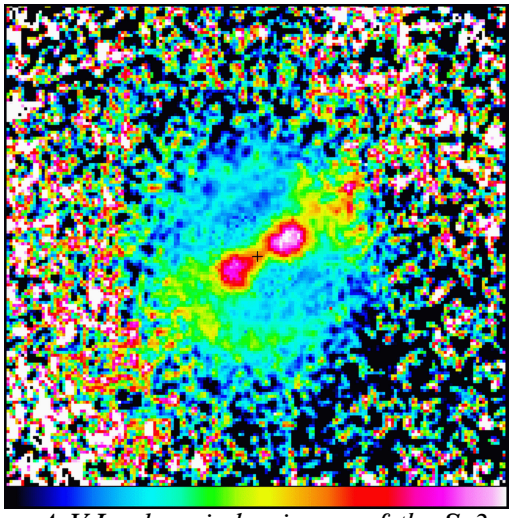
The 2-m telescope of NAO-Rozhen during observations

The globular stellar cluster M10

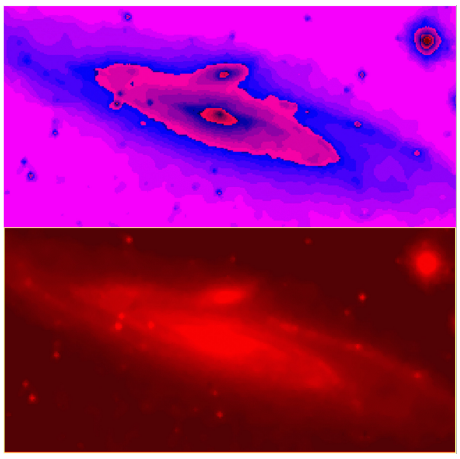
Unknown stellar clusters were discovered near the Galactic center using Sloan Digital Sky Survey infrared images. Some important parameters as extinction, distance, age and mass were published for these newly detected objects. Other objects, observed in the dense Galaxy flat component, were suspected as stellar cluster candidates. The reddening towards these objects was assessed of about 20 magnitudes. Most of them are related with gaseous nebulae and probably belong to a generation of young newly formed stellar clusters. There is morphological evidence for one of these objects to be a true globular cluster.

Investigations on Galaxies and Cosmology

The main directions in the investigations are Individual galaxies, Nearby galaxies and Cosmology. Basic fields of interest are **Physical processes** and **chemical abundance in galaxies**, systems of galaxies and the Universe. Photometry and Surface photometry of **normal and active galaxies** and galaxies in Voids are carried out. Disk profiles and starformation in galaxies, irregular galaxies, and the movement of ionized gas are investigated. Monitoring of **blazars**, **novae** and **supernovae** is carried out. Structures of galaxies and clusters of galaxies are searched for.

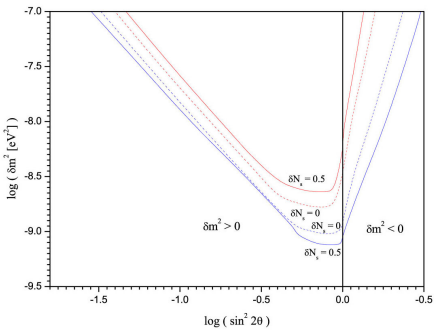


A V-I colour index image of the Sy2 galaxy Mrk 573, observed with the 2-m telescope of NAO. There could be seen the ionization cones (coded white-red) and the extended [OIII] emission (coded yellow-green); the cross marks the position of the galaxy nucleus



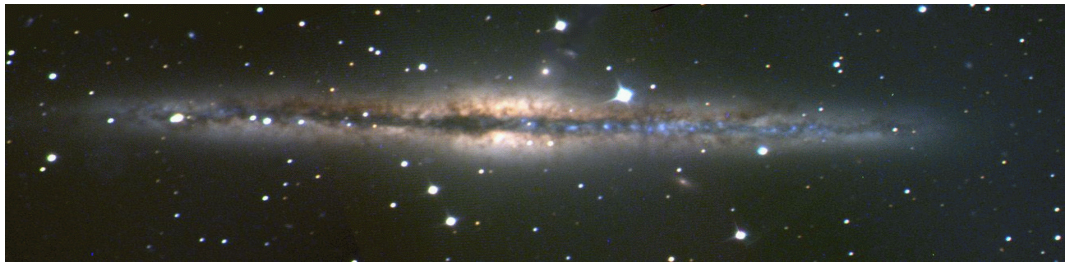
A CCD frame in R-band of Mrk 1040 — a Sy1 galaxy with a satellite from the 2-m RCC telescope. The object is a strong variable X-ray source. The spectrum is characterized with many optical emission lines. The pseudo-colours are specially chosen to stress on the faint filaments and bridges in the disk of the galaxy. The top picture shows the isophotes of the light distribution

Investigations of voids, based on the analysis of galaxy clysters, are carried out. Large scale structure in the Universe is studied. Primordial nucleosynthesis and chemical evolution of the light elements in the presence of neutrino oscillations is analysed. Cosmological constraints on oscillation parameters are obtained. Different baryogenesis scenarios are investigated. Possibilities of antimatter in the Universe are studied.

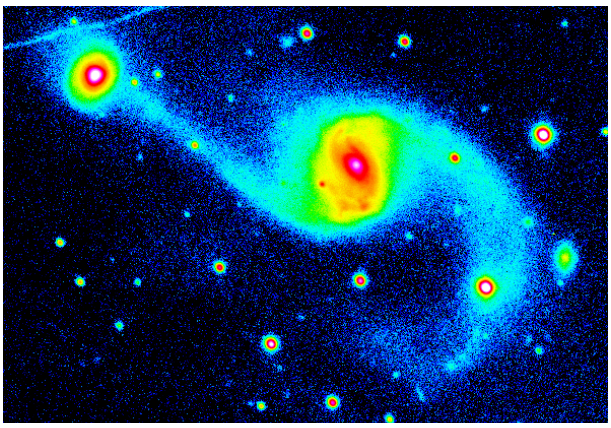


Cosmological constraints on neutrino oscillations parameters, which are by an order of magnitude more precise than the available previously in literature. The lower two curves correspond to 3% He-4 uncertainty, the upper — to 5% He-4 uncertainty

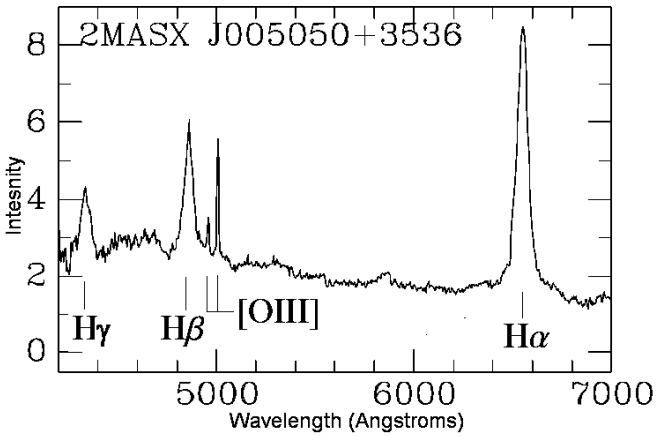
A modern direction to use all the tremendous quantity of astronomical data all over the world is the GALAXIAN Virtual observatory , a part of the Bulgarian Virtual Observatory. Extragalactic investigations are part of wide active participations in National research and educational programs — e.g. National Cosmic Program, supervision with M.S. and PhD students, lectures in Bulgarian universities, activities in national astronomical organizations — National committee of Astronomy and Bulgarian Astronomical Society, etc.



A panorama of the giant spiral galaxy NGC 891, visible edge-on. The gas-dust flat component of the galaxy is visible as a dark band. The bluish spots in this band are unresolved associations of young hot stars, giving evidences of undergoing high-rate global star formation (from multicolor observations with the 2-m telescope of NAO - Rozhen)



The interacting galaxy pair UGC 11680 (in the centre) and Mrk 897. The bridge, connecting the galaxies, and the counter-arm are evidences of the tidal interaction between the galaxies, which could have driven the nuclear activity of Mrk 897

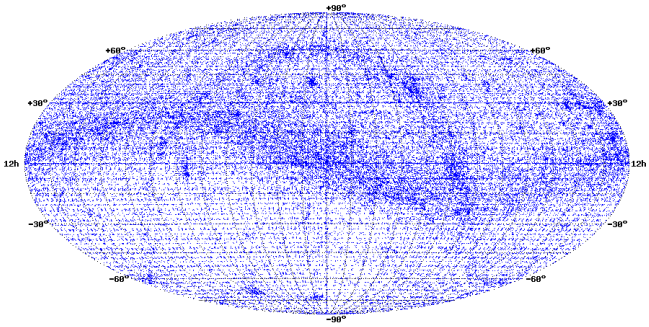


A spectrum of the quasar 2MASXJ005050+353, obtained at NAO - Rozhen. The quasars are active nuclei of distant galaxies, powered most probably by accretion of gas onto a supermassive central black hole

Applications of the archival astronomical observations

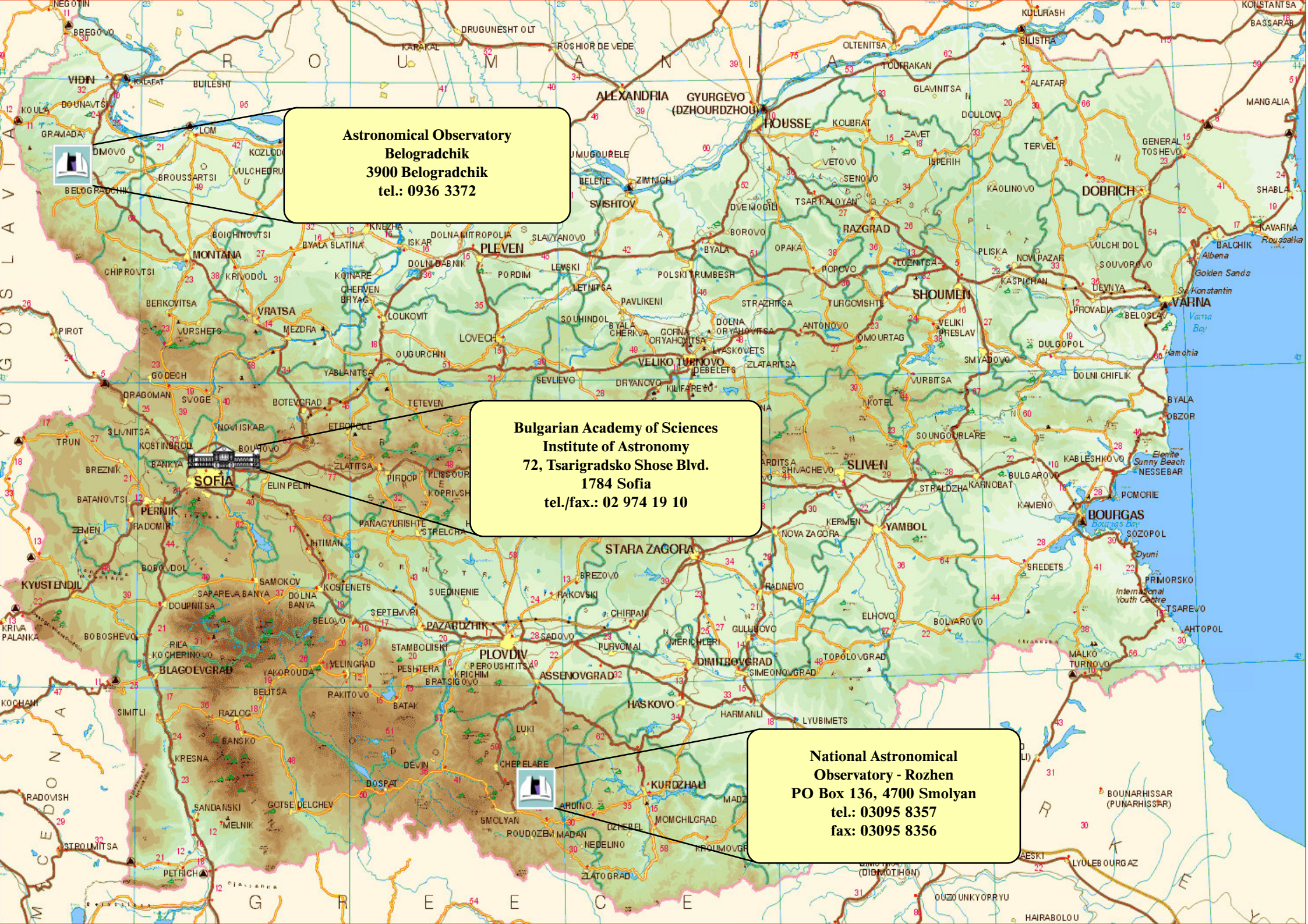
The astronomical observations made in NAO - Rozhen, are archived and will be prepared for inclusion in the international virtual observatory in the future. NAO - Rozhen possesses an archive of more than 10000 photographic plates, obtained with the 2-m RCC and 50/70 cm Schmidt telescopes. The recent CCD observations are saved on compact disks and an on-line connection to them from other astronomical institutes is planned.

The Wide-Field Plate Database (WFPDB) is the basic source of information for the photographic wide-field astronomical observations, stored in the archives of 125 observatories worldwide, whose total number for the period 1872 — 2002 is estimated to 2 200 000. Of them, 530 000 are included in WFPDB to the beginning of 2008, thus reaching a completeness of 25%. WFPDB is on-line accessible at http://www.skyarchive.org/, as well as through the VizieR system of the Strasbourg Data Centre at http://webviz.u-strasbg.fr/viz-bin/VizieR?-source=VI/90. The new development of WFPDB is connected with the forthcoming creation of a Bulgarian Virtual Observatory as a part of the global international net of virtual observatories.



All-sky distribution in equatorial coordinates of the centers of plates, included in WFPDB

Cover pages of periodical editions of IA and from an international conference for young astronomers, organized in AO Belogradchik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