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The Project ASV

N. Pejović[1], **Ž. Mijajlović**[2]

[1]Faculty of Mathematics, University of Belgrade, Studentski trg 16, 11000 Belgrade, Serbia

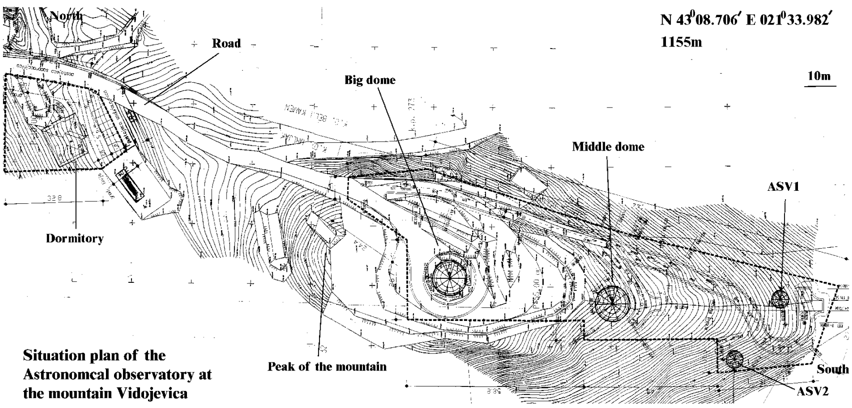
[2]Faculty of Mathematics, University of Belgrade, Studentski trg 16, 11000 Belgrade, Serbia

Abstract. The initiative for building of an astronomical station at the mountain Vidojevica appeared in 2000, while the construction of the station started in 2004, and the ending of the first stage is expected in the autumn 2006. The aim of the paper is to present the idea of this project, the main technical characteristics of the station, equipment and scientific projects that are planned to be carried out when the station becomes operational.

Several astronomers from the Faculty of mathematics of the University of Belgrade and the Astronomical Observatory in Belgrade (AOB) started in the year 2000 the joint initiative for building the astronomical station (ASV) at the mountain Vidojevica, near Prokuplje in southern Serbia. In fact, the idea of building an astronomical station at Vidojevica is more than 20 years old. The project was postponed, almost forgotten, due to the circumstances that appeared in the former Yugoslavia during the last two decades. Eventually, the Serbian Ministry of Science decided in 2003 to allocate funds to AOB for building ASV, as well as for equipping it. Now, the first phase of the project is in the final stage, and it is expected that ASV will start operating during the autumn of 2006. The first phase, ASV1, consists of an observatory dome equipped with a reflector of 60cm aperture, and the living house for crew. The planned research themes will include inertial frames, exploration of binary stars, spectroscopy, etc. It will be used also for training students of astronomy. Further plan include robotization and automatic guidance of the system. It is also planed obtaining another identical telescope with the purpose of combining both telescopes into one system, a multiple telescope. The goal is to do optical and near-IR interferometry. This is seen as an inexpensive way to build a big mirror (in this case of 85cm aperture). The CHARA array is the most famous project in the world of this kind. Forming a very precise time base is assumed, while mathematical methods will include image processing and wavelet theory.

1 Site

The whole complex ASV is situated at the peak of the mountain of Vidojevica (1155m, N $43^0 08.706'$ E $021^0 33.982'$) in Southern Serbia and it is about 20 km far by road to the South from the town of Prokuplje (30.000 population). Other places relatively close to ASV are Niš (about 30 km north-eastward, 250.000 population) and Leskovac (about 30 km south-eastward, 50.000 population). The peak is almost flat and occupies about 1000 m^2. The infrastructure at the site is good. The main road is in good conditions and it passes about 2.5 km from the station. Also, there is a macadam road connecting ASV and the main road. The site is supplied with electric power and there is a wellspring nearby. There are no significant obstacles on the horizon. The sky is open, particularly to the south. The light pollution is negligible, there are some traces of light pollution in the north, coming from the town of Prokuplje.

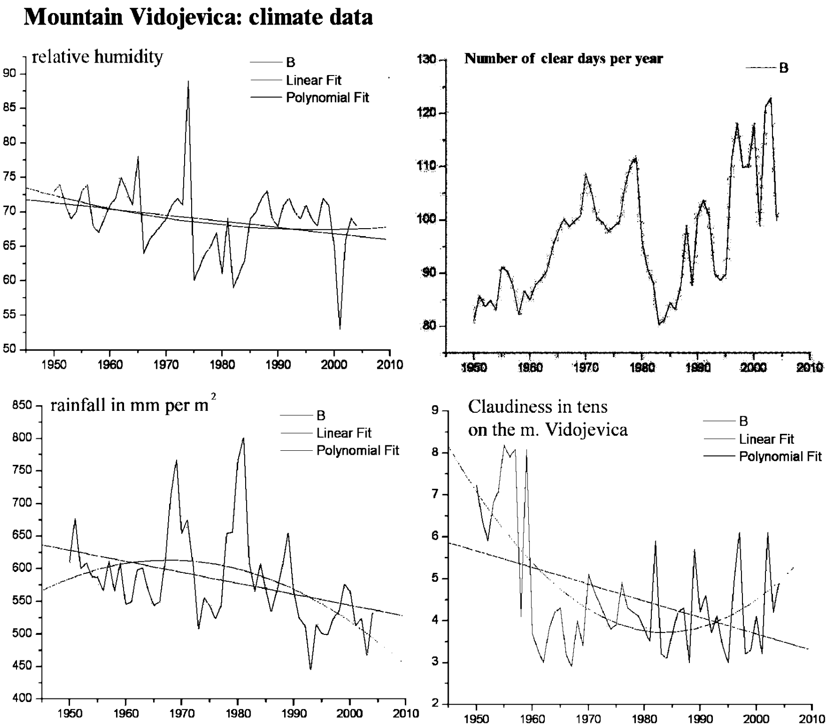


Situation plan of the Astronomcal observatory at the mountain Vidojevica

2 Astroclimate

Astroclimate conditions are also good, in fact best in Serbia. According to meteorological measurements, some of them dating from 1900, most of them since 1950, there are on the average about 120 clear nights a year. This region is one of the driest areas in Serbia. In Prokuplje the total rainfall is 580mm, while on Vidojevica it amounts only 533mm. Measurements in the last two decades show even decreasing of rainfall (the rainfall was above 600mm until 1980). Other collected data include temperature, rainfall, relative humidity, insolation, haze, cloudiness and number of days with clear sky and all of them show that this site is advantageous for astronomical observations.

The microclimate characteristics of the mountain of Vidojevica is rather interesting. Vidojevica is deeply extended into the continental climate, therefore there is the influence of this type of climate in this region. Vidojevica is under snow



1-2.5 months. The temperature on the peak of Vidojevica is lower about 4°C in comparison to the temperature of Toplica valley, in accordance to the temperature gradient principle. However, in wintertime, temperature inversions often appear. It is interesting that the river Toplica which crosses Toplica valley is the coldest hydrological object in the region in summertime. It could be colder up to 7°C than objects on the land. This produces the following interesting phenomena. The colder air along the river keeps under the worm air along the mountain, and on the peak of Vidojevica (nearly flat, area about 4 ha) appears the stream. There it splits into two parts, one directed to the Toplica valley, other goes to the atmosphere. This streaming on the peak can be sensed on the human body, as the temperature difference can amount up to 10°C.

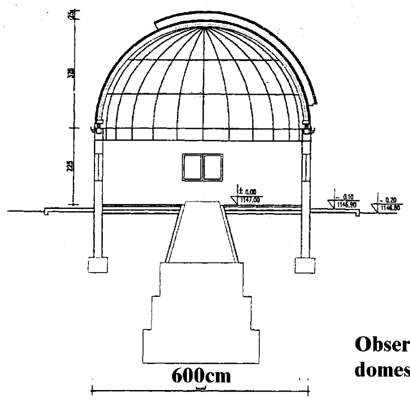
3 The Project ASV

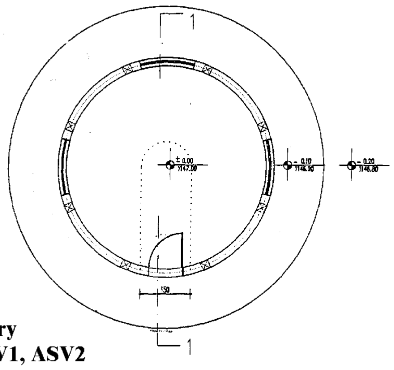
As it was aforementioned, the project is a renewal of an idea, old almost 30 years. Namely, it was planned in the 80's of the last century to build an astronomical station comprising a reflector of 2m aperture at the adjacent mountain Rgaj (1050m). Due to various circumstances, this project was not realized and

it was almost forgotten. It is interesting how this idea appeared again and it should be mentioned here. In mean time, an astronomical society, *Magellan's clouds* appeared in the town of Prokuplje. Members of the society, in particular Aleksandar Valjarević and Aleksandar Simonović, were searching for a good place where to place a small dome for the society's telescope. Finally, they came on the peak of Vidojevica, and introduce senior members of the society, Stevo Šegan and Žarko Mijajlović, professors of the Faculty of mathematics in Belgrade (MATF), with the possibility of building the dome there. They recognized at once the value of the site and recalled the old idea of building of an astronomical station here. The idea was accepted and supported by Milan Dimitrijević, then the director of AOB, and the following director Zoran Knežević who started the realization of the project. Of course, many other people were involved, and they are still working on it: Ištvan Vince (AOB), Nadežda Pejović (MATF), Gojko Djurašević (AOB), Slobodan Ninković (AOB), Vojislava Protić-Benišek (AOB), Dušan Ćirić (Department of mathematics of the University of Niš), many people from the community of Prokuplje and others.

The original project of the whole complex comprises four observatory domes. First, two identical small observatory domes are projected. Telescopes of apertures up to 65cm can be mounted there. According to the project, the third (middle) dome can contain a reflector up to 1 m, while the fourth and the largest dome is projected for a reflector of 2 m aperture. The living house for the crew is about $200m^2$ and it is planned for housing 12 persons. The first stage of the project, ASV1, comprises the building of one small observatory dome and living house, and it should be finished during 2006. A telescope of 60 cm aperture has been already bought with some accessories and one spectrograph.

The total cost of the first stage, ASV1, of the project is about 350000EU, and it is financed completely by the Serbian Ministry of Science.

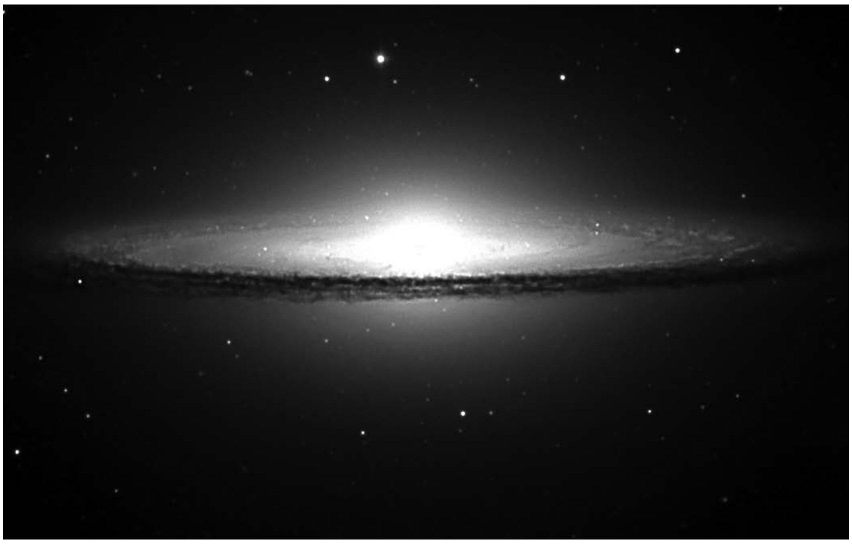




Observatory domes ASV1, ASV2

Here are some technical details of the telescope. The 60cm-reflector is produced by the German company ASTROOPTIK, it has Lomo Sitall optics, primary focal ratio $f/3$ and system focal ratio $f/10$. The servomotor encoders are with $< 0''.08$ resolution, while the maximum slow rate is 3^0 per second. The software and the controlling system of the telescope are based on a PC WIN XP operating system with standard functions for computerized telescopes. It admits also remote control. The accessories include a reducer ($0.6\times$ for an effective focal length of 2500mm), field corrector, of axis guider and high-accuracy encoders (Heidenhain ERA 780 C Encoders with a very large diameter [473mm] and a very high resolution in both axes [0.2" accuracy per axis]). As can be seen from the following picture taken with the same telescope, stars of the 21st visual magnitude are observable.

However, a group of Serbian astronomers started to think about an alternative as a change of the original project. The alternative would consist of building an array of small identical telescopes (at least three of them, each of 60 cm aperture). They would make a multiple telescope for doing optical and near-infrared interferometry. For this reason, the Faculty od Mathematics applied for the project *Reinforcing research potential in astronomy and applied mathematics* by the European Union under FP6 framework. The project is managed by prof. Nadežda Pejović (MATF). In fact, the main project objective is to reinforce and improve research capacities in astronomy and applied mathematics in Serbia and Western Balkan (WB). It is planned to do that by upgrading and raising scientific and technological potentials of ASV and exchanging and training scientists and students through networking with other European research centers and neighboring countries. This stage of the project is called ASV2. Our partners in the project would be: **a.** Instituto de Astrofísica de Andalucía, Granada, Spain, key person: Dr Emilio J. Alfaro. **b.** Astronomical Institute, Academy of Sciences of the Czech Republic, Prague, key person: Dr. Jan Vondrak **c.** Oxford University



The picture of m104 taken with Astropotik 60cm-reflector.

Computing Laboratory, Numerical Analysis Group, United Kingdom, Oxford, key person: Prof. Endre Süli. **d.** School of Informatics, University of Manchester, Manchester, United Kingdom, key person: Dr. Goran Nenadić.

4 ASV2 in Details

The project ASV2 assumes obtaining of a computerized telescope, identical to the already mentioned ASTROOPTIK reflector, then a small supercomputer consisting of a cluster of PC computers and a GPS equipment necessary for a precise time base and the telecommunication equipment. The project consists of the following section parts.

4.1 The multiple telescope

The purpose is to prepare the system to do optical and near-IR interferometry. This is considered as an inexpensive way to build a big mirror. A further enlargement of the array of telescopes will be possible. The classical principle of interferometry has been little present at optical wavelengths. Interferometry helps to improve the resolving power of an instrument (a telescope). For instance, by synthesizing several small apertures it is possible to achieve the effect of a large aperture. This improvement can be, quantitatively, to an order of magnitude. The base can attain even 100 m. At the given location such a base is available to us. The first experiments are planned to be performed with two already mentioned identical telescopes over a base 70 m long. One such a telescope is already purchased and it will be settled at ASV during the summer 2006. A multiple telescope of an equivalent aperture of 85 cm will be obtained. The necessary time base will be provided through a qualitative station possessing a GPS which will be based in future on European system Galileo. Mathematical methods will include image and signal processing, frequency analysis and wavelet theory. Additional mathematics includes numerical solutions of ordinary and partial differential equations for solving certain astronomical problems, e.g. in celestial mechanics, then developing algorithms for error correction for applying to the GPS system.

4.2 Robotization and automatic guidance for this system

This will permit a distant guidance and use of each telescope, separately, as well as the system as a whole. Besides, high-tech advanced modern mathematical methods will be used, e.g. the Groebner basis as an important tool in modern computational algebra and analysis. Bearing in mind that a low-budget station is raising, open-source application will be used, where it is appropriate for a professional use. Namely, the revolution in astronomy does not stop at the hardware. Research-grade telescopes at observatories from Spain to Korea are under the control of open-source software and Linux based computers. Under the open-source model, we are free to modify the control software. With a source code freely available, a peer review now occurs not only on the data, but on the gathering as well. In our research, we consider the forefront on this open-source astronomy in *Talon* (can be downloaded at observatory.sourceforge.net). Talon was originally developed by Ellwood Downey as the Observatory Control and Astronomical Analysis Software (OCAAS). As already mentioned, a part of the controlling software for the telescope that is foreseen for purchasing is coming with the telescope, too.

4.3 Data transfer and processing

The objective is an on-line use of the system, transfer of collected data, their storing and manipulating for research purposes. In the previous item we described the intended software platform. Firstly, we plan to develop software for remote control of the multiple telescope and automatic guidance, as of sky patrolling. Secondly, we are planning to develop an application for efficient on-line transfer of so collected data, but off-line, as well. We consider an open-source software for this task, too. For example, a part of this task can be done by software package Talon, as it supports network operations, using X session. However, the quantity and complexity of data that are obtained by astronomical observations may grow rapidly. Therefore, there is an apparent need to provide an efficient data storage, access and processing. In particular, the research objectives would be a sofisticated data mining to discover patterns of any kind, including images and numbers. In particular, we consider a pattern recognition for use in interferometry. Namely, data on light waves collected by telescopes are digitized by DSP processors and so a sequence of numbers is obtained. If two synchronized identical telescopes are used in the same time interval, two nearly equal sequences of numbers will be obtained with a small shift on the time line. The pattern recognition will be used for finding the same base point on the time line for both sequences of light waves. This will enable one to post-process data for the purpose of interferometry. A good time base is needed, of course. We consider this approach as an innovation in interferometry, or generally in astronomy, versus the methods applied elsewhere.

5 Research

The following scientific programs are planned to be performed immediately after finishing the ASV1 stage. Of course, some of them will be possible only after finishing the ASV2 stage.

5.1 Time base

As it is well known, the Official Source of Time for the WB region does not exist. It is a very important service for reintegrating the WB region in the European traffic, industry and defence systems, as well as the navigating one. The standard unit for the measurement of intervals of time is the SI second, which is defined by adoption of a fixed value for the frequency of a particular transition of caesium atoms. Caesium frequency standards, hydrogen masers, ion storage devices, and other such devices are able to count seconds and subdivide them very precisely. Thus, such a device can provide a time base and a time-scale whose accuracy is dependent of the measurement precision and the device stability. The results of the measurements of about 200 frequency standards located throughout the world are combined to form a standard time-scale that can be used for identifying uniquely the instants of time at which events occur on the Earth. This standard time-scale is known as International Atomic Time (TAI). It is the basis for all time-scales in the general use. It is distributed by many different means, including radio time signals; navigation systems such as GPS (Global Positioning System), LORAN-C, and OMEGA; communications satellites; and precise time standards. Both the Transit satellite system and the Global Positioning System (GPS) can be used for one-way time transfer. Although the GPS system is designed for navigation purposes, it also coordinates most of the major time-scales in the world. The GPS system has an accuracy of 10 ns for ten-day averaging. The most accurate time comparison by GPS is based on a common satellite procedure. GPS satellites on a flyby mode make two separate comparisons with respect to the GPS satellite clock. A linear rate for the satellite clock is assumed. This method does not provide the same accuracy as the common view procedure, but the accuracy is enough for the astronomical events registration, among them, for the optical interferometry reduction of the observations. The differential delay effects caused by the Earth's atmosphere and other different sources should not exceed a few nanoseconds. Time has a specific purpose in astronomy. The observational data, with precise time identification by GPS one-way transfer, are then brought together for correlation so that precise values for the differences between the clocks at the individual telescopes can be determined. A base of about 100 m will provide to establish the coordinate accuracy by an order of magnitude better than that obtained with a single telescope. To achieve this accuracy, 400-850 nm bandwidths are required. This process requires distinct measurements based on prearranged experiments involving different locations. The results of the time comparisons are not available unless the two data sets are brought together and correlated. In theory, a sufficiently large data sets are available and sufficiently large bandwidths can be obtained, the synchronization method is mainly limited in accuracy by the difficulty of determining the overall system delay and the atmospheric delay.

5.2 Other astronomical programs

Here we shall mention in short other types of astronomical research at ASV:

1. Monitoring of Main belt asteroids and near - Earth asteroids.

2. Planetary transits.

3. Investigation of binary stellar systems, in particular eclipse binary stars and close binary stars.

4. Monitoring of Solar activity.

5. Processing of photometric and spectroscopic data.

6. Synthetical spectra of stars.

7. Writing software for guiding telescopes and domes.

8. Education and training students of astronomy.

6 Conclusion

The Project will significantly help the preparation of groups of Serbian scientists in the fields of astronomy and applied mathematics for future Community research. By upgrading and reinforcing ASV by low budget-equipment, it will help technological development policy activities too, including monitoring and assessment activities. In particular, new experiences and connections with European centers will be obtained through partner network activities: conferences, workshops, studies and analyses, working groups and expert groups, operational support and dissemination, information and communication activities. Along this course, the ASV2 Project has a strong support from four leading European scientific institutions and the Serbian leading scientific and high-level educational institution, the Belgrade University.

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