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What astronomy with meter-class telescopes? Sharing experience with the next-door observatory

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Abstract. When asking what astronomical observations are most relevant to meter-class telescopes we will get a lot of answers - usually as many as astronomers have been interviewed. The aim of our review is to give some useful hints having observational practices and scientific projects carried out at the Rozhen National Observatory as examples. We discuss in brief the topics concerning observations of comets and asteroids - observed both photometrically and positionally, exo-planets - newly found and already known transits, optical monitoring of large variety of variable stars and stellar systems on different time-scales - from short term to very long term, hunting for novae in our Galaxy and in nearby galaxies, supernovae search and monitoring, active galactic nuclei and their photometric behavior.

Key words: telescopes – instrumentation – methods – techniques

1. Introduction

Main goal of this opening lecture is to focus your attention on what is to have, what is to observe with, and what is to manage meter-class telescopes. And, hopefully, to share the experience. In my home-institution, we have three meter-class telescopes, some smaller telescopes, and one two-meter telescope on top of it.

Let's start with the question - how many meter-class telescopes are they today? If we try to keep our definition as wide as possible, from fairly sub-meter class telescopes with 0.4 meter mirrors, to the very upper limit of about 2.0 meter mirrors, the fairly correct answer would be - many hundred. It is obvious that this is the most numerous class of telescopes we have available as astronomical community. The second question is - why? Because meter-class telescopes are an absolutely winning solution for carrying out scientific research, university education, and public actions, often called by journalists as "science for the society". All three together, or any combination between two of those purposes.

It is obvious also that meter-class telescopes are not a mere alternative of "big" telescopes – a cheap alternative, to be honest. They occupy a very specific niche of research. Their own niche, and hopefully we will extensively discuss it, and describe it during the conference. Meter-class telescopes are telescopes with a complex and unique mission, and we have found here three key words for it - accessible, flexible, versatile. We can call them "little big telescopes".

2. What magnitudes?

Doing photometry with meter-class telescopes means stepping down to 20-th magnitude stars. Simple calculations show that with a 100-cm main mirror for 600 sec exposure time we can reach 20-th magnitude in R-filter with a signal-to-noise ratio of about 50 that corresponds to the one-sigma level accuracy of about $0\overset{m}{.}02$. It is still possible to keep the one-sigma level accuracy of about $0\overset{m}{.}005$ for 18-th magnitude stars. It should be stressed however, that there is very well pronounced dependence on seeing conditions, filter pass-bands, and last but not least, CCD-camera characteristics - mainly detective quantum efficiency (DQE) and read-out noise value.

According to publications on the topic we have most often a typical field-of-view in the range from $10' \times 10'$ to $25' \times 25'$, and (2k × 2k) or (4k × 4k) as typical dimensions of the CCD-chips. Due to this, fast and low-noise CCD-cameras are widely used. Cooling method seems to be the crucial point in searching for good compromise between reading speed and read-out noise.

Concerning the photometric systems of general use we have found mainly Johnson/Cousins UBVRI, and Sloan filter-set u′g′r′i′z′. Nevertheless, any other filter-set of special interest can be used, keeping in mind especially narrow-band comet filters, e.g. CN (390 nm), C_3 (406 nm), CO^+ (426 nm), H_2O^+ (616 nm), and [OI] (630 nm). Other very informative narrow-band filters of common use can be H-alpha (656 nm), and why not - [OIII] (500.7 nm), or even [SII] (672 nm). In addition narrow-band imaging with wide-field telescopes provides almost endless possibilities for astrophotography.

Doing spectroscopy with meter-class telescopes means to go beyond 10-th magnitude. With a 100-cm main mirror, a fiber-fed echelle, and 600 sec exposure time a signal-to-noise ratio of about 50 can be reached for 15-th magnitude stars in a low-resolution mode (R $\sim$ 500), and for 10-th magnitude stars in a mid-resolution mode (R $\sim$ 40 000). A typical image scale in use is $2''$- $3''$ per fiber. As for example, in order to have radial velocity measurements with the one-sigma level accuracy below $100\,\mathrm{m\,s^{-1}}$, a low-noise CCD-camera and an echelle spectrograph mounted in thermo-stabilized box are needed. In a low-resolution mode using grisms (with or without slit) offers another very promising opportunity for obtaining spectra of faint objects - stars, planetary nebulae, galaxies, etc.

3. What objects?

We can successfully practice optical astronomy in all of its general modes: astrometry, photometry, spectroscopy, polarimetry, and interferometry with meter-class telescopes. Confirmation of this fact was easily found when digging in the observing log archives of our observatory. A short list of key topics and objects begins with Solar system bodies. Here we have near-Earth (NEOs) and trans-Neptunian objects (TNOs), space debris and arte-facts, nearly one hundred new asteroids discovered, twenty of them - already named. Good example of what can be done with photometric rotational curves of bright asteroids can be found in the paper of Apostolovska et al. (2011). Then - photometry and polarimetry of comets and comet tails - Borisov et. al (2011) and Waniak et. al (2011). Low- and high-resolution spectroscopy of comet C/2009 R1 (McNaught) is described in Borisov et. al. (2012).

Next example presents studying exo-planets by using transit timing variations in collaboration between the Rozhen National Observatory and the Jena University Observatory - Maciejewski et. al. (2010). Another photometric multi-site campaign aimed to high amplitude δ Sct stars is described in Ulusoy et al. (2013). Results of studying spectroscopic binary systems with unknown orbital periods since no eclipses occur can be found in Iliev et al. (2002). Rozhen Stellar Cluster Survey is targeting open clusters of different ages. It is presented in Paunzen et al. (2006). Multicolor UBVRI flickering in the symbiotic star MWC 560 is studied in Zamanov et al. (2011).

Novae and nova-like stars studies are illustrated with an example of the recurrent object RS Oph and its short-term flickering behavior - Zamanov et al. (2010). Photometric search for such kind of stars in M31 is described in Ovcharov et al. (2012). Intra-night BVRI light curves of the quasar 3C454.3 made by quasi-simultaneous observations (three telescopes, two observing sites) are reported in the paper of Bachev et al. (2011). Nearly the same observational approach has been used to study photometric behavior of two blazars - 1ES 1959+650 and 1ES 2344+514 (Gaur *et al.*, 2012). In this case a collaboration of five telescopes observing at four different sites has been organized. Results of yet another multi-site photometric and spectroscopic campaign, this time pointed to the rare long period binary star EE Cep, can be found in Mikolajewski et al. (2005). Spectral observations taken from six different low- and mid-resolution spectrographs attached to meter-class telescopes have been used. We will finish our list of objects and observing techniques with the last kind of possible objects - supernovae. The example is SN2011dh - a new member of the rare SN IIb-subtype family (Dimitrov, Kjurkchieva 2013).

We can conclude that flexible-class telescopes allows completely different observational strategies and tactics - starting with "make history on objects with history", and finishing with "shoot everything that moves or flashes". EE Cep, ϵ Aur, AZ Cas, CH Cyg, V838 Mon, MWC 560, Cyg X-1, KR Aur all they belong to the first type of objects, and for the second we can just add our very abridged target list comprising cataclysmic variables, symbiotic stars, X-ray binaries, Delta Sct stars, Algols (and pulsating Algols too), Gamma Dor stars, Wolf-Rayet stars, M-dwarfs, brown dwarfs, RS CVn stars, PMS flare stars, mirids, Novae (both Galactic and extra-galactic), SN, AGN, and many others.

We can have meter-class telescopes as survey telescopes, and as target-of-opportunity telescopes as well; we can use them for participating in multi-site international observational campaigns - WEBT, YETI, ..., or for supporting, making follow-ups, and/or working on the legacy of many different space missions - just to mention Hubble, Hipparcos, STEREO, Kepler, GAIA, ...

4. What management?

Successful management of meter-class telescopes requires nearly the same administrative, technical, and scientific elements and structures we put in use for larger telescopes and observatories.

First, this is keeping clear, simple and flexible time allocation policy including observing schedules, and some fine tuning instruments of the time allocation like "director discretionary time", "technical nights", "support astronomer", and "service mode". Web-site of our Time Allocation Committee (TAC) can be found here - http://docs.astro.bas.bg/~observations/index_EN.html.

Second, special attention on the data acquisition procedures, data-flow, data reducing, and data archiving is badly needed. Nowadays the amount of raw CCD-data can easily reach several gigabytes per night. This side of the management includes providing any particular data file with complete and comprehensive FITS-header, establishing correct and powerful reduction pipelines, keeping data-archives consistent with the VO-standards and obeying the open-data access rules.

Third, it becomes clear that special hardware and even software require specially trained "guru(s)" to care for them. This side of the management includes also any kind of automation - from simple pointing and guiding the telescope to complete remote controlled observations.

Finally, funding. Money really matters. Here we have to take into account not only the operational costs and maintenance, but also future hardware and infrastructure improvements. It is obvious that a meter-class telescope with a 1M-class funding would be quite different from another meter-class telescope with 100k-class funding. In this mere example the ten times ratio is much more important than the name of the currency.

Our experience in telescope and observatory management can be summarized in two sentences only. Instrumentation and data acquisition are as important as the telescope itself, so they need permanent additional spending. People who work with the telescopes are even more important, so they need permanent additional learning.

Thus we come to the next very important function of meter-class telescopes as a perfect tool for successful university education. It's impossible to underestimate the role of "learning by doing (observing)" in contemporary astronomy, so the most efficient way to do this is to educate students close to the telescope. As close as possible. Since our science is so attractive not only because of the sky above, but also because of the ways we choose to reach it.

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