ASTROMETRY WITH SMALL INSTRUMENTS

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Abstract
Based on an analyze concerning Bucharest astrometric instruments, a modernization project was elaborated. There are exposed the general aims of the project and the preliminary results obtained: the selection of data from astronomical catalogues, data acquisition concerning instrument positioning and tracking, data selection from astronomical image acquisition system and data processing by means of specific procedures.

I. Observational astrometry in Romania

Main topics of research in Romanian astrometry were connected with the use of 4 instruments: Prin-Merz Astrograph, Meridian Circle Gauthier-Prin, Zeiss Transit Telescope and Danjon Astrolabe.

Meridian Circle Gauthier-Prin 19/235 cm was installed in 1926, it had an important contribution in improving, in an extended international cooperation, stellar catalogues. Zonal and local catalogues for different purposes were built using this instrument. The developments of CCD astrometry and the difficulties of financing such a special project obliged us to stop visual observations. Now the Meridian Circle is preserved and we are studying the opportunity of future modernization.

Zeiss Transit Telescope 10/100 cm was set up in 1956 and was used for Earth rotation monitoring. After using 30 years, taking into account the new development of this class of instruments we stopped the observations. In the future, such an astronomic instrument has no use, except for education.

Danjon Astrolabe 10/100 cm was borrowed from Brussels Observatory and installed in 1993. After being modified for performing CCD observations, it was used in the study of vertical deviation: geodetic and astronomical determinations were compared and a computation method was elaborated. We expect to use such class of instrument for astro-geodetic measurements in defining the relative position of the geoid relative to WGS84 ellipsoid.

Prin-Merz Astrograph 38/600 cm is a twin telescope installed in 1911 and used for photographic astrometry a very long time. A project of modernization of this instrument is in work (October 2002 - October 2004).

II. Main topics of Romanian astrometric researches.

1. Wide-Plate Archive

A database containing 13000 plates is the result of the about 80 years observational period using the Prin-Merz Astrograph. The database contains a lot of astronomical information difficult to be evaluated. The work on this database was connected with IAU Commission 41, Wide-Plate Archives Working Group having collaborators M. Tsvetkov and K. Tsvetkova from the Institute of Astronomy of Sofia. The aim of this work was the storage and digitizing of our plate archive.

Currently, under a contract with Politechnical University Bucharest, we are developing software for high-speed identifying of the objects from the catalogues, for identifying from all the images from the plates: position, flux (magnitude) and diameter. We work also for searching of unknown objects (not contained in the catalogues). The final result will be a self-adaptive configuration database in distributed platforms (grid databases analysis).

2. Narrow-field astrometry

Astrometry of Solar System bodies is performed in international collaboration with the aim of studying mutual phenomena of planetary satellites, to contribute for improving the orbits of PHAs, to study taxonomic families of PHAs. CCD astrometry and also photometry of these bodies is included in this study.

3. Connection of Radio and Optical Reference Frames

Our institute is included in a group of collaborators: Kiev University Astronomical Observatory, Nikolaev Astronomical Observatory, and Pulkovo Astronomical Observatory. In the interval 1992 - 2000, there were observed, in photographic mode, 188 areas [1].

The topic includes the improvement of optical/radio stars' positions by narrow-field CCD observations. There were made studies concerning: the non-coincidence between radio and optical centers at least for ICRF extended sources, high accuracy densification of the optical frame in post-Hipparchos era mainly for radio-optical connection. Now is in study a first set of 12 radio-sources. There are used in the Compiled Catalogue of

Reference Stars around Extra-Galactic Radio Sources to be finalized in Pulkovo [2].

4. Vertical deviation measured with astronomical methods

In collaboration with the Faculty of Geodesy, Technical University of Civil Engineering, we are working for the introduction of a new national ellipsoid, for the compensation of geodetic net, needed for local ellipsoid special purposes. There were performed geodetic measurements (distances, directions / angles) on the surface of the ellipsoid for relative positioning of geoid-ellipsoid (WGS or Krasovsky).

In conclusion, the demands of narrow field CCD astrometry in our institute are:

- To modernize one of the most valuable instruments Prin-Merz Double Astrograph, in order to continue our astrometric tradition;
- To invest in a new instrument Geodetic Total Station and to modernize it by adding a CCD camera;
- To initiate observational programs using appropriate detection methods of the image;
- To concentrate on software development in order to balance technical improvements and low finance budget.

III. Modernization plans and results

Prin-Merz Astrograph, a 38/600-cm twin telescope, with a $2^0 \times 2^0$ field, was selected for the modernization process, being the most valuable instrument, figure 1.

Fig.1 - Prin-Merz Double Astrograph

In October 2002 we started the project, financed by Romanian Space Agency. It was included in the general idea of development and applying optoelectronic techniques of acquisition and image processing in order to improve the accuracy and efficiency of ground-base astronomical observations by using the automatic control of the positioning and data processing with appropriate software. We include INCDMF - CEFIN (Center of Fine Mechanics) as manager for this project.

The project goals were:

- The research and application of the optoelectronic observation techniques by means of a system of image acquisition with CCD camera;
- The development and use of stepper motor intelligent driver systems, use of planetary gear-box, specific mechanisms, electronic drivers;
- The development and accomplishment of a position control system with absolute encoder;
- The accomplishment of data acquisition and transmission interfaces.

Mounted on the visual telescope, the new optical system has a 7.6×7.6 arcmin field of view, an angular resolution of 0.447 arcsec / pixel which allowed to reach a limit magnitude of 18.

The CCD camera is a 1024×1024 Apogee AP47P, with pixel size 13×13μm, quantum efficiency >90% at 650nm, read noise: 7 - 9 e^-, digital resolution: 16 bit, 50 kHz and frame transfer 20 sec, figure 2.

Fig. 2 - Apogee AP47P CCD Camera mounted on the optical telescope

The tracking system was installed on a Zeiss refractor (with a field of 14×14 arcmin) mounted on the Prin-Merz telescope. It allows real time tracking using a CCD-TV MINTRON 12V camera.

The driving system modernization includes a stepper motor and planetary gearbox electromagnetic coupled which was mounted on the declination circle. It has a rotation speed of 90 degrees/min. The position control system has an absolute encoder with a min. 20-bit resolution, mounted on the declination circle and connected with data processing system. The accuracy of the positioning is less than 5 arcsec.

The operation and data processing system consist in:

1. Selection of data from astronomical catalogues.

Projected to perform narrow-field astronomical CCD observations, the system uses USNO B1-0 Catalogue of ~ 500 million stars with good enough stellar density [3].

It is possible to use about 80 stars to compute plate solution for each frame with a mean square error of about 0.17 arcsec.

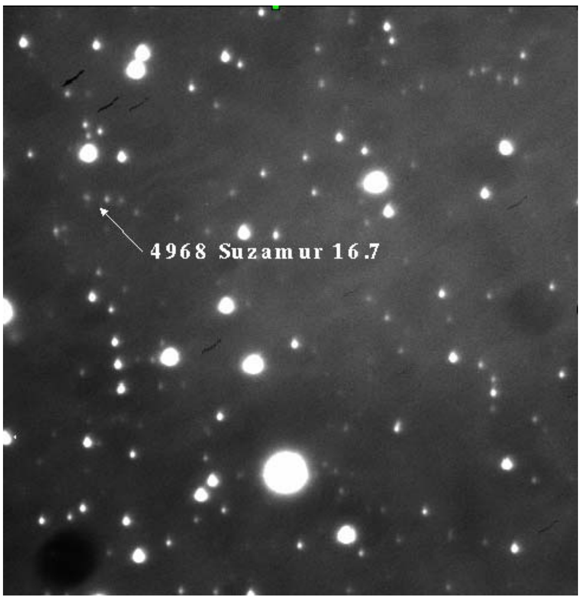


Fig. 3 - 4968 Suzamur, M=16.7

2. Data acquisition concerning instrument positioning and tracking.

The MINTRON Camera is used for positioning and tracking. The position of a star-target (up to 12th magnitude) is measured 10 times/sec and used as feedback for instrument pointing correction.

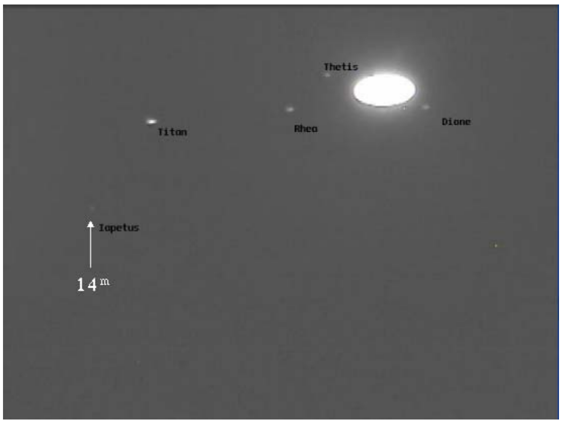
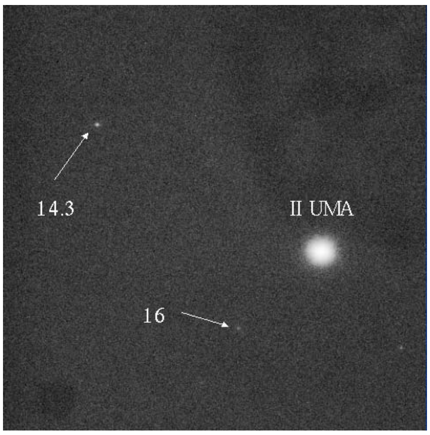


Fig. 4 Image of Saturn's satellites on Mintron Camera

3. Data selection from astronomical image acquisition system.

We showed two 1K×1K FITS files of the eclipsing binary II UMa (8th magnitude). In figure 5, the exposure time was 7 sec, which allowed reaching 16th magnitude and figure 6 with an exposure time of 10×7-sec, reaching 17.5th magnitude.



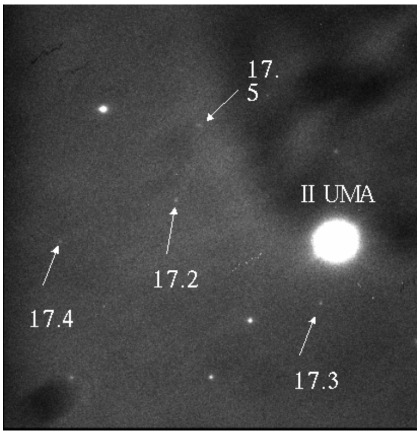


Fig. 5

Fig. 6

Another image, figure 7, with 30×1-min exposure shows some more details and figure 8, of 18.5 - 18.9 magnitude.

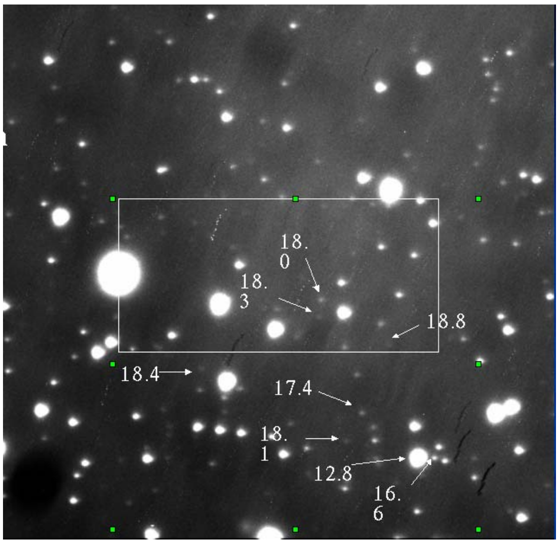


Fig. 7

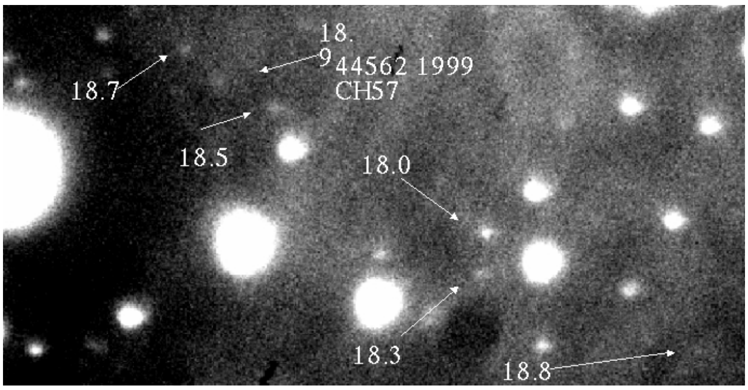


Fig. 8

4. Data processing by means of specific procedures.

The FITS frames were processed using IRAF (dark, bias, flat corrections) [4]. The image quality is to be evaluated and information used in automatic focus. The method involves short exposures that are added to obtain up to 30 minutes of total exposure. The frames are shifted to compensate drift in image telescope tracking; this drift will be eliminated after the finder feedback loop will be set-up. This is a methodology used for fast moving object astrometry in order to obtain accurate position of asteroids from faint reference stars [5]. To facilitate the detection, we built one image (sum of 3 FITS images, one image = sum of 30×1 min frames separated by 20 min) shifted in respect with reference stars position. The same set of images were shifted in respect with asteroid position.

5. Interactive, flexible dedicates software.

Any implementation of nearly real time digital processing must relay on automated image analysis software. The automated detection, classification (centroid position, magnitude) of the objects are implemented on a hardware running system a near real-time operating system (*NIX). An intuitive interface together with IRAF package will provide a smooth, flexible and versatile system to the user. Batch-mode operation is also available for remote use of the system.

IV. Conclusions

Narrow-field CCD astrometry is possible with small instruments: the maximum magnitude detected during performing test observations allows us to initiate new observational programs. The experience in the work of this project permits the continuation of the development and accomplishment of a remote control operation system of astronomical instruments. In this idea, it is necessary to follow the modernization programs in order to maintain the capabilities of our observatories, to valorize our astronomical scientific and technical heritage: databases and instruments.

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