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ADAS: Asiago-DLR Asteroid Survey

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Introduction

The project to adapt a CCD camera to the S67/92 cm Schmidt telescope at Cima Ekar is a joint collaboration between the Department of Astronomy and the Astronomical Observatory of Padova on one side, and DLR Berlin on the other. The main scientific driver is the discovery and follow up of moving objects (asteroids, NEOs, NEAs, TNOs, KBOs, etc.). Hence the name **ADAS: Asiago-DLR Asteroid Survey** given to the project. The Minor Planet Center has attributed to ADAS **the survey code 209.**

Other scientific programs will be possible: no filter is at moment provided, but a filter wheel device is available and it will be mounted in the near future.

DLR has provided the SCAM-1 camera which can be operated both in Time-Delay Integration mode and in normal mode, the software for image acquisition and quick look, and for astrometry and automatic detection of moving objects by comparing 3 frames (Rackis). Photometry and centroiding of all stars on the frame is accomplished by using Sextractor, a public domain software package developed by E. Bertin and S.Arnouts (1996). The thick front-illuminated CCD is a grade A 2048x2048 LORAL chip with a pixel size of 15x15 µm (1".437x1".437 on the sky), and covers an area of 49x49 arcmin (0.67 sq deg). In TDI, the effective exposure time for each star is of 196s at the equator. The camera is equipped with a precision shutter, the shortest exposure time being 0.1 sec. The chip is refrigerated by a two-stage cooling device, where the primary stage is a Peltier cooler and the secondary one consists of a closed-circuit liquid refrigerator. The achieved CCD operational temperature is –63 °C.

The system (see Fig. 1) obtained useful data since December 21st,2000. Till the middle of February 2001, the focal plane was folded to the CCD camera via a (slightly undersized) flat metal mirror kindly provided by Officine Galileo (Firenze); the mirror is a spin-off of the very successful prototype built for the Halley Multicolour Camera on board GIOTTO, now produced in large quantities for several non-astronomical applications.

A new flat mirror in glass, with larger dimensions in order to collect all the light beam, and excellent optical quality, was produced by Ottica ZEN (Venezia); it was installed at the telescope the 21st of February 2001.

Several tools for ADAS have been adapted from available software packages. The astrometric residuals are evaluated by a comparison with the asteroids positions (MPC format) in the **asteroid server** developed by **J. Skvarc** through the web interface:
http://astro.ago.uni-lj.si/asteroids/residuals.html
This service uses several programs and information sources developed by different people. The asteroid database is maintained at **Lowell Observatory** by **E. Bowell**. Propagation of asteroid positions is done by a program called **Orbfit,** part of a NEO information tool **NEODyS** developed by the **Orbfit consortium**. Identification of the asteroids is made using the MPC tool:

MPChecker http://cfaps8.harvard.edu/~cgi/CheckSN?s=m

Fig. 1 – The SCAM camera head and its electronics attached to the NW side of the S/67-92cm telescope at Cima Ekar

1 – The First Phase, 20 Dec. 2000 – 20 Feb. 2001

The first phase of our work, using the metal mirror, lasted from Dec. 20, 2000 through Feb. 20, 2001. Although the optical quality had not reached its optimal value, the limiting magnitude was already sufficiently faint to give hope to have a competitive system. For instance, the faintest observed object the very first night was 1998 KN45, V(JPL) = 19.94 (there is no filter in front of the CCD, the effective band is essentially V+R), with an exposure time of 80 sec.

Examples of images, namely asteroid (8965) Citrinella and nebula M42 in Orion, are given in Figs. 2 and 3.

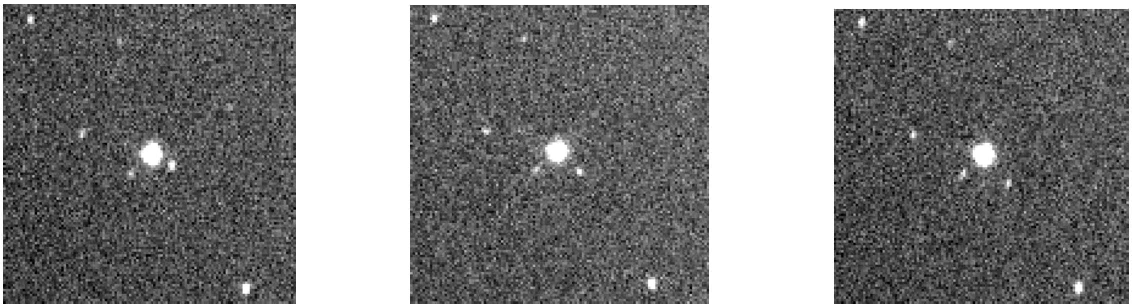

Fig. 2 ? Three images for the detection of asteroid (8965) Citrinella (V=19.03), exp. time 80 s each

Fig. 3 – M42 in Orion, metal mirror, no filter, exp. time 15 sec. Image processing courtesy of R. Falomo

The nights of the 13th, 14th, and 15th February 2001 the telescope was pointed toward **known NEOs** in order to test the performances of ADAS also in this application. Table 1 gives the results.

Table 1 – Observations of known NEOs

Object	Exp. Time (sec)	Rate RA (arcsec/h)	Rate DE (arcsec/h)	Rate (arcsec/h)	mag
2001 CC32	100	-203.3	-229.3	306.4	17.6
2001 CB32	100	271	-116.6	214.6	17.1
2000 YM29	100	55.8	64.6	85.3	19.0
2001 CP36	80	-1063	128.7	1070.8	16.9
2001 CQ36	80	-87.2	-215.6	232.6	17.7
2001 CC21	80	311.3	23.2	312.2	16.3
2001 CK42	100	-64.8	13.46	66.2	19.0
2001 CL42	100	-55.1	21.8	59.25	19.0

In this first part of the ADAS program, we have essentially operated in guided mode. The following figures summarize the obtained data:

Total asteroids detections: 374
Covered square degrees: 33.3
Number of detected asteroids per square degrees: 11.2
Smallest detected angular displacement rate: 3.9 arcsec/h.
Smallest detected angular displacement: 1.6 arcsec

2 – The second phase, since 21 Feb. 2001

The **second phase of ADAS** started on 21 Feb 2001, when the new excellent glass mirror was mounted. The optical quality improved and the alignment of the CCD columns with the Hour Angle was optimized, so that the TDI scan mode could be implemented.

With the TDI technique and 30 min long scans, we cover a field of 6.15 sq deg for 3 times in 1.7 hours, approximately 3.6 sq deg/h. In winter time (10h observing runs), the total surveyed field will be of 36.0 sq deg; in summer time (6h observing runs) the total surveyed field will be of 21.6 sq deg.

Here are the results obtained from Feb. 21st to date:
total number of found asteroids: 652
covered area: 56.3 sq. deg
asteroids per sq. deg: 11.6
smallest angular displacement rate: 4.5 arcsec/h.
smallest angular displacement: 2.5 arcsec

Table 2 and Fig. 4 provides an indication of the astrometric precision achieved in the second phase, the residuals have been calculated only on numbered asteroids.

Table 2 – The astrometric quality obtained in the second phase

Residuals (arcsec)	N? of observations	Percentage
< 0.2	52	14.3 %
< 0.5	189	52.1 %
< 1.0	319	87.9 %
< 2.0	358	98.6 %
> 2.0	5	1.4 %
All observations	363	

Average RA residual	-0.27 ? 0.54 arcsec
Average DE residual	0.15 ? 0.35 arcsec
Average total residual	0.56 ? 0.43 arcsec

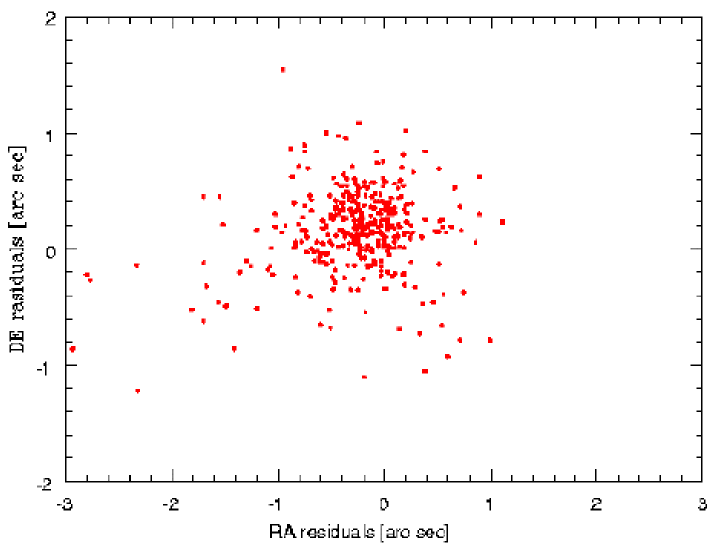

Fig. 4– The distribution of the astrometric residuals in the second phase

Table 3 gives the orbital classification of non-Main Belt objects detected in till now.

Table 3 – Orbital classification of non - Main Belt objects detected in till now

Orbital Classification	Nr.
MARS CROSSER	2
HILDA	4
TROJANS	5

3 – Overall Results till end of September 2001

Six batches with the positions of detected asteroids have been submitted to the Minor Planet Center, and fully analysed. Thirty-eight objects have been preliminary designed as ADAS discovery; Table 4 provides orbital information on them.

Table 4 – Asteroids discovered by ADAS

Asteroid	Orbit	Orbital clas.	Asteroid	Orbit	Orbital clas.
2001 AC53	None	-	2001 FT167	8-day arc	MAIN BELT
2001 CF48	None	-	2001 FU167	None	-
2001 CH48	None	-	2001 FW167	None	-
2001 CJ48	None	-	2001 FN168	31-day arc	MAIN BELT
2001 CL48	None	-	2001 FP168	3-day arc	MAIN BELT
2001 CO48	None	-	2001 FR169	4 opps 1992-2001	MAIN BELT
2001 CP48	None	-	2001 FS169	None	-
2001 CA49	None	-	2001 FT169	7-day arc	MAIN BELT
2001 DN106	58-day arc	MAIN BELT	2001 FE185	None	-
2001 DP106	3 opps 1998-2001	MAIN BELT	2001 FF185	None	-
2001 DQ106	None	-	2001 FG185	None	-
2001 DW106	None	-	2001 FH185	None	-
2001 DX106	None	-	2001 FJ185	None	-
2001 DY106	None	-	2001 FH191	None	-
2001 DZ106	None	-	2001 FJ191	None	-
2001 DA107	None	-	2001 FK191	None	-
2001 DB107	None		2001 FY191	None	-
2001 FF154	24-day arc	MAIN BELT	2001 FZ191	None	-
2001 FG154	25-day arc	HILDA	2001 FA192	None	-

Fig. 5 shows the magnitude distribution of all 1161 detected objects till now (not necessarily different, several asteroids might well have been detected twice). The faintest detected asteroid was 2001 FE168, V = 21.0.
The 23.0% of detected asteroids has magnitude > 19.5.

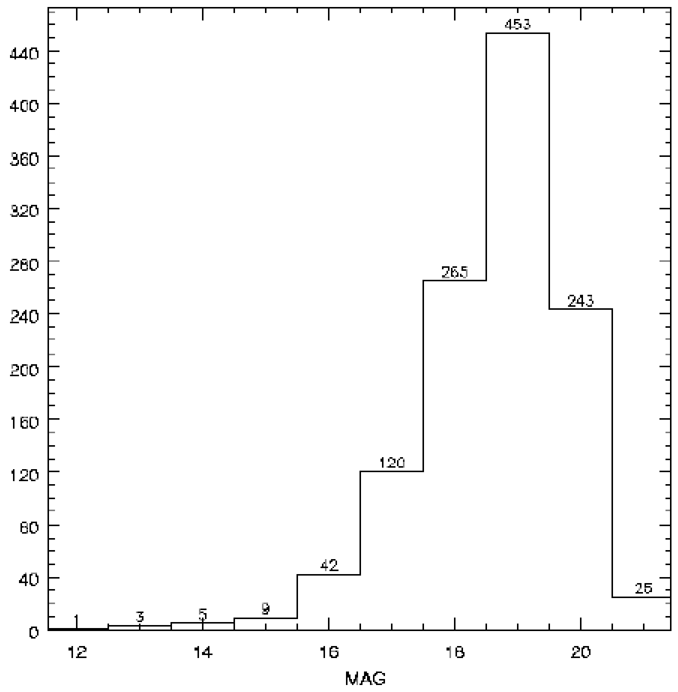

Fig. 5 – The magnitude distribution of all detected asteroids

4 – Observing at small solar elongations

A present we are testing a third phase of ADAS, pointing to sky zones whose angular distance from the Sun is ? 90°.

Several studies have shown the presence of a bias between the observed Aten-NEA fraction and the real one (Boattini and Carusi 1998, Michel et al. 2000). This bias is due to the fact that the large asteroid surveys observe near the opposition, where Atens spend the least of their time. Moreover until today no asteroid with orbit completely inner to that of the earth has been discovered: this type of asteroids can be detected only with observations at small solar elongations.

Table 5 – Small solar elongations areas observed till now

Ecliptic latitude	$?_{field}$-$?_{sun}$ deg	Surveyed sq deg
-15º < ß < 15º	[50,60[	3.9
	[70,80[	10.5
	[80,90[	4.7
? > 15º	[40,50[	0.7
	[50,60[	9.6
	[70,80[	6.7

On the other hand, the search of objects at small solar elongations is carried out under non-optimal observing conditions, and in some cases exclude the ecliptic plane, considerably lowering the total number of observable asteroids. This expectation is born out by the available data (see Table 5):

total number of detected asteroids: 25
surveyed area: 36.1 sq deg
asteroids per sq deg: 0.69

5 - Further developments

Several improvements are being sought of:

1. several broad band filters apt for CCDs are available to the Observatory; their mounting is under way
2. full automatization of the telescope and dome. A first phase of this work is in progress, all the electronics for telescope and dome position and time acquisition read-out is being rebuilt in order to ameliorate the precision and speed up the process of writing the headers.

References

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