Poster *SAIt 2002*, Padova, April 2002

ADAS

Asiago-DLR Asteroid Survey

Cesare Barbieri[1], Ivano Bertini[1], Sara Magrin[1], Luciano Salvadori[1]
[1]Department of Astronomy, University of Padova

Massimo Calvani[2], Riccardo Claudi[2], Giuliano Pignata[2]
[2]Astronomical Observatory of Padova

Gerhard Hahn[3], Stefano Mottola[3],
[3]DLR Institute of Space Sensor Technology and Planetary Exploration, Berlin (Germany)

Martin Hoffmann[4]
[4]Institute for Geology, Geophysics and Geoinformatics,
Freie Universität Berlin (Germany)

Abstract

ADAS, the Asiago-DLR Asteroid Survey, is the joint program among the Department of Astronomy and Astronomical Observatory of Padova and the DLR Berlin, dedicated to the search of asteroids. The Minor Planet Center has attributed to ADAS the survey code 209. On the Web, ADAS is described in: **http://planet.pd.astro.it/planets/adas**.

The project is carried out since the end of December 2000 with the S67/92cm telescope at Asiago - Cima Ekar equipped with the SCAM-1 camera of DLR, in Time Delay Integration mode, in a strip from –5° to +15° around the celestial equator. The camera has a front illuminated Loral chip of 2048x2048 pixels of 15 micrometers each, covering a field of 49’x49’ with a resolution of 1”.4/pixel.

This paper presents the main results obtained till March 15, 2002, when the telescope has been closed for a complete overhaul. ADAS will resume presumably at the end of June 2002.

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.** An updated view of ADAS can be found on the Web site: **http://planet.pd.astro.it/planets/adas**
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.

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

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).

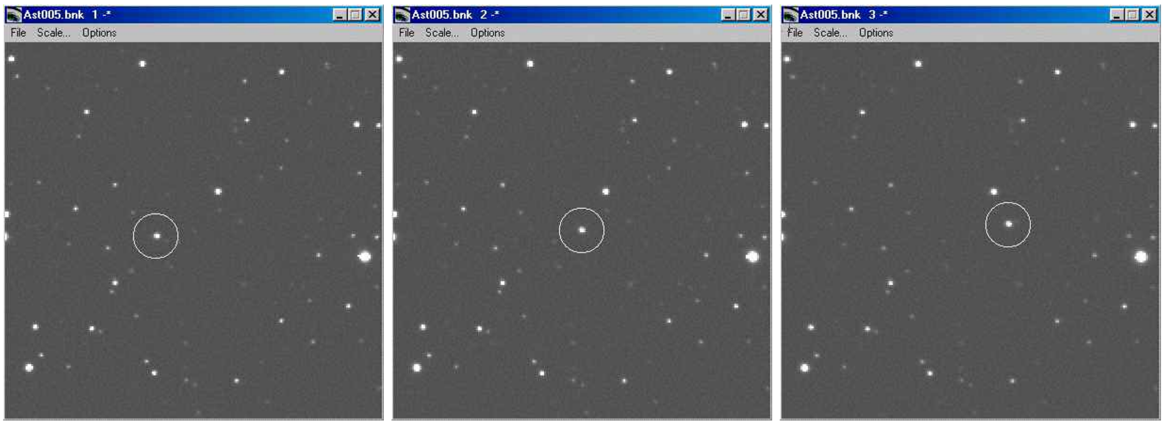

Fig. 4 – Three images for the detection of an asteroid. TDI mode.

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 Vincent 45 precision shutter, the shortest exposure time being 0.1 sec; because the diameter of the shutter is of 45 mm, a slight vignetting is introduced. 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. A complete characterization of the chip and its electronics was performed thanks to the kind help of Catania Astrophysical Observatory (Claudi et al. 2002).

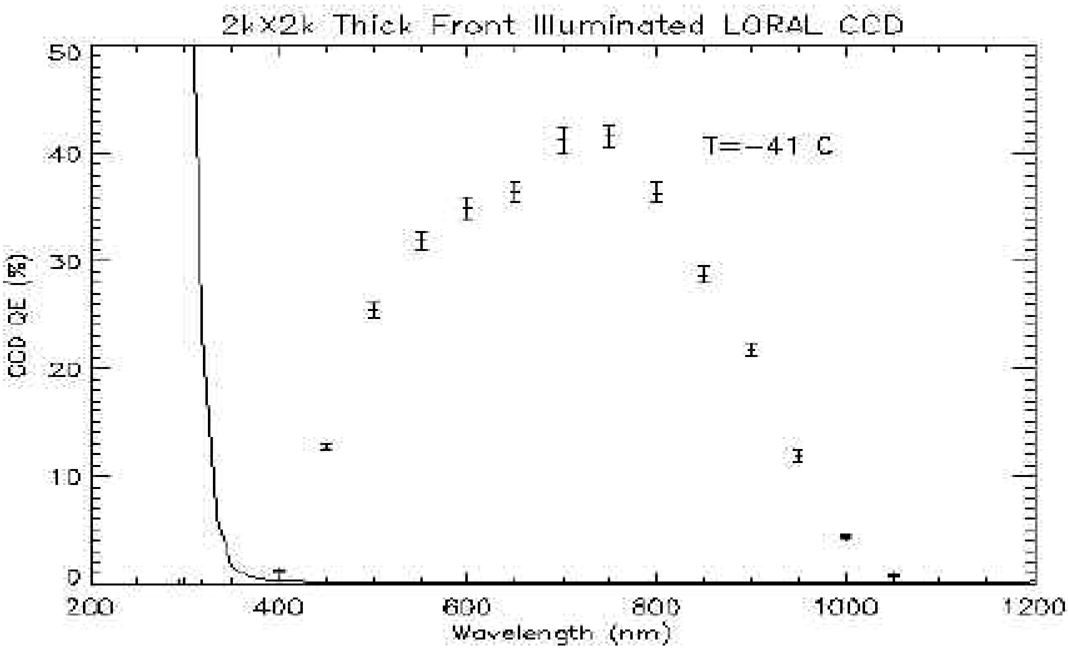

Fig. 2 – The quantum efficiency of the Loral chip. The continuous curve is the “opacity” of the BK7 dewar window (Claudi et al. 2002)

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.

Fig. 3 – Comet Ikeya-Zhang (2002 C1)

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

The asteroid positions are referred to the USNO SA2.0 and to the GSC 1.1 Astrometric Catalogues.

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

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. In this first part of the ADAS program, we have essentially operated in guided mode.

2 – The Second Phase, since 21 Feb. 2001 till 15 March 2002, TDI mode

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 has been of 36.0 sq deg; in summer time (6h observing runs) the total surveyed field has been of 21.6 sq deg.

The image quality can be maintained good only in the interval of declination (-5°,+10°), on higher declination the curvature of the sky becomes noticeable, but several data were nevertheless obtained at Hour Angles not too far from the meridian. The observing time was divided essentially among 2 different programs:

1. survey of asteroids around the meridian, in particular around Saturn's Lagrangian points and near the opposition
2. survey of asteroids at small solar elongations.

For both point we give a detailed account in paragraph 3 and 4.

The area covered in TDI mode is shown in
Fig. 5.

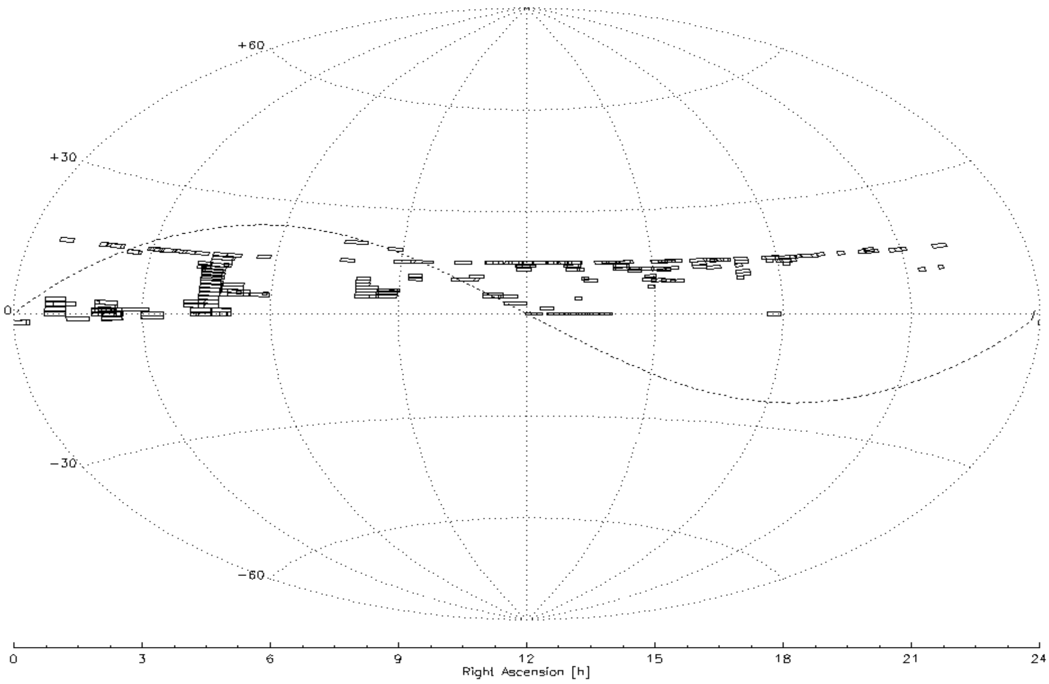

Fig. 5 – Area of sky covered in TDI mode.

Table 1 gives the statistics of the results obtained to date.

New Designations: 218
Total number of Positions: 13372
New Objects' Positions: 1523
Single-Night Positions: 3314
New orbits: 81
Special asteroids discovered: 2 Trojans, 1 Hilda, 1 Hungaria
2 Mars crossers: 2002 AN7,2002 CS

Table 1 – The results obtained from December 2000 to March 2002.

3 – Observing around the meridian

Table 2 – Observational statistics around the meridian

Ecliptic Latitude	Surveyed (sq deg)	Detected asteroids	Asteroids per sd deg
-15º < β < 15º	625.6	3877	6.20
β > 15º	263.2	542	2.06

total number of detected asteroids: 4419
surveyed area: 888.8 sq deg
asteroids per sq deg: 4.97
smallest angular displacement rate: 4.5 arcsec/h.
smallest angular displacement: 2.5 arcsec

The astrometric and photometric precision achieved can be best estimated by comparing our positions and magnitude with those of some 181,000 astrometric catalog stars (see Fig. 6 and Fig. 7)

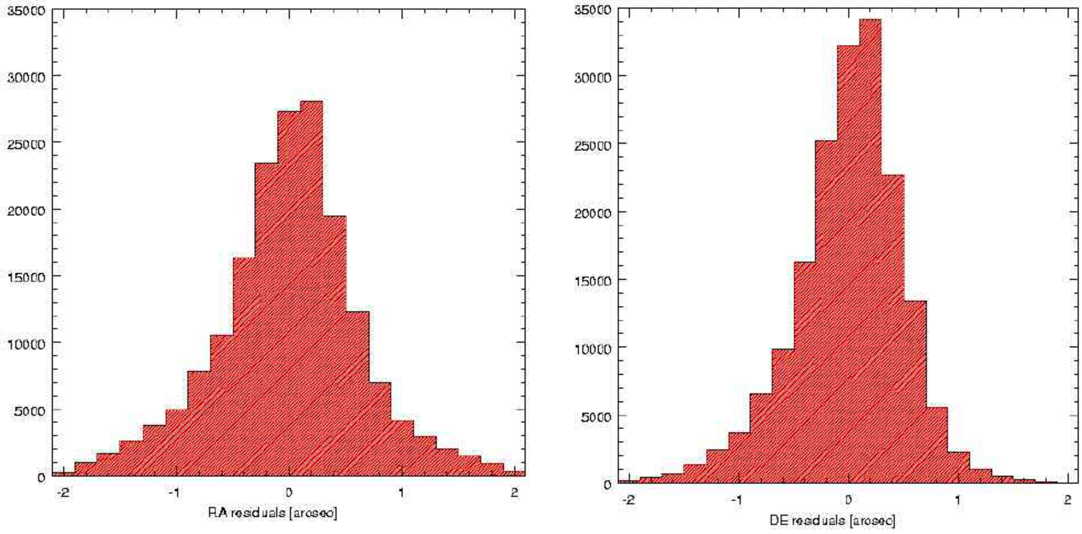

Fig. 6 – Distribution of astrometric residuals relative to reference stars.

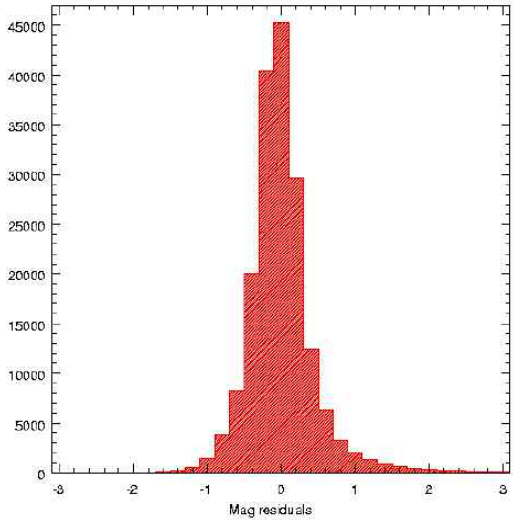

Fig. 7 – Distribution of photometric residuals relative to reference stars.

$\overline{R_\alpha} \pm \sigma_\alpha$	$\overline{R_\delta} \pm \sigma_\delta$	$\overline{R}_m \pm \sigma_m$
0.00 ± 0.62	0.00 ± 0.49	0.01 ± 0.46

Table 3 - Internal errors of photometry and astrometry

Notice that the errors in RA are larger than those in Dec due to the TDI mode.

Comparing the positions with those given by the MPC for the *numbered asteroids* in common, the errors will comprise therefore all sources of internal (including centroiding and timing errors on our images) and external factors (astrometric catalog errors, orbital uncertainties). The results for objects observed around the meridian are given by **Table 4** and **Fig. 8** .

Residuals (arcsec)	N° of observations	Percentage
< 0.2	342	14.0 %
< 0.5	1382	56.7 %
< 1.0	2249	92.2 %
< 2.0	2426	99.5 %
> 2.0	12	0.5 %
All observations	2438	

Average RA residual	-0.04 ± 0.48 arcsec
Average DEC residual	0.20 ± 0.34 arcsec
Average total residual	0.52 ± 0.35 arcsec

Table 4 – The astrometric quality for numbered asteroids observed around the meridian.

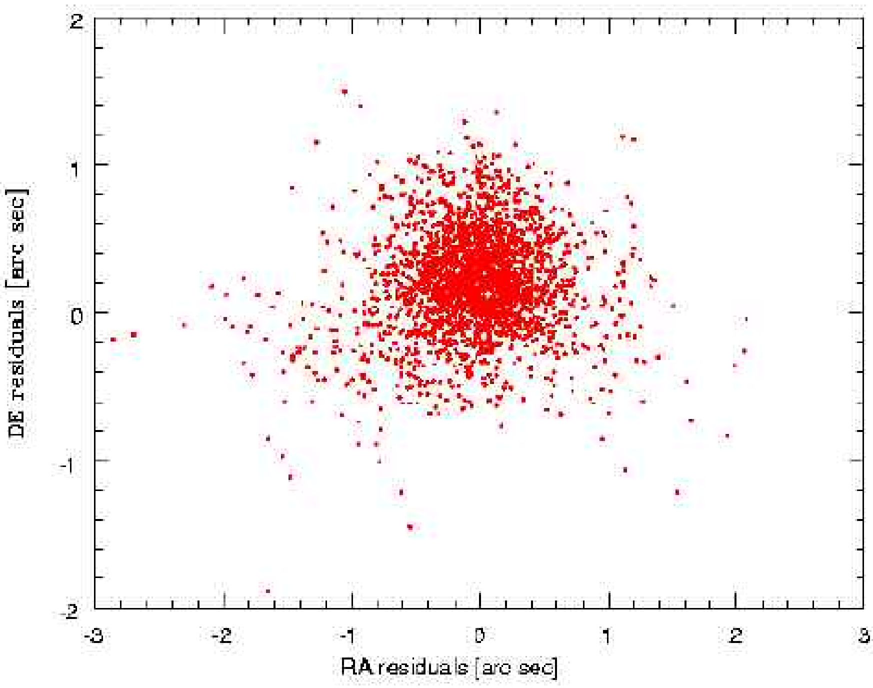

Fig. 8– The distribution of the astrometric residuals of numbered asteroids observed by ADAS around the meridian.

Fig. 9 shows the magnitude distribution of all asteroids detected till now.

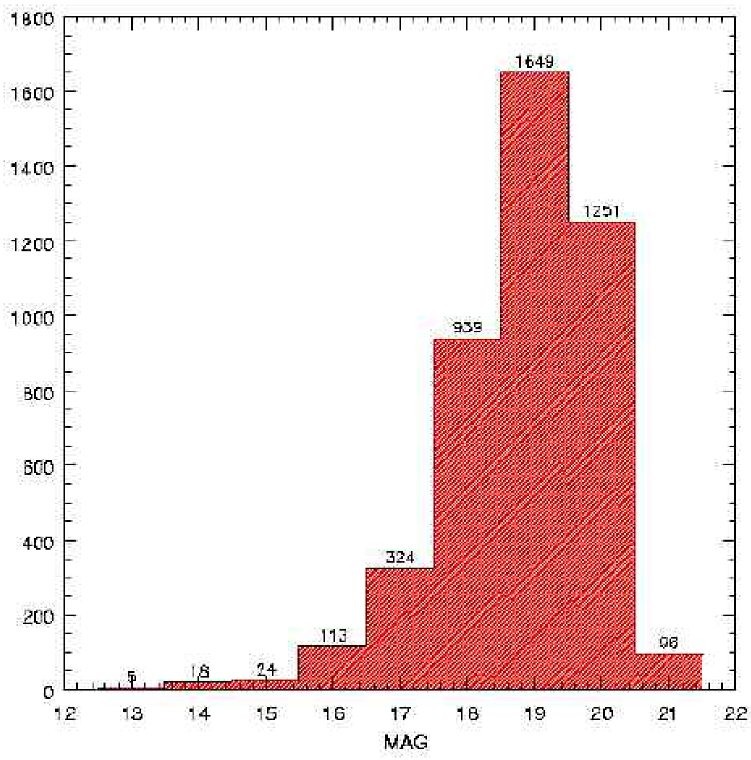

Fig. 9– The magnitude distribution of all asteroids detected by ADAS around the meridian.

4 – Observing at small solar elongations

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, Tabachnick and Evans 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. 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 (Tholen et al 1998).

This expectation is born out by the available data as shown in Table 5:

Table 5 – Observational statistic at small solar elongations

Ecliptic latitude	Solar elongation (deg)	Surveyed (sq deg)	Detected asteroids	Asteroids per sd deg
$-15^\circ < \beta < 15^\circ$	[40,50[	9.8	8	0.82
	[50,60[	2.6	10	3.85
	[60,70[	26.1	29	1.11
	[70,80[	24.9	70	2.81
	[80,90[	60.3	91	1.51
	[0,90[	123.7	208	1.68
$\beta > 15^\circ$	[40,50[	42.5	2	0.05
	[50,60[	75.8	1	0.01
	[60,70[	39.2	2	0.05
	[70,80[	68.4	3	0.04
	[80,90[	83.7	6	0.07
	[0,90[	309.6	14	0.05

total number of detected asteroids: 222
surveyed area: 433.3 sq deg
asteroids per sq deg: 0.51

Fig. 10 and Table 6 give the astrometric precision. Fig. 11 gives the photometric precision.

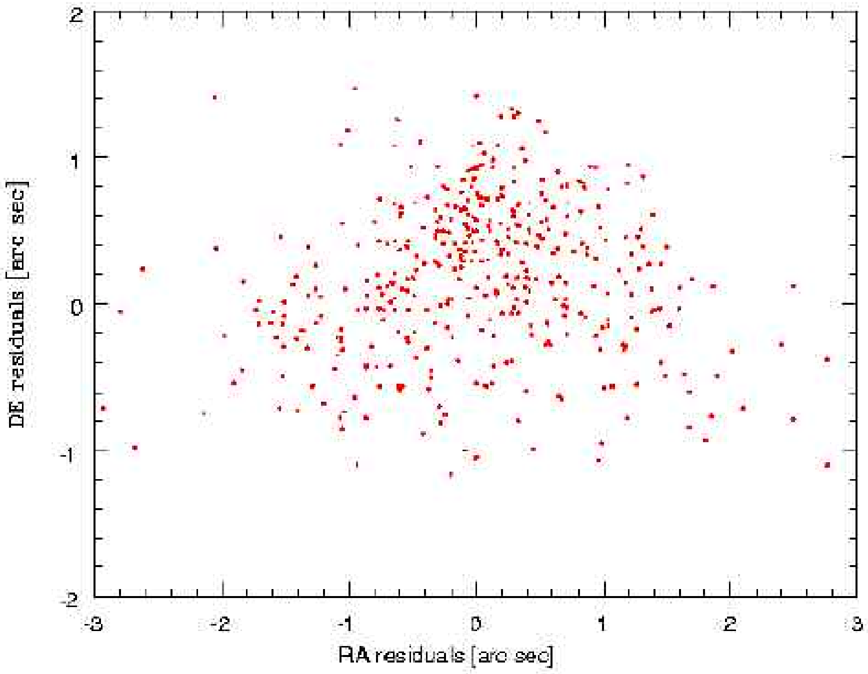

Fig. 10– The distribution of the astrometric residuals of numbered asteroids observed by ADAS at small solar elongations.

Table 6 – The astrometric precision of numbered asteroids at small solar elongations

Residuals (arcsec)	N° of observations	Percentage
< 0.2	10	2.5 %
< 0.5	70	17.4 %
< 1.0	252	62.7 %
< 2.0	387	96.3 %
> 2.0	15	3.7 %
All observations	402	

Average RA residual	0.01 ± 0.92 arcsec
Average DEC residual	0.19 ± 0.53 arcsec
Average total residual	0.94 ± 0.52 arcsec

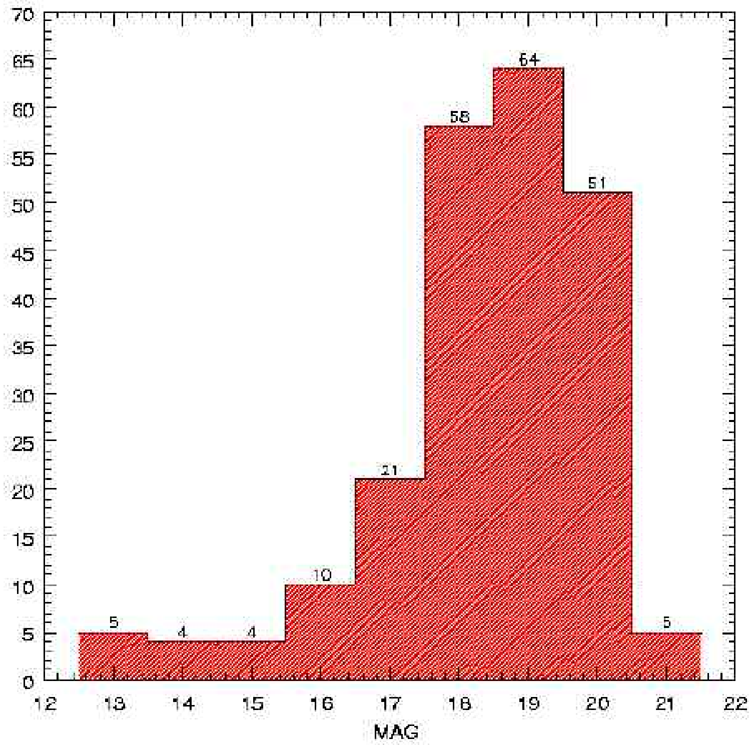

Fig. 11– The magnitude distribution of all asteroids detected by ADAS at small solar elongations.

The loss in accuracy and magnitude is plainly evident.

5 - Further developments

Several improvements will be carried out in the central part of 2002:

1. a filter wheel with several broad band filters is under construction,
2. full automatization of the telescope and dome. New motors and cabling will be installed.
3. a new control room at the ground floor, capable to host several persons

It is expected to resume the observations in June.

Acknowledgements

Thanks are due to the personnel of the Catania Astrophysical Observatory for the kind helping characterizing the CCD and associated electronics. The development of the control software for the filter wheel is also under preparation at Catania.

References

Bertin, E., Arnouts, S. 1996, *Sextractor: Software for source extraction,* Astron. & Astrophys. Suppl. v. 117, pp.393-404.

Boattini, A., Carusi, A., 1998 *Aten: Importance among Near-Earth-Asteroids and search strategies,* Vistas in Astronomy Vol. 41, No. 4, pp. 527-541

Claudi R.U., Pignata, G., Strazzabosco, D., Bonanno, G., Belluso, M., Bruno, P., Calì, A., Cosentino, R., Timpanaro, M.C., Scuderi, S. 2002, *CHARACTERIZATION OF THE 67/90 SCHMIDT TELESCOPE CCD Padova and Asiago Observatories*, Technical Report n. 19 January 2002

Michel, P., Zappalà, V., Cellino, A., Tanga, P. 2000, *Estimated Abundance of Aten and asteroids evolving on orbits between Earth and Sun*, Icarus, Volume 143, Issue 2, pp. 421-424.

Tabachnick, S. A., Evans N. W. 2000, *Asteroids in the inner Solar system – I. Existence,* Monthly Notices of the Royal Astronomical Society, Volume 319, Issue 1, pp. 80-94.

Tholen, D. J., Whiteley, R. J. 1998, *Results From NEO Searches At Small Solar Elongation,* American Astronomical Society, DPS meeting #30, #16.04; Bulletin of the American Astronomical Society, Vol. 30, p.1041