UCAC–S: A NEW HIGH PRECISION, HIGH DENSITY ASTROMETRIC CATALOGUE IN THE SOUTHERN HEMISPHERE

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ABSTRACT

The U.S. Naval Observatory CCD Astrograph Catalogue (UCAC–S) project is planned to start in the second half of 1997 at Cerro Tololo (CTIO) in Chile. This program will cover the entire Southern Hemisphere with a 2–fold overlap pattern to 16 mag. Within 2 years about 40 million stars will have been observed. A catalogue accuracy of 20 mas per coordinate is expected for stars in the 7 to 13.5 magnitude range, increasing to about 70 mas at the limiting magnitude. A 4k CCD camera will be used with the 5–element 206 mm lens in a 579–642 nm bandpass, covering 1 square degree at 0.9 arcsec/pixel. Dark and flat field tests revealed the high cosmetic quality of the Kodak CCD chip. The telescope is currently being upgraded for automatic operation and test observations are underway at the Washington DC site before relocation. Tycho stars will be used for preliminary reductions, and a direct tie to the Hipparcos stars will be feasible using block adjustment techniques. In addition to the program fields, minor planet and calibration field observations as well as longer exposures around extragalactic reference frame sources are planned. Thus an extension of the Hipparcos frame exceeding the density of the Guide Star Catalog but with an accuracy similar to the Tycho Catalogue will be achieved. The catalogue will have an impact on deriving proper motions and will provide faint reference stars for current and future requirements for large telescope CCD observations.

Key words: CCD astrometry; position catalogue; Southern Hemisphere; densification of reference frame; proper motions for faint stars.

1. INTRODUCTION

The Hipparcos Catalogue (ESA 1997) provides positions of about 118 000 stars, accurate to ≈ 10 mas at current epochs. The Tycho Catalogue (ESA 1997), combined with available ground–based data for improving proper motions, gives positions on the 20–50 mas level for one million stars to 11 mag. Positions of even fainter stars can be provided from Schmidt plate scans, however with an expected accuracy on the 200 mas level. The UCAC–S project aims at a densification of the Hipparcos/Tycho system towards many million stars on an accuracy level of 20 mas. A strong link to Hipparcos stars and extragalactic sources will be part of the observing program. The instrument is currently being tested at the USNO Washington DC site, before being sent to the Cerro Tololo Interamerican Observatory (CTIO), Chile later this year.

Table 1. Parameters of the telescope optics.

clear aperture	206	mm
focal length	2057	mm
plate scale	100	arcsec/mm
number of lens elements	5	
spectral bandpass of lens	550–710	nm
Airy disc diameter (610nm)	15	μm
useable flat field of view	≈ 9	degree

Table 2. Parameters of the 4K CCD camera.

number of pixels	4096 × 4096	
pixel size	9.0	μm
pixel scale	0.9	arcsec/pixel
spectral bandpass used	579–642	nm
filter replaces window	λ /4	optical quality
readout	14	bit
readout noise	13	e^-
full well capacity	85 000	e^-
operating temperature	≈ −30	C
limiting magnitude	≈ 16.0	2 min.

2. INSTRUMENT

In 1990 the U.S. Naval Observatory Twin Astrograph obtained a new lens, corrected for the red spectral bandpass, which replaces the 'blue lens' (Table 1). The detector is a Kodak 4k by 4k CCD camera (Table 2). The 'yellow lens' remained on the telescope and is now used as the guide scope with a ST–4 autoguider on an x,y–stage at its backend. The instrumental photometric system will be between V and R. A 4–hole Hartmann screen is used for focusing. The telescope uses a Boller and Chivens mount. It is now fully under computer control (Germain 1996, Rafferty et al. 1997). A Pentium PC controls the telescope and is used as an interface to the camera for data acquisition. An HP workstation will be used for the astrometric reductions.

3. PROJECT PLAN

A two-fold, centre-in-corner overlap of the entire Southern Hemisphere is planned. With a field of view of just over 1 square degree, observations of about 44 000 fields will be necessary. On each field 2 exposures are planned, 120 and 30 seconds respectively. The 120 s exposure frames will reach 16 mag. The Tycho Catalogue (ESA 1997) will be used for the astrometric and photometric reduction of all CCD frames. The 30 s exposures will saturate at about $V = 7$ mag and thus allow the observation of most Hipparcos stars. This then gives the option for a block adjustment solution (Eichhorn 1960, Zacharias 1992) of the entire data based only on the Hipparcos Catalogue (ESA 1997). Additional long exposures (≈ 600 s) in some 200 fields of extragalactic reference frame sources are also planned, which will give 20 mas accuracy for 16 mag stars. Together with deep CCD frames of these sources at larger telescopes, a stong link to the ICRS (International Celestial Reference System) can be utilized. Possible systematic errors will be controlled by additional calibration observations with the astrograph of selected fields, utilizing reversal of the telescope, rotation of the camera, and using a diffraction grating in front of the lens. Astrometric reductions will run in parallel to the observing program. First results are expected to be made available about 1 year after the start of the project. The survey will start at the South Celestial Pole and work its way towards the equator with epoch differences of overlapping frames made as small as possible. Table 3 summarizes the characteristics of the UCAC–S project. This is intended to be a fast, efficient, low–cost project.

Table 3. Characteristics of the UCAC–S project.

CCD detector	4k × 4k	Kodak
field of view	61 × 61	arcmin
exposure times	30 & 120	seconds, guided
observing throughput	≥ 13	fields/hour
overlap pattern	2	fold
coverage	$\delta \leq +2°$	
req. observing time	≈ 4000	hours, $\leq$ 2 years
average density	2000	stars / square degree
total	40	million stars
catalogue accuracy	20	mas, R = 7 – 13.5 mag
	70	mas, R = 16 mag

4. CURRENT STATUS

- 1995: tests with 1k × 1.5k camera, proof of concept, (Zacharias & Rafferty 1995, Zacharias 1997);
- 1996: initial plan (Gauss et al. 1996);
- 1997, January: 4k camera arrived;
- 1997, February: analysis of CCD chip quality: no dark pixels, no column defects;
- 1997, March 6: first light!
- 1997, March 9: confirmation of astrometric precision:
  - profile fit precision to 10 mas (Figure 1);
  - saturation limit at 9.5 mag for 120 s exposure;
  - frame–to–frame transformations accurate to 20 mas (Figure 2);
- 1997, April: improving hardware, PC interface;
- 1997, April: comparison with Tycho data successful, (Zacharias et al. 1997);
- 1997, May: most of the software ready;
- 1997, June: calibration tests, automatic observing mode.

Table 4. Data of the UCAC-S project.

number of fields	44 000	
number of exposures	2	per field
total number of frames	100 000	incl. overhead
raw data	3.2	TB compressed FITS
backup on	600	exabyte tapes
	2500	CD–ROMs
reduction output	≈ 200	bytes/object
total reduction output	40	GB
astrometric catalogue	1	GB

5. CATALOGUE PROPERTIES

Based on observing results obtained so far, the expected catalogue accuracy is shown in Figure 3 as a function of magnitude. The limiting magnitude will depend on the actual conditions encountered at CTIO and the exposure time chosen for the project. The catalogue will be in the new extragalactic system (ICRS) which is oriented consistently with the FK5/J2000 system. The huge amount of data is characterized in Table 4, and Figure 4 shows the location of the fields in the sky. A few years ago, the best astrometric catalogue (IRS), had fewer stars. All raw data (several Tbytes) will be saved in loss–less compressed files to be archived on hundreds of exabyte tapes and thousands of CD–ROMs. The astrometric catalogue will be only about 1 Gbyte and can be distributed easily.

6. APPLICATIONS

With an expected density of about 350 to 6000 stars per square degree, depending on galactic latitude, the catalogue will be suitable for many applications, including:

- general small field astrometry, particularly for current and future large telescope observations;
- astrometric calibration of small and large telescopes;
- near-Earth orbit minor planet predictions;
- improved Schmidt plate reductions;
- ideal reference star catalogue for major and minor planet astrometric observations;
- reductions of individual CCD chips of mosaic–CCD camera; observations such as the SDSS project;
- input catalogue for future space missions;
- new epoch data for proper motions of faint stars.

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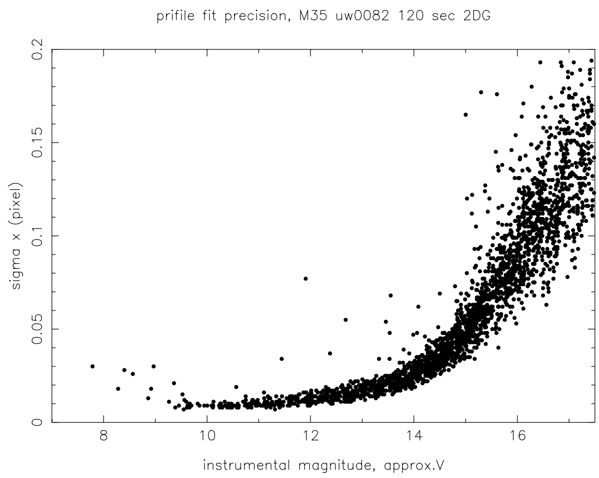

Figure 1. Image profile fit precision. Results for the x–coordiante are shown, the precision for y is similar. Data of a single 120 s exposure frame of the M35 open cluster is shown. Saturation occurs around 9 mag.

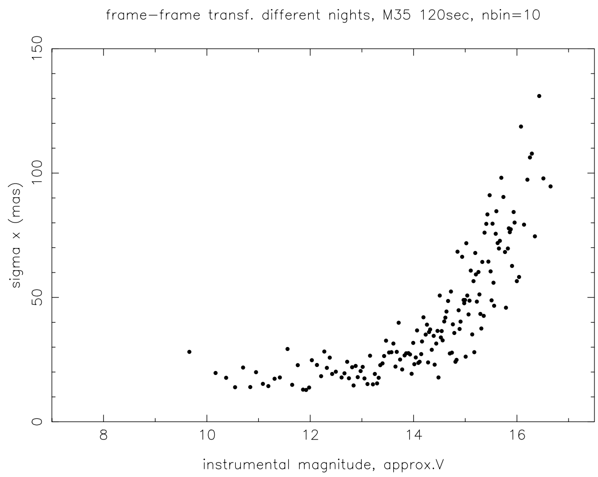

Figure 2. Frame–to–frame accuracy.

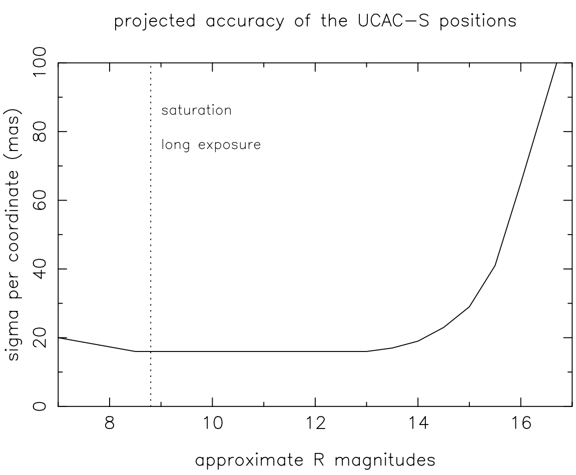

Figure 3. Estimated catalogue accuracy.

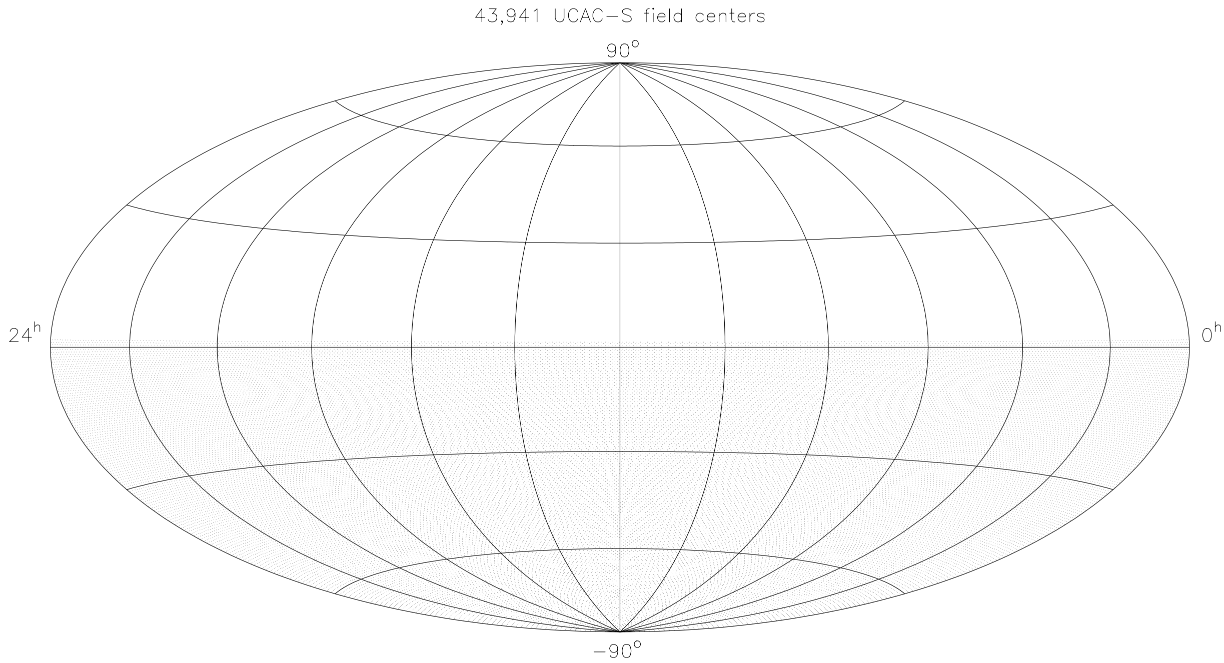

Figure 4. Location of field centres in the sky.