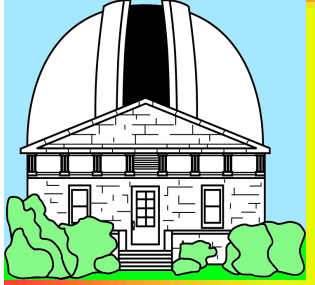

UCAC and URAT: optical astrometric catalog observing programs

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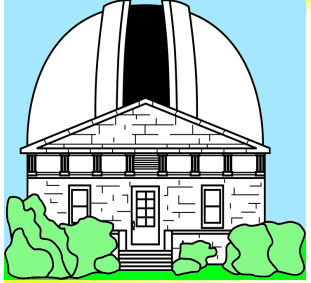
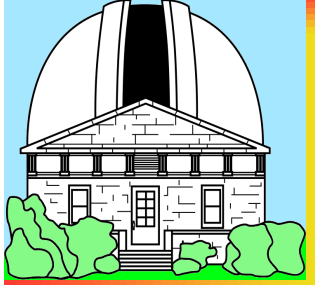


layout of talk

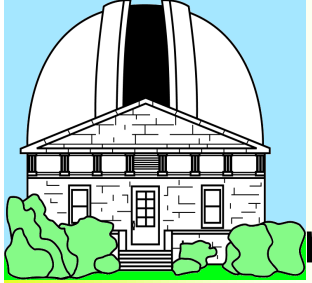
- overview: global astrometry, other projects
- UCAC (all sky, 8 ... 16 mag, 20 mas)
- status of current optical reference frame
- URAT (USNO astrograph + 4-shooter camera)



overview

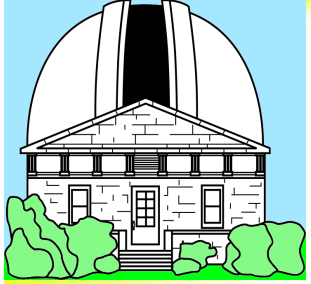
other projects / catalogs

where do UCAC and URAT fit in ?

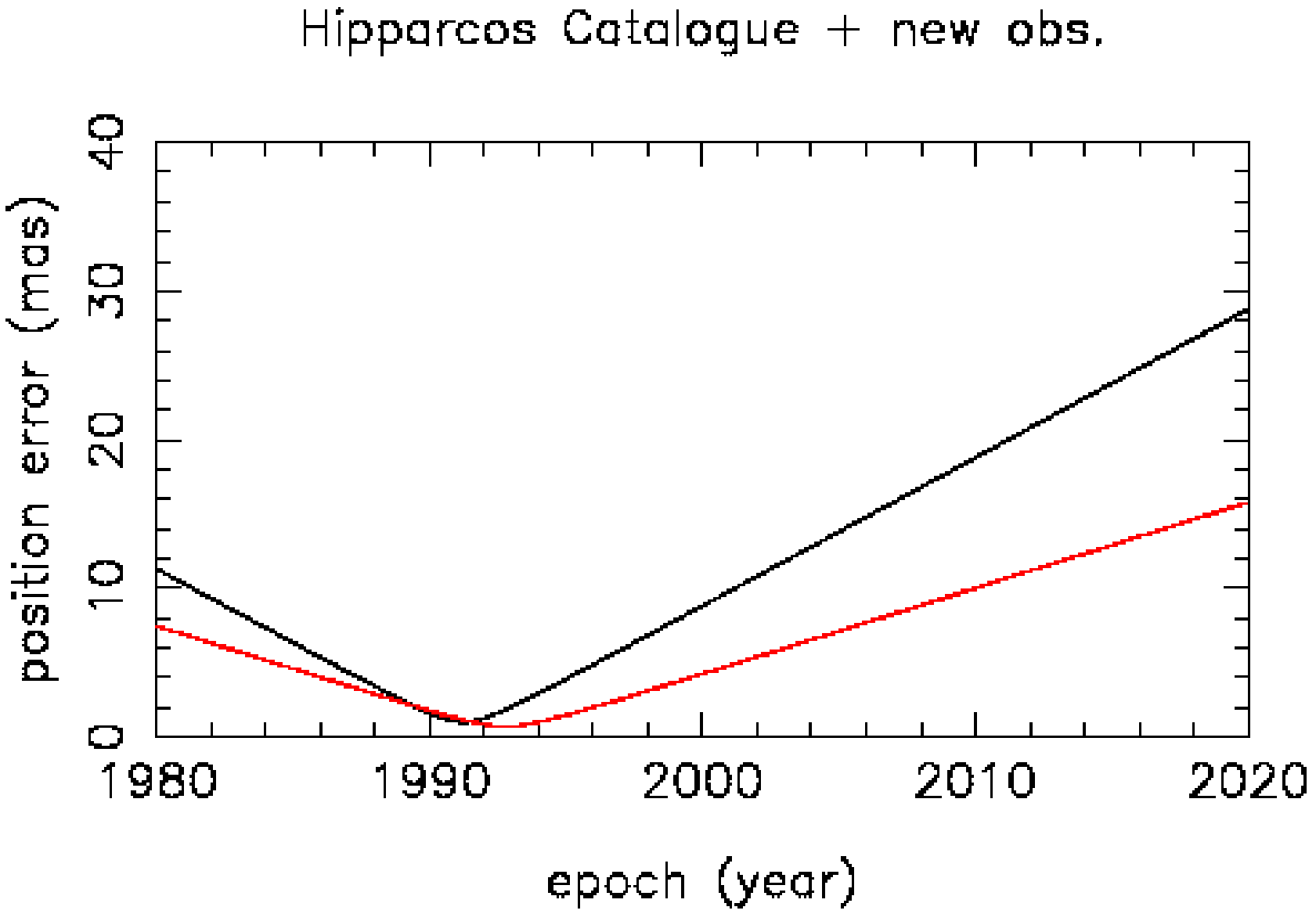


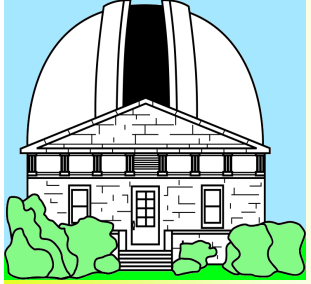
catalogs / projects

name of catalog	ground space	proper motion	mag range	numb stars	pos.err (mas)	year
ICRF2	G	QSO	radio	3414	0.3	2009
Hip.	S	yes	<= 12	100 K	1.0	1997
Tycho-2	G/S	yes	<= 12	2.5 M	10..100	2000
UCAC	G	yes	8..16	100 M	20.. 70	2004+
2MASS	G	no	IR	500 M	90	2003
USNO-B	G	yes	12..21	1000 M	200	2003
PanSTARRS	G	yes	17..23	2000 M	<30	2010
URAT	G	yes	9..18	500 M	5..30	2011
JASMINE	S	yes	near IR	M	3.0	2011+
JMAPS	S	yes	0..14	30 M	1.0	2013
Gaia	S	yes	6..20	1000 M	0.025	2020
SIM	S	yes	0..20	20,000	0.004	dead

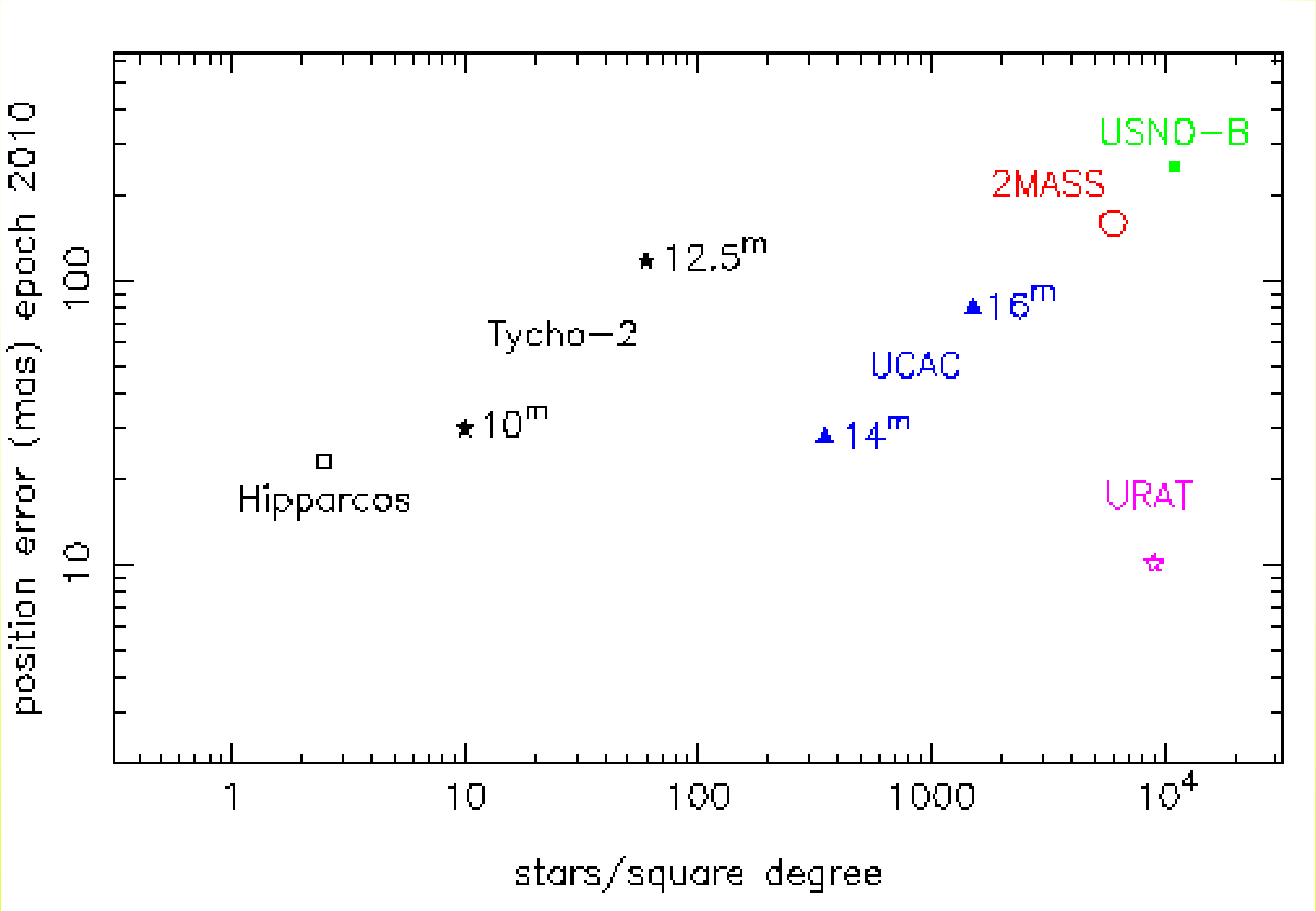


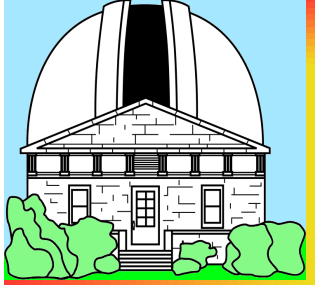
position error increases with time





accuracy of catalogs





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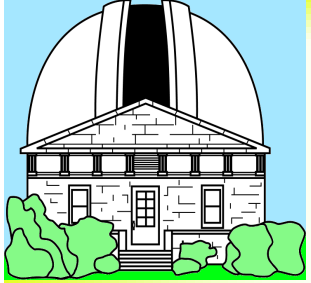
C a t a l o g

PI: Norbert Zacharias

Astrometry Department

U.S. Naval Observatory



UCAC observing

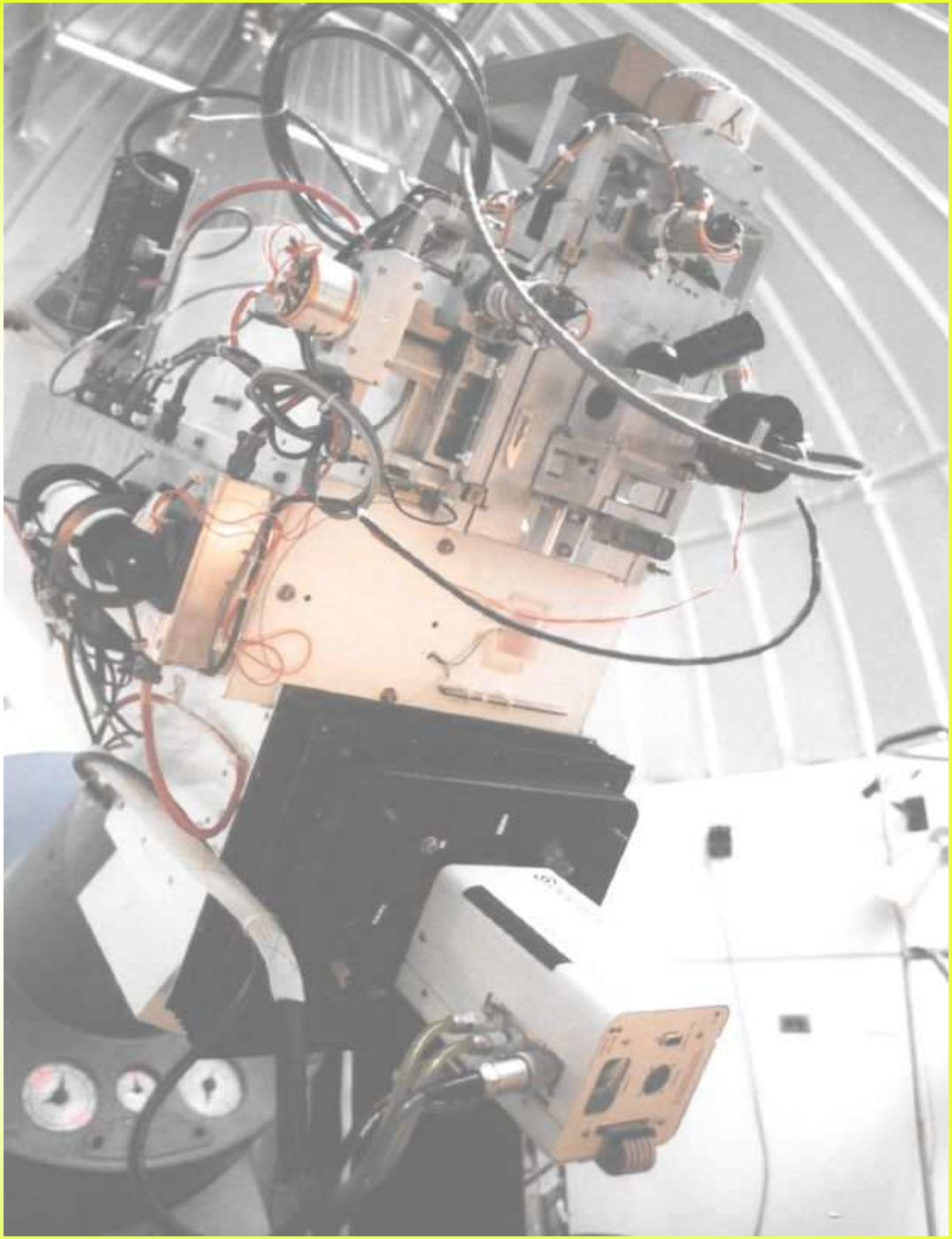
- 1997 – 2004 (all-sky completed)
- 579 – 642 nm bandpass
- R = 8 to 16 mag
- 4k x 4k CCD = 1 sq. degree FOV
- over 278,000 exposures taken (20 – 150 sec)
- positions accurate to 20 mas (10 – 14 mag)
- incl. proper motions (various early catalogs)

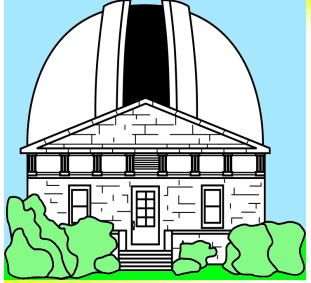

observing at CTIO

x-y slide

backend of astrograph

4k camera

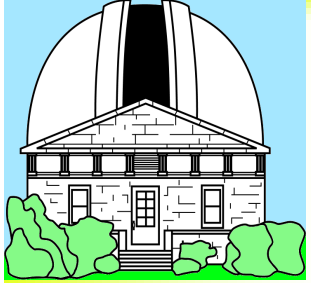




UCAC products

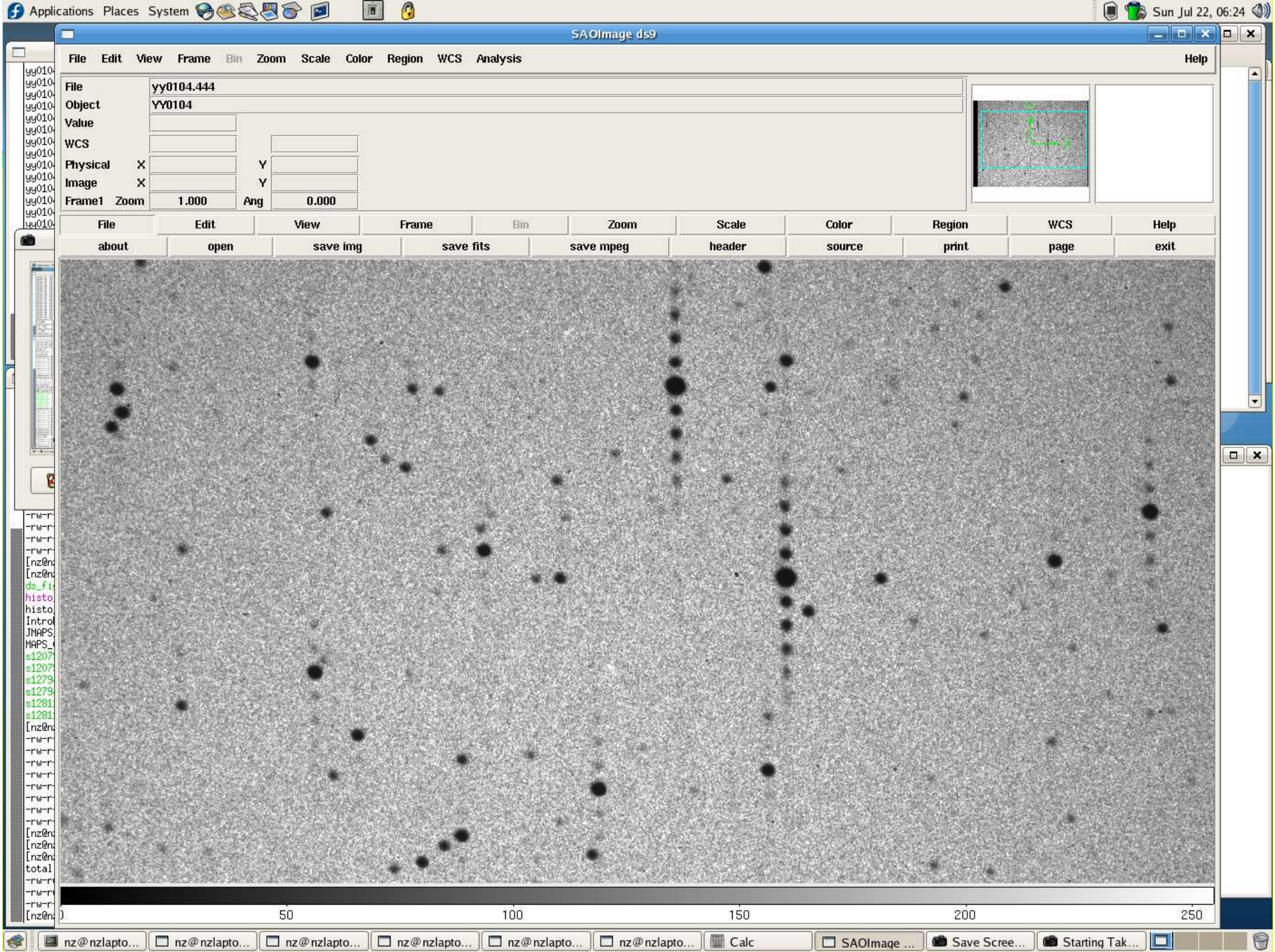
- UCAC1 (2000) : part of Southern Hemisphere
- UCAC2 (2003) : -90 to +50 deg decl.
- UCAC3 (2009) : all-sky, about 100 million stars
  - re-processing all pixel data (4.5 TB compressed)
  - improved completeness (bright stars, doubles, fainter)
  - improved astrometry (empirical profile fits)
  - new data for proper motions
  - improved photometry (1 band)

StarScan plate measure machine
Washington, DC



StarScan plate measuring

- early epoch data for proper motions
- CCD camera, step-stare mode
- accurate to <= 0.5 micrometer absolute
- 1930 AGK2: 1,900 plates done
- 1976..1995 ZA: 2,300 plates: done
- 1983..1990 BB: 900 plates: done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SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File yy0104.444
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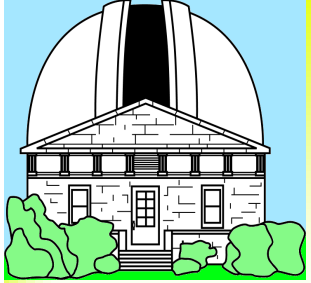
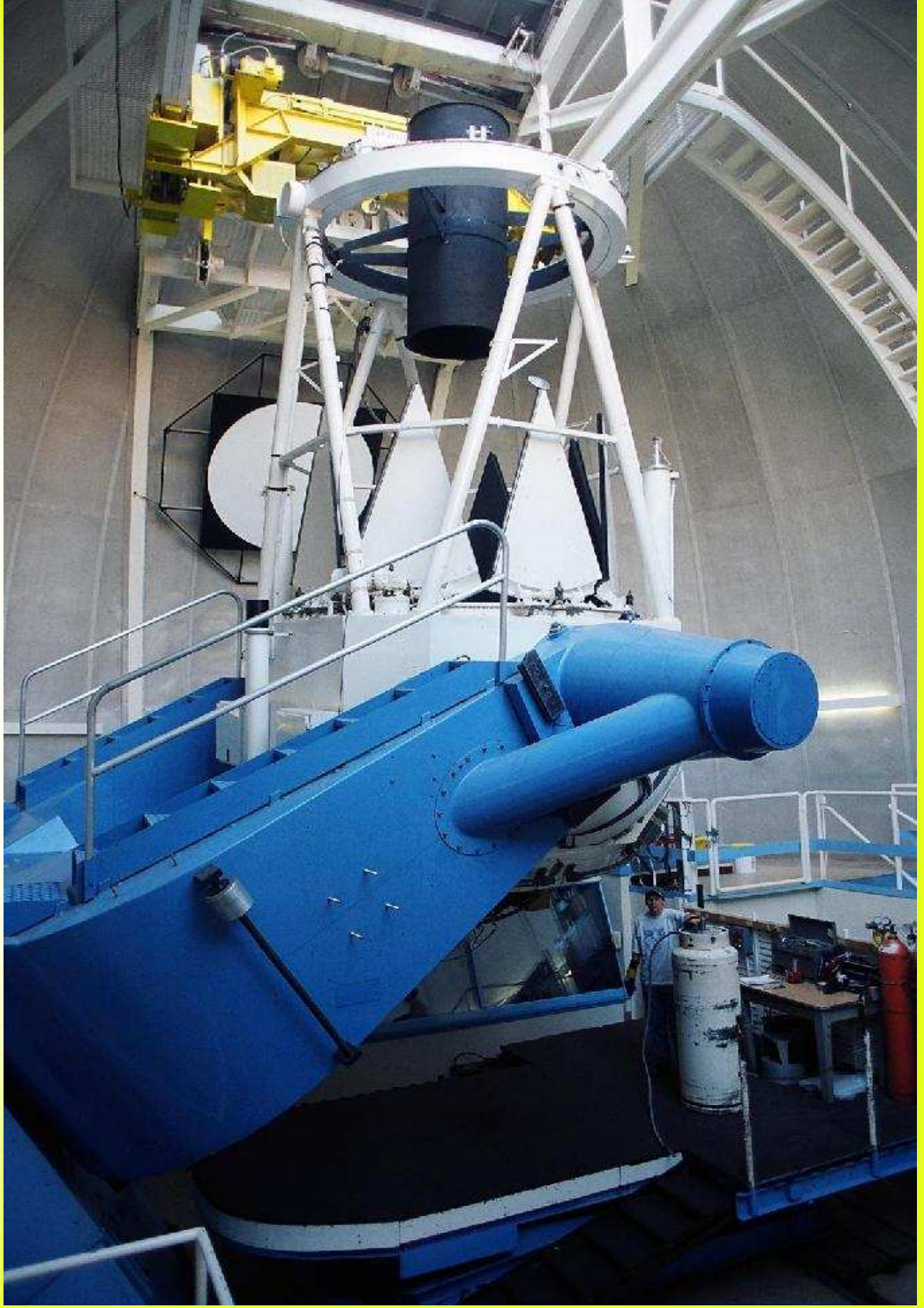


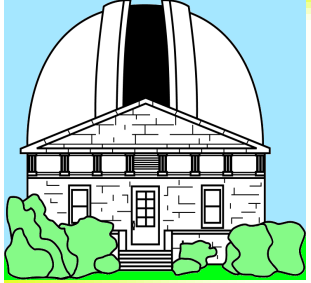
KPNO 2.1 m

CTIO 0.9 m

KPNO 0.9 m

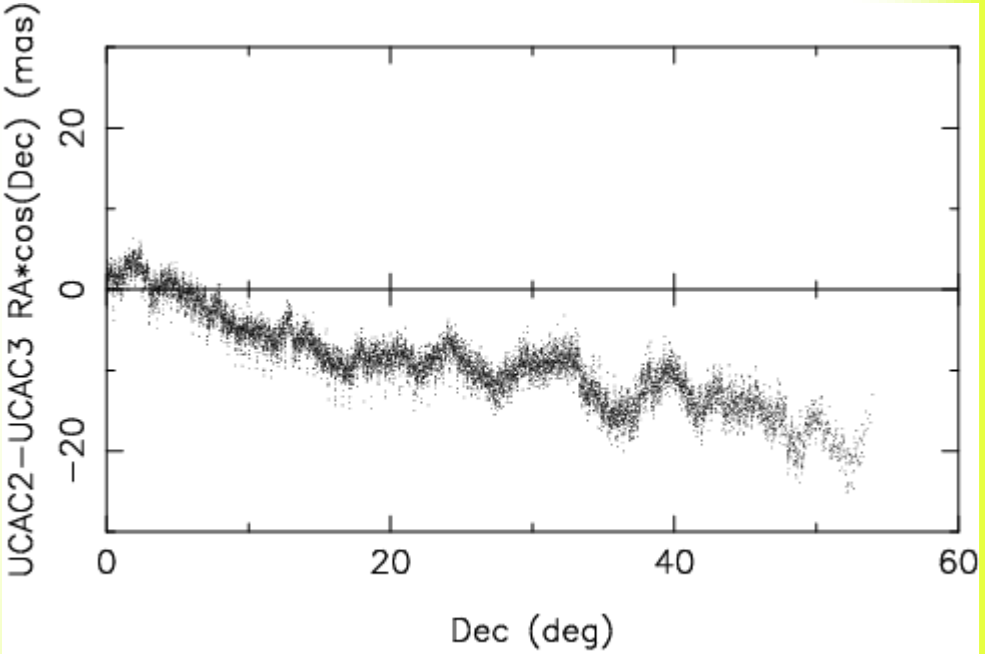
extragalactic
reference frame link:
observing in parallel
with astrograph for
> 500 ICRF sources

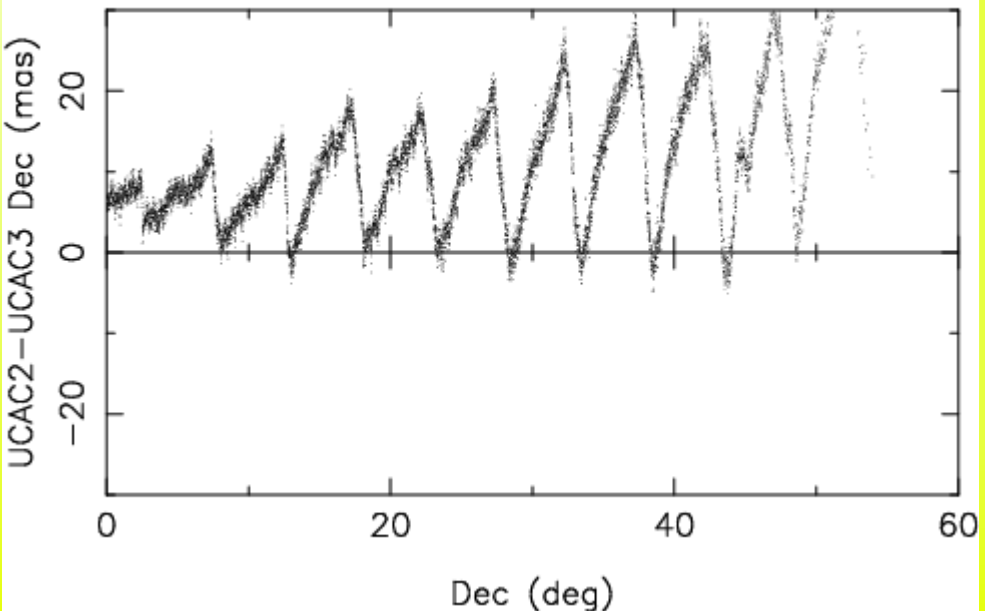


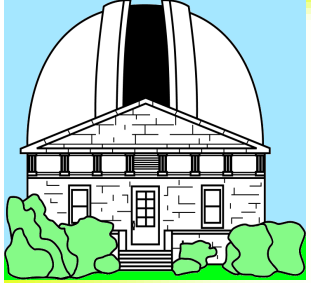


What's wrong with UCAC3 ?

- rush job (deadline for an all-sky catalog with PM)
- about 1% of stars listed twice, others not at all (bug in code)
- PM faint stars taken from Schmidt survey for Dec > -30 deg (poor quality)
- accept low S/N stars, thus not as clean as UCAC2



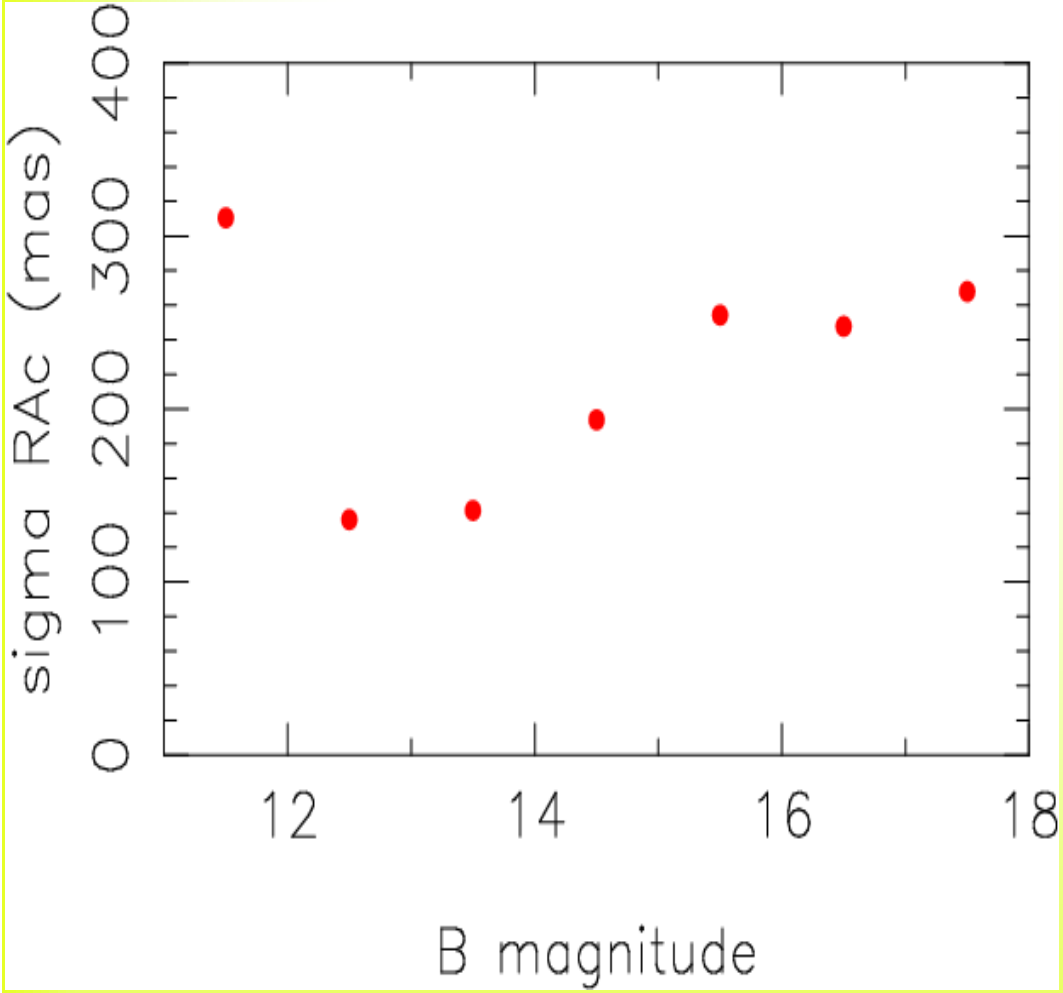


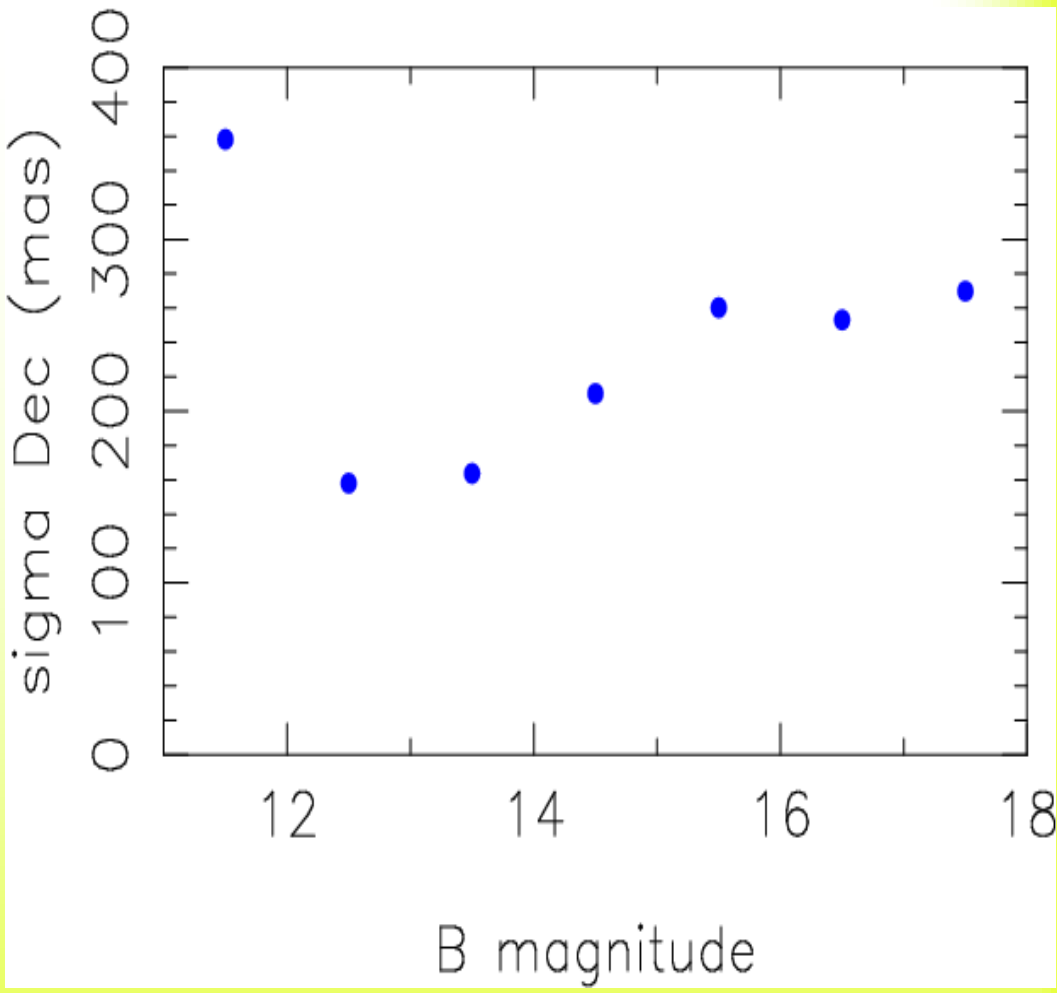


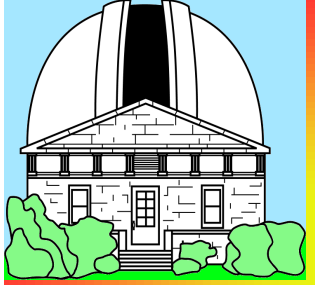
UCAC4 = final release

- PM faint stars Dec > -30 deg:
  - new reductions of NPM 1st epoch blue plates by T.Girard (Yale) and USNO based on PMM scans
  - small systematic errors, random err. 4-5 mas/yr
- analytic CTE solution (mag.eq. errors)
- overlap iteration of CCD frames
- release: spring 2011 after extensive testing
- additional data: individ. positions at epoch ...

NPM 1st epoch blue plates done

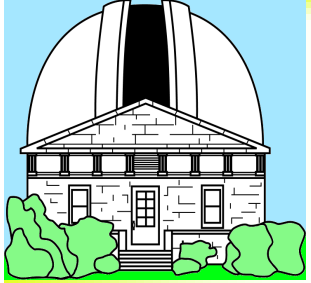






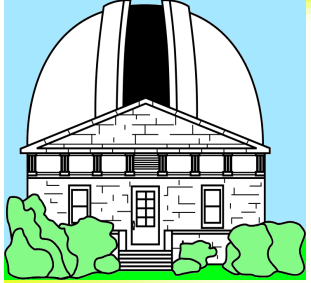
Status of current
optical reference frame

20 years after Hipparcos
5-10 years before Gaia



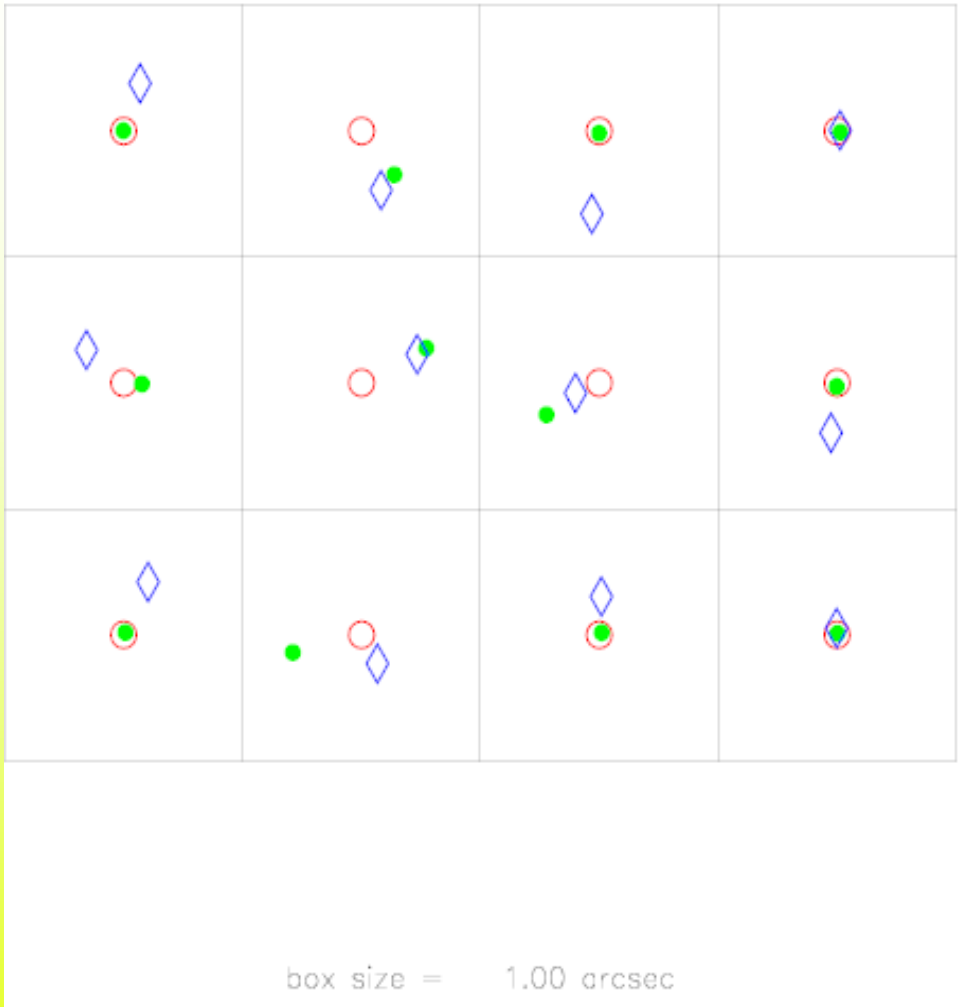
Limits of primary optical system

- Hipparcos
  - orientation of axes: still good to ~ 1 sigma (2.7 mas) error w.r.t. ICRF, based on 46 radio stars (Boboltz et al. 2007); max.rotation 0.55 +-0.36 mas/yr
  - 1 mas/yr PM error → 20 mas at 2011 epoch
  - some stars much worse (Zacharias et al. 2009)
- Tycho-2
  - begin to see systematic errors, zonal, mag.eq.
  - UCAC3 data shown 1-2 mas/yr level for Tycho stars
  - local system (degree scale) position errors 30 mas ?



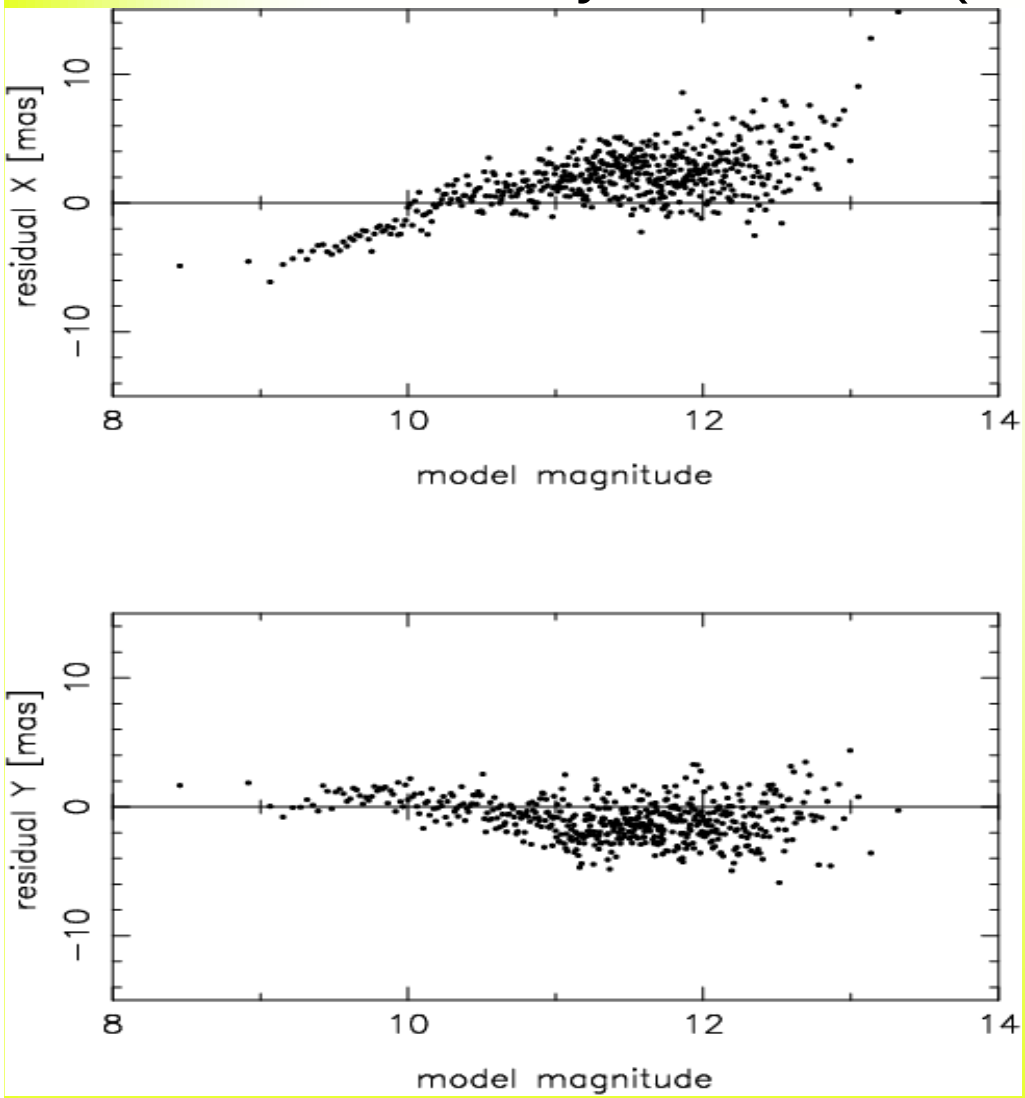
Some discrepant Hipparcos stars

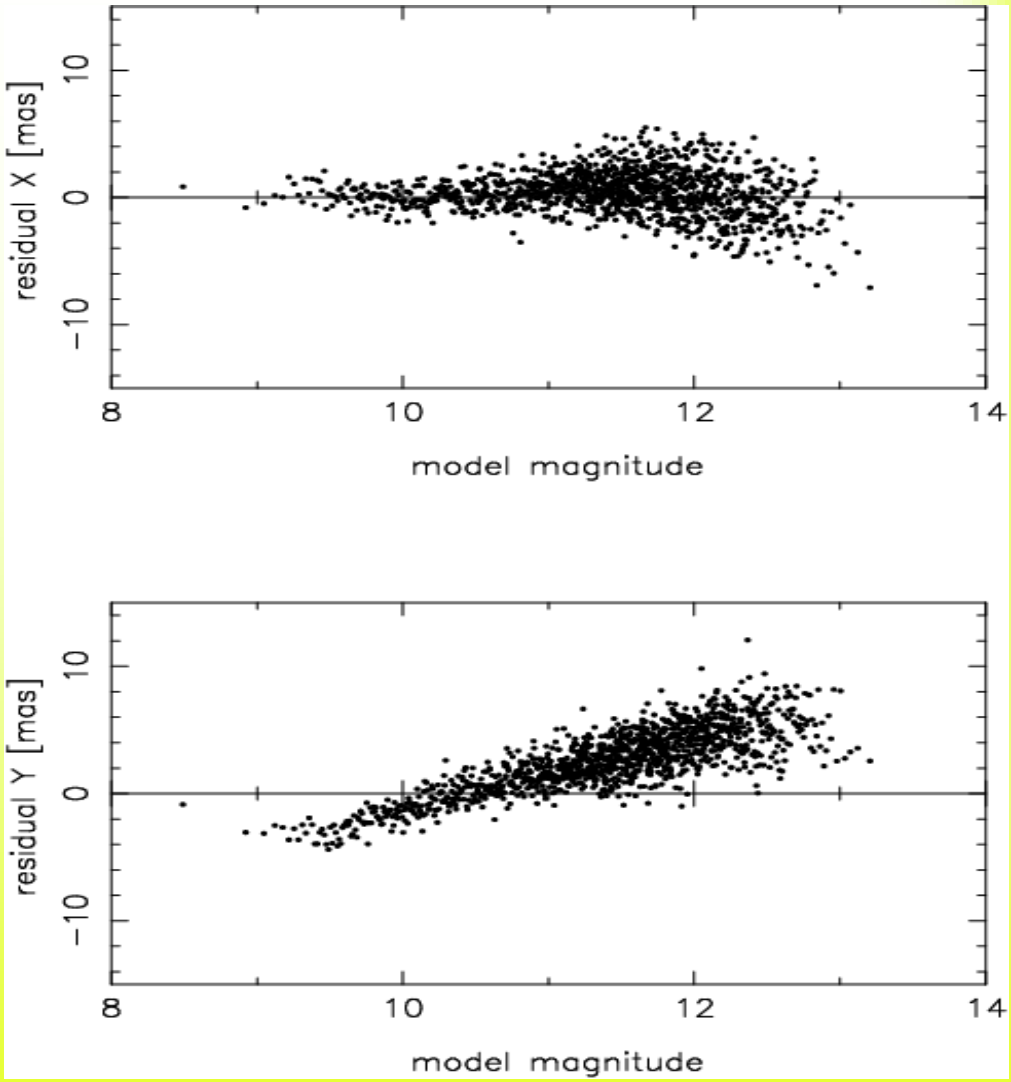
- compare positions at UCAC epoch (~ 2000)
- use Hipp. PM, parallax
- red = new Hipp.red.
- green = orig.Hipp.red.
- blue = UCAC position
- box size = 1000 mas !
- Zacharias et al. 2009, DDA meeting



Zonal mag.eq. Tycho-2 ?

- UCAC3 – Tycho2: north (NOFS), south (CTIO)





ICRF radio-optical offsets real or catalog errors ?

Significant radio-optical reference frame offsets from CTIO data

Marion I. Zacharias (USNO)
Norbert Zacharias (USNO)
IAU XXVII General Assembly
Rio de Janeiro, Brazil
August 03-14, 2009

Abstract

We present results from the first application of UCAC3 data. A re-reduction of optical positions of extragalactic reference frame sources from CTIO 0.9m observing with UCAC3 gave consistent results with earlier reductions based on UCAC2. However, for many of the ICRF sources a significant offset in the order of 30 to 80 mas between the radio and optical positions is seen. Thus either the optical and radio centers of emission of some of these sources do not coincide, or the optical reference frame as represented by Tycho-2 and based on Hipparcos might have local deviations.

Astrograph reference stars

Wide-field images of ICRF source fields were taken with the USNO Twin Astrograph as part of the USNO CCD Astrograph Catalog (UCAC) project. These observations were contemporaneous to the NOAO observing runs. For each observing run an individual reference star catalog was constructed using Astrograph data and UCAC2 reduction procedures with Tycho-2 reference stars. For 1 observing run (runz) the reductions were repeated using the new UCAC3 reduction pipeline with improved systematic error control (runz3).

Deep frame observations

Deep frames were observed with the CTIO 0.9m telescope (Fig. 3). A customized filter was used to match the spectral bandpass of the USNO Twin Astrograph. At least 4 frames were taken per source. The sky distribution of the optical counterparts of ICRF sources of the all southern observing runs can be seen in Figure 2, whereby a faint optical source has a signal/noise ratio of 5 or less. For a potential problem source the (optical-radio) position difference is greater than 3-sigma of the total, estimated errors.

Deep frame reductions

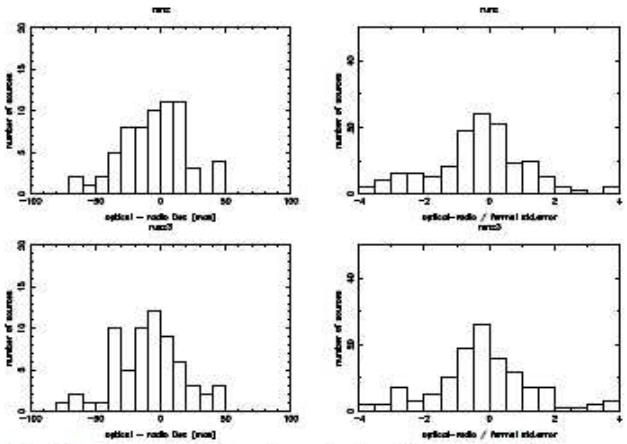
Each deep CCD frame was reduced using a dedicated secondary reference star catalog from astrograph data. A field distortion pattern was derived from residuals and corrections applied. A linear plate model was adopted for the final adjustment. Thus optical positions of reference frame counterparts could be obtained on the HCRF.

Optical–radio results

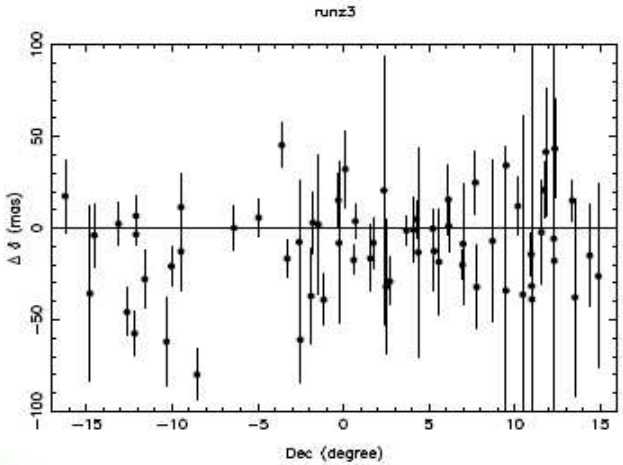
Table 1 shows results of "problem" sources from a single observing

source	Opt-Radio (sigma)		Opt-Radio (mas)		run
0147−076	-3.1	8.1	-53.1	139.8	Sep 1999
	-0.6	3.0	-20.4	107.1	Dec 1999
	-3.0	7.3	-61.2	147.5	Sep 2000
0215+015	-7.2	-3.1	-62.9	-26.9	Dec 1999
	-4.5	-0.5	-59.5	-7.2	Sep 2000
0238−084	3.2	-4.6	62.1	-88.4	Sep 1999
	0.3	-2.4	8.3	-72.8	Dec 1999
	2.2	-6.8	36.6	-113.2	Sep 2000
0405−123	-0.6	-2.7	-9.8	-48.7	Sep 1999
	-1.3	-5.7	-10.0	-42.0	Dec 1999
	-0.4	-3.7	-4.9	-44.5	Sep 2000
2128−123	-4.3	0.4	-39.6	3.8	Jun 1999
	-5.7	1.2	-39.0	8.5	Sep 1999
	-9.4	-0.8	-51.2	-4.3	Sep 2000

The following histograms show the (optical-radio) position difference distribution and the distribution of total optical position errors.



The following plots display the optical−radio position differences in declination as function of declination for the 2 reductions, respectively.



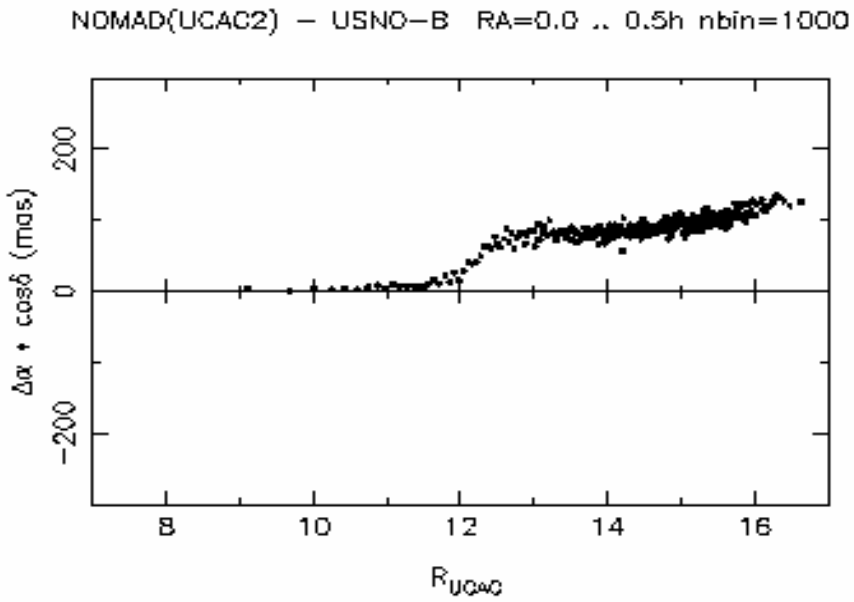
Conclusions

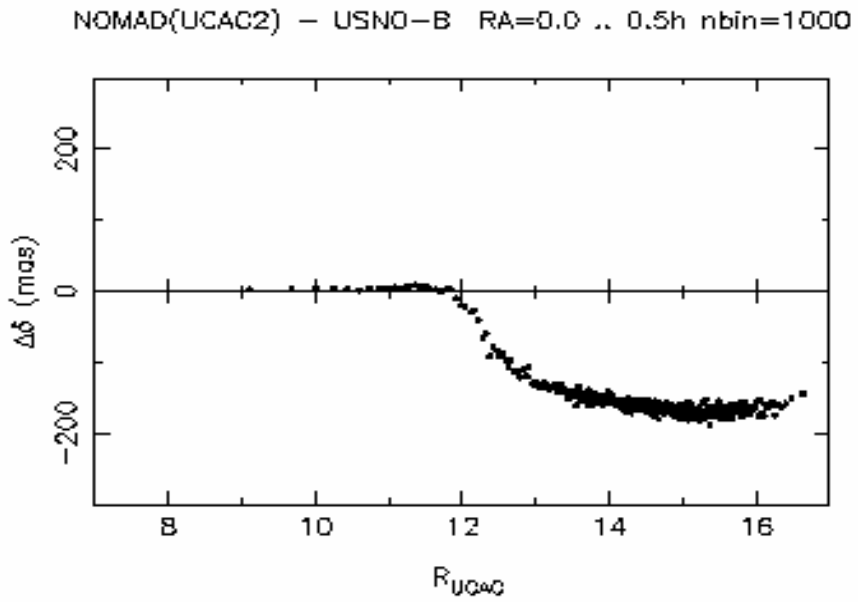
The results from UCAC2 based and UCAC3 based data are very consistent. This indicates that even the old UCAC2 based results likely are correct on the 20 mas level. Optical position results of problem sources are also very consistent between observing runs, sometimes separated by several years.
Assuming the UCAC and deep CCD data are correct, the only explanation for the significant offsets between radio and optical position seen for more sources than can be explained by random errors is either a real physical offset between the centers of emission at radio and optical wavelengths, or a problem in the optical reference frame. Maybe we begin to see local, zonal errors in the Tycho-2 catalog.

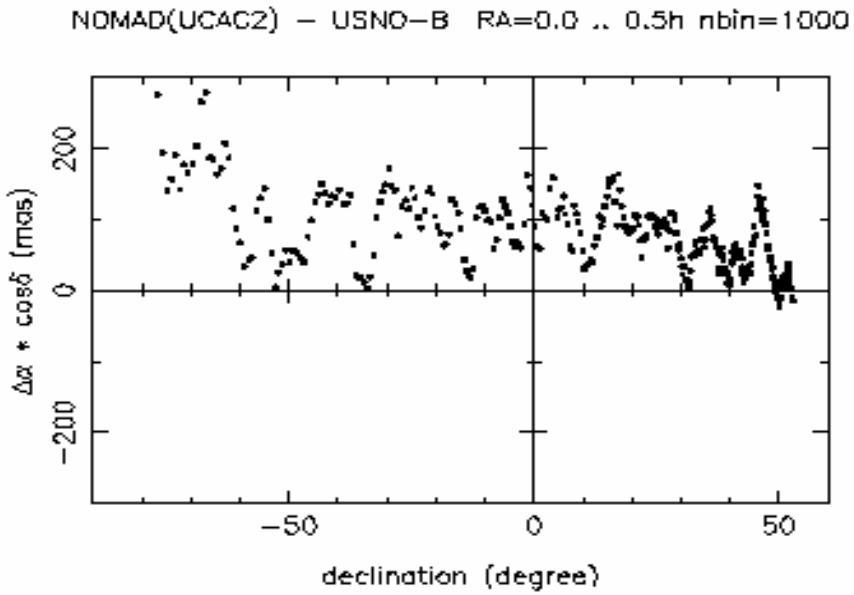
References and Acronyms

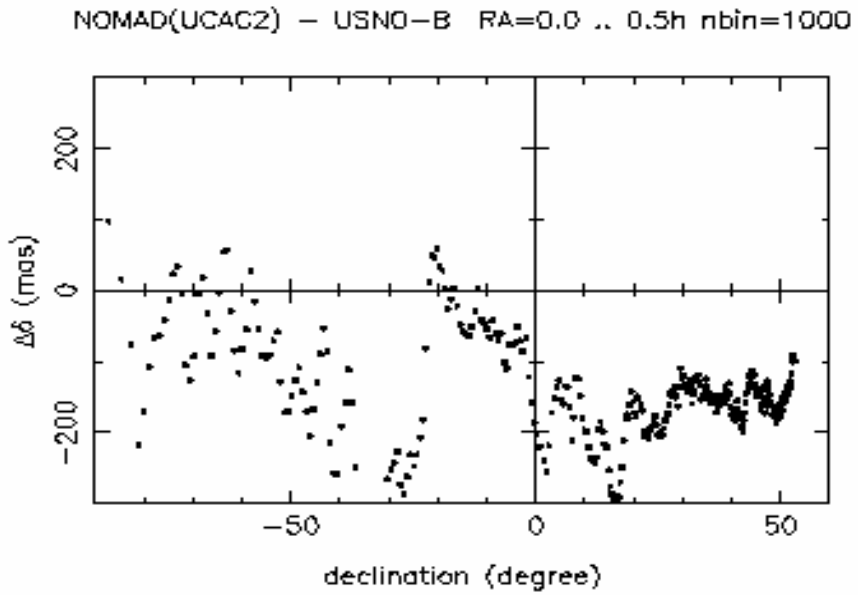
- Zacharias,N., et al. 1999, AJ, 118, 2511-2525, "Accurate Optical Positions of Extragalactic Radio Reference Frame Sources"
- de Vegt,C., et al. 2001, AJ, 121, 2815-2818 "A Catalog of Faint reference Stars in 398 Fields of Extragalactic Radio Reference Frame Sources"
- Assafin,M., et al. 2003, AJ, 125, 2728-2739

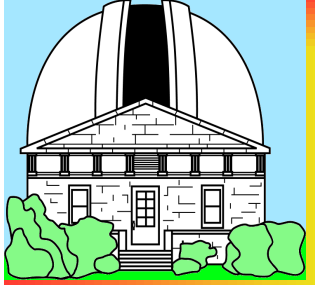
Faint stars: Schmidt plate pattern









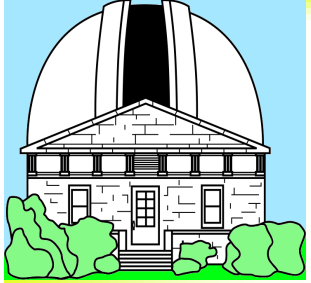


U S N O
R o b o t i c
A s t r o m e t r i c
T e l e s c o p e

PI: Norbert Zacharias

Astrometry Department

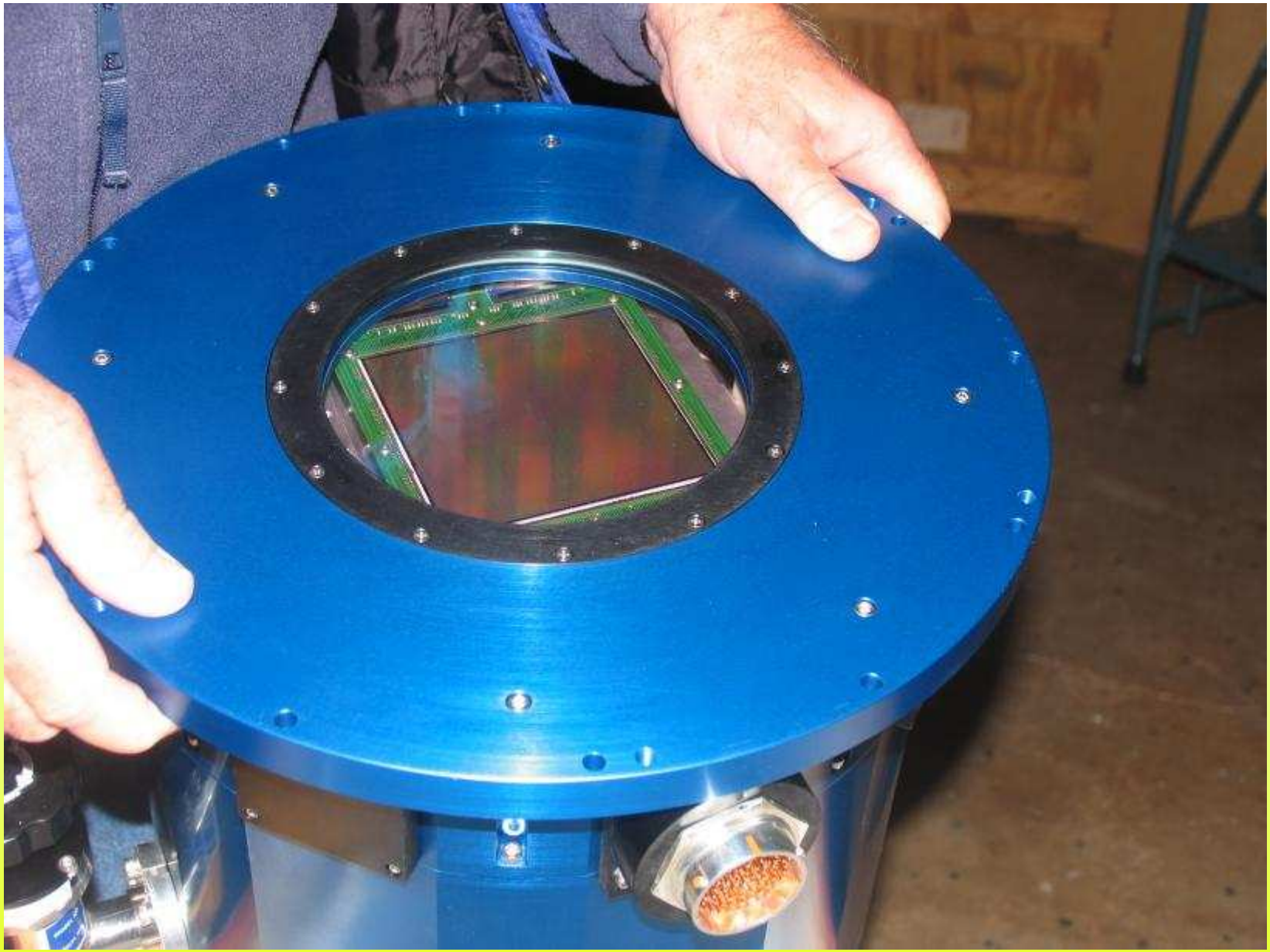
U.S. Naval Observatory



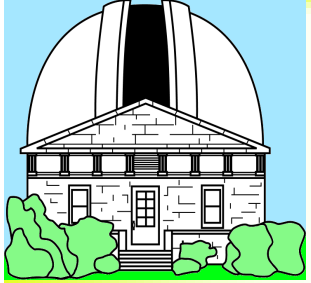
URAT project

- complete re-make of astrograph 2008-2010
- 28 sq. deg. per exposure! (4 detectors)
- single bandpass (670 – 750 nm)
- 10 mas per image (well exposed star)
- multiple sky overlaps / year, 7 - 18 mag
  - clocked anti-blooming: extend dynamic range
  - neutral density spots: option to observe 1-6 mag
- observe 2-3 years each at NOFS, then CTIO
- solve for positions, motions + parallax

10k camera dewar 2007/2008

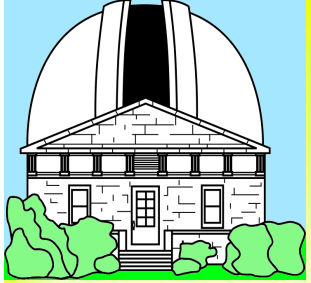


astrograph with single10k camera at NOFS 2007/2008



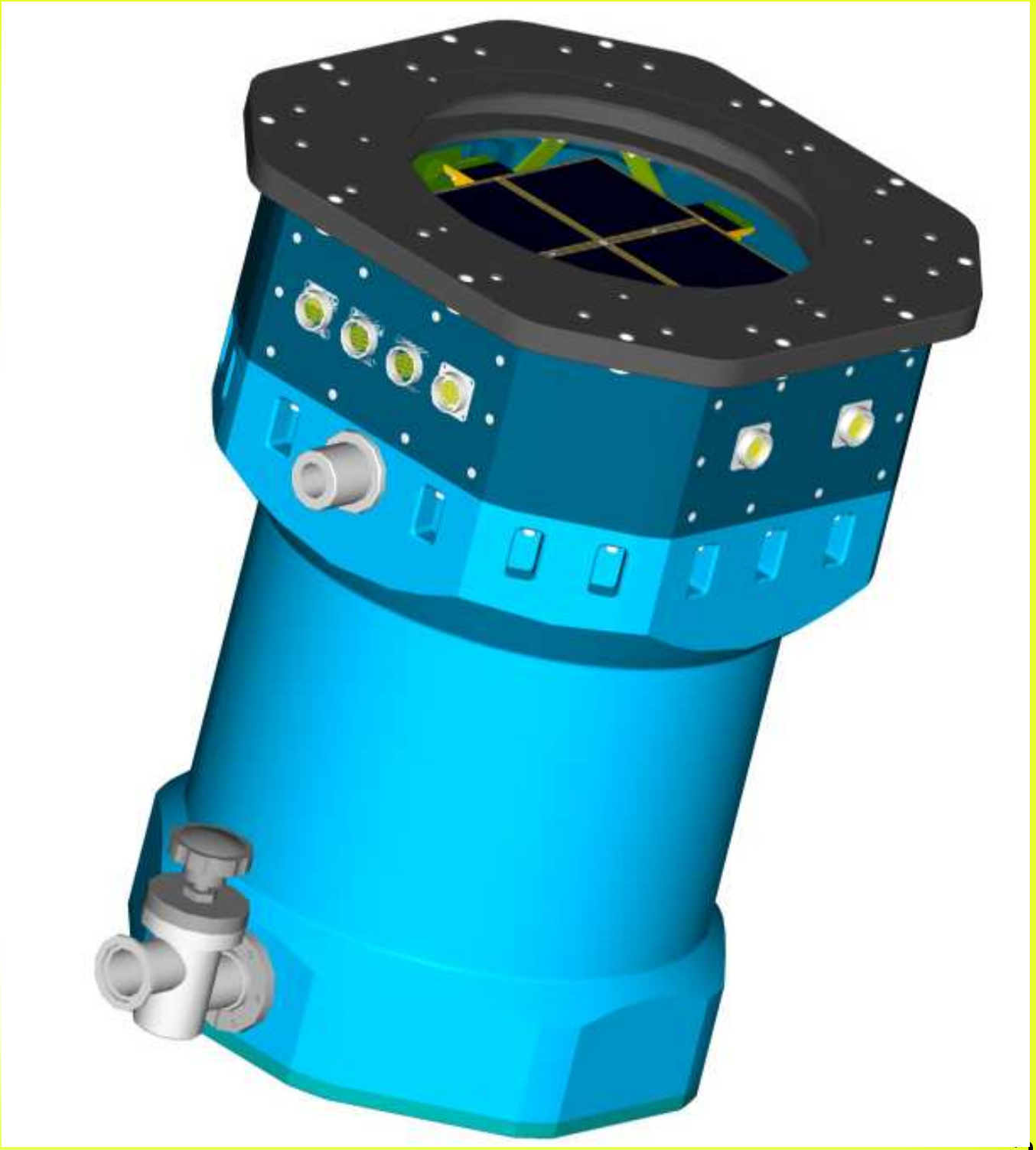
status of URAT project

- use “red lens” of USNO 20 cm astrograph
  - automate 2 mounts (Washington DC, NOFS)
- detector:
  - 10.5k by 10.5k CCD chips produced successfully
  - 10k test camera complete, 1st light October 2007
  - “4-shooter” camera funded fiscal year 2008
  - first successful thinned 10k chip June 2010
- expect first light of URAT Nov 2010

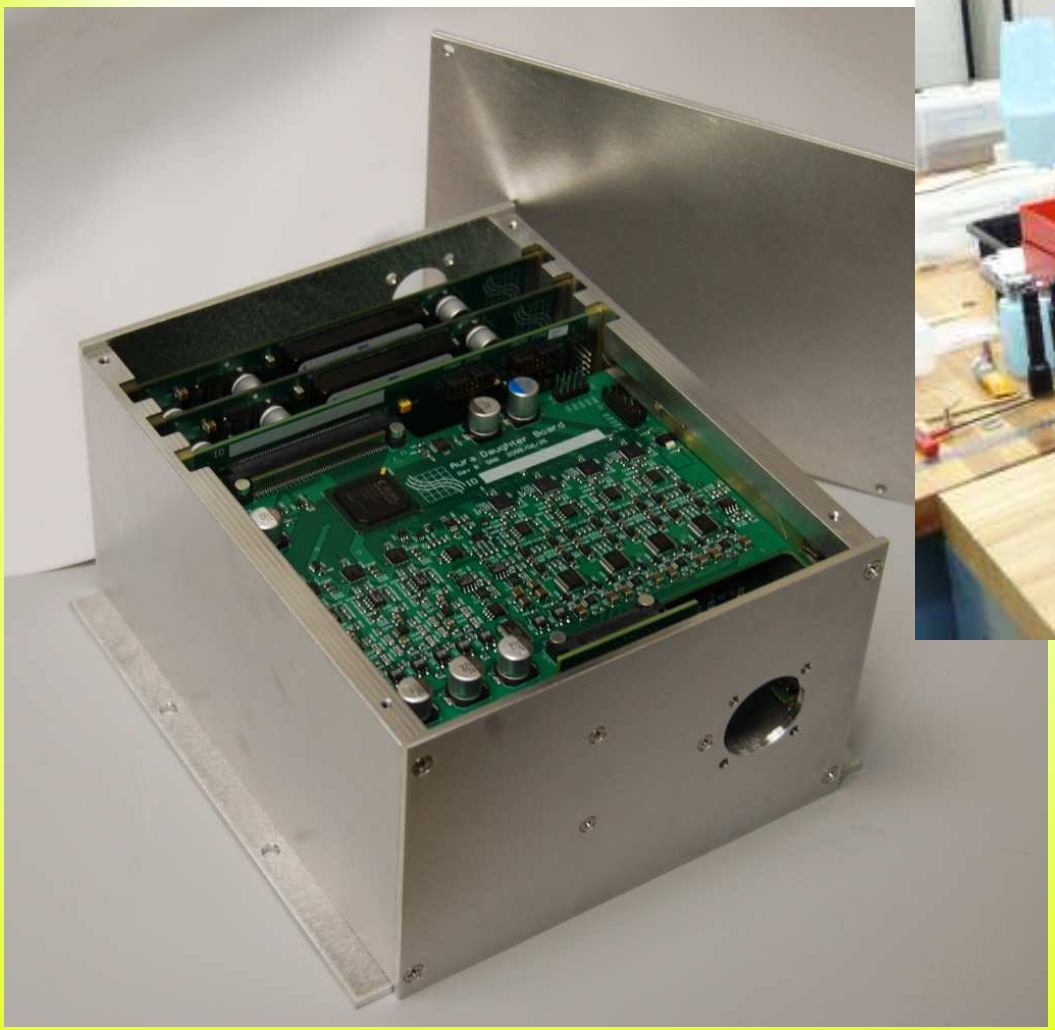


4-shooter camera dewar assembly

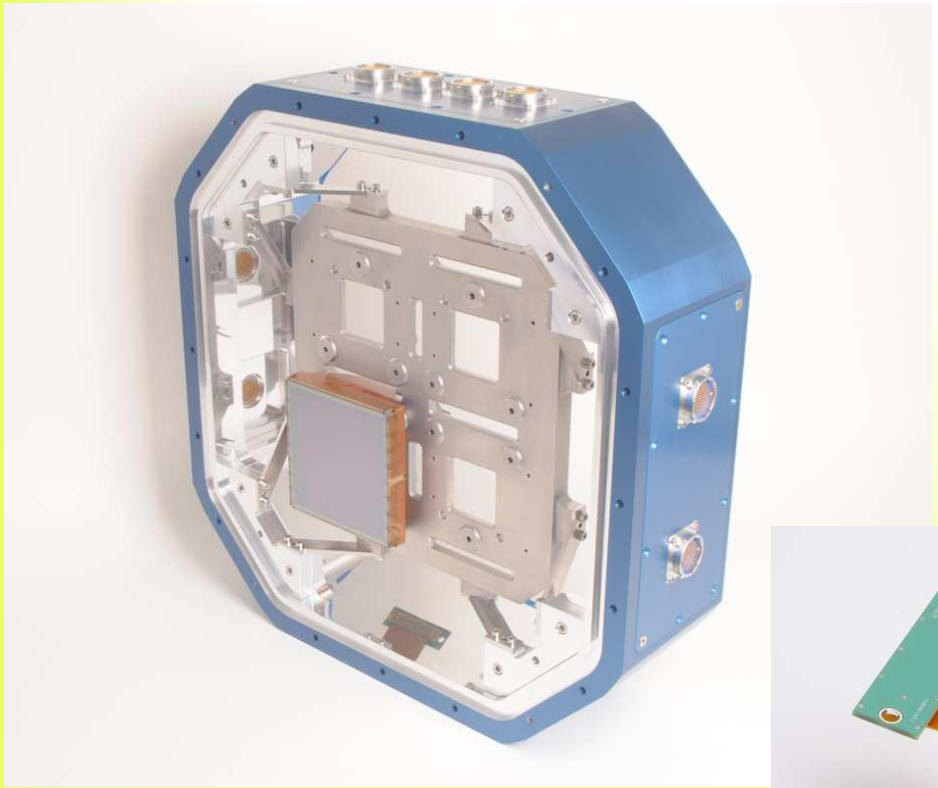
300 mm aperture 140 kg

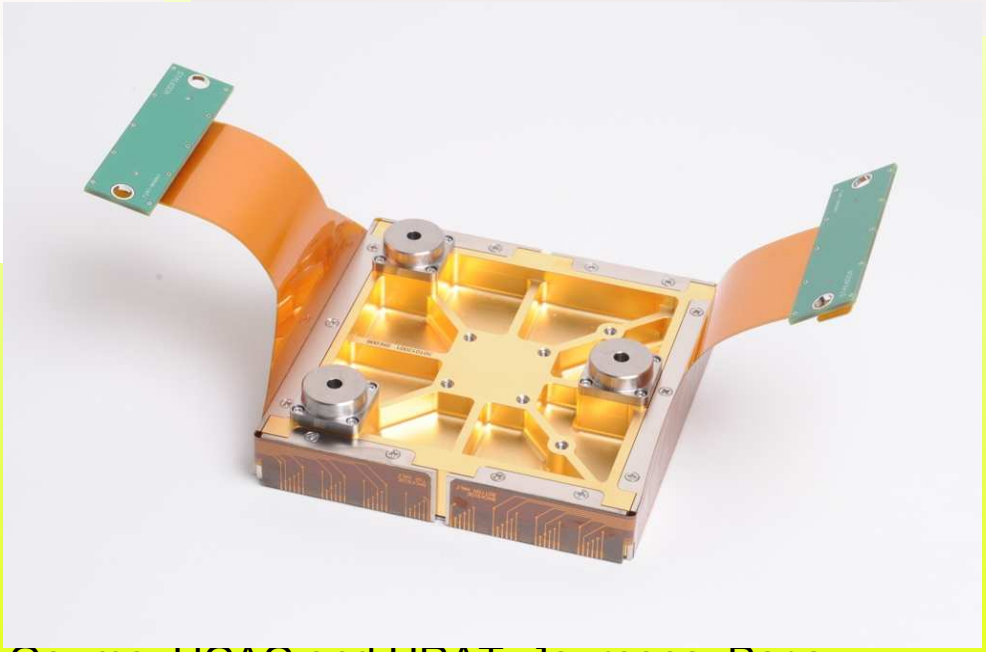


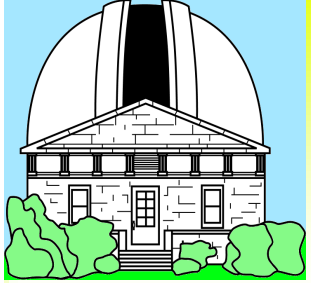
spring 2010, electronics, dewar



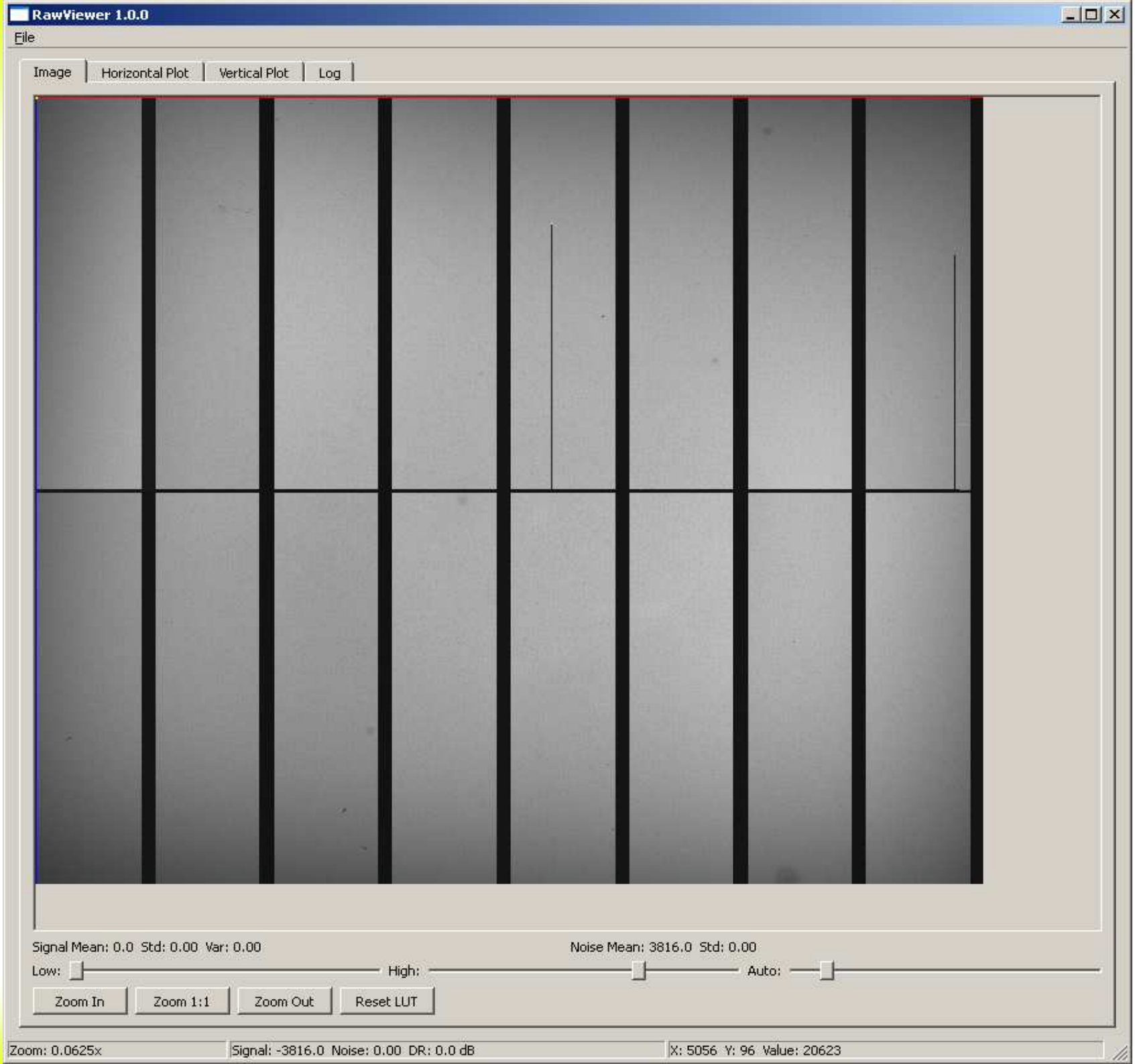
spring 2010, 10k packaging

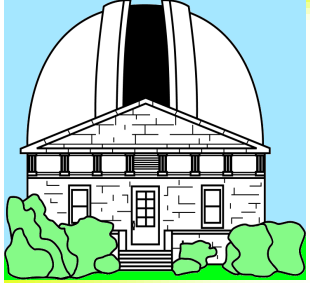


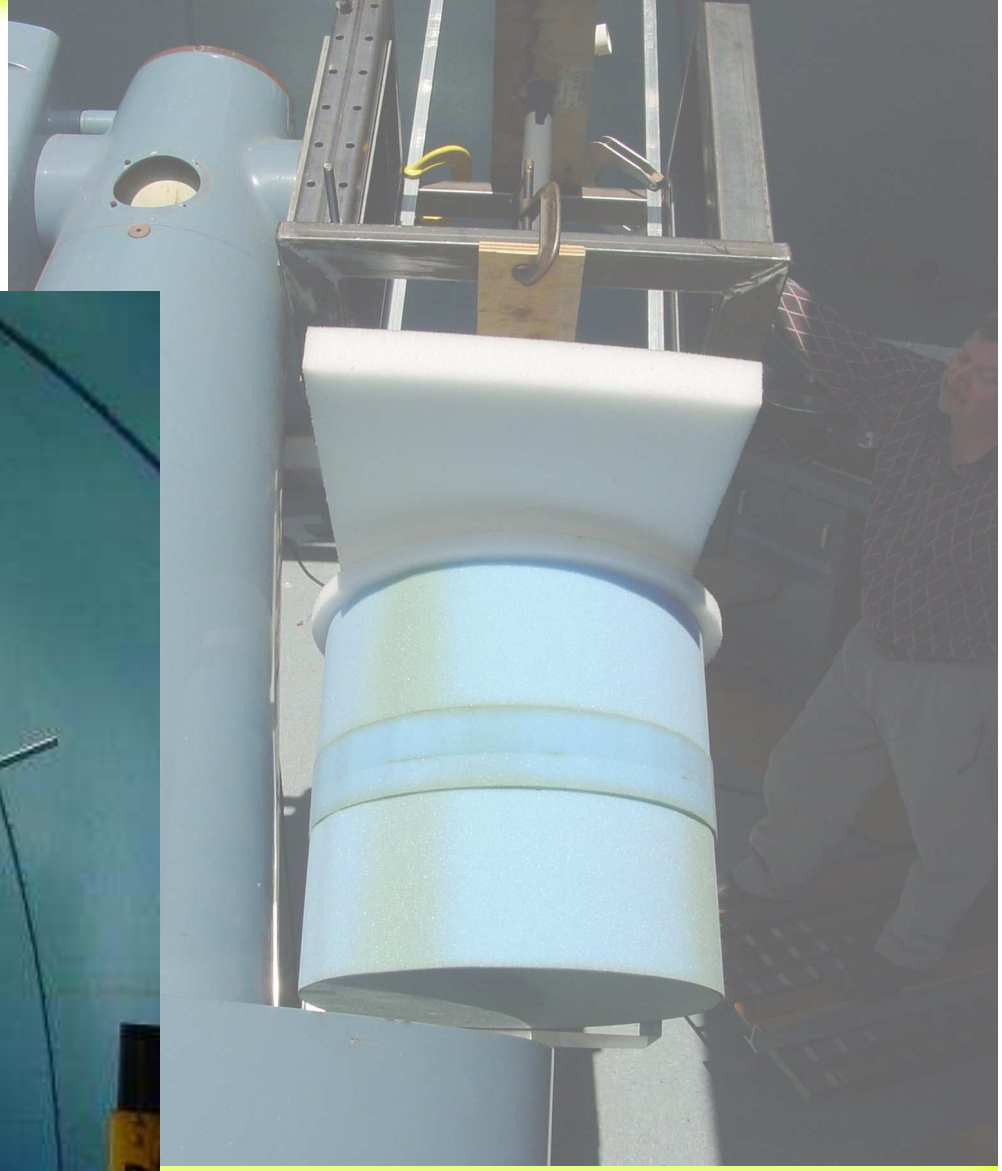


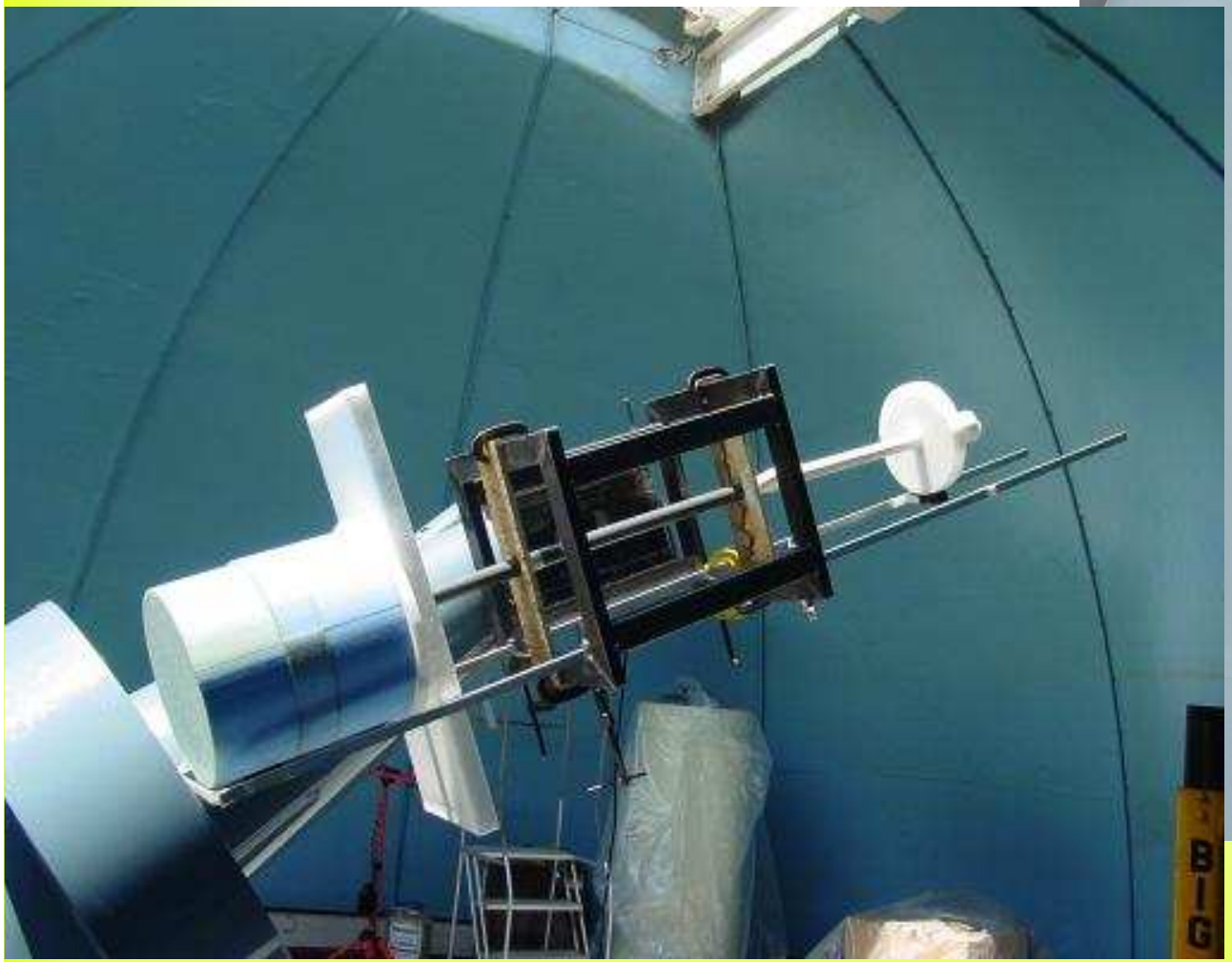


2010, June 29: successful image backside, thinned 10k detector in lab at STA, 16 outputs





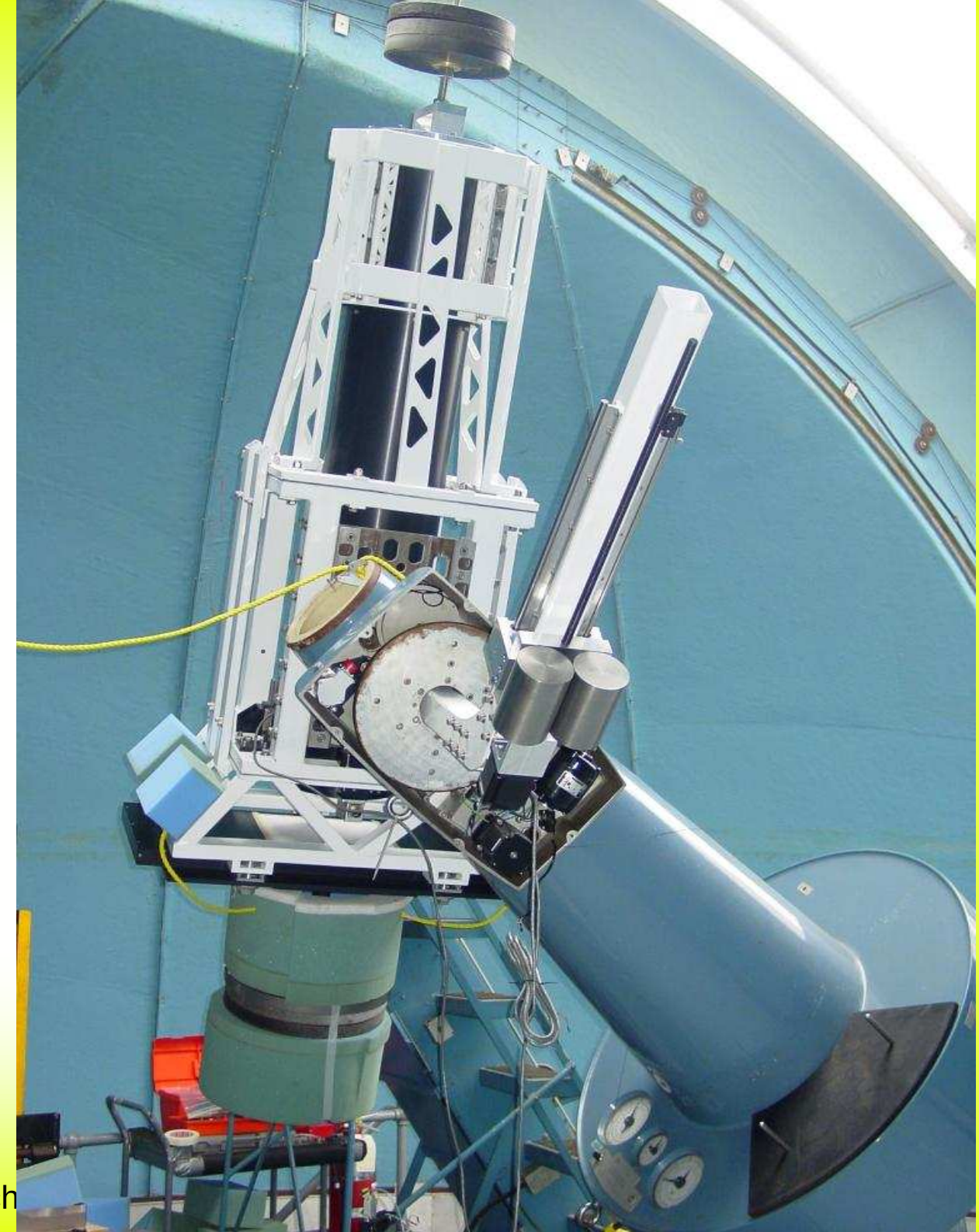


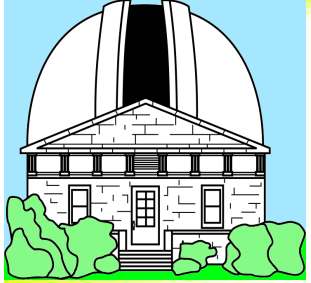


rebuilding astrograph in 24inch dome, 2008

Astrograph mechanical work complete

May 2009 at USNO





summary

- UCAC3: all-sky to 16th mag, 2009 catalog release
- UCAC4: final release 2011, good PM, bug fixes
- URAT: new all-sky astrometric survey
  - use re-furbished astrograph, 7-18 mag, 5-30 mas
  - 111 million pixel CCD detector at astrograph 2007
  - “4-shooter” camera ordered in 2008, delivery 2010
  - 28 sq.degree per exposure, single band (670-750nm)
  - first catalog release scheduled for 2013