



Astrometric Star Catalogs

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layout of talk

- Overview, DoD relevance
- Tycho-2 (USNO provided proper motions)
- UCAC (all sky to magnitude 16, 20 mas)
- USNO-B (all sky to magnitude 21, 200 mas)
- NOMAD = merged dataset ("best" info each star)
- WDS ... WMC (double stars, orbits ...)
- future: URAT

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overview

DoD relevance
Reference Frame
Projects /Catalogs
Stars are moving !

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DoD relevance

- **star tracker:**
- **bright stars**, highest positional accuracy, ref.system
- "clean" stars: avoid double/binary stars
- **Space Situation Awareness :**
- **faint stars**, high density (numb. stars/sq.deg)
- high positional accuracy,
- brightness, color, estimate other bands, variability
- **new, better catalogs open new possibilities!**

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recommendations

- **ICRF** = International Celestial Reference Frame
- all the following are on that system ("J2000")
- see **handout USNO policy** (Instruction 5700)
- point of contact for classified star catalog issues:
 - Bryan Dorland, bdorland@usno.navy.mil
- for copy of this talk, URAT white paper
 - Norbert Zacharias, nz@usno.navy.mil

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catalogs /projects

name of catalog	ground space	proper motion	mag range	numb stars	pos.err (mas)	year
ICRF	G	QSO	radio	500	0.3	2000+
Hip.	S	yes	<= 12	100 K	1.0	1997
Tycho-2	G/S	yes	<= 12	2.5 M	10..100	2000
UCAC2	G	yes	8..16	40 M	20.. 70	2003
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	2007
SST	G	(see classified talk this meeting)				
URAT	G	yes	14..21	1000 M	5..20	2009
MAPS	S	yes	2..15	40 M	0.5	2010
Gaia	S	yes	?..20	1000 M	0.02	2013
SIM	S	yes	0..20	20,000	0.004	2015

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currently best positions

- **Hipparcos** Catalogue
- 100,000 stars
- -1 to 12 mag, complete only to $V = 7.3$
- mean observing epoch = 1991.25
- mean position error (1991) = 1 mas
- mean error proper motions = 1 mas/year
- **position errors increase with time**
- **multiple stars**: centroid offsets + orbital motion
- often unknown and/or wrong proper motions

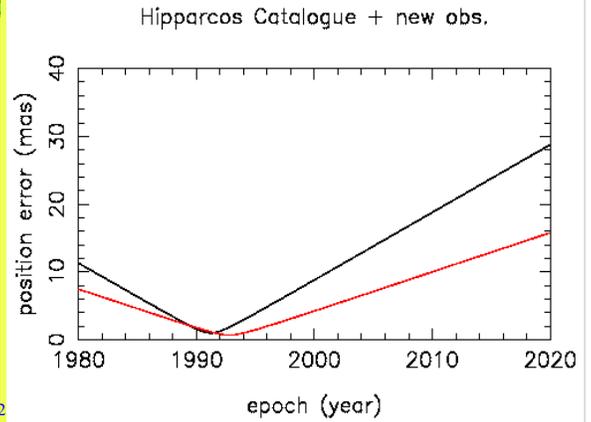
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position error increases with time



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Tycho-2

- **2.5 million** brightest stars to $V = 11.5$
- 10 to 100 mas positional accuracy
- 1991.25 epoch from **Hipparcos Satellite**
- **proper motions**: include **ground-based** catalogs!
 - work done at USNO (PI: Sean Urban)
 - major data: Astrographic Catalogue (~1900)
 - **systematic error level** higher than Hip.main catalog

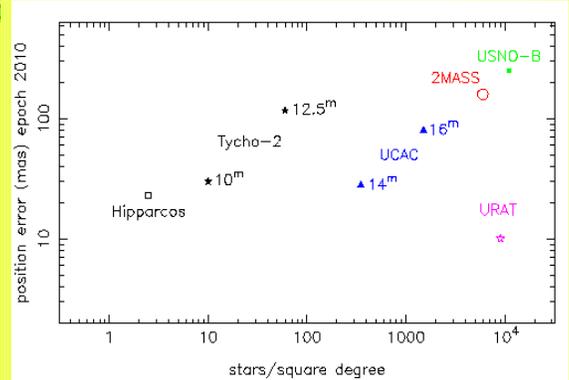
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accuracy of catalogs



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U S N O C C D A s t r o g r a p h C a t a l o g

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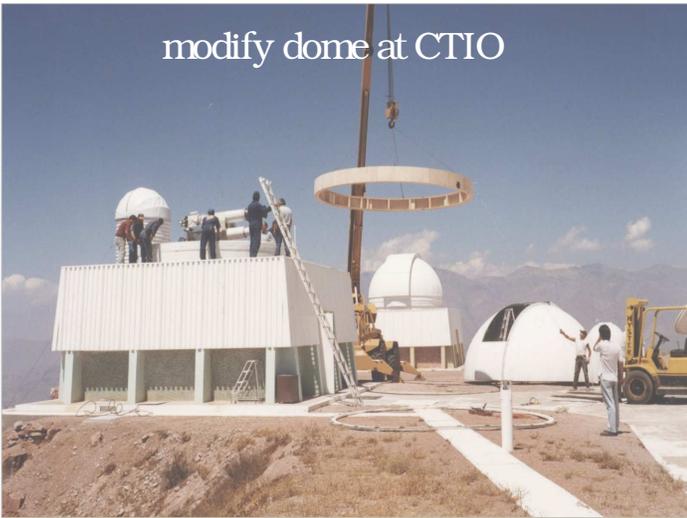
UCAC observing

- 1997 – 2004 (**all-sky completed**)
- 579 – 642 nm bandpass
- $R = 8$ to 16 mag
- positions accurate to **20 mas** (10 – 14 mag)
- incl. **proper motions** (various early catalogs)
- most accurate astrometry for fainter than Hip.

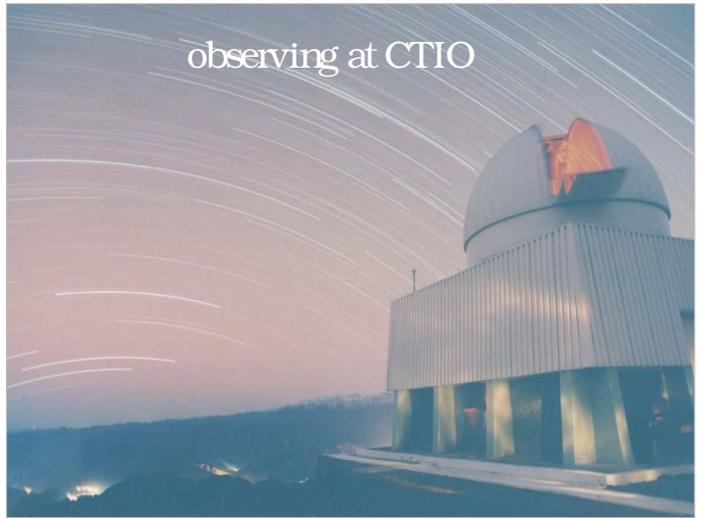
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modify dome at CTIO



observing at CTIO



x-y slide

backend of
astrograph

4k camera



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astrograph at NOFS



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UCAC products

- UCAC1 (2000) : part of Southern Hemisphere
- UCAC2 (2003) : -90 to +50 deg decl.
- UCAC3 (end of 2006) :
 - all-sky coverage; re-processing all pixel data
 - much improved completeness (bright stars, doubles)
 - improved astrometry
 - improved photometry (1 band)

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improved UCAC3 proper motions:
StarScan, Washington DC



KPNO 2.1 m

extragalactic
reference frame link



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USNO - B

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USNO - B properties

- scan of 7435 **Schmidt plates**
- 2 epochs, incl. **proper motions**
- 3+ colors, photogr. **photometry**
- **1 billion stars** to about $V = 21$
- **200 mas** positional errors
- saturated images brighter about 12th mag

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N a v a l O b s e r v a t o r y M e r g e d A s t r o m e t r i c D a t a s e t

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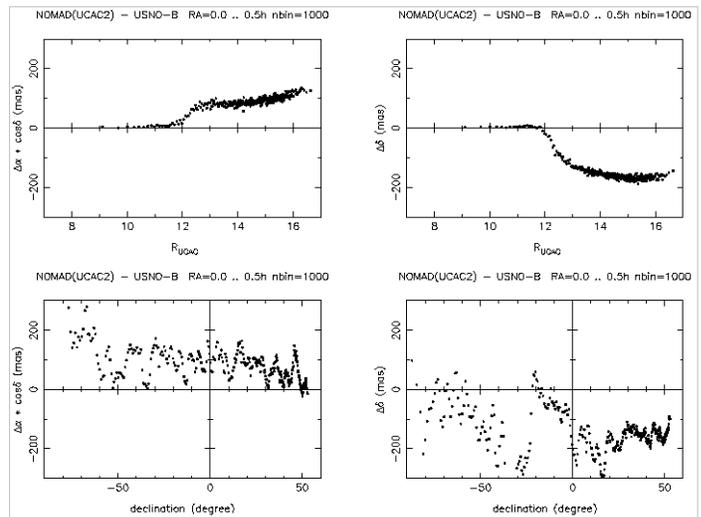
NOMAD overview

- **all-sky, all stars:** Sirius to 21st mag
- positions + proper motions + photometry
- pick "**best**" data each star (not compiled cat.)
 - Hipparcos + Tycho-2
 - UCAC + "Yellow Sky" + USNO-B
 - 2MASS ...
- <http://www.nofs.navy.mil/nomad> on-line
- 100 GB hard disk copy upon request

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Double Stars

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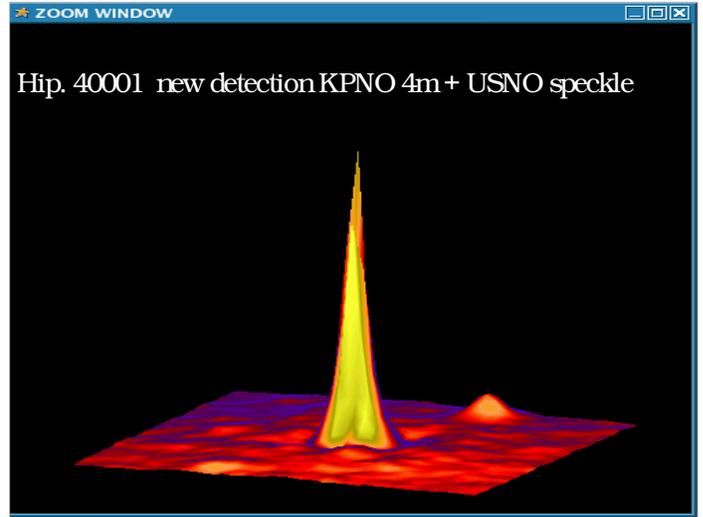
double star work at USNO

- “world headquarters” IAU mandate
- observing program: 26 inch speckle interferom.
- WDS = Washington Double Star catalog
 - over 100,000 systems; daily updates; on-line
- Orbit Catalog (6th edition); graded, daily updates
- WMC = Washington Multiplicity Catalog
 - work on 1st release in progress
- combine all double star observing techniques results

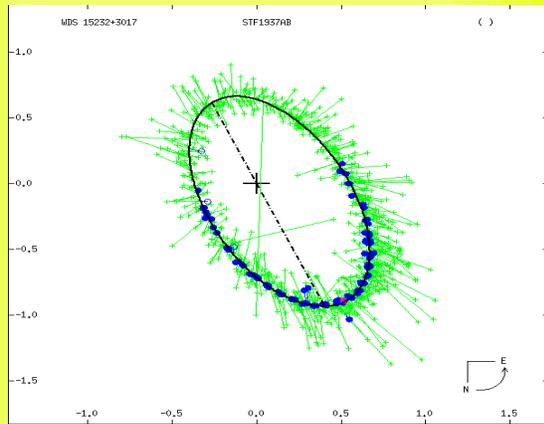
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Eta CrB: example “good” orbit



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USNO Robotic Astrometric Telescope

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URAT overview

- USNO Robotic Astrometric Telescope
 - 0.85 m aperture, focal length = 3.6 m
 - 4.5 degree diameter field of view
 - large format **detector** (world largest CCD)
 - 2 px /FWHM at 1.0 arcsec seeing
 - 9 micrometer pixel size
 - 4 CCDs, each 95 mm on a side
 - 50 s /250 s integration
 - **13 to 21 mag**
 - goal **5 mas** for 'well exposed stars'

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goals of the URAT project

- regular survey: **14 to 20 mag** stars
 - overlap with UCAC stars (8 to 16 mag)
 - direct link to faint, extragal. ref. frame sources
 - optimized for astrometry, absolute positions
 - **5 - 20 mas** positional accuracy = f (mag)
 - **bright stars**: 8 to 13 mag regular (narrow filter)
 - **very bright stars**: <= 7 mag targeted observations
 - **all sky**: 2 locations (north and south)
 - robotic: low operation costs
 - multiple overlap in 1 - 2 years per hemisphere

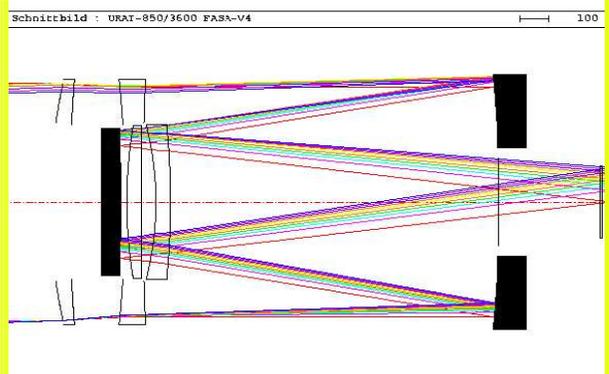
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URAT optical design

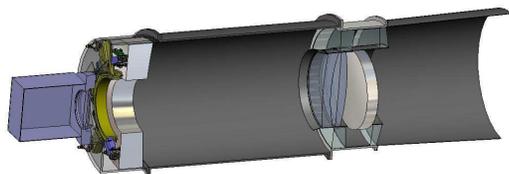


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URAT cut side view



EOST, 2005

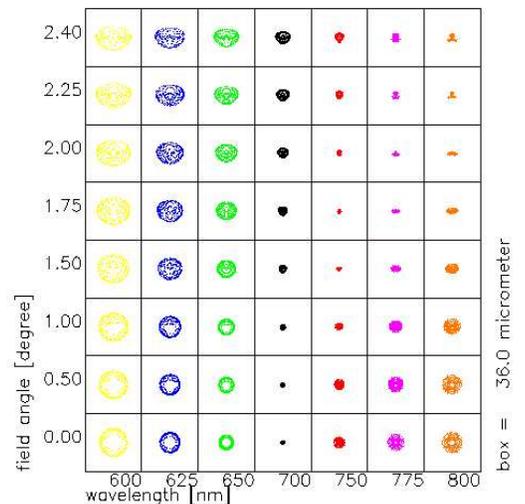
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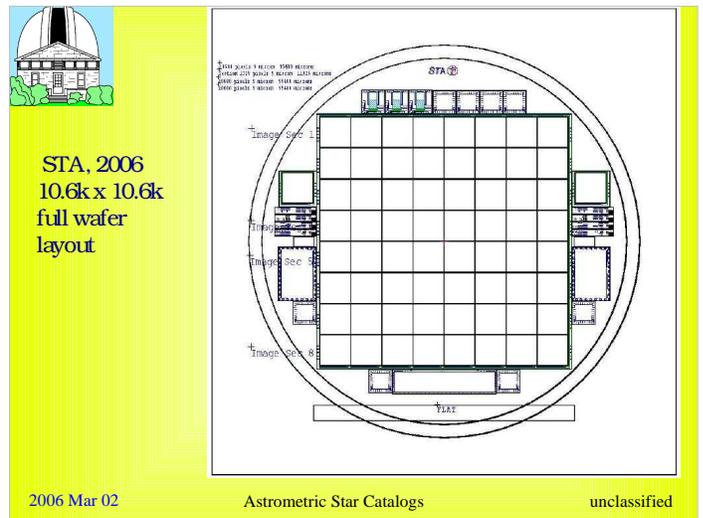
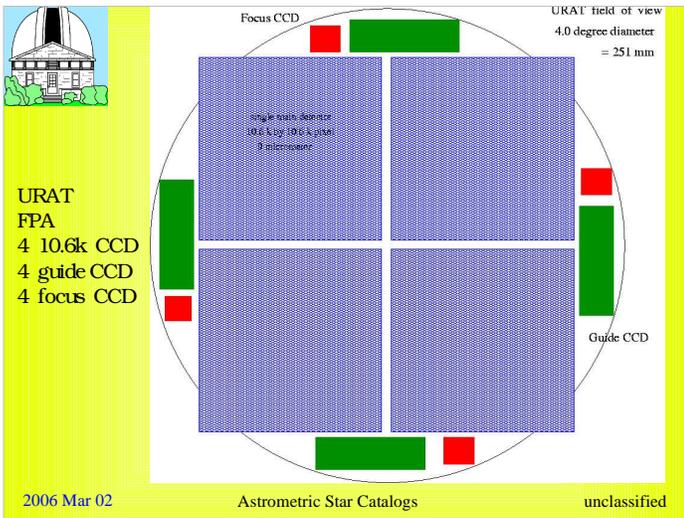
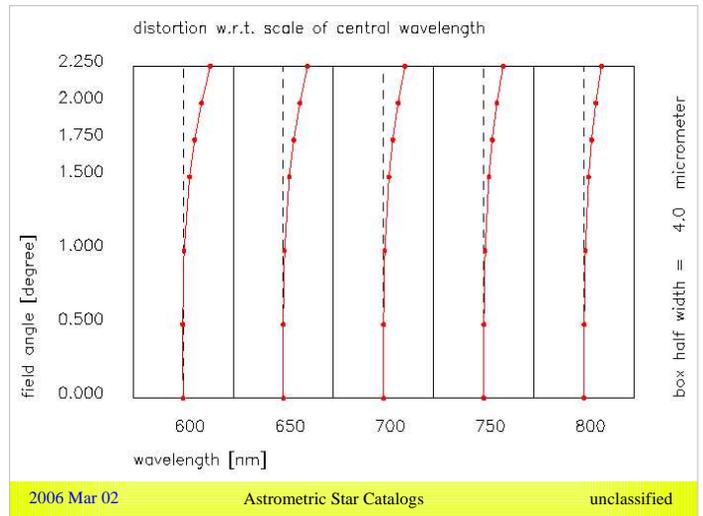
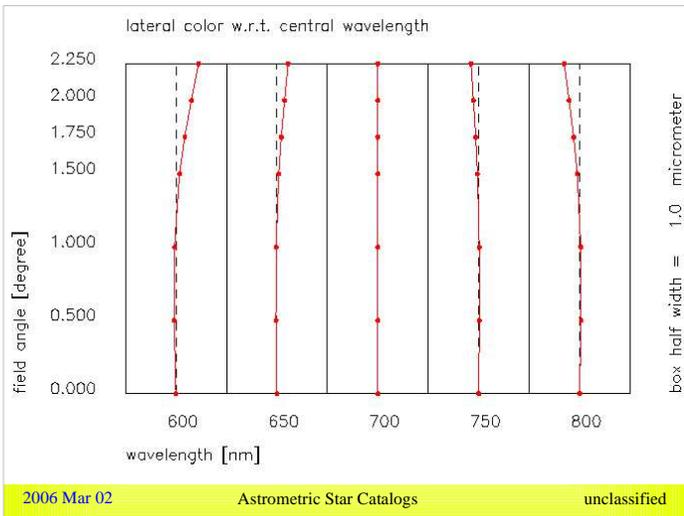
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URAT
FASA2
(EOST 2005)



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status of URAT project

- telescope:
 - optical design studies completed
 - offer received in July 2005
 - contract for primary mirror in place
- detector:
 - SBIR phase II signed Dec. 2006
 - 10.6k by 10.6k CCD chip is in production
 - first light prototype camera end of 2006

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We work for DoD

- world leader in astrometric catalogs
 - public site <http://ad.usno.navy.mil>
 - offer custom products /services for DoD
 - expertise in star catalog data and compilations
- strong observing program
 - own telescopes and instruments
 - act upon requests /requirements
- you tell us what you need!

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