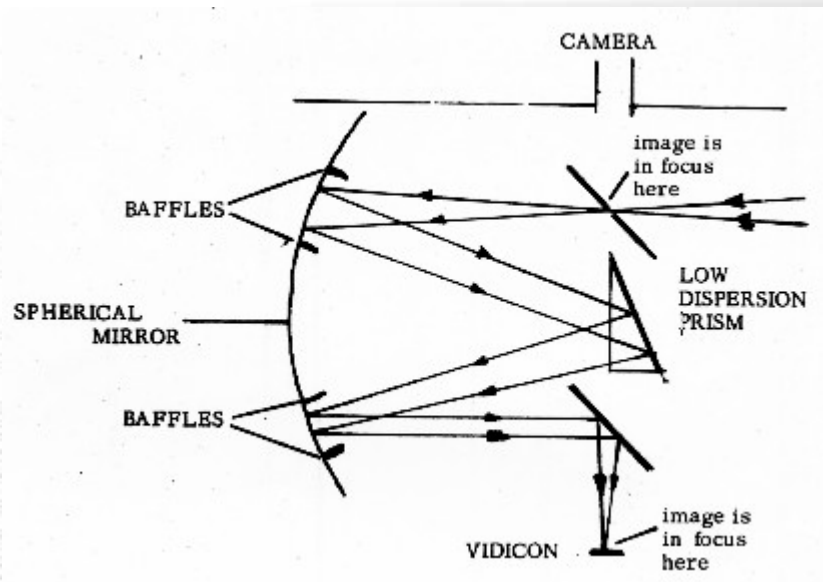


**From Planets to Stars to
Galaxies:
Putting things in their places**

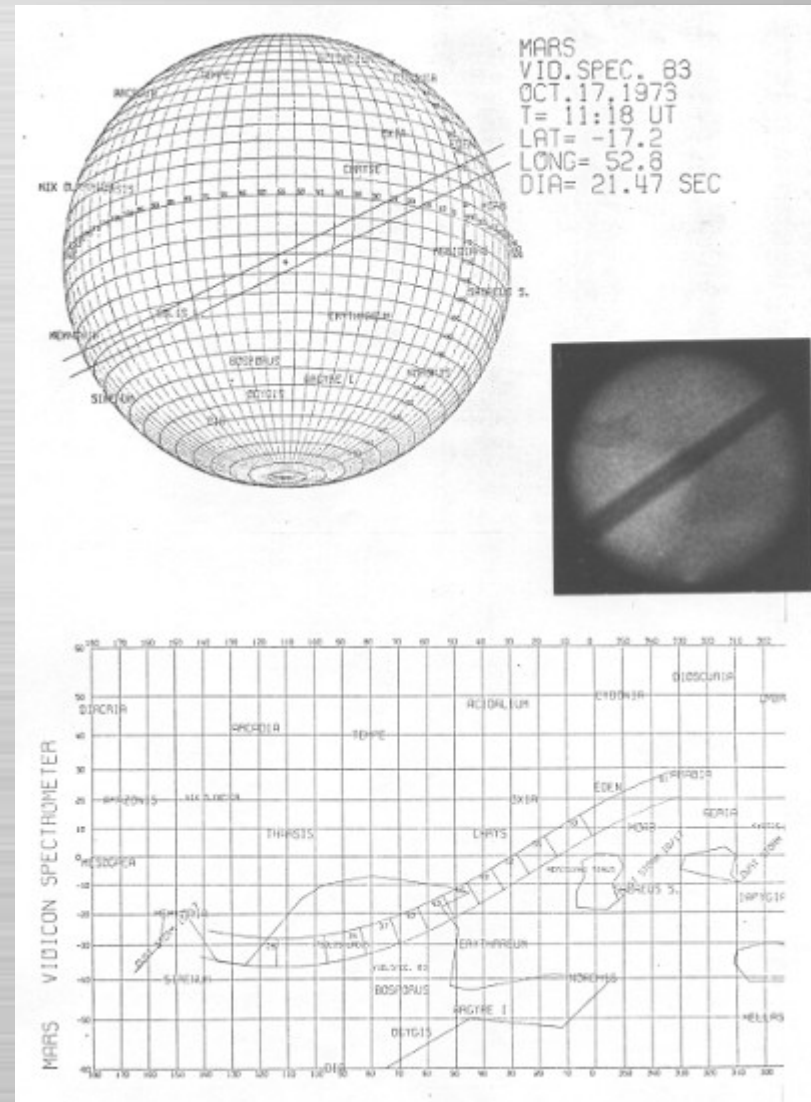
**By
Doug Mink
Smithsonian Astrophysical Observatory**

It All Started With Mars

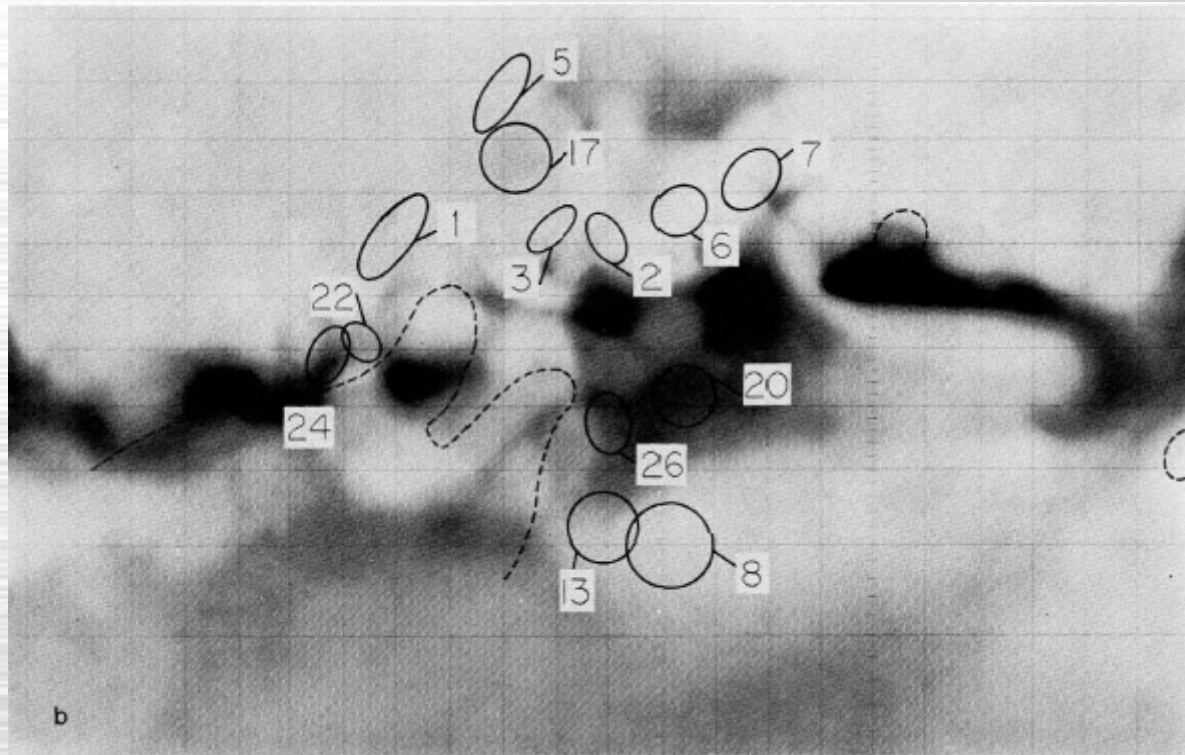


MIT Vidicon Spectrometer with camera monitoring slit in mirror

**Spectrometer slit reprojected across Mercator projection of Mars surface
(Mink, MIT S.M. Thesis 1974)**



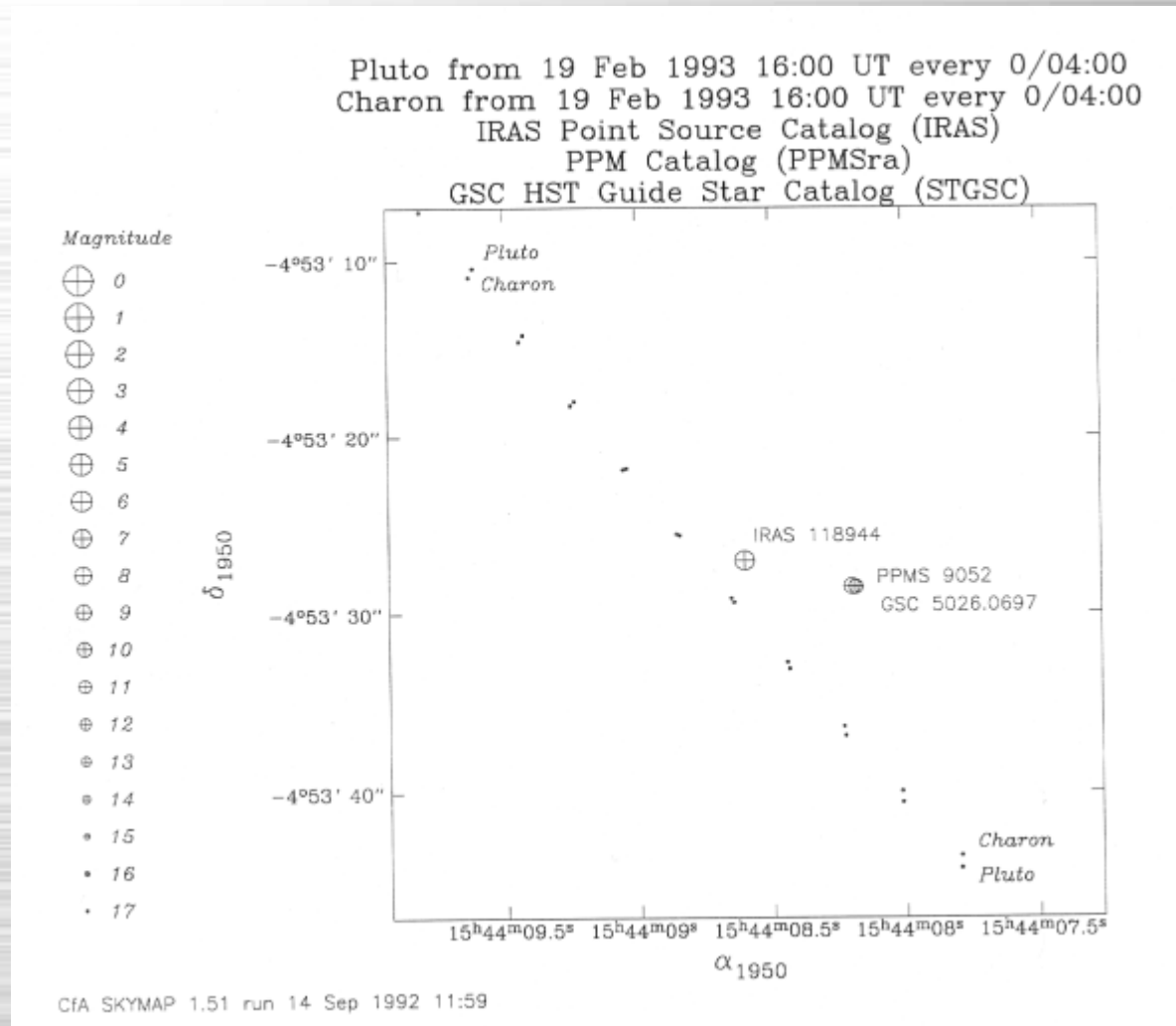
It All Started With Mars



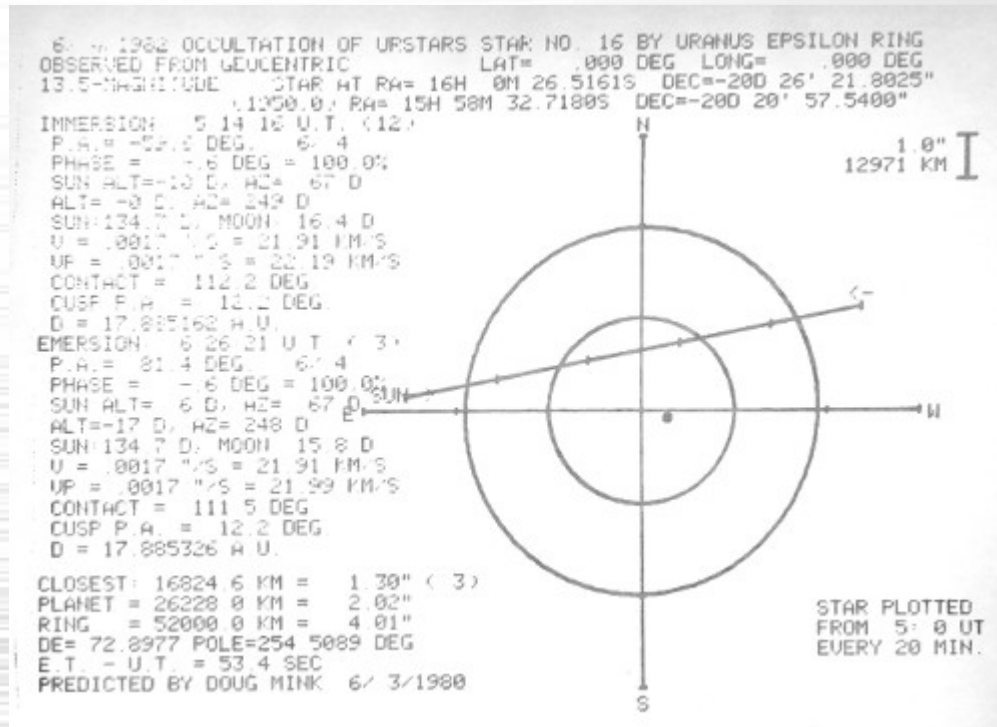
**Aperture photos projected on observed planet disk
and reprojected onto Mercator projection of Mars**

(Mccord, Huguenin, Mink, and Pieters, Icarus 31, 1977)

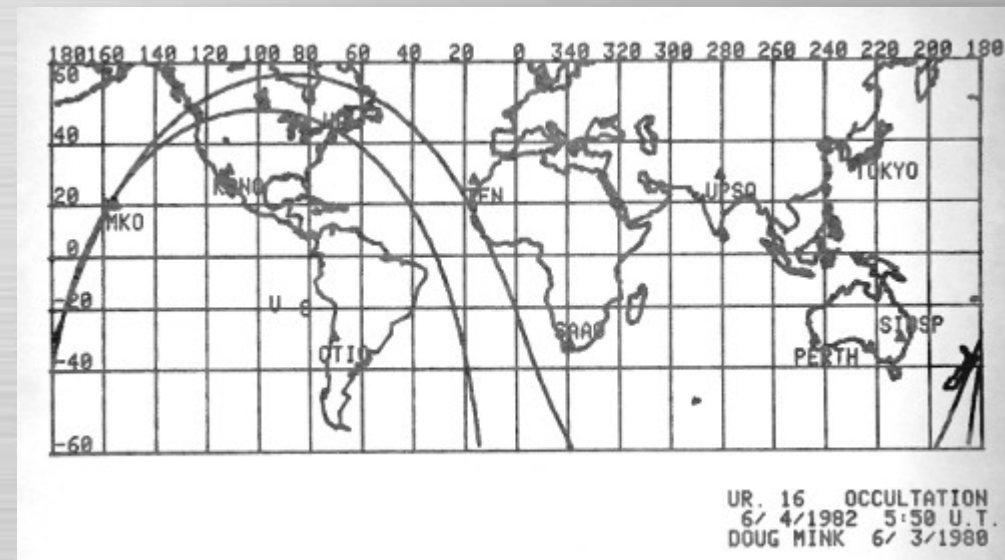
Finding Stars to be Occulted



Mapping observability



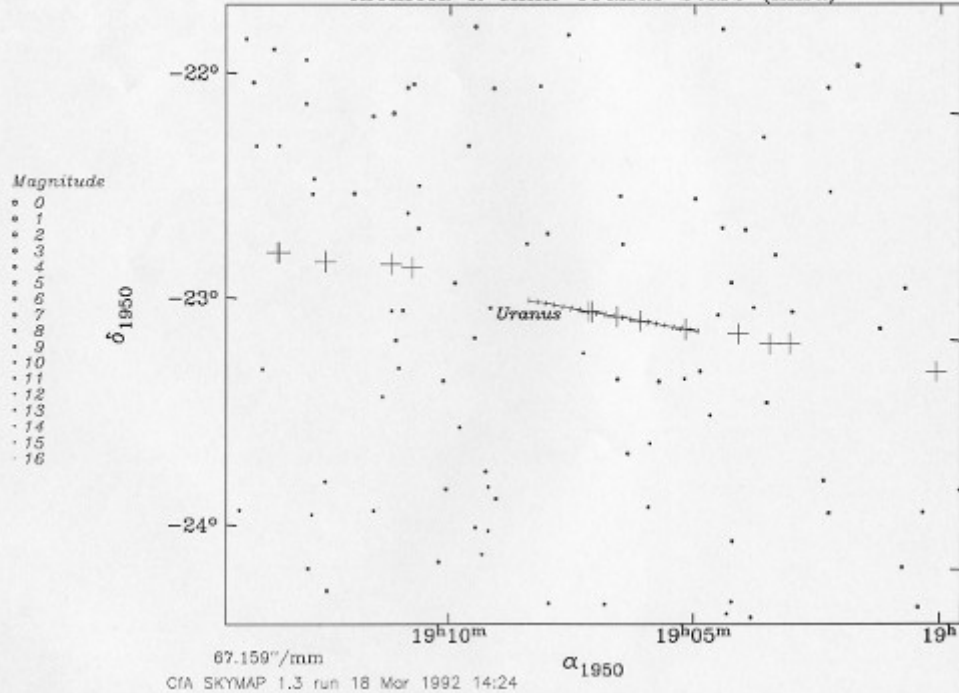
Geocentric prediction of Uranus 16



Sun down, Uranus up for Uranus 16

Predicting Occultations

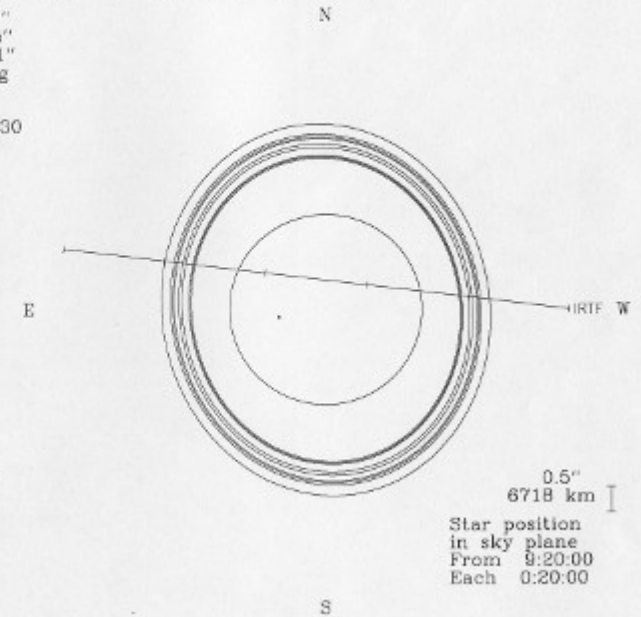
Centered on kmu 102 $19^{\text{h}}07^{\text{m}}05.365^{\text{s}}$ $-22^{\circ}58'47.1''$
 Uranus from 1 July 1992 0:00 UT every 1 day
 SAO Catalog (SAOra)
 Klemola & Mink Uranus Stars (kmu)



Palomar Sky Survey overlay
 for stars occulted by Uranus

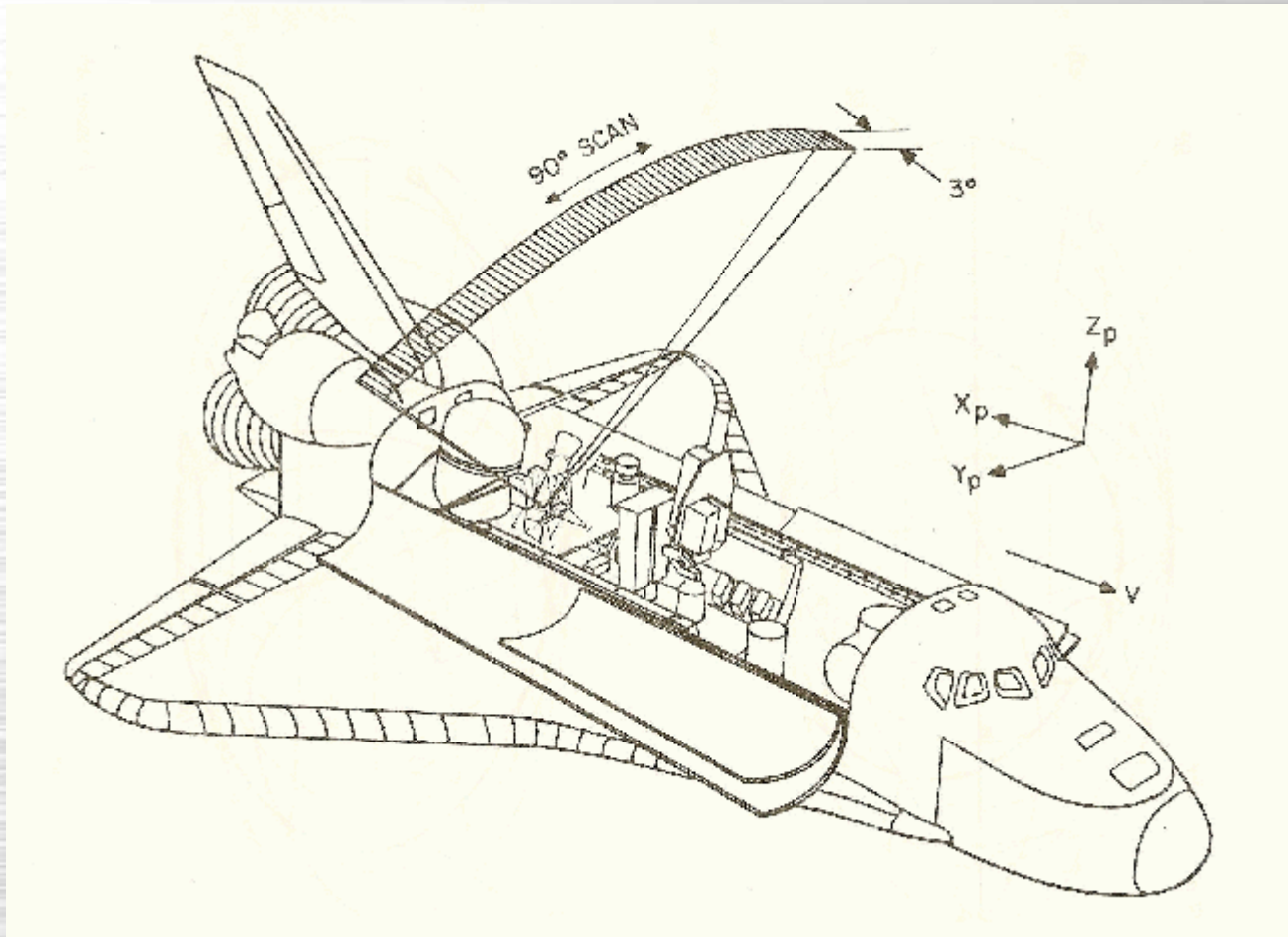
July 8 1992 Occultation of kmu 102 by Uranus epsilon ring
 Observed from IRTF Mauna Kea 3.8m Long= 155 28 15.0 Lat= 19 49 34.0
 13.01-magnitude star at RA= 19h 09m 40.3332s Dec= -22d 54' 34.113"
 (1950) RA= 19h 07m 05.3650s Dec= -22d 58' 47.100"

Closest at 10: 7:25 U.T.
 Radial= 8025.7 km = 0.60"
 Planet= 26145.0 km = 1.95"
 Ring = 51149.3 km = 3.81"
 DE= 60.4757 Pole= 99.7807 deg
 V=0.0017 "/s = 23.05 km/s
 D= 18.525434 AU
 ET - UT = 59.3660 sec DE-130
 Immersion: 9:35:43 U.T.
 P.A.= 273.4 deg. 7/ 8
 R = 44574.2 km = 3.32"
 Phase = 0.0 deg = 100.0%
 Alt= 47 d, Az= 164 d
 Sun alt=-47 d, Az=-17 d
 Sun:179.4 d, Moon: 73.4 d
 V =0.0017 "/s = 23.05 km/s
 VP=0.0019 "/s = 25.88 km/s
 D = 18.525427 A.U.
 Emersion: 10:39:54 U.T.
 P.A.= 73.0 deg. 7/ 8
 R = 45649.7 km = 3.40"
 Phase = 0.0 deg = 100.0%
 Alt= 49 d, Az= 185 d
 Sun alt=-49 d, Az= 4 d
 Sun:179.3 d, Moon: 72.8 d
 V =0.0017 "/s = 23.05 km/s
 VP=-.0019 "/s = -25.89 km/s
 D = 18.525442 A.U.
 Doug Mink 13:33 Mar 18 1992



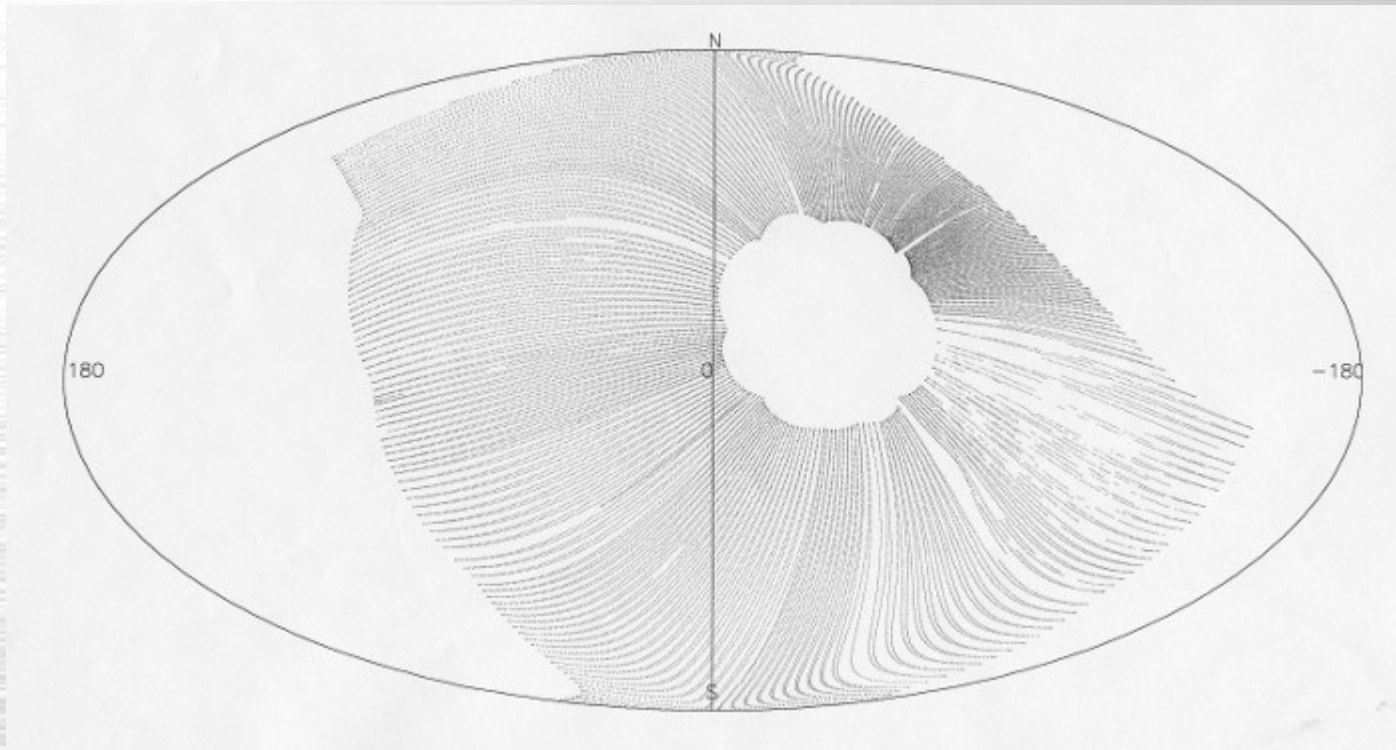
Sky plane map of Uranus
 ring occultation of KMU102

All-Sky IR Mapping from Space



Spacelab 2 Infrared Telescope
(Space Shuttle Challenger, July 1985)

All Sky IR Mapping from Space



1985 Day 213, Orbit 4, 50,964 0.1-sec frames

Spacelab 2 Infrared Telescope

(Space Shuttle Challenger, July 1985)

Galactic Center from Spacelab 2

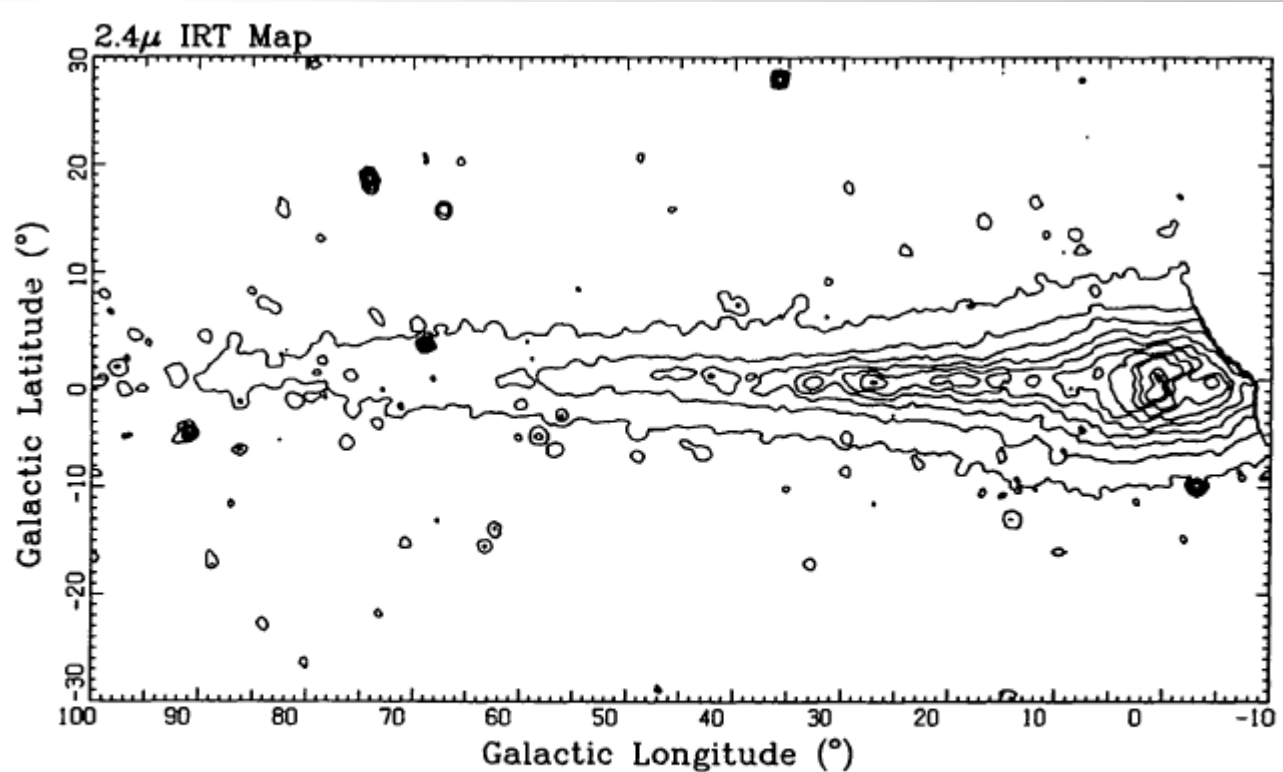
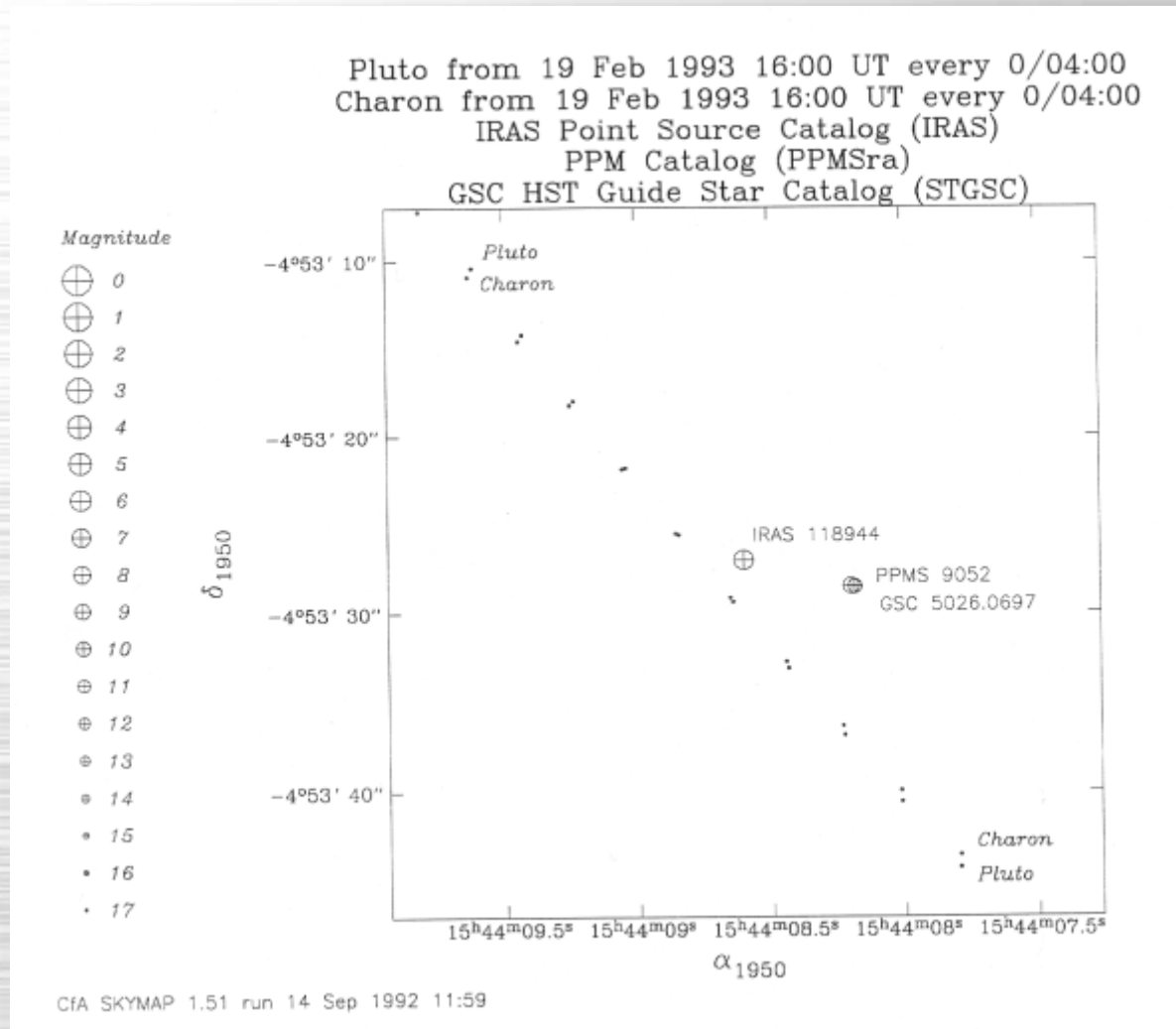


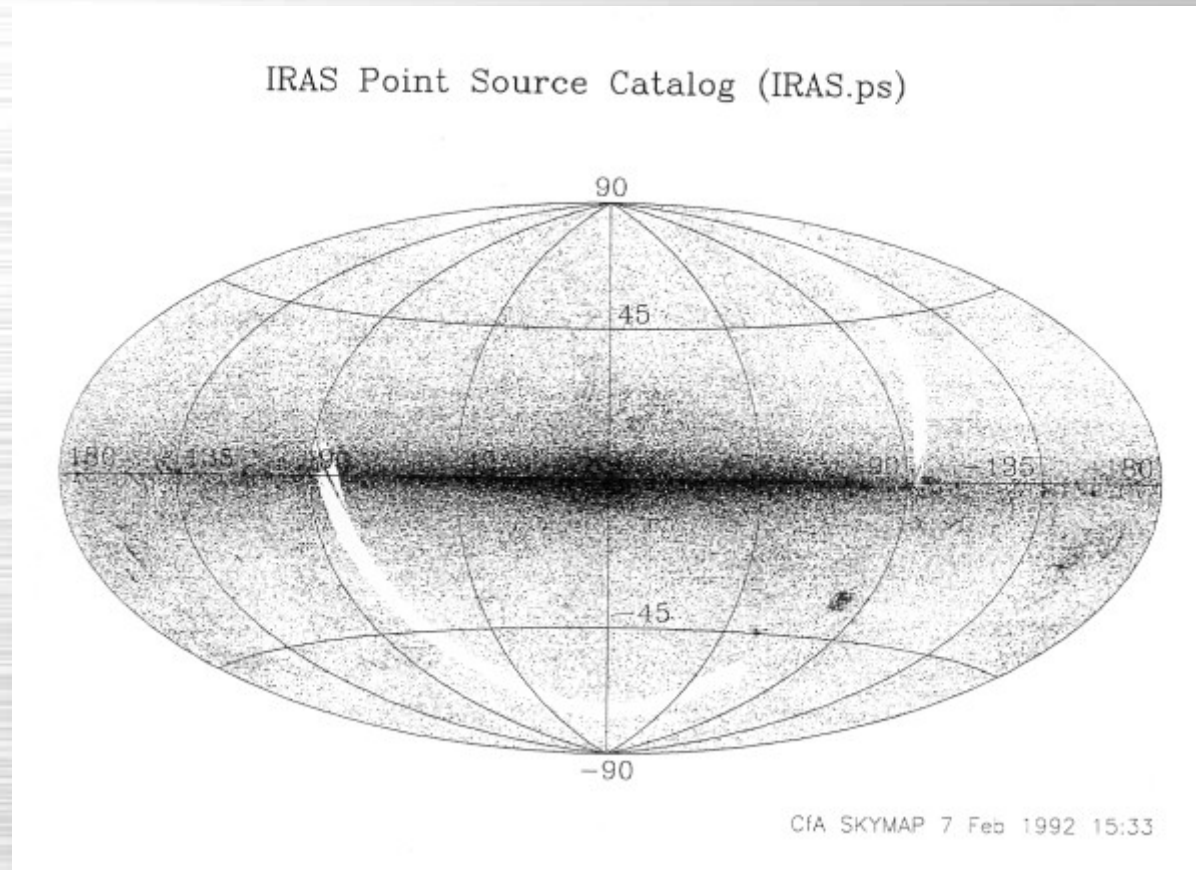
FIG. 5.—Contour map of the $2.4 \mu\text{m}$ emission from the Galactic plane region. The contours are spaced logarithmically in 10 steps between 0.67×10^{-10} and $16 \times 10^{-10} \text{ W cm}^{-2} \mu\text{m}^{-1} \text{ sr}^{-1}$.

(Kent, Mink, Fazio, Koch, Melnick, Tardiff, Maxson, ApJS 78:403-408, 1992)

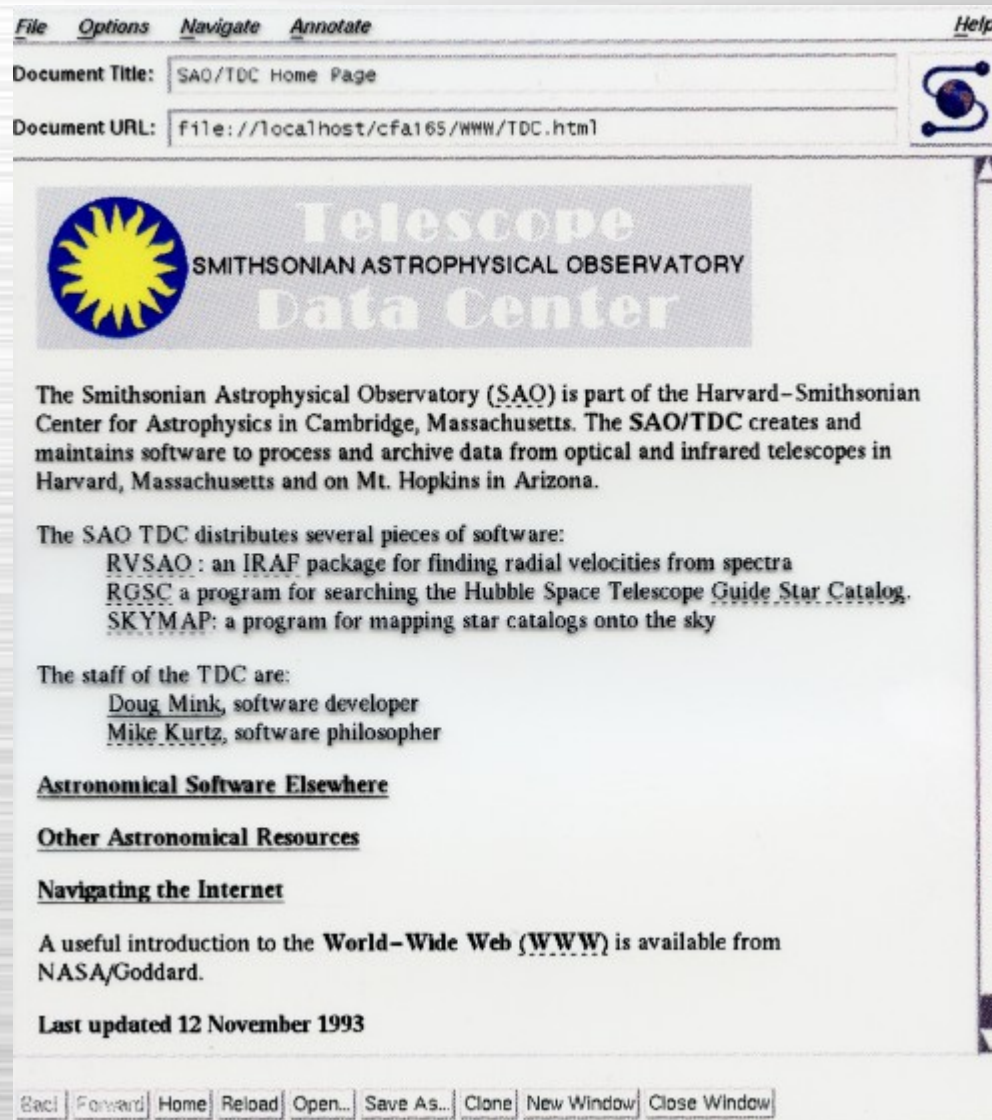
Mapping Multiple Catalogs



All-Sky Maps meet Catalogs



Onto the World Wide Web




The screenshot shows a Netscape browser window with the following content:

File Options Navigate Annotate Help

Document Title: SAO/TDC Home Page

Document URL: file:///localhost/cfa165/www/TDC.html

 **Telescope**
SMITHSONIAN ASTROPHYSICAL OBSERVATORY
Data Center

The Smithsonian Astrophysical Observatory (SAO) is part of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. The SAO/TDC creates and maintains software to process and archive data from optical and infrared telescopes in Harvard, Massachusetts and on Mt. Hopkins in Arizona.

The SAO TDC distributes several pieces of software:

- [RVSAO](#): an [IRAF](#) package for finding radial velocities from spectra
- [RGSC](#): a program for searching the Hubble Space Telescope Guide Star Catalog.
- [SKYMAP](#): a program for mapping star catalogs onto the sky

The staff of the TDC are:

- [Doug Mink](#), software developer
- [Mike Kurtz](#), software philosopher

Astronomical Software Elsewhere

Other Astronomical Resources

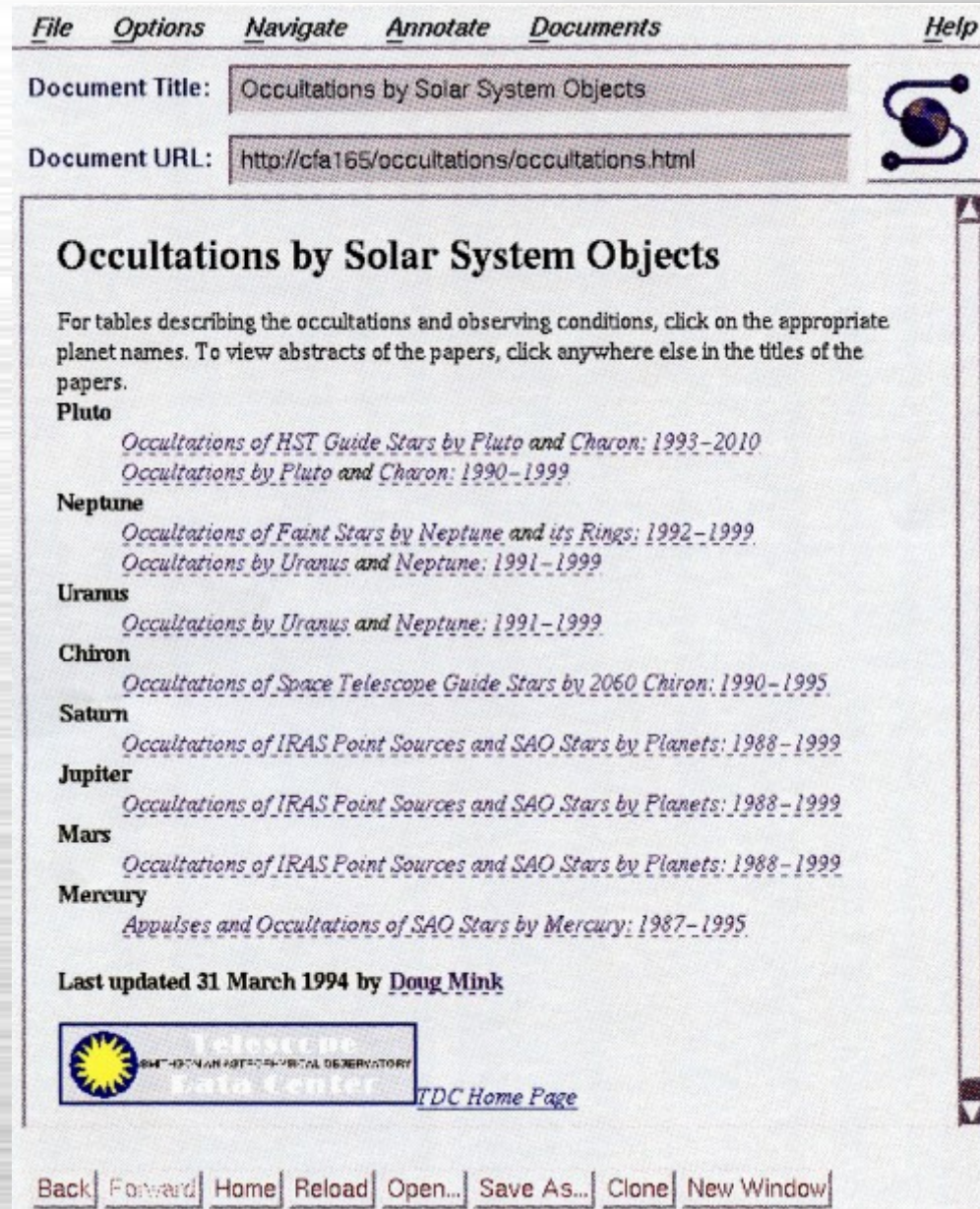
Navigating the Internet

A useful introduction to the **World-Wide Web (WWW)** is available from NASA/Goddard.

Last updated 12 November 1993

[Back](#) [Forward](#) [Home](#) [Reload](#) [Open...](#) [Save As...](#) [Clone](#) [New Window](#) [Close Window](#)

Onto the World Wide Web

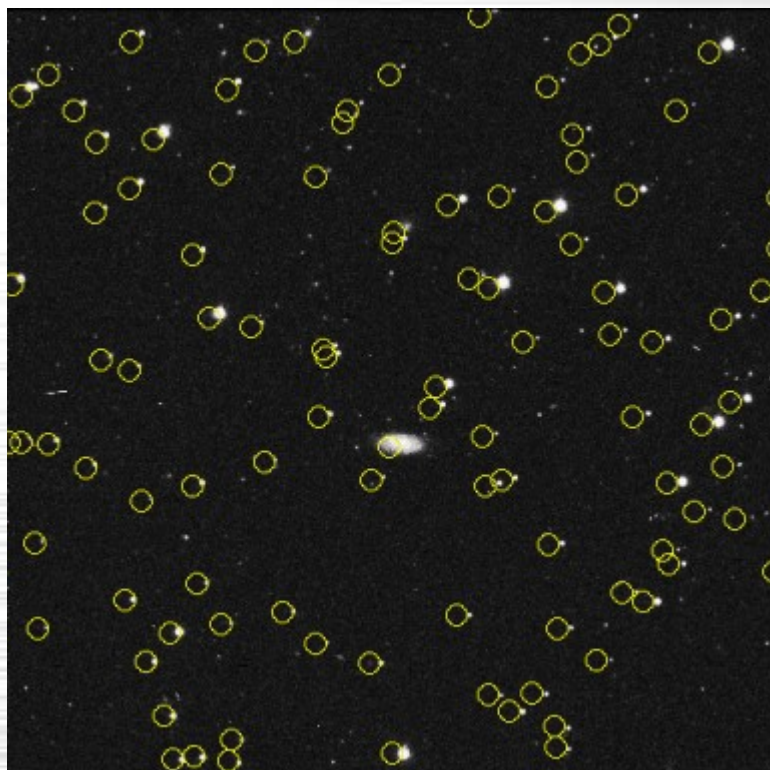


The screenshot shows a Netscape browser window with the following content:

- Menu Bar:** File Options Navigate Annotate Documents Help
- Document Title:** Occultations by Solar System Objects
- Document URL:** http://cia165/occultations/occultations.html
- Page Content:**
 - Occultations by Solar System Objects**
 - For tables describing the occultations and observing conditions, click on the appropriate planet names. To view abstracts of the papers, click anywhere else in the titles of the papers.
 - Pluto**
 - [Occultations of HST Guide Stars by Pluto and Charon: 1993-2010](#)
 - [Occultations by Pluto and Charon: 1990-1999](#)
 - Neptune**
 - [Occultations of Faint Stars by Neptune and its Rings: 1992-1999](#)
 - [Occultations by Uranus and Neptune: 1991-1999](#)
 - Uranus**
 - [Occultations by Uranus and Neptune: 1991-1999](#)
 - Chiron**
 - [Occultations of Space Telescope Guide Stars by 2060 Chiron: 1990-1995](#)
 - Saturn**
 - [Occultations of IRAS Point Sources and SAO Stars by Planets: 1988-1999](#)
 - Jupiter**
 - [Occultations of IRAS Point Sources and SAO Stars by Planets: 1988-1999](#)
 - Mars**
 - [Occultations of IRAS Point Sources and SAO Stars by Planets: 1988-1999](#)
 - Mercury**
 - [Appulses and Occultations of SAO Stars by Mercury: 1987-1995](#)
- Last updated 31 March 1994 by Doug Mink**
- Telescope Data Center** logo (Smithsonian Astrophysical Observatory) and [TDC Home Page](#)

- Navigation Bar:** Back Forward Home Reload Open... Save As... Clone New Window

Fitting a WCS using WCSTools

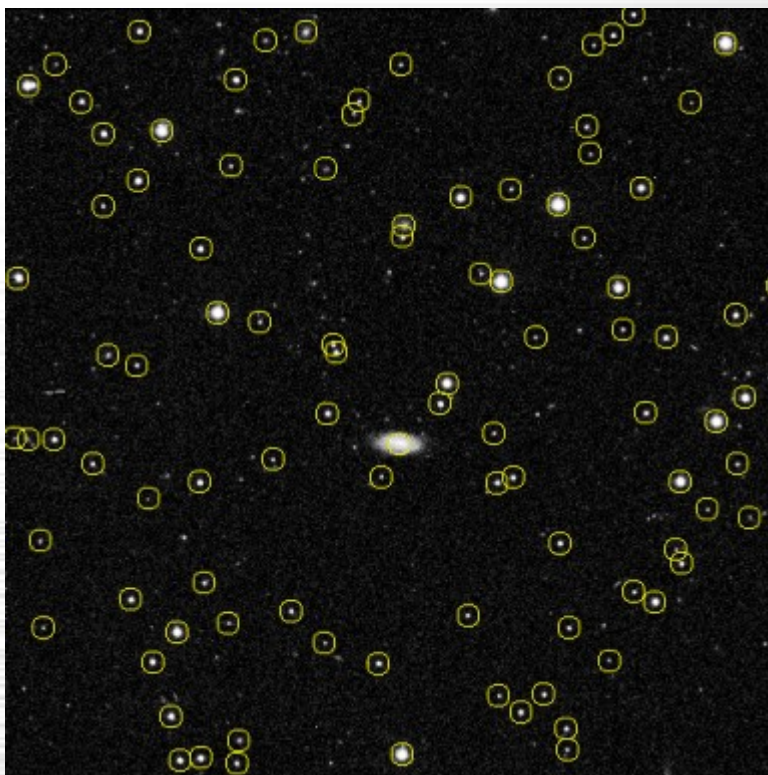


USNO-B1.0 Catalog plotted over image using telescope pointing

```
NAXIS = 2 / NUMBER OF AXES
NAXIS1 = 1024
NAXIS2 = 1024
RA = '16:15:56' /MEAN RA
DEC = '31:25:10' /MEAN DEC
EPOCH = 2000 /MEAN EPOCH
DATE-OBS= '1995-03-06T10:04:50' /UT DD/MM/YY AT END OF EXPOSURE
EXPTIME = 240.00 /INTEGRATION TIME, SECONDS
HJDN = 2449871.91686 /HELIOCENTRIC JULIAN DAY AT MIDDLE OF EXPOSURE
SECPIX = 0.652 /SEC OF ARC SPATIAL PIXEL , SET BY PARAMETERS
```

FITS header with limited WCS keywords from telescope

Fitting a WCS using WCSTools



USNO-B1.0 Catalog plotted over image after imwcs WCS fit

```
NAXIS = 2 / NUMBER OF AXES
NAXIS1 = 1024
NAXIS2 = 1024
RA = '16:15:56.591'
DEC = '+31:25:07.35'
EPOCH = 2000
RADECSYS= 'FK5'
EQUINOX = 2000
CRPIX1 = 516.9970
CRPIX2 = 513.4151
CD1_1 = -0.000178936537
CD1_2 = 0.000000555651
CD2_1 = 0.000000278868
CD2_2 = 0.000178740421
WCSRFCAT= 'ub1'
WCSIMCAT= 'testx90n.sex'
WCSMATCH= 147
WCSNREF = 217
WCSTOL = 2.5000
CTYPE1 = 'RA---TAN'
CTYPE2 = 'DEC---TAN'
CRVAL1 = 243.985795481
CRVAL2 = 31.418709691
SECPIX1 = 0.6442
SECPIX2 = 0.6435
WCSSEP = 0.257
```

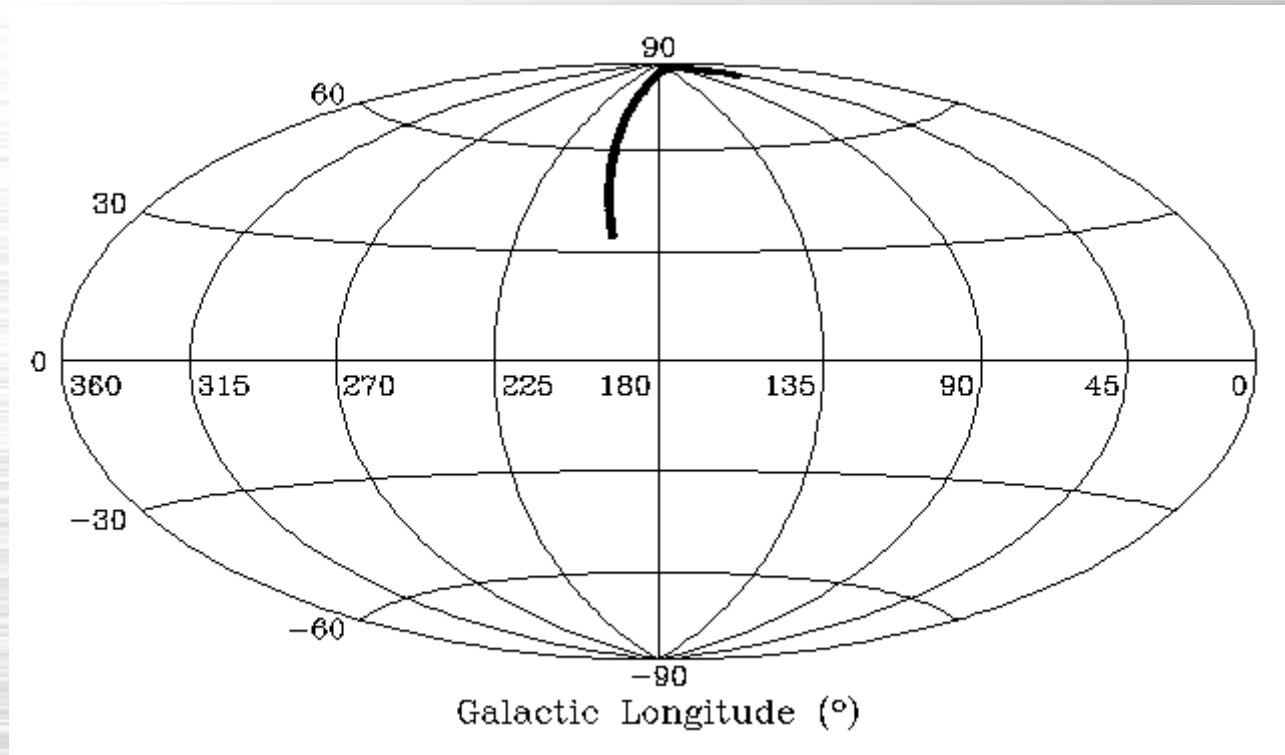
FITS header with WCS keywords after WCS fit using imwcs

More Catalogs

These catalogs are available and supported by [SAO/TDC search and mapping software](#).

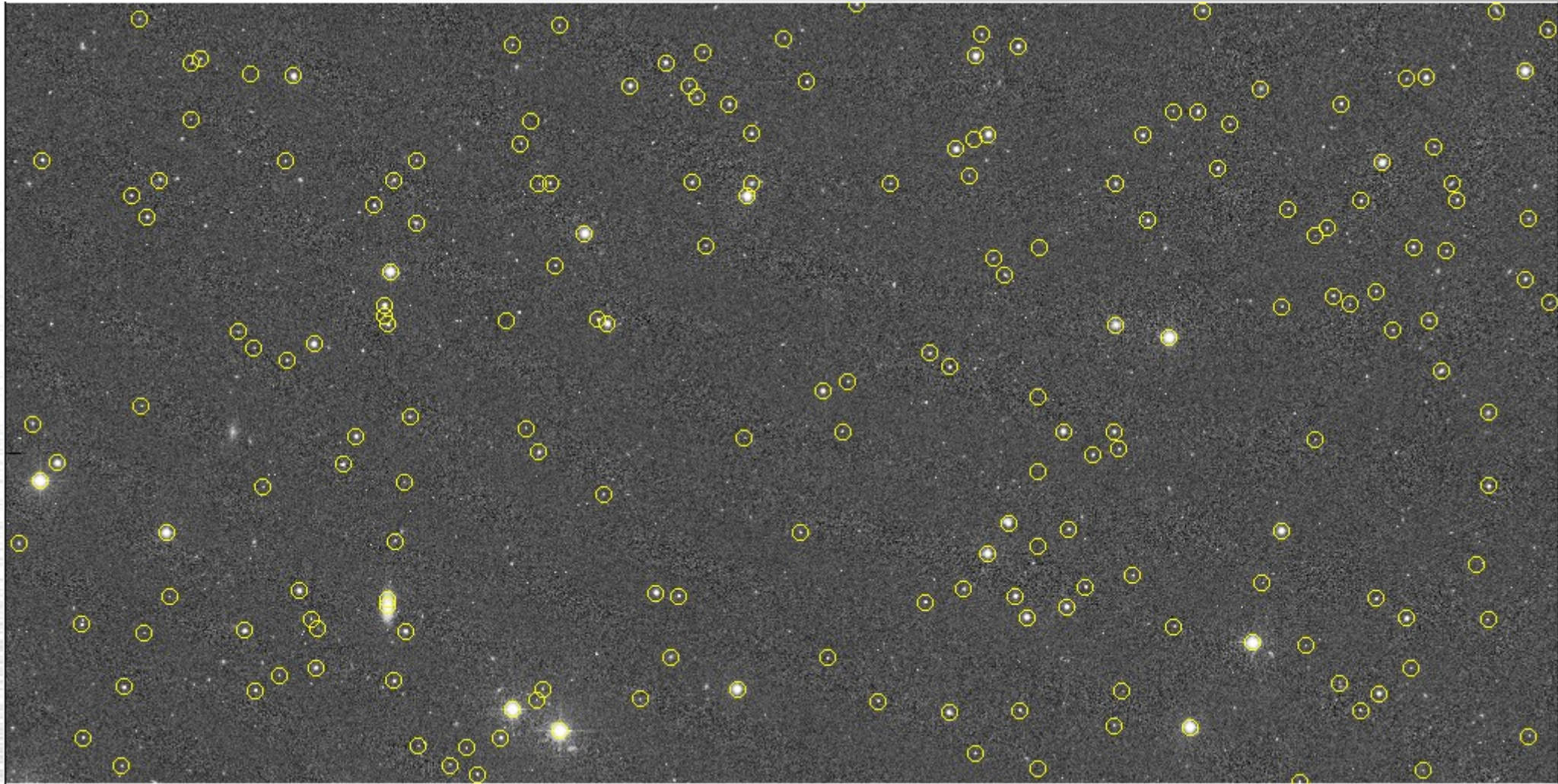
Catalog or Format	No. Stars	Bytes	Region Search	Image Search	Mapping
USNO-B1.0 Catalog	1,036,366,767	83,614,060,960	sub1 (scat)	imub1 (imcat)	
GSC II Catalog (2.2.01)	998,402,801	>80,000,000,000	sgsc2 (scat)	imgsc2 (imcat)	
2MASS Point Source Catalog	470,992,970	31,775,592,000	stmc (scat)	imtmc (imcat)	
2MASS Extended Source Catalog	1,647,599	11,533,193	stmx (scat)	imtmx (imcat)	
USNO UCAC3 Catalog	100,766,420	8,536,270,559	sucac3 (scat) ,	imucac3 (imcat)	
USNO UCAC2 Catalog	48,366,996	2,128,147,841	sucac2 (scat) ,	imucac2 (imcat)	
GSC-ACT Catalog	25,541,952	1,231,787,520	sgsca (scat)	imgsca (imcat)	
SDSS Photometry Catalog	53 million (DR1)		?? ssdss (scat)	imscdss (imcat)	
HST Guide Star Catalog	25,541,952	1,231,787,520	sgsc (scat)	imgsc (imcat)	skymap
Tycho-2 Catalog	2,539,913	528,721,576	sty2 (scat)	imty2 (imcat)	
USNO/Hipparcos ACT Catalog	988,758	318,380,076	sact (scat)	imact (imcat)	
SKY2000 Catalog	299,167	11,368,374	ssky2k (scat)	imsky2k (imcat)	skymap
PPM Catalog	378,910	22,734,656	sppm (scat)	imppm (imcat)	skymap
SAO Catalog	258,996	15,539,876	ssao (scat)	imsao (imcat)	skymap
IRAS Point Source Catalog	245,889	7,376,698	siras (scat)	imiras (imcat)	skymap
Hipparcos Catalog	118218	4492312	ship (scat)	imhip (imcat)	skymap
Yale Bright Star Catalog	3256	291548	sbsc (scat)	imbsc (imcat)	skymap
Starbase tab-delimited ASCII	varies	varies	scat	imcat	
TDC Space-Delimited ASCII	varies	varies	scat	imcat	skymap
TDC Binary	varies	varies	scat	imcat	skymap
USNO-A2.0 Catalog	526,280,881	6,315,370,572	sua2 (scat)	imua2 (imcat)	skymap
USNO-SA2.0 Catalog	55,368,239	664,418,868	susa2 (scat) ,	imusa2 (imcat)	
USNO-A1.0 Catalog	488,006,860	5,856,082,320	sua1 (scat)	imua1 (imcat)	skymap
USNO-SA1.0 Catalog	54,787,624	657,451,488	susa1 (scat)	imusa1 (imcat)	skymap
USNO J-1.0 Catalog	19,911,514	238,938,168	sujc (scat)	imujc (imcat)	

Testing Catalog Accuracy



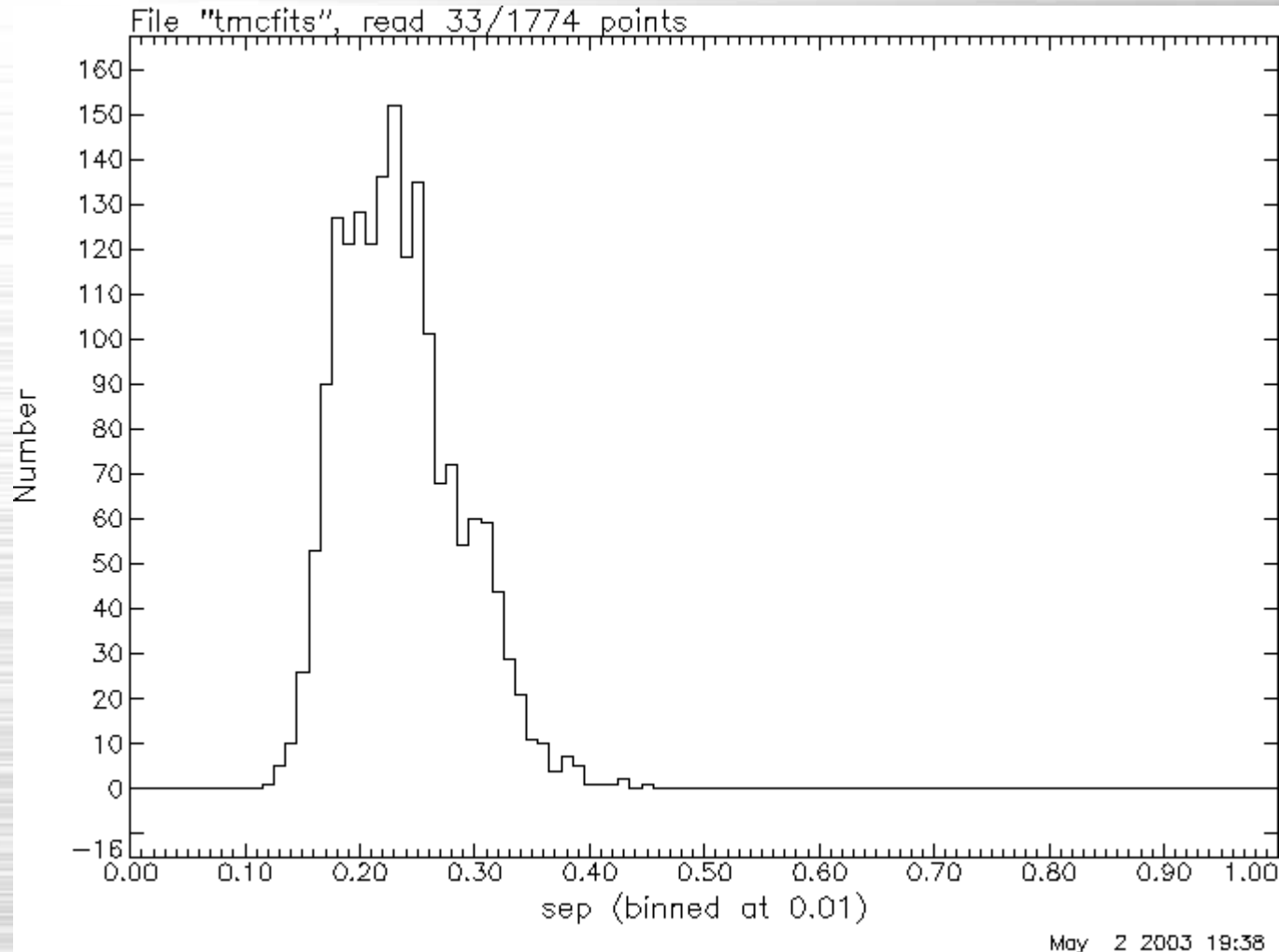
216 1x1 degree fields from the 8K array on the KPNO 36-inch telescope cover half of the CfA Century survey, 50 degrees across the sky

Testing Catalog Accuracy



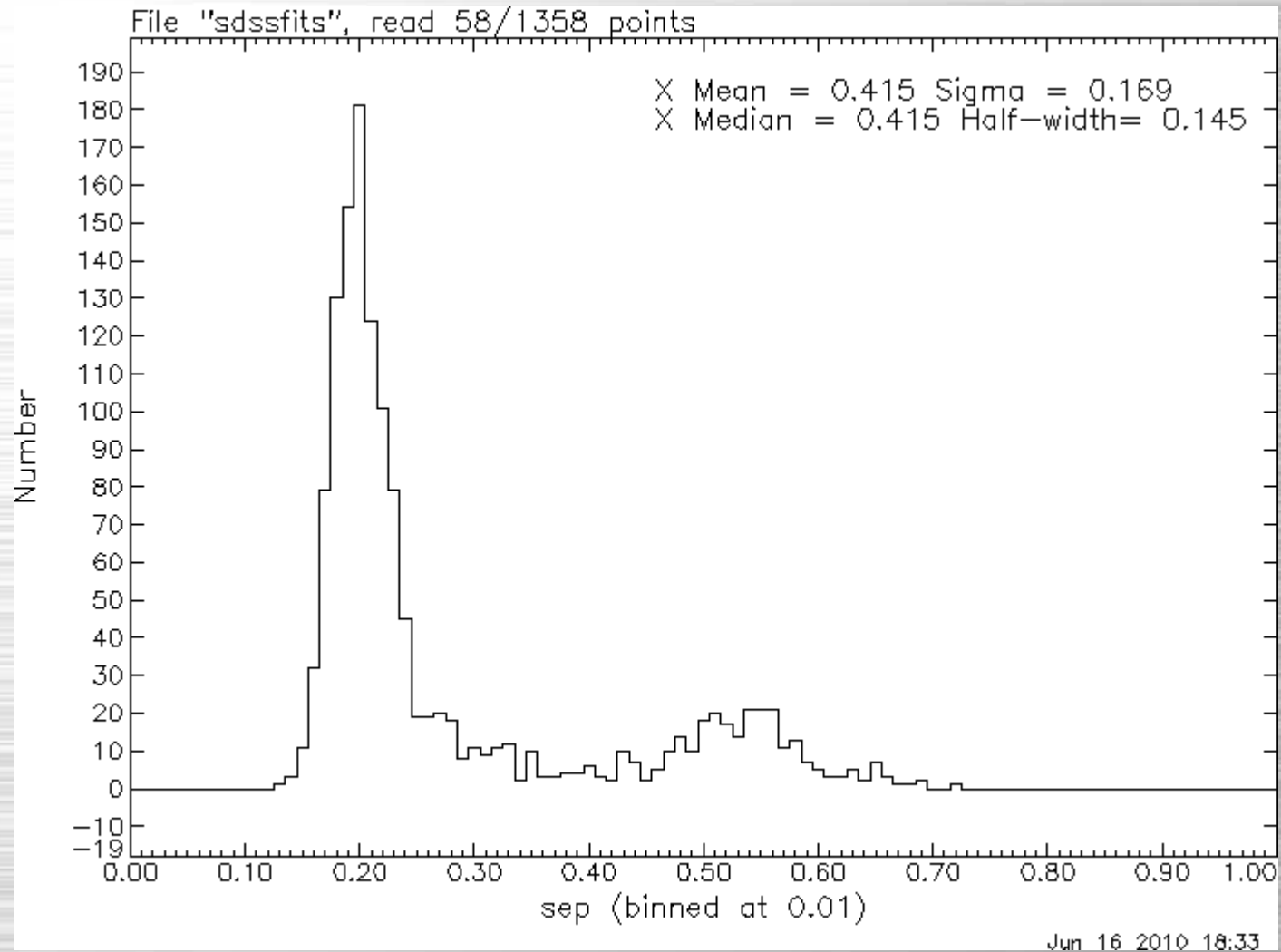
The 2MASS Point Source Catalog plotted over one of the 1728 test images

Testing Catalog Accuracy



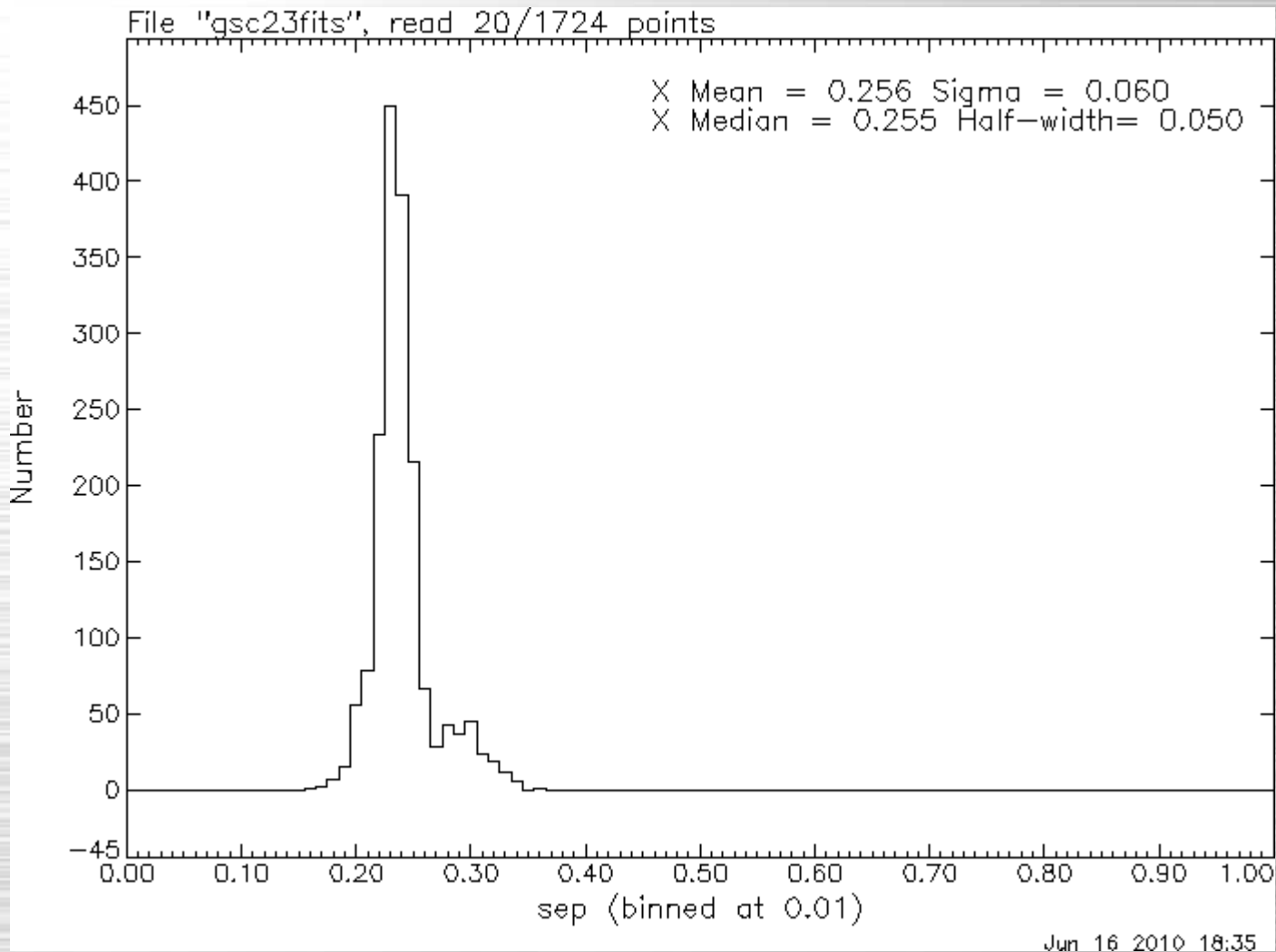
Differences between the 2MASS Point Source Catalog and a WCS fit to all of the images

Testing Catalog Accuracy



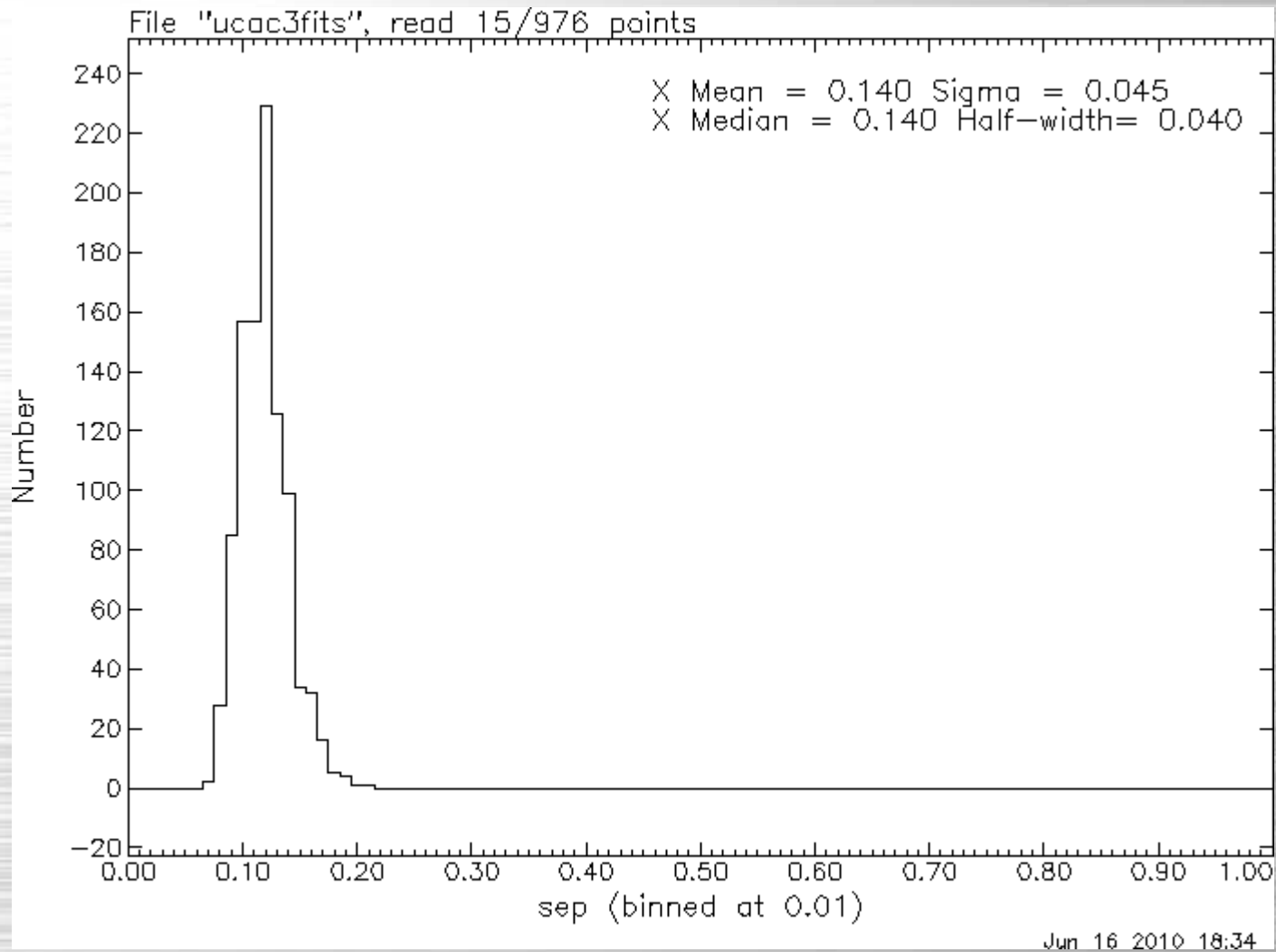
Differences between the Sloan Digital Sky Survey Catalog and a WCS fit to all of the images

Testing Catalog Accuracy



**Differences between the GSC 2.3 Catalog
and a WCS fit to most of the images**

Testing Catalog Accuracy



Differences between the 3rd USNO CCD Astrometric Catalog (UCAC3) and a WCS fit to half of the images

