How I Found My Place in the Universe
(and helped everybody else find theirs)

By

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Smithsonian Astrophysical Observatory

Harvard Smithsonian Center for Astrophysics, May 6, 2015

Outline

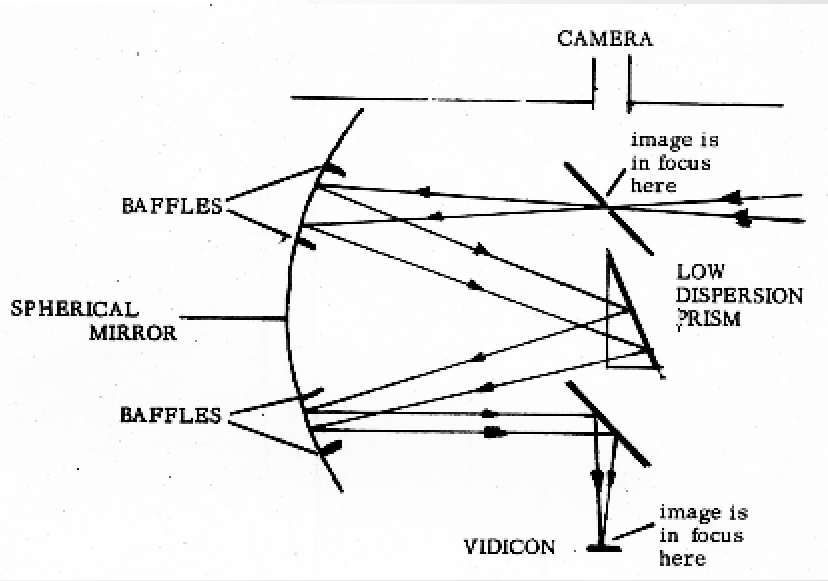
Planet Surfaces: 1973-4 Mars Observations

Stars and Planets: 1976-1990 Occultations

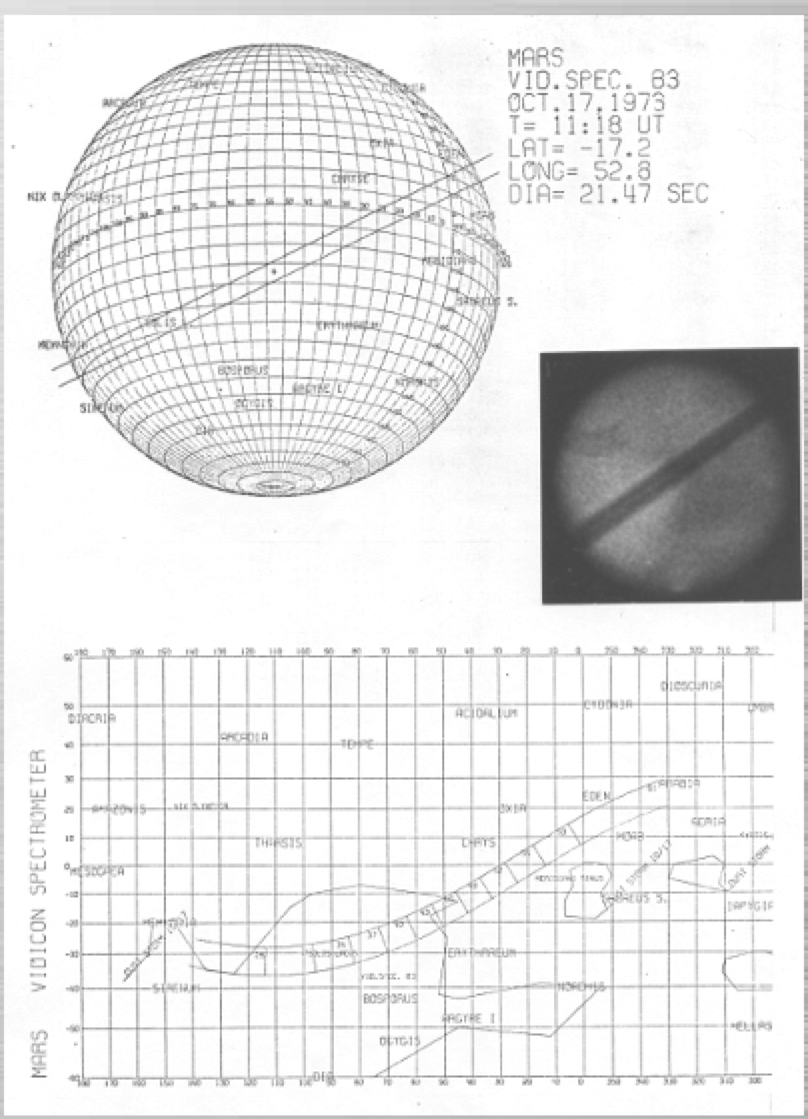
Milky Way: 1985-1990 IRAS and Spacelab 2 IRT

The Universe: 1990-2015 WCS, Plates, and Spectroscopy

It All Started With Mars



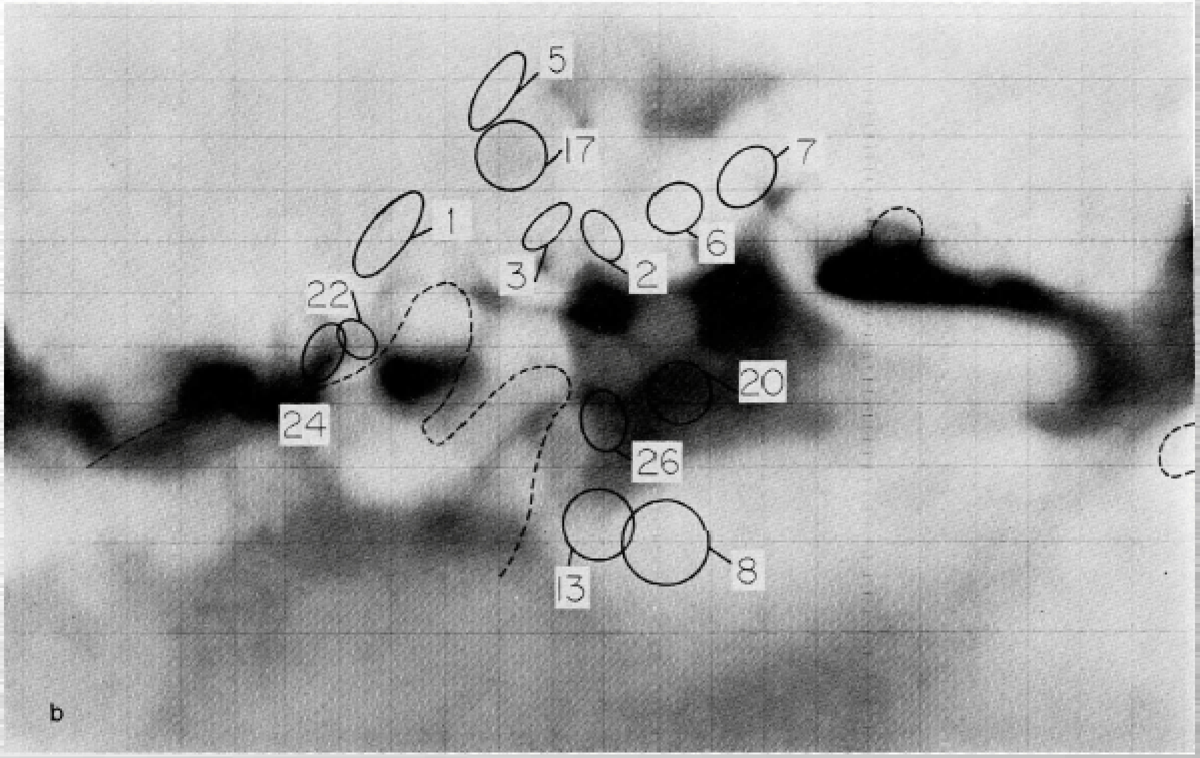
MIT Vidicon Spectrometer with camera monitoring slit in mirror



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)

Mars Photometry Projections

Orthographic: Face-on planet in sky

Mercator: Map of entire planet surface

Sky Plane Planetocentric: Predictions

Then Came Uranus

Circular No. 3047

Central Bureau for Astronomical Telegrams
INTERNATIONAL ASTRONOMICAL UNION
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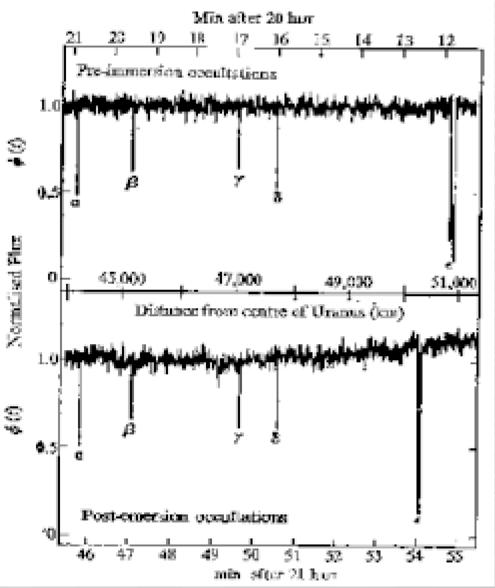
Telephone: (617) 864-5758

OCCULTATIONS BY URANUS AND (6) HEBE

R. Barrow, Gerard P. Kuiper Airborne Observatory, has relayed word from Perth of successful observations by J. L. Elliot in the southern Indian Ocean of last night's occultation of SAO 158687 by Uranus. A secondary occultation was also observed, this presumably being caused by a small body (not Miranda) in orbit about Uranus. J. Hers reports that heavy rain prevented observations in the vicinity of Johannesburg.

Preliminary reports reaching D. Dunham, Computer Sciences Corporation, suggest that the central line of the occultation of gamma Cet by (6) Hebe passed between 50 and 90 km north of Mexico City. Near the latter point the event lasted 55, beginning on Mar. 5d02h34m54s UT. A 2.5s-duration occultation was observed in Mexico City itself.



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OCCULTATION OF SAO 158687 BY URANUS AND SATELLITE BELT

Amplifying the brief announcement on IAUC 3047, J. L. Elliot reports that several secondary occultations of SAO 158687 on Mar. 10 were observed by E. Dunham, D. Mink and himself from the Kuiper Airborne Observatory and also by R. L. Millis, P. Birch and D. Trout at the Perth Observatory. Both groups independently concluded that these occultations were caused by bodies that are apparently part of a satellite belt about 40 000 km distant from the center of Uranus. The diameters of the satellites range from 100 km to much smaller values. The occultation by Uranus itself was successfully observed from the Airborne Observatory (located at Long. = -90o, Lat. = -50o) and lasted ~ 25 min centered on 21h06m UT. The Uranus occultation did not occur at the Perth Observatory. The secondary occultations took place during an 8-9 min interval around 20h16m UT and during a similar interval around 21h50m UT (although dawn prevented observations of the latter events in Perth).

M. K. V. Bappu, Indian Institute of Astrophysics, cables: "Using the 102-cm reflector at Kavalur (Long. = -5h15m19s.6, Lat. = +12o34'32"), Bhattacharyya and Kuppuswamy found the diminution of SAO 158687 during the occultation by the atmosphere of Uranus to be 0.046 magnitude at an effective wavelength of 7500 A. Visually and photoelectrically they observed the complete disappearance of the star for 8s.9 beginning at 20h19m15s UT and ascribe this to obscuration by a hitherto unknown satellite of the planet."

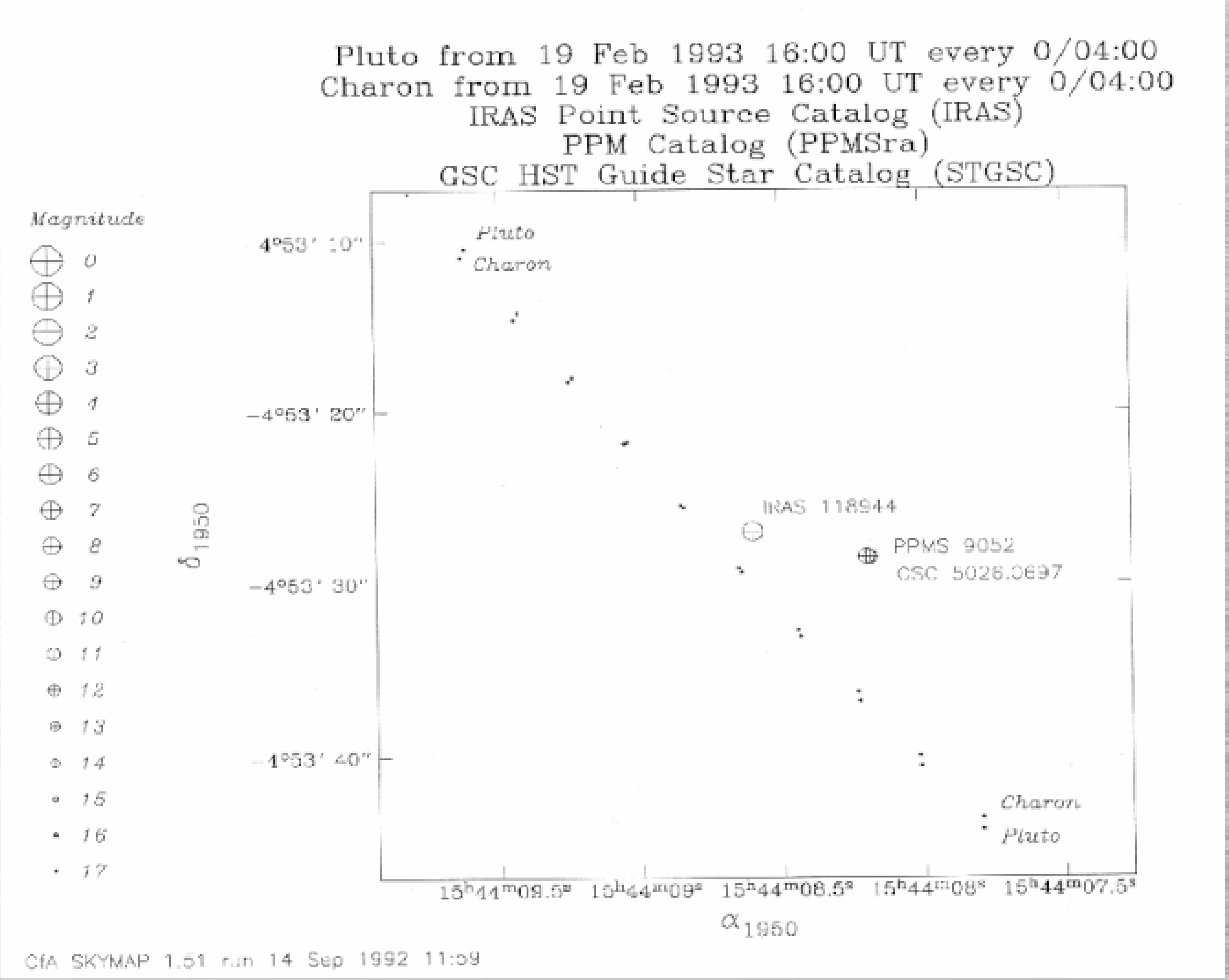
Computations by the undersigned show that the asymmetry in the times of the satellite occultations about the main occultation (as observed at the Airborne Observatory) is consistent with the existence of a circular belt in the plane of Uranus' equator. Allowance for foreshortening yields the radii of the inner and outer edges of the belt as 44 000 and 51 000 km, respectively. The Kavalur observation suggests occultation by a 100-km-sized body near the outer edge of the belt. Other observers are urged to examine their records for further evidence of this belt. At Sutherland, times of mid-occultation by the belt would have been 20h22m and 21h59m UT; at Mauritius, 20h23m and 21h54m; at Lembang, 20h20m and 21h46m; at Kyoto, 20h22m; at Helwan, 21h56m. Those wishing to attempt to detect the satellite belt directly are advised that at the present opposition it should be located from 3".5 to 4".0 to the north and south of the center of Uranus and from 2".7 to 3".1 to the east and west; the brightest bodies in it are expected to have mv ~ 19.

1977 March 14   (3048)   Brian G. Marsden

Occultation of SAO 158687 by Uranus and Its Rings

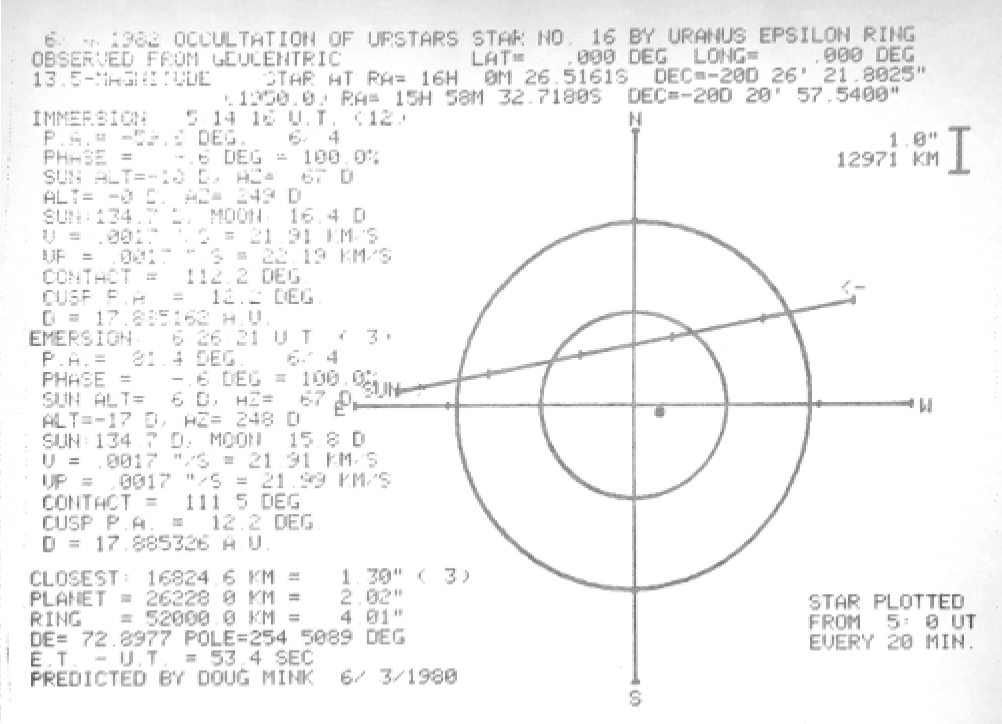
(Eliot, Dunham, and Mink, Nature 261, 328, May 26 1977)

Finding Stars to be Occulted

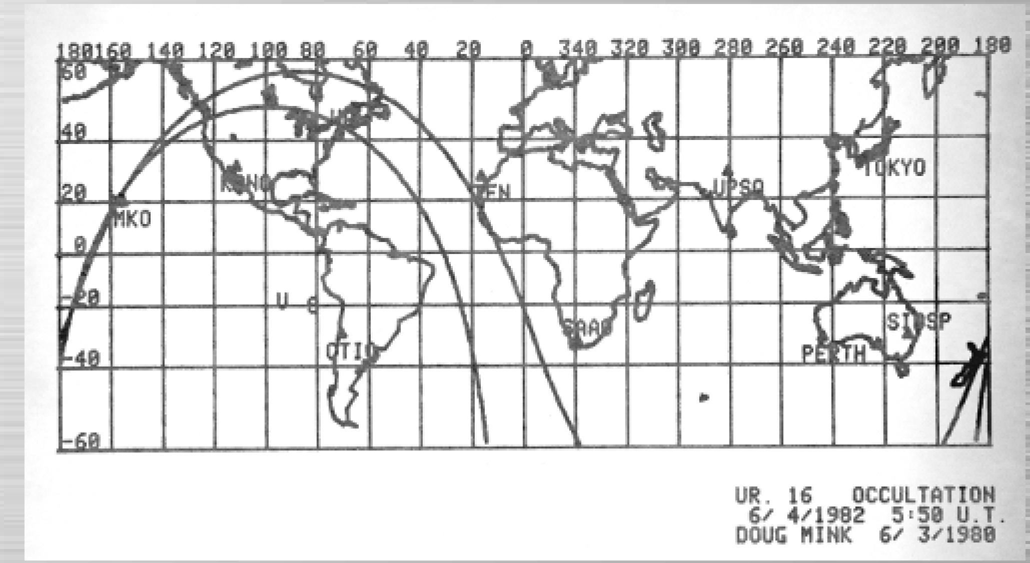


Map showing appulse of the Pluto/Charon system to a star
Note rotation of Charon around Pluto and variations in star position

Mapping observability

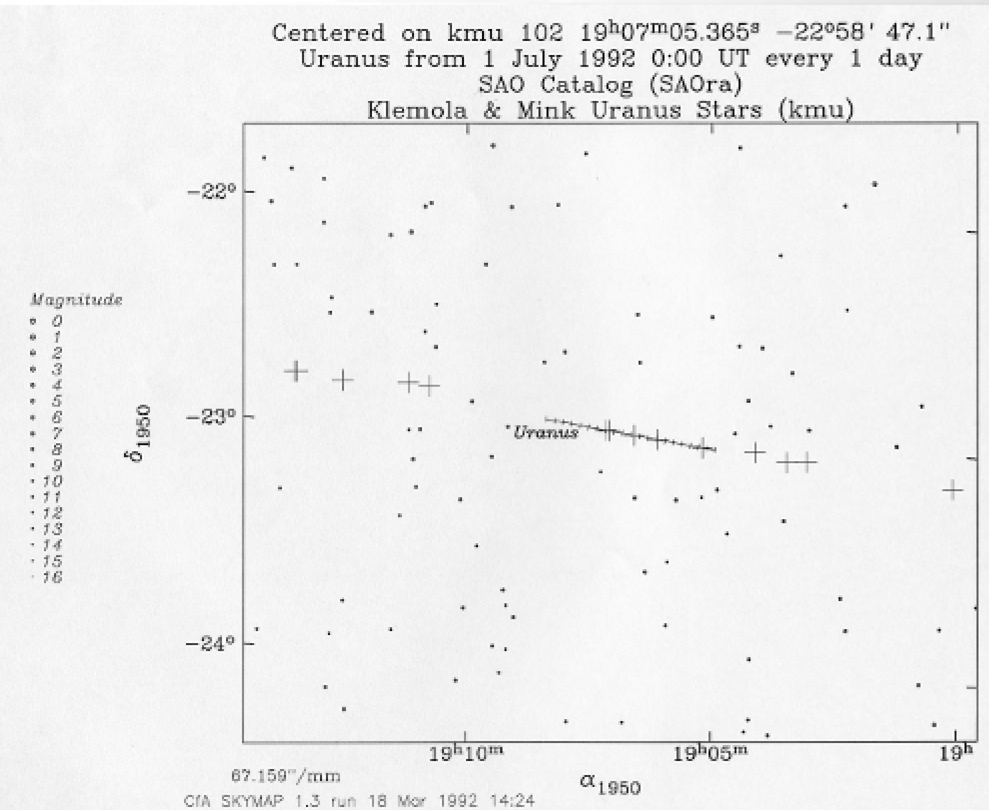


Geocentric prediction of Uranus 16

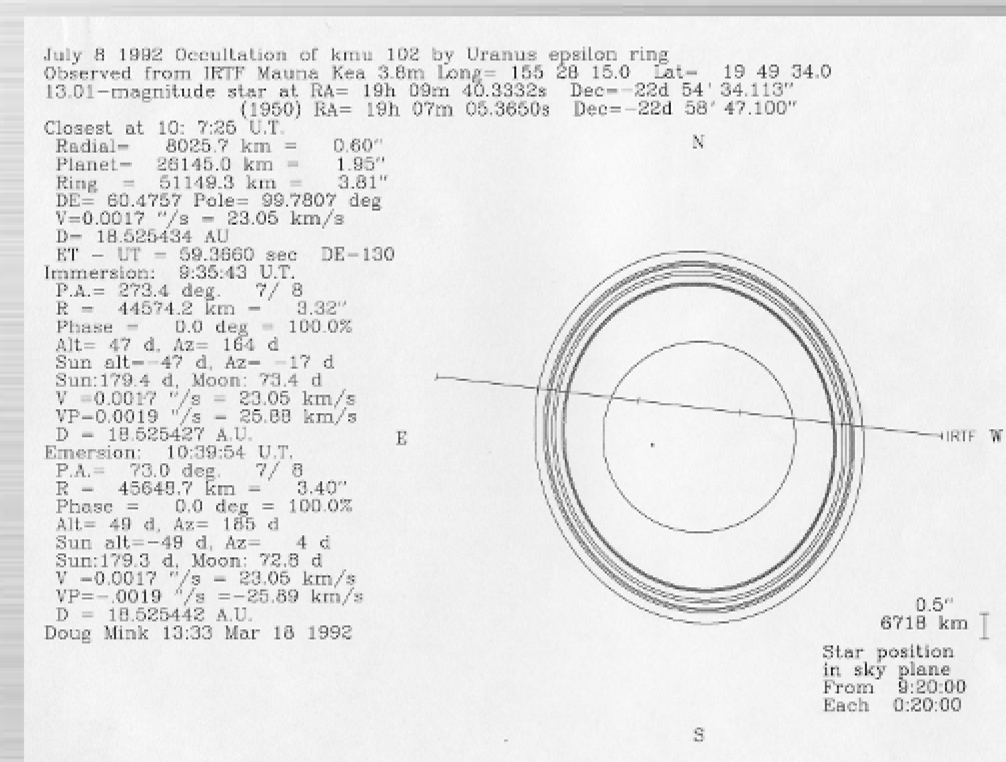


Sun down, Uranus up for Uranus 16

Predicting Occultations



Palomar Sky Survey overlay
for stars occulted by Uranus



Sky plane map of Uranus
ring occultation of KMU102

Predicting Occultations

Venus Occultation of SAO 160149 on January 21, 2003

Click here for predictions for various cities

Catalog positions at 2003-01-21 11:00 UT

The arcsec column gives the distance from the SAO position

SAO_number	RA2000	Dec2000	Mag	Type
160149	16:53:54.416	-19:18:50.17	8.20	G0

PPM_number	RA2000	Dec2000	Mag	Type	Arcsec
232288	16:53:54.583	-19:18:48.54	8.60	G0	2.87

Tycho2_num	RA2000	Dec2000	MagB	MagV	Arcsec
6226.02681	16:53:54.550	-19:18:51.04	9.14	8.57	2.08

The following positions are at the catalog epochs

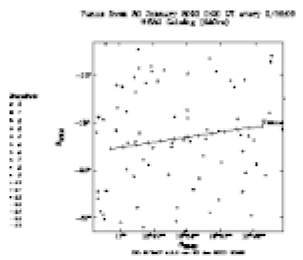
GSC_number	RA2000	Dec2000	Mag	Class	Band	N	Arcsec
6226.0268	16:53:54.509	-19:18:50.44	8.51	0	8	1	1.28

GSC-ACTnum	RA2000	Dec2000	Mag	Class	Band	N	Arcsec
6226.0268	16:53:54.552	-19:18:50.15	8.51	0	8	1	1.84

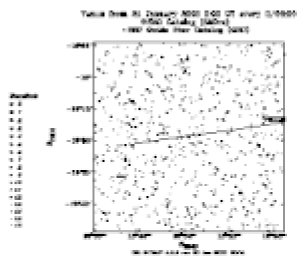
2MASS_num.	RA2000	Dec2000	MagJ	MagH	MagK	Arcsec
25.2772036	16:53:54.544	-19:18:50.92	7.399	7.151	7.067	1.93

USNO_A2_number	RA2000	Dec2000	MagB	MagR	Plate	Arcsec
0675.16930485	16:53:54.562	-19:18:48.34	9.2	9.9	808	2.62

Finding Charts

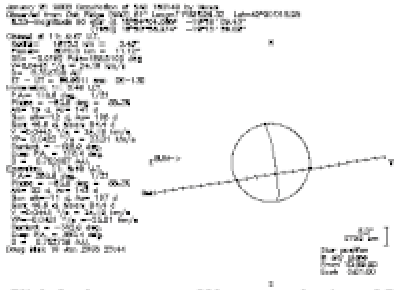


Click for larger map of 5º field around star

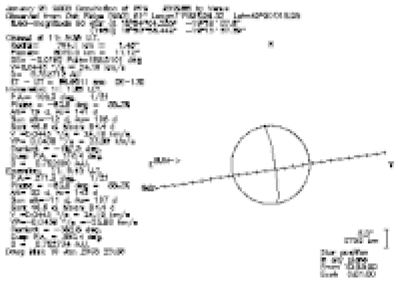


Click for larger map of 1º field around star

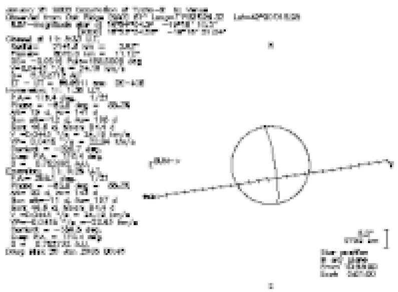
Predictions for Different Catalog Positions



Click for larger map of Venus occultation of SAO position



Click for larger map of Venus occultation of PPM position



Click for larger map of Venus occultation of Tycho-2 position

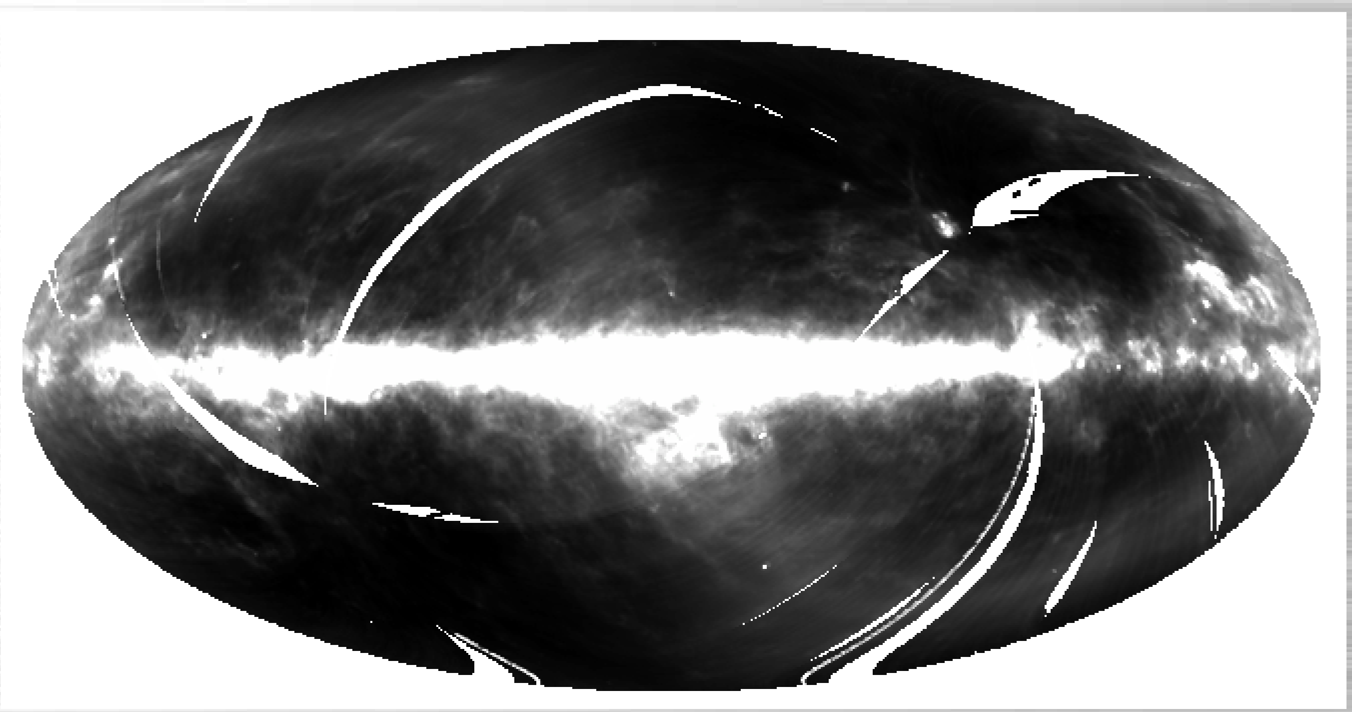
Occultation Projections

Mercator: Observability maps of earth's surface

Linear: Sky maps with stars and planets

Sky Plane: Planetocentric Occultation Predictions

All Sky IR Mapping from Space



IRAS 120 µm

Aitoff All-Sky Projection

1984 Data Release HCON 1

IRAS Projections
(used with IRT, too)

Infrared Astronomical Satellite (IRAS) Explanatory Supplement (1988)
Edited by C.A. Beichman, G. Neugebauer, H.J. Habing, P.E. Clegg, T.J. Chester
X. The Formats of the IRAS Catalogs and Atlases, D. Extended Emission

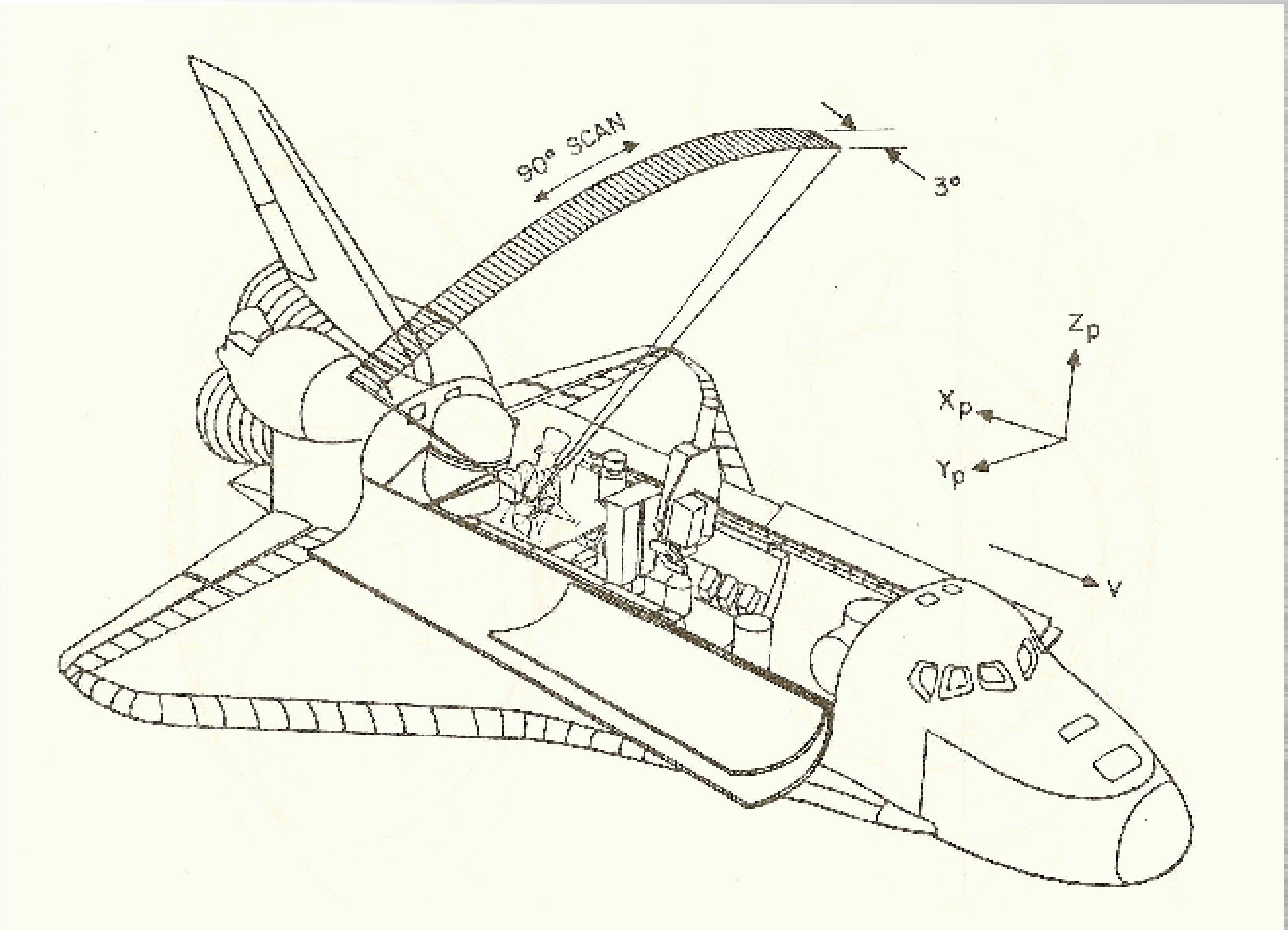
Polar: Maps of sky around North and South Poles

Aitoff: Map of entire sky

Sinusoidal: Maps of galactic plane

Gnomonic: Maps of regions of sky

All-Sky IR Mapping from Space



Spacelab 2 Infrared Telescope

(Space Shuttle Challenger, July 1985)

All Sky IR Mapping from Space

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COMMENT   PROJECTION FORMULAE:
COMMENT    FORWARD FORMULA; XLON0 IS THE CENTER LONGITUDE OF THE
COMMENT        MAP.  ARC-SINE AND ARC-COSINE FUNCTIONS ARE REQUIRED.
COMMENT     R2D = 45. / ATAN(1.)
COMMENT     PIX = 2.
COMMENT     RHO = ACOS( COS(XLAT) * COS((XLON-XLON0)/2.) )
COMMENT     THETA = ASIN( COS(XLAT) * SIN((XLON-XLON0)/2.) / SIN(RHO) )
COMMENT     F = 2. * PIX * R2D * SIN(RHO/2.)
COMMENT     SAMPLE = -2. * F * SIN(THETA)
COMMENT     XLINE = -F * COS(THETA)
COMMENT     IF(XLAT .LT. 0.)  XLINE = -XLINE
COMMENT
COMMENT    REVERSE FORMULA; XLON0 IS THE CENTER LONGITUDE OF THE MAP.
COMMENT         ARC-SINE AND ARC-COSINE FUNCTIONS NEEDED.
COMMENT     R2D = 45. / ATAN(1.)
COMMENT     PIX = 2.
COMMENT     Y = -XLINE / (PIX * 2. * R2D)
COMMENT     X = -SAMPLE / (PIX * 2. * R2D)
COMMENT     A = SQRT(4.-X*X-4.*Y*Y)
COMMENT     XLAT = R2D * ASIN(A*Y)
COMMENT     XLON = XLON0 + 2. * R2D * ASIN(A*X/(2.*COS(XLAT)))
COMMENT
COMMENT   REFERENCES:
COMMENT    IRAS SDAS SOFTWARE INTERFACE SPECIFICATION(SIS)  #623-94/NO. SF05
COMMENT    ASTRON. ASTROPHYS. SUPPL. SER. 44,(1981) 363-370 (RE:FITS)
COMMENT   RECONCILIATION OF FITS PARMS W/ SIS SF05 PARMS:
COMMENT    NAXIS1 = (ES - SS + 1); NAXIS2 = (EL - SL + 1);
COMMENT    CRPIX1 = (1 - SS);      CRPIX2 = (1 - SL)
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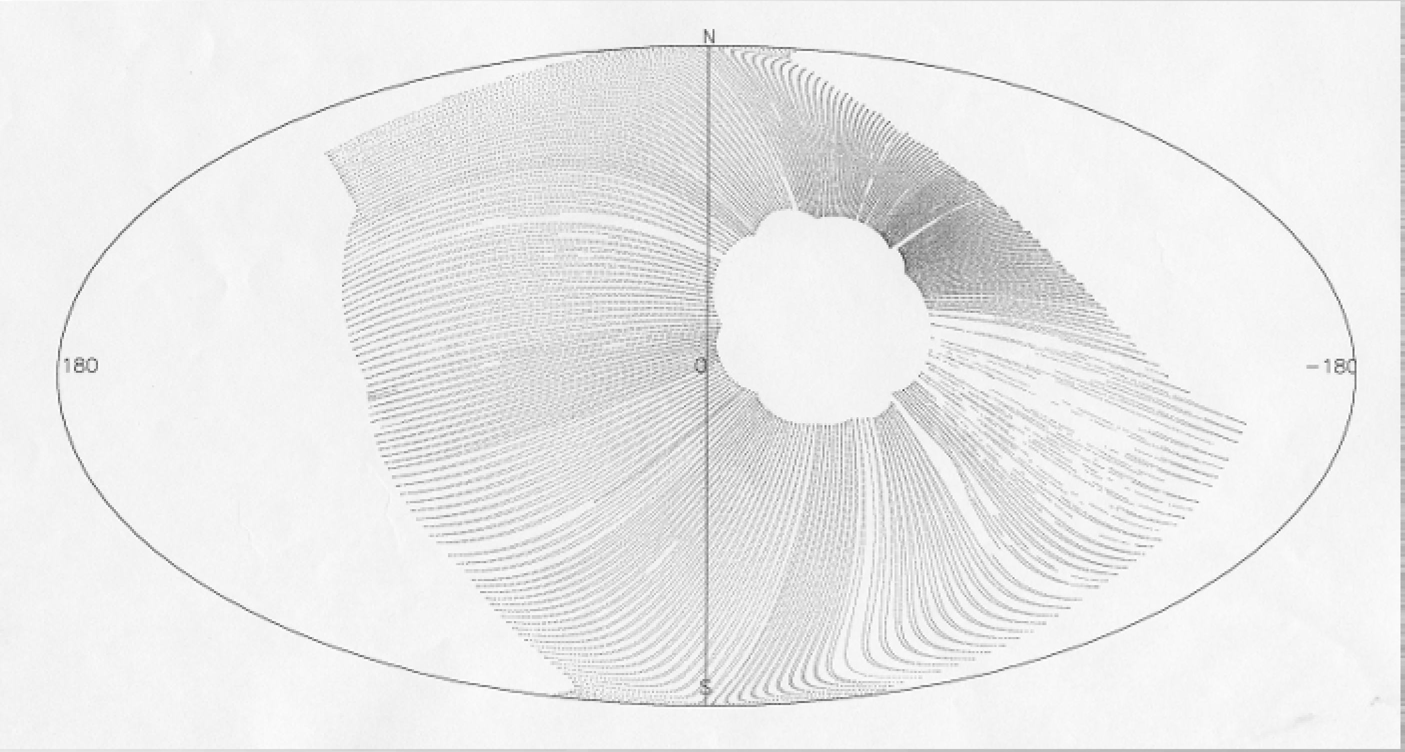
IRAS Aitoff All-Sky Projection Fortran Code in FITS Header

All Sky IR Mapping from IRT



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

Spacelab 2 Infrared Telescope

(Space Shuttle Challenger, July 1985)

Galactic Center from IRT

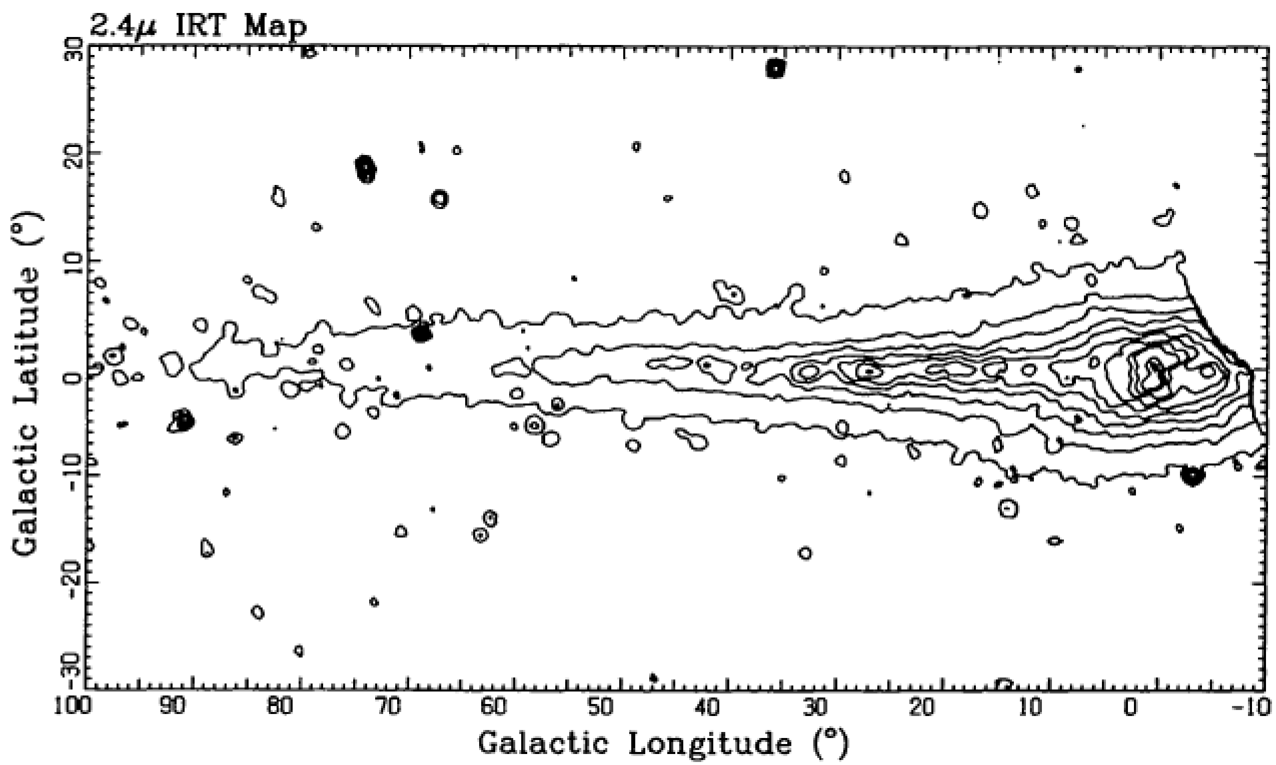
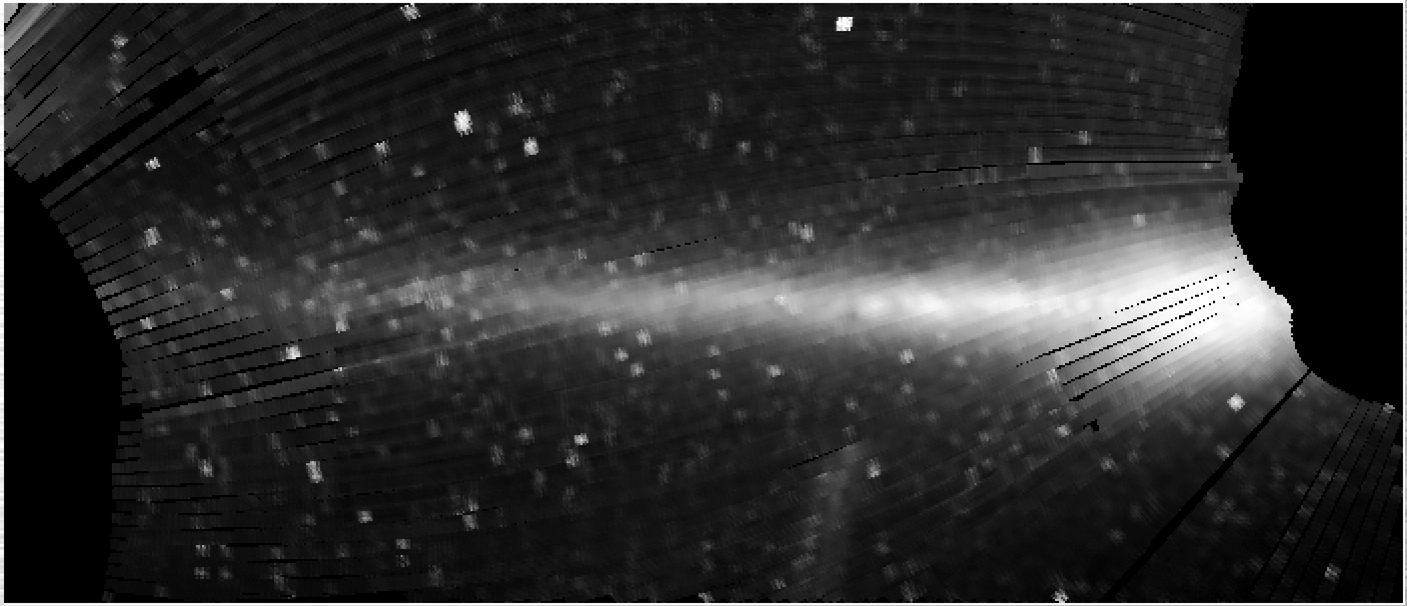


FIG. 5.—Contour map of the 2.4 μm emission from the Galactic plane region. The contours are spaced logarithmically in 10 steps between 0.67×10^{-10} and 16×10^{-10} W cm^{-2} μm^{-1} sr^{-1}.

Linear Projection in Galactic Coordinates

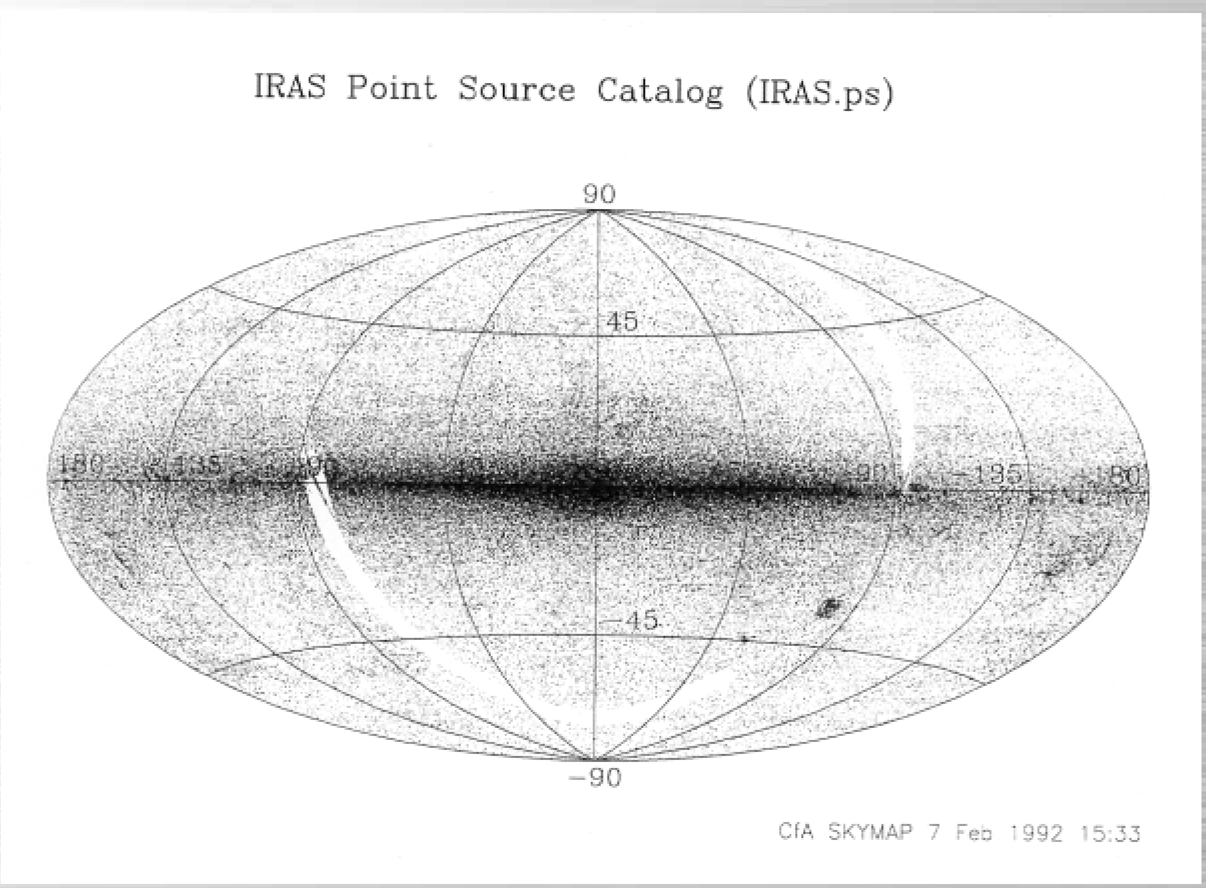
(Kent, Mink, Fazio, Koch, Melnick, Tardiff, Maxson, ApJS 78:403-408, 1992)

Galactic Center from IRT

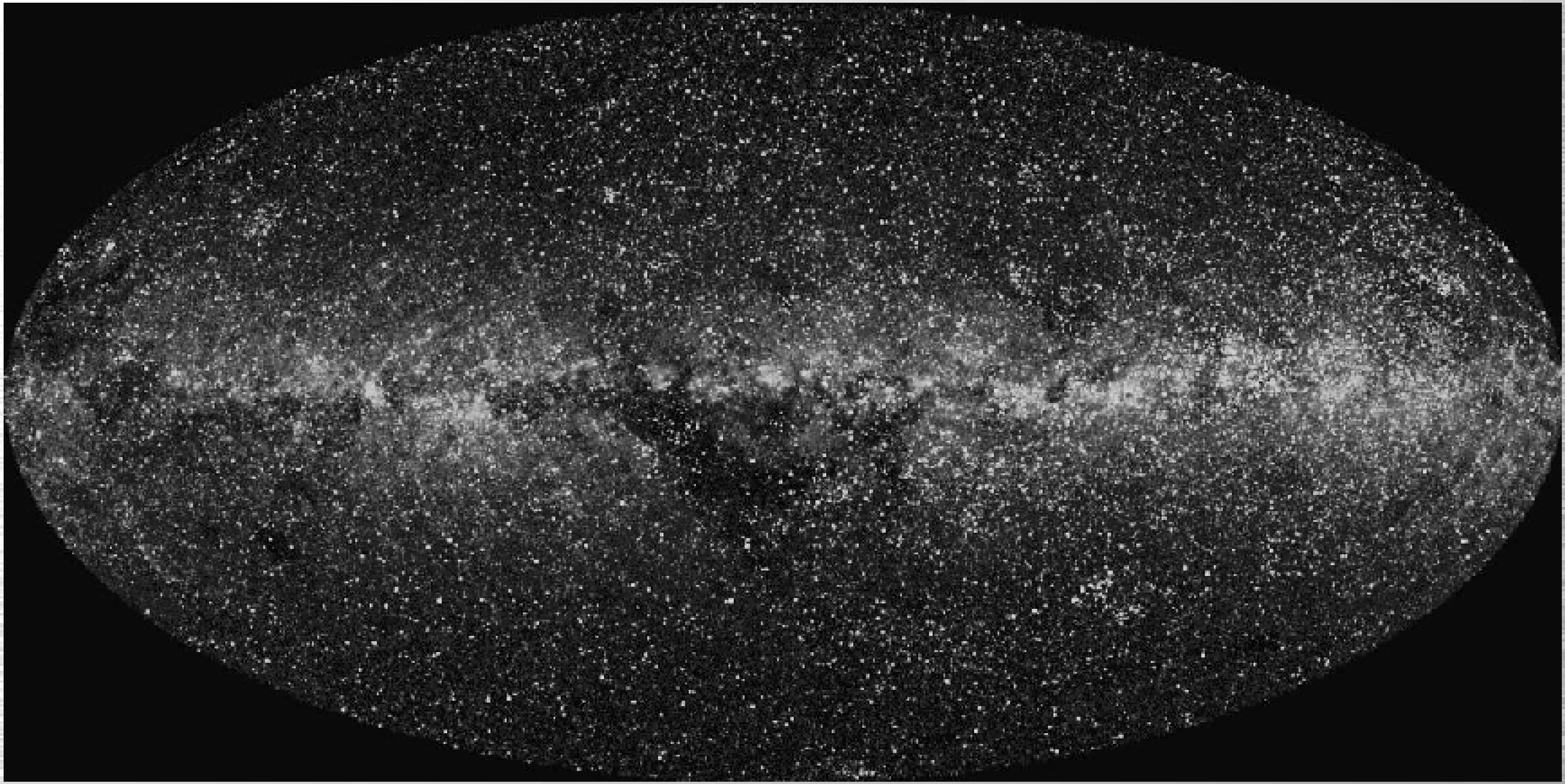


Linear Projection in Galactic Coordinates
(Mink, August 1990, unpublished)

All-Sky Maps meet Catalogs

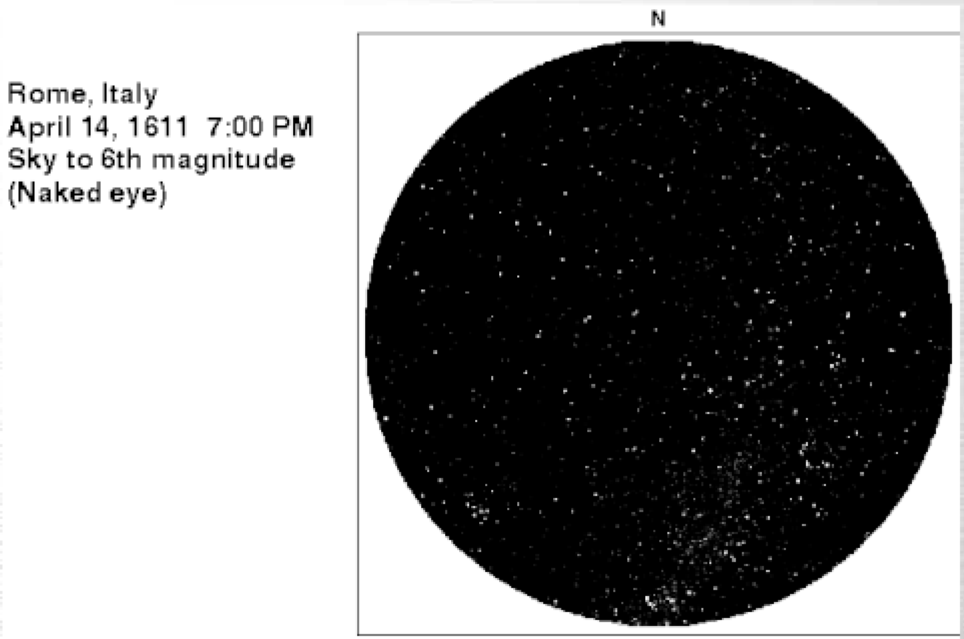


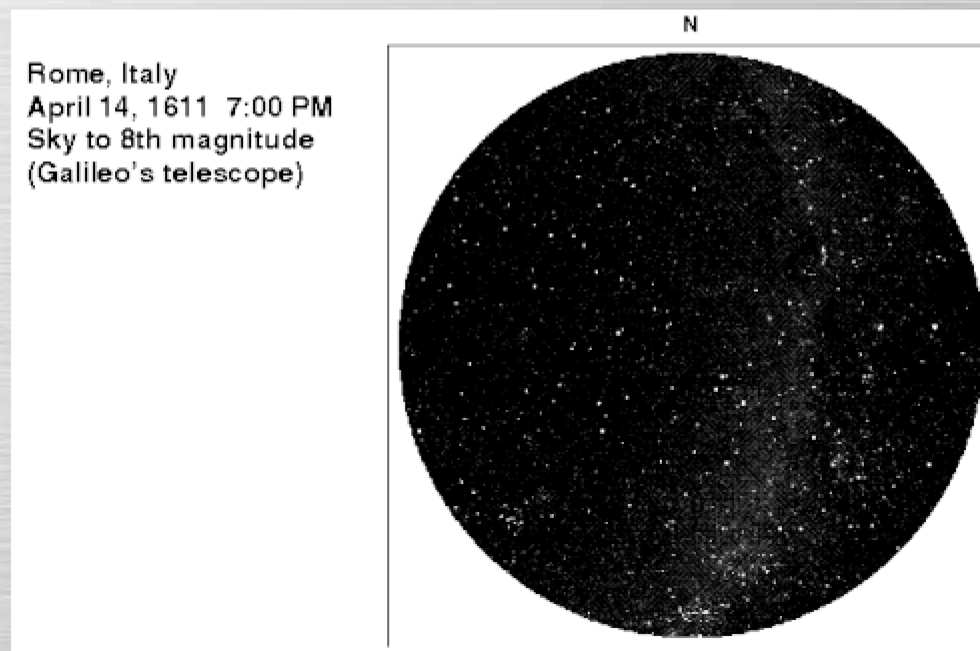
All-Sky Maps meet Catalogs



Space Telescope Guide Star Catalog, Galactic Plane, Aitoff Projection
(Mink, D.J. 1994. In Astronomical Data Analysis Software and Systems III, A.S.P. Conference Series, Vol. 61, 1994, Dennis R. Crabtree, R.J. Hanisch, and Jeannette Barnes, eds., p. 191)

Galileo's Telescope Expands the Sky

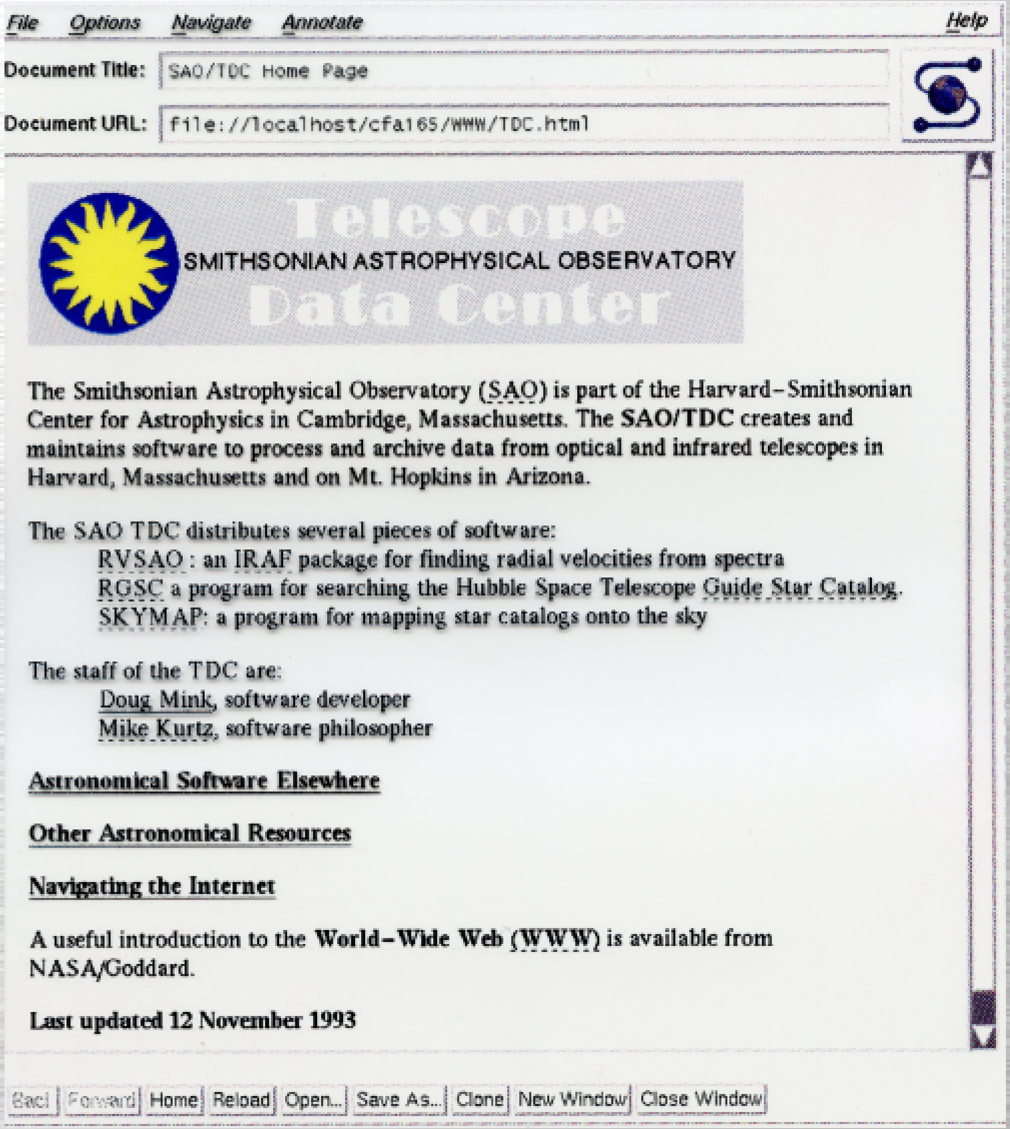




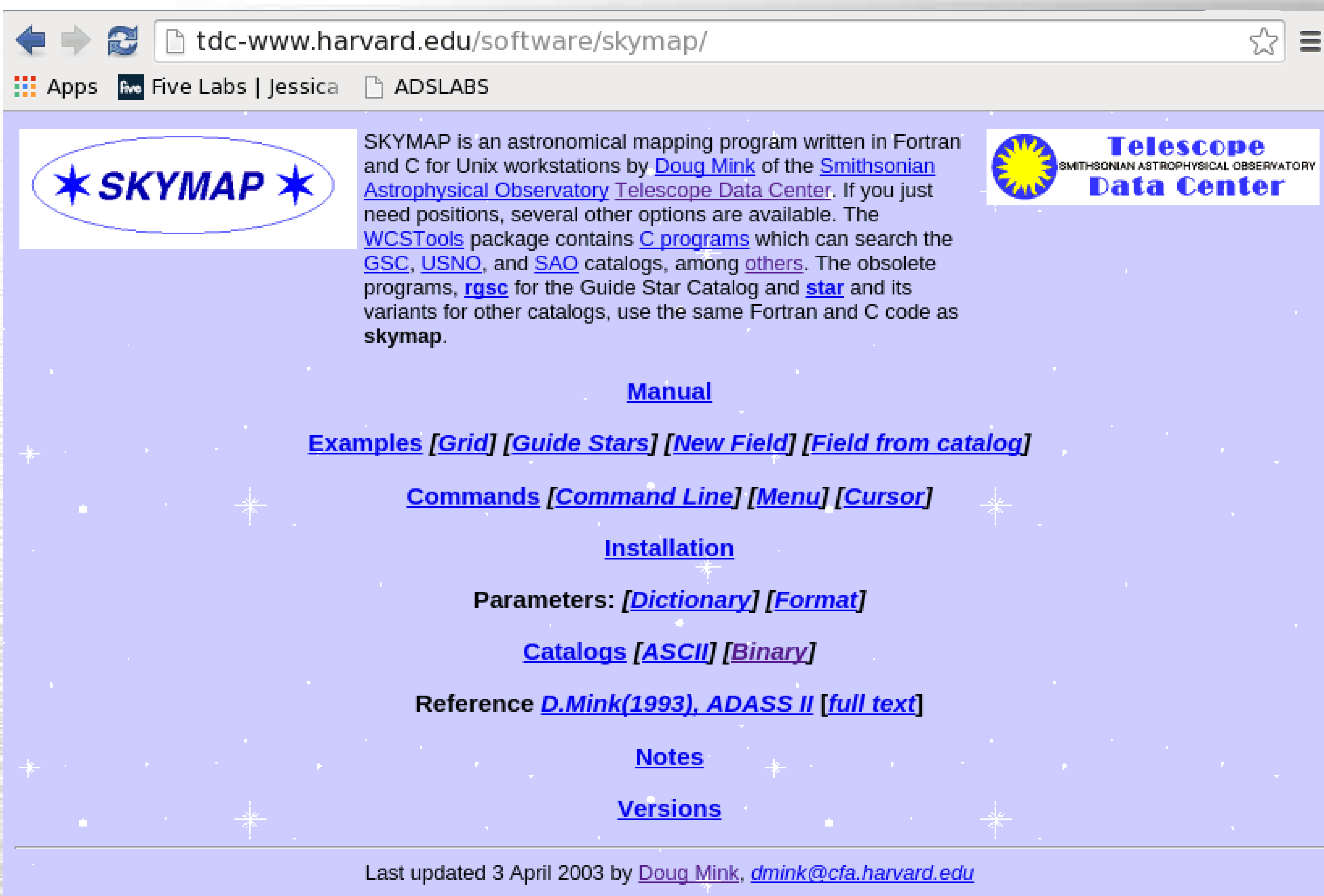
Polar projections centered on local apex in Rome

Owen Gingerich will present a keynote address at a conference sponsored by the American Academy of Rome celebrating the moment in 1611 when Galileo Galliei proudly presented the "telescope" to the intelligentsia of Rome... the Academy asked Paine Professor of Astronomy and director of the Harvard-Smithsonian Center for Astrophysics Irwin Shapiro and his Center colleague Douglas Mink to produce a map of the stars as they appeared over Rome on the night of April 14, 1611. For their efforts, Shapiro and Mink received a Jeroboam of champagne; Gingerich, however, got a trip to Rome.
(Harvard Gazette, April 10, 1997)

Onto the World Wide Web



Documentation on the World Wide Web



Digitized Sky Survey Projection

AURA (1993-1994), "The Digitized Sky Survey" CDROM Manual
Doggett, J. (1997), http://gsss.stsci.edu/Software/GetImage/GetImage.htm
Mink, Jessica (1999), "WCSTools: Image Astrometry Toolkit", http://tdc-www.harvard.edu/software/wcstools/

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UT      = '06:02:00.00     ' /UT time of observation
EPOCH   =  1.9552226562500E+03 /Epoch of plate
PLTRAH  =                   10 /Plate center RA
PLTRAM  =                    7 /
PLTRAS  =  5.5528480000000E+01 /
PLTDECSN= '+               ' /Plate center Dec
PLTDECD =                   17 /
PLTDECM =                   17 /
PLTDECS =  3.8380860000000E+01 /
EQUINOX =  2.0000000000000E+03 /Julian Reference frame equinox
EXPOSURE=  5.0000000000000E+01 /Exposure time minutes
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PLTGRADE=                    1 /Plate grade
PLTSCALE=  6.7200000000000E+01 /Plate Scale arcsec per mm
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SITELONG= '-116:51:48.00   ' /Longitude of Observatory
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CNPIX2  =                 2023 /Y corner
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AMDX4   = -1.3607216767070E-05 /
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AMDY3   = -6.8591056129270E+01 /
AMDY4   = -1.3176449798960E-05 /
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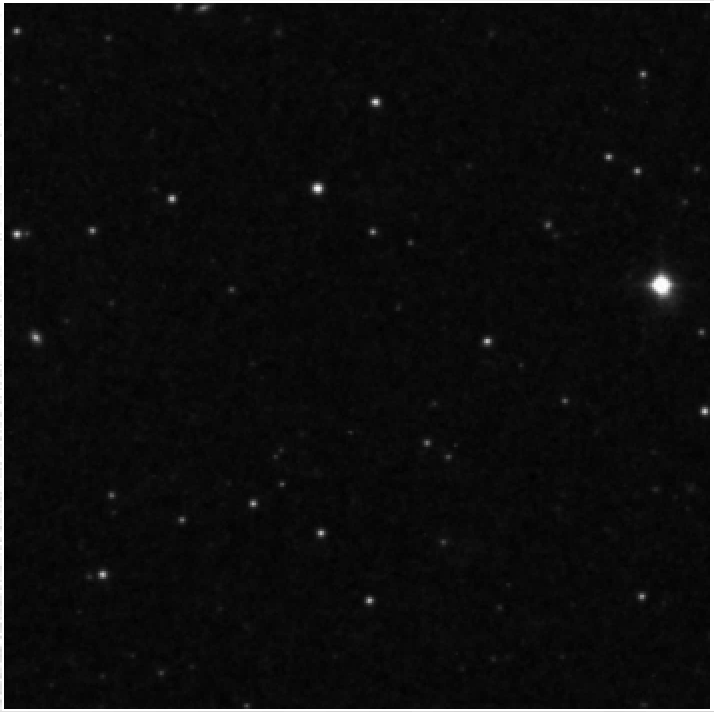
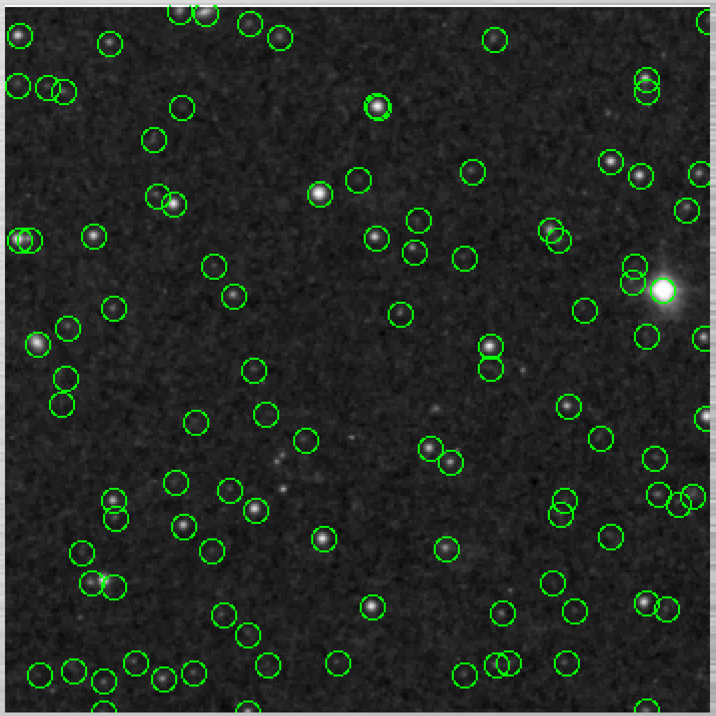
Digitized Sky Survey Projection

Mink, Jessica (1999), "WCSTools: Image Astrometry Toolkit"
, http://tdc-www.harvard.edu/software/wcstools/



DS9 display of DSS image with previous header



DS9 display of same DSS image with regions generated by WCSTools imcat program which remotely accessed the GSC2 catalog

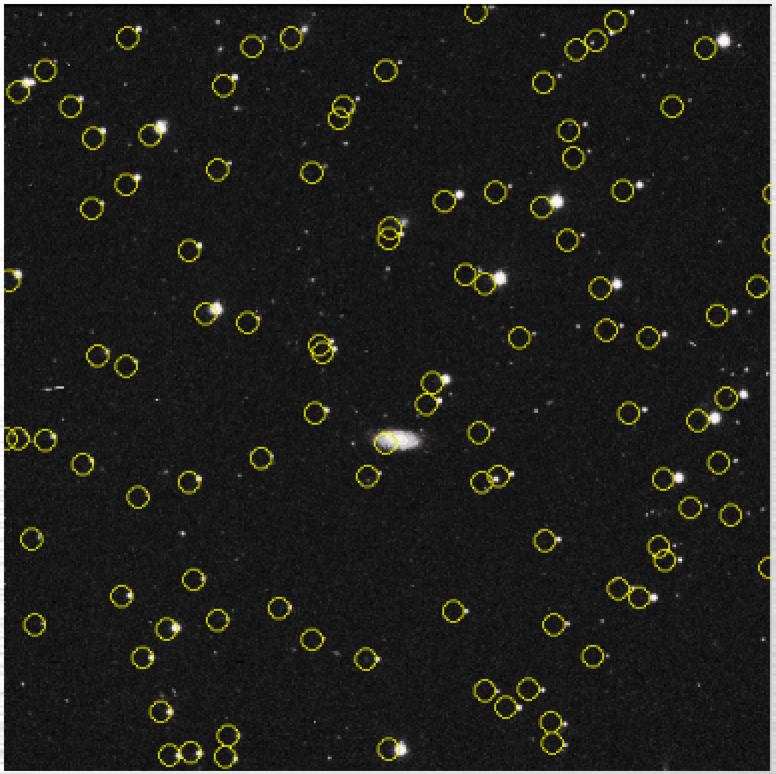
AIPS Projections

The eight most commonly-used projections of classic AIPS may be computed using the *worldpos* and *worldpix* subroutines written by Bill Cotton and Eric Greisen of NRAO:

SIN: Orthographic projection
TAN: Tangent plane projection
ARC: Zenithal equidistant projection
NCP: North celestial pole projection
GLS: Sanson-Flemsteed sinusoidal projection
MER: Mercator projection
AIT: Hammer-Aitoff equal area all-sky projection
STG: Stereographic projection
(zenithal orthomorphic)

AIPS Memo 27: 1983-11-15: "Non-Linear Coordinate Systems in AIPS" Eric W. Greisen, NRAO
AIPS Memo 46: 1986-05-20: "Additional Non-linear Coordinates" Eric W. Greisen, NRAO

Fitting a WCS using WCSTools



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NAXIS2  =                 1024
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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
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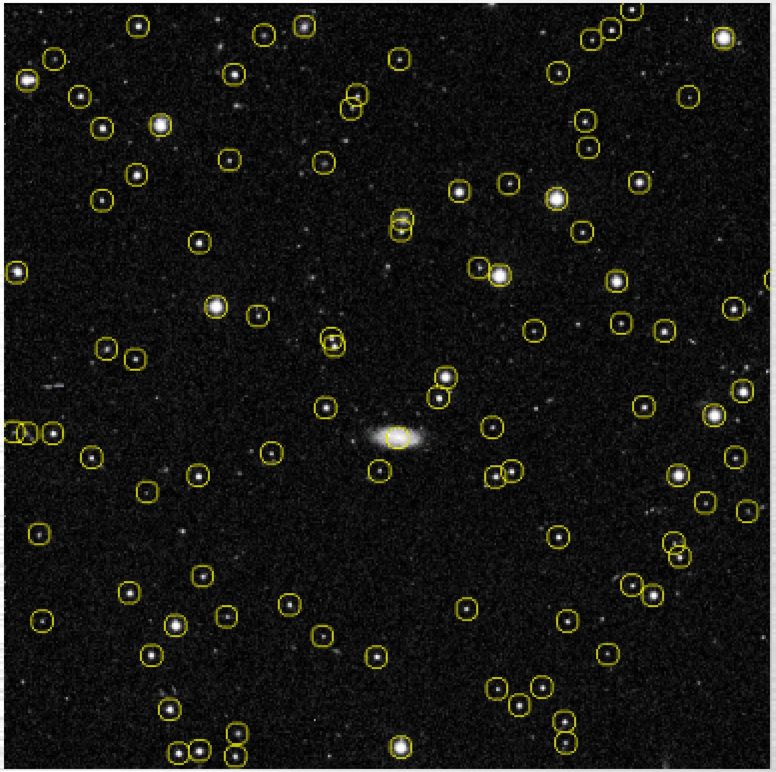
USNO-B1.0 Catalog plotted over image using telescope pointing

FITS header with limited WCS keywords from telescope

Fitting a WCS using WCSTools



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

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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= 'testx90m.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

Finding Stars for WCSTools

WCSTools supports several ways to find
the star-like objects in an image

- WCSTools IMSTAR task (also built into IMWCS)

- IRAF DAOFIND task
 (its X,Y,Magnitude is WCSTools standard position format)

- Sextractor
(output formattable to WCSTools standard)

FITS-WCS Projections

Calabretta, M.R., & Greisen, E.W., (2002),"Representations of celestial coordinates in FITS", Astronomy & Astrophysics, 395, 1077-1122.

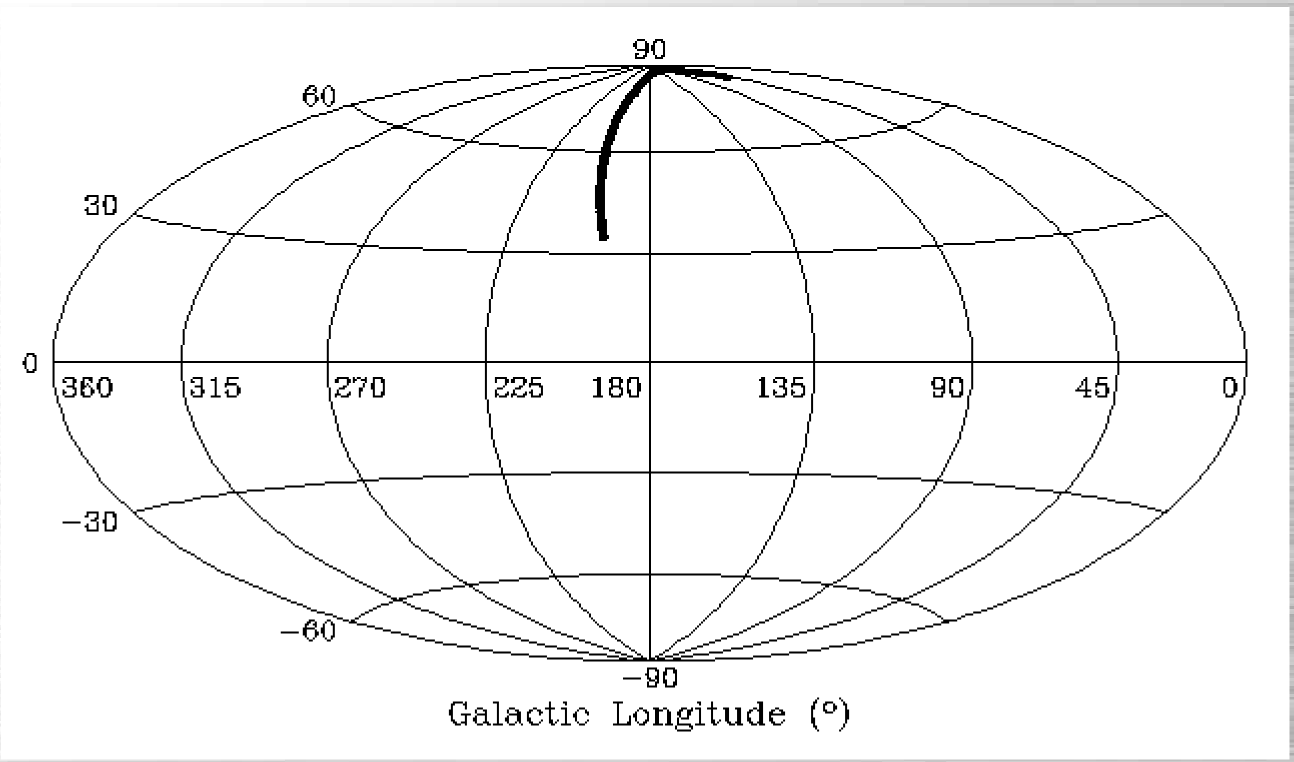
AZP: Zenithal (Azimuthal) Perspective
SZP: Slant Zenithal Perspective
TAN: Gnomonic = Tangent Plane
SIN: Orthographic/synthesis
STG: Stereographic
ARC: Zenithal/azimuthal equidistant
ZPN: Zenithal/azimuthal PolyNomial
ZEA: Zenithal/azimuthal Equal Area
AIR: Airy
CYP: CYlindrical Perspective
CAR: Cartesian
MER: Mercator
CEA: Cylindrical Equal Area
COP: COnic Perspective
COD: COnic equiDistant
COE: COnic Equal area
COO: COnic Orthomorphic
BON: Bonne
PCO: Polyconic
SFL: Sanson-Flamsteed
PAR: Parabolic
AIT: Hammer-Aitoff equal area all-sky
MOL: Mollweide
CSC: COBE quadrilateralized Spherical Cube
QSC: Quadrilateralized Spherical Cube
TSC: Tangential Spherical Cube
NCP: North celestial pole (special case of SIN)
GLS: GLobal Sinusoidal (Similar to SFL)

More Catalogs

These catalogs are available and supported by SAO/TDC search and mapping software.

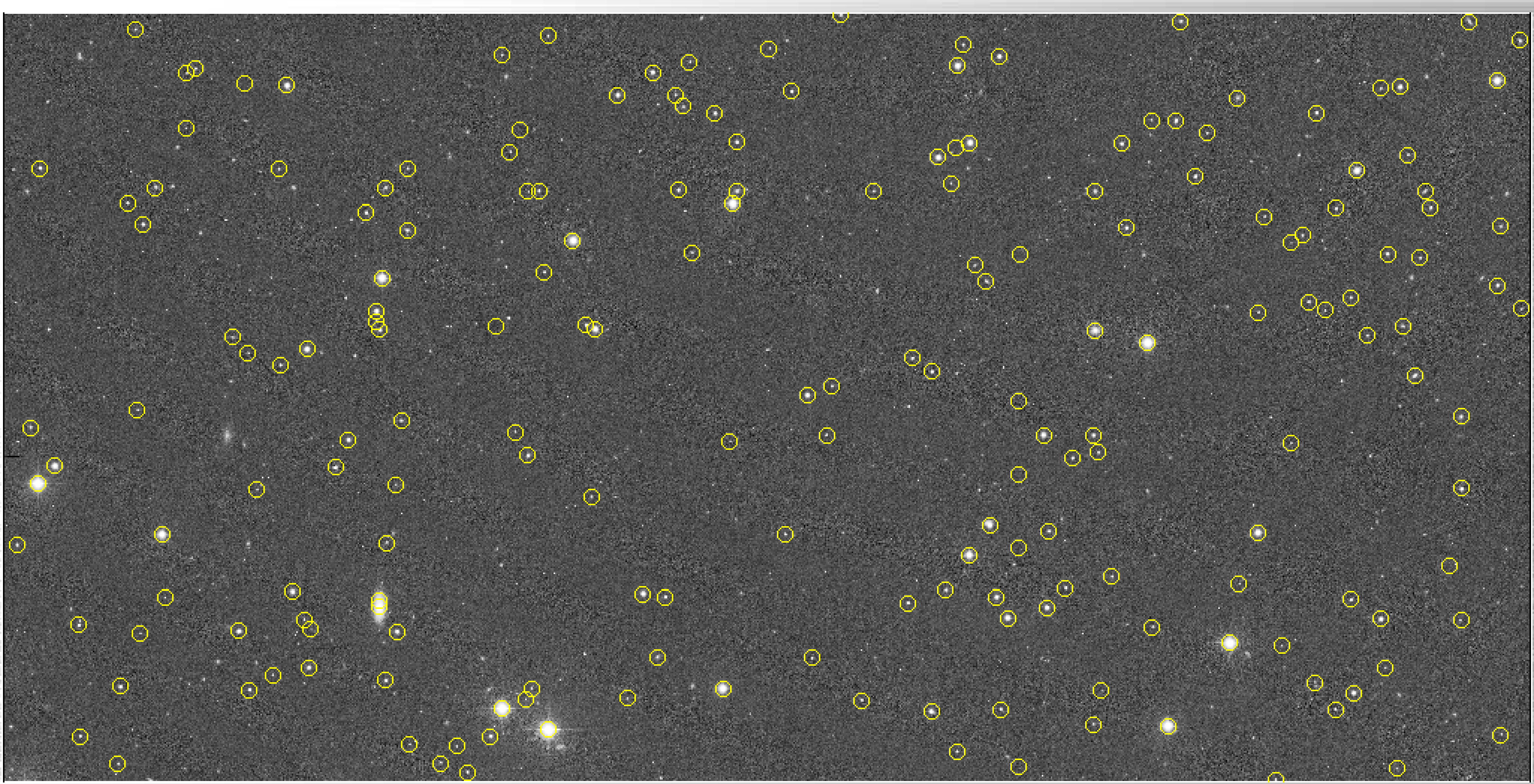
Catalog or Format	No. Stars	Bytes	Region Search	Image Search	Mapping
USNO-B1.0 Catalog	1,036,366,767	83,614,060,960	sub1 (scat)	imub1 (imcat)	
GSC II Catalog (2.2.01)	998,402,801	>80,000,000,000	sgsc2 (scat)	imgsc2 (imcat)	
2MASS Point Source Catalog	470,992,970	31,775,592,000	stmc (scat)	imtmc (imcat)	
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)	imsdss (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

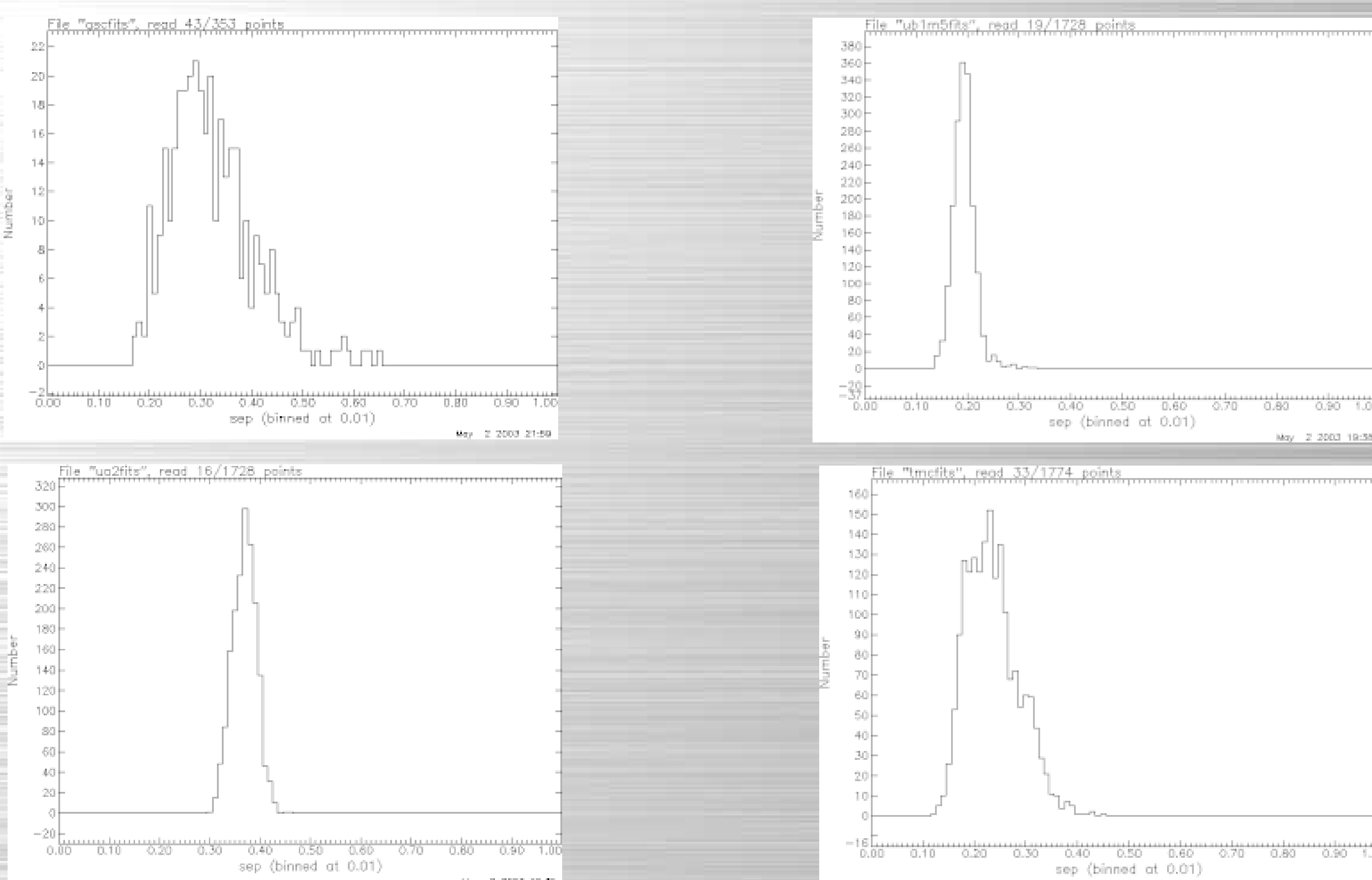
Testing Catalog Accuracy



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

Testing Catalog Accuracy

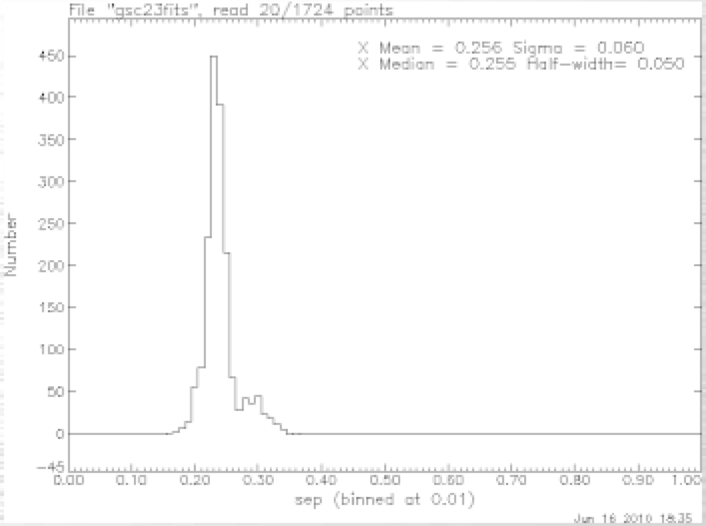
D. J. Mink, W. R. Brown, M. J. Kurtz (2004) A Comparison of Large All-Sky Catalogs Astronomical Data Analysis Software and Systems XIII, F. Ochsenbein, M. Allen, and D. Egret, eds. ASP Conference Series, Vol. 314, p. 141

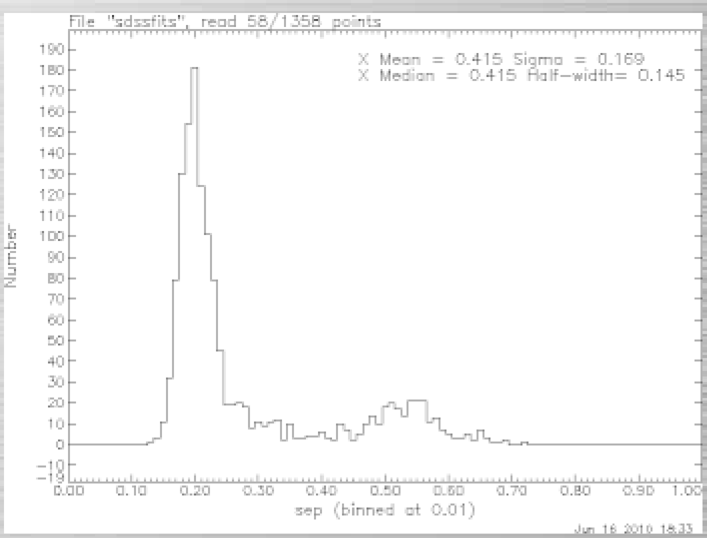


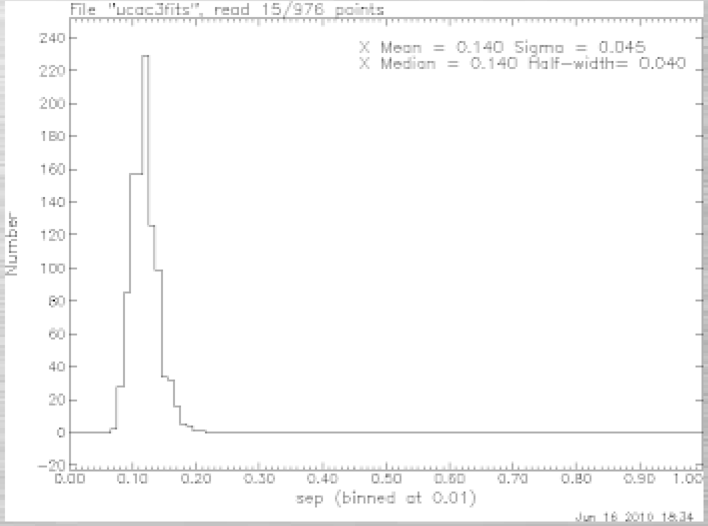
Differences between catalogs and WCS fits to 1726 images

Testing Catalog Accuracy

D. J. Mink (2010) Unpublished







Differences between catalogs and WCS fits to 1726 images

Accommodating image distortions in WCSTools

WCSTools supports several methods of fitting distiortions to images as this seems not to be standardizable

- **Digitized Sky Survey Plate Model**
- **IRAF TNX and ZPX projections with polynomial distortion**
- **Spitzer/STScI polynomial distortion model**
- **SWARP polynomial distortion model**

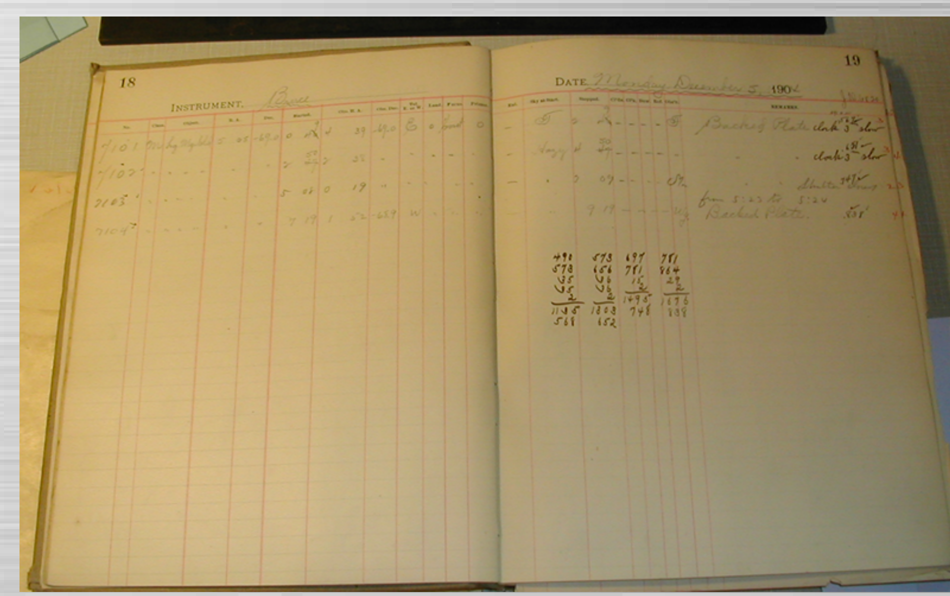
WCS projections supported by WCSTools

Code	Projection
PIX	Pixel WCS
LIN	Linear projection
AZP	Zenithal/Azimuthal Perspective
SZP	Zenithal/Azimuthal Perspective
TAN	Gnomonic = Tangent Plane
SIN	Orthographic/synthesis
STG	Stereographic
ARC	Zenithal/azimuthal equidistant
ZPN	Zenithal/azimuthal Polynomial
ZEA	Zenithal/azimuthal Equal Area
AIR	Airy
CYP	CYlindrical Perspective
CAR	Cartesian
MER	Mercator
CEA	Cylindrical Equal Area
COP	Conic Perspective
COD	Conic equidistant
COE	Conic Equal area

Code	Projection
COO	Conic Orthomorphic
BON	Bonne
PCO	Polyconic
SFL	Sanson-Flamsteed (Global Sinusoidal)
PAR	Parabolic
AIT	Hammer-Aitoff
MOL	Mollweide
CSC	COBE quadrilateralized Spherical Cube
QSC	Quadrilateralized Spherical Cube
TSC	Tangential Spherical Cube
NCP	Special case of SIN from AIPS
GLS	Same as SFL from AIPS
DSS	Digitized Sky Survey plate solution
PLT	Plate solution (SAO corrections)
TNX	Tangent Plane (NOAO corrections)
ZPX	Zenithal Polynomial (NOAO corrections)
TPV	Tangent Plane (SCAMP corrections)
TAN-SIP	Tangent Plane (Spitzer corrections)

Putting Positions on Harvard's Plates

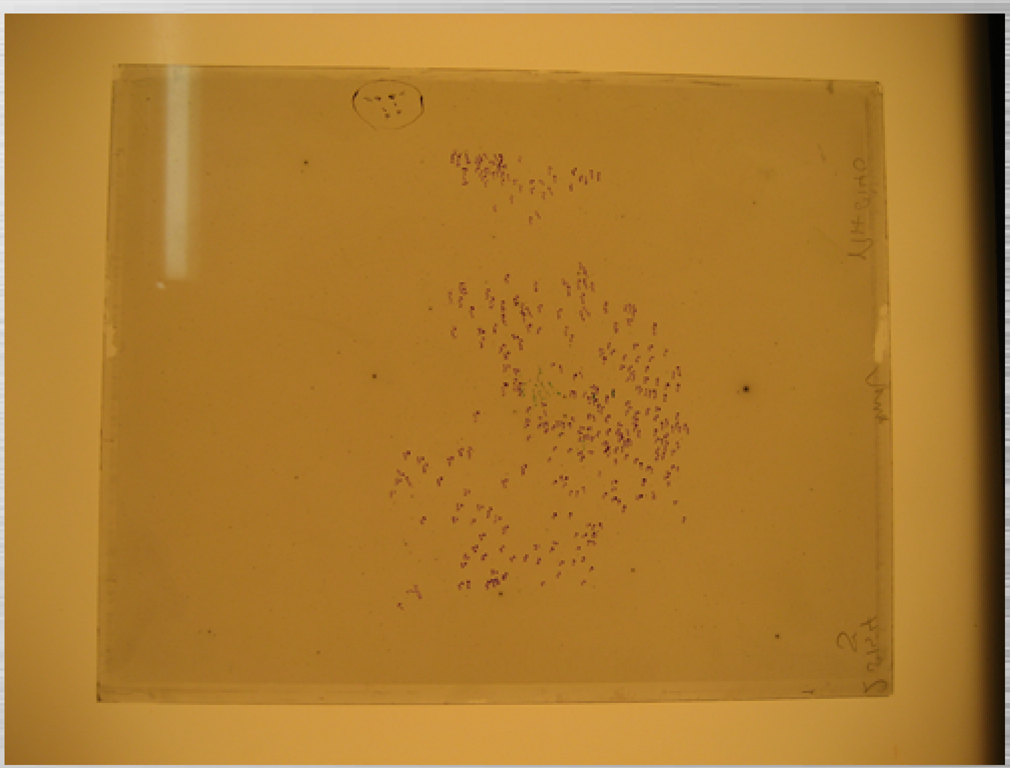
Mink, D.; Doane, A.; Simcoe, R.; Los, E.; Grindlay, J. (2006). "The Harvard Plate Scanning Project" in Virtual Observatory: Plate Content Digitization, Archive Mining and Image Sequence Processing, iAstro workshop, Sofia, Bulgaria, 2005 proceedings, Sophia: Heron Press Ltd.



From hand-written cards and logbooks

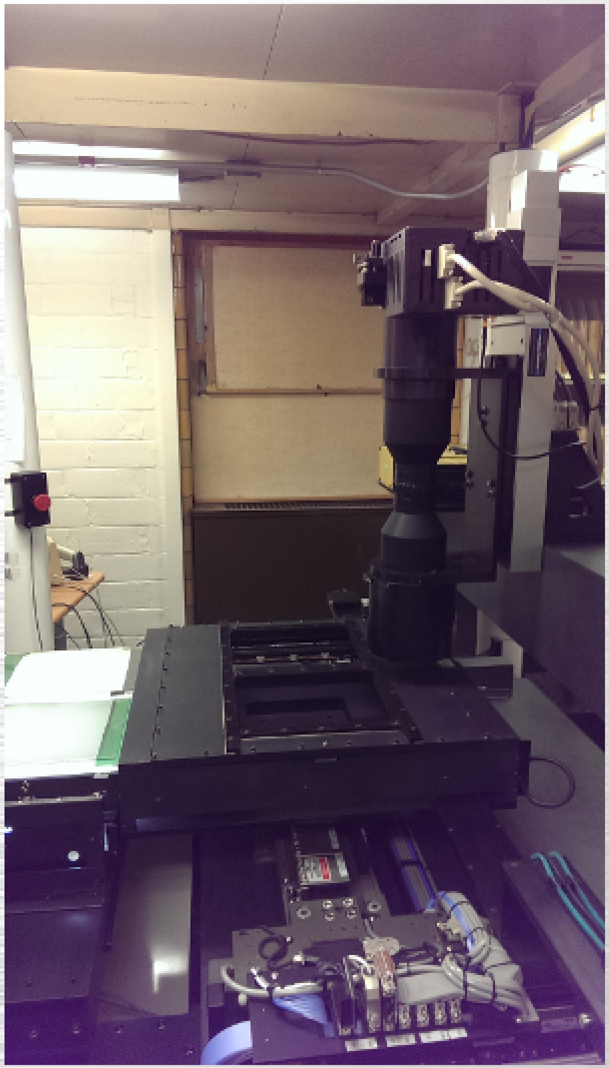
Putting Positions on Harvard's Plates

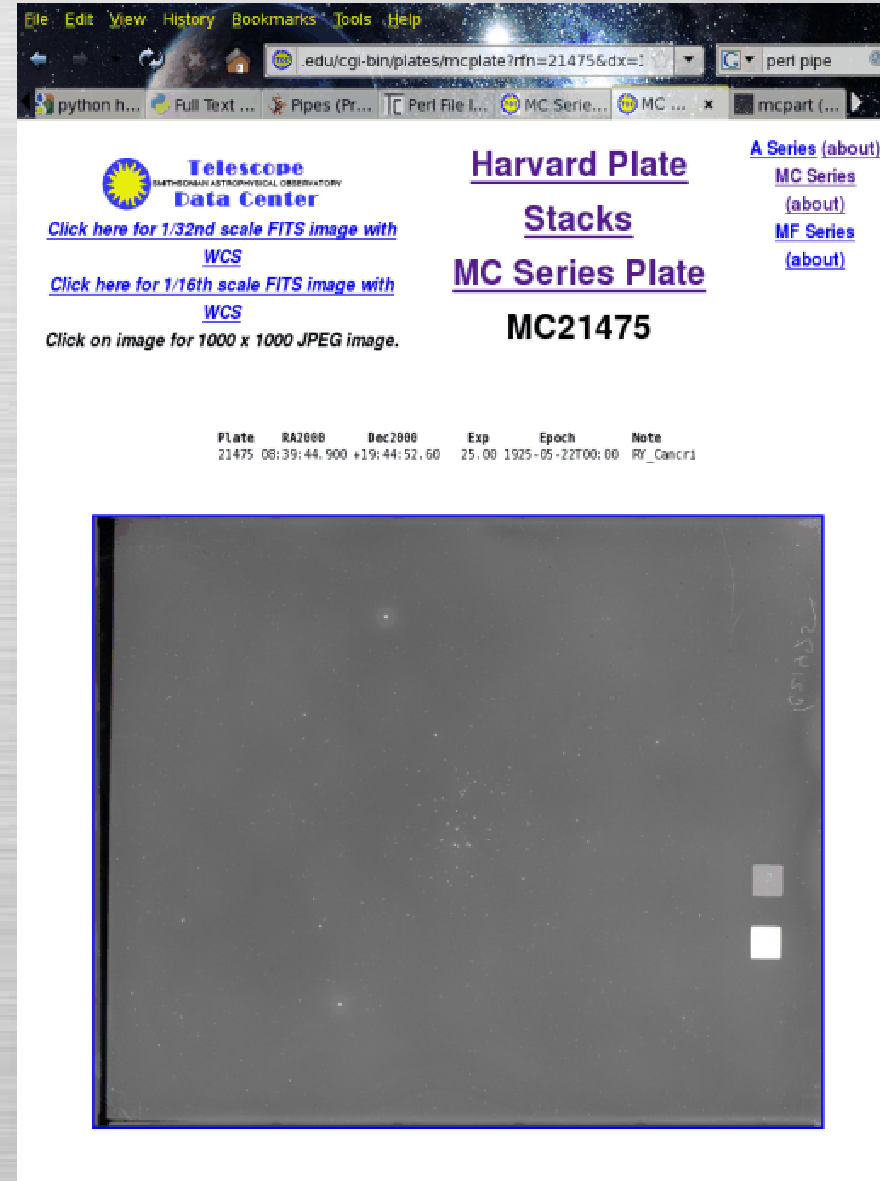
Mink, D.; Doane, A.; Simcoe, R.; Los, E.; Grindlay, J. (2006). "The Harvard Plate Scanning Project" in Virtual Observatory: Plate Content Digitization, Archive Mining and Image Sequence Processing, iAstro workshop, Sofia, Bulgaria, 2005 proceedings, Sophia: Heron Press Ltd.



From three floors of cabinets of glass plates

Putting Positions on Harvard's Plates

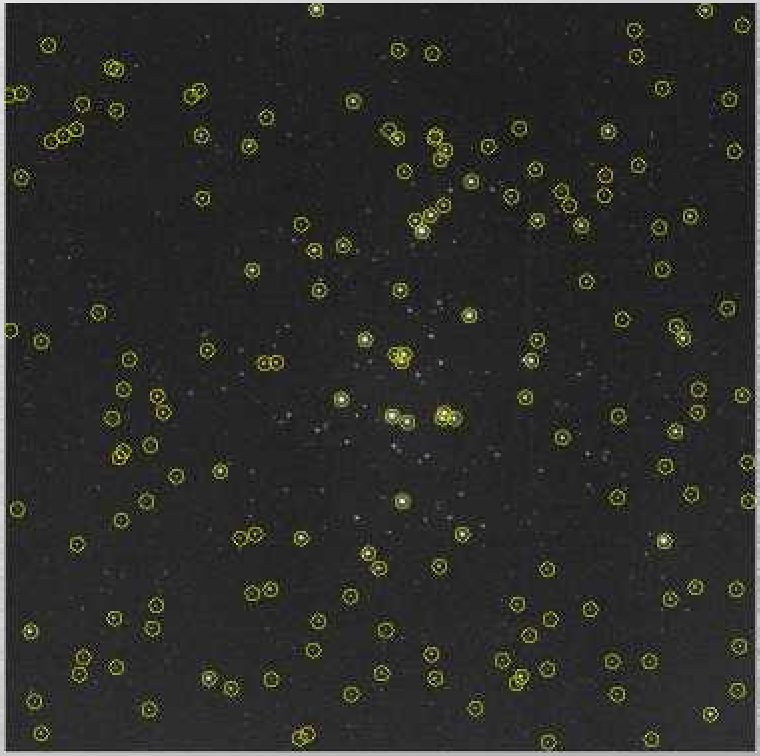




From glass to bytes on home-built scanner

Putting Positions on Harvard's Plates

M44 in Plate MC21438



M44 in Plate MC21438
with Tycho 2 Catalog stars marked

Zoom in and overplot stars using WCS

Putting Positions on Harvard's Plates

100,000th Plate Scanned, April 7, 2015

sethead sets values of keywords in FITS Headers

Each keyword should be followed by an equal sign and the value to which it is to be set

Values which are all numeric are assumed to be numbers and are aligned as such within the header.

A list of filenames may be used by prefacing the name of the file containing the list with a @.

Multiple FITS extension headers may be changed at once using -x [range of extension numbers]

Change the right ascension and declination of a FITS image to a different epoch.

```
Before:
RA      = '9:51:19.45'        /MEAN RA
DEC     = '69:15:26.42'       /MEAN DEC
EPOCH   = 1950                /MEAN EPOCH

$ sethead -nvkr X ra='09:55:25.177' dec='+69:01:13.72' epoch=J2000 test.fts
SETHEAD WCSTools  3.9.1, 24 March 2015, Jessica Mink (jmink@cfa.harvard.edu)
Set Header Parameter Values in FITS image file test.fts
RA = 09:55:25.177
DEC = +69:01:13.72
EPOCH = 2000
teste.fts: rewritten successfully.

After:
XRA     = '9:51:19.45'        /MEAN RA
XDEC    = '69:15:26.42'       /MEAN DEC
XEPOCH  = 1950                /MEAN EPOCH
...
RA      = '09:55:25.177'
DEC     = '+69:01:13.72'
EPOCH   =             2000
SETHEAD = 'SETHEAD 2.5 1998-09-01 13:31 RA, DEC, EPOCH updated'
```

gethead extracts information from FITS headers

Keyword names may be entered in either upper or lower case

Tab-separated table output, with column headers, is an option

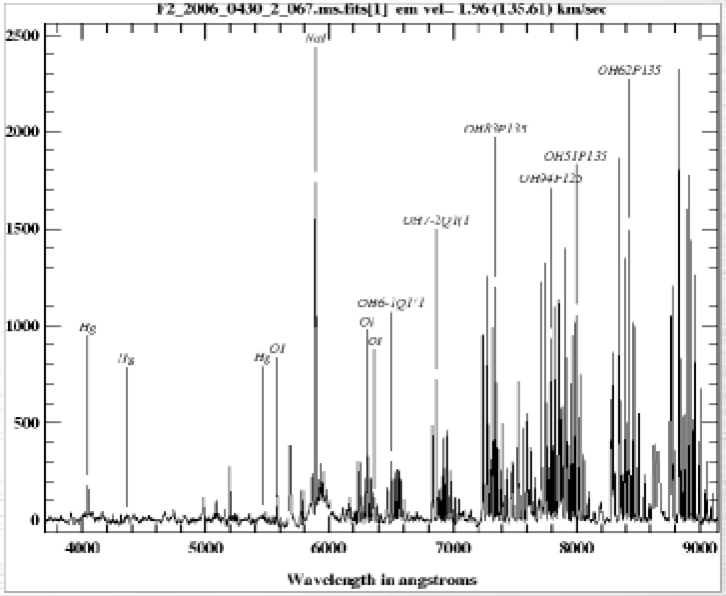
Afile containing a list of filenames may be used by prefacing it with a @.

Multiple parameters from list of FITS files

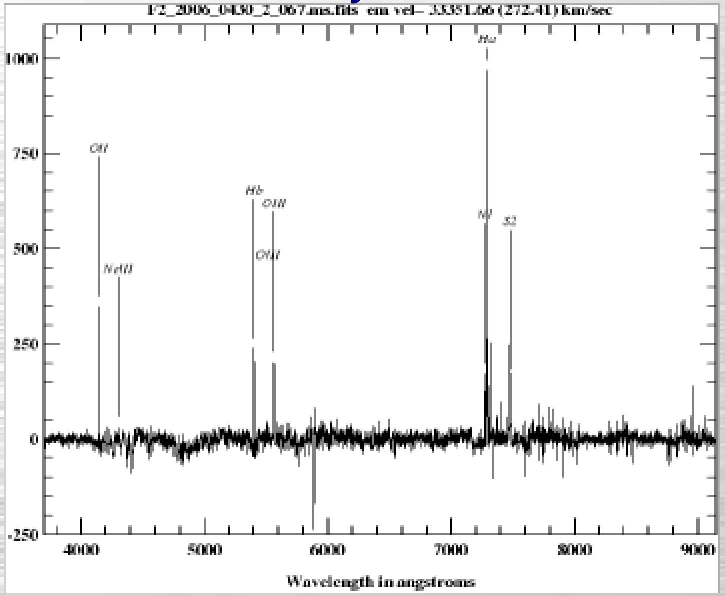
Get the image sizes from the NAXIS, NAXIS1, and NAXIS2 header keywords from a list of FITS and IRAF files, printing the output in tab table format:

```
$ gethead -th @fits.list naxis naxis1 naxis2
FILENAME        NAXIS   NAXIS1  NAXIS2
--------        -----   ------  ------
0083.19083010-0706459.fits      2       2720    161
hiptest.fits    2       600     600
test.fits       2       2720    161
test_fabien.fits        2       2080    2048
testbin.fits    2       765     510
testbinf.fits   2       680     450
testbinfg10x10.fits     2       765     510
testbinfg20x20.fits     2       765     510
testbinfg40x40.fits     2       680     450
webccd-1.fits   2       680     450
webccd-2.fits   2       765     510
```

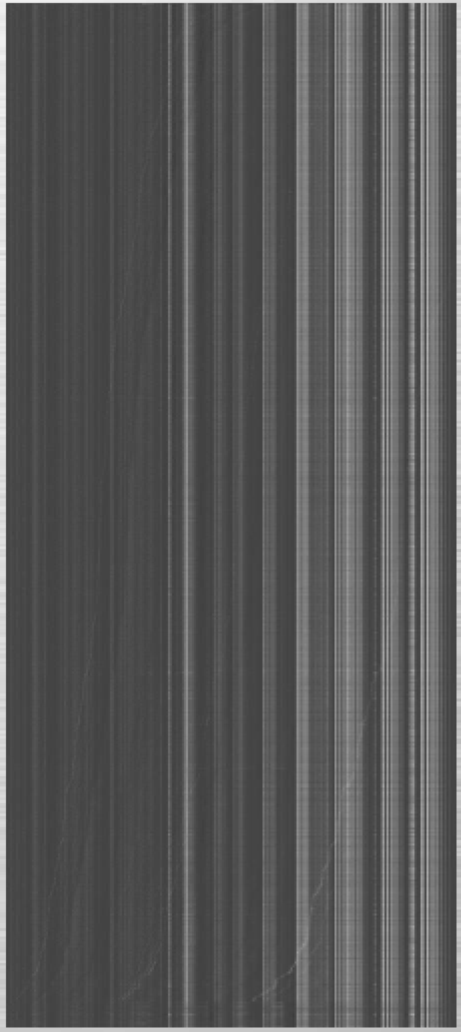
Redshifting Into the Universe



Before Sky Removal



After Sky Removal



Before Sky Removal

After Sky Removal

12,553 Spectra from the Hectospec SHELS survey

Questions?

WCSTools:	http://tdc-www.harvard.edu/software/wcstools
RVSAO:	http://tdc-www.harvard.edu/iraf/rvsao/
SKYMAP:	http://tdc-www.harvard.edu/software/skymap/
Jessica:	http://tdc-www.harvard.edu/mink/ http://www.jessicamink.com/change.html

Answers

Women In Astronomy

Tuesday, December 16, 2014

On Being a Transgender Astronomer

Posted by Jessica Kirkpatrick

Today's guest post is by Jessica Mink, a positional astronomer and software developer at the Smithsonian Astrophysical Observatory, who has written the commonly used software packages WCSTools and RVSAO and worked on a variety of astronomical projects over 40 years. Much of her story is told in this interview with the American Astronomical Society's Working Group on LGBTIQ Equality (WGLE).

While I consider myself to be a woman astronomer, I have not always been one. Since I made much of my reputation with a different gender expression and remain in the field, I have to accept the fact that I am also a transgender astronomer, and as a representative of that small group, serve as an ambassador to the rest of the astronomical world.

While gradually (over 40 years!) transitioning from male to female, I have thought a lot about gender and its various facets, but when I volunteered to write a blog entry representing my gender minority for the Women in Astronomy blog, I realized that I hadn't been very systematic about it. It is likely that most readers don't have any trans* friends (that they know about), but this far into the 21st century, most thinking people are aware of our existence and might even know of one of us.

Each human being has a gender identity. Most of us don't think about it much because it usually matches our biological sex, but sometimes it doesn't, and then we fall into the broad category of trans* people. Even though we are grouped with Lesbian, Gay, and Bisexual people under LGBT, and its variants, our category is not tied to our sexual orientation, so many of our issues are different. It appears that gender identity is usually innate, even when it does not match our biological sex. That means that many trans* people might not **appear** any different than their knowledge of their biological sex (how a person's genes express in their physical appearance) would lead you to believe, while others may take hormones, have surgery, or simply change their wardrobe and appearance to match the gender which they feel themselves to be. Thus gender presentation or expression is a separate thing from gender identity, though it is often related. It should also be noted that while trans* people have many similar experiences, my view from the male-to-female side is not the same as that of my friends transitioning from female to male, nor is it identical to anyone going the same way I am.