Forty-Five Years of Turning Data Into Science 1973-2018

By
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Smithsonian Astrophysical Observatory

MITPAL 50th Anniversary, April 17, 2018

Outline

First Data: 1971 MIT 12.143

Vidicon Spectrometer: 1973-4 Mars Observations

High-Speed Photometry: 1976-1990 Occultations

Spacelab 2 IRT: 1985-1990 IRAS and Spacelab 2 IRT

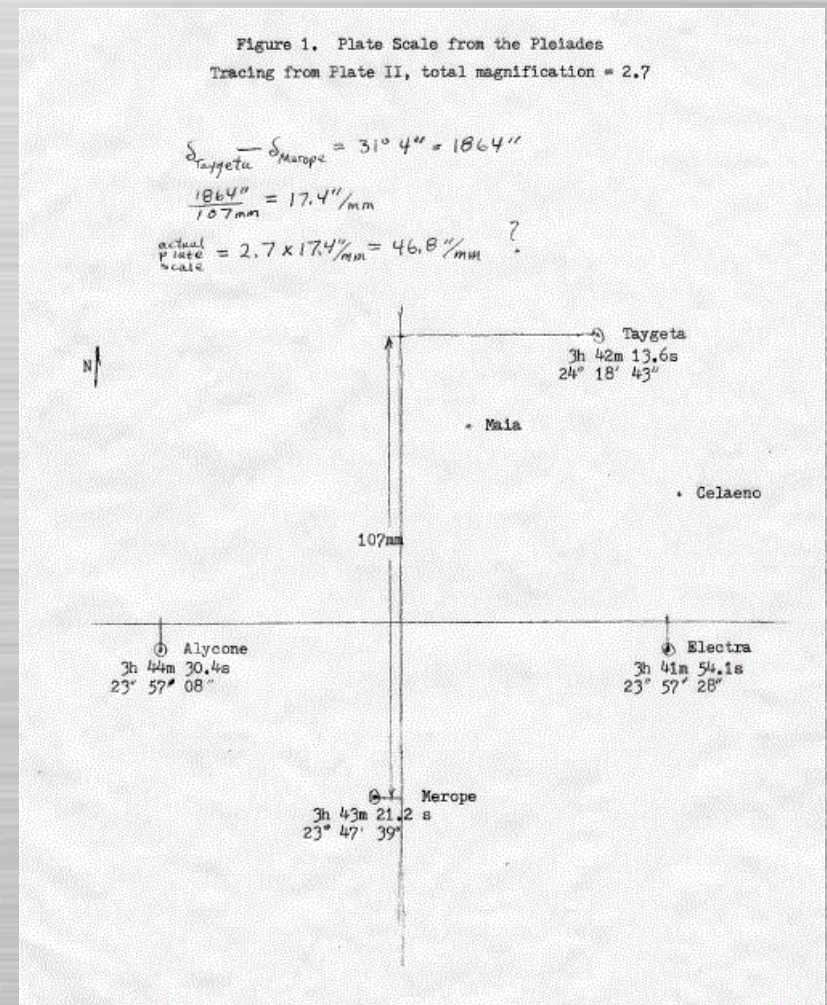**Long-slit Spectroscopy: 1990-2018 Z-Machine, FAST**

Digitizing Images: 2002-2018 Harvard Photographic Plates

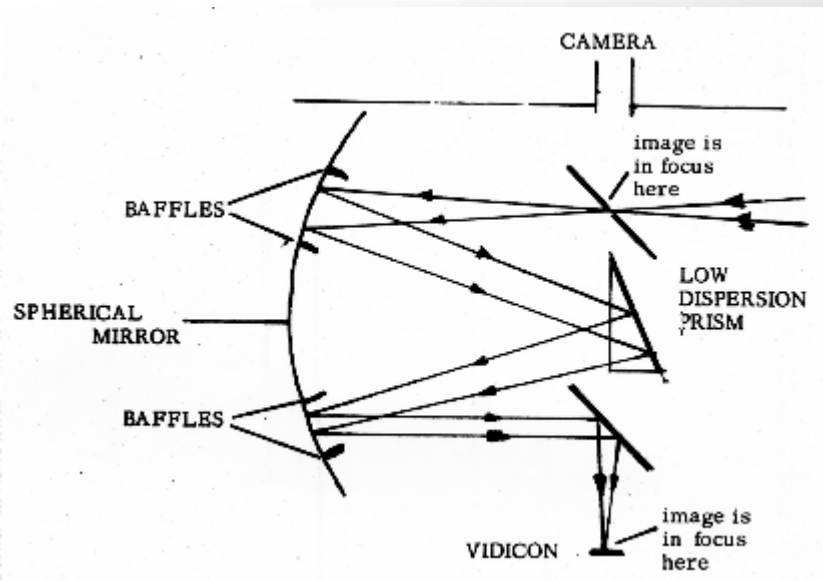**Multi-Fiber Spectroscopy: 2003-2018 Hectospec and Hectochelle**

Echelle Spectroscopy: 2009-2018 TRES

MIT 12.143: Plate Scale and Tracking Accuracy of the MIT Wallace Observatory 16 inch Telescope

December 15, 1971

II. Pleiades (M.45)
 exposure: 8 min
 film: Kodak Tri-X
 development: D-19, 10 min
 magnification: 2.7
 comment: drive speed not correctly adjusted

PLATE II

Figure 1. Plate Scale from the Pleiades
Tracing from Plate II, total magnification = 2.7

$$\delta_{Taygeta} - \delta_{Merope} = 31^\circ\ 4'' = 1864''$$

$$\frac{1864''}{107mm} = 17.4''/mm$$

$$\text{actual plate scale} = 2.7 \times 17.4''/mm = 46.8''/mm \quad ?$$

N

107mm

Taygeta
3h 42m 13.6s
24° 18′ 43″

• Maia

• Celaeno

Alycone
3h 44m 30.4s
23° 57′ 08″

Electra
3h 41m 54.1s
23° 57′ 28″

Merope
3h 43m 21.2 s
23° 47′ 39″
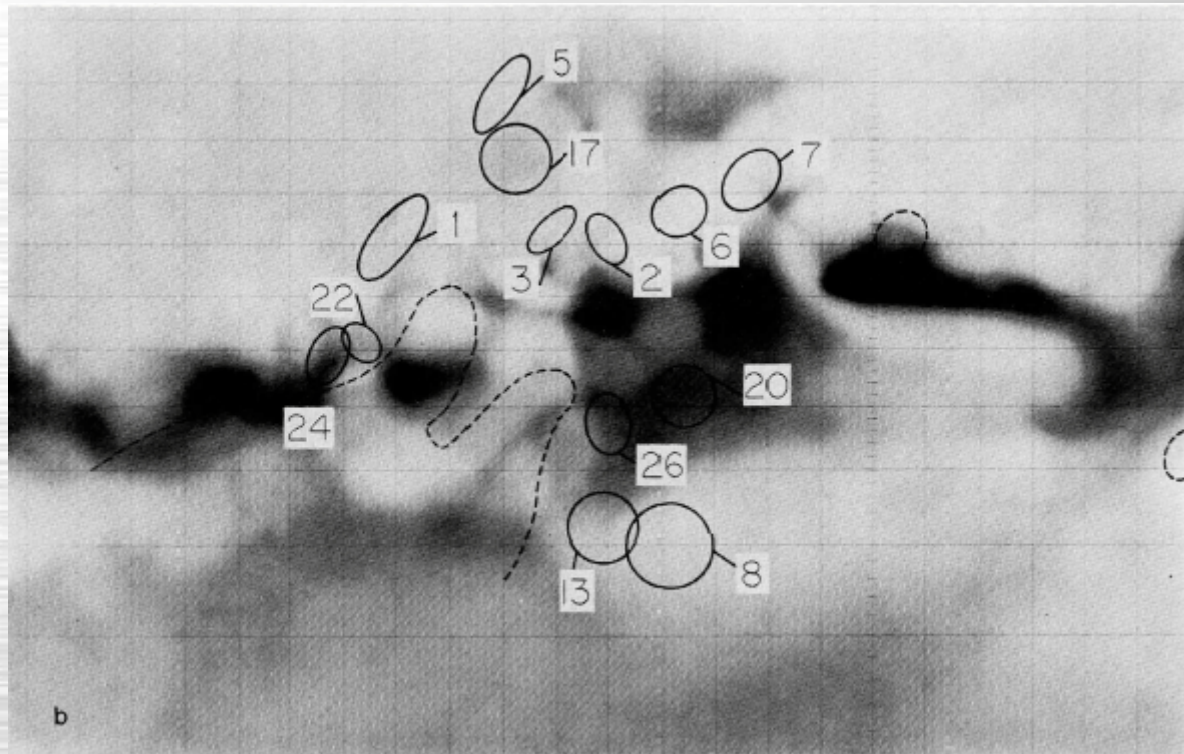
MIT Vidicon Spectrometer
1973 Mars Opposition

MIT Vidicon Spectrometer with camera monitoring slit in mirror

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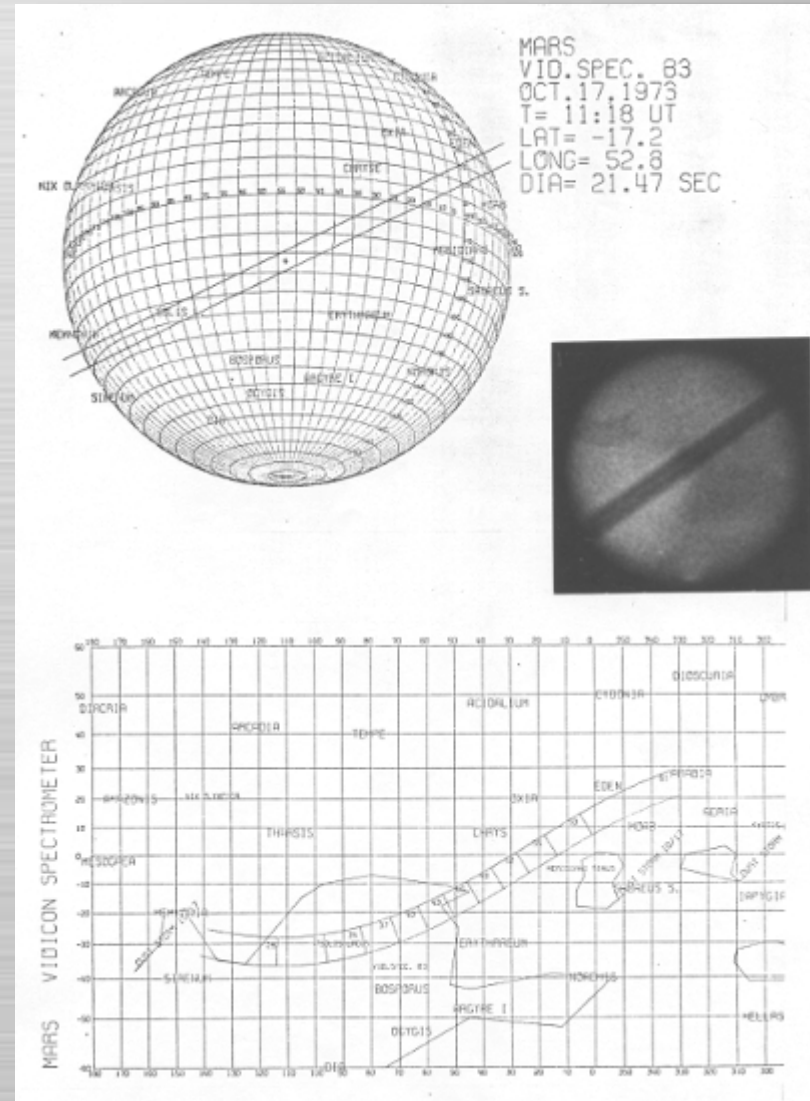
Mars Opposition Photometry

**Aperture photos projected on observed planet disk
and reprojected onto Mercator projection of Mars**
(Mccord, Huguenin, Mink, and Pieters, Icarus 31, 1977)

Not Grad School, But ...

CORNELL UNIVERSITY
Center for Radiophysics and Space Research

SPACE SCIENCES BUILDING
Ithaca, New York 14853

Telephone (607) 256-4971   Laboratory for Planetary Studies

March 17, 1976

Mr. Douglas Mink
1055 Beacon Street
Apt. #2
Brookline, MA   02146

Dear Doug:

Thanks for your recent letter. I was glad to
hear that your wife, Missy, has been accepted in Ecology
and Evolutionary Biology here. Unfortunately, because
of a deluge of first rate applicants and a still con-
stricted budget for the support of graduate students,
we have not been able to admit you as a graduate student.
I am sorry to have to report this, but the competition
was simply too tough. On the other hand, if by any
chance you will be here, we would certainly be happy to
have you work in our laboratory and -- if a little money
can be found -- try to pay you at least part time.

With all good wishes,

Cordially,

Carl Sagan

CS/csk
cc: Y. Terzian

CORNELL UNIVERSITY
Center for Radiophysics and Space Research

SPACE SCIENCES BUILDING
Ithaca, New York 14853

Telephone (607) 256-4971   Laboratory for Planetary Studies

June 3, 1976

Mr. Douglas Mink
1055 Beacon Street #2
Brookline, Mass. 02146

Dear Doug:

Thanks for your recent letter which, for several different
reasons, I was delighted with. I think it certainly is true
that once you are here we will have an excellent chance to
better assess your skills and abilities and I'm sure it will
increase your chance of being admitted to this department. But
also we have an extremely interesting job opening up involving
data processing and analysis in a set of quite exciting contexts.
We are not yet sure that we will have money to support this
position, but I would say that the prospects are at least moderately
good. Let me urge you to contact -- certainly by the time you are
out here but preferably even before -- Dr. James Elliot of this
Laboratory to whom I'm sending a copy of this letter. It would
probably be a good idea for you to lay out your previous computer
and instrumentation experience to Dr. Elliot. I very much hope
things will work out well for you.
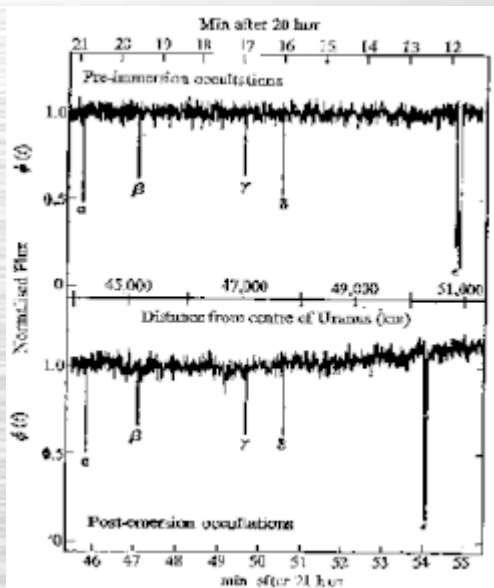
With all good wishes,

Cordially,

Carl Sagan

Discovery of Uranian RIngs

Occultation of SAO 158687 by Uranus and Its Rings
(Eliot, Dunham, and Mink, Nature 261, 328, May 26 1977)

3-Channel Photometer on KAO
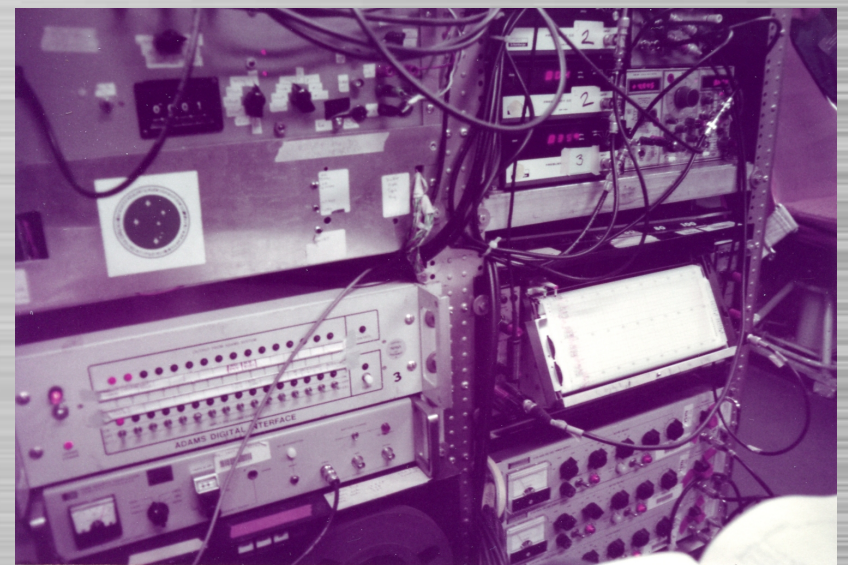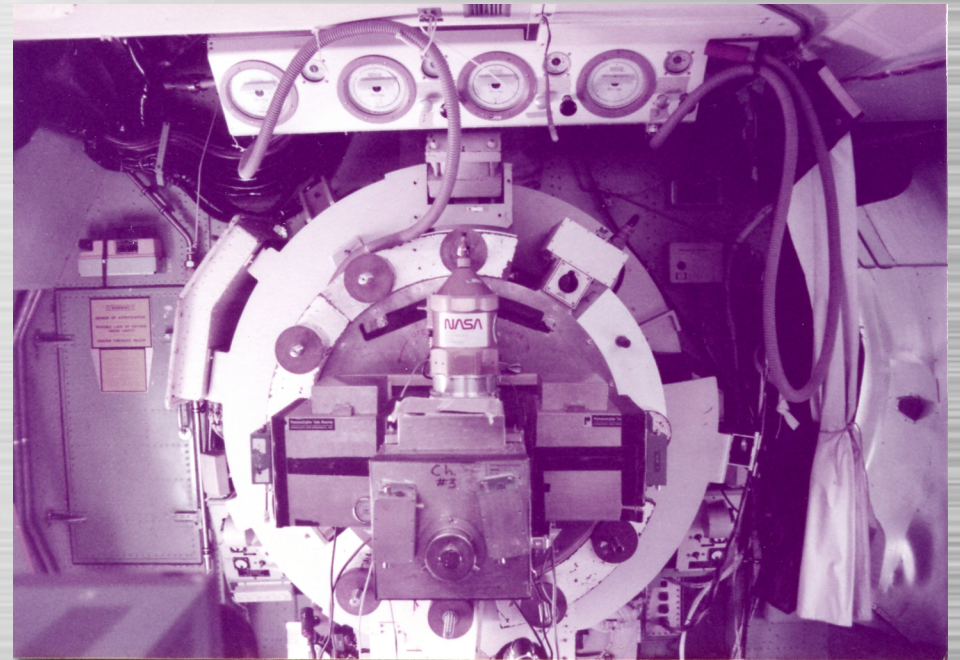
Faith Vilas on Guam, 1983

Occultation Prediction Pipeline

Existing Star Catalog

Compute Search Boxes
Search Star Catalog
Merge resulting regions

Photographic Plates

Compute planetary ephemeris
Take plates on astrograph
Measure plates
Merge plates

Make candidate catalog

Sort by RA
Remove duplicate entries
Renumber
Make binary file
Find close stars in 10" boxes
Run predictions

Publish close event predictions in AJ article

Predicting Occultations
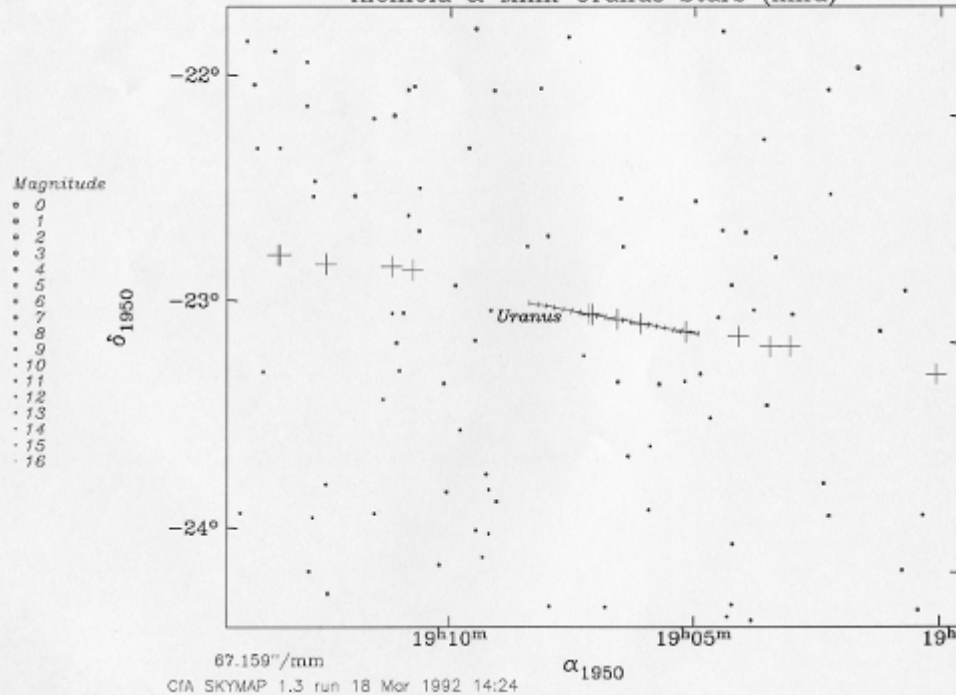
**Palomar Sky Survey overlay
for stars occulted by Uranus**

**Sky plane map of Uranus
ring occultation of KMU102**

All-Sky IR Mapping from Space
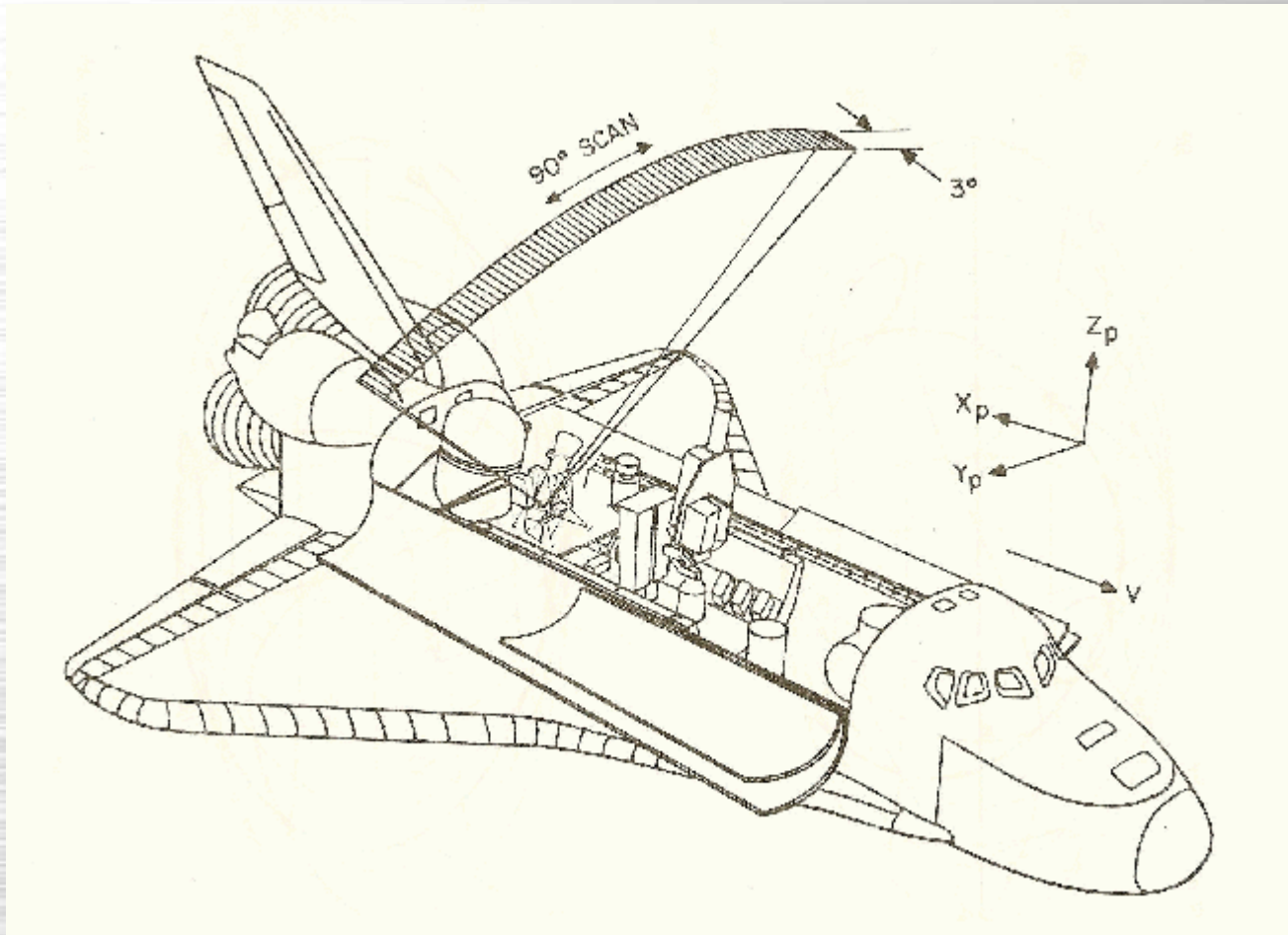
Spacelab 2 Infrared Telescope
(Space Shuttle Challenger, July 1985)

For Maps, Write a Graphics Terminal

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XTERM(1)                        X Window System                        XTERM(1)

NAME
       xterm - terminal emulator for X

SYNOPSIS
       xterm [-toolkitoption ...] [-option ...] [shell]

DESCRIPTION
       The xterm program is a terminal emulator for the X Window System.  It
       provides DEC VT102/VT220 and selected features from higher-level
       terminals such as VT320/VT420/VT520 (VTxxx).  It also provides
       Tektronix 4014 emulation for programs that cannot use the window system
       directly.  If the underlying operating system supports terminal
       resizing capabilities (for example, the SIGWINCH signal in systems
       derived from 4.3BSD), xterm will use the facilities to notify programs
       running in the window whenever it is resized.

       The VTxxx and Tektronix 4014 terminals each have their own window so
       that you can edit text in one and look at graphics in the other at the
       same time.  To maintain the correct aspect ratio (height/width),

SEE ALSO
        resize(1), luit(1), uxterm(1), X(7), pty(4), tty(4)

       Xterm Control Sequences (this is the file ctlseqs.ms).

       http://invisible-island.net/xterm/xterm.html
       http://invisible-island.net/xterm/ctlseqs/ctlseqs.html
       http://invisible-island.net/xterm/xterm.faq.html

AUTHORS
       Far too many people, including:

       Loretta Guarino Reid (DEC-UEG-WSL), Joel McCormack (DEC-UEG-WSL), Terry
       Weissman (DEC-UEG-WSL), Edward Moy (Berkeley),  Ralph  R.  Swick  (MIT-
       Athena),  Mark  Vandevoorde  (MIT-Athena),  Bob McNamara (DEC-MAD), Jim
       Gettys (MIT-Athena), Bob Scheifler (MIT X Consortium), Doug Mink (SAO),
       Steve  Pitschke  (Stellar),  Ron Newman (MIT-Athena), Jim Fulton (MIT X
       Consortium), Dave Serisky (HP),  Jonathan  Kamens  (MIT-Athena),  Jason
       Bacon, Jens Schweikhardt, Ross Combs, Stephen P. Wall, David Wexelblat,
       and Thomas Dickey (invisible-island.net).

Patch #330                         2017-06-20                          XTERM(1)
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IRT Data Pipeline

Telemetry from Space Shuttle:

Position of Space Shuttle
Scan Position of Telescope in Payload Bay
Counts from 4 He-chilled masked photometers

In Computer Room at Johnson Space Center:

Convert each sample to sky position and intensity
Record scan positions in graphic Aitoff all-sky map
Record in image mapped to Aitoff all-sky projection using mask shape

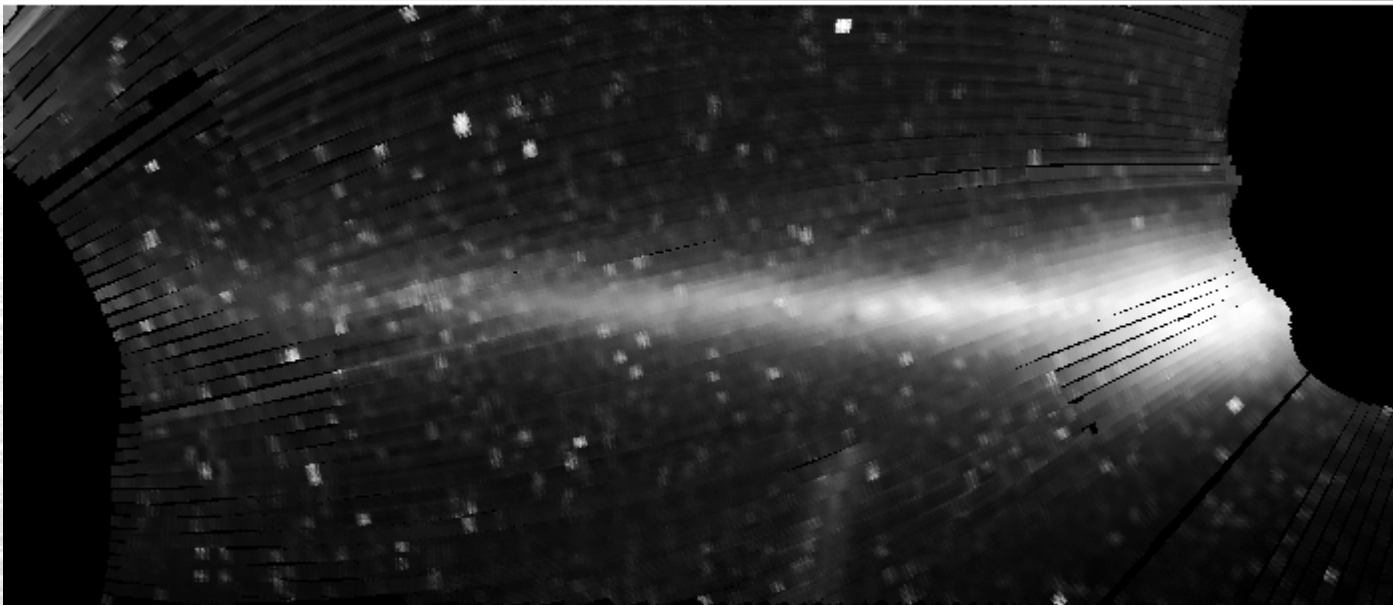# All Sky IR Mapping from IRT
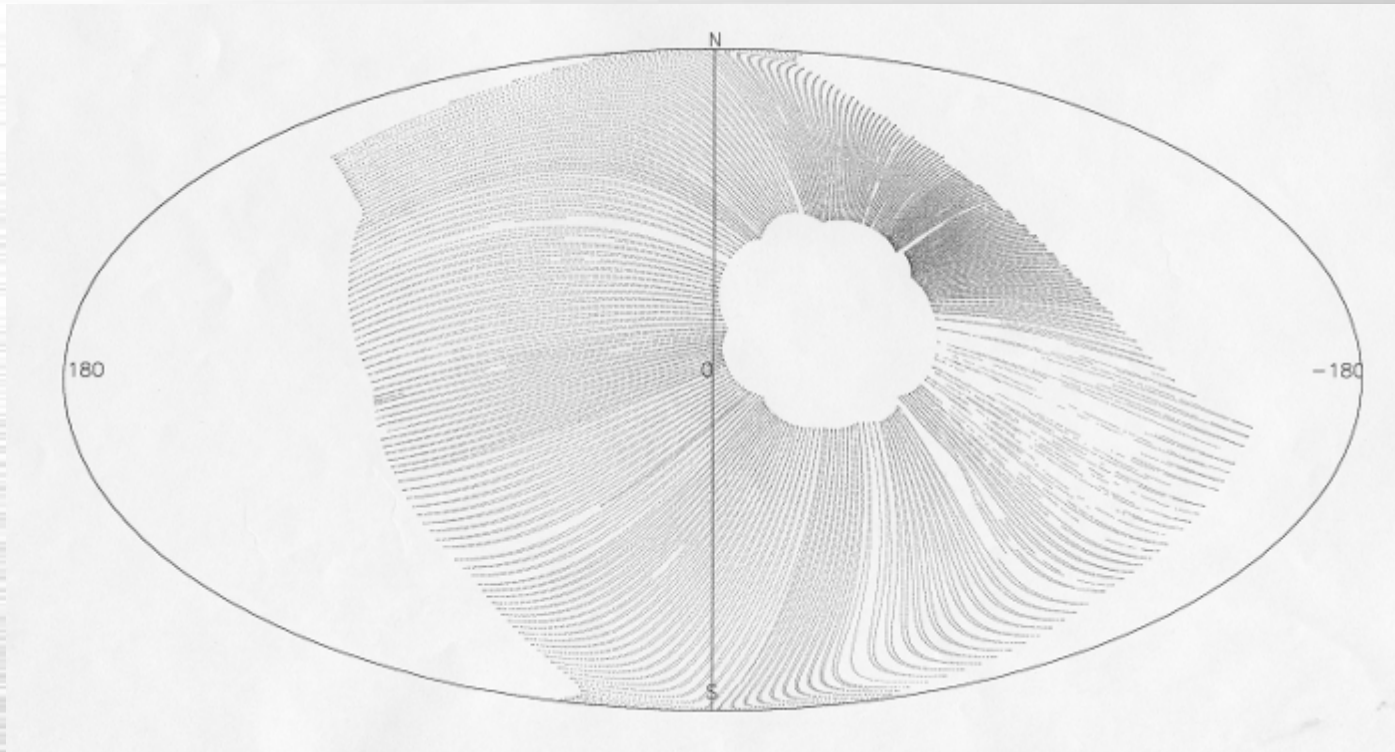
1985 Day 213, Orbit 4, 50,964 0.1-sec frames

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

MITPAL 50th, April 17, 2018

Galactic Center from Spacelab 2

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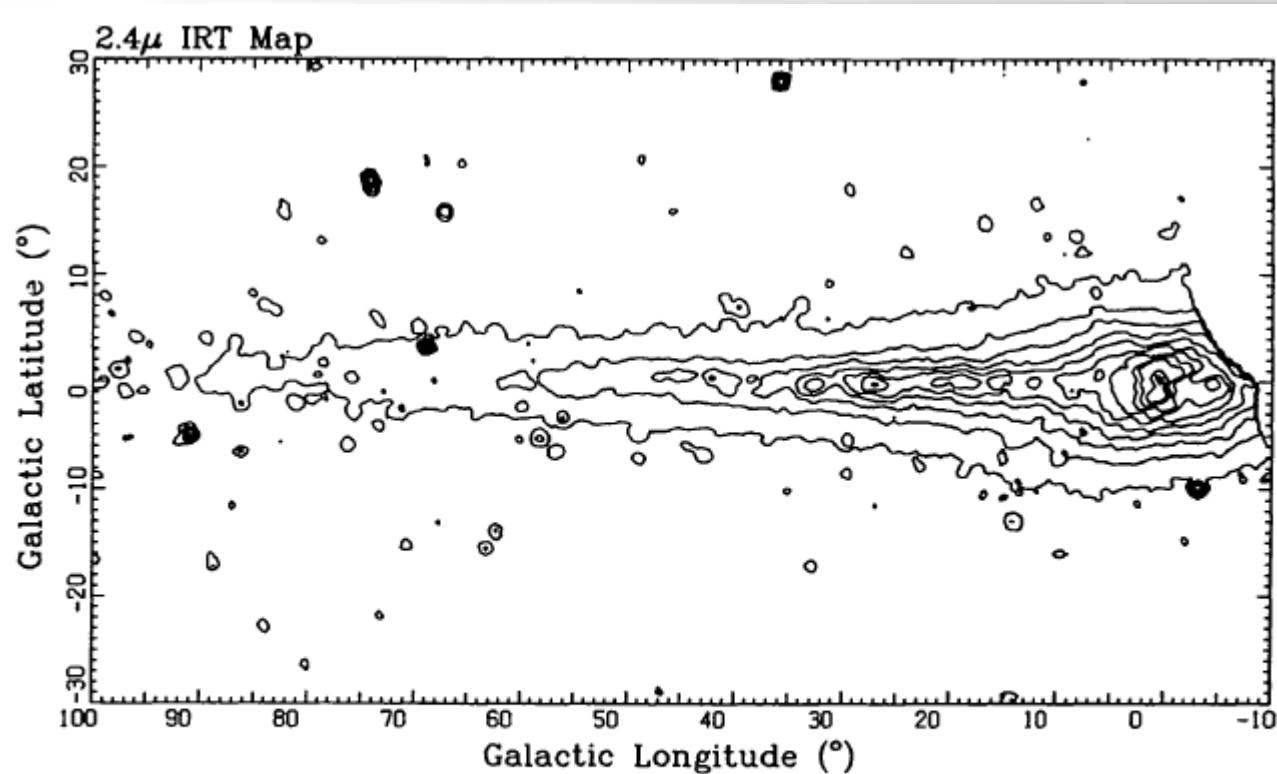*(Mink, August 1990, unpublished)*

Galactic Center from Spacelab 2

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}.
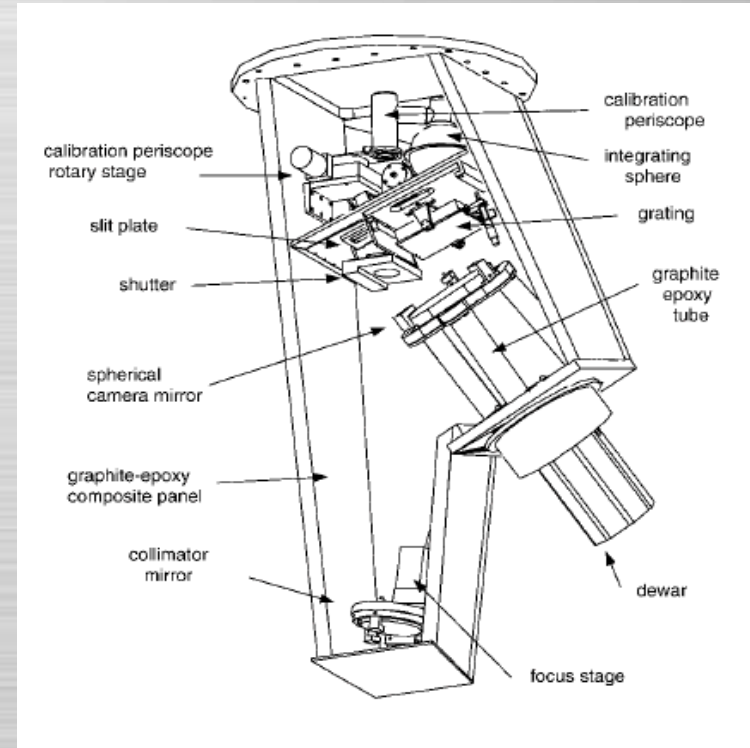
Linear Projection in Galactic Coordinates
(Kent, Mink, Fazio, Koch, Melnick, Tardiff, Maxson, ApJS 78:403-408, 1992)

FAST Single Slit Spectrograph

FAST mounted on the 1.5-meter Reflector

FAST Spectrograph

FAST Spectrograph Pipeline

For Each Night:

Transfer data from Mt. Hopkins, AZ to Cambridge, MA

Create a digital log for the night

Copy raw data to configuration directories

Catalog raw data

For Each Configuration:

Process spectrum images

Fit wavelength solutions to all HeNeAr calibration spectra

Apply wavelength solution to entire object spectra images

Find the objects on the slits

Extract 1D sky-subtracted spectrum images

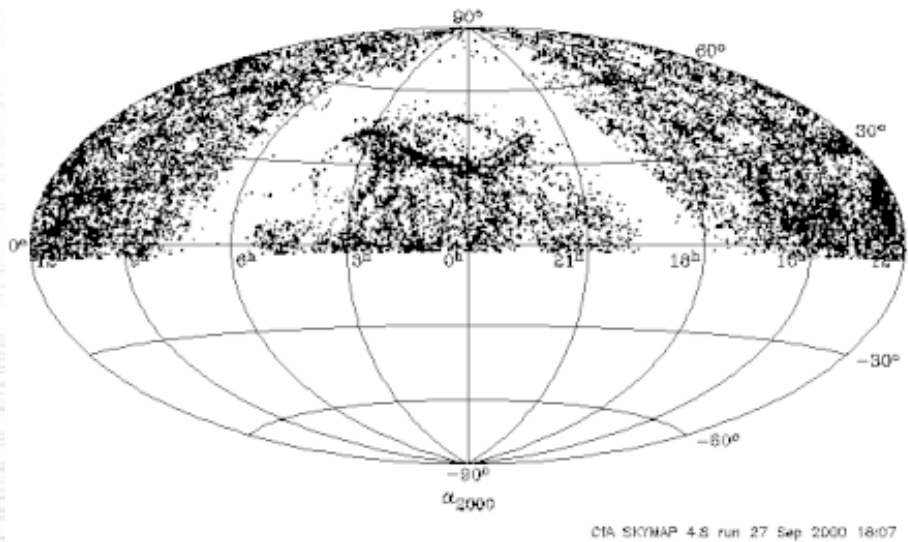**Find a velocity using cross-correlation to templates**

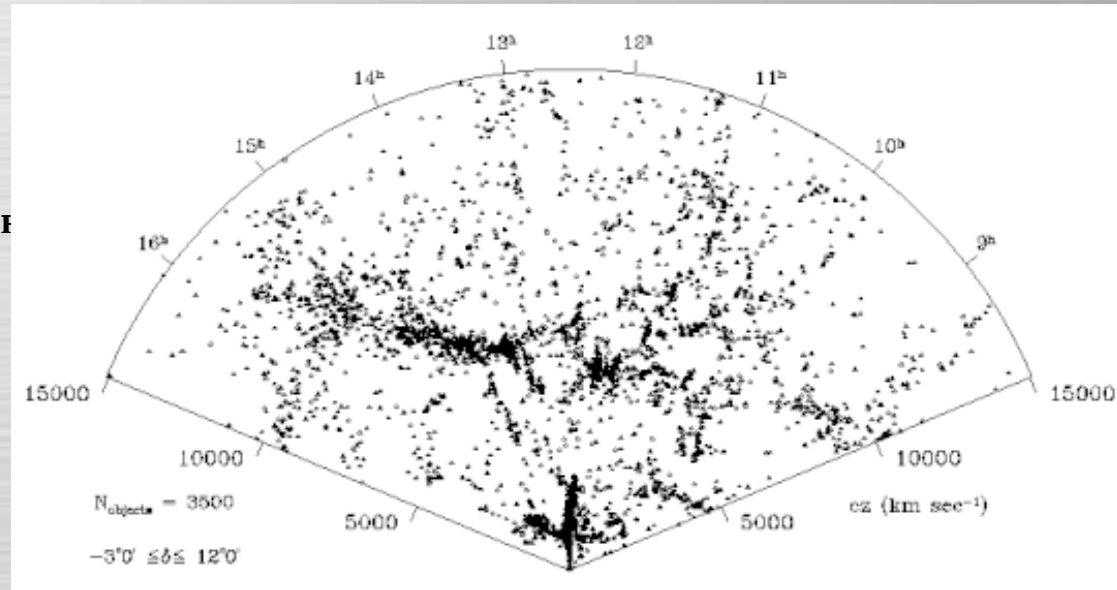**Check results, assign a quality (Q,?,X)**

Catalog spectrum metadata

Copy spectra to archive

Update Zwicky Catalog Galaxies with Redshifts


Updated Zwicky Catalog galaxies displayed on an Aitoff-Hammer all-sky projection

Galaxies RA 8h - 17h, Dec -3° - +12°, cz < 15,000 km/sec

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.
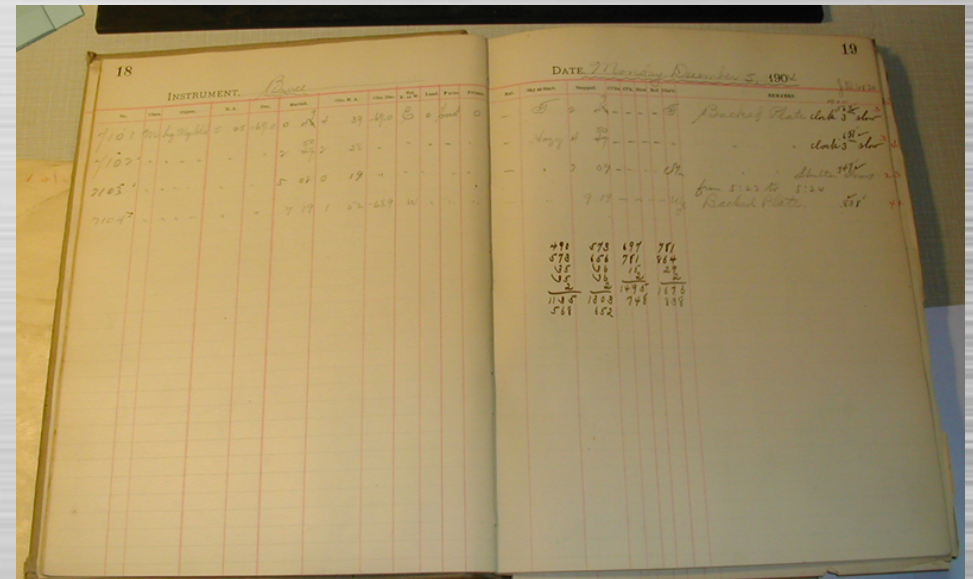
From hand-written cards and logbooks
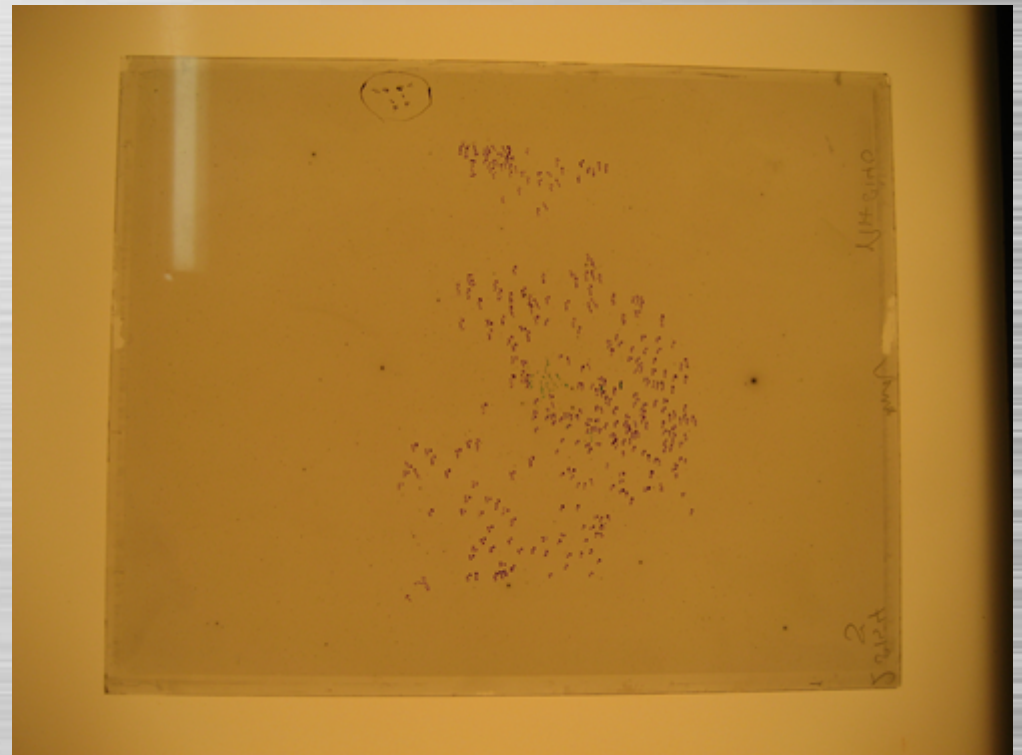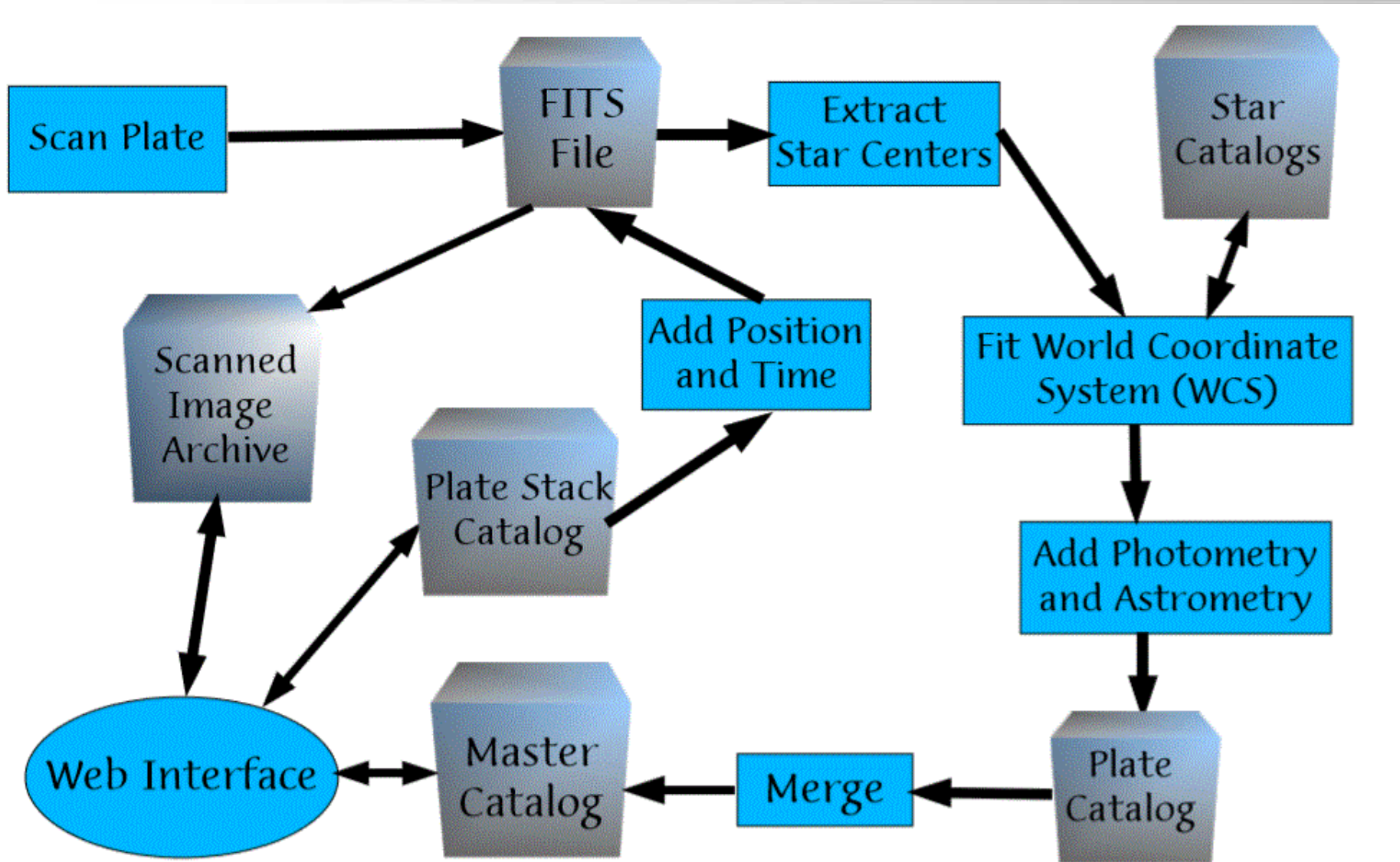
Putting Positions on Harvard's Plates

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.
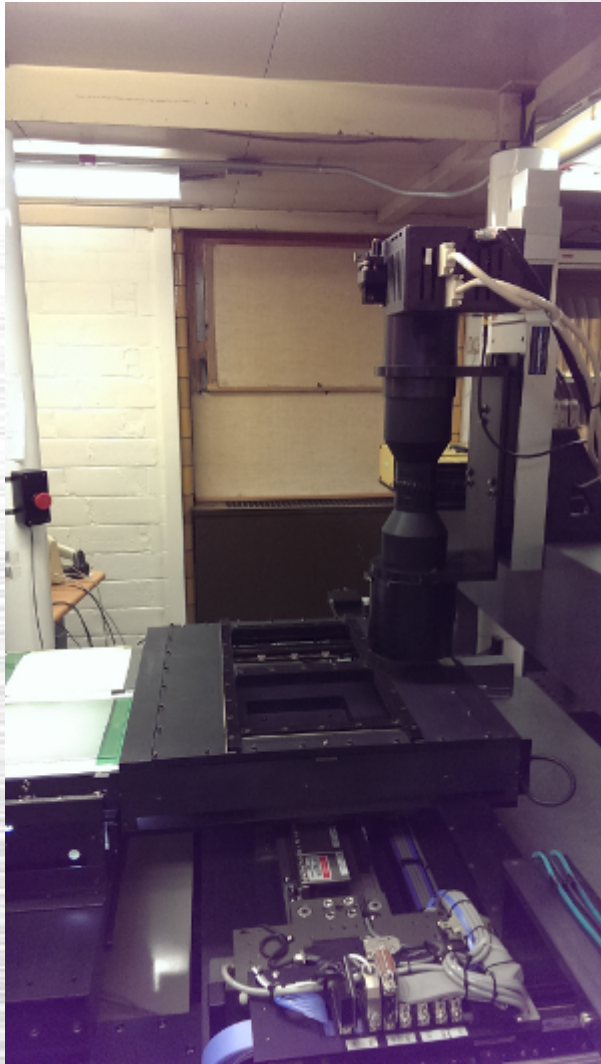

From three floors of cabinets of glass plates

Harvard Plate Pipeline

Putting Positions on Harvard's Plates

From glass to bytes on home-built scanner

Putting Positions on Harvard's Plates

M44 in Plate MC21438
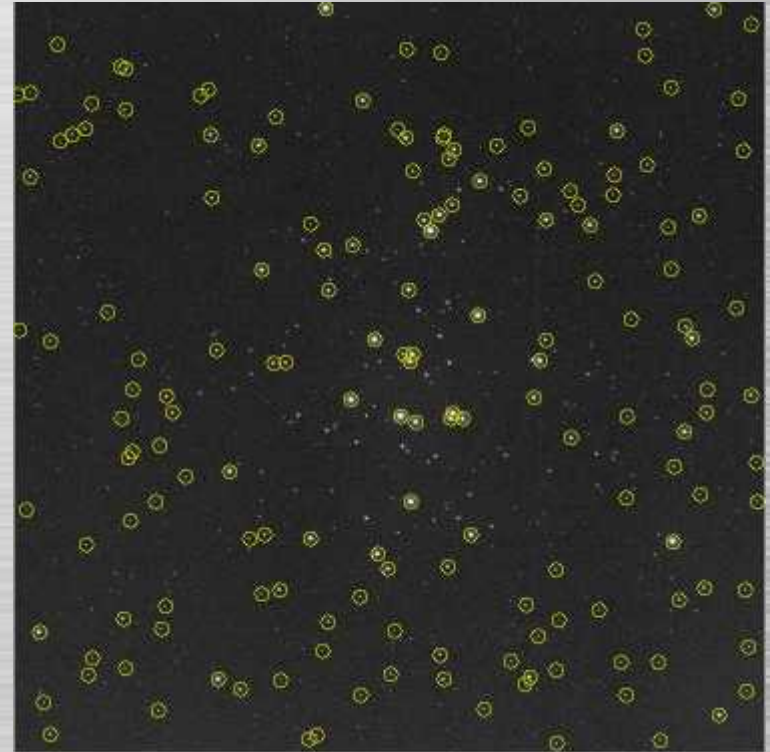
**M44 in Plate MC21438
with Tycho 2 Catalog stars marked**

Zoom in and overplot stars using WCS

MITPAL 50th, April 17, 2018

Putting Positions on Harvard's Plates

100,000th Plate Scanned, April 7, 2015

Hectospec 300-Fiber Spectrograph
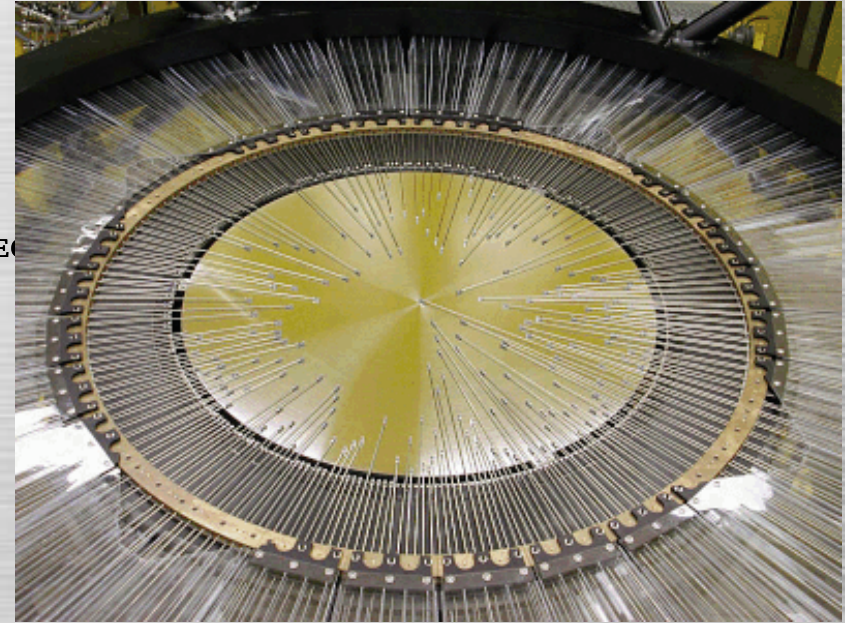
Hectospec mounted on the 6.5-meter MMT

Hectospec Focal Plane with Fibers Positioned

Hectospec Data Pipeline

SPECROAD
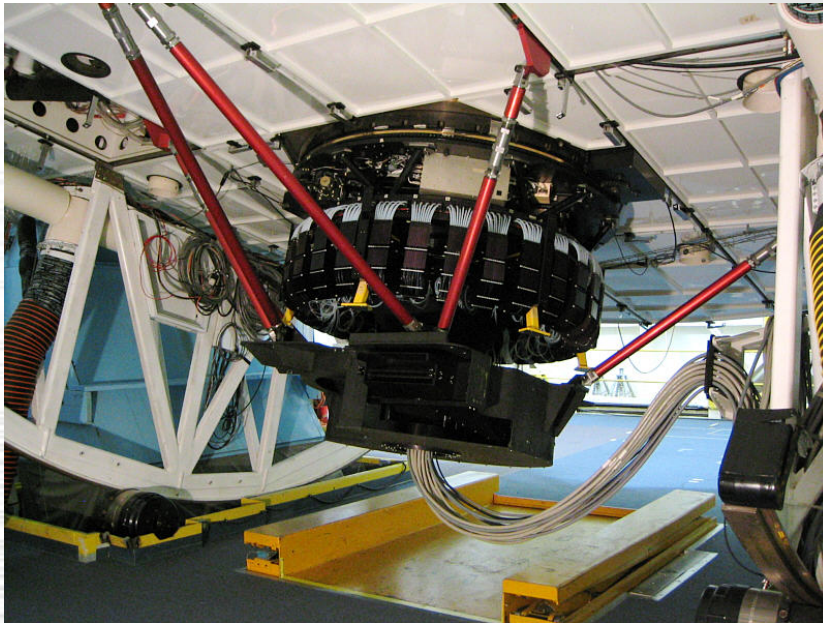1. hscreen   * Sorts files
2. mapcheck   * Makes sure that sky->fiber->aperture maps are present and properly formatted
3. hcalibproc   * Processes bias and dark field image files using HPROC (per amplifier files)
4. multihproc   * Runs HPROC on all calibration lamp (comp), sky flat, and dome flat images.
5. multihmerge   * Runs HMERGE to merge the 4 amps into 1 image for all calibration files
6. multicombine   * Combines dome flats -> domeflat.fits, sky flats -> sflat.fits, comps -> comp.fits

SPECROADCAL
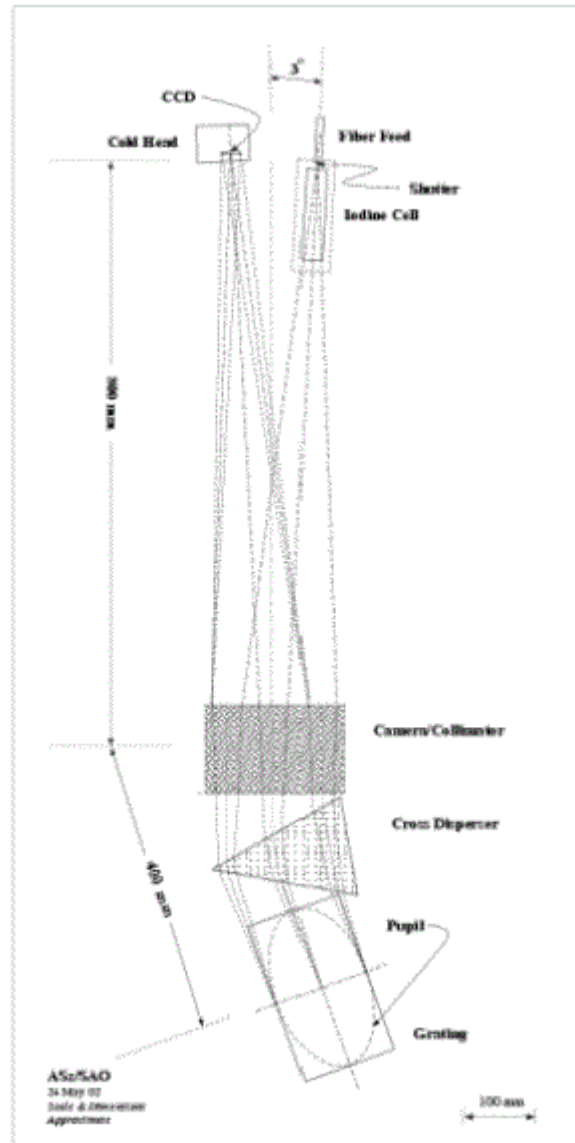1. apflatten   * creates aperture mask, flat.fits
2. multihflat   * Runs HFLAT to flatten all dome, comp, sflat calibrations
3. multihextract   * Run HEXTRACT to extract spectra from domes, comps, sflats; makes *.ms files
4. hcal   * create dispersion function
5. hlin   * linearize the skyflat in wavelength
6. maketran   * make throughput correction file tpc_sflat.ms.fits
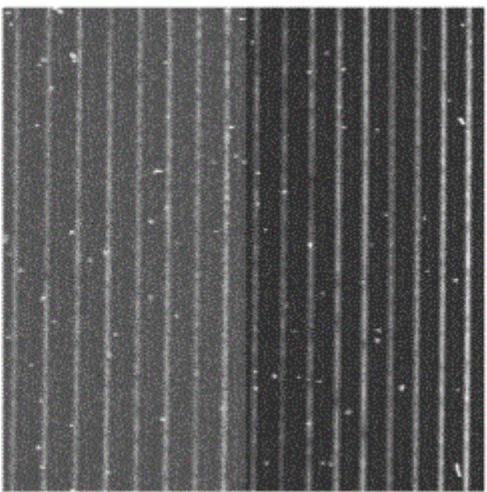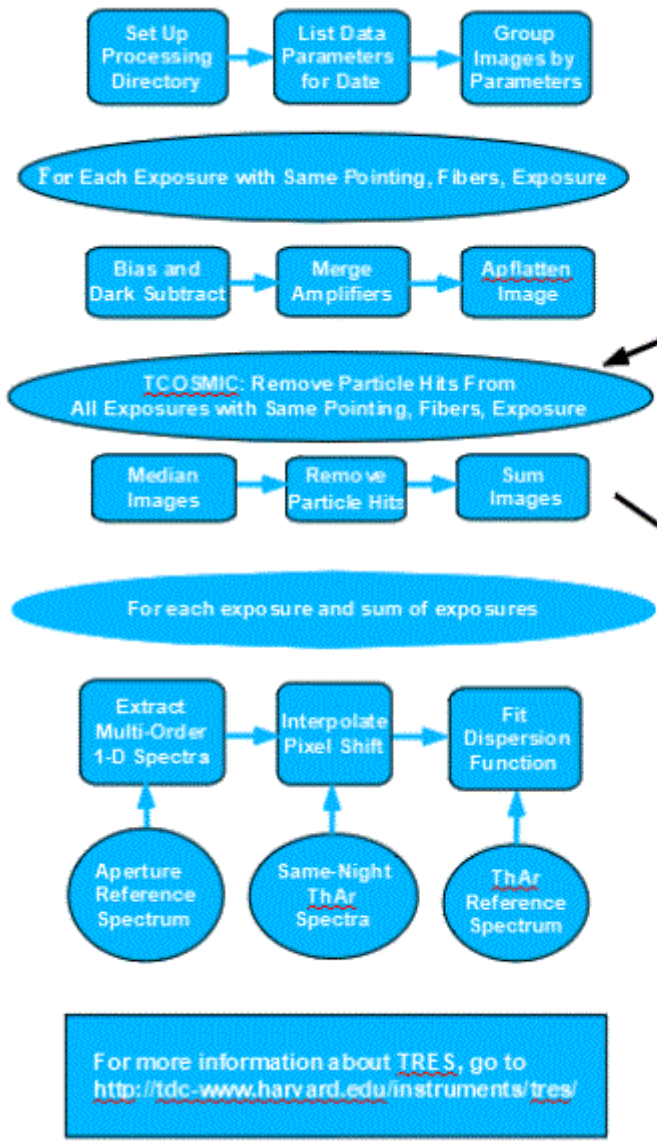
SPECROADOBJ
1. multihproc   * Runs HPROC on all object files
2. multihmerge   * Runs HMERGE to merge 4 amplifier extensions for all object images
3. multihflat   * Flattens all object files
4. multihextract   * Uses HEXTRACT to extract object exposures to IRAF multispec .ms.fits files
5. multihlin   * Linearizes object multispec files to same wavelength range and resolution
6. multihscombine   * Combines each field's multispec files to a single one
7. multihtran   * Does throughput correction on each field's combined .ms file
                      * Removes selected sky absorption features
                      * Fits and removes "red leak" from all spectra
8. multihsplit   * Splits the _r.ms files to 300 spectra, into 1d_pointing directories
9. multiskyproc   * Runs SKYPROC on each 1d_* subdirectory, saves in skysub_* directories
10. multixcsao   * Use XCSAO to run cross-correlations on skysub_* directories

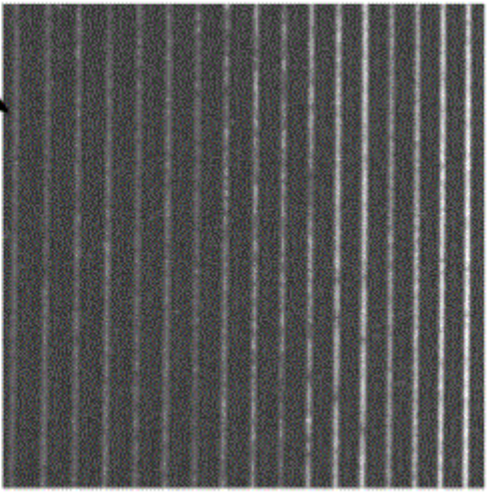# Redshifting Into the Universe

Before Sky Removal

After Sky Removal

Before Sky Removal   After Sky Removal

12,553 Spectra from the Hectospec SHELS survey
MITPAL 50th, April 17, 2018

TRES 51-order Echelle Spectrograph

TRES Spectrograph Pipeline