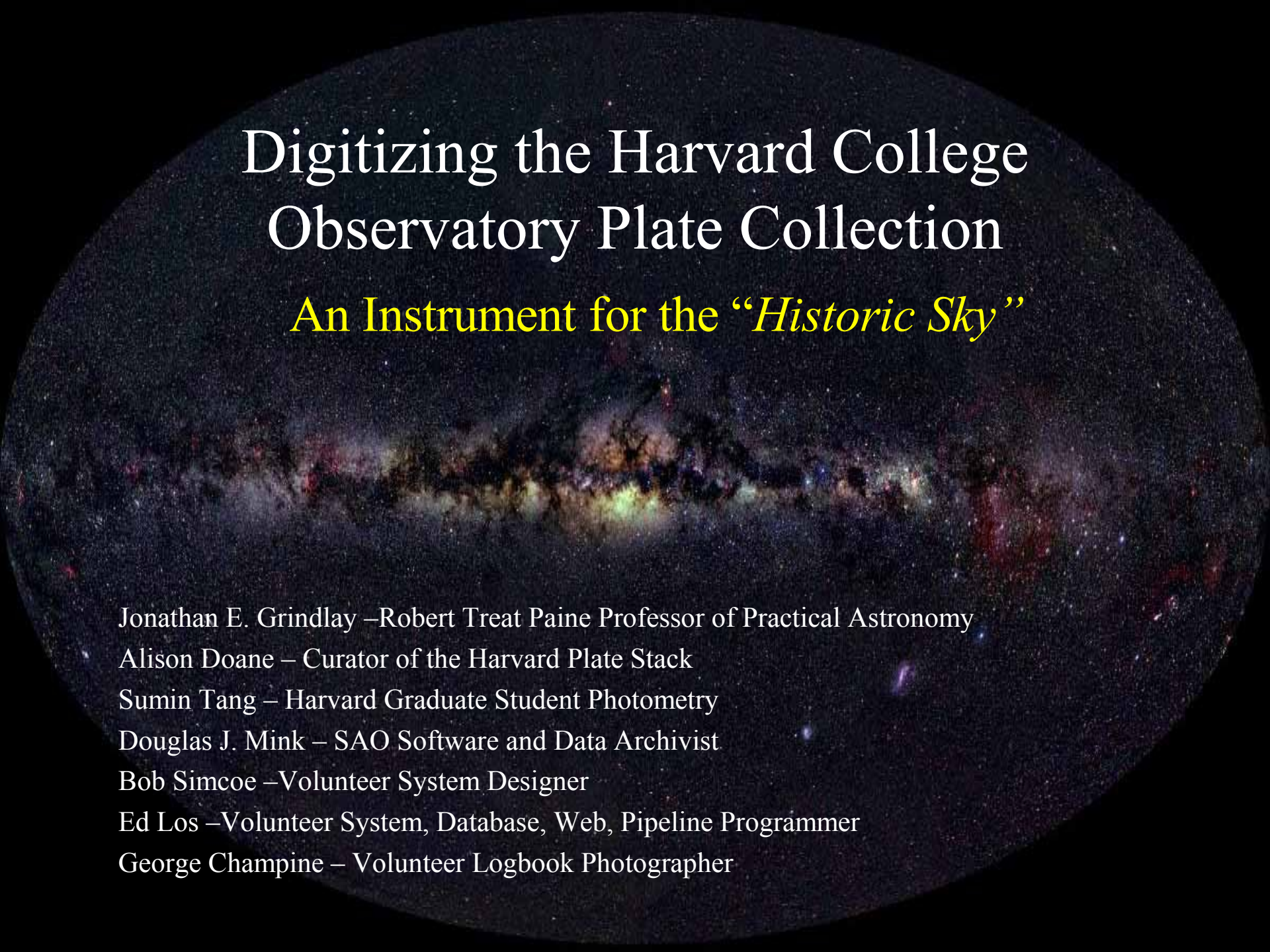


Digitizing the Harvard College Observatory Plate Collection

An Instrument for the "*Historic Sky*"

Jonathan E. Grindlay –Robert Treat Paine Professor of Practical Astronomy

Alison Doane – Curator of the Harvard Plate Stack

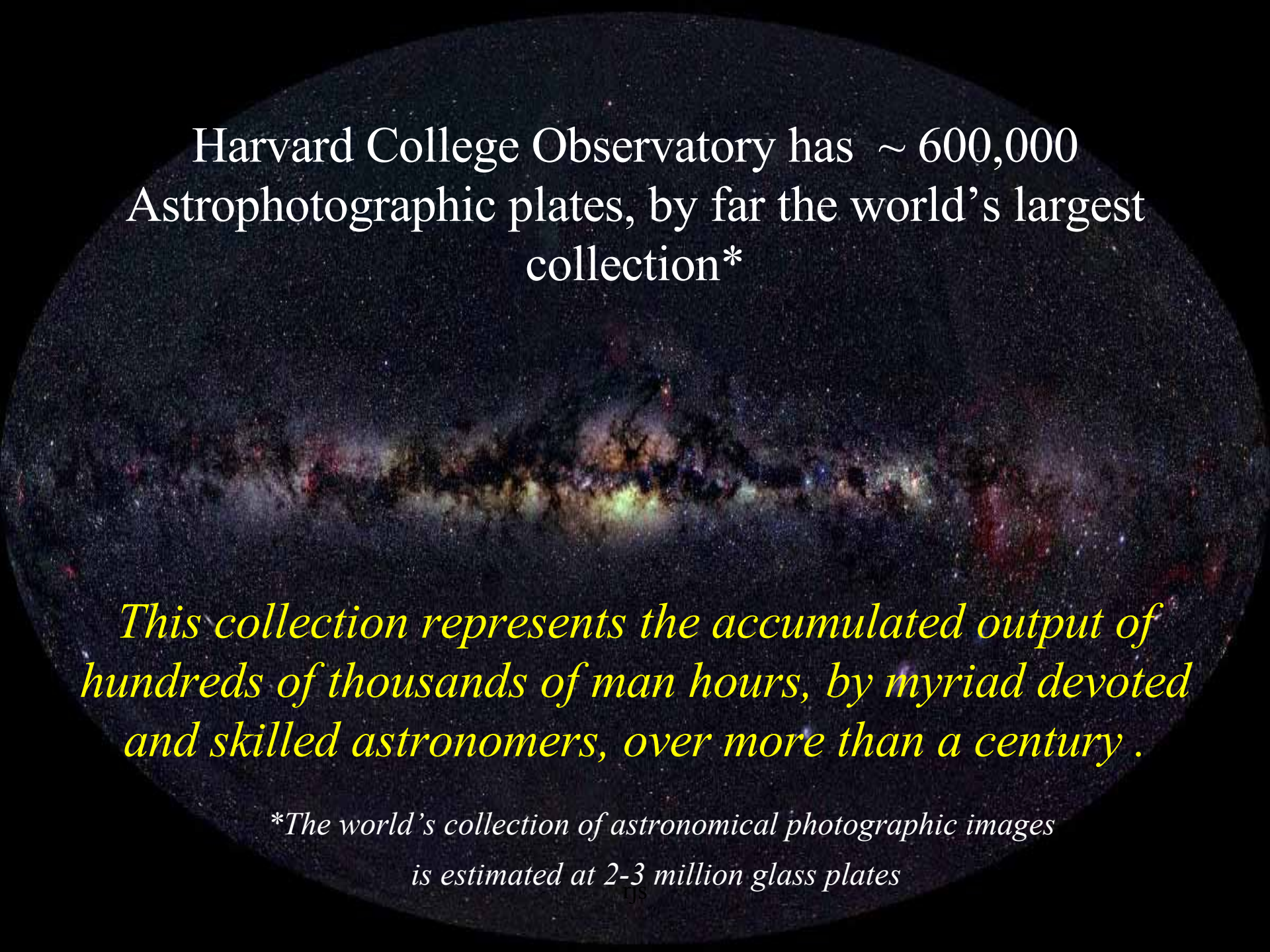
Sumin Tang – Harvard Graduate Student Photometry

Douglas J. Mink – SAO Software and Data Archivist

Bob Simcoe –Volunteer System Designer

Ed Los –Volunteer System, Database, Web, Pipeline Programmer

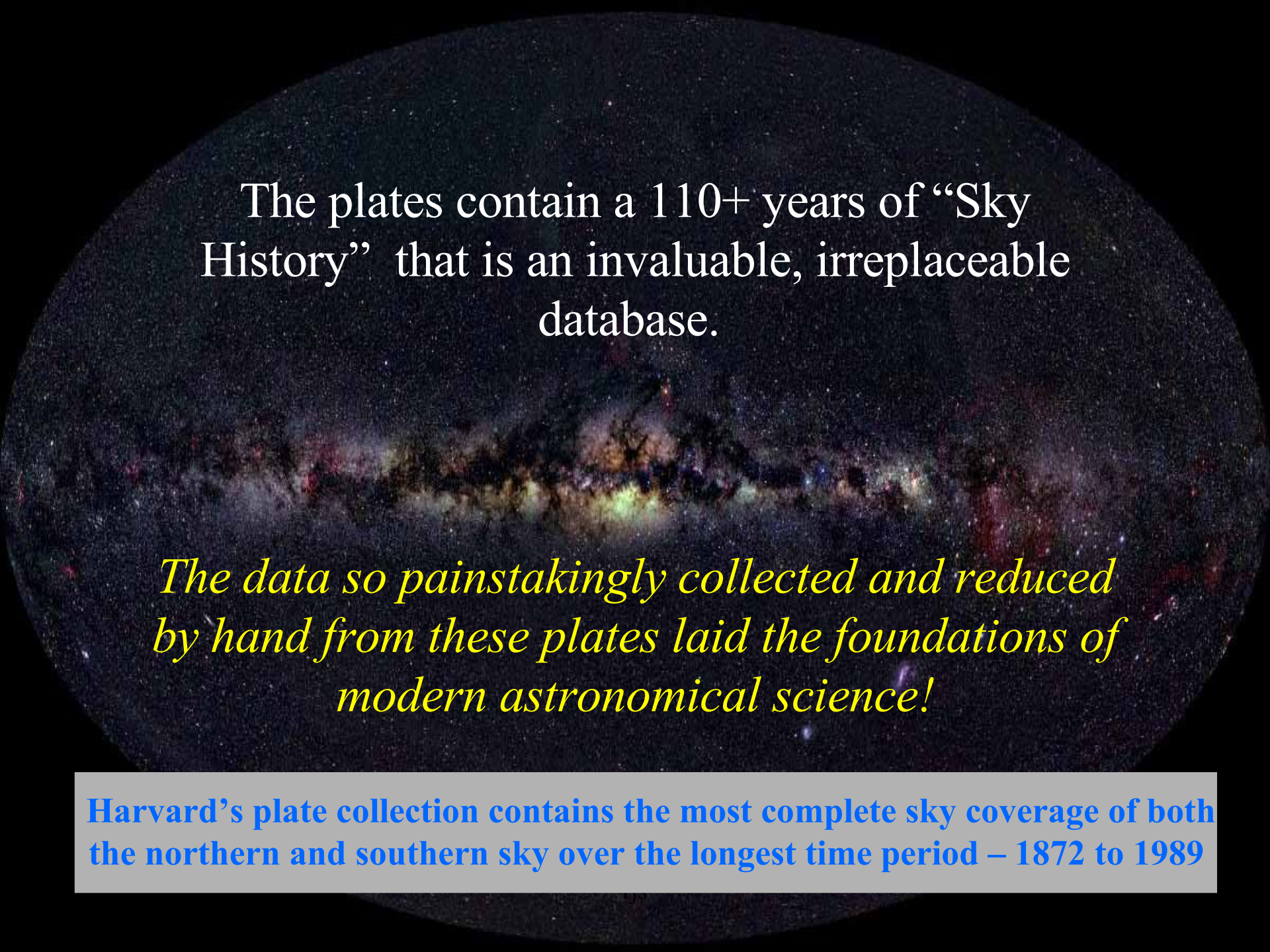
George Champine – Volunteer Logbook Photographer



Harvard College Observatory has ~ 600,000 Astrophotographic plates, by far the world's largest collection*

This collection represents the accumulated output of hundreds of thousands of man hours, by myriad devoted and skilled astronomers, over more than a century .

**The world's collection of astronomical photographic images is estimated at 2-3 million glass plates*



The plates contain a 110+ years of "Sky History" that is an invaluable, irreplaceable database.

The data so painstakingly collected and reduced by hand from these plates laid the foundations of modern astronomical science!

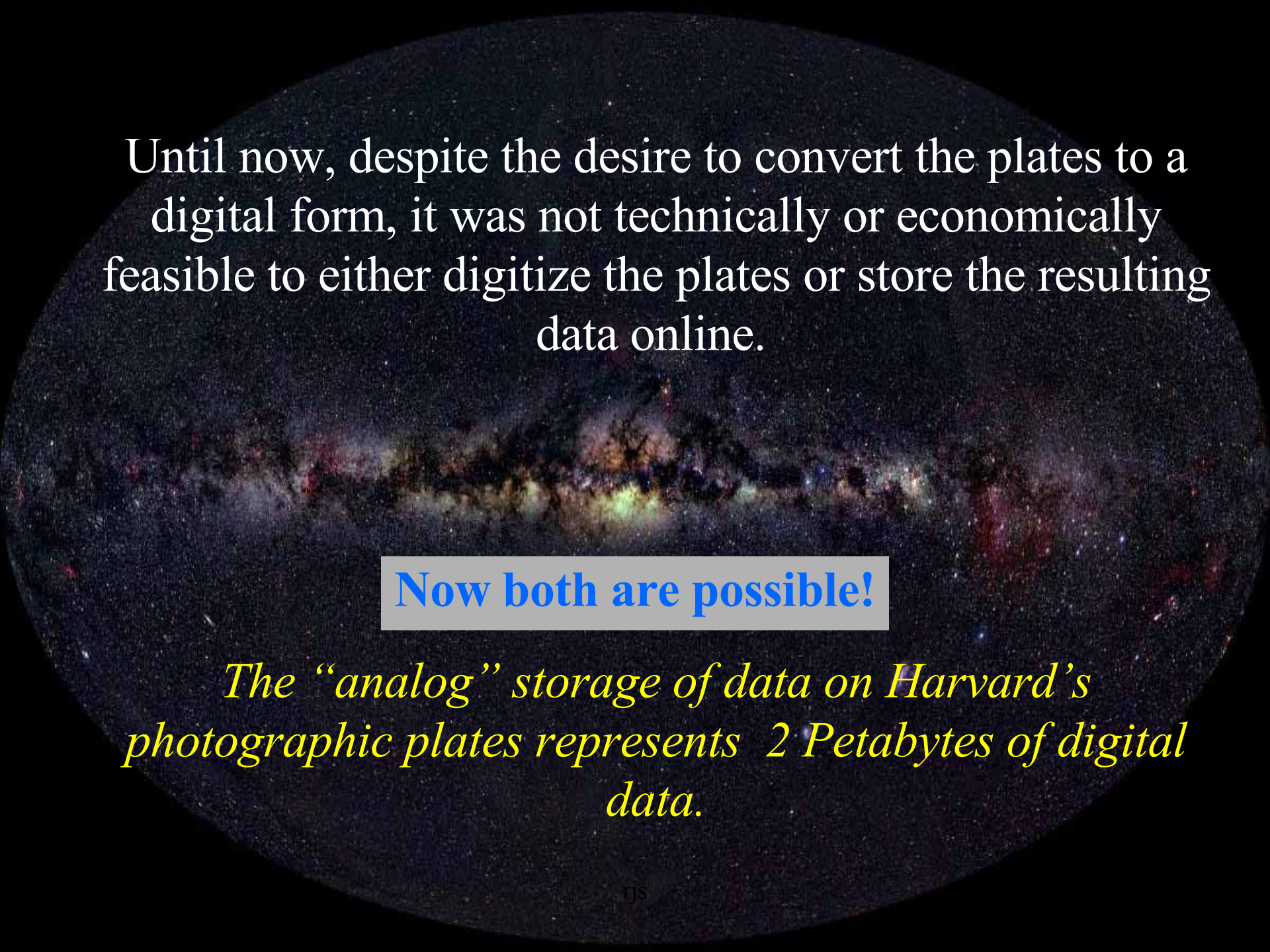
Harvard's plate collection contains the most complete sky coverage of both the northern and southern sky over the longest time period – 1872 to 1989

Harvard's collection, and other collections around the world, are already nominally in the public domain. But as a resource they are seriously under-exploited. The main reasons are:

a) Lack of catalog information in digital form about the plates

b) Lack of digitized data from the plates

The modern tools of astronomy require digital data!

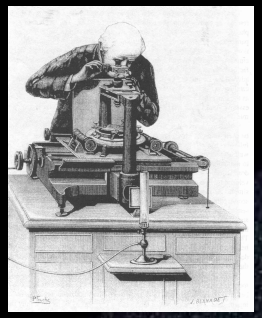


Until now, despite the desire to convert the plates to a digital form, it was not technically or economically feasible to either digitize the plates or store the resulting data online.

Now both are possible!

The "analog" storage of data on Harvard's photographic plates represents 2 Petabytes of digital data.

Automating the Measurements

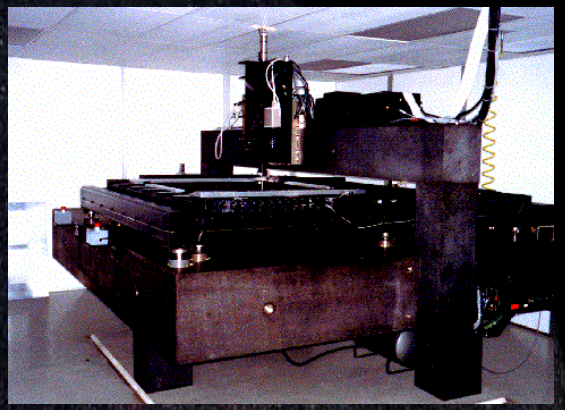


1886

*Gaertner single screw engine 1916

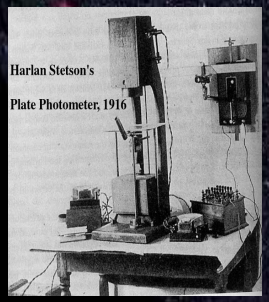
*The Grant 2 Measuring Engine-1967

**PMM (NRO ~1988)

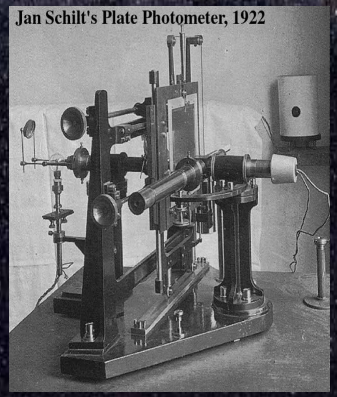


Astrometric

Photometric



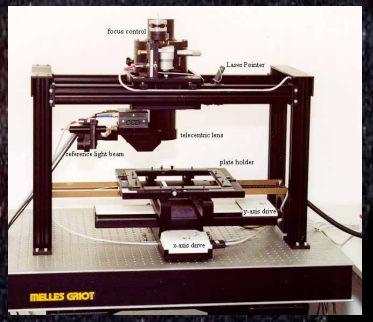
*1916



Jan Schilt Photometer -1922

*Perkin-Elmer

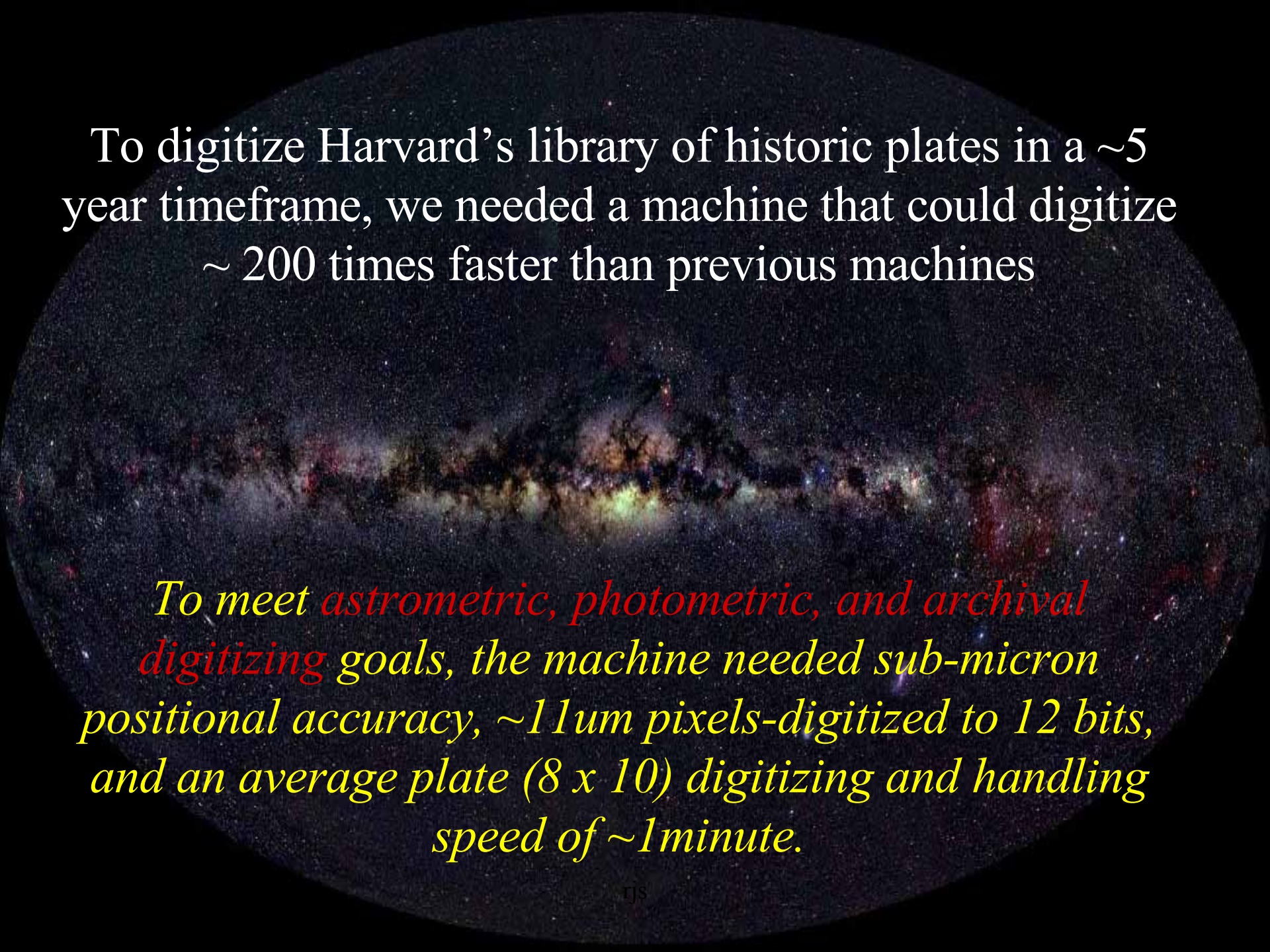
PDS ~1980



Tautenburg~1995

*http://www.astro.virginia.edu/~rjp0i/museum.html

**http://www.nofs.navy.mil/projects/pmm/pmm_caption.html



To digitize Harvard's library of historic plates in a ~5 year timeframe, we needed a machine that could digitize ~ 200 times faster than previous machines

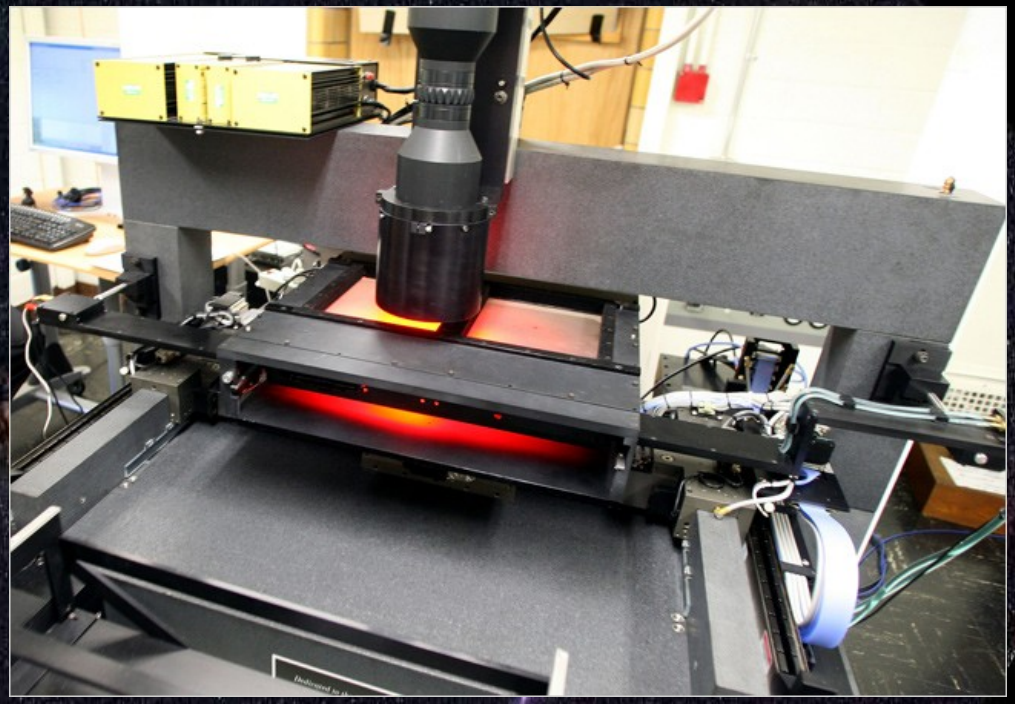
To meet astrometric, photometric, and archival digitizing goals, the machine needed sub-micron positional accuracy, ~11um pixels-digitized to 12 bits, and an average plate (8 x 10) digitizing and handling speed of ~1minute.

Using technology common to semiconductor wafer and flat panel display inspection stations, a machine was built that does ultra-fast, ultra-precise digitizing.

It will digitize two 8 x 10 inch plates or an 14 x 17 inch plate in about 90 seconds of machine time, generating enough data in that time to fill a DVD (2.8 Gigabytes-2 scans 14 x 17 plate).

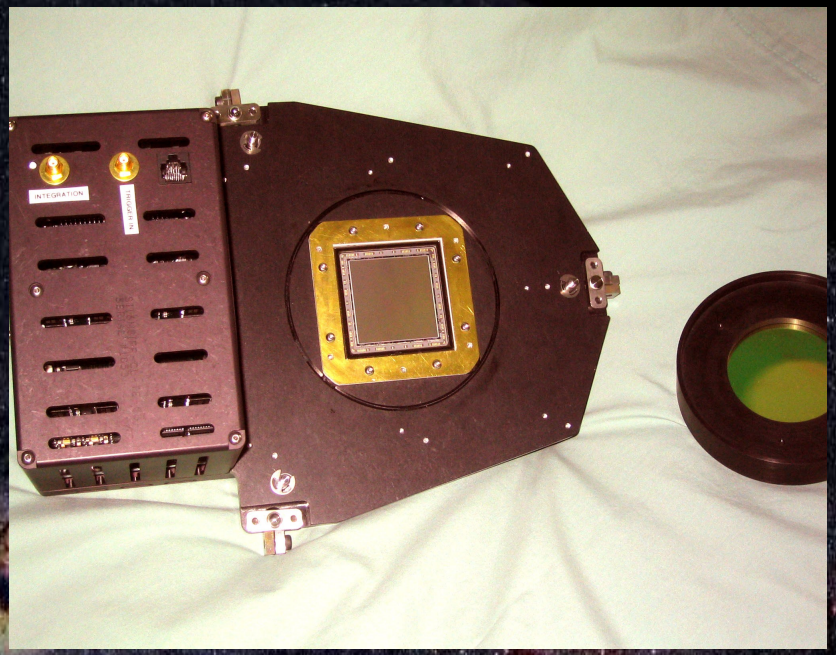
Digitizer Subsystems

- CCD Camera
- Lens
- X-Y (Z) table
- Isolation stand
- Illumination
- Fixture to hold plates
- Computer/storage system



CCD - Issues

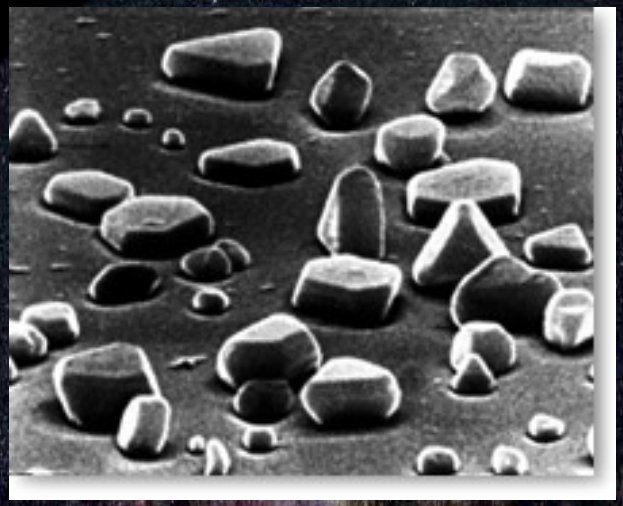
- What size pixels capture all of the information on the film?
- What speed readout?
- What sizes are available?
- How large is practical/affordable?
- Dealing with defects



-Solutions

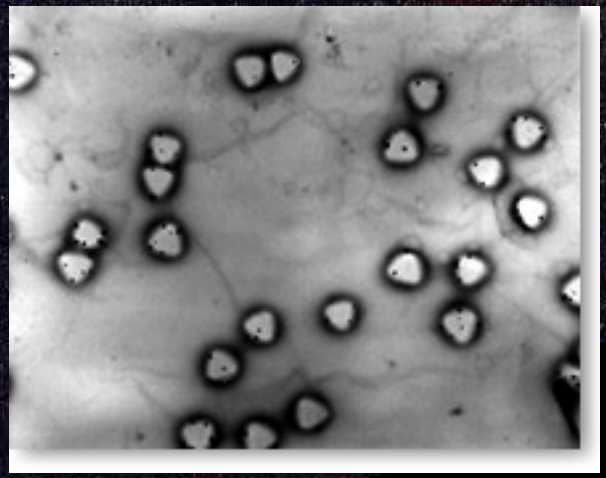
- Best candidate –ATMEL chip-**AT71201M** (old Thompson group)
- 4K x 4K, 11 um pixel, 7 frames/sec, 4 quadrant @40MHz
- No commercially available camera……but
- Generous Donor supplied a camera with a nearly perfect chip!!
- 12 bit Digitizing -32Megabytes/frame
- Scan pattern plan- ½ frame overlapping pictures in x direction, -variable overlap in y direction

Capturing all of the data on the plates



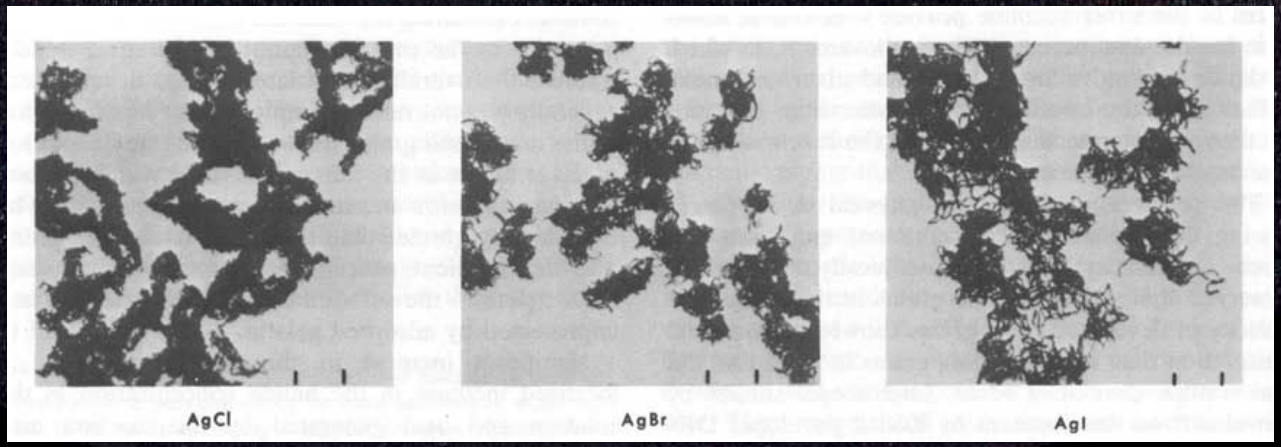
Unexposed crystal grains

Beginning to develop exposed grains

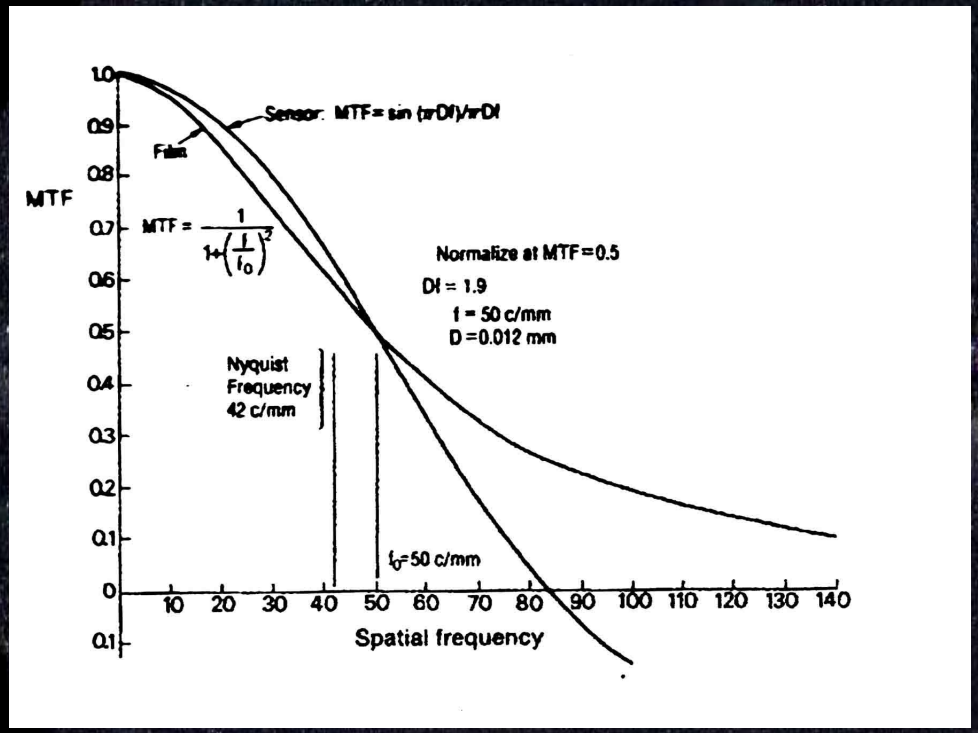


Grains develop into silver filaments

The developed grains turn into "silver wool" blobs



MTF analysis tells us the needed pixel size



STsci POSS I and II surveys used 30um and 15um pixel sizes

11um pixel = 2309dpi

Smallest star image ~ 30um

A 8 x 10 plate at this resolution is 764 Mbytes for the mosiac. (1.4 GByte for the tiles)

Film Equivalent Pixel Sizes

ISO Speed	Pixel Size
100	12um
200	14um
400	19um
1000	26um

Lens –

Issues

- Double telecentric desired
- Wide field

61mm diagonal on 45mm square CCD)

- 1:1 magnification
- large front lens
- Distortion?
- Custom design?

Solution –lucky find, commercially available lens

- Sill Optics double telecentric lens
- 1:1 magnification
- 70mm max object size
- .01% claimed .03% observed Largest source of error in system
- 180mm working distance

X-Y Table -Issues

- Accuracy in not well controlled environment
- Speed of move and settling with fixture weight
- Size of the plates/size of the table
- Getting it into the building, access limited to a 4 foot by 4 foot window and interior limited by ~50 " steel support grid!
- Table configuration impact on illumination system

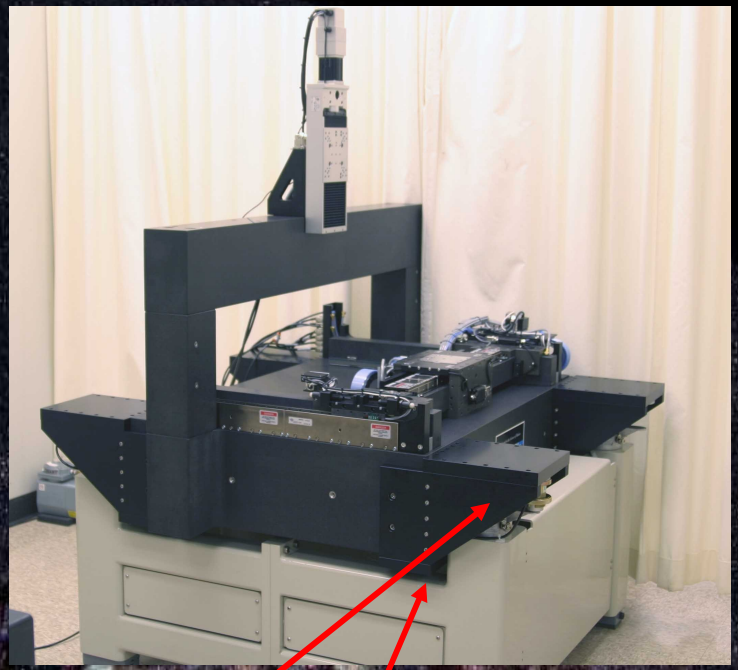
Solutions

- Chose Aerotech ABL-9000 380mm x 460mm customized table
  - Air bearing, linear motor – 75Kg load max (45-50 lb expected)
  - 22.5 mm move to +/-.1um final position in ~280 ms (light load)
  - Zerodur linear encoders, 4um multiplied to 10nm/encoder count.
  - 2D laser correction to .2u over table surface, our frame positions each laser mapped
- Table size ~4 x the largest plate size ~ min 28 in by 34 in (33.2 x 44.6{54.6})
- Table and stand must be modularized to go in through this window.
- H configuration chosen, ***No*** illumination through granite

Isolation stand

Issue

- The table is lightweight for the load and speed
- Testing showed a 5 Hz horizontal ~.5um ringing



Solution

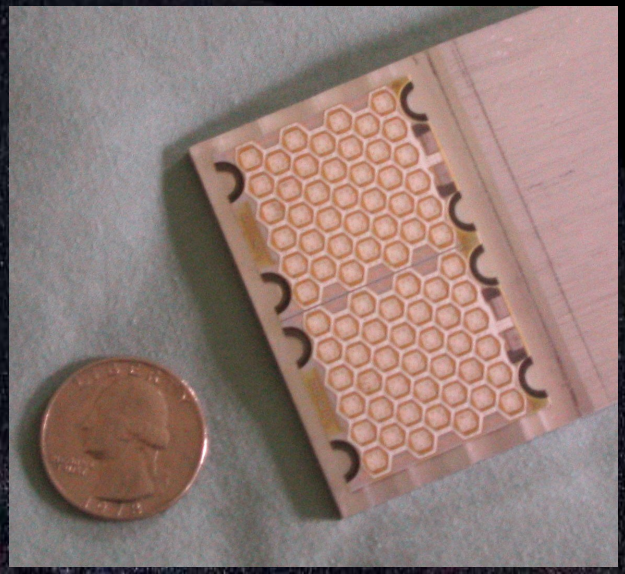
- Extension brackets for the 4 corners of the table
- Brackets allow lowering the center of gravity for the isolators and extends the effective table size.
- Added velocity control dampener devices to control x and y movement of the granite base.

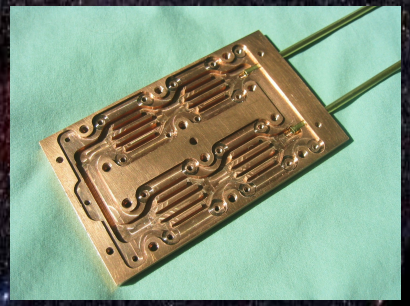
Illumination System

Issues

- Illuminate only CCD or whole plate
- How much light needed for

  10-50 ms exposure?
- Diffuse vs. collimated light
- Strobe light or shutter?
- Evenness of light, flat fielding issues

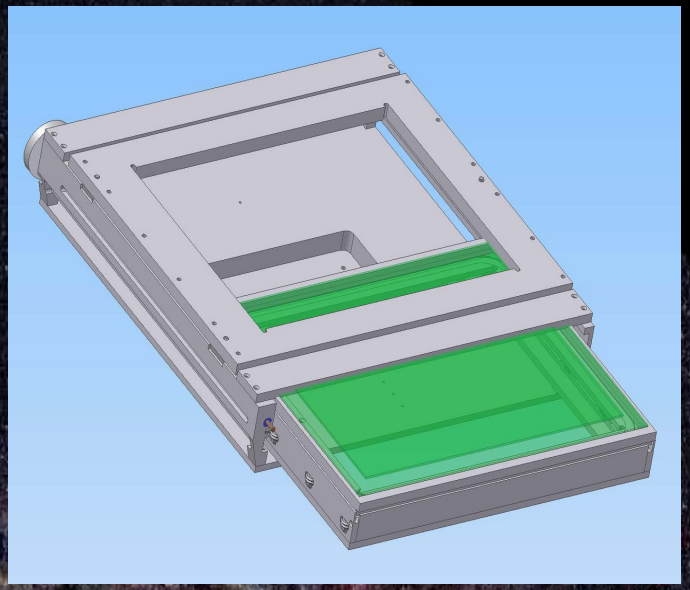




Solutions

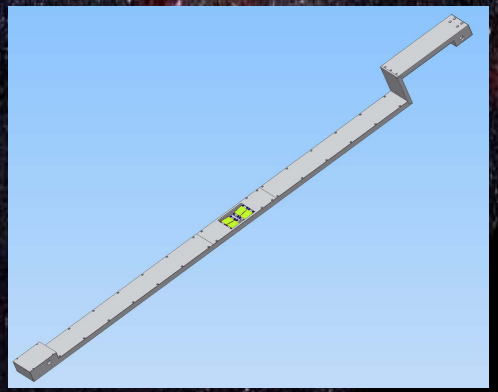
- Illuminate only the CCD –light system stationary while fixture moves
- Limited light source and support to ½ inch high 3 inch wide strip
- Strobe high power 618 nm Red LED array
- Diffuse the light with multiple layers of flash opal glass (also supports plates)
- After much experimentation, chose 4-Lamina 1inch LED arrays (117 LED's per array, 468 total). LED arrays strobed with ~140W constant current –10amp pulse! 7-50 ms duration.
- Water cooling to maintain constant temperature

Plate Holding Fixture



Issues:

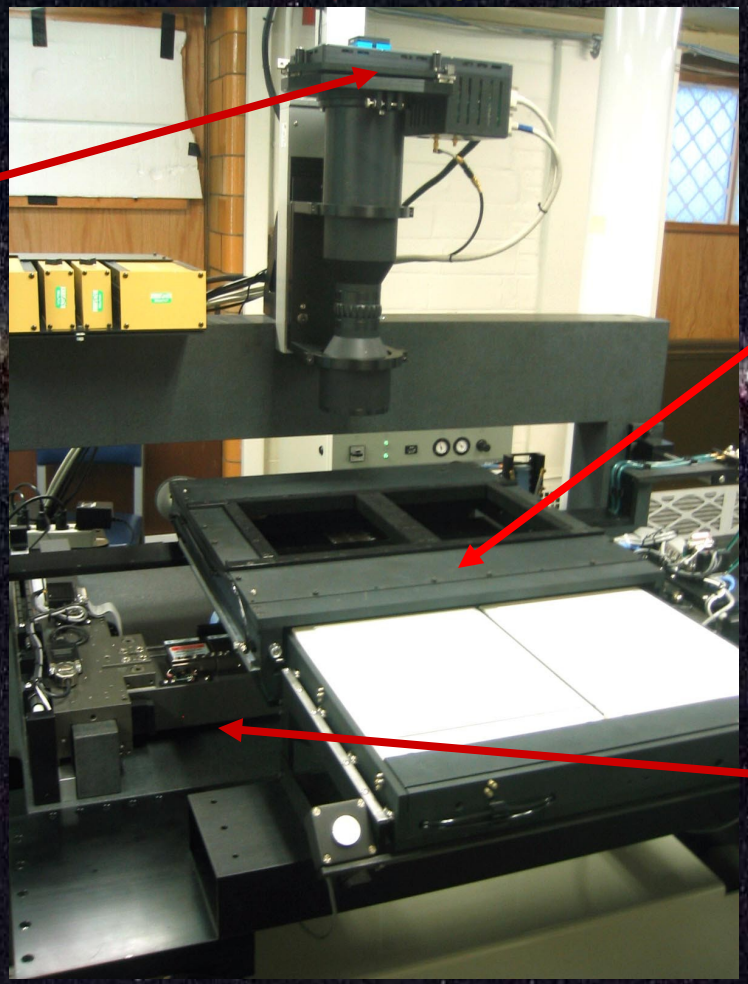
- Holding the plates flat, emulsion side up
- Some old plates are not square and have considerable wedge
- Prevent Newton ring problems
- Support the plates above illumination system
- Make it easy to load and unload plates
- Allow modular changes for different size plates
- Fixture must move around light system



Solutions:

- Pneumatically hold plate against a kinematic mounted top plate
- Use glass support on moving platform to ease loading
- Support this above light system
- Use Nitrile rubber linear O ring under the support glass to equalize pressure for uneven plates

The digitizer provides astrometric and photometric accuracy while generating archival quality digital data.



A camera can scan two 8 x 10 inch plates or a single 14 x 17 inch plate

Special fixtures to hold 14 x 17, 14 x 14,10 x 10, 2(8 x 10), and smaller plates as needed

Table accurate to .2 um over the working surface

Camera is capable of ~7 frames per second. We aim for 3 fps

Camera takes ~ 60 pictures in 45 seconds (2 exposures for each of ~30 sites for 8 x 10 plate).

11um pixels

Computer System -Digitizer

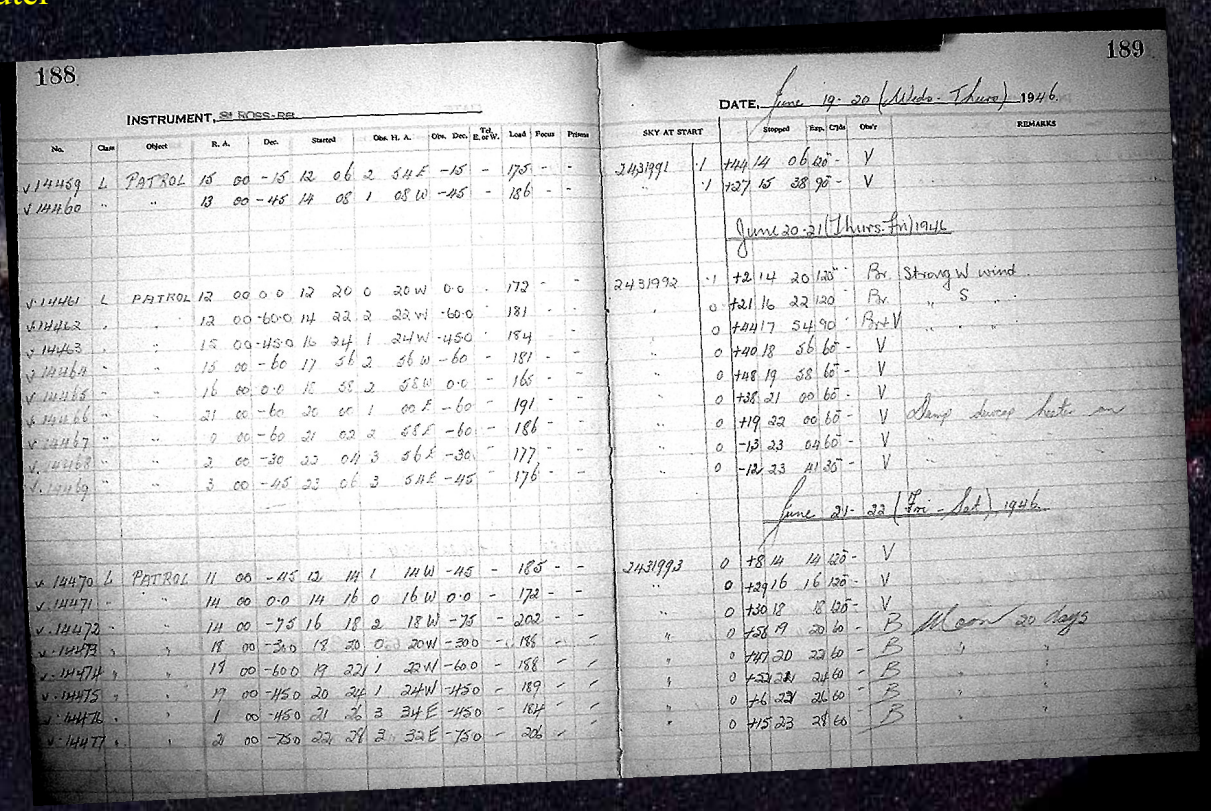
- Dual 3.2Ghz Xeon server motherboard(SuperMicro X5DAE)
- 2Gbyte ECC memory
- Dalsa (formerly Coreco) Video capture X64-CL Dual card (PCI 133)
  2 – 400 MHz Camera link base links (24 bits wide)
- Aerotech PCI 500-Ultra motion control card
- Single SATA II disk for data capture (formerly Raid 10 SATA I)
- Runs Microsoft XP operating system.

Computer System – Dasch1

- Dual/Quad Xeon 64-bit dual core processor with front side bus speeds of up to 1.333 GHz
- SuperMicro X7DAE server motherboard
- 8Gbyte ECC memory
- SATA II raid array 32 disks 4 sets of 8 disk arrays (2 disks/array can fail)
- Currently 500Gb disks for 16TB of raw storage 12 TB of formatted storage (24Tb with ! TB disks)
- Plus two internal disk locations for operating system
- Runs Fedora Core 5 Linux
- Data movement to Digitizer by physically changing disks! Also 1Gbit Ethernet direct connection

Logbook -- Metadata conversion

1. Photograph all pages -- Done (~ 80K pages)
2. Type in each plates entry
3. Check for errors
   - By computer
   - By eye



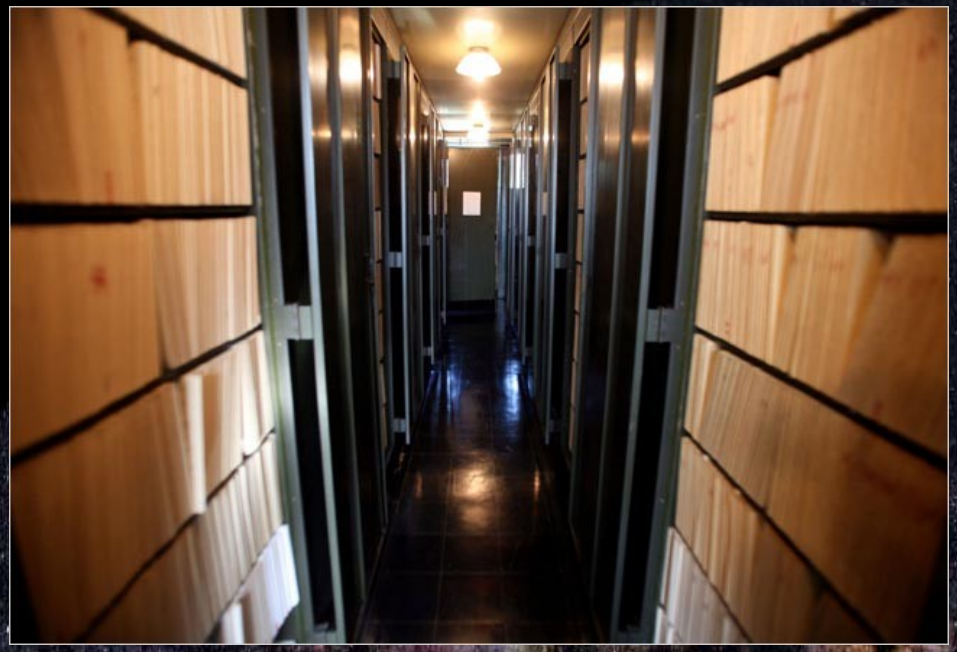
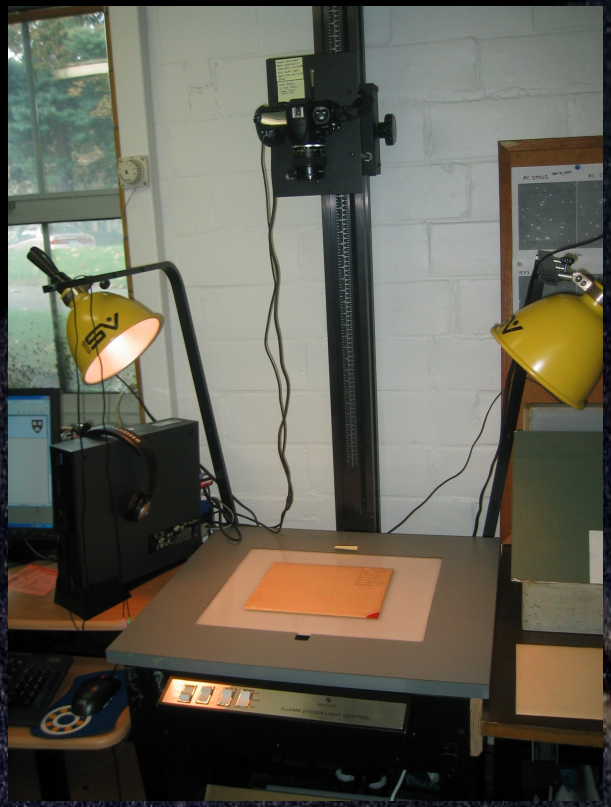
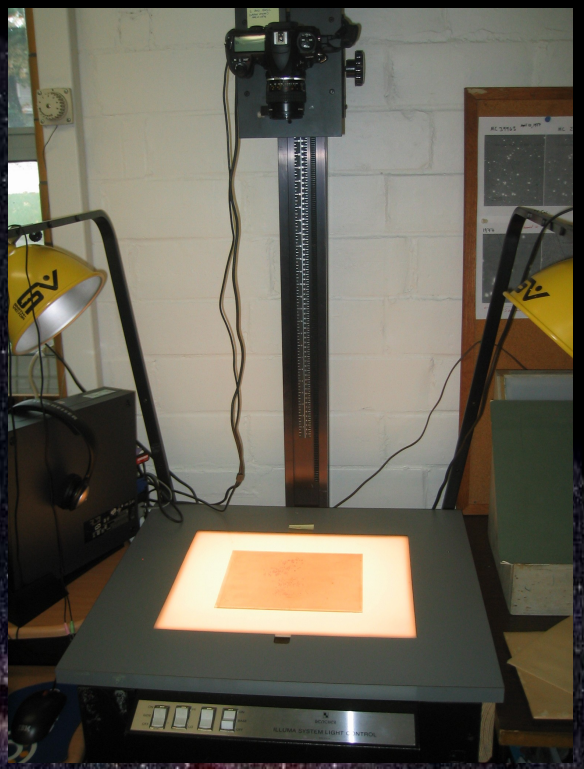


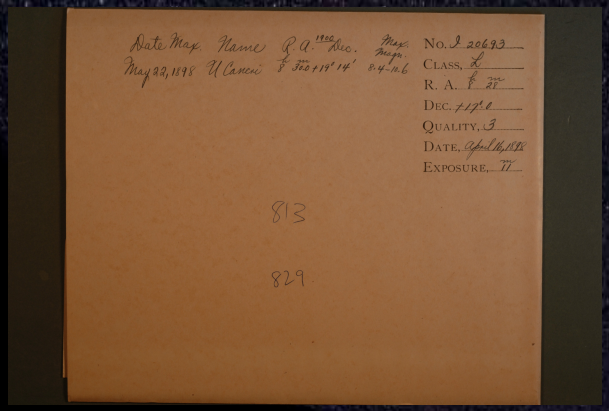
Plate Stacks 3 floors

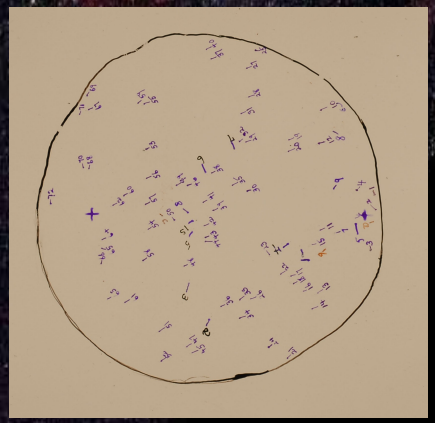
~ 160 Tons

Nikon D200 Station






Date Max
May 22, 1998
Name
U Cancri
R.A. 1950
8 30m
Dec.
+19° 14'
Max. Mags.
8.4-11.6
No. 1 20693
Class, L
R. A. 8 27m
Dec. +19°.0
Quality, 3
Date, April 16, 1998
Exposure, 11
813
829



Cleaning station

Two planned

VOC without external exhaust

DASCH

Digital Access to a Sky Century @ Harvard

A New Look at the Temporal Universe

- Home
- Project Status
- Sample Plate (i31013)
- Search the Database
- Plate Series
- Plate Class
- Observatories
- Database Contents
- Logbooks
- Scanner
- Gallery
- DASCH Photometry Results
- Project Team
- DASCH in the News
- DASCH Publications
- Links

Plate Database Search

A blank field implies that all values in the database will be included. A specified object name overrides any specified coordinates.
Only one exposure is displayed for scanned or fitted plates. The browser stop button will interrupt the search.

Series: PlateNumber: Plate Class:

Starting Date (yyyy-mm-dd or year. frac) Ending Date (yyyy-mm-dd or year. frac) Maximim Results to Display 1000

Object Name Radius (arcsec) to extract: 200 FITS JPEG TAR ZIP

Right Ascension (hh:mm:ss.sss) Declination (dd:mm:ss.sss) B1950 J2000

Search Entire Database Search Scanned Plates Search WCS Fitted Plates Submit

Plate Information for i31013

Observatory Name	Cambridge
W. Longitude (deg)	71.1292
Latidude (deg)	42.38
Aperture (m)	0.2
Scale (arcsec/mm)	163.24
Telescope	8-inch Draper Doublet, Voistlander Reworked by Clark
Plate Class	L
Photograph of the Plate Jacket	View the Plate Jacket (3.1MB)
Photograph of Plate Annotations	View the Plate Annotations (2.8MB)

Plate Exposure Information

Exposure Number	0
Exposure Time (minutes)	10
Right Ascension	08:43:39.523
Declination	+20:18:28.29
Geocentric Date	1903-10-20T09:31:50.6
Heliocentric Date	1903-10-20T09:30:14.4
Plate Center Source	imWCS
Date Source	Logbook
Exposure Notes	m44
Time Accuracy (days)	0.0007

Raw Logbook Data - View the Logbook Page (0.5MB)

Exposure Number	0
Exposure Time (minutes)	10
Right Ascension	8 38
declination	+21.0
Date	Oct 19 1903
Exposure Start Time	6 33
Exposure Stop Time	6 43
Exposure Hour Angle	2 05E
Logbook Remark Present	
Logbook Notes	m44
Error Type	

Scan Data

612 Pixel High JPEG Thumbnail	View the Thumbnail
Image 0.375 deg radius at 130.0925 deg RA 19.672 deg DEC J2000	View the JPEG Image
Scan Number	0
Mosaic Number	0
Scan Date	2006-09-08T18-32-16
Average Tile ADU	2044
Average Tile Saturation (pixels)	0
Maximum Tile Saturation (pixels)	0
Scan Comment	
Mosaic Comment	
Mosaic Binning	01,16
WCS Fit Solution	Available
Mosaic Rotation	180

rjs

Database Contents

Plate Selection

Observatory Location

Plate Class

Plate Jacket Photographs

Plate Annotation Photographs

Exposure Information

Geocentric and Heliocentric Dates

Plate Center Source and Date Source

Exposure Notes

Time Accuracy

Logbook Information

Exposure Start and Stop Times

Hour Angle

Logbook Remark

Logbook Notes

Errors Detected Automated Checks

Scan and Mosaic Information

Scan Number .

Mosaic Number

Scan Date

Average Tile ADU

Average and Maximum Tile Saturation

Scan Comment

Mosaic Comment

Mosaic Binning

WCS Fit Solution

Mosaic Rotation

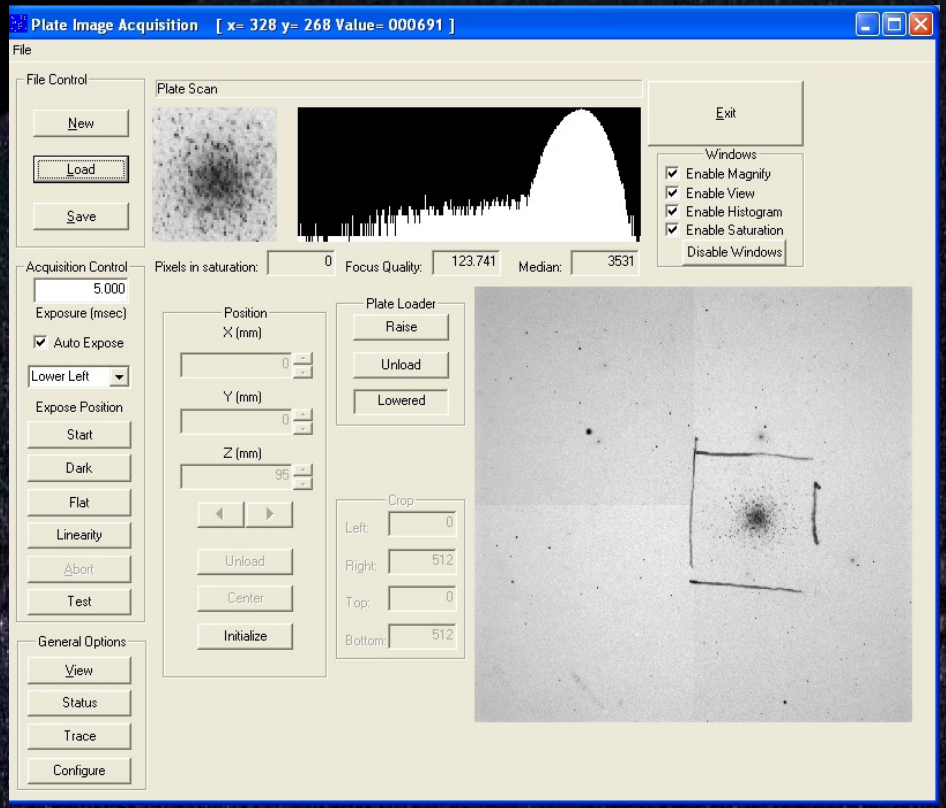
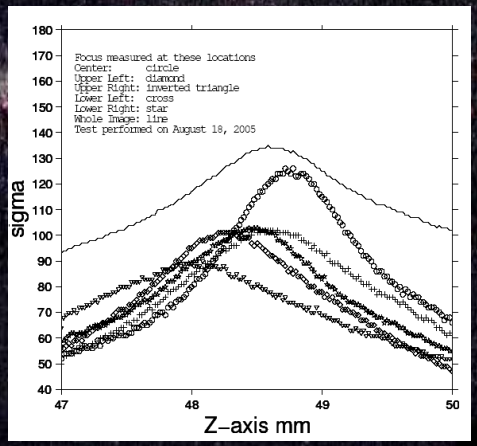
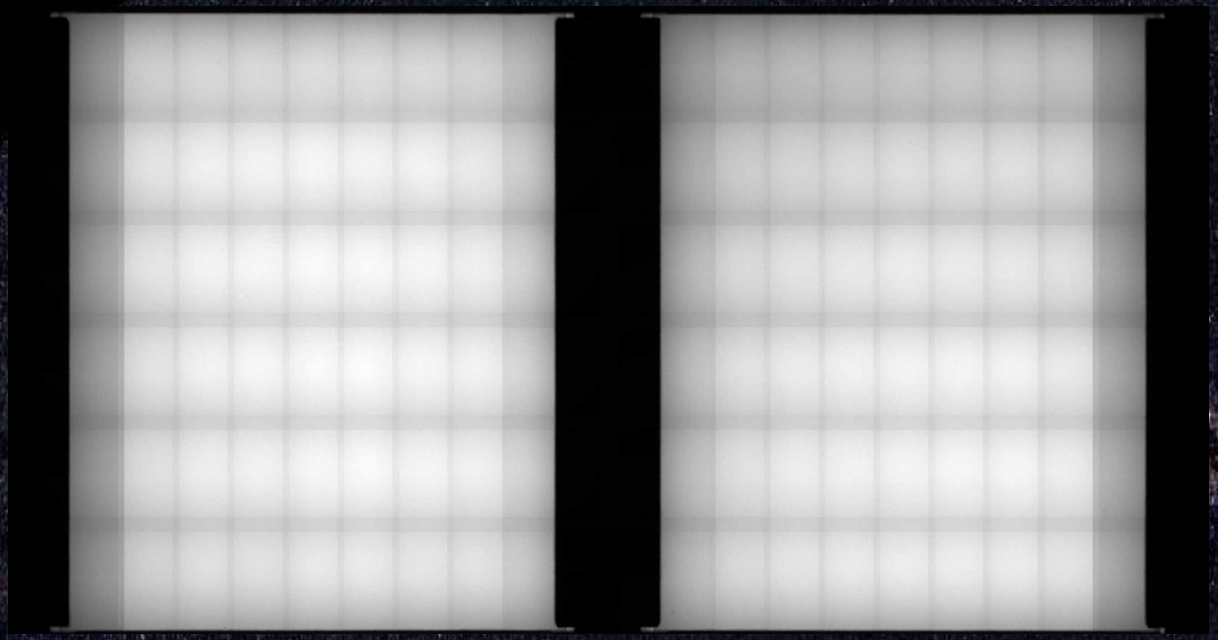


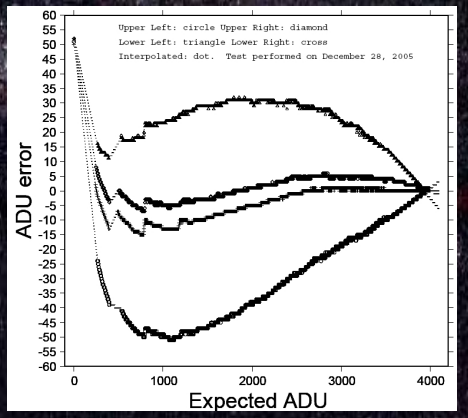
Plate Image Acquisition [x= 328 y= 268 Value= 000691]
File
File Control
New
Load
Save
Plate Scan
Exit
Windows
Enable Magnify
Enable View
Enable Histogram
Enable Saturation
Disable Windows
Acquisition Control
5.000
Exposure (msec)
Auto Expose
Lower Left
Expose Position
Start
Dark
Flat
Linearity
Abort
Test
Pixels in saturation: 0
Focus Quality: 123.741
Median: 3531
Position
X (mm)
Y (mm)
Z (mm)
Unload
Center
Initialize
Plate Loader
Raise
Unload
Lowered
Crop
Left: 0
Right: 512
Top: 0
Bottom: 512
General Options
View
Status
Trace
Configure


Focus measured at these locations
Center: circle
Upper Left: diamond
Upper Right: inverted triangle
Lower Left: cross
Lower Right: star
Whole Image: line
Test performed on August 18, 2005
sigma
Z-axis mm
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
47
48
49
50

Flat Fielding



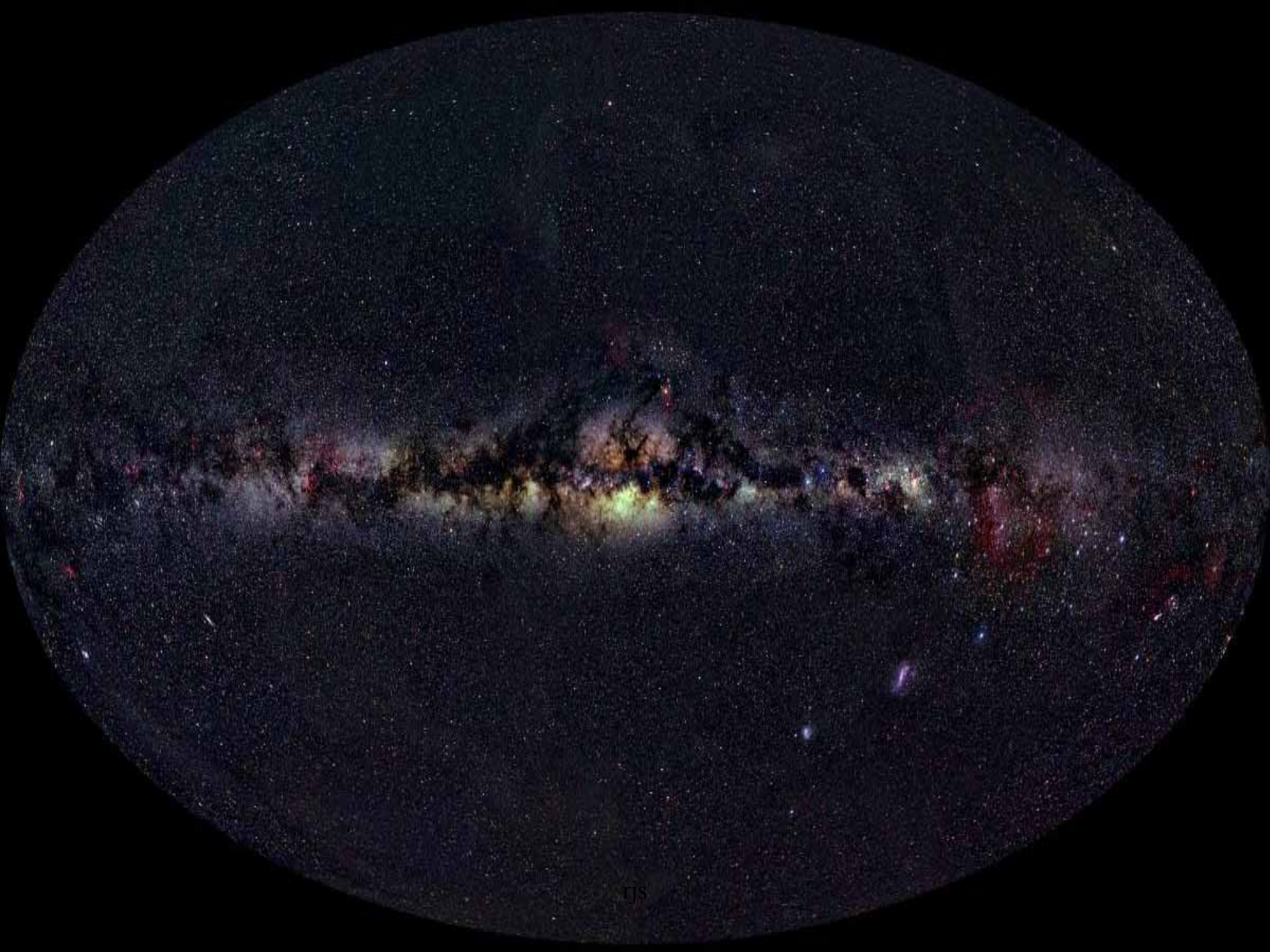
Two 8 x 10 plates shown



Non linearities in the

4 quadrants

of the CCD



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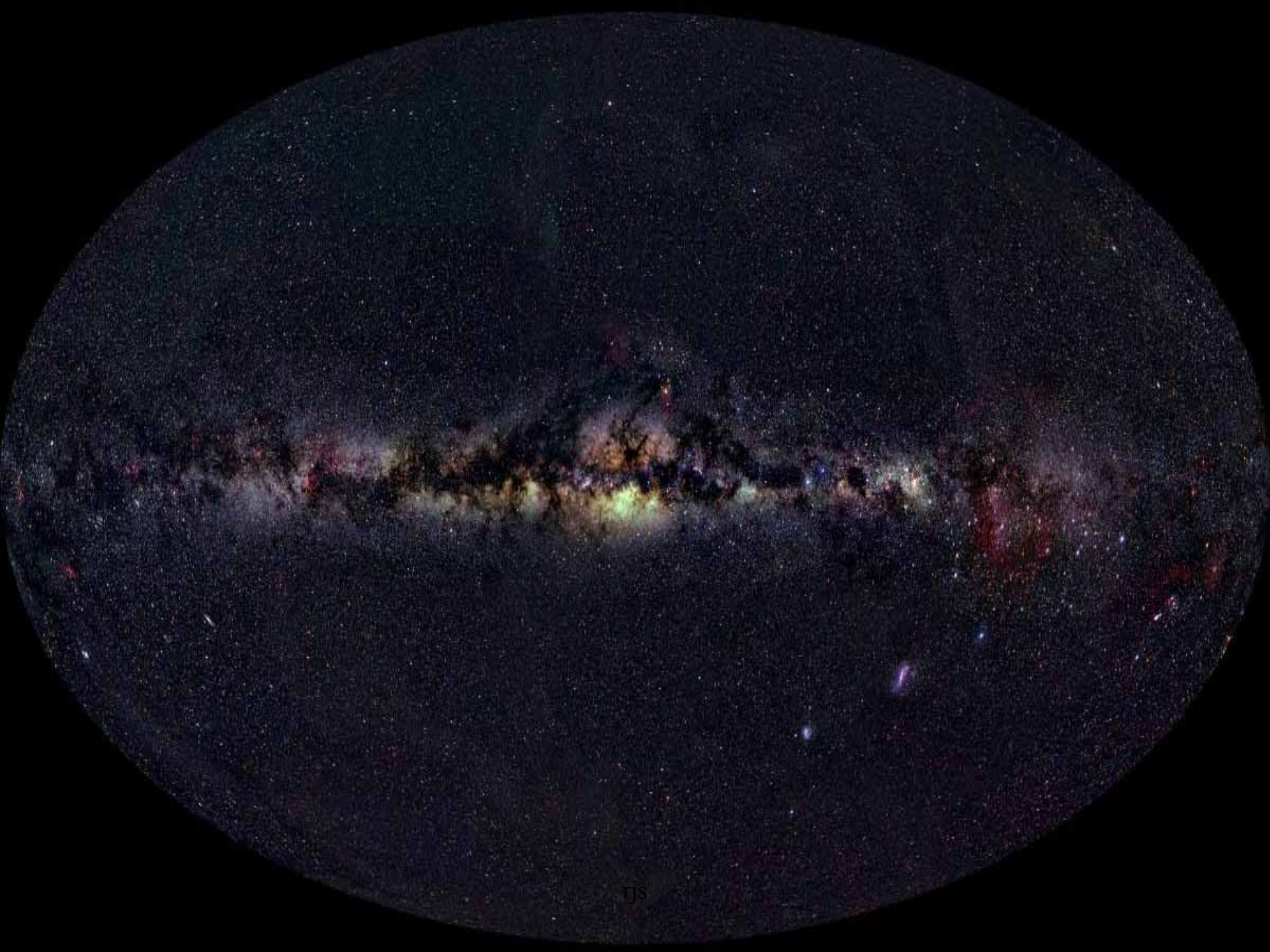

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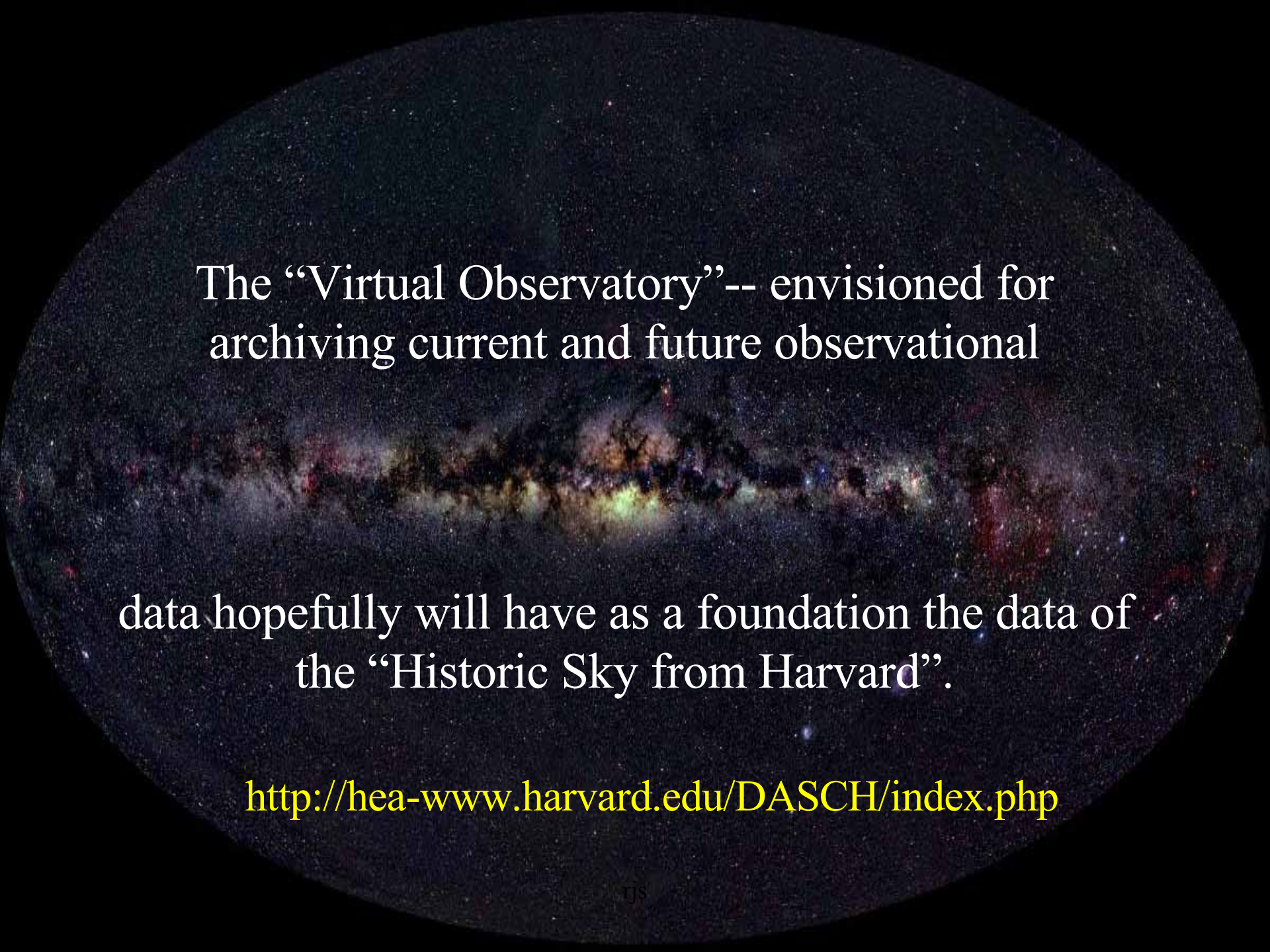

The “Virtual Observatory”-- envisioned for archiving current and future observational

data hopefully will have as a foundation the data of the “Historic Sky from Harvard”.

http://hea-www.harvard.edu/DASCH/index.php


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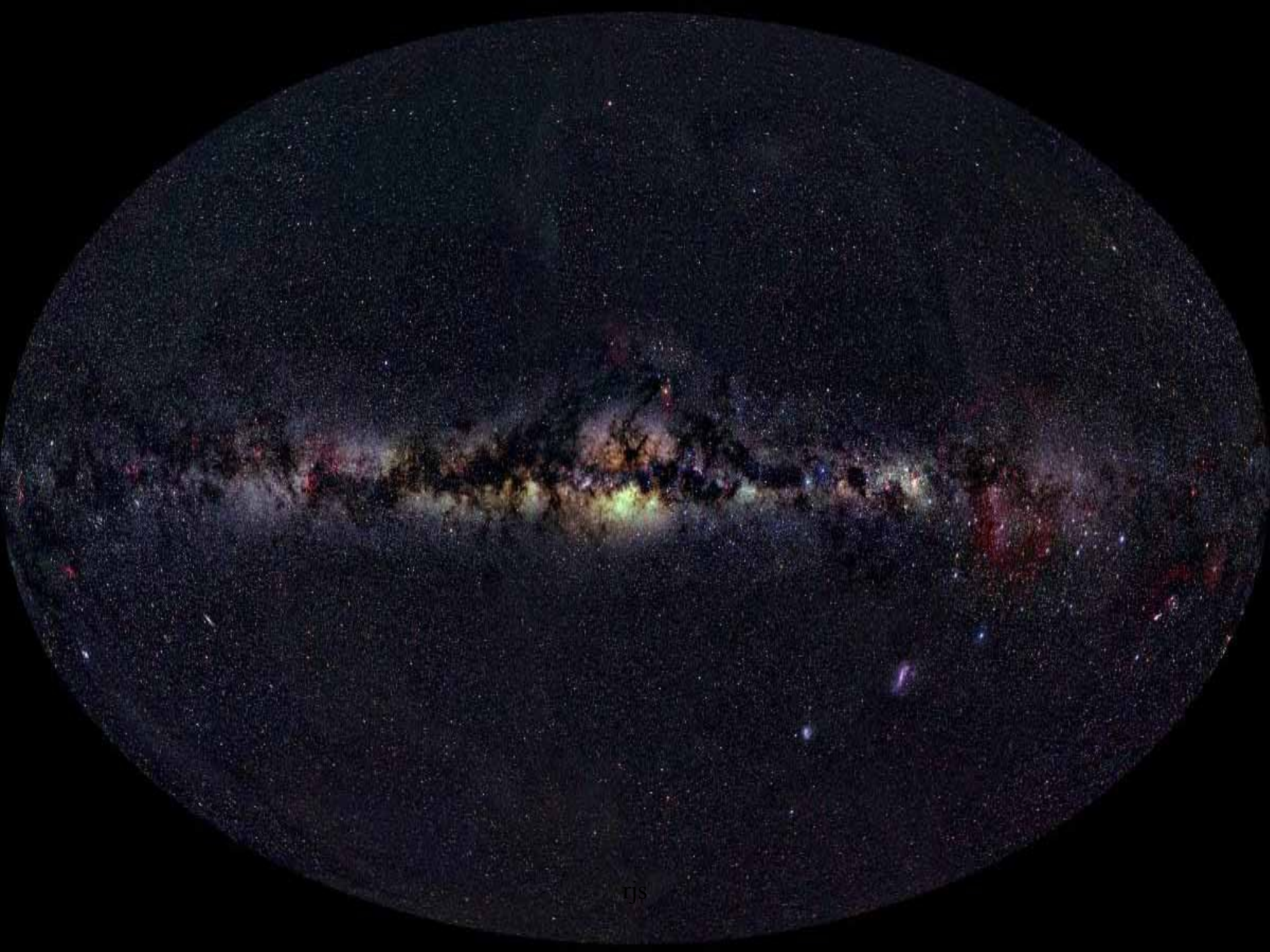

rjs