Solar System Science with the Hubble Space Telescope

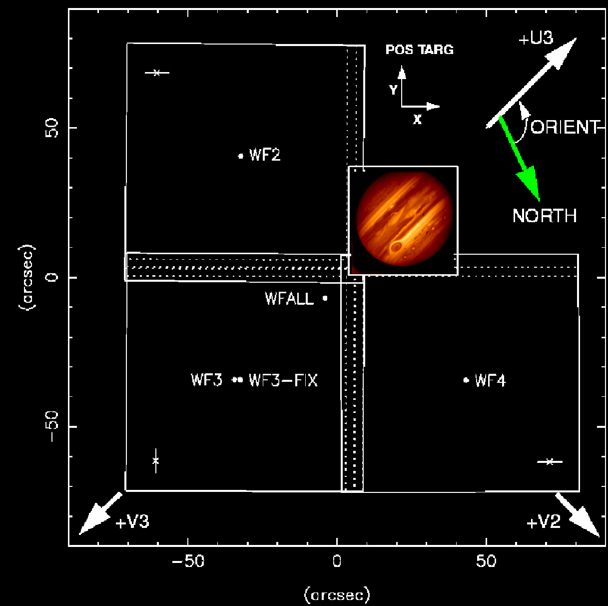
Susana Deustua, STSCI

ISWI Workshop, Quito, Ecuador 11 October 2012

The Planet Pipeline

(and Citizen Science)

Data curation and mining of
Solar System images from WFPC2



ORIENT is defined as the Position Angle of the +U3 Axis on the Sky.

Hubble Cycle 18 Legacy Archival Research proposal 12142
Max Mutchler, Mike Wong, Alberto Conti, Susana Deustua, Pamela Gay,
Alex Viana, Corey Lehan, Justin Higgins, Sean McKenna, Dan Golombek, John Grunsfeld

Hubble Space Telescope

mass: 11,110 kg (24,500 lb)

Near-circular low Earth orbit

low earth orbit: 559 km above surface

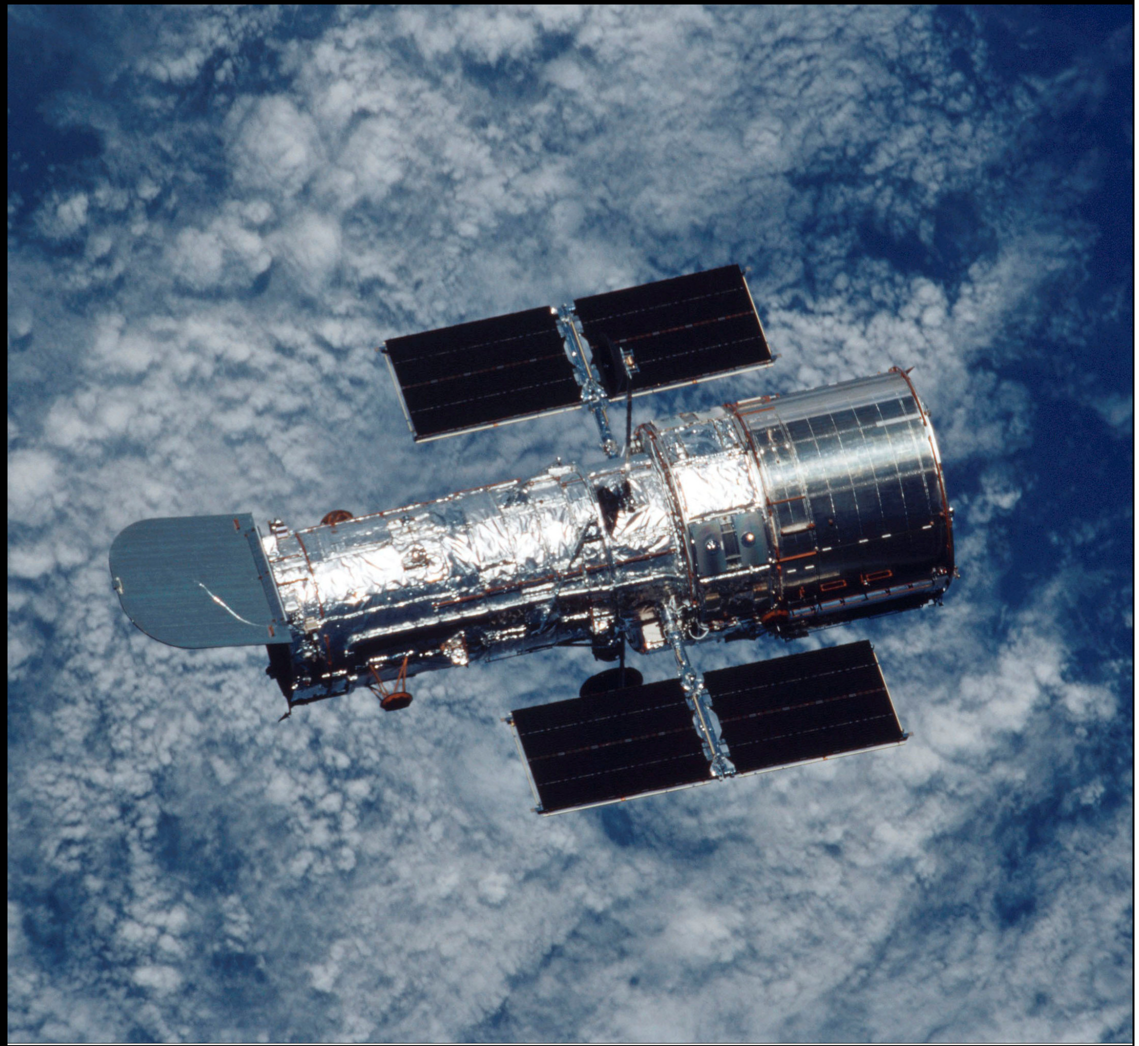
orbital period: 96–97 minutes

Orbit velocity: 7,500 m/s

Acceleration due to gravity
8.169 m/s2

2.4m, Ritchey–Chrétien reflector

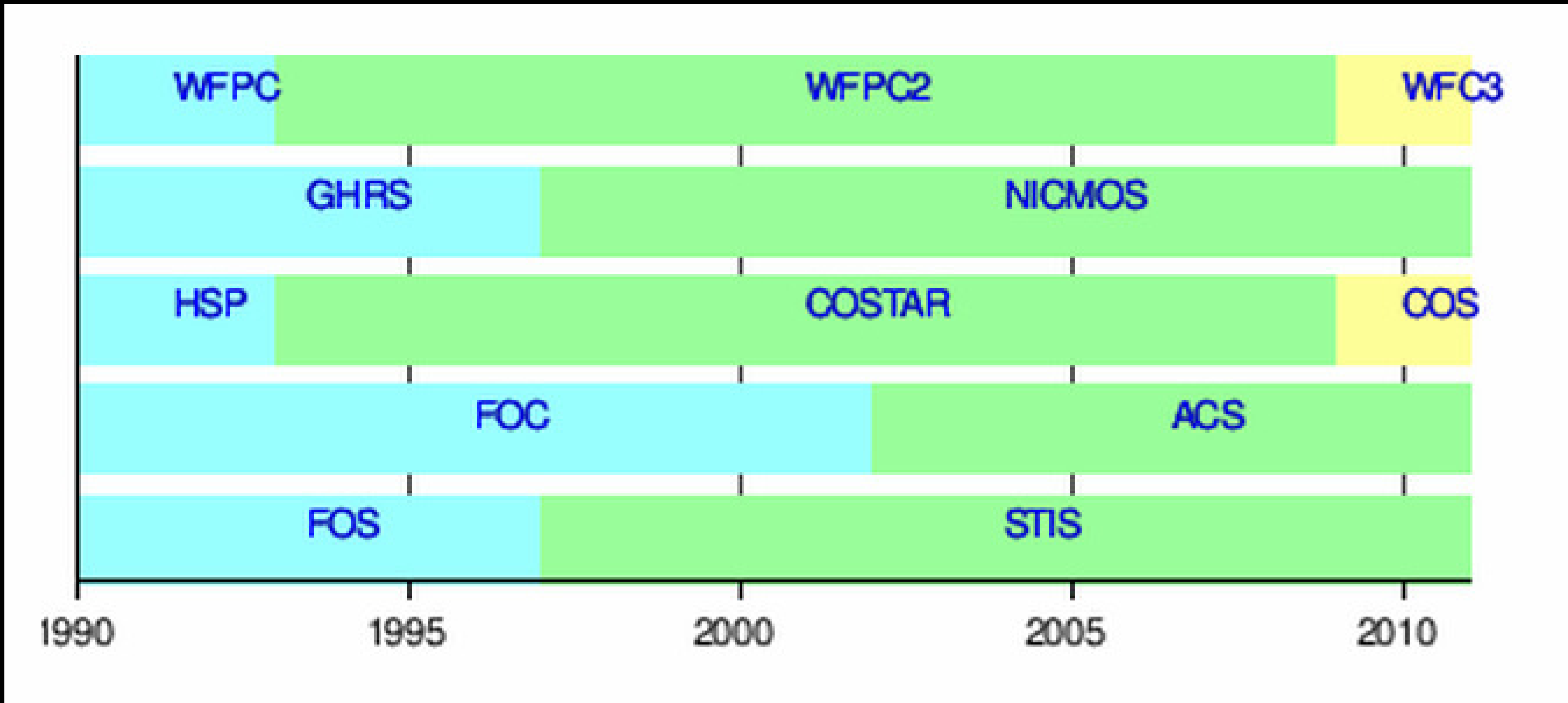
ultraviolet, visible, near-infrared



Hubble Floating Free

Image Credit: NASA, 2002

Hubble Space Telescope Instruments



HST Instruments

Retired

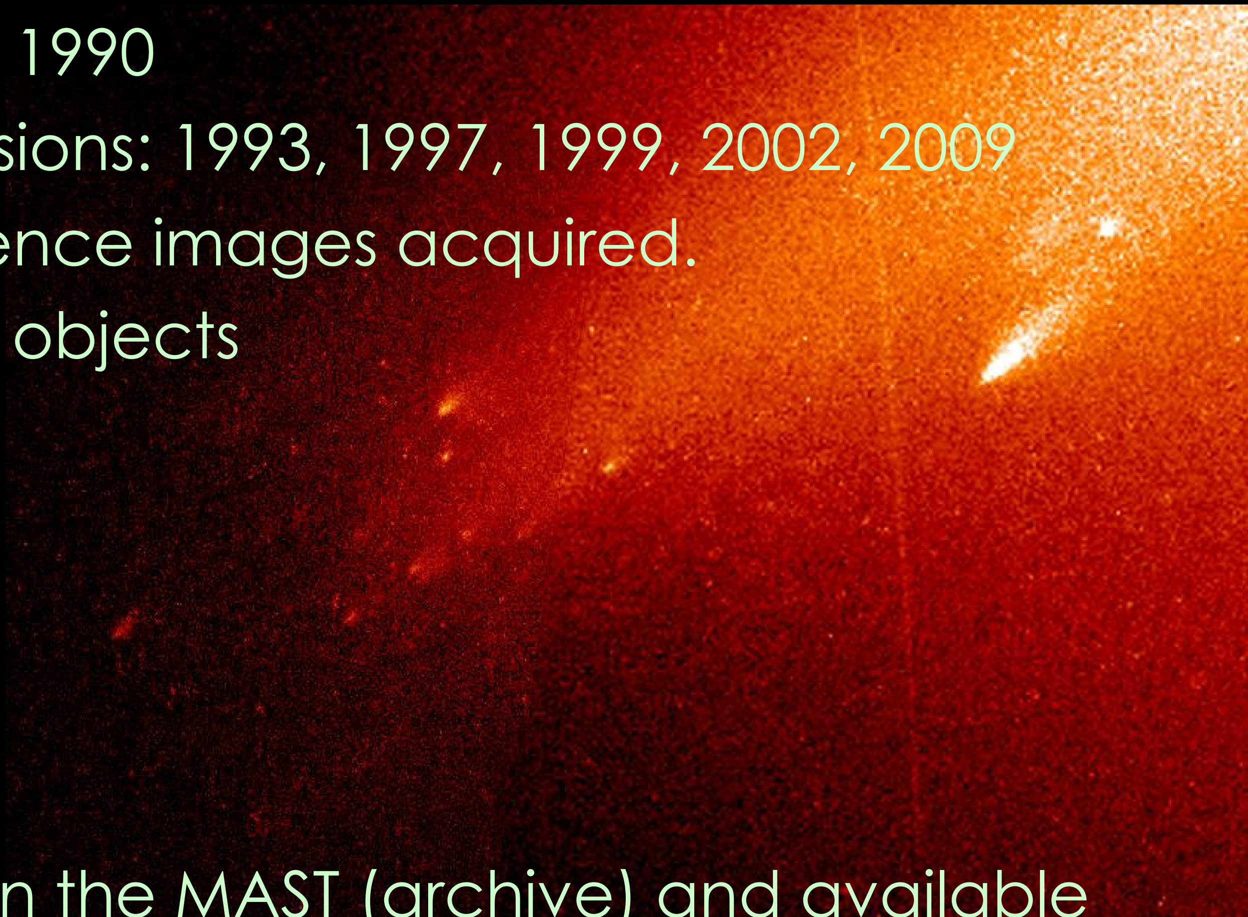
- •FOC- faint object camera
- •FOS: faint object spectrograph
- •GHRS: goddard high resolution spectrometer
- •HSP: high speed photometer
- •WFPC: wide field planetary camera
- •WFPC2: wide field planetary camera 2
- •NICMOS: near infrared camera & multiobject spectrograph

Active

- •ACS: Advanced Camera for Surveys
- •COS: Cosmic Origins Spectrograph
- •WFC3: Wide Field Camera 3
- •STIS: Space Telescope Imaging Spectrograph

Hubble Space Telescope

- 22+ years of operation
  – launched in 1990
- 5 servicing missions: 1993, 1997, 1999, 2002, 2009
- 1,000,000+ science images acquired.
  – solar system objects
  – stars
  – nebulae
  – star clusters
  – galaxies
  – exoplanets



All HST data are in the MAST (archive) and available to anybody, anywhere (free!)

PlanetPipeline

Over 10,000 datasets from 15 years of WFPC2 operations on solar system objects

a treasure trove for investigating

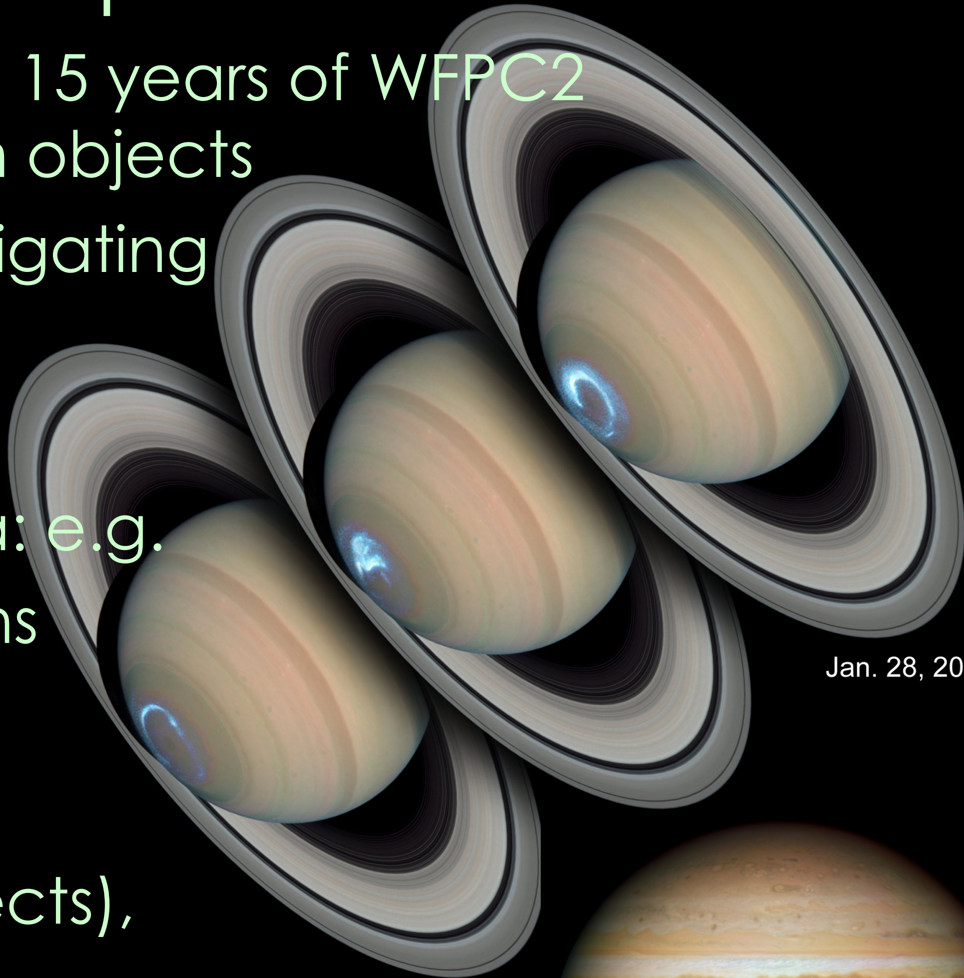
- planet atmospheres
- moon surfaces
- transient phenomena: e.g.
  - impacts & eruptions
- asteroids

and finding new objects

- KBO (Kuiper Belt Objects),
- asteroids, moons

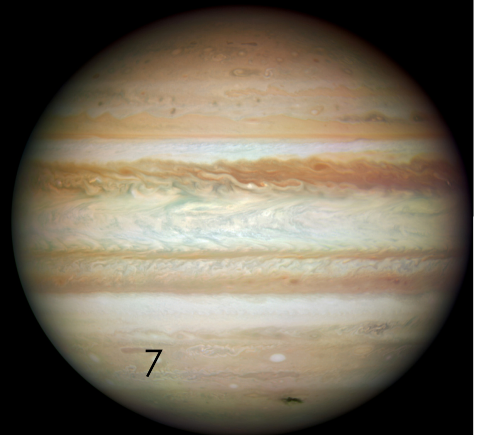
and more …

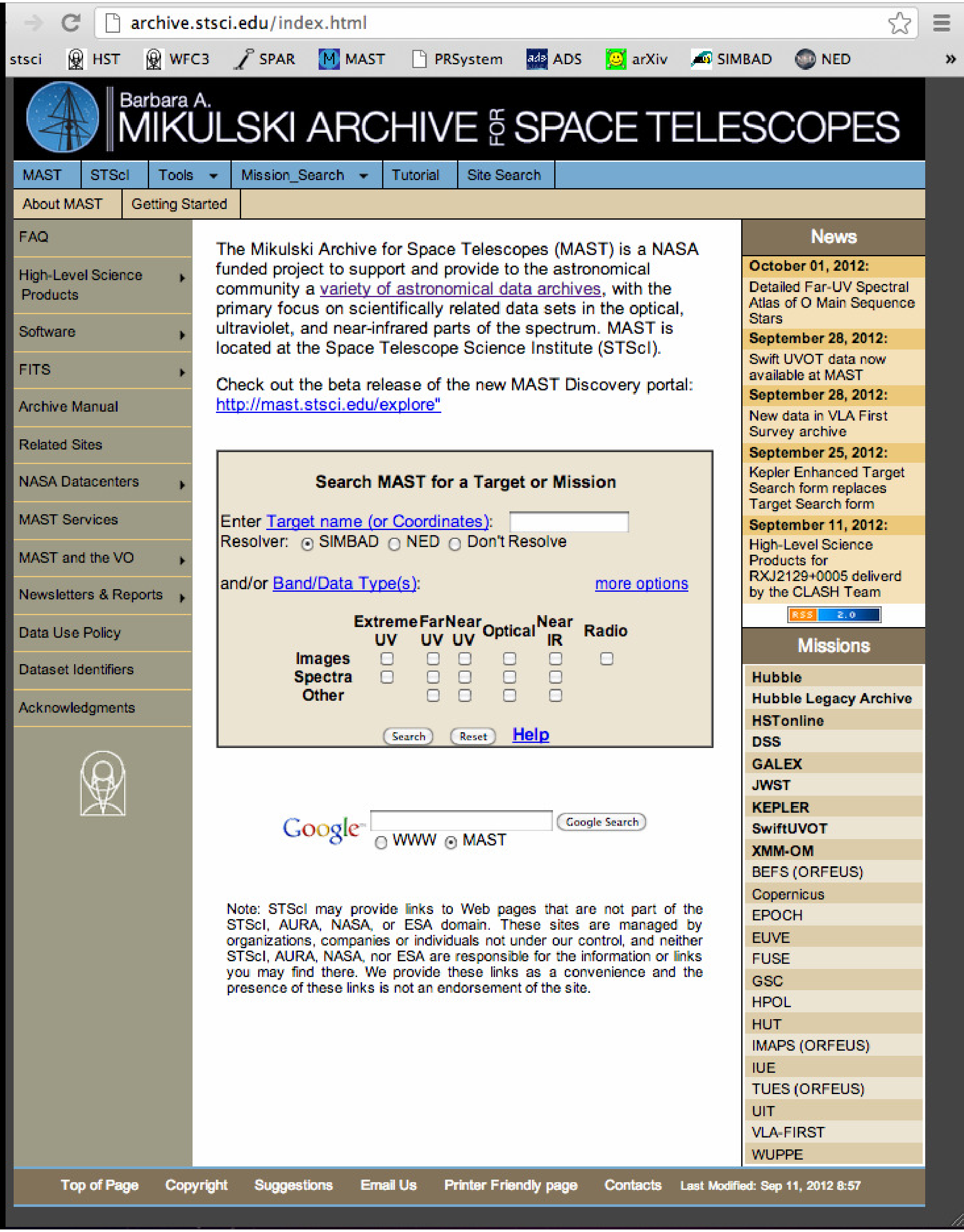
solar system weather (?)



Jan. 28, 2004

Jan. 24, 200

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Acknowledgments
The Mikulski Archive for Space Telescopes (MAST) is a NASA funded project to support and provide to the astronomical community a variety of astronomical data archives, with the primary focus on scientifically related data sets in the optical, ultraviolet, and near-infrared parts of the spectrum. MAST is located at the Space Telescope Science Institute (STScI).
Check out the beta release of the new MAST Discovery portal: http://mast.stsci.edu/explore"
Search MAST for a Target or Mission
Enter Target name (or Coordinates):
Resolver: SIMBAD NED Don't Resolve
and/or Band/Data Type(s):
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News
October 01, 2012:
Detailed Far-UV Spectral Atlas of O Main Sequence Stars
September 28, 2012:
Swift UVOT data now available at MAST
September 28, 2012:
New data in VLA First Survey archive
September 25, 2012:
Kepler Enhanced Target Search form replaces Target Search form
September 11, 2012:
High-Level Science Products for RXJ2129+0005 deliverd by the CLASH Team
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Barbara A.
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Archive Status

HST Search Form

(Help)
Field Descriptions

Error: target **Jupiter** not found, no coordinates returned

Standard Form   File Upload Form

Search   Reset   Clear Form

Target Name: saturn   Resolver: NED   Radius (arcmin): 3.0

Right Ascension   Declination   Equinox: J2000

Imagers	Spectrographs	Other
ALL NONE	ALL NONE	ALL NONE
STIS	STIS	FGS
NICMOS	NICMOS	HSP
WFPC2	GHRS	
WF/PC	FOS	
FOC	FOC	
ACS	ACS	
WFC3	WFC3	
COS	COS	

Start Time   Exp Time   Proposal ID   Release Date

Dataset   Filters/Gratings   Obset ID   Archive Date

Target Descrip   Apertures   Observations: ☑ Science ☐ Calibration

PI Last Name

User-specified field 1   Field Descriptions   User-specified field 2   Field Descriptions

Mission Search / Missions / Contacts / STScI / MAST Columns Help / Archive Status

HST Search Results

Edit Query

Display numeric columns graphically using VOPlot

Object name saturn resolved by Simbad (via SANTA cache) to **NAME SATURN NEBULA** (Star)
RA: 21 4 10.88 **Dec:** -11 21 48.26 (**J2000**)

number of rows returned = 96

Click on Dataset or Target Name entries to preview information on data set.
Click on Ref entries to display list of published papers.
Click on Proposal ID entries to display information on observing program.
Records with a @ character next to the mark button are proprietary, and may only be retrieved by authorized users.

Click on top column headers to sort the table on the column contents.
Click on bottom column headers for more information about the data in that column.

Plot marked spectra | Submit marked data for retrieval from STDADS
Mark all | Unmark all | Mark public | Unmark public | Mark proprietary | Unmark proprietary

Mark	Dataset	Target Name	RA (J2000)	Dec (J2000)	Ref	Start Time	Stop Time
☐	O5G601HTQ	NGC7009-CSTAR	21 04 10.810	-11 21 47.91	6	2000-08-15 20:17:38	2000-08-15 20:20
☐	O5G602WFQ	NGC7009-CSTAR	21 04 10.810	-11 21 47.91	6	2000-08-12 05:25:35	2000-08-12 05:28
☐	O5G603LJQ	NGC7009-CSTAR	21 04 10.810	-11 21 47.91	6	2000-08-09 13:04:33	2000-08-09 13:07

Jupiter Search / if know PI name

☐	N4WL03FNQ	ANY	23 59 59.447	+00 00 31.32	7	1998-08-08 22:59:05	1998-0
☐	N4WL03FPQ	ANY	23 59 59.447	+00 00 31.32	7	1998-08-08 23:00:14	1998-0
☐	N4WL03FRQ	ANY	23 59 59.447	+00 00 31.32	7	1998-08-08 23:01:40	1998-0
☐	N4WL03FSQ	ANY	23 59 59.447	+00 00 31.32	7	1998-08-08 23:03:21	1998-0
☐	N4WL03FUQ	ANY	00 00 00.846	-00 00 31.72	7	1998-08-08 23:08:17	1998-0
☐	IBDG01E4Q	JUPITER-IMPACT-EAST-1	21 22 01.138	-16 29 31.32	4	2009-11-02 21:18:57	2009-1
☐	IBDG01E5Q	JUPITER-IMPACT-EAST-1	21 22 00.817	-16 29 37.60	4	2009-11-02 21:23:58	2009-1
☐	IBDG01E7Q	JUPITER-IMPACT-EAST-1	21 22 00.963	-16 29 29.01	4	2009-11-02 21:31:53	2009-1
☐	IBDG01E8Q	JUPITER-IMPACT-EAST-1	21 22 01.199	-16 29 31.03	4	2009-11-02 21:36:31	2009-1
☐	IBDG01E9Q	JUPITER-IMPACT-EAST-1	21 22 01.210	-16 29 30.98	4	2009-11-02 21:40:23	2009-1
☐	IBDG01EAQ	JUPITER-IMPACT-EAST-1	21 22 01.221	-16 29 30.93	4	2009-11-02 21:43:53	2009-1
☐	IBDG01EBQ	JUPITER-IMPACT-EAST-1	21 22 01.110	-16 29 30.42	4	2009-11-02 21:48:29	2009-1
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☐	IBDG03JSQ	JUPITER-IMPACT-EAST-3	21 22 07.404	-16 29 03.99	4	2009-11-03 06:59:17	2009-1
☐	IBDG03JTQ	JUPITER-IMPACT-EAST-3	21 22 08.025	-16 28 57.86	4	2009-11-03 07:05:17	2009-1
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☐	IBDG03JVQ	JUPITER-IMPACT-EAST-3	21 22 08.041	-16 28 59.48	4	2009-11-03 07:13:46	2009-1
☐	IBDG03JWQ	JUPITER-IMPACT-EAST-3	21 22 08.054	-16 28 59.42	4	2009-11-03 07:17:16	2009-1
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☐	IBDG03JZQ	JUPITER-IMPACT-EAST-3	21 22 07.984	-16 28 54.76	4	2009-11-03 07:33:32	2009-1
☐	IBDG03K0Q	JUPITER-IMPACT-EAST-3	21 22 08.127	-16 28 59.07	4	2009-11-03 07:37:58	2009-1
☐	IBCZ21DOQ	JUPITER-IMPACT-SITE	21 49 07.314	-14 16 37.61	6	2009-07-23 18:12:25	2009-0
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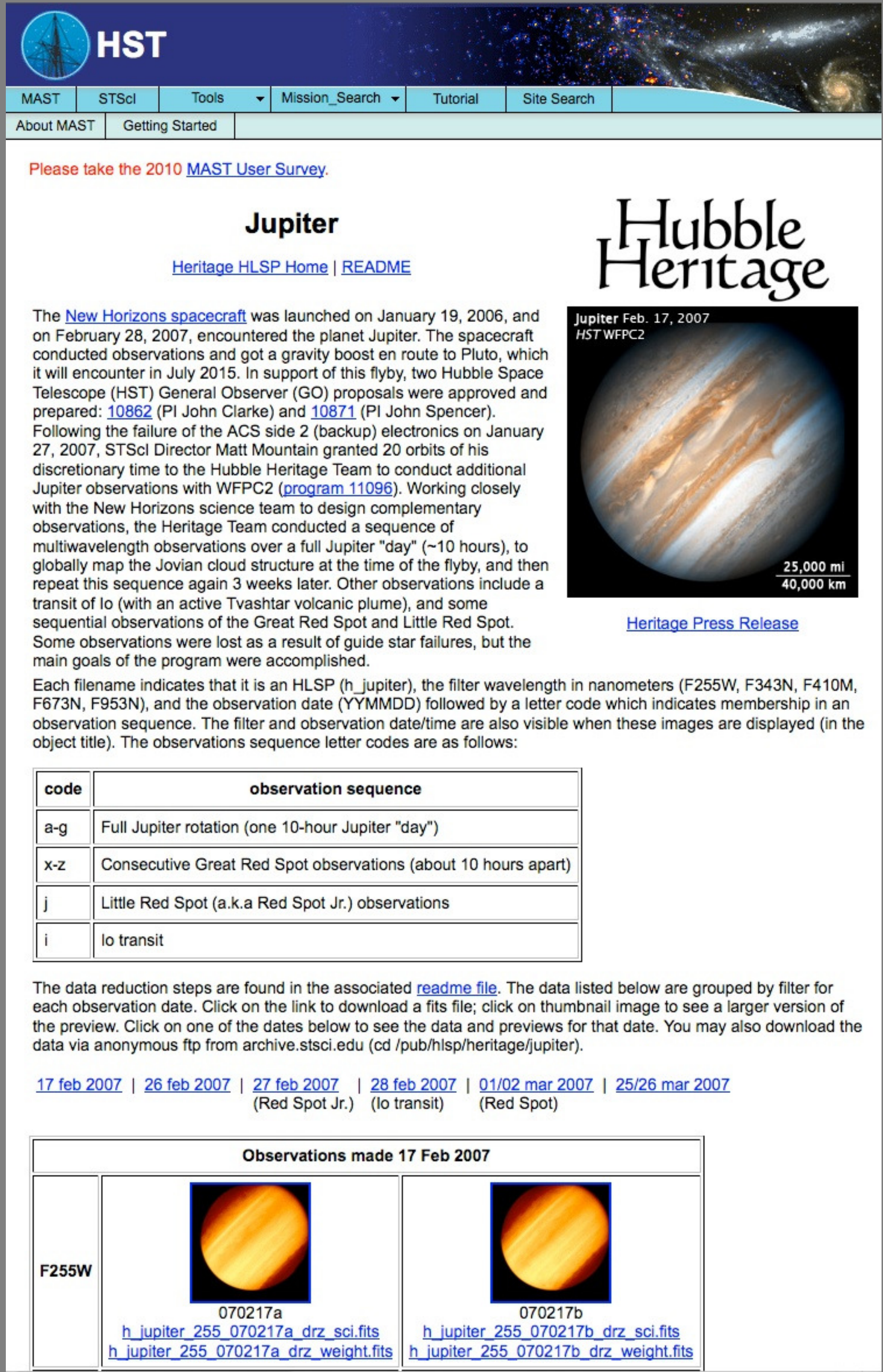

HST

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Jupiter

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Hubble Heritage

Heritage Press Release

The New Horizons spacecraft was launched on January 19, 2006, and on February 28, 2007, encountered the planet Jupiter. The spacecraft conducted observations and got a gravity boost en route to Pluto, which it will encounter in July 2015. In support of this flyby, two Hubble Space Telescope (HST) General Observer (GO) proposals were approved and prepared: 10862 (PI John Clarke) and 10871 (PI John Spencer). Following the failure of the ACS side 2 (backup) electronics on January 27, 2007, STScI Director Matt Mountain granted 20 orbits of his discretionary time to the Hubble Heritage Team to conduct additional Jupiter observations with WFPC2 (program 11096). Working closely with the New Horizons science team to design complementary observations, the Heritage Team conducted a sequence of multiwavelength observations over a full Jupiter "day" (~10 hours), to globally map the Jovian cloud structure at the time of the flyby, and then repeat this sequence again 3 weeks later. Other observations include a transit of Io (with an active Tvashtar volcanic plume), and some sequential observations of the Great Red Spot and Little Red Spot. Some observations were lost as a result of guide star failures, but the main goals of the program were accomplished.

Each filename indicates that it is an HLSP (h_jupiter), the filter wavelength in nanometers (F255W, F343N, F410M, F673N, F953N), and the observation date (YYMMDD) followed by a letter code which indicates membership in an observation sequence. The filter and observation date/time are also visible when these images are displayed (in the object title). The observations sequence letter codes are as follows:

code	observation sequence
a-g	Full Jupiter rotation (one 10-hour Jupiter "day")
x-z	Consecutive Great Red Spot observations (about 10 hours apart)
j	Little Red Spot (a.k.a Red Spot Jr.) observations
i	Io transit

The data reduction steps are found in the associated readme file. The data listed below are grouped by filter for each observation date. Click on the link to download a fits file; click on thumbnail image to see a larger version of the preview. Click on one of the dates below to see the data and previews for that date. You may also download the data via anonymous ftp from archive.stsci.edu (cd /pub/hlsp/heritage/jupiter).

17 feb 2007 | 26 feb 2007 | 27 feb 2007 (Red Spot Jr.) | 28 feb 2007 (Io transit) | 01/02 mar 2007 (Red Spot) | 25/26 mar 2007

Observations made 17 Feb 2007		
F255W	070217a h_jupiter_255_070217a_drz_sci.fits h_jupiter_255_070217a_drz_weight.fits	070217b h_jupiter_255_070217b_drz_sci.fits h_jupiter_255_070217b_drz_weight.fits

Our goal is to optimally re-process all WFPC2 Solar System images.

Our processed images and object catalogs will be ingested into MAST as High Level Science Products (similar to the existing Jupiter HLSP at left).

Our “Planet Pipeline” search interface will be optimized for mining Solar System data.

The barriers

Data Access: Can't reliably find all HST Solar System data in our archive

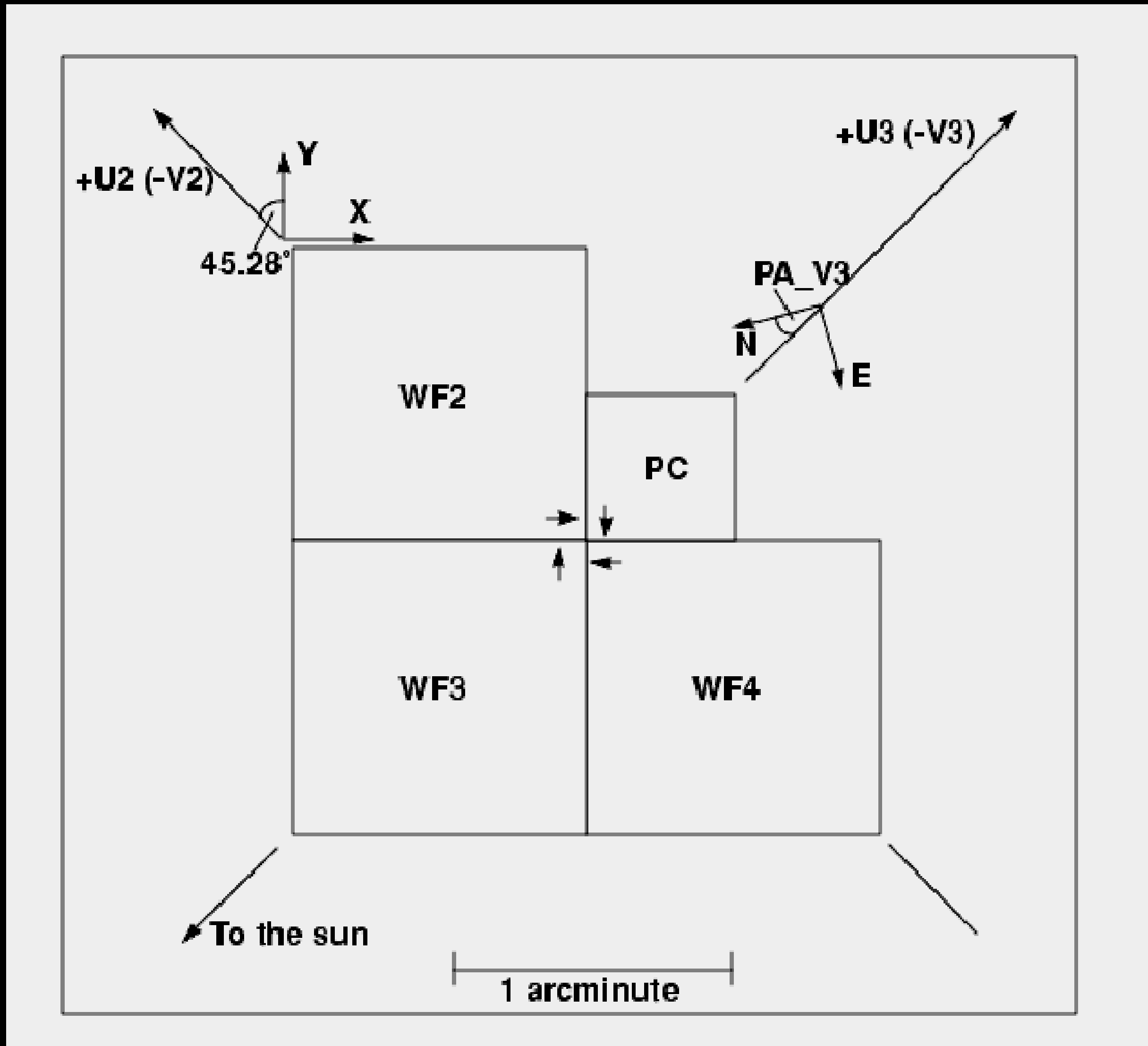
Data Reduction: Pipeline is optimized for fixed targets

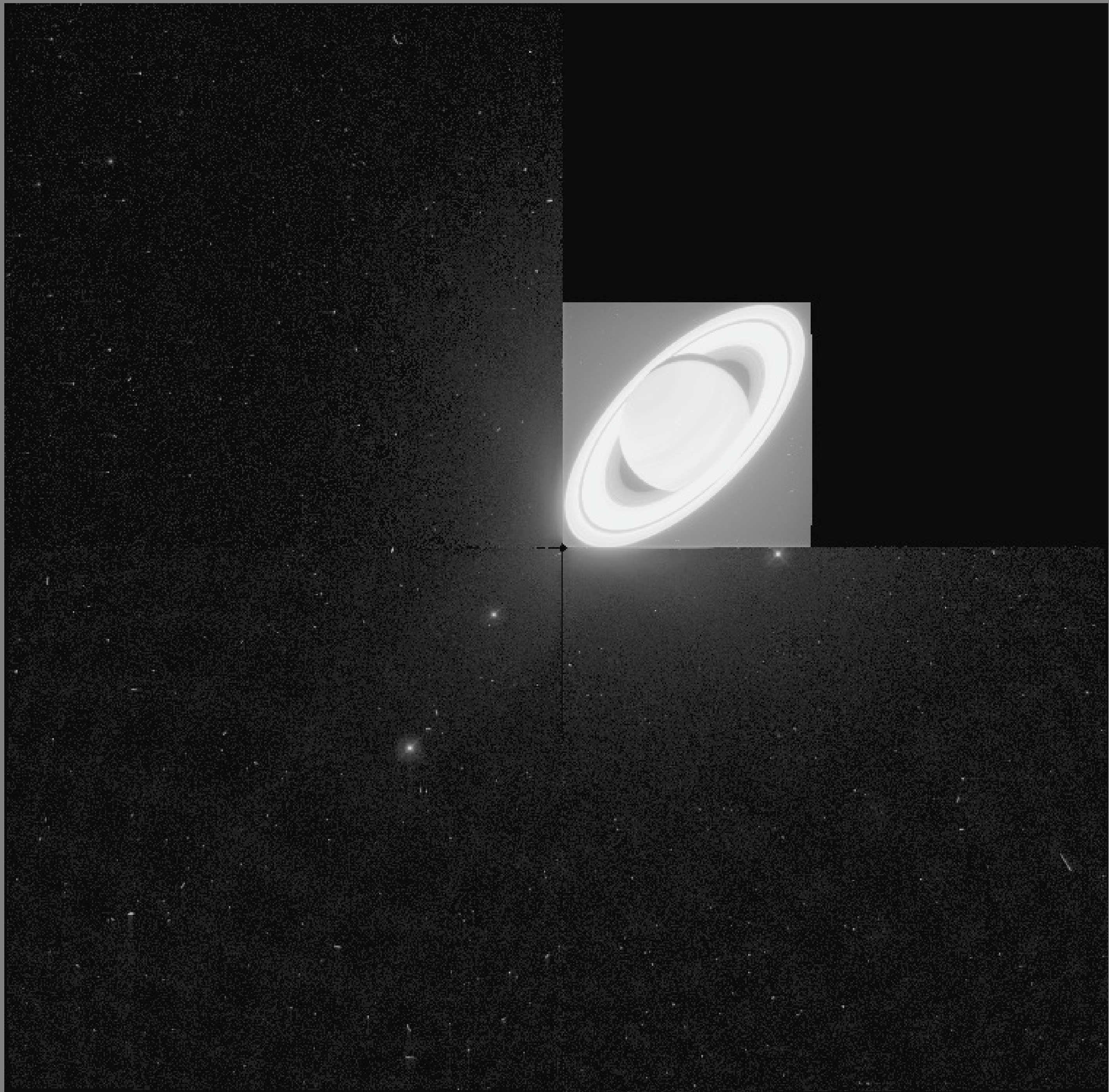
•Pipeline does not reject cosmic rays and detector artifacts

•WFPC2 drizzled (combined) mosaics at the low-resolution of the Wide Field scale, at random orientations and removes transient features

Catalog: Not much useful planetary observation info in image headers

WFPC2





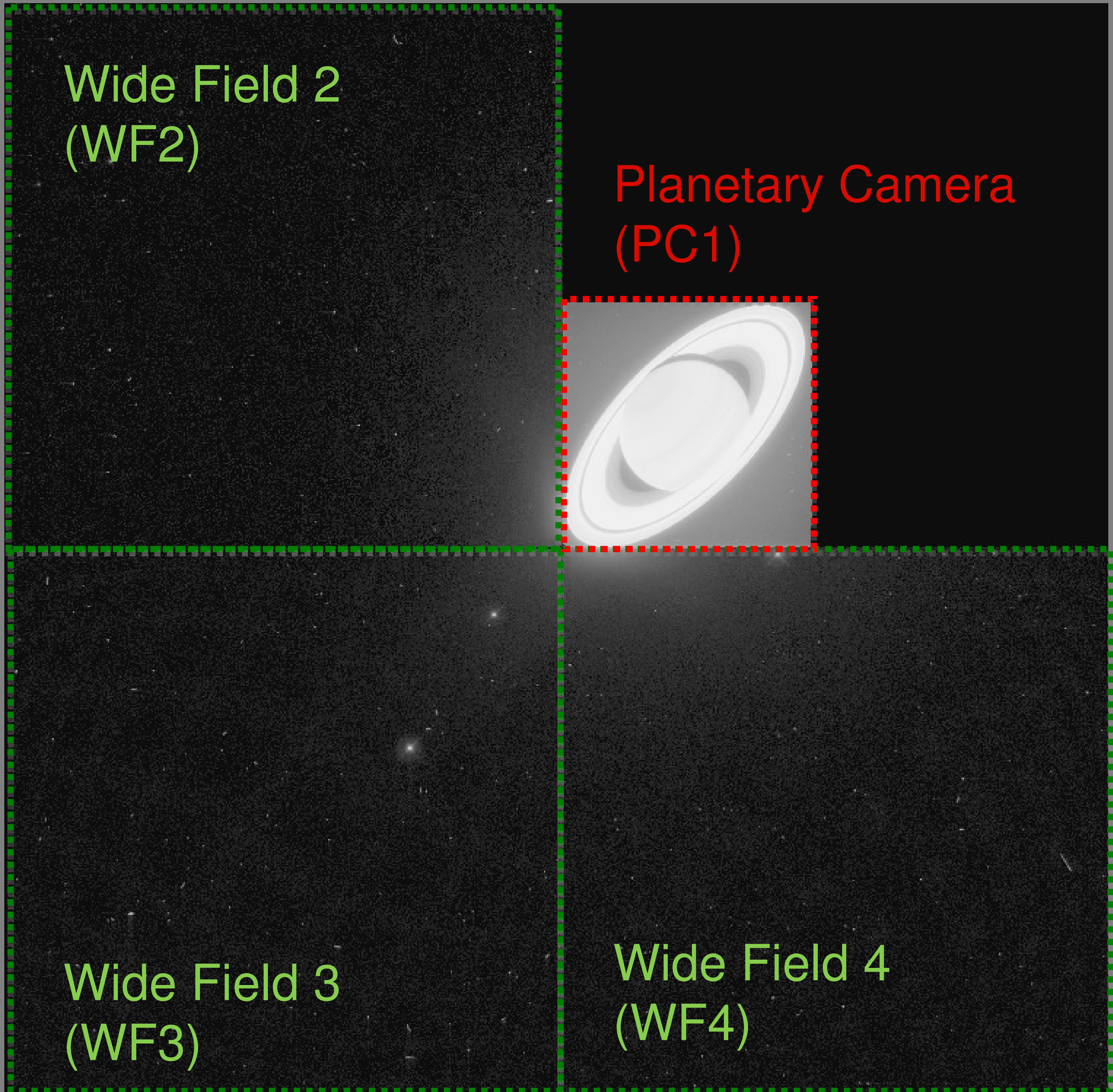
Hubble's WFPC2:

both the camera and it's archival images are *kinda weird*

Archival mosaics are drizzled to WF pixel scale -- which means PC pixels are binned by 2X

No rejection of cosmic rays or detector artifacts -- or worse, <u>bad</u> rejections!

Also -- what is on the WF chips? How many of the WF chips have <u>never</u> been inspected by anyone?



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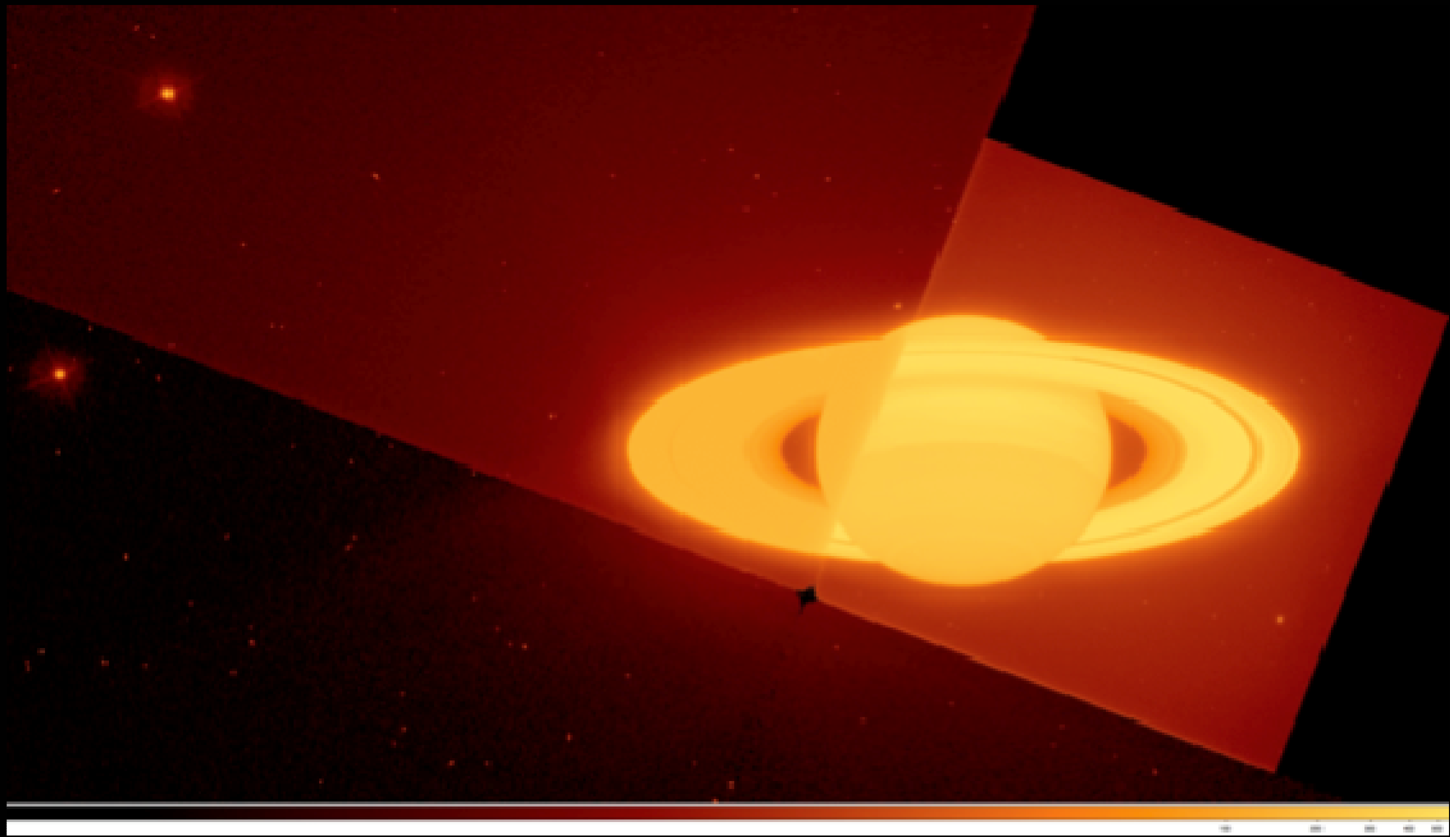
Our science-ready images are mosaics which are clean, resampled, distortion-free, and include cataloged secondary objects and features, with planetary parameters embedded in their headers



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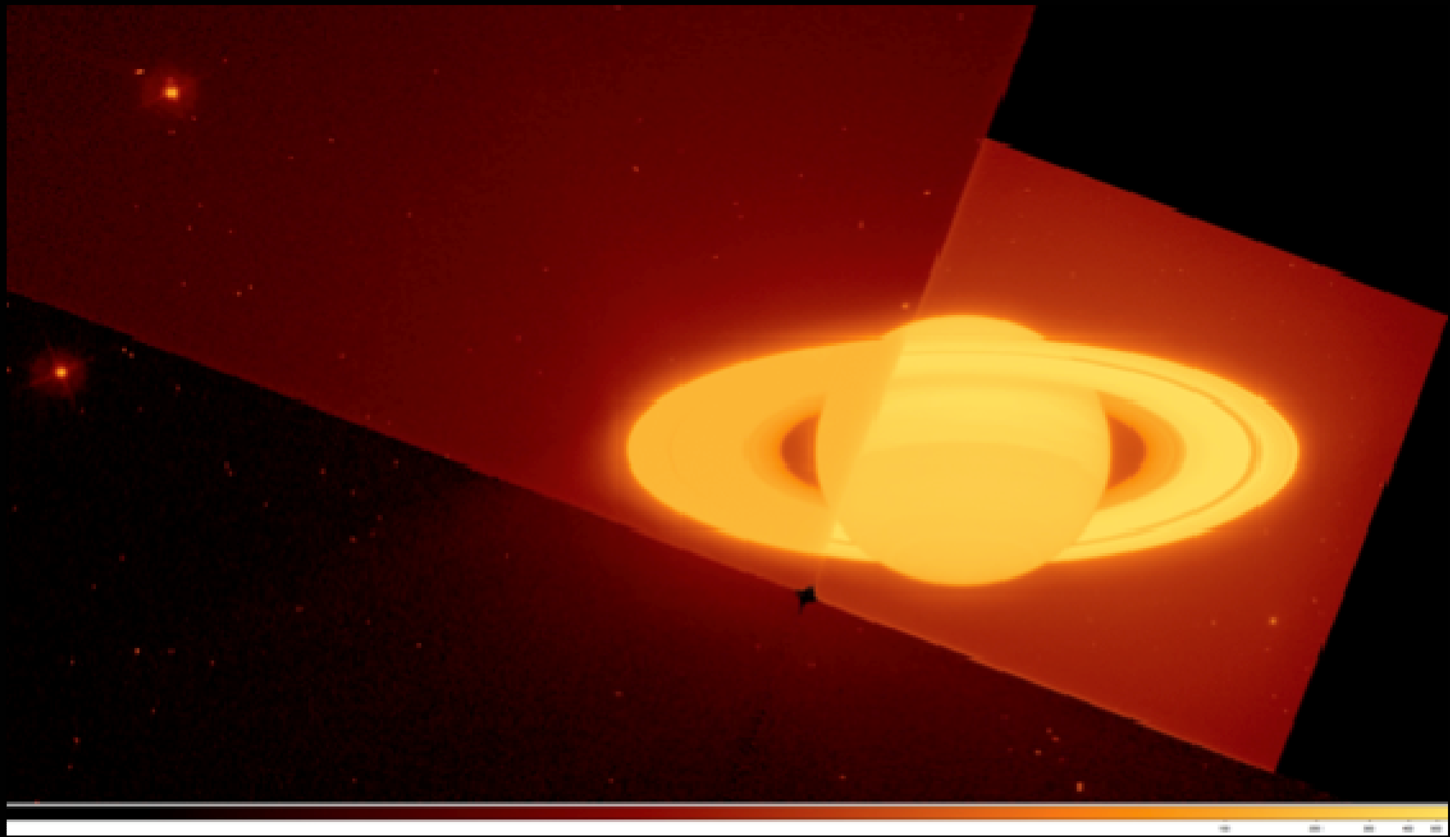
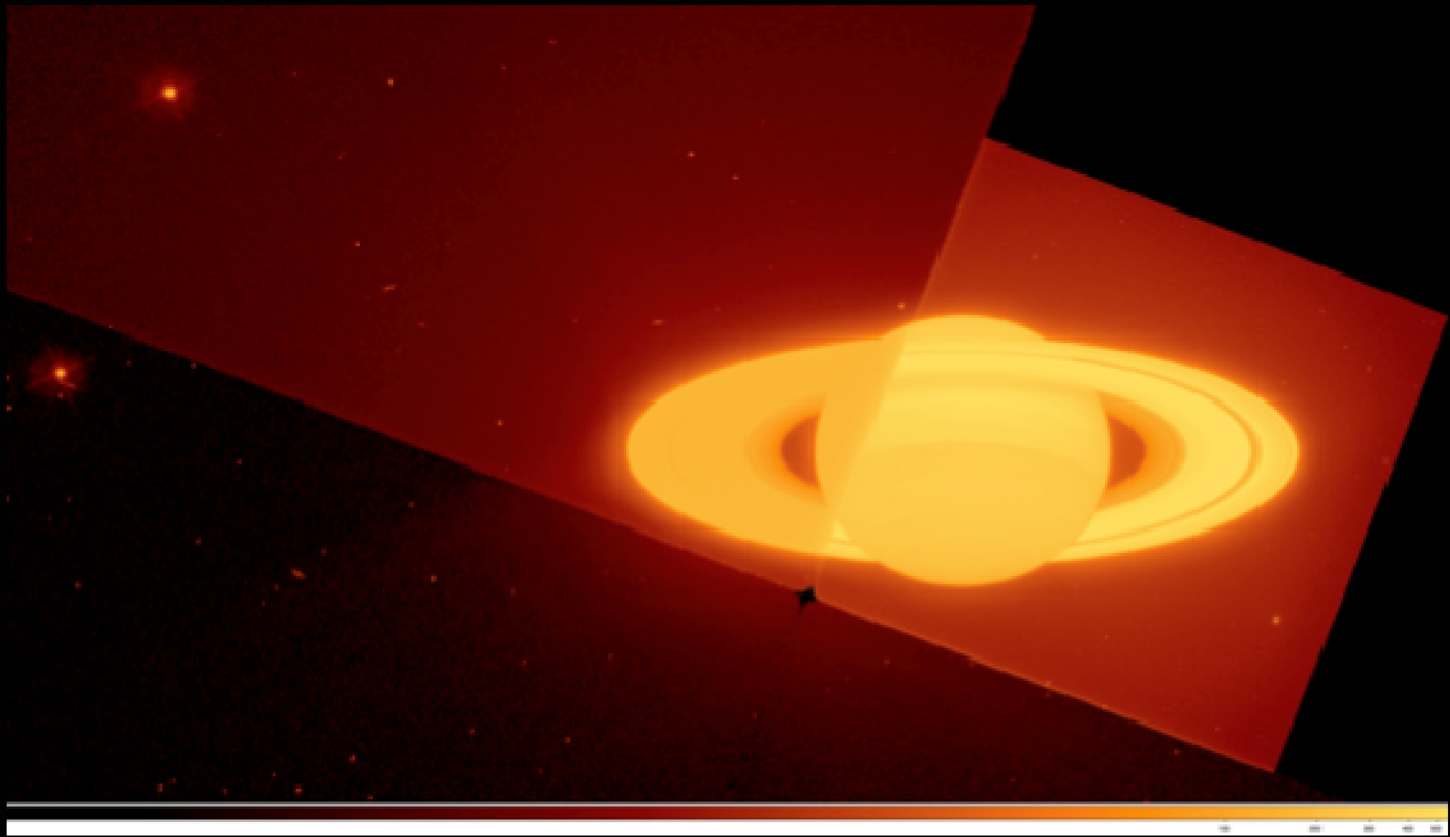
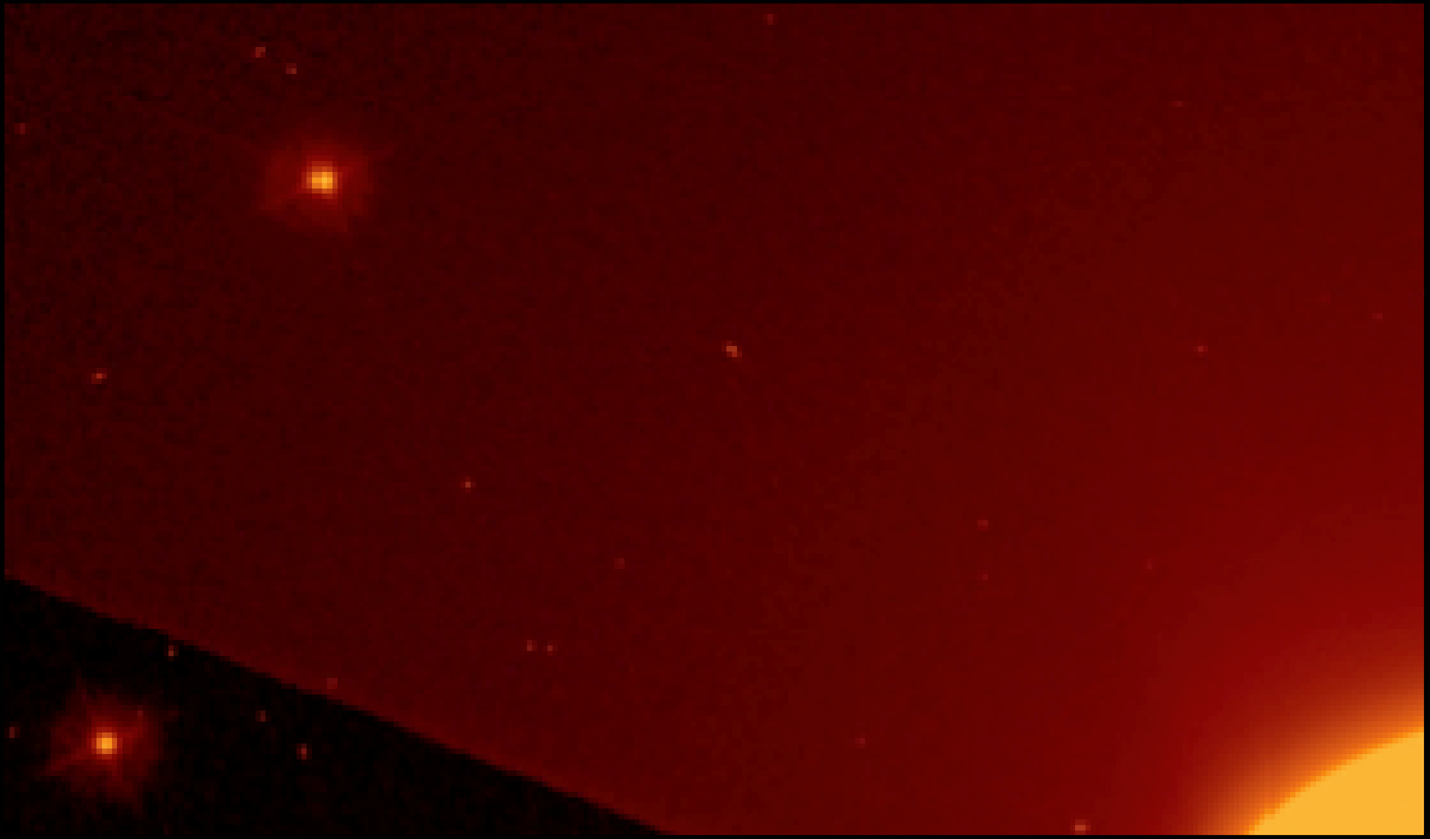


Our science-ready images are mosaics which are clean, resampled, distortion-free, and include cataloged secondary objects and features, with planetary parameters embedded in their headers

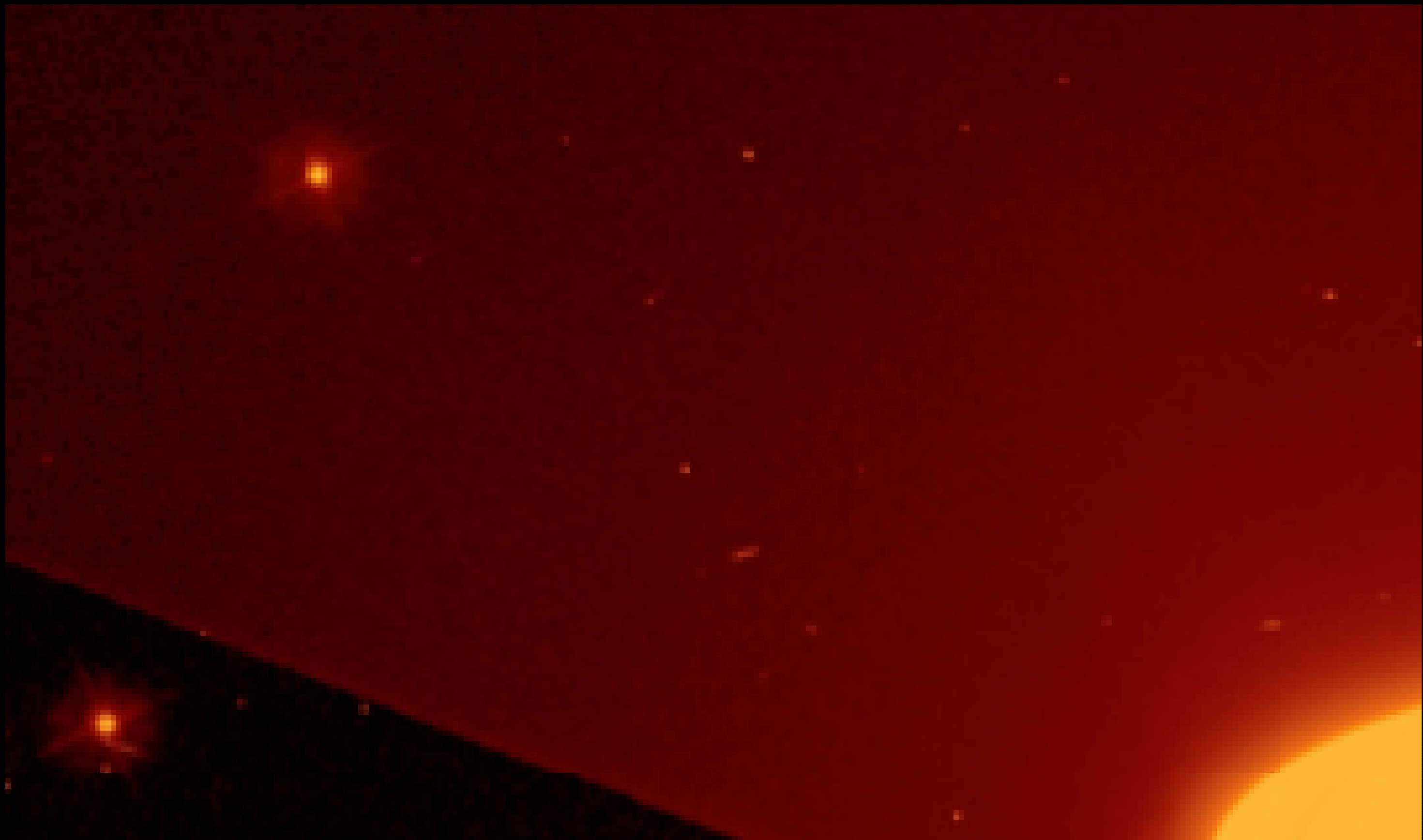


Zoom in view



zoom in view

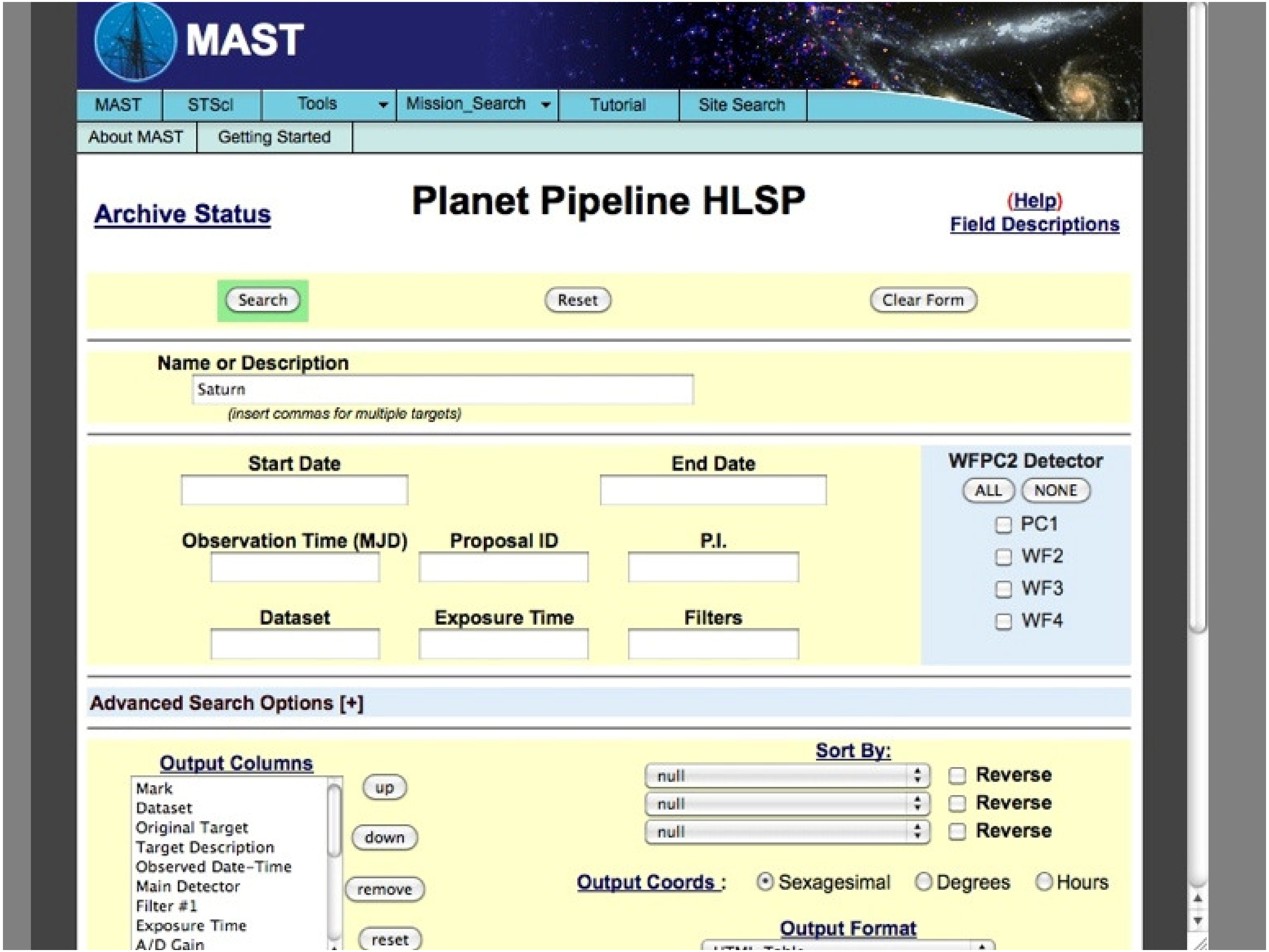
zoom in view



New and improved database

r new and improved database of moving target data Will eventually link our prepared WFPC2 images... and ACS, and WFC3...

- Standardized target names and categories for reliable querying
- Enriched with observation data from JPL Horizons and PDS Rings Node
- Results in a complete catalog of all objects in each image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Name or Description
Saturn
(insert commas for multiple targets)
Start Date
End Date
WFPC2 Detector
ALL
NONE
PC1
WF2
WF3
WF4
Observation Time (MJD)
Proposal ID
P.I.
Dataset
Exposure Time
Filters
Advanced Search Options [+]
Output Columns
Mark
Dataset
Original Target
Target Description
Observed Date-Time
Main Detector
Filter #1
Exposure Time
A/D Gain
up
down
remove
reset
Sort By:
null
Reverse
null
Reverse
null
Reverse
Output Coords :
Sexagesimal
Degrees
Hours
Output Format

PLANETPIPELINE Search

Planet Pipeline: Exploring the S... | PLANETPIPELINE Search

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Columns Help / Archive Status

PLANETPIPELINE Search Results

Edit Query

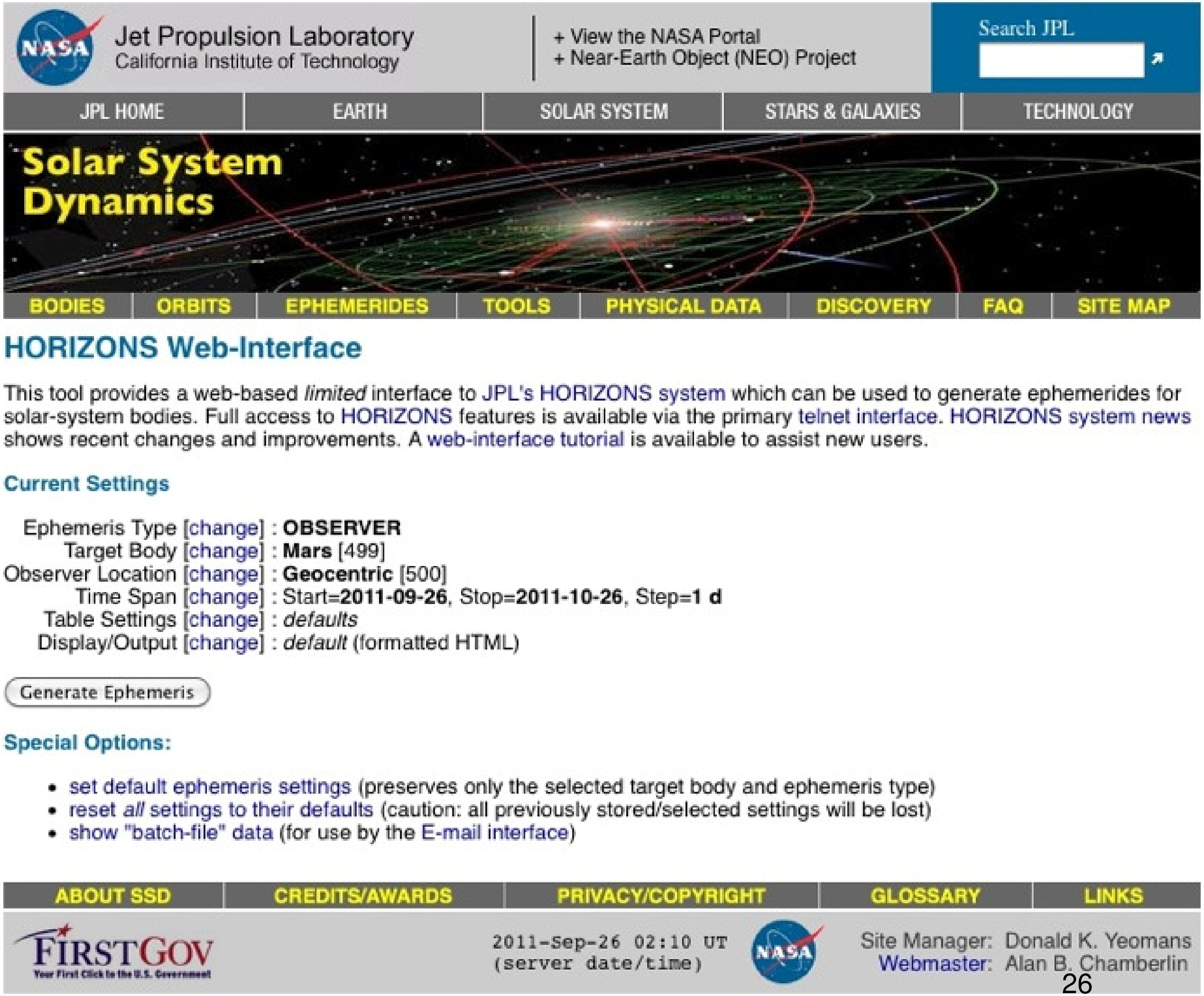
Display numeric columns graphically using VOPlot

number of rows returned = 756

Previous 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 Next   Page 1 of 16

Mark	Dataset	Original Target	Target Description	Observed Date-Time	Main Detector	Filter #1	Exposure Time	A/D Gain	Detector Orientation	Target RA	Target DEC	Angular Diameter	Phase Angle	Heliocentric Range	Sub-Observer Longitude	P.I.	Proposal ID	Line Number
☐	u2iq0101t	SAT-N-AUR1	planet saturn	1994-10-09 11:06:16	1	F673N	2.000	15	85.306	22 36 07.67	-10 56 21.3	18.646	3.747	9.705	41.770	trauger	5219	1.100
☐	u2iq0102t	SAT-N-AUR1	planet saturn	1994-10-09 11:13:16	1	F160BN15	1500.000	7	85.289	22 36 07.44	-10 56 21.6	18.646	3.749	9.705	52.740	trauger	5219	1.200
☐	u2iq0103t	SAT-N-AUR1	planet saturn	1994-10-09 12:29:16	1	F160BN15	1000.000	7	85.289	22 36 06.98	-10 56 25.2	18.645	3.752	9.705	93.180	trauger	5219	1.300
☐	u2kr0104t	SATURN	planet saturn	1994-12-01 05:14:16	1	F410M	6.000	15	113.019	22 34 31.78	-10 58 39.9	17.158	5.832	9.690	332.440	beebe	5776	1.040
☐	u2kr0109t	SATURN	planet saturn	1994-12-01 05:34:16	1	FQCH4P15	100.000	15	113.175	22 34 31.84	-10 58 38.5	17.158	5.833	9.690	344.140	beebe	5776	1.090
☐	u2iq0104t	SAT-N-AUR1	planet saturn	1994-10-09 12:52:16	1	F160BN15	1000.000	7	85.289	22 36 06.70	-10 56 25.7	18.644	3.754	9.705	106.130	trauger	5219	1.300
☐	u2iq0107t	SAT-N-AUR1	planet saturn	1994-10-09 14:46:16	1	F673N	2.000	15	85.307	22 36 05.86	-10 56 29.8	18.643	3.761	9.705	165.630	trauger	5219	1.400
☐	u2iq0105t	SAT-N-AUR1	planet saturn	1994-10-09 14:05:16	1	F160BN15	1000.000	7	85.289	22 36 06.23	-10 56 29.3	18.643	3.757	9.705	147.230	trauger	5219	1.300
☐	u2iq0106t	SAT-N-AUR1	planet saturn	1994-10-09 14:29:16	1	F160BN15	800.000	7	85.289	22 36 05.96	-10 56 29.8	18.643	3.760	9.705	159.810	trauger	5219	1.310
☐	u2on0104t	SATURN	planet saturn	1995-05-22 02:04:17	1	FQCH4N	400.000	7	-69.297	23 37 58.16	-04 29 47.1	16.645	5.564	9.642	347.370	bosh	5782	1.020
☐	u2on0106t	SATURN	planet saturn	1995-05-22 03:10:16	1	FQCH4N	7.000	7	-69.297	23 37 58.95	-04 29 43.7	16.646	5.566	9.642	22.680	bosh	5782	1.040

You are encouraged to help us verify our database with a "vanity search"



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+ Near-Earth Object (NEO) Project

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HORIZONS Web-Interface

This tool provides a web-based *limited* interface to JPL's HORIZONS system which can be used to generate ephemerides for solar-system bodies. Full access to HORIZONS features is available via the primary telnet interface. HORIZONS system news shows recent changes and improvements. A web-interface tutorial is available to assist new users.

Current Settings

Ephemeris Type [change] : **OBSERVER**
Target Body [change] : **Mars** [499]
Observer Location [change] : **Geocentric** [500]
Time Span [change] : Start=**2011-09-26**, Stop=**2011-10-26**, Step=**1 d**
Table Settings [change] : *defaults*
Display/Output [change] : *default* (formatted HTML)

Generate Ephemeris

Special Options:

- set default ephemeris settings (preserves only the selected target body and ephemeris type)
- reset *all* settings to their defaults (caution: all previously stored/selected settings will be lost)
- show "batch-file" data (for use by the E-mail interface)

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2011-Sep-26 02:10 UT
(server date/time)

Site Manager: Donald K. Yeomans
Webmaster: Alan B. Chamberlin

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California Institute of Technology

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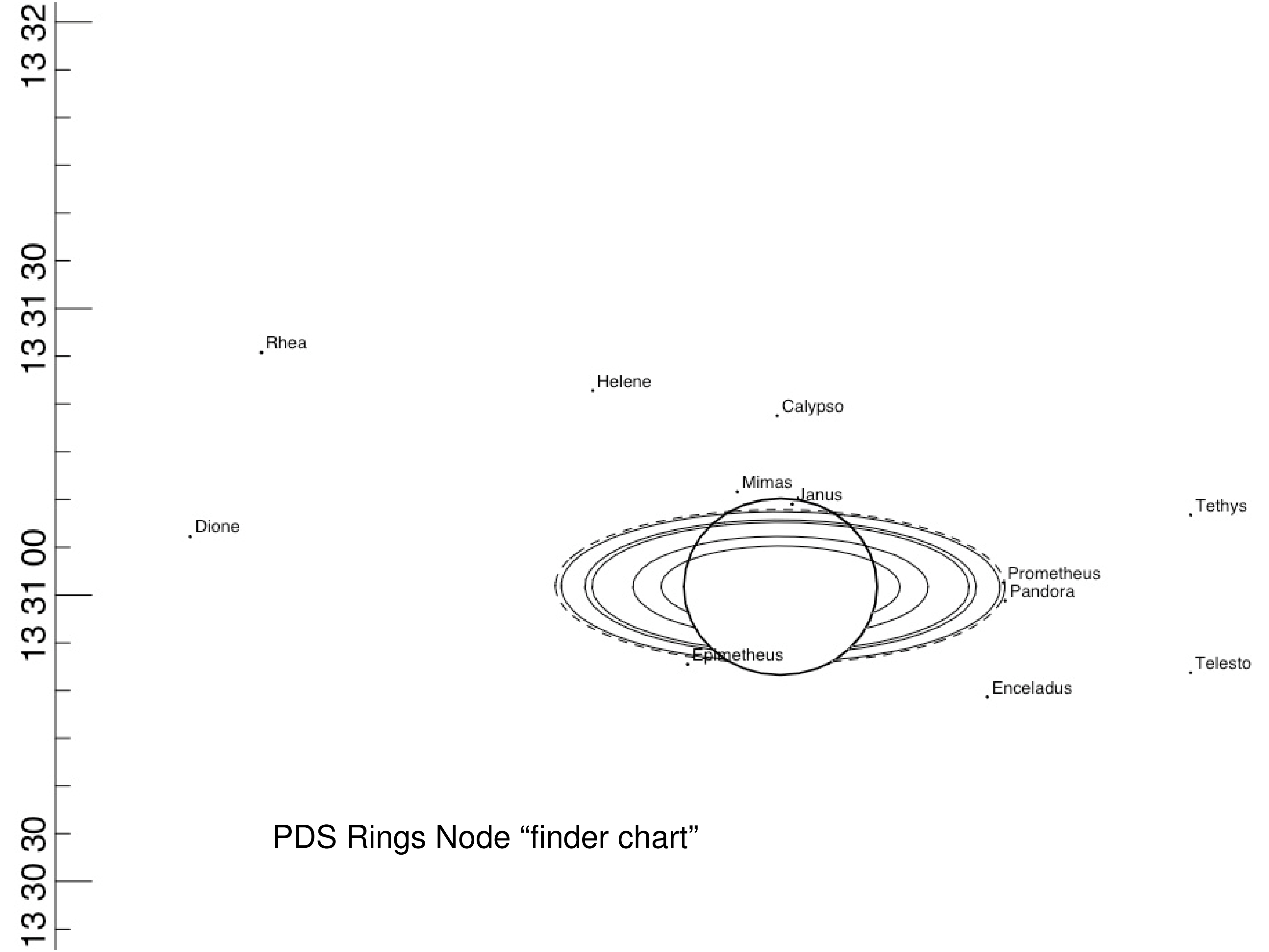
Solar System Dynamics

1. [x] Astrometric RA & DEC
*2. [ ] Apparent RA & DEC
3. [ ] Rates; RA & DEC
*4. [ ] Apparent AZ & EL
5. [ ] Rates; AZ & EL
6. [x] Sat. X & Y, pos. ang
7. [ ] Local app. sid. time
8. [ ] Airmass
9. [ ] Vis mag. & Surf Brt
10. [x] Illuminated fraction
11. [ ] Defect of illumin.
12. [ ] Sat. angle separ/vis
13. [x] Target angular diam.
14. [x] Obs sub-lng & sub-lat
15. [x] Sun sub-long & sub-lat
16. [ ] Sub Sun Pos. Ang & Dis
17. [x] N. Pole Pos. Ang & Dis
18. [ ] Helio eclip. lon & lat
19. [x] Helio range & rng rate
20. [x] Obsrv range & rng rate
21. [x] One-Way Light-Time
22. [ ] Speed wrt Sun & obsrvr
23. [ ] Sun-Obsrvr-Target angl
24. [x] Sun-Target-Obsrvr angl
25. [ ] Targ-Obsrv-Moon/Illum%
26. [x] Obsr-Primary-Targ angl
27. [ ] Pos. Ang;radius & -vel
28. [ ] Orbit plane angle
29. [ ] Constellation ID
30. [ ] Delta-T (CT - UT)
*31. [ ] Obs eclip. lon & lat
32. [ ] North pole RA & DEC
33. [ ] Galactic latitude
34. [ ] Local app. SOLAR time
35. [ ] Earth->Site lt-time
> 36. [ ] RA & DEC uncertainty
> 37. [ ] POS error ellipse
> 38. [ ] POS uncertainty (RSS)
> 39. [x] Range & Rng-rate sig.
> 40. [ ] Doppler/delay sigmas

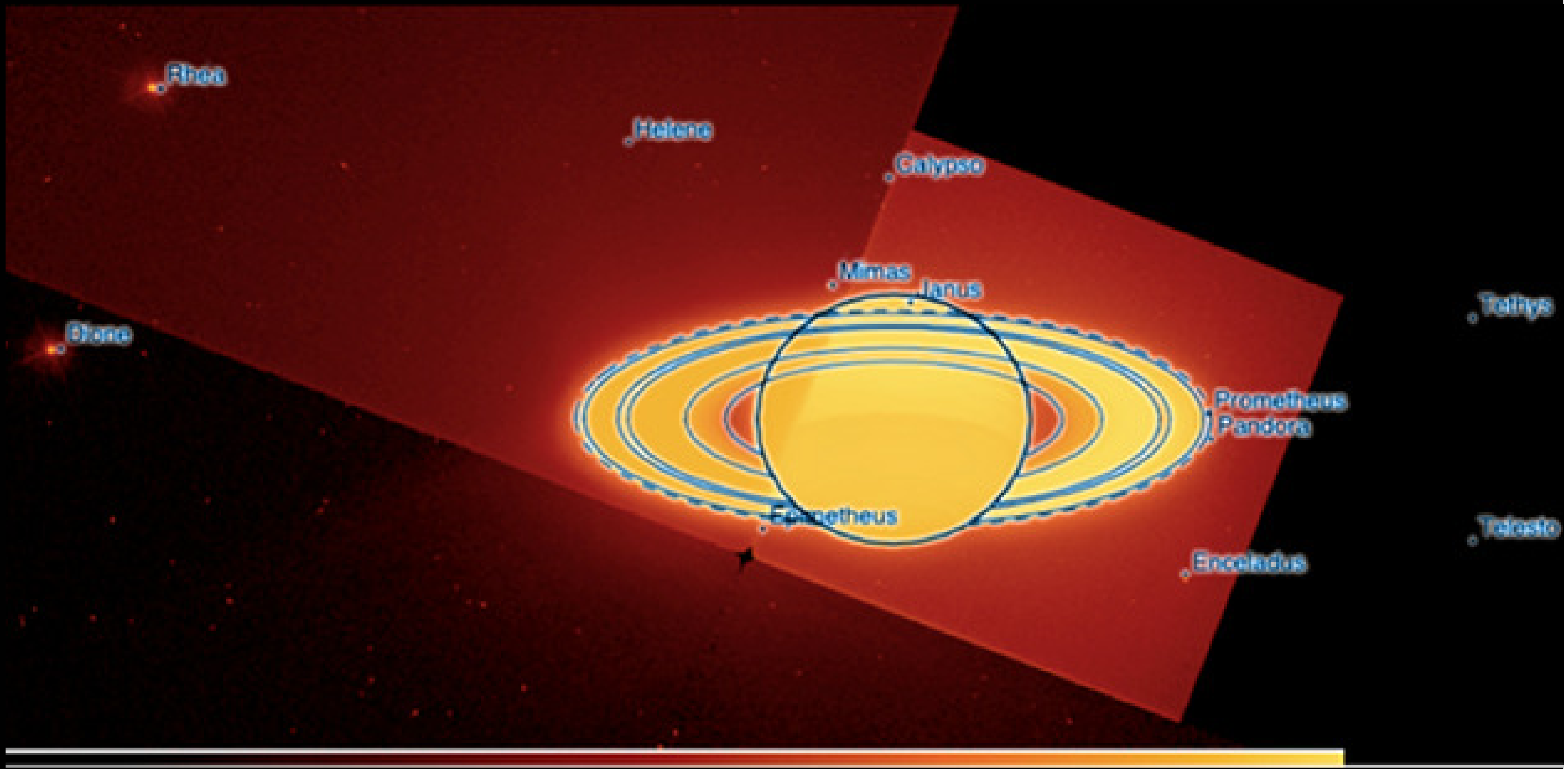
Notes:
* affected by apparent position estimation (atmospheric refraction model, see below)
> requires object orbit covariance

Observer quantities are described in the HORIZONS documentation.

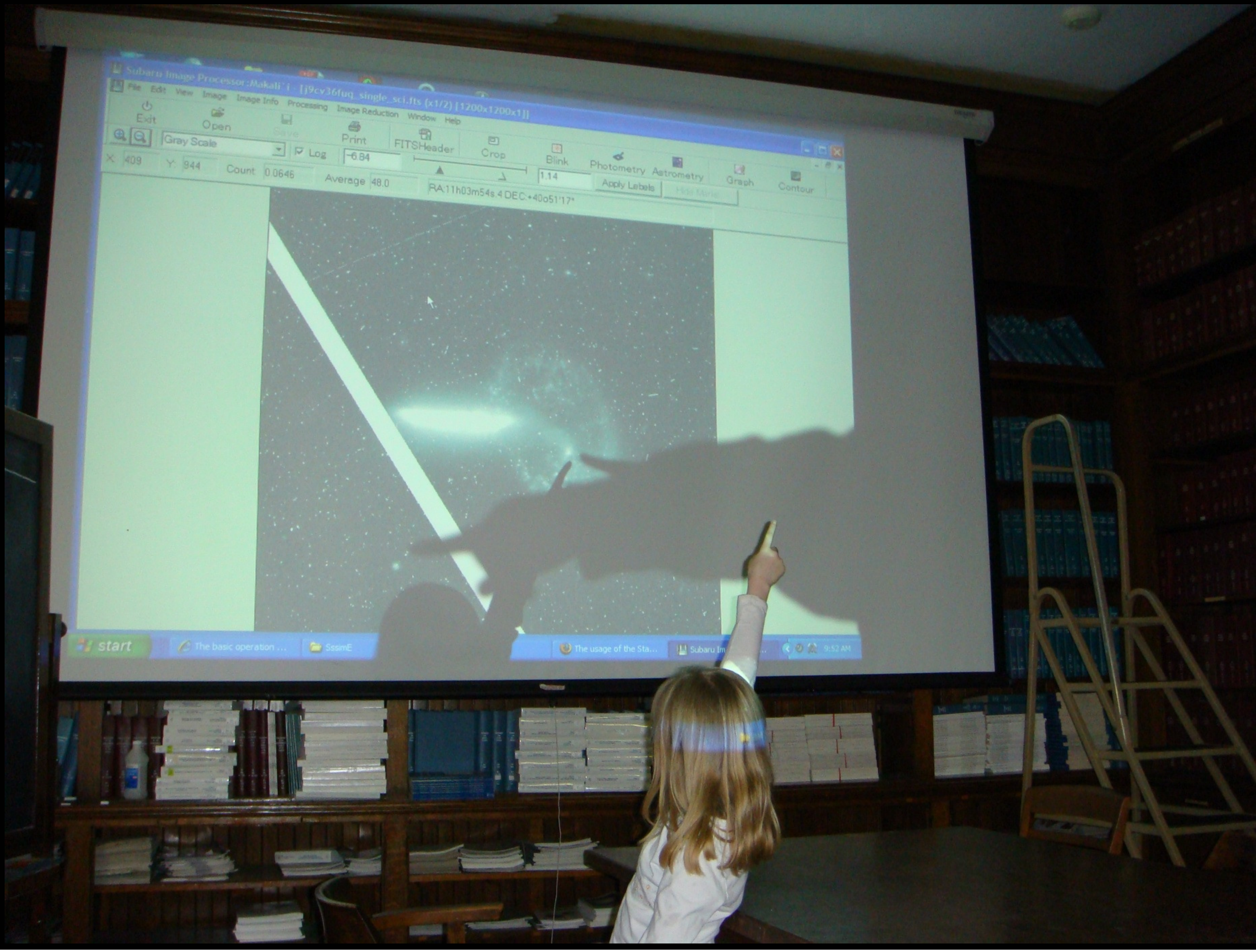


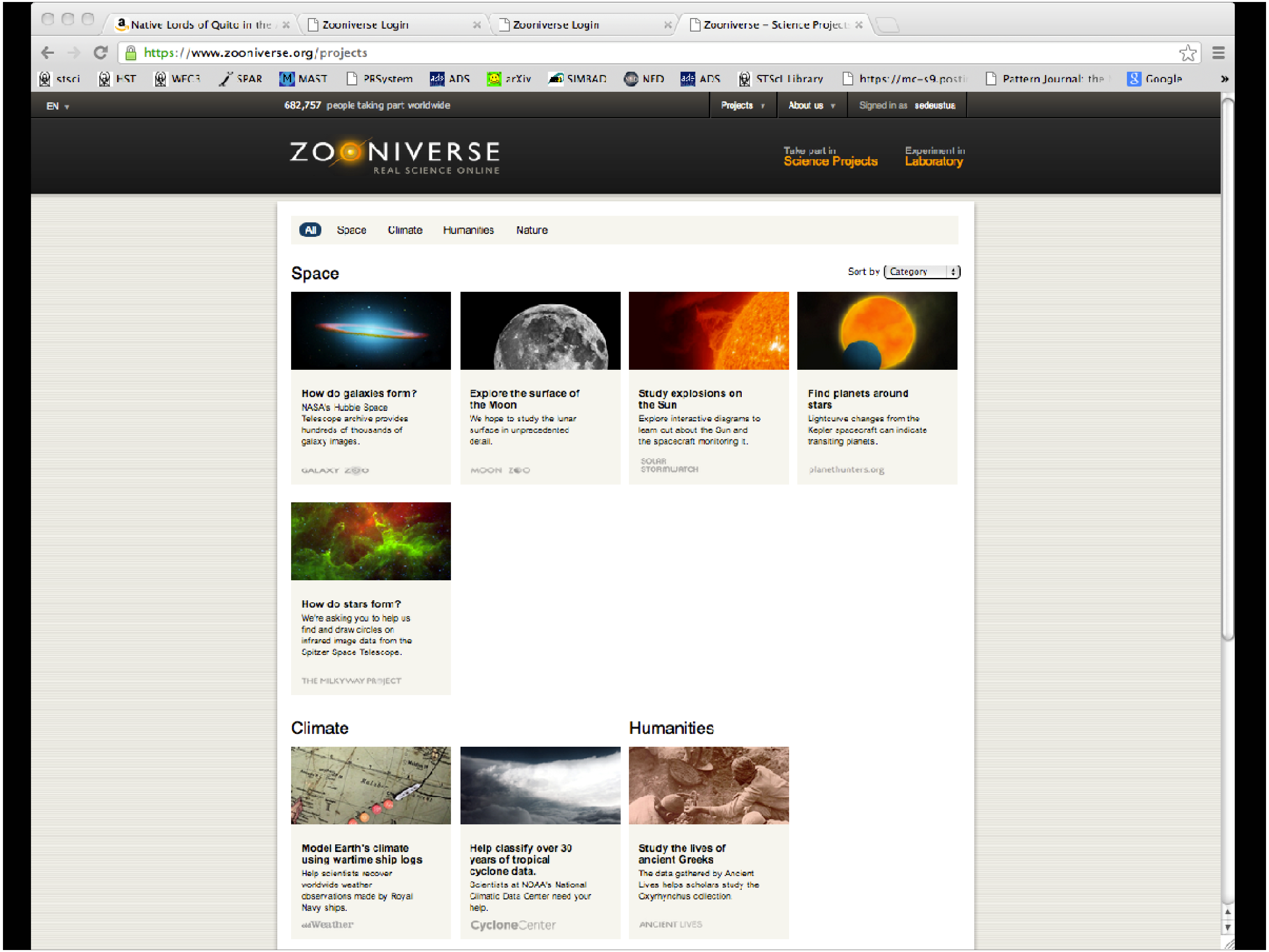
PDS Rings Node “finder chart”

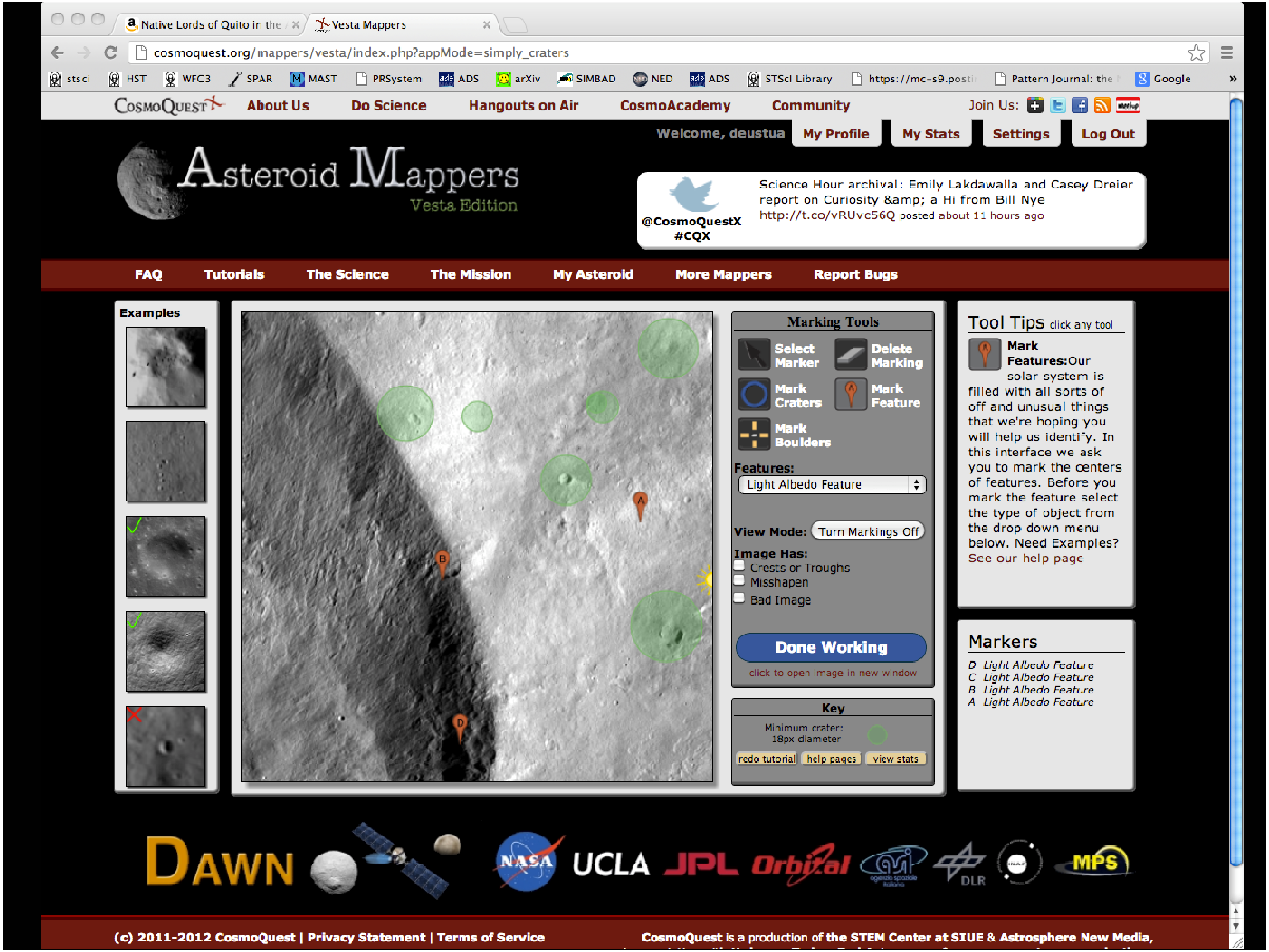
In addition to providing finder charts for each observation, we'd like to actually catalog the contents of each image -- what is actually detected (and what is the data quality)?



Where citizen science enters our pipeline processing: visual inspections to verify rejections, identify objects




Native Lords of Quito in the
Zooniverse Login
Zooniverse Login
Zooniverse – Science Project
https://www.zooniverse.org/projects
stsci
HST
WFC3
SPAR
MAST
PRSystem
ADS
arXiv
SIMBAD
NED
ADS
STScI Library
Pattern Journal: the
Google
EN
682,757 people taking part worldwide
Projects
About us
Signed in as sedeustua
ZOONIVERSE
REAL SCIENCE ONLINE
Take part in Science Projects
Experiment in Laboratory
All
Space
Climate
Humanities
Nature
Space
Sort by Category
How do galaxies form?
NASA's Hubble Space Telescope archive provides hundreds of thousands of galaxy images.
GALAXY ZOO
Explore the surface of the Moon
We hope to study the lunar surface in unprecedented detail.
MOON ZOO
Study explosions on the Sun
Explore interactive diagrams to learn out about the Sun and the spacecraft monitoring it.
SOLAR STORMWATCH
Find planets around stars
Lightcurve changes from the Kepler spacecraft can indicate transiting planets.
planethunters.org
How do stars form?
We're asking you to help us find and draw circles on infrared image data from the Spitzer Space Telescope.
THE MILKYWAY PROJECT
Climate
Model Earth's climate using wartime ship logs
Help scientists recover worldwide weather observations made by Royal Navy ships.
oldWeather
Help classify over 30 years of tropical cyclone data.
Scientists at NOAA's National Climatic Data Center need your help.
CycloneCenter
Humanities
Study the lives of ancient Greeks
The data gathered by Ancient Lives helps scholars study the Oxyrhynchus collection.
ANCIENT LIVES


Native Lords of Quito in the
Vesta Mappers
cosmoquest.org/mappers/vesta/index.php?appMode=simply_craters
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Tutorials
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The Mission
My Asteroid
More Mappers
Report Bugs
Examples
Marking Tools
Select Marker
Delete Marking
Mark Craters
Mark Feature
Mark Boulders
Features:
Light Albedo Feature
View Mode: Turn Markings Off
Image Has:
Crests or Troughs
Misshapen
Bad Image
Done Working
click to open image in new window
Key
Minimum crater: 18px diameter
redo tutorial
help pages
view stats
Tool Tips click any tool
Mark Features: Our solar system is filled with all sorts of odd and unusual things that we're hoping you will help us identify. In this interface we ask you to mark the centers of features. Before you mark the feature select the type of object from the drop down menu below. Need Examples? See our help page
Markers
D Light Albedo Feature
C Light Albedo Feature
B Light Albedo Feature
A Light Albedo Feature
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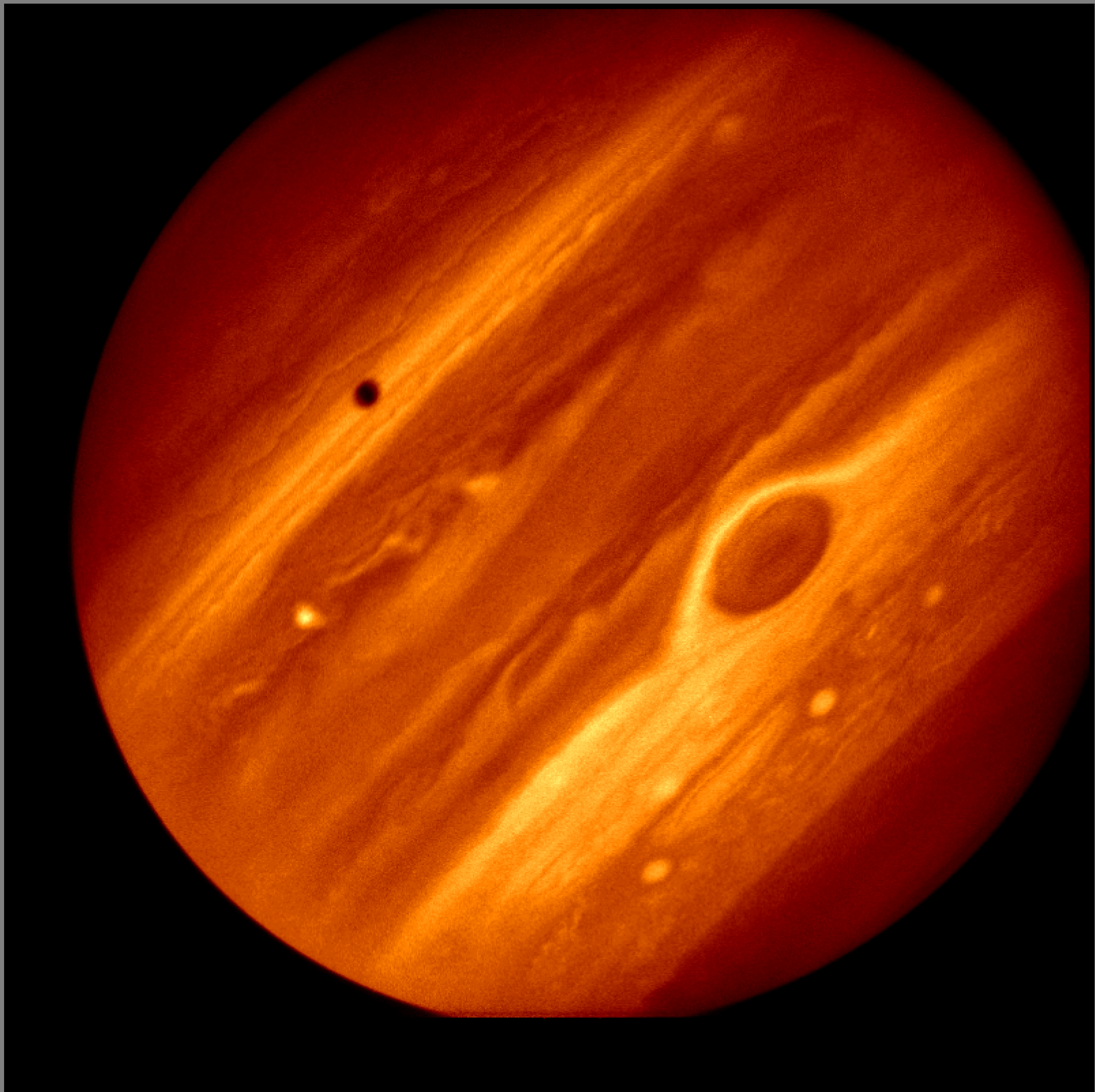
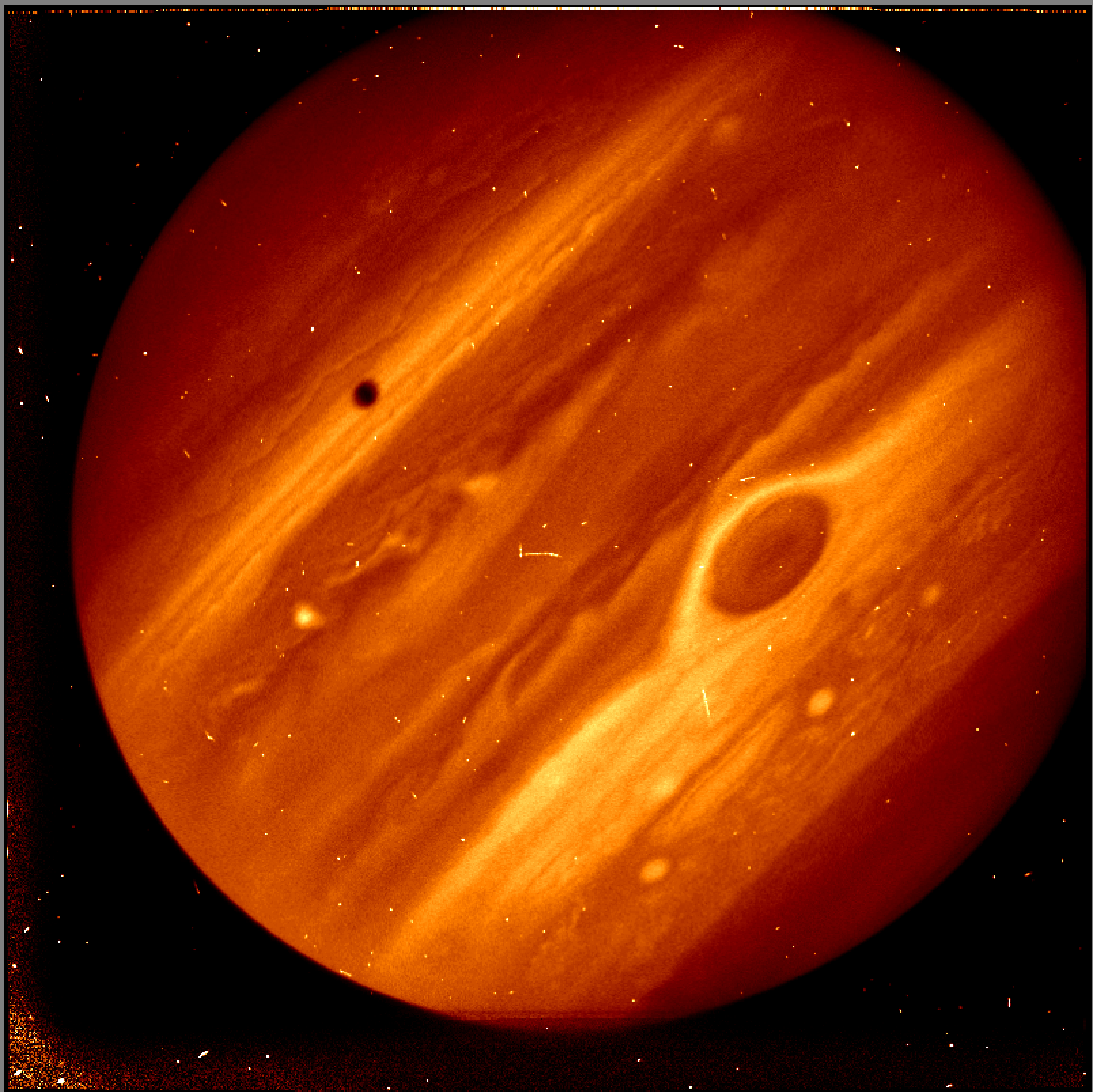
The standard calibration pipelines are not optimized for moving targets



Single-image
cosmic ray rejection:
requires visual verification,
iteration, and masking

The standard calibration pipelines are not optimized for moving targets



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English
The Science
The Data
Discuss Images
Gallery
Help
My Results
Help scientists with the Hubble Space Telescope track storms, identify which moons are bright enough to appear in which images, flag image defects like cosmic rays, and discover storms, and random travelers like asteroids and Kuiper Belt Objects that wonder through the field of view.
Please mark both image 1 and 2.
cosmic ray
appearing object
moving object
mark feature
flag oddity
erase marking
Contrast:
high
low
Finding Chart:
on
off
Show Image:
1
2
or
blink
Done Working
Tool Tip
click any tool to see tips
Cosmic Rays: Pellentesque ultrices commodo facilisis. Morbi lacinia, elit nec facilisis dictum, purus tellus tempus mauris, et bibendum libero massa ut sapien. Phasellus lorem eros, accumsan eu pharetra vitae, molestie ac sapien. Suspendisse massa ante, iaculis eget varius quis, consectetur non risus. Suspendisse luctus mollis massa, eu consectetur lacus posuere et. Morbi iaculis massa eget metus adipiscing vel elementum quam venenatis.
Markers & Flags
A impact
B white storm
C dark storm
D Europa
By the Numbers
10
Days Since Launch: 297
Total Contributors: 1,234,566
Images Analyzed (everyone): 123,456,789
Images Analyzed (by you): 9
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or
blink
Done Working
Tool Tip
click any tool to see tips
Cosmic Rays: Pellentesque ultrices commodo facilisis. Morbi lacinia, elit nec facilisis dictum, purus tellus tempus mauris, et bibendum libero massa ut sapien. Phasellus lorem eros, accumsan eu pharetra vitae, molestie ac sapien. Suspendisse massa ante, iaculis eget varius quis, consectetur non risus. Suspendisse luctus mollis massa, eu consectetur lacus posuere et. Morbi iaculis massa eget metus adipiscing vel elementum quam venenatis.
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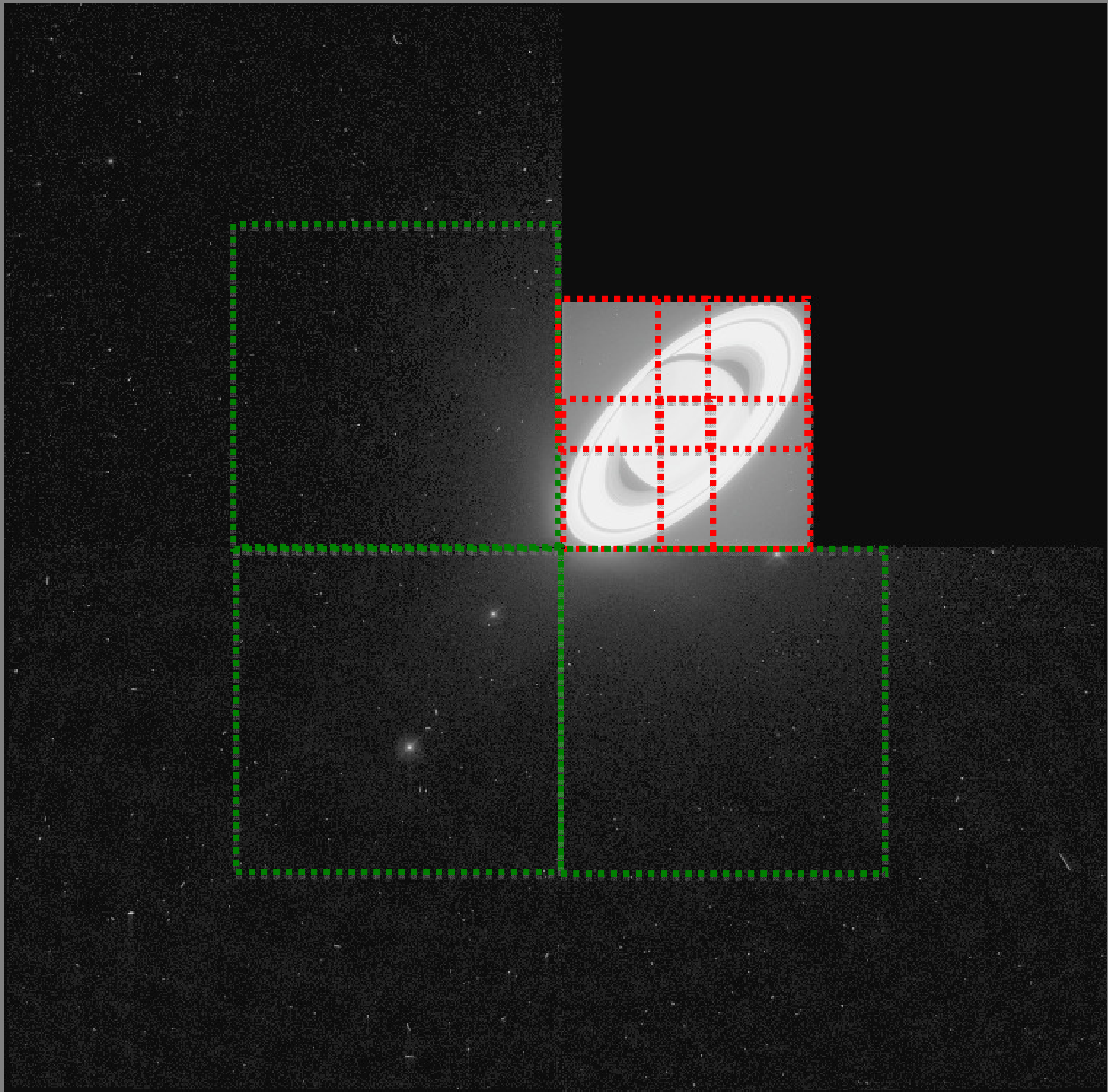
Inspection leverage: discerning real objects from artifacts

- before/after rejection
- chronological: expected vs random motion
- stretch: linear vs unsharp
- finder chart (verify known moons)
- small “slices” to limit fatigue... and enable citizen science

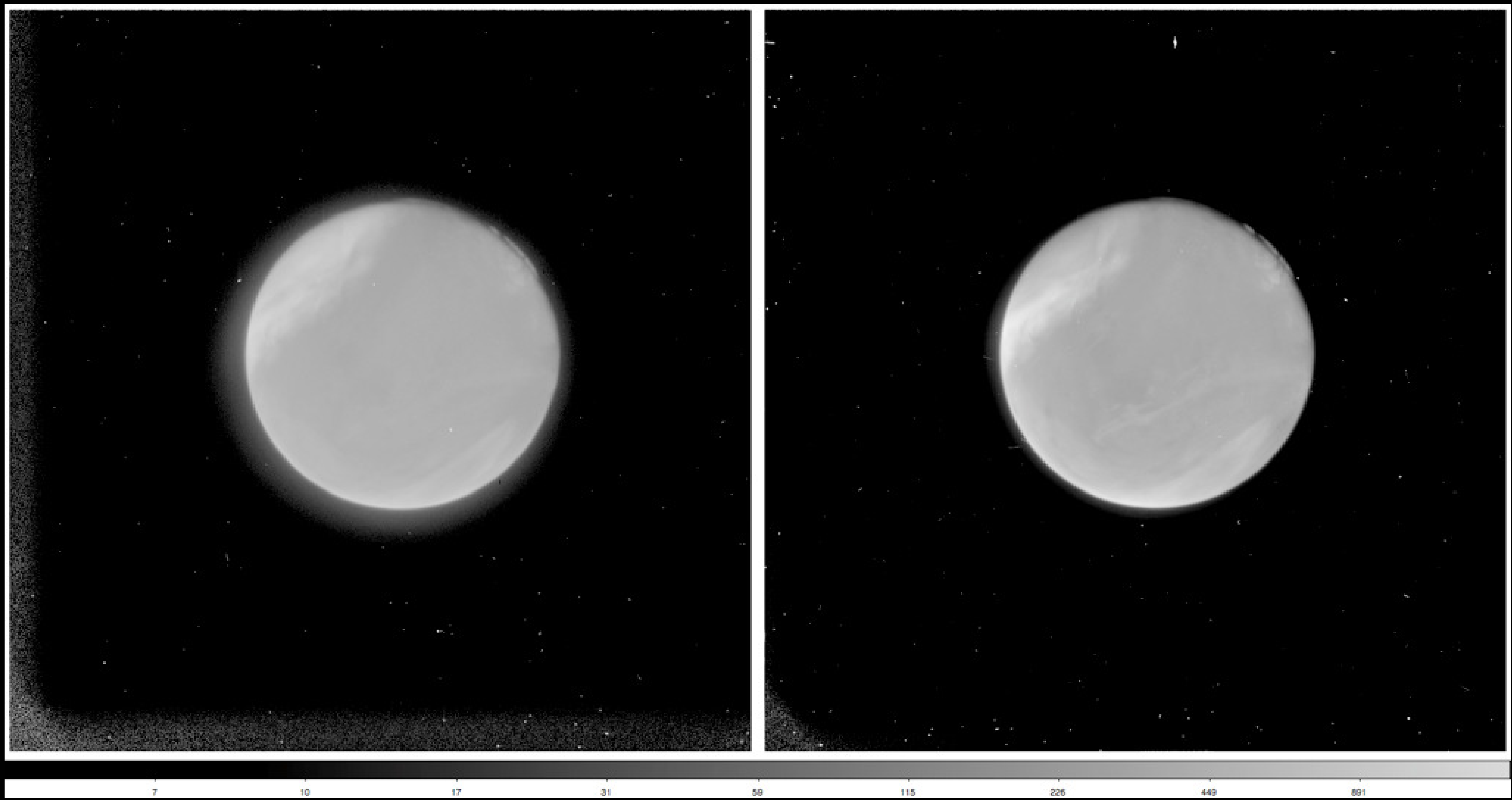


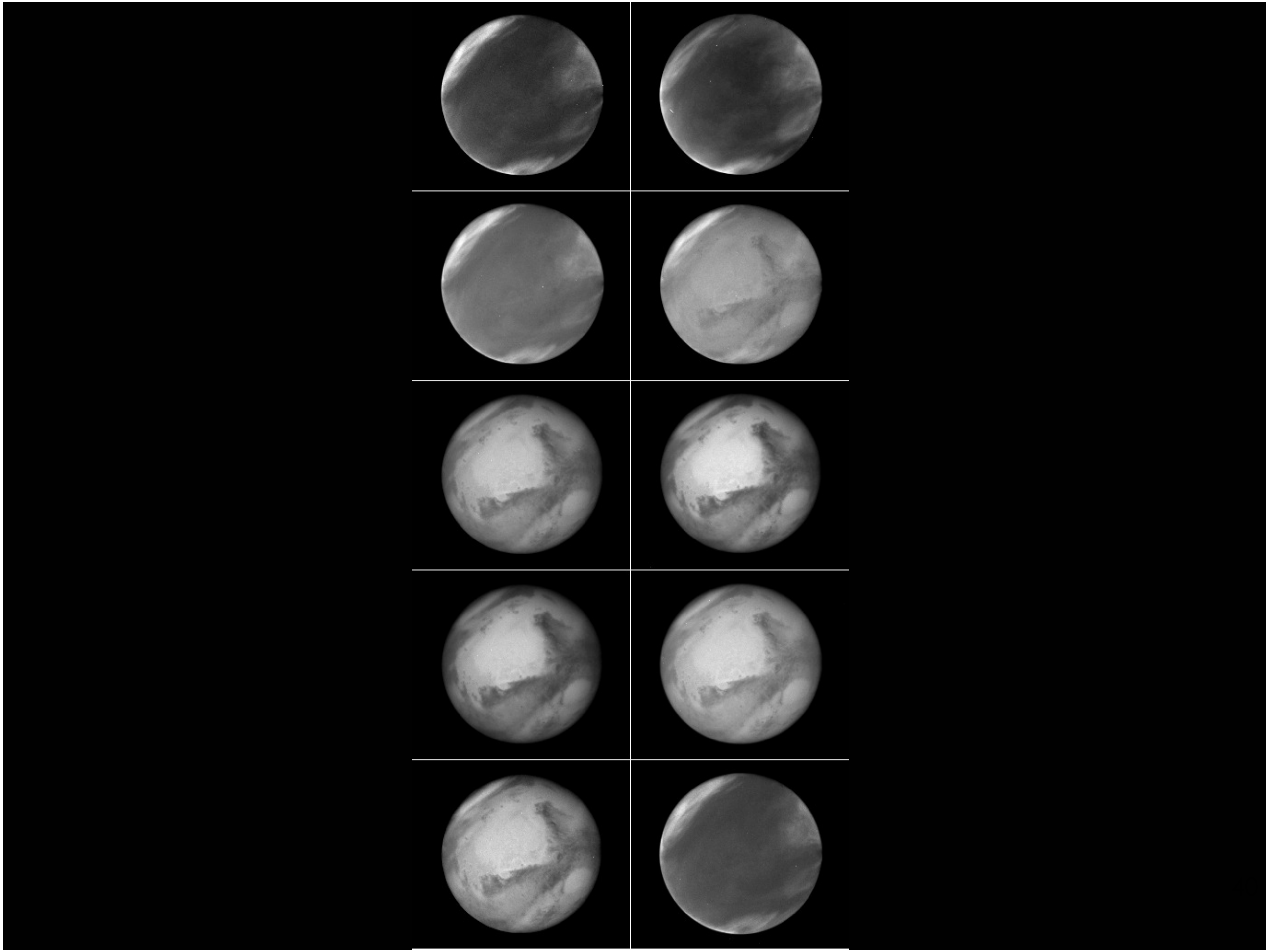
450 pixel slices on PC (red) and WF (green)

bin WF by 2X to search entire chip at once? then 450x450 would include a bit of PC for reference?

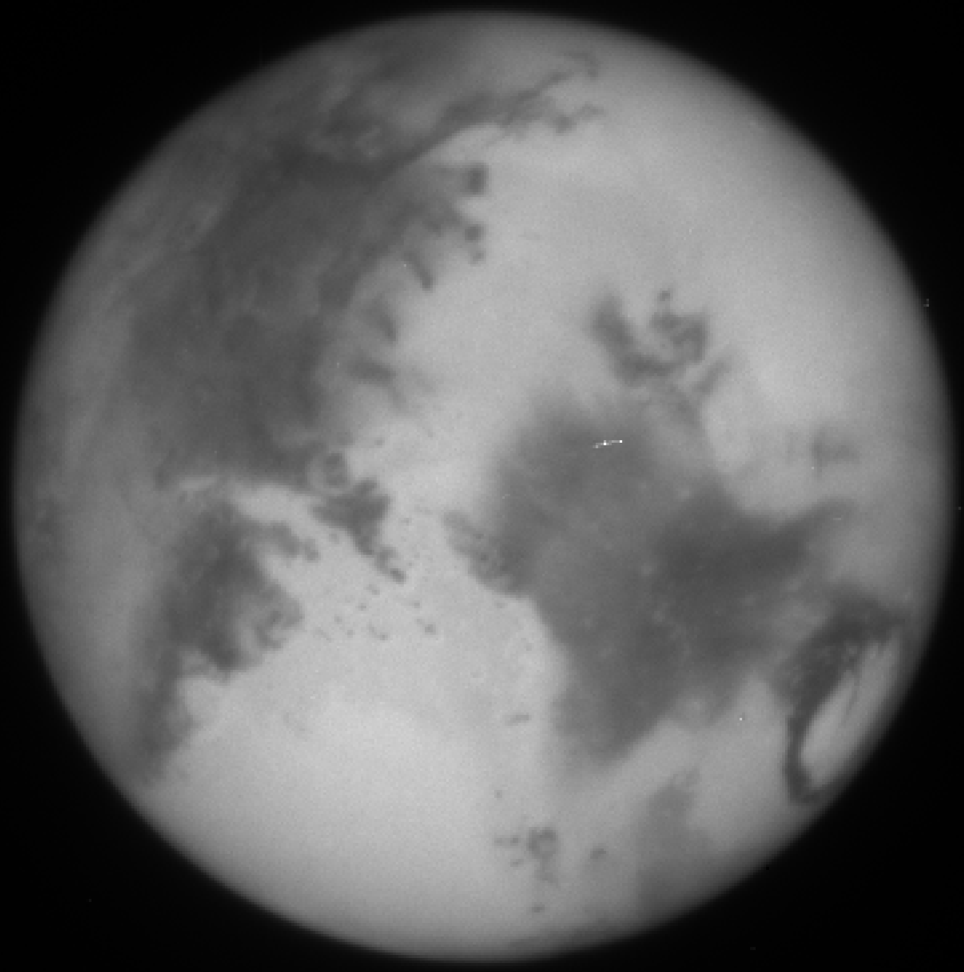
But difficult to catalog moons or deproject with slices... may need final mosaics for that...

Chronological blink pairs

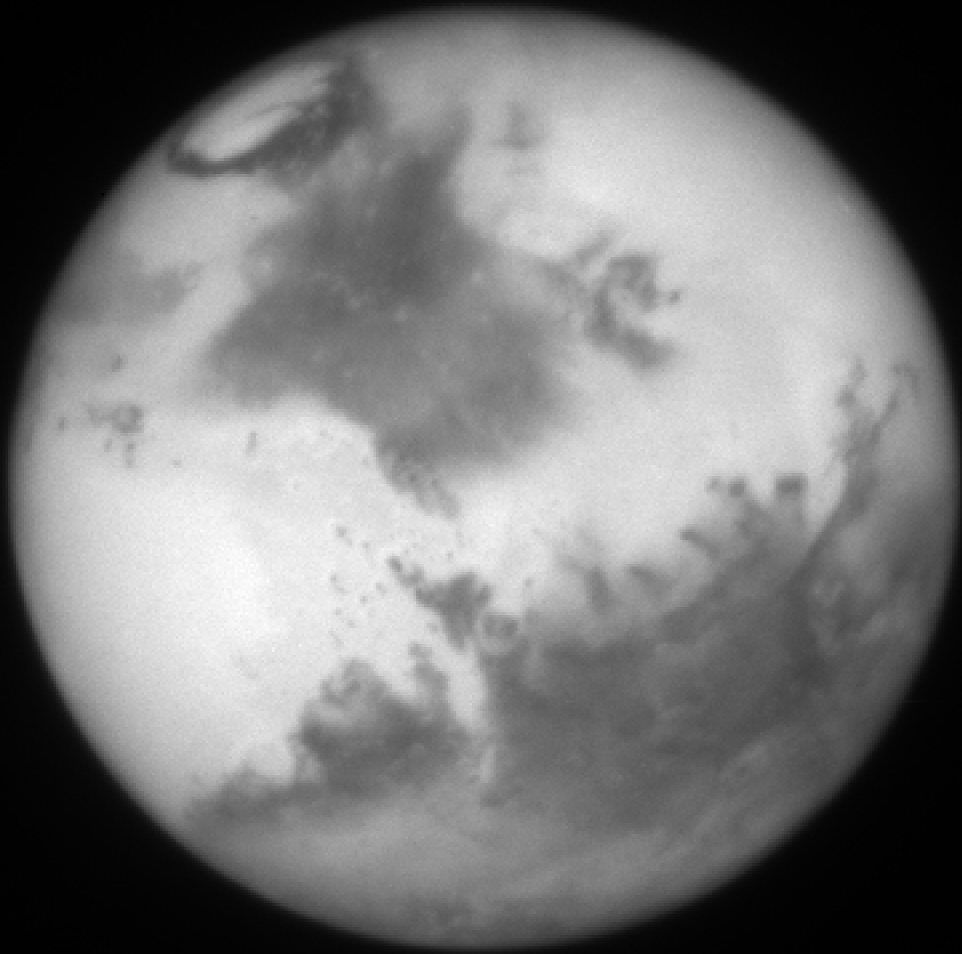




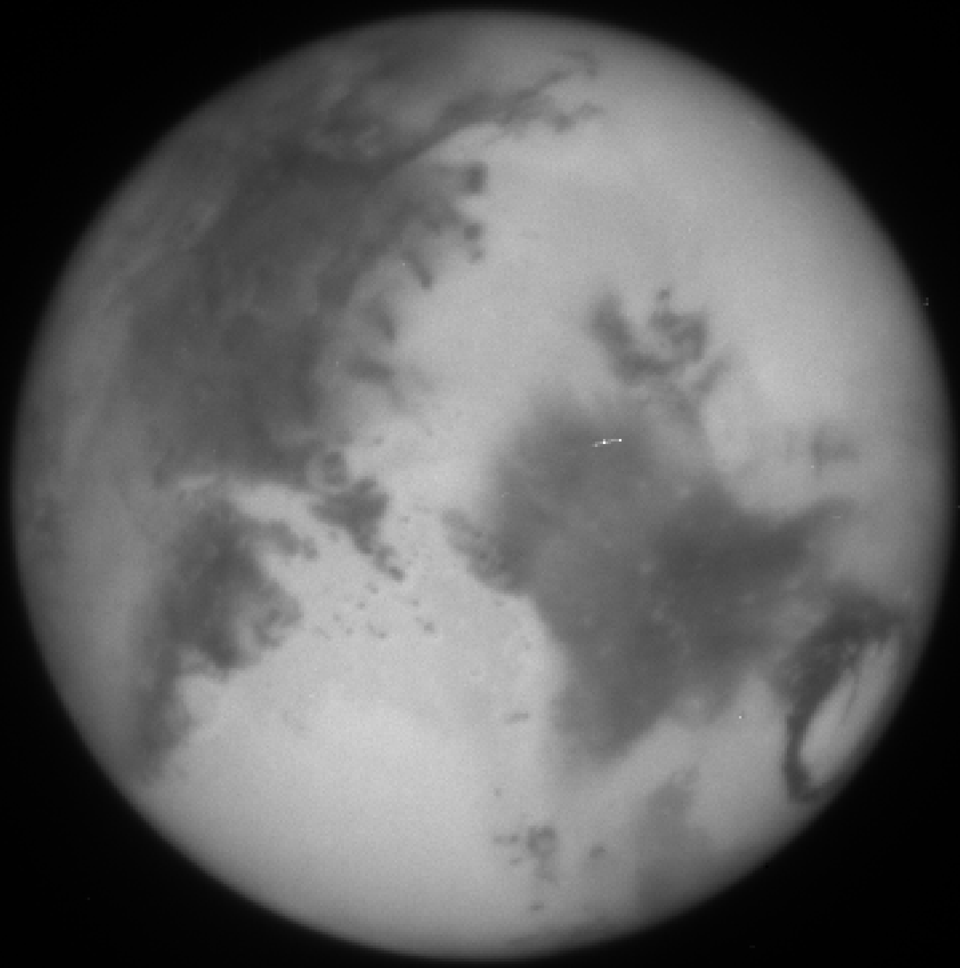
Mars



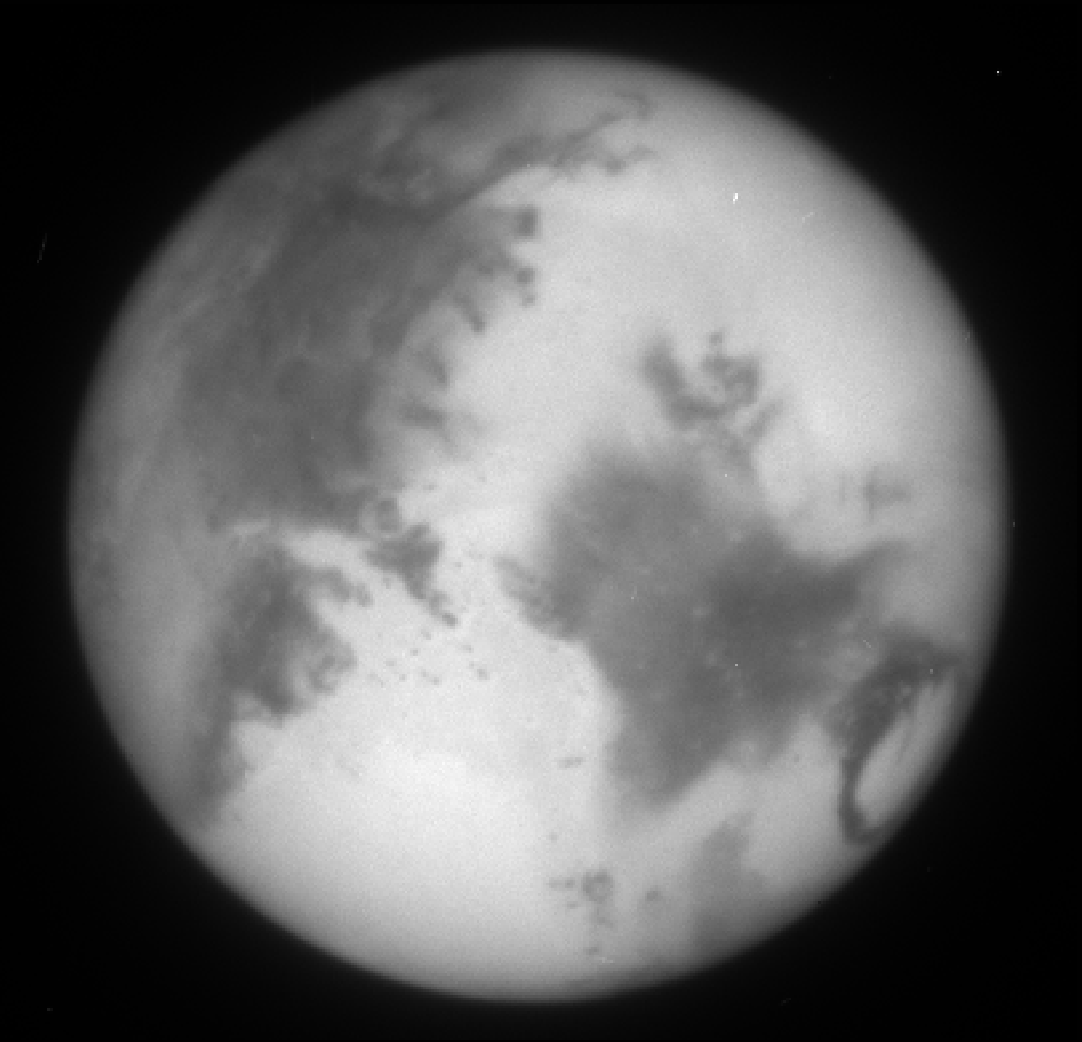
Mars



Mars

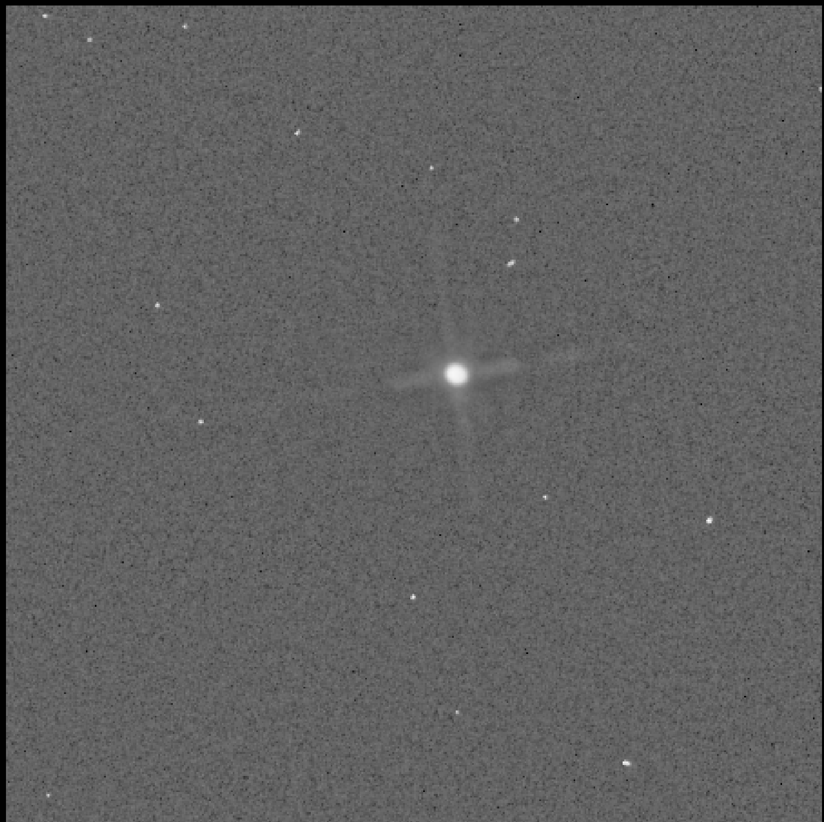


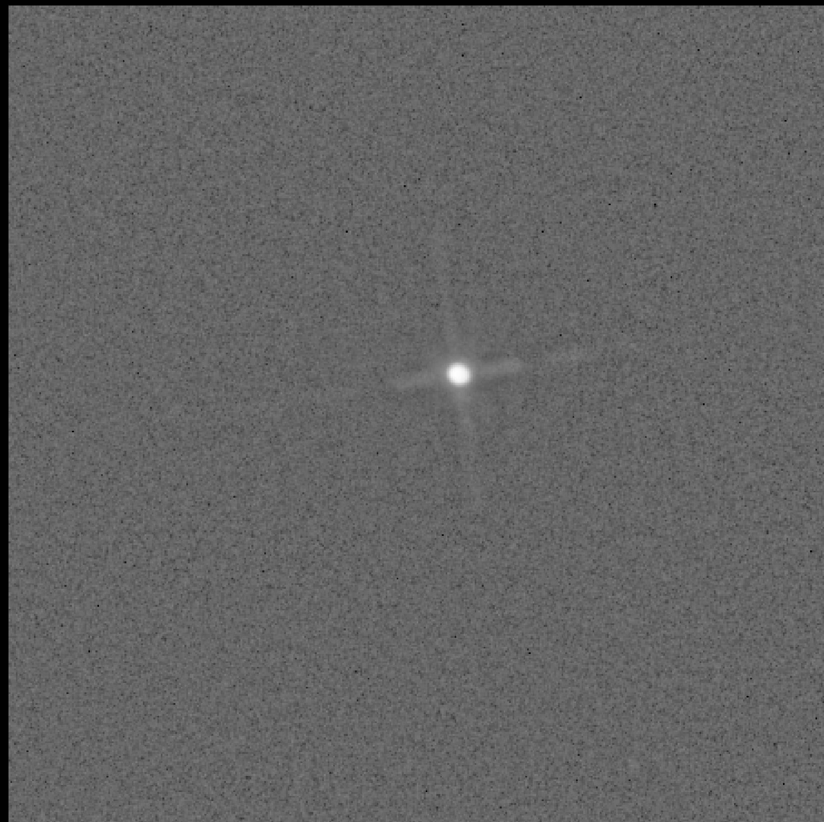
Mars



Vesta

- Pipeline image before CR rejection
- After CR found, and cleaned





What we hope to enable

- Our new and improved database of moving target data will eventually link our prepared WFPC2 images... and ACS, and WFC3...
- Lower barriers to subsequent steps: deconvolutions, deprojections, etc.
- Lower barriers for scientists to conduct the widest possible range of future HST Solar System archival research
- Lower barriers for teachers and students wishing to use "real data"
- More ambitious citizen science projects with HST data
- Incorporate ACS and WFC3 moving targets... and JWST

links

Space Telescope Science Institute

http://www.stsci.edu

http://archive.stsci.edu/index.html

Citizen Science Links

http://zooniverse.org

http://cosmoquest.org