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**January**  
**23–24,**  
**2018**

# Hubble Legacy Archive and Hubble Source Catalog

Rick White

Current HLA/HSC Team:

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Anton Koekemoer, Steve Lubow, Brian McLean,  
Armin Rest, Geoff Wallace, Rick White,  
Brad Whitmore



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# Overview

- What is the HLA
- What is the HSC
- Highlights from the past year
- Schedule and future plans

# Hubble Legacy Archive goals

1. Process HST data to produce higher-level, science-ready data products: combined images, mosaics, source catalogs
  - Based on software developed for data analysis (e.g., Astrodrizzle)
2. Develop advanced web interfaces to the archive using next-generation browser technology
  - Portal is replacing the HLA interface, although some HLA tools (e.g., fitscut and interactive display) remain in use

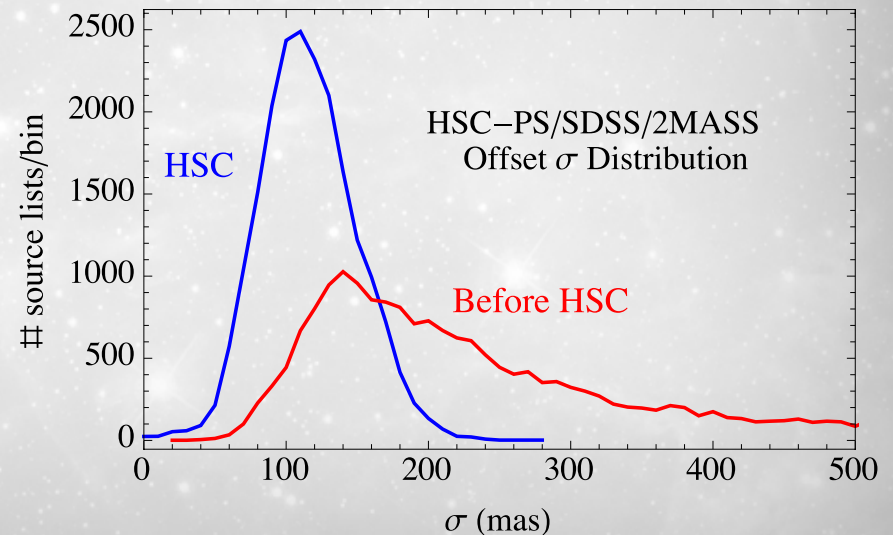
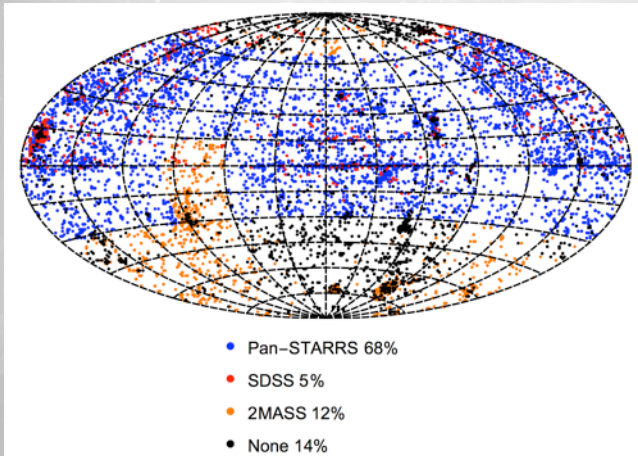


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# Hubble Source Catalog

1. Combines tens of thousands of SourceExtractor HLA source lists into a **single master catalog**. Uses matching algorithm from Budavári and Lubow 2012.
2. Includes **WFPC2, ACS/WFC, WFC3/UVIS and WFC3/IR**.
3. **Absolute astrometry** is good to  $\sim 100$  mas (calibrated using PanSTARRS and 2MASS). This will be improved in the next release (HSC v3, March 2018) to  $\sim 10$  mas using Gaia observations).

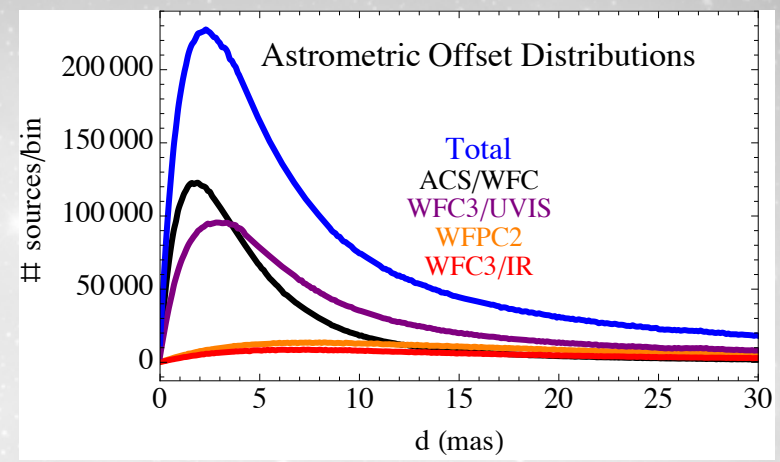




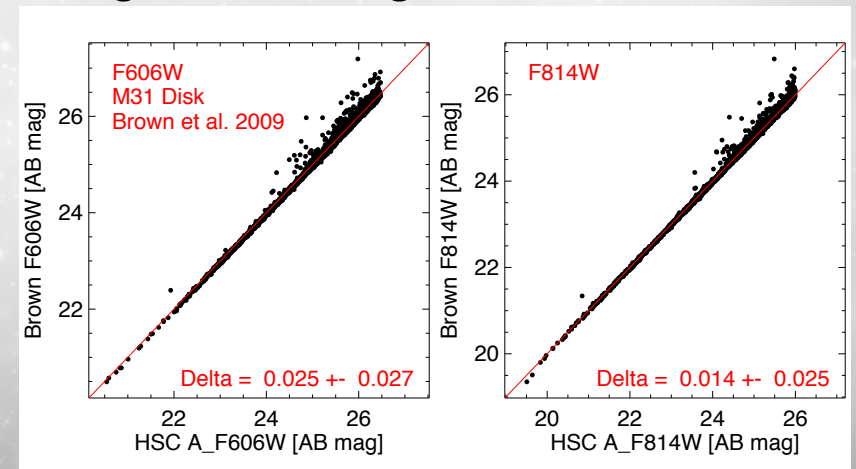
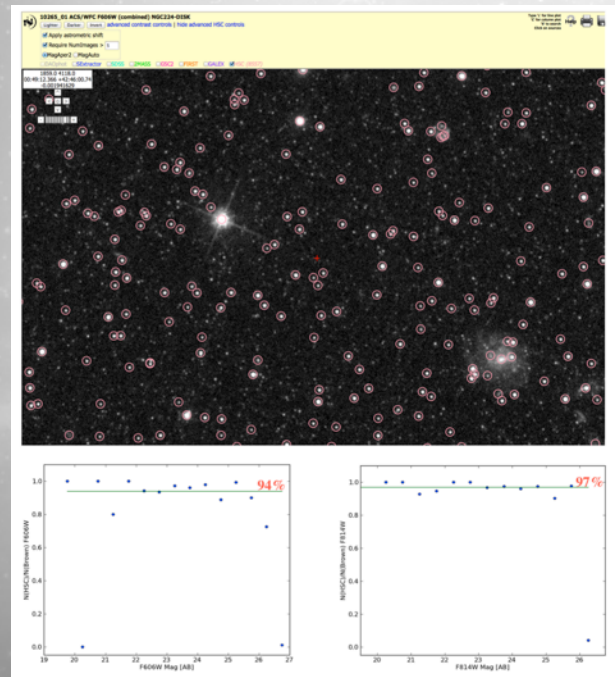
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# Hubble Source Catalog

4. **Relative astrometry** good to better than  $\sim 10$  mas;  $\sim 2$  mas is the peak of the distribution.



5. **Photometry** (aperture) typically good to 0.10 mag and 0.02 mag when S/N is sufficient.

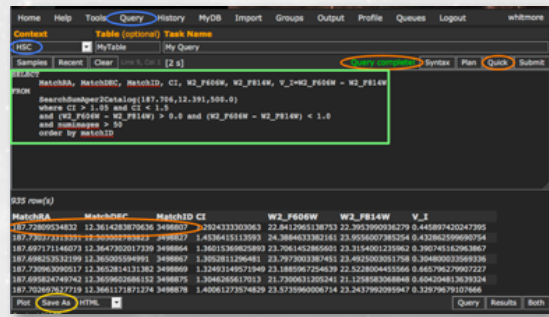
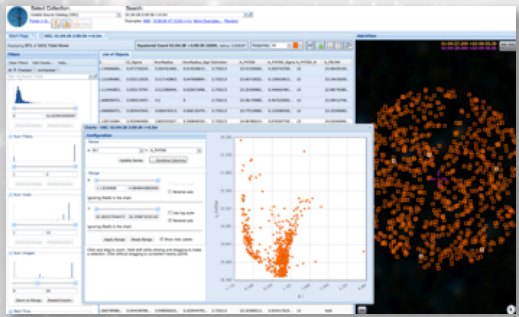




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# Hubble Source Catalog

6. Interfaces include the **MAST Portal** (easy with useful tools), a **CasJobs** interface (similar to SDSS) for larger and more complex database queries, a **simple search form** for special cases and scripted queries, and other **MAST API** and **VO** interfaces.



7. A range of **documents and learning aids** are available (e.g., FAQ, use cases, videos, journal article – Whitmore et al. (2016) – “Version 1 of the HSC”).

**A Hubble Source Catalog (HSC) Use Case**  
Example #3: Using the Discovery Portal to search for Variable Objects in the HSC  
(Time Variability in the dwarf irregular galaxy IC 1613)

**GOAL:** This tutorial shows you how to use the **MAST Discovery Portal** to search for variable objects in the HSC.  
**SCIENCE CASE:** The science case is searching for variable objects (i.e. in the irregular galaxy IC 1613; Bernard et al. 2010, Apr 712, 1259).

VERSION 1 OF THE HUBBLE SOURCE CATALOG  
Whitmore C., Wilner J., Annis S., Burgin A., Casali P., Davis B., DePasquale S., Gwynn A., Gwynn R., Hubble Space Telescope Science Center, Johns Hopkins University, Baltimore, MD, USA  
2016, Apr 712, 1259

**ABSTRACT**  
The Hubble Source Catalog is designed to help scientists access the Hubble Space Telescope data archive for the discovery and study of variable objects. Version 1 of the catalog includes WFC3/UVIS, WFC3/OAIS, and WFC3/IR channels. It is the first public release of the catalog and is available for download. The catalog is a multi-wavelength, multi-band, multi-filter, multi-epoch data set. It is the first public release of the catalog and is available for download. The catalog is a multi-wavelength, multi-band, multi-filter, multi-epoch data set. It is the first public release of the catalog and is available for download.

**INTRODUCTION**  
The Hubble Space Telescope (HST) has been in orbit for over 35 years. In that time it has observed a vast array of celestial objects. The data it has collected are a treasure trove for astronomers. However, with a few exceptions, these data have not been fully exploited. One reason for this is that the data are so large that it is difficult to search through them. Another reason is that the data are not always in the format that scientists need. The Hubble Source Catalog (HSC) is a new catalog of data from HST. It is the first public release of the catalog and is available for download. The catalog is a multi-wavelength, multi-band, multi-filter, multi-epoch data set. It is the first public release of the catalog and is available for download.



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# Highlights from the past year

- HSC 2.1 (January 25, 2017)
  - Same objects as HSC 2.0 (September 2016)
  - Additional spectroscopic matches
  - New tables that provide median rather than mean magnitudes for sources with multiple measurements
  - New table that provides cross-match information between HSCv2 sources and HSCv1 sources
- HLA DR10 (January 8, 2018)
  - All new ACS and WFC3 images and source lists
    - Many improvements in processing
  - Includes all public data as of 2017 October 1
    - 25% more ACS data, twice as much WFC3 data as DR9
  - New ACS and WFC3 deep/wide multi-visit mosaic images
  - Improved products for ACS/SBC and moving targets



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# New HLA mosaics

- Project to make “super mosaics” using HLA data was led by Anton Koekemoer
  - Deep and/or wide images combining visits and proposals
  - Offsets from the HSC between are used to align exposures
  - Sky matching eliminates “seams”
- Quality is excellent
  - HSC offsets are sufficient for making mosaics
  - Very few images were rejected on review
- DR10: 1348 pointings with 4306 single-filter images
  - Up to 120 exposures per filter & 285 exposures per mosaic
  - ACS and WFC3 products use matching pixel grids



0 0 r=180 RA = 0.000000 Dec = 0.000000 r = 180.000000 [00:00:00.000 +00:00:00.00]

Results 1-10 of 10 (5373 before filtering) Show 100 results per page

Click to select images [Add selection to cart](#)  
Show selected rows: [First](#) [Mixed](#) [Only](#) [Not](#) [Select all](#) [Reset selection](#)  
Filters: Level=4



**KK16 (color)**  
**ACS/WFC F814W/F606W multi mos\_0009731**  
[Interactive Display](#)  
Download Data: [FITS-Color \(609.0 MB\)](#)  
Download Source Lists: None [More...](#)



**NGC602 (color)**  
**ACS/WFC F814W/F658N/F555W WFC mos\_0012228**  
[Interactive Display](#)  
Download Data: [FITS-Color \(365.5 MB\)](#)  
Download Source Lists: None [More...](#)



**NGC1300-POS2 (color)**  
**ACS/WFC F814W/F555W/F435W WFC mos\_0017053**  
[Interactive Display](#)  
Download Data: [FITS-Color \(1253.1 MB\)](#)  
Download Source Lists: None [More...](#)



**M16-PT2 (color)**  
**ACS/WFC F658N/F502N WFC mos\_0017392**  
[Interactive Display](#)  
Download Data: [FITS-Color \(809.5 MB\)](#)  
Download Source Lists: None [More...](#)



**NGC7090 (color)**  
**ACS/WFC F814W/F625W/F606W multi mos\_0019749**  
[Interactive Display](#)  
Download Data: [FITS-Color \(617.7 MB\)](#)  
Download Source Lists: None [More...](#)



**WARPS1415+36 (color)**  
**ACS/WFC F850LP/F775W WFC mos\_0023727**  
[Interactive Display](#)  
Download Data: [FITS-Color \(916.8 MB\)](#)  
Download Source Lists: None [More...](#)



**NGC0253-WIDE4 (color)**  
**ACS/WFC F814W/F606W/F475W WFC mos\_0035156**  
[Interactive Display](#)  
Download Data: [FITS-Color \(3445.7 MB\)](#)  
Download Source Lists: None [More...](#)



**NGC-2366-2 (color)**  
**ACS/WFC F814W/F555W WFC mos\_0068496**  
[Interactive Display](#)  
Download Data: [FITS-Color \(982.7 MB\)](#)  
Download Source Lists: None [More...](#)



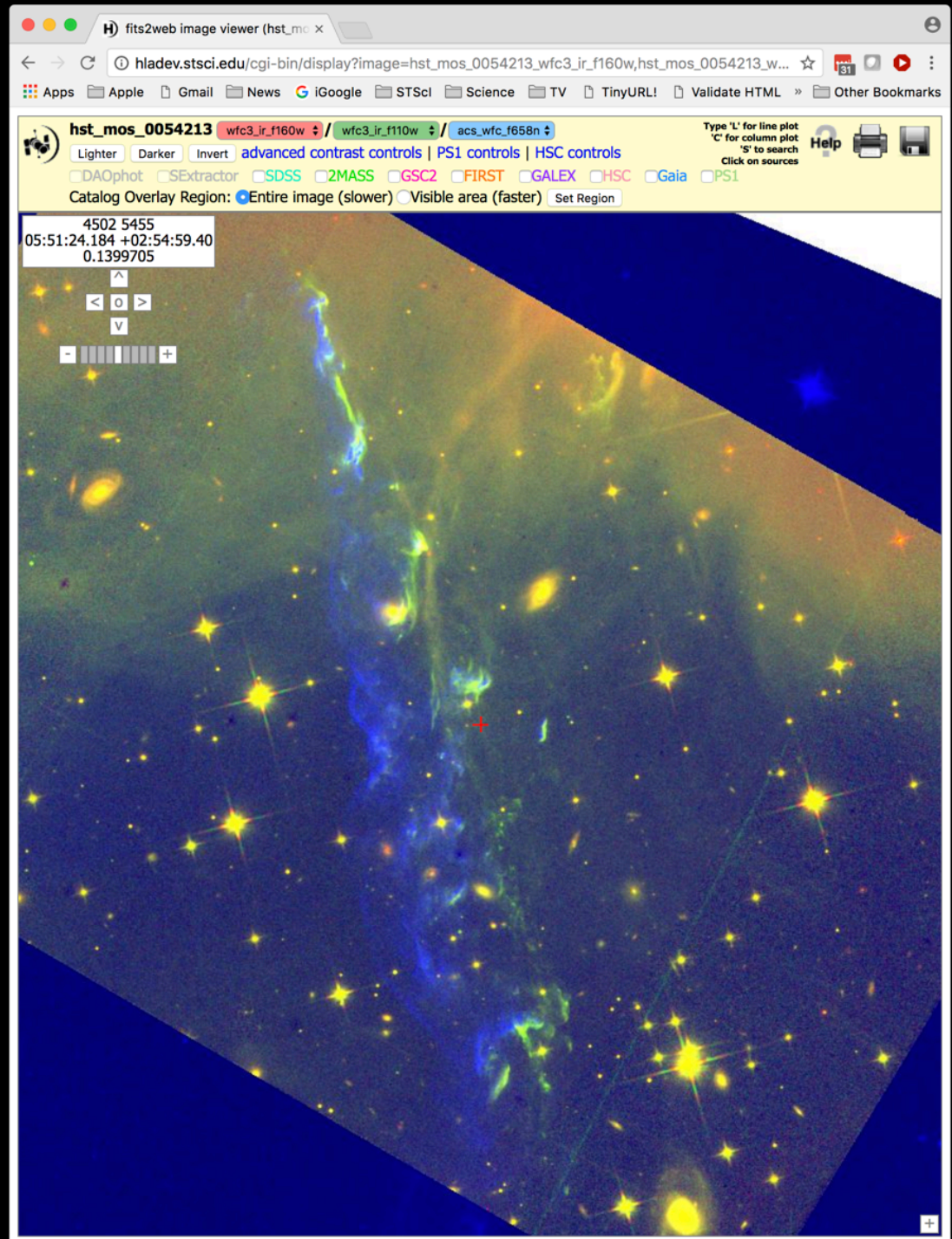
**NGC7293-POS9 (color)**  
**ACS/WFC F658N/F502N WFC mos\_0092949**  
[Interactive Display](#)  
Download Data: [FITS-Color \(6809.1 MB\)](#)  
Download Source Lists: None [More...](#)



**NGC-2174 (color)**  
**WFC3/IR F160W/F125W/F105W IR-FIX mos\_0368021**  
[Interactive Display](#)  
Download Data: [FITS-Color \(739.6 MB\)](#)  
Download Source Lists: None [More...](#)

# DR10 Mosaic

WFC3/IR  
+  
ACS/WFC





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# Highlights of HLA DR10 updates

- Many updates and improvements to HLA image and source list pipelines
  - Many of them are driven by problems identified in the HSC by the Hubble Catalog of Variables project at the National Observatory of Athens
- Pipeline can now process essentially all observation modes (<0.01% fail in processing)
  - All old catalogs are replaced
- Processing starts with HST online cache data (best available calibration)
  - Includes CTE correction for WFC3/UVIS images
- Eliminated use of WFC3/IR “blob” flag



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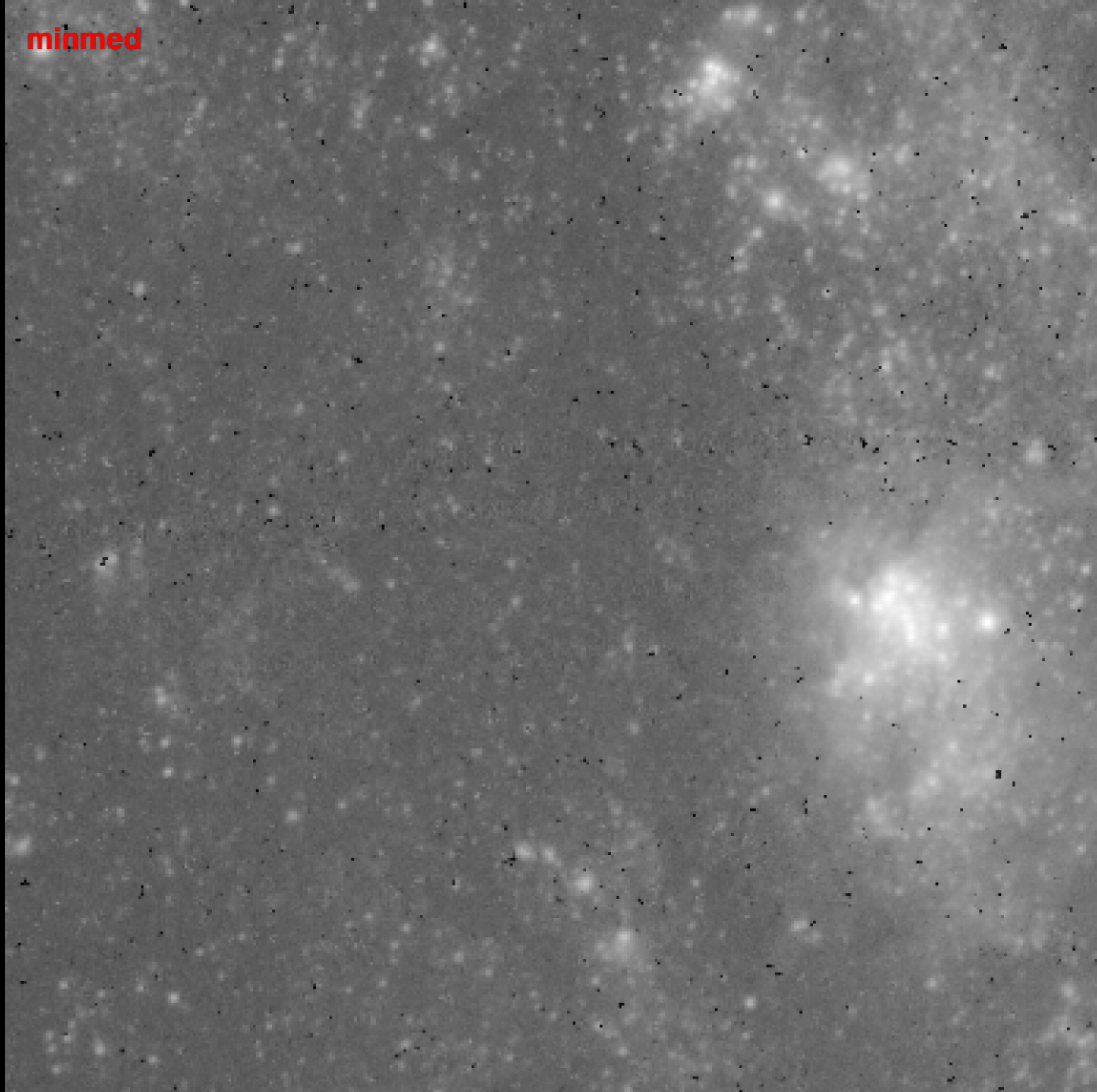
# Highlights of HLA DR10 (cont.)

- Fixed problem with SourceExtractor background near image edges
  - Filtering near edges also improved
  - Catalogs should be much better near edges
- Reduced artifacts in visits with short and long exposures
- Improved saturated images
- Improved detection image quality when sky varies
- Fixed major pipeline bug that prevented exposure alignment
  - Now exposures are aligned across filters too!

minmed

Short-Long  
exposures  
("grot")

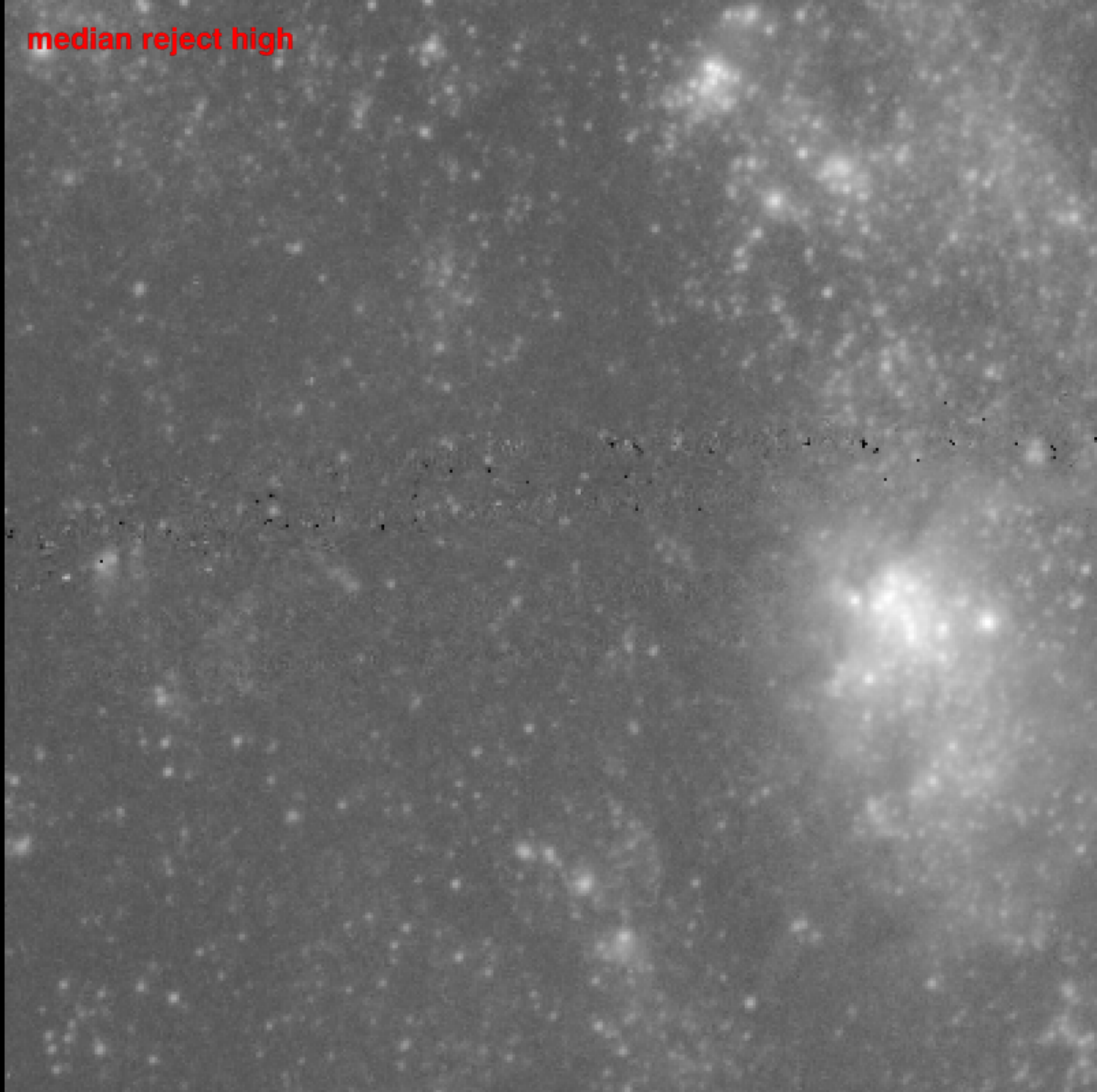
DR9  
version



median reject high

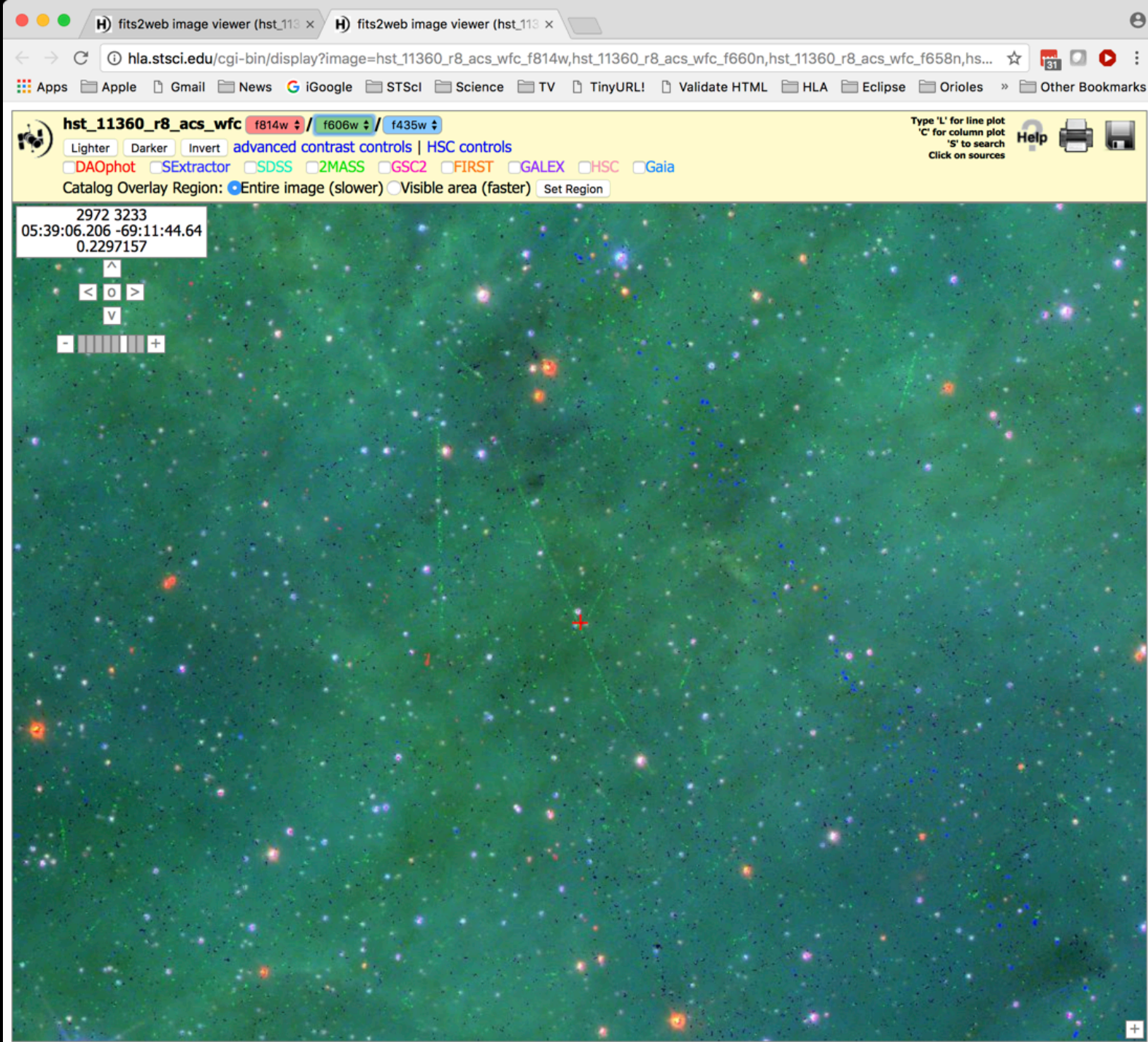
Short-Long  
exposures  
("grot")

DR10  
version



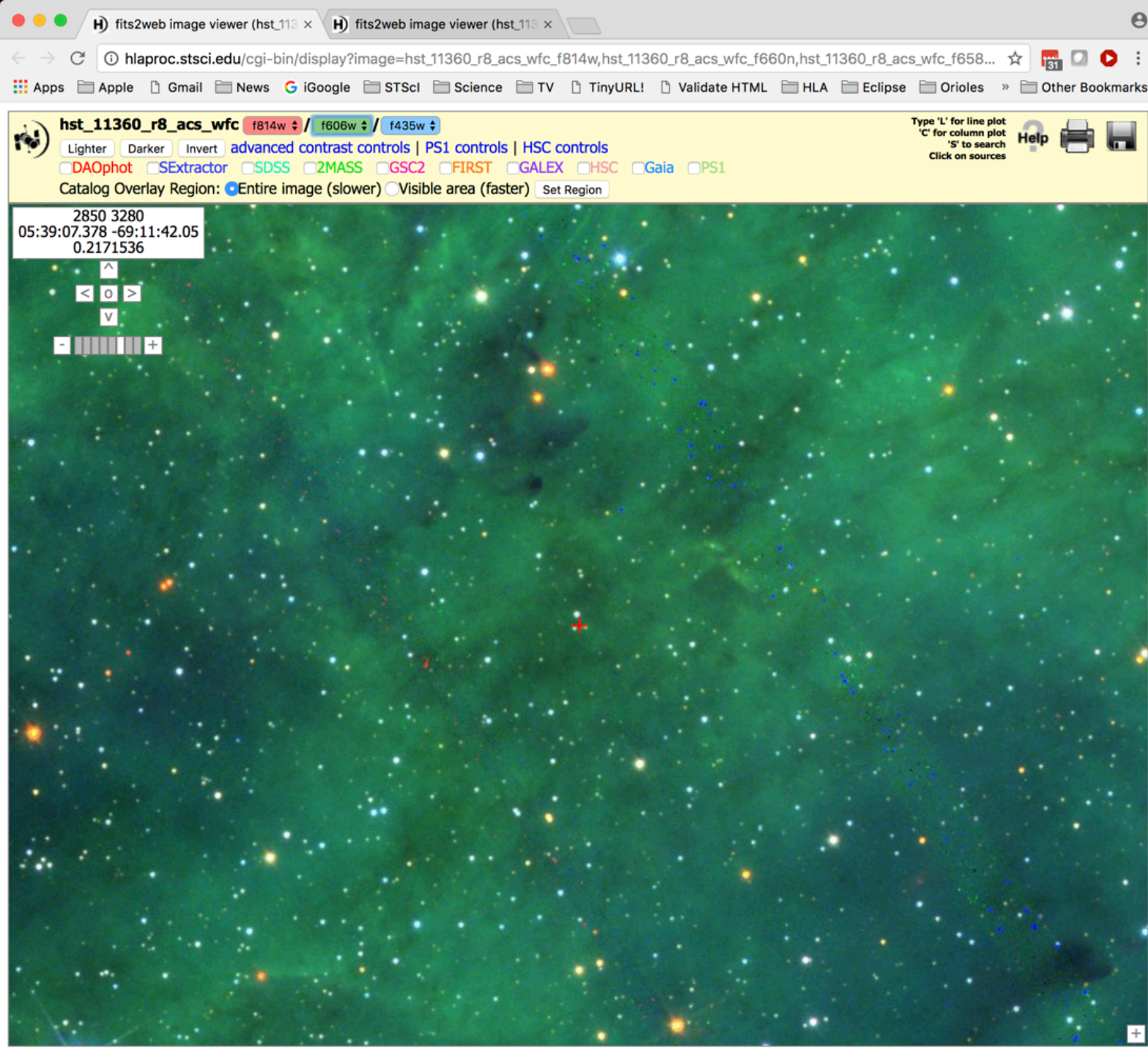
Short-Long  
exposures  
("grot")

DR9  
version



Short-Long  
exposures  
("grot")

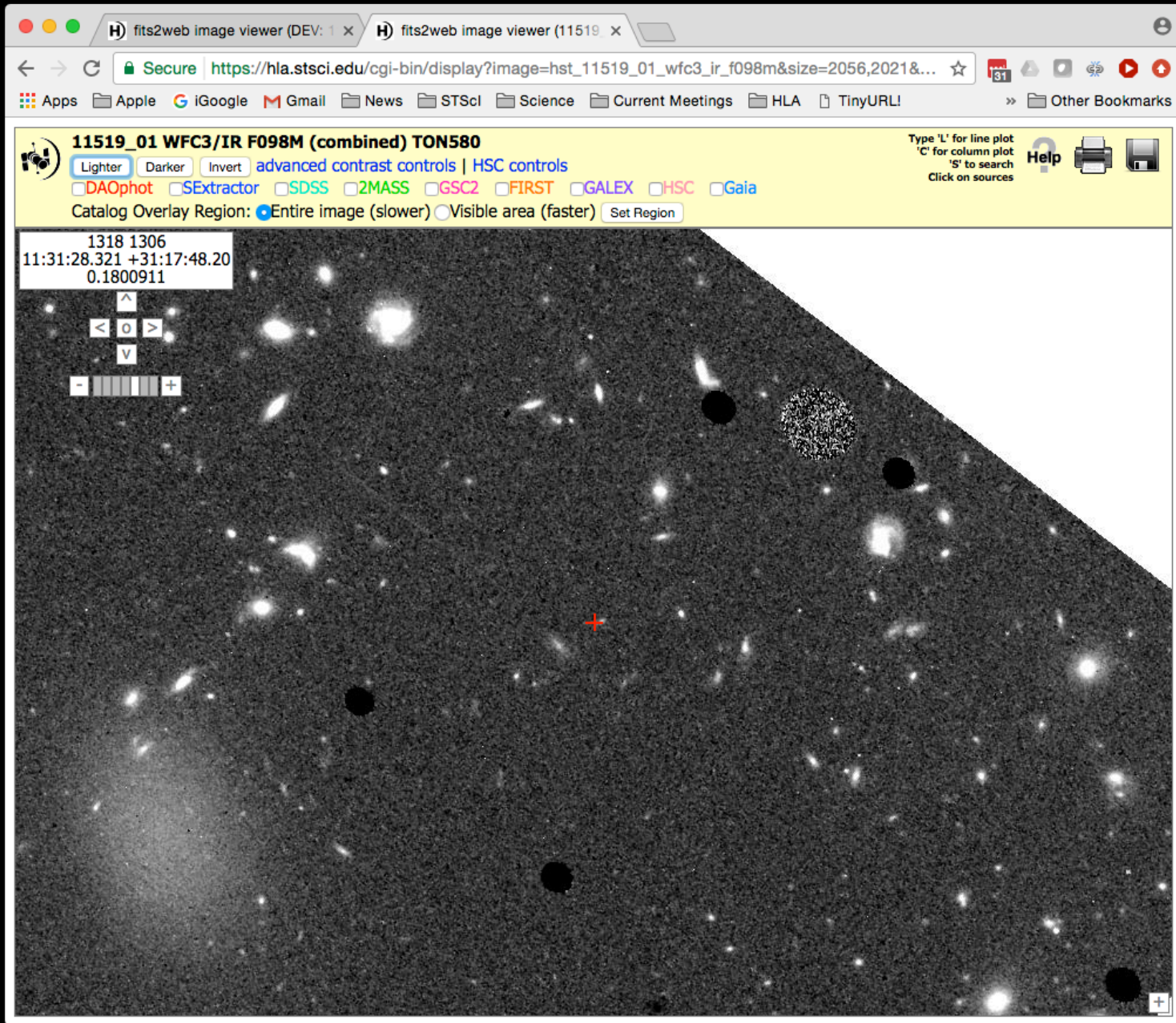
DR10  
version





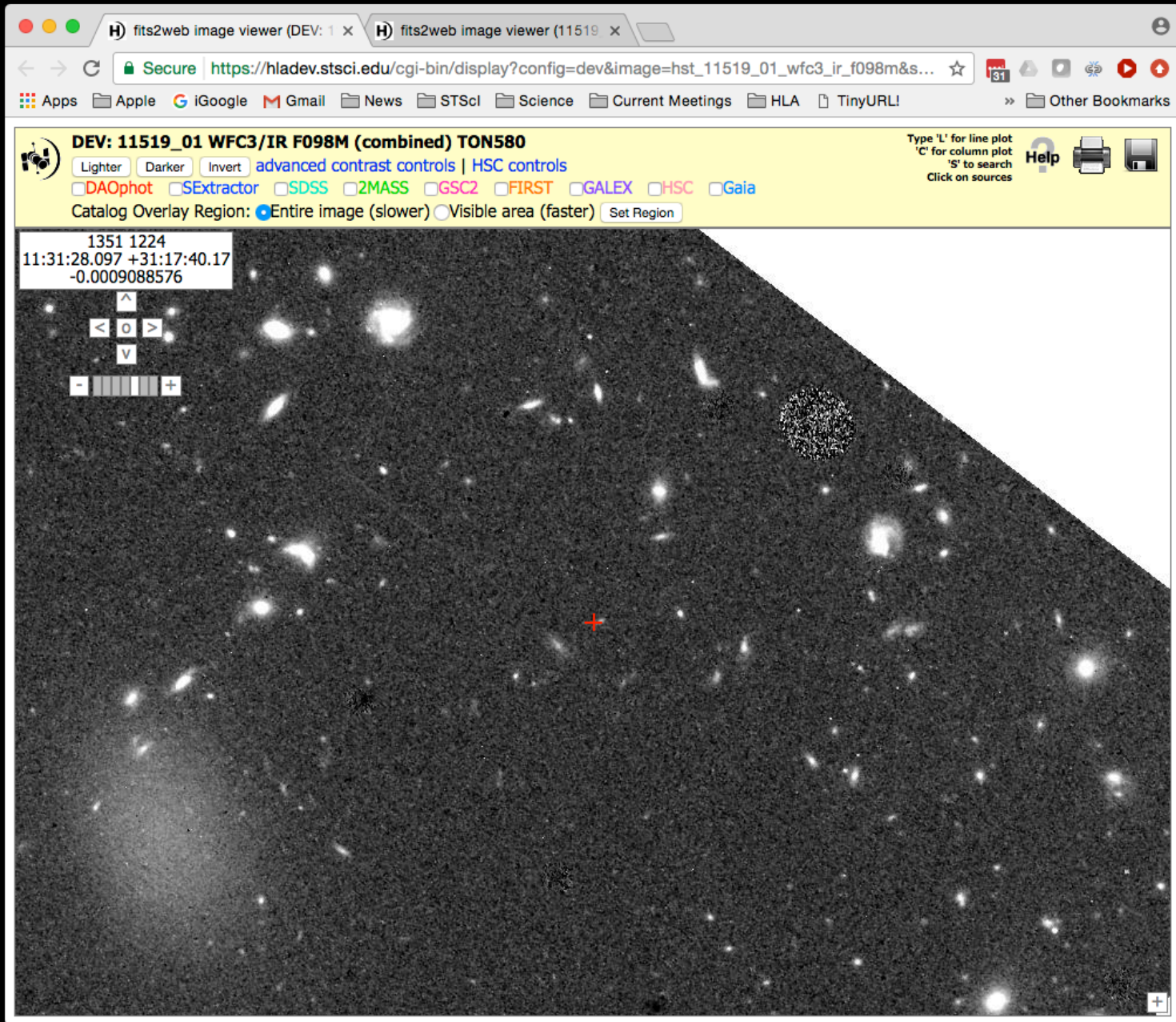
WFC3/IR  
blobs

DR9  
version

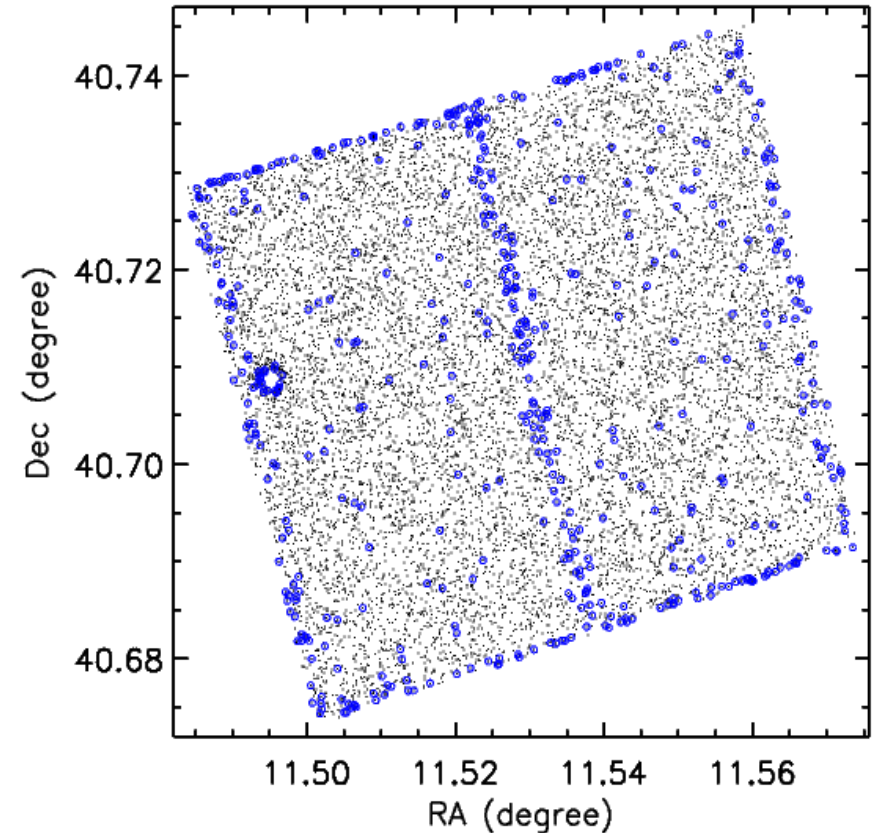
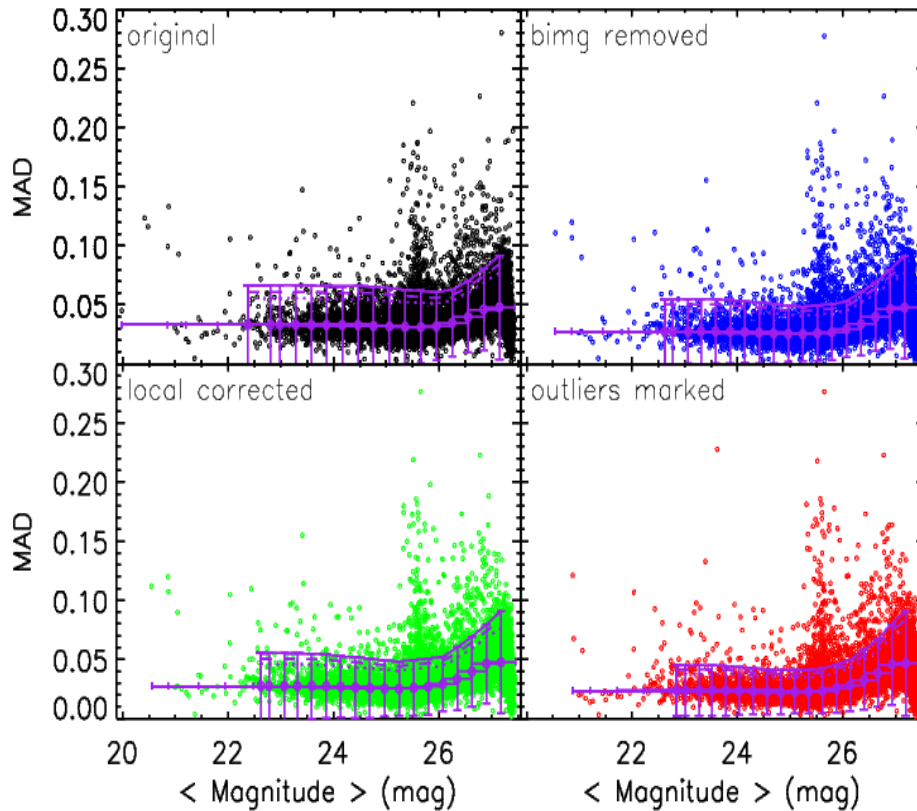


WFC3/IR  
blobs

DR10  
version



- Pre-processed data with edge effect (M31halo11; F606W)

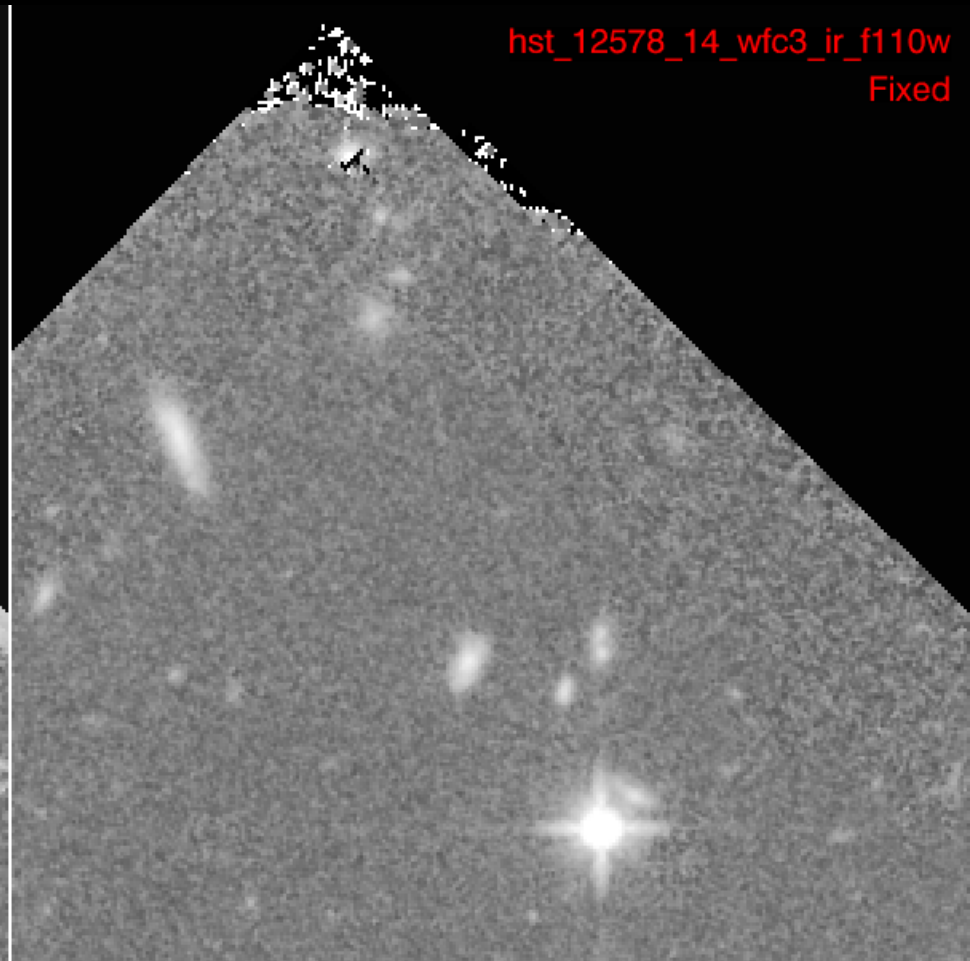
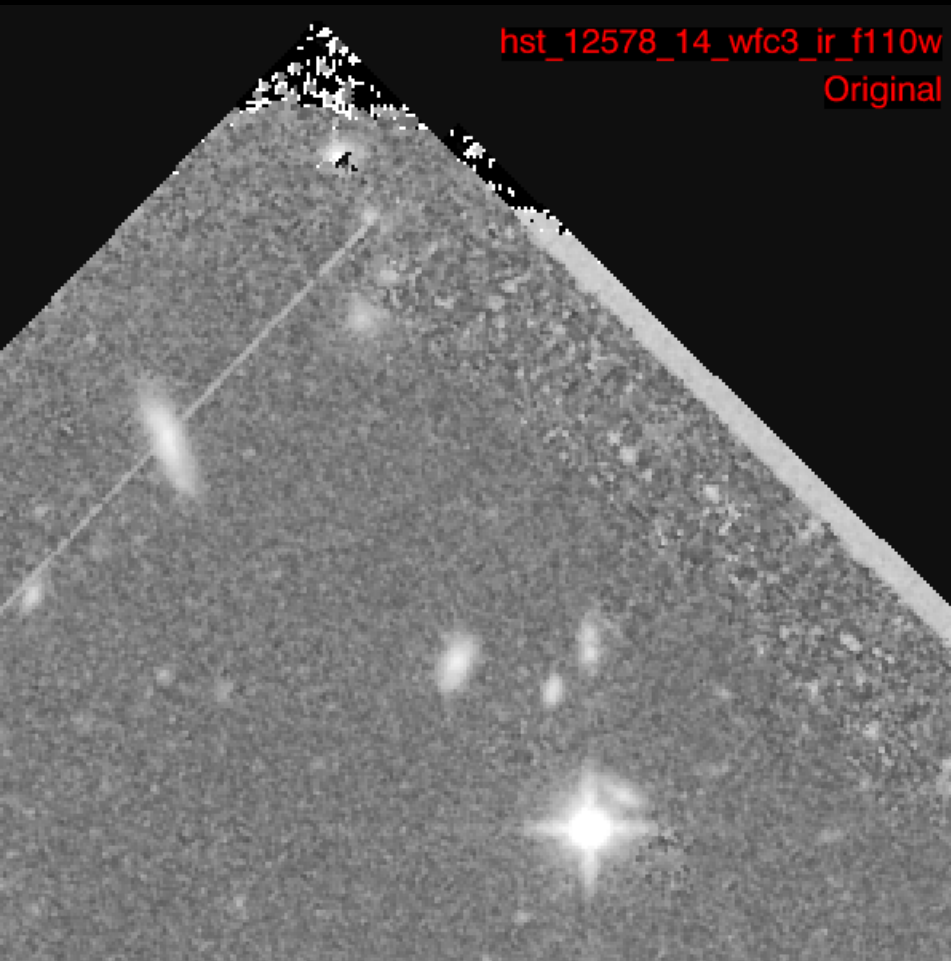


# Background/Edge Bug #1: Bad WFC3/IR sky matching

Fix: correct for pixel size difference between camera, drizzled image

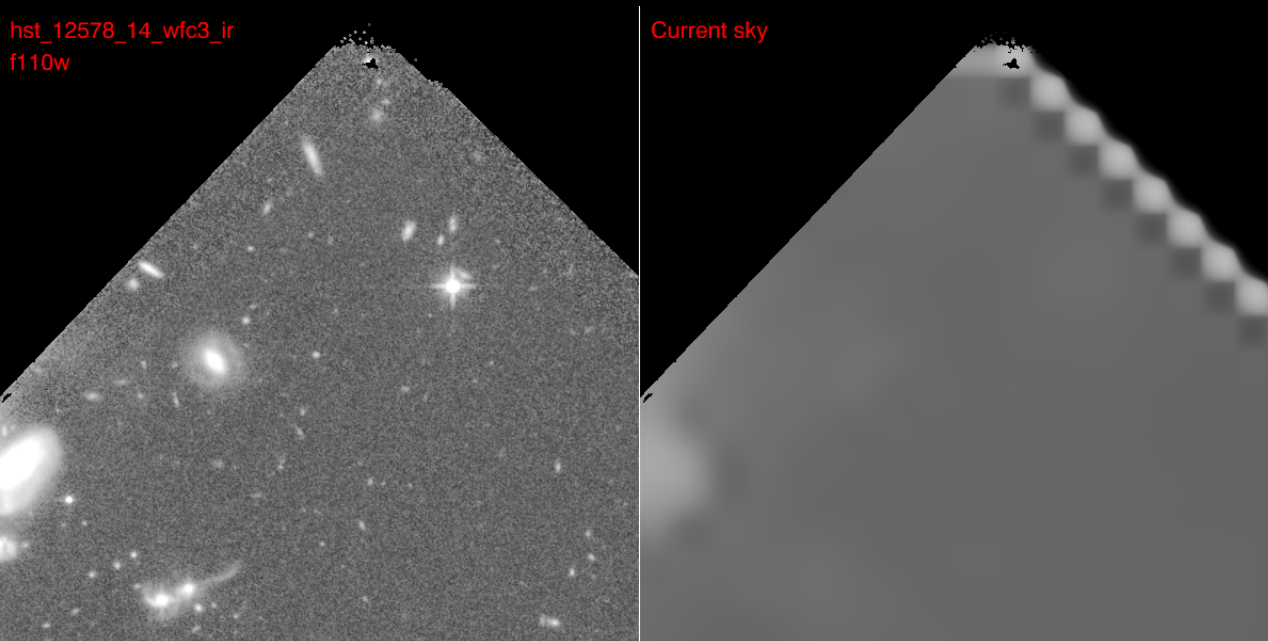
Much improved sky & better quality image

Big effect for some WFC3/IR visits



# Background/Edge Bug #2: Bad SExtractor sky calculation

SE estimates sky as a function of position in image  
Near edges, sky has very bad ringing

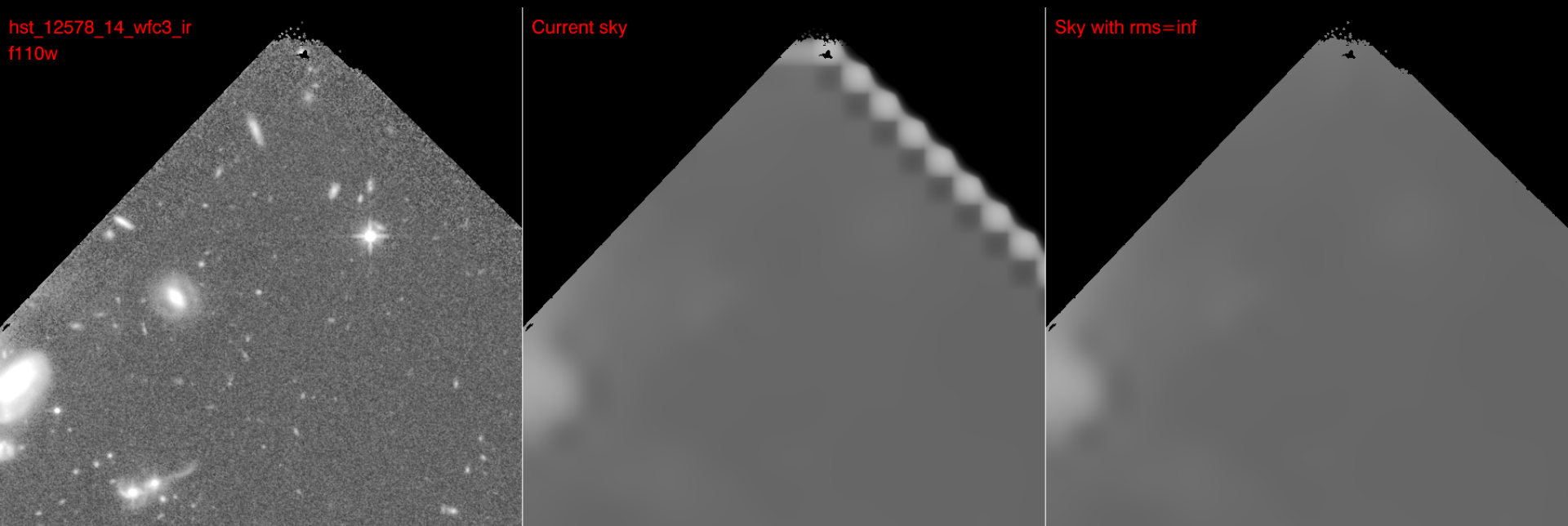


(Note this image has bug#1 fixed)

# Background/Edge Bug #2: Bad SExtractor sky calculation

SE estimates sky as a function of position in image  
Near edges, sky has very bad ringing

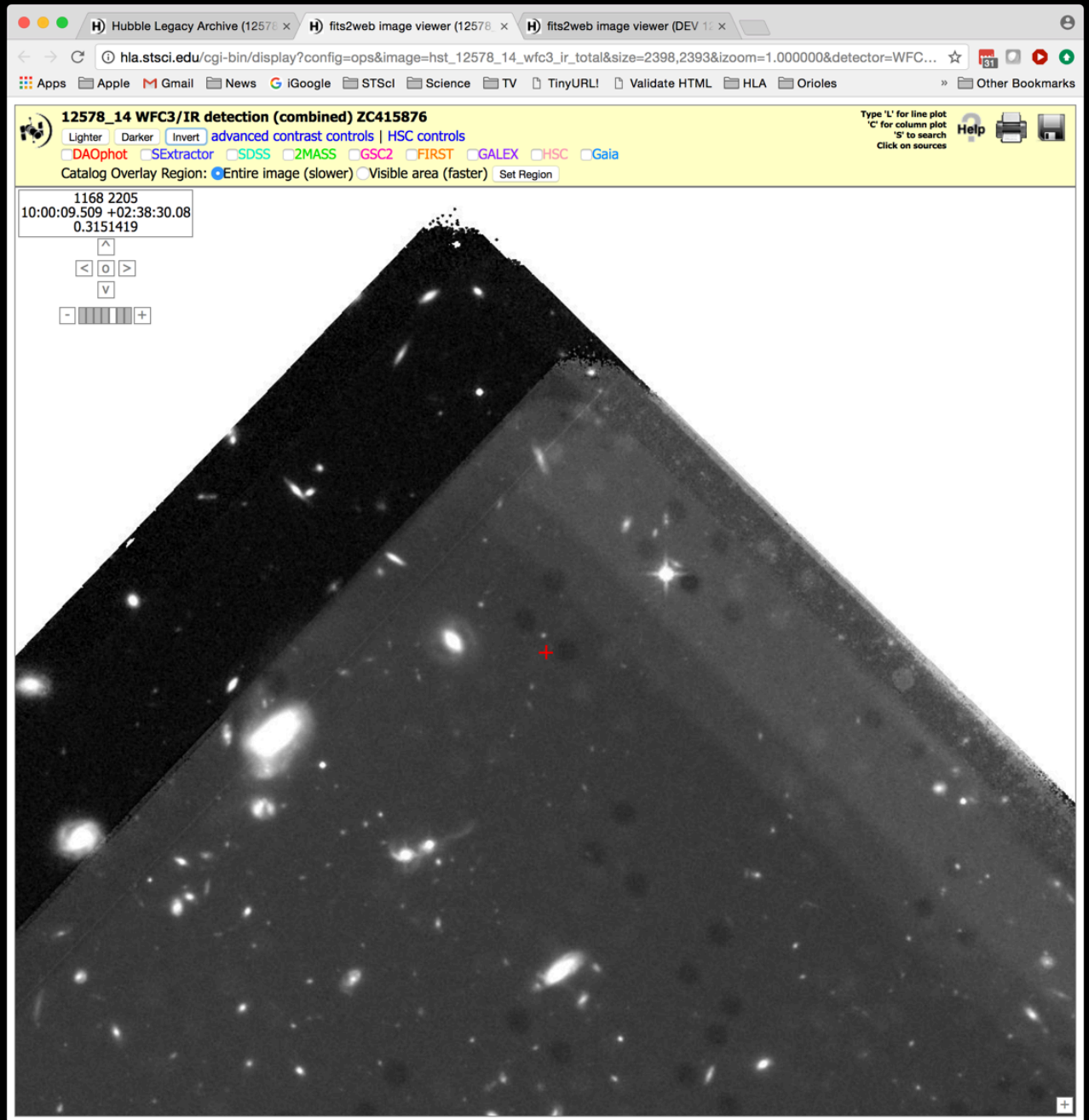
Reason: SE ignores "flag" image, includes pixels off edge marked as bad  
Fix: Set rms image to infinity where data is bad to ignore those pixels



(Note this image has bug#1 fixed)

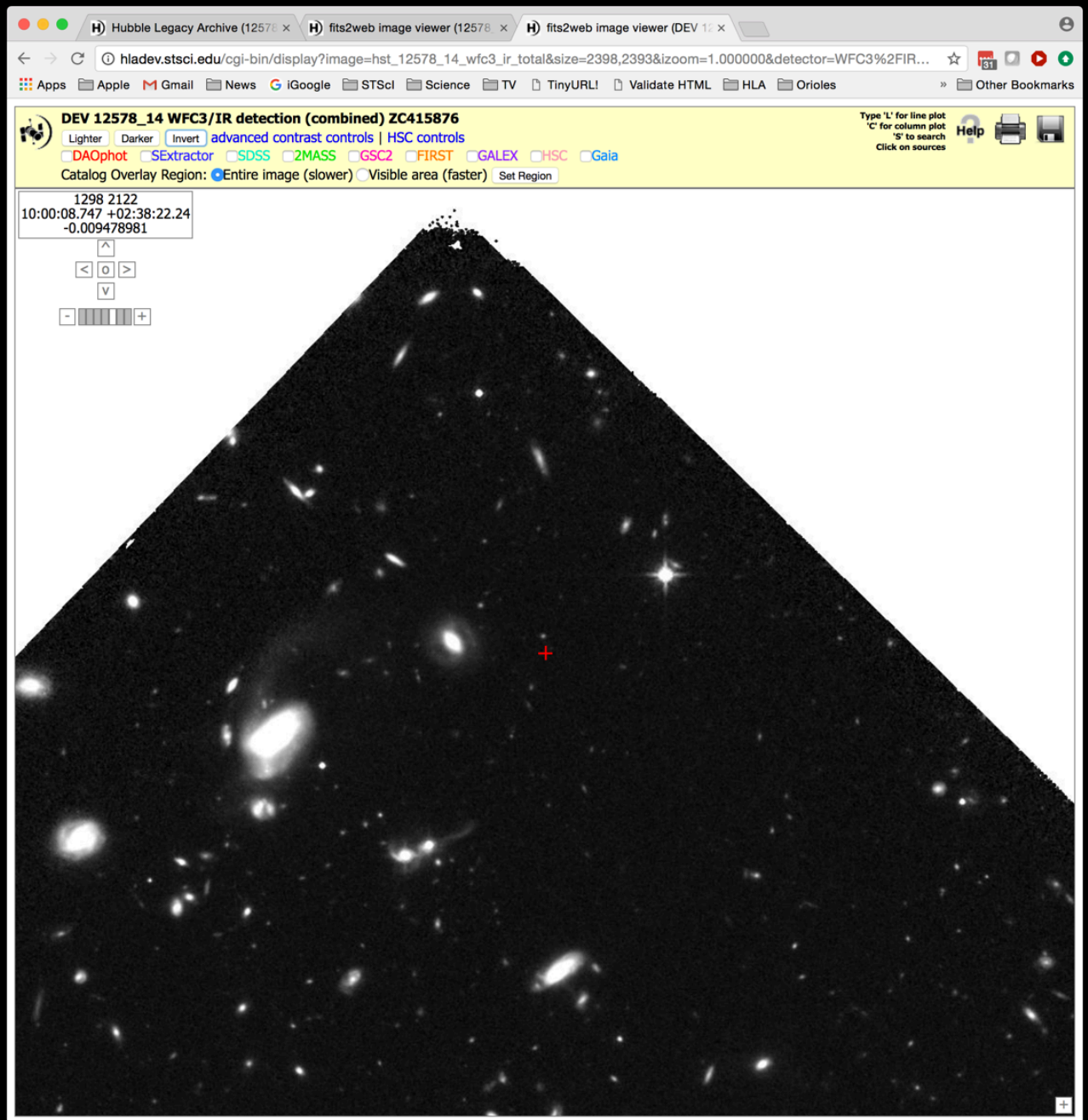
WFC3/IR  
total sky  
matching

DR9  
version



WFC3/IR  
total sky  
matching

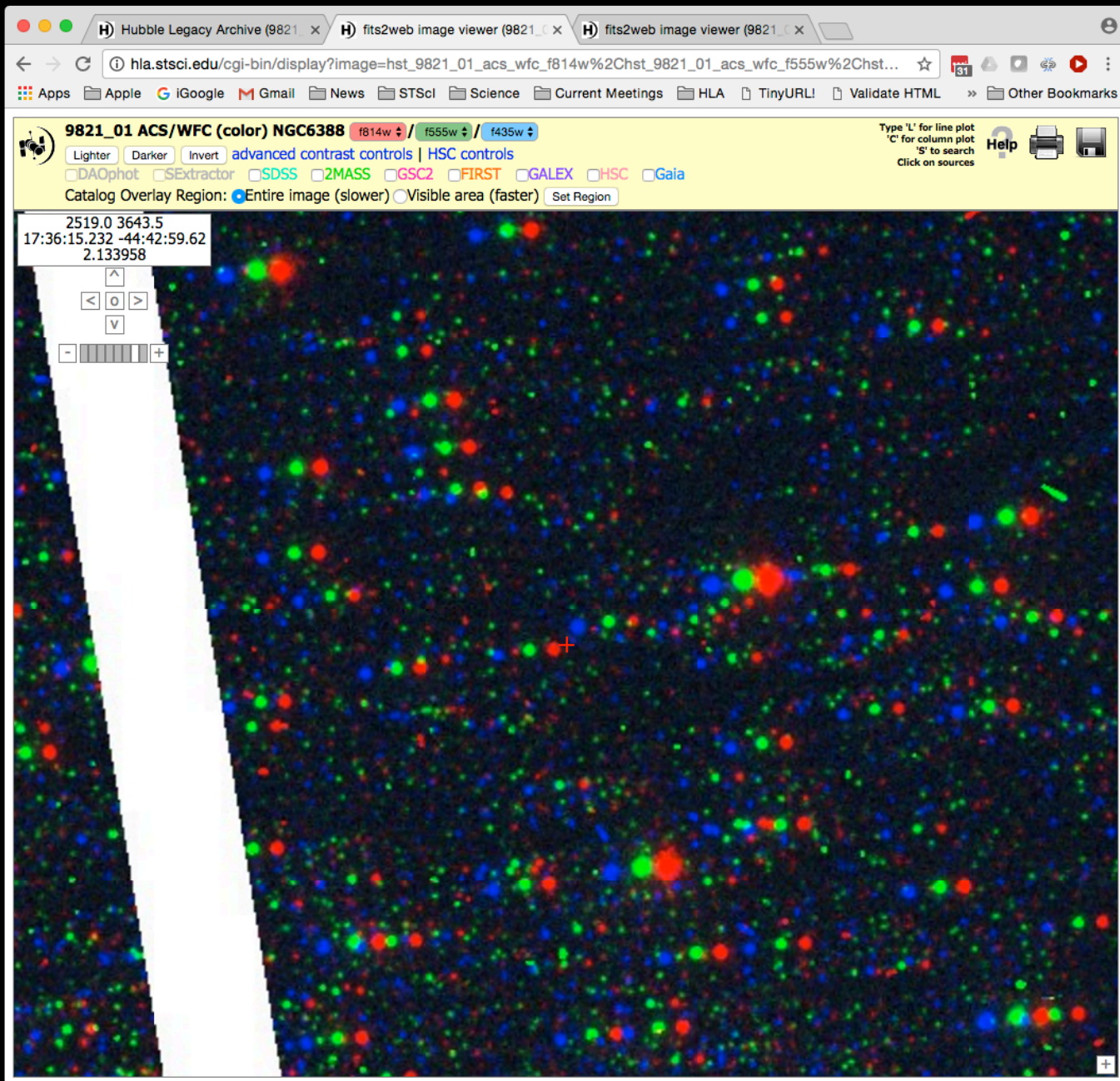
DR10  
version





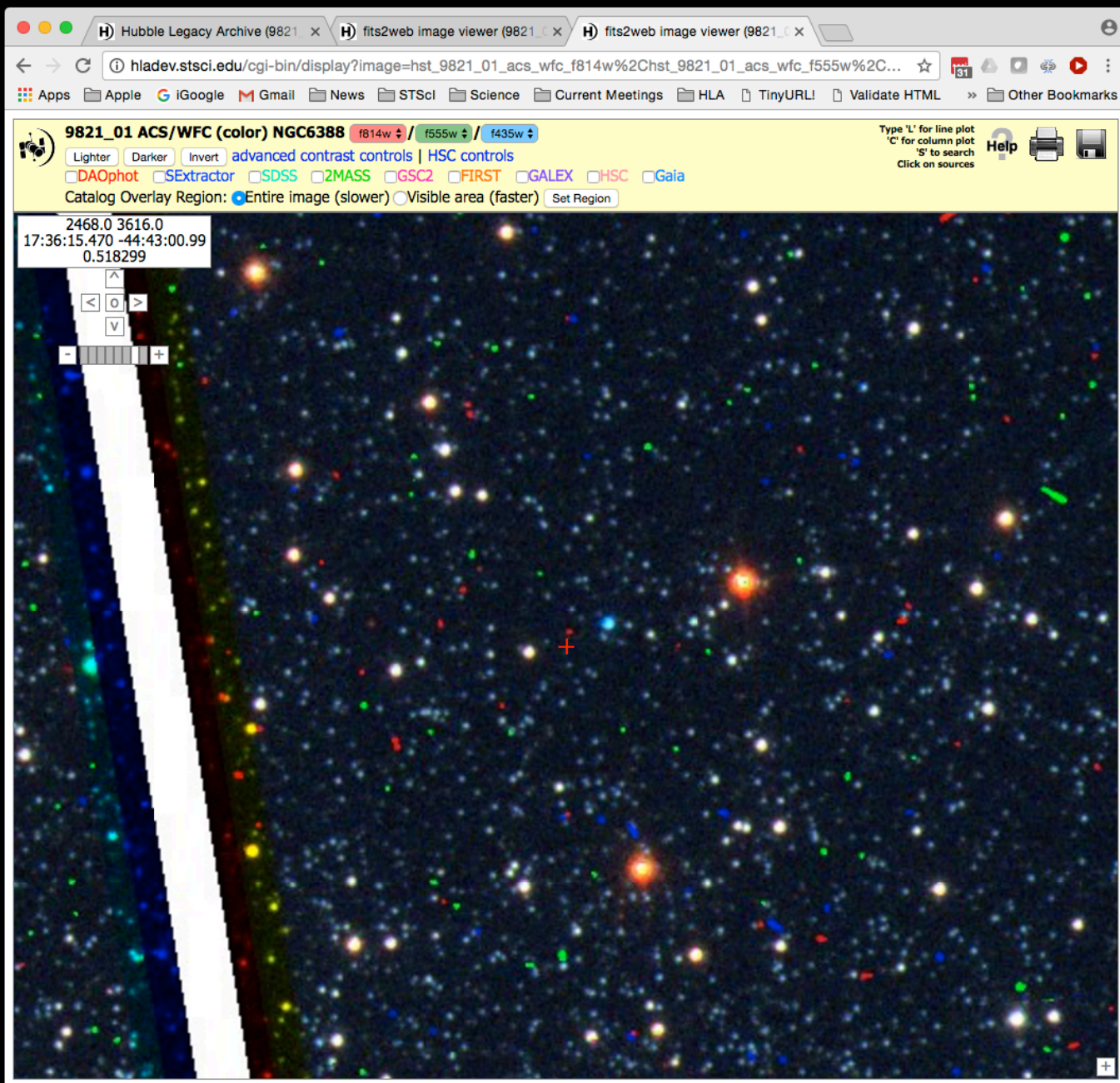
# Alignment

DR9  
version



# Alignment

DR10  
version



**12911\_0l WFC3/UVIS (color) M-4** f775w / f467m

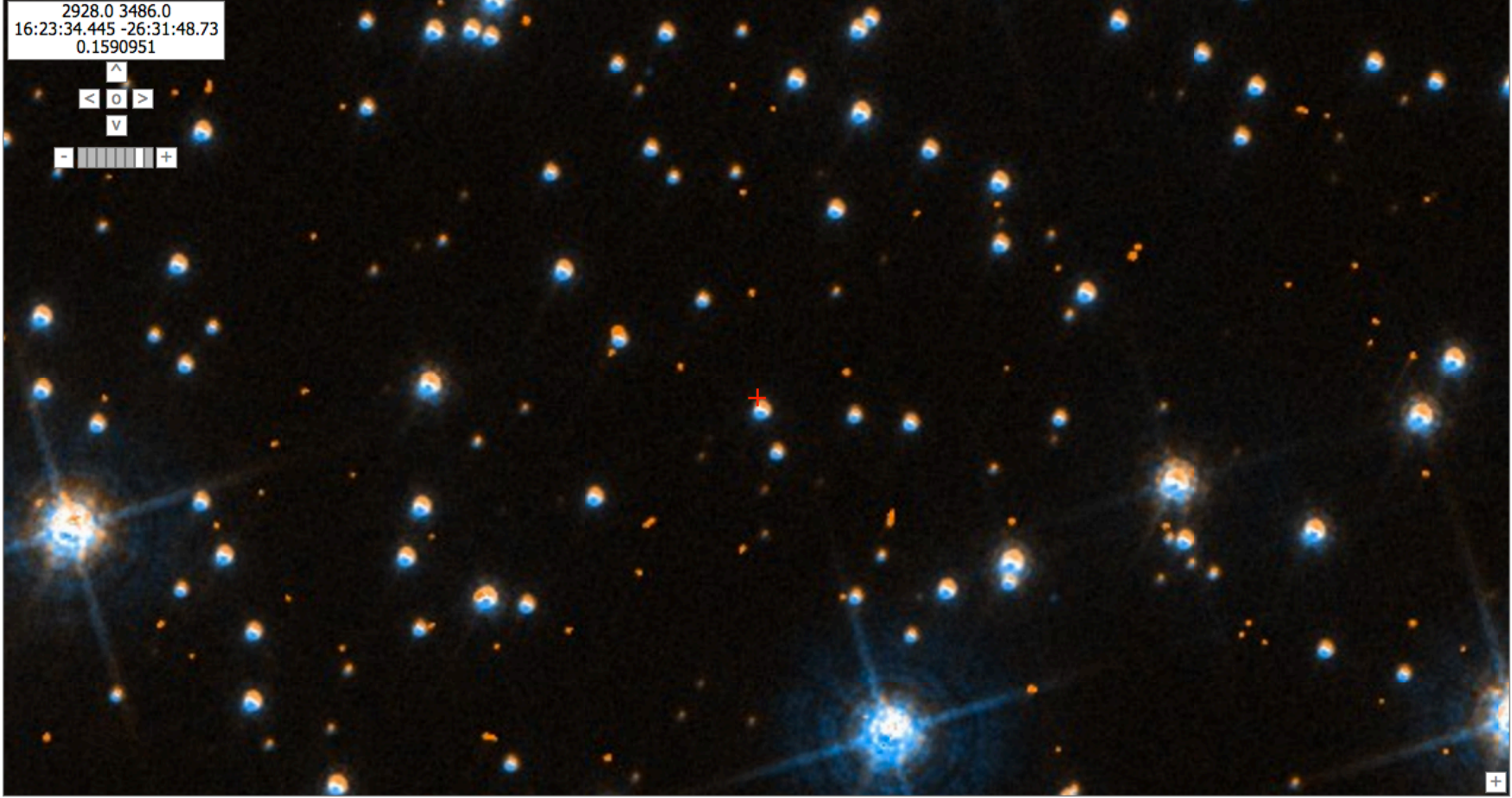
Lighter Darker Invert advanced contrast controls | HSC controls

DAOPhot  SExtractor (6244)  SDSS  2MASS  GSC2  FIRST  GALEX  HSC  Gaia

Catalog Overlay Region:  Entire image (slower)  Visible area (faster)

Type 'L' for line plot  
'C' for column plot  
'S' to search  
Click on sources

Help



**12911\_0l WFC3/UVIS (color) M-4** f775w / f467m

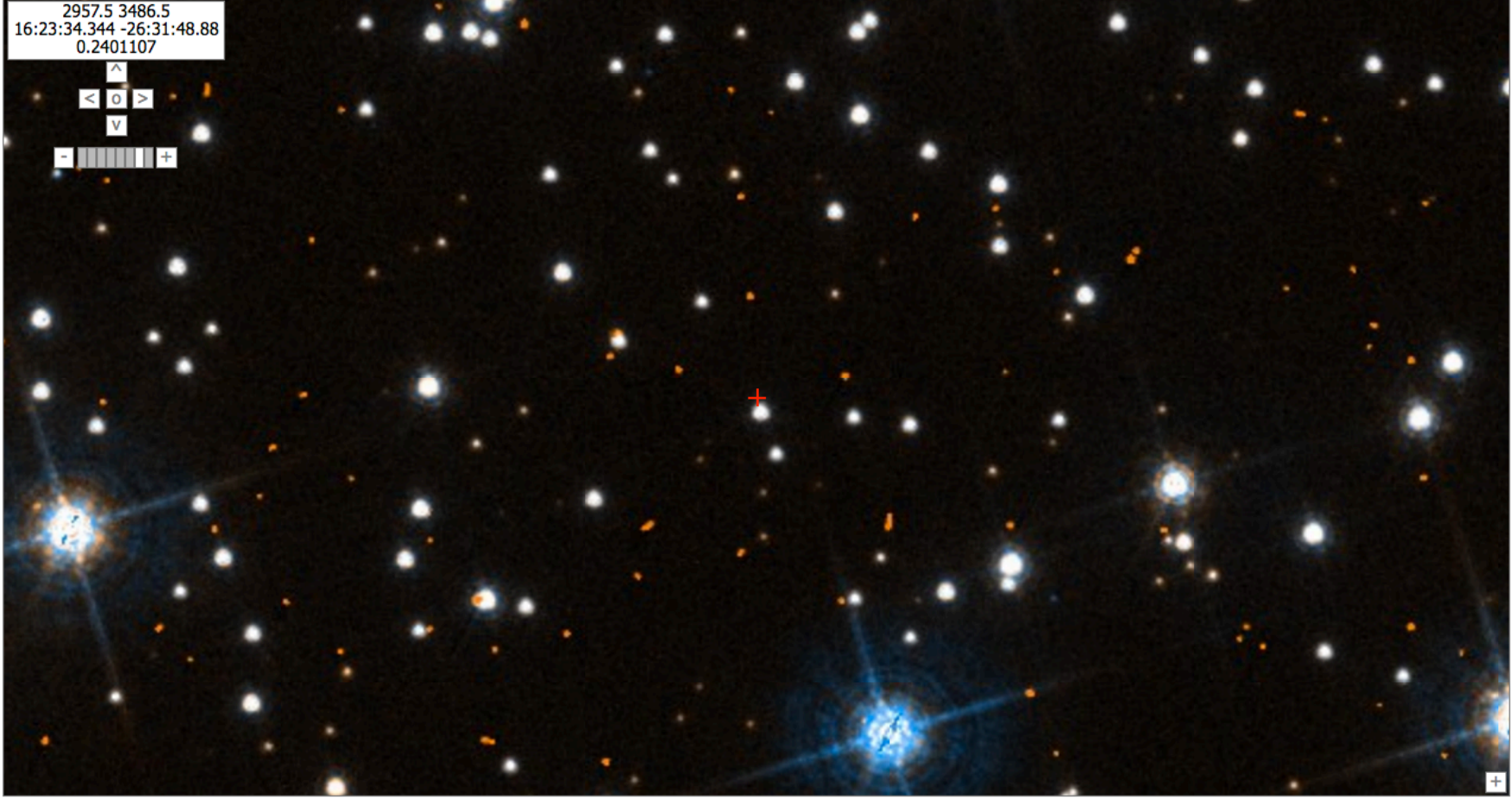
Lighter Darker Invert advanced contrast controls | HSC controls

DAOPhot  SExtractor (5961)  SDSS  2MASS  GSC2  FIRST  GALEX  HSC  Gaia

Catalog Overlay Region:  Entire image (slower)  Visible area (faster) [Set Region](#)

Type 'L' for line plot  
'C' for column plot  
'S' to search  
Click on sources

Help



# Exposure Alignment

DR9  
version

HLA Dataset Review (0 0 r=1) x fits2web image viewer (12163 x) fits2web image viewer (12163 x)

Secure [https://hla.stsci.edu/cgi-bin/display?image=hst\\_12163\\_2b\\_wfc3...](https://hla.stsci.edu/cgi-bin/display?image=hst_12163_2b_wfc3...)

Apps Apple iGoogle Gmail News STScI Science Current Meetings Other Bookmarks

**12163\_2b WFC3/IR F153M (combined) IC-342** Type 'L' for line plot 'C' for column plot 'S' to search Click on sources Help Print Save

Lighter Darker Invert advanced contrast controls | HSC controls

DAOPhot  SExtractor  SDSS  2MASS  GSC2  FIRST  GALEX  HSC  Gaia

Catalog Overlay Region:  Entire image (slower)  Visible area (faster) Set Region

551 239  
03:46:48.349 +68:05:16.45

The image shows a dark, grainy astronomical field with a bright, diffuse nebula in the lower right. A red crosshair is centered on the brightest part of the nebula. In the upper left, there is a control panel with directional arrows (up, down, left, right) and a zoom slider. A small box above the controls displays the coordinates 551 239 and 03:46:48.349 +68:05:16.45. The top of the page features a navigation bar with various application icons and a search bar.

# Exposure Alignment

DR10  
version

HLA Dataset Review (0 0 r=1) x fits2web image viewer (12163 x) fits2web image viewer (12163 x)

Secure https://hladev.stsci.edu/cgi-bin/display?image=hst\_12163\_2b\_w...

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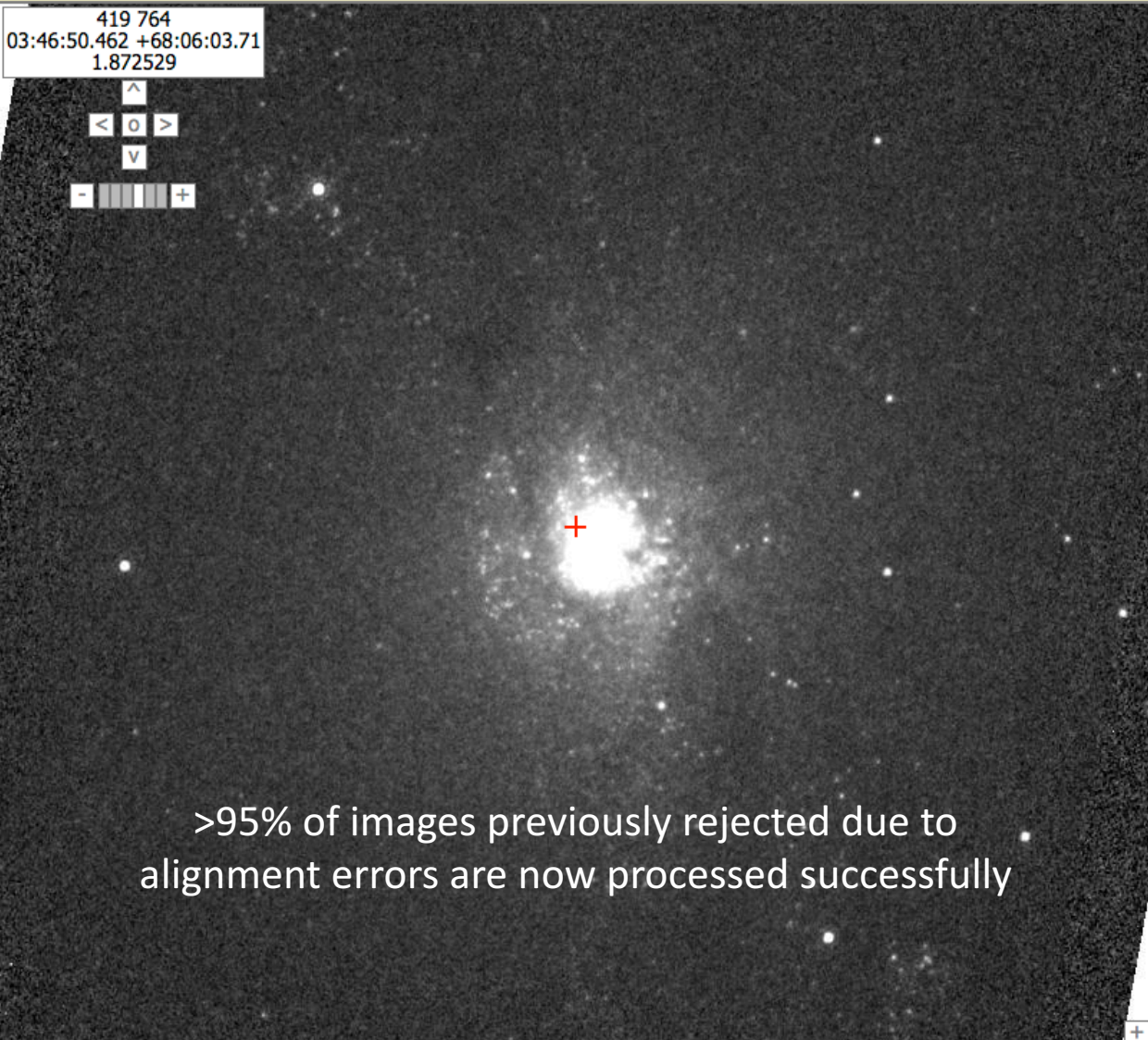
**12163\_2b WFC3/IR F153M (combined) IC-342** Type 'L' for line plot 'C' for column plot 'S' to search Click on sources Help Print Save

Lighter Darker Invert advanced contrast controls | HSC controls

DAOPhot  SExtractor  SDSS  2MASS  GSC2  FIRST  GALEX  HSC  Gaia

Catalog Overlay Region:  Entire image (slower)  Visible area (faster) Set Region

419 764  
03:46:50.462 +68:06:03.71  
1.872529



>95% of images previously rejected due to alignment errors are now processed successfully

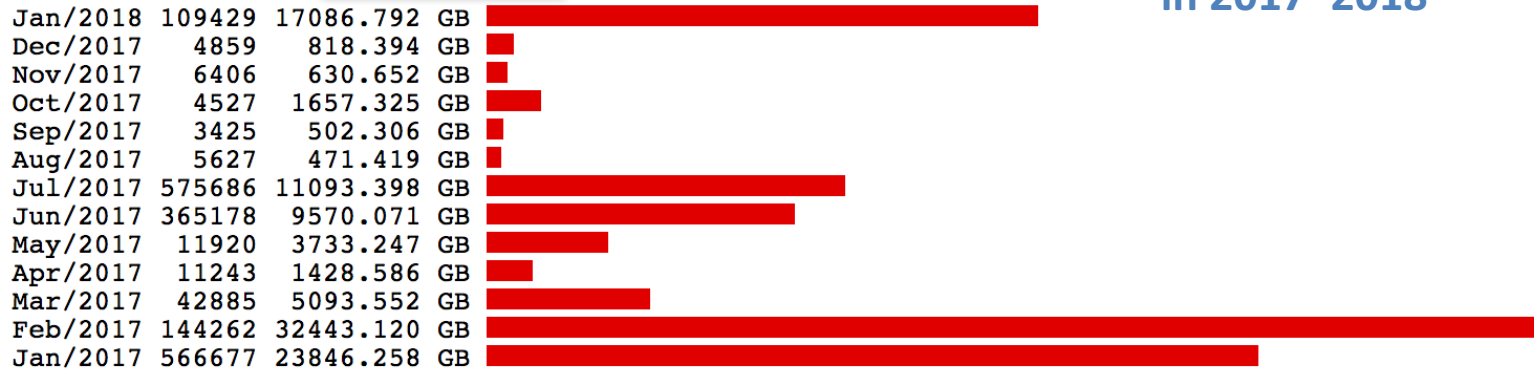
# Recent HLA download metrics

## HLA Downloads generated on Fri Jan 19, 2018 15:26

Stats for 201[78] grouped by MONTH.

Total download size: 108375.394 GB total downloads: 1,853,159

Dates:



108 TB downloaded  
in 2017–2018

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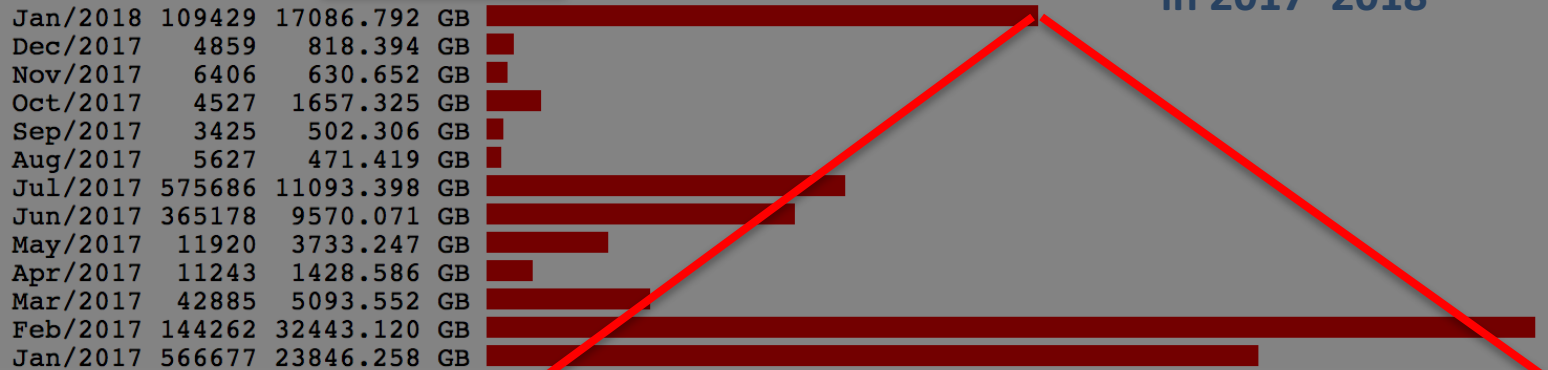
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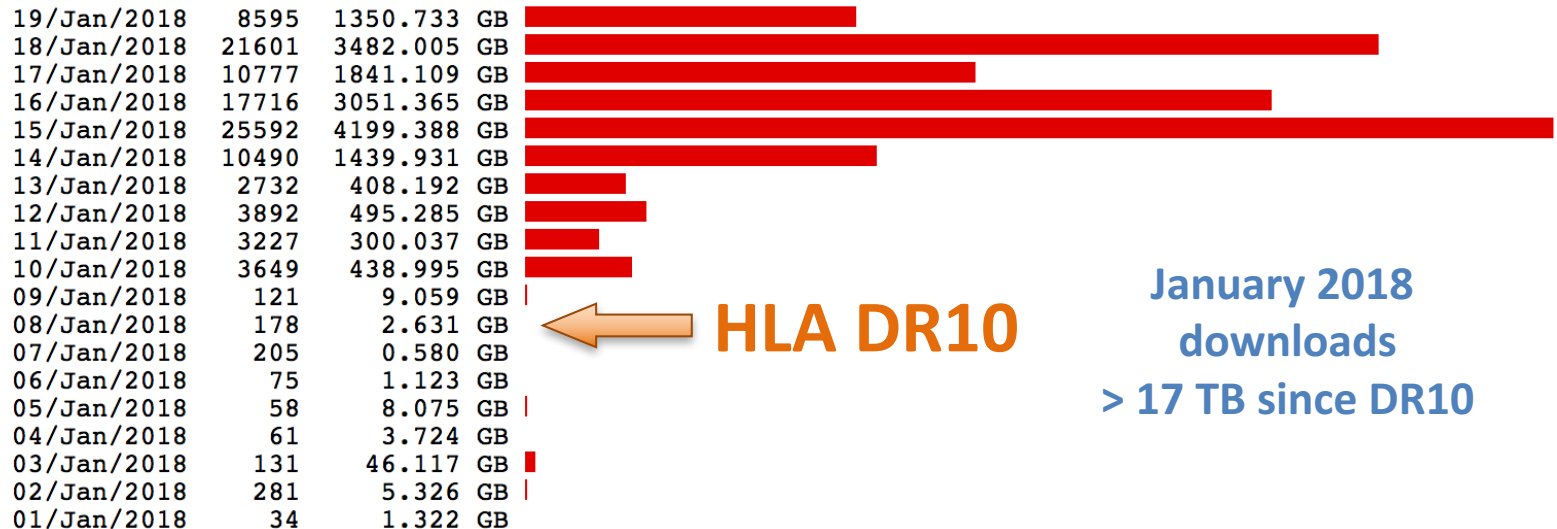
Dates:



108 TB downloaded  
in 2017-2018

Total download size: 17085.008 GB, total downloads: 109,421

Dates:



← HLA DR10

January 2018  
downloads  
> 17 TB since DR10

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# HLA/HSC schedule

- HSC v3 (March 2018)
  - Based on HLA DR10 source lists
- HLA DR10.1 (April 2018)
  - Updated astrometry using HSC v3 alignment corrections
- HSC v3.1 (June 2018?)
  - Reprocess a subset of fields using Gaia DR2 with HSC proper motions
- HLA DR11 (Summer 2018)
  - New WFPC2 images and catalogs
- HLA Migration Project (starting soon, completion TBD)
  - Automate generation of HLA data products and make them part of routine HST data processing
  - Remove single points of failure and ensure longevity of the project



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# Highlights of HSC v3 updates

- Use Gaia catalog as core astrometric reference
  - Gaia-calibrated PanSTARRS catalog is primary reference when there are too few Gaia stars
- Most HLA improvements lead directly to HSC improvements
  - Edge and alignment fixes will significantly improve photometry
- HSC v3.1: Calculation of proper motions
  - Accurate PM calculation needs PMs from Gaia DR2 (April 2018) to establish reference frame



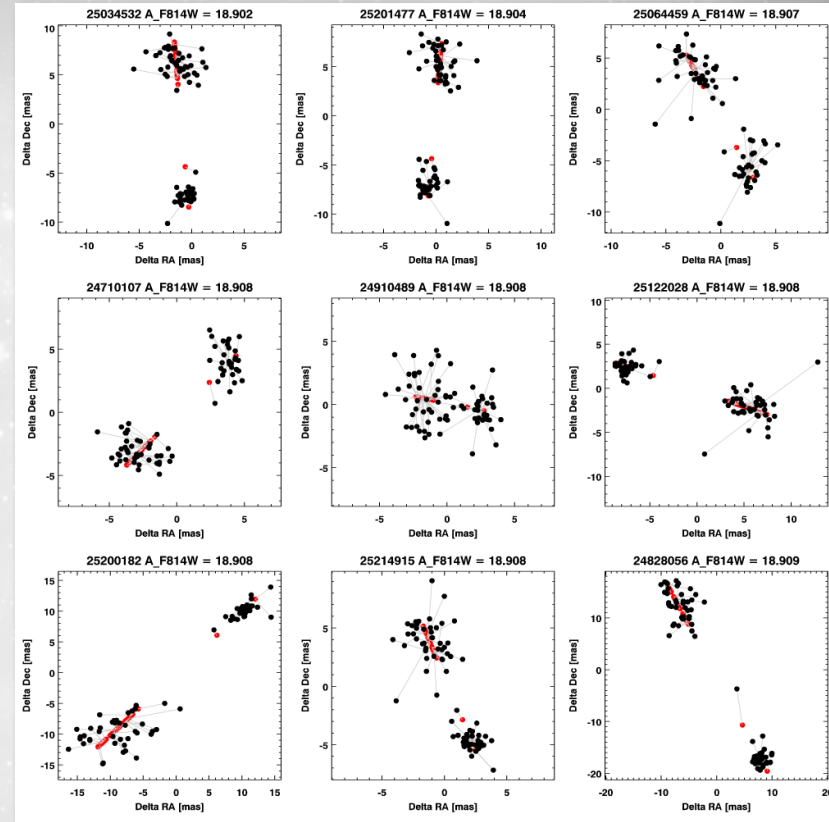
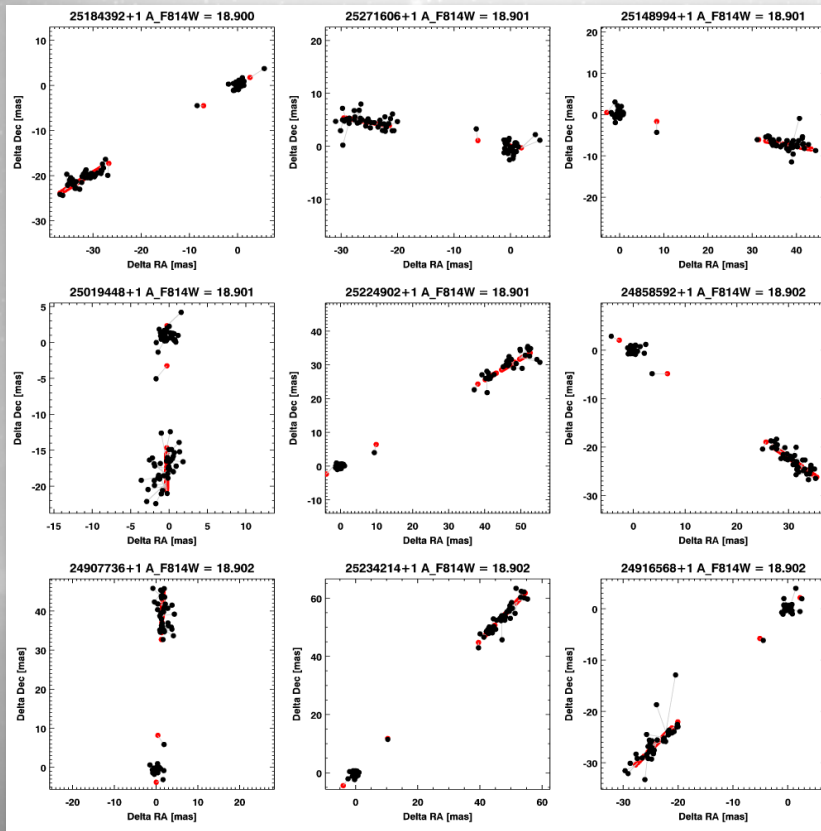
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# HLA/HSC additions – Astrometry

HSC v2 proper motions  
in SWEEPS Galactic  
bulge field

9 objects fainter than 18.9  
that have close neighbors



Objects that are not split  
also have proper motions

HSC v3.1 will include proper  
motion measurements.



# Future HLA/HSC additions: Hubble Catalog of Variables (HCV)

- We encourage the development of value-added products such as “The Hubble Catalog of Variables”, a 3-year ESA program to use the HSC to find variable stars.  
[http://archive.stsci.edu/archive\\_news/2016/07-Jul/index.html#article4](http://archive.stsci.edu/archive_news/2016/07-Jul/index.html#article4)
- PI = Alceste Bonanos – based at the University of Athens
- The group has tested a wide variety of different algorithms to select candidates (Sokolovsky et al. 2016) and has visually validated about 50,000 variables (Yang et al. arXiv:1711.11491).
- The HCV will be ingested into the MAST archives in the spring of 2018.



# Future HLA/HSC additions: Photometry on Demand (POD)

- Potential HSC users may not be able to use the “general usage” source lists employed by the HLA.
- Examples are that they might want/need:
  - PSF-fitting photometry for crowded regions,
  - deeper limiting magnitudes,
  - better time resolution (e.g., the Athens group), ...
- Photometry on Demand is an HSC-related tool designed to provide an easy and flexible way for users to obtain “fine-tuned” photometry for the specific datasets, and science needs, they are interested in.
  - In development now (Armin Rest)



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# Future of the HLA interface

- HLA user interface concepts (and some technology) have been adopted by portal and used for many other MAST services
- Current plan, discussed last year with MUG, is to retire the HLA interface after the Portal can replace its capabilities
- The cost of supporting the existing HLA interface is now low
  - HLA web servers are being virtualized, removing our dependence on aging hardware
  - Software maintenance costs are small
- Our current opinion is that retiring the HLA interface is not an urgent problem but will have a long-term benefit for both users and developers.