

# Hubble Legacy Archive and Hubble Source Catalog

Rick White & Brad Whitmore

Current teams:

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Brad Whitmore



# Hubble Legacy Archive (HLA)

<http://hla.stsci.edu>

- Goals:
  - 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., Multidrizzle) and research projects (e.g., Anton's pipelines for GOODS, COSMOS, etc.)
  - Develop advanced web interfaces to the archive using next-generation browser technology
- Primary recent & future focus is on data product generation as MAST portal becomes the user interface
  - HLA user interface concepts (and some technology) adopted by portal and used for many other MAST services already
- History: DR1 (2008 Feb 08) through DR9 (2015 Dec 11)





# Hubble Source Catalog (HSC)

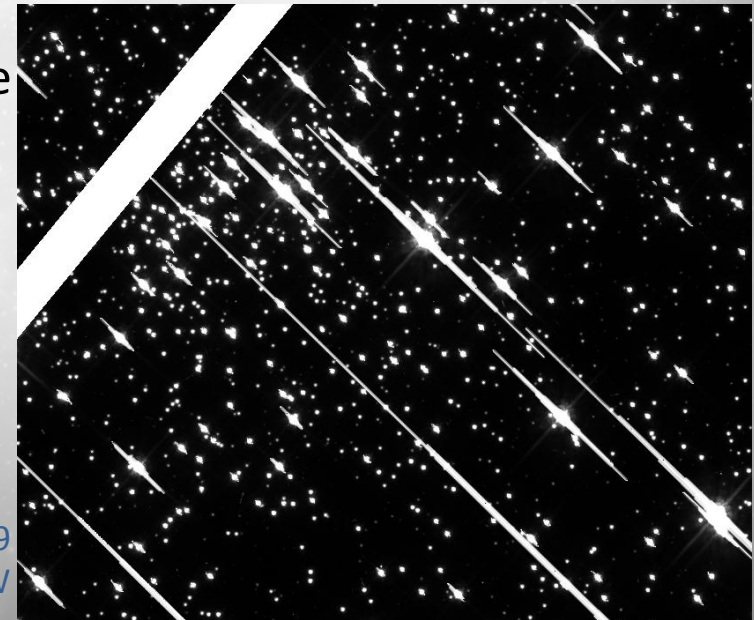
<http://archive.stsci.edu/hst/hsc>

- Goal: Create master catalog of objects from HST images to enable database-driven research
- Challenges:
  - Highly inhomogeneous sky coverage, hundreds of filters
  - Unreliable astrometry makes cross-matching hard
- History:
  - **Beta 0.1 (2012 June)**: ACS/WFPC2 HLA SExtractor source lists (Budavári & Lubow 2012 paper)
  - **Beta 0.2 (2013 May)**: Improved source matching (using automated pre-offsets from 2MASS), improved tools (HLA source overlays, summary form, ...)
  - **Beta 0.3 (2014 March)**: Includes WFC3/UVIS and WFC3/IR HLA source lists, better source matching (fewer spurious sources)
  - **Version 1 (2015 February 25)**: Deep WFC3 source lists, improved astrometry, access through CasJobs and MAST portal



# HLA highlights for 2015

- **DR8.1 (2015 February 25)**
  - Interface enhancements to support release of HSC version 1
- **DR9 (2015 December 11)**
  - New & reprocessed ACS data with astrodrizzle-based pipeline
    - Higher quality products in same format as WFC3 products
    - 40% more processed data
  - Much improved ACS source lists
    - Deeper and cover more visits
    - Will be used for HSC version 2





# HSC Highlights for 2015

- **HSC version 1 release (2015 Feb 24)**
  - Science-quality catalog with tools for simple and advanced projects
- **Hubble Catalog of Variables project begins**
  - 3-year ESA-funded project at National Observatory of Athens, Greece, to build a catalog of variable objects starting from the HSC
  - Leading the way toward higher quality HSC photometry
- **AJ paper describing HSC completed**
  - Expect acceptance for publication soon
- **Talks at IAU, ADASS, AAS**

## VERSION 1 OF THE HUBBLE SOURCE CATALOG

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*Draft: December 20, 2015*

### ABSTRACT

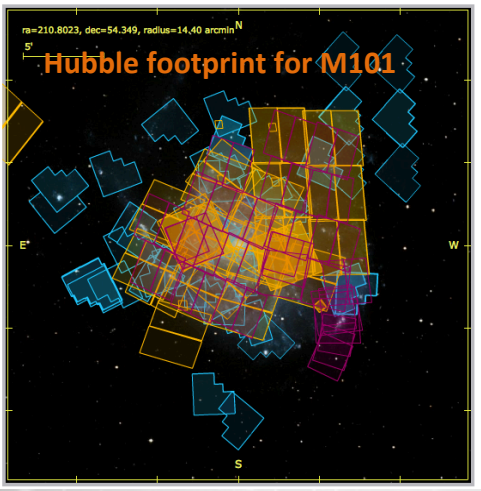
The Hubble Source Catalog is designed to help optimize science from the *Hubble Space Telescope* by combining the tens of thousands of visit-based source lists in the Hubble Legacy Archive into a single master catalog. Version 1 of the Hubble Source Catalog includes WFPC2, ACS/WFC, WFC3/UVIS, and WFC3/IR photometric data generated using SExtractor software to produce the individual source lists. The catalog includes roughly 80 million detections of 30 million objects involving 112 different detector/filter combinations, and about 160 thousand HST exposures. Source lists from Data Release 8 of the Hubble Legacy Archive are matched using an algorithm developed by Budavári & Lubow (2012). The mean photometric accuracy for the catalog as a whole is better than 0.10 mag, with relative accuracy as good as 0.02 mag in certain circumstances (e.g., bright isolated stars). The relative astrometric residuals are typically within 10 mas, with a value for the mode (i.e., most common value) of 2.3 mas. The absolute astrometric accuracy is better than  $\sim 0.1$  arcsec for most sources, but can be much larger for a fraction of fields that could not be matched to the PanSTARRS, SDSS, or 2MASS reference systems. In this paper we describe the database design with emphasis on those aspects that enable the users to fully exploit the catalog while avoiding common misunderstandings and potential pitfalls. We provide usage examples to illustrate some of the science capabilities and data quality characteristics, and briefly discuss plans for future improvements to the Hubble Source Catalog.

*Keywords:* astrometry – catalogs (HSC) – techniques: photometric – virtual observatory tools



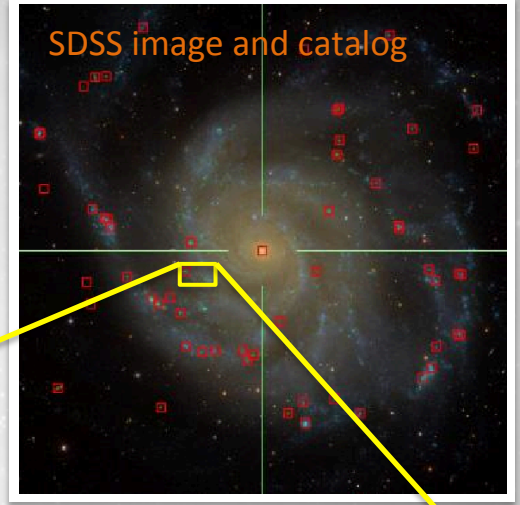
# The volume and diversity of Hubble data provides a challenge

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<input checked="" type="checkbox"/> ACS	209
<input type="checkbox"/> ACSGrism	0
<input checked="" type="checkbox"/> WFPC2	361
<input type="checkbox"/> WFPC2-PC	0
<input type="checkbox"/> NICMOS	0
<input type="checkbox"/> NICGrism	0
<input checked="" type="checkbox"/> WFC3	63
<input type="checkbox"/> COS	0
<input type="checkbox"/> STIS	0
<input type="checkbox"/> FOS	0
<input type="checkbox"/> GHRS	0



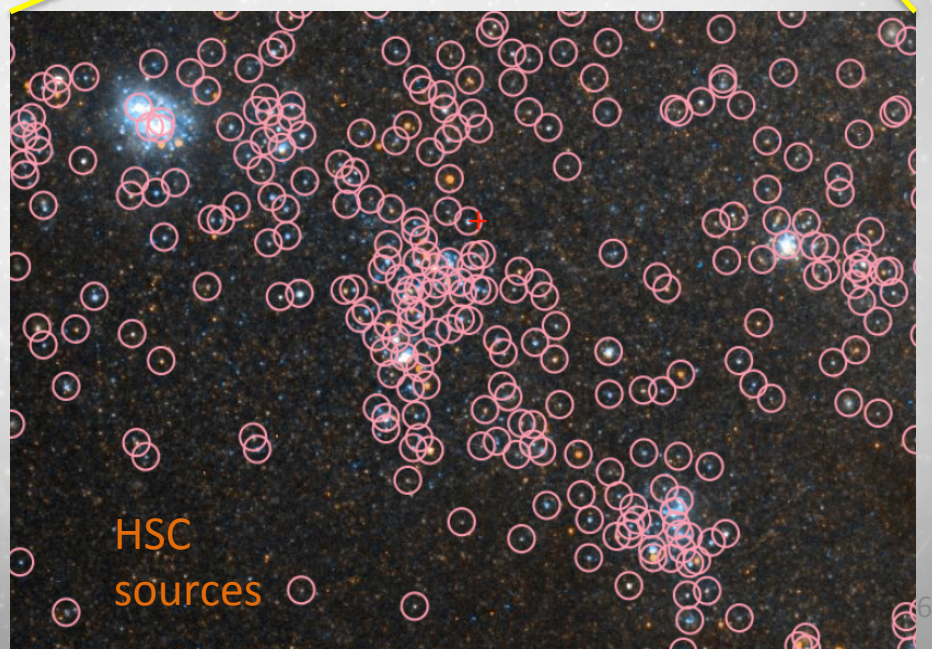
The HSC is NOT your standard, uniform, all-sky catalog.

It uses deep pencil beam observations and a variety of instruments and filters.



## The Hubble Source Catalog:

- Combines tens of thousands of HLA visit-based source lists into a **master catalog**.
- Will be a fundamental reference for **JWST** users, and upcoming **surveys** (e.g., PanSTARRS, LSST).

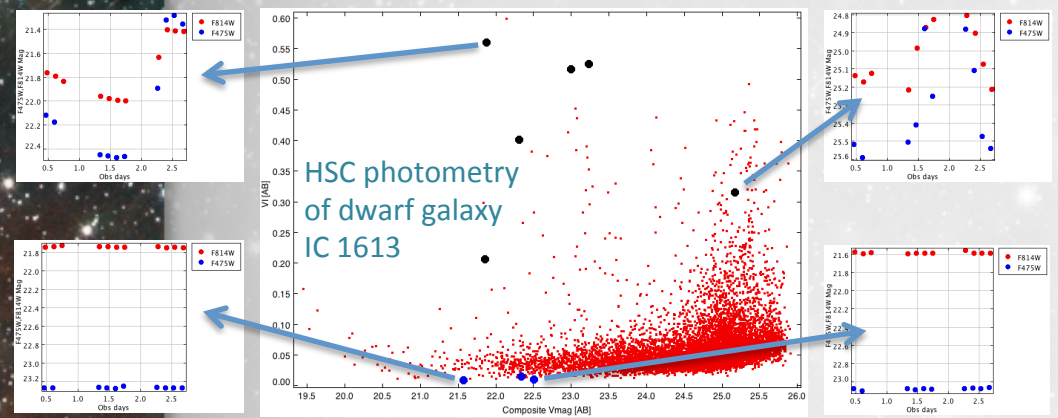




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# Three reasons to build the HSC

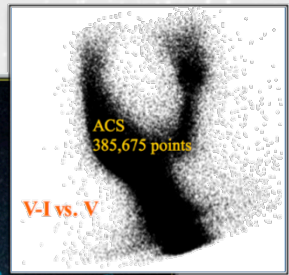
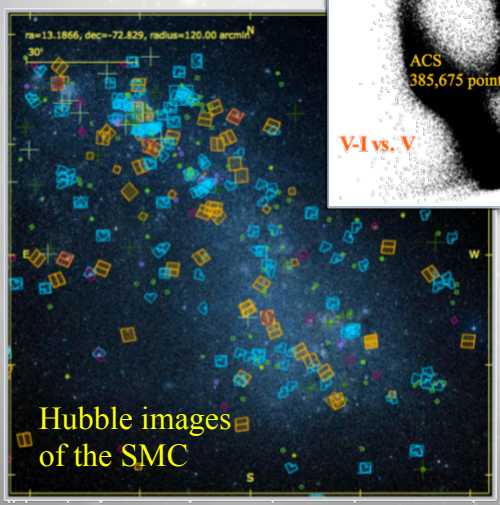
1. **Time-variable phenomena** – The HSC supports time-variable studies over **>20 year baseline**.



2. **Mosaics** – Accurate spatial offsets between observations are needed to build the HSC. These can then be used to make **mosaics**.



Instruments	#Footprints
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<input checked="" type="checkbox"/> ACSGrism	0
<input checked="" type="checkbox"/> WFC2	1539
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<input checked="" type="checkbox"/> WFC3	347
<input checked="" type="checkbox"/> COS	912
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<input checked="" type="checkbox"/> FOS	185
<input checked="" type="checkbox"/> GHRS	84

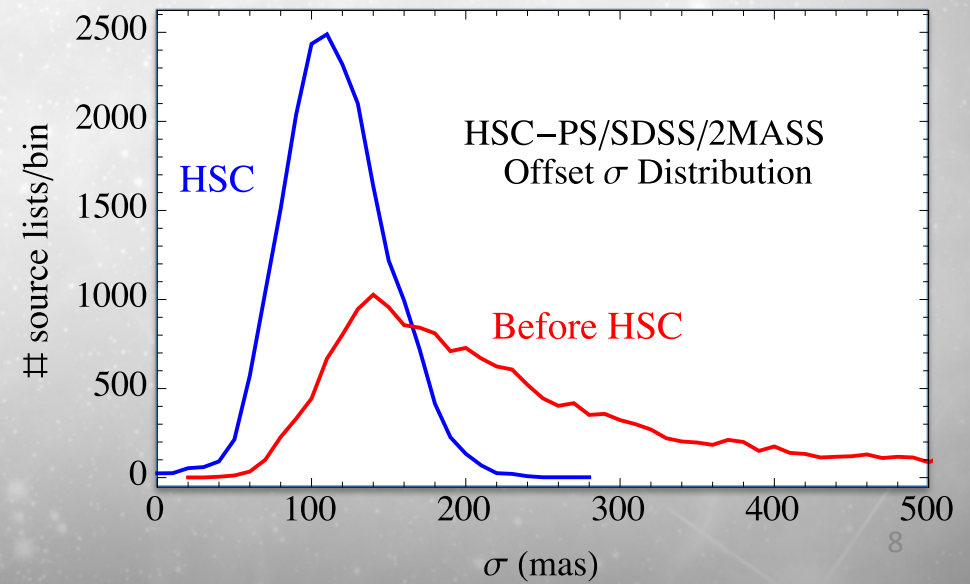
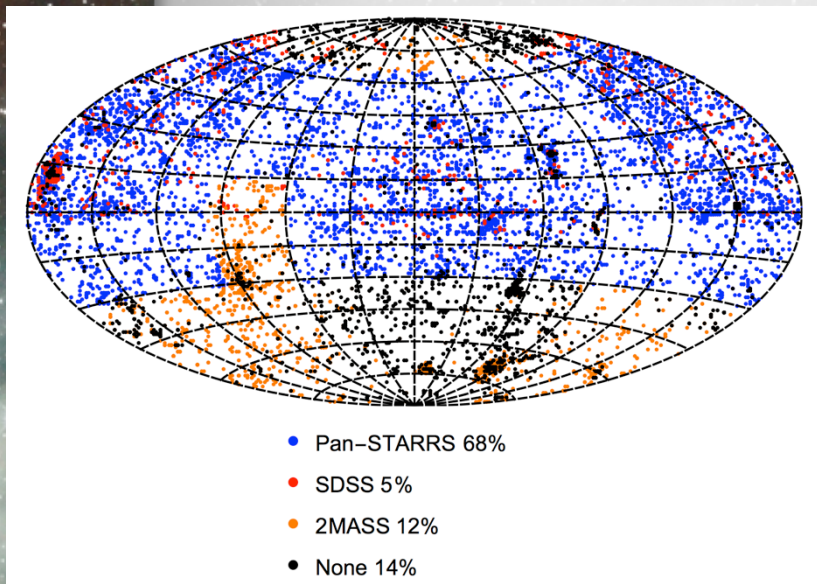


3. **Very large datasets** – Replicating what is available in the HSC in seconds would take most researchers weeks, months, or years to produce.



# HSC Basics

1. Combines tens of thousands of SourceExtractor HLA source lists into a single **master catalog**. Uses matching algorithm from **Budavari & Lubow 2012**.
2. Includes **WFPC2, ACS/WFC** (before 2011), and **WFC3**.
3. **Absolute astrometry** is good to  **$\sim 0.1$  arcsec** (relative to PanSTARRS and 2MASS). This can eventually be improved to  $\sim 0.01$  arcsec using GAIA observations.





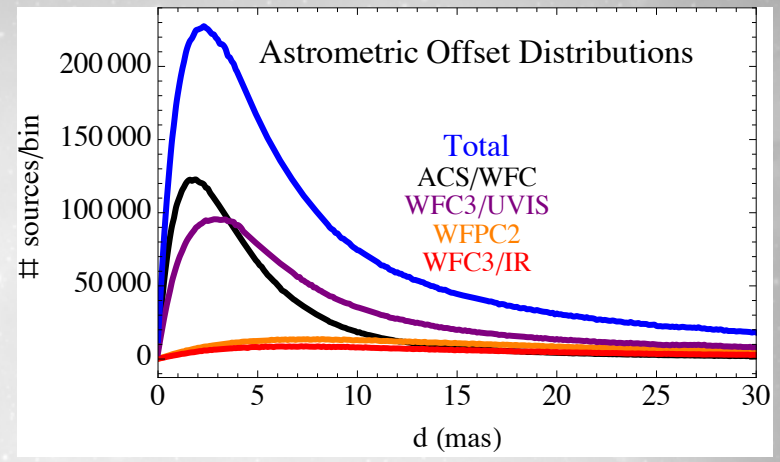


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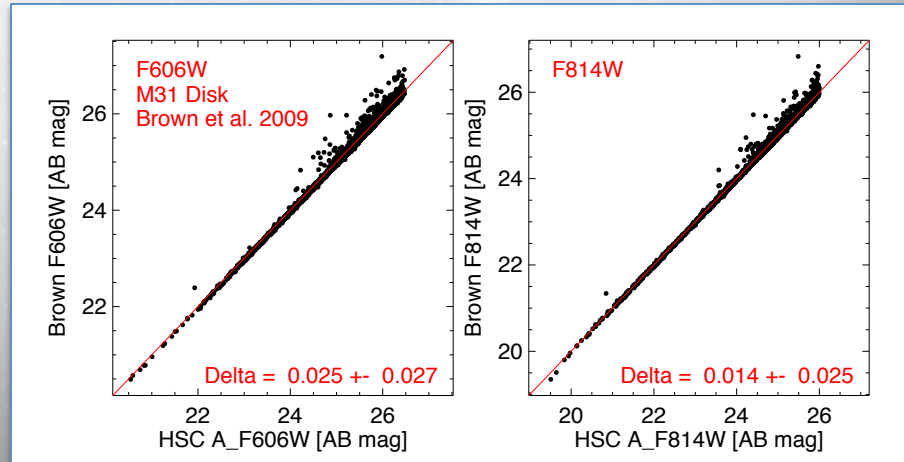
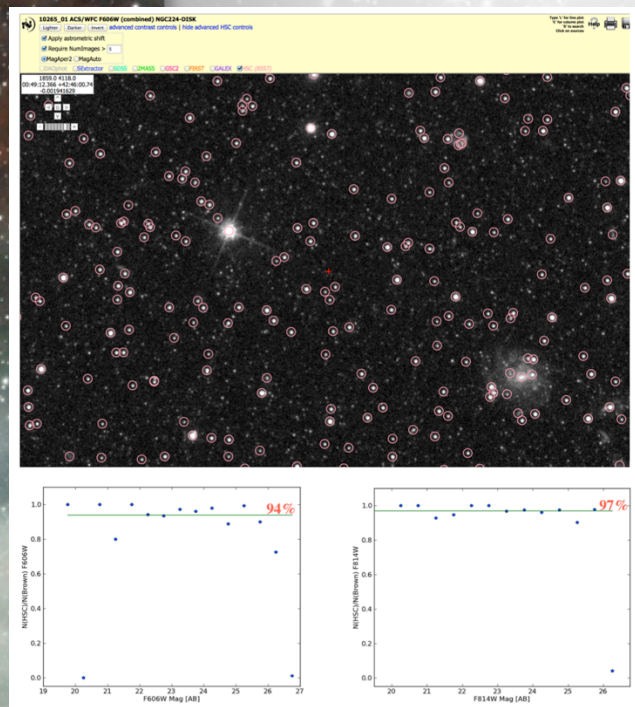
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# HSC Basics

4. **Relative astrometry** good to better than  $\sim 0.01$  arcsec (i.e., **10 mas**, and  **$\sim 2$  mas** in many cases.)



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

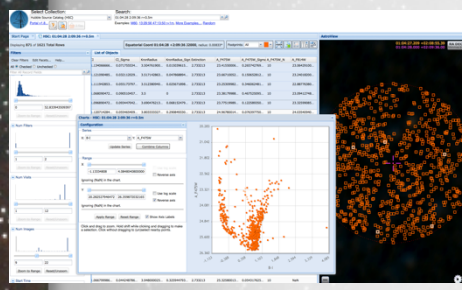




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# HSC Basics

6. The **MAST Discovery Portal** is our primary interface, but we also have a **CasJobs** (similar to SDSS) interface for larger and more complex queries, and the **HSC Home Page** for special cases.



```

Home Help Tools Query History MySQL Import Groups Output Profile Queues Logout whitmore
[HSC] [Optional] [My Query]
Samples Recent Clear [2 g] [Syntax] [Quick] [Submit]
MATCHID MatchHSC MatchCI W2_F606W W2_F814W V_IHQ_F606W - W2_F814W
FROM
SearchNumber2Catalog(187_706_12_391_500_0)
WHERE CI > 1.0 AND CI < 1.5
AND (W2_F606W - W2_F814W) > 0.0 AND (W2_F606W - W2_F814W) < 1.0
AND numImages > 50
ORDER BY matchID;

515 row(s)
MatchID MatchHSC MatchCI W2_F606W W2_F814W V_I
187.72809534812 12.3614283870236 3498807 -34241332063 -228412965138763 22.395199928279 0.445897420247395
187.69624232189 12.3650009098704 3498817 -145346111893 24.386633378162 22.955007802626 0.432625296690754
187.69717146073 12.3647320317339 3498864 1.3601569825893 23.7061452865601 23.3154001233962 0.390745142963867
187.69624232189 12.3650009098704 3498867 3.3622812296819 23.797303387481 22.492500201781 0.35460031098318
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187.695824749242 12.3651992088152 3498875 1.3046255617013 21.7730631205241 21.1258583068848 0.604204813639324
187.702059782719 12.365111871274 3498878 1.4061732374829 23.373266006074 23.243799205947 0.3257907037666
Plot Save As HTML
Query Results Both
  
```

7. A range of **help documents** and learning aids are available (e.g., FAQ, use cases, videos, draft article)

**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**

David C. Whalen, Anna R. Geller, David Howell, Thomas Cravens, Robert A. Simons, Paul H. T. Füll, Steven S. Lauer, Lisa Dixon, Lisa-Greer Rowan, Greg Wilentz, Robert Williams

July 26, 2012

**ABSTRACT**

The Hubble Source Catalog is designed to help astrophysicists access the Hubble Space Telescope by conducting the first of a series of data-based experiments in the Hubble Legacy Archive using the WFC3/ISS instrument data generated using the Science Archive software to process the individual science images. A list of the catalog entries is available in the form of a table containing the following information: MatchID, MatchHSC, MatchCI, W2\_F606W, W2\_F814W, V\_IHQ\_F606W, and W2\_F814W. The image quality information is available in the form of a table containing the following information: MatchID, MatchHSC, MatchCI, W2\_F606W, W2\_F814W, V\_IHQ\_F606W, and W2\_F814W. The image quality information is available in the form of a table containing the following information: MatchID, MatchHSC, MatchCI, W2\_F606W, W2\_F814W, V\_IHQ\_F606W, and W2\_F814W.

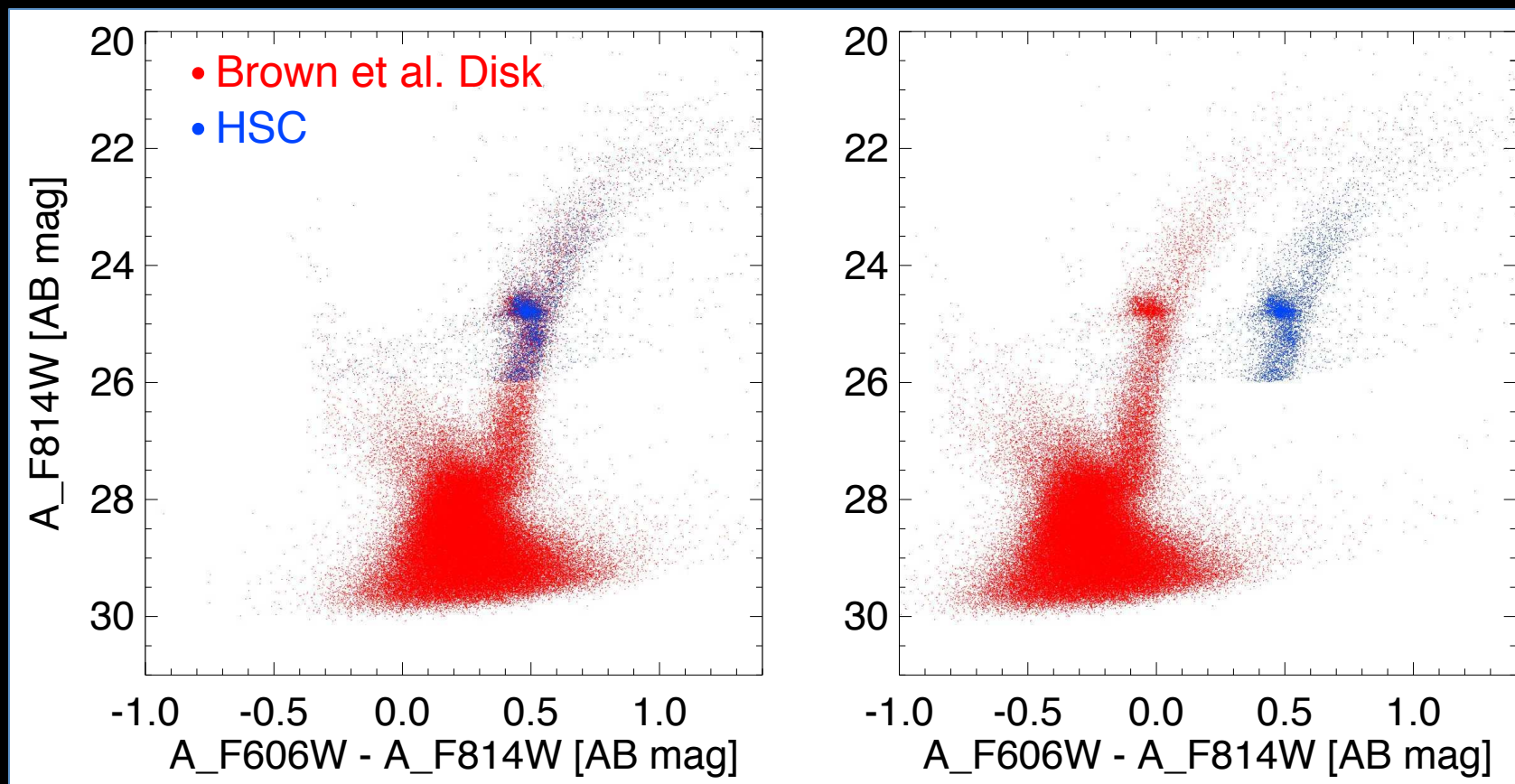
**Keywords:** astronomy — catalogs (HSC) — redshifts — photometry — variable stars

**1. INTRODUCTION**

The Hubble Space Telescope (HST) has been in orbit for nearly 30 years. It has provided us with a wealth of data that has revolutionized our understanding of the universe. The Hubble Source Catalog is a key resource for researchers who want to use the Hubble Legacy Archive to study the Hubble Source Catalog. This paper describes the Hubble Source Catalog and provides information on how to use it. The Hubble Source Catalog is a key resource for researchers who want to use the Hubble Legacy Archive to study the Hubble Source Catalog. This paper describes the Hubble Source Catalog and provides information on how to use it.

# How well does the HSC re-create various science results?

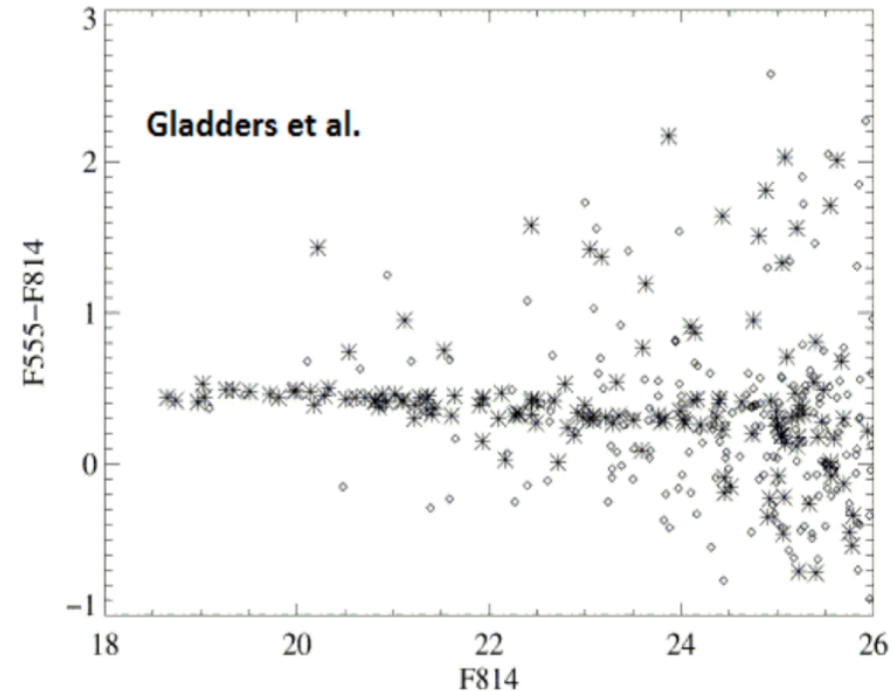
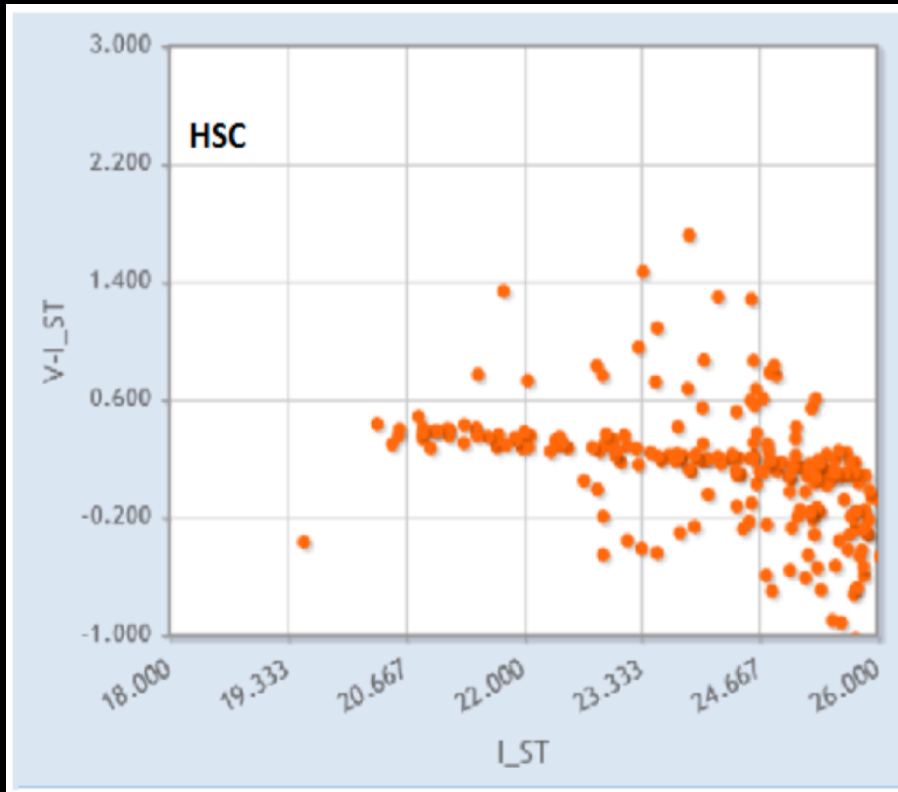
## HSC Use Case # 1 – M31 Photometry – Brown et al. 2008



While the agreement in the region of overlap is very good, the HSC is much shallower, since it uses visit-based HLA source lists rather than a deep mosaic adding all 30 visits together.

# How well does the HSC recreate various science results?

## HSC Use Case # 6 – Red sequence for galaxies



Re-creation of red sequence for elliptical galaxies in **Abell 2390** by **Gladders et al. (1998)**. The agreement with the resulting slope is quite good, i.e.,  $m = -0.042 \pm 0.007$  using the HSC and  $m = -0.037 \pm 0.004$  from Gladders et al. 1998.



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# HLA & HSC Future Plans

## Hubble Legacy Archive

- DR9.1 (Summer 2016): Astrometry from HSC incorporated into HLA images & catalogs
- DR10 (Fall 2016): New WFPC2 images processed using AstroDrizzle and improved WFPC2 source lists
- Future:
  - NICMOS and STIS astrodrazzled images with source lists
  - Wide and deep mosaics with source lists using HSC astrometry
  - Incorporate HLA pipeline products into standard HST data processing

## Hubble Source Catalog

- Version 2 (May 2016)
  - New ACS catalogs from HLA DR9
  - Spectral cross-matches with Hubble spectrographs (COS, GHRS, FOS, ACS grism)
  - Discovery Portal Integration Phase 2 (advanced search capabilities and other additions)
- Version 3 (Early 2017)
  - New WFPC2 catalogs from HLA DR10
  - Inclusion of ACS/HRC source lists
  - More spectral cross-matches including STIS spectra
- Future
  - NICMOS and STIS imaging source lists included
  - Mosaic image source lists included
  - Hubble Catalog of Variables data products and algorithmic improvements (e.g., improved photometry)
  - Forced photometry and photometry-on-demand
  - Photometric redshifts, SEDs, and other higher-level products

*Detecting the Unexpected:* Workshop at STScI 2017 Feb 27 – Mar 2  
(with HSC participation)