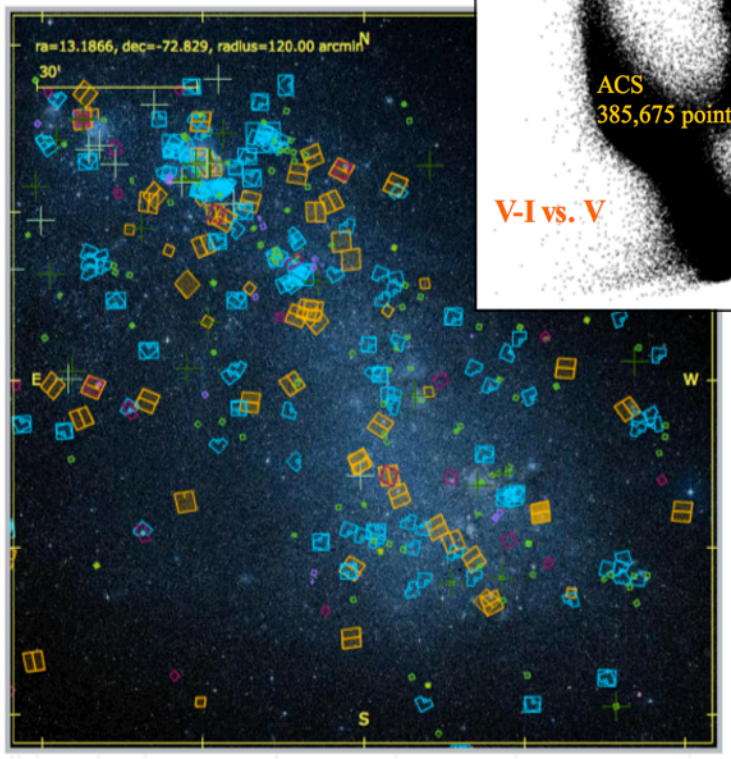
Update on the Hubble Legacy Archive and Hubble Source Catalog

STUC meeting – Oct. 21, 2016

Brad Whitmore for the HLA, HSC, and MAST Portal teams

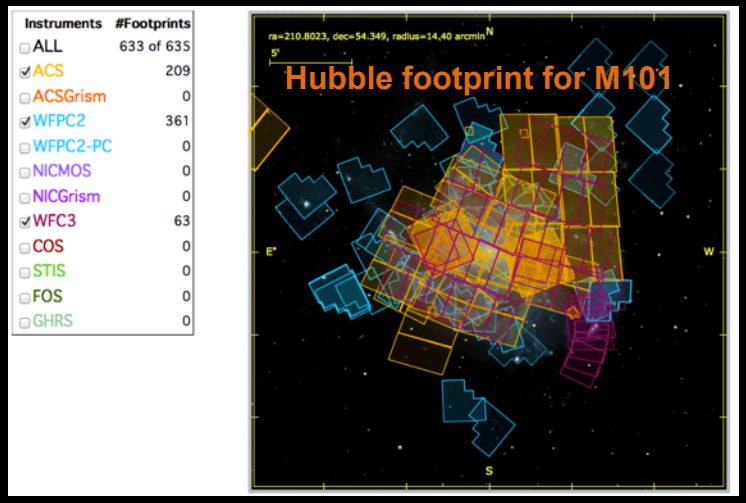
Instruments	#Footprints
☑ALL	7289
☑ACS	1366
☑ACSGrism	0
☑WFPC2	1539
☑WFPC2-PC	1232
☑NICMOS	217
☑NICGrism	17
☑WFC3	347
☑COS	912
☑STIS	1390
☑FOS	185
☑GHRS	84

HLA Footprints for SMC



This query takes less than two minutes using the HSC !

The volume and diversity of Hubble data provides a challenge



The Hubble Source Catalog (HSC) is NOT your standard, uniform, all-sky catalog.

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

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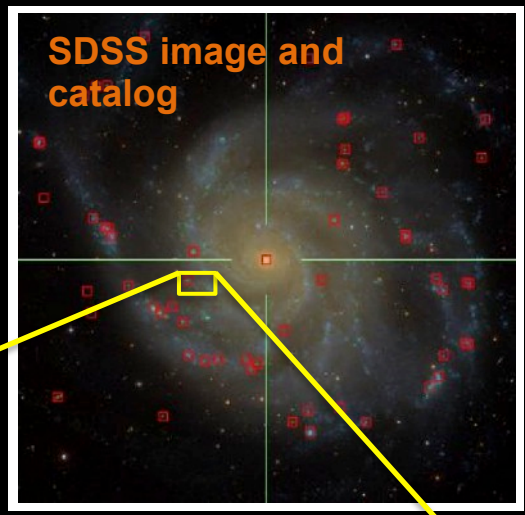
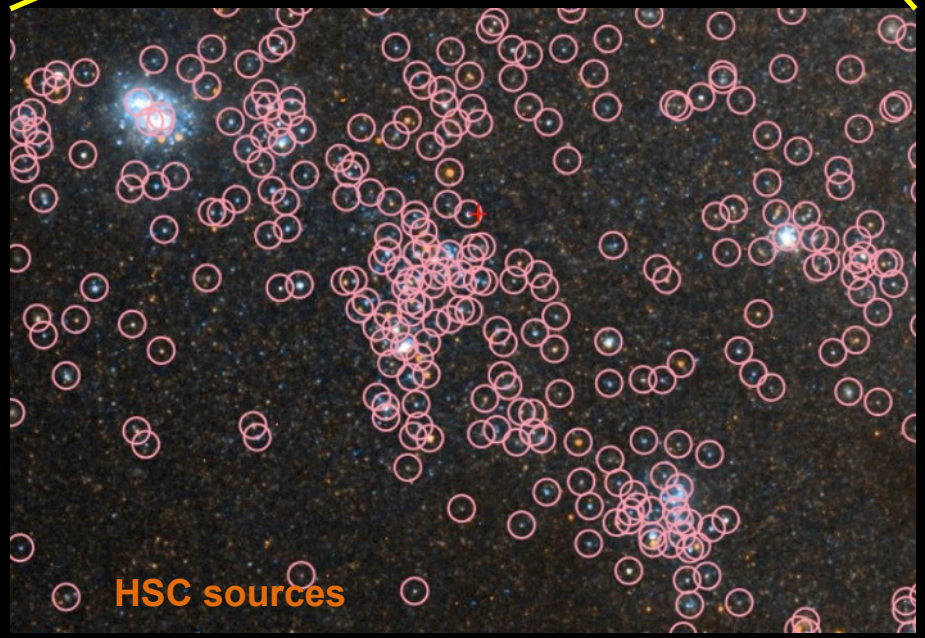




The Hubble Source Catalog:

- **Combines tens of thousands of Hubble Legacy Archive (HLA) visit-based source lists into a single master catalog.**
- **It will be a fundamental reference for JWST users, and upcoming surveys (e.g., PanSTARRS, LSST, WFIRST, …).**
- **Provides entry into the field of database astronomy (e.g, SDSS).**

Four coordinated releases on Sept 29, 2016

HSC 2.0

- Four additional years of ACS source lists. All ACS source lists go deeper than version 1
- One additional year of WFC3 source lists
- Cross-matching between HSC sources and spectroscopic COS, FOS, GHRS and ACS grism observations

HLA 9.1

- All new ACS and WFC3 source lists (for data public on June 2015)
- Much faster overlays (e.g., “visible area” only option)
- Gaia overlays

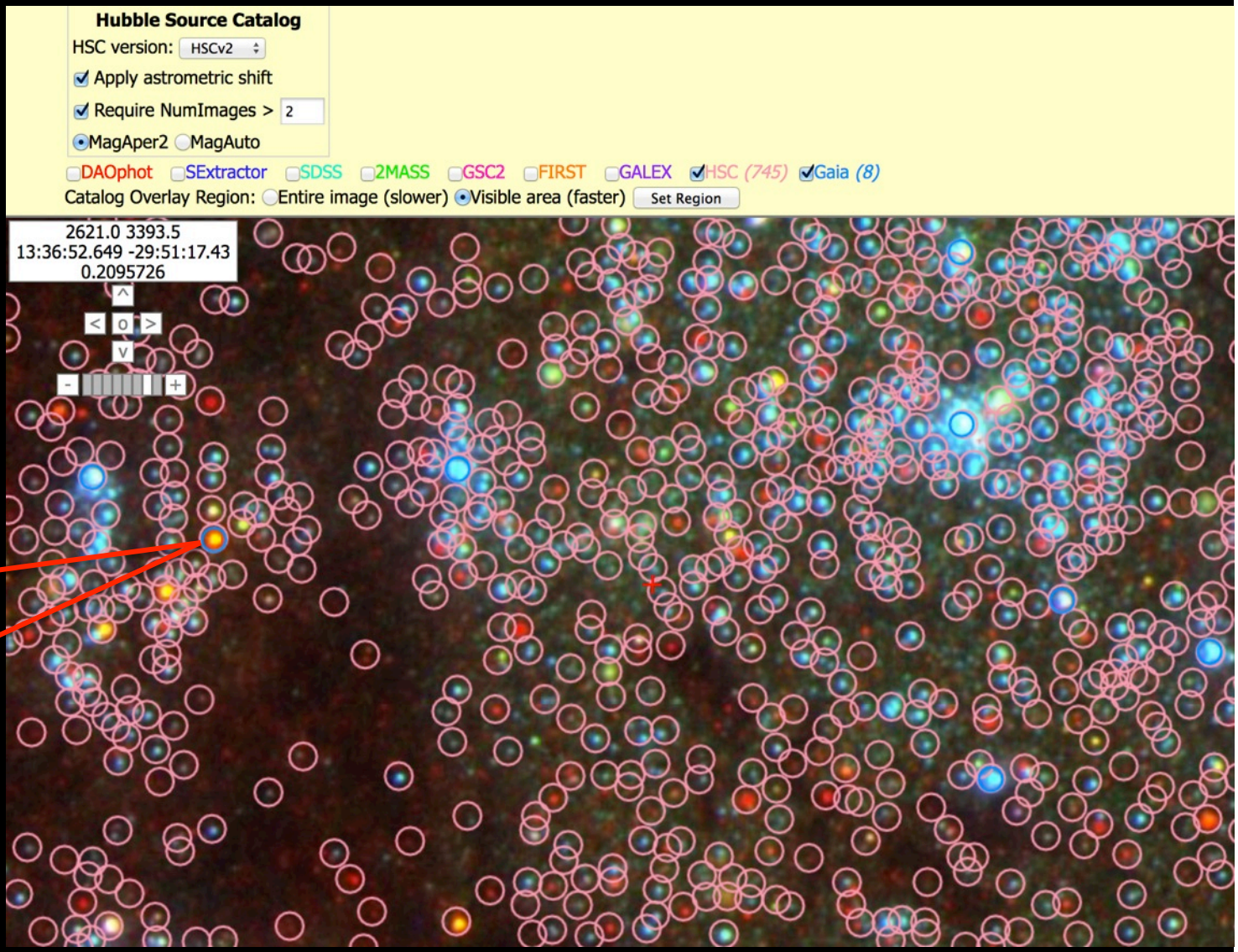
MAST Portal 2.7

- New Advanced Search interface
- HSC spectral results page and crossmatching available
- Number of sources displayed has increased from 10K to 50K

HSC CasJobs 2

- Include HSC version 2 (and supporting tables)

Example of HSC and Gaia overlays on an HLA image

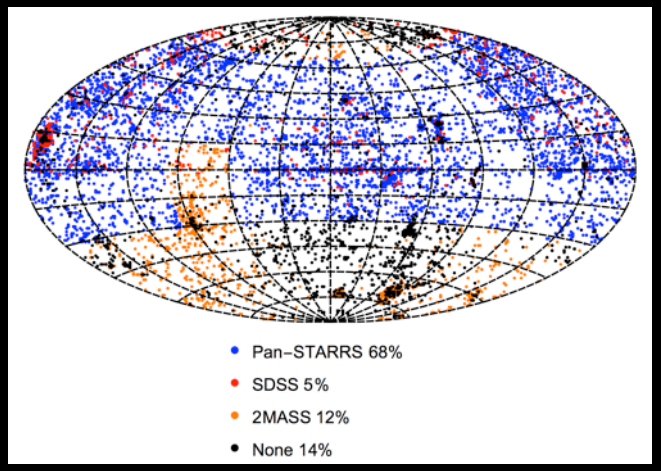


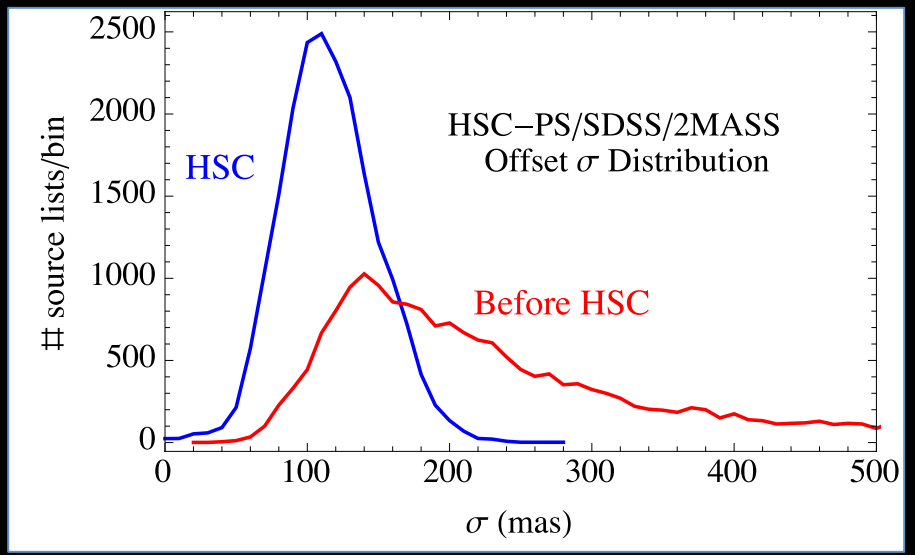
HSC Basics

1. Combines tens of thousands of SourceExtactor HLA source lists into a single master catalog. Uses matching algorithm from Budavari and Lubow 2012.

2. Includes WFPC2, ACS/WFC, and WFC3.

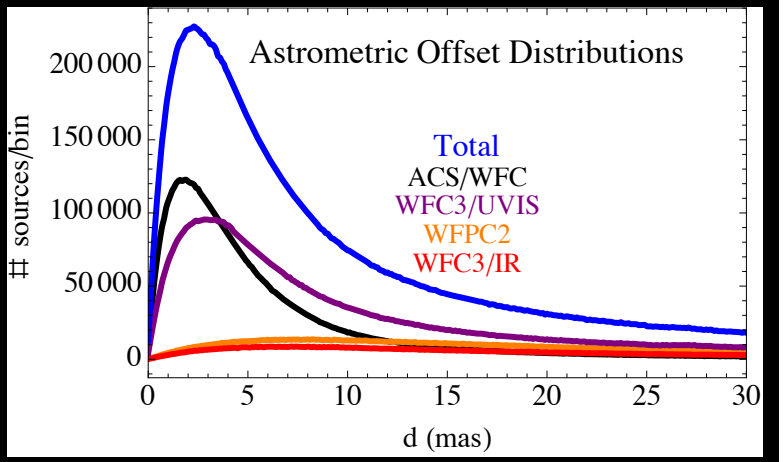
3. Absolute astrometry is good to ~100 mas (relative to PanSTARRS and 2MASS). This can eventually be improved to ~10 mas using Gaia observations).

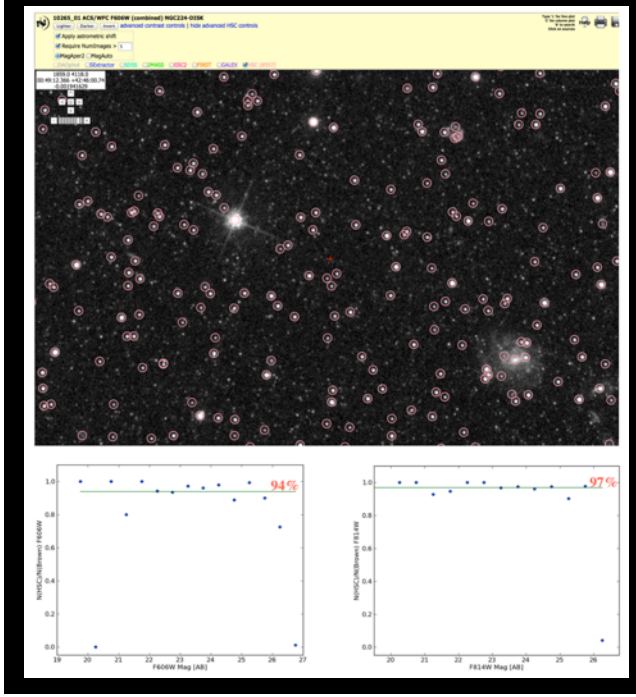




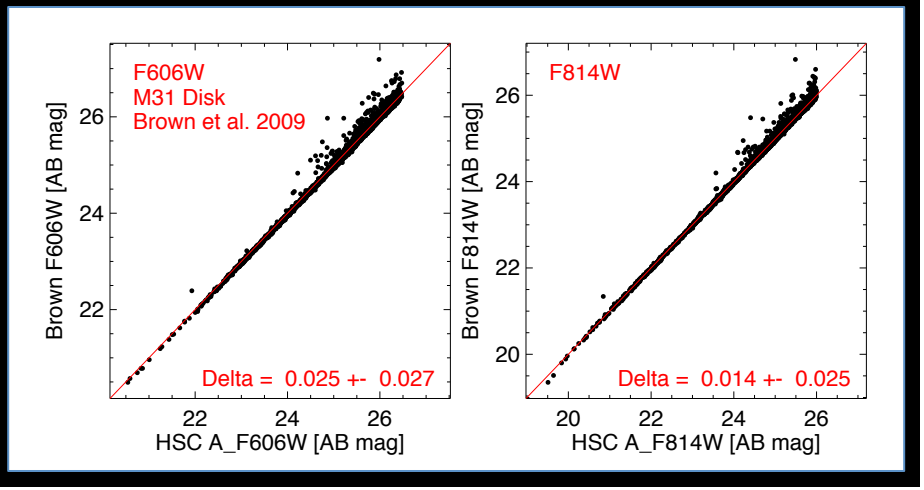
HSC Basics

4. Relative astrometry good to better than ~10 mas; ~2 MAS is the peak of the distribution.



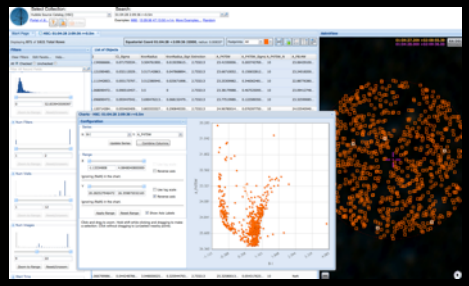


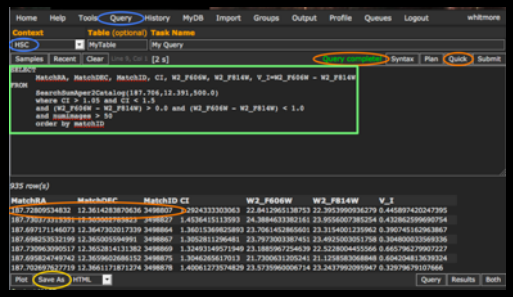
5. Photometry (aperture) typically good to 0.10 mag, and 0.02 mag when S/N is sufficient.

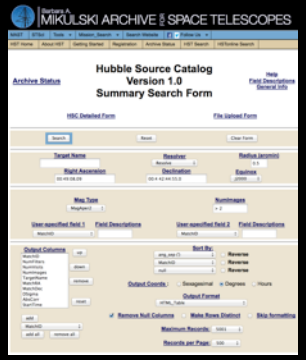


HSC Basics

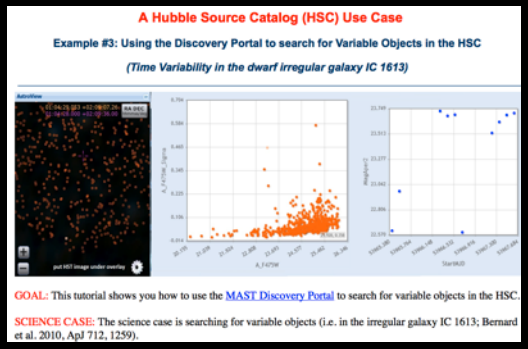
6. The MAST Portal is our primary interface, but we also have a CasJOBS (similar to SDSS) interface for larger and more complex queries, and the HSC Home Page for special cases.







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



Whitmore et al. 2016

Future HLA/HSC Plans

Version 3 – spring/summer 2017

- **Improved WFPC2 source lists**
- **Use of WFC3/UVIS CTE corrected images**
- **HLA mosaics and incorporation of mosaic-based source lists and forced photometry (possibly version 3 for the latter)**
- **Additional spectral capabilities – better integration with HST Spectral Legacy Archive (HSLA) – see Osten (Nov 2015 STUC)**

Version 4 – spring/summer 2018

- **Inclusion of NICMOS and ACS/HRC source lists**
- **Further automation of HLA and HSC to keep up to date better**
- **Prototype integration with JWST (e.g., NIRCAM mosaics)**

Related Topics - Astrometry

1. **HSC absolute astrometry will be inserted into the headers of HLA images as part of Verson 2.1 (~ November 2016)**

2. **An STScI-wide Astrometry Working Group, under the leadership of Mike Fall, has developed plans to:**
   - **Use Gaia to improve PanStarrs astrometry, in collaboration with researchers at the Navel Observatory. This will also provide a better astrometric backbone for the HSC.**
   - **Fix the coordinates in the headers of all HST images in the archives.**
   - **Consider similar improvements for JWST.**

Makarov, Berghea, and Fall (2015) white paper. Shows systematic deviations in PanStarrs in range 50 to 300 mas.

A joint (USNO/STScI/PanStarrs) project is underway to use Gaia to produce improvements, potentially to the ~10 mas level.

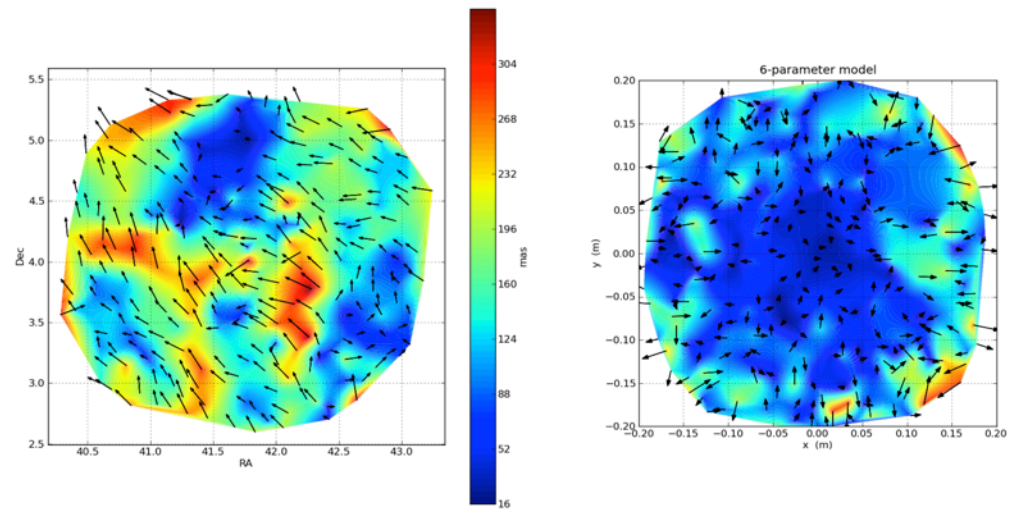
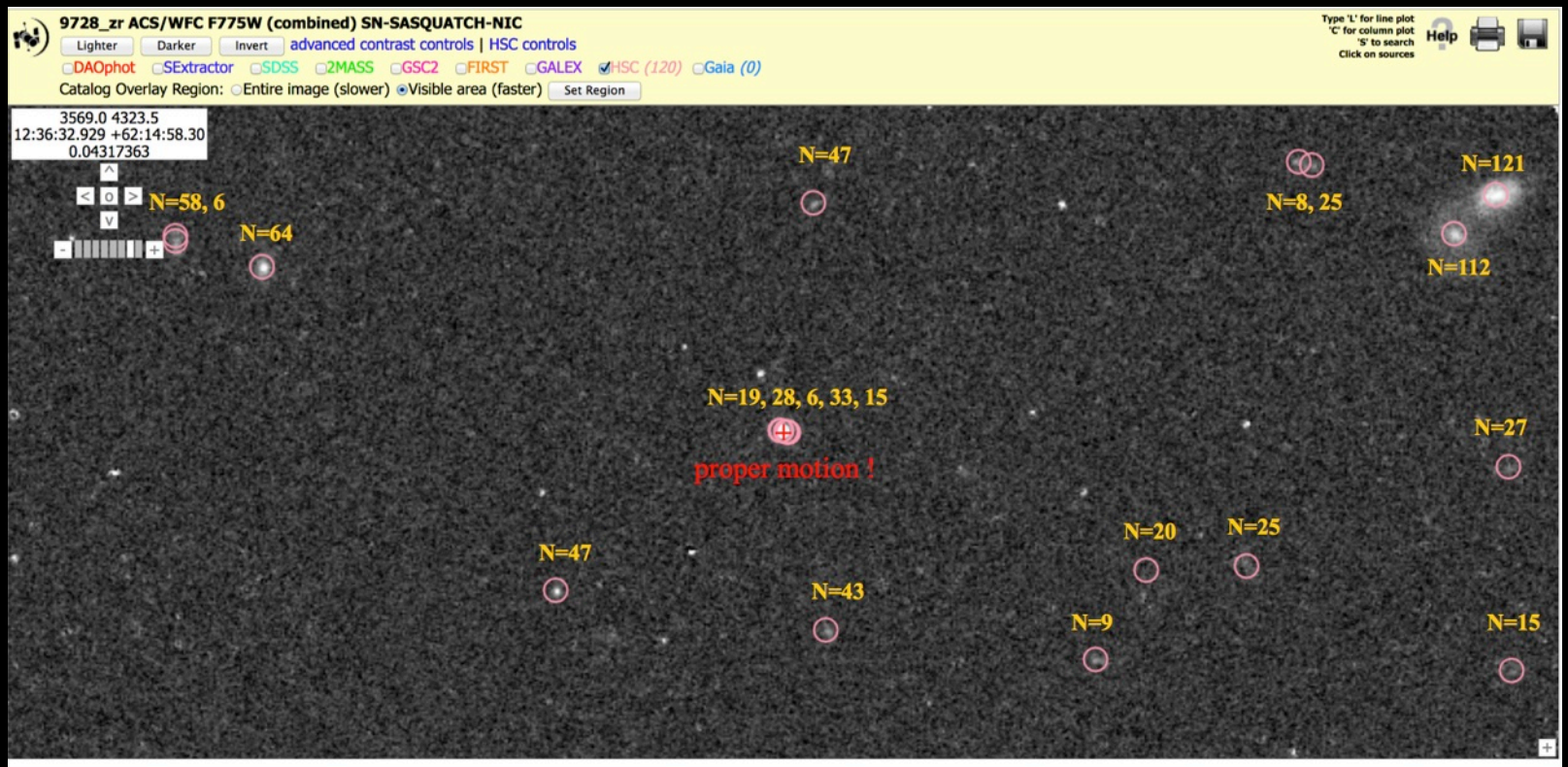


Figure 2. Left: example of small-scale error in PS1 data obtained by comparing to URAT1 stars. Right: residu
after a first order mapping of the mosaic coordinates and the sky coordinates.

Astrometry - (continued)

3. **While examining a potential quality issue with HSC version 2 we found that there were many cases where we can measure proper motion ! This will be incorporated into future releases of the HSC.**



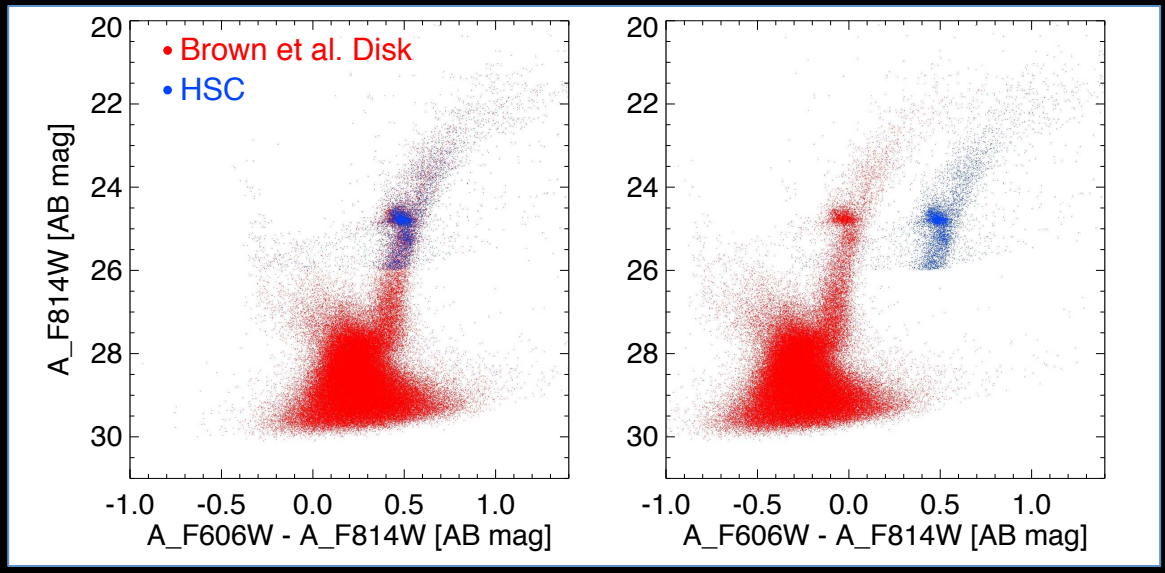
MatchRA	MatchDec	DSigma	AbsCorr	NumFilters	NumVisits	NumImages	StartTime	StopTime
12:36:30.334	62:15:02.37	12.03914709568819	Y	4	16	19	Nov 7 2012 02:48:58:423AM	Sep 15 2014 11:31:
12:36:30.338	62:15:02.37	8.067128081906963	Y	7	19	28	Apr 20 2011 05:43:40:593AM	Feb 27 2013 12:14:
12:36:30.343	62:15:02.39	10.12493472367022	Y	1	6	6	Sep 16 2009 03:29:01:707AM	Apr 20 2011 01:04:
12:36:30.356	62:15:02.41	8.137843870449188	Y	3	16	33	Apr 5 2003 10:48:54:113AM	Apr 12 2005 06:11:
12:36:30.361	62:15:02.42	9.997269977964626	Y	5	7	15	Sep 19 2001 12:11:15:077AM	May 25 2003 09:45:

Related Topics - Mosaics and Forced Photometry

A project to make "super mosaics" using HLA data has begun, under the leadership of Anton Koekemoer (using algorithms he developed for Frontier Fields - see Koekemoer (Nov 2015 STUC)

This will address one of the main shortcoming of the HLA/HSC, namely the use of visit-based rather than deep mosaic images for the detections.

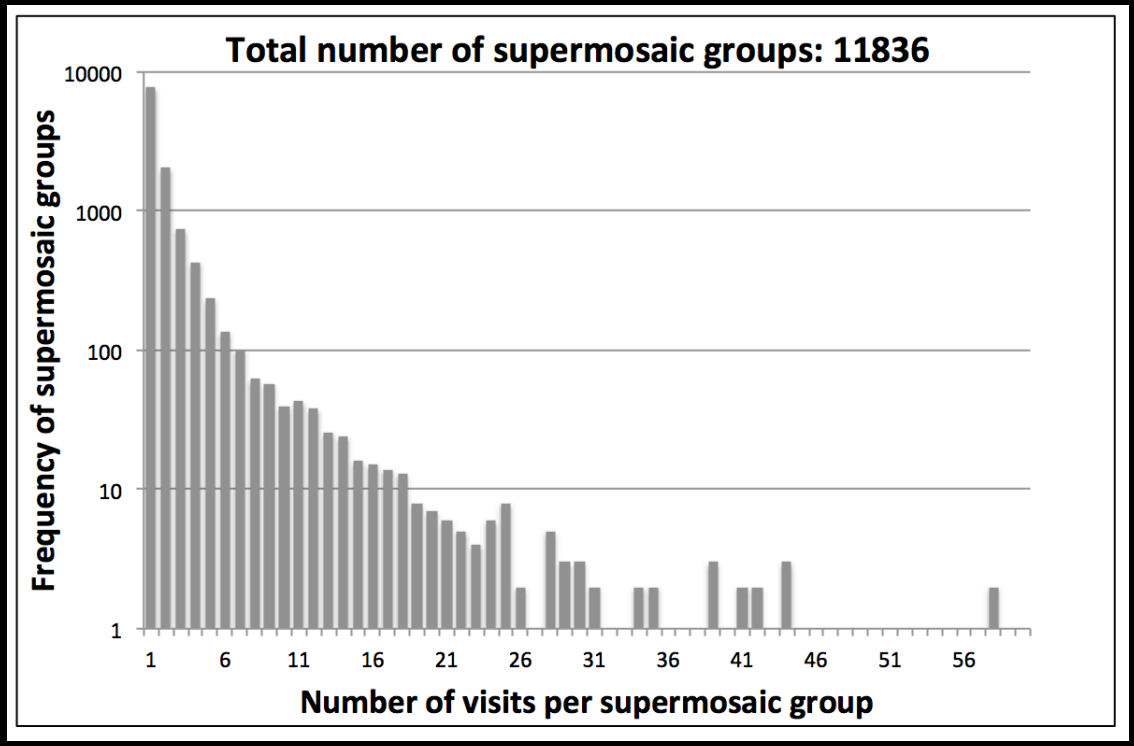
The excellent relative astrometry of the HSC makes this possible.



In certain datasets this will allow us to go several magnitudes deeper.

Mosaics and Forced Photometry

- 7700 images contain just 1 visit (i.e., no additional gain)
- 4108 contain 2–59 visits (*MOST GAIN* - we will start with these)
- 28 contain 60–1721 visits (e.g., HDF, UDF, …, most already have mosaics - will consider these later).

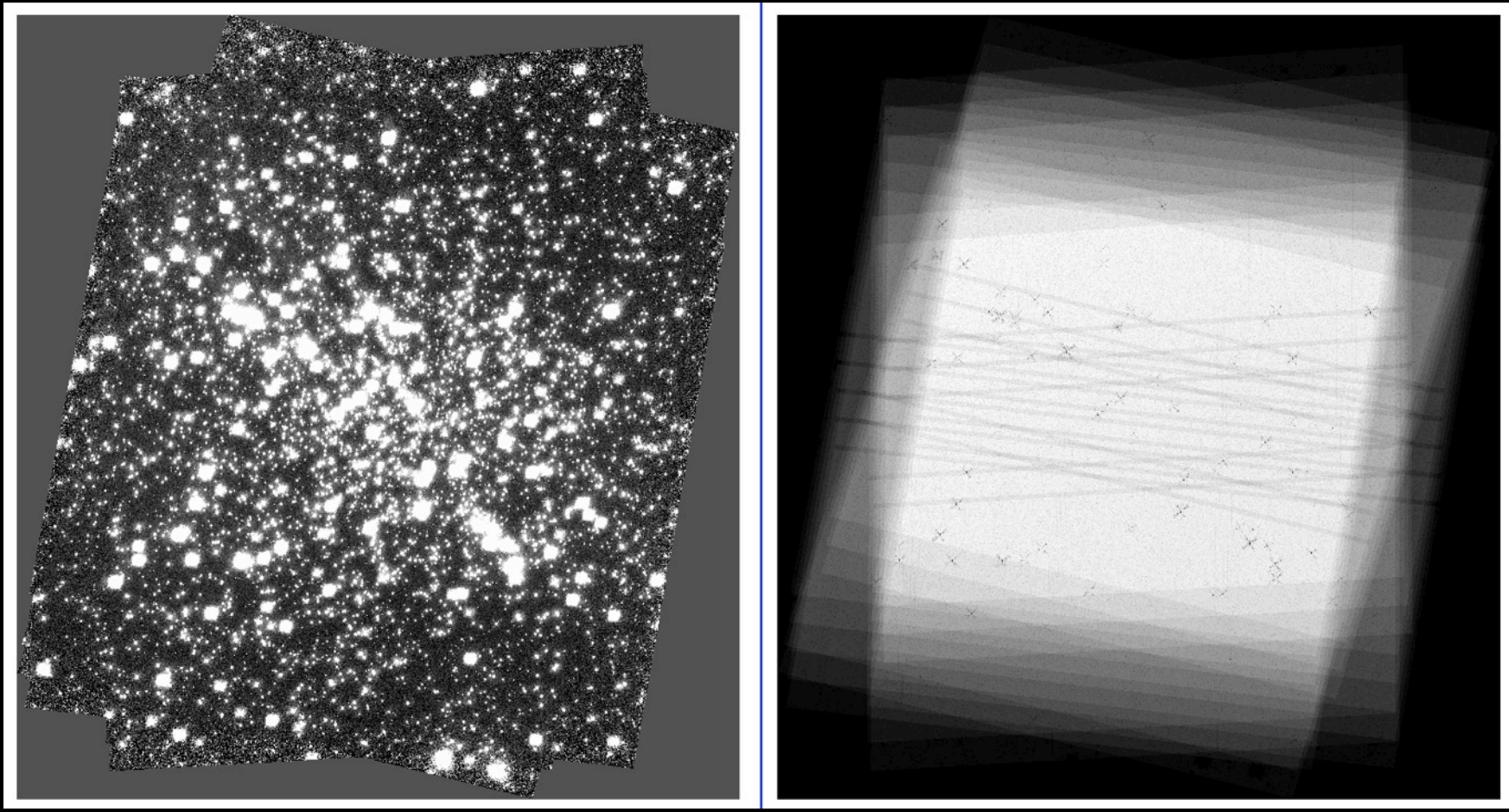


Following the development of super mosaics we will explore the possibility of making PI-only mosaics (visit based, available to PI shortly after their data is taken).

Mosaics and Forced Photometry

A test mosaic in the globular cluster M4 developed using the offsets between the images as determined by the HSC.

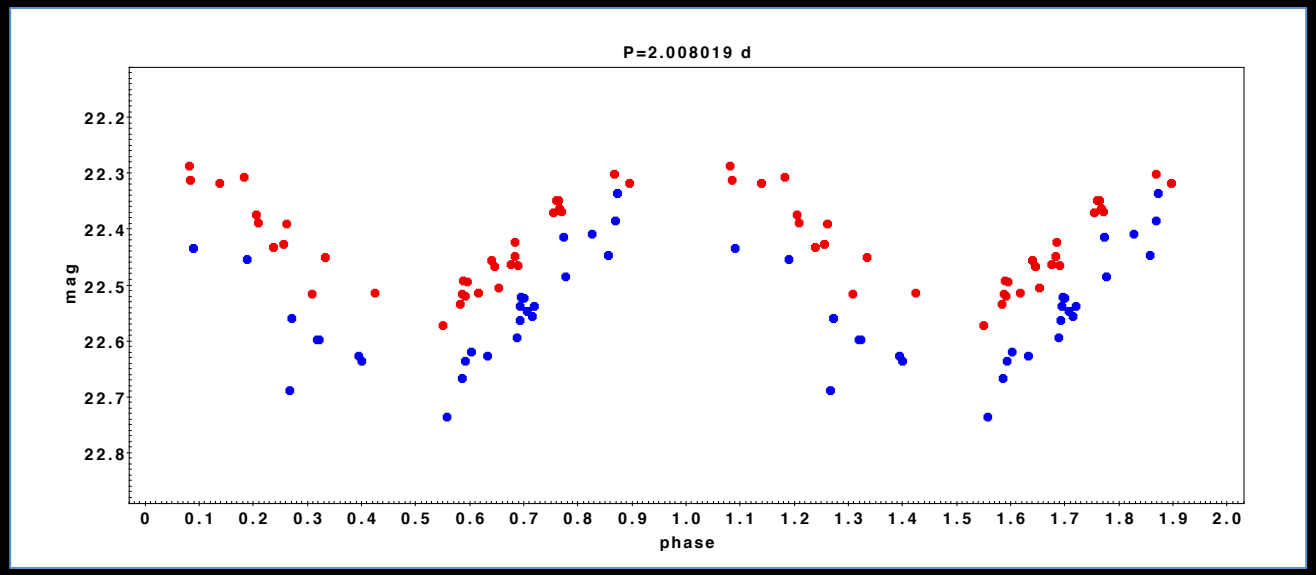
Quality is good - HSC offsets will be sufficient for making mosaics.



Related Topics - The Hubble Catalogue of Variables

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

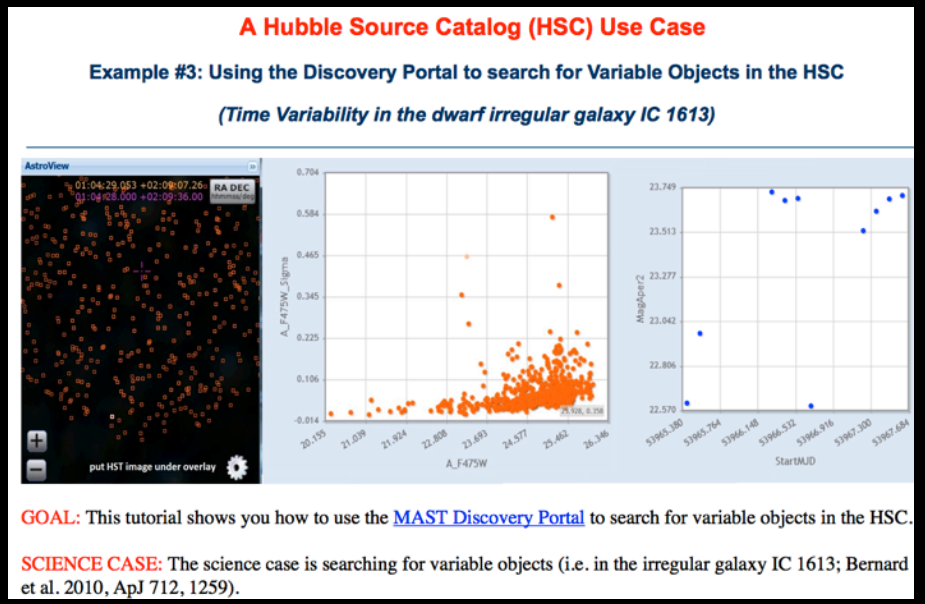
- **PI = Alceste Bonanos – based at the University of Athens**
- **The group will validate the candidates using a wide variety of different algorithms (Sokolovsky et al. 2016).**
- **The HCV will be ingested into the MAST archives in the spring of 2018.**

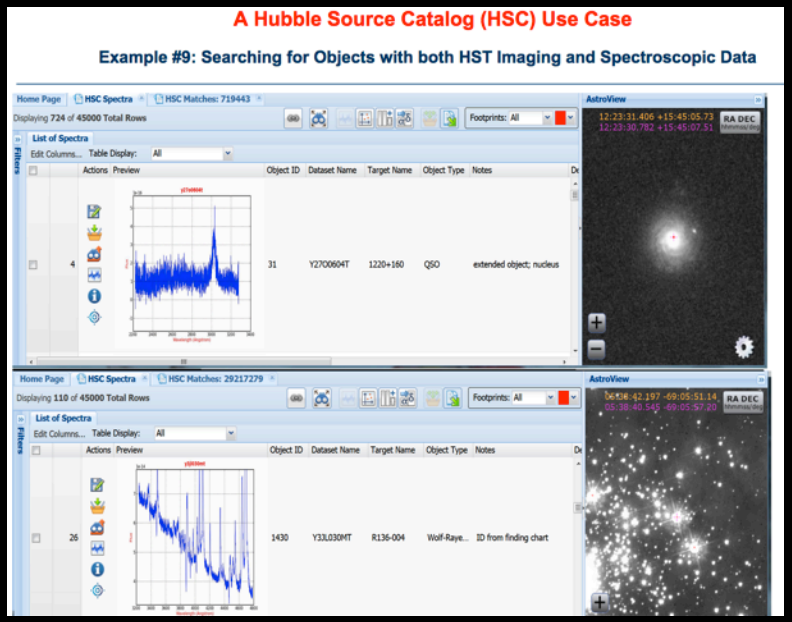


"Phased lightcurve of the new Cepheid variable HSCv1 27271321 found in M31. Blue points represent observations in the F606W filter, red points - F814W."

Demos

- **HSC Use Case # 3 – "Time Variability in the dwarf irregular galaxy IC 1613"**





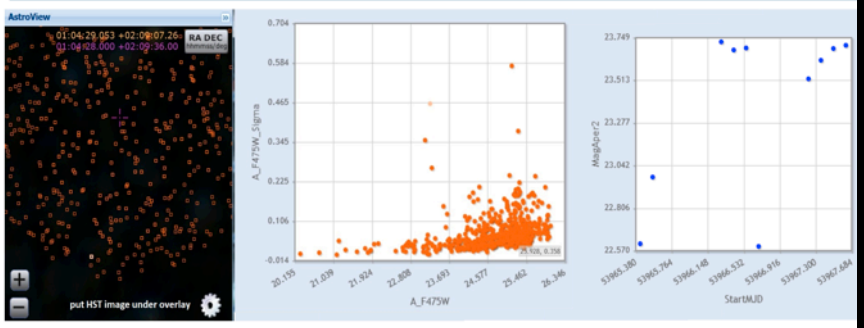
- **HSC Use Case # 9 – "Searching for Objects with both HST Imaging and Spectroscopic Data"**

Backup (if demo does not work) >> > Step-by-Step Use Cases

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)

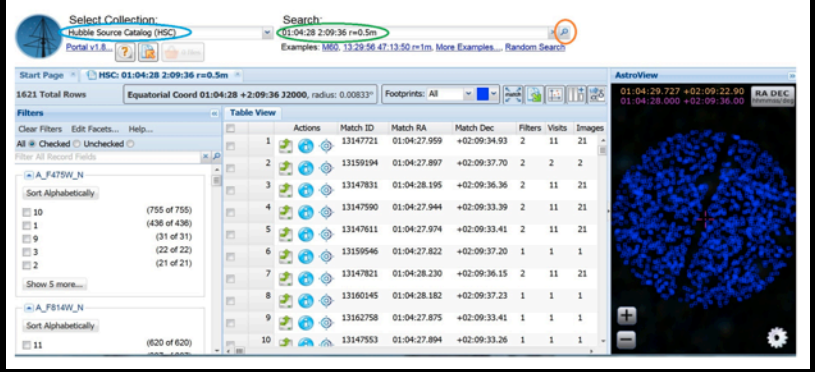


GOAL: This tutorial shows you how to use the MAST Discovery Portal to search for variable objects in the HSC.

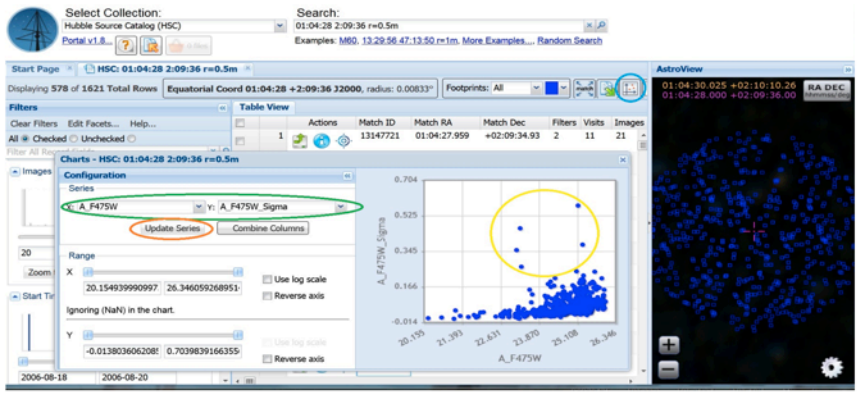
SCIENCE CASE: The science case is searching for variable objects (i.e. in the irregular galaxy IC 1613; Bernard et al. 2010, ApJ 712, 1259).

Step 1 - Go to the MAST Discovery Portal.

Use the pull down menu under Select Collection to choose the HSC (blue). Enter (you can just cut and paste if you like) the coordinates and search radius (i.e. 01:04:28 2:09:36 r=0.5m) in the Search box (green); note that this is in the outskirts of IC 1613. Perform the search by just hitting a carriage return or by clicking on the (orange). The results are display in the Table View, while the AstroView window shows the objects against the DSS image. **[REPLACE THIS WITH AN HST IMAGE]**. The left column is a series of Filters that can be used to refine the data selected.



Step 3 - Make a plot by clicking the "View charts for these data" icon (blue). Under Configuration, select X = A_F475W and Y = A_F475W_Sigma (green). Click on the Update Series button (orange) to plot the ACS F475W magnitudes vs. the RMS scatter for each data point. The variable stars have large Sigmas (yellow).



Step 7 - To make sure the variability is real (i.e. that there are no image artifacts "causing" the magnitude scatter), you should examine the images. Clicking on the image in the Preview column in the Table View will bring up the HLA's Interactive display. Show the advanced HSC controls (blue) and select Apply astrometic shift, as well as set Require NumImages to be greater than 20 (green). Click in the HSC box (orange) and the HSC catalog is overlaid on the image. Find the star of interest (click on the object to verify the identification (yellow)) and verify that the object is free from artifacts. Ideally, you would do this for all the images.