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SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

NAVO

NASA Astronomical Virtual Observatories

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The Virtual Observatory

The Virtual Observatory (VO) is a collective term referring to an ecosystem of standards and the organizations and tools which use those standards.

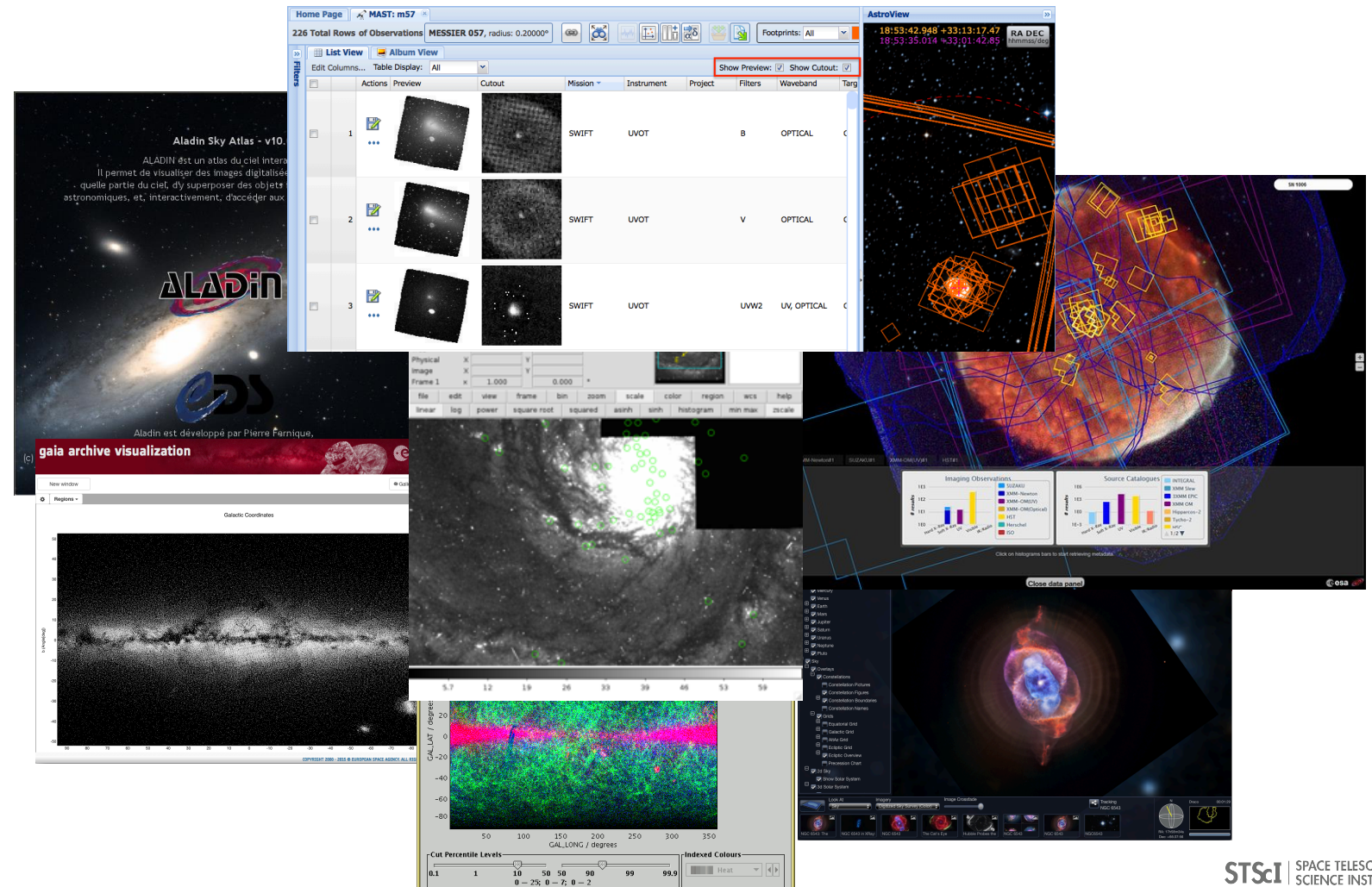
- Note: “The VO” is *not* a single application or web page.
- The standards, organizations and tools together enable the discovery and exchange of astronomical data.
- Basic standards define how to perform cone searches on catalogs, and image and spectral product collections.
 - The MAST Portal uses those basic standards to search collections from around the world:
<https://www.youtube.com/watch?v=rldyyvW77F8>
 - MAST provides access to many, but not all, of its catalogs, images and spectra via those standards.
- More complex standards define, for example:
 - How to register data services
 - SQL-style database queries
 - Event notification
 - Image cutout services
 - Server-side user storage
 - Metadata for describing data collections and products



Virtual Observatory Tools

Many existing tools make use of the VO for data discovery and access

- MAST Discovery Portal
- ESA Sky
- WorldWide Telescope
- Gaia Archive
- Aladin
- Topcat
- DS9





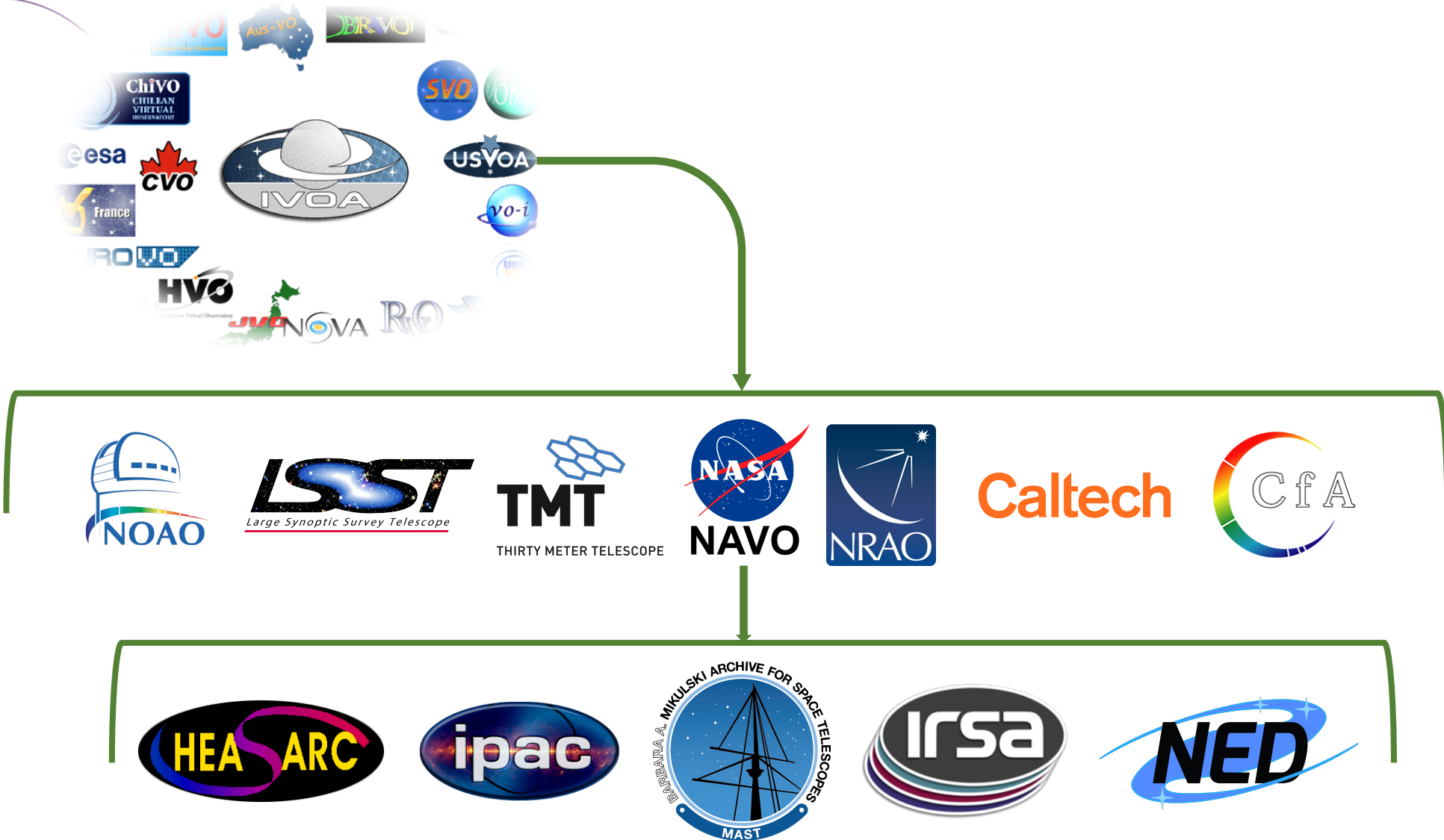
The IVOA

- VO standards are defined by the International Virtual Observatory Alliance (IVOA - <http://www.ivoa.net>) which is composed of nation-level organizations, including the US Virtual Observatory Alliance (USVOA).
- Although background work continues year round, the IVOA holds in-person interoperability workshops twice a year to further standards development.
- MAST participates in the standards development process (as part of the USVOA), and currently has two people serving as vice-chairs of IVOA working groups.





VO Organization





The USVOA

The USVOA (<https://hea-www.cfa.harvard.edu/USVOA/>) is a US-wide collaboration endorsed by the AAS to expand and promote VO tools and services.

So far, participating institutions include:

- Association of Universities for Research in Astronomy (AURA)
 - NOAO, LSST, TMT
- Associated Universities, Inc. (AUI)
 - NRAO
- California Institute of Technology (Caltech)
- Harvard Smithsonian Center for Astrophysics (CfA)
 - HCO, SAO, CXC
- NASA Astronomical Virtual Observatories (NAVO)
 - HEASARC, IPAC, NED, IRSA, STScI (MAST)



NAVO

NASA Astronomical Virtual Observatories (NAVO) is a NASA-funded program coordinate the VO work of the NASA astronomy archives to provide comprehensive and consistent access to data through standardized interfaces.

NAVO's specific mandate includes:

- Engage with the community for VO education and feedback.
- Participate in IVOA processes to create effective standards that are useful to the community.
- Operations
 - Maintain registry of all VO resources. (MAST)
 - Maintain existing VO services. (All)
 - Implement VO services for new data sets and new IVOA standards. (All)
 - ▶ Coordinate this work where possible, so that the NASA archives all offer the same services.
 - Service monitoring for validation and usage statistics. (HEASARC)



2017 NAVO Highlights - Registry

MAST maintains an instance of an IVOA Registry

- Searchable directory of astronomy data resources, including IVOA standard services
- Requires ongoing curation, user support and automated harvesting to/from peer registries

New registry search page:

- <https://vao.stsci.edu/keyword-search/>

Integrated with STScI single sign-on

- Allows data providers to maintain their own registry entries

The screenshot displays the NAVO Directory search page. At the top, there is a navigation bar with 'Search', 'Publish', 'Developers', and 'Help' links. The main heading is 'Find Astronomical Data Resources'. Below this, there is a search input field containing 'HST' and a 'Search Q' button. A text box provides instructions on how to use the search interface. Below the search field, there are examples of search terms and a link to the Data Discovery Tool. The search results are displayed in a table with columns for 'Subject', 'Publisher', 'Resource Type', 'Content Level', 'Validation Level', and 'Capability Type'. The first result is 'HST Cosmic Evolution Survey' by 'Space Telescope Science Institute Archive'. The details for this result are shown below the table, including the ID, title, short name, date, publisher, and description.

NAVVO Directory

Search Publish Developers Help

Hosted By
Space Telescope Science Institute

Find Astronomical Data Resources

Enter terms in the text box that describe the type of data you are looking for, or use the filters below to browse data by facet. Results will show catalogs and data collections that have these terms as part of their descriptions. Note that the search interface ignores slashes by default, so when searching for full or partial IDs you may want to put the search string in quotes (e.g. "ivo://mast.stsci/ssap/befs").

All Fields ▾ HST Search Q

Examples: quasar, AGN, binary stars, Chandra, GALEX, far ultraviolet

Use the [Data Discovery Tool](#) to search and view data for a particular object or position.

Limit your search

Subject >

Publisher ▾

Space Telescope Science Institute Archive x 26

Resource Type >

Content Level >

Validation Level >

Capability Type ▾

You searched for: HST x Capability Type > Simple Image Access Protocol x Start Over

Publisher > Space Telescope Science Institute Archive x

« Previous | 1 - 10 of 26 | Next »

Sort by relevance ▾ 10 per page ▾

1. HST Cosmic Evolution Survey

ID: ivo://mast.stsci/siap/hst.cosmos

Title: HST Cosmic Evolution Survey

Short Name: HST.COSMOS

Date: 14 Apr 2017 21:05:51

Publisher: Space Telescope Science Institute Archive

Description: COSMOS (P.I. Nicholas Scoville, California Institute of Technology, USA/CA) is an HST Treasury Program to survey a 2 square degree equatorial field, centered on RA=10:00:28.6 and DEC=+02:12:21.0 with the ACS in the I band of the VIMOS equatorial field. Parallel observations with WFPC2 and NICMOS were also obtained.



2017 NAVO Highlights – New Services

Table Access Protocol (TAP) allows SQL-like queries on archive databases.

- Similar to CasJobs functionality

Via tools like Topcat and Aladin, end users can perform SQL-like queries on

- The VO Registry
- MAST Observations
 - Single table simplified view
 - Full CAOM database view
 - ▶ Allows access to more information than the MAST Discovery Portal
- Hubble Source Catalog (nearly complete)



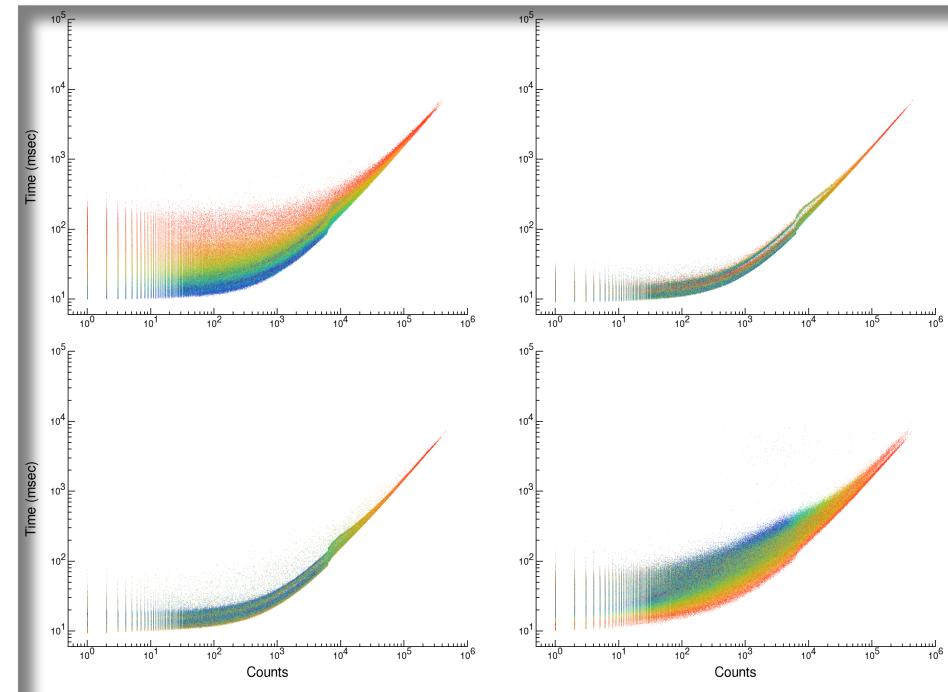
2017 NAVO Highlights - Studies

Metadata representation

- When query results don't contain metadata, they cannot be understood programmatically.
 - E.g., with a CSV version of a catalog, a program cannot recognize that the catalog contains flux and error values in 3 different bands.
- The IVOA is considering different proposals for metadata representation.
 - MAST conducted experiments to determine the complexity and practicality of the proposals.
 - Complexity is still a major concern
 - More proposals and experiments needed

Database Performance

- MAST worked with IPAC to compare database query performance based on certain variables
 - Tessellation scheme (HTM vs. HEALPix) and depth
 - PostgreSQL vs. MS SQL Server





Community Outreach

VO standards sometimes criticized as not useful to the astronomy community.

- Partially true.
 - Standards created painfully slowly.
 - IVOA is a somewhat insular organization, thus has not always been in sync with community needs.
- Partially misplaced expectations.
 - “Virtual Observatory” sounds like an end-user tool.
 - Standards intended to enable data interoperability within an ecosystem of such tools.
 - Often don’t realize when data access is utilizing VO standards.

IVOA outreach and process improvements

- Actively soliciting input and participation from major missions (e.g., LSST)

- New social media presence (IVOAastro)



- Beginning retooled web presence to make VO more approachable for general community
- Streamlined standards approval process
 - But with added emphasis on demonstrating the utility of the new standards.



Community Outreach – Python

Python now commonly used in astronomy data processing and analysis.

- Used everywhere from large-scale data pipelines to end-user applications.
- Success fueled by ease of programming, versatile development environments, and a wide array of general-use and astronomy-specific libraries.
- Central to that success is the Astropy Project, which is

“a community effort to develop a common core package for Astronomy in Python and foster an ecosystem of interoperable astronomy packages. “

- Growing numbers of data collections are now searchable through the affiliated package, AstroQuery.
 - AstroQuery provides a common pattern for data queries, but each query and result is somewhat unique.
 - The VO provides homogenous queries, with results that are somewhat unique.

Integrating VO into astropy seems a natural and necessary step for community engagement

- Astropy and VO have overlapping goals of interoperability and data access
- Enable homogeneous queries (e.g., in a loop) across multiple archives
- Working more directly with end users helps ensure that evolving standards are relevant and useful.



Community Outreach – Python Workshop

At AAS 231, NAVO held a workshop: *Using Python to Search NASA's Astrophysics Archives*

- Created Jupyter Notebooks with “real” science cases that used VO services to find data.
 - Main notebook: https://github.com/NASA-NAVO/aas_workshop_2018/blob/master/workshop.ipynb

Initial lessons

- Accessing VO services through Python has real scientific use.
- Existing astropy VO functions not always compatible with existing VO services
 - Some of our services not fully compliant with standards
 - Some of the astropy functionality not complete
 - This knowledge not only helps validate services, but also feeds back into standards process where complexity or lack of clarity may be an issue.
- Searching the VO registry for services is complex, and thus a barrier to entry for VO programming.
 - During the AAS hack day, we implemented a basic AstroQuery module for simplified registry search
 - ▶ [Jupyter Notebook with hack example](#)



MAST NAVO Priorities - 2018

1. Continued engagement with astropy community
 - More workshops and public science examples
 - AstroQuery module to facilitate use of VO services.
 - Need to integrate cleanly with existing astropy VO functionality
 - Robust service validation
2. Review MAST VO services to ensure compliance and utility
3. Table Access Protocol support for MAST catalogs
 - PanSTARRS next; other priorities being assessed
4. Ongoing Registry operations and support
5. Continue studying metadata representations
6. IVOA standards development