Infrared Processing and Analysis Center

NASA Astrophysics Archives

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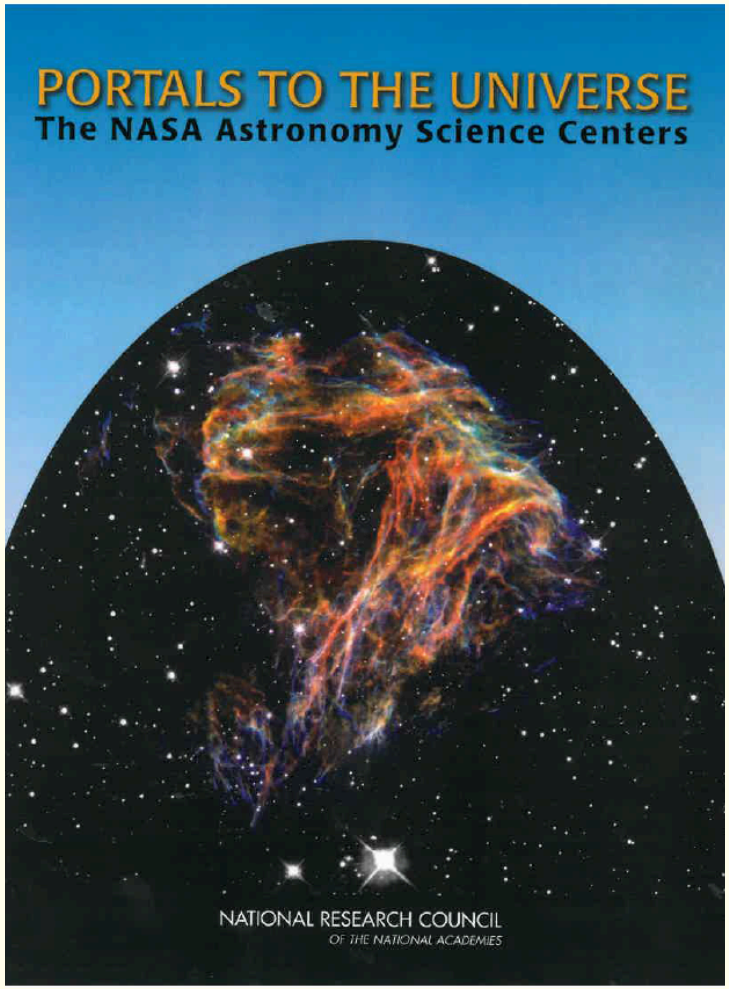
NASA's Commitment to Astrophysics Data Archives

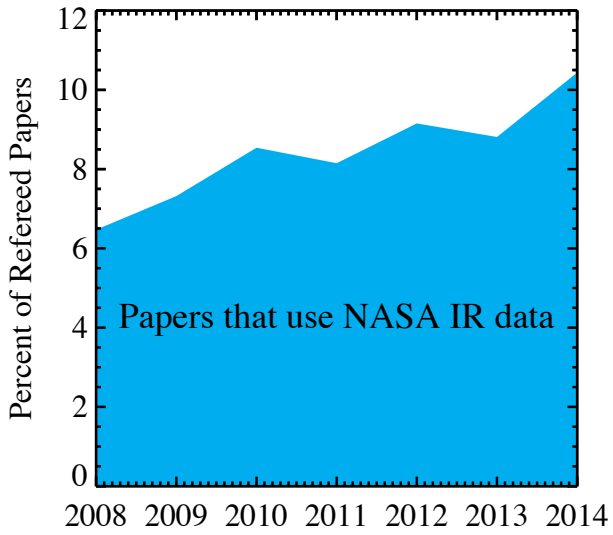
- "NASA has regarded data handling and archiving as an integral part of space missions."
- "This support now provides the major return on the considerable investment the agency made… over the past 20 years."

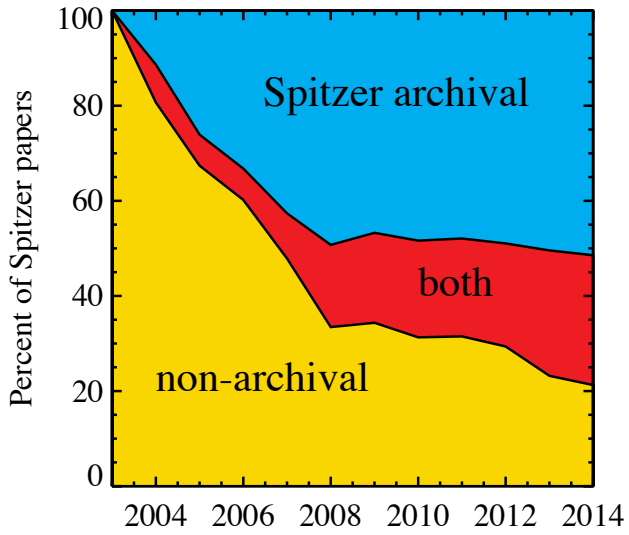
"A Sustainable Archive"

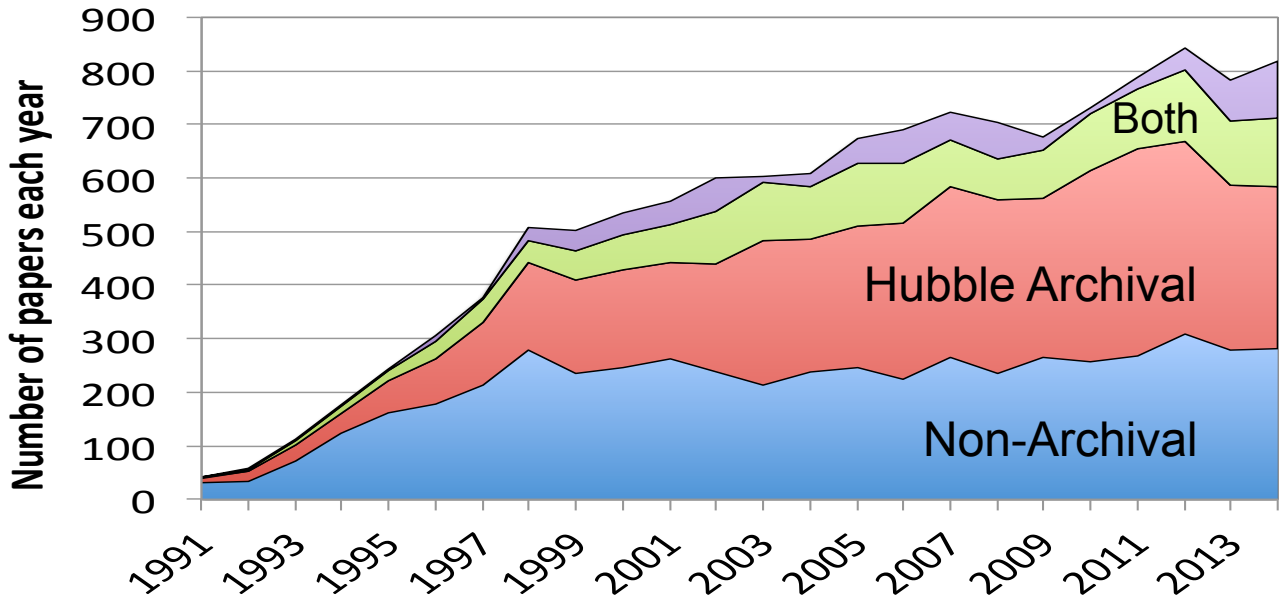
- Continually facilitates production of new scientific results
- Has a strategic goal to enable more and better science
- Contains high-quality, reliable data
- Provides simple and useful tools to a broad community
- Provides user support to the novice as well as to the power user
- Has many diverse uses (and users)
- Adapts and evolves in response to community input



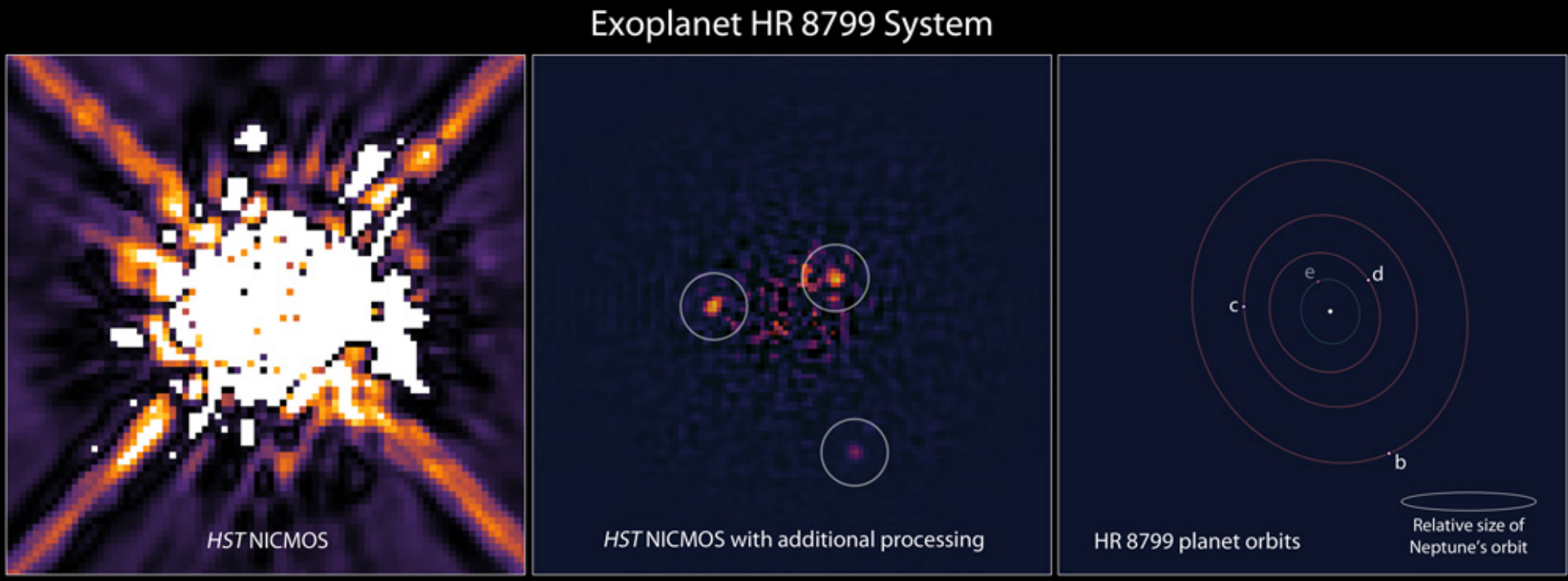
Archival Papers Outnumber non-Archival (GO/PI) Papers







Archive Science Example: HR8799 b,c,d imaged by HST in 1998



planet b:
83,000x fainter than star
at 1.72 arcsec

planet c:
36,000x fainter than star
at 0.96 arcsec

planet d:
33,000x fainter than star
at 0.60 arcsec

These results were made possible by post-processing speckle subtraction and achieve over an order of magnitude contrast improvement over the state of the art when the data was taken in 1998.

Soummer et al. 2011, Pueyo et al. 2014

IRSA Science Highlights

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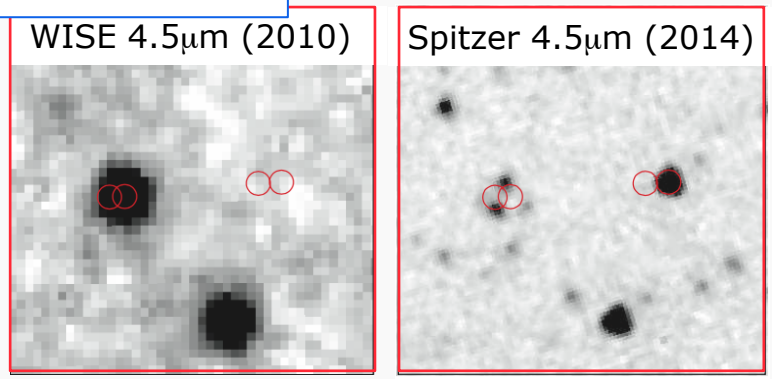
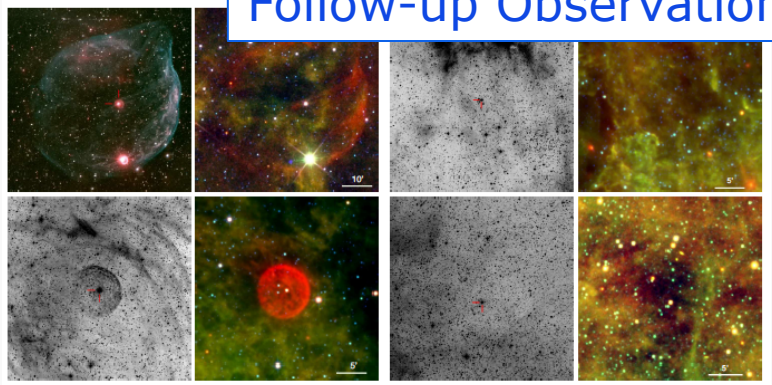
Time domain



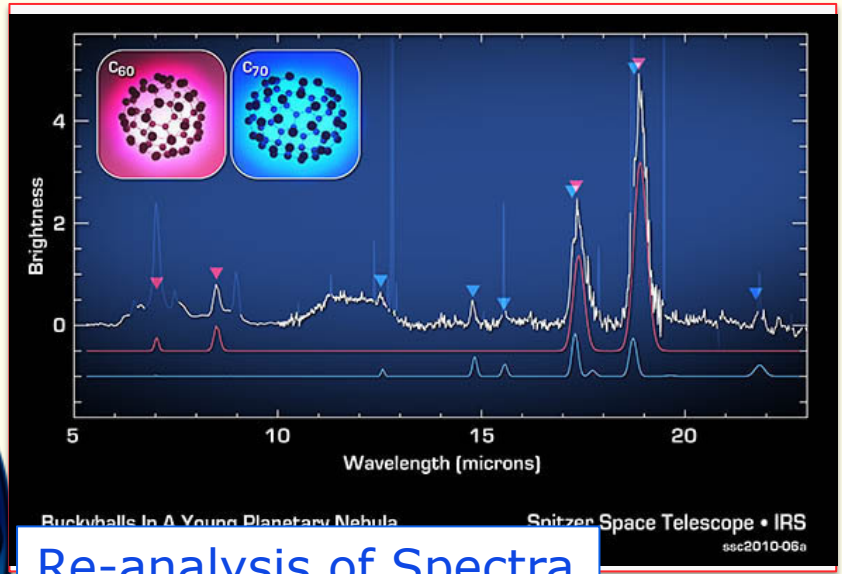
WISE+Spitzer discover the coldest brown dwarf (Luhman 2014, ApJL 786, L18)

Follow-up Observations

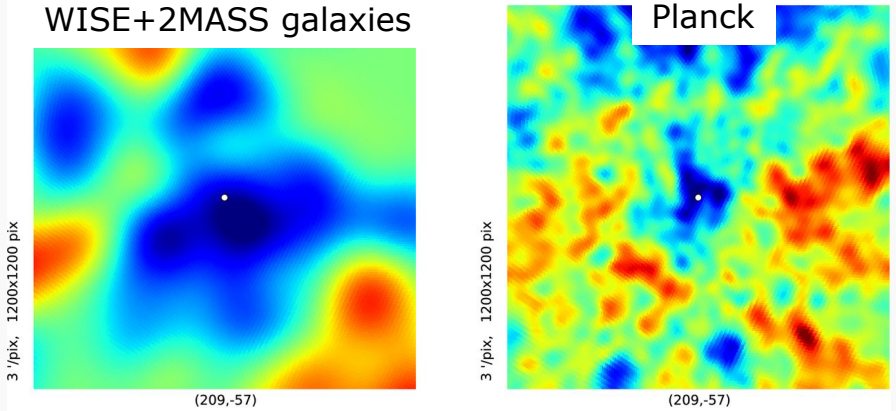


WISE morphological study of Wolf-Rayet nebulae, Toala et al. (A&A 2015, arXiv:1503.06878)

Re-analysis of Spectra



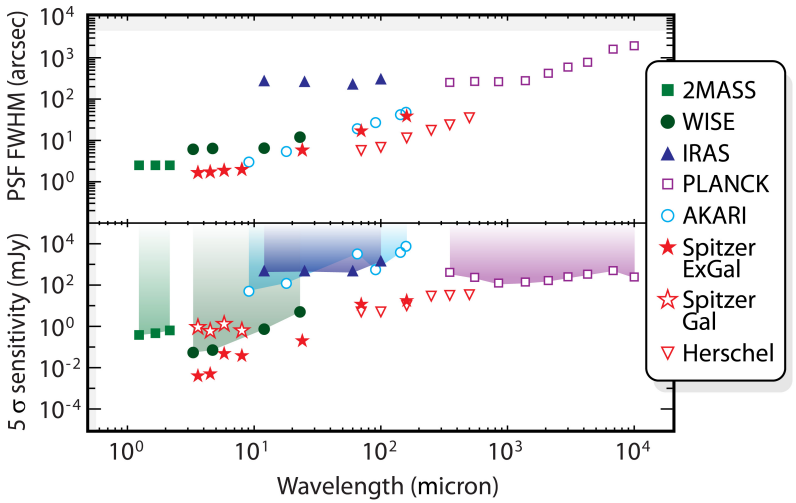
Combination of Surveys



WISE+2MASS+PanSTARRS data may reveal super-void in CMB cold spot seen by Planck; (Szapudi et al. 2015, MNRAS, 450, 288)

IRSA : NASA's IR/sub-mm archive

- IRSA ensures the legacy of NASA's "golden age" of IR
  - *Enable research that has not yet been envisioned.*
  - *Priorities set by missions and the community*
  - *Support future flight missions*
- IRSA is continuing rapid expansion
  - *Since 2011, holdings more than doubled (will be 1 PB by 2017);*
  - *# table rows increased by factor of 15 (almost 100 billion)*
  - *Over 13 million queries in 2014*



- *All-sky 20 photometric bands from 1 micron to 1 cm*
- *About 40% of approved ADAP programs involve analysis of IR data sets*

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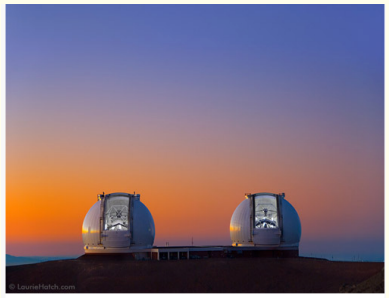
Spitzer WISE Planck Herschel 2MASS IRAS AKARI MSX SWAS IRTS BLAST SOFIA

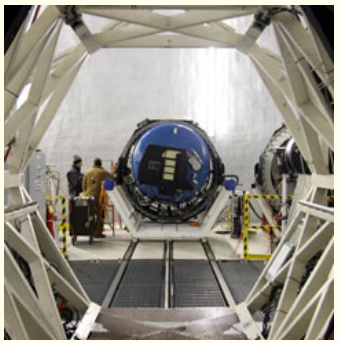
NASA's other Primary Astrophysics Archives

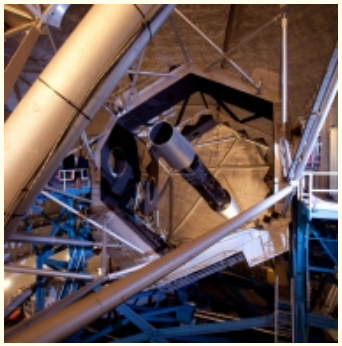
- **MAST**: a NASA astrophysics data archive center
  - *Archive established with HST launch in 1990*
  - *Multi-mission since addition of IUE in 1998*
  - *4 active missions including Hubble, Kepler*
  - *Many legacy missions: GALEX, IUE, FUSE, …*
  - *Future: TESS, JWST, …*

- **HEASARC**: The High Energy Astrophysics Science Archive Research Center
  - *Established in 1990 at GSFC*
  - *The primary archive for NASA's missions studying electromagnetic radiation from extremely energetic cosmic phenomena ranging from black holes to the Big Bang.*
    - Chandra, XMM-Newton, Fermi, Suzaku, NuSTAR, INTEGRAL, ROSAT, etc.
  - *Merged with Legacy Archive for Microwave Background Data Analysis (LAMBDA) in 2008 to include data from space missions, balloons, and ground-based facilities that have studied the relic cosmic microwave background (CMB) radiation*
    - COBE, WMAP, ACT, etc.

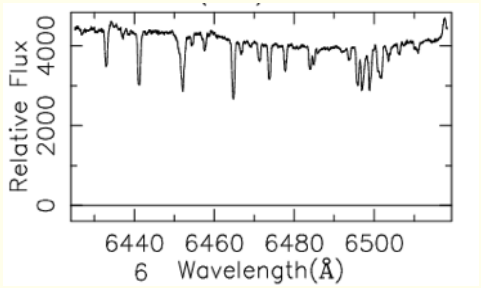
The Keck Observatory Archive







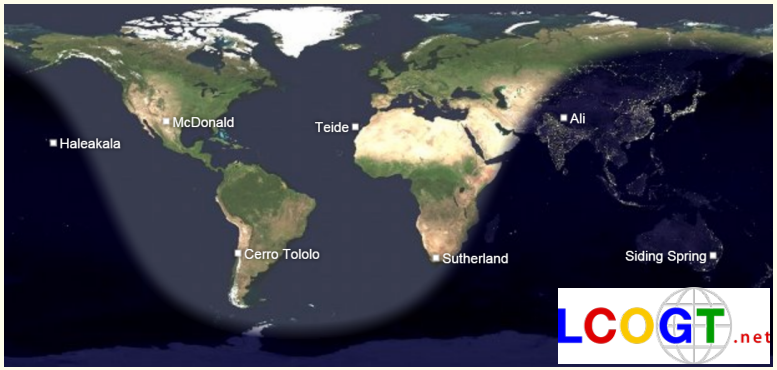
- NASA-funded collaboration between WMKO and IPAC/NExScI.
- Started with HIRES
- Systematic/automated capture of metadata ensures efficiency
- Now data from all ten instruments since their dates of commissioning
  - *decommissioned instruments Summer 2015.*
  - *proprietary period of at least 18 mo.*
- KOA creates browse products for three instruments by automating pipelines.



KOA creates extracted HIRES browse spectra for every order of each object raw frame. Shown: T Tau. (PI: Reipurth).

Other IPAC Archives following the NASA model (non-NASA funded)

- **LCOGT: Las Cumbres Observatory Global Telescope Network**
  - *integrated set of robotic telescopes, distributed at 7 sites around the world,*
  - *designed to emphasize time-domain astrophysics*
  - *Fully automated scheduling, pipeline, and archive ingestion*
- All data (since April 2014) from science imagers in archive hosted by IPAC
  - *About 3 billion sources*
  - *About 1 million images*



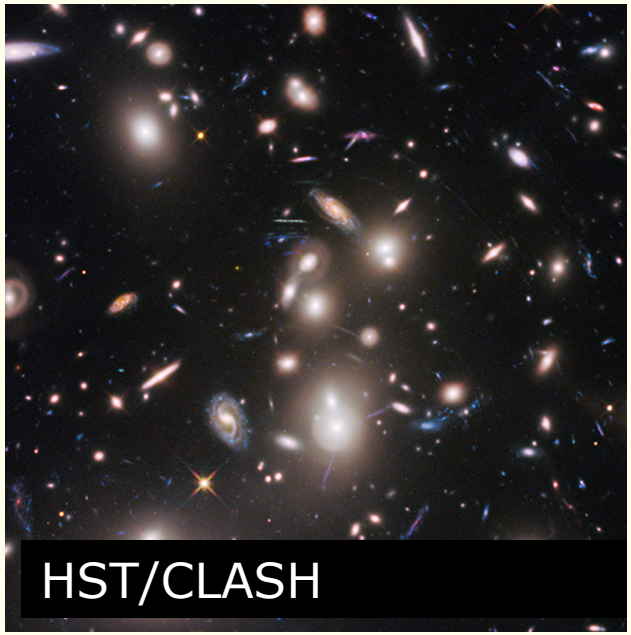
- **Palomar Observatory**
  - *Zwicki Transient Facility (2017+)*
  - *intermediate Palomar Transient Factory (iPTF; 2013-2016)*
  - *Palomar Transient Factory (2009-2012)*
- Fully automated wide-field survey with 1.2 m Oschin telescope
- Publicly accessible survey data products available at IPAC
  - *single frame exposures for selected regions of the sky,*
  - *source catalog files for those same regions.*

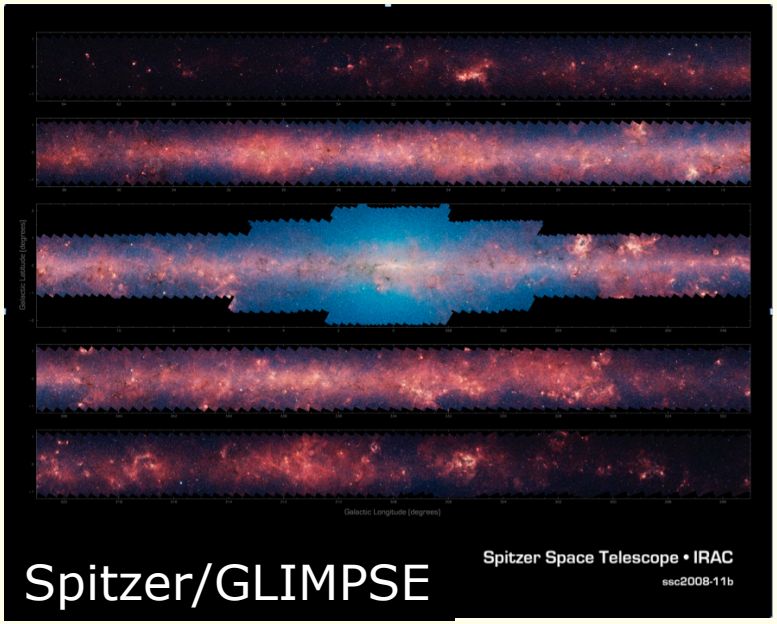
An Archive's Job

- Ingest new data
- Maintain/serve vital repository of irreplaceable data
  - *Support for observation planning*
  - *Resource for original science*
  - *High level science products*
- Enable cutting-edge research
  - *API and Virtual Observatory*
  - *User support by experts*
  - *New/enhanced services*

High Level Science Products

- Greatly enhance the science return of the archives
  - *Hubble Legacy HLSP are used 10x as much as typical pipeline products*
- Make complex data sets accessible to a wider audience of researchers
- Expand the use of large, coherent projects
  - *Hubble Treasury*
  - *Spitzer Legacy and Exploration Science*
- Generated by the community or by the archive





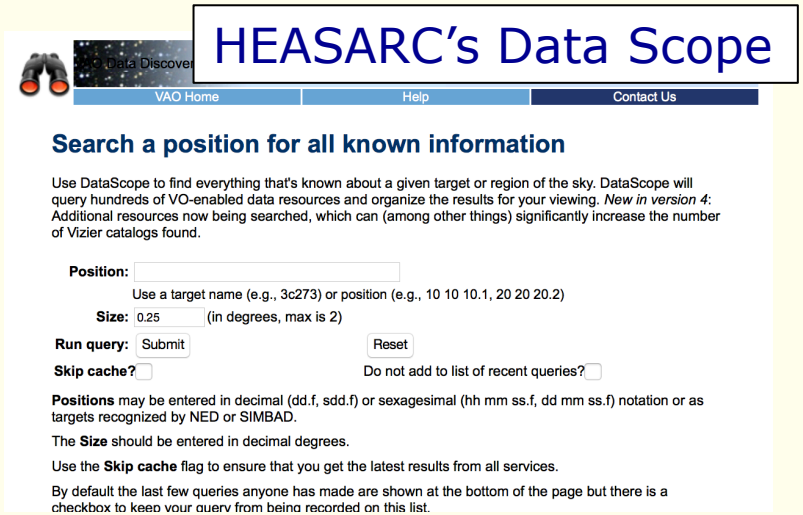
Science User Support

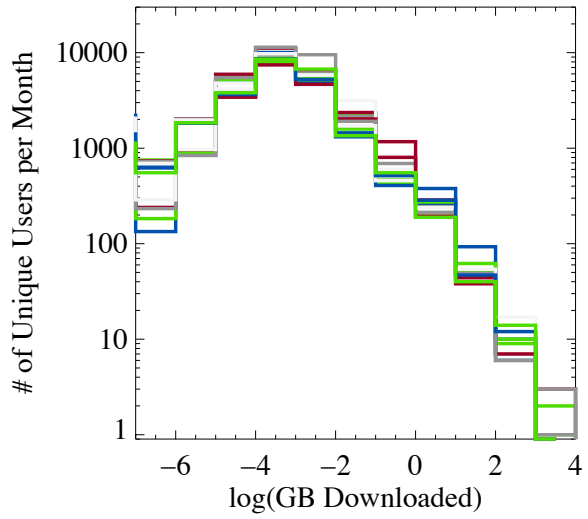
- *Helpdesk* some tickets are simple, others extremely complex
- *Documentation*
  - *tools/data releases*
  - *updates in response to tickets*
  - *Handouts*
- *Demos*
  - *Live (AAS, ADASS, DPS)*
  - *Video tutorials (IRSA has 60 videos; 3,000 views total)*

- The complexity of Science User needs increases with time.

VO broadens audience and API supports power users

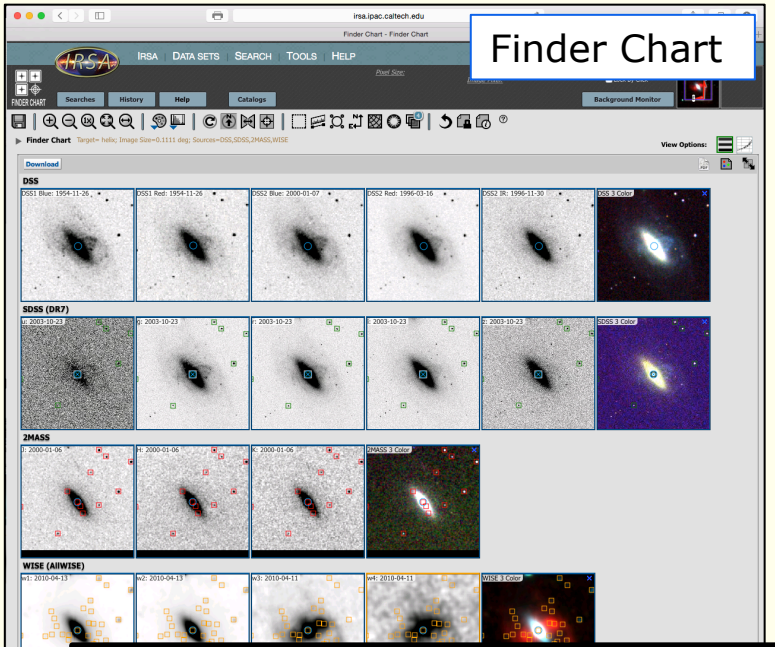
- Virtual Observatory
  - *Standardized protocols for interoperability between archives*
  - *Data discovery*
- Application Program Interface
  - *Allows scripted access to archive data*
  - *Enables complex projects*

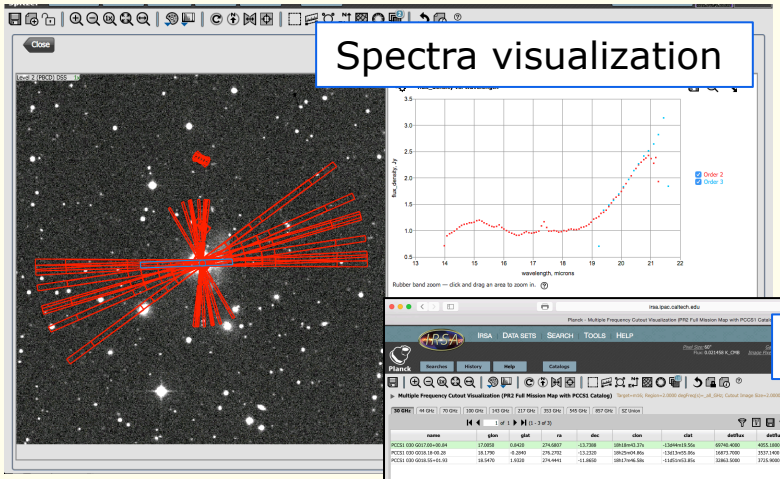


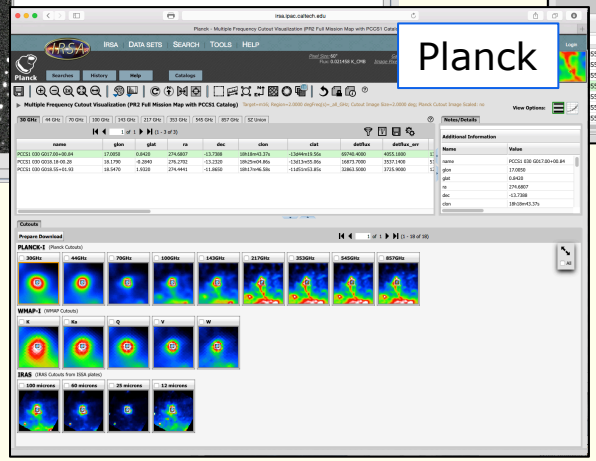


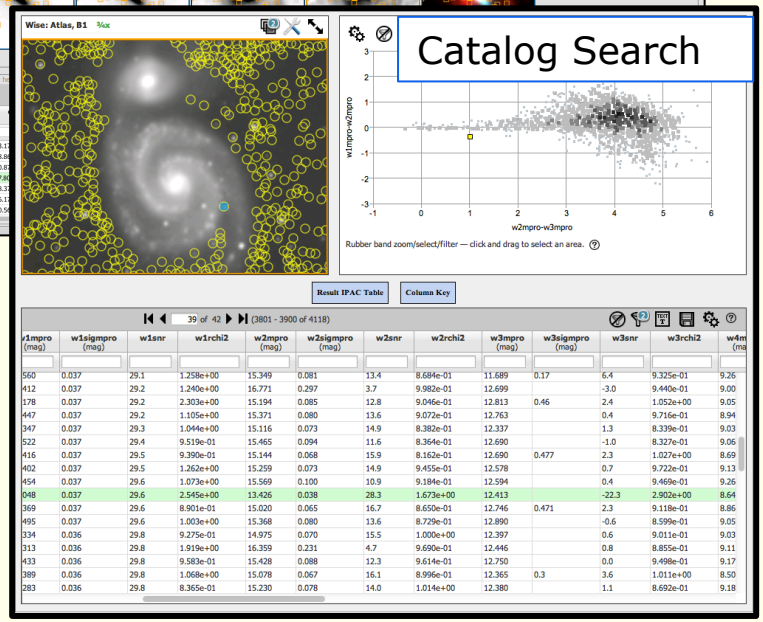
Data Exploration Services broaden audience and support non-power users.

- Search & display can be tailored to various instrument/science contexts, using reusable visualization components
- Combining images, plots, tables, spectra
- Supports observation planning









Lessons Learned

- Long-term, stable archives greatly increase the return on observatory investment

- Robust support for both expert and novice users pays off
- User support by instrument experts is crucial
- Standardization of tools within an archive increases efficiency
- Integrity of science data as obtained must be maintained
- Interoperability between archives benefits everyone
- High level data products can expand the reach of large data sets

Spitzer image of infrared dark clouds