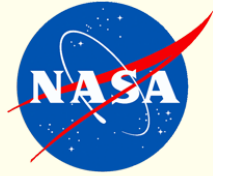


Caltech



Astrophysics Archives at IPAC

Harry Teplitz



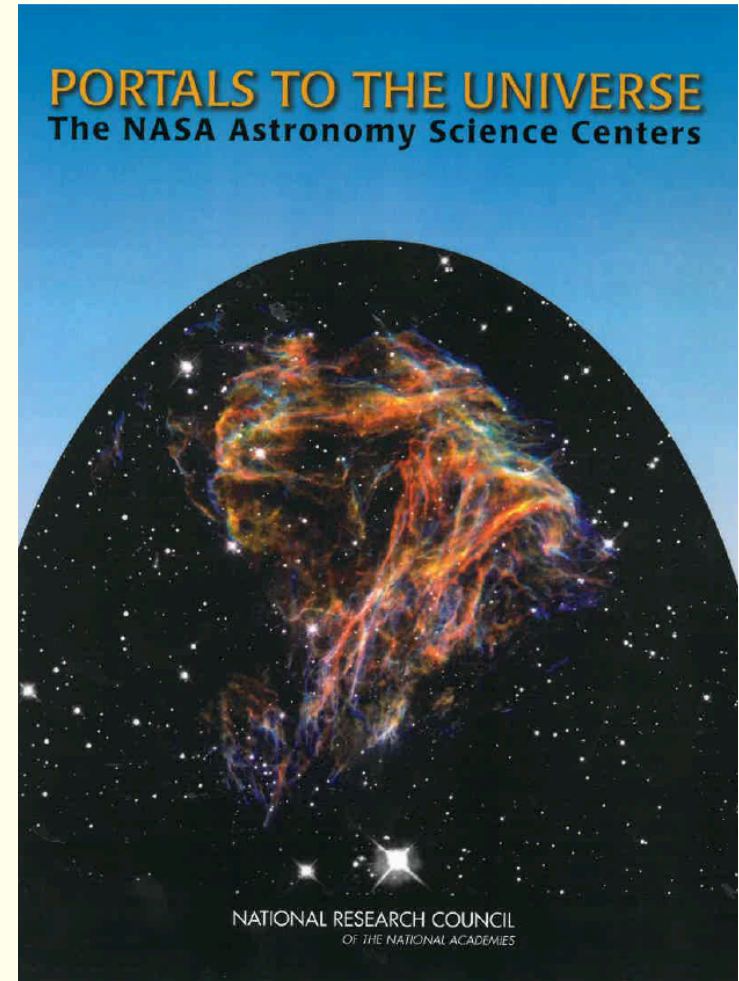
NASA's Commitment to Astrophysics Data Archives

- ◆ "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."



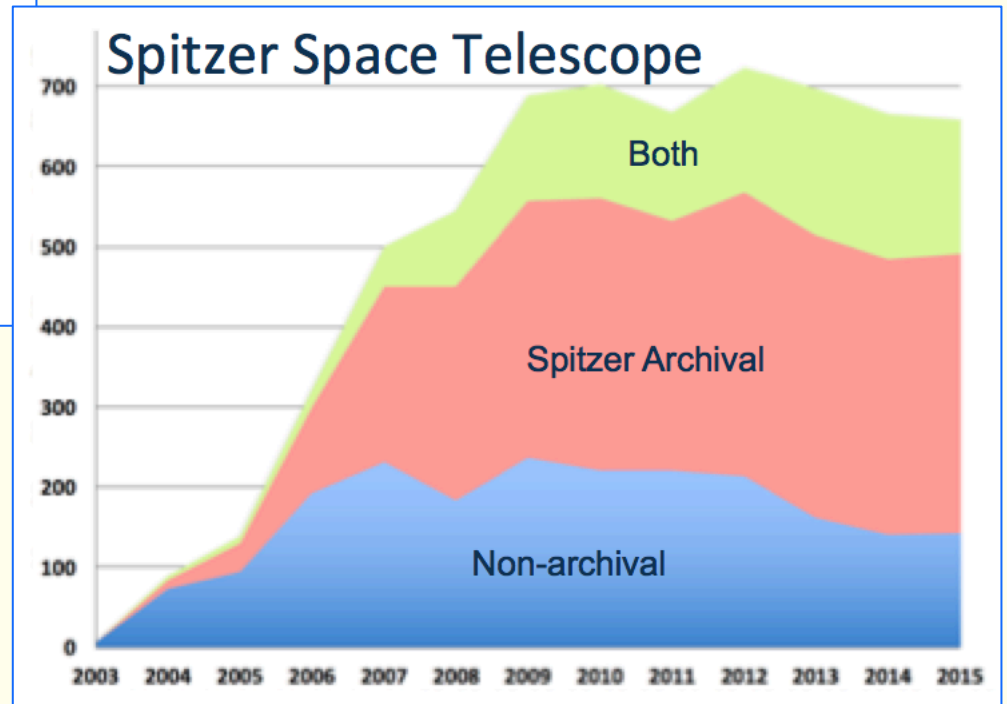
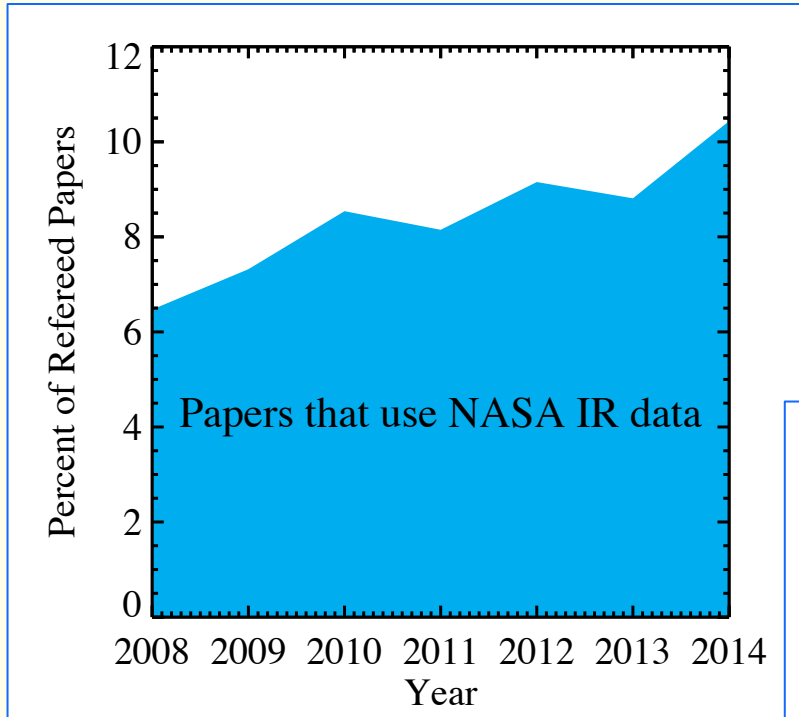
“A Sustainable Archive”

- ◆ 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





Archives Double the Number of Papers from the Observatory

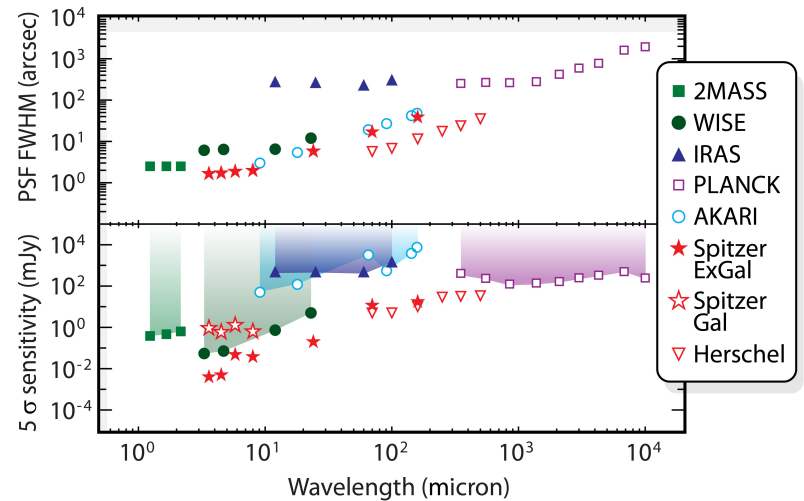




IRSA : NASA's IR/sub-mm archive

- ◆ 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 (now > 1 PB);
 - ❖ # table rows increased by factor of 15 (>100 billion)
 - ❖ Almost 40 million queries in 2016



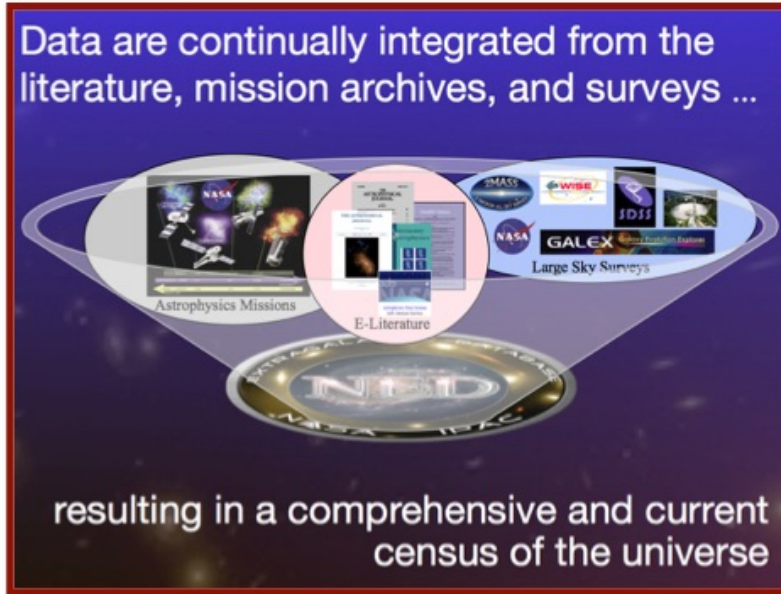
- All-sky 20 photometric bands from 1 micron to 1 cm
- About 40% of approved ADAP programs involve analysis of IR data sets



NED : managing complex data sets



Overview – NED in a Nutshell



NED is where you find...

- Objects with $z > 2.0$ and available GALEX NUV flux
- Most precise z -independent distance measurement to M82
- SED, spanning gamma-rays through radio, for quasar 3C 279
- Spiral galaxies with stellar bars and Type 2 AGNs

Published:

- Names
- (α, δ)
- Redshifts
- D_{10pc}
- Fluxes
- Sizes
- Attributes
- References
- Notes

Contributed:

- Images
- Spectra

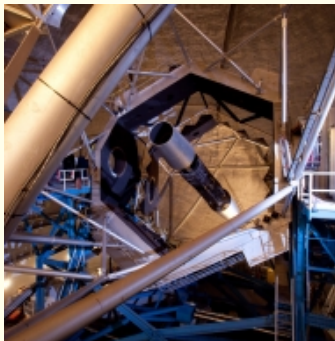
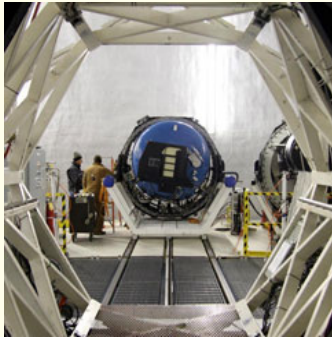
Derived:

- Distances
- Metric sizes
- Luminosities
- Velocity corrections
- Cosmological corrections
- SEDs
- A_{λ}

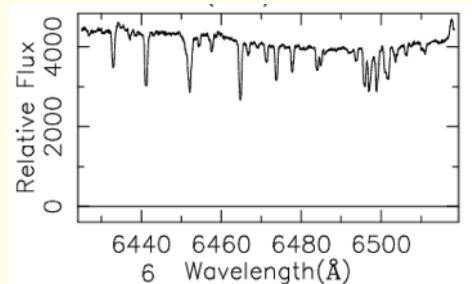


Extragalactic papers have grown to 3,500 per year, with unique measurements for millions of objects

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).*



NASA EXOPLANET ARCHIVE

A SERVICE OF NASA EXOPLANET SCIENCE INSTITUTE

FOR THE PUBLIC
PLANETQUEST

- Home
- About the Archive
- Data
- Tools
- User Guides & Help Desk

3,375 Confirmed Planets
08/25/2016 →

570 Multi-Planet Systems
08/25/2016 →

4,696 Kepler Candidates
09/18/2015 →

View more Planet and Candidate statistics →

Explore the Archive

Search

? Advanced Search →

Transit Surveys 21,853,310 Light Curves

The first space mission to search for Earth-sized and smaller planets in the habitable zone of other stars in our neighborhood of the galaxy.

Light Curves →	Objects of Interest (KOI) →
Threshold-Crossing Events →	Search Stellar Data →
Completeness and Reliability Products →	Documentation →

Kepler
K2
KELT
SuperWASP
More

Meet the New Neighbor: Proxima Cen b

August 25, 2016 • New Data

Proxima Centauri b, the new Earth-sized planet that has the astronomy world buzzing this week, is in the Archive. To view its parameters, click to see its Planet Overview page.

News →
1 2 3 4
Plots →
1 2 3 4

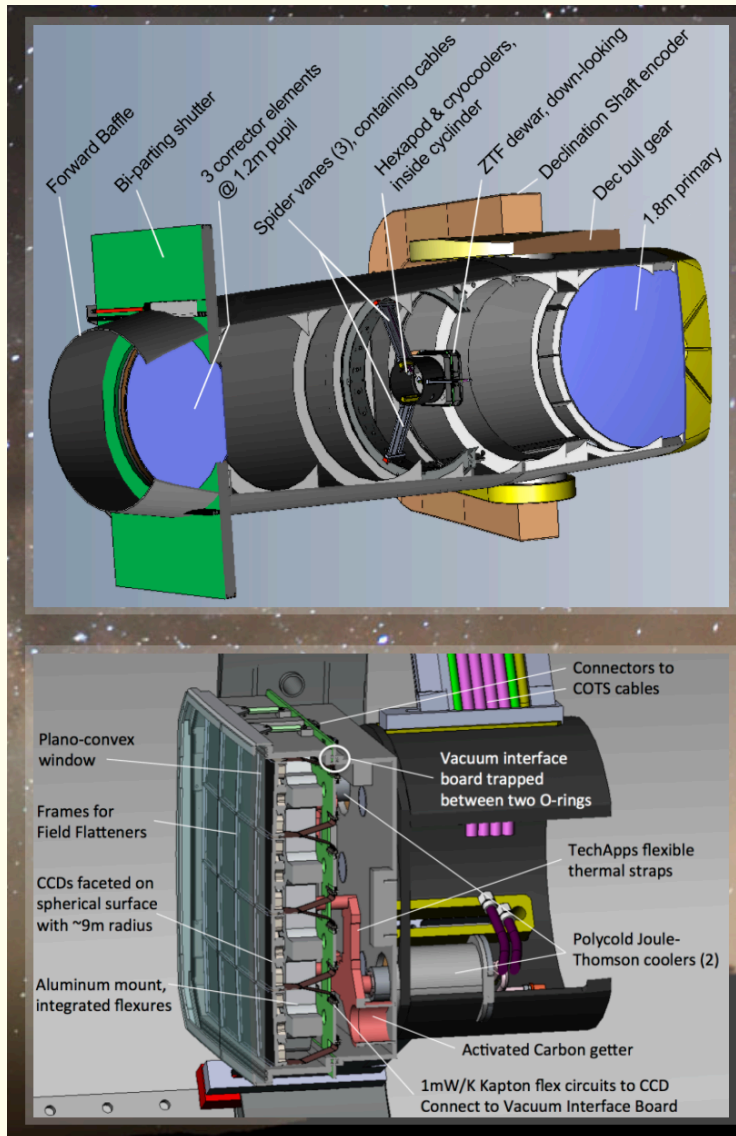
Tools & Services

Periodogram →	Predicted Observables for Exoplanets Service →
Transit and Ephemeris Service →	Build a Query (API) →
Search Interactive Tables →	Search Extended Planet Data →

Work with Data

Confirmed Planets Plotting Tool →	Confirmed Planets Table →
Search K2 Targets →	Bulk Download Service →
Transit Spectroscopy →	ExoFOP →

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



- ◆ **Palomar Observatory**
 - ❖ *Zwicky 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.*



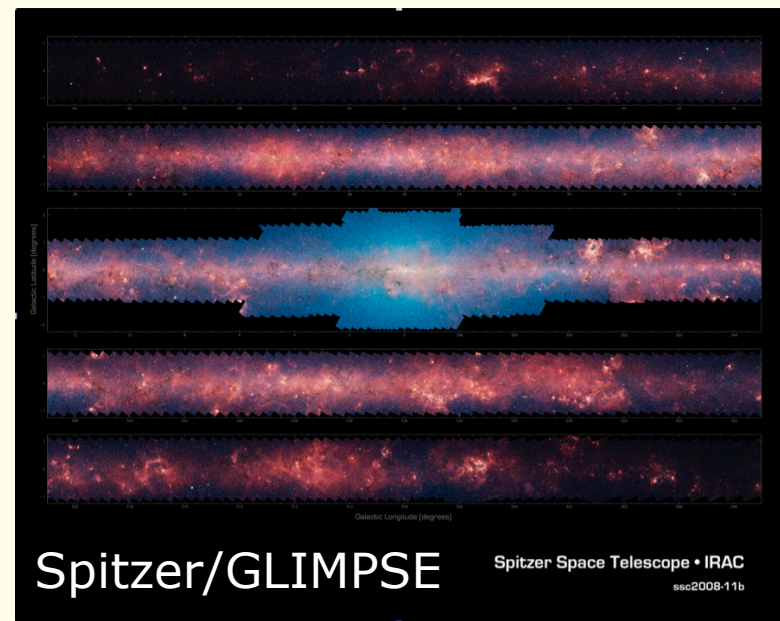
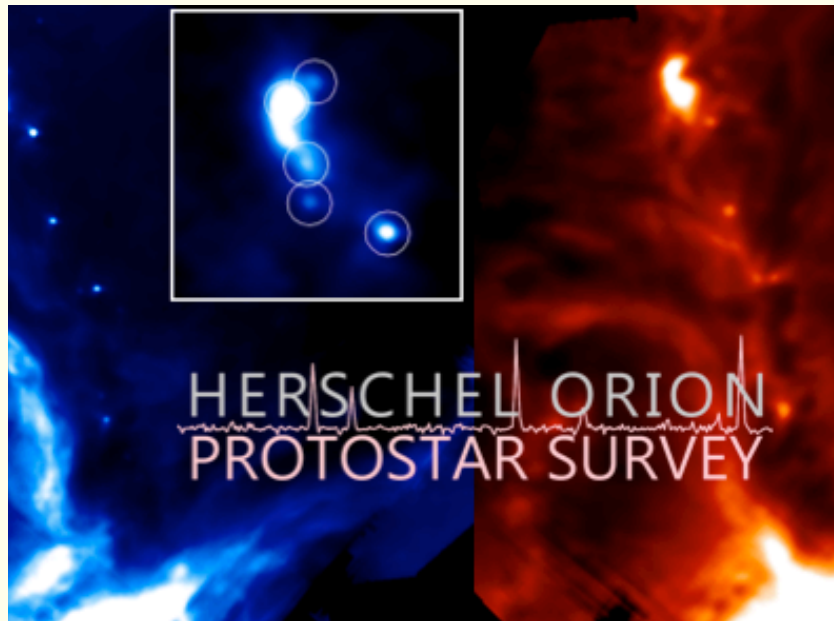
An Archive's Job

- ◆ 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
 - ❖ *Herschel Key Projects*
 - ❖ *Spitzer Legacy and Exploration Science*
- ◆ Generated by the community or by the archive



Technical Synergy and Innovation



- ◆ IRSA implemented innovative indexing techniques for NEO/WISE, optimized to meet the required use cases for database queries
 - ❖ *single position spatial searches (using a recursively subdivided triangular mesh)*
 - ❖ *simultaneous matching of large user-supplied lists of positions (using a file-based index outside of the database).*
- ◆ Challenges presented by WISE were used as opportunities to extend IPAC's capabilities
 - ❖ *ZTF will require databases that are at least an order of magnitude larger*



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)*
- ◆ The complexity of Science User needs increases with time.



Data Exploration and Visualization Services

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

Spectra visualization

Planck

name	glon	glat	ra	dec	class	class	distArc	distArc_err
PC031 030 020 020 00 00	17.085	0.428	274.6807	-13.729	1891643.37%	8776.400	405.180	
PC031 030 020 010 00 00	16.976	-0.288	276.2762	-13.202	1892040.0%	8973.100	373.150	
PC031 030 020 010 00 00	16.878	0.102	274.4441	-11.402	1891746.53%	3263.500	375.500	

Finder Chart

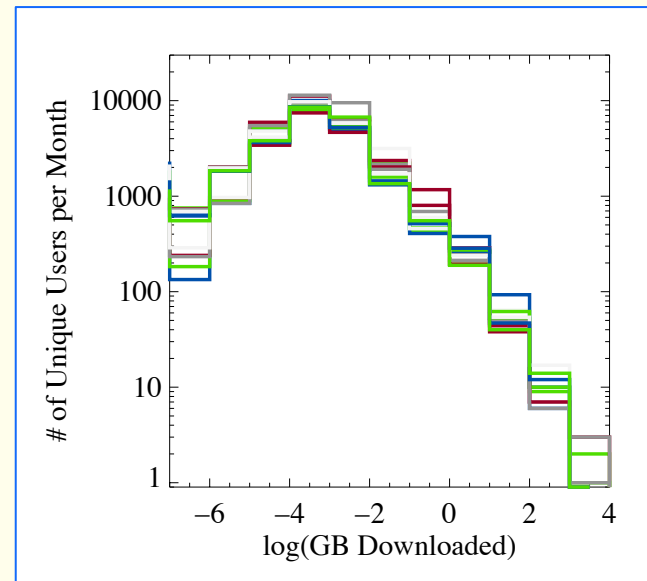
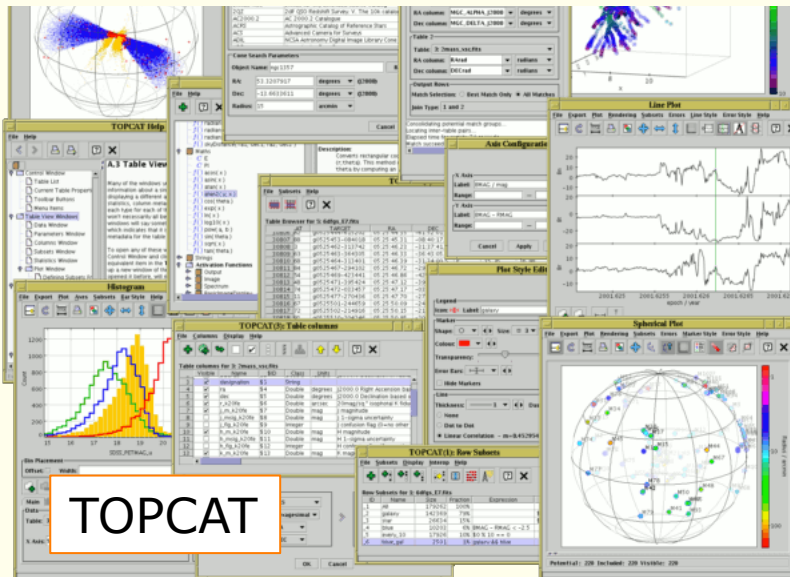
Catalog Search

	l1mpro	w1sigmpro	w1snr	w1rch2	w2mpro	w2sigmpro	w2snr	w2rch2	w3mpro	w3sigmpro	w3snr	w3rch2	w4m
560	0.037	29.1	1.258e+00	15.349	0.081	13.4	8.684e-01	11.689	0.17	6.4	9.325e-01	9.26	
412	0.037	29.2	1.240e+00	16.771	0.297	3.7	9.982e-01	12.699		-3.0	9.440e-01	9.00	
178	0.037	29.2	2.303e+00	15.194	0.065	12.8	9.046e-01	12.813	0.46	2.4	1.052e+00	9.05	
447	0.037	29.2	1.105e+00	15.371	0.080	13.6	9.072e-01	12.763		0.4	9.716e-01	8.94	
347	0.037	29.3	1.044e+00	15.116	0.073	14.9	8.382e-01	12.337		1.3	8.339e-01	9.03	
522	0.037	29.4	9.519e-01	15.465	0.094	11.6	8.364e-01	12.690		-1.0	8.327e-01	9.06	
416	0.037	29.5	9.390e-01	15.144	0.068	15.9	8.162e-01	12.690	0.477	2.3	1.027e+00	8.69	
402	0.037	29.5	1.262e+00	15.259	0.073	14.9	9.455e-01	12.578		0.7	9.722e-01	9.13	
454	0.037	29.6	1.073e+00	15.569	0.100	12.8	9.184e-01	12.594		0.4	9.469e-01	9.26	
548	0.037	29.6	2.545e+00	13.426	0.038	28.3	1.673e+00	12.413		-22.3	2.902e+00	8.64	
369	0.037	29.6	8.901e-01	15.020	0.065	16.7	8.650e-01	12.746	0.471	2.3	9.118e-01	8.86	
495	0.037	29.6	1.003e+00	15.368	0.080	13.6	8.729e-01	12.890		-0.6	8.599e-01	9.05	
334	0.036	29.8	9.275e-01	14.975	0.070	15.5	1.000e+00	12.397		0.6	9.011e-01	9.03	
313	0.036	29.8	1.919e+00	16.359	0.231	4.7	8.690e-01	12.446		0.8	8.855e-01	9.11	
423	0.036	29.8	9.583e-01	15.428	0.088	12.3	9.614e-01	12.750		0.0	9.498e-01	9.17	
389	0.036	29.8	1.068e+00	15.078	0.067	16.1	8.996e-01	12.365	0.3	3.6	1.011e+00	8.50	
283	0.036	29.8	8.365e-01	15.230	0.078	14.0	1.014e+00	12.380		1.1	8.692e-01	9.18	



VO broadens audience; API supports diverse users

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





Data Analysis Tools

- ◆ Analysis “near the data”
 - ❖ *As data sets grow beyond local resources, researchers look to data centers to provide computing power and tools*
- ◆ Interactive tools
 - ❖ *WISE Coadder*
 - ❖ *Planck map making*
 - ❖ *IRAS tools*
 - ❖ *Spitzer imaging and spectra*
- ◆ Looking Forward
 - ❖ *“Big data means you can’t move it all”, suggesting the analysis must move to the data*

The screenshot shows the NASA/IPAC Infrared Science Archive (IRSA) website. The main heading is "NASA/IPAC INFRARED SCIENCE ARCHIVE" with navigation links for IRSA, DATA SETS, SEARCH, TOOLS, and HELP. The specific tool is the "WISE/NEOWISE Coadder".

The interface includes a "Submit" button and a "Reset" button. Below these are three tabs: "Single Position" (selected), "Multiple Positions", and "Moving Object/Stacking".

The form fields are as follows:

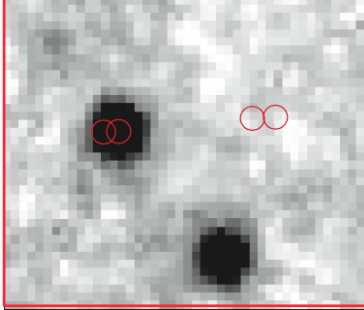
- Coordinates/Object Name:** 185.47898 4.47359
- Coordinate Examples:** Default is Equatorial J2000. Example: 202.46963 +47.19517 | 13h 29m 52.71s +47d 11m 42.6s Equ J2000 | 104.85135 +68.56084 gal
- WISE band number:** 1 [1, 2, 3, or 4]
- Output coadd X size:** 0.03 [0.003 - 3.0 deg]
- Output coadd Y size:** 0.03 [0.003 - 3.0 deg]
- Rotation angle of output coadd (+Y axis W of N):** 0 [0 - 360 deg]
- Output coadd pixel size:** 1.0 [≥ 0.3 arcsec]
- Click for Point-Source Response weighted interpolation:**
- Click for resolution enhancement (HiRes):**
- Image Selection (if needed):**
 - Minimum allowed frame quality:** 5 [5 or 10, since qual_frame has values 0(worst), 5, 10(best) and 0 is currently excluded.]
 - Minimum distance from Moon:** 20.0 [0 - 180 deg]
 - Minimum distance from South Atlantic Anomaly (SAA) edge:** 0.0 [-25 - 180 deg, but ≥ 0 best]
 - Earliest observation date (UTC):** 07Jan2010 01:45:14 [ddmmmyyyy hh:mm:ss]



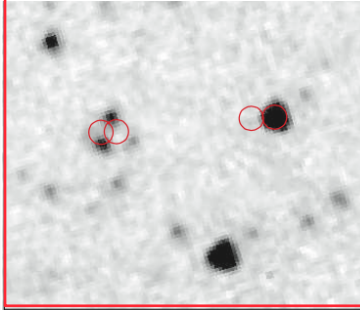
IR Science Highlights

Time domain

WISE 4.5 μ m (2010)

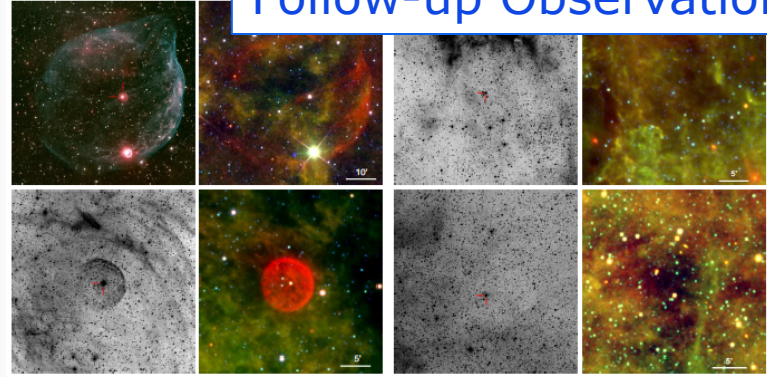


Spitzer 4.5 μ m (2014)

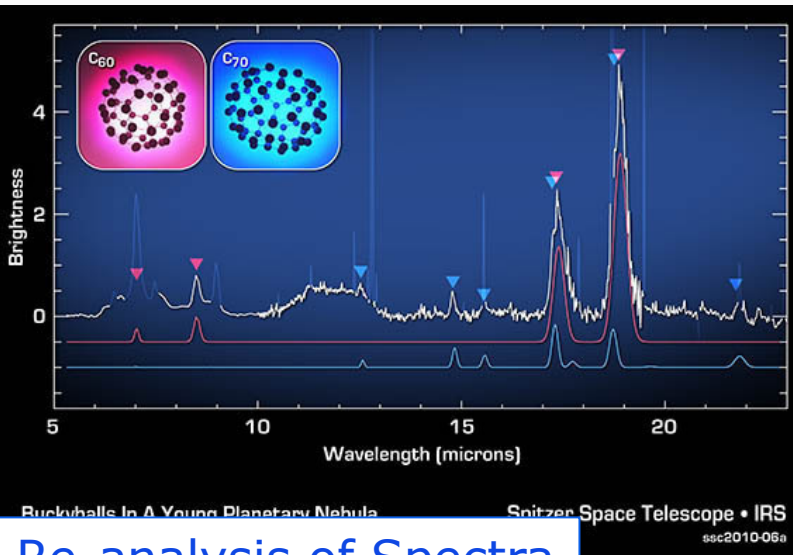


WISE+Spitzer discover the coldest brown dwarf (Luhman 2014, ApJL 786, L18)

Follow-up Observations

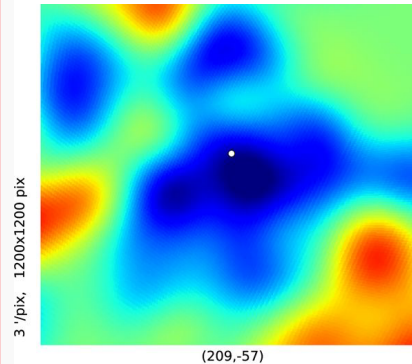


WISE morphological study of Wolf-Rayet nebulae, Toala et al. (A&A 2015, arXiv:1503.06878)

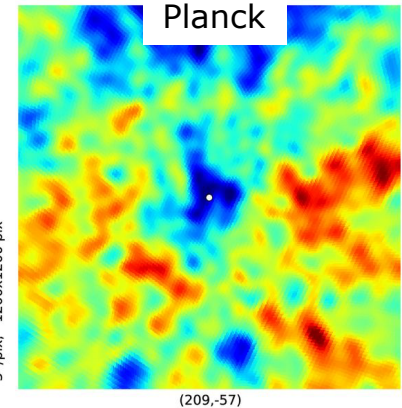


Re-analysis of Spectra

WISE+2MASS galaxies



Planck



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

Combination of Surveys

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