Caltech

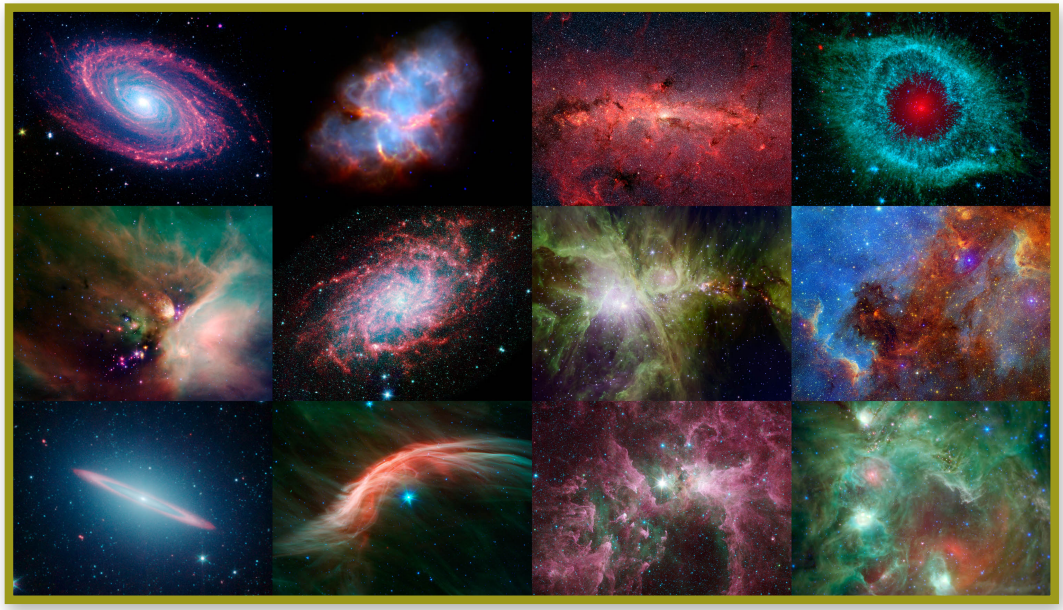
Infrared Processing and Analysis Center

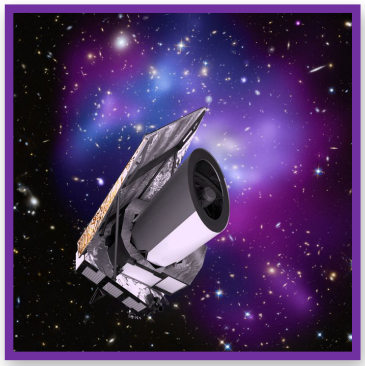
# Astrophysics Archives at IPAC

Steve Groom

# IPAC's Mission

- **Science & Data Center for Astrophysics & Planetary Sciences, located at Caltech**
- Science operations, data archives, and community support for astronomy and planetary science missions
- Special emphasis on infrared-submillimeter astronomy and exoplanet science
- Science Center functions for NASA missions and privately funded projects





# NASA's Commitment to Astrophysics Data Archives

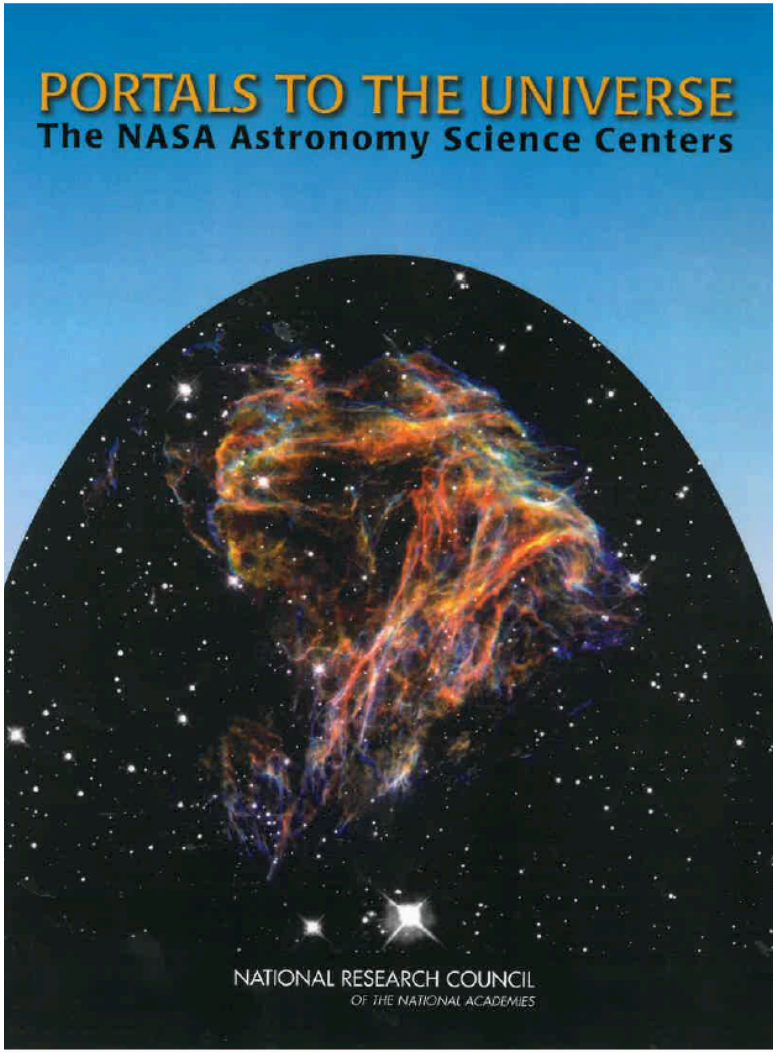
- "NASA has regarded data handling and archiving as an integral part of space missions."

- "This support now provides the major return on the considerable investment the agency made… over the past 20 years."

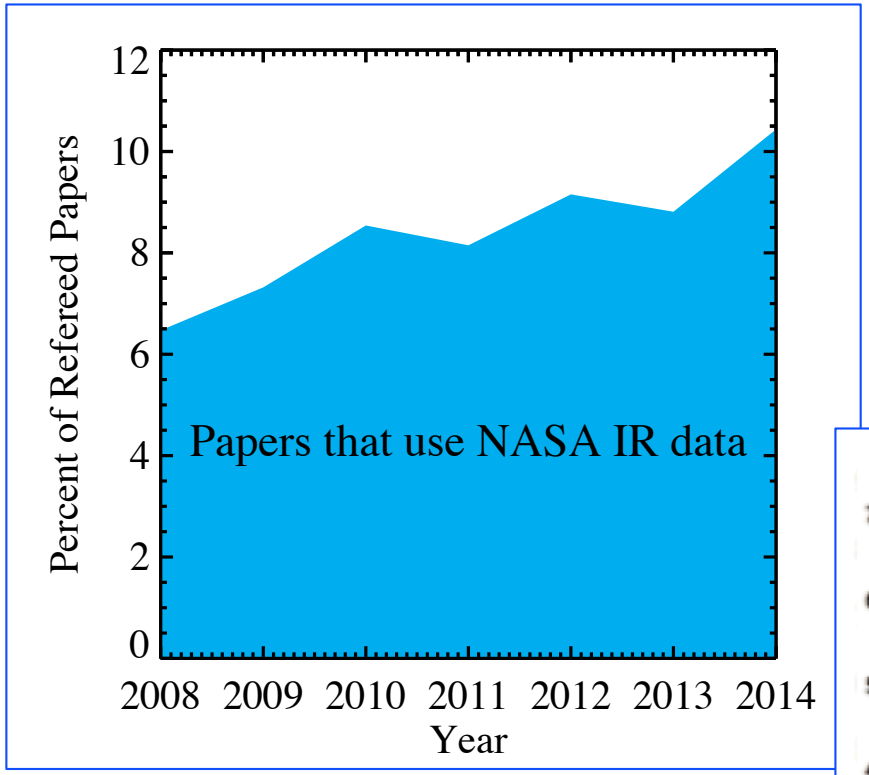
# Sustainable Archives

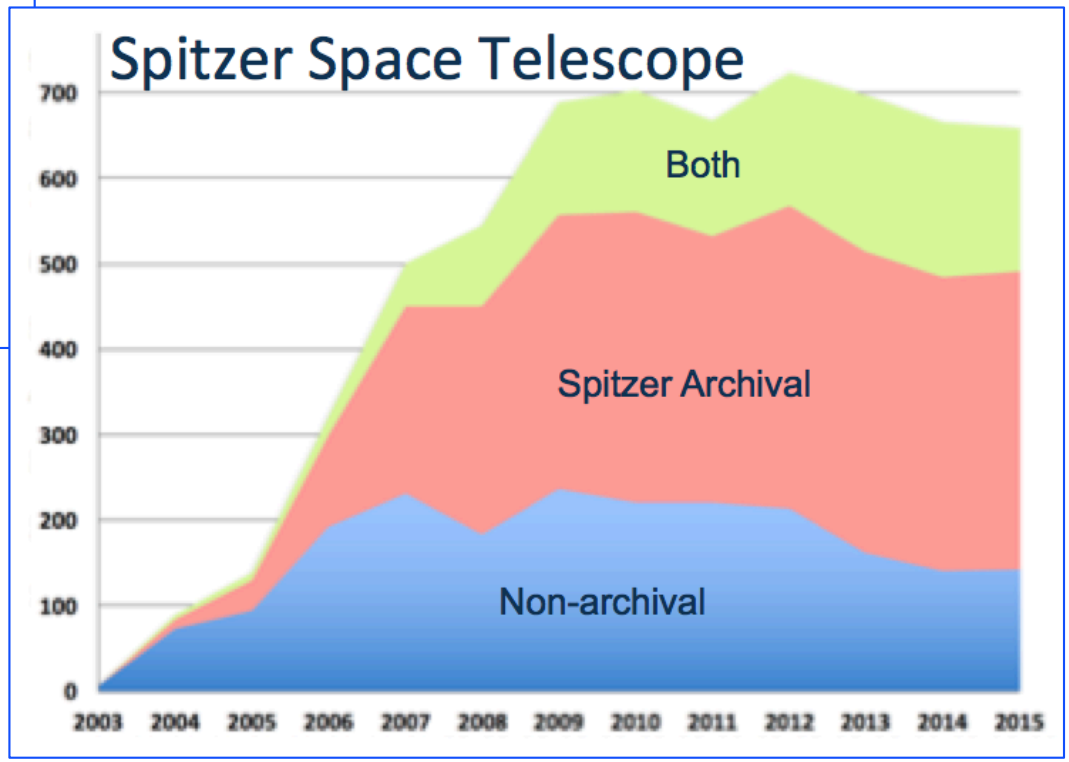
- Continually facilitates production of new scientific results
- Contains high-quality, reliable data
- Provides simple and useful tools to a broad community
- Provides user support to the novice as well as to the power user

*"Successful research using archival data sets is dependent on the resident expertise and corporate memory that resides at the science centers."*



# Archives Double the Number of Papers from the Observatory



# Recent News

"All the News That's Fit to Print"

The New York Times

Late Edition

Today, patchy morning fog, partly sunny, warm, high 64. Tonight, mostly cloudy, mild, low 52. Tomorrow, clouds and sunshine, showers, high 66. Weather map is on Page B9.

VOL. CLXVI ... No. 57,517 © 2017 The New York Times Company NEW YORK, THURSDAY, FEBRUARY 23, 2017 $2.50

A rendering of newly discovered Earth-size planets orbiting a dwarf star named Trappist-1 about 40 light-years from Earth. Some of them could have surface water.

JPL-CALTECH/NASA

## Circling a Star Not Far Away, 7 Shots at Life

By KENNETH CHANG

Not just one, but seven Earth-size planets that could potentially harbor life have been identified orbiting a tiny star not too far away, offering the first realistic opportunity to search for signs of alien life outside the solar system.

The planets orbit a dwarf star named Trappist-1, about 40 light-years, or 235 trillion miles, from Earth. That is quite close in cosmic terms, and by happy accident, the orientation of the orbits of the seven planets allows them to be studied in great detail.

One or more of the exoplanets in this new system could be at the right temperature to be awash in oceans of water, astronomers said, based on the distance of the planets from the dwarf star.

"This is the first time so many planets of this kind are found around the same star," Michael Gillon, an astronomer at the University of Liege in Belgium and the leader of an international team that has been observing Trappist-1, said during a telephone news conference organized by the

Continued on Page A17

## Uber's Culture Of Gutsiness Under Review

By MIKE ISAAC

SAN FRANCISCO — When new employees join Uber, they are asked to subscribe to 14 core company values, including making bold bets, being "obsessed" with the customer, and "always be hustlin'." The ride-hailing service particularly emphasizes "meritocracy," the idea that the best and brightest will rise to the top based on their efforts, even if it means stepping on toes to get there.

Those values have helped propel Uber to one of Silicon Valley's biggest success stories. The company is valued at close to $70 billion by private investors and now operates in more than 70 countries.

Yet the focus on pushing for the best result has also fueled what current and former Uber employees describe as a Hobbesian environment at the company, in which workers are sometimes pitted against one another and where a blind eye is turned to infractions from top performers.

Interviews with more than 30 current and former Uber

Continued on Page A18

## Migrants Hide, Fearing Capture on 'Any Corner'

By VIVIAN YEE

No going to church, no going to the store. No doctor's appointments for some, no school for others. No driving, period — not when a broken taillight could deliver the driver to Immigration and Customs Enforcement.

It is happening in the Central Valley of California, where undocumented immigrants pick the fields for survival wages but are keeping their children home from school; on Staten Island, where fewer day laborers haunt street corners in search of work; in West Phoenix's Isaac School District, where 13 Latino students have dropped out in the past two weeks; and in the horse country of northern New Jersey, where one of the many undocumented grooms who muck out the stables is thinking of moving back to Honduras.

If deportation has always been a threat on paper for the 11 million people living in the country illegally, it rarely imperiled those who did not commit serious crimes. But with the Trump administration intent on curbing illegal immigration — two memos outlining the federal government's plans to accelerate deportations were released Tuesday, another step toward making good on one of President Trump's signature campaign pledges — that threat, for many people, has now begun to distort every movement.

Continued on Page A14

**IMMIGRATION** A police department worries a crackdown will harm work to fight gangs. PAGE A14

**MEXICO** The secretary of state pays a visit at a time of rising tensions. PAGE A15

## TRUMP RESCINDS OBAMA DIRECTIVE ON BATHROOM USE

ENTERING CULTURE WARS

Question of Transgender Rights Splits DeVos and Sessions

*This article is by Jeremy W. Peters, Jo Becker and Julie Hirschfeld Davis.*

WASHINGTON — President Trump on Wednesday rescinded protections for transgender students that had allowed them to use bathrooms corresponding with their gender identity, overruling his own education secretary and placing his administration firmly in the middle of the culture wars that many Republicans have tried to leave behind.

In a joint letter, the top civil rights officials from the Justice Department and the Education Department rejected the Obama administration's position that nondiscrimination laws require schools to allow transgender students to use the bathrooms of their choice.

That directive, they said, was improperly and arbitrarily devised, "without due regard for the primary role of the states and local school districts in establishing educational policy."

The question of how to address the "bathroom debate," as it has become known, opened a rift inside the Trump administration, pitting Education Secretary Betsy DeVos against Attorney General Jeff Sessions. Mr. Sessions, who had been expected to move quickly to roll back the civil rights expansions put in place under his Democratic predecessors, wanted to act decisively because of two pending court cases that could have upheld the protections and pushed the government into further litigation.

But Ms. DeVos initially resisted signing off and told Mr. Trump that she was uncomfortable because of the potential harm that rescinding the protections could cause transgender students, according to three Republicans with direct knowledge of the internal discussions.

Mr. Sessions, who has opposed expanding gay, lesbian and transgender rights, pushed Ms. DeVos to relent. After getting nowhere, he took his objections to the White House because he could not go

nature

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

*Seven potential Earth-like worlds orbiting low-mass star TRAPPIST-1*

PAGES 421 & 456

PLANET SUITE

EPITRANSCRIPTOMICS

CAUGHT IN TRANSLATION

*Tracking the chemical tags on RNA*

PAGES 406 & 503

REPRODUCIBILITY

PUT TO THE TEST

*Add independent preclinical trials to biomedical papers*

PAGE 409

CLIMATE SCIENCE

A MODEL FOR MELTING

*Predictability of ice ages affirmed*

PAGES 419, 427 & 468

NATURE.COM/NATURE

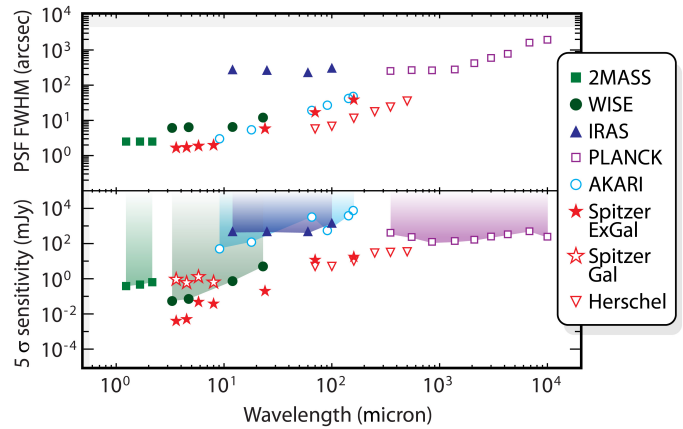
23 February 2017 £10

Vol. 542, No. 7642

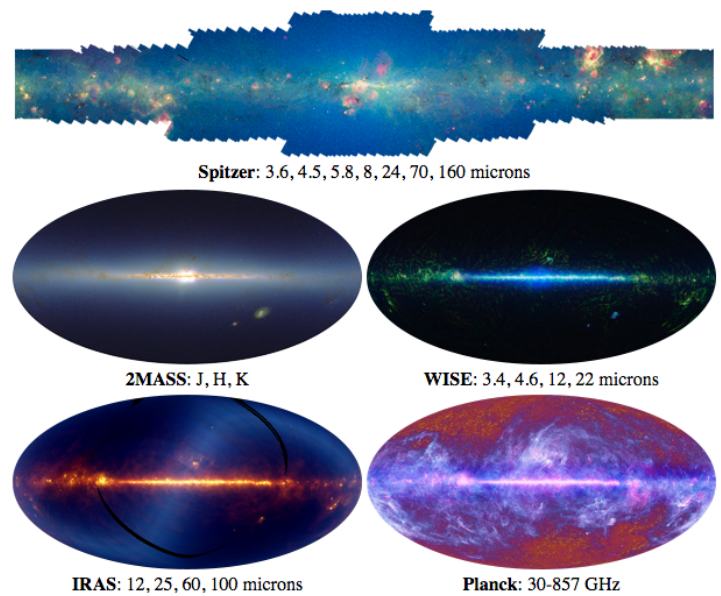
23 Feb 2017: Spitzer followup of TRAPPIST-1 ground-based observations reveals 7 Earth-sized planets around a nearby star, 3 of them in Habitable Zone

# 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*



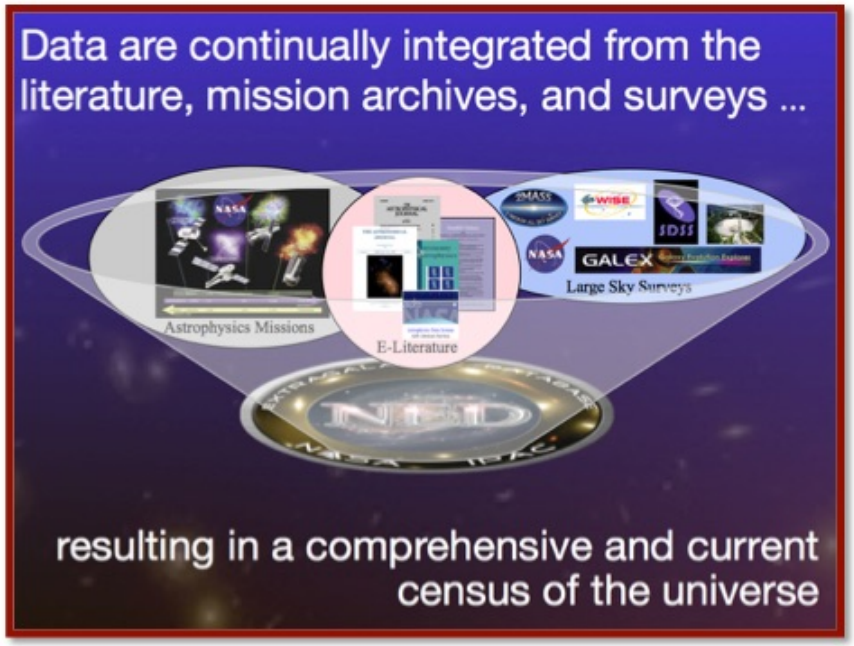

- IRSA is continuing rapid expansion
  - *Since 2011, holdings more than doubled (now > 1 PB);*
  - *# table rows increased by factor of 15 (>120 billion)*
  - *Almost 40 million queries in 2016*




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

# NED : managing complex data sets

## Overview – NED in a Nutshell




**Published:**
- Names
- (α,δ)
- Redshifts
- $D_{Mpc}$
- Fluxes
- Sizes
- Attributes
- References
- Notes

**Contributed:**
- Images
- Spectra

***Derived:***
- *Distances*
- *Metric sizes*
- *Luminosities*
- *Velocity corrections*
- *Cosmological corrections*
- *SEDs*
- $A_\lambda$

***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

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

Infrared Processing and Analysis Center

# NASA EXOPLANET ARCHIVE

A SERVICE OF NASA EXOPLANET SCIENCE INSTITUTE

FOR THE PUBLIC PLANETQUEST

Home | About Us | Data | Tools | Support | Login

3,458 Confirmed Planets 03/02/2017

578 Multi-Planet Systems 03/02/2017

4,696 Kepler Candidates 09/18/2015

View more Planet and Candidate statistics

## Explore the Archive

Name or Coordinates | Search

Optional Radius (arcsec)

Advanced Search

## Transit Surveys

22,649,919 Light Curves

Kepler

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.

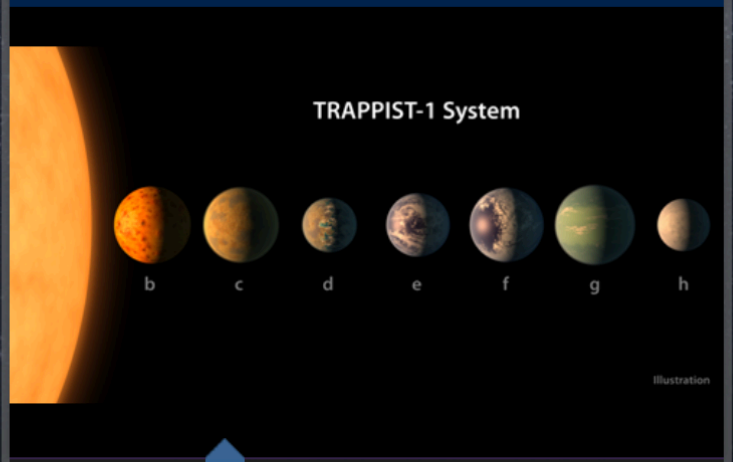
- Light Curves
- Objects of Interest (KOI)
- Threshold-Crossing Events
- Search Stellar Data
- Completeness and Reliability Products
- Documentation

Kepler | K2 | KELT | SuperWASP | More

## New TRAPPIST Planet Data Added!

**February 22, 2017 • New Data**

We've added data for the TRAPPIST-1 system confirmed to have seven Earth-size planets, some of which are in the habitable zone. (Click for details)




News 1 2 3 4 | Plots 1 2 3 4

## Tools & Services

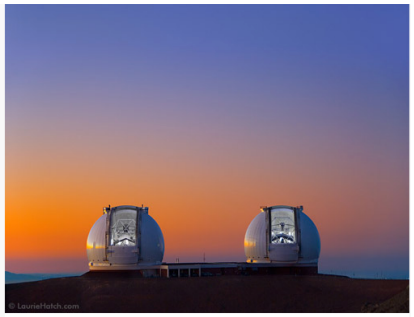
- Periodogram
- Predicted Observables for Exoplanets Service
- Transit and Ephemeris Service
- Build a Query (API)
- Search Interactive Tables
- Search Extended Planet Data
- Bulk Download Service
- Confirmed Planets Plotting Tool

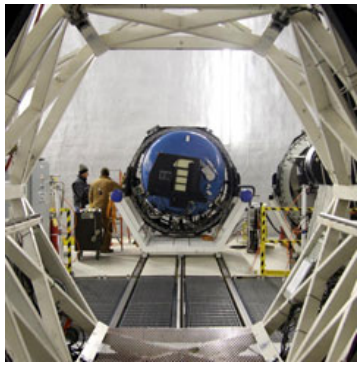
## Work with Data

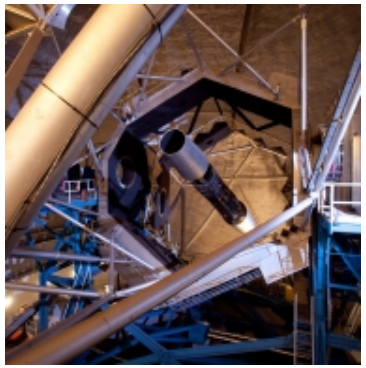
- Mission Stars
- Confirmed Planets
- Emission Spectroscopy
- Pre-Generated Plots
- Transmission Spectroscopy
- ExoFOP
- Microlensing Planets
- Contributed Data

FAQ | Documentation | Videos | Contact Us

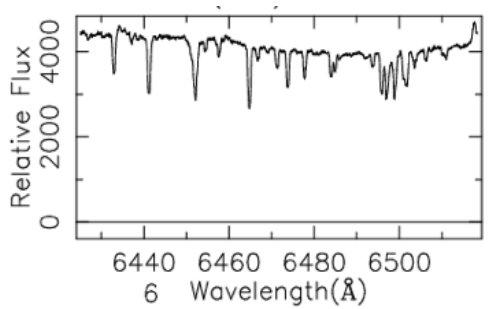
# The Keck Observatory Archive





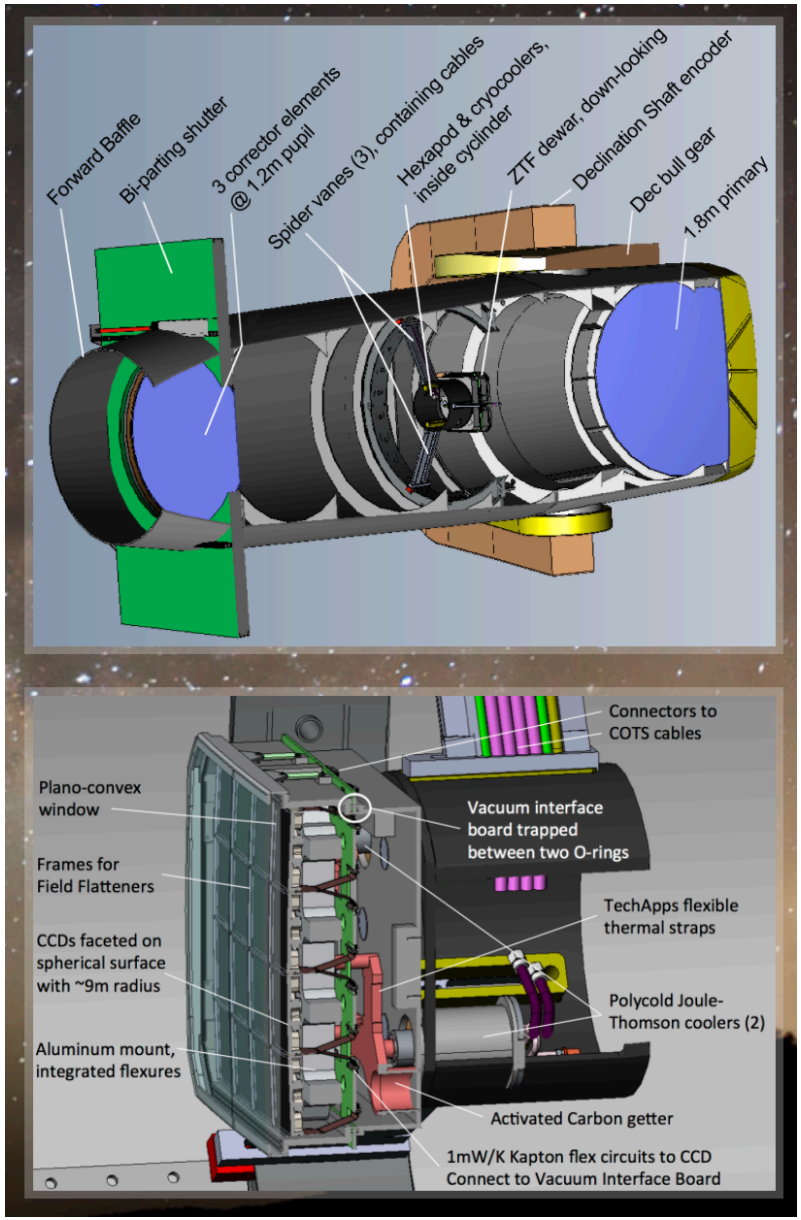


- NASA-funded collaboration between WMKO and IPAC/NExScI.
- Started with HIRES
- Systematic/automated capture of metadata ensures efficiency
- Now data from all ten instruments since their dates of commissioning
  - *decommissioned instruments Summer 2015.*
  - *proprietary period of at least 18 mo.*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




- **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.*

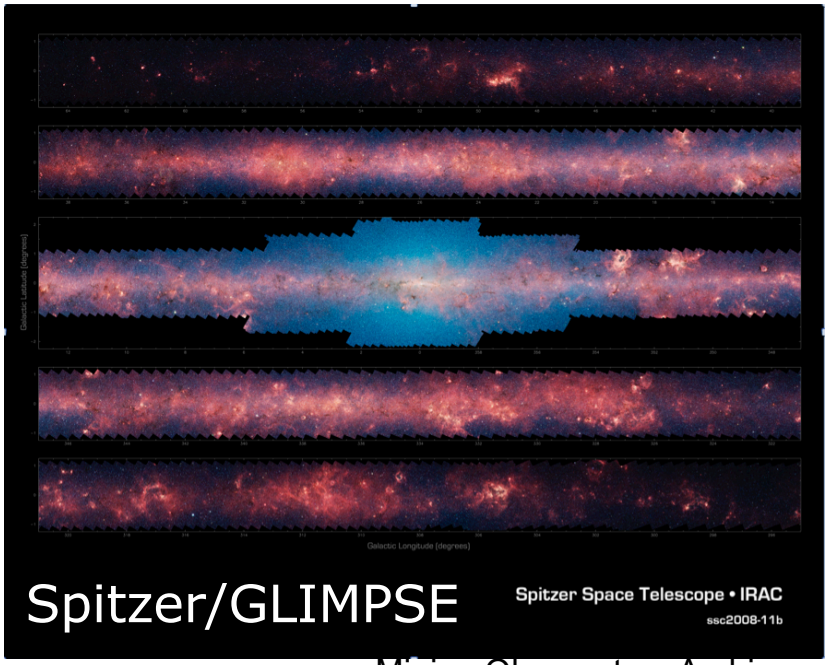
# An Archive's Job

*"Enabling research that has not yet been envisioned"*

- Ingestion of 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*

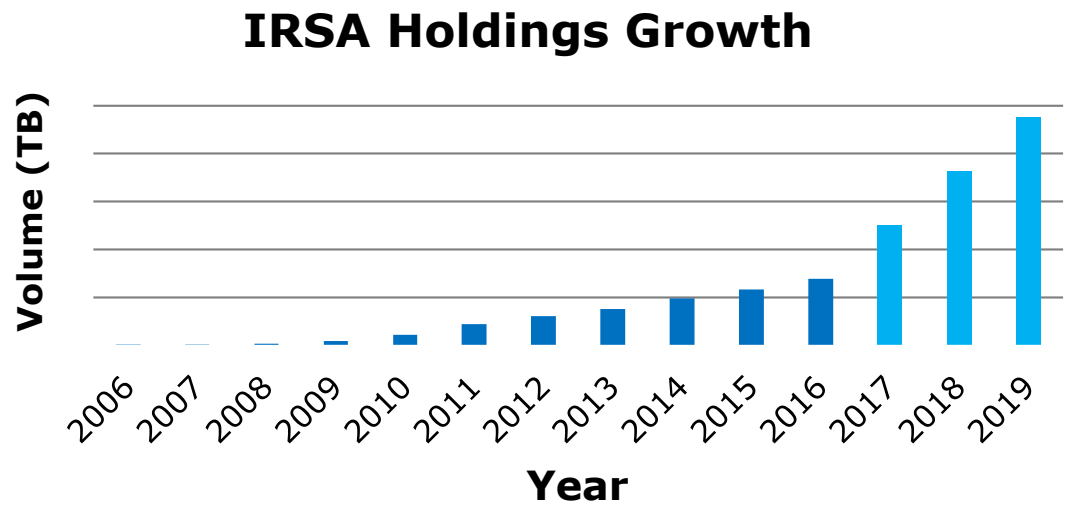
# High Level Science Products

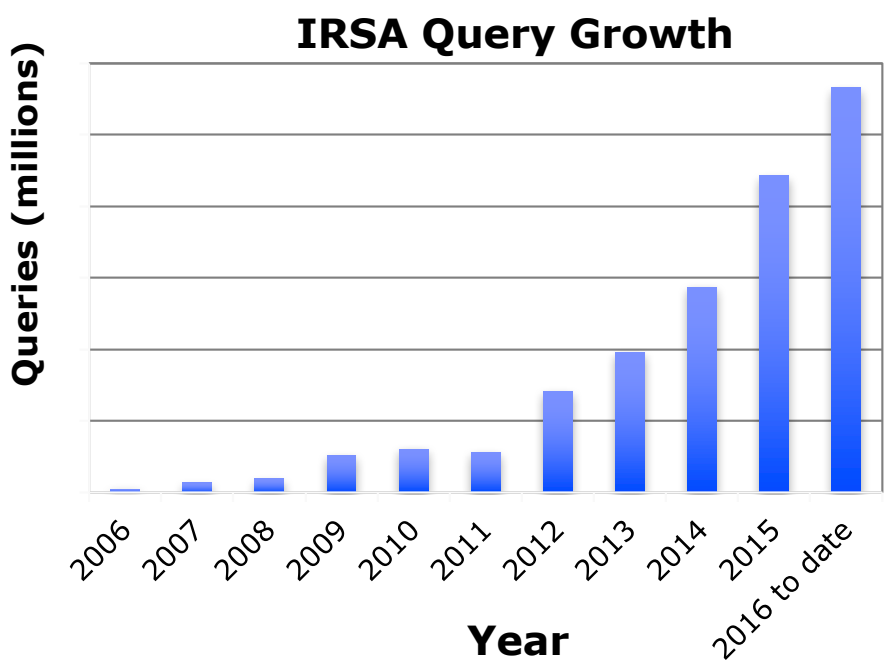
- Greatly enhance the science return of the archives
  - *Hubble Legacy HLSP are used 10x as much as typical pipeline products*
- Make complex data sets accessible to a wider audience of researchers
- Expand the use of large, coherent projects
  - *Herschel Key Projects*
  - *Spitzer Legacy and Exploration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



# Challenges shifting over time

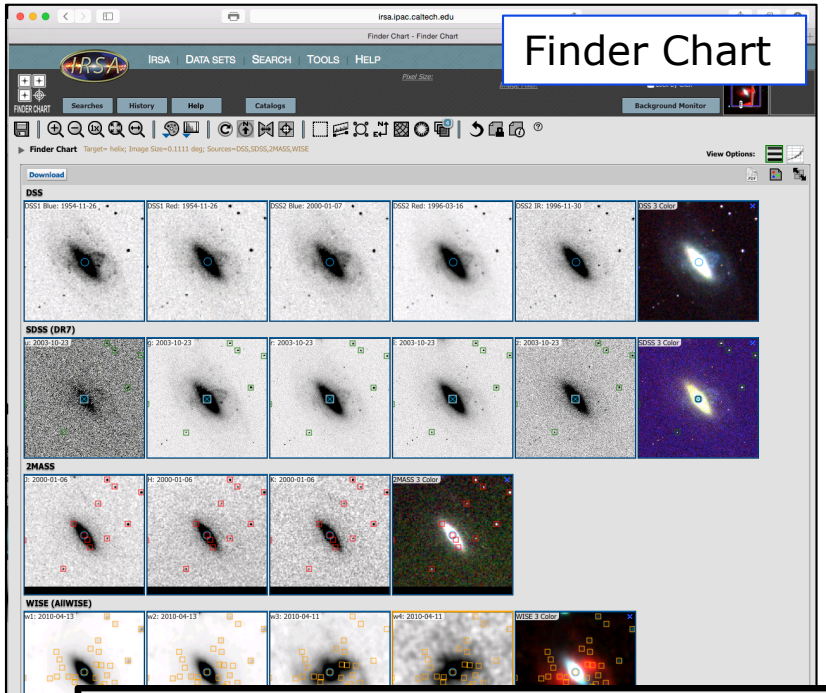
- Growth over time leads to richer content, which draws new, more complicated use cases
- Growing per-user data and query demand
- Increasing need to utilize data "close to" the archive

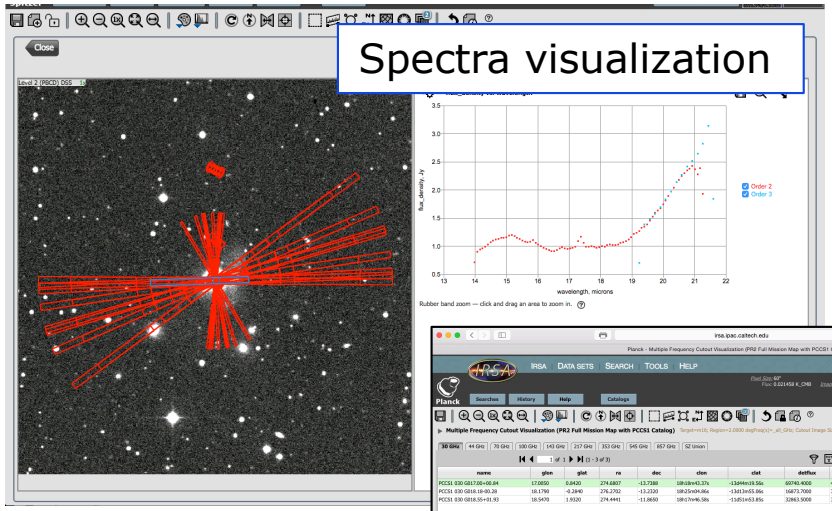


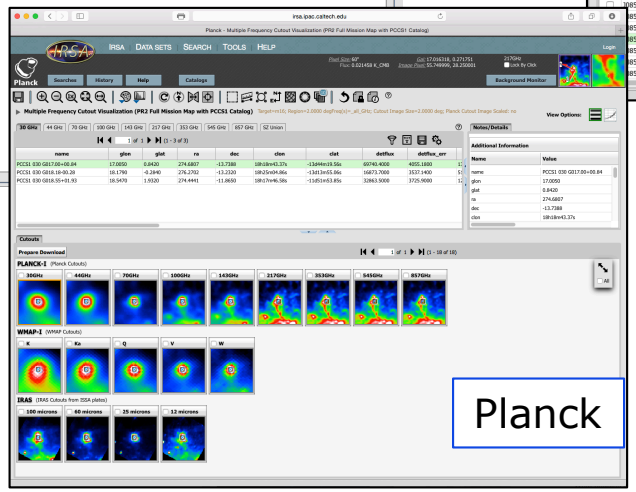



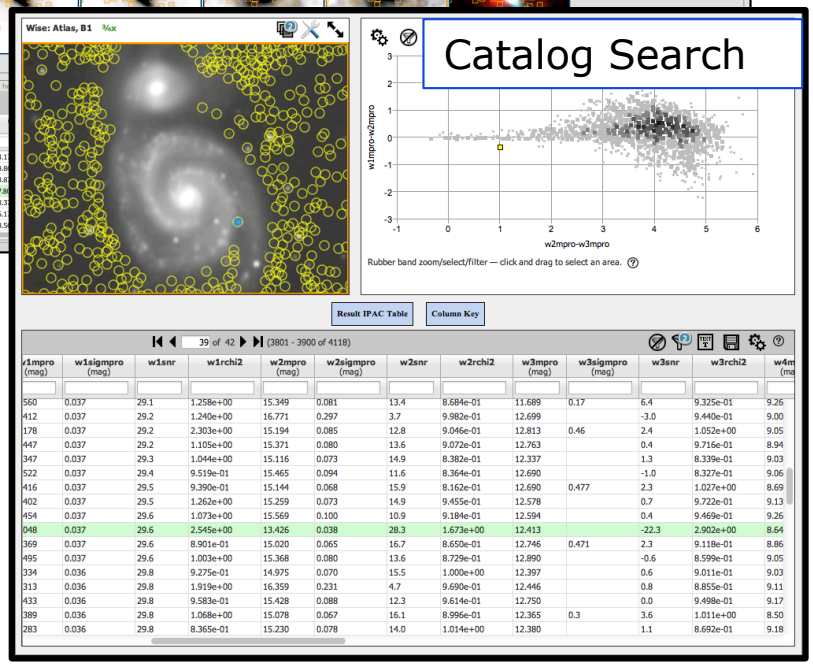
# Data Exploration and Visualization Services

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



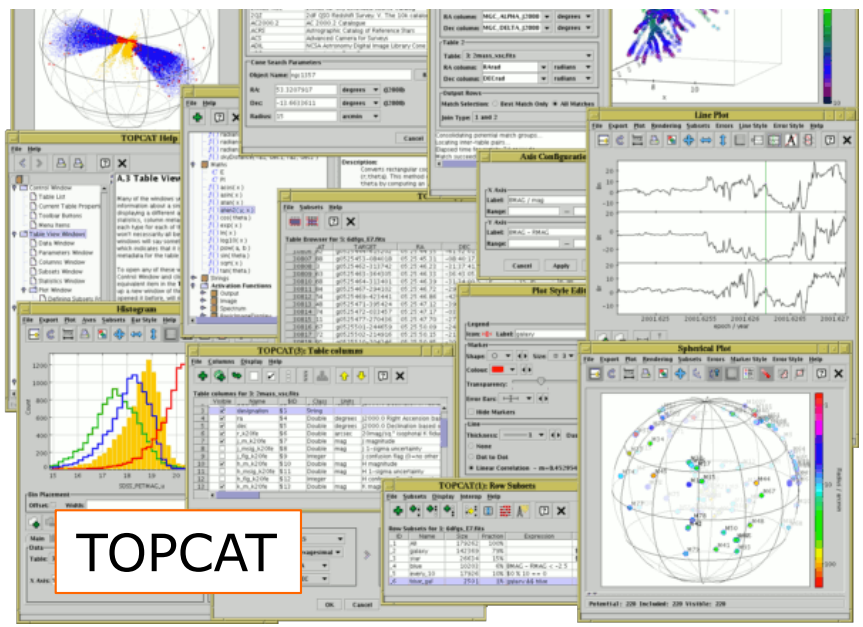



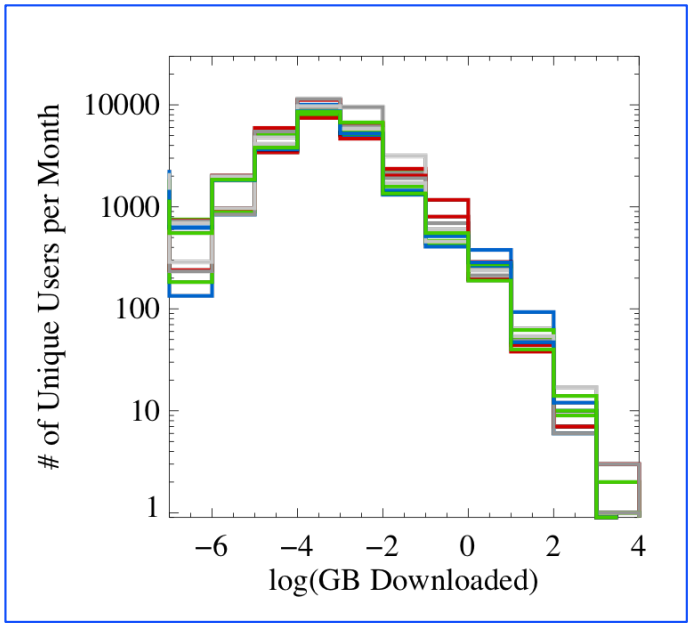

Infrared Processing and Analysis Center

ipac

# VO broadens audience; API supports diverse users

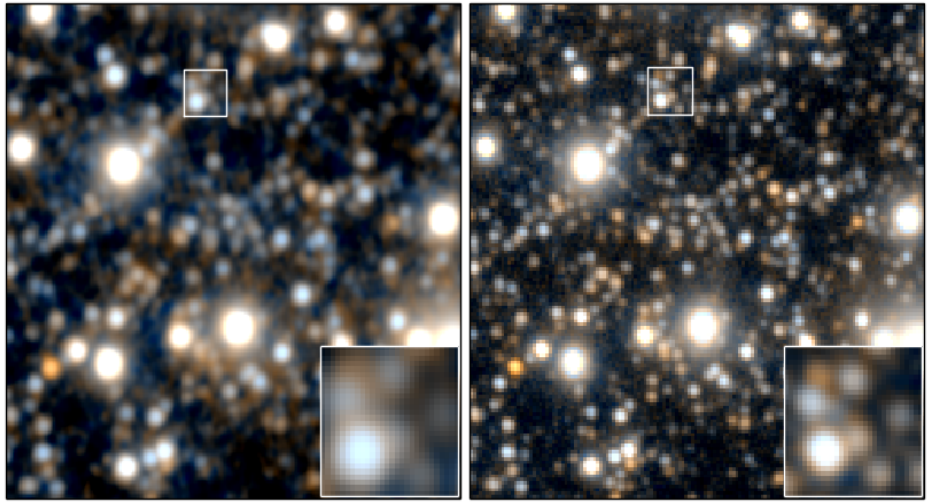
- Virtual Observatory
  - *Standardized protocols for interoperability between archives*
  - *Data discovery*
  - *Independent Tools*
- Application Program Interface
  - *Allows scripted access to archive data*
  - *Enables complex projects*



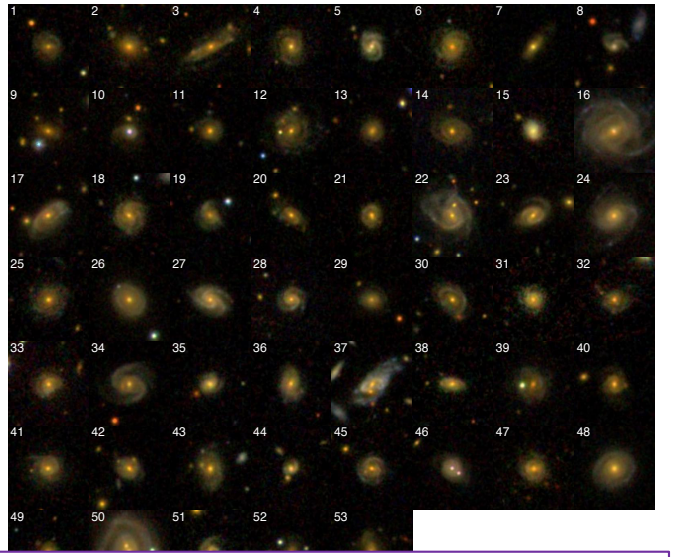



# Archival Science is becoming a "Big Data" field

- Reprocessing & combining large data sets, multiple surveys
- New interest in Machine Learning
- Starting to unlock the potential of discovering patterns by looking at all the data at once



*Lang (2014) reprocessed WISE single-exposure images to optimize measurements for extended sources.*



*Ogle et al (2016) discover a new class of superluminous spiral galaxy using data from NED, challenging theories of galaxy formation and evolution*

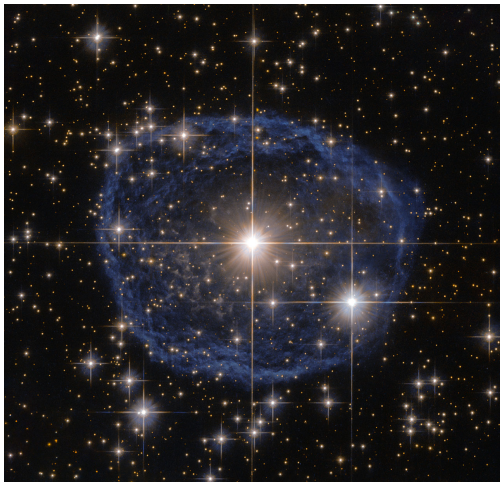


Image credit: ESA/HUBBLE & NASA

*Morello et al. (in prep) are using machine learning on NASA IR catalogs (Spitzer, 2MASS) to identify Wolf Rayet bubbles that are not detectable at visible wavelengths.*

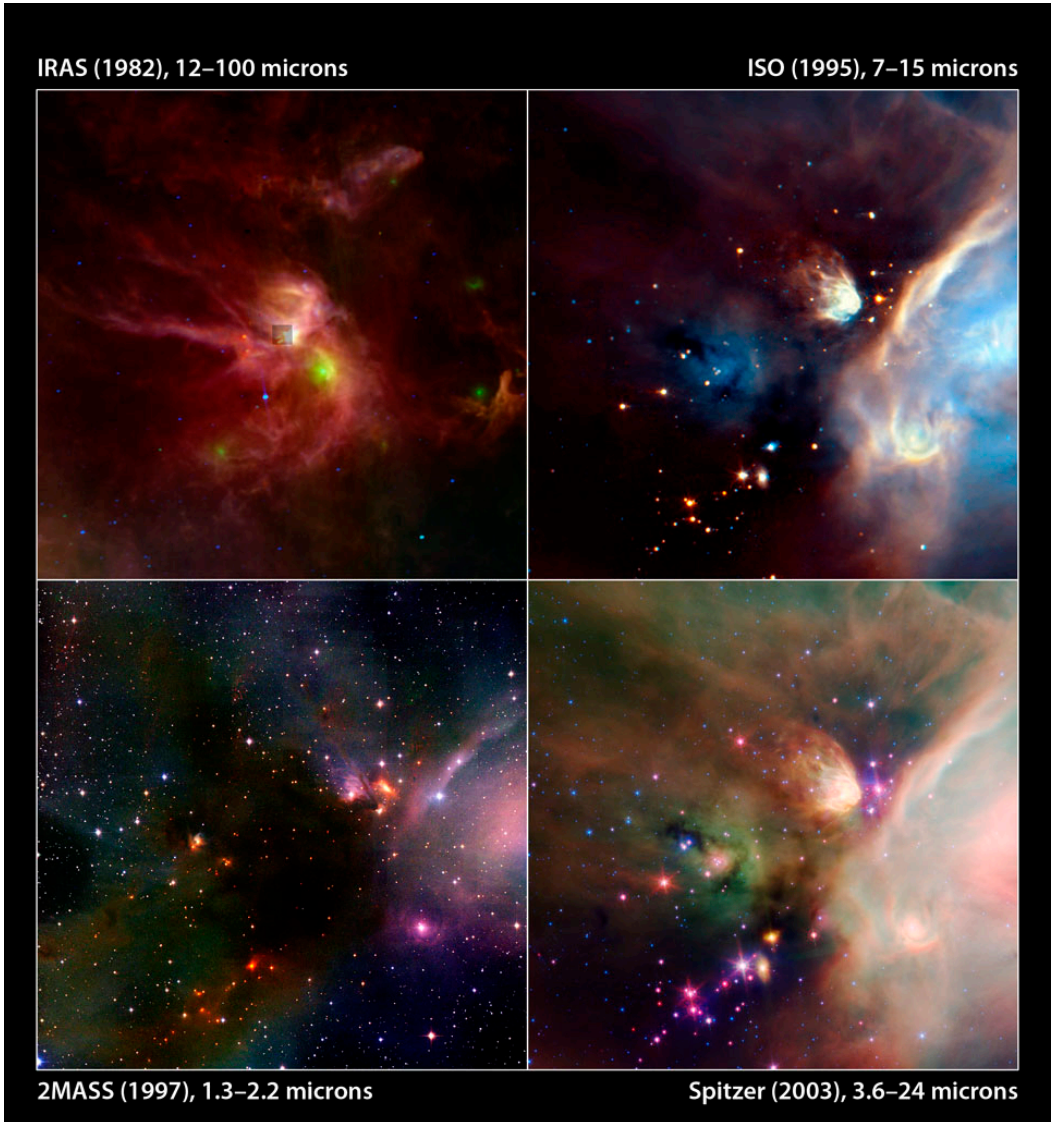
# Implications for Archives

- **Data discovery tools will become increasingly important – selecting the right data**
  - *Data flooding in from many projects*
  - *Interoperability means IRSA users have access through the VO to a multitude of data sets*
  - *How can we help users find the ones they are most interested in?*

- **Analysis at the archives will become increasingly important**
  - *Deep analysis and custom processing requires general access to all the data*
  - *Fixed services won't sustain flexible, growing demand*
  - *"Big data means you can't move it all", suggesting the analysis must move to the data*

- **Challenge providing resources to meet science analysis needs**
  - *Potential for improvements to existing services to support out-of-archive analysis*
  - *Bridging the resource gap between what archives & analysis*
  - *Archives used as analysis platform*

# Thank You




**IPAC IYA Legacy Image: Rho Ophiuchus Star-Forming Region**