WISE

Wide-Field Infrared Survey Explorer

Wright et al., (2010; http://adsabs.harvard.edu/abs/2010AJ....140.1868W)
Mainzer et al. (2014; http://adsabs.harvard.edu/abs/2014ApJ...792...30M)

http://wise.ssl.berkeley.edu http://neowise.ipac.caltech.edu/

Next two weeks

- Note: Updated the syllabus on github

- Class today will be on WISE
- I'm then away Tuesday through Friday next week
- Wednesday class will be on PHAT (by Ben Williams)

- No class on Monday, Feb 16th
- Wednesday, Feb 18th will be the first two seminars
  - John & Lisa

Seminars

- Kepler (John // February 18th)
- VLA FIRST (Lisa // February 18th)
- GALEX (Joachim)
- VISTA (Bryce)
- MWA (Patti)
- PTF (Paul // March 2nd)
- CFHT-LS
- Fermi
- UKIDSS
- CRTS
- 2MASS
- RAVE
- …

Syllabus

January:

- ~~5-Jan Monday: No class (AAS Meeting)~~
- ~~7-Jan Wednesday: No class (AAS Meeting)~~
- 12-Jan Monday: Introduction to Survey Science
- 14-Jan Wednesday: Basic software tools
- ~~19-Jan Monday: No class (MLK Day)~~
- 21-Jan Wednesday: Databases
- 26-Jan Monday: SQL Joins, Pandas, and LSD
- 28-Jan Wednesday: Visualization (Data Science Seminar)

February:

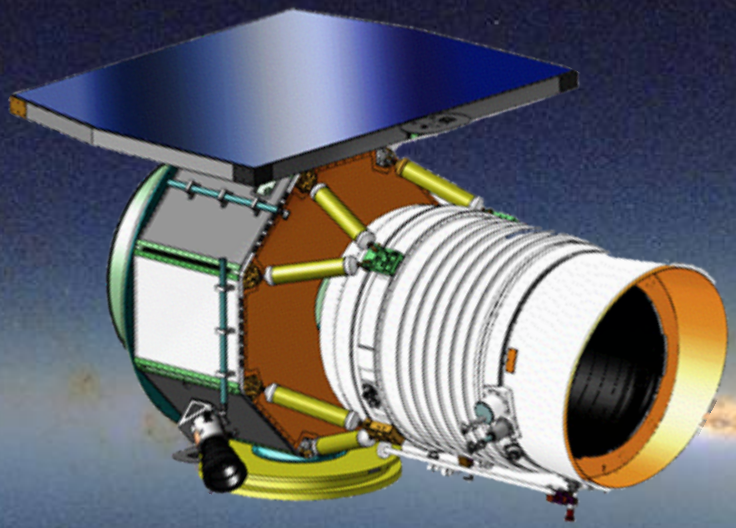
- 2-Feb Monday: Large Survey Database
- 4-Feb Wednesday: SDSS: the Sloan Digital Sky Survey
- 9-Feb Monday: WISE: the Wide-field Infrared Survey Explorer
- 11-Feb Wednesday: PHAT: The Panchromatic Hubble Andromeda Treasury (presented by Ben Williams)
- ~~16-Feb Monday: No class (Presidents' Day)~~
- 18-Feb Wednesday: Survey Seminar Presentations #1 (**Homework #1 Due**)
- 23-Feb Monday: Survey Seminar Presentations #2
- 25-Feb Wednesday: Survey Seminar Presentations #3

March:

- 2-Mar Monday: Survey Seminar Presentations #4
- 3-Mar Tuesday: Upcoming Surveys: GAIA (presented by Zeljko Ivezic)
- 4-Mar Wednesday: Upcoming Surveys: Pan-STARRS PS1 and DES
- 9-Mar Monday: Large Synoptic Survey Telescope (**Homework #2 Due**)
- 11-Mar Wednesday: Hack Day
- 20-Mar Thursday: **Class project due**

WISE

Wide-field Infrared Survey Explorer



WISE mapped the sky in infrared light, searching for the nearest and coolest stars, the origins of stellar and planetary systems, and the most luminous galaxies in the Universe.

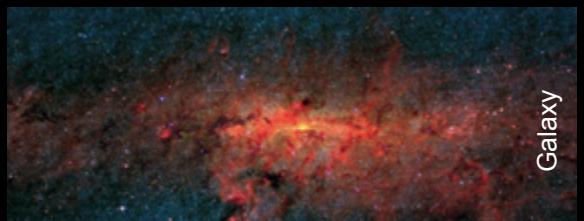
WISE delivered to the scientific community:

Approximately 1.5 million images covering the whole sky in 4 infrared wavelengths

Catalogs of ~ 560 million objects seen in these 4 wavelengths

asteroids

brown dwarfs



Galaxy

ULIRGs

wise.ssl.berkeley.edu

Original Slide/Graphics Credit: NASA (http://wise.ssl.berkeley.edu/gallery_mission_overview.html)


December 14, 2009
Image Credit: NASA

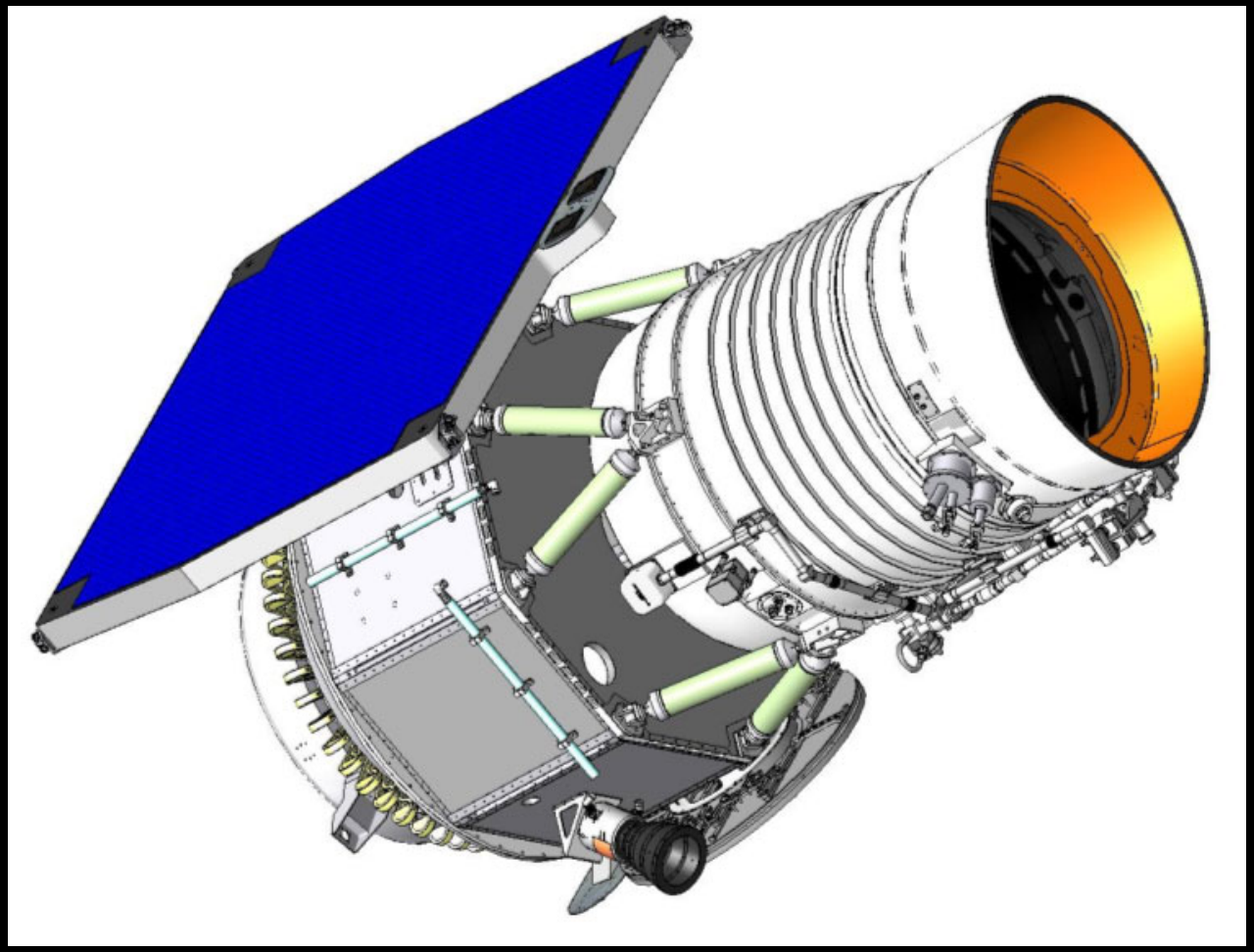
Two decades ago IRAS gave us what is still our best view of the mid-infrared sky.

Original Slide/Graphics Credit: NASA

WISE mapped the entire sky with resolution comparable to the view shown here.

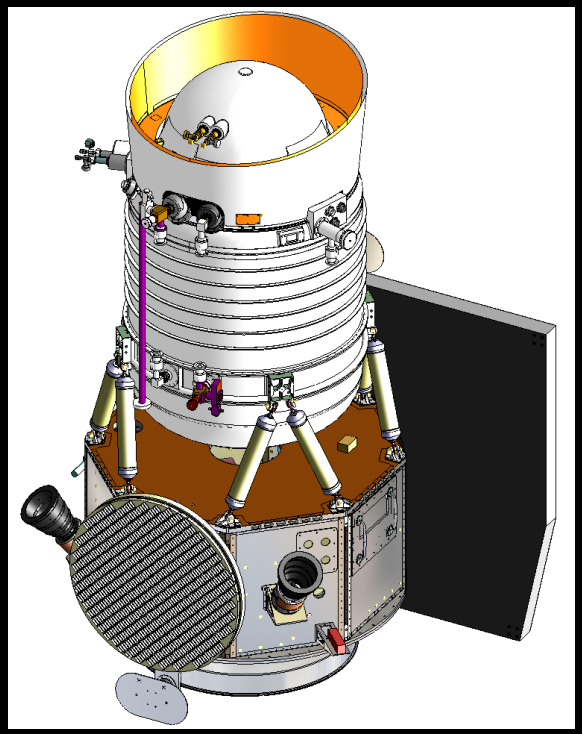
Original Slide/Graphics Credit: NASA

WISE Mission: Spacecraft



A cold 40 cm telescope in Earth orbit

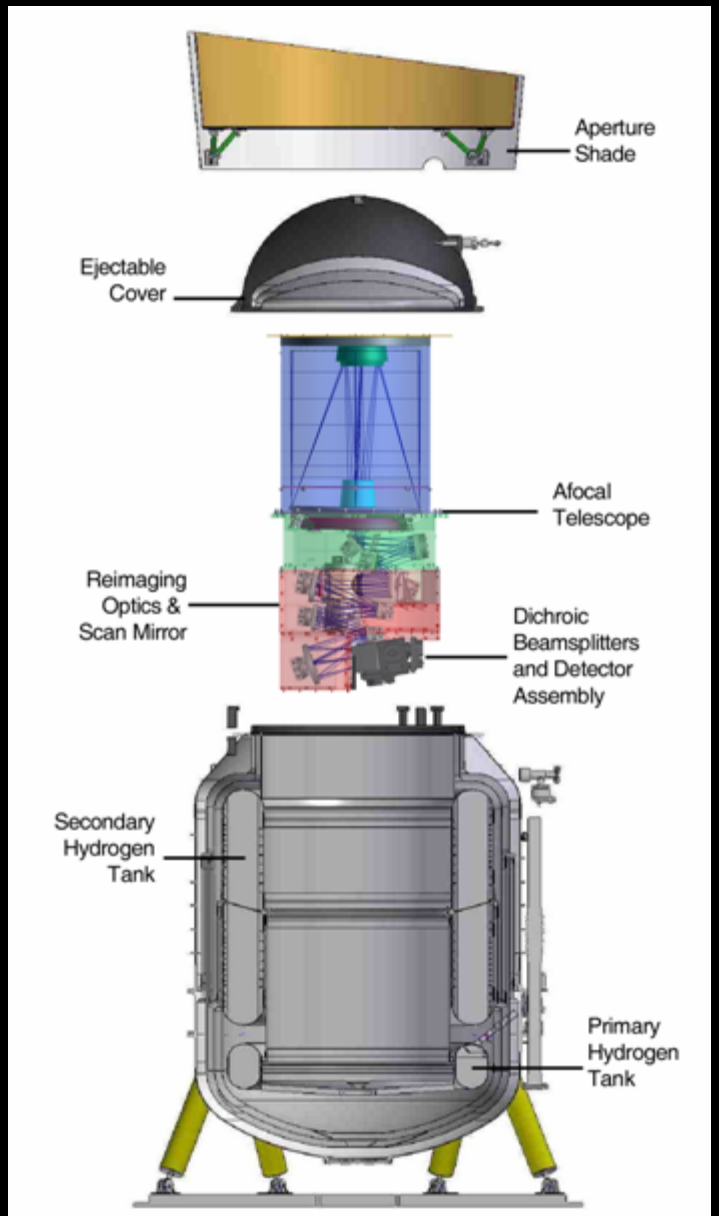
Enabled by new megapixel infrared detector arrays

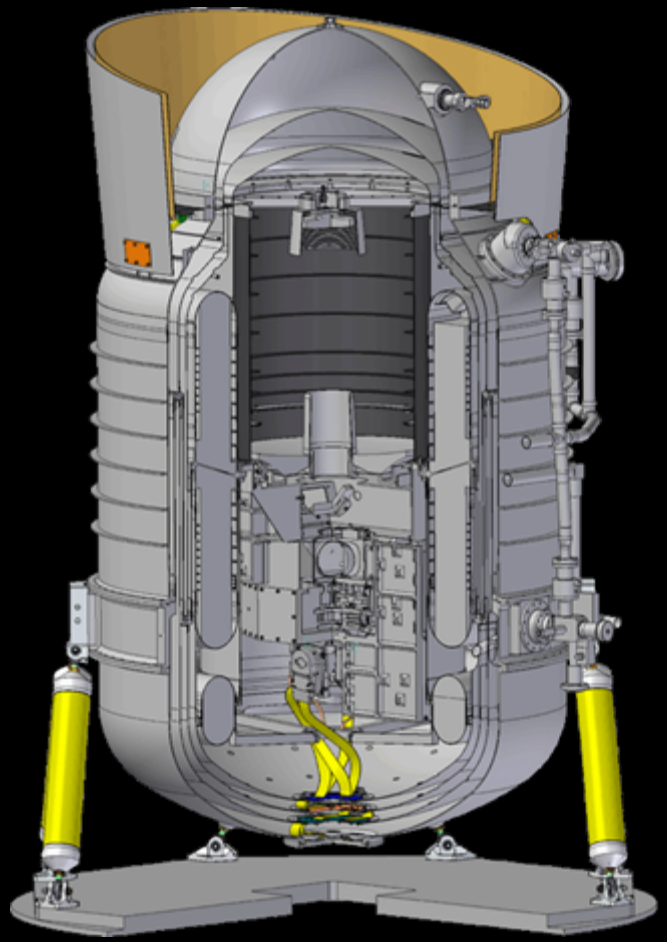


By being in space, the 40 cm WISE telescope is much more capable than >10m apertures on Earth.

Original Slide/Graphics Credit: NASA

WISE Mission: Payload





Original Slide/Graphics Credit: NASA

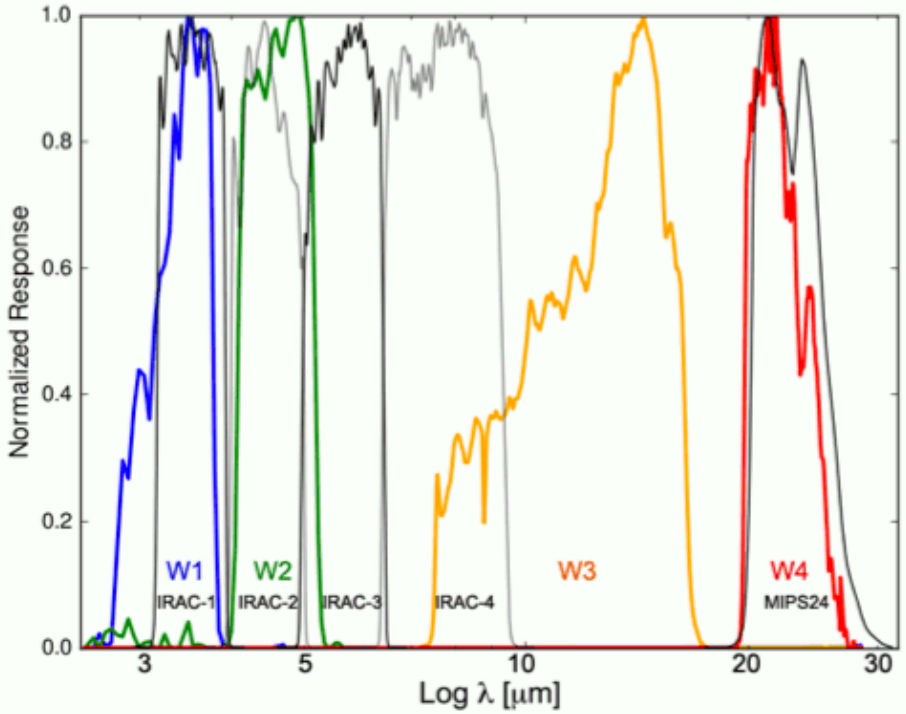
WISE Mission: Wavelengths

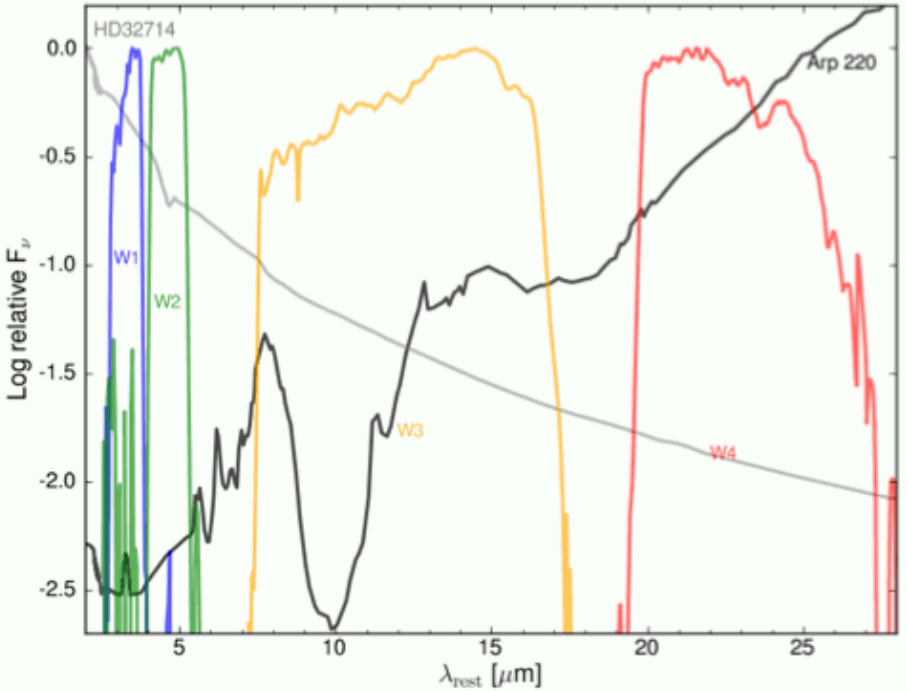
WISE surveyed the sky in two near infrared channels:
3.4 and 4.6 μm (known as W1 and W2)

Also in two mid-infrared channels:
12 and 22 μm (known as W3 and W4)

Original Slide/Graphics Credit: NASA

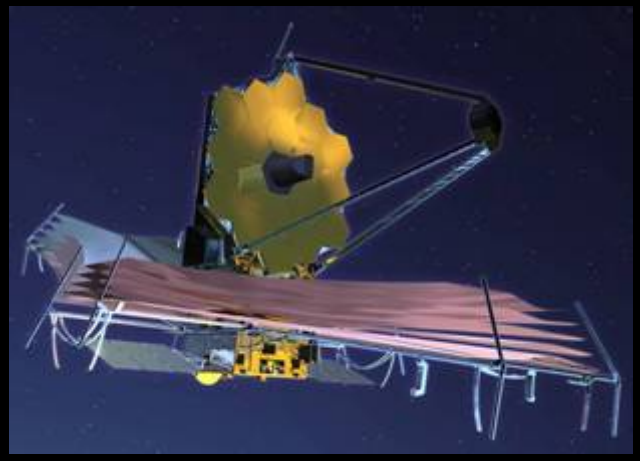
WISE Bandpasses

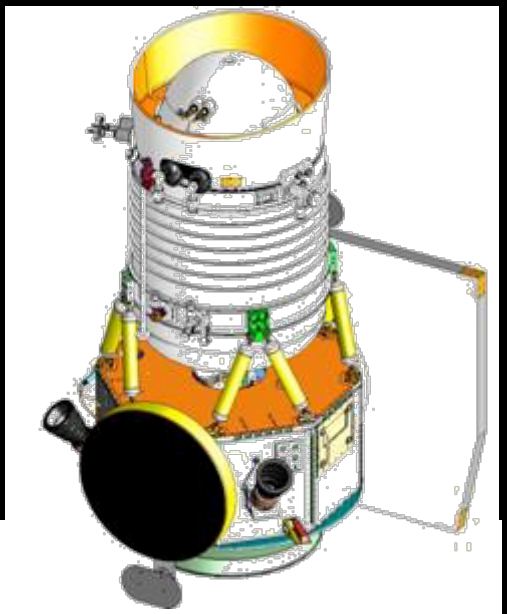


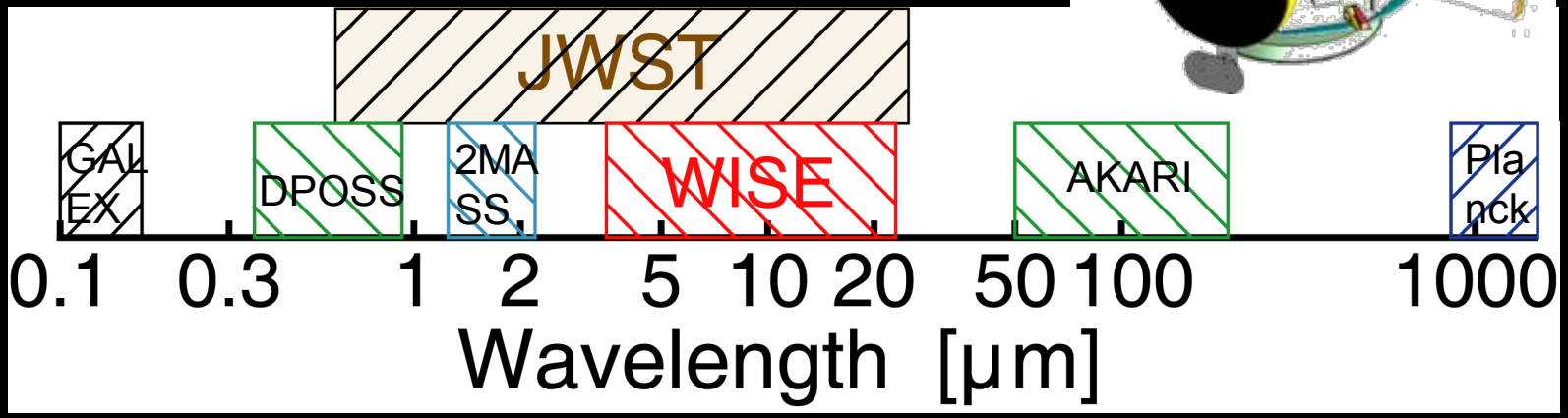


http://wise2.ipac.caltech.edu/docs/release/prelim/expsup/sec4_3g.html#WISEZMA

WISE Data Fills “the Gap”



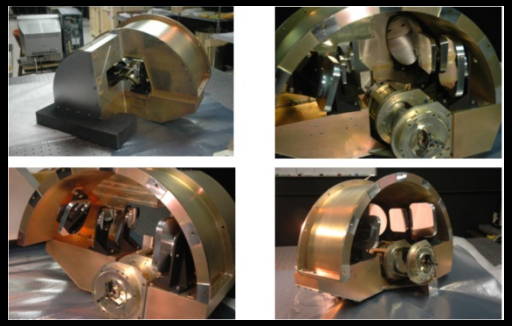


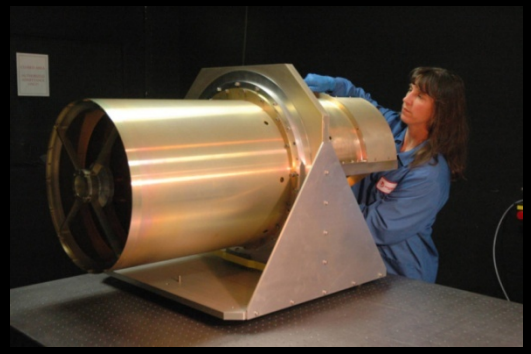


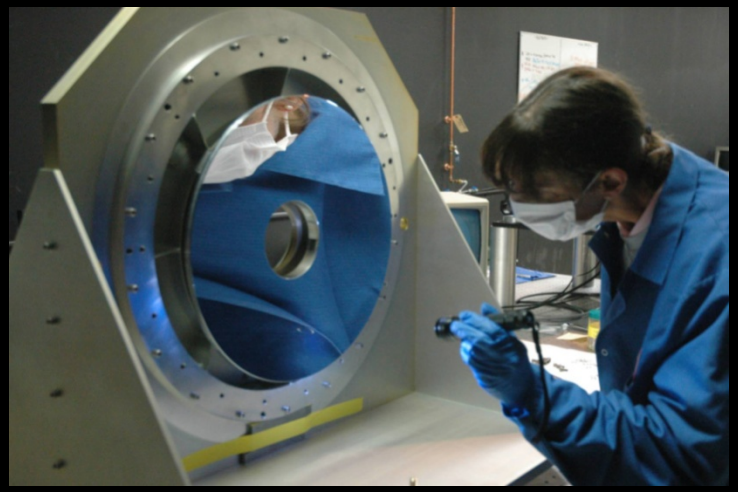
- WISE fills the gap in wavelengths covered by sensitive all sky surveys
- Many pointed JWST observations will be in this wavelength gap

Original Slide/Graphics Credit: NASA

WISE Mission: Payload



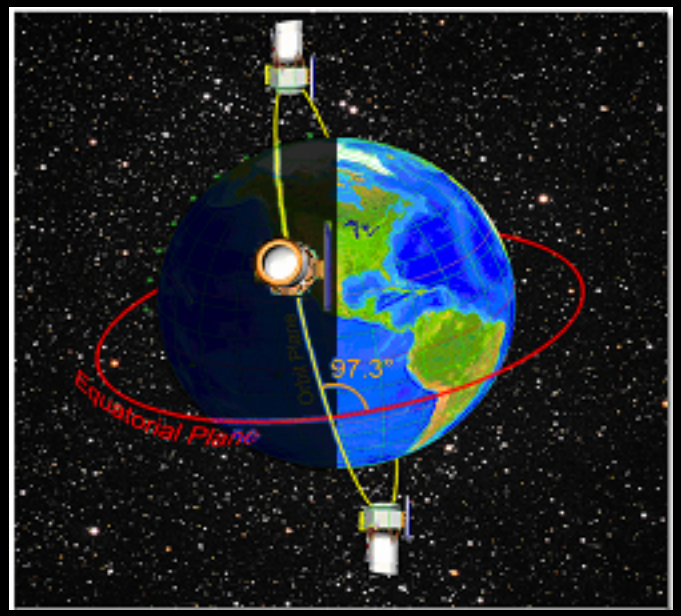




Original Slide/Graphics Credit: NASA

WISE Mission: Orbit

WISE orbits the Earth cart-wheeling once per orbit to always stay pointing up and will keep its solar panels to the Sun.



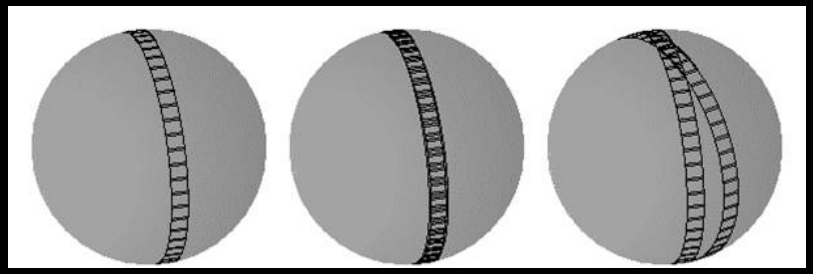
As Earth orbits the Sun, WISE's orbit also rotates to maintain the spacecraft's orientation to Earth and Sun

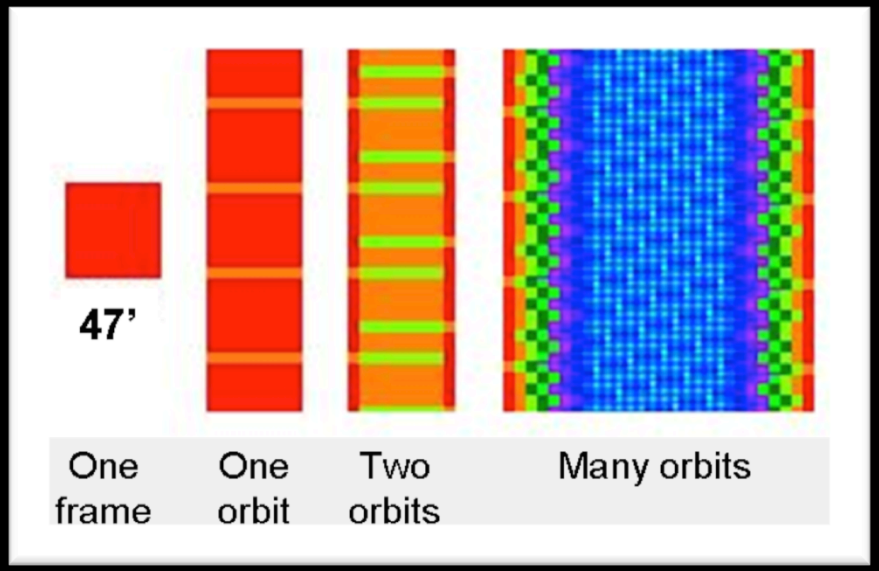
Original Slide/Graphics Credit: NASA

WISE Mission: Surveying

Each image exposure lasts 11-sec and is matched to the orbit.

Each orbit, a circular strip of the sky is imaged.





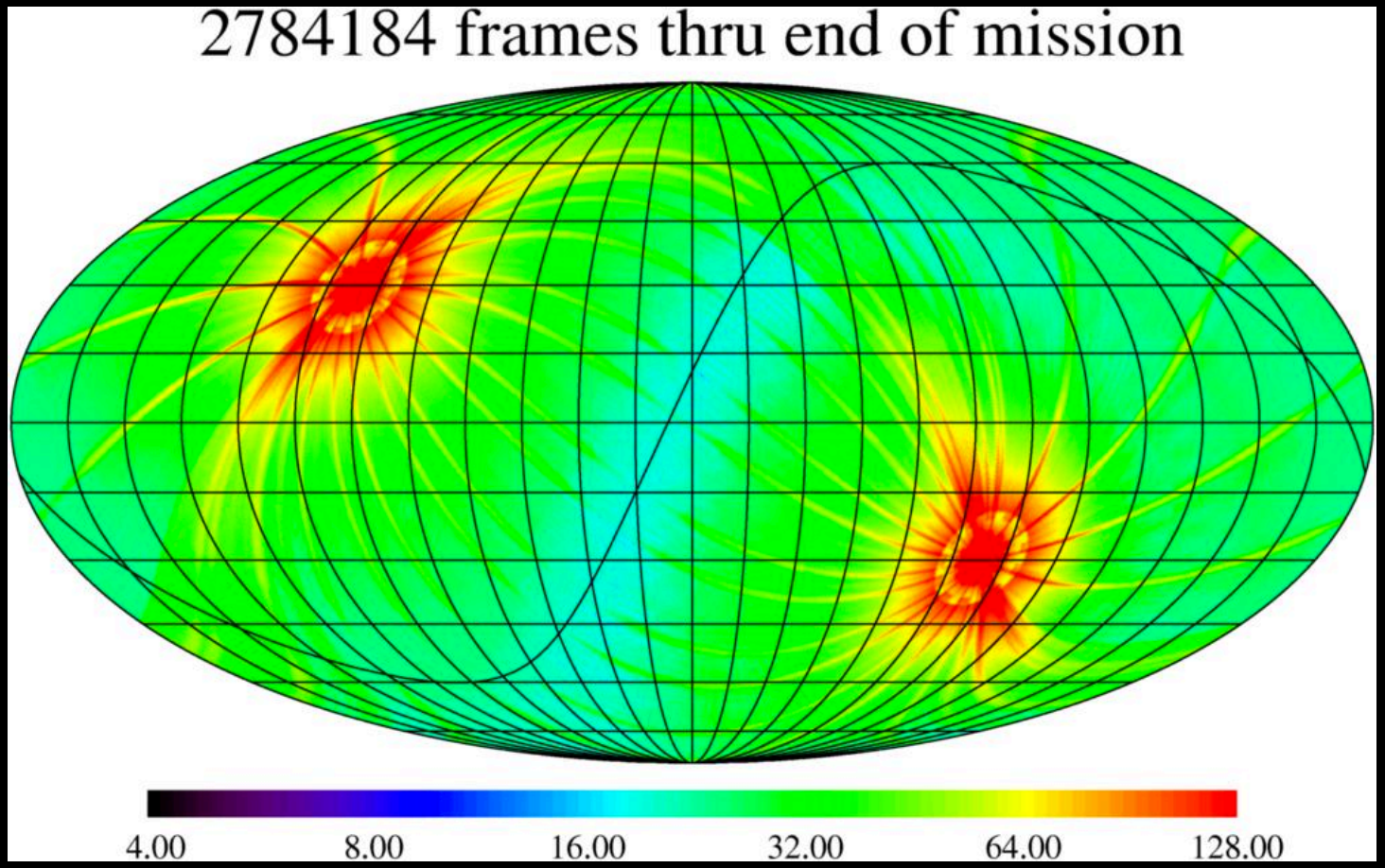
As the orbit itself rotates, a slightly different strip is imaged.

In 6 months, the entire sky is imaged

There have been 9 or more exposures at each position over more than 99% of the sky.

Original Slide/Graphics Credit: NASA

Coverage Maps



- Blue areas along the southern ecliptic are less covered due to the South Atlantic Anomaly. The partial second coverage allowed by a 9 month survey cuts out half of this undercovered portion of the sky.

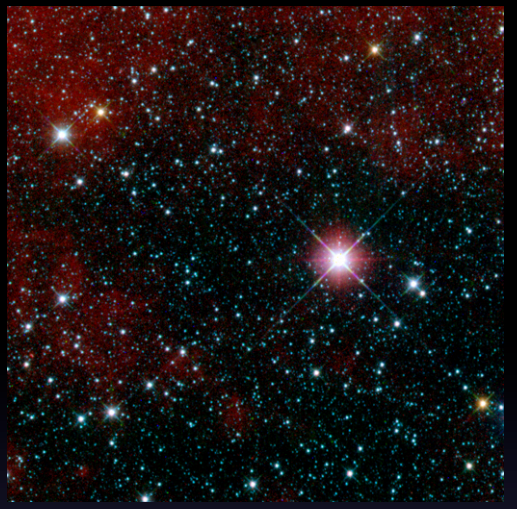
Original Slide/Graphics Credit: NASA

Major Milestones

- Launch: December 14, 2009
- First light: January 6, 2010 (right)
- Survey start: January 14, 2010
- Survey end: ~Aug 10, 2010 (coolant begins to be exhausted)

- NEOWISE phase: September 29, 2010
- Hibernation: February 1st, 2011

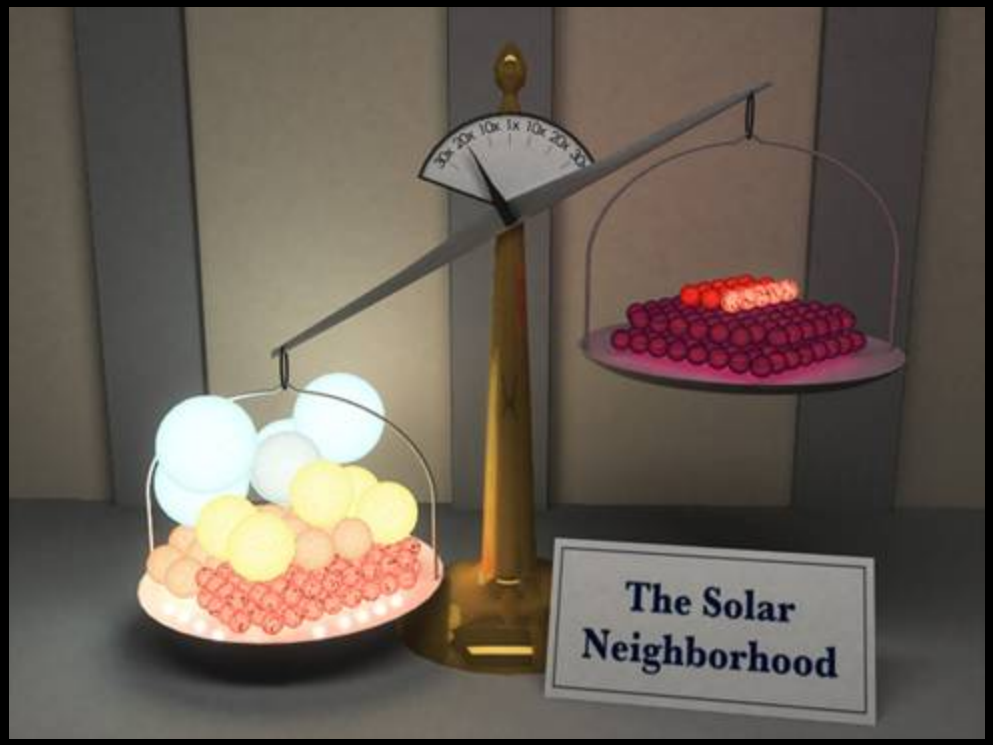
- Reactivation: August 21st, 2013
- NEOWISE-R "next light": December 19, 2013



WISE first light image
Credit: NASA/JPL-Caltech/UCLA

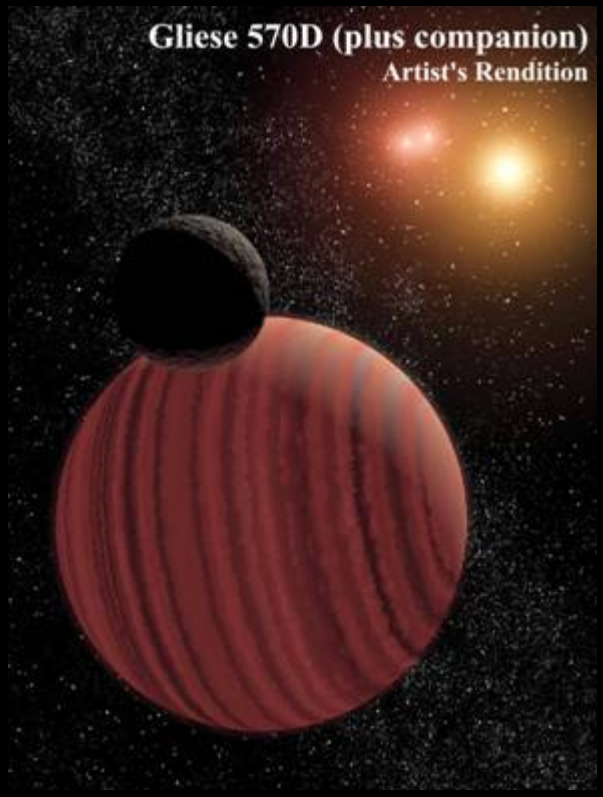
NEOWISE-R "next light" image

Science: Cool Stars



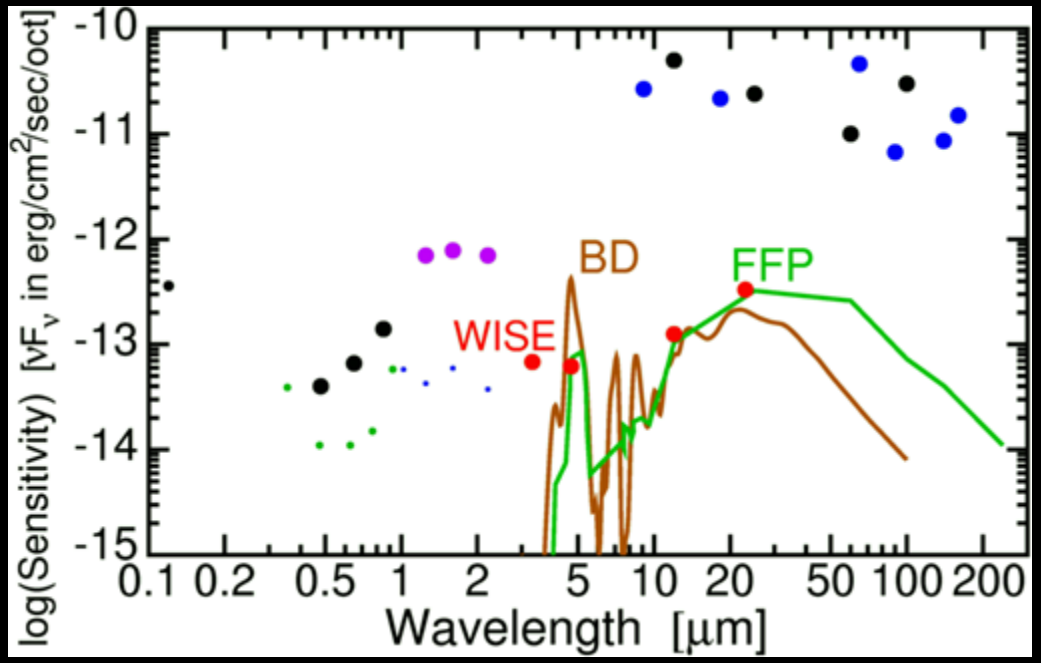
Red and Brown Dwarf stars are the most common type of star.

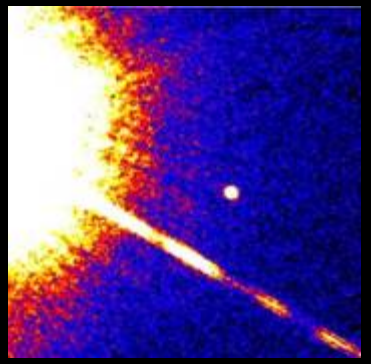
They have lowest masses and are the coolest stars.



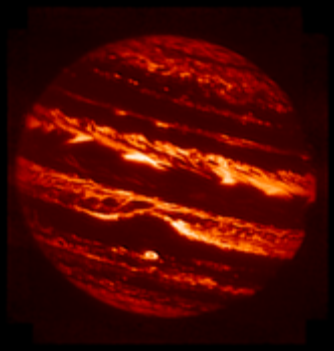
They emit most of their energy in infrared light and are faint.

Science: Brown Dwarfs

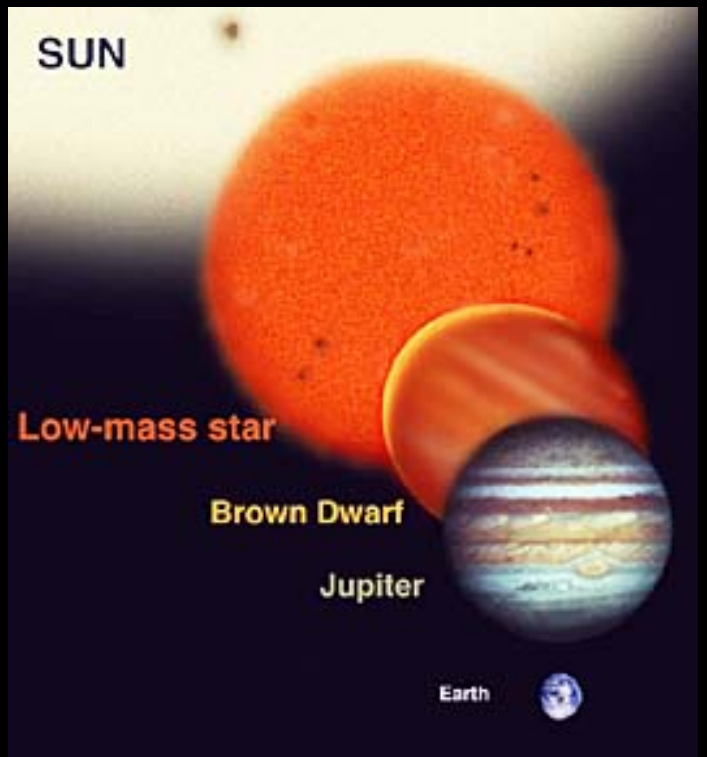




GL 229B



Jupiter at 5 μm



- Brown Dwarfs (BDs): stars with too little mass to fuse H into He.
- WISE 3.3 & 4.7 μm filters tuned to methane dominated BD spectra.
- WISE could identify Gliese 229B (10^{-5} $L_\odot$) to 150 light years, a free floating planet (FFP) like Jupiter (10^{-9} $L_\odot$) to 1 light year, BDs with T > 200 K (10^{-8} $L_\odot$) if closer than α Centauri.

Cool Stars: Discoveries

- Discovery of coldest spectroscopically confirmed brown dwarfs to day
  - Effective temperatures of ~300-500K
  - Cushing et al. 2011 (http://adsabs.harvard.edu/abs/2011ApJ...743...50C)

- Discovery of more than 100 brown dwarfs, including 6 Y dwarfs
  - Kirkpatrick et al. 2011 (http://adsabs.harvard.edu/abs/2011ApJS..197...19K)

THE SUN'S CLOSEST NEIGHBORS

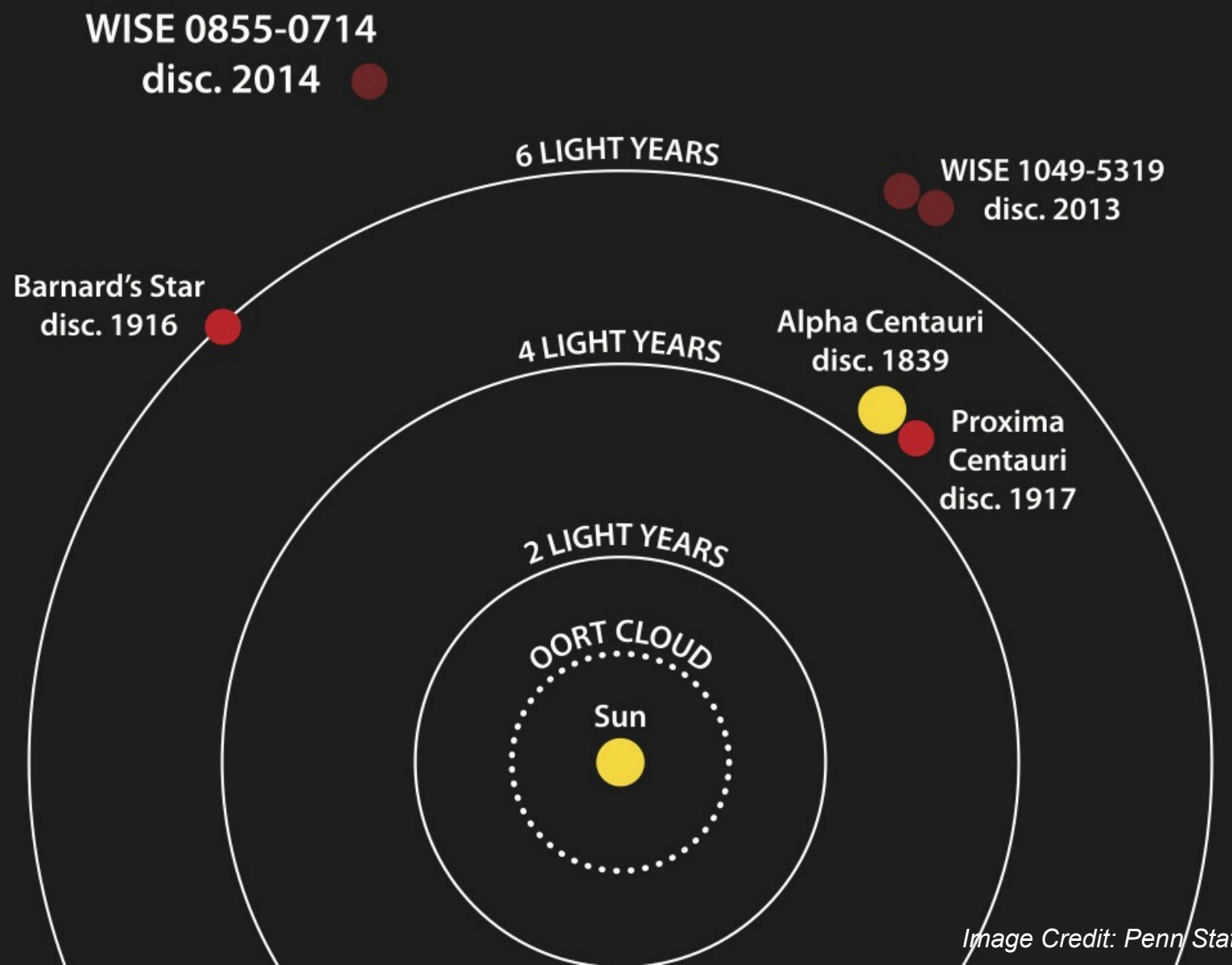
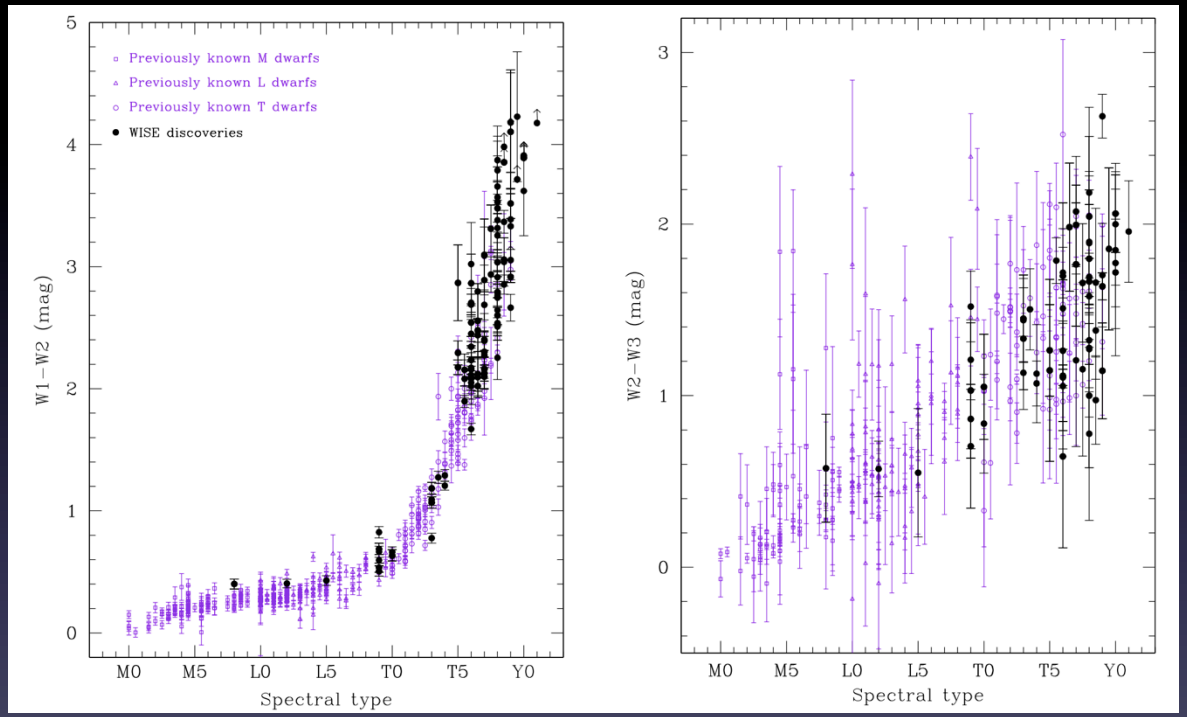
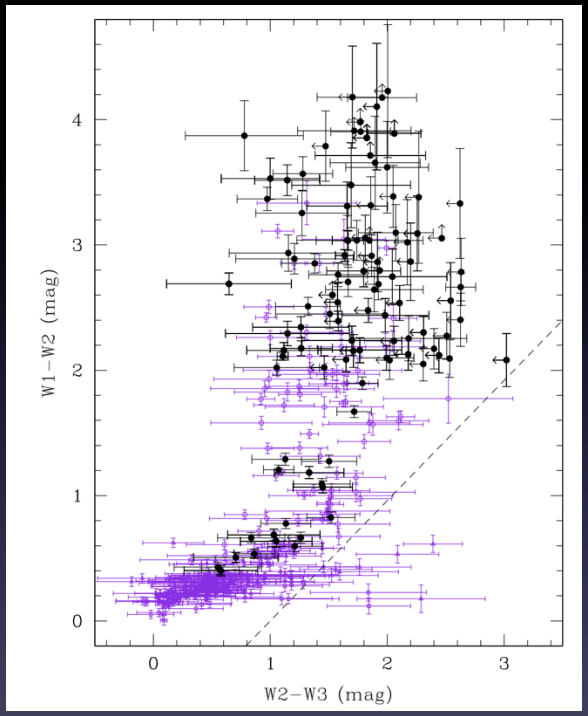


Image Credit: Penn State University

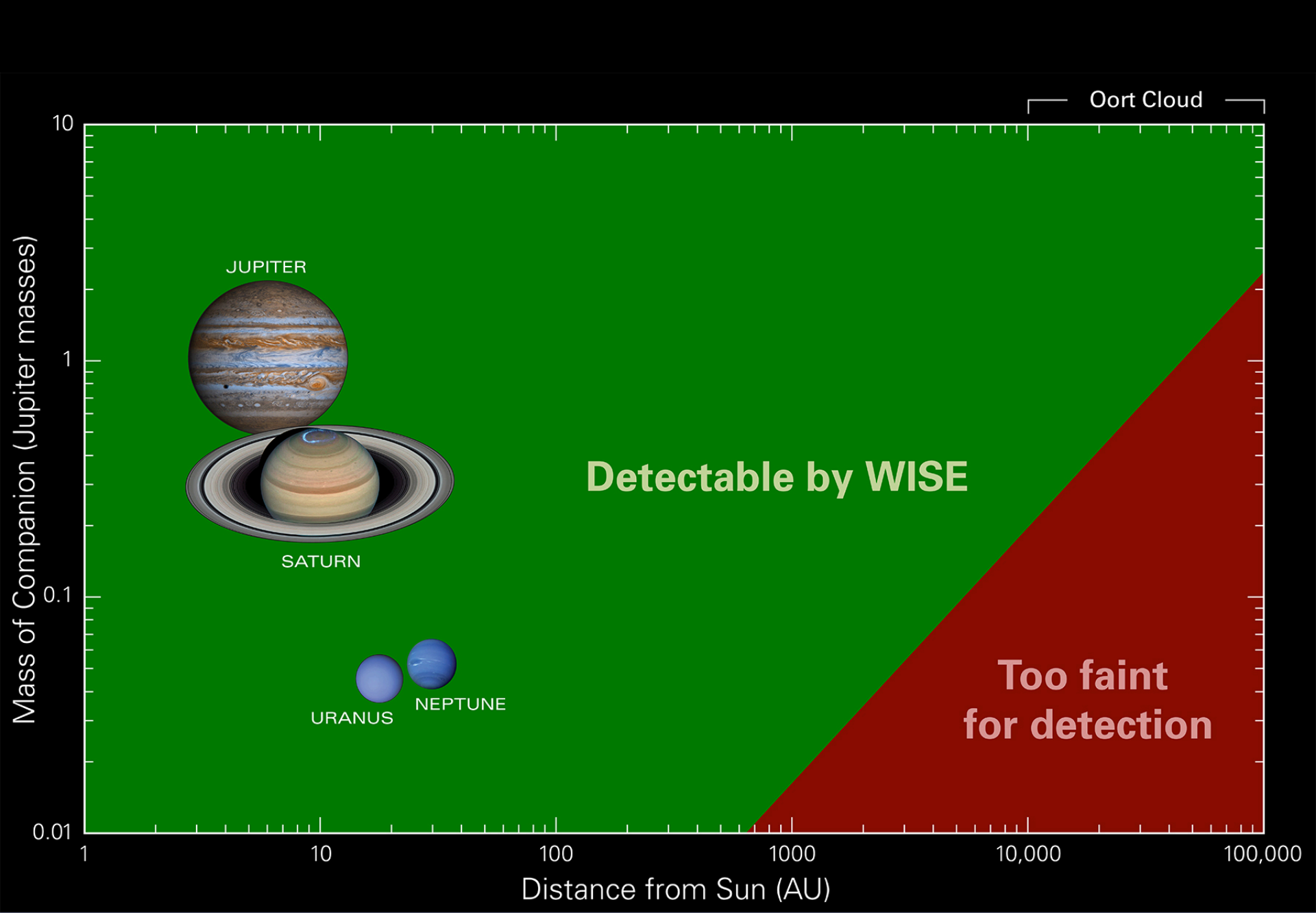
Searching for Cool Stars





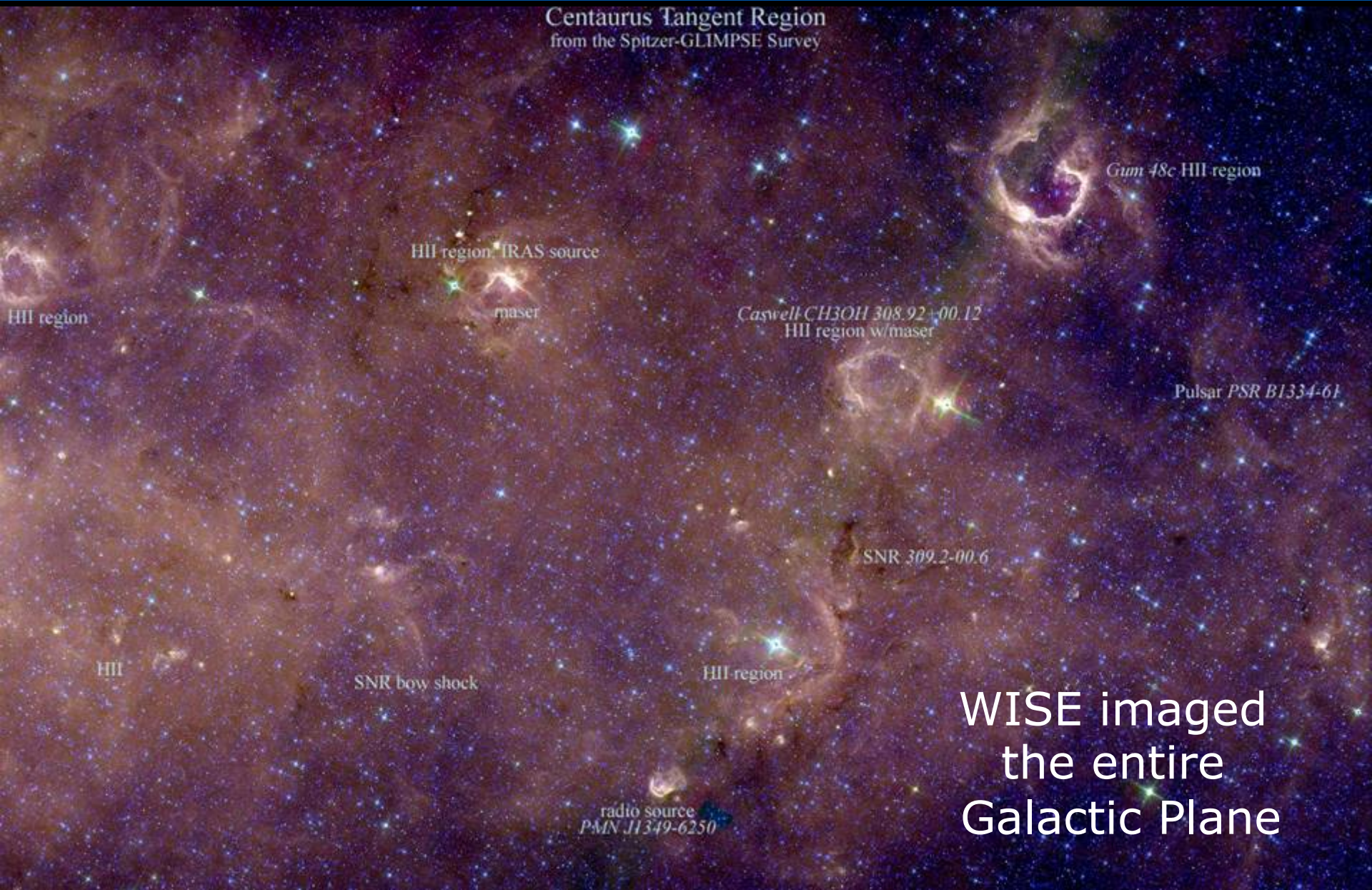
- Color cuts
- Proper motion cuts

Kirkpatrick et al. (2011)



Non-detection of "Planet X" (Luhman 2014)

Science: The Milky Way



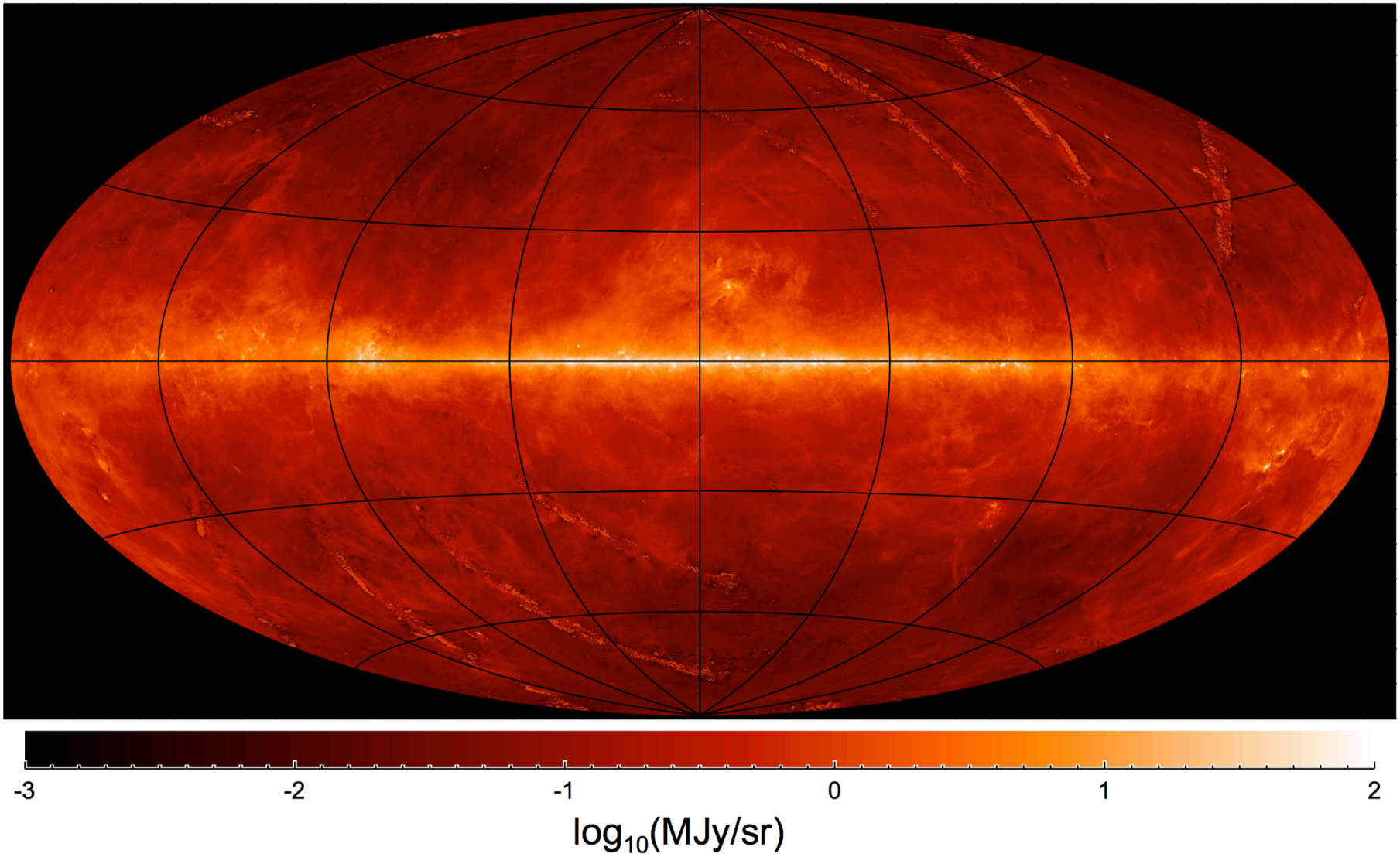
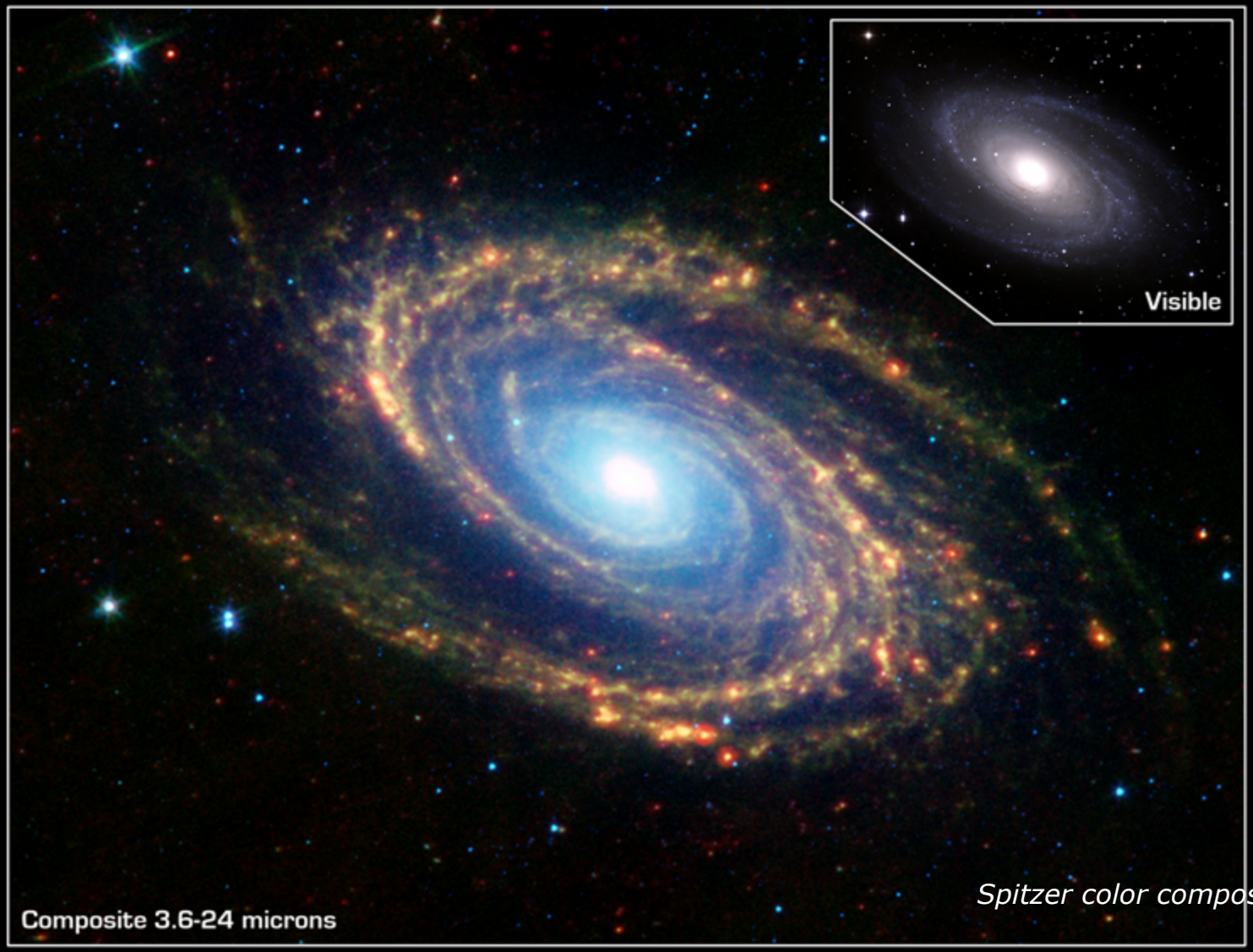


FIG. 11.— Our full-sky, 12μm map, binned to 7′ resolution, in Hammer-Aitoff projection, on a logarithmic stretch.

Diffuse Galactic Dust Emission maps; Meisner & Finkbeiner (2014)

Science: Extragalactic

WISE contains imaging of all nearby galaxies



Spitzer color composite of M81

WISE color composite of M81 (left) and M82 (right)

M81 and M82

NASA/JPL-Caltech/WISE Team

wise.astro.ucla.edu

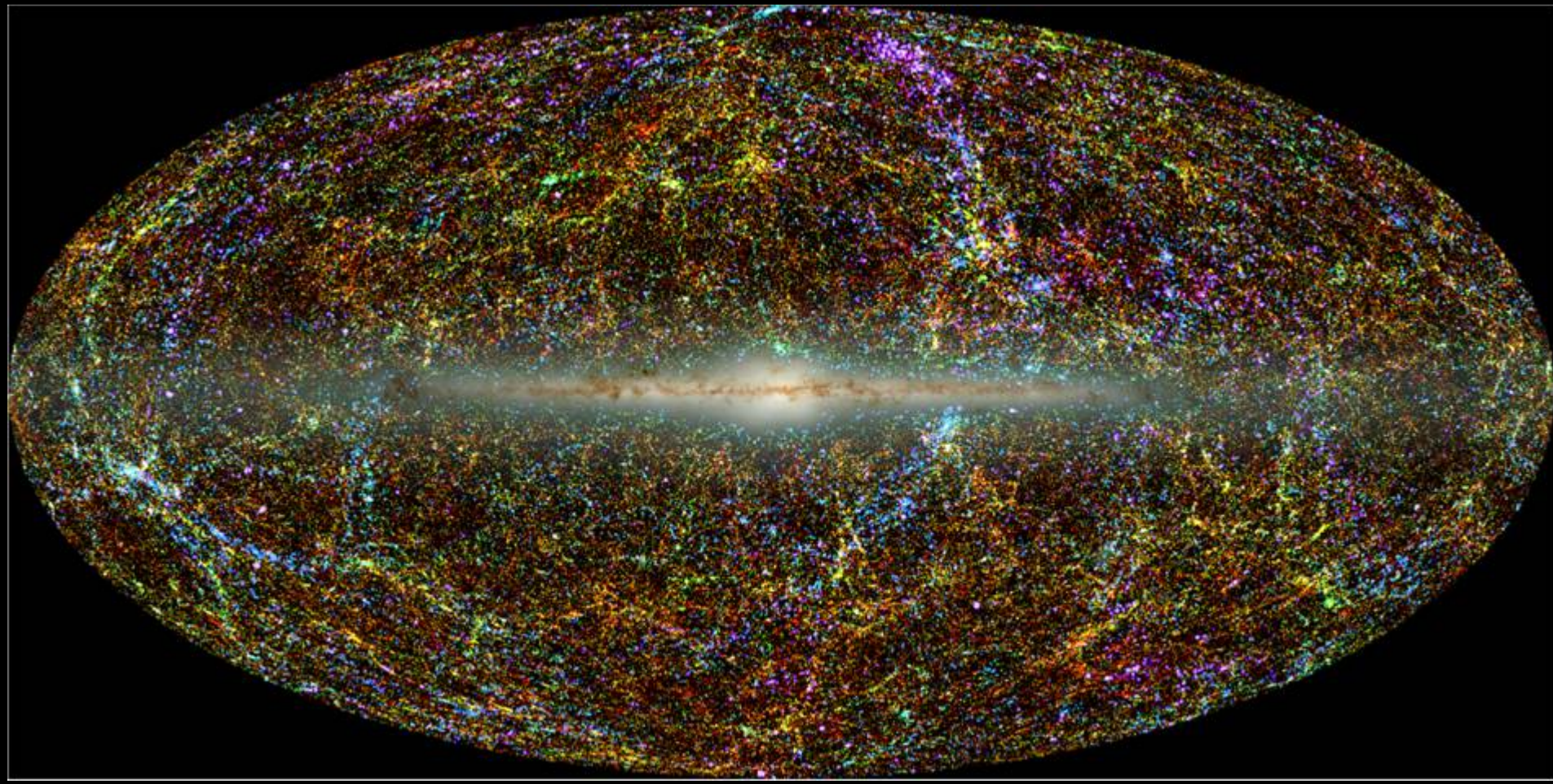
Wide-field **I**nfrared **S**urvey **E**xplorer

WISE 2011-002

Extragalactic Science: AGNs

- Finding AGN candidates
  - Stern et al. (2012), http://adsabs.harvard.edu/abs/2012ApJ...753...30S
  - Assef et al. (2013), http://adsabs.harvard.edu/abs/2013ApJ...772...26A
- AGN property studies
  - Donoso et al. (2012), http://adsabs.harvard.edu/abs/2012ApJ...748...80D

Science: Cosmology

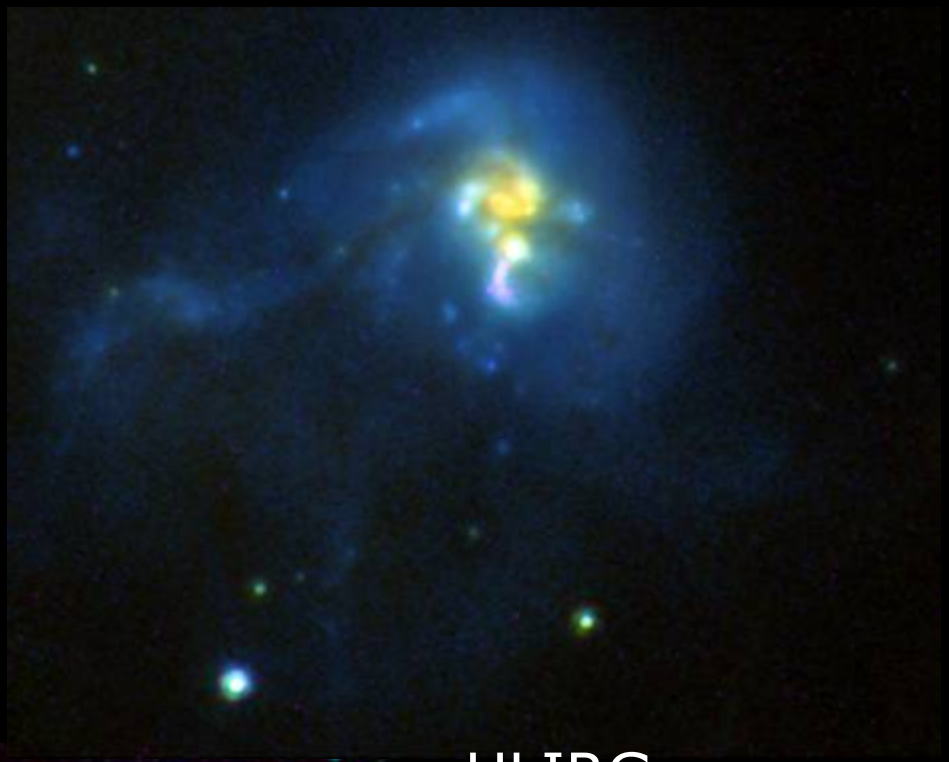


2MASS Surveyed Large Scale Structure out to 1.3 Billion Light-years (z ~ 0.1)

WISE surveyed out to 6.7 Billion Light-years (z ~ 0.5)

Science: Extragalactic

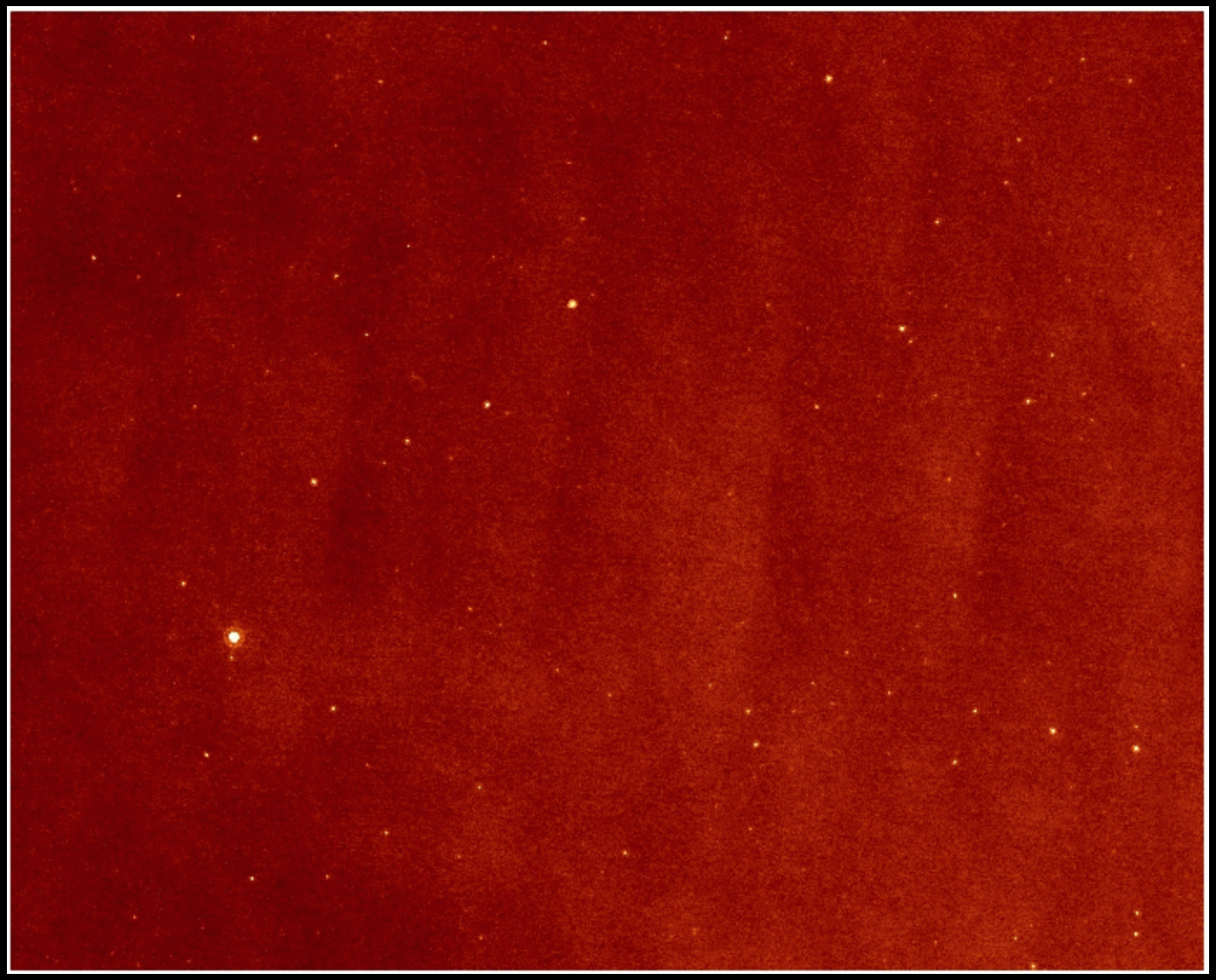
WISE will find the most luminous galaxies in the Universe:
Ultra-luminous Infrared Galaxies (ULIRGs)



ULIRGs are merging galaxies whose collisions lead to dust-enshrouded bursts of star formation.

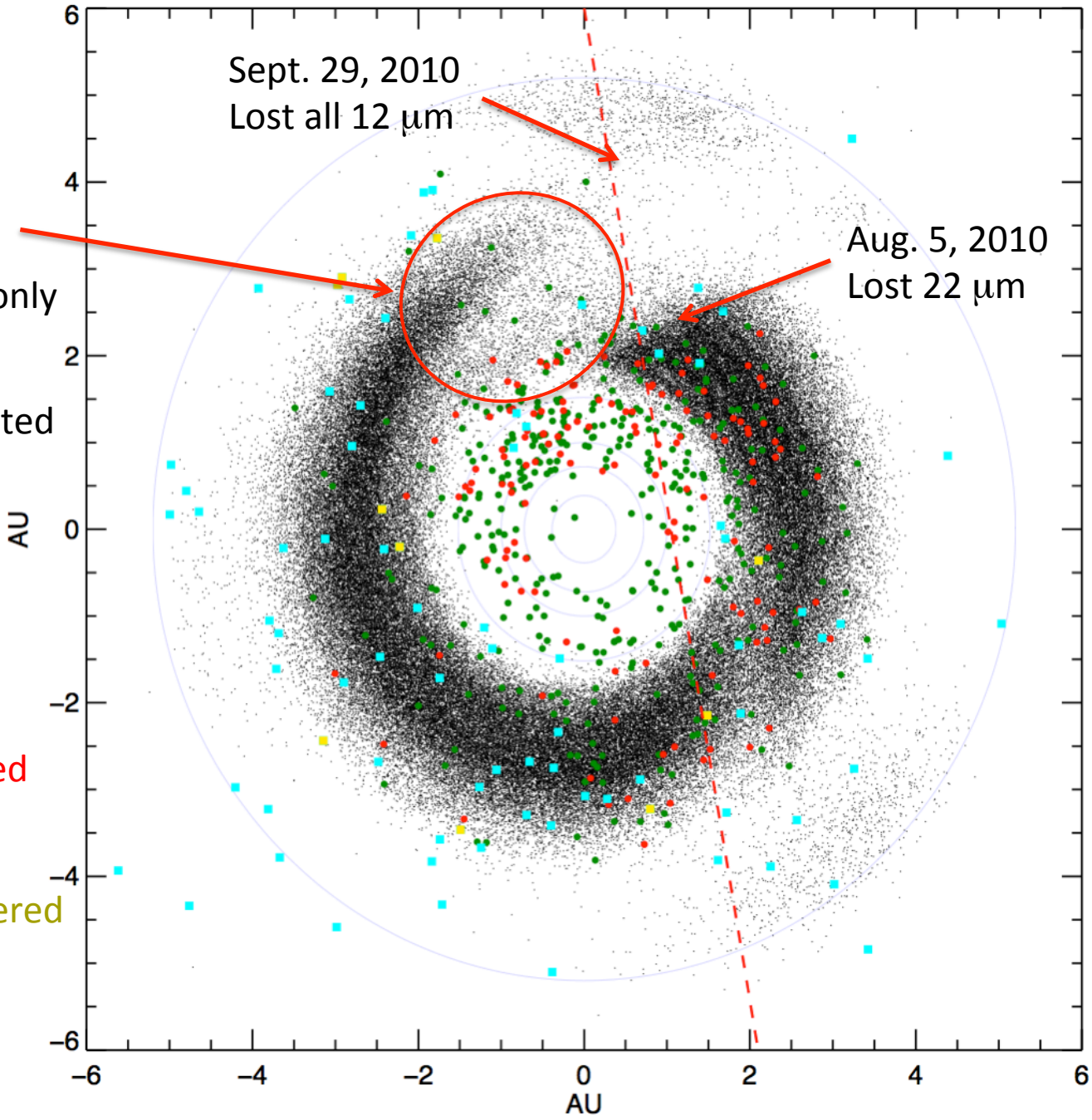
Science: Asteroids

- Spitzer 24 μm data in Taurus
- Most of the bright objects are asteroids!
- Size 0.7° ≈ WISE FOV
- Thermal IR provides diameters, needed for hazard assessment



Slide by A. Meinzer

1 YEAR NEOWISE SURVEY

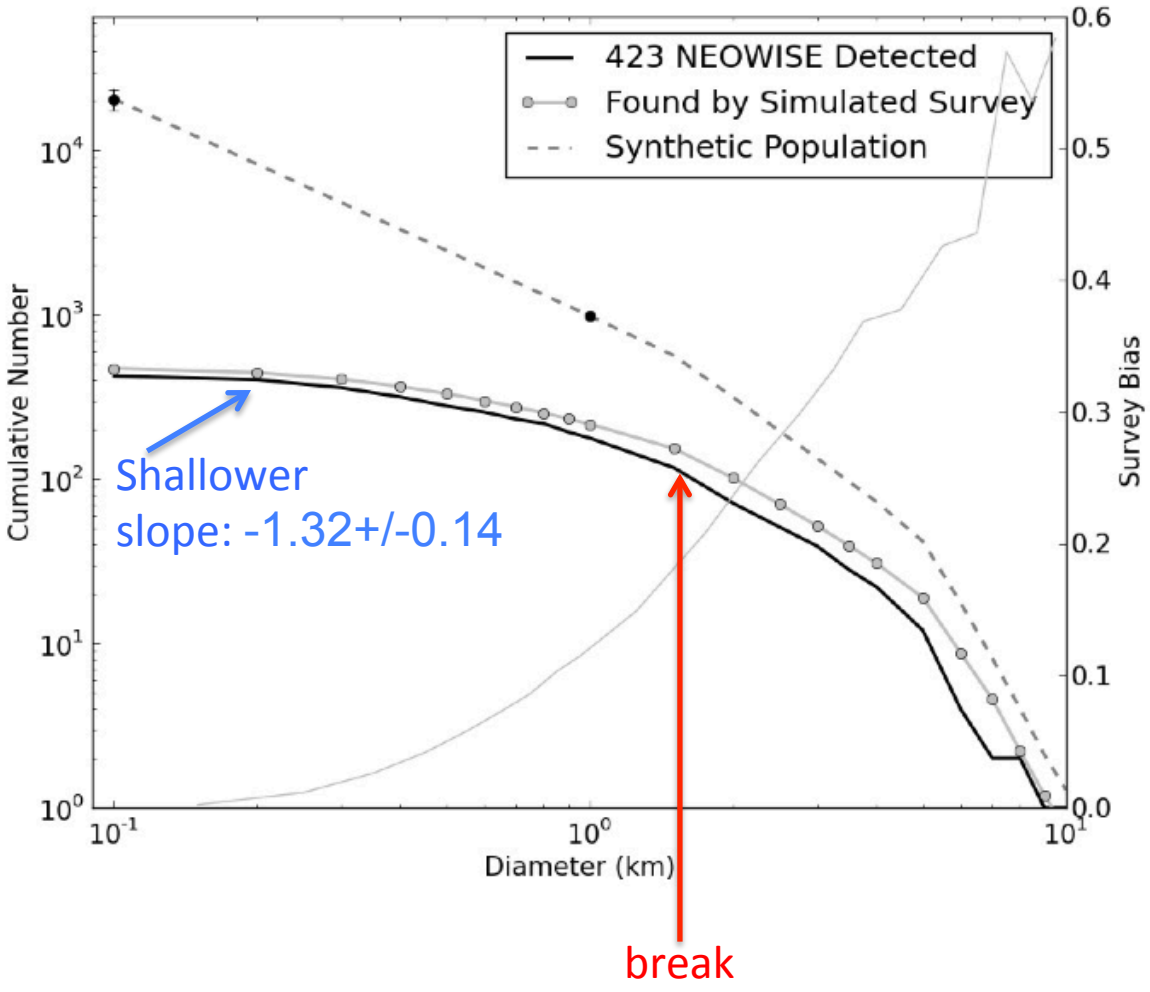


- >158,000 asteroids detected
- >34,000 new discoveries
- ~750 NEOs detected
- 135 new discoveries
- 150 comets detected
- 21 comets discovered

NEOs – NEOWISE-discovered
NEOs – others' detected
Comets – others' detected
Comets – NEOWISE-discovered
All other detected objects

Slide by A. Meinzer

Near-Earth Asteroid Numbers & Sizes

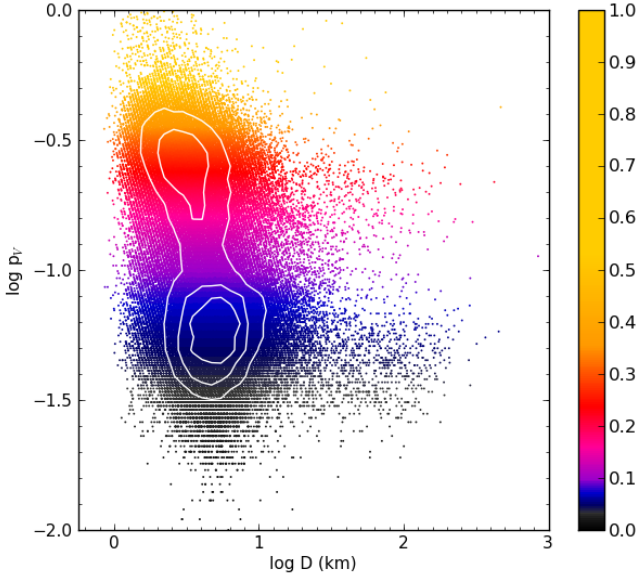


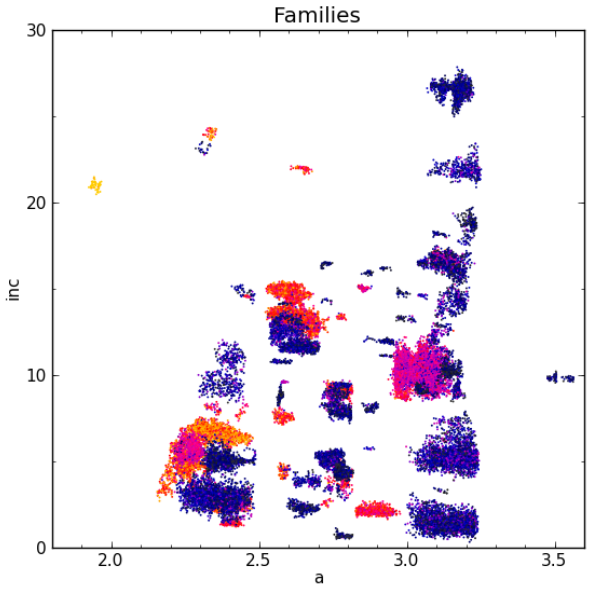
- Use well-known sensitivity & uniformity of four band survey to compute total numbers from observed sample
- 20,500+/-3000 @ 100m vs. prior estimates of 36,000 – 100,000
- >90% of 1 km and larger NEAs have been discovered: Spaceguard goal
- Mainzer et al. 2011 ApJ 743, 156

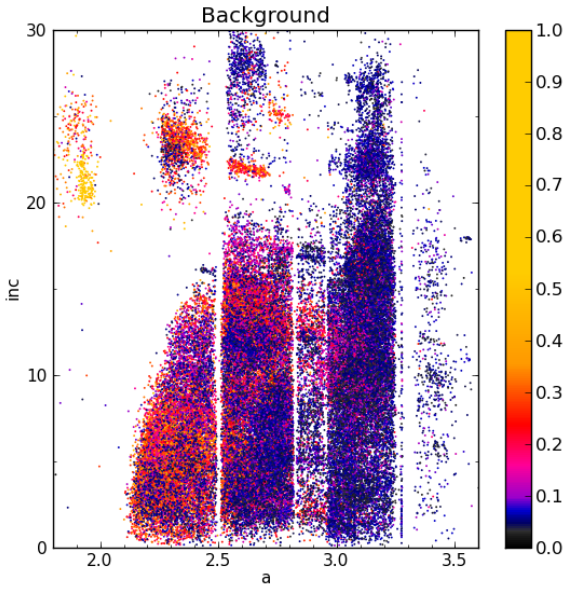
Slide by A. Meinzer

Asteroid Families

- Masiero et al. 2013 ApJ 770, 7 “Asteroid Family Identification using the Hierarchical Clustering Method and WISE/NEOWISE Physical Properties”
- Use albedo + velocity cuts in HCM method to identify new families/family members w/ ~120,000 Main Belt Asteroids detected by NEOWISE
- Link ~38,300 asteroids into 76 families







WISE Data Releases

- Preliminary data release: April 14, 2011 (57% of the sky)

- **WISE All-Sky Release: March 14, 2012**

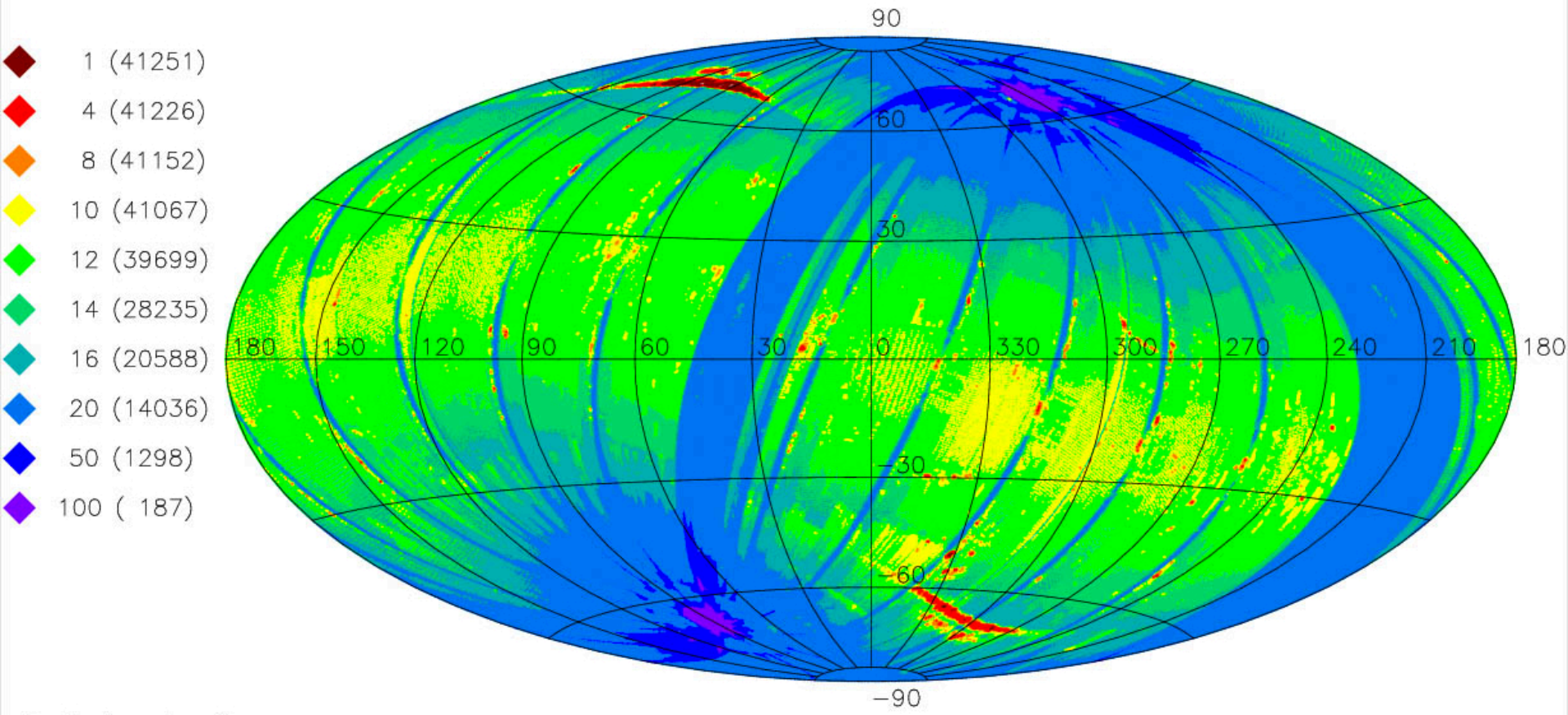
- NEOWISE Post-Cryo Preliminary Data Release: July 31, 2012
- NEOWISE Post-Cryo Data Release: May 22, 2013

- **AllWISE: November 13, 2013**

WISE All-Sky Release

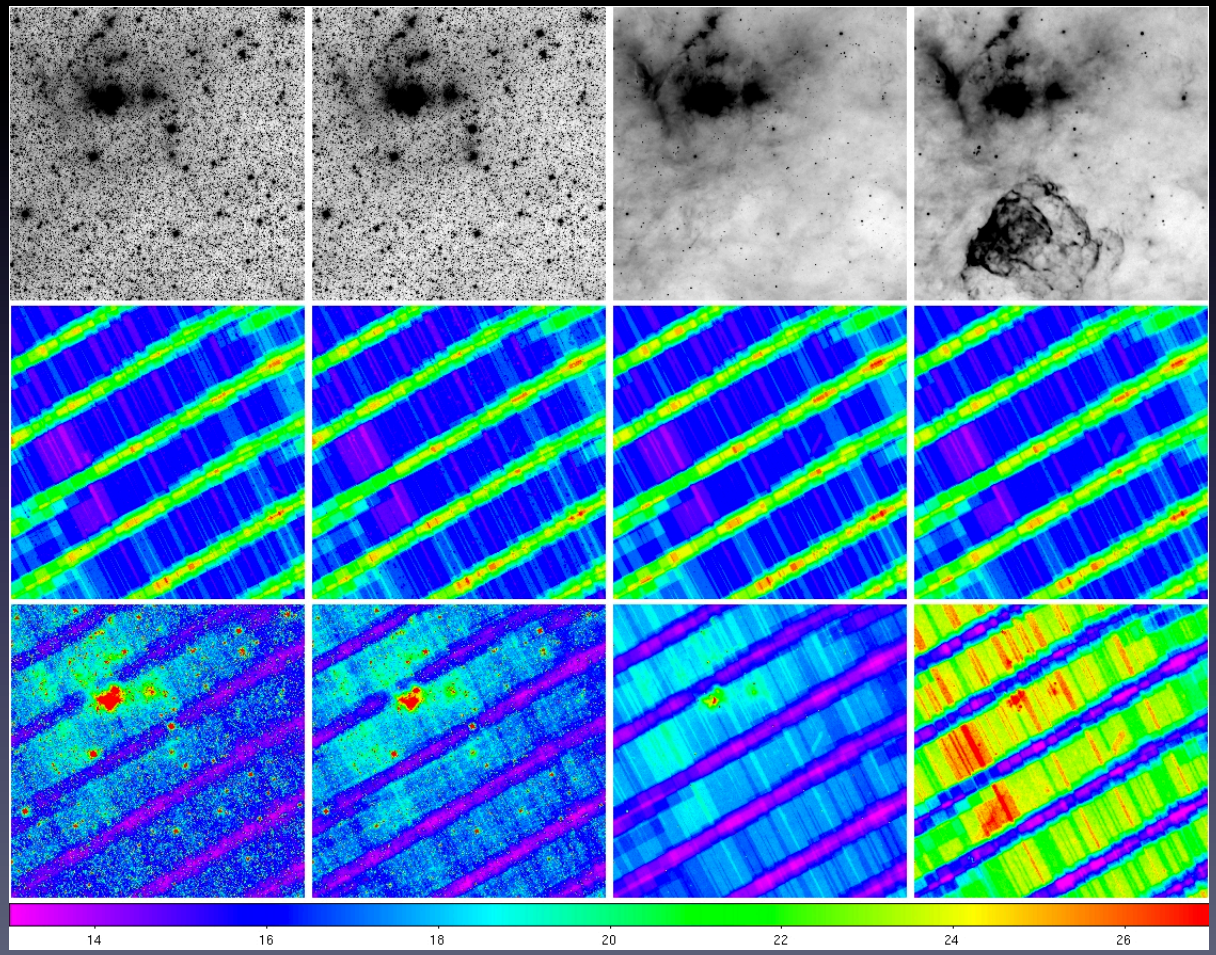
- **Source Catalog**
  - Measurements for 563,921,584 point sources detected on co-added images (detected with SNR>5)
  - Flux limit: 16.6, 15.6, 11.3, 8.0 (W1,2,3,4; Vega magnitudes); saturates at 8.1, 6.7, 3.8 and -0.4
  - Astrometric accuracy: ~200 mas
- **Image Atlas**
  - 18,240 4095x4095 image sets in FITS format (1.375"/pixel)
  - Coadded data from all observations, tiling the entire sky
- **Ancillary Products**
  - Rejects table
  - Single-exposure image sets (~1.5 million)
  - Single-exposure source database (~9.4 billion source detections)
  - Moving object tracklet database
  - Known Solar System object possible association list

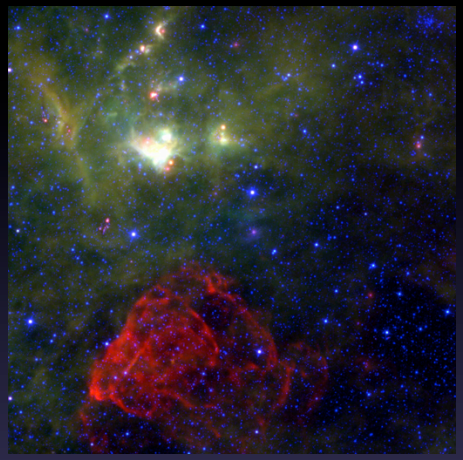
WISE Sky Map



http://wise2.ipac.caltech.edu/docs/release/allsky/

Image Sets





Left: 3.4, 4.6, 12, 22 μm intensity images (top row), depth-of-coverage maps (middle), and uncertainty maps (bottom) for the Atlas Tile 1253m425_ab41 that contains the Puppis A supernova remnant.

Above: 4.6, 12, 22 μm color composite intensity map of the same area.

http://wise2.ipac.caltech.edu/docs/release/allsky/

AllWISE Data Release

- **Includes the NEOWISE data**
  - 747 million objects detected on atlas images
  - 42 billion photometric measurements (multi-epoch photometry)

- **Improvements over WISE All-Sky Release**
  - Better W1 and W2 photometric sensitivity
  - Astrometric accuracy ~2x better
  - Measuring object motion
  - Includes extended sources
  - Includes light curves
  - See http://wise2.ipac.caltech.edu/docs/release/allwise/expsup/sec1_4.html for more

Data Access

- Accessible through IPAC's Infrared Science Archive (IRSA) website:
  - http://irsa.ipac.caltech.edu/Missions/wise.html
- Bulk download:
  - http://irsadist.ipac.caltech.edu/wise-allsky/
  - http://irsadist.ipac.caltech.edu/wise-allwise/

WISE continues

- NEOWISE-R: http://neowise.ipac.caltech.edu/
  - Three year survey to search for and characterize near-earth objects
    - W1 and W2 (3.4 and 4.6 μm) bands active
    - References: Mainzer et al. 2014, ApJ, 792, 30

- Dataset:
  - All-sky measurements of broad-band IR SEDs of ~750M objects!
  - Relatively new dataset (~2012), not yet utilized to its fullest extent
    - AGNs, ULIRGs, more opportunities for searches for low-mass stars, etc.
  - Studies of diffuse structures (Galactic dust)