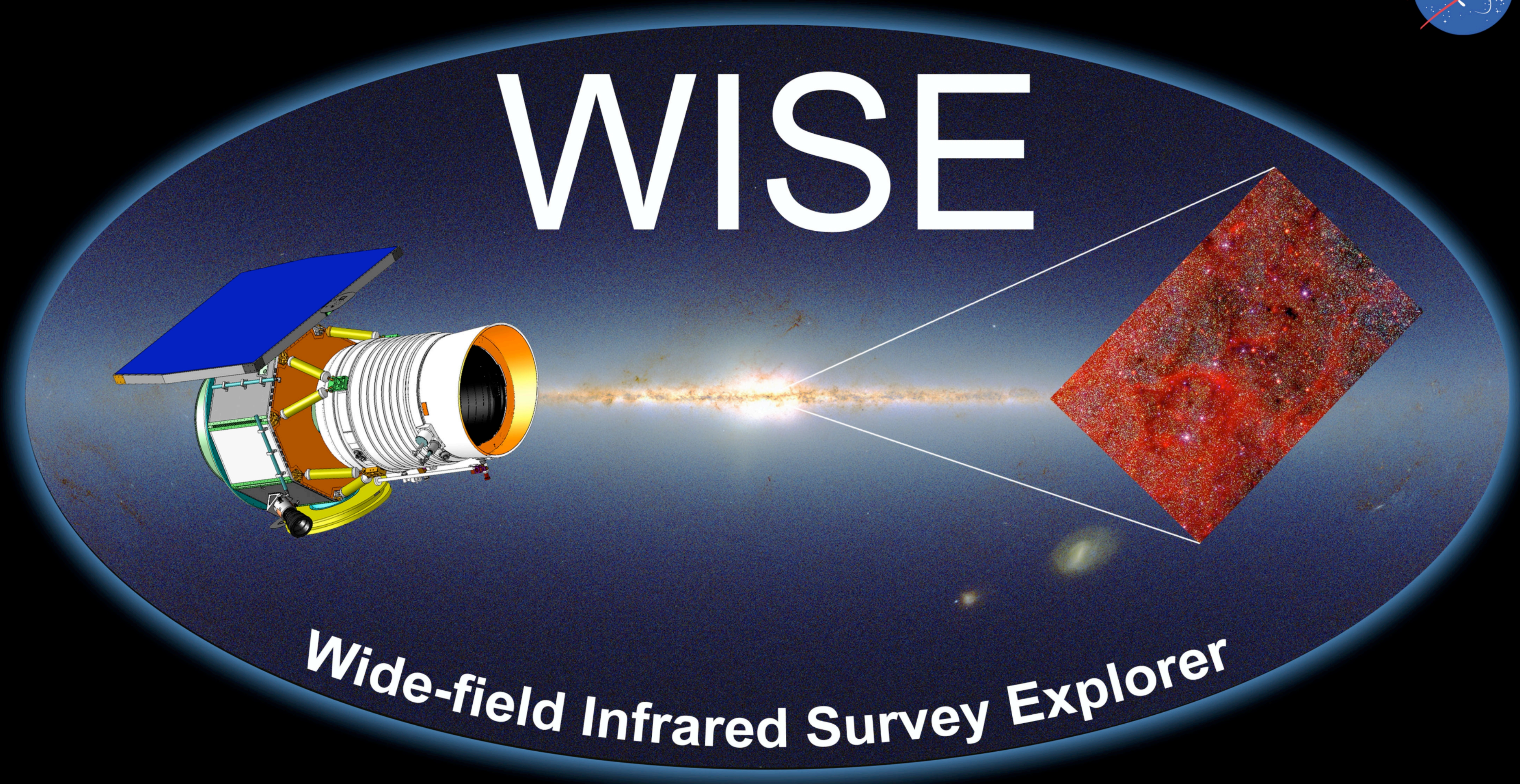
National Aeronautics and Space Administration



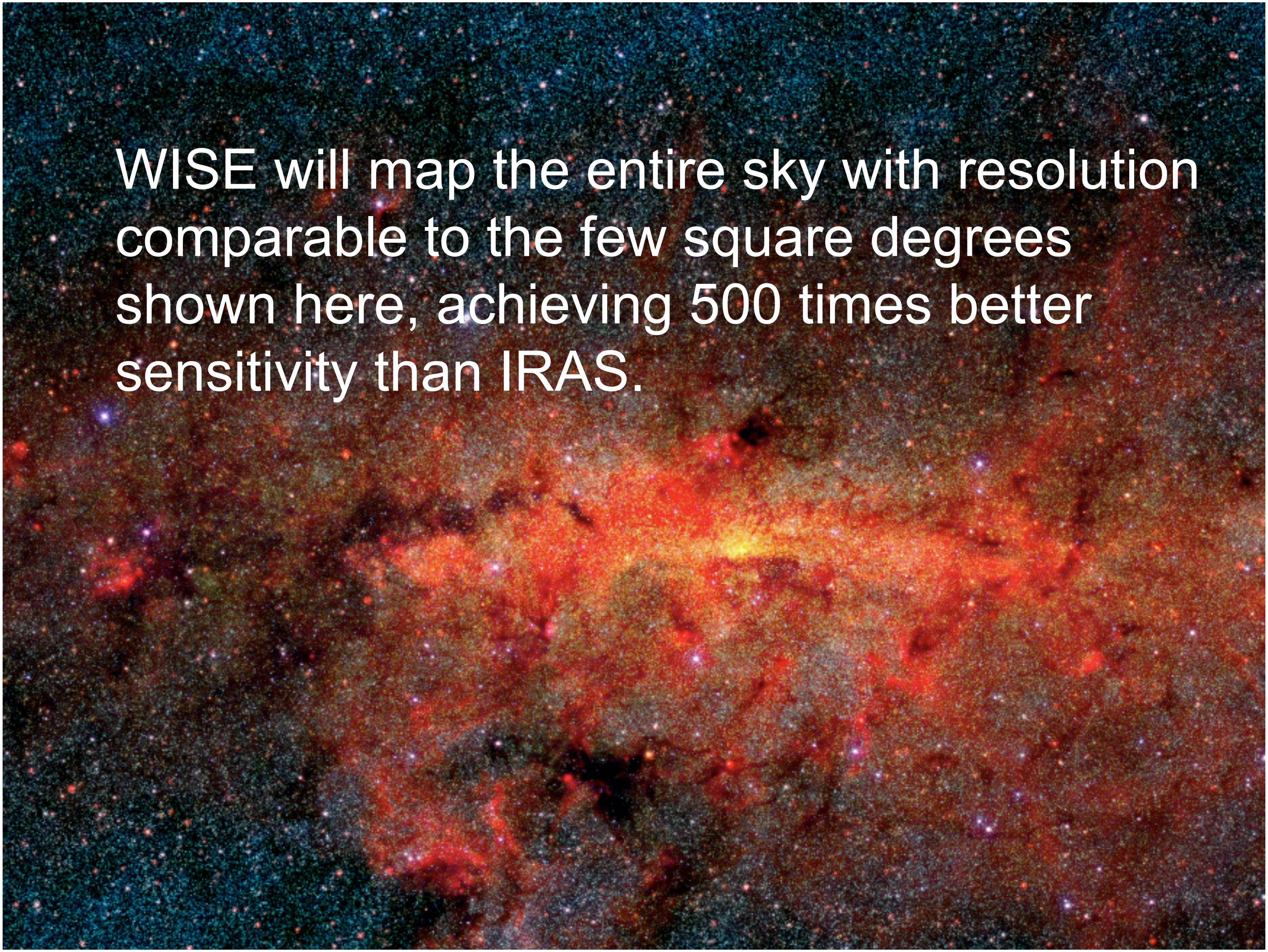
http://wise.astro.ucla.edu

UCLA • JPL • BALL • SDL • IPAC • UCB

Peter Eisenhardt (JPL)

2008 January 29


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


WISE will map the entire sky with resolution comparable to the few square degrees shown here, achieving 500 times better sensitivity than IRAS.

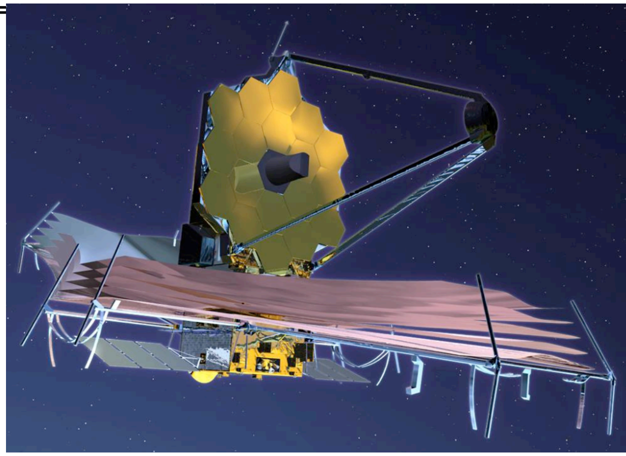
What Is WISE?

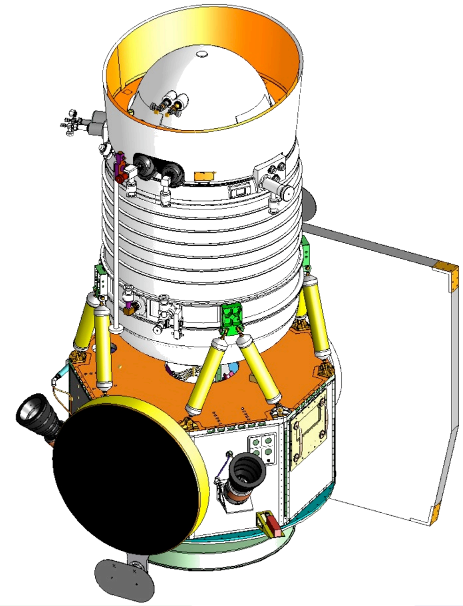
- A Medium Explorer (MIDEX) Mission
- The Wide-field Infrared Survey Explorer (WISE)
  - An all-sky survey at 3.3, 4.7, 12 & 23 μm with 3 to 6 orders of magnitude more sensitivity than previous surveys
  - A cold 40 cm telescope in a sun-synchronous low Earth orbit
  - 6” FWHM (12” at 23 μm)
  - Enabled by Megapixel infrared detector arrays
- WISE will deliver to the scientific community
  - Over 1 million calibrated rectified images covering the whole sky in 4 infrared bands
  - Catalogs of $\approx 5 \times 10^8$ objects seen in these 4 IR bands

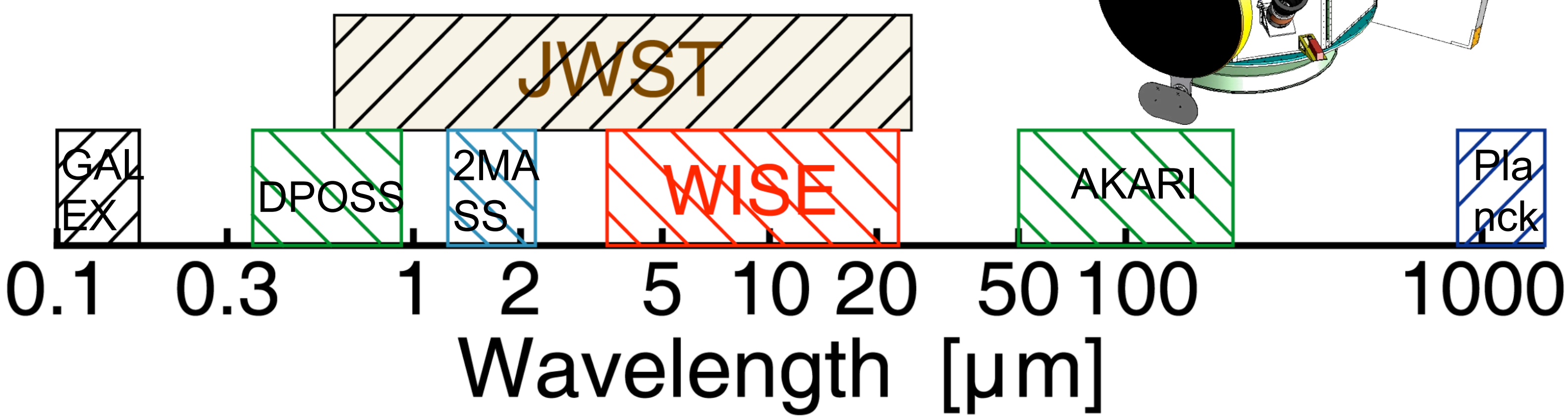
WISE Milestones

- WISE was initially proposed as NGSS in 1998
  - Selected for Phase A study, but not flight
- Re-proposed in 2001
- Initial Confirmation Review 2004 August 25
- Mission Confirmation Review 2006 October 13
- Mission CDR 2007 June 18 - 21
- Launch November 2009
  - 1 month IOC
  - 6 months survey (baseline - 12 months Phase F)
- Preliminary catalog 6 mos. after end of survey
- Final catalog 17 mos. after end of survey

WISE Will Fill "the Gap"

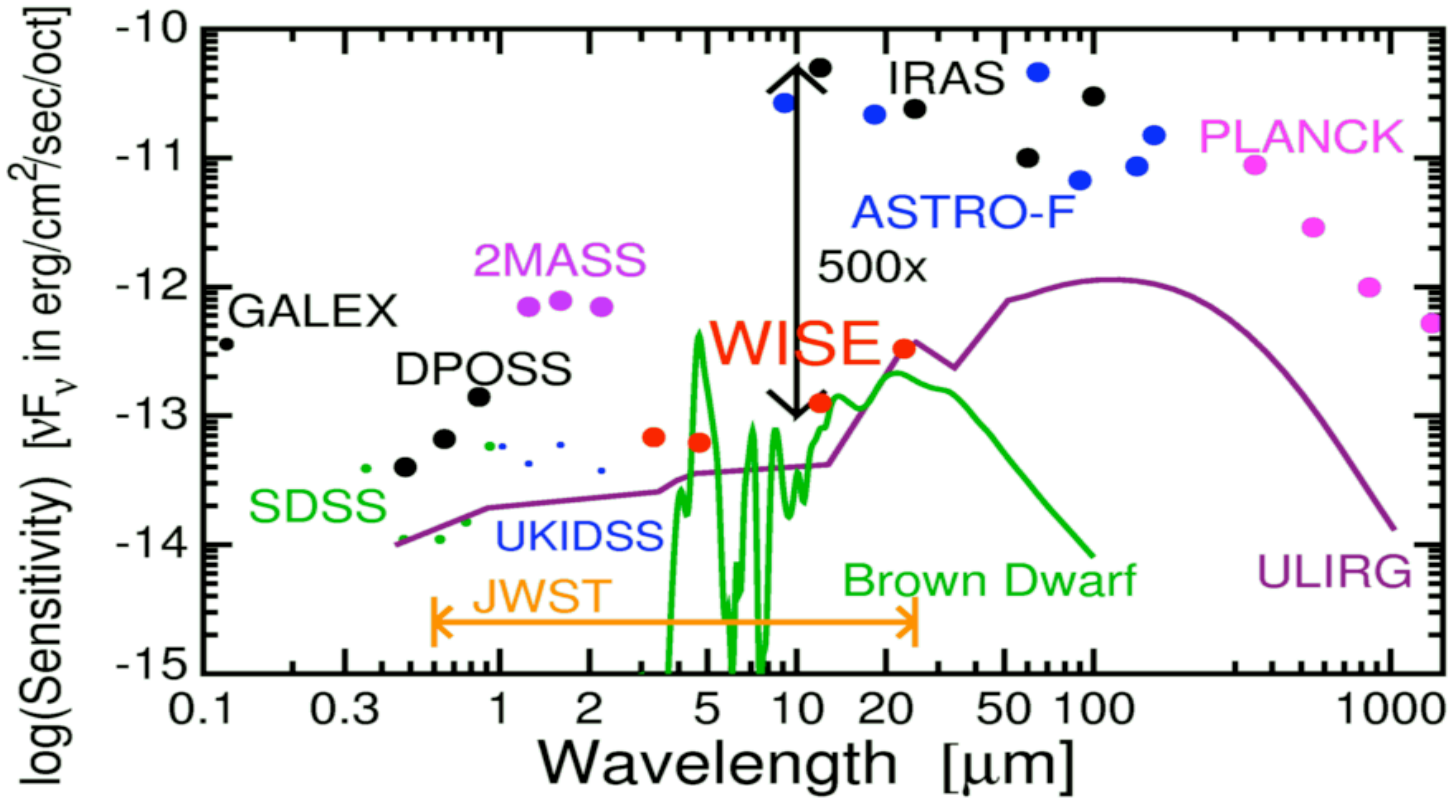






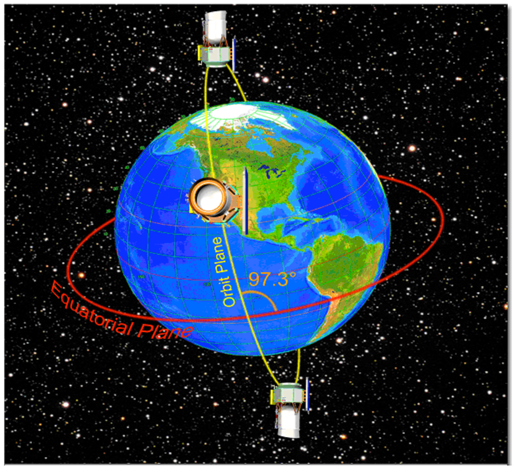
- WISE will fill the gap in wavelengths covered by sensitive all sky surveys
- Many pointed JWST observations will be in this wavelength gap

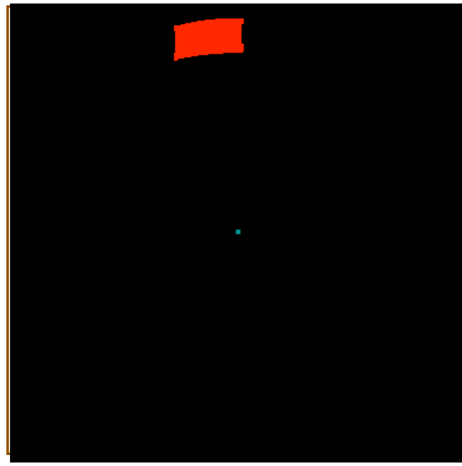
Great Advance in Sensitivity

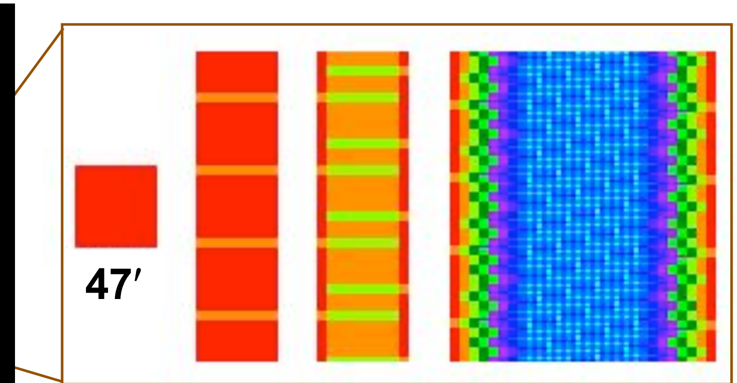


WISE is orders of magnitude better than previous surveys in the mid-IR

Simple Mission Design

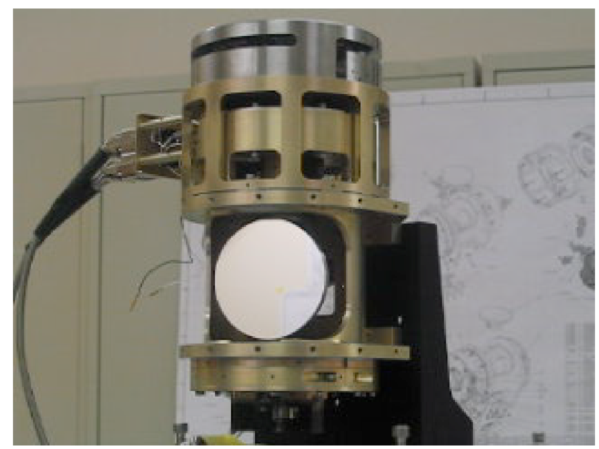






- Delta 7320 launch – WTR
- 523 km, circular, polar sun-synchronous orbit
  - Nodal crossing time 6:00 PM
  - One month of checkout
  - 6 months of survey operations
- One simple observing mode – half orbit scan

•Scan mirror “freezes” orbital motion
- enabling efficient mapping
  - 8.8-s exposure/11-s duty cycle
  - 10% frame to frame overlap
  - 90% orbit to orbit overlap

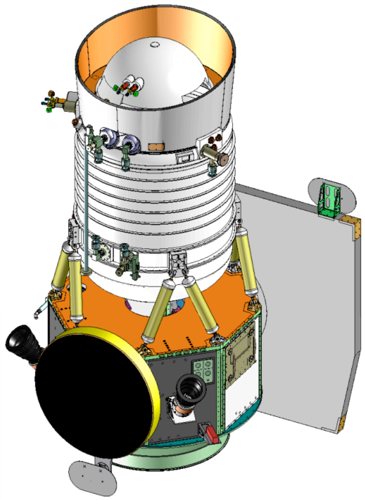


•Expect to achieve at least 8 exposures/position after losses to Moon and SAA

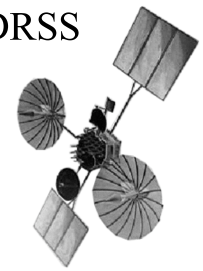
•Uplink, downlink, calibrations at poles
- 4 TDRSS tracks per day

WISE Mission Components

Cryogenic Telescope
(SDL)
Spacecraft
(BATC)



TDRSS



Delta II

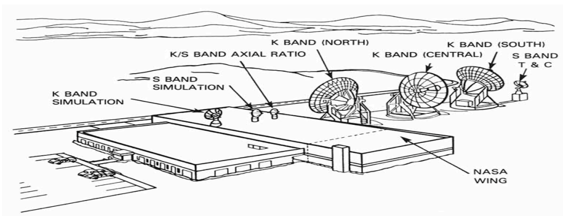
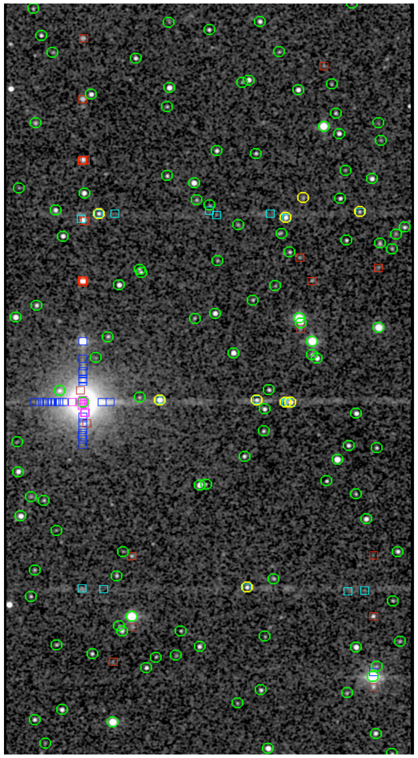


Figure 6–11. White Sands Ground Terminal

White Sands Ground Terminal



Science Data Processing
(IPAC)

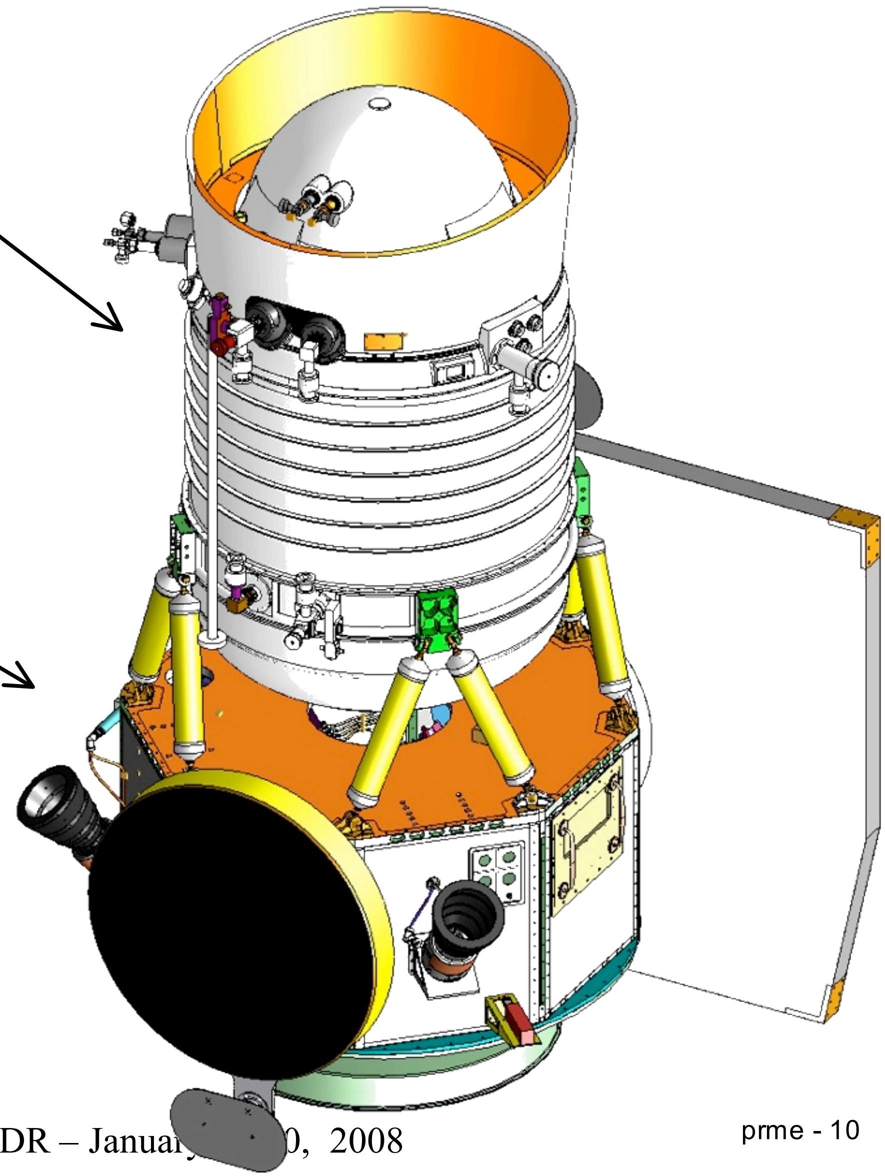
Engineering Operations System
(JPL)

Science Survey Planning
(UCLA)

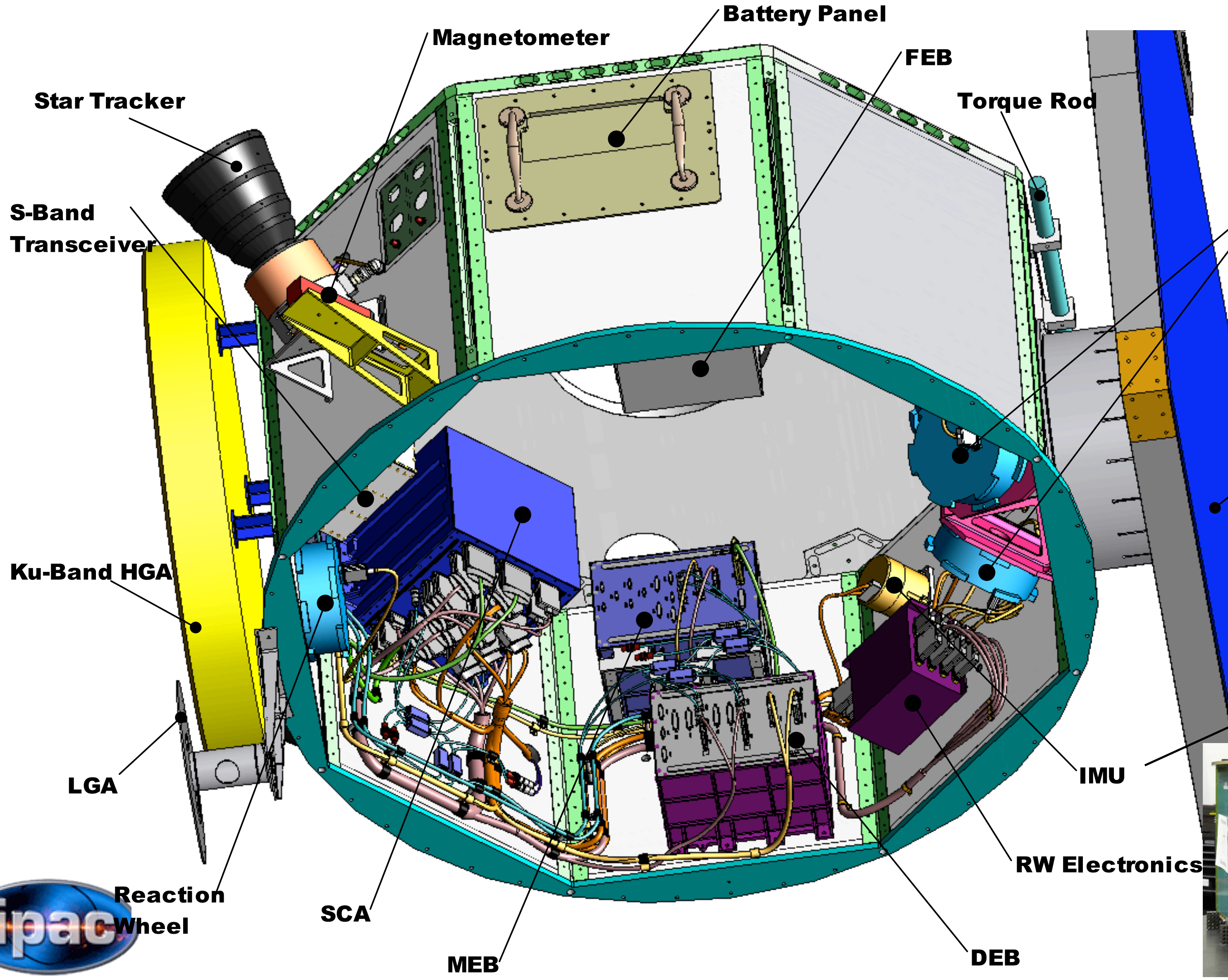
Flight System

Payload (SDL)
- 2-Stage Solid H_2 cryostat
    - 13.5 months life time (7 required)
- All aluminum reflective optics: <17K
    - 40-cm telescope
- Dichroic beamsplitters separate wavelengths onto four 1024^2 pixel arrays
- 2 HgCdTe detectors: 3.3, 4.7 microns (32K)
- 2 Si:As detectors: 12, 23 microns (7.8K)
- 3 electronics boxes (mounted in spacecraft)

Spacecraft (Ball Aerospace)
- Orbital Express architecture
- Augmented single string
- No mechanisms, no deployables, no propulsion
- 3-axis stabilized
- Pointing stability/accuracy: ~ 1”/ ~1’
- Ku band science data link: 100Mbps
- 3.5 days (96 GB) of science data storage



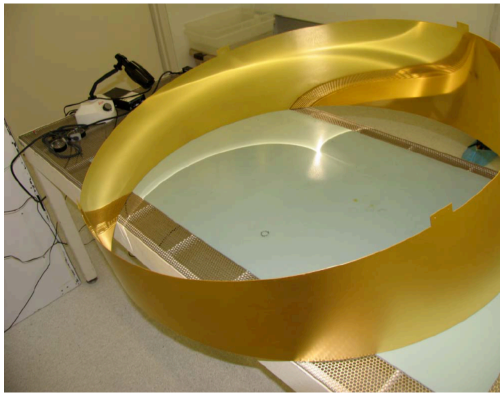
Spacecraft

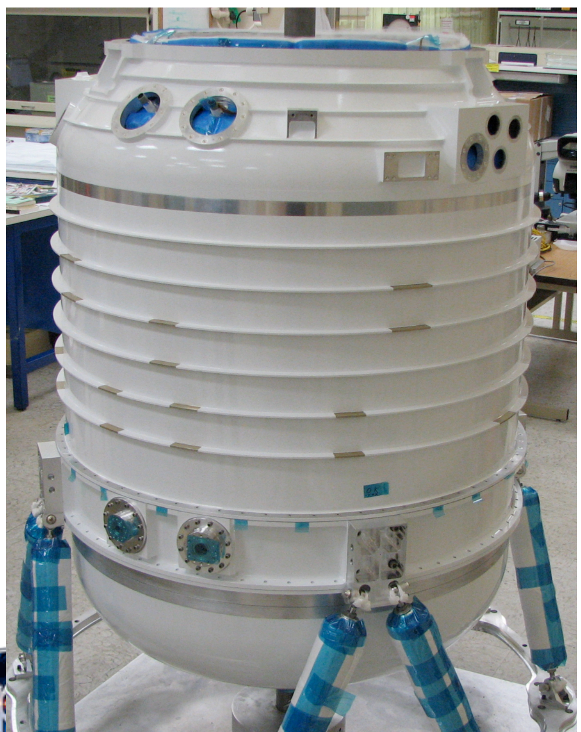

Battery Panel
Magnetometer
FEB
Star Tracker
Torque Rod
S-Band Transceiver
Reaction Wheels
Solar Array
Ku-Band HGA
LGA
IMU
RW Electronics
Reaction Wheel
SCA
MEB
DEB

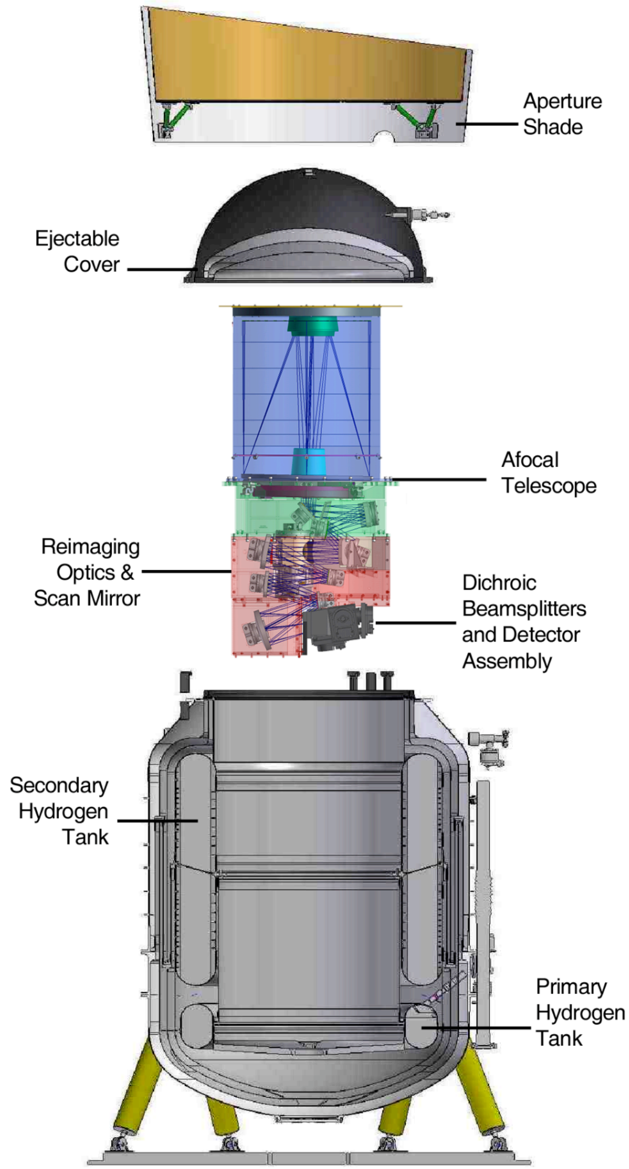

CAUTION!!
HANDLE WITH EXTREME CARE

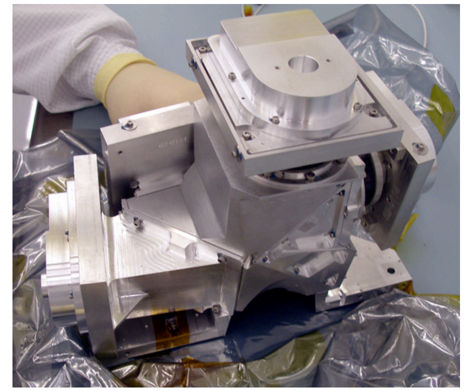
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

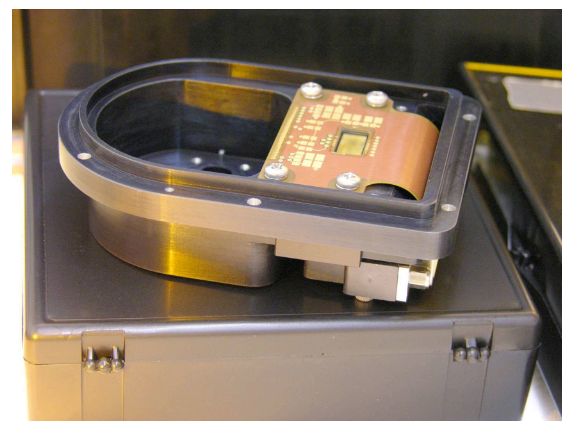
Payload











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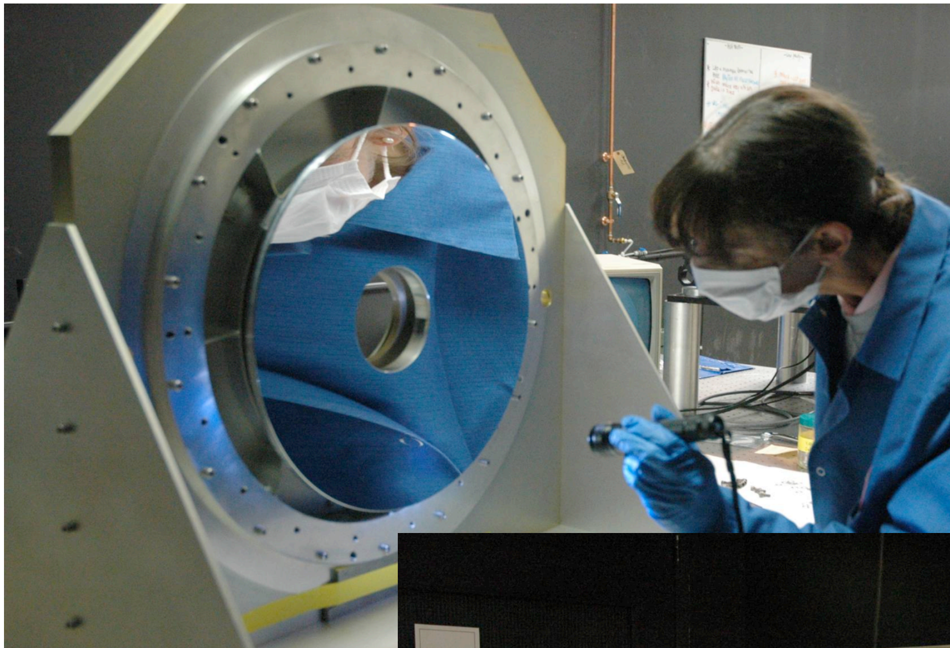
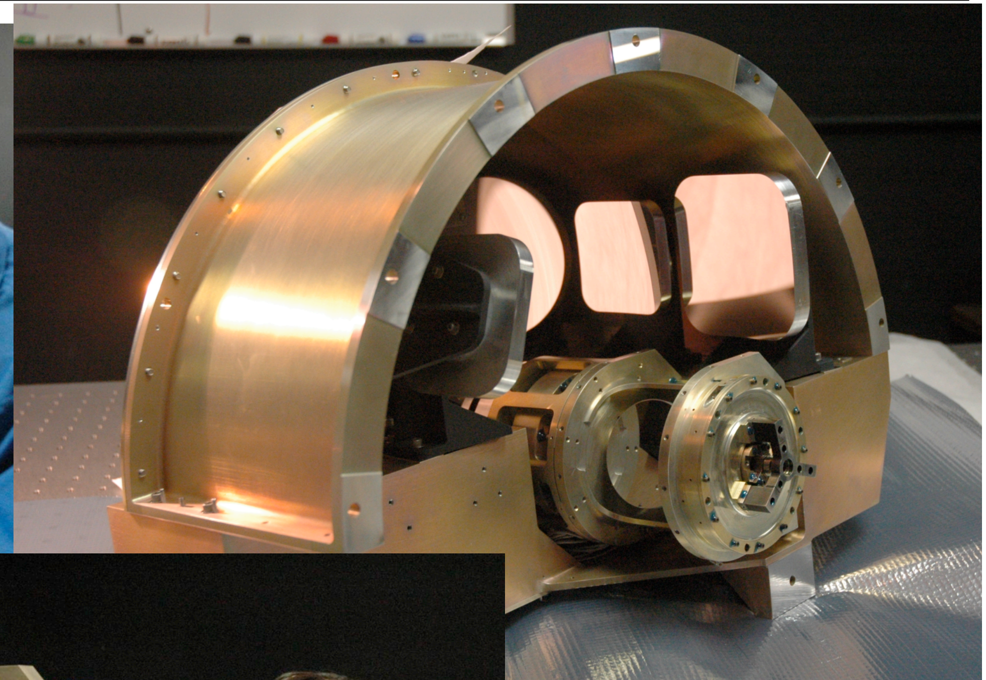
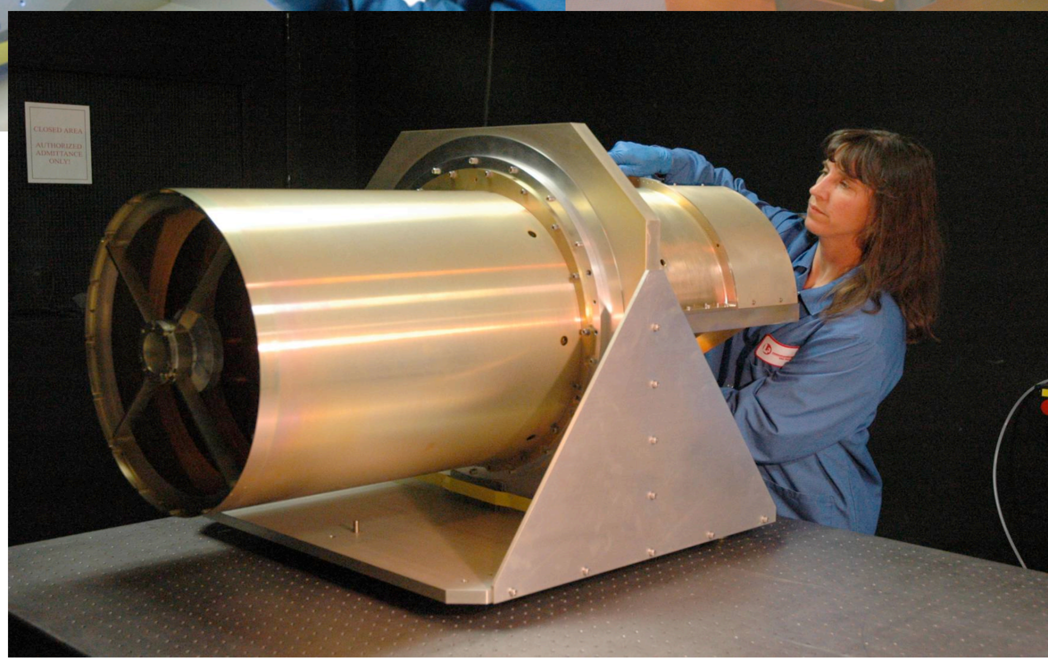
WISE Optics







WISE Science Team

- Edward L. Wright UCLA (PI)
- Andrew Blain Caltech
- Martin Cohen MIRA
- **Roc Cutri IPAC/Caltech**
- Peter Eisenhardt JPL
- T. Nick Gautier JPL
- Isabel Hawkins UC Berkeley
- **Thomas Jarrett IPAC/Caltech**
- **J. Davy Kirkpatrick IPAC/Caltech**
- David Leisawitz GSFC
- **Carol Lonsdale IPAC/Caltech**
- Amanda Mainzer JPL
- John Mather GSFC
- Ian McLean UCLA
- Robert McMillan Univ. of Arizona
- **Deborah Padgett IPAC/Caltech**
- Michael Ressler JPL
- Michael Skrutskie Univ. of Virginia
- S. Adam Stanford UC Davis
- Russell Walker MIRA

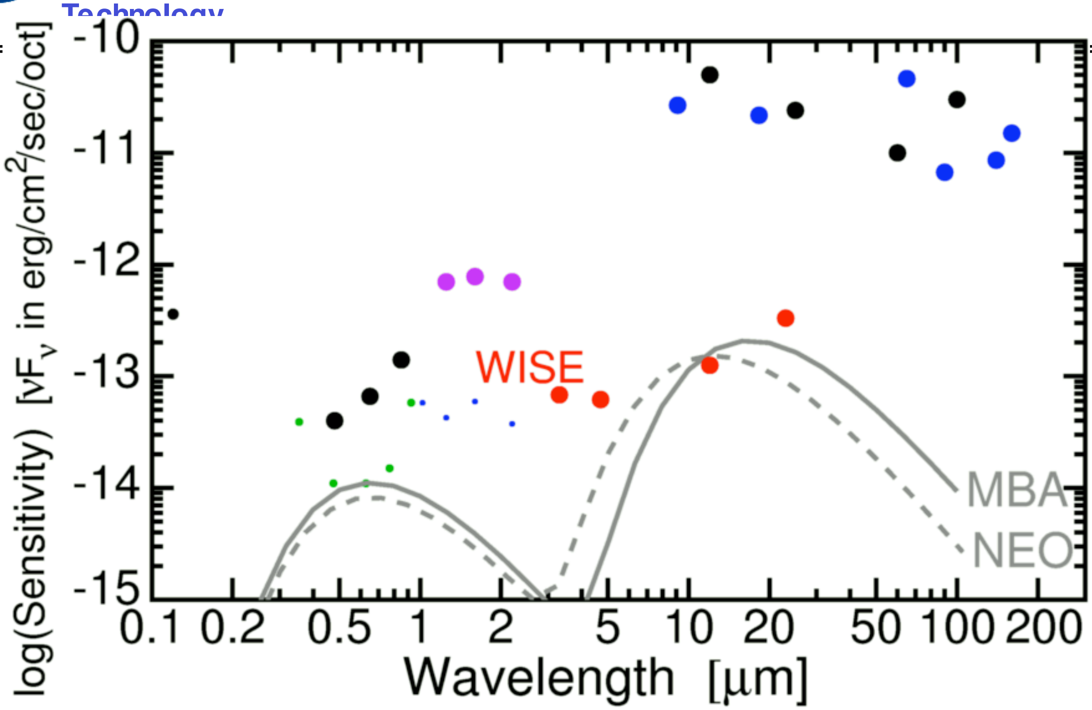
Level 1 Requirements

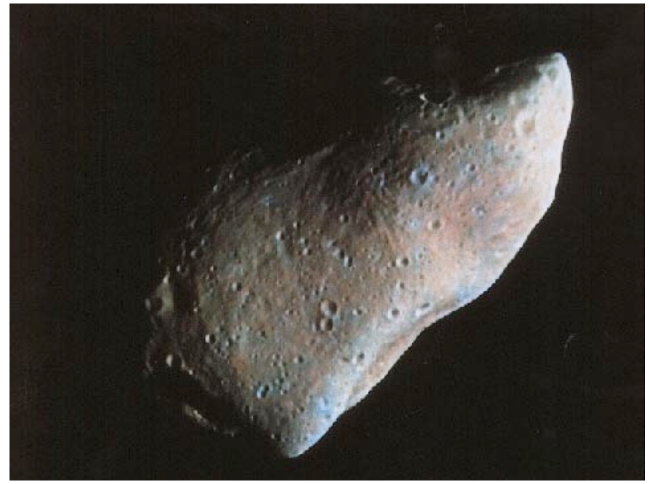
Baseline Minimum Requirement
Four bands centered within 10% of 3.3, 4.7, 12,and 23 microns Three bands between 2.2 and 50 microns
At least 4 independent exposures in each filter over at least 95% of the sky 2 exp. over 90 %
SNR 5 on 0.12/0.16/0.65/2.6 mJy at 3.3/4.7/12/23 microns SNR 5 on 1.1/1.6/4.0/7.7 mJy
Digital image atlas combining multiple exposures at each sky position same
Catalog of sources associated with image atlas same
Reliability > 99.9% for SNR > 20 same
Completeness > 95% for SNR > 20 > 90%
<7% relative photometric accuracy for SNR > 100 <10 %
Position error <0.5" wrt 2MASS for SNR > 20 < 1.0”
Include sources to SNR 5 in any band, characterize completeness and reliability at all flux levels
Image atlas and catalog publicly available via IRSA within 17 months of end of on-orbit data collection
Survey sky for at least 6 months following checkout
~500 km Sun Synchronous 6am/pm Polar Orbit via Delta II 7320
Launch any day of year; launch readiness in November 2009
Compatible with data return through TDRSS
$299.3 M RY$ project funding
Use WTR, GSFC, TDRSS, IRSA
Conduct an E/PO program
Images available for outreach purposes within 1 month of start of normal operations

Level 1.5 Science Requirements

- Bandpasses:
  - 2.8 (but up to 3.2) to 3.8 um
  - 4.1 to 5.2 um
  - Centered at 12 um; bandwidth 6 to 9 um
  - 20 to > 25 um
- Out of band response < 1% of in-band response for
  - All bands for A0 star (goal B0), 800K BD (Band 1), and Class 2 circumstellar disk (Bands 2 and 3)
- Sensitivity allocations:
  - Effective confusion noise: 63/62/344/950 uJy in bands 1/2/3/4
  - Payload: 102/147/551/2420 uJy in bands 1/2/3/4
- Time interval between first and last exposure at a sky position > 30 minutes
- **Image Atlas registered to 0.5" relative to 2MASS**
- **Image Atlas photometric calibration tied to catalog**
- Saturation > 0.11/0.06/0.25/0.3 Jy in bands 1/2/3/4
- **Preliminary Catalog (first 50% of survey to SNR 20) within 6 months of end of on-orbit data collection**

WISE and Asteroids





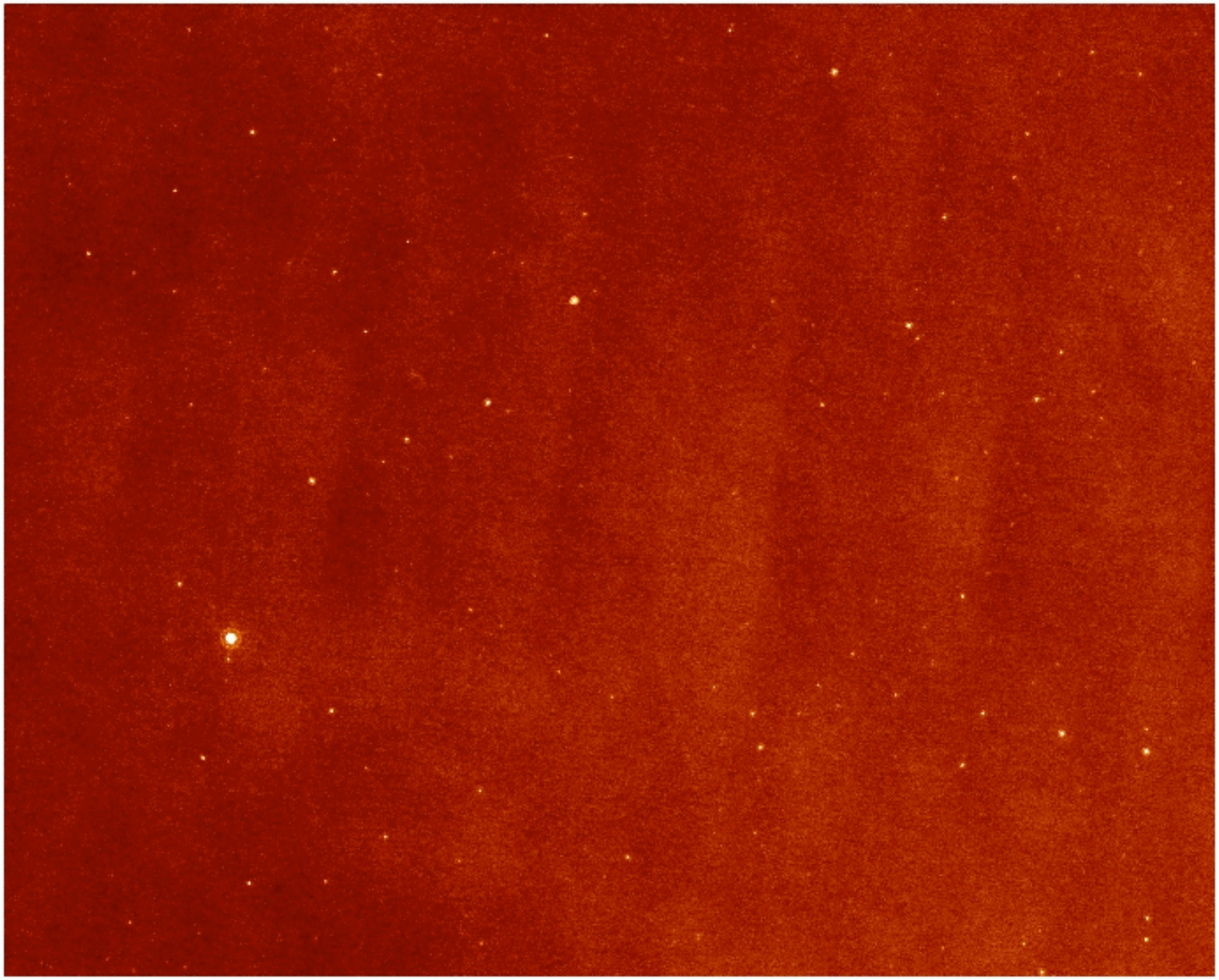
Gaspra

Asteroids move

- Asteroids are much brighter in the IR than in the optical: 100 to 400 times more photons.
  - 1km Main Belt Asteroid (MBA) and 200m Near Earth Object (NEO) shown
- They move in the hours between WISE frames.
- For asteroids with known orbits, WISE sensitivity will be slightly better than for fixed celestial objects:
  - Asteroids generally move in the same direction that WISE scans and thus get more repeated observations than stars.

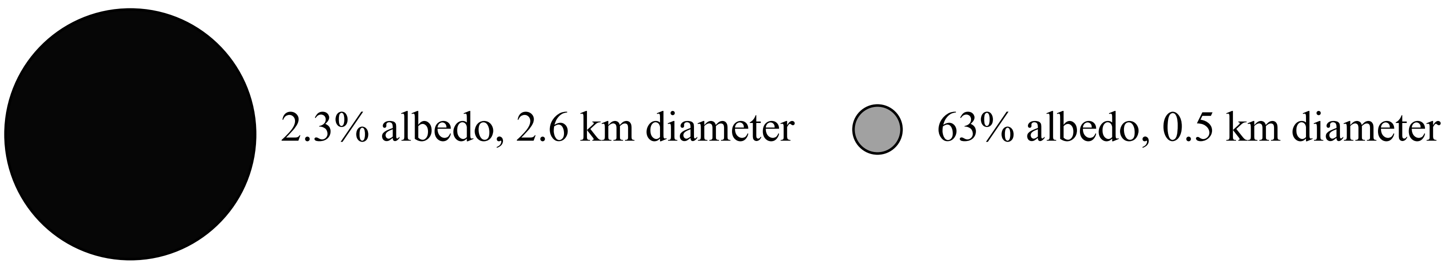
WISE Will See Many Asteroids

- Spitzer 24 μm
- Flux limit 0.7 mJy
- Size 0.7° ≈ WISE FOV
- Thermal IR provides diameters, needed for hazard assessment



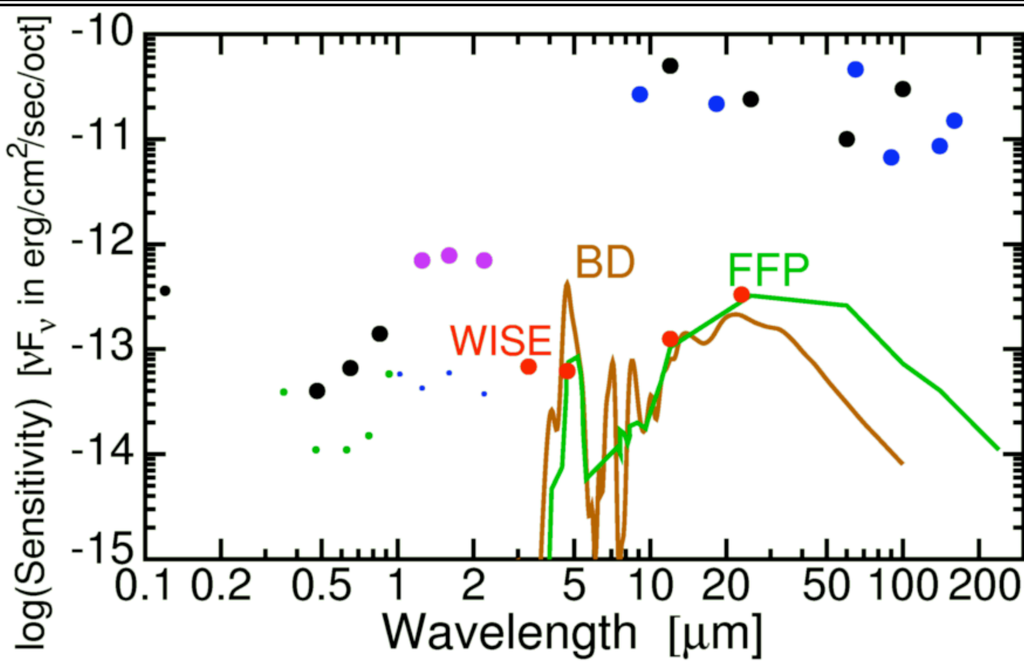
Value of IR Asteroid Data

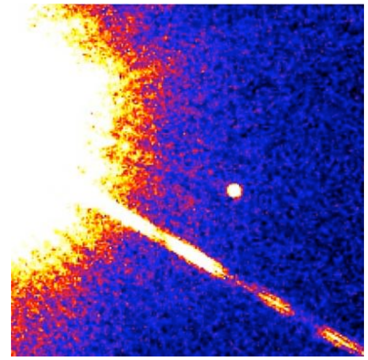
- The total flux of an asteroid, integrated over frequency and angle, gives the power intercepted from the Sun and thus the diameter.
- The range in optical albedo (Stuart & Binzel, 2004) corresponds to more than a factor of 5 in diameter, for the same (reflected) optical flux.

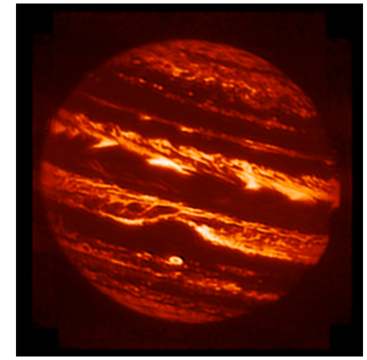


- The range in IR emission due to absorbed and reradiated sunlight for a given diameter asteroid is much smaller (Walker 2003).
- With both IR & optical data the diameter and albedo are well determined.
  - Albedo also provides an estimate of asteroid composition and density, hence mass.
  - Asteroid mass is essential for hazard assessment.

WISE and Brown Dwarfs

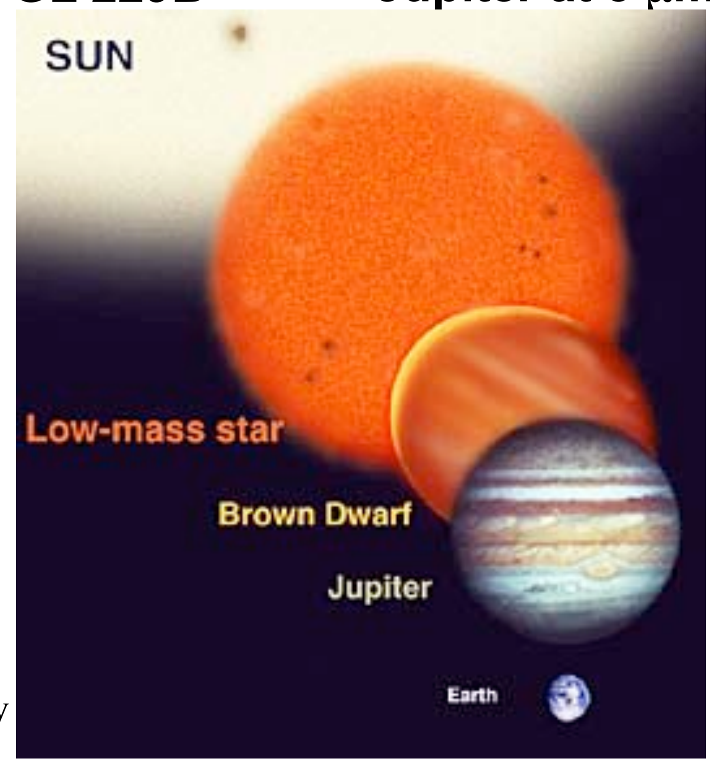






GL 229B

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.

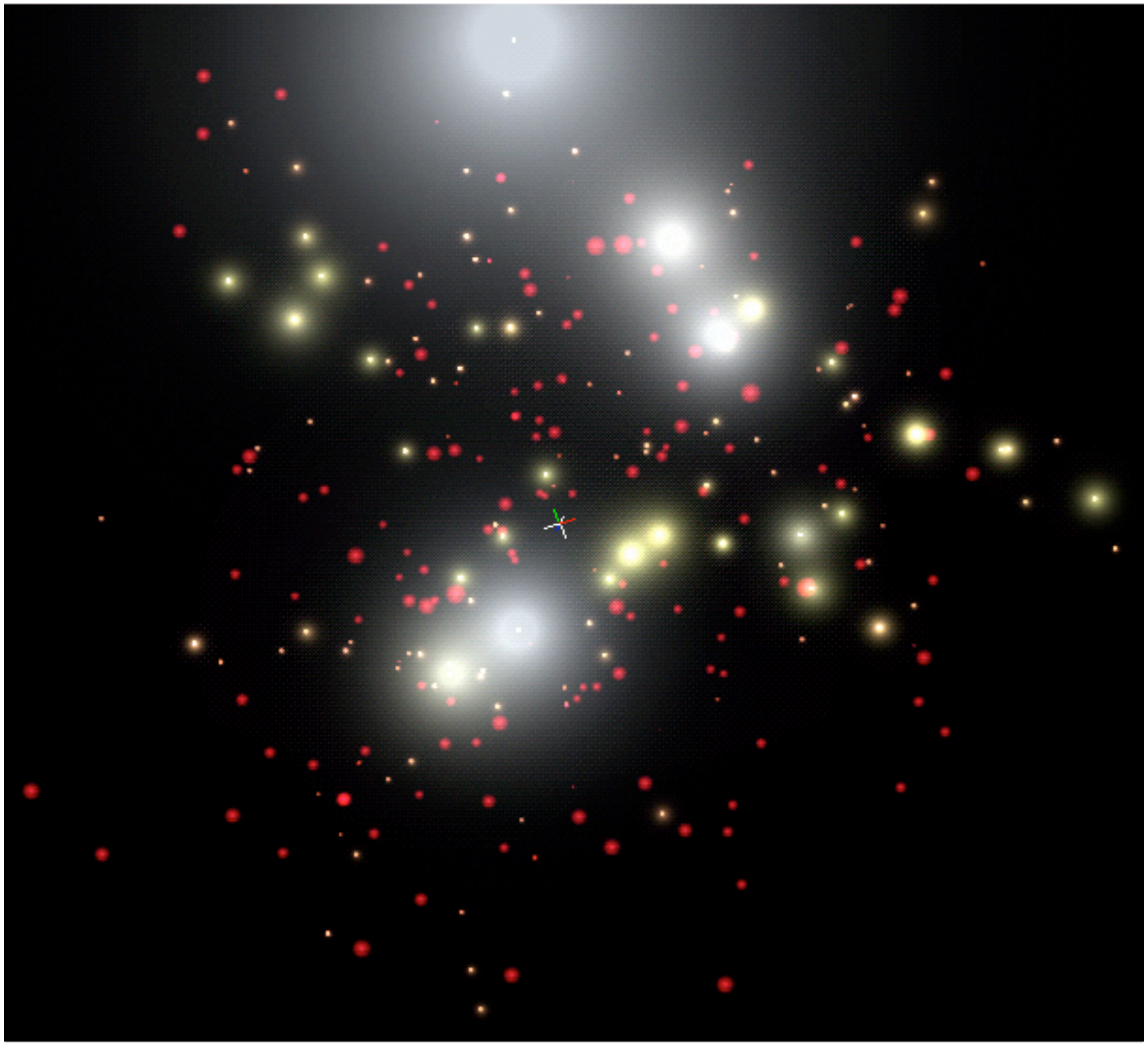
How many BDs will WISE see?

Mass Function	$T_{eff} < 300$	$T_{eff} < 500$	$T_{eff} < 750$	d < 1.3 pc
Chabrier etal log-normal	7	221	1340	0.88
Reid etal $M^{-0.7}$	5	121	671	0.53
Reid etal $M^{-1.0}$	11	197	921	0.93
Reid etal $M^{-1.3}$	22	330	1310	1.74

Assuming uniform star formation rate over the past 10 billion years and that WISE just meets its 4.6 μm sensitivity requirement.

At present, no Brown Dwarfs with T < 650 K have been found, even using Spitzer data.
WISE will find about one thousand such objects, including perhaps the nearest planetary system to our own.

WISE Will Find the Nearest Stars



W] **WISE stars within 25 lightyears**

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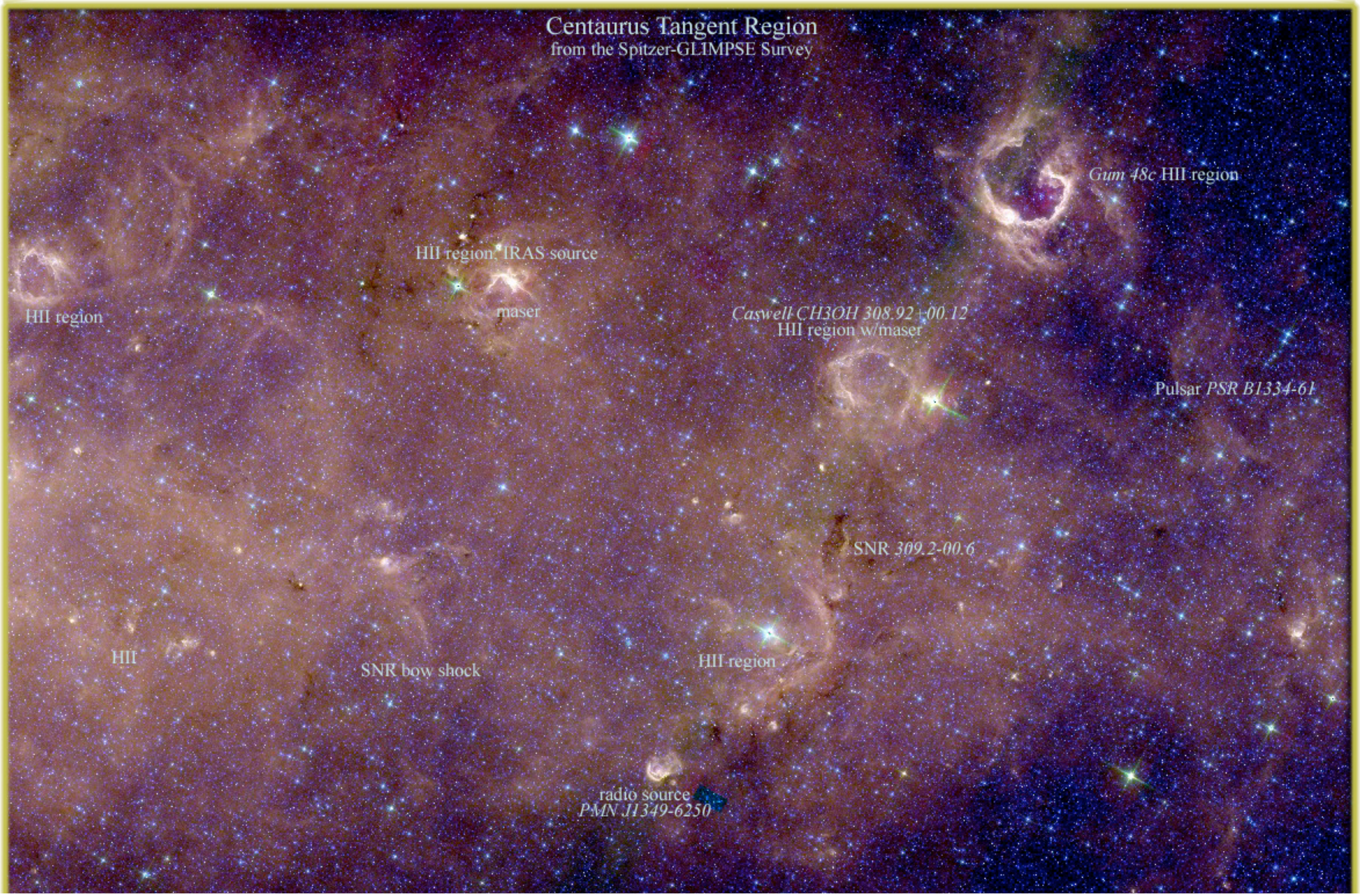
WISE Will Image the Entire Galactic Plane

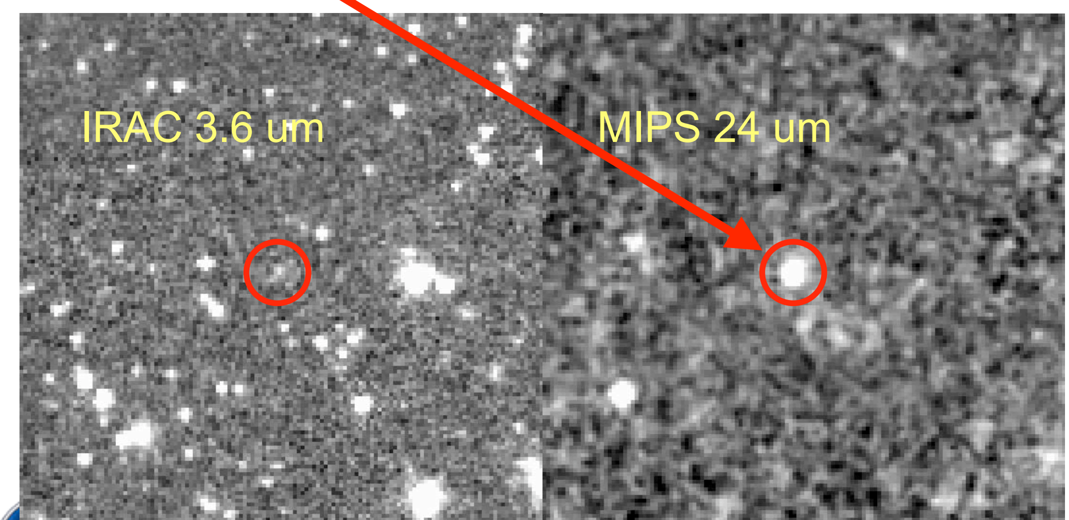


WISE Will Image All Nearby Galaxies

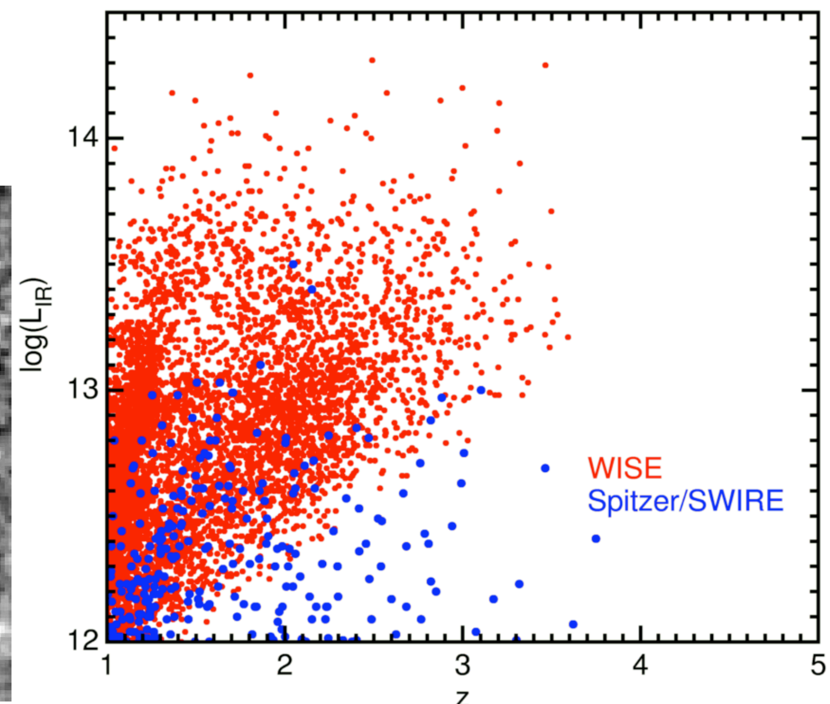
Sombrero Galaxy (M104, NGC 4594)
Spitzer SINGS Legacy data

WISE Will Find the Most Luminous Galaxies

- Normal galaxies bright at shorter IR wavelengths
- Ultra-Luminous (up to ten trillion solar luminosities) IR Galaxies emit primarily at longer infrared wavelengths
- Bottom up structure formation has a hard time producing high z and high L objects, but these ULIRGs are seen.
- Spitzer first look survey images at 3.6 and 24 um
- ULIRG at z=2.5 (Yan, Sajina, et al 2005)

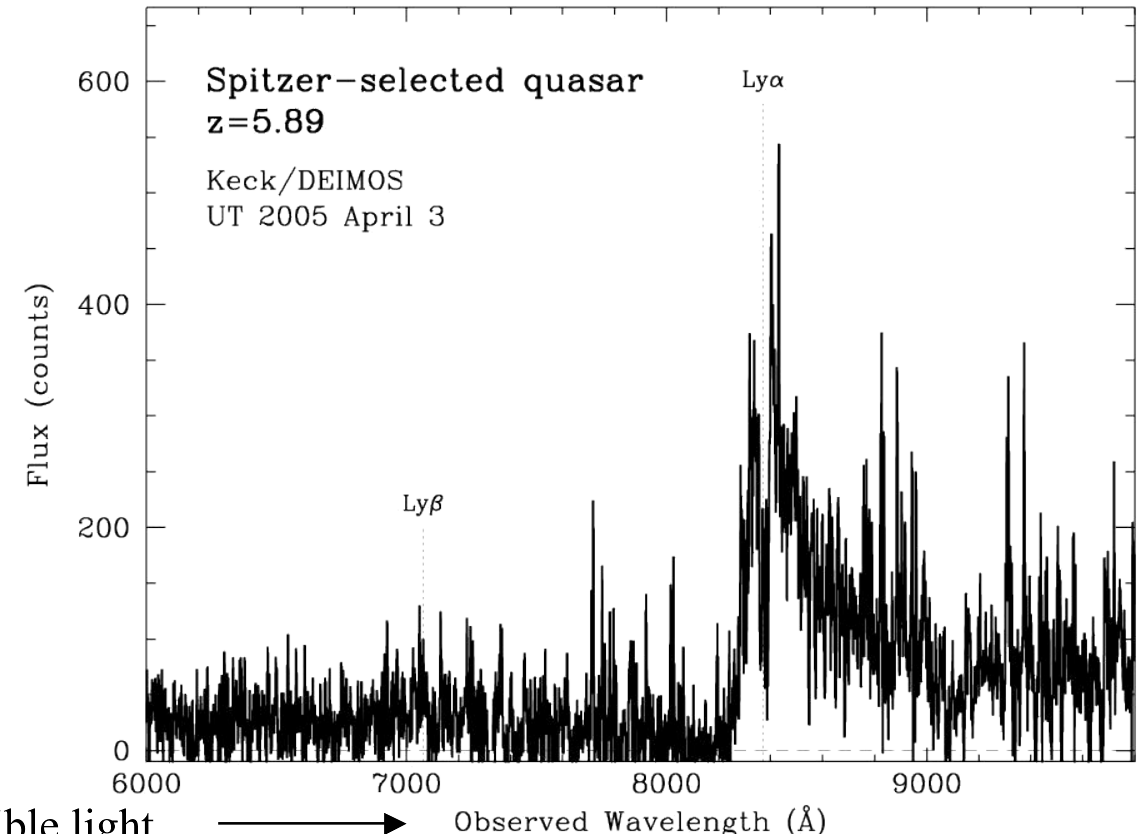


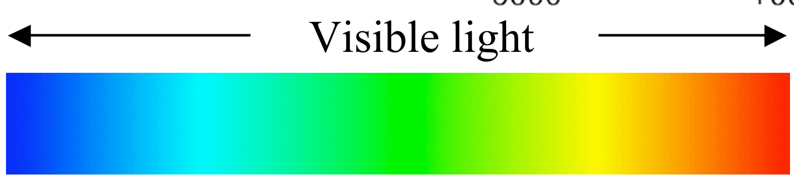
- WISE will give nearly a 1000 times more sky coverage than Spitzer.
- WISE expects to find objects > 10 times more luminous than in the largest Spitzer extragalactic survey (SWIRE).



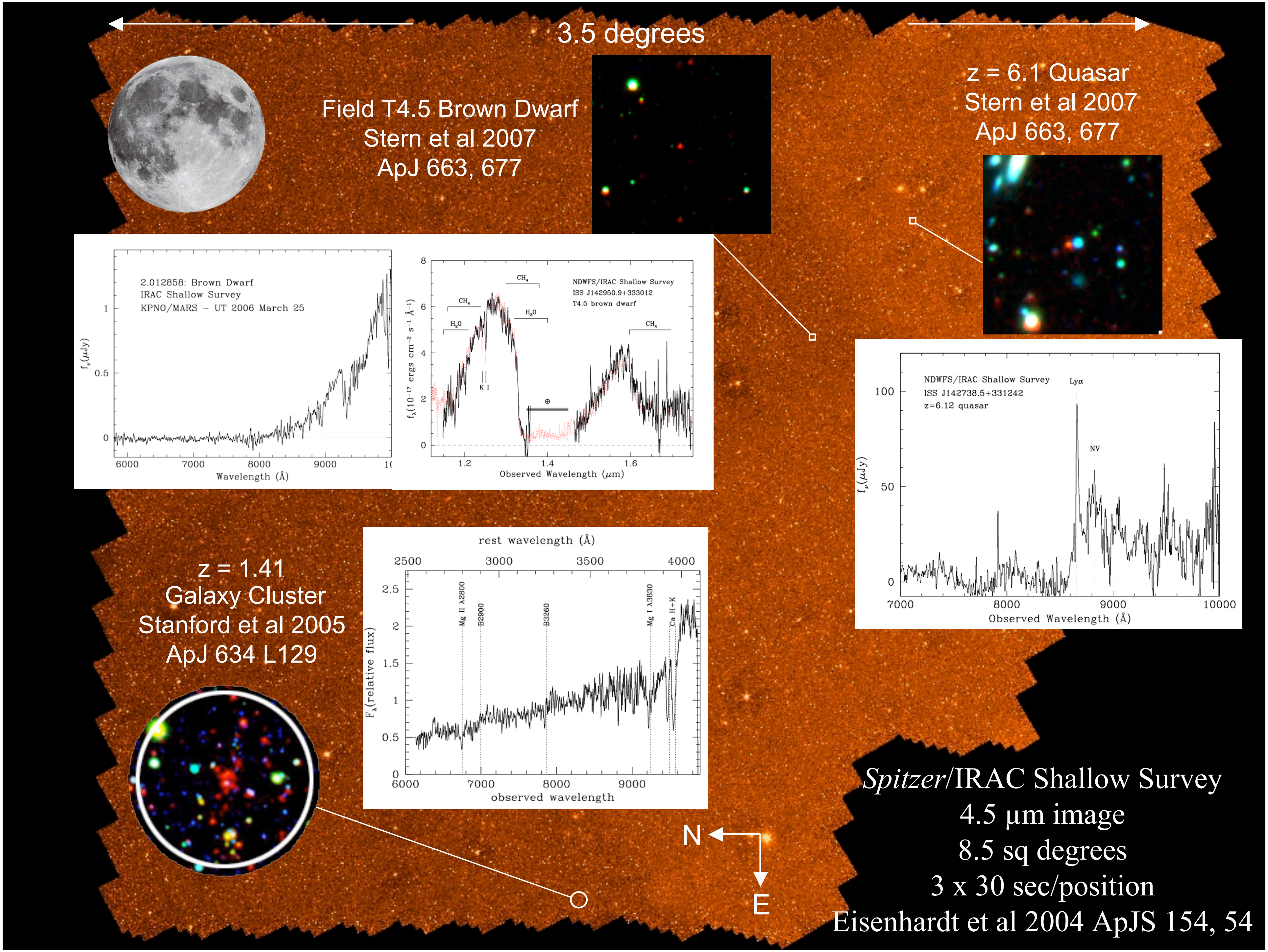
WISE Will Find Quasars Redshifted Beyond Optical

- Redshift 5.9 quasar found in the 9 sq. deg Spitzer/ IRAC shallow survey
  - IRAC fluxes ≈ 35 μJy, somewhat better than WISE performance
- WISE will survey 5000× more area
- WISE should find 1000’s of these QSOs and perhaps 100’s at z > 7
  - Undetectable optically
  - Critical for reionization



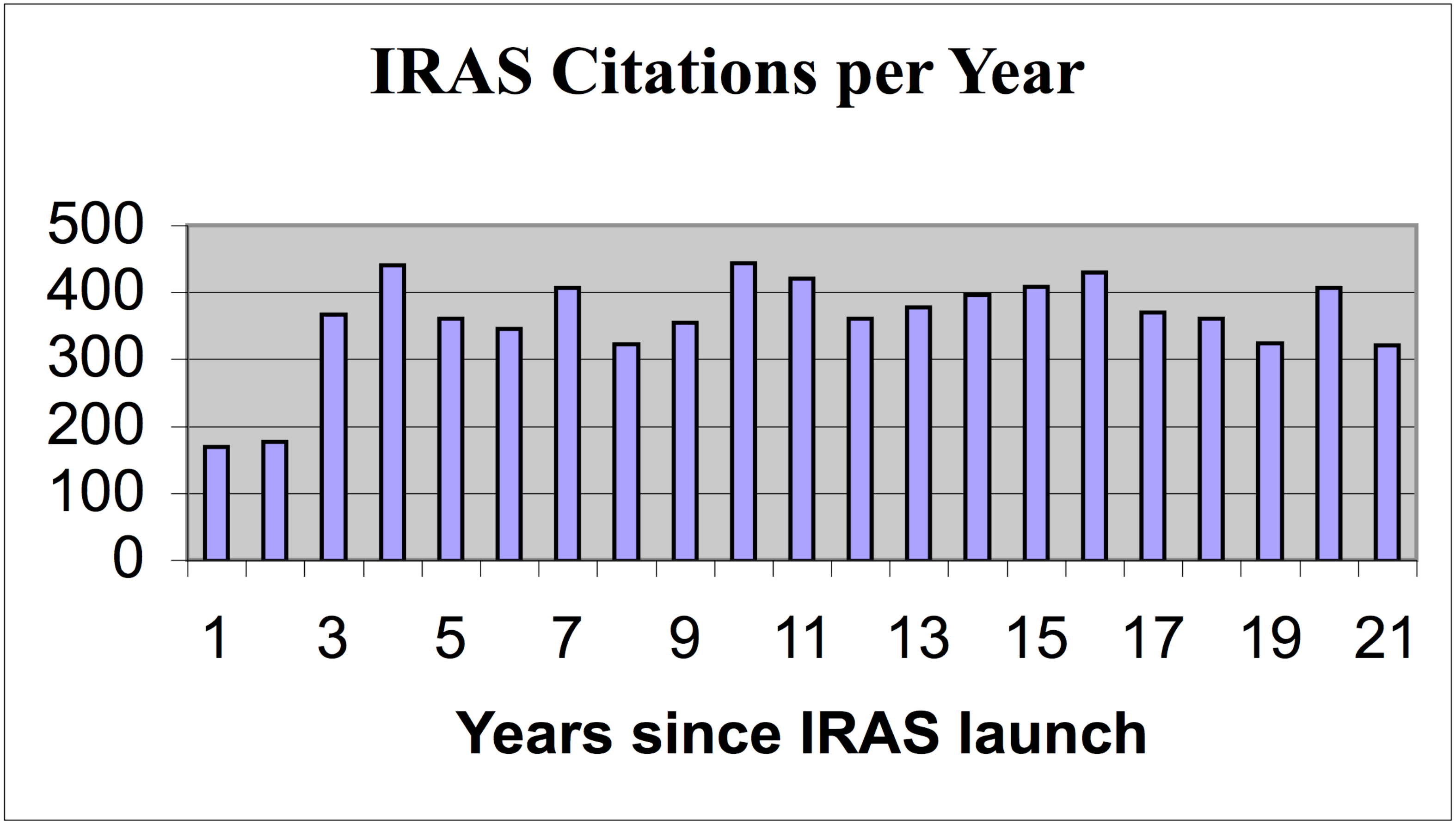


Spectrum by D. Stern & H. Spinrad



3.5 degrees
Field T4.5 Brown Dwarf
Stern et al 2007
ApJ 663, 677
z = 6.1 Quasar
Stern et al 2007
ApJ 663, 677
2.012858: Brown Dwarf
IRAC Shallow Survey
KPNO/MARS – UT 2006 March 25
Wavelength (Å)
NDWFS/IRAC Shallow Survey
ISS J142950.9+333012
T4.5 brown dwarf
Observed Wavelength (μm)
NDWFS/IRAC Shallow Survey
ISS J142738.5+331242
z=6.12 quasar
Lyα
NV
Observed Wavelength (Å)
z = 1.41
Galaxy Cluster
Stanford et al 2005
ApJ 634 L129
rest wavelength (Å)
observed wavelength
F_λ(relative flux)
Mg II λ2800
B2900
B3260
Mg I λ3830
Ca H+K
N
E
Spitzer/IRAC Shallow Survey
4.5 μm image
8.5 sq degrees
3 x 30 sec/position
Eisenhardt et al 2004 ApJS 154, 54

The Legacy of All Sky Surveys Endures for Decades



Summary

- WISE results will excite both scientists and the general public:
  - Measure radiometric diameters for >200,000 asteroids
  - Find the 2/3 of the stars in the solar neighborhood that have not yet been seen, including *the closest stars to the Sun*
  - Study star forming regions in the Milky Way and in *the most luminous galaxies in the Universe*
- WISE will provide a legacy that endures for decades, enabling studies of objects that have yet to be discovered

The Solar Neighborhood After WISE

Produced by:

Brian Abbott (AMNH/Hayden)

WISE Simulations provided by:

Davy Kirkpatrick (CalTech)

Digital Universe provided by:

American Museum of Natural History
Hayden Planetarium
http://www.haydenplanetarium.org/

WISE on the Web:

http://wise.ssl.berkeley.edu/