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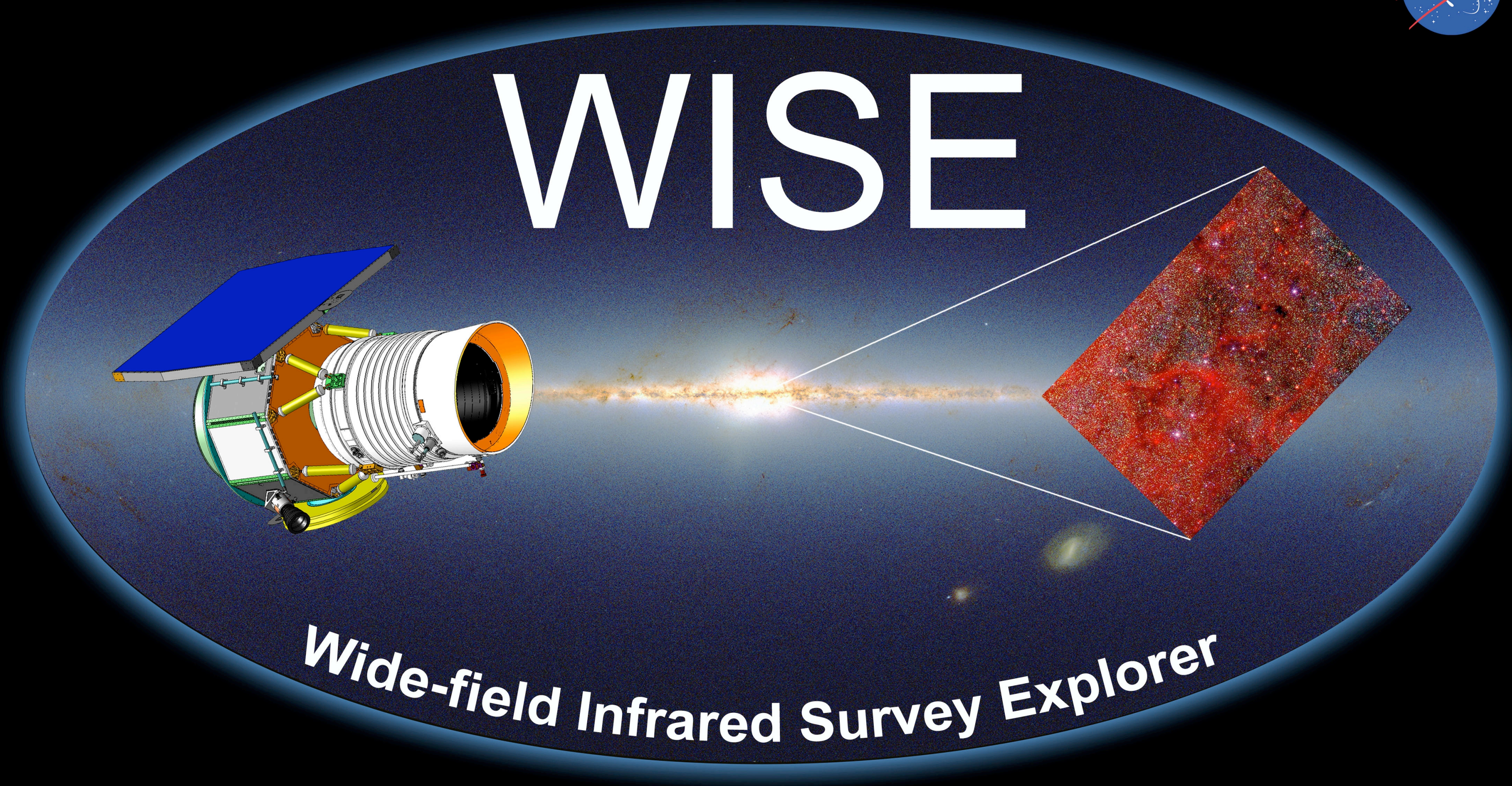
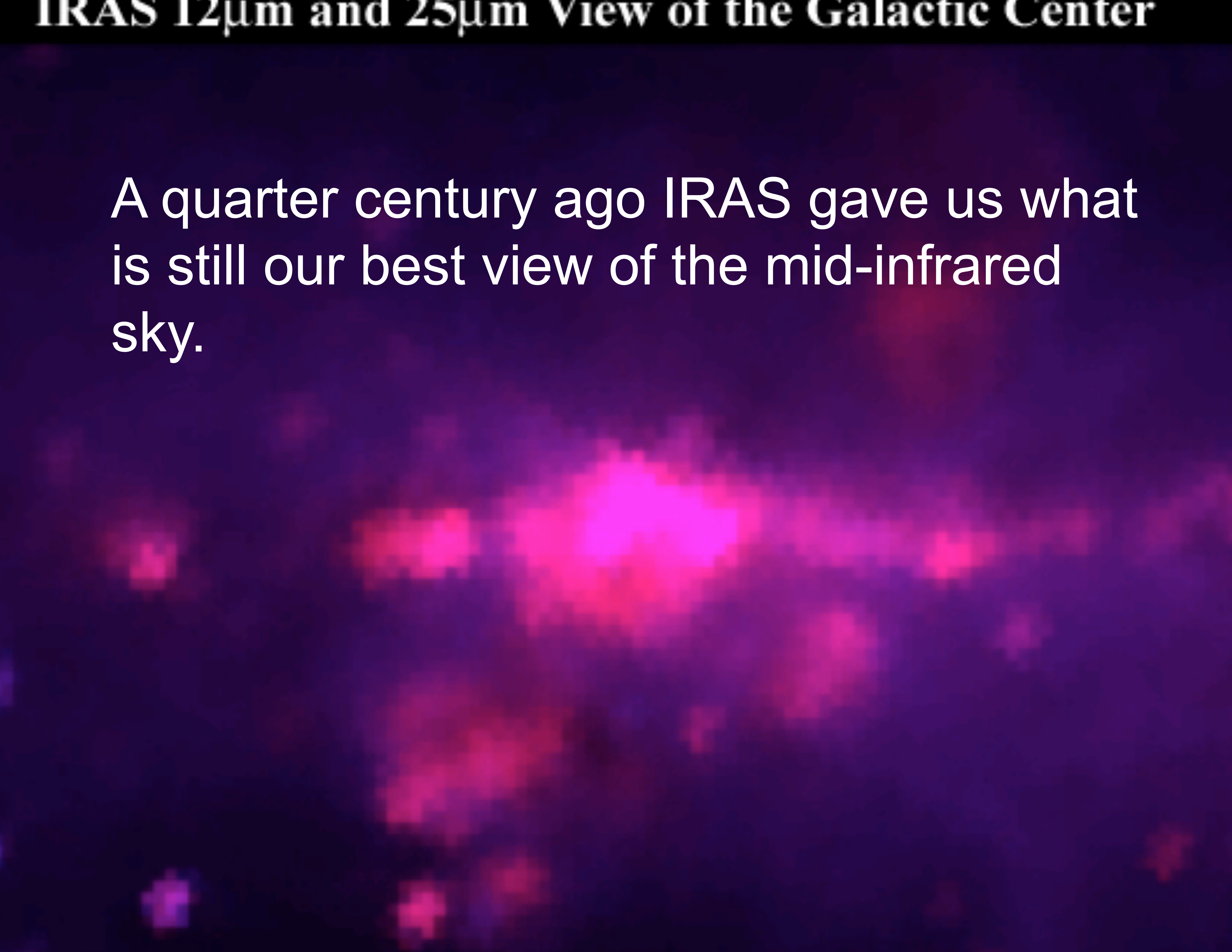


http://wise.astro.ucla.edu

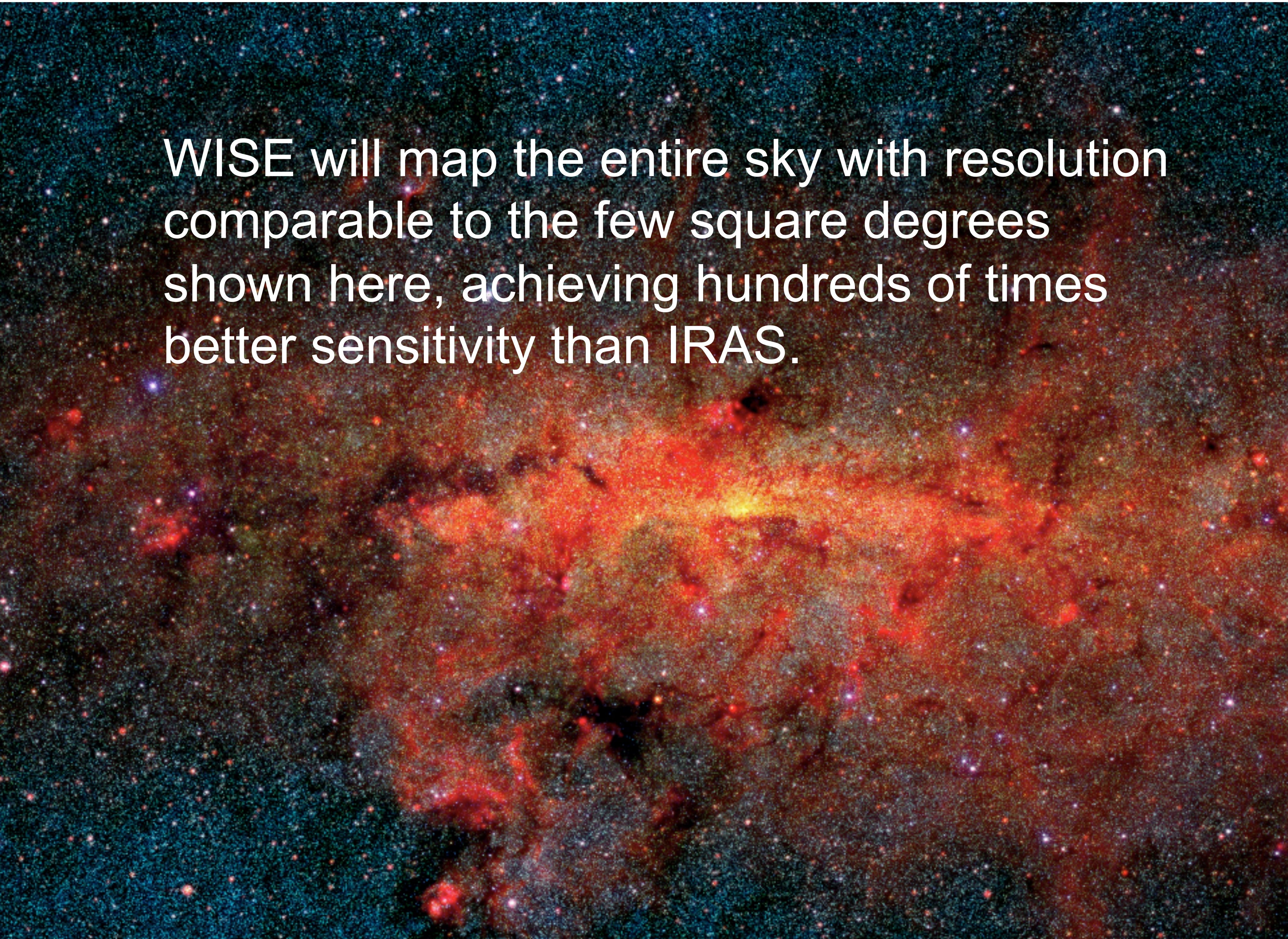
UCLA • JPL • BALL • SDL • IPAC • UCB

Peter Eisenhardt (JPL)

2009 May 28 - Giovanni Fest



A quarter century 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 hundreds of 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 hundreds to hundreds of thousands of times better 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
- Mission SIR 2008 November 18
- Launch 2009 November 1
  - 1 month IOC
  - 6 months survey (baseline; 9 months extended)
- Final catalog 17 mos. after end of survey

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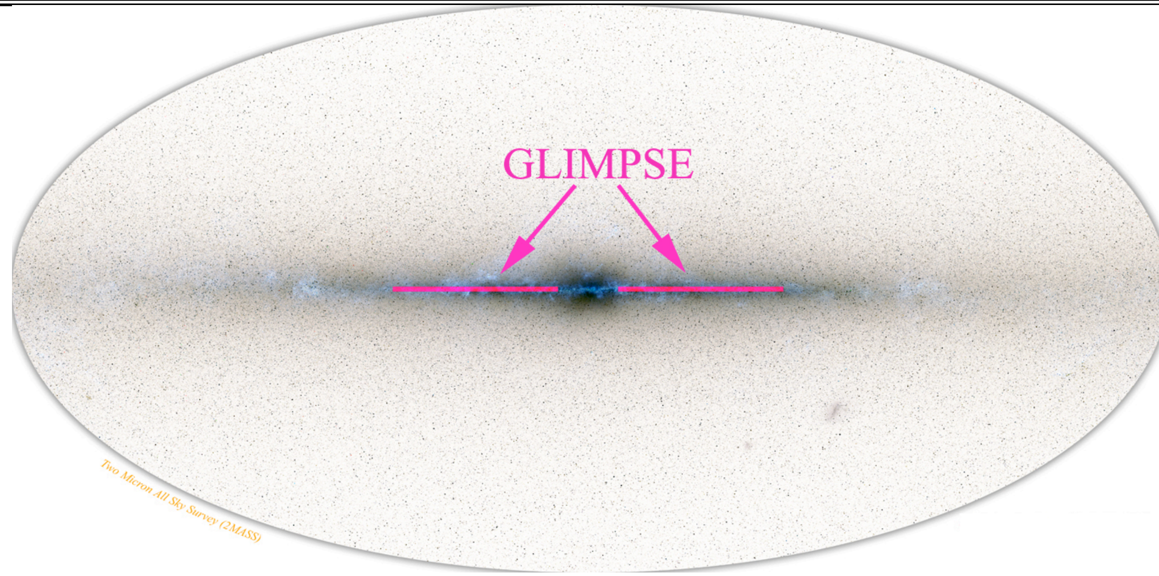
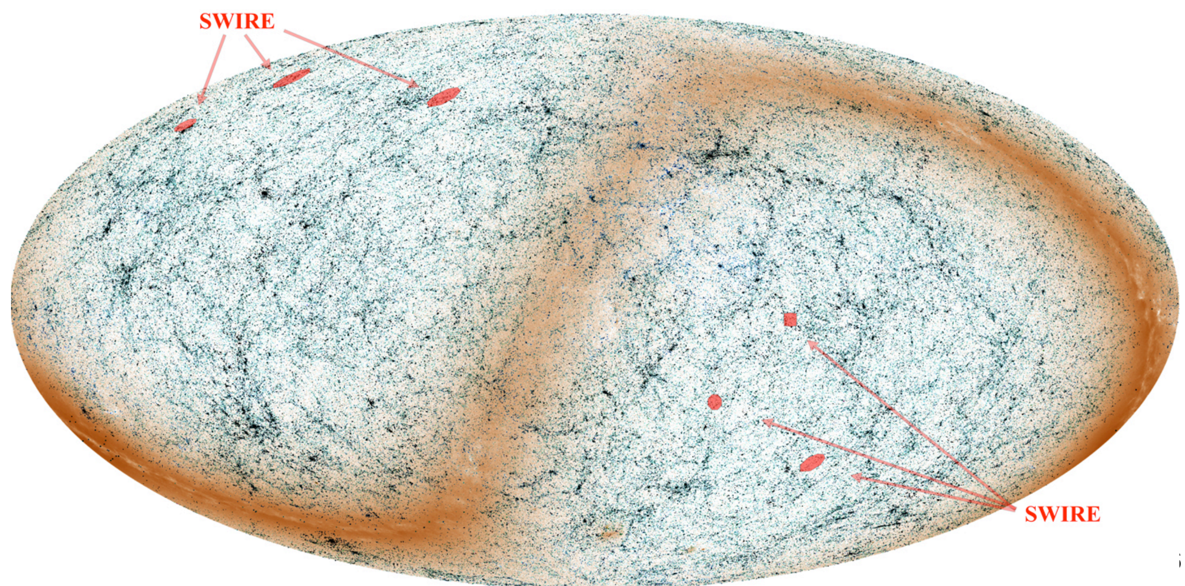
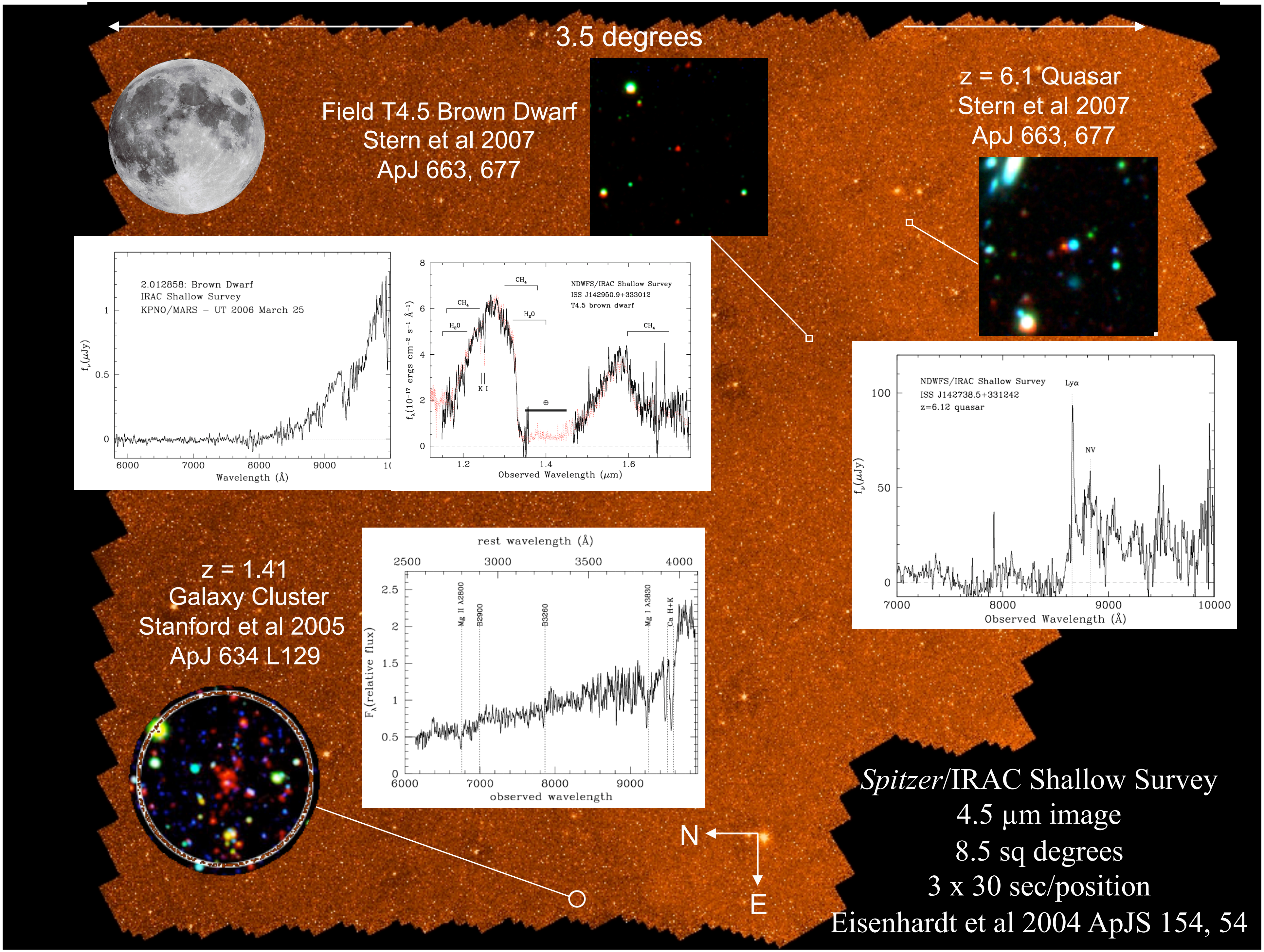
WISE and Spitzer: Complementary Missions

- Detailed information available for Spitzer sources will define characteristics of the most interesting WISE sources
- WISE will survey 170x GLIMPSE and 800x SWIRE area
- For > 99% of the sky, JWST will benefit from WISE data for efficient targeting






3.5 degrees
Field T4.5 Brown Dwarf
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)
z = 6.1 Quasar
Stern et al 2007
ApJ 663, 677
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)
Mg II λ2800
B2900
B3260
Mg I λ3830
Ca H+K
F$_\lambda$(relative flux)
observed wavelength
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

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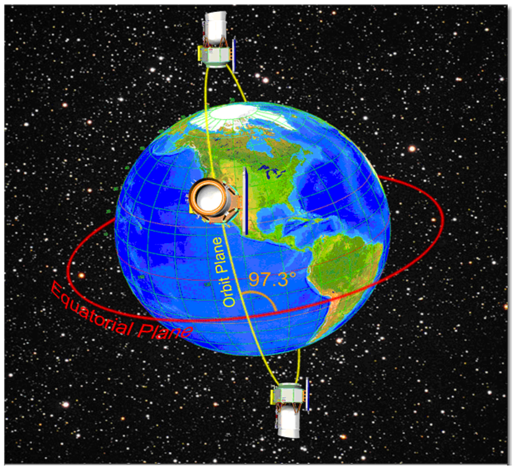
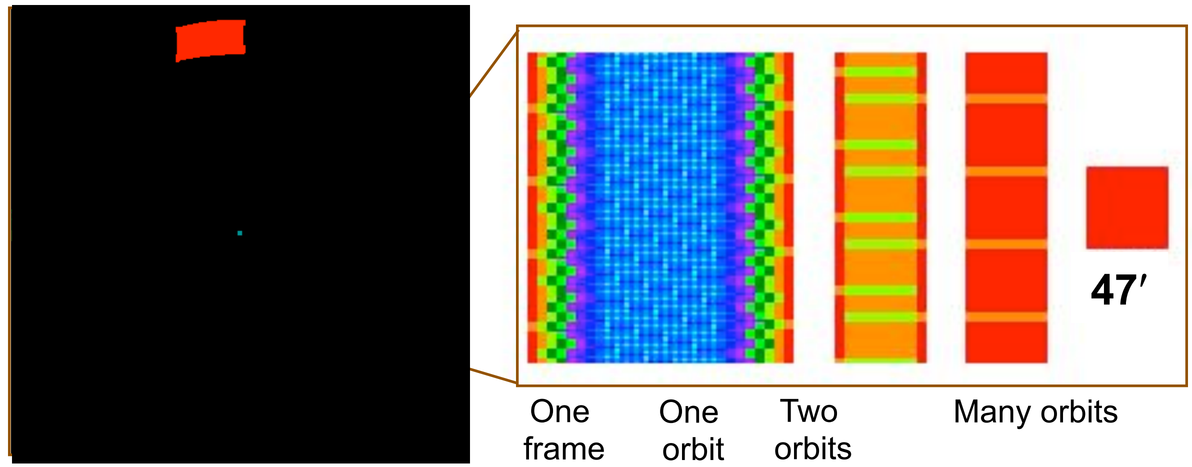
Simple Mission Design



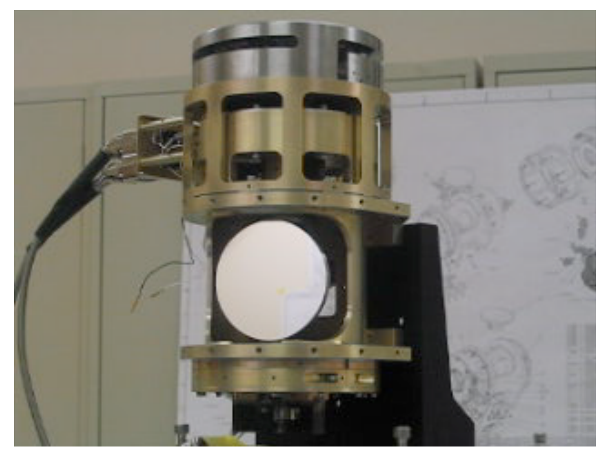


- Delta 7320 launch – WTR
- 523 km, circular, polar sun-synchronous orbit
  - Nodal crossing time 6:00 PM
  - One month of checkout
  - 6 months of survey operations
- One simple observing mode – half orbit scan

•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



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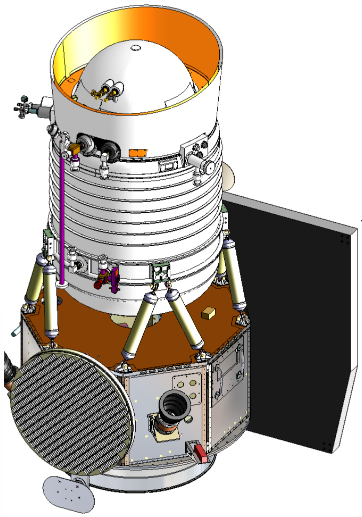
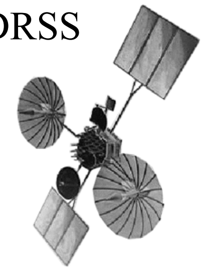
WISE Mission Components

Cryogenic Telescope
(SDL)
Spacecraft
(BATC)



TDRSS



Science/Stored Telemetry
100Mbs Ku-Band
24 GB/day (compressed - 50GB/day uncompressed)

Commands/Telemetry
S-Band

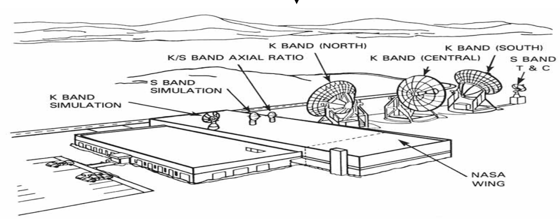
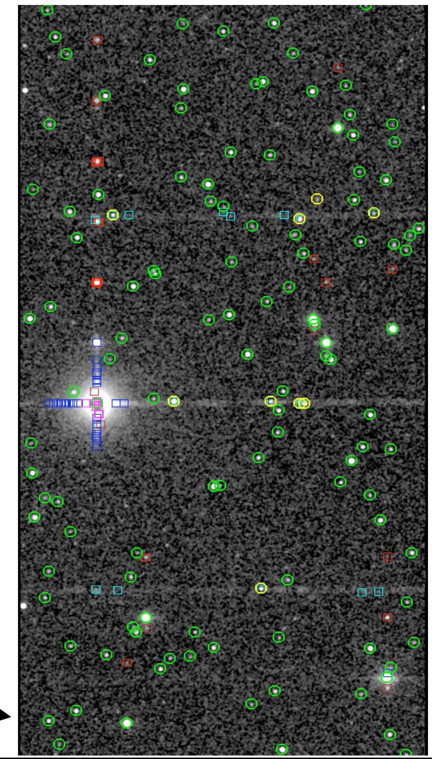


Figure 6-11. White Sands Ground Terminal

White Sands Ground Terminal



Delta II
(ULA)

Engineering Operations System
(JPL)

Science Survey Planning
(UCLA)

Science Data Processing
(IPAC)

Infrared Science Archive
(IPAC)

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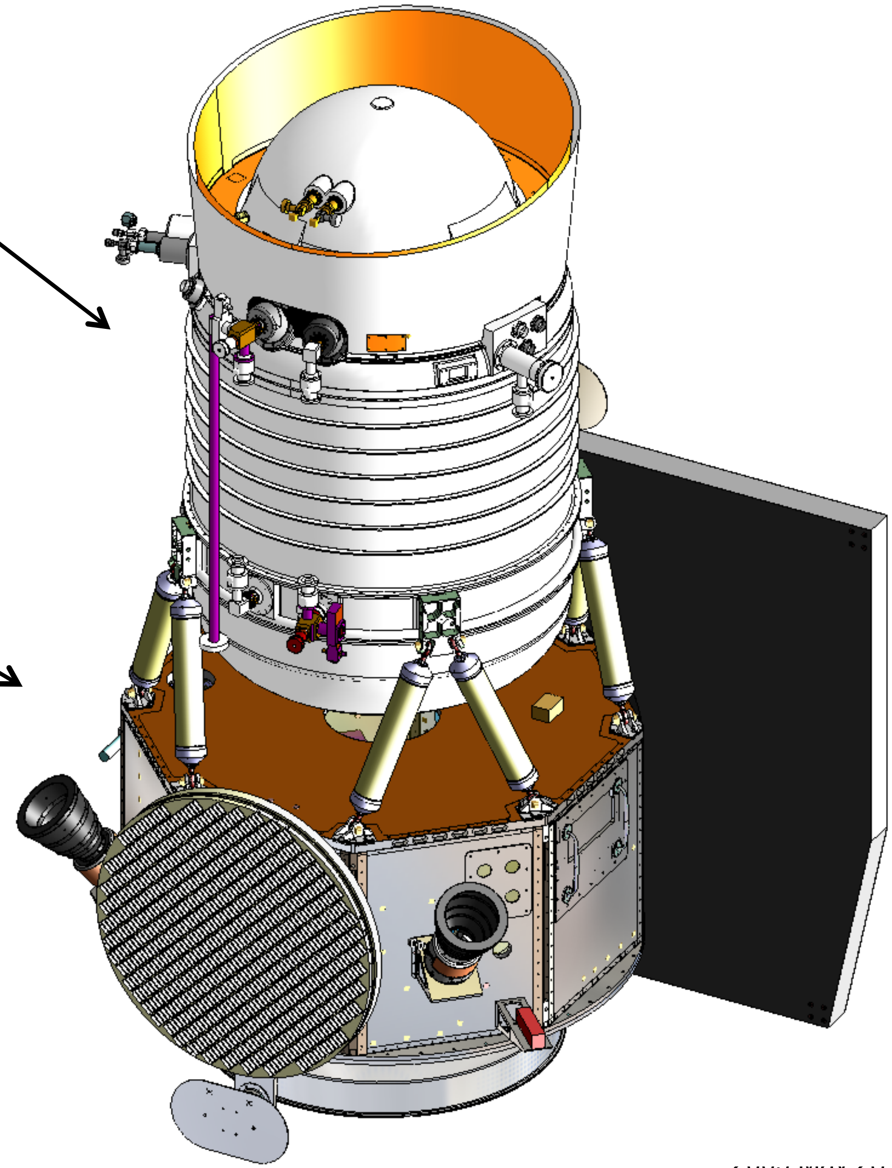
Flight System

Payload (SDL)

- 2-Stage Solid H_2 cryostat
  - 10 month lifetime
- 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 (7.3K)
- 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



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Flight System (some non-flight items shown)

Payload (SDL)

Spacecraft (Ball Aerospace)

Project Scientist (JPL)

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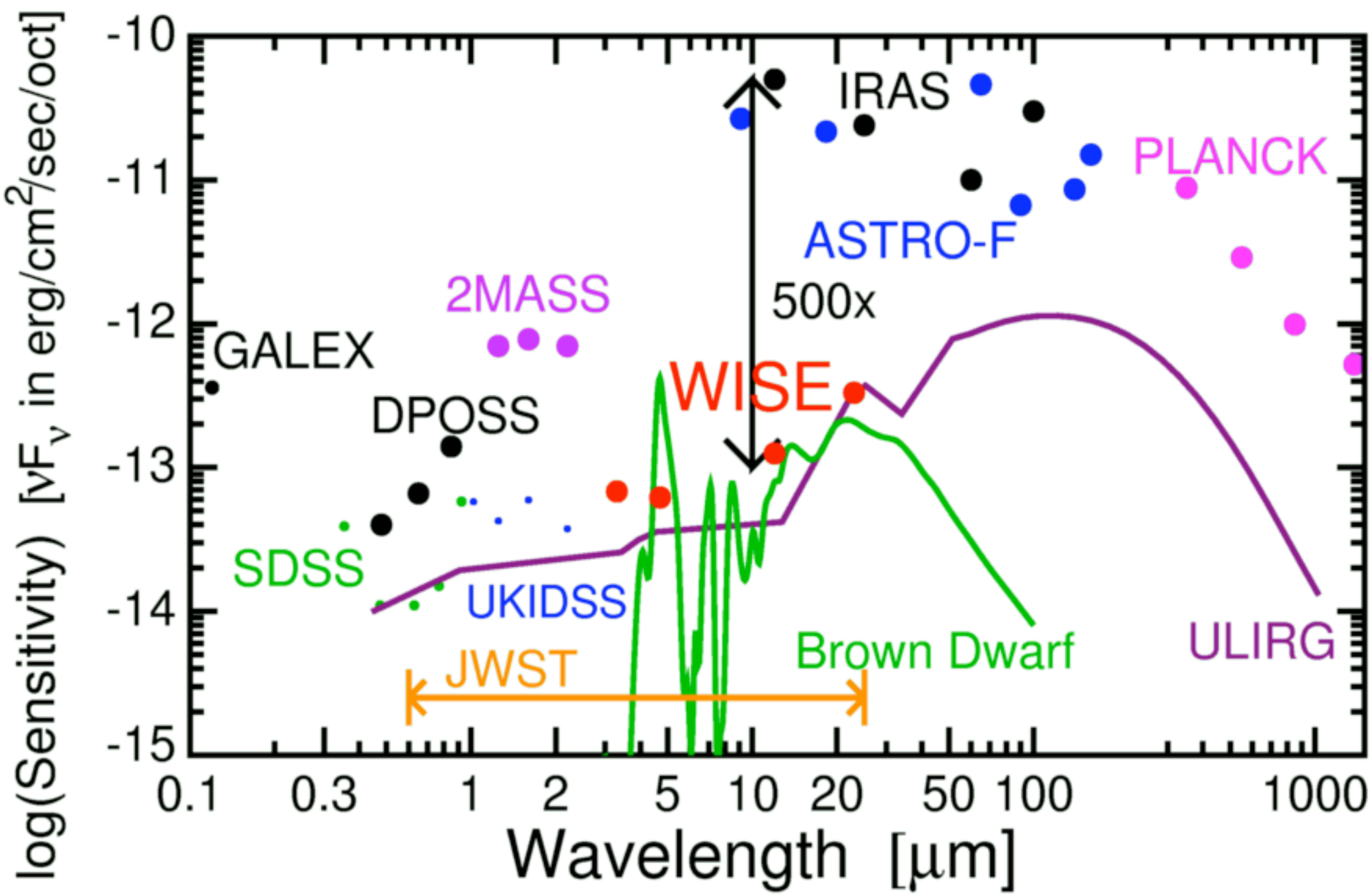
Great Advance in Sensitivity



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

WISE Science Team

- **Edward L. Wright** UCLA (PI)
- Dominic Benford GSFC
- 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 Univ. of Virginia
- Amanda Mainzer JPL
- John Mather GSFC
- Ian McLean UCLA
- Robert McMillan Univ. of Arizona
- Bryan Mendez UCB/SSL
- Deborah Padgett IPAC/Caltech
- Michael Ressler JPL
- Michael Skrutskie Univ. of Virginia
- S. Adam Stanford UC Davis
- Russell Walker MIRA

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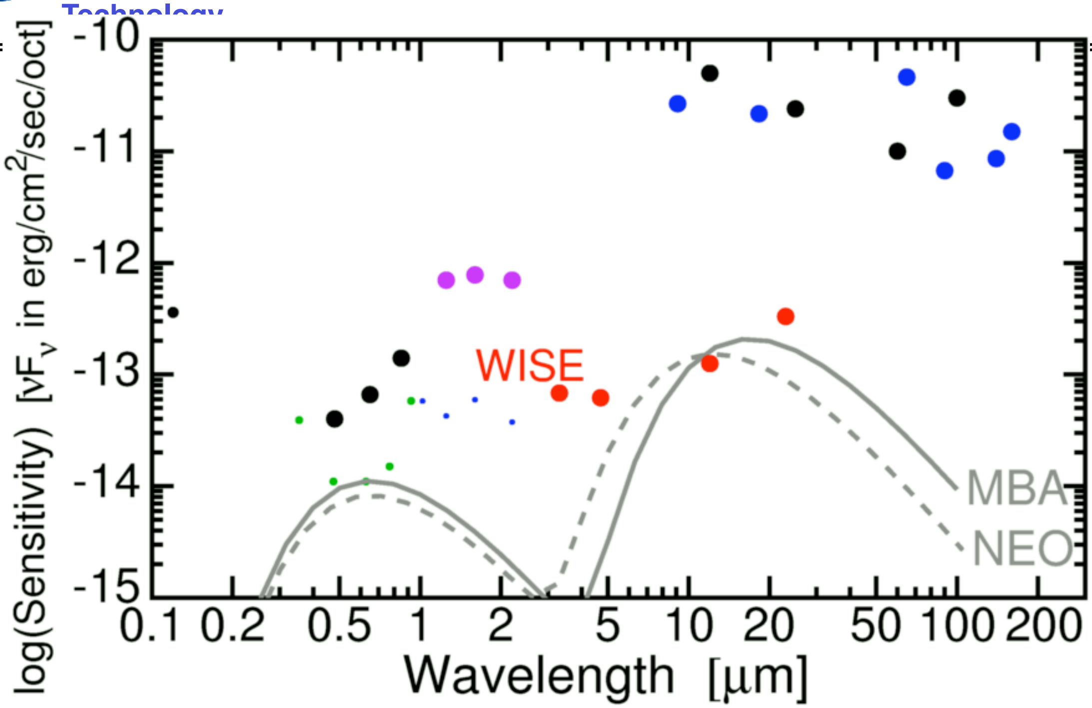
WISE and Asteroids



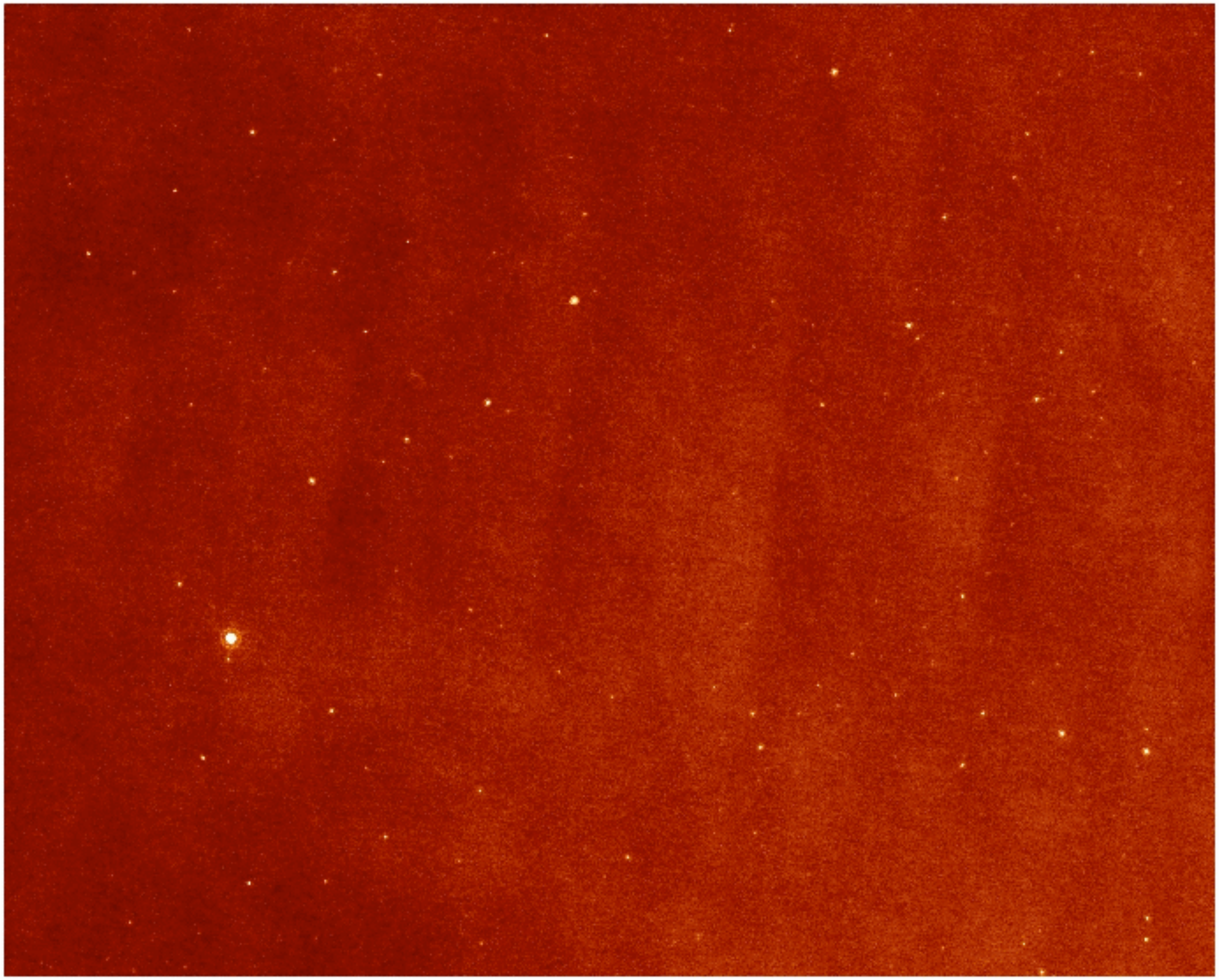
Gaspra

Asteroids move

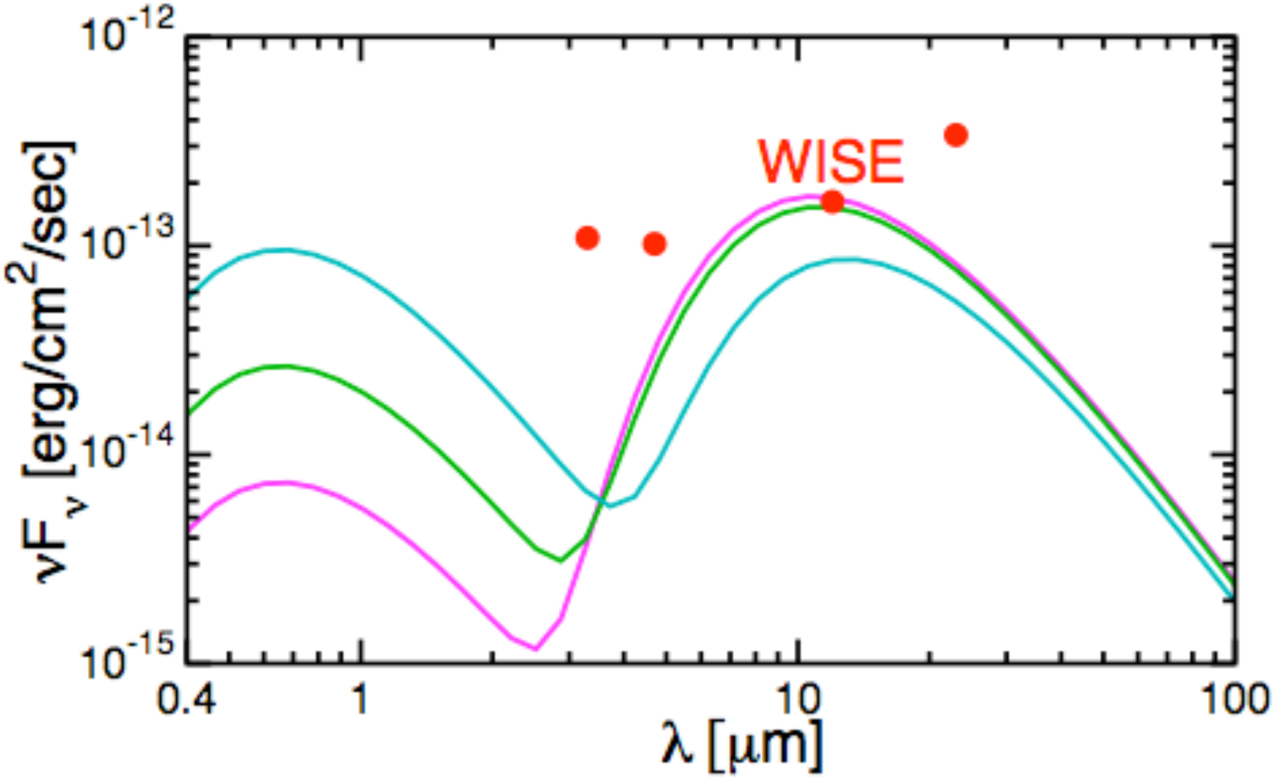
- Asteroids are much brighter in the IR than in the optical: 100 to 400 times more photons.
  - 1km Main Belt Asteroid (MBA) and 200m Near Earth Object (NEO) shown
- They move in the hours between WISE frames.
- For asteroids with known orbits, WISE sensitivity will be slightly better than for fixed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



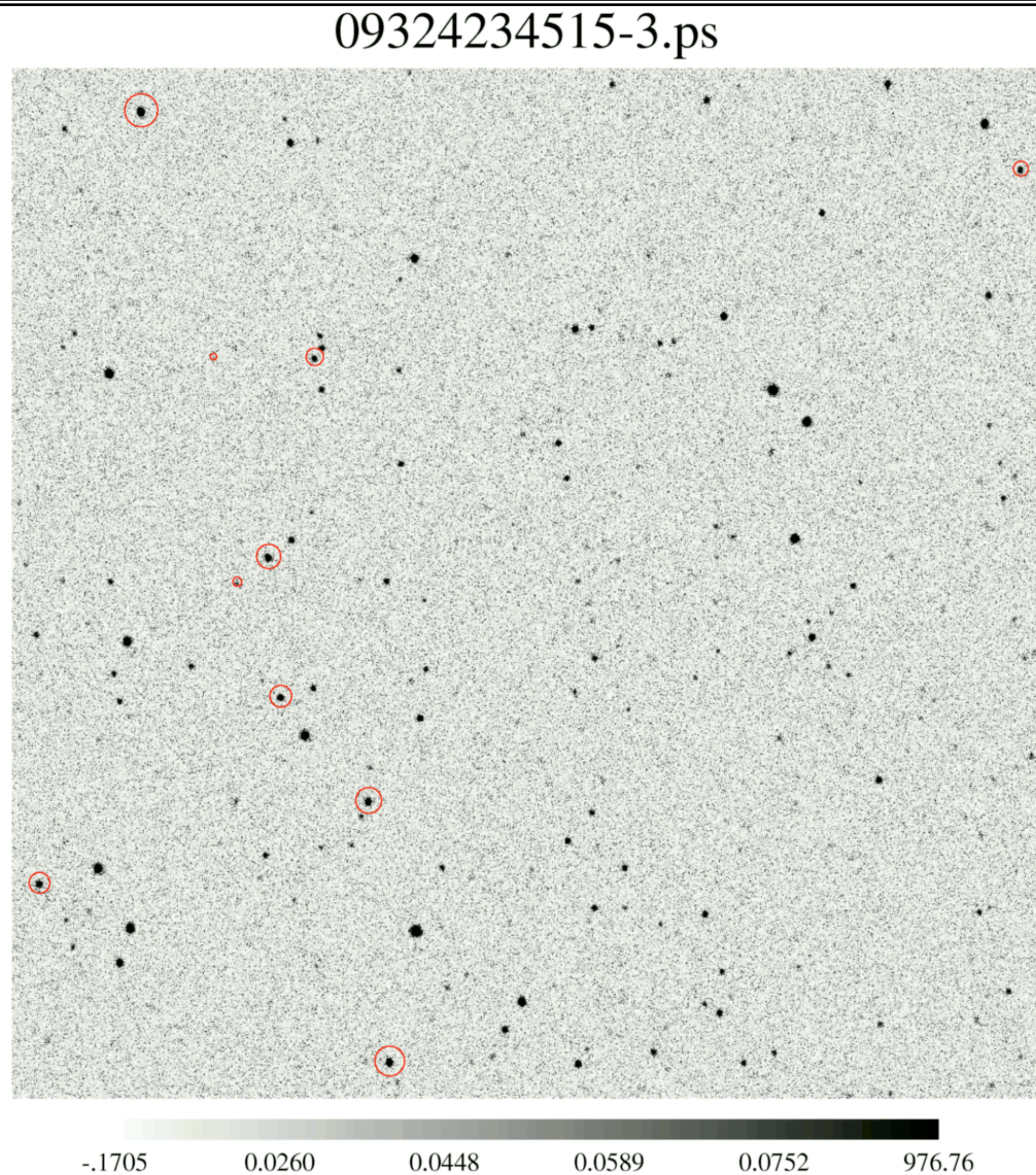
NEOWISE



- The curves show flux from a 100m diameter NEO 0.5 au from WISE, for albedos of 0.04 (purple), 0.14 (green), and 0.52 (blue), compared to WISE sensitivity.
- NASA's NEO Program Office has funded development of software to identify new asteroids in WISE data (1 - 2 NEOs/day, thousands of main belt asteroids/day) and report them within several days to the Minor Planet Center for followup.

Simulated 12 μm data

- 20 Nov 2009
- Ecliptic coords 332.65,-14.49
- Unusually large number of objects for this far off the ecliptic.



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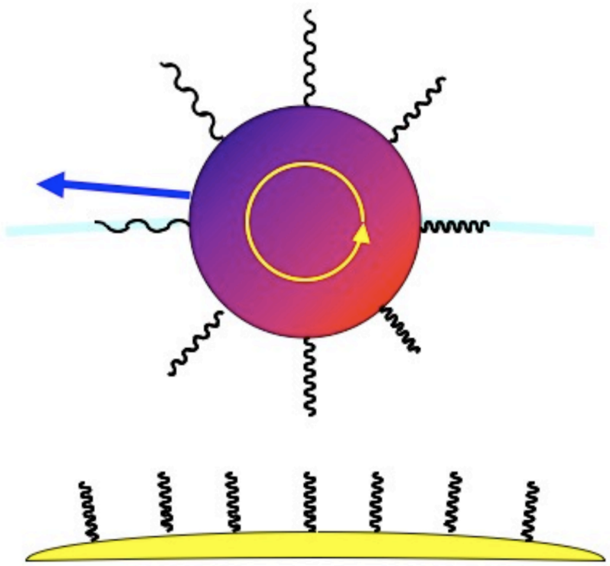
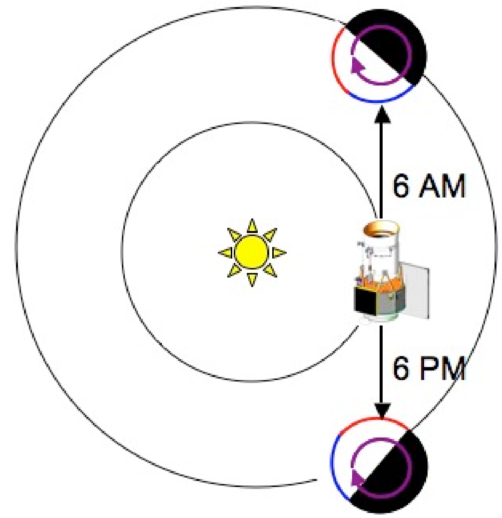
Yarkovsky Effect





- Due to thermal inertia, afternoon is hotter than morning - on Earth and on asteroids.
- More afternoon thermal radiation leads to net radiation force, changing the asteroid's orbit.
- Yarkovsky effect can dominate uncertainty in whether a NEO will impact Earth.
- WISE can measure the temperature difference between morning and afternoon.

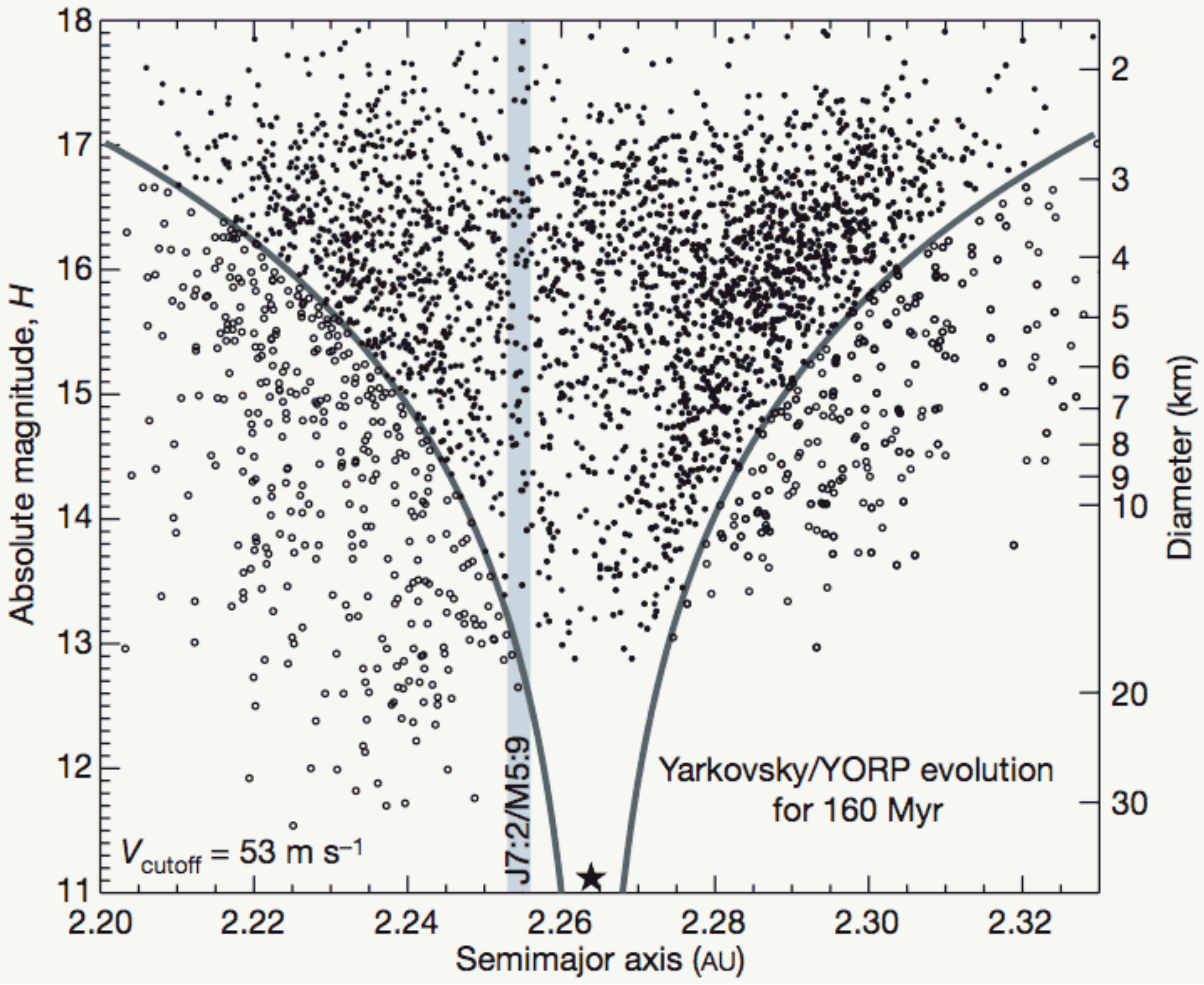
What killed the dinosaurs?

- A big impact
- But probably not this big!

What Killed the Dinosaurs?

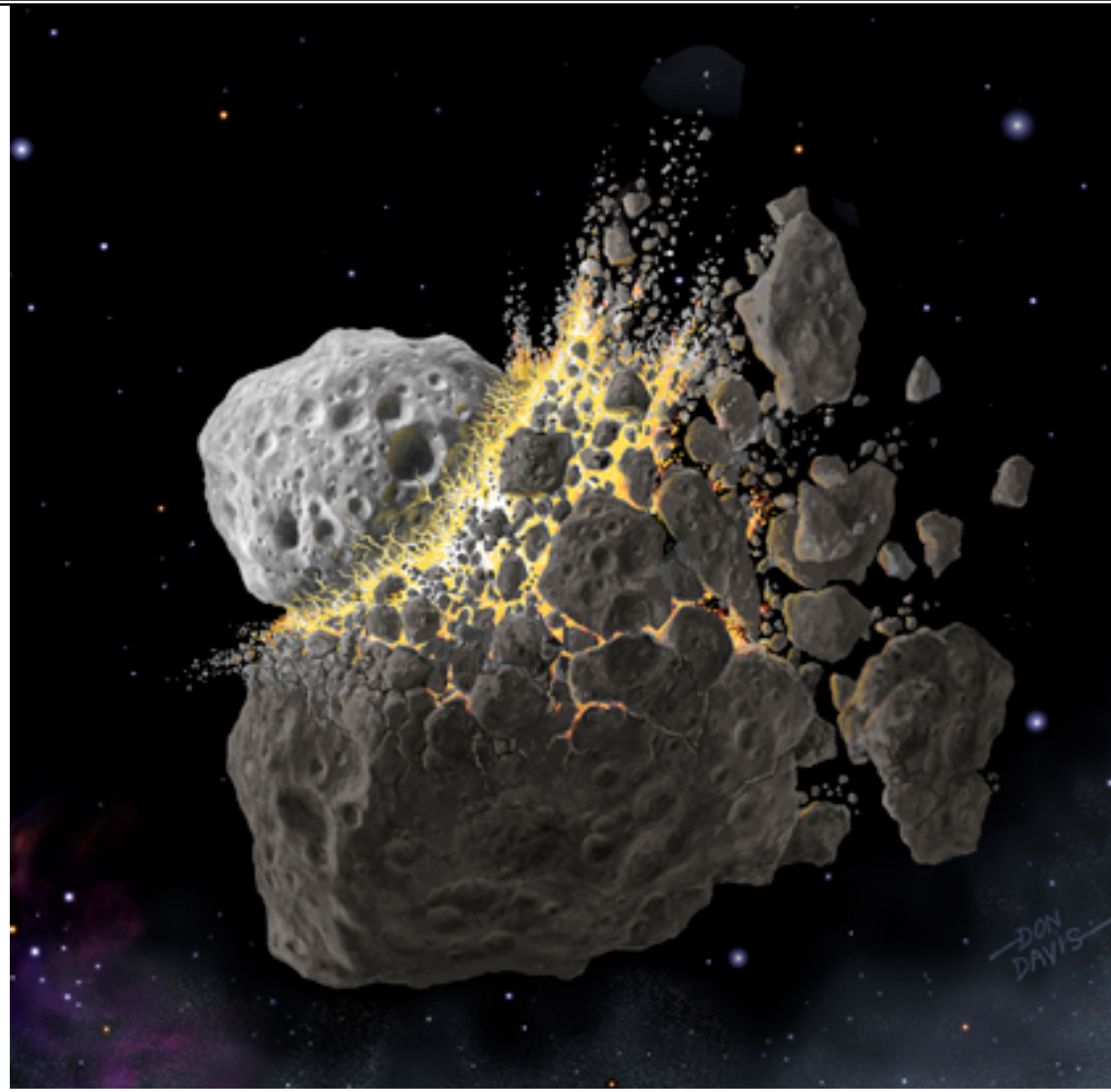
- Bottke et al (2007, Nature, 449, 48) propose a member of the Baptistina family of asteroids killed the dinosaurs.
- Evidence: the spread of orbital elements vs size is consistent with the Yarkovsky effect perturbing the orbits for 160 million years, so the asteroid collision and breakup that made the Baptistina family occurred 160 million years ago.
- Orbits get perturbed into the 7:2 resonance with Jupiter, which generates Earth crossers, producing a broad peak of the impact rate about 100 million years ago.
- Many NEOs today have colors similar to Baptistina family objects.

Baptistina family



Collision makes many fragments

- Velocity of big fragments only about 40 ±10 m/s.
- Initial orbit spread is quite small (0.01 AU).
- Rest of spread generated post-collision by the Yarkovsky force.



What WISE Can Add

- Observing Baptistina family members in both the morning and evening passes allows us to calculate the Yarkovsky force plus we also get the diameter implying a mass.
- This gives the Yarkovsky acceleration which should be a linear function of the semi-major axis with 1/slope giving the formation time and the zero crossing giving the origin of the family, allowing a verification of this whole chain of reasoning.

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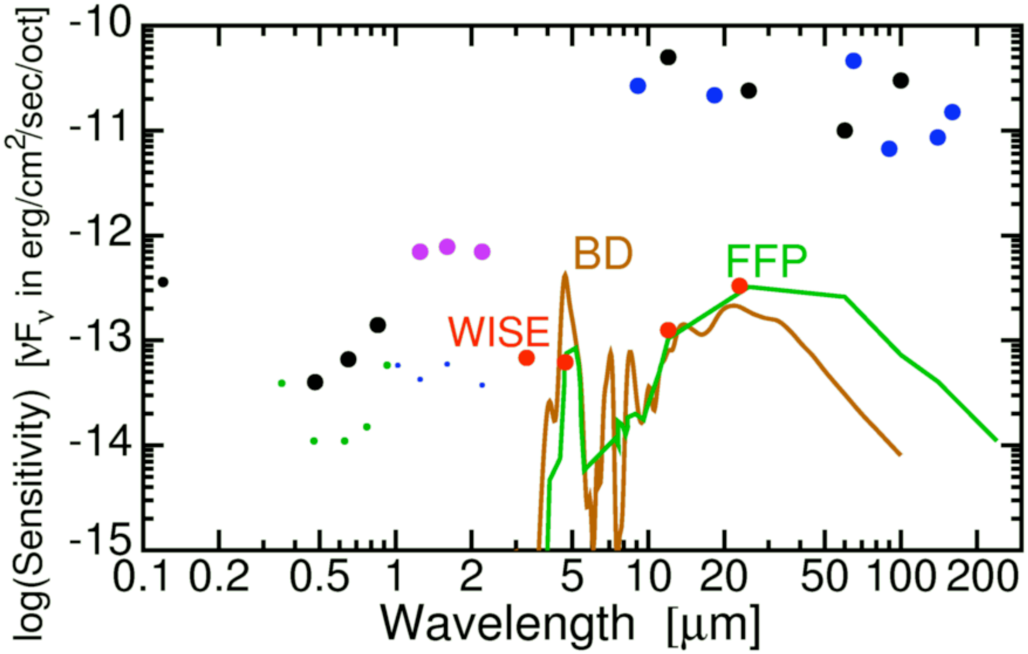
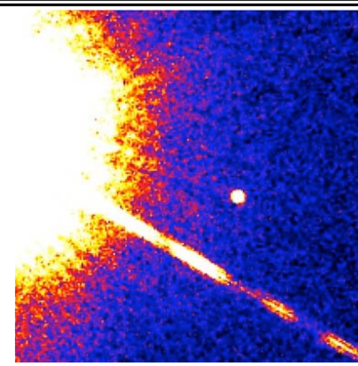
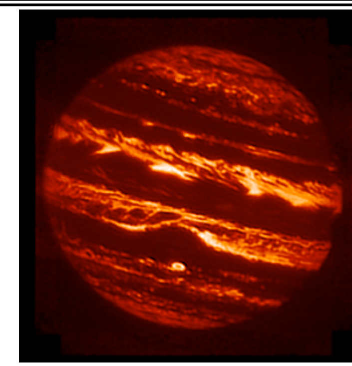
WISE and Brown Dwarfs

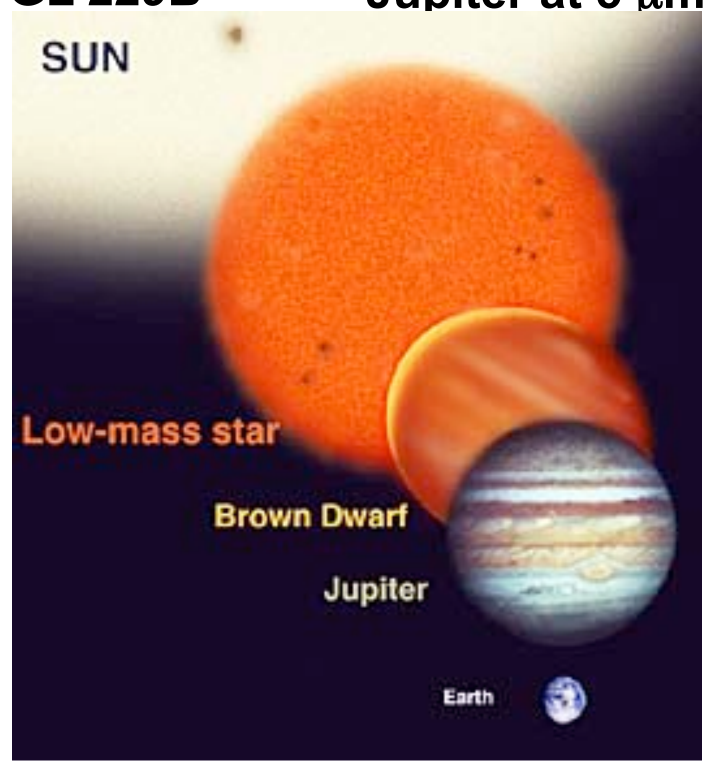




GL 229B



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 4.7 μm sensitivity requirement.

At present, coolest known Brown Dwarfs have T ~ 600 K, even using Spitzer data, and only four have T < 750 K.
WISE will find about one thousand such objects, including perhaps the nearest planetary system to our own.
SDWFS survey (40x less volume) implies WISE will find ~700 such objects.

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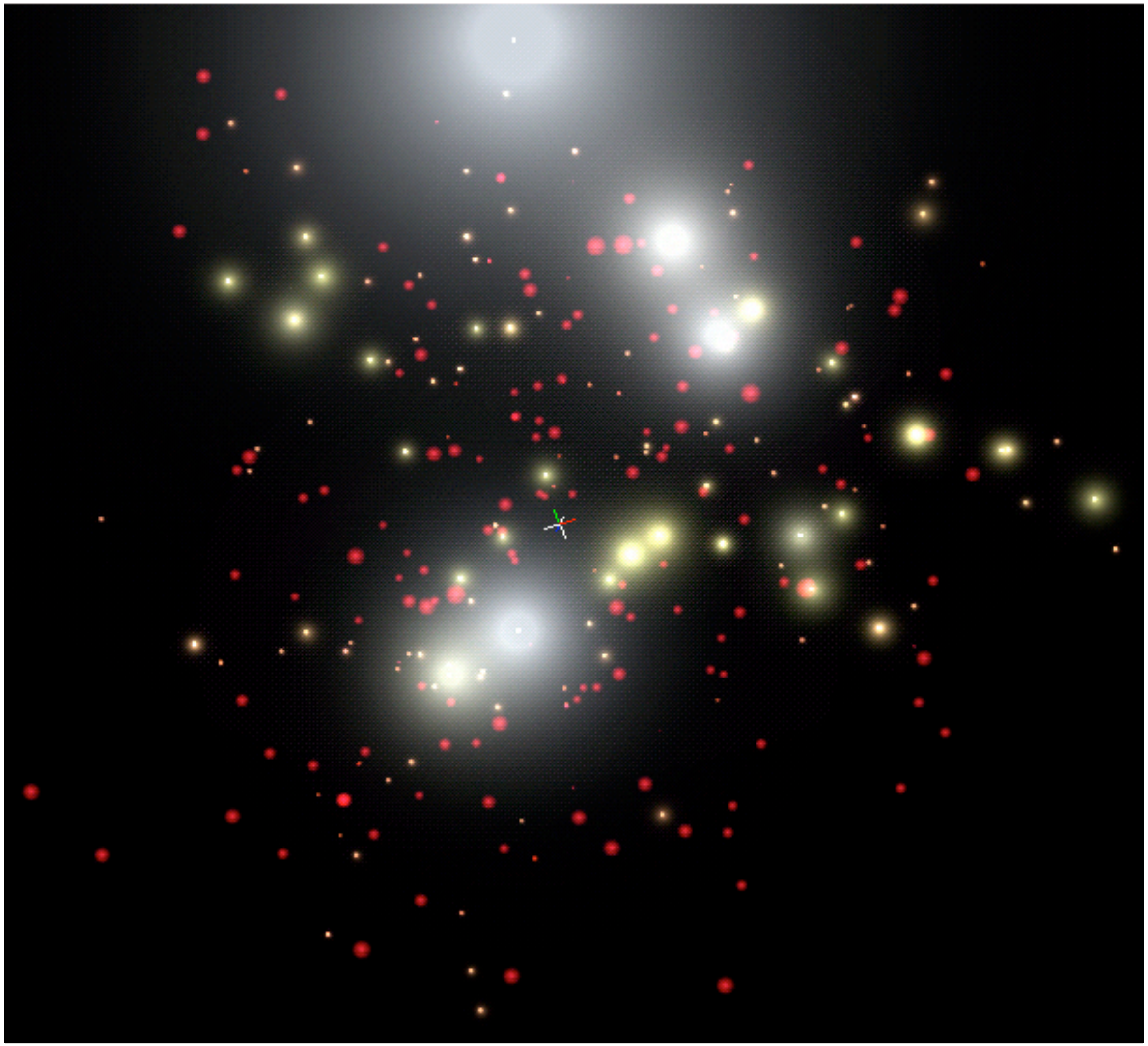
WISE Will Find the Nearest Stars



WISE stars within 25 lightyears

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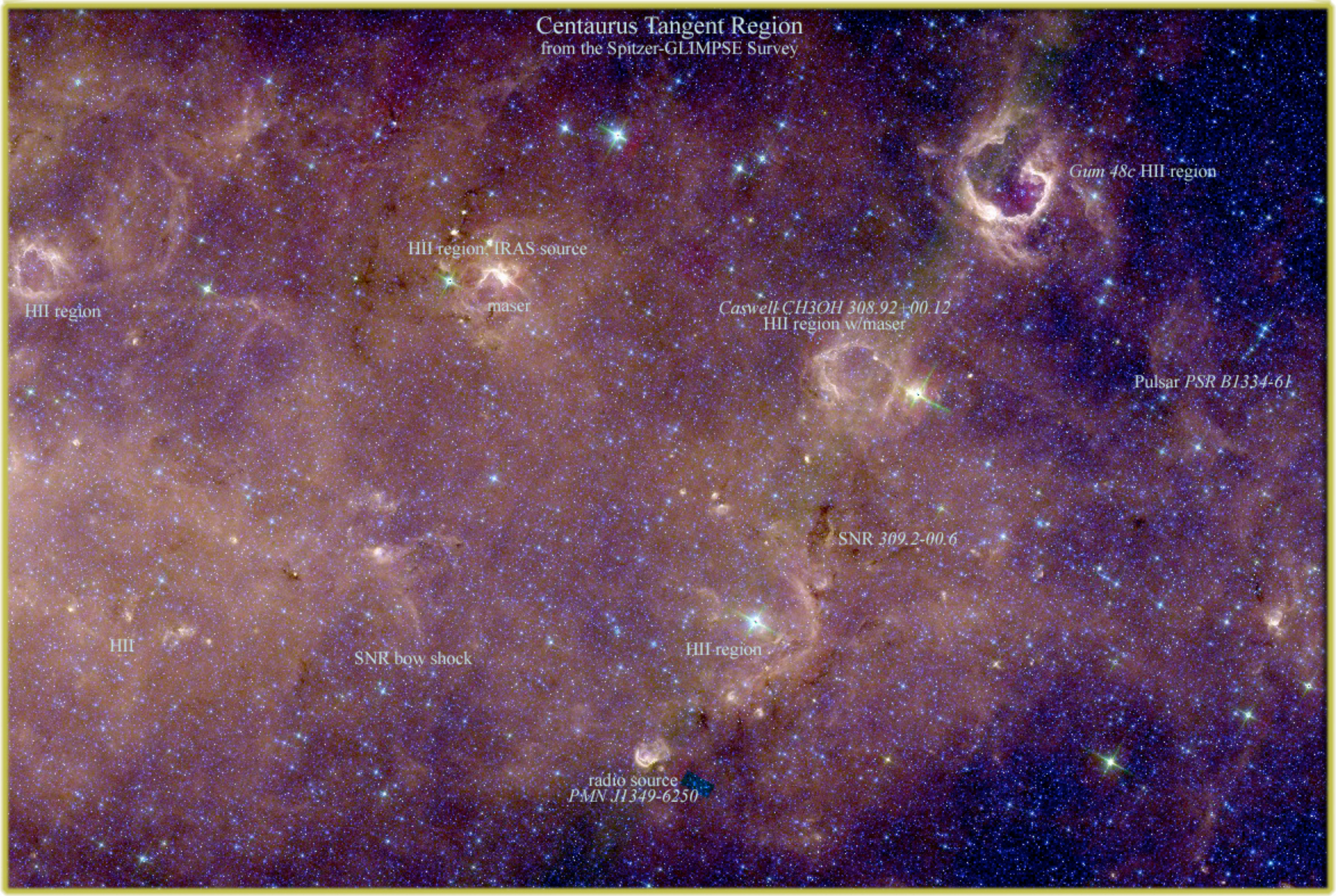
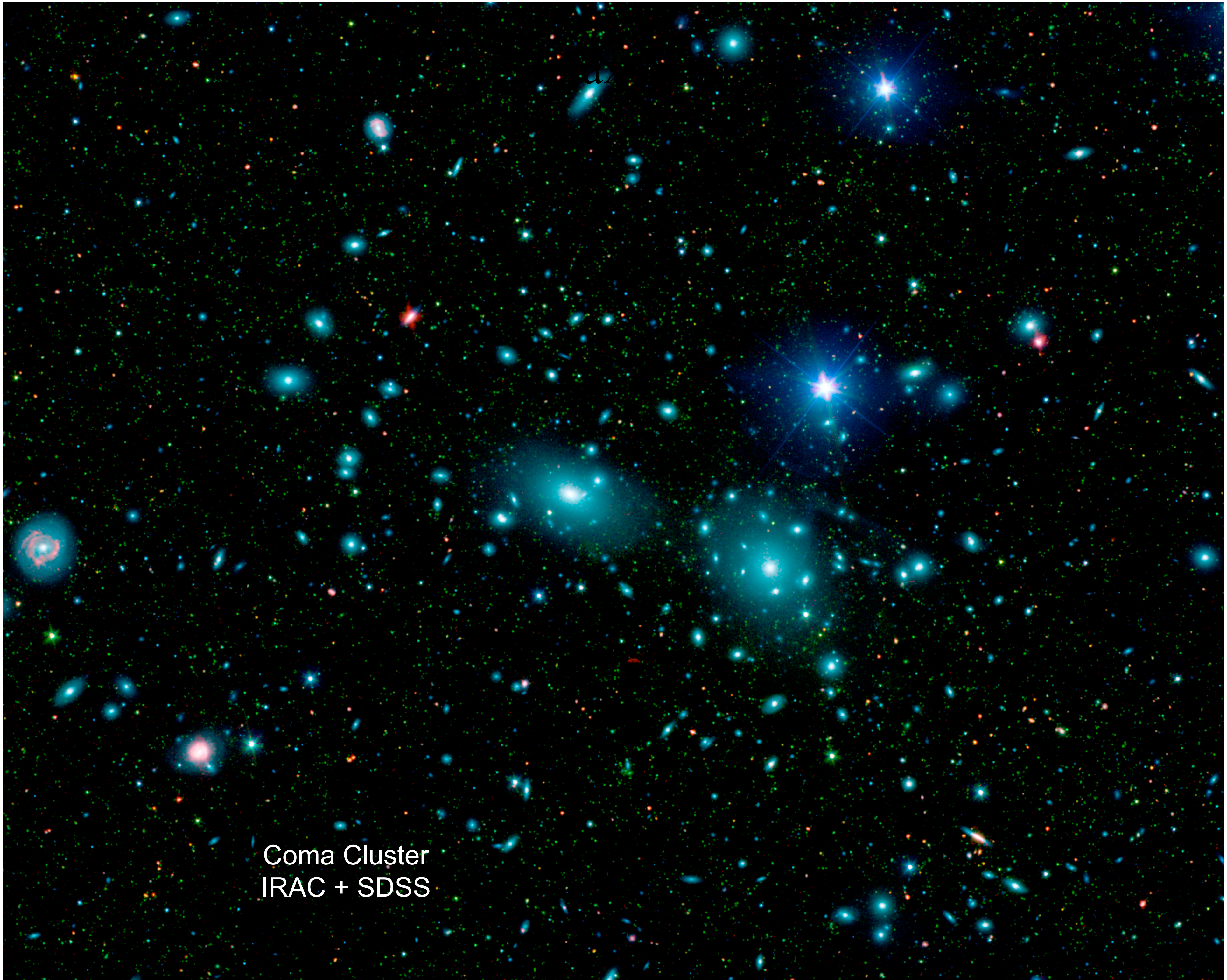
WISE Will Image the Entire Galactic Plane



WISE Will Image All Nearby Galaxies


Coma Cluster
IRAC + SDSS

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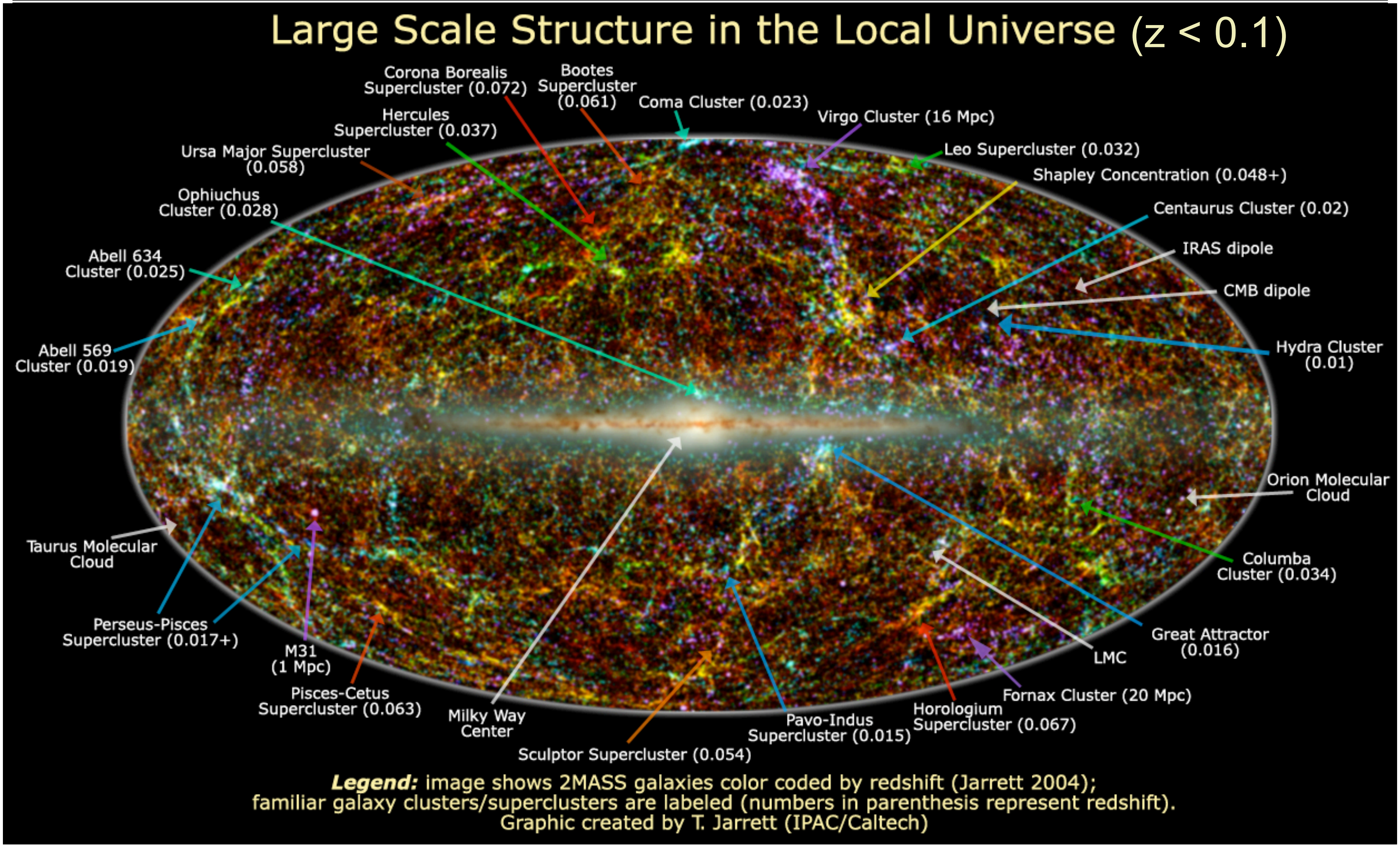
WISE Will Map the Cosmic Web to z ~ 0.5



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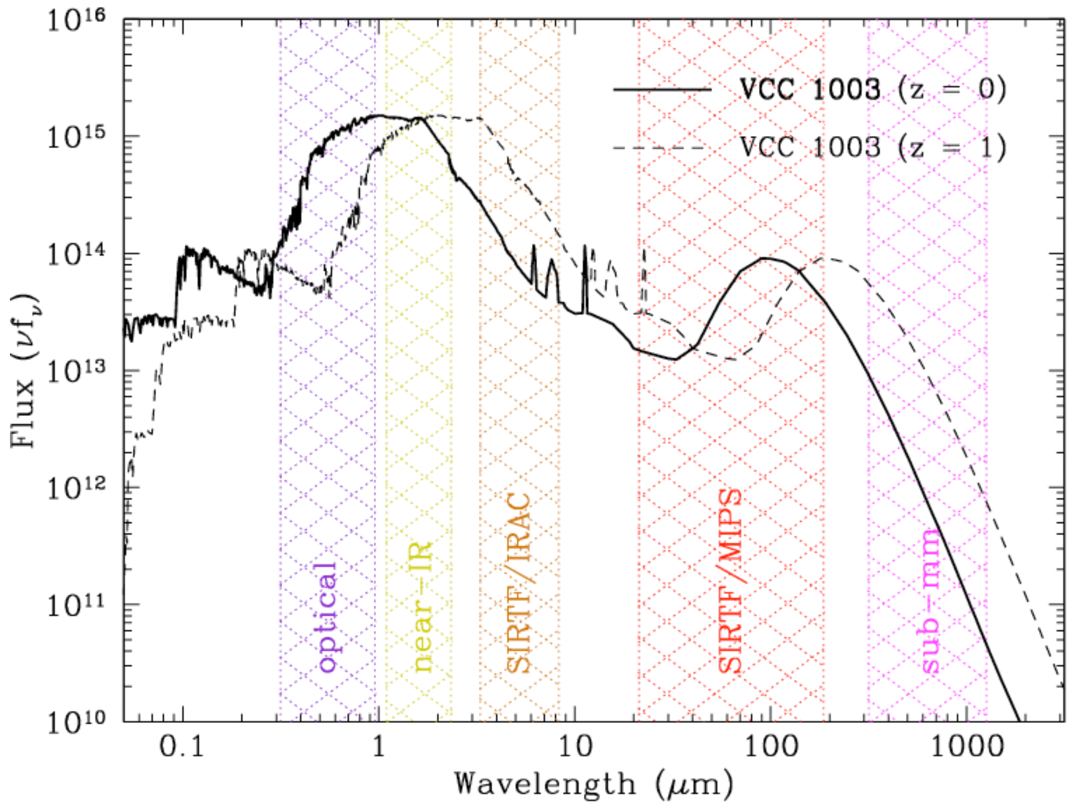
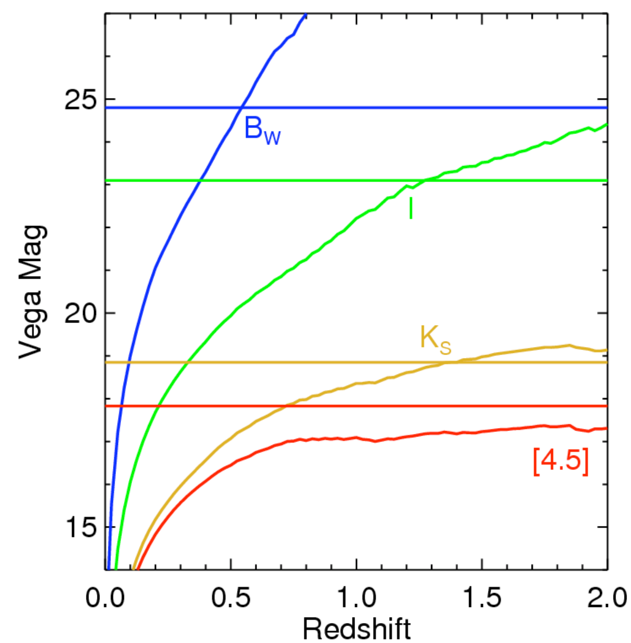
Mid-IR is a Good Place to Select Distant Galaxies

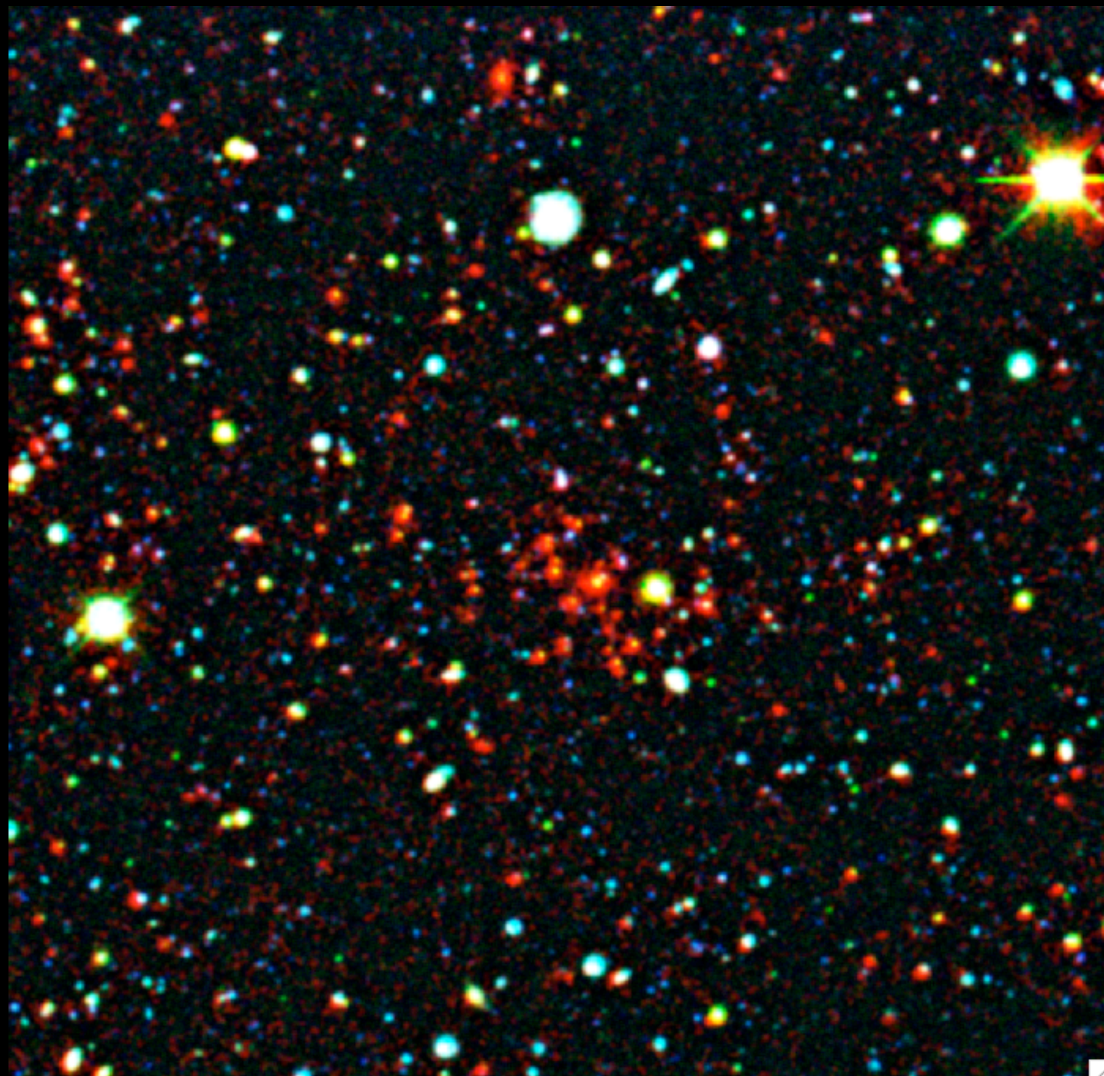




Optical
Alone

Eisenhardt et al. (2008)

Optical
+
Mid-IR



<z> = 1.26

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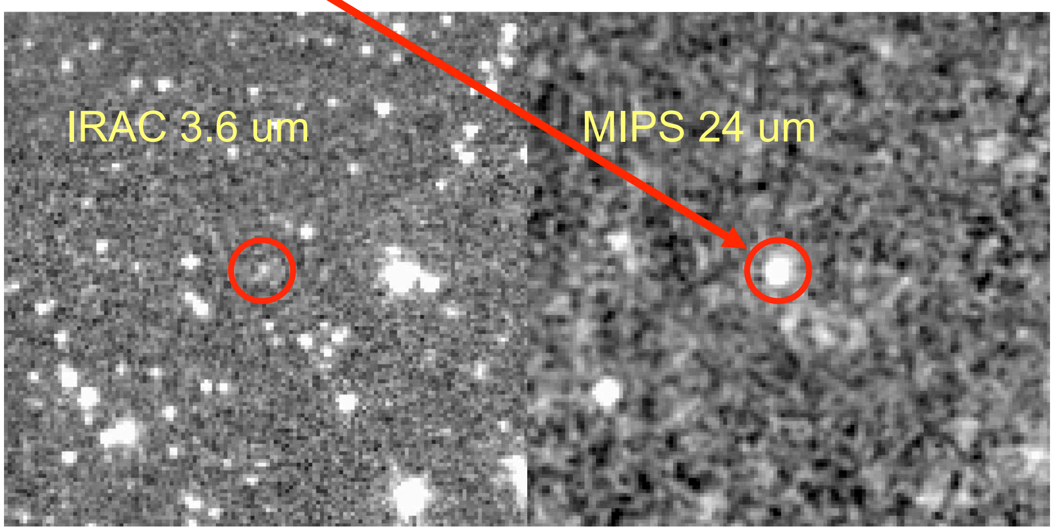
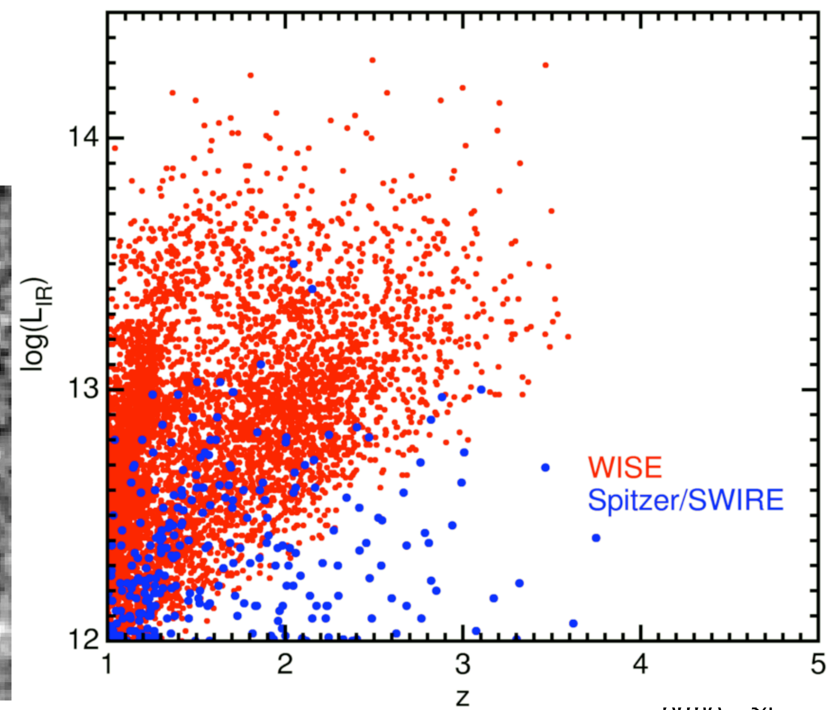
WISE Will Find the Most Luminous Galaxies

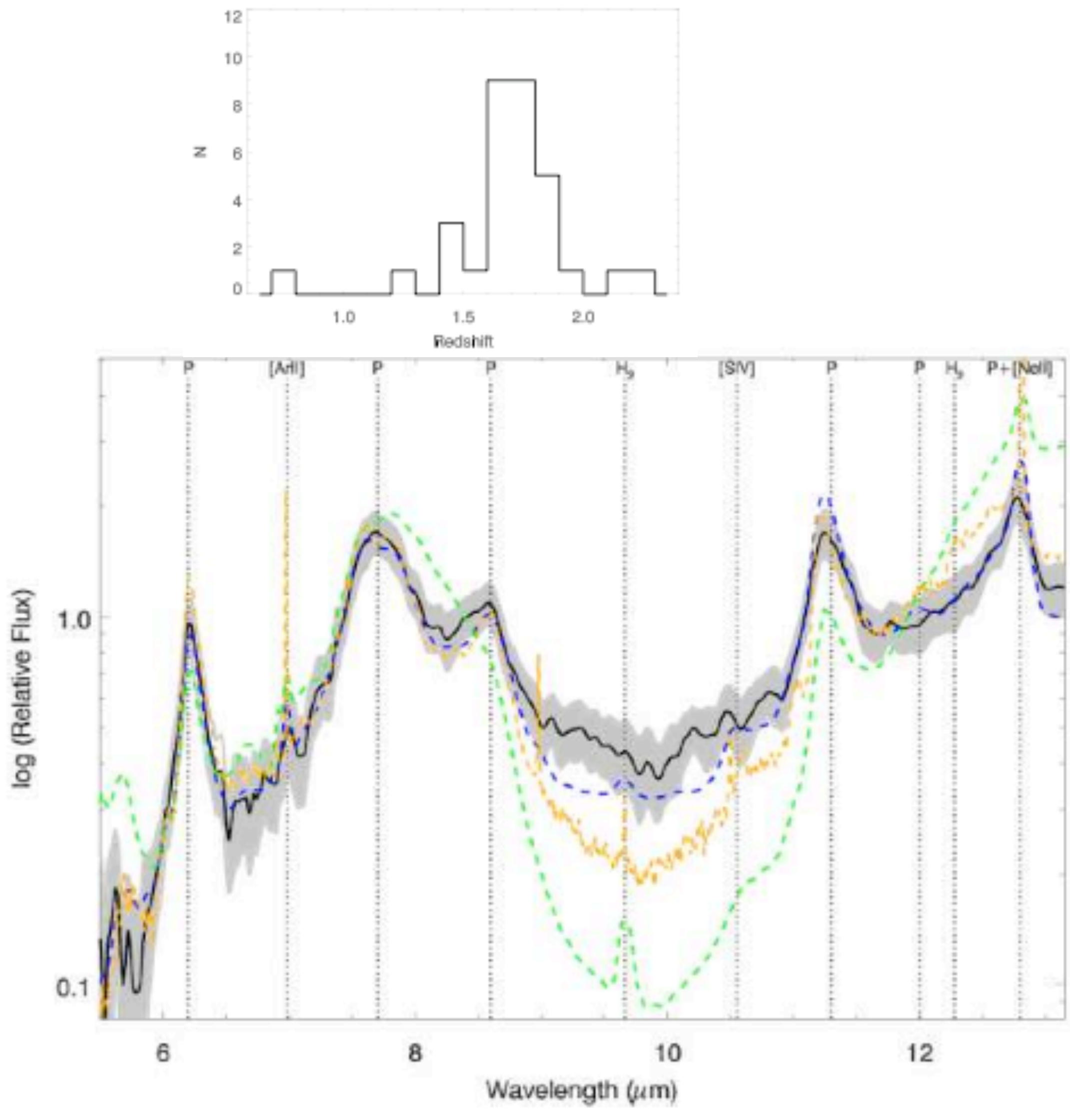
- Normal galaxies bright at shorter IR wavelengths
- Ultra-Luminous (up to ten trillion solar luminosities) IR Galaxies emit primarily at longer infrared wavelengths
- Bottom up structure formation has a hard time producing high z and high L objects, but these ULIRGs are seen.
- Spitzer first look survey 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 SWIRE.



Ultraluminous InfraRed Galaxies



Farrah, Lonsdale et al 2008 ApJ 677, 957

- Using 3.6, 4.5, 5.8, and 24 micron photometry from Carol Lonsdale's 50 sq deg SWIRE survey with Spitzer, redshift ~ 2 ULIRG candidates with 10^{13} L_{sun} were identified.
- Spitzer IRS spectra of 32 of these are all very similar (black line at left).
- Strong PAH features indicate star formation rather than quasars are energy source. Spectra more similar to local starbursts than local ULIRGs.
- Over 1000 Msun/yr of star formation needed - enough to make galaxy in < galactic year - Protogalaxies!
- Use this to develop 4-band WISE criteria for ULIRG's

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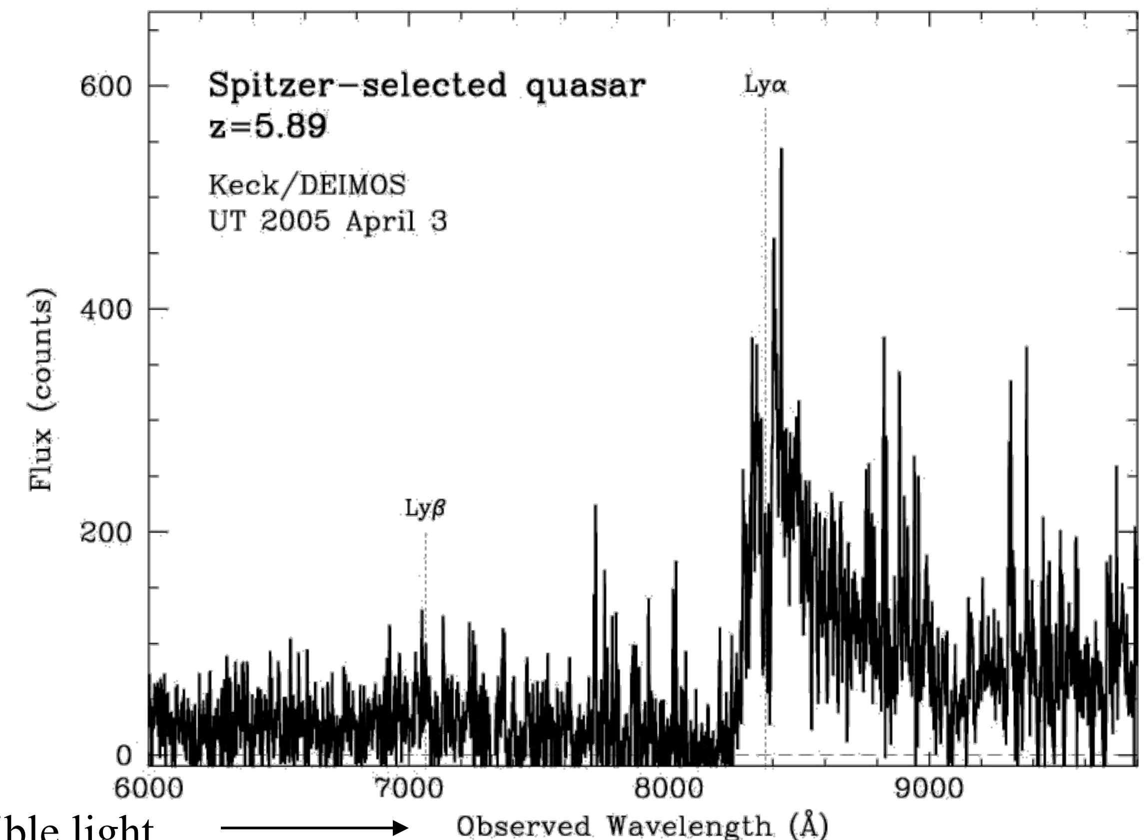
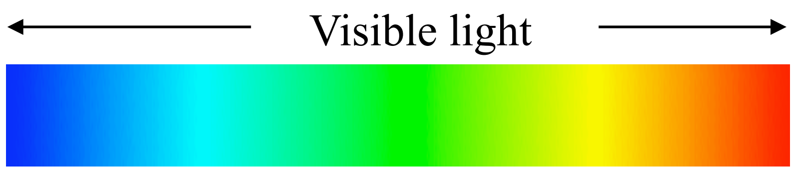
WISE Will Find Quasars Redshifted Beyond Optical

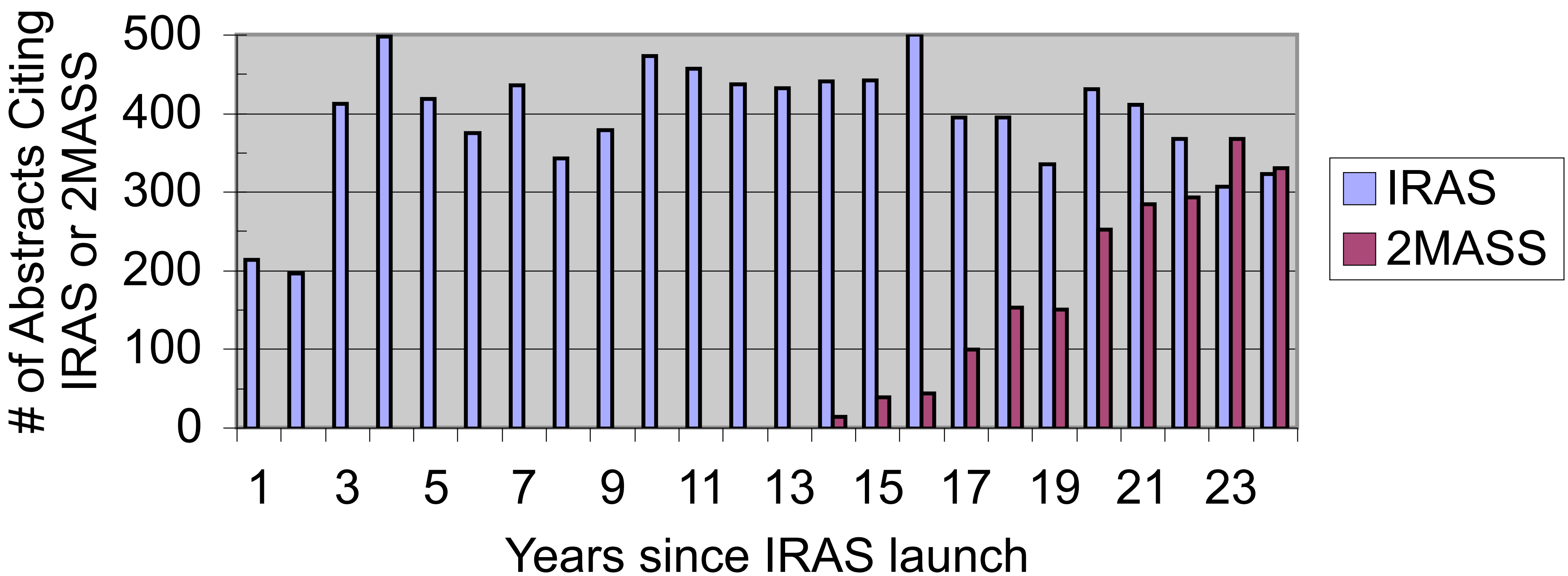
- Redshift 5.9 quasar found in the 9 sq. deg IRAC shallow survey
  - IRAC fluxes ≈ 35 μJy, somewhat better than WISE performance
- WISE will survey 5000× more area
- WISE should find 1000's of these QSOs and perhaps 100's at z > 7
  - Undetectable optically
  - Critical for reionization





Spectrum by D. Stern & H. Spinrad

The Legacy of All Sky Surveys Endures for Decades



1 Introduction

1.1 Recent Advances in Infrared Technology

Over the past 25 years infrared astronomy has experienced a remarkable growth, due principally to advancement in two areas of technology development. The first has been in the improvements in new infrared detector materials, fabrication techniques, and detector preamplifiers....Even more rapid in growth has been the development...of two dimensional monolithic arrays of infrared detectors bonded to integrating readout multiplexers... Arrays as large as 58 x 62 pixels are now being used for astronomical observations and 256 x 256 pixel arrays are being developed....The second major technology advance has been the ability to place and operate reliably cryogenically cooled telescopes in space....In 1983 the Infrared Astronomy Satellite (IRAS), the first orbiting, cryogenically cooled telescope for infrared astronomy....carried out an all sky survey in four broad wavelength bands....Although numerous and exciting scientific results were produced by this satellilte...it was only a beginning....Today, with the availability of infrared array detector technology a thousand times more detectors can be placed at the focal plane of the telescope, and each of these detectors would be considerably more sensitive than those of IRAS.

infrared telescope to liquid helium temperatures and placing it above the atmosphere allows