Exploring the Universe with WISE

Ned Wright (UCLA)

Project Overview

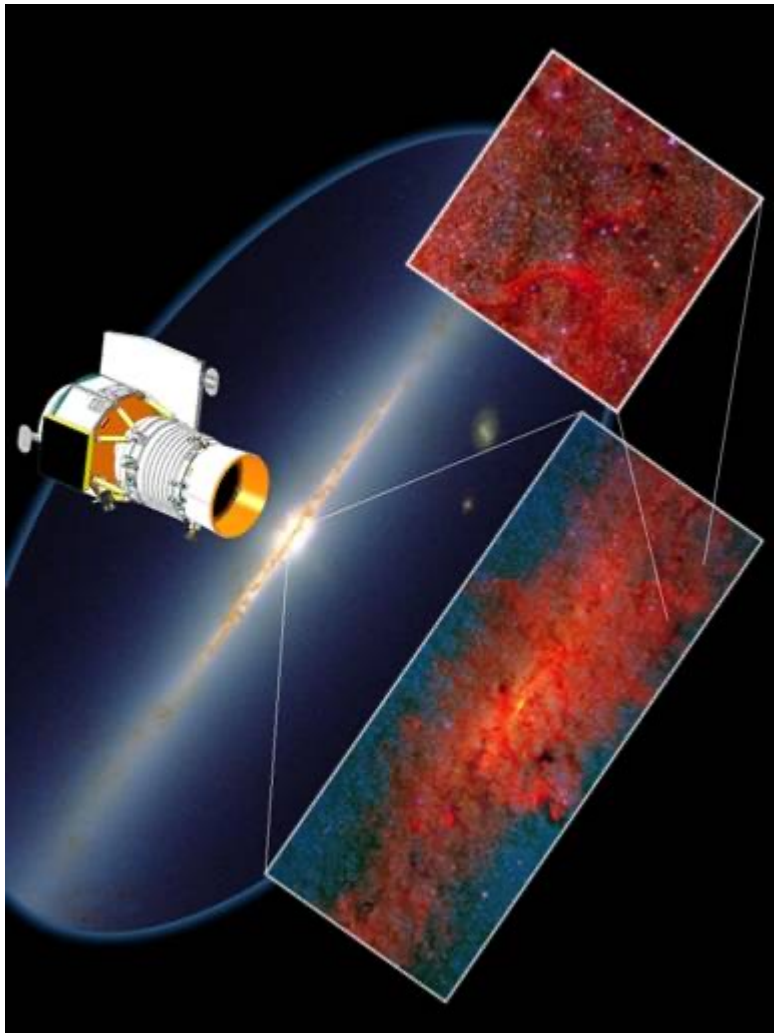
Science

- *Sensitive all sky survey with 8X redundancy*
  - *Find the most luminous galaxies in the universe*
  - *Find the closest stars to the sun*
  - *Provide an important catalog for JWST*
  - *Provide lasting research legacy*

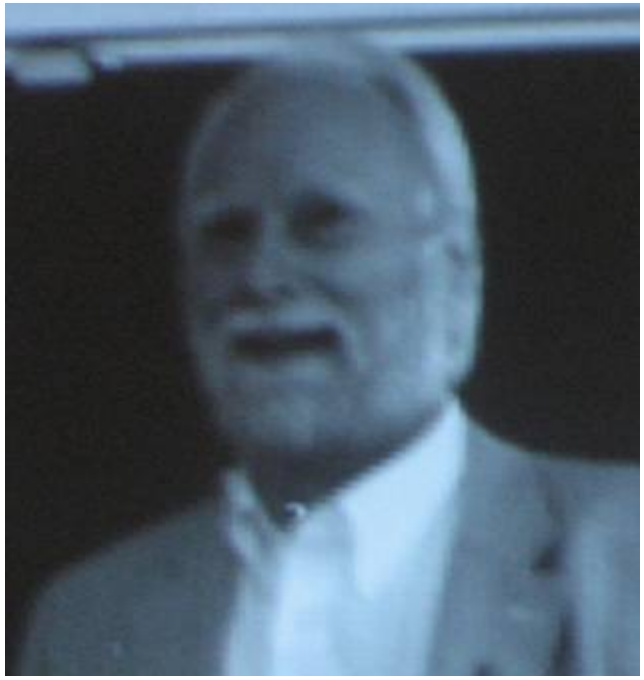
Salient Features

- *4 imaging channels covering 3 - 25 microns wavelength*
- *40 cm telescope operating at <17K*
- *Two stage solid hydrogen cryostat*
- *Delta launch from WTR: 14 Dec 2009*
- *Sun-synchronous 6am/6pm 500km orbit*
- *Scan mirror provides efficient mapping*
- *Expected life: 10 months*
- *4 TDRSS tracks per day*

Wide Field Infrared Survey Explorer



Infrared



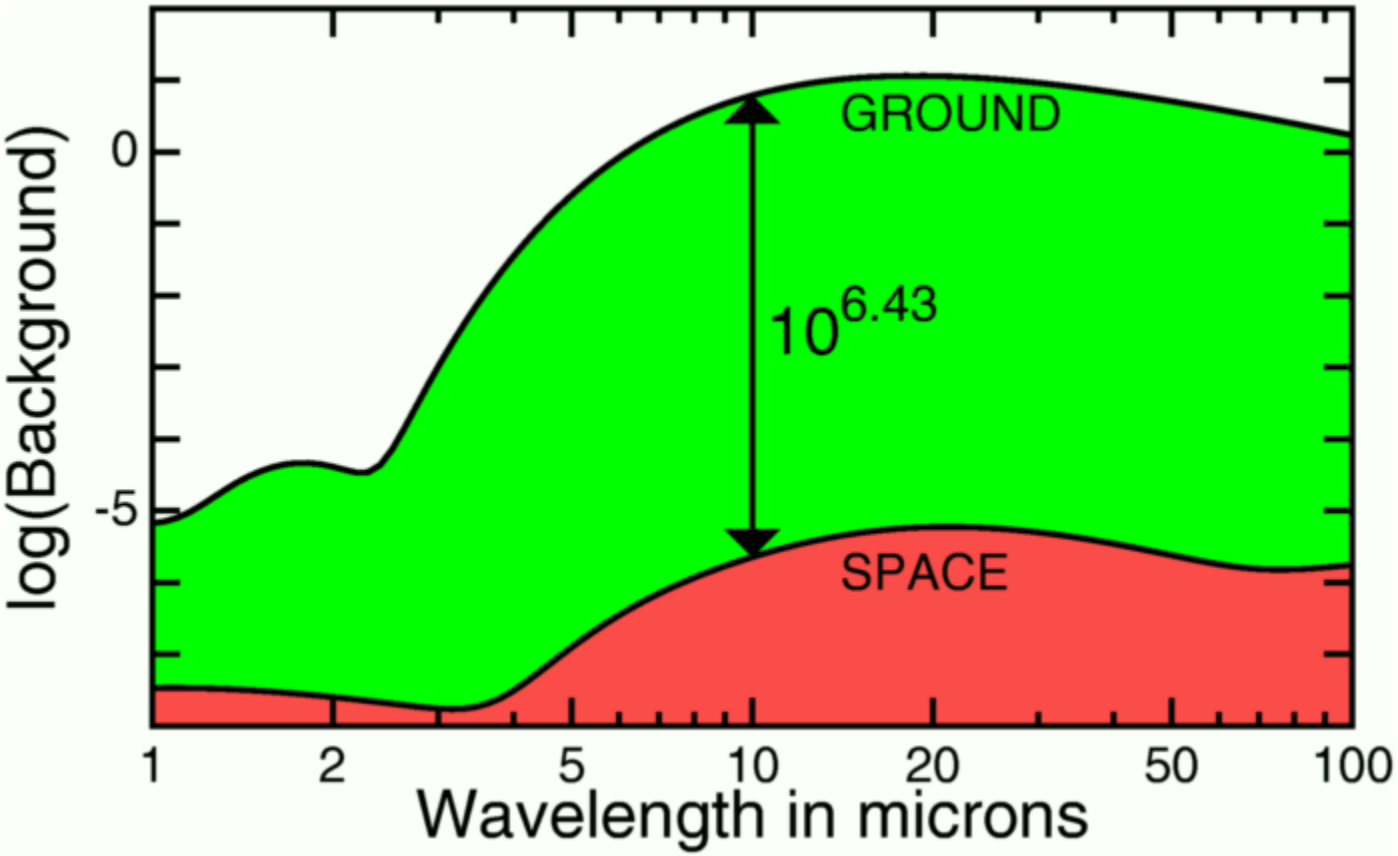
- Optical
- Reflected light

Near-IR
different colors

Thermal-IR
emitted radiation

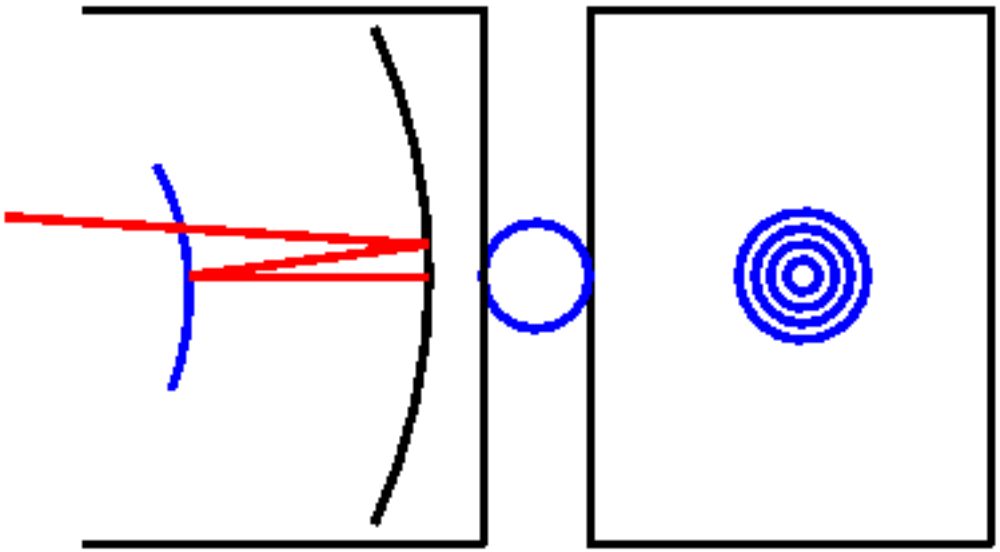
Why Space?

"Ground-based infrared astronomy is like observing stars in broad daylight with a telescope made out of fluorescent lights" — George Rieke.



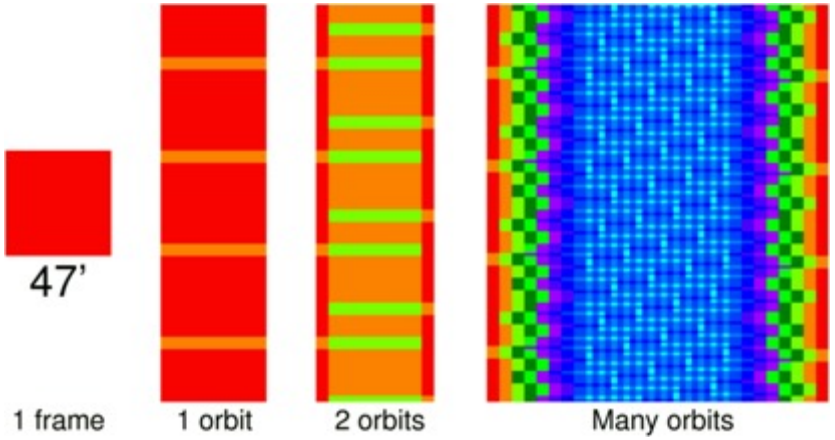
40 cm WISE telescope in space equals six thousand 8-meter telescopes on the ground!

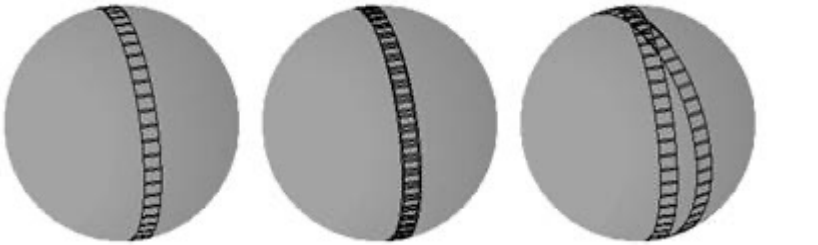
Animated Scan Mirror Icon



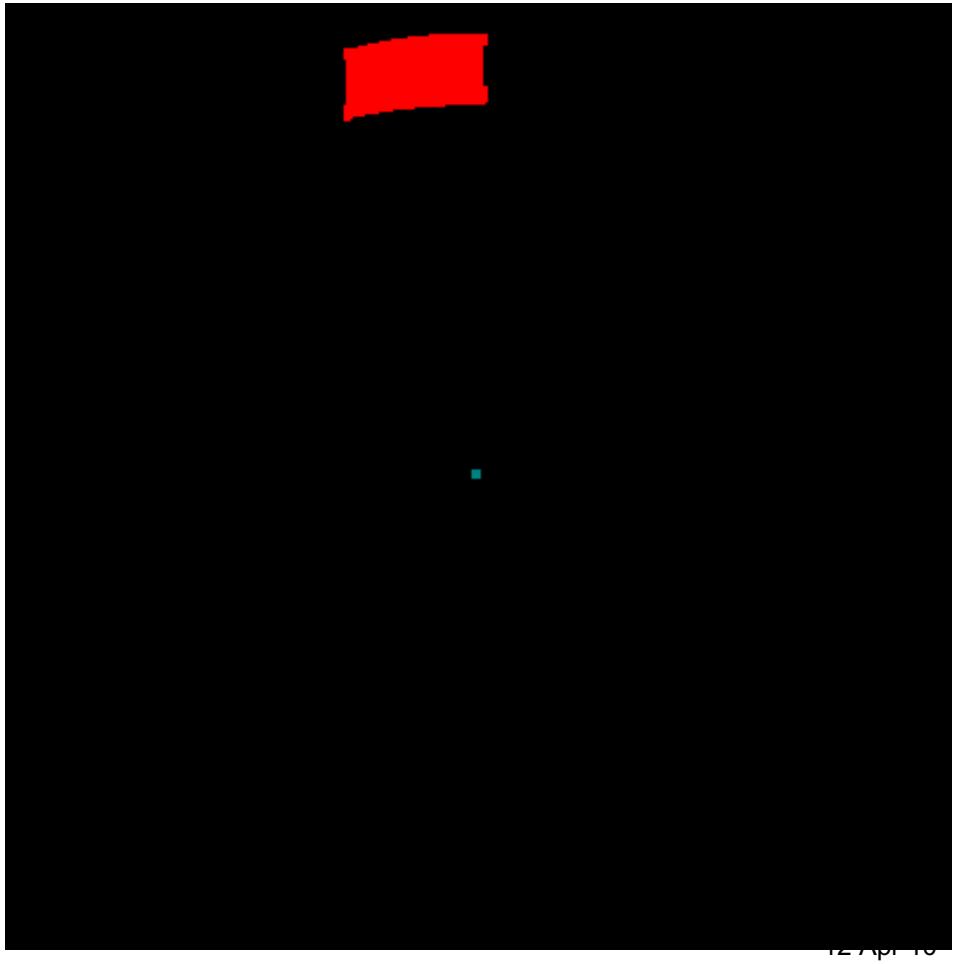
WISE Survey Strategy Provides Minimum of 8 Exposures Per Position

- Scan mirror enables efficient surveying
  - 8.8-s exposure/11-s duty cycle
- 10% frame to frame overlap
- 90% orbit to orbit overlap
- Sky covered in 6 months observing

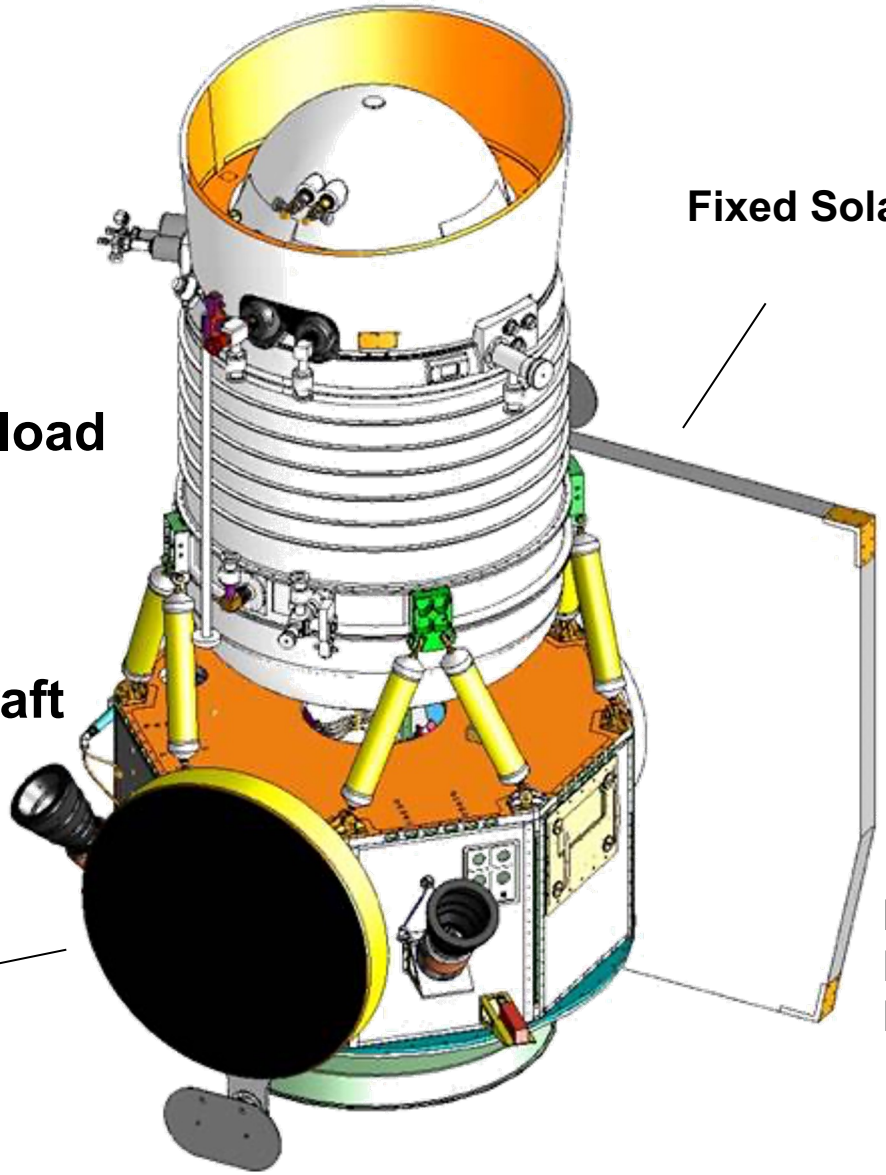




- Single observing mode
- Minimum 8, median 14 exposures/position after losses to Moon and SAA



WISE Components & Partners



Fixed Solar Arrays

SDL provides the payload

BATC provides the RS300-based spacecraft

Fixed High Gain Antenna

Mass: 663 kg
Power: 335 W
Data Rate: 78 GB/d

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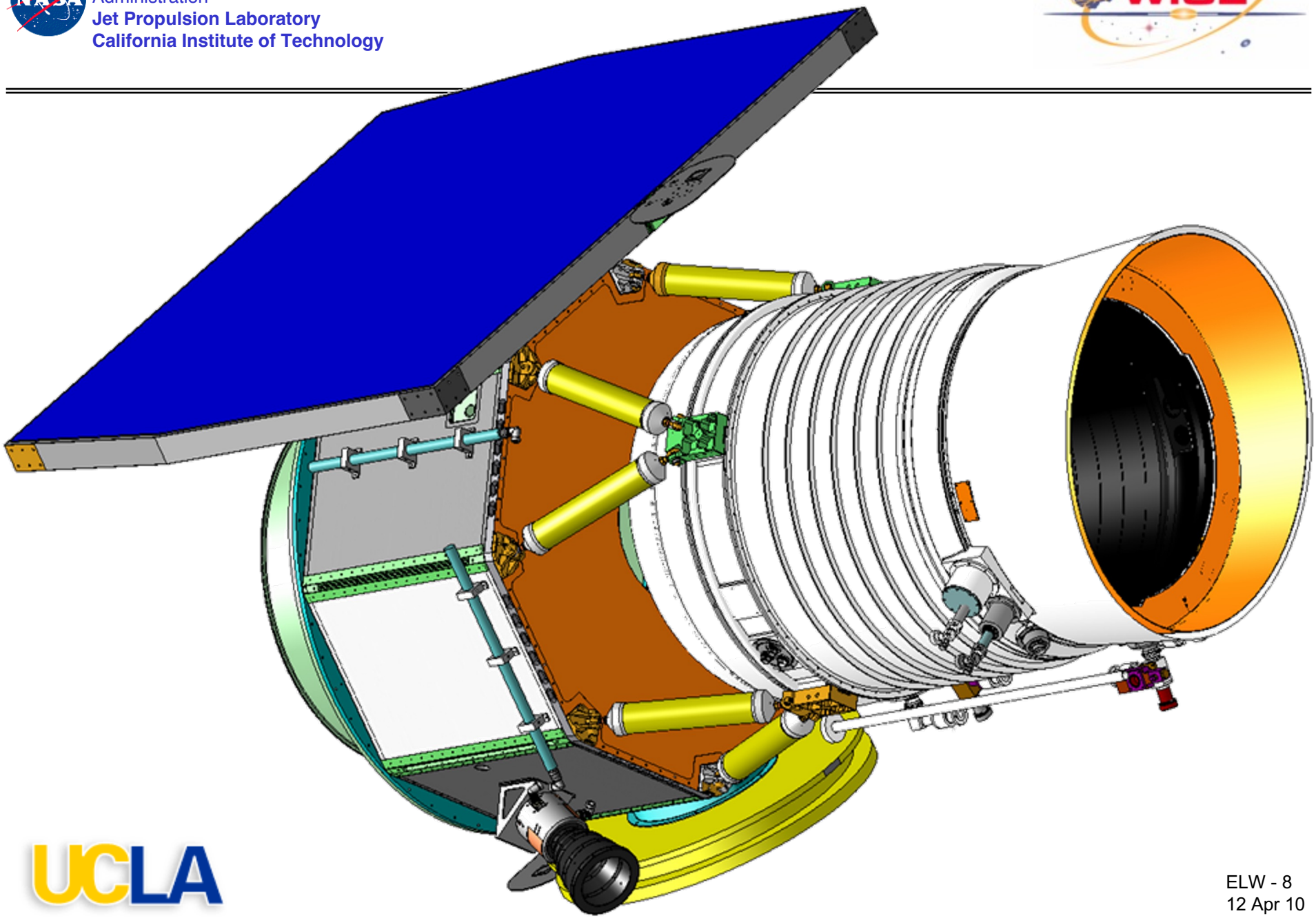
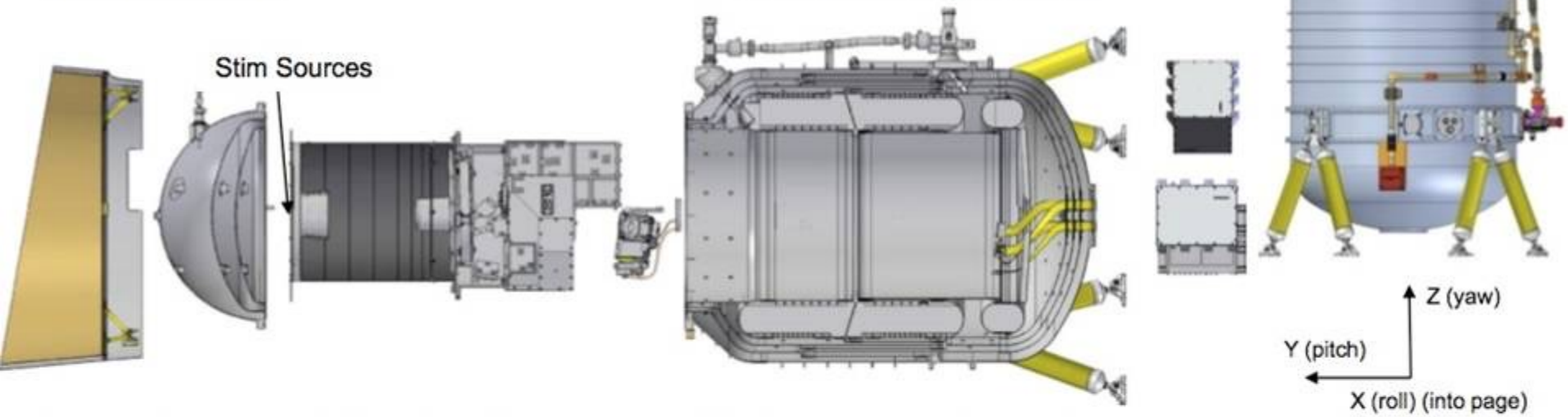


Inside the cryostat

2-Stage Aperture Shade
- Radiatively cooled
- Protects aperture from stray sun/ earth radiation
- Inner shade <110 K

Telescope
- 40-cm afocal front end
- Scan mirror
- Reflective imager

Cryostat
- 2-stage solid hydrogen
- Secondary tank cools optics & HgCdTe FPAs
- Primary tank cools Si:As FPAs
- 2 vapor-cooled shields
- Composite support-tube structure



Aperture Cover
- Deployed on-orbit
- Seals vacuum space on ground

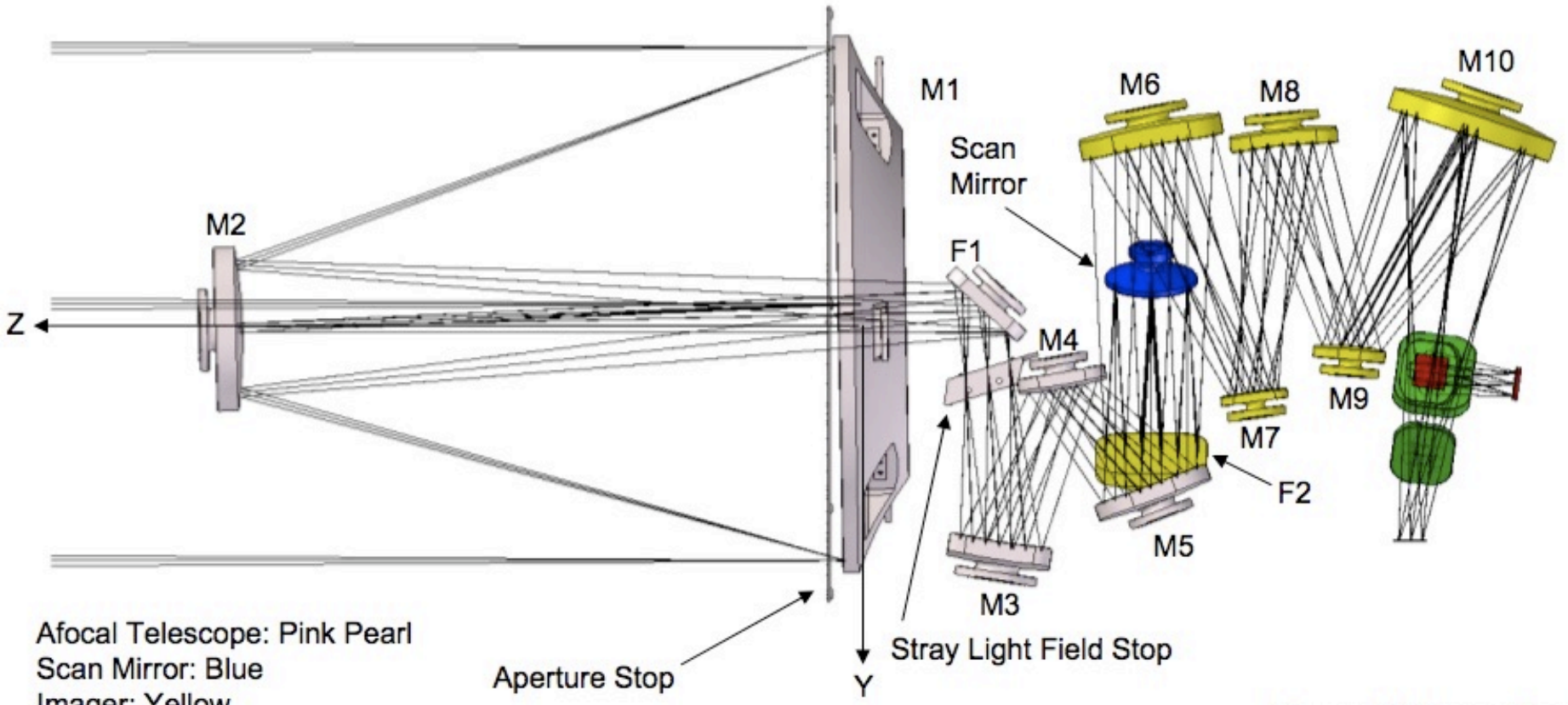
Beamsplitter Assembly
- 3 beamsplitters
- 4 FPMA mounts
- Isolation for LW FPAs

Focal Planes
- 2 MWIR HgCdTe arrays
- 2 LWIR Si:As arrays
- Cryogenic cables

Electronics
- Focal-plane electronics
- Monitor Electronics
  - Housekeeping/scan-mirror control
  - Pyro firing circuitry
- Digital Electronics
  - Sample up the ramp processing
  - Binning for LW channels

Tanks filled with Al Foam

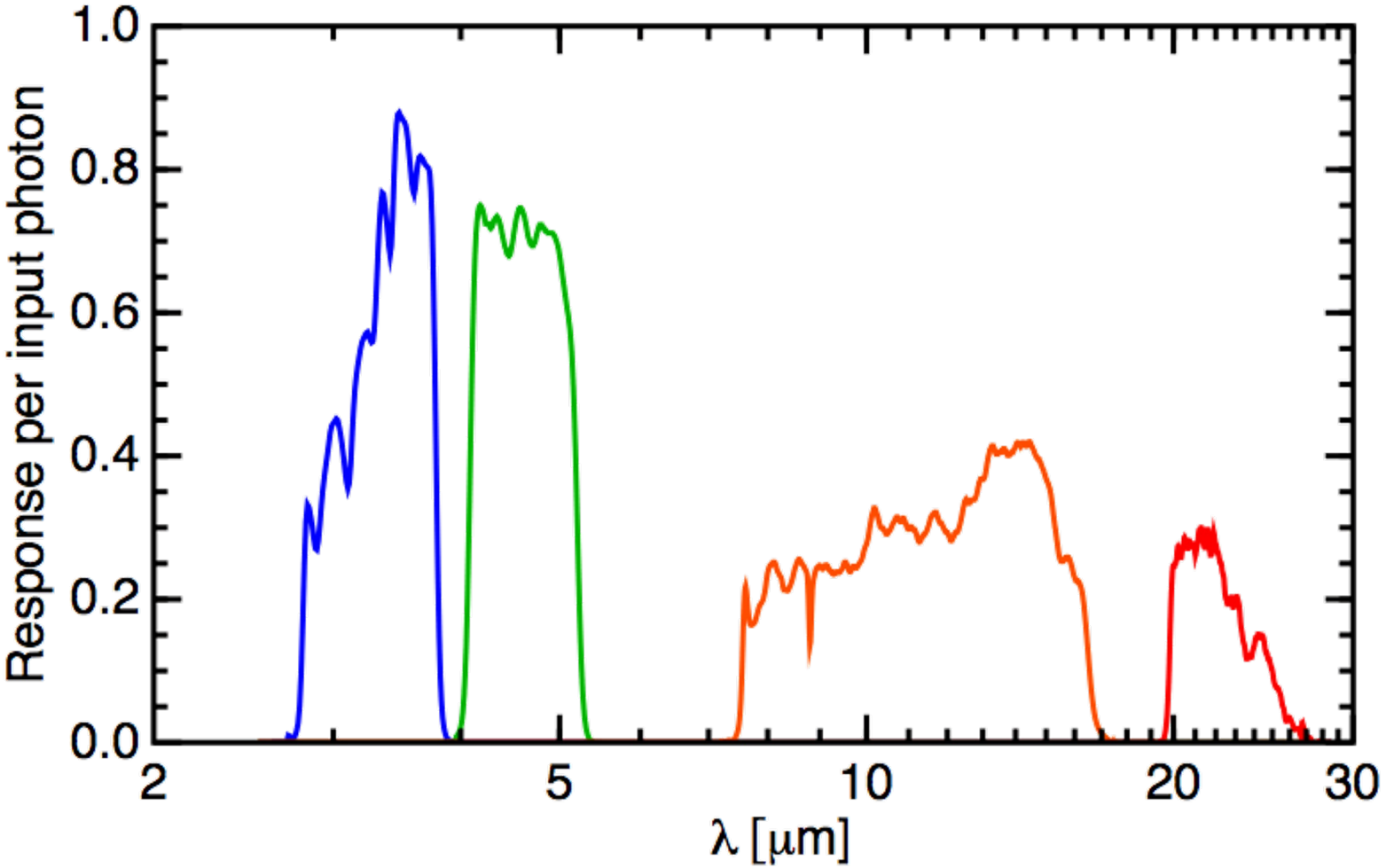
WISE Optical Diagram



Afocal Telescope: Pink Pearl
Scan Mirror: Blue
Imager: Yellow
BSA Dichroics: Green
BSA Filters: Red

Powered Mirrors: M prefix
Flat Mirrors: F prefix

System Throughput



- Long waves transmitted through thick BS1 leading to losses.

Filling with Hydrogen

Transporting to the launch pad

WISE in the Fairing

Cooling Still Needed

- The cryostat required 24x7 maintenance following completion of the hydrogen fill.
- Two 500 liter liquid helium dewars were transported to level 5 of SLC2 daily, from Nov 20 to Dec 14.

Launch seen from South VAFB

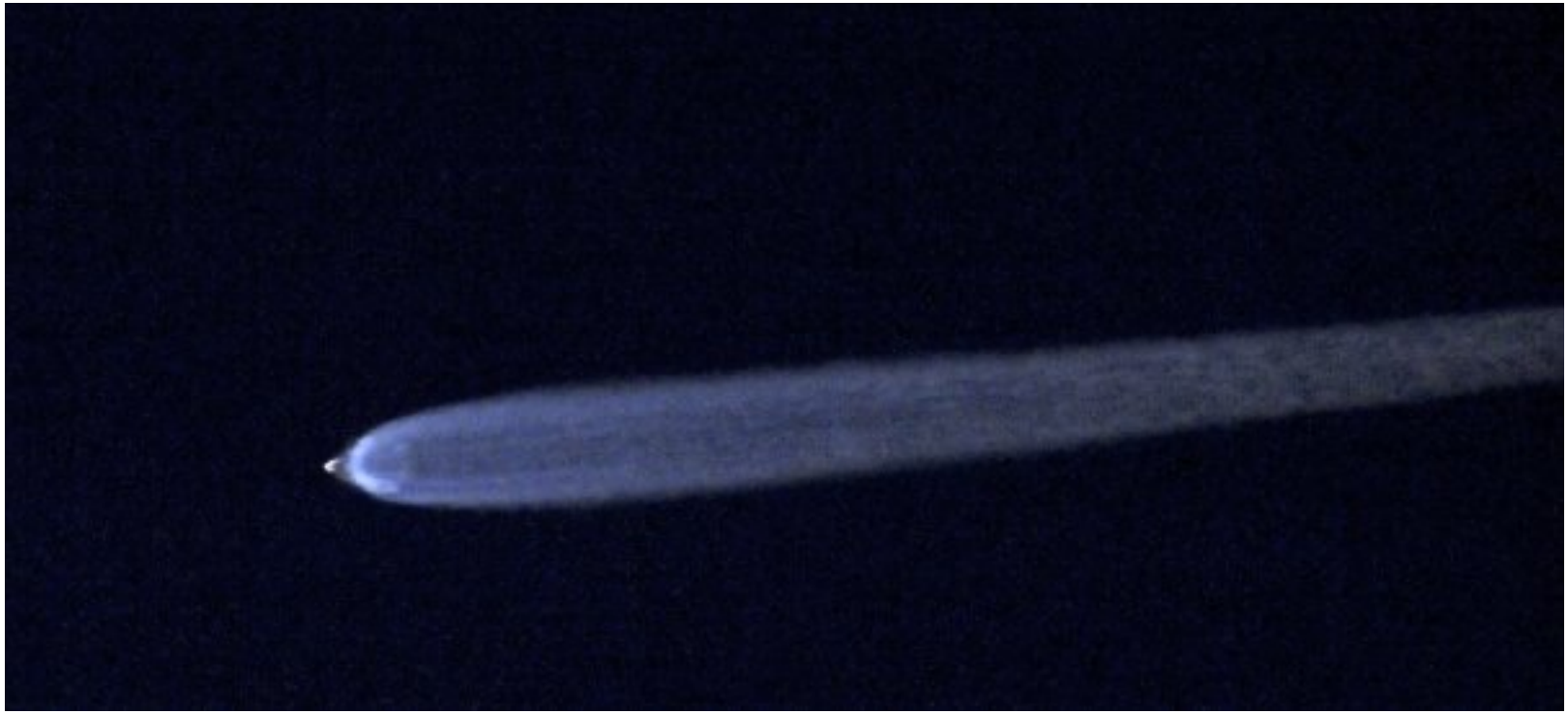
- I was about 10 miles away, in the control room, and did not see the launch directly. The deputy project manager took this picture from just outside the building I was in.

Launch from the viewing site

- Credit: Bill Hartenstein, ULA

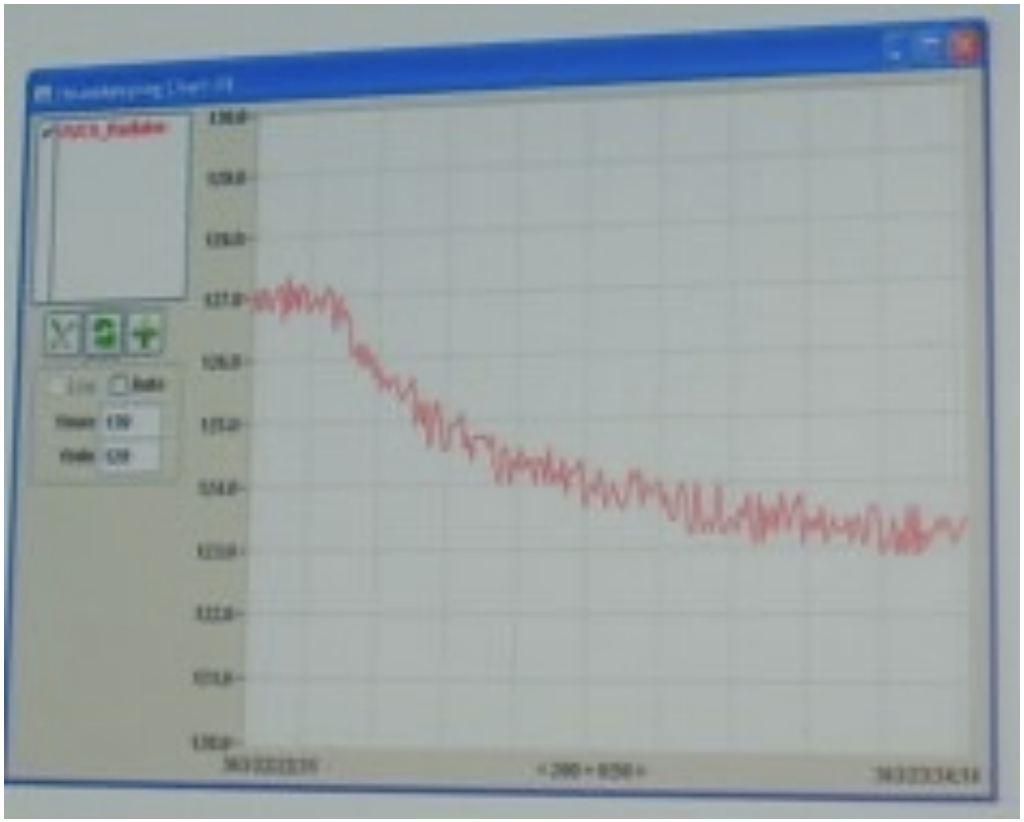
Launch in the IR

Launch from Tujunga



- © William Ling, 280 mm FL equivalent, handheld, with VR

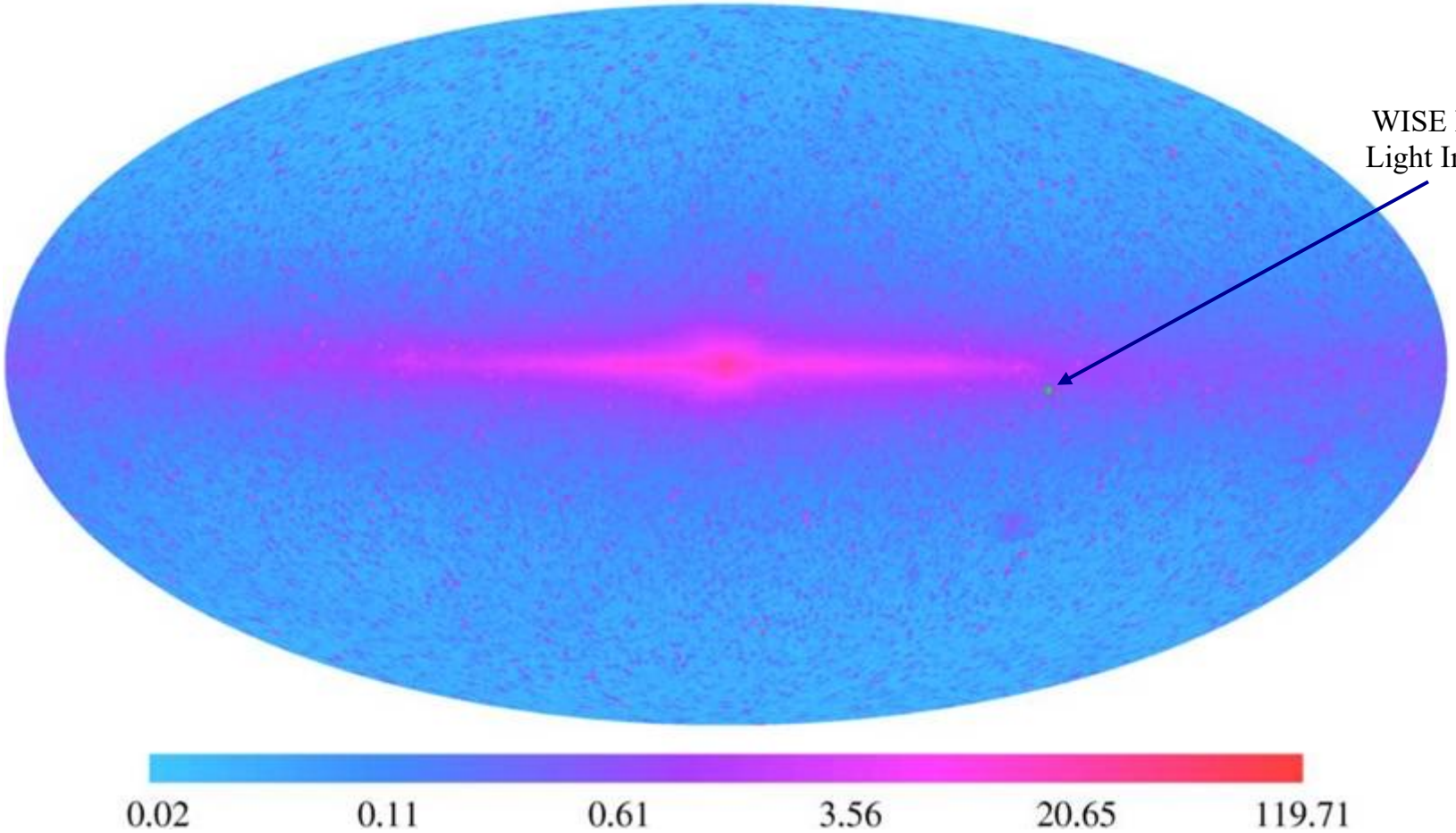
Cover Ejection 12/29/09



- Angular momentum telemetry on left, radiator cooling on right
- No “cover cam” to fail like the separation cam

Previous Survey in W1 & W2

DIRBE at 3.5 Microns



- DIRBE on COBE surveyed the sky at 3.5 & 5 microns

Zoom in on DIRBE

↑

Ecliptic North

1.15 degree field

at (l,b) = (279,-5)

Moon to scale

DIRBE 3.5 microns

IRAS 12 microns

WISE

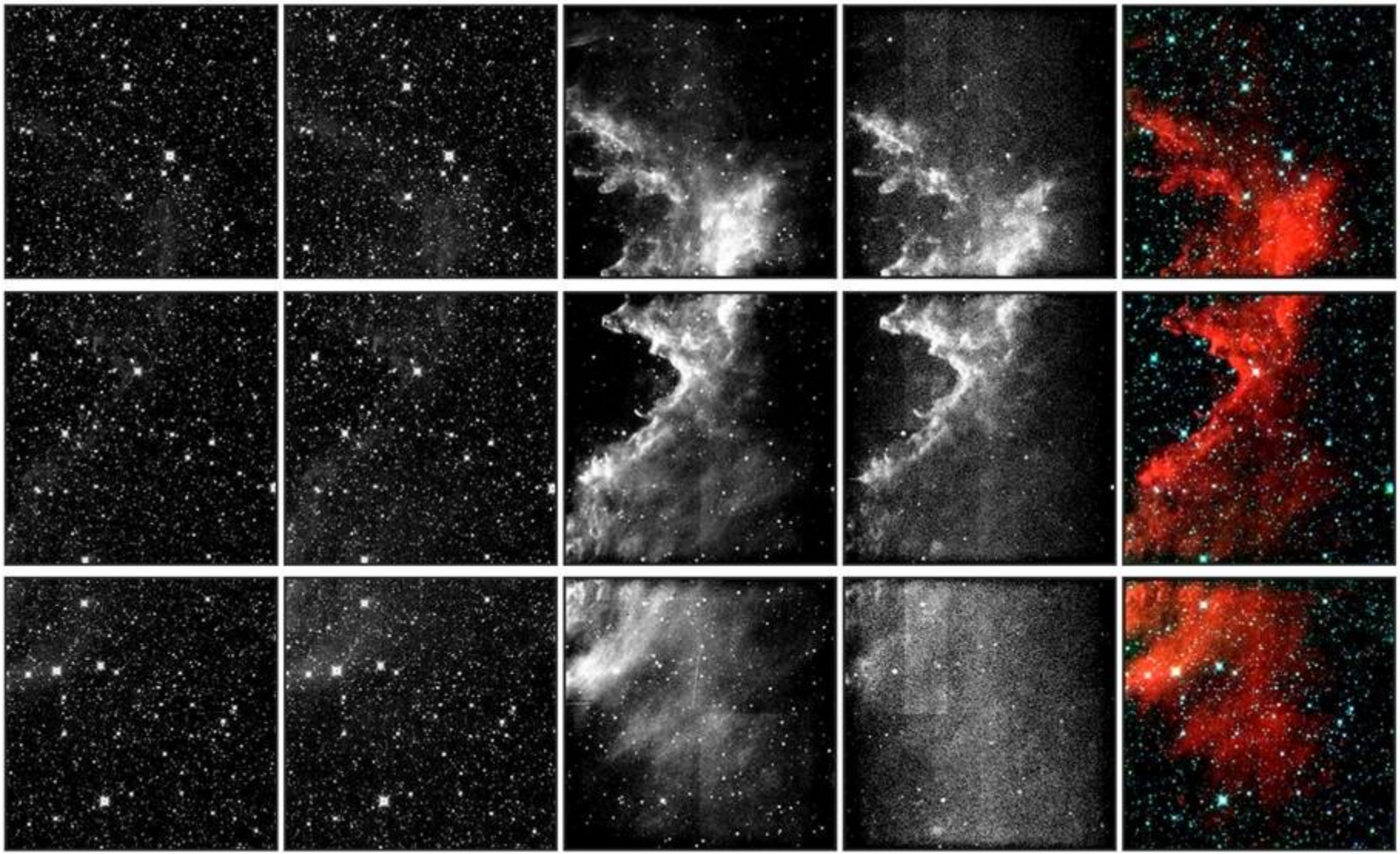
3.4, 4.6, 12 microns

47’ FOV

2.75” pixels

6” FWHM

On to Survey Mode



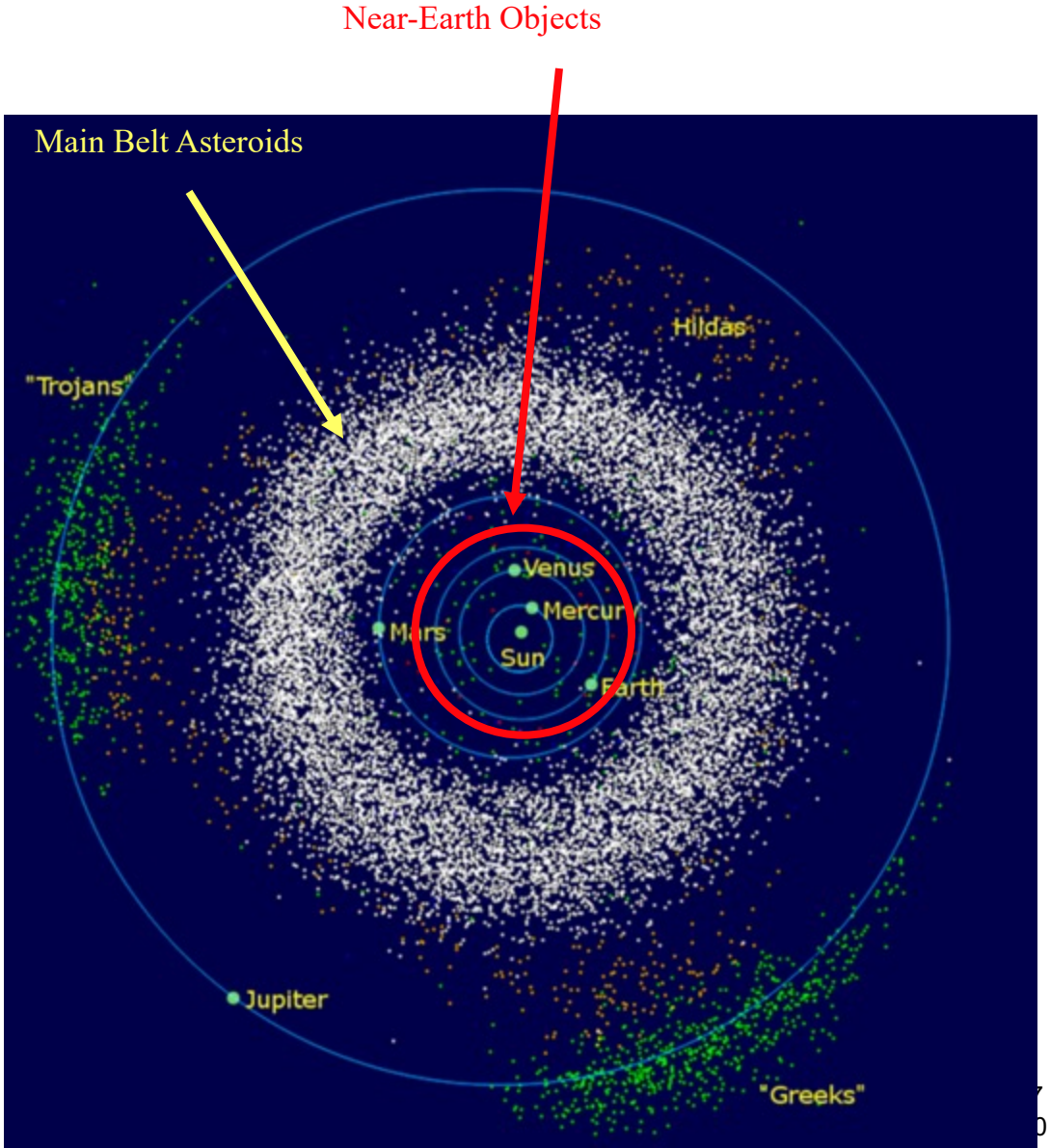
- 33 seconds in the life of WISE, 3 of >7000 frames/day

G 118.1+4.9

- Sometimes the automated Quality Assurance images are just astoundingly beautiful. Now an Image of the week.

WISE and Asteroids

- WISE will find lots of asteroids — many never seen before
  - Hundreds of thousands of Main Belt Asteroids
  - Hundreds of Near-Earth Objects (NEOs)
- This will help us the understand the size distribution of asteroids, as well as their compositions
- This will help us understand the probability of impacts on Earth



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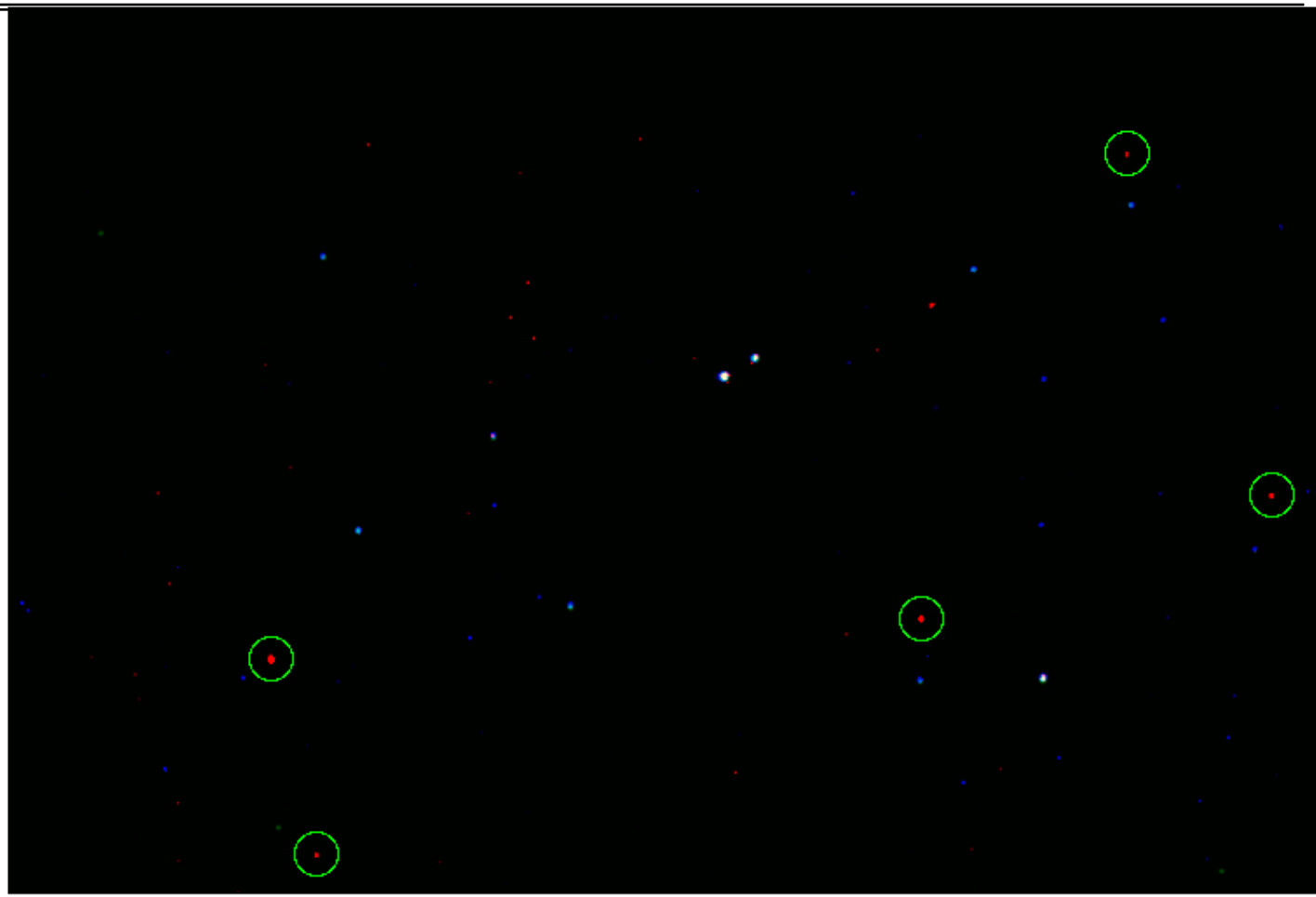
Wide-field Infrared Survey Explorer (WISE)

Asteroids Observed by WISE

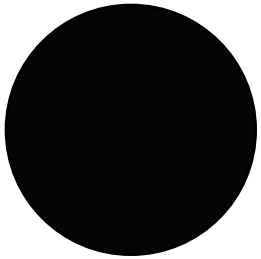
- Four frames of data taken on 2010 Jan. 8 during in-orbit checkout.
- Blue = 3.6um; green = 4.6um; red = 12um
- Circled asteroids are (L to R in the first frame, diameters in km):
  17818 MBA D~12.4
  153204 MBA D~2.8
  22006 MBA D~11.5
  87355 MBA D~4.3
  80590 MBA D~4.1



Field of view = 34 x 25 arcmin (whole WISE FOV is 47 x 47 arcmin)

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.



2.3% albedo, 2.6 km diameter

63% albedo, 0.5 km diameter

- 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.

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Wide-field Infrared Survey Explorer (WISE)

WISE's First NEO

- 2010 AB78
- Orbit:
  - a = 2.302
  - e = 0.553
  - inc = 33.3
- Size, about 1 km
- Not a Potentially Hazardous Object since its Minimum Orbit Intersection Distance or MOID is large.

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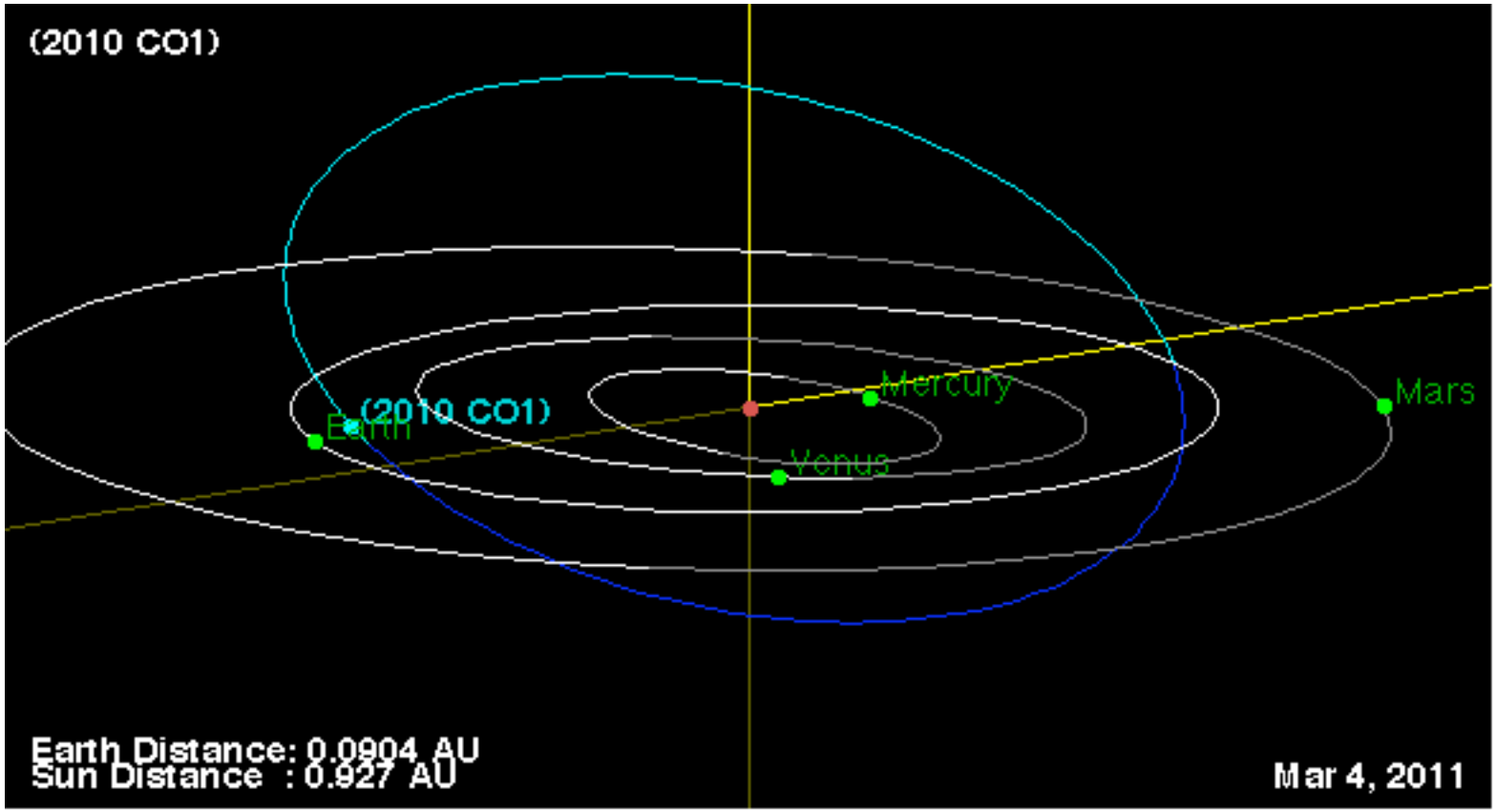
WISE's 1st PHA: 2010 CO1

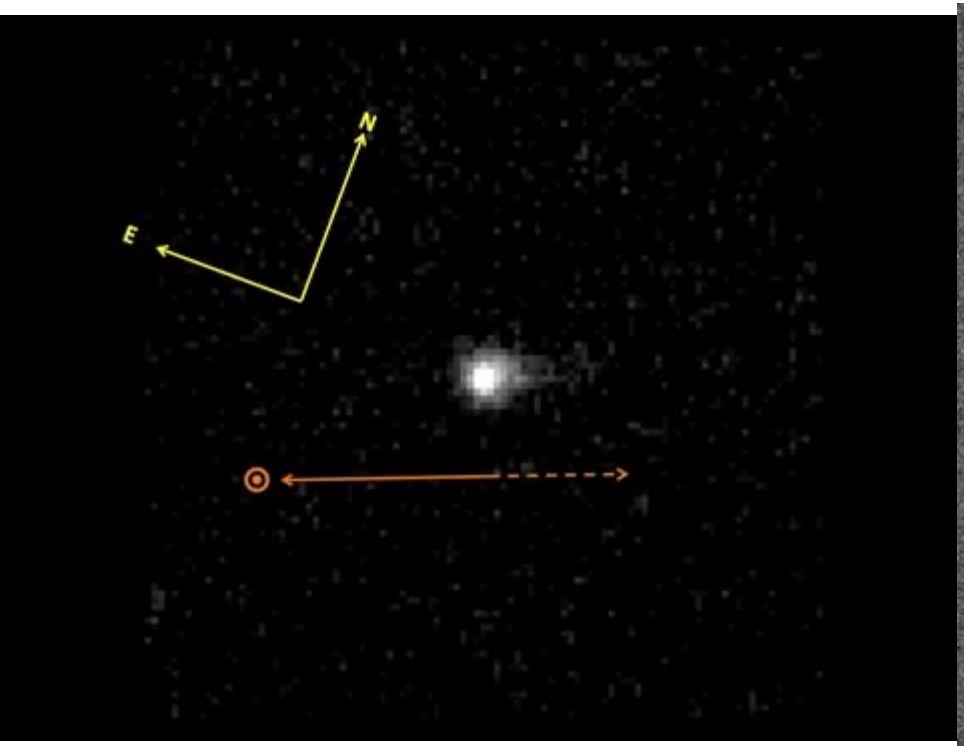
- Makes close approach to Earth March 4, 2011: 0.091 AU



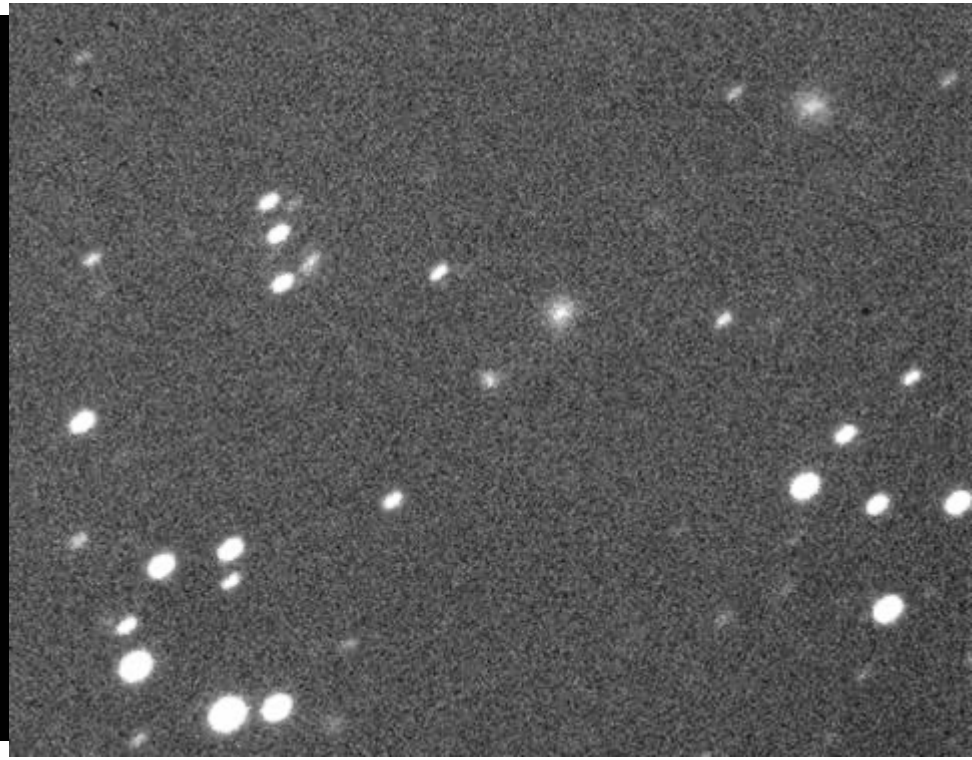
Comets

- Red giants are blue, and comets are red.
- M3 globular cluster and Comet Garradd
- WISE Image of the Week posted 26 Mar 2010

Comet P/2010 B2 (WISE)



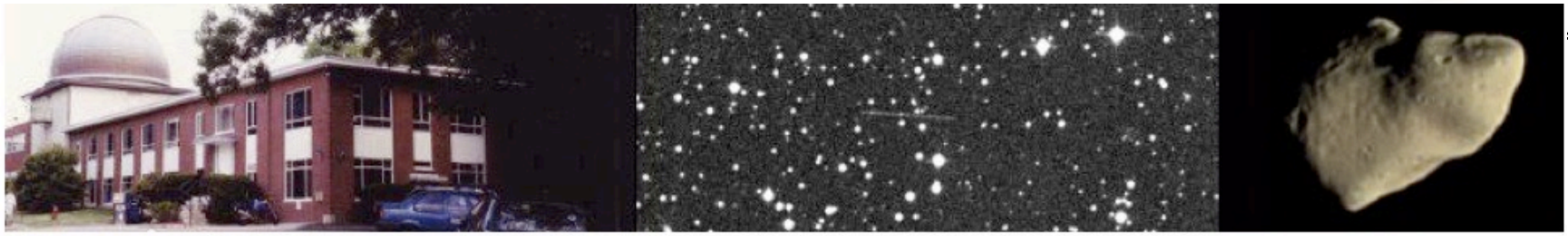
WISE band 3



Megaprime on CFHT

- a = 2.993, e = 0.463, i = 8.9°, P = 5.18 yrs
- About 20th magnitude visually

Pipeline to the MPC



The NEO Confirmation Page

Please ensure that you have read the additional notes on the NEOCP.
Please do not report observations of non-NEOCP objects in the same message as observations of objects on this page!

Get NEO Ratings to see whether you should report a possible NEO.

- ☑ W009igt [2010 Mar. 30.7 UT. R.A. = 07 07.7, Decl. = +26 29, V = 19.4] Added Apr. 1.93 UT
- ☑ W009h6a [2010 Mar. 25.3 UT. R.A. = 18 34.7, Decl. = +08 02, V = 22.4] Added Apr. 1.93 UT
- ☑ W009gxm [2010 Mar. 28.1 UT. R.A. = 06 56.6, Decl. = +19 37, V = 22.3] Added Apr. 1.82 UT
- ☑ W009iho [2010 Mar. 27.1 UT. R.A. = 18 48.7, Decl. = -64 53, V = 22.2] Added Apr. 1.51 UT
- ☑ W009gwd [2010 Mar. 27.5 UT. R.A. = 07 01.0, Decl. = +39 49, V = 22.5] Added Apr. 1.51 UT
- ☑ W009f9x [2010 Mar. 26.8 UT. R.A. = 07 16.9, Decl. = +56 17, V = 22.4] Added Apr. 1.51 UT
- ☑ W009h9w [2010 Mar. 26.0 UT. R.A. = 07 04.9, Decl. = -19 44, V = 21.4] Added Apr. 1.48 UT **[1 nighter]**
- ☑ W009h8n [2010 Mar. 28.3 UT. R.A. = 06 32.8, Decl. = -21 59, V = 20.4] Added Apr. 1.48 UT
- ☑ W009h74 [2010 Mar. 27.6 UT. R.A. = 18 44.1, Decl. = -55 20, V = 21.4] Added Apr. 1.48 UT
- ☑ W009g3z [2010 Mar. 28.2 UT. R.A. = 18 48.5, Decl. = -54 11, V = 20.3] Added Apr. 1.48 UT
- ☑ W009fim [2010 Mar. 29.1 UT. R.A. = 18 08.4, Decl. = +58 22, V = 22.3] Added Apr. 1.48 UT
- ☑ W009fc9 [2010 Mar. 30.7 UT. R.A. = 07 38.5, Decl. = +49 27, V = 21.4] Added Apr. 1.48 UT
- ☑ W009e05 [2010 Mar. 28.8 UT. R.A. = 19 27.0, Decl. = -52 17, V = 22.5] Added Mar. 31.45 UT **[1 nighter]**
- ☑ W009dmg [2010 Mar. 17.2 UT. R.A. = 17 38.0, Decl. = -64 33, V = 18.4] Updated Mar. 29.87 UT

- On 1 Apr 2010, 14 out of 14 candidate NEOs needing confirmation were WISE discoveries.

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Jet Propulsion Laboratory
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A small subset of WISE discoveries

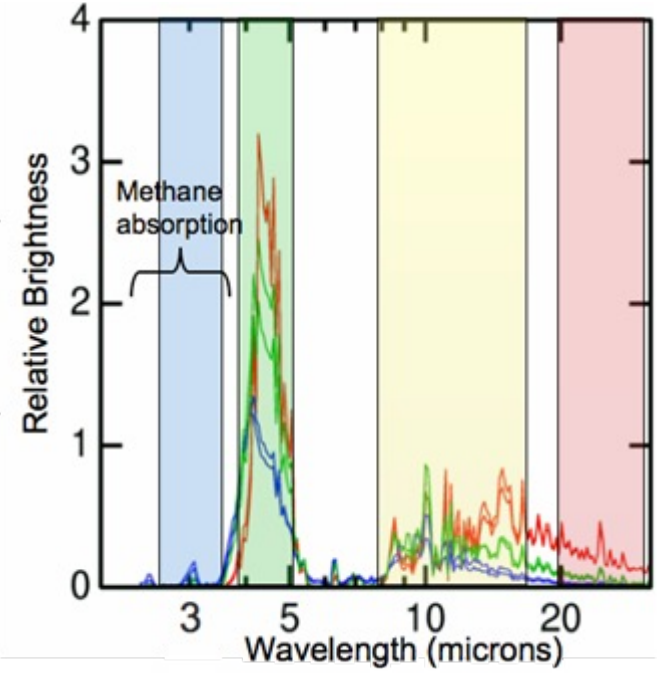
WISE Related Minor Planet Electronic Circulars

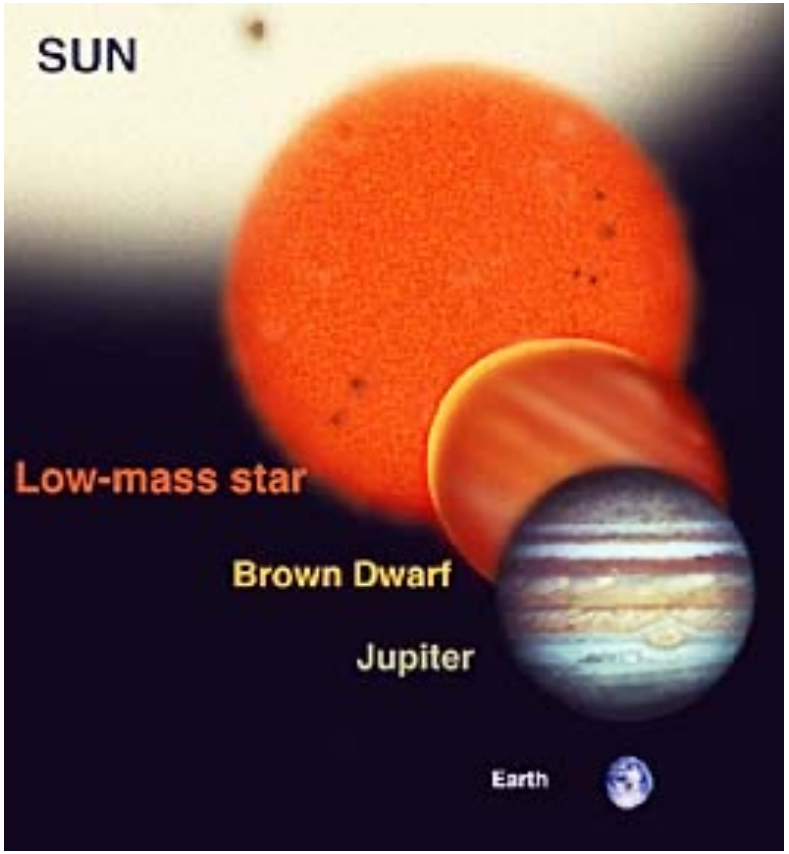
1. 2010 GF25, Mars, Earth, Venus & Mercury crosser
2. 2010 GE25
3. 2010 GK23, eccentric (e=0.71) Earth crosser
4. 2010 GJ23
5. 2010 FJ81
6. 2010 FH81, PHA (MOID=0.0347)
7. 2010 FG81, PHA (MOID=0.0191)
8. 2010 FC81, PHA (MOID=0.0223)
9. 2010 FB81, PHA (MOID=0.0401)
10. 2010 FA81, PHA (MOID=0.0337)
11. 2010 FZ80, Earth crosser
12. 2010 FY80, comet-like orbit
13. 2010 FX80
14. 2010 EX119, an Earth crosser.
15. Comet C/2010 E3 (WISE)
16. 2010 EN44, PHA (MOID=0.0187)
17. Comet C/2010 D4 (WISE), with perihelion
18. 2010EH20, a fairly big NEO.
19. Comet C/2010 D3 (WISE)
20. 2010 DJ77, Aten
21. 2010 DH77
22. 2010 DG77, PHA (MOID = 0.0061 AU)
23. 2010 EX11, PHA (MOID = 0.0281)
24. Comet C/2010 D2 (WISE)
25. 2010 DM56, PHA (MOID = 0.0068 AU)
26. 2010 DJ56, Earth Crosser
27. 2010 DH56, Earth Crosser
28. 2010 DG56, Dead Comet? Actually not dead: Comet C/2010 DG56 (WIS
29. 2010 DK34, Earth and Venus Crosser
30. 2010 CN141, very dark PHA (MOID = 0.0431 AU)
31. 2010 DM21, Earth Crosser
32. 2010 CR140, i=75 Trojan?
33. 2010 CP140, Earth Crosser
34. Comet P/2010 D1 (WISE)
35. 2010 CC55, Earth Crosser
36. 2010 CA55, Earth and Venus Crosser
37. Comet P/2009WJ50 (La Sagra). Previously classified as an asteroid until
38. 2010 CU19
39. 2010 CH18
40. 2010 CG18
41. 1996 GQ, PHA (MOID = 0.0201)
42. 2010 CO1, PHA (MOID = 0.0224)
43. Comet P/2010 B2 (WISE)
44. 2010 AG79
45. 2010 AB78

http://www.astro.ucla.edu/~wright/WISE/WISE-MPECs.html

WISE and Brown Dwarfs

- Brown Dwarfs are stars with too little mass to fuse Hydrogen into Helium.
- WISE two short wavelength filters are tuned to methane dominated brown dwarf spectra.



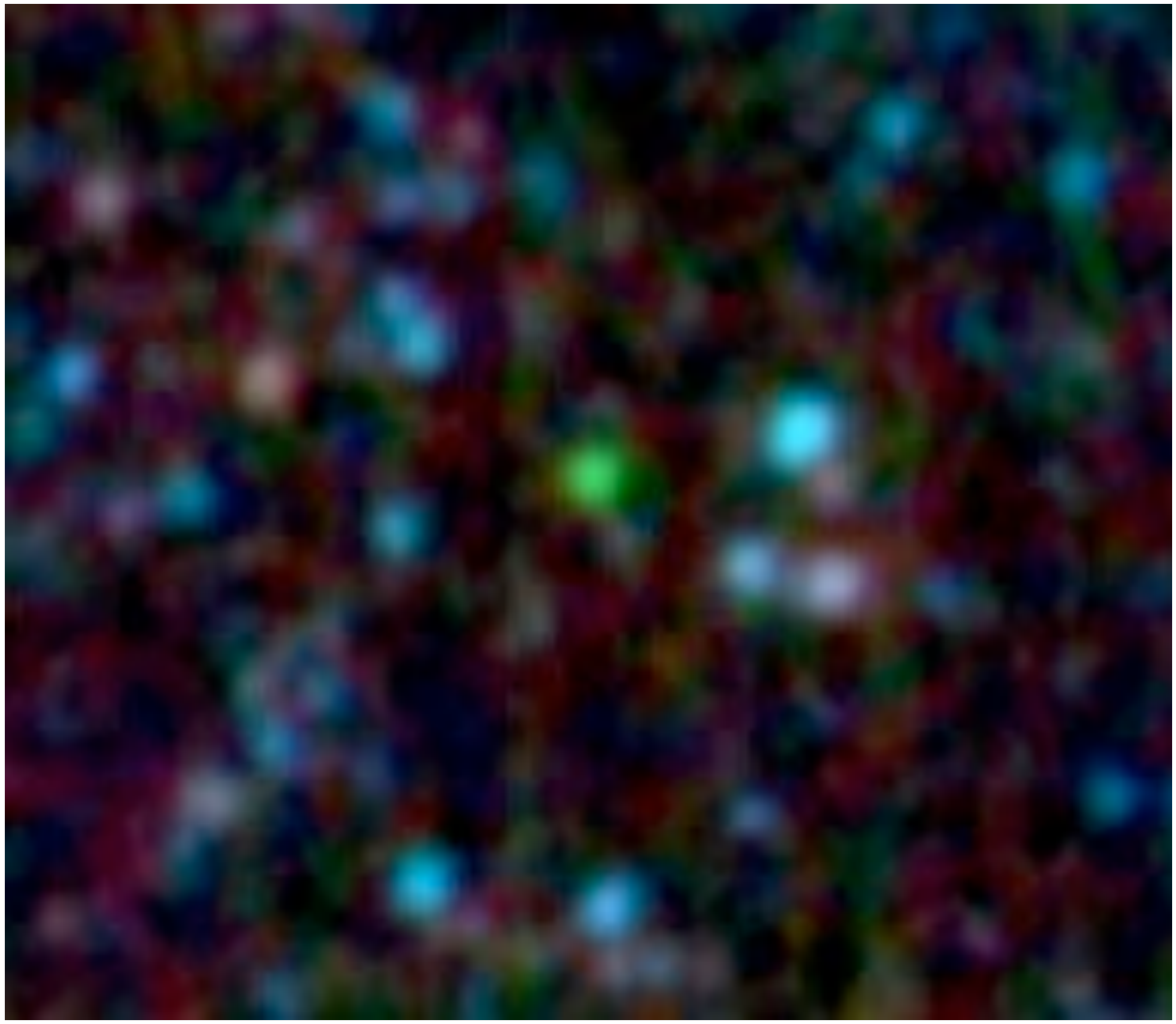


- WISE could identify brown dwarfs as cool as 200 Kelvin (-100 Fahrenheit) out to 4 light years, the distance to the nearest known star.

Brown Dwarf Energy Source

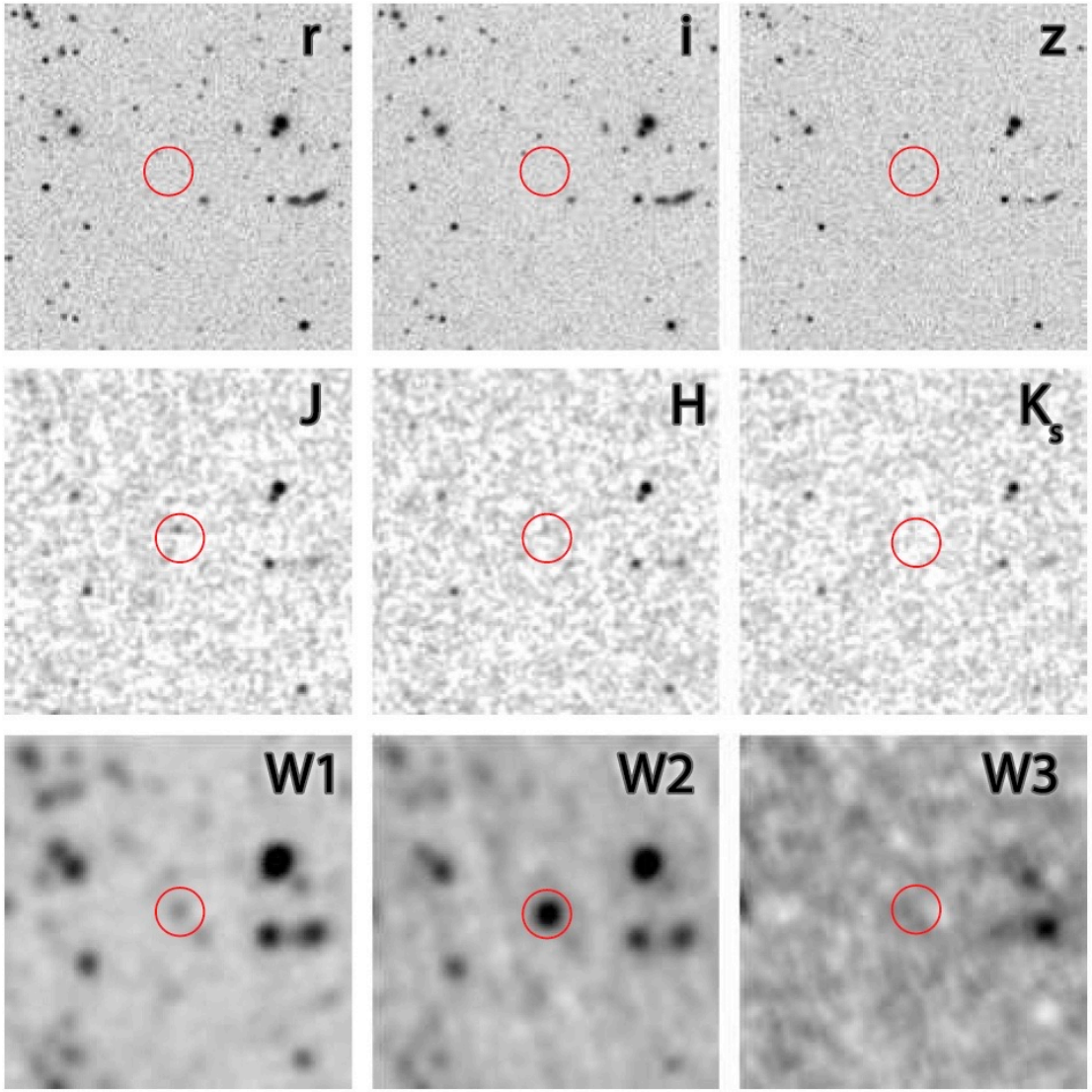
- Not hot enough in the center to run nuclear fusion like stars
- Energy from initial collapse slowly leaks out
- Order of magnitude of the gravitational energy is GM^2/R
  - For a uniform density sphere $(3/5)GM^2/R$, $\rho \approx 1/r^2$ gives $(1)GM^2/R$
- Order of magnitude of luminosity is energy/age or GM^2/Rt
- Fit gives $L = 0.02(GM_J^2/[R_J * 1\text{Gyr}])(M/M_J)^{1.93}([1\text{ Gyr}]/t)^{1.18}$ or about $L/L_\odot = 3 \times 10^{-8}$ for 10 M_J at 10 Gyr
  - About 25 times cooler than the Sun or 231 K. Brr!
  - Detectable by WISE to a distance of 12 light years

A WISE discovered BD



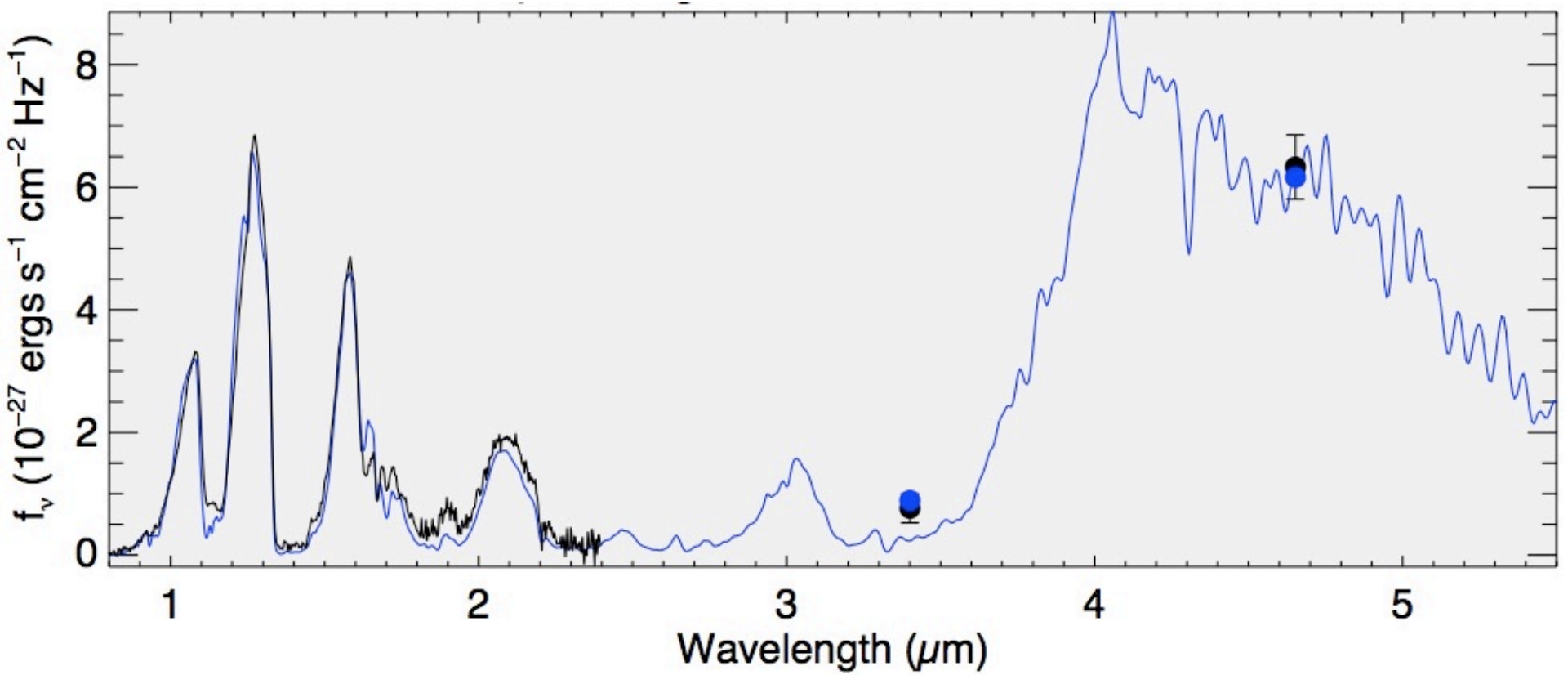
- The green star: bright in W2 but faint in W1 and W3

More bands



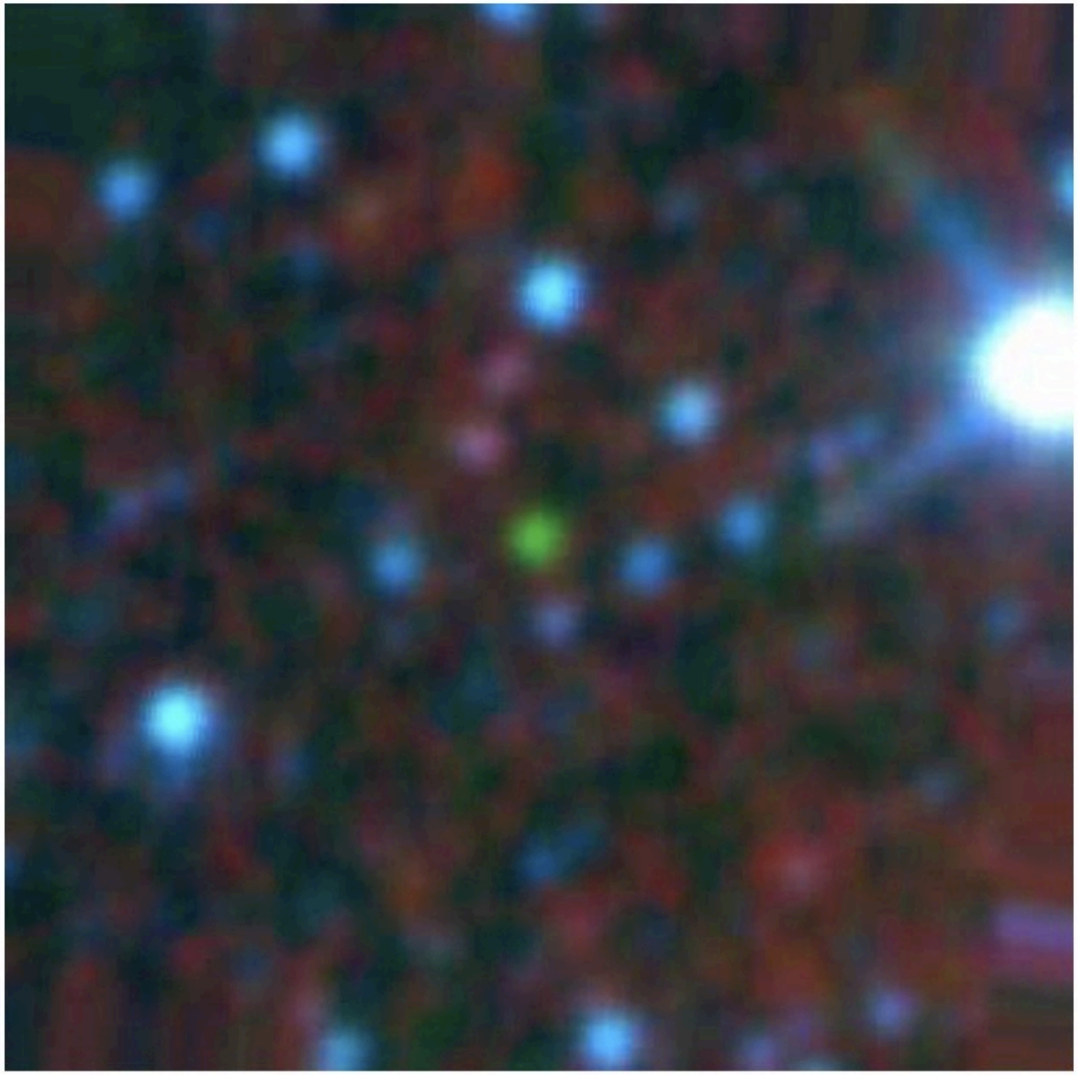
- Moved 4” in 10 years since 2MASS

Spectral Confirmation



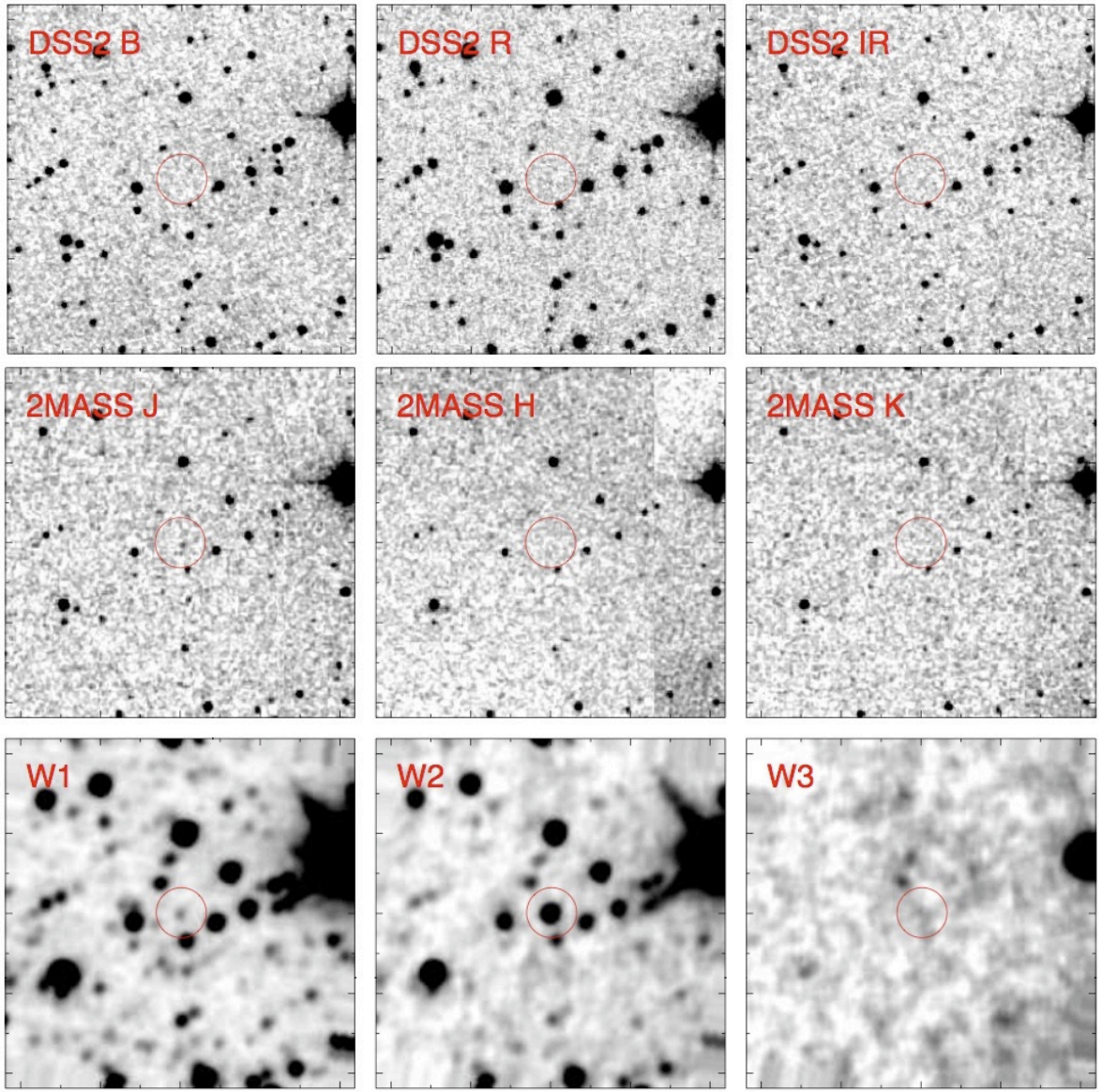
- Specs on IRTF, also NIRSPEC on Keck
- Model has T_{eff} = 800 K

Another Green Star



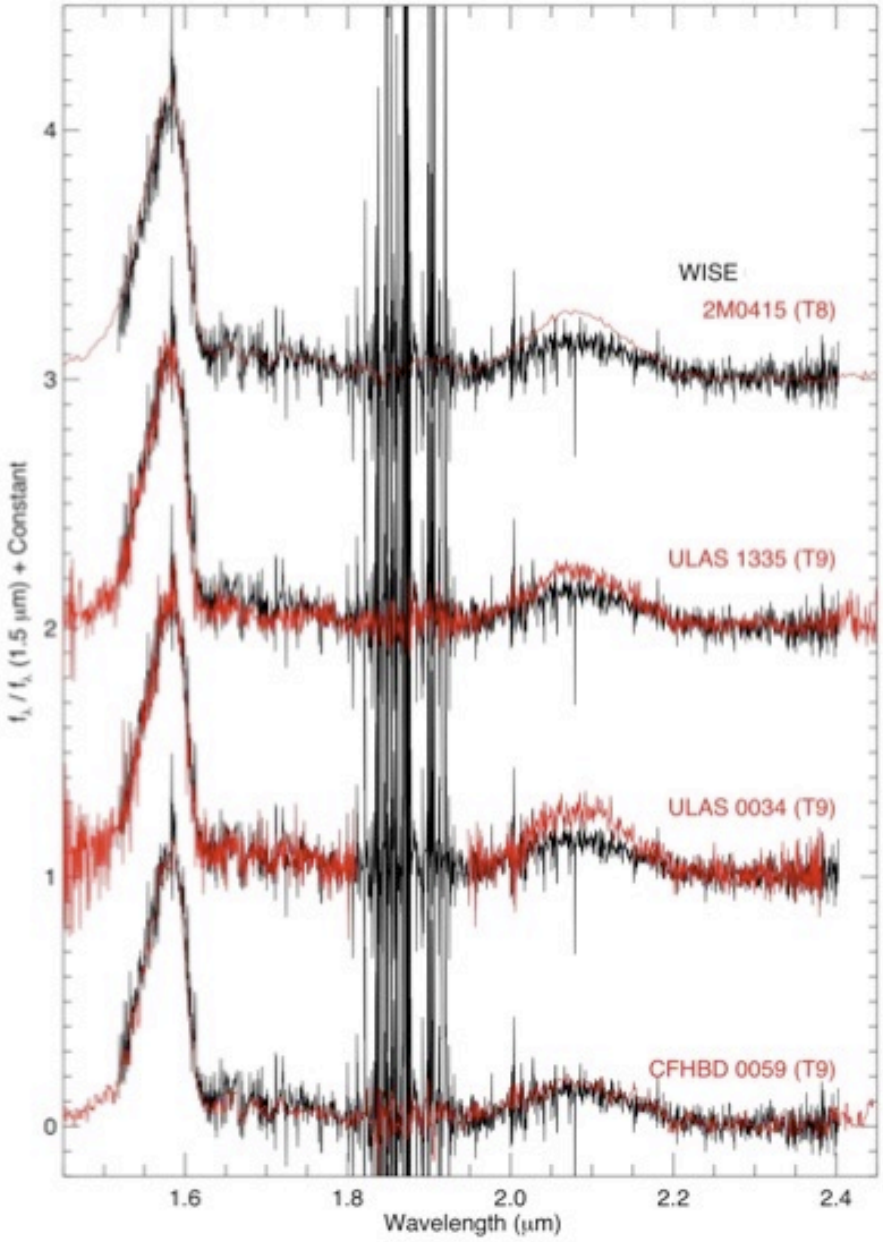
- Even redder in WISE

Multiband postage stamps

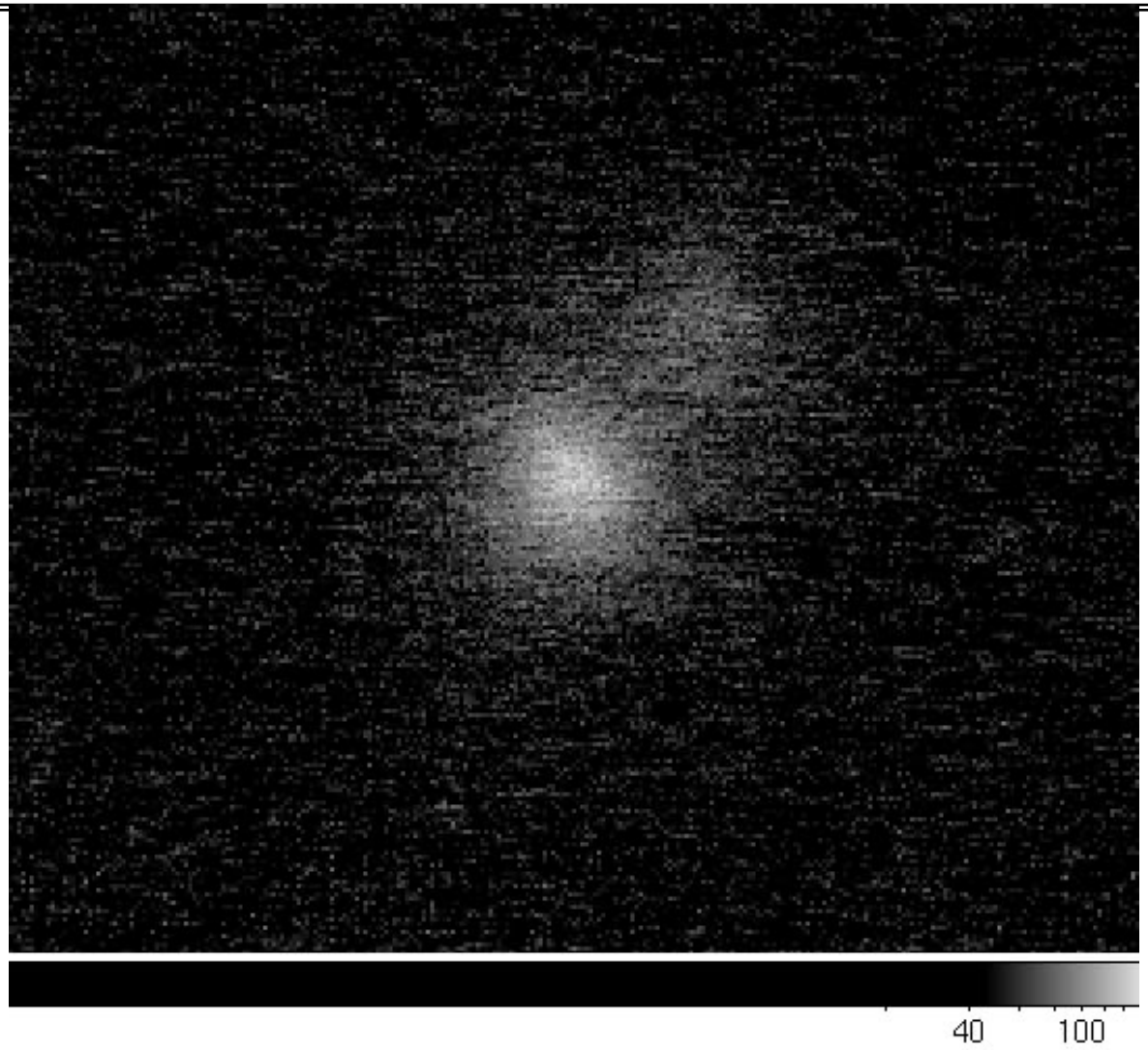


Spectral confirmation

- Spectrum from LUCIFER on LBT.
- Looks to be as late or later than any known T9.

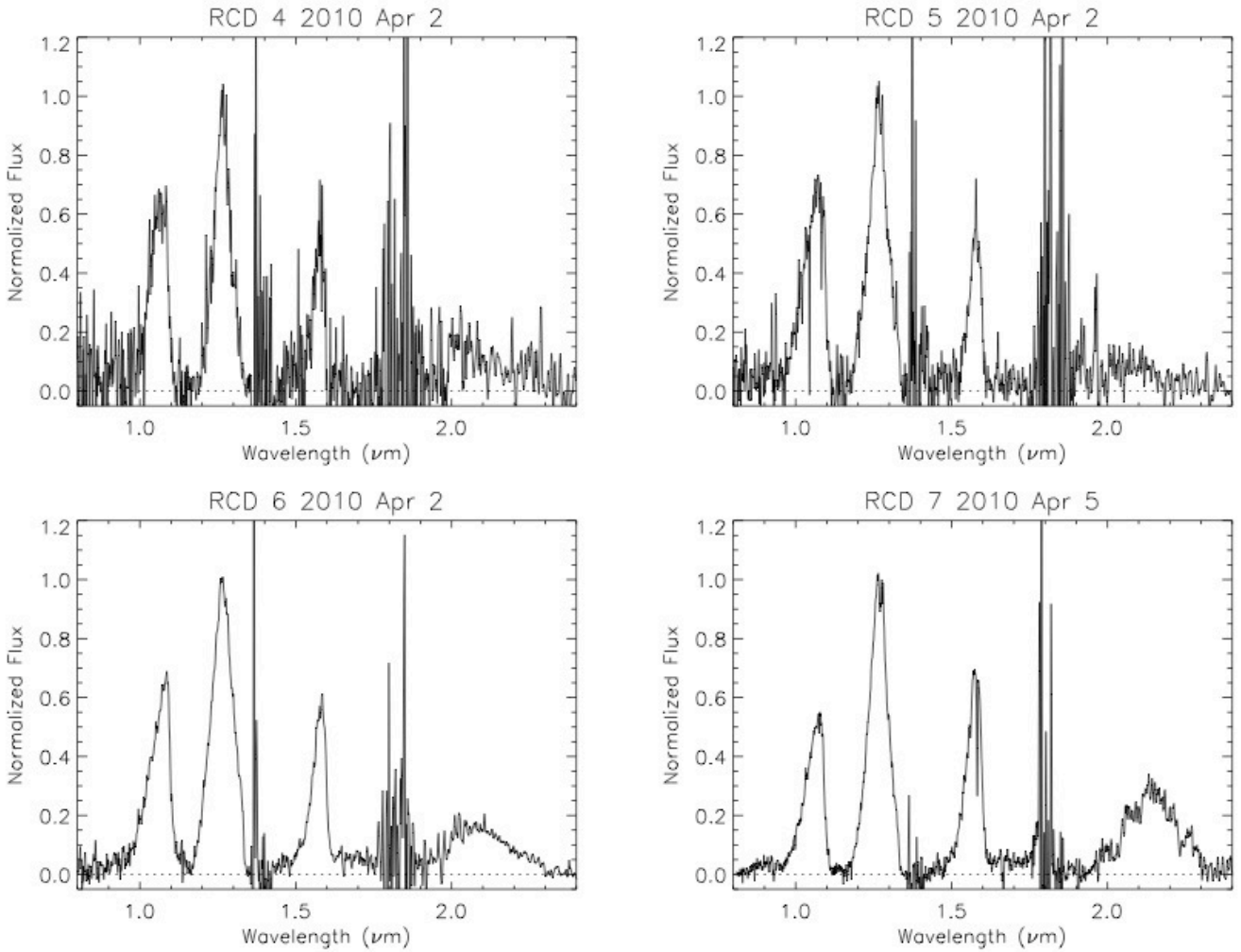


It's a binary!



- 0.5" separation – $\Delta m \approx 1$ mag

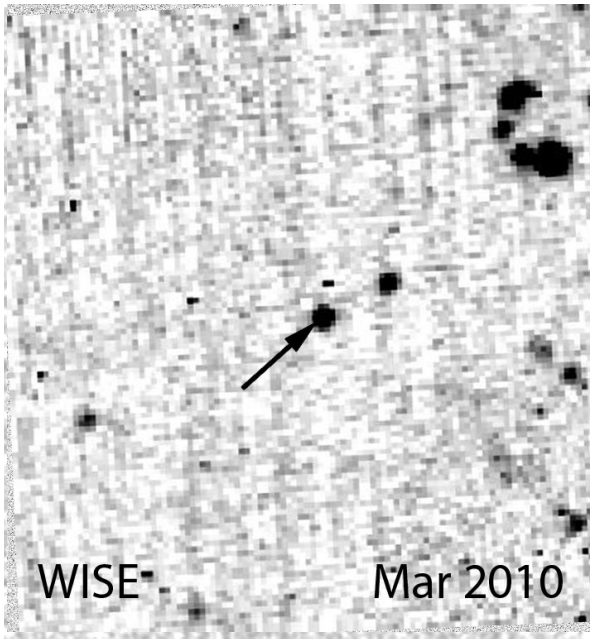
Late Flash – 4 more WISE late T BDs



- FIRE on Magellan thanks to Rob Simcoe

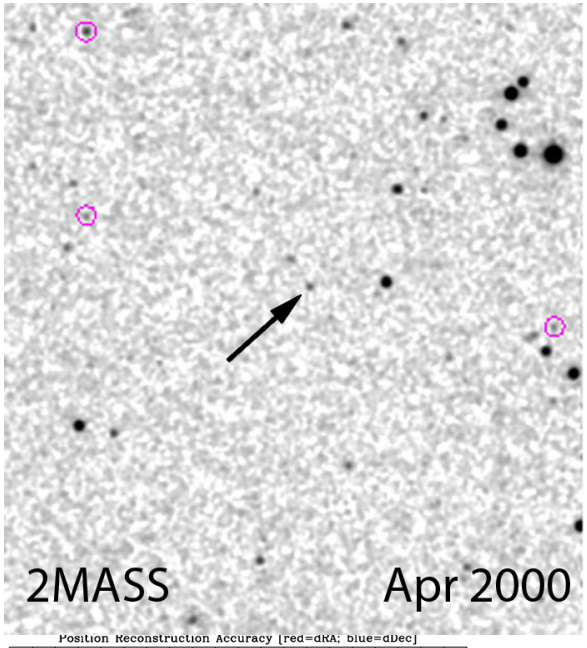
A Fast Mover

- WISE: W1-W2 = 2.92, W2=12.37

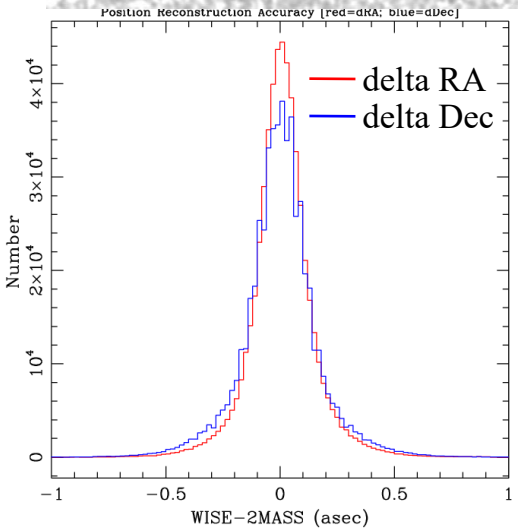


A Fast Mover

- WISE: W1-W2 = 2.92, W2=12.37
- 2MASS: J=16.45, J-H=0.09
- Proper Motion: 1.57 “/yr

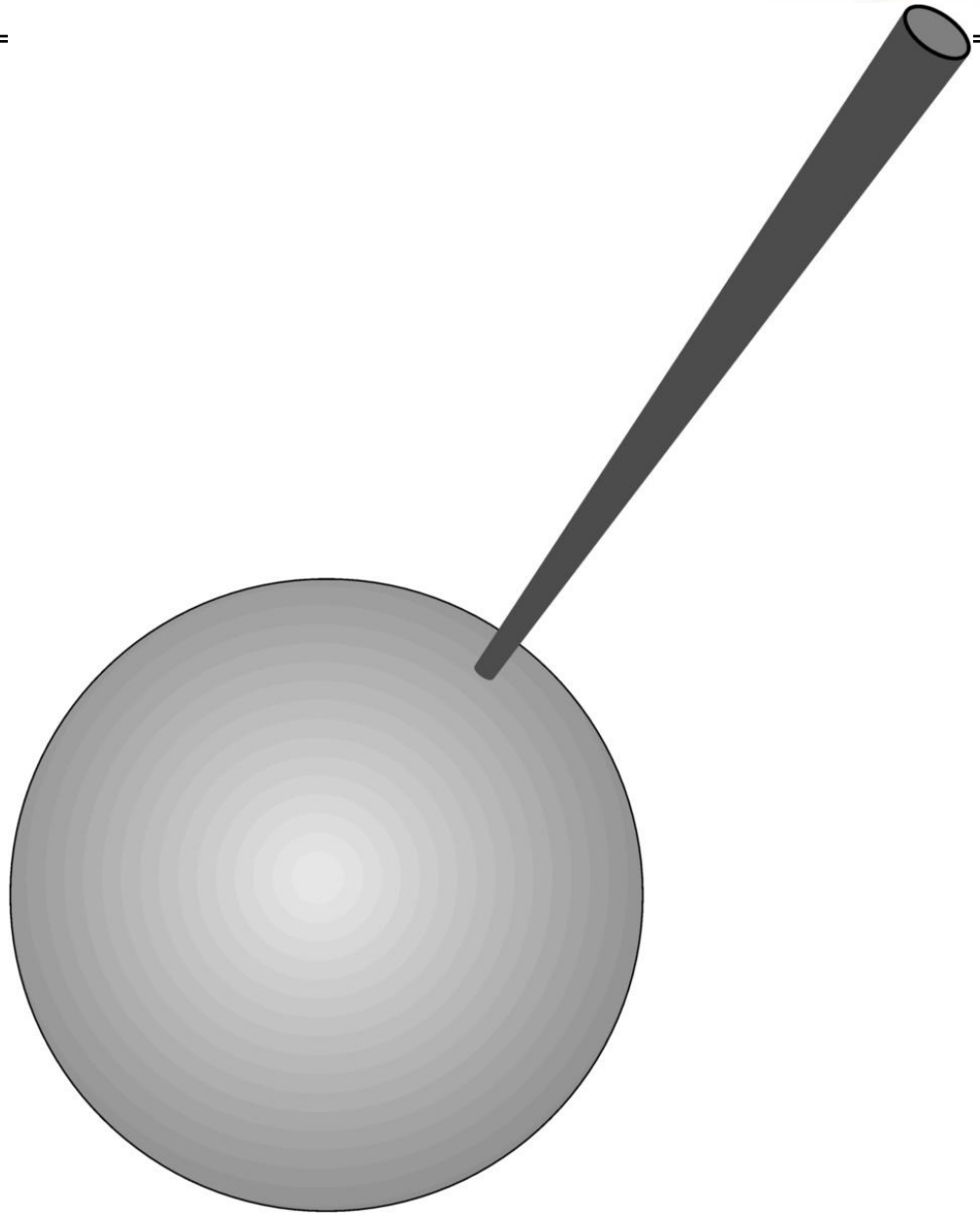


- Absolute WISE astrometric accuracy with respect to 2MASS is ~0.15” RMS on each axis.
- Relative astrometric accuracy between two WISE “epochs” will be up to 2x better because 2MASS astrometric error is not present.

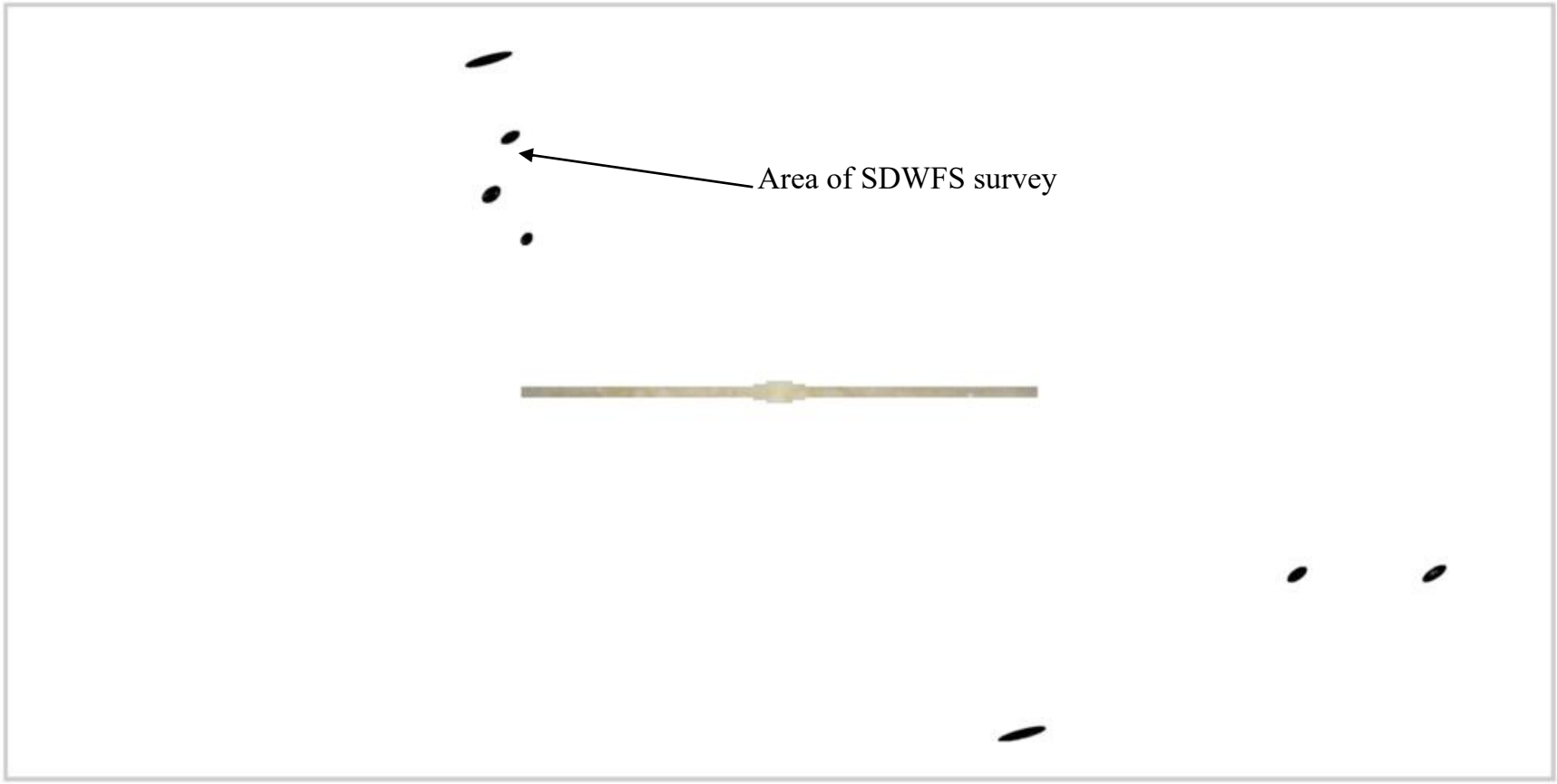


WISE has 73x the Volume

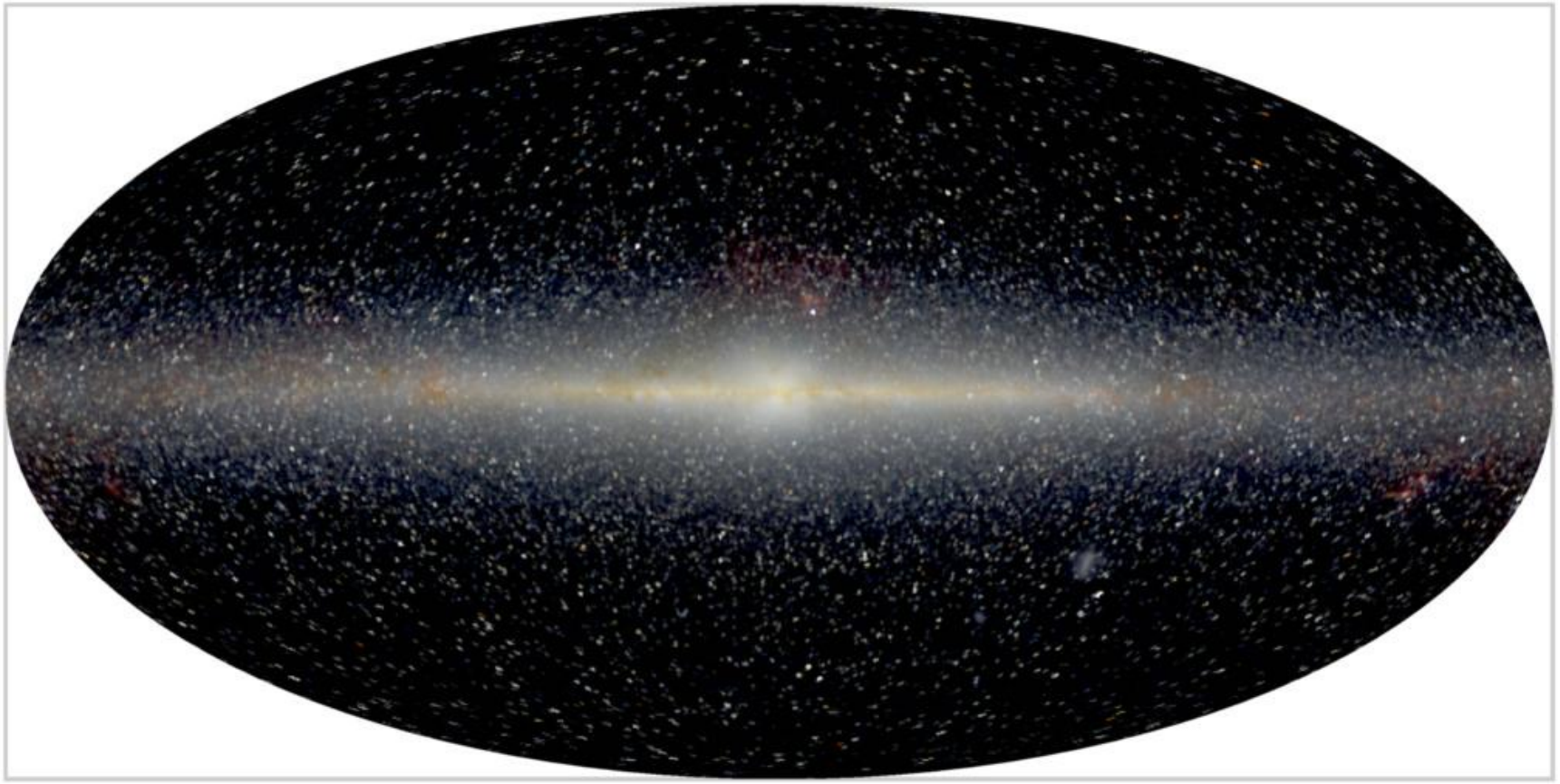
- WISE covers 4000x more solid angle than SDWFS.
- SDWFS goes to 3.8x greater distance.
- SDWFS found about 8 late T's and 1 Y? BD
- WISE should find 660 or so late T's and Y's.



Spitzer Sky Coverage



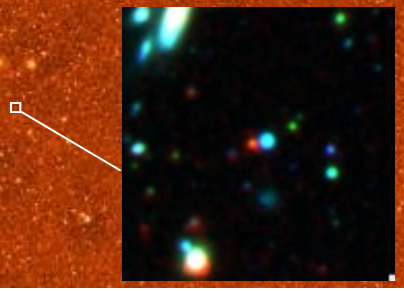
WISE Sky Coverage

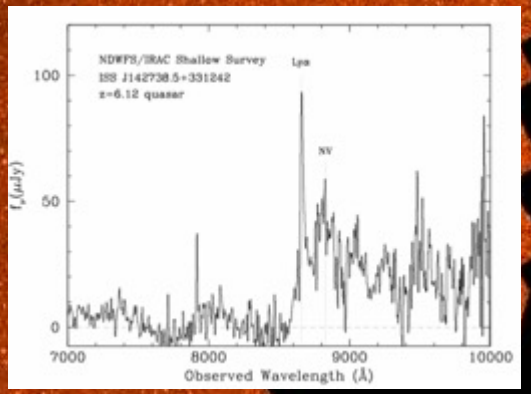


The all-sky WISE survey will cover 40-70x more volume than SDWFS, finding many hundreds of cool brown dwarfs, including perhaps the nearest planetary system to the Sun.

One of 10 Known Quasars with Redshift > 6

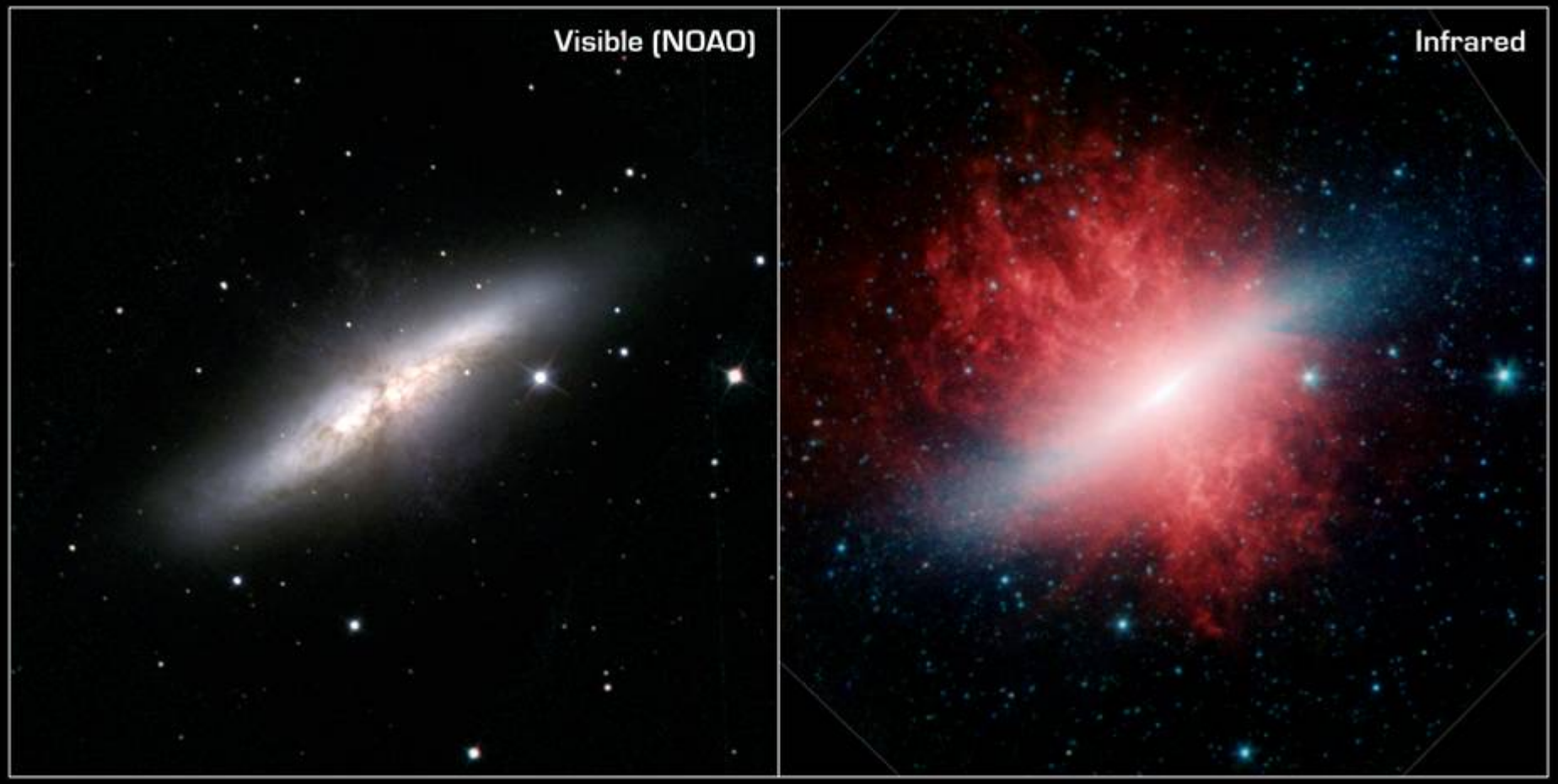
- More luminous quasars tend to have higher IR:X-ray ratios, and thus an IR survey like WISE can find a large number of quasars, especially at higher redshifts.
- WISE at 22 μm will see 350,000 quasars with median redshift 1.2 based on Hopkins, Richards & Hernquist (2006) luminosity function model. This model predicts 14 quasars with z > 6 and 1 with z > 7 for WISE.
- WISE will see more quasars in its more sensitive shorter bands.



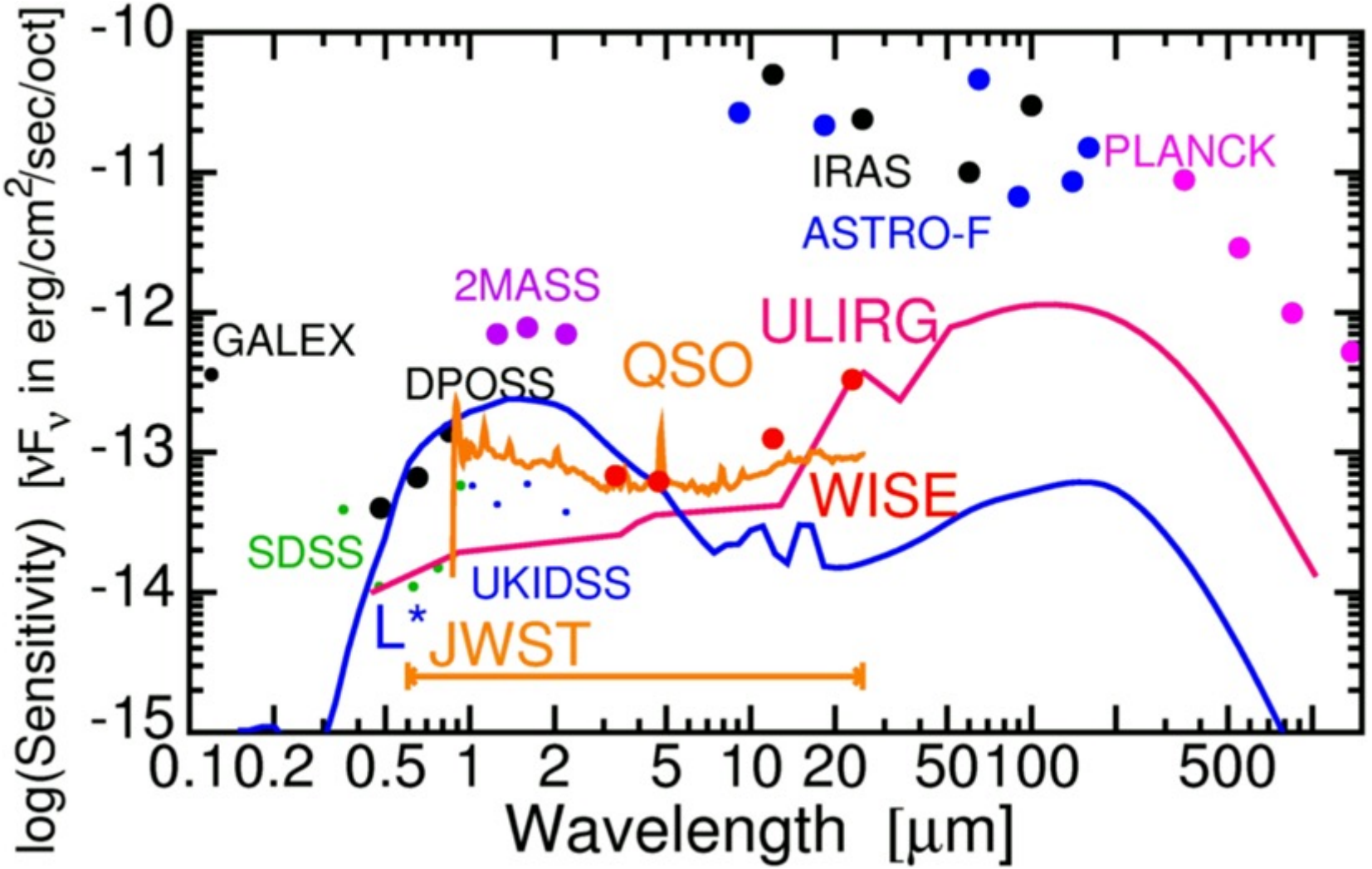


z = 6.1 Quasar
Stern et al 2007 ApJ, 663, 677

- Most star formation today occurs in starburst galaxies like M82, which generates about 10 solar masses of new stars each year.
- Starbursts heat dust which glows in the infrared, seen by Spitzer and WISE.

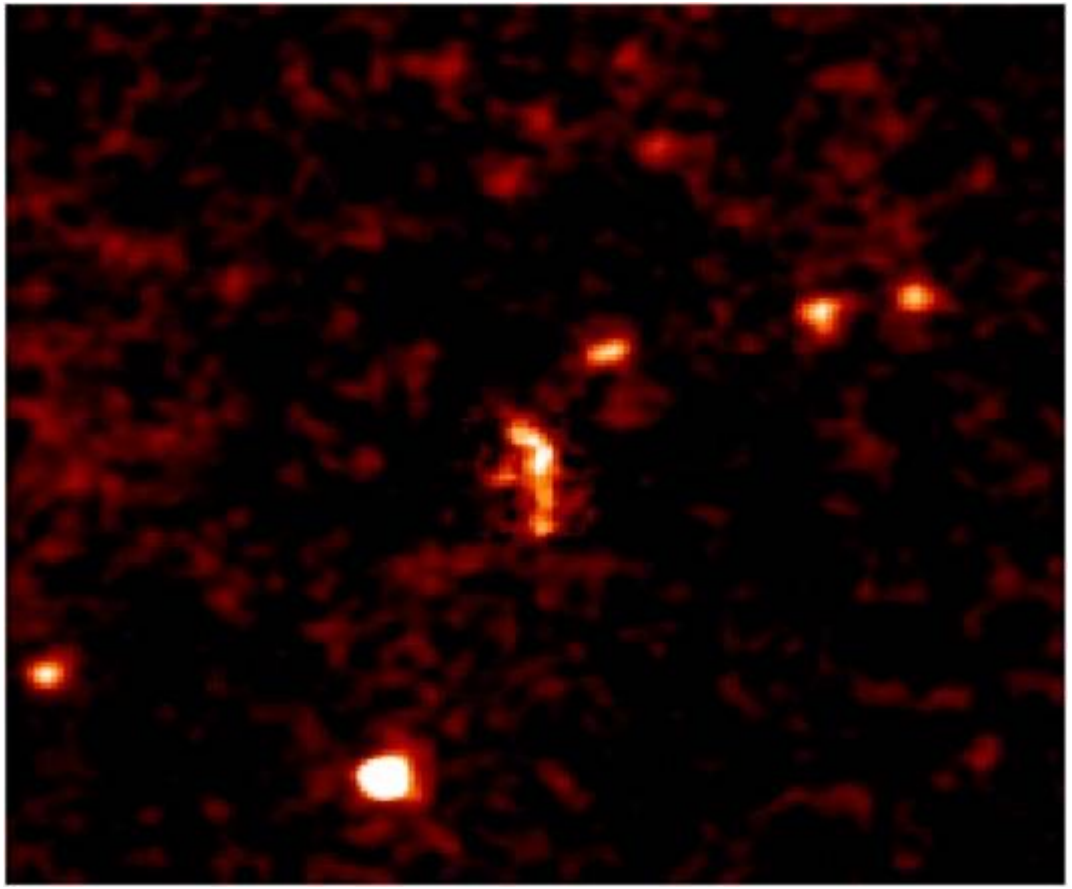


The far-off Universe



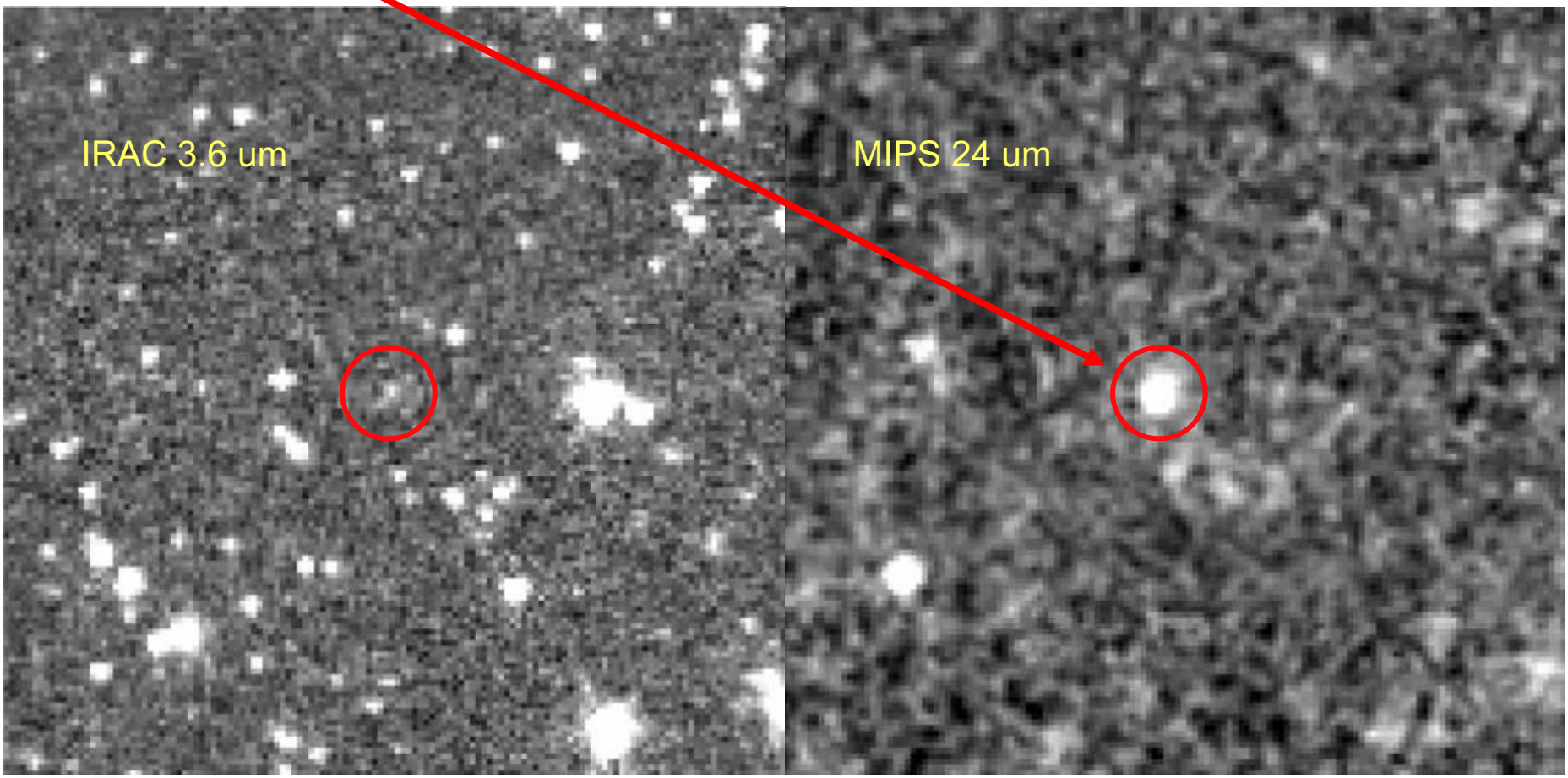
Faint Foreground at 12 & 23 μm

- ISO image of Abell 370 at 15 μm
- 2nd from right at 2 o'clock is a z=2.8 ULIRG
- WISE will cover 10^7 times more sky to this level.



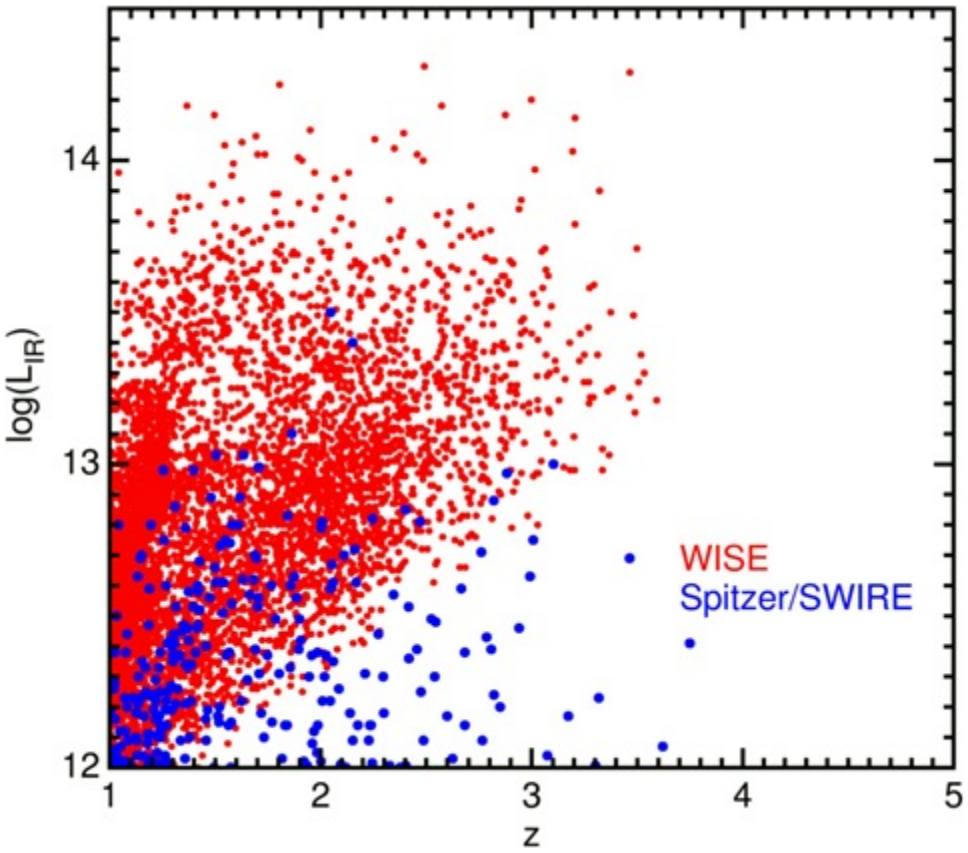
WISE Will Find the Most Luminous Galaxies

- Spitzer first look survey images at 3.6 and 24 um
- ULIRG at z=2.5 (Yan et al 2005)

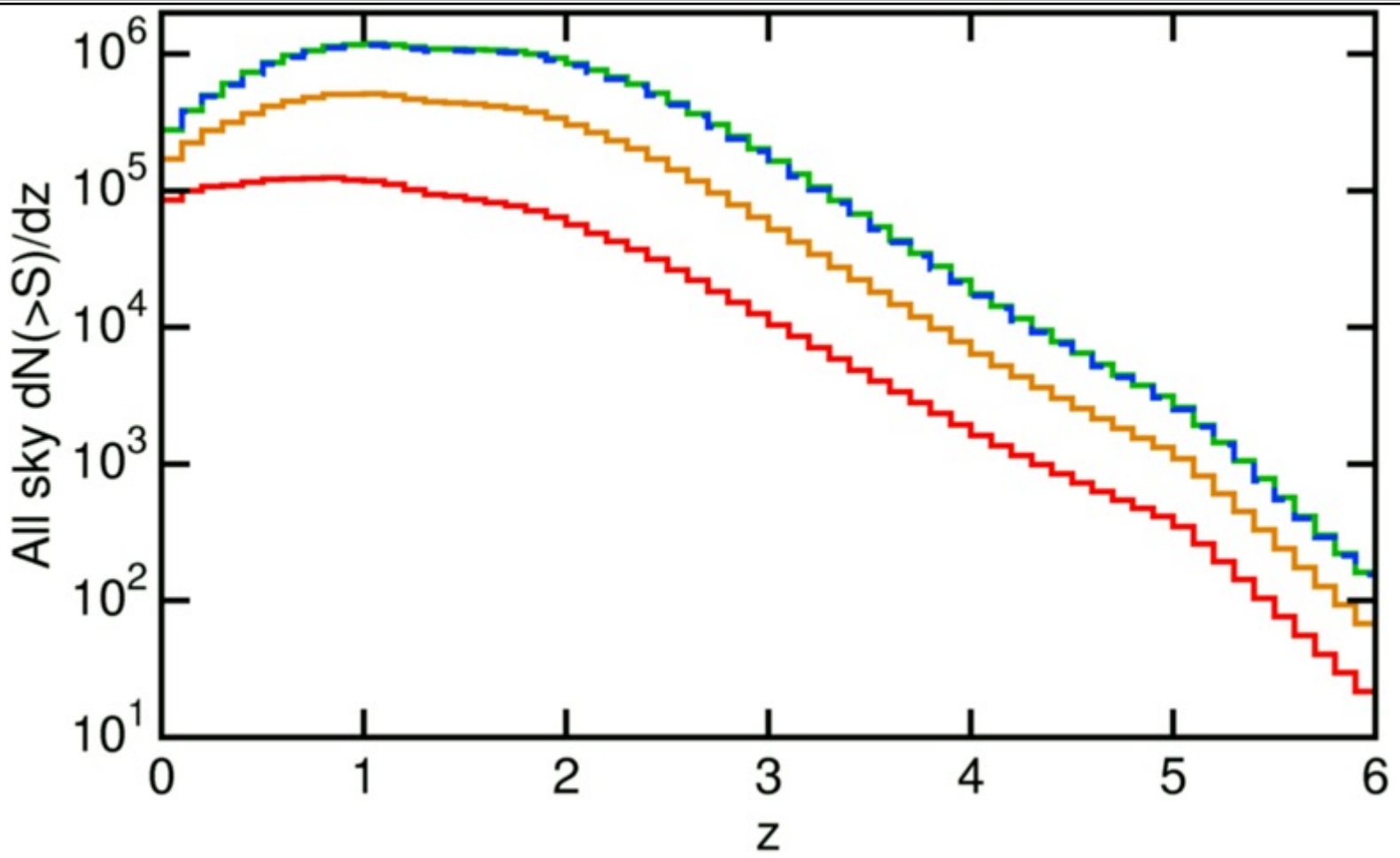


Scientific Context for ULIRGs

- Bottom up structure formation has a hard time producing high z and high L objects, but these ULIRGs are seen.
- JWST will want to observe high L objects at z=15, so an understanding of the high L end of the luminosity function will be important.
- WISE will give nearly a 1000 times more sky coverage than Spitzer.
- For a steep high-end power law luminosity function WISE will find objects 16 times more luminous and with 16 times higher fluxes than the top end of the largest Spitzer legacy survey, allowing for detailed study by JWST



How Many QSOs?

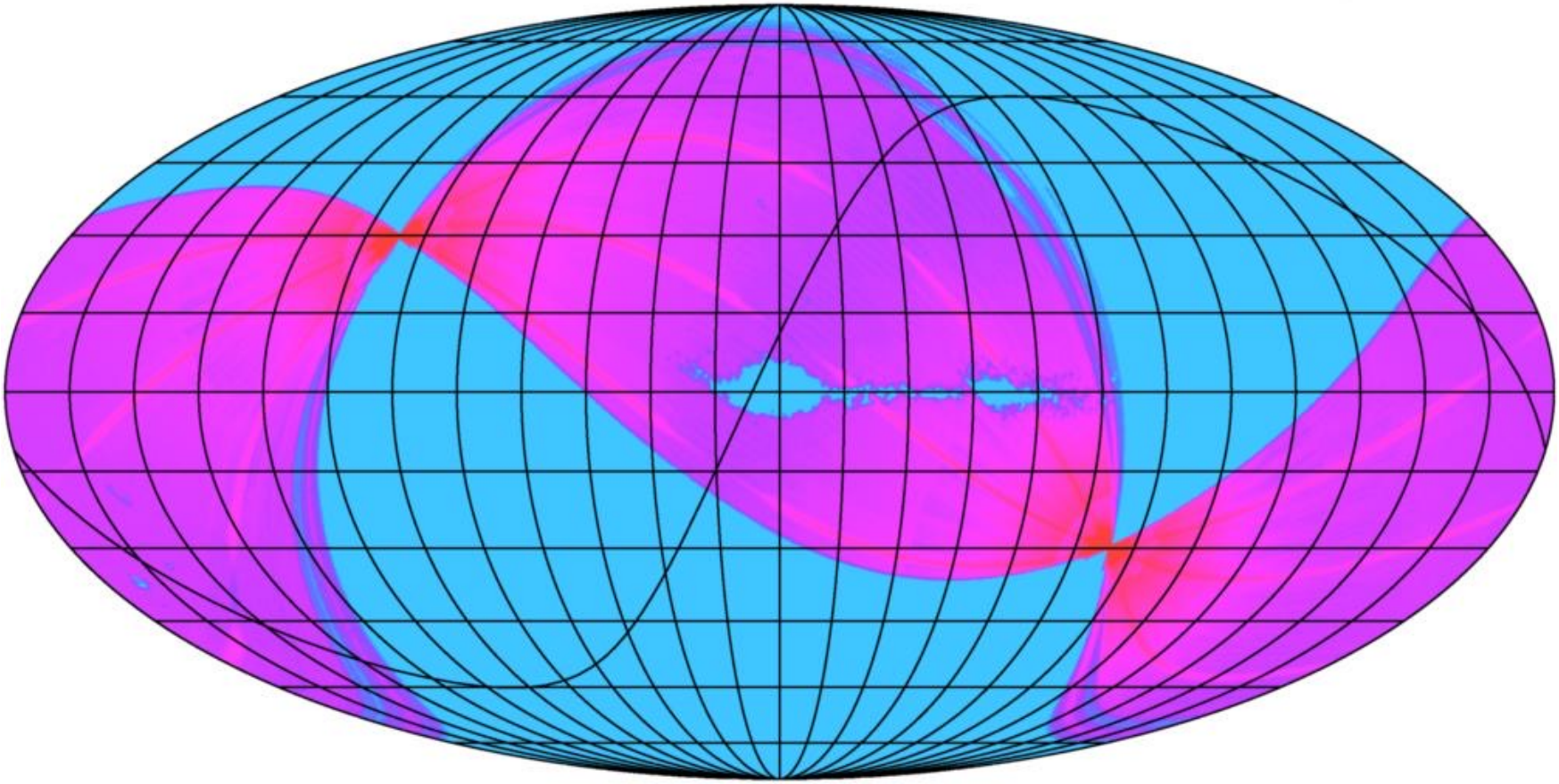


Hopkins etal, astro-ph/0605678

WISE will see 350,000 QSOs at 22 μm, its least sensitive band.

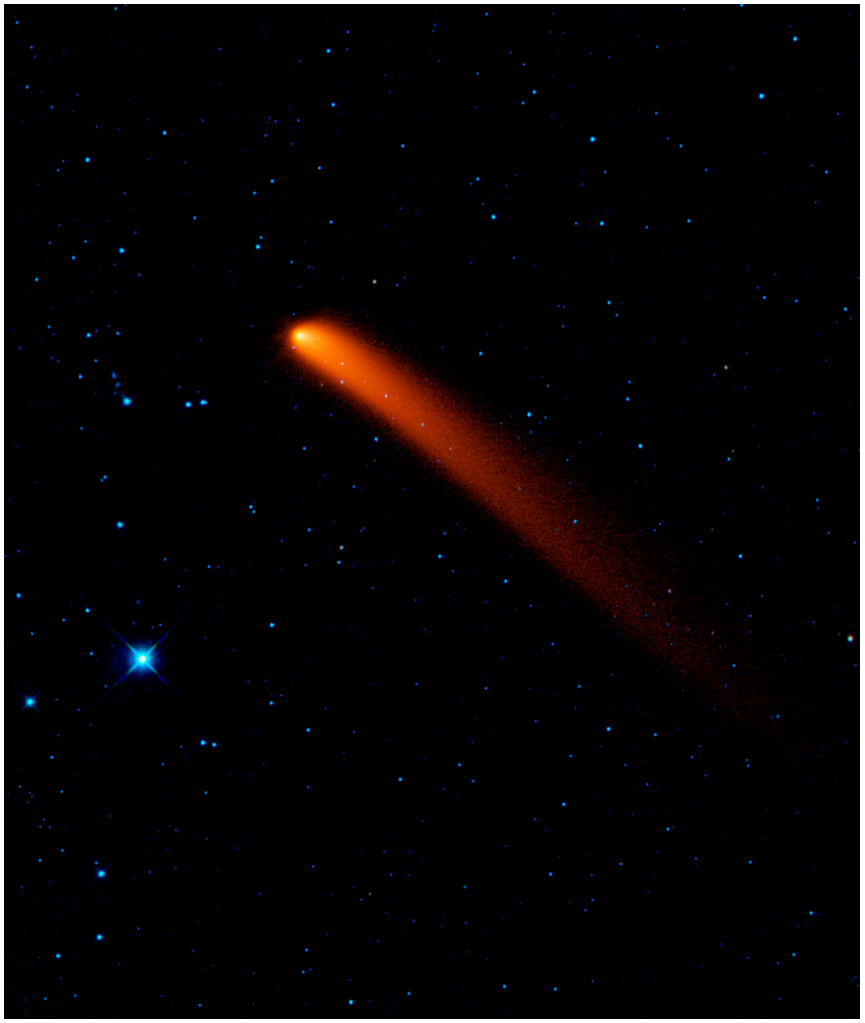
Coverage up to 12 Apr 2010

662757 frames thru 10-102.5; 51.3% to depth > 7



- More than two trillion pixels

Early Release Observations

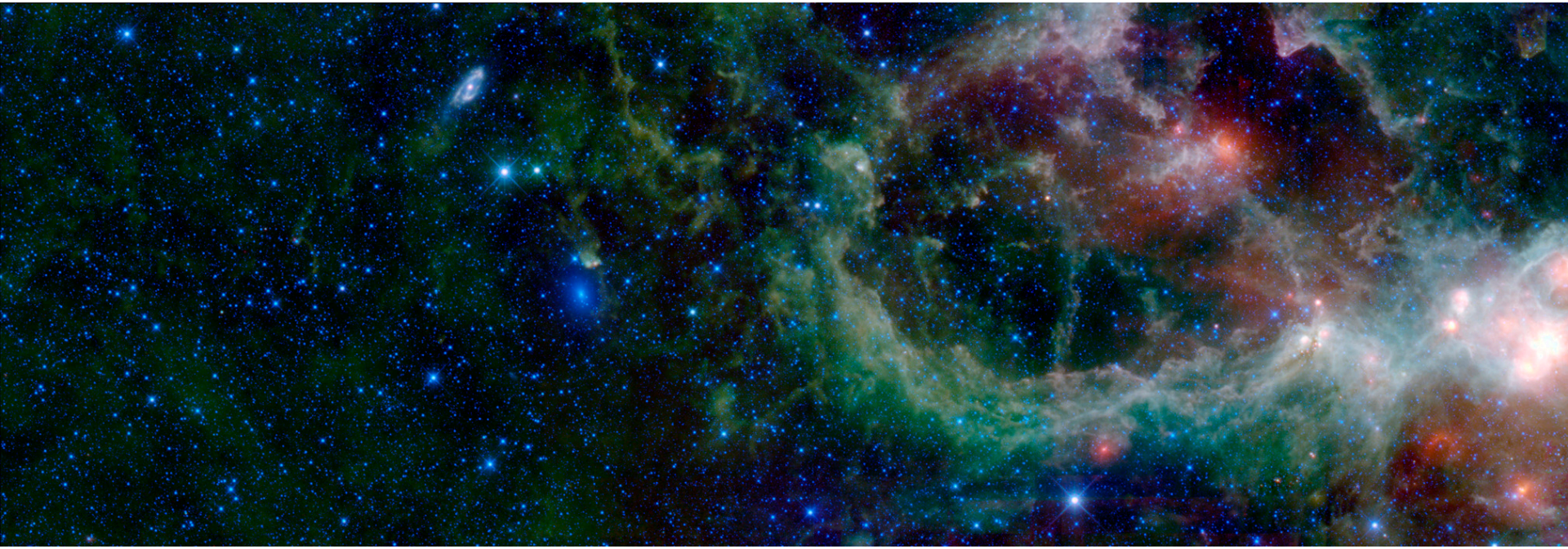


- Released Wednesday 16 Feb 2010

Early Release Observations

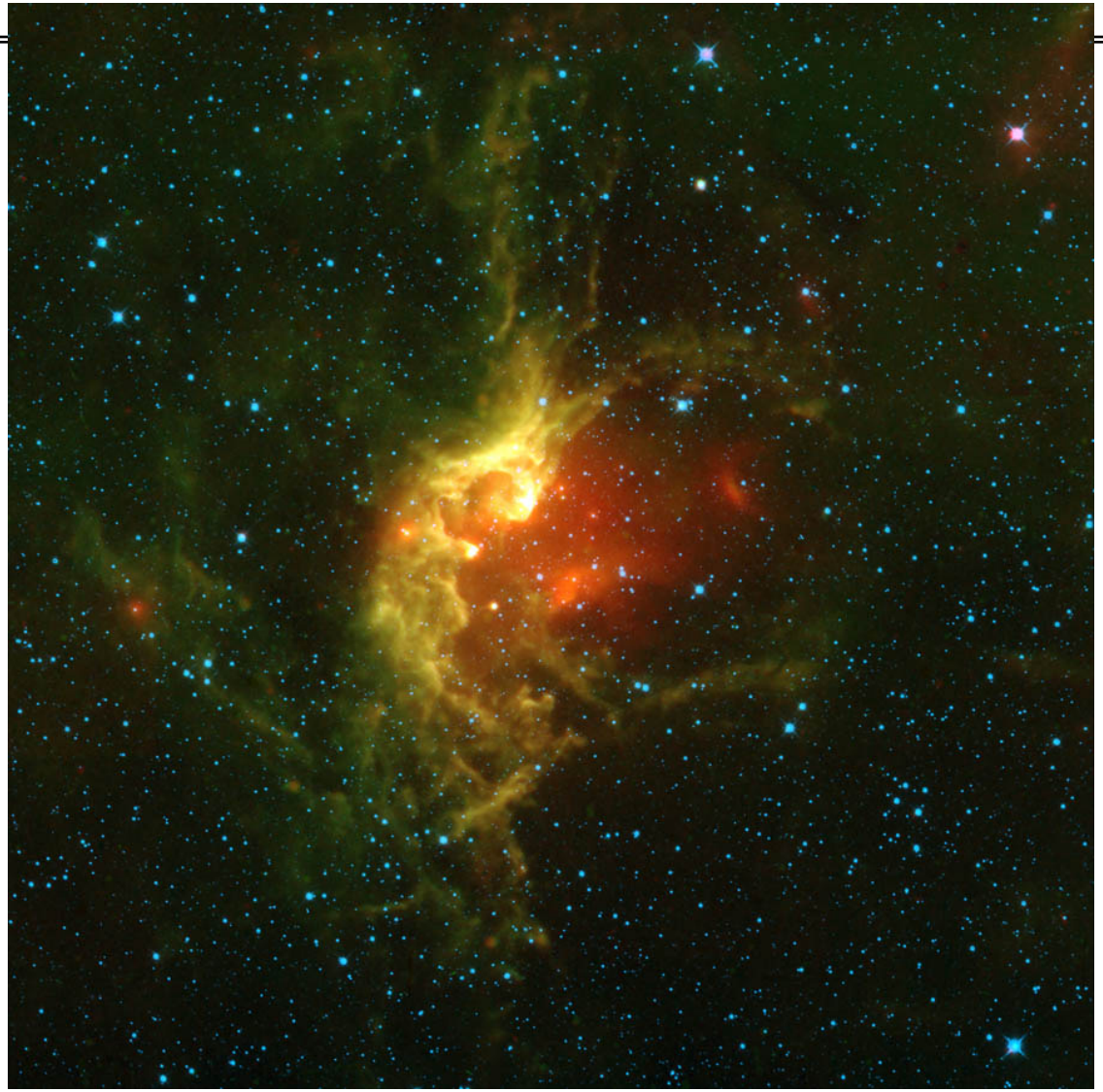
- Released Wednesday 16 Feb 2010

Images of the Week



- Maffei 1 and Maffei 2, and part of IC 1805 (the Heart Nebula)

Images of the Week



- NGC 7380

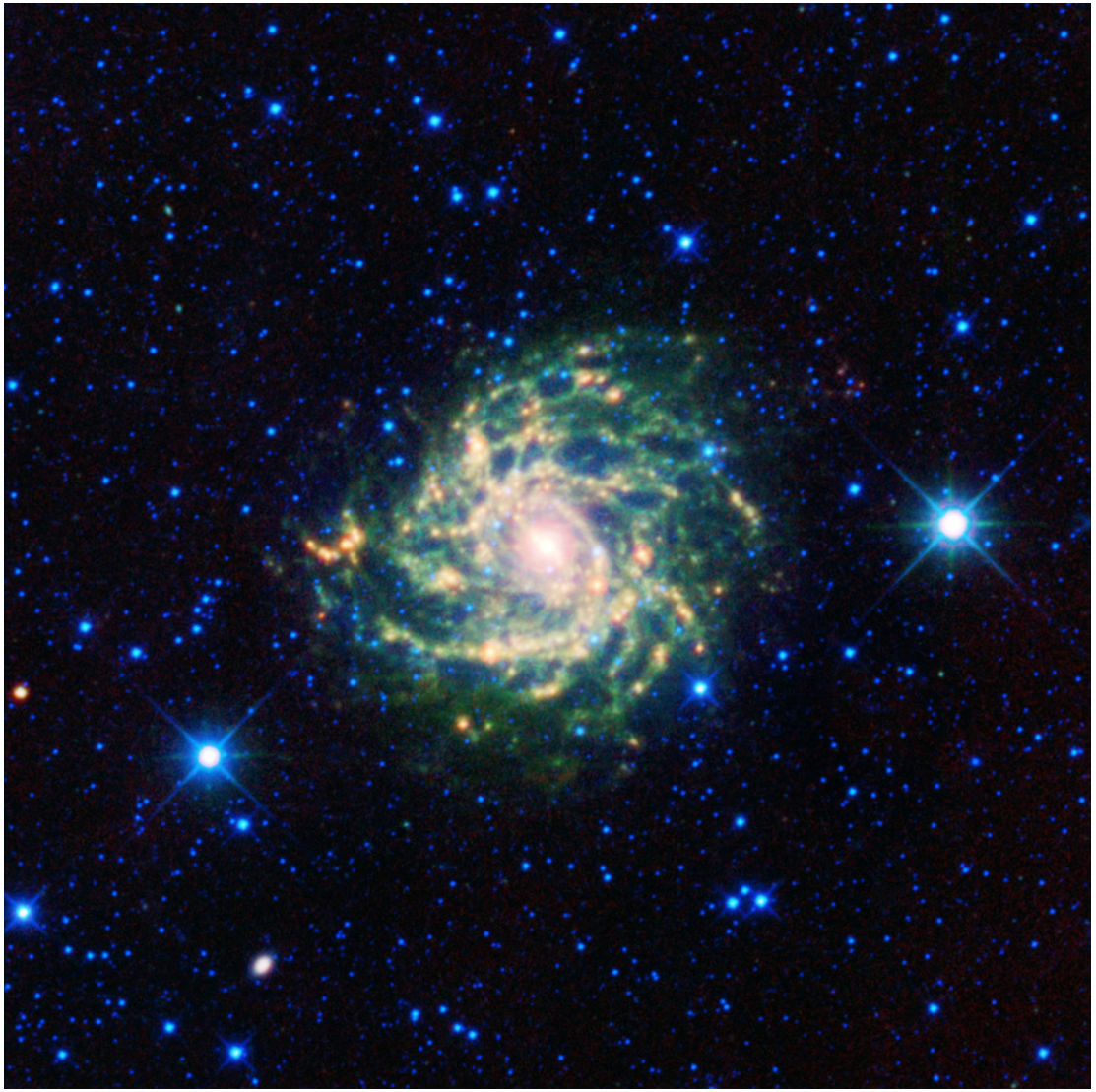
Images of the Week

- Our old friend - AFGL 3193

Images of the Week

- The Soul Nebula – IC 1848

Images of the Week



- IC 342 – about 8 million light years away

Thus WISE will...

- Discover many new Aten class potentially hazardous asteroids and give radiometric diameters for 100,000 or more objects.
- Find the ½ to ⅔ of the stars in the solar neighborhood that have not yet been seen, including the closest stars to the Sun.
- Survey star formation in the Milky Way and in massive Ultra-Luminous Infrared Galaxies.
- Provide a large scale structure map to $z \approx 1$.

WISE Science Team

PI: Edward L. Wright - UCLA

- Dominic Benford - GSFC
- Andrew Blain - Caltech
- Martin Cohen - MIRA
- Roc Cutri - IPAC
- Peter Eisenhardt -JPL
- Nick Gautier - JPL
- Tom Jarrett - IPAC
- Davy Kirkpatrick - IPAC
- David Leisawitz - GSFC
- Carol Lonsdale - NRAO
- Amy Mainzer - JPL
- John Mather - GSFC
- Ian McLean - UCLA
- Robert McMillan - UA
- Bryan Mendez - UCB
- Deborah Padgett - IPAC
- Michael Ressler - JPL
- Michael Skrutskie - UVa
- Adam Stanford - LLNL
- Russell Walker - MIRA

WISE Summary

- Ready to launch early Nov 2009, but ULA & VAFB delayed launch until 14 Dec 2009, 14:09:33 UT
- Band centers 3.4, 4.6, 12 & 22 microns
- Sensitivity should be better than 78, 108, 850 & 5200 microJy
- Saturation at 0.3, 0.5, 0.7 & 10 Jy point sources
- Angular Resolution 6, 6, 6 & 12 arc-seconds
- Position accuracy better than 0.5 arc-seconds with respect to 2MASS reference frame
- Data release plans:
  - Preliminary release of first 50% of the data 6 months after last data taken
  - Final release 11 months later
- Data products include image atlas and point source catalog