WISE - the Wide-field Infrared Survey Explorer

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UCLA

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

Wide-field Infrared Survey Explorer (WISE)

Project Overview

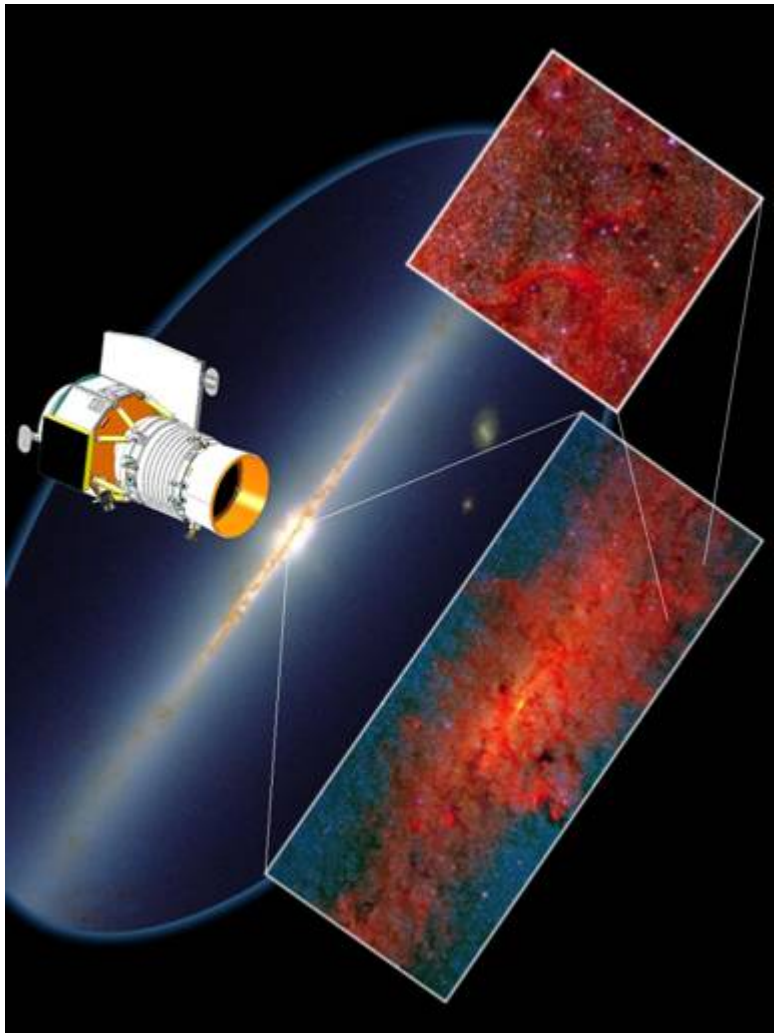
Science

- *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



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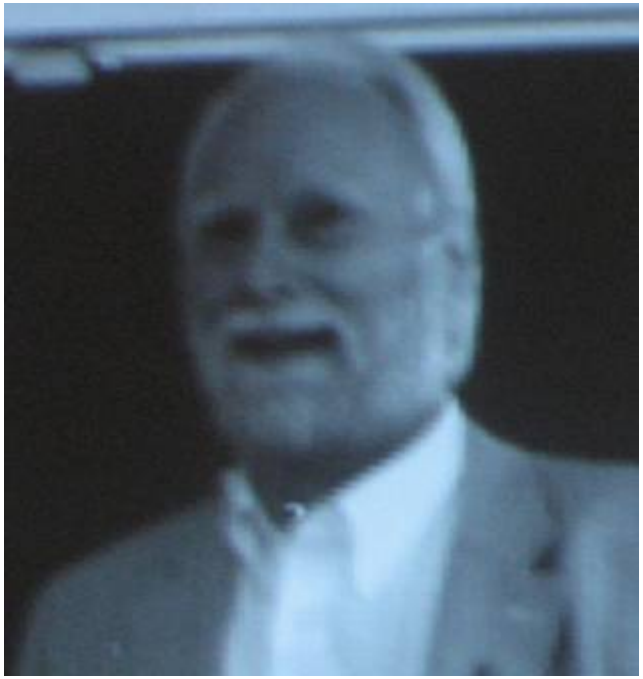
Infrared



- Optical
- Reflected light

Near-IR
different colors

Thermal-IR
emitted radiation

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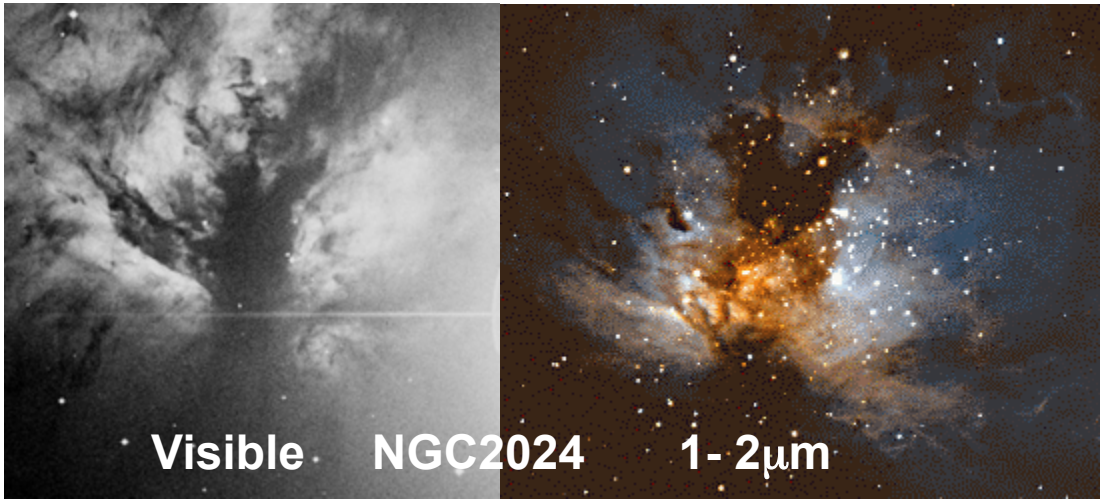
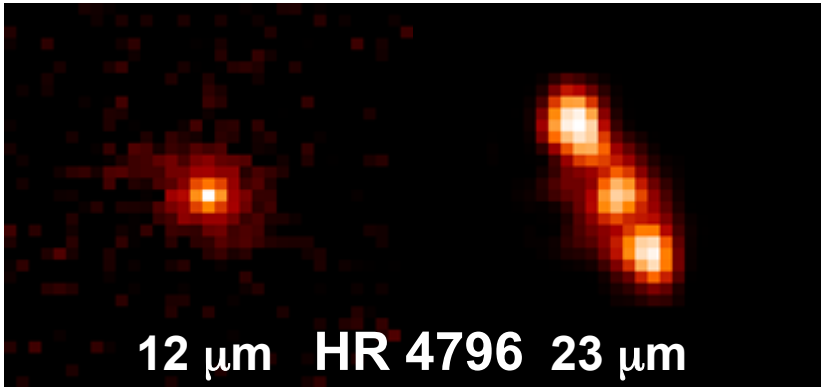
Wide-field Infrared Survey Explorer (WISE)

Infrared Observations Probe:

The Distant Universe



The Dusty Universe



The Cold Universe

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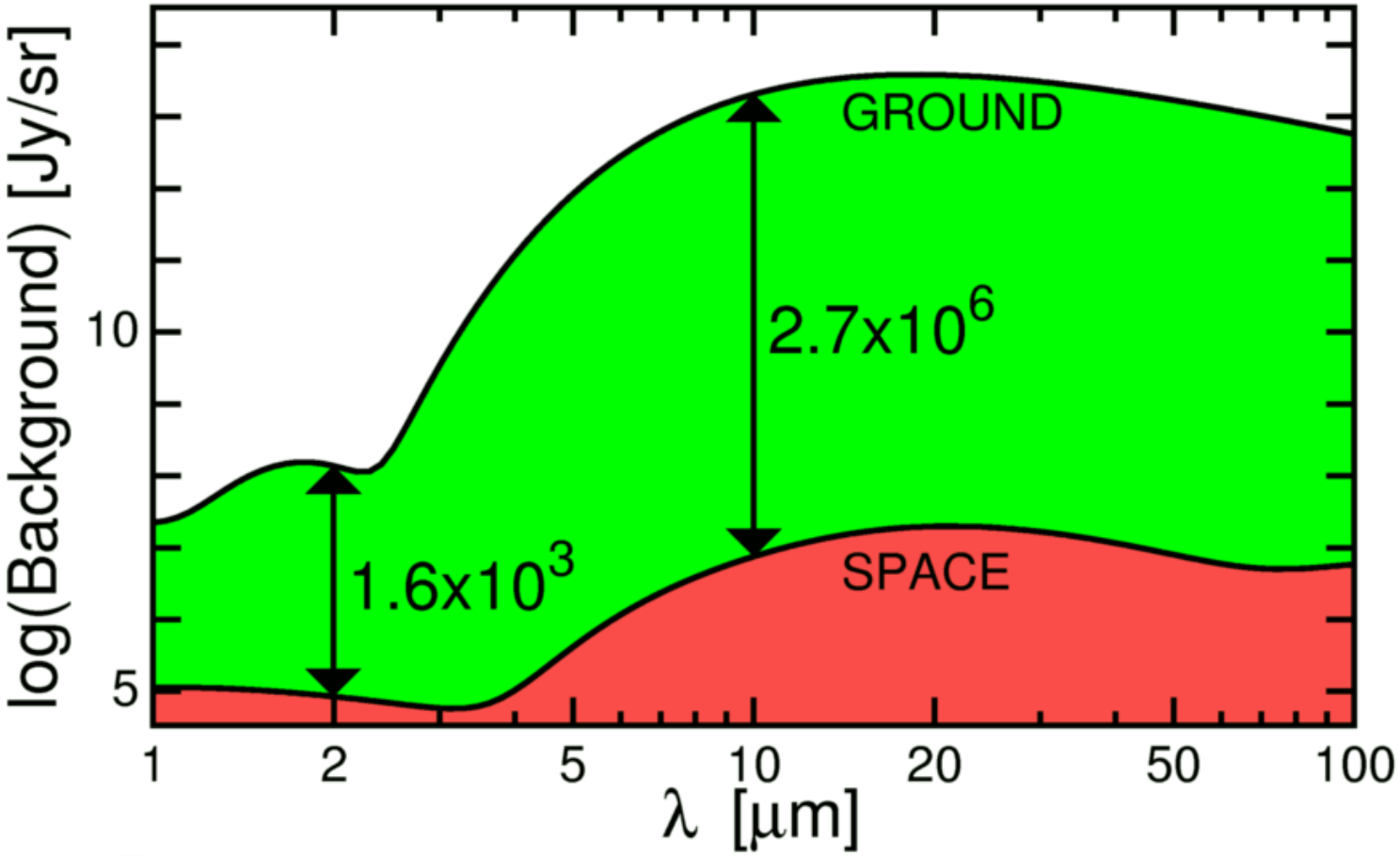
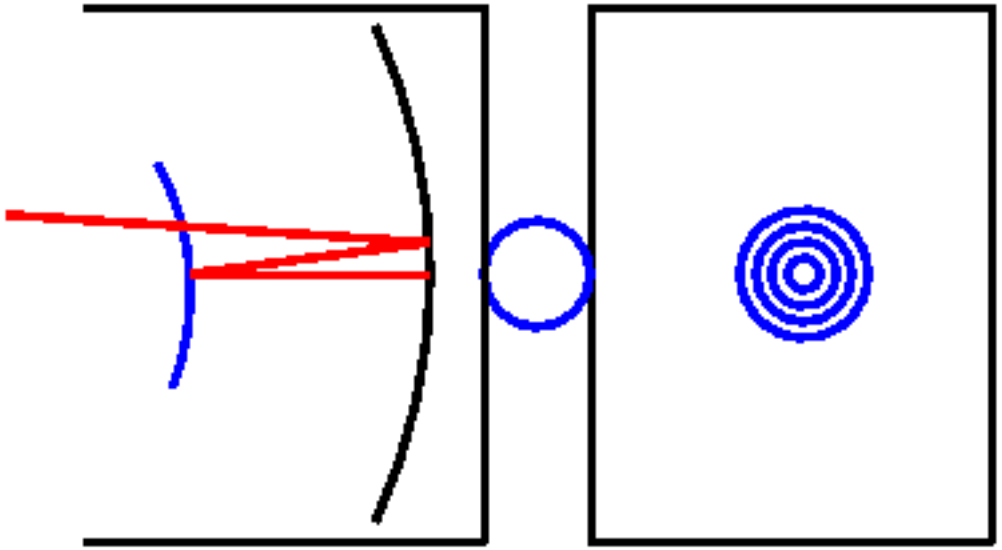
Why Space?

"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!

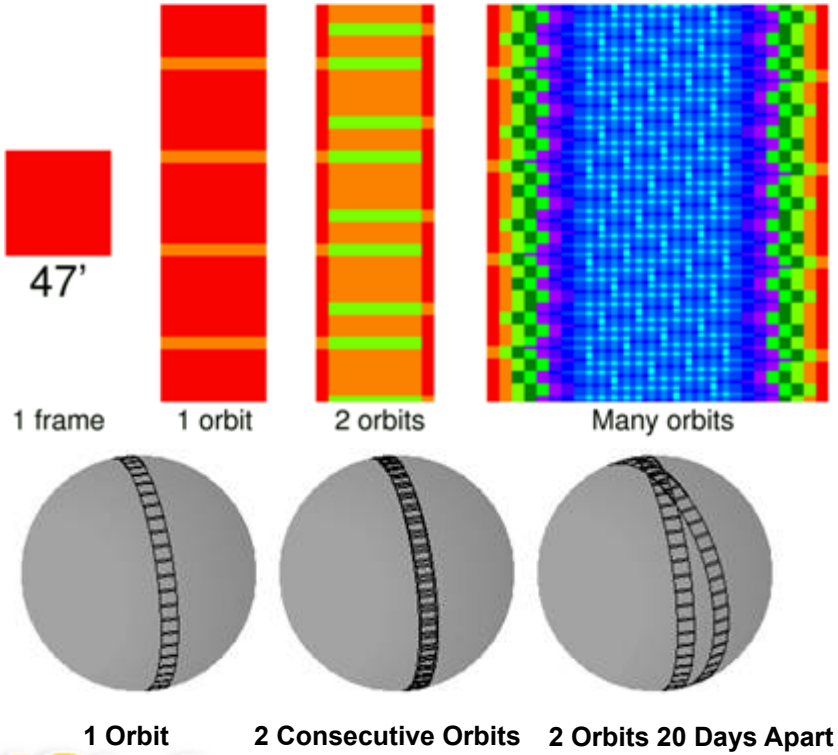
Animated Scan Mirror Icon



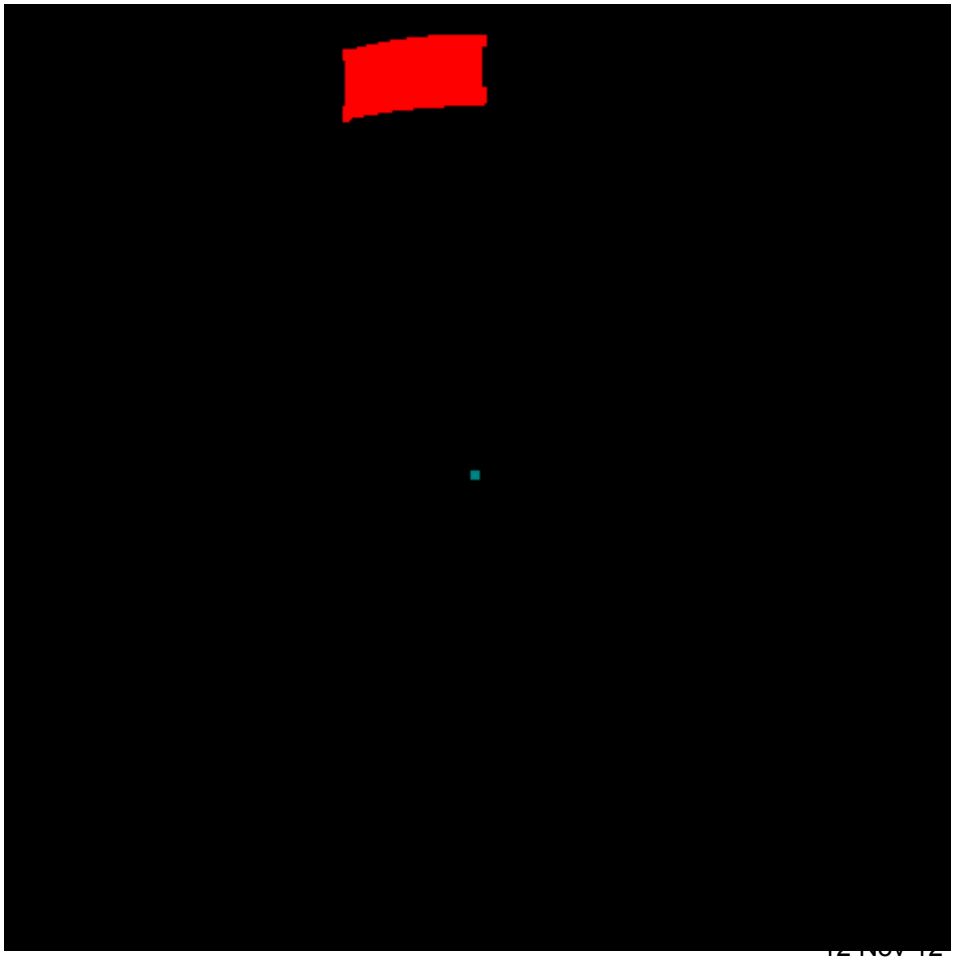
Wide-field **I**nfrared **S**urvey **E**xplorer (WISE)

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



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WISE Science Heritage

- NIRAS SMEX proposal in 1988. CJL & ELW as co-I's.
- Review panel suggested ground-based survey which became 2MASS.
- NIRST mission concept study in 1994. PRME & ELW as co-PI's.
- NGSS proposal in 1998.
- NGSS Phase A study in 1999.
- NGSS proposal in 2001.
- NGSS Phase A study in 2002.
- Renamed WISE in 2003

PROPOSAL TO
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FOR A
NEAR-INFRARED ASTRONOMY SATELLITE

P1976-9-88

For the period 1 July 1989 through 30 September 1993

Total Estimated Cost: $15,457,092
(not including costs from NASA Centers)

Volume I - Investigation and Technical Plan

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

NIRAS 1988

- All sky survey.
- Big arrays (58x62).
- Continuous slew.
- Scan mirror to freeze image on array.
- Exposures every 4.5 seconds.

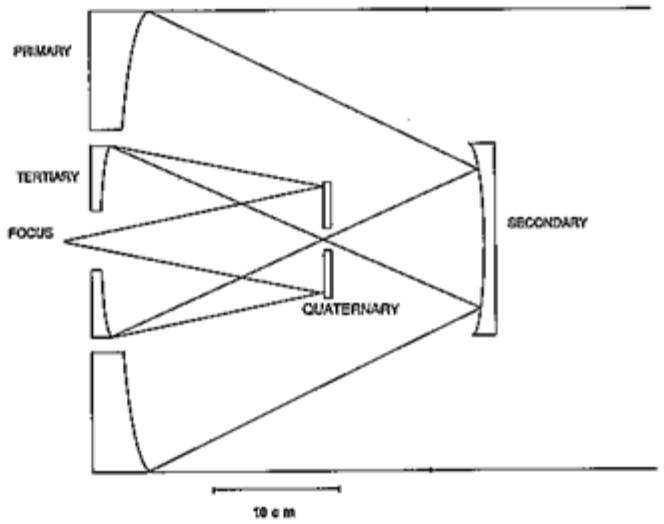


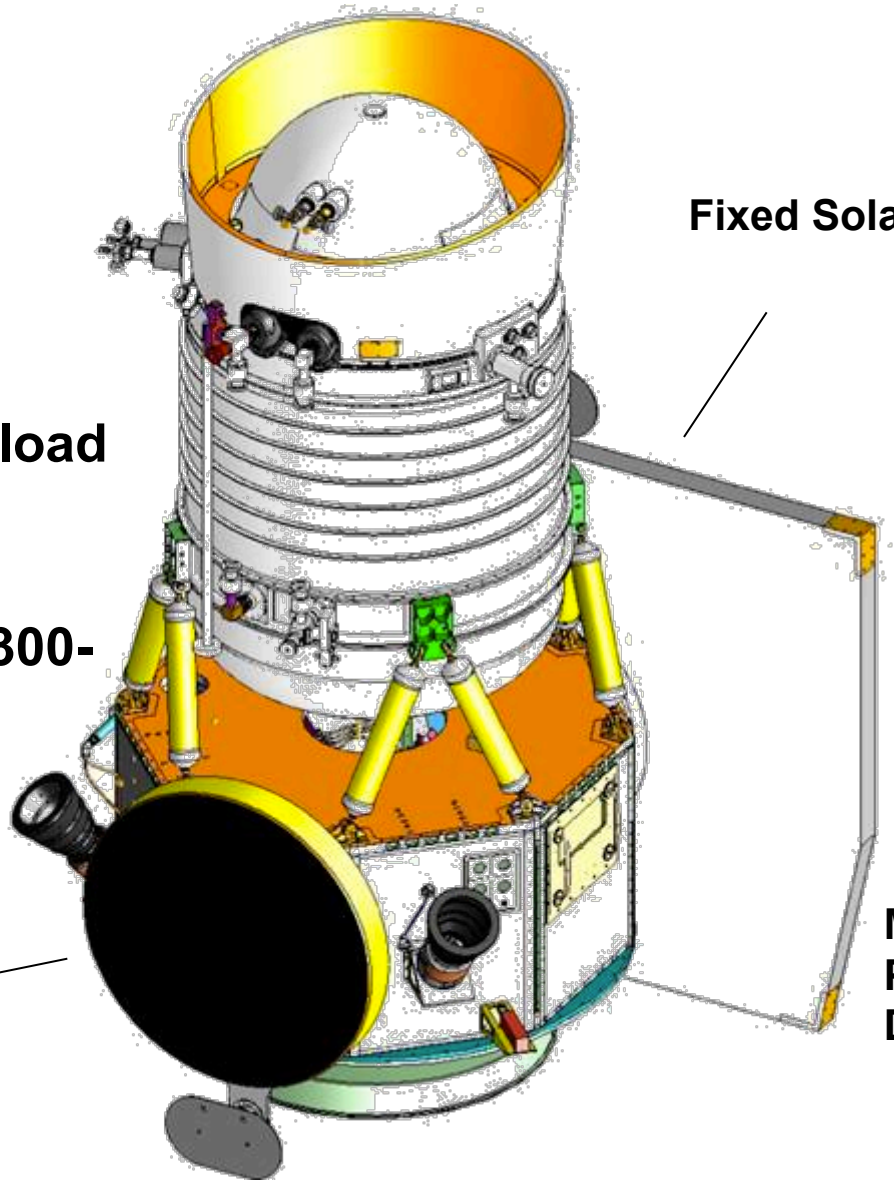
Figure 3-3. Optical Diagram of the Telescope

A scan mirror is used to freeze the sky field-of-view on the detectors for a period of 4.3 seconds as the spacecraft rotates at the orbital rate. The field-of-view is then advanced within 0.2 seconds.

Table 3-1. NIRAS Sensitivity

WAVELENGTH (microns)	BANDWIDTH (microns)	S/N	NUMBER OF PASSES	FLUX DENSITY POINT SOURCE (mag)	POINT SOURCE (mJy)	DIFFUSE (μJy/arcsec²)
1.87	1.14	1	1	14.6	1.2	1.8
		5	1	12.8	6.0	
		1	4	15.3	0.5	0.9
		5	4	13.6	3.0	
3.52	2.16	1	1	13.4	1.2	1.7
		5	1	11.7	6.0	
		1	4	14.2	0.5	0.9
		5	4	12.4	3.0	

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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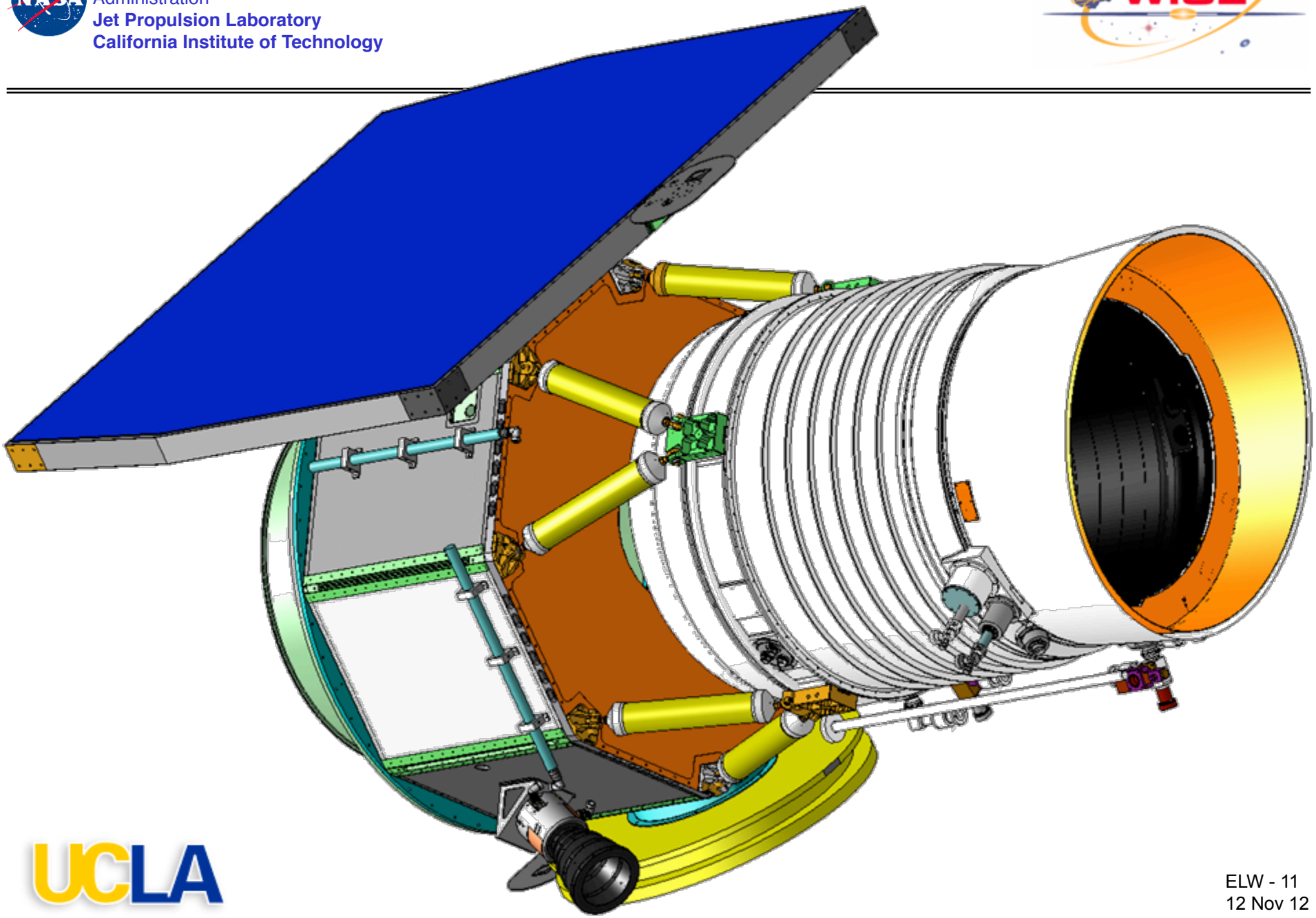
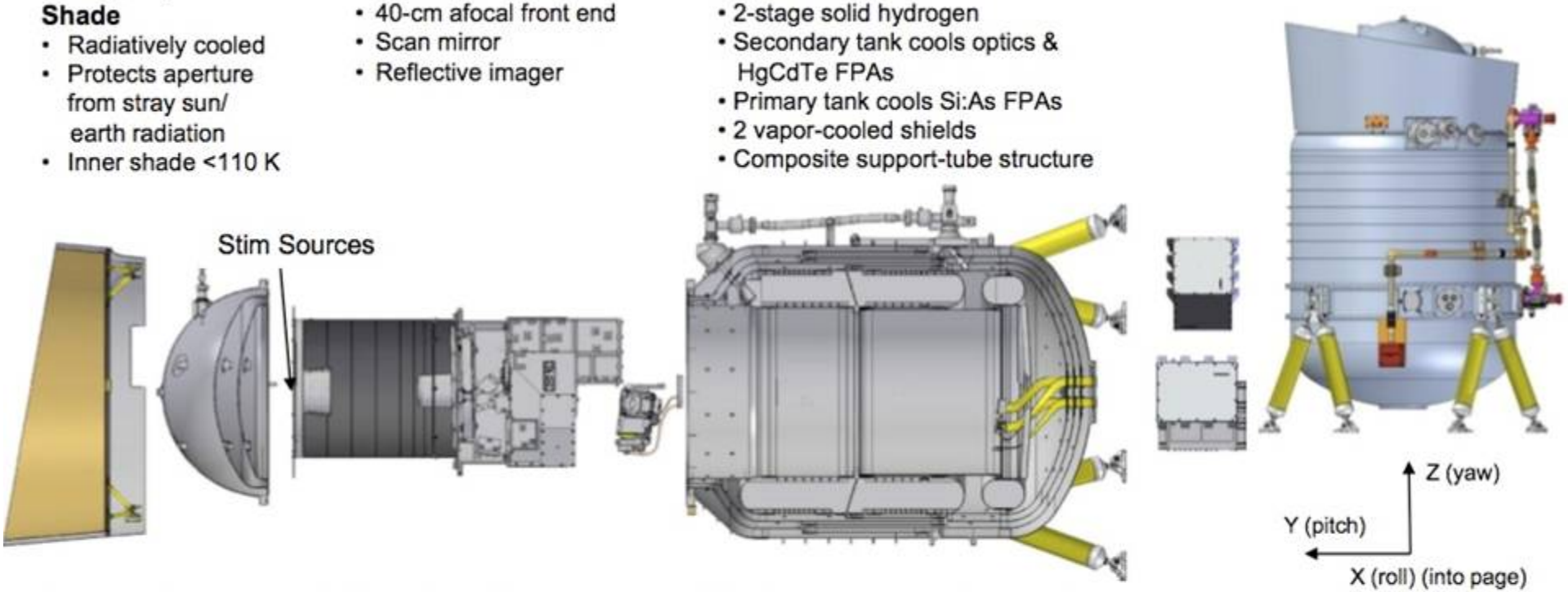


Inside the cryostat

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



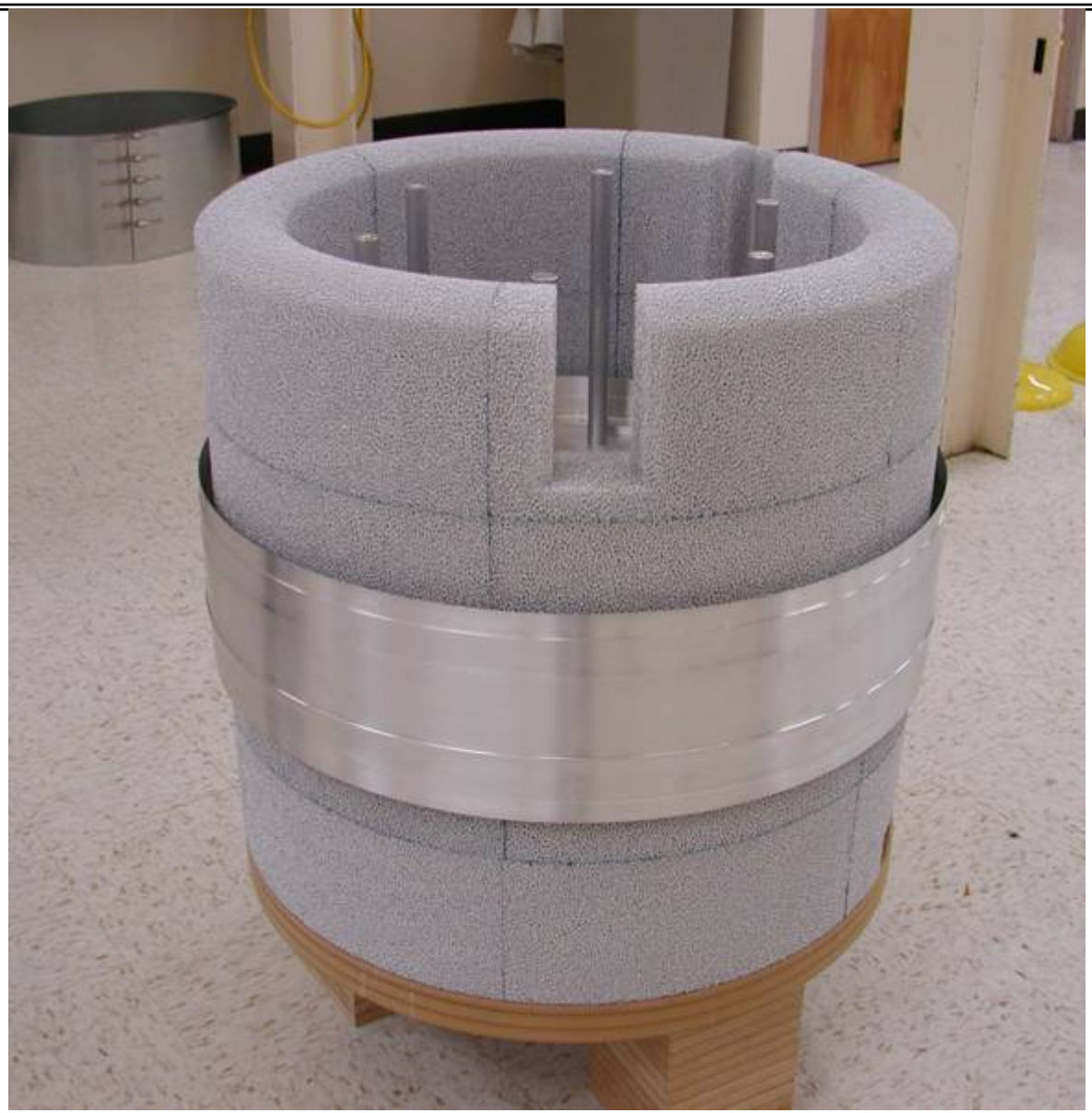
Aperture Cover
- Deployed on-orbit
- Seals vacuum space on ground

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

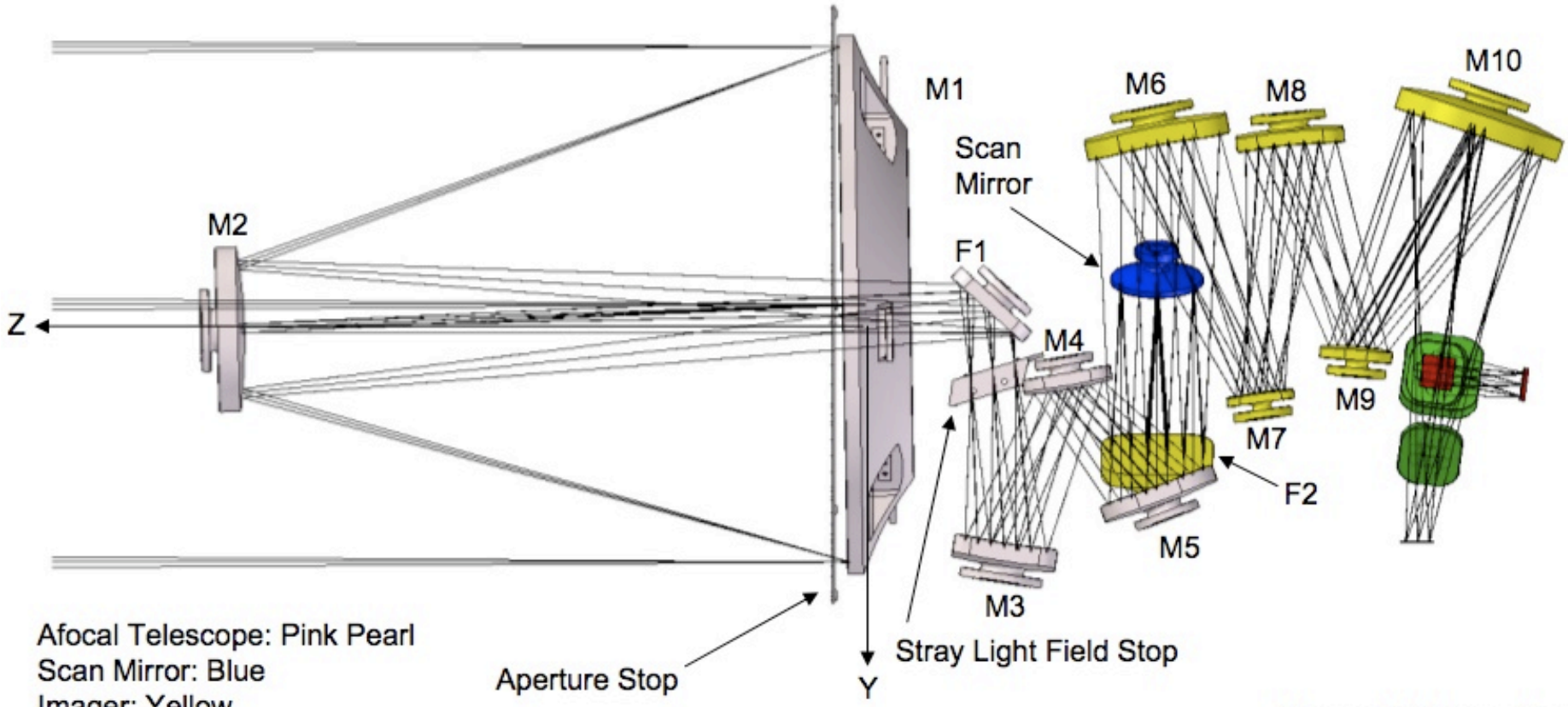
Focal Planes
- 2 MWIR HgCdTe arrays
- 2 LWIR Si:As arrays
- Cryogenic cables

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



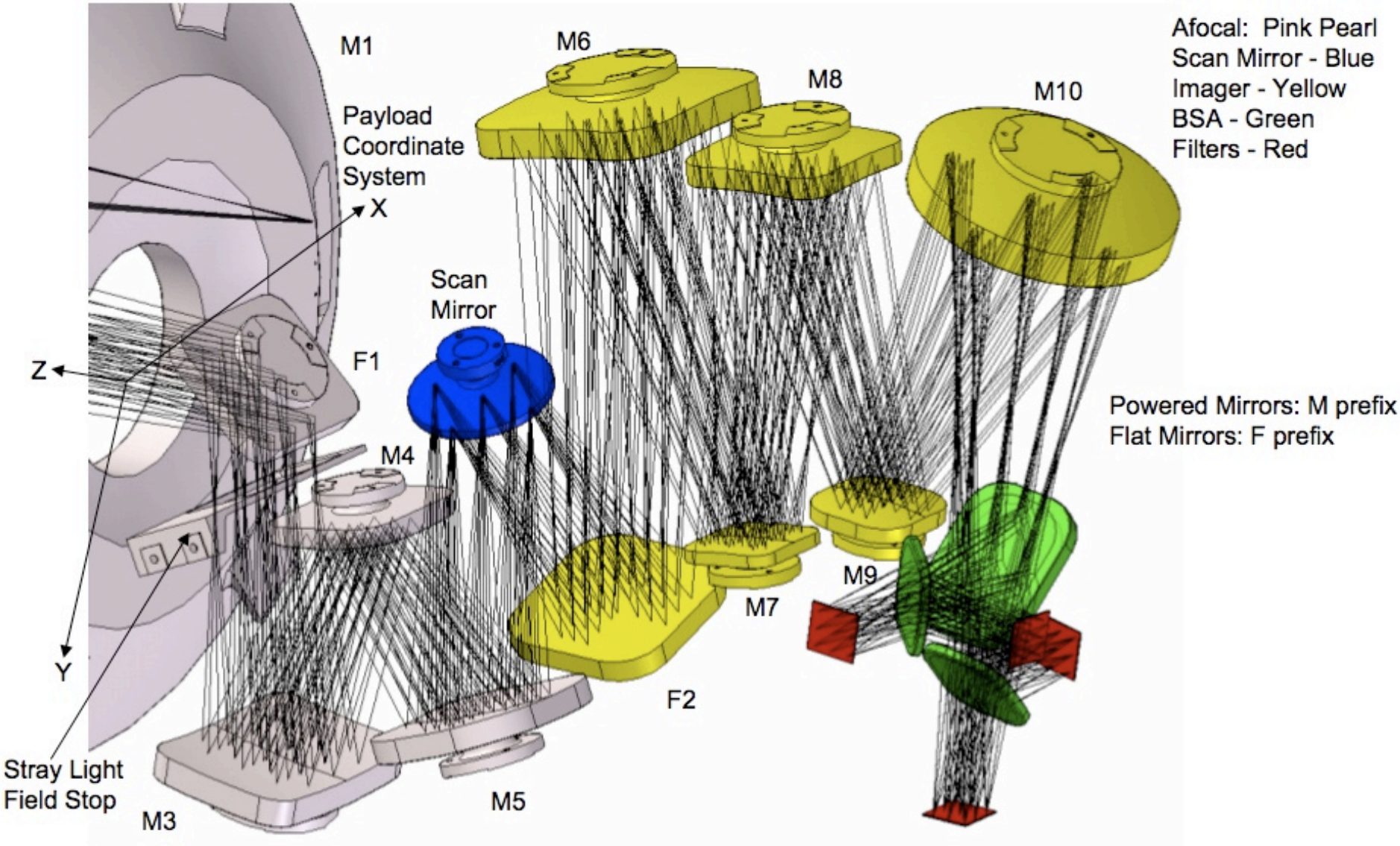
WISE Optical Diagram



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

Powered Mirrors: M prefix
Flat Mirrors: F prefix

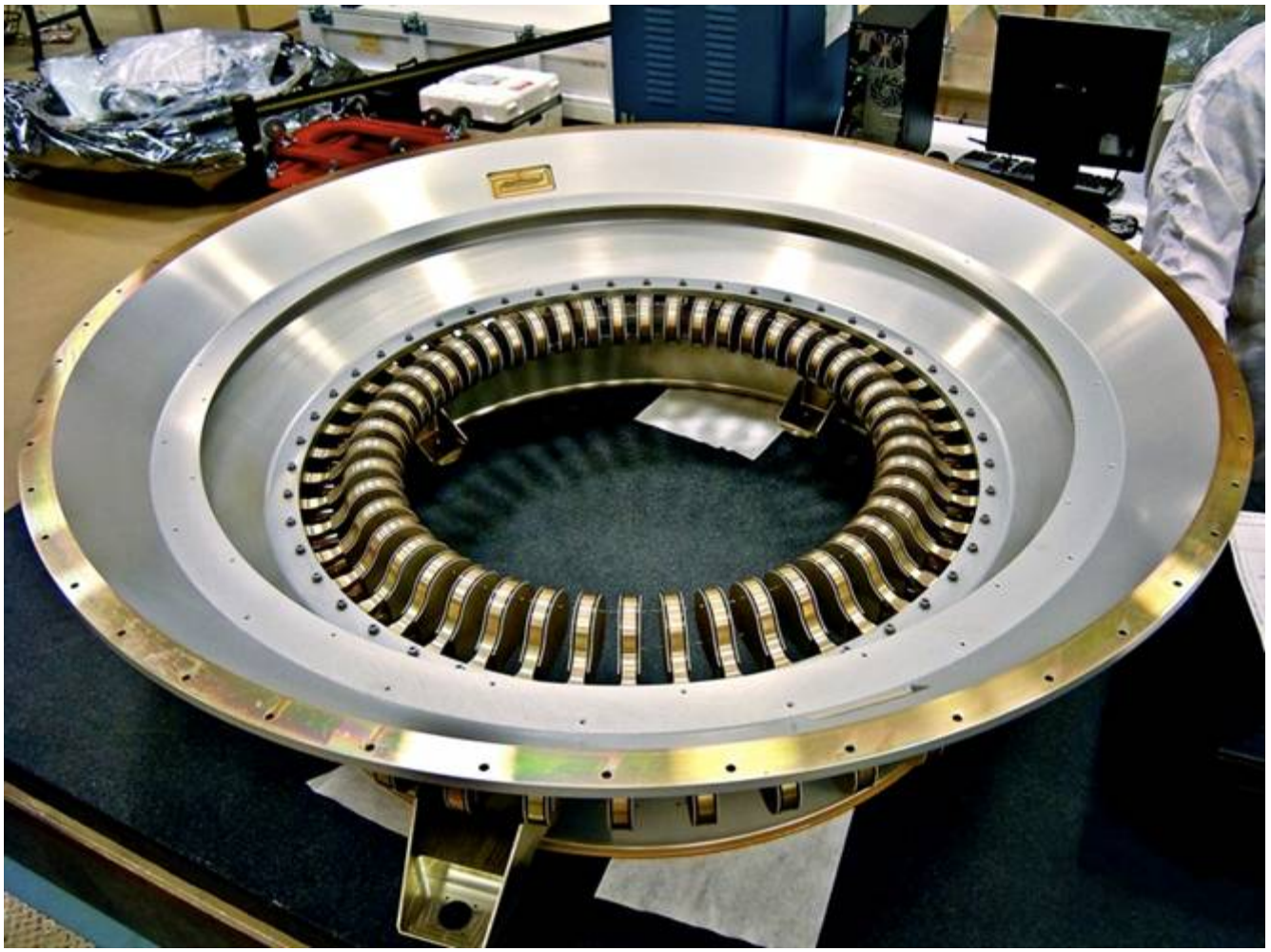
Backend Optical Diagram



TMDS Vibration Test Rig

- Thermal Mass Dynamics Simulator was used instead of hydrogen-filled cryostat during the system level “shake and bake”.
- TMDS vibration test completed successfully on the second try.
- Measured responses matched predictions well.

Added a Soft Ride

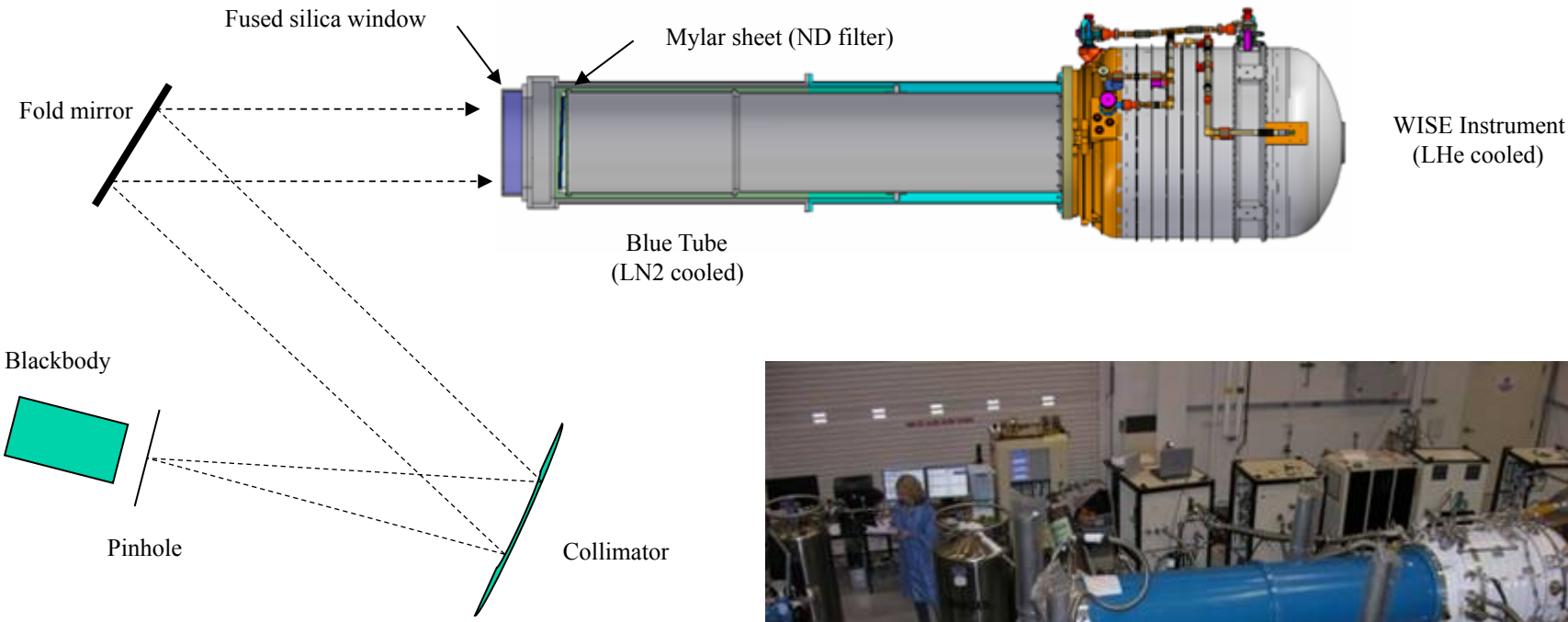


- Delivered on time and on budget by CSA, Inc.

TMDS+S/C Vibe Test

Integrated Optics in Cryostat

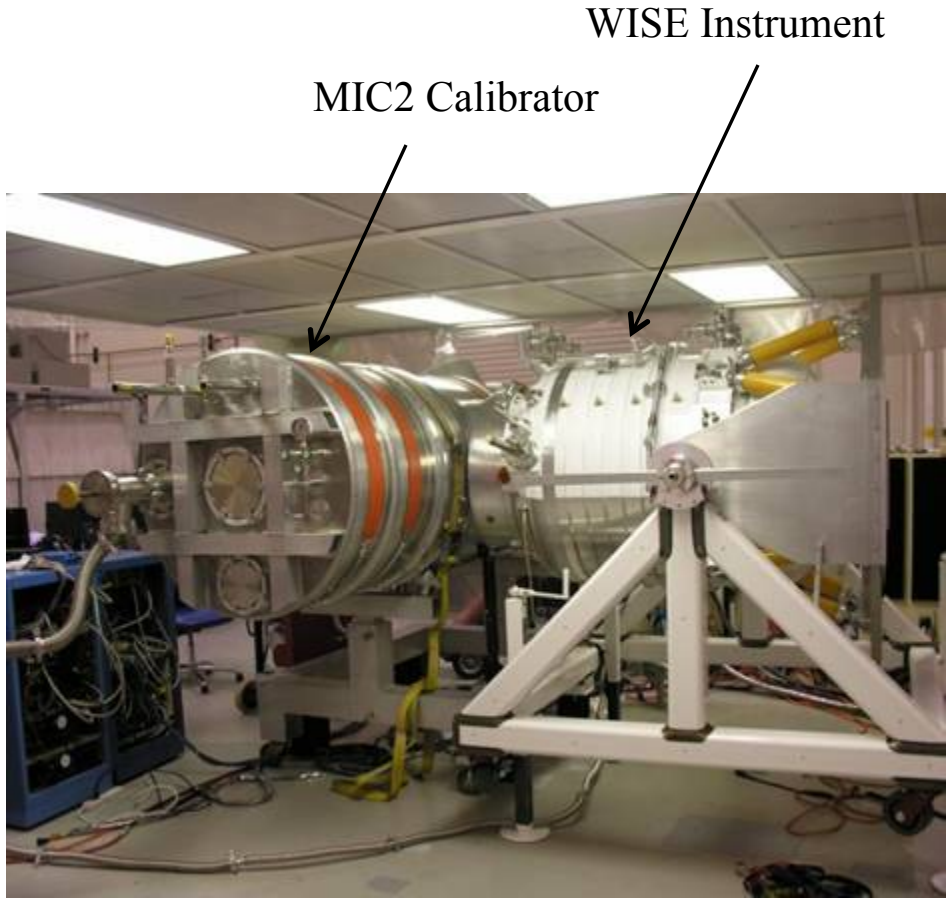
Pre-Environmental Blue Tube Test



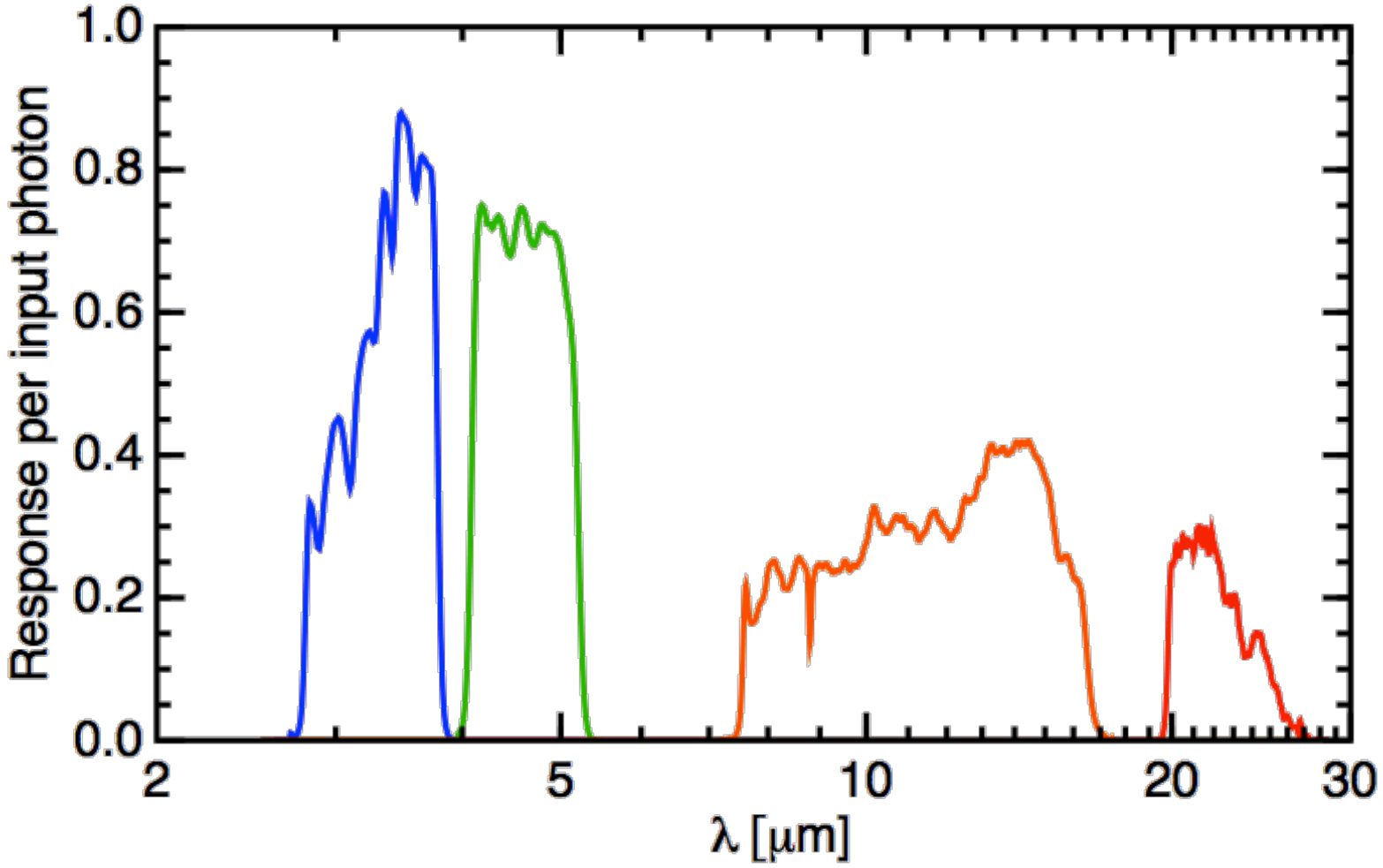
- Four Blue Tube Tests have been completed
  - BT1 and BT2 developed configuration
  - BT3 measured defocus
  - BT4 confirmed pre-environmental focus
- Baselined B1 image quality
- Report: *WISE Focus Verification* (SDL/09-157)

Pre-Environmental MIC2 Test

- MIC2 source configurations
  1. Collimator (FTS or BB)
  2. Scatter source (FTS or BB)
  3. Extended source (cold or warm)
- MIC2 does not completely fill WISE aperture
- All characterization measurements were made during a single cold cycle
  - Confocality check
  - Scanner linearity & PRFs
  - Distortion
  - Flatfield/peak radiance responsivity
  - Dark offset / dark & gain variation
  - Saturation, latency & droop
  - Response nonlinearity
  - Inband and out-of-band RSR
  - Repeated nonlinearity, D&G and scanner linearity with EM FEB
- All raw data delivered to IPAC



System Throughput



- Long waves transmitted through thick BS1 leading to losses.

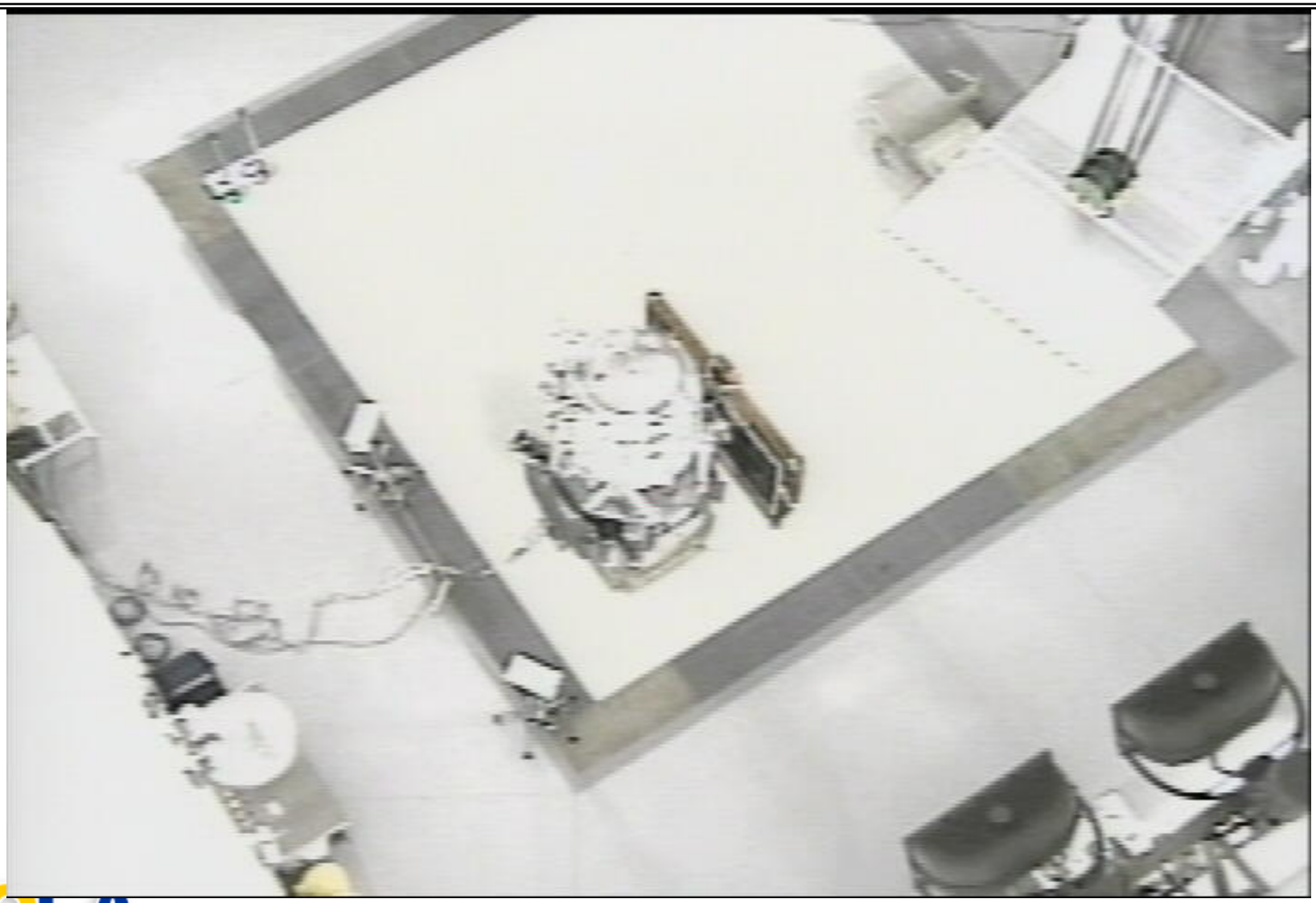
Hydrogen Test Setup

- Jan-Feb 2009
- Ground hold time: tanks sealed off, how long to reach triple point. Measured at 52 hours vs 44 hour requirement.
- Hydrogen flow rate tested at two different internal power levels. Correction for outer shell temperature gives 10 month lifetime estimate.

S/C+Instrument

Arriving at VAFB

Webcam @ ksc.nasa.gov



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.

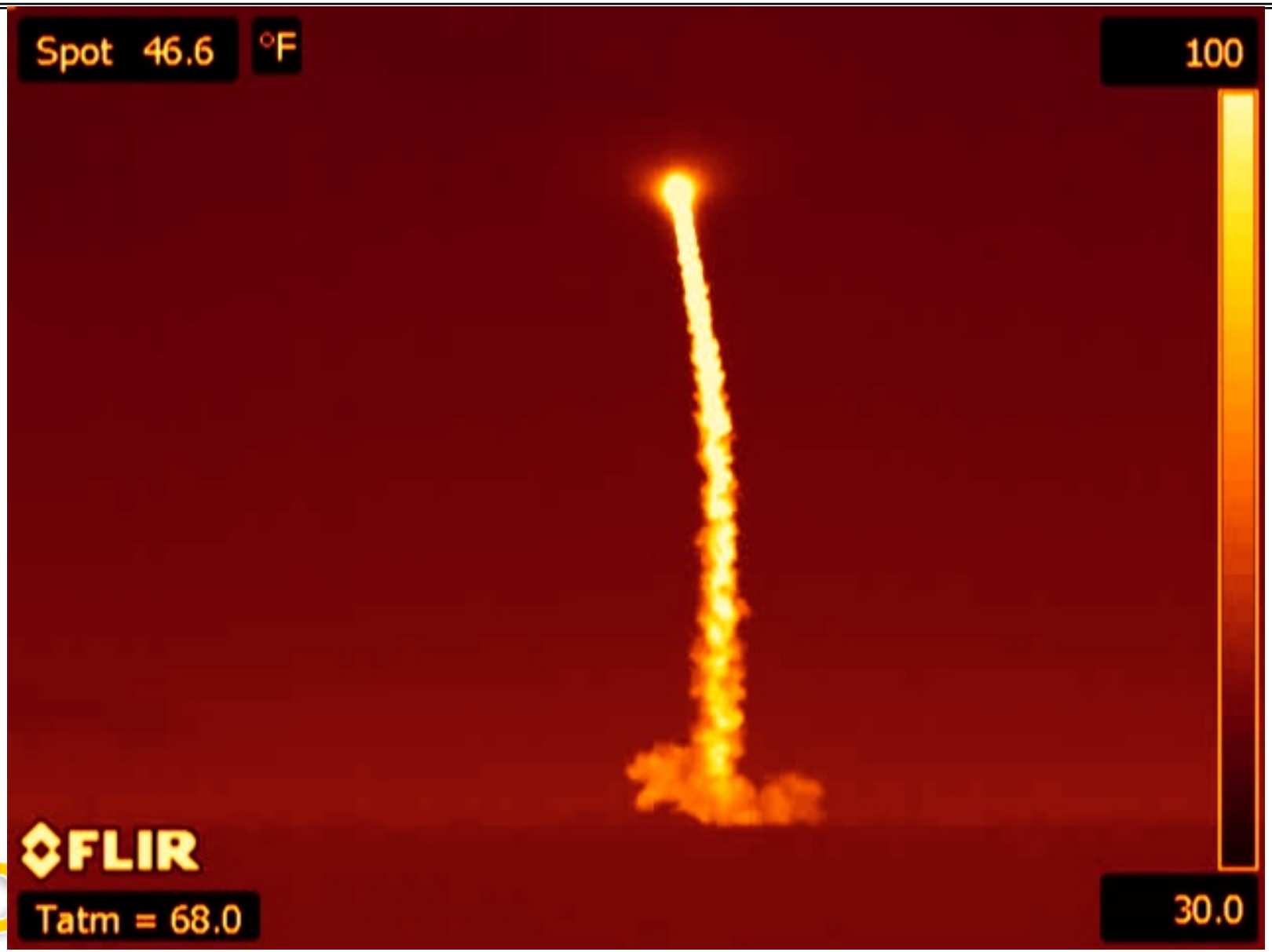
Launch seen from South VAFB

- 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.

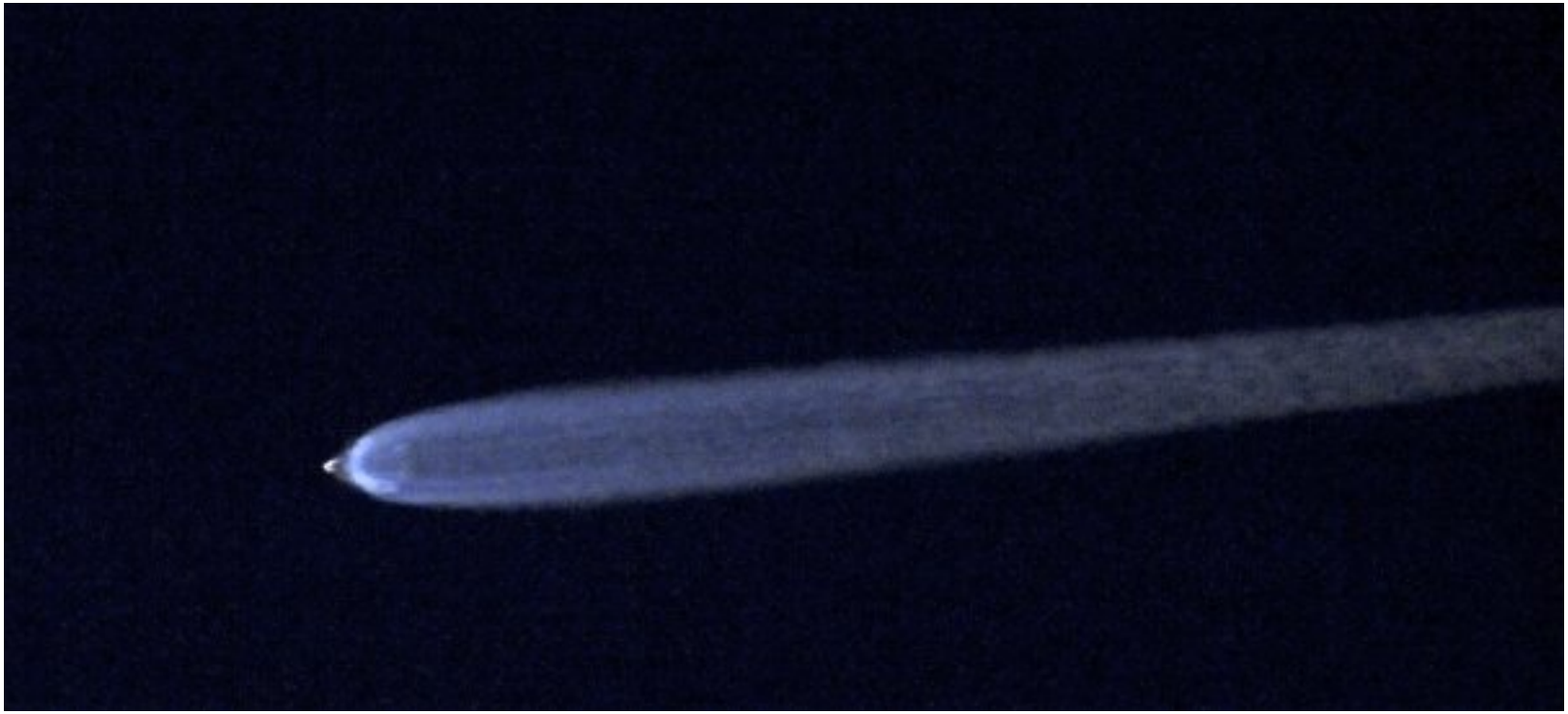
Launch from the viewing site

• Credit: Bill Hartenstein, ULA

Launch in the IR



Launch from Tujunga



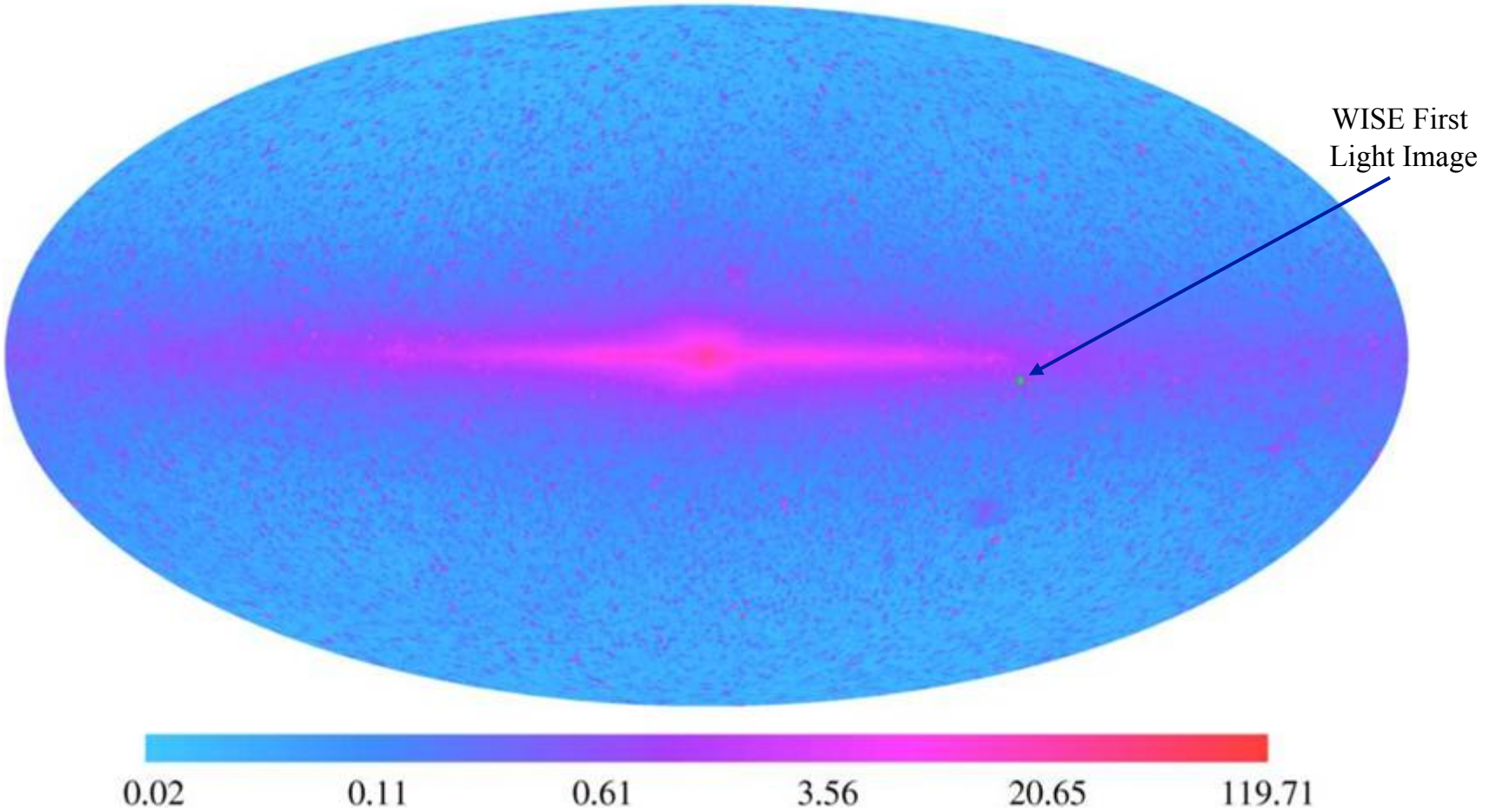
- © William Ling, 280 mm FL equivalent, handheld, with VR

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

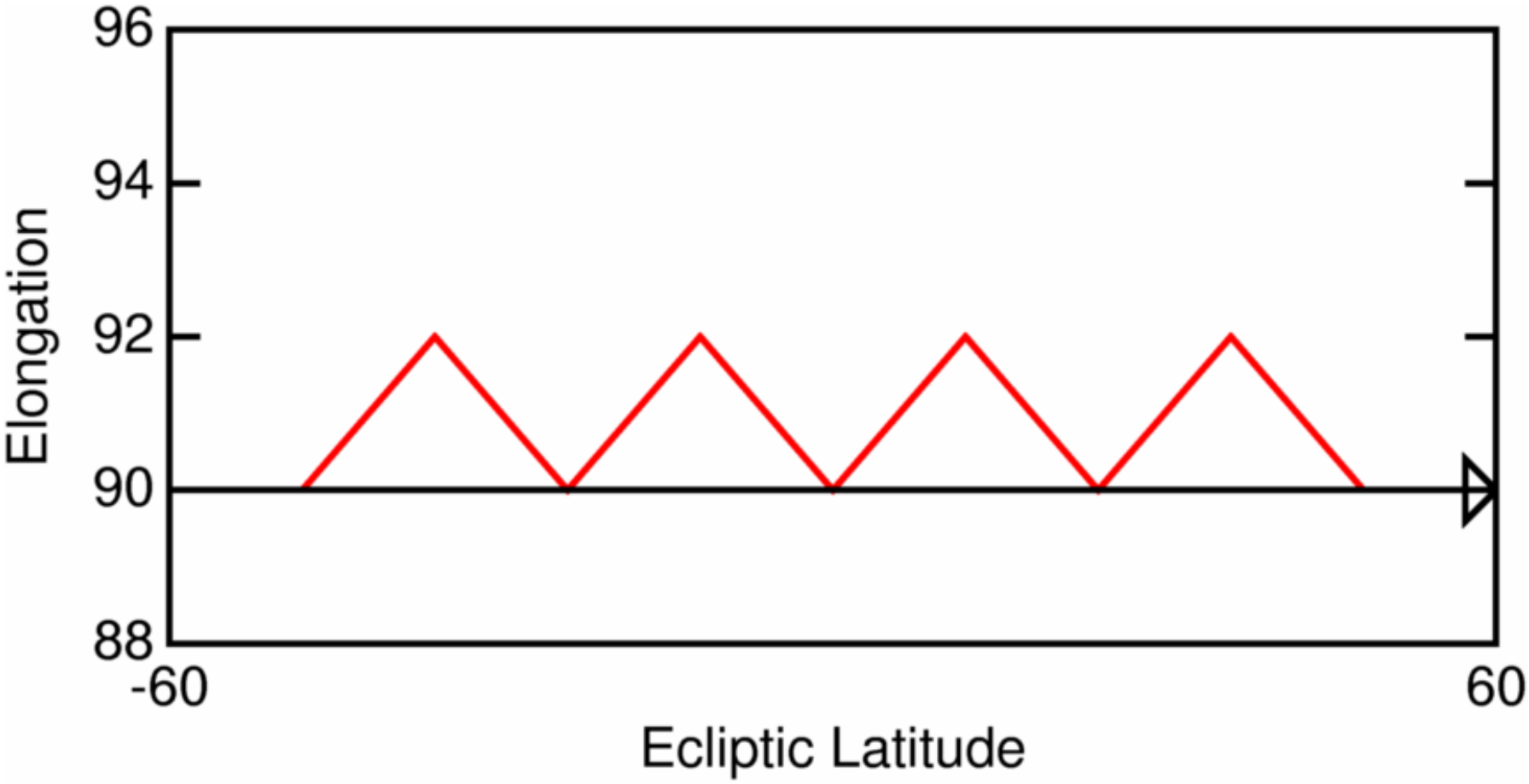
3.4, 4.6, 12 microns

47’ FOV

2.75” pixels

6” FWHM

Matching Scan Rates



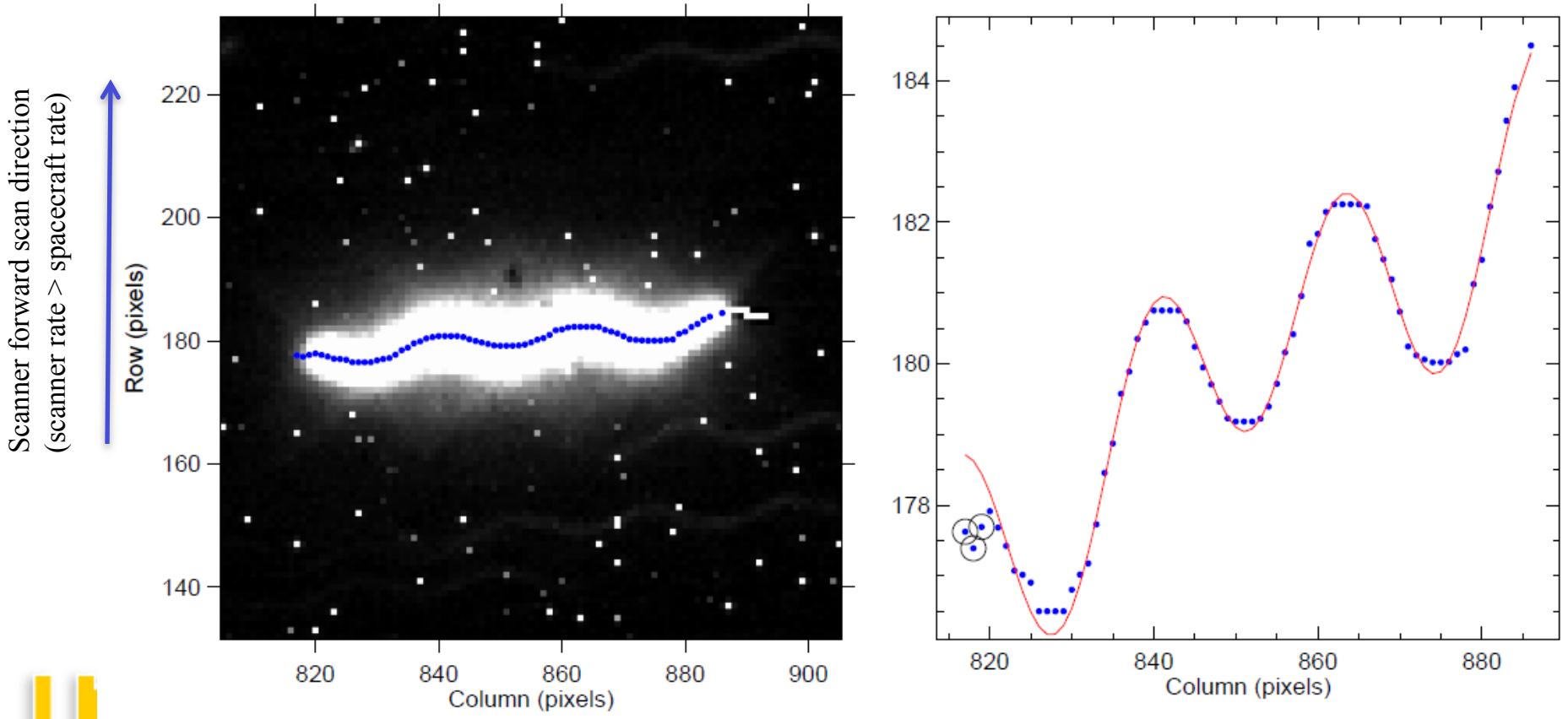
- "Oscilloscope" Scans

Example Seagull

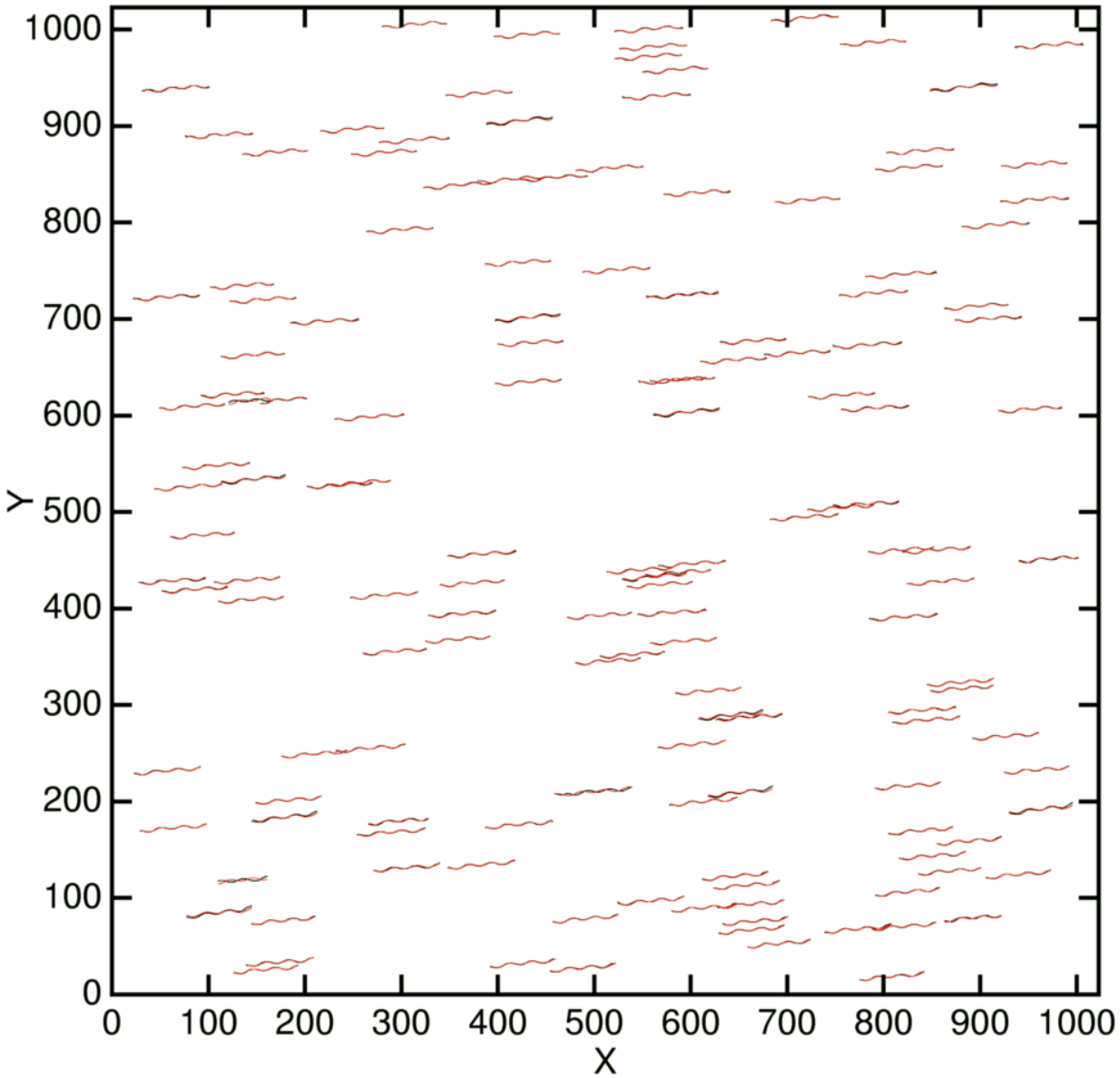
File: 00650a005-w1-int-0.fits.gz

ID: 00650a005w1_08510180

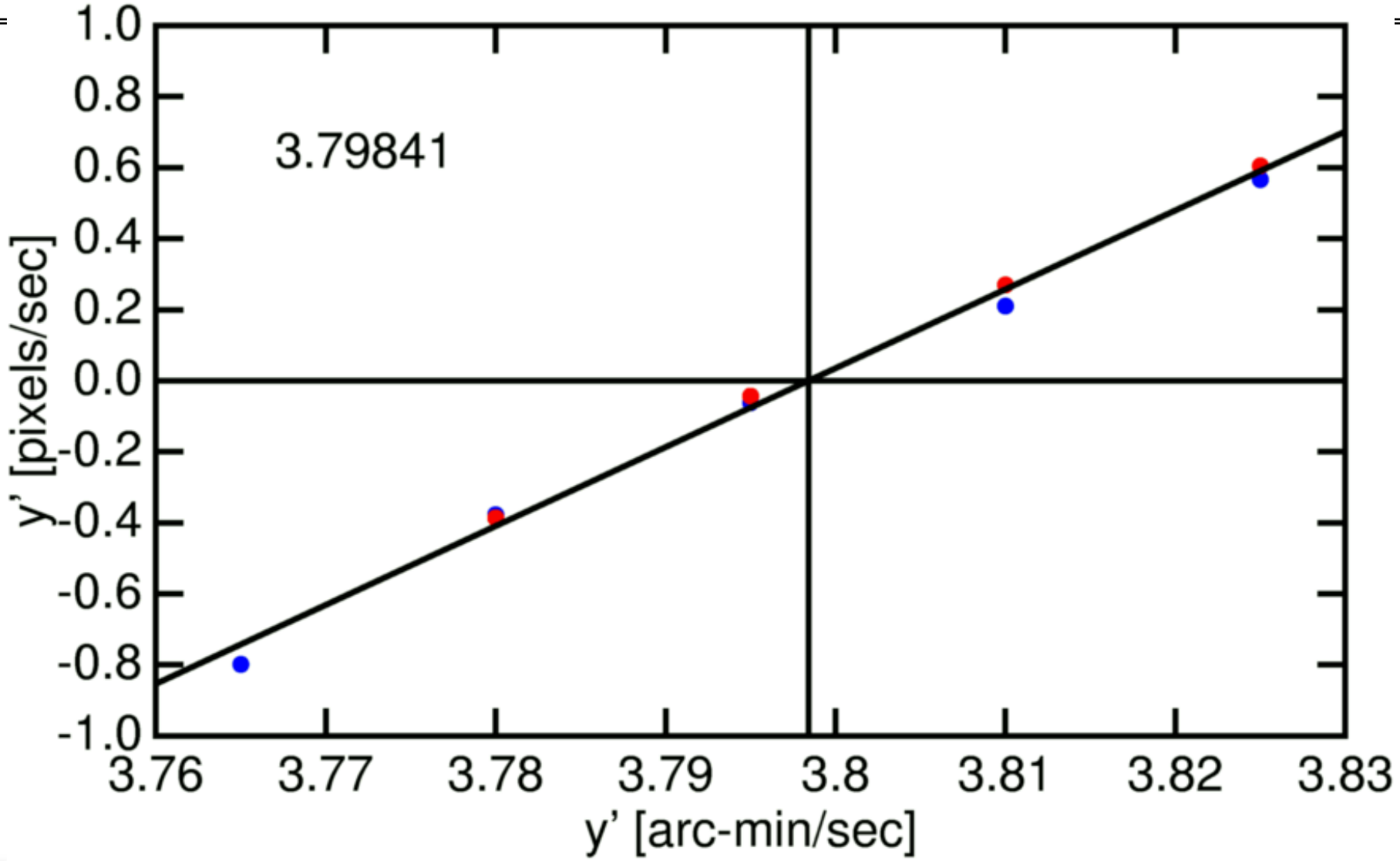
Spacecraft scan direction (star and time move right to left)



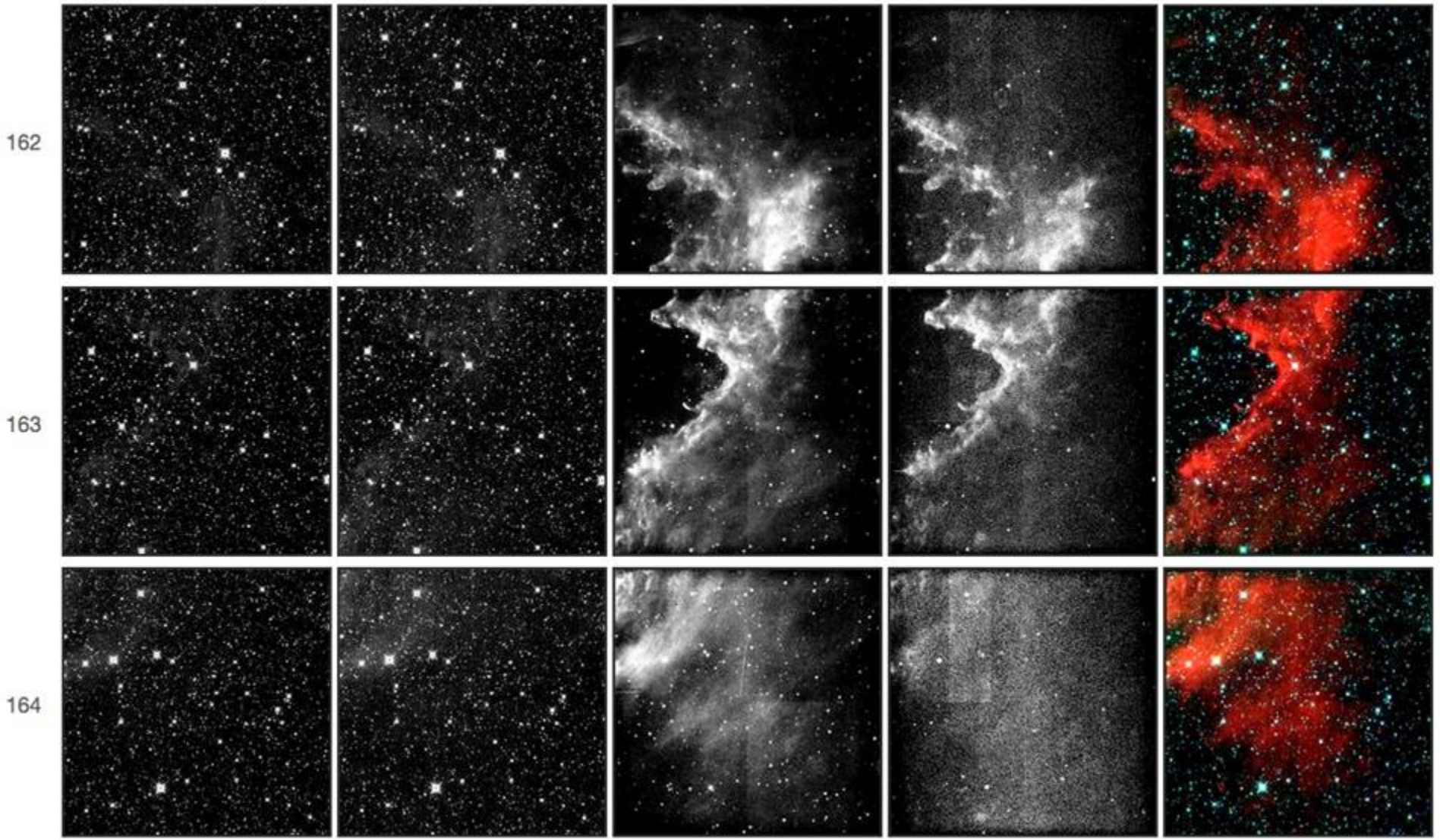
Global Seagull Fit



Matching the Scan Rate



On to Survey Mode

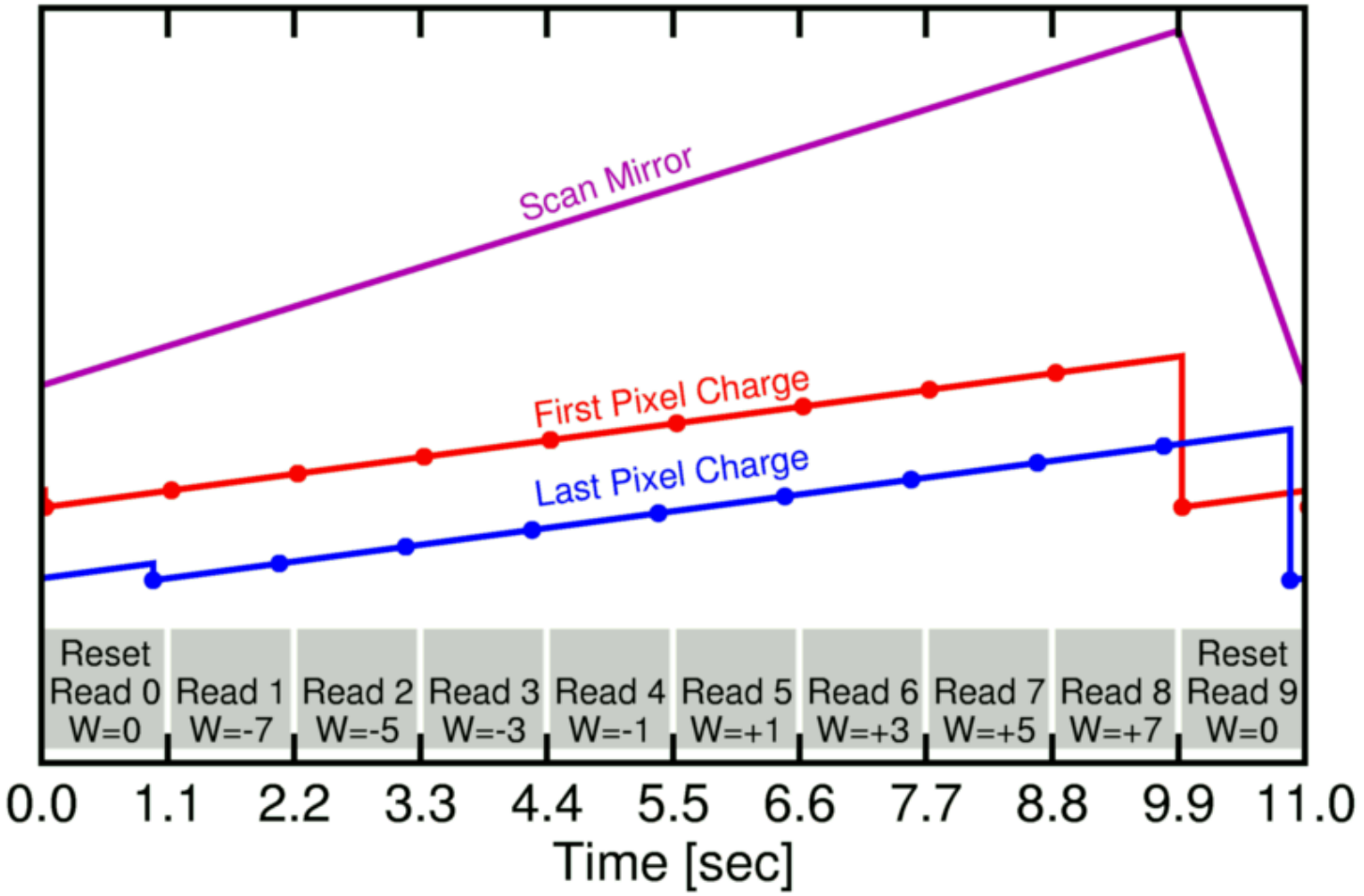


- 33 seconds in the life of WISE, 3 of >7000 frames/day

G 118.1+4.9

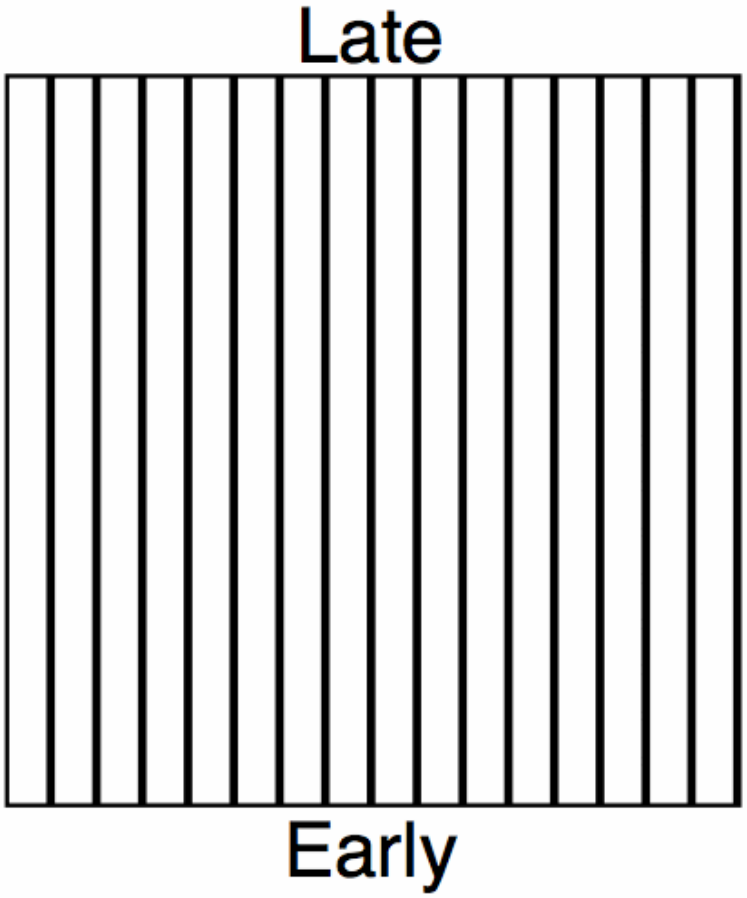
- Sometimes the automated Quality Assurance images are just astoundingly beautiful. Now an Image of the week.

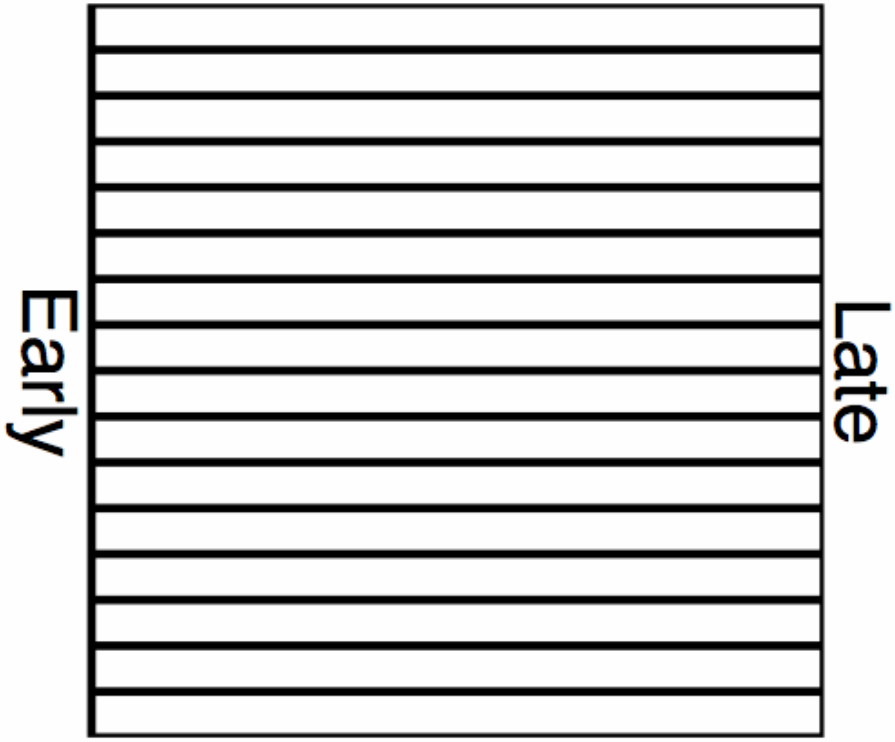
Array Timing: W1 & W2



- Due to first sample noise, only 7.7 seconds of the 8.8 second integration time was used for bands 1 & 2

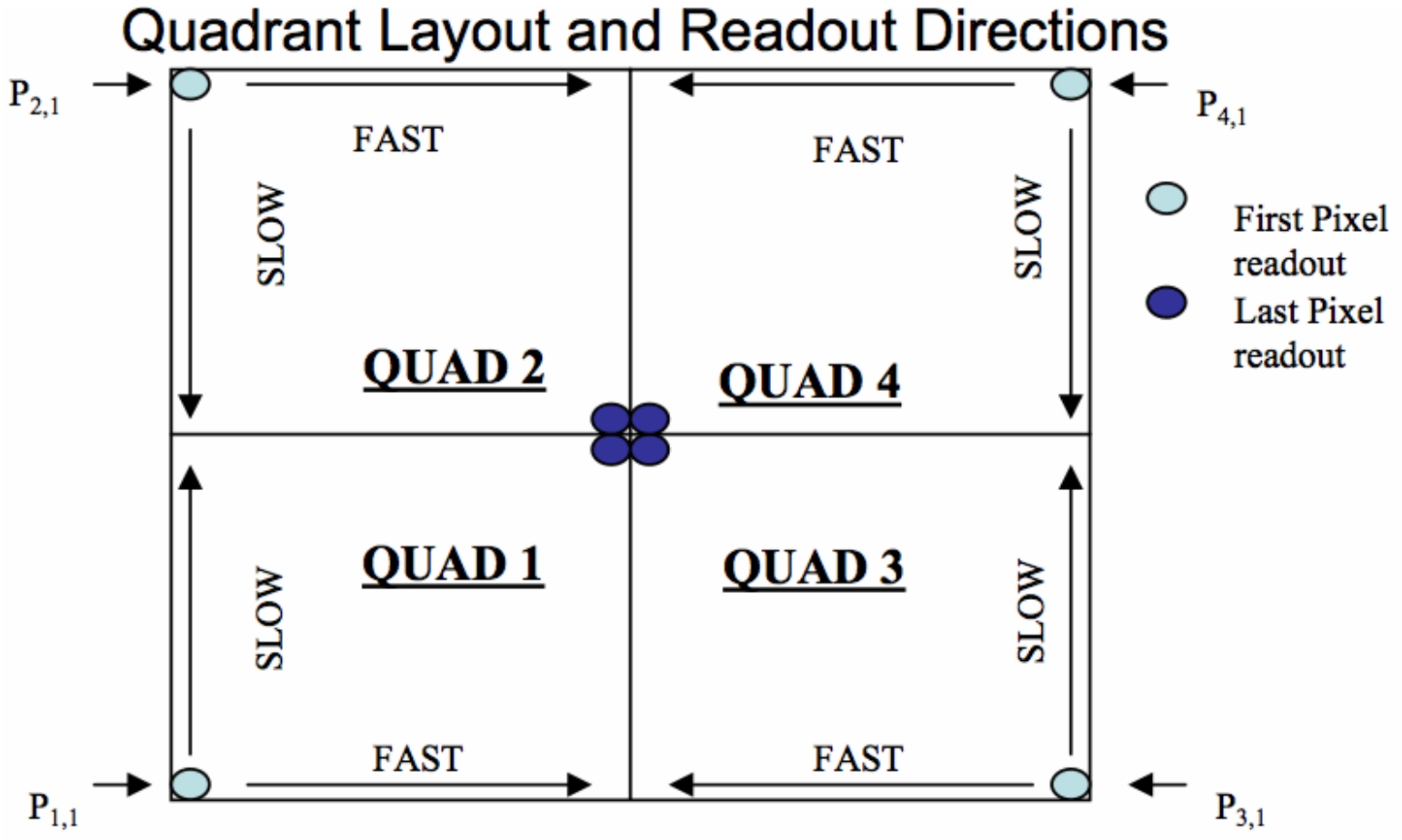
Array Timing: W1 & W2





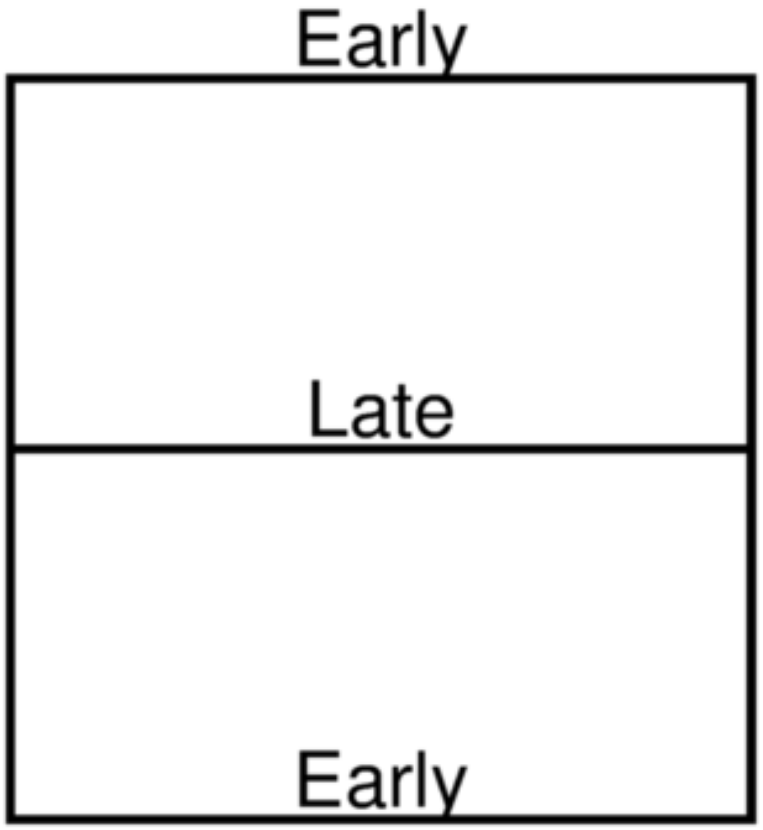
- 16 output amplifiers lead to the slight striping seen in the QA images. 1.05 seconds between early and late.

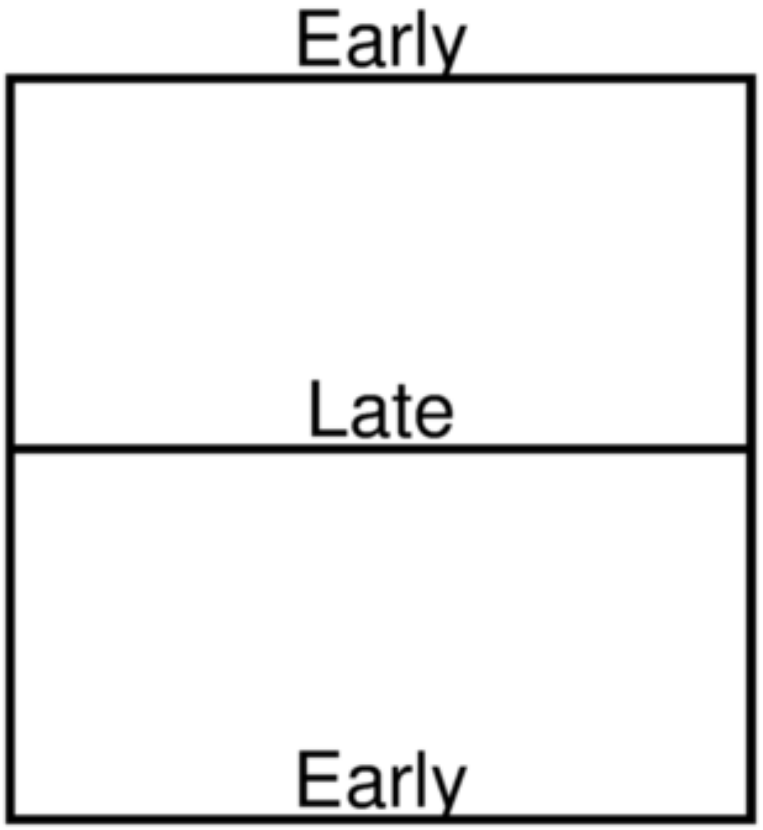
Array timing: W3 & W4



- Quadrant structure with 4 amplifiers

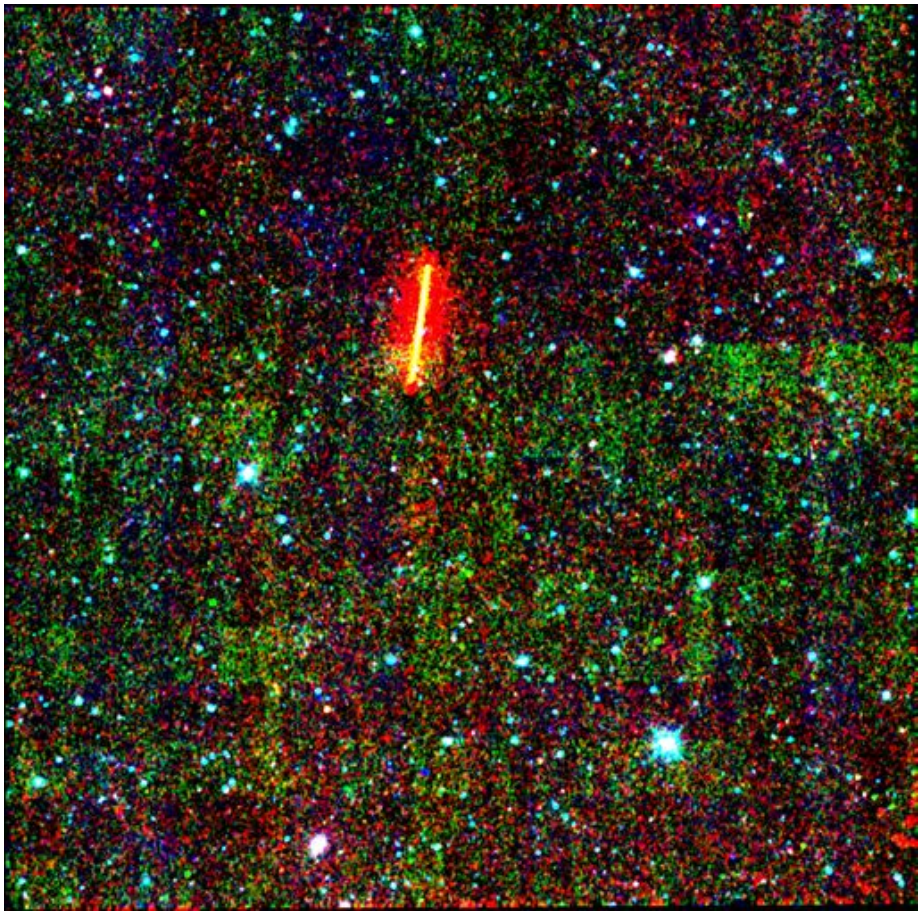
Timing Map for W3 & W4

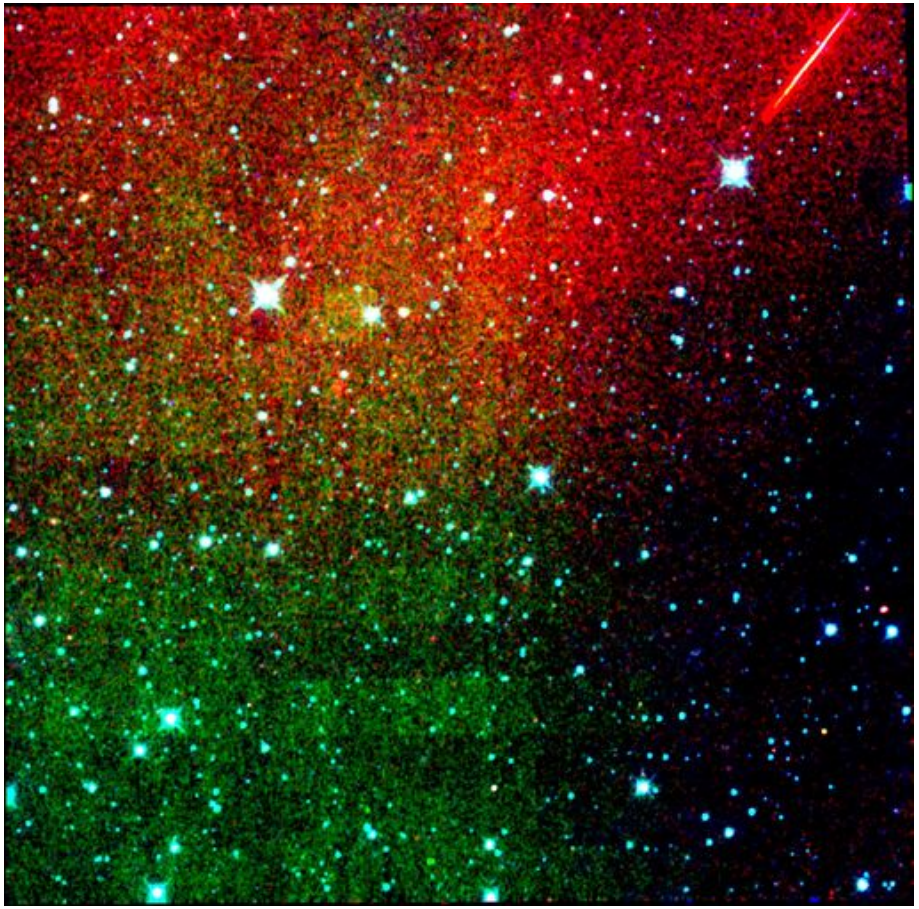




- The “equator” is scanned last.

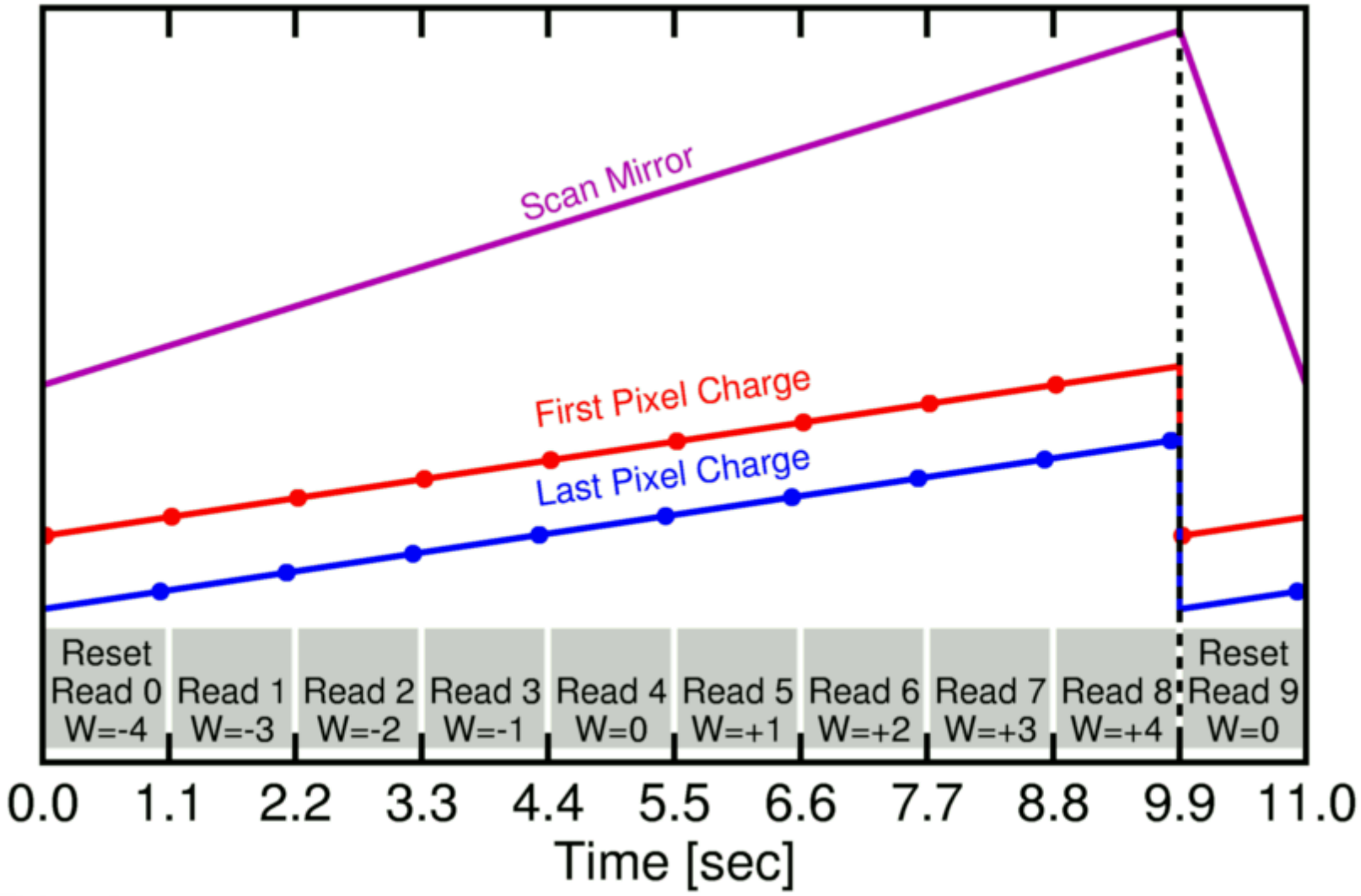
HEO Satellites in QA





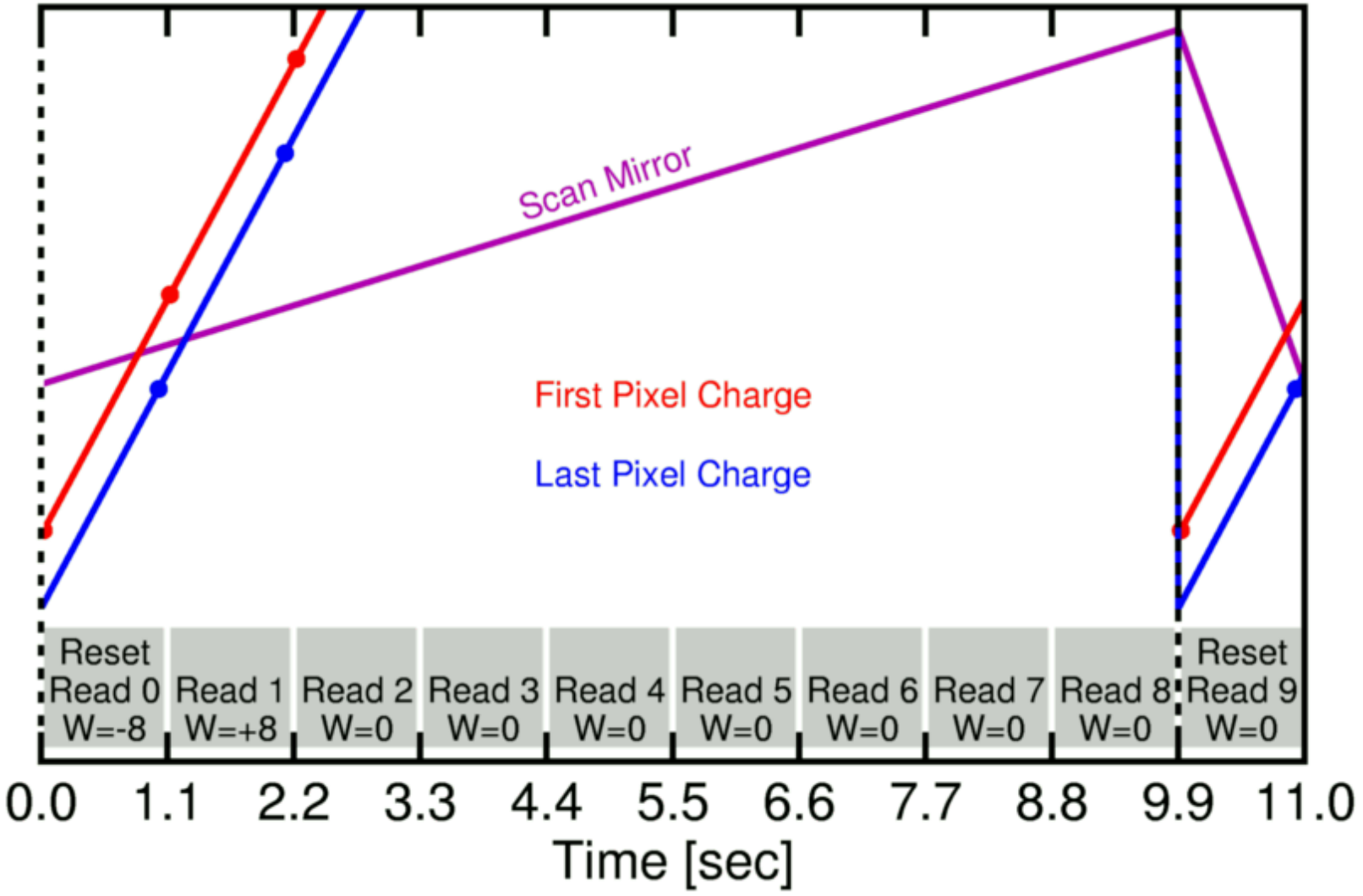
- Note the red stub at the bottom of the trail, and how it is longer on the right image.

Sample-Up-the-Ramp: W3 & 4



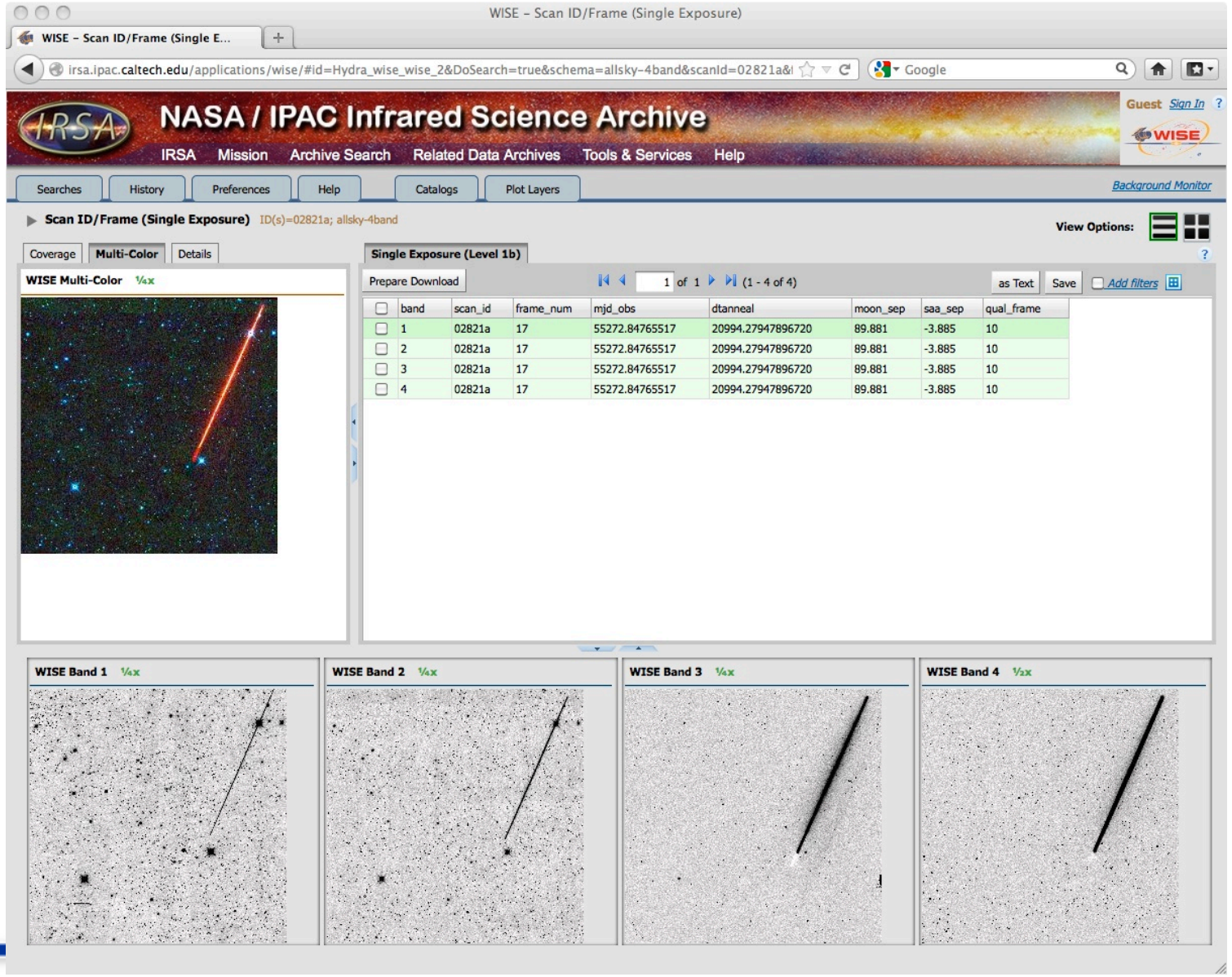
- Uses a bulk reset

3 band cyro weights

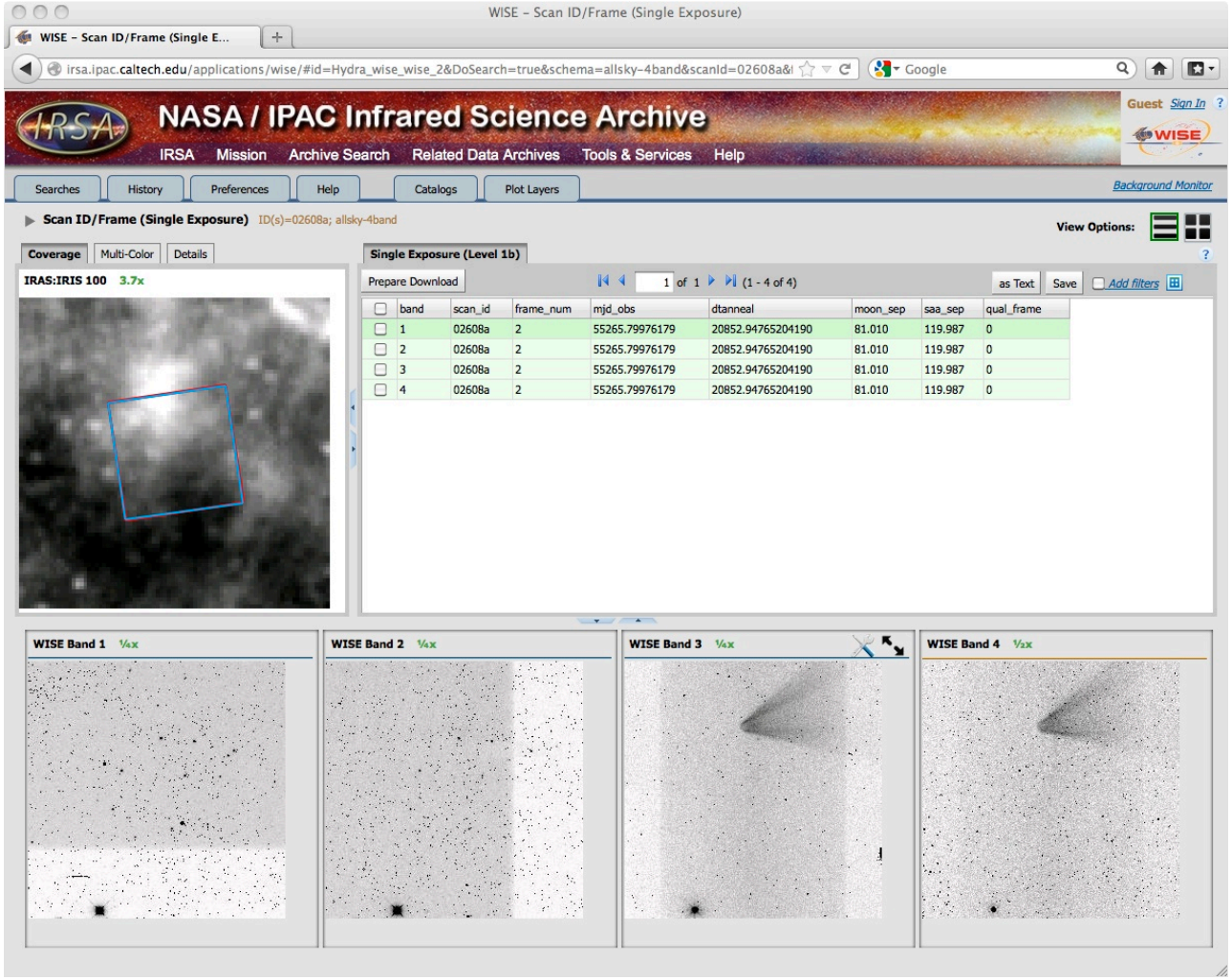


- High background when telescope warmed up

Online at IRSA



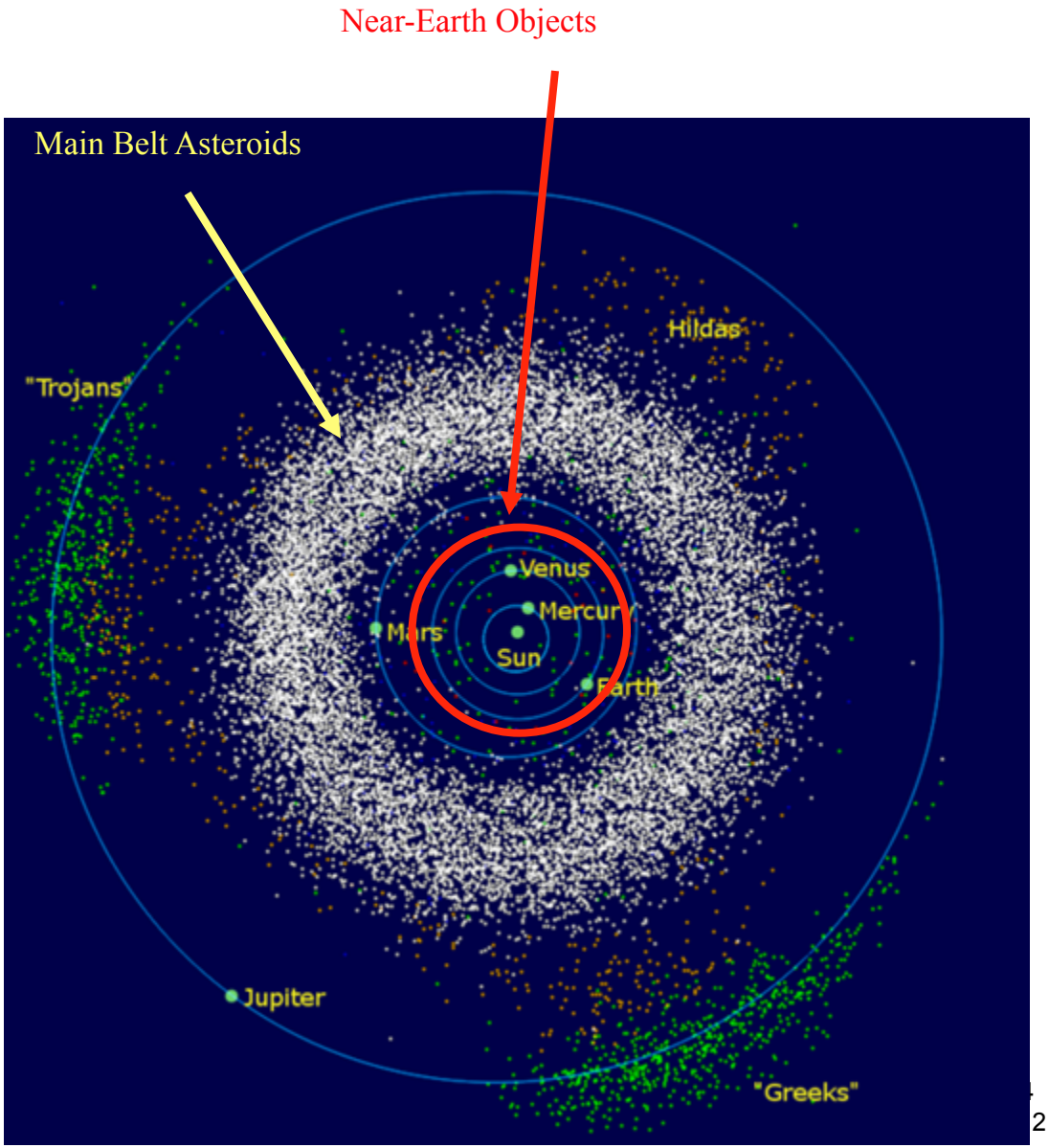
Zooming Donut



- A zooming "donut" – something very small and nearby giving an out of focus image.

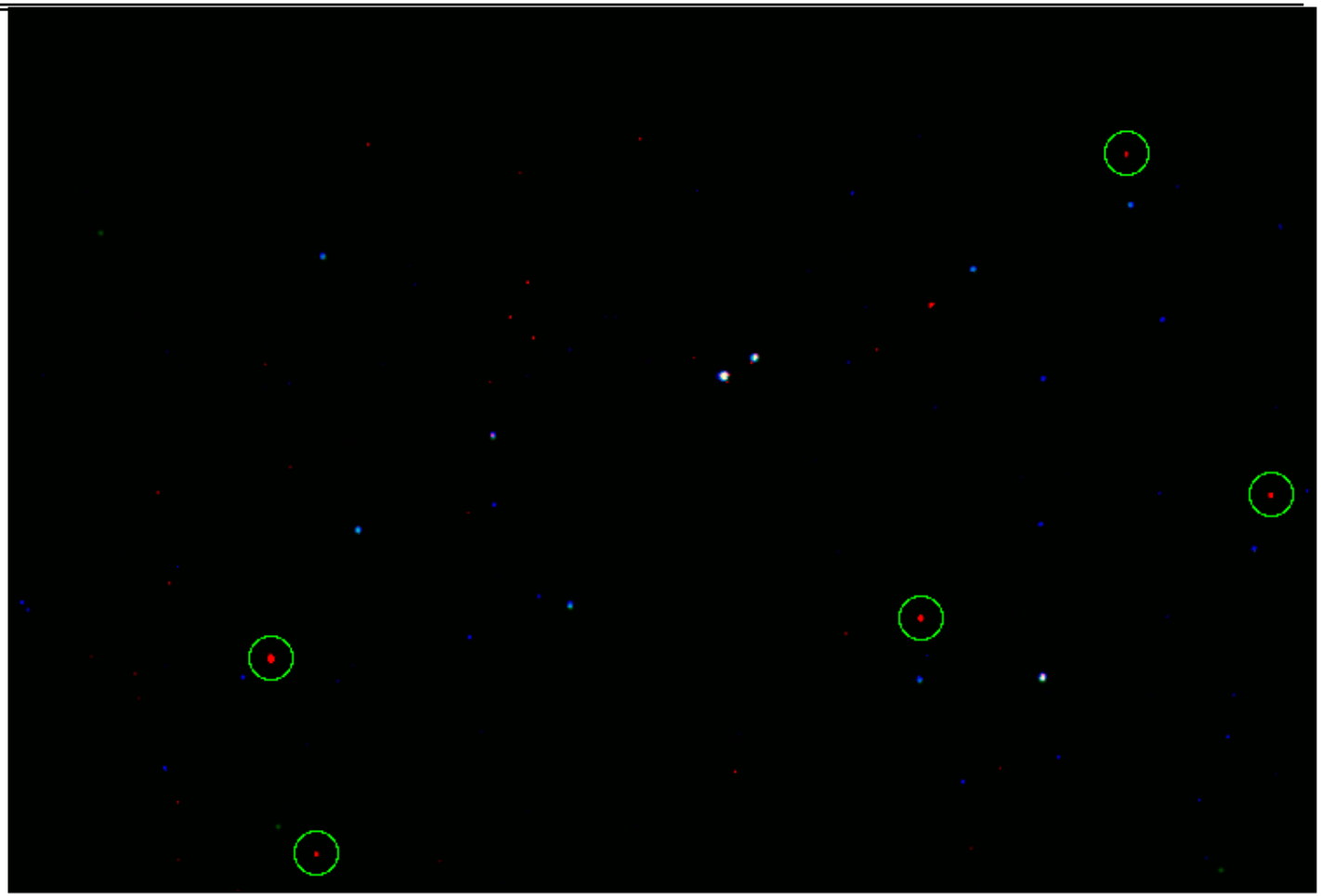
WISE and Asteroids

- 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



Asteroids Move

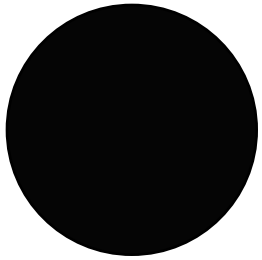
- Four frames of data taken on 2010 Jan. 8 during in-orbit checkout.
- Blue = 3.6um; green = 4.6um; red = 12um
- Circled asteroids are (L to R in the first frame, diameters in km):
  17818 MBA D~12.4
  153204 MBA D~2.8
  22006 MBA D~11.5
  87355 MBA D~4.3
  80590 MBA D~4.1



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

Value of IR Asteroid Data

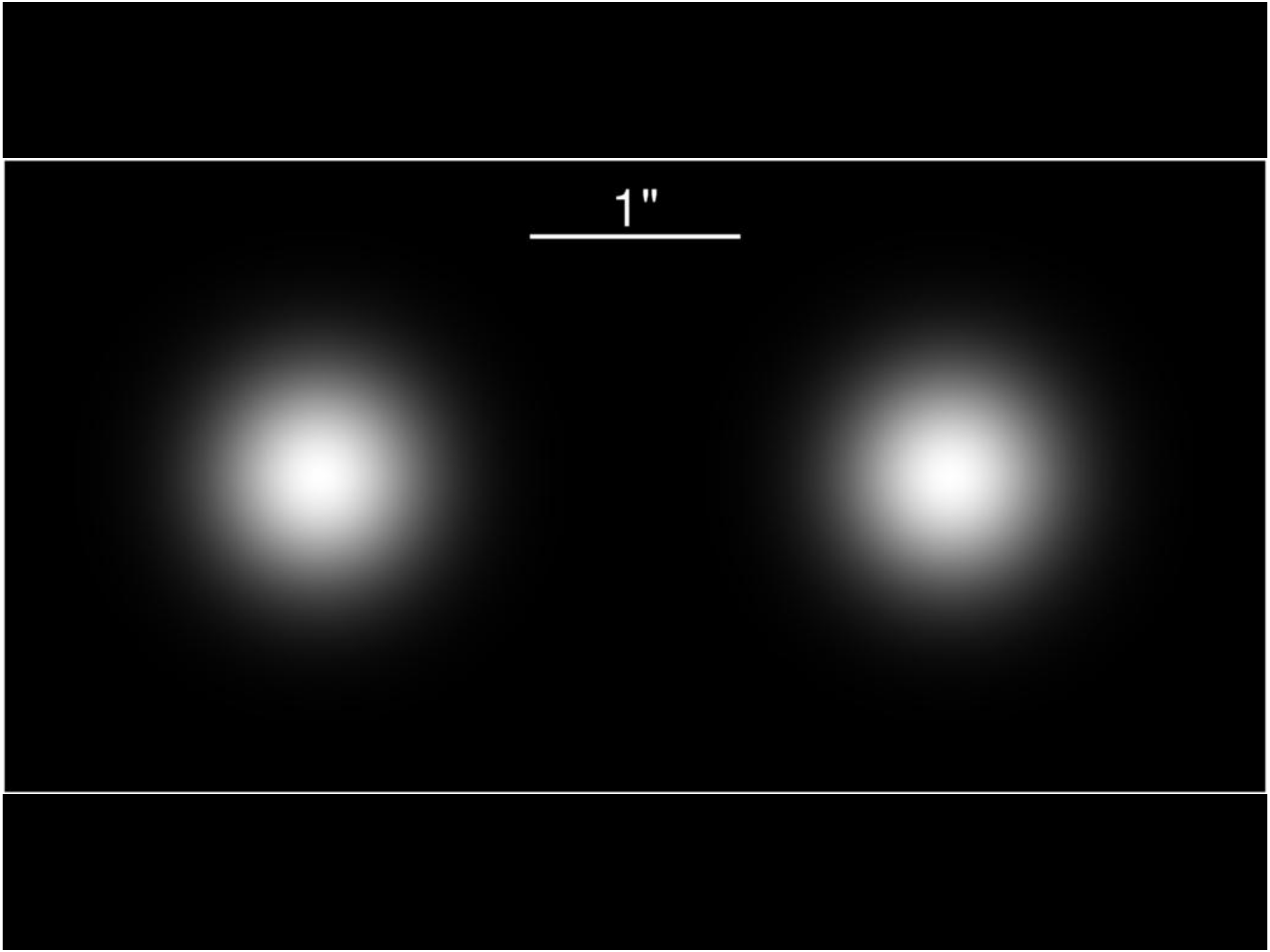
- The total flux of an asteroid, integrated over frequency and angle, gives the power intercepted from the Sun and thus the diameter.
- The range in optical albedo (Stuart & Binzel, 2004) corresponds to more than a factor of 5 in diameter, for the same (reflected) optical flux.

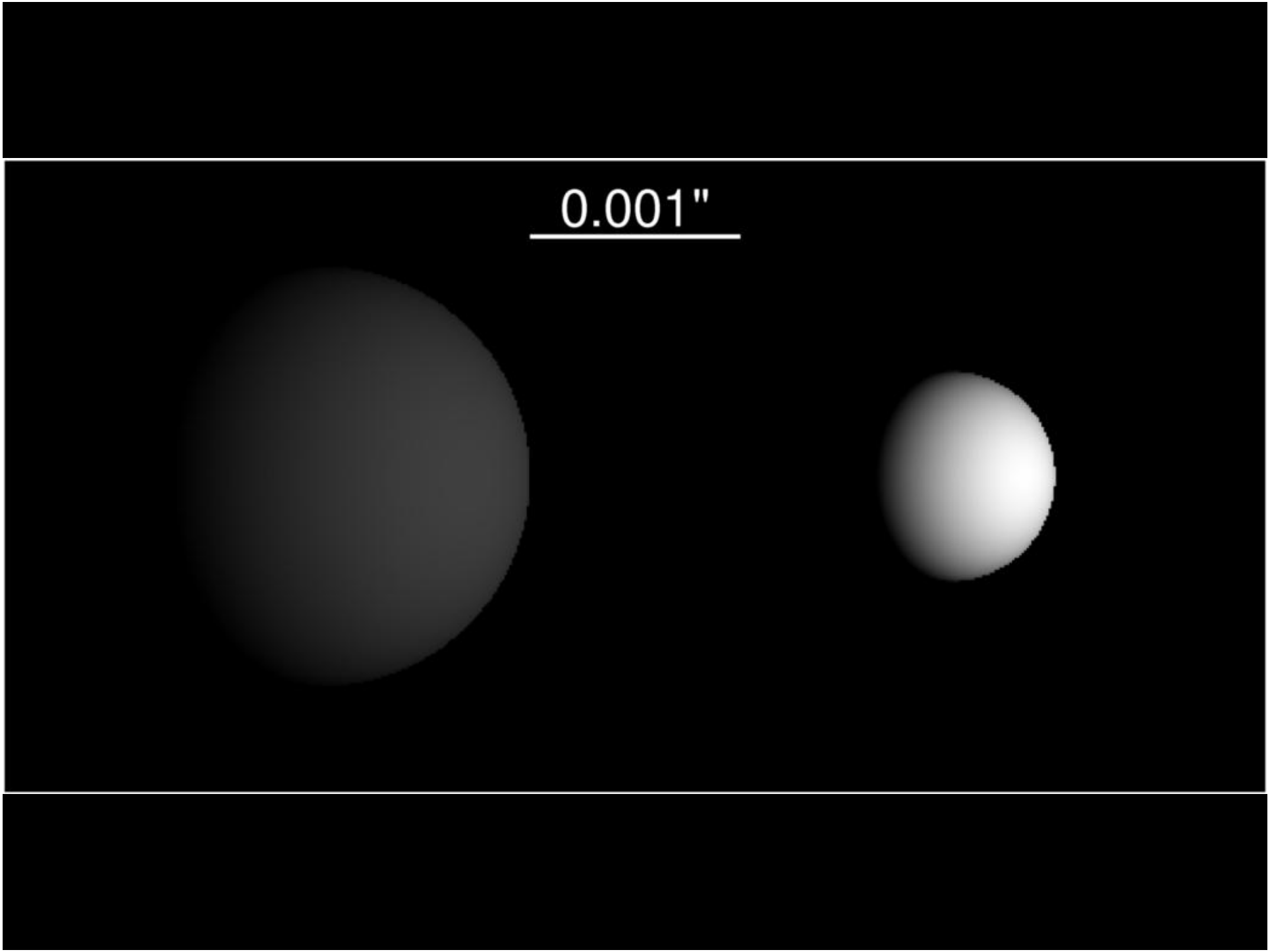


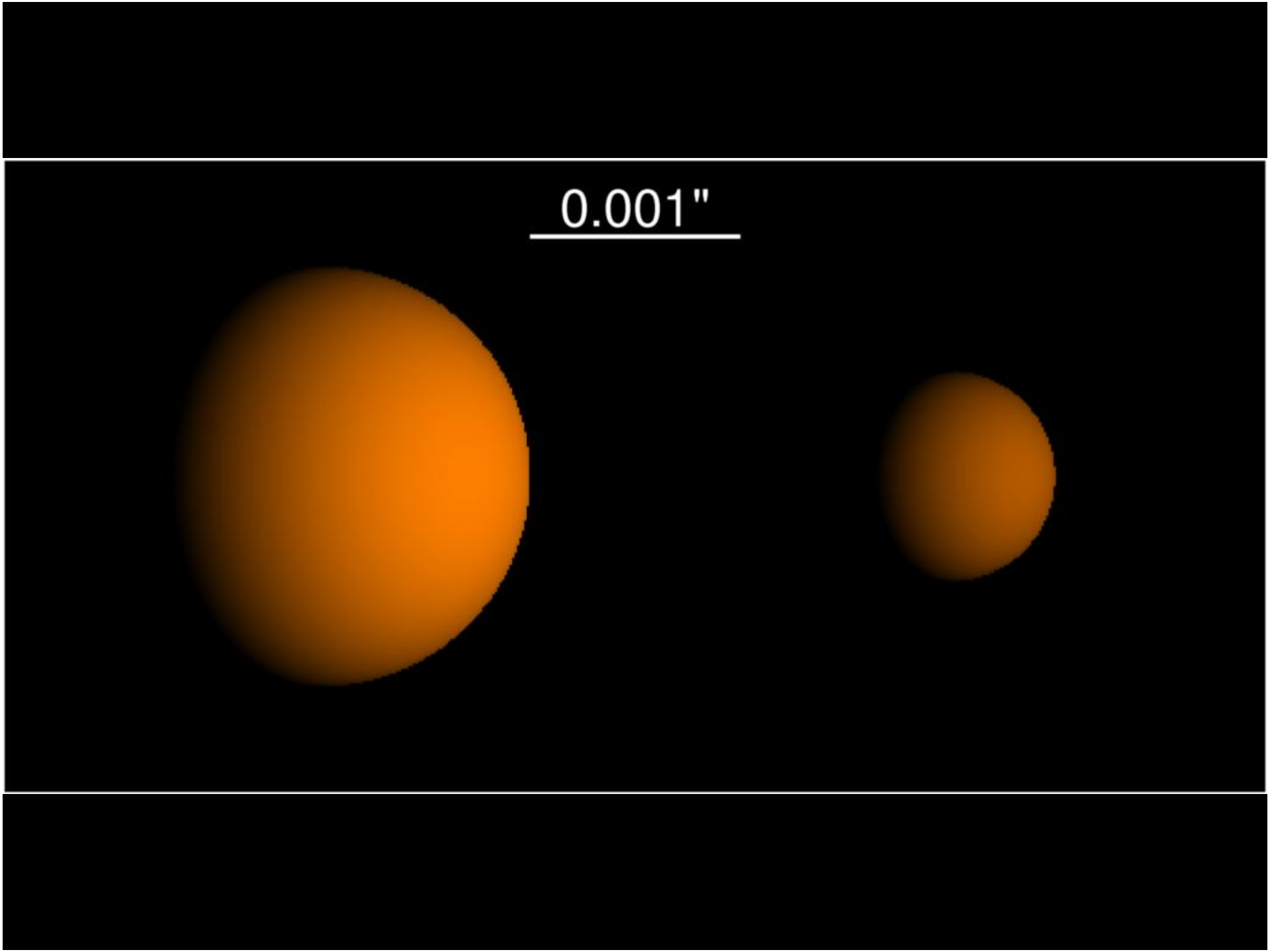
2.3% albedo, 2.6 km diameter

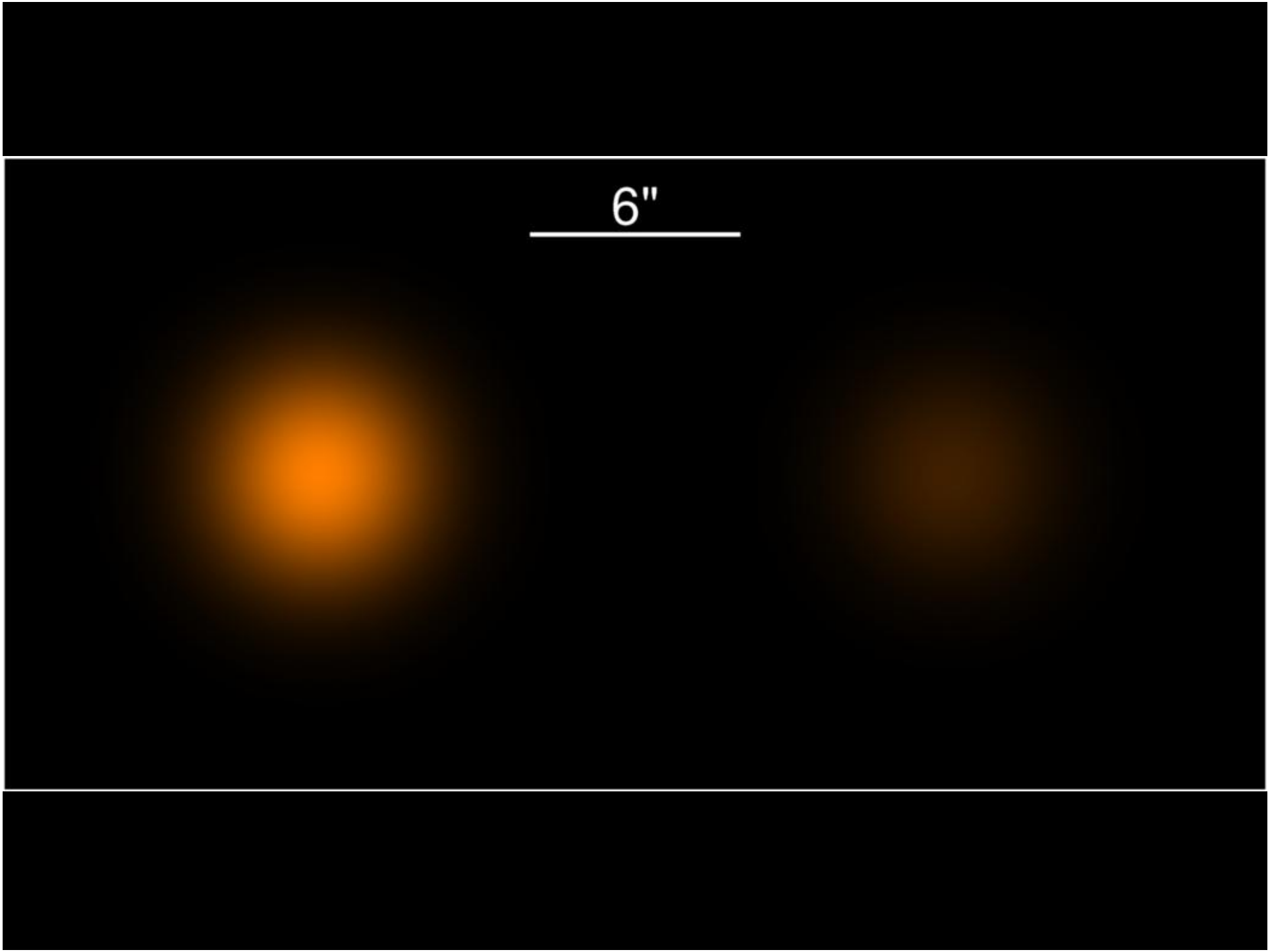
63% albedo, 0.5 km diameter

- 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.

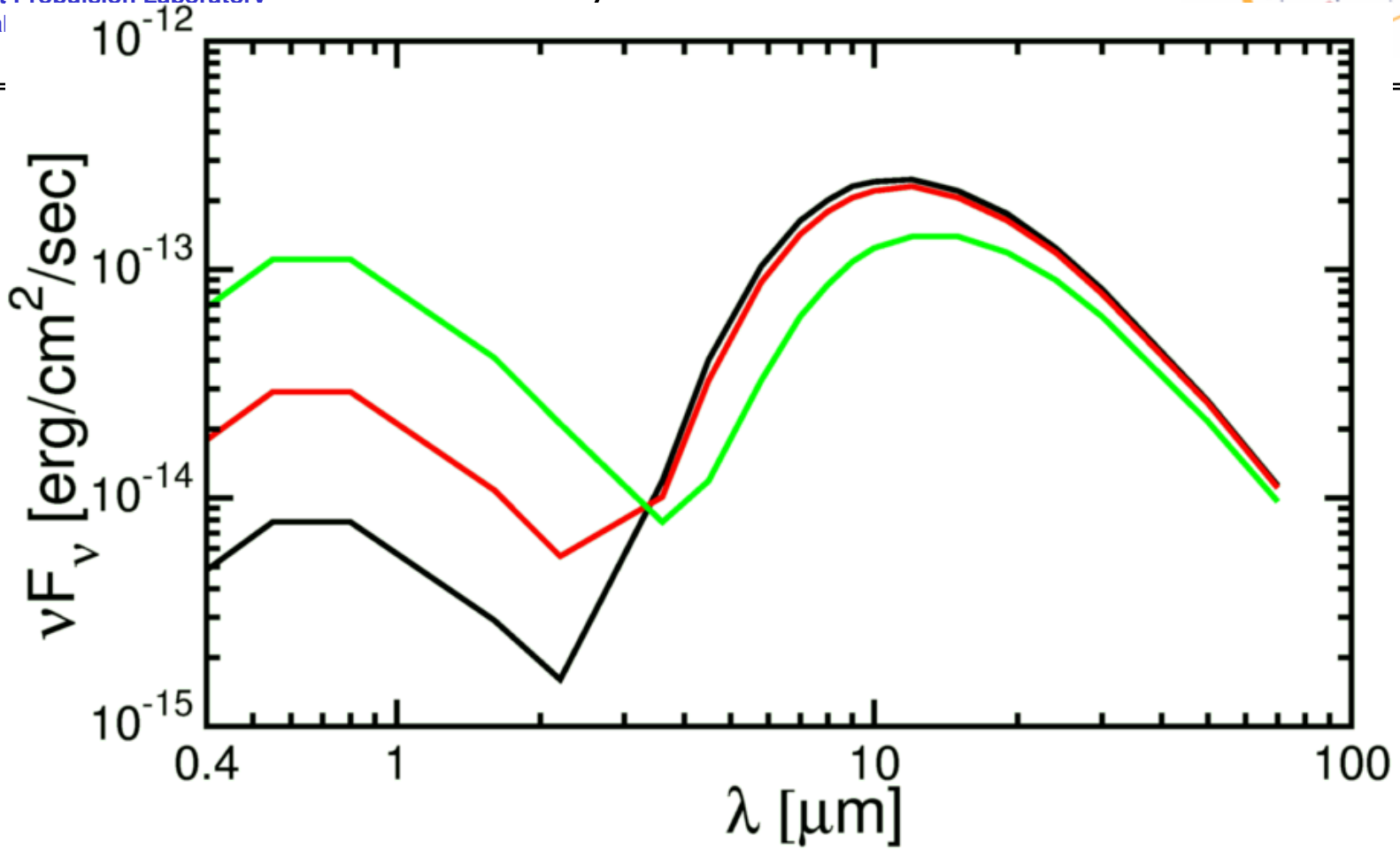

1"


0.001"


0.001"


6"

Utility of IR data



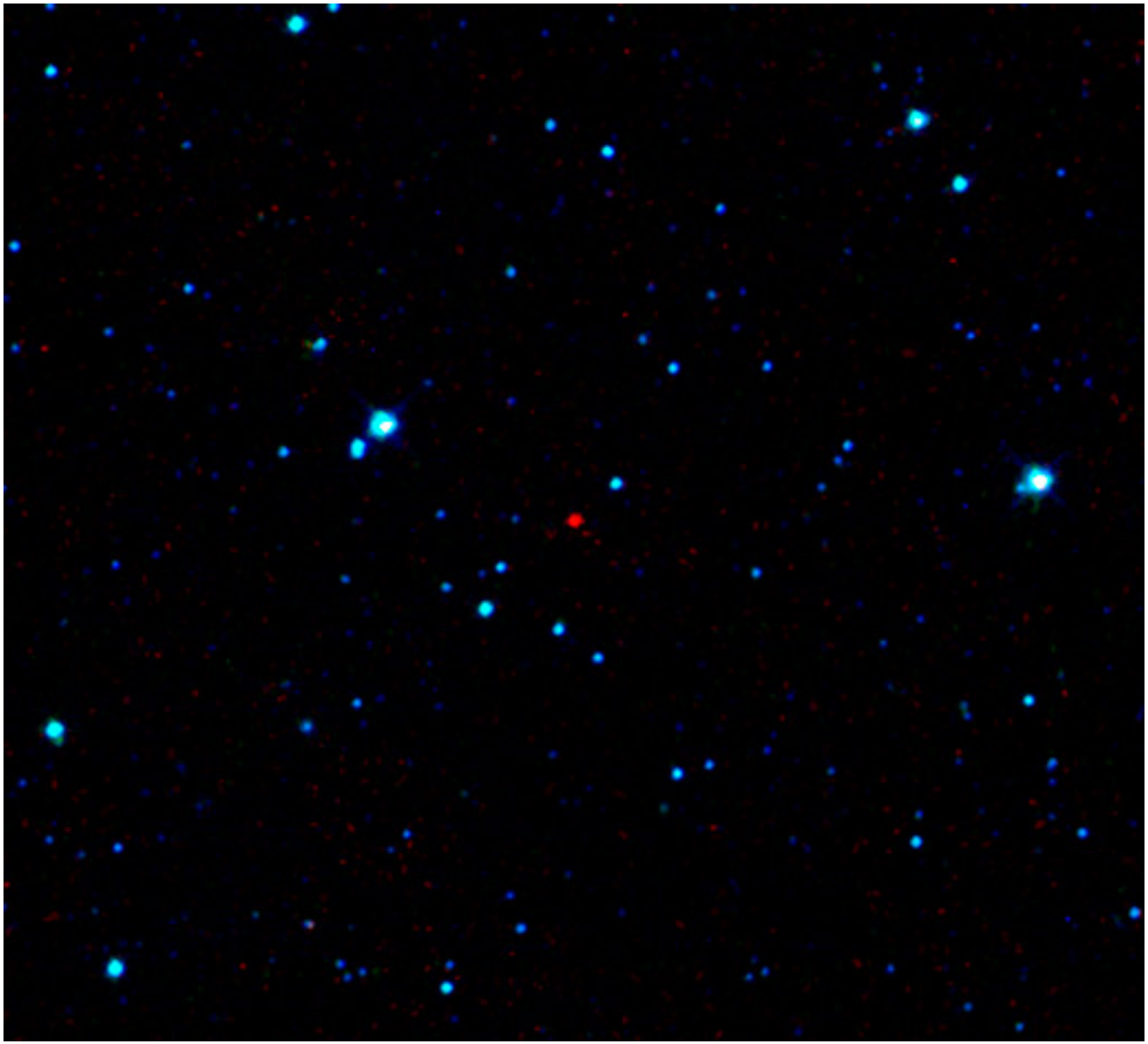
- Albedos of NEOs cover a wide range from 0.01 to 0.75 or more. This graph shows the flux of an NEO at 0.5 AU distance, 60º elongation, 150 m diameter, for albedo = 0.04, 0.145 & 0.52. Optical fluxes vary greatly, IR less so. IR+optical gives a good diameter, IR alone gives a fair diameter, optical alone gives a poor diameter.

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

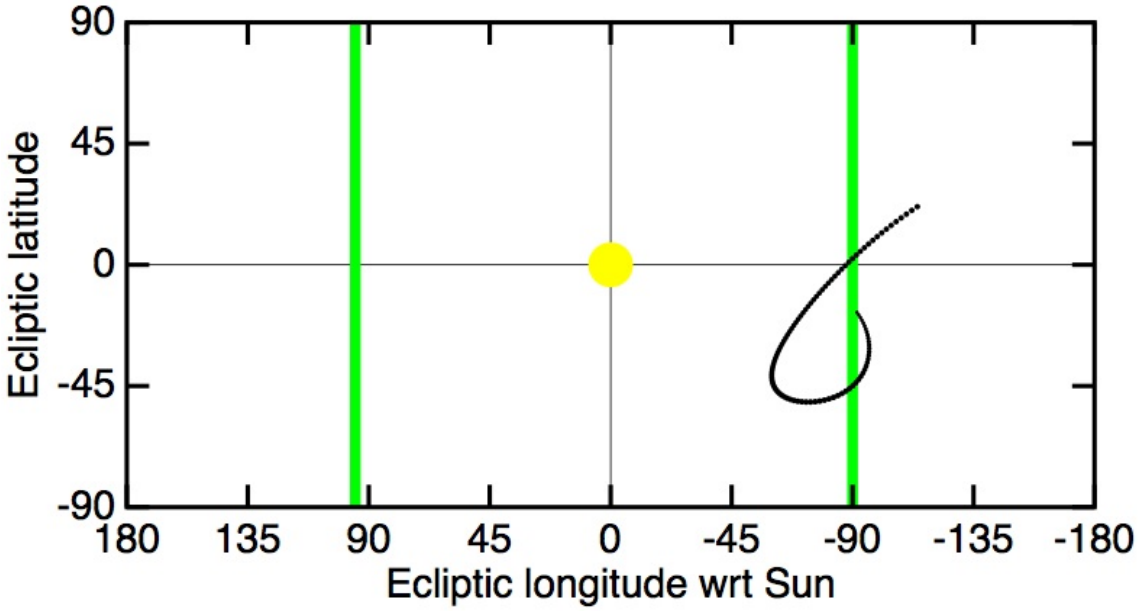
Wide-field Infrared Survey Explorer (WISE)

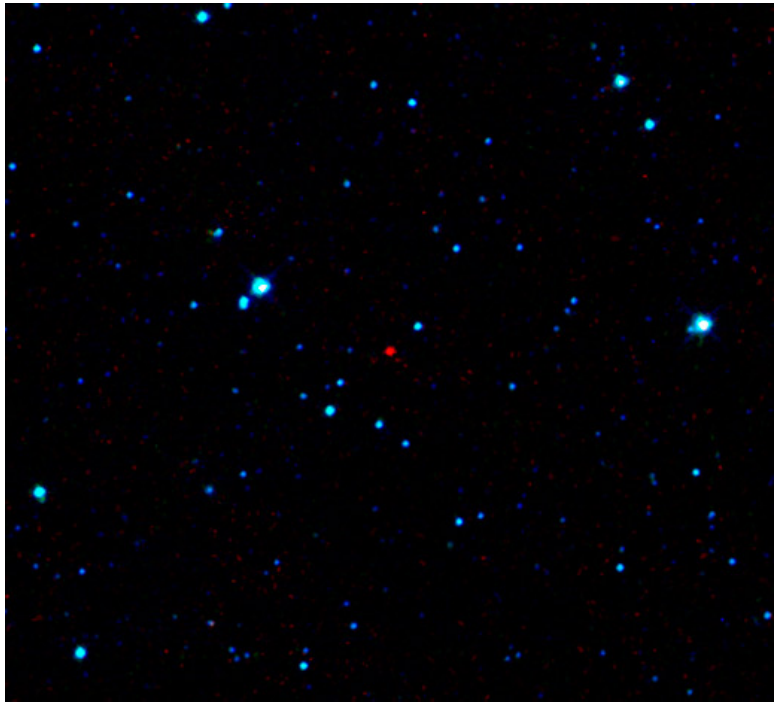
WISE's First NEO

- 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.



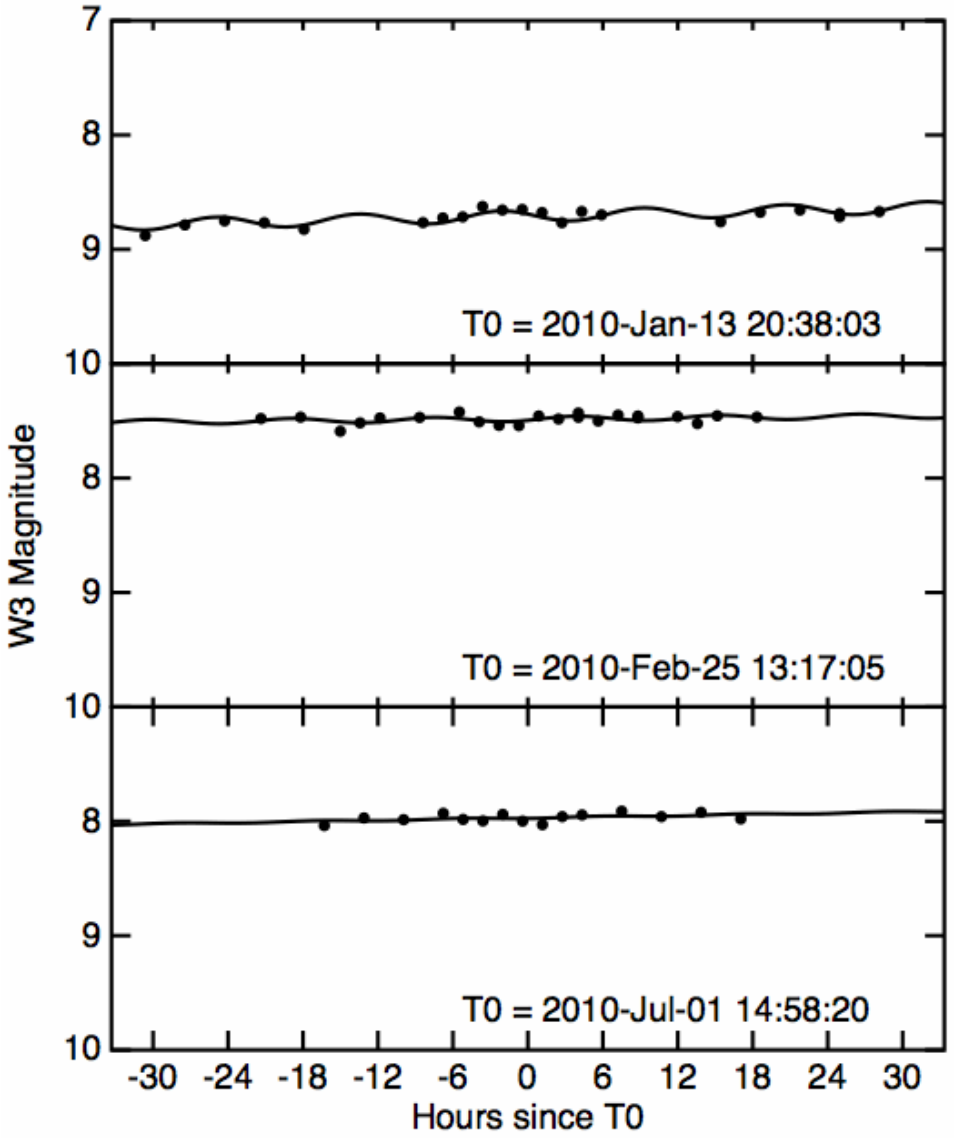
2010 AB_{78}


90
45
0
-45
-90
Ecliptic latitude
180
135
90
45
0
-45
-90
-135
-180
Ecliptic longitude wrt Sun



Magnitude vs time

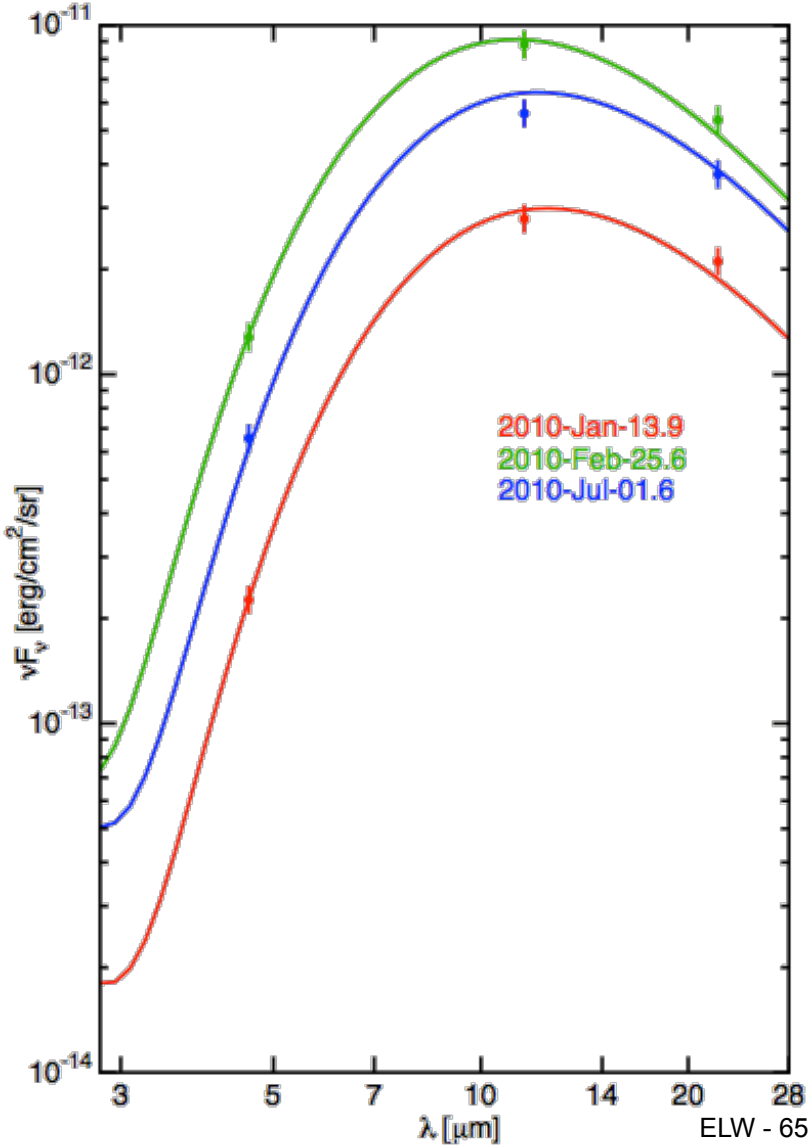
- In each apparition, fit to sloping baseline plus sinusoid
- Maximum amplitude seen is ±0.05 mag
- Period of sinusoid is 11.37 hours for a 22.74 hour rotation period.
- Could be aliased by orbital period sampling, if so rotation period is about 3 hours



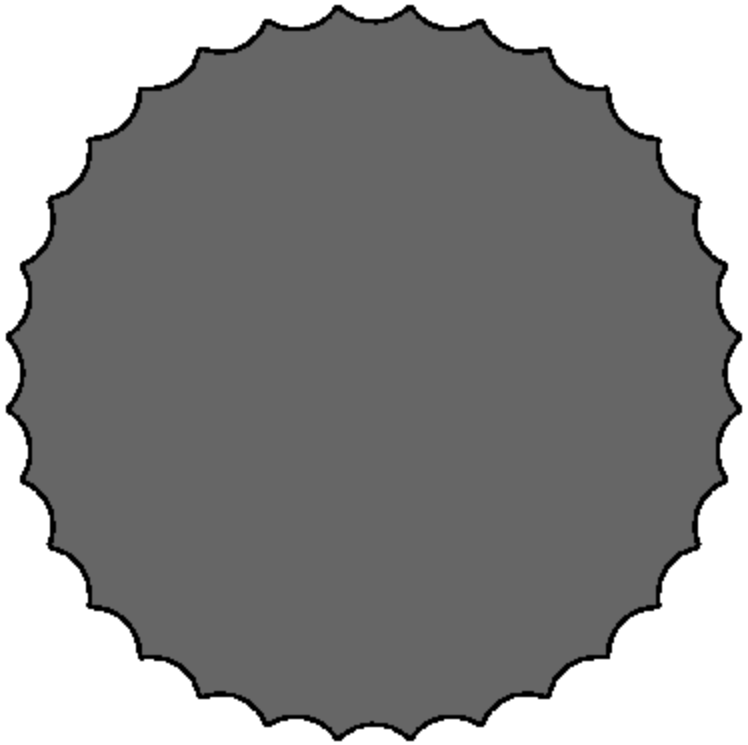
Near Earth Asteroid Thermal Model Fits

- 1 η, 1 D: chi^2 = 32.4
  - η = 0.92; D = 1.27 km
- 3 η, 1 D: chi^2 = 6.1
  - η = 0.90, 0.87, 1.17; D = 1.27
- 3 η, 3 D: chi^2 = 3.5
  - η = 0.93, 0.91, 1.03
  - D = 1.32, 1.32, 1.19 km

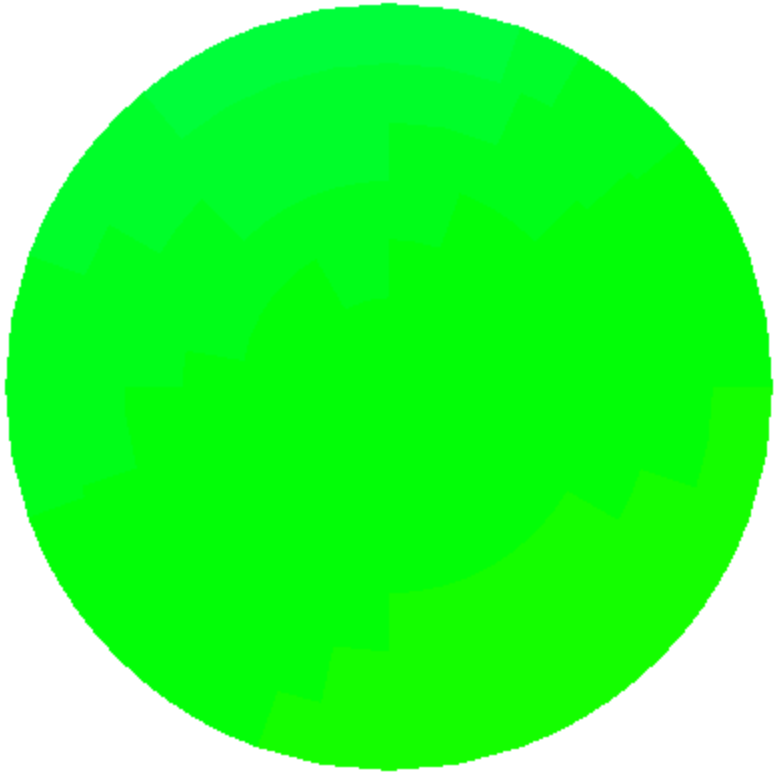
- η is the "beaming parameter" which adjust the surface temperature: high η gives a cooler surface.



Rotating Cratered Model

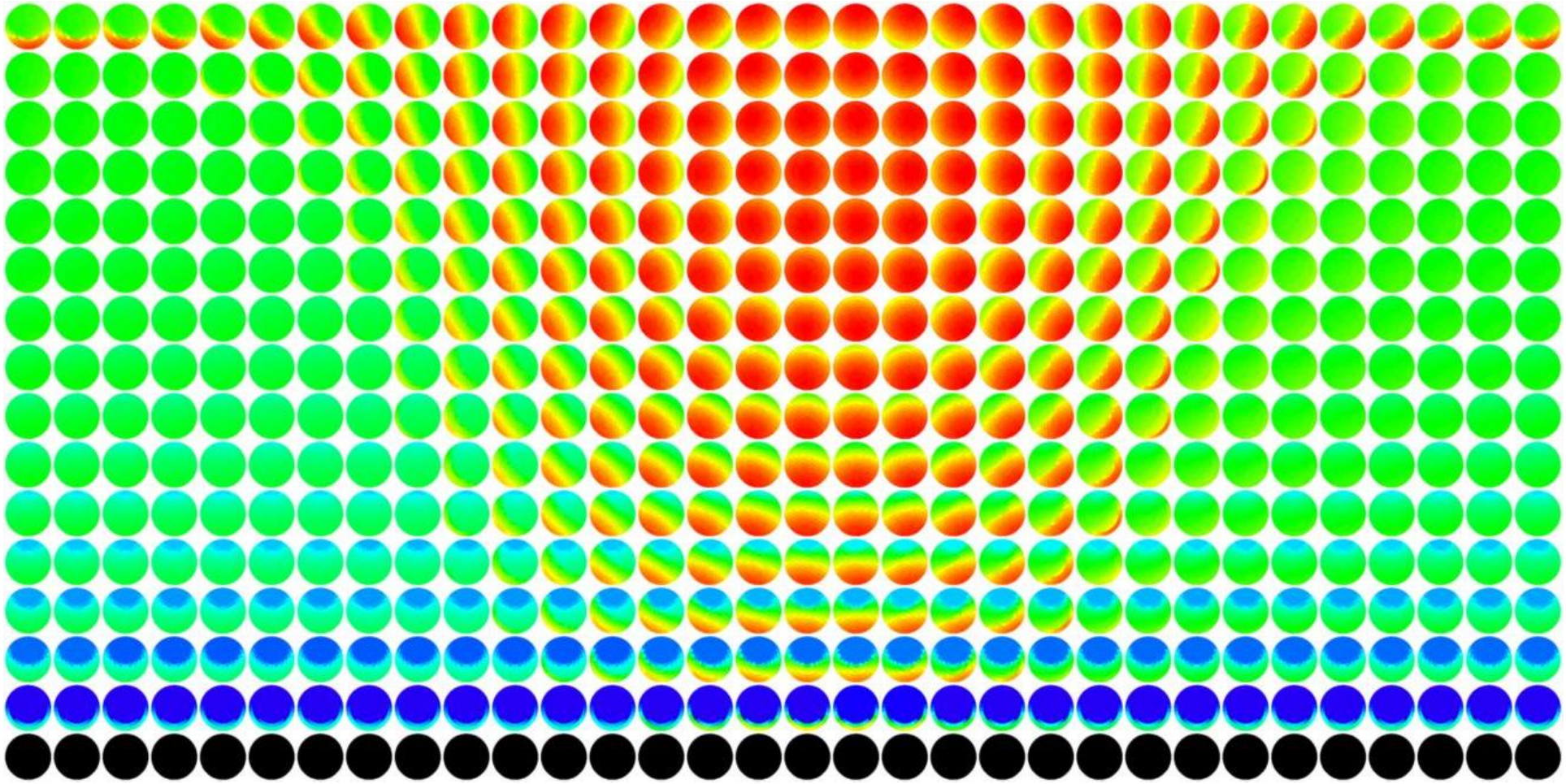


Crater temperature movie



- Latitude 19º, Sun latitude 30º

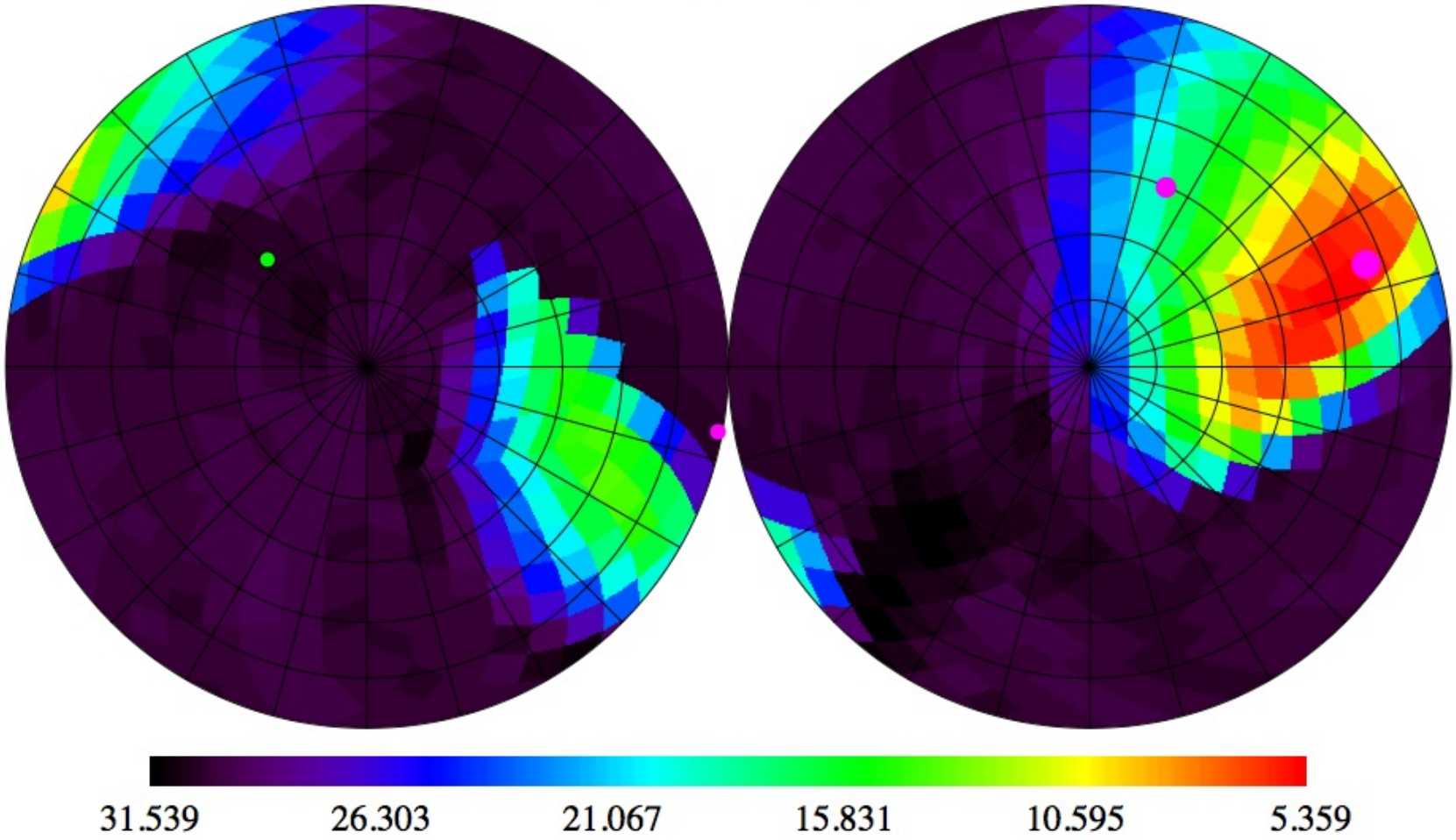
Overall Temperature Map



- 32 times, 16 latitudes

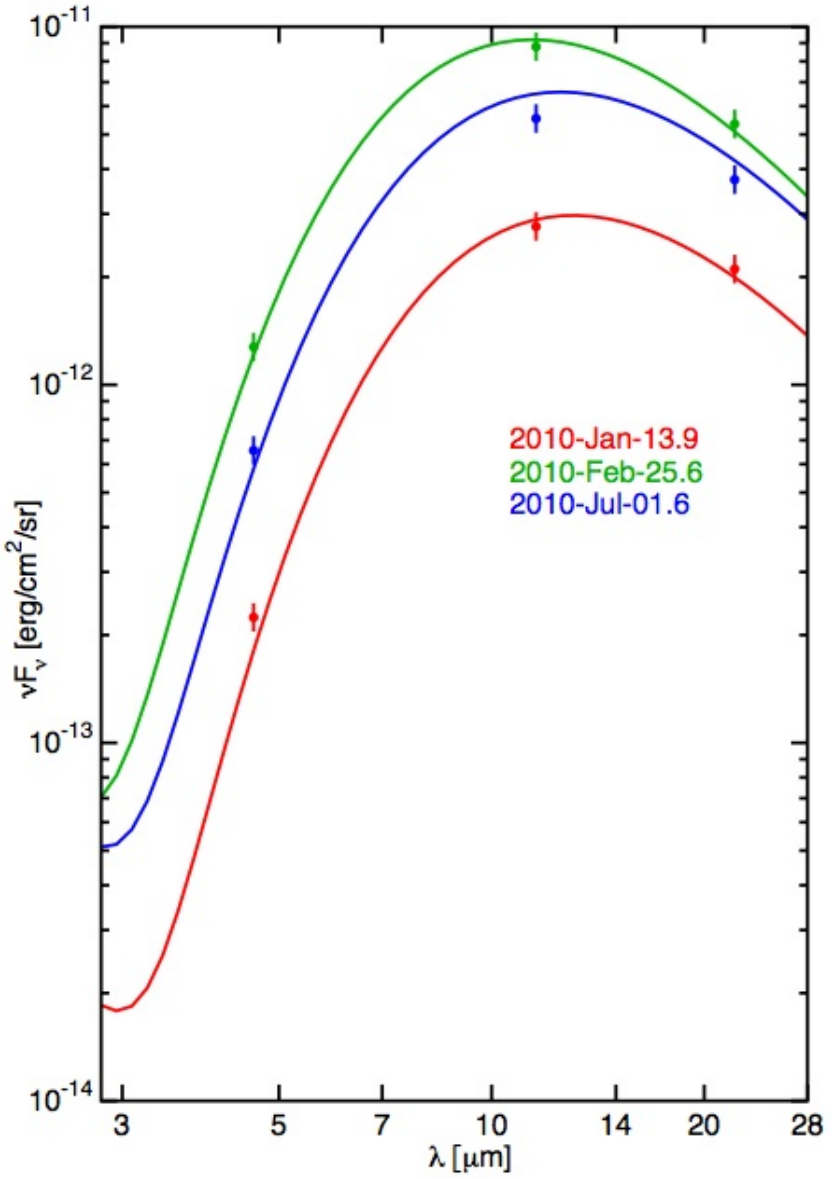
Scan for pole

Chi^2 vs Rotation Pole

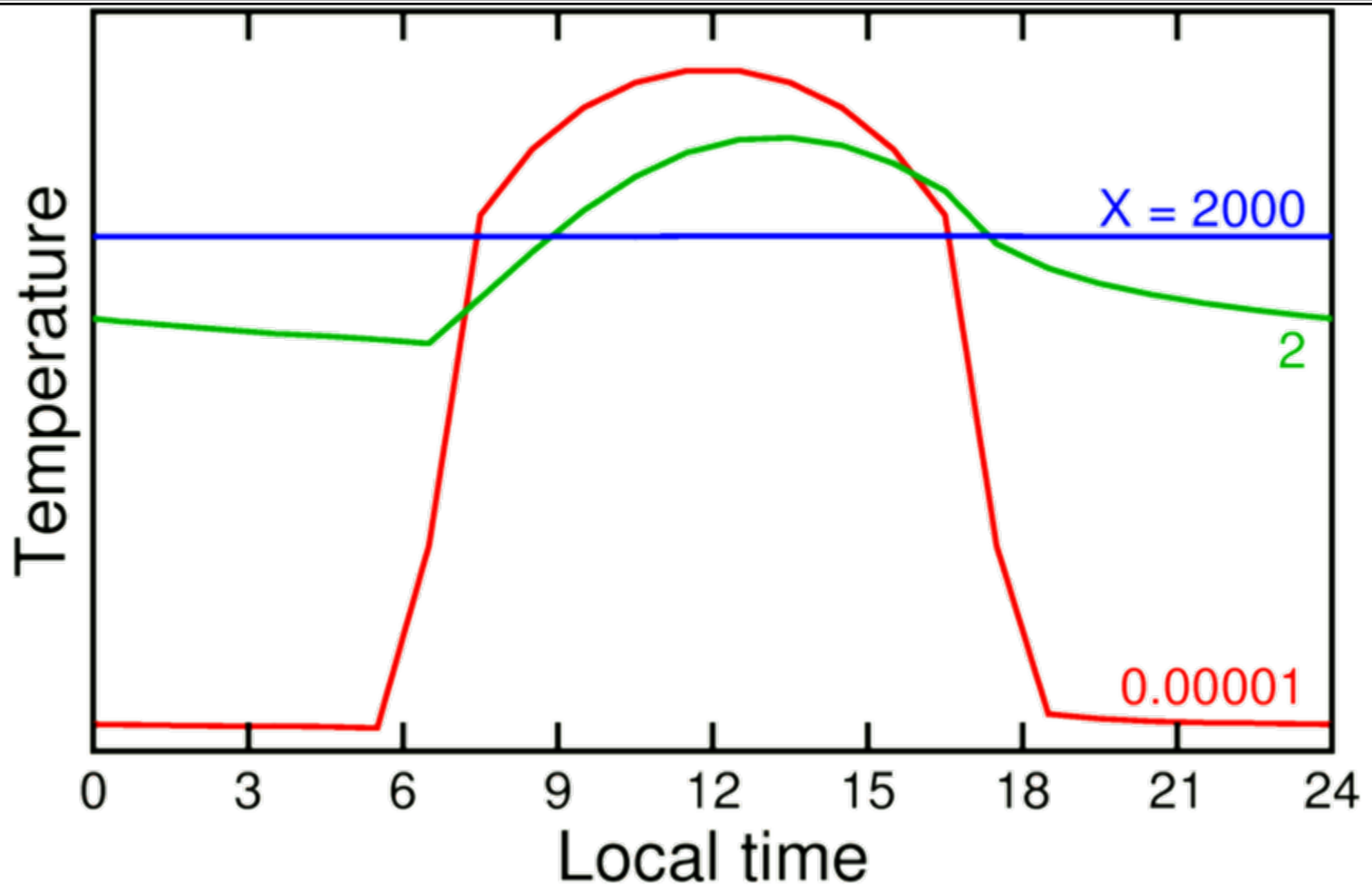


Results

- Pole at (α,δ) = (185±26°,-35±13°)
- Obliquity of pole is 90±17° with respect to the orbit
- Θ = 0.55 at 1 AU from Sun
- $\sqrt{\kappa\rho C}$ = 220 ± 110 J/K/m²/√s

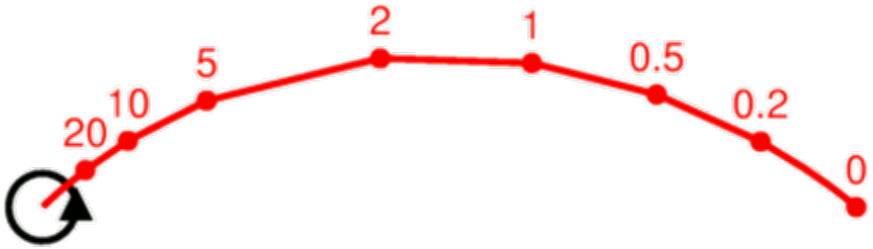


Yarkovsky Effect: Thermal Inertia



- It's hottest in the afternoon, so thermal reradiation creates a net force. X is a thermal inertia parameter.

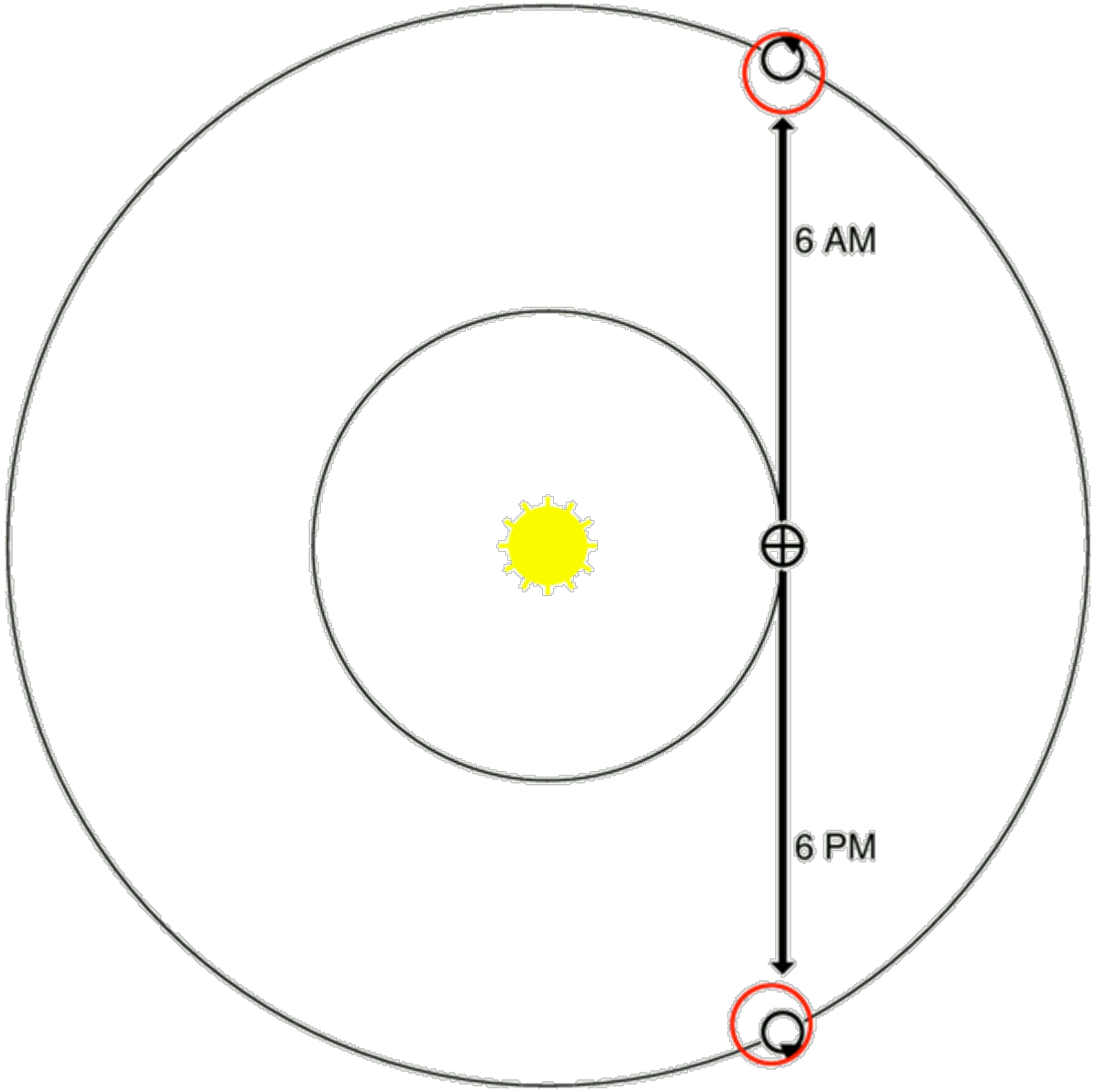
Yarkovsky Force vs Thermal Inertia X



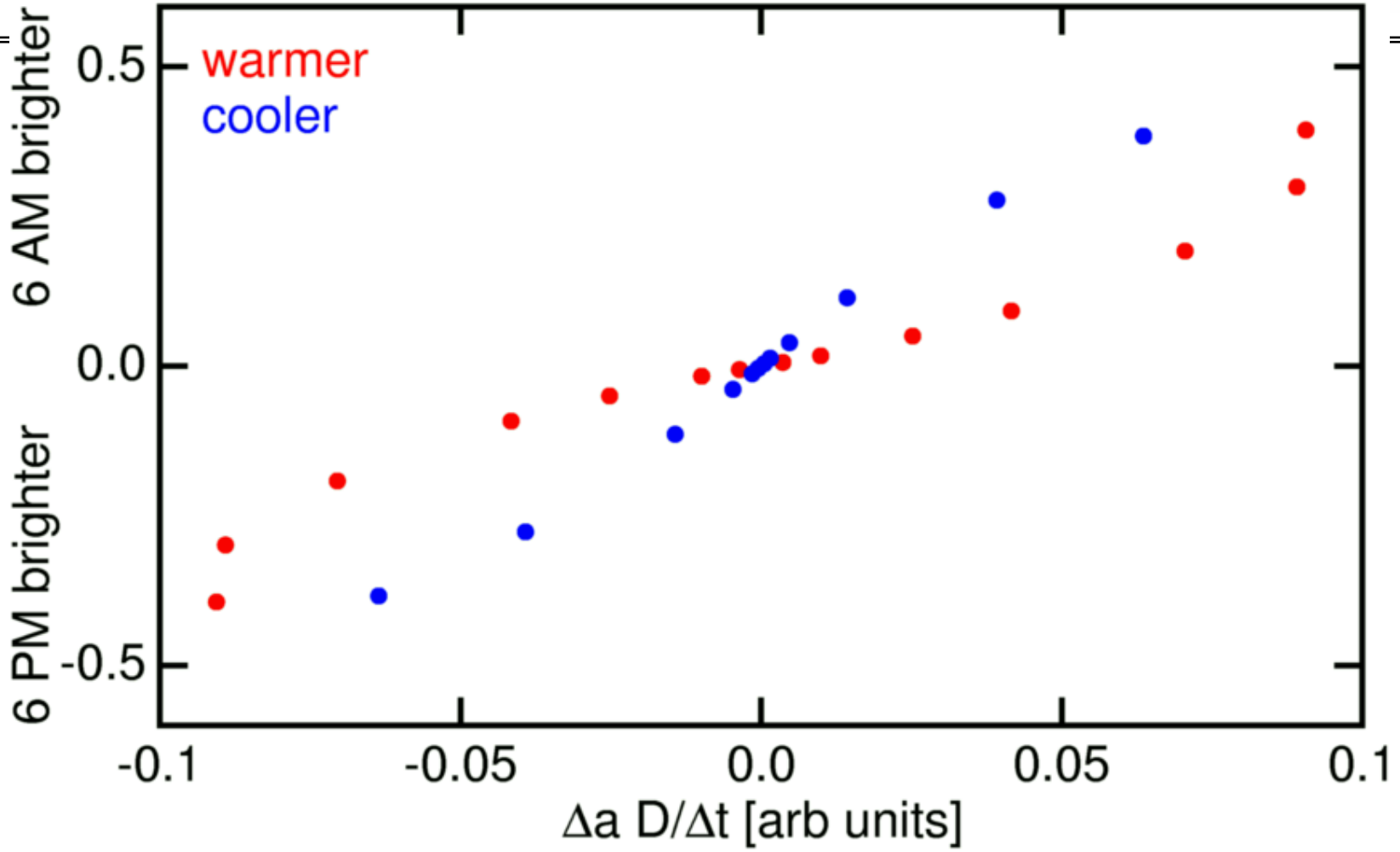
$$X = \frac{\sqrt{\kappa\rho C\Omega}}{\epsilon\sigma T_\odot^3} = \frac{I\sqrt{\Omega R^3}}{(\epsilon\sigma)^{1/4}[(1-A)L_\odot/4\pi]^{3/4}}$$

- X (often called Θ) is the dimensionless parameter indicating the importance of thermal inertia on the IR emission.
- In this diagram a mirror pointed at the Sun would give a force vector equal to the Sun-asteroid distance.
- Broad maximum about 20% of the solar radiation pressure gives force ∝ D^2 vs mass ∝ D^3 or an acceleration ∝ 1/D

Rotating Coordinate System

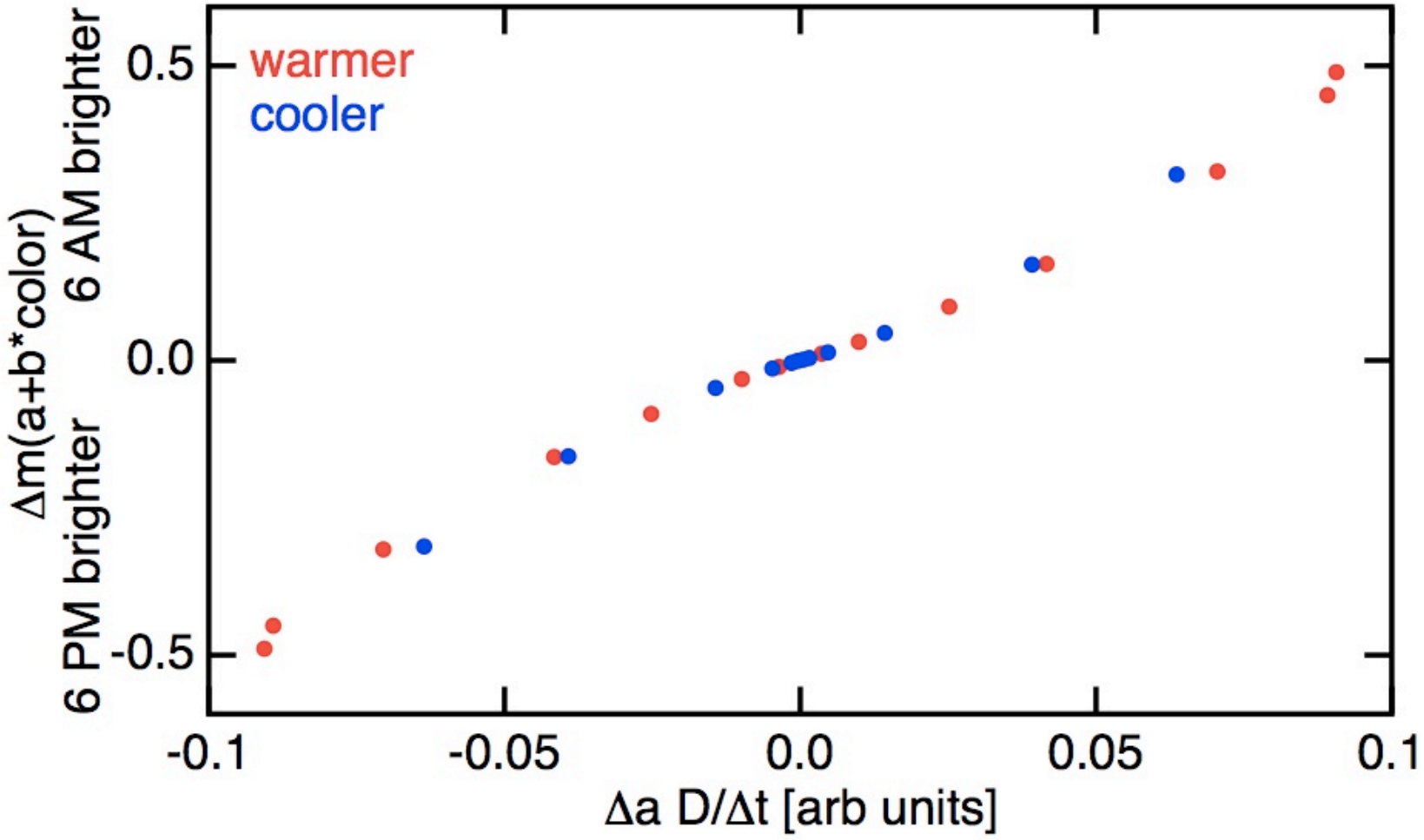


Can Measure Yarkovsky Force



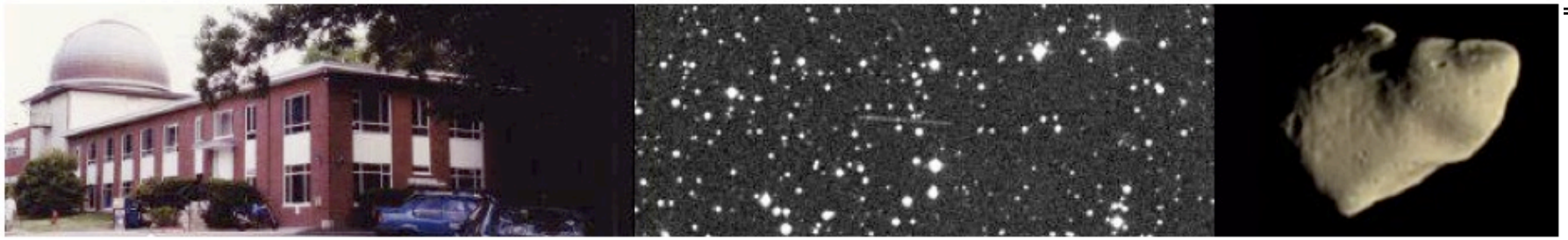
Y-axis shows the magnitude difference measurable by WISE, while the x-axis shows the transverse radiation force integrated over 4π. For a Baptistina family object with a = 2.3 AU.

After color correction



- Corrected using a linear function of the color

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.
Please ensure that you use the NEOCP designations when reporting follow-up observations. Do not use your own temporary designations: if you do, the observations will not get filed correctly by the automated routines.
Please report unsuccessful attempts to detect objects listed here that are NOT listed as 'updated' or that have not been updated in the past 24 hours. You may use the Observers Comment to report failed or successful attempts to observe these objects.
Please note that observations and orbits of objects accessible via this service are made available only for your personal use. They are not to be promulgated via any medium. The data are preliminary until they appear on an

Select object(s) from the current list of objects needing confirmation (discovery date, rough current position and magnitude given):

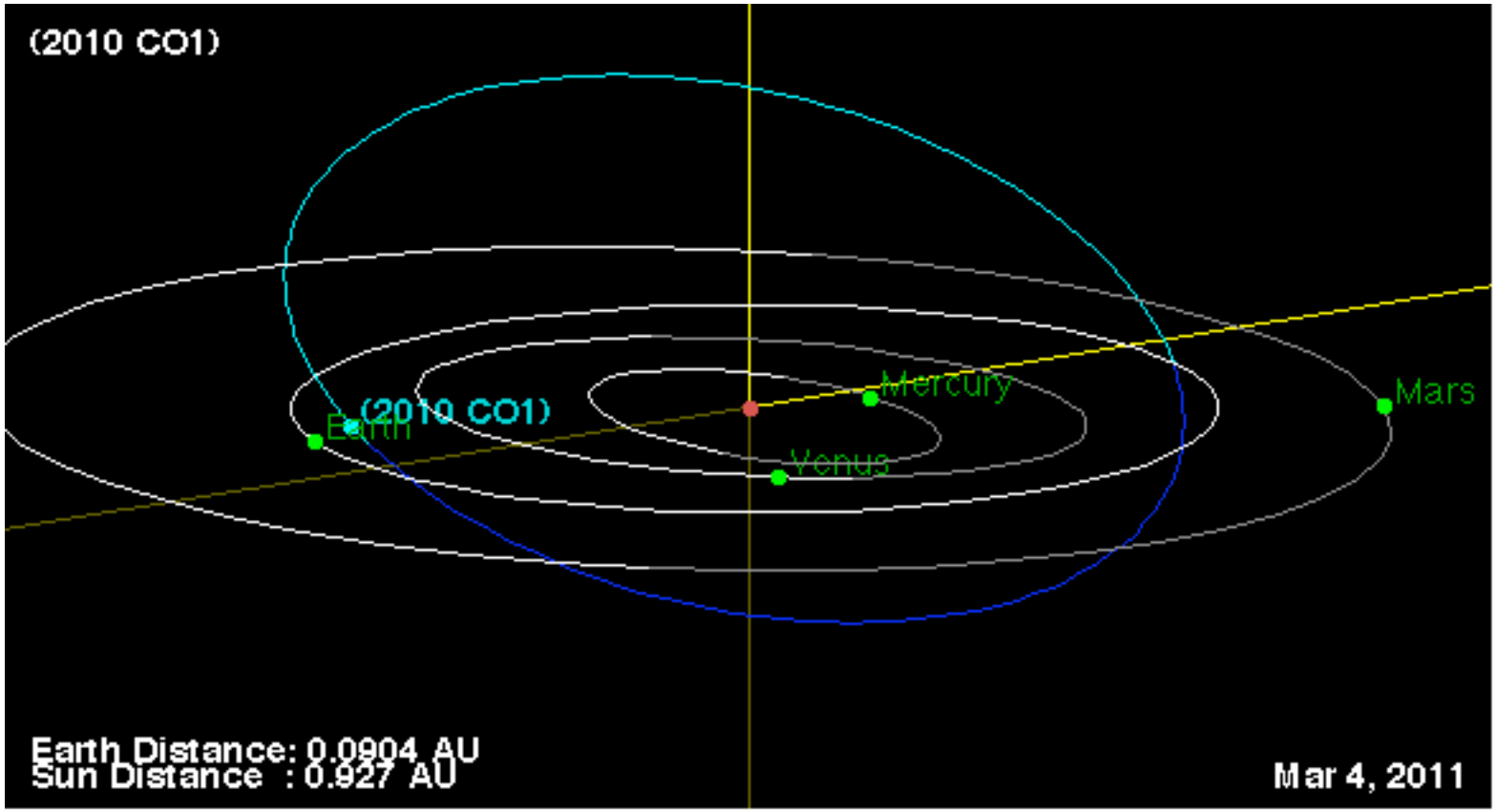
- ☑ W008y4c [2010 Feb. 26.3 UT. R.A. = 05 10.3, Decl. = -15 05, V = 22.5] Added Mar. 4.01 UT
- ☑ W008vzs [2010 Mar. 01.7 UT. R.A. = 05 10.4, Decl. = -02 09, V = 21.0] Updated Mar. 4.49 UT
- ☑ W008wvt [2010 Feb. 28.0 UT. R.A. = 17 15.0, Decl. = +41 55, V = 21.4] Updated Mar. 3.90 UT
- ☑ W008x40 [2010 Feb. 26.5 UT. R.A. = 06 36.2, Decl. = -73 03, V = 21.4] Updated Mar. 3.89 UT
- ☑ W008ure [2010 Feb. 25.6 UT. R.A. = 03 42.5, Decl. = +70 33, V = 21.6] Updated Mar. 3.14 UT
- ☑ W008u6s [2010 Feb. 23.7 UT. R.A. = 16 41.3, Decl. = -24 35, V = 22.3] Added Feb. 27.13 UT
- ☑ W008saa [2010 Feb. 19.1 UT. R.A. = 11 29.8, Decl. = -73 41, V = 20.7] Updated Feb. 23.54 UT
- ☑ W008qg4 [2010 Feb. 20.4 UT. R.A. = 07 30.1, Decl. = -76 50, V = 22.4] Updated Feb. 23.54 UT
- ☑ W008qf1 [2010 Feb. 19.3 UT. R.A. = 04 30.0, Decl. = +16 49, V = 21.5] Updated Feb. 23.54 UT

UCLA

- On 4 Mar 2010, 9 out of 9 candidate NEOs needing confirmation were WISE discoveries.

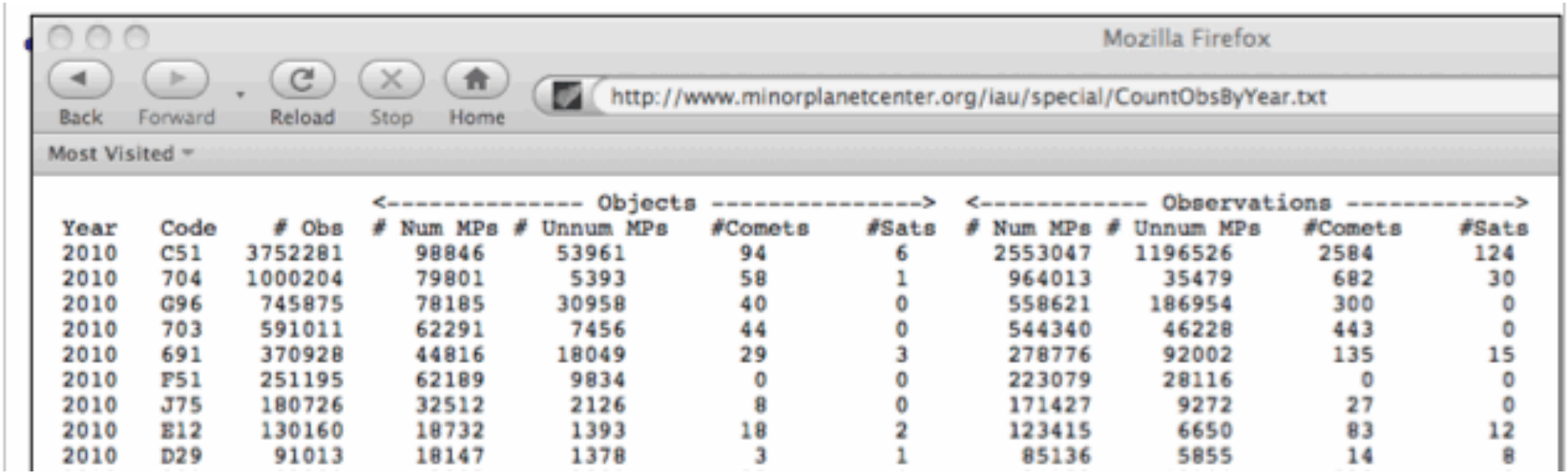
WISE's 1st PHA: 2010 CO1

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



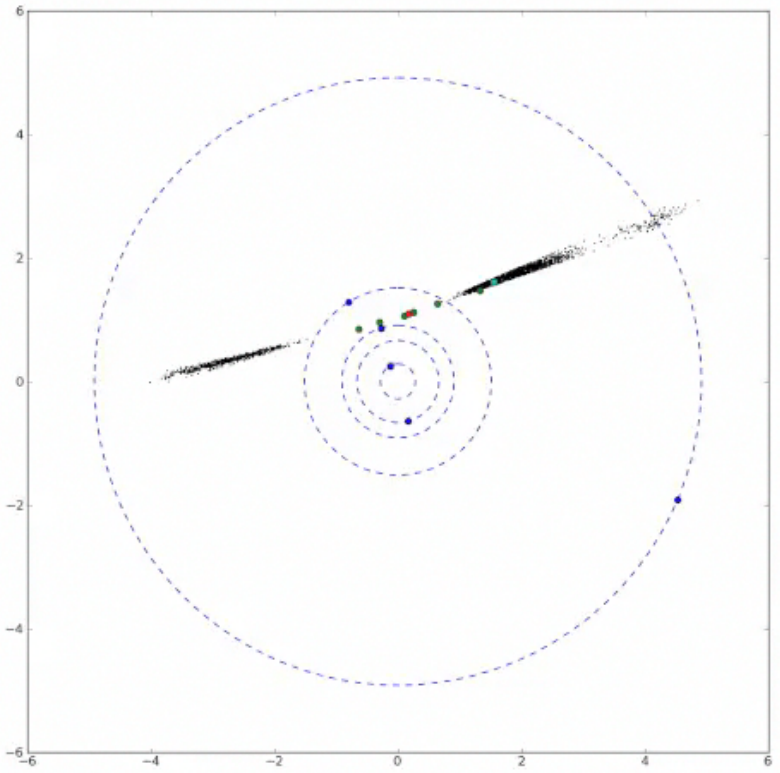
Thus WISE has

- Discovered many new Aten class and potentially hazardous asteroids, has determined give radiometric diameters for more than 150,000 objects.
- Nearly 4 million asteroid observations, the most of any observatory in 2010 so far.

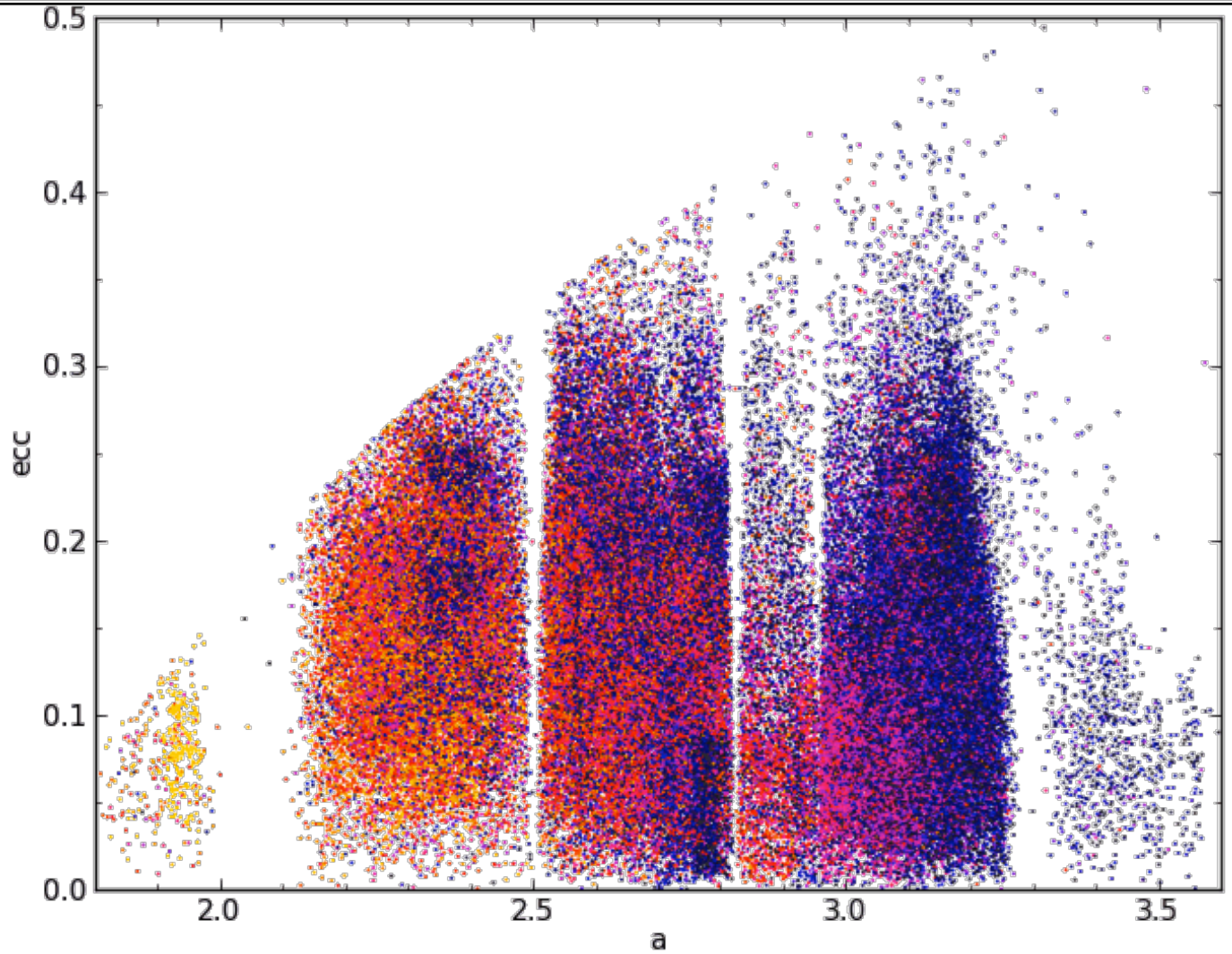


		<---------- Objects ---------->				<---------- Observations ---------->			
Year	Code	# Obs	# Num MPs	# Unnum MPs	#Comets	#Sats	# Num MPs	# Unnum MPs	#Comets	#Sats
2010	C51	3752281	98846	53961	94	6	2553047	1196526	2584	124
2010	704	1000204	79801	5393	58	1	964013	35479	682	30
2010	G96	745875	78185	30958	40	0	558621	186954	300	0
2010	703	591011	62291	7456	44	0	544340	46228	443	0
2010	691	370928	44816	18049	29	3	278776	92002	135	15
2010	F51	251195	62189	9834	0	0	223079	28116	0	0
2010	J75	180726	32512	2126	8	0	171427	9272	27	0
2010	E12	130160	18732	1393	18	2	123415	6650	83	12
2010	D29	91013	18147	1378	3	1	85136	5855	14	8

WISE observed asteroids



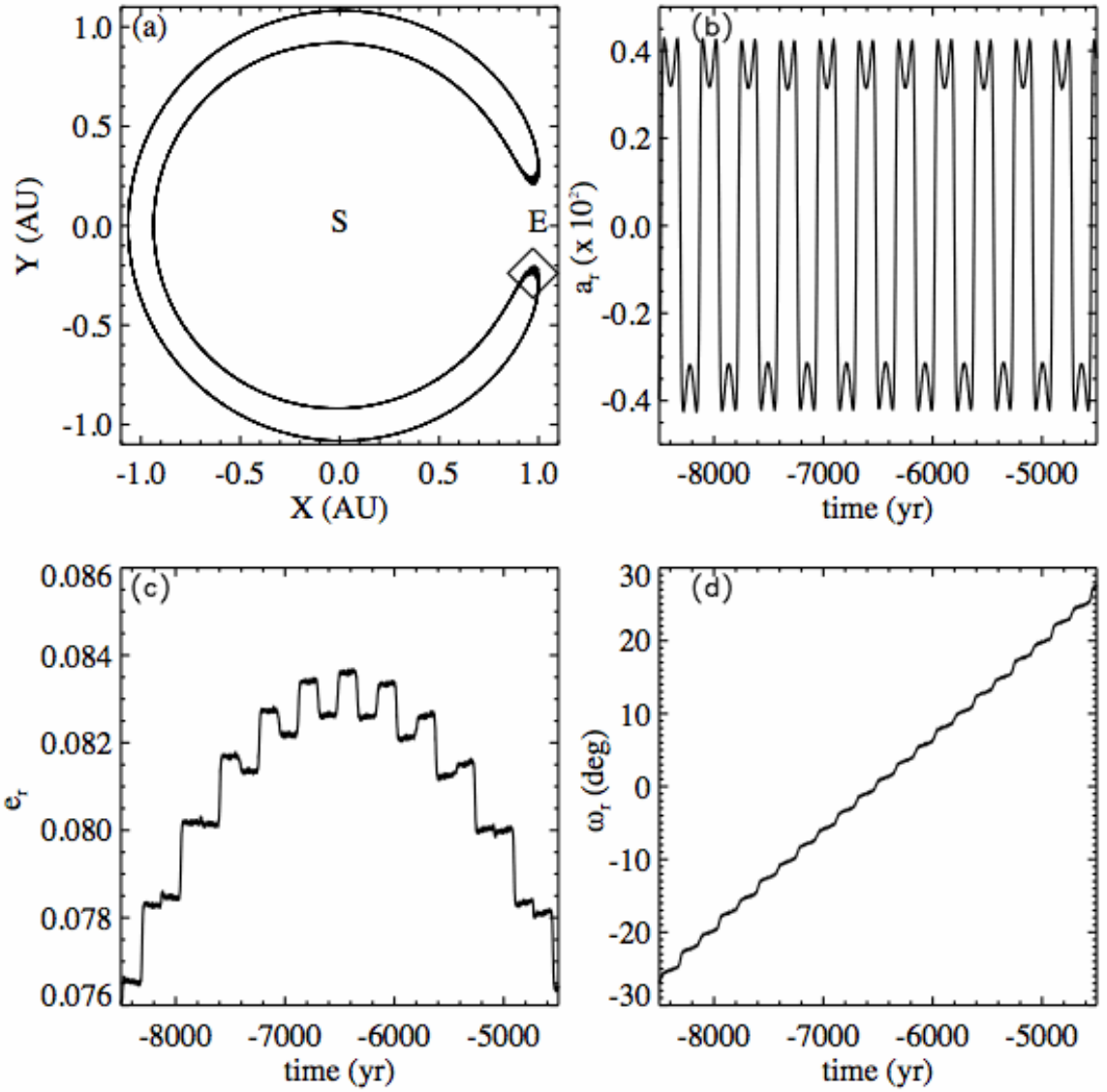
>100,000 Measured Albedos



Color shows albedo – Masiero etal 2011, arXiv:1109.4096

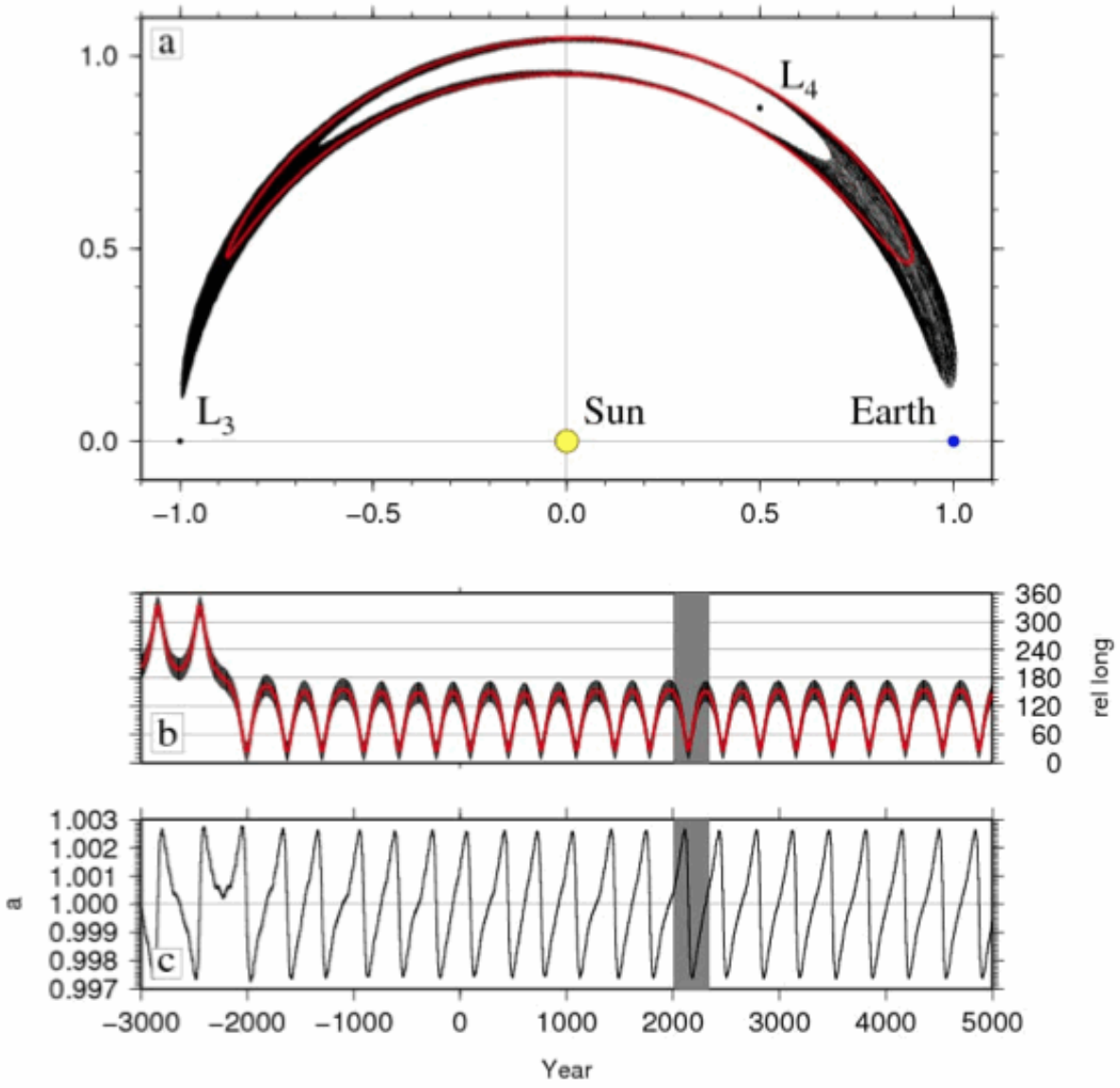
Big Horseshoe Orbit Object

- 2010 SO16 stable for 3×10^5 years
- Origin unclear
- Note that radial excursion magnified by 20× in this figure
- Plots show the guiding center in frame co-rotating with Earth
- Christou & Asher, arXiv:1104.0036

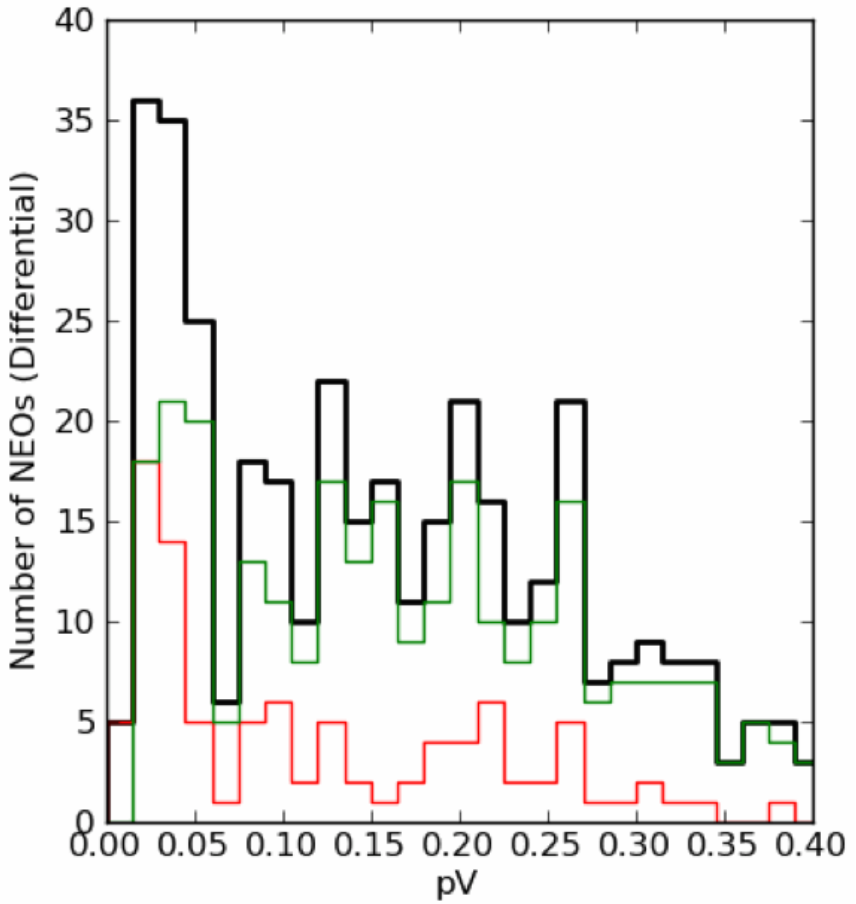


2010 TK7: First Earth Trojan?

- Connors et al, 2011, Nature, 475, 481
- Big libration about L4 allowed WISE to see it 90° from Sun
- Stable for 10,000 years
- WISE data on size to be analyzed but first glance suggests it is pretty dark and a few hundred meters



NEO Albedo Distribution

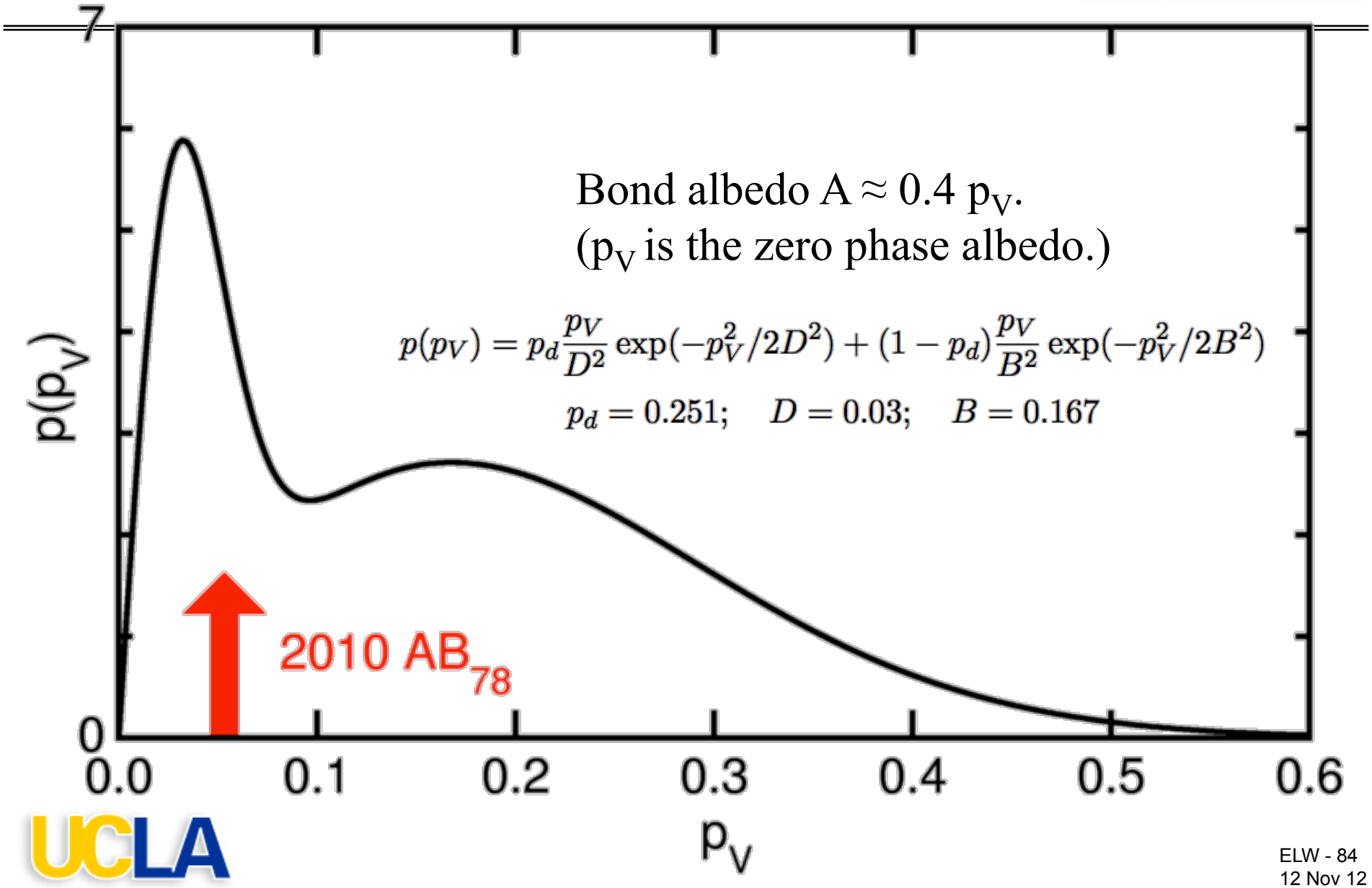


Total
WISE discoveries
Previously known

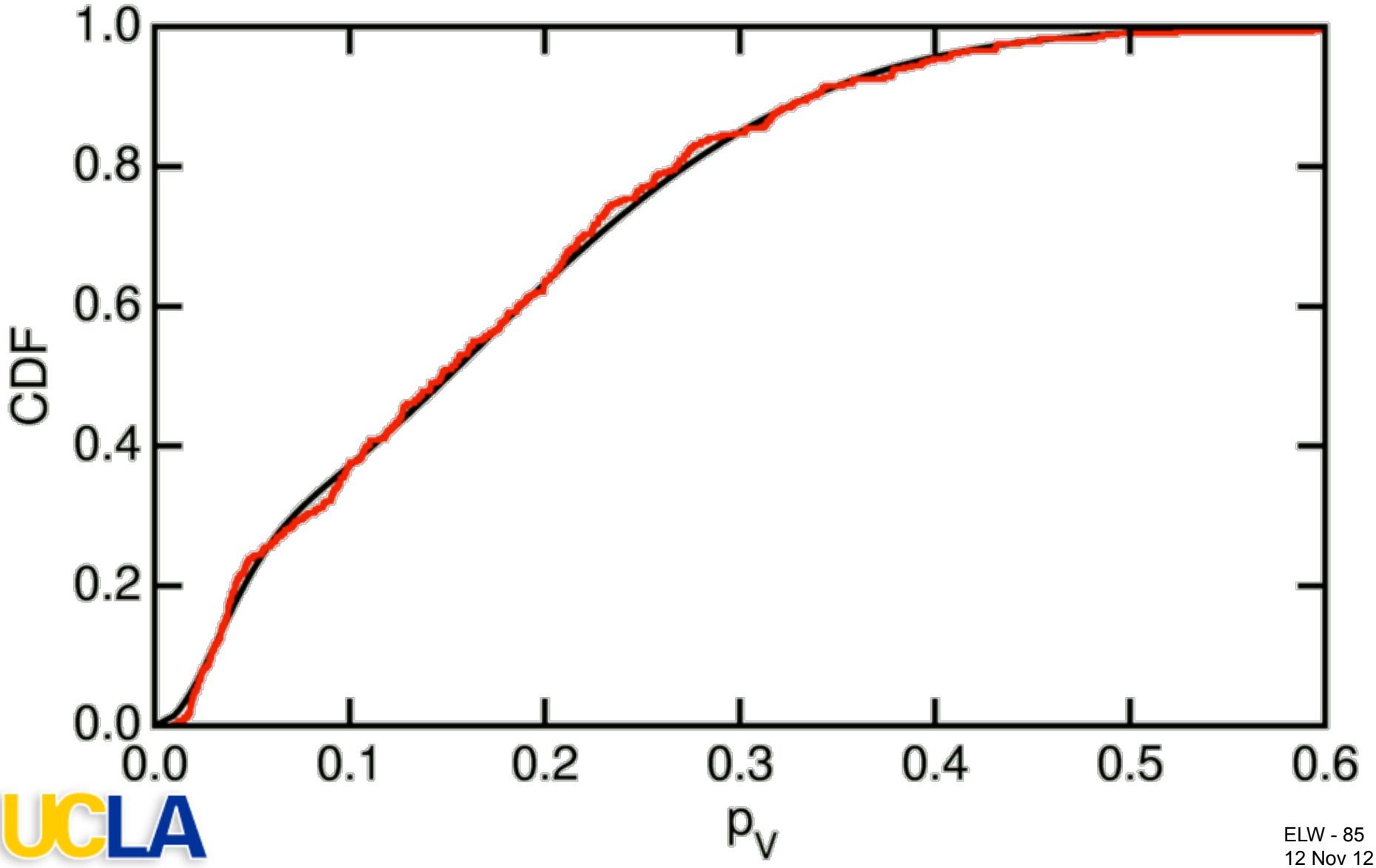
- Some very dark NEOs found, but not a whole bunch
- Estimate 13200±1900 NEOs > 140 meter diameter

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

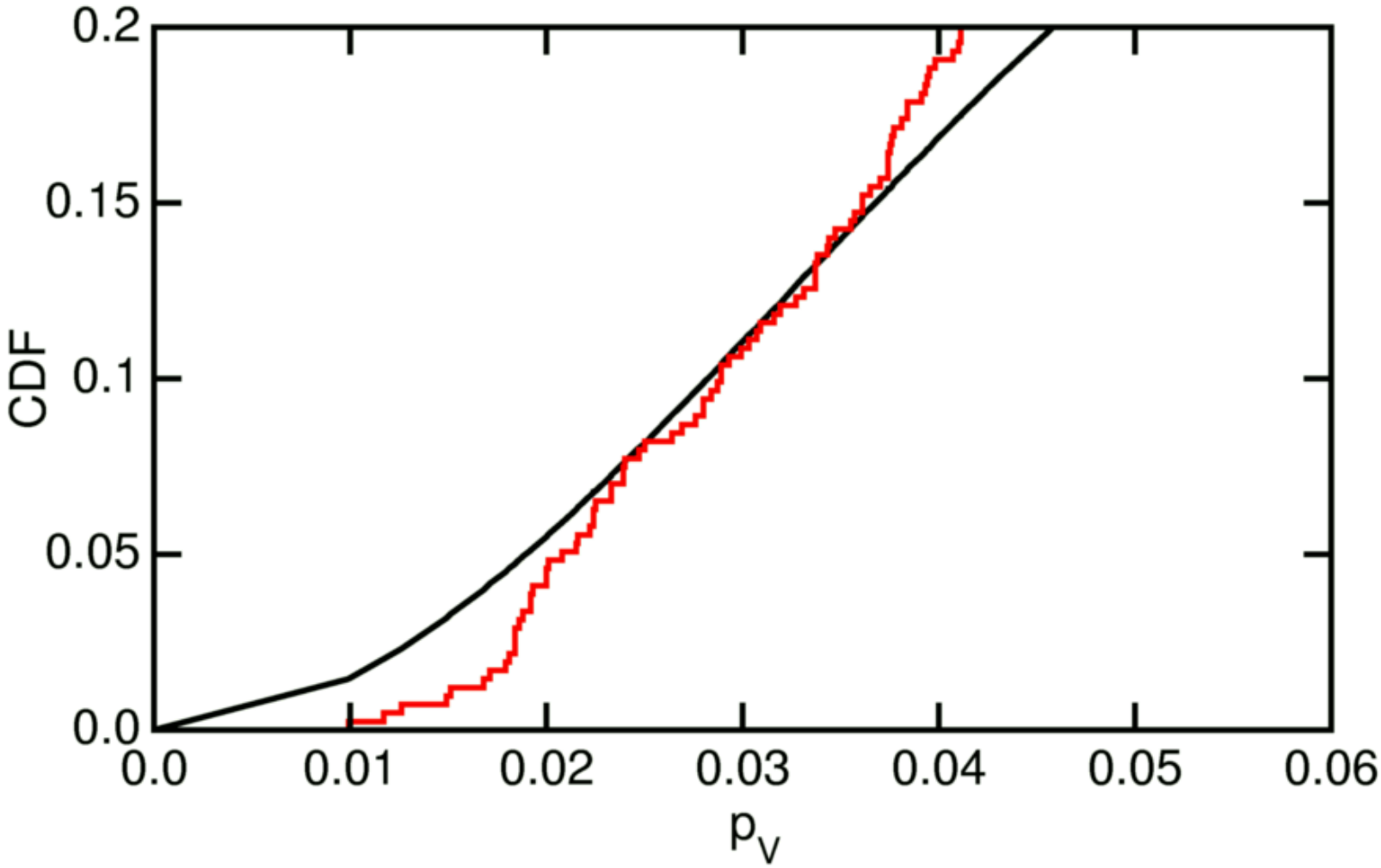
NEO albedo distribution model



Good K-S test

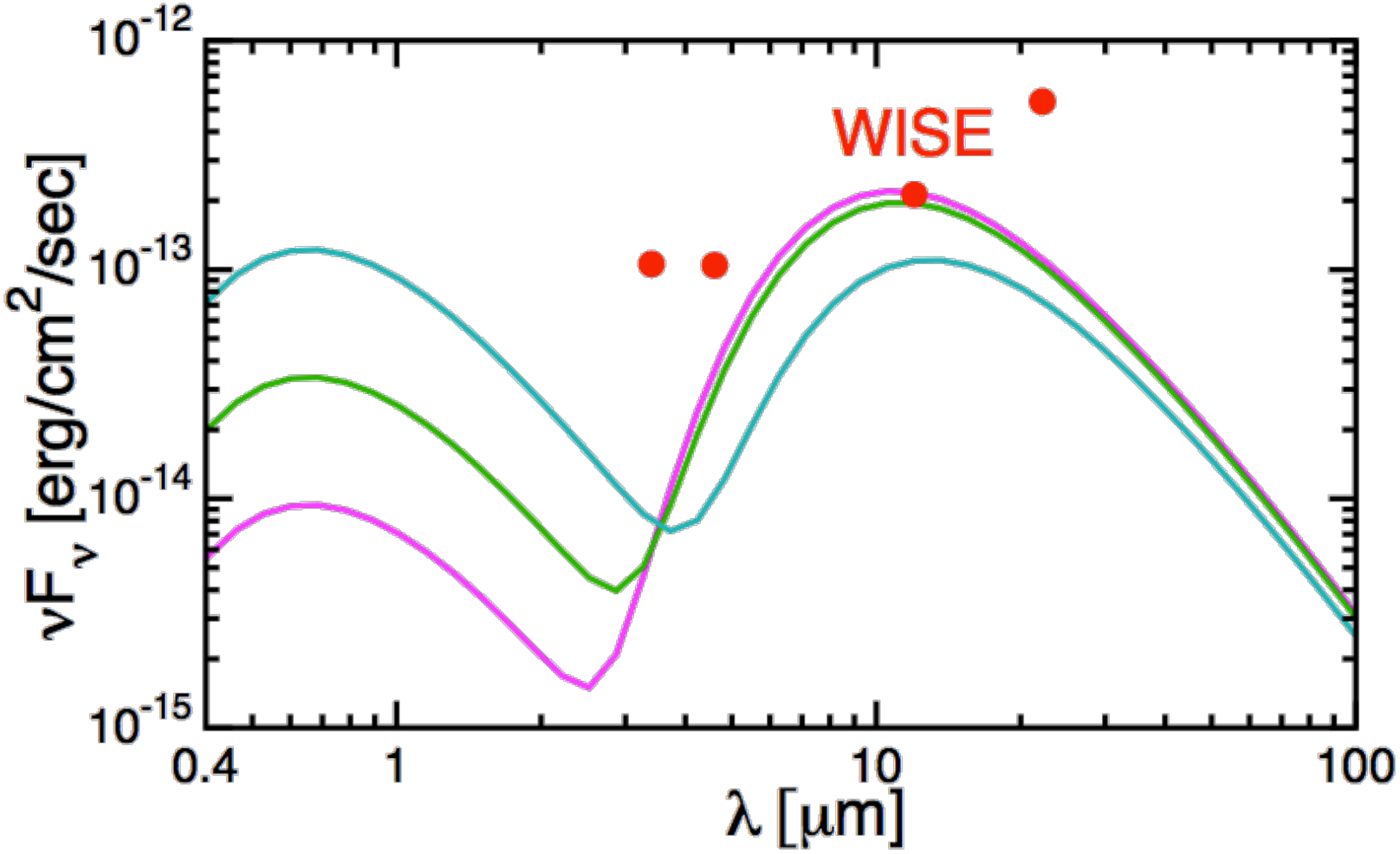


To Reach 90%



- Need to scope optical survey with $p_V = 0.03$ or absolute magnitude H = 23.7 for 140 meter diameter

NEO Detectability

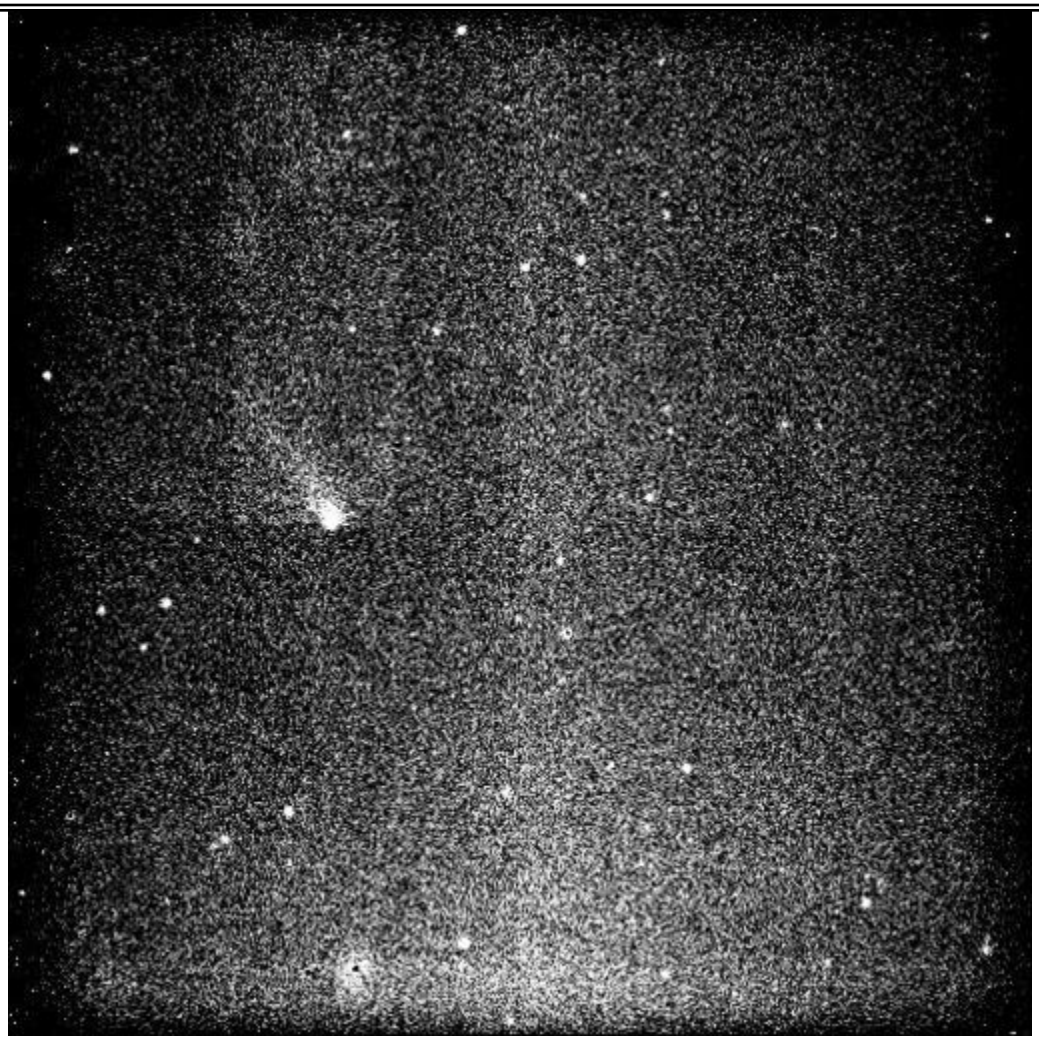


- 130 m diameter at 0.5 AU, 90^o elongation
- 0.04, 0.145 and 0.52 albedos

Comets

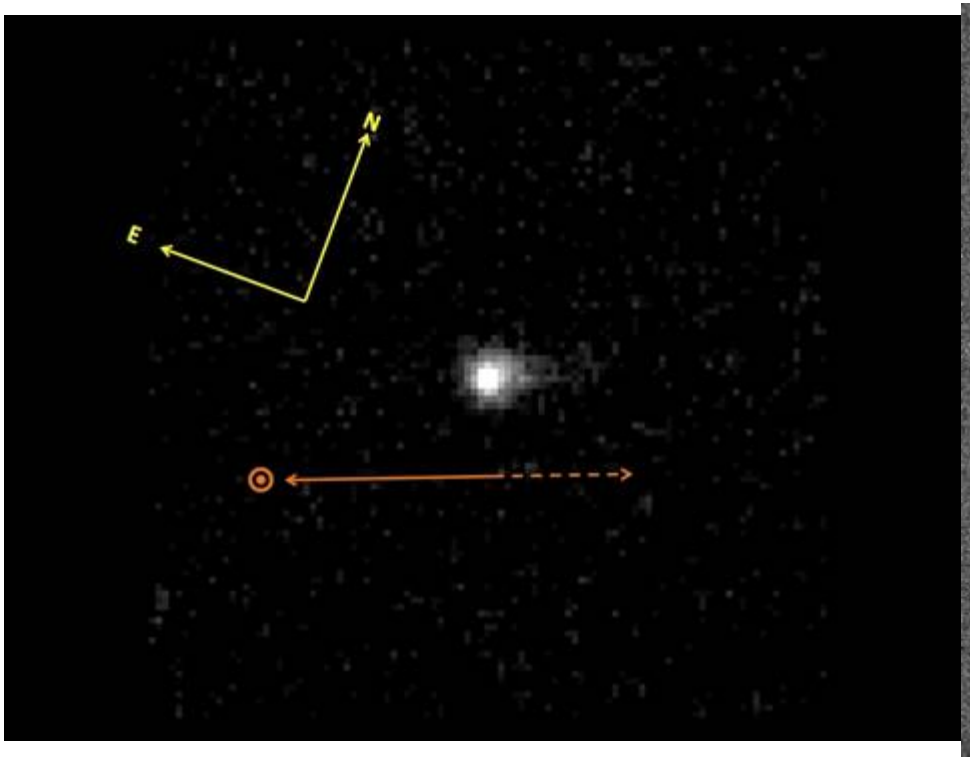
- Red giants are blue, and comets are red.
- M3 globular cluster and Comet Garradd
- WISE Image of the Week posted 26 Mar 2010

I "found" a comet

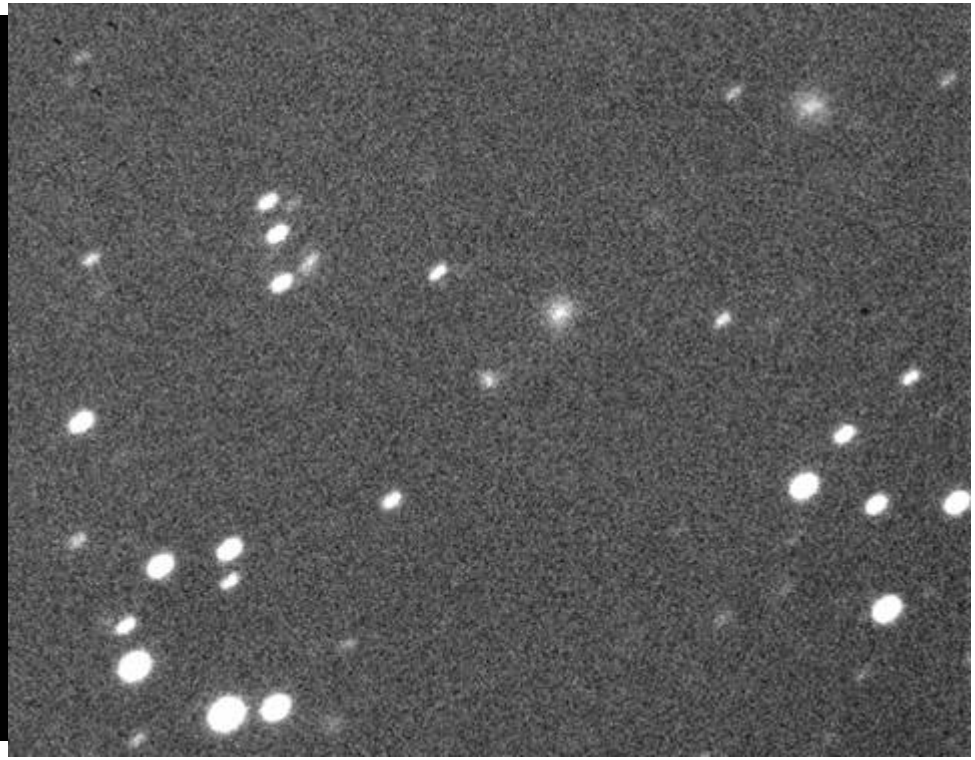


- Already known: Comet N1 2008 (Holmes)
- Not the big outburst Comet Holmes

Comet P/2010 B2 (WISE)



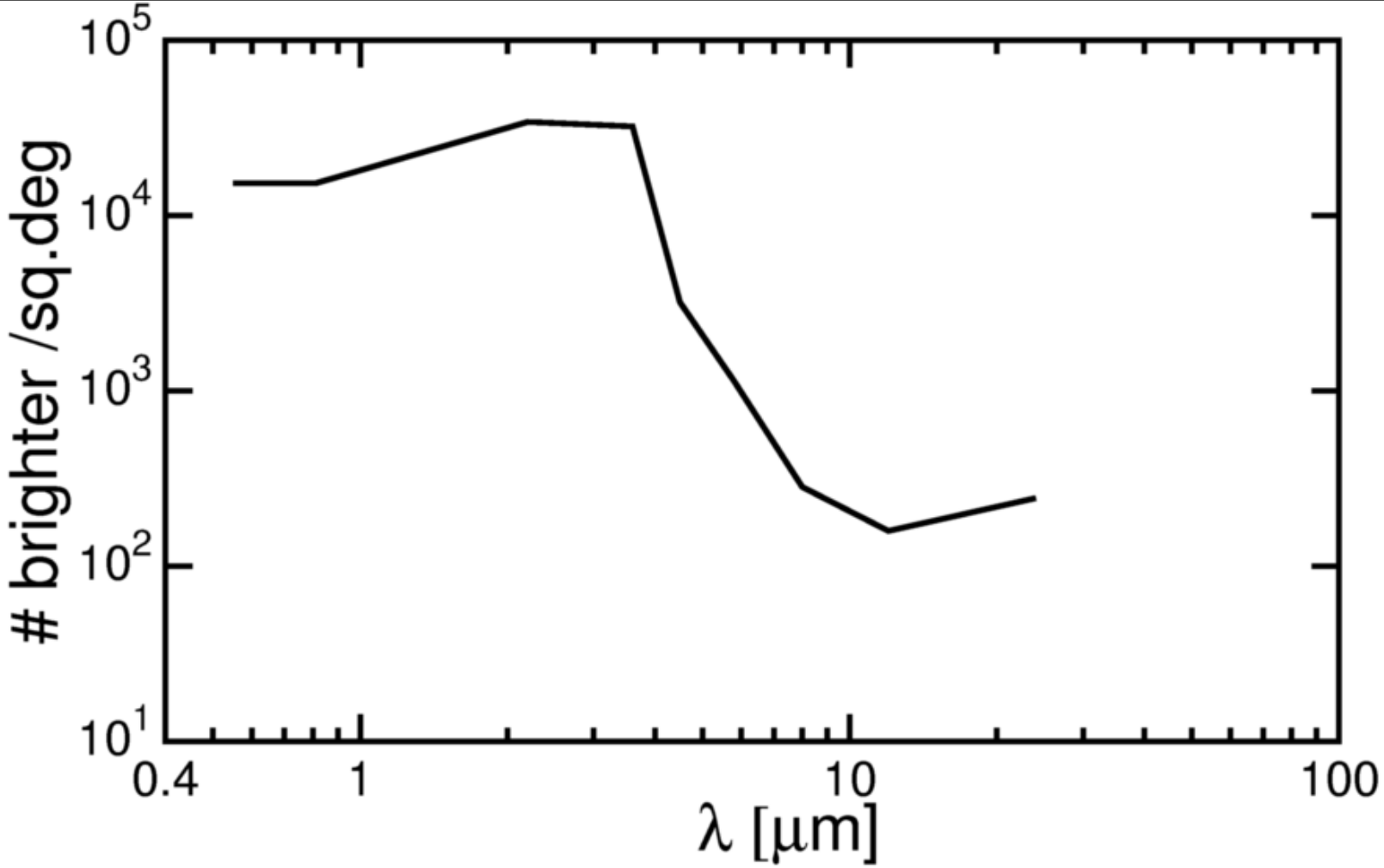
WISE band 3



Megaprime on CFHT

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

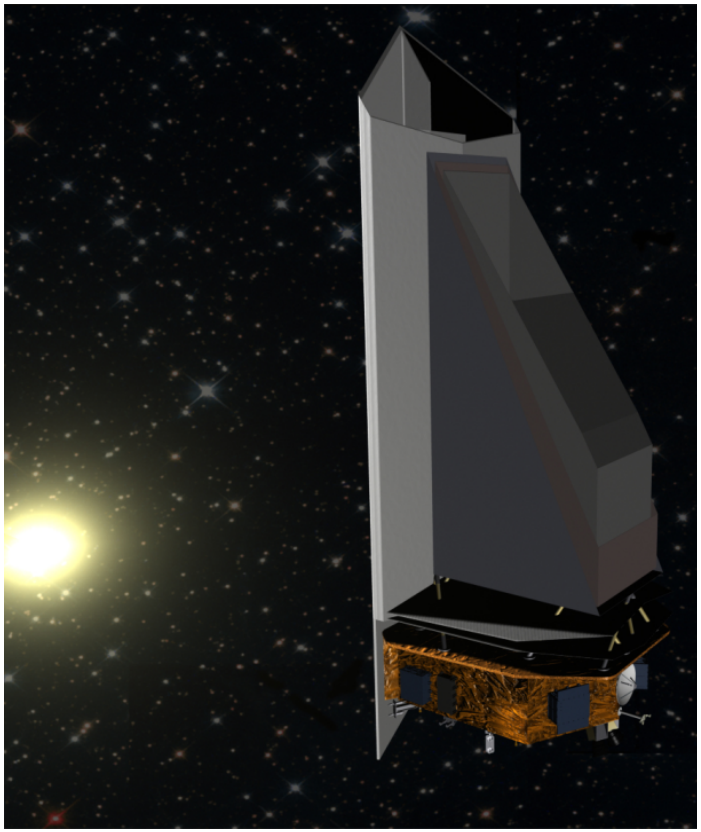
Celestial Source Confusion



- Source density brighter than a 150 m diameter asteroid seen at DE = 0.5 AU

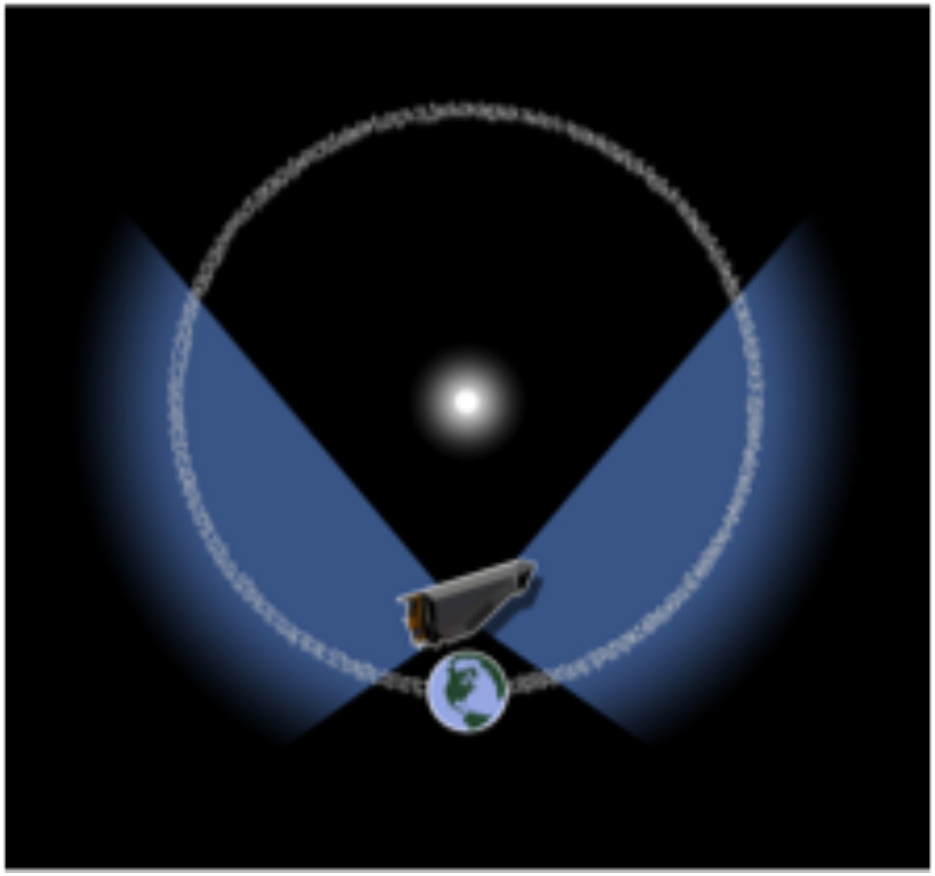
The Future?

- Discovery Mission Proposal (2006 & 2010)
- Science Objectives:
  - Study the origins and evolution of the NEOs, MBAs and comets
  - Assess the present-day risk of NEO impact
- NEOCam achieves multiple NASA goals by
  - Addressing fundamental issues in Solar System science:
    - NEO origins and evolution
    - Chronology of breakups in Main Belt
    - Origins and evolution of comets
  - Precisely quantifying PHO impact hazard. Detect and characterize 2/3 of all PHOs >140 m in diameter in 4 years
  - Identifying and characterizing asteroids as destinations for human exploration



NEOCam

- NEOCam is a dual-channel imager operating in a single step-and-stare survey mode. It includes:
  - 50 cm telescope, 3 mirrors, FOV 14.4 deg^2
  - Two 16 megapixel HgCdTe focal planes at 4-5.4 and 6-10.3 μm simultaneously imaged
  - Detectors passively cooled to 35K, optics to 55K
  - Daily sky coverage: 2300 deg^2 imaged twice
  - 23/7 science ops, 13GB/day (compressed)
- 4 year Mission, launch 2016
- Earth-Sun L1 orbit



WISE Science Team

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- Andrew Blain - Caltech
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- Roc Cutri - IPAC
- Peter Eisenhardt -JPL
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- Michael Ressler - JPL
- Michael Skrutskie - UVa
- Adam Stanford - LLNL
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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 equal to or 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 releases:
  - Preliminary release of first 50% of the data in April 2011
  - All-sky release March 2012; 3-band cryo June 2012; post-cryo July 2012
- Data products include image atlas and point source catalog