New Views of Asteroids and Comets Enabled by Infrared Detectors

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2018 II-VI Workshop

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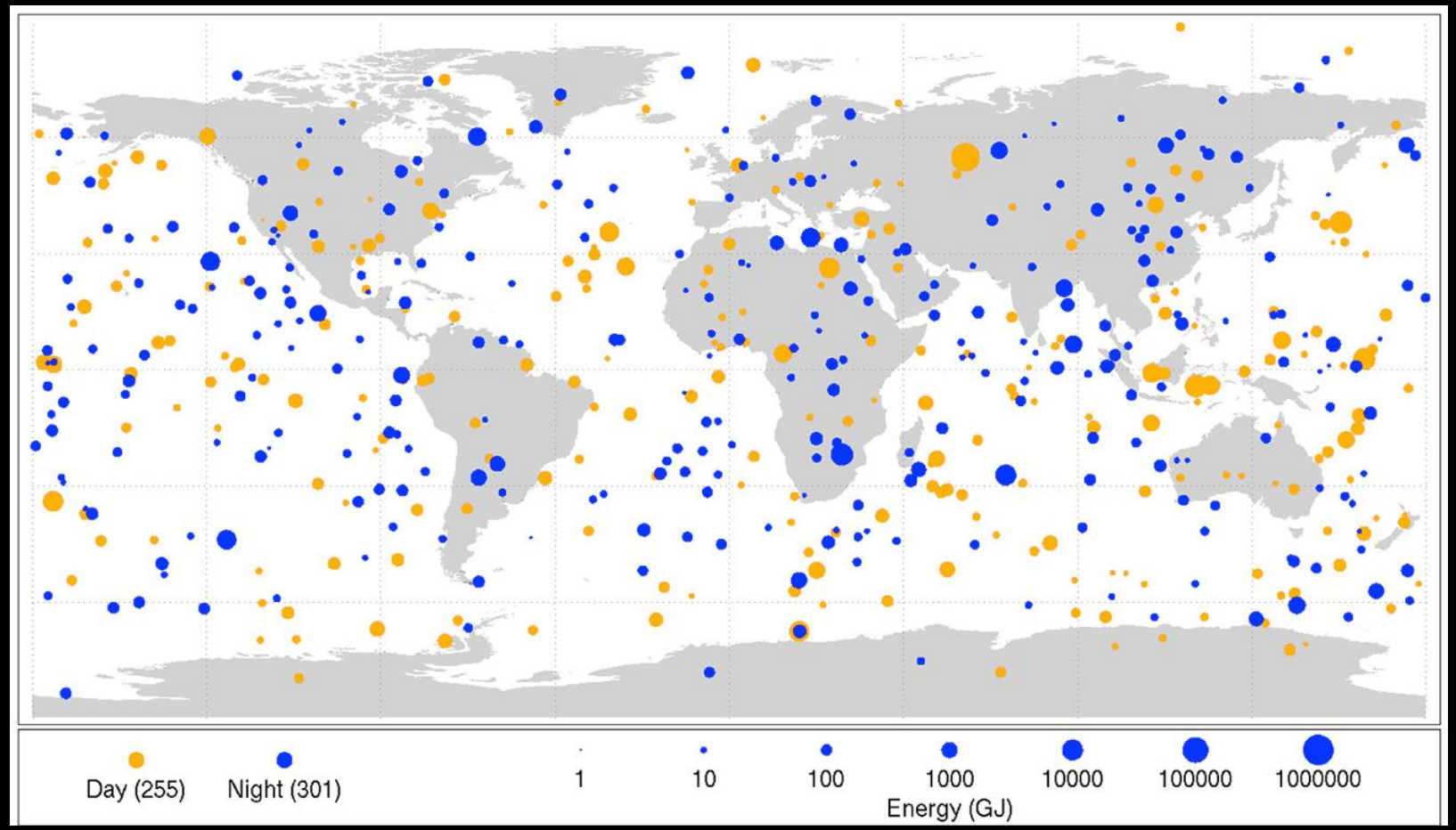
WHY LOOK FOR ASTEROIDS?

Asteroid encounters are common occurrences



Planetary Science Institute via NASA

WHY LOOK FOR ASTEROIDS?

Asteroids have a significant impact on Earth's history

Mark Garlick, via Science Source

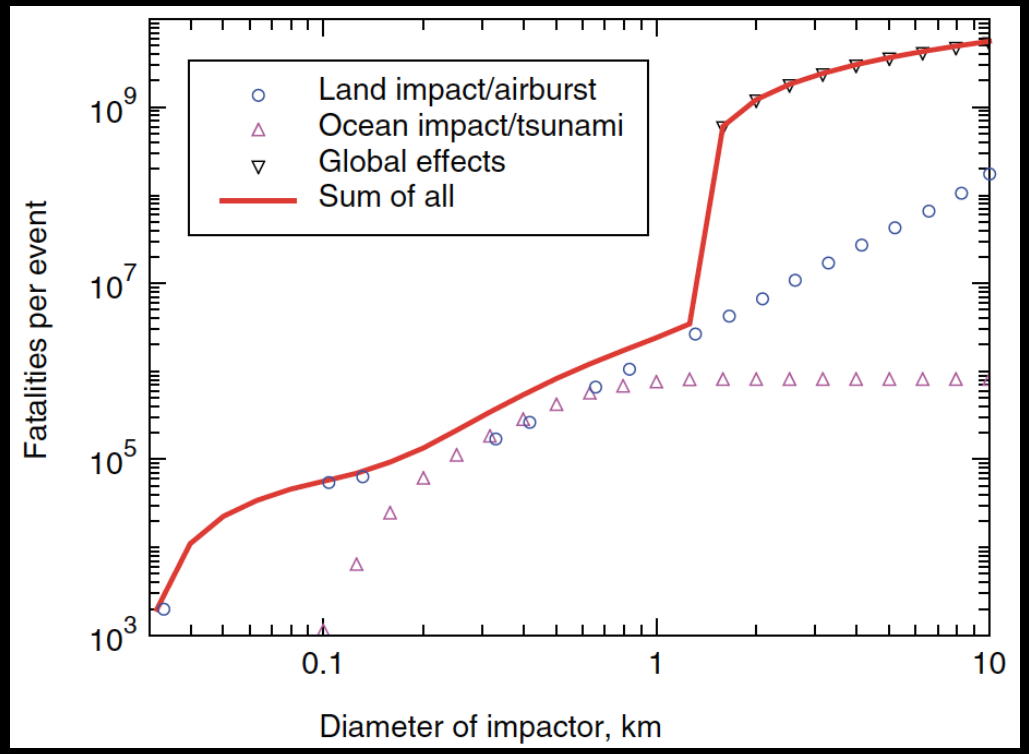
Взрыв метеорита над Челябинском via https://www.youtube.com/watch?v=iCawTYPtehk

WHY LOOK FOR ASTEROIDS?

Early location of cataclysmic asteroids is key to mitigating future impacts

	Diameter (m)	Impact Energy (MT)	Impact Interval (Yrs)
Airburst	25	1	200
Local Scale	50	10	2,000
Regional Scale	140	300	30,000
Continental Scale	300	2,000	100,000
Below Global Catastrophe Threshold	600	20,000	200,000
Possible Global Catastrophe	1,000	100,000	700,000
Above Global Catastrophe Threshold	5,000	10 million	30 million
Mass Extinction	10,000	100 million	100 million

Defending Planet Earth: Near-Earth-Object Surveys and Hazard Mitigation Strategies



WHAT HAVE WE DONE SO FAR?

Numerous methods are currently used to find and characterize asteroids

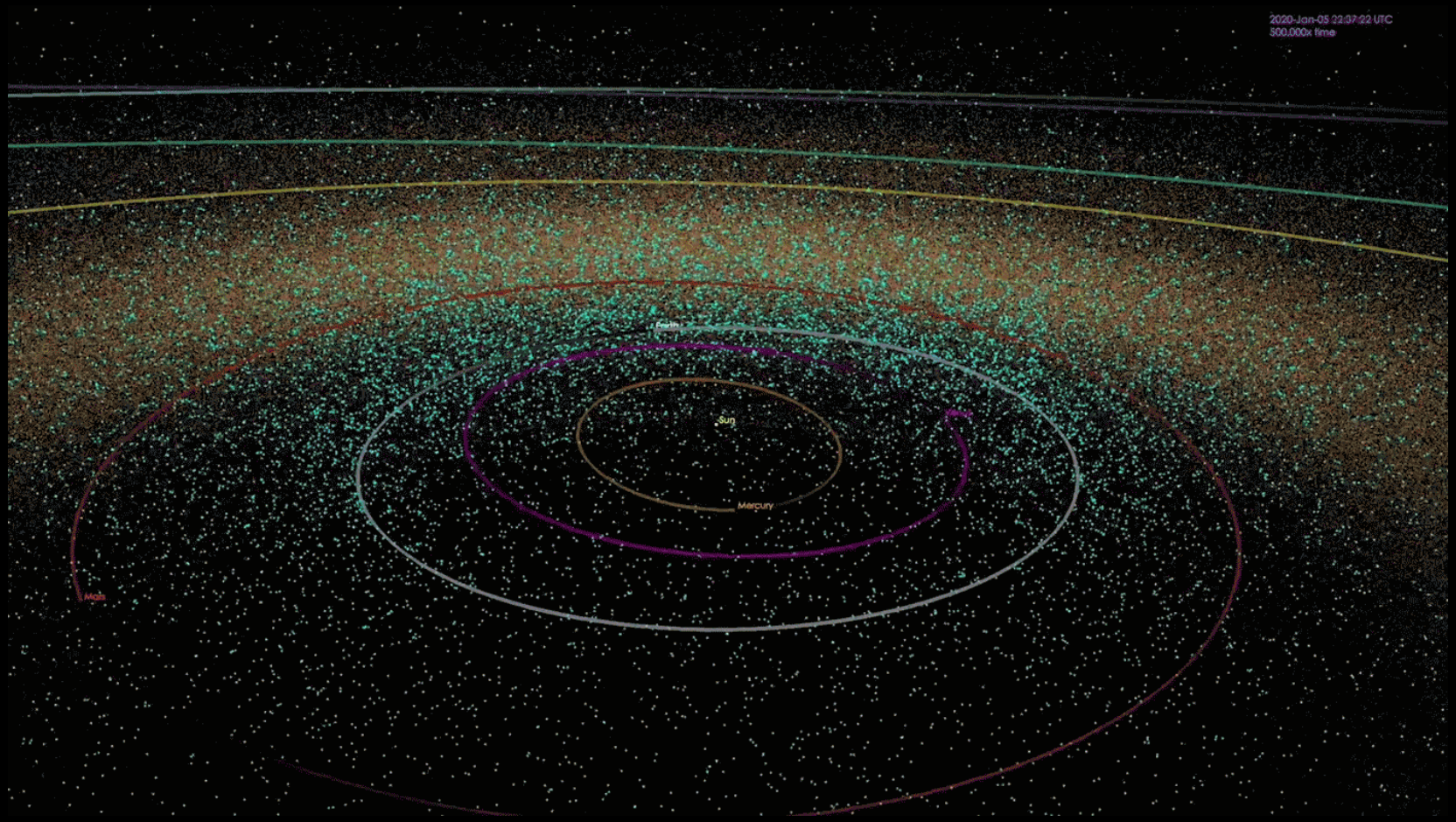
https://panstarrs.stsci.edu/

nasa.gov

www.naic.edu

WHAT HAVE WE DONE SO FAR?

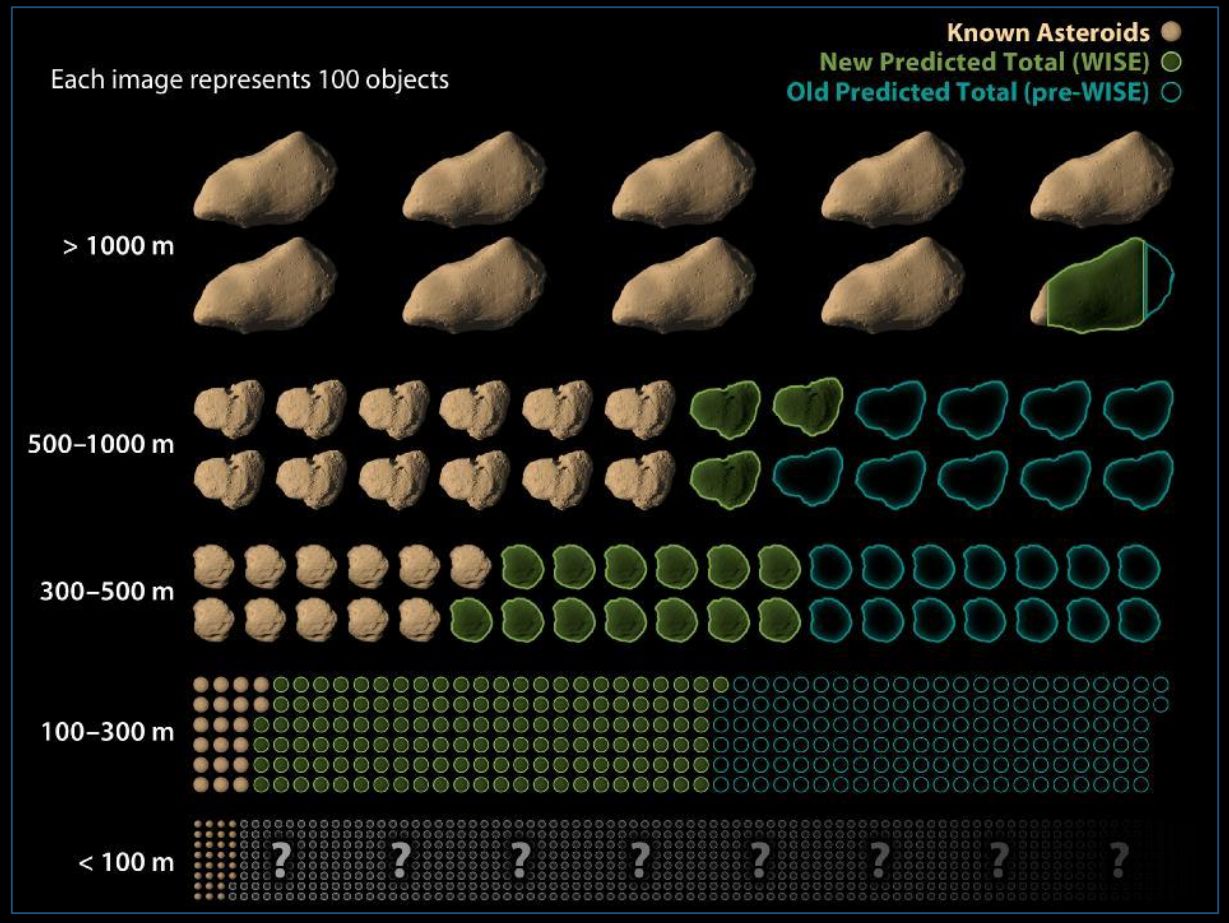
18,863 near-earth objects (NEOs) discovered so far



https://cneos.jpl.nasa.gov/

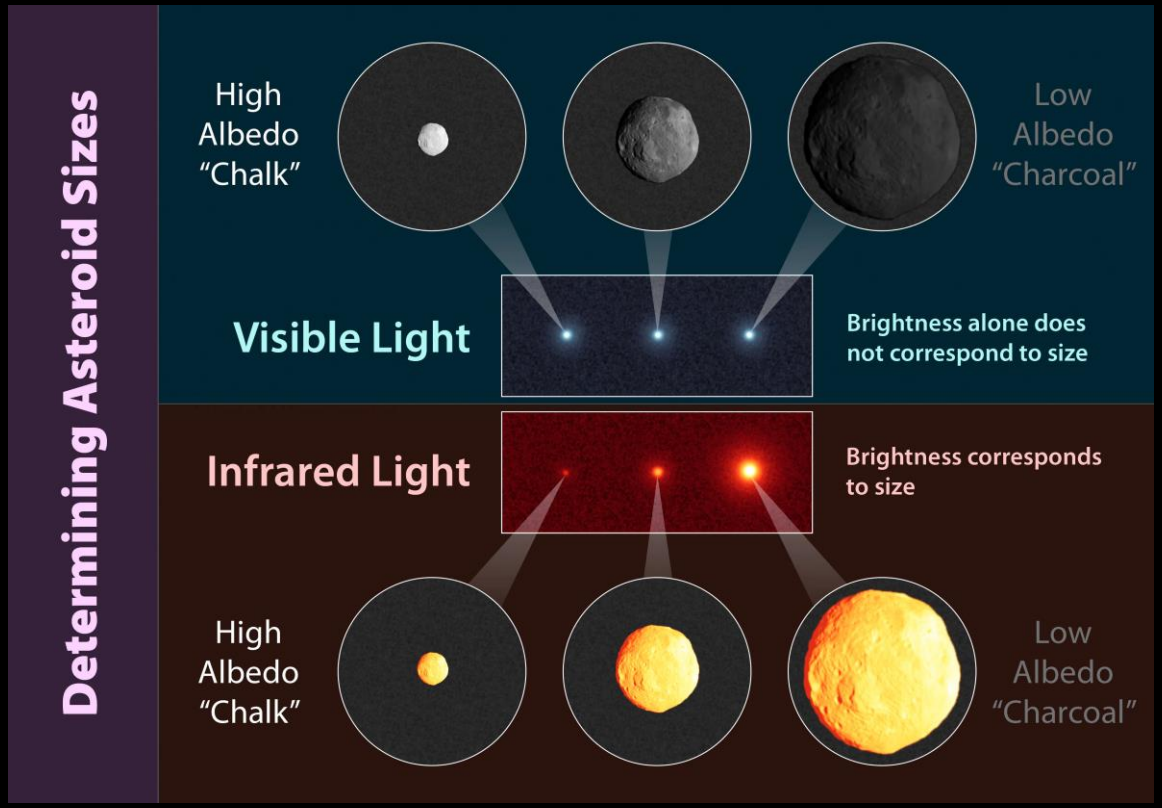
WHAT HAVE WE DONE SO FAR?

Much of the NEO population remains undiscovered



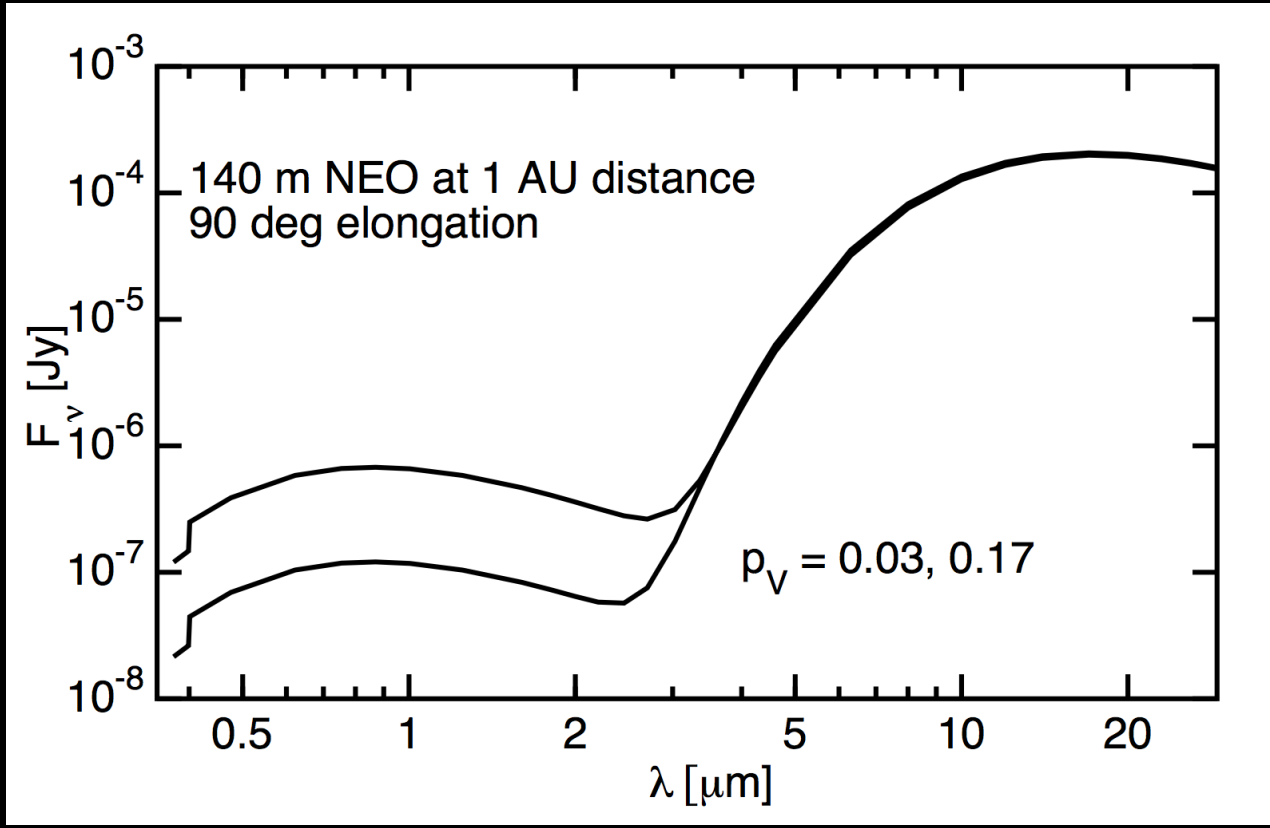
WHY INFRARED?

Asteroid infrared brightness do not depend on albedo



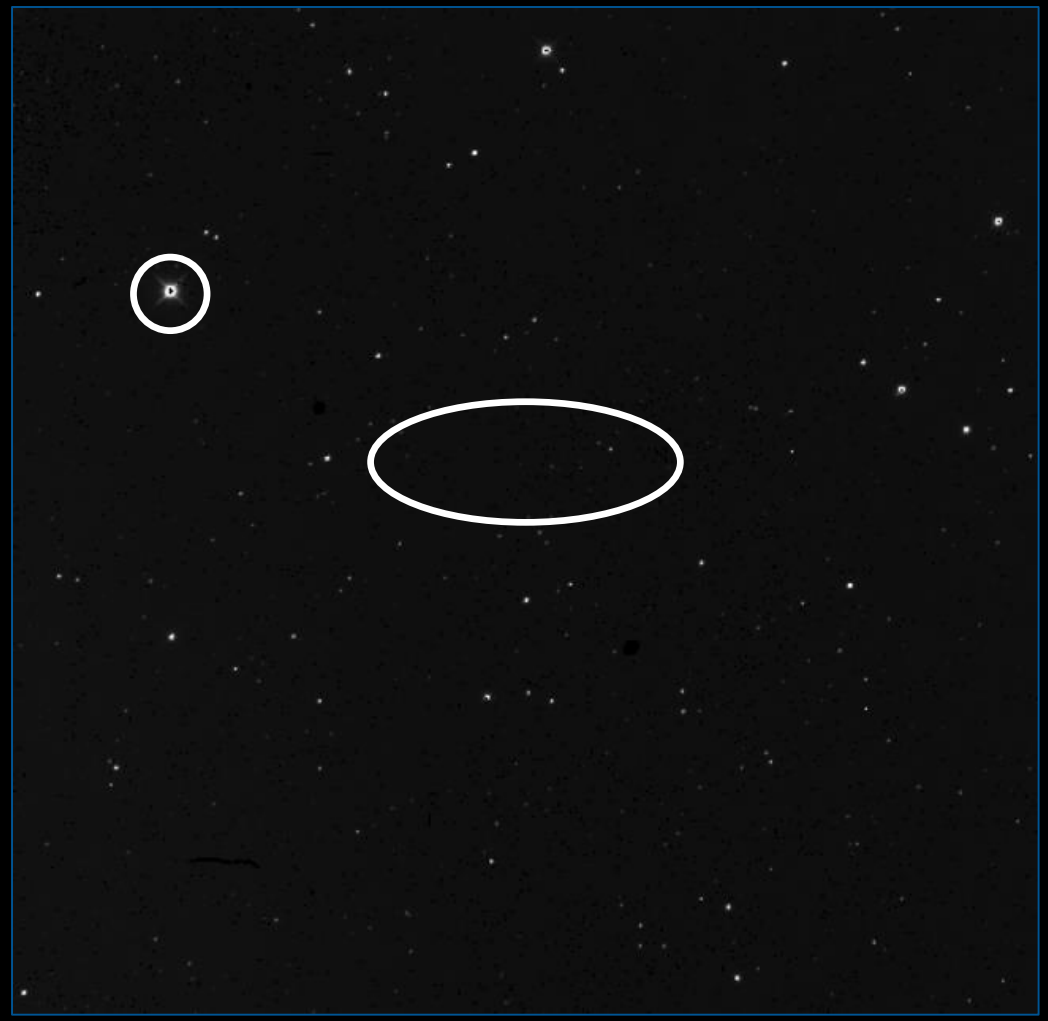
WHY INFRARED?

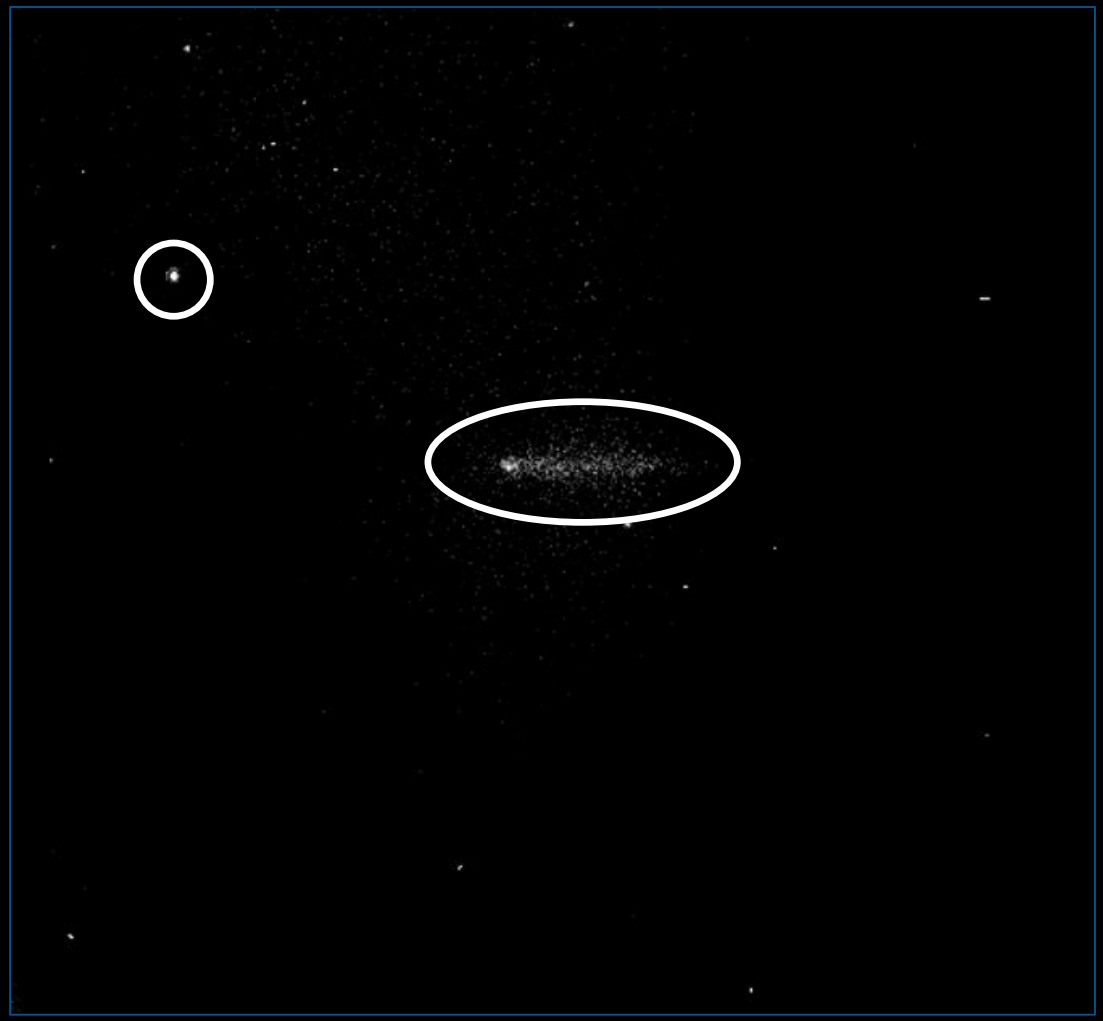
Asteroid blackbody curves peak in the infrared



WHY INFRARED?

Stellar fluxes are much lower in the infrared





EXISTING INFRARED SURVEYS

The NEOWISE Project

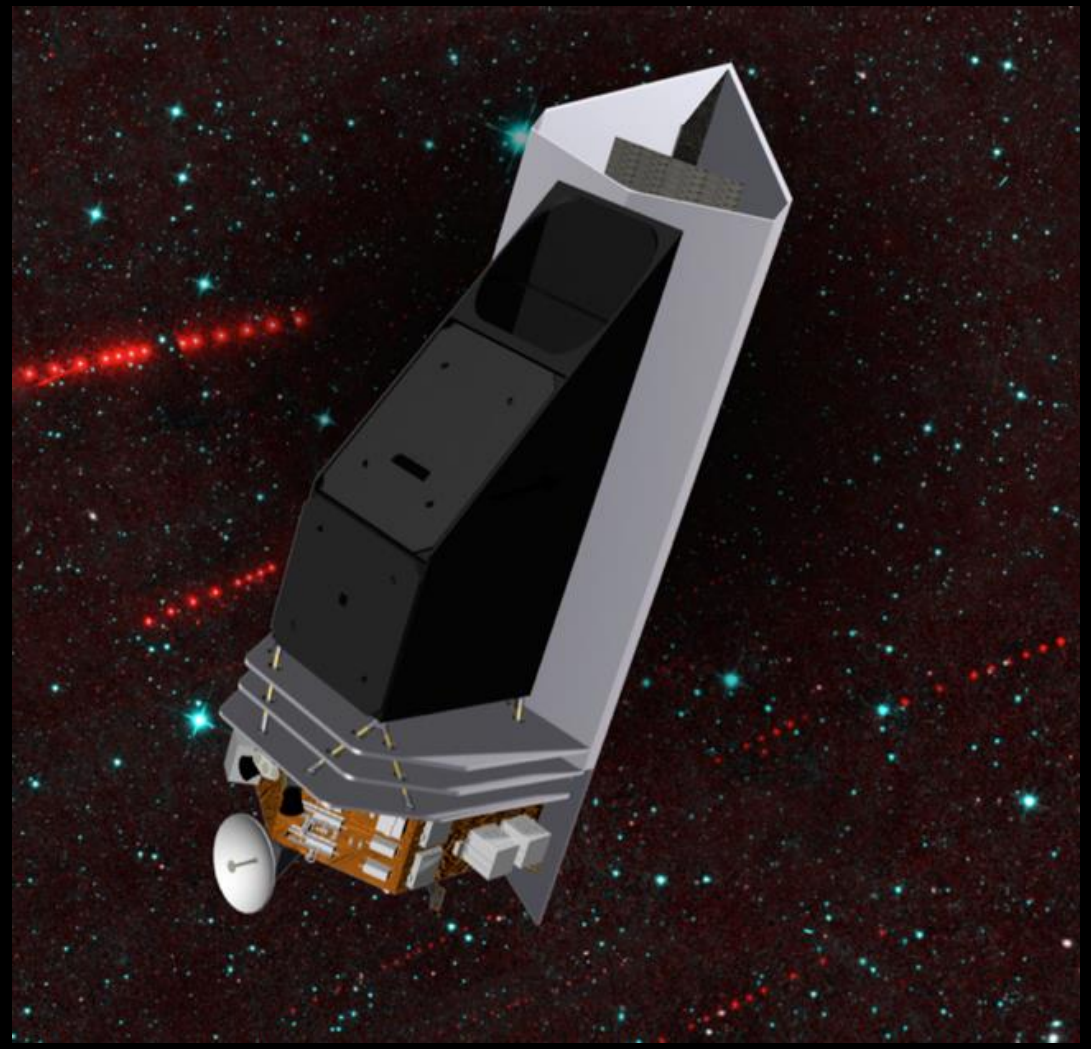
nasa.gov

- *WISE + NEOs = NEOWISE*
  - *Reactivation of WISE satellite in 2011*
  - *Post-Cryogen Exhaustion*
  - *525 km, circular, polar sun-synchronous orbit*
- *Infrared Payload*
  - *40cm Telescope*
  - *3, 4, ~~12~~, ~~22~~um channels*
- *~160,000 small bodies detected to date, including ~1300 NEOs*

THE FUTURE OF INFRARED SURVEYS

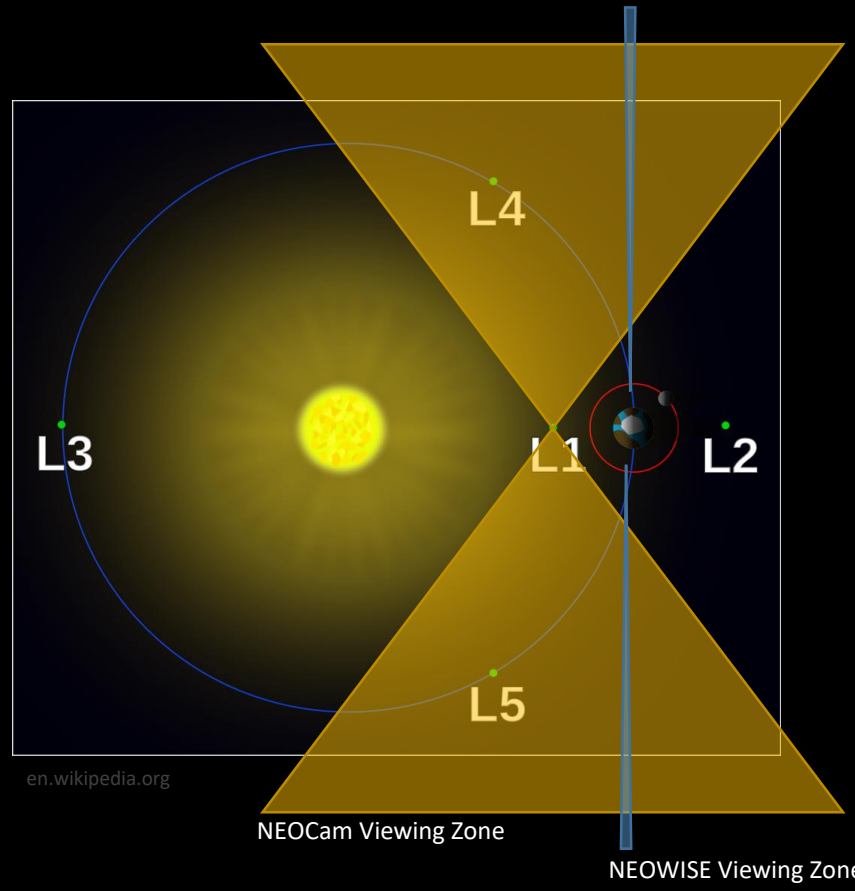
Near-Earth Object Camera (NEOCam)

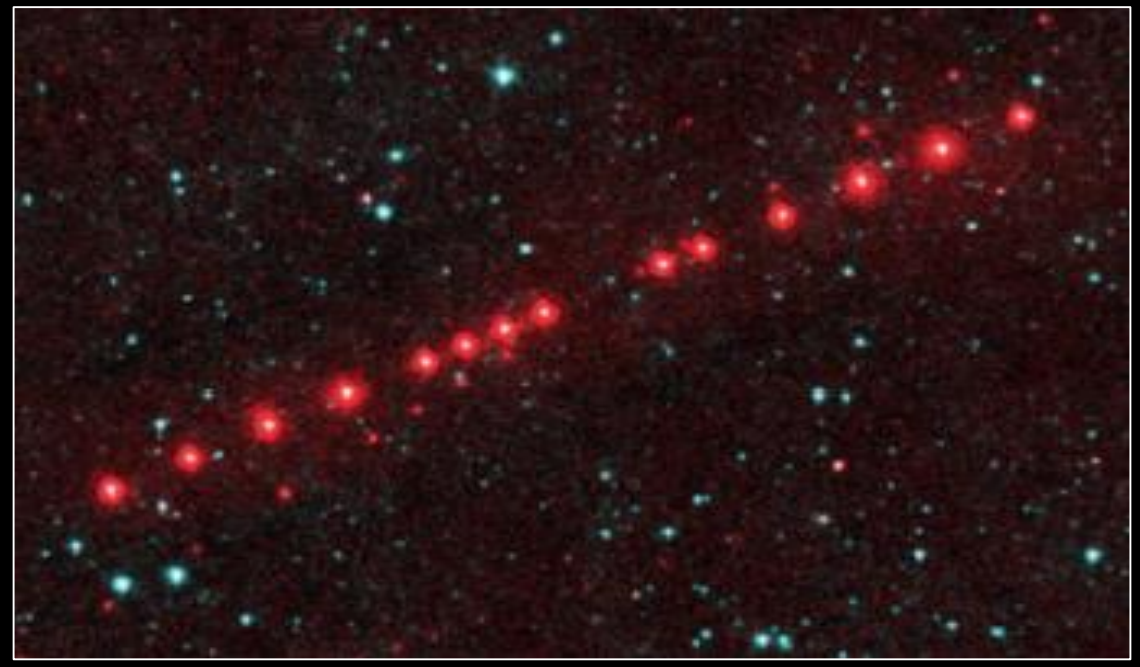
- *Asteroid Detection / Characterization Mission*
  - *Currently in Extended Phase A Study*
  - *NASA Planetary Defense Coordination Office*
- *Mission Design Concept*
  - *L1 Orbit; 5-year prime mission*
  - *Observes ±40° ecliptic latitudes*
  - *13-day observing cycle*
- *Single Instrument Payload*
  - *50cm Three-Mirror Anastigmat Telescope*
  - *Passively Cooled Thermal System*
  - *2 IR Channels, 16Mpix each*
    - *NC1: MWIR 4-5.2um*
    - *NC2: LWIR 6-10um*



HOW DOES NEOCAM FIND ASTEROIDS?

NEOCam performs a repeated survey of the solar plane

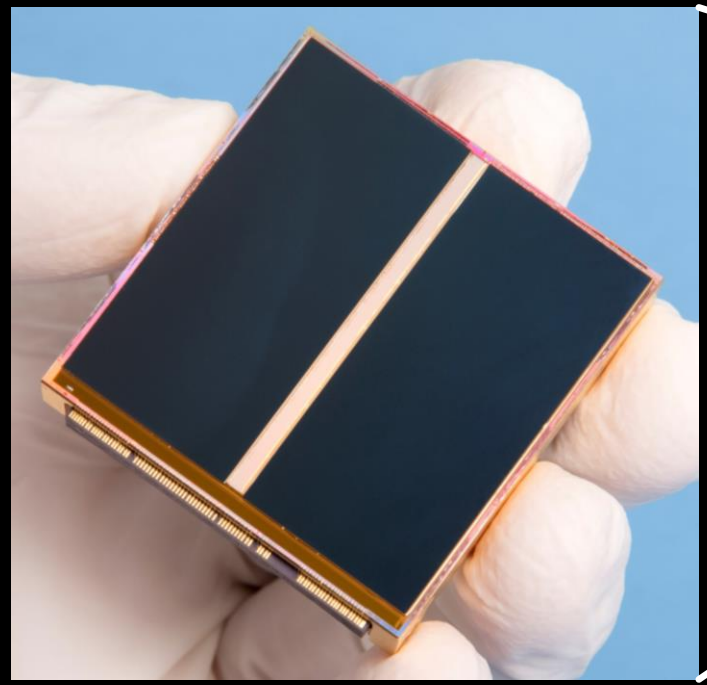




NASA / JPL

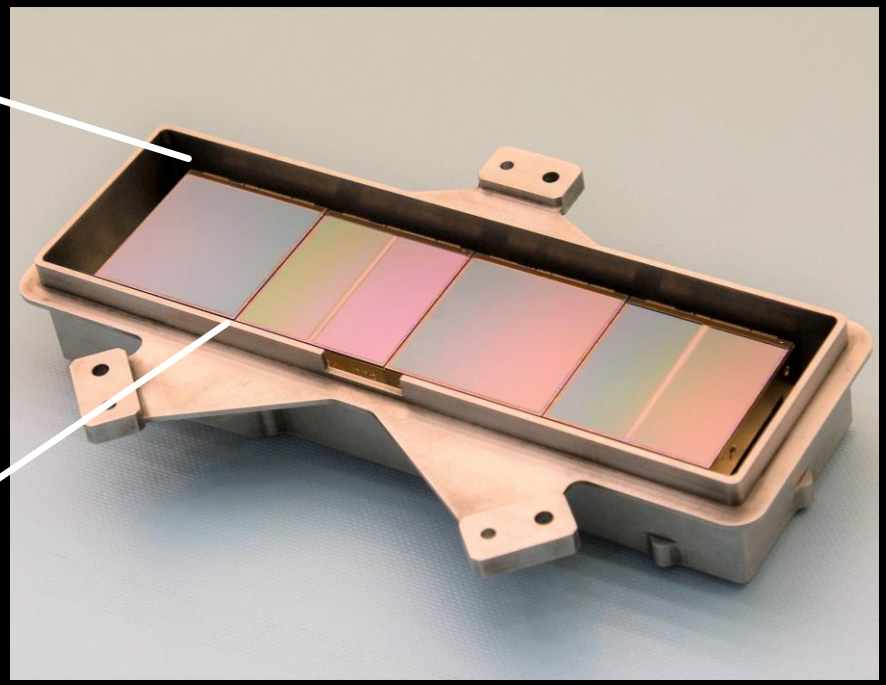
HOW DOES NEOCAM FIND ASTEROIDS?

NEOCam utilizes a mosaic of high-performance HgCdTe detectors



Sensor Chip Assemblies

- HgCdTe Detectors
  - MWIR = 5.7um-cutoff
  - LWIR = 10.5um-cutoff
- 2Kx2K H2RG ROIC



Focal Plane Module

- 4x SCAs each bandpass
- Molybdenum Mosaic Plate w/ 91% Fill Factor

WHY IS NOW THE RIGHT TIME?

The NEOCam detectors are the result of a successful partnership…

TELEDYNE TECHNOLOGIES
Everywhereyoulook™

University of Rochester

Jet Propulsion Laboratory
California Institute of Technology

Targeted development goals enabled NEOCam

High Operating Temperature → Passive Thermal Architecture

High Operability → Increased Survey Efficiency

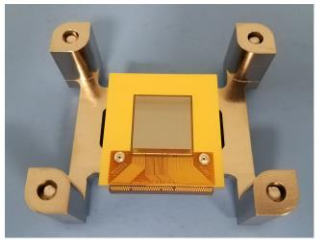
Close Buttable Arrays → Increased Survey Efficiency

Large Format Arrays → Simplified Electronics Architecture

WHY IS NOW THE RIGHT TIME?

Incremental improvements to the NEOCam detectors

2010

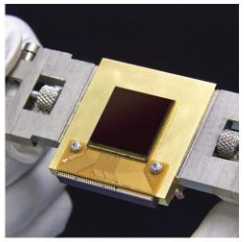


Detector Format:
H1RG “36µm”
512×512 pixels

Median Dark Current:
10 e-/s/pixel

Operability (<100e/s):
69%

2012

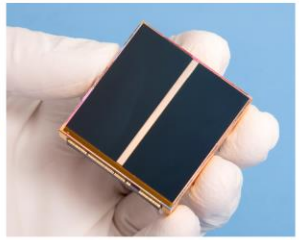


Detector Format:
H1RG “18µm”
1024×1024 pixels

Median Dark Current:
< 1 e-/s/pixel

Operability (<200e-/s):
>95%

2015

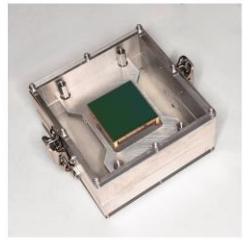


Detector Format
H2RG “Duplex”
1900×2048 pixels

Median Dark Current:
<1 e-/s/pixel

Operability (<200e-/s):
>96%

2016



Detector Format:
H2RG
2048×2048 pixels

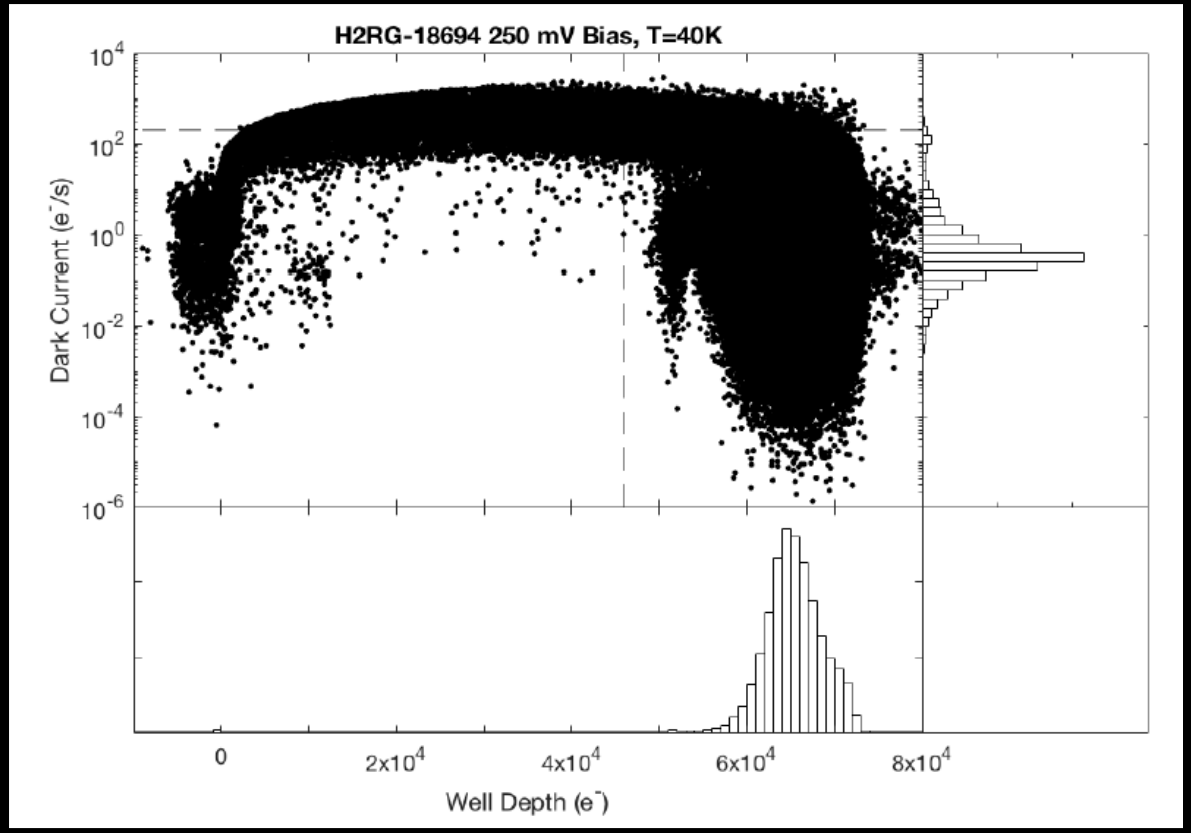
Median Dark Current:
<1 e-/s/pixel

Operability (<200e-/s):
>98%

WHY IS NOW THE RIGHT TIME?

NEOCam has exceptional LWIR detectors

	NEOCam Requirements	H2RG-18694 Performance
Quantum Efficiency (%)	>55	71
CDS Read Noise (e- RMS)	<36	19
Dark Current (e-/s/pix)	<200	0.3
Well Depth (e-)	>44,000	65,000
Operability (%)	>90%	98.9



Dorn, 2018

Further Reading:

- Mainzer, A., et al. "**Survey simulations of a new near-earth asteroid detection system**." The Astronomical Journal 149, no. 5 (2015): 172.
- Stokes, G. H., et al. "**Update to determine the feasibility of enhancing the search and characterization of NEOs**." 2017.
- McMurtry, Craig W., et al. "**Candidate 10 micron HgCdTe arrays for the NEOCam space mission.**" In High Energy, Optical, and Infrared Detectors for Astronomy VII, vol. 9915, p. 99150D. International Society for Optics and Photonics, 2016.
- Dorn, Meghan, et al. "**A monolithic 2k x 2k LWIR HgCdTe detector array for passively cooled space missions**." In High Energy, Optical, and Infrared Detectors for Astronomy VIII, vol. 10709, p. 1070907. International Society for Optics and Photonics, 2018.
- Dorn, Meghan L., et al. "**Proton irradiation results for long-wave HgCdTe infrared detector arrays for Near-Earth Object Camera.**" Journal of Astronomical Telescopes, Instruments, and Systems 2, no. 3 (2016): 036002.

Acknowledgements:

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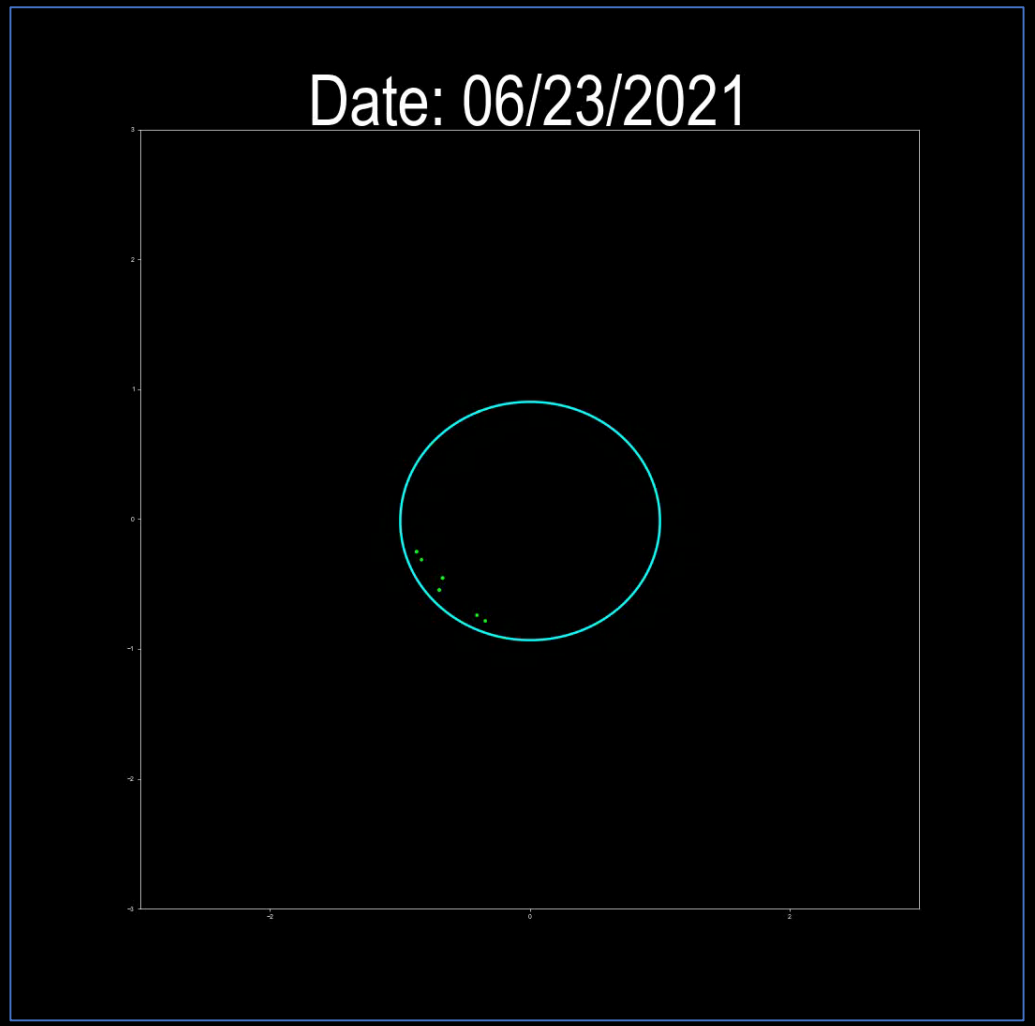


BACKUP SLIDES

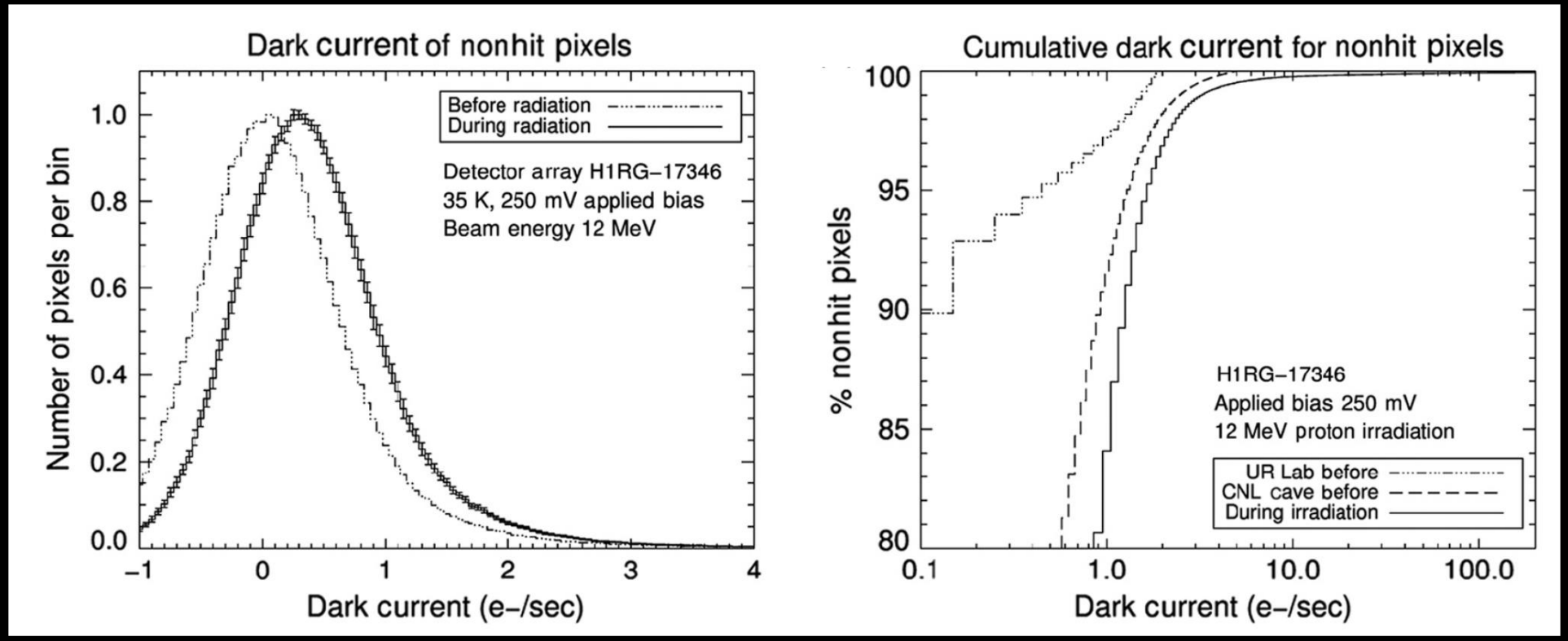
WHY LOOK FOR ASTEROIDS?

George E. Brown, Jr. Near-Earth Object Survey Act (Public Law 109-155 Sec.321)

"The Administrator shall plan, develop, and implement a Near-Earth Object Survey program to detect, track, catalogue, and characterize the physical characteristics of near-Earth objects equal to or greater than 140 meters in diameter in order to assess the threat of such near-Earth objects to the Earth. It shall be the goal of the Survey program to achieve 90 percent completion of its near-Earth object catalogue (based on statistically predicted populations of near-Earth objects) within 15 years after the date of enactment of this Act."

WHY IS NOW THE RIGHT TIME?

NEOCam LWIR detectors passed radiation testing



Dorn, 2016