4th IAA Planetary Defense Conference – PDC 2015
13-17 April 2015, Frascati, Roma, Italy

IAA-PDC-15-02-05
Building on the NEOWISE Legacy with NEOCam, the Near-Earth Object Camera

Mainzer[(1)], T. Grav[(2)], J. Bauer[(1)], R. M. Cutri[(3)], J. Masiero[(1)], E. L. Wright[(4)], C. Nugent [(3)]

[(1)]*Jet Propulsion Laboratory, Pasadena, CA USA*
[(2)]*Planetary Science Institute, Tucscon, AZ USA*
[(3)]*Infrared Processing and Analysis Center, California Institute of Technology, Pasadena, CA USA*
[(4)]*University of California, Los Angeles, CA USA*

Keywords: *asteroids, surveys, infrared, catalogs*

Extended Abstract—

The ∼12,000 NEOs known so far are believed to represent only a small fraction of the total population. Statistical approaches to quantifying the hazard from the undiscovered population indicate that while the risk of a very large impact is low over the next several thousand years, dangerous NEO impacts remain a stochastic process on human timescales. In 2004, the U. S. Congress mandated that NASA should find >90% of all NEOs larger than 140 m in diameter by the year 2020. The process of surveying for NEOs has proven extremely beneficial to planetary science. The survey data used to discover, catalog and characterize NEOs are responsible for finding the majority of comets, Main Belt asteroids, Jovian Trojans, and Centaurs known today, a tremendous boon to those interested in understanding the origins and evolution of our solar system.

There is precedent for using space-based IR telescopes to discover and characterize asteroids in large numbers. NEOs emit a significant fraction of their bolometric luminosity at thermal infrared (IR) wavelengths, and the stellar and galactic backgrounds against which they are detected are typically much dimmer than in visible light. NEO thermal emission is only a weak function of an object's geometric albedo, unlike its visible light brightness, so a telescope surveying at IR wavelengths is essentially equally sensitive to low and high albedo objects [1]. Moreover, surveying at IR wavelengths offers the opportunity to constrain an object's diameter with much improved accuracy over visible wavelengths alone. Independent IR surveys are therefore useful when extrapolating the observed sample to determine properties of the population such as size frequency distributions. No conversion between H and diameter is needed, since diameter is determined directly, eliminating the uncertainty associated with the large range of possible asteroid albedos. If both visible and IR fluxes are obtained, it is possible to compute geometric albedo [2][3][4].

NEOWISE, the asteroid-hunting portion of NASA's Wide-field Infrared Survey Explorer (WISE) mission [5], discovered and characterized >158,000 asteroids and comets throughout our solar system during its year long prime mission; >34,000 were new discoveries [6]. Included in the sample were ∼700 NEOs, of which 135 were new discoveries [1][7][8].

Using a space-based telescope operating at thermal IR wavelengths to discover and characterize large numbers of NEOs is not a new concept. Others ([9][10][11][12][13]) have considered space-based thermal IR telescopes observing from Earth orbit, the Earth-Sun L2 Lagrange point, and a Venus-like orbit using HgCdTe detectors cooled by mechanical cryocoolers. However, the 2003 report of the NASA NEO Science Definition Team [14]) opted not to consider a space- based IR system on the grounds that sufficiently large, high-operability long-wavelength focal plane arrays did not exist at the time. The largest ∼10μm HgCdTe detectors designed for low-background astronomical background applications were in a 512x512 format. Nevertheless, the initial results of that pilot program lead by the University of Rochester and Teledyne Imaging Systems were encouraging [15][16][17][18].

Motivated by the possibility of discovering NEOs in thermal IR wavelengths with WISE but aware of its limitations in terms of lifetime and field of view, our group revisited the space-based NEO survey designs. The major advance that resulted in WISE's improved sensitivity and spatial resolution over IRAS was the increase in its focal plane formats to 1024x1024 from 62 pixels, despite WISE's smaller primary mirror (40 cm vs. 60 cm). Moreover, the focal planes of the Spitzer Space Telescope [19] stabilized at 29 K after the cryogen ran out in 2008 [20]. This suggested that if 10 μm HgCdTe arrays could be enlarged to a 1024x1024 format and could achieve high operability at ~35 K, it would be possible to cool the detectors and telescope purely passively. An orbit that maintains enough separation from the Earth to minimize its heat load while still maintaining a nearly constant distance, thus supporting high-bandwidth communications, can be found at the Earth-Sun L1 Lagrange point. While WISE is constrained by its orbit and sunshade to viewing a narrow strip close to 90◦ solar elongation, a mission at L1 with a taller sunshade can point much closer to the Sun.

The resulting mission concept, called the Near-Earth Object Camera (NEOCam) was first proposed to NASA's Discovery program in 2005 and again in 2010. In 2010, the project was awarded technology development funding to mature the long-wavelength IR HgCdTe arrays. The results of that effort have produced new 10 μm-cutoff 1024^2 arrays with very high pixel operability at 35-40 K [21]. The mission design allows for long lifetime, high data transfer rates supporting downlink of full-frame images, and the ability to view large swaths of Earth's orbit instantaneously. By enabling full-frame downlinks, standard astronomical data processing techniques for extracting sources and producing accurately calibrated astrometry and photometry can be employed.

Space telescopes at either L1 or Venus-trailing orbits can spend much of their time surveying the region of sky that is in the daytime sky for ground-based observers. Therefore, the ability to perform "self follow-up" is essential; the cadence must ensure that detection, follow-up, and accurate orbit determination are built into routine operations.

We compared the performance of surveys in either Venus-trailing or L1 orbit and found that the Venus-trailing survey detects slightly fewer PHAs >140 m than the L1 survey, even assuming that no degradation results from the inability to downlink full-frame images. While the Venus-trailing survey discovers more Amors than the L1 survey, these objects are less likely to constitute impact hazards compared to Atens and Apollos. The L1 survey discovers more IEOs, Atens, and Apollos than the Venus-trailing survey. These results demonstrate that the cost, complexity, and risk associated with sending a survey telescope to a Venus-trailing orbit is unwarranted. While neither survey is capable of fulfilling the 2005 Congressional mandate to NASA to find 90% of all near-Earth objects larger than 140 m in diameter by 2020, an advanced space-based survey can make significant progress quickly [22].

References: [1] Mainzer et al. (2011) ApJ 743, 156 [2] Harris (1998) Icarus 131, 291 [3] Mainzer et al. (2011) ApJ 736, 100 [4] Mainzer et al. (2011) ApJL 737, 9 [5] Wright et al. (2010) AJ 140,1868 [6] Mainzer et al. (2011) ApJ 731, 53 [7] Mainzer et al. (2012) ApJL 760, 12 [8] Mainzer et al. (2014) ApJ 792, 30 [9] Cellino et al. (2000) Proc. SPIE 4013, 433 [10] Cellino et al. (2003) Memorie della Società Astronomica Italiana, 74, 245 [11] Cellino et al. (2004) Advances in Space Research 33, 1576 [12] Cellino et al. (2006) Advances in Space Research 37, 153 [13] Tedesco et al. (2000) PSS 48, 801 [14] Stokes et al. (2003) Study to Determine the Feasibility of Extending the Search for Near-Earth Objects to Smaller Limiting Diameters, NASA Office of Space Sciences Solar System Exploration Division [15] Bacon et al. (2003) Proc. SPIE 4850, 927 [16] Bacon et al. (2004) Proc. SPIE 5167, 313 [17] Bacon et al. (2004) Proc. SPIE 5563, 35 [18] Bacon et al. (2010) Proc. WPIE 7742, 50 [19] Werner et al. (2004) ApJS 154, 1 [20] Storrie-Lombardi & Dodd Proc. SPIE 8448, 1 [21] McMurtry et al. (2013) Optical Engineering 52, 1804 [22] Mainzer et al. (2015) AJ in press