Observations of Cybeles with NEOWISE

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Introduction: The Nice model is currently favored as the leading hypothesis for quantitatively explaining many of the characteristics seen in the current Solar System, from the giant planet orbits, the Jovian and Neptunian Trojan populations, the Kuiper Belt and the origin of the late heavy bombardment [1, 2, 3, 4, 5]. The insertion of primitive trans-Neptunian objects into the outer main belt using the Nice model can reproduce the general aspects of both the taxonomic and size distributions seen in the outer main belt, Hilda and Jovian Trojan populations. However, deeper understanding of the current taxonomy, sizes and physical properties of these populations is needed to better constrain the Nice model. In previous papers we have reported on these properties for the Hilda and Jovian Trojan populations based on mid-infrared observations of the NEOWISE extension of the Wide-field Infrared Survey (WISE) mission [6, 7, 8]. Here we report on the results of the NEOWISE observations of the Cybele population.

The Cybeles are asteroids that occupy the region just beyond the edge of the main asteroid belt, with semi major axis between the 2:1 (at $\sim$ 3.27AU) and 5:3 (at $\sim$ 3.7AU) mean motion resonances with Jupiter. Historically the population has been restricted to eccentricity less than 0.3 and inclination less than 25 degrees [9]. The Cybeles currently consist of over 2000 known objects. Generally thought of as a breakup of a large asteroid in the early part of the formation of the Solar System, the Cybeles are dominated by the primitive C, P and D taxonomic class from the Tholen taxonomic system [10].

To test whether the Cybele population have experienced significant shattering events after insertion it is important to determine the size distribution of this population. The Infrared Astronomical Satellite (IRAS) observed 71 Cybeles among their thermal data of 2228 asteroids [11, 12], but did not go into a deeper detailed analysis of this population. The Akari satellite (formerly Astro-F) performed a survey that observed 5120 asteroids in the mid-thermal [13], of which 107 were objects in the Cybele population [14]. This survey found that the 78 small Cybeles with diameters between 10 and 80 kilometers have a diversity of C, P and D types and a shallow cumulative power-law size distribution of 0.86 ± 0.03. By contrast, the 29 largest Cybeles, with diameters larger than 80 kilometers are dominated by C and P type objects and have a much steeper power-law slope index of 2.39 ± 0.18

NEOWISE Results: In this paper we present the thermal observations of 1218 objects from the Cybele population using the WISE satellite during its cryogenic phase. WISE is a NASA mission launched on 2009 Dec 14 and operated until it was placed into hibernation on 2011 Feb 17 [15, 16, 17]. Orbiting the Earth ever 90 minutes the mission surveyed the entire sky near 90° solar elongation in four infrared wavelengths: 3.4, 4.6, 12 and 24 μm (denoted W1, W2, W3 and W4, respectively). The scan pattern resulted in 10-12 images on the ecliptic, increasing to several hundred at the ecliptic poles. Before launch, the WISE baseline data processing pipeline was augmented with the NEOWISE project, designed to independently discover new minor planets in near real-time. NEOWISE resulted in $\sim 34,000$ discoveries among the over $158,000$ asteroids detected.

The WISE mission ended up divided into three phases. The full cryogenic phase, where all four channels were available, lasted from survey start in mid-January of 2010 until the outer hydrogen tank was depleted on 2010 August 5. This was followed by a month long phase were temperatures rose as the inner hydrogen tank depleted and 3 out of the four bands were available. Subsequently a four month, two band, phase was conducted, before the spacecraft was put into hibernation [17, 18]. The mission was reactivated in November of 2013 and is currently operating the two shortest wavelength channels to detect asteroids and comets [19, 20, 21].

In this paper we focus on the 1252 Cybele asteroids identified in the fully cryonic phase of the mission. The thermal modeling performed is the same as described in detail in previous work [6, 7, 8]. The thermal model fits show a mostly homogeneous population. A vast mjority of the objects are dark with albedos of less then 10%, with the mean albedo being $5.2 \pm 3.0\%$, which is similar to that of the Hilda population ($5.5 \pm 1.8\%$) [7], and darker than the Jovian Trojan Population (7 ± 3) [6].

There were 70 objects that were observed by both the IRAS and NEOWISE surveys and the comparison of the diameter and albedos fits are given in Figure 1. In addition there were 106 objects that were observed by both the Akari and NEOWISE surveys and the comparison of the diameter and albedos fits are given in Figure 2. Our results are in general agreement with these other surveys.

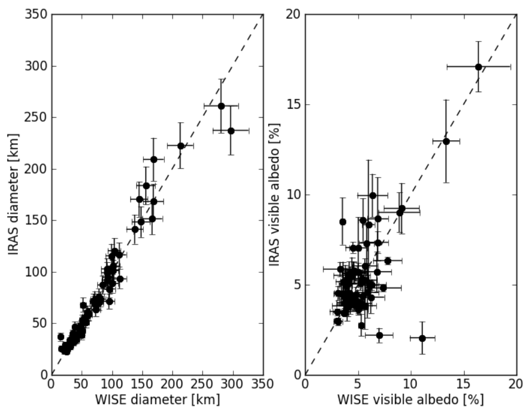

Figure 1: Comparing the 70 objects that were observed by both IRAS and NEOWISE surveys reveal that the diameters and visible albedos are in general agreement.

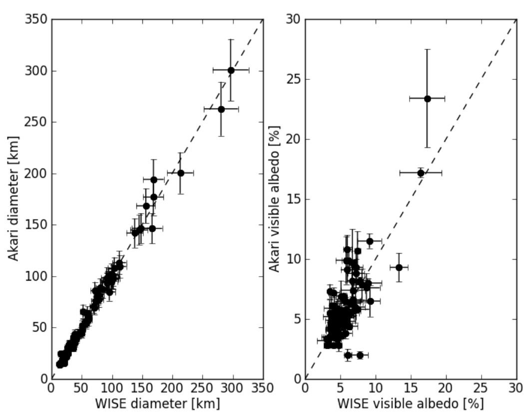

Figure 2: Comparing the 106 objects that were observed by both Akari and NEOWISE surveys reveal that the diameters and visible albedos are in general agreement.

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