Thermophysical Modeling of NEAs Using SHERMAN: 1627 Ivar. Jenna L. Crowell[1], Ellen S. Howell[2], Christopher Magri[3], Yanga R. Fernandez[1], Sean E. Marshall[4], Brian D. Warner[5] and Ronald J. Vervack, Jr.[6], [1]University of Central Florida, Orlando, FL, USA. [2] LPL/University of Arizona, Tucson, AZ, USA [3]University of Maine at Farmington, Farmington, ME, USA [4]Cornell University, Ithaca, NY, USA [5]Center for Solar System Studies - Palmer Divide Station, Rancho Cucamonga, CA, USA [6]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA

Introduction: Our research goal is to investigate the complexity of the surfaces of near-Earth asteroids (NEAs). We have incorporated delay-Doppler images and lightcurves to produce detailed shape models of NEAs such as 1627 Ivar, an Amor class NEA with taxonomic type of Sqw [1] and a rotation period of $4.795162 \pm 5.4 * 10^{-6}$ hours [2]. Using these shape models and near-IR observations, we use the thermophysical modeling software SHERMAN to analyze the thermal and scattering properties of the asteroid's surface. We present our findings on Ivar and compare these to those of other asteroids studied in this manner.

Observations: During Ivar's close approach in 2013, we obtained CCD light curves, radar data, and near-IR spectra. Radar data consists of CW runs and delay-Doppler imaging with 300 m resolution and were obtained using the Arecibo Observatory's 2380 MHz radar. Light curve data were gathered using the 0.35m telescope at the Palmer Divide Station. The NIR spectra encompass reflected and thermal regimes (0.8 – 4.1 µm) and were acquired using the SpeX instrument at the NASA IRTF.

Background: We have used the software SHAPE [4,5] to incorporate these recent radar and light curve datasets in order to determine the best shape model for Ivar that updates the results presented by Kaasalainen et al. [6], which were based solely on light curves. During this procedure, we use penalty functions and parameters that must be tailored specifically to the target asteroid in order to steer asteroid shapes away from those that are overly complex and implausible.

Results: We have used the thermal-modeling code SHERMAN [7,8,9] to create a thermophysical model of Ivar in order to study the heterogeneity of its surface. Input parameters for SHERMAN include the asteroid's IR emissivity, optical scattering law and thermal inertia in order to complete thermal computations based on the shape model. We also model different degrees of cratering on the surface which, combined with the shape model, explores effects that have previously been described by beaming parameters. The software creates synthetic near-IR spectra that can be compared to our own observed spectra, which cover a wide range of Ivar's rotational longitudes and viewing geometries. The spectra show changes with rotation and phase angle. SHERMAN lets us determine which reflective, thermal, and surface properties for Ivar best reproduce our spectra. We have found the results for Ivar to be substantially different from others studied in this fashion. In the case of Ivar, we see clear signs of heterogeneity. We find that one of the ends has thermal properties that are consistently different from those of the rest of surface [10,11]. While we are unable to find a set of parameters that match the entirety of Ivar's surface, Howell et al., has shown that with a given set of thermal parameters, we can adequately model all observations of HW1 [12] regardless of phase angle or orientation.

Future Work: Once we have concluded our thermal model of Ivar, we intend to conduct a similar investigation of the Kaasalainen et al., lightcurve model. Comparing the similarity, or dissimilarity, of these results would be incredibly useful since there exists an extensive database of shape models produce using lightcurve inversion techniques. We also intend to continue comparing the results of Ivar with similar asteroids, in type, size, etc. With the results produced by SHERMAN and these comparisons, we will learn more about the detailed regolith and surface properties of Ivar and how those properties compare to those of other S-complex asteroids.

References: [1] DeMeo et al. 2009, Icarus 202, 160-180. [2] Crowell, J. et al. 2015, LPSC 46. [3] Ostro, S. et al. 1990, Astron. J., 99, 2012-2018. [4] Magri, C. et al. 2011, Icarus 214, 210-227. [5] Crowell, J. et al. 2014, AAS/DPS. [6] Kaasalainen, M. et al. 2004, Icarus

167, 178-196. [7] Magri C. et al. 2007, Icarus 186, 152-177. [8] Marshall, S. et al. 2013, AAS/DPS 45. [9] Howell, E. et al. 2015, TherMoPS II. [10] Crowell, J. et al. 2015, TherMoPS II. [11] Crowell, J. et al. 2015, AAS/DPS. [12] Howell, E. et al. 2015, AAS/DPS 47. This work is partially supported by NSF (AST-1109855), NASA (NNX13AQ46G), CLASS (NNA14AB05A), and USRA (06810-05).