Astronomy in Focus - XXX
Proceedings IAU Symposium No. XXX, 2018
M. T. Lago, ed.

doi:10.1017/S1743921319003430

Asteroid Families and the Next Generation Surveys

Joseph Masiero

NASA Jet Propulsion Laboratory, Caltech
4800 Oak Grove Dr, MS 183-301, Pasadena, CA 91109, USA
email: joseph.masiero@jpl.nasa.gov

Asteroid families represent unique sets of data for testing the physical and mechanical properties of protoplanets and other small bodies. One of the main sources of data on the physical properties for these bodies has been large-scale astronomical surveys that have collected incidental observations of a large number of minor planets. Surveys such as the Sloan Digital Sky Survey (SDSS; Ivezić *et al.* 2001; Parker *et al.* 2008) and the Wide-field Infrared Survey Explorer (WISE; Mainzer *et al.* 2011; Masiero *et al.* 2011) have provided griz colors (SDSS) and albedos and diameters (WISE) for tens of thousands of members of asteroid families.

Given the utility of these astronomical surveys to understanding Solar system objects, we naturally look forward to the next generation of surveys to further our knowledge of families, and provide us unique insights. The assets that will have the nearest-term impact on our understanding of families are those that are currently either ongoing, or will become operational in the next few years. While there are many groups conducting a wide range of astronomical surveys across the electromagnetic spectrum, two in particular stand out as likely to have the biggest impact on the study of families: Gaia and LSST.

Gaia is ESA's all-sky astrometric survey, which has already provided milliarcsecond astrometry for thousands of asteroid family members and will soon release measurements for the full moving object data set containing $\sim 120,000$ family asteroids (Spoto *et al.* 2018). Future data releases will also increase the baseline of these measurements, which will enable constraints on the masses for hundreds of family members. When combined with known diameters, density measurements as a function of size will test predictions of rubble pile reaccumulation from family formation simulations. Future Gaia data releases will also contain low resolution spectra of tens of thousands of family members, providing improved taxonomic classifications.

The Large Synoptic Survey Telescope (LSST, *lsst.org*), is currently under construction in Chile, with a planned first light in 2021 and a formal beginning of survey in late 2022. With an 8.4 m diameter primary mirror and a 3.2 Gpix camera, LSST will conduct a 10 year survey of the sky in 5 optical bandpasses, repeating coverage every 3 days. These survey data would provide optical colors for possibly millions of asteroid family members, greatly expanding on the results from SDSS.

Beyond the immediate future, the surveys that are currently planned or proposed offer us a view of what new data may become available for asteroid families. These designs and debates highlight where the interest lays in the broader astronomical community for future survey strategies, and what the probable next-steps are going to be.

Two upcoming missions focus on high precision photometric surveys in the near-infrared. ESA's Euclid space telescope (http://sci.esa.int/euclid/) with planned launch date in 2021, and NASA's Wide Field InfarRed Survey Telescope (WFIRST, https://www.nasa.gov/wfirst) with launch date targeting the mid 2020's, would focus on conducting a photometric survey from the visible to 2 μm to study dark energy. Incidental observations of asteroid family members would enable NIR photometric taxonomies similar to those developed by e.g. Sykes *et al.* (2000), Popescu *et al.* (2018). When combined with data from LSST, these would provide full visible-to-NIR taxonomic classifications for hundreds-of-thousands of asteroid family members.

SphereX (http://spherex.caltech.edu/) has been selected by NASA for Phase B development, targeting a 2023 launch date. The goal of this mission is to perform an all-sky spectroscopic survey from $0.5 - 5$ μm, by sweeping a series of low resolution dispersion elements over the sky during the telescope's low-Earth polar orbit. Spectra would be built piece-wise, so moving objects would only receive partial spectral coverage or would need to be reassembled after accounting for rotation, but tens of thousands of family members would receive some spectral characterization, including of the water absorption features near 3 μm.

The Near-Earth Object Camera (NEOCam, https://neocam.ipac.caltech.edu/) is a proposed mid-infrared asteroid survey mission, with a launch date targeting the mid 2020's. NEOCam would collect observations simultaneously at $4 - 5.2$ μm and $6 - 10$ μm, detecting millions of Main Belt asteroids and enabling thermal modeling to characterize their diameters. When combined with data from LSST, albedo measurements for these millions of asteroids would also be possible. While it is specifically designed for observations of near-Earth objects, incidental observations of family members at multiple epochs would also support detailed thermophysical modeling of the surface.

Beyond the next few decades, it becomes harder to guess what kinds of surveys and data streams will be needed and desired by astronomers, or how those data will be used in light of the discoveries that precede them. Looking to the past, we see that new detector technologies often mature into pioneering surveys, while successful surveys often are repeated when order-of-magnitude improvements become possible.

One obvious area of future exploration will be deeper, all-sky moderate resolution spectral surveys. The rapid growth of integral field unit (IFU) spectroscopy will enable a spectral survey of all objects in the sky, even asteroids, to be carried out. This could provide taxonomic classifications for a large fraction of the known members of asteroid families. Another probable future survey is a next-generation version of Gaia after a few decades have passed that would expand our measurements of masses via gravitation perturbations and Yarkovsky drift measurements to many thousands of family members, or more.

In addition to new instrumentation, new processing of survey data will also allow us to expand our knowledge of families and family-forming impacts. In particular, we can expect that ongoing surveys will continue to detect asteroids that have recently undergone catastrophic impacts, and that the rate of these events will increase as new surveys come online. But it is also probable that as our catalog of objects increases and our knowledge of their orbits improves with new astrometric surveys we will soon be able to not just witness, but to predict asteroid-asteroid collisions before they occur. This will enable us to study the objects pre- and post-collision, and thereby observe the details of catastrophic impacts on a protoplanetary-scale, possibly even with *in situ* spacecraft.

The future of asteroid family studies already promises to be one of revolutionary ideas and understandings. I for one look forward with anticipation to what we will learn in the second century of asteroid families.

References

Ivezić, Ž., Tabachnik, S., Rafikov, R. *et al.* 2001, *AJ*, 122, 2749
Mainzer, A., Bauer, J., Grav, T. *et al.* 2011, *ApJ*, 731, 53
Masiero, J., Mainzer, A., Grav, t., *et al.* 2011, *ApJ*, 741, 68
Parker, A., Ivezić Ž., Jurić, M. *et al.* 2008, *Icarus*, 198, 138
Popescu, M., Licandro, J., Carvano, J.M., *et al.*, 2018, *A&A*, 617, A12
Gaia Collaboration, Spoto, F., Tanga, P., Mignard, F., *et al.* 2018, *A&A*, 616, A13
Sykes, M., Cutri, R., Fowler, J., *et al.*, 2000, *Icarus*, 146, 161