DETECTING NON-GRAVITATIONAL EFFECTS ON SMALL-SIZED NEOS WITH ACCURATE GROUND-BASED ASTROMETRY: THE CASE OF 2011 MD. M. Micheli[1], D. J. Tholen[1] and G. T. Elliott[1], [1]Institute for Astronomy, University of Hawaii, 2680 Woodlawn Dr., Honolulu, HI 96822, USA (micheli@ifa.hawaii.edu, tholen@ifa.hawaii.edu, elliott@ifa.hawaii.edu).

Introduction: In the last few years, the improved capabilities of optical surveys have led to the discovery of many hundreds of very small Near-Earth Objects, with diameters around or below 10 m, considered too small to cause significant ground damage in case of a collision. However, because of their low masses, they are extremely interesting test cases to investigate the action of non-gravitational effects in the solar system, that may have relevant implications for the impact predictions of larger and more dangerous objects.

With the use of large optical telescopes, together with accurate astrometric reduction procedures, astrometric precisions with random errors around 0.1" can currently be obtained. These data, if properly and carefully analyzed, allow us to directly measure the dynamical effects of non-gravitational forces acting on the body, and therefore infer interesting physical information on the targets, such as their densities.

Analysis, debiasing and rejection of observations: Because of their sizes, most of these small objects can only be observed from the ground for a limited time, during extremely close encounters with our planet. During these short observational windows hundreds or thousands of observations are often collected and submitted to the Minor Planet Center, mostly by amateurs. These datasets, together with follow-up observations from professional facilities, can be enough to detect the weak signature of a non-gravitational effect acting on the object. However, because most of these data come from many different sources, with different performances and accuracies, it is necessary to treat them carefully to make sure that meaningful scientific information can be extracted.

Data analysis techniques. Two of the most important effects that must be taken into account are systematic biases and outliers. Since most of the systematic biases are known to come from intrinsic biases in the reference astrometric catalogs, debiasing methods have been developed [1], based on the catalog that was used in the astrometric reduction.

We recently developed a rejection method for astrometric observations, based on the little known Peirce criterion [2], that allows a mathematically founded approach to the rejection of observational data, specifically tailored for Rayleigh-distributed quantities (such as the optical astrometric residuals). This method, presented in [3], allowed us to obtain a definite detection of radiation pressure acting on one of these small objects, 2009 BD, based on a 3-opposition arc. The detection and the associated value of Area to Mass Ratio (AMR) were then confirmed with additional data collected during its 2011 apparition.

A difficult test case: 2011 MD: We then decided to apply our analysis techniques to a recently discovered object, 2011 MD. The object is small enough to be significantly affected by non-gravitational forces, but the observability window was restricted to a few months, and only one single opposition.

We followed-up the object for two months with the telescopes on Mauna Kea, Hawaii, until it became too faint for ground-based observations. However, the total available arc, including observations from various stations around close approach and our follow-up effort, is only about 70 days.

The detection. We applied both a catalog-based debiasing procedure and our rejection algorithm to all these data. Even with such a short arc, we can detect a weak but convincing signal of radiation pressure acting on the object. The associated AMR is very similar to the value detected for 2009 BD, as it is to be expected since the two objects have almost identical sizes.

An interesting preliminary result: The values for the AMR derived from radiation pressure can be converted into an estimated bulk density for the object, with an estimate of its absolute magnitude and assumptions on the albedo. Within the currently known NEO population, only three objects (2011 MD, 2009 BD and 2006 RH120) have enough data for this kind of studies. However, all of them show densities that are water-like, or less, and they are incompatible with typical rock-like densities (unless we assume unreasonably high albedoes).

This fact, if confirmed on more objects, may be a hint to the fact that small objects, usually thought to be monolithic rocks, may be more porous than expected. This may in turn have significant implications in our understanding of the ground damage that can be caused by this objects, when they impact our planet.

References: [1] Chesley S. B. et al. (2010) *Icarus, 210*, 158–181. [2] Peirce B. (1852) *AJ, 2*, 161–163. [3 Micheli M. et al. (2012) *New Astronomy*, *17*, 446–452.

Acknowledgement: This work was funded by grant AST 0709500 from the U.S. National Science Foundation.