EPSC Abstracts
Vol. 13, EPSC-DPS2019-626-2, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Distinguishing between Solar System Formation Models with Manxes (or maybe not)

Benjamin Boe (1), **Robert Jedicke** (1), Paul Wiegert (2), Karen J. Meech (1), Alessandro Morbidelli (3), Robert J. Weryk (1), Karen J. Morenz (4) and the Pan-STARRS1 Science Collaboration
(1) Institute for Astronomy, University of Hawai'i, 2680 Woodlawn Drive, Honolulu, HI 96822, USA, (jedicke@hawaii.edu), (2) Western University, London, ON, Canada, (3) Observatoire de la Cote d'Azur, Nice, France, (4) University of Toronto, Toronto, ON, Canada.

Abstract

We compare the results of a 'traditional' measurement of the size-frequency distribution (SFD) of essentially inactive objects (Manxes) on long period (LP) orbits to the results of [1] who introduced a new technique for extracting the SFD of LP cometary nuclei. Both sets of data were obtained with the Pan-STARRS1 system (PS1) on Haleakala, Maui, over the course of about eight years. Given that the inactive Manxes must be much more difficult to detect compared to the active LPCs it is surprising that PS1 has identified 65 Manxes and only 148 LPCs. This implies that there must be a large population of Manxes. The identification of Manxes with asteroidal S-class spectra indicates that some inner solar system material from the proto-planetary disk has been stored for billions of years in the Oort Cloud (OC). Different solar system formation models predict the ratio of OC objects that should be from the outer and inner solar. We have measured this ratio to confront the solar system formation scenarios.

1. Introduction

No-to-low activity comets on LP orbits [4] discovered by PS1 [3, 2] may provide a new technique for distinguishing between solar system formation models. The tailless LP objects, dubbed 'Manx' objects, display orders of magnitude less volatile activity than normal active comets and therefore must contain far less volatile material by mass than their active LP counterparts [4]. Spectra of the Manx comet C/2014 S3 is consistent with that of an S-class asteroid and it is therefore likely that it formed in the inner solar system. Thus, C/2014 S3 may be the first representative of a new class of objects that were ejected from the inner solar system early in its formation history only to return in recent times. Since the various solar system formation models predict that different amounts of inner and outer solar system material will be ejected into the OC we attempt to use the LPC to Manx ratio to distinguish between the models. We will use the LPC initialism to refer to active objects or those that have the potential to become active should they enter the inner solar system, while 'Manxes' refer to objects with such low levels of internal volatile species that they would never become 'active'.

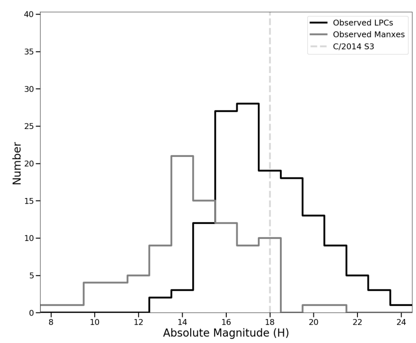

Figure 1: The nuclear absolute magnitudes (H_N) of LPCs and Manxes detected by PS1 [1]. The reported H_N for LPCs have been corrected by 5.5 mags as described by [1].

2. Solar System Formation Models

There are currently two broadly competing scenarios to explain the origin and characteristics of the asteroid belt located roughly between the orbits of Mars and Jupiter. The 'massive proto asteroid belt' (MMB) scenarios begin with about an Earth mass of material while the 'depleted proto asteroid belt' (DMB) models assume that it was never massive. The relative contribution of 'asteroidal' inner solar system material to the OC between the two categories of models is substantially different. Based on published estimates of the re-distribution of material within the solar system we estimate that the MMB scenarios create an OC with an LPC:Manx ratio in the range 1000-100:1. In the DMB scenarios the proto main belt does not effectively contribute to the Manx population embedded in the OC and the predicted ratio should be about 1,000$\times$ higher than expected in the MMB models. The tremendous difference between the predictions provides a means of distinguishing between the two classes of models. The problem is that measuring the ratio requires a well calibrated astronomical survey to correct for the dramatic differences in LPC and Manx discovery efficiency.

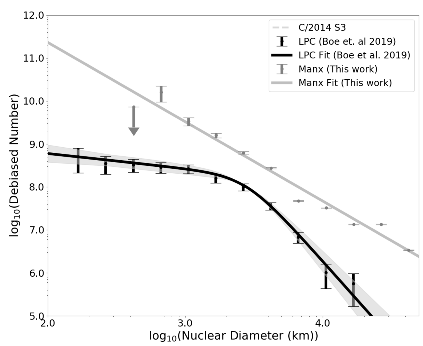

Figure 2: (bold) The debiased LPC incremental SFD as a function of diameter (assuming an albedo of $p_V = 0.04$ [1]) and (gray) our preliminary debiased Manx incremental SFD.

3. PS1 LPCs and Manxes

In the ~ 8 years of PS1 surveying considered in this analysis the system detected 148 LPCs and 65 Manxes (fig. 1). These statistics alone should cause the reader to pause. The active LPCs are bright and visible at large distances due to their comae and tails, and may be distinguished in astronomical images by their non-stellar morphologies. The Manxes have none of these advantages and must be detected by their unusual rates of motion — they are 'stealth' members of the LP population. Thus, we found it surprising that PS1 identified only about twice as many LPCs than Manxes. Given the observational advantages of LPCs to Manxes there *must* be a substantial number of dull, nearly inactive Manxes compared to the shiny, flamboyant LPCs.

4. LPC and Manx populations

We have corrected for the observational selection effects in Pan-STARRS1's discovery of both LPCs and Manxes. We term this activity 'debiasing' the discoveries. The LPC work was described in detail by [1] and extended to include Manxes in this work. There are clearly far more Manxes than LPCs as a function of their nuclear diameter, inconsistent with the predictions of both the MMB and DMB scenarios (fig. 2). Furthermore, our results suggest the identification of the single S-class C/2014 S3 Manx is difficult to reconcile with either scenario.

5. Summary and Conclusions

We have employed the results of the PS1 survey telescope to measure the ratio of LPC to Manxes in the Oort Cloud. The ratio is much lower than expected from back-of-the-envelope calculations beginning with either a massive or depleted proto-planetary main belt. The discovery of the single S-class Manx object, C/2014 S3 is similarly difficult to understand within the context of our current understanding of the formation of these objects.

Acknowledgements

We thank Larry Denneau, Eva Lilly, Serge Chastel, and Beau Bierhaus, the IAU's MPC, and the NASA supported JPL Small-Body Database Search Engine. The Pan-STARRS1 Surveys, PS1, and the PS1 public science archive have been made possible through contributions by institutions and funding agencies too numerous to list within the page limit.

References

[1] Boe, B., Jedicke, R., Wiegert, P., Meech, K., Morbidelli, A., Weryk, R. J., Morenz, K. J., et al. 2016, accepted for publication in Icarus.

[2] Chambers, K. C., Magnier, E. A., Metcalfe, N., et al. 2016, arXiv e-prints , arXiv:1612.05560.

[3] Hodapp, K. W., Kaiser, N., Aussel, H., et al. 2004, Astronomische Nachrichten, 325, 636.

[4] Meech, K. J., Yang, B., Kleyna, J., et al. 2016, Science Advances, 2, e1600038.