EPSC Abstracts
Vol. 8, EPSC2013-98, 2013
European Planetary Science Congress 2013

Applied Astronomy: Asteroid Prospecting

Martin Elvis
Harvard-Smithsonian Center for Astrophysics (martinselvis2@gmail.com)

Abstract

In the age of asteroid mining the ability to find promising ore-bearing bodies will be valuable. This will give rise to a new discipline- "Applied Astronomy". Just as most geologists work in industry, not in academia, the same will be true of astronomers. Just how rare or common ore-rich asteroids are likely to be, and the skills needed to assay their value, are discussed here, with an emphasis on remote - telescopic - methods. Also considered are the resources needed to conduct extensive surveys of asteroids for prospecting purposes, and the cost and timescale involved. The longer-term need for applied astronomers is also covered.

1. Introduction

Astronomers were once employed because their skills were important to exploration and commerce. Celestial navigation mattered. That astronomers also discovered things about our universe – and until the late 19th century these discoveries were mainly limited to the Solar System – provided a bonus of prestige. After a century in which astronomy has enjoyed a golden age of pure academic discovery, the re-emergence of applied astronomy is imminent.

Asteroid mining demands accurate and reliable assaying of the resources of the asteroids. The relatively small numbers of asteroids that have been characterized for research are inadequate for mining.

Here I show why that is and describe the astronomy observations and resources needed to carry out the asteroid prospecting task in a timely fashion.

2. Ore-bearing

In mining terms "*Ore is commercially profitable material"* [1]. Few mountains on Earth contain ore, and few NEAs may be ore-bearing.

We can quantify the number of ore-bearing NEAs as the product of several factors [2]:

$$N_{ore} = P_{type} \times P_{rich} \times P_{dv} \times P_{eng} \times N(>M_{min}). \quad (1)$$

Here P_{type} is the probability that an asteroid is of the resource bearing type, P_{rich} is the probability that this type of asteroid is sufficiently rich in the resource, P_{dv} is the probability that the asteroid is in an orbit with a sufficiently low delta-v to be accessible, P_{eng} is the probability that the engineering challenges of mining this asteroid can be overcome, and $N(>M_{min})$ is the total number of asteroids larger than a threshold mass, M_{min}, for profitability for the identified resource. Other factors can be added to this equation as the calculations become more refined, but this captures the essence of the problem.
Putting in numbers (Table 1) for the platinum group metals (PGMs) gives a surprisingly small number of potentially profitable, ore-bearing, asteroids, about a dozen. For water the numbers are much more promising, but these small asteroids are hard to find and characterize.

Of the terms in Equation 1, all but P_{rich} and P_{Eng} can be determined remotely by telescopic means, and hence can be applied in bulk by astronomers. The small numbers in Table 1 imply that their work will be valuable.

Table 1. Estimates of occurrence rates for PGM- and Water-ore bearing NEOs.

Parameter	PGMs	Water
P_{type}	3 – 5%	25 - 50%
P_{rich}	10 – 20%	10%
Richness	0.02 - 10 ppm	1 – 20%
P_{dv}	10%	10%
P_{ore}	(3 – 10) x 10^{-4}	(2.5 - 5) x 10^{-3}
D_{min}	100 m	22 m
$N(>D_{min})$	20,000	250,000
N_{ore}	6 - 20	500 – 1500

3. Telescopic Techniques

The astronomical equivalent of geological surveys can determine P_{type} and P_{dv}. P_{dv} depends only on orbital parameters, while P_{type} requires spectral information.

3.1 The Characterization Bottleneck

NEAs are being discovered at a rate of ~400/year, based on Minor Planet Center statistics. Of these 2/3 of the smaller ones have poorly determined orbits (U > 3) that can compromise their being re-acquired on their next apparition a few years later (Figure 1).

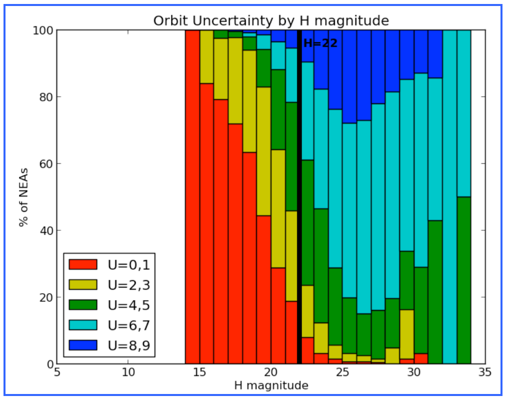

Figure 1. Orbit uncertainty parameter (U) vs. H magnitude for NEAs. H=22 corresponds to a diameter of ~100m. U>3 makes an NEA hard to recover on the next apparition [3].

The NEA discovery rate is set to increase by factors of 5 or more with enhanced ground-based searches at the Catalina Sky Survey, Pan-STARRS, the Palomar Transient Factory and ATLAS. The small pixels of Pan-STARRS allows 0.15 arcsecond position errors. This is several times better than the typical astrometric errors and should reduce U in many cases.

Characterizing NEAs is the bottleneck to finding ore-bearing asteroids. About 100/year are having optical-near-infrared spectra taken which can classify them into one of 24 taxonomic types (deMeo et al. 2009), that allow a surface composition to be determined, dividing the NEAs into carbonaceous, stony and metallic with some ambiguity and some finer-grained typing). The taxonomic type gives an improved albedo estimate, which in turn gives a more accurate size. A similarly small number per year have their rotation rates determined from their time variability.

5. Resources and Timescale

A ground-based telescope loses observing time for faint NEAs to the full moon, bad weather and instrument failures and maintenance. About 210 nights/year are useable for NEA work. If a spectrum takes an hour then about 2000 NEA spectra/year could be obtained from one telescope, about 20 times the current rate. A decade long program could then gather ~20,000 NEA spectra, roughly the total number larger than 100 meters diameter.

To obtain a large number of NEA spectra, and to choose the more interesting ones, requires being able reaching to at least an optical visual magnitude of V=20. In the near-infrared this needs a large 6-meter class telescope. Improved removal of the strong background due to OH molecular emission from high in the atmosphere may make smaller telescopes more powerful. This background means that 1 m space-based telescope would be as powerful as a current 10 m ground-based telescope for spectroscopy.

It is important to characterize NEAs within days of their discovery. Most fade within a week to fainter than V=20, and are several magnitudes fainter on their next apparition [3].

6. Summary and Conclusions

Ore-bearing asteroids are quite rare. Hence identifying them has value. Characterization of NEAs is the current bottleneck to assaying their properties to find ore-bearing asteroids. Scaling up this rate by a factor 20 is possible with large dedicated ground-based telescope. A space-based telescope would be far more effective, and more costly.

Once the NEAs have been prospected, applied astronomers will stay in business by shifting their attention to the far more numerous Main Belt asteroids.

Acknowledgements

I thank José Luis Galache, Charlie Beeson, BC Crandall, Jonathan McDowell, Mark Sonter and Rick Binzel for their invaluable assistance.

References

[1] Sonter M.J., 1997, *The Technical and Economic Feasibility of Mining the Near-Earth Asteroids*, Acta Astronautica, 41, no.4-10, pp.637-647.

[2] Elvis M., 2013, *How many ore-bearing near-Earth asteroids?*, Planetary and Space Sciences, submitted.

[3] Beeson C., Galache J.L. & Elvis M., 2013, *Scaling Near-Earth Asteroid Characterization Rates*, in preparation.