Origin and Mineralogy of Olivine- Dominated Near-Earth Asteroids

Massachusetts Institute of Technology

Harvard-Smithsonian Center for Astrophysics

Brian Burt[1], Francesca DeMeo[2], Richard Binzel[1]

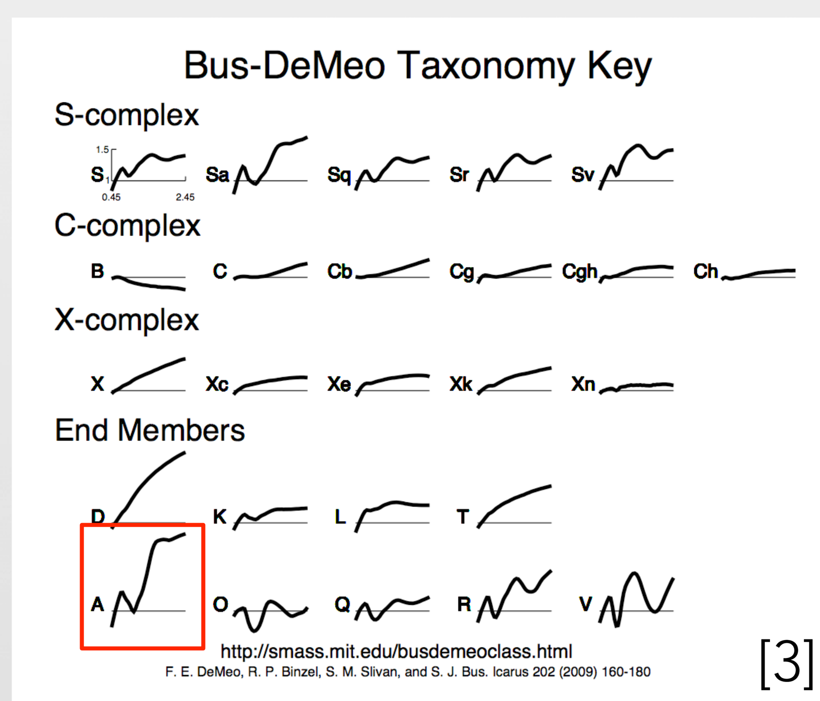
[1]Massachusetts Institute of Technology, [2]Harvard-Smithsonian Center for Astrophysics

ABSTRACT

The near-Earth Asteroid (NEA) population, because of its proximity, allows us to explore asteroids at a size range not possible among asteroids in the Main Belt. Olivine-dominated asteroids are associated with the mantle of differentiated parent bodies. There are very few olivine-dominated asteroids identified as spectroscopic A-types [1,2,3]. We identify (1951) Lick, (5261) Eureka, and a new, third A-type object, (5131) 1990 BG. Using a radiative transfer, mixing model [4], we characterize the mineralogy and compare these three olivine-rich A-type asteroids. Additionally, using a source region probability model [2], we give the source region for (5131) 1990 BG.

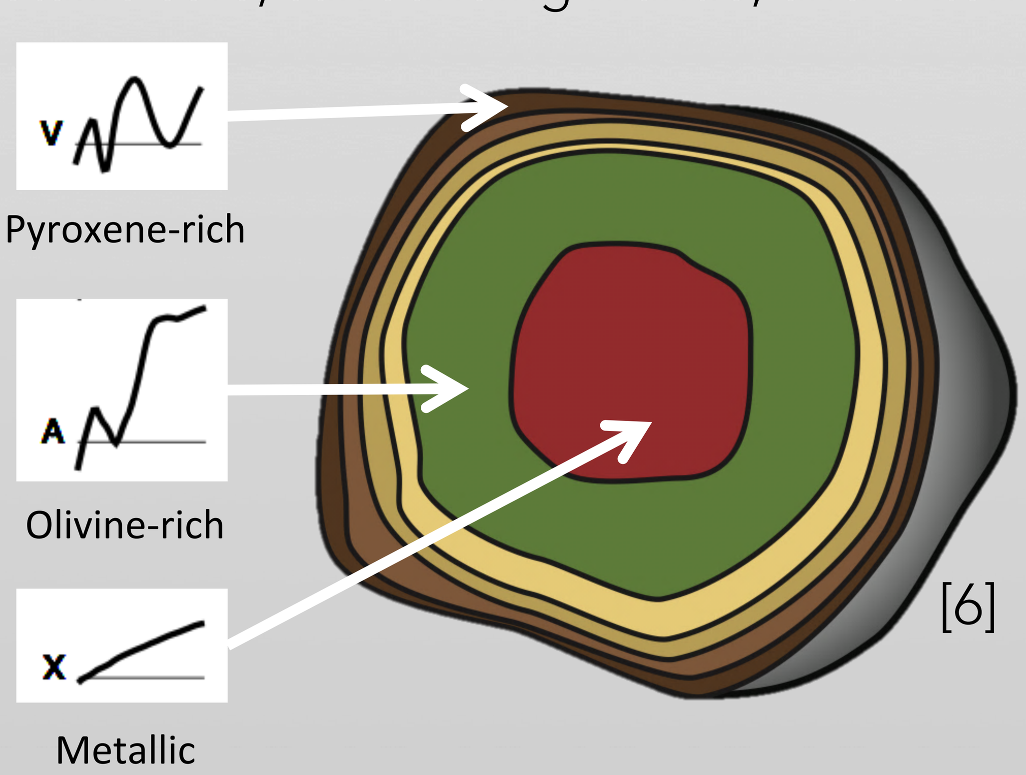
ASTEROID TYPES

Asteroids come in many flavors. Spectroscopic observations of asteroids reveal features that can be used to classify asteroids. Types are differentiated by the 1 and 2 micron absorption features and by the spectral slope. A-type asteroids are distinguished by a very deep and broad 1.1 micron absorption feature and high slope. Olivine causes a feature at 1.1 microns and pyroxene shows features at 1 and 2 microns.



DIFFERENTIATED BODIES

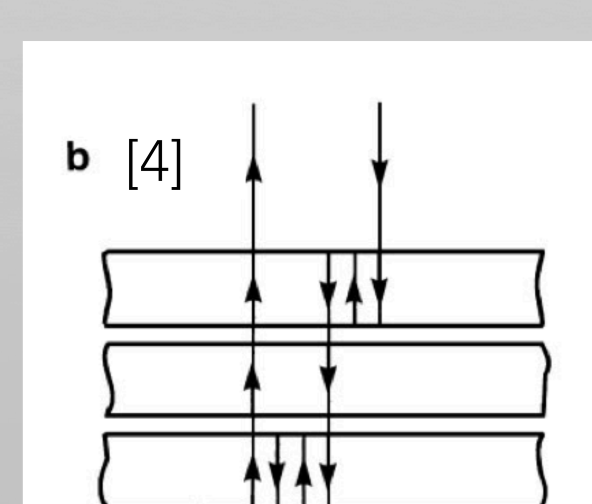
Bodies that have heated and undergone differentiation will develop a metallic core, surrounding mantle, and exterior silicate crust. V-type asteroids are representative of the crust; their spectra are composed of mainly pyroxenes. A-types are the mantle material and have spectra that consist predominantly of olivine. Featureless spectra could represent a range of compositions, but some of them are expected to be the core material.

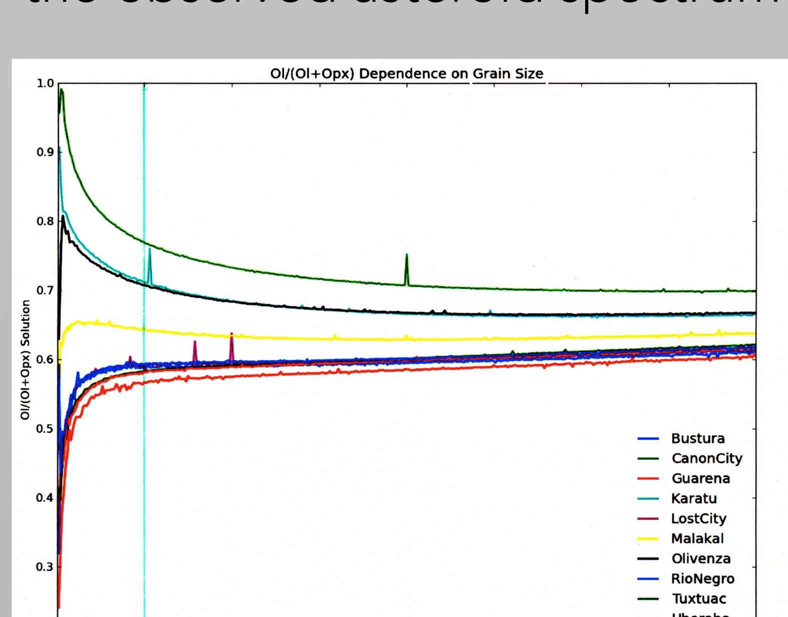


Above: Cartoon representation of a differentiated body. Shown are the core (red), mantel (greed), and silicate crust (yellow to brown).

SHKURATOV MODELING

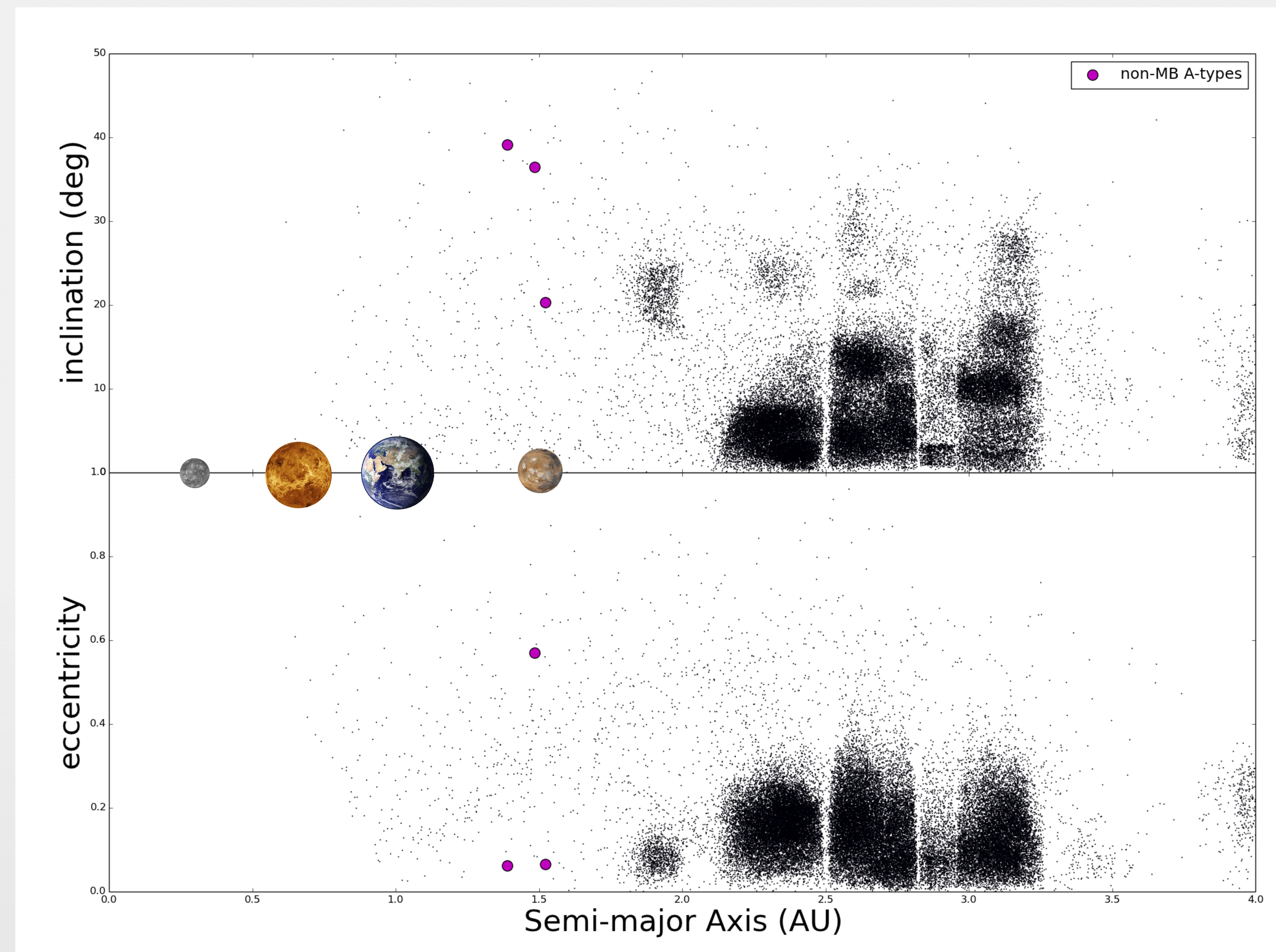
The Shkuratov model [4] is a radiative transfer, composition mixing model. It models the reflected light after the incident light has interacted with a surface of a body of a mixed composition. We determine the composition of an asteroid surface by mixing compounds until the observed asteroid spectrum is best matched.





The Shkuratov model is capable of determining the grain size of the asteroid surface material. However, we define a lower limit to grain size determinations because the model breaks down as the grain size solution approaches the length of the observed wavelengths.

Left: Shkuratov model solutions as a function of fixed grain size (x-axis). Solutions become unstable < about 50 microns. **Above:** Cartoon of light path approximated by the Shkuratov model.



Above: Orbital element diagram of non-Main Belt A-types (purple) along with a representative population of Main Belt and NEA asteroids (black). Mercury, Venus, Earth, and mars are shown for orientation.

It was shown [6] that the near-Infrared (NIR) wavelength regime broke a classification degeneracy among S- and A-types in the visible wavelengths. As a consequence, only a small handful of asteroids remained classified as A-types after the work of [3]. With the addition of NIR data, (1951) Lick was shown to in fact be an A-type [7] with an olivine fraction of 90±10% and has undergone significant space weathering [8]. Asteroid (5162) Eureka is a Mars Trojan Asteroid (orbits in Mars L5 Lagrange point) and was later shown to have an olivine fraction larger than 65% [9]. We provide the first A-type classification for (5131) 1990 BG using visible and NIR wavelength data.

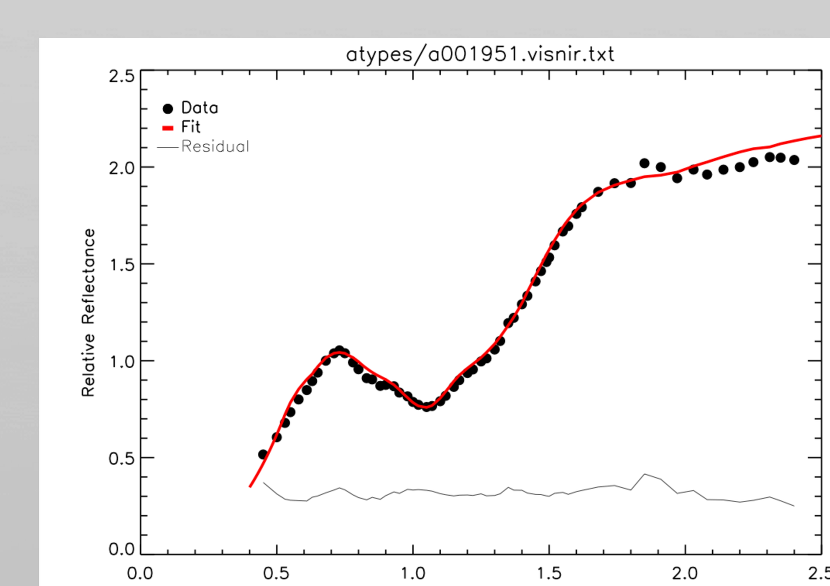
(5131) 1990 BG SOURCE REGION

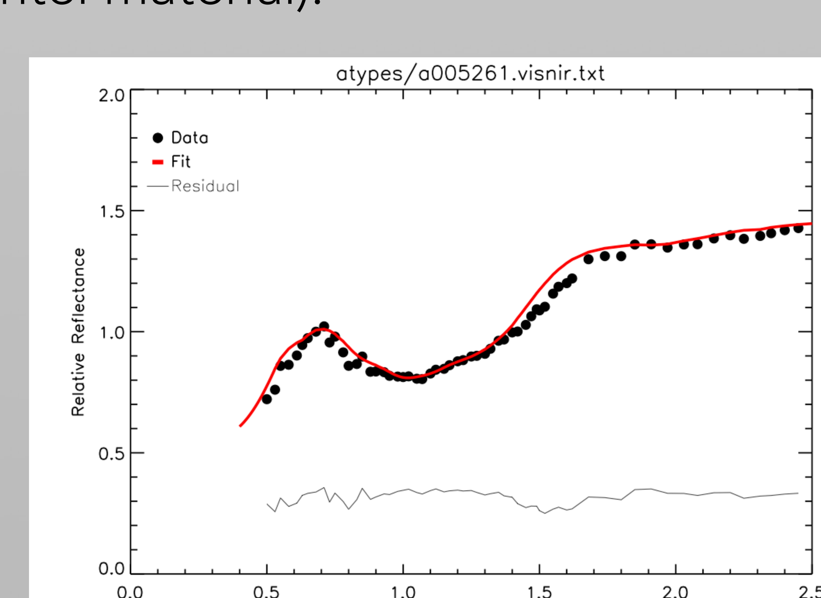
Source region probabilities are determined by integrating backwards the NEA orbit [7]. Unfortunately, Mars interactions make the determinations uncertain such that the source locations of (1951) Lick and (5261) Eureka cannot be found. However, we find that (5131) 1990 BG source region probabilities to be:

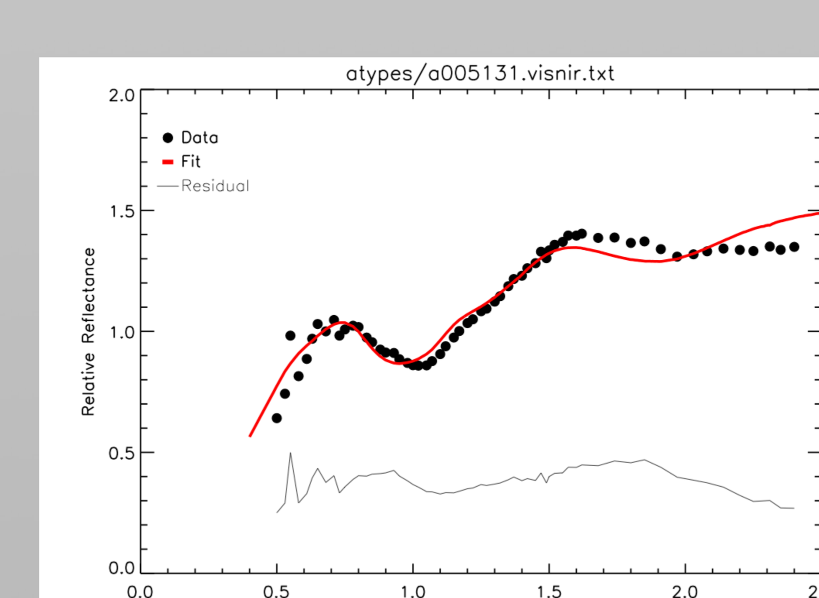
ν6 – 48% Mars Crossing Region – 29% 3:1 – 23%.

MODEL RESULTS

We use the Shkuratov model to determine the compositions of three A-type asteroids. We find (1951) Lick and (5261) Eureka to have surfaces consistent with 100% olivine. (5131) 1990 BG is found to have an ~85% olivine surface. All three asteroids have olivine solutions consistent with A-types (i.e., mantel material).







Abov: Shkkuratov solution fits to asteroids (1951) Lick, (5261) Eureka, and (5131) 1990 BG. Interpolated data are black dots and red line is Shkuratov fit. All objects have about 85% olivine or greater.

References
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