All About A-type Asteroid 446 Aeternitas

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Introduction

Asteroid dynamical work has suggested that differentiated asteroids, precursors of metallic (core), olivine (mantle), and basaltic (crustal) fragments, may have formed in the terrestrial planet region and are now interlopers to the main-belt. Based on the geochemical diversity of iron meteorites, at least ~108 asteroid parent bodies experienced partial or total melting, hence differentiation and core formation, within the first few Myr of solar system history. However, aside from chips of 4 Vesta (Vestoids and HED meteorites), mantle and crustal fragments from differentiated asteroids are rare. Mantle fragments are represented in the asteroid population by taxonomic A-types, but these pure-olivine and olivine-rich objects remain cryptic among the spectrally observed asteroids. Here, we present data from several observational campaigns, acquired mostly using ground-based telescopes, for olivine-rich A-type asteroid 446 Aeternitas.

The main-belt asteroid Aeternitas ($a = 2.79$ AU) was discovered in 1899 by Wolf and Schwassmann. Knowledge regarding the physical properties of this object has greatly increased over the past three decades. Inversion techniques using our photometric lightcurves collected over three apparitions yield a refined sidereal rotation period of 15.72743 ± 0.00005 h, and generated a convex-hull shape model of the asteroid. Our results reveal that Aeternitas is a prograde rotator with an angular shape, and is likely a collisional fragment. Accordingly, for mantle material to be exposed the parent asteroid must be fragmented or its interior exposed via collisions.

Visible and near-infrared (VISNIR) spectra indicate that Aeternitas is an olivine-rich A-type with an ol/(ol+px) ratio of 0.92, with a minor (~8%) pyroxene component. Several inferences of mineral chemistry derived from these spectra suggest Mg-rich olivine compositions, analogous to pallasites. However, recent results suggest that the R-chondrites are a possible meteorite analog. We performed NEATM thermal modeling utilizing WISE (12 and 22 μm) data, employing refined absolute magnitude and slope parameter values. These results provide new estimates for effective diameter ($D_{25}$) 56 ± 3 km, geometric albedo ($P_g$) 0.167 ± 0.030, infrared albedo ($P_{ir}$) 0.403 ± 0.040, and beaming parameter ($\eta$) 1.48 ± 0.10 for Aeternitas.

The Lightcurves

Figure 1. – Reported rotational periods from photometric lightcurves for 446 Aeternitas. (a) from Florczak et al., 1997 (b) from Behrend - Observatoire de Genève website, 2006 (c) from Fauré et al., 2008 (d) from Lucas et al., 2012 (e) from Lucas et al., 2011. Lightcurve data in (c,d,e) were inverted to produce the shape model of this asteroid.

The Spectrum

The Meteorite Analogues

Figure 2. – VISNIR spectrum (green) and WISE IR fluxes (black x’s) of 446 Aeternitas with reflected NEATM model fit (black line). VIS data is from SMASS II (Bus and Binzel, 2002), NIR data is from (Sunshine et al., 2007), IR fluxes (3.4, 4.6, 12, 22 μm) from WISE (Mainzer et al., 2011).

The Shape Model

Figure 3. – Shape model of 446 Aeternitas shown in ecliptic view with pole solution (z-axis) of \( \beta = +52^\circ, \lambda = 356^\circ \) indicated. In this view the observer and asteroid are on the ecliptic plane (asteroid on ascending or descending node of orbit) with phase angle of 0°. The diameter of Aeternitas is 56 ± 3 km for scale.

Figure 4. – Shape model of 446 Aeternitas from four different viewing geometries (Lucas et al., 2012). Aeternitas is a prograde rotator with a distinct angular shape. Planar areas in the convex hull shape model suggest concavities, possibly large craters or saddles. The diameter of Aeternitas is 56 ± 3 km for scale.

The Thermal Model

Figure 5. – VISNIR spectra of six olivine-dominated asteroids, 2 μm absorption bands due to pyroxene are absent for three asteroids (left) and are thus pure-olivine A-types; three asteroids (right) display slight absorptions due to pyroxene and are thus olivine-rich A-types (Sanchez et al., 2013). Three possible olivine-rich meteorite analogues for 446 Aeternitas (green) are shown above; R chondrites (top), brachinites (middle), and pallasites (bottom).

Figure 6. – Derived thermal model for 446 Aeternitas for the date 2010-04-05.552 and a heliocentric distance of 2.57 AU. The rotational pole (z-axis) is to the upper left in this view.

Figure 7. – 22 μm fluxes with a model thermal rotational lightcurve. A thermal inertia ($\gamma$) of 200 J m$^{-2}$ K$^{-1}$ s$^{-1/2}$ provides the best amplitude fit with the fluxes.

Table 1. – Parameters for the derived shape model of 446 Aeternitas. A total of 1787 photometric data points were used in the lightcurve inversion technique to produce the shape model.

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<th>Parameter</th>
<th>Value</th>
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<tr>
<td>$D_{25}$ (km)</td>
<td>56 ± 3</td>
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<tr>
<td>$P_g$</td>
<td>0.167 ± 0.030</td>
</tr>
<tr>
<td>$P_{ir}$</td>
<td>0.403 ± 0.040</td>
</tr>
<tr>
<td>$\eta$</td>
<td>1.48 ± 0.10</td>
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Table 2. – Mineralogical and physical parameters for Aeternitas.

<table>
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<tr>
<td>$\gamma$</td>
<td>200 J m$^{-2}$ K$^{-1}$ s$^{-1/2}$</td>
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Acknowledgements

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References

- Lucas et al. (2011), MLucas9@utk.edu.