(486958) Arrokoth Coordinate System Document

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1 Introduction

This document defines the coordinate system used by the New Horizons Team for (486958) Arrokoth (a.k.a. 2014 MU_{69}) which the New Horizons spacecraft flew by on 1 January 2019. This coordinate system has not been defined or accepted by the International Astronomical Union (IAU), but does follow guidelines established by the IAU Working Group on Cartographic Coordinates and Rotational Elements (WGCCRE).

The "coordinate system" referred to in this document is the body-fixed coordinate system which describes surface features.

Arrokoth is a bi-lobate contact binary (Spencer et al. 2020) which presents challenges for traditional mapping applications, due to its irregular shape (Figure 1). This document supersedes Beyer et al. (2019) written shortly after the flyby.

2 IAU Guidelines

The IAU WGCCRE has guidelines on how coordinate frames are to be assigned to irregular objects (Archinal et al. 2018, 2019). For minor planets like Arrokoth,

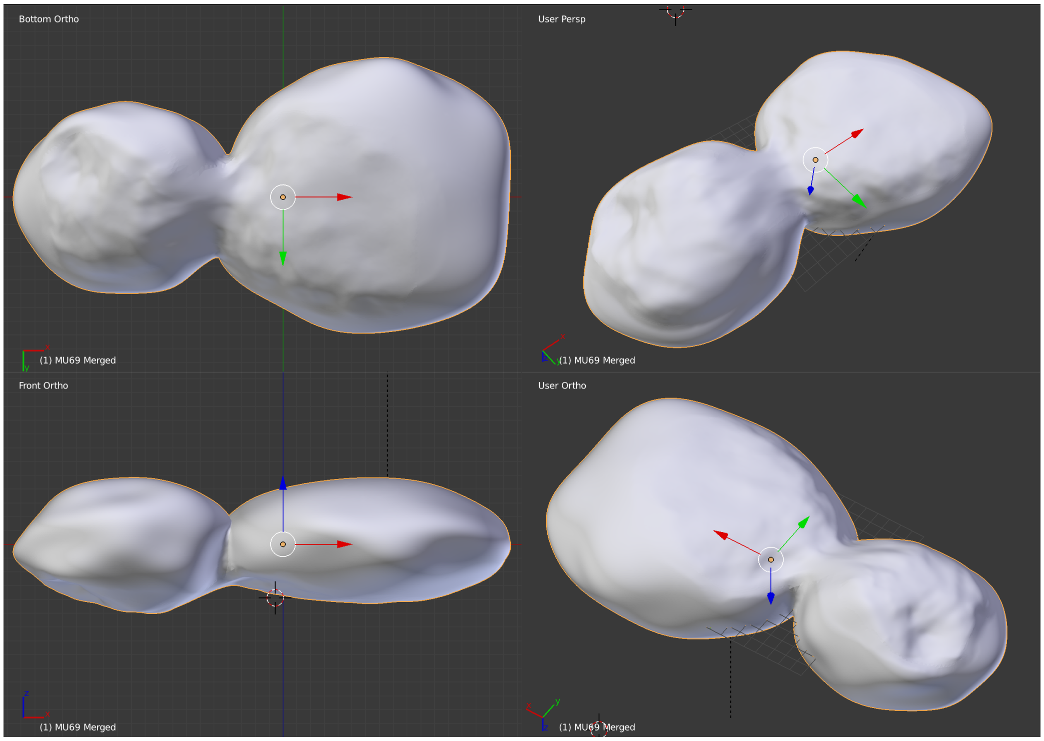

Figure 1: Visualization of the Arrokoth merged shape model (Spencer et al. 2020). The orange dot indicates the center of mass, the blue arrow indicates the positive spin pole, and the red arrow points towards the prime meridian.

the positive rotation pole and the direction of increasing longitude should follow the right-hand rule. The location of the prime meridian is arbitrary, but should be defined by a suitable observable feature or features.

3 Rotational Pole

The following information is from Spencer et al. (2020). The rotational period of Arrokoth is 15.91 ± 0.02 hours. The positive rotational pole points to right ascension $317.5 \pm 1°$, declination $-24.9 \pm 1°$ in the J2000 epoch.

Approach and departure imaging of Arrokoth allowed determination of the center of mass of the bi-lobate object which the center of rotation passes through.

4 Prime Meridian

The New Horizons team did not select a specific surface feature in order to fix the longitude, instead Arrokoth has a very clear long axis which is defined dynamically, and the prime meridian was placed along the long axis on the largest lobe (Figure 2). The long axis of the binary is the most unique and definable feature to choose as the fiducial longitude, as it is constrained by the entire approach imaging sequence. In contrast, the equatorial areas of Arrokoth were only sparsely imaged in the close approach image.

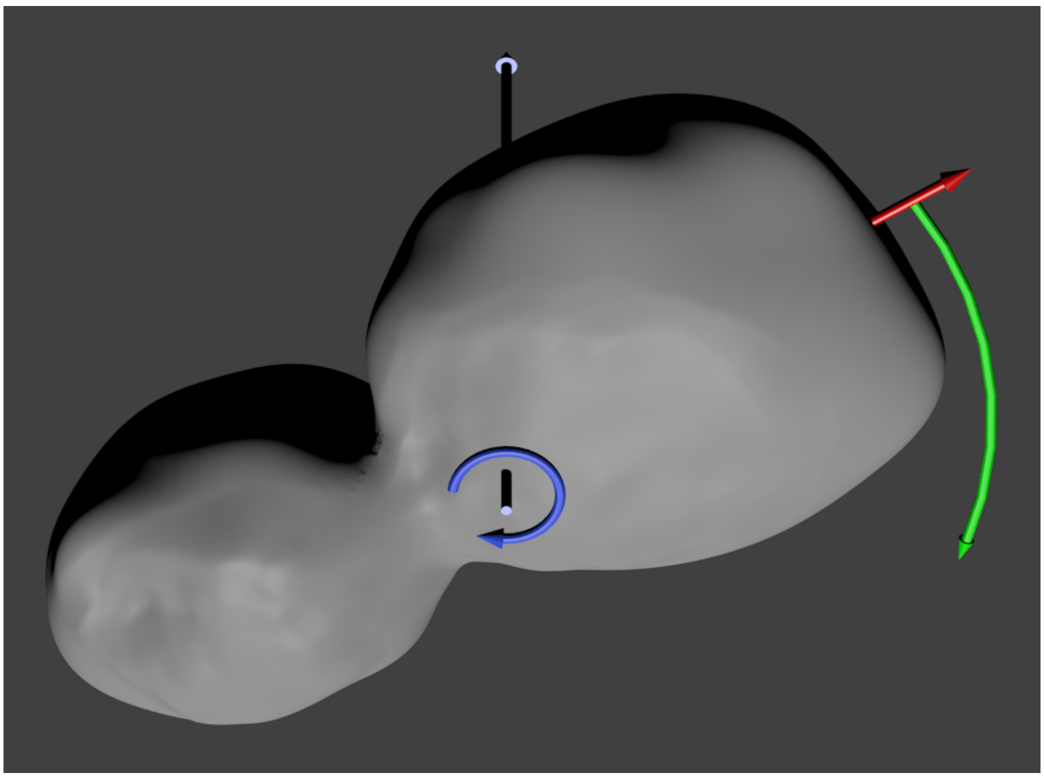

Figure 2: Visualization of the Arrokoth merged shape model (Spencer et al. 2020) with illumination similar to the flyby conditions. The positive spin pole and the direction of rotation are indicated by the blue arrows. The red arrow points out of the equator at the prime meridian. The green arrow indicates the direction of increasing longitude according to the right-hand rule.

Selection of this prime meridian then allowed us to solve for ω_0 and ω_1 referenced to the J2000 epoch, they are approximately 184.5 and 542.8, but values with more significant figures for the rotation pole orientation and the prime meridian can be found in the NAIF PCK kernels, and look like this:

```
BODY2486958_POLE_RA  = ( 317.4880752   0.          0. )
BODY2486958_POLE_DEC = ( -24.8876496   0.          0. )
BODY2486958_PM       = ( 184.4589465 542.7774192 0. )
```

5 Mapping and Visualization

The above discussion establishes a planetocentric coordinate scheme for the entire bi-lobate Arrokoth object, but this isn't particularly suitable for mapping and cartographic applications.

The New Horizons team experimented with planetodetic systems that attempted to place a very flattened longitude / latitude graticule on each of Arrokoth's two lobes, but this ended up being impractical, while a straightforward Cartesian system worked well, and was compatible with a wide variety of software tools.

The Arrokoth Cartesian coordinate system has its +Z axis aligned with the positive rotation pole (blue axis in Figure 3), and its +X axis aligned with the prime meridian (red axis in Figure 3 and as detailed in Archinal et al. 2018, Fig. 2).

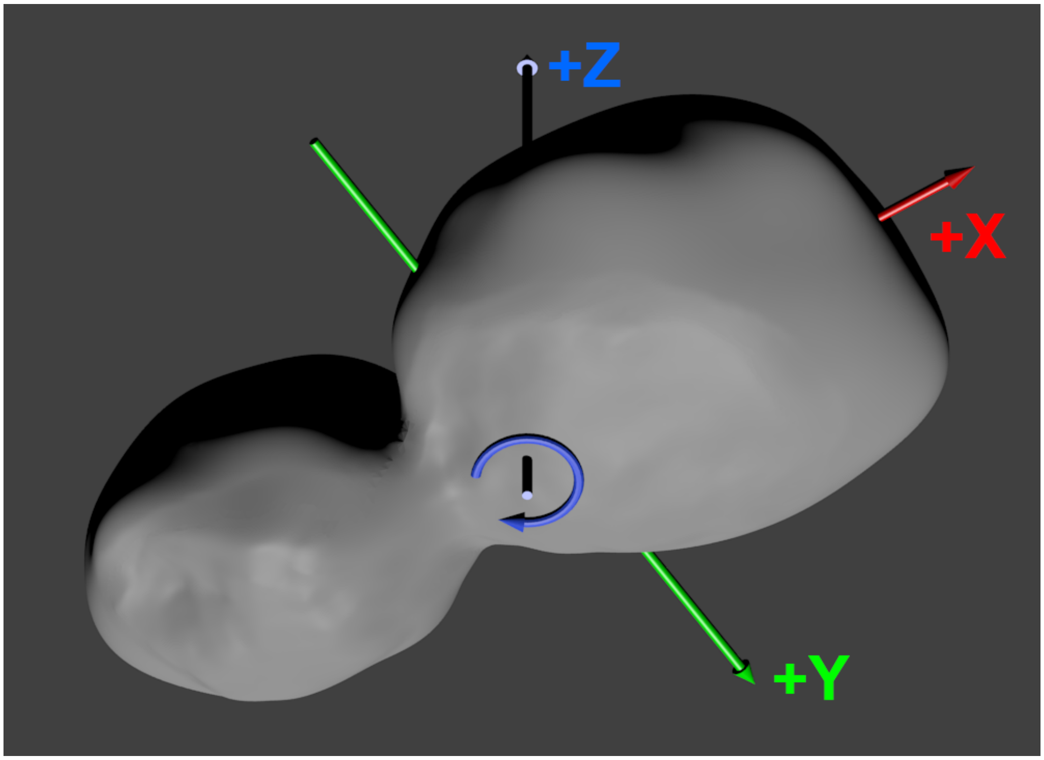

Figure 3: Visualization of the Arrokoth merged shape model (Spencer et al. 2020) with illumination similar to the flyby conditions. The positive spin pole and the +Z axis are coincident, indicated in blue. The red arrow points out of the equator at the prime meridian and defines +X. Then via the right-hand rule, the green arrow is the +Y axis.

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