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Discovery of a Highly Eccentric Orbit for Fomalhaut *b*

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Abstract

Fomalhaut is a bright (m_v = 1.3 mag), nearby (d = 7.7 pc) main-sequence star (SpT = A3V) with age 440 Myr [6] that is surrounded by dusty debris from the collisional evolution of comets and asteroids. Optical coronagraphic observations of dust scattered light with the Hubble Space Telescope (HST) in 2004 reveal a sharp inner edge at ~133 AU and a geometric center that is offset from the star by ~15 AU, providing indirect evidence for a dynamical perturbation by a planet mass object [2]. Follow-up observations in 2006 revealed a faint common proper motion companions, Fomalhaut *b*, that appeared to orbit 18 AU interior to the dust belt [3].

Here we present new optical detections of Fomalhaut *b* obtained with HST/STIS in 2010 and 2012 (Figure 1). A Markov chain Monte-Carlo analysis [1] of the entire HST astrometric data set reveals that the orbit of Fomalhaut b is highly eccentric (e = 0.8 ± 0.1), and in the sky-plane projection it will appear to cross the dust belt approximately two decades in the future [4]. The current uncertainties in the orbit determination specify that the mutual inclination between Fomalhaut *b* and the belt is ≤36°, and only 12% of possible orbits have nodes crossing through the belt. Therefore it is not known if Fomalhaut *b* will directly interact with belt material.

With periastron and apastron at approximately 32 AU and 322 AU, respectively, Fomalhaut *b* may be dynamically linked to other planet mass objects in the system. If hypothetical Fomalhaut planets orbit at 30 AU or at 120 AU, the Tisserand parameter is in the range 2 - 3, similar to highly eccentric solar system objects. The possibility that Fomalhaut *b* interacts with other planet mass objects suggests that the current orbital configuration is relatively short-lived like that of solar system Centaurs.

Fomalhaut *b* may be optically detectable due to reflection from planetary rings [4] or the collisional evolution of irregular satellites [5]. We suggest that periastron passage will tidally strip material orbiting Fomalhaut *b*, such that Fomalhaut *b* must have at least the mass of a dwarf planet to maintain a circumplanetary dust cloud of sufficient radial extent to be consistent with the scattered light hypothesis. If Fomalhaut *b* is significantly more massive and passes directly through the belt, then the belt is not necessarily destroyed because apastron resides beyond the belt and the crossing itself is of order 10% the orbital timescale. However, our new observations also reveal that there is a 50 AU wide azimuthal gap in the belt northward of Fomalhaut *b*'s present location (Figure 1). The Fomalhaut system is therefore more dynamically complex than previously known, and may illustrate a period of instability analogous to the solar system's Late Heavy Bombardment.

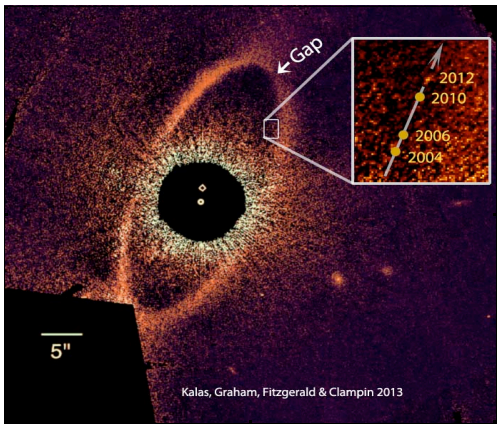

Figure 1: HST optical image of the Fomalhaut system from the combined 2010 and 2012 STIS coronagraphic data. North is up, East is left. The small open circle shows the stellar position and the diamond marks the geometric center of the belt. The belt gap resides northward of Fomalhaut *b*. The inset tracks the four epochs of astrometry relative to the star for Fomalhaut *b*.

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