FOMALHAUT

Main belt structure and the orbit of Fomalhaut b

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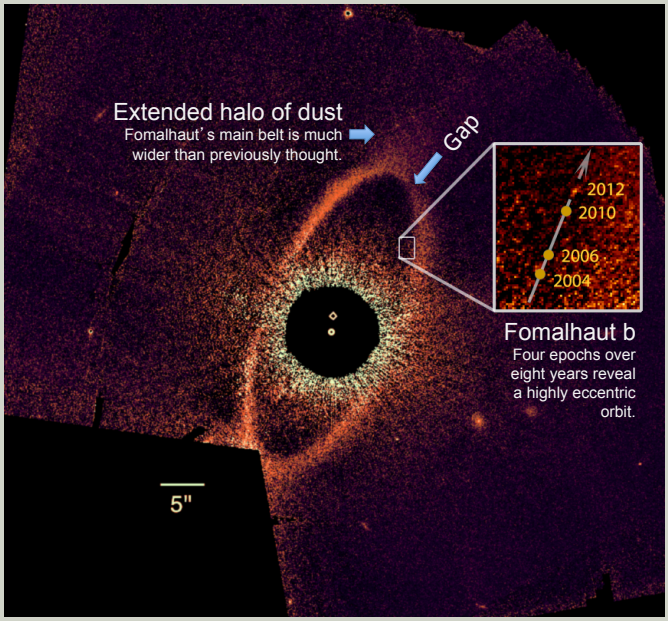
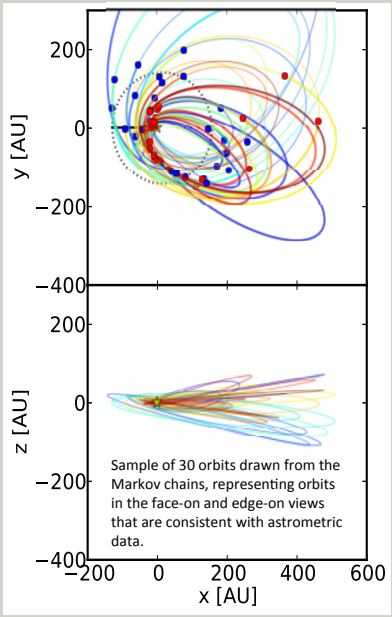
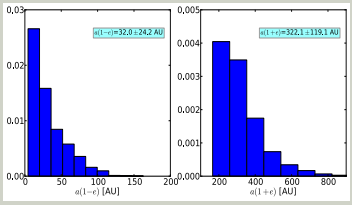
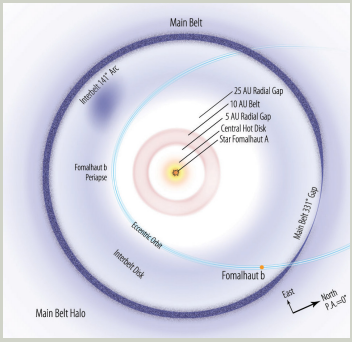






Posterior distributions of periapse and apoapse.



Sketch of the Fomalhaut system based on observational evidence.

Introduction

Kalas et al. 2008 | Acke et al. 2012 | Boley et al. 2012

• Fomalhaut at d = 7.7 pc, age= 440 Myr, and SpT=A3V has a dusty debris disk discovered with IRAS in 1984 (Backman & Paresce 1993).

• JCMT observations revealed a belt of material in thermal emission (Holland et al. 1998), confirmed with Spitzer (Stapelfeldt et al. 2004).

• The first optical images of Fomalhaut, obtained with HST in 2004, show a narrow dust belt seen in scattered light, which is offset from the star by 15 AU, and with a sharp inner edge (Kalas et al. 2005). These findings are consistent with dynamical perturbations from a planet on an eccentric orbit (Wyatt et al. 1999).

• A common proper motion companion, *Fomalhaut b*, was discovered at two epochs with HST optical coronagraphy, but it was not detected in the infrared, suggesting that we may be detecting stellar light reflected from circumplanetary dust (Kalas et al. 2008). The model-dependent mass for Fomalhaut b is less than about a Jupiter mass (Janson et al. 2012).

• *The present work represents a major advance in estimating Fomalhaut b's orbital parameters.*

Observations

• Re-analysis of astrometry and error sources for 2004, 2006 ACS data, and 2010 STIS data.

• New Observations with HST/STIS obtained May 2012:

12 orbits, 12 roll angles

STIS coronagraphic wedge, blocks 2.5 arcsec

0.05077"/pix, no filters, 0.2-1.0 micron

Use self-subtraction at multiple rolls, no PSF star

Core Results

• Fomalhaut b is detected again in 2010 and 2012 using HST / STIS in the optical.

• Also confirmed in 2010 and 2012 are two new main belt features: (1) an extended halo of dust that shows the belt is much wider than previously known, and (2) an azimuthal gap in the belt located northward of Fomalhaut b's position.

• Photometric variability for Fomalhaut b cannot be confirmed due to the effects of speckle noise on the photometry.

• Fomalhaut b itself appears extended with an elliptical morphology, but we can attribute this to speckle noise. Future observations are required to confirm any extended morphology.

Orbit of Fomalhaut b

• We use an MCMC method to sample the posterior probability distribution for the orbital elements based on 4 epochs of astrometry.

• Our new estimates for Fomalhaut b orbital elements are:

a = 177 ± 68 AU [Main Belt ~ 140 AU]

e = 0.8 ± 0.1 [Main Belt ~ 0.1]

q = 32 ± 24 AU, Q = 322 ± 119 AU

I = 17° ± 12° [mutual inclination w.r.t. belt]

Ω = 152° ± 13° [Main Belt 156.2° ± 0.1°]

ω = 26° ± 25° [Main Belt 30° ± 1°]

P ~ 1700 yr [Main Belt 1100-1400 yr]

• The high eccentricity makes the orbit of Fomalhaut b appear belt crossing in the sky plane projection, but it is not known if the two orbital planes are coplanar due to the uncertainties.

• Fomalhaut b and the belt show apsidal alignment.

• The periastron distance for Fomalhaut b is now known to be significantly closer to the star, suggesting that it could have been scattered outward due to a dynamical instability involving interior planets yet to be detected.

• Fomalhaut b had periastron 125 years ago and will appear to cross the belt beginning two decades from now.

Take Home Points

• Fomalhaut b is confirmed in four optical coronagraphic observations with HST spread over eight years, and in independent analyses of the 2004, 2006, & 2010 data sets performed by Kalas et al. (2008), Currie et al. (2012), and Galicher et al. (2013).

• The 2012 epoch presented here yields the surprising result that Fomalhaut b's orbit is highly eccentric (Kalas et al. 2013).

• Also detected are the main belt outer dust halo to >209 AU radius, and an azimuthal gap in the main belt located at PA ~ 331°.

• *The Fomalhaut system is dynamically complex and may represent a brief, chaotic period of dynamical instability in a planetary system.* Key open questions are:

(1) Why is Fomalhaut b on a highly eccentric orbit while at the same time showing apsidal alignment with belt?

(2) What is the dynamical stability of the system, particularly if other hypothetical planets are required to account for the known features? Where is a hypothetical Fomalhaut c?

(3) Is Fomalhaut b a scattered planet in a multi-planet system, or is it analogous to a short period comet or Centaur in our solar system?

Kalas et al. 2013, submitted to ApJ; http://lanl.arxiv.org/abs/1305.2222