Something’s Fishy in Fomalhaut

Allegheny Observatory Public Lecture Series

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Outline

1. Discovery of Planet Fomalhaut b
   - Fomalhaut the star
   - How to Find a Planet
   - The First Photograph of a Planet Around Another Star

2. Controversy and Doubt
   - How Did Fomalhaut b Form?
   - Why is it so Bright?
   - Why is it Invisible?

3. The “Zombie Planet”
   - So What’s in the Pictures?
Fomalhaut

The Southern Fish

The Fish’s Mouth
Fomalhaut

- 17th brightest star in the sky
- 25 light-years away
- Type A star
What Makes Fomalhaut Interesting?

Images of the Fomalhaut Debris Disk

HUBBLE
0.5 micron

HERSCHEL
70 microns

ALMA
850 microns
Debris Disks and Planets

The Sun’s Debris Disk

Comparison of Fomalhaut System and Solar System
How to Find a Planet

From Easiest to Hardest

- Transits (video)
- Doppler Shift (demo)
- Direct Imaging
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Discovery of Planet Fomalhaut b

Space Searched So Far

- See Exoplanet Encyclopedia (http://exoplanet.eu) for the current list.
First Directly Imaged Exoplanet

Fomalhaut

HST ACS/HRC

Dust ring

Scattered starlight "noise"

Location of Fomalhaut

Coronagraph mask

No data

Background Star

No data

100 AU

13"

Fomalhaut b planet

2004

2006
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Planet Formation in the Solar System
Core Accretion

Growth from ‘dust’ to planetary building blocks

- Meter-size barrier
- Rapid radial drift
- Fragmentation
- Sweep-up growth

Timeline

- Core formation
- Core + hydrostatic envelope
- Runaway accretion

Total mass
Core mass

Planet mass vs. time
Problem: Protoplanetary Disk Lifetimes

- It takes about 10 Myrs to form Jupiter
- This time INCREASES with distance from the star
Solution 1: Gravitational Instability
Disk Fragmentation

Mass of Disk in Jupiter Masses vs. Distance from Fomalhaut in AU
(1 AU is Earth-Sun distance)
Disk Fragmentation

Too Little Mass to Clump

Mass of Disk in Jupiter Masses vs. Distance from Fomalhaut in AU (1 AU is Earth-Sun distance)
Disk Fragmentation

Too Much Mass to Cool

Too Little Mass to Clump

Distance from Fomalhaut in AU
(1 AU is Earth-Sun distance)

Mass of Disk in Jupiter Masses
Disk Fragmentation

Too Much Mass to Cool

Just Right!

Too Little Mass to Clump

Distance from Fomalhaut in AU
(1 AU is Earth-Sun distance)

Mass of Disk in Jupiter Masses
Disk Fragmentation

- Too Much Mass to Cool
- Too Little Mass to Clump
- Just Right!
Taking it Further: Dust Settling

**How Close to the Star?**

![Graph showing the relationship between the time and the mass of the star](image)

- The graph plots the time (in Myr) on the x-axis and the 
  - Fringe distance (in AU) on the y-axis.
- Data points for different ages of the star (0.5 Myr, 1 Myr, 5 Myr, 10 Myr) are represented.
- The relationship between the time and the fringe distance is linear.

**Legend:**
- Orange circles: 0.5 Myr
- Purple squares: 5 Myr
- Red triangles: 1 Myr
- Blue diamonds: 10 Myr
Solution 2: Planet Migration

Type 1 (< 10 Earth-Masses)

Type 2 (> 10 Earth-Masses)
Solution 3: Planet-Planet Scattering

Nice Model: Maybe Uranus and Neptune switched places

Explains:
- Kuiper belt orbital resonances with Neptune
- Lack of small objects in outer Solar System
- Late heavy bombardment
- (video)
Problem: Why is Fomalhaut b so Bright?

The Hubble image shows visible light:
- Must be reflected from the star
- Fomalhaut b must be big (radius)

The debris disk is intact:
- If Fomalhaut b was too big, it would disrupt the debris disk
- Fomalhaut b must be small (mass)
Solution: Rings
Problem: Fomalhaut b Should be Bright in IR Light
BIG Problem: Fomalhaut b is Missing in IR Light

It Should be at Arrow 1

**Celebrated Exoplanet Vanishes In a Cloud of Dust—Or Maybe Not**

Every week, astronomers add new extrasolar planets to a roster that now numbers more than 700. But on rare occasions, a finding comes along that threatens to knock one of those discoveries off the list. Last week, Fomalhaut b, an exoplanet that once enjoyed celebrity status, faced an identity crisis after astronomers failed to spot it in a new round of observations.

So Janson applied for time on NASA's space-based Spitzer telescope—a powerful infrared imager—to look at Fomalhaut. Despite his hunch that the planet didn't exist, “I would have been happy to find something,” Janson says. “Weird things happen in nature, and if we would have found something, that would have been fantastic.”

Janson was one of several times as sensitive as the infrared observations Kalas's group had made—they should have detected something. To be visible in optical light, Janson argued, the planet's ring would have to be several times wider than the planet itself and would have to be tilted to reflect the star's light into earthly telescopes—an improbable combination. “Toward the end, I said I wouldn’t call this a planet myself,” Janson says. After returning from the conference, he and his colleagues completed their analysis and wrote a paper that has just been accepted by *The Astrophysical Journal*.

Janson does not dispute that Kalas's group saw something. “There is certainly something...”
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New Observations

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The “Zombie Planet”
What is it?

Three Related Possibilities

- A planet with a huge ring?
- A planet surrounded by a cloud of debris?
- The remnants of a catastrophic collision?

Fomalhaut c?

- There must be at least one more planet to explain the debris disk
- We never found the planet that we went looking for in the first place!
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Questions?