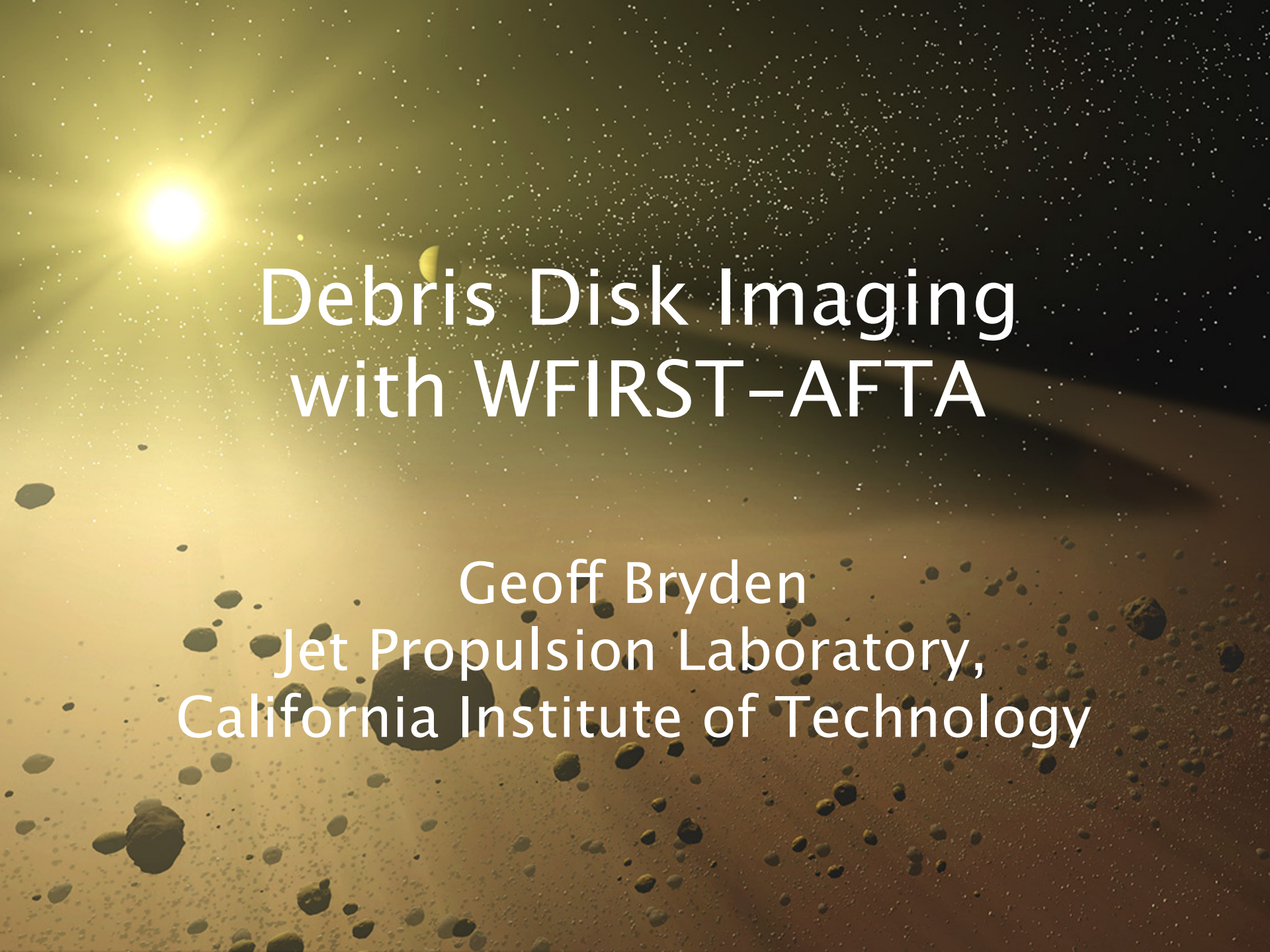

Debris Disk Imaging with WFIRST-AFTA

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What & Why

What are debris disks?

- Remnants of planet formation
- Direct: Second-generation dust produced through asteroid collisions and comet sublimation
- Infer: at least km-size planetesimals
- Example: the Solar System

Why study debris disks?

- Map the general architecture of planetary systems
- Identify specific disk-sculpting planets

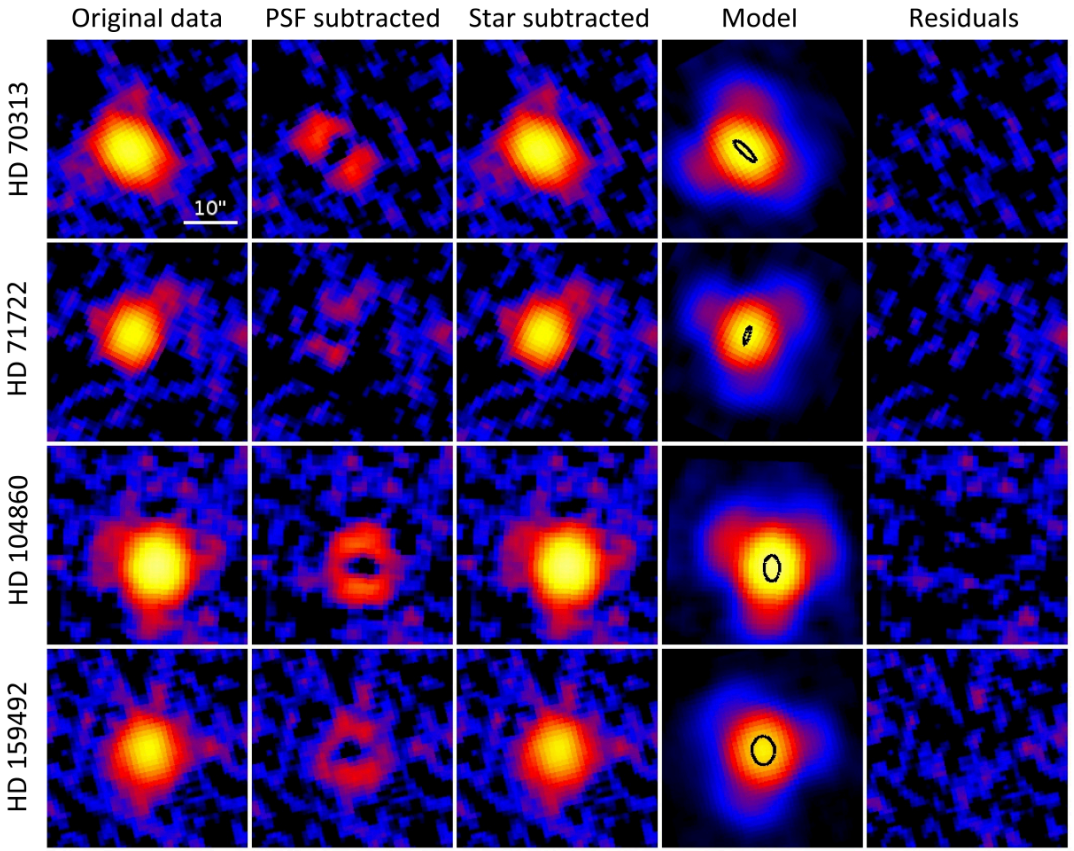
→ A unique way to probe planetary systems beyond the snow line

Current Status: Herschel

Herschel has (marginally) resolved many debris disks.

Model fits measure the disk
- radius
- inclination
- position angle

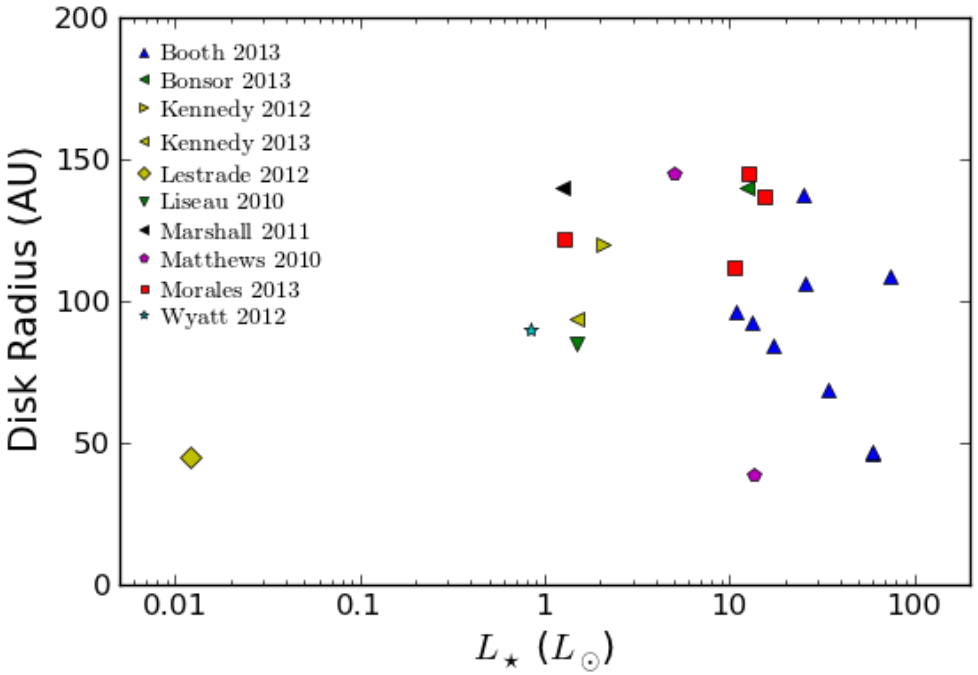
Disk shapes are usually consistent with a thin ring, but overall provide little information about the disks' radial profiles.



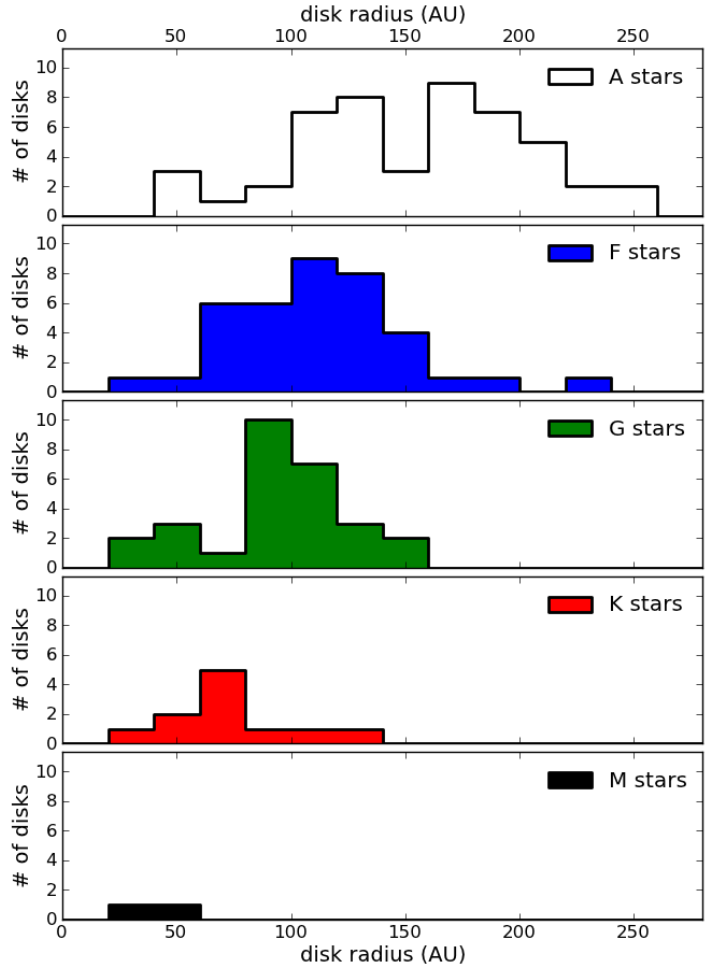
Morales+ 2013

Over 100 Disks Resolved by Herschel

From detailed modeling of individual systems



To statistical trends within a large sample

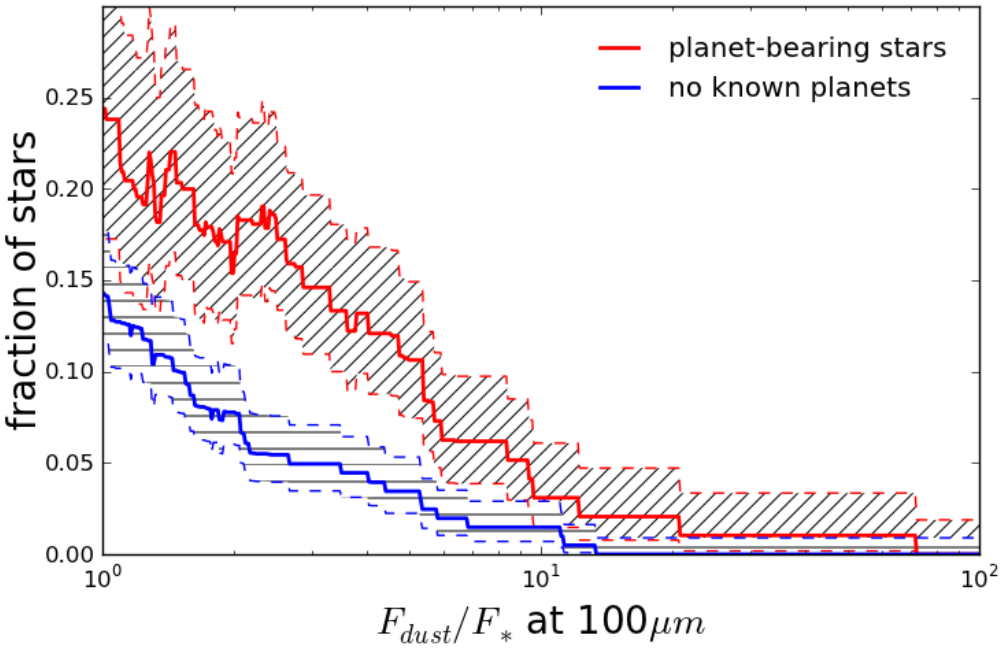


Planet–Disk Correlation

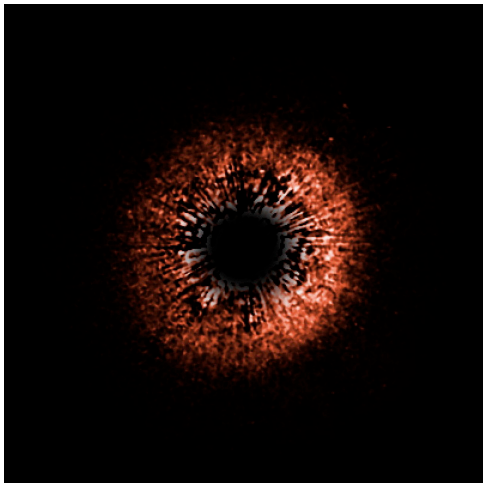
Herschel surveys reveal a strongly significant correlation between inner RV planets and cold outer debris.

Many theories predict relationships between planets and debris; the simplest is that planets and debris are both correlated with their initial protostellar disk mass.

Far-IR disk brightness distributions



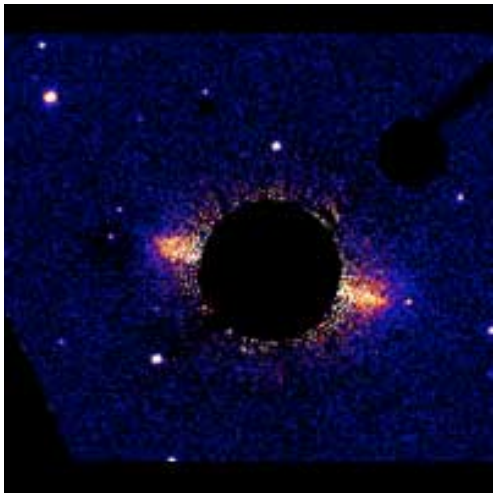
Current Status: Hubble



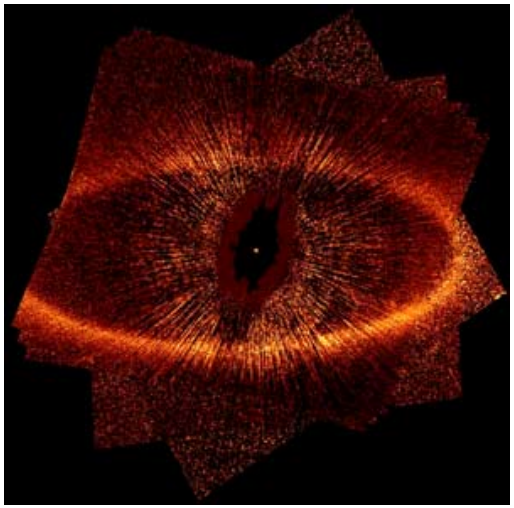
HD 107146; Ardila+ 2004

Hubble imaging at much higher resolution reveals a variety of disk structures:

- broad belts & narrow rings
- sharp edges & diffuse halos
- offsets, warps, & other asymmetries



HD 15115; Kalas+ 2007

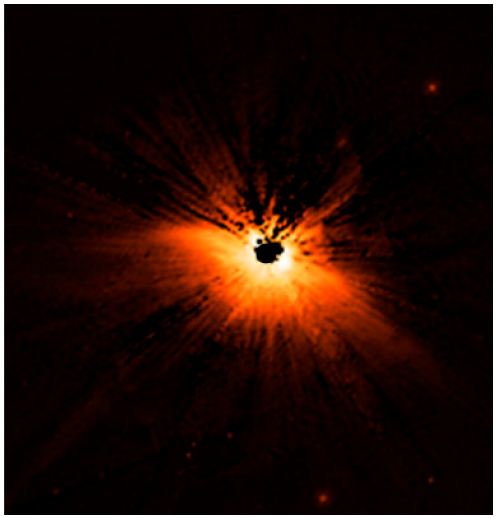


Fomalhaut; Kalas+ 2005

Only ~20 disks total, covering a broad range of spectral types, ages.

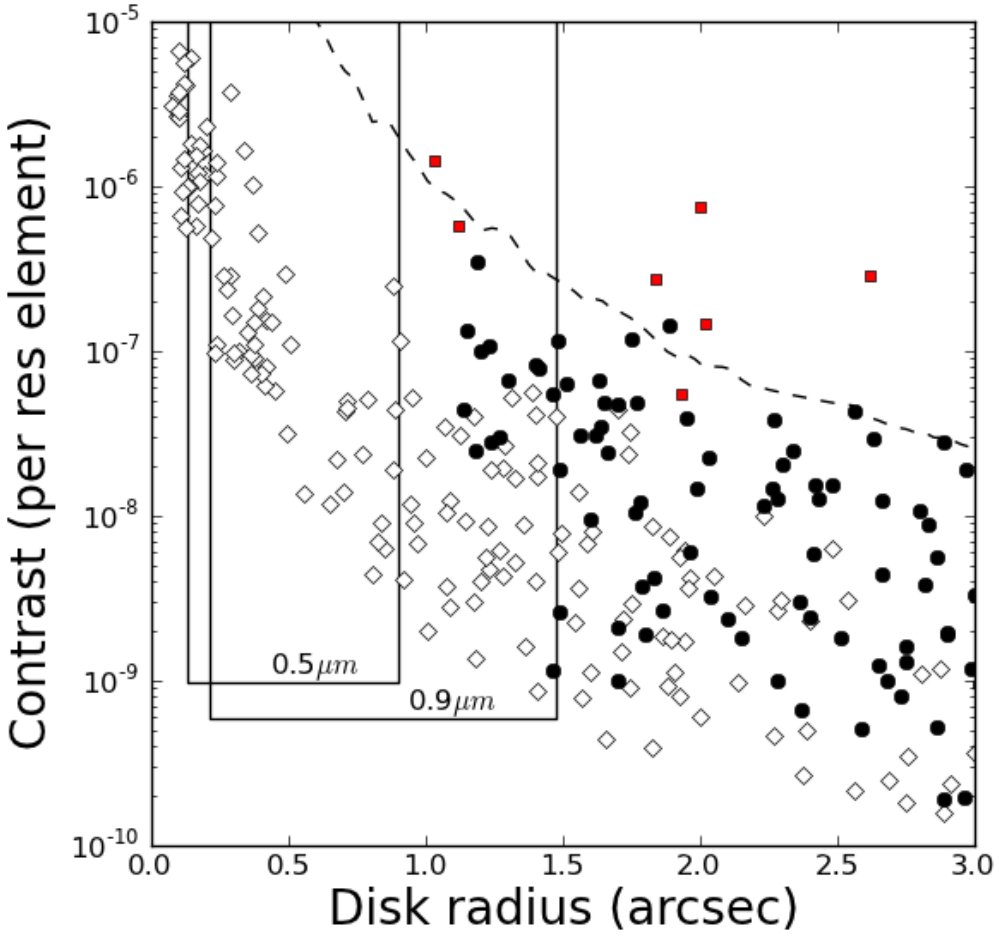
Desired capability:

- fainter disks
- closer to central star



HD 61005; Hines+ 2007

WFIRST-AFTA Disk Detection Phase Space



WFIRST-AFTA will dramatically increase the number of disks resolved in scattered light.

Figure shows known disks.
Red squares = HST detections
Black circles = Herschel resolved
Open diamonds = SED estimates
Dashed line = JWST sensitivity

Note that WFIRST-AFTA will resolve disks fainter than detectable by Spitzer/Herschel.

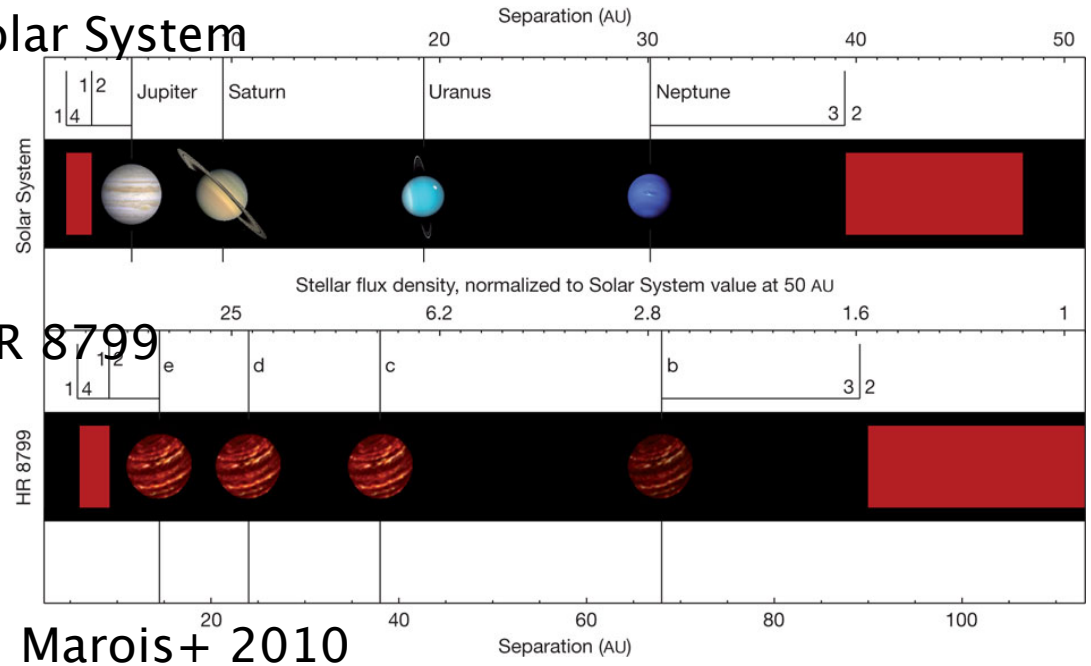
Goal 1: System Architecture

With ~100x better resolution than Herschel, WFIRST-AFTA will easily measure each disk's radial profile and will thereby distinguish between single or multiple belts of material.

WFIRST-AFTA will also probe the low levels of residual dust flowing between the dominant belts, e.g. by P-R drag.

Solar System

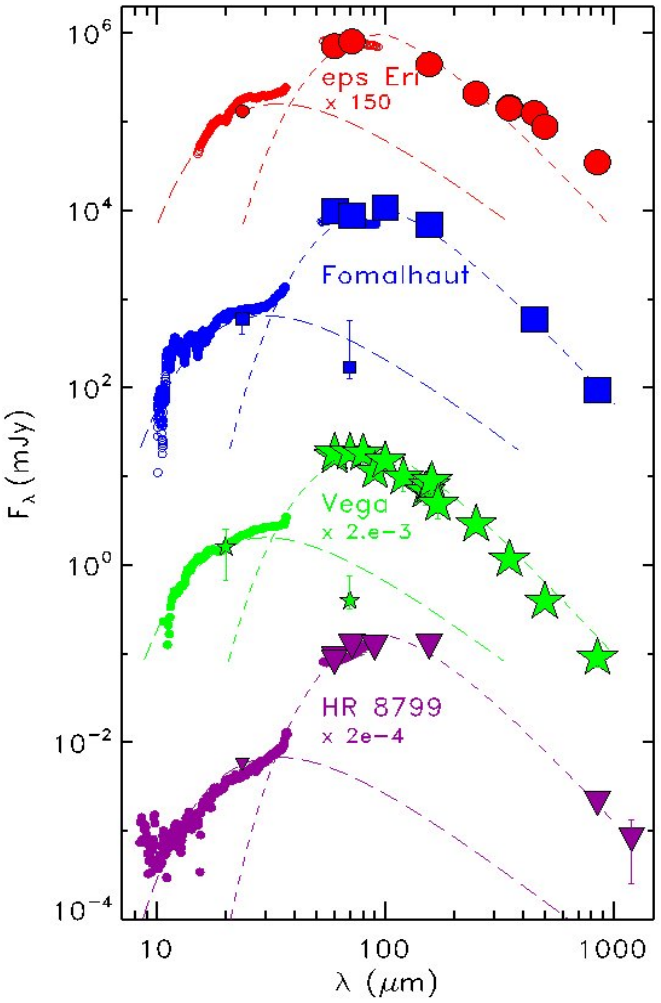
HR 8799



Marois+ 2010

Two-belt architectures may suggest the presence of intermediate planets.

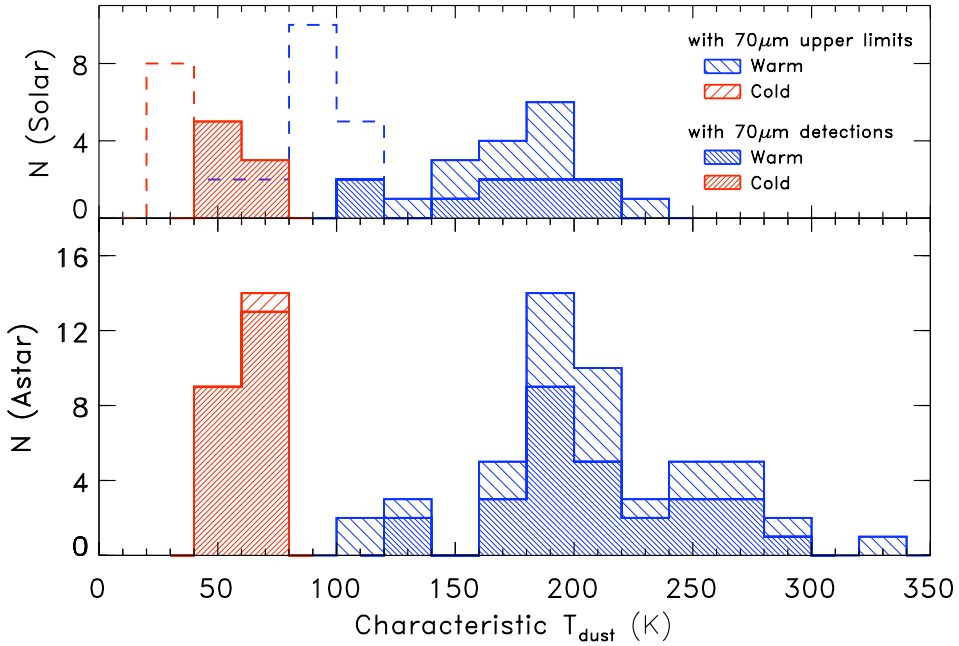
Goal 1: System Architecture



Su+ 2013

SED analysis of unresolved disks finds that two-belt systems are common.

The break occurs at a fixed temperature, not at a fixed location. Ice line?

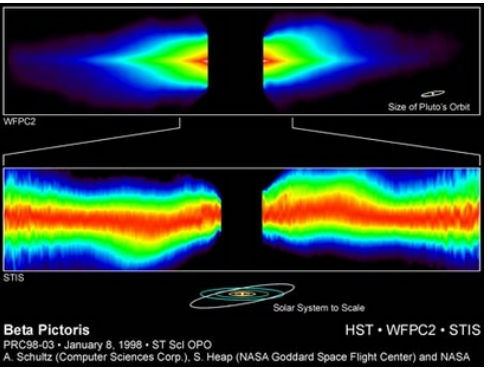


Morales+ 2011

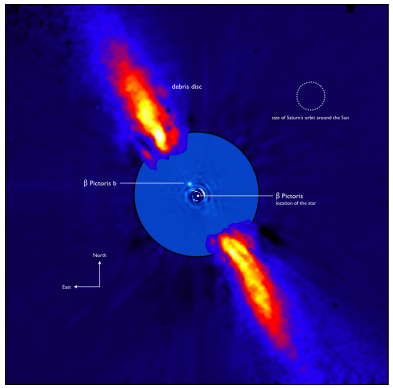
Goal 2: Planet-Induced Structure

Warp

beta Pic b –
planet mass/semi-major axis predicted by Mouillet (1997) based on inner disk warp



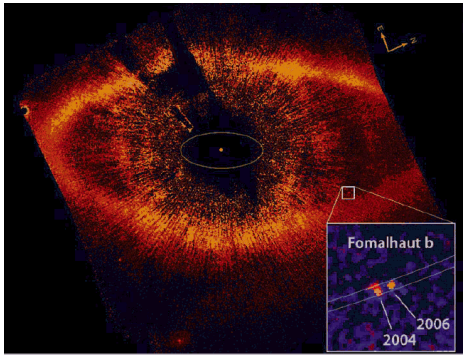
Heap+ 2000



Lagrange+ 2009

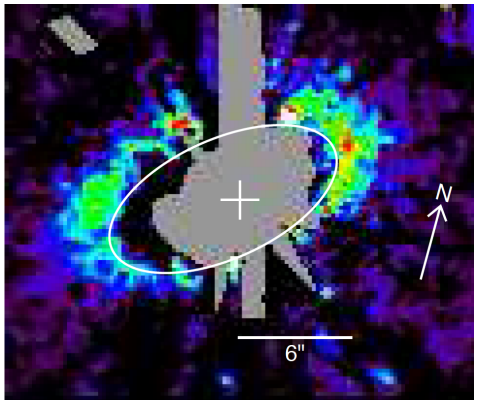
Sharp-edged offset rings

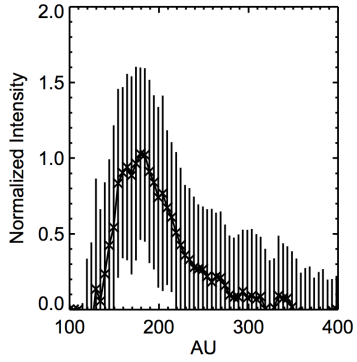
Fomalhaut



Kalas+ 2005

HD 202628



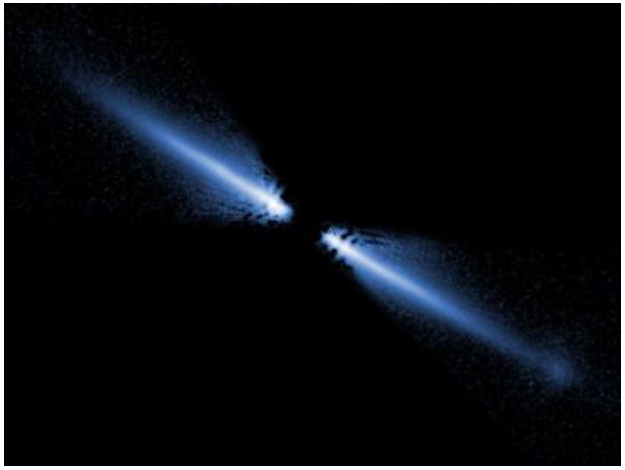


~2-Gyr-old, G2V star
e=0.18, a=158 AU
Krist+ 2012

Goal 3: Disk Physics

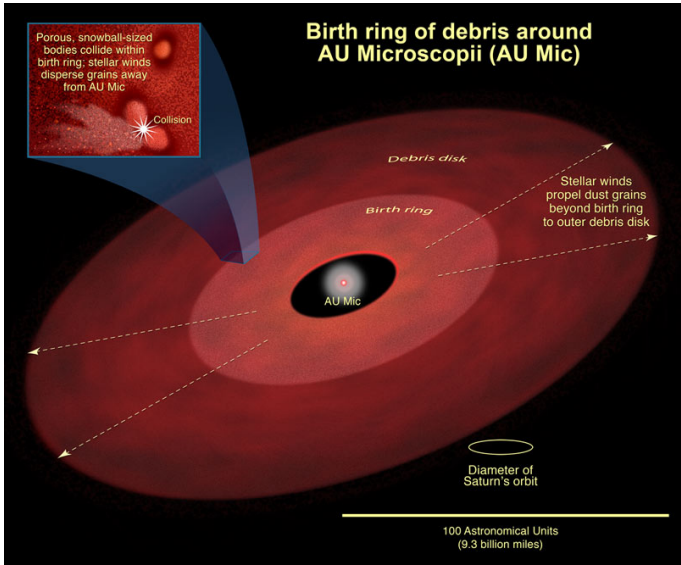
High-resolution disk images help to determine how dust is created and transported within each system.

Measurables:
dust distribution, disk morphology, color, albedo
→ Constraints on grain size and composition



AU Mic's blue disk, indicative of small grains
Krist+ 2005

A new regime of disk physics:
Known disks are dominated by collisions and blowout. WFIRST-AFTA will be able to image fainter disks where P-R drag is dominant, as in the Solar System. Resonant capture of dust is expected.



Summary

A dedicated WFIRST-AFTA survey can resolve many known debris disks.

WFIRST-AFTA's planet imaging survey will meanwhile image many new disks around the closest stars.

These high-resolution images will:

- Determine the prevalence of two-belt planetary system architectures like the Solar System's.
- Reveal the presence of unseen planets via their influence on disk structure.
- Explore the physics and evolution of debris disks by characterizing the dust size and disk morphology.