

Hubble Space Telescope Coronagraphs

John Krist

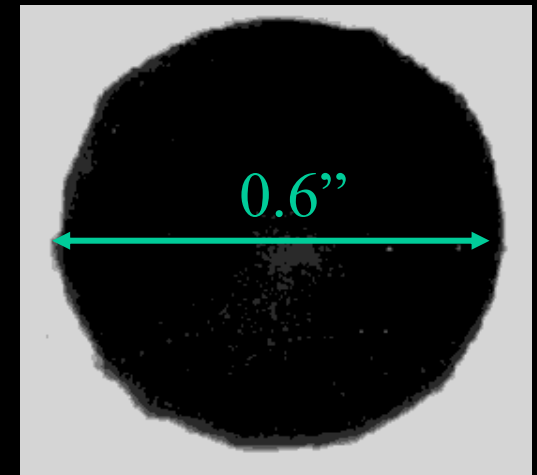
JPL

HST Cameras with Coronagraphs

- **NICMOS Camera 2**
 - 20'' x 20'', 76 mas pixels
 - $\lambda = 0.9 - 2.2 \mu\text{m}$, multiple filters
- **STIS (will be repaired in next mission)**
 - 52'' x 52'', 50 mas pixels
 - $\lambda = 0.2 - 1.0 \mu\text{m}$ (no filter)
- **ACS High Resolution Camera (HRC)**
 - 26'' x 29'', 25 mas pixels
 - $\lambda = 0.2 - 1.0 \mu\text{m}$, multiple filters

NICMOS Coronagraph

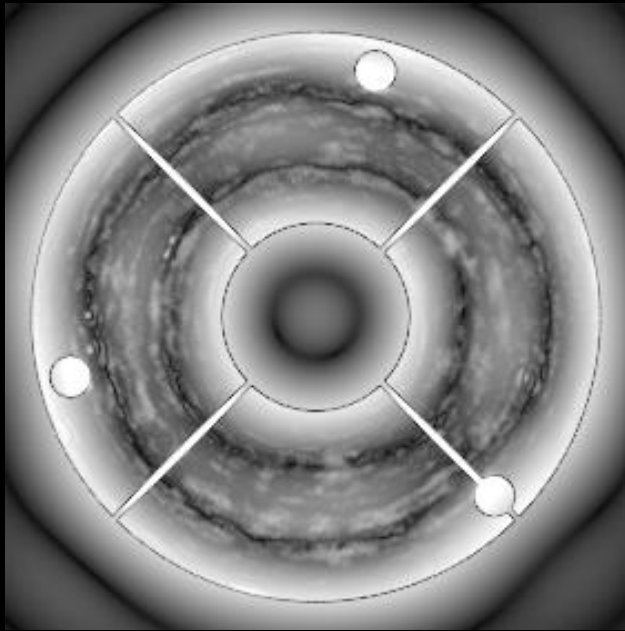
- 76 mas pixels, 20'' x 20'' field
- Multiple filters over $\lambda = 0.9 - 2.2 \mu\text{m}$
- Occulting spot is $r = 0.3''$ ($1.7 - 3.5 \lambda/D$) hole drilled in mirror at intermediate focal plane
- Spot and Lyot stop always in-place



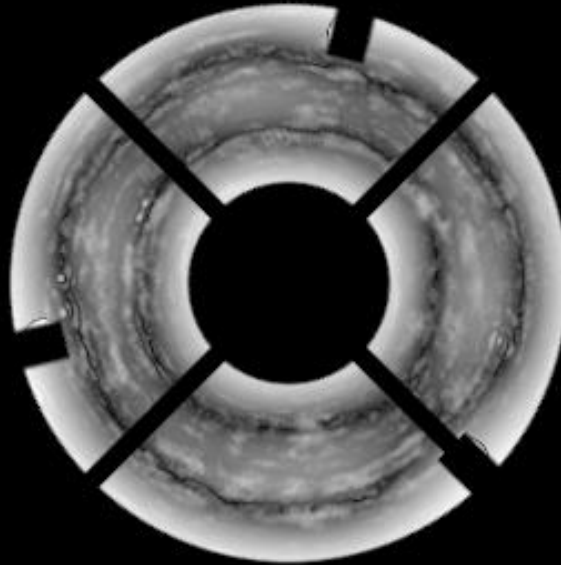
NICMOS Coronagraph Pupil

Models

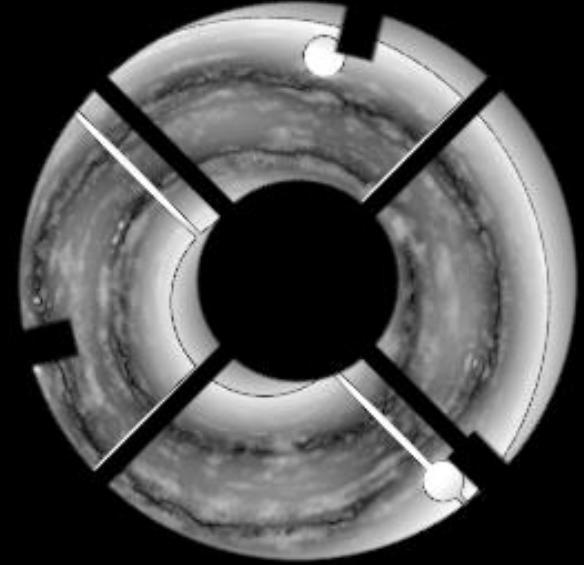
Pupil after spot



With an Aligned
Lyot Stop



With a Misaligned
Lyot Stop



Effects of NICMOS Lyot Stop Misalignment

F110W (\sim J band)



Aligned Lyot Stop
Model



Misaligned Lyot Stop
Model



Observed

Misalignment results in 2x more light in the wings + spikes

NICMOS Image of HD 141569

F110W (~J band)

Science results in Weinberger et al. (1999)

HD 141569



Image1 – PSF1

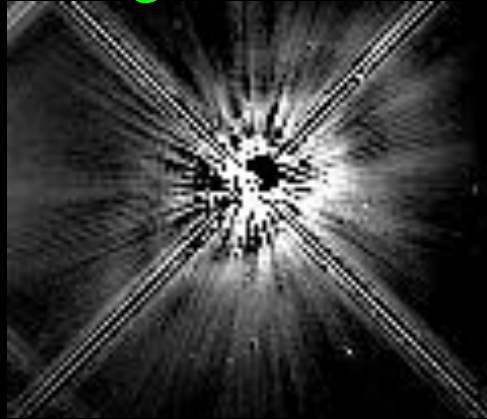
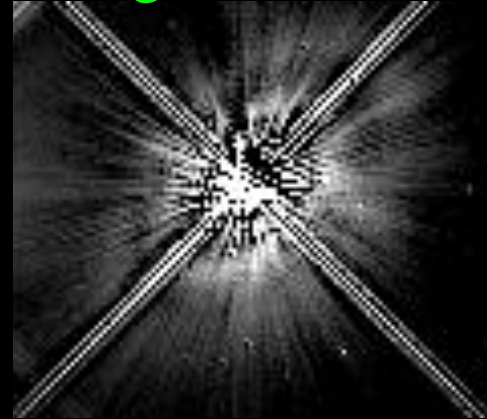


Image1 – PSF2



Reference Star

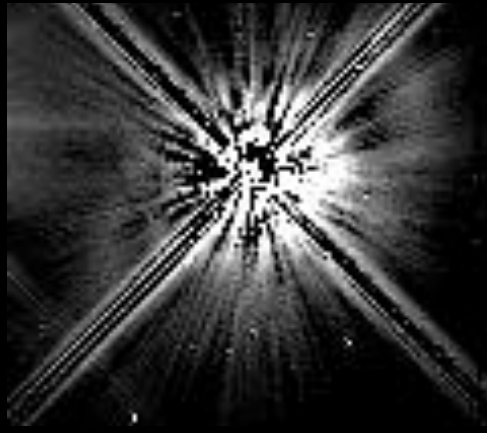


Image2 – PSF1

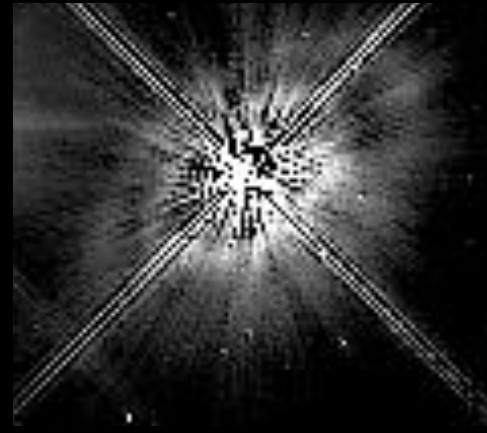
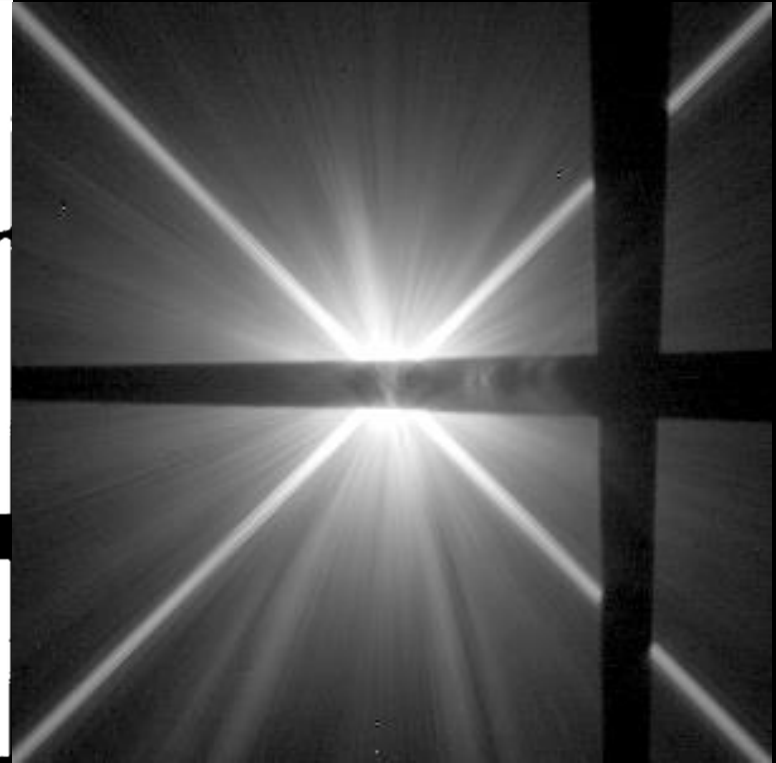


Image2 – PSF2

STIS Coronagraph

- Primarily a spectrograph
- CCD, 50 mas pixels, 52'' x 52'' field
- Unfiltered imaging over $\lambda = 0.2 - 1.0 \mu\text{m}$
- Occulters are crossed wedges: $d = 0.5''\text{-}2.8''$
($r = 5\lambda/D - 30\lambda/D$ @ V)
- Lyot stop always in the beam

STIS Occulters



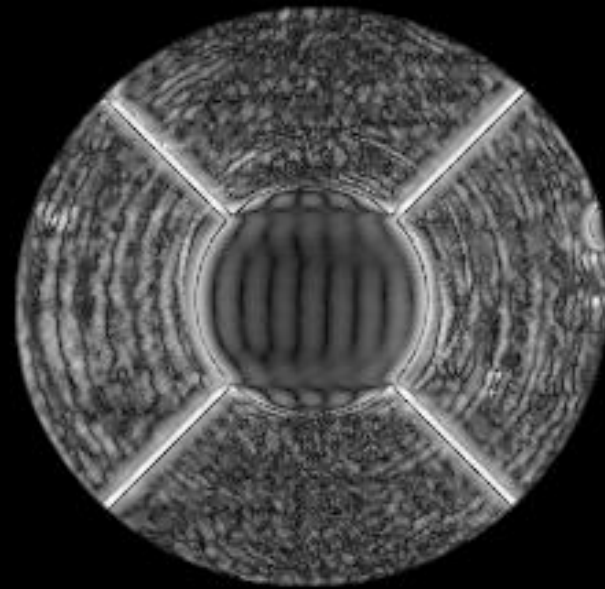
STIS Coronagraph

Computed Intensity at Lyot Stop

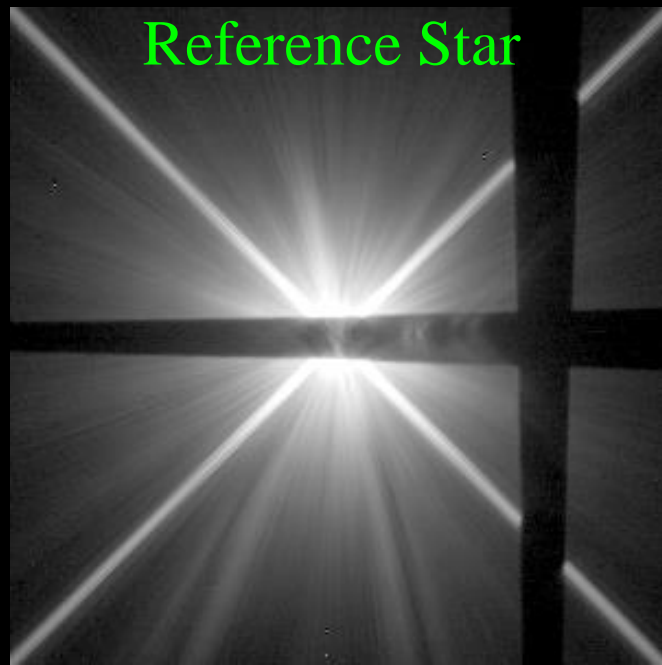
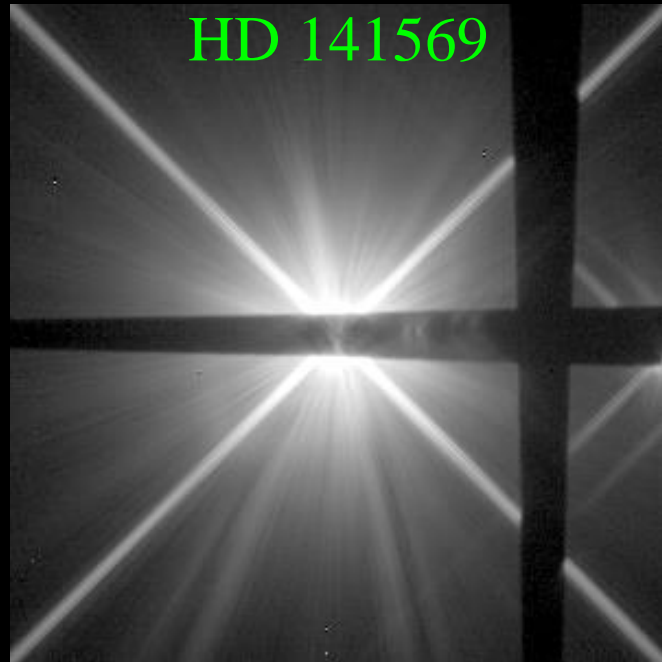
After Occulter,
Before Lyot Stop



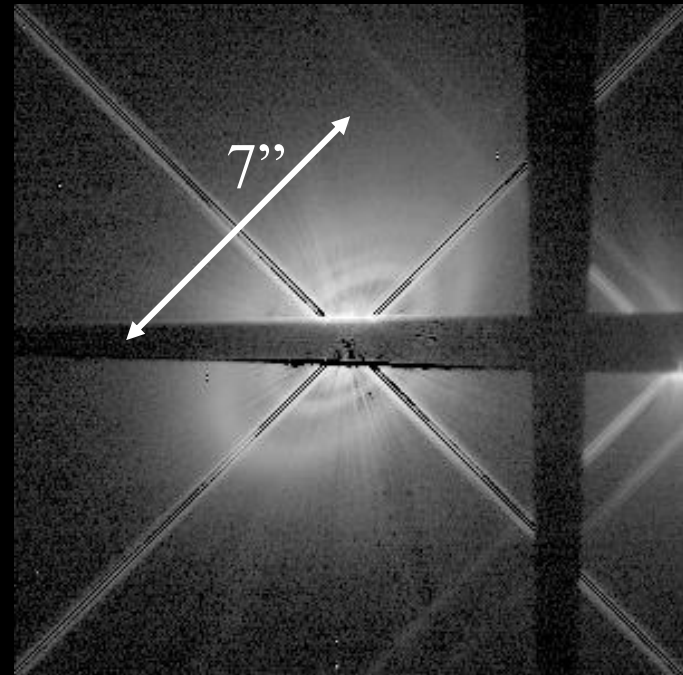
After Lyot Stop



STIS Image of HD 141569



HD 141569 - Reference Star



Science results in Mouillet et al. (2001)

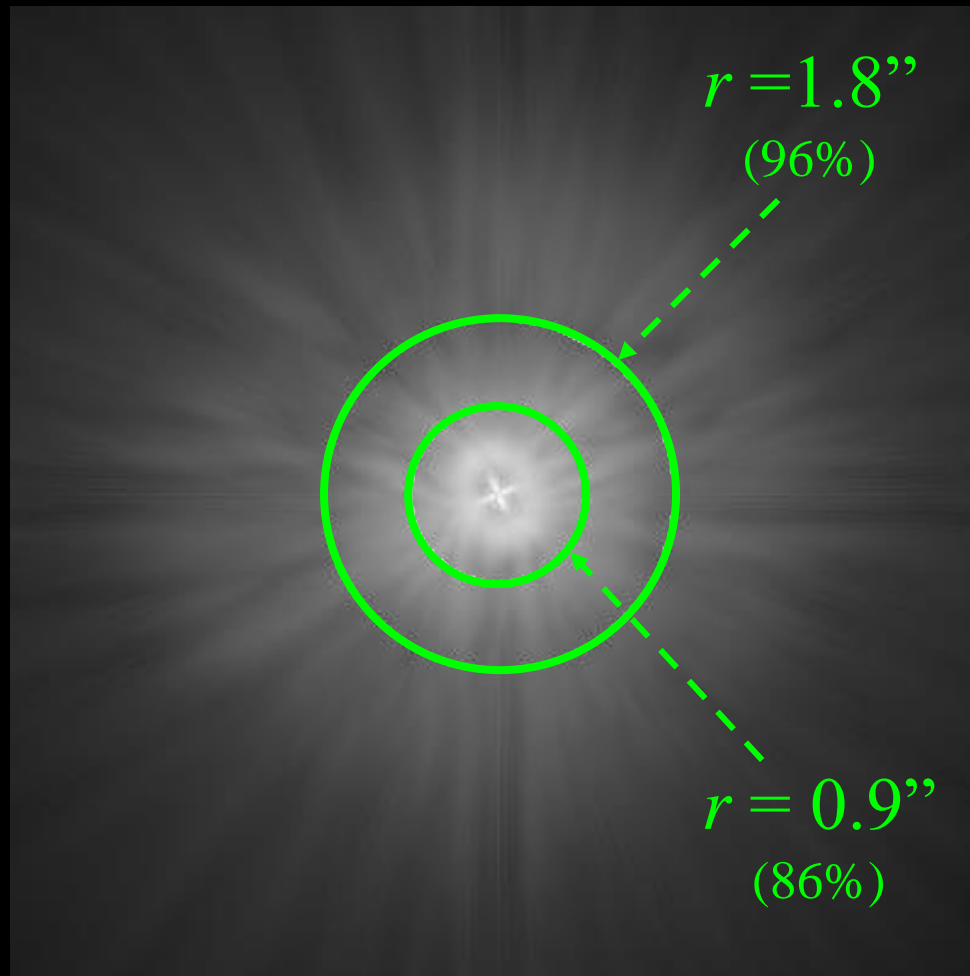
ACS/HRC Coronagraph

- CCD, 25 mas pixels, PSF FWHM=50 mas @ 0.5 μm
- Multiple filters over $\lambda = 0.2 - 1.0 \mu\text{m}$
- Selectable mode in the HRC: the occulting spots and Lyot stop flip in on command
- Two occulting spots: $r = 0.9''$ and $1.8''$ ($38\lambda/D - 64\lambda/D$ @ V)
- Occulting spots in the aberrated beam from HST, before corrective optics

ACS Coronagraph

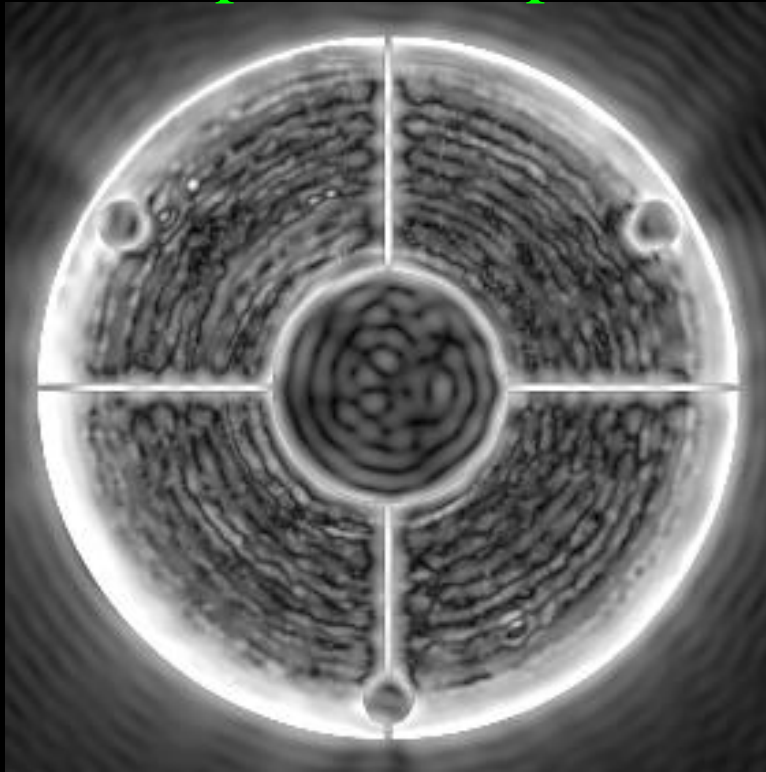
1st (Aberrated) Image Plane

Model

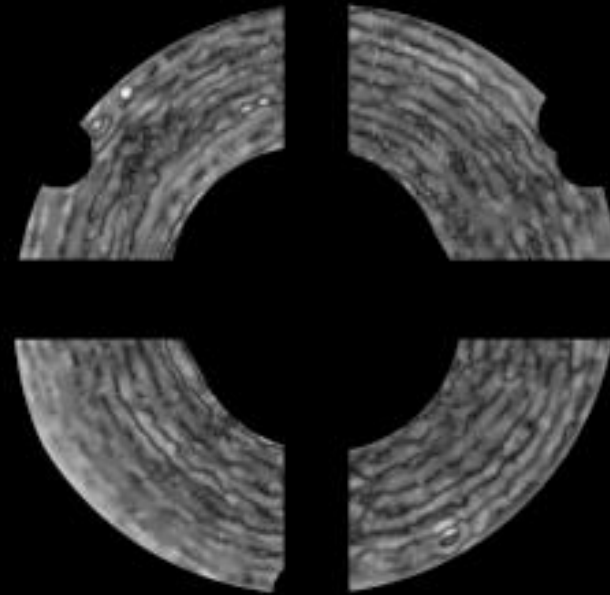


ACS Coronagraph Pupil Models

Pupil After Spot



Pupil After Lyot Stop

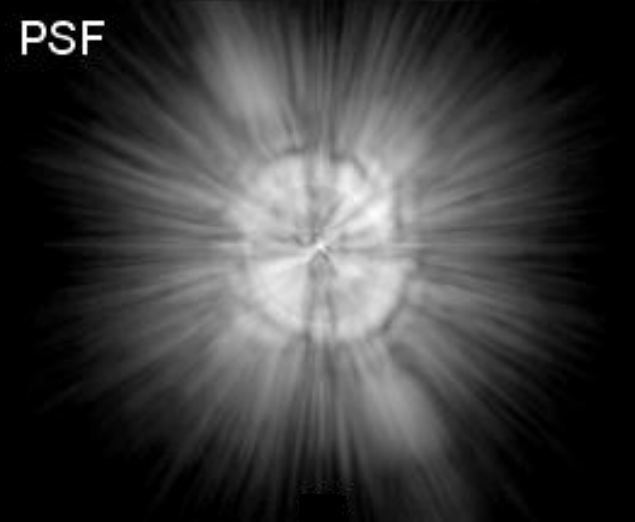


ACS Coronagraph Image of HD 141569

Raw

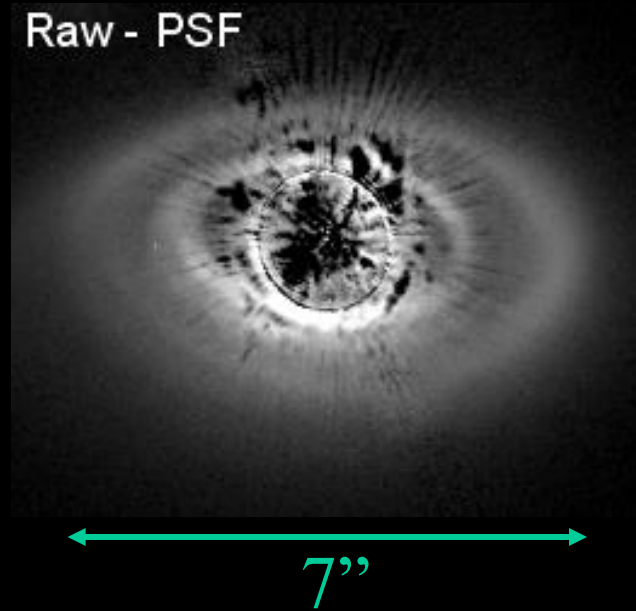


PSF



V band (F606W)

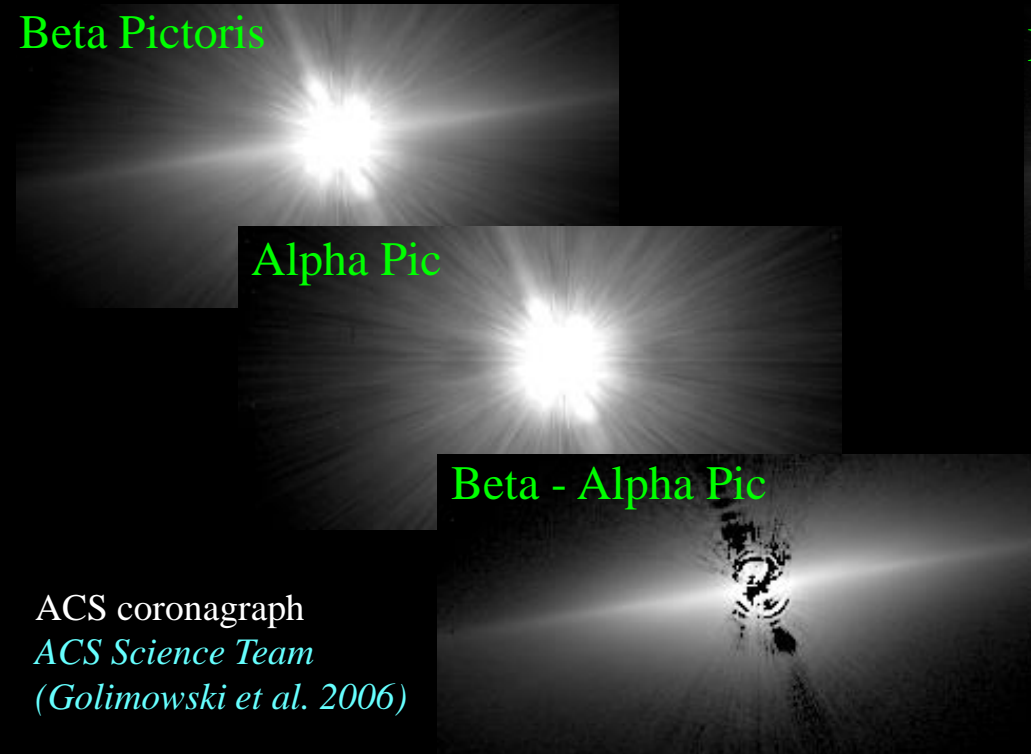
Raw - PSF



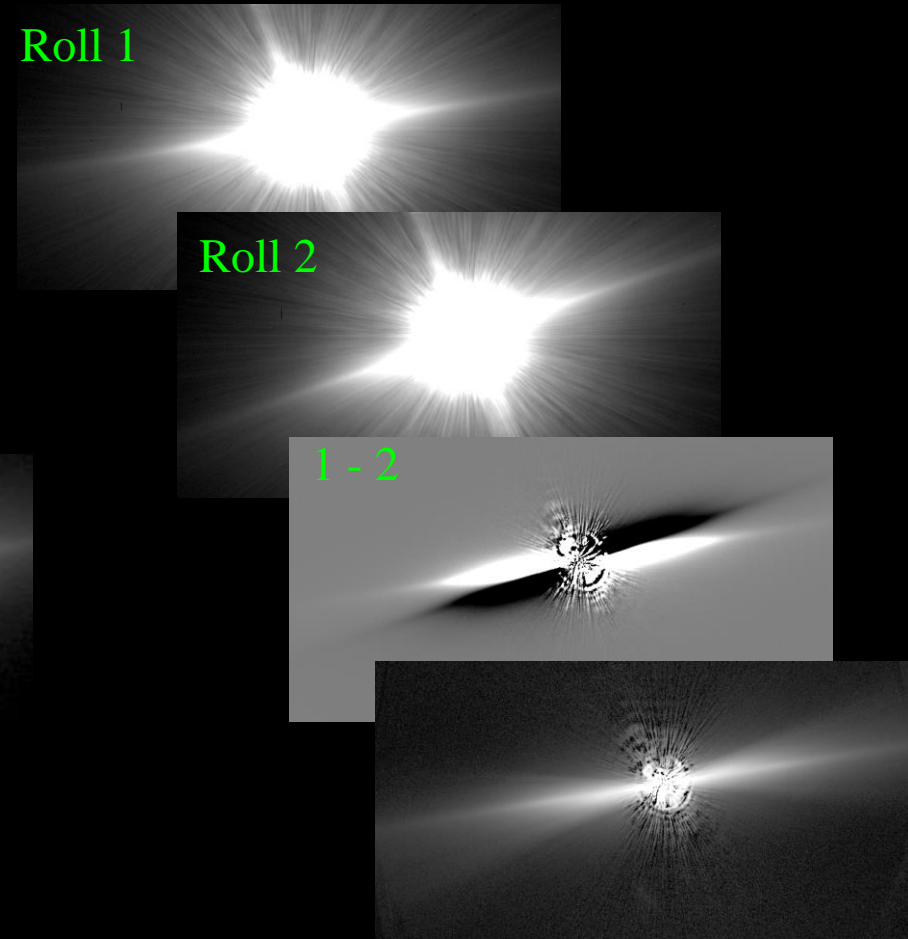
Science results in Clampin et al. (2003)

PSF Subtraction

Reference PSF Subtraction



Roll Subtraction



ACS Coronagraph Images of Beta Pic

Separated by 10 degrees in orientation, 5 hours in time



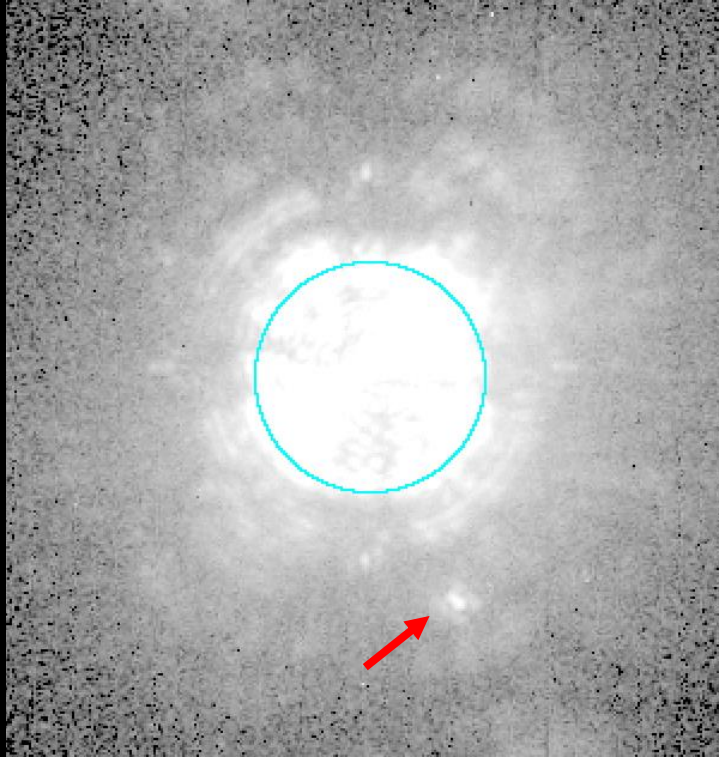
20''

Spectral Deconvolution

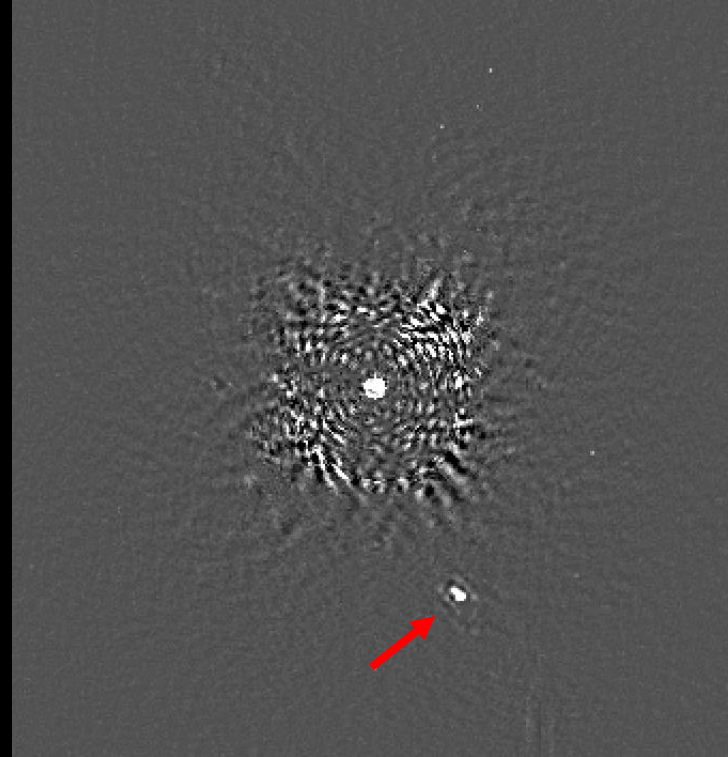
Sparks & Ford (2002)

Images courtesy of Bill Sparks

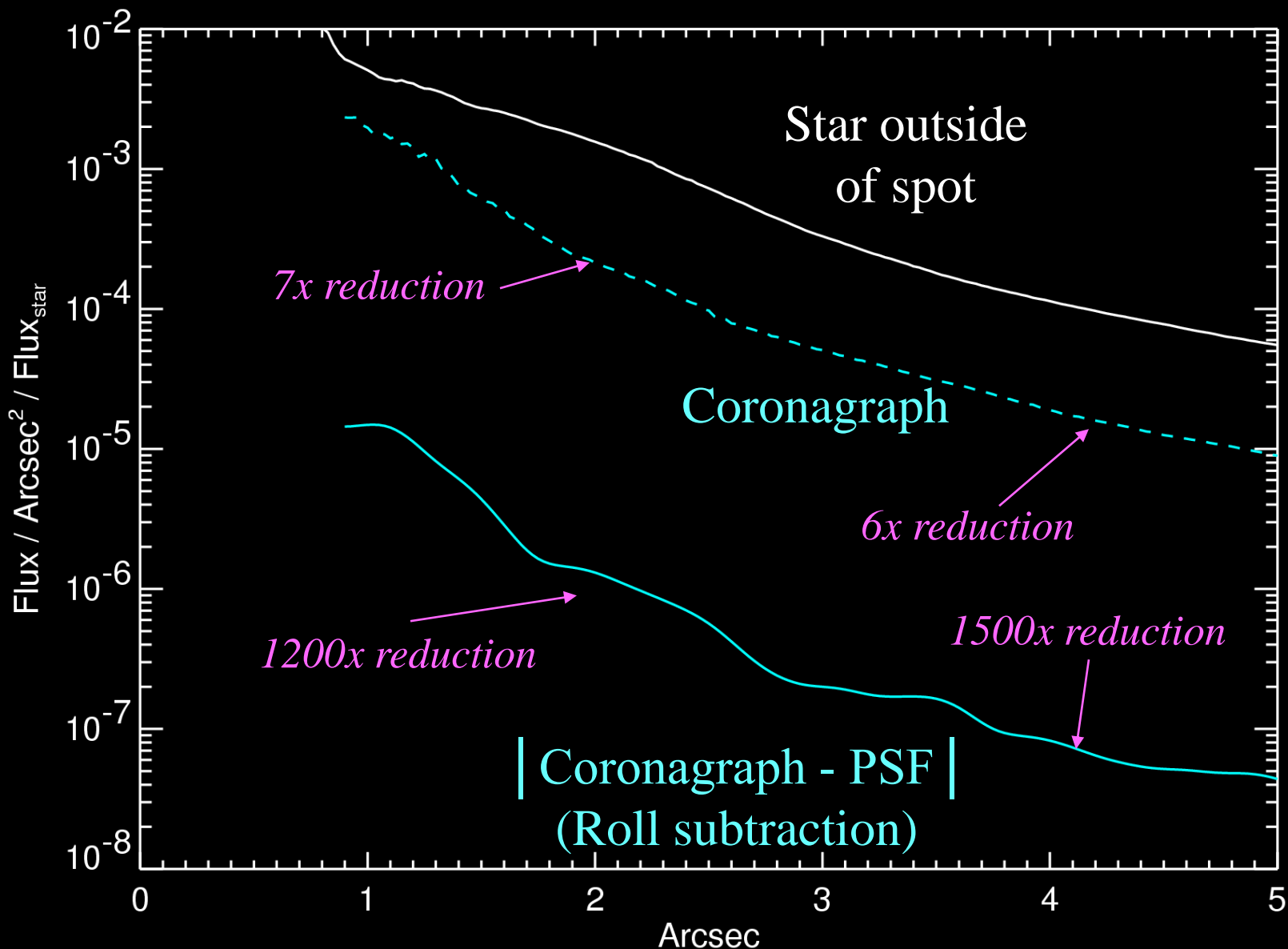
HD 130948 (ACS Coronagraph)



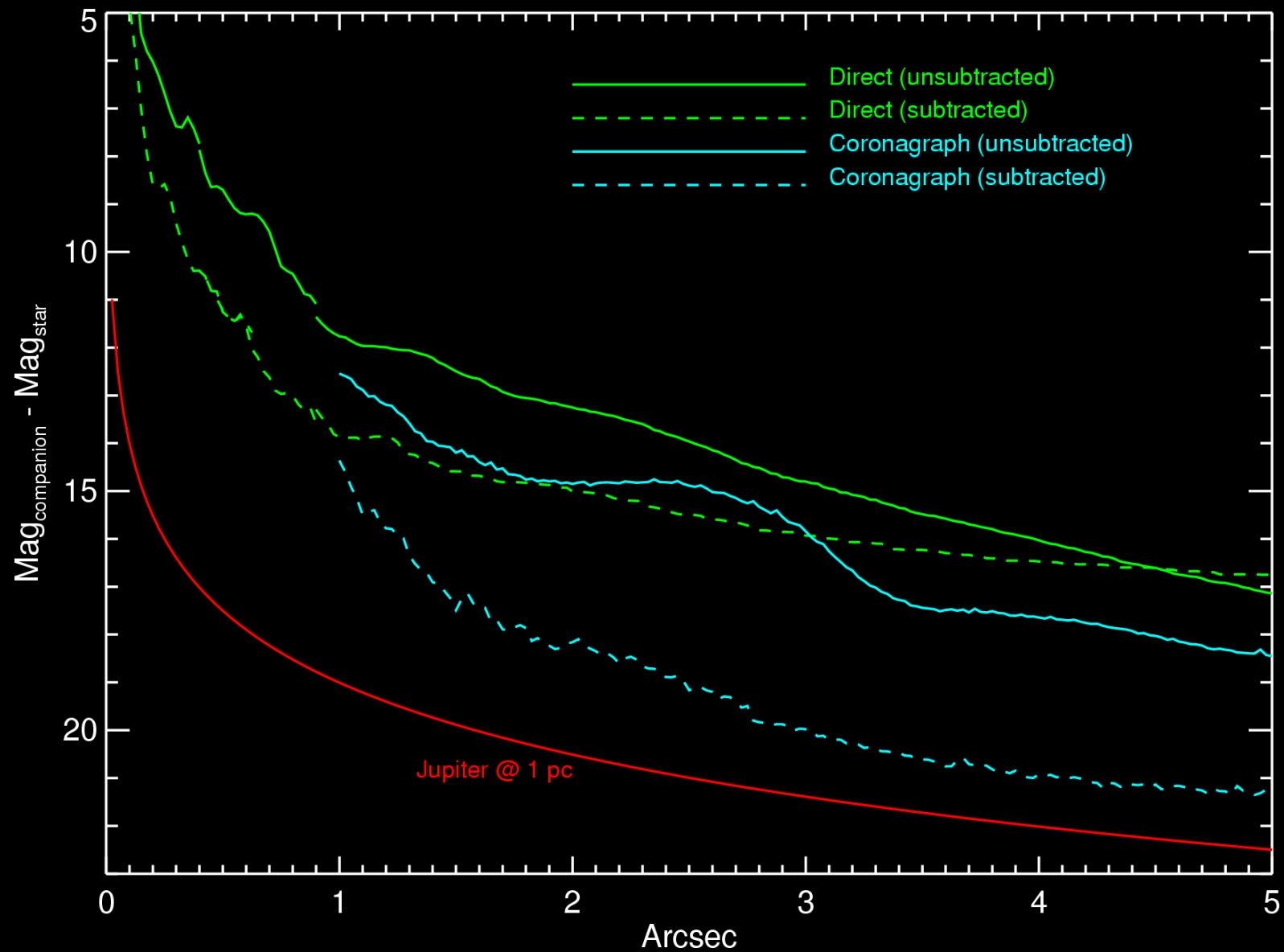
After Spectral Deconvolution &
Unsharp Masking



ACS PSF Mean Brightness Profiles (V)

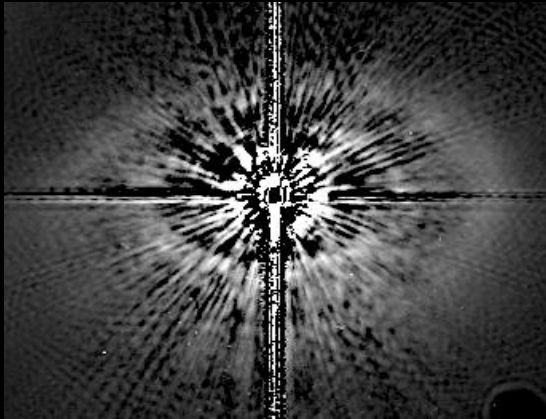


ACS V-Band Point Source Detection Limits

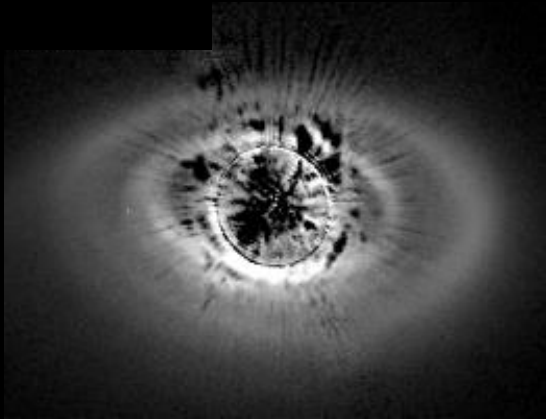
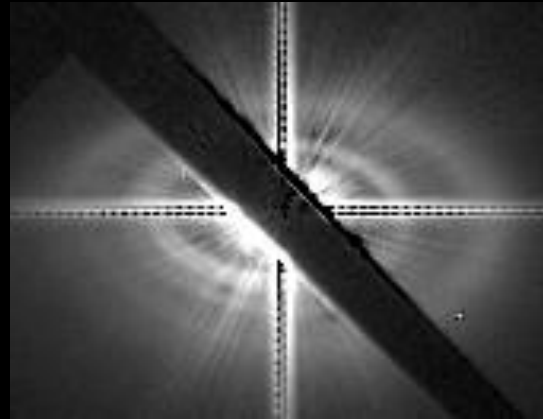


HST vs. Ground: HD 141569

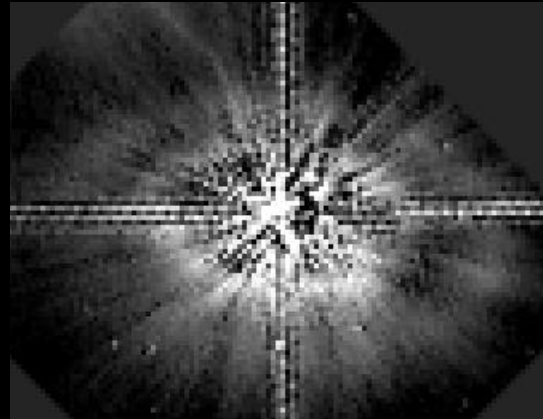
ACS Direct (V)



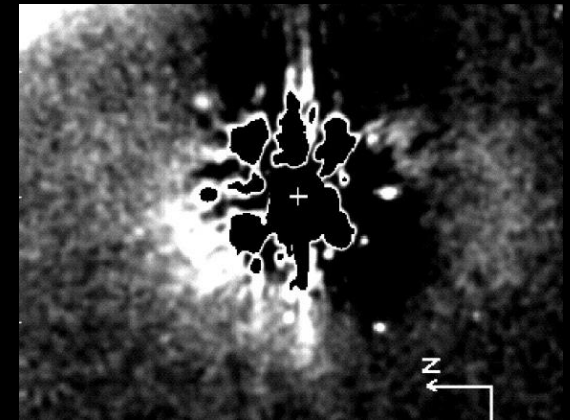
STIS Coronagraph (U→I)



ACS Coronagraph (V)



NICMOS Coronagraph (J)



Palomar AO
Coronagraph (2.2 μm)
Boccaletti et al. 2003
(Their image)

HST vs. Ground Coronagraphs

- HST limited to inner radius of $r > 0.6''$ (near-IR) and $r > 0.7''$ (visible, if STIS repaired, else $1.1''$ with ACS); on ground, $4\lambda/D$ at $2\text{ }\mu\text{m}$ with a 10 m scope is $0.17''$
- HST stability allows PSF subtraction providing up to an additional 200x improvement in contrast (coronagraph improves contrast up to 7x); ground scope stability limited in most cases to $< 10x$ (PSF subtraction or SDI) and limited AO correction radius
- HST is much better than ground for most disk imaging at radii $> 1''$; large scopes on ground better for point sources closer in

