CONTACT: Glenn Schneider, Steward Observatory, 933 North Cherry Avenue, University of Arizona 85721 USA, gschneider@as.arizona.edu, http://nicmosis.as.arizona.edu:8000, 520-621-5865 77 TEAM: G. Schneider, K. Stapelfeldt, D. Padgett, C. Grady, M. Silverstone, D. Hines, A. Cotera, M. Clampin, D. Wilner, J. Krist, C-E McCabe, J. Kim, F. Menard, T. Henning, B. Stecklum, S. Wolf Introduction: During HST Cycle 13 we conducted a highly sensitive 52-target NICMOS coronagraphic circumstellar disk imaging survey. Our survey provides: (a) critically needed high resolution scattered-light imagery of protoplanetary and debris disks to assist in discriminating between proposed evolutionary scenarios in the epochs of planet-building, (b) a legacy of cataloged disk morphologies for interpreting mid- and far-IR SEDs (e.g., Spitzer) and (c) reliable, spatially resolved, photometry and flux density limits for nondetections. Our high-contrast scattered-light imagery yields, directly, the spatial distribution of the grains for disks detected within the sensitivity limits of our survey and which cannot be uniquely inferred from (longer-wavelength) spectral energy distributions alone.

Asymmetries (e.g., warps, gaps, arc, spirals, rings, axial anisotropies, etc.) in the spatial distributions of dusty debris in evolved disks provide evidence for unseen co-orbital planetary-mass companions through their dynamical interactions with the disk grains.

Spatially resolved flux-density limits for non-detections provide constraints to break degeneracies in possible disk geometries and compositions which are otherwise coupled in SED models of thermally emissive disks. We provide an overview of our survey,

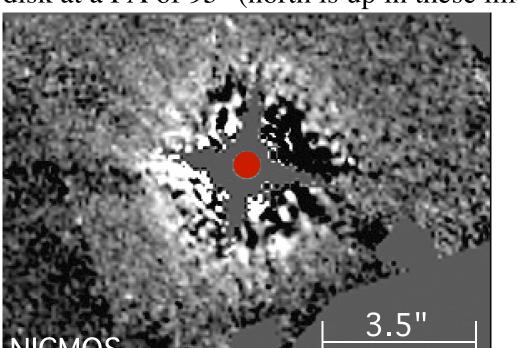
highlighted with observational results from both our YSO and debris disk targets. Young Stellar Object (YSO) Sample. A < 10 Myr sample of 26 optically-thick YSO disk candidates: 18 T Tauri (d < 150 pc) stars of spectral types G-M, with mm continuum excesses and/or intrinsically high optical polarizations; 8 A-F (d < 200 pc), including 4 Herbig AeBe stars with thermal IR and/or mm emission well above their photospheric levels. Several of these YSO disks were previously detected with HST in the optical: (WFPC-2: GO Tau, DoAr 25, Sz 82, Haro 6-33; STIS: AA Tau, DM Tau, DL Tau),

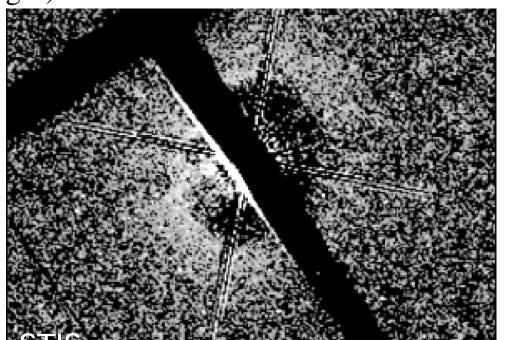
with possible detections about three others (CW Tau, CY Tau, RNO 91) and two (LK Ca 15 and HD 169142) with ground based simultaneous dual-beam polarimetry in the near-IR.

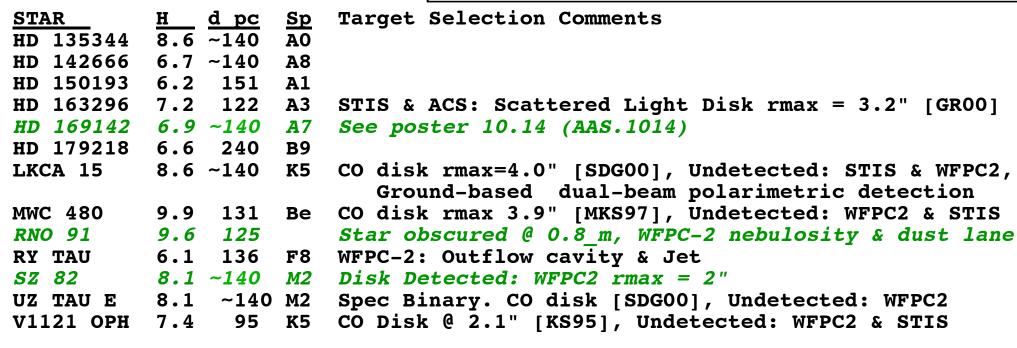
STAR	H d pc	<u>Sp</u>	Target Selection Comments								
AA TAU	8.5 ~140	MO	CO Detection rmax = 2.2", STIS Detection with jet								
BP TAU	8.2 53	K5	CO rmax 0.8" [SDG00], Undetected: WFPC2								
CI TAU	8.4 ~140	G	CO rmax 1.5", Undetected: WFPC2 & STIS								
CQ TAU	7.1 100	F2	CO & mm emission r<0.6" [MS00], Undetected: STIS								
CW TAU	8.2 ~140	K5	CO rmax 1.6", Disk Undetected: WFPC2 & STIS,								
jet maged with STIS											
CY TAU	9.0 ~140	M2	CO disk rmax 1.9" [SDG00], STIS HH knots								
DL TAU	8.7 ~140	\boldsymbol{G}	CO disk rmax 3.7" [SDG00], STIS & WFPC2 see jet								
DM TAU	9.8 ~140	K5	CO disk rmax 5.7" [SDG00], STIS: Ring-like disk r=2"								
DOAR 25			Disk Detected: WFPC2 rmax = 1.1" & Ground Pol.								
DQ TAU	9.5 ~140		MO Spec. Binary. CO @ 1.5", Undetected WFPC-2								
GO TAU	<i>9.8</i> ~140	K5	WFPC-2 Scattered Light to $rmax = 1.5$ ", CO detection								
HARO-6 33		C									
HD 36112	6.6 204	A2									

KS95: Koerner & Sargent 1995; GR00: Grady et al 2000; MS00: Mannings & Sargent 2000; SDG00: Simon, Dutrey & Guilloteau 2000; MKS97: Mannings, Koerner & Sargent 1997

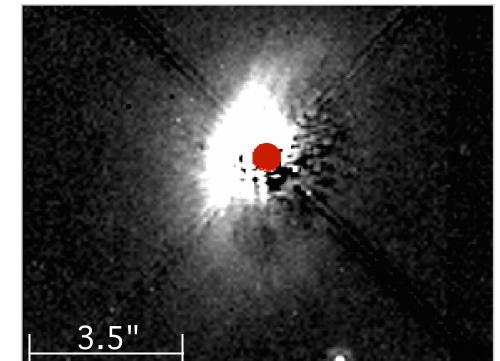
DM Tauri: A faint disk (peak surface brightness ~ 17 μJy arcsec⁻²) seen around | GO Tauri (K5V, H=9.8). NICMOS PSF-subtracted cornonagraphy shows that the DM Tau (K5, H=9.8) at 1.6 µm with NICMOS (left) was also detected in the optical with STIS (right) as previously reported by Grady. The disk appears to be inclined appx 37° from the line-of-sight. The interior of the disk, to a distance of ~ 1.8 " (240) AU), appears relatively dark (cleared?), though with a brightening toward east. A "bright" ring, at ~ 320 AU, is hemispherically asymmetric in surface brightness, and there is a hint of a darker azimuthal sector (shadowing?) in the outer portion of the disk at a PA of 95° (north is up in these images)

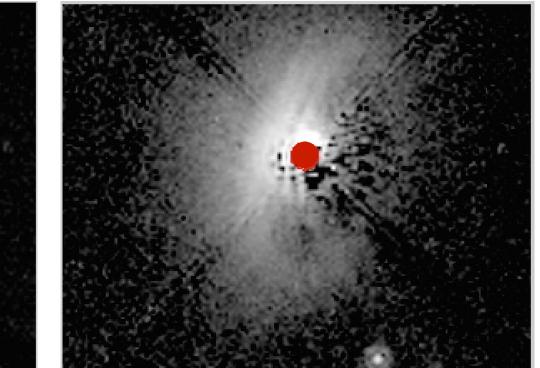




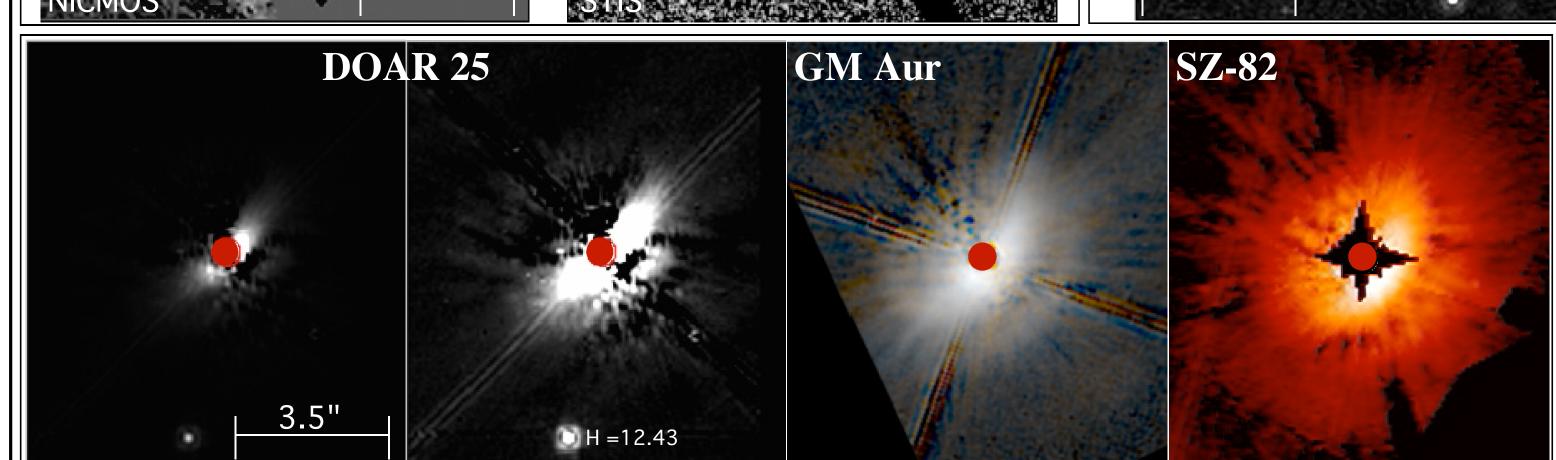


morphology of the GO Tau disk is similar to GM Tau, but slightly more inclined. The disk also exhibits a much stronger brightness asymmetry along the minor axis. The dark zone in the GO Tau disk extends to ~ 2.4 " (290 AU). The disk semimajor axis is ~ 4.5 " (540 AU). Striated structures (above the disk midplane) are seen the regions of high surface brightness. Left: linear display 0 to 0.134 mJy arcsec⁻². Right: log display 0.02 to 3.2 mJy arcsec⁻².



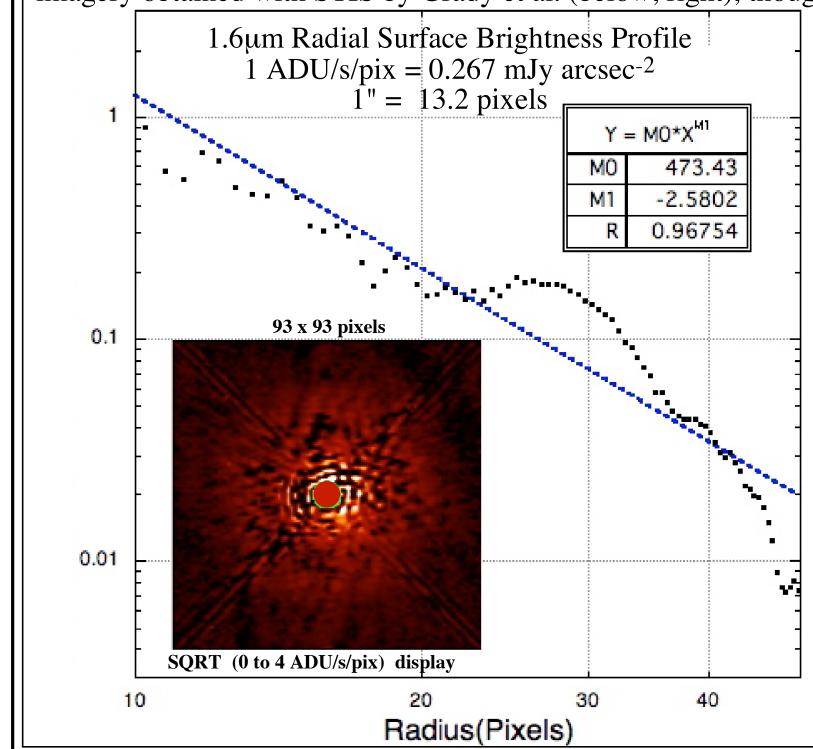


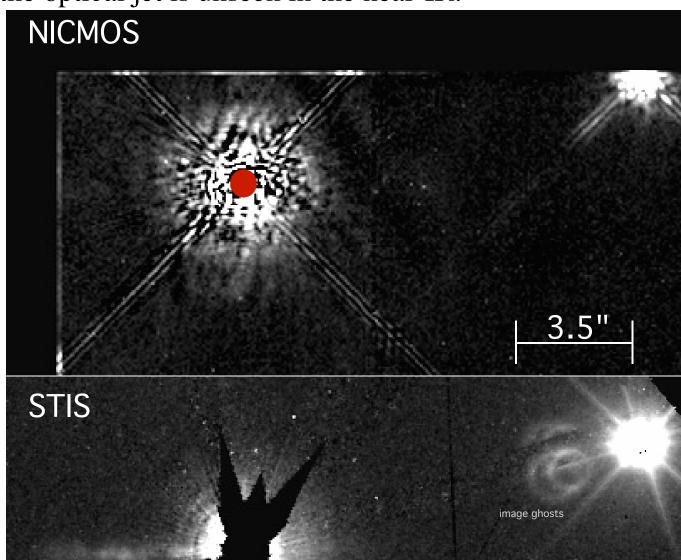
Targets highlighted in green are discusse

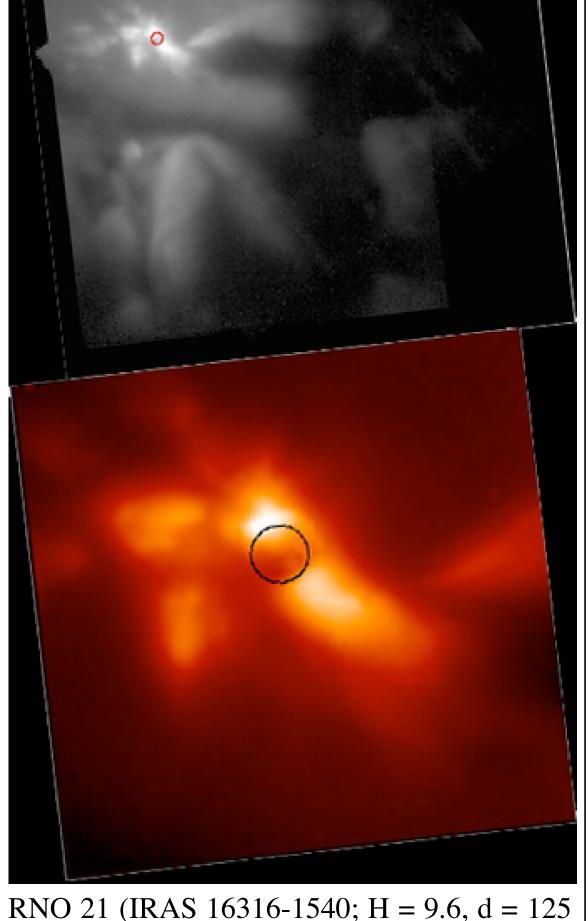


Left: The circumstellar disk about the T Tauri star and X-ray source DOAR 25 (K7V, H = 8.4; ROXR1 23) in the ρ Oph star forming region was imaged with NICMOS 1.6 μ m PSF-subtracted coronagraphy. The r = 2.7" DOAR 25 disk, (left: 0 to 5.3) mJy arcsec⁻²; adjacent: 0 to 0.53 mJy arcsec⁻²), is similar to the less-inclined GM Aur disk (middle right; NICMOS 1.1 and 1.6 µm two color image; Schneider et al 2003). The dark DOAR disk mid-plane, 0.7" from the star and the "lower" scattering surface of the disk are seen below and to the right of the star. Right: A strikingly similar morphology is seen in the disk of the weak-lined T-Tauri star SZ-82 (IM Lup) in the NICMOS 1.6µm PSF-subtracted coronagraphic image.

DL Tau (GV:e; H = 8.68) appears to have a nearly circularly symmetric scattered light disk at extending to $r \sim 3.5$ " as seen in NICMOS PSF-subtracted 1.6 µm coronagraphic images. This morphology generally agrees with earlier corongraphic imagery obtained with STIS by Grady et al. (below, right), though the optical jet is unseen in the near-IR.



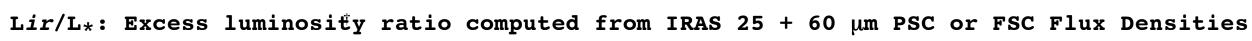


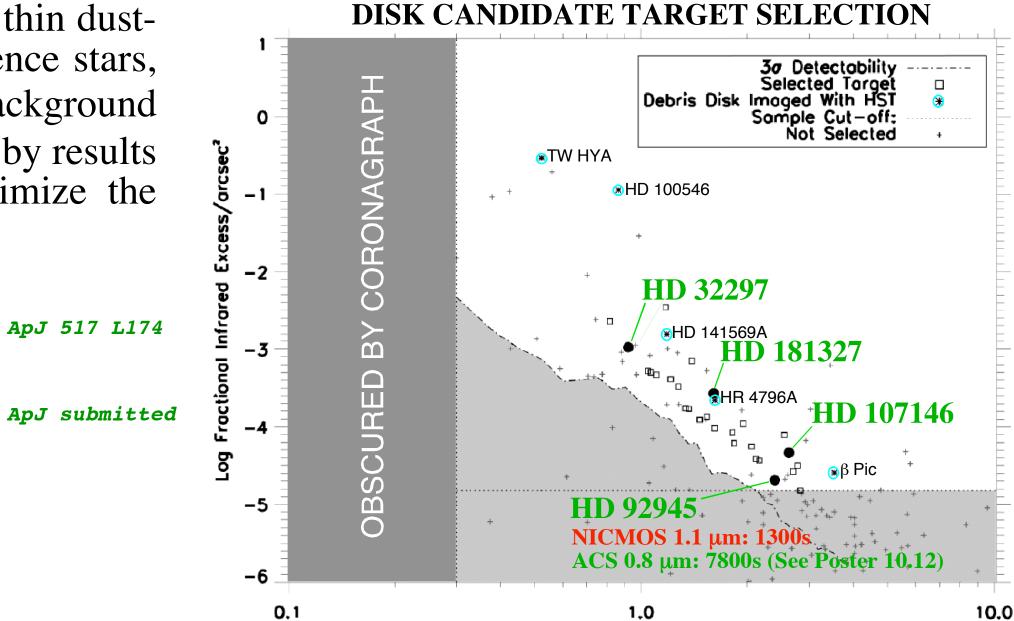


pc) is an embeded (and optically obscured) T-Tauri star in the Ophiuchus L43 cloud. The class II source ($L \sim 2.7 \text{ L(sun)}$, $M \sim 0.5$ M(sun)) and surrounding nebulosity, recently discussed by Lee & Ho 2005 (ApJ, 624, 841), is shown above in a NICMOS 1.6 µm twoorientation combined coronagraphic image without PSF-subtraction. Top panel: 27"x27" Bottom panel: 5.5" x 5.5". The source, in the late stages of star formation, exhibits 450 µm 3.6 cm continuum emission, a CO outflow. and shocked H₂ emission.

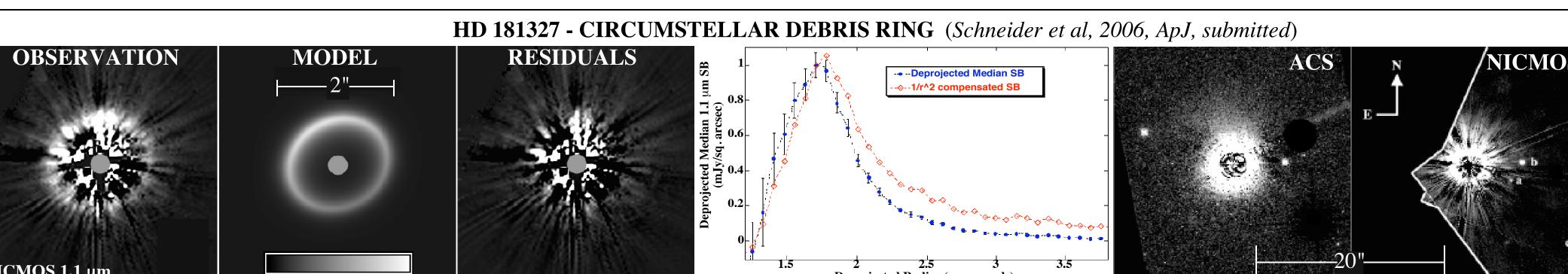
Debris Disk Candidate Sample. A > 10 Myr sample of 26 optically thin dustdominated debris disk candidates (d < 150 pc), A0–K2 main sequence stars, with IRAS far-IR excesses[†], L_{ir} / $L_* > 3 \times 10^{-4}$, unconfused by background nebulosity at $b > 10^{\circ}$. Our selection criteria were predicated, in part, by results from earlier NICMOS disk surveys, and were designed to maximize the likelihood of imaging spatially resolved circumstellar disks.

	inclineda of imaging spatially resolved effectivities along.															
d :	in th	is or n	eighb	oring	pos	ters (10	0.12,	10.1	(4)							
	STA	AR	J	d pc	Sp	<u>Lir/L</u> *				STA	R	J	<u>d pc</u>	<u>Sp</u>	<u>Lir/L</u> *	
	HD	15745	6.7	64	FO	1.8e-3				HD .	107146	5.9	29	G2	1.0e-3	ı
	HD	22128	6.9	142	A5	1.6e-3				HD :	124718	7.6	61	G5	1.0e-3	
	HD	30447	7.2	78	F3	5.4e-4				HD :	143840	7.0	99	F1	1.3e-3	
	HD	<i>32297</i>	7.7	112	AO	2.8e-3	ApJ (639 L	227	HD :	164249	6.2	47	F5	7.6e-4	
	HD	34739	8.4	122	F7	1.8e-3	_			HD .	<i>181327</i>	6.2	<i>51</i>	F5.5	2.2e-3	
	HD	35841	8.2	145	F3	9.7e-4				HD :	185053	7.6	51	F5.5	4.3e-3	
	HD	38207	7.7	130	F2	7.9e-4				HD 2	204366	8.4	102	G0	1.8e-3	
	HD	39944	8.4	104	G1	1.5e-2				HD 2	204942	7.3	81	F7	6.5e-4	
	HD	72390	8.1	111	F7	1.9e-3				HD 2	211231	6.6	122	FO	6.1e-4	
	HD	83870	6.7	68	G5	5.4e-4				HD 2	220750	7.0	148	AO	8.8e-4	
	HD	92945	6.3	<i>22</i>	K1	3.7e-4	AAS 2	207.1	012	HD 2	221853	6.6	71	FO	3.8e-4	
	HD	95146	8.1	149	F3	1.7e-3				SAO	84773	7.0	29	K2	1.0e-3	
	HD	105781	8.9	109	G3	4.8e-3				SAO	93101	6.4	68	KO	7.4e-4	

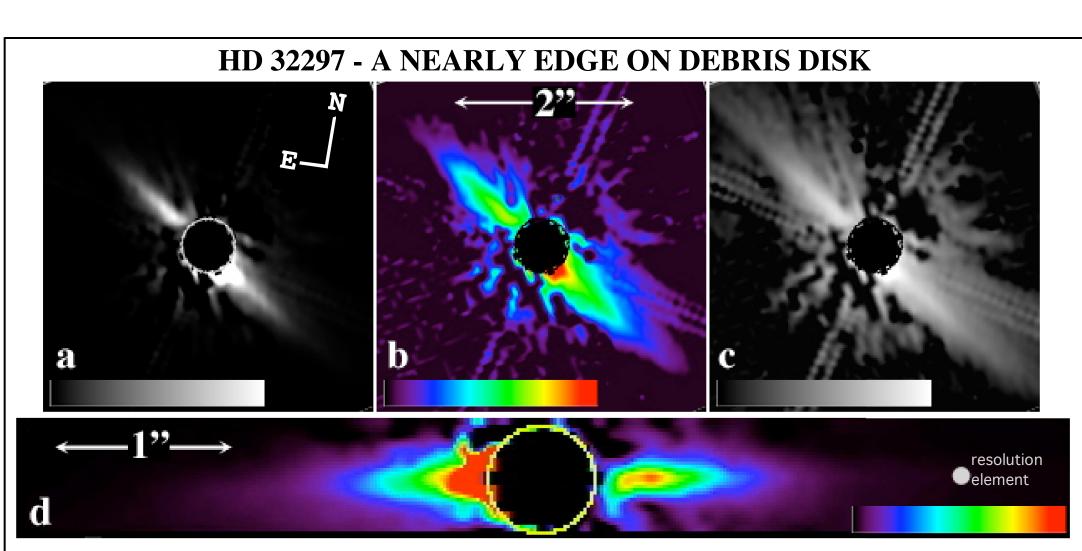




Estimated Disk Radius (Arcseconds)

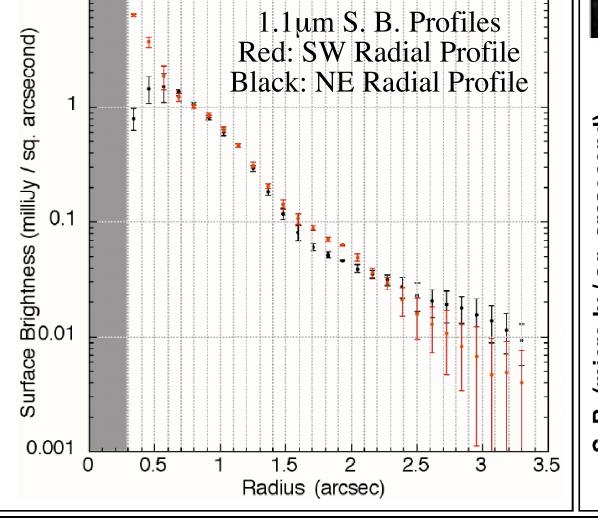


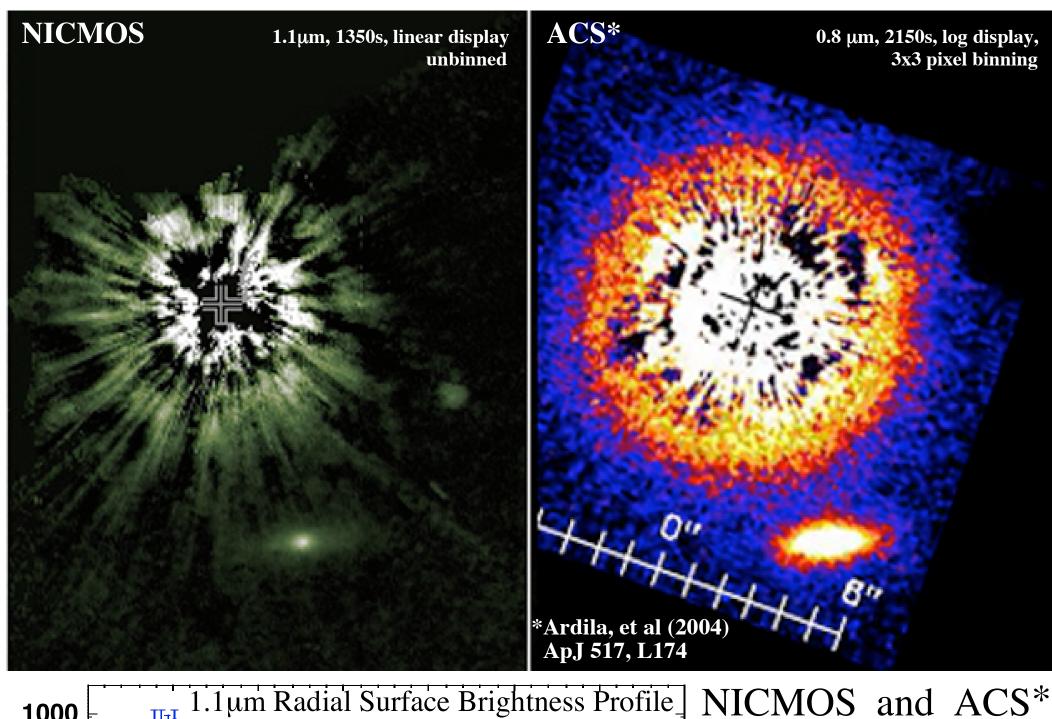
NICMOS PSF-subtracted coronagraphic observations of HD 181327, a member of the \sim 12 Myr β Pic moving group, reveal a ringlike disk of circumstellar debris seen in 1.1 µm light scattered by the disk grains, surrounded by a diffuse outer scattering region of low surface brightness (SB). The annular disk is inclined by $31.7^{\circ} \pm 1.6^{\circ}$ from face on with the disk major axis PA at $152^{\circ} \pm 2^{\circ}$. The total 1.1 μ m flux density of the light scattered by the disk (at 1.2" < r < 5") of 9.6 mJy \pm 0.8 mJy is 0.17% \pm 0.015% of the starlight. Seventy percent of the light from the scattering grains is confined in a 36 AU wide annulus centered on the peak of the radial SB profile 86.3 AU \pm 3.9 AU from the star with an azimuthally medianed SB at that distance of 1.00 \pm 0.07 mJy arcsec⁻². The ring is bilaterally symmetric, with strong directionally preferential scattering well represented by a Henyey-Greenstein scattering phase function with $g = 0.30 \pm 0.03$. No photocentric offset is seen in the ring relative to the position of the central star. A low surface brightness diffuse halo is seen in the NICMOS image to a distance of ~ 4". Deeper 0.6 µm ACS PSF-subtracted coronagraphic observations reveal a faint $(V \sim 21.5 \text{ mag arcsec}^{-2})$ outer nebulosity from 4" < r < 9", asymmetrically brighter to the North of the star. Modeling the disk we infer a maximum vertical scale height of 4-8 AU at the 87.6 AU radius of maximum surface density. The model also predicts a total maximum mass $\sim 4~{\rm M}_{Moon}$ of collisionally replenished grains with a minimum grain size of $\sim 1~{\rm \mu m}$.



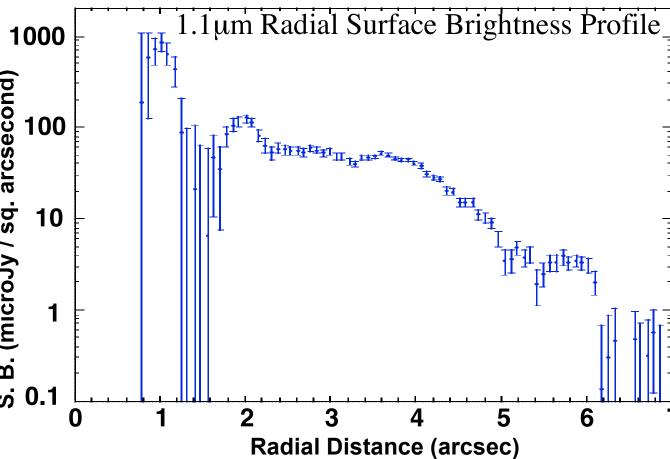
NICMOS PSF-subtracted coronagraphic imagery of the recently discovered circumstellar disk of HD 32297* (A0V) (possibly of comparable age to HR 4796A and β Pictoris, ~ 10 My).

Radial surface brightness asymmetries along NE and SW "halves" of the HD 32297 disk major axis may implicate the existence of a planetary $\frac{1}{2}$ 0.1 modifying perturber distribution azimuthal circumstellar scattering grains. (Region in gray obscured by the NICMOS coronagraph.) *Schneider G., et al. (2005) ApJ, 639, L227





HD 107146 - A NEARLY FACE ON DEBRIS DISK



two-roll combined P SF - s ub t r ac t e d coro nagraphich images, and 1.1 µm (NIČMOS) SB profile, nearly face-on debris disk, r ~ 150 AU. about the 30-250 Myr ¹ Sun-like star **HD 107146**. (*see poster 10.12)

This display paper (#10.13), presented at the 207th meeting of the American Astronomical Society (Washington, D. C., 09 January 2006) may be downloaded from: http://nicmosis.as.arizona.edu:8000/POSTERS/AAS_JAN_2006_GO10177.pdf This work is based on observations made with the NASA/ESA Hubble Space Telescope, obtained at the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555. These observations are associated with program 10177. Support for program 10177 was provided by NASA through a grant from the Space Telescope Science Institute.