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# HST Imaging of Circumstellar Disks

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**Abstract.** The stability of the Hubble Space Telescope's diffraction-limited point spread function (PSF) is exploited by the observatory's complement of second generation instruments, NICMOS and STIS, to produce very high contrast direct and PSF-subtracted coronagraphic images of disks around young stars. The direct detection and imaging of disks in a variety of evolutionary stages with high spatial resolution (50–150 mas) in the optical and near-IR has yielded spatial information from the scattered light components of such disks in unprecedented detail.

## 1. Introduction

We illustrate the diversity in disk morphologies which has been revealed through an ensemble of disk images obtained with HST. We include proto-stellar disks as young as L1551 ($\lesssim$ 1 Myr), where the "embedded" source has been identified, to the older ($\sim$ 8 Myr), evolved debris ring around HR 4796A. In conjunction with other images of intermediate age disks, and likely declining gas:dust ratios (HH 30, GM Aur, TW Hya, HD 141569A), such observations provide key insights into the mechanisms of disk (and planet) formation and evolution.

## 2. $\lesssim$ 1 Myr Disks

Proto/young circumstellar disks ($\lesssim$ 1 Myr), with embedded or obscured central stars, may be imaged directly. Such systems often exhibit polar outflows as their envelopes collapse toward an optically-thick mid-plane. Older disks, centrally-cleared (e.g., by Poynting-Robertson drag and radiation pressure), present a contrast challenge requiring PSF-subtracted coronagraphy (Schneider et al. 2002a).

*L1551-IRS5.* A compact source is coincident with the northern of two embedded stellar objects in the region of this class 1 Young Stellar Object (Fig. 1a). The reflection nebula is associated only with IRS 5A and is unlikely due to scattering off a circumbinary disk. A dense clump of dust interacting with IRS 5, and a twisted jet of outflow material are seen (Cotera et al. 2002).

*HH 30.* A flared optically-thick disk with a dusty midplane, decreasing in opacity with wavelength, circumscribes this young T Tauri star (Fig. 2b). A polar jet seen in WFPC-2 images (Stapelfeldt et al. 1999) is much less prominent in NICMOS passbands (Cotera et al. 2001). The parity of a lateral asymmetry in the brighter meniscus at visible wavelengths is inverted in the later epoch near-IR implicating intrinsic variability (perhaps due to stellar rotation).

*GM AURIGAE.* The intrinsic morphology of GM Aur's disk is similar to HH 30, but the central star is unobscured due to a significantly higher inclination of the mid-plane to the line-of-sight (Fig. 1c). Diffuse polar lobes of red (outflow?) material are seen, rather than a collimated jet, as is a broad ribbon of bluer material extending from the mid-plane (Schneider et al. 2002b).

## 3. 5–10 Myr Disks

Dusty disks with brightness anisotropes and complex morphologies, possibly indicative of dynamical interactions with planetary mass companions, have been imaged around young stars (5–10 Myr) with HST. Observations of 1–5 Myr transitional systems are discussed elsewhere (e.g., Grady 2002).

*TW HYDRAE.* This K7 PMS classical T-Tauri star has a pole-on circularly symmetric disk with a break in its surface brightness profile at 120 AU (Krist et al. 2000; Weinberger et al. 2002). Evidence for an azimuthally and radially confined arc-like depression is seen in both STIS and WFPC-2 images (Fig. 1d).

*HD 141569A.* A broad, 400 AU radius disk with a partially filled asymmetric gap at $\sim$ 250 AU (Fig. 1e) circumscribes this $\sim$ 5 My (Weinberger et al. 2000) Herbig Ae/Be star (Weinberger et al. 1999; Mouillet et al. 2001). A widening spiral "arclet" in the gap on the brighter and broader side of the disk is seen.

*HR 4796A.* This $\sim$ 8 Myr "Vega-like" A0V star has a fractional far-IR excess exceeding that of $\beta$ Pictoris. HST images reveal a 70 AU radius ring of debris asymetrically confined in a zone $\sim$ 12 AU wide (Schneider et al. 1999; 2002a). The disk grains are intrinsically red, exhibit directionally preferential scattering along the line-of-site, and a 20% "hemispheric" brightness asymmetry about the disk minor axis. The particle confinement, brightness asymmetries, and colors may implicate the existence of unseen co-orbital evolved bodies.

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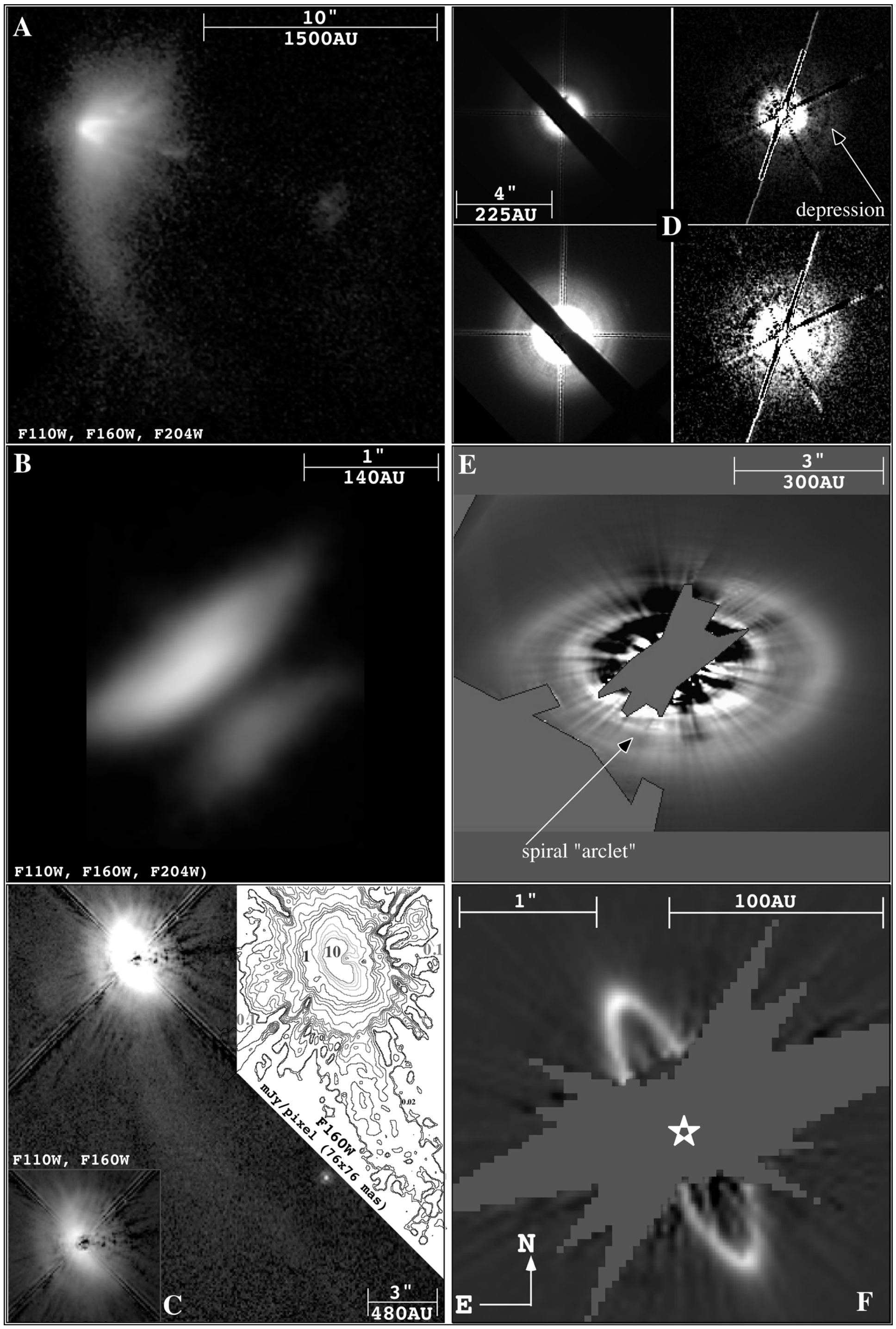


Figure 1. HST PSF-subtracted direct (A & B) and coronagraphic (C–F) images circumstellar disks around young stars [1]. A: L1551 IRS-5. B: HH 30. C: GM Aur. D: TW Hya (left STIS; right WFPC-2). E: HD 141569A. F: HD 4796A.

[1]http://nicmosis.as.arizona.edu:8000/POSTERS/GILLETT_SYMPOSIUM.jpg