HST and Spitzer Observations of the HD 207129 Debris Ring

(Author: Krist et al.[2010])

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Introduction

- Circumstellar debris disks are created by the collisions or disruptions of solid bodies. (E.g. asteriods, comets, planets.)
- They are removed by Radiation pressure, Poynting–Robertson drag, and stellar winds.
- Seeing a disk means either recent major collision or continuous debris replenishment.
- Either way, it signifies the presence of some kind of planetary system.

Poynting Robertson Drag

Poynting Robertson Drag

is a process in which the solar radiation causes a dust grain orbiting a star to lose angular momentum relative to its orbit around the star.

Examples

In the case of the Solar System, this can be thought of as affecting dust grains from 1 μm to 1 mm in diameter.

Poynting-Robertson Force

$$F_{PR} = \frac{r_g^2 L_s}{4c^2} \sqrt{\frac{GM_s}{R_{orb}^5}} \tag{1}$$

Debris Disk Imaging

- Many debris disks are resolved around solar-type stars.
- Many debris disks are resolved in far-infrared flux densities using the instruments like [1]IRAS, [2]ISO, and Spitzer.
- Few have been resolved in long-wavelength emission with Spitzer and sub-millimeter radio telescopes.
- For the resolved disk imaging, high contrast imaging techniques are required. E.g. We can use a coronagraph to suppress the diffraction pattern of the star and get a resolved image.

[1] IRAS: InfraRed Astronomical Satellite
[2] ISO: Infrared Space Observatory

So ... What's a Coronagraph ?

- A coronagraph is a telescope which blocks out the direct light from a star.
- Most coronagraphs are intended to view the corona of the Sun.
- Stellar coronagraphs are used to find extrasolar planets and circumstellar disks around the nearby stars.

Coronoragraph Images

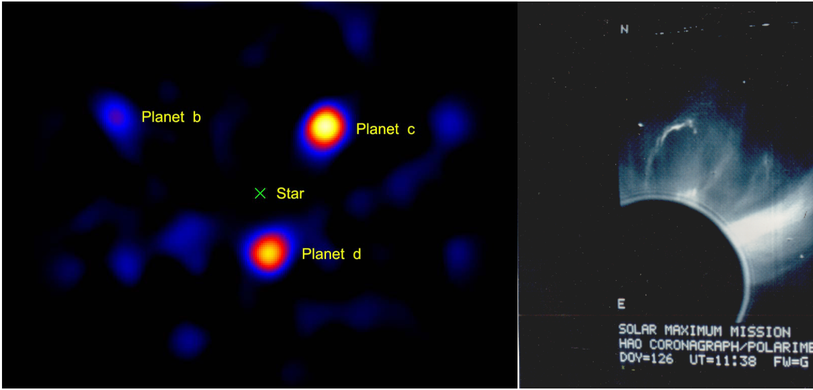

Figure: Left: Exo-planets around the star HR8799, Right: Sun's corona. (Source: Wikipedia)

Problems with Ground Based Telescopes

- There is a lack of wavefront stability due to the atmospheric turbulence, even after correction by adaptive optics.
- Due to the image instabilities, it leads to significant PSF subtraction residuals.
- Space based observations solve these problems.

Target Selection

- The debris disk images are the probe to the planetary systems around the other stars.
- For the most direct comparison with the solar system, debris disks around mature solar-type stars are chosen particularly.
- We consider here the nearby Sun-like star HD 207129, a G0V star at a Hipparcos measured distance of 16.0 [3]pc.

[3] 1 pc equals to $648000/\pi \ au = 3.26 \ ly = 30 trillion \ km = 19 trillion \ miles$

Quick Reminder of Star Classification

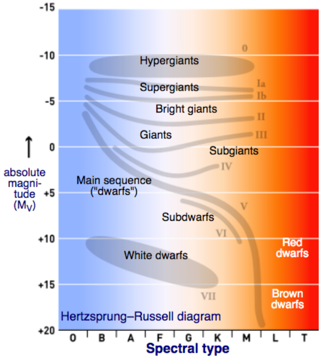

Figure: H-R diagram (Source: Wikipedia)

Class	Effective temperature[1][2][3]	Vega-relative chromaticity[4][nb 1]	Chromaticity (D65)[5][6][7][nb 2]	Main-sequence mass[1][8] (solar masses)
O	≥ 30,000 K	blue	blue	≥ 16 $M_\odot$
B	10,000–30,000 K	blue white	deep blue white	2.1–16 $M_\odot$
A	7,500–10,000 K	white	blue white	1.4–2.1 $M_\odot$
F	6,000–7,500 K	yellow white	white	1.04–1.4 $M_\odot$
G	5,200–6,000 K	yellow	yellowish white	0.8–1.04 $M_\odot$
K	3,700–5,200 K	light orange	pale yellow orange	0.45–0.8 $M_\odot$
M	2,400–3,700 K	orange red	light orange red	0.08–0.45 $M_\odot$

Figure: Star Classification (Source: Wikipedia)

Previous Observations of the Object

- Walker et al. (1988) noted that it had a small IRAS 60 μm excess.
- Habing et al. (1996) measured 60 and 90 μm ISO excesses.
- Jourdain de Muizon et al. (1999) obtained additional ISO observations over 2.5 *to* 180 μm.
- They verified the lack of circumstellar material near the star.

Degeneracies

- Sheret et al. (2004) derived a disk radius of 260 ± 50 [4]AU.
- Zuckerman & Song (2004) derived a 35 AU.
- Degeneracies exist among the grain size, emissivity, temperature, and distance from the star.
- The size scale of the disk is uncertain.

[4]The Mean sun-earth distance 1 AU equals to 150 billion m = 93 million miles = 4.8 μpc

Breaking the Degeneracies

- By directly measuring the location of the dust, resolved images of the disk can break these degeneracies.
- Then reliable grain properties can be derived.
- Here, we utilized the [5]ACS coronagraph to image disk candidate stars.
- The coronagraph on the ACS provided the highest contrast imaging on HST.

[5]ACS: The Advanced Camera for Surveys (ACS) is a third-generation Hubble Space Telescope (HST).

Our object

- We chose eight targets previously unobserved by HST.
- The dust luminosities were

$$\frac{L_{dust}}{L_*} = 1 - 7 \ x \ 10^{-4}$$

- We report here the detection of a disk around HD 207129 and non detection for other candidates.

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HST ACS Observations

- The star HD 207129 was observed on 2006 May 3 with the coronagraph in the ACS High Resolution Camera.
- Two 0.1 s exposures were done in the narrowband filter F502N for automated acquisition.
- One 100 s exposure and four 520 s exposures were done in F606W.

HST ACS Filters Used

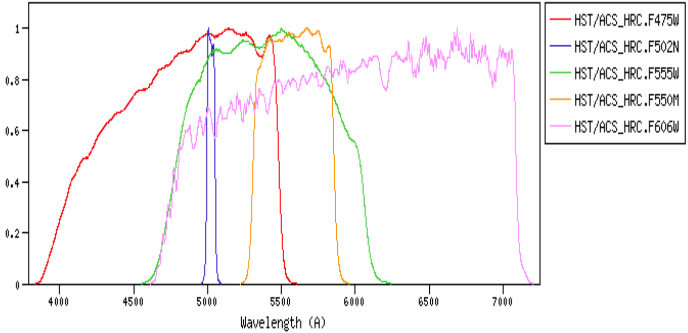

Figure: Source: http://svo2.cab.inta-csic.es/

Halo of light around the star

- The coronagraph suppresses the diffraction pattern created by the telescope.
- It does not reduce the scattering by optical surface errors that create a halo of light around the star.
- This halo is typically subtracted using an image of another isolated star observed in the same manner.

HST ACS PSF Subtraction

- The designated PSF subtraction reference star HD 211415 was a binary.
- To replace it, 10 similarly observed alternative reference stars were collected.
- Each was subtracted from the combined long-exposure HD 207129 images iteratively.
- None of these subtractions indicated the presence of any circumstellar material above the level of the residuals.

Alternative PSF Subtraction

- Use the image of HD 207129 taken at one orientation to subtract the starlight from the image taken at the other and vice versa.
- This process is called roll subtraction.
- They verified the subtraction algorithm by producing a reliable result for a simulated disk.
- This disk is so faint that it might have been detected only by using roll subtraction.

Roll Subtracted Images

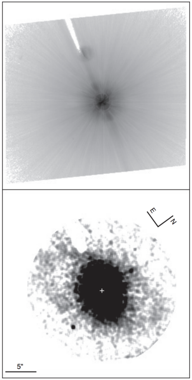

Figure 1. ACS F606W coronagraphic observations of HD 207129. Each frame is 30.″2 on a side. Top: coronagraphic image from the first orientation prior to PSF subtraction. Shadows of the occulting finger and larger occulting spot are seen toward the upper left corner. The diagonal streak stretching from the upper left to lower right is instrumentally scattered light. This image is displayed with logarithmic intensity scaling. Bottom: image of the HD 207129 ring after applying the iterative roll subtraction method described in the text to the exposures taken at each orientation. The images were rebinned to 0.″1 sampling prior to processing, and the result was additionally smoothed using a median filter. This image is displayed with a quarter-root intensity scaling with a much lower maximum value compared to the top image.

Figure: Roll Subtracted Images

Roll Subtracted Images (Contd.)

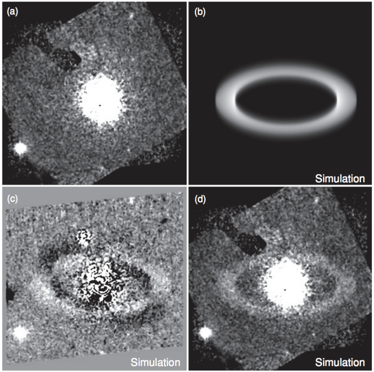

Figure: a) Algorithm prior to adding disk model. b) Model disk that approximately matches the observed HD 207129 ring. c) Direct subtraction of the image from the second orientation from that the first. d) Application of the roll subtraction algorithm to the ring-added images.

Spitzer Photometry and Spectroscopy

- The Multiband Imaging Photometer for Spitzer (MIPS) instrument was used to image HD 207129 at 24 μm on 2004.
- MIPS 160 μm observations were carried out on 2007.
- Spitzer's InfraRed Spectrograph (IRS) was used to observe HD 207129 on 2007.

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HST ACS Results

- The ACS image reveals that the HD 207129 disk is a ring inclined $60^o \pm 3^o$.
- The annulus is $\sim 1.9''$ wide with a mean radius of $\sim 10.2''$.
- The [6]ansae have a surface brightness of $V = 23.7 \pm 0.3\ mag\ arcsec^{-2}$
- This makes the HD 207129 ring the faintest extrasolar circumstellar disk.

[6]ansa: (Latin ansa = handle) The most protruding part of planetary rings as seen from distance.

Spitzer Results

- There is no significant extended emission from the disk at 24 μm.
- The source is clearly extended at 70 μm.
- At 160 μm the measured source is extended along [7]P. A. 137^o.

[7]PA or Position Angle: angle measured relative to the north celestial pole.

Spitzer Result Image

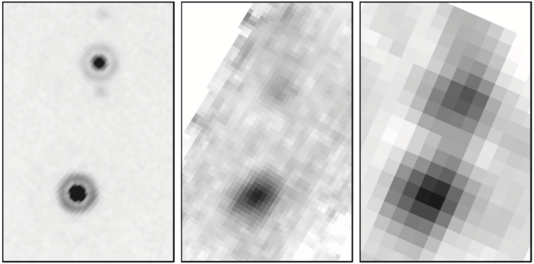

Figure 3. *Spitzer* MIPS images of HD 207129 (lower center), from left to right at 24, 70, and 160 μm, respectively. The field of view is $100'' \times 150''$, with N up and E to the left. The 24 μm image is shown in log stretch, while the 70 and 160 μm images are in linear stretch. Only the 70 μm fine scale image is shown. The spectral leak has been subtracted from the 160 μm image shown. The star CD-47 13929 is seen $75''$ N of HD 207129 at 24 μm. A very red background object is located $59''$ N of HD 207129.

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Conclusions

- HST coronagraphic images detect the debris disk of HD 207129 as a narrow ring with radius 160 AU.
- The ring size and orientation are comparable to that inferred from resolved MIPS images of the source at 70 μm.
- The narrowness of the ring, its apparently sharp inner edge, and large central cleared region are similar to the [8]Fomalhaut system.
- Further observations with Herschel could refine the ring emission properties.

[8]Fomalhaut is the brightest star in the constellation of Piscis Austrinus and one of the brightest stars in the sky. It is a class A star on the main sequence approximately 25 light-years (7.7 pc) from the Sun as measured by the Hipparcos astrometry satellite.(Source: Wikipedia)

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End Note

This paper was published in Astronomical Journal and was authored by Krist et al. [2010].

References

J. E. Krist, K. R. Stapelfeldt, G. Bryden, G. H. Rieke, K. Y. L. Su, C. C. Chen, C. A. Beichman, D. C. Hines, L. M. Rebull, A. Tanner, D. E. Trilling, M. Clampin, and A. Gáspár. HST and Spitzer Observations of the HD 207129 Debris Ring. *The Astronomical Journal*, 140:1051–1061, October 2010. doi: 10.1088/0004-6256/140/4/1051.