

HST and Spitzer Observations of the HD 207129 Debris Ring

(Author: Krist et al.[2010])

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1 Introduction

2 Observations and Data Processing

3 Results

4 Conclusions

5 References

Table of Contents

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Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

1 Introduction

2 Observations and Data Processing

3 Results

4 Conclusions

5 References

- Circumstellar debris disks are created by the collisions or disruptions of solid bodies. (E.g. **asteroids, 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

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Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

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 $1 \mu\text{m}$ to 1 mm in diameter.

Poynting-Robertson Force

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

Debris Disk Imaging

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Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

- Many debris disks are resolved around solar-type stars.
- Many debris disks are resolved in **far-infrared** flux densities using the instruments like ¹IRAS, ²ISO, 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.

¹IRAS: InfraRed Astronomical Satellite

²ISO: Infrared Space Observatory

So ... What's a Coronagraph ?

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Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

- 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.

Coronagraph Images

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Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

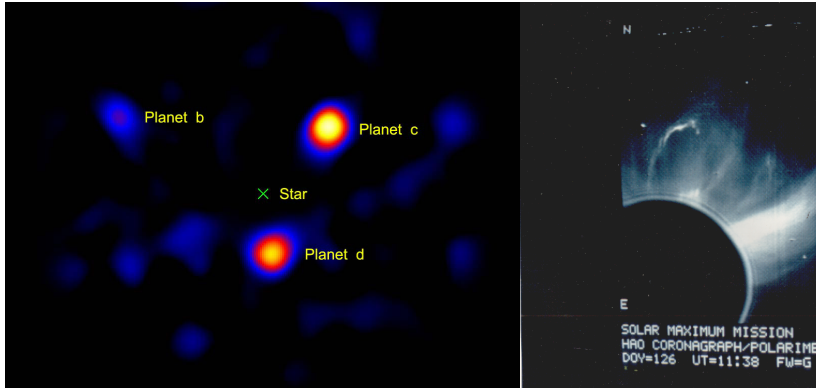


Figure: Left: Exo-planets around the star HR8799, Right: Sun's corona. (Source: Wikipedia)

Problems with Ground Based Telescopes

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Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

- 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.

- 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 .

$^3 1 \text{ pc}$ equals to
 $648000/\pi \text{ au} = 3.26 \text{ ly} = 30 \text{ trillion km} = 19 \text{ trillion miles}$

Quick Reminder of Star Classification

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Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

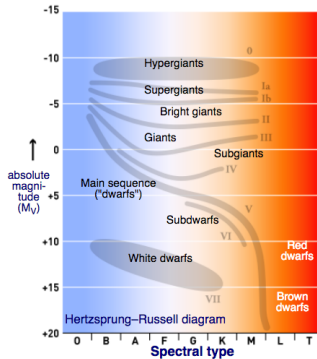


Figure: H-R diagram (Source: Wikipedia)

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	$\geq 30,000$ K	blue	blue	$\geq 16 M_{\odot}$
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

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Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

- 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.

- Sheret et al. (2004) derived a disk radius of 260 ± 50 ⁴AU.
- 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.

⁴The Mean sun-earth distance 1 AU equals to 150 billion m = 93 million miles = $4.8 \mu\text{pc}$

Breaking the Degeneracies

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Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

- 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 ⁵ACS coronagraph to image disk candidate stars.
- The coronagraph on the ACS provided the highest contrast imaging on HST.

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

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

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

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



Table of Contents

AstroSeminar
2018

Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

1 Introduction

2 Observations and Data Processing

3 Results

4 Conclusions

5 References

- 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

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Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

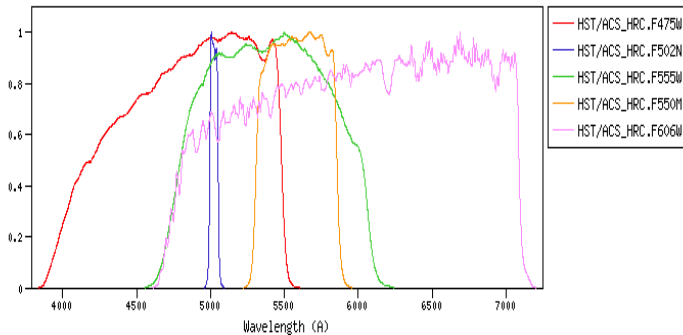


Figure: Source: <http://svo2.cab.inta-csic.es/>

Halo of light around the star

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Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

- 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.

- 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

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Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

- 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

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Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

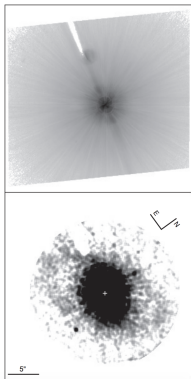


Figure 1. ACS F606W coronagraphic observations of HD 207129. Each frame is $30''.2$ on a side. Top: coronagraphic image from the first orientation prior to PSF subtraction. Shadows of the occulting finger and larger occulting spot are seen toward the upper left corner. The diagonal streak stretching 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.)

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Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

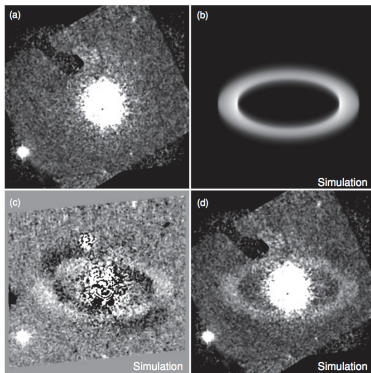


Figure: **a)** Algorithm prior to adding disk model. **b)** Model disk that approximately matches the observed HD 207129 ring. **c)** Direct subtraction of the image from the second orientation from that from the first. **d)** Application of the roll subtraction algorithm to the ring-added images.

Spitzer Photometry and Spectroscopy

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2018

Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

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



Table of Contents

AstroSeminar
2018

Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

1 Introduction

2 Observations and Data Processing

3 Results

4 Conclusions

5 References

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

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

- There is no significant extended emission from the disk at $24\ \mu\text{m}$.
- The source is clearly extended at $70\ \mu\text{m}$.
- At $160\ \mu\text{m}$ the measured source is extended along ${}^7\text{P. A. } 137^\circ$.

${}^7\text{PA}$ or Position Angle: angle measured relative to the north celestial pole.

Spitzer Result Image

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Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

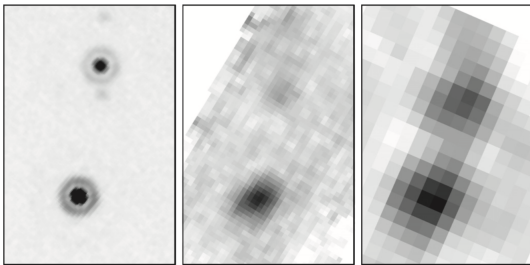


Figure 3. *Spitzer* MIPS images of HD 207129 (lower center), from left to right at 24, 70, and 160 μm , respectively. The field of view is $100'' \times 150''$, with N up and E to the left. The 24 μm image is shown in log stretch, while the 70 and 160 μm images are in linear stretch. Only the 70 μm fine 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.



Table of Contents

AstroSeminar
2018

Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

1 Introduction

2 Observations and Data Processing

3 Results

4 Conclusions

5 References

- 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 ⁸Fomalhaut system](#).
- Further observations with Herschel could refine the ring emission properties.


⁸Fomalhaut 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) 



Table of Contents

AstroSeminar
2018

Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

1 Introduction

2 Observations and Data Processing

3 Results

4 Conclusions

5 References



End Note

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Poudel,
Bhishan

Introduction

Observations
and Data
Processing

Results

Conclusions

References

References

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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.