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# Modeling the Spatial Structure of Debris Disks

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in collaboration with  
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- What do we see?
  - The  $\alpha^1$  Eridani Debris Disk
  - The HD 107146 Debris Disk
- What can we hope to find?
  - Modeling Planet-Disk Interaction in Debris Disks
- Observational perspectives: ALMA

## Modeling of Debris Disks

optically thin systems with potentially complex grain size and radial dust distribution

### debris

- High accuracy SEDs and images of dust distributions
- Scattered light & thermal reemission
- Very flexible

### SAnD

- Fast fitting tool for SEDs & radial profiles
- Fitting technique: simulated annealing

### modust

(Rodmann 2006)

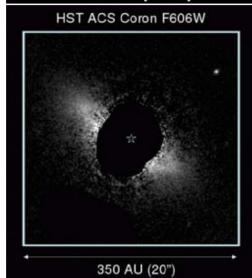
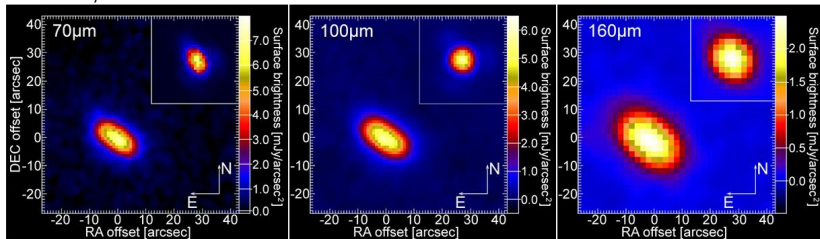
- n-body code
- Complex spatial dust distributions due to planet-disk interaction

## Modeling available data:

q<sup>1</sup> Eri – A Heavy Solar-System Analog

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Herschel/PACS resolved data

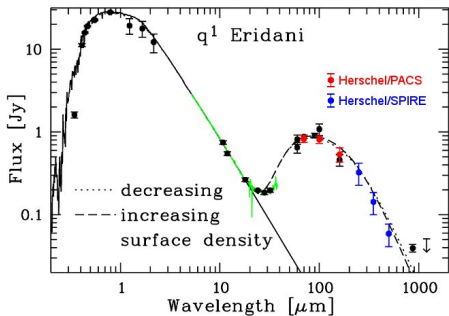
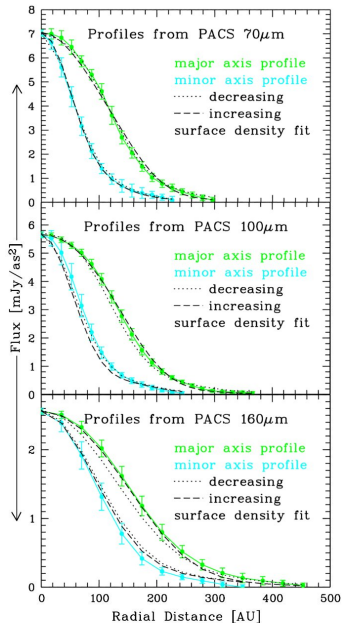


## The System

| Star            |                     | Known planet    |                    |
|-----------------|---------------------|-----------------|--------------------|
| Distance        | 17.43 pc            | Mass            | 0.9 M <sub>J</sub> |
| Spectral Type   | F8V                 | Semi major axis | 2 AU               |
| Mass            | 1.2 M <sub>⊙</sub>  | Eccentricity    | 0.1                |
| Luminosity      | 1.57 L <sub>⊙</sub> |                 |                    |
| Effective Temp. | 6155 K              |                 |                    |
| Mean Age        | 2 Gyr               |                 |                    |

Stapelfeldt et al. (in prep.)

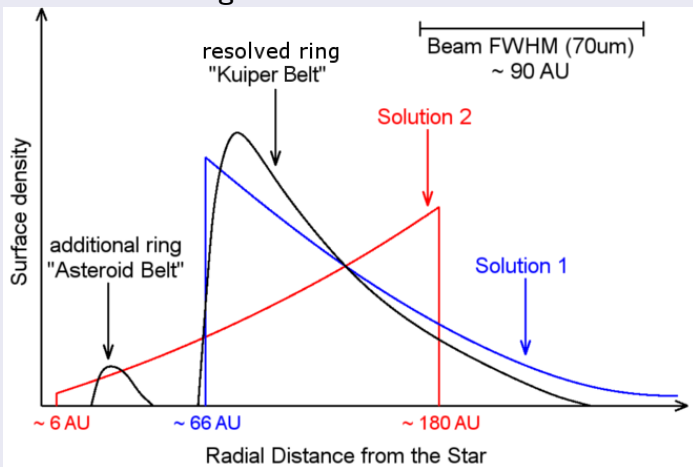
# q<sup>1</sup> Eri – A Heavy Solar-System Analog



|                     | Solution 1                     | Solution 2                     |
|---------------------|--------------------------------|--------------------------------|
| $R_{\text{in}}$     | 66 AU                          | 6 AU                           |
| $R_{\text{out}}$    | 600 AU                         | 180 AU                         |
| $\alpha$            | -1.4                           | 1.3                            |
| $a_{\text{min}}$    | 2.0 $\mu$ m                    | 2.8 $\mu$ m                    |
| $\gamma$            | -3.7                           | -3.7                           |
| $M_{\text{dust}}$   | $1.7 \times 10^{-7} M_{\odot}$ | $9.5 \times 10^{-8} M_{\odot}$ |
| $\chi^2$            | 1.79                           | 1.54                           |
| $N_{\text{models}}$ | $\sim 5 \times 10^9$           | $\sim 8 \times 10^{11}$        |

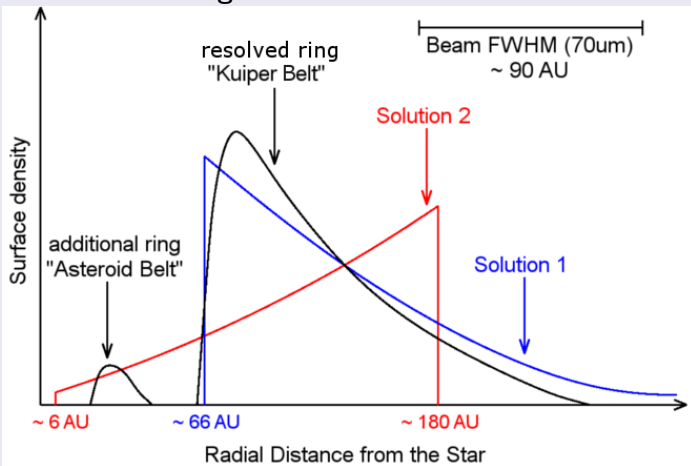
# q<sup>1</sup> Eri – A Heavy Solar-System Analog

Explanation: Multi-ring structure!



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Solution 1 consistent with scattered light data (Stapelfeldt, pers. comm.)





## Modeling available data:

HD 107146 – More than Power-Law Fitting

# HD 107146 – More than Power-Law Fitting

$d = 28.5$  pc

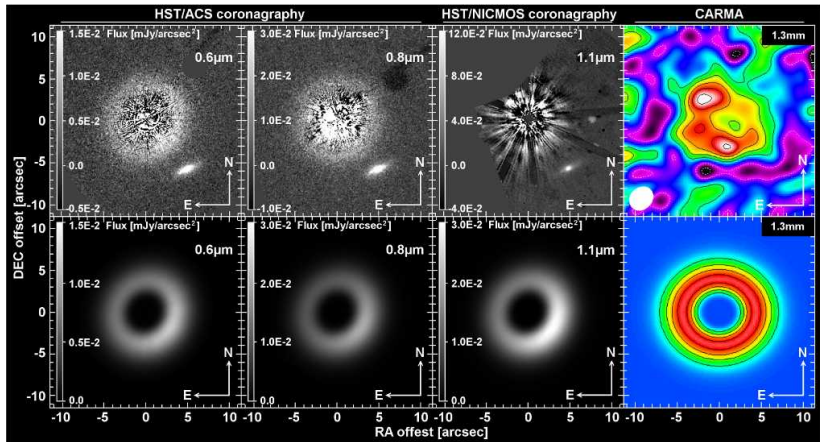
$i = 25^\circ$  (from face-on)

Spectral Type: G2V

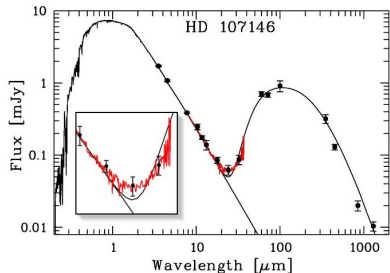
Age: 100 Myr

$L = 1.1 L_\odot$

$T_{\text{eff}} = 5850$  K

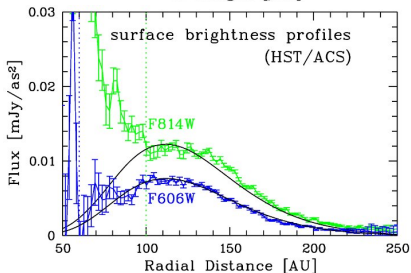


# HD 107146 – More than Power-Law Fitting



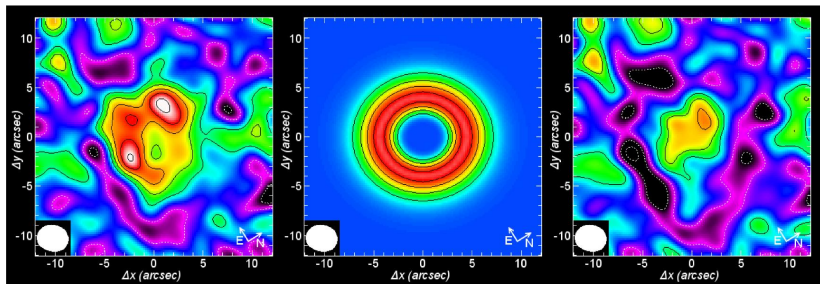
## The Debris Disk

|                   |                                |
|-------------------|--------------------------------|
| $R_{\text{peak}}$ | 131 AU                         |
| $a_{\text{min}}$  | $2.5 \mu\text{m}$              |
| $\gamma$          | -3.6                           |
| $M_{\text{dust}}$ | $6.5 \times 10^{-7} M_{\odot}$ |



⇒ Evidence for an additional inner, warm dust component from unsatisfactory fit on the Spitzer spectrum!

# HD 107146 – More than Power-Law Fitting



CARMA 1.3 mm map:

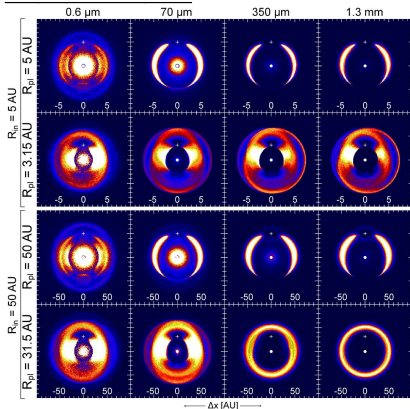
- Disk slightly too extended, but over all structure consistent
- Two blobs not reproduced by observations simulated from our model

⇒ Real structure?

Exploring what is possible:  
Planet-Disk Interaction in Debris Disks

# Planet-Disk Interaction in Debris Disks

## General models



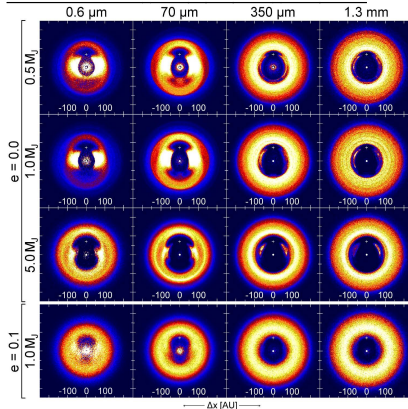
### Disk (initial)

$R_{\text{in}}$ : see graphic  
 $R_{\text{out}} = 1.1 R_{\text{in}}$   
 $n(R) \propto R^{-1.0}$

### Planet

$M_{\text{pl}} = 1.0 M_{\text{J}}$   
 $e = 0.0$   
 $R_{\text{pl}}$ : see graphic

## HD 107146 motivated models



### Disk (initial)

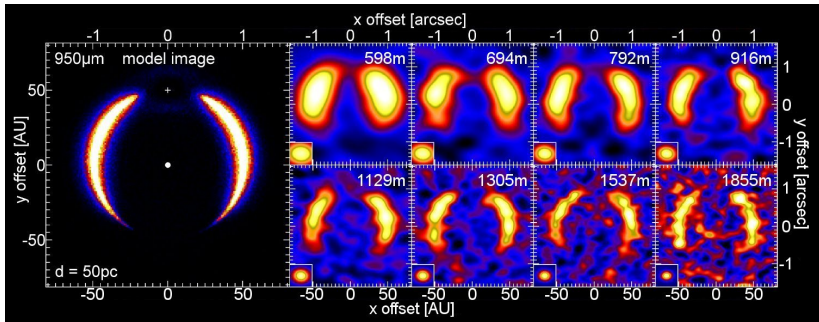
$R_{\text{in}} = 70 \text{ AU}$   
 $R_{\text{out}} = 250 \text{ AU}$   
 $n(R) \propto R^{-1.5}$

### Planet

$M_{\text{pl}}$ : see graphic  
 $e$ : see graphic  
 $R_{\text{pl}} = 70 \text{ AU}$

# Observational Perspectives for ALMA

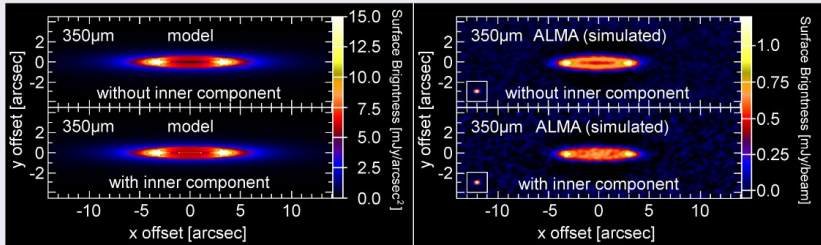
# Observational Perspectives: ALMA



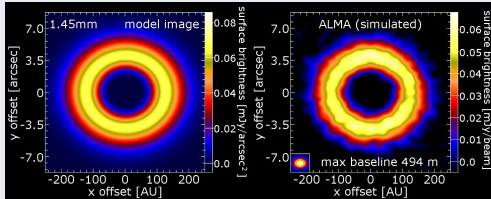
- High spatial resolution  $\iff$  high sensitivity to surface brightness
- Small baselines sufficient to resolve prominent structures  $\implies$  Early Science?



# ALMA: Science Cases



q<sup>1</sup> Eri: Resolve and confirm the inner disk  $\implies$  Planets?



HD 107146: High resolution & sensitivity images to confirm, resolve, and model structures  $\implies$  Planets?

## q<sup>1</sup> Eri

- A heavy Kuiper Belt analog revealed
- Evidence for an additional, inner Asteroid Belt analog

## HD 107146

- A broad disk revealed, no simple power-law radial density distribution
- Evidence for an additional, inner dust component
- CARMA structures can not be ruled out to be real structures

## Planet-disk interaction

- Produces prominent structures that allow constraints on the planets
- Structures more prominent in scattered light than in thermal reemission

## ALMA observations on debris disks

- ALMA is capable to detect prominent structures in bright debris disks
- Compact array configurations to be preferred
- HD 107146, q<sup>1</sup> Eri good first candidates

More about Herschel/DUNES: Talks by Torsten Löhne, Carlos Eiroa

Thank you very much!