Thermal Reemission from Debris Disks at High Angular Resolution

– From Herschel to ALMA and SPICA –

Steve Ertel (IPAG UJF Grenoble)

Representing the
Herschel/DUNES team
(PI: C. Eiroa)

and the debris disk groups at

IPAG UJF Grenoble
(Head: J.-C. Augereau)

and **ITAP CAU Kiel**
(Head: S. Wolf)

Overview

- **Herschel/DUNES**
  - Strategy
  - Statistics, Highlights
- **SPICA/SAFARI: Possible science cases**
  - The DUNES strategy with SPICA/SAFARI
  - Detailed composition for bright disks
  - Even spatially resolved for nearby/extended disks
- **Planet-disk interaction in debris disks**
  - Structures
  - Observations

Prologue – What are debris disks?

- **Optically thin** dust disks around **old stars** (main sequence), nearly **no gas**
- Dust **not primordial** (time scales), produced through collisions of larger objects
- Usually extents up to several 100 AU (radius), **inner holes** of several 10 AU

Prologue – Why do we care?

- Colliding objects: planetesimals (**planet formation**)
- Dynamics of dust influenced through **interaction with planets**
- Dust: large surface $\Rightarrow$ **observable**
- Analogy to **Solar System**

Prologue – Debris disk key projects on Herschel

- **GTKP** “Stellar Disk Evolution” (PI: G. Olofsson)
  Few known, resolved debris disks & younger disks, 61 h
- **DUNES** OTKP (PI: C. Eiroa)
  Sensitivity limited survey, 140 h
- **DEBRIS** OTKP (PI: B. Matthews)
  Flux limited survey, 140 h
- **GASPS** OTKP (PI: B. Dent)
  Gas in young systems, few young debris disks, 400 h

Herschel/DUNES: Strategy

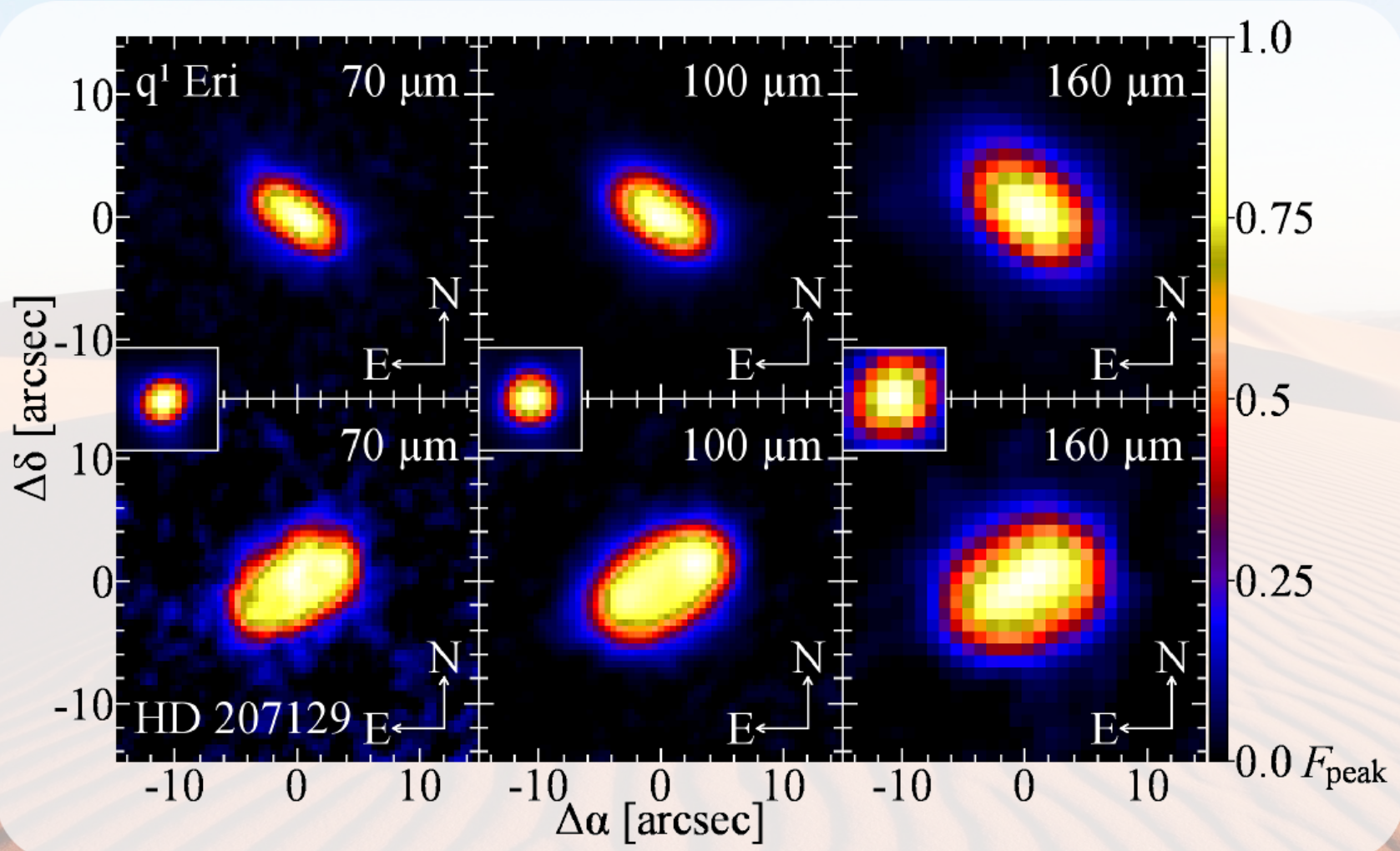
- Volume & sensitivity limited sample of solar-type stars (F, G, K)
- $d \leq 20\,\mathrm{pc}$
- Some additional sources $20\,\mathrm{pc} \leq d \leq 25\,\mathrm{pc}$ (*Spitzer* excess or planet host stars)
- Observations at $100\,\mu\mathrm{m}$ & $160\,\mu\mathrm{m}$
- Detect stellar photosphere with 3σ at $100\,\mu\mathrm{m}$
- Follow-up observations with SPIRE & at $70\,\mu\mathrm{m}$ if reasonable

Herschel/DUNES: Statistics

Sp. Type	F	G	K	Total
Sample	28	53	52	133
Non-excess	17	37	38	92
Excess (New)	9 (2)	14 (6)	11 (5)	34 (13)
	32%	26%	21%	26%
“Peculiar”	2	2	4	8
Resolved	4 (3)	8 (4)	4 (2)	12 (9)
Excess + Planet	2 (2)	7 (1)	2 (1)	11 (4)

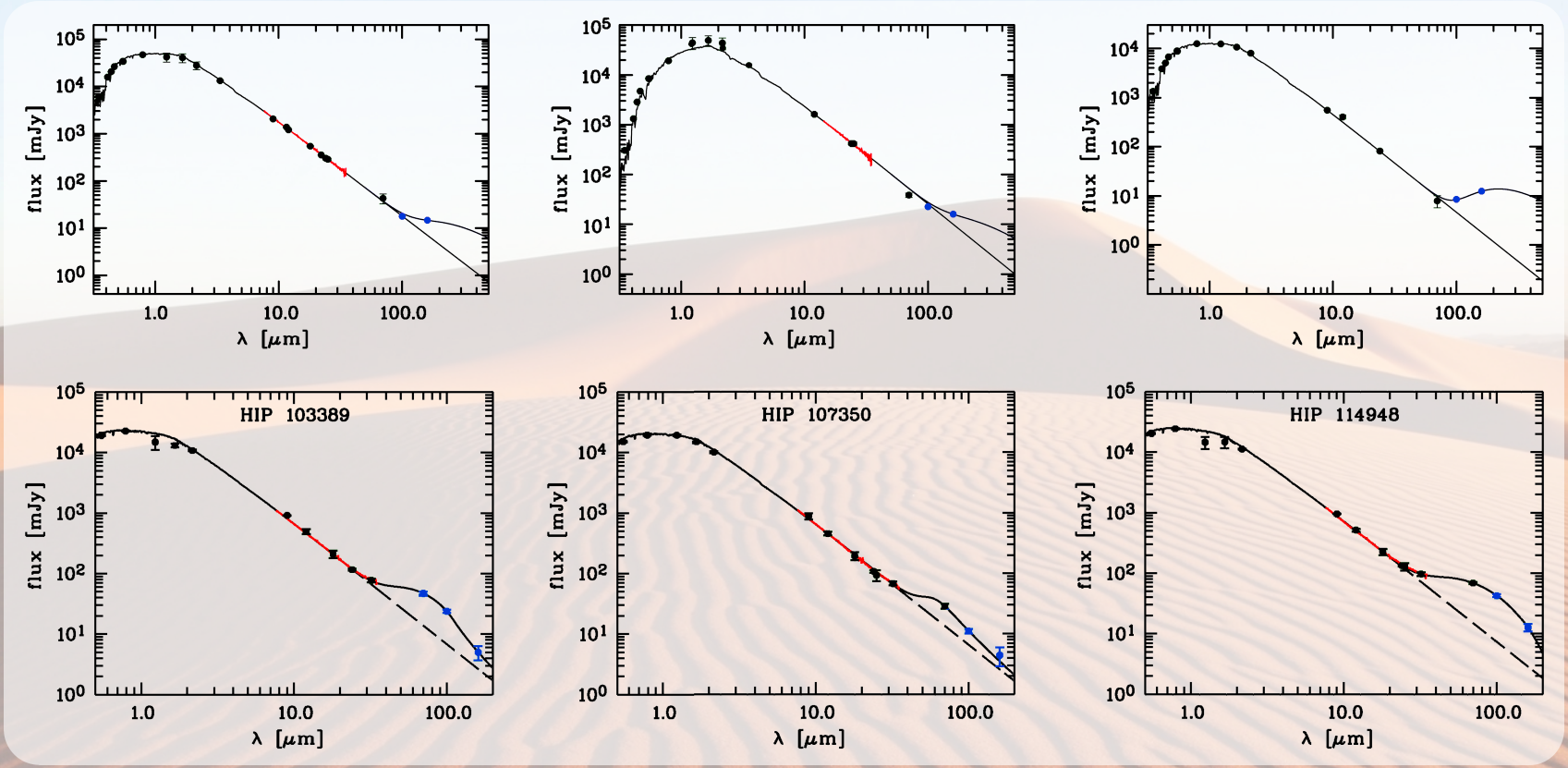
Eiroa et al. (in prep.)

Herschel/DUNES: Spatially resolved disks



HD 207129: Marshall et al. (2011), Löhne et al. (2012)
q^1 Eri: Liseau et al. (2010), Augereau et al. (in prep.)

Herschel/DUNES: Peculiar disks



- **Top:** Cold disks – $T_{bb} \leq 22\,K$, but $R_{disk} \leq 92$ / 56 / 130 AU (Eiroa et al., 2011; Marshall et al., submitted)
- **Bottom:** Steep SEDs – Significant under abundance of large grains, $R_{disk} \sim 30\,AU$, $a \sim 10\,\mu m$ (Ertel et al., submitted)

SPICA/SAFARI: Possible science cases

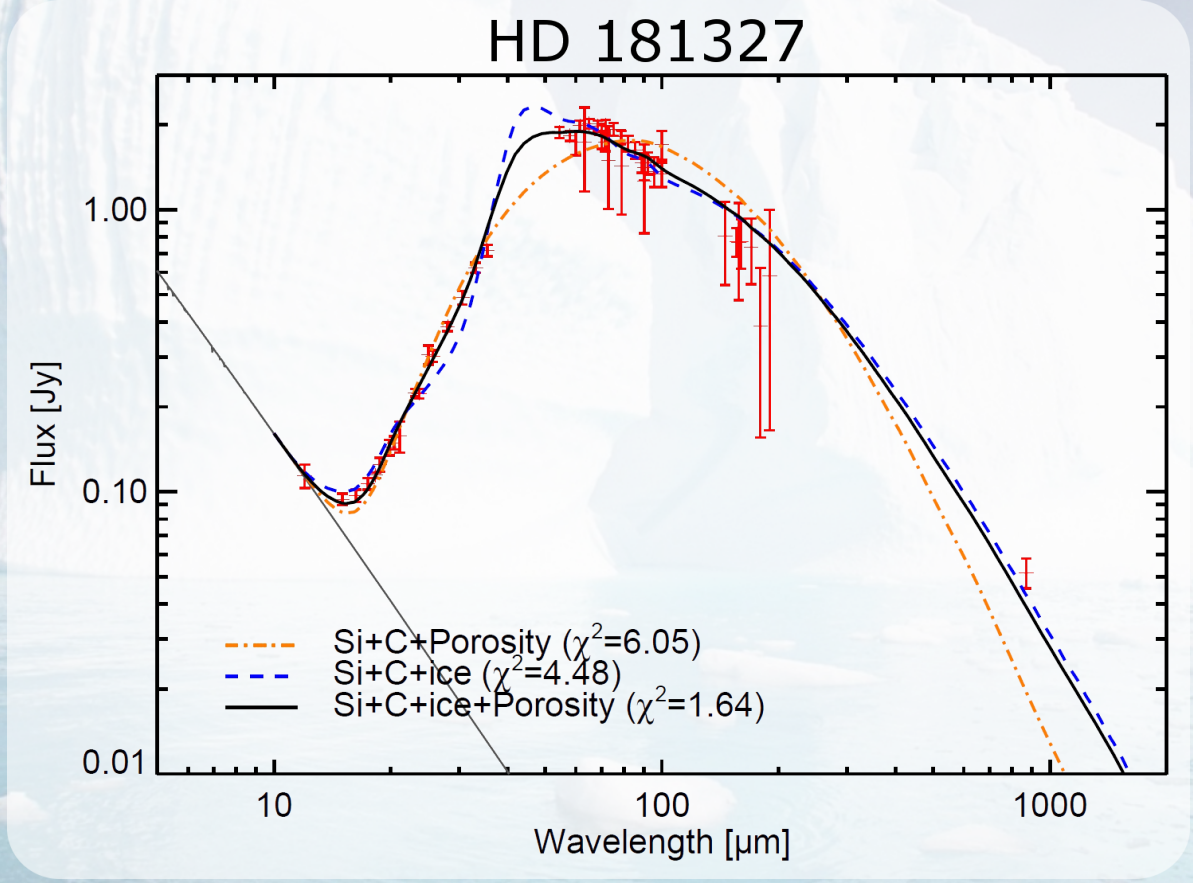
The DUNES strategy with SPICA/SAFARI

Higher sensitivity and broad spectroscopic capabilities

- Factor 100 in sensitivity $\Rightarrow$ factor 10 in distance
  - **Problem:** Photometric calibration, confusion (ALMA might help!)
  - Same strategy, larger sample ($d \leq 100\,\mathrm{pc}$: 133 $\Rightarrow \sim$ 16000 stars, $\sim$ 4300 disks)
- Low resolution spectroscopy: Really determine SED shape in the far IR (steep SEDs, cold disks)
  - Total flux less relevant, as long as shape of the spectrum is well defined
  - Same strategy, $d \leq 20\,\mathrm{pc}$, but spectroscopy

SPICA/SAFARI: Possible science cases

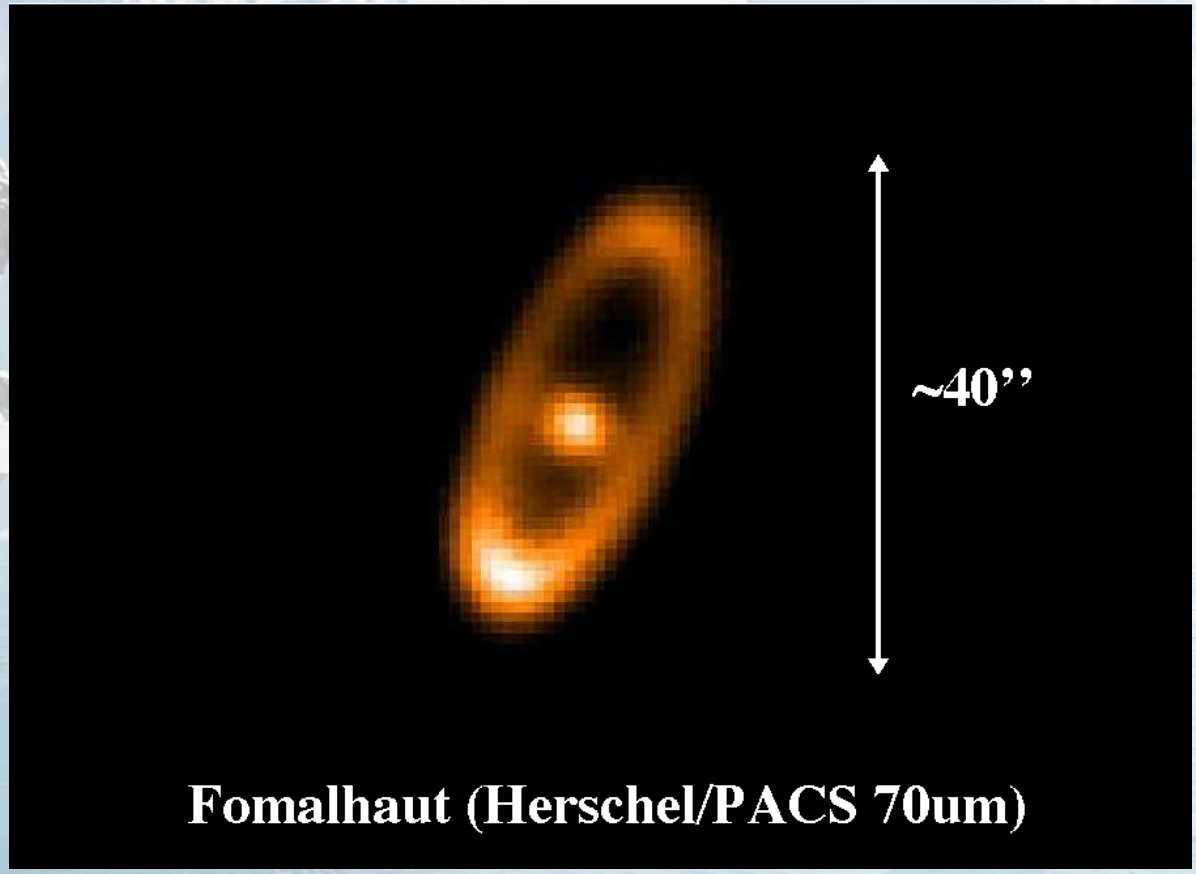
Detailed composition of the dust



GASPS, Lebreton et al. (2012)

SPICA/SAFARI: Possible science cases

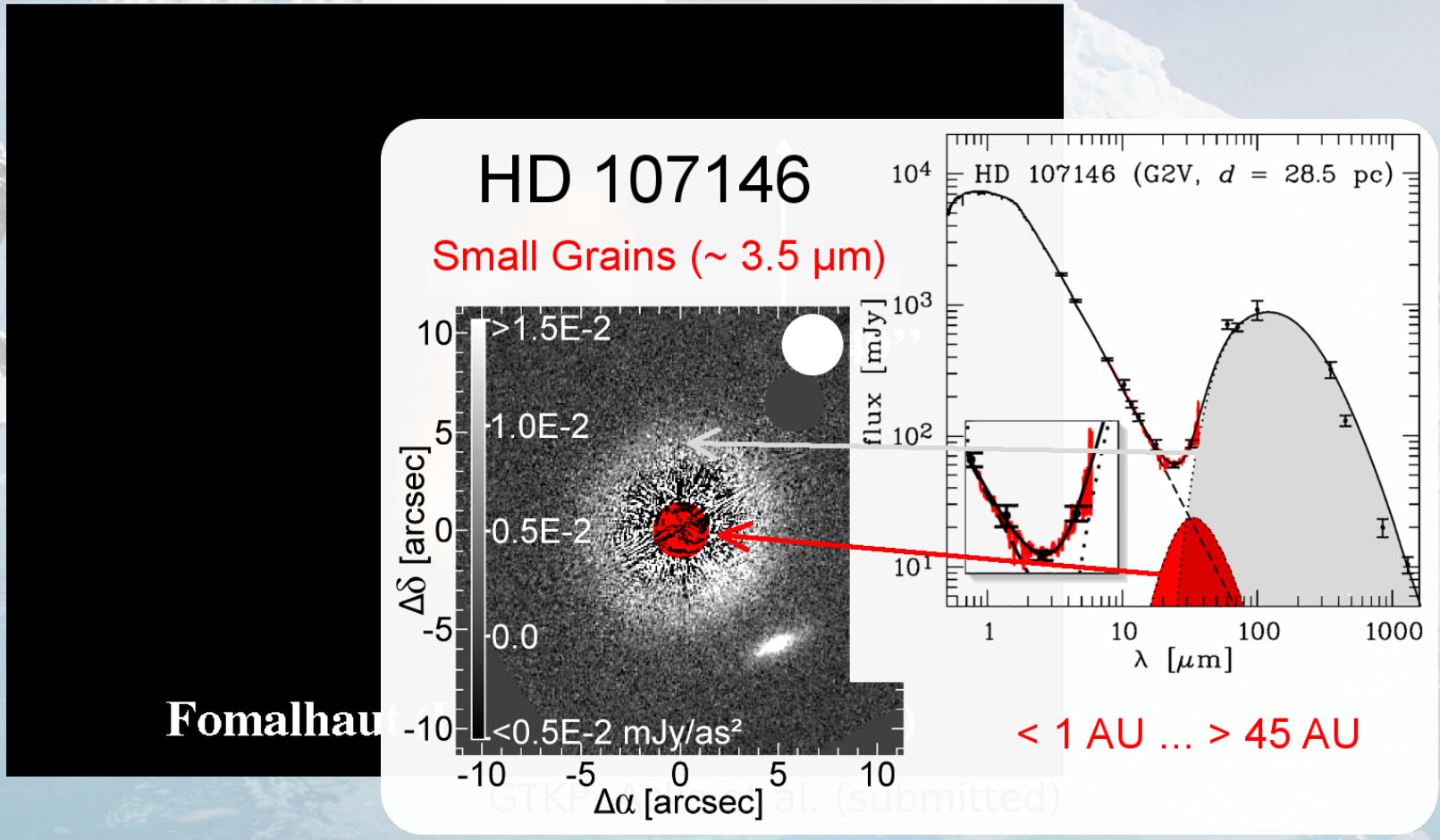
Even spatially resolved for nearby/extended disks



GTKP, Acke et al. (submitted)

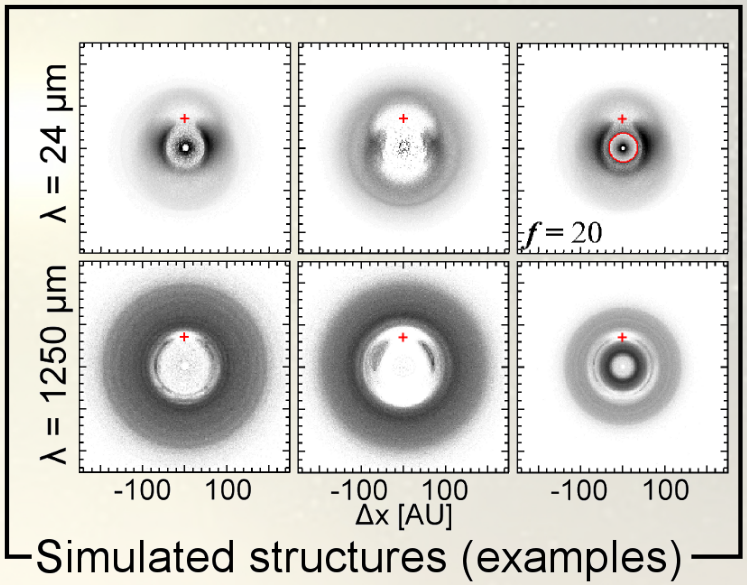
SPICA/SAFARI: Possible science cases

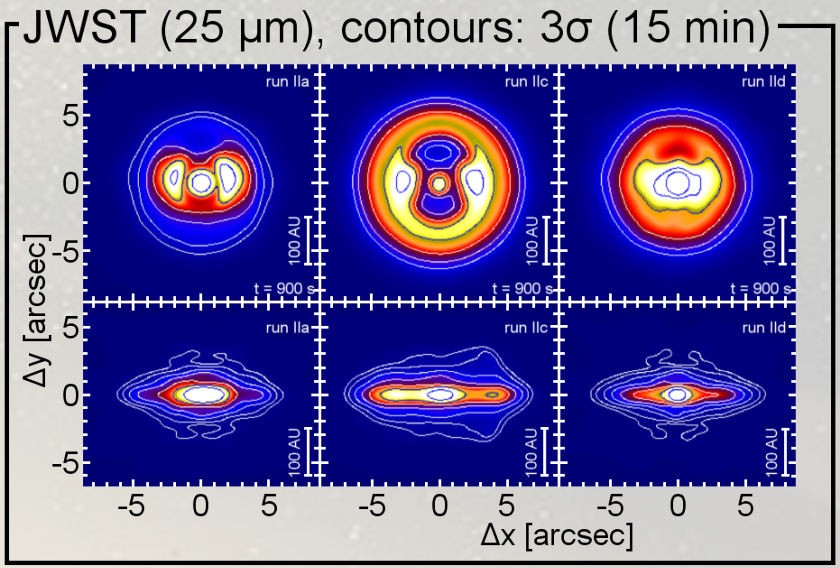
Even spatially resolved for nearby/extended disks

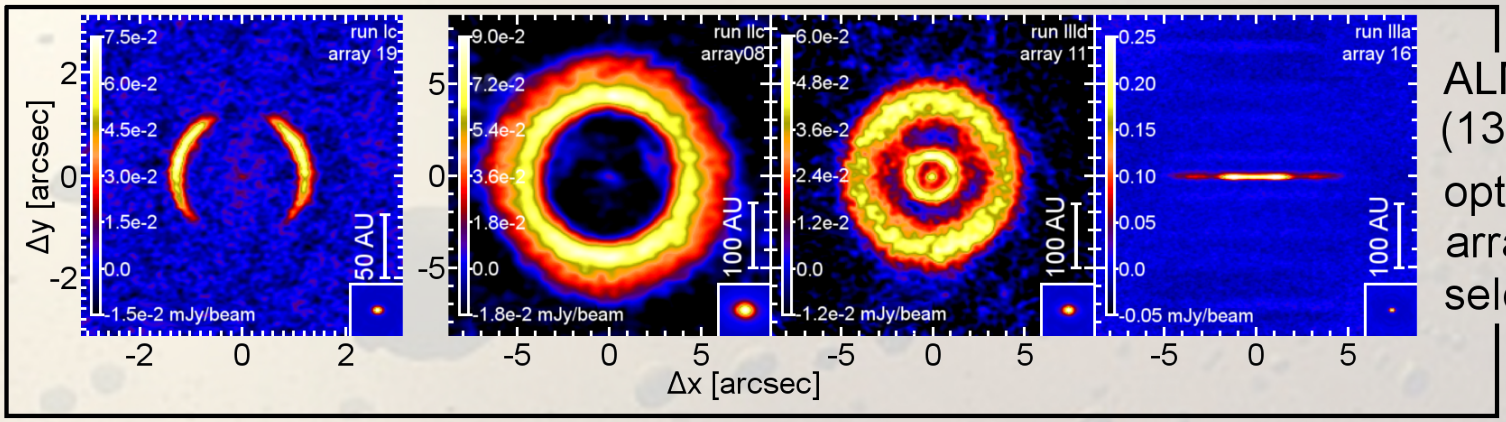


Ertel et al. (2011)

Planet-disk interaction in debris disks







ALMA (1300 μm)
optimum array selected

Ertel et al. (in prep.)

Conclusions

In the context of debris disks, due to high sensitivity, broad spectroscopic capabilities, and sufficient spatial resolution ...

... SPICA/SAFARI is great for:

- Large, unbiased surveys
- Detailed studies of grain composition/shape through well determined far-IR SEDs
- Spatially resolved studies of grain composition/shape for nearby/extended disks
- **At shorter wavelength, mostly NOT SAFARI:** Spatially resolved studies of structures due to planet-disk interaction