

Debris disc studies with Herschel/DUNES: A search for Edgeworth-Kuiper belt analogues



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and the DUNES team



DUNES People

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Outline

- DUNES description
 - Objectives
 - Advantages of Herschel
 - Sample and observing strategy
 - Illustrate some “difficulties”
- Results
- DUNES discs versus some stellar properties
- Discs characteristics
- A few objects
- Conclusions



DUNES: Herschel OTKP

Dust around Nearby Stars

-Main goal: To detect/characterize with Herschel faint exo-solar analogues to the Edgeworth-Kuiper belt (EKB)

-Other specific objectives:

- i. dependence of planetesimal formation on stellar mass
- ii. collisional and dynamical evolution of exo-EKBs
- iii. presence of exo-EKBs versus presence of planets
- iv. dust properties and size distribution in exo-EKBs.

✓ Formation and evolution of planetary systems

➤ Data analysis and interpretation by using a variety of modelling tools/codes including:

- radiative
- collisional
- dynamical

Grenoble, Jena, Kiel:

SAND ,GRATER
ACE, SEDUCE , SUBITO



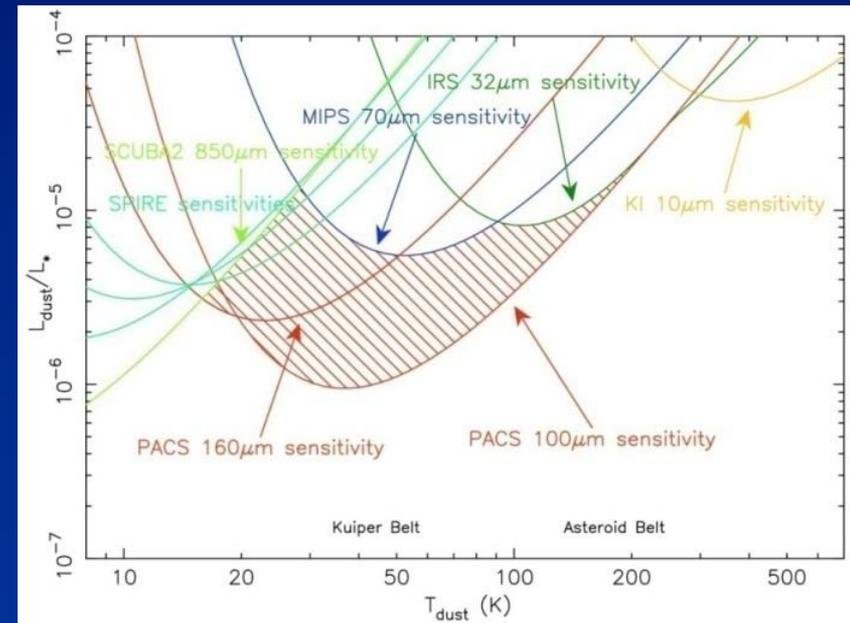
Herschel advantages wrt previous facilities

- ✓ Large mirror: larger resolution, less confusion, fainter discs,
- ✓ Spectral range: sensitive to $\lambda > 70 \mu\text{m}$

- PACS 100 μm : best for faint discs in the range $\sim 20\text{-}100 \text{ K}$
 :: Optimal: 30 - 40 K

- $L_{\text{dust}}/L_{\text{star}} \sim \text{few times } 10^{-7}$

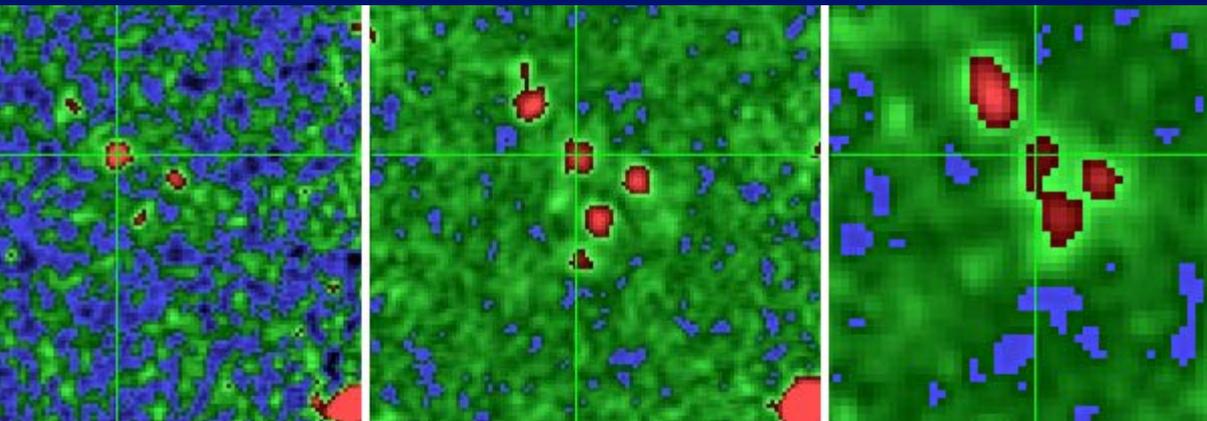
EKB: $L_{\text{dust}}/L_{\odot} \sim 10^{-7}\text{-}10^{-6}$



Detection limits for a G5V star at 20 pc versus T_{dust}



Herschel wrt Spitzer resolution

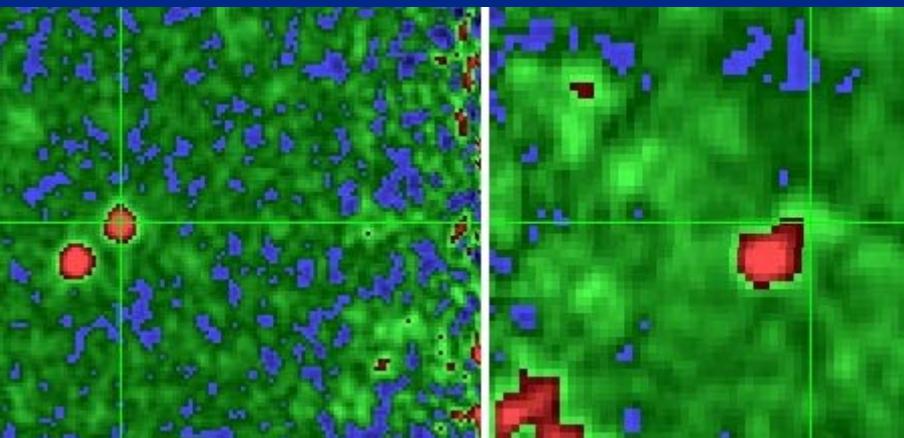


MIPS70 = 37.1 ± 6.1 mJy (star = 9.0)

PACS70 = 12.7 ± 0.9 mJy (star = 9.0)

PACS100 = 12.0 ± 0.6 mJy (star = 4.4)

PACS160 = 12.3 ± 1.1 mJy (star = 1.7)



MIPS70 = 41.2 ± 3.1 mJy (star = 18.4)

PACS100 = 15.1 ± 0.9 mJy (star = 7.7)

PACS160 = 7.7 ± 1.5 mJy (star = 3.5)

→ after deconvolution



DUNES:

Sample + observing strategy

- **Sample:** 133 FGK main sequence stars
 - $d < 20$ pc
 - stars with known planets ($d < 25$ pc)
 - Spitzer debris discs ($d < 25$ pc)
 - + 106 stars shared with OTKP DEBRIS
- PACS photometry at 100, 160 μm + some at 70 μm
- SPIRE photometry at 250, 350, 500 μm (some)
- **Strategy:** to integrate as long as needed to reach the 100 μm photospheric flux, only constrained by background confusion
 - F_* (100 μm) $\gtrsim 4$ mJy (see next slide)
 - EKB analogue at 10 pc, 100 μm : $\sim 5 - 10$ mJy
 - ✓ Sensitivity, volume limited (20 pc) sample

Table 1. Summary of spectral types in the DUNES sample and the shared sources observed by DEBRIS.

Sample	F stars	G stars	K stars	Total
Solar-type stars observed by DUNES (the DUNES sample)	27	52	54	133
20 pc DUNES subsample	20	50	54	124
Shared solar-type stars observed by Debris	51	24	8	83
Shared 20 pc subsample	32	16	8	56



Photospheric predictions

Large number of targets with $100 \mu\text{m}$ fluxes at the $5\sigma/1\text{hour}$ sensitivity level

:: We do have detected all targets

→ We are happy

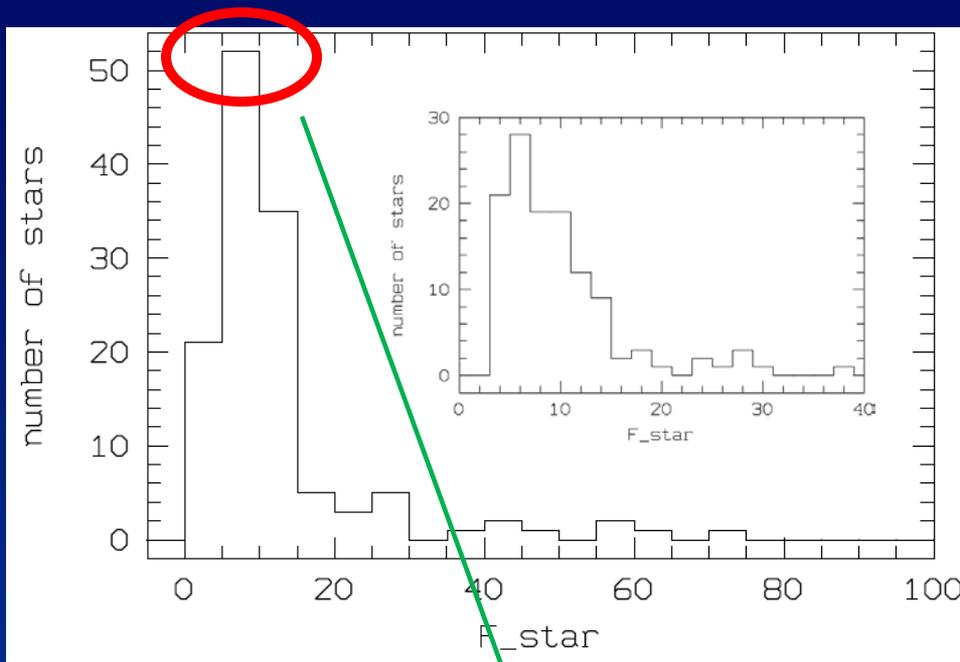


Table 3.3. PACS photometer sensitivity

central wavelength	70 μm	100 μm	160 μm
scan mapping 1 σ -1second (mJy)	30.6	36.0	68.5
mini-scan mapping 5 σ -1hour (mJy)	4.7	5.5	10.5



A difficulty: Confusion

Sky at 70/100/160 μm very complex and different

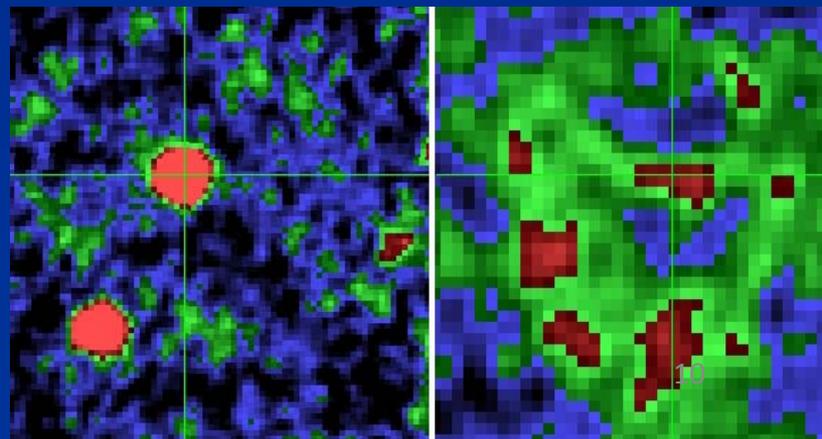
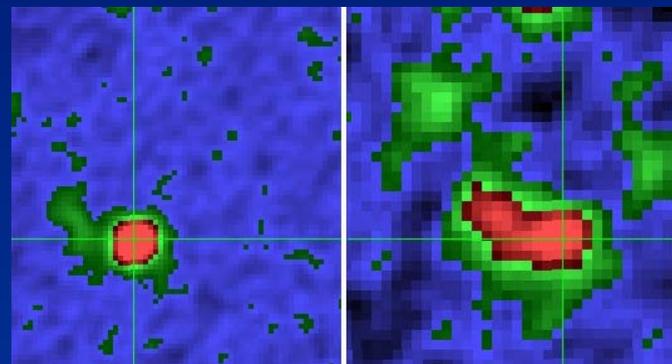
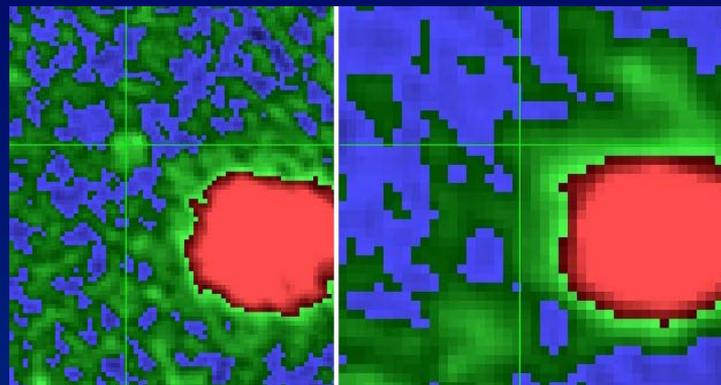
➤ **Coincidental alignment**

➤ **Confusion produced by:**

- extragalactic objects
- field stars
- extended ism structures, e.g. cirrus

✓ **Potential problems for:**

- flux estimates
- identification of target stars
- + "associated extended emission"





Identification criteria

➤ Positional coincidence (optical versus PACS100)

- **Herschel pointing accuracy: 2.4" (1σ)**

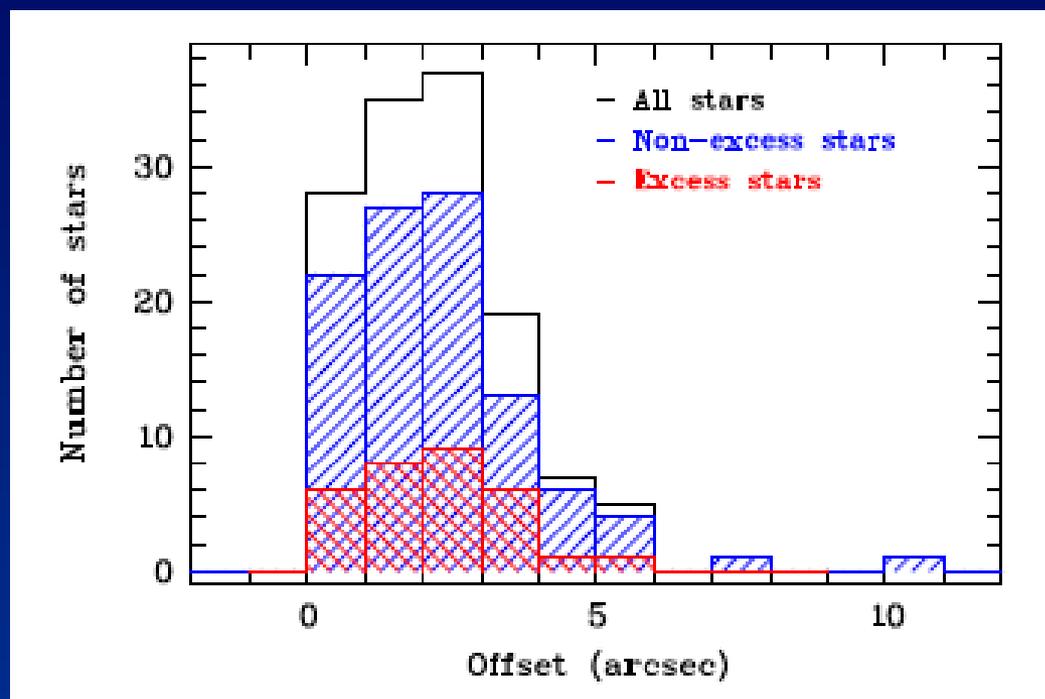
- ✓ **some sources with larger offset**

:: In these cases:

- 100/160 μm check
- Predicted flux easily achieved with the integration time

➤ Photospheric agreement:

(for non-excess sources at one PACS band -generally 100 μm)



By the way, errors very tricky



Results: Summary

(only stars observed by DUNES)

	F-type	G-type	K-type	Total
Observed	27	52	54	133
Non-excess	18	39	44	101
Excess (New)	9 (2)	13 (4)	10 (6)	32 (12)
“Doubtful objects”	3	2	3	8
“Structured field”		2	2	4
Excess Sources:				
Resolved (New)	6 (5)	6 (4)	4 (4)	16 (13)
Planets(Excess, New)	5(2)	10(2, 1)	5(2, 1)	20 (6, 2)

!!! Numbers in the table could change a bit



Results: Summary

- **Excess sources: > 24.1 % (but less than 30%)**
 - ✓ New: 38% (out of 32 the excess sources)
 - but some previous (Spitzer) discs were "false"
 - ✓ New sources increase from F-type to K-type
 - ✓ Most of the K-type excess sources are new
 - ✓ Some ranges of the dust properties:
 - T: $\lesssim 30$ - ~ 60 K**
 - L_{dust}/L_{star}: $\sim 10^{-4}$ - $\sim 5 \times 10^{-7}$**

- **"Doubtful objects":**
 - ✓ Marginal excess (at one band)
 - ✓ Offset positions different at 100/160 μm
 - ✓ Included as non-excess sources
 - but some may be excess sources (careful check to be done)**

- **Resolved sources:** 50% (from these, new 81.3%)

- **Stars with planets + discs:** 6 (2 are new)

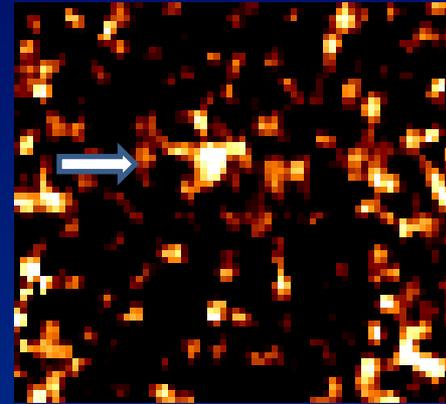
Non-excess stars

➤ **Fractional luminosity:**
 (upper limit, 1σ noise, $T_{\text{dust}} = 50\text{ K}$)

$L_{\text{dust}}/L_{\text{star}} \leq \text{few } 10^{-7} - 10^{-6}$
 preliminary mean value: $(1.0 \pm 0.7) \times 10^{-6}$

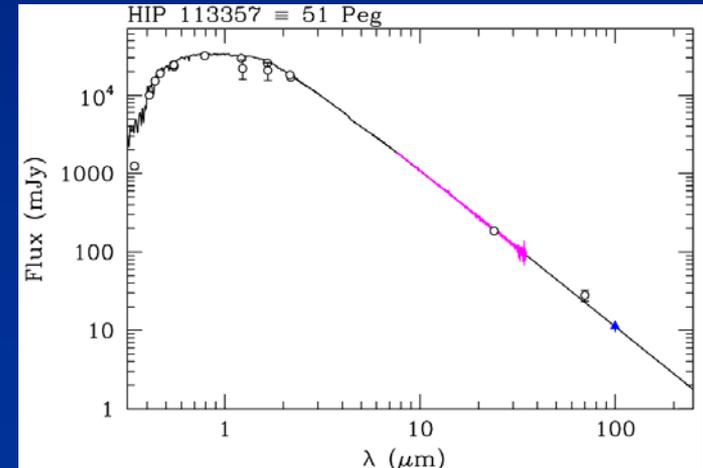
function of:

- T_{eff}
- integration time



51 Peg:
 PACS100
 Offset: 6.5''

$F_{100} = 11.3 \pm 1.7\text{ mJy}$





Stellar properties: Binaries

- ✓ Sources: SIMBAD, WDS, CCDM, Tycho, SB9, catalogue of eclipsing binaries

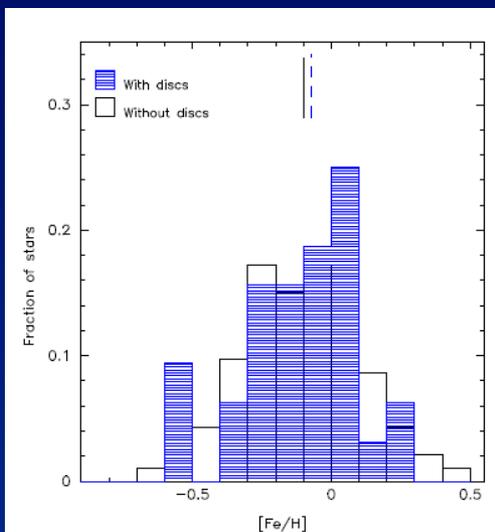
- **All stars (133):** 62 “single”, 61 binaries/multiple

- **Excess sources (32):** 12 binaries/multiples
(3 spectroscopic binaries)

- **Not all with evidences of “physical binaries”**

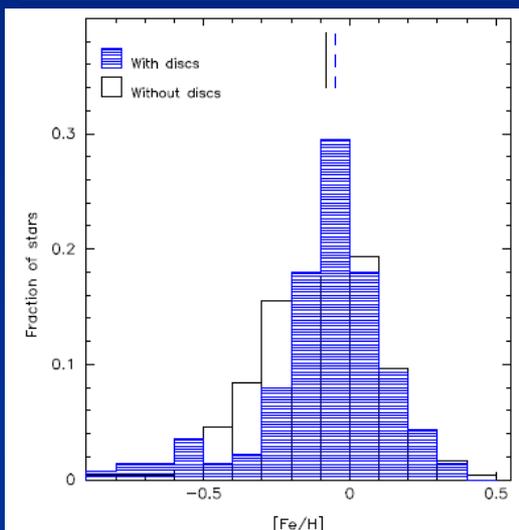
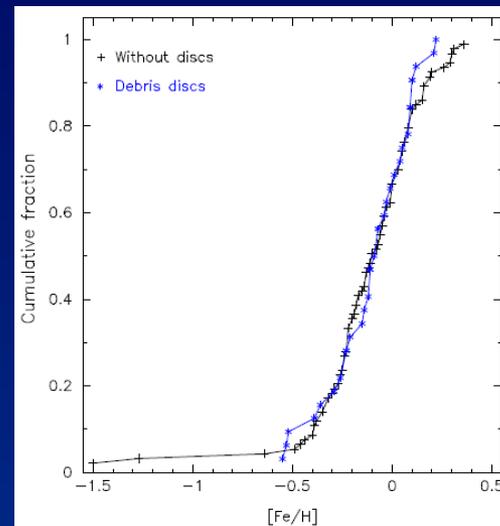


Stellar properties: Metallicity



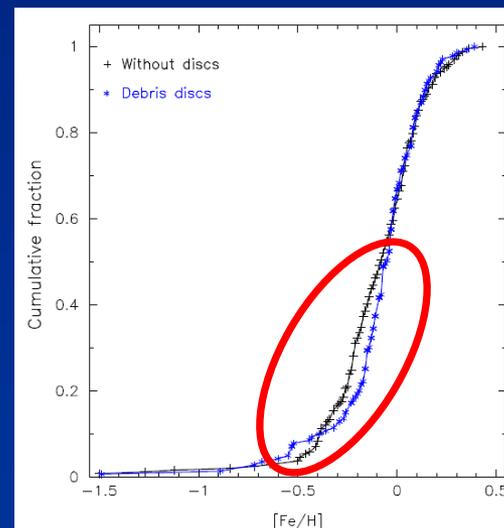
DUNES

←→



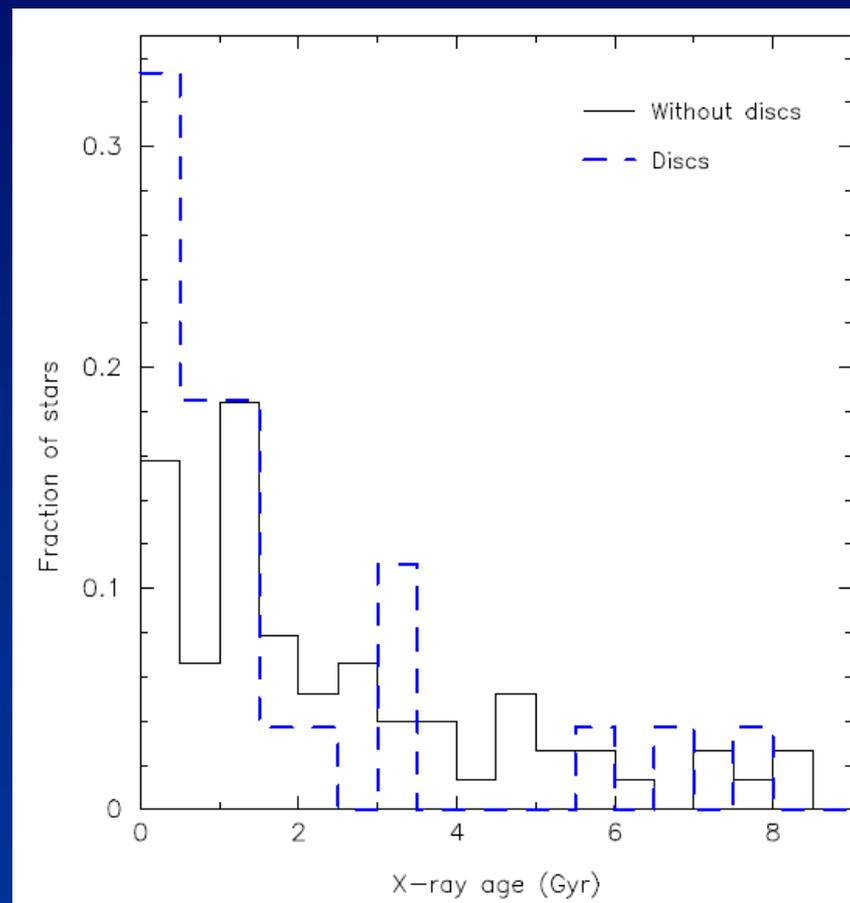
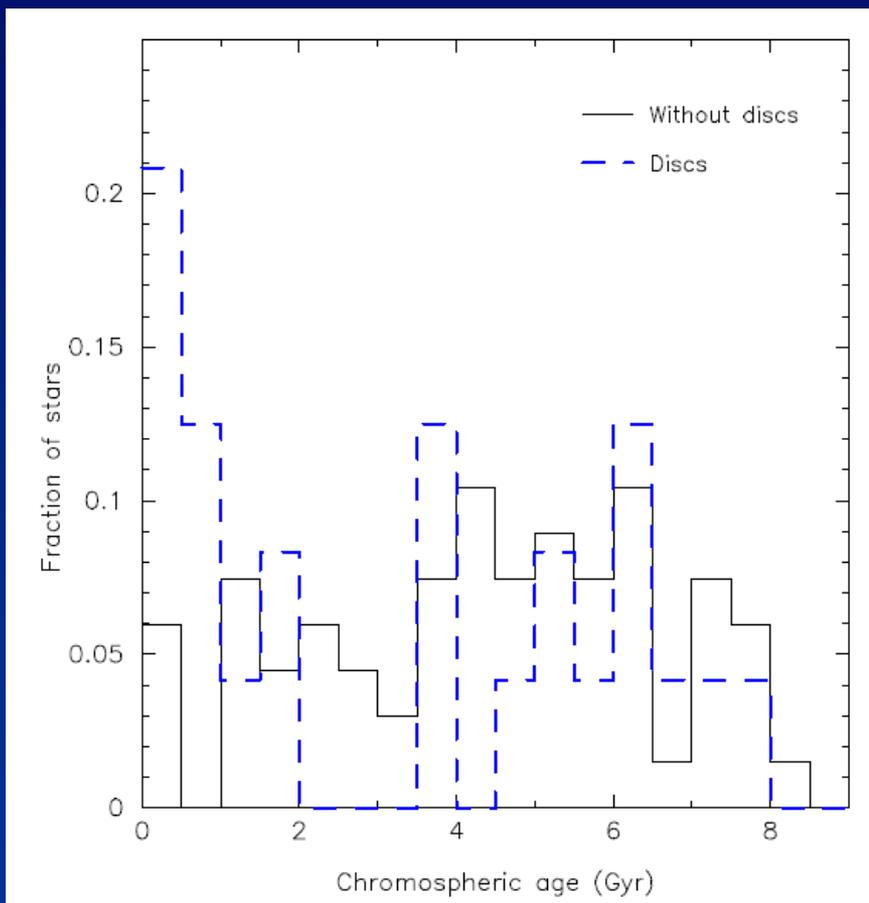
**DUNES +
Maldonado
et al. (2012)**

←→



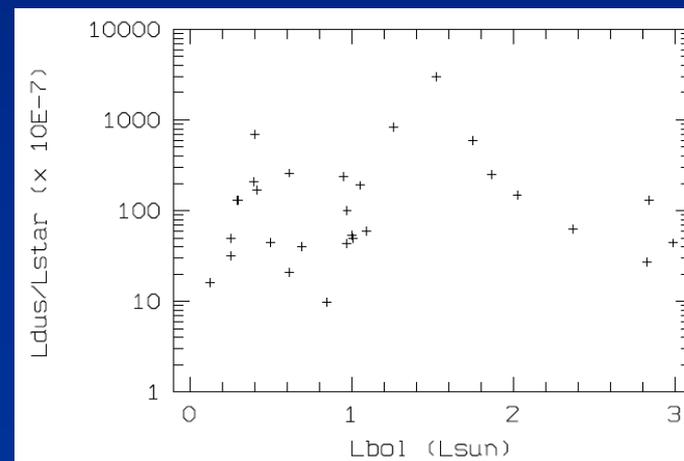
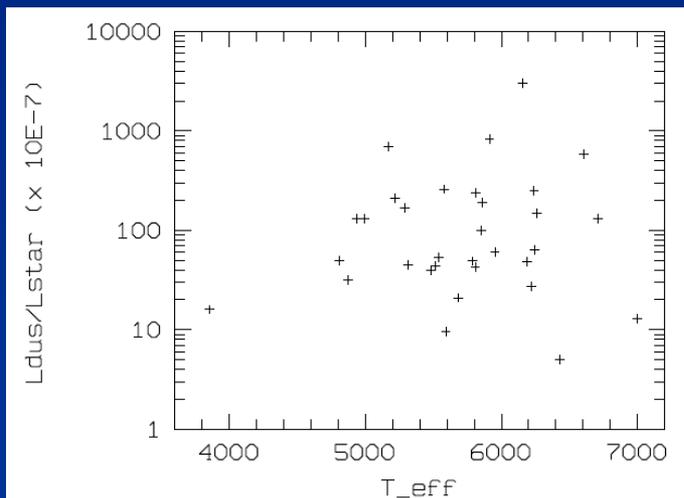
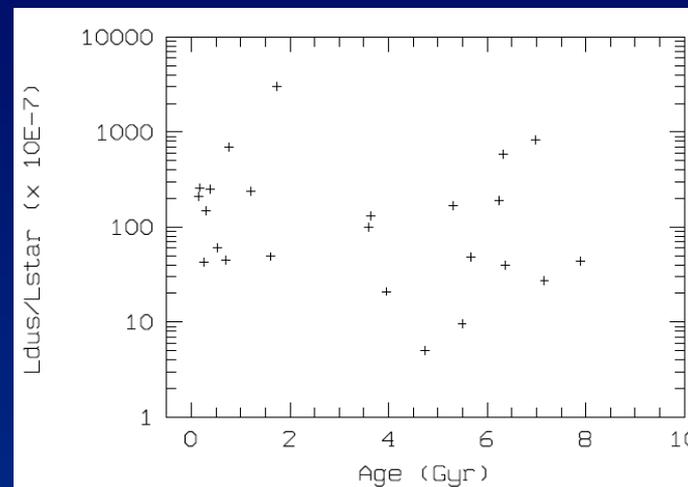
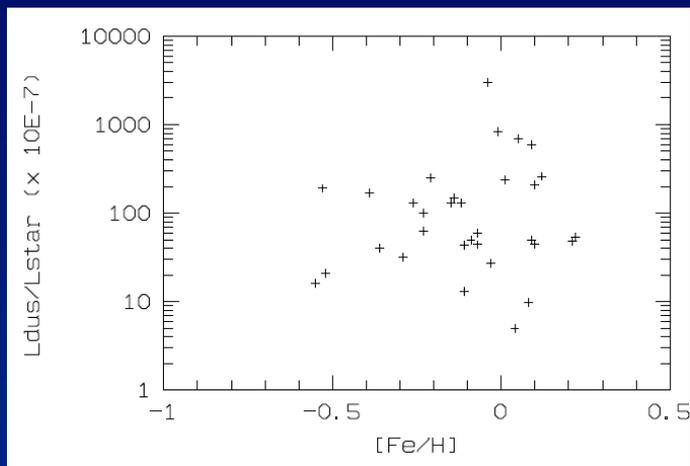


Stellar properties: ages

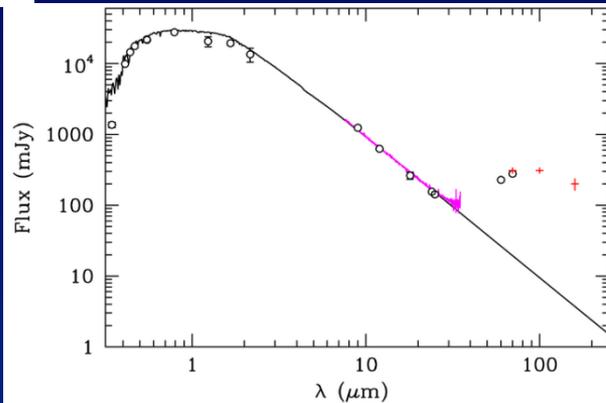




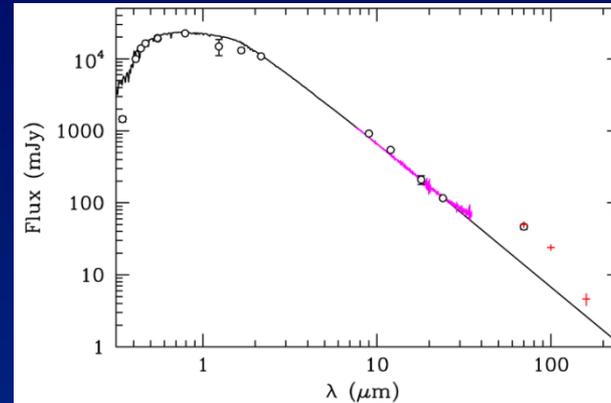
L_{dust} versus ...



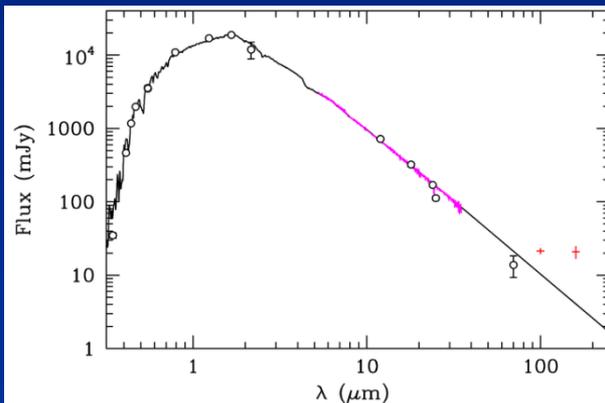
SEDs



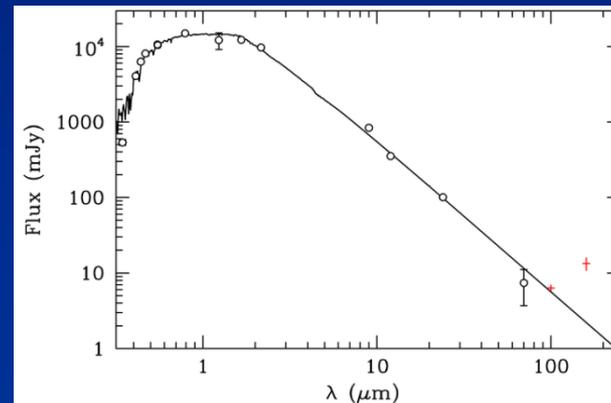
Very prominent excesses at all λ s – all well resolved



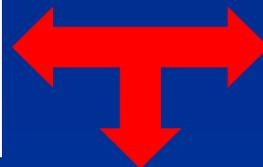
Ring-like SEDs



Small 100 μ m excess



Only 160 μ m excess

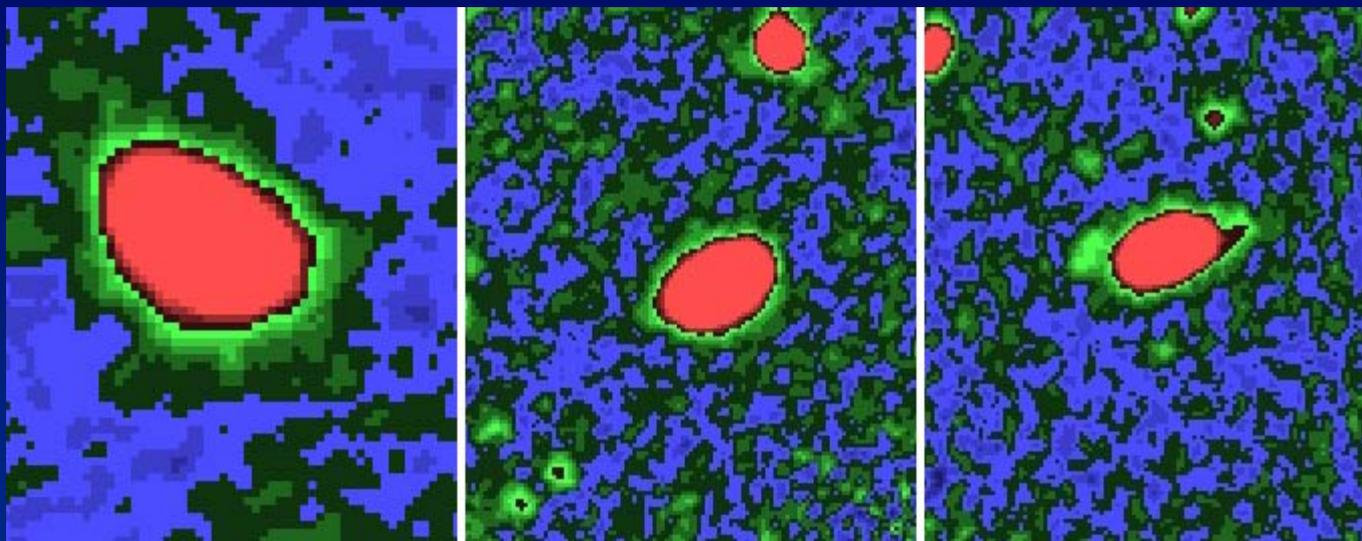


**Very cold discs: $T \lesssim 30$ K
(new class)**

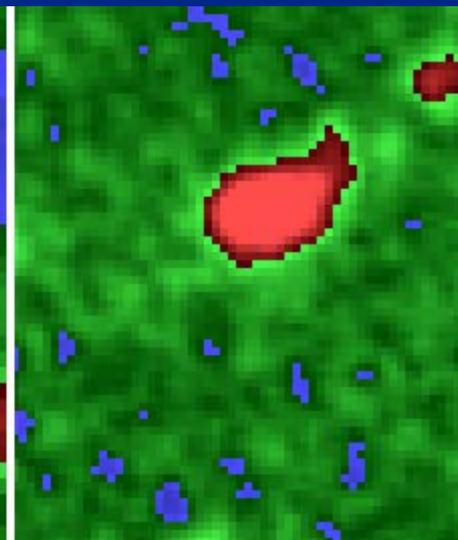
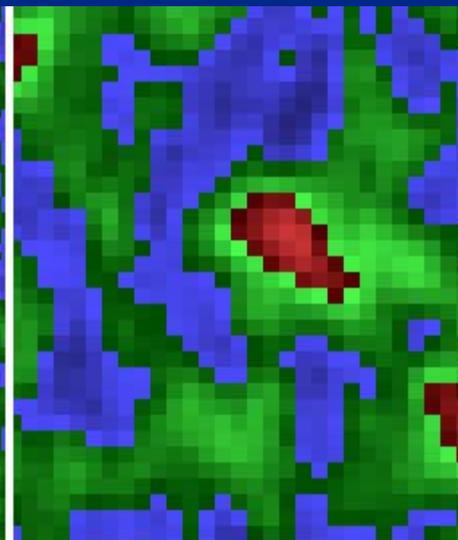
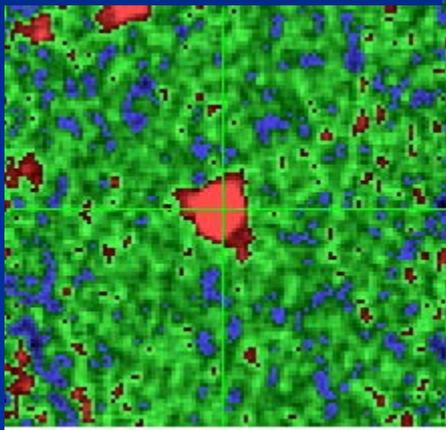


Resolved discs

Previously known discs



Some new Resolved discs





ζ^2 Reticuli (new)

Star: G1V, $d = 12.03$ pc, $0.97 L_{\odot}$,
Age ~ 3 Gyr

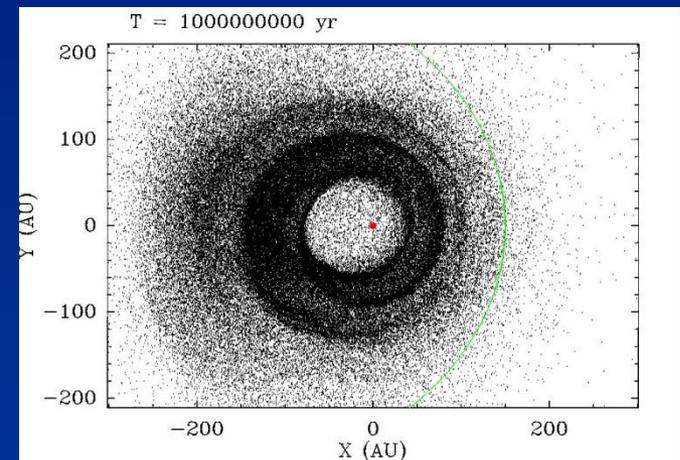
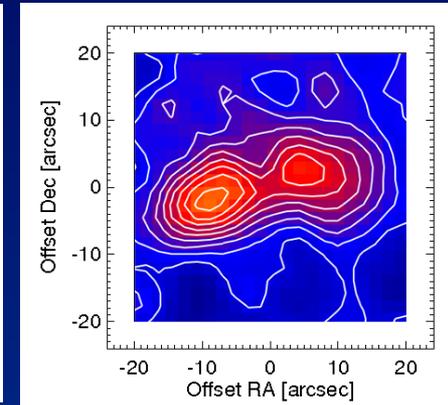
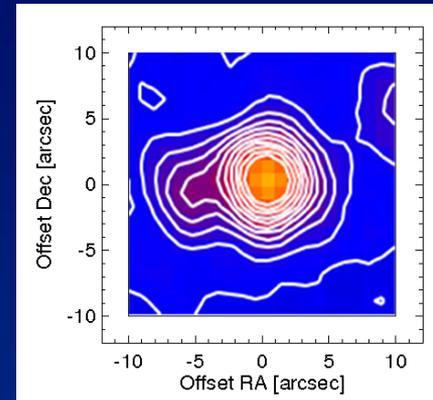
Debris disc:

- Eccentric dust ring-like structure
of ~ 100 AU semi-major axis and
 $e \sim 0.3$

- $T_{\text{dust}} \sim 40$ K, $L_{\text{dust}}/L_{\star} \approx 10^{-5}$

Eiroa et al. A&A 518, L131

✓ **Asymmetry:** signature of
an unseen planet?



Dynamical simulation of an exoplanet
around ζ^2 Reticuli (**V. Faramaz.**)



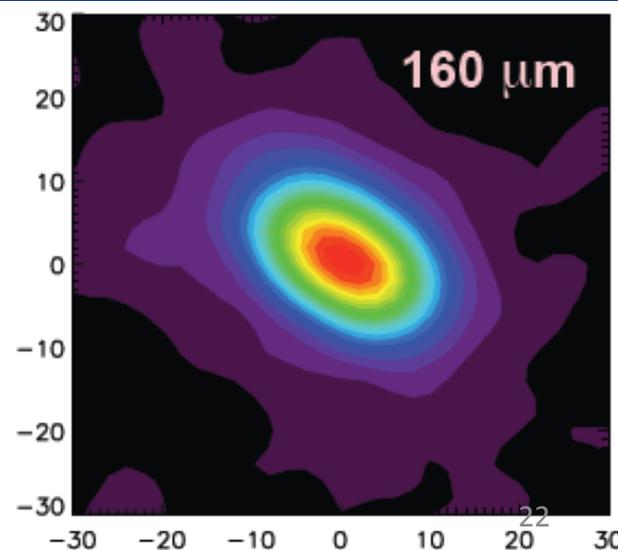
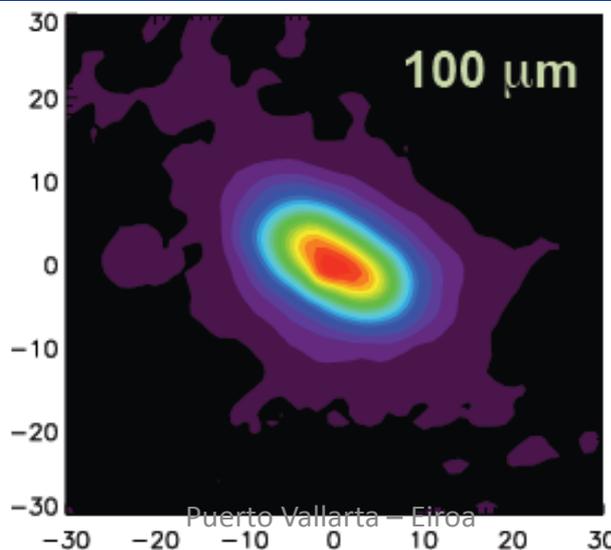
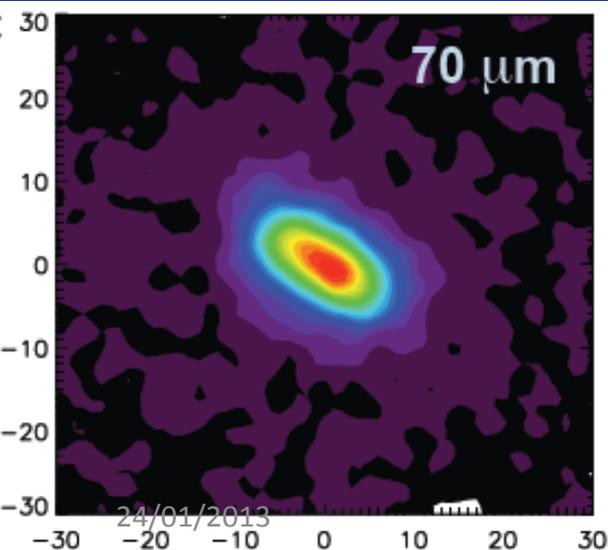
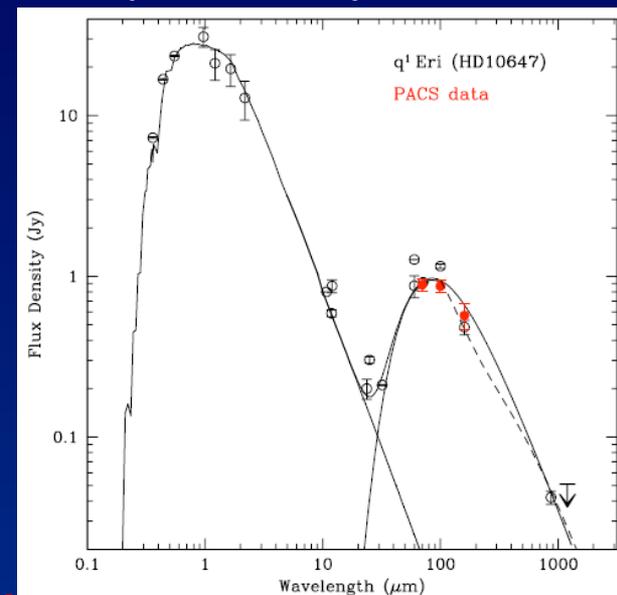
q¹ Eri: resolved disc (known)

- **Star:** F8/9V, d=17.35 pc, 1.2 L_☉, Age ~ 2 Gyr, 0.9 M_J planet at 2 AU

➤ q¹ Eri debris disc: unprecedented detail

- 40 AU wide ring at ~ 85 AU
- i ~ 63° (assuming circular shape)
- T_{dust} ~ 60 K
- L_{dust}/L_{star} ~ 10⁻⁴

- Liseau et al. A&A 518L, 132L





HD 207129 (known)

Star: G2V, $d = 16$ pc, $1.26 L_{\odot}$,
Age: 1.5 - 3.2 Gyr

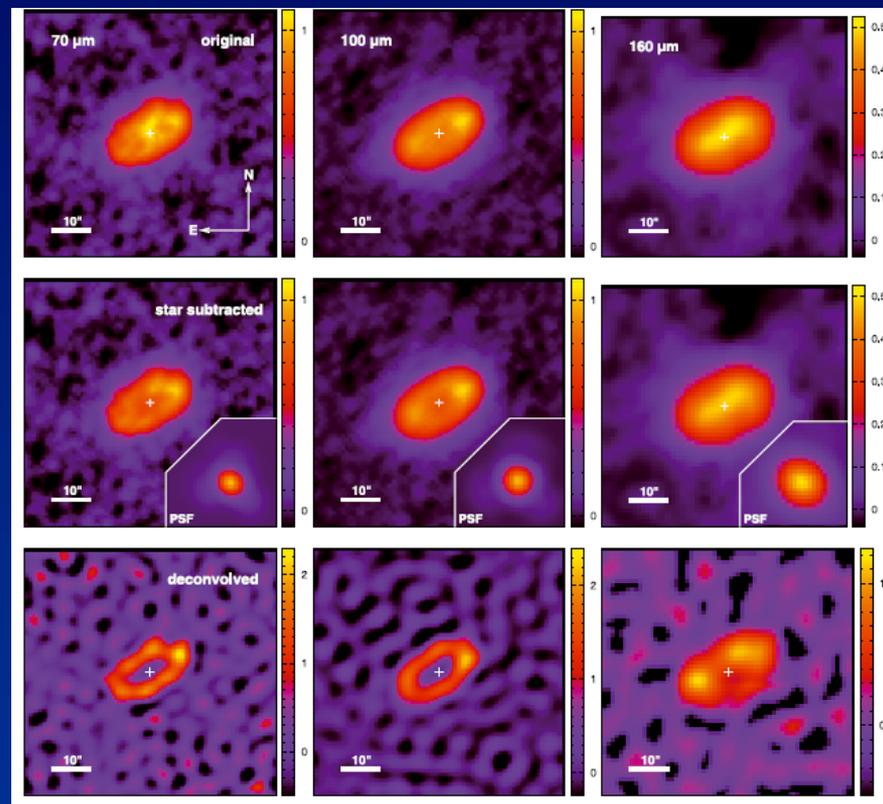
Debris disc:

Size: 144×72 AU

Position angle: 120°

Inclination: 60°

$T_{\text{dust}} \sim 50$ K, $L_{\text{dust}}/L_{*} \approx 1.5 \times 10^{-5}$



Marshall et al. A&A 529, A117 (observational)
Löhne et al. A&A 537, A110 (detailed modelling)

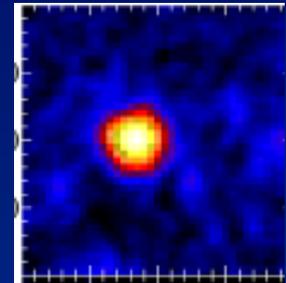


Steep (peculiar) SED sources

- Spectral index:

$$\Delta = \frac{\partial \log F_\nu}{\partial \log \nu}$$

$$\Delta_{\nu_1, \nu_2} = \frac{\log F_{\nu_2} - \log F_{\nu_1}}{\log \nu_2 - \log \nu_1}$$



For a black body: $\Delta = 2$ (Rayleigh-Jeans regime)

Steep SED sources: $\Delta > 2$
(any combination 70/100/160)

- SED inconsistent with standard equilibrium collisional cascade
- Detailed modeling and possible alternatives by Ertel et al., submitted

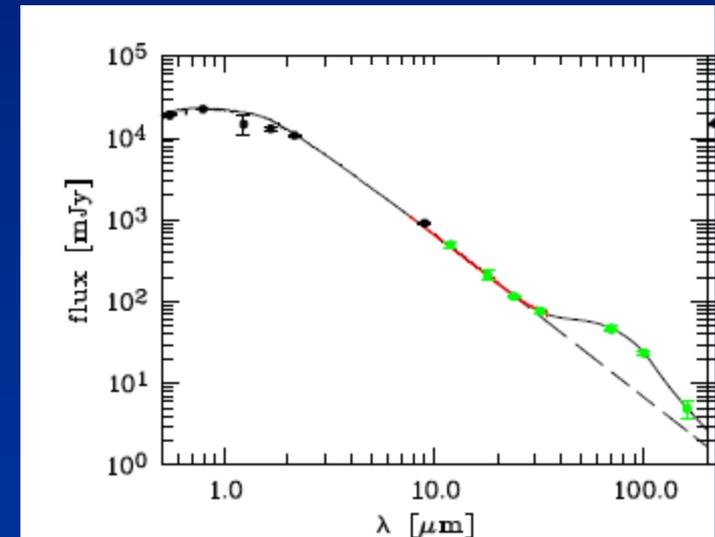
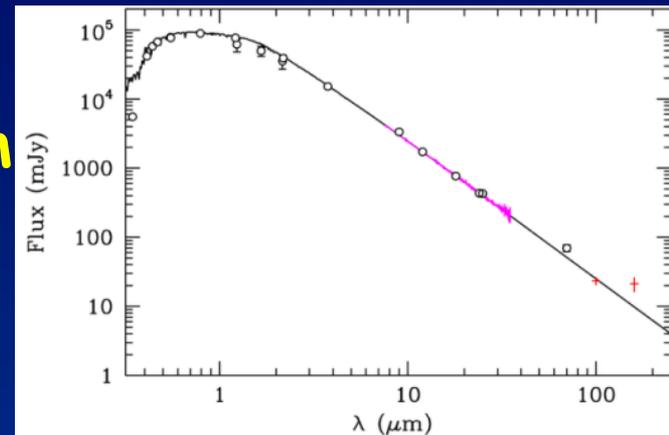


Fig. 3. Final models from the SANd approaches. The astronomical silicate (Sect. 5).



Cold discs

- Some stars with excesses at $160\ \mu\text{m}$ only, or + faint $100\ \mu\text{m}$ excess
(Eiroa et al. 2011, Marshall et al. submitted)



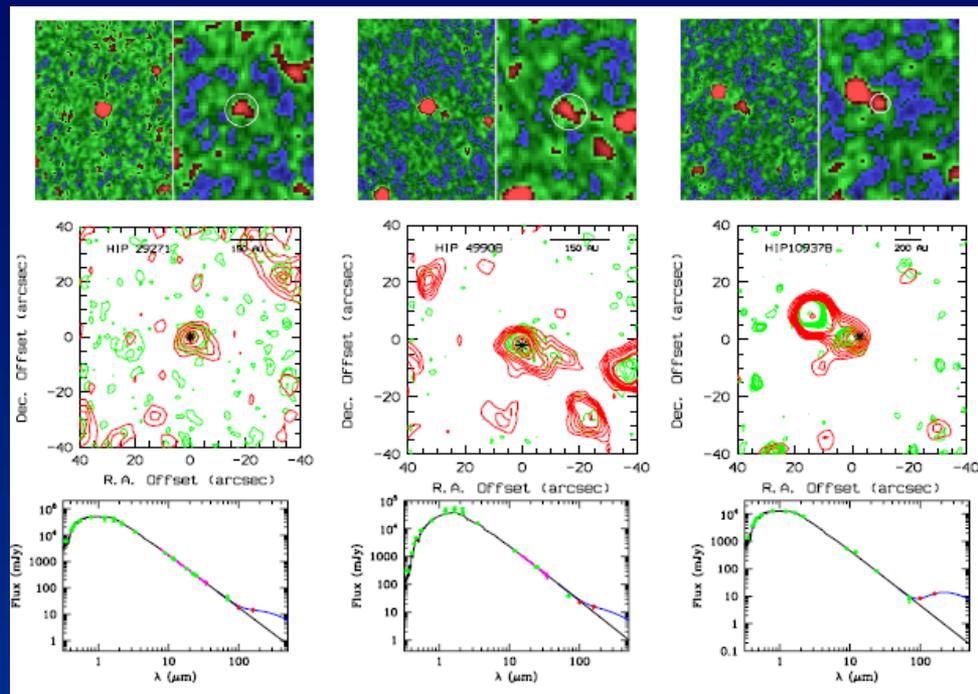
✓ Simple interpretation

- ✓ **Cold** ($T_{\text{dust}} \lesssim 30\ \text{K}$),
- ✓ **Faint** ($L_{\text{dust}}/L_{\text{star}} \sim 5 \times 10^{-7} - 10^{-5}$) **debris discs**

Cold discs

- These are the coldest and less luminous debris discs known
- Observed sizes are smaller than implied from the BB temperature.
- In other words: $T_{\text{dust}} < T_{\text{bb}}$ (i.e subthermal)

Modeling is challenging
(Krivov et al. in prep.)



Eiroa et al. 2011 A&A 536, L4

Table 4. Black body dust temperatures from the far-IR excesses, T_{dust} , and the corresponding estimated radii.

Star	T_{dust} (K)	Size			f
		Est. (AU)	Orig. (AU)	Deconv. (AU)	
α Men	≤ 22	≥ 147	92	81	9.7×10^{-7}
HD 88230	≤ 22	≥ 62	56	51	1.6×10^{-6}
HD 210277	22	160	≤ 130		5.4×10^{-6}

Notes. Observed 3σ linear sizes (semi-major axes) of the extended emission at $160 \mu\text{m}$ in the original and deconvolved images. f is the fractional luminosity of the dust.



Summary/Conclusions

- ~ 24% - \lesssim 30% debris discs
 - remarkable increase of previous statistics
 - New discs mainly in late type stars (K-type)
- ~ EKB flux levels practically achieved
- Large number of resolved discs
 - 5 times previous number
 - unprecedented details
- "New class" of debris discs:
 - Steep SEDs
 - 160 μm -only excesses
 - :: Very cold, $T \lesssim 30$ K, faint discs which might represent a new physical regime.
 - :: More often in late-type stars.

*We are happy
and have fun*