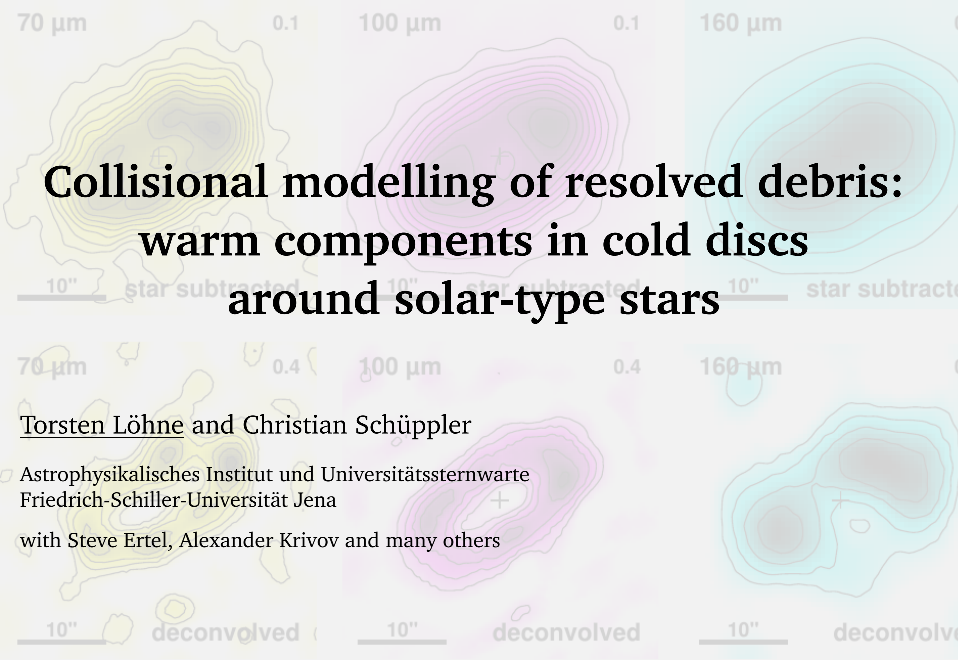


Collisional modelling of resolved debris: warm components in cold discs around solar-type stars

Torsten Löhne and Christian Schüppler

Astrophysikalisches Institut und Universitätssternwarte
Friedrich-Schiller-Universität Jena

with Steve Ertel, Alexander Krivov and many others

Collisional modelling of resolved debris: **warm components** in cold discs around solar-type stars

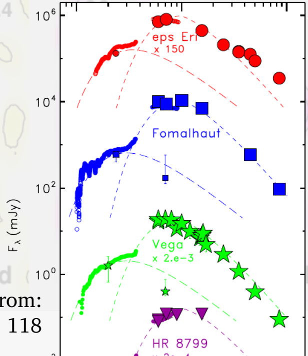
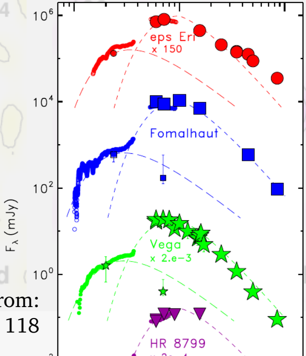


figure from:
Su et al., ApJ 763 (2013), 118

2/3 of discs have multiple components:
Ballering et al. 2013
Chen et al. 2014
Pawellek et al. 2014
Kennedy & Wyatt 2014

Collisional modelling of resolved debris: **warm components** in **cold discs** around solar-type stars



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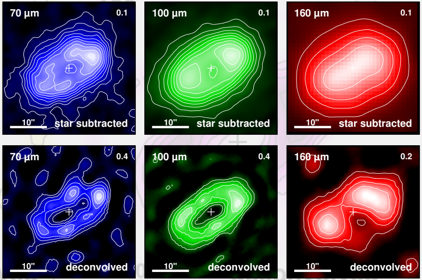

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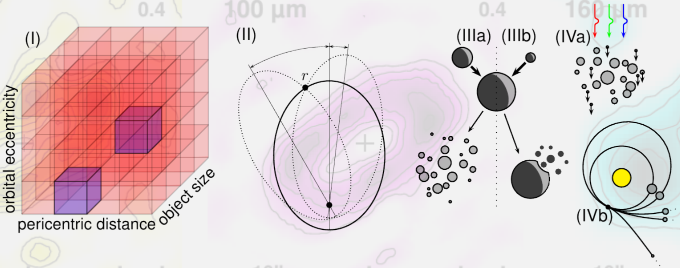


“ACE” code: Krivov et al. (2000, 2005, 2006), Löhne et al. (2008), . . .

Collisional modelling of resolved debris: warm components in cold discs around solar-type stars

DUst around NEarby Stars

Sample: 133 (+100) nearby FGK main-sequence stars
Data: Herschel/PACS und SPIRE, images and photometry
Disc detection rate: 20 %
P.I.: Carlos EIROA (UA Madrid, Spain)

HD 207129

System properties

Star

Mobile no.:	HIP 107649
Spectral type:	G1 V
Distance:	16.0 pc
Age:	≈ 1–3 Gyr

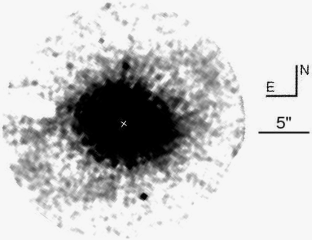
Planets?

None detected.

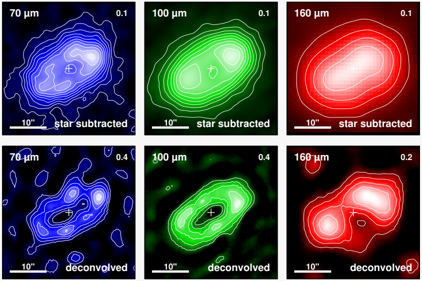
Debris disc

IRAS, ISO, Spitzer, HST, APEX, Herschel:

- cold dust, 100–1000 times more luminous than Kuiper belt
- ring at ∼ 160 au (KRIST et al. 2010)



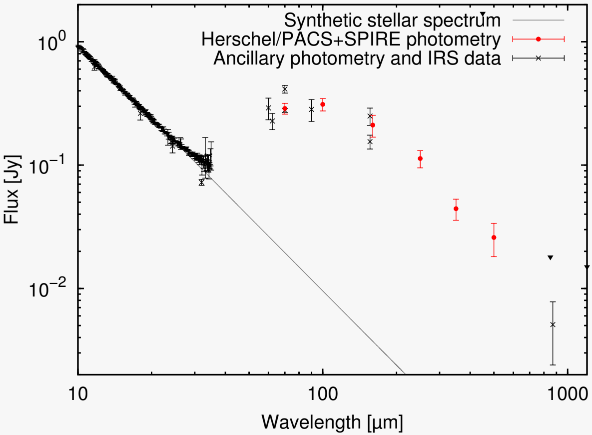
(HST/ACS, Krist et al. 2010)



(Herschel/PACS, Marshall et al. 2011)

HD 207129

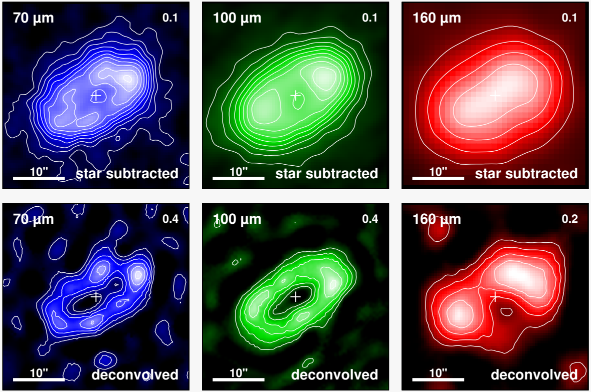
Observational data: spectral energy distribution (Marshall et al., 2011)



- fractional luminosity: $L_{\rm dust}/L_{\rm star} = 10^{-4}$
- blackbody temperature: 50 K
- blackbody distance of 34 AU

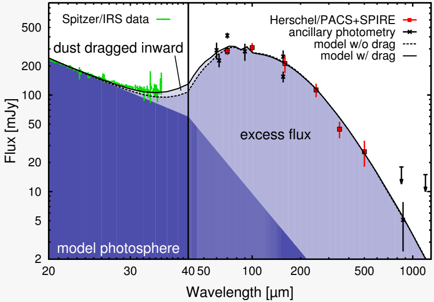
HD 207129

Observational data: images (MARSHALL et al., 2011; LÖHNE et al., 2012)

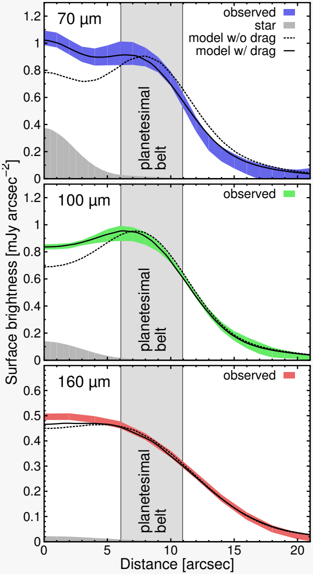


- Ring with peak intensity at about 145 AU $\Longrightarrow$ no blackbody grains!
- Slight brightness asymmetry SE–NW

Spectral energy distribution



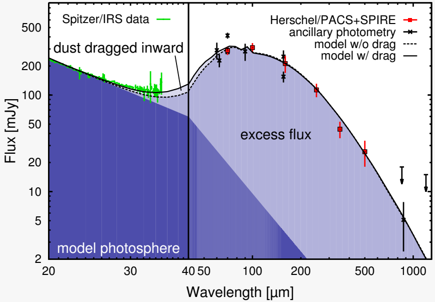
Radial profiles



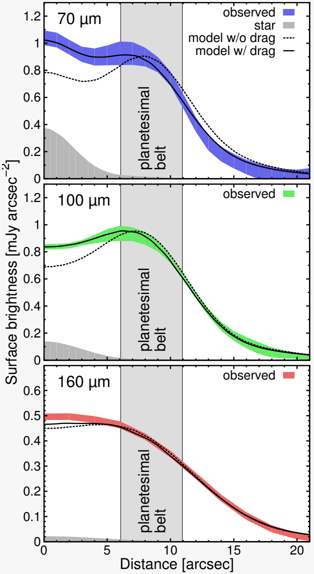
HD 207129

Results (Löhne et al., 2012)

Spectral energy distribution



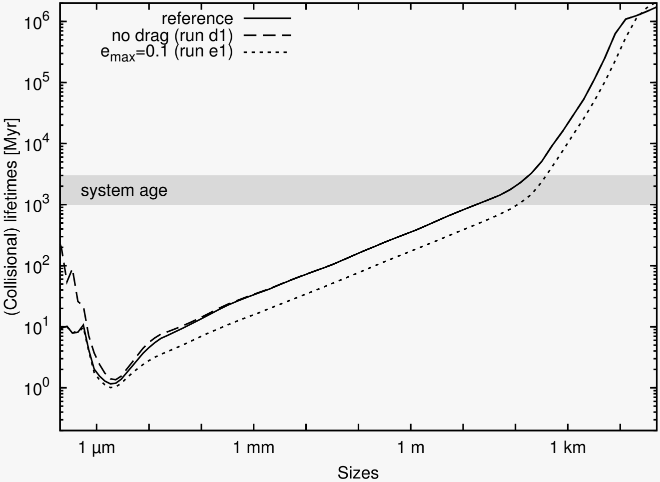
Radial profiles



Results

Outer radius:	$\approx$ 170 AU (steep outer edge)
Optical depth:	decreasing inward
Eff. min. grain size:	(1...)5 μm (depending on distance)
Dust mass:	7×10^{-3} Earth masses ($M_\oplus$)
Orbital eccentricities:	$\lesssim 0.05$ (fairly low)
Mass loss rate:	$0.04\, M_\oplus/\mathrm{Gyr} \sim 1\,\mathrm{EKB/Gyr}$

HD 207129
Timescales



- objects $\gtrsim 100\,\mathrm{m}$ remain passive, if they exist

HD 207129

Summary

- Huge dust-producing planetesimal belt can explain bulk of observations.
- Dynamical excitation of the disk is rather low.
- Typical grains are big: ~ 10 times the blowout size.
- Low rate of mass loss.
- Drag can sufficiently fill the inner gap.

HIP 17439

System properties

Star

Landline: HD 23484
Spectral type: K2 V
Distance: 16.0 pc
Age: ≈ 1–4 Gyr
X-ray activity: consistent with strong stellar wind (∼25× solar strength)

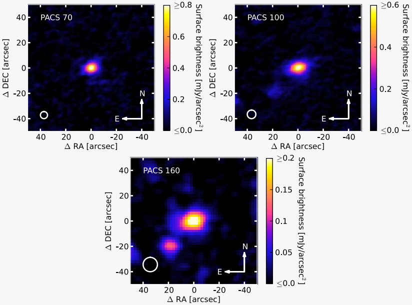
Planets?

None detected.

Debris disc

IRAS, Spitzer, Herschel:

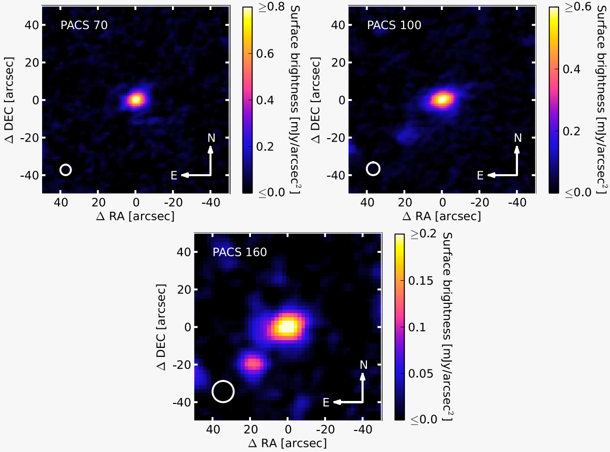
- cold dust, 100–1000 times more luminous than Kuiper belt
- located at $\gtrsim 90$ au (Ertel et al. 2014)



(Herschel/PACS, Ertel et al. 2014)

HIP 17439

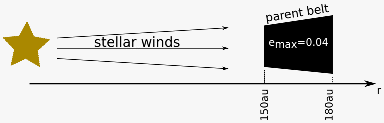
Observational data: images (ERTEL et al., 2014)



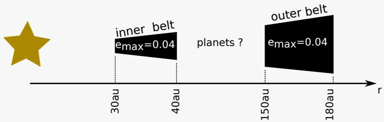
- resolved at all three wavelengths, no clear ring visible
- apparent disc sizes strongly increase from 70 to 160 μm
- **disc is structured or extended (to ∼ 170 au) radially**

Two scenarios (SCHÜPPLER et al., 2014)

(1) transport + cold belt:

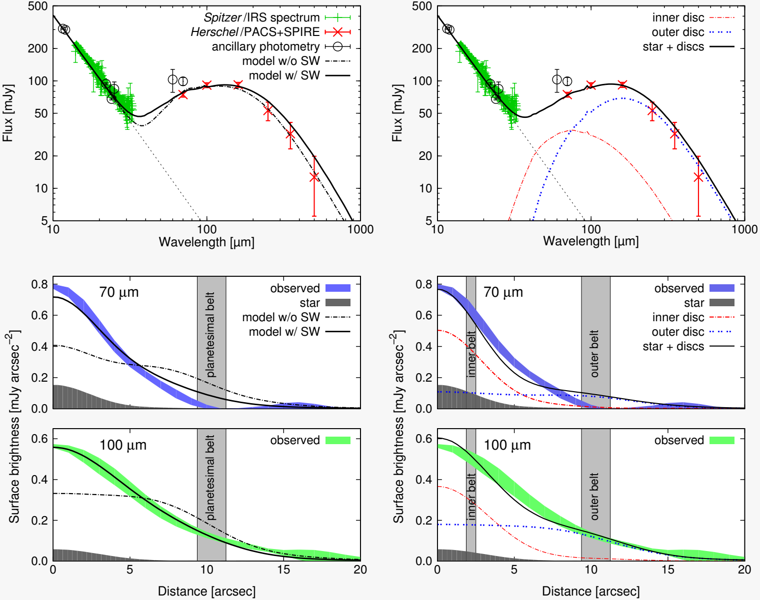


(2) warm belt + cold belt:

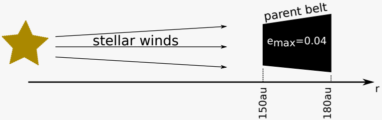


HIP 17439

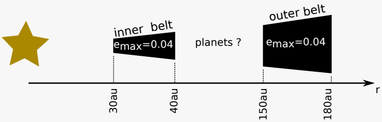
Results (Schüppler et al., 2014)



(1) transport + cold belt:



(2) warm belt + cold belt:

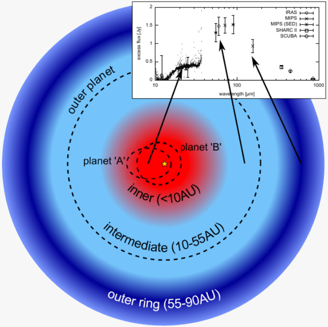


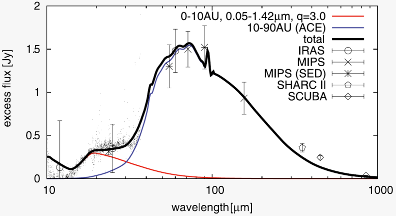
Parameters

Radial extent [au]	$\sim$150–180	$\sim$30–40	$\sim$150–180
Orbital eccentricities	$\lesssim$0.04	$\lesssim$0.04	$\lesssim$0.04
Dust mass [$M_\oplus$]	9.5×10^{-3}	5.5×10^{-5}	1.1×10^{-2}
Mass loss rate [$M_\oplus$/Gyr]	0.05	0.03 (combined)	

- **Overall: very similar to HD 207129.**
- Huge dust-producing planetesimal belt can explain bulk of observations.
- **Wind drag** can sufficiently fill the inner gap.
- Two-belt scenario is possible as well.
- Dynamical excitation of the disk is rather low.
- Typical grains are big: 10 times the blowout size.
- Low rate of mass loss.
- Where are the planets?

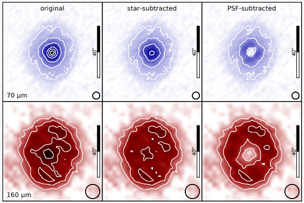
ε Eridani (K2 V)



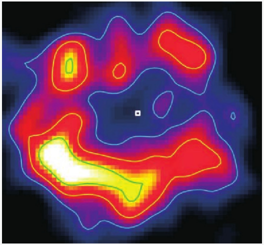


Reidemeister et al. (2011)

ε Eridani (K2 V)



Greaves+ (2014, Herschel)

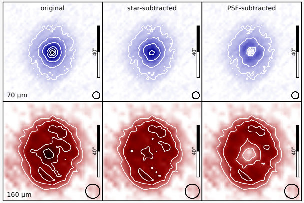


Greaves+ (2005, JCMT/SCUBA)

- consistent w/ cold disc + drag

Beyond DUNES

ε Eridani (K2 V)



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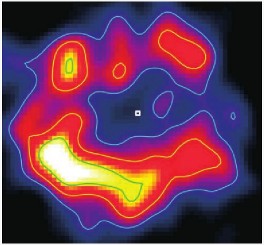

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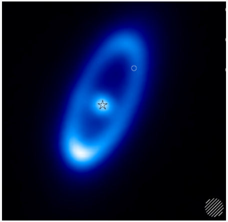
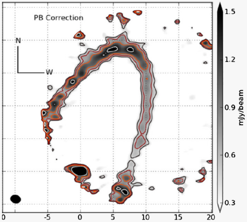
Fomalhaut (A4 V)



Acke+ (2012, Herschel)

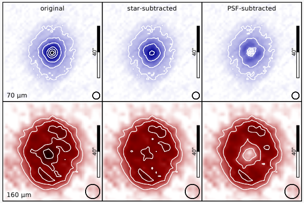


Boley+ (2012, ALMA)

- separate inner component

Beyond DUNES

ε Eridani (K2 V)



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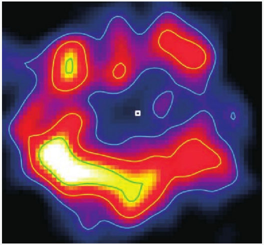

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- ► consistent w/ cold disc + drag

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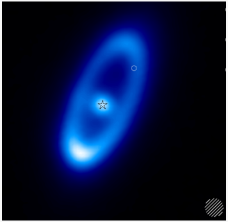

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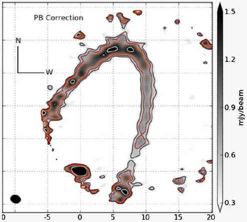

Boley+ (2012, ALMA)

- ► separate inner component

AU Microscopii (M1 V)

wait for Schüppler/Ertel et al. (in prep.)!

Conclusions

. . . and more open questions

- Bright debris discs can have low mass loss rates.
- For dynamically cold discs, the effective minimum grain size is (much) larger than the blowout size.
- When sufficiently resolved, most (all?) discs appear as narrow rings (plus an inner and/or outer halo).
- Warm components seem common; indicating transport or structure similar to the solar system?
- Are the discs self-stirred or perturbed by planets?
- How do significant offsets/asymmetries fit in this picture?

Conclusions

. . . and more open questions

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- Warm components seem common; indicating transport or structure similar to the solar system?
- Are the discs self-stirred or perturbed by planets?
- How do significant offsets/asymmetries fit in this picture?
- The solar system is tiny!