Disc radii and grain sizes in Herschel-resolved debris discs

Nicole Pawellek[1], Alexander V. Krivov[1], Jonathan P. Marshall[2 3], Benjamin Montesinos[4], Péter Ábrahám[5], Attila Moór[5], Geoffrey Bryden[6], Carlos Eiroa[3]

[1] Astrophysikalisches Institut und Universitäts-Sternwarte, Friedrich-Schiller-Universität, Schillergäßchen 2–3, 07745 Jena
[2] School of Physics and Australian Centre for Astrobiology, University of New South Wales, Sydney NSW 2052, Australia
[3] Departamento de Física Teórica, Facultad de Ciencias, Universidad Autónoma de Madrid, Cantoblanco, 28049 Madrid
[4] Departamento de Astrofísica, Centro de Astrobiología (CAB, CSIC-INTA), PO Box 78, 28691 Villanueva de la Cañada, Madrid
[5] Konkoly Observatory, Research Centre for Astronomy and Earth Science, Hungarian Academy of Science, PO Box 67, H-1525 Budapest, Hungary
[6] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

since 1558

Introduction

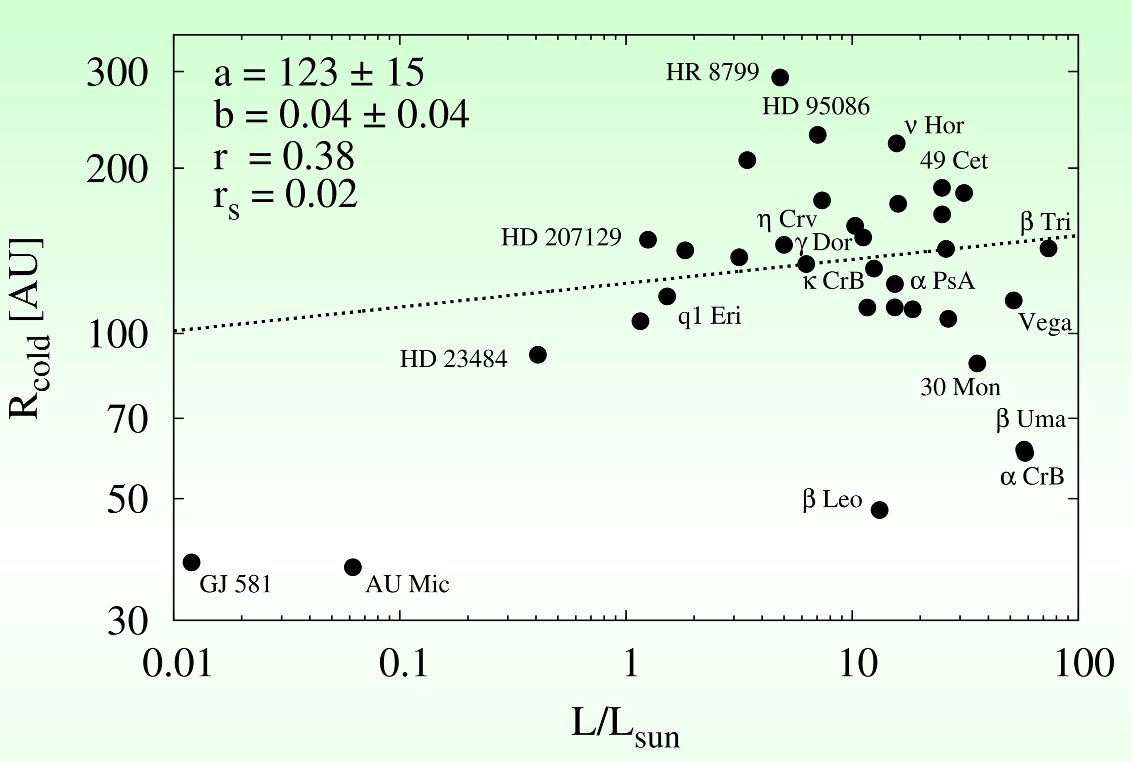
The disc radii of debris discs reveal zones in which planetesimals formed, survived depletion and scattering, and were sufficiently stirred.
The size distribution of dust in debris discs should result from interplay between grain-grain collisions, radiation pressure, and various transport processes. As a result, it should sensitively depend on the mechanical and optical properties of dust, the dynamical excitation of the disc, and the radiative and corpuscular field of the central star.

One difficulty of deducing the grain sizes from observations is that there is a degeneracy between particle size and disc radius. This degeneracy can be removed if resolved images are available and thus the location of the emitting dust is known. Here we try to constrain typical grain sizes by fitting the SEDs of a selection of discs for which disc radii can be estimated from the resolved Herschel images. The SEDs are fitted with a size distribution assuming astrosilicate grains. A warm component was included if necessary.

Target selection, data acquisition, and modelling

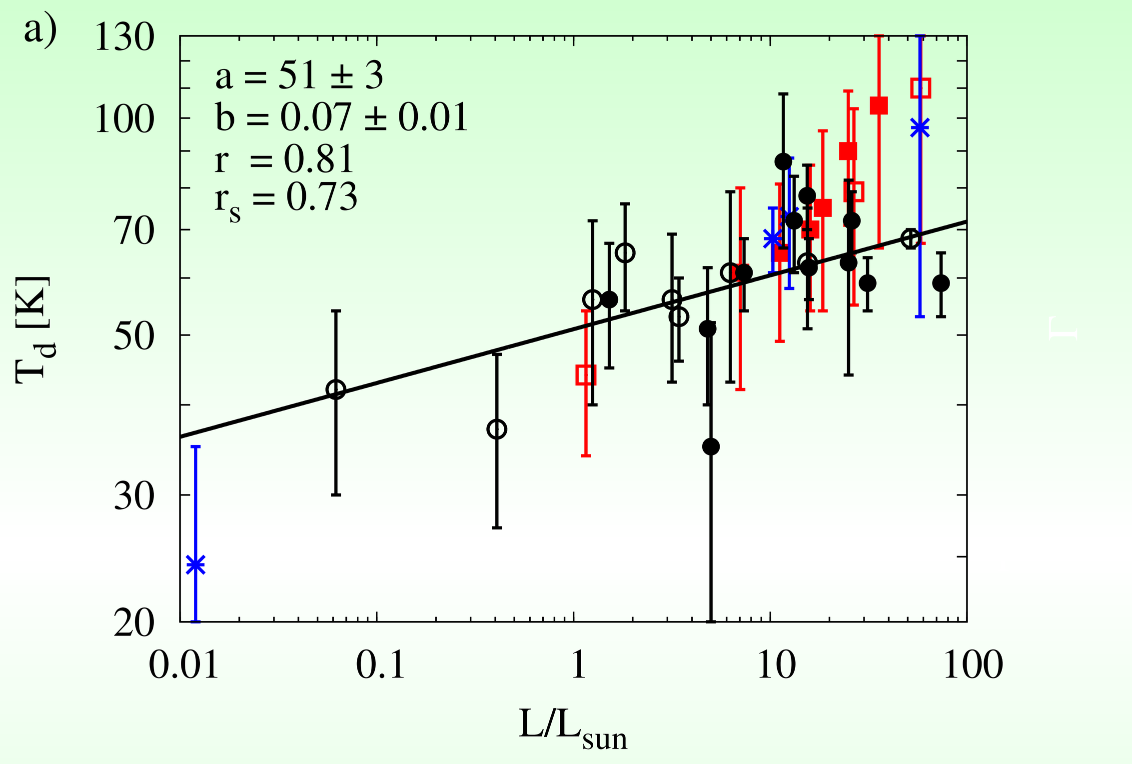
- Targets
  - 34 discs around AFGKM stars with ages of 100 Myr – 10 Gyr, well resolved in several Herschel programmes
  - disc radii R_{cold} was derived from FWHM of resolved images at 100 µm
  - discs without peculiarities (such as substantial asymmetries in resolved images)
- Data:
  - photometric data collected from various catalogues and surveys such as 2MASS, WISE, AKARI, Spitzer, SCUBA
  - Herschel data taken from papers or reduced by us
- Modelling:
  - stellar photospheres calculated with a Hauschildt et al. (1999) model
  - SED fitting done with extended version of SEDUCE (Müller et al. 2010)
  - flux of warm disc subtracted from total flux to better constrain cold component

Disc radii



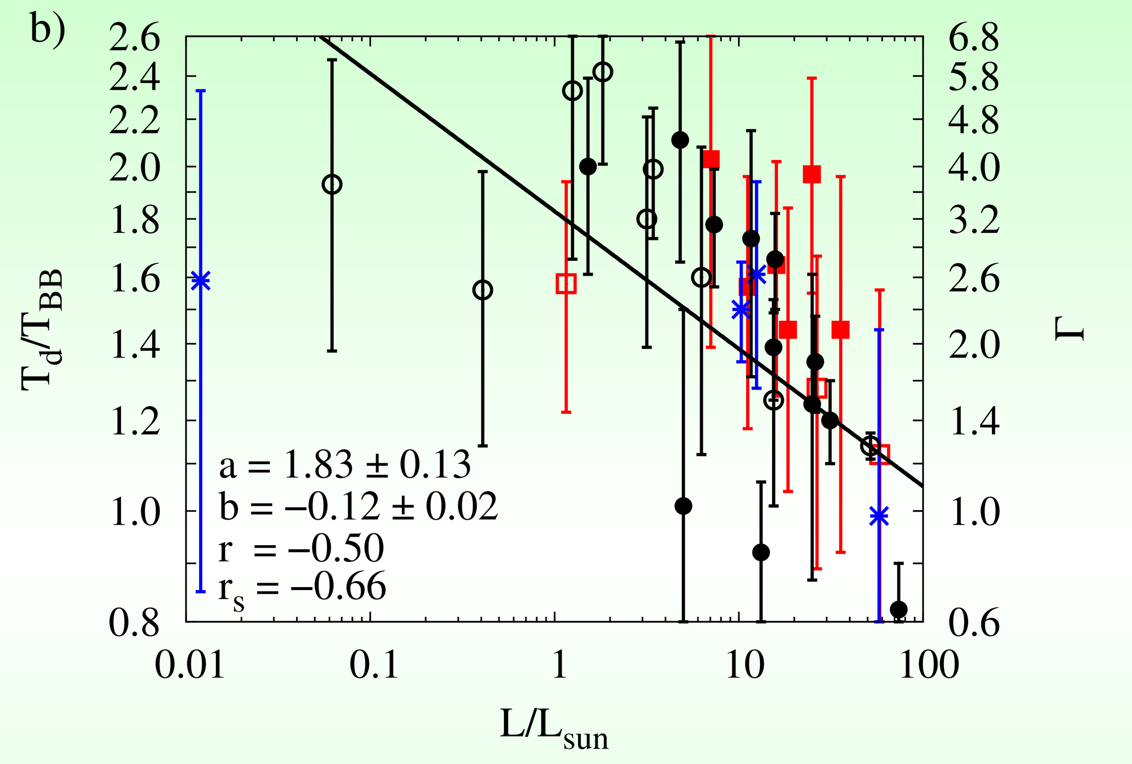
- trend line $y = a(L/L_{\odot})^b$; r, r_s are correlation coefficients
- large scatter of radii over whole luminosity range
- disc radii do not seem to correlate with stellar luminosity
- roughly consistent with Eiroa et al. (2013)

Dust temperatures



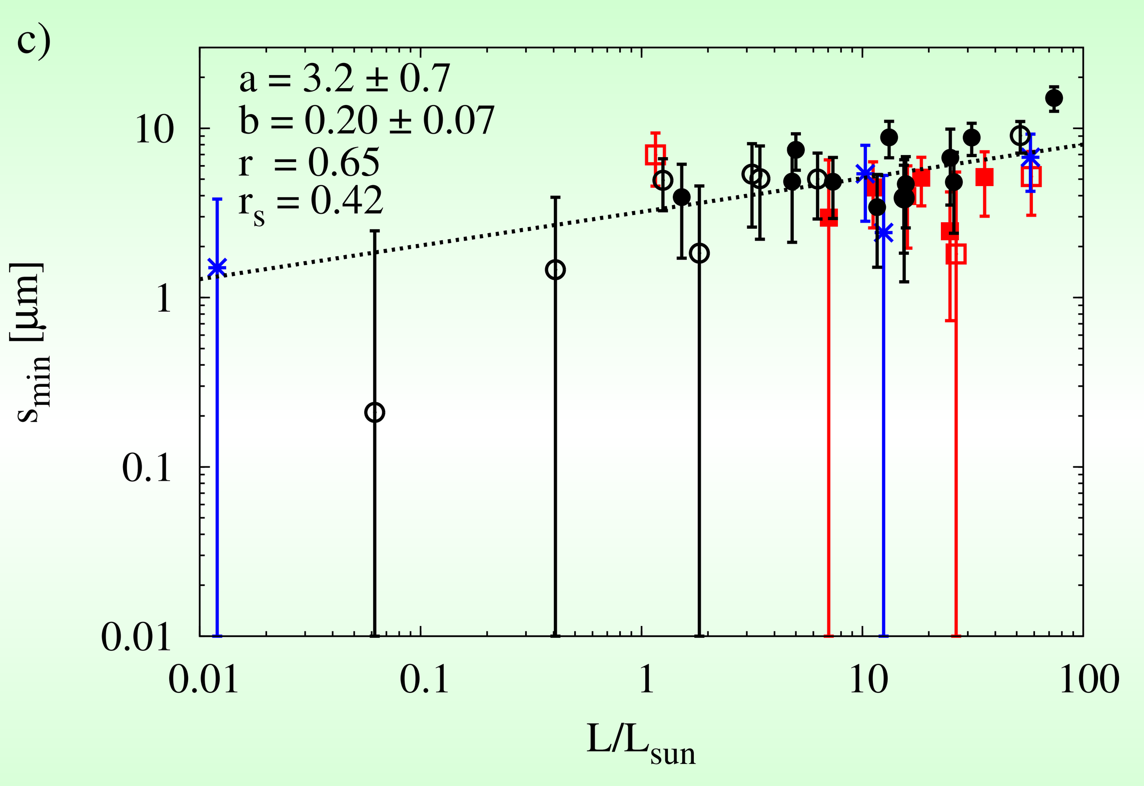
- dust temperature increases with increasing luminosity
- good agreement with other Herschel-based studies such as Booth et al. (2013)

Temperature ratio

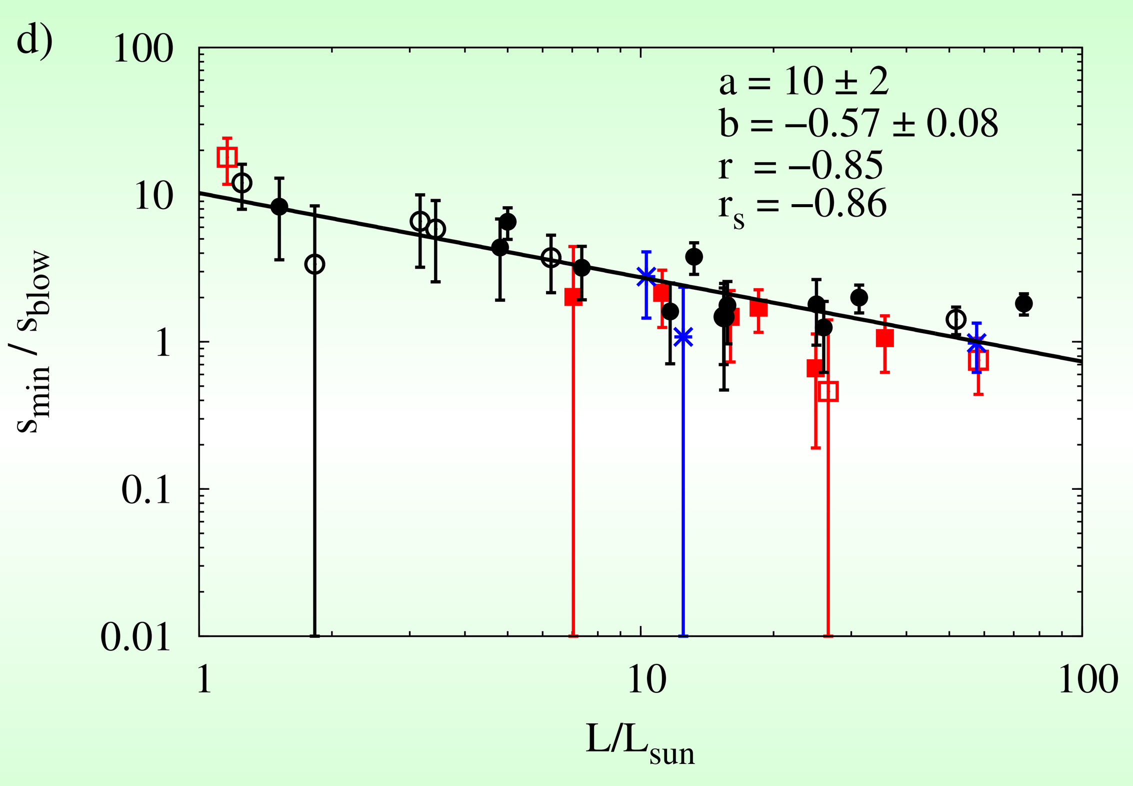


- ratio of dust to blackbody temperatures decreases with increasing luminosity, as well as the ratio of resolved to blackbody radii $\Gamma = R_{cold}/R_{BB}$
- consistent with Booth et al. (2013)

Minimum grain size and grain size ratio



- s_{min} increases with increasing luminosity (due to radiation pressure)
- increasing s_{min} explains decrease of T_d/T_{BB}
- s_{min} in blowout units (s_{min}/s_{blow}) decreases with increasing luminosity
- possible explanation of size ratio trend:
  - dust composition or porosity my change s_{min} and/or s_{blow}
  - s_{min} may be constrained additionally by impact energy (Krijt & Kama 2014)
  - discs of earlier-type stars may be more strongly stirred, causing typical grains to be smaller



Conclusions

- around two thirds of discs show warm components
- no significant correlation between R_{cold} and stellar luminosity found, thus R_{cold} not set by ice lines
- large scatter of R_{cold} (diversity of initial conditions or evolutionary path)
- cold disc trends from late- to early-type stars:
  - dust temperature increases
  - minimum dust size increases
  - ratio of dust to blowout sizes roughly decreases from 10 to 1
  - possible explanation of size ratio trend:
    - ⋆ differences in composition and porosity
    - ⋆ smallest fragment size limited by surface tension (Krijt & Kama 2014)
    - ⋆ earlier-type stars have more dynamically excited discs

References

- Duchêne et al. 2014, ApJ, 784, 148
- Krijt & Kama 2014, A&A, 566, L2
- Matthews et al. 2014, ApJ, 780, 97
- Bonsor et al. 2013, MNRAS, 431, 3025
- Booth et al. 2013, MNRAS, 428, 1263
- Eiroa et al. 2013, A&A, 555, A11
- Moór et.al. 2013, ApJL, 775, L51
- Moór et al. 2013, ApJL, 777, L25
- Acke et al. 2012, A&A, 540, A125
- Lestrade et al. 2012, A&A, 548, A86
- Churcher et al. 2011, MNRAS, 410, 2
- Morales et al. 2011, ApJ Lett., 730, L29
- Matthews et al. 2010, A&A, 518, L135
- Müller et al. 2010, ApJ, 708, 1728
- Sibthorpe et al. 2010, A&A, 518, L130
- Su et al. 2006, ApJ, 653, 675
- Hauschildt et al. 1999, ApJ, 525, 871

ADS link

Pawellek et al. (2014)
ApJ, 792:65

Contact

nicole.pawellek@uni-jena.de