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Near-infrared Emission from Sublimating Dust in Collisionally Active Debris Disks

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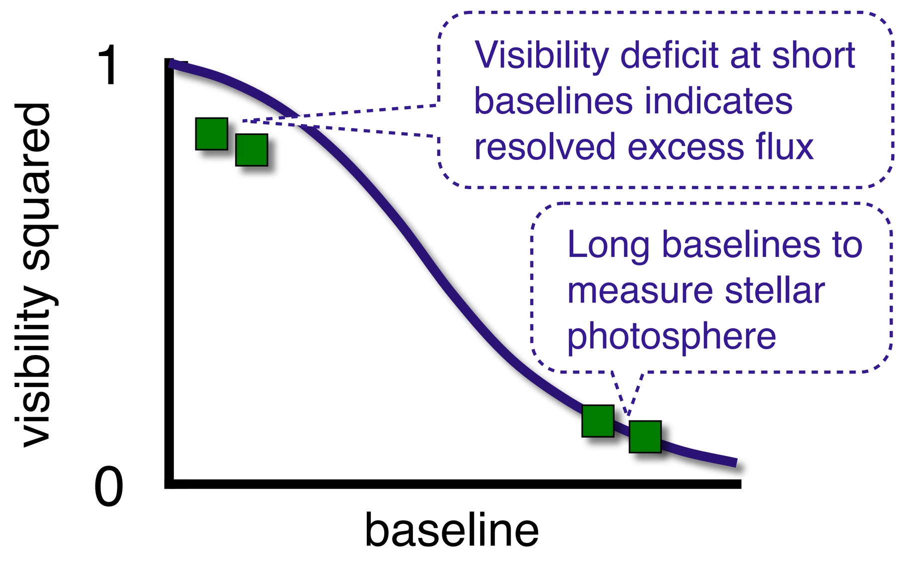
Motivation

Near-infrared interferometers find excess flux (~1% of photospheric flux) from the inner parts of some debris disk systems (e.g., Vega, Absil et al. 2006)



This is interpreted as thermal emission from hot (> 1000 K) exozodiacal dust, very close to the central star (<< 1 AU)

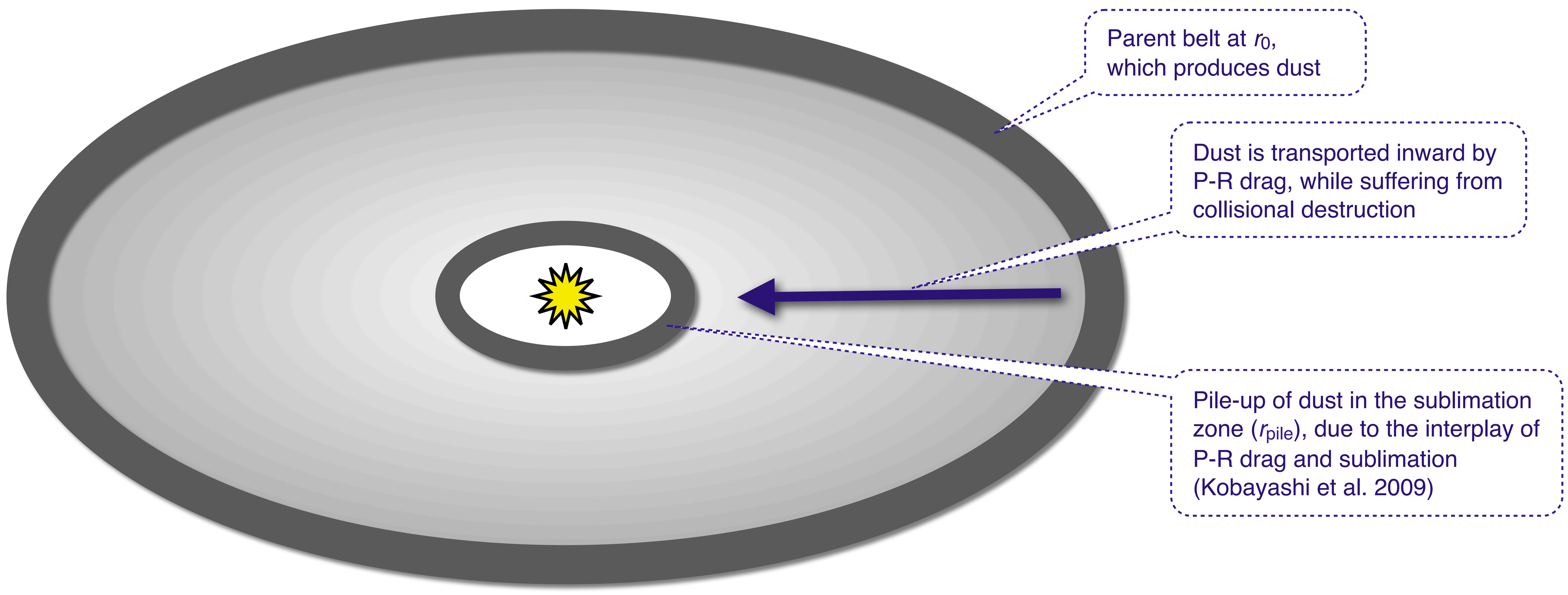
What is the origin of this material?

Research questions

Can Poynting-Robertson (P-R) drag supply enough dust from a distant parent belt to explain the interferometry data?

Does the pile-up of dust in the sublimation zone also occur in collision-dominated systems?

Modeling the inner disk



Analytical model

Assumptions: circular orbits, single grain size, collisions are always destructive

Solve the balance between collisions and P-R drag (Wyatt 2005)

Pile-up at r_{pile}, where timescales for P-R drag and sublimation are equal

Grains survive at r_{pile} for one sublimation timescale

Numerical model

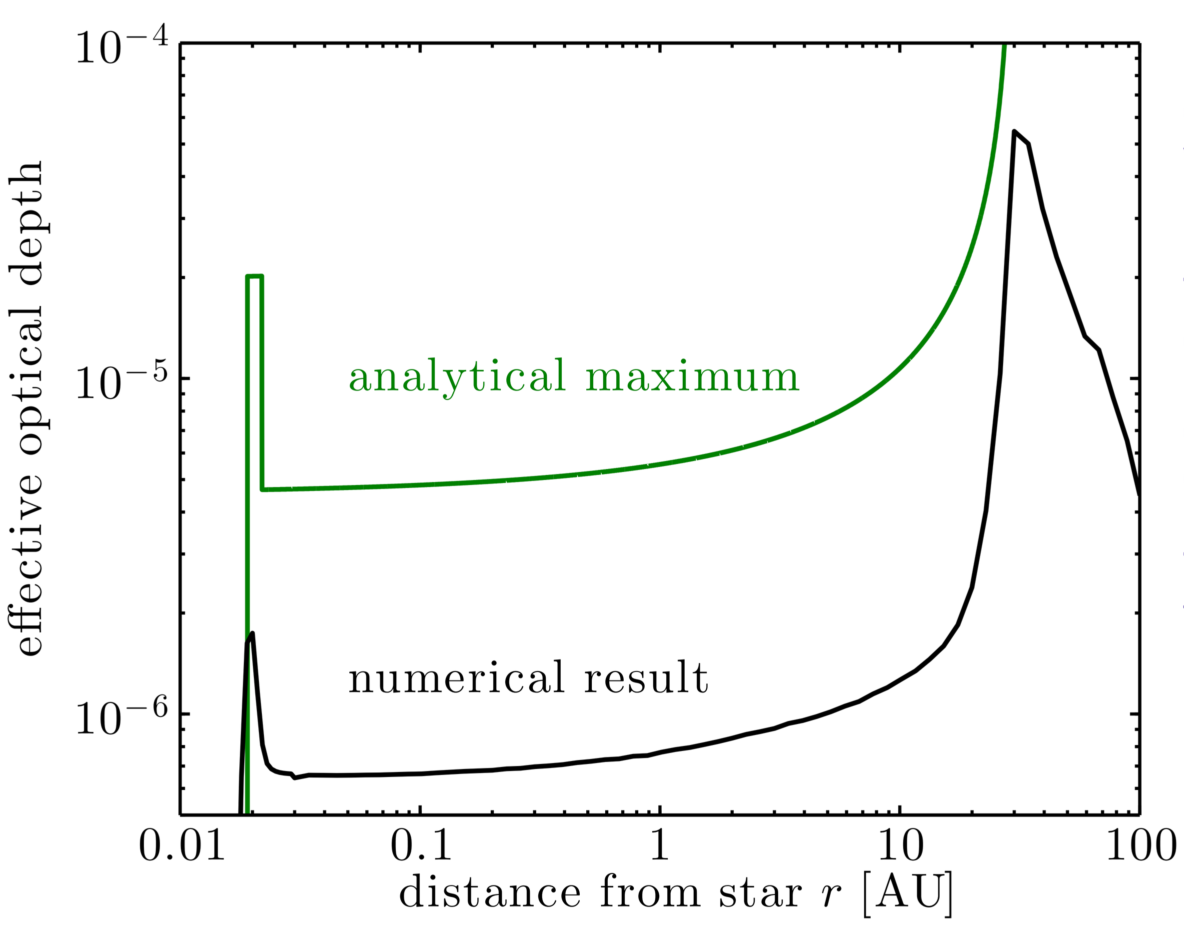
Statistical method that follows the evolution of the dust distributions in grain mass, orbital size, and orbital eccentricity (Krivov et al. 2006)

Self-consistently treats stellar gravity, direct radiation pressure, P-R drag, destructive collisions, and sublimation

Allows multiple grain sizes and eccentric orbits

Results

Radial distribution

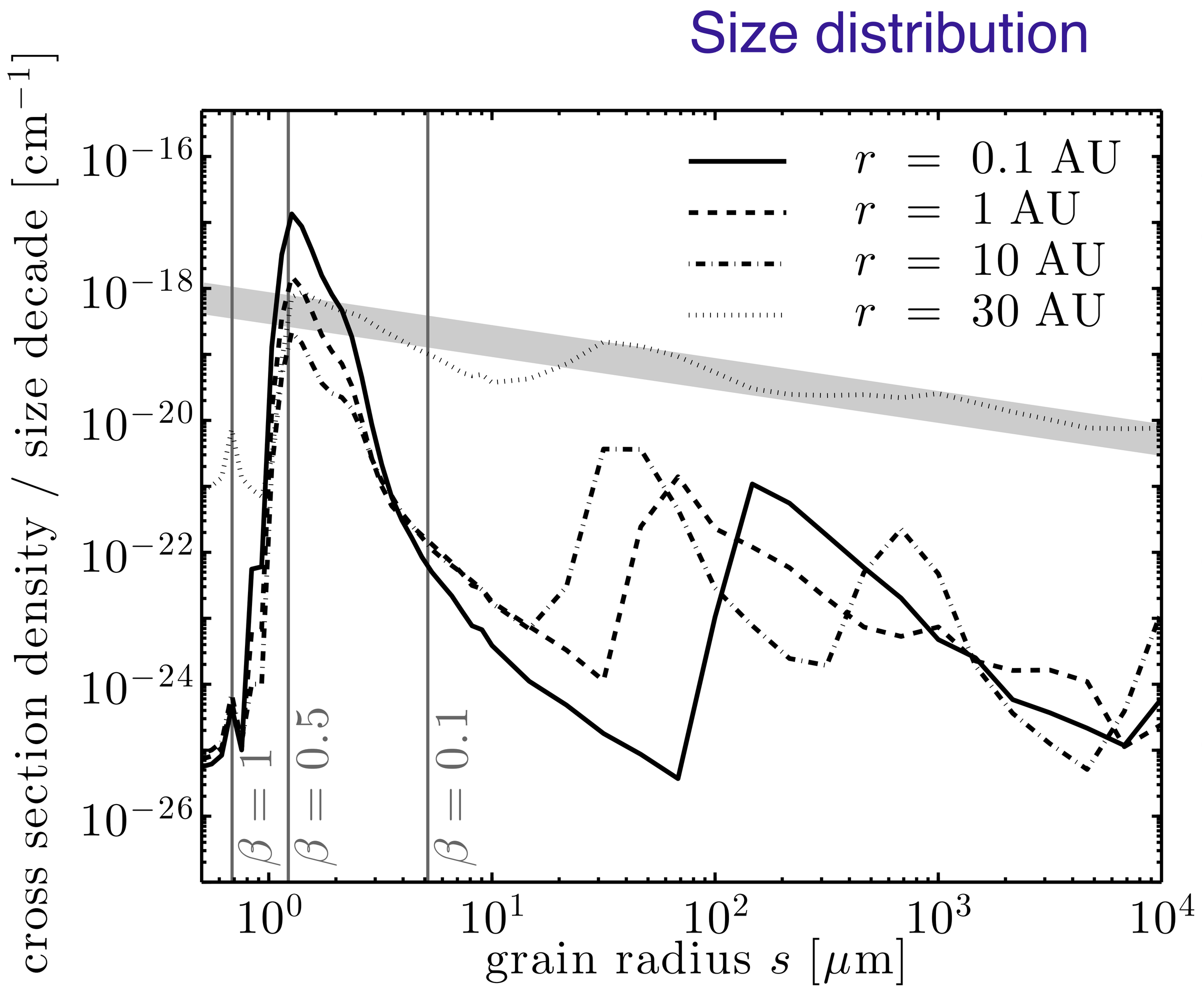


Maximum dust levels for a debris disk around a solar-type star with a parent belt at 30 AU, using carbonaceous dust

The analytical model overestimates the level of dust by a factor of about 7, because it does not consider eccentric orbits

The numerical model confirms that dust pile-up still occurs (at r_{pile}) when collisions are taken into account

Size distribution



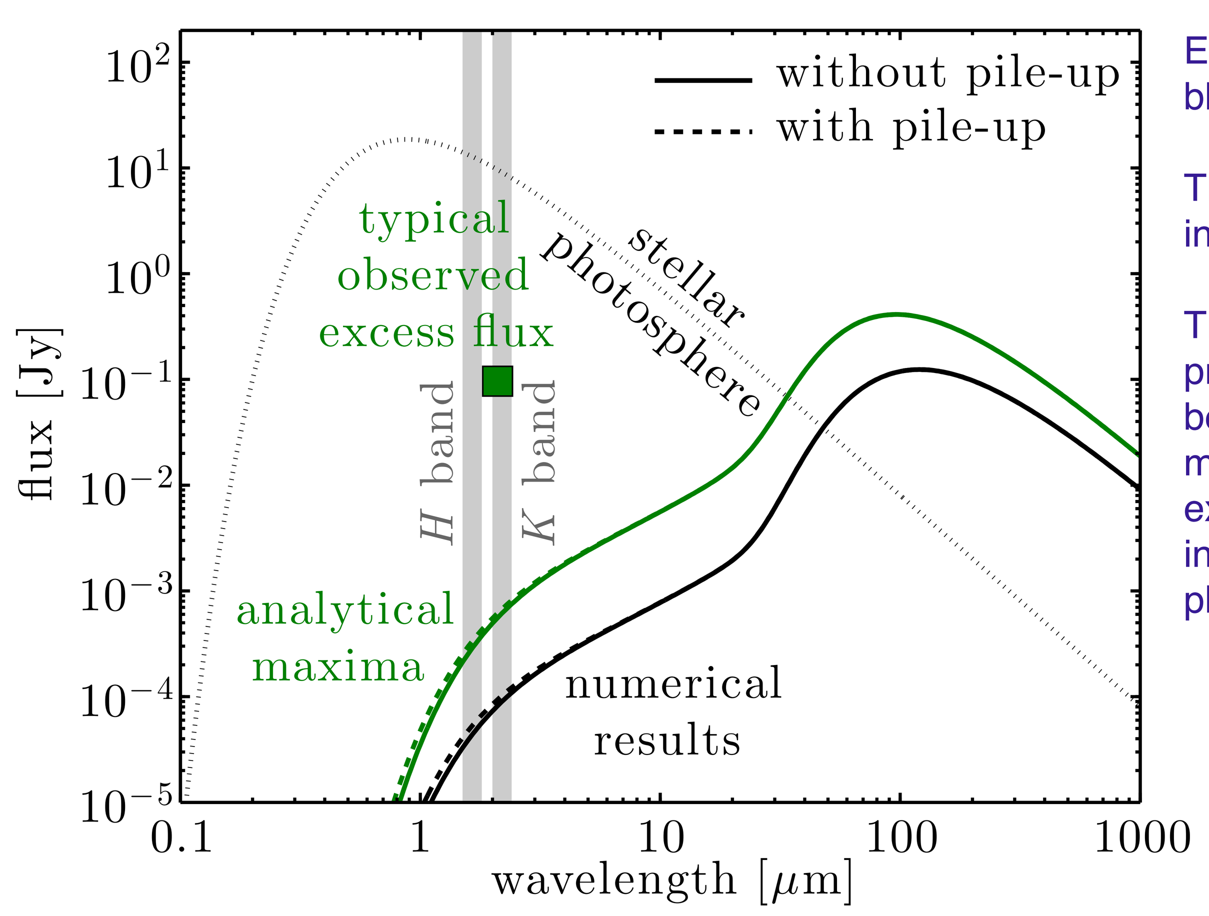
In the parent belt (r = 30 AU), the size distribution follows a $dn / ds \propto s^{-3.5}$ power law (grey band), with a superimposed wave pattern related to the discontinuity at the blowout size

Further in, the wave pattern becomes stronger, and the size distribution is steeper

In the innermost regions, barely bound ($\beta \approx 0.5$) grains clearly dominate the cross-section

(The numerical model does not include cratering collisions)

Spectral energy distribution

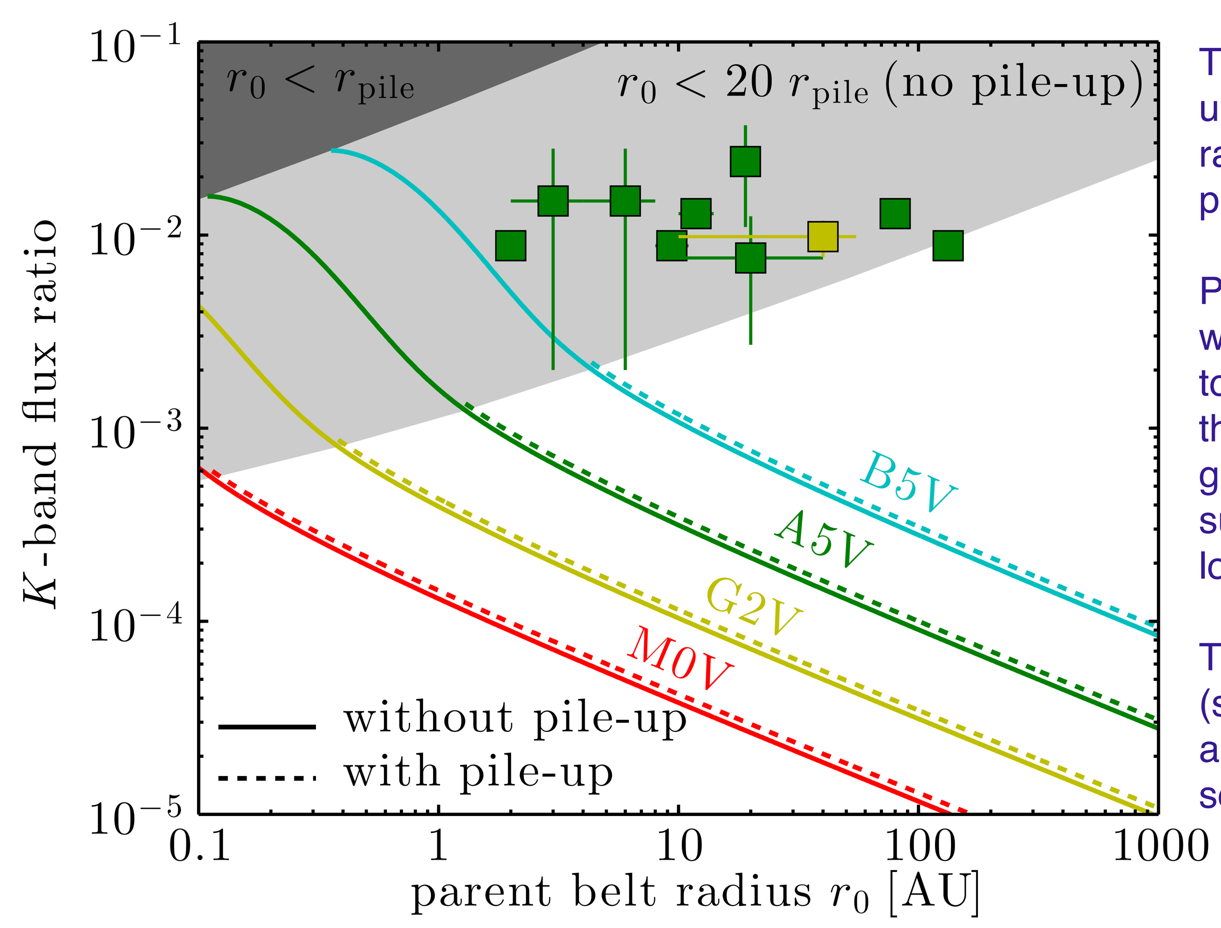


Emission SEDs assuming black-body temperatures

The effect of the pile-up is insignificant

The near-infrared excess produced by this disk (parent belt at 30 AU, solar-type star) is much lower than the typical excess flux derived from interferometry (~1% of the photospheric flux)

Maximum excess ratios



The analytical model can be used to derive maximum excess ratios for any stellar type and parent belt location

Pile-up of dust does not occur when the parent belt is too close to the sublimation zone, because the orbital eccentricities of small grains cannot circularize sufficiently (pile-up requires very low eccentricities)

The observed excess ratios (squares, mostly A-type stars) are all higher than the maxima, so the mechanism does not work

Conclusions

1. P-R drag brings dust to the sublimation zone, but about 7 times less (in terms of cross-section) than previously expected
2. This material is not enough to explain the interferometric data
3. Pile-up of dust occurs even when collisions are considered, but its effect on the SED is insignificant
4. Barely bound grains dominate the cross-section in the inner parts of dense debris disks

References

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