q[1] Eri in the Light of *Herschel*

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on behalf of the *DUNES* consortium

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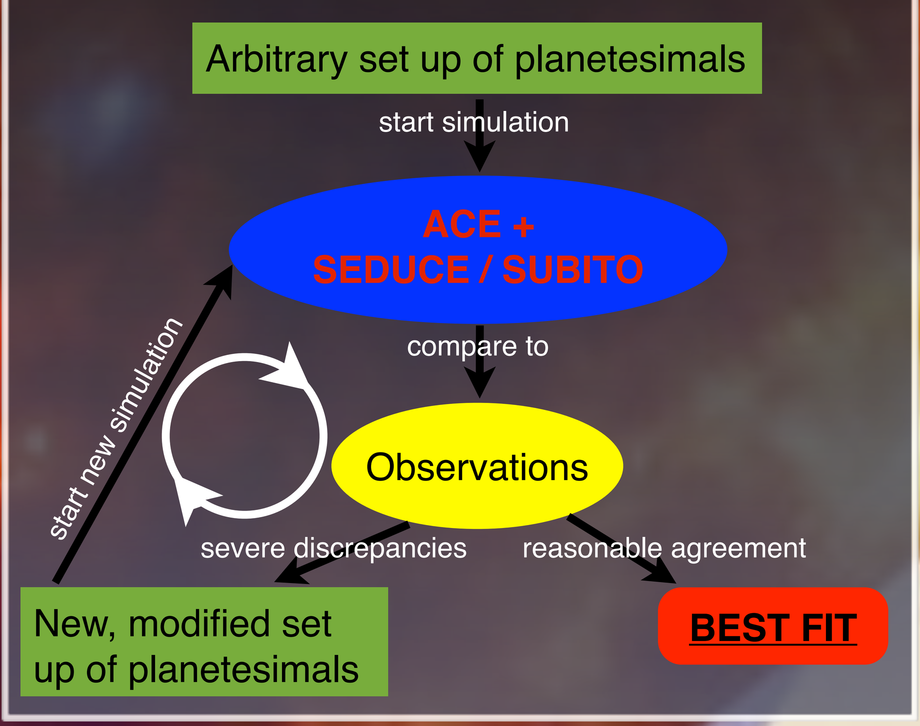
Abstract

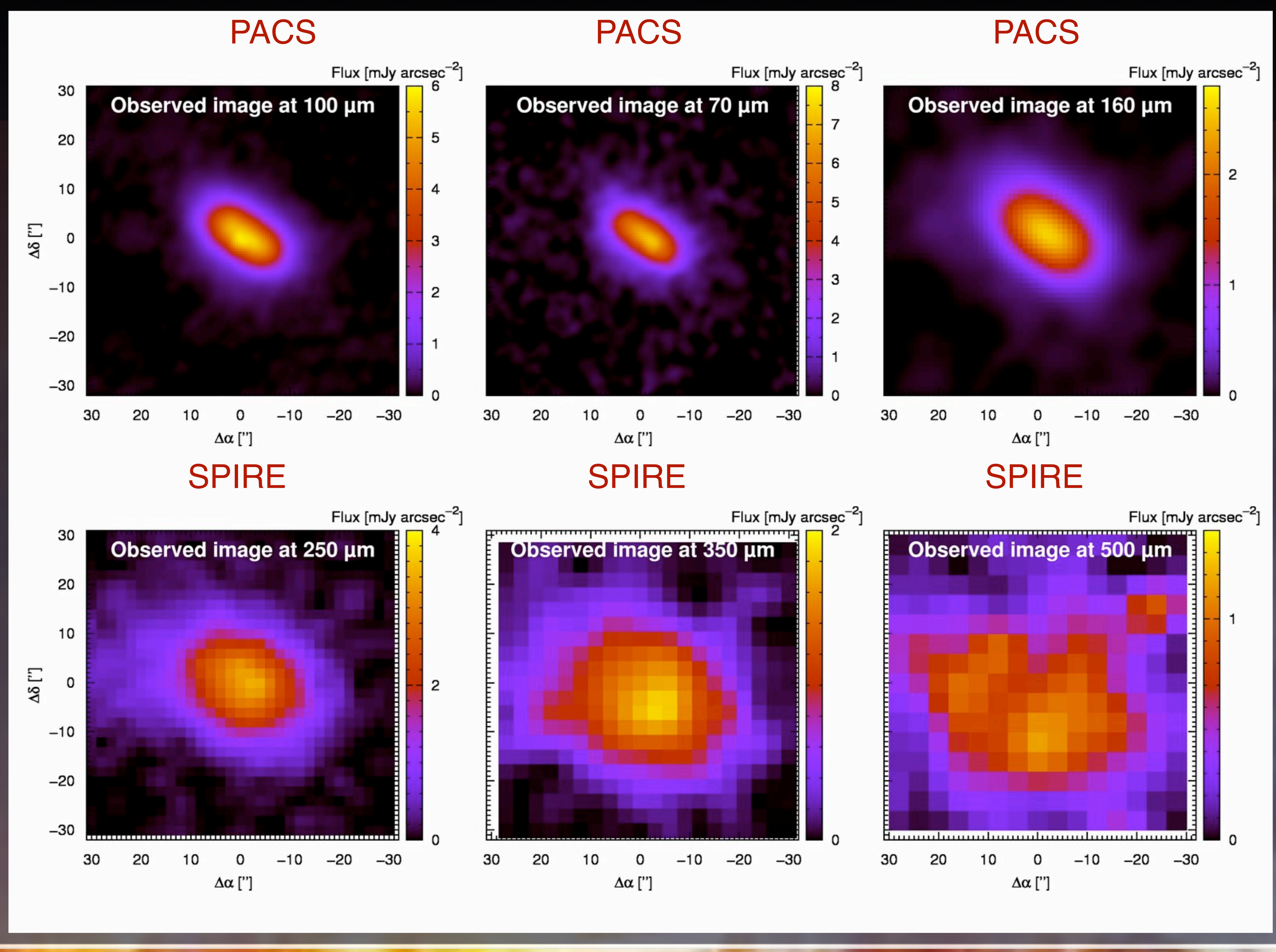
DUNES (DUst arond NEarby Stars) is an OTKP for the Herschel mission concentrating on debris disks. Such disks are the end stage of planet formation. Especially Spitzer has shown that they are a common featur around main-sequence stars. They are observed by dust thermal emission in the IR. Dust is steadily produced by mutual collisions among large, invisible planetesimals. In recent years we have developed a new way to modeling the whole debris disk, dust and planetesimals (Müller et al. 2010). Here we apply this approach to the prominent debris disk around the sun-like star q[1] Eri that was observed with PACS and SPIRE at 70, 100, 160, 250, 350, and 500 μm in scan-map mode.

Modeling Approach

We use our collisional code ACE to simulate the collisional evolution of the q[1] Eri disk starting with an initial set up of planetesimals. The resulting SED and brightness profiles are then computed with SEDUCE and SUBITO. The procedure works as follows:



New Herschel Observations



Conclusions

Using the collisional approach we were able to reproduce new Herschel observations together with already existing data on the q[1] Eri debris disk with a planetesimal belt between 75 – 125 AU. In particular, SED and surface brightness profiles extracted from the new PACS images were modeled. The results are in general agreement with the outcome of classical modeling approaches. The extraordinarily high required disk mass may be an indication for the collisional evolution operating over much shorter timescales than the suggested stellar age of 2 Gyr. The lack of emission in the mid-IR in the SED and in the central parts of the 70 and 160 μm profiles can be a hint on an additional, unresolved inner disk component. Appreciable amounts of water ice admixtures are essential in the model. PACS spectroscopy follow-up observations have been requested to search for possible spectral features which are expected for ice in this spectral region.

The System

Star:
about 2 Gyr old F8V star at 17.43 pc

Planet (Mayor et al. 2003, Butler et al. 2006):
one 0.93 M_{Jup} mass at a = 2.03 AU with e = 0.1

Disk:
An IR-excesses was detected in the mid- and far-IR and in the radio. A mid-IR spectrum was obtained with IRS. Both HST and Spitzer were able to resolve the disk marinally.

References

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Mayor et al.,
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Vitense et al., ApJ ??, ??, 2010

Acknowledgements

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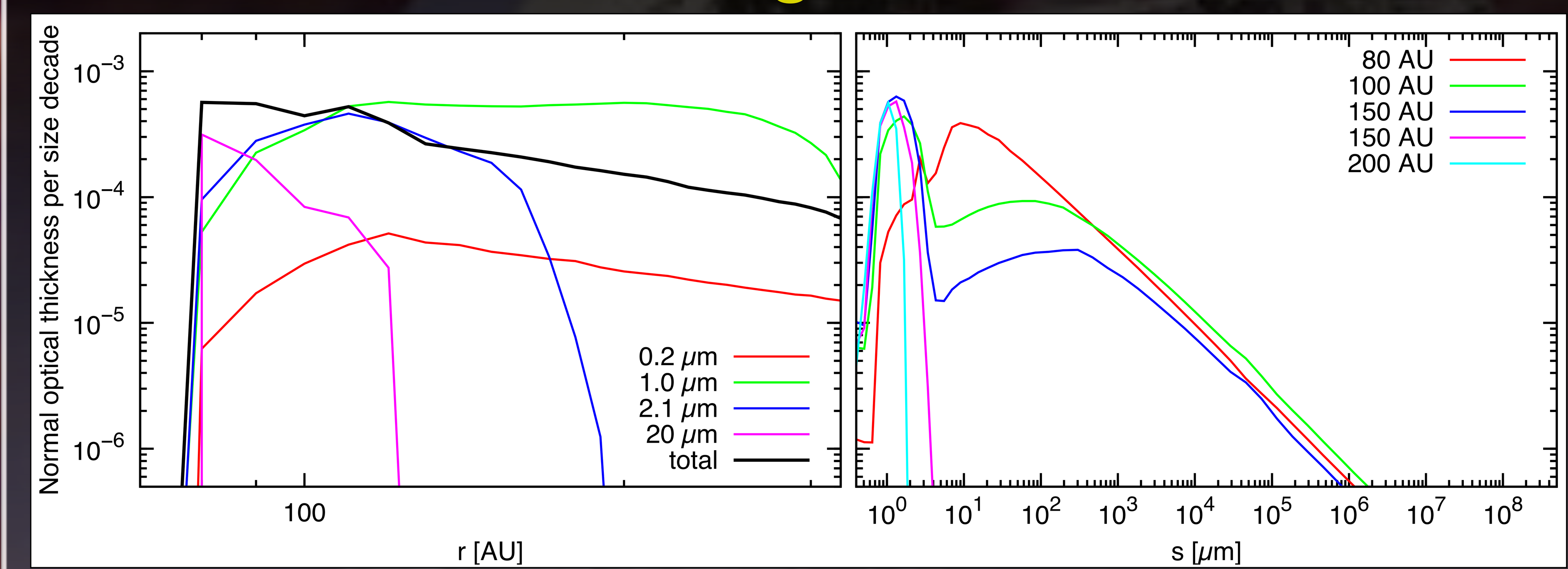
Collisional Modeling - Dust Distribution



In our best fit a silicate-ice mixture (50:50) was required. The material strength was relatively low. Most large objects remain within the planetesimal belt (75 – 125 AU), while grains < 0.7 μm are quickly removed from the system by stellar radiation pressure. The planetesimals' dynamical excitation was low (e < 0.05).

The best fit model comprises a total disk mass of 934 $M_\oplus$, implying an initial disk mass of 1,413 $M_\oplus$. This is unrealistically high, since the disk would probably be object to gravitational instability. However, assuming the disk to evolve for only 500 Myr the disk mass can be reduced to realistic values of 102 $M_\oplus$ (initially 206 $M_\oplus$).

Comparison with Classical Modeling

Traditionally, debris disks are modeled under the assumption of dust distributions of the kind $N \sim r^{-\xi} s^{-\eta}$. In the DUNES modeling team two routines have been developed:

- GRaTer (LAOG, France): Bayesian analysis of the parameter space
  $3.9 \times 10^{-2} M_\oplus$ between 74 – 600 AU with $\xi = 2.0$ and $\eta = 1.3$
- SAnD (Kiel, Germany): Simulated annealing
  $2.9 \times 10^{-2} M_\oplus$ between 4 – 184 AU with $\xi = -1.2$ and $\eta = 1.8$
  caution: outward increasing surface density!

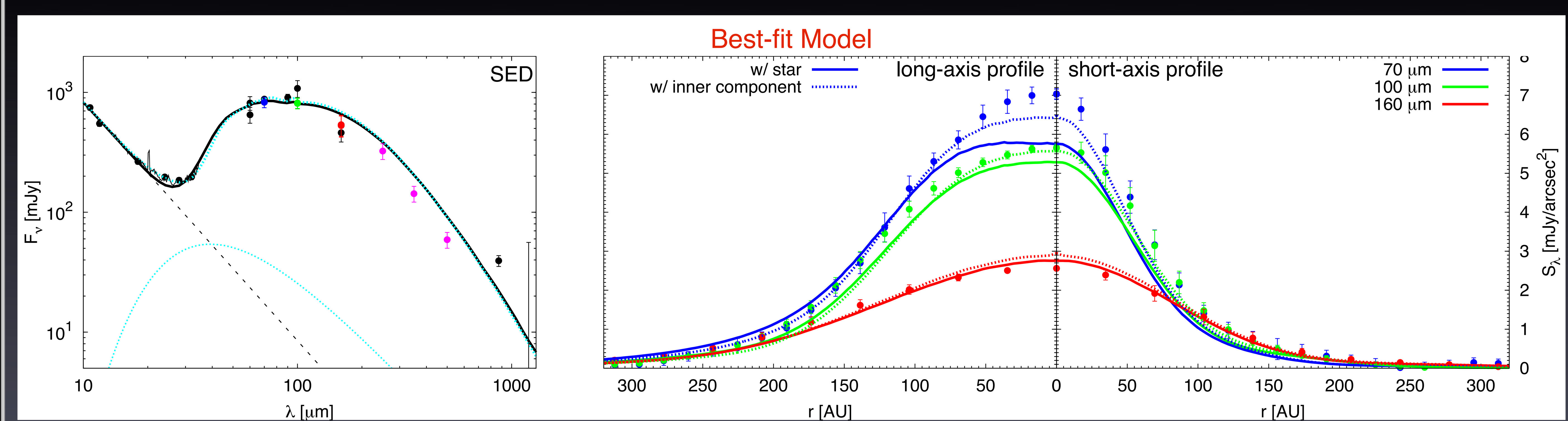
Like in the collisional approach silicate-ice mixtures improve the fits.

The classical approach provides higher dust masses. This is because the power-law size distributions are in general flatter than the simulated ones.

Advantages and disadvantages of the two approaches:

Collisional Modeling	Classical Modeling
☺ deep physical modeling from the sources	☺ fast exploration of large parameter space
☺ realistic description of disk properties	☺ limited initial constraints
☺ information about unseen planetesimals	☹ simplistic description of disk properties
☹ computationally demanding	☹ no direct link to planetesimals

Collisional Modeling - Thermal Emission



SED and brightness profiles along the long and short (only marginally resolved) axis show reasonalbe agreement (solid lines). Still, there is a lack of short wavelength emission in the mid-IR SED and the 70 and 160 m profile, which cannot be explained with stellar emission. A possible solution is an additional, unresolved inner component. Adding a 130 K blackbody (≙ 5 AU) improves the fit significantly (dotted lines). However, required dust mass appears unrealistically high. It corresponds to ?? times the presumed Kuiper belt (Vitense et al. 2010), or ?? times the asteroid belt.