Time dependent 3D radiative transfer of AGB stars and their dust

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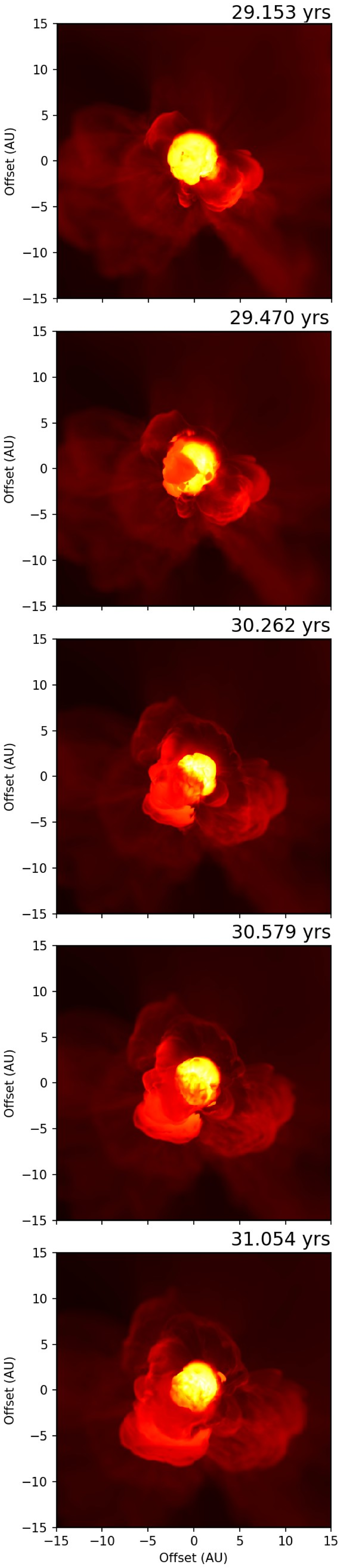
Abstract

During the asymptotic giant branch (AGB) phase, low-to-intermediate mass stars (0.8 - 8 $M_\odot$) are characterised by strong mass loss. Important chemical elements (e.g. carbon) produced in their stellar cores are transported by convection to the surface and by intense stellar winds to the interstellar medium. Crucial for these outflows is the formation of dust. Silicate dust (e.g. Mg_2SiO_4) can form close to the surface of O-rich AGB stars and is a prime candidate for driving the wind, since grains of sizes between 0.1 to 1 μm experience strong radiation pressure due to scattering.

The EXWINGS team develops global radiation-hydrodynamical (RHD) simulations with CO5BOLD to model the interior of giant stars, outflow of gas, and formation of dust. The first 3D 'star-and-wind-in-a-box' models were presented by Freytag & Höfner (2023). We have, as well, successfully translated such data for radiative transfer computations with RADMC-3D. First radiative transfer results of one time snapshot of one model are published by Wiegert et al. (2024). Here, we showcase time dependent synthetic observables (images and spectra) of two models with different dust formation efficiency (sticking coefficients, α_{Stick}).



This is part of ongoing work to study the effects and dynamics of clumpiness, porosity, other asymmetric morphologies in circumstellar environments, and observability of the vicinity of AGB stars.

Basic parameters

Models:
- st28gm06n052
  α_{Stick} = 1
- st28gm06n074
  α_{Stick} = 0.1

Stellar radius:
~355 $R_\odot$

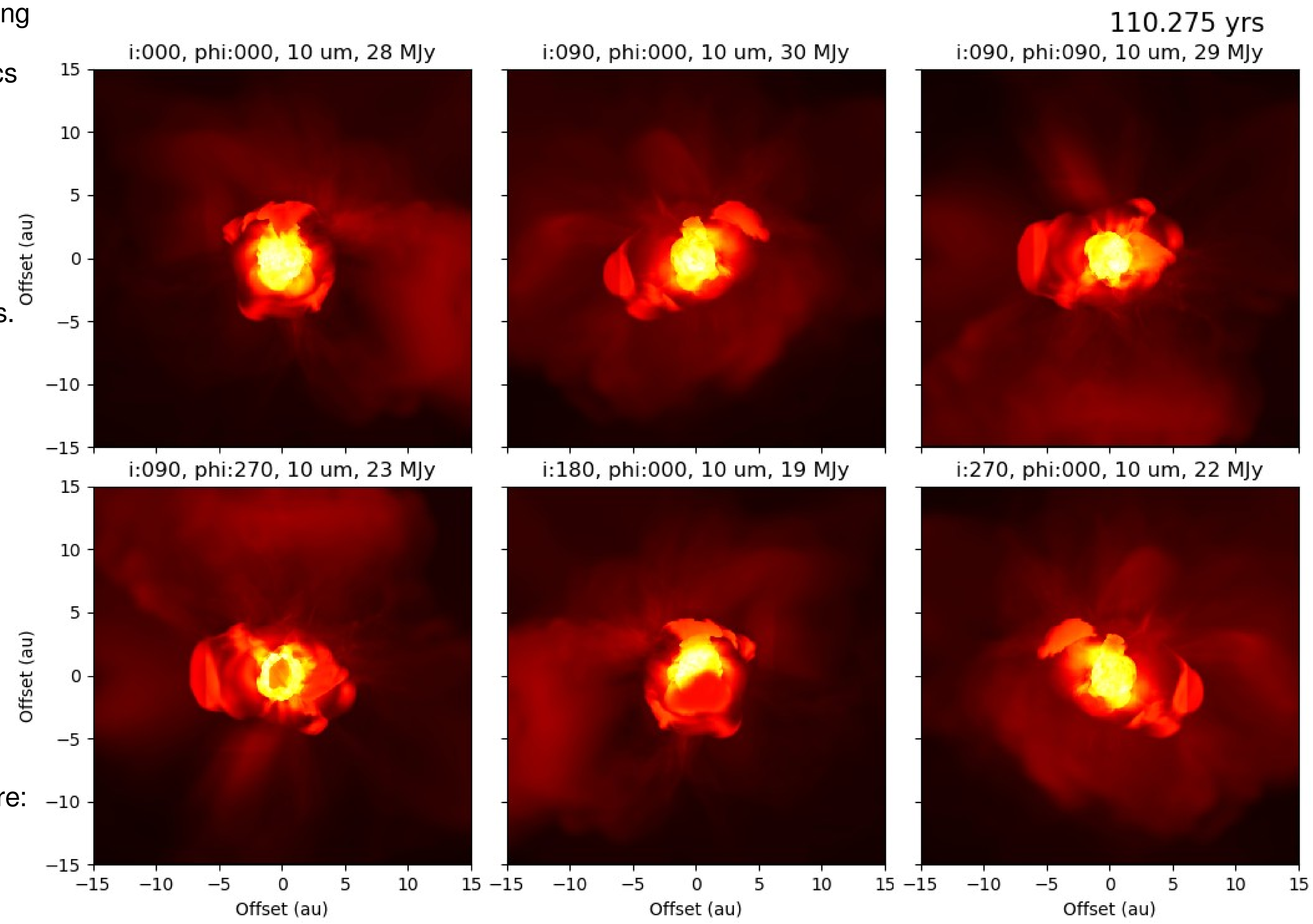
Stellar luminosity:
~7000 $L_\odot$

Stellar Mass:
1 $M_\odot$

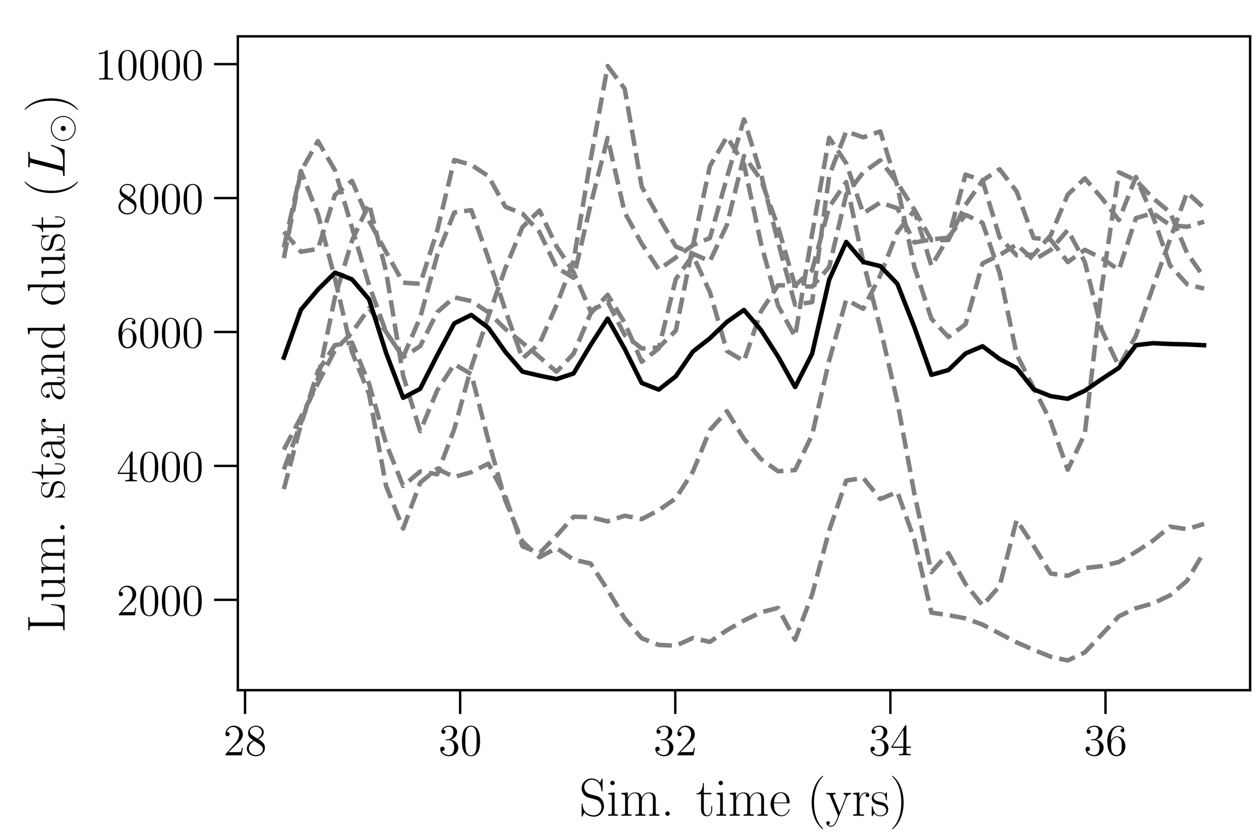
Effective temperature:
~2800 K

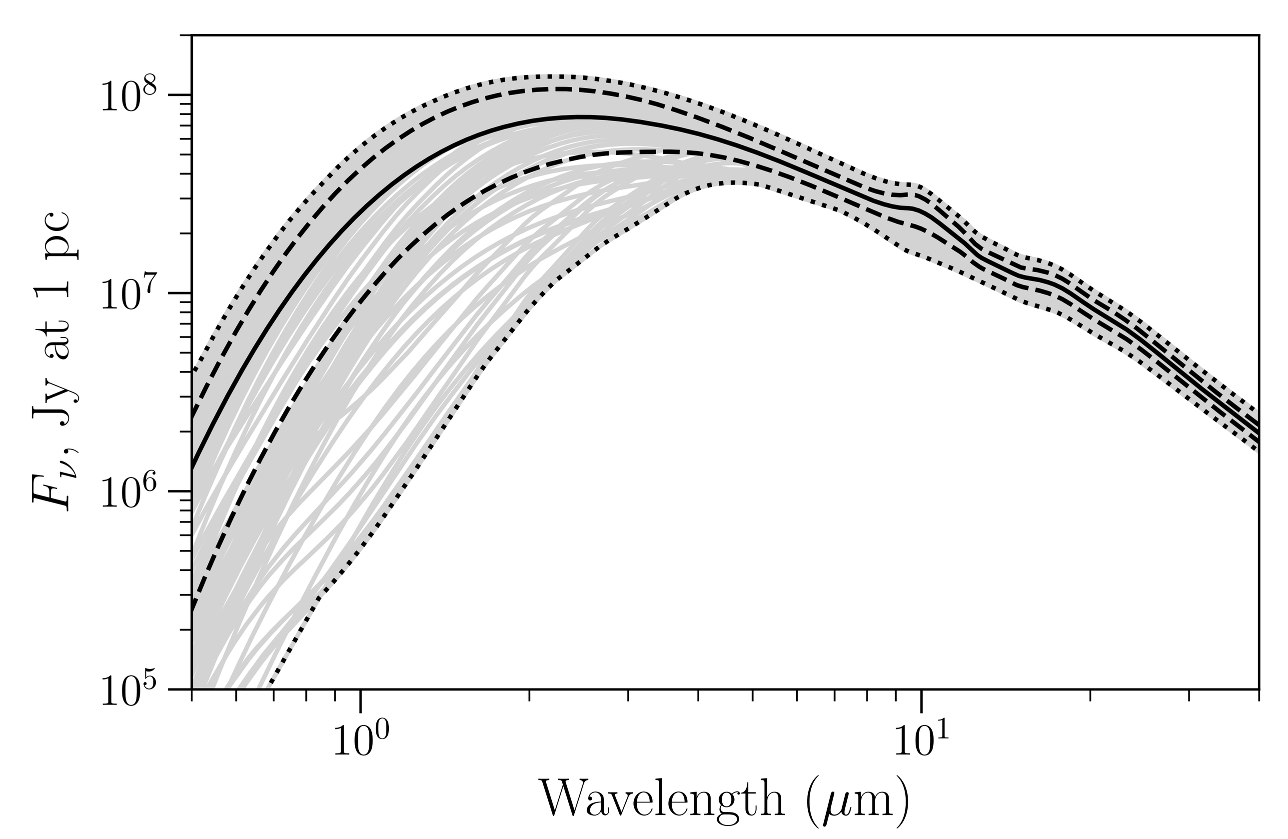
Dust composition:
Mg_2SiO_4

Computation box size:
30^3 AU^3



Above: One time snapshot of model st28gm06n074 shown in six different viewing angles as indicated above each panel. Images are at the wavelength 10 μm to show silicate dust emission.





Above left: Bolometric luminosities of st28gm06n052. Dashed lines show integrated flux densities in six different directions. Black line shows the average luminosity.

Above right: SEDs of all six viewing directions from all time snapshots (simulated so far) of st28gm06n074. Black line shows average flux densities, dashed line are standard deviations.

Left: A time sequence of simulated images at 10 μm, showcasing the formation and dissipation of one major dust cloud in st28gm06n052.

RADMC-3D: Monte Carlo-based radiative transfer in 3D (Dullemond et al. 2012). https://www.ita.uni-heidelberg.de/~dullemond/software/radmc-3d/

CO5BOLD: COnservative COde for the COmputation of COmpressible COnvection in a BOx of L Dimensions with L = 2, 3. Simulates convection, pulsations, waves, shocks, and winds of various types of stars (Freytag et al. 2012).

Project EXWINGS aims to understand the winds of cool (super)giant stars. https://www.astro.uu.se/exwings/index.html

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