Evolved stars and their dust production

Flavia Dell'Agli

& the STARDUST collaboration:

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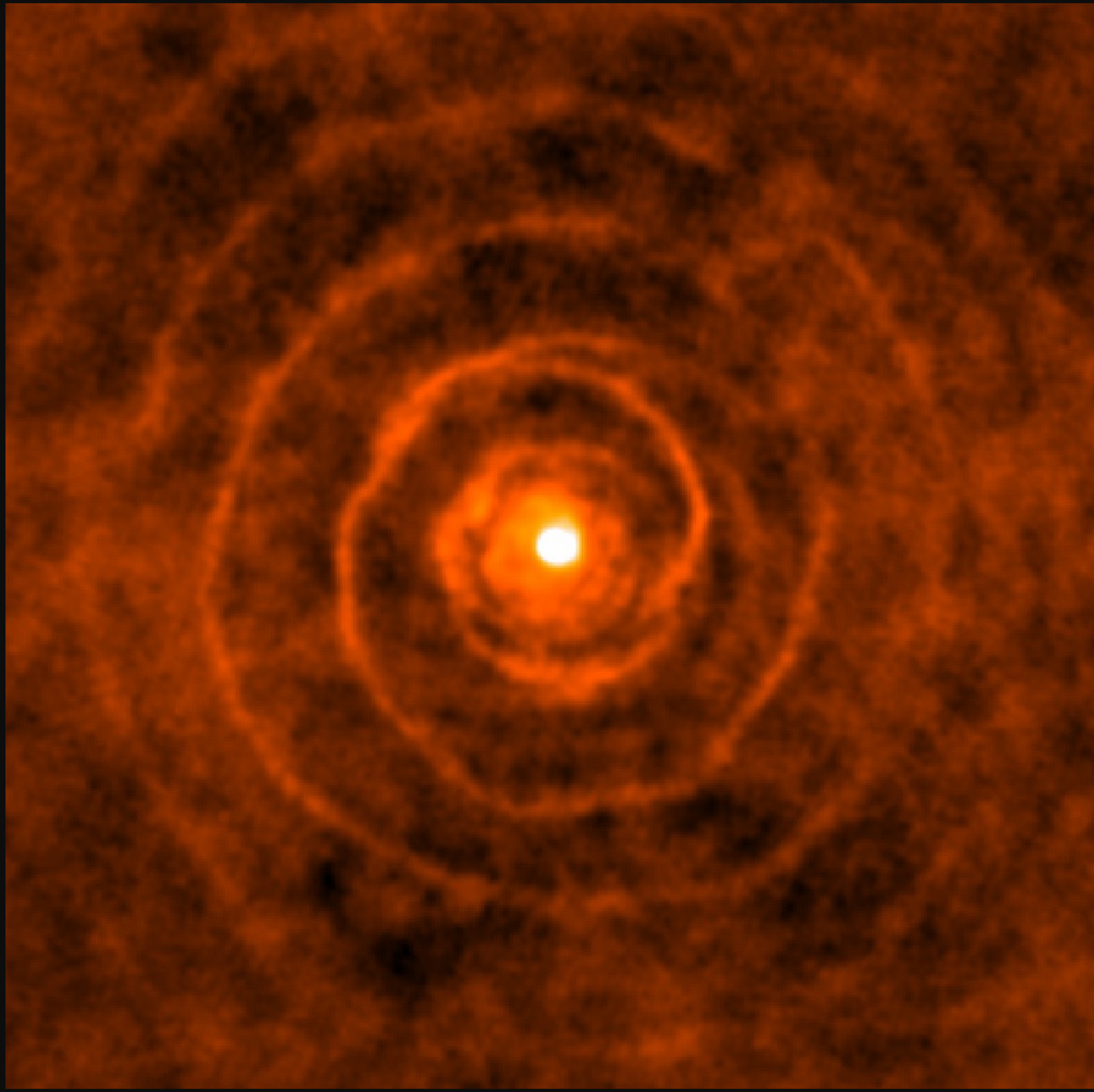


Figure: Kim et al. 2017, Nature Astronomy, 1, 60

Low-intermediate mass stars during their final phases (asymptotic giant branch, AGB):

Gas reprocessed by the internal nucleosynthesis

+

Dust production in their circumstellar envelope

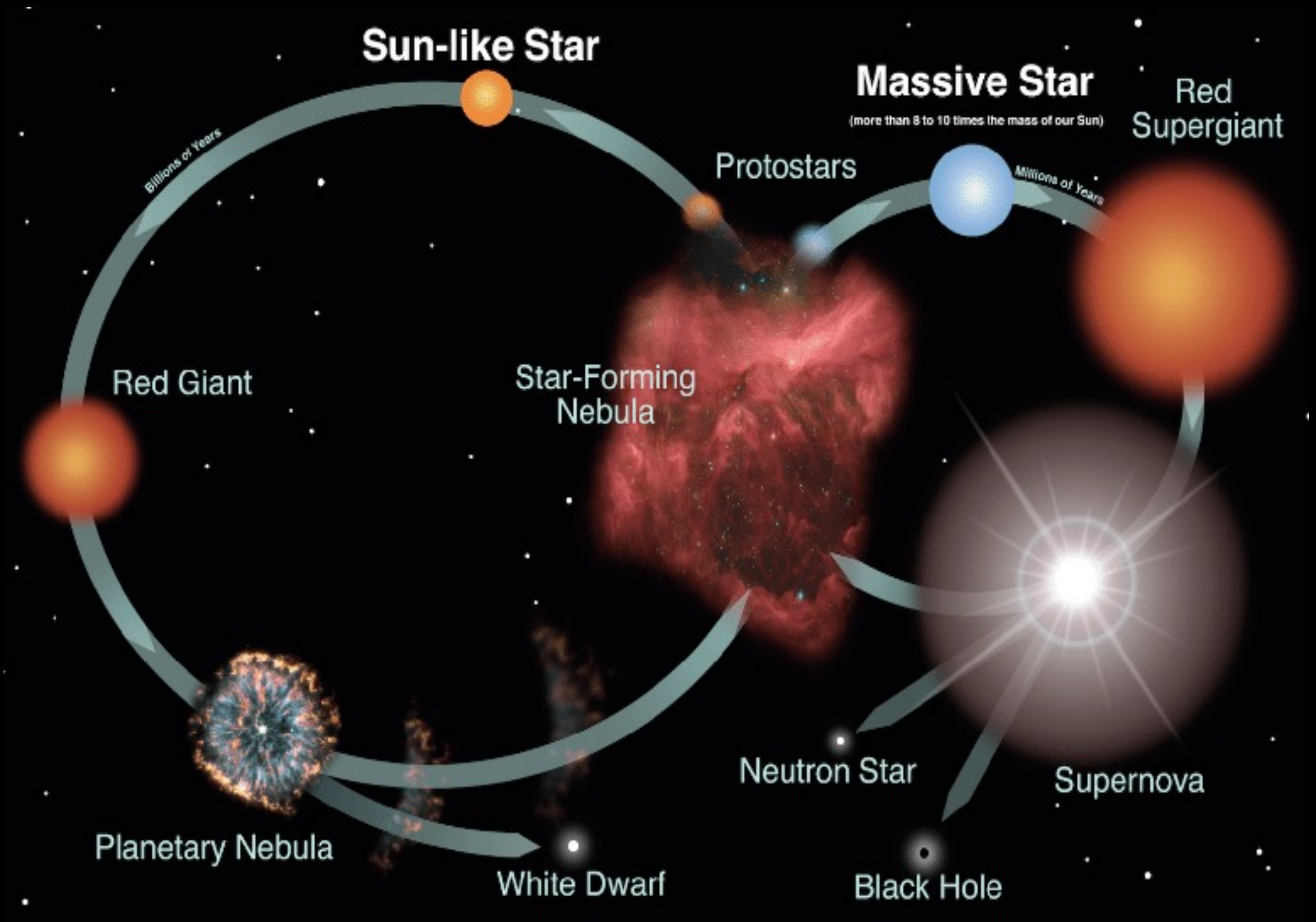


Figure credits: NASA/JPL, Astronomical Society of the Pacific).

Last decade:

Early '10s

Modelling dust production from low-intermediate mass stars during the asymptotic giant branch (AGB) phase (e.g. Ventura et al. 2012a, b, Nanni et al. 2013a, b….)

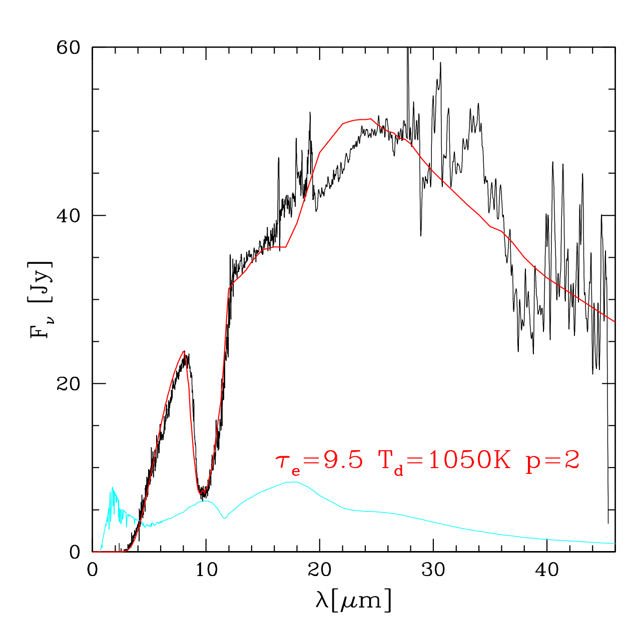
2012-today

ATON code @OAR: Yields of dust for a wide range of masses and metallicities (Ventura et al. 2014, 2018, 2020, Di Criscienzo et al. 2013, Dell'Agli et al. 2014, 2017, 2019)

2014-today

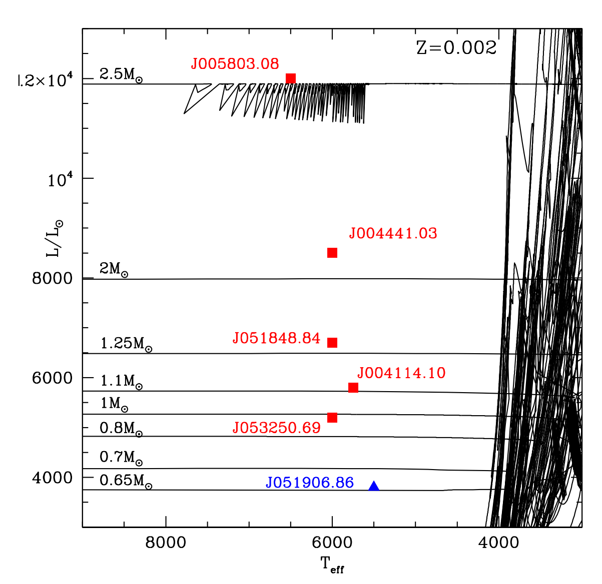
Dust production rate and dust budget in the Magellanic Clouds (Schneider et al. 2014; Dell'Agli et al. 2015a, b; Marini et al. 2019a, b, 2020, 2021) and in the Local Group dwarf galaxies (Dell'Agli et al. 2016, 2018, 2019)

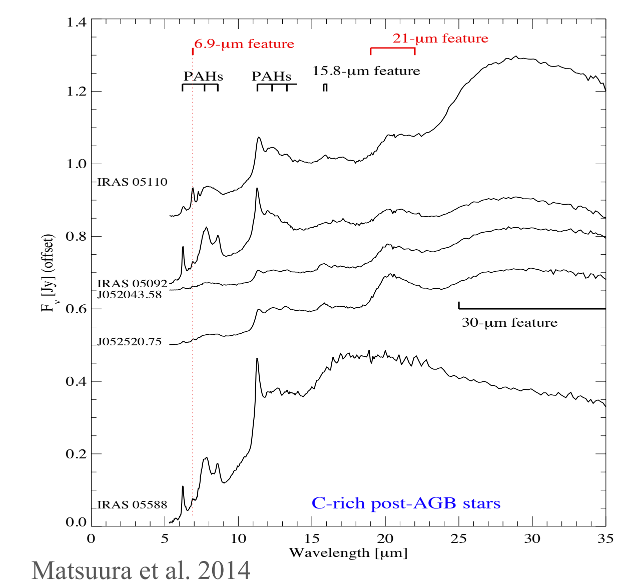
Ongoing



Galactic AGBs and their ISO spectra (Marini et al. in prep.)

PostAGBs: characterization and mass-loss history
(Tosi et al. in prep.)

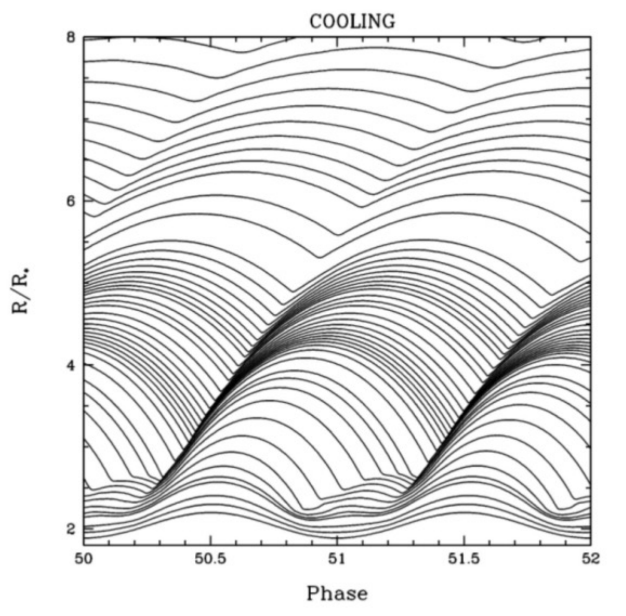


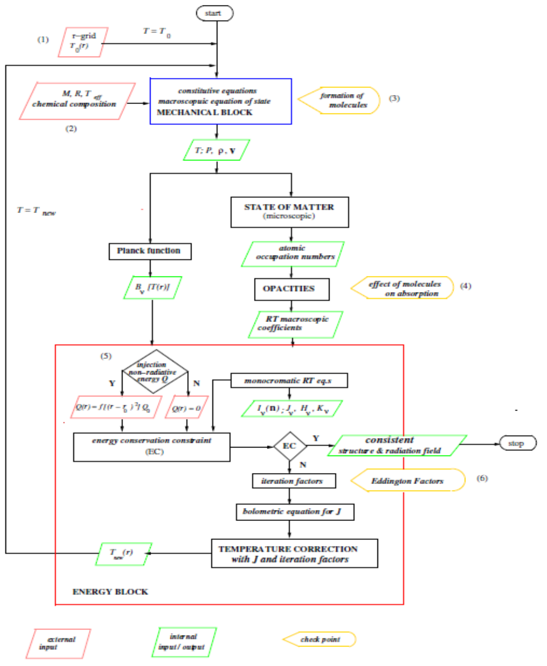


PAHs: network for their computation
(Carini et al. in prep.)

The VULCAN code

- VULCAN **follows the propagation of shocks in the circumstellar envelopes of AGB stars.** Hydrodynamic equations are solved explicitly in a lagrangian scheme.
- The chemical network implemented contains 114 species and 474 reactions. It is similar to the network used in Gobrecht et al. (2016).
- Radiative Transfer is implemented with the Implicit Integral method, which avoid convergence problems at large optical depths.
- We aim at coupling this hydro code with the *FUNS* stellar evolutionary code.





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Article

AGB Stars and Their Circumstellar Envelopes: An Operative Approach to Computing Their Atmospheres

Lucio Crivellari [1,2,*], Sergio Cristallo [3,4] and Luciano Piersanti [3,4]

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Article

AGB Stars and Their Circumstellar Envelopes. I. the VULCAN Code

Sergio Cristallo [1,2,*], Luciano Piersanti [1,2], David Gobrecht [3], Lucio Crivellari [4,5] and Ambra Nanni [6]

Dust nucleation

Gobrecht+ 2017

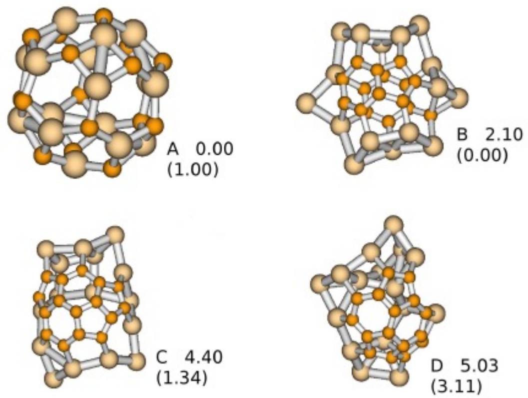
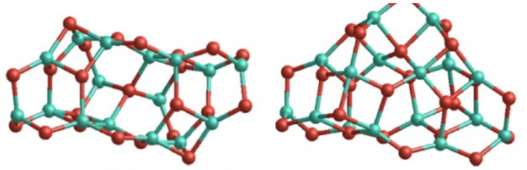
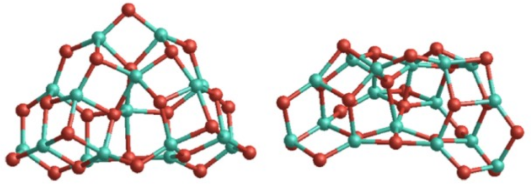


Figure 21. Stable isomers of $Si_{16}C_{16}$ clusters.

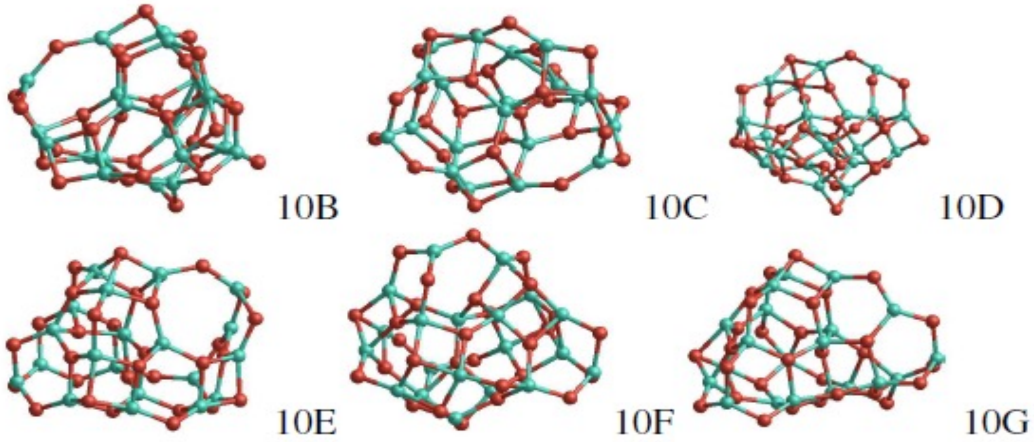
Gobrecht+ 2018



ninimum structure 8A at the B3LYP/6-311+G(d) level seen from two distinct perspectives (that are perpendicular to each c
red. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this ar



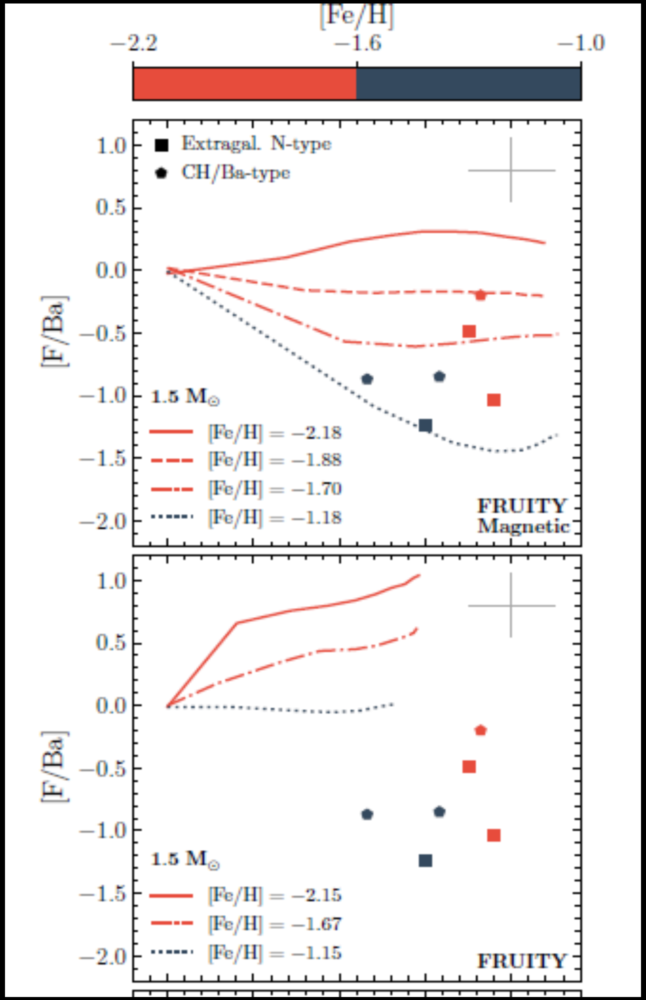
Gobrecht+ 2022



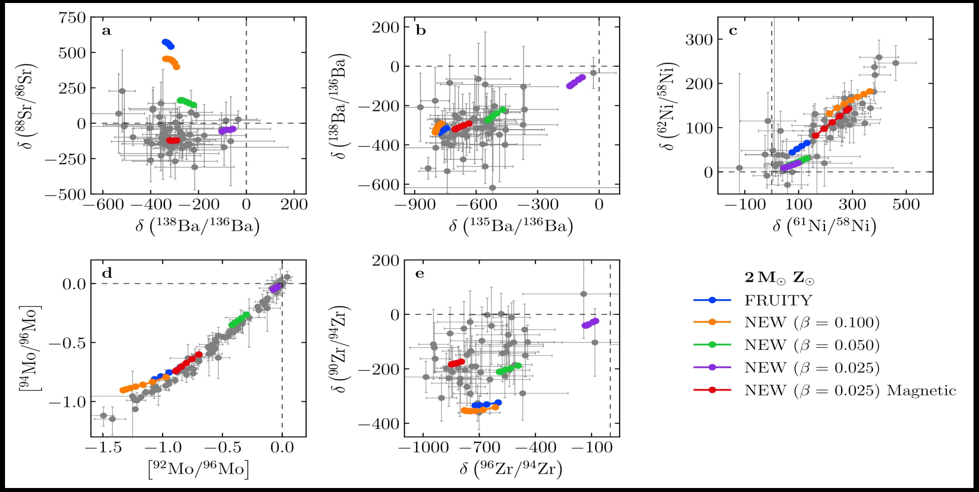
- Sub-nanometer sized objects like clusters of molecules and dust grains regulate the rate at which the star looses its material.
- The idea is to use chemical reactions for clusters of molecules up to the maximum size allowed by computer power, time, feasibility, followed by a solid-state treatment.
- A bottom-up approach, starting with prevalent molecules in the gas phase (e.g. SiC, SiO) and successive growth to clusters by molecular (addition) reactions, seems to be suitable.
- We intend to confine the cluster size, at which the transition from a quantum cluster to periodically ordered crystal occurs.

APES: Advanced phases of evolving stars - P.I.: Luciano Piersanti

Magnetic induced mixing



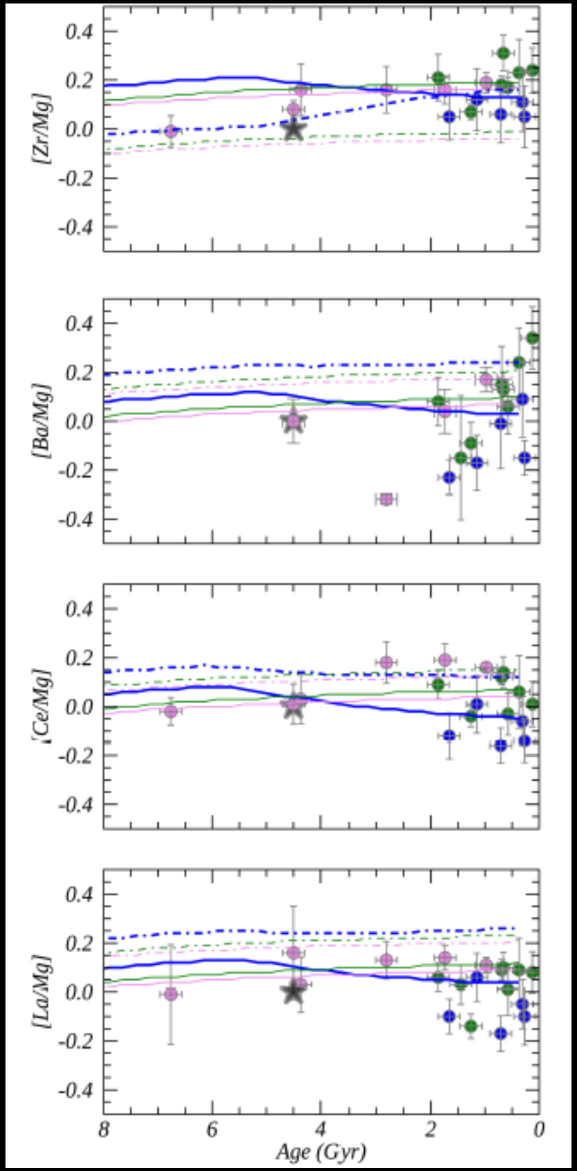
Vescovi+ 2021



Vescovi+ 2020

Better agreement with:

1. Presolar grains;
2. Young Open Clusters;
3. Fluorine @ low Z.

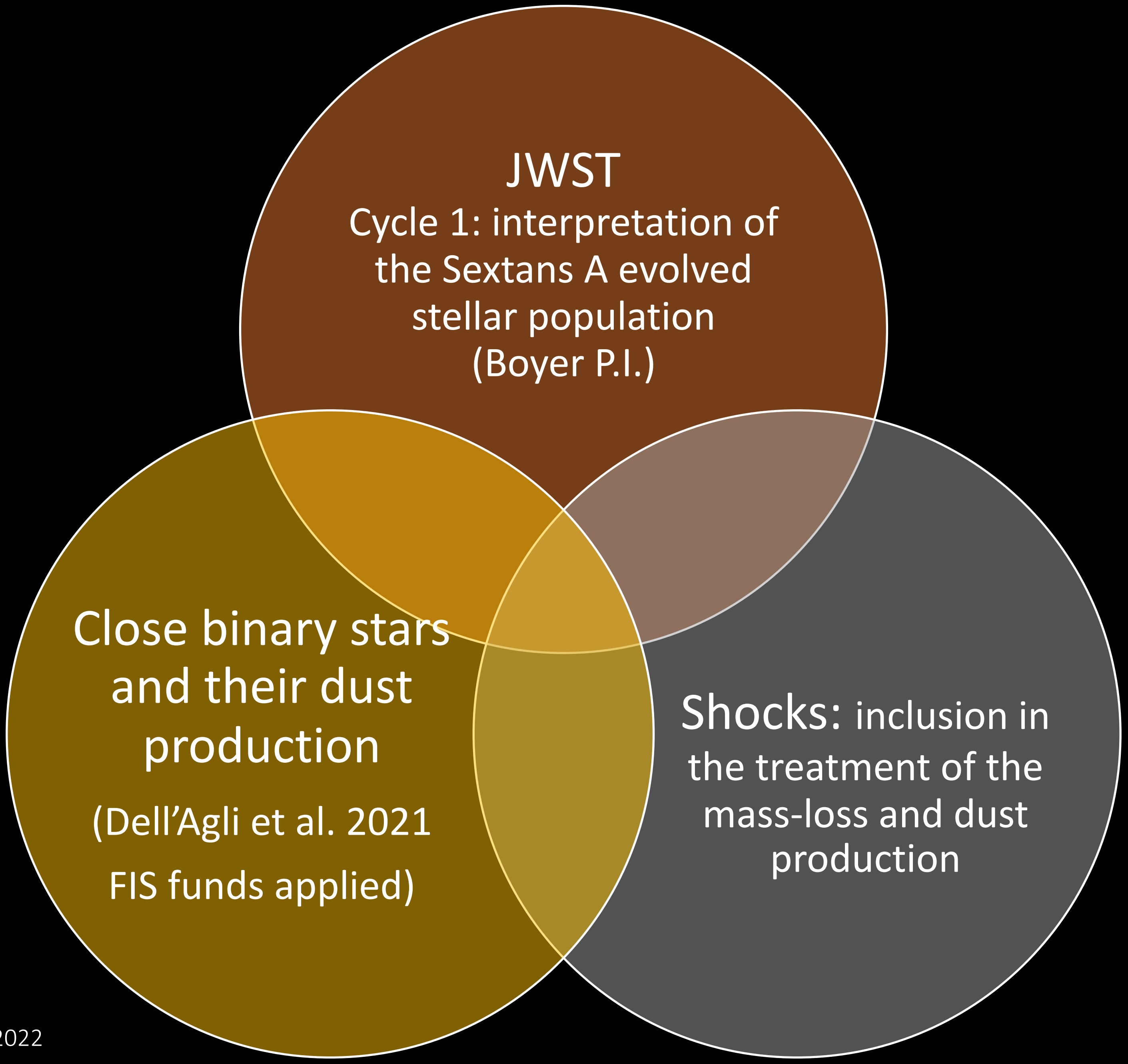


Magrini+ 2021

GIANTS: Gruppi Italiani di Astrofisica Nucleare Teorica e Sperimentale – P.I. Oscar Straniero

- *Objectives*: Understanding the synthesis of the elements requires a precise knowledge of the nuclear cross sections at the physical conditions experienced in stellar interiors and in the early Universe.
- *4 international collaborations*: LUNA 400 kV + LUNA MV (INFN-LNGS); ERNA (Uni Vanvitelli-CIRCE lab); n_TOF (CERN); PANDORA (INFN-LNS).
- *Last year most relevant results*:
  1. Measure of the $^{13}C(a,n)^{16}O$ reaction rate, the most important neutron source for the s process in AGB stars (Ciani et al, 2021, PhysRevLett. 127.152701);
  2. In the more general framework of a CNO cycle review, a detailed study of the low-energy resonances of the $^{17}O(p,g)^{18}F$ reaction (Pantaleo et al. 2021, PhysRevC 104.025802);
  3. Destruction of the cosmic γ -ray emitter 26Al in massive stars: Study of the key $^{26}Al(n,p)$ reaction (Lederer-Woods 2021 PhysRevC 104.L022803)

STARDUST future perspectives:



Leadership

International reference point for the AGB evolution and dust production in their circumstellar envelope

> 70 publications

3 international conferences organized; > 5 invited and review talks on the topic

Critical areas

Funds to sustain the activities

Thank you!