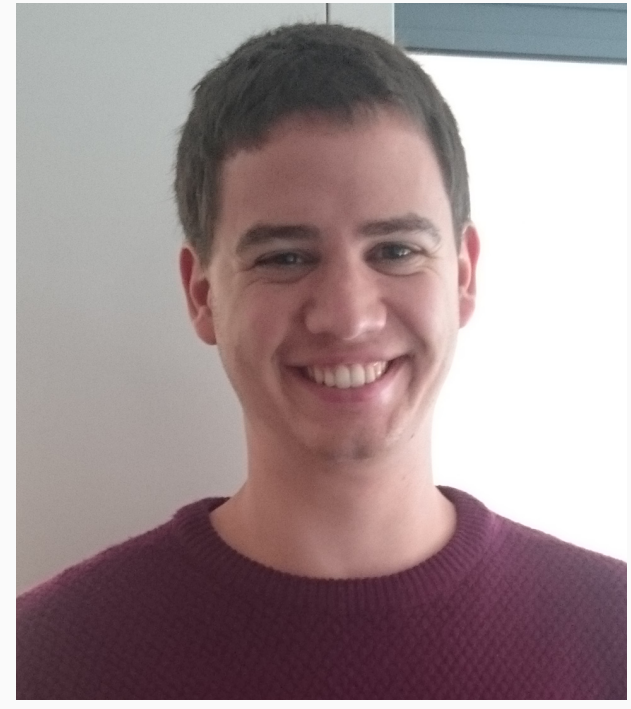




Cesam2k20: A community stellar evolution code



L. Manchon¹, M. Deal², Y. Lebreton^{1,3}, and J. P. C. Marques⁴

¹LESIA, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Université de Paris, 92195 Meudon, France

²LUPM, Université de Montpellier, CNRS, place Eugène Bataillon, 34095 Montpellier, France

³Université de Rennes, CNRS, IPR (Institut de Physique de Rennes) – UMR 6251, 35000 Rennes, France

⁴IAS, Université Paris Saclay, Orsay, France



Many names, one code

- CESAM : *Code d'Evolution Stellaire, Adaptatif et Modulaire*. Early developments by Pierre Morel (OCA) back to 1989. [Morel+1997](#)
 - CESAM2k : CESAM of the 2000s. Modernization in Fortran 90 (P. Morel, B. Pichon, and many others !); [Morel&Lebreton+2008](#)
 - CESTAM : T = Transport. Implementation of angular momentum transport by J. P. C. Marques [Marques+2013](#)
 - Cesam2k20 : Most recent, and public, version. ([Manchon, in prep](#) ; [Deal, in prep](#)).
- Current developers : M. Deal, Y. Lebreton, J. P. C. Marques, L. Manchon.

A modular code

Written in modern Fortran.

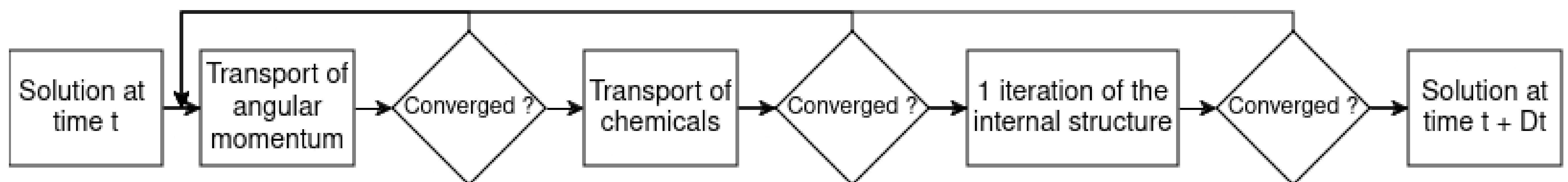
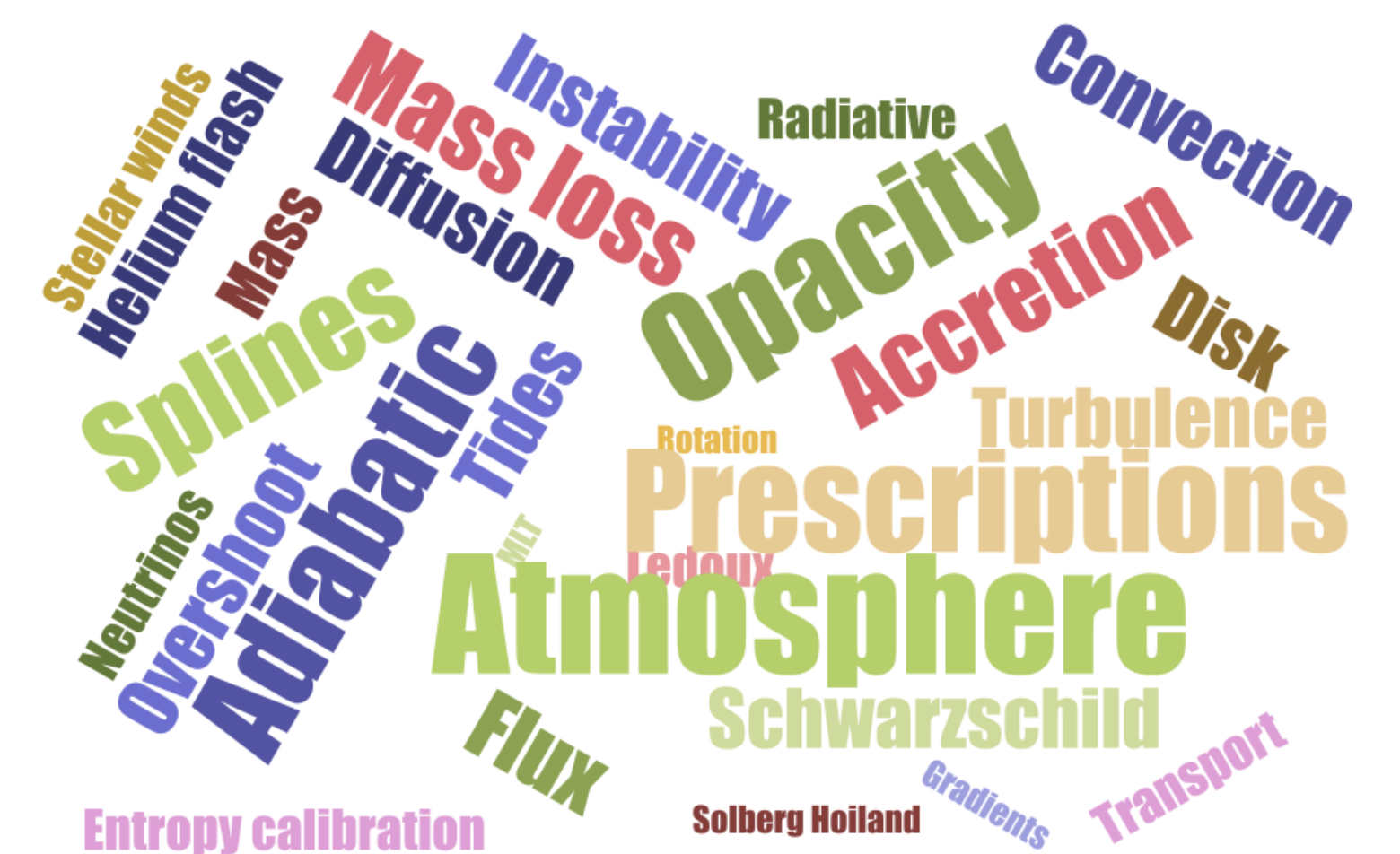
Two layers: Physics / Numerics.

No need to have a deep knowledge of the code to implement new physical ingredients.

A Python module designed for the post-processing: `pycesam`.

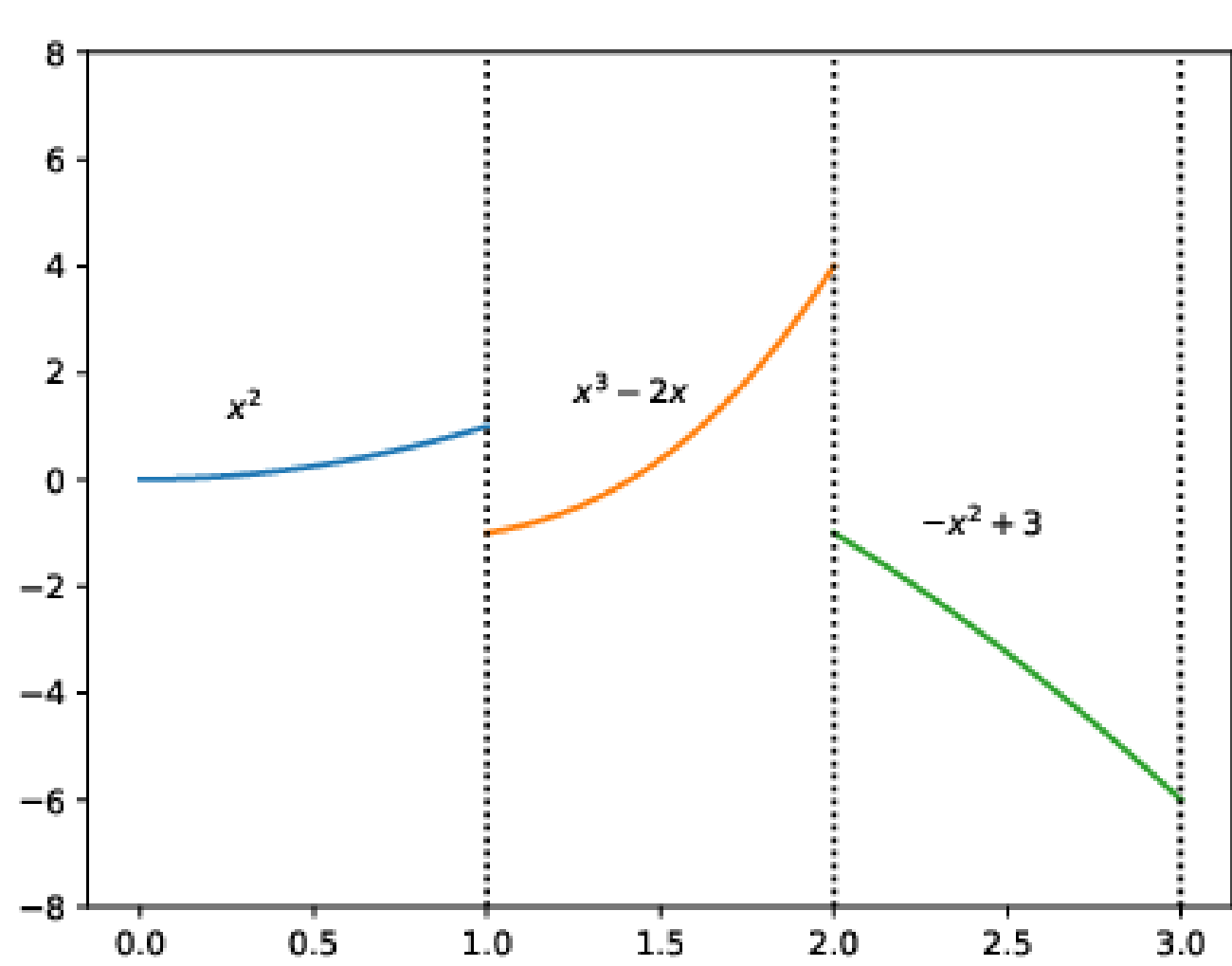
> 400 pages of documentation.

Used in workshops or practical work for students in astronomy.



Some features

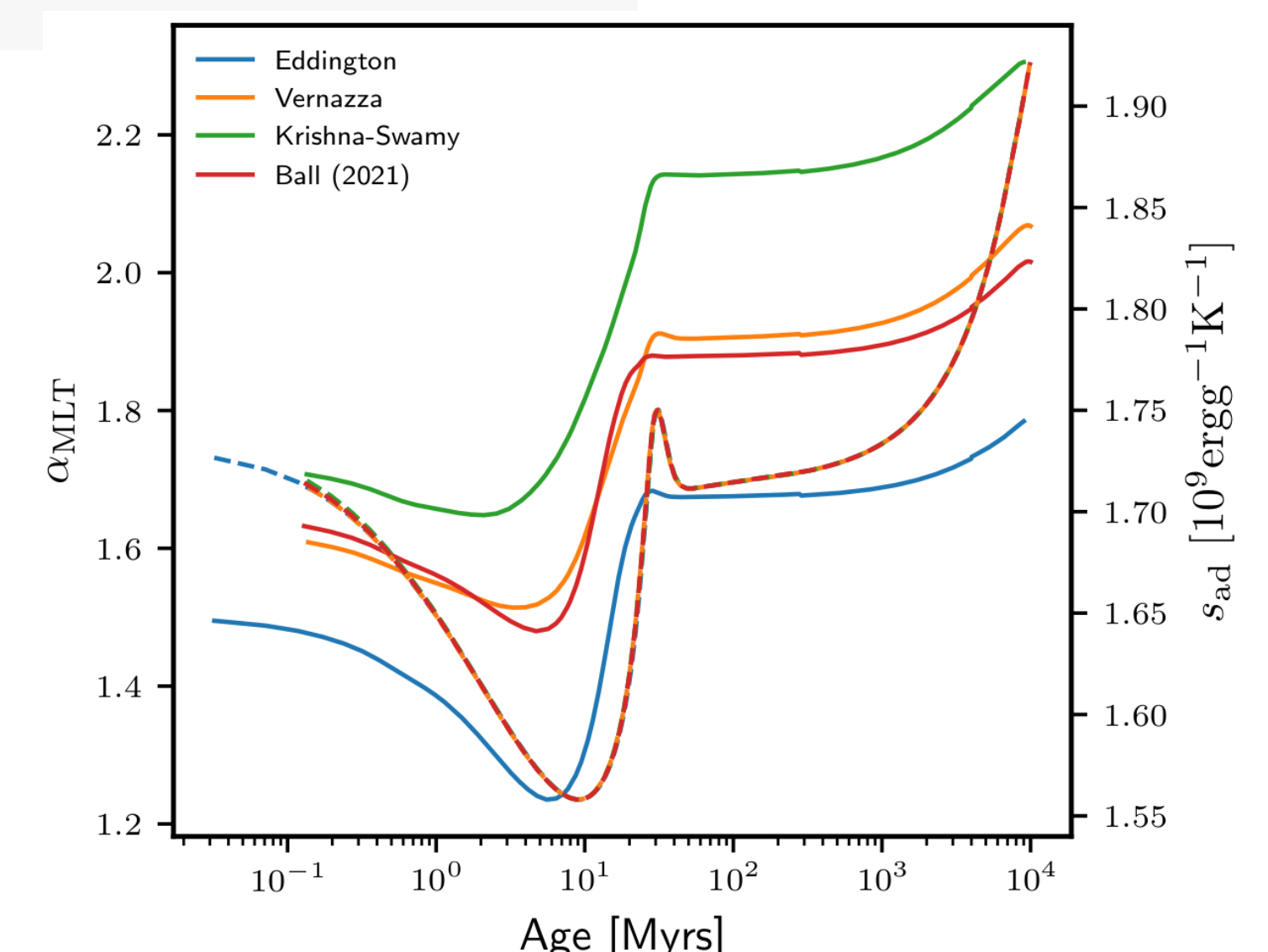
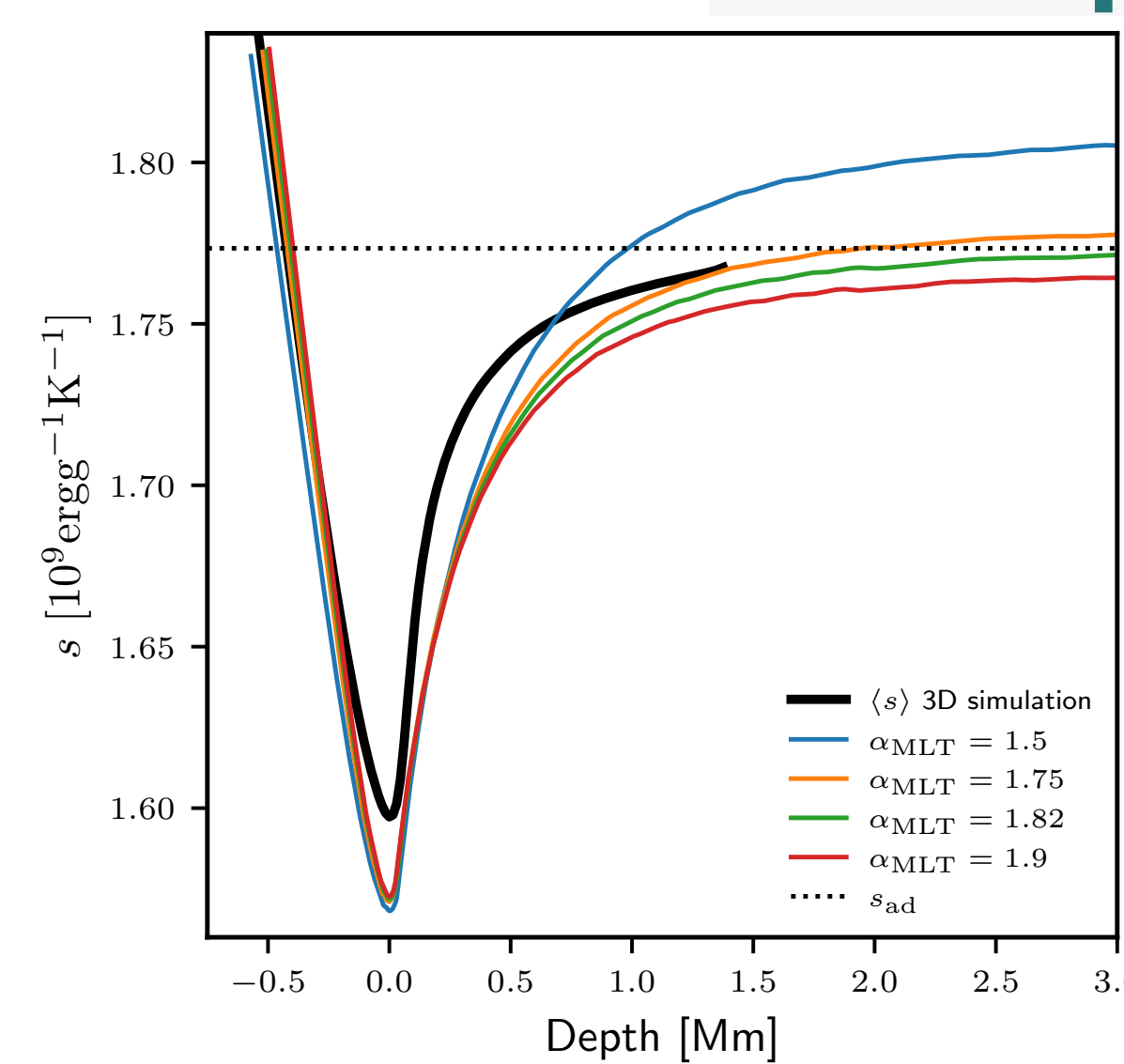
Numerical methods



- Unknowns \rightsquigarrow order m piecewise polynomial functions (PPF), used for structure, chemical composition, angular velocity, etc.
- Possible to set the degree of discontinuity at break-points.

- \Rightarrow Different meshes for structure, chemicals, angular velocity, etc.
- PPF are projected on a local basis of normalized splines \rightarrow Eqs. are only solved for coeffs. of these PPF.

Entropy calibration



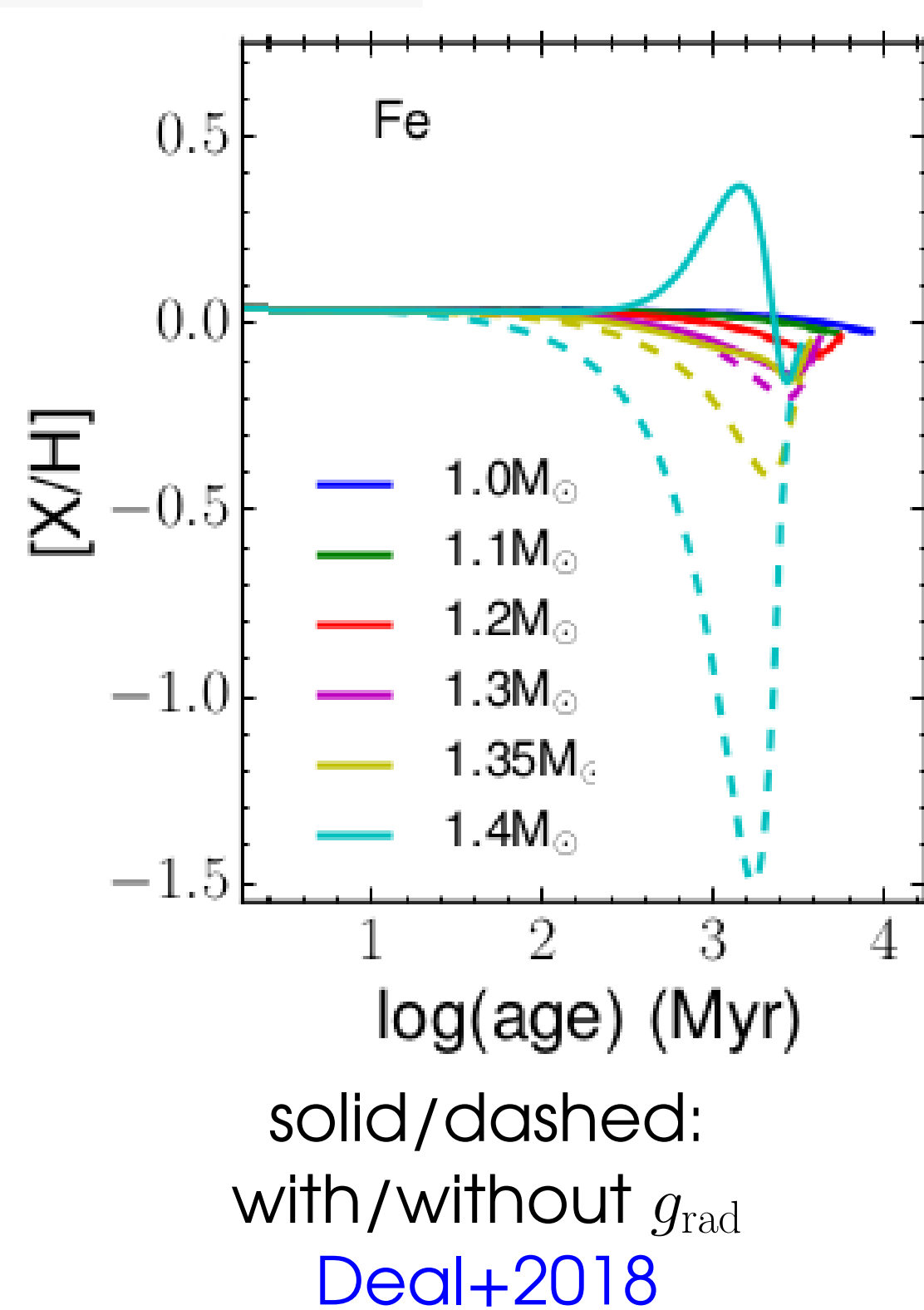
Adjust α_{MLT} during evolution so that entropy of adiabat matches a prescription (based on 3D models).

[Manchon+2024](#)

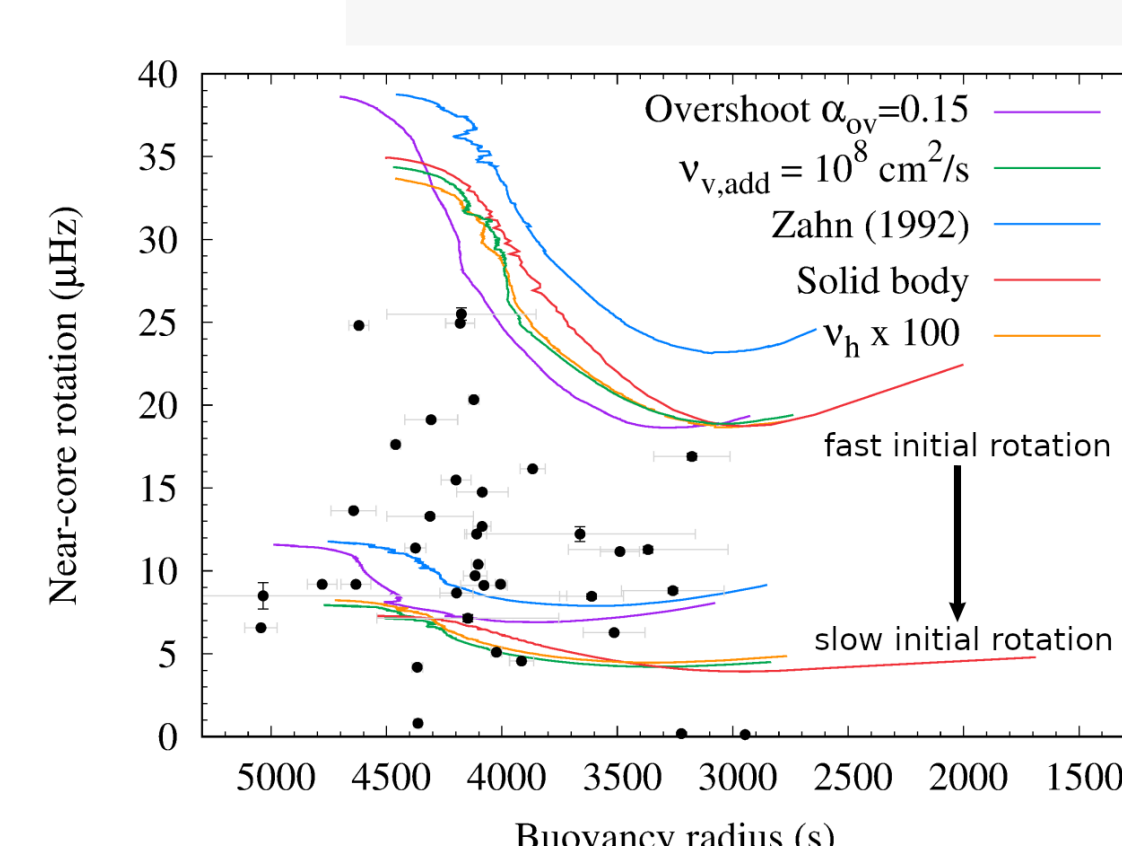
Diffusion of chemicals

Many options for the diffusion:

- **Gravitational settling:** [Michaud & Proffitt 1993](#) or [Burger 1983](#);
- **Turbulent diffusion:** Fingering convection, shear-induced, ad hoc, ...
- **Radiative accelerations:** see [Deal+2018](#); [Moedas+2022,2024](#).



Transport of angular momentum



[Ouazzani+2019](#)

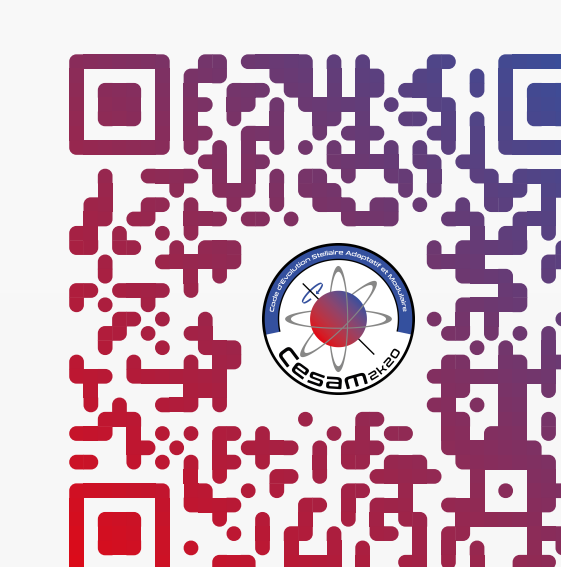
Long history with transport of angular momentum.

- Advecto-diffusive process (meridional circulation / shear-induced turbulence).
- Includes additional transport processes: (M)HD instabilities, waves.
- 2D features

Public release:



New workshop:



The DYNAMOS team:

