CONVECTIVE-REACTIVE NUCLEOSYNTHESIS IN CONVECTIVE O-C SHELL MERGERS

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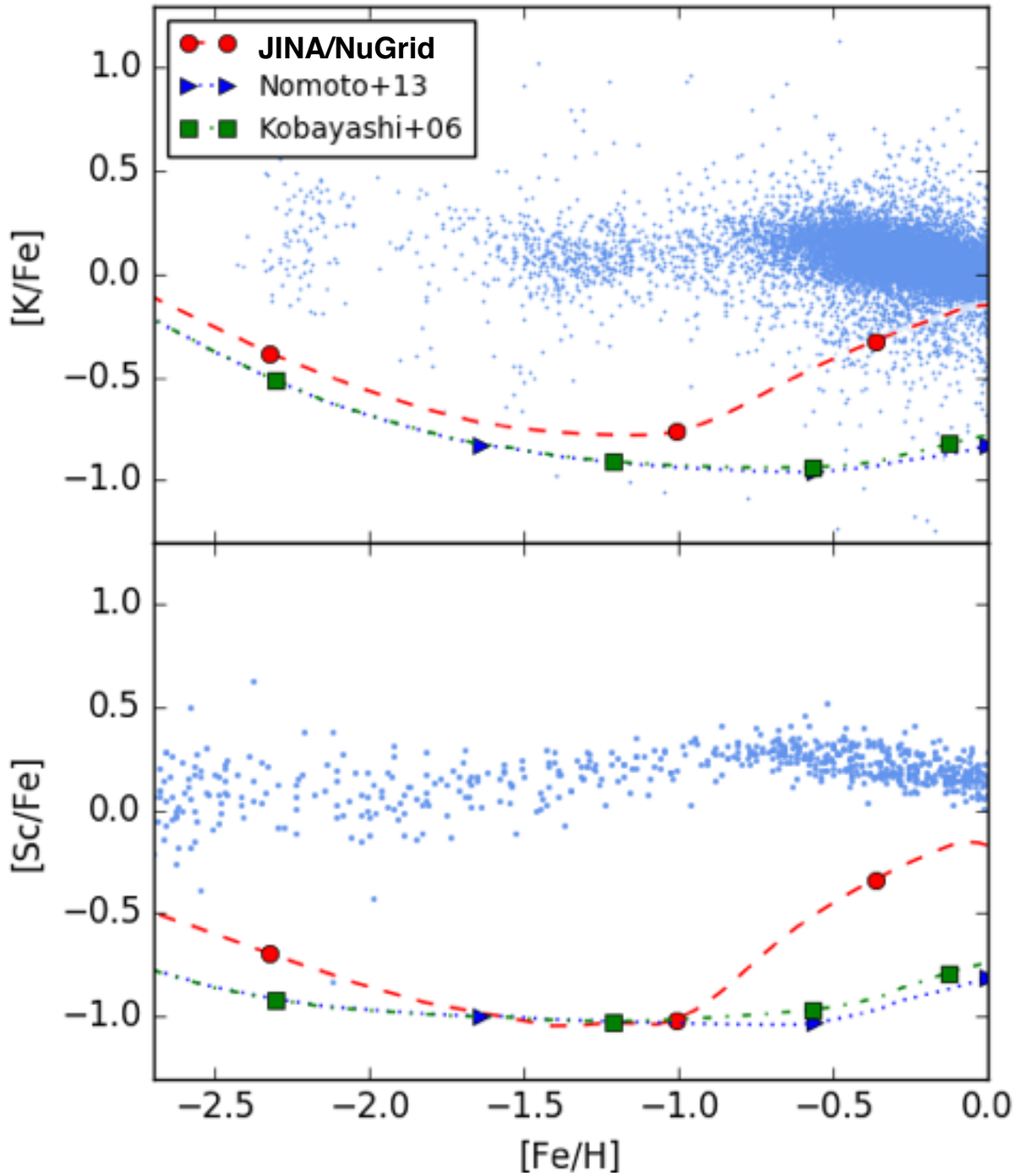
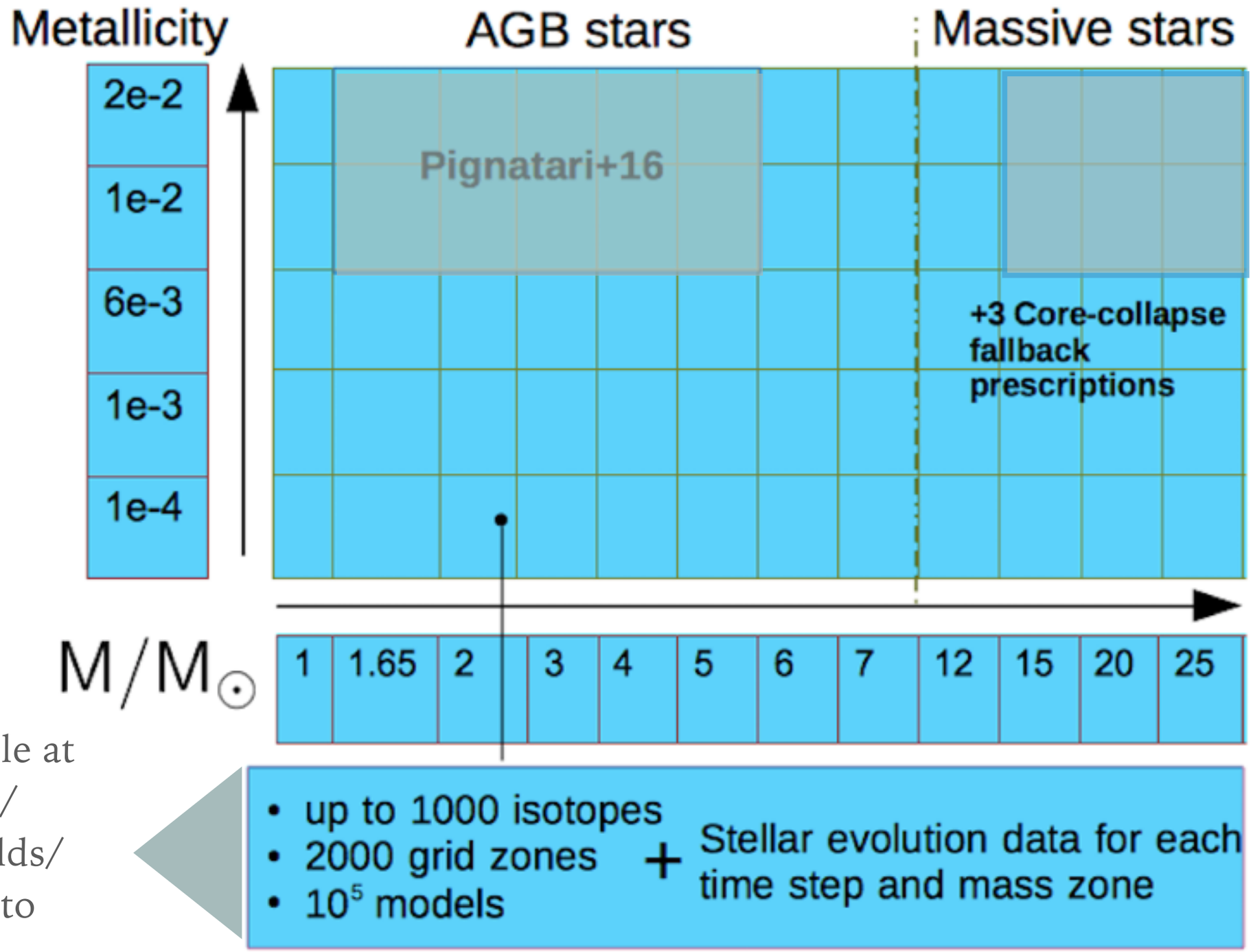
THE ORIGIN OF K AND SC

- Underproduction of odd-Z elements K and Sc in Milky Way models compared to disk and halo stars
- Several production mechanism have been considered for Sc: vp process (Froehlich+06), jet-induced SN explosions (Tominaga 09), hypernova (Sneden+16)



Milky Way data references: APOGEE R13, Battistini+15, Roederer+14, Ishigaki+12/13

JINA/NUGRID YIELDS

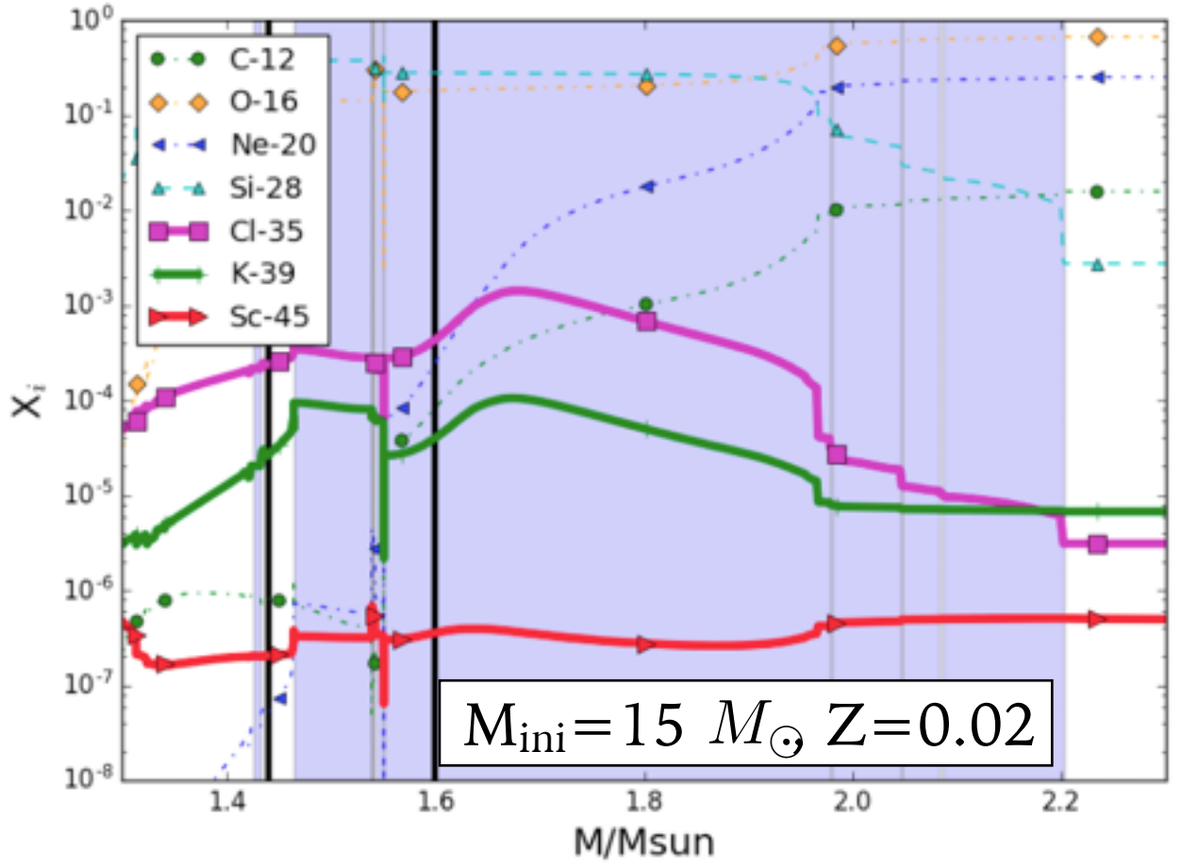


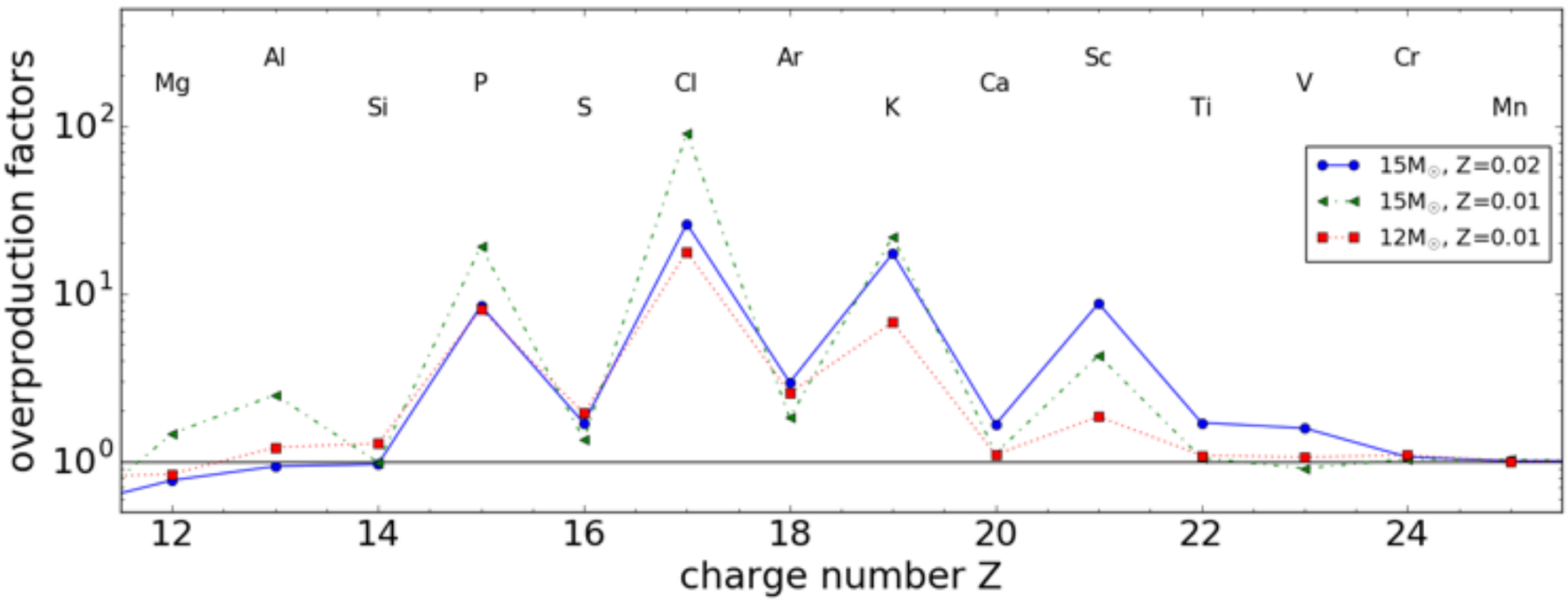
Reference data available at http://nugridstars.org/data-and-software/yields/set-1 w/ python tools to analyze and explore.

C. Ritter, F. Herwig, S. Jones, M. Pignatari, C. Fryer, R. Hirschi 2017, in prep.

NUCLEOSYNTHESIS IN CONVECTIVE O-C SHELL MERGER

- Convective O-C shell mergers in 1D massive stars models JINA/ NuGrid grid
- Effective production of odd-Z elements P, Cl, K and Sc in shell mergers





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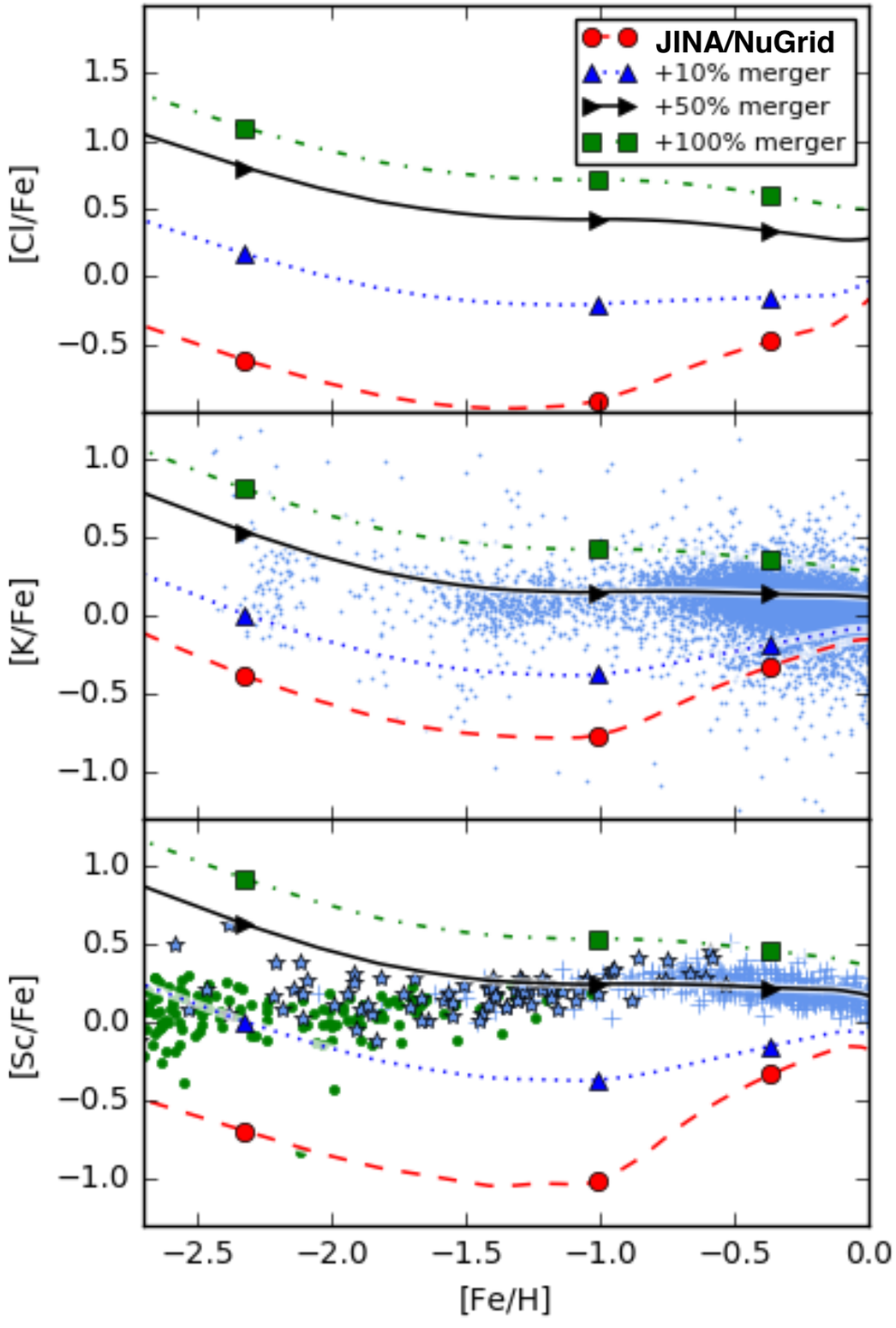
NUCLEOSYNTHESIS IN CONVECTIVE O-C SHELL MERGER

- Addition of O-C shell-merger material to the ejecta of massive stars
- Preliminary GCE tests show that a 50% merger rate in pre-SN models could reproduce the observed abundance of K and Sc
- *Reactive-convective nucleosynthesis* during shell merger require 3D hydrodynamic simulations

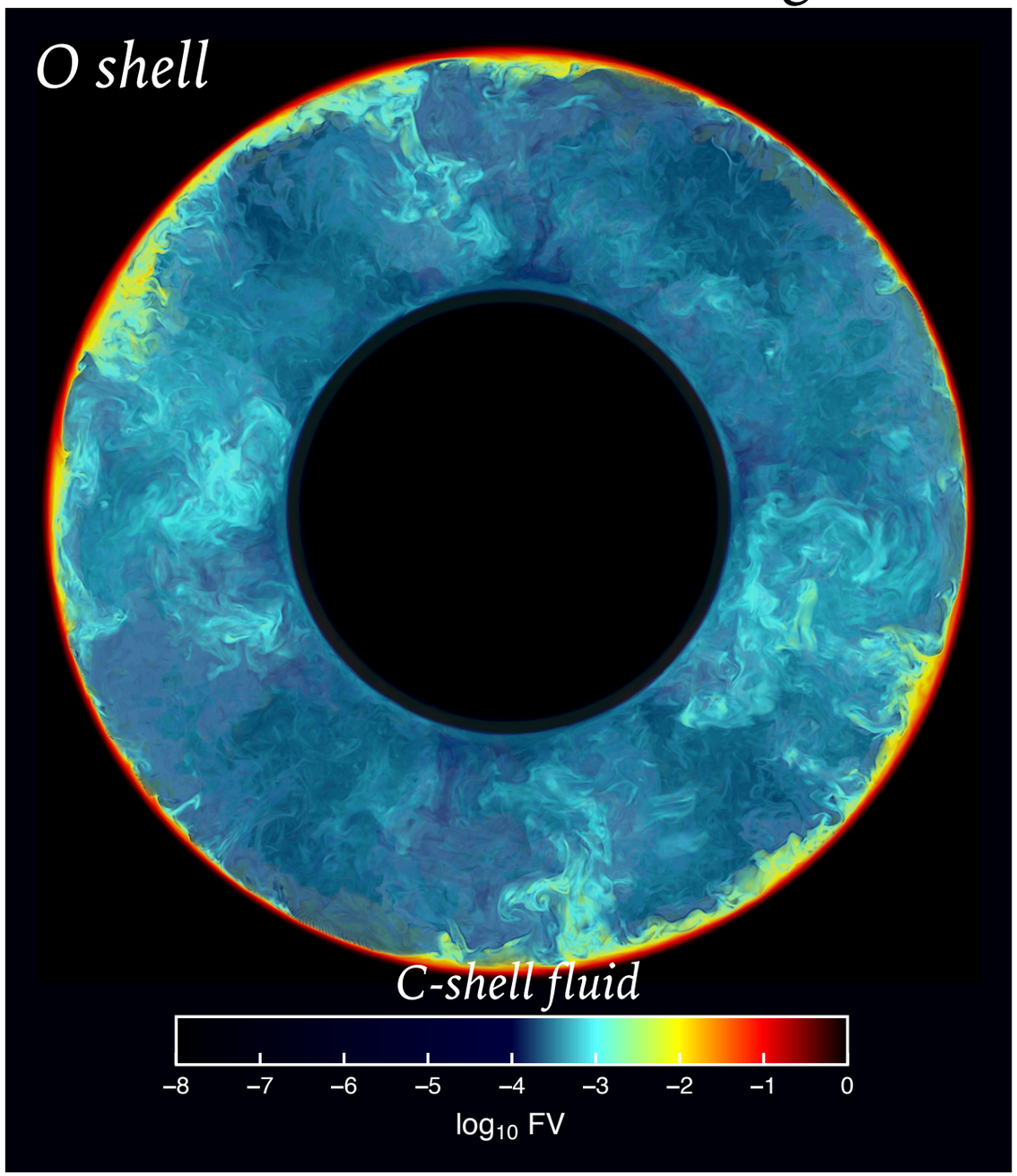


3D HYDRODYNAMIC SIMULATIONS OF THE O SHELL

- C-shell fluid entrainment in O shell motivated by hydrodynamic simulations of Jones+16
- 4π star-in-box simulation of stellar model with $M_{ini}=25 M_{\odot}$ at Z=0.02
- Entrainment and burning of the ingestion C-shell fluid

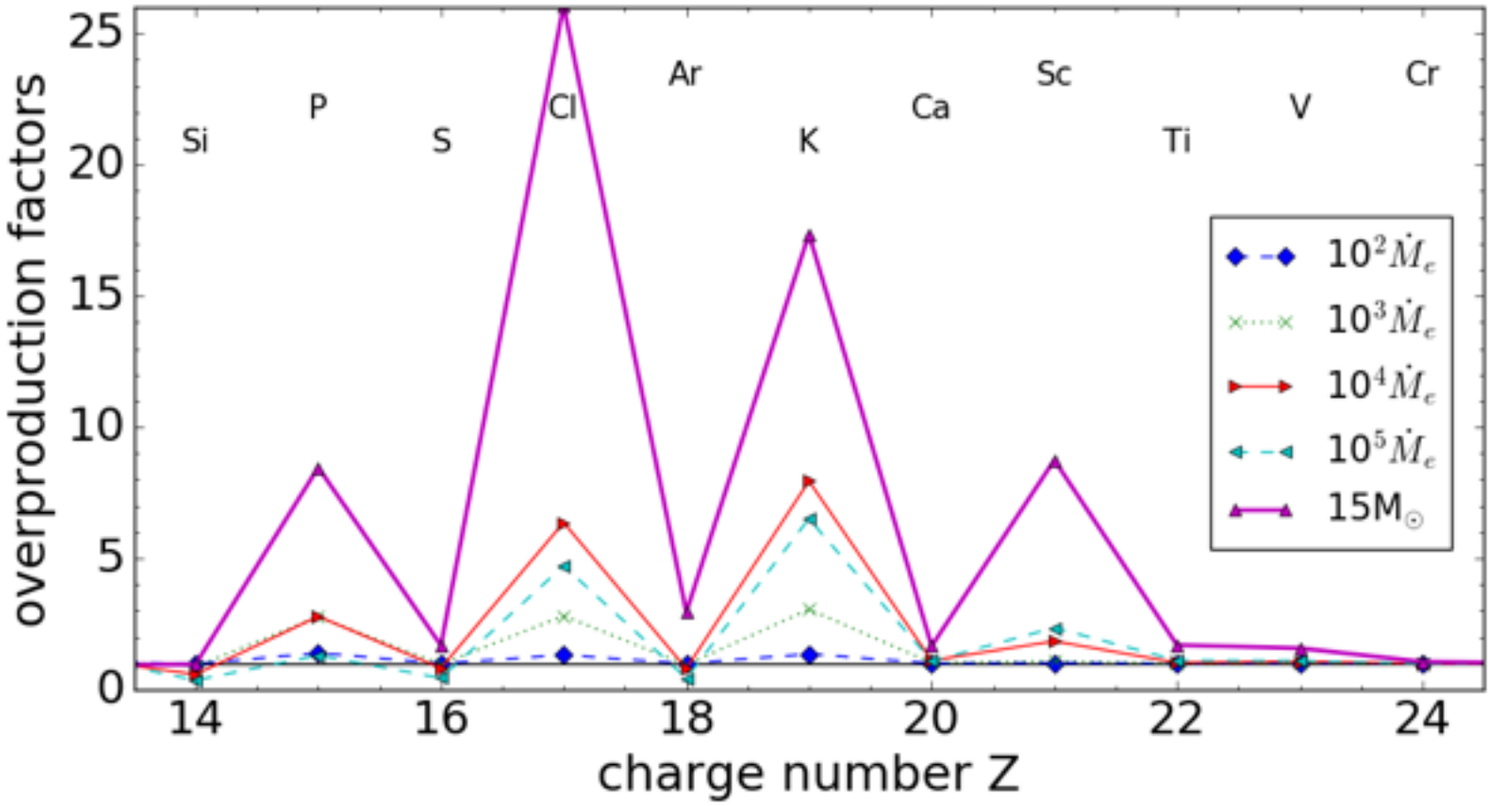
See Robert Andrassy's poster!

After 148min of C-fluid ingestion



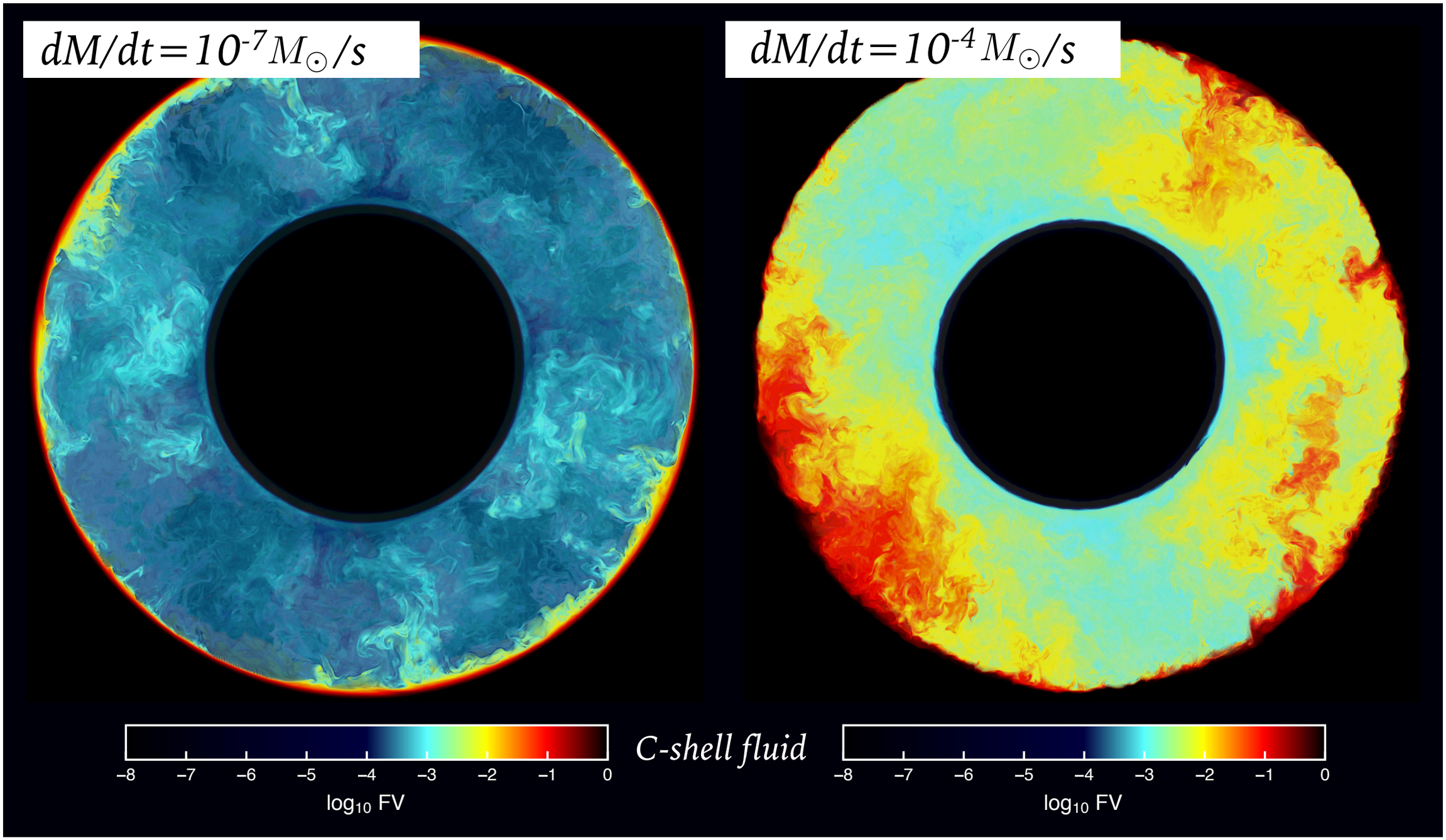
NUCLEOSYNTHESIS IN CONVECTIVE O-C SHELL MERGER

- Derive diffusion coefficient for 1D setup from spherically-averaged steady-state solution
- Comprehensive nucleosynthesis in 1D with strongly increased entrainment rates confirms large production of odd-Z nuclei



3D HYDRODYNAMIC SIMULATIONS OF THE O SHELL

- Larger entrainment rates (dM/dt) are required for effective production
- Do they launch catastrophic events?



SUMMARY

- Convective O-C shell merger produce odd-Z elements P, Cl, K, Sc under reactive-convective conditions which require 3D hydrodynamic simulations
- Chemical evolution models show that a ~50% merger rate in pre-SN models could reproduce the Galactic abundance of K and Sc
- 1D calculations informed by hydrodynamic simulations support production but require large entrainment rates of $10^{-4} M_{\odot}$/s

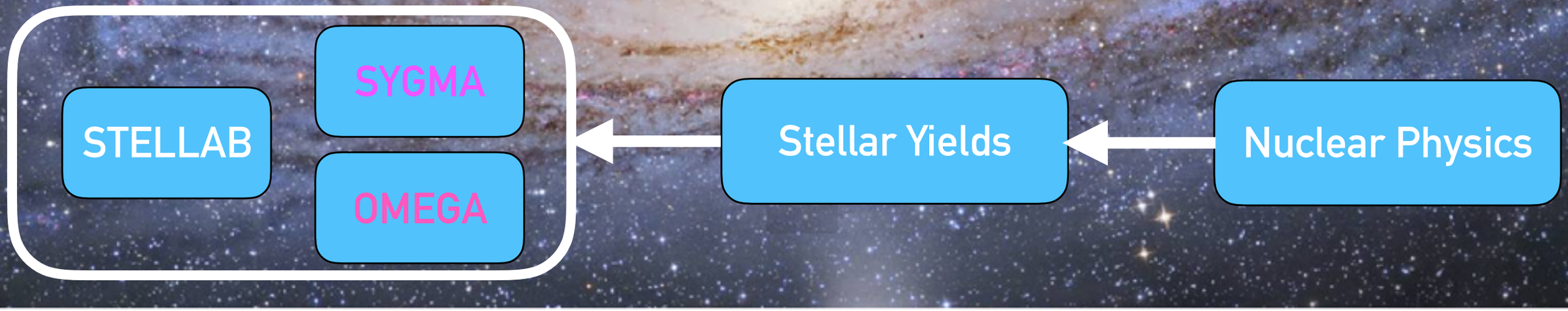
- Boost of p nuclei production, Nucleosynthesis in Si-O-C shell merger

- Are shell merger signature visible in inhomogeneous mixed systems such as ultra-faint dwarf galaxies?
- Are *reactive-convective conditions* in stars the source of odd-Z elements as C ingestion and H ingestion events (Herwig+11) indicate?

NuPyCEE

NuGrid Python Chemical Evolution Environment

A NEW GENERATION python galaxy framework

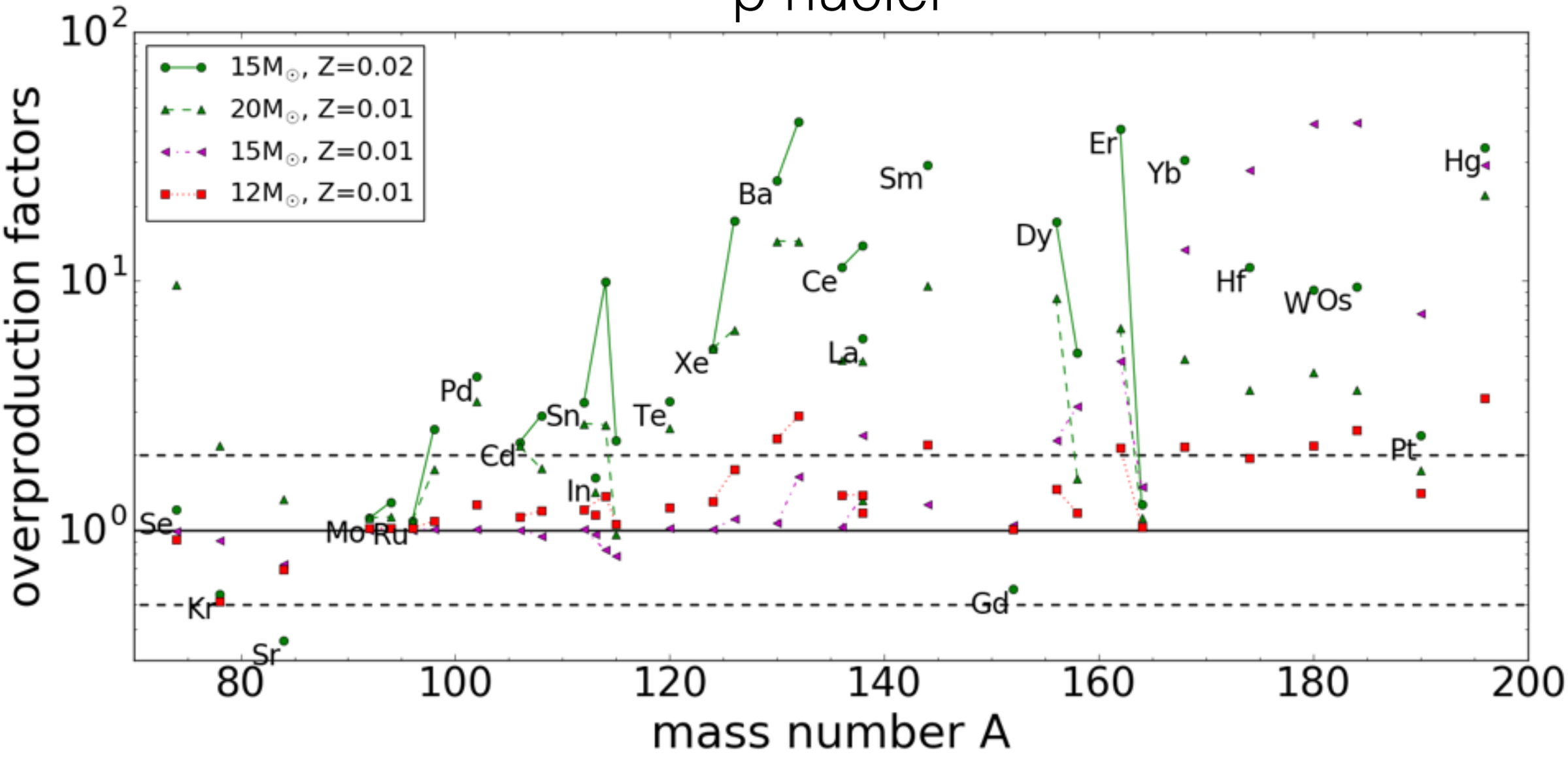


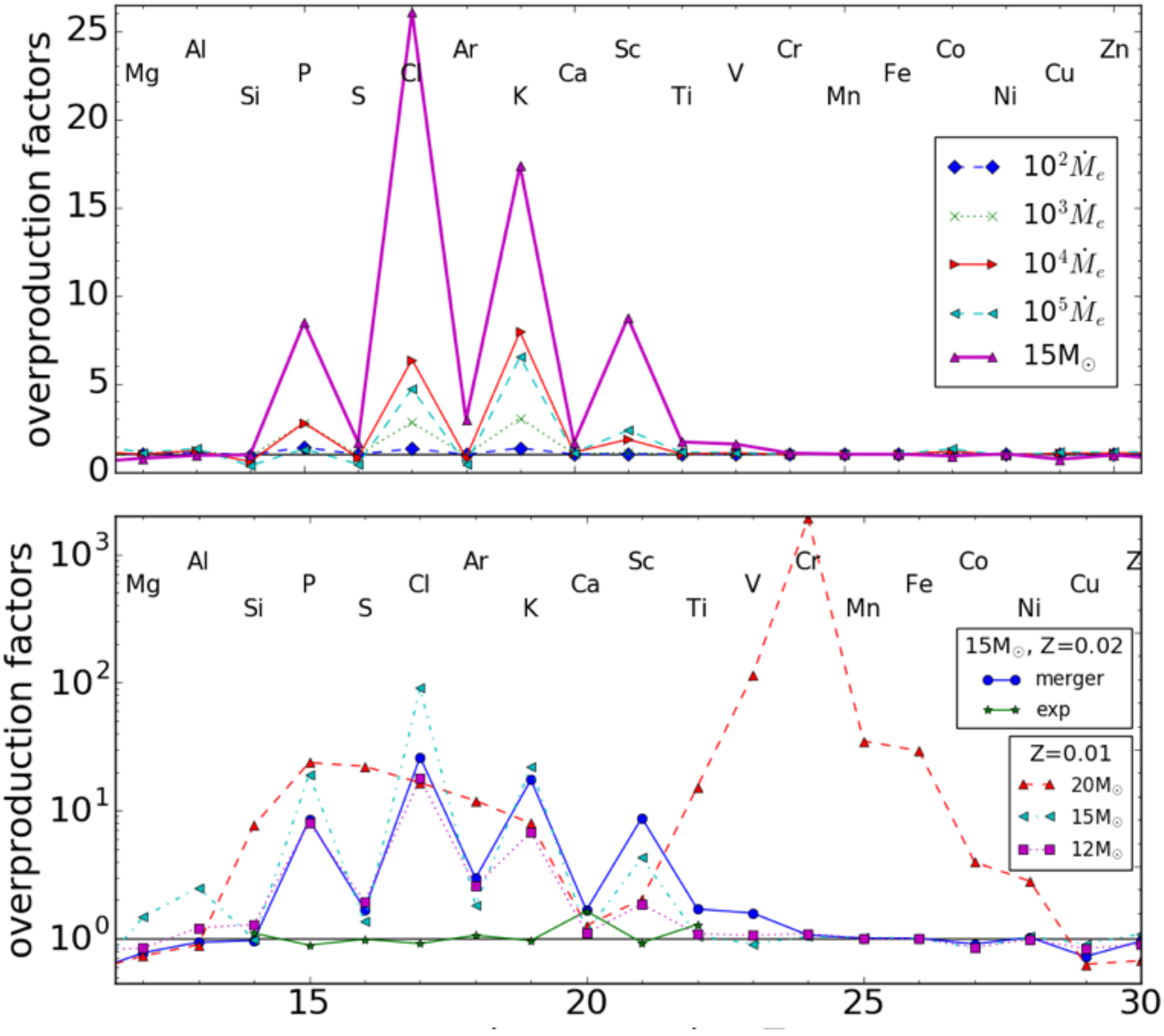
NUGRID

University of Victoria

JINA–CEE

p nuclei


15M⊙, Z=0.02
20M⊙, Z=0.01
15M⊙, Z=0.01
12M⊙, Z=0.01
overproduction factors
mass number A
Se
Kr
Sr
Mo
Ru
Pd
Cd
Sn
In
Te
Ba
Ce
Xe
Sm
La
Dy
Er
Yb
Hf
W
Os
Hg
Pt
Gd


overproduction factors
25
20
15
10
5
0
Mg
Al
Si
P
S
Cl
Ar
K
Ca
Sc
Ti
V
Cr
Mn
Fe
Co
Ni
Cu
Zn
$10^2\dot{M}_e$
$10^3\dot{M}_e$
$10^4\dot{M}_e$
$10^5\dot{M}_e$
15M$_\odot$
overproduction factors
10^3
10^2
10^1
10^0
15M$_\odot$, Z=0.02
merger
exp
Z=0.01
20M$_\odot$
15M$_\odot$
12M$_\odot$
15
20
25
30
charge number Z