Simulations of X-ray Bursts and Superbursts

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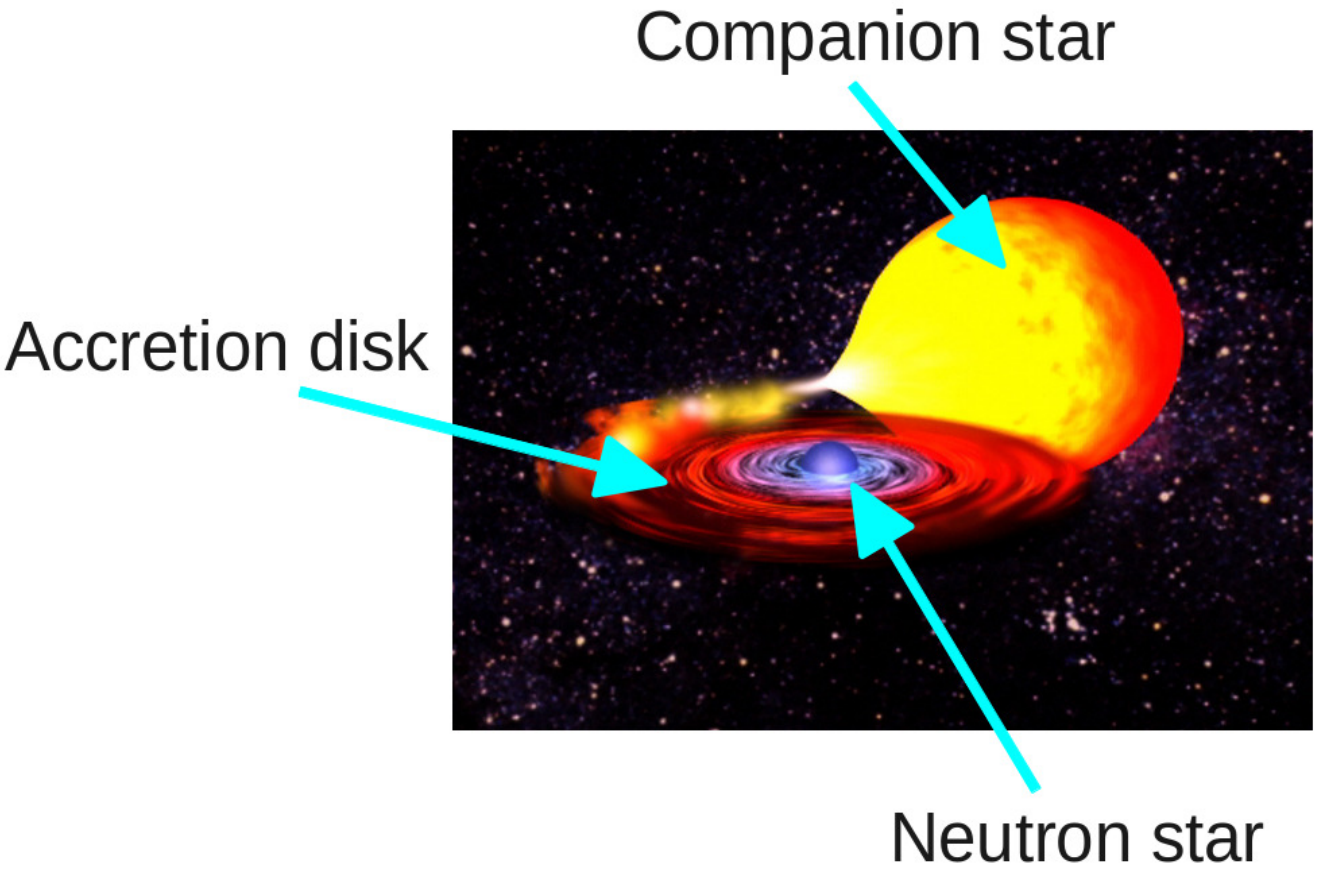

Companion star
Accretion disk
Neutron star

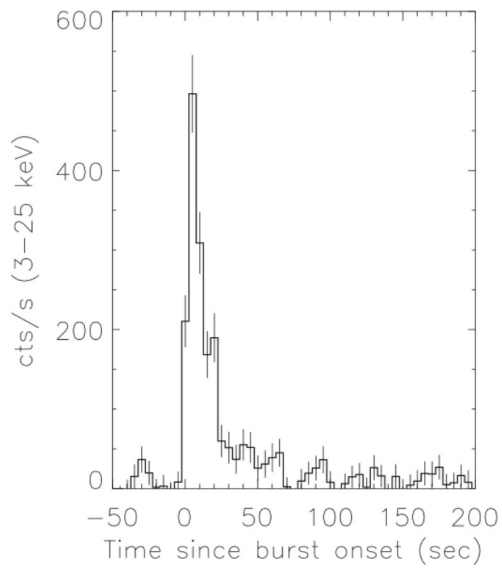
X-Ray Bursts and Superbursts

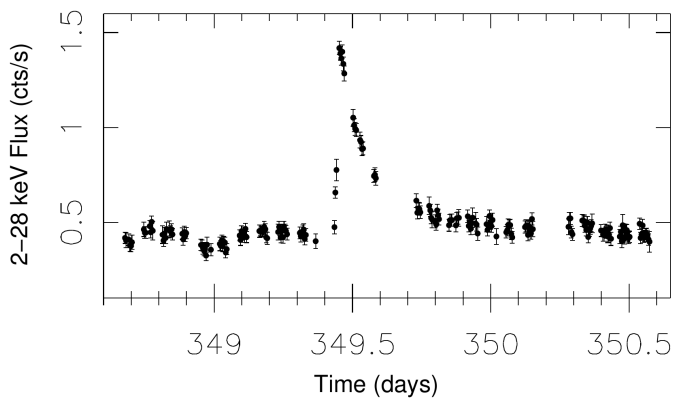
X-Ray Bursts

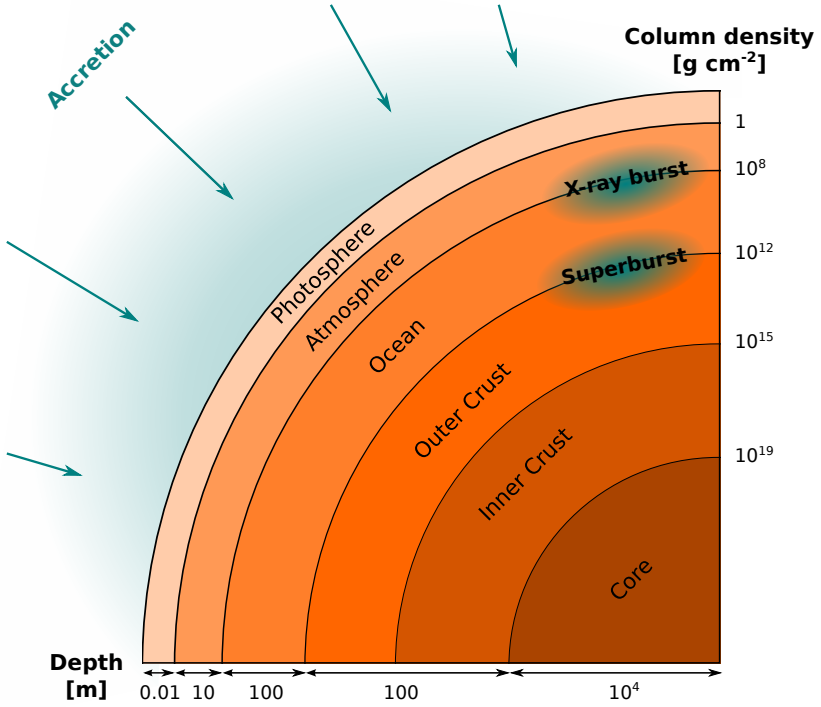
- Energy release: 10^{39} [ergs]
- Luminosity : 10^{38} [ergs/s]
- Burst time : sec-min
- Burst recurrence: hours-days

Superbursts

- Energy release: 10^{42} [ergs]
- Luminosity : 10^{38} [ergs/s]
- Burst time : hours-days
- Burst recurrence: years







X-Ray Bursts

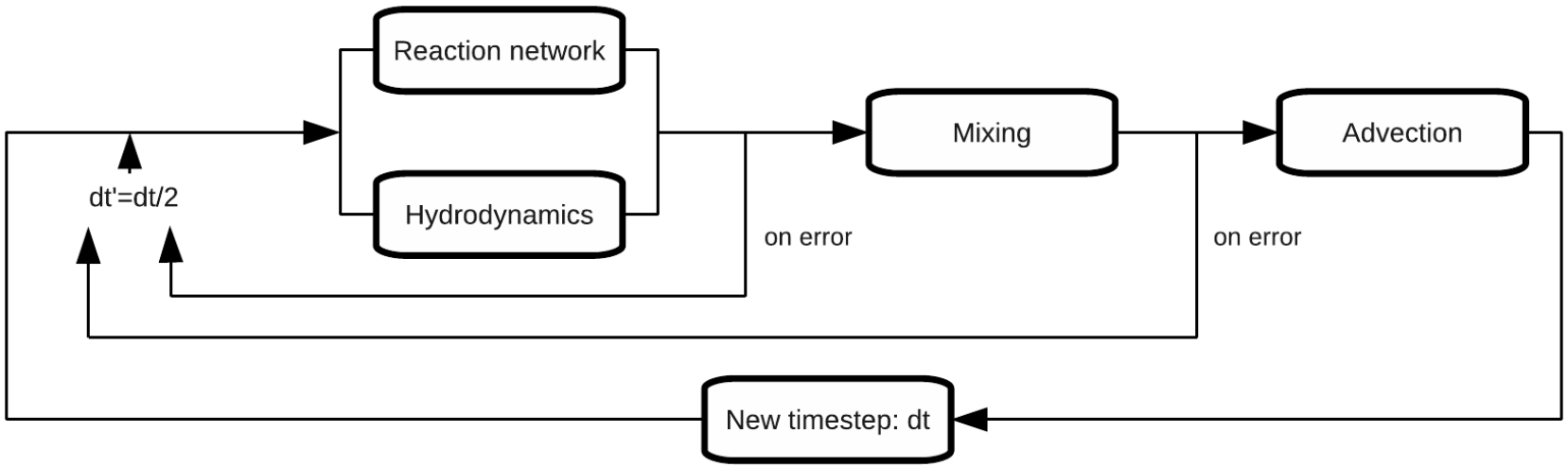
Unstable hydrogen and helium burning

Superbursts

Unstable carbon burning

$X_{^{12}C} \gtrsim 0.1$ (Cumming et al., 2006; Hashimoto et al., 2014)

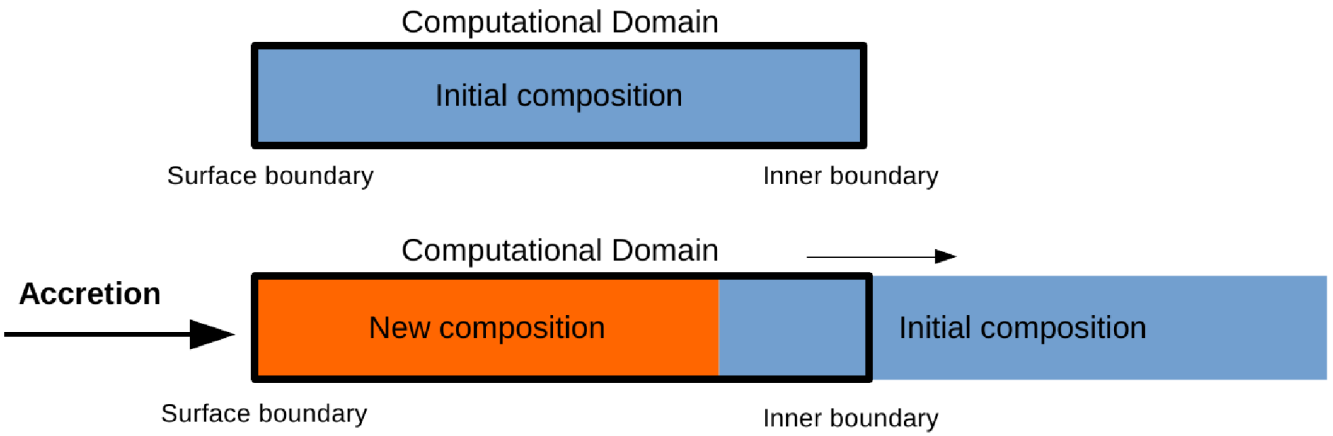
1D-Model



Code J.Fisker, S.Fehlmann, M. Liebendörfer

- General relativistic hydrodynamics: AGILE (M. Liebendörfer, 2002)
- Nuclear Network (W. R. Hix & F.-K. Thielemann, 1999)
- Convection
- Heat transport: Conduction and Radiation

Initial Model



- The computational domain:
  $m = 4.8 \cdot 10^{24}$g
  $r \approx 85$m
- Adaptive grid with 218 zones

Initial Parameters

- Netron star: $r = 11.2$km, $m = 1.41 M_\odot$
- K. Nomoto's EOS
- Accreted solar composition with constant accretion rate
- Fixed heat source Q_{heat} as an inner boundary condition

Parameter Sets with solar accretion composition

I: varying crustal heating
from $0.3 - 1.1$ MeV per nucleon in steps of 0.1 MeV/nuc

accretion rate

- $0.5 \cdot 10^{17}$ g s^{-1}
- $1 \cdot 10^{17}$ g s^{-1}
- $1.5 \cdot 10^{17}$ g s^{-1}

composition

$X_H = 0.706$
$X_{He} = 0.275$
$X_{rest} = 0.019$

II: varying accretion rate
from $0.1 - 1.5 \cdot 10^{17}$ g s^{-1} in steps of $0.1 \cdot 10^{17}$ g s^{-1}

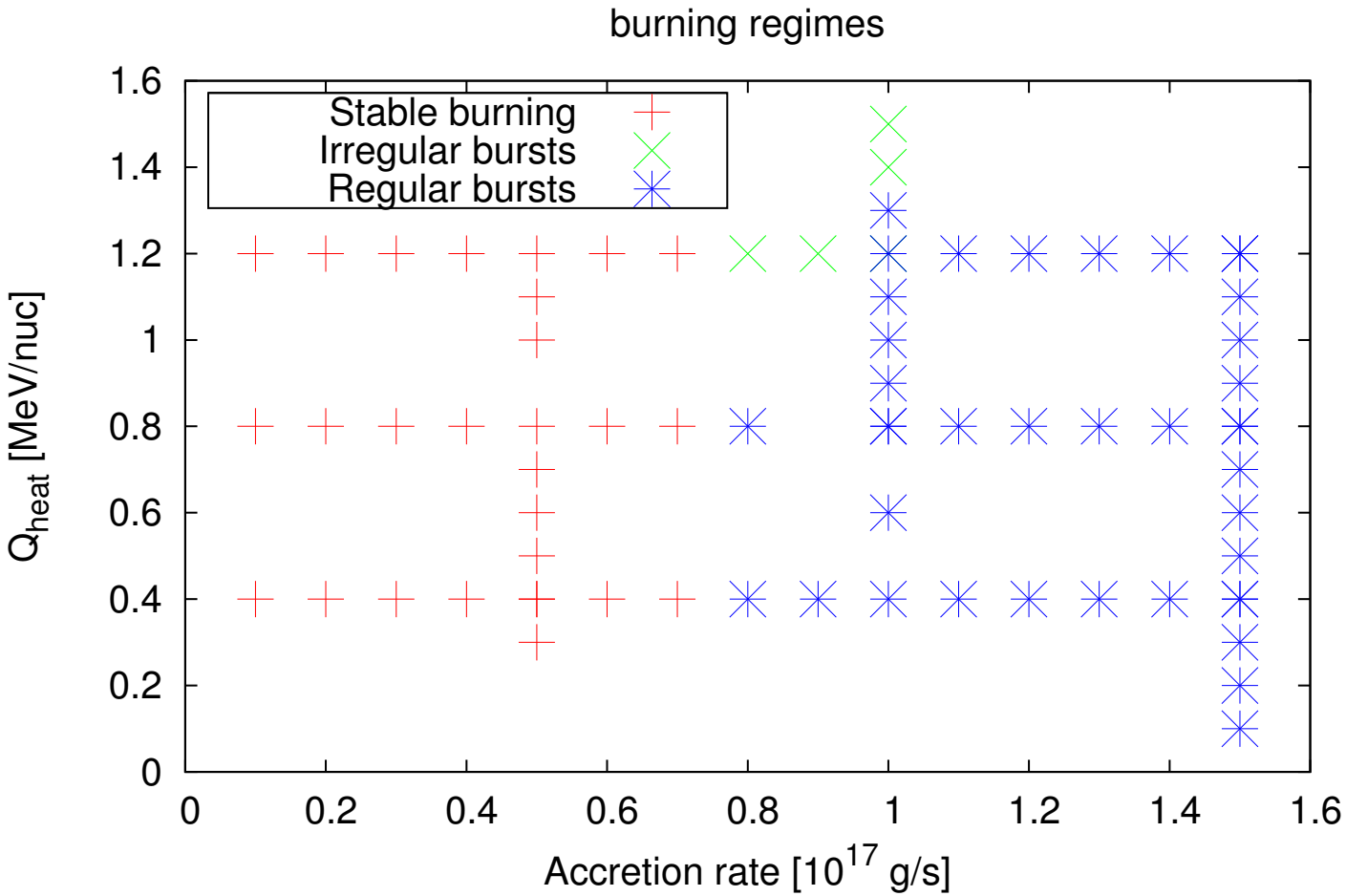
crustal heating

- 0.4 Mev nuc^{-1}
- 0.8 Mev nuc^{-1}
- 1.2 Mev nuc^{-1}

composition

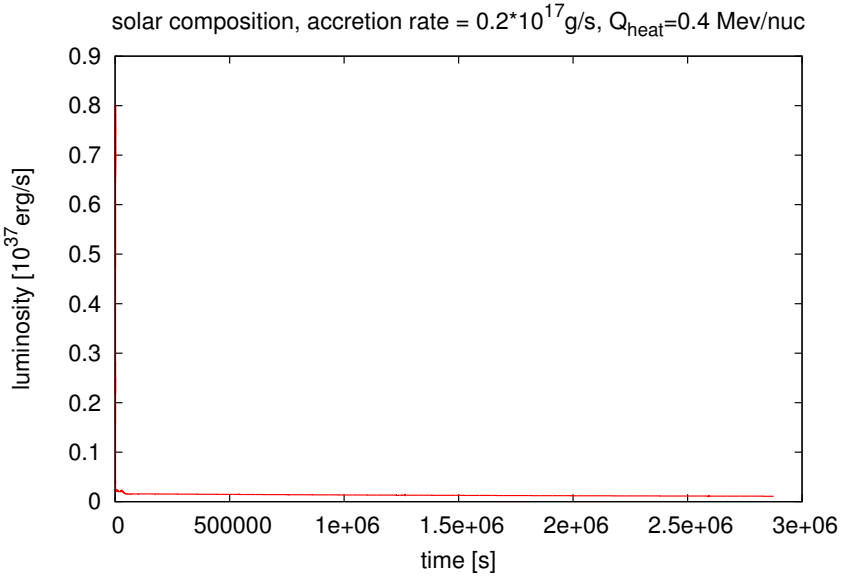
$X_H = 0.706$
$X_{He} = 0.275$
$X_{rest} = 0.019$

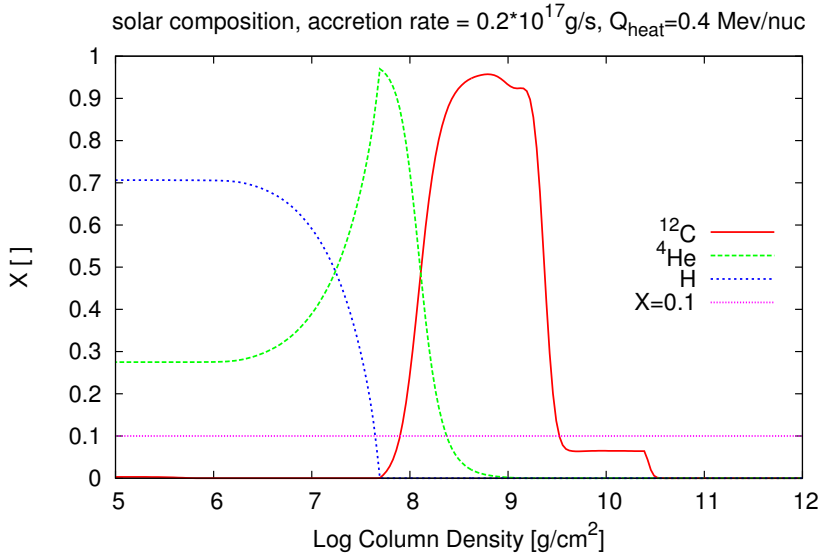
solar composition: (Anders&Grevesse solar abundances taken from Arnett92)


burning regimes
Stable burning
Irregular bursts
Regular bursts
Q_{heat} [MeV/nuc]
Accretion rate [10^{17} g/s]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6

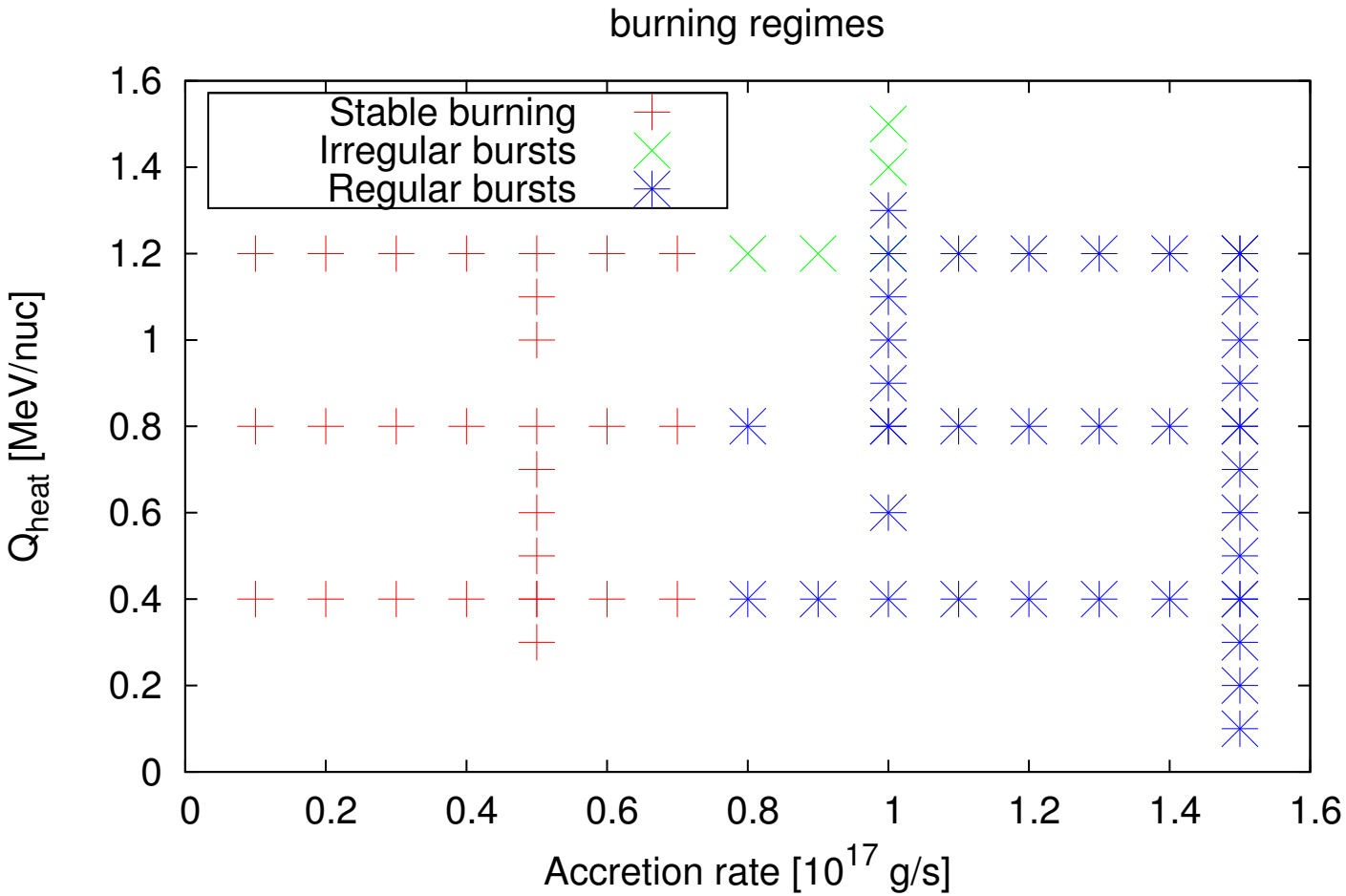
Stable burning regime

solar abundances with 0.4 MeV/nuc crustal heating



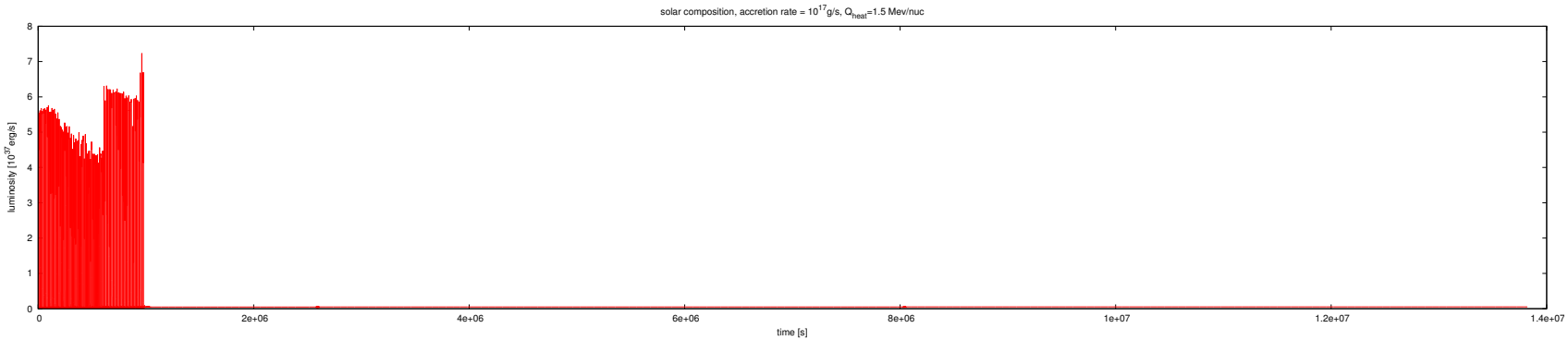


"New regime of stable nuclear burning" (L. Keek and A. Heger, 2015)

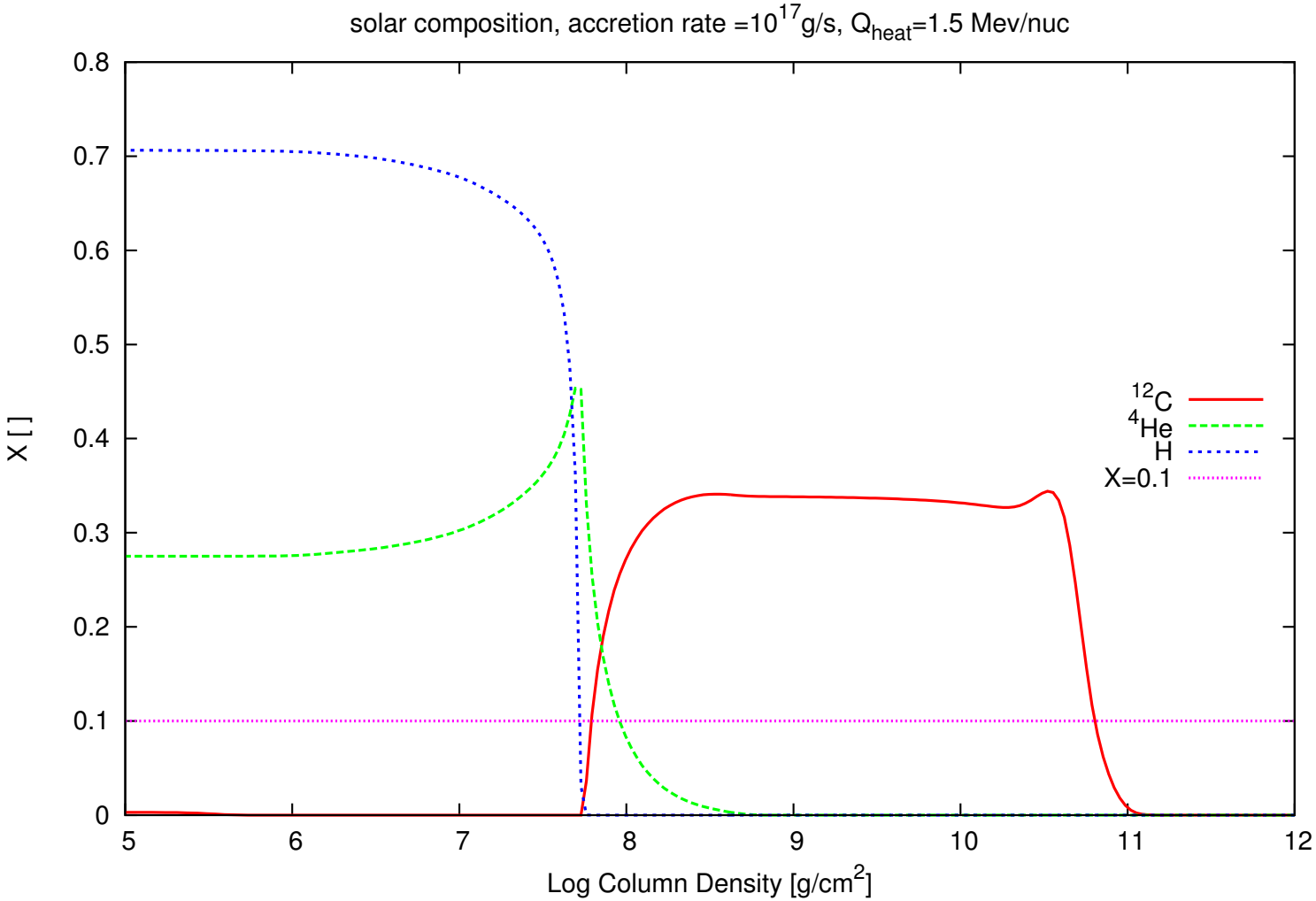

burning regimes
Stable burning
Irregular bursts
Regular bursts
Q_{heat} [MeV/nuc]
Accretion rate [10^{17} g/s]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6

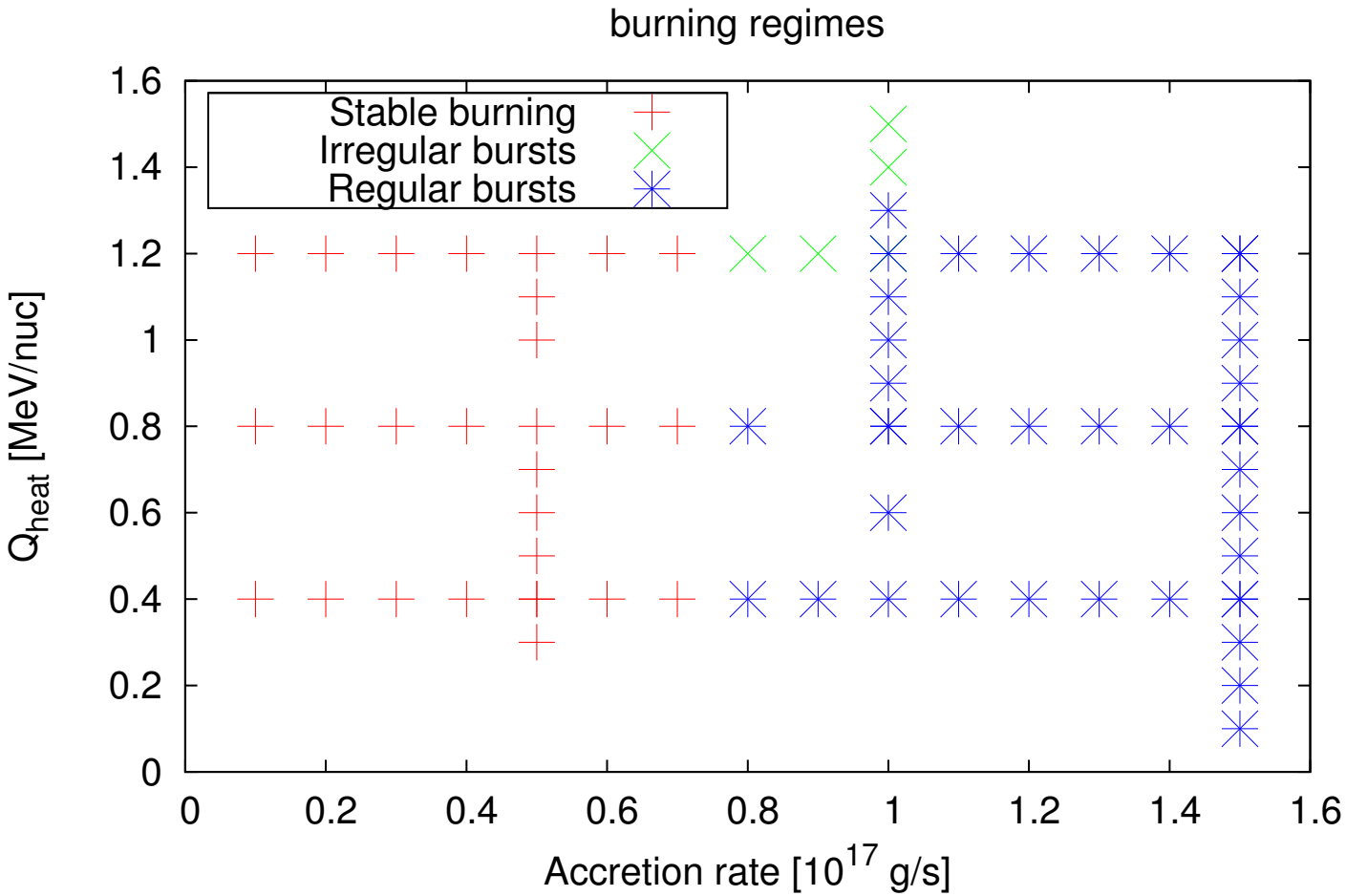
Irregular bursts regime

solar abundances with $1 \cdot 10^{17}$ g s^{-1} accretion rate



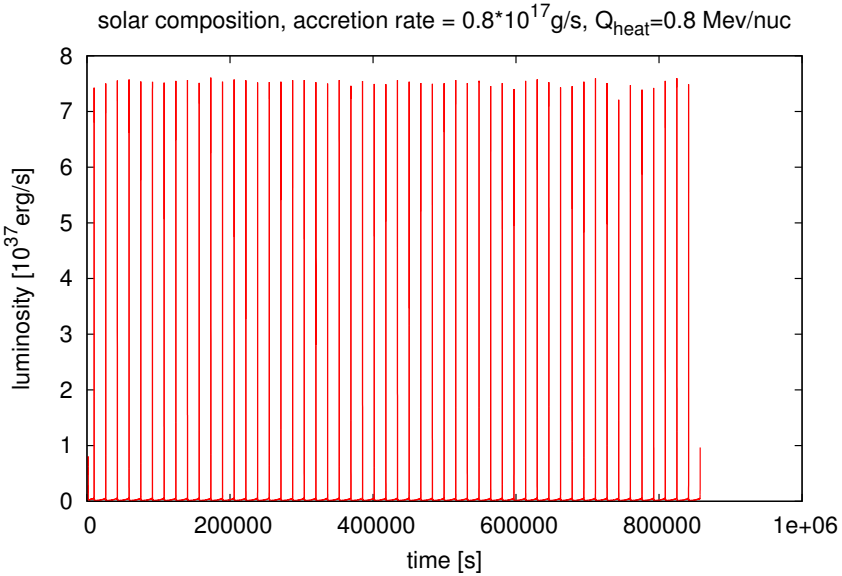
irregular burst $\rightarrow$ stable burning

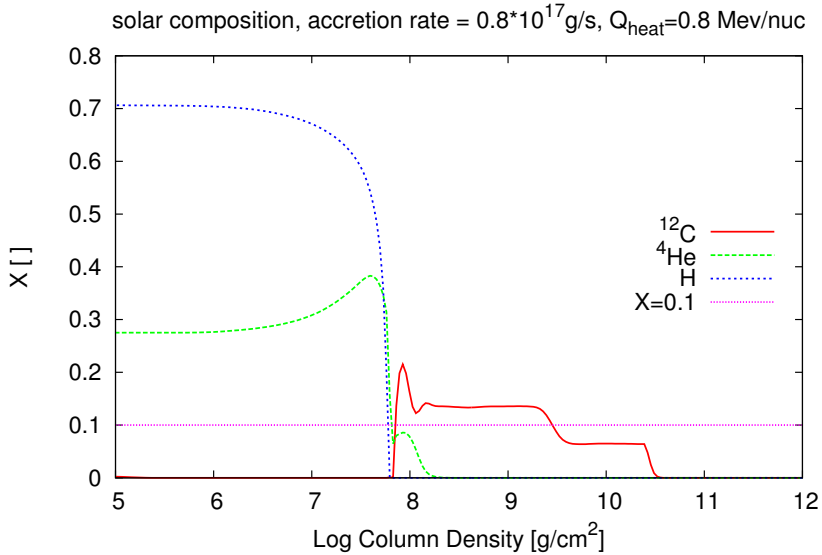

solar composition, accretion rate =10^17g/s, Q_heat=1.5 Mev/nuc
X [ ]
Log Column Density [g/cm^2]
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
6
7
8
9
10
11
12
12C
4He
H
X=0.1

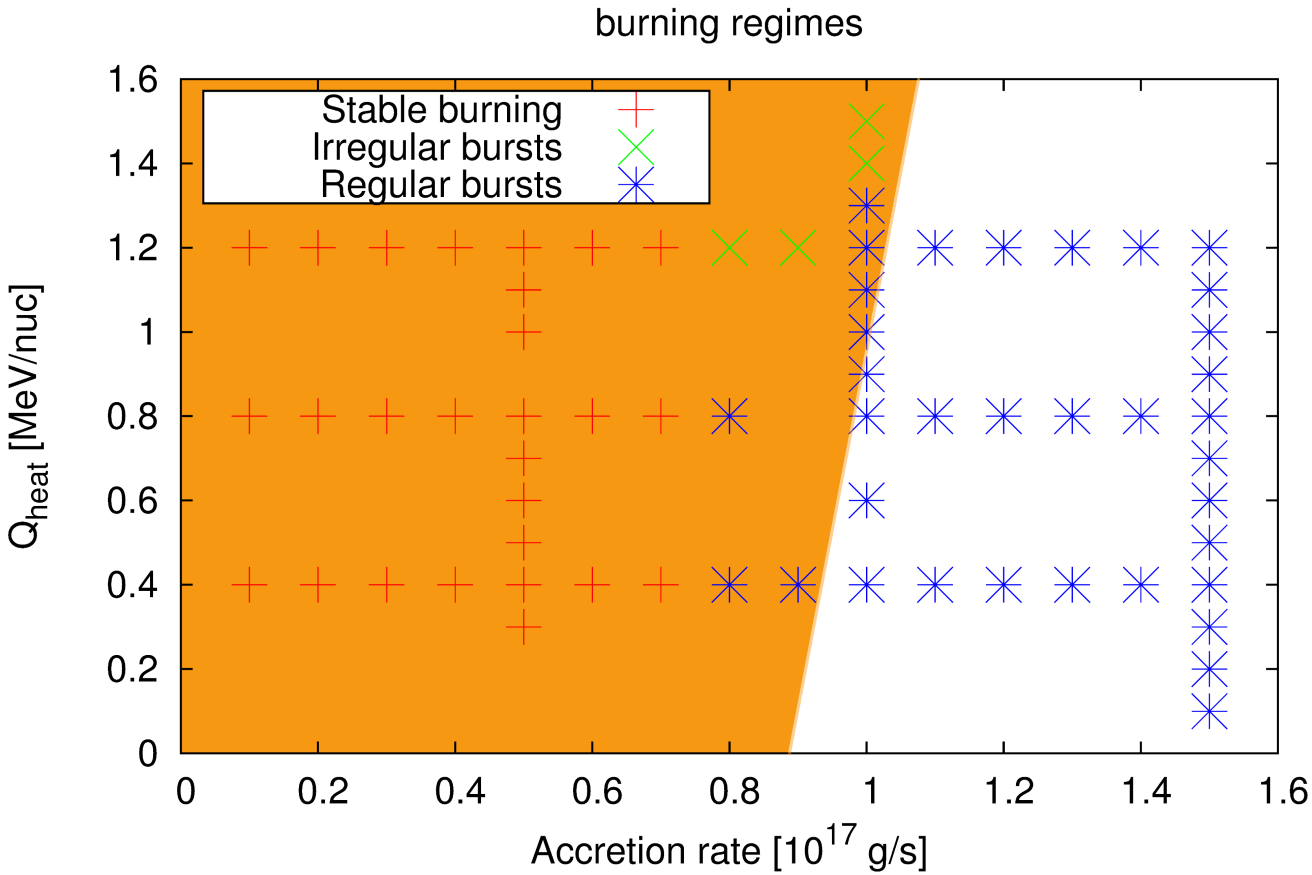

burning regimes
Stable burning
Irregular bursts
Regular bursts
Q_{heat} [MeV/nuc]
Accretion rate [10^{17} g/s]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6

Regular bursts

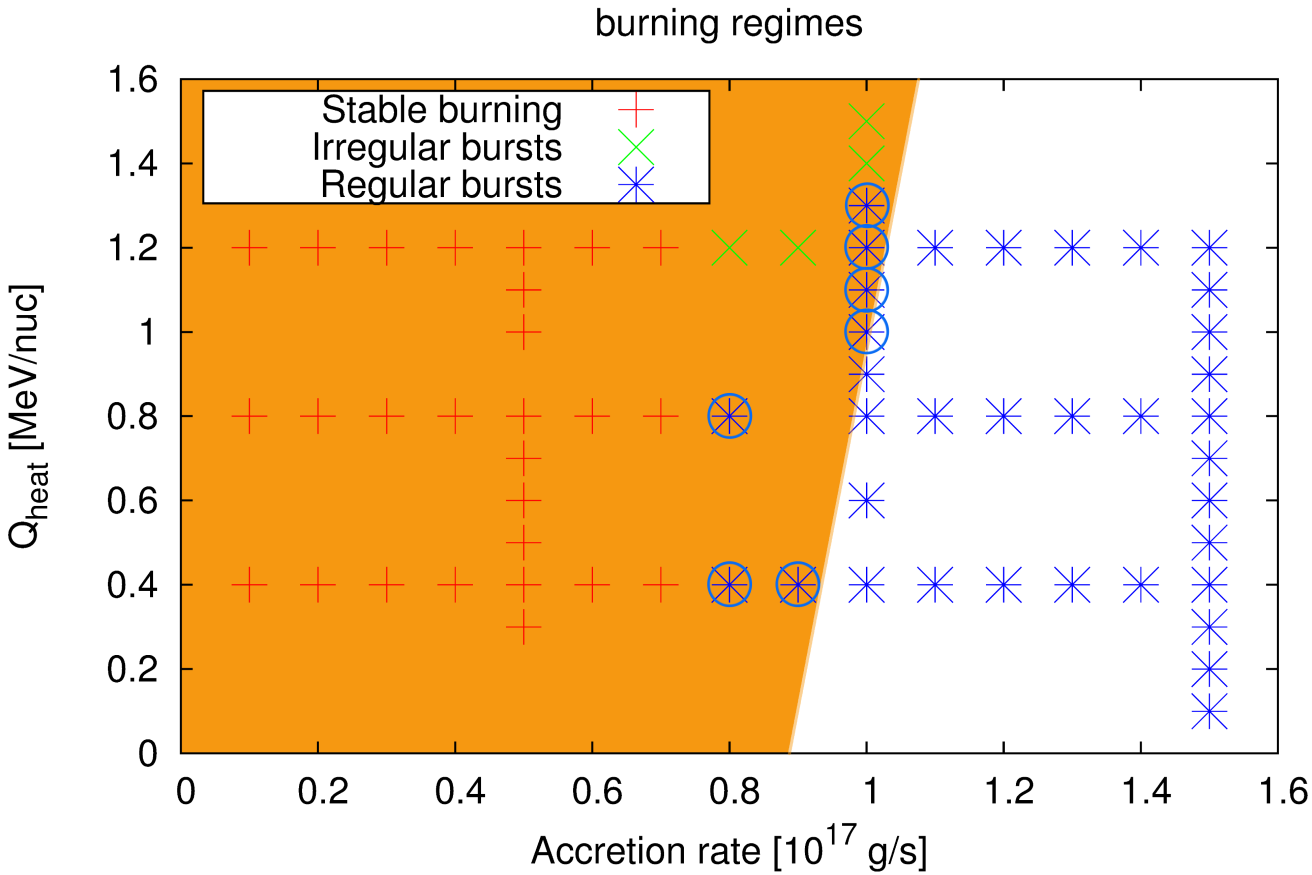
solar abundances with 0.8 MeV/nuc crustal heating







the orange region corresponds to the parameter sets which produce $X(^{12}C) > 0.1$



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Thank You for your attention!