Pair-instability supernovae and Gamma-ray bursts

Andrey Baranov

LAPTH, Universite de Savoie, Annecy-le-Vieux, France
Universite Nice Sophia Antipolis, Nice, France

Supervisor: Pascal Chardonnet

Pair-instability SN

[Barkat et al., (1967)]

Population III stars could reach masses more than 100 solar masses

[Bromm et al. (1999)]

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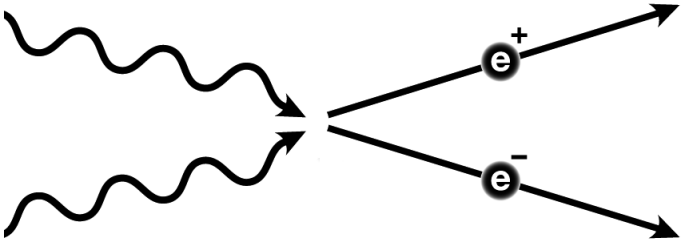

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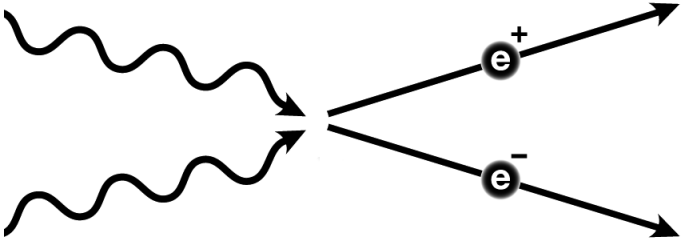
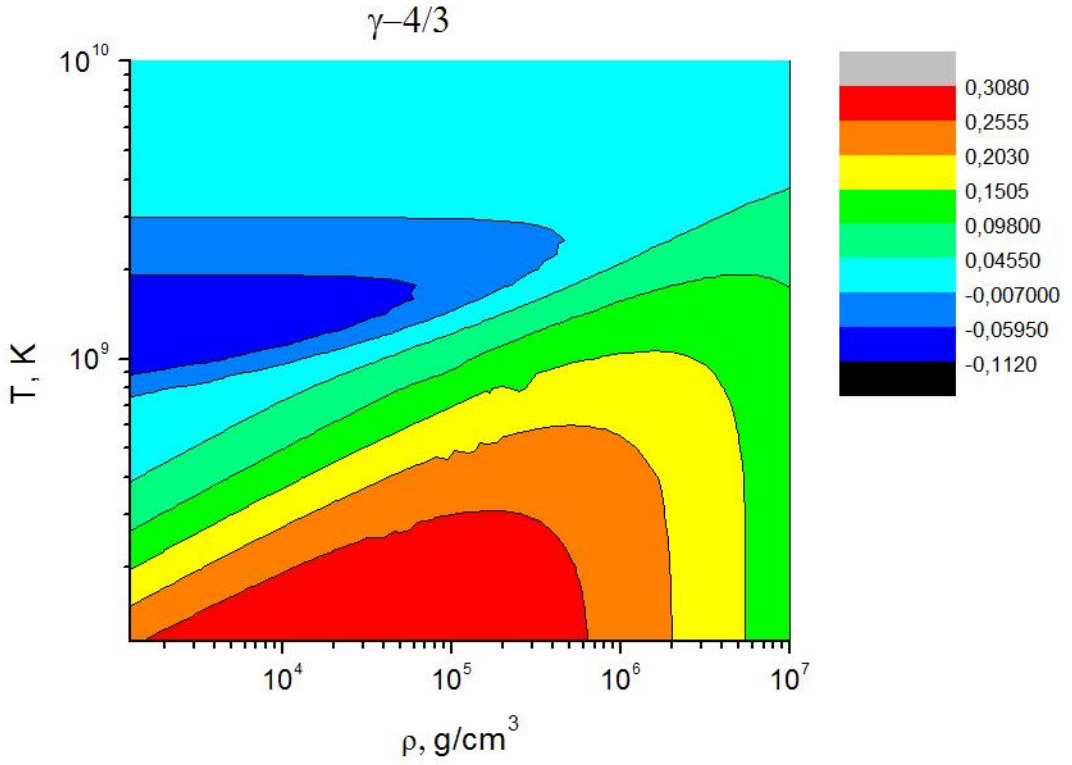
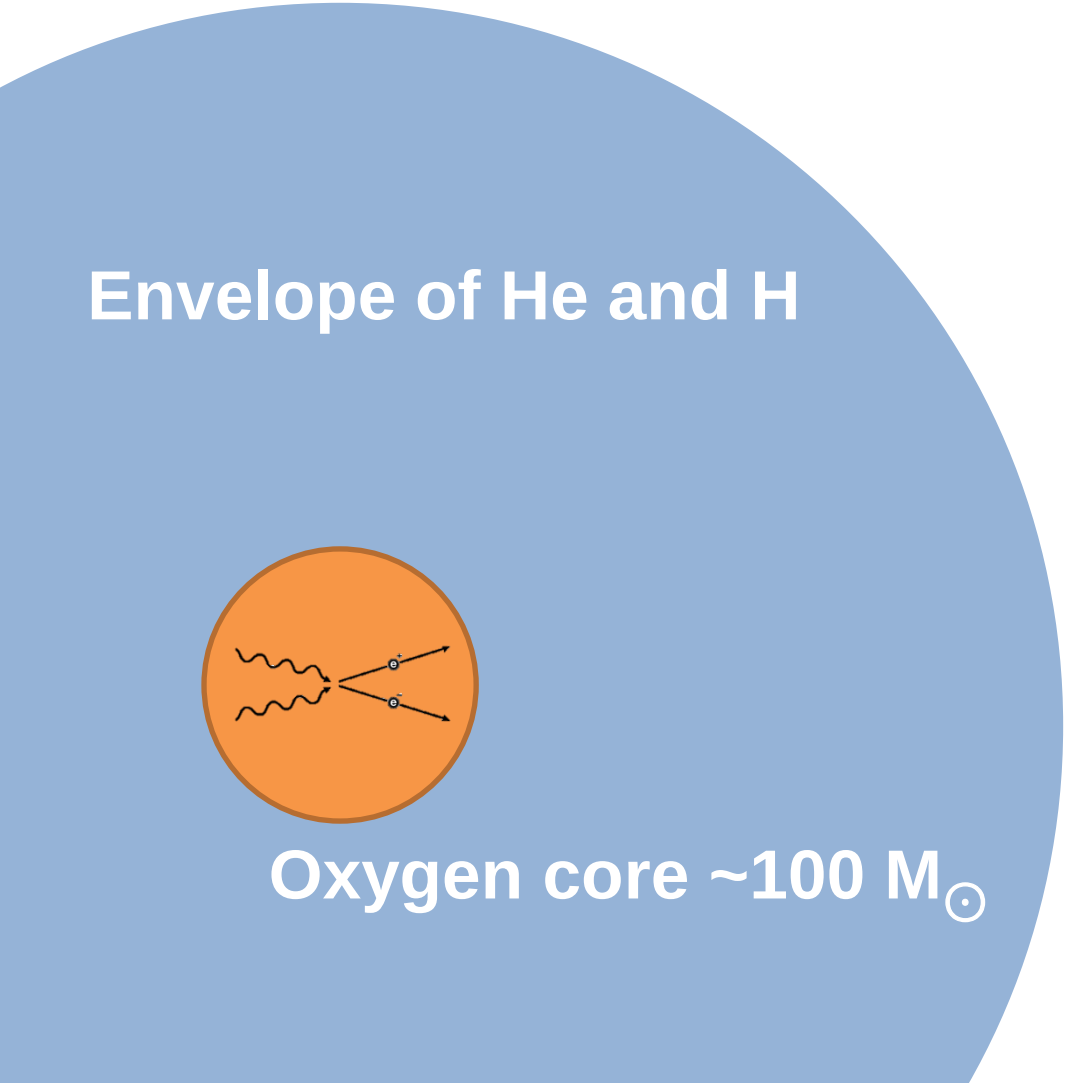




Numerical simulations



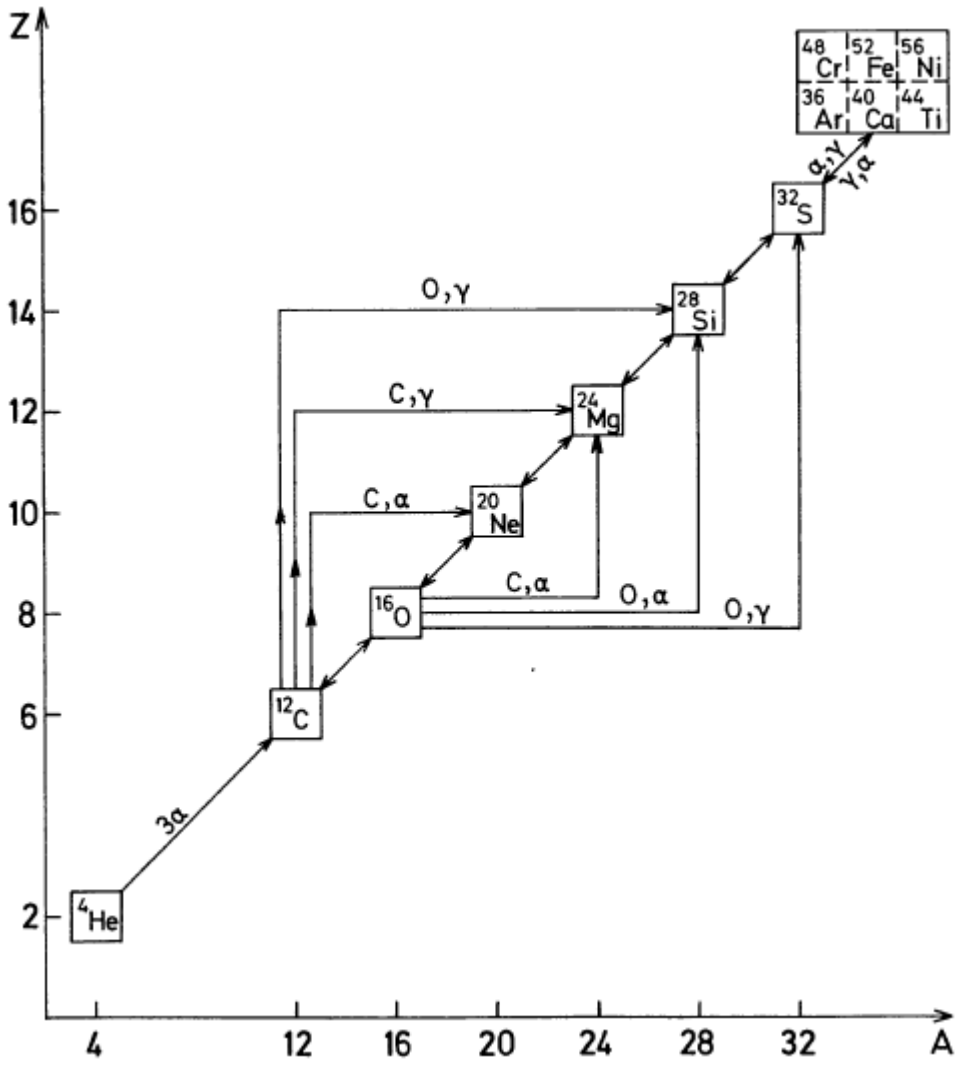
- Spherical symmetry
- Computation of the core only
- Polytrope with $\gamma=4/3$

$$P=K\rho^{\gamma}$$

System of equations

$$
\begin{cases}
\partial r/\partial t & = v \\
\partial v/\partial t & = -Gm/r^2 - 4\pi r^2(\partial P/\partial m) \\
\partial T/\partial t & = (-4\pi\frac{\partial(r^2 v)}{\partial m}T(\partial P/\partial T)_\rho + \varepsilon_{nucl} - \varepsilon_\nu)/(\partial E/\partial \rho)_\rho \\
P(\rho, T, Y_i) & = EOS(\rho, T, Y_i) \\
\ldots & \\
dY_j/dt & = Y_k Y_l \rho R_{jk,l} - Y_j Y_l \rho R_{jl,m} + Y_i \lambda_{i,j} - Y_j \lambda_{j,k} \\
\ldots &
\end{cases}
$$

Nuclear reactions



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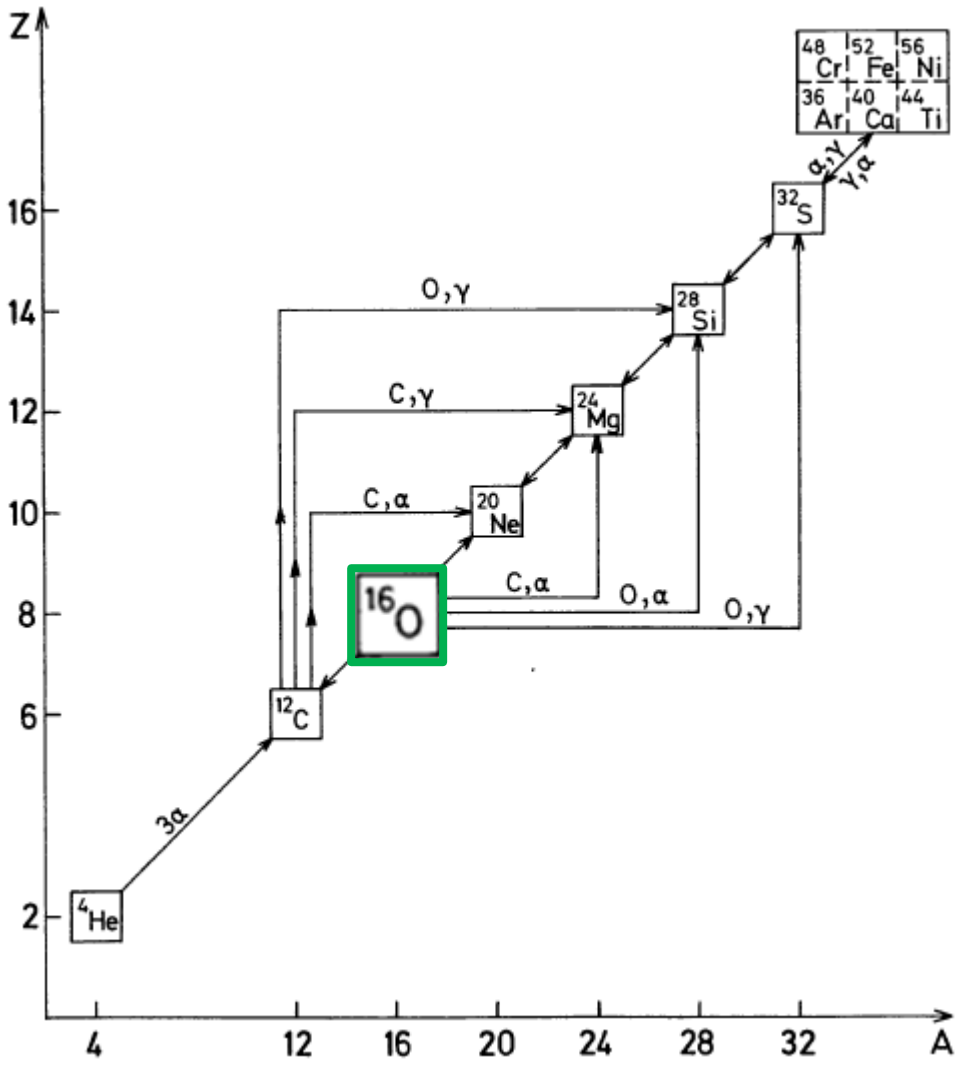
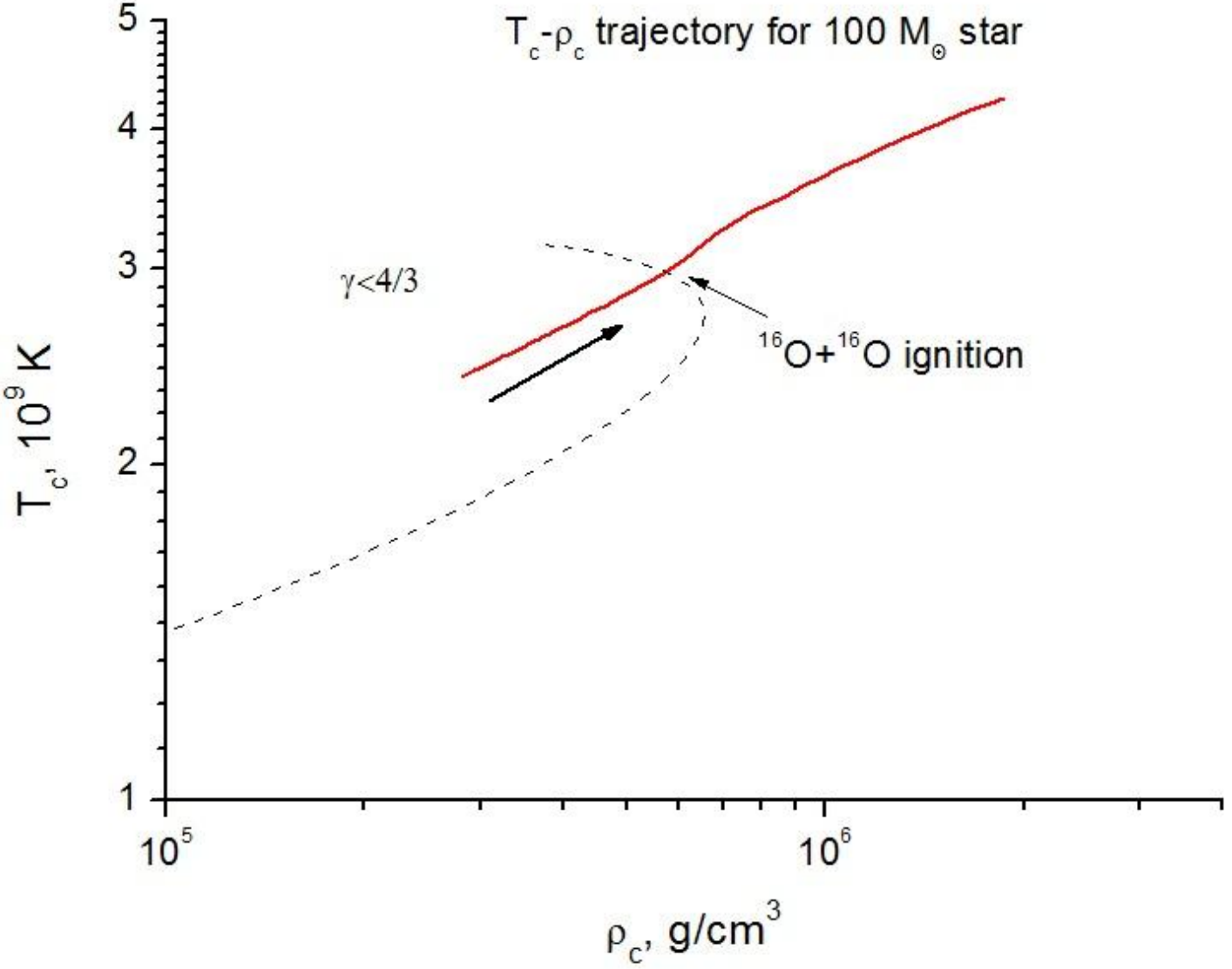
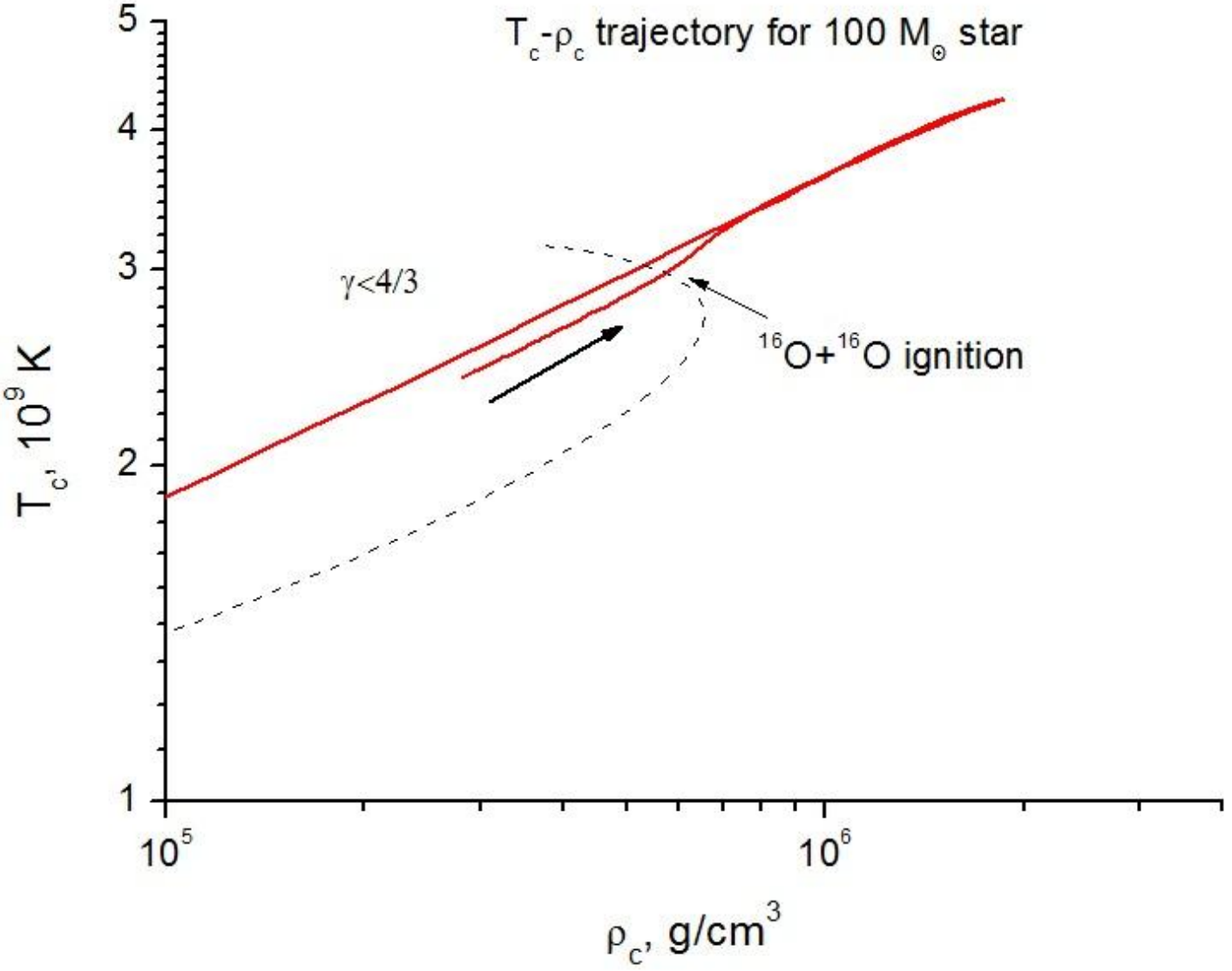


Results


T_c-ρ_c trajectory for 100 $M_\odot$ star
γ<4/3
$^{16}O+^{16}O$ ignition
T_c, 10^9 K
ρ_c, g/cm^3
5
4
3
2
1
10^5
10^6

Results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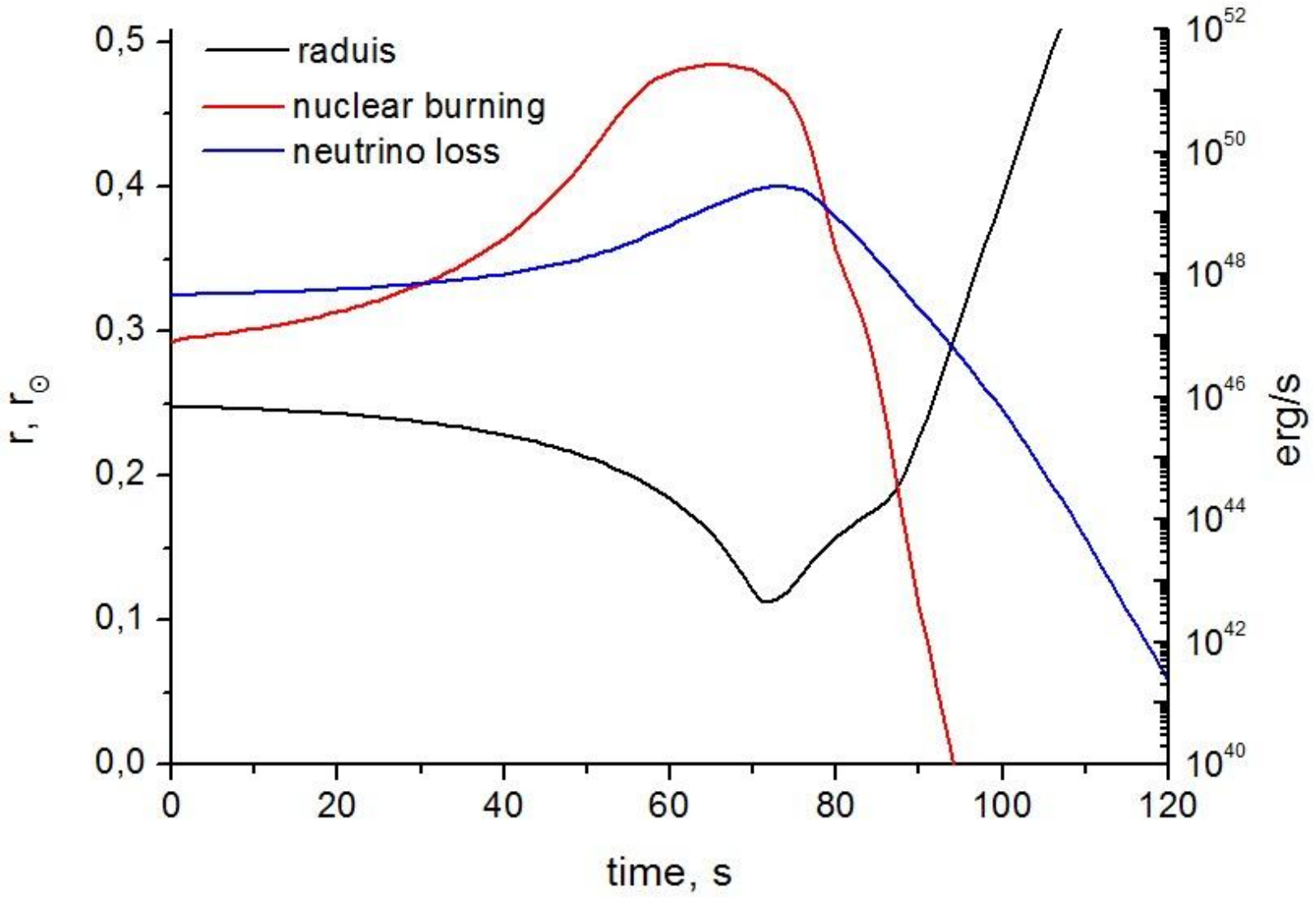
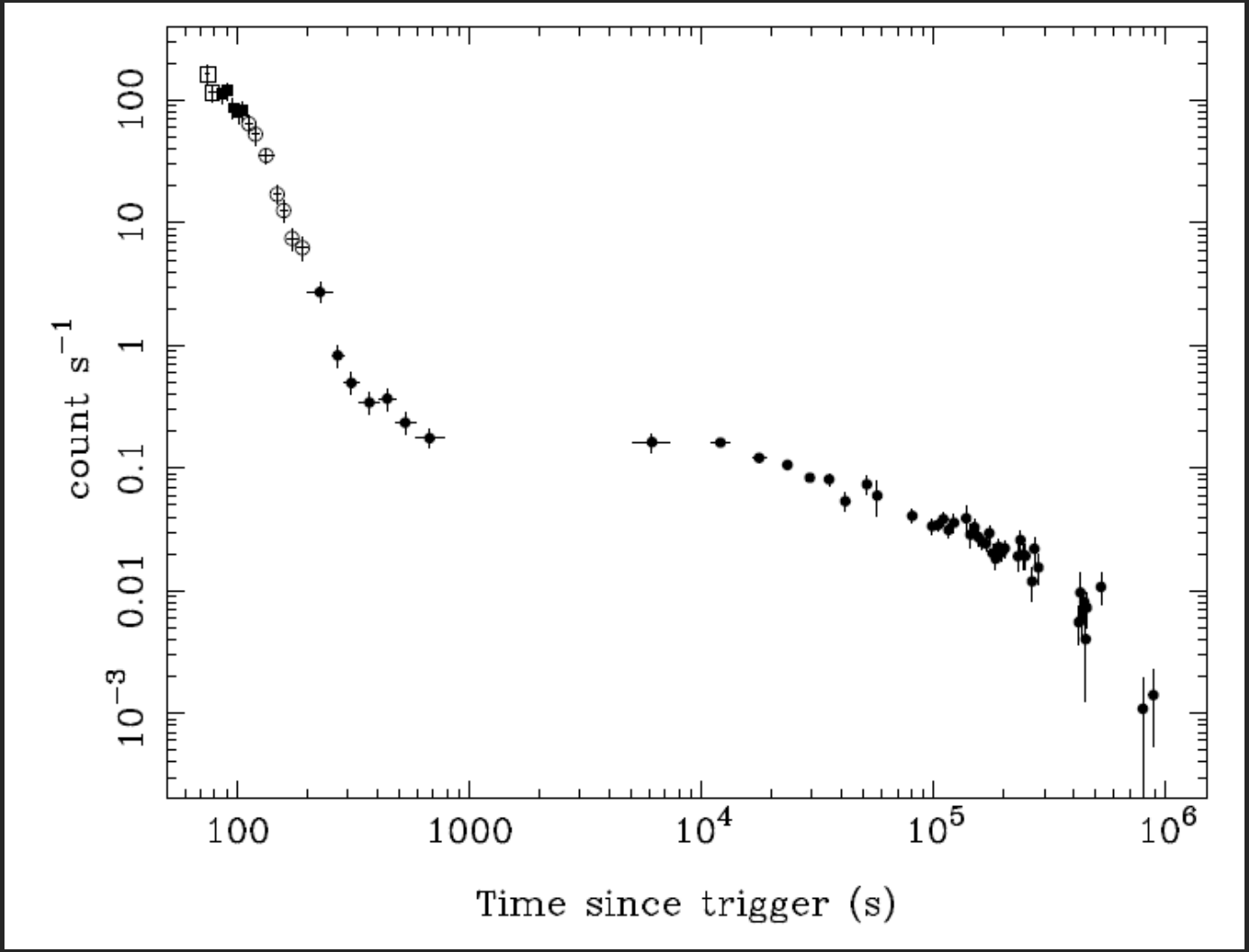

raduis
nuclear burning
neutrino loss
0,5
0,4
0,3
0,2
0,1
0,0
r, r⊙
0
20
40
60
80
100
120
time, s
10^52
10^50
10^48
10^46
10^44
10^42
10^40
erg/s

GRB

- Cosmological phenomena
- Energy budget: 10^{51} - 10^{54} ergs
- Timescale of the prompt emission: 1-100 sec

GRB

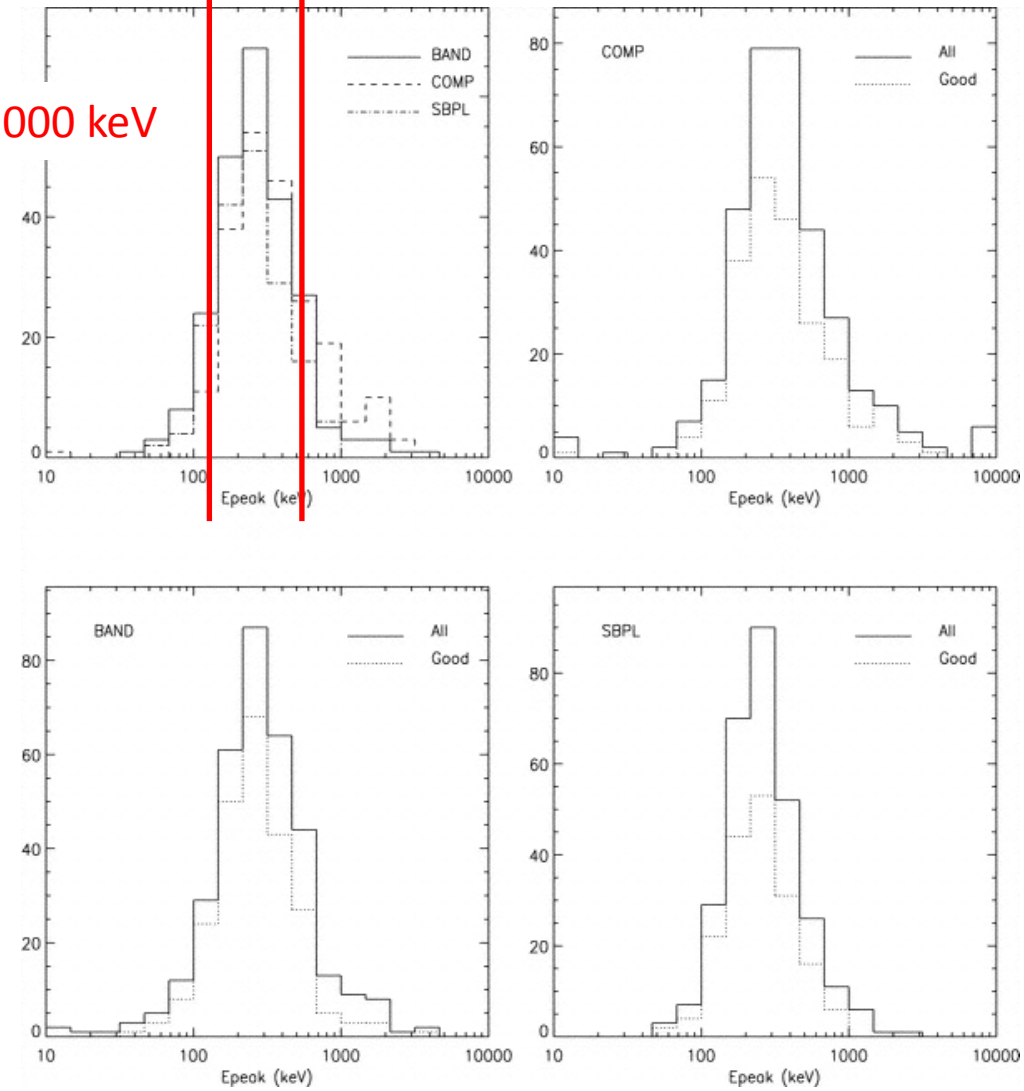

count s^{-1}
10^{-3}
0.01
0.1
1
10
100
100
1000
10^4
10^5
10^6
Time since trigger (s)

Results

$M/M_{\odot}$	$\rho_c, g/cc$	T_{max}, keV	$E_{nuc}, 10^{52}$ ergs
60	$1.15 \cdot 10^5$	351	2.23
78	$3.0 \cdot 10^5$	330	2.46
100	$2.65 \cdot 10^5$	371	4.12
100	$2.5 \cdot 10^5$	421	4.80
100	$2.4 \cdot 10^5$	463	5.11
112	$2.0 \cdot 10^5$	470	7.06

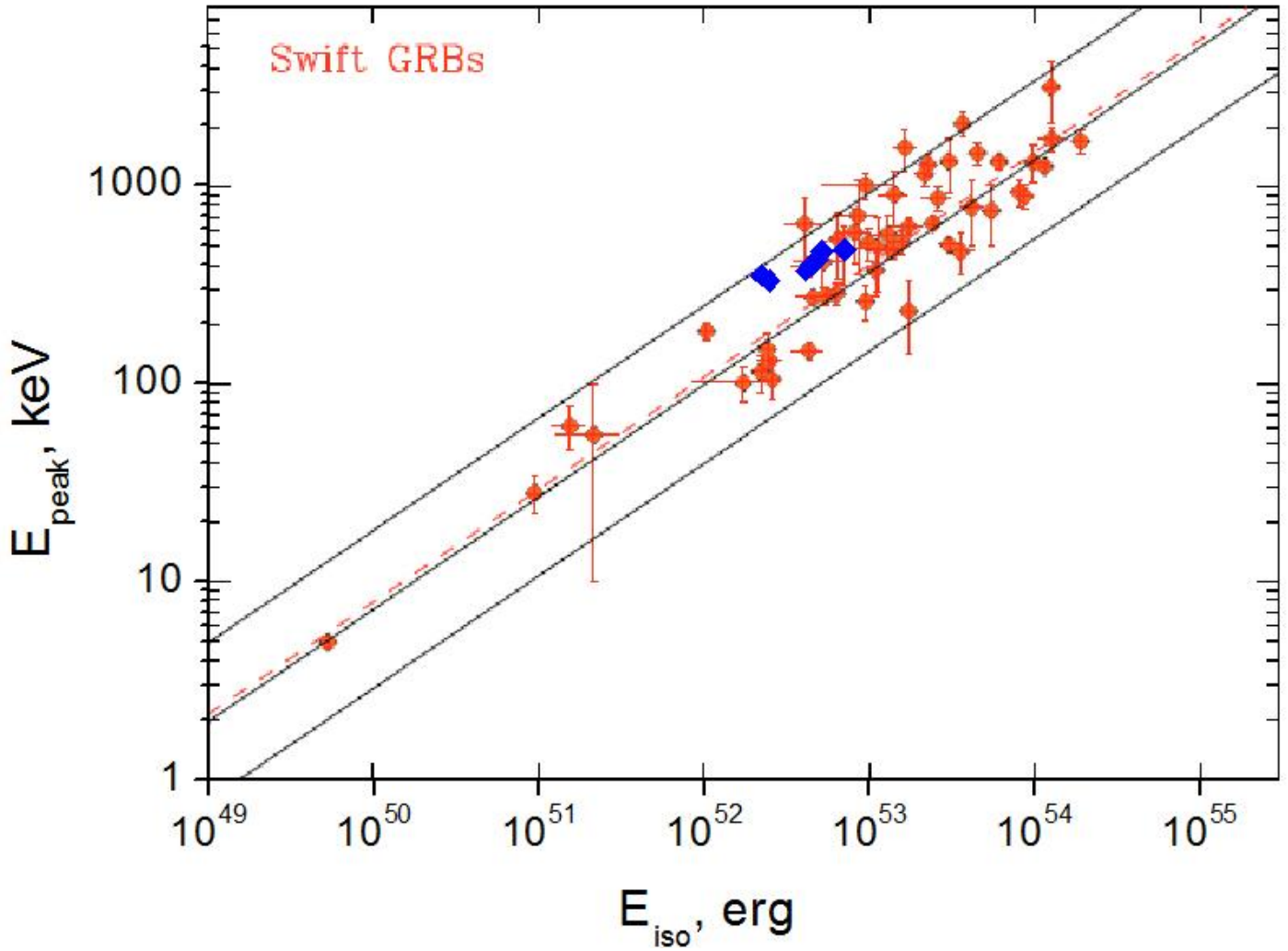
Spectral properties of GRBs

100 – 1000 keV



Kaneko et al., The Complete Spectral Catalog of Bright BATSE Gamma-Ray Bursts, 2006

On a physical interpretation of the Amati Relation



Amati relation from [L. Amati, F. Frontera and C. Guidorzi, 2009]

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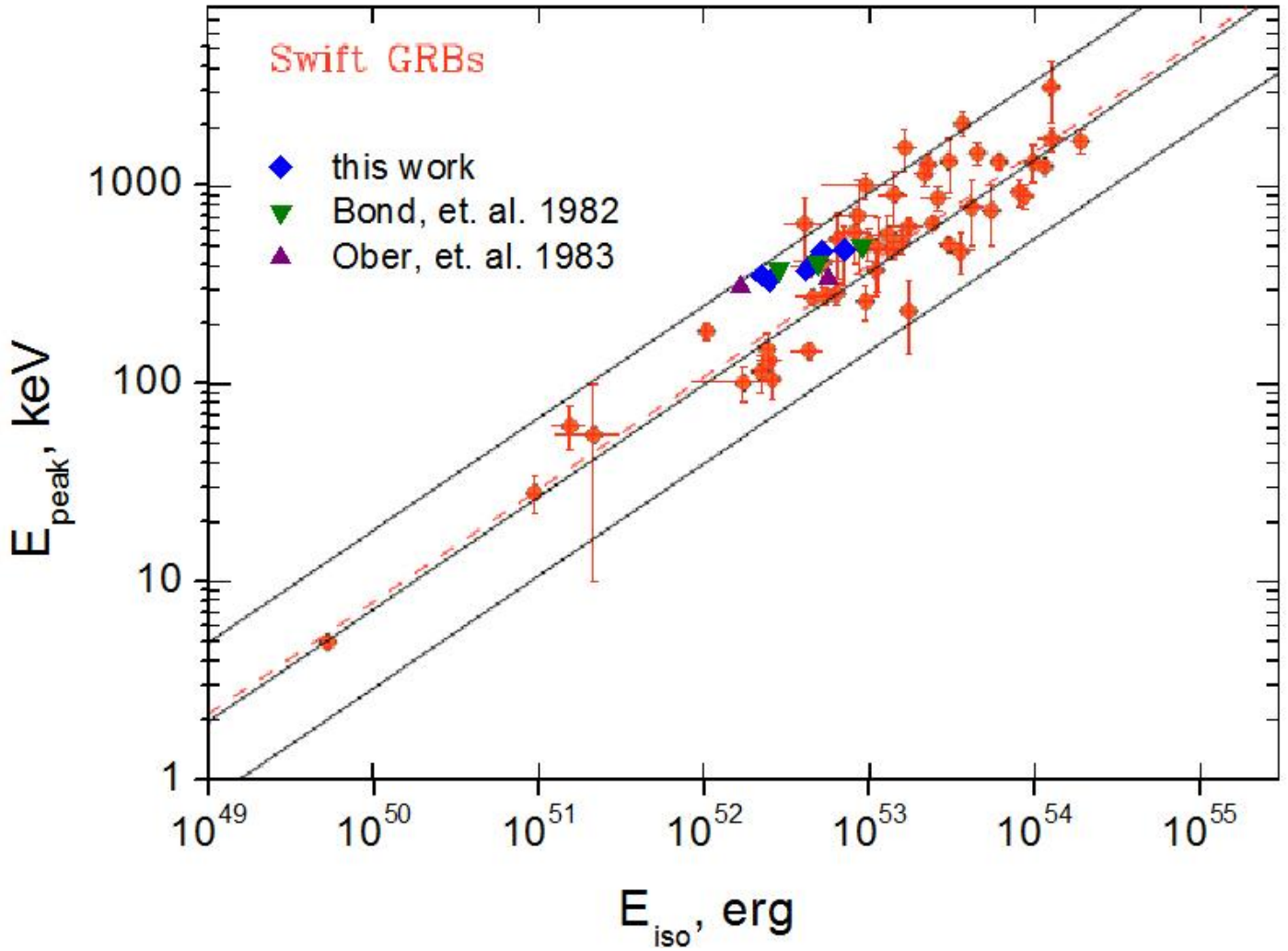

Amati relation from [L. Amati, F. Frontera and C. Guidorzi, 2009]

Conclusions

- New scenario of GRBs is proposed
- 1D simulations: timescale and energy budget are OK
- Amati relation could be related to the mass of the progenitor

Thank you for your attention!

Acknowledgments:
Chechetkin V., Filina A., Popov M.