s-process of fifty years

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古代宇宙学与人类认识史一样早

地球中心说：天像一把伞罩着平坦大地；天地像一只蛋，中心是地，周围是天。

太阳中心说，银河中心说，总之，宇宙有心，心即是我。

人类认识到宇宙无中心，无界限，人类本身是宇宙中普通的一员。仅到此时，人类才真正进入了宇宙的研究。

爱因斯坦猜想：

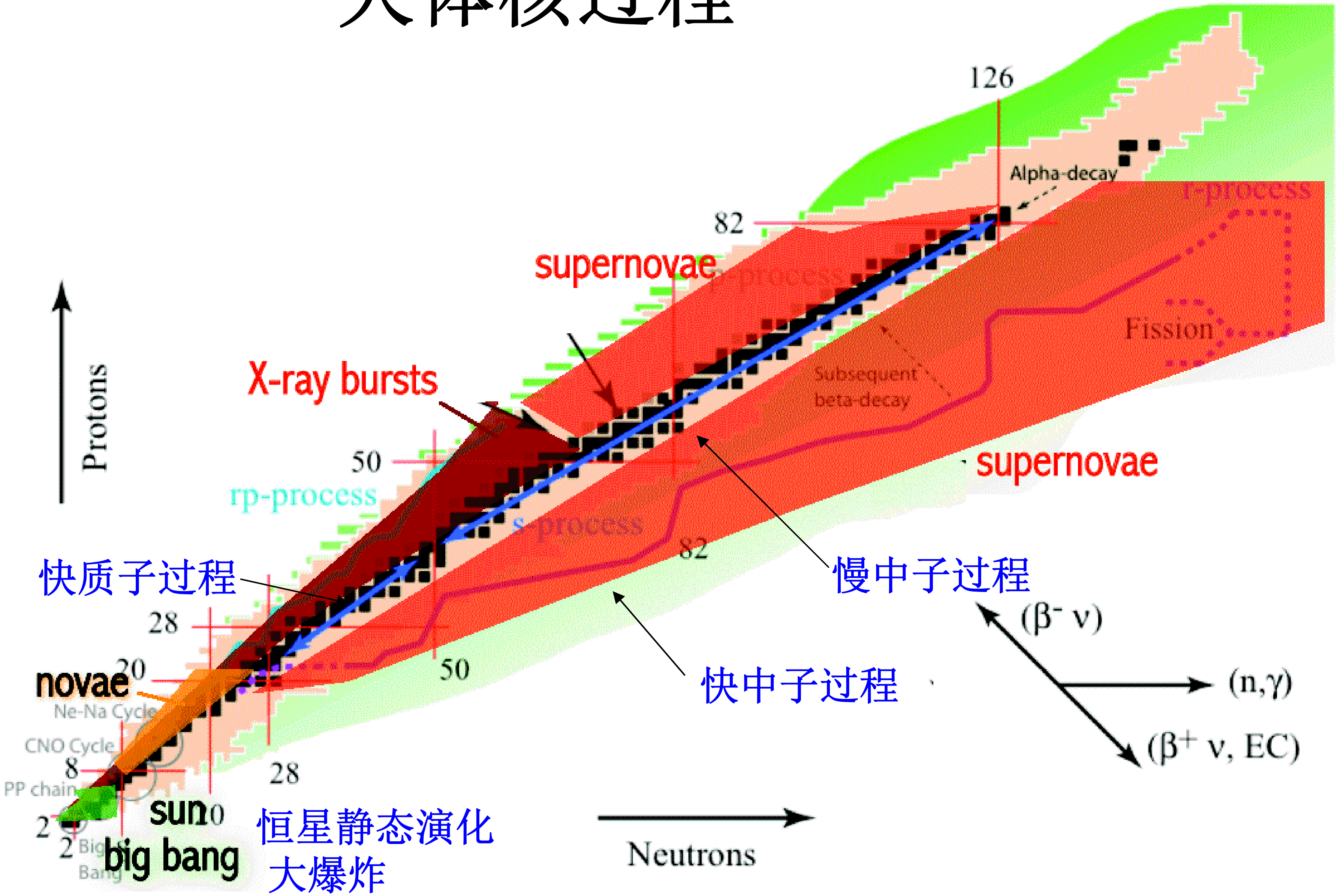
在大尺度上，宇宙是均匀的，各向同性的。
宇宙没有中心，也没有边界。
在任何一个星系上观测宇宙及其规律都是一样的。

爱因斯坦猜想，后来被称为宇宙学原理

百年宇宙学

五十年慢中子过程

天体核过程



126
Alpha-decay
r-process
82
supernovae
p-process
Fission
Subsequent
beta-decay
X-ray bursts
50
supernovae
rp-process
s-process
82
Protons
快质子过程
慢中子过程
28
(β^- ν)
novae
20
50
Ne-Na Cycle
快中子过程
(n,γ)
CNO Cycle
8
(β^+ ν, EC)
PP chain
28
2
sun
恒星静态演化
2
big bang
大爆炸
Neutrons

Origin of heavy elements

Elements heavier than the iron peak are mainly produced through neutron capture reactions in two main processes, the s-process (slow) and r-process (rapid).

s-nuclei are produced during the thermally pulsing asymptotic giant branch phase of low- mass stars (of 2-4 M_sun)

r-nuclei are produced in explosive conditions in SNeII.

ESIC

元素核合成中的关键科学问题研究

Key Issues of Elements Synthesis in Cosmos

Nuclear uncertainties in s-process

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Nuclear uncertainties

Network equations of s-process

$$\frac{dN(A)}{dt} = n_n(t) < \sigma v > (A-1)N(A-1) - n_n(t) < \sigma v > (A)N(A)$$

$$\frac{dN(A)}{dt} = \lambda_n(A-1)N(A-1) - [\lambda_-(A) + \lambda_n(A)]N(A)$$

$$\lambda_n = n_n(t) < \sigma v >$$

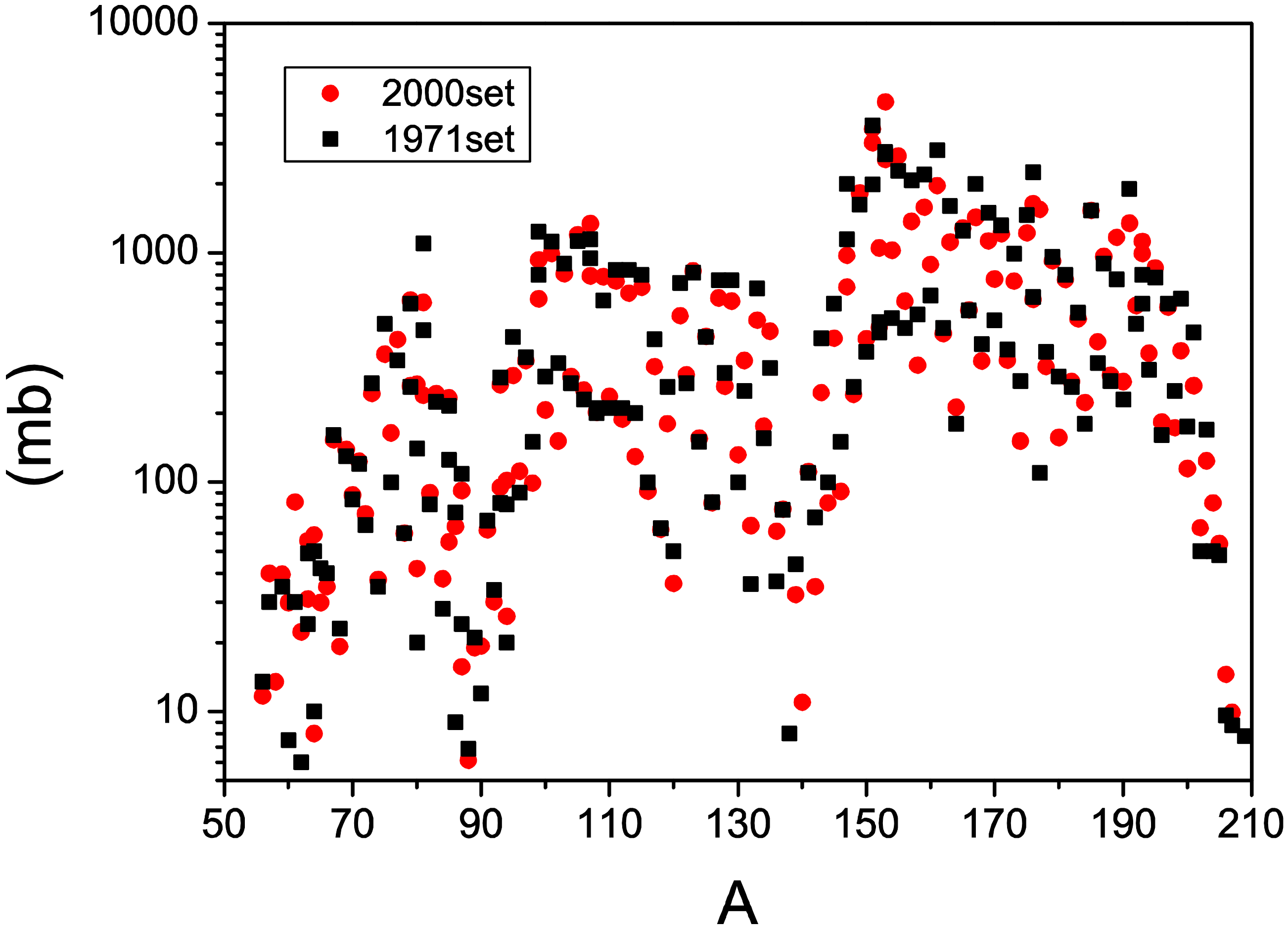
$$\frac{dN(A)}{dt} = \lambda_n(A-1)N(A-1) - [\lambda_{ec}(A) + \lambda_+(A) + \lambda_-(A)]N(A)$$

$$\frac{dN(A,Z)}{dt} = \lambda_n(A-1,Z)N(A-1,Z) + [\lambda_{ec}(A,Z+1) + \lambda_+(A,Z+1)]N(A,Z+1) - \lambda_n(A,Z)N(A,Z)$$

$$Changing\ \ t\ \ to\ \ irradiation(or\ exposure)\quad \tau \equiv \int_0^t n_n(t')V_{Th}dt'$$

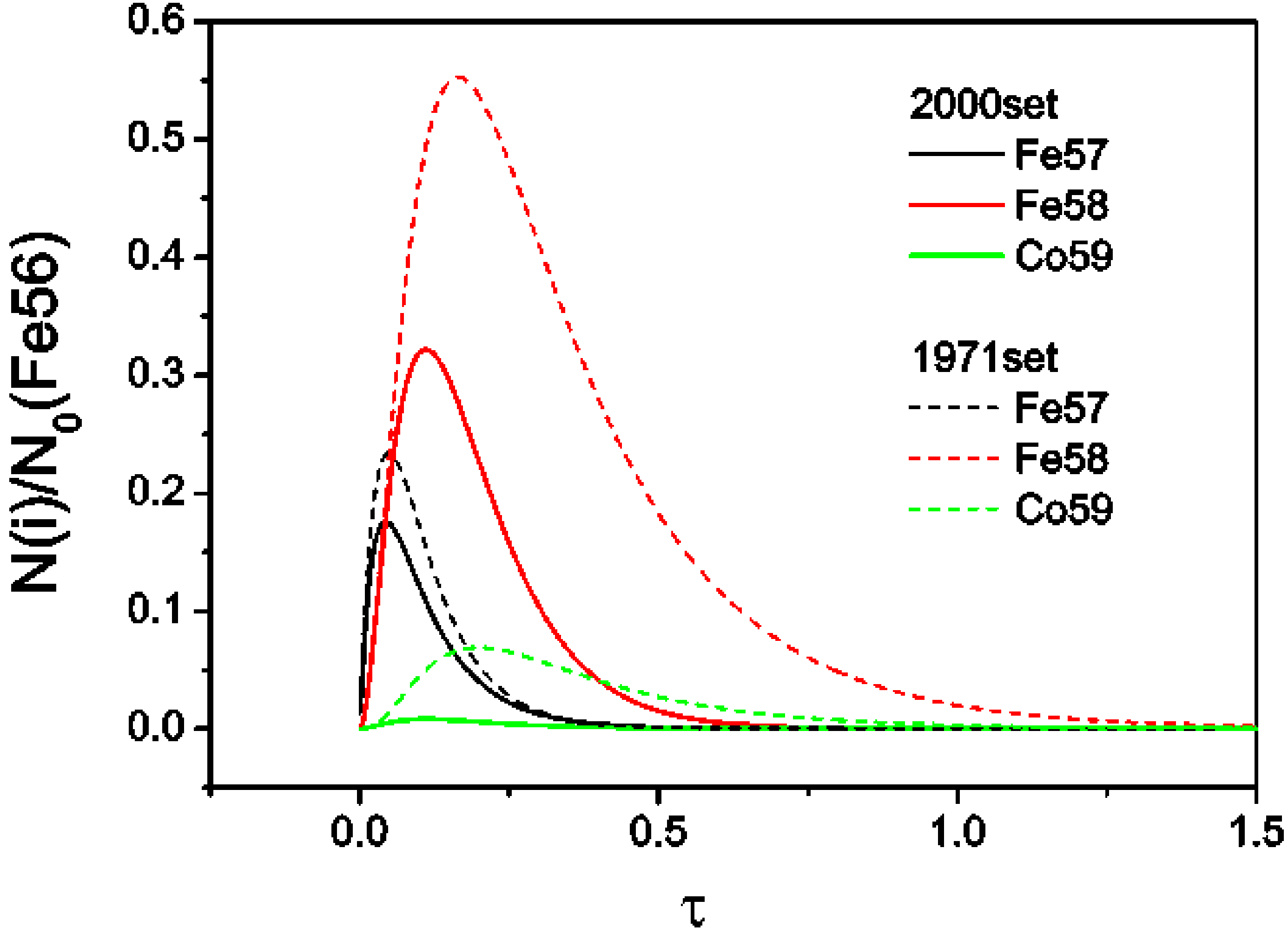
Nuclear uncertainties

Neutron cross section



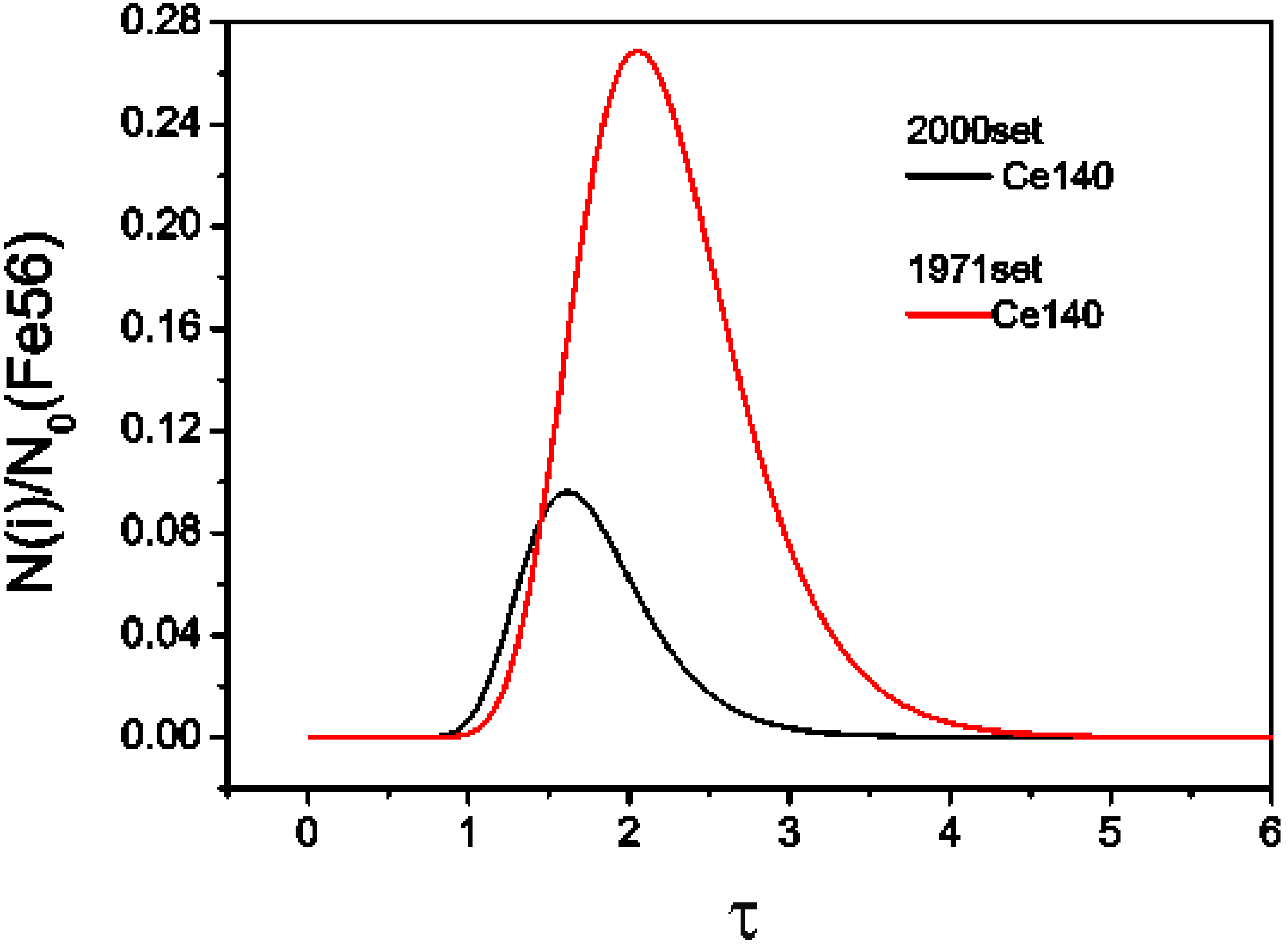
Nuclear uncertainties

Abundances of Fe-family



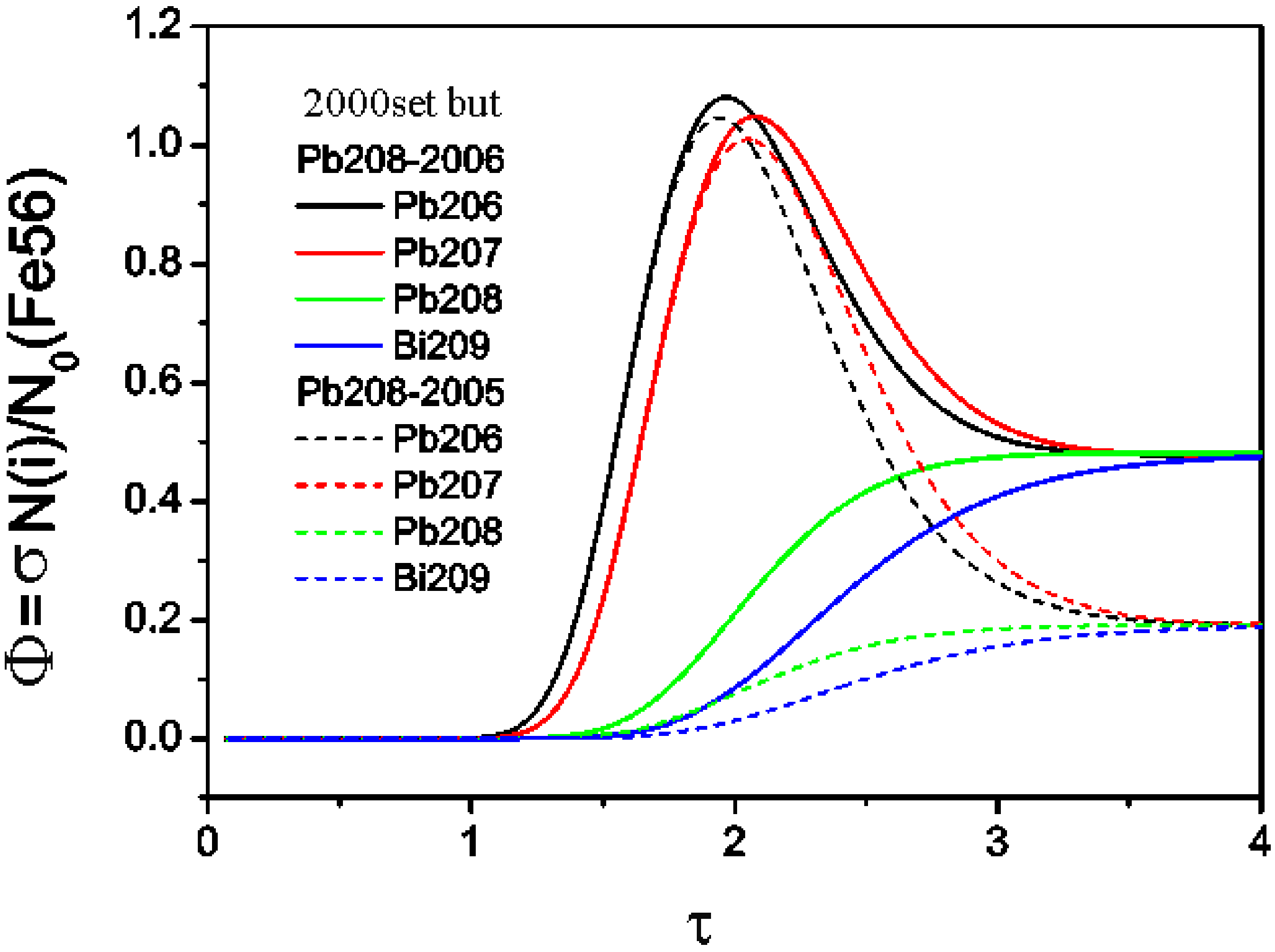
Nuclear uncertainties

Abundances in middle of s-chain



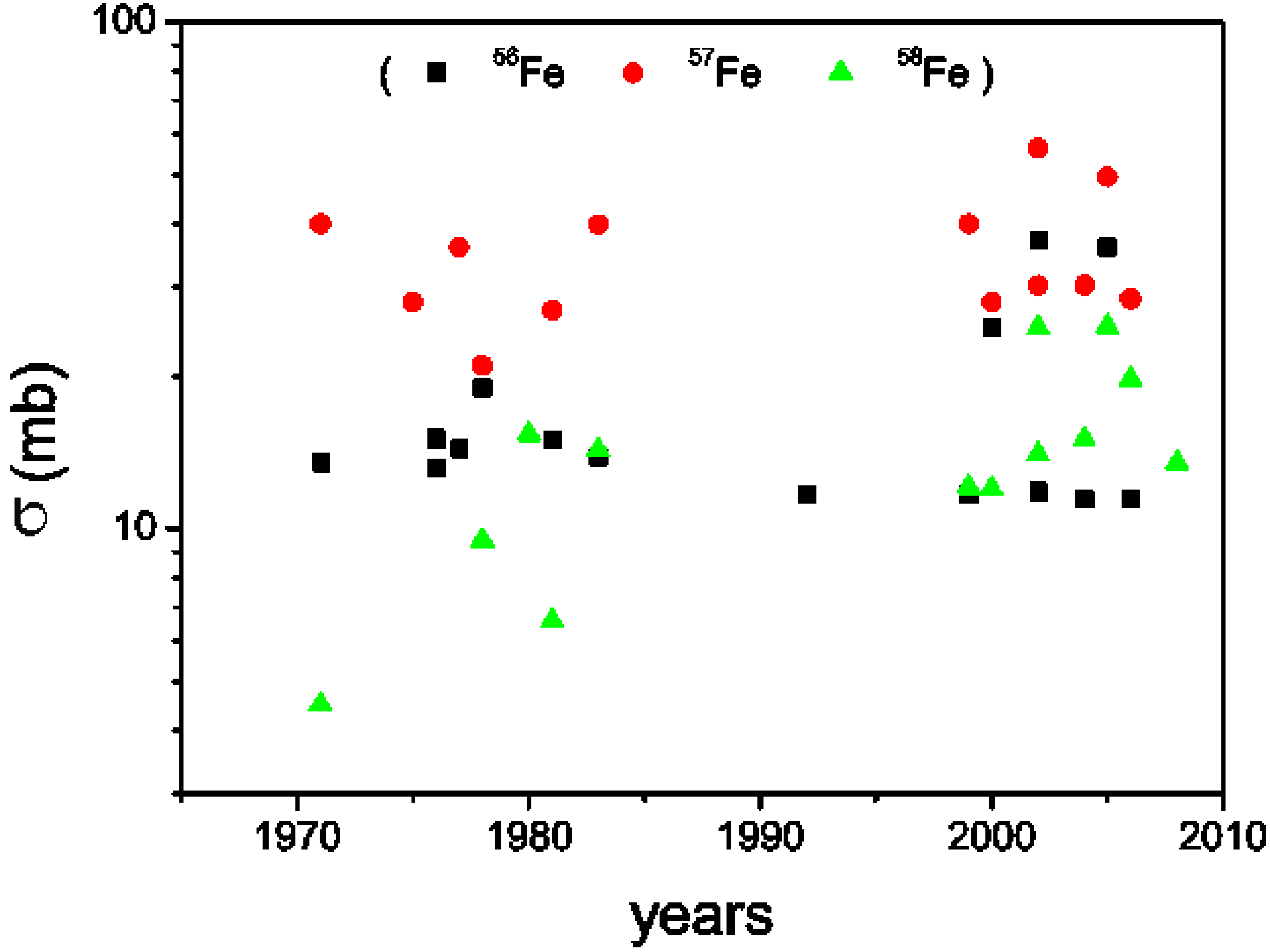
Nuclear uncertainties

Solutions of s-termination nuclei



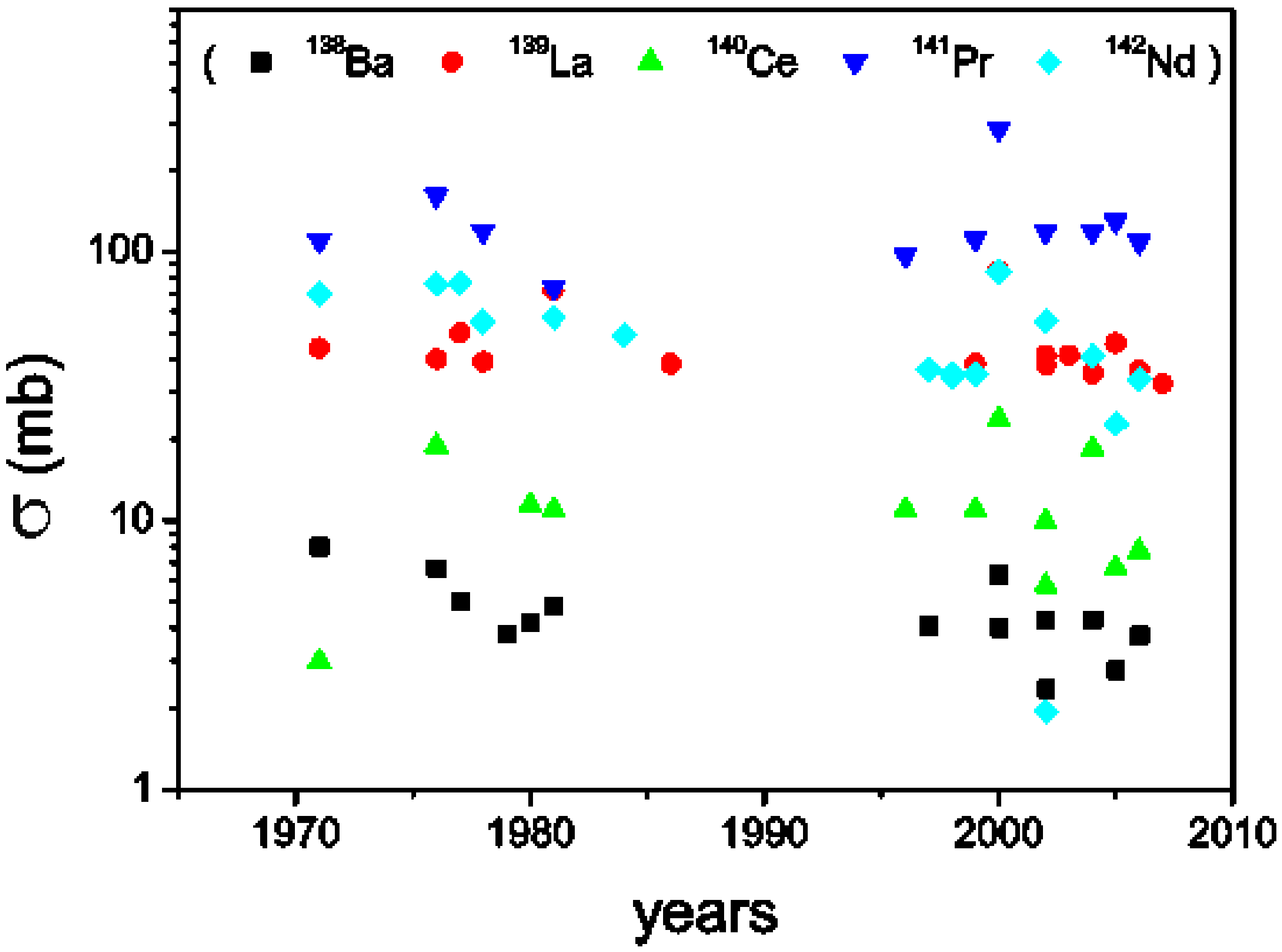
Neutron capture cross sections

Bigenning of s-chain



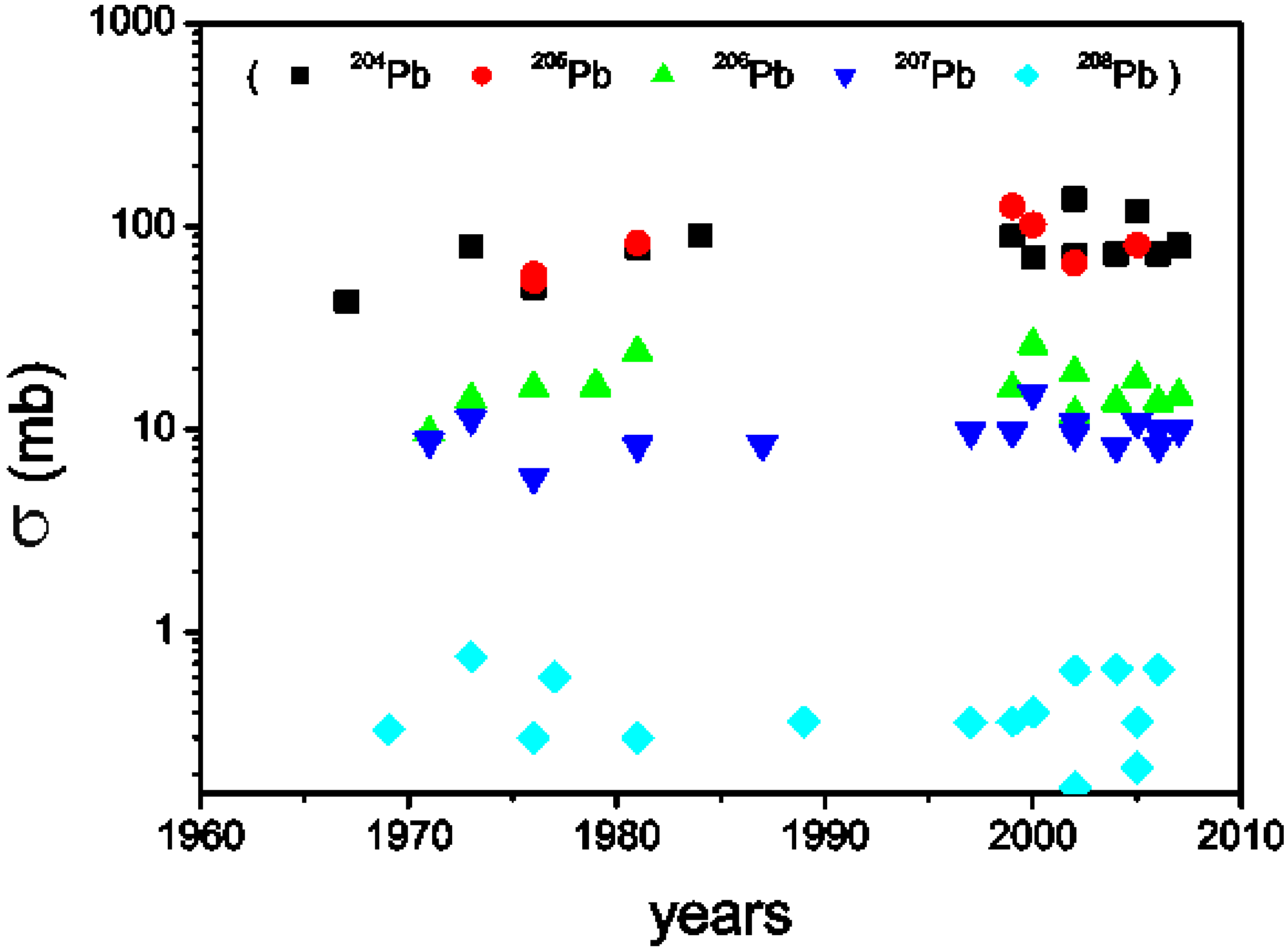
Neutron capture cross sections

Middle of s-chain



Neutron capture cross sections

Termination of s-chain



Odd-even difference of Ba abundances

Understanding the relative importance of
s- and r- synthesis mechanisium
throughout the Galaxy history

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Astronomy & Astrophysics

Barium even-to-odd isotope abundance ratios in thick disk and thin disk stars*

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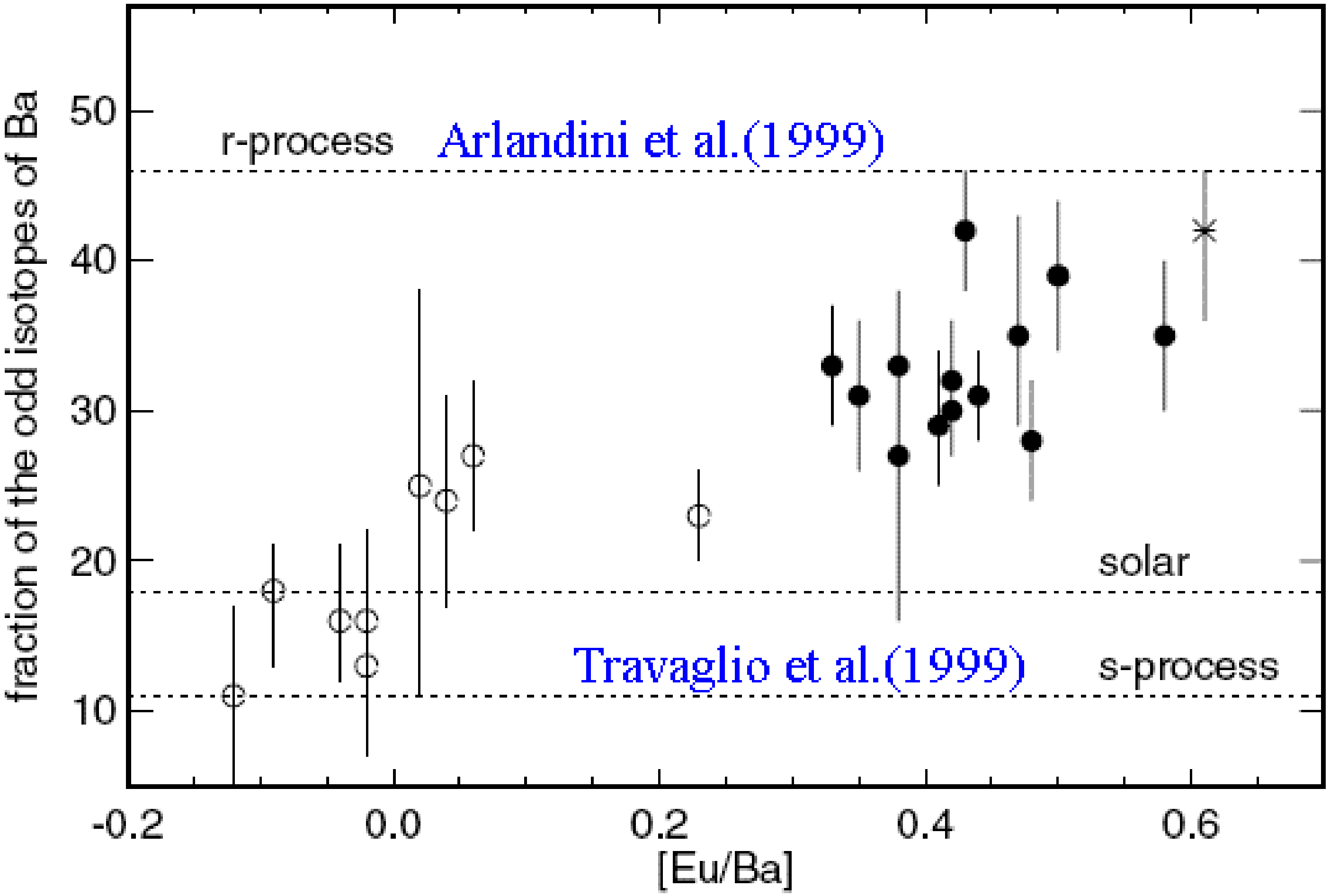
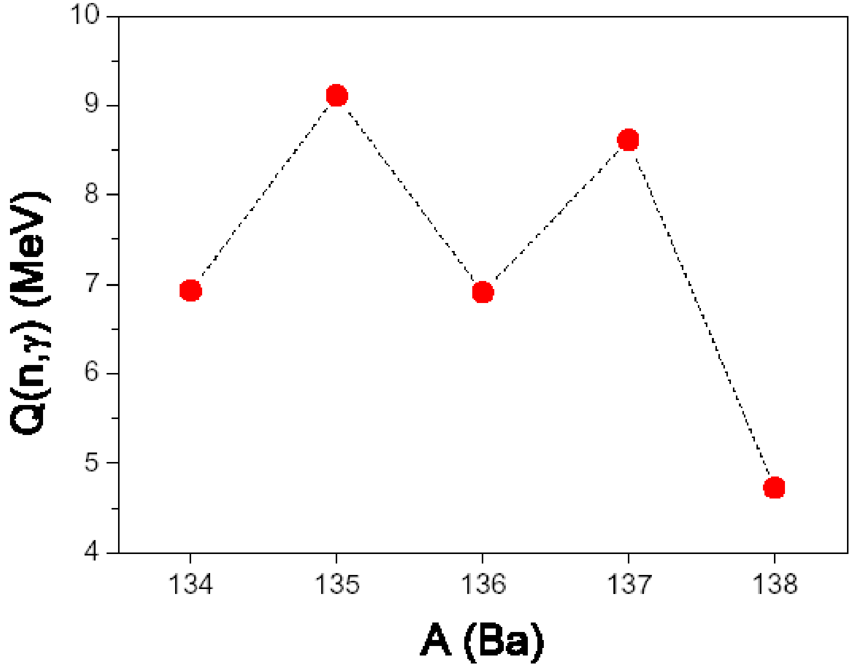
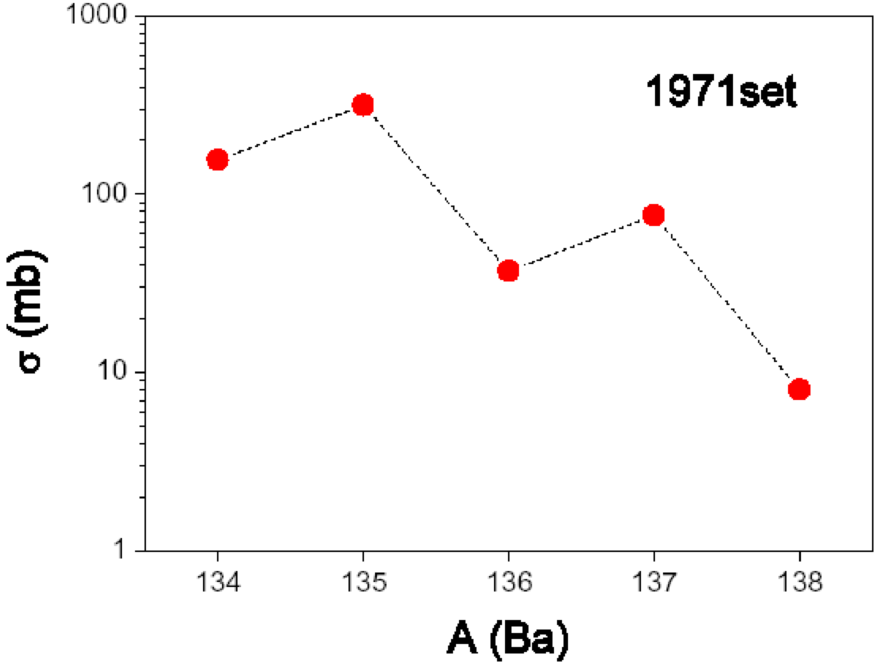
Odd-even difference of Ba abundances



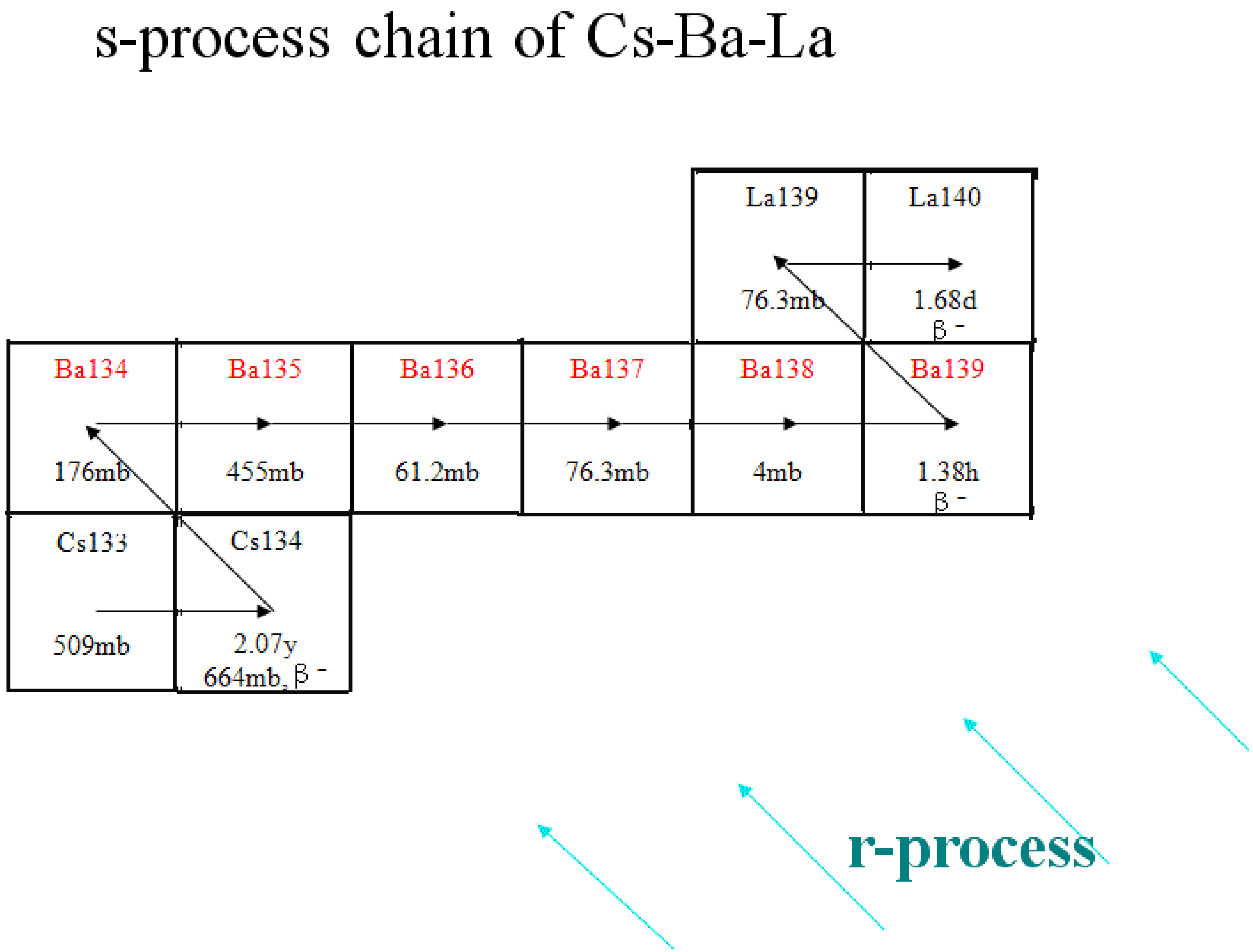
Odd-even difference of Ba abundances

Pairing correlation
Shell effects





Odd-even difference of Ba abundances



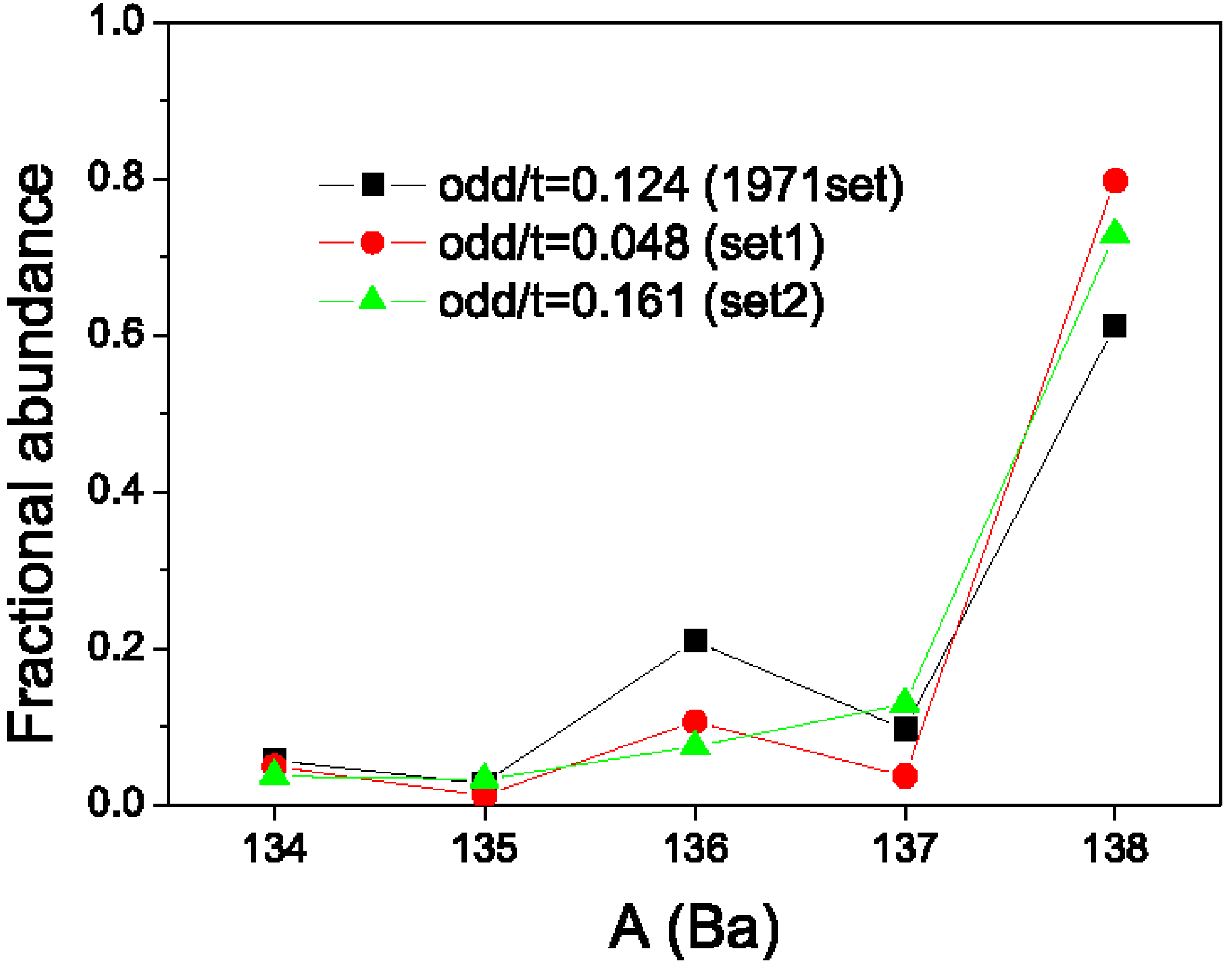
Odd-even difference of Ba abundances

Neutron capture cross section σ (mb)

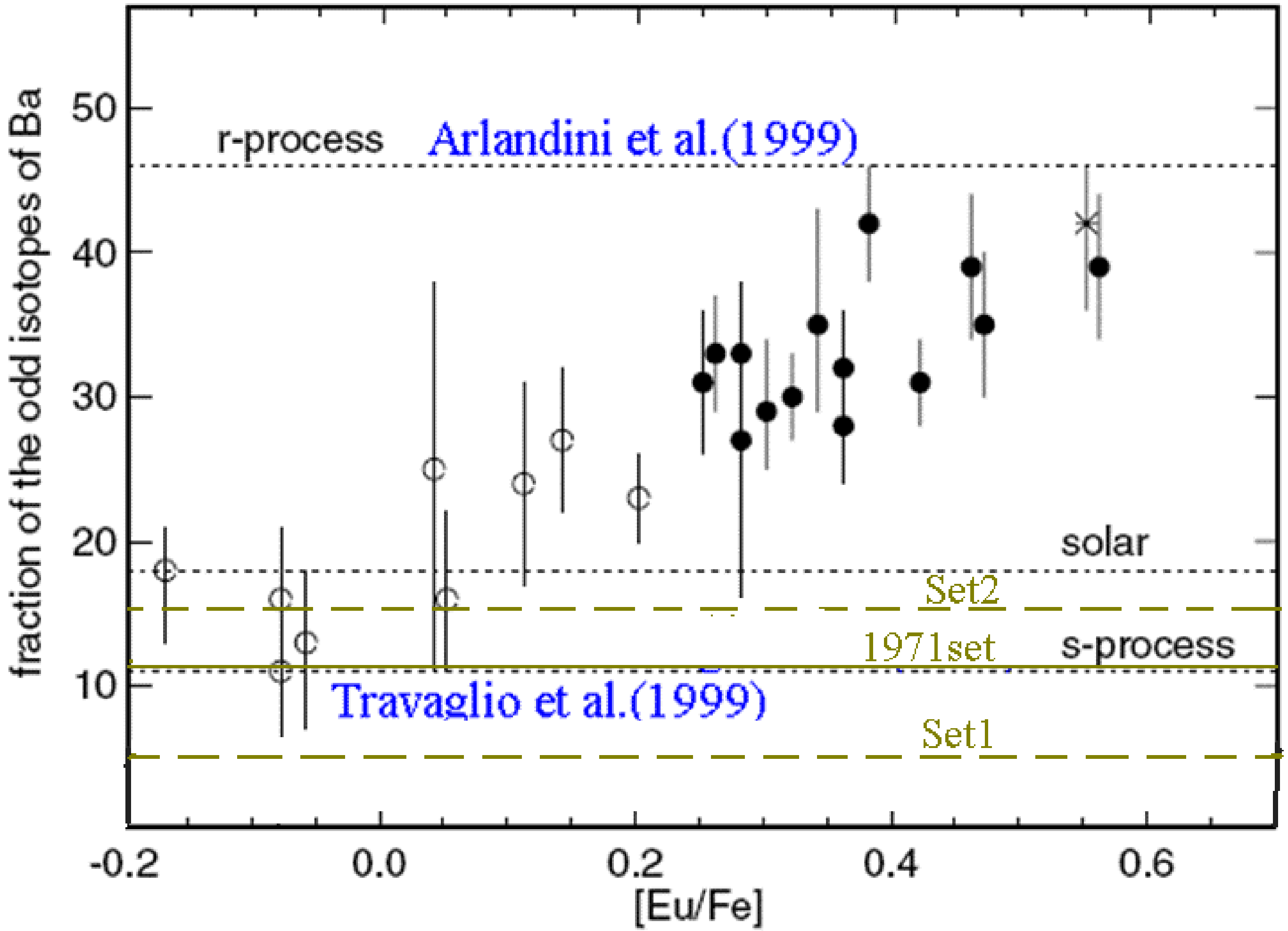
	1971set	Set1 (2000-2010)	Set2 (2000-2010)
^{134}Ba	155	117	232.5
^{135}Ba	315	500.8	259
^{136}Ba	37	49.4	108
^{137}Ba	76	140	58.4
^{138}Ba	8	2.38	6.3

Odd-even difference of Ba abundances

Calculated Ba-abundances



Odd-even difference of Ba abundances



Remarks

* Two important stages for the fifty years of s-process
Solar system → Galaxy
Start of s-process study → r- and s- process (twin processes)
Stable nuclei → unstable nuclei

* Many n-capture cross sections for s-nuclei must be improved

* The nucleosynthesis theory is not able to predict the yields of the r-process;
The nucleosynthesis theory is not able to predict enough accurately the yields of the s-process.

Thank you