Motivation	Measurement 0000	Capture Rate 00	Nucleosynthesis 00	Summary

Measurement of the ${}^{17}C(n, \gamma){}^{18}C$ Rate and Implications on the *r*-Process Nucleosynthesis

Marcel Heine for the R³B Collaboration

NAVI Physics Days



January 18, 2016



Image: A math a math

Motivation	Measurement 0000	Capture Rate 00	Nucleosynthesis 00	Summary
1	Neutron Capture in <i>r</i>	-Process Nucleos	ynthesis	
2	The R ³ B-LAND Setu • Coulomb Dissociati • Definition of the R • Experimental Spect • Energy-Differential	p ion with Neutron eaction Channel troscopic Factors Cross Sections	Evaporation C^2S	
3	Neutron Capture Rate • Completion of the • Stellar Reaction Ra	e of ¹⁷ C Transition Matrix ate	:	
4	Implications on the <i>r</i> - • Carbon Abundance • Final <i>r</i> -Process Ab	-Process Nucleosy s in the <i>r</i> -Process undances	nthesis 5 Flow	

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Motivation	Measurement 0000	Capture Rate	Nucleosynthesis 00	Summary

r-Process Flow Including Light Exotic Nuclei



modified, from: M. Terasawa et al., ApJ, 562, 470, 2001

- neutrino-driven wind of core-collapse Type II supernovae
- ejecta of the accretion disk in binary neutron star mergers

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Motivation	Measurement 0000	Capture Rate 00	Nucleosynthesis 00	Summary

r-Process Flow Including Light Exotic Nuclei



modified, from: M. Terasawa et al., ApJ, 562, 470, 2001

Coulomb dissociation of ¹⁸C 18 C $(\gamma^*,n)^{17}$ C



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- neutrino-driven wind of core-collapse Type II supernovae
- ejecta of the accretion disk in binary neutron star mergers





background from:

- nuclear reactions
- beam line
- → statistical subtraction:
 - carbon target run
 - data without target

efficiency and acceptance:

- simulation of detector response
 - gamma detector
 - neutron detector[‡] (energy dependent)



Wotivation		ient	00)	Summary
Experimental Sp	pectroscopic Factors (C ² S				
			σ_{sp}^{\dagger} : Indepe	endent F	Particle Mode	I (IPM)
C	$\sigma^2 S = \sigma_{exp} / \sigma_{exp}$	sp	$^{18}{ m C}(0^+)$	$\leftrightarrow^{17}\mathrm{C}(3)$	$3/2^+)\otimes u$ (0d	3/2)
				$\oplus^{17}\mathrm{C}(1)$	$1/2^+) \otimes \nu(1s)$	1/2)
				$\oplus^{17}\mathrm{C}(5)$	$5/2^+)\otimes u$ (0d	(5/2)
					, , , ,	-/-/
	<i>E</i> * [MeV]	I^{π}		<i>C</i> ² <i>S</i>		=
			Coulomb Breal	kup	Knockout*	=
			stat.	sys.		_
	0.0	$3/2^{+}$	$1.18\pm0.48\pm0$).19	\leq 0.67	
	0.22	$1/2^{+}$	$0.52 \pm 0.11 \pm 0$).07	0.39 ± 0.07	
	0.33	$5/2^{+}$	$1.74\pm0.24\pm0$).04	2.39 ± 0.27	_

[†] S. Typel
* Y. Kondo et al., PRC, 79, 014602, 2009



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transitions to exited states:

- spectroscopic factors*
- single particle cross sections[†]

- photo absorption: E1 excitations
- $|^{18}C(0^+)\rangle$: unambiguous assignment of ^{17}C state and neutron wave function (IPM)
- $|^{18}C(2^+)\rangle$: eight such contributions

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* T. Neff
† S. Typel
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thermal equilibrium with stellar environment:

- neutrons: Maxwell-Boltzmann distribution
- target nuclei: stellar enhancement



- grey: present (exp.) data
- blue: Hauser-Feshbach* (HF)
- red: direct capture model[†]

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    * T. Sasaqui et al., ApJ, 634, 1173, 2005
    <sup>†</sup> H. Herndl et al., PRC, 60, 064614, 1999
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- Exp [%]: capture to the ground state
- $\lambda_{\rm HF}/\lambda_{\rm exp}$: ratio of HF and present results



DQC

Motivation	Measurement 0000	Capture Rate 00	Nucleosynthesis ●○	Summary
Carbon Abundances in the	r-Process Flow			

parametrization mimicking thermodynamics of:

- high entropy and fast expansion ejecta of core-collapse supernovae
- ejecta from the accretion disk formed during a binary neutron star merger





M. Terasawa et al., ApJ, 562, 470, 2001

Motivation	Measurement 0000	Capture Rate 00	Nucleosynthesis ○●	Summary
Final <i>r</i> -Process Abundanc	es			

- quasi equilibrium states along carbon chain during *r*-process
- build up of heavier nuclei regulated by the isotopes with relative large abundances and short beta-decays half-lives: $^{18}\rm{C},~^{20}\rm{C}$



 abundance of ¹⁷C low: minor affect on overall behavior of neutron captures during the later phase of freeze-out

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Motivation	Measurement 0000	Capture Rate 00	Nucleosynthesis 00	Summary

- $\bullet\,$ Coulomb dissociation of ^{18}C has been measured with the $R^3B\text{-}LAND$ setup
- exclusive cross sections were derived and confined by theoretical photo absorption calculations (IPM)
- experimental neutron capture cross sections were derived
- transitions to excited states in ¹⁸C were distributed by shell model theory (OXBASH) and semi classical calculations (IPM)
- the stellar reaction rate for neutron capture on ¹⁷C was obtained
- the influence of the updated rate on the *r*-process nucleosynthesis was investigated

Thank You For Listening!!