The Joint Institute for Nuclear Astrophysics

Breakout of the CNO cycle and the $^{15}O(\alpha,\gamma)$ reaction rate

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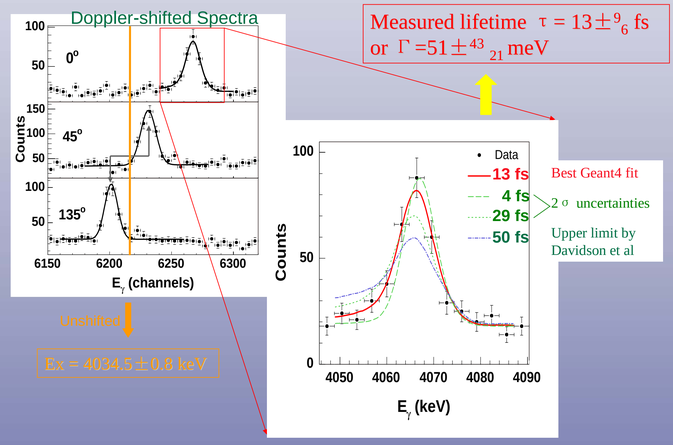
- **$^{15}O(\alpha,\gamma)^{19}Ne$** is critical to break out the hot CNO cycle and trigger the thermonuclear runaways in accreting neutron star of a close binary system.
- It is very sensitive to the burst amplitude and periodicity of X-ray bursters.
- It is probably also key to the amount of C to be ignited for superbursts.

17O(3He,n-γ)19Ne Experiment

- Lifetimes were measured using Doppler-shift attenuation method
- Full line shape analysis with Geant4 simulation was used to deal with tailing effects and the feeding from higher lying states
- Gamma spectra in coincidence with neutrons were measured in three setups

Lifetime of the 4.03-MeV state



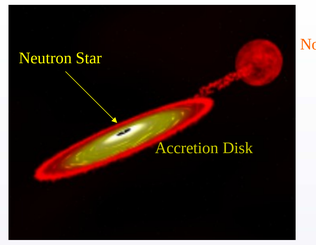
Summary of Lifetime Results

Compilation (TUNL)			Present work	
E* [keV]	J^π	τ_m [fs]	E*[keV]	τ_m[fs]
1507.56±0.3	5/2-	$1.4^{+0.5}_{-0.6}\times10^3$	1507.51±0.35	1.7±0.3x10³
1536.0±0.4	3/2+	28±11	1536.05±0.36	16 ±4
1615.6±0.5	3/2-	143 ±31	1615.4±0.4	80 ±15
2794.7±0.6	9/2+	140 ±35	2794.2±0.4	100 ±12
4032.9±2.4	3/2+	<50	4034.5±0.8	15^{+5}_{-4}
4140±4	(9/2)-*	<300	4143.5±0.6	18^{+2}_{-3}
4197.1±2.4	(7/2)-*	<350	4200.3±1.1	43^{+12}_{-9}
4379.1±2.2	7/2+	<120	4377.8±0.6	5^{+3}_{-2}
4549±4	(1/2,3/2)-	<80	4547.7±1.0	15^{+11}_{-5}
4600±4	(5/2+)	<160	4601.8±0.8	7^{+5}_{-4}
4635±4	13/2+	>1x10³	4634.0±0.9	>1x10³

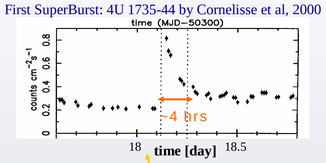
* Our study shows the spin assignments should be exchanged

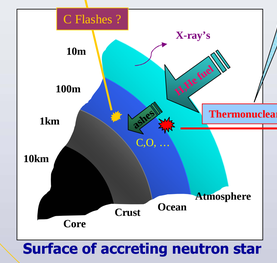
W.P. Tan et al, Phys. Rev. C72, 041302R (2005)

X-ray Binaries



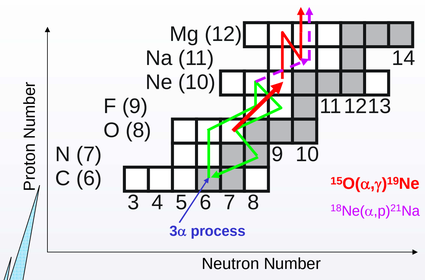
First SuperBurst: 4U 1735-44 by Cornelisse et al, 2000



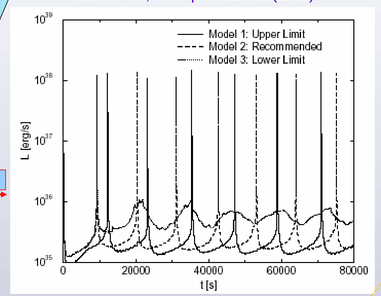


Surface of accreting neutron star

Breakout of the hot CNO cycle



Fisker et al., astro-ph/0410561 (2005)



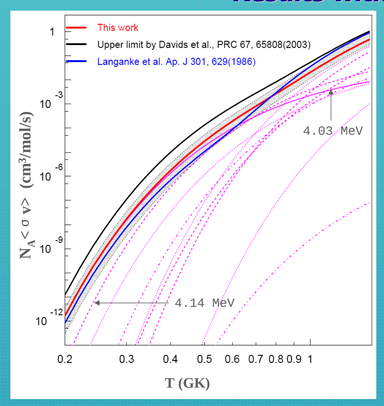
Sensitivity to the 15O(α,γ) rate

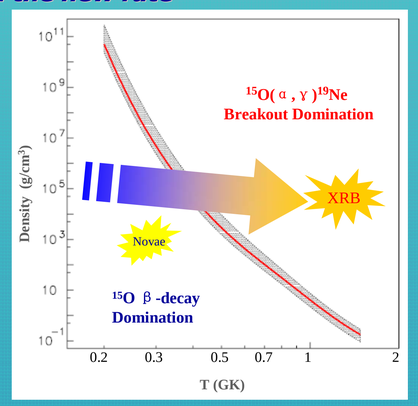
τ=ħ/Γ

Bα's

Reaction rate ∝ ωγ ∝ ΓγBα

Results with the new rate

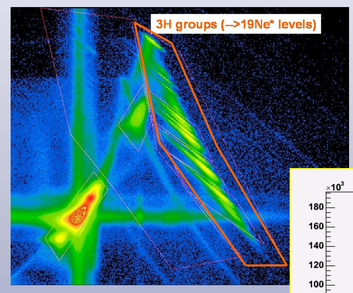




- We have significantly improved our knowledge on the reaction rate of $^{15}O(\alpha,\gamma)^{19}Ne$
- Further investigation with X-ray model simulations using our new rate will probably answer various questions related to X-ray bursts and superbursts.

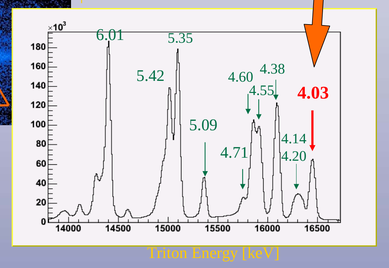
Alpha-decay Branching ratios measurement via 19F(3He, t-a)15O

A million of 3H detected for 4.03 MeV State



… to reach the sensitivity of 10^{-4} in B_α

… after two weeks



Results of α-decay Branching Ratios

Ex [MeV]	Magnus90	RIKEN	Laird02	Rehm03	Davids03	Visser04	This work
4.03		<0.03	<0.01	<6x10⁻⁴	<4.3x10⁻⁴		2.9±2.2x10⁻⁴
4.14, 4.20			<0.01				1.2±0.5x10⁻³
4.38	0.044±0.032	<0.04		16±5x10⁻³	<3.9x10⁻³	(>0.0027)	1.2±0.3x10⁻³
4.55	0.07±0.03	$0.09^{+0.04}_{-0.02}$			0.16±0.04	0.06±0.04	0.07±0.02
4.60	0.25±0.04	$0.29^{+0.06}_{-0.04}$	0.32±0.03		0.32±0.04	0.208±0.026	0.26±0.03
4.71	0.82±0.15	$0.67^{+0.23}_{-0.14}$			0.85±0.04	$0.69^{+0.11}_{-0.14}$	0.80±0.15
5.09	0.90±0.09	$1.11^{+0.17}_{-0.13}$	1.8±0.9	0.8±0.1	0.90±0.06	$0.75^{+0.06}_{-0.07}$	0.87±0.03

Preliminary

- Magnus90: Magnus et al, Nucl. Phys. A 506, 332 (1990)
- RIKEN: private communication from T. Motobayashi
- Laird02: Phys. Rev. C 66, 048801 (2002)
- Rehm03: Phys. Rev. C 67, 065809 (2003)
- Davids03: Phys. Rev. C 67, 012801R (2003)
- Visser04: Phys. Rev. C 69, 048801 (2004)

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