^{17}O destruction rate in stars

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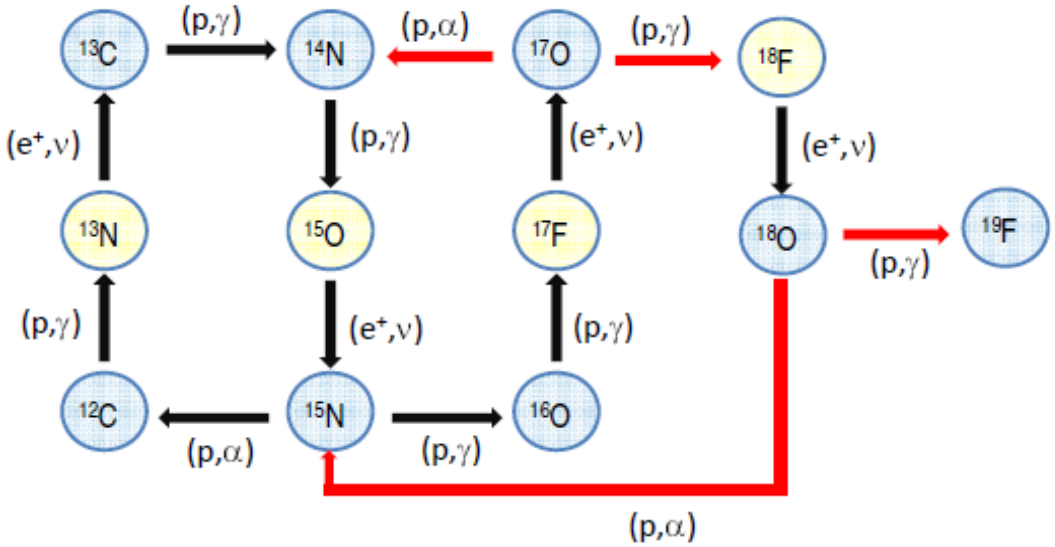
CNO cycle related reaction cross section

- starlib discontinued
- Many CNO reaction studied in LUNA
  - $^{14}N(p,\gamma)^{15}O$ - $^{15}N(p,\gamma)^{16}O$ - $^{17}O(p,\gamma)^{18}F$ - $^{17}O(p,\alpha)^{14}N$ - $^{18}O(p,\gamma)^{19}F$ - $^{18}O(p,\alpha)^{15}N$
  - $^{12}C(p, \gamma)$, $^{13}C(p, \gamma)$, $^{16}O(p, \gamma)$ –> in progress
- R-Matrix
  - more common in Nuclear Astrophysics
  - more accurate (multi-level Breit-Wiegner)
  - it can include interference and DC effects
  - AZURE2 readily available ☺



Astro background

AGB stars: mixing mechanisms and isotopic composition $^{16}O/^{17}O$ (atmosphere and extrasolar grains)

Novae explosions: influences ^{19}F and ^{15}N abundances as measured in pre-solar grains and satellite observations of $^{18}F(\beta^+,\nu)^{18}O$

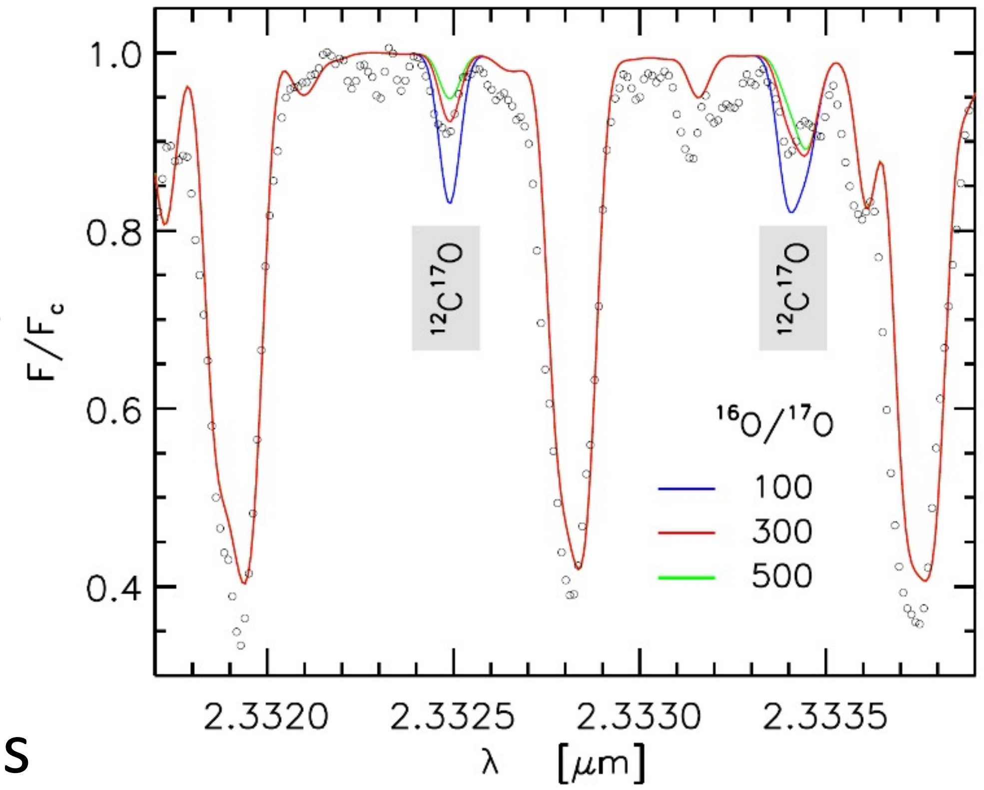


Fig. 1. Observed spectrum of HD 27292 (dots) showing two $^{12}C^{17}O$ lines. The three synthetic spectra (solid lines) are for T_{eff}=4000 K and log$g$=1.5 with $^{16}O/^{17}O$=100, 300, and 500.

Procedure

1. Poles fit
2. S Factor evaluation
3. Reaction rate calculation

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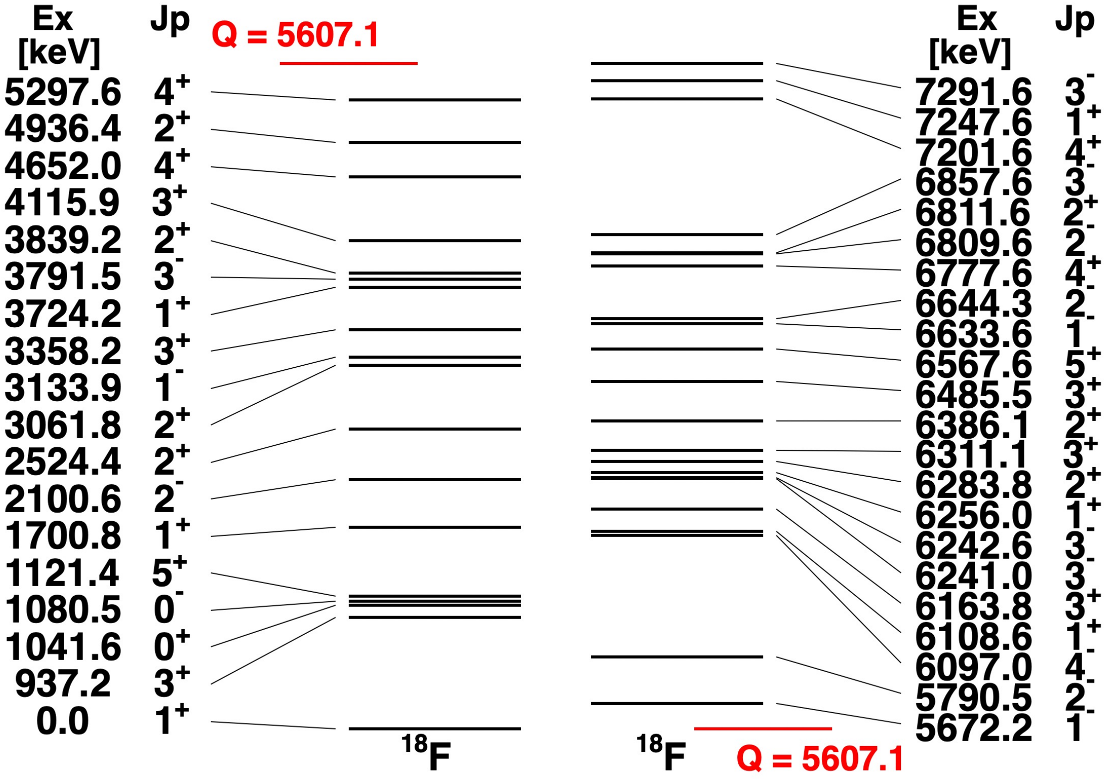
Data Literature

- Resonant parameters
  * "Charged-particle thermonuclear reaction rates" Longland, Iliadis et al. 2010 Nuclear Physics A 841
  * more recent works
  * Tilley et. al 1995 Nuclear Physics A595 (or similar)
- Cross section
  * everything available

Procedure

1. Poles fit



AZURE2

- multi-channel – (p,γ) and (p,α) or (p,p)
- multi-level: states up to 2 GK, high energy poles, relevant subthreshold states – here for primary γ-rays
- fit - poles widths most probable value and uncertainty DC, low energy tail of higher energies resonances and interference included

estimates from LUNA and Blackmon (p,α) measurements – bad agreement, choice to be made
recently directly measured in LUNA 30(6) neV – Piatti et al. PRL under review

Procedure

1. Poles fit

E_x [keV]	6097.0	6163.8	6242.6	6283.8	6311.1	6386.1	6567.6	6777.6
0	0	0.2(2)	0	0.40(2)	4.0(7)	1.4(3)	0	0
937	4.4(4)	50.3(6)	4.1(3)	65.7(3)	10.6(1.0)	74.8(2.5)	15.2(1.6)	12.6(9)
1040	0	0	0	0.9(1)	0	0	0	0
1121	57.3(1.8)	1.2(1)	0	0	0	0	0	25.2(1.3)
1700	0	0	0	5.7(1)	3.0(8)	8.5(5)	0	0
2100	25.5(1.0)	0	71.2(3.0)	1.7(1)	0	0	0	0
2523	0	6.7(2)	0	0.7(1)	4.0(5)	0	0	0
3062	0	2.2(1)	0	0	57(3)	0	0	0
3133	0	0	0	1.3(1)	0	0	0	0
3358	0	0	0.8(3)	2.1(1)	0	0	83(3)	0
3724	0	0	0	2.5(1)	1.4(7)	0	0	0
3791	1.3(2)	10.2(2)	11.6(6)	0	0	0	0	0
3839	0	22.1(3)	0.9(2)	13.3(1)	4.6(1.0)	12.3(7)	0	0
4115	1.7(2)	1.9(2)	1.1(4)	3.7(1)	2.4(1.7)	3.1(4)	0	0
4226	0	1.2(2)	8.2(4)	0	0	0	0	0
4360	0	0	0	2.1(1)	0	0	0	0
4398	1.5(2)	2.4(1)	2.1(3)	0	0	0	0	0
4652	7.1(3)	0	0	0	0	0	0	62(2)
4964	0	0	0	0	13.0(1.5)	0	0	0
5298	0	0	0	0	0	0	2.3(6)	0

E_{cm} [keV]	E_x [keV]	$\omega\gamma$ [eV]	J^π	Γ_p [eV]	Γ_α [eV]	Γ_γ [eV]
64.48(54)	5671.6(2)	$2.95(60)\times10^{-11}$	1^-	$3.50(68)\times10^{-8}$	130(5)	0.44(2)
182.73(58)	5789.9(3)	$1.66(12)\times10^{-6}$	2^-	$4.00(24)\times10^{-3}$	13.3(5.5)	$1.1(3)\times10^{-2}$
489.3(1.2)	6096.4(1.1)		4^-	138(26)	106(17)	$3.07(50)\times10^{-2}$
500.9(3.0)	6108(3)		1^+	0.20(2)	33.6(3.3)	0
529.4(6)	6136.5(3)	0.110(25)				
556.1(1.0)	6163.2(9)		3^+	140074(257)	5.0(6)	0.595(134)
633.3(9)	6240.4(8)	0.16(26)	3^-	58.2(7.0)	133(24)	0
634.9(3.0)	6242(3)		3^-	40.8(3.7)	137(35)	0.73(11)
654.9(2.6)	6262.0(2.5)		1^+	27(3)	575(120)	0
676.1(1.0)	6283.2(9)		2^+	11121(186)	28.1(5.0)	0.603(29)
703.4(9)	6310.5(8)		3^+	525(117)	426(82)	0.17(4)
778.4(1.8)	6385.5(1.7)		2^+	109(11)	286(87)	0.270(68)
877.8(1.6)	6484.9(1.5)	$1.93(17)\times10^{-2}$	3^+	277(91)	123(25)	0
959.9(1.6)	6567.0(1.5)		5^+	1.2(1)	560(132)	$2.6(5)\times10^{-2}$
1026(10)	6633(10)		1^-	2920(315)	77090(2000)	0
1036.6(9)	6643.7(8)	0.275(28)	2^-	368(61)	231(40)	0
1169.9(1.5)	6777.0(1.4)		4^+	9000(1000)	150(24)	0.31(8)
1196.0(1.6)	6803.1(1.5)	$2.70(92)\times10^{-2}$				
1201.9(5.0)	6809(5)		2^-	16570(1600)	71500(2000)	0
1203.9(7.5*)	6811(7.5*)		2^+	2750(450)	210(67)	0
1250(10)	6857(10)		3^-	5000(1000)	30(7)	0
1270.3(1.8)	6877.4(1.7)	$5.0(1.9)\times10^{-2}$				
1593.9(2.1)	7201(2)		4^+	29400(1000)	500(58)	0
1639.9(2.1)	7247(2)		1^+	5000(1000)	55000(5000)	0
1683.4(2.1)	7291(2)		3^+	15820(1426)	44180(15000)	0

Procedure

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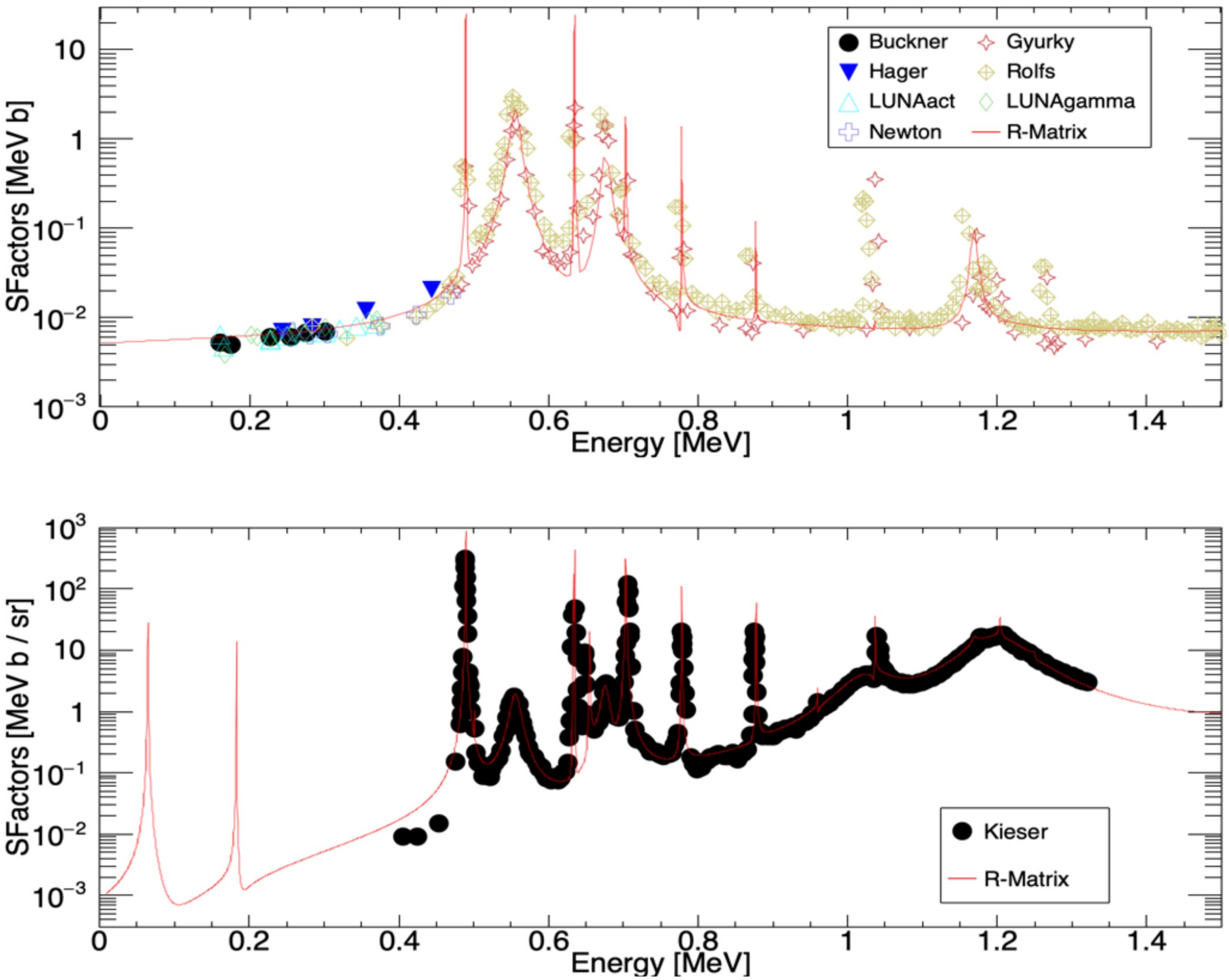

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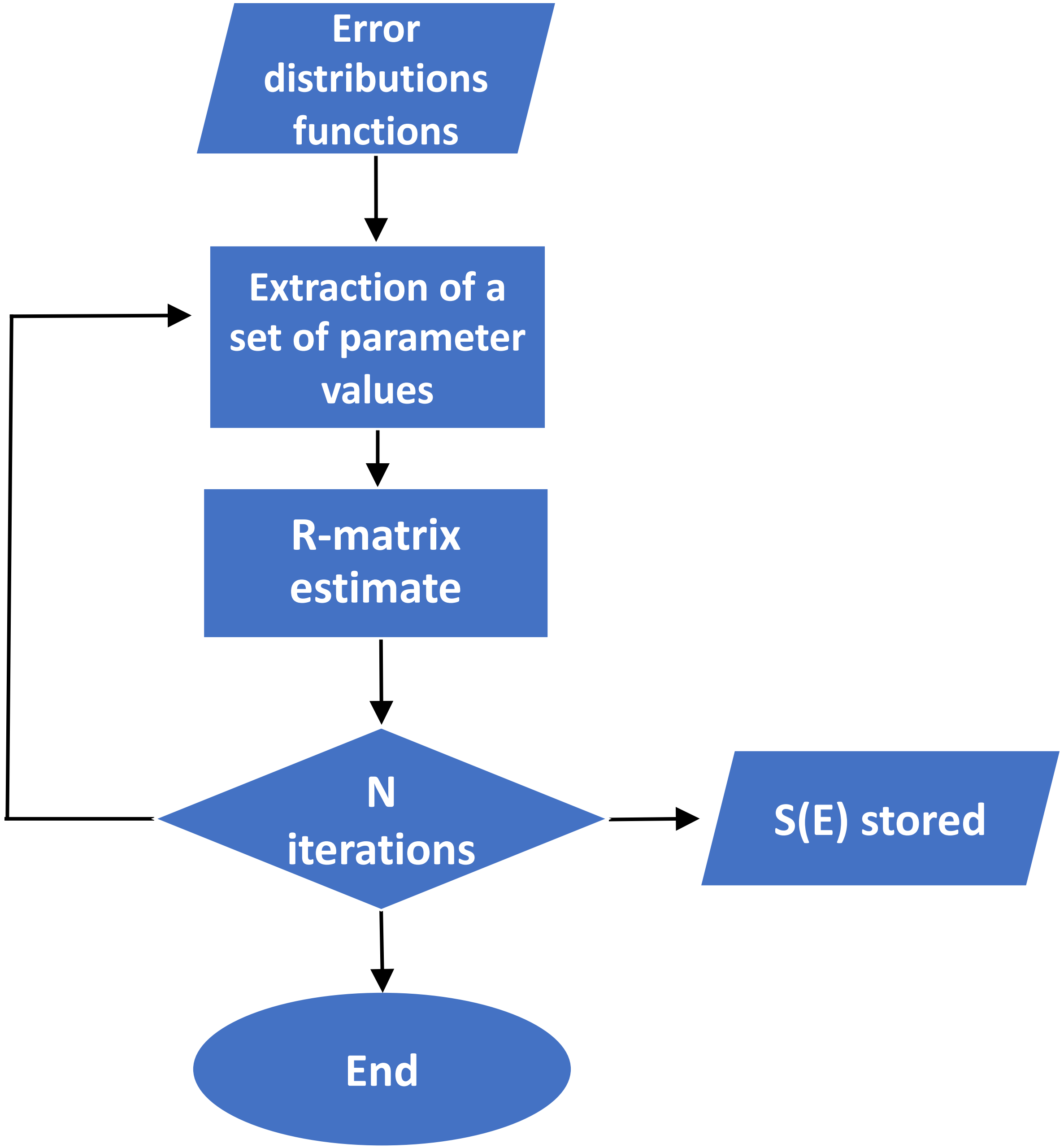

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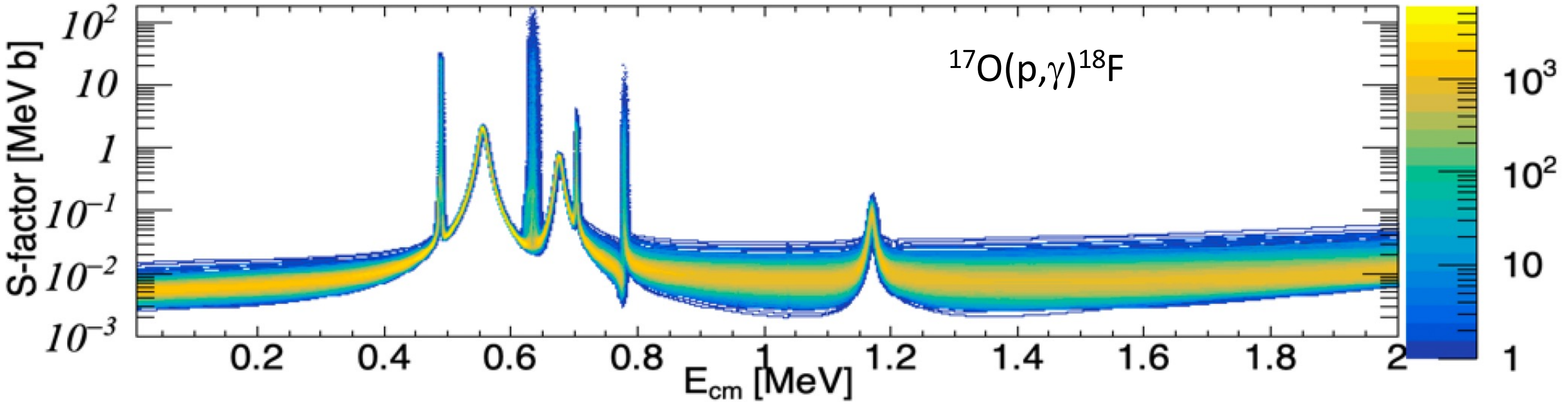

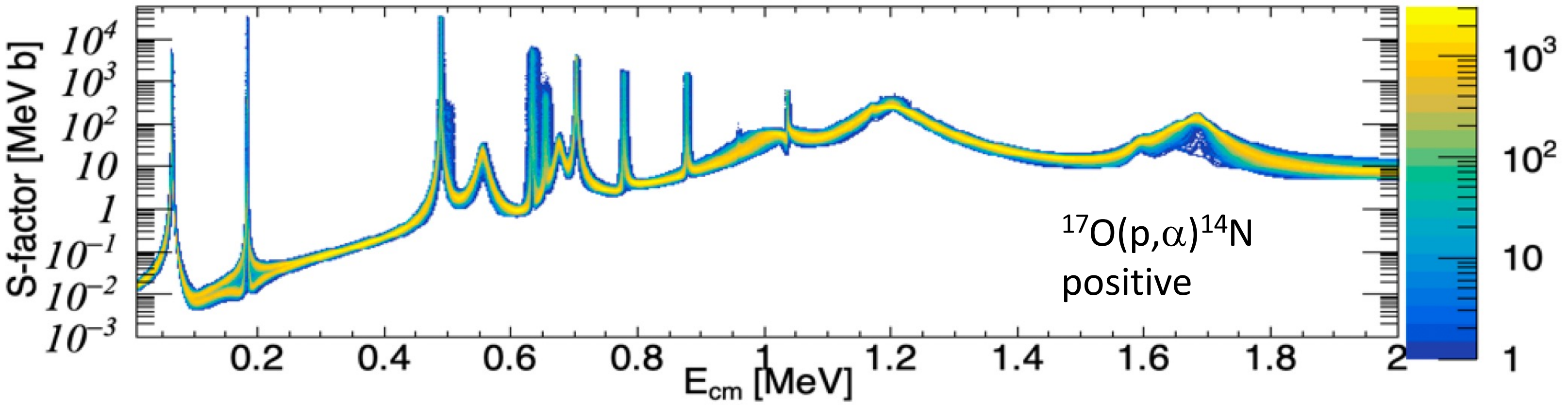

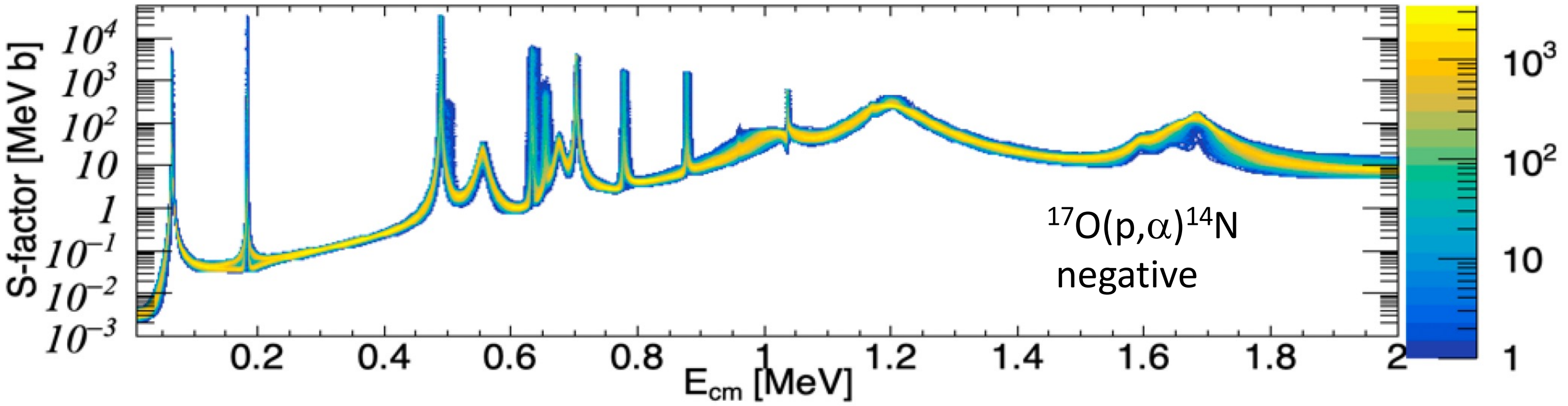

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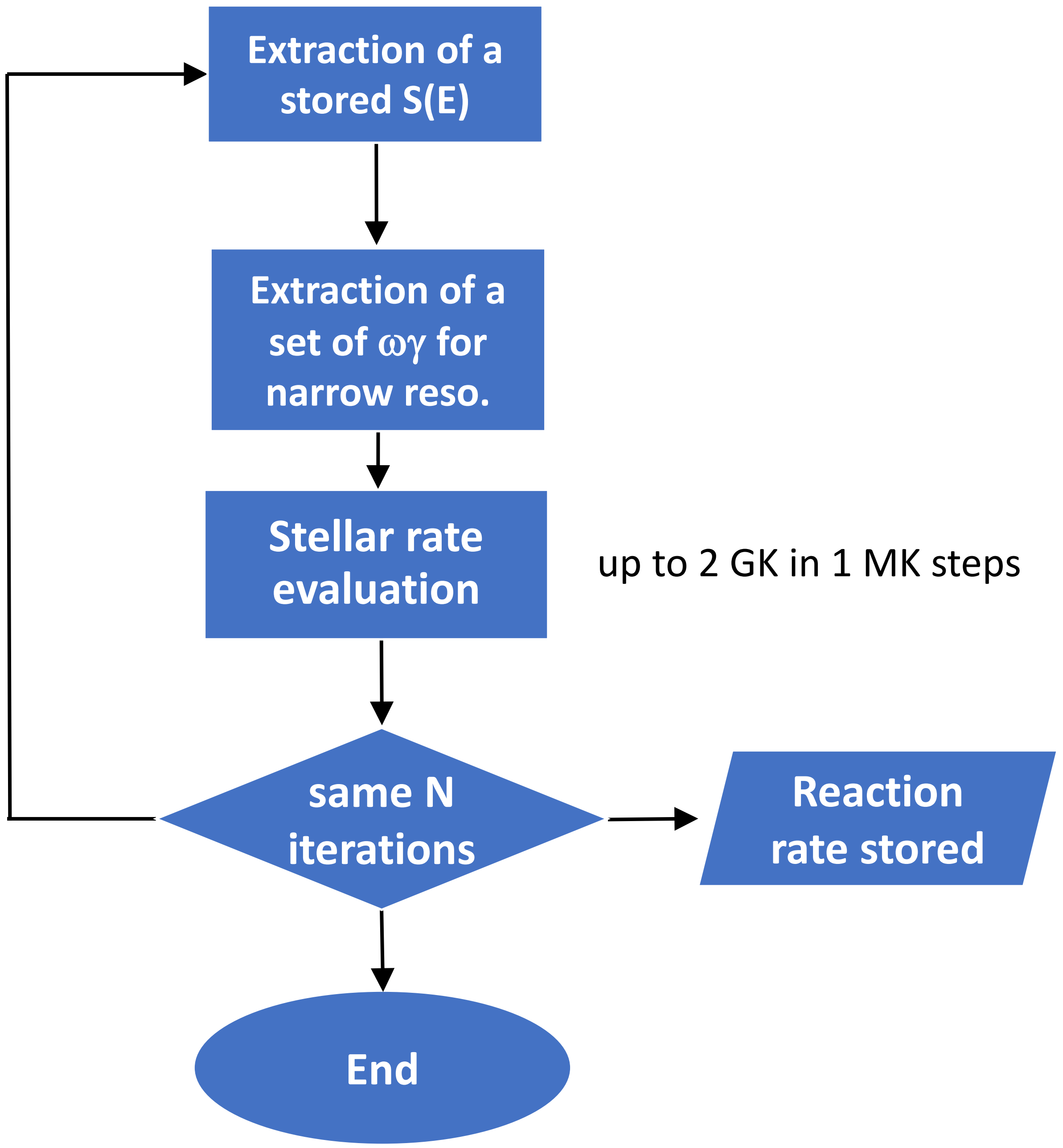

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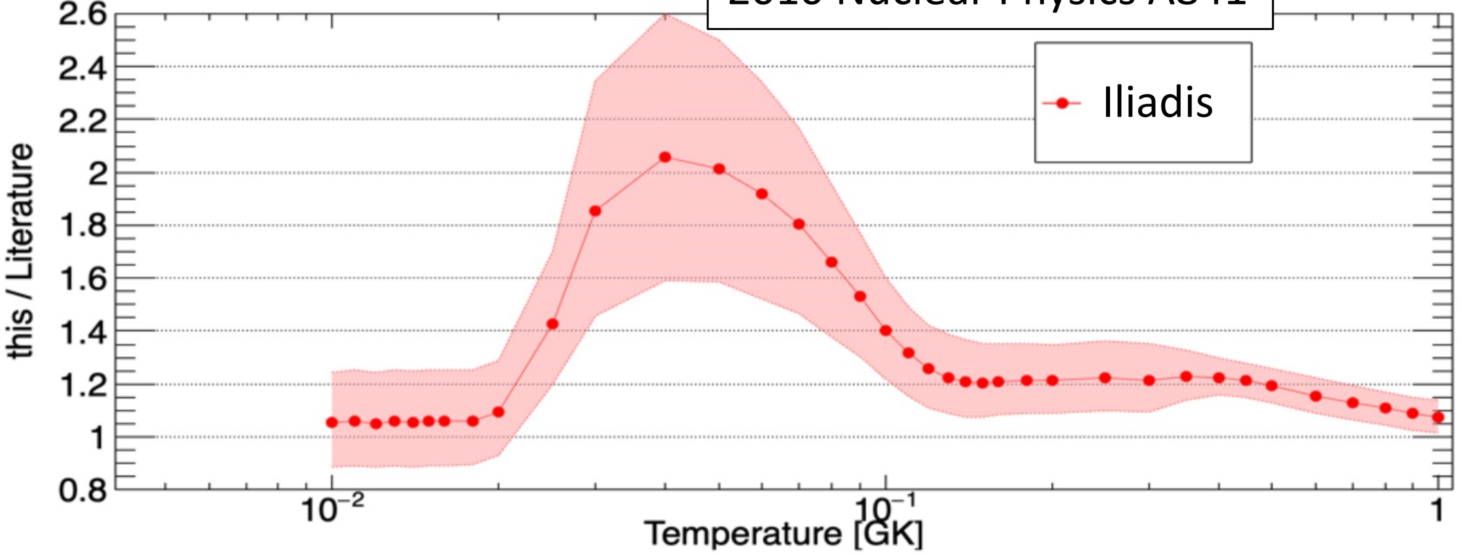
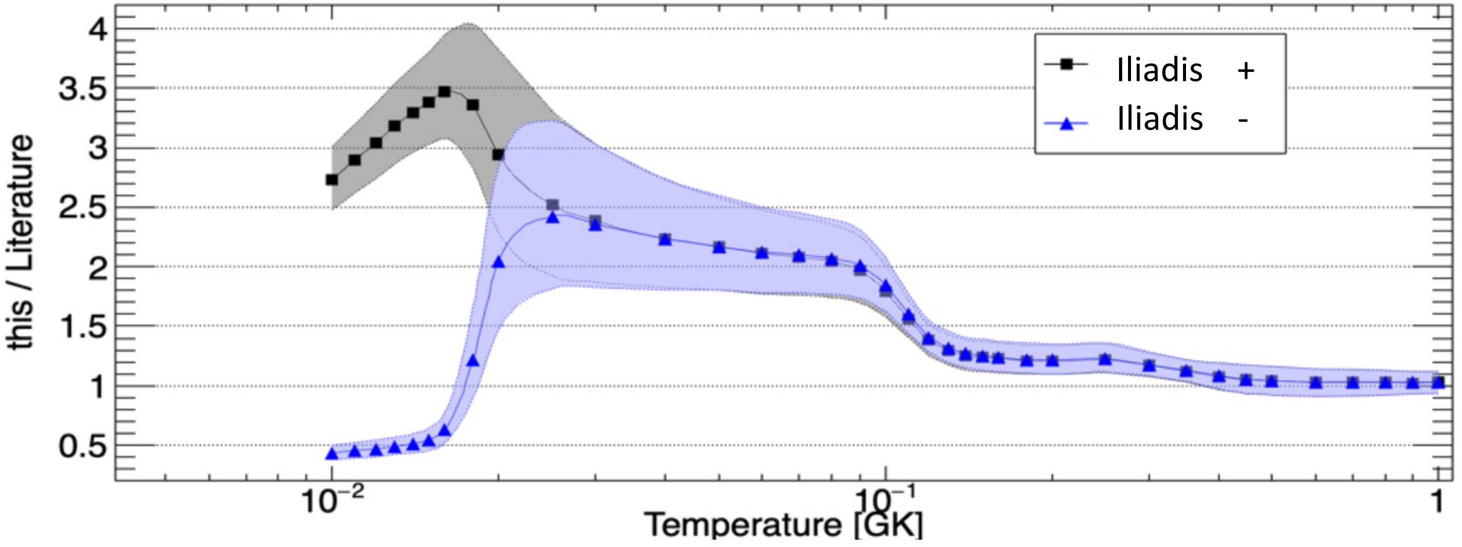
Comparison with Iliadis
2010 Nuclear Physics A841



steps



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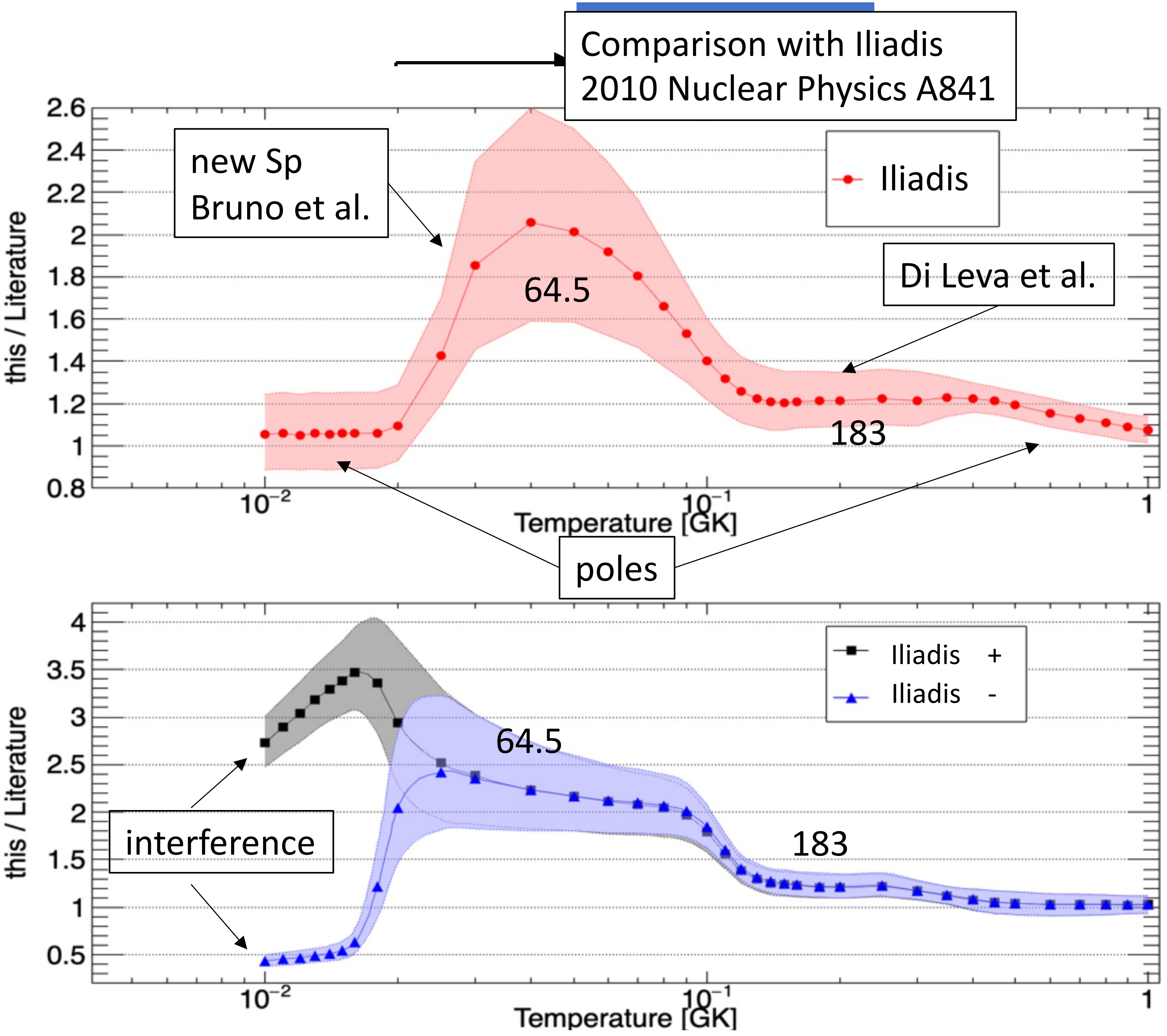

steps

on
red

Outlooks

- astrophysical impact under evaluation, publication soon
- $^{14}N(p,\gamma)^{15}O$ - $^{15}N(p,\gamma)^{16}O$ - $^{17}O(p,\gamma)^{18}F$ - $^{17}O(p,\alpha)^{14}N$ - $^{18}O(p,\gamma)^{19}F$ - $^{18}O(p,\alpha)^{15}N$
  $^{12}C(p, \gamma)$, $^{13}C(p, \gamma)$, $^{16}O(p, \gamma)$ –> in progress

complete — in progress — next future

Thank you for your attention!!!

The CNO LUNA Working Group: Carlo Broggini, Daniel Bemmerer, Carlo Gustavino, Axel Boeltzig, Paola Marigo, Antonio Caciolli, Andreas Best, Matthias Junker, Carlo Bruno, Marialuisa Aliotta, Antonino Di Leva, Alba Formicola, David Rapagnani, Maria Lugaro, Gianluca Imbriani, Oscar Straniero