γ - spectroscopic study of key resonances in ^{31}S for the $^{30}P(p,\gamma)^{31}S$ reaction in ONe novae

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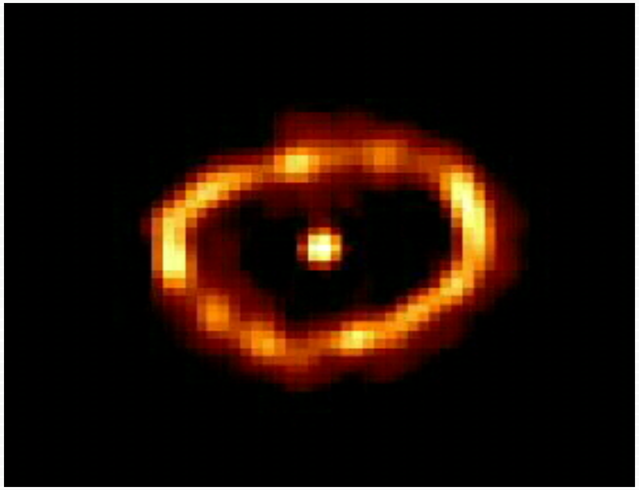
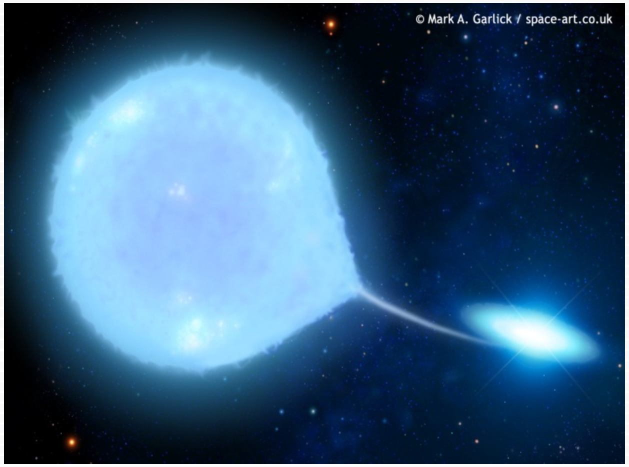
CLASSICAL NOVAE

- Occur in binary systems consisting of a white dwarf and a Roche lobe filling main sequence star.
- $T_{peak} \sim 10^8$ K, low mass accretion rates.
- Novae ejecta give an insight into the composition of white dwarfs thereby constraining stellar evolution models.

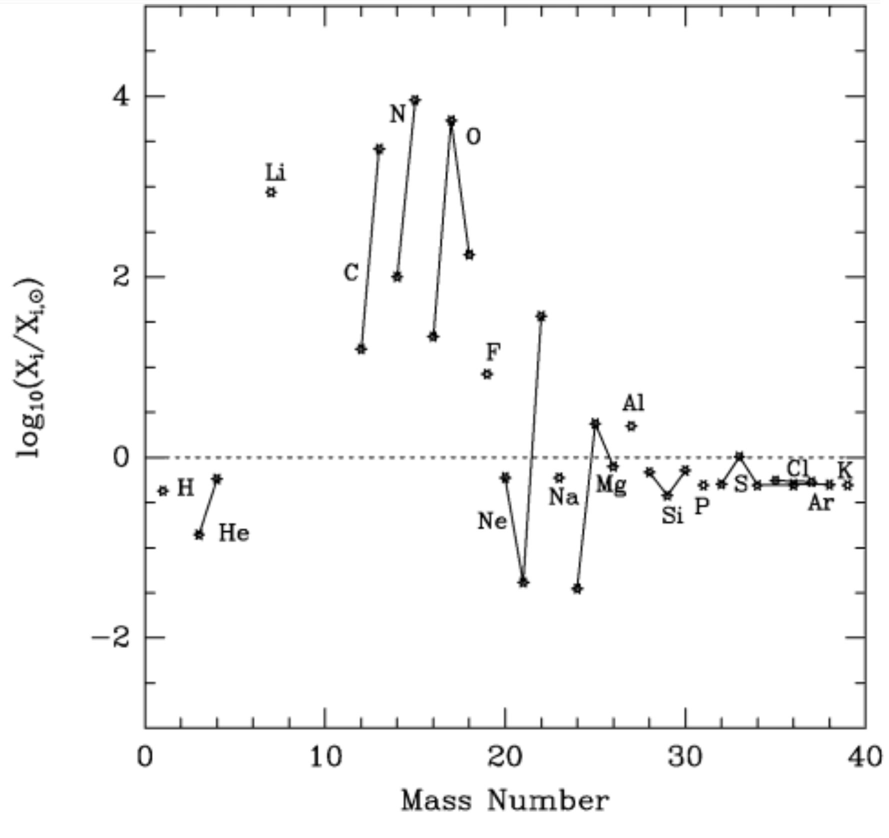


Nova Cygni 1992

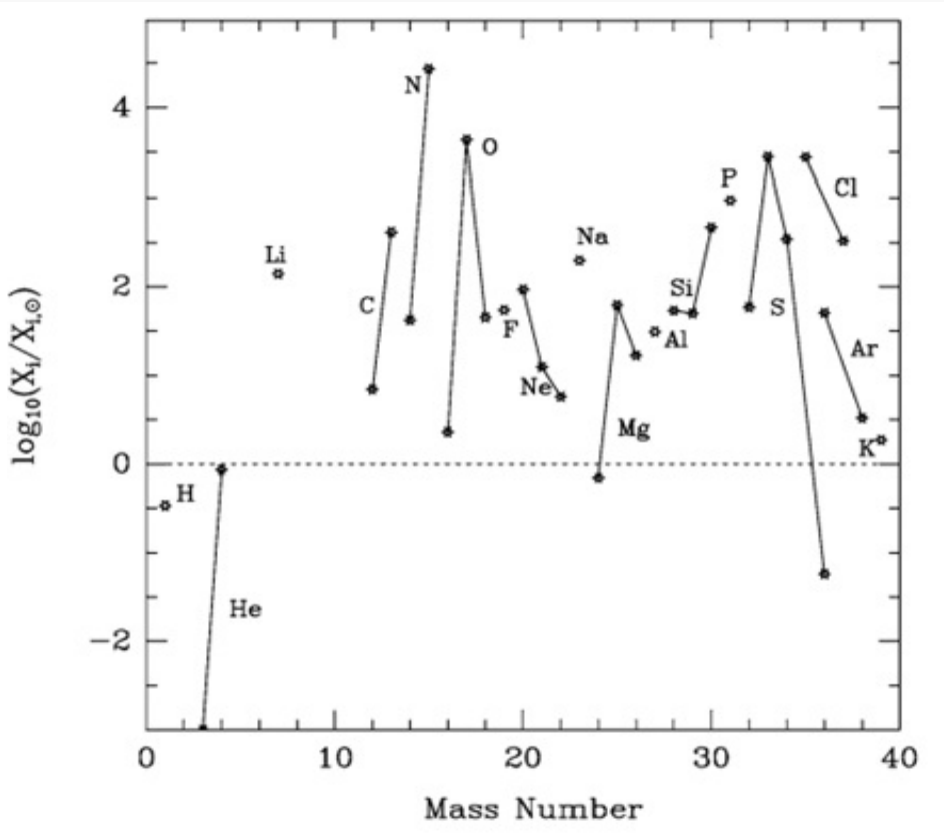


ABUNDANCES IN NOVAE EJECTA

1.15M⊙ CO nova

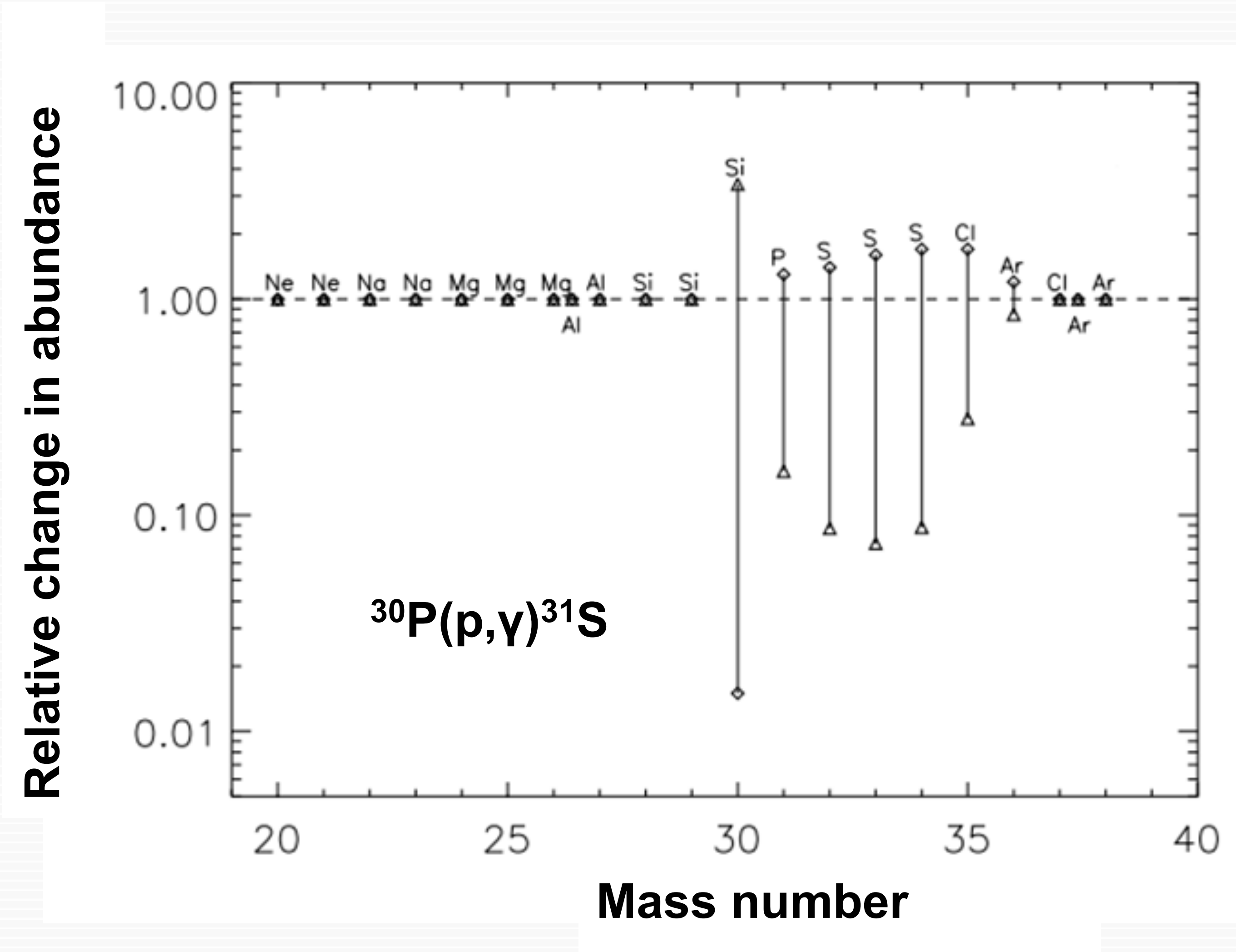


1.35M⊙ ONe nova



J. José, M. Hernanz, C. Iliadis. Nucl Phys A**, 777**, (2006), 550-578

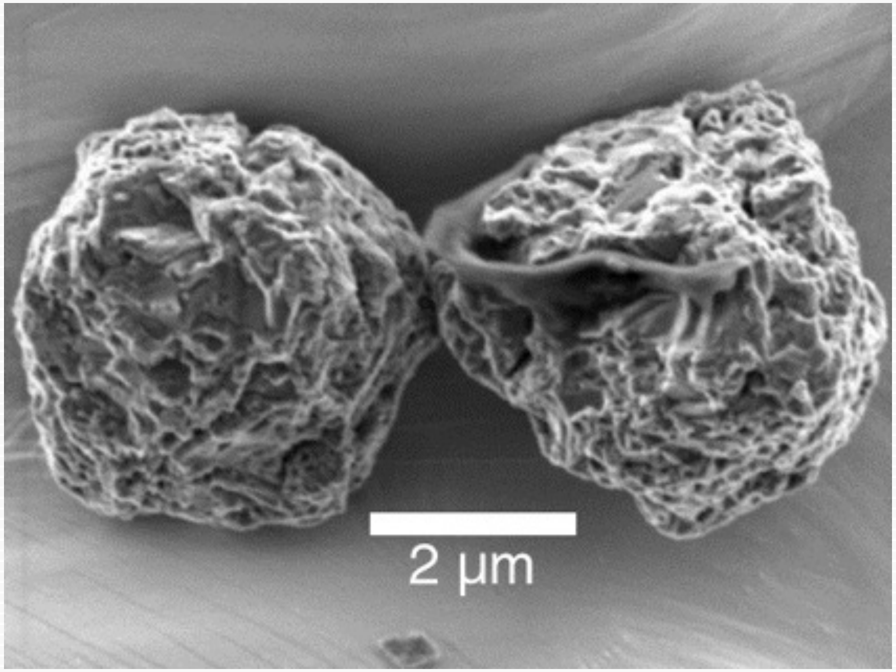
ABUNDANCES IN NOVAE EJECTA



C. Iliadis, A. Champagne, J José *et al.,* Astrophys. J. Suppl. Ser. **142,** 105 (2002)

PRESOLAR GRAINS

- **Grains of nova origin are thought to have a large $^{30}Si/^{28}Si$ ratio.**
- **Abundance of ^{30}Si is determined by the competition between the ^{30}P β^+ decay and the $^{30}P(p,\gamma)^{31}S$ reaction rate.**



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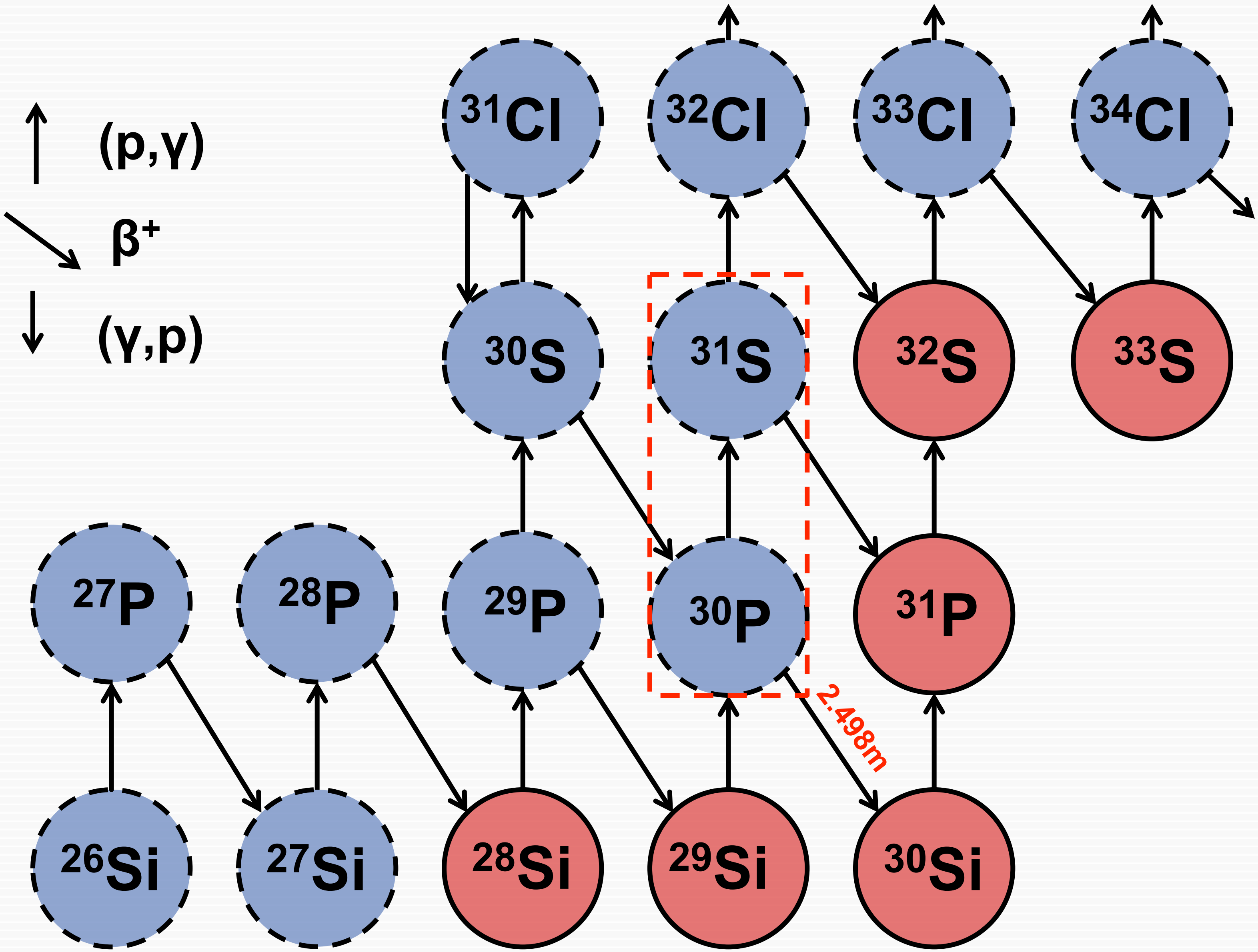
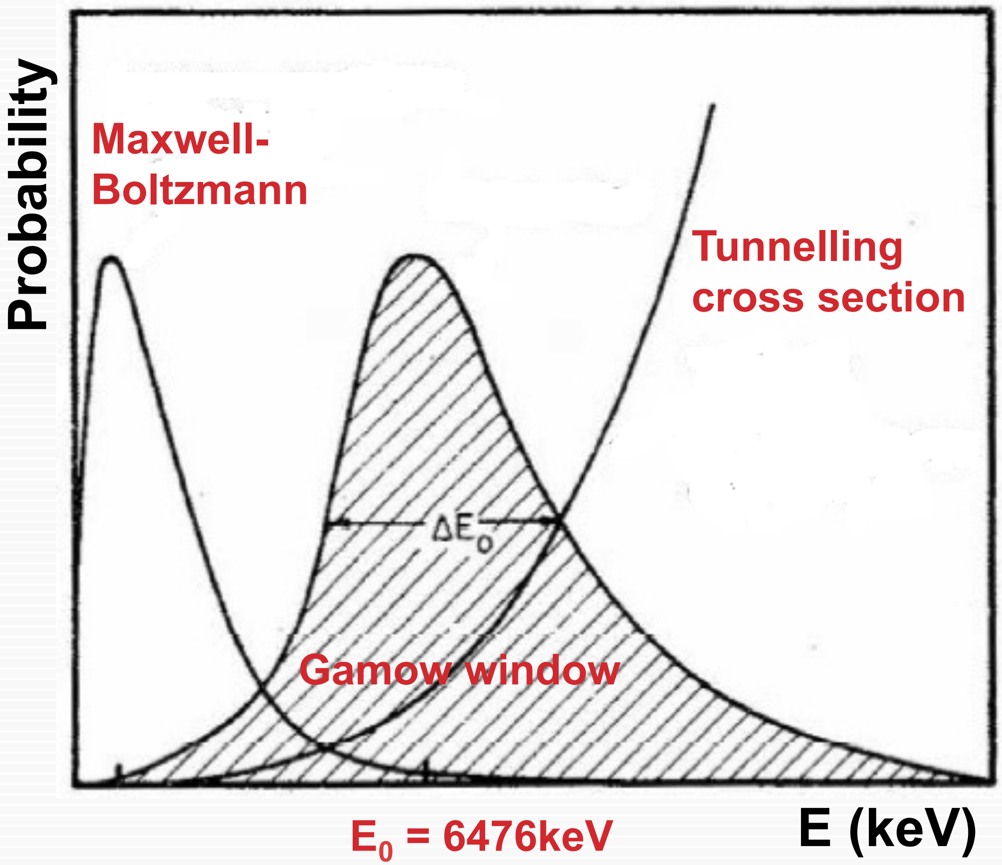
NOVAE NUCLEOSYNTHESIS



ASTROPHYSICALLY IMPORTANT LEVELS

- ^{30}P has a low spin (1^+) ground state.
- Reaction rate dominated by the low spin levels due to centrifugal barrier.
- Many resonances located with ~600keV of the threshold.

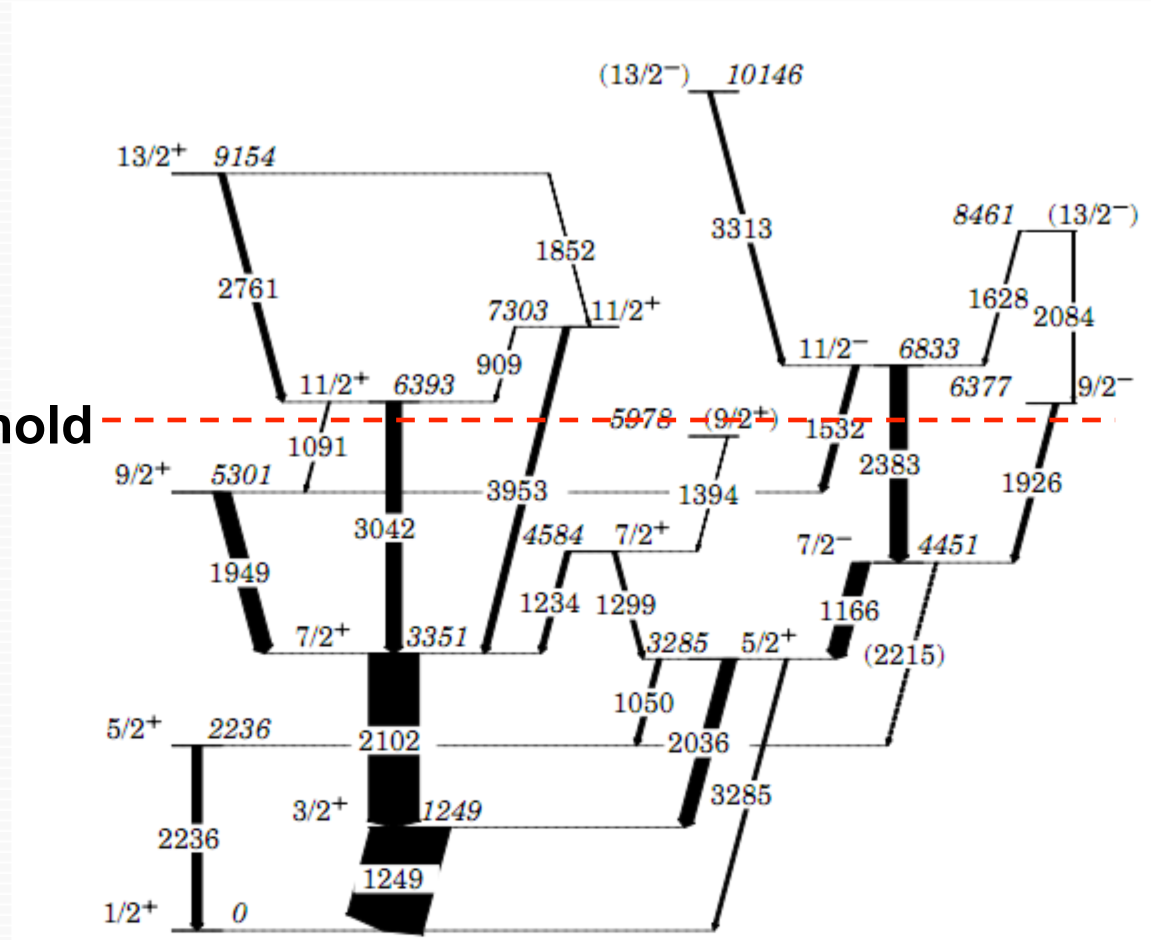


C.E. Rolfs, W.S. Rodney, Cauldrons in the Cosmos, The University of Chicago press, Chicago, 1988

KNOWN ^{31}S LOW LEVEL SCHEME

- States populated by ^{20}Ne(^{12}C,n)^{31}S

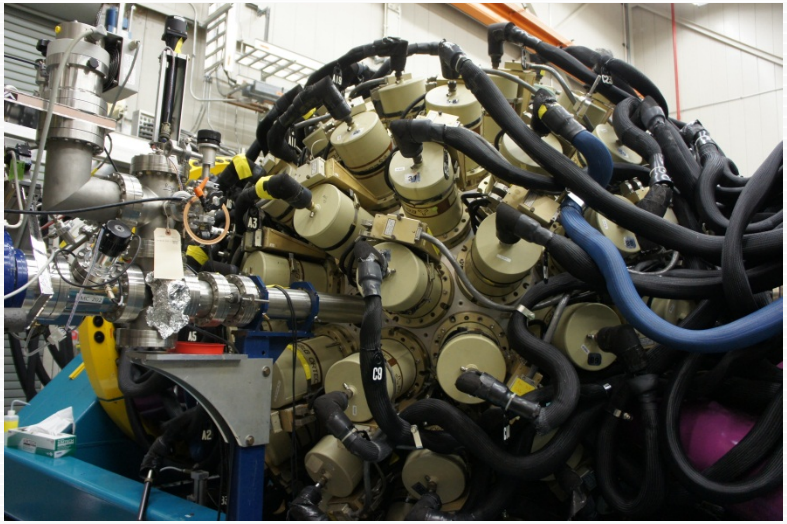
^{31}S proton threshold

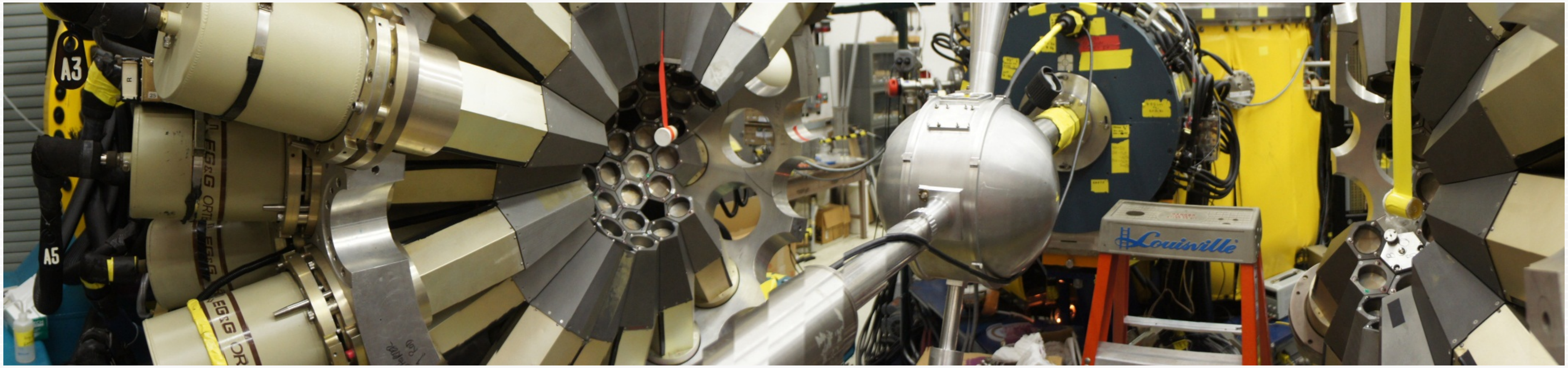


D.G. Jenkins et al, Phys. Rev. C. **72.** (2005)

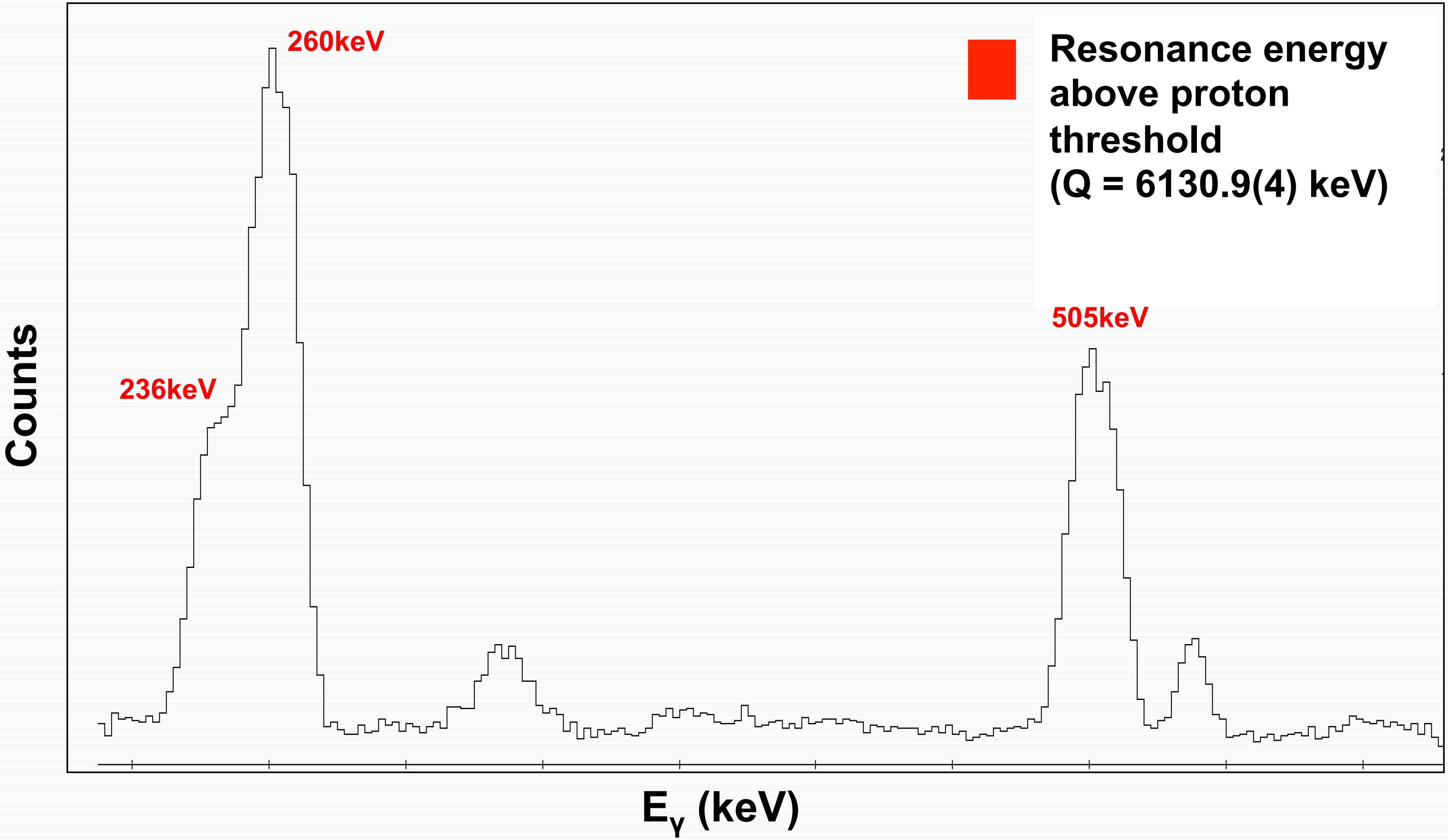
IDENTIFYING LOW SPIN RESONANCES

- Indirect investigation of the $^{30}P(p,\gamma)^{31}S$ reaction.
- Low spin states in ^{31}S populated via the $^{28}Si(^{4}He,n)$ reaction.
- Resulting γ decays detected by Gammasphere, an array of 110 Compton suppressed germanium detectors.



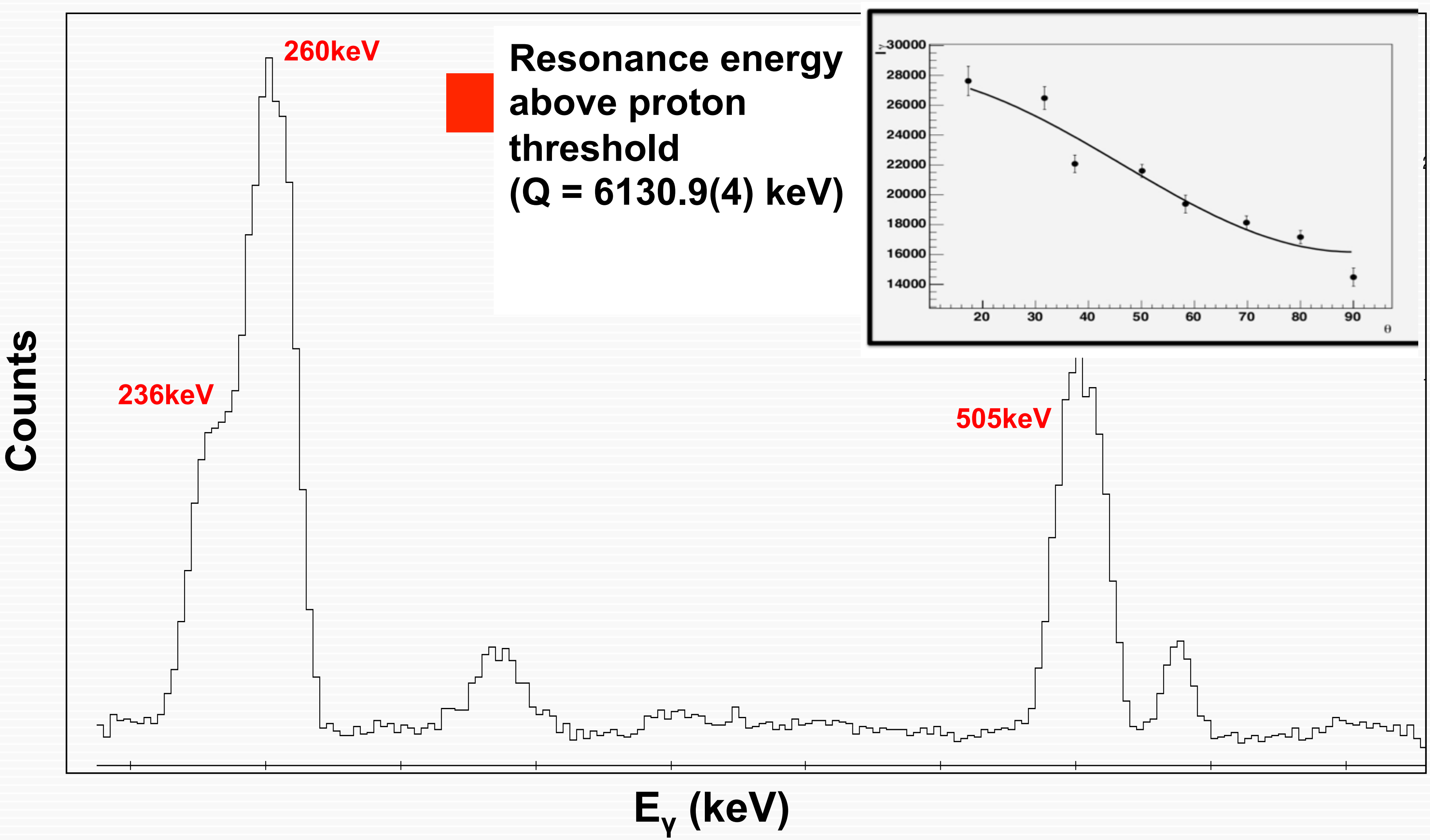


LEVELS ABOVE THE THRESHOLD

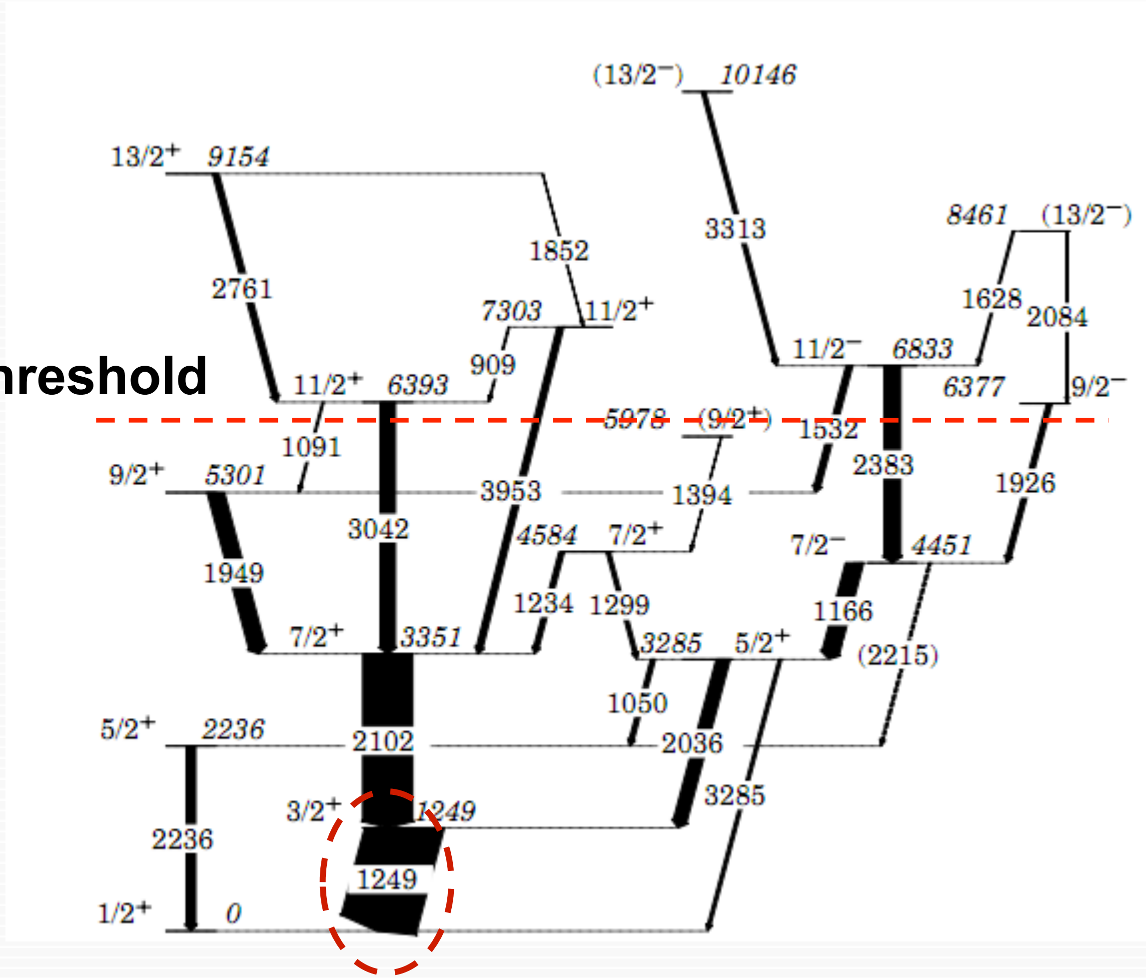


LEVELS ABOVE THE THRESHOLD

- **Resonance energy above proton threshold (Q = 6130.9(4) keV)**



KNOWN ^{31}S LOW LEVEL SCHEME

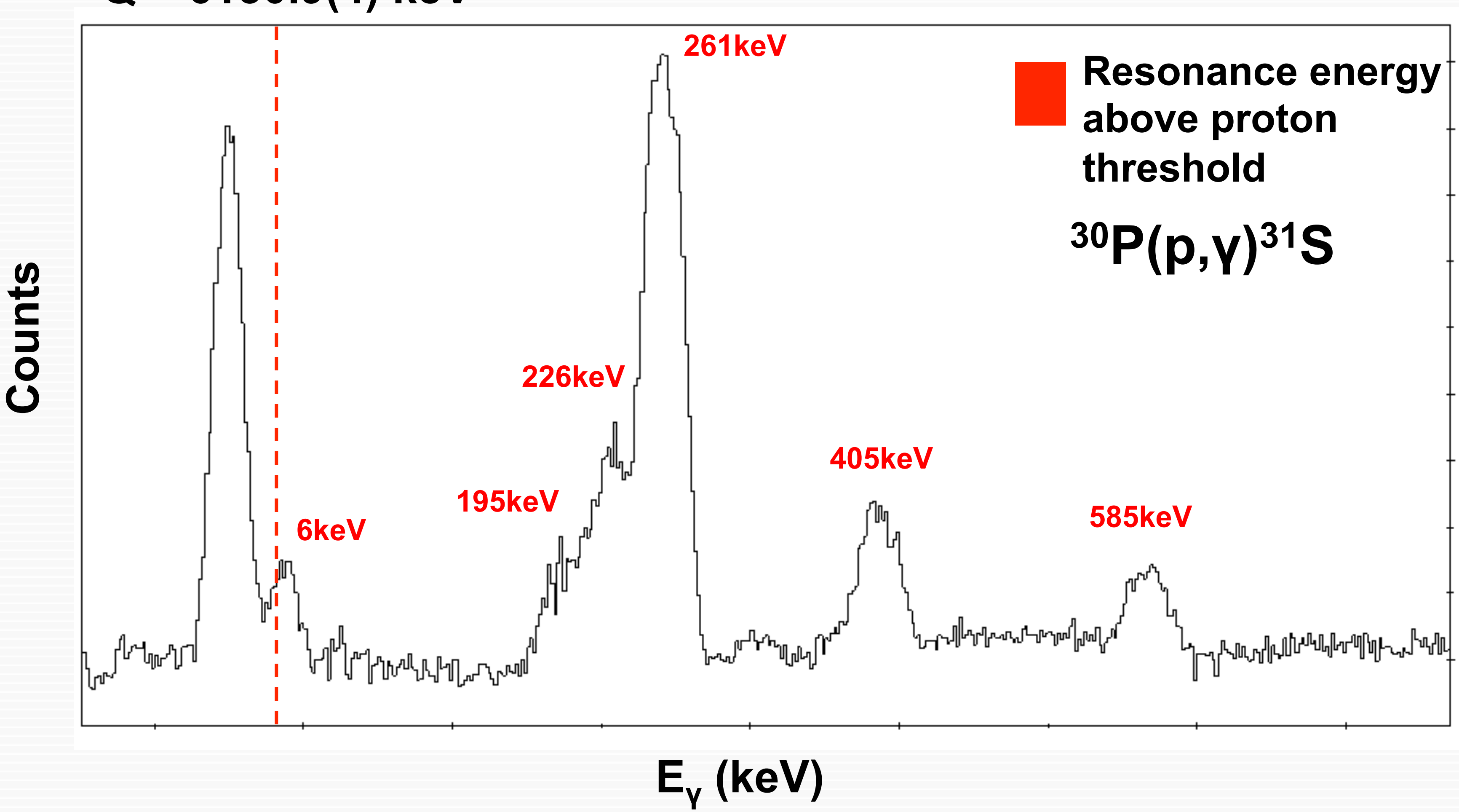


- Gating on E_γ = 1249keV in order to investigate higher lying low-spin levels

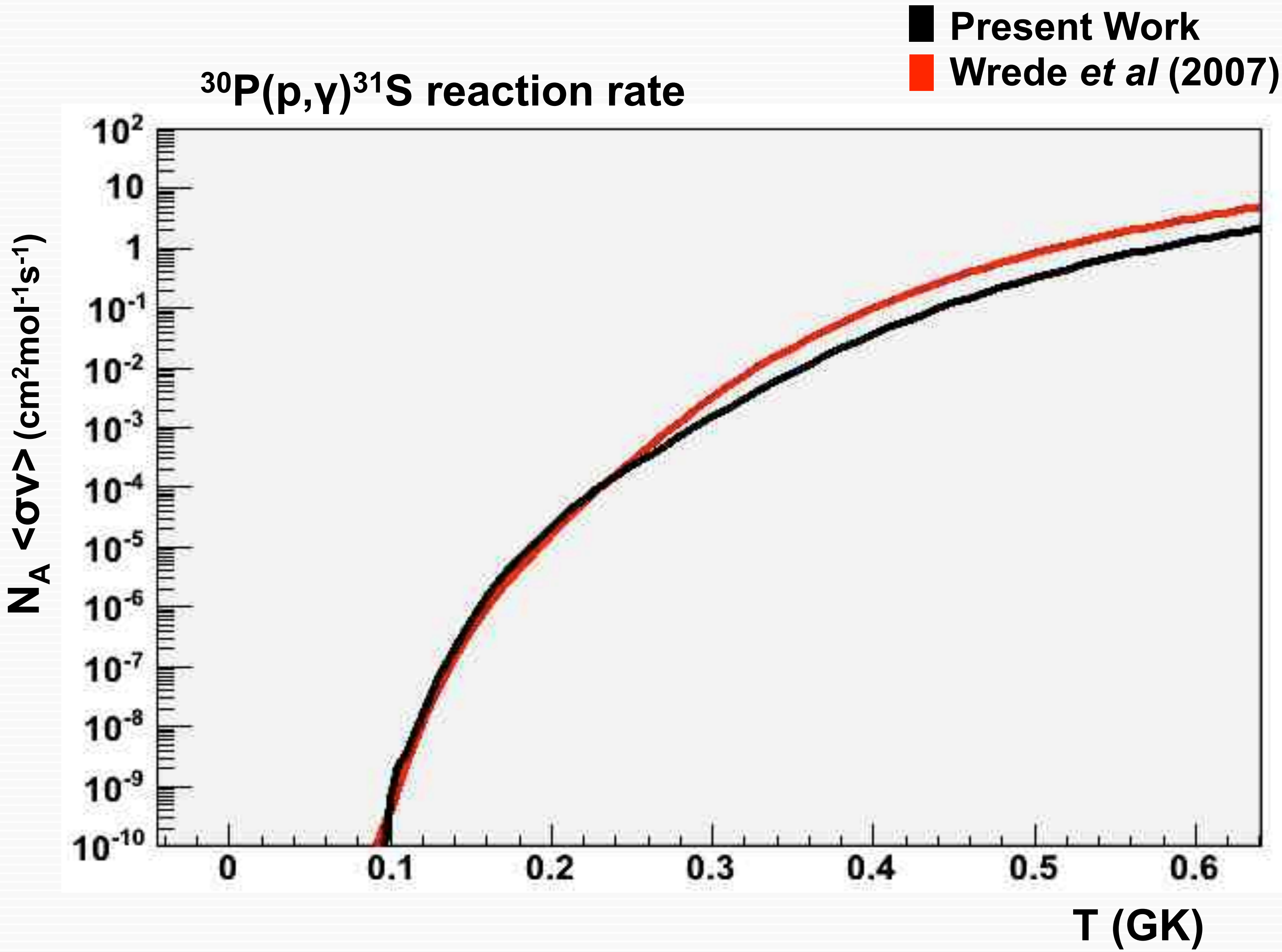
D.G. Jenkins et al, Phys. Rev. C. **72.** (2005)

LEVELS ABOVE THE THRESHOLD

^{31}S proton threshold
Q = 6130.9(4) keV

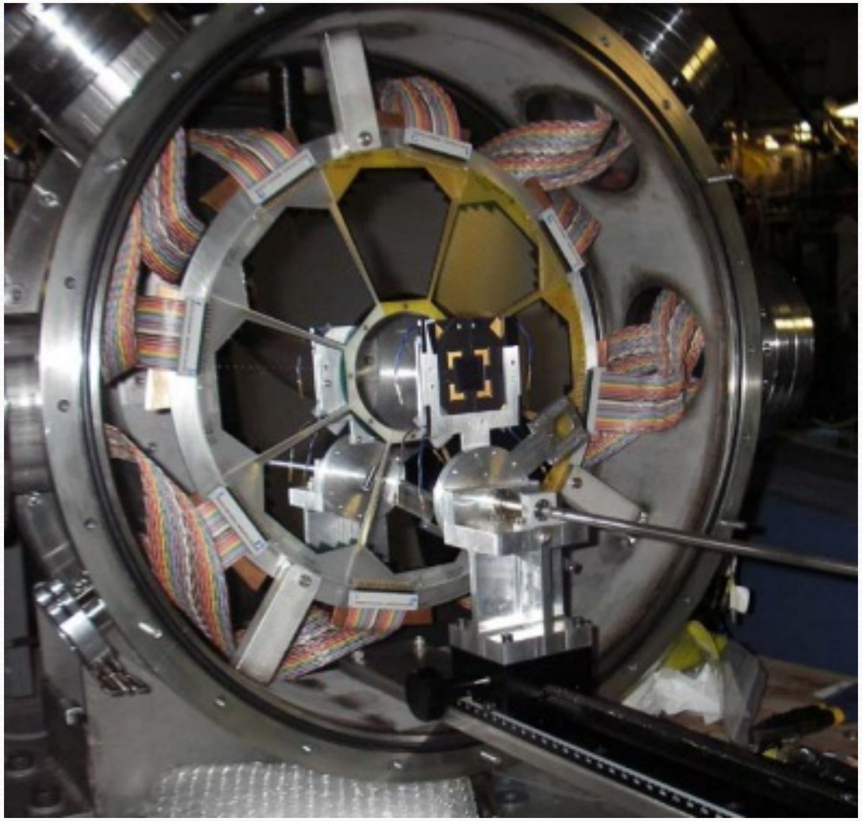


ASTROPHYSICAL IMPLICATIONS



THE NEXT STAGE...

- Spectroscopic factors for most resonant states uncertain or completely unknown.
- Transfer reactions, e.g. ^{30}P(d,p) are planned in order to measure spectroscopic factors.
- Possible systems include, TECSA (pictured).



B. T. Roeder et al, Nucl. Instrum. Meth. A, **634**, (2011) 71-76

THANKYOU!

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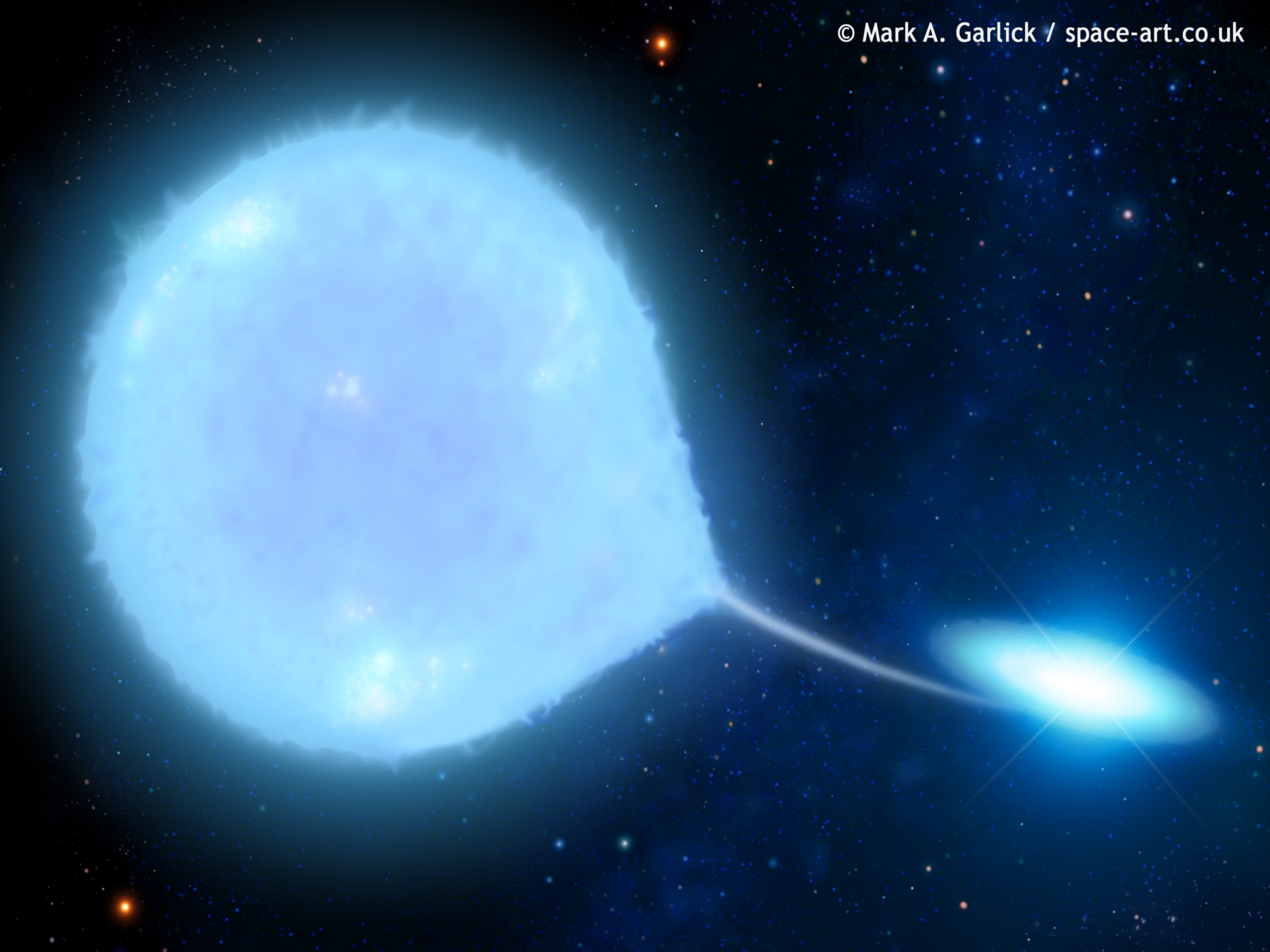
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TABLE 12

INFLUENCE OF REACTION-RATE VARIATIONS ON ISOTOPIC ABUNDANCES IN NOVA NUCLEOSYNTHESIS[a]

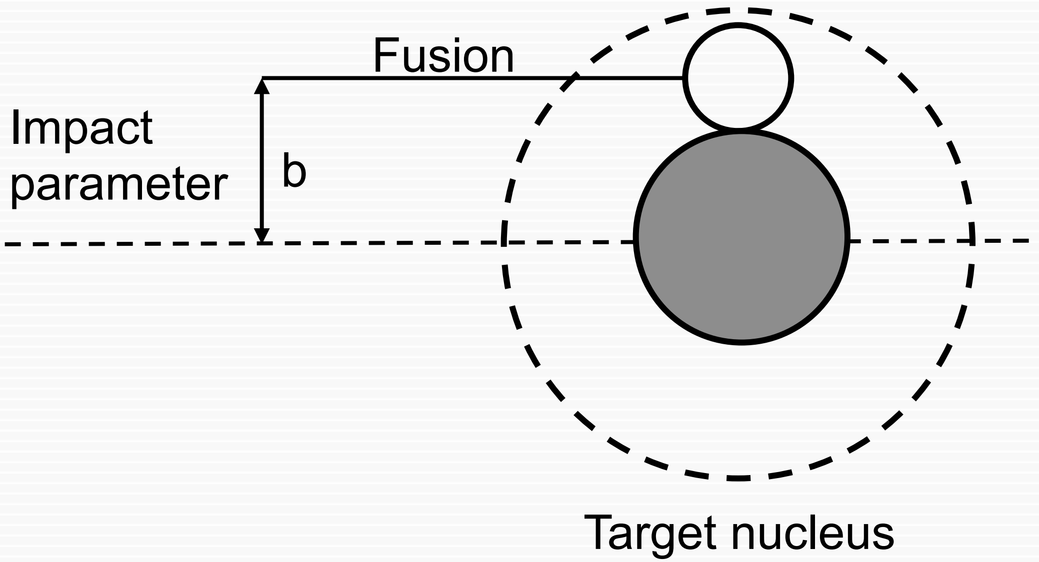
Reaction-Rate Variation[b]	Isotopic Abundance Change[c]
CO Nova Models	
$^{17}O(p,\gamma)^{18}F$	^{18}F
$^{17}O(p,\alpha)^{14}N$	^{17}O, ^{18}F
$^{18}F(p,\alpha)^{15}O$	^{18}F
$^{22}Ne(p,\gamma)^{23}Na$	^{22}Ne, ^{23}Na, ^{24}Mg, ^{25}Mg, ^{26}Al
$^{23}Na(p,\gamma)^{24}Mg$	^{24}Mg
$^{26}Mg(p,\gamma)^{27}Al$	^{26}Mg
$^{26}Al^{g}(p,\gamma)^{27}Si$	^{26}Al
ONe Nova Models	
$^{17}O(p,\gamma)^{18}F$	^{17}O, ^{18}F
$^{17}O(p,\alpha)^{14}N$	^{17}O, ^{18}F
$^{17}F(p,\gamma)^{18}Ne$	^{17}O, ^{18}F
$^{18}F(p,\alpha)^{15}O$	^{16}O, ^{17}O, ^{18}F
$^{21}Na(p,\gamma)^{22}Mg$	^{21}Ne, ^{22}Na, ^{22}Ne
$^{22}Ne(p,\gamma)^{23}Na$	^{22}Ne
$^{23}Na(p,\gamma)^{24}Mg$	^{20}Ne, ^{21}Ne, ^{22}Na, ^{23}Na, ^{24}Mg, ^{25}Mg, ^{26}Mg, ^{26}Al, ^{27}Al
$^{23}Mg(p,\gamma)^{24}Al$	^{20}Ne, ^{21}Ne, ^{22}Na, ^{23}Na, ^{24}Mg
$^{26}Mg(p,\gamma)^{27}Al$	^{26}Mg
$^{26}Al^{g}(p,\gamma)^{27}Si$	^{26}Al
$^{26}Al^{m}(p,\gamma)^{27}Si$	^{26}Mg
$^{29}Si(p,\gamma)^{30}P$	^{29}Si
$^{30}P(p,\gamma)^{31}S$	^{30}Si, ^{32}S, ^{33}S, ^{34}S, ^{35}Cl, ^{37}Cl, ^{36}Ar, ^{37}Ar, ^{38}Ar
$^{33}S(p,\gamma)^{34}Cl$	^{33}S, ^{34}S, ^{35}Cl, ^{36}Ar
$^{33}Cl(p,\gamma)^{34}Ar$	^{33}S
$^{34}S(p,\gamma)^{35}Cl$	^{34}S, ^{35}Cl, ^{36}Ar
$^{34}Cl(p,\gamma)^{35}Ar$	^{34}S
$^{37}Ar(p,\gamma)^{38}K$	^{37}Cl, ^{37}Ar, ^{38}Ar
$^{38}K(p,\gamma)^{39}Ca$	^{38}Ar

- **$^{30}P(p,\gamma)$ dramatically affects the abundances of ^{30}Si, $^{32,33,34}S$, $^{35,37}Cl$, $^{36,37,38}Ar$.**

[1] C. Iliadis, A. Champagne, J José *et al.,* Astrophys. J. Suppl. Ser. **142,** 105 (2002)

A PREVIOUS STUDY…

- **States in ^{31}S and ^{31}P populated via the fusion evaporation channels; $^{12}C(^{20}Ne,n)$ and $^{12}C(^{20}Ne,p)$.**
- **γ rays detected by Gammasphere.**
- **Only gamma rays corresponding to high spin resonances reported.**



Angular momentum transfer to compound nucleus:

$$\underline{l} = \underline{b} \times \underline{p}$$
$$= \underline{b} \times m\underline{v}$$

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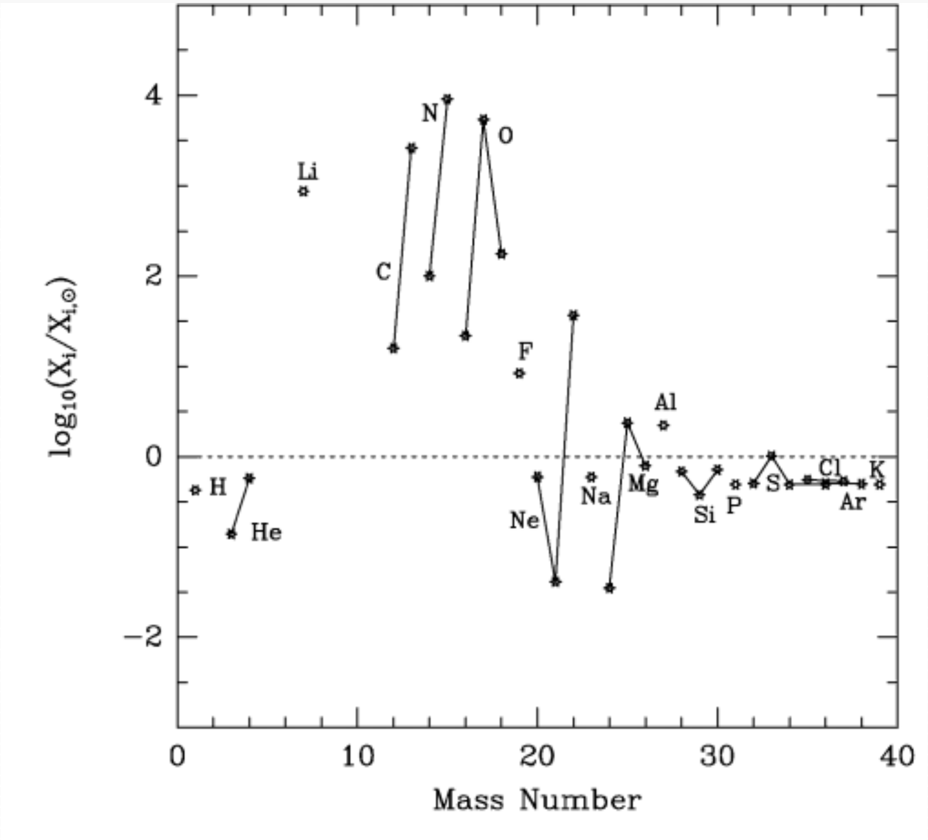


[2] J. José, M. Hernanz, C. Iliadis. Nucl Phys A**, 777**, (2006), 550-578

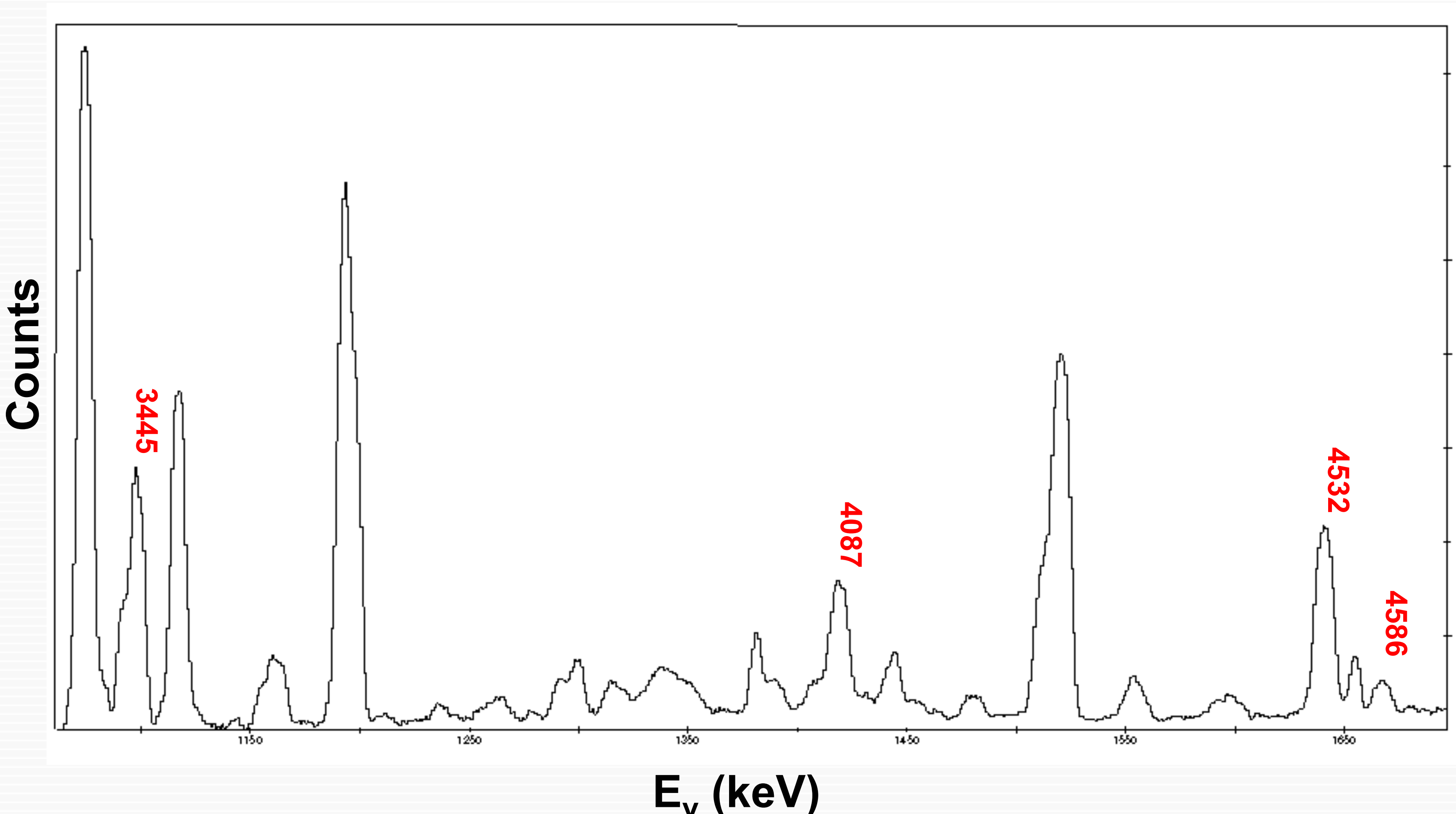
IMPORTANCE OF LOW SPIN RESONANCES

- ^{30}P has low spin ground state; 1^+
- The relatively low temperatures (T~10^8K) of classical novae limit the number of nuclei which are thermally excited to levels beyond the ground state.

$$V_l = \frac{l(l+1)\hbar^2}{2\mu r^2}$$

INITIAL RESULTS

- Gated γ-ray spectrum



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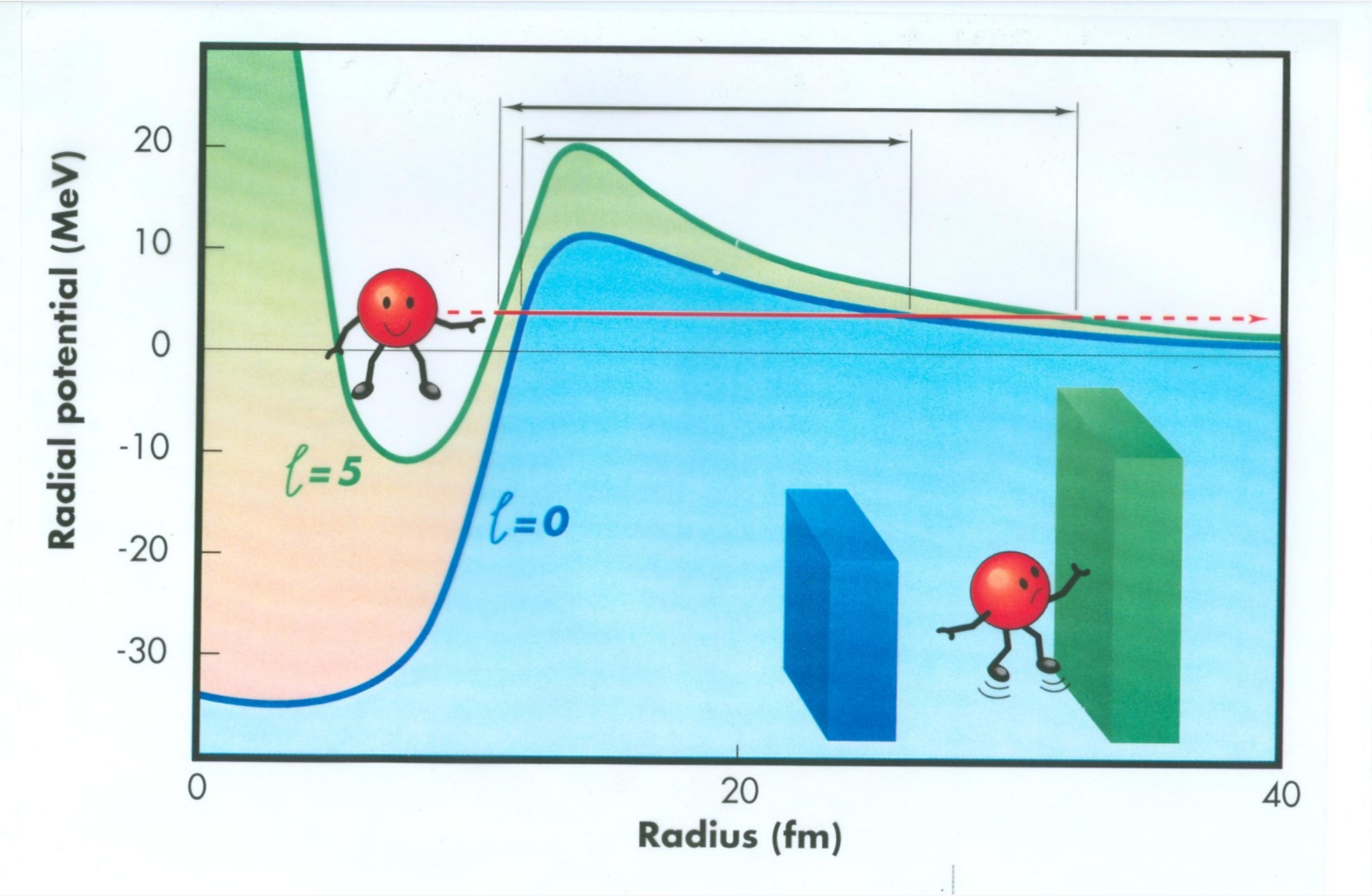

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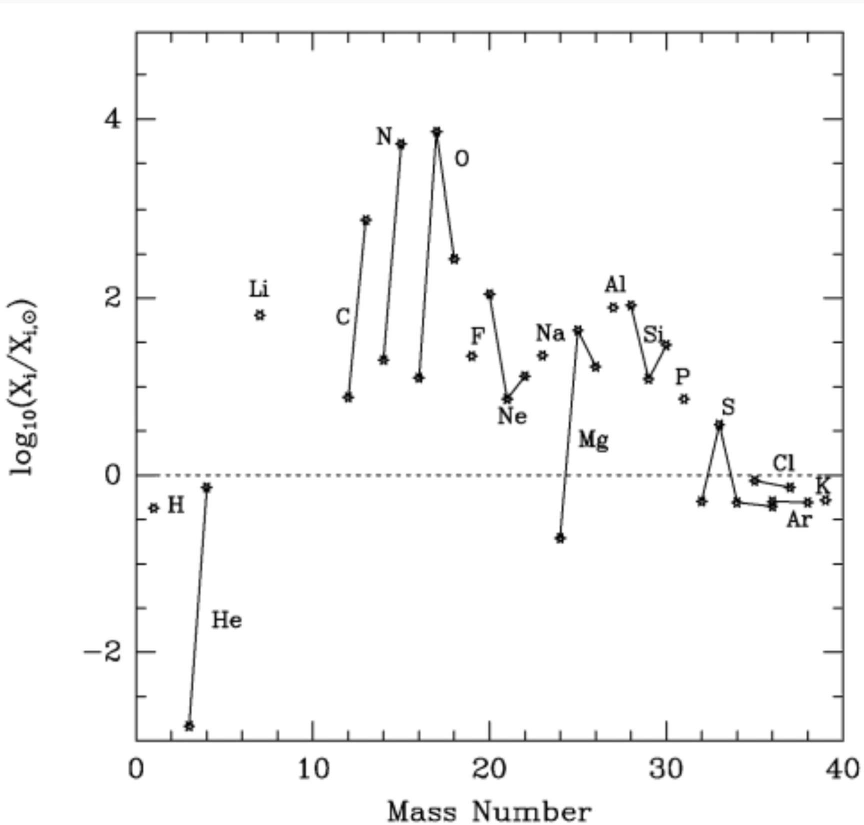
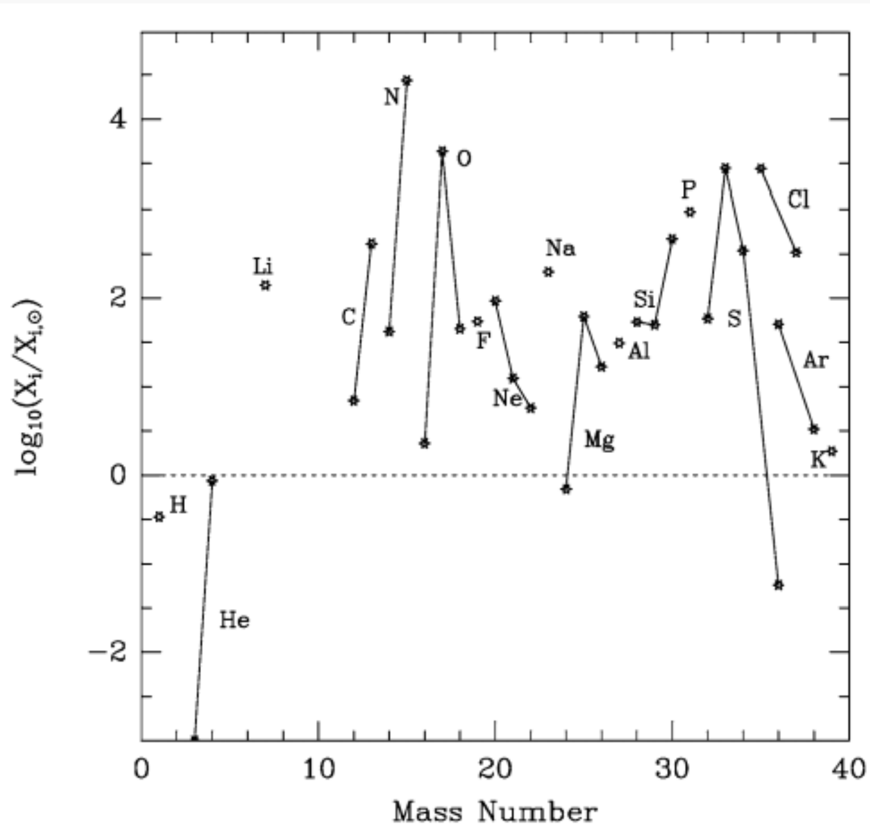


$1.35M_{\odot}$ ONe novae



[2] J. José, M. Hernanz, C. Iliadis. Nucl Phys A, **777**, (2006), 550-578

- Resulting γ decays detected by Gammasphere, an array of ~100 Compton suppressed germanium detectors.
- A previous spectroscopic study utilising Gammasphere reported only the identification of high spin ^{31}S resonances via $^{20}Ne(^{12}C,n)^{31}S$