Astrophysics Task Force

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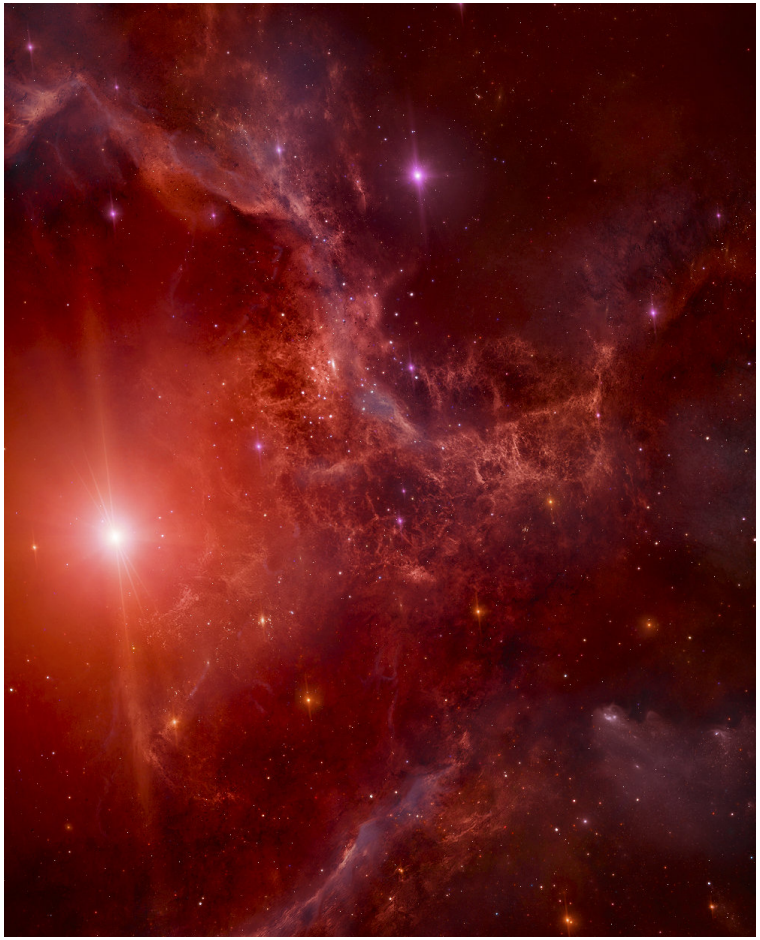
ORNL Physics Division

USNDP Contributors to this report

- Argonne National Laboratory
- Oak Ridge National Laboratory
- McMaster University
- Brookhaven National Laboratory



Argonne NATIONAL LABORATORY

McMaster University
Inspiring Innovation and Discovery

National Nuclear Data Center
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OAK RIDGE National Laboratory

Brookhaven National Laboratory -- Boris Pritychenko et al.

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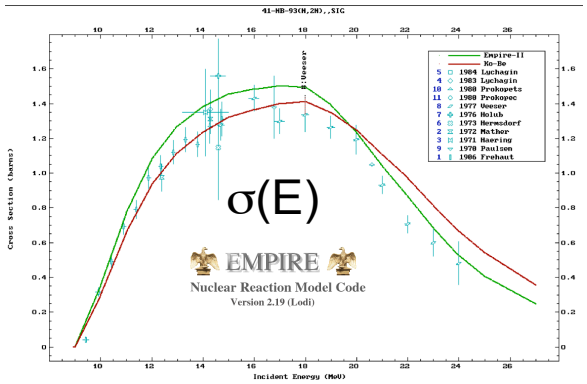


astro simulation → predictions

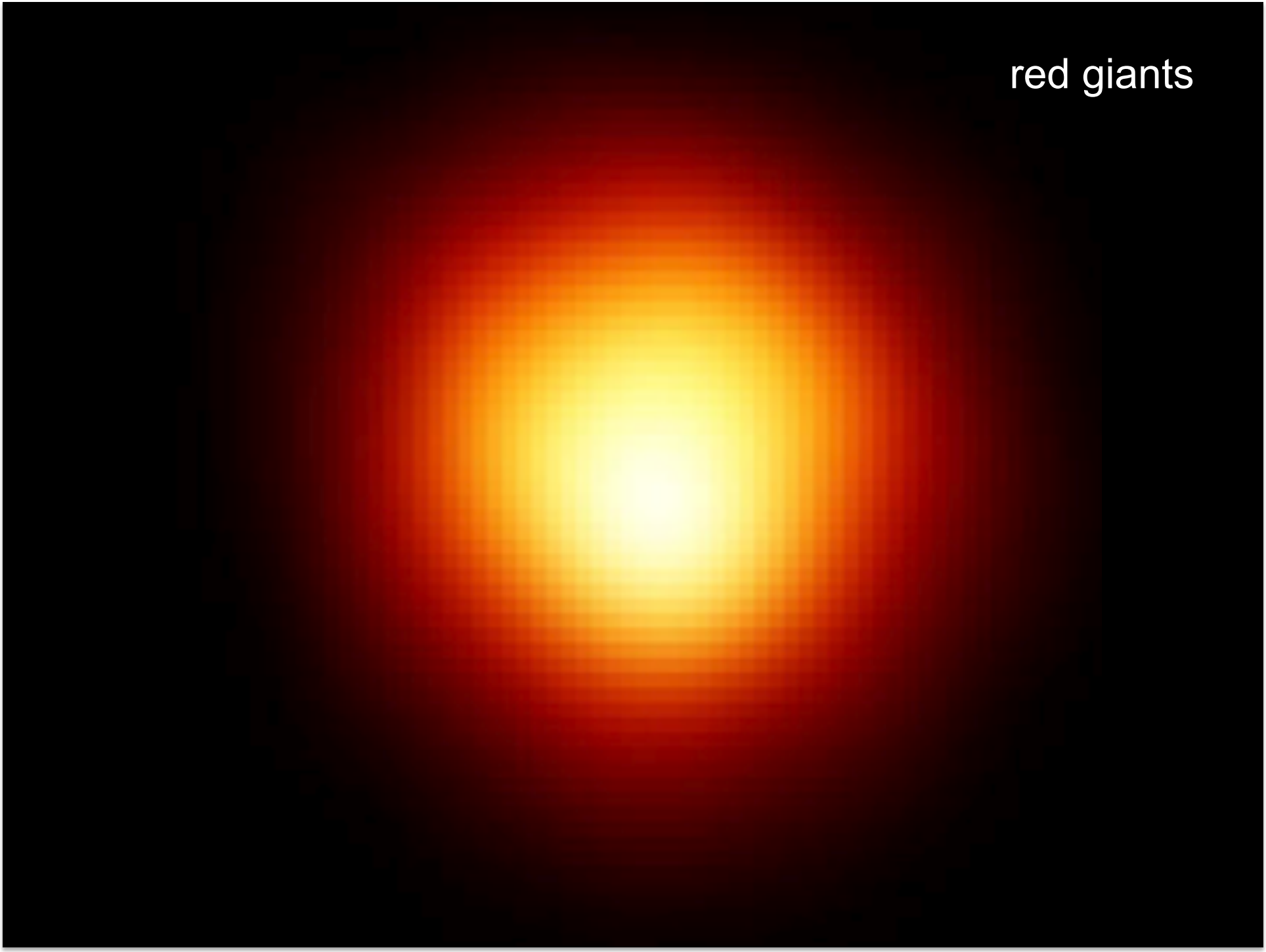
MACS

$$\sigma^{Maxw}(kT) = \frac{2}{\sqrt{\pi}} \frac{a^2}{(kT)^2} \int_0^\infty \sigma(E_n^L) E_n^L e^{-\frac{aE_n^L}{kT}} dE_n^L$$

The calculation of **Maxwellian-averaged cross sections (MACS)** from neutron-induced reaction cross sections in **ENDF** enables the astrophysics community to use this valuable library in their simulations

MACS have now become an **integral part** of the ENDF library development effort

- for the first time, in ENDF/B-VII.1, MACS and uncertainties are included in the ENDF paper
- comparisons of ENDF MACS with those in the **KADONIS** library have became a powerful quality assurance tool
- this has triggered ENDF evaluation updates for ^{3}He,^{9}Be,^{10}C,^{16}O, ^{58}Co
- ENDF evaluators now treat KADONIS seriously (ignored in the past)
- Wick Haxton has used ENDF cross sections in his recent assessment of the cold, early r-process scenario (a PRL paper)
- active support of nuclear astrophysics influence on ENDF library development at NNDC (Michal Herman) and LANL (Mark Chadwick)


red giants

Brookhaven National Laboratory -- Boris Pritychenko et al.

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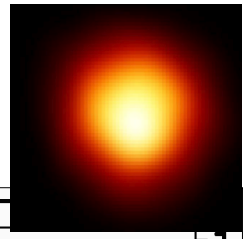
Project: Maxwellian-Averaged Cross Sections **from ENDF/B-VII.1**



Approach:

generate MACS from ENDF/B-VII.1 and UNCERTAINTIES via low-fidelity covariances

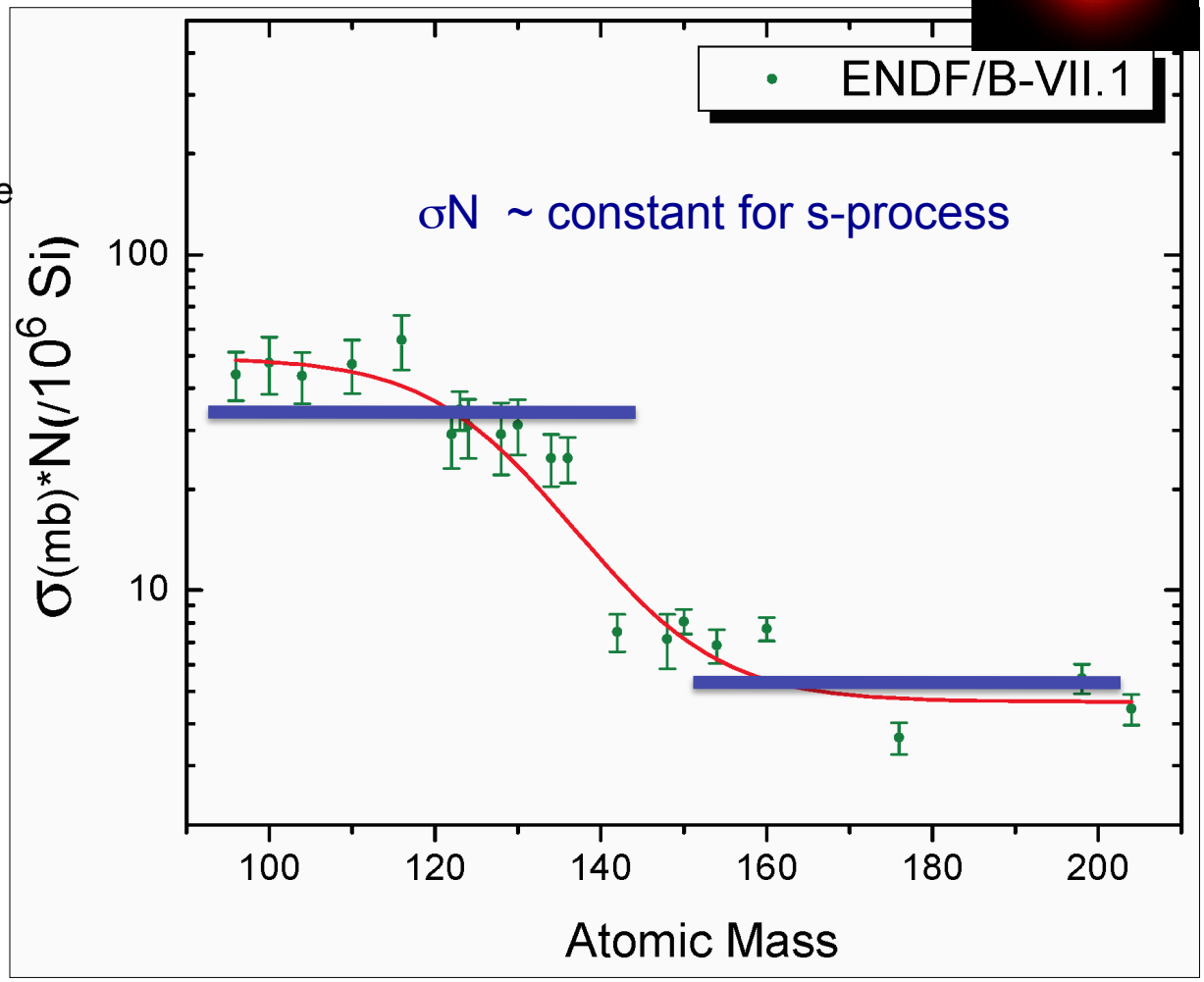
improve deficiencies in ENDF via comparisons with KADONIS database

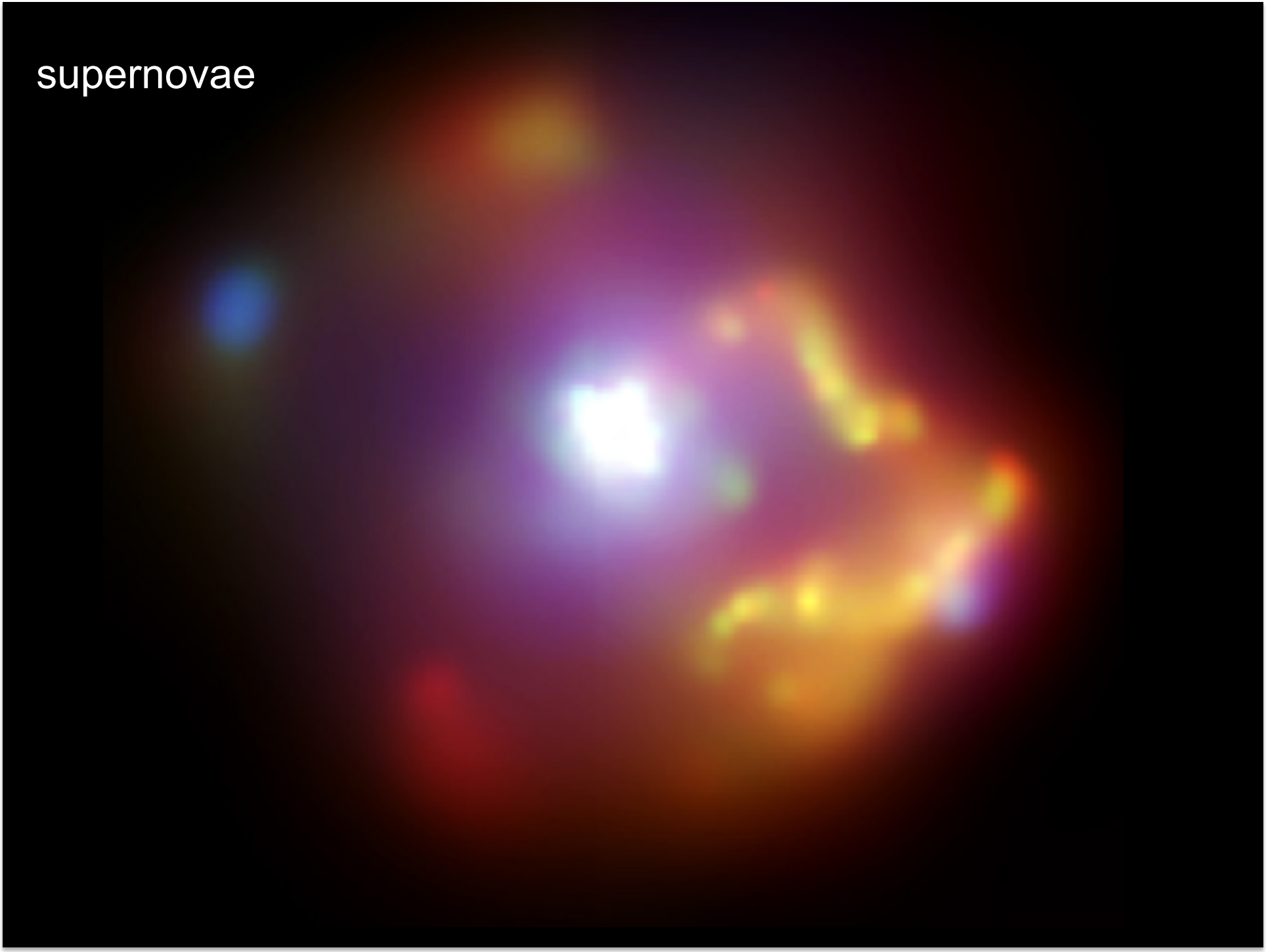
Results:

Verification of famous "σN " curve for s-process nucleosynthesis *with uncertainties*

these can be used in Monte Carlo studies of heavy element creation in red giant stars

MACS are now integrated into ENDF development !




supernovae

Oak Ridge National Laboratory – S. Ahn et al.

Project: determination of level properties of ^{81}Ge

Background:

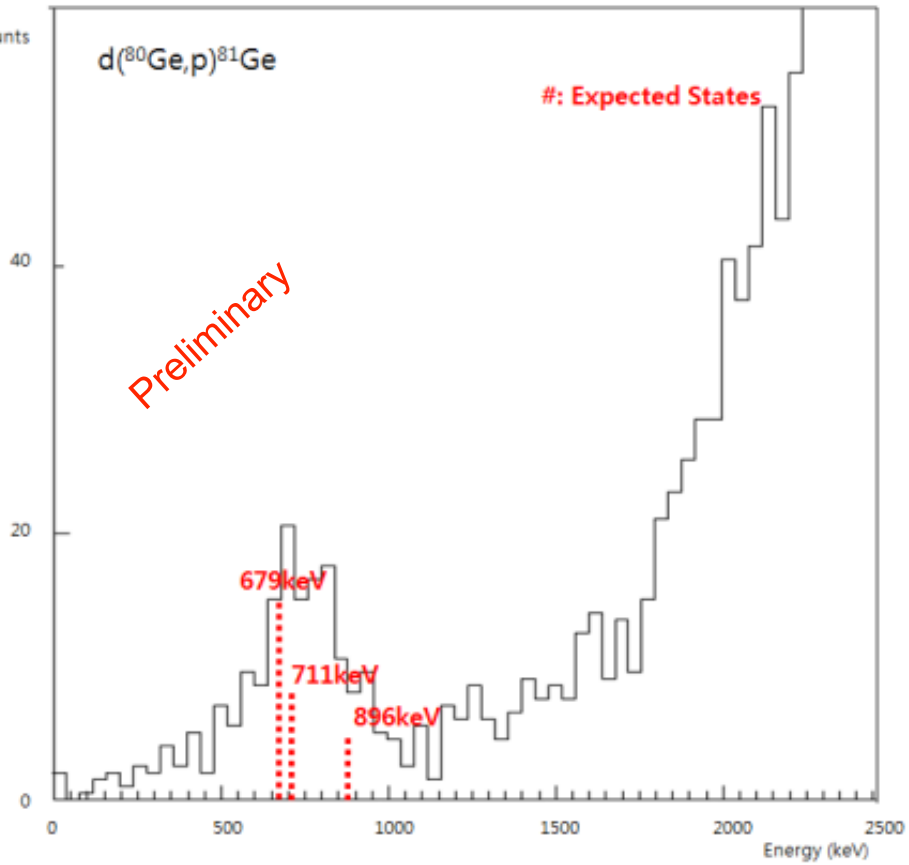
neutron capture cross sections near closed neutron shells can significantly influence final abundances in r-process nucleosynthesis in supernovae

^{81}Ge near the closed N=50 shell, ^{80}Ge(n,γ) may be cru

However – no firm spin assignments of low-lyi ^{81}Ge levels

partly based on the systematics of odd-mass N=49 isotones and from beta decay studies

need to confirm first & third three excited state … 679 keV -- ½$^{+}$ & 879 keV -- ½$^{-}$

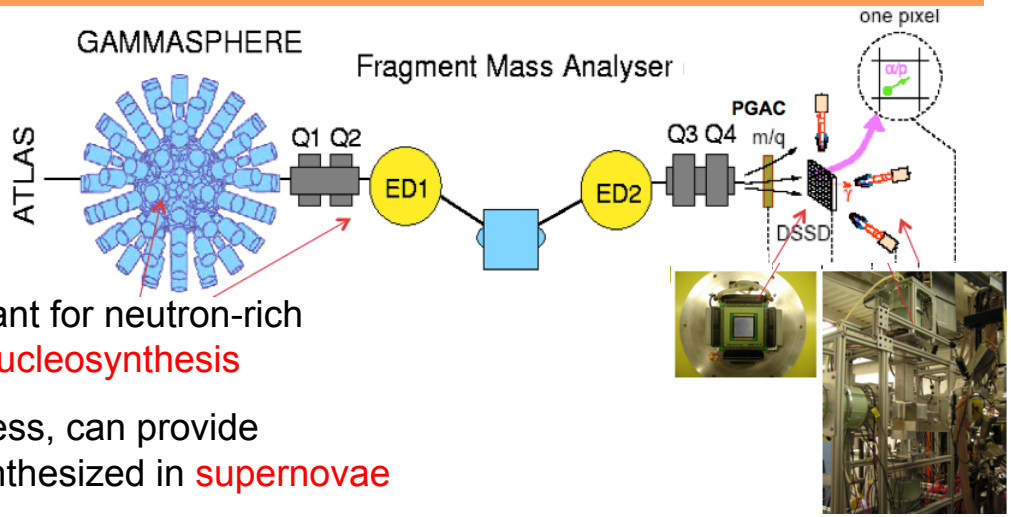


This project:

^{80}Ge(d,p)^{81}Ge in inverse kinematics was measured at HRIBF, ORNL.
Results are being analyzed and is the PhD thesis of Sunghoon Ahn (UTK)
Assessment of levels will be made in this analysis work

Argonne National Laboratory -- C. Nair, Filip Kondev
[with US Naval Academy]

Project: Decay Modes of $^{179\text{-}180}$Tl



Background:

experimental information on Fission Barriers (FB) for nuclei far from stability is scarce

accurate knowledge of FBs is particularly important for neutron-rich nuclei that are located on the path of *r*-process nucleosynthesis

fission of these nuclei could terminate the *r*-process, can provide r-process seeds, & impacts final abundances synthesized in supernovae

important to study the decay properties of heavy neutron-rich nuclei, including beta-delayed fission

This study:

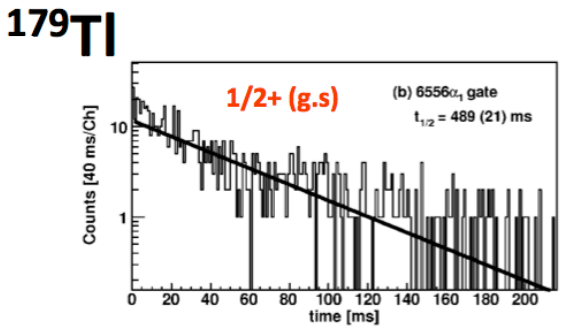
Measure alpha decays, alpha-gamma coincidences, $\varepsilon + \beta^+$ decays of $^{179\text{-}1880}$Tl at ANL-ATLAS; precursor to future studies with n-rich nuclei

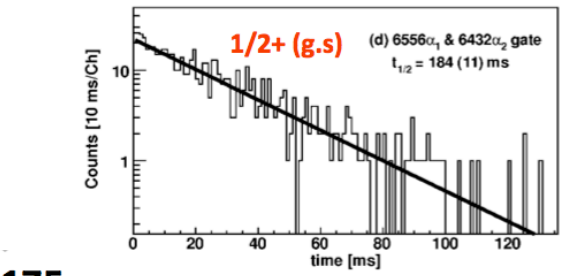
Results:

^{179}Tl: measured decay correlations in both long lived ½+ g.s. and short-lived 11/2- isomer were able to establish the "missing" ground state of 175Au

^{180}Tl: measured a single decaying state

Future work: explore astrophysical implications of these decay schemes





175Au

Wick Haxton et al. use of ENDF cross sections

Project: cross sections from ENDF used for cold early r-process calculations

Background:

standard scenario for r-process is right above newly-formed neutron star in a core collapse supernova
alternate scenario: in He shell of a core collapse supernova, driven by neutrino-induced reactions on ^{4}He

This alternate was ruled out as a general r-process mechanism as it only operates
at low metallicities and at low temperatures [early times] and cannot produce all the r-elements

This study:

Haxton et al. PRL106 (2011) 201104 revisit this scenario to see if it can be ONE POSSIBLE r-process mechanism

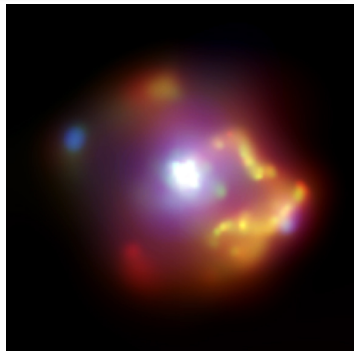
cross sections for ^{12}C+n and ^{16}O+n needed for this calculation, and taken from ENDF, JENDL …

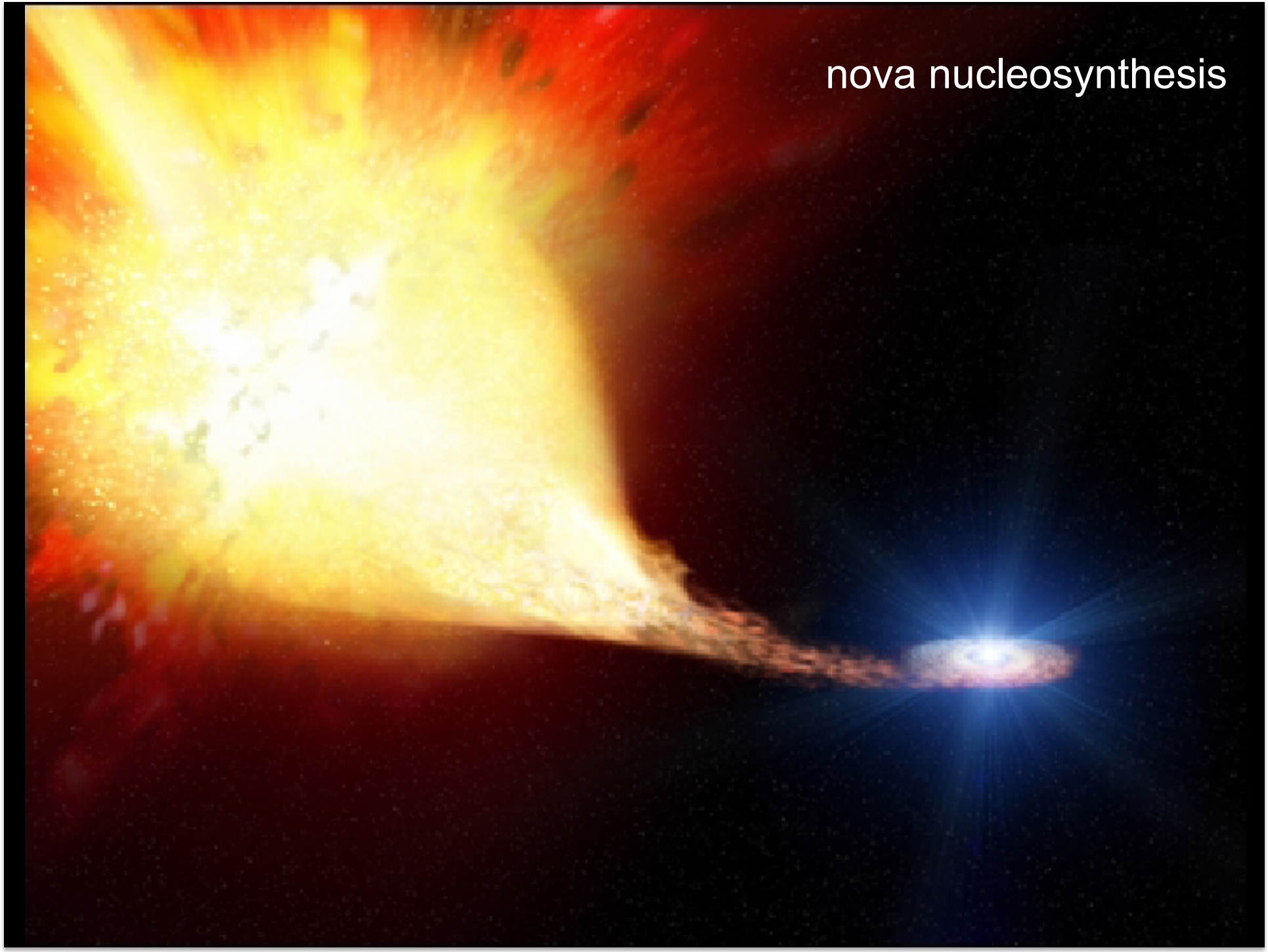
$1/r^2$ of the inner He zone and NC ν channels in neutron production (which in the outer He zone lead to ^{7}Li). One source of uncertainty comes from the ^{12}C and ^{16}O (n, γ) cross sections, which differ by factors of ~3 and 45 (10 and 160) at $T_8 \sim 0.85$ (3) between the Evaluated Nuclear Data File and the Japanese Evaluated Nuclear Data Library [17]. The differences reflect the energy range over which s-wave capture is assumed to dominate. Pending resolution of this discrepancy, parametric studies will be needed [16].

Results:

Discrepancy of cross sections for ^{12}C+n and ^{16}O+n from ENDF and JENDL lead to a **serious uncertainty** in evaluating the viability of this new scenario

Need to resolve this discrepancy




nova nucleosynthesis

McMaster University -- K. Setoodehnia, D. Irvine, Alan Chen, Jun Chen

- Two reactions evaluated: **^{29}P(p,γ)^{30}S** and **^{30}P(p,γ)^{31}S**
- Both closely tied to Alan Chen's nuclear astro research program
  - ^{29}P(p,γ)^{30}S, thesis project of Kiana Setoodehnia
    - studied ^{30}S levels of astrophysical interest via (*p,t*) and (^{3}*He,n*γ)
    - discovered a new dominant state
  - ^{30}P(p,γ)^{31}S, thesis project of Dan Irvine
    - studied ^{31}S levels of astrophysical interest via (*d,t*)
    - data analysis in progress
- Rates submitted using the Computational Infrastructure for Nuclear Astrophysics at **nucastrodata.org**
- Further update expected from the results of our group's research

McMaster University -- K. Setoodehnia, D. Irvine, Alan Chen, Jun Chen

Project: Evaluation of $^{29}P(p,\gamma)^{30}S$ rate

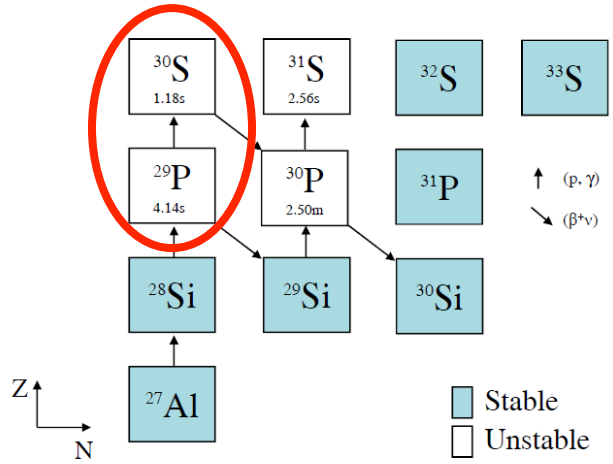
- The ^{29}Si and ^{30}Si abundances are important to understand nova nucleosynthesis, and they depend on the $^{29}P(p,\gamma)^{30}S$ rate

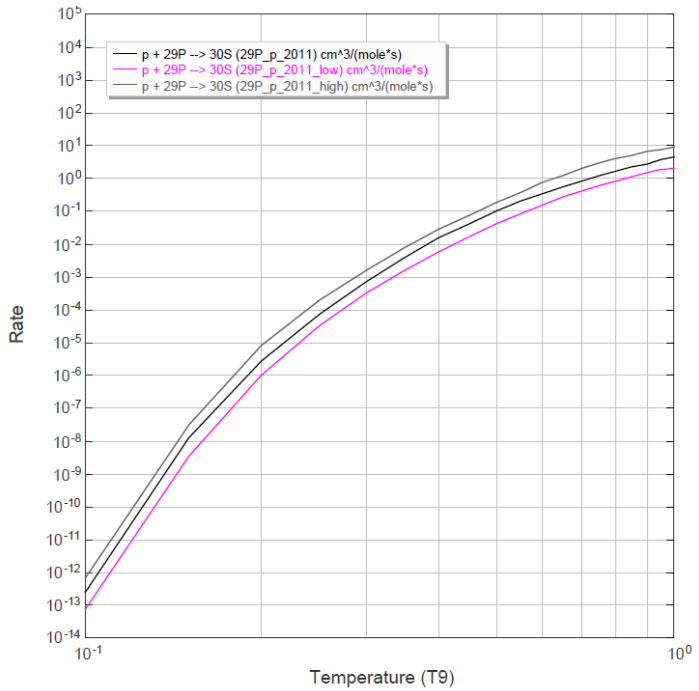
- ^{30}Si abundance increased via $^{29}P(p,\gamma)^{30}S(\beta^+)^{30}P(\beta^+)^{30}Si$ reactions

- $^{29}P(p,\gamma)^{30}S$ rate is uncertain due to poorly understood level structure in ^{30}S above ^{29}P+p threshold

- Rate dominated at Nova temperatures (0.1-0.4 GK) by two resonances at E_R=296 and 412 keV with unknown strengths

- Sp=4399(3) keV from Audi's compilations in 2011

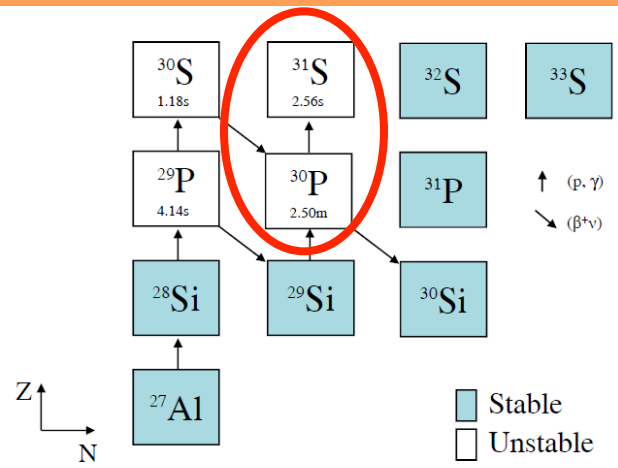


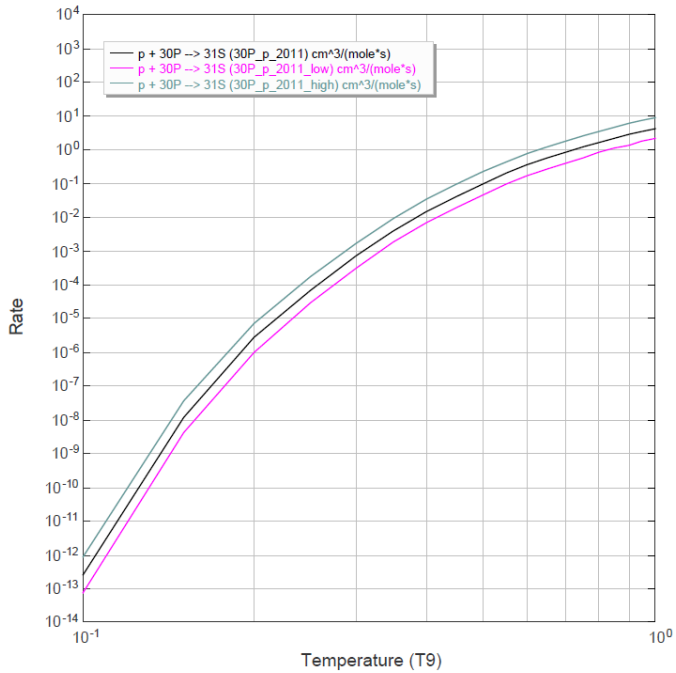


McMaster University -- K. Setoodehnia, D. Irvine, Alan Chen, Jun Chen

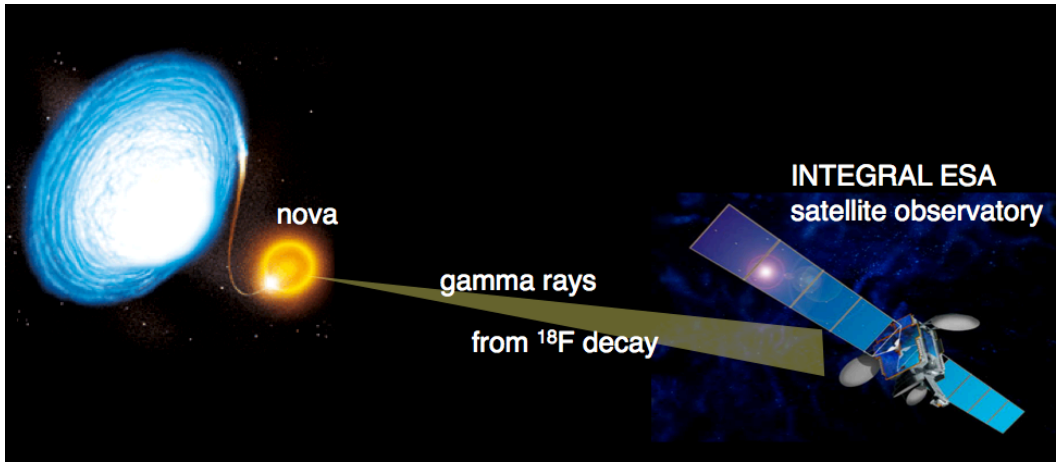
Project: Evaluation of $^{30}P(p,\gamma)^{31}S$ rate

- $^{30}P(p,\gamma)^{31}S$ rate strongly influences Si isotopic abundance ratios in presolar meteoric grains of possible nova origin
- It destroys ^{30}P, bypassing production of ^{30}Si from $^{30}P(\beta^+)^{30}Si$
- Large uncertainties in level parameters above the proton threshold still remain
- Rate dominated by states up to about $E_x \sim 7$ MeV. Uncertainty is mainly from resonance strengths.
- Sp=6130.9(4) keV from new mass measurement by Kankainen et al. (2010), 6131.4(10) from Audi's compilation in 2011





Project: measurements & reaction assessments for nova nucleosynthesis



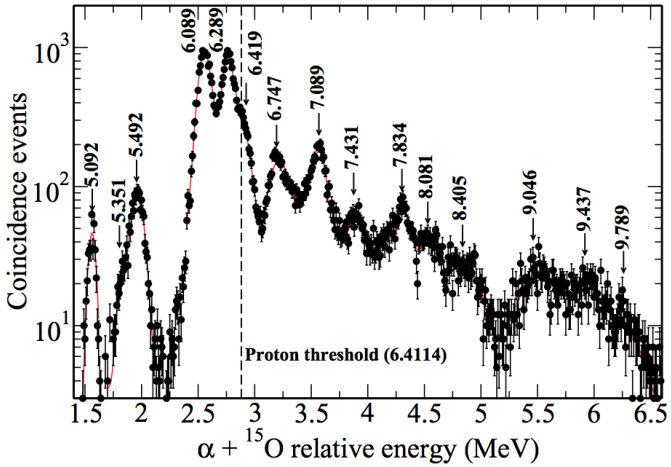


FIG. 1. (Color online) $\alpha + {}^{15}$O coincidences versus relative energy in ^{19}Ne. The shaded circles are experimental data while the red curves are the fit. Excitation energies in MeV are indicated.

^{18}F + p burning:

A.S.Adekola et al., Phys.Rev. C **83**, 052801 (2011)
First proton-transfer study of ^{18}F + p resonances relevant for novae

^{18}F produced in nova explosions, has a 2 hour decay that is a target of gamma ray astronomy

many direct and indirect studies of ^{18}F + p burning in novae

proton transfer never investigated …
at ORNL HRIBF, we measured (d,n) for the first time with radioactive ^{18}F beam

nice results on strength of lowest lying resonances not accessible by direct measurements,
included re-assessment of low-lying levels in ^{19}Ne

Project: measurements & reaction assessments for nova nucleosynthesis

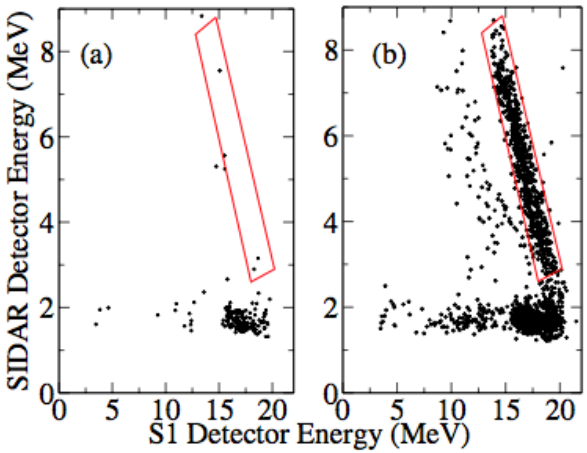
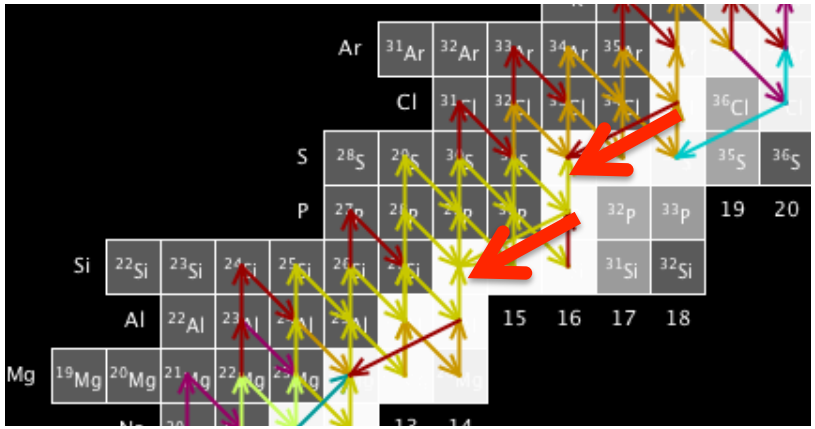


Fig. 3. The energy of particles detected in SIDAR plotted against the energy of coincident particles in the S1 detector for incident ^{31}P energies of 19.73 MeV (a) (off-resonance) and 19.78 MeV (b) (on-resonance). The drawn box is where (p, α) events are expected to fall.



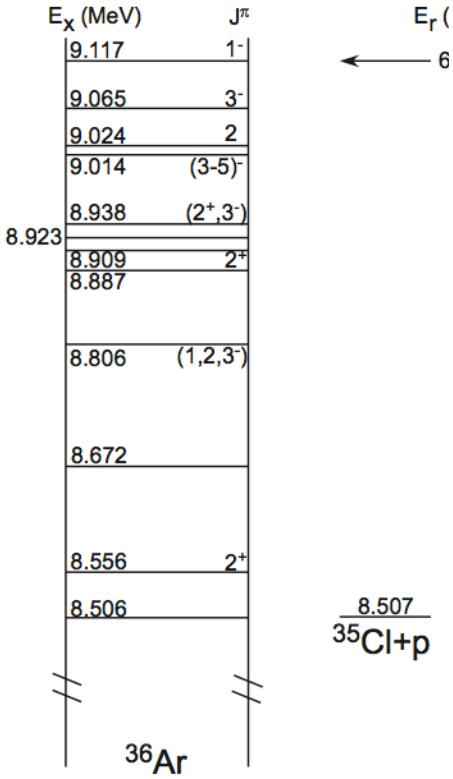


Fig. 7. The relevant excitation energy range in ^{36}Ar is along with an arrow indicating the resonance directly m in the present work. Excitation energies and spins ar from ref. [5].

mass 30 – 40 nova nucleosynthesis

B.H.Moazen et al., Eur.Phys.J. A **47**, 66 (2011) *Direct studies of low-energy resonances in ^{31}P(p, α)^{28}Si and ^{35}Cl(p, α)^{32}S*

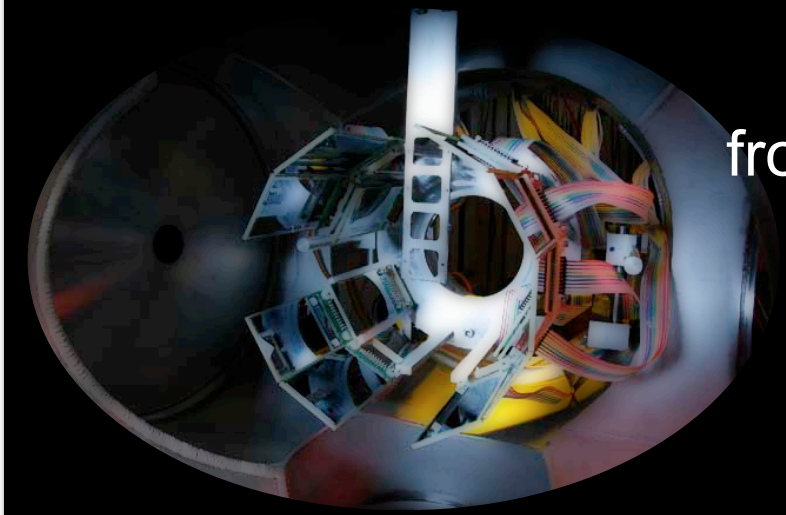
Burning in mass range 30 – 40 influences **maximum mass** synthesized in nova outbursts

(p,α) reactions direct mass flow to *lower* masses – a reaction *cycling*

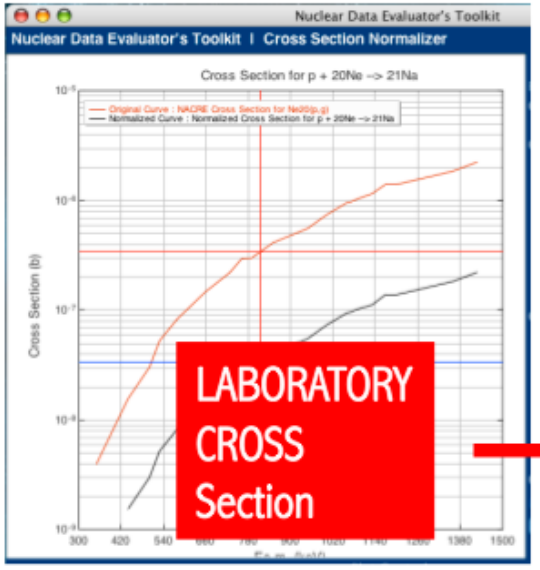
recent measurements at ORNL on (p,α) on ^{31}P and ^{35}Cl as prototypes for radioactive beam measurements at ReA3 at MSU

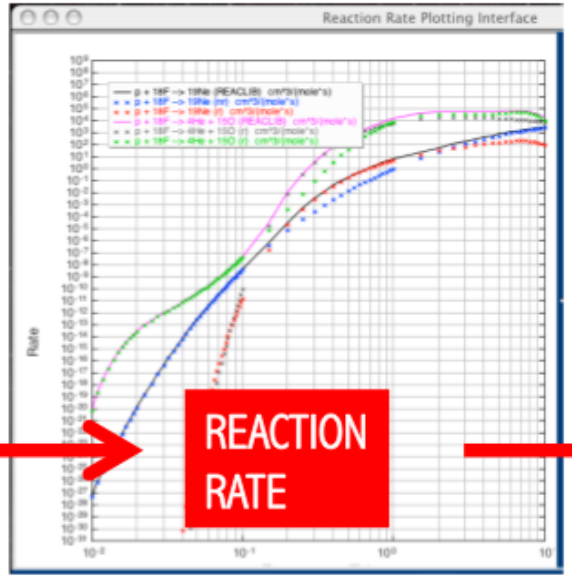
strengths of a number of resonances were lower than previously determined – resulting in less cycling

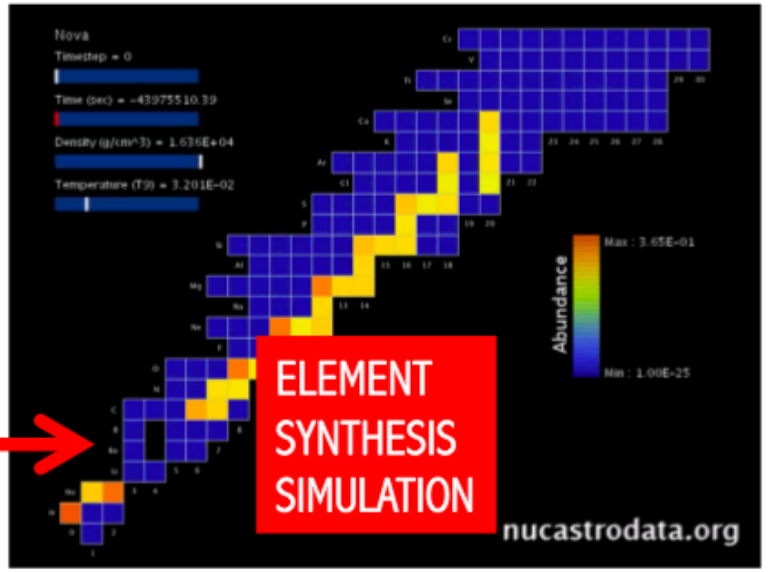
work includes **assessments of levels in ^{31}P + p and ^{35}Cl + p**



from the lab to the stars …



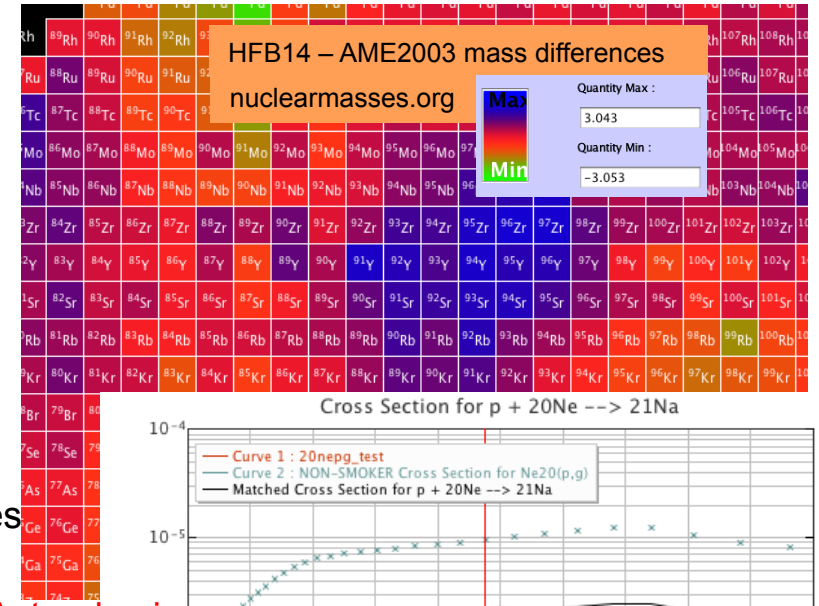


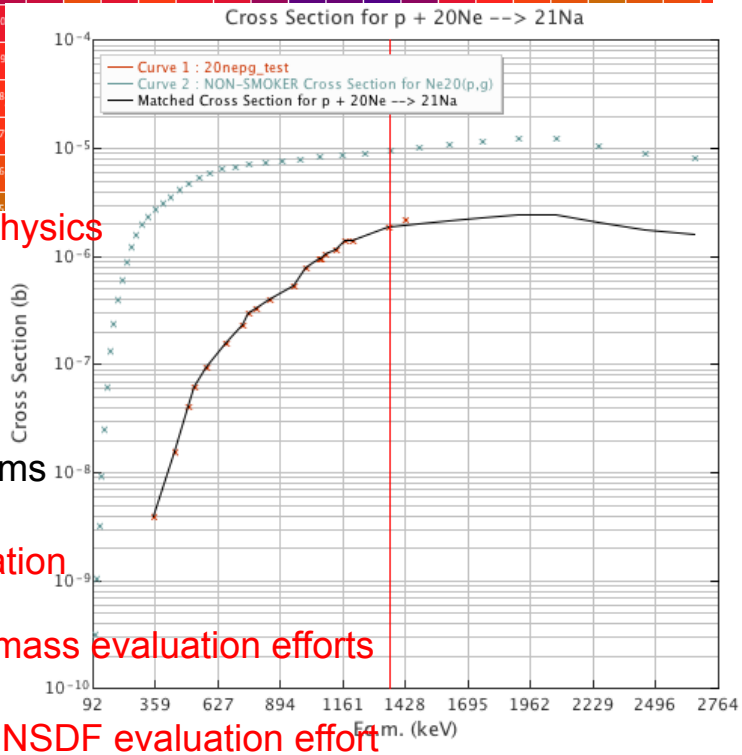


Oak Ridge National Laboratory -- Michael Smith, Eric Lingerfelt, Caroline Nesaraja

OAK RIDGE National Laboratory

Project: software systems for nuclear astrophysics research





Background:

nuclear information not easy to access, visualize, share, process into astrophysical models

not easy to determine astrophysical impact of new nuclear physics information

This study:

significant improvements in our unique on-line software suites for research in nuclear astrophysics and nuclear science

nucastrodata.org / Computational Infrastructure for Nuclear Astrophysics

nuclearmasses.org

Results:

researchers in 114 institutions in 29 countries use our online systems

details of recent improvements in ORNL Progress Report presentation

our nuclear mass software makes an excellent platform for future mass evaluation efforts

some of our workflow management software could be helpful for ENSDF evaluation effort

Closing Comments

there are really interesting astro-related projects carried out by USNDP institutions

some of your projects could possibly be extended or enhanced to have astrophysical implications

we would like to explore such possibilities with you !