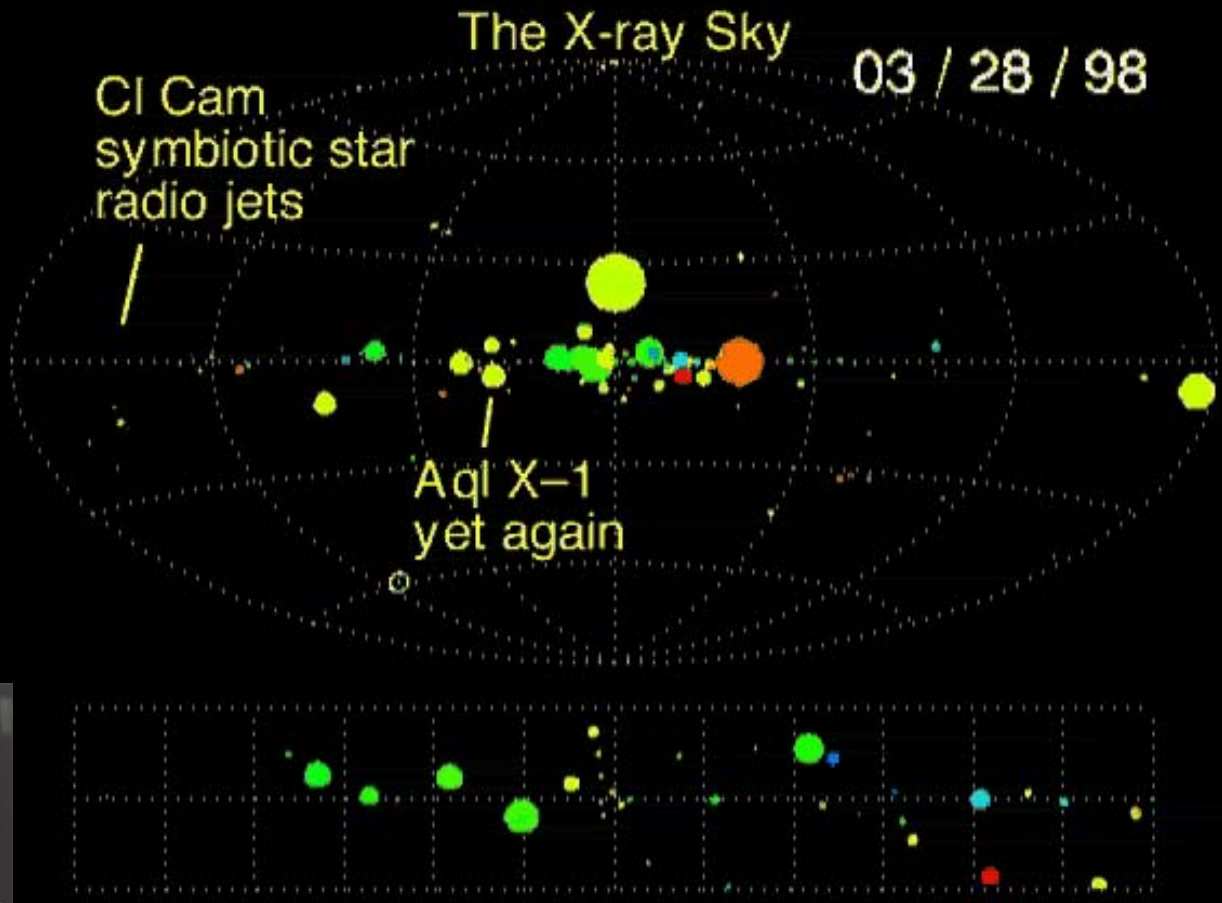
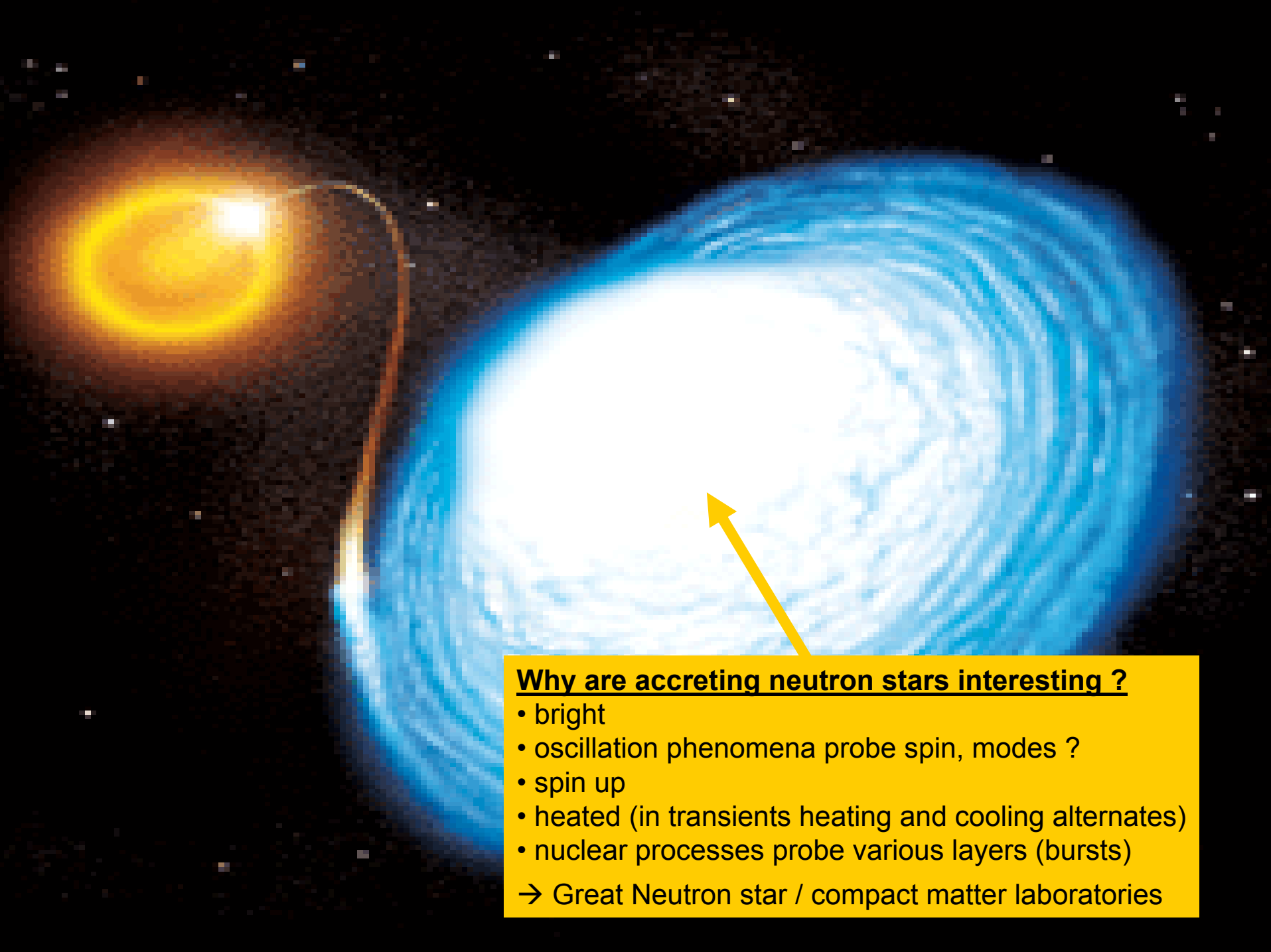
JINA Science – MRC 2
X-ray binaries – accreting neutron stars



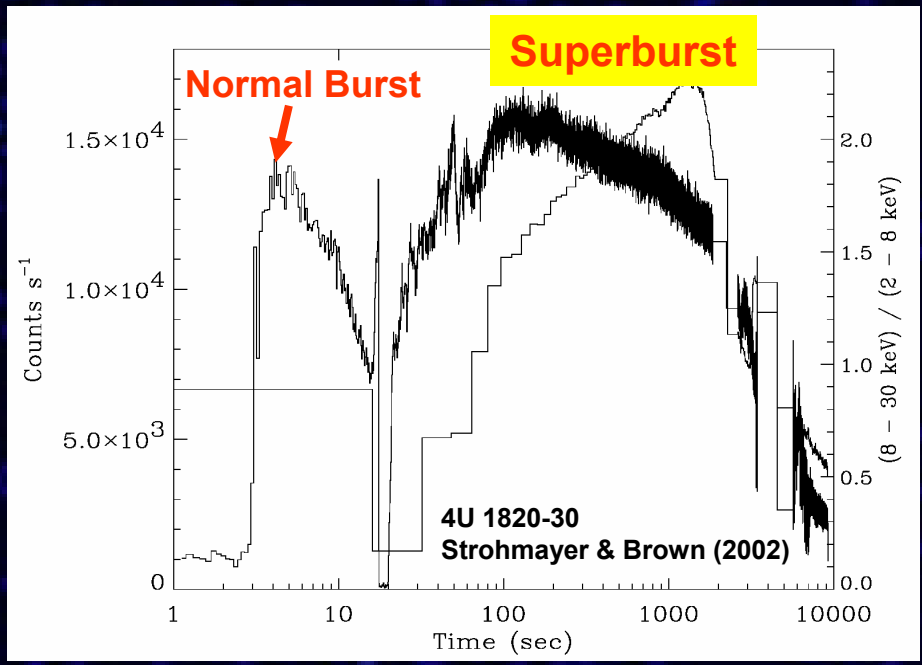
Nobel Price in Physics 2002
for Riccardo Giacconi

D.A. Smith, M. Muno, A.M. Levine,
R. Remillard, H. Bradt 2002

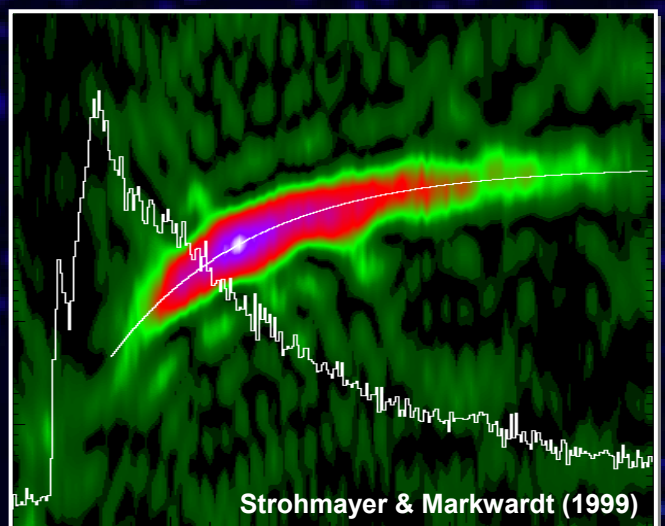

Why are accreting neutron stars interesting ?
• bright
• oscillation phenomena probe spin, modes ?
• spin up
• heated (in transients heating and cooling alternates)
• nuclear processes probe various layers (bursts)
→ Great Neutron star / compact matter laboratories

Era of Discoveries

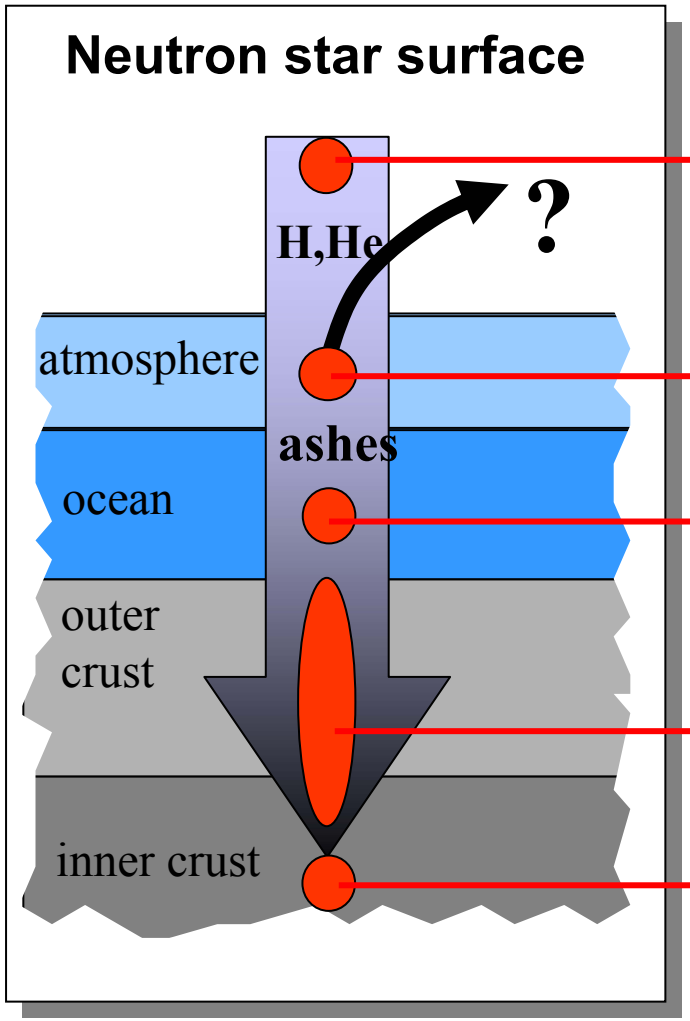
Off state transient
KS 1731-260
(Wijands 2001)



Burst oscillations



Nuclear physics – all addressed by JINA



Metal spallation

H, He burning (rp-process) ($\rho=10^{5\text{-}6}$ g/cm^3)

- normal type I bursts
- stable burning

deep C burning ? ($\rho=10^{9}$ g/cm^3)

- superbursts

electron capture ($\rho=10^{8\text{-}14}$ g/cm^3)

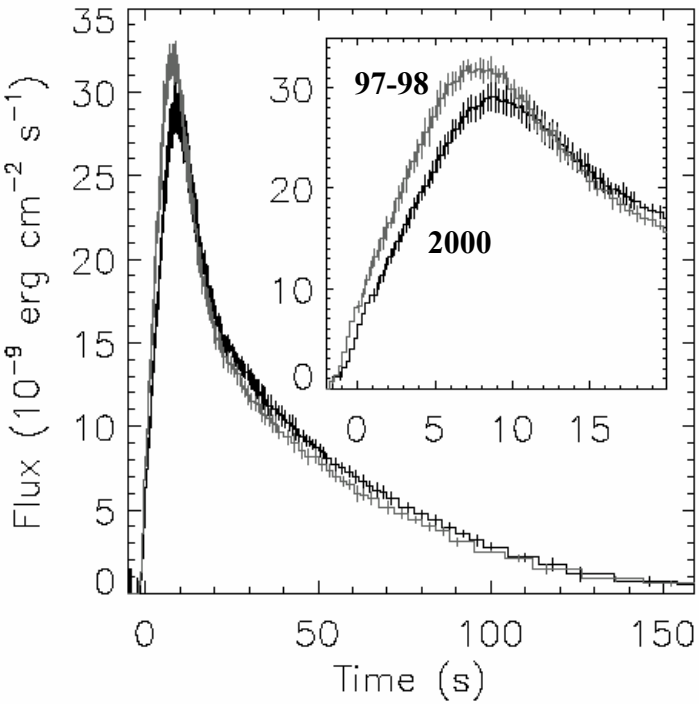
pycnonuclear fusion reactions

- heat during off-state
- magnetic field changes
- gravitational waves ?

Nuclear physics matters

Precision X-ray observations

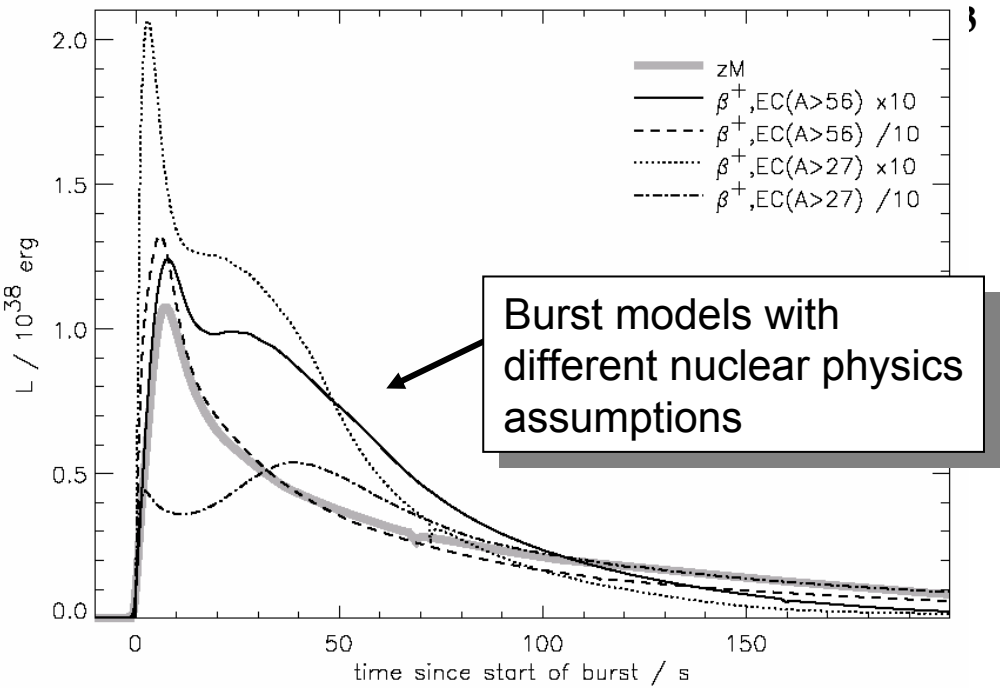
(NASA's RXTE)



→ GS 1826-24 burst shape changes !

(Galloway 2003 astro/ph 0308122)

Uncertain models due to nuclear physics



Woosley et al. 2003 astro/ph 0307425

- Need much more precise nuclear data to make full use of high quality observational data

Burst and accretion modeling
- Models 1D: LANL, LLNL, MSU, ND, UCSC Basel, MSU, ND
- Models Multi D models: ND, Arizona, MSU ?
- Models stable burning: MSU, UCSB, UCSC
- Astro theory (diffusion, modes, etc): Chicago, MSU, UCSB
- Nuclear theory: Aarhus, Barcelona, Basel, MSU, ND

Crust modeling
- Full nuclear physics crust model: Aarhus, Barcelona, LANL, Mainz, MSU, ND, UCSB

Reaction Database:
- reaclib: Basel, MSU, ND
- planned: public refereed archive

Future Facilities:
- Active role in ARIA for RIA design

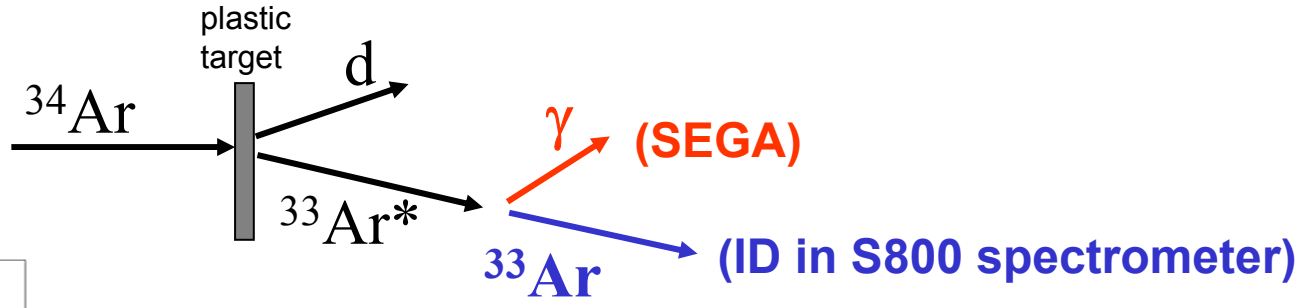
MRC2

Experimental nuclear physics
- NSCL program (decay, rates, r-process masses charge exchange, EOS experiments)
- ND program (rates)
- ANL program (decay, masses, rates)
- RCNP program (rates)
- other RIBs: LLN, TRIUMF

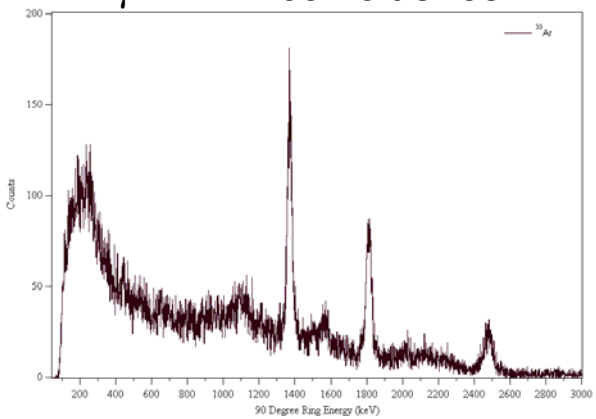
Observations:
- links to observers at GSFC, MIT, MSU

^{32}Cl(p,g)^{33}Ar rate at MSU/NSCL (Clement et al. 2004)

p(^{34}Ar,^{33}Ar)d

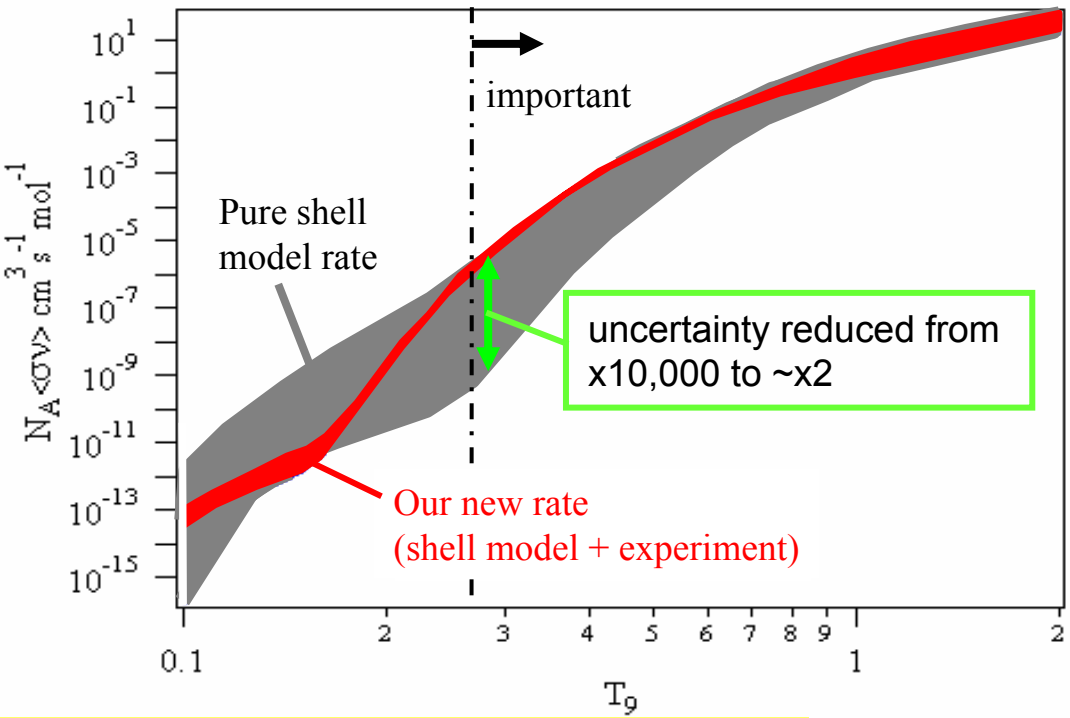


γ in ^{33}Ar coincidence



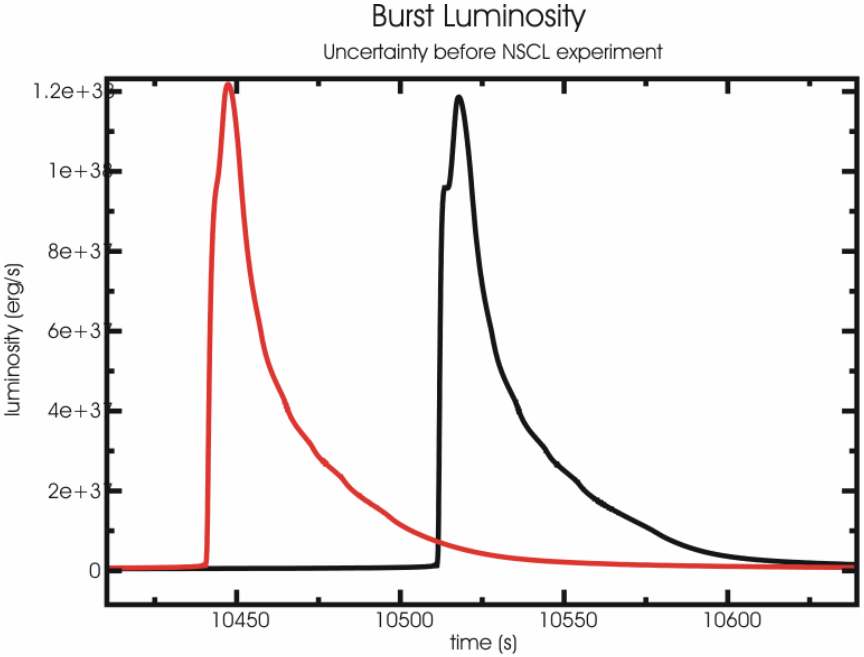
level energies in ^{33}Ar are resonance energies in ^{32}Cl+p

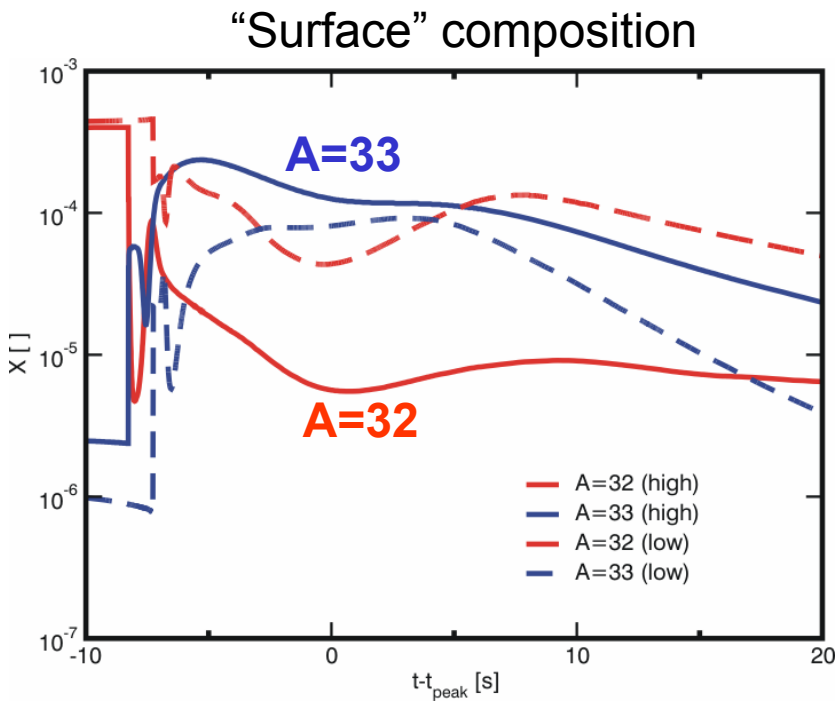
New astrophysical ^{32}Cl(p,γ)^{33}Ar rate



→ Most rp-process nuclei within reach at MSU/NSCL

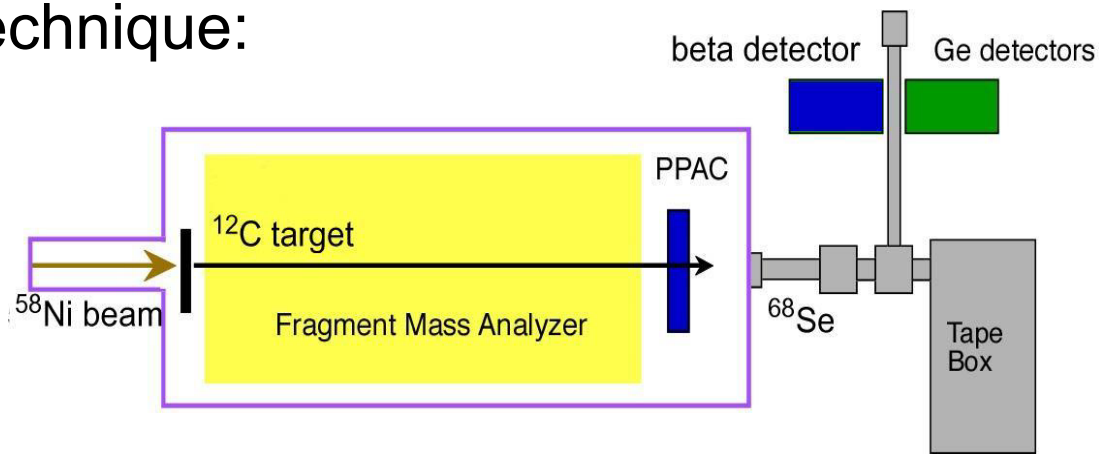
1D X-ray burst calculations on impact of previous $^{32}Cl(p,g)^{33}Ar$ uncertainty by J. Fisker et al.



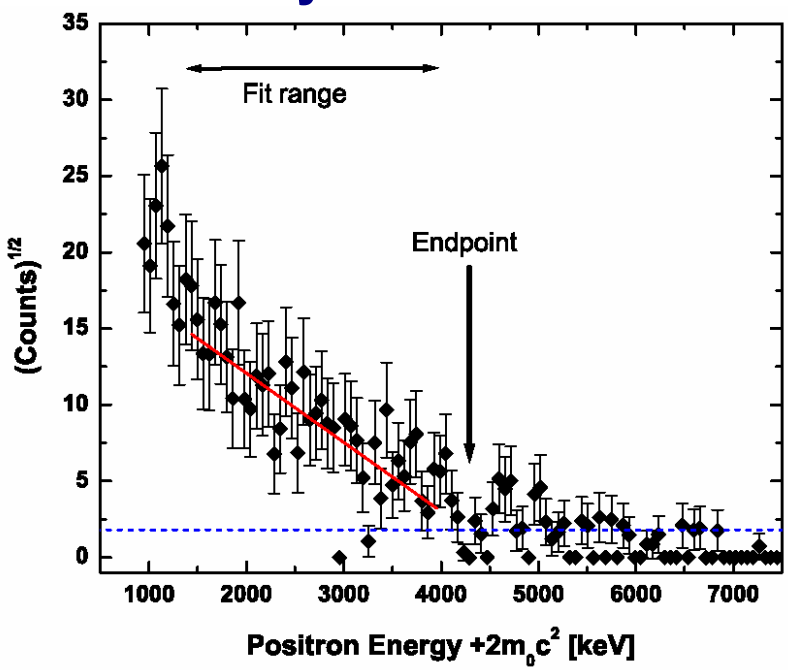


Measurement of ^{68}Se mass at ANL (Woehr et al. 2004)

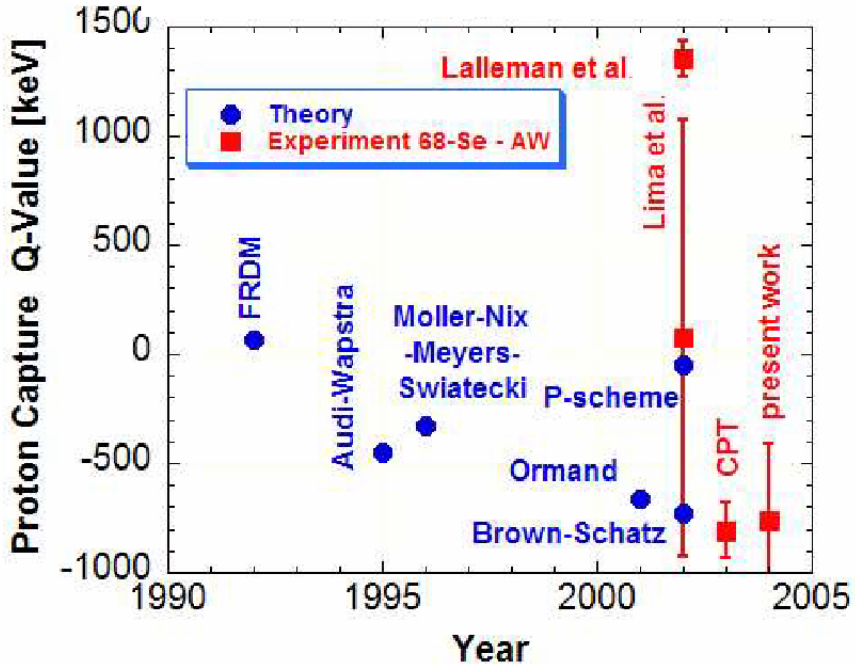
β-endpoint technique:



Decay curve for ^{68}Se

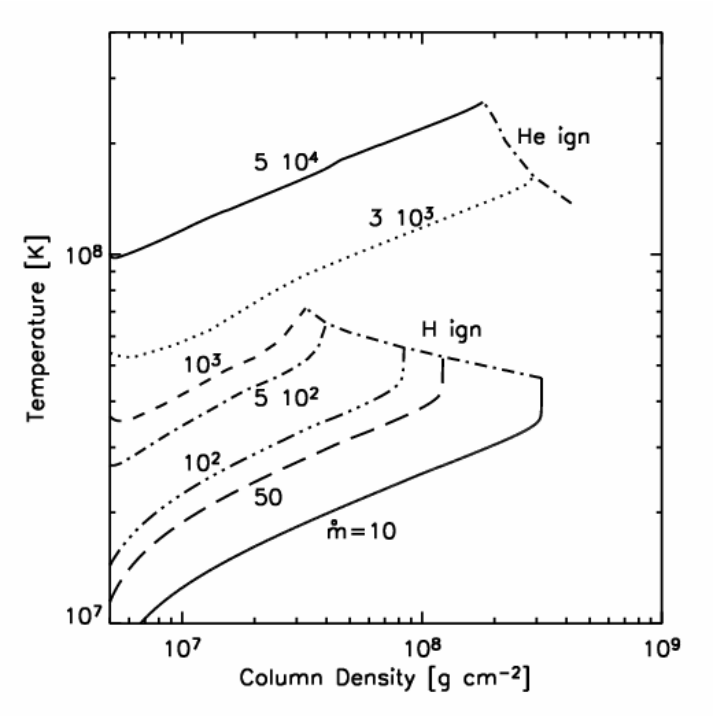


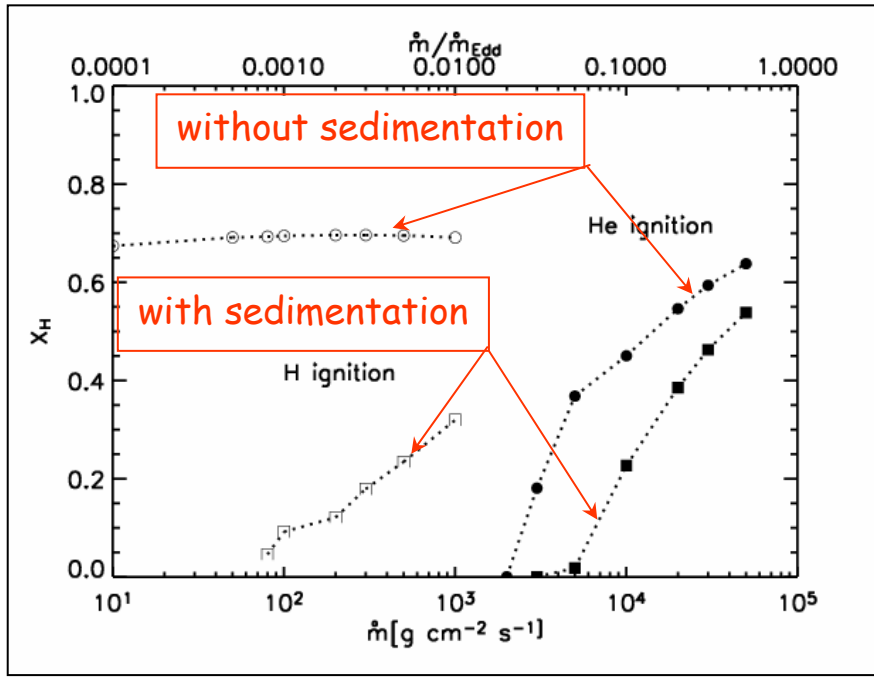
Q-value of ^{68}Se(p,γ)^{69}Br



Sedimentation and X-ray Bursts

In a plasma, H “floats” upward and heavier ions (He, C, ...) settle.





Peng, Brown & Truran, *in preparation*

- Affects H/He ratio at ignition
- Important for determining rp-process ”ashes”

JINA Workshop in Santa Barbara April 23-24, 2004

Workshop goals:

- bring together JINA collaboration on MRC2
- generate new ideas
- trigger new collaborations
- determine direction of research program

Few examples for new initiatives and collaborations:

→ MSU/Chicago calculation of diffusion in X-ray bursts – new collaboration with LANL/ND to implement diffusion in full 1D models

→ 1D modelers will compare codes and results

→ Need detailed model of burning front propagation, impacts nuclear physics

→ Sensitivity studies to take advantage of experimental opportunities

Participants:
MSU: E. F. Brown, S. Gupta, M. Ouellette, H. Schatz
ND : D. Balsara, J. Fisker, M. Wiescher
UCSB: P. Arras, L. Bildsten, P. Chang, T. Piro
UCSC: J. Macbeth
LANL: A. Heger
GSFC: T. Strohmayer
MIT: D. Chakrabarty

Theorists
Experimental
Observers