Nucleosynthesis in novae

C. Iliadis

REACTION RATES FOR NOVA NUCLEOSYNTHESIS

C. ILIADIS

UNIVERSITY OF NORTH CAROLINA

AND

TUNL

ORGANIZATION

- MOTIVATION
- MODEL
- NEW REACTION RATES
- EXPERIMENTS
- CONCLUSIONS

MOTIVATION : HOW DO STARS EXPLODE ?

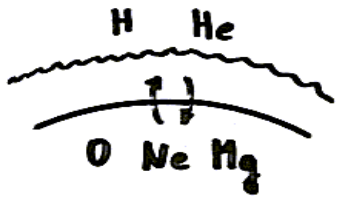
NOVA CYGNI 1992

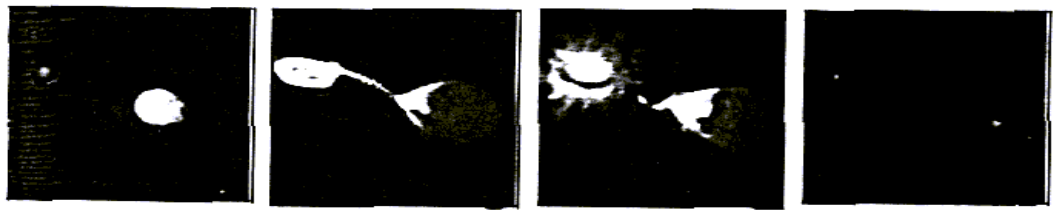
SIGNATURES

- LIGHT CURVES
- EJECTED MASS
- RADIOACTIVITIES (^{22}Na, ^{26}Al)
- ELEMENT ABUNDANCES

OBSERVED ENRICHMENTS IN Ne, Na, Al, Si, P, S, Ar

MODEL





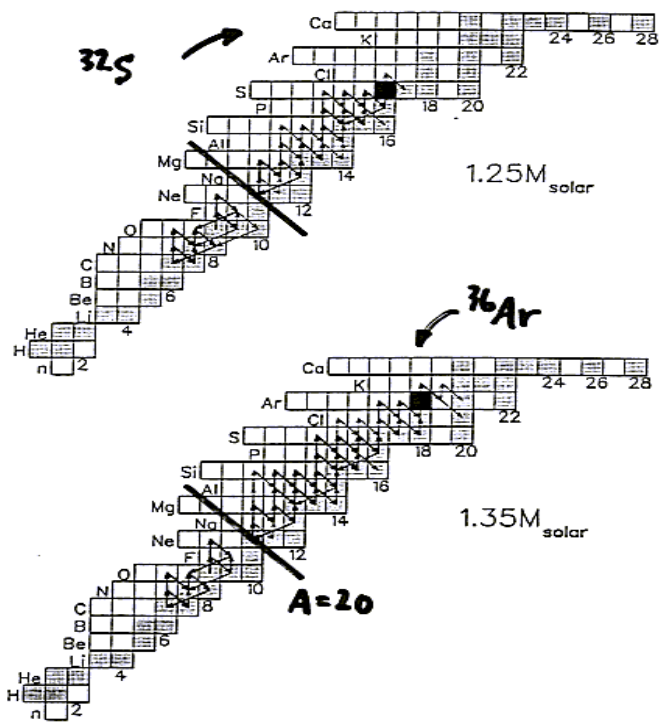
Ne, Mg $\xrightarrow[\text{NUCLEAR REACTIONS}]{\text{EXPLOSIVE BURNING}}$ Ne, Si, S, Al, Ar

©1999. The American Astronomical Society. All rights reserved. Printed in U.S.A.

EXPLOSIVE HYDROGEN BURNING OF ^{27}Si, ^{31}S, ^{35}Ar, AND ^{39}Ca IN NOVAE AND X-RAY BURSTS

CHRISTIAN ILIADIS
University of North Carolina at Chapel Hill, and Triangle Universities Nuclear Laboratory, Durham, NC 27708-0308; iliadis@tunl.duke.edu
PIETER M. ENDT
R. J. Van de Graaff Laboratorium, Universiteit Utrecht, P.O. Box 80000, 3508 TA Utrecht, Netherlands
NIKOS PRANTZOS
Institut d'Astrophysique de Paris, 98bis Boulevard Arago, F-75014 Paris, France; prantzos@iap.fr
AND
WILLIAM J. THOMPSON
University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3255; wmjthompson@msn.com
Received 1998 April 24; accepted 1999 May 28

[T-ρ PROFILES FROM STARRFIELD, ARIZONA S.U.]



$T_9^{PEAK} = 0.29$

$T_9^{PEAK} = 0.35$

NEW REACTION RATE COMPILATION

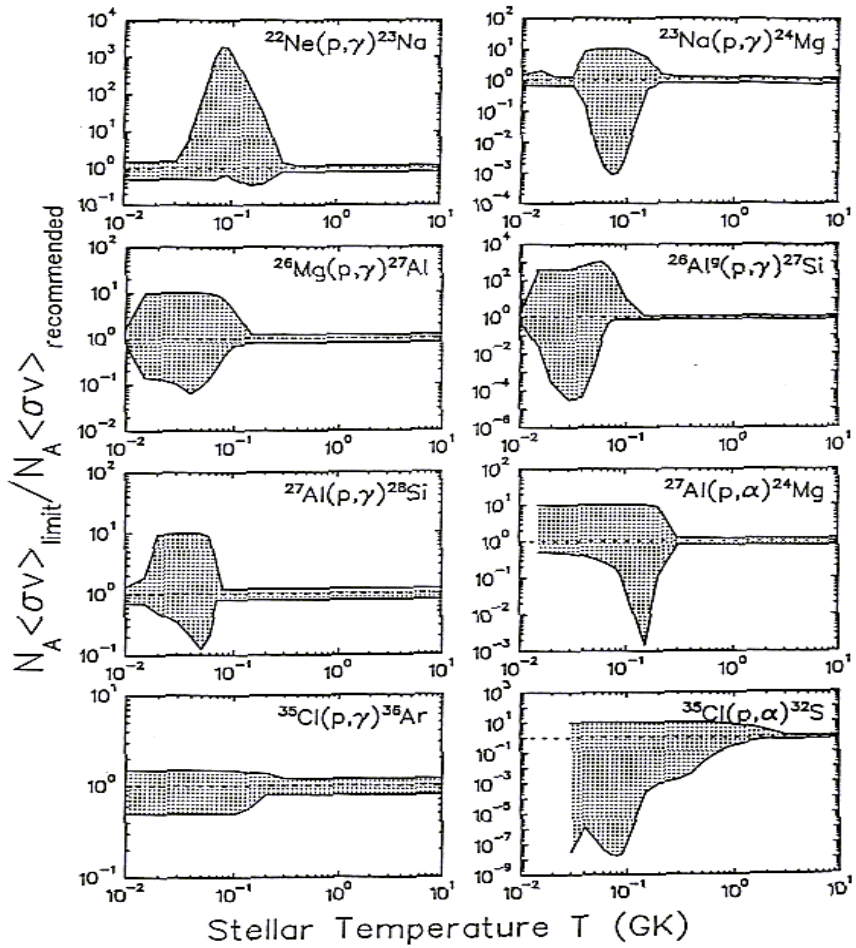
[ILIADIS, D'AURIA, STARRFIELD, THOMPSON, WIESCHER, IN PREPARATION (2000)]

INTEREST: NUCLEOSYNTHESIS IN A=20-40 RANGE

		(p,γ) AND (p,α) IN A=20-40	
COMPILATION	TOTAL RATES	STABLE RATES	UNSTABLE RATES
CF88	159	17	6
NACRE	86	15	3
PRESENT	54	26	28

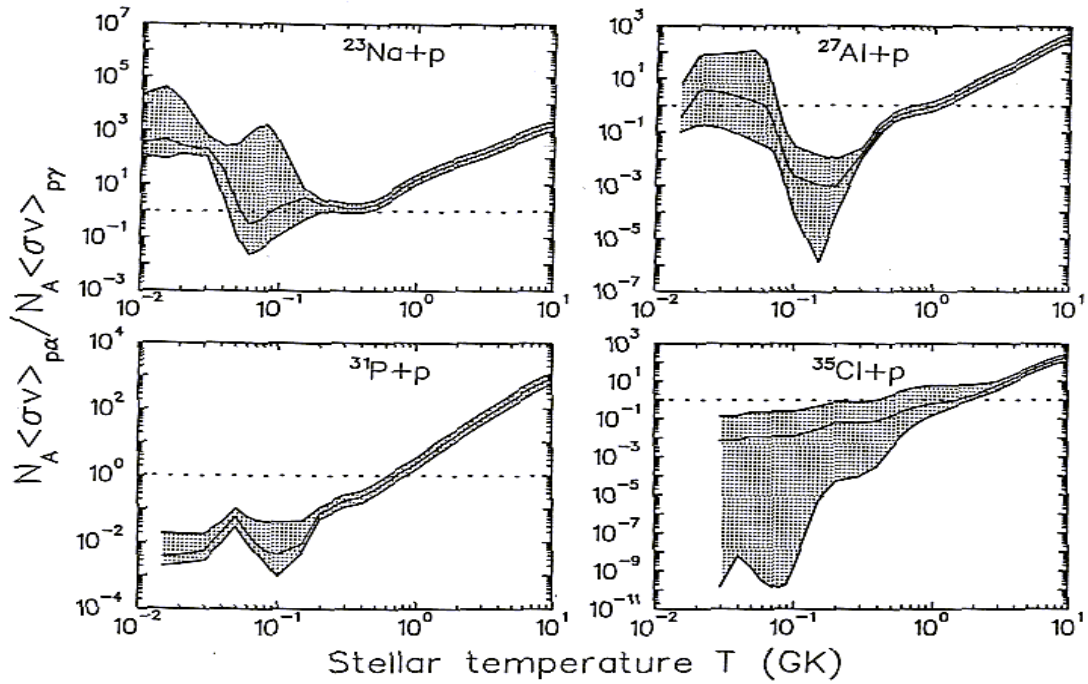
REACTION RATE ERRORS

[THOMPSON AND ILIADIS, NPA 647, 259 (1999)]



REACTION CYCLES

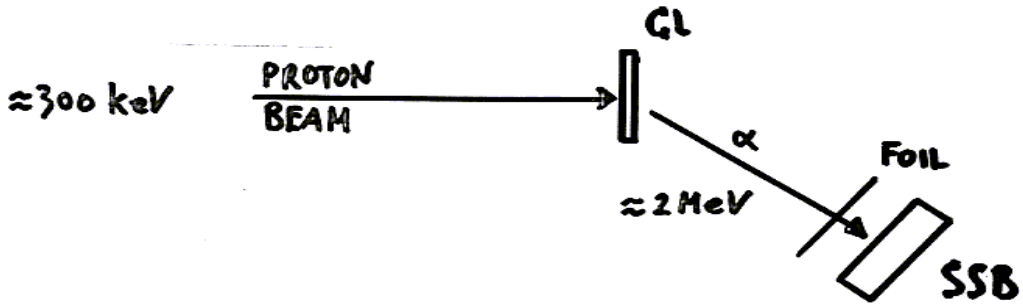
(p,α) vs. (p,γ)



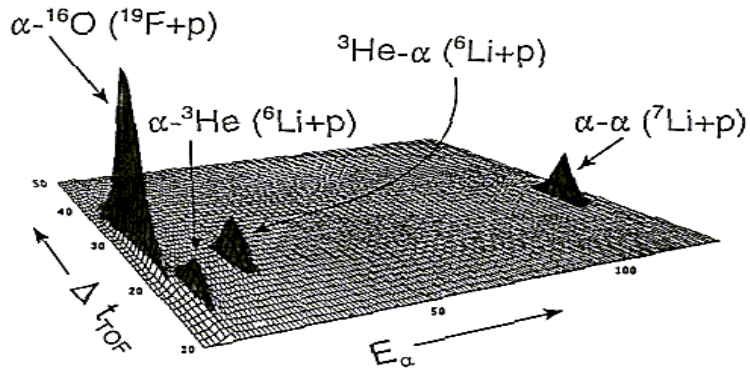
REACTION CYCLES

EXAMPLE: $^{35}Cl(p,\alpha)^{32}S$

	K 35 190 ms β+ γ 2963; 2590... Sp 1,425; 1,705; 1,555...	K 36 342 ms β+ 9,9... γ 1970; 2432; 2206... Sn 0,970; 5,380... Sα 2,018; 2,725...	K 37 1,22 s β+ 5,1... γ 2796...	K 38 924,6 ms | 7,6 m β+ 7,9 | β+ 2,7... γ 2196...
Ar 33 174,1 s β+ 9,8; 10,6... γ 810; 1542; 2223*... Sp 3,17...	Ar 34 844 ms β+ 5,0... γ 666; 3129... 0	Ar 35 1,78 s β+ 4,9... γ 1219; (1763...)	Ar 36 0,337 σ 5,6 σn,α 0,1355	Ar 37 35,0 d ε no γ σn,p 69 σn,α 1970
Cl 32 291 ms β+ 8,8; 11,7... γ 221; 479... Sα 2,28; 1,67... Sp 0,891; 0,782; 1,234...	Cl 33 2,51 s β+ 4,5... γ (841; 1966; 2567...)	Cl 34 32,9 m | 1,53 s γ 146 β+ 4,5	Cl 35 75,77 σ 44 σn,p 0,4 σn,α 0,00008	Cl 36 3,0 · 10⁵ a β− 0,7 ε; β+... no γ σ < 10
S 31 2,58 s β+ 4,4... γ 1256...	S 32 95,02 σ 0,55 σn,α 0,007	S 33 0,75 σ 0,46 σn,α 0,190 σn,p 0,002	S 34 4,21 σ 0,29	S 35 87,5 d β− 0,2 no γ

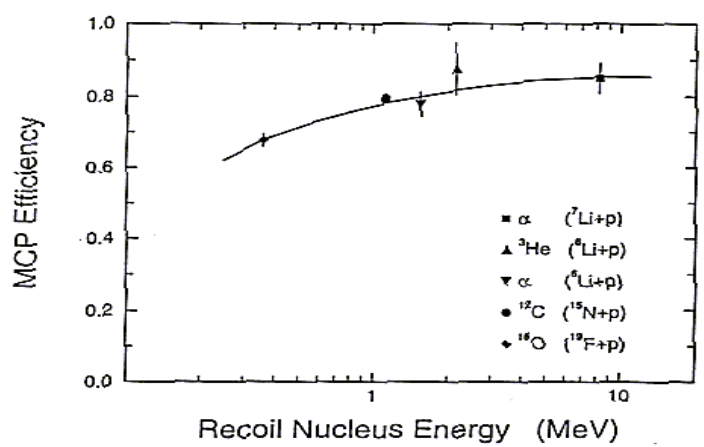


p → LiF



MOSHER, ILIADIS et al., SUBMITTED

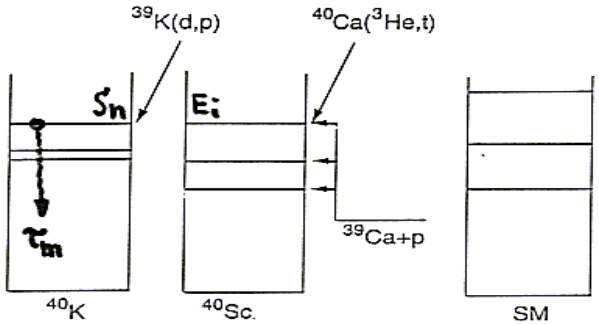
MICROCHANNEL PLATE EFFICIENCIES

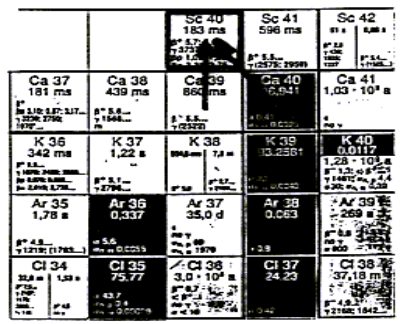


$$\eta_{MCP} = \frac{I_{TDC}}{I_{SSB}}$$

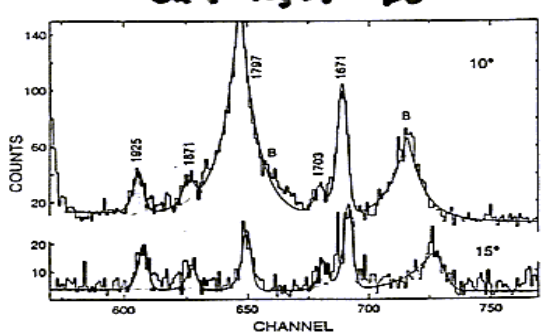
NUCLEAR STRUCTURE STUDIES: $^{39}Ca(p,\gamma)^{40}Sc$

$$N_A\langle\sigma v\rangle \sim \sum_i \omega\gamma_i \, e^{-E_i/kT} \quad \text{WITH} \quad \omega\gamma \sim \frac{\Gamma_p \Gamma_\gamma}{\Gamma}$$





$^{40}Ca(^3He,t)^{40}Sc$



$$E_R = E_x - Q_{p\gamma}$$

0.5 MeV

HANSPER et al., PRC 61, 023301 (2000)

$^{39}K(d,p)^{40}K$

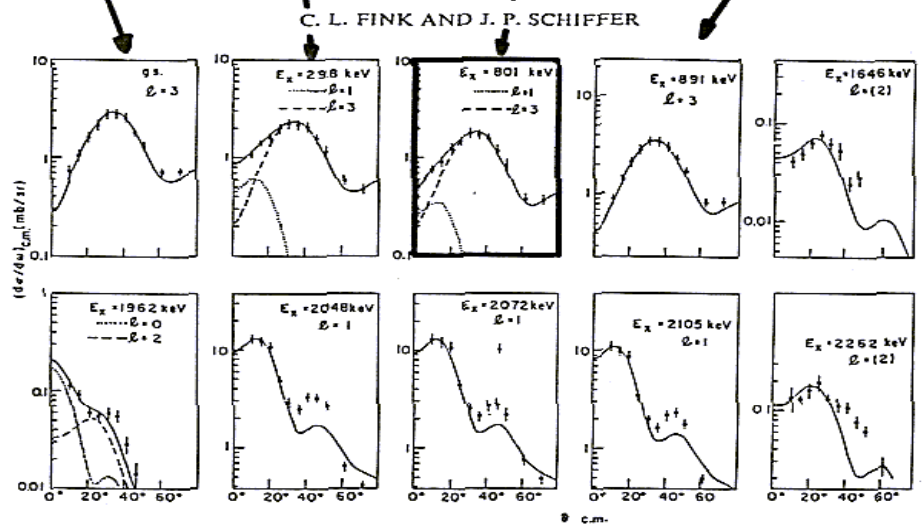
C^2S

0.90 4_1^-

0.013, 0.90 3_1^-

0.014, 0.92 2_1^-

0.81 5_1^-

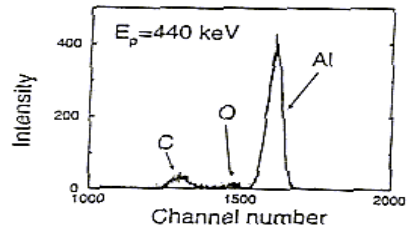


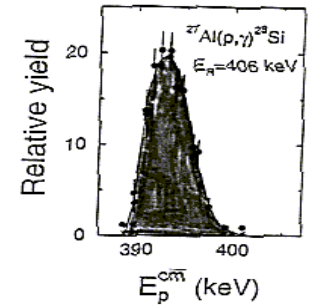
CONCLUSIONS

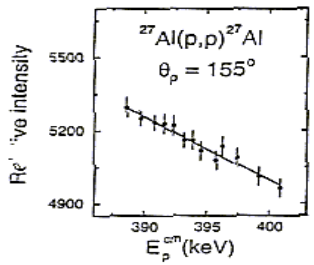
NEED MUCH MORE EXPERIMENTAL AND THEORETICAL WORK IN ORDER TO UNDERSTAND NOVA NUCLEOSYNTHESIS

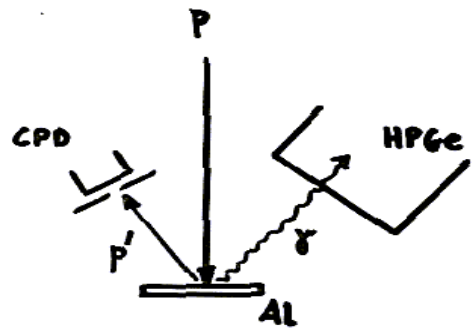
ABSOLUTE RESONANCE STRENGTHS

POWELL, ILIADIS et al., NPA 644, 263 (1998)









$$\omega\gamma \sim \frac{1}{B_\gamma}\frac{\Omega_{CPD}}{\varepsilon_\gamma}\int \frac{N_\gamma(E)}{N_{p'}(E)}\,\sigma_{RUTH}(E)\,dE$$

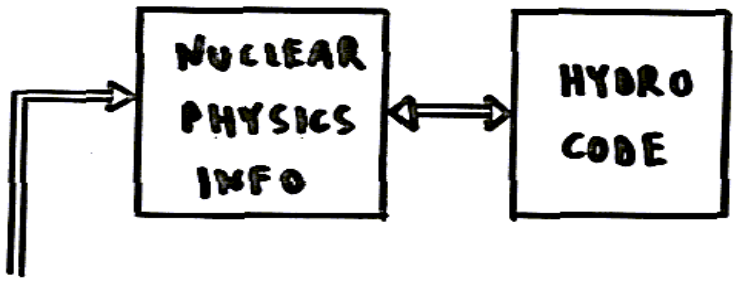
$= 8.63\cdot 10^{-3}$ eV (±6%) PRESENT

[$1.0\cdot 10^{-2}$ eV (±20%) PREVIOUS]

PROBLEMS

- ONeMg WHITE DWARF MASS ?
- MASSES OF ACCRETED/EJECTED MATTER ?
- MIXING OF MATTER ?
- NUCLEAR PHYSICS INFORMATION

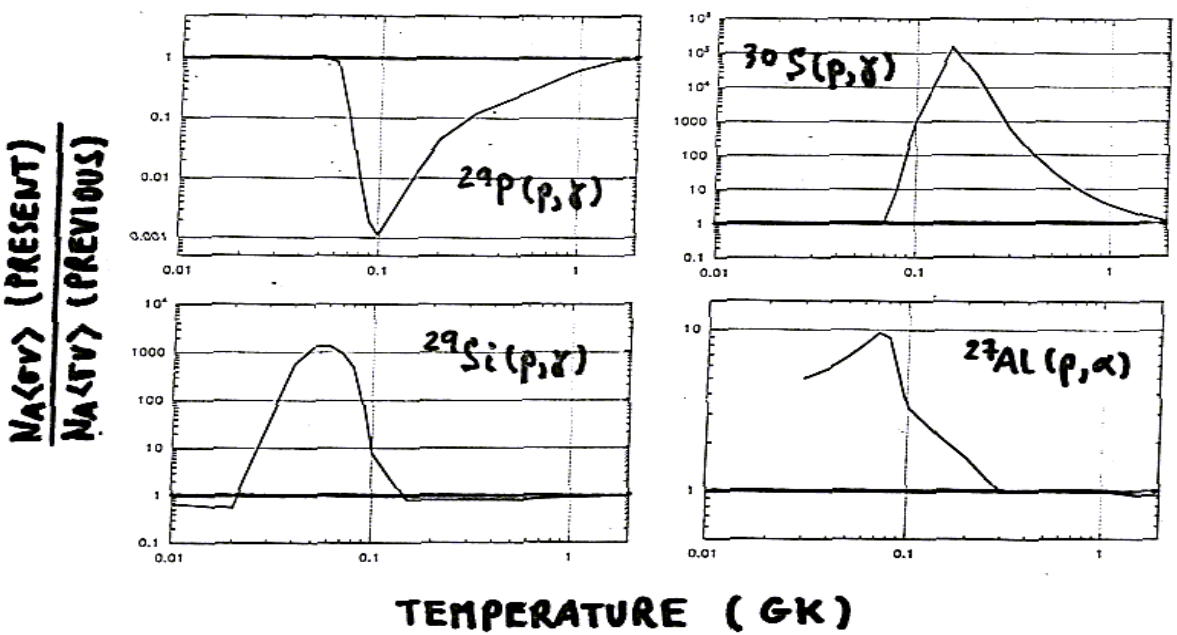
NUCLEAR PHYSICS CRUCIAL IN ORDER TO UNDERSTAND NATURE OF STARS !



- MASSES
- β-DECAYS
- REACTION RATES (p,γ) (p,α)

FEATURES

- REACTION RATE ERRORS
- RESONANCE STRENGTH STANDARDS
- TRANSFER REACTION STUDIES

RESULTS

COMPARISON OF REACTION RATES FROM PRESENT AND PREVIOUS WORK