The Project in a Nutshell

NUclear CLustering Effects in Astrophysical Reactions

NUCLEAR

European Research Council
Established by the European Commission

UK Research and Innovation

Nucleosynthesis in First Stars and Other Puzzles

Long-Standing Questions in Nuclear Astrophysics

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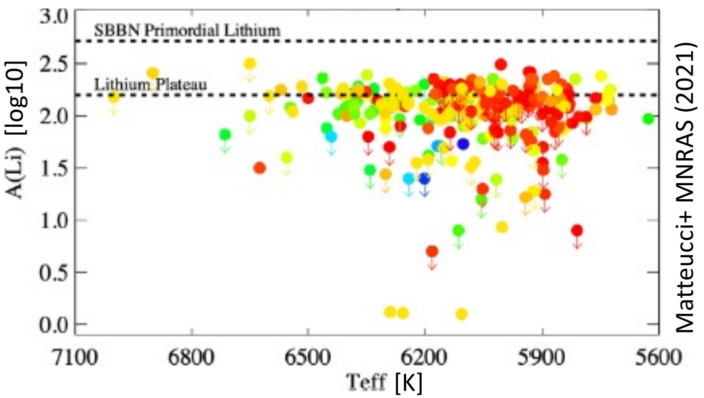
Q1. Cosmological Lithium Problem



factor of 3 discrepancy between observed and predicted Li abundance

↓

Standard Model of Particle Physics + Cosmology

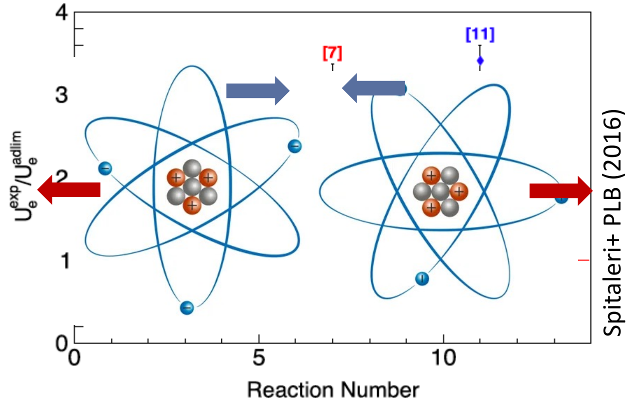
Q2. Nucleosynthesis in First Stars

made of pristine H and He
very massive → need CNO nuclei

↓

Chemical Evolution of Early Universe + Astronomical Observations (JWST)

Q3. Electron Screening Puzzle



discrepancy between experiment and theory remains unexplained

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Reactions in Plasmas
Fusion-driven Energy Generation

Long-Standing Questions in Nuclear Astrophysics

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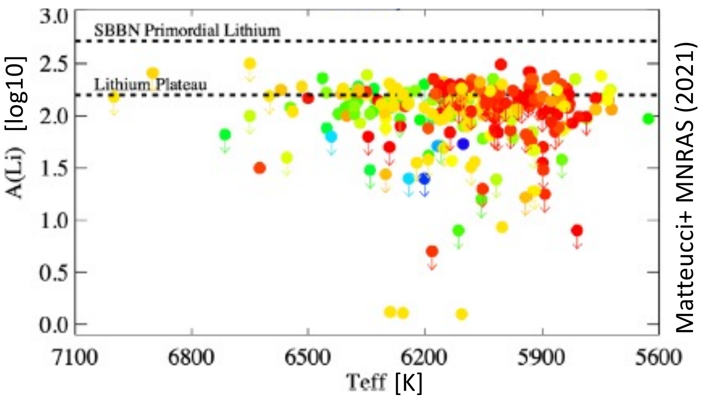

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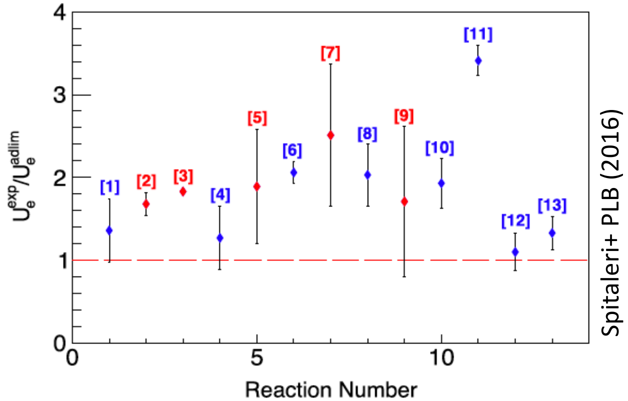


discrepancy between experiment and theory remains unexplained

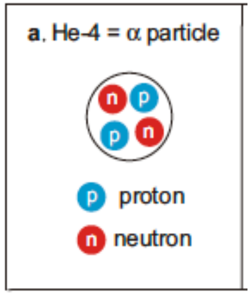
key idea:

Nuclear Clustering

⬇

key to unlock all three puzzles

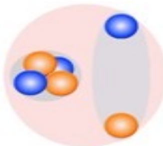
Nuclear Clustering



very stable configurations

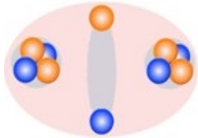
→ building blocks for other nuclei

^{6}Li



α ⊕ d

^{10}B



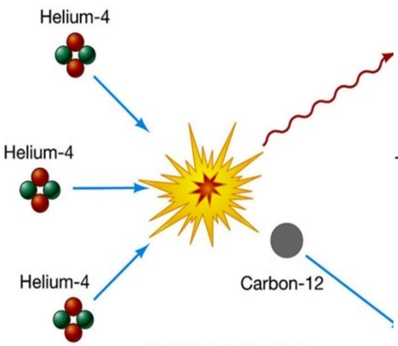
α ⊕ d ⊕ α

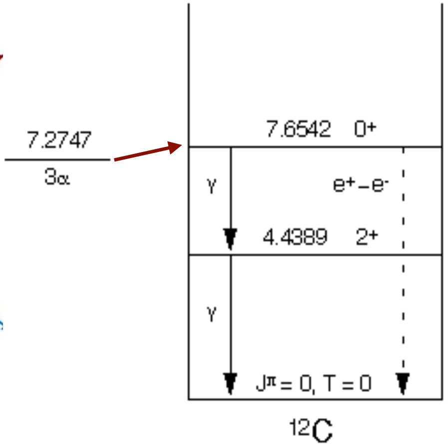
nuclear clustering may greatly

enhance fusion probabilities

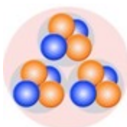
at low (i.e. astrophysical) energies

triple alpha process



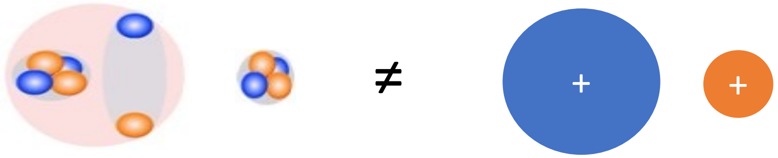


Hoyle state



~10^{7} times faster

electron screening puzzle



lower Coulomb barrier → enhanced fusion

Idea and Current Status

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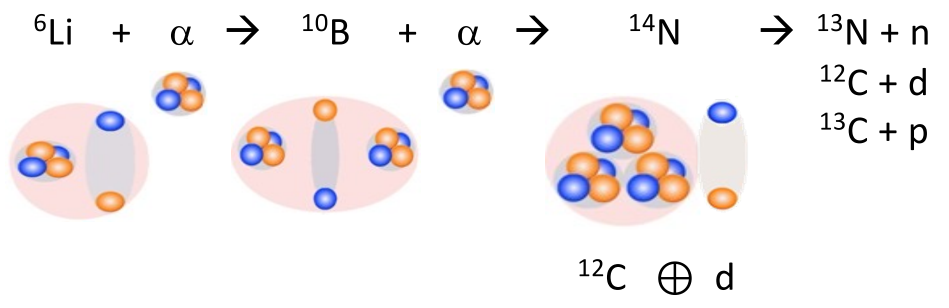
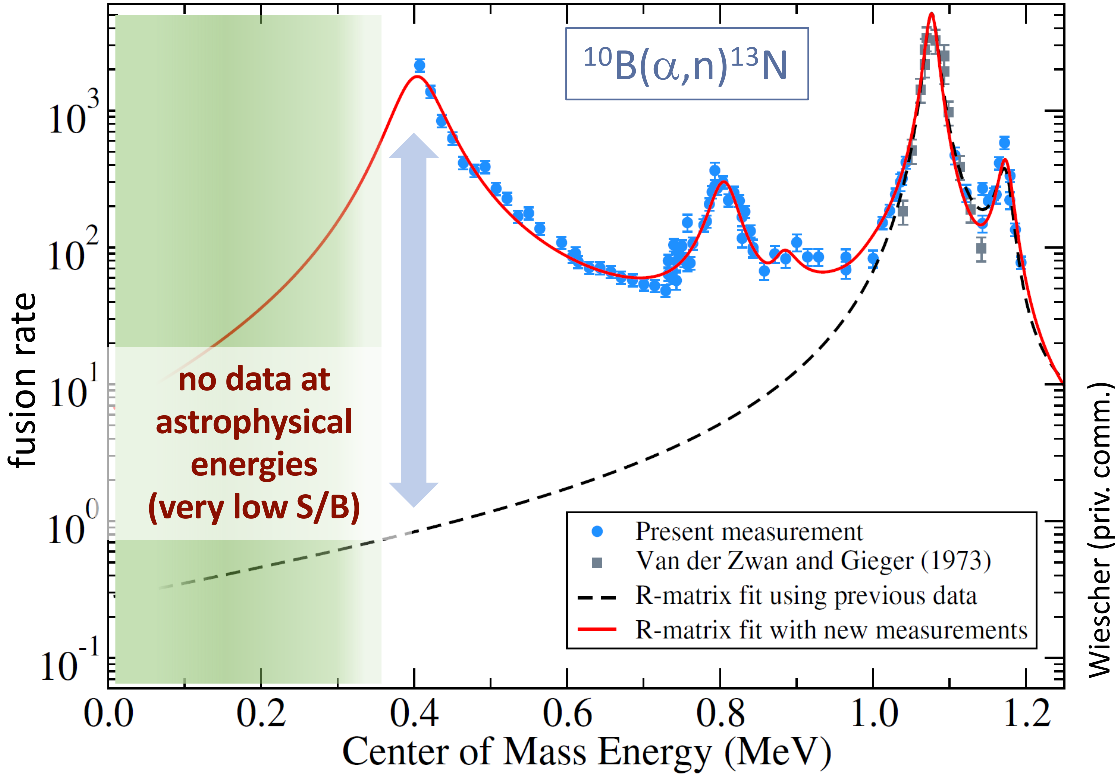
α-induced reactions on Li and B proposed to produce CNO and destroy Li if enhanced by clustering



hypothesis untested both experimentally and theoretically until recently

tantalizing new evidence of cluster structures enhancing fusion rates in α-induced reactions on Li and B



Work Programme and Outcomes

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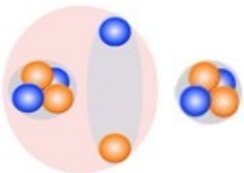
Theoretical Programme

WP2a: PDRA2

G Hupin



- cluster structures at low energies
- impact on astrophysical reactions & electron screening

RJ deBoer

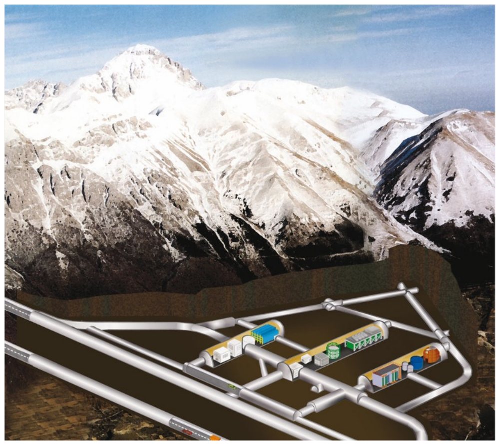
WP2b: **PI**, PDRA2

- improved R-matrix capabilities
- robust reaction rates

Experimental Programme

WP1: **PI**, PDRA1, PhD1,PhD2

Laboratory for Underground Nuclear Astrophysics

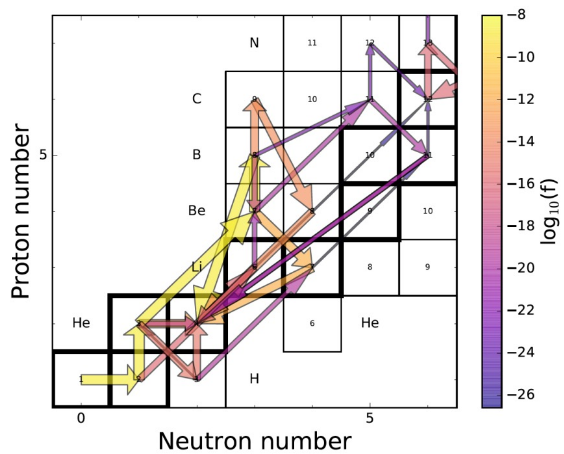


- α+Li and α+B reactions (Q1-Q3)
- ultra-low background @LUNA
- lowest-energy data (world best)

Computational Programme

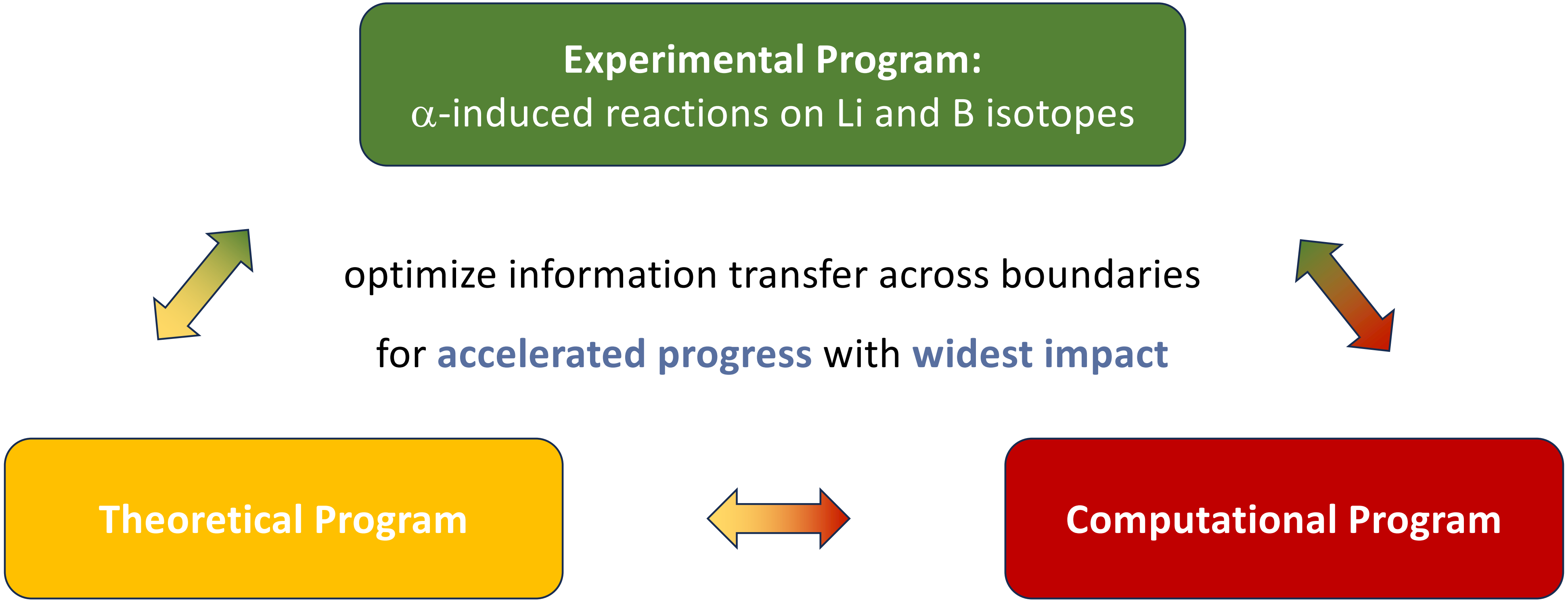
WP3: **PI**, PDRA3

M Pignatari



- stellar models for first stars (MESA)
- nucleosynthesis networks (NuGRID)
- impact on Q1 and Q2

Strategic Approach: Synergic Exploitation of Critical Expertise



Timeline

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		NUCLEAR: NUclear CLustering Effects in Astrophysical Reactions									
		PI: Marialuisa Aliotta									
Task	Assigned to	**Year 1**		**Year 2**		**Year 3**		**Year 4**		**Year 5**	
WP1: Experimental program		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
T1a	PhD1, PDRA1, PI				M1a						
T1b	PhD2, PDRA1, PI							M1b			
WP2: Theoretical program											
T2a.1	PDRA2, GH				M2a.1						
T2a.2	PDRA2, GH					M2a.2					
T2b.1	PDRA2, JdB										
T2b.2	PDRA2, JdB									M2b	
T2b.3	PDRA2, JdB, PI										M2b
WP3: Computational program											
T3.1	PDRA1, PDRA3, PI					M3.1					
T3.2	PDRA3, MP							M3.2			
T3.3	PDRA3, MP										M3.3
Direction and Oversight											
	PI										

Milestones

M1a: low-energy cross sections data for 10B+a reactions
M1b: low-energy cross sections data for 6,7Li+a radiative captures
M2a.1: theoretical evaluation of reaction cross sections with N isotopes as compound nuclei
M2a.2: complete theoretical evaluation of radiative capture cross sections
M2b: evaluation of uncertainty in R-matrix fits and extrapolation with inclusion of improved potential models and electron screening
M3.1: initial stellar reaction rates evaluations from available and new experimental data (from WP1) as they become available
M3.2: nucleosynthesis calculations in first-generation stars (zero metallicity) with input from from T3.1
M3.3: complete nucleosynthesis simulations for largest progenitor stellar masses

Grant Start Date: 1 December 2024

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erc nuclear

nuclear clustering effects in astrophysical reactions

Home News Project People Outputs Collaborations Contact

https://www.erc-nuclear.uk

Meet the Team

Michael Wiescher
(Deus ex Machina)

Marialuisa Aliotta
PRINCIPAL INVESTIGATOR

Guillaume Hupin
TEAM MEMBER

Richard James deBoer
TEAM MEMBER

Marco Pignatari
TEAM MEMBER

Other Team Members

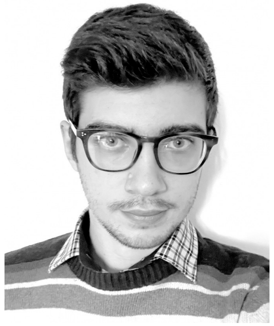
PhD Students

Jamie Jones, PhD
(September 2024)

Rhys Bonnell, PhD
(December 2024)

Lavinia Dalla Vedova
(from September 2025)

Post-Docs



Alessandro Compagnucci
(February 2025)

Kevin Becker
(from July 2025)

LUNA collaborators
Zoltan Elekes
Piero Corvisiero
Jakub Skowronski
Axel Boeltzig
Gianluca Imbriani
Tom Davinson
Ragan Sidhu
Carlo Bruno
Lucia Barbieri
Duncan Robb
Joao Cruz
Gyuri Gyürky
Sandra Zavatarelli, ...

Notre Dame team
Khachatur Manukyan
local students & PhD...

ERC-NUCLEAR Kick-off Event - 15 May 2025

09:30	09:45		**welcome and introductions**	Marialuisa (MLA)
09:45	10:00		ERC Overview	MLA
10:00	10:40		Scientific Goals	Michael + MLA
10:40	11:00		discussion	
11:00	11:30		coffee break	
			Experimental Programme	
11:30	12:00		10B(a,p) and 10B(a,d)	Jamie
12:00	12:30		10B(a,n)	Rhys
12:30	13:00		6,7Li(a,g)	Alessandro
13:00	14:00		Lunch & Photo	
			Computational Programme	
14:00	14:40		First Stars: Stellar Models and Nucleosynthesis	Marco
			Theoretical Programme	
14:50	15:30		Reactions with clusters	Guillaume
15:30	16:00		Coffee Break	
16:00	16:40		R-matrix developments	James
16:40	17:00		Closing Remarks and Next Steps	
19:30			Dinner at Nok's Kitchen by the Castle	