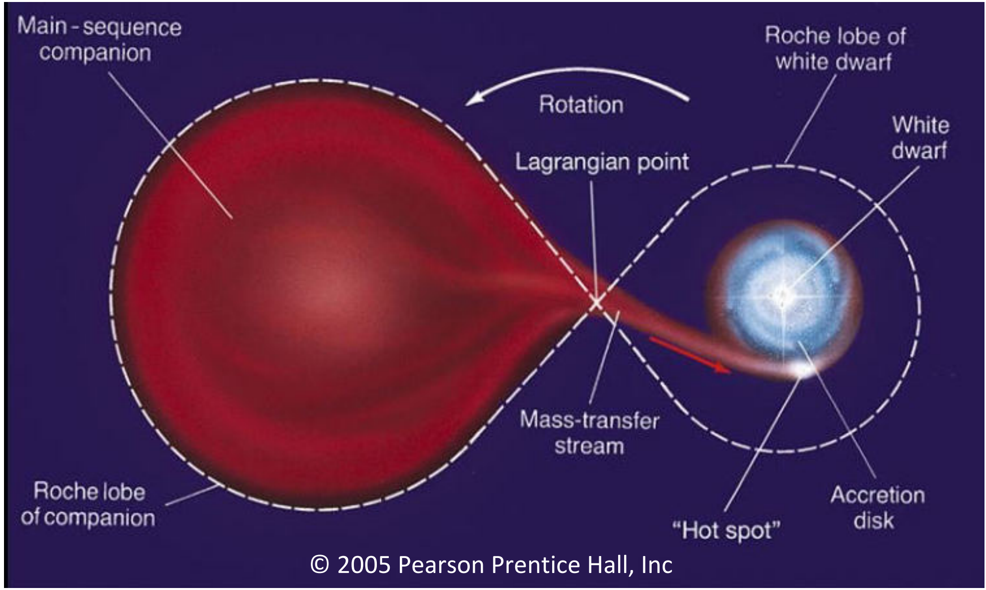
Exploring Calcium Discrepancies in Nova Models

Mallory Loria
University of Victoria/TRIUMF
03/08/24

Falk Herwig, Pavel Denissenkov, Chris Ruiz

CLASSICAL NOVAE ARE…

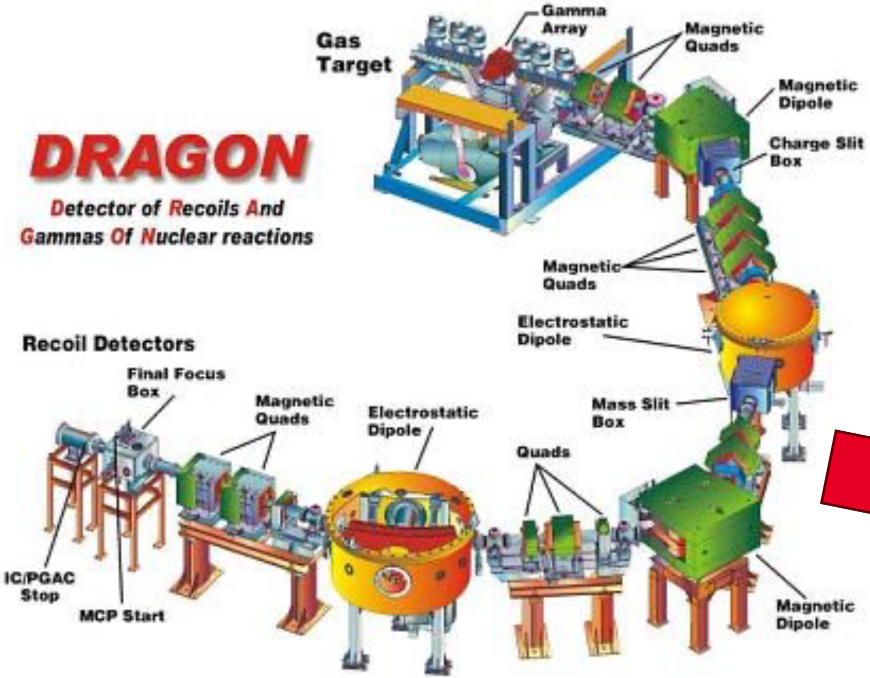


- Events where a white dwarf (WD) accretes material from a low-mass, main-sequence companion (Chomiuk+ 21)

- One of the most common types of explosions in our galaxy (20 – 70 per year)

- Important to study because they offer insights into explosive nucleosynthesis processes that we can then study in the laboratory (Lovely+ 21)

EXPERIMENTAL NUCLEAR PHYSICS FOR NOVAE



NOVA MODELS FOR HEAVY ELEMENT PRODUCTION

- Performed multi-zone post-processing nucleosynthesis simulations (NuGrid MPPNP) on five Modules for Experiments in Stellar Astrophysics (MESA) nova models
- Gathered abundances from nine observed novae that report Ca abundance

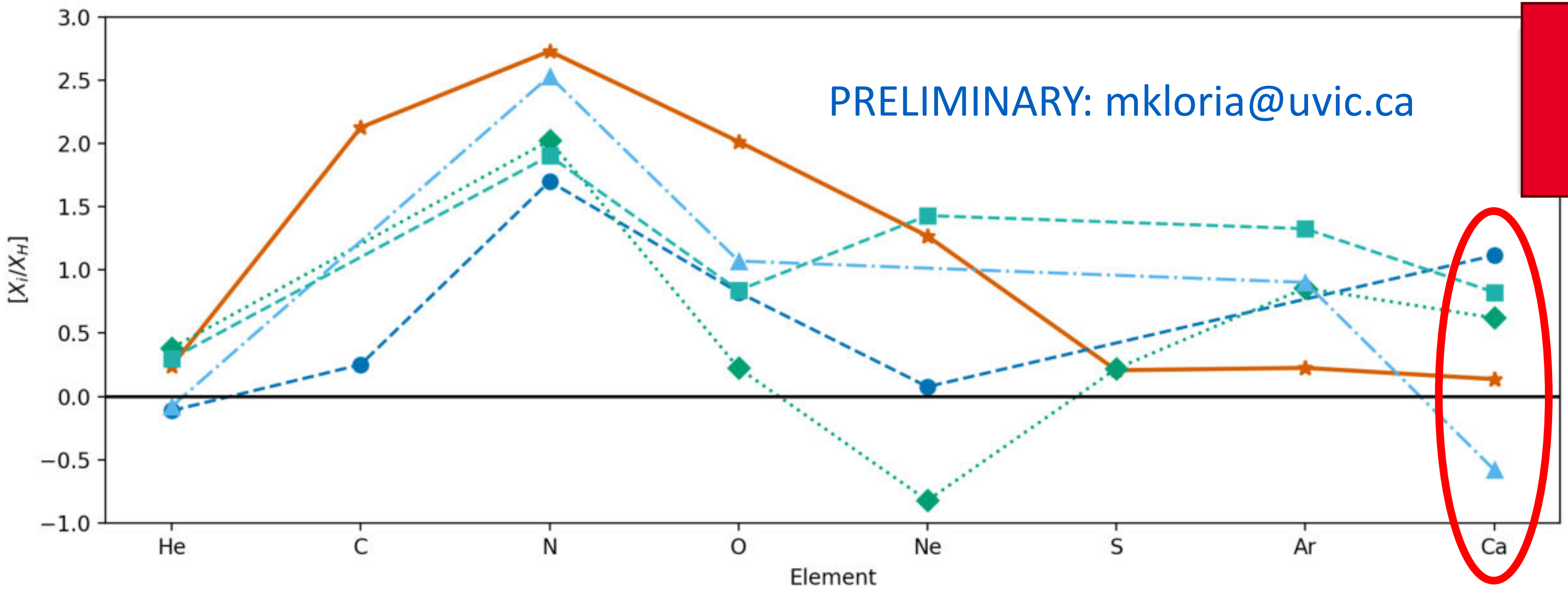
Contact mkloria@uvic.ca for model parameters

The hotter and more extreme the nova, the greater the production of heavy elements!

Table 1: MESA nova model parameters, similar to Denissenkov+ 14

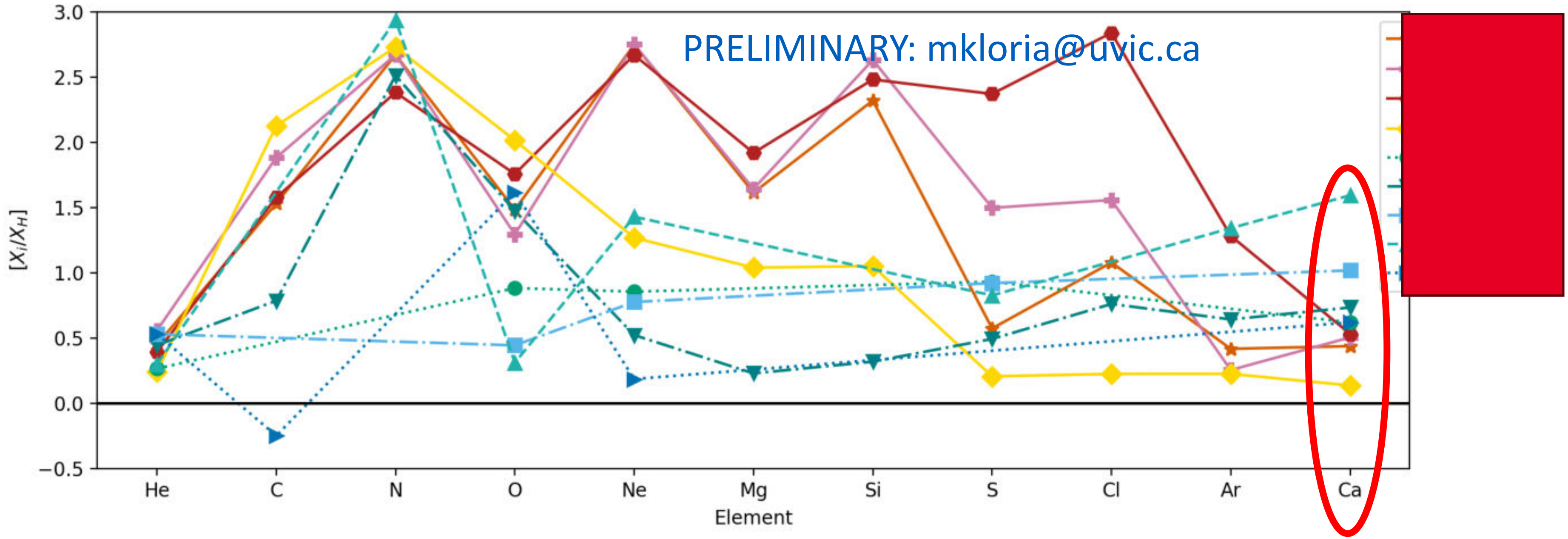
Ca OVERABUNDANCE IN CO NOVAE

$[X_i/X_H] = \log_{10}(X_i/X_H)_{nova} - \log_{10}(X_i/X_H)_{\odot}$



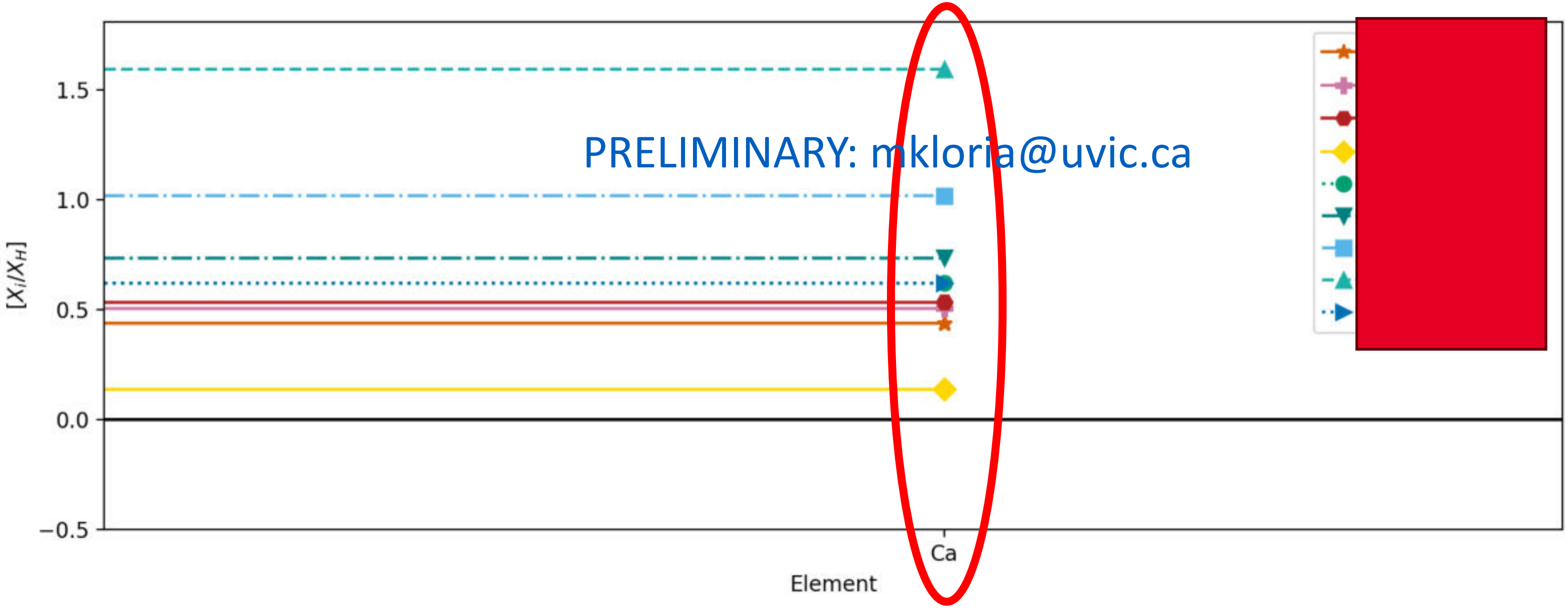
Ca OVERABUNDANCE IN CO & ONe NOVAE

$[X_i/X_H] = \log_{10}(X_i/X_H)_{nova} - \log_{10}(X_i/X_H)_{\odot}$



Ca OVERABUNDANCE IN CO & ONe NOVAE

$$[X_i/X_H] = \log_{10}(X_i/X_H)_{nova} - \log_{10}(X_i/X_H)_{\odot}$$

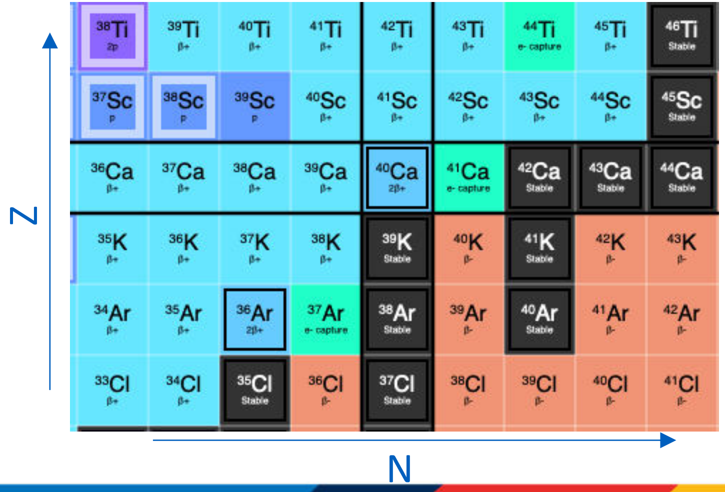


WHAT CAUSES THIS DISCREPANCY?

- Could it be the nuclear physics uncertainties in our models?
  - Certain reactions are not well studied thus the uncertainties in their rates are large

- Performed Monte Carlo (MC) simulations of single-zone post-processing (NuGrid PPN) nucleosynthesis that vary nuclear reaction rates by a factor of 10 up and down
  - (p, γ), (p, α), (α, γ), (α, p)
  - ^{33}Cl to ^{41}Cl and up to ^{38}Ti to ^{46}Ti

- Calculate Pearson correlation coefficients to get the important reactions for element production



IMPACT OF VARIED NUCLEAR REACTION RATES ON Ca PRODUCTION

- **$^{39}K(p, \gamma)^{40}Ca$** and **$^{38}K(p, \gamma)^{39}Ca$** identified as the most correlated to the production of Ca in *all* nova models

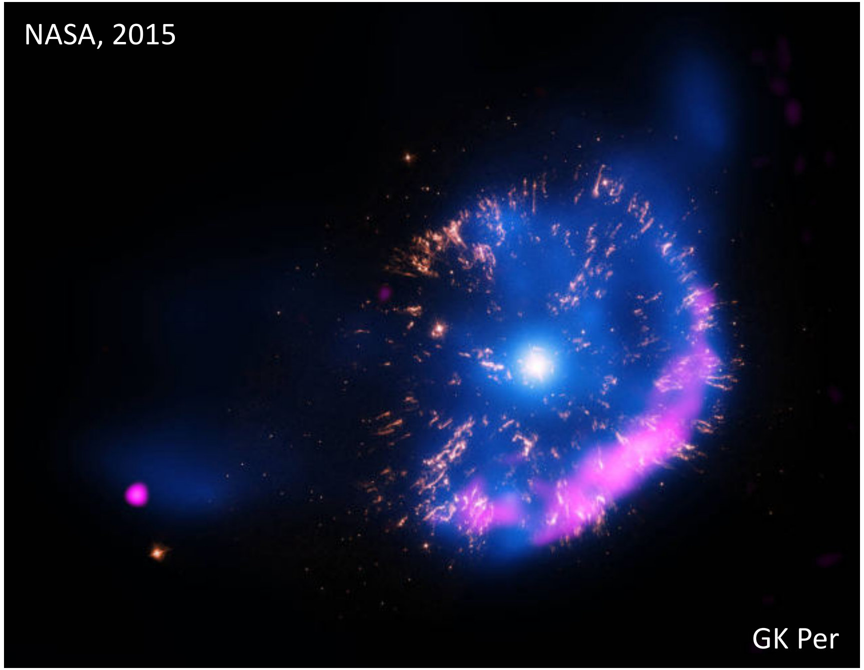
- $^{39}K(p, \gamma)^{40}Ca$ rate increased by a factor of 13 (Fox+ 24)

- Changed only reaction rate of $^{39}K(p, \gamma)^{40}Ca$ by a factor of 10 for our hottest nova model → minimal increase in Ca

NUCLEAR PHYSICS UNCERTAINTIES CANNOT ACCOUNT FOR THIS DISCREPANCY

WHAT ELSE COULD EXPLAIN Ca OVERABUNDANCE?

1. Dust fractionation (Schneider & Maiolino 23)
2. Evolved stellar companion (Godon & Sion 23)
3. Mixing and mass loss mechanisms are still poorly understood (Denissenkov+ 13)



SUMMARY

1) Ca is overabundant in observations of novae compared to our nova models

2) Nuclear physics uncertainties cannot explain these differences