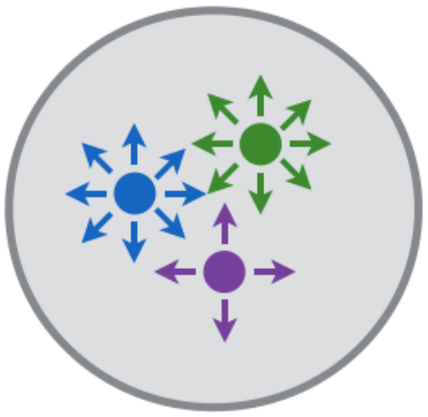
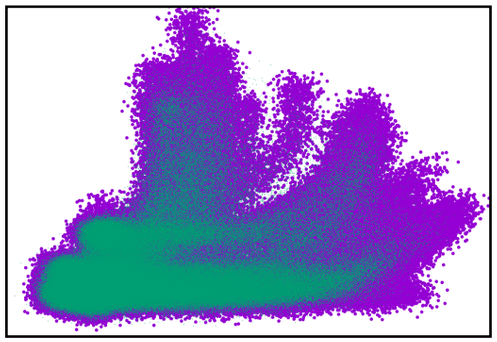
Multiplicity of the first stars from machine learning-based classification of stellar fossils





Tilman Hartwig

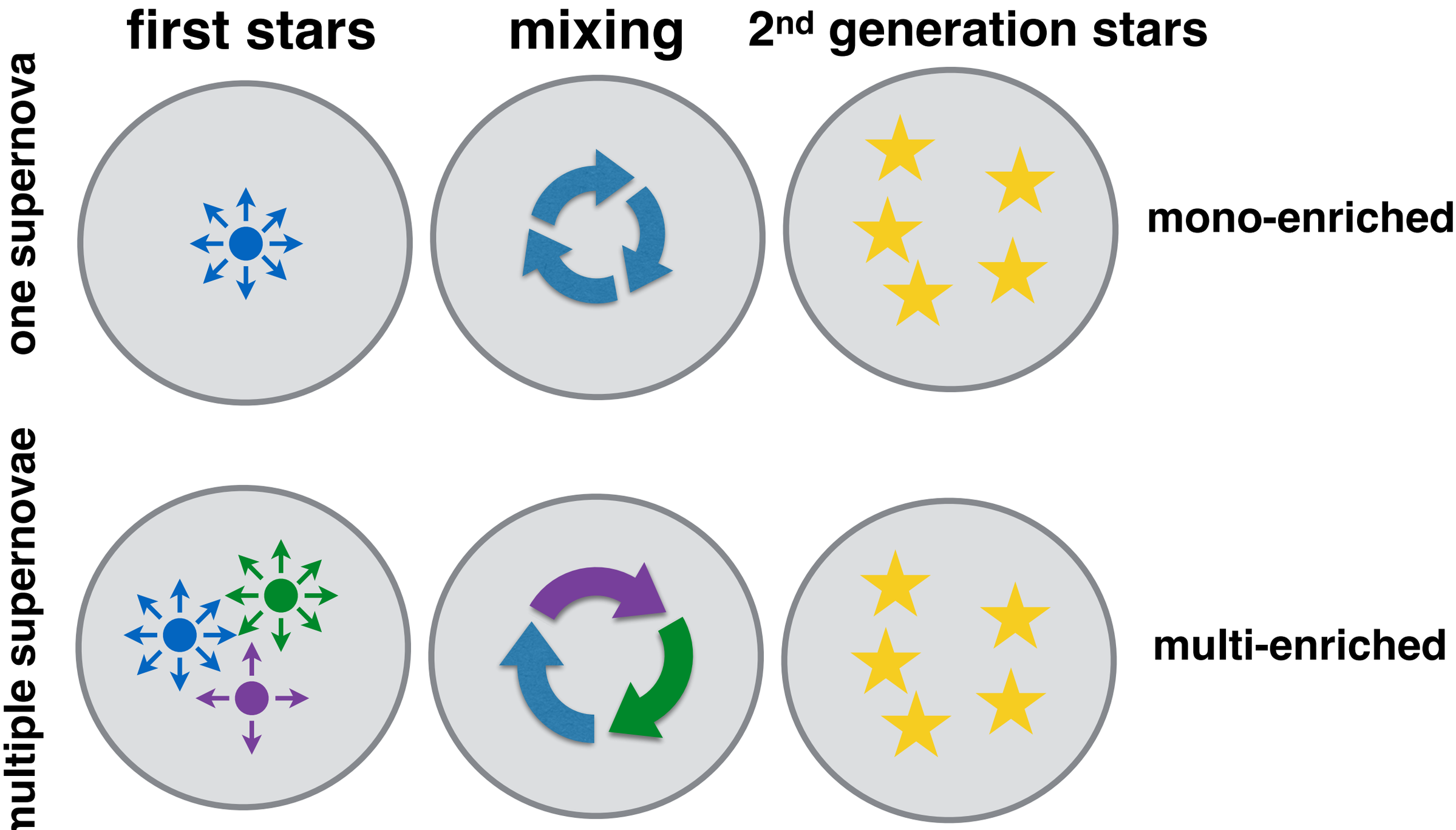
with Miho Ishigaki & Naoki Yoshida

Institute for Physics of Intelligence
知の物理学

THE UNIVERSITY OF TOKYO

Geneva, September 10th

Star formation after the first SNe



Star formation after the first SNe

Salvadori+19:

Metal-poor star BD+80 245

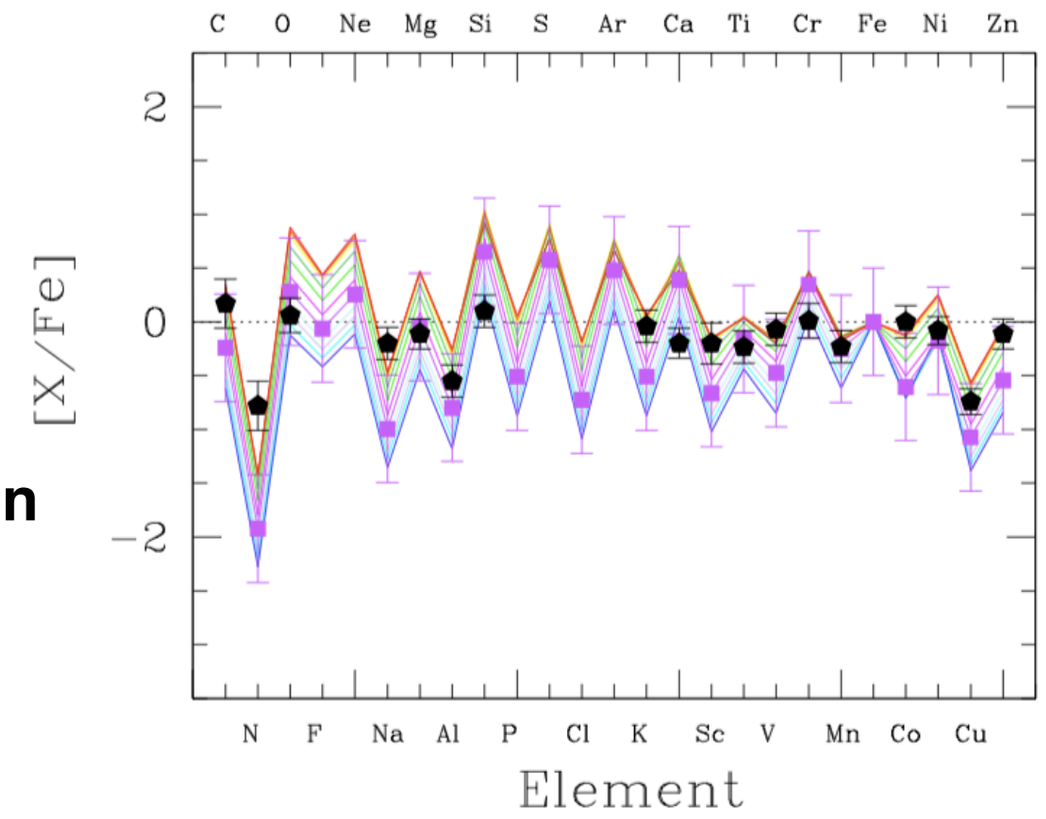
Abundance pattern best reproduced by

223M_{sun} Pair-Instability SN

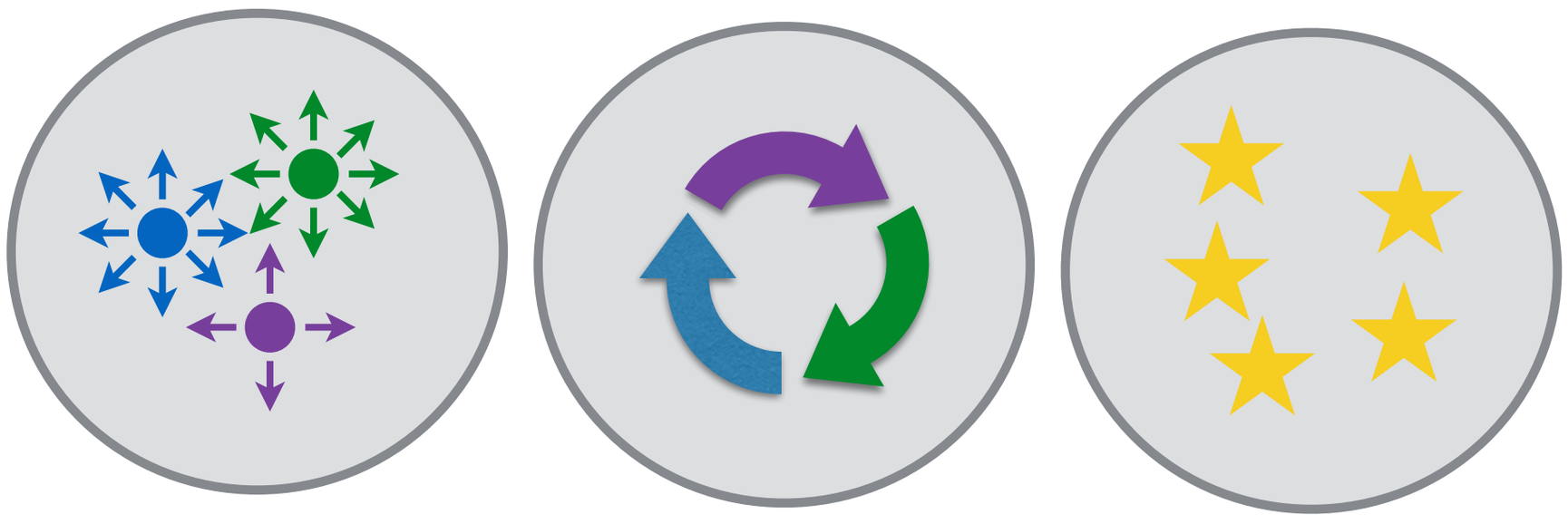
+

Metals from 30Myr old stellar population

"multi-enriched"



multiple supernovae



multi-enriched

Mock Observations from Theoretical Data

mono-enriched

$15M_{sun}$ Supernova:

Element	C	N	O	...	Fe			C/Fe
Mass	x	5	x	...	2			5

$20M_{sun}$ Supernova:

Element	C	N	O	...	Fe			C/Fe
Mass	6	4.5	x	...	3			2

multi-enriched

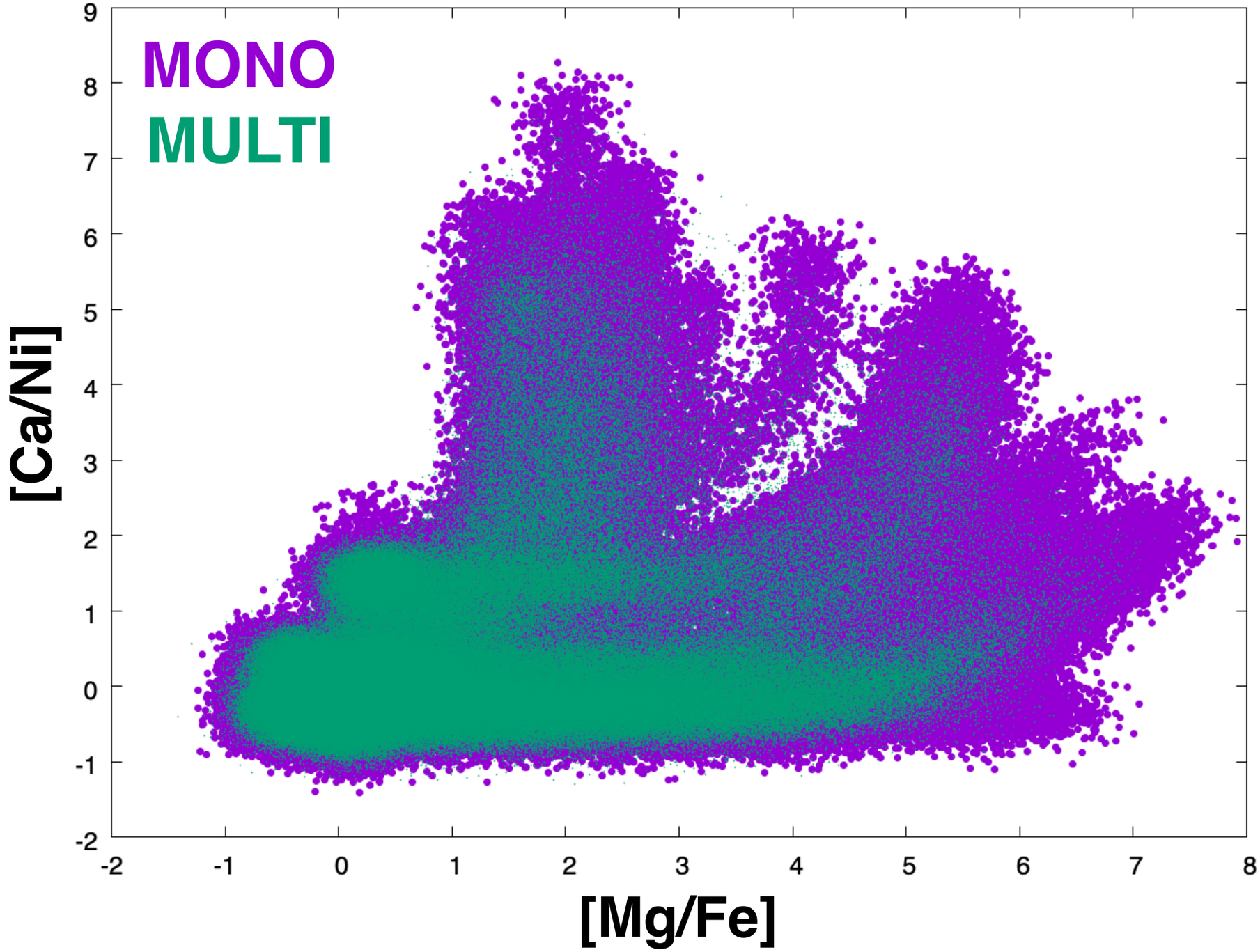
$15M_{sun}$ Supernova + $20M_{sun}$ Supernova

Element	C	N	O	...	Fe			C/Fe
Mass	16	x	x	...	5			3.2

data from Ishigaki+18

Data **Tilman Hartwig**

Classification in 2D



Data

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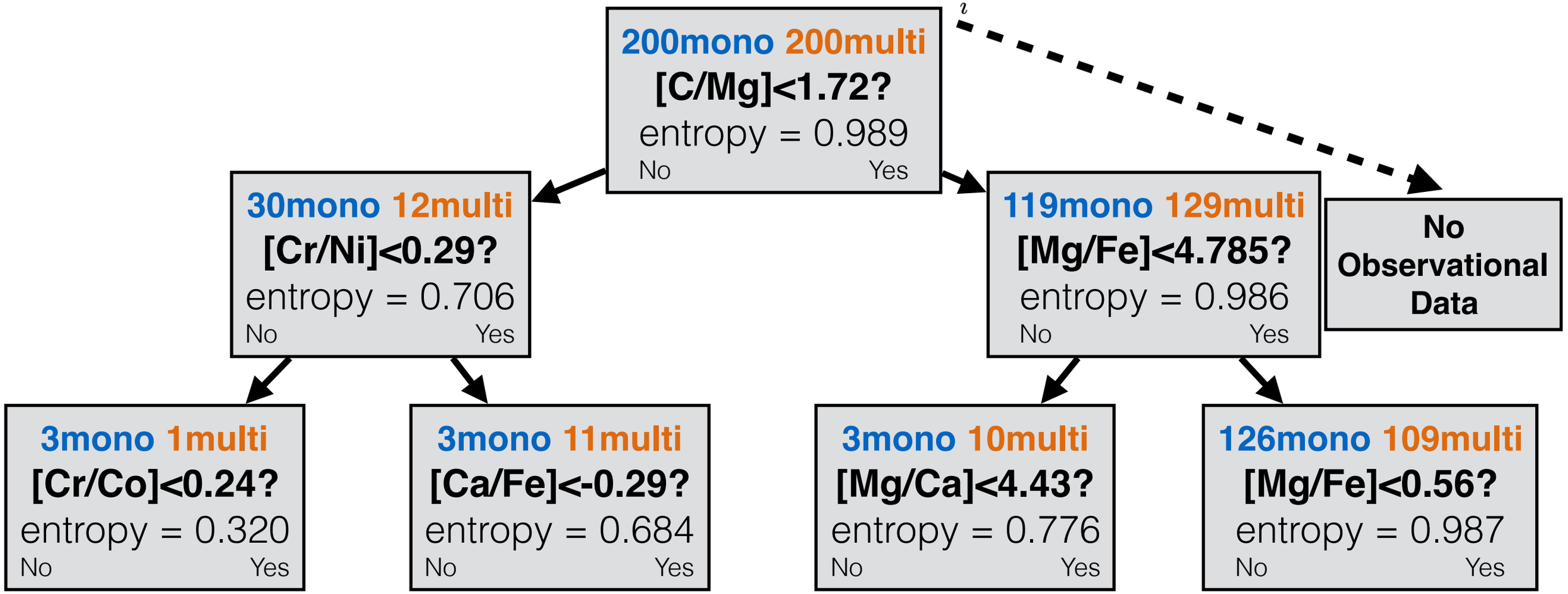
Machine-Learning Based Classification of EMP Stars

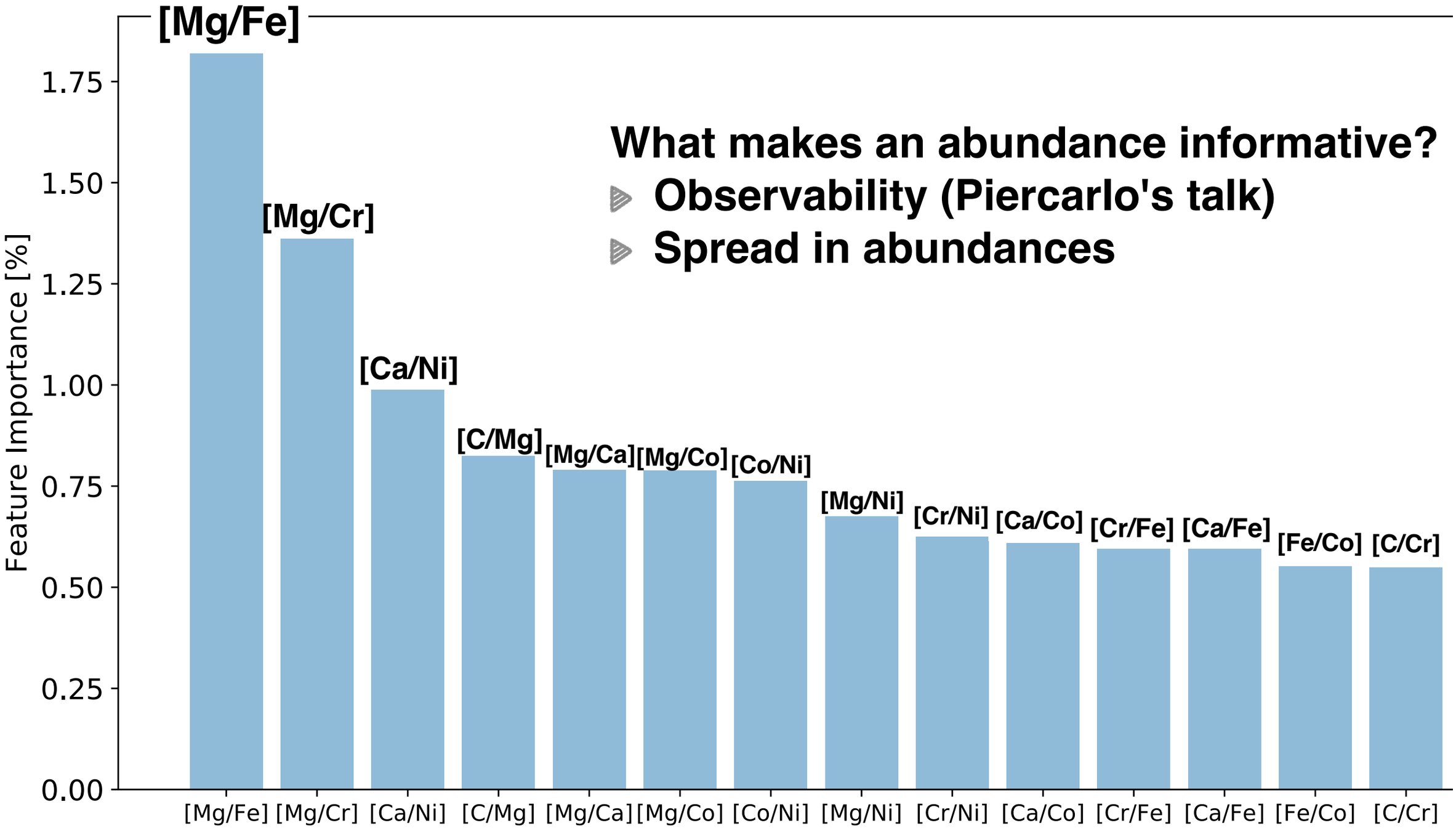
Train tree on mock data catalogues (mono/multi-enriched) by minimising information entropy $S = -\sum_i P_i \log P_i$



Decision Trees

Tilman Hartwig

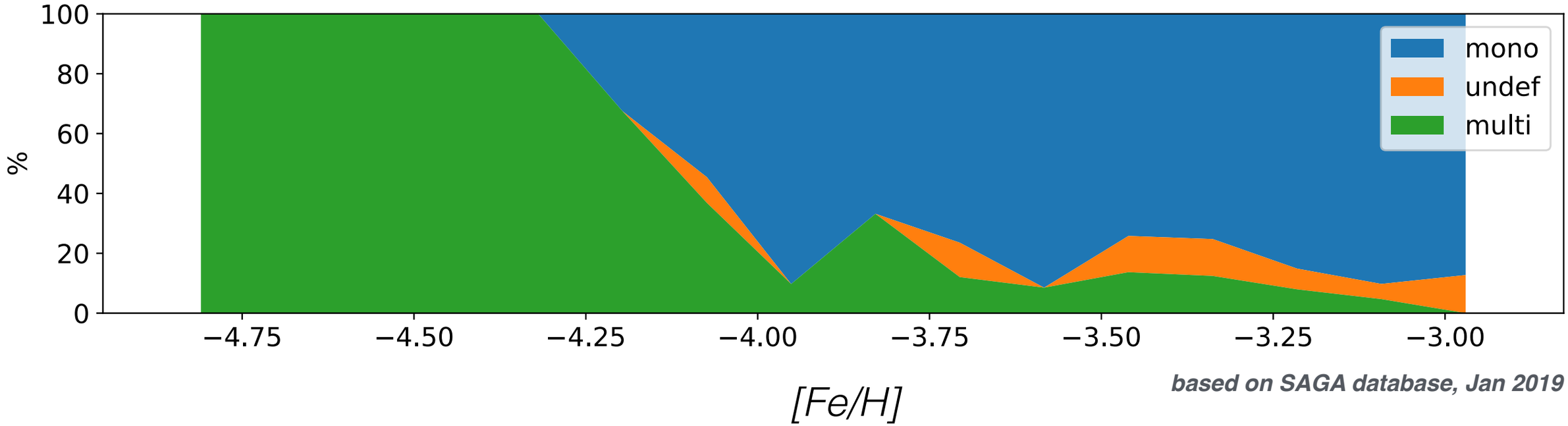
Feature Importance



What makes an abundance informative?

- **Observability (Piercarlo's talk)**
- **Spread in abundances**

Multiplicity of the First Stars

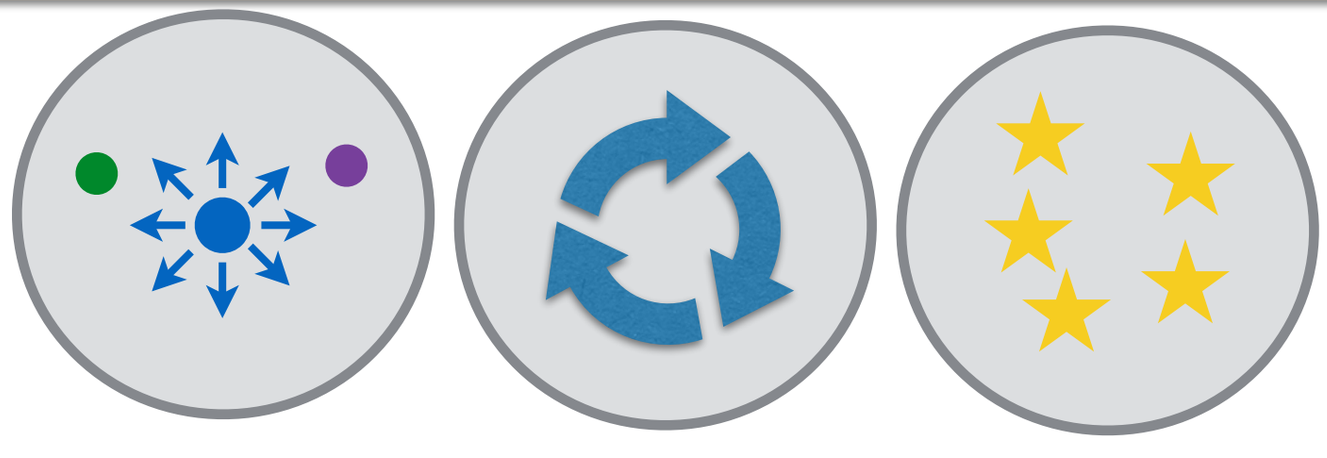


based on SAGA database, Jan 2019

- **80% mono**
- **10%multi**
- **Poisson Statistics:**
  p(1)=0.8, p(2)=0.1
- **0.3 SNe per halo**
- **~1.5 Pop III stars per minihalo**

Only 0.3 SNe per PopIII-forming minihalo?

1 SN



EMP stars:
Interpretation: 1 SN

many SNe

NO EMP stars:
Interpretation: No SN?

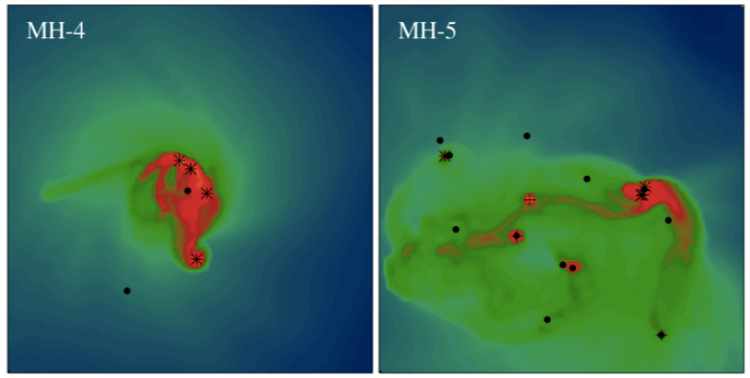
- We obtain Information about SN explosion energies instead of number of SNe? *(Chiaki+18)*

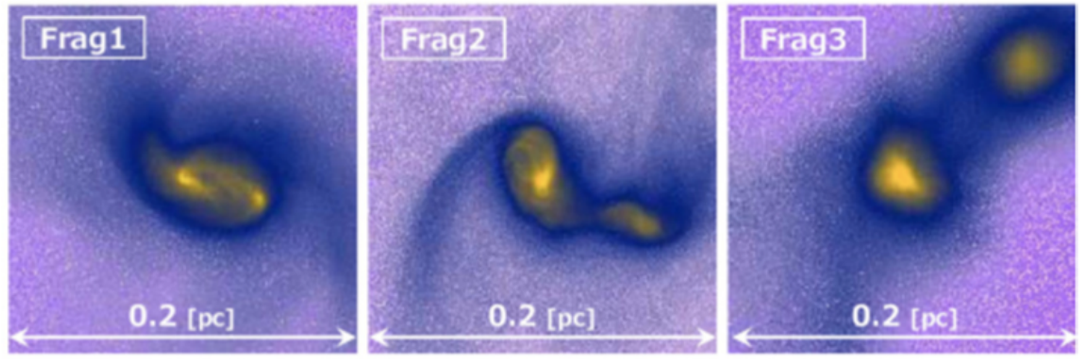
Discussion **Tilman Hartwig**

Multiplicity of the First Stars: Interpretation

- How efficient is **fragmentation** in metal-free gas (Wei Ting's talk, Susa+19)?

Greif+11





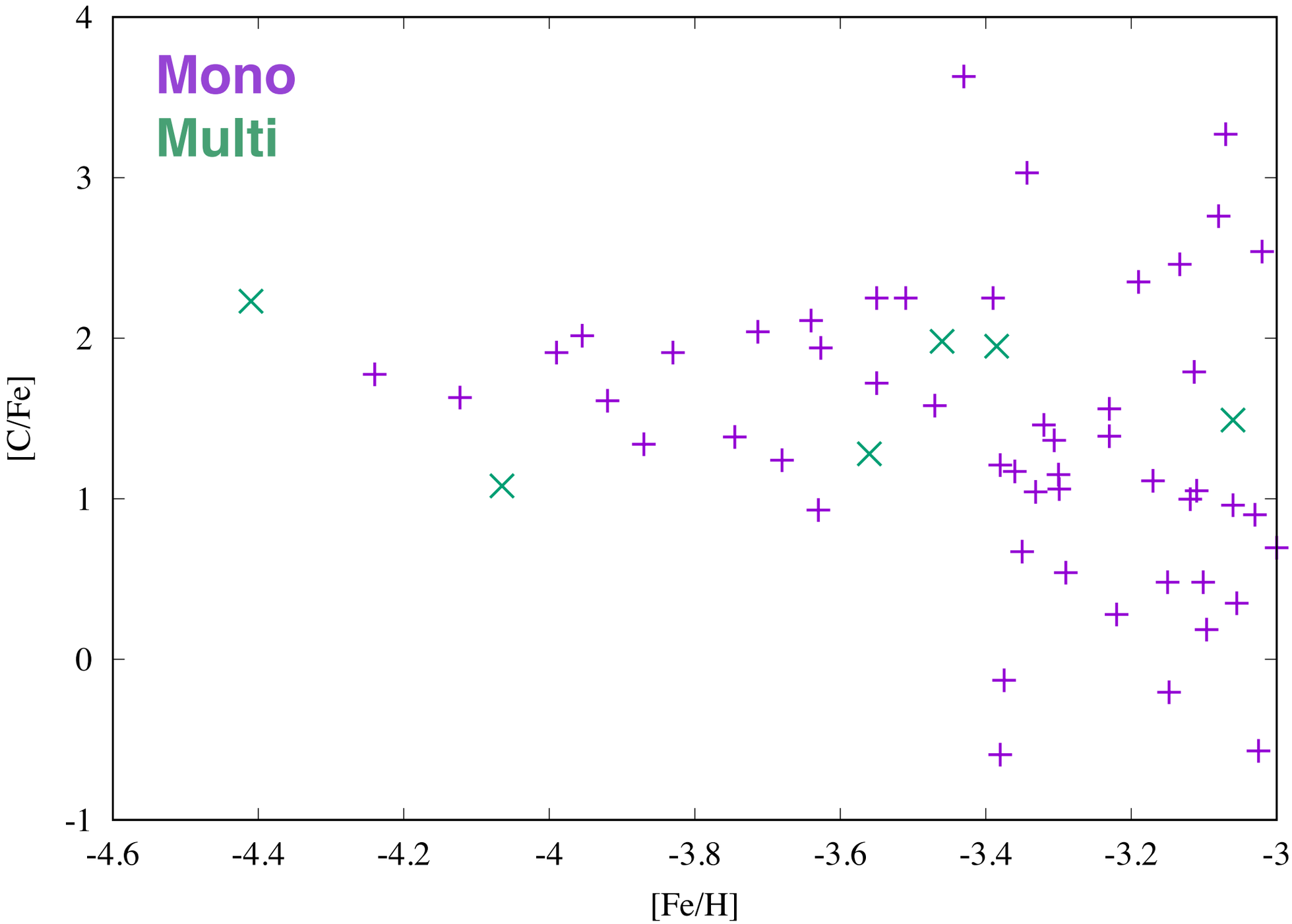
Hirano+14

- What is the **star formation efficiency** (stellar mass per halo mass) in the first galaxies? Contribution to Reionization (Anne's talk)?

- What is the **binarity** of PopIII stars?

Discussion **Tilman Hartwig**

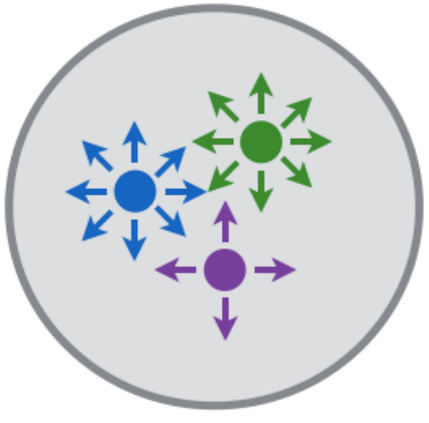
Peculiarity of CEMP stars?

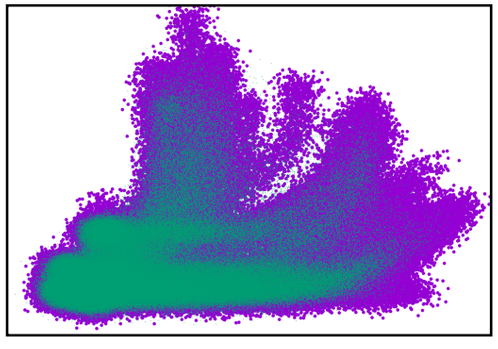


Discussion — **Tilman Hartwig**

Conclusion

- First observational confirmation of the **multiplicity of the first stars**: important to understand their contribution to, e.g., reionization, 21cm signal, formation of first supermassive black holes, binary black hole mergers,...
- **Feature importance** identifies most informative elements and therefore helps to **optimise upcoming surveys**.
- **Caveat**: we only trace PopIII stars that allow for subsequent EMP star formation. Making a virtue of necessity: this allows to constrain the **coupling efficiencies of PopIII SNe** to ISM.
- Code will be made **public**.





Discussion — Tilman Hartwig