

Abundances in Metal-Poor Stars and Implications for Early Nucleosynthesis

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U.S. DEPARTMENT OF
ENERGY

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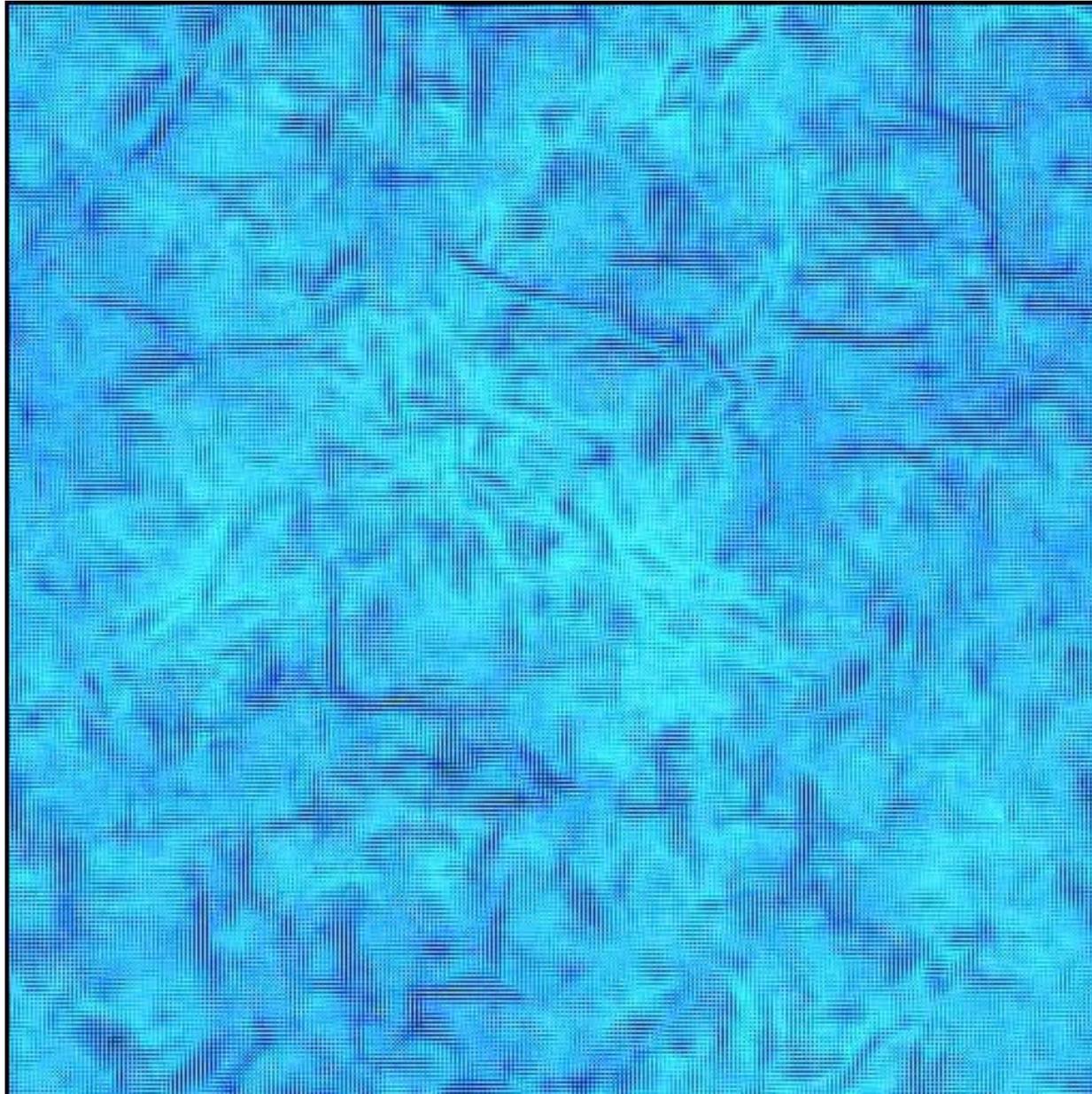


Network for Neutrinos,
Nuclear Astrophysics,
and Symmetries

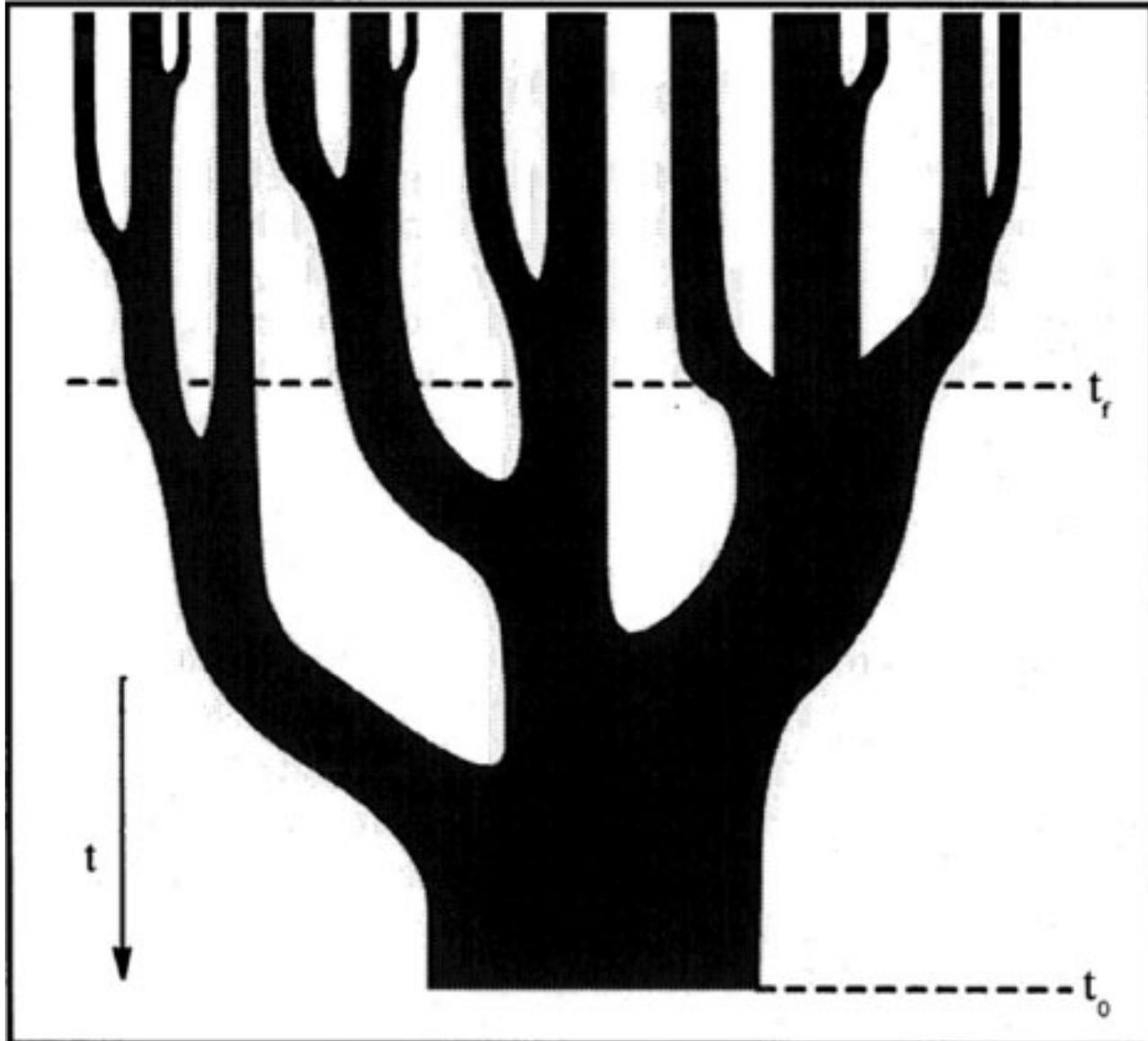
PHYSICS FRONTIER CENTER

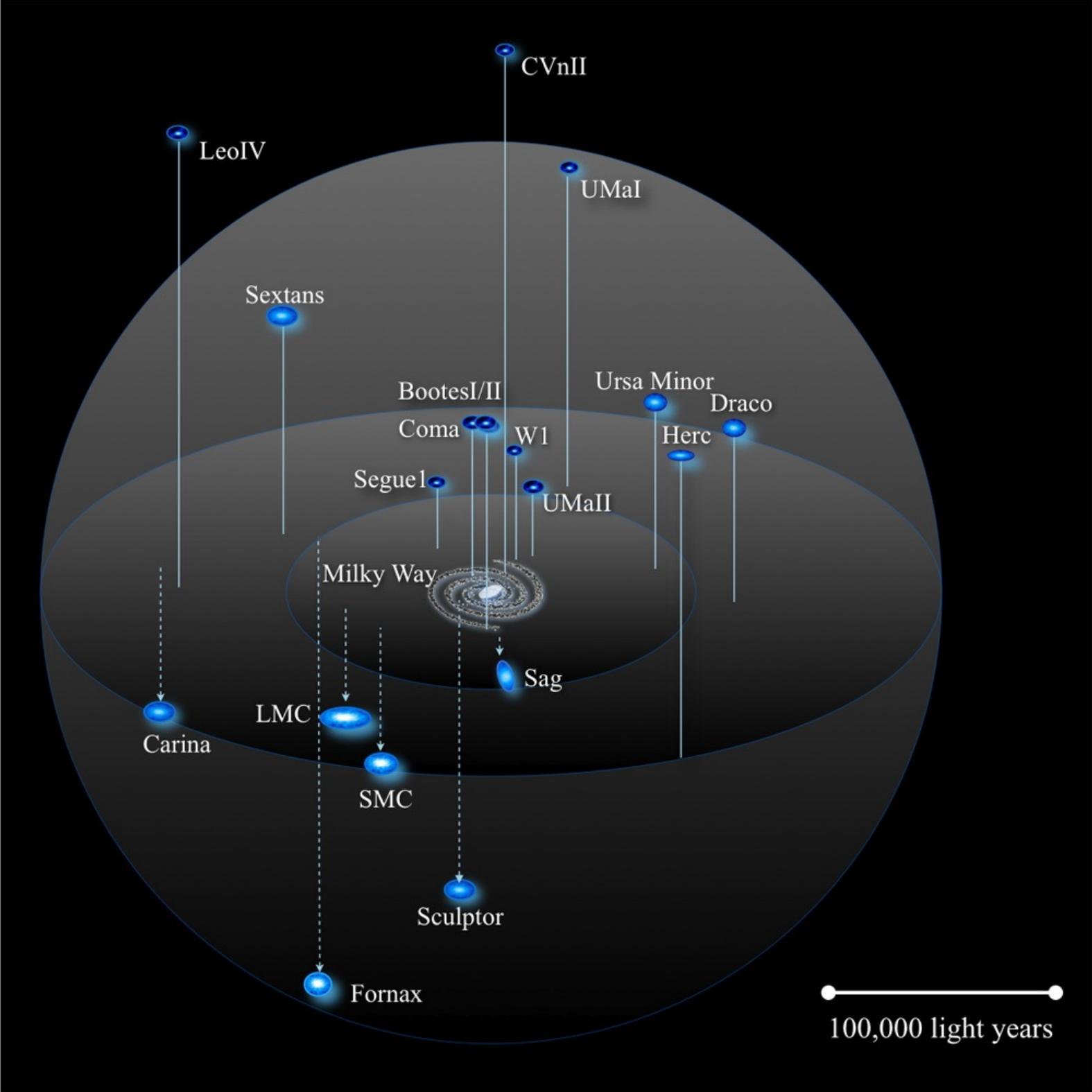


Hierarchical Structure Formation

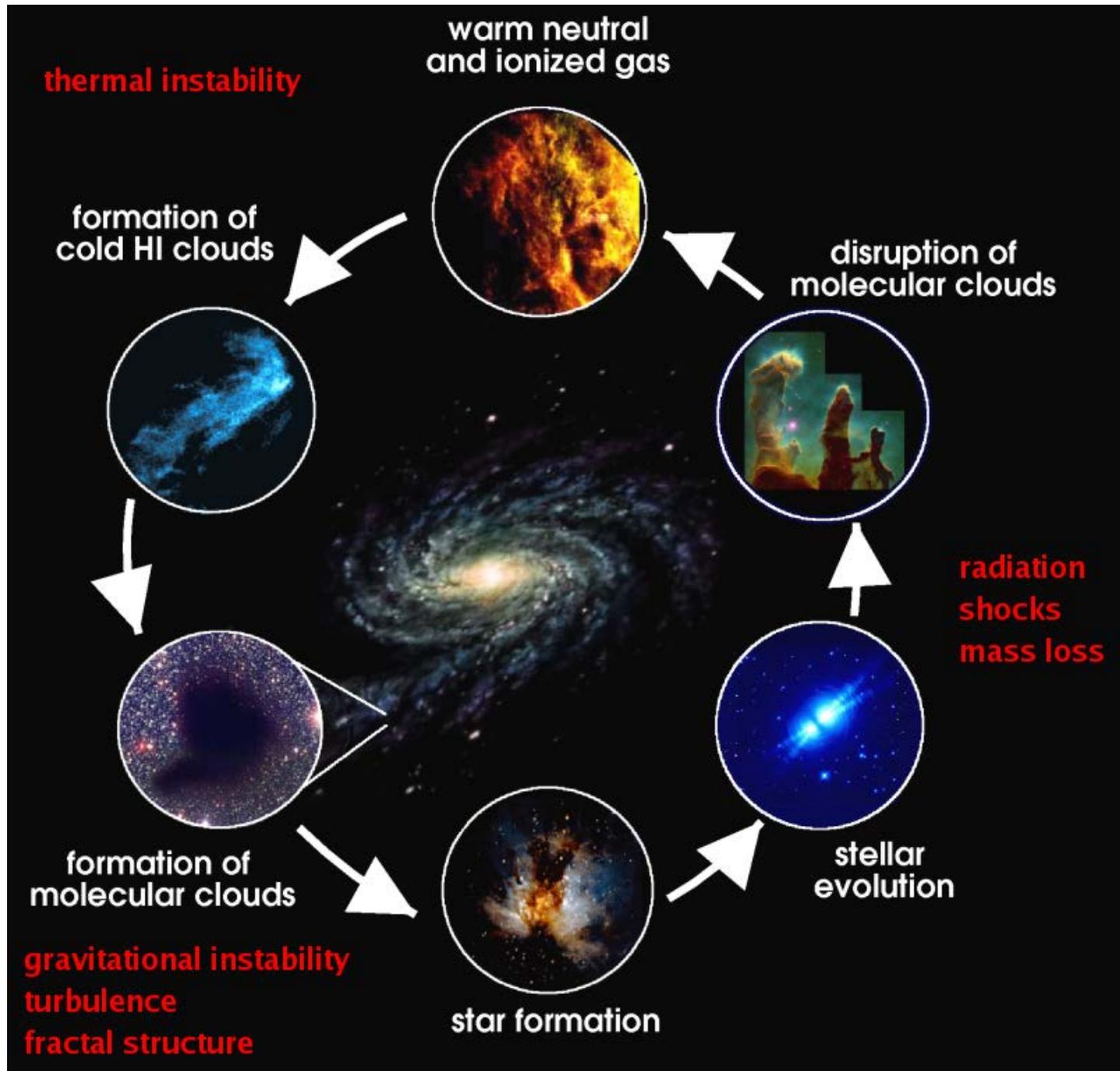


Merger Tree

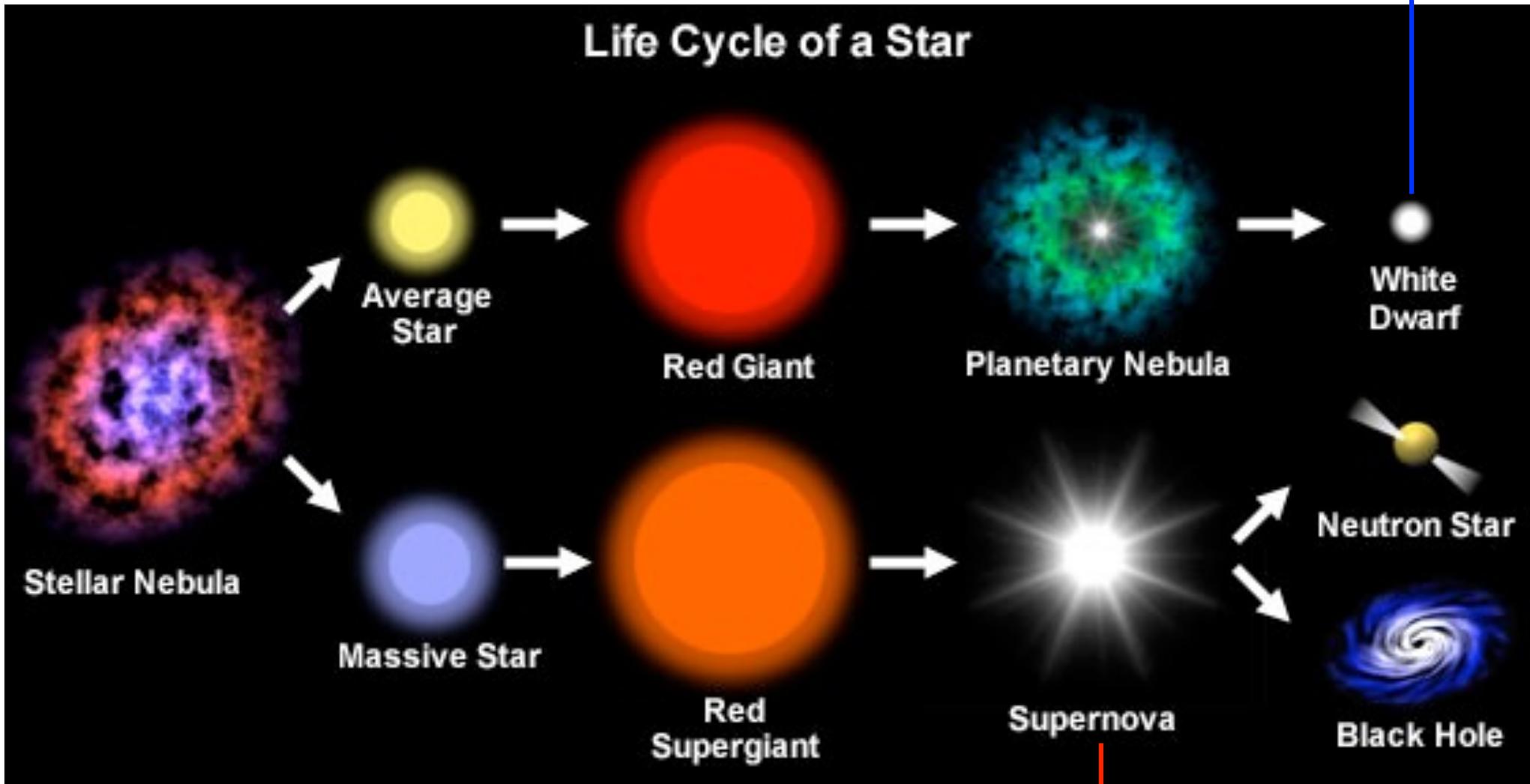




Life Cycle of Interstellar Medium

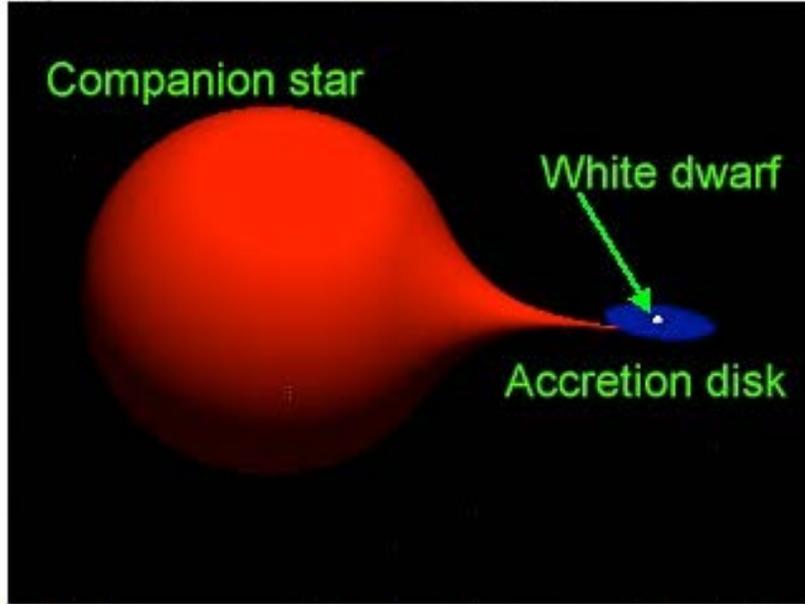


Type Ia SNe

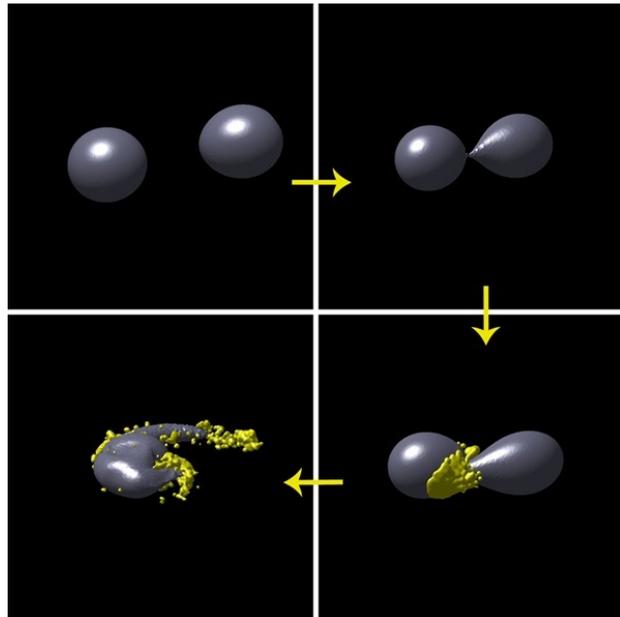


core-collapse SNe (mostly Type II)
~ 10 Myr

SNe Ia: Accreting and Merging White Dwarfs

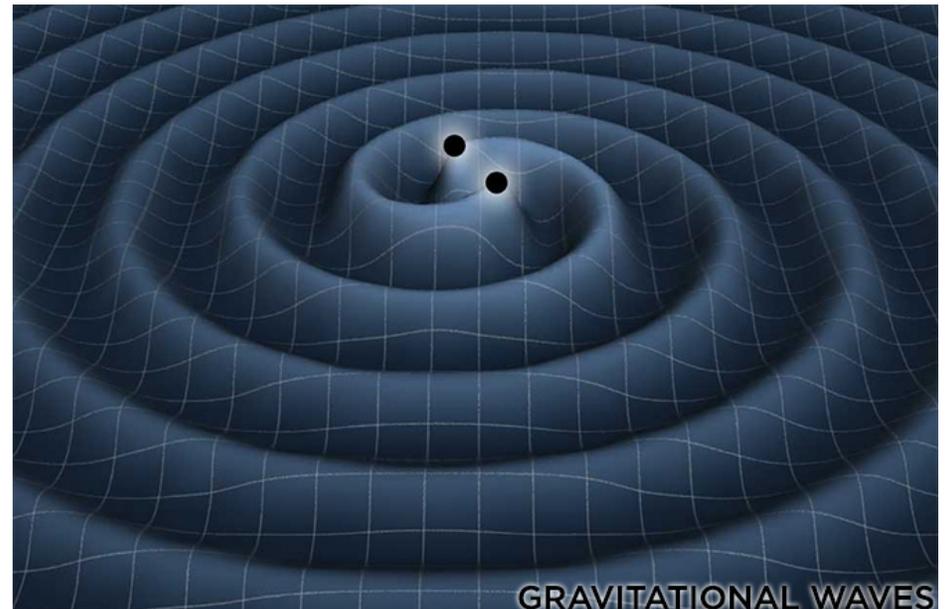


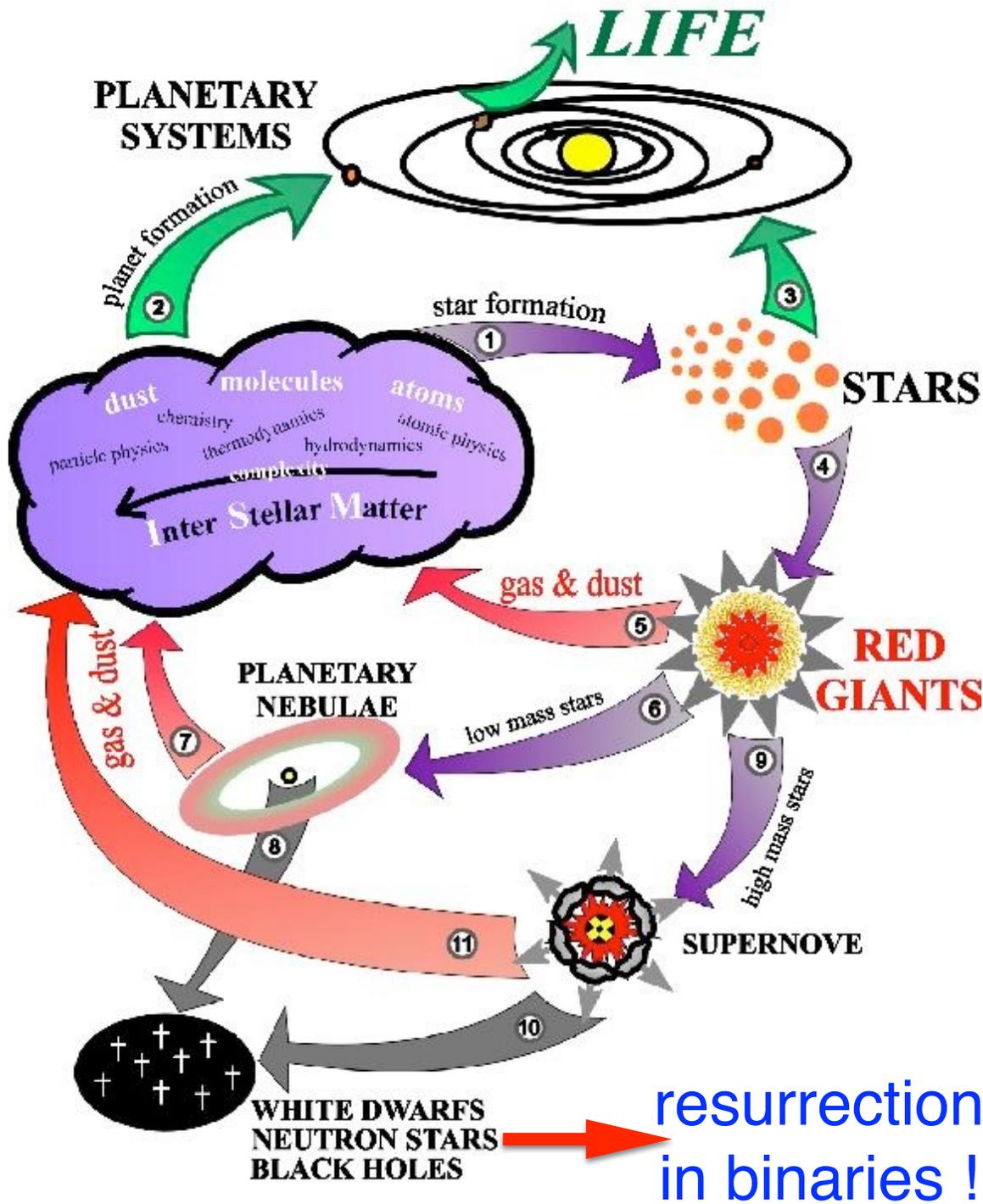
~1 Gyr



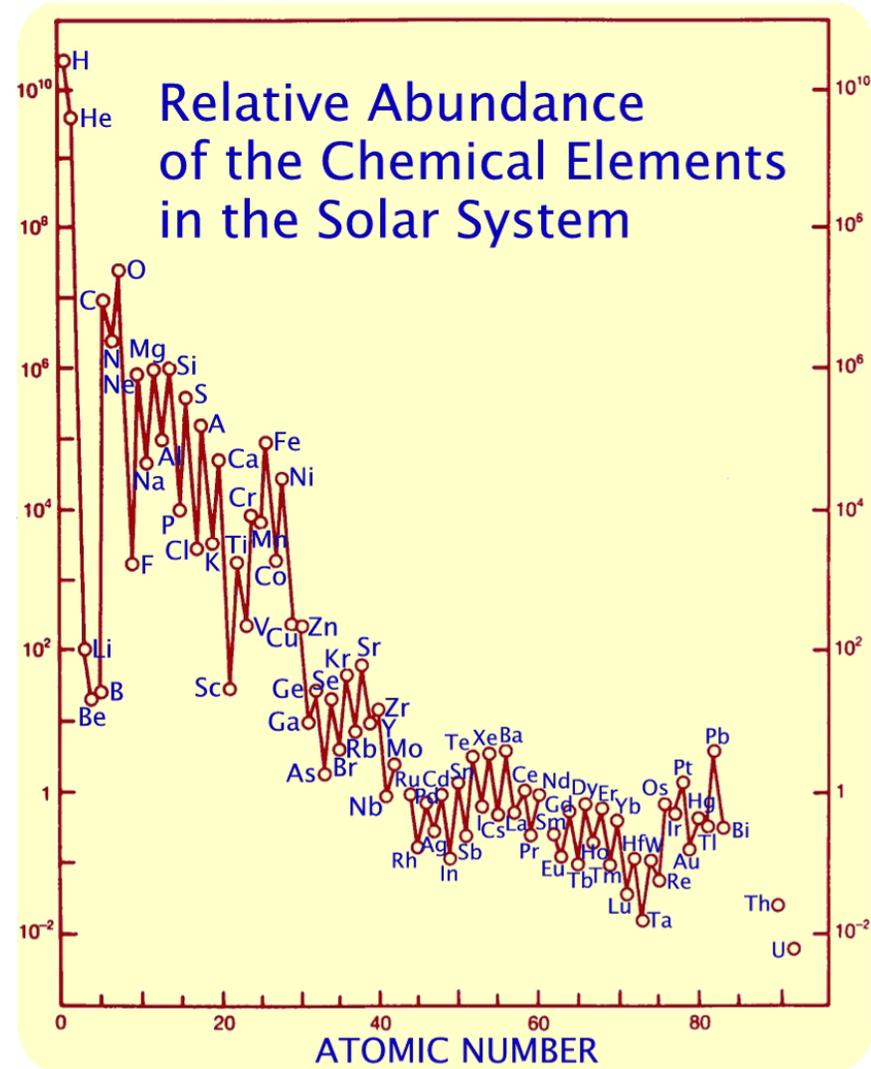
Neutron
Star
Mergers

~100 Myr

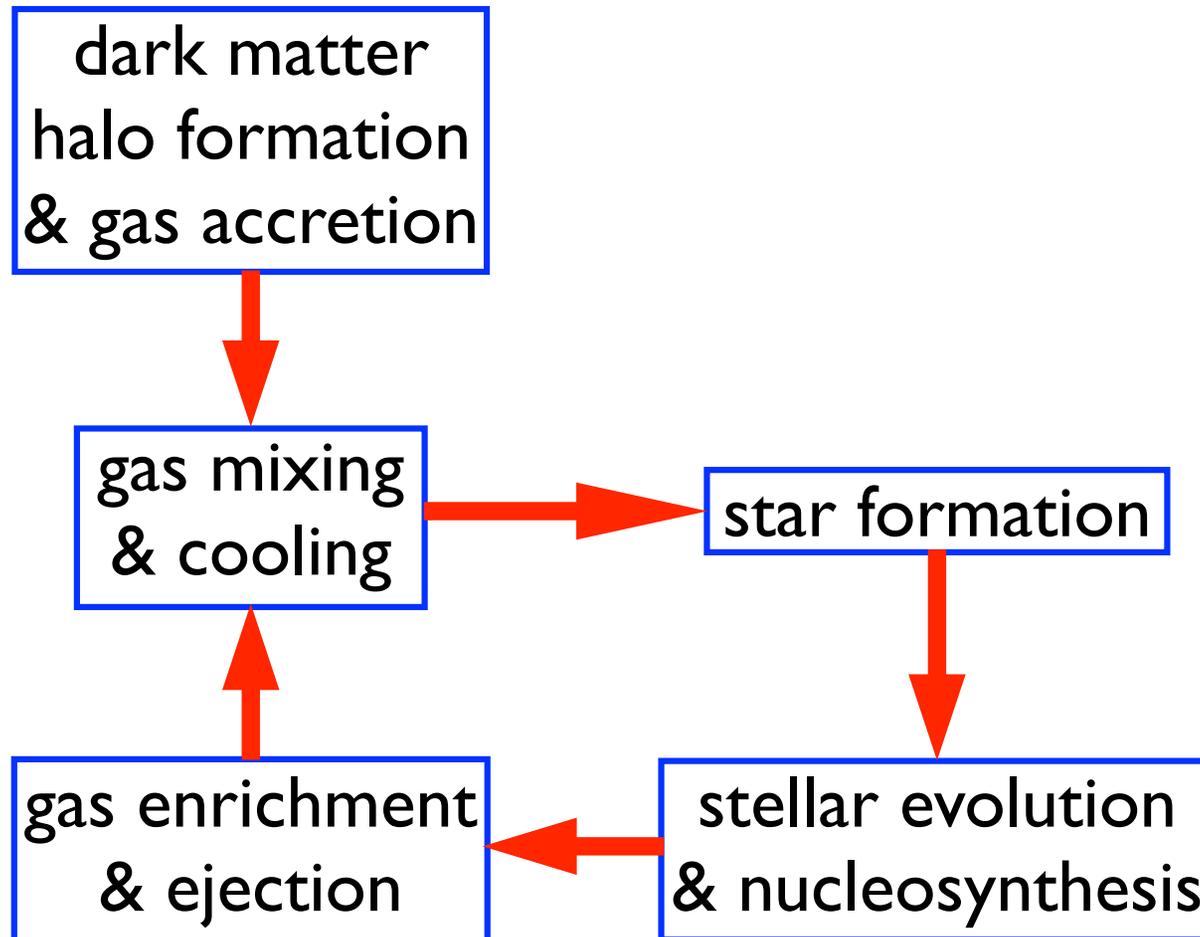




Arise from the Ashes



Ab Initio Model of Chemical Evolution



Data-Driven Nuclear Forensics

nuclear input: masses;
reaction rates,
including beta-decay,
n-capture, fission

+

astrophysical input:
electron fraction (Y_e),
entropy (S), expansion
timescale (t_{exp})

production patterns $(E/Fe)_i$

$$\left(\frac{E}{Fe}\right) = \sum_{i=1}^n x_i \left(\frac{E}{Fe}\right)_i, \quad \sum_{i=1}^n x_i = 1$$

abundances in stars (E/Fe)

Early Chemical Evolution (~ First Gyr)

dominant sources: Core-Collapse SNe & NS Mergers

$$\left(\frac{E}{Fe}\right) = x \left(\frac{E}{Fe}\right)_1 + (1 - x) \left(\frac{E}{Fe}\right)_2$$

R-Process Alliance search for r-process-enhanced stars in the Galactic Halo: data on (Sr/Fe), (Ba/Fe), (Eu/Fe) for 195 stars
(Holmbeck et al. 2020)

$$[E/Fe] = \log(E/Fe) - \log(E/Fe)_{\text{sun}}$$

$$[Sr/Fe]_1 = -0.49, [Ba/Fe]_1 = -3.00, [Eu/Fe]_1 = -0.77$$

$$[Sr/Fe]_2 = 0.90, [Ba/Fe]_2 = 0.91, [Eu/Fe]_2 = 1.30$$

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CCSNe: Fe, Sr

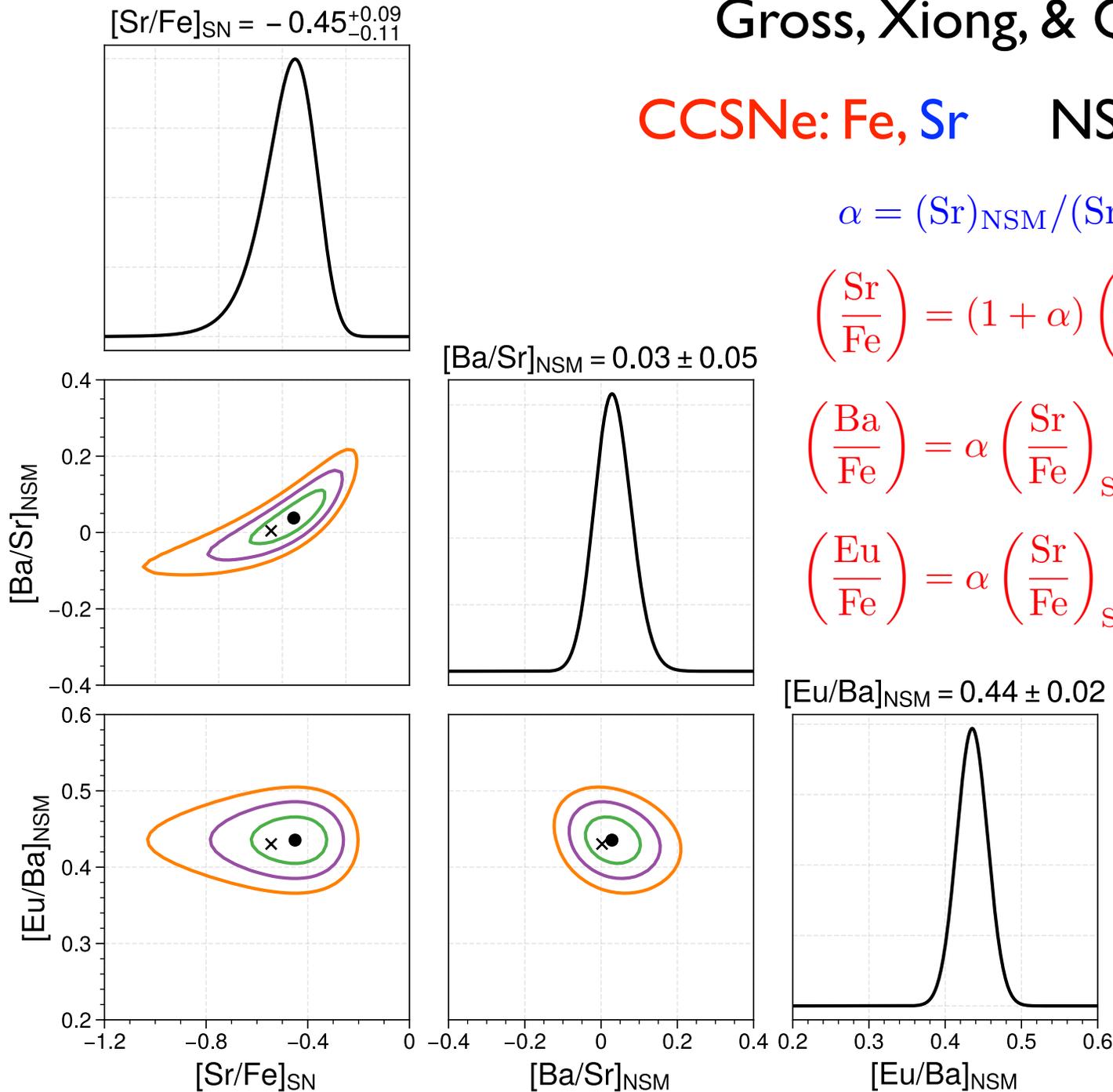
NSMs: Sr, Ba, Eu

$$\alpha = (\text{Sr})_{\text{NSM}} / (\text{Sr})_{\text{SN}}$$

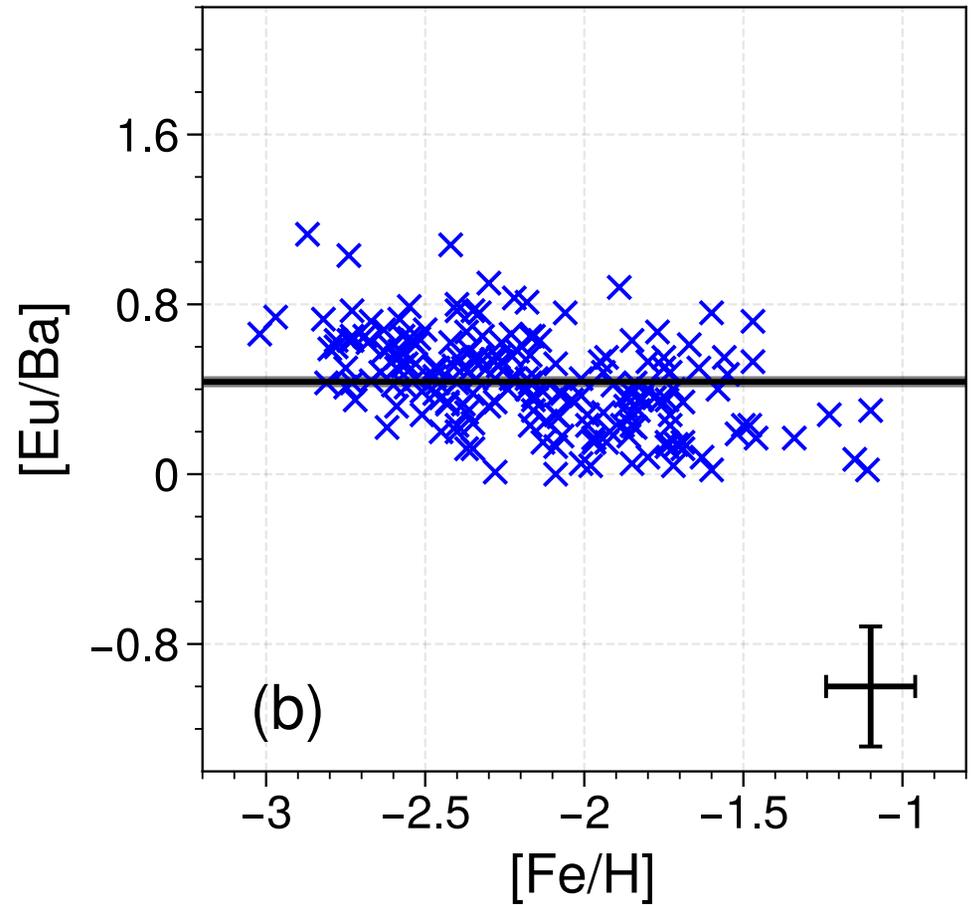
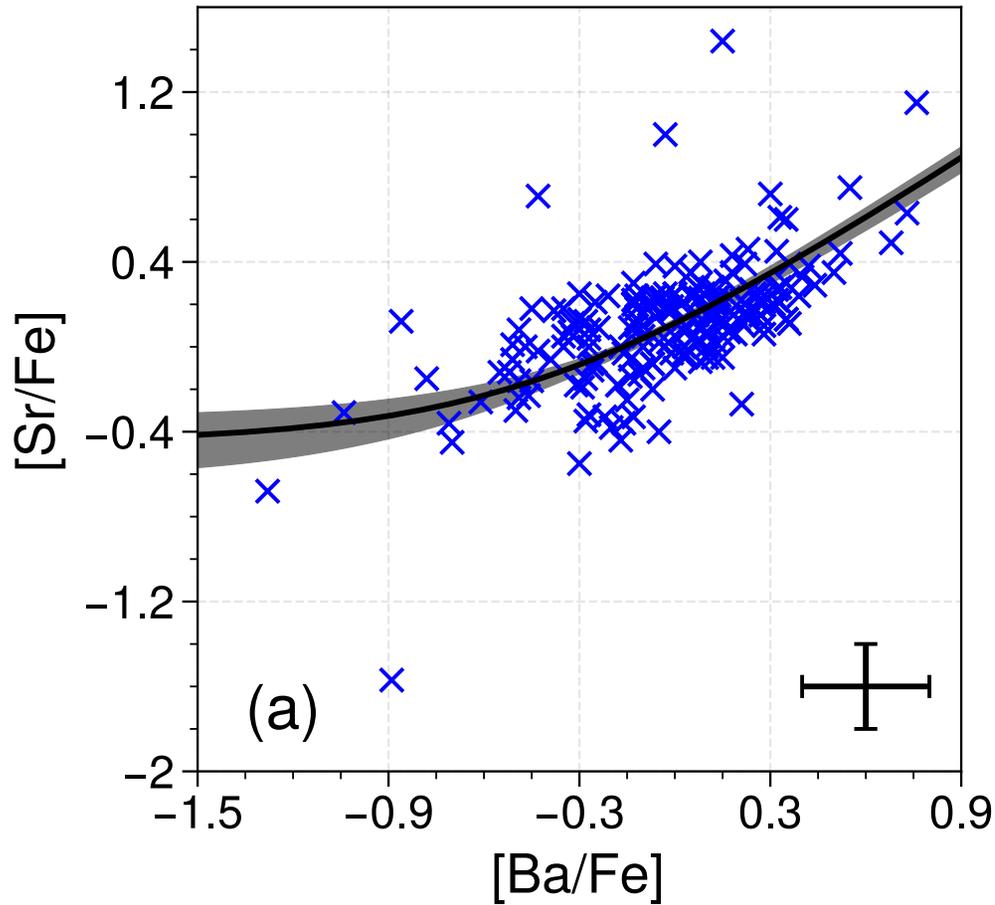
$$\left(\frac{\text{Sr}}{\text{Fe}}\right) = (1 + \alpha) \left(\frac{\text{Sr}}{\text{Fe}}\right)_{\text{SN}}$$

$$\left(\frac{\text{Ba}}{\text{Fe}}\right) = \alpha \left(\frac{\text{Sr}}{\text{Fe}}\right)_{\text{SN}} \left(\frac{\text{Ba}}{\text{Sr}}\right)_{\text{NSM}}$$

$$\left(\frac{\text{Eu}}{\text{Fe}}\right) = \alpha \left(\frac{\text{Sr}}{\text{Fe}}\right)_{\text{SN}} \left(\frac{\text{Ba}}{\text{Sr}}\right)_{\text{NSM}} \left(\frac{\text{Eu}}{\text{Ba}}\right)_{\text{NSM}}$$

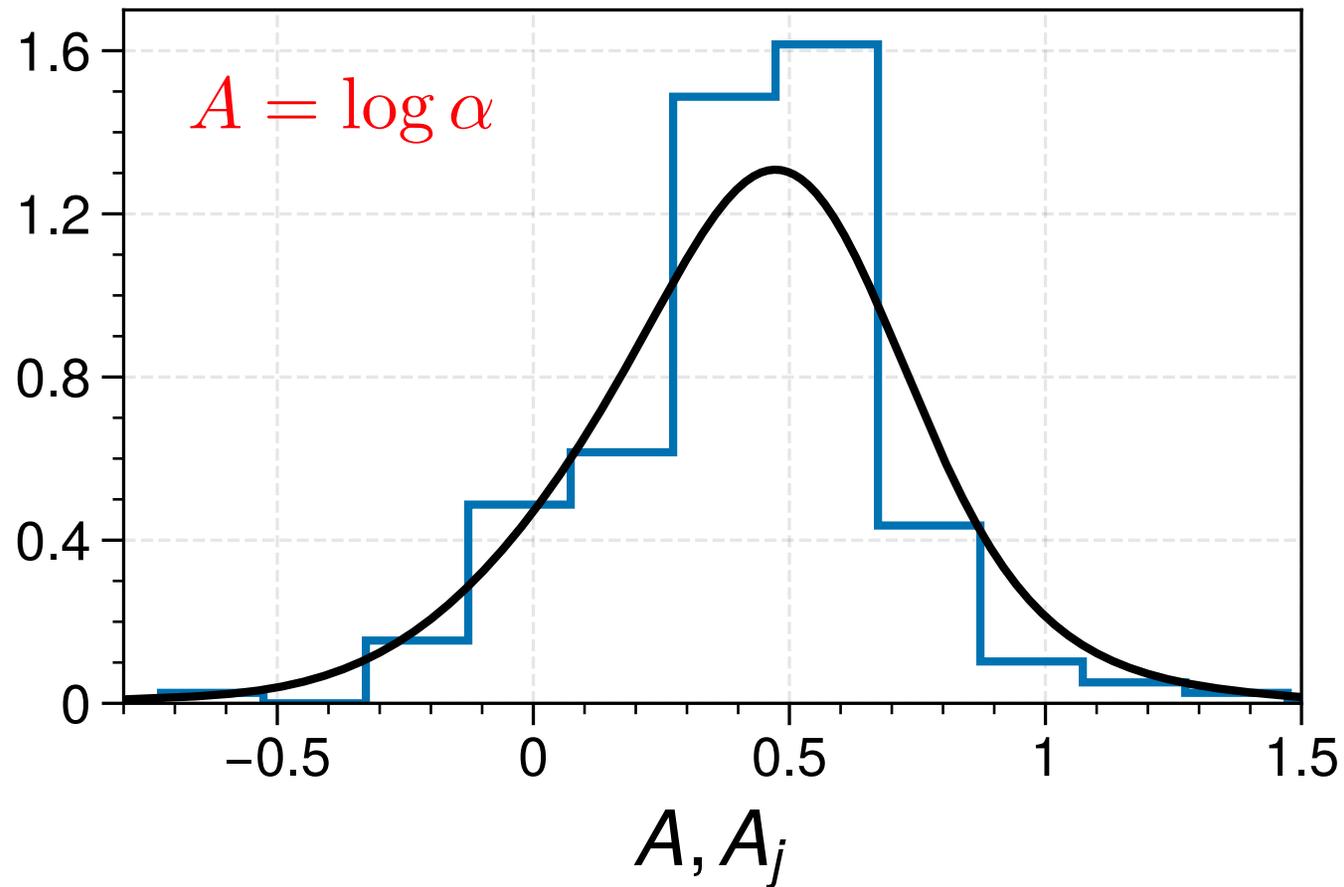


Gross, Xiong, & Qian 2023



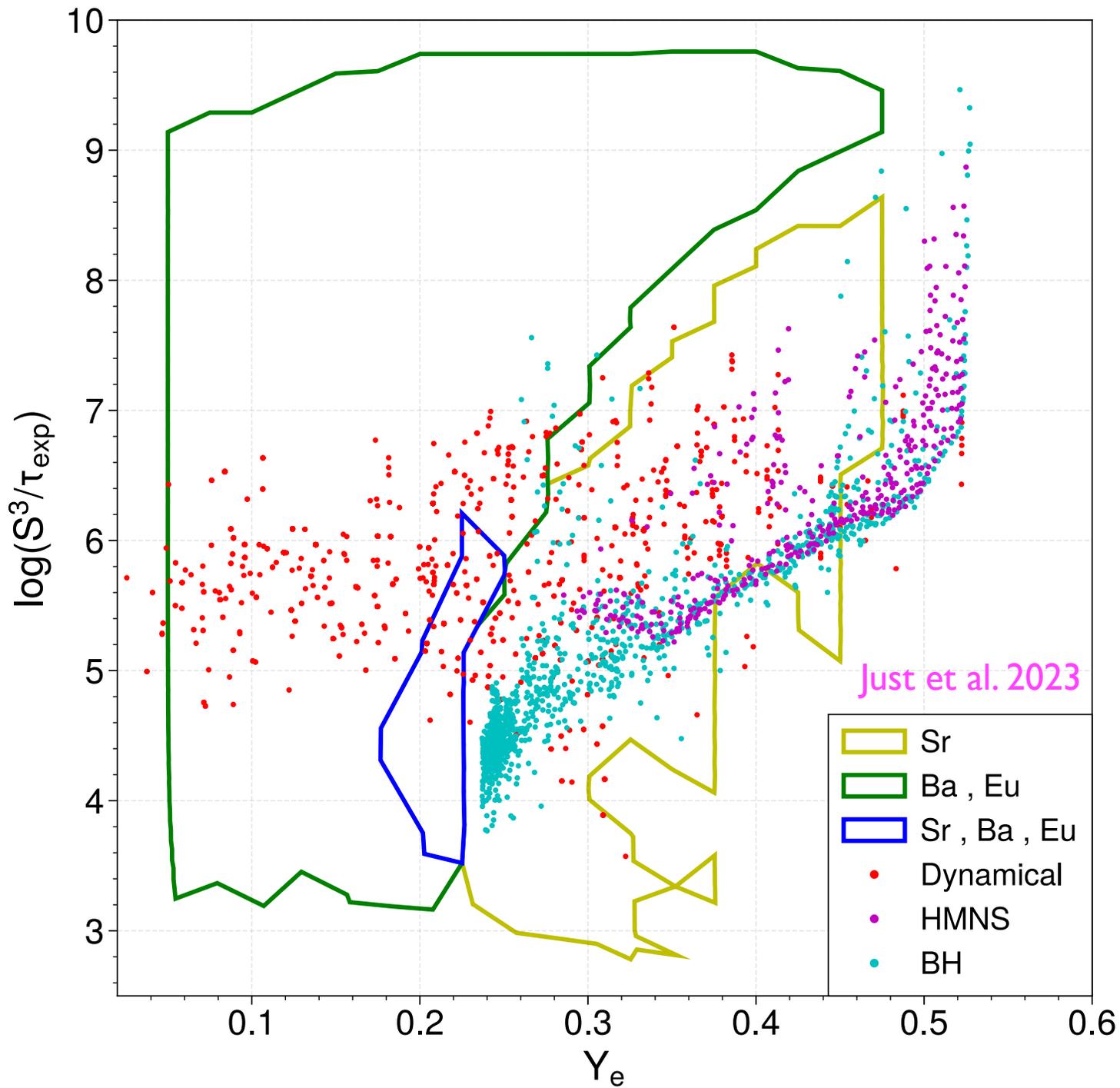
$$\left(\frac{\text{Sr}}{\text{Fe}}\right) = \left(\frac{\text{Sr}}{\text{Fe}}\right)_{\text{SN}} + \left(\frac{\text{Sr}}{\text{Ba}}\right)_{\text{NSM}} \left(\frac{\text{Ba}}{\text{Fe}}\right)$$

Gross, Xiong, & Qian 2023



$$\alpha_{\odot} \approx \frac{(\text{Sr}/\text{Eu})_{\text{NSM}}(\text{Eu})_{\odot}}{(\text{Sr}/\text{Fe})_{\text{SN}}(\text{Fe})_{\odot,\text{SN}}} \approx 3 \Rightarrow (\text{Fe})_{\odot,\text{SN}} \approx (\text{Fe})_{\odot}/3$$

Gross, Xiong, & Qian 2023



Gross, Xiong, & Qian 2023

