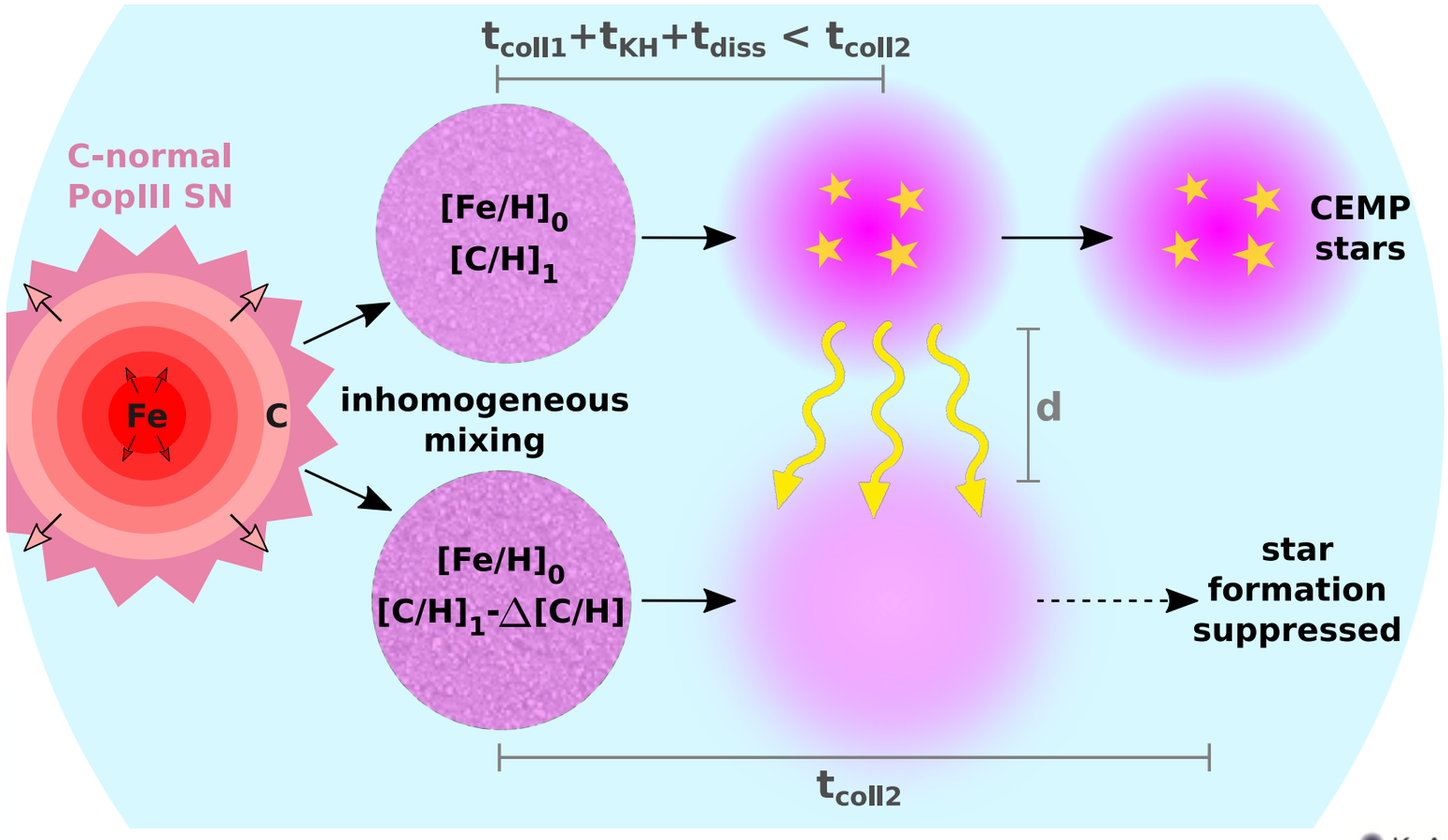
Carbon-enhanced metal-poor stars as a consequence of inhomogeneous metal mixing



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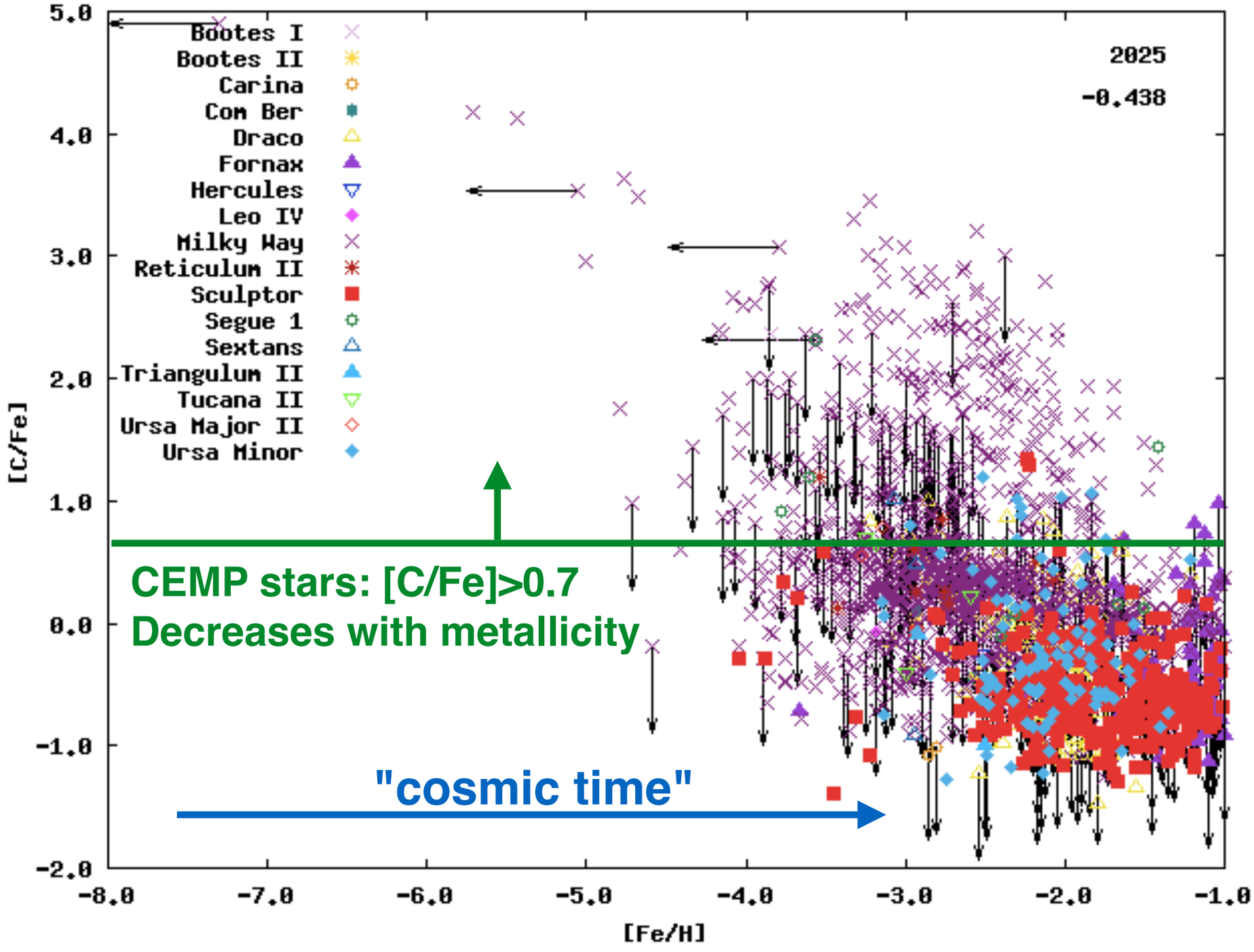
Today on arXiv:1812.01820

Carbon-enhanced metal-poor stars

see also:
Piercarlo,
Suda-san,
this afternoon

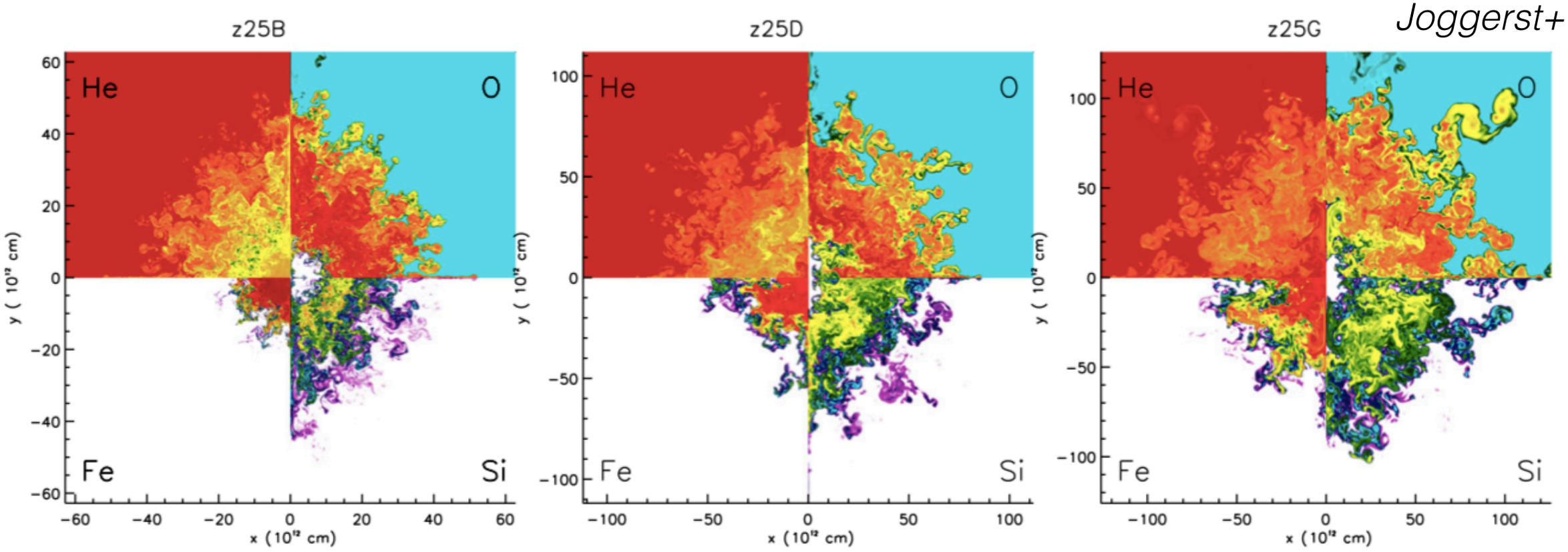


Saga database,
Suda-san

Is iron well mixed with alpha-elements?

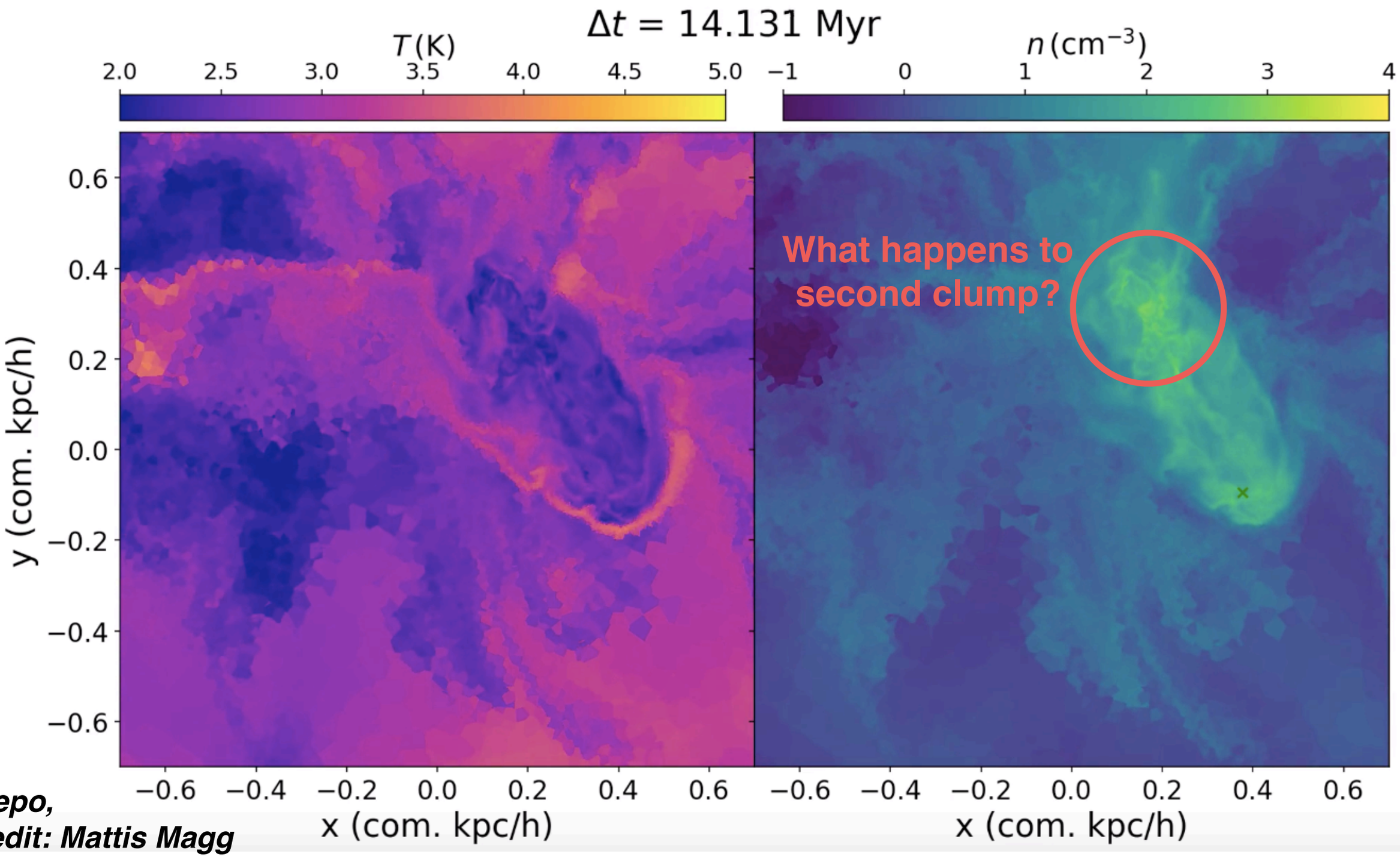
Aspherical Explosions (Tominaga-san, Rana)?

Joggerst+10



Chiaki-san & Britton: homogeneous mixing (Z+H) only on scales <10pc
See also Ritter+15,16, Sluder+16

After PopIII SN: several clumps may form



Arepo, credit: Mattis Magg

New Scenario

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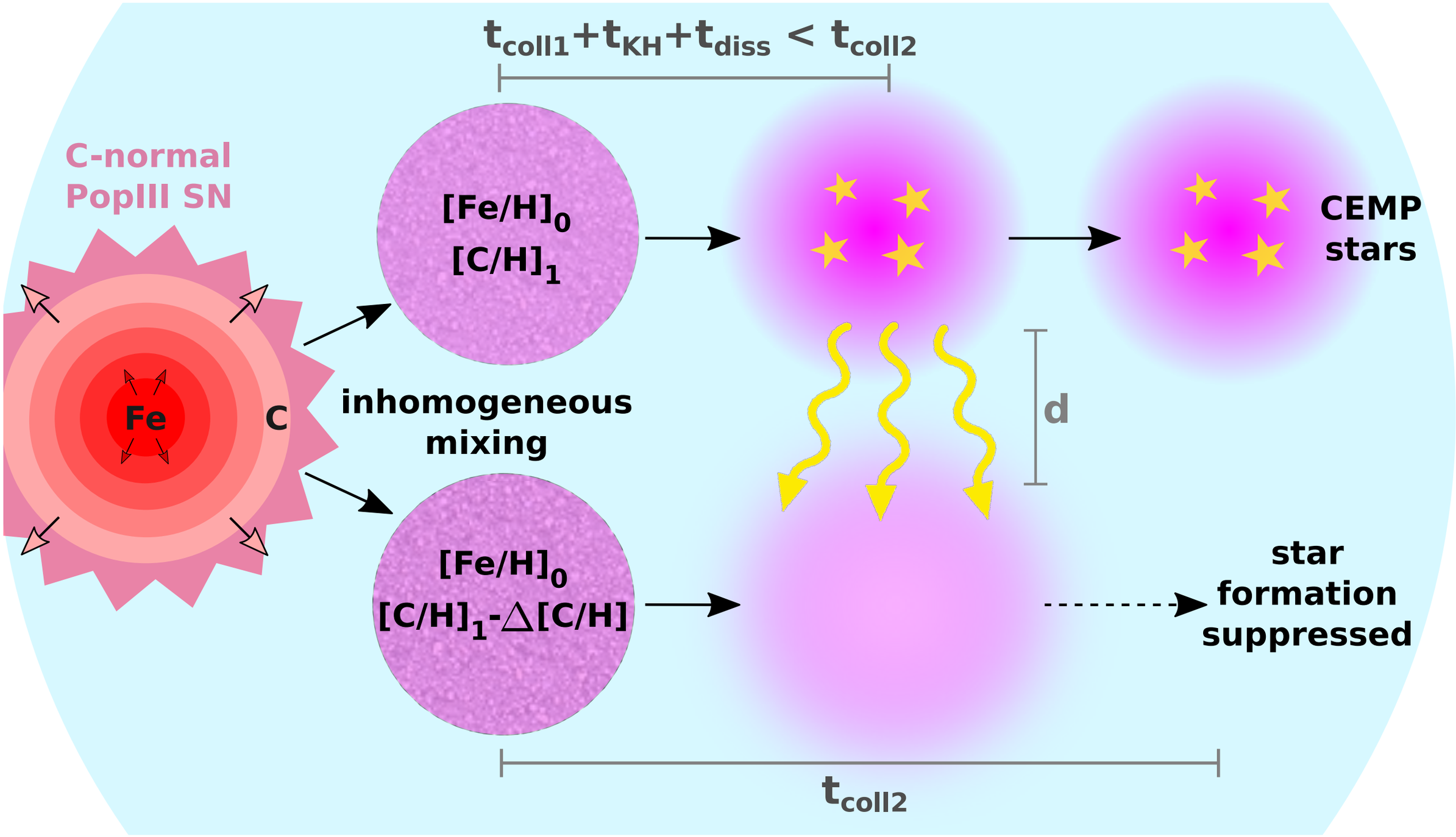
Carbon-enhanced metal-poor stars as a consequence of inhomogeneous mixing of metals in the interstellar medium?



New Scenario

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Characteristic Timescales

Kelvin-Helmholtz: $t_{\rm KH} = 0.1\,{\rm Myr}\left(\frac{M_*}{10\,{\rm M}_\odot}\right)^2\left(\frac{R_*}{5.3\,{\rm R}_\odot}\right)^{-1}\left(\frac{L_*}{5750\,{\rm L}_\odot}\right)^{-1}$

LW dissociation: $t_{\rm dis} = 0.2\,{\rm Myr}\left(\frac{M_{\rm clump}}{1000\,{\rm M}_\odot}\right)^{1/3}\left(\frac{n}{10^3\,{\rm cm}^{-3}}\right)^{2/3}\left(\frac{D}{10\,{\rm pc}}\right)^2$

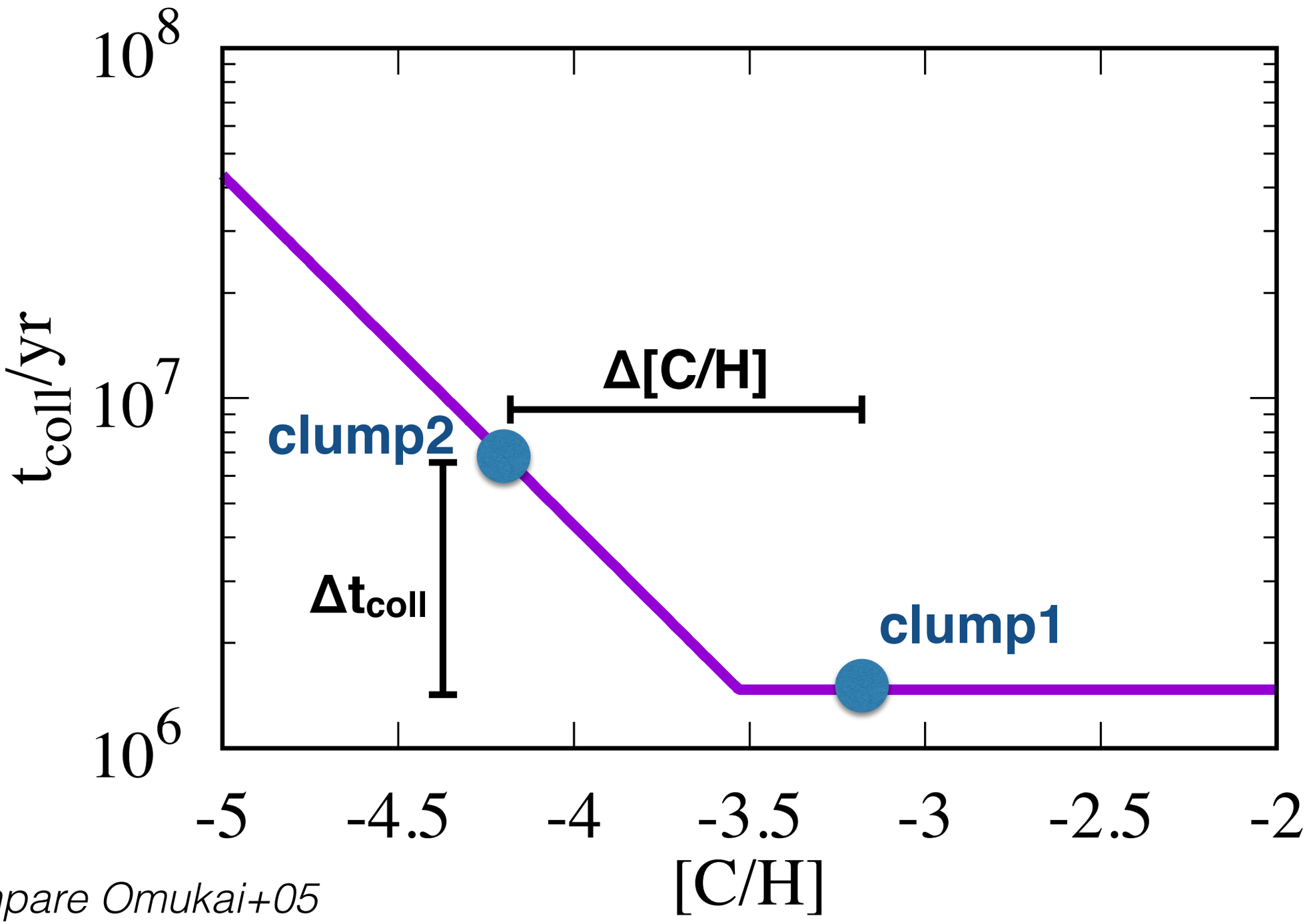
Collapse time: $t_{coll} = \max(t_{ff}, t_{cool})$

Cooling Rate: $\frac{\Lambda_{\rm CII}}{{\rm erg\,cm^{-3}\,s^{-1}}} = 4.8\times10^{-21}\left(\frac{n_H}{10^3\,{\rm cm}^{-3}}\right)^2\exp\left(-\frac{92\,{\rm K}}{T}\right)$ x $10^{[C/H]}$

Condition: $\boldsymbol{t_{coll1} + t_{KH} + t_{diss} < t_{coll2}}$

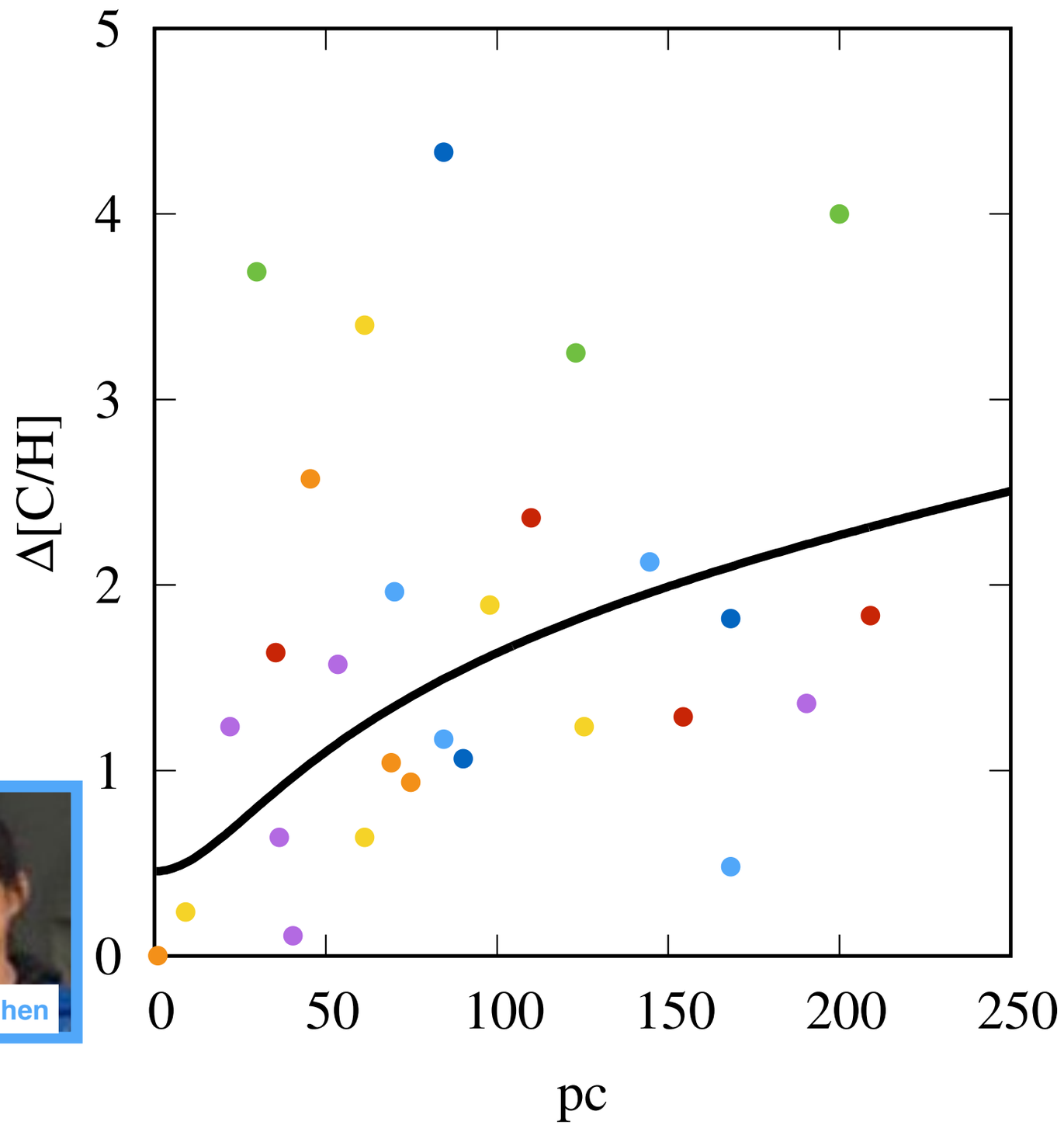
$$\Delta[{\rm C/H}] > [{\rm C/H}] + 3.6 + \log_{10}\left(\frac{13000 + 2\times10^5 d_{10}^2 n_3^{2/3} + 1.5\times10^6 n_3^{-1/2}}{1.7\times10^6} n_3\right)$$

Characteristic Timescales, illustrated



compare Omukai+05

Required Inhomogeneity



Results

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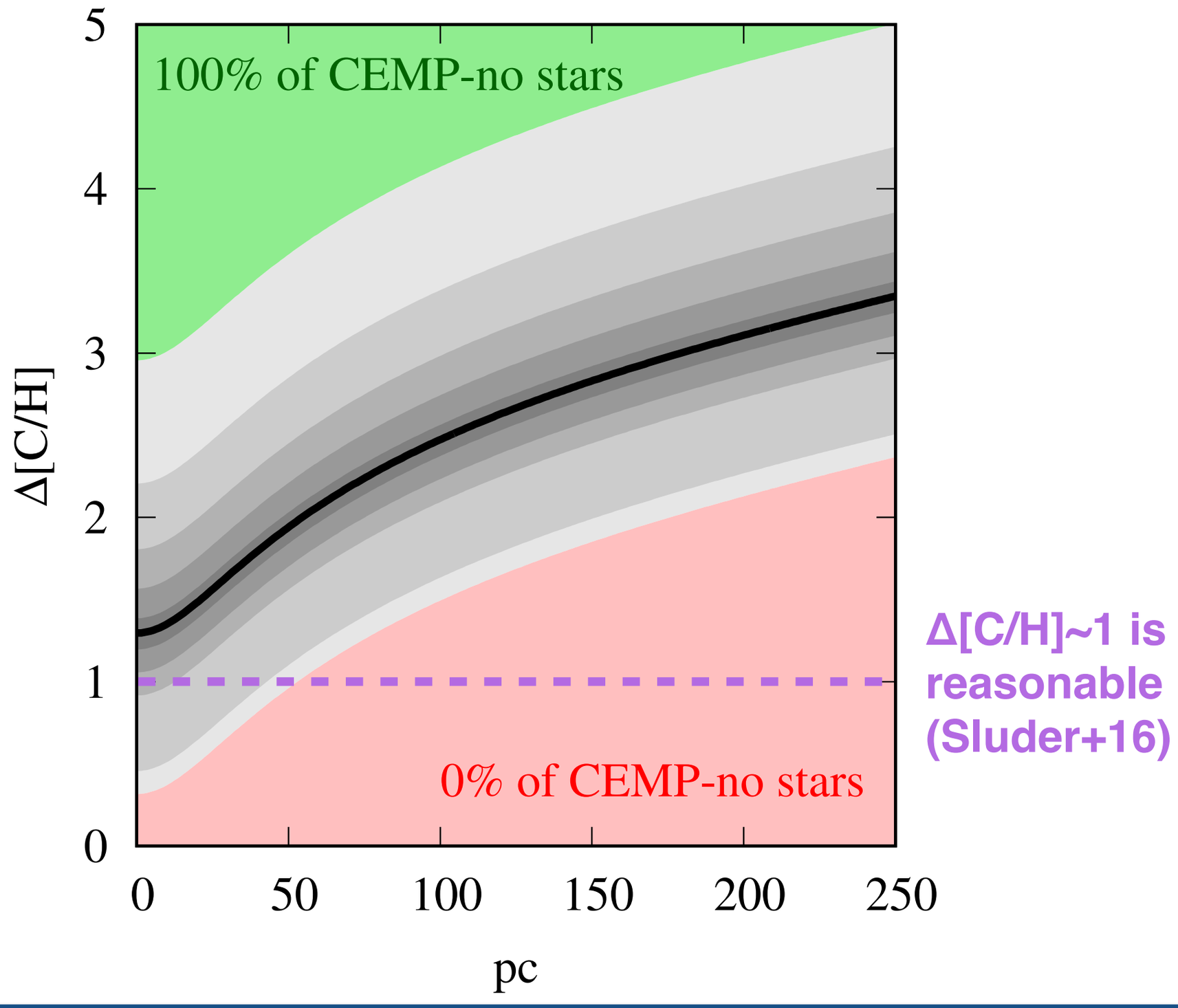
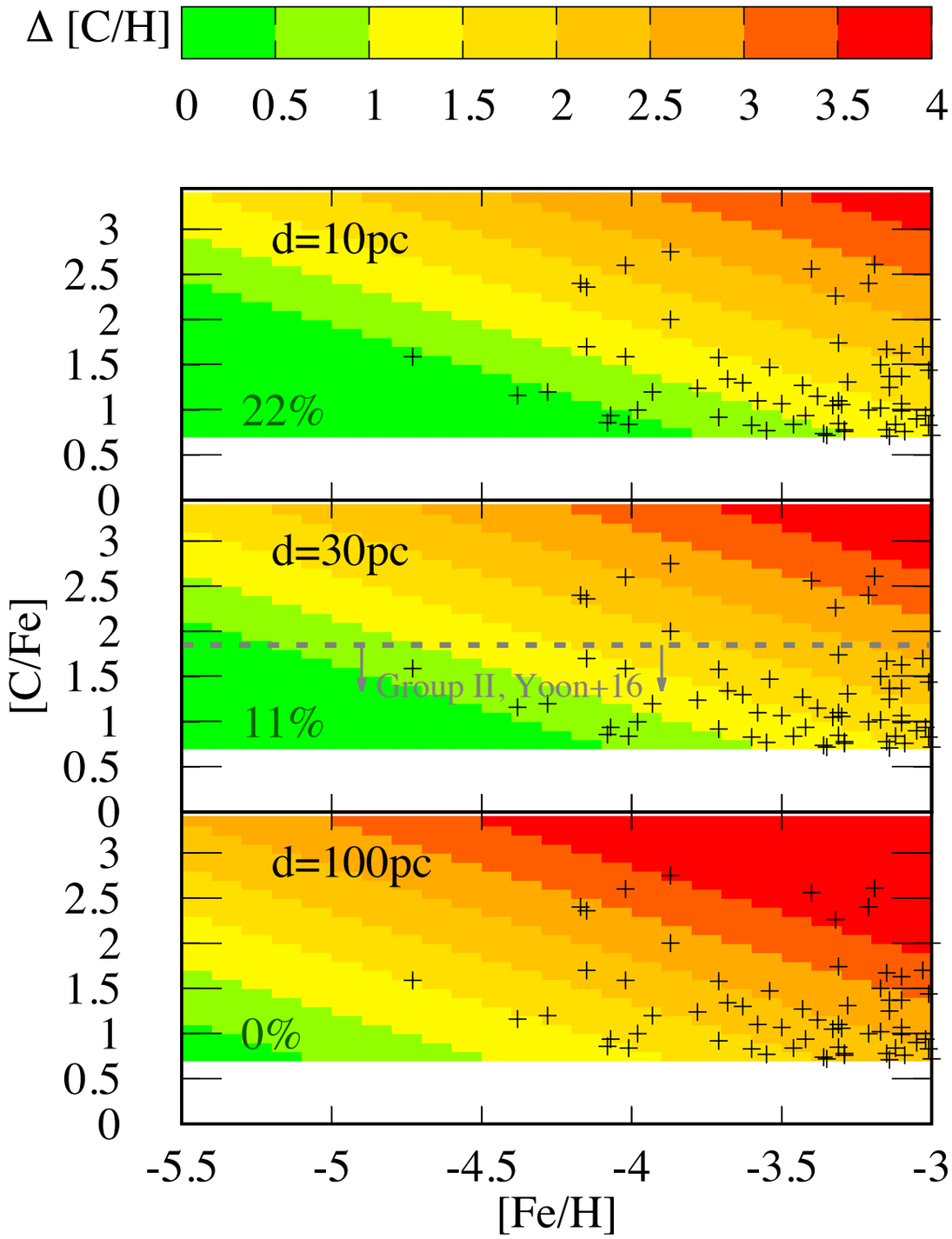
Required Inhomogeneity



Δ[C/H]~1 is reasonable (Sluder+16)

Comparison to Observations



- **0-22% of CEMP-no stars can be explained for Δ[C/H]~1**
- **up to 89% for Δ[C/H]~2**

Inhomogeneous Mixing: The Enemy of "Stellar Archaeology as a Time Machine to the First Stars"

yt: "Color Ink Drops in Water Slow Motion HD" by Abracadabra TV

Outlook

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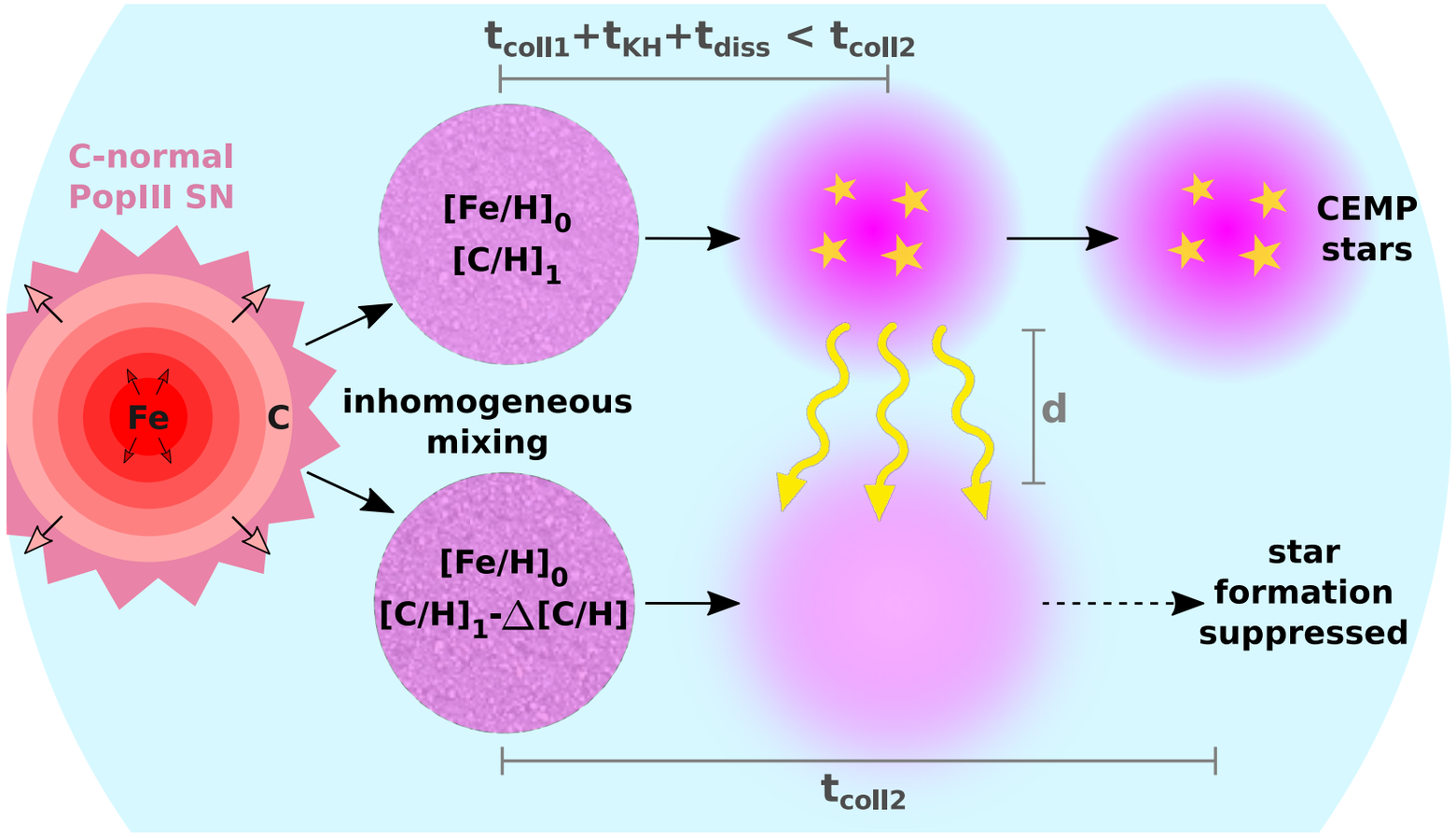
A novel formation scenario for carbon-enhanced metal-poor stars

- 0-89% of CEMP-no stars could have formed by inhomogeneous metal mixing
- Caveats: only carbon (no dust or oxygen), simplistic analytical treatment
- Mathematica notebook public on gitlab
- Next step: 3D simulations
- Inhomogeneous metal mixing: general importance for interpreting stellar abundance patterns



Summary

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