The First Supernovae and the Origins of Metal-poor Stars

Ke-Jung (Ken) Chen

陳科榮

ASIAA

Collaborators: Stan Woosley(UCSC), Alex Heger (MOCA), Dan Whalen (ICG), Volker Bromm (UT-Austin), Ralf Klessen (ITA), Katharina Wollenberg (ITA) Shingo Hirano (Kyushu),Tilman Hartwig (IPMU)

中央研究院
天文及天文物理研究所
ACADEMIA SINICA
Institute of Astronomy and Astrophysics

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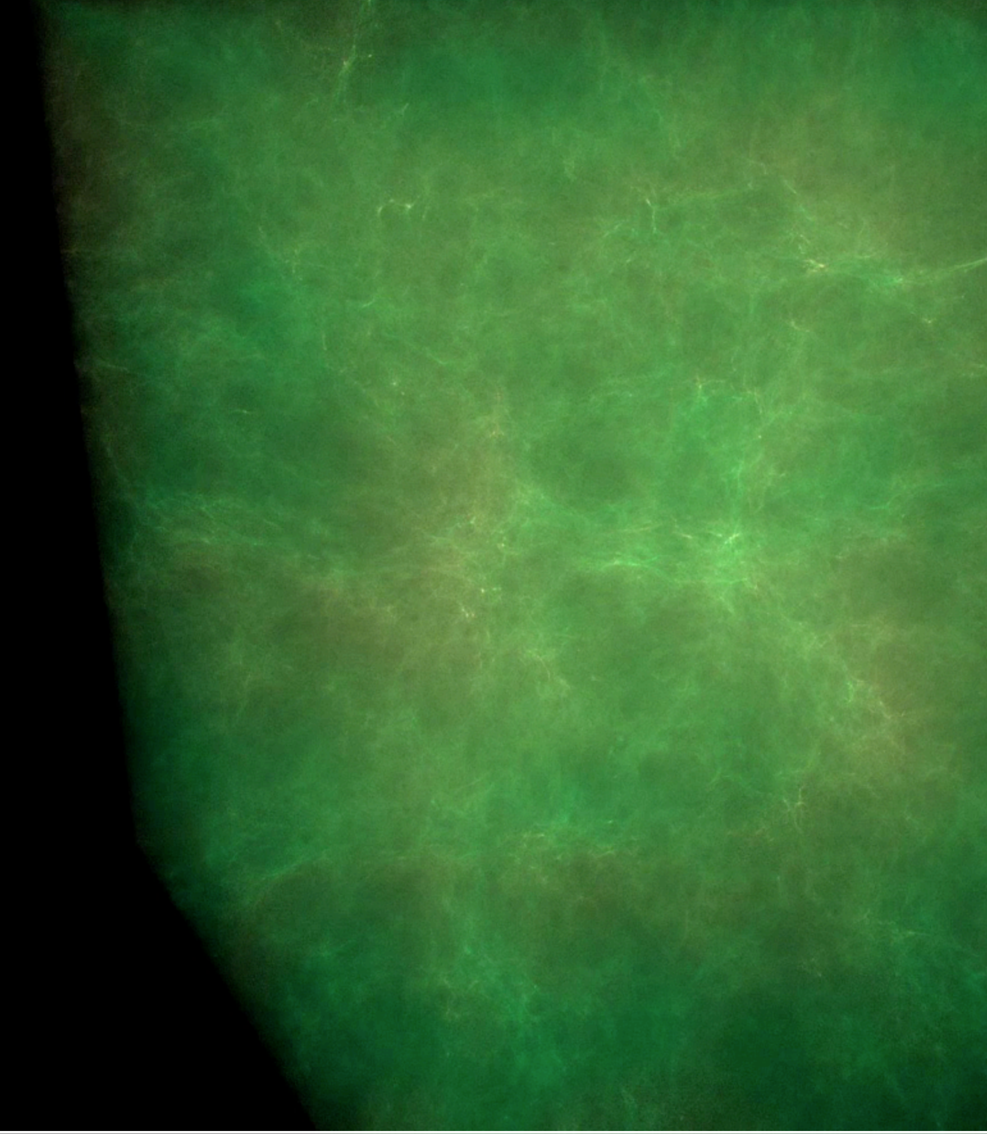
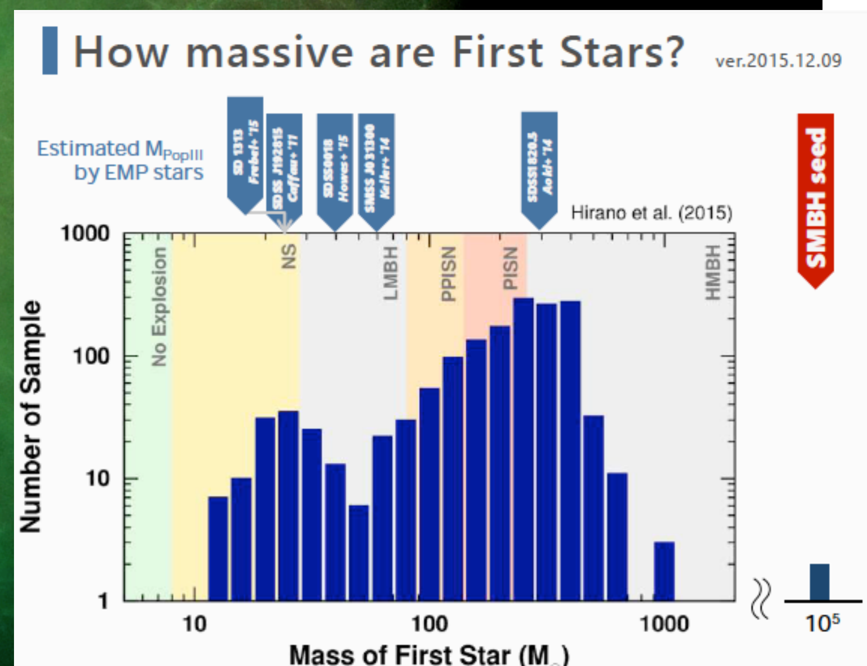
ASIAA Folks at this meeting.
(contributing 2 talks+ 2 posters)

Time Machine

Cosmic Dawn

Talks by Takashi, Shingo, Anna



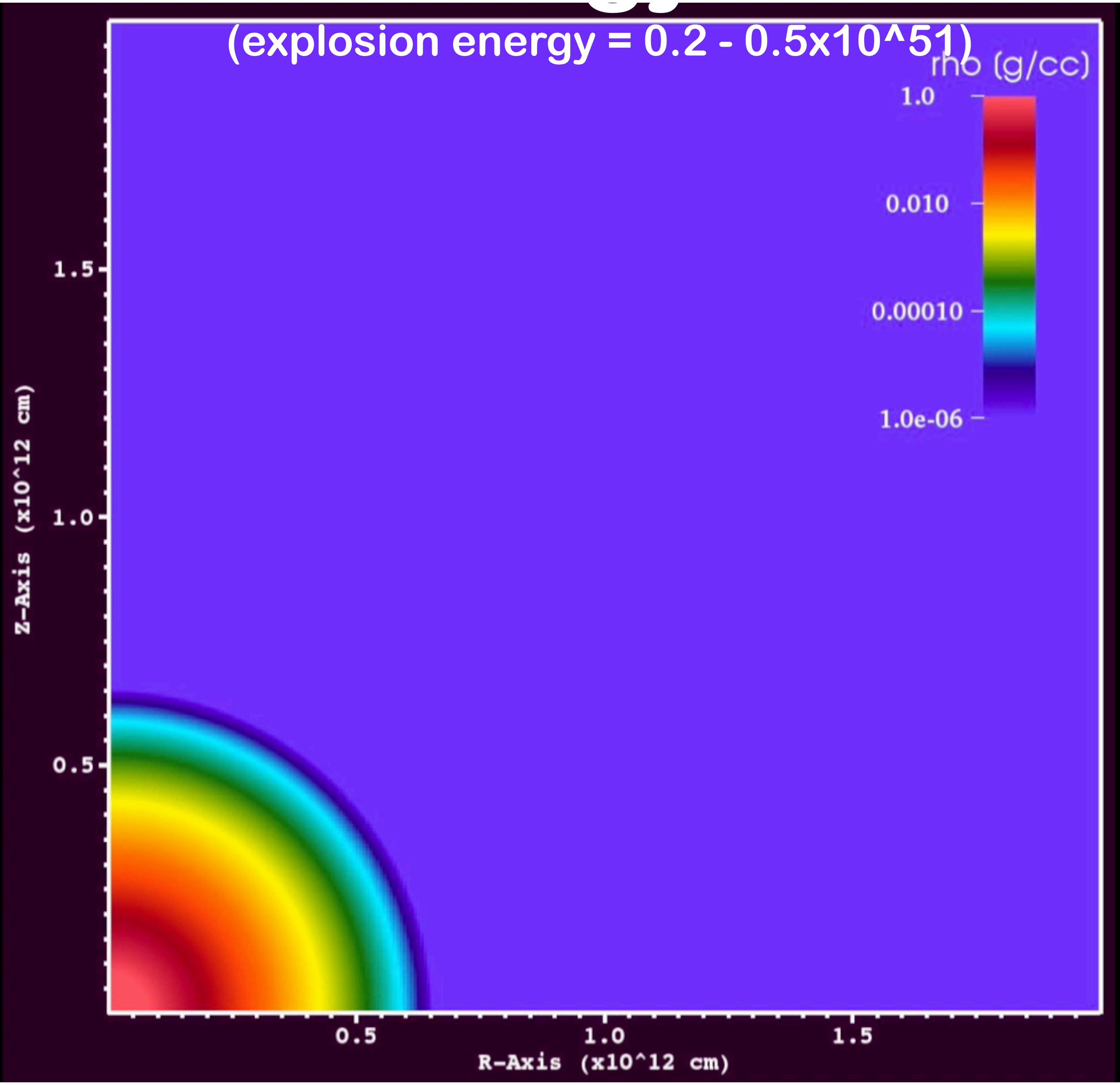


Courtesy of Hirano

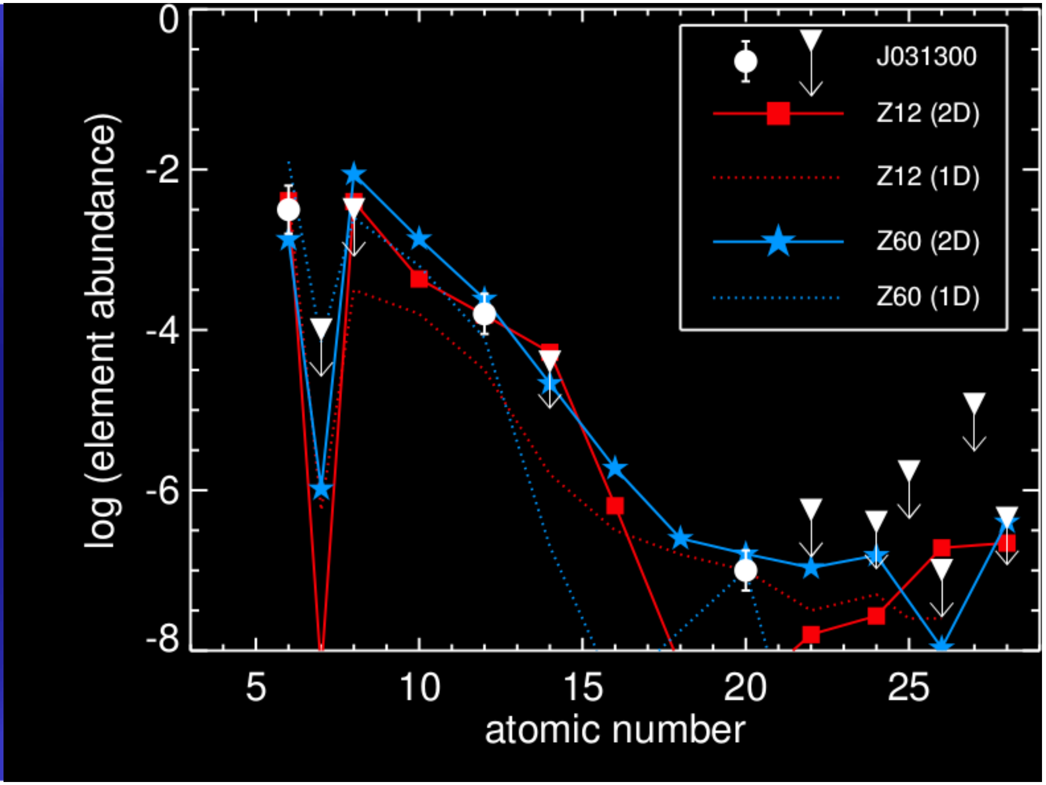
Where were the metals from? Core-collapse Supernovae Explosions

Courtesy of Jason Nordhaus

(explosion energy = 0.2 - 0.5x10^51)



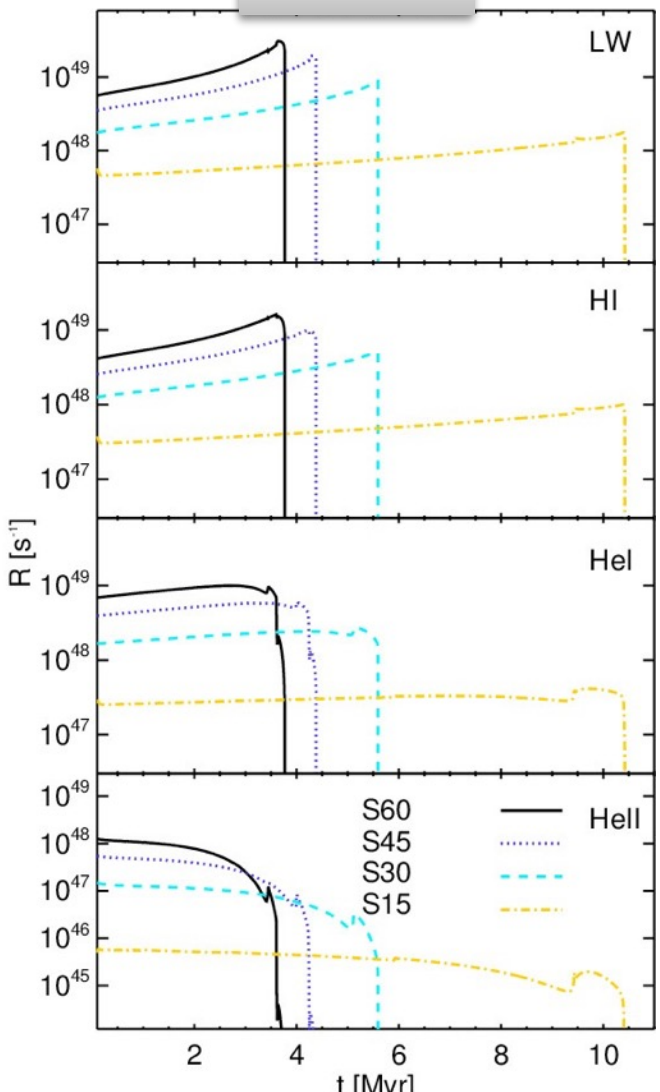

The First Mixing of Metals


log (element abundance)
atomic number
J031300
Z12 (2D)
Z12 (1D)
Z60 (2D)
Z60 (1D)
0
-2
-4
-6
-8
5
10
15
20
25

Stellar Feedback of Pop III Stars

Inputs to Cosmological Simulations

Radiation



Mass ($M_\odot$)	MS (Myr)	post-MS (Myr)	total (Myr)	fates	metals (SN/HN) ($M_\odot$)
15	9.478	1.031	10.51	SN	1.388
30	5.208	0.509	5.77	BH, HN	6.876
45	3.995	0.394	4.39	BH, HN	13.26
60	3.426	0.345	3.77	BH, HN	20.66

Table 10.1 Stellar lifetimes and fates

Supernovae

X[a]	Type	Masses ($M_\odot$)	E^a (B)	mass ejection	Notes
S	SN	$\lesssim 25$	1.2	all but $\sim 1.5\,M_\odot$	leaves neutron star
B	BH	$\gtrsim 25$	0	None	complete collapse to BH
H	HN	$\lesssim 25$	10	$\sim 90\,\%$	big explosion, leaves black hole

Table 10.2 Summary of assumed stellar fate characteristics: [a] sentinel used in model names to indicate fate of star. [b] Explosion energy.

Radiation

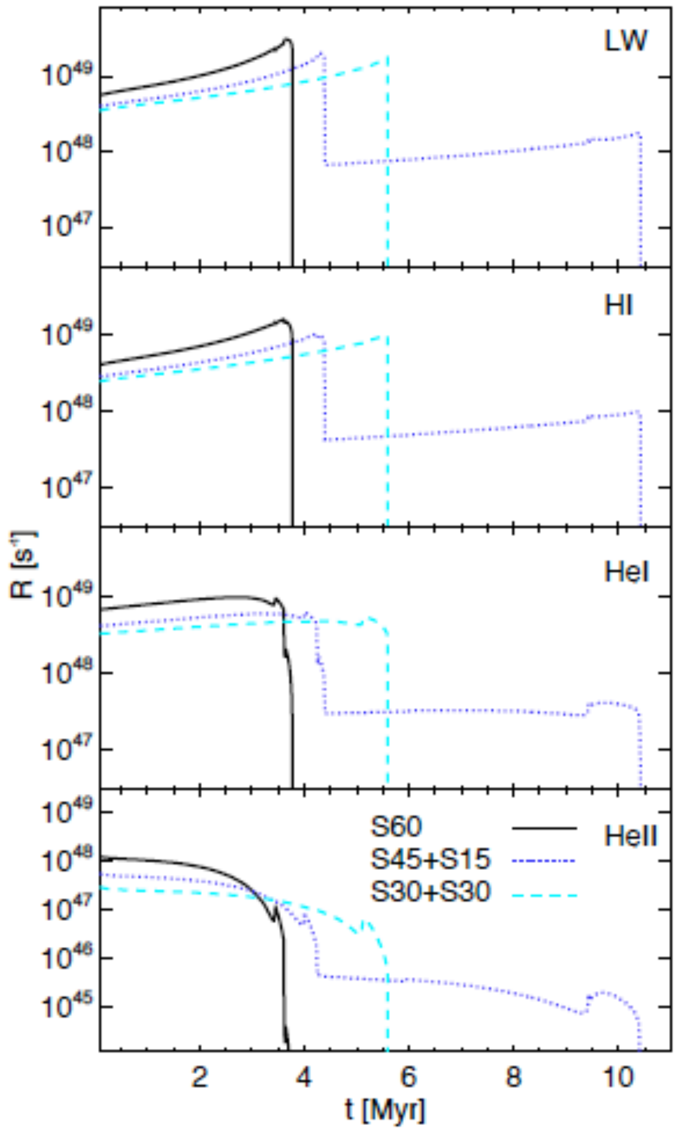
Mass ($M_\odot$)	HI (10^{63})	HeI (10^{63})	HeII (10^{61})
15	0.64	0.16	0.10
30	1.82	0.72	1.37
45	2.98	1.45	4.34
60	4.18	2.21	8.31

Table 10.3 Number of ionizing photons emitted over the lifetime of a star.

Paving the highway for chemical enrichment

Chen, Bromm, Heger+ ApJ (2015)

Stellar Feedback of Pop III Binaries
Inputs to Cosmological Simulations

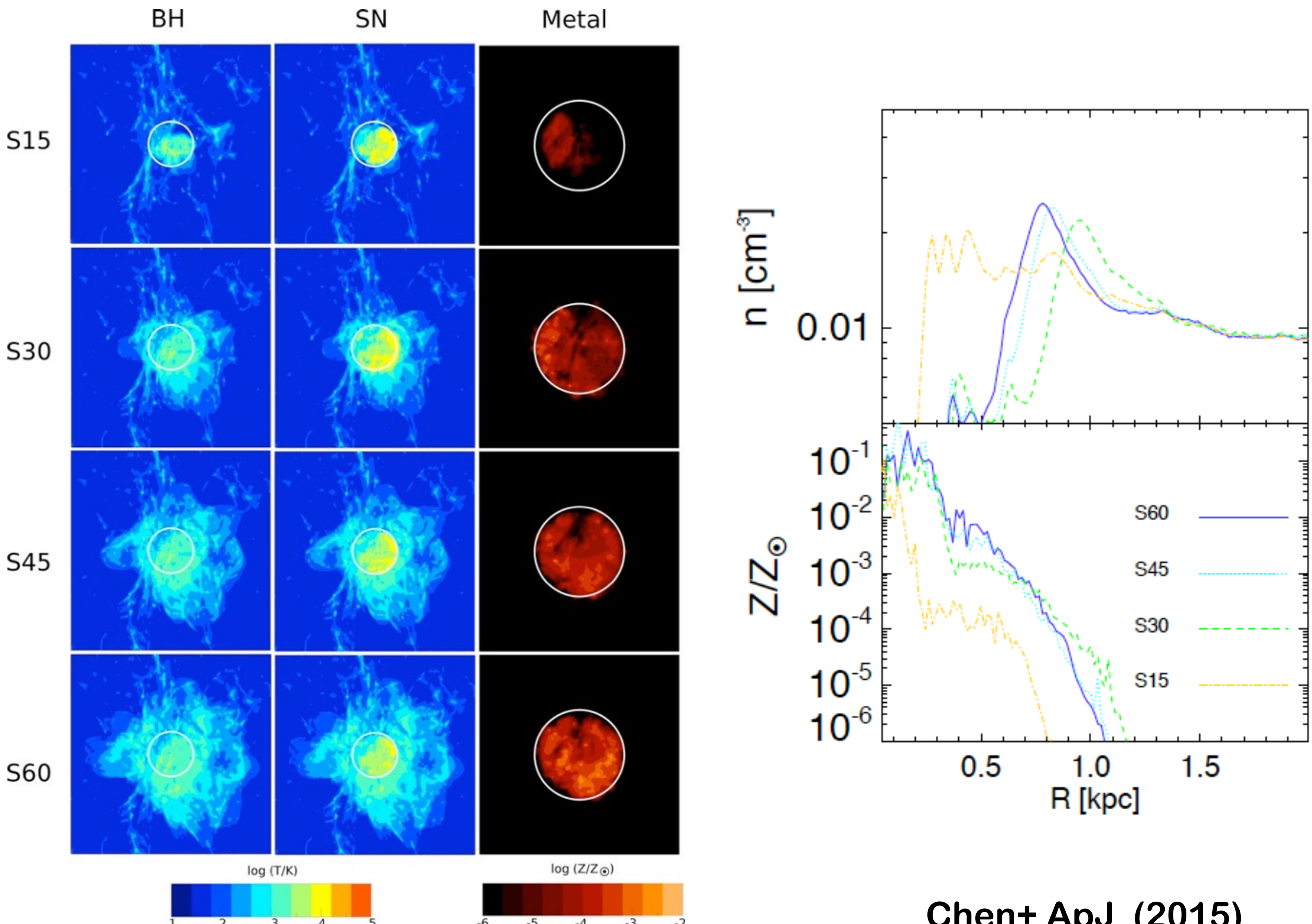


Binary	HI (10^{63})	HeI (10^{63})	HeII (10^{61})	t_*^a (Myr)
S30+S30	3.64	1.44	2.74	5.77
S45+S15	3.62	1.61	4.43	10.51
S60	4.18	2.21	8.31	3.77

Case	Masses ($M_\odot$)	Separation (distance)	Fate 1	Fate 2	metals (SN/HN) ($M_\odot$)
I	30+30	wide	HN	HN	13.74
II	30+30	wide	BH	BH	0.00
III	45+15	close	BH	..	0.00
III	45+15	close	HN	..	13.26
IV	60	..	HN	..	20.66

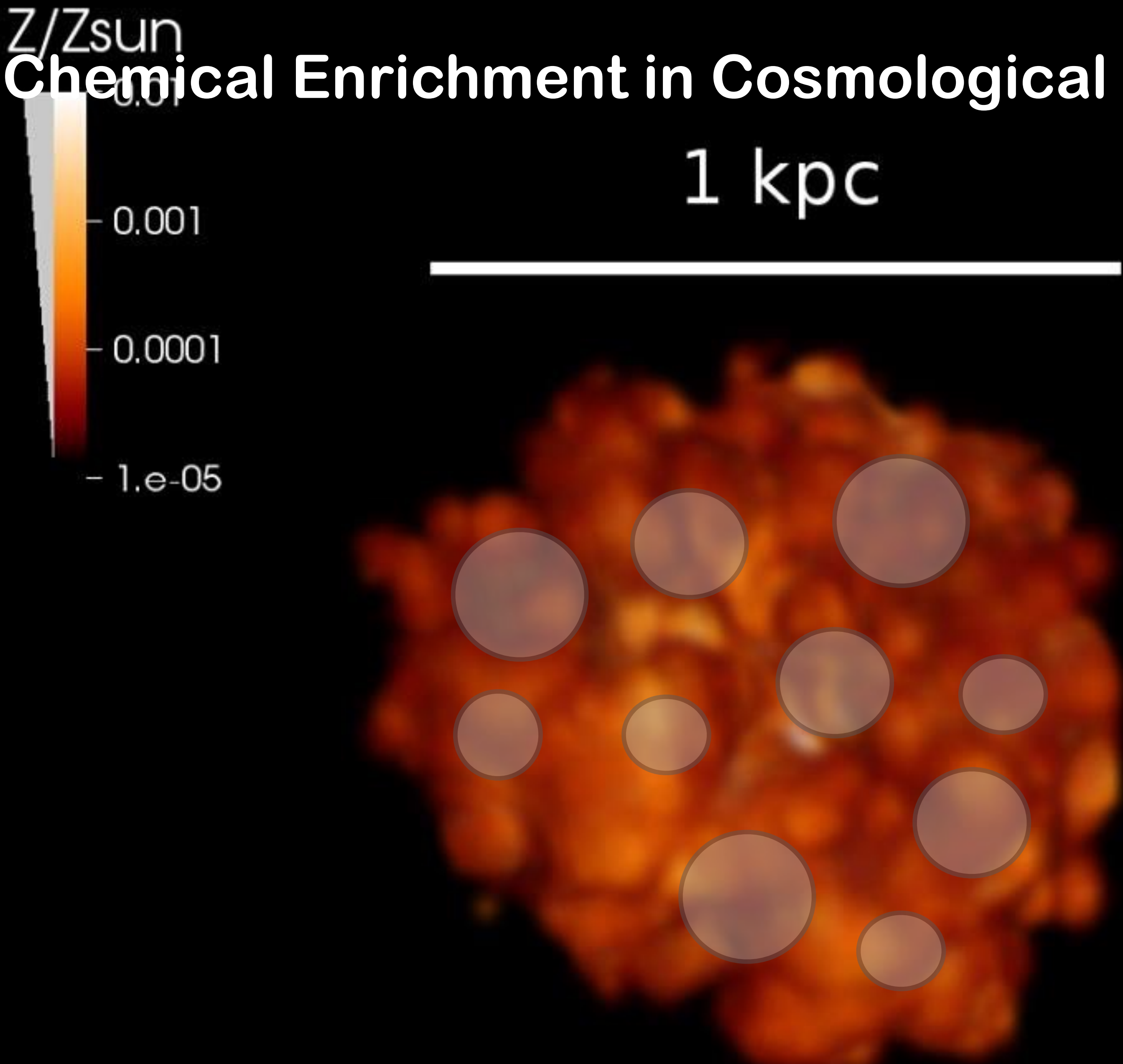
Poster by Sung-Han Tsai

Radiative+Supernova Feedback



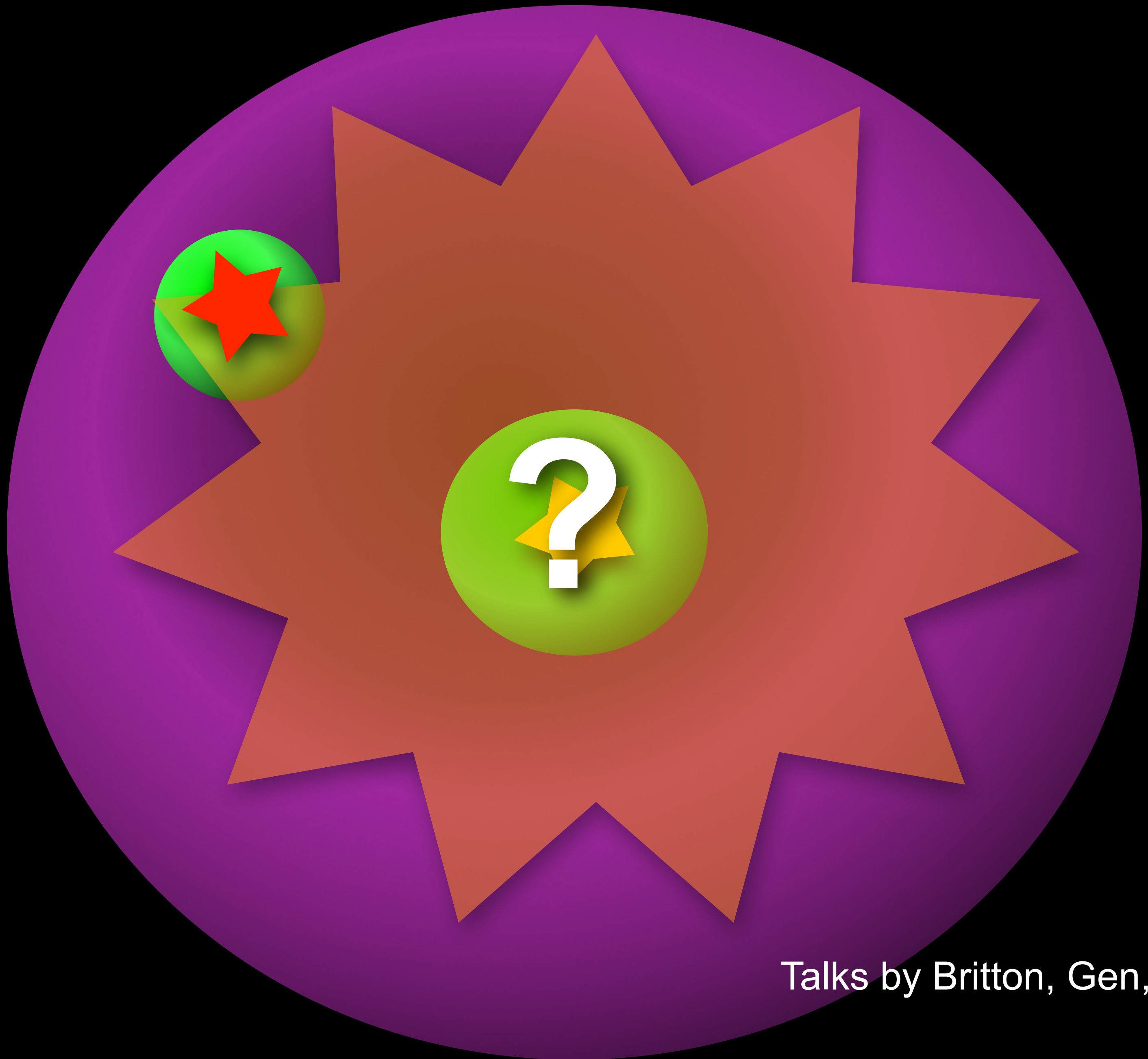
Chen+ ApJ (2015)

Chemical Enrichment in Cosmological Simulations



Chen+ 2015

External Enrichment Channel

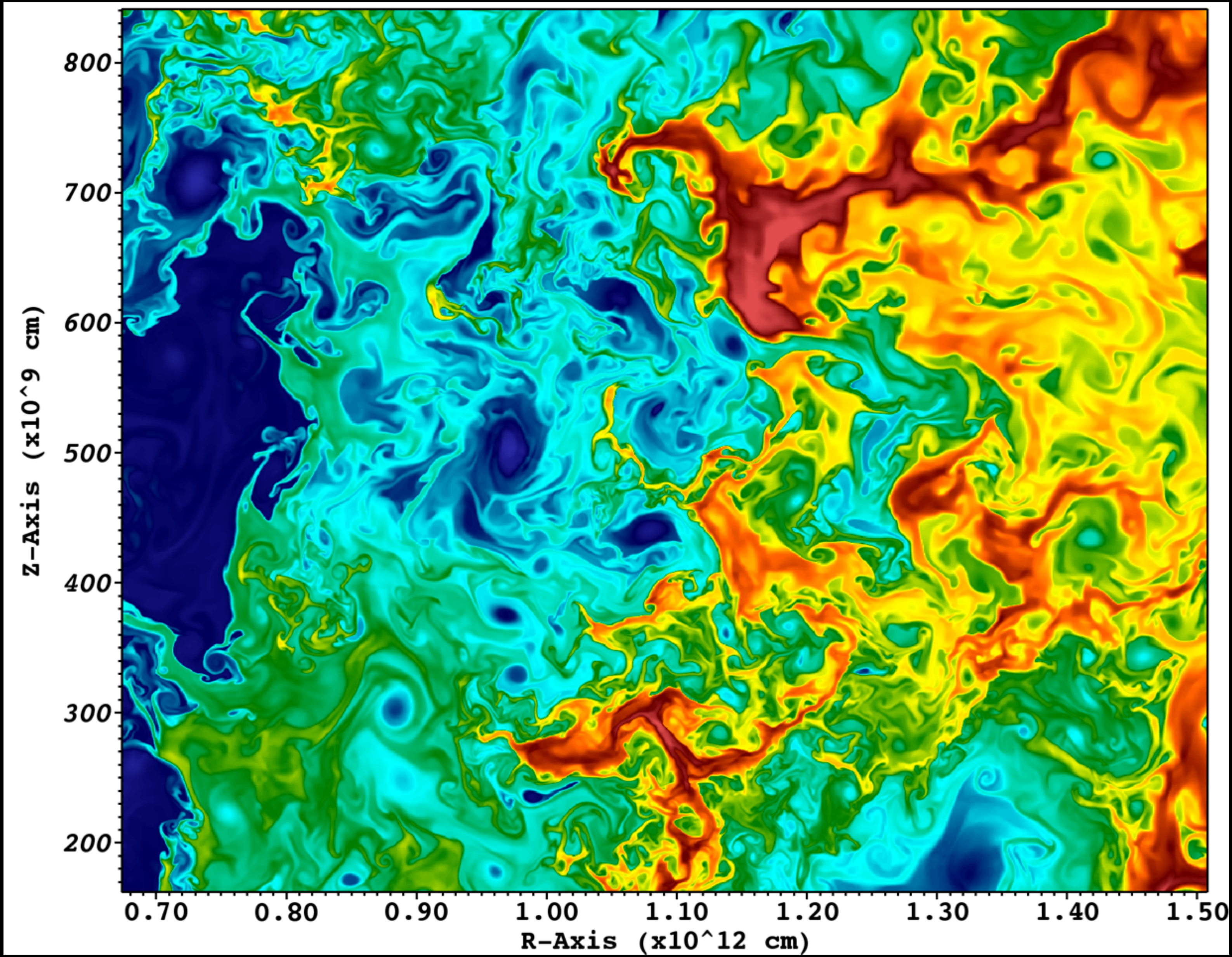


Talks by Britton, Gen, & Mattis

Chemical Enrichment in the Universe?

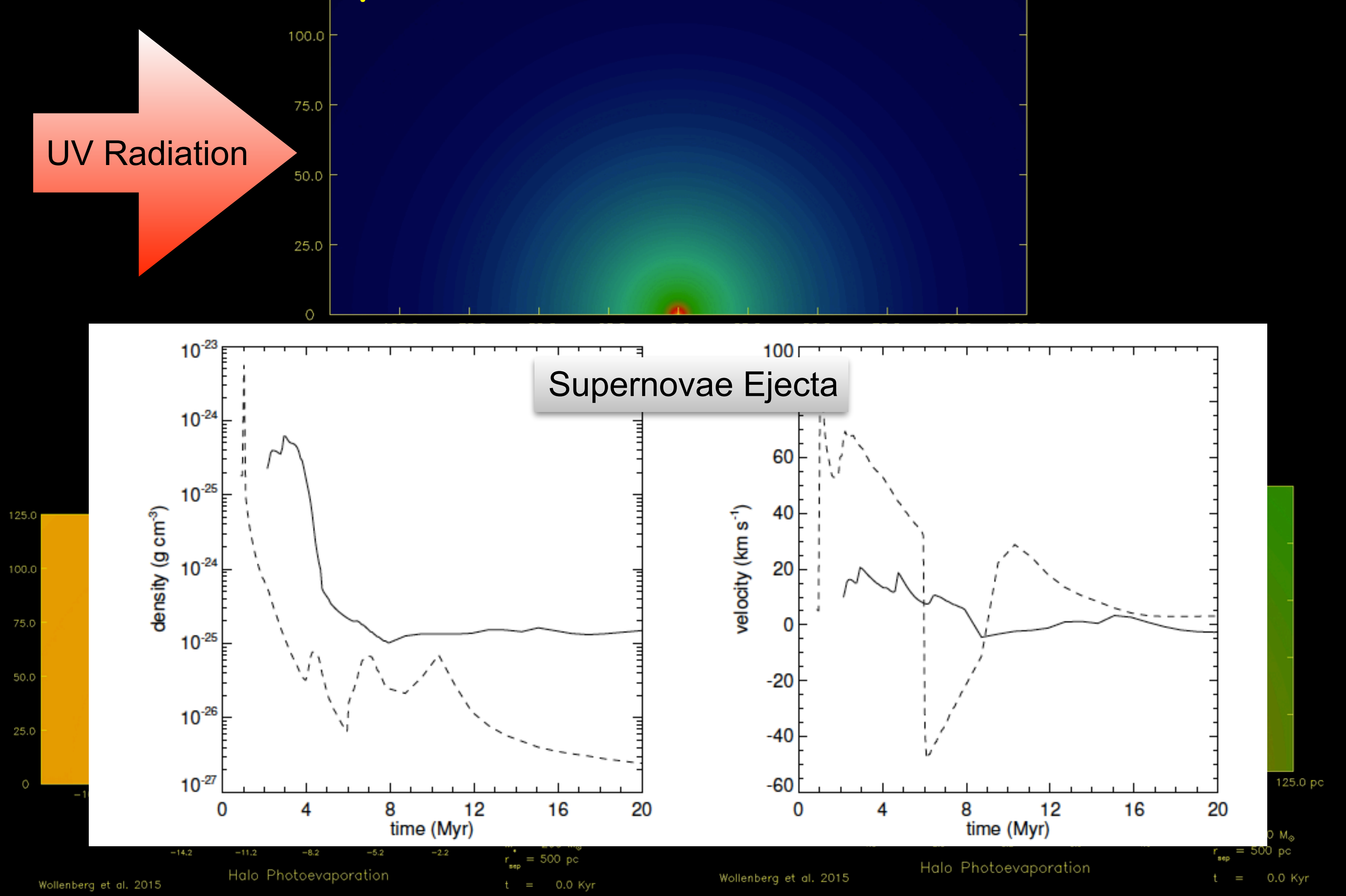
Cosmologist's Midas Touch

Resolving the small scales to understand mixing

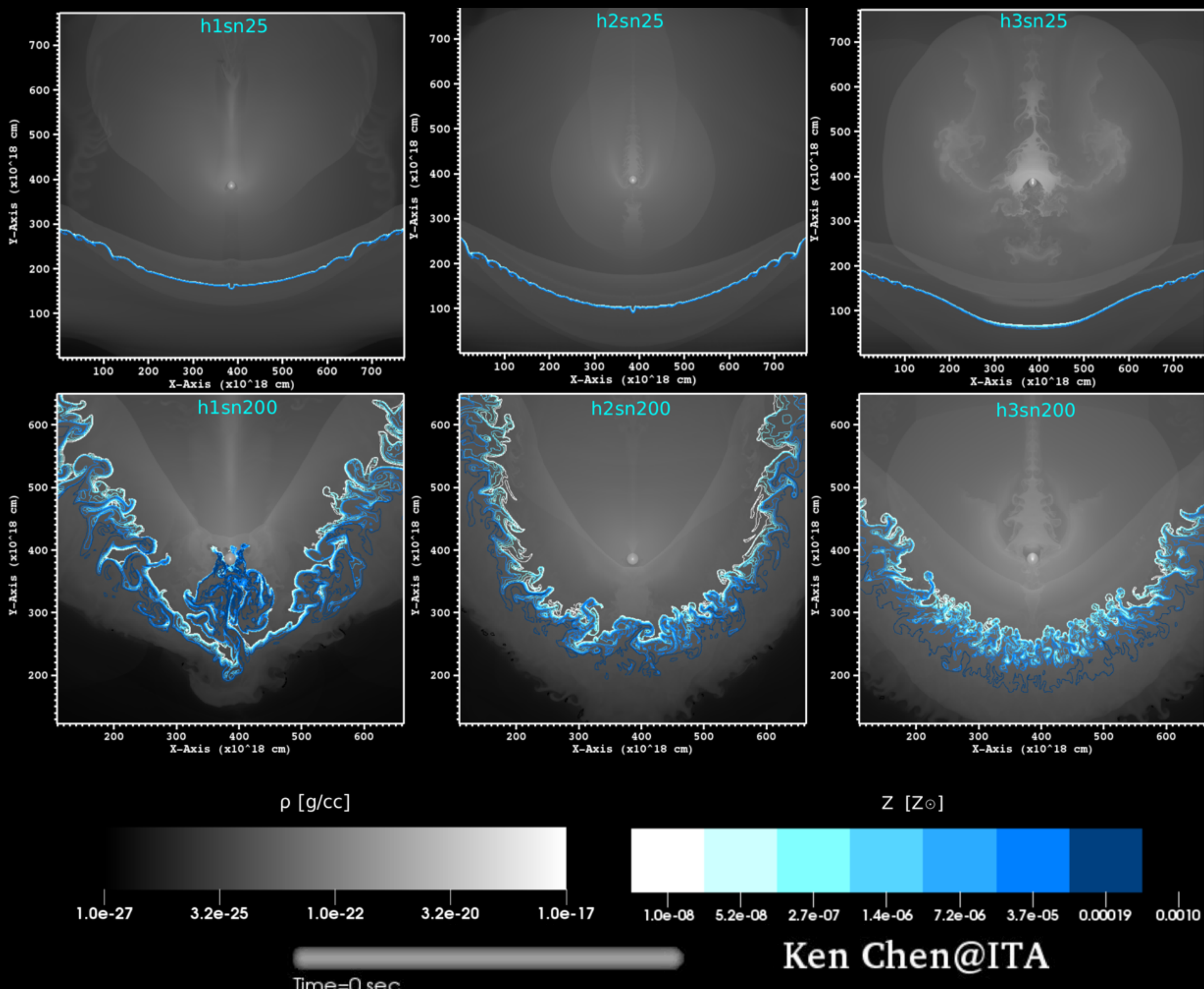


Multi-code Simulation Approaches

1D Kepler/ZEUS+ 2D ZEUS+ 2D/3DCASTRO



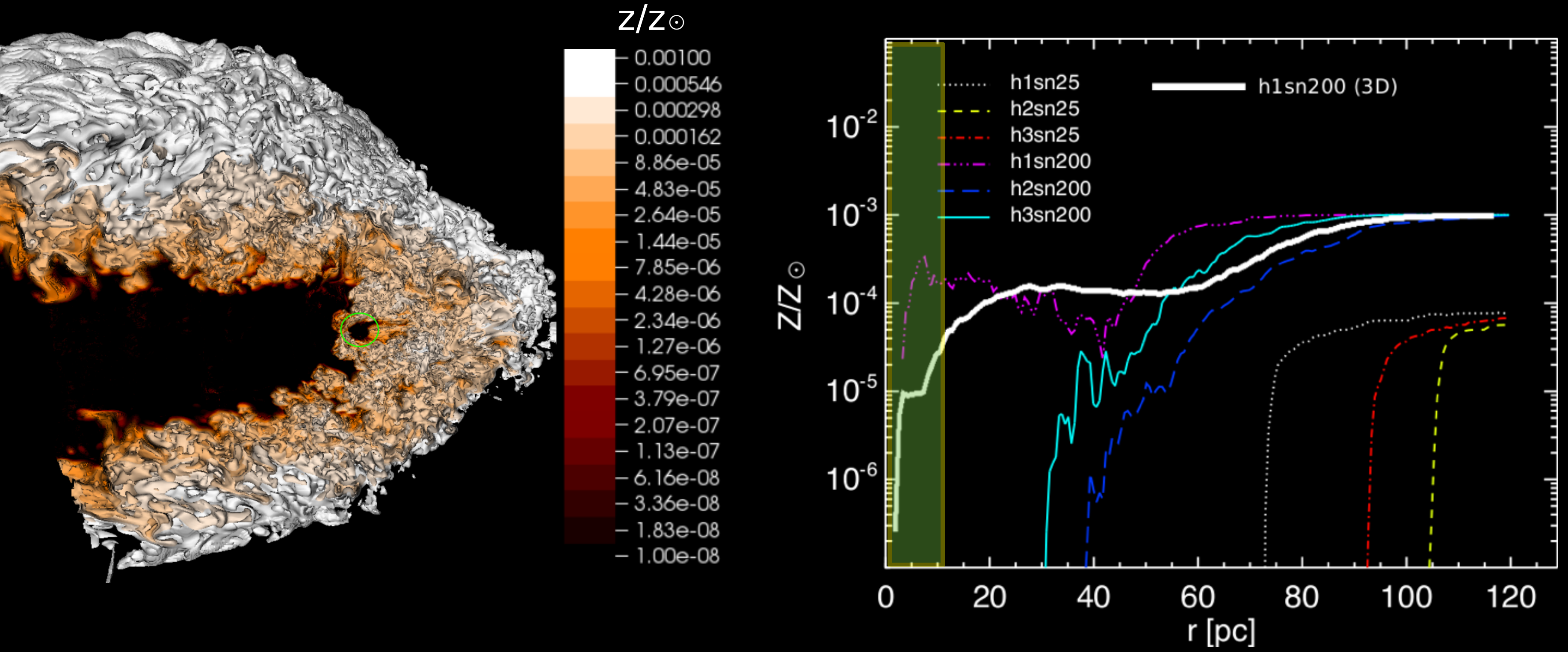
SN enrichment in the realistic setup



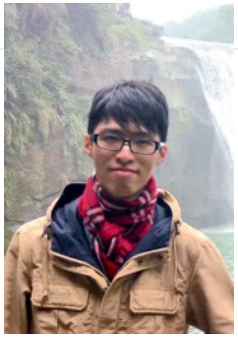
Ken Chen@ITA

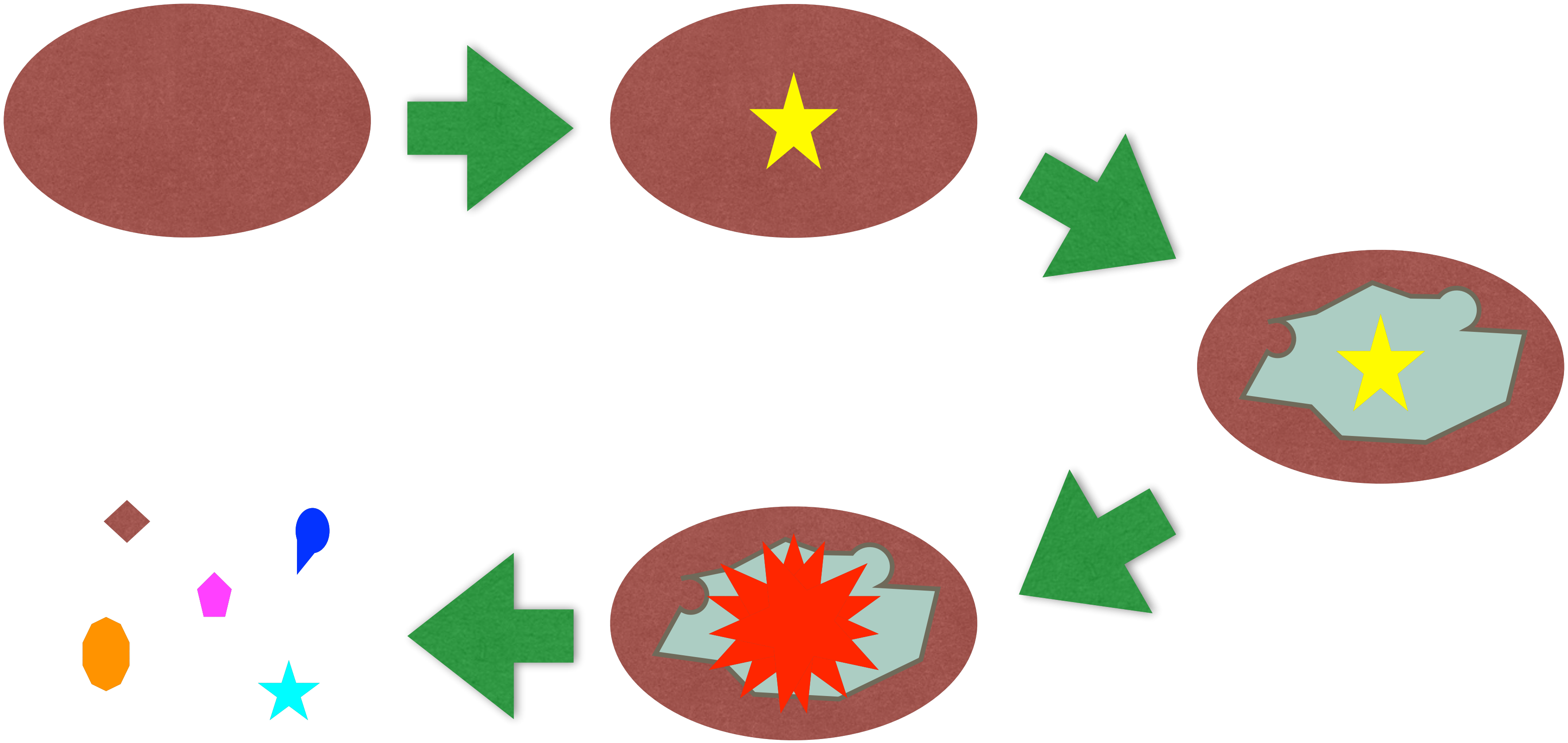
How deep can the metal go ??

Chen+ ApJ 844 111 (2017)



It requires very massive stars to do external enrichment

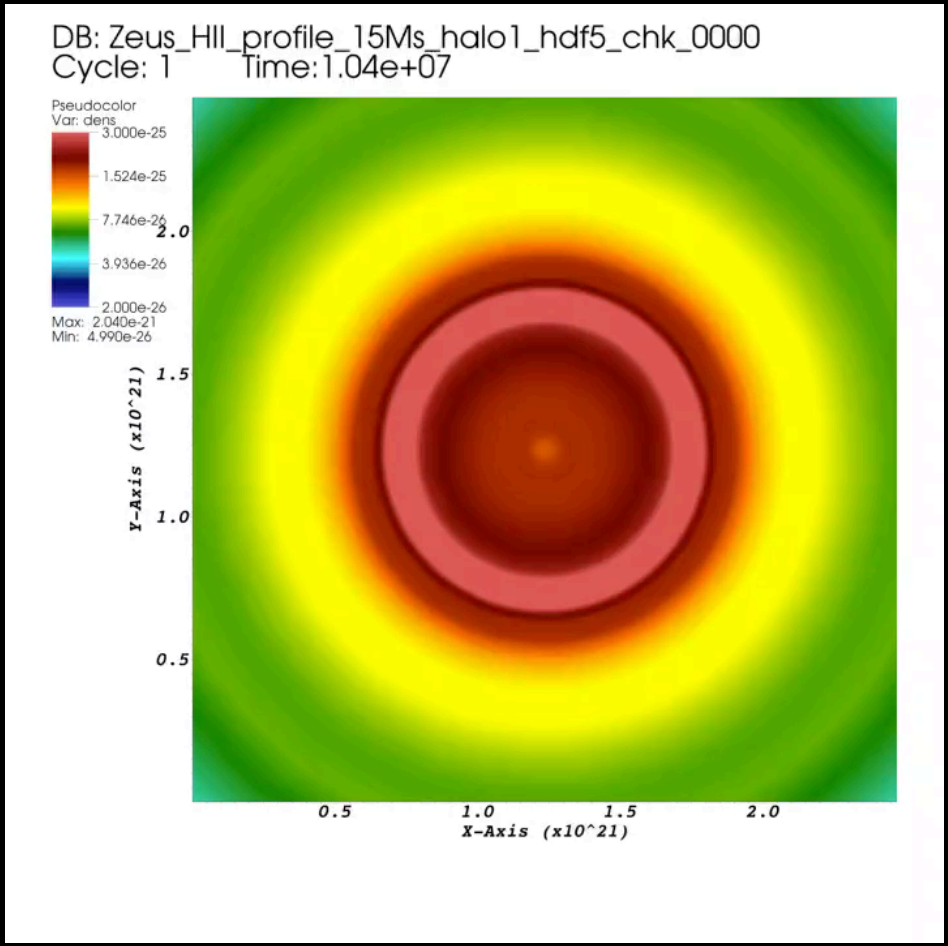




Mixing of the First Supernovae Metal

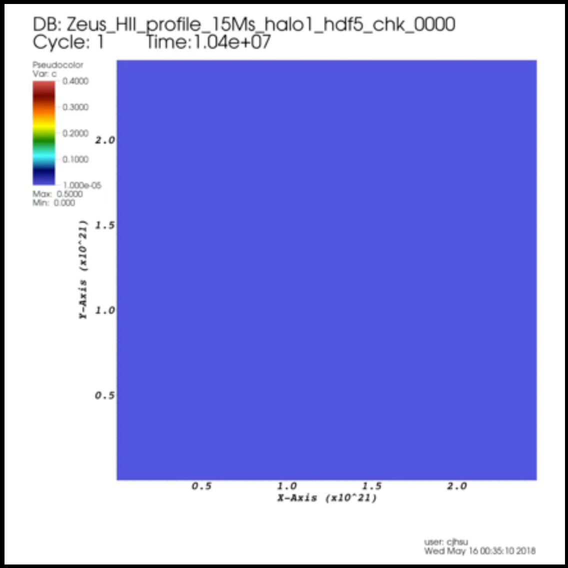
Chia-Jung Hsu
Chalmers University of Technology

- ZEUS-MP and FLASH
- Supernova in a photo-evaporated halo
- 15 solar-mass star with 10^{51} erg energy
- 10^{6} solar-mass halo



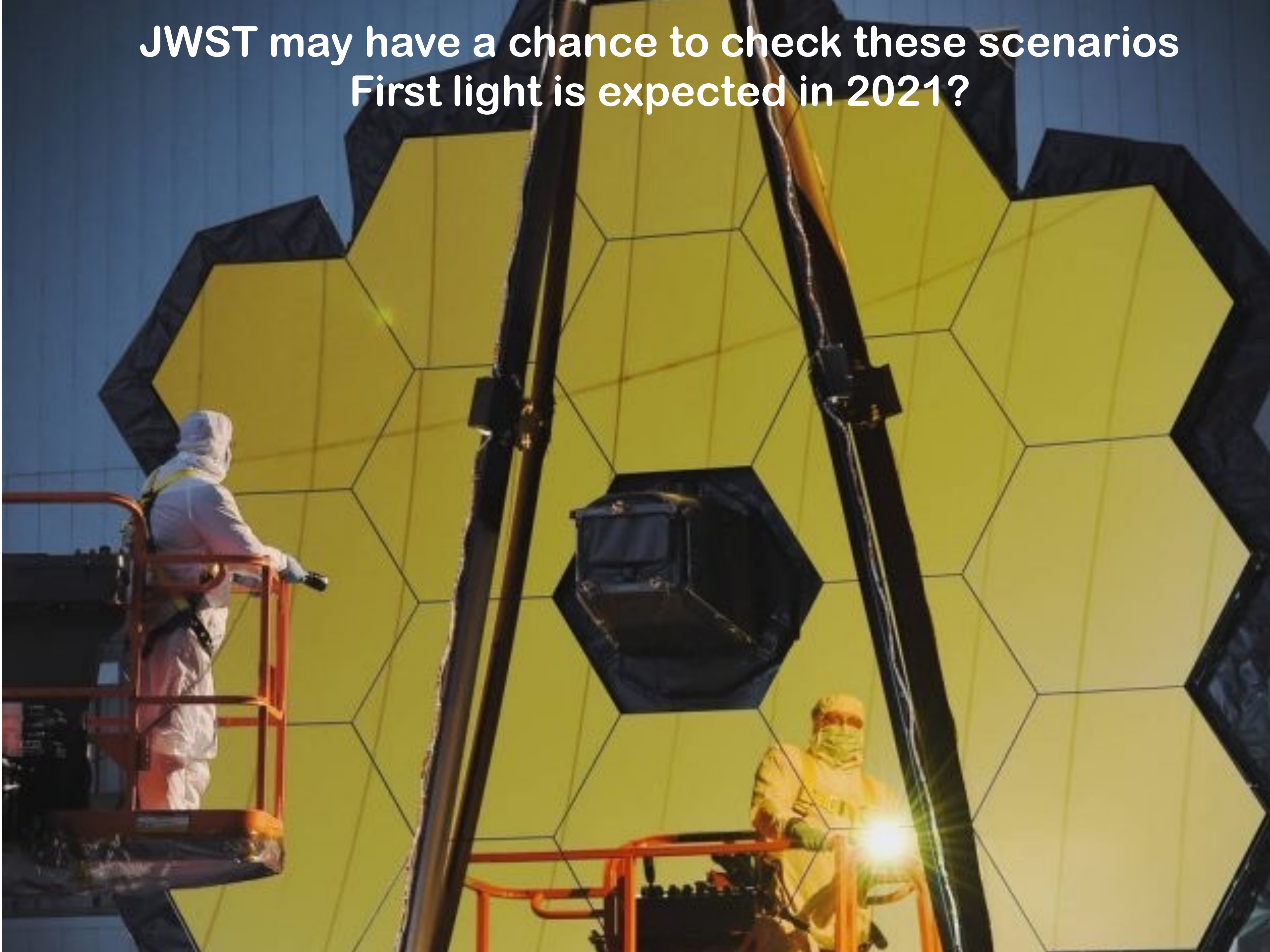
metal

dens



See Chia-Jung's Poster

JWST may have a chance to check these scenarios
First light is expected in 2021?



Many thanks for your attention

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