Type Ia supernova Nucleosynthesis

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Project Researcher

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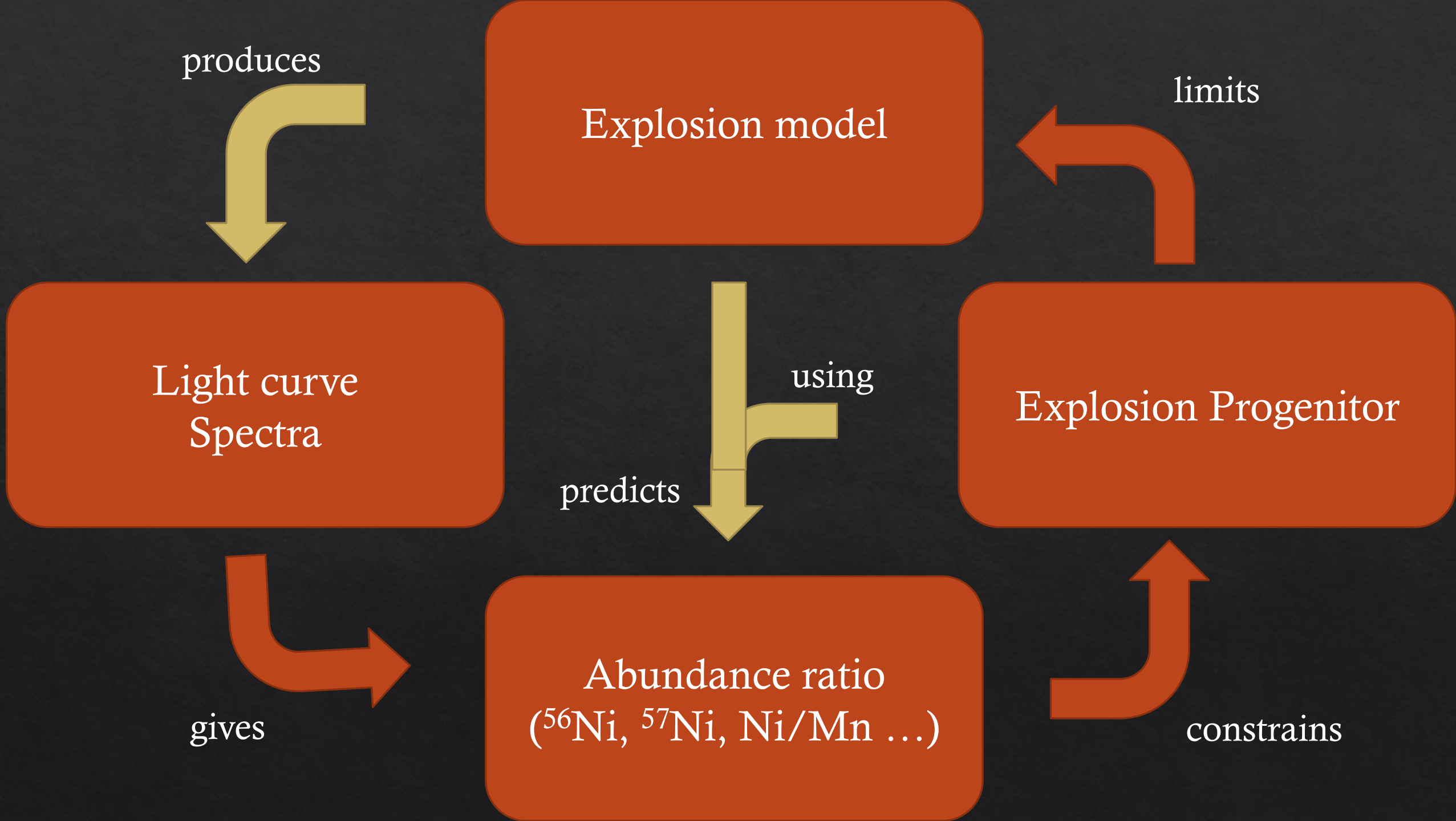
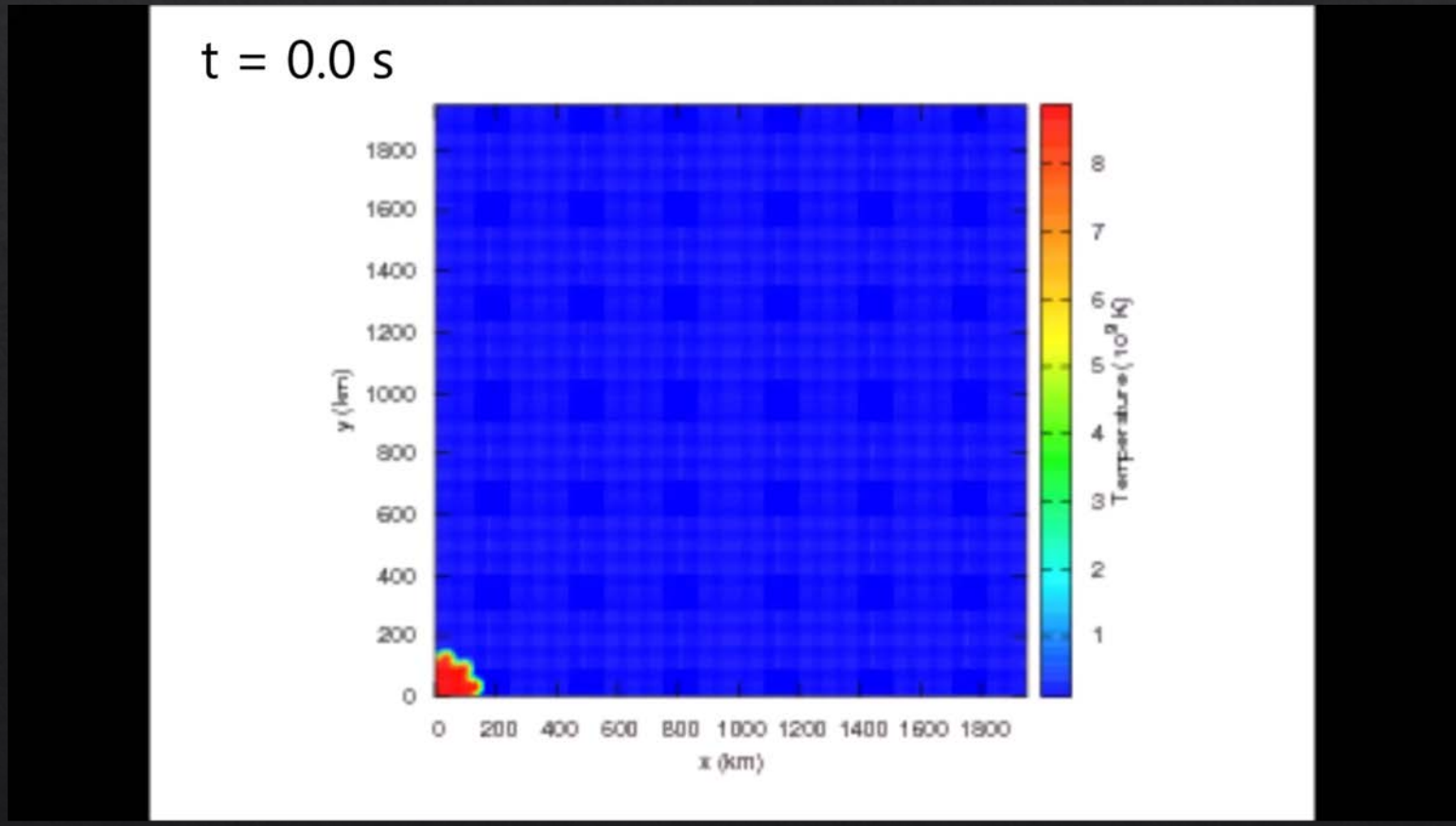
Based on Leung & Nomoto, submitted to ApJS, arXiv:1701.10007, 2019

In collaboration with Prof. Ken'ichi Nomoto (IPMU), Chiaki Kobayashi (Herts)


produces
Explosion model
limits
Light curve
Spectra
using
predicts
Explosion Progenitor
gives
Abundance ratio
(^{56}Ni, ^{57}Ni, Ni/Mn …)
constrains

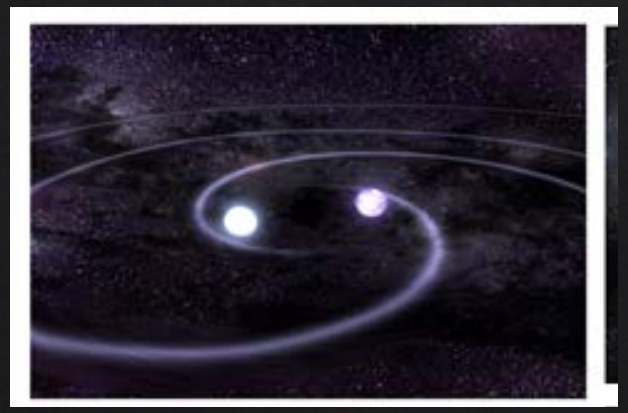
Chandrasekhar mass model

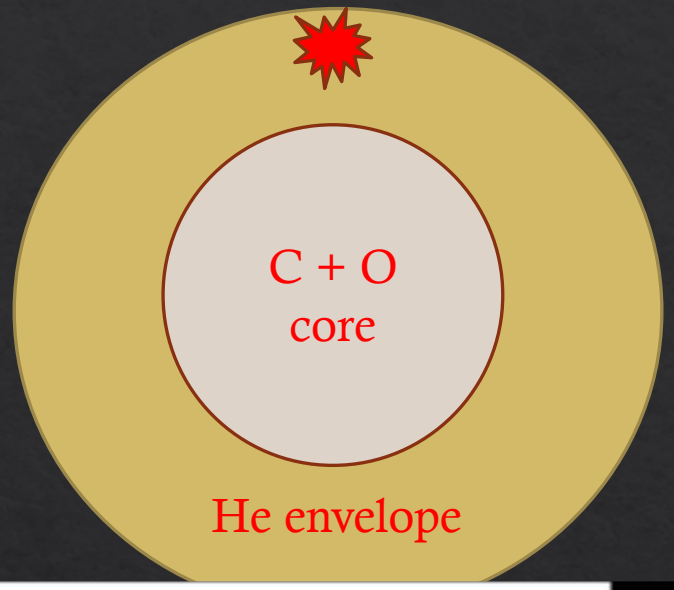
- ~50 models
- Turbulent deflagration model with deflagration – detonation transition
- Mass: 1.3 – 1.38 M_{sun}
- Metallicity: 0 – 5 Z_{sun}
- Center and off-center burning

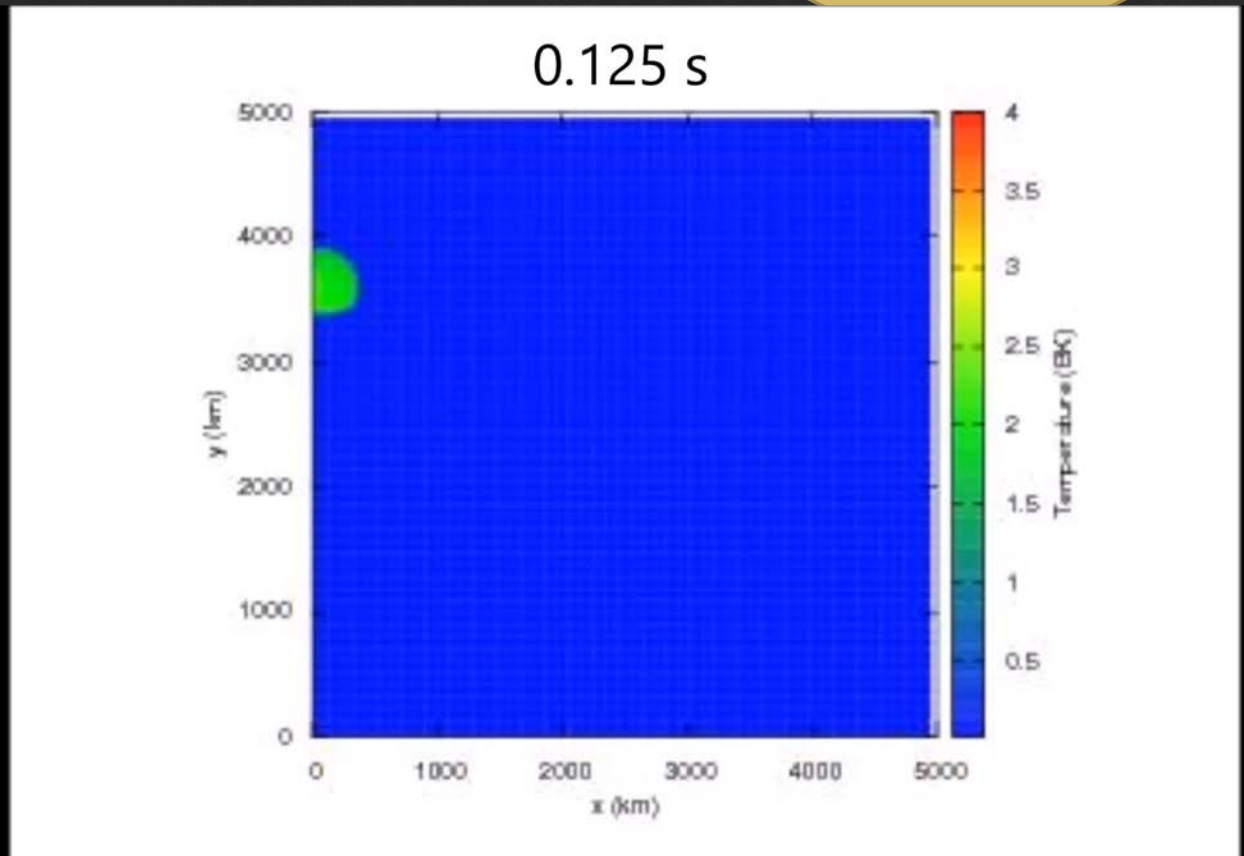


Sub-Chandrasekhar mass model

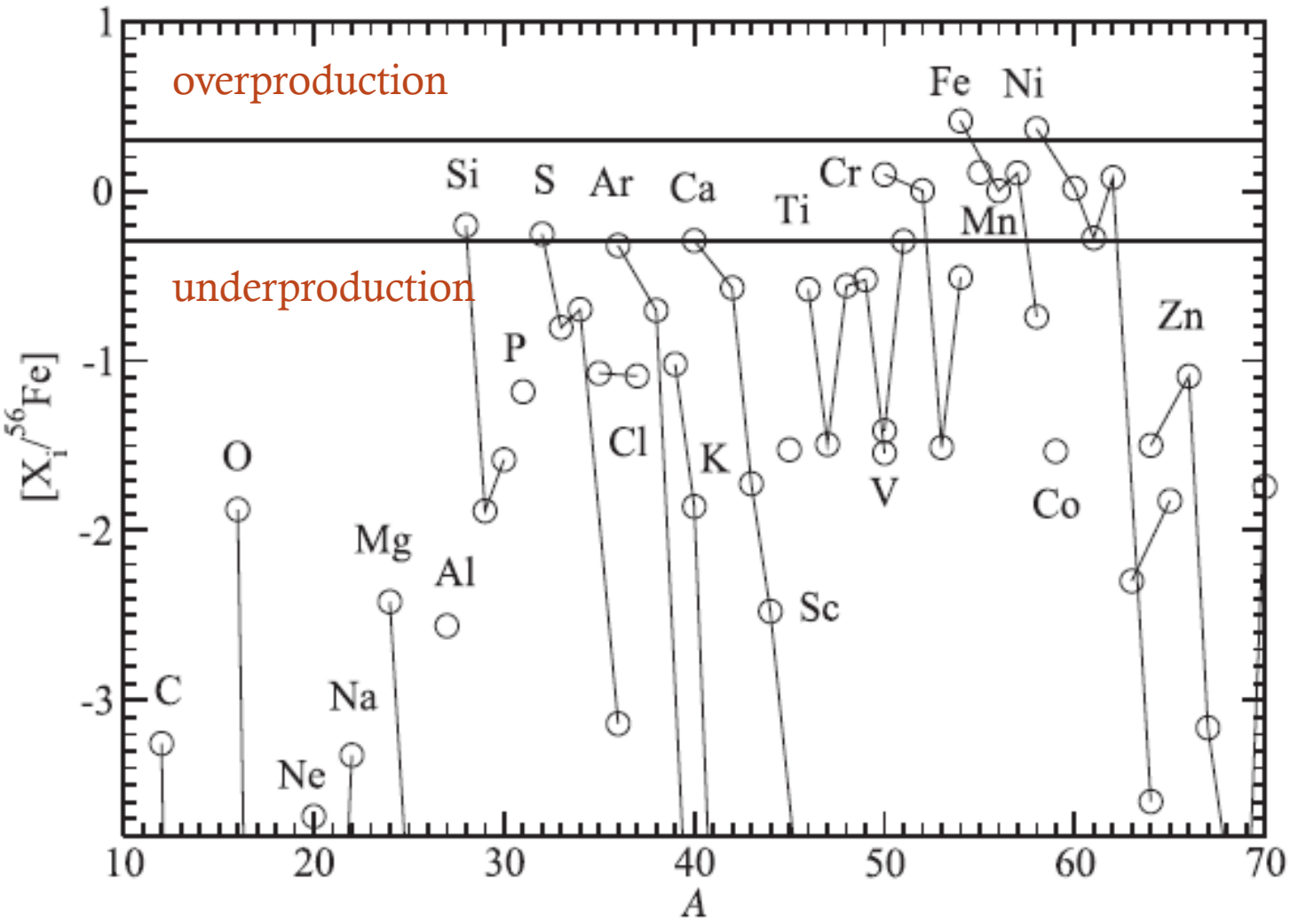
- ~50 models
- Double detonation model
- Mass: 0.9 – 1.25 M_{sun}
- Helium mass: 0.05 – 0.3 M_{sun}
- Metallicity: 0 – 5 Z_{sun}
- Spherical and aspherical initial detonation







Chandrasekhar mass model
Nucleosynthesis yield

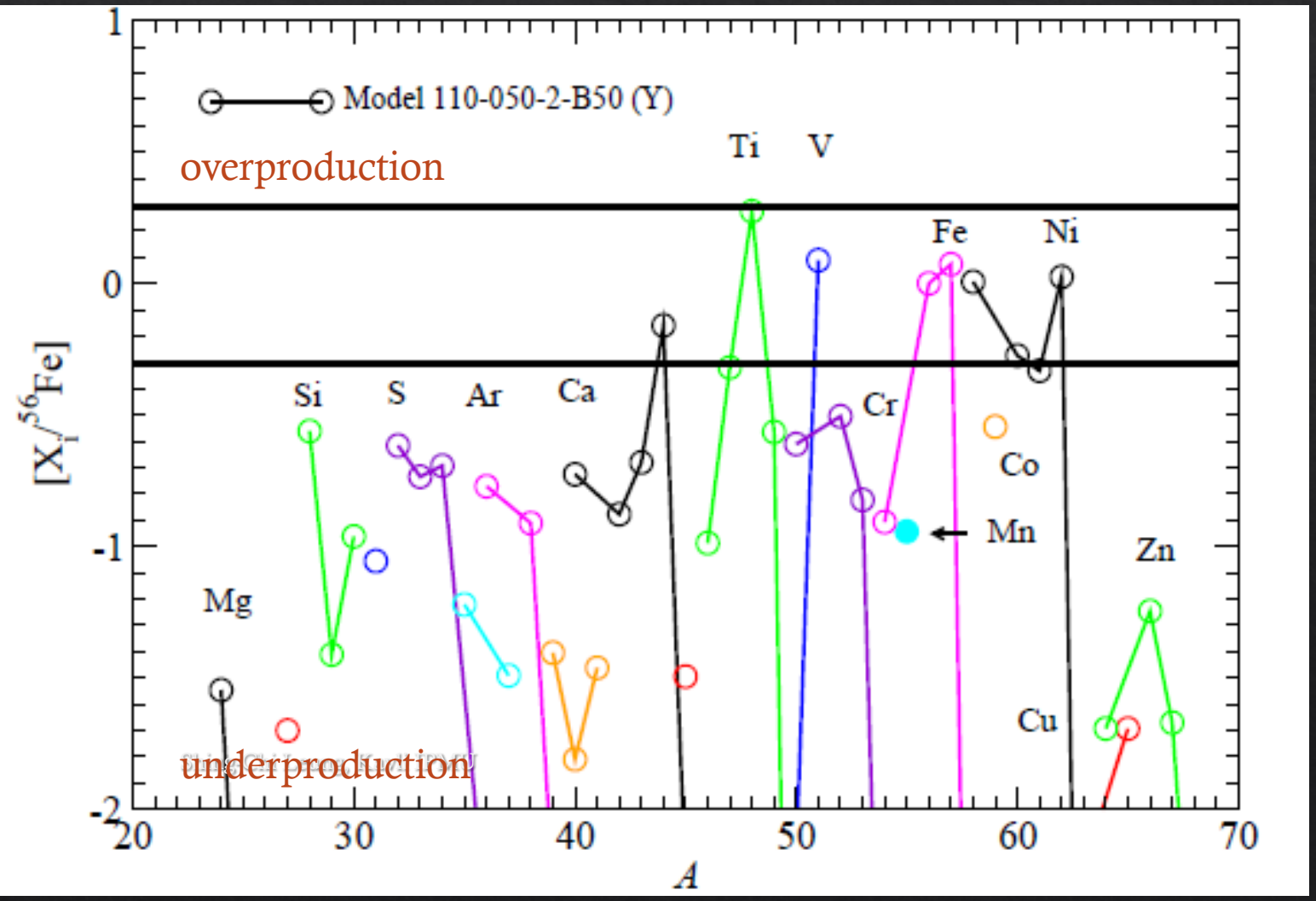


Benchmark model:
M = 1.37 solar mass
Z = 0.02
No helium envelope
Kalorvitz number ~ 1
$M(^{56}Ni) = 0.6\ M_{sun}$
$M(^{55}Mn) \sim 0.01\ M_{sun}$

$$[X/^{56}Fe] = \log_{10}[(X/^{56}Fe)_{model}/(X/^{56}Fe)_{sun}]$$

Reference:
Leung & Nomoto, ApJ 2018

Sub-Chandrasekhar mass white dwarf Nucleosynthesis Yield (M_{He} = 0.05)

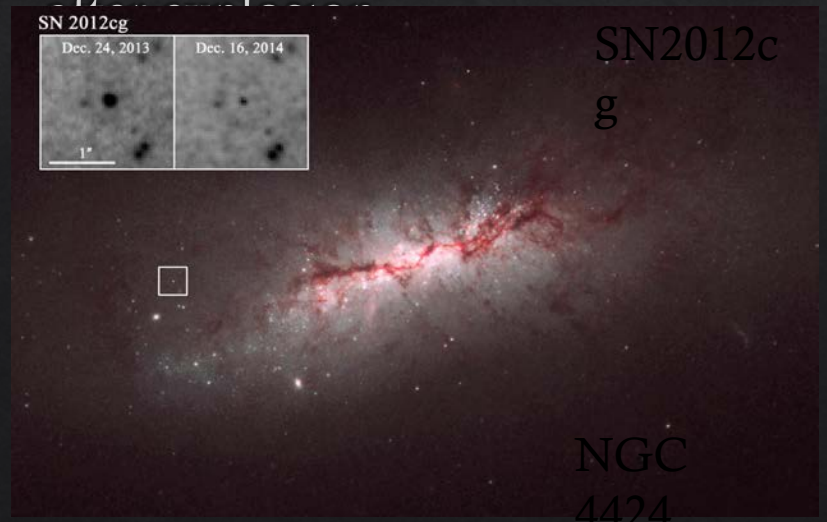


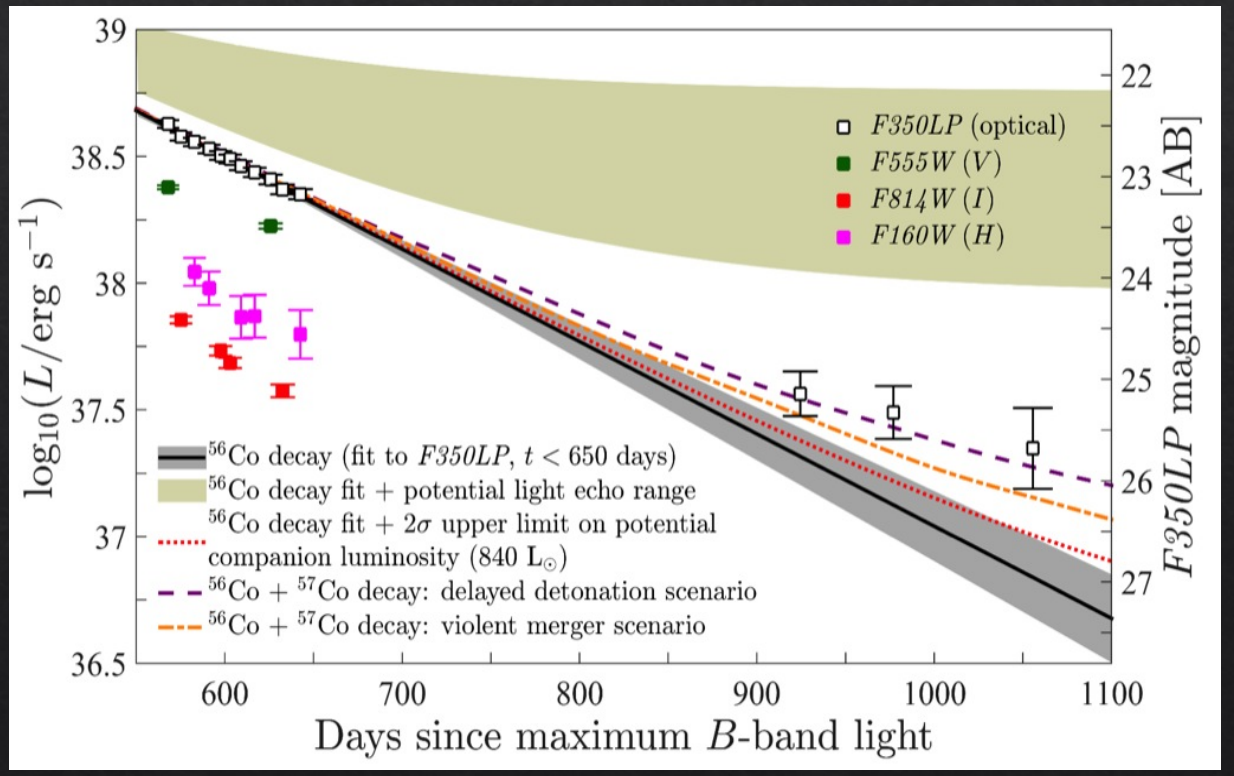
Benchmark model:
M = 1.0 M_{sun}
M(He) = 0.05 M_{sun}
Z = 0.02
Helium ring
M(^{56}Ni) = 0.6 M_{sun}

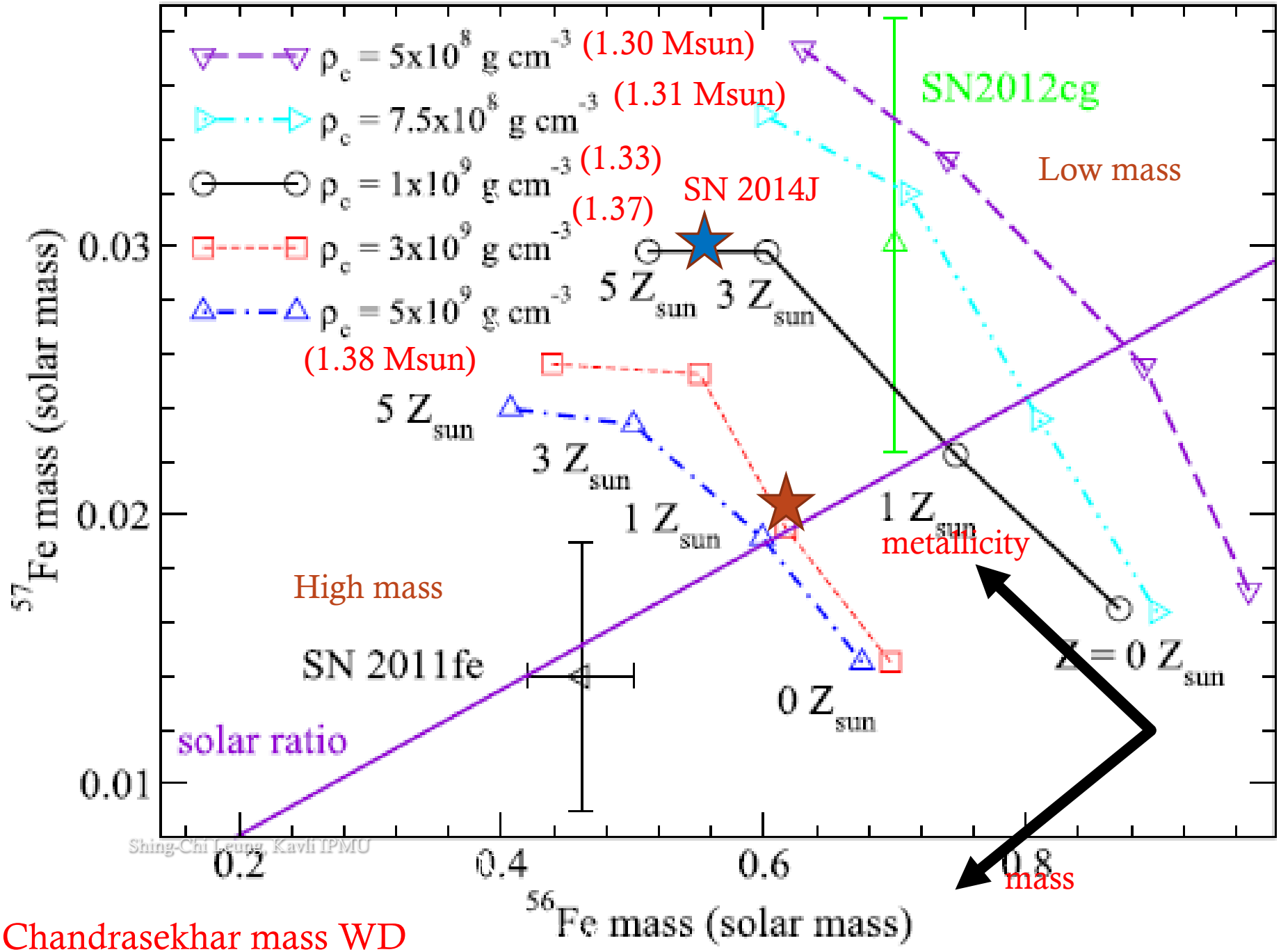
Reference:
Nomoto & Leung, SSRv 2018
Leung & Nomoto, submitted to ApJS, arXiv:1701.10007, 2019

Application 1a: Progenitor of observed SN Ia light curve

- The SN Ia after ~600 days becomes transparent (Nebular phase)
- Reveal the radioactive ^{57}Ni
- In Graur et al., ApJ (2016) the SN 2012cg is traced till ~1000 days







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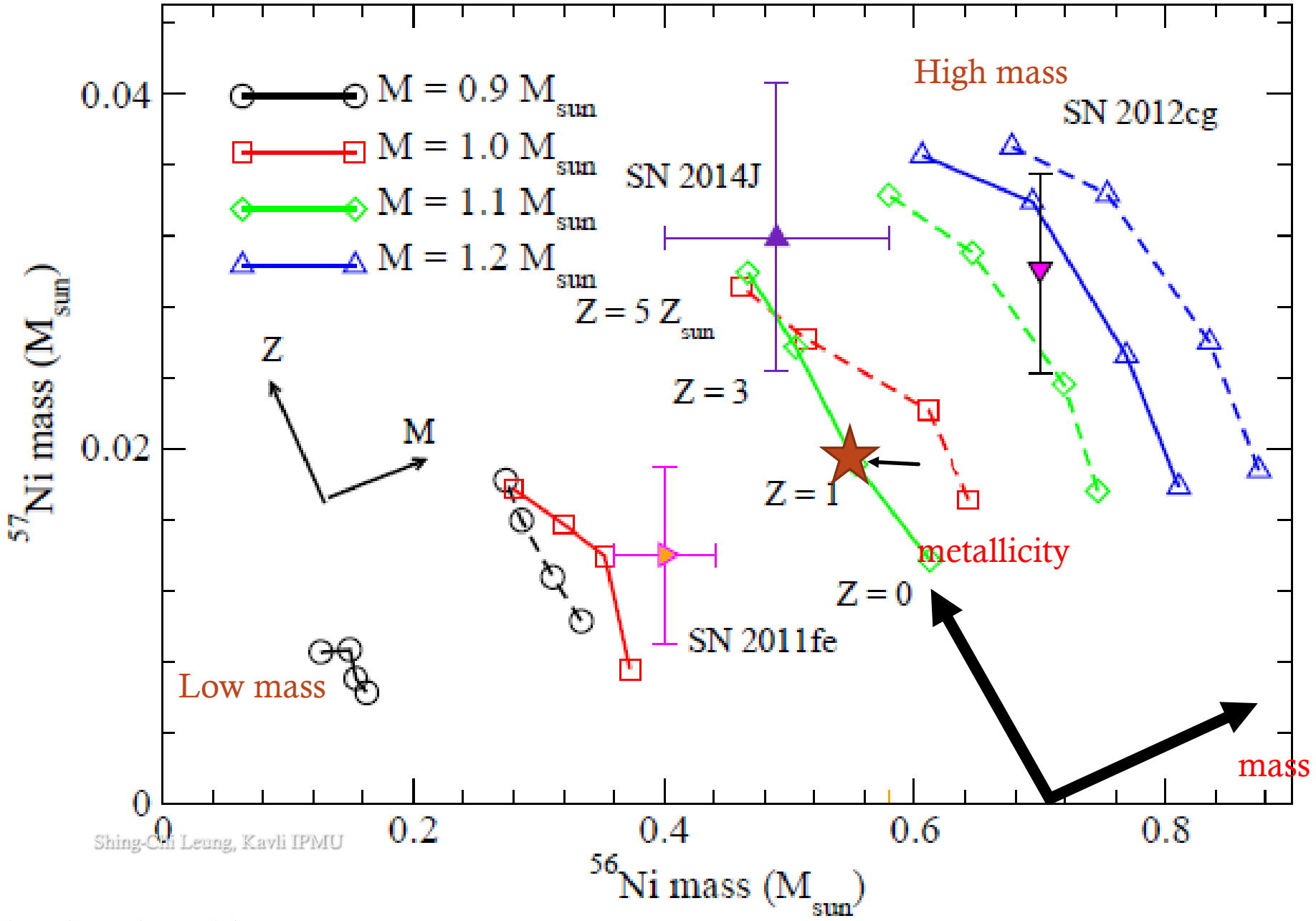
Chandrasekhar mass WD

Reference:
Leung & Nomoto, ApJ 2018

The coordinate in the mass-metallicity Parameter space

Benchmark model:
M = 1.37 M_{sun}
Z = 0.02
Central burning
M(^{56}Ni) = 0.6 M_{sun}
M(^{55}Mn) = 0.01M_{sun}



Sub-Chandrasekhar mass WD

Reference:Reference :
Leung & Nomoto, ApJS,
arXiv: 1901.10007
submitted

The coordinate in the mass-metallicity Parameter space

Benchmark model:
$M = 1.0\ M_{sun}$
$Z = 0.02$
Helium ring
$M(^{56}Ni) = 0.6\ M_{sun}$

Application 1b: Progenitor of observed SN Ia remnant spectra

- 3C 397: SN Ia remnant ~6 kpc away
- Irregular structure
- Exploded 1000 years ago

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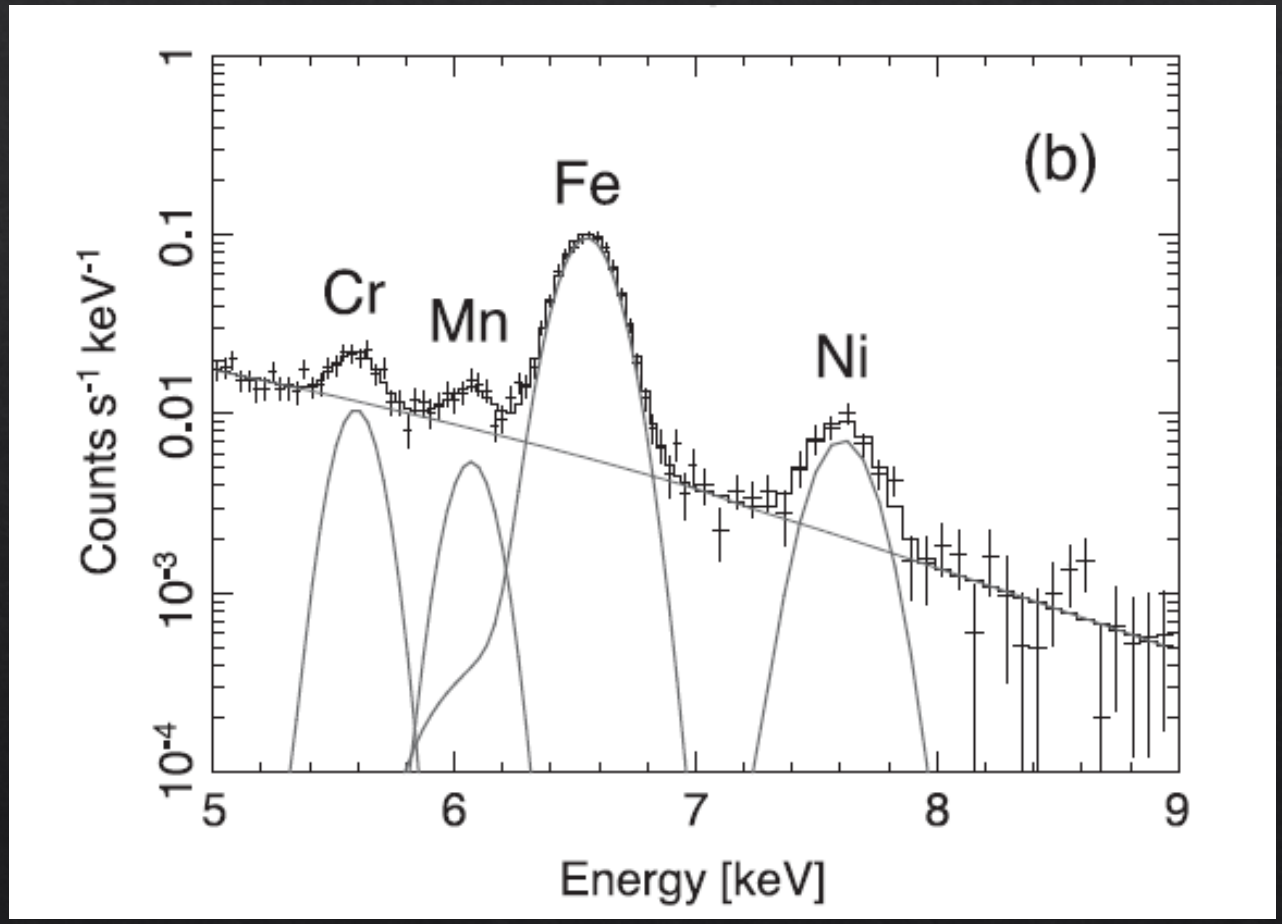
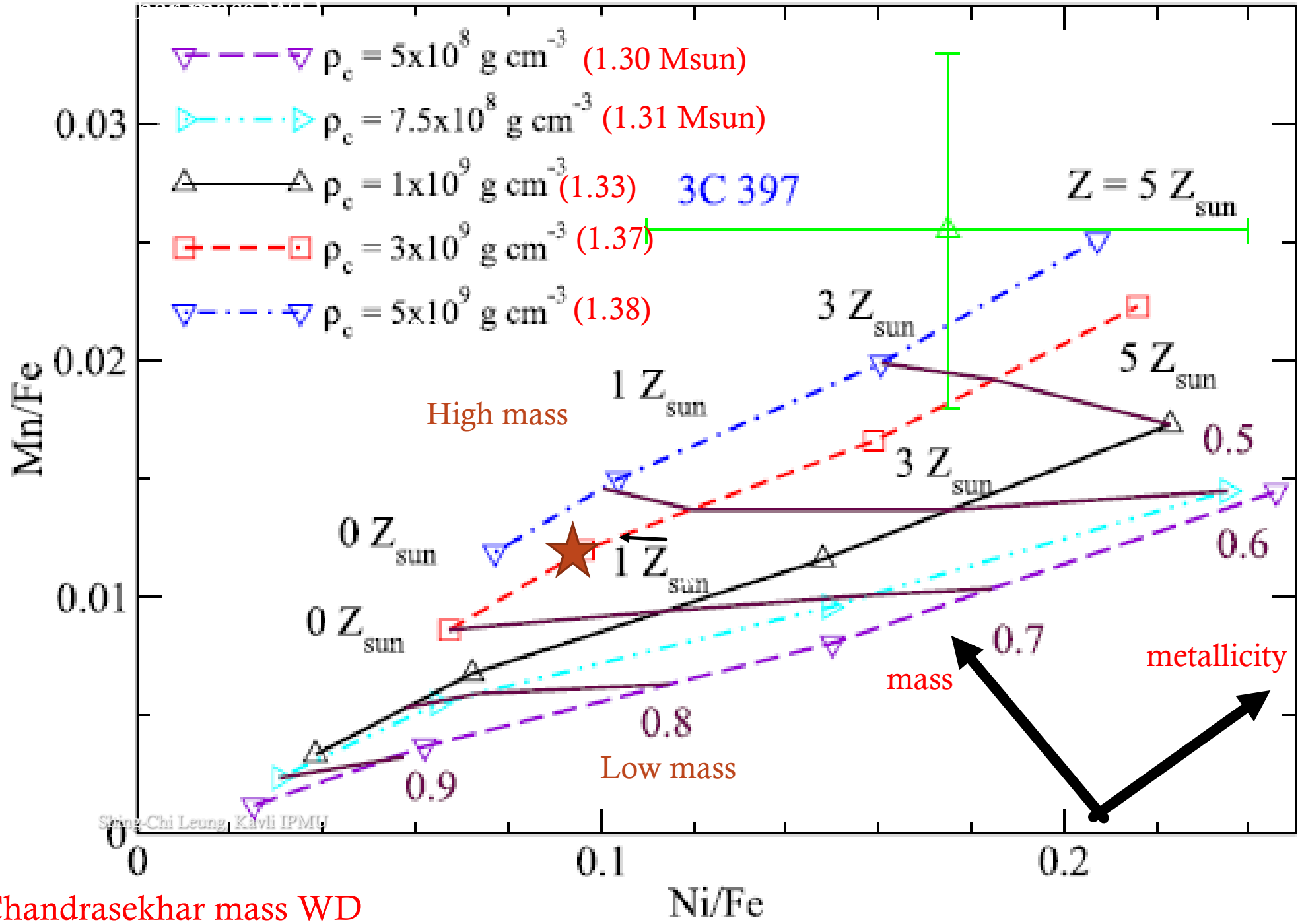


- Yamaguchi, H. et al., ApJ (2015)

X-ray spectra measured by Chandra and Suzaku

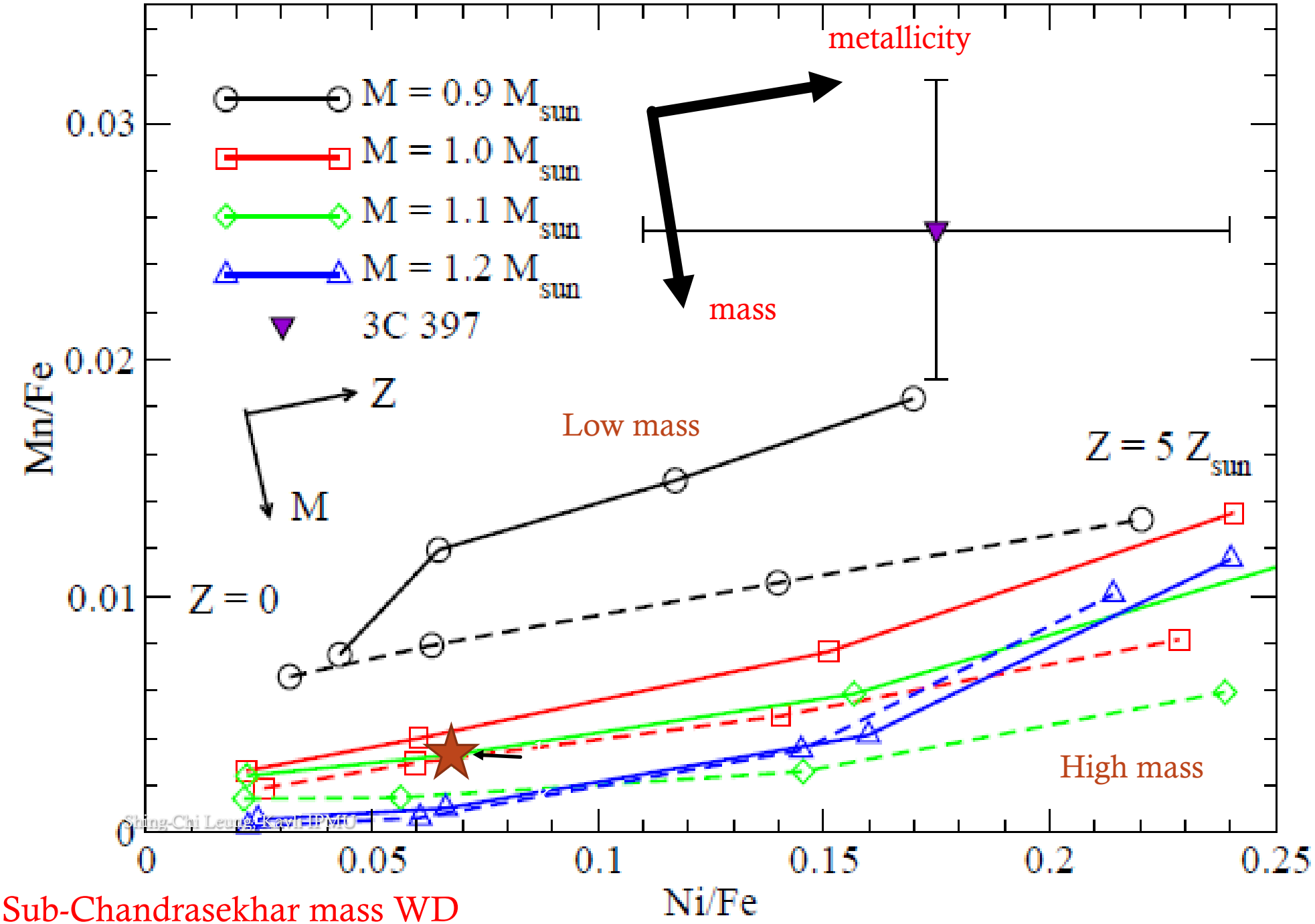


Reference: Leung & Nomoto, ApJ 2018

The coordinate in the mass-metallicity Parameter space

Chandrasekhar mass WD

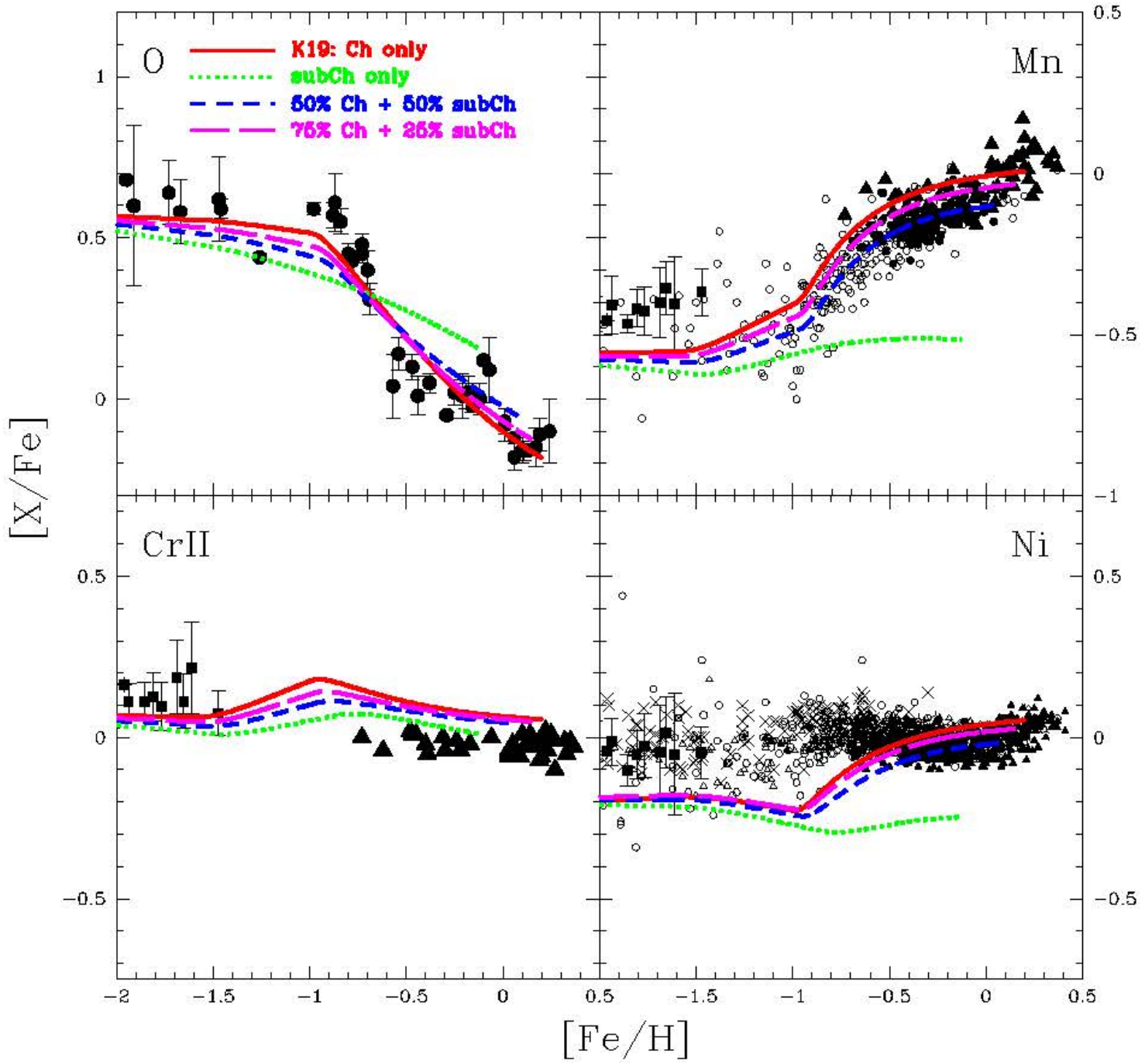
asekhar mass WD



Sub-Chandrasekhar mass WD

Reference:
Leung & Nomoto, ApJS, arXiv: 1901.10007 submitted

The coordinate in the mass-metallicity Parameter space



Galactic chemical evolution

- At least 75% of Chand Mass channel is necessary

Kobayashi, SCL, Nomoto, submitted to ApJ

Conclusion

	Chandrasekhar mass model	Sub-Chandrasekhar mass model
SN remnant	Yes	No
SN light curve	Yes SN2012cg, SN2014J	Yes SN2011fe, SN2012cg, SN2014J
Galactic chemical evolution	Majority	Minority

- More supernova remnant data?
  - Spatial distribution?
- How to reproduce observed diversity?