Cas A 超新星残骸中のダストの進化と熱放射

野沢　貴也

東京大学数物連携宇宙研究機構（IPMU）

共同研究者

小笹 隆司(北大), 冨永望 (国立天文台), 前田啓一(IPMU), 梅田秀之 (東大), 野本憲一 (IPMU/東大)

1-1. Introduction

○ Dust in SNRs

- CCSNe are important sources of dust?
  - — formation of dust in the ejecta of SNe
  - — destruction of dust by the reverse shock

  ➔ What kind and how much amount of dust are supplied by CCSNe?

- physical processes of dust in shocked gas
  - — erosion by sputtering and collisional heating

- IR thermal emission from shock-heated dust

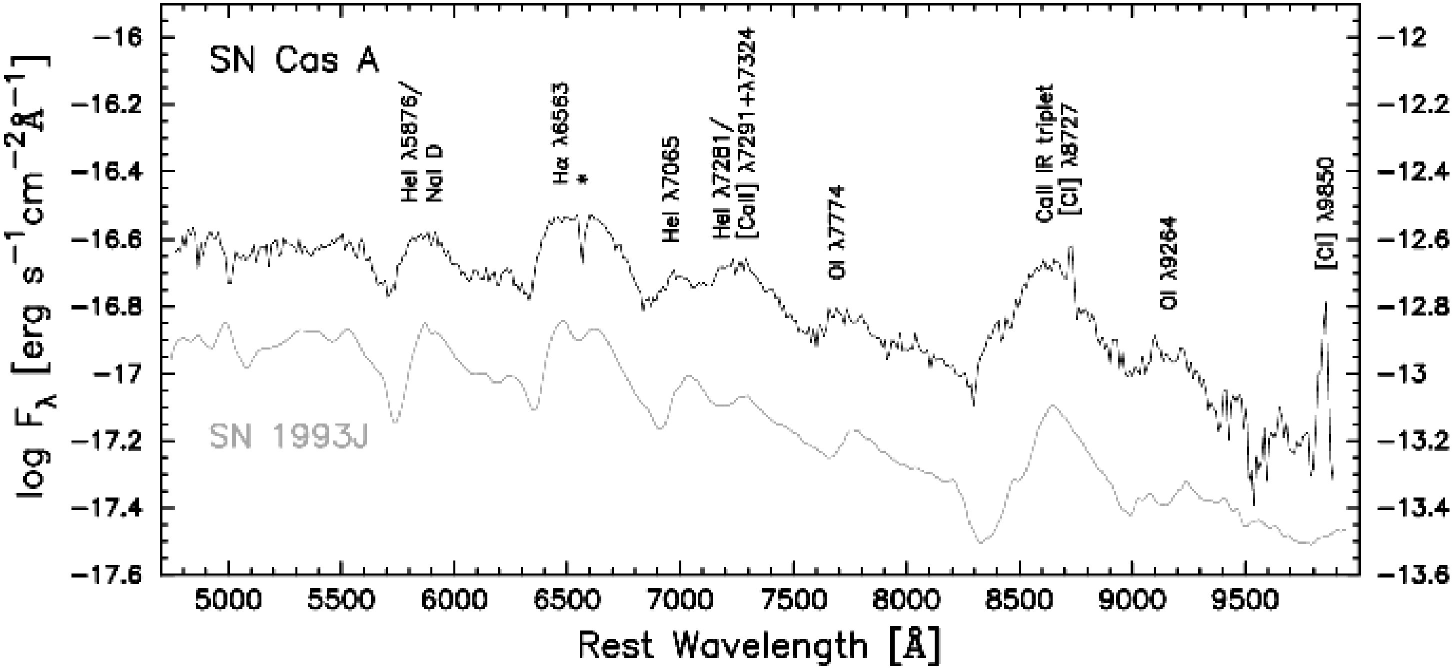
  ➔ structure of circumstellar medium and mass-loss history of progenitor star

➡ young remnants of CCSNe!

1-2. Cassiopeia A SNR

○ Cas A SNR

- age: ~340 yr (Thorstensen et al. 2001)
- distance: d=3.4 kpc (Reed et al. 1995)



...)

- **SN type : Type IIb** (M$_{star}$=15-20 M$_{sun}$)

(Usuda-san's talk; Krause et al. 2008)

1-3. Aim of our study

- **Formation of dust in the ejecta of Type IIb SN**

  ➔ **composition, size, and mass of newly formed dust**
  ➔ **dependence of dust formation process on types of SNe (on the thickness of H envelope)**

- **Evolution of dust in shocked gas within the SNR**

  ➔ **What fraction of newly formed dust can survive and is injected into the ISM?**

- **Thermal emission from shock-heated dust**

  ➔ **comparison with IR observations of Cas A**
  ➔ **constraint to gas density in the ambient medium**

2-1. Dust formation calculation

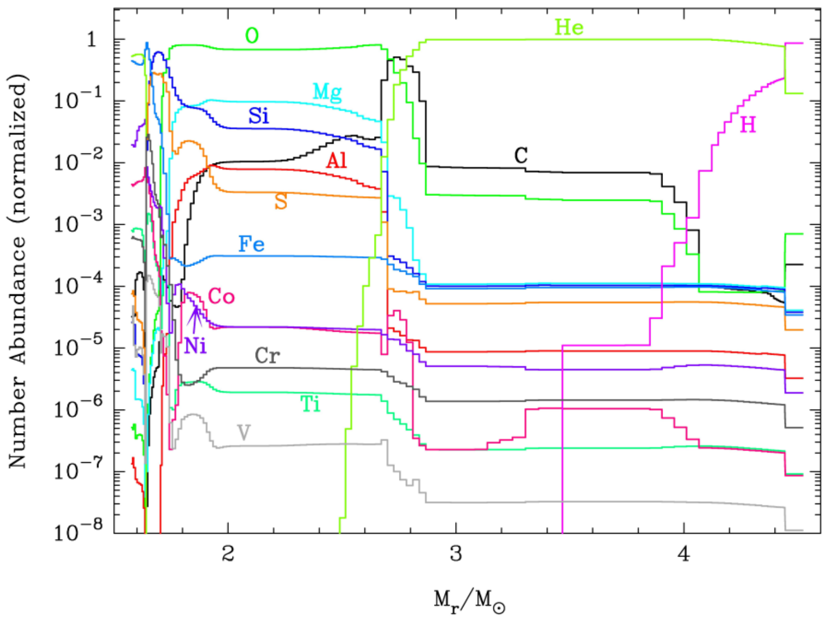
○ Type IIb SN model

(SN1993J-like model)

– M_{eje} = 2.94 M_{sun}
  $M_{H\text{-}env}$ = 0.08 M_{sun}
  M_{star} = 18 M_{sun}

– E_{51} = 1

– $M(^{56}Ni)$ = 0.07 M_{sun}

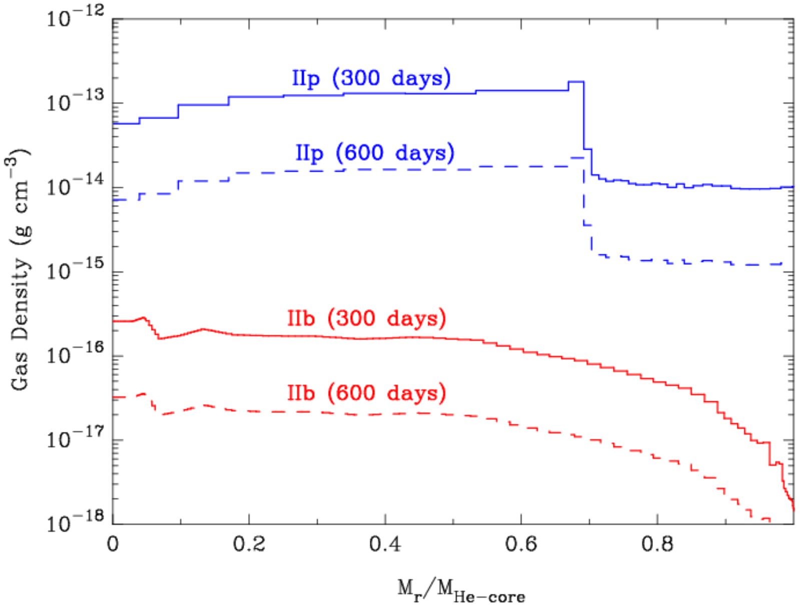


○ Dust formation calculation

– non-steady nucleation and grain growth theory

(Nozawa et al. 2003)

– onion-like composition



2-2. Composition and mass of dust formed

Mass of dust formed

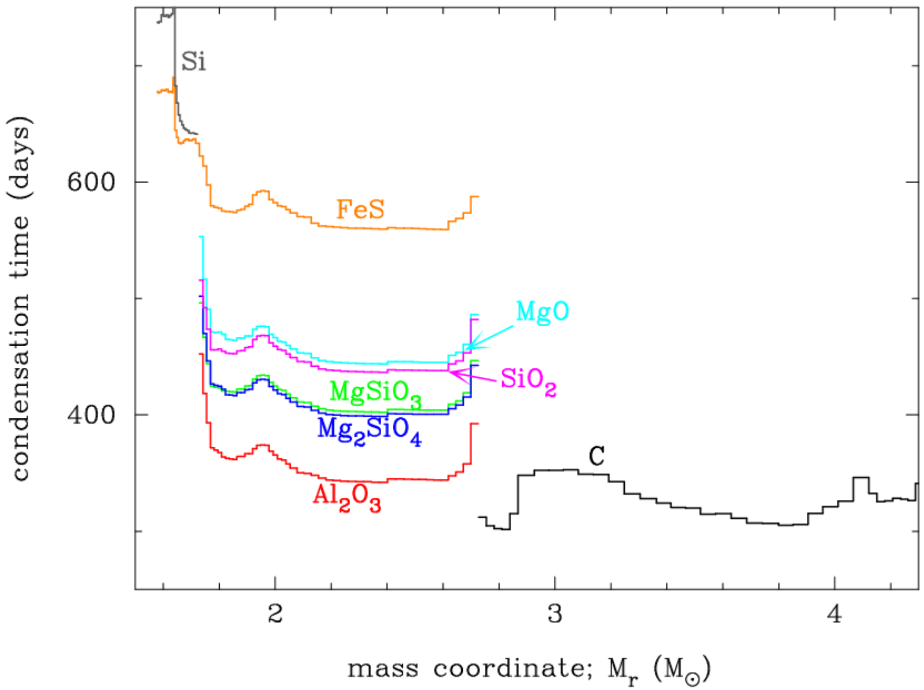
dust species	$M_{d,j}$ ($M_\odot$)	$M_{d,j}/M_{d,total}$
C	7.08×10^{-2}	0.423
Al_2O_3	6.19×10^{-5}	3.7×10^{-4}
Mg_2SiO_4	1.74×10^{-2}	0.104
$MgSiO_3$	5.46×10^{-2}	0.326
SiO_2	1.57×10^{-2}	0.094
MgO	2.36×10^{-3}	0.014
FeS	1.47×10^{-3}	0.009
Si	5.07×10^{-3}	0.030
total	0.167	1

Total mass of dust :

0.167 Msun in SN IIb

0.1-2 Msun in SN IIP

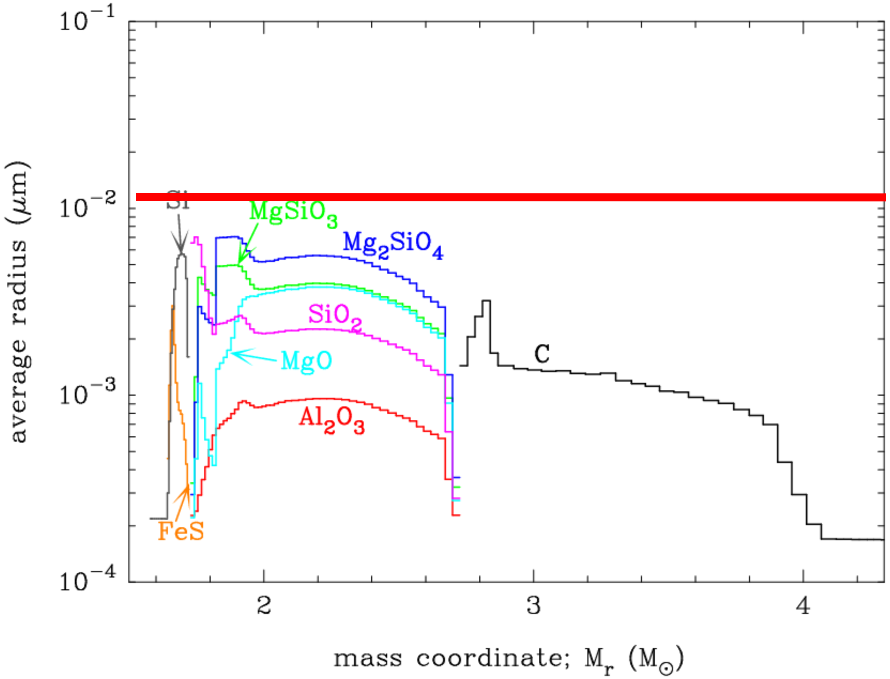
condensation time

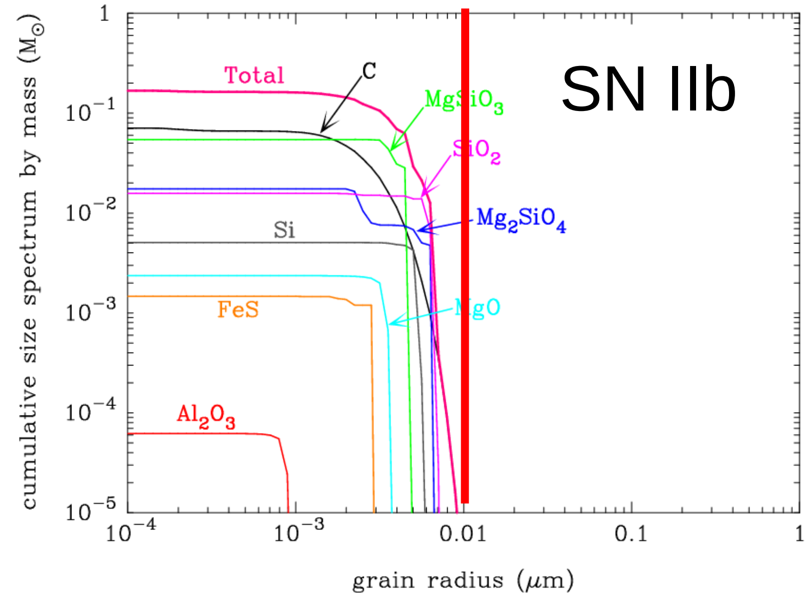


- various kinds of dust can condense in each layer
- condensation time: 300-700 days

2-3. Radius of dust formed in the ejecta

average radius



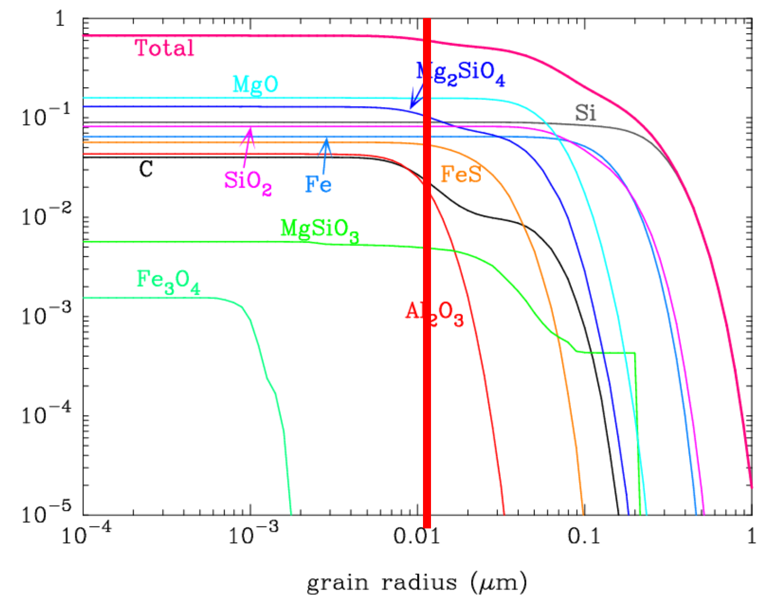


Grain radius

➔ **> 0.01 μm for SN IIP**

➔ **< 0.01 μm for SN IIb**

Dust grains formed in H-deficient SNe are small



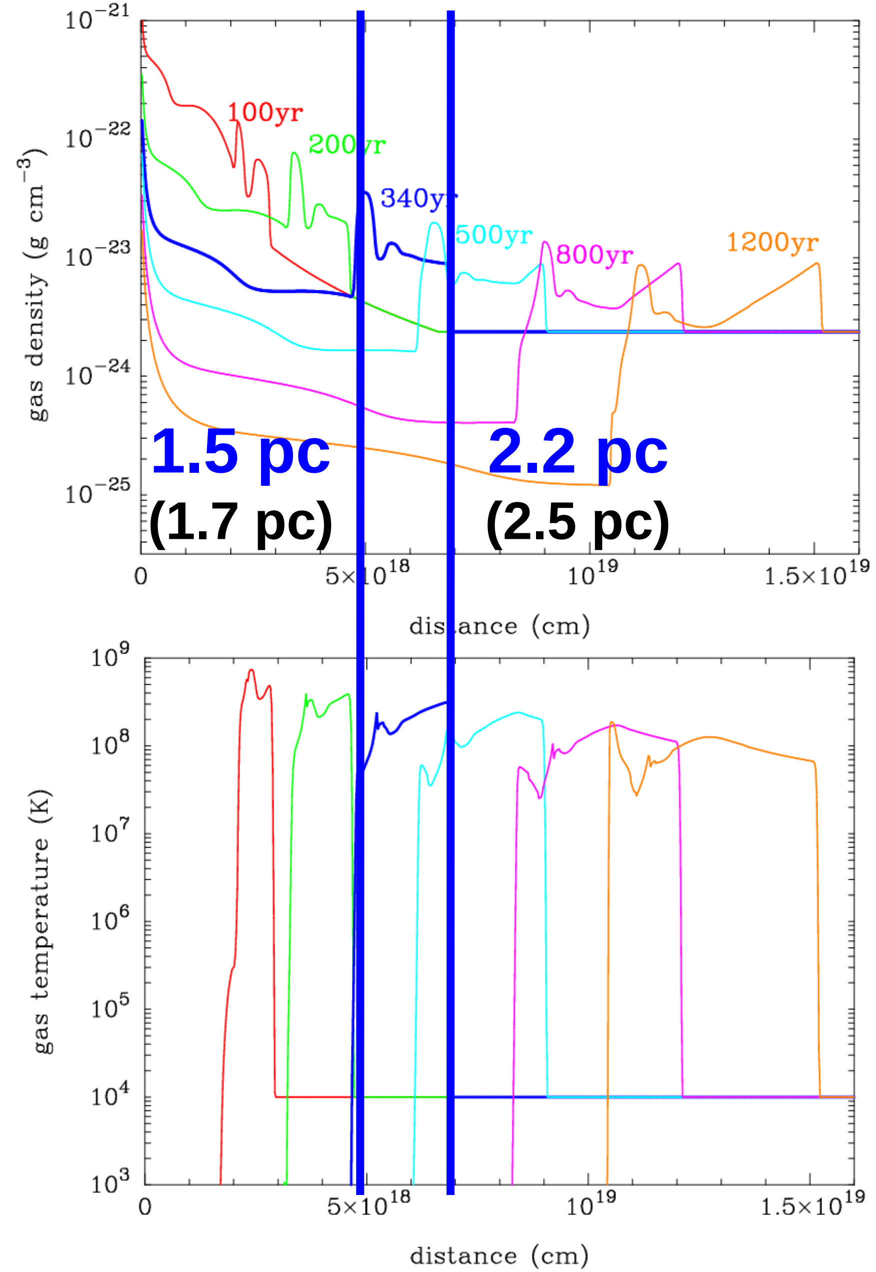
SN IIp (Mstar=20 Msun)

3-1. Calculation of dust evolution in SNRs

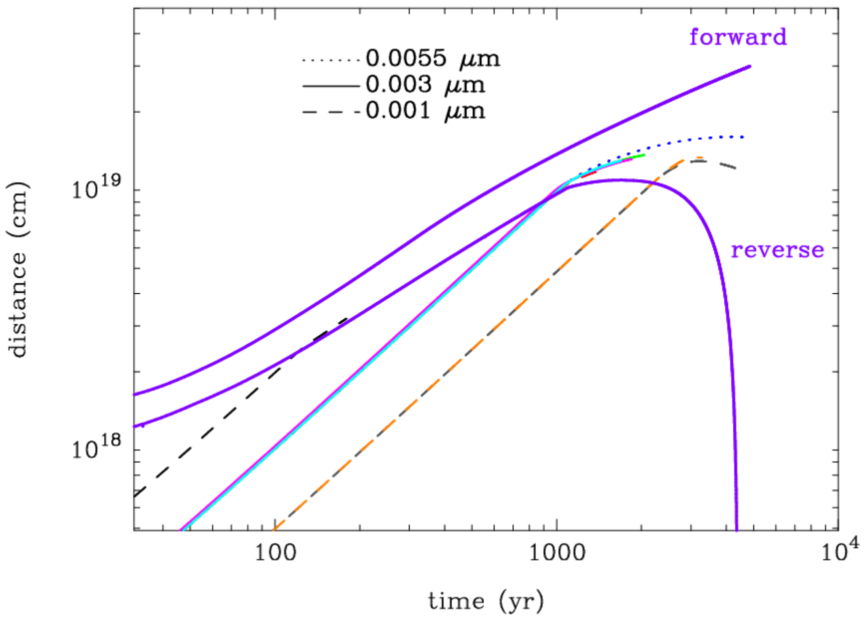
○ Model of calculations

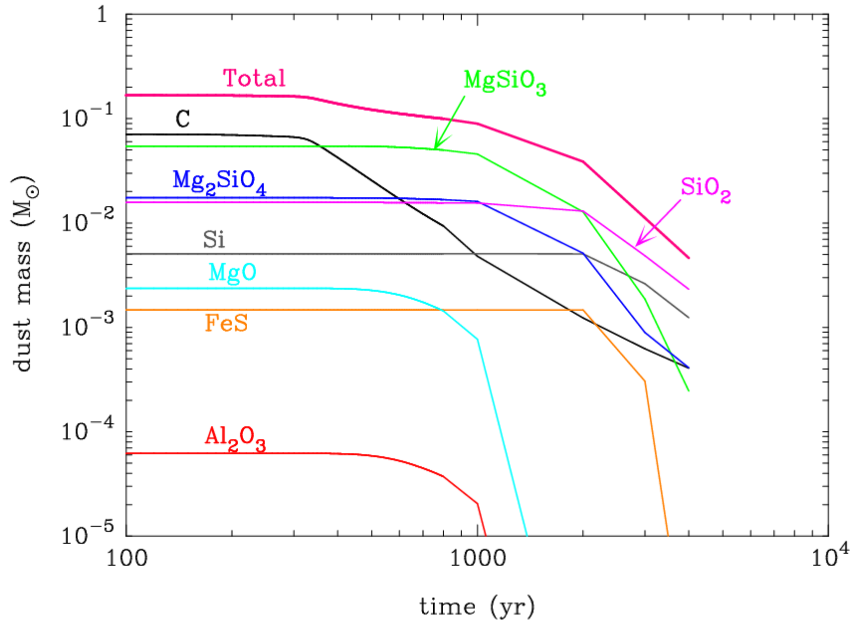
(Nozawa et al. 2006, 2007)

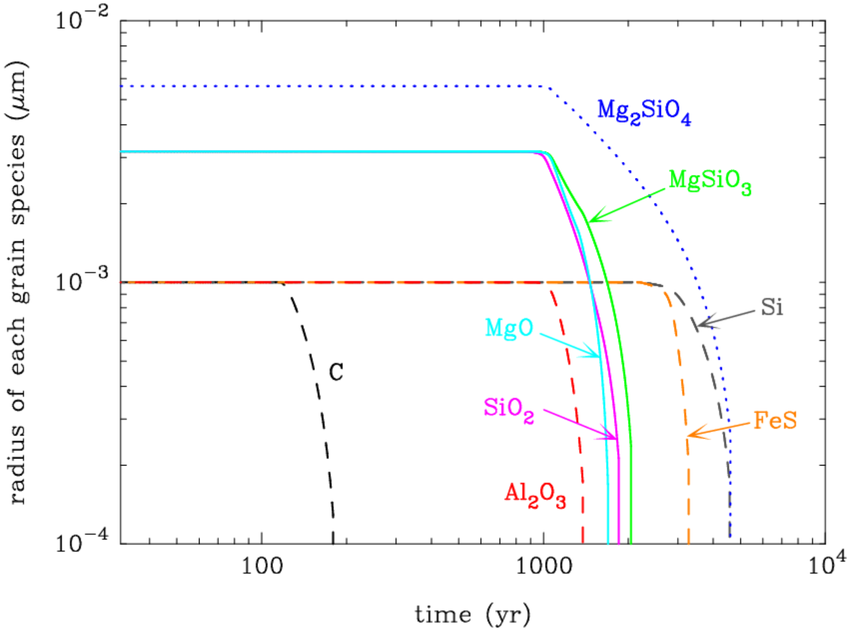
- ejecta model
  - hydrodynamic model for dust formation calculation
- ISM
  - $T_{gas} = 10^4$ K
  - $\rho(r) = M/(4 \pi r^2 v_w)$ g/cm^{-3} (M = 2×10^{-5} M_{sun}/yr)
- treating dust as a test particle
  - erosion by sputtering
  - deceleration by gas drag
  - collsional heating
    ➔ stochastic heating



3-2. Evolution of dust in Cas A SNR

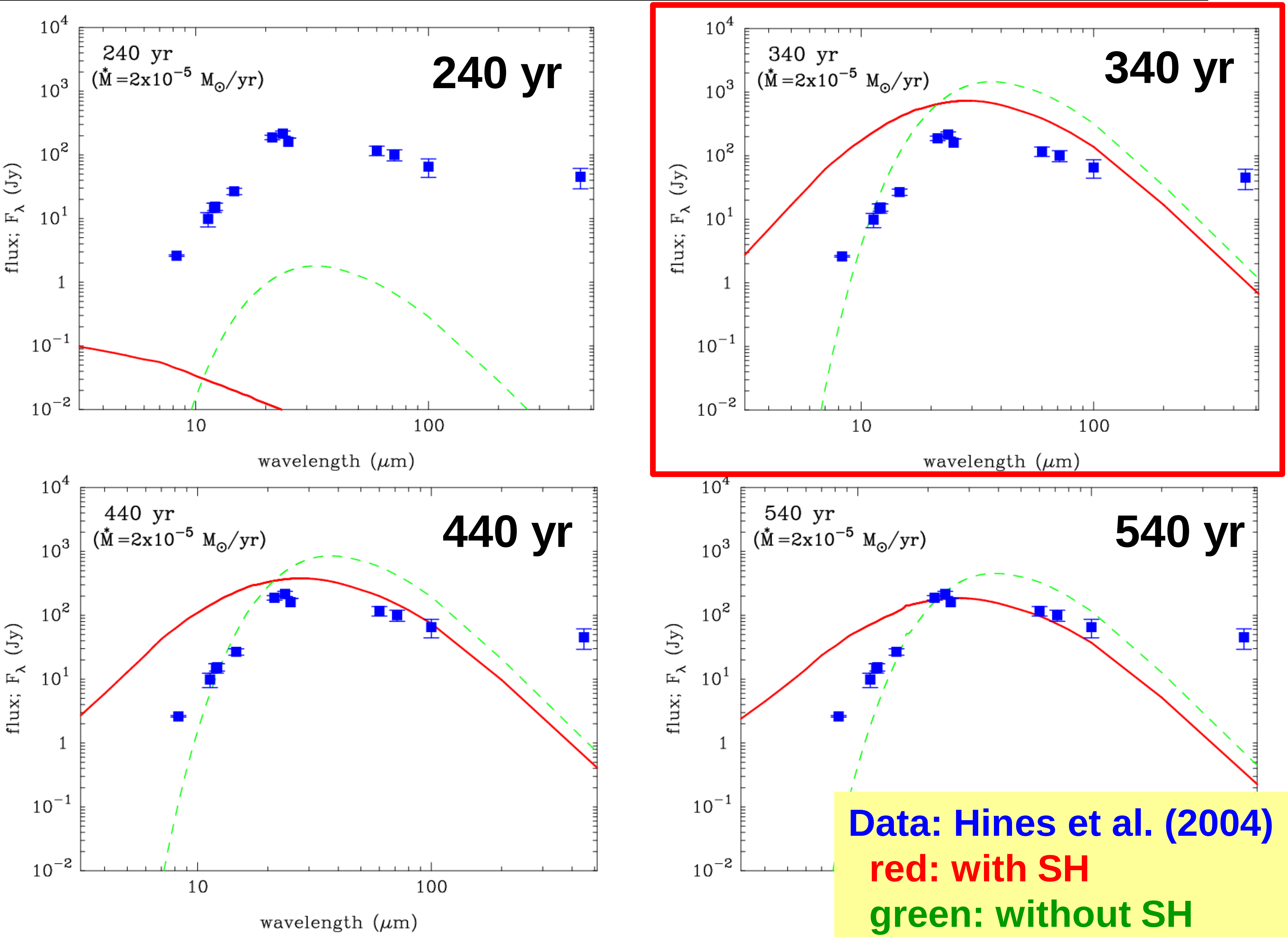




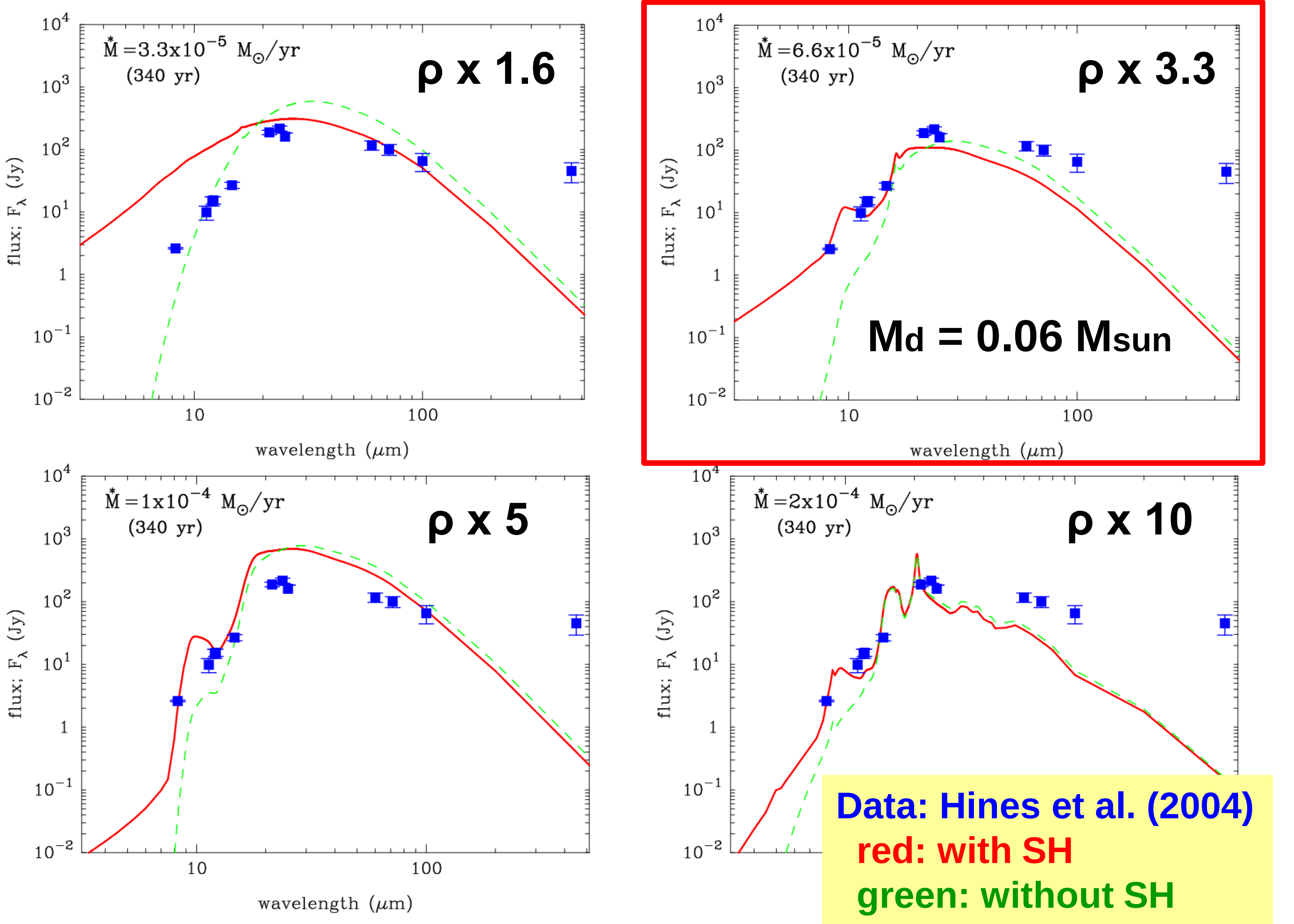


- Most of newly formed dust are destroyed in the hot gas bacause their radii are small

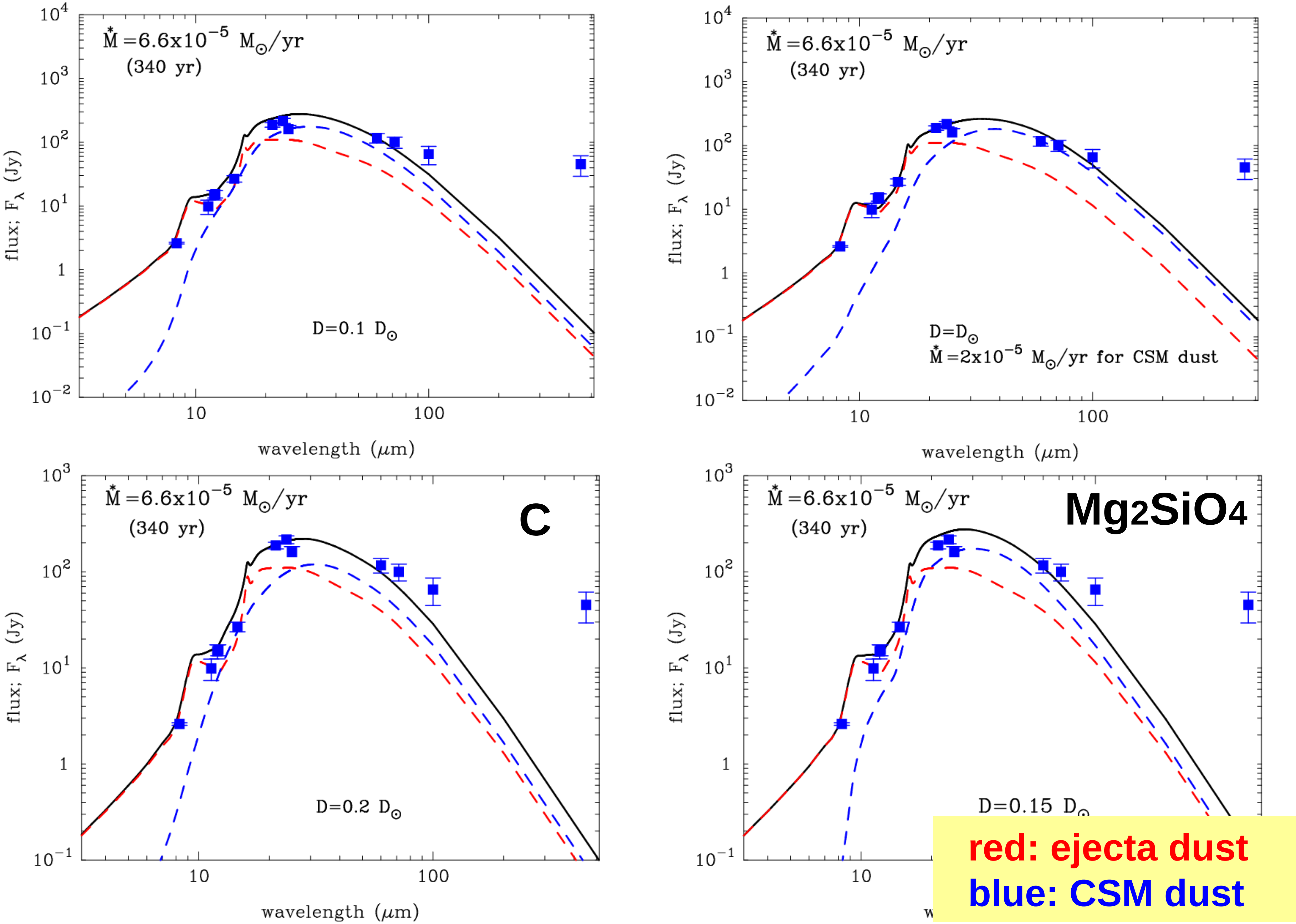
4-1. Time evolution of IR SEDs for Cas A SNR



4-2. Dependence of IR SED on ambient density



4-3. Contribution from circumstellar dust



red: ejecta dust
blue: CSM dust

Summary

1) The radius of dust formed in the ejecta of Type IIb SN is relatively small (< 0.01 μm) because of low ejecta density

2) Small dust grains formed in Type IIb SN cannot survive destruction by the reverse shock

3) Model of dust destruction and heating in Type IIb SNR to reproduce the observed SED of Cas A is

   $M_{d,eje} = 0.06\ M_{sun}$, $M_{d,ism} = 0.03\text{-}0.07\ M_{sun}$

   $dM/dt = 6.6\times10^{-5}$ Msun/yr

   ➔ ejecta-dust in denser clump

4) IR SED reflects the destruction and stochastic heating

   ➔ density structure of circumstellar medium