High-z Metal Enrichment Traced by Extinction Curves

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1. Extinction as a Tracer of Metals

Half of metals in interstellar medium are in dust grains.
→Dust formation is important to trace metal production.

Extinction curve:
Wavelength dependence of dust cross section

Key to understand the dust properties (composition, size distribution etc.)

Pei (1992)

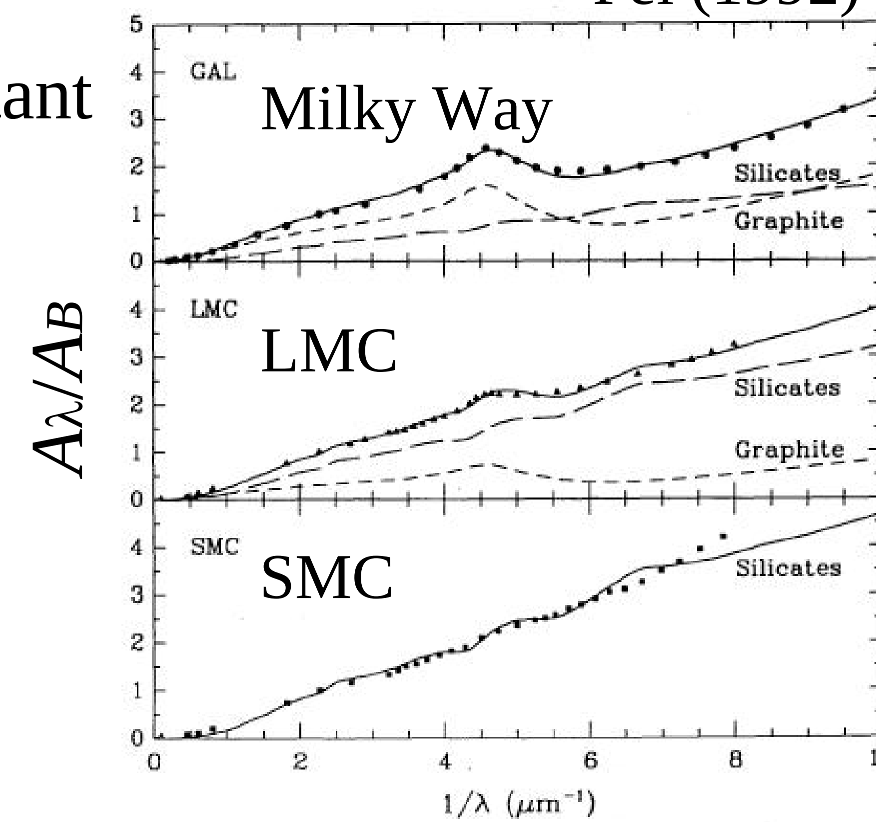
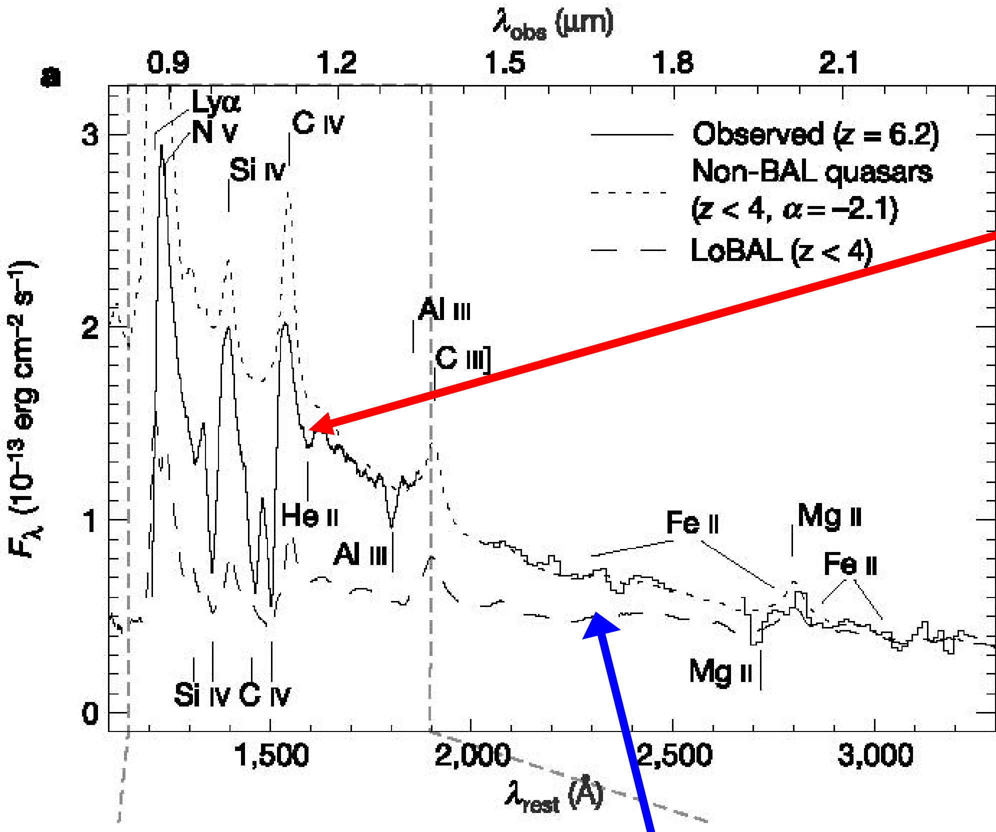


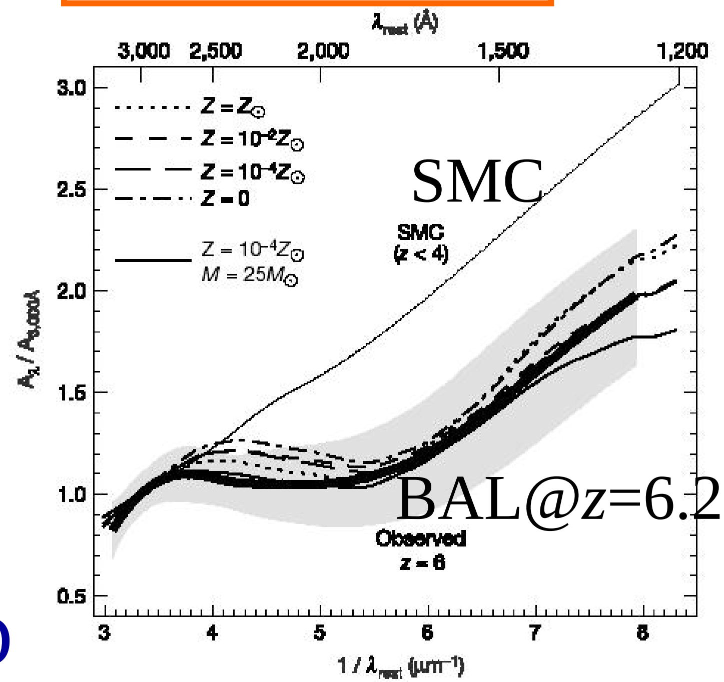
FIG. 5.—Comparisons between the model and empirical extinction curves in the Milky Way, LMC, and SMC. The short and long-dashed lines show, respectively, the relative contributions from graphite and silicate grains, with the sum of the two shown as the solid lines.

Extinction of a BAL QSO at z = 6.2

Maiolino et al. (2004)



BAL at z = 6.2



BAL at z < 4: Non-BAL SED
+ SMC extinction (reddening)

Different dust properties at high redshift.

Origin of High-*z* Dust

Young cosmic age at $z > 5$
→ No dust supply from low-mass stars

Supernovae whose progenitors are massive stars with short lifetimes predominantly supply dust grains.

We calculate extinction curves of dust formed in SNe.
→Compared to observations at $z = 6.2$
to constrain metal production in the early Universe.

2. Dust Produced in SNe

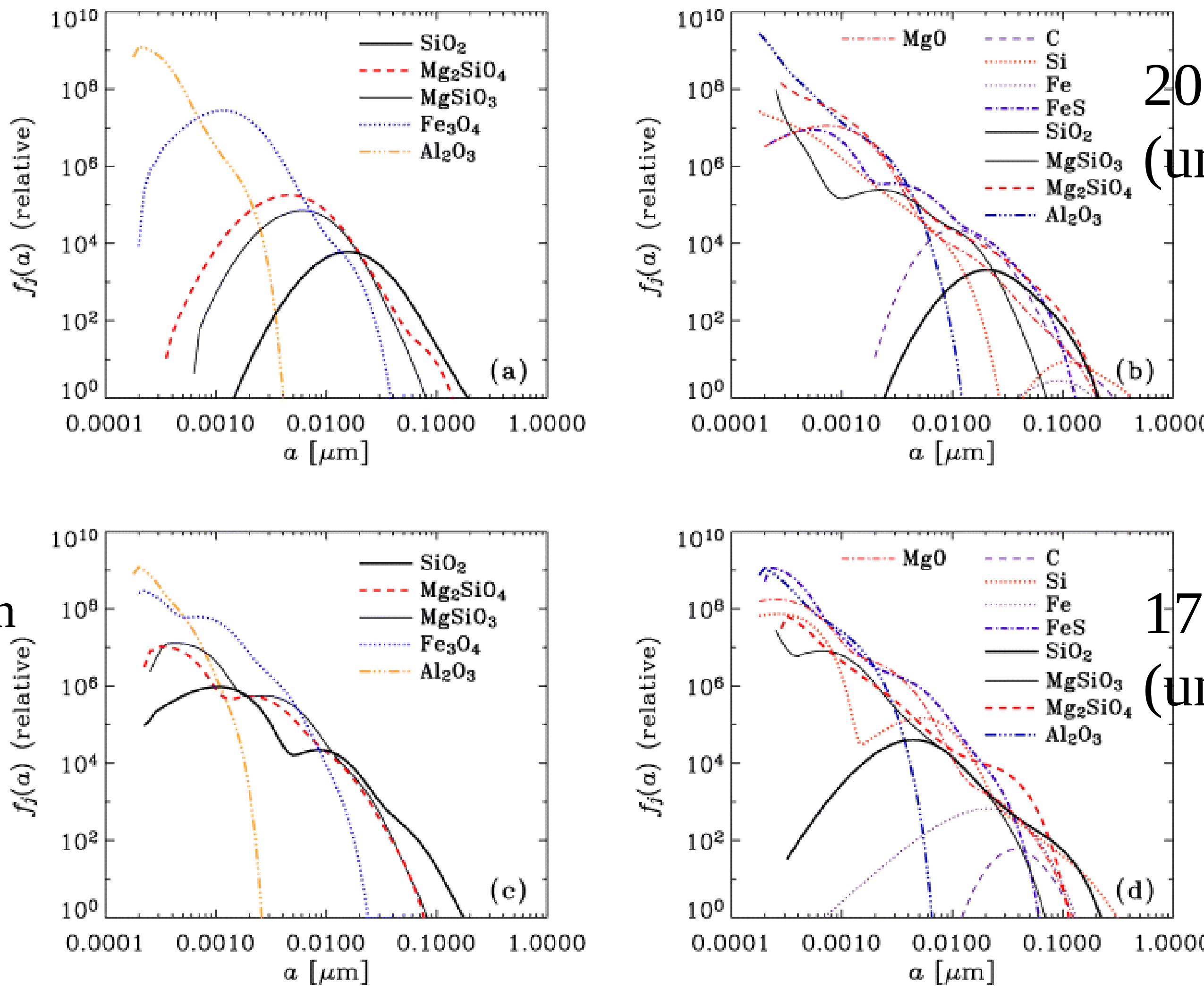
Nozawa et al. (2003)

20 Msun (mixed)

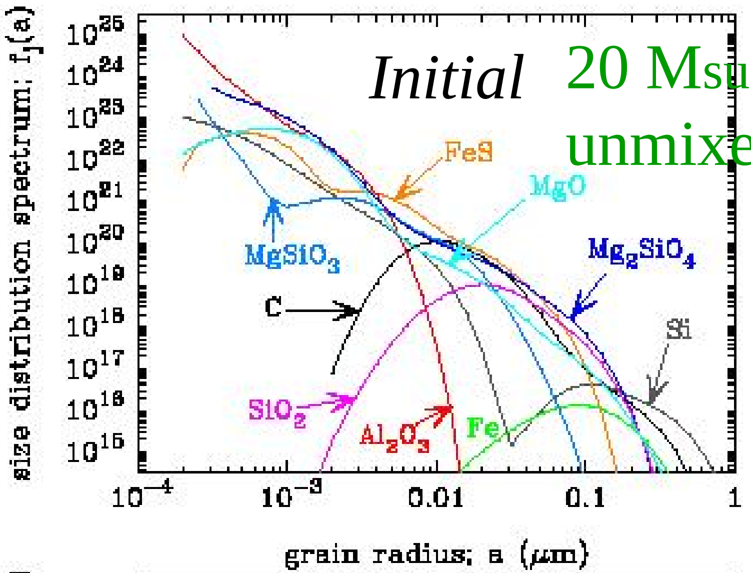
20 Msun (unmixed)

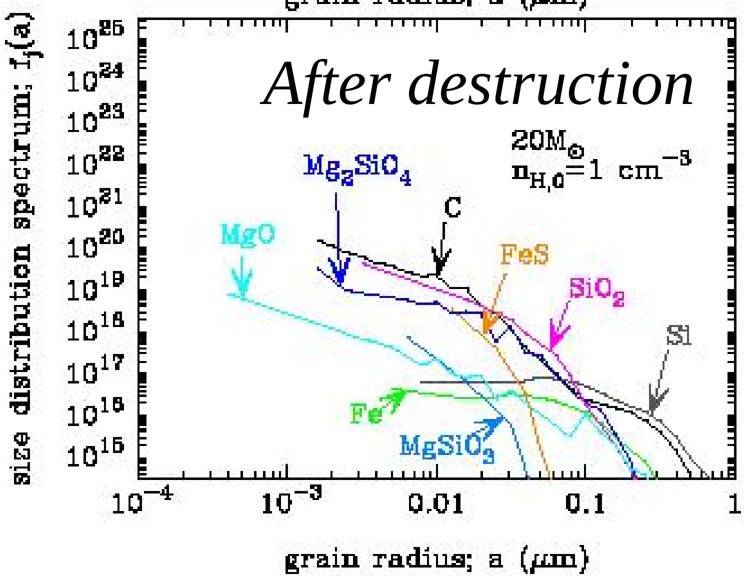
170 Msun (mixed)

170 Msun (unmixed)



Effect of Dust Destruction





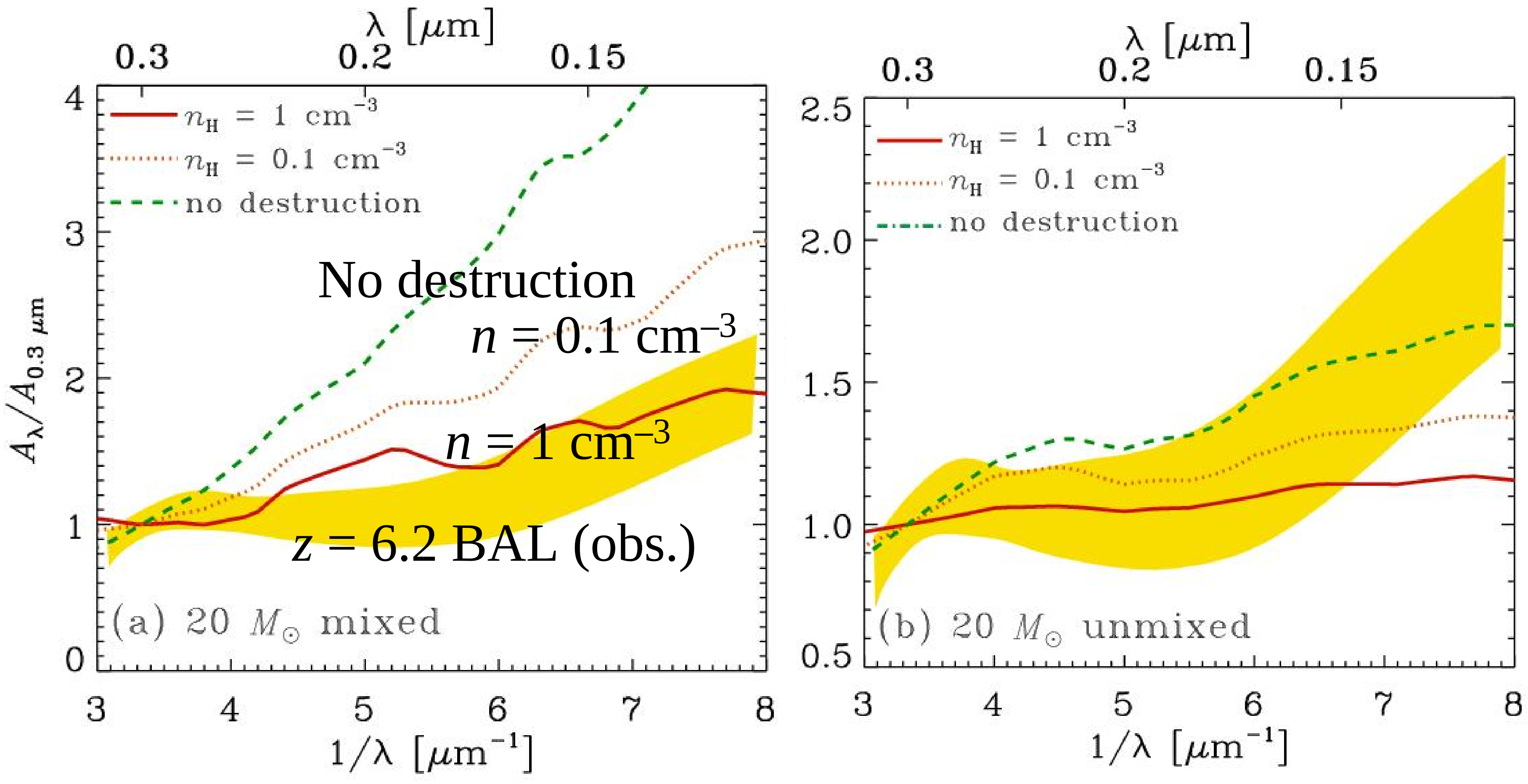
Nozawa et al. (2007)

Destruction by reverse shock (Sputtering)
→Small grains are destroyed more easily than large grains.

Extinction Curves tend to become flat.

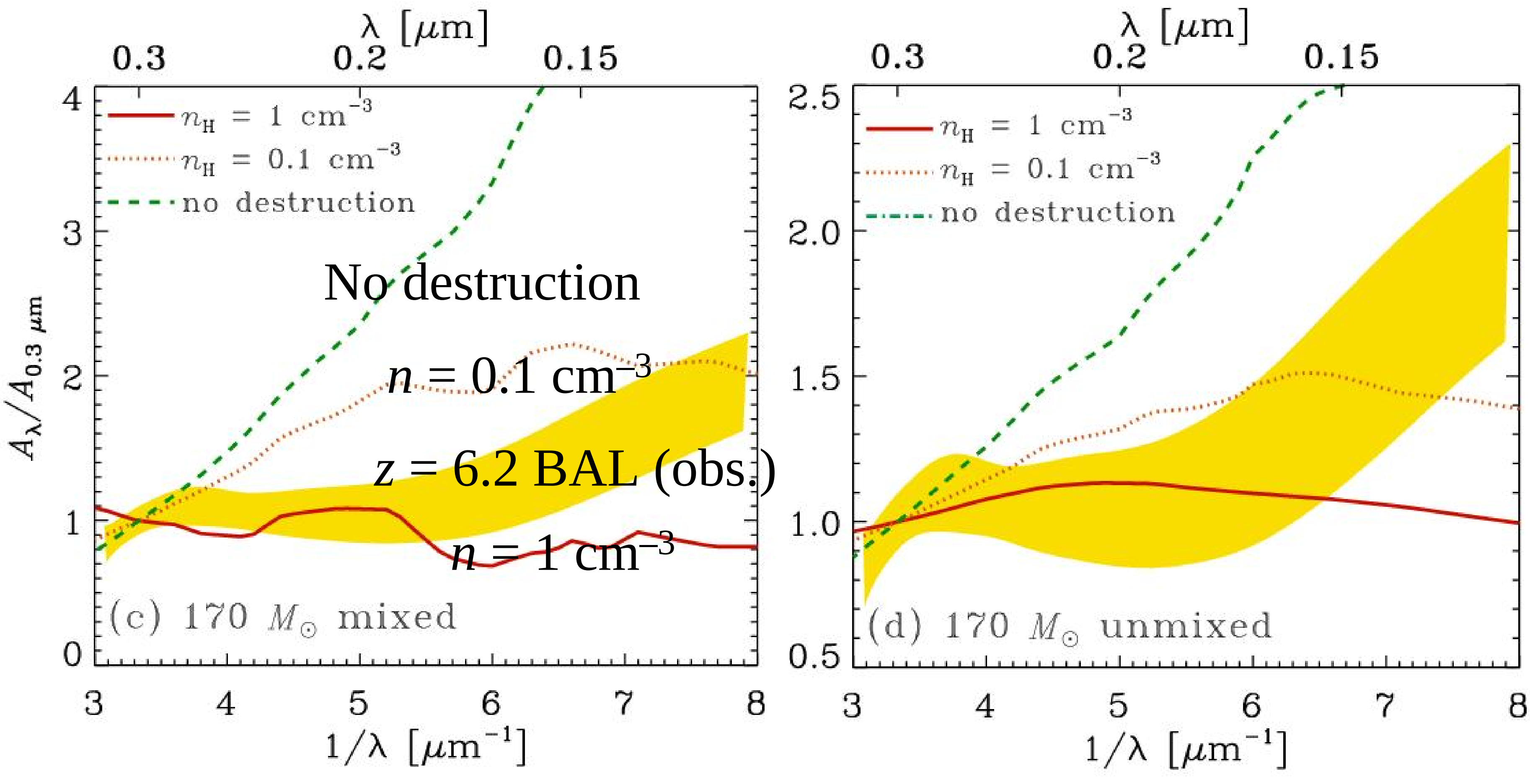
Effect of Dust Destruction

20 Msun progenitor



Effect of Dust Destruction

170 Msun progenitor



3. Summary and Discussion

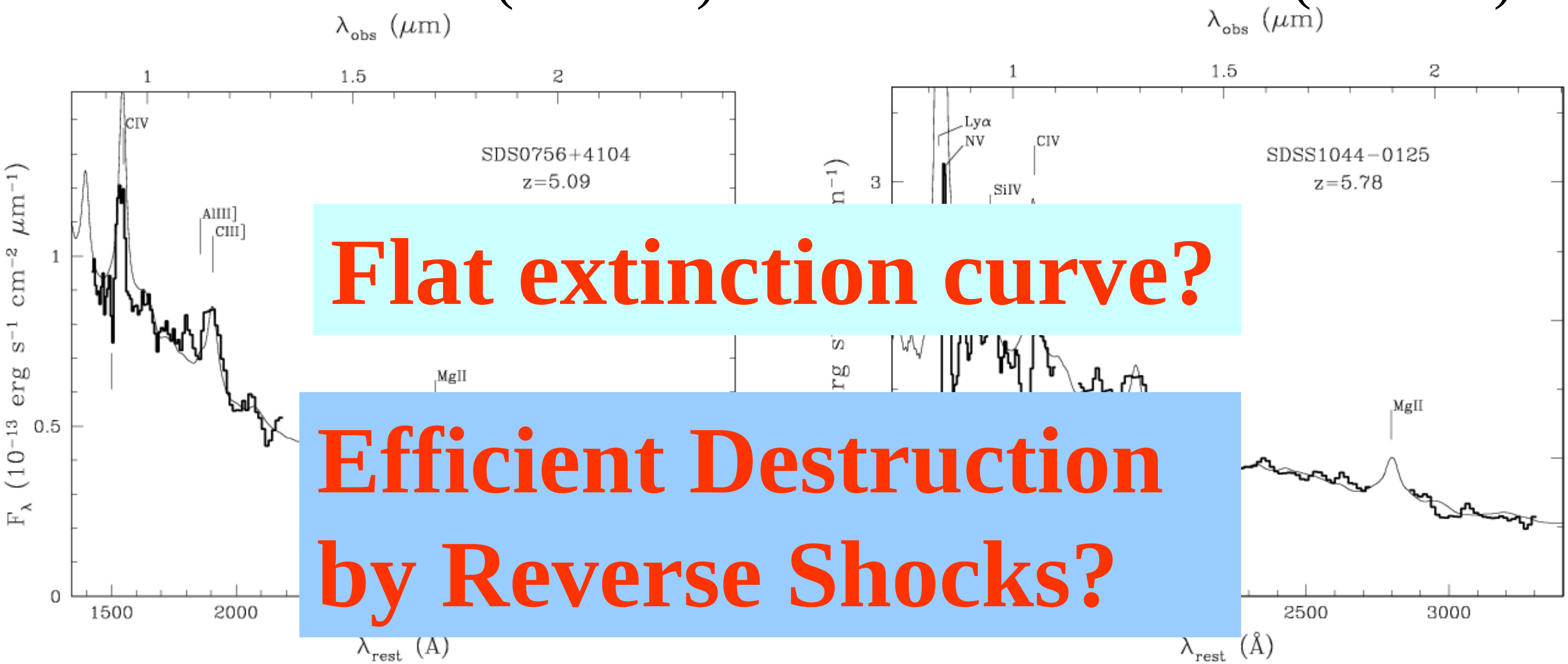
Destruction by reverse shocks tend to
flatten extinction curves.

The extinction curve observed for a $z = 6.2$ BAL can be explained by
dust produced in SNe.
However, too dense an environment such as $n > 1$ cm^{-3} flatten extinction curves too much.

BALs without Reddening

Maiolino et al. (2004)

SDSS1044–0125 (z = 5.78) SDSS0756+4104 (z = 5.09)



Flat extinction curve?

Efficient Destruction by Reverse Shocks?

Consistent with non-BAL template ⇒ no reddening

But detected in sub-mm (10^8–10^9 M_{sun} dust:Priddey’03)