IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

2011/05/31

Missing-Dust Problem in SNe:
Approach from extremely young SNRs

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at 10-100 years
middle-aged SNe?

Masaomi Tanaka, TN, et al., submitted to ApJ

1. Difference in estimated mass of dust in SNe

・Theoretical studies

— at time of dust formation : M_{dust}=0.1-1 M_{sun} in CCSNe
(Nozawa+'03; Todini & Ferrara'01; Cherchneff & Dwek'10)

— after destruction of dust by reverse shock (SNe II-P) :
M_{surv}~0.01-0.8 M_{sun} (Nozawa+'07; Bianchi & Schneider'07)

dust amount needed to explain massive dust at high-z

・Observational works

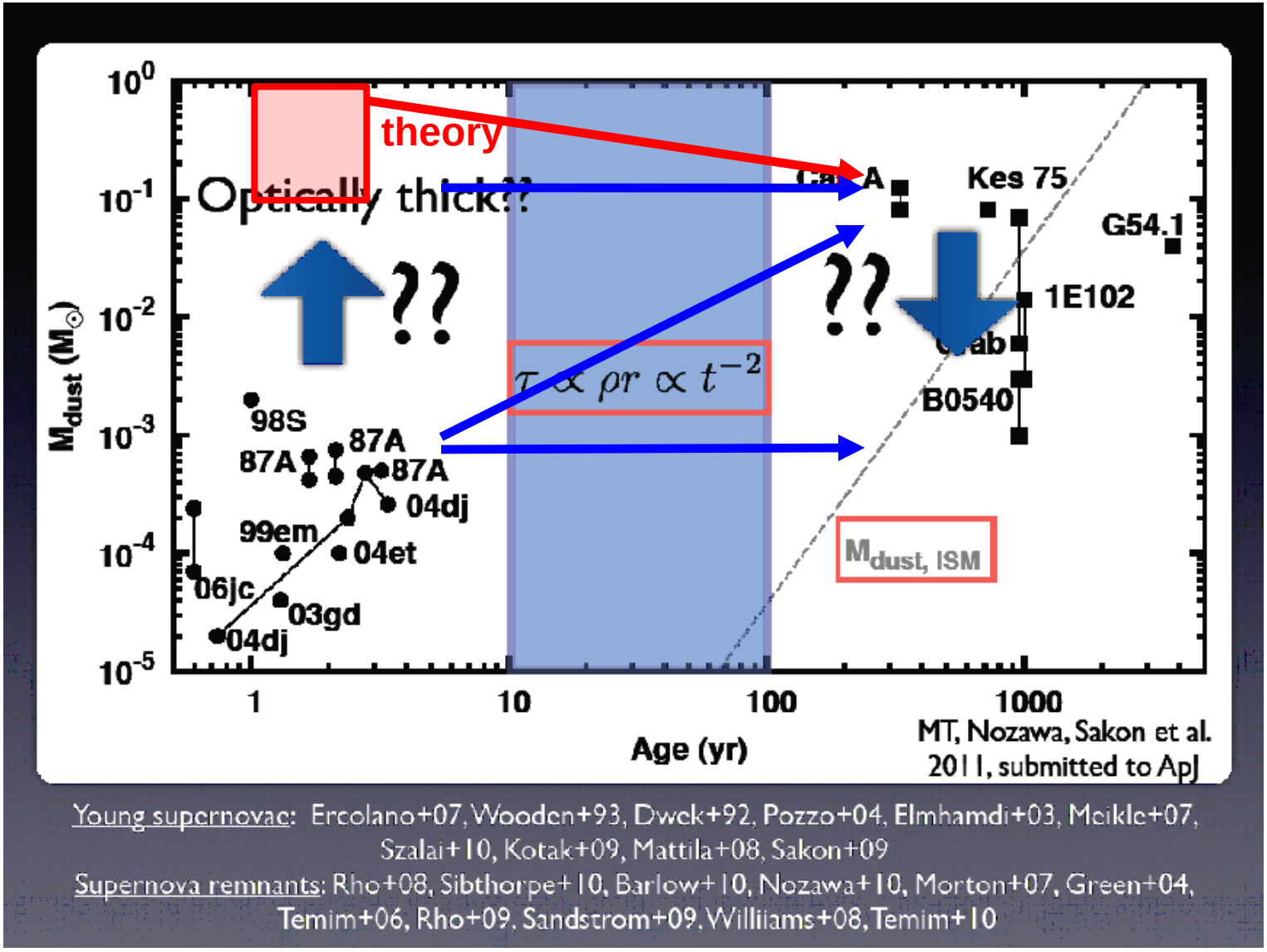
— MIR observations of SNe : $M_{dust} < 10^{-3}$ M_{sun}
(e.g., Ercolano+'07; Sakon+'09; Kotak+'09)

— submm observations of SNRs : $M_{dust} > 1$ M_{sun}
(Dunne+'03; Morgan+'03; Dunne+'09)

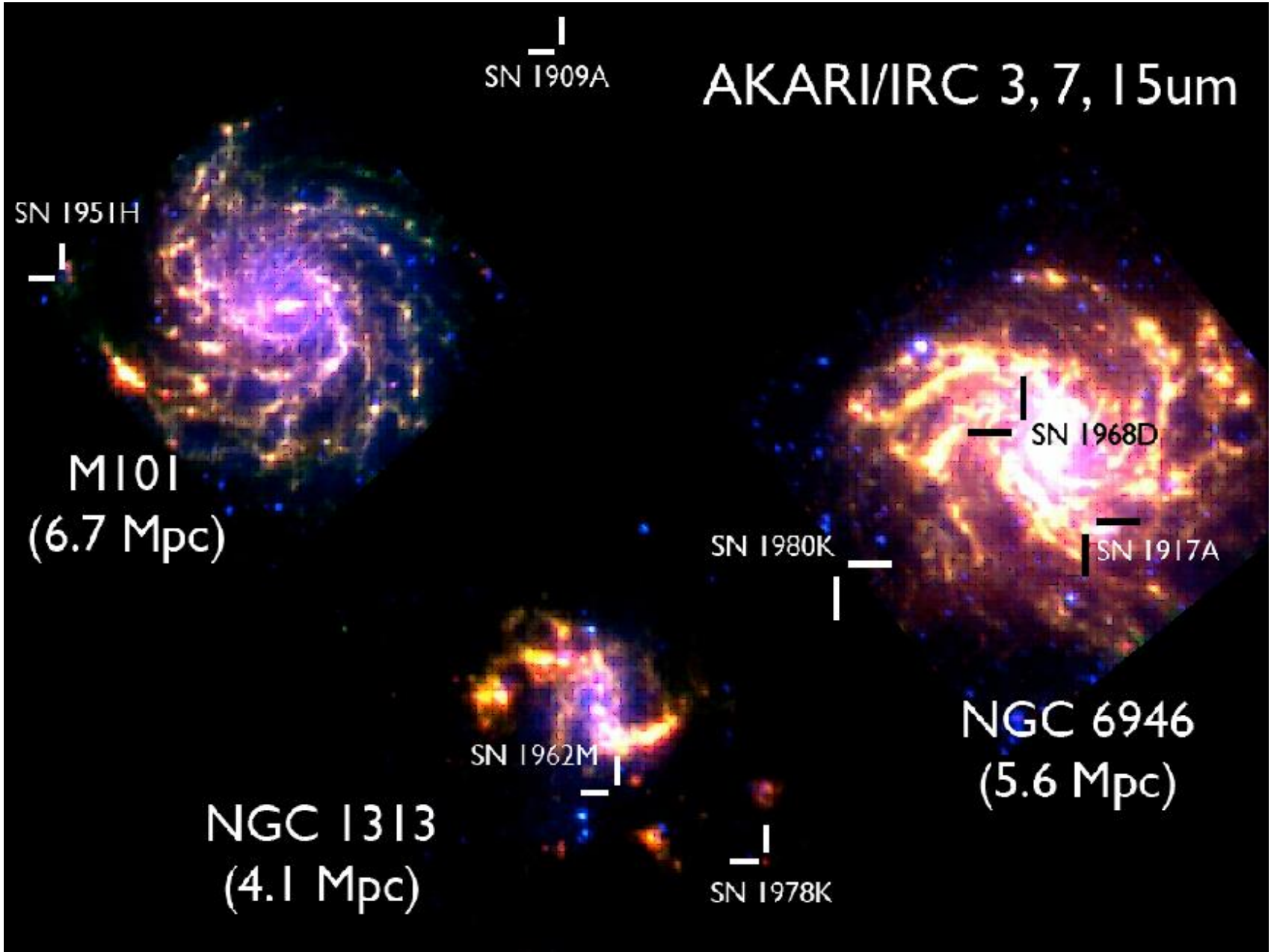
— MIR/FIR observation of Cas A : M_{dust}=0.02-0.075 M_{sun}
(Rho+'08; Sibthorpe+'09; Barlow+'10)

2. Missing-dust problem in CCSNe

Tanaka, TN,+'11, submitted



3. Search for dust in middle-aged CCSNe



4. What is the origin of dust in SN 1978K?

・SN 1978K

- extremely X-ray/radio luminous SNe
  Lx ~ 10^{39} erg/s

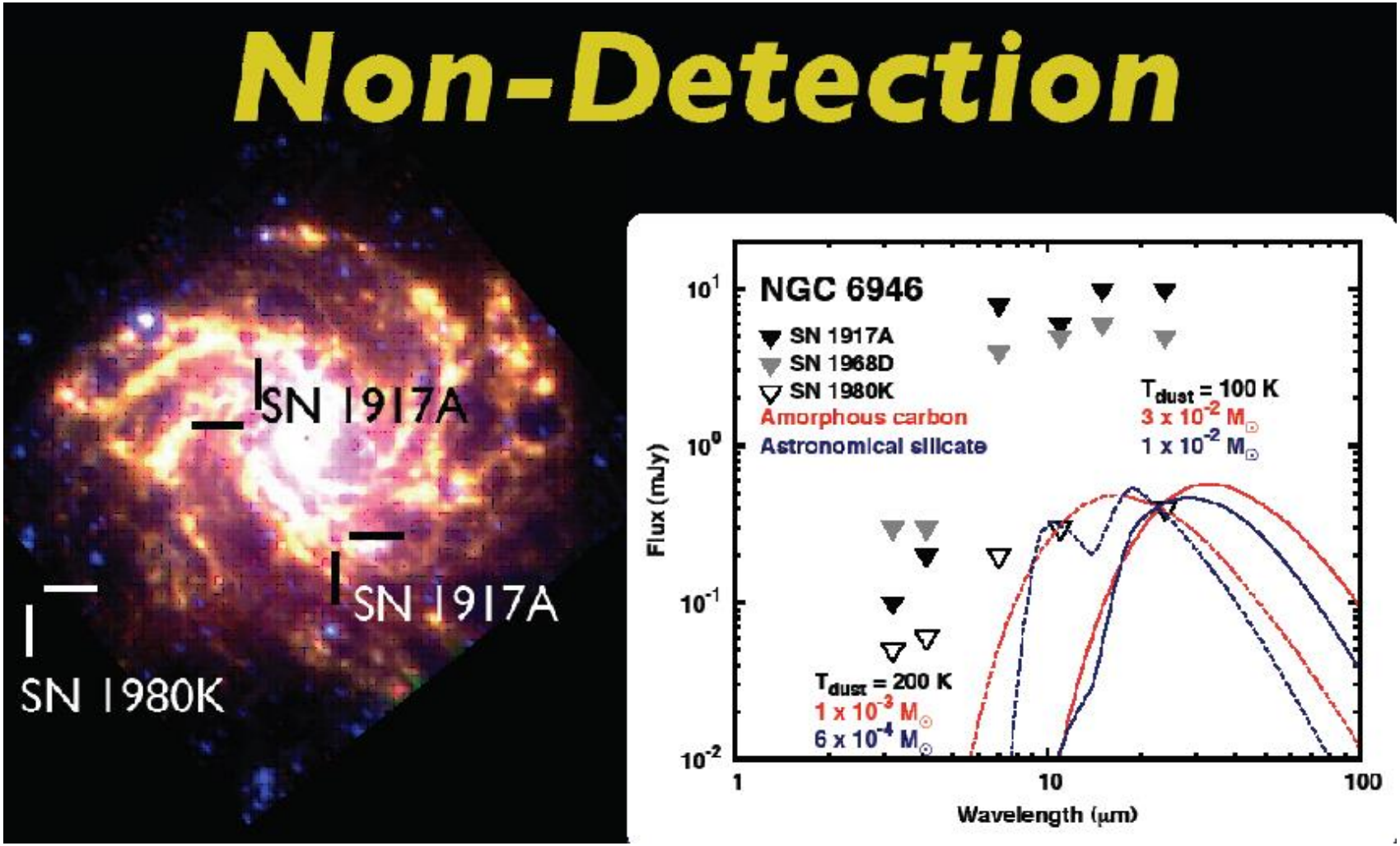
- Type IIn SNe interacting with very massive CSM
  mass-loss rate ~ 10^{-4} M_{sun}/yr
  ➔ dust formed in mass-loss winds of the progenitor

- IR to X-ray flux ratio of order of unity
  ➔ collisionally heated dust in the hot plasma
  (e.g., Dwek+2008)

- high dust temperture ~ 230 K

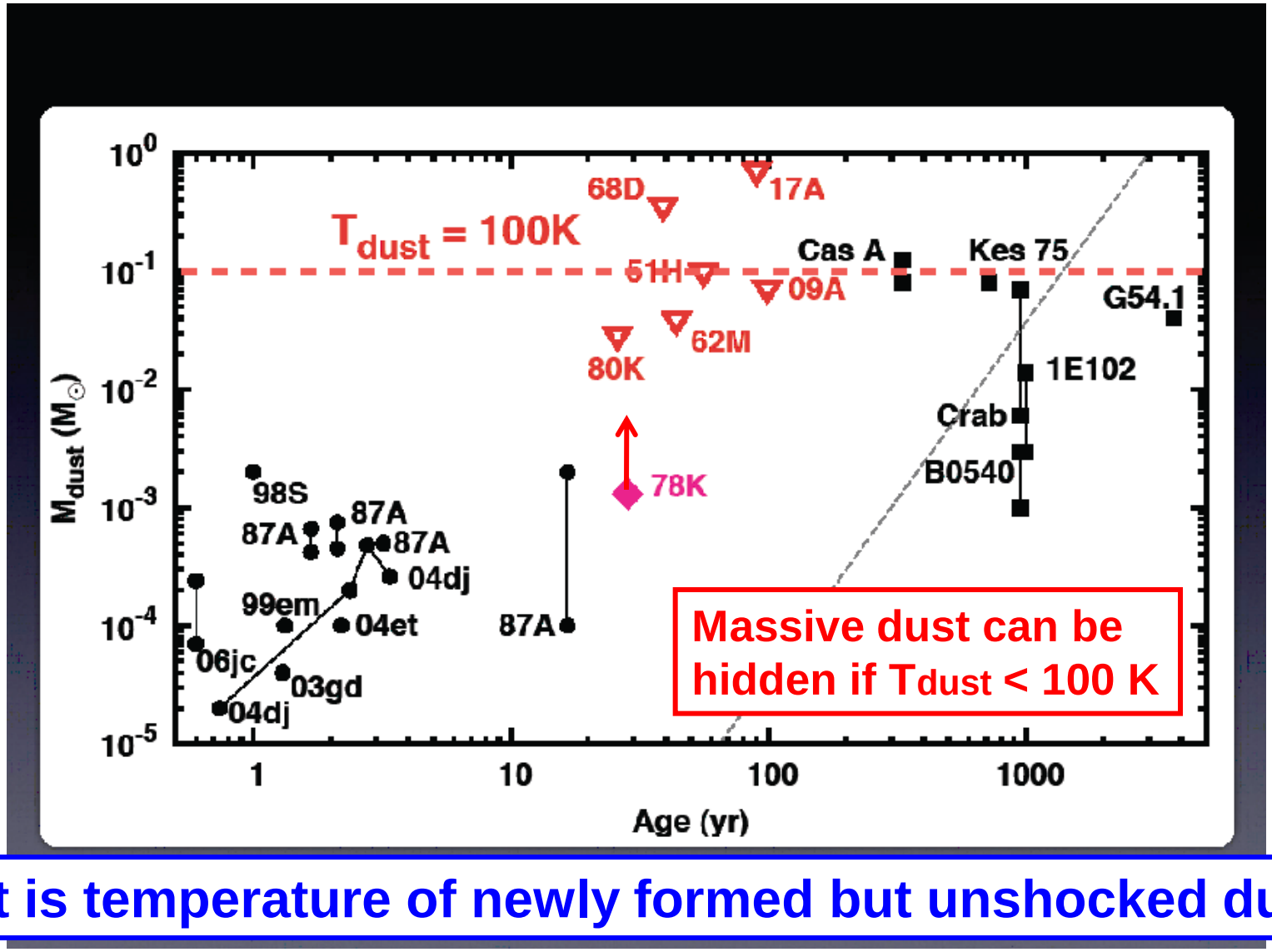
Dust associated with SN 1978K may be of circumstellar origin, which was formed in intense stellar winds and is now shock-heated

5. Constraint on dust mass from non-detection



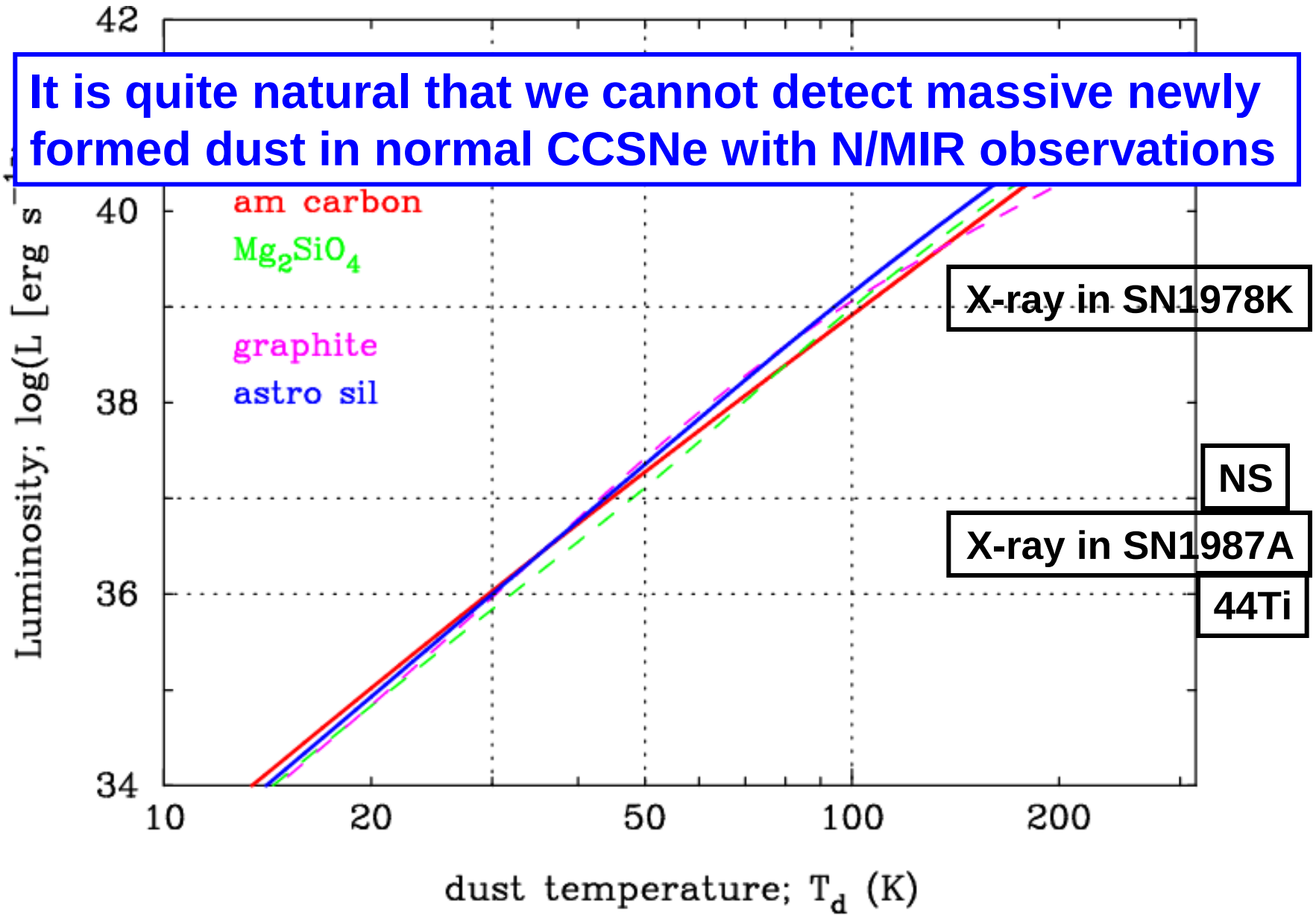
6. Upper mass limit of dust in middle-aged SNe

Tanaka, TN,+'11, submitted

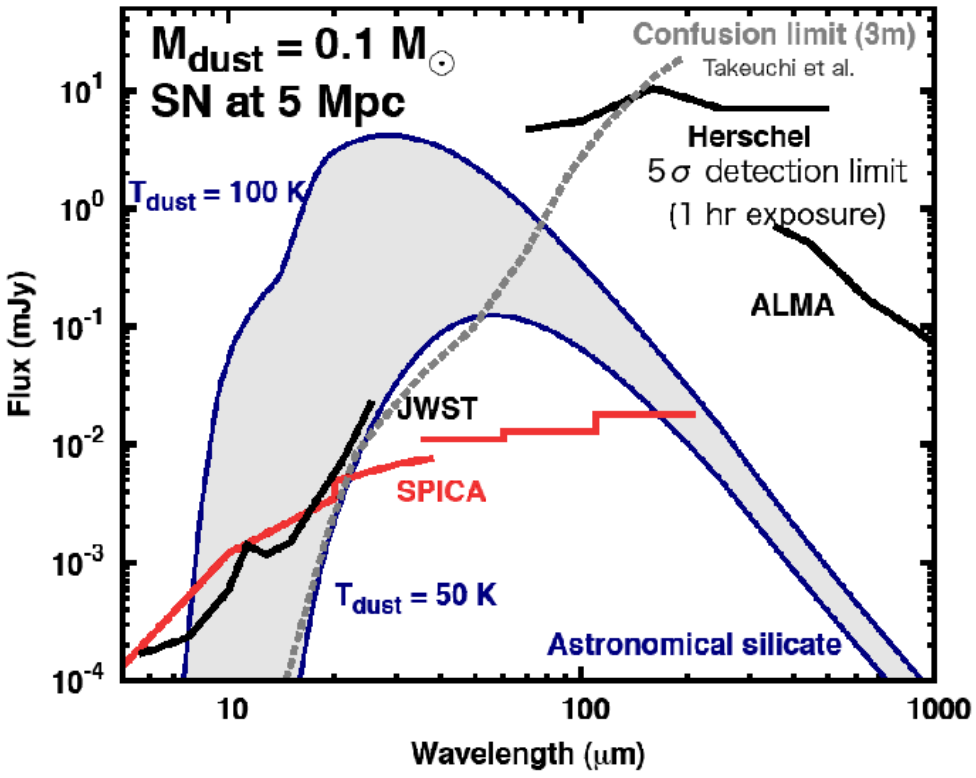


What is temperature of newly formed but unshocked dust?

7. Dust temperature and luminosity budget



8. Possible targets in the future



- **Possible targets**
  SN 1978K, SN 1993J, SN 2004dj, SN 2004et

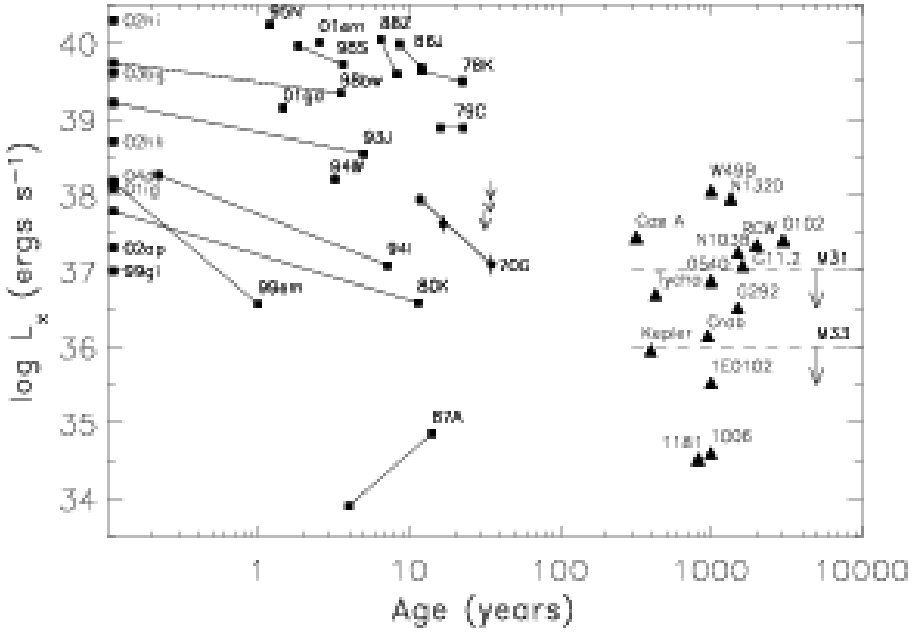
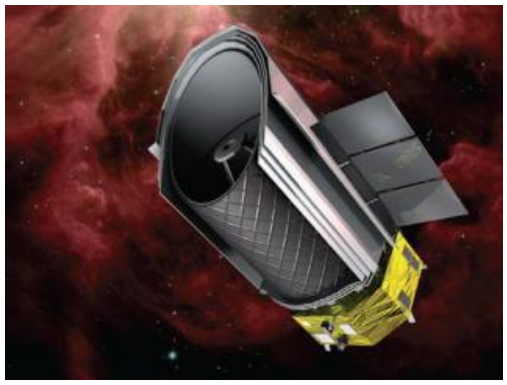


FIG. 2.— Soft (0.3–2 keV) band X-ray luminosities of all SNe detected to date (filled squares) and historical SNRs (filled triangles) as a function of age (in units of years). The X-ray lightcurve of SN 1970G is marked by filled diamonds with error bars (from left to right: *ROSAT* PSPC, *ROSAT* HRI and *Chandra* ACIS). *XMM-Newton* EPIC upper limits are indicated by arrows.



Immler & Kuntz 2005, ApJ, 632, L99

9. Summary

- **Middle-aged SNe with the ages of 10-100 yr are good targets to measure the mass of dust formed in SNe**
- **We detect emission from SN 1978K, which is likely from shocked circumstellar silicate dust with 1.3×10^{-3} M_{sun}**
- **The non-detection of the other 6 objects seems to be natural because our present search is sensitive only to the total luminosity of $>10^{38}$ erg/s**
- **IR observations with the future satellites can detect newly formed grains if grains are > 0.1 M_{sun} and >50 K (if the SNe are as UV/X-ray luminous as $>10^{37}$ erg/s)**