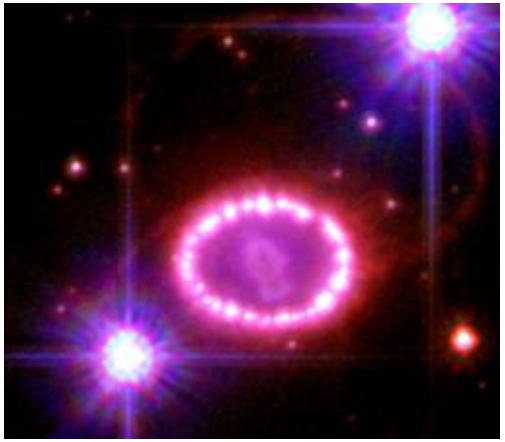

Dust formation by Supernova 1987A

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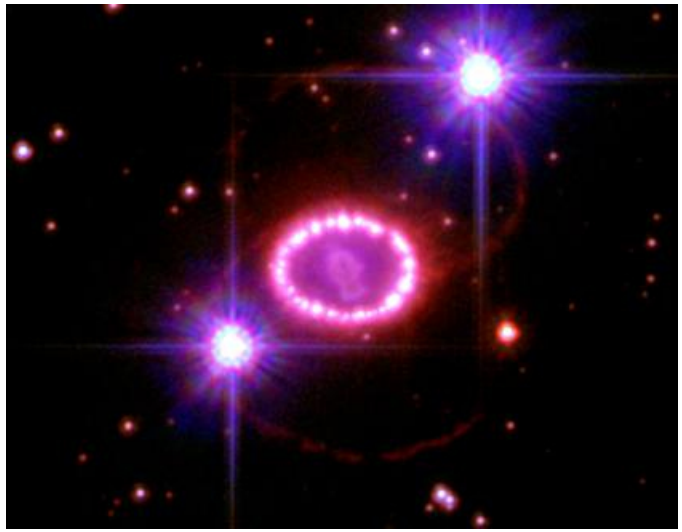
Current major problems

How much dust can be formed in supernovae?

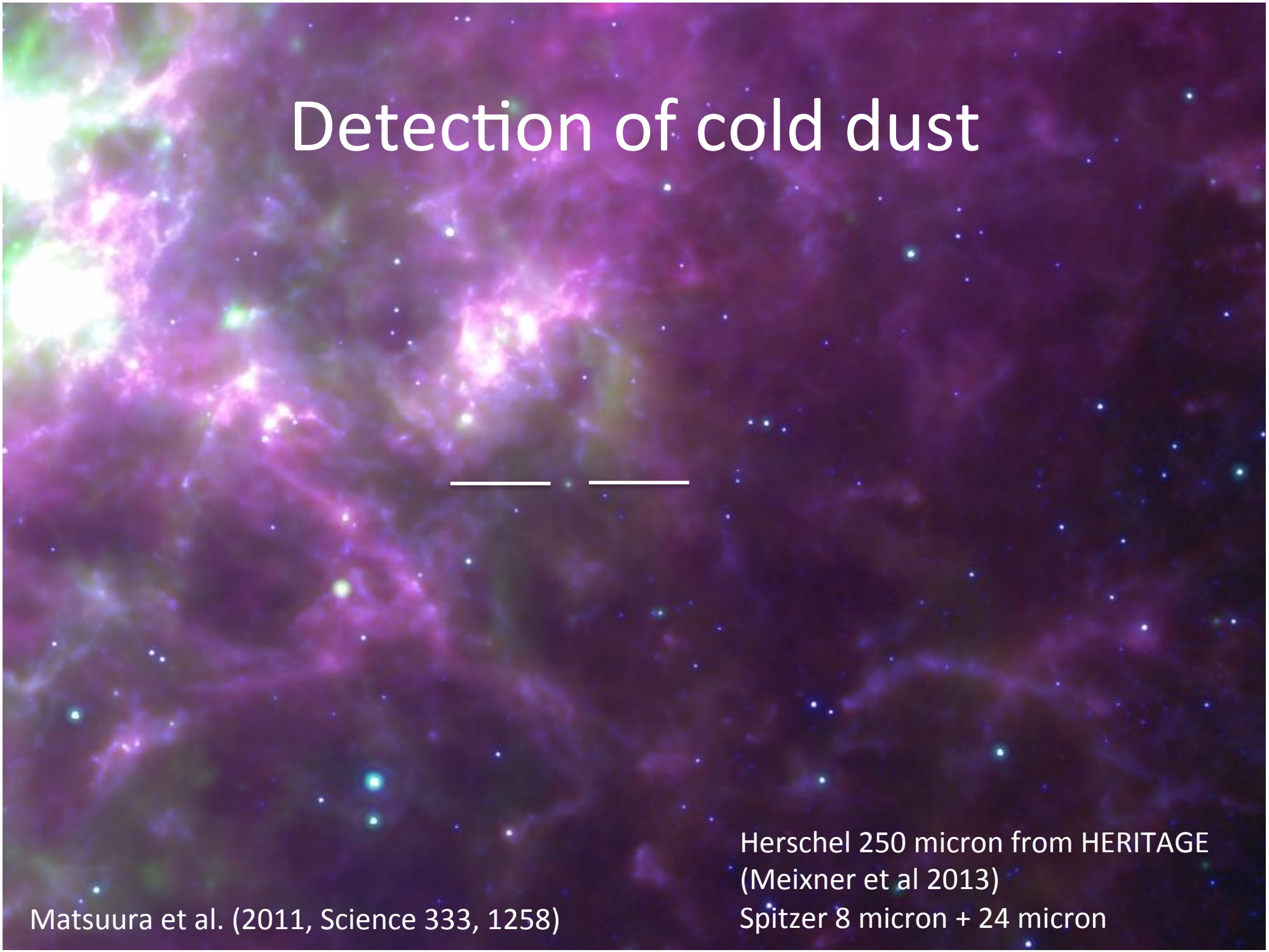
Can SNe be important source of dust in the ISM of galaxies?

SN 1987A

- Located in the Large Magellanic Cloud (50 kpc)
- Closest SN explosion detected in 400 years
  - Evolution of supernova remnants
    - Real-time astronomy



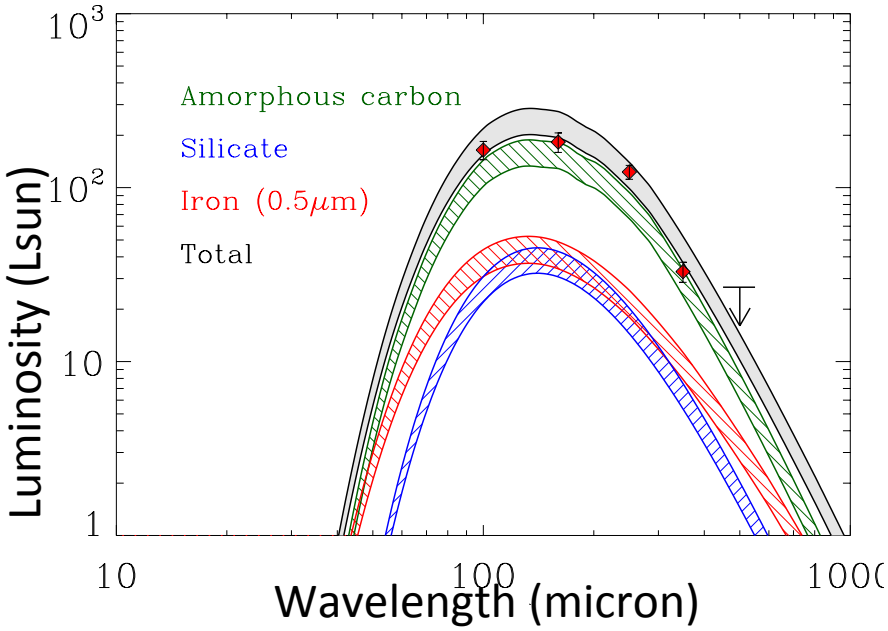
Detection of cold dust



Herschel 250 micron from HERITAGE
(Meixner et al 2013)
Spitzer 8 micron + 24 micron

Matsuura et al. (2011, Science 333, 1258)

Dust mass in SN 1987A



- Significantly large dust mass:
  - 0.4-0.7 $M_\odot$ of dust
    - Previously reported dust mass: 10^{-6} -10^{-4} $M_\odot$
    - Progenitor star: 20 Msun

Matsuura et al. (2011, Science 333, 1258)

Questions raised by communities

Surprisingly large inferred dust mass (0.4-0.7 Msun)

A large mass of dust must have formed in the SN ejecta where rich metals are available

- 20 Msun of the progenitor star
- 2 Msun of the metal mass

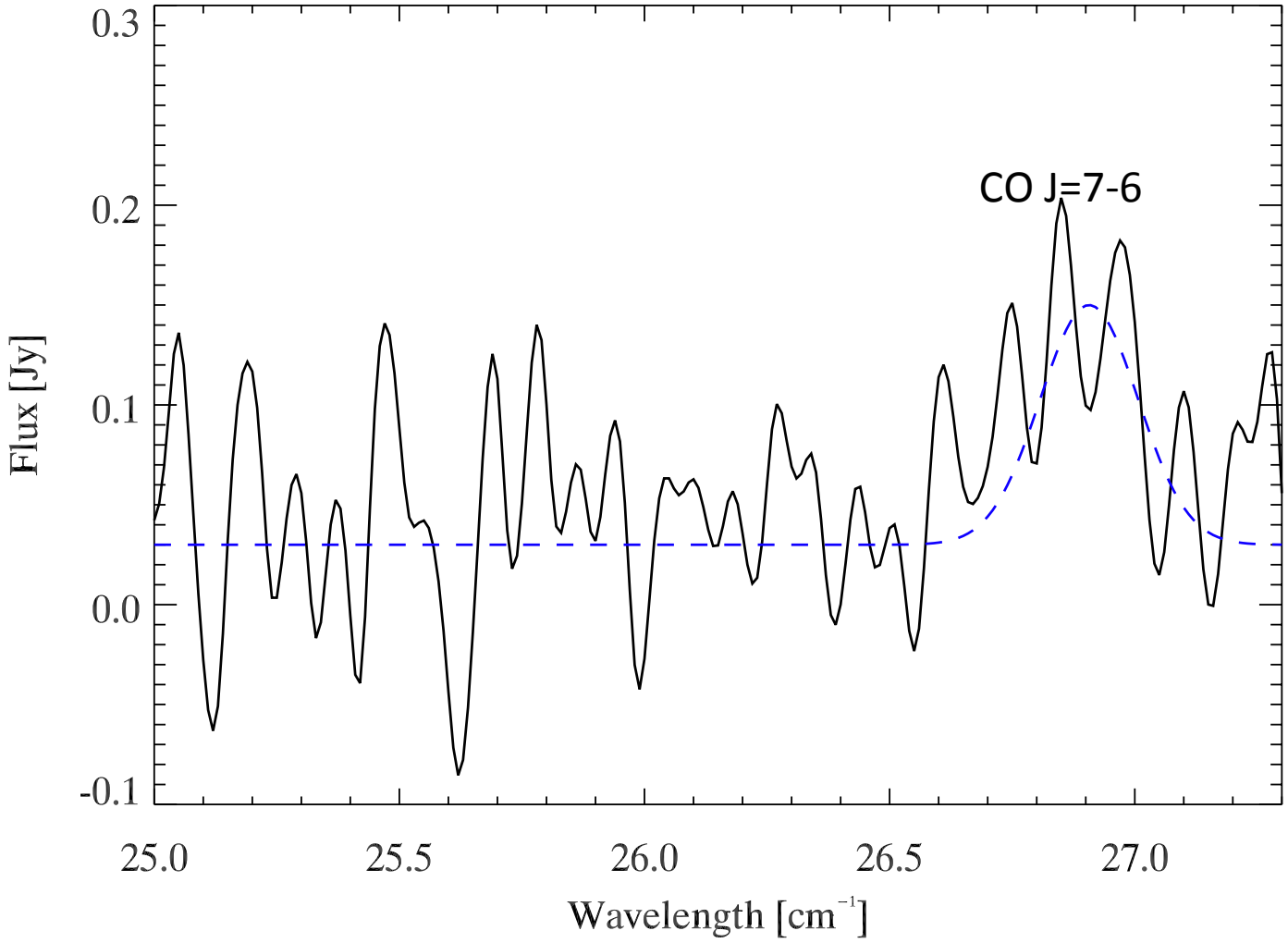
- Are the detection real?
- Are dust from ejecta?
  - Alternatives: progenitor, ISM
- Any contamination of lines into broad band photometric measurements
  - dust mass may be overestimated?

Questions raised by communities

- Surprisingly large inferred dust mass (0.4-0.7 Msun), supposed to be from the SN ejecta
  - 20 Msun of the progenitor star
  - 2 Msun of the metal mass

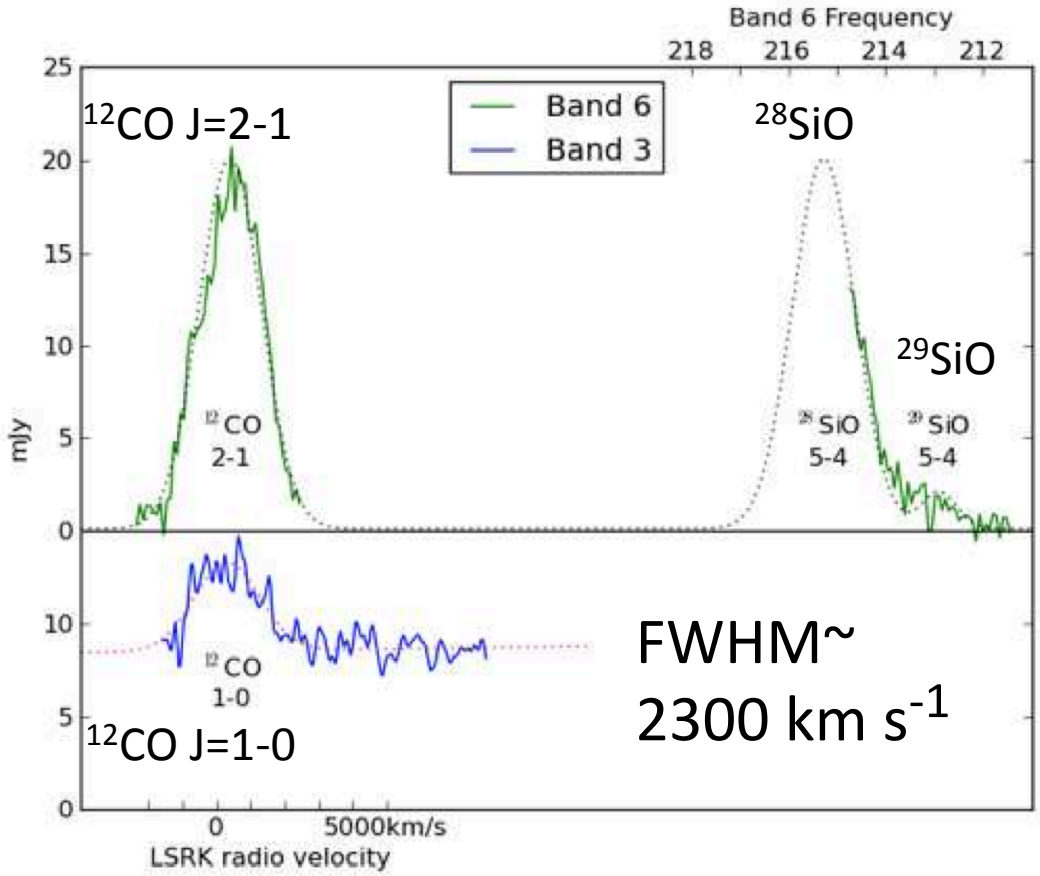
- Are the detection real?
- Are dust from ejecta?
  - Alternatives: progenitor, ISM
- Any contamination of lines into broad band photometric measurements
  - dust mass may be overestimated?

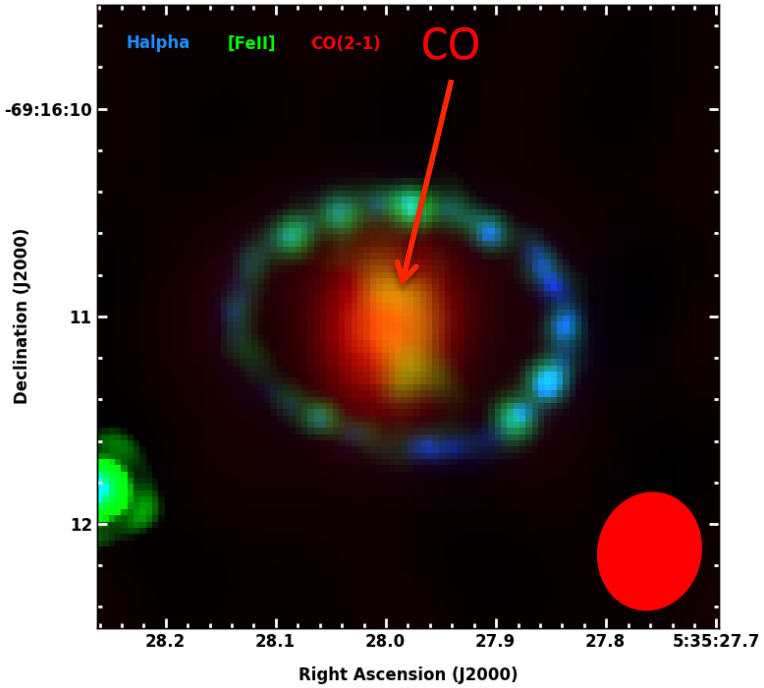
CO detection in Herschel spectra



- First detection of sub/mm molecular lines in supernovae/supernova remnants

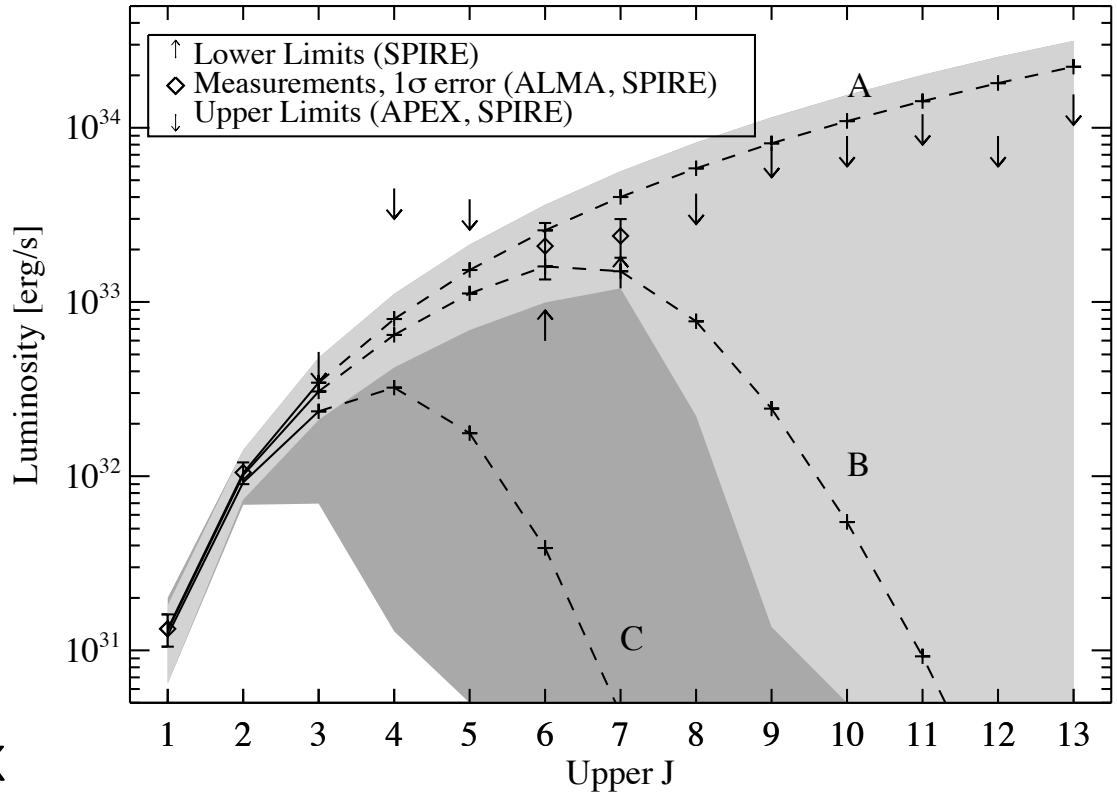
Cold molecular gas in the ejecta of SN 1987A





(Kamenetzky et al. 2013)

CO Temperature & mass



ALMA optically thick

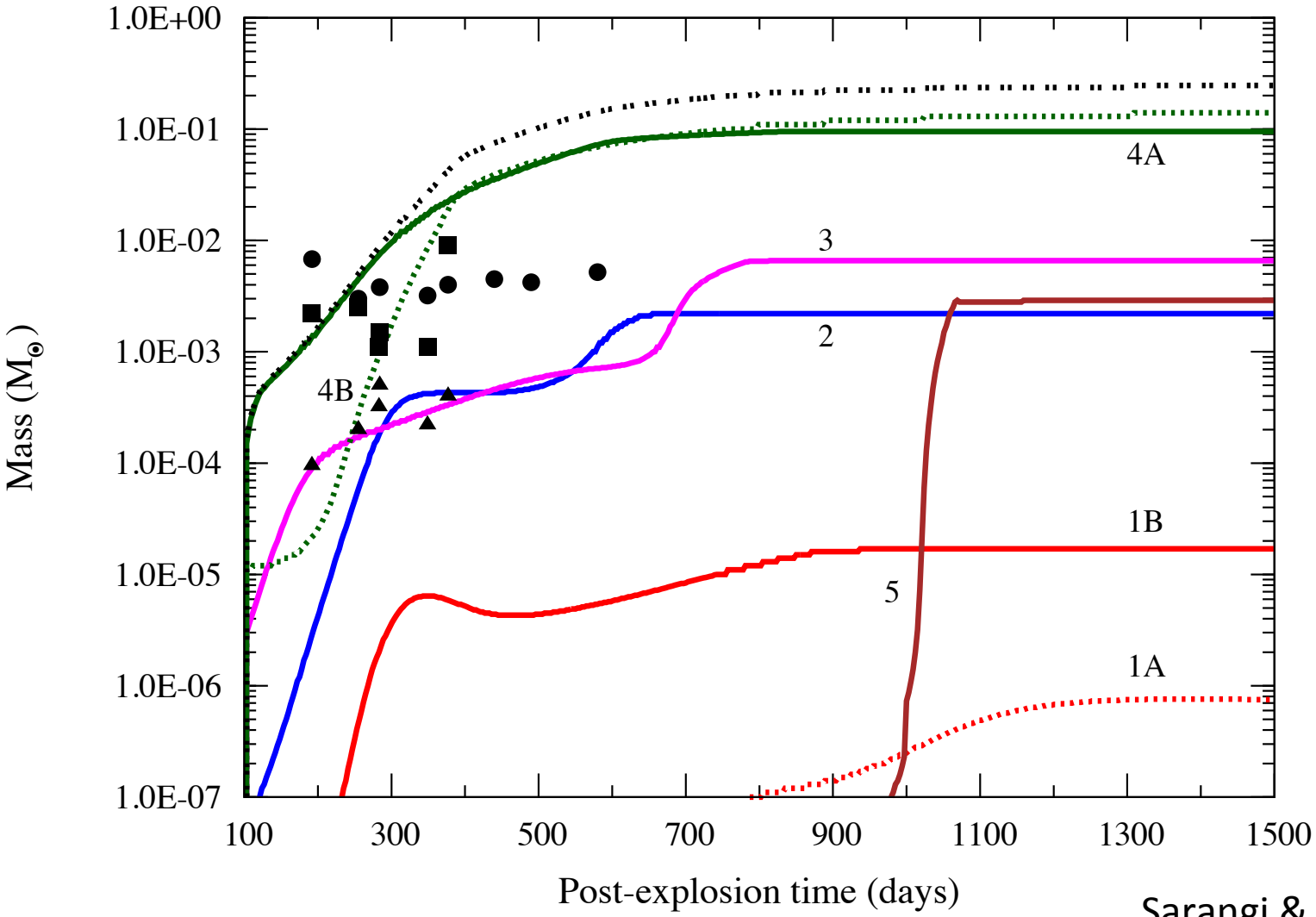
Kamenetzky et al. 2013

- >0.01 $M_\odot$ of CO; T~39 K
- larger than previously CO reported mass ($5x10^{-5}$ $M_\odot$ at d~255- days; Spyromilio et al. 1988)

CO line contaminations: <12 % of in-band flux to SPIRE 350 micron band
dust is the dominant contributors to photometry bands

Chemical modelling

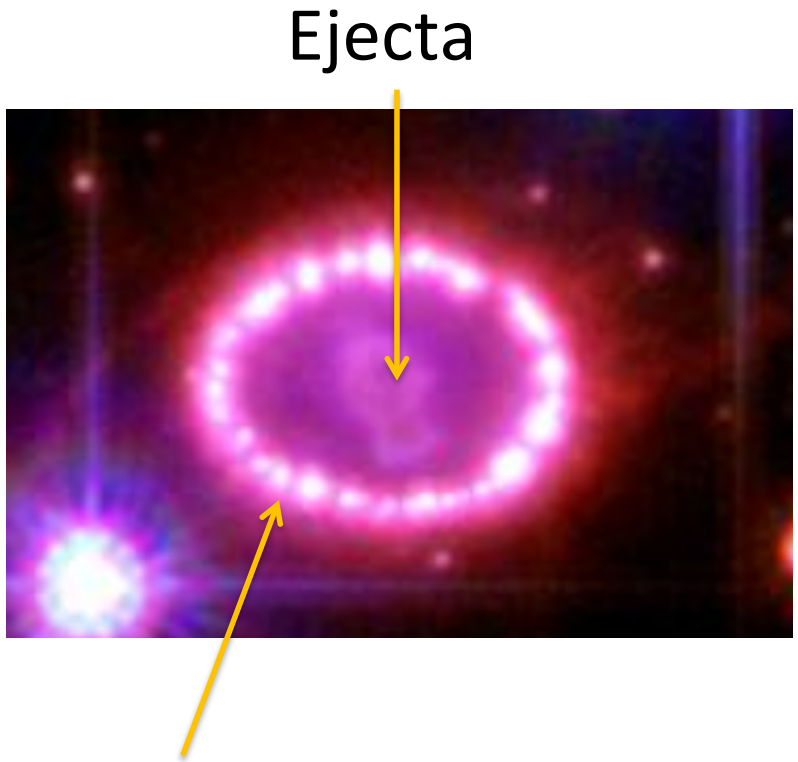
CO mass increases in time



9000 days

Sarangi & Cherchneff 2013

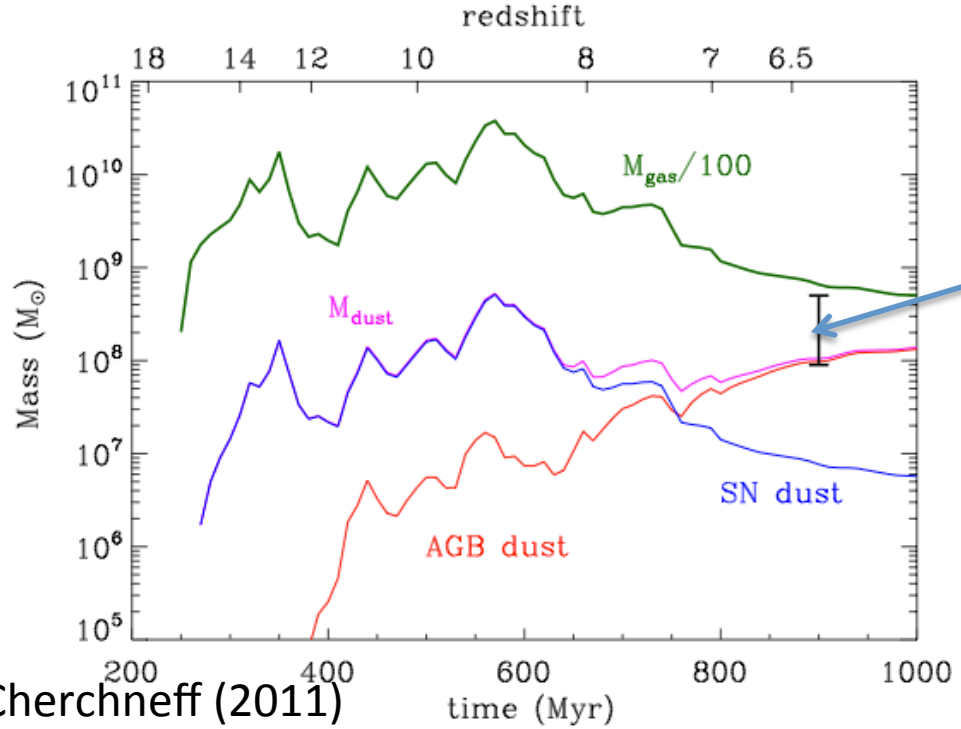
The ejecta of SN 1987A



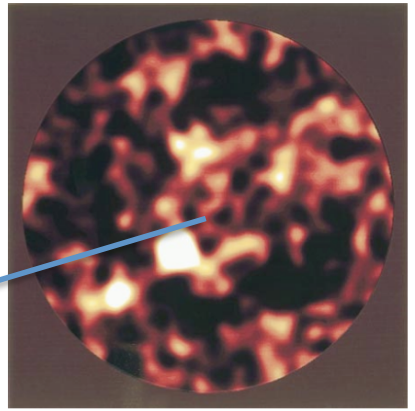
- Cold and dense gas in the ejecta < 25 years after the explosion
  - ~20 K of dust
  - <100 K of molecules
- Rich with molecules and dust
- Efficient cooling with adiabatic, lines and dust radiations

What are the major sources of dust in galaxies?

- Two hypotheses
  - Stellar origin (SNe + AGB stars) : On average 0.1 Msun of dust per SNe
  - ISM grain growth



Dwek & Cherchneff (2011)



Submm galaxy
At z~6.4; ~0.4 Giga years
(e.g. Bertoldi et al. 2003)

Summary of Herschel studies of SN 1987A

- Cold dust and molecules from the SN ejecta
  - Far-IR : dust in the ejecta (0.4-0.7 Msun)
  - Molecules (<100 K; 0.05 Msun)
- Time scale of dust condensation is unknown
- SNe can be significant source of dust in the ISM