Spitzer Studies of Core-collapse supernovae

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+ Mid-IR Supernova Consortium

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Uni. of California, Berkeley (Filippenko, Foley)

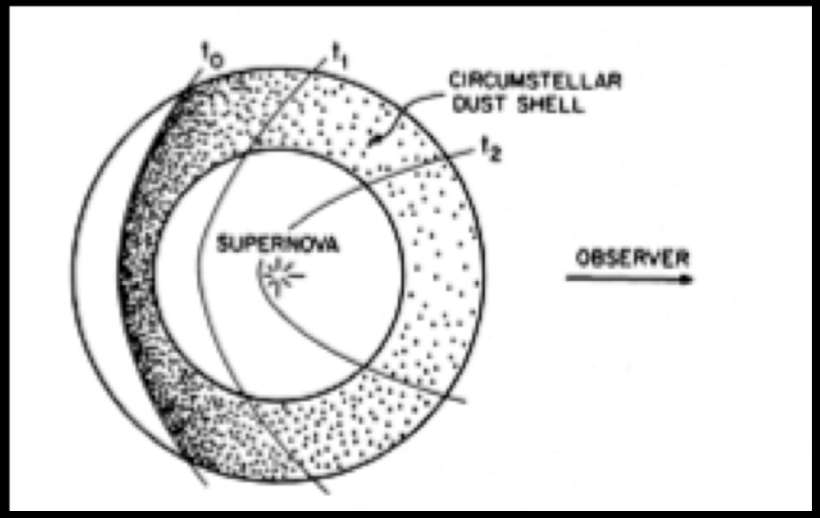
Uni. Of Texas, Austin (Wheeler)

- When does dust form?
- Under what conditions? ➔ Molecules always necessary?
- How much dust?
- What is the composition?

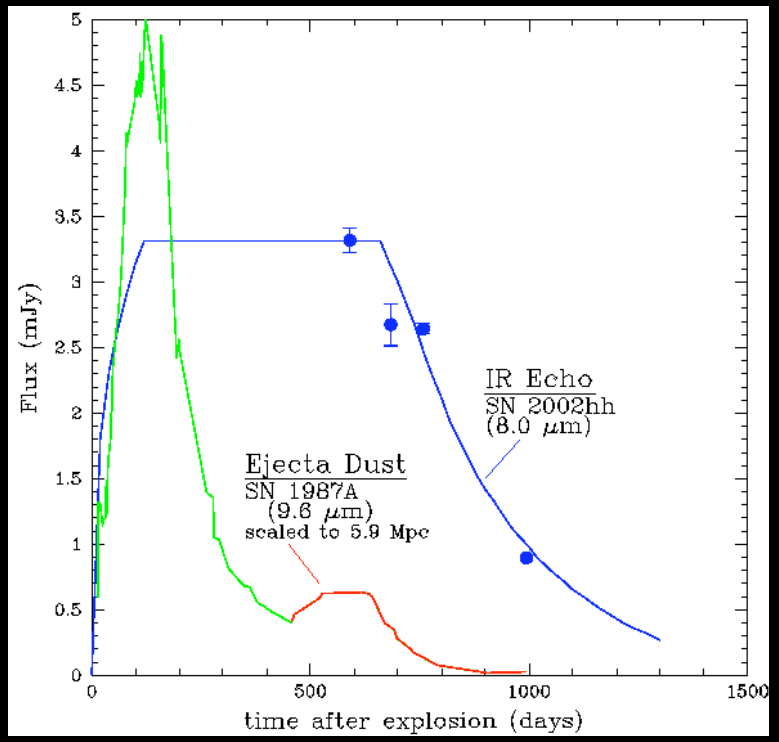
Thermal emission

Direct detection of dust

….. But could be due to pre-existing dust in the circumstellar medium (CSM)



Dwek (1983)



⇒ Monitoring

Bouchet et al. 1989, 93
Meikle et al 2006

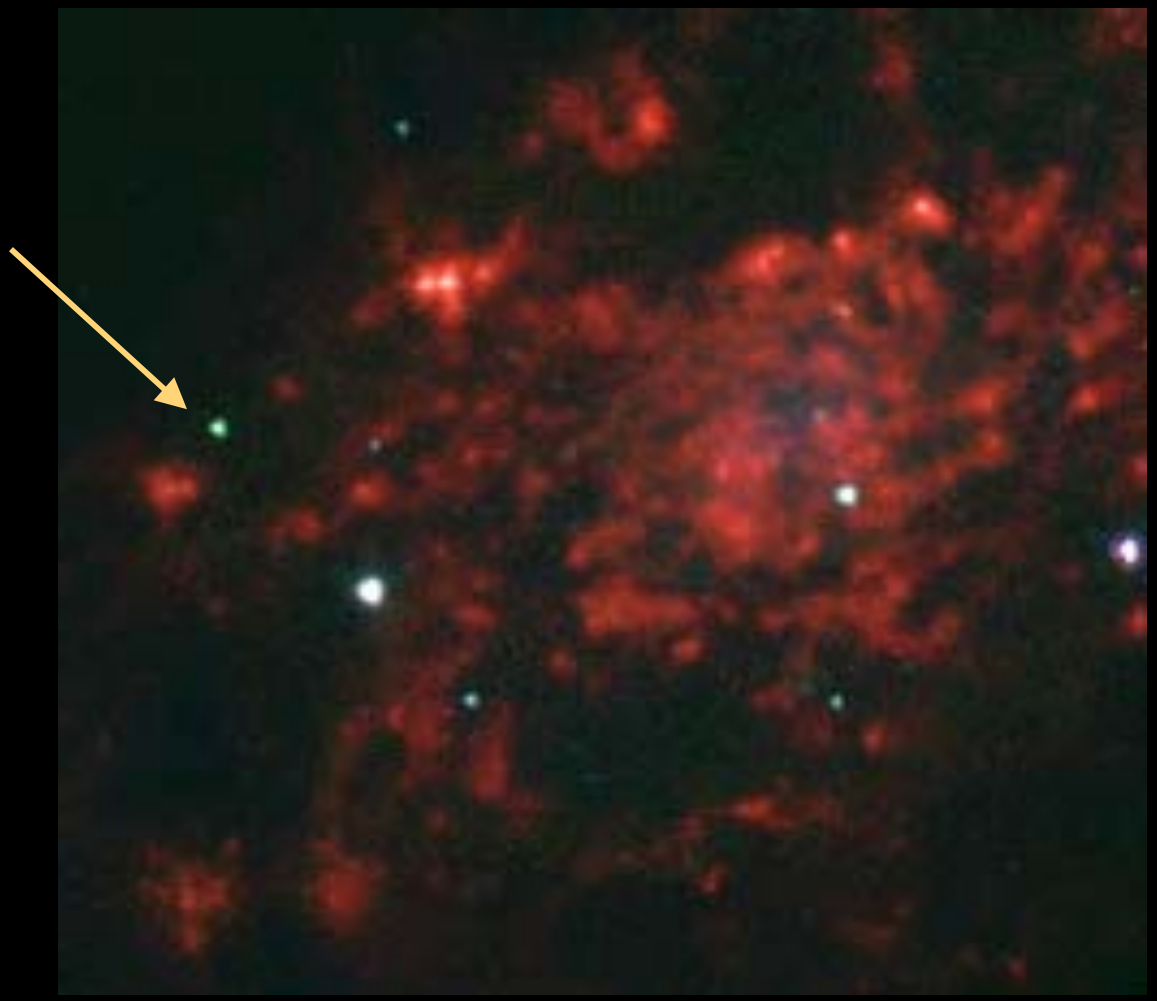
Mid-IR monitoring extremely challenging from the ground.

No mid-IR studies of SNe since SN 1987A

MISC Supernova programme with Spitzer:

- ~145 hrs over cycles 1,2,3
- Sample of nearby targets (photometry + spectroscopy)
- to assess the ubiquity of dust formation in core-collapse supernovae

SN 2004dj (type II-P)



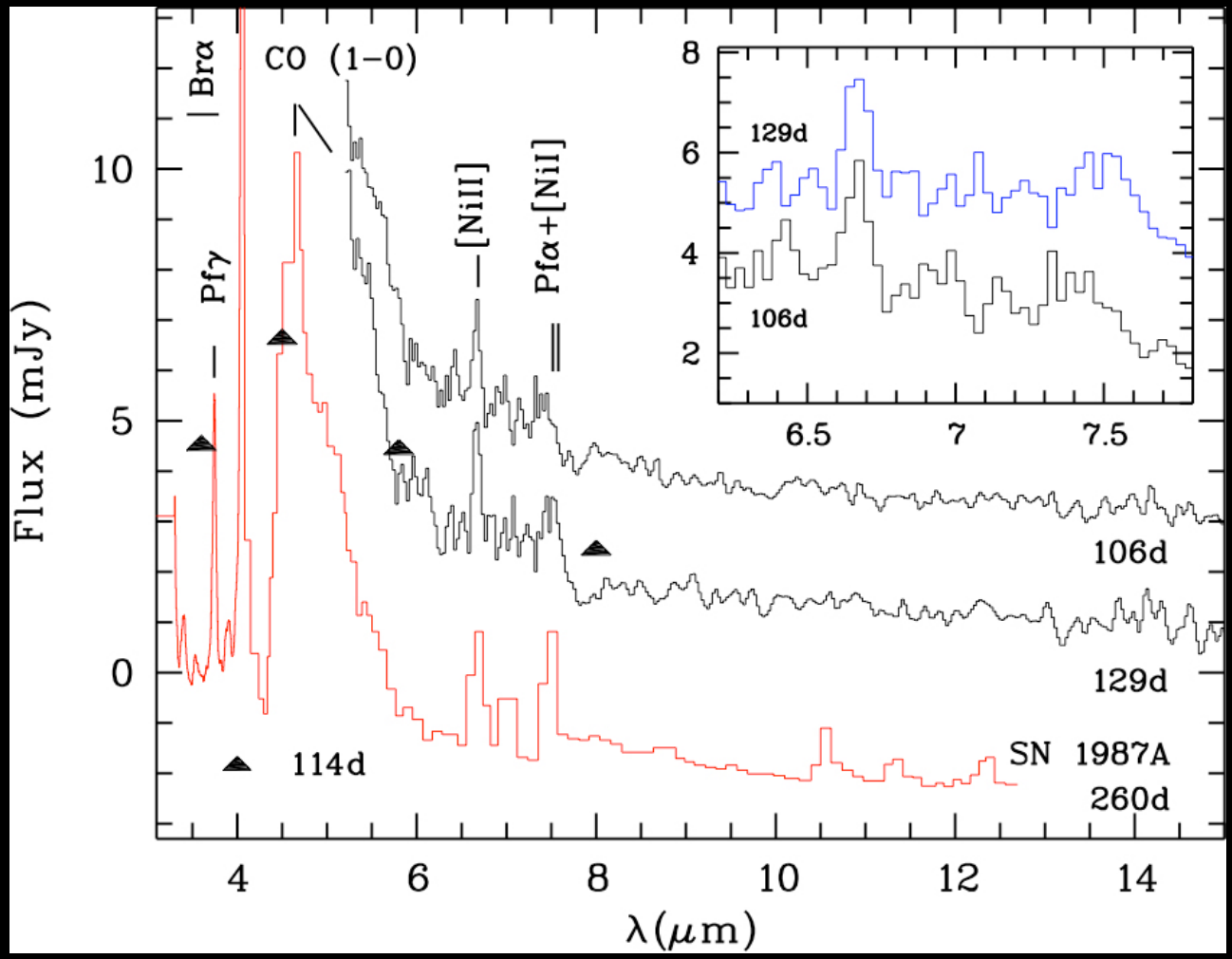
Blue 3.6μm

Green 4.5μm

Red 8.0μm

The first mid-IR spectrum of any SN since SN 1987A

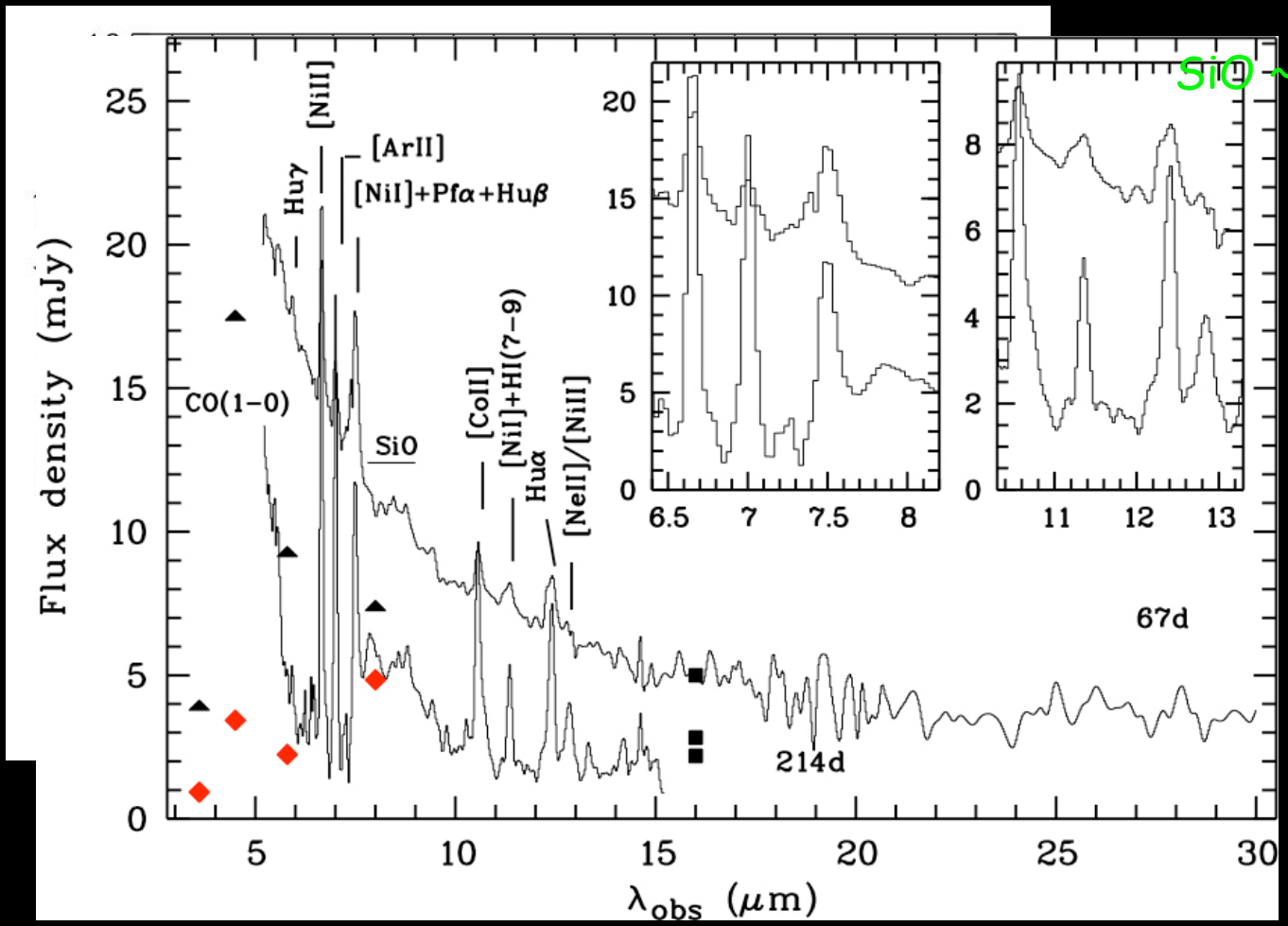
SN 2004dj



Kotak et al. (2005); Wooden et al. (1991)

First detection of SiO since SN 1987A

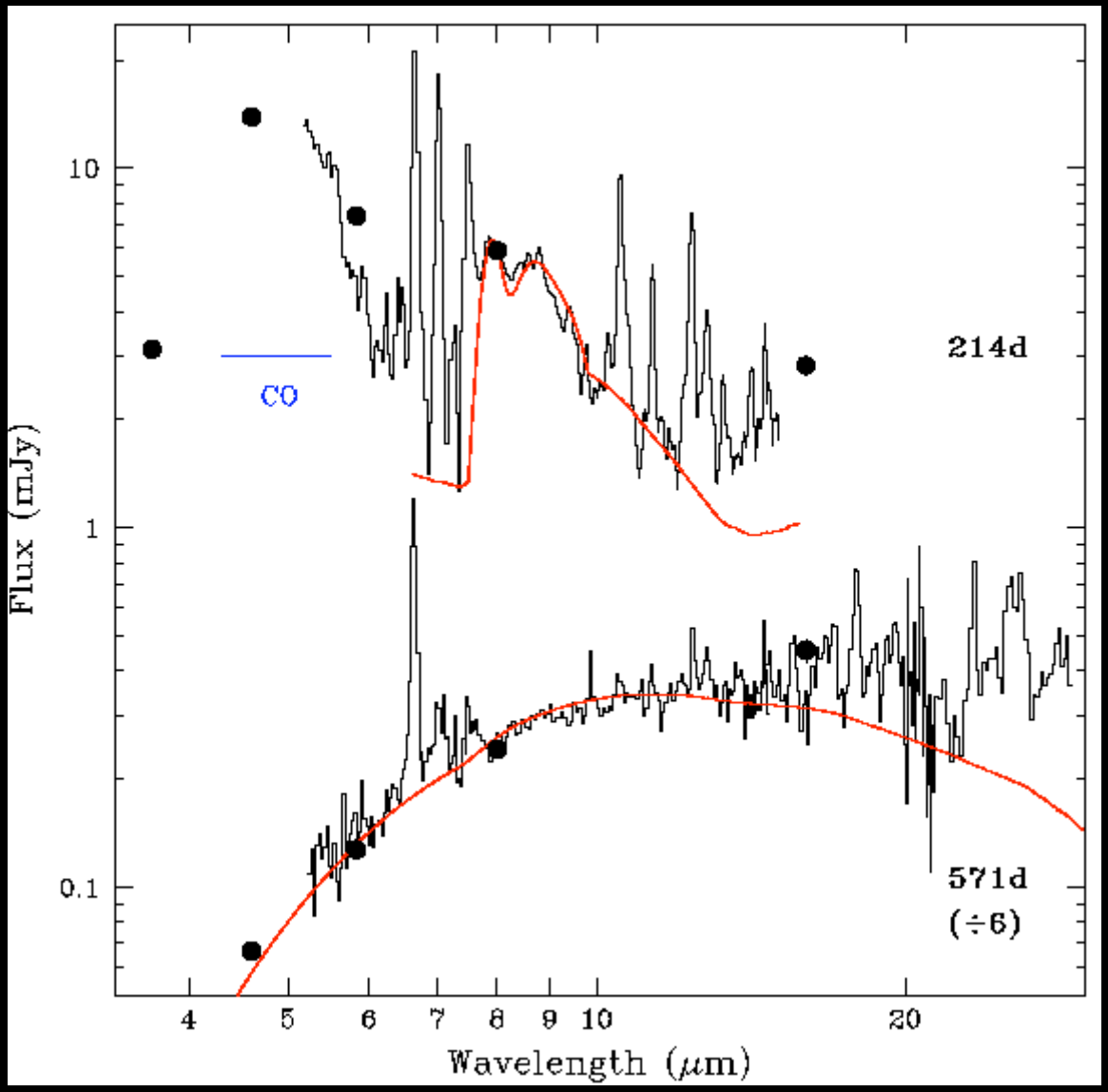
SN 2005af (type IIP)

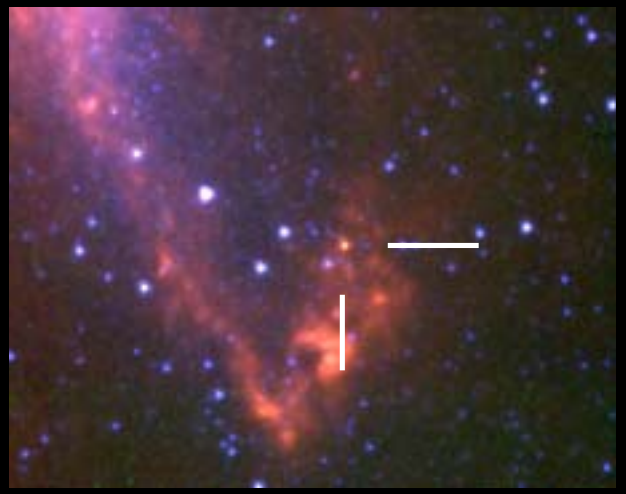


SiO ~ 2×10^{-4} $M_\odot$

Kotak et al. (2006)

SN 2005af





Spitzer IRAC 3.6-8 μm 576d

Age (d)	Temp. (K)	Md (10^{-4} $M_\odot$)	f
214	800	0.015	0.07
571	420	4.0	0.32

Recent claims of a large dust mass in SN 2003gd (IIP)

0.02 $M_\odot$ of dust -- Sugerman et al. (Science, 2006)

	Sugerman et al. (2006)	Meikle et al. (2007)		
24μm /~700d	106±16	380±90	μJy	(same data)

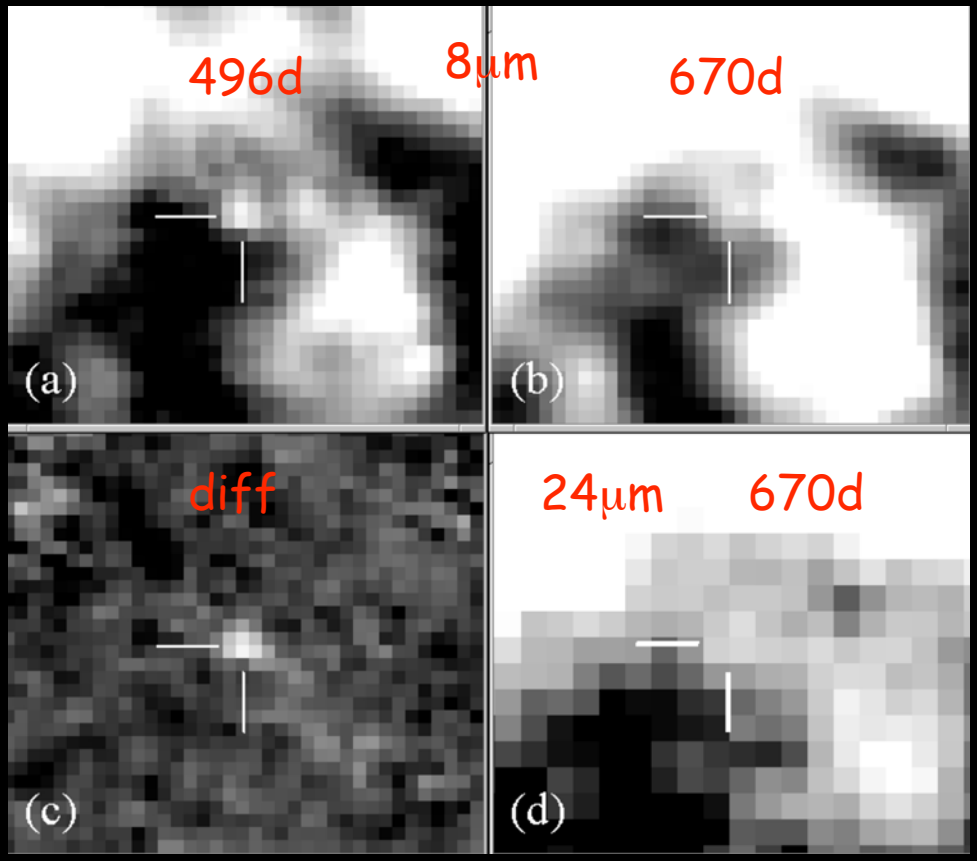
Sensitivity overestimate: 106 μJy ⇒ S/N ~ 1 (not 6.5)
Error in 24μm /~700d flux of Sugerman et al.

- Outer limit of dust-forming zone > metal line velocities from late-time spectra (~2000km/s) ⇒ unphysical
- Total luminosity > 4 x total radioactive luminosity deposited in ejecta

⇒ severe energy deficit

Directly detected dust: SN 2003gd produced no more than few 10^{-5} $M_\odot$

For details see Meikle et al. (2007)


496d
8μm
670d
(a)
(b)
diff
24μm
670d
(c)
(d)

Summary

- CO and SiO detected in all of our nearby type IIP sample
- Before Spitzer, no evidence of dust formation in the most common type of core-collapse SNe (IIP).
- We find evidence for (direct) dust condensation in all of our type IIP events.
- Currently only 10^{-3} - 10^{-5} $M_{\odot}$ of dust 10-100x lower than needed.

-- more may exist in optically-thick clumps

Core-collapse supernovae as massive dust factories?

"Definitely Maybe"