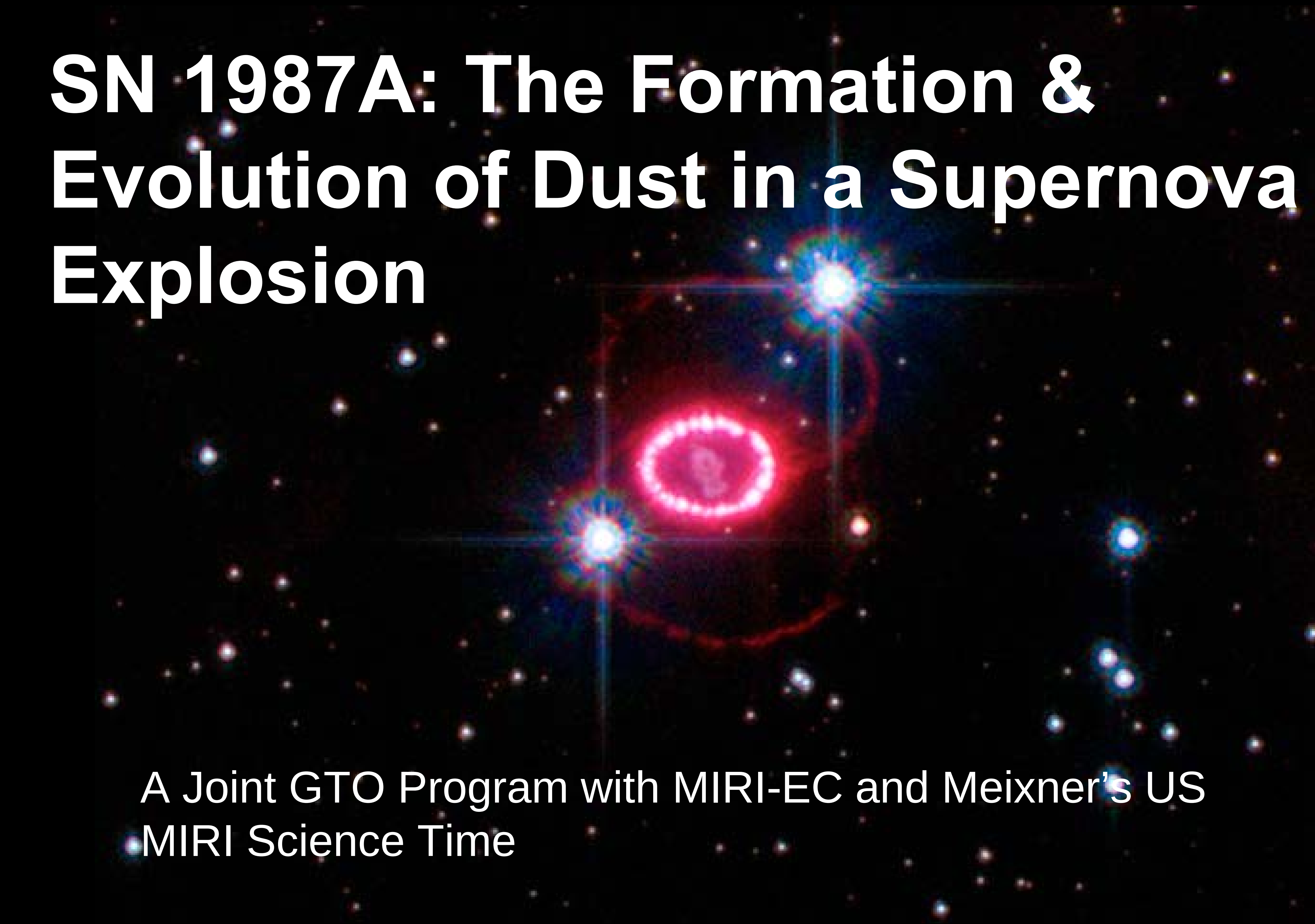
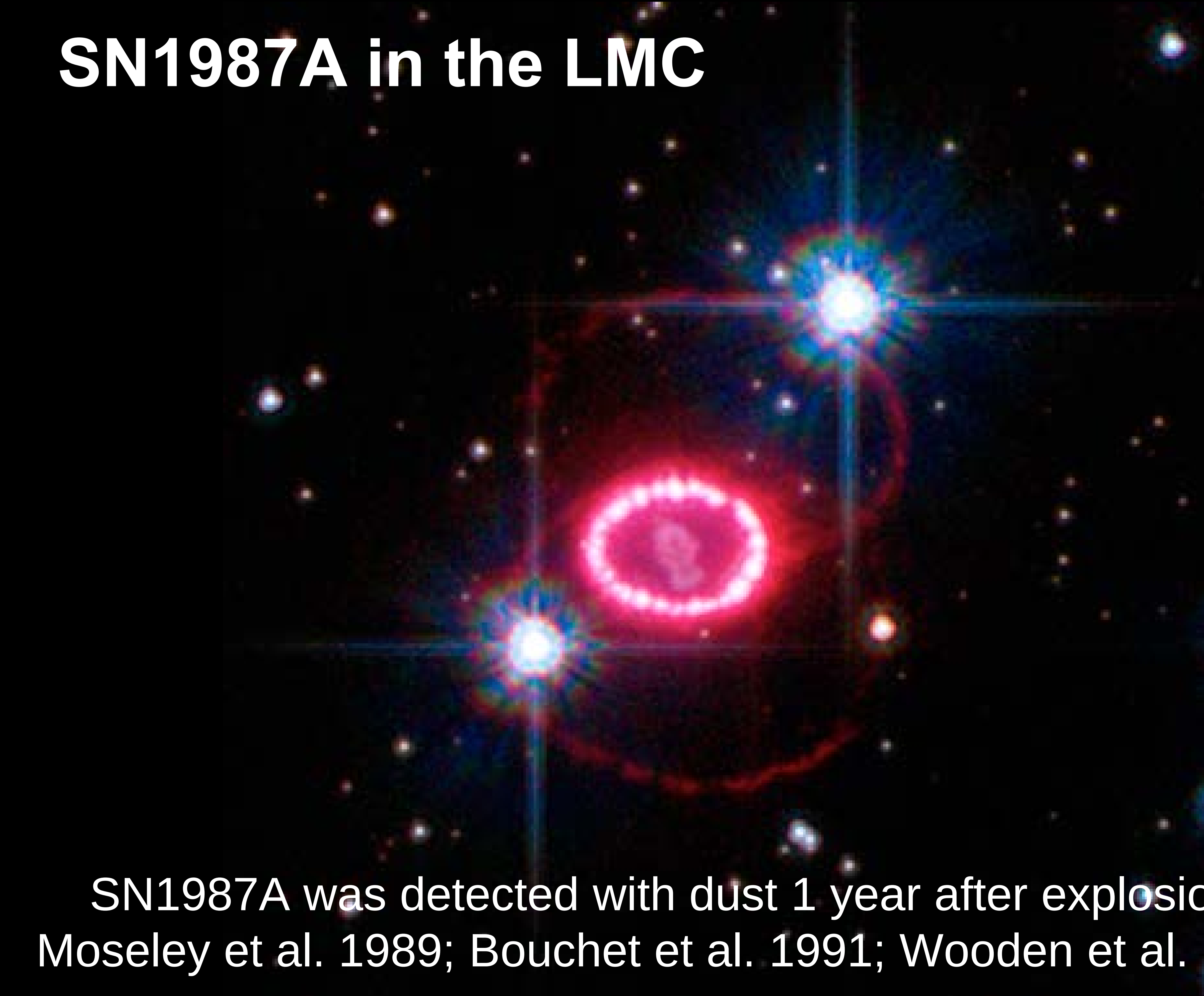
SN 1987A: The Formation & Evolution of Dust in a Supernova Explosion

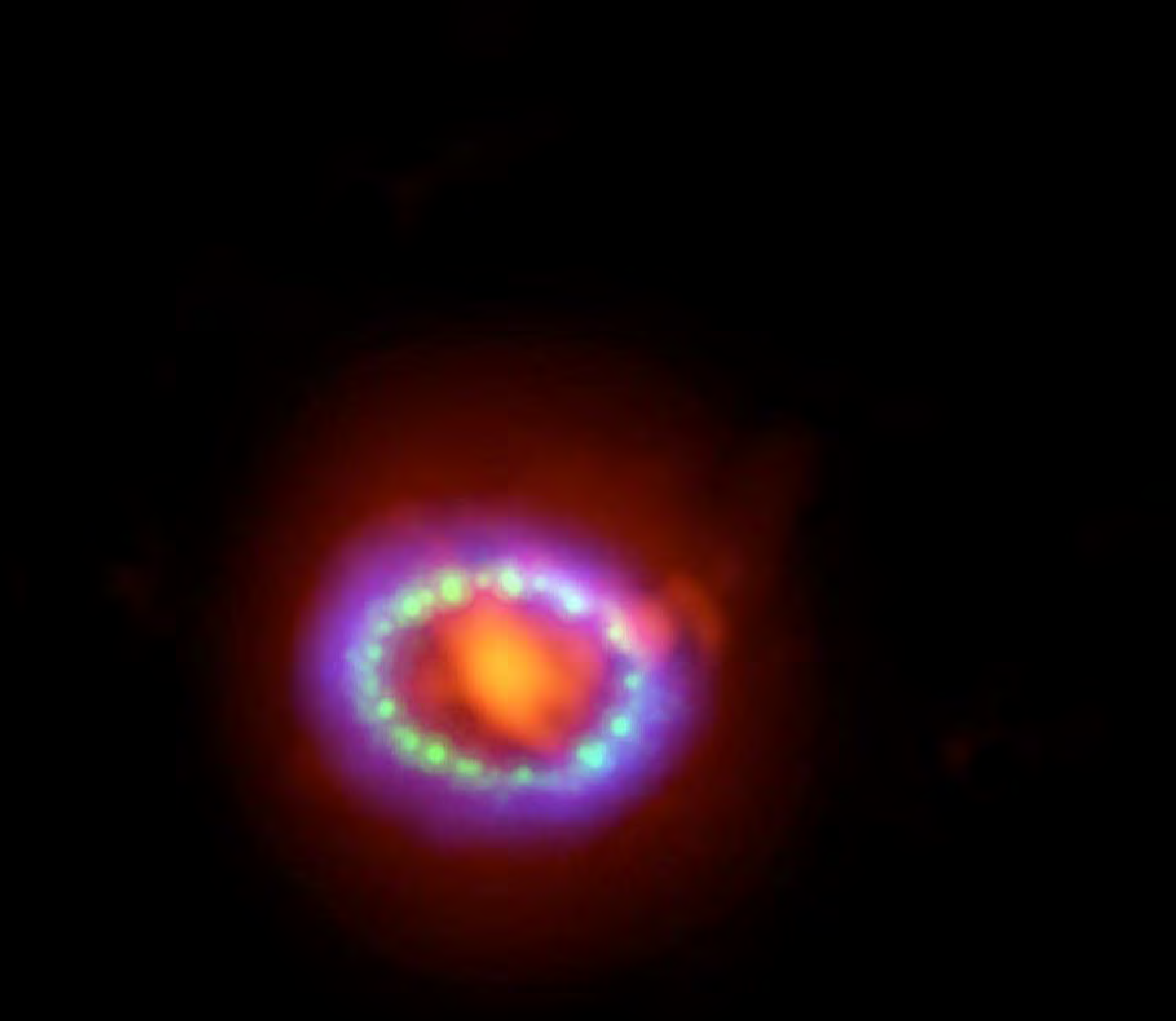


A Joint GTO Program with MIRI-EC and Meixner's US MIRI Science Time

SN1987A in the LMC

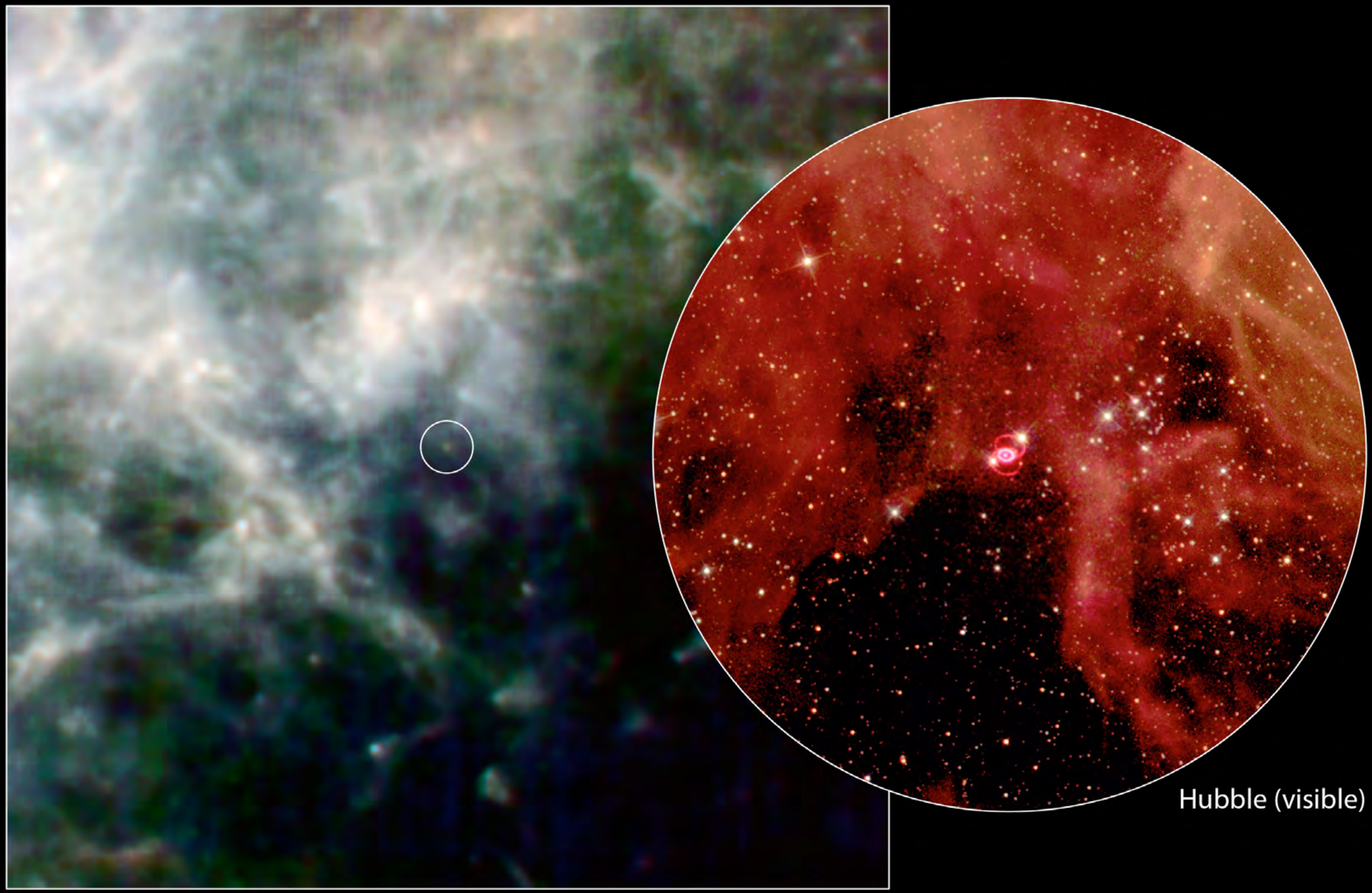


SN1987A was detected with dust 1 year after explosion (
Moseley et al. 1989; Bouchet et al. 1991; Wooden et al. 1993).



The central stellar ejecta of SN 1987A is surrounded by a ring of progenitor gas and dust that is being shocked by the blast wave of the explosion.

Dust formation in SN ejecta



Herschel (far-infrared)

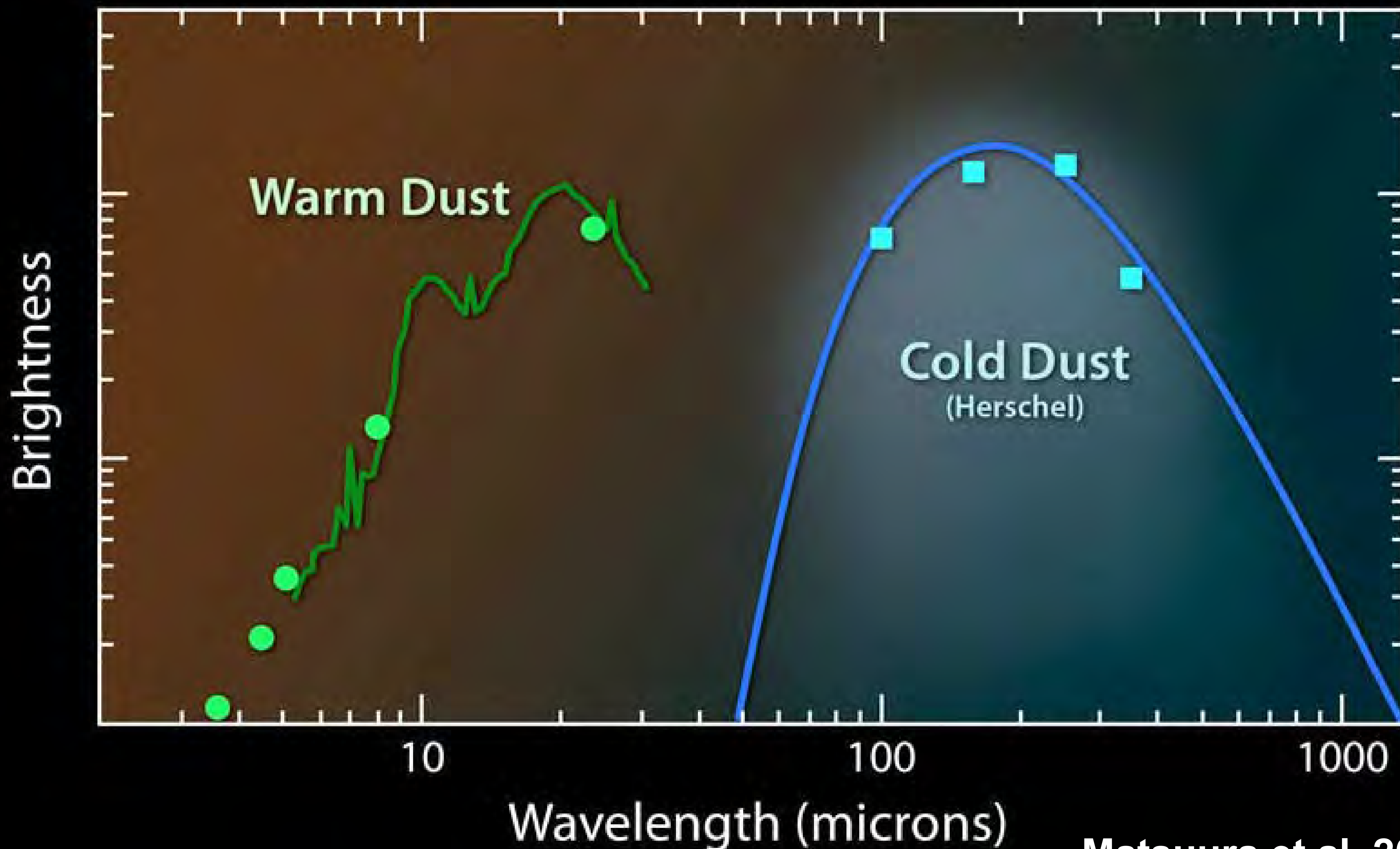
(HERITAGE; Meixner et al. 2010)

Herschel Finds Enormous Stores of Dust in Supernova 1987A

ESA/NASA-JPL/Caltech/UCL

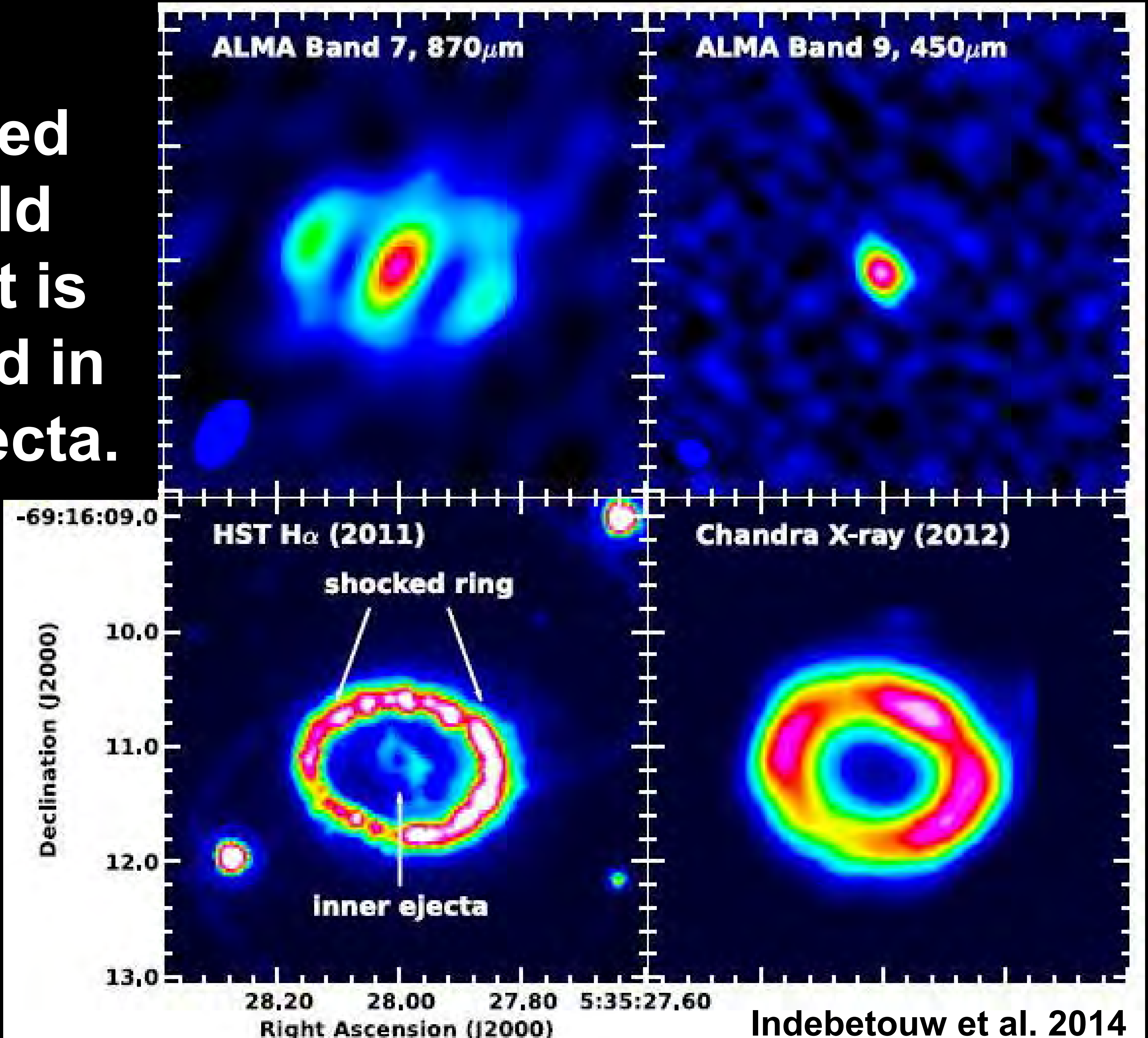
Matsuura et al. 2011

Herschel detected ~0.5 Msun of dust

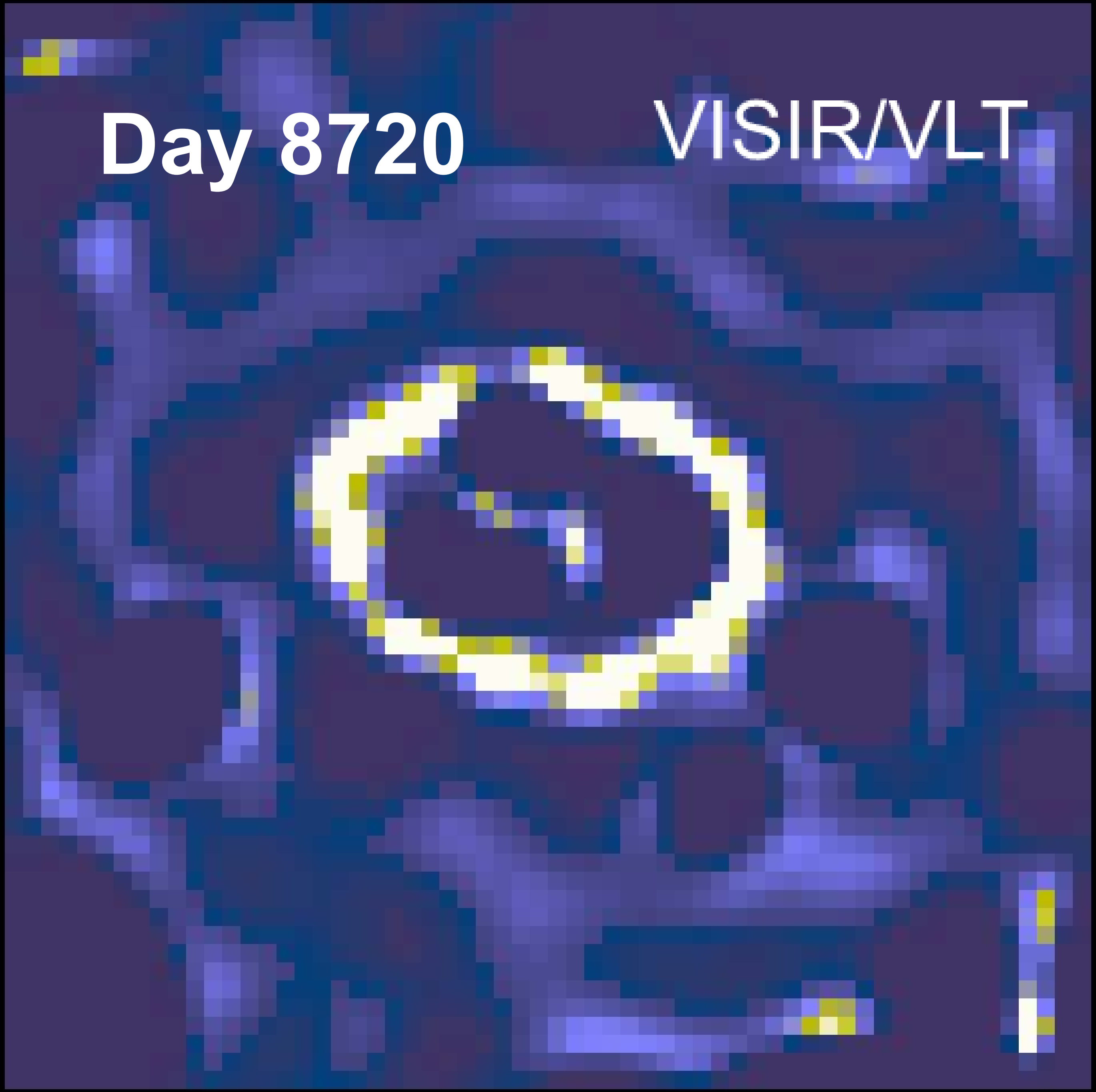


Matsuura et al. 2015

ALMA resolved the cold dust. It is located in the ejecta.



Indebetouw et al. 2014



$M_{dust,ejecta} = 10^{-4} – 10^{-3} M_{\odot}$

80<T<100K

Bouchet et al. 2011

We want to understand how massive stars explode, how their ejecta forms dust and molecules and how the blast wave from the explosion affects their surroundings.

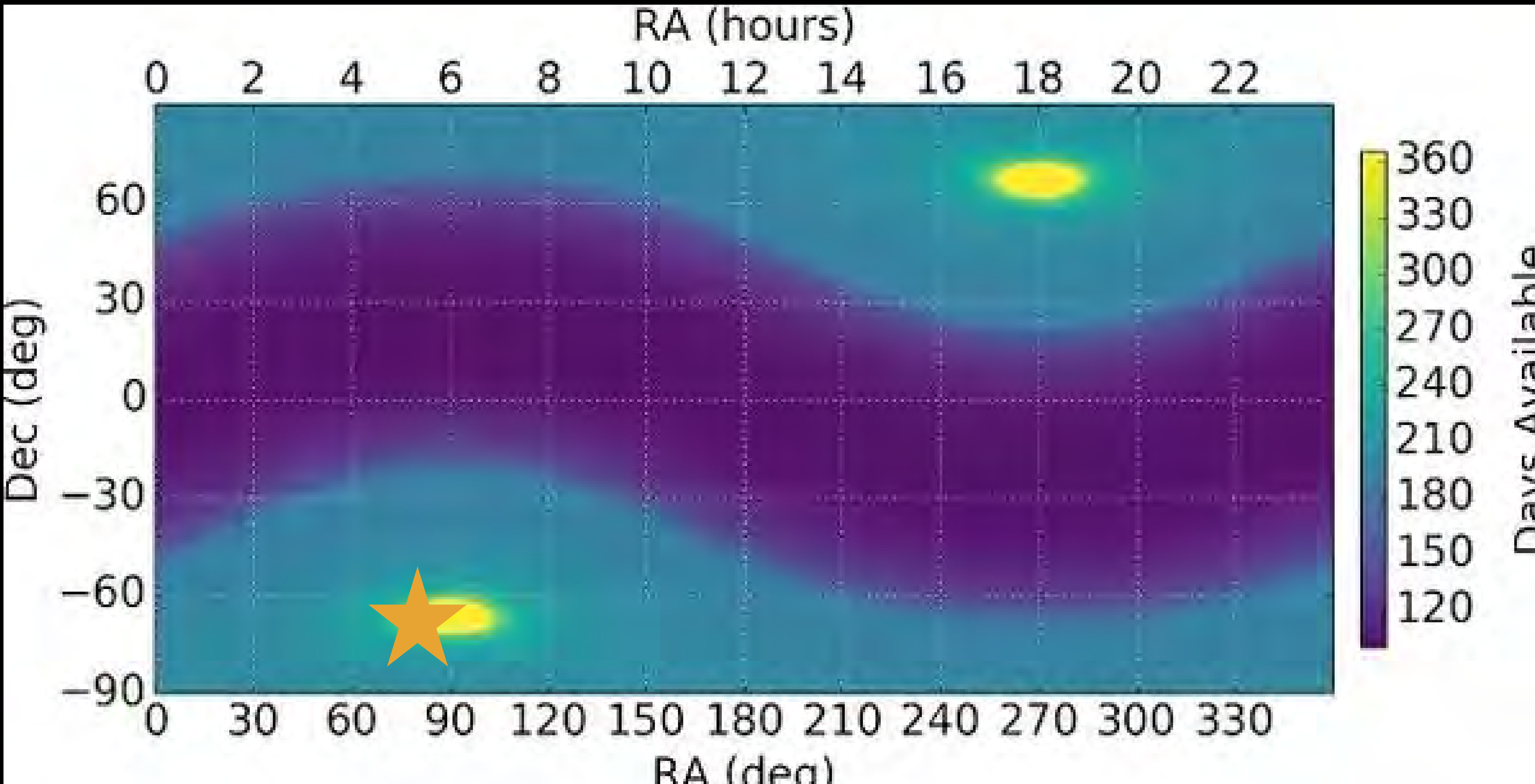
What *can* JWST do for us?

- Exquisite resolution in the infrared (0.6-28 microns) — Accurately resolve both the ring and ejecta.

- Sensitivity — detect faint emission from ejecta & the warm dust emission from the circumstellar ring.

- Medium and high resolution IFU imaging spectroscopy — provides line & continuum measurements of the gas & dust which is interacting with the expanding shock wave.

SN1987A is in the continuous viewing zone



We can observe changes in SN1987A over a wide temporal base-line.

What *will* JWST do for us?

We are going to observe the ring and ejecta of SN1987A at two epochs using:

- MIRI imaging: F560W, F1000W, F1800W & F2550W
- MRS IFU and NIRSpec IFU imaging spectroscopy
- Plus parallel observations with the MRS & MIRI simultaneous imaging (when possible).
- Total observing time (inc. overheads): ***9 hours***

MIRI Imaging

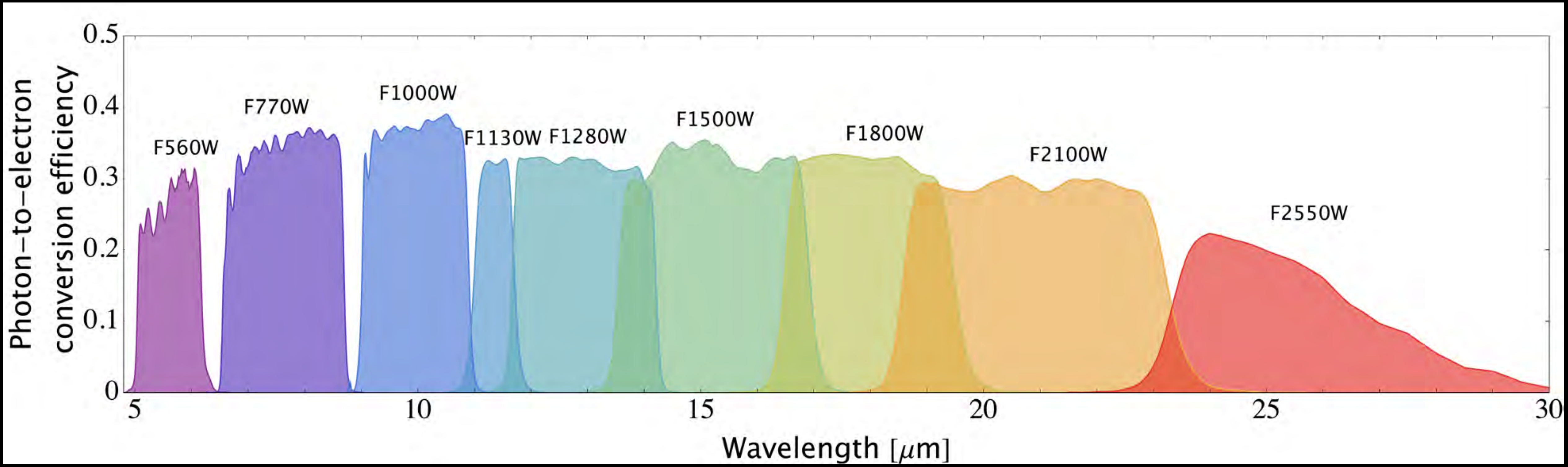
Goal 1: Study the interaction of the blast wave with the equatorial ring.

- Map the dust temperature distribution.
- Obtain light curves at different wavelengths.
- Determine whether dust grains are destroyed.

Goal 2: Search for mid-IR emission from the dust ejecta.

Goal 3: Look for a remnant neutron star.

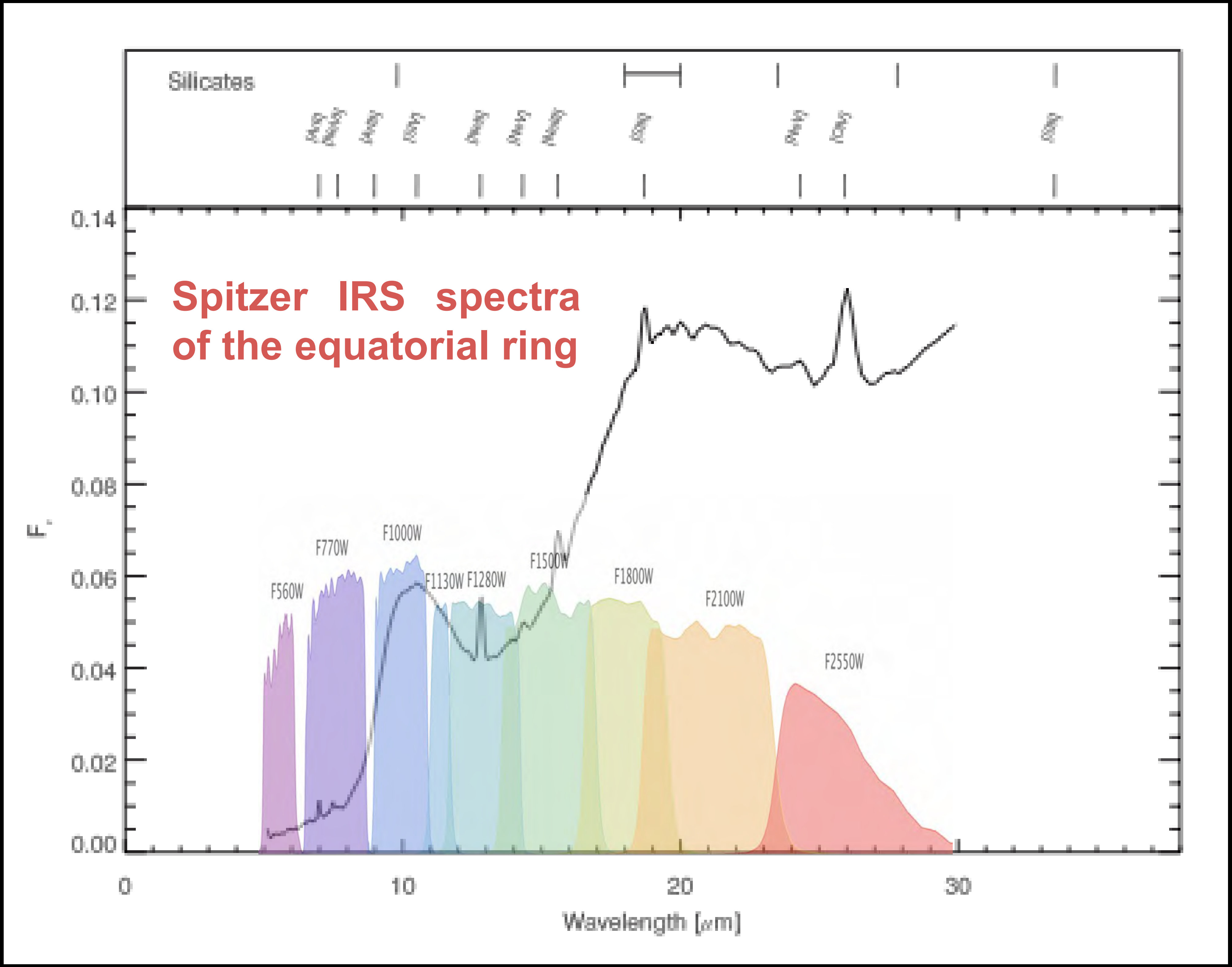
High S/N MIRI imaging at F560W, F1000W, F1800W & F2550W



MIRI imager has 0.11”x0.11” pixels -> better spatial resolution than MRS spaxels.

Caution: The ring is very bright, but any dust emission from the ejecta is faint. Need to use a subarray & many dithers to avoid saturation.

MIRI imaging at F560W, F1000W, F1800W & F2550W



MIRI MRS spectroscopy

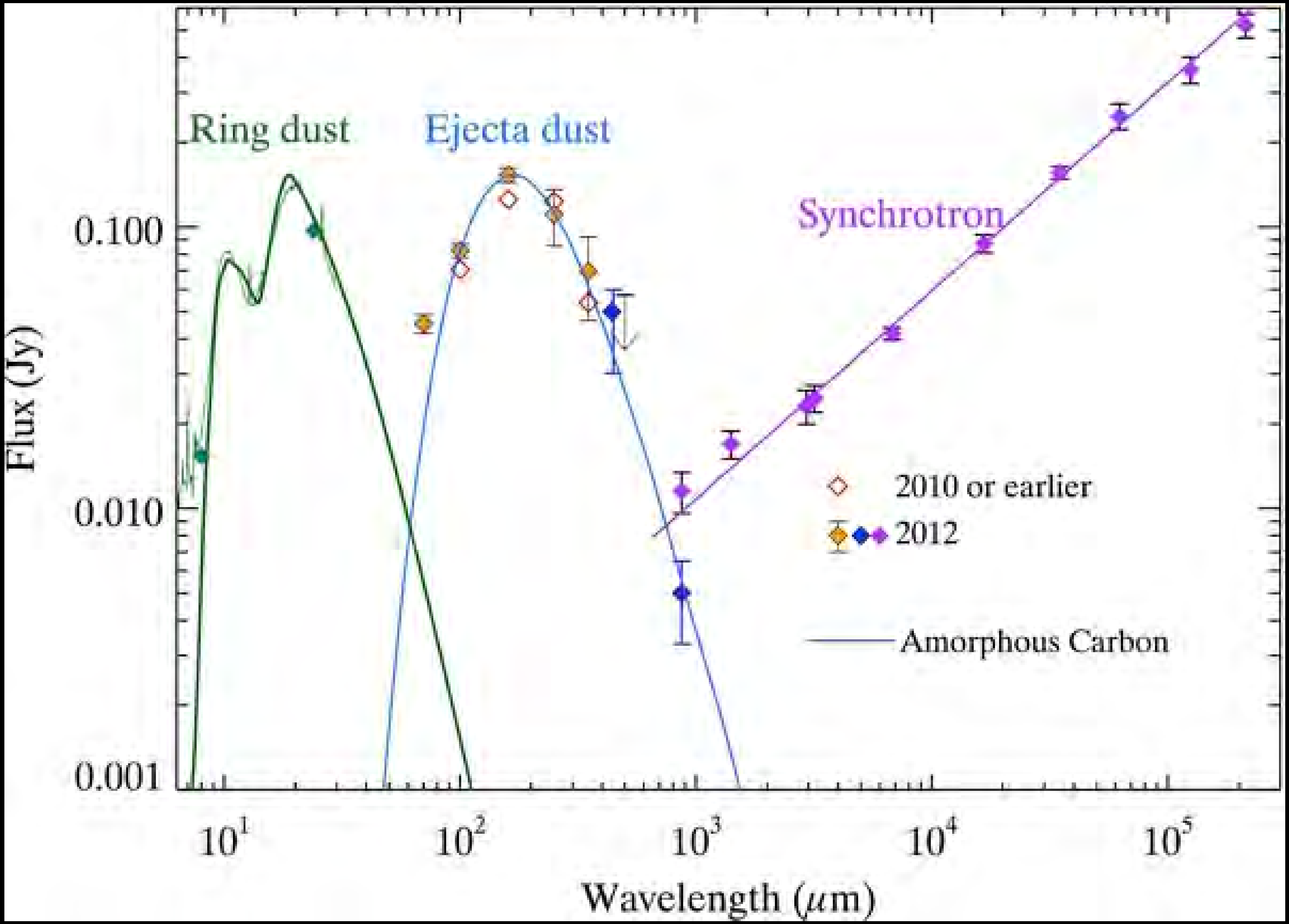
Goal 1: What is the composition of the dust in the stellar ejecta.

Goal 2: Constrain elemental abundances, temperature and densities in both the ring and the stellar ejecta.

Goal 3: How does the dust and molecules change as they undergoes processing due to the blast wave. Are there unknown dust and molecular components in the equatorial ring?

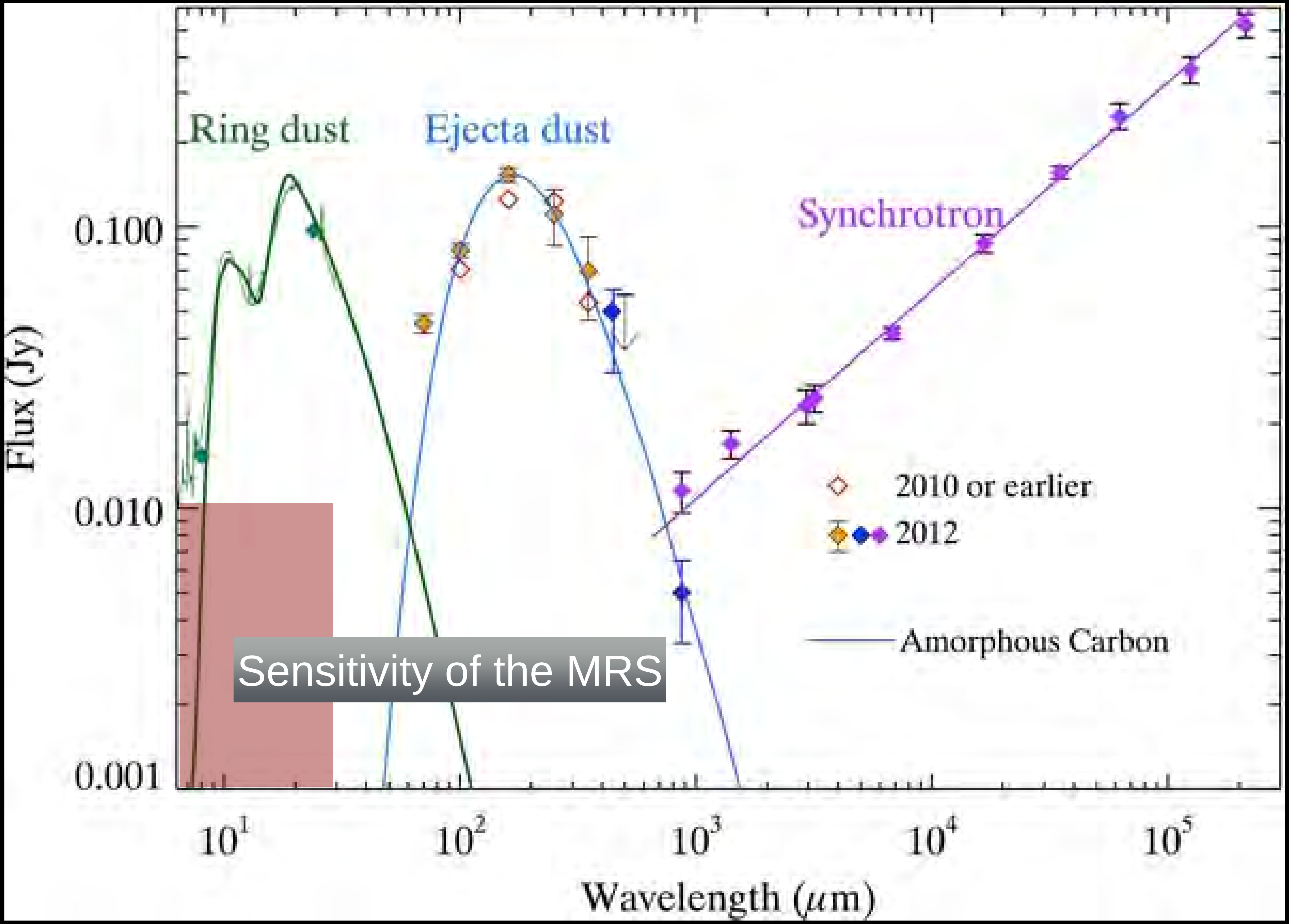
Goal 4: Understand the physics behind the shock.

What is the composition of the dust in the ejecta of SN1987A?



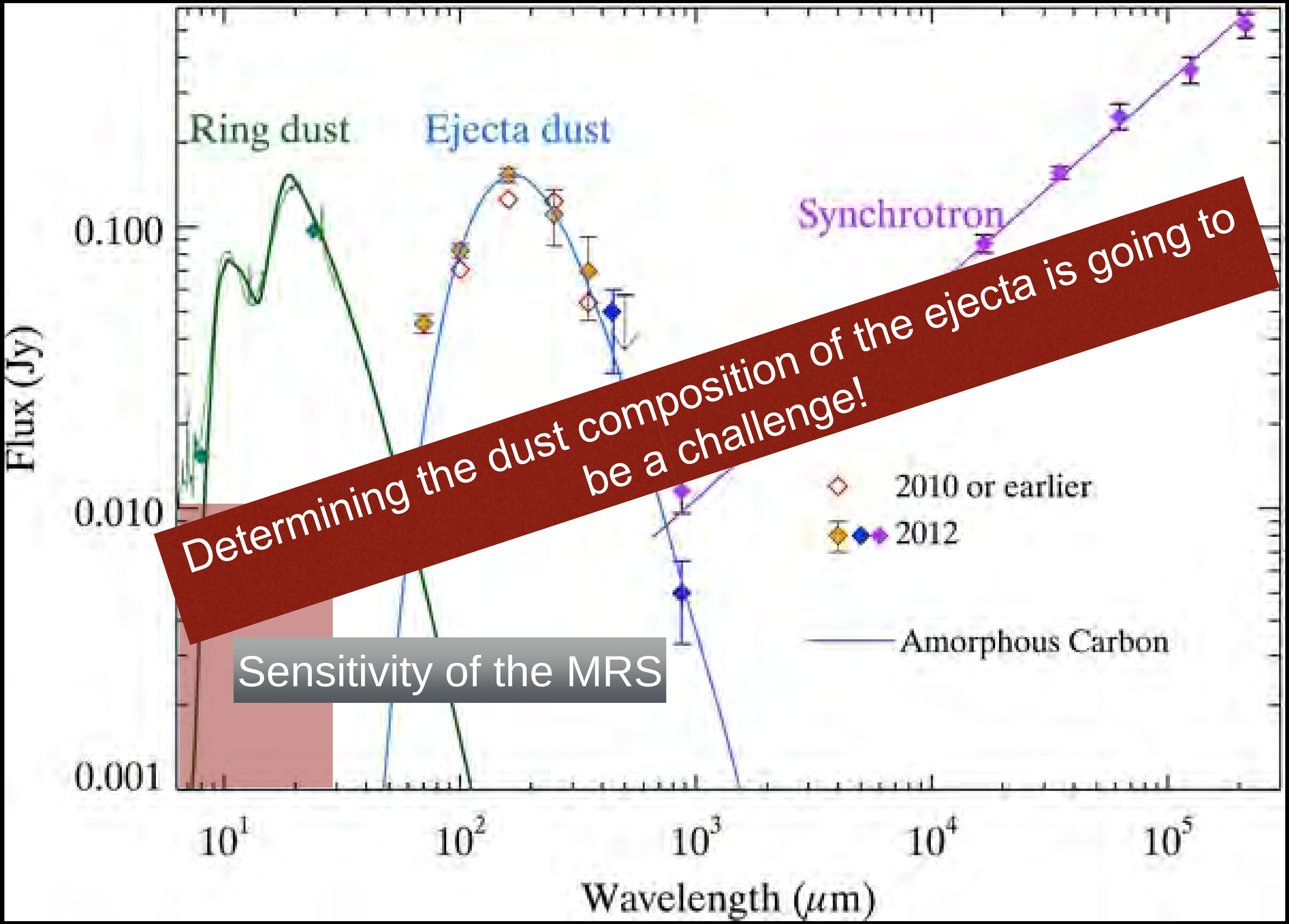
Matsuura et al. 2015

What is the composition of the dust in the ejecta of SN1987A?



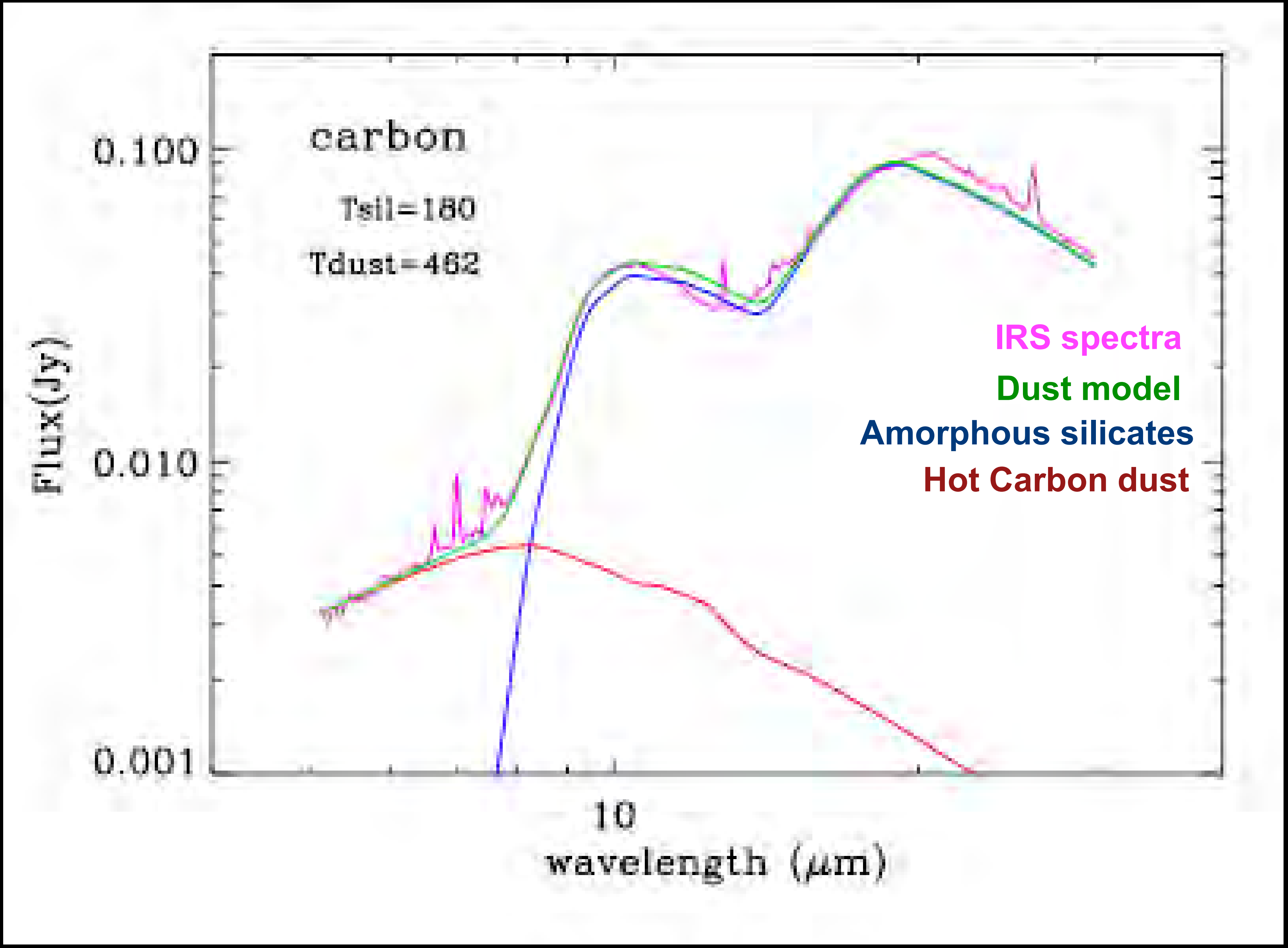
Matsuura et al. 2015

What is the composition of the dust in the ejecta of SN1987A?



Matsuura et al. 2015

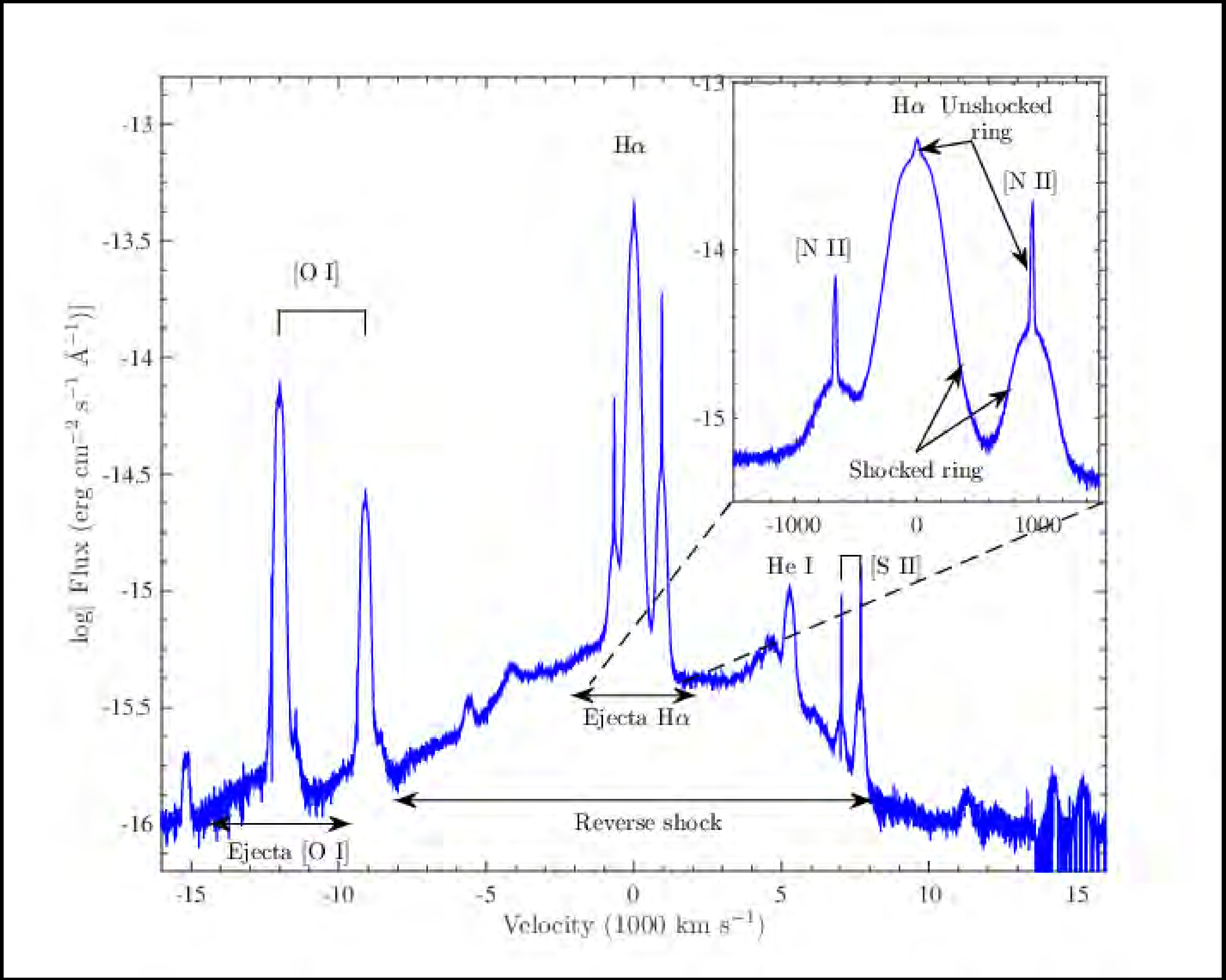
Is a hot dust component *also* present in the equatorial ring of SN 1987A ?



Dwek et al. 2010

NIRSpec IFU spectroscopy

Velocity components in the UVES/VLT spectrum



Un-shocked ring
V~10 km/s

Shocked ring
V ~ 300–700 km/s

SN ejecta (inner core)
V~2000–3000km/s

Reverse shock
V~ 11,000 km/s

Migotto et al. in prep.

Many low & high ionization lines seen with Spitzer.

Offer very useful diagnostics of the shocked ring & the explosion mechanism.

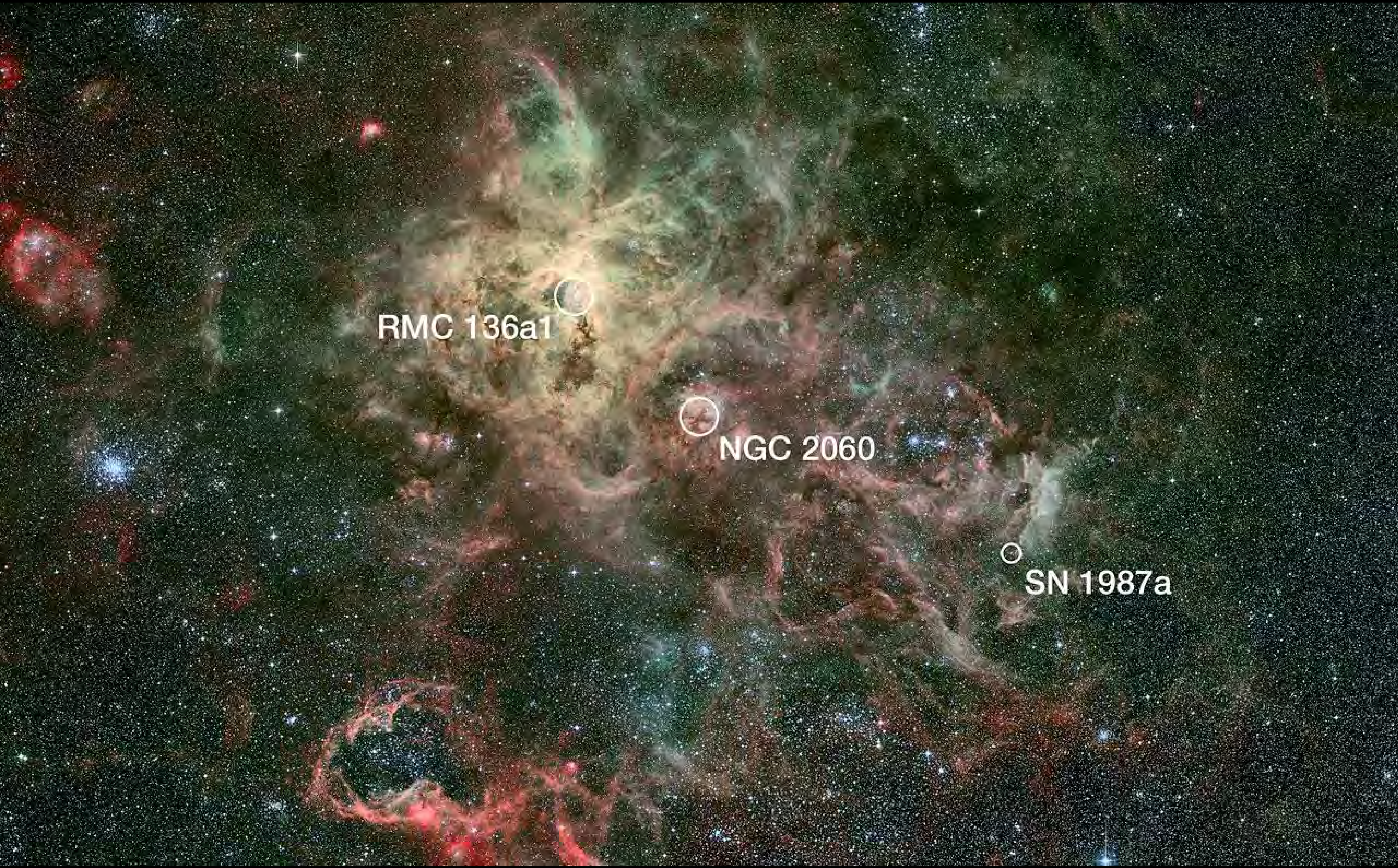
Most interesting lines: He I 2.058 μm & H_2 2.12 & 2.43 μm

Possibly use lines to obtain 3D structure of SN1987a.

NB: Molecular hydrogen is excited by UV or non thermal electrons. Dust or line emission outside the ring - excited by X-rays.

Caution: Mind the gap!
Avoid high resolution (R = 2700) gratings as coverage gaps where key lines are. Use the medium resolution IFU instead.

Parallel Observations


RMC 136a1
NGC 2060
SN 1987a

When MRS is prime

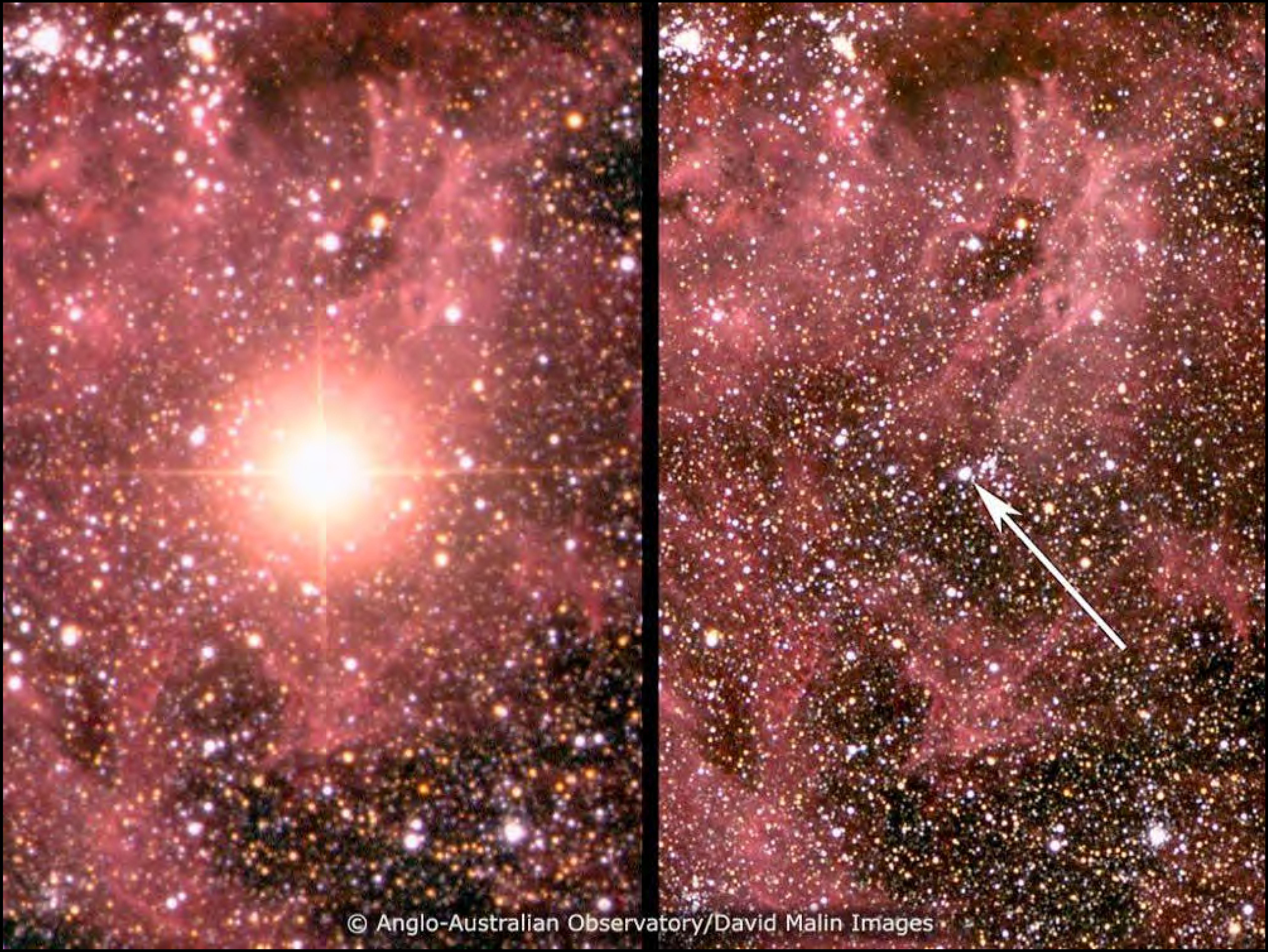
MIRI simultaneous imaging in the 5.6, 7.7 and 25 micron filters to measure the dust emission from young stellar objects & the surrounding interstellar medium.

When MIRI imager is prime

The MRS will provide critical background measurements of both the telescope emission & the ISM background. This is essential to reducing systematic issues with the MRS measurement of SN1987A.

Science goals

1. Study the interaction of the blast wave with the equatorial ring.
2. Determine the nature of the ring's hot dust component.
3. Search for mid-IR emission from the 0.5 M_{sun} of ejecta dust that was discovered at far-IR wavelengths by Herschel.
4. Study the evolution of the dust and molecules in the ejecta.
5. Look for a remnant neutron star.
6. Study the environment adjacent to SN1987A which has significant star formation (30 Dor!) using parallel fields.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