Title	Spitzer IRAC Observations of Cassiopeia A
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Unveiling the Nucleosynthetic Layers of Cassiopeia A with Spitzer

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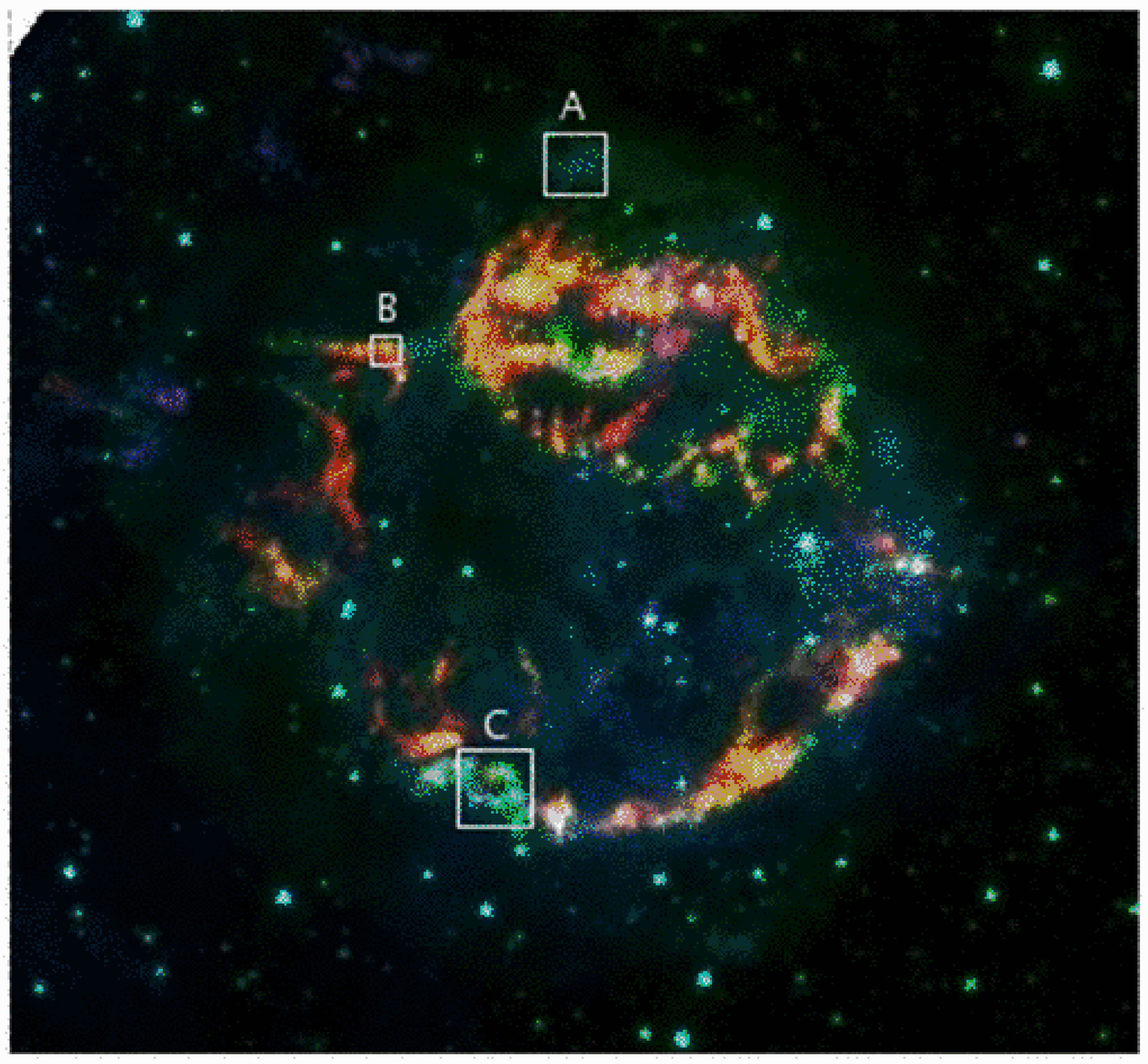
KEY FINDING:
IRAC images of Cassiopeia A, supported by IRS spectra, indicate that in each direction, different explosive burning layers are currently encountering the reverse shock, reflecting the explosion asymmetries. The respective nucleosynthesis products in different directions are seen in IR, visible and X-ray lines and newly formed dust.

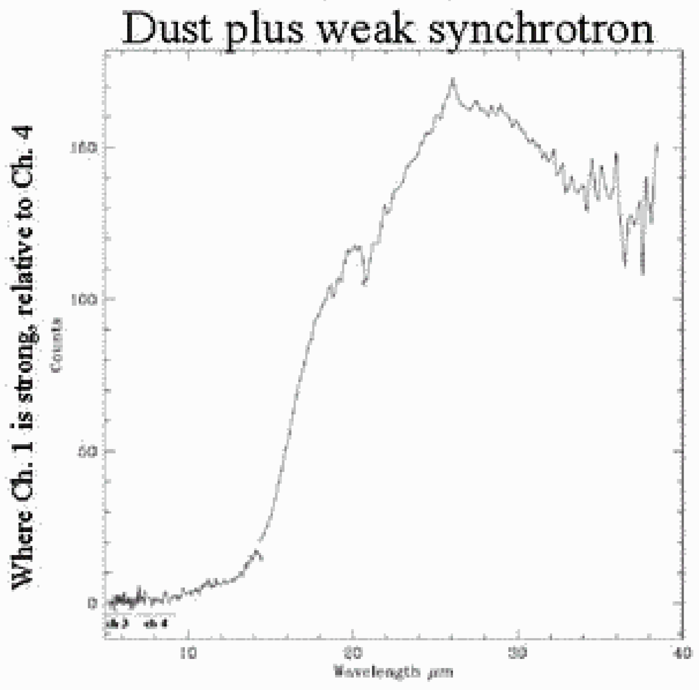


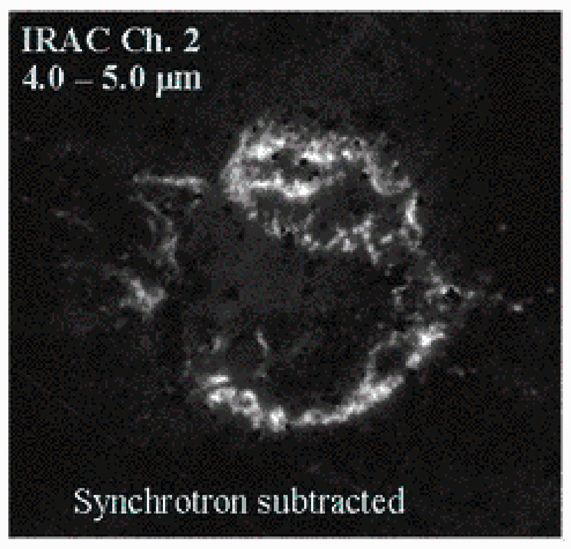
ABOVE: Color composite of IRAC Channels 4 (red), 2 (green) and 3 (blue). Emission is seen throughout the remnant in all IRAC bands. However, the ***relative strength*** in each band varies considerably across the remnant. The three labeled regions (A, B, C) correspond to the broadband IRS spectra shown at right. A: Ch. 1 relatively strong; B: Ch. 4 relatively strong.; C: Ch. 2 & 3 relatively strong.

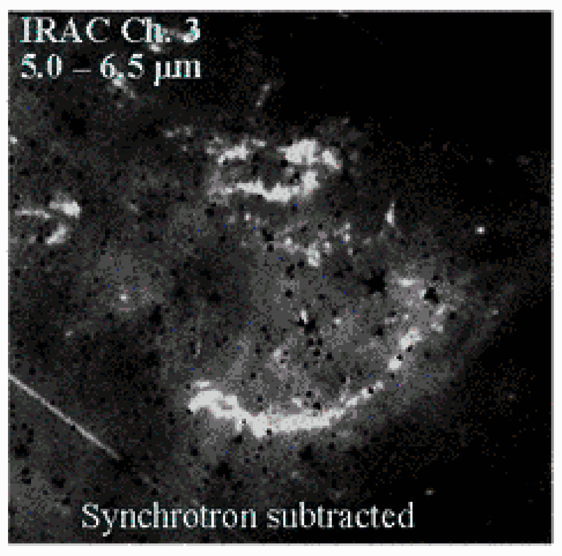
IRAC Images

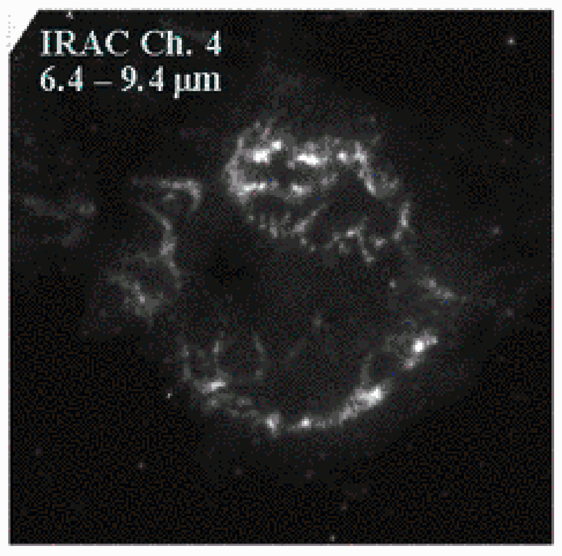
Images from the four IRAC bands, next to characteristic spectra of where each of the bands is dominant. Channels 2 and 3 as shown here have had a scaled version of Channel 1 subtracted, to remove synchrotron radiation contributions.

A Shock heated (~10^2K) Circumstellar Dust plus weak synchrotron

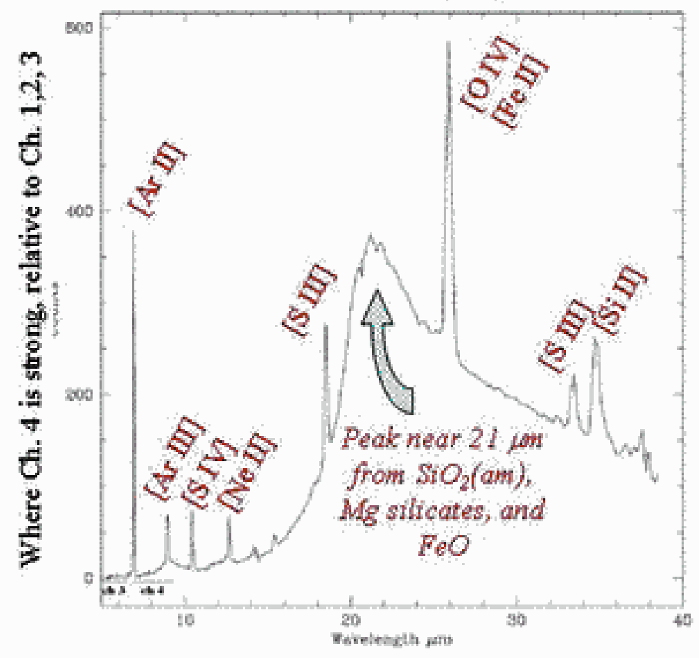




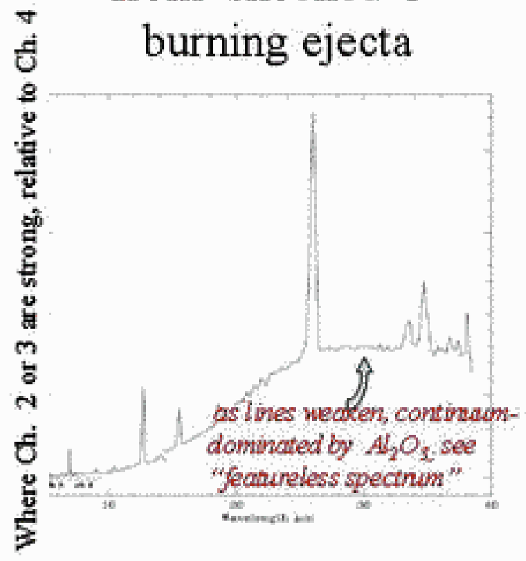




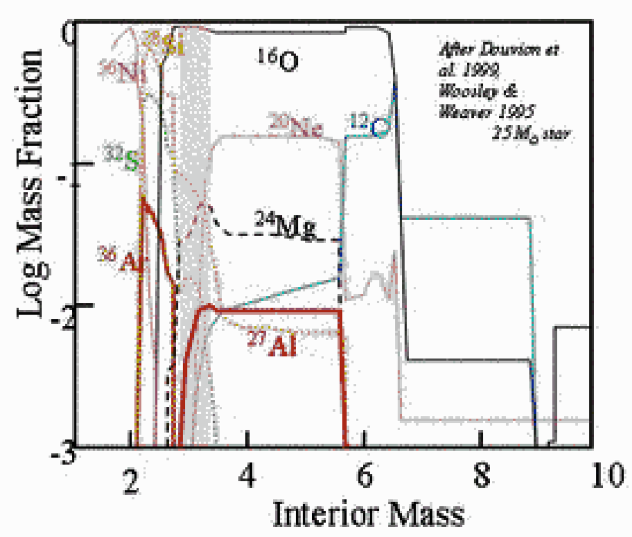
B Dust and gas from shocked O- and Si- burning ejecta



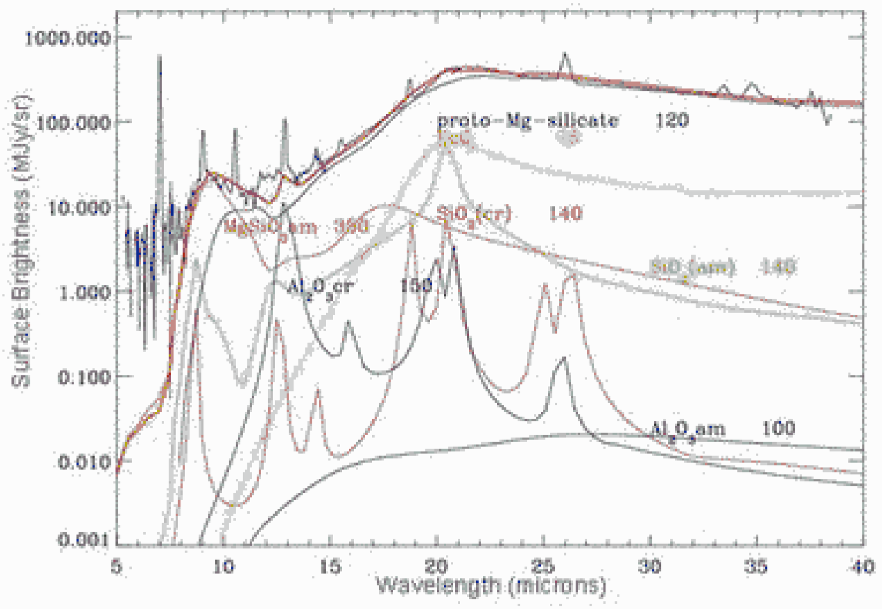
C Dust and gas primarily from shocked C-burning ejecta



Mass Estimates

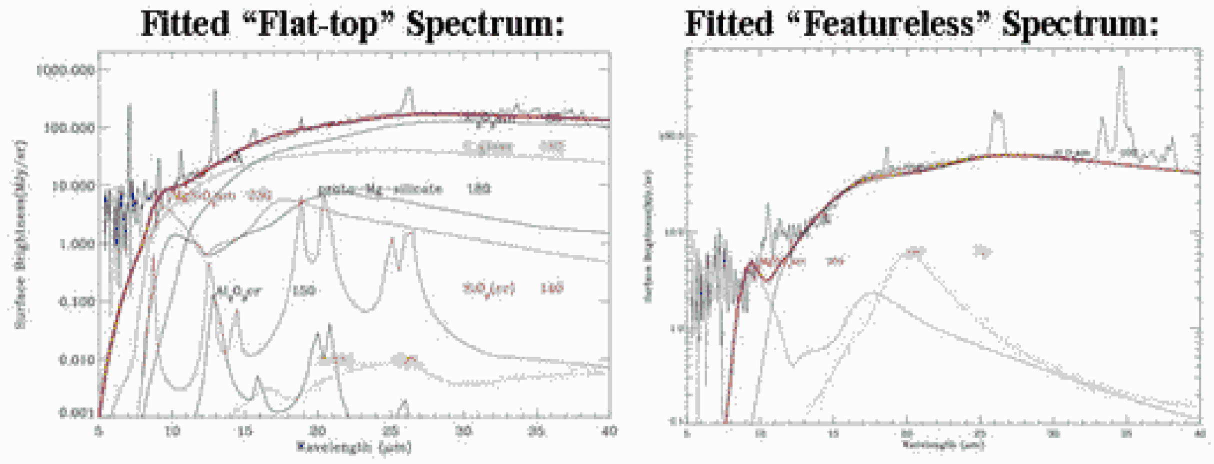


Fitted Peak Spectrum:



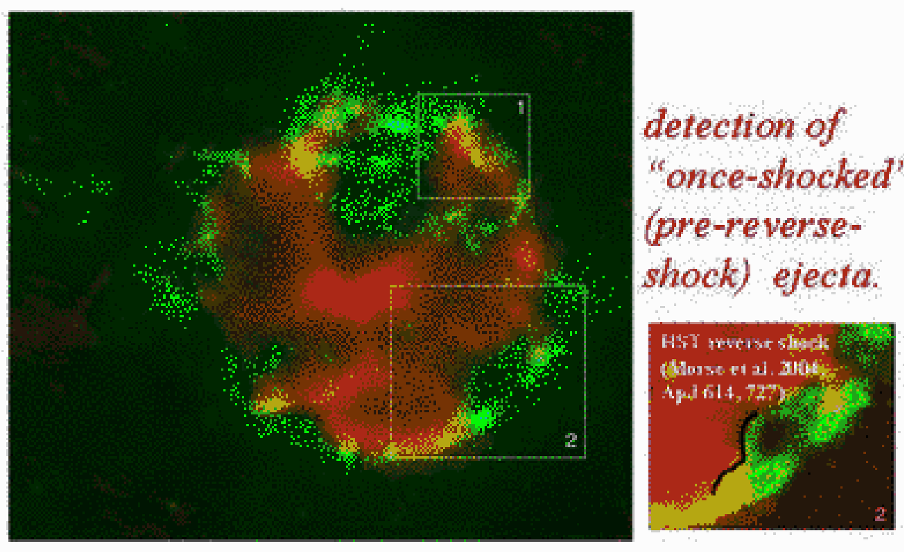
Two Possible Manifestations of This One Spectral Classification

Fitted "Flat-top" Spectrum: **Fitted "Featureless" Spectrum:**



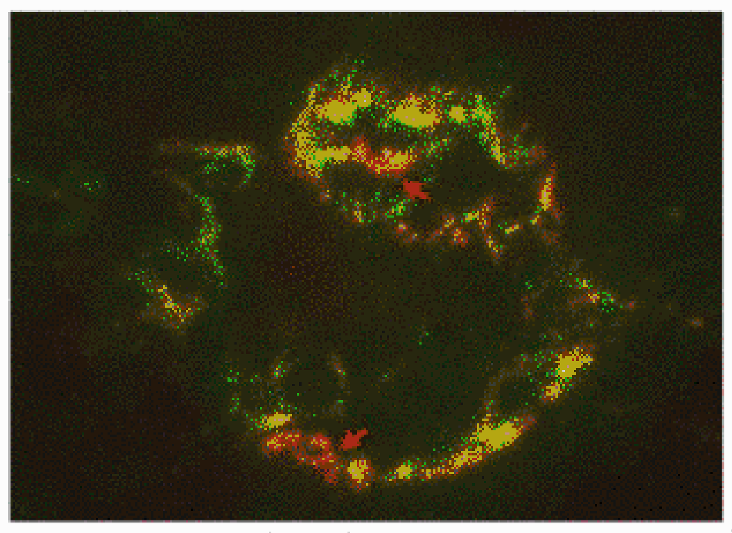
Propagation of the Reverse Shock into Expanding Ejecta

Image constructed from IRS mapping of [Si II] (red) and IRAC Ch. 4 (green). We suggest that Si started with a wide range of velocities – the bright ring of fast material (~5000 km/s) is now encountering the reverse shock and is slowed and heated to X-ray temperatures, while the interior, slower moving cool material ([Si II]) would now be only ionized and heated by X-ray emission from the reverse shock. We also see this once-shocked material in S and Si Doppler structure, as detailed below.



IRAC evidence for bipolar ejecta structure

Two color image: IRAC Ch. 2 (red), Ch. 4 (green). Red regions, such as the crescents noted with red arrows, indicate where [Ar II] is relatively weak, and IRS spectra show [Ne II] to be relatively strong. These crescents show only C-burning products, and are symmetrically placed around the X-ray point source. The Doppler results are detailed below.



OBSERVATIONS / RESULTS

We present Spitzer IRAC images of the supernova remnant Cassiopeia A, supplemented by IRS mapping data. Where different IRAC channels dominate we find different patterns of line emission and different types of dust.

› Channel 1 contains a significant synchrotron component, matching the radio emission; IRS spectra of *relatively* bright Channel 1 regions (mostly outer shock) show a broad 26 µm peaked spectra, likely from shock heated circumstellar/interstellar dust.

› Channel 4 dominates the other IRAC channels where [ArII] is strong. These structures are similar to those seen in the optical and X-ray. IRS spectra of bright Channel 4 regions also show a sharp 21 µm peaked spectra, likely caused by dust from the O- and Si- burning layers.

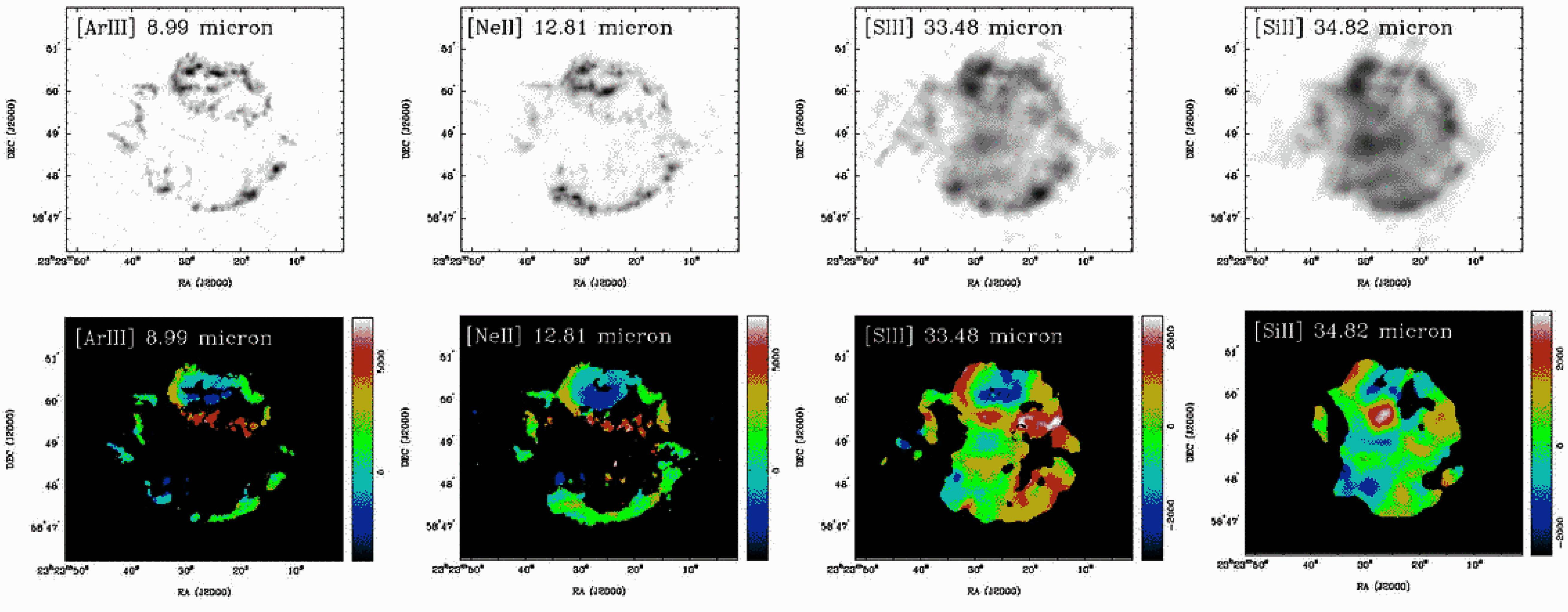
› Channels 2 or 3 are stronger relative to Ch. 4 where [ArII] is weak. In those regions, the IRS spectra (flattop and featureless spectra) rise gradually and then flatten longward of 23 µm, without a 21 µm peak. Lines and dust emission are dominated by C-burning products such as Ne and O.

› In the interior, we see [SiII] and [SIII] emission -- the probable first emission from ejecta that have not reached the reverse shock.

Integrated line images and Doppler images of [ArIII], [NeII], [SIII], and [SiII]. The Doppler structure is an excellent match to optical Doppler structure (Lawrence et al. 1995) and matches the structure of the low-resolution X-ray Doppler measurements (Hwang et al. 2001, Willingale et al. 2002), though the actual velocities systematically differ. High-resolution X-ray Doppler measurements also match structurally, but at higher resolution, show even more Doppler structure than we show here (Lazendic et al. 2006).

The Ne image shows bright emission to the southeast which has no bright optical or X-ray counterpart. Ne is also bright on the blue-shifted ring to the north – perhaps suggesting a bipolar outflow of Ne-rich ejecta corresponding with the bipolar ejecta structure seen in IRAC Ch. 2 above.

The S and Si images show considerable diffuse, interior emission with Doppler structure. This is the ejecta material that has not yet encountered the reverse shock, as detailed above.



The IRS spectra were reconstructed from mapping observations using the CUbe Builder for IRS Spectra Maps, CUBISM
http://turtle.as.arizona.edu/jdsmith/cubism.php

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