NASA Telescopes Show Famous Exploded Star in Its Best Light

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PURDUE UNIVERSITY
On behalf of a larger collaboration

Press Conference
Monday January 8, 2024
243rd Meeting of the AAS

Supernova Remnant Cassiopeia A

Cas A is the best Galactic supernova remnant (SNR) to investigate the progenitor systems and explosion dynamics of massive star explosions

- **Youngest example (age ~ 340-350 years)**
- **Nearby (approximately 3.3 to 3.4 kpc)**
- **Only SNR with secure spectroscopic classification**
- **Excellent case study for formation/destruction of dust and molecules**
- **Important yet enigmatic neutron star**
- **Observed across wavelengths, especially with all major NASA facilities**

Broad implications: SNe help galaxies grow; they produce neutron stars, black holes, and some gamma-ray bursts; they are a major site of nucleosynthesis, dust production, and cosmic rays; and they produce neutrinos, and gravitational waves, that can now be studied with multimessenger facilities.

JWST Cycle 1 program to survey Cas A

Our team was awarded 45 hr of JWST time to fulfill the following scientific objectives:

1) map unshocked ejecta that can be directly compared to current supernova simulations,
2) constrain the grain size distribution, clump size, and density contrast of shocked supernova dust,
3) test hypotheses about the nature of Cas A's neutron star

The observations were made up of NIRCam and MIRI image mosaics, along with four regions of exploratory NIRSpec and MIRI/MRS IFU spectroscopy.

A JWST Survey of the Supernova Remnant Cassiopeia A

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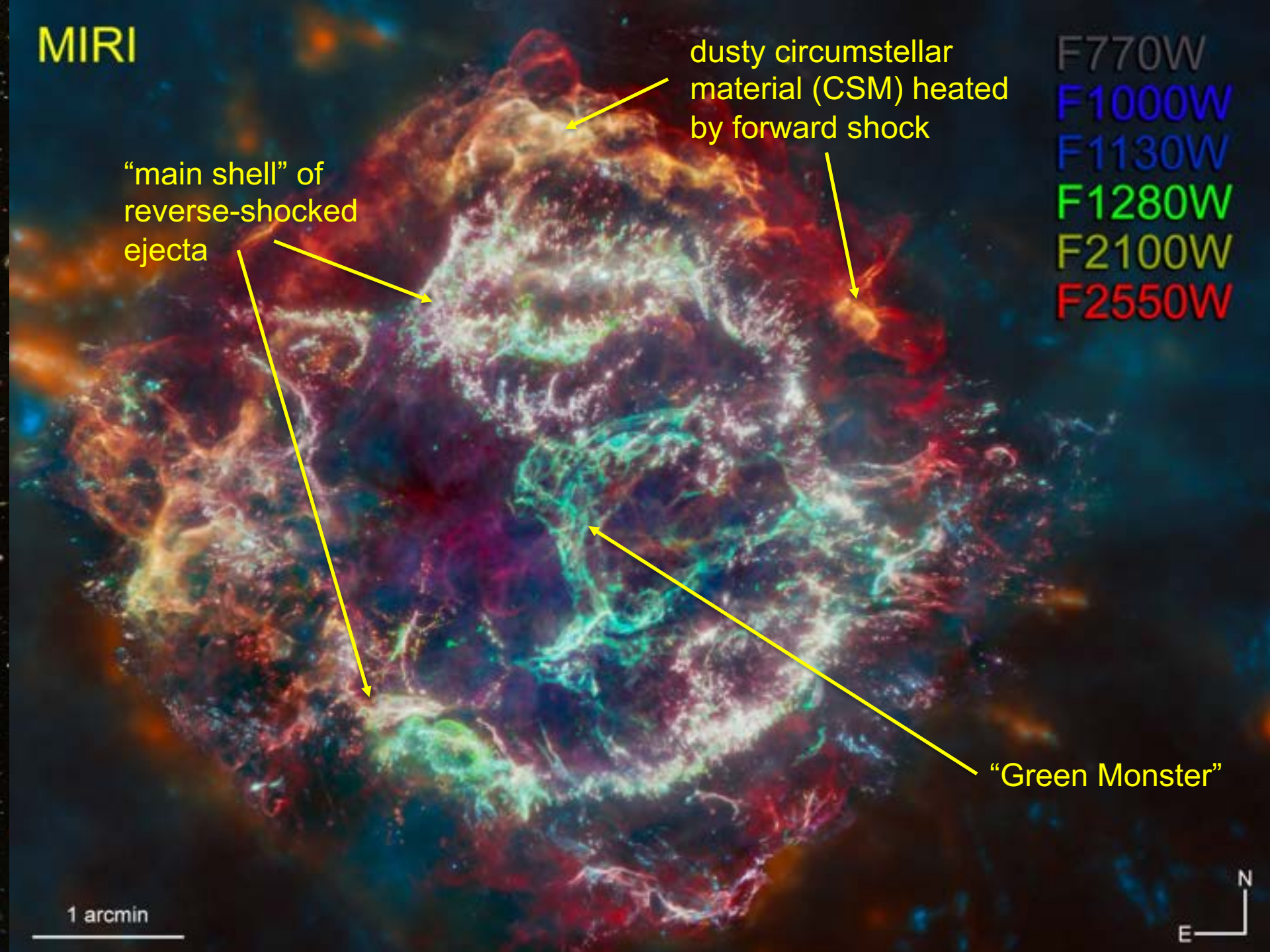
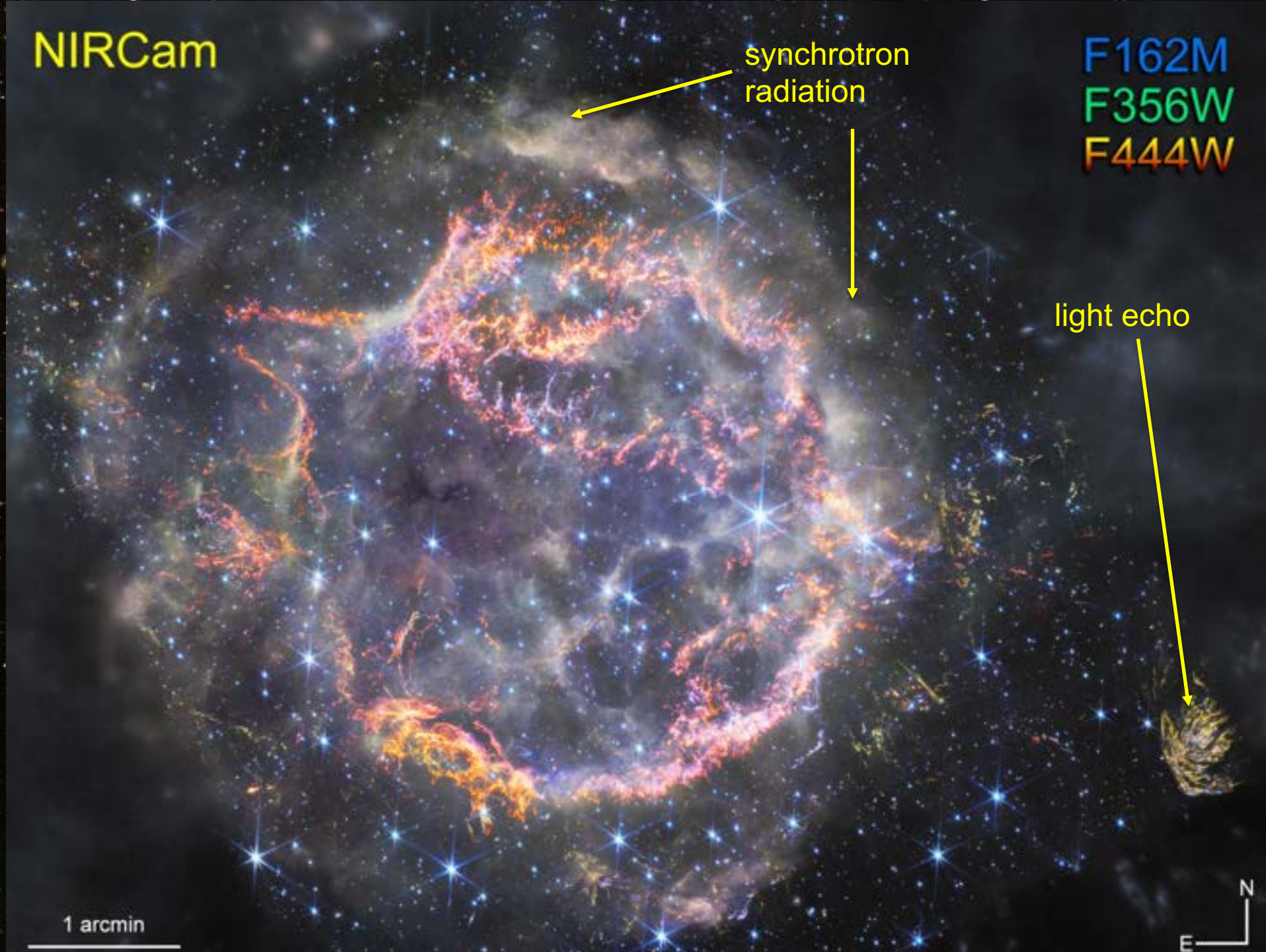

MIRI
dusty circumstellar material (CSM) heated by forward shock
"main shell" of reverse-shocked ejecta
F770W
F1000W
F1130W
F1280W
F2100W
F2550W
"Green Monster"
1 arcmin
N
E


NIRCam
synchrotron
radiation
F162M
F356W
F444W
light echo
1 arcmin
N
E

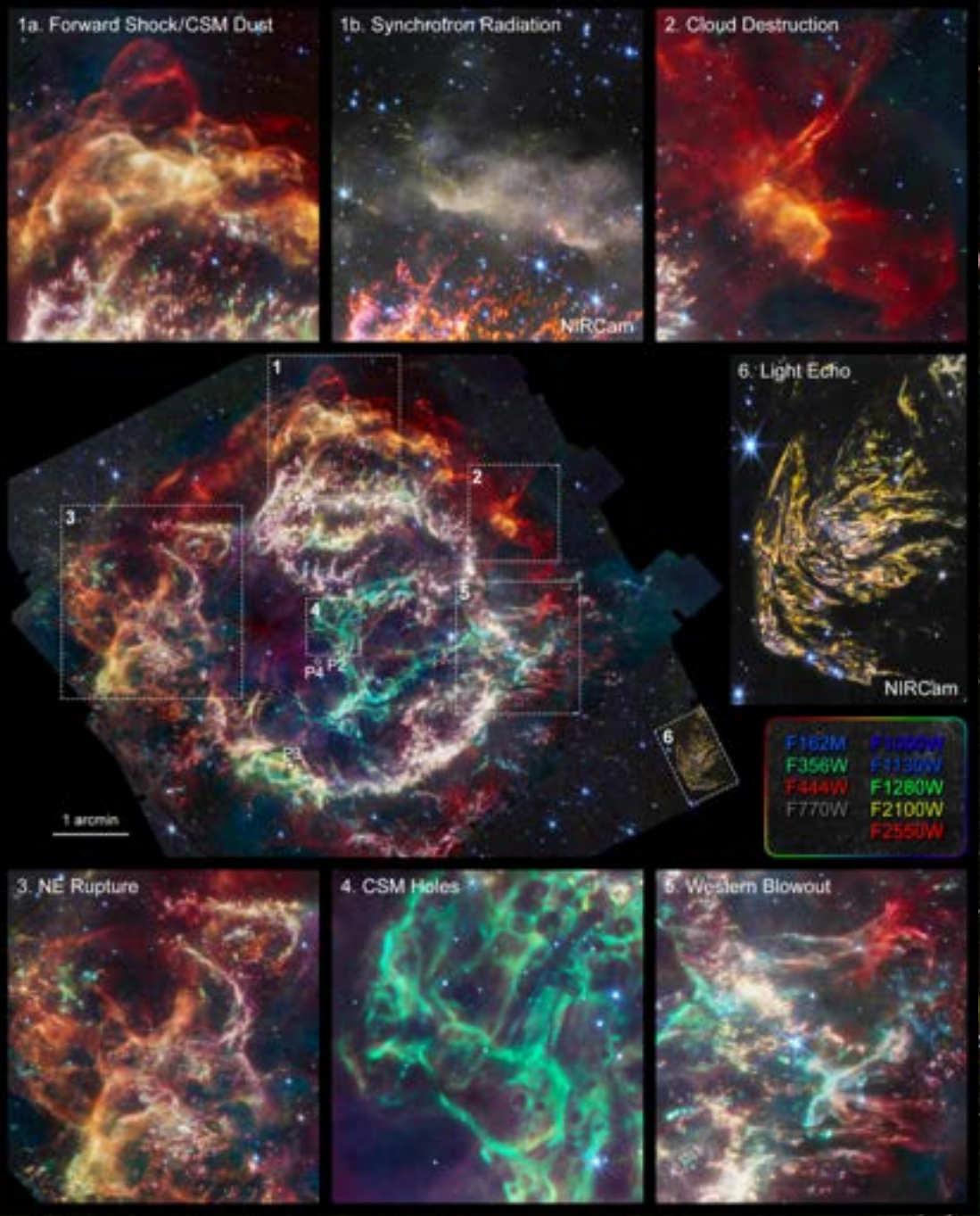
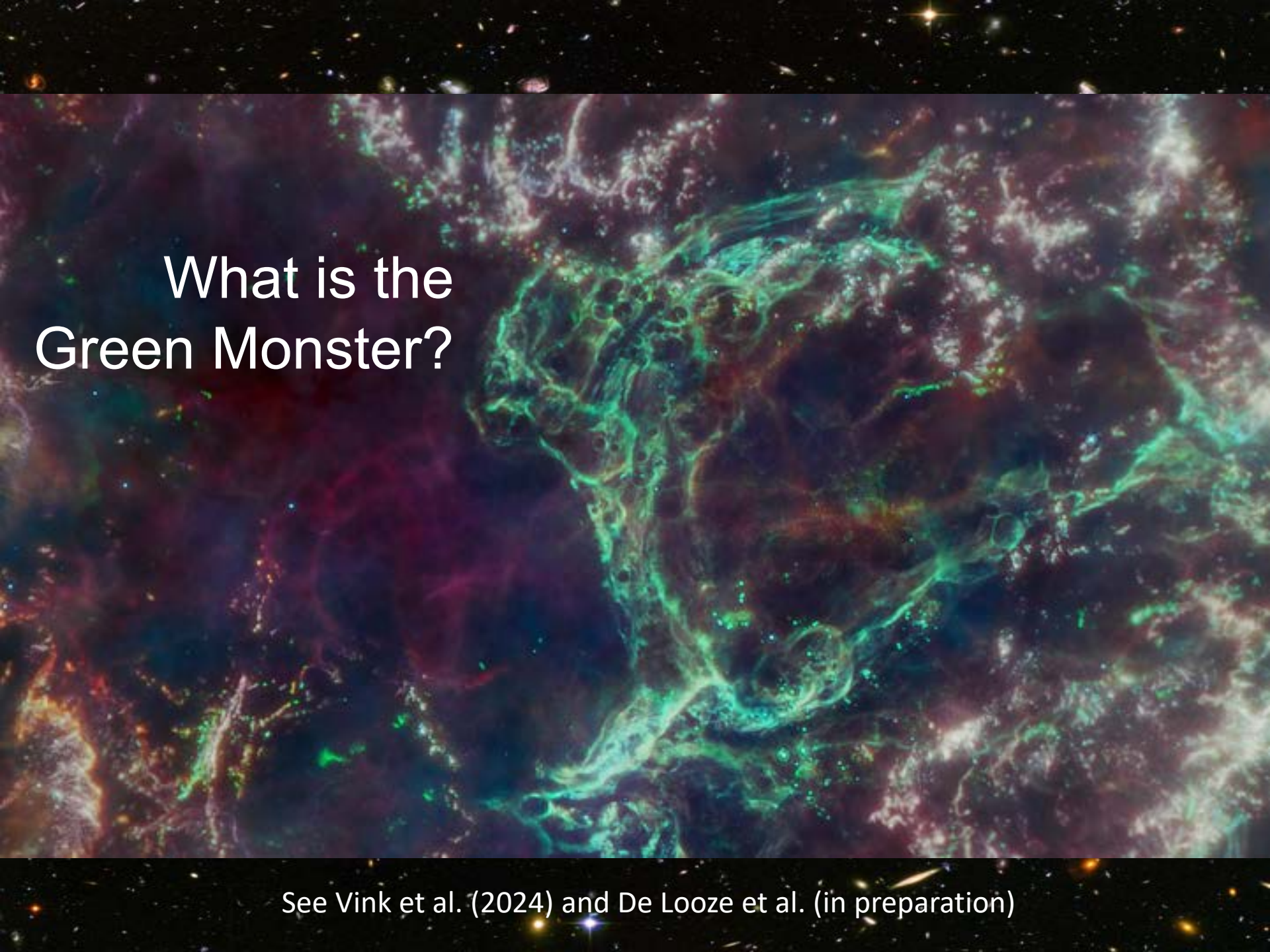
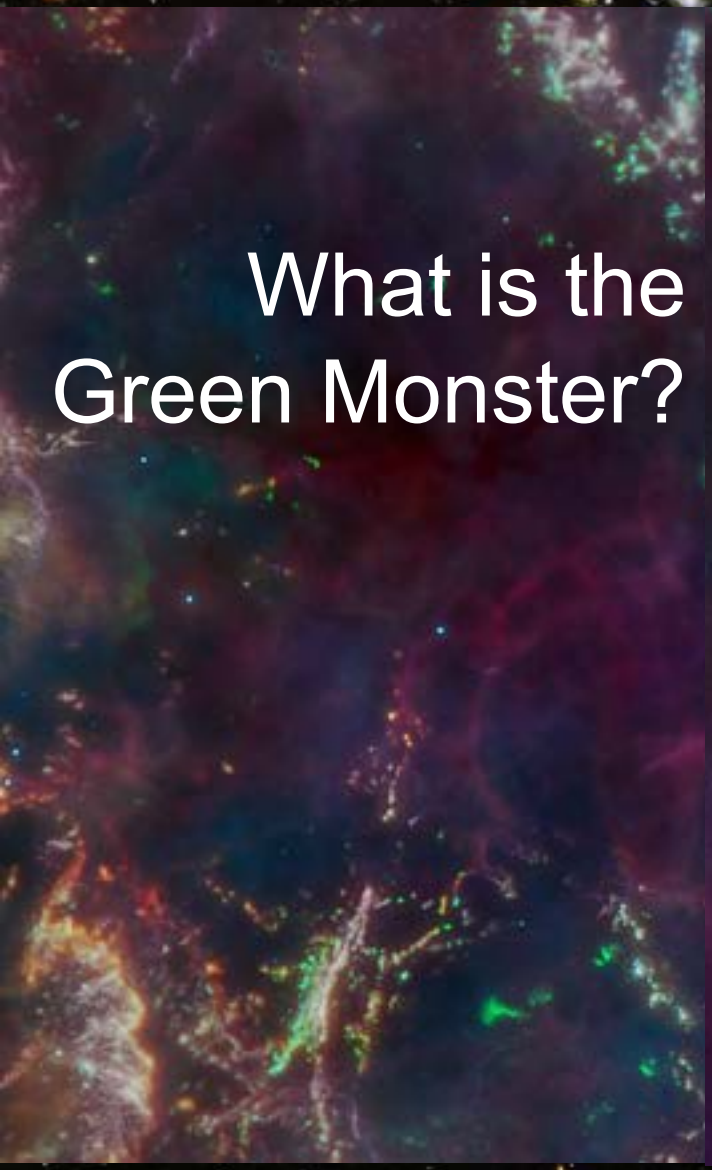


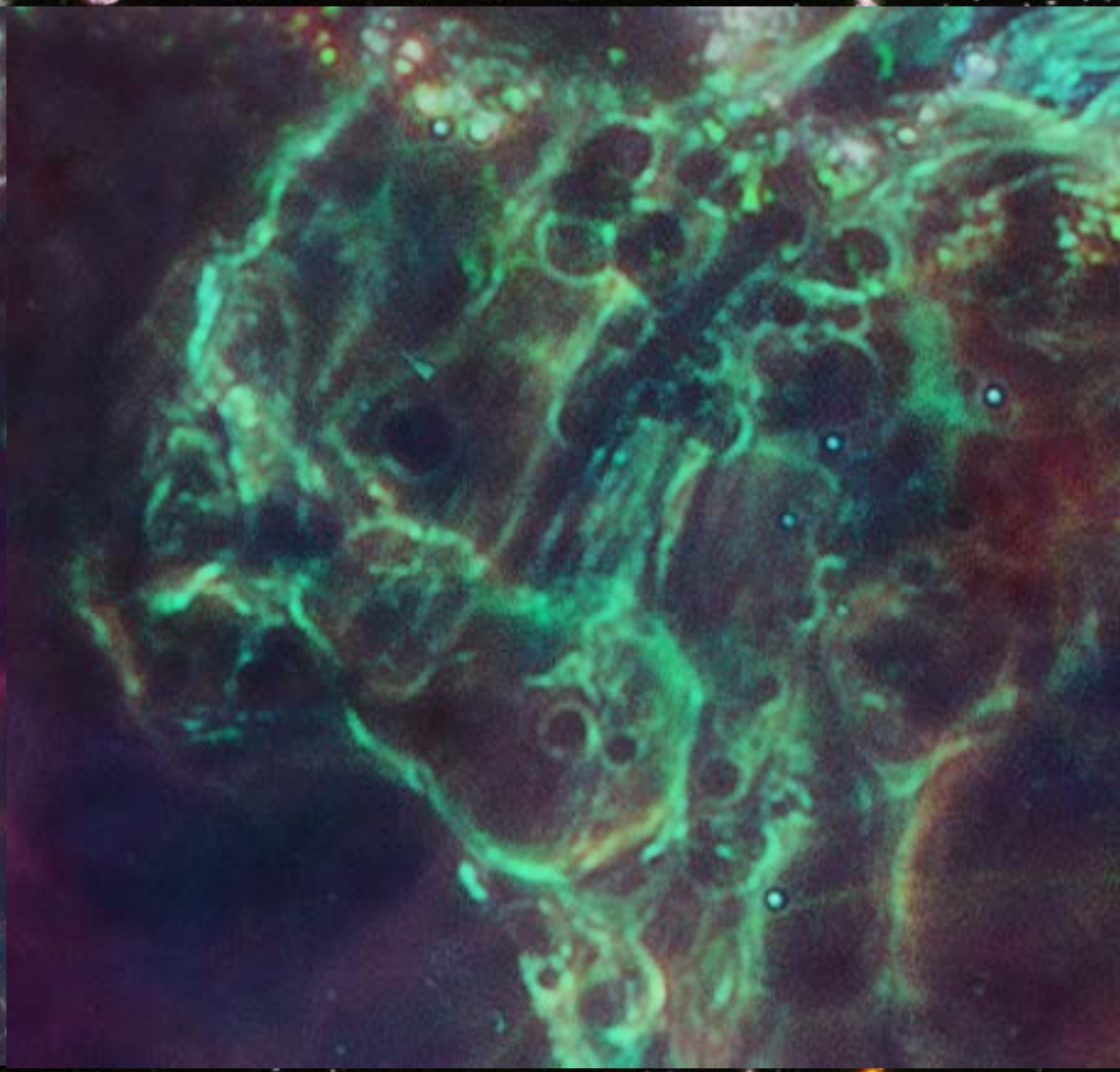
Figure 3 from Milisavljevic et al. (2024)



See Vink et al. (2024) and De Looze et al. (in preparation)

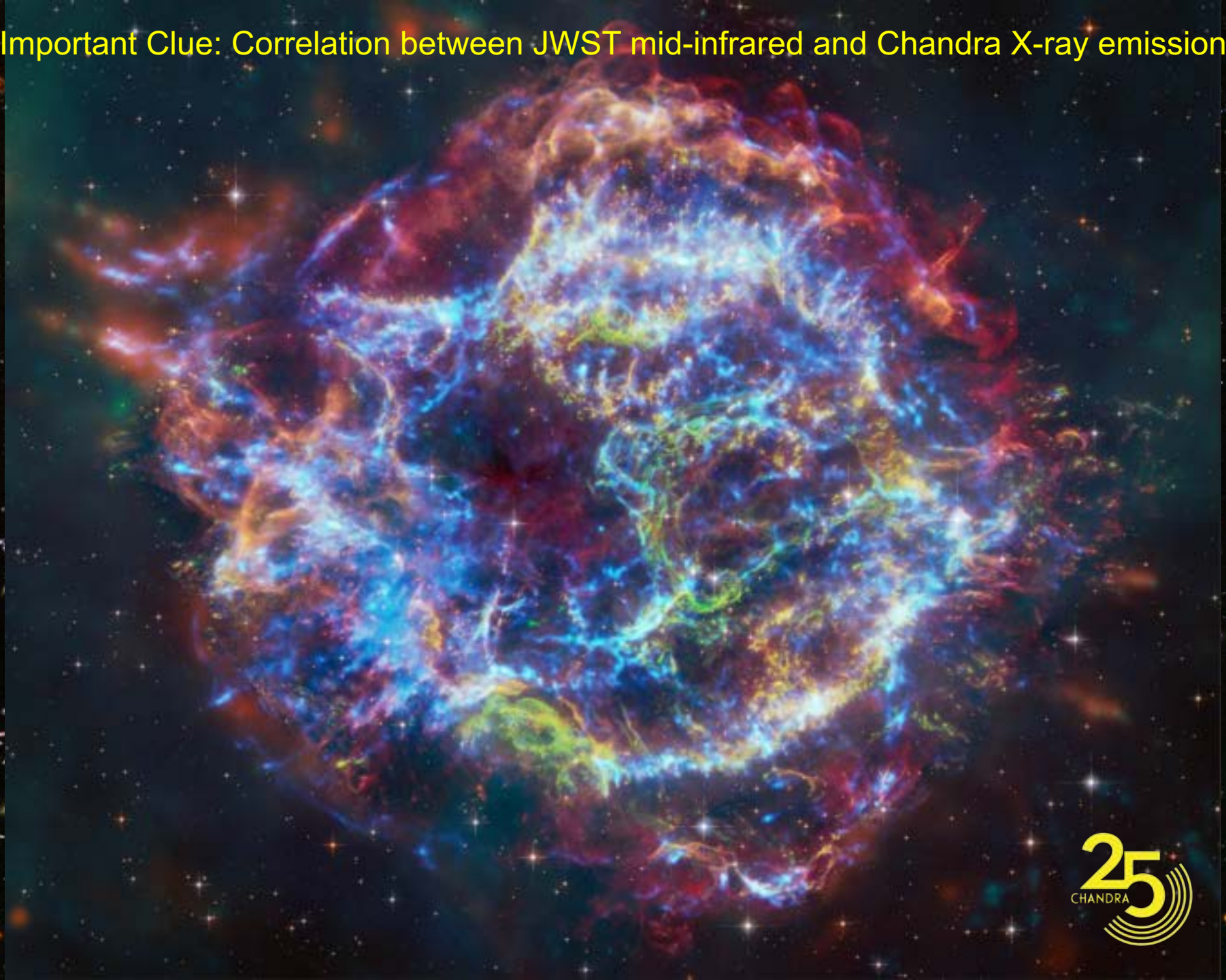
What is the Green Monster?

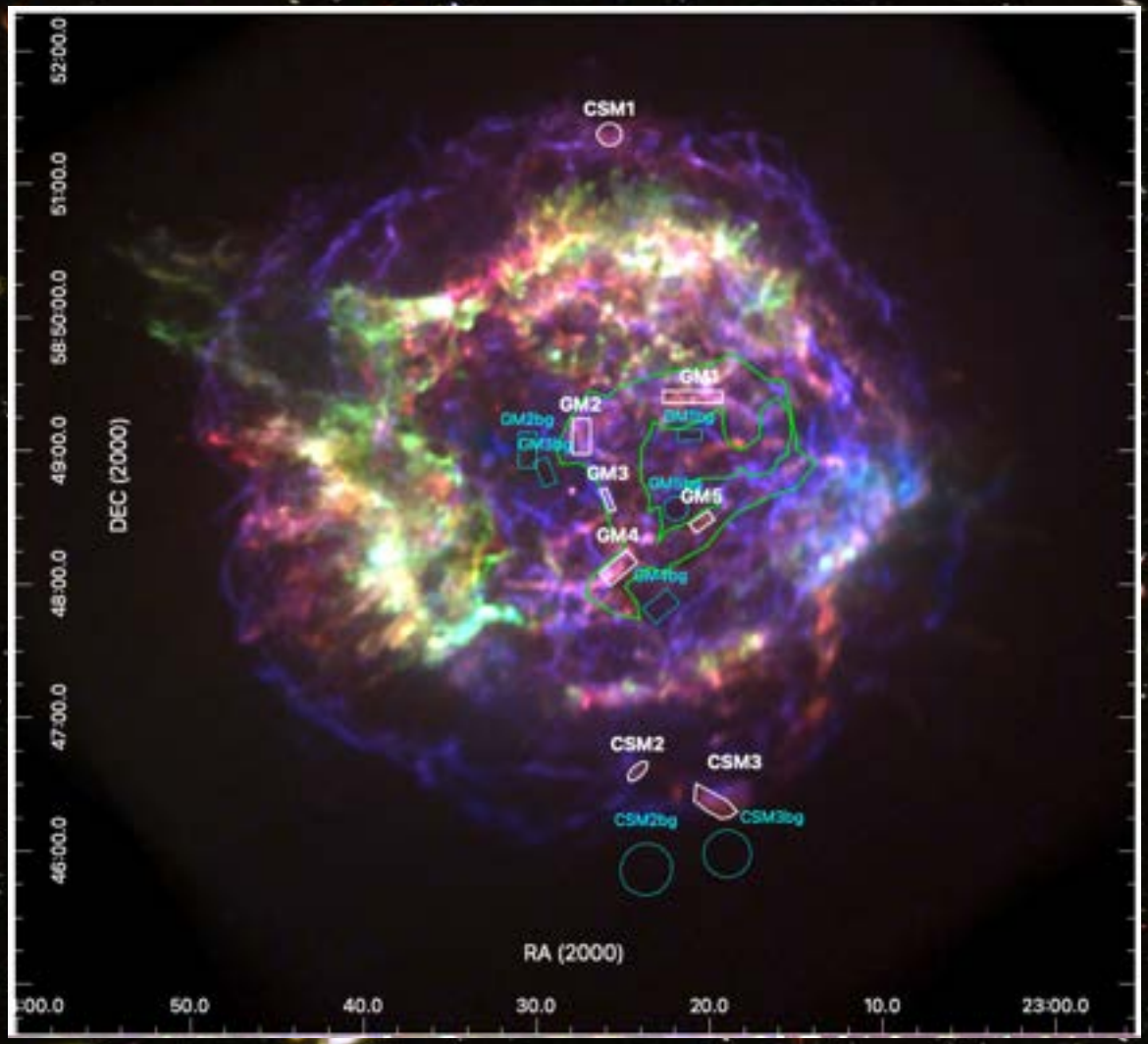


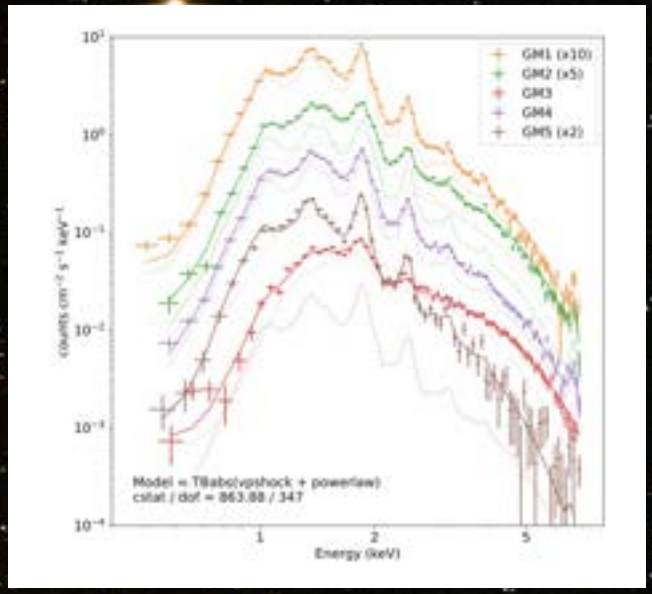


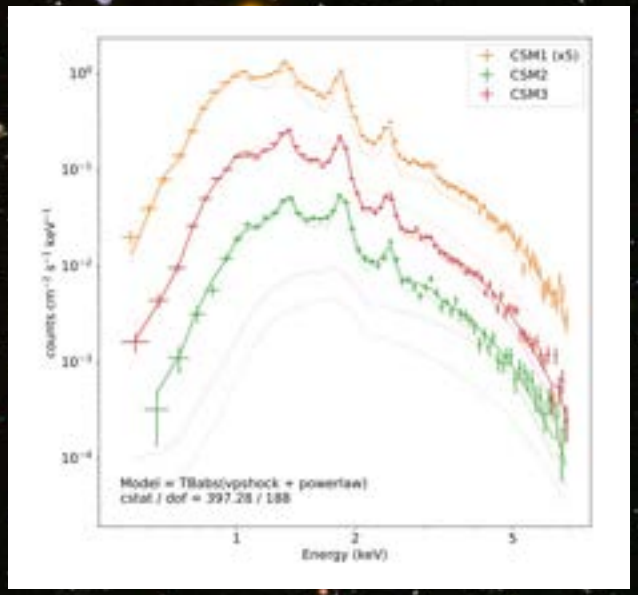
See Vink et al. (2024) and De Looze et al. (in preparation)

Important Clue: Correlation between JWST mid-infrared and Chandra X-ray emission





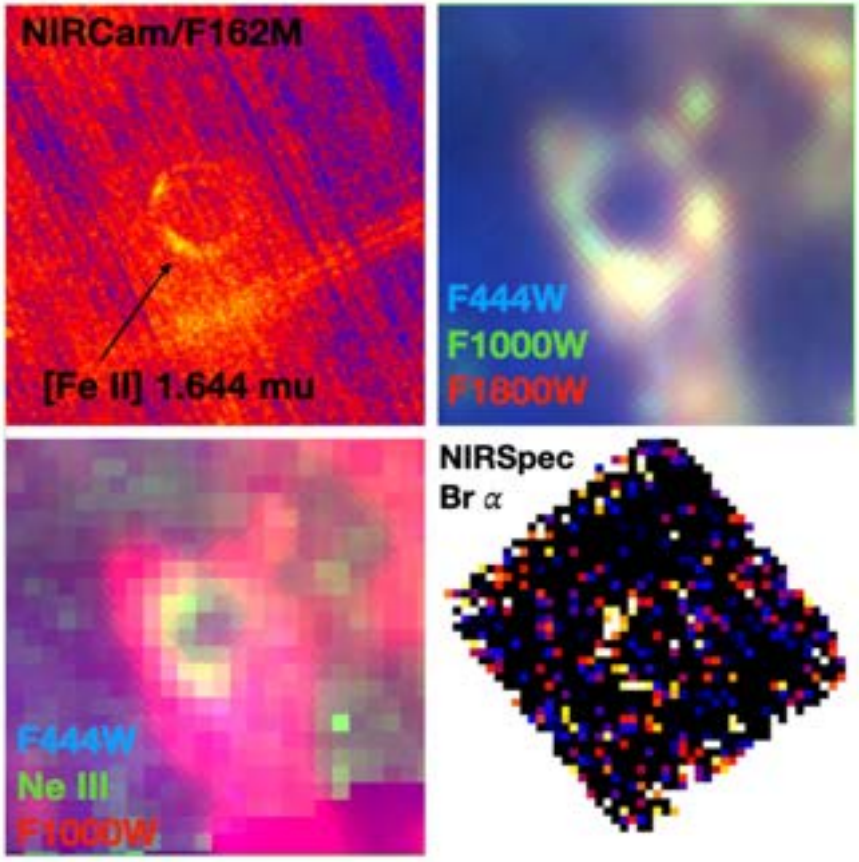




Chandra analysis presented in Vink et al. (2024) shows that “Green Monster” emission properties are similar to those of the shocked CSM.

Spectral zoom-in on one of the ring structures

1.)



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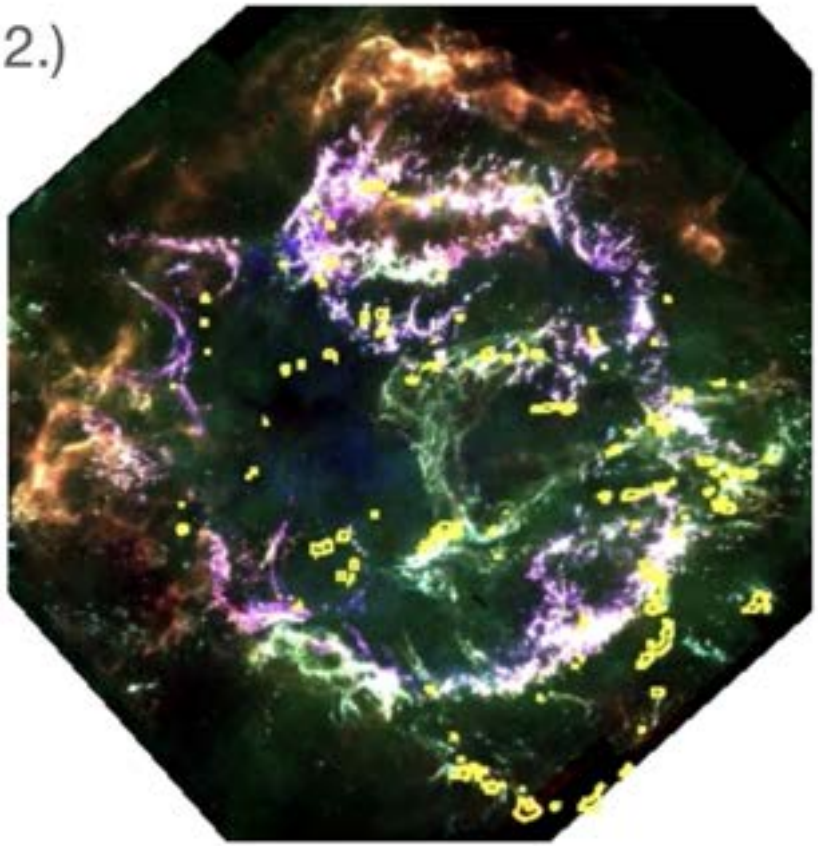
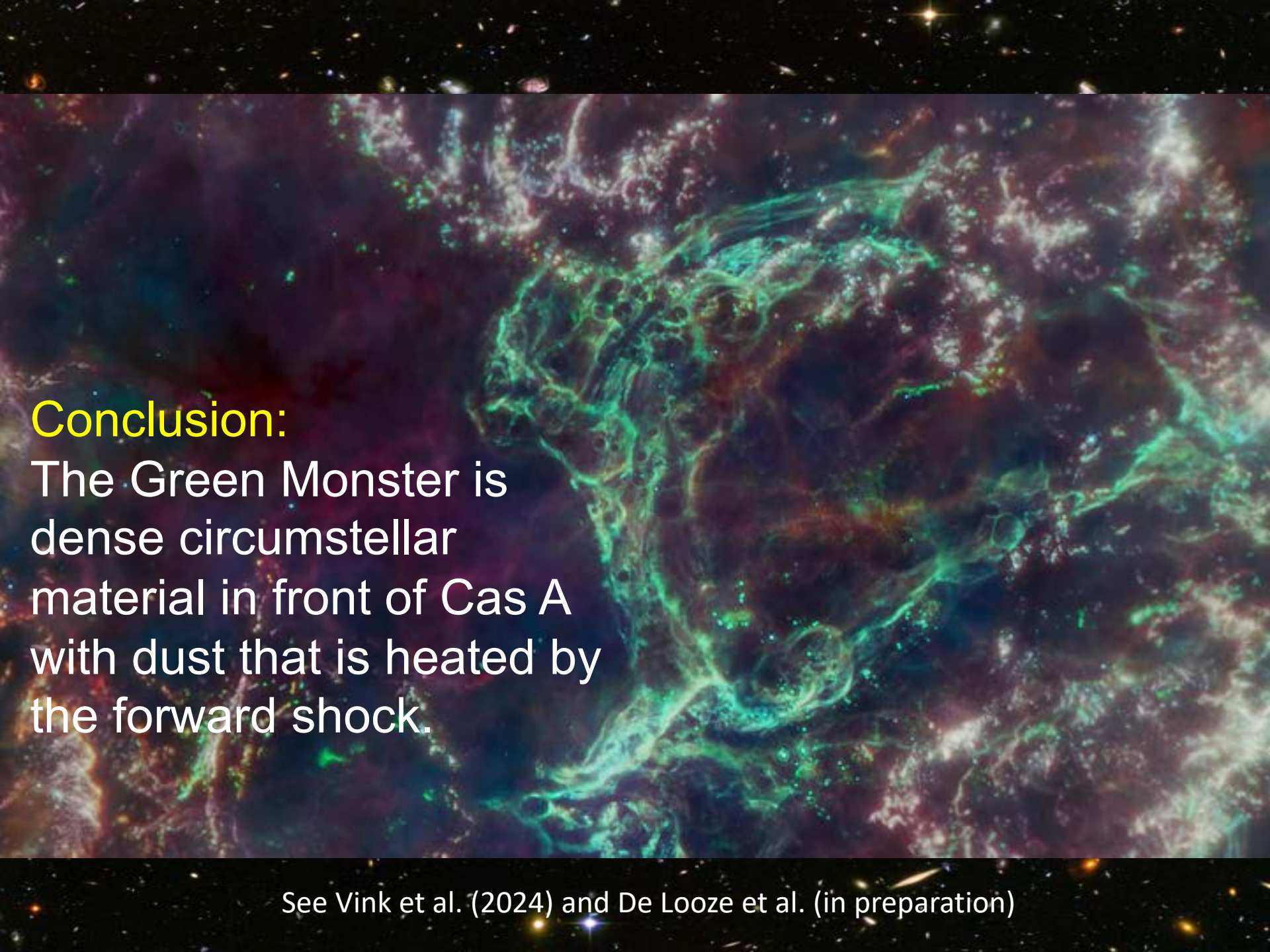


Additional clues from De Looze et al.: Near rest-frame H, Ne and Fe lines, dense CSM clumps (yellow contours) trace southern arc of CSM dust, and typical CSM dust compositions



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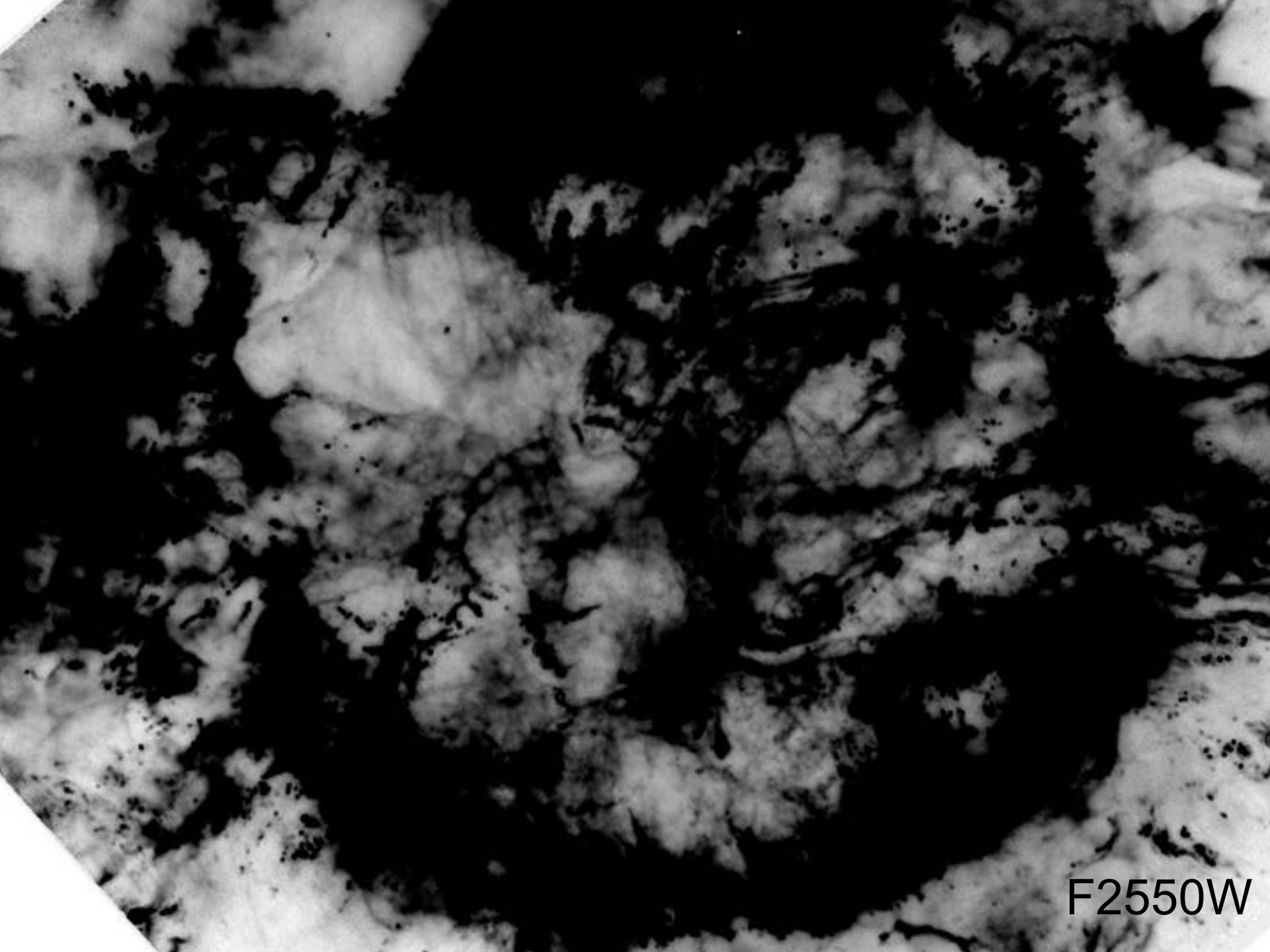
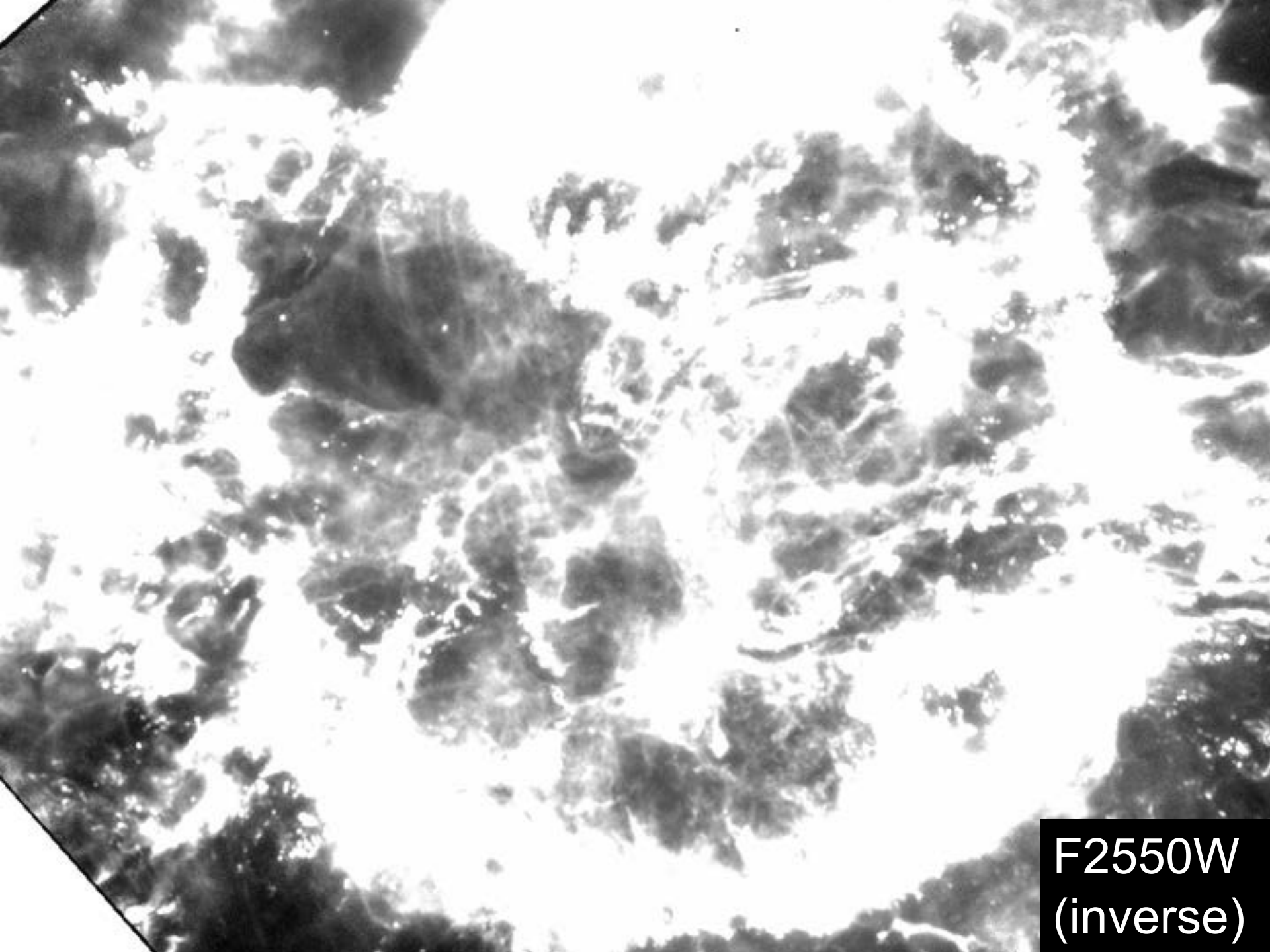
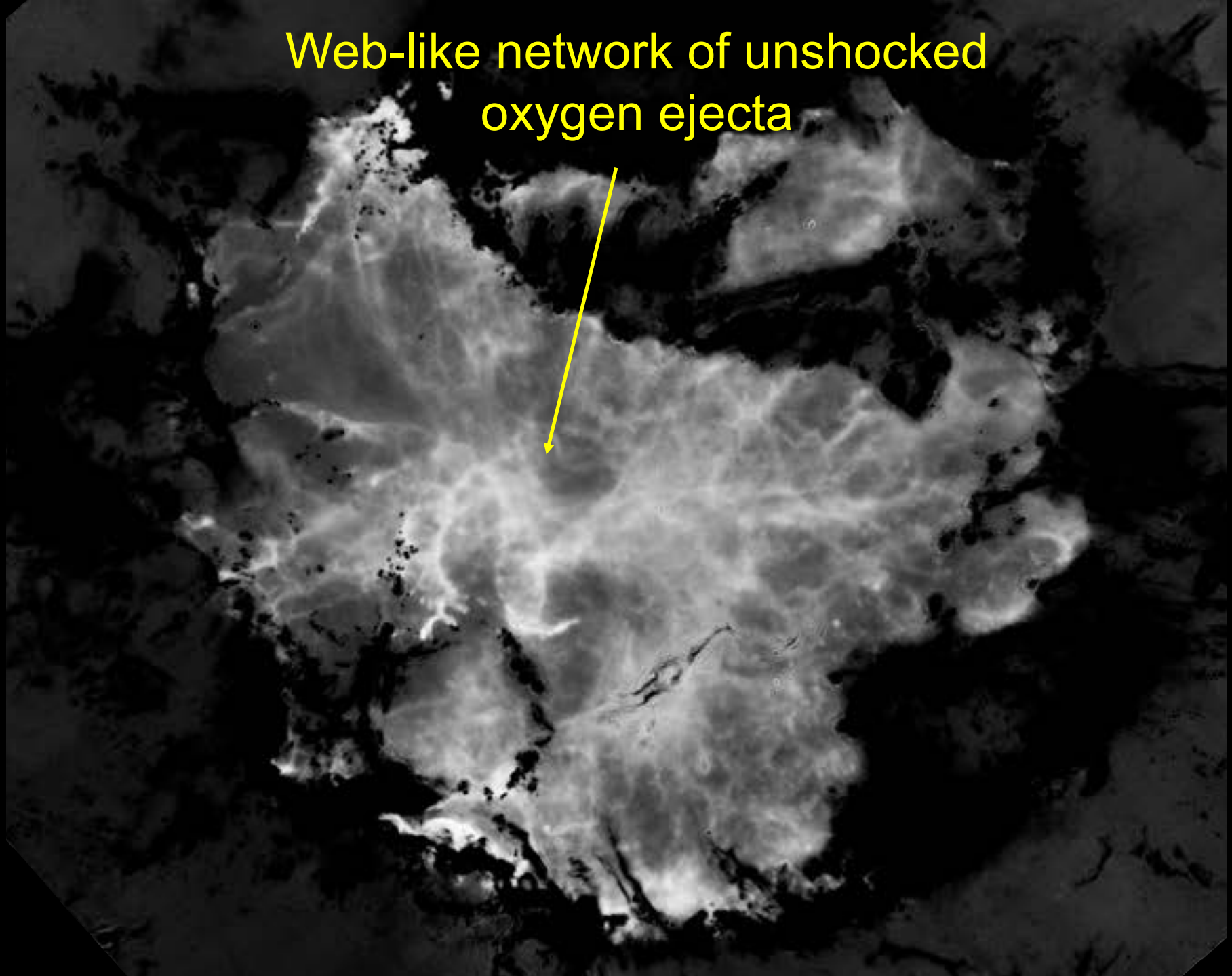
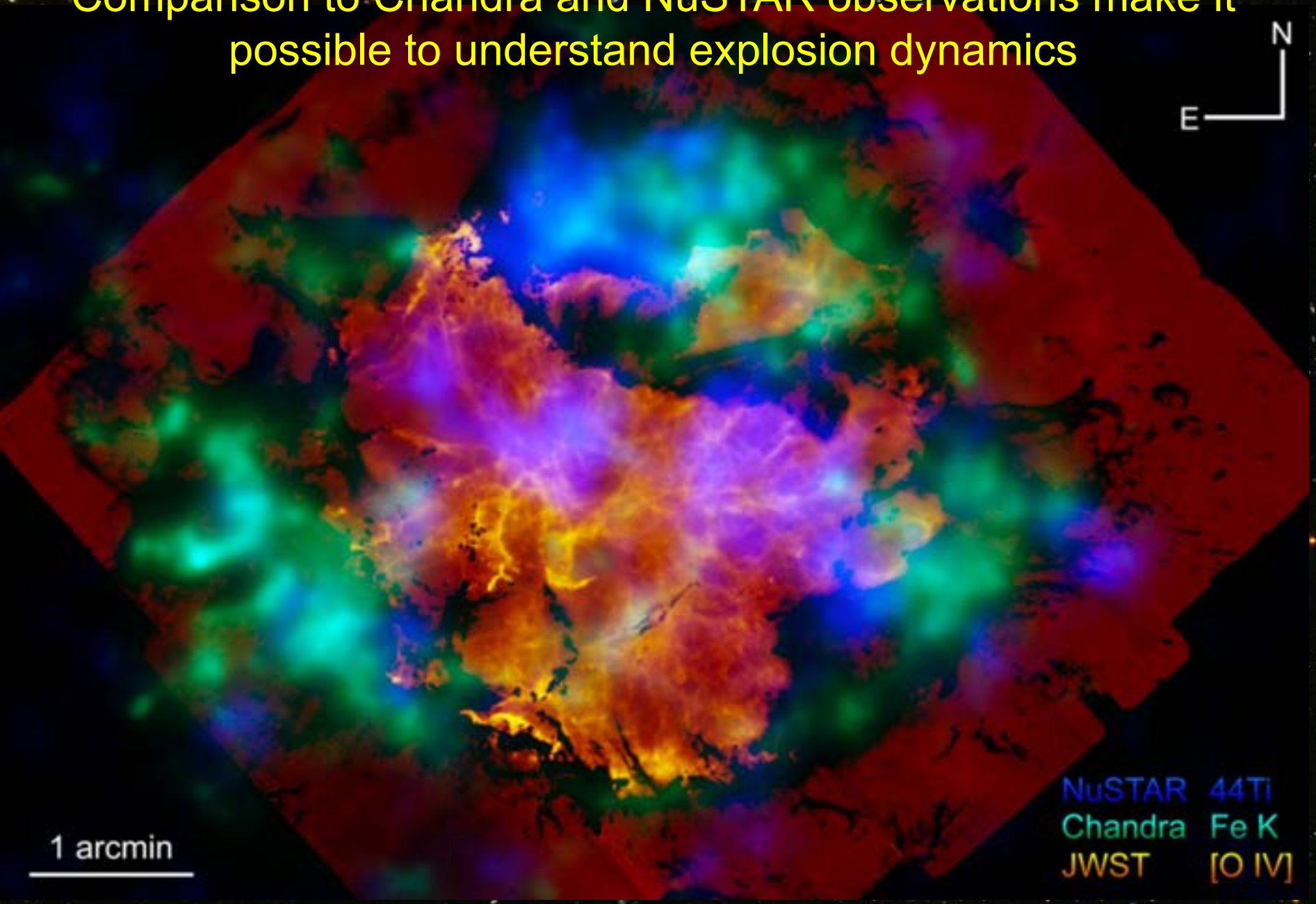
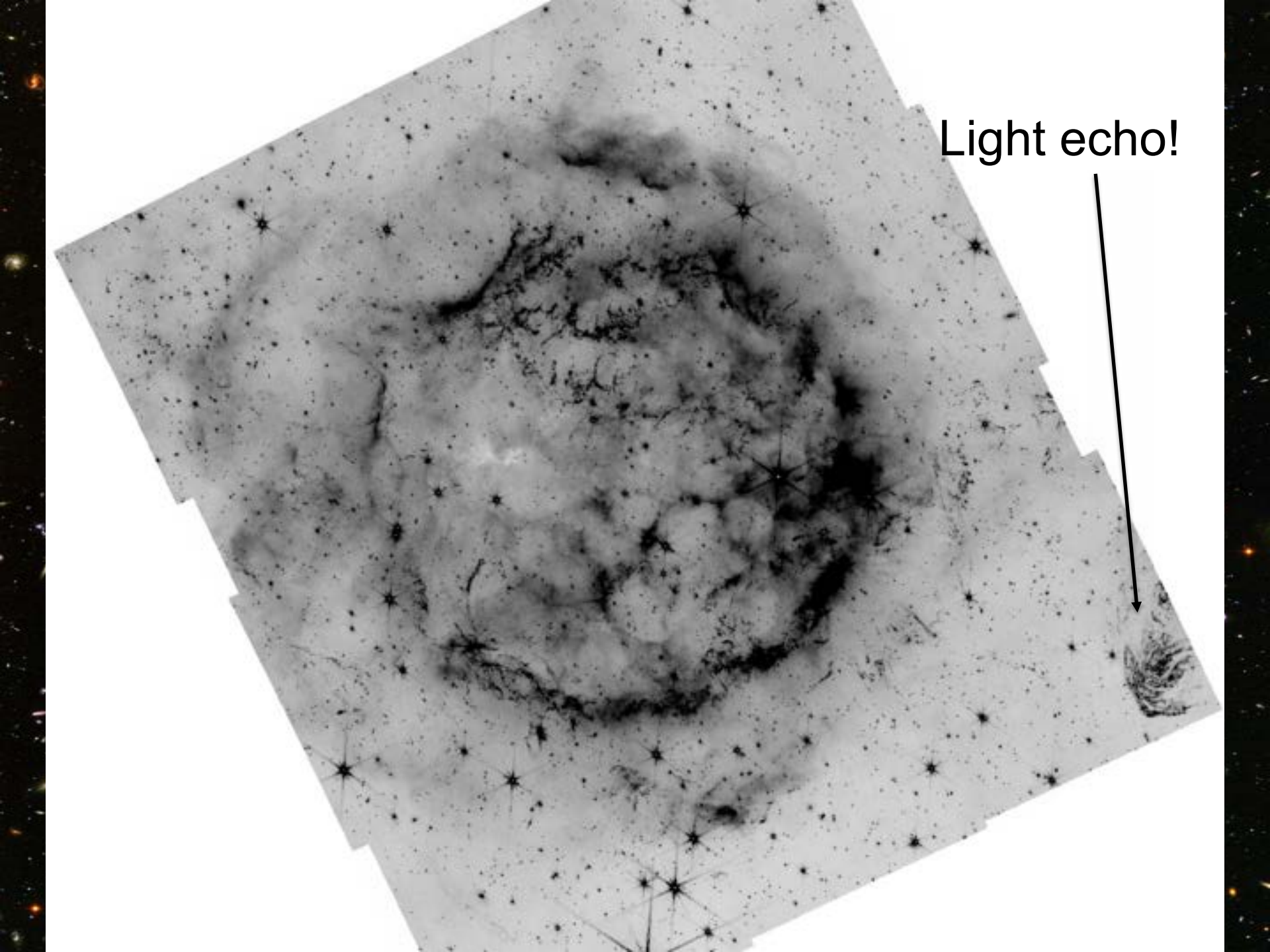

F2550W


F2550W
(inverse)

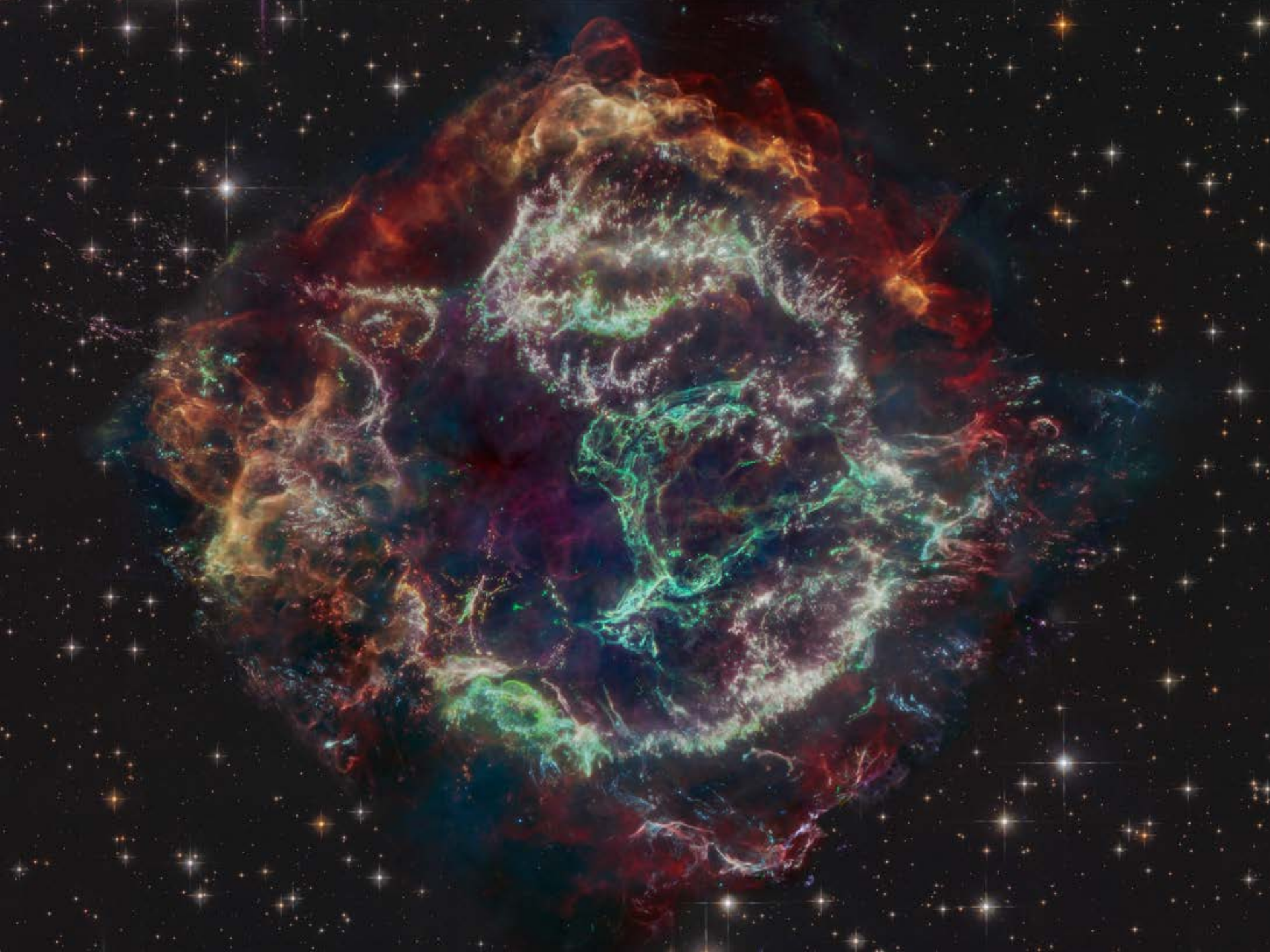

Web-like network of unshocked
oxygen ejecta

Comparison to Chandra and NuSTAR observations make it possible to understand explosion dynamics




Light echo!

Is the dust not mixed uniformly into the ISM gas, or is the gas also structured this way? Are magnetic fields involved? Is this structure typical of the large ISM clouds?



This JWST survey of Cas A provides the most detailed and comprehensive mapping ever of its ejecta, CSM/ISM, and associated dust and molecules at NIR and MIR wavelengths. New insights abound about its ejecta distribution, the progenitor system and its mass loss history, the explosion dynamics of the original supernova, dust and molecule production and destruction, and compact object formation.

This information helps to address unresolved questions about massive star explosions that have broad implications for the formation and evolution of stellar populations, and the metal and dust enrichment of galaxies.

See Milisavljevic+ (arXiv:2401.02477) and Vink+ (arXiv:2401.02491), along with several papers in preparation soon to be submitted by De Looze+, Rho+, and Koo+. See also AAS presentation 328.03.

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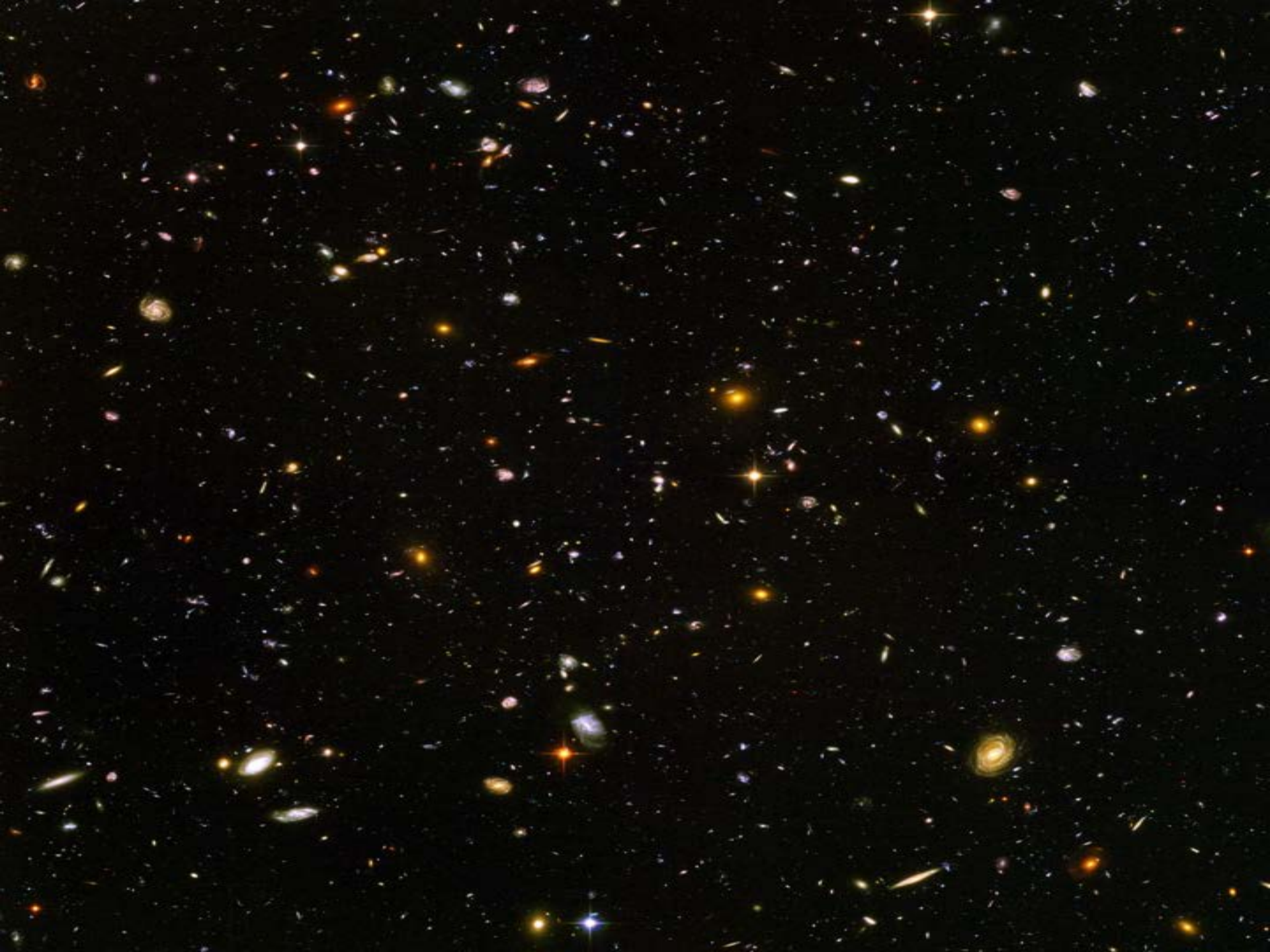
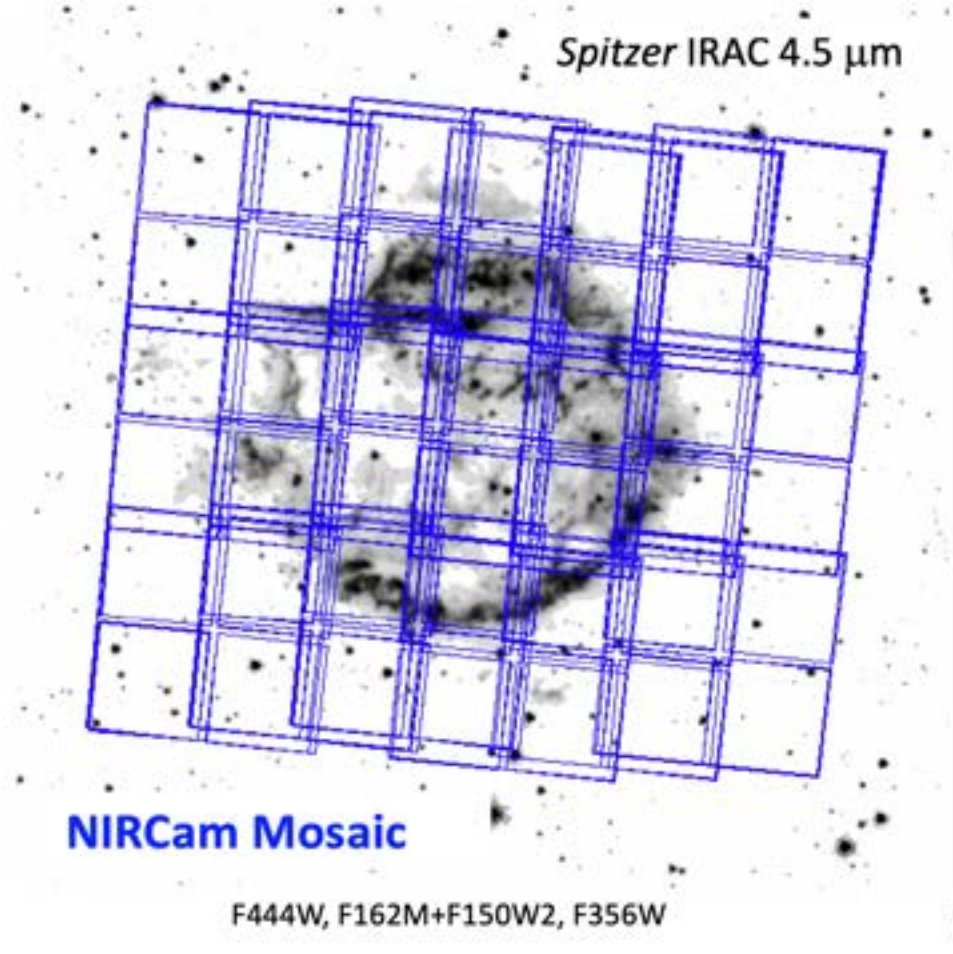
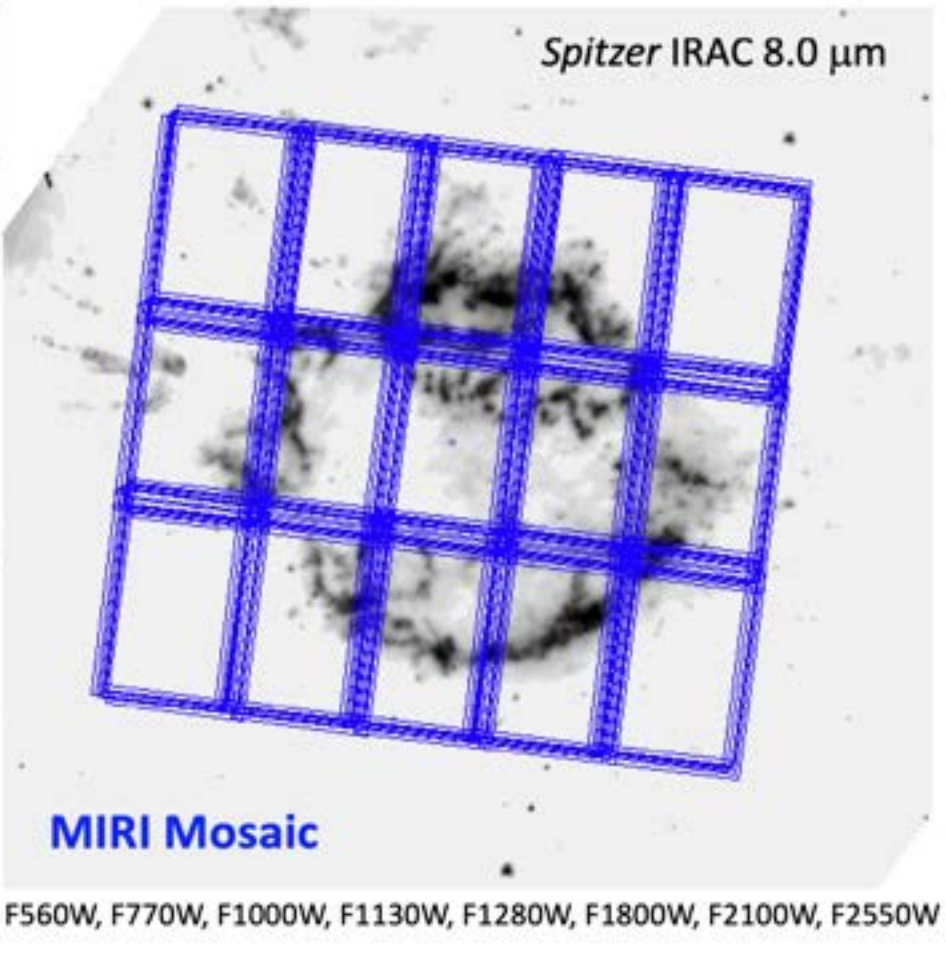
Thank you




EXTRA SLIDES

JWST Cycle 1 program to survey Cas A





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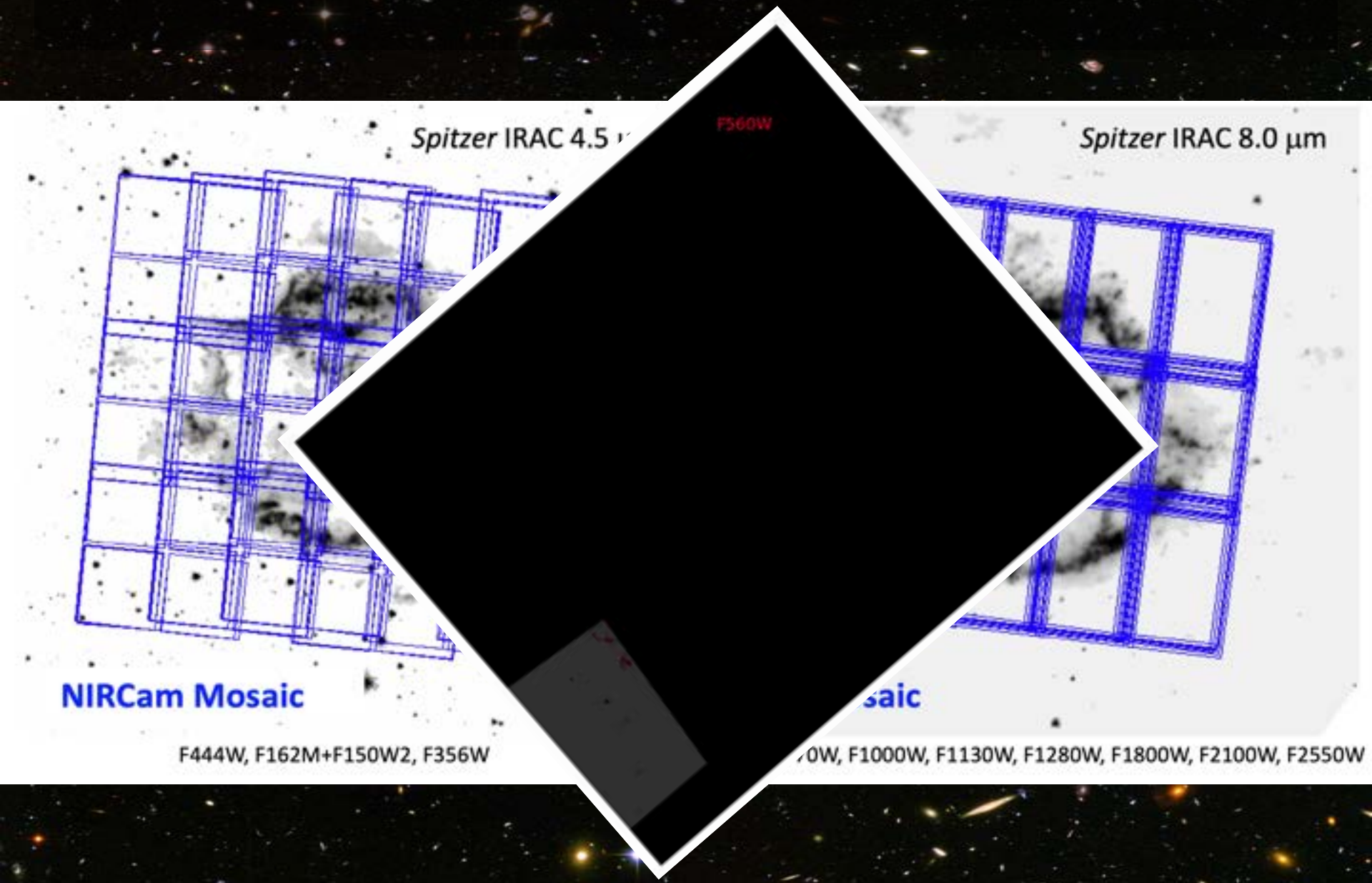
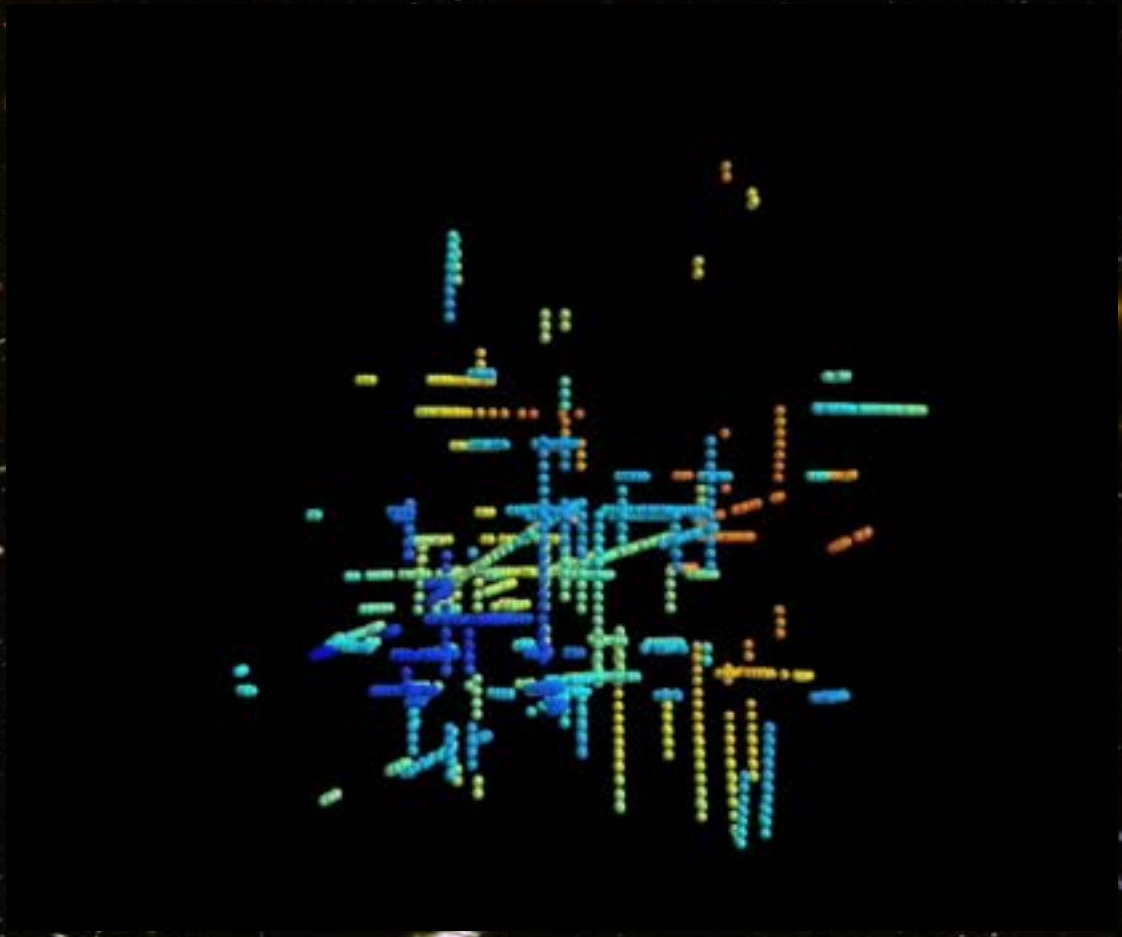


Spitzer 24 micron
(enlarged)


JWST/MIRI F2550W
(enlarged)

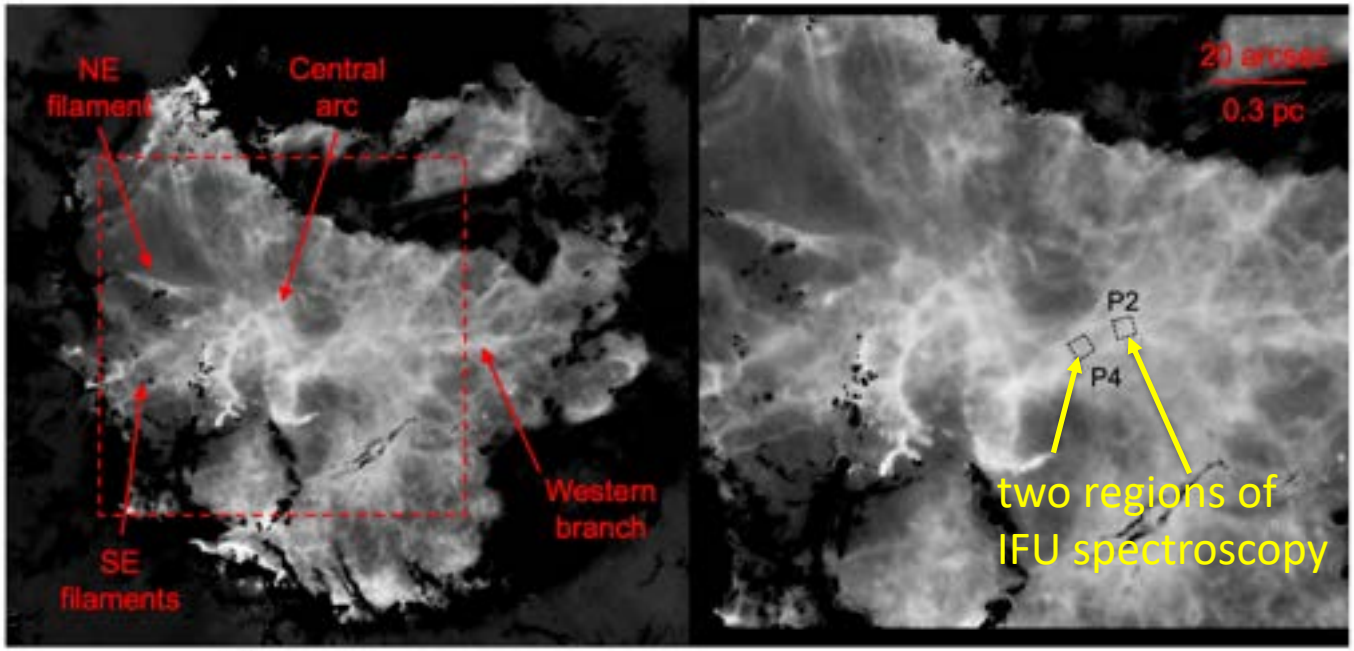
What does the "inside" of Cas A look like?

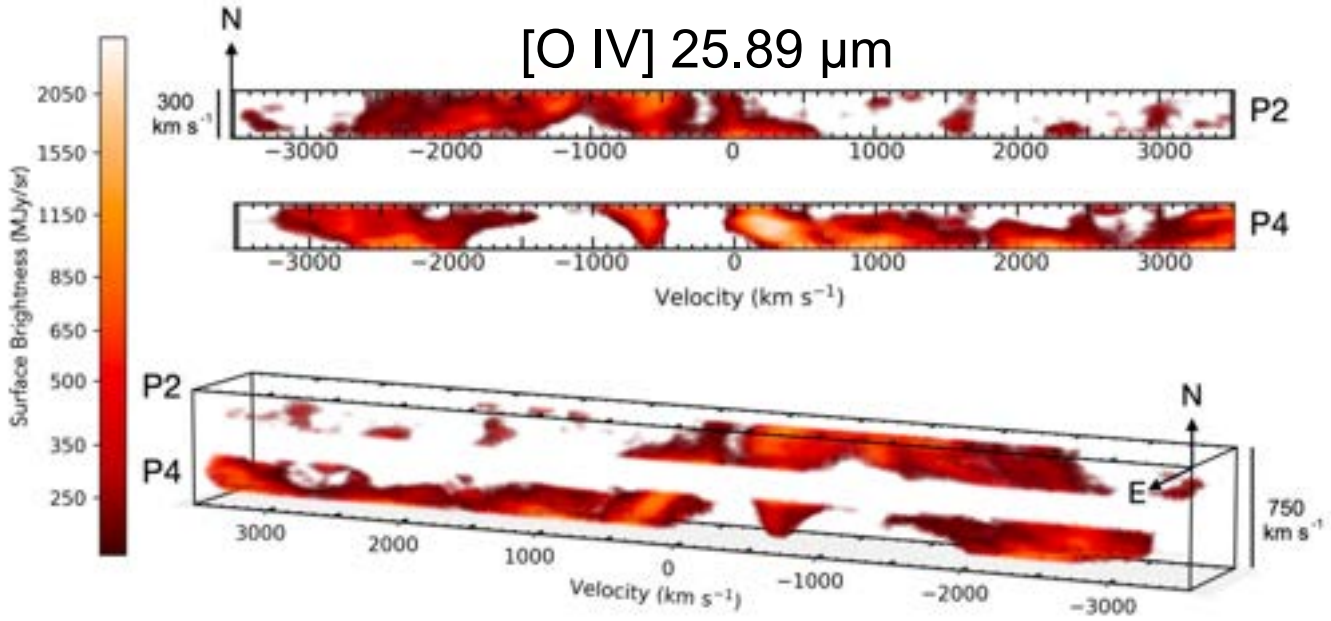


Milisavljevic & Fesen (2015, *Science*)

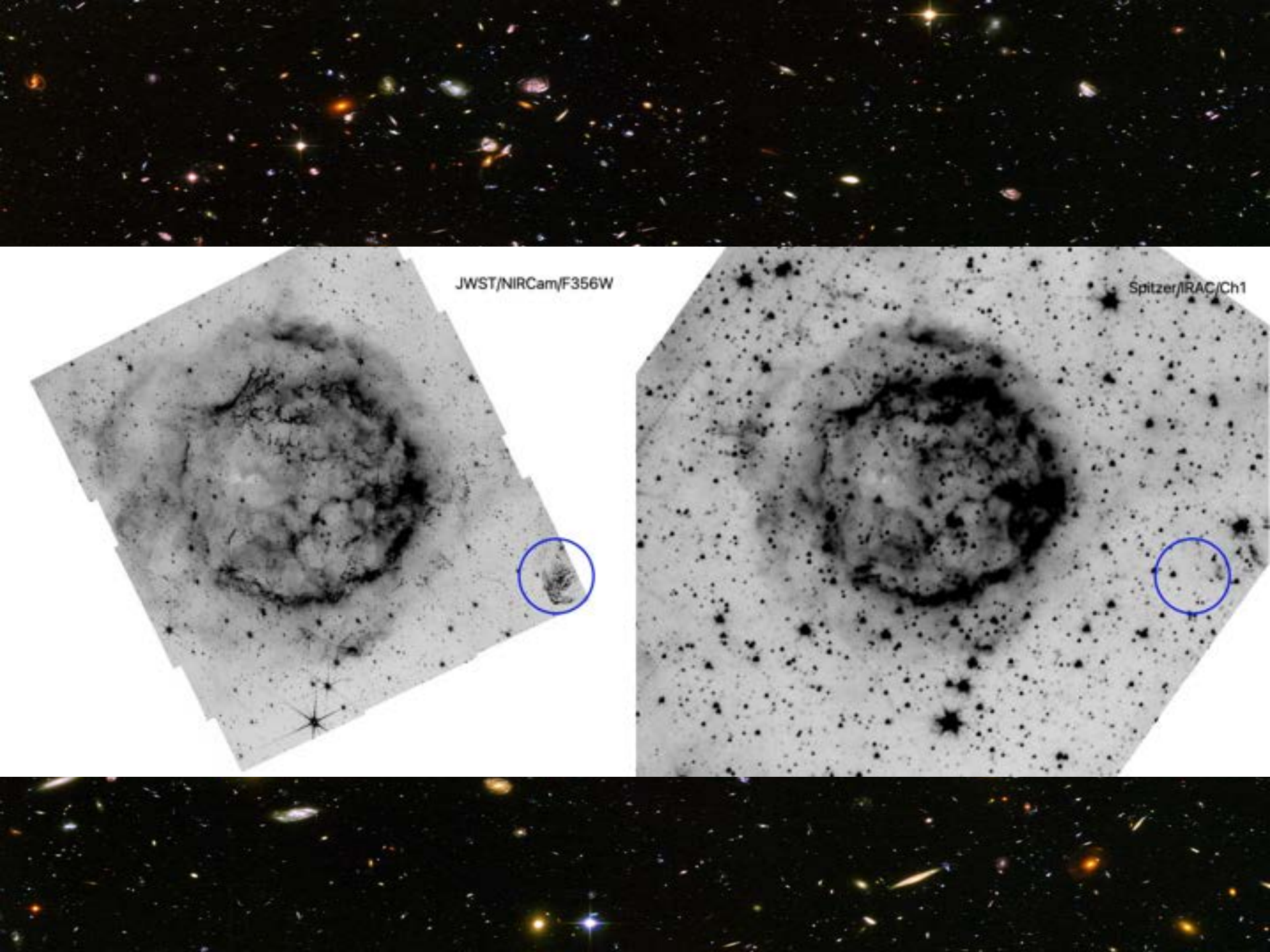
Ejecta distribution exhibits large-scale coherent structure that was imprinted early in the explosion.

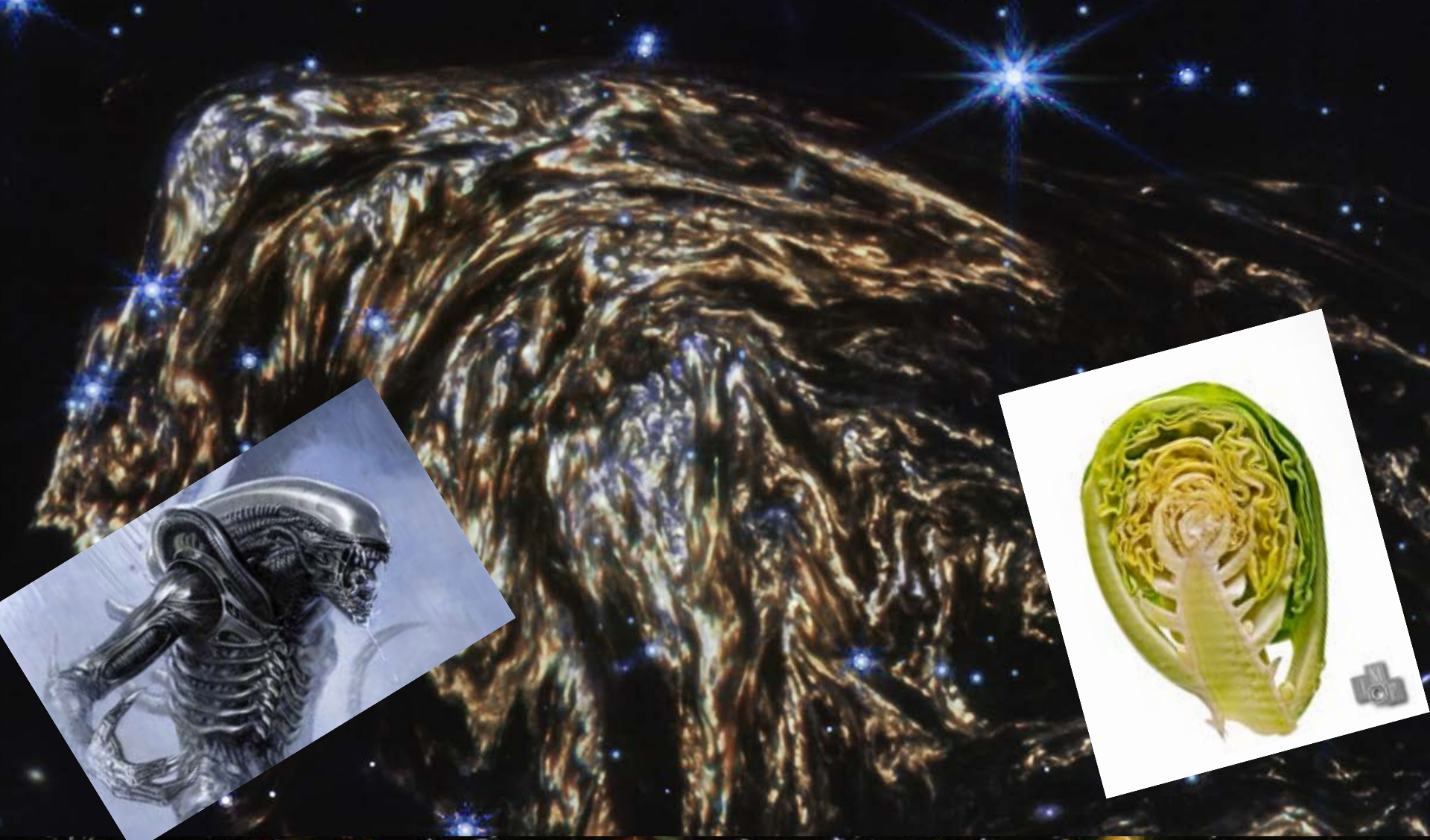
For the first time, JWST can access the majority of cool, interior unshocked gas closest to where the original explosion took place.





Emission probed by MRS spectra is rich and complex.
Ejecta filaments at < 1 arcsecond (0.01 pc) scale.


JWST/NIRCam/F356W
Spitzer/IRAC/Ch1



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