Unveiling the First Binary-System Supernovae

Born as a Pair, United by Gravity, Torn Apart by a Supernova, Reunited in the Aftermath

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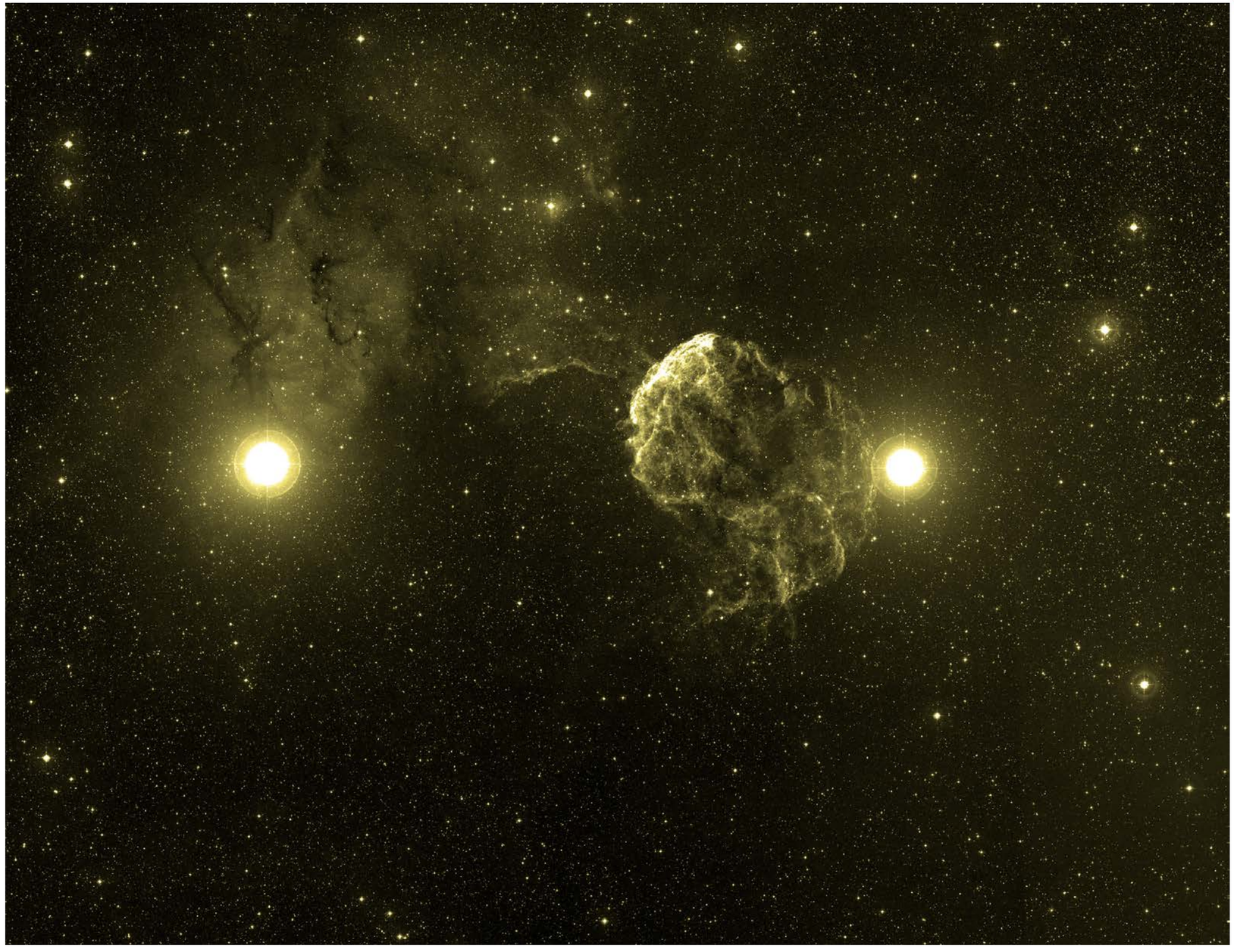
A Binary Story Written in Supernovae?

Unraveling the IC 443 Complex:

❶ IC 443: A Supernova Remnant



Credit: NASA Goddard Space Flight Center and M. Michailidis et al. 2026; yellow: optical, DSS

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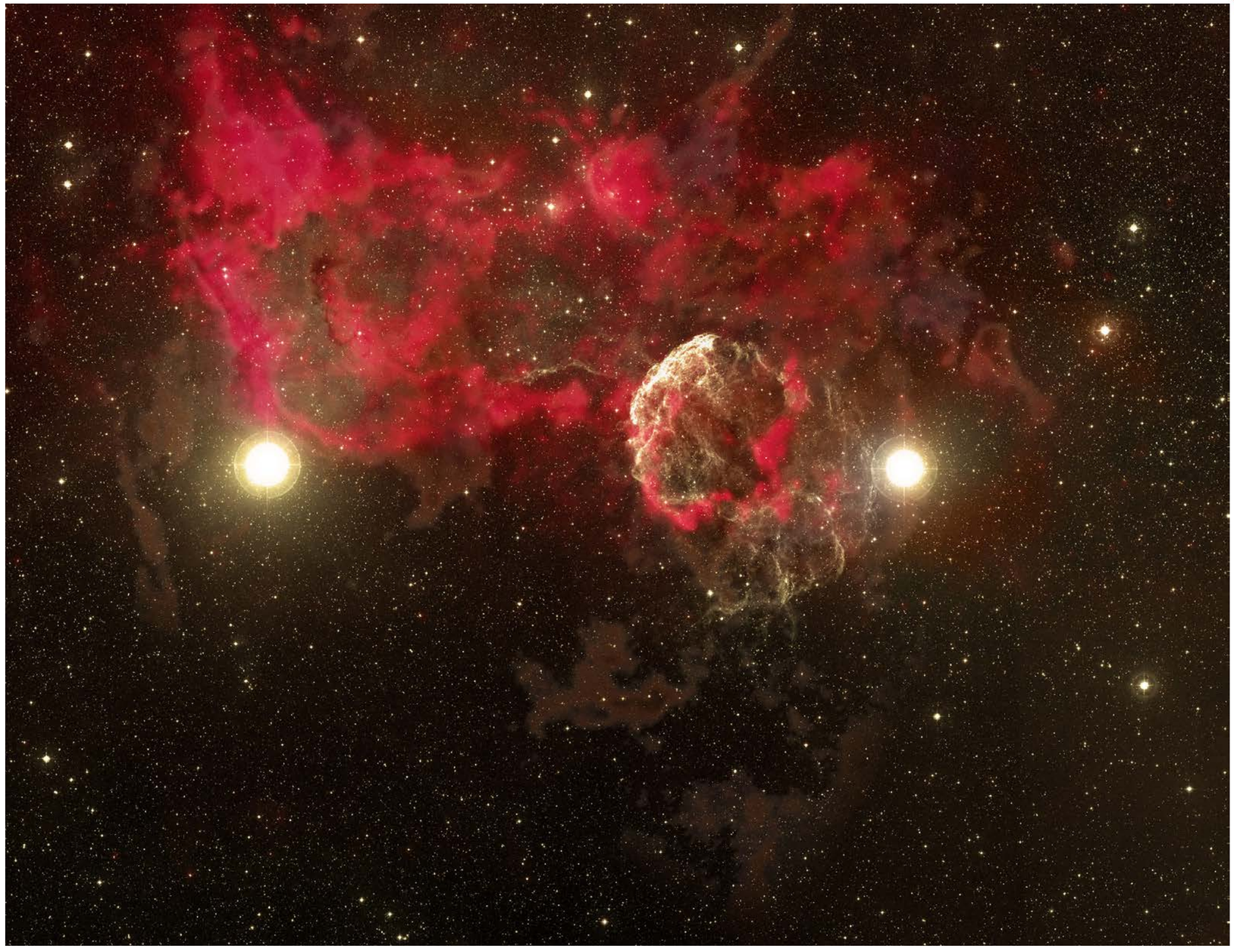

Credit: NASA Goddard Space Flight Center and M. Michailidis et al. 2026; orange, brown: radio, ESA/Planck and MWISP; yellow: optical, DSS; red: infrared, NASA/WISE

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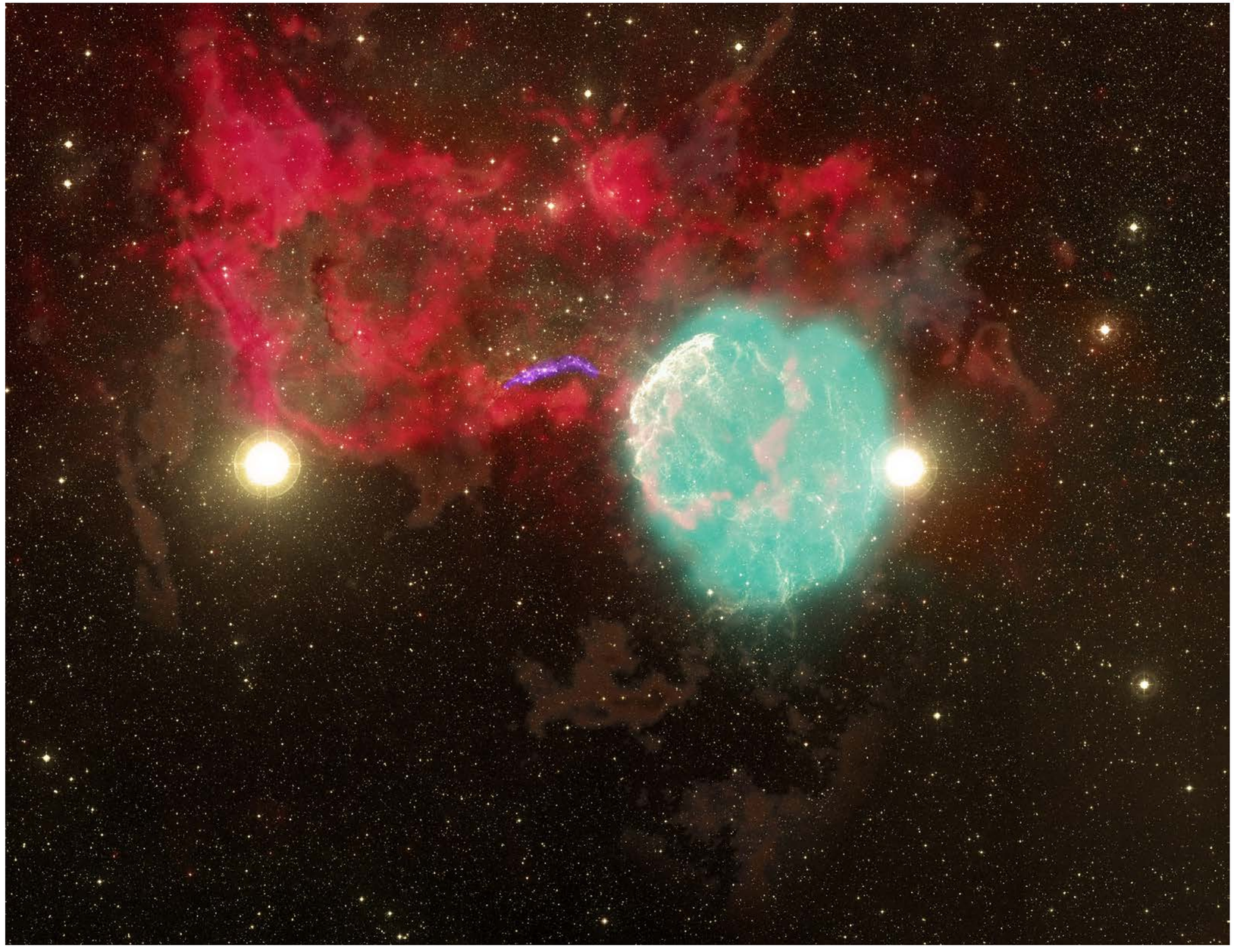

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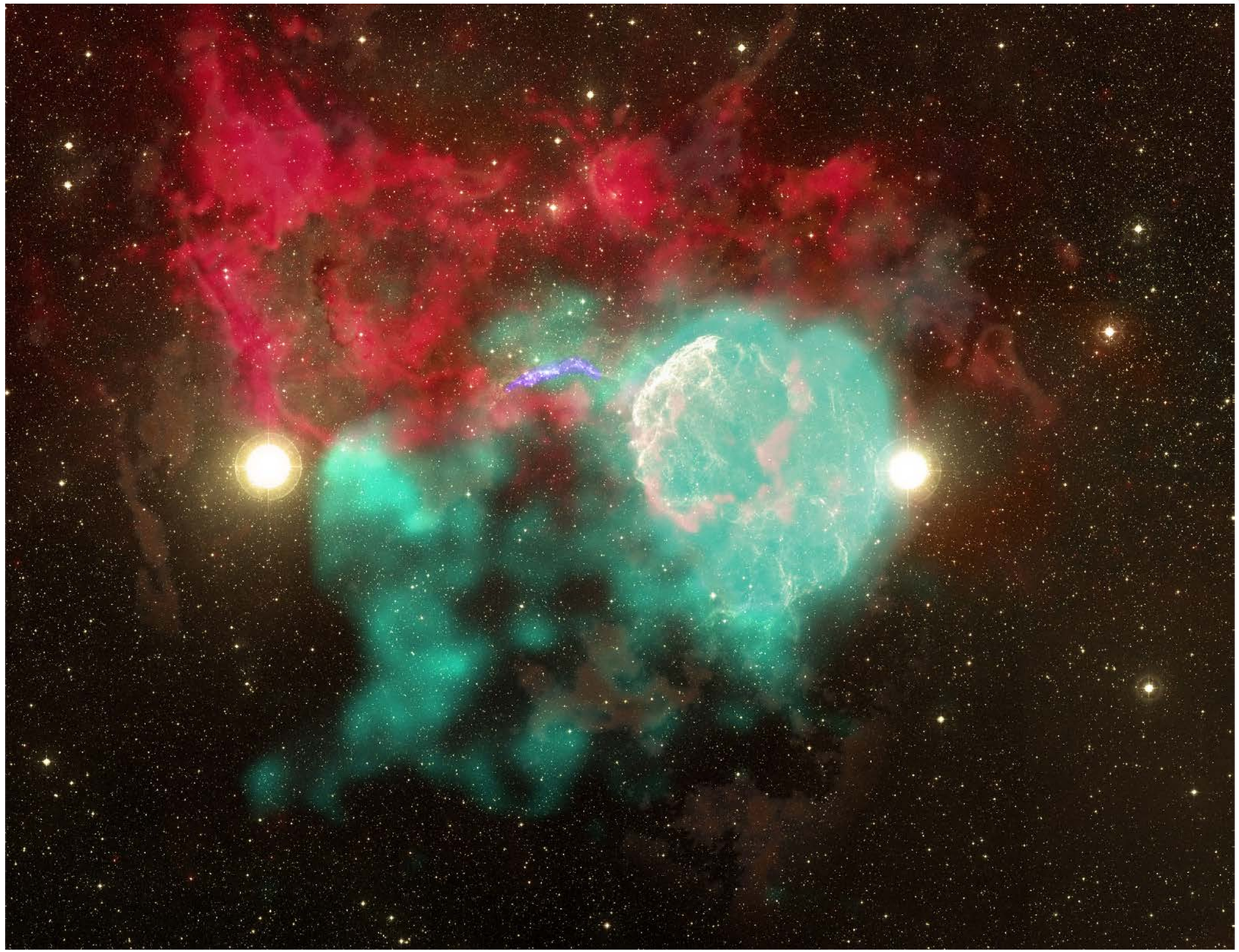
❸ + G189.6+3.3: A Second Supernova Shell



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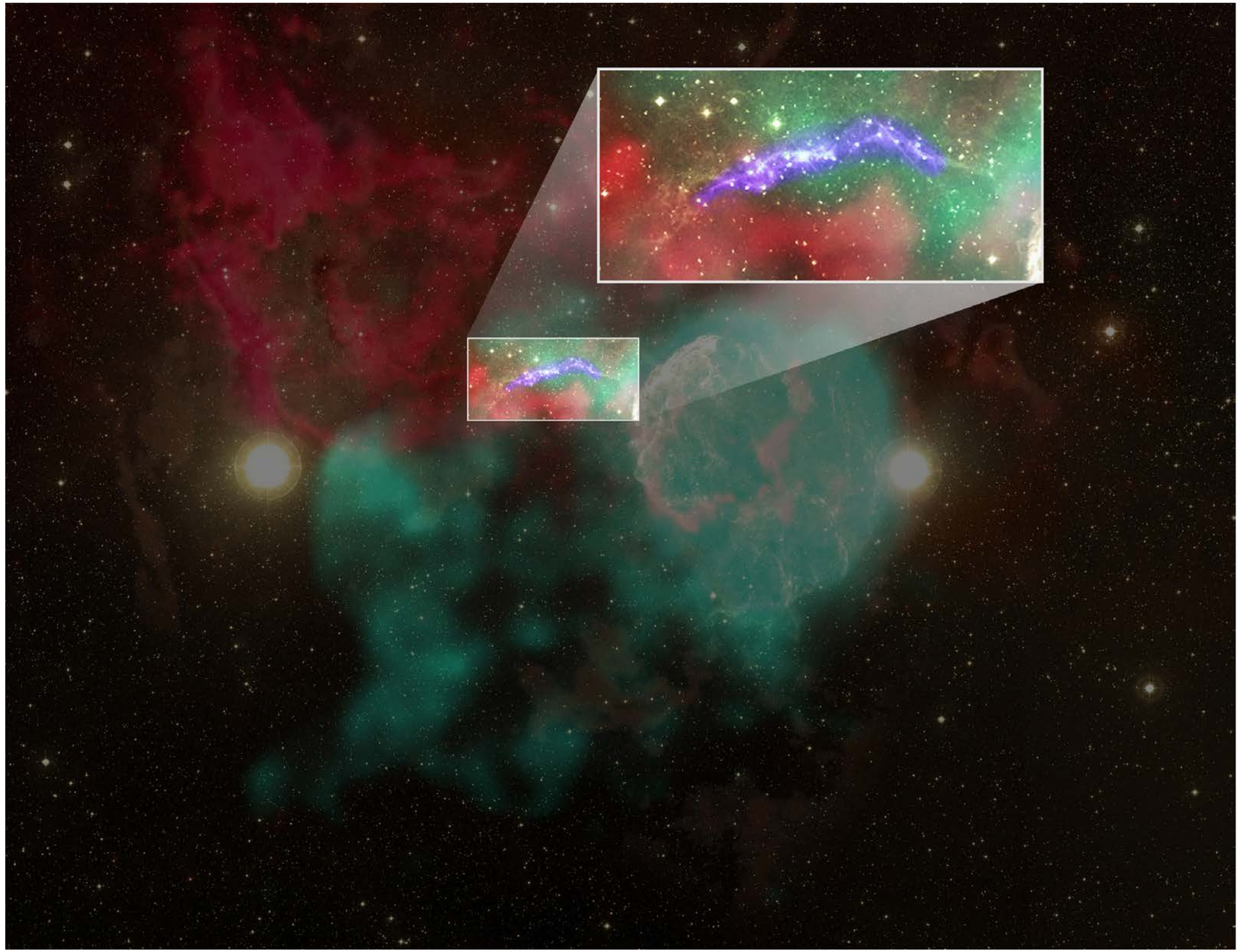

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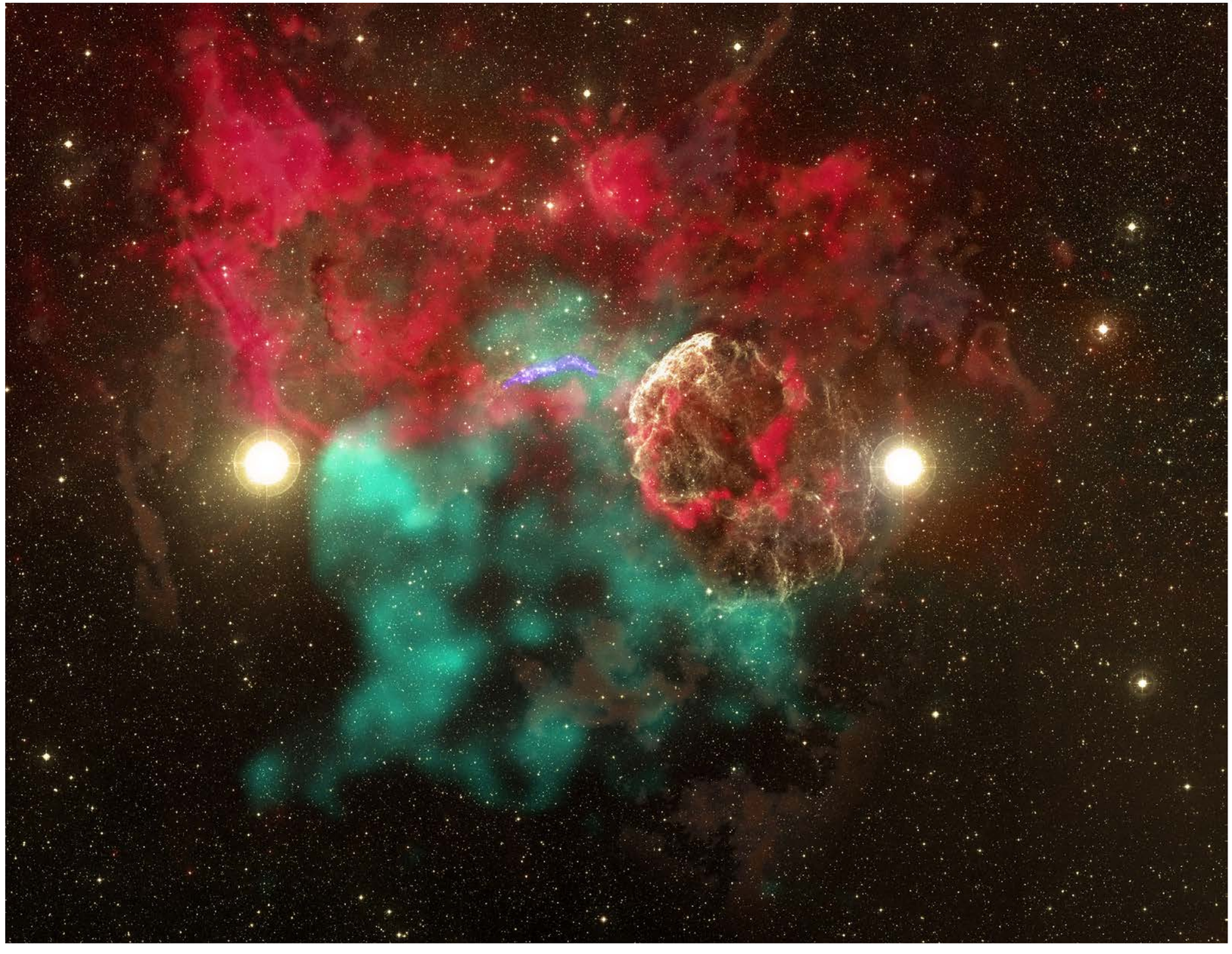

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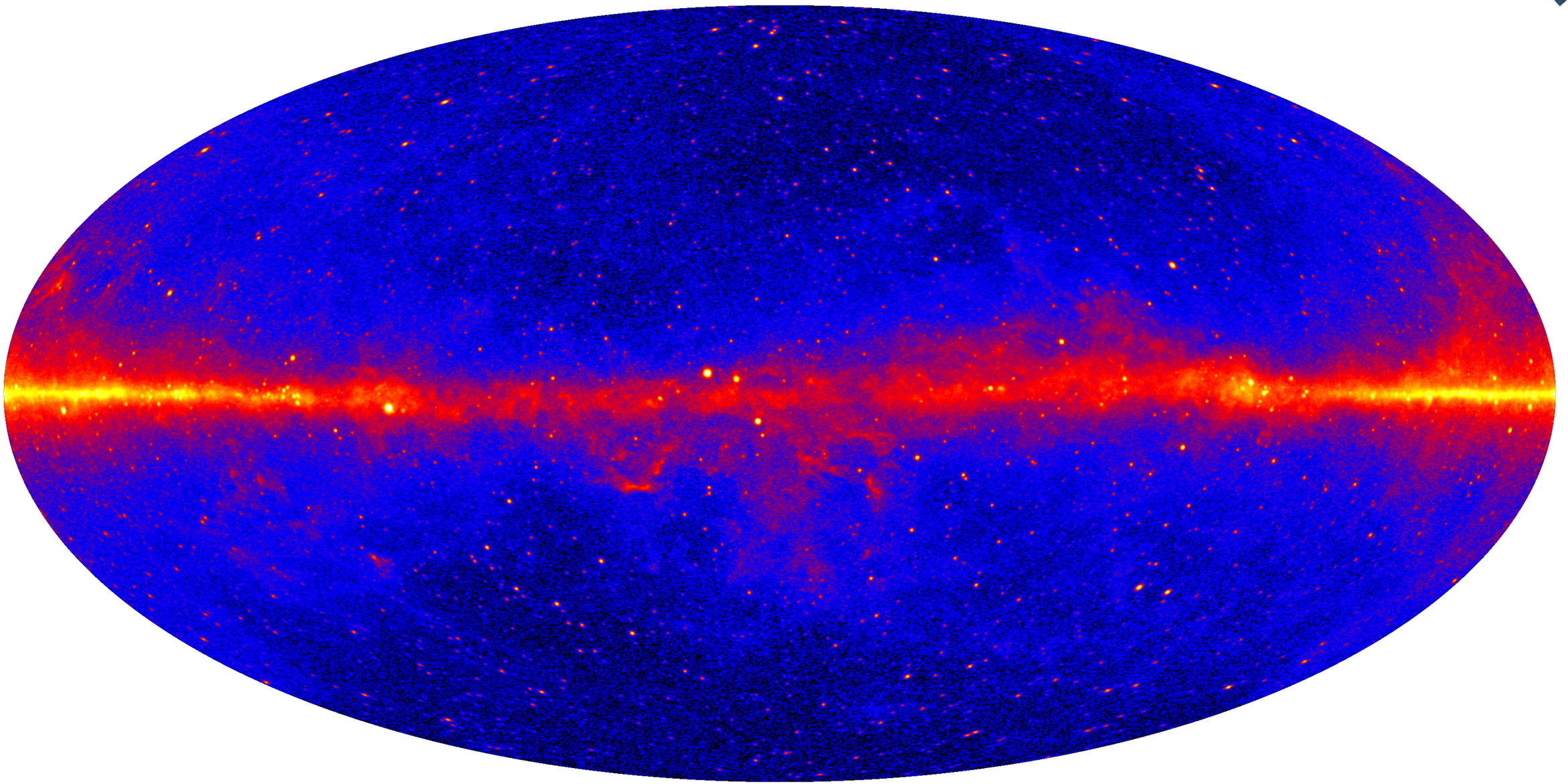
IC 443: One of the Milky Way's Most Famous Cosmic-ray Accelerators



Credit: NASA/DOE/Fermi LAT Collaboration

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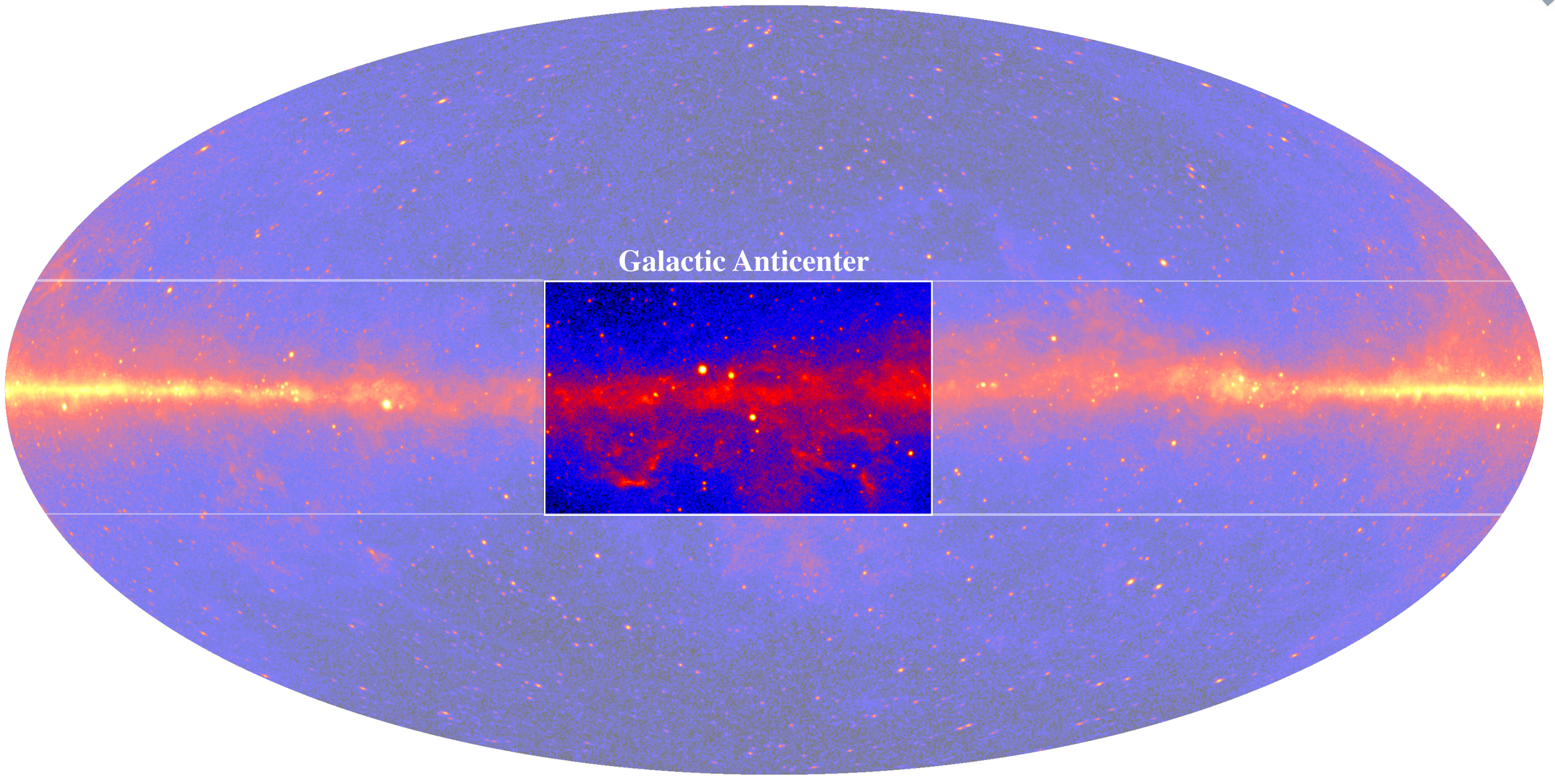

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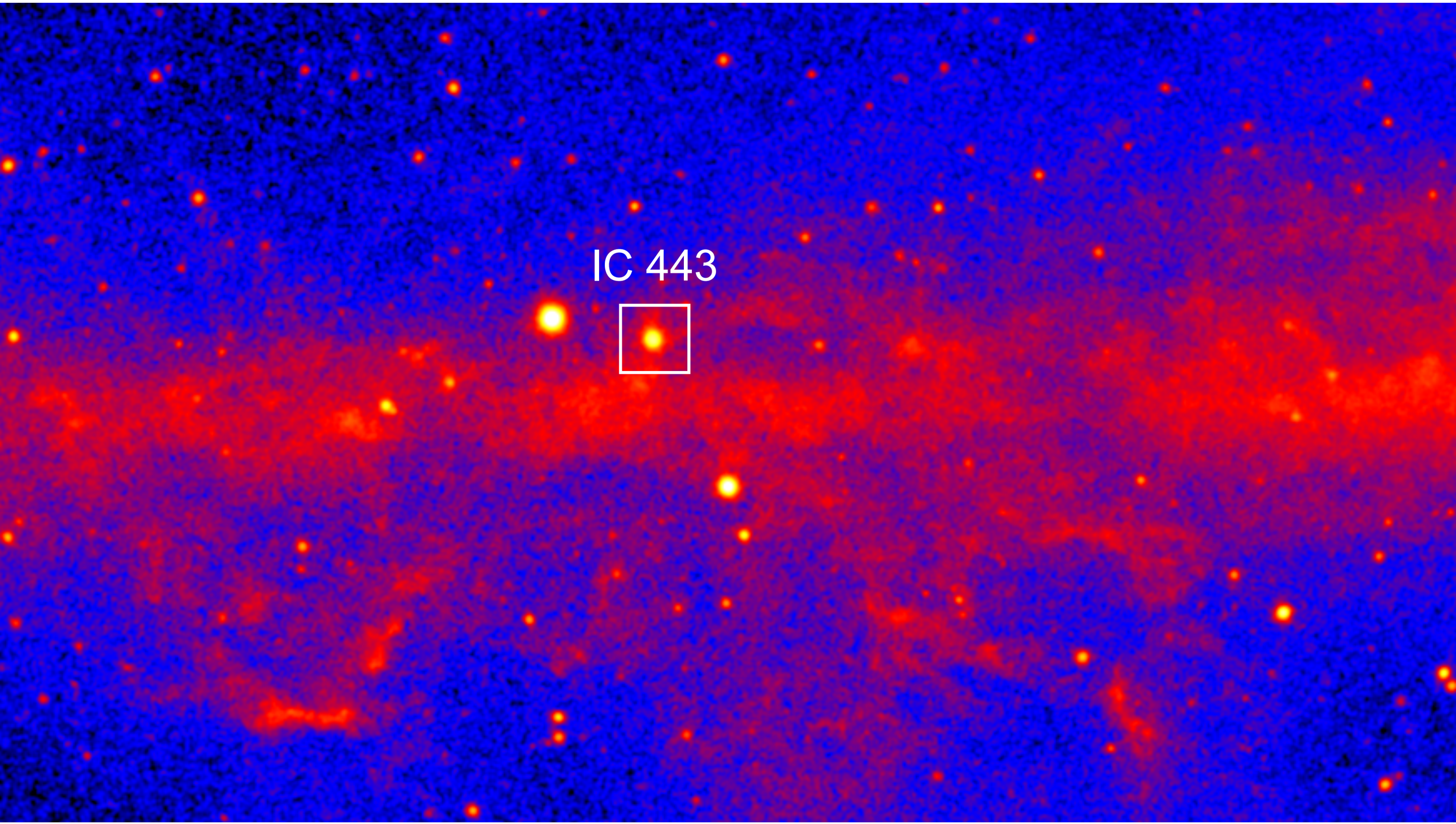
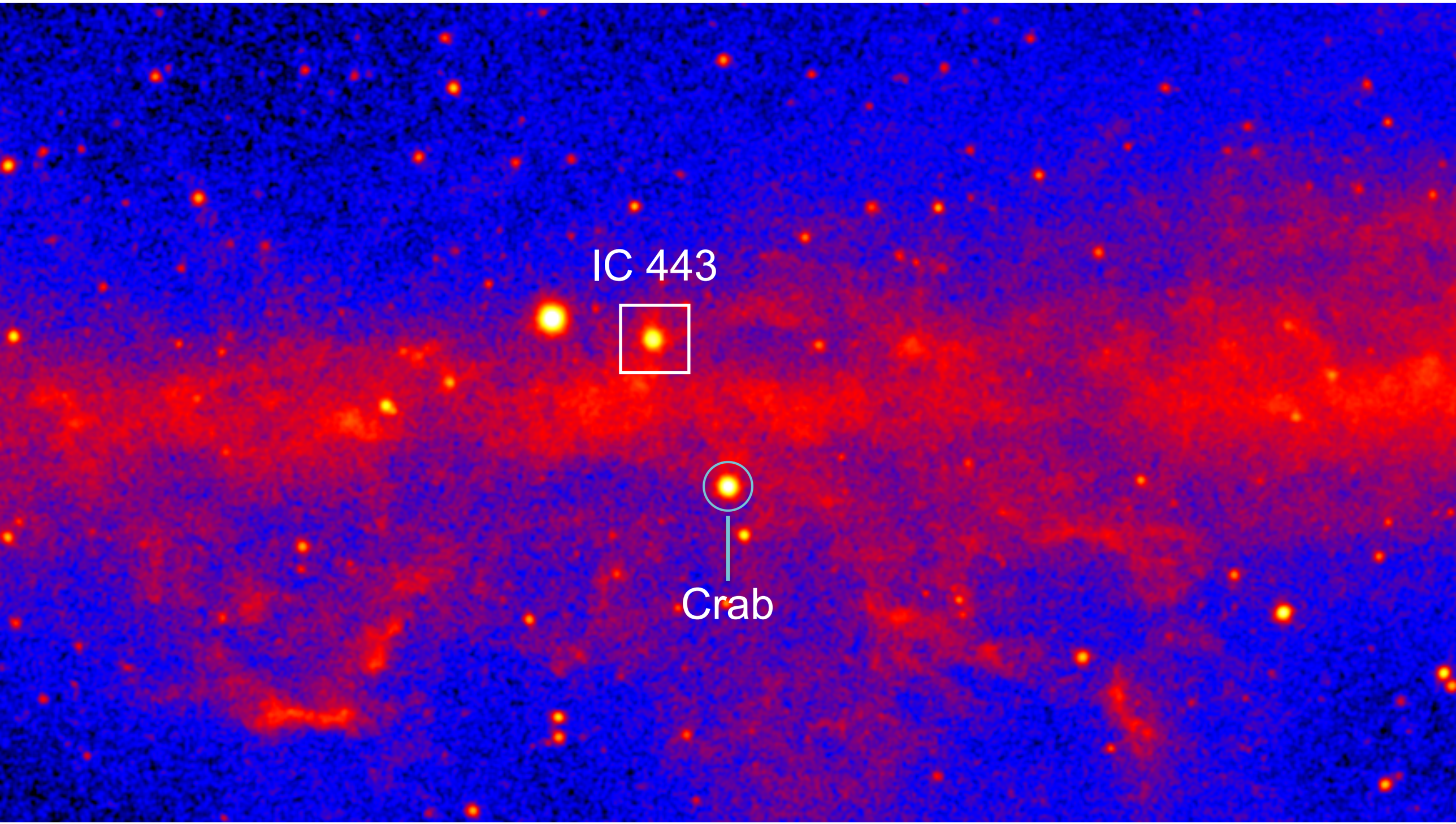
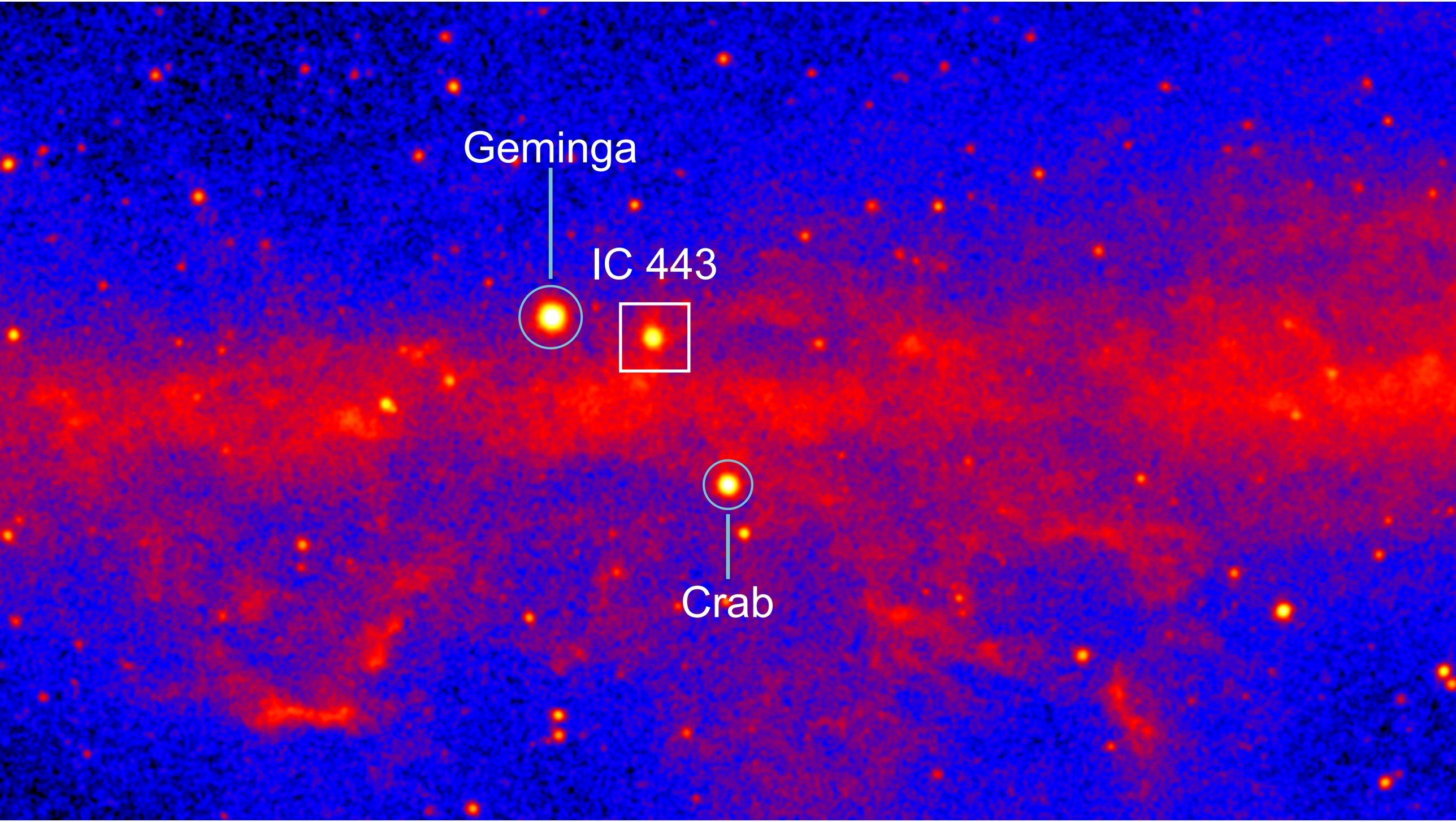

IC 443


IC 443
Crab

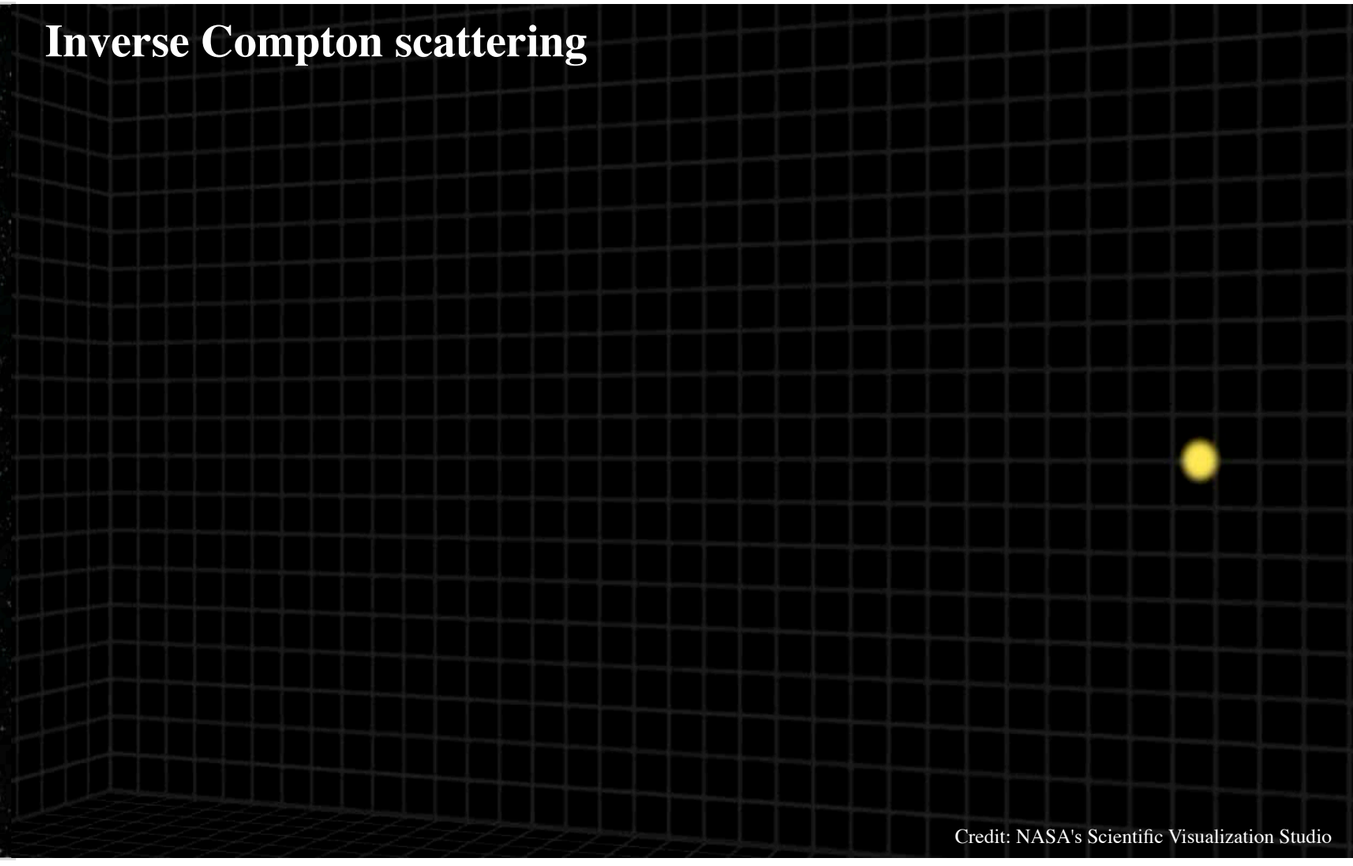

Geminga
IC 443
Crab

Where Do Gamma Rays Come From?

Proton collisions

Credit: NASA's Scientific Visualization Studio

Inverse Compton scattering

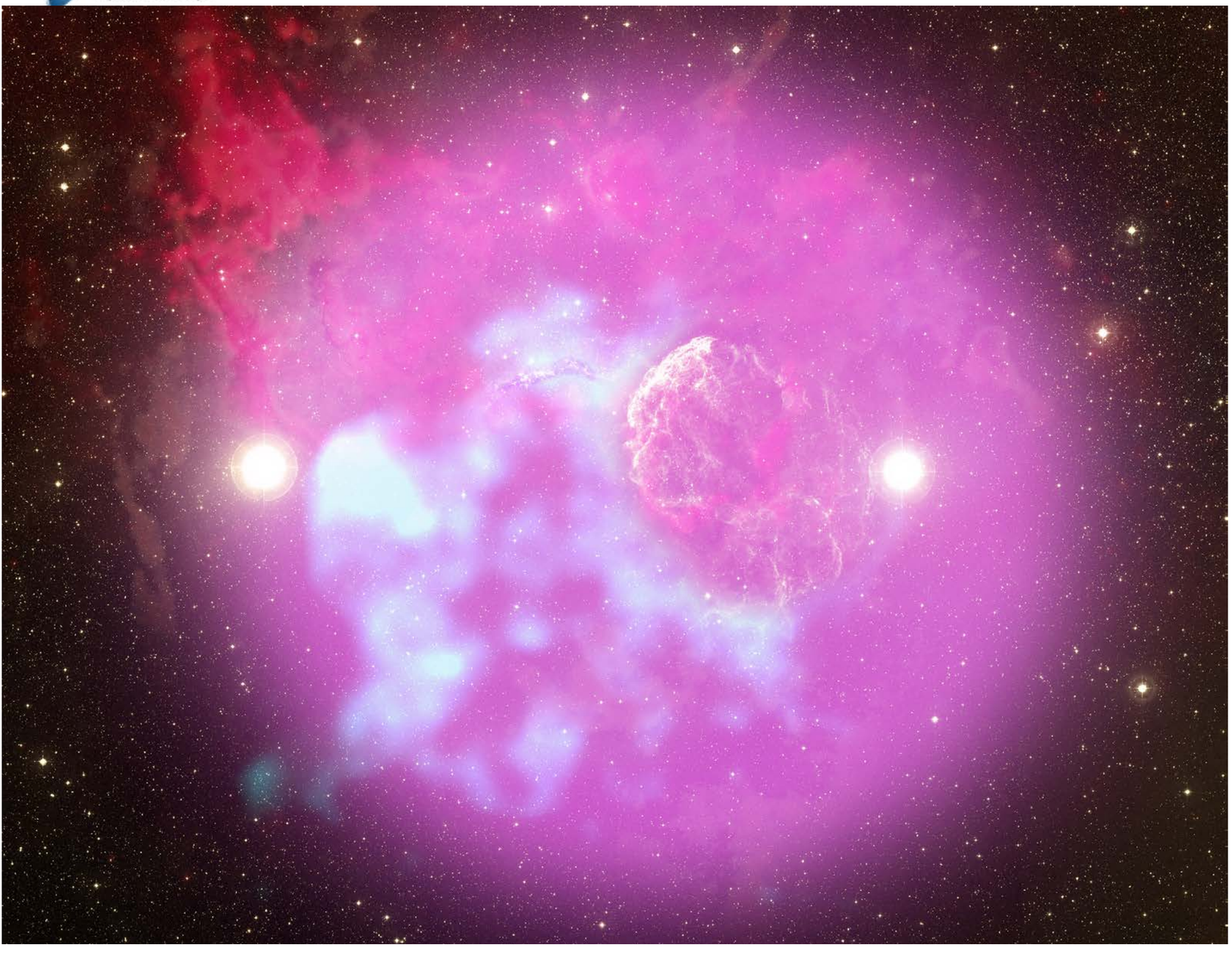


Credit: NASA's Scientific Visualization Studio

Particles Surfing a Cosmic Shock Wave

Credit: NASA's Scientific Visualization Studio

A Long-Standing Assumption

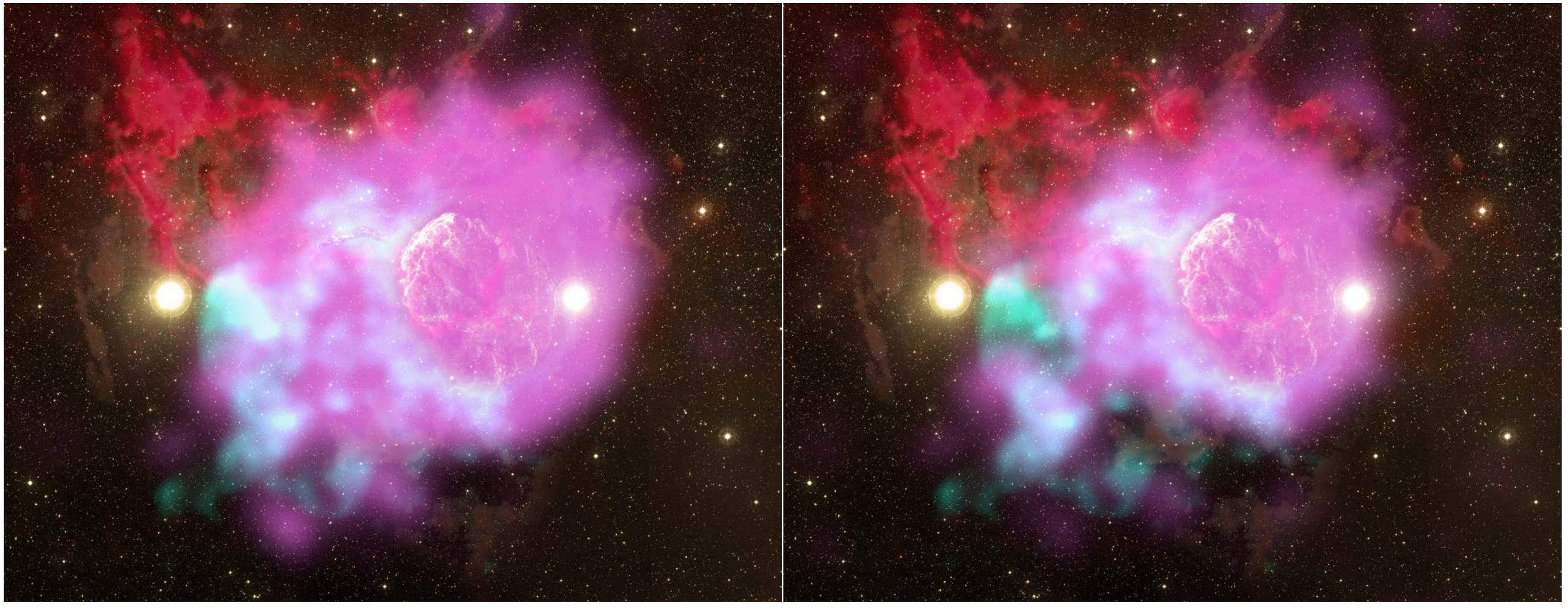


Low-Energy Gamma Rays: One Bright Gamma-Ray Beacon

Credit: NASA Goddard Space Flight Center and M. Michailidis et al. 2026; orange, brown: radio, ESA/Planck and MWISP; yellow: optical, DSS; red: infrared, NASA/WISE; violet: ultraviolet, NASA/Swift; teal: X-rays, SRG/eROSITA; magenta: gamma rays, NASA/DOE/ Fermi LAT Collaboration

The Beacon Begins to Break Apart

Higher-energy gamma-rays



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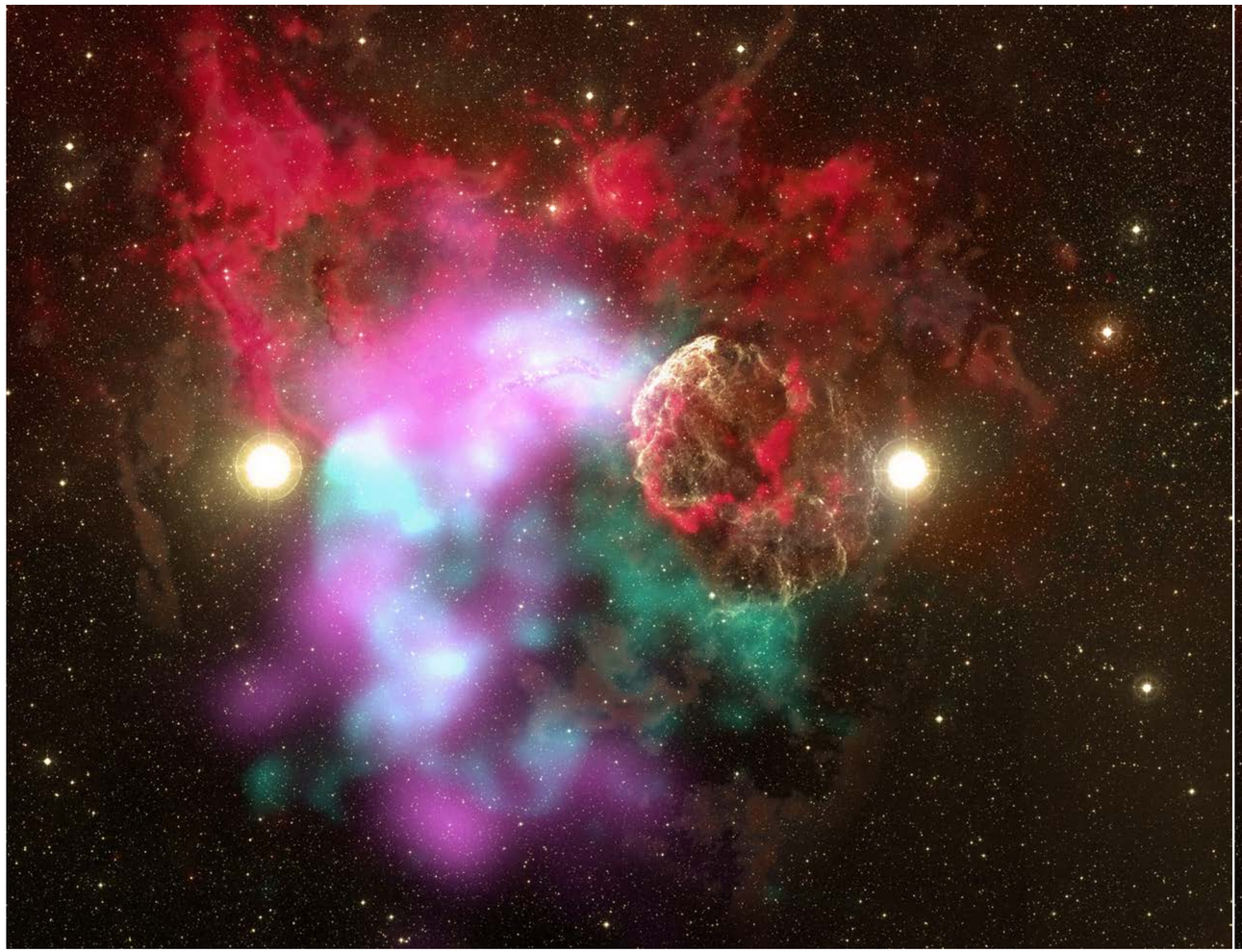
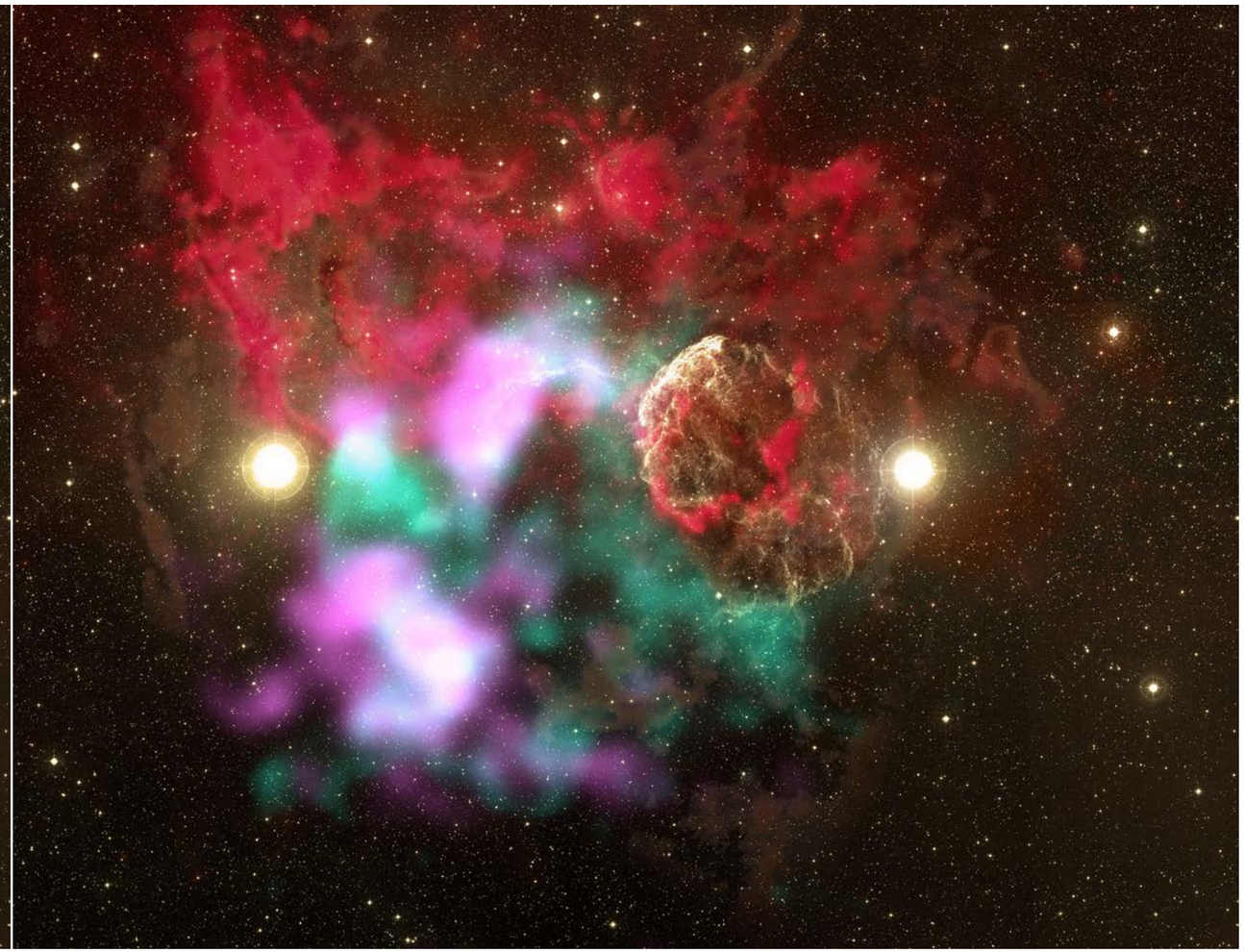
A Hidden Particle Accelerator Emerges

Higher-energy gamma-rays: Removing the contribution from IC 443





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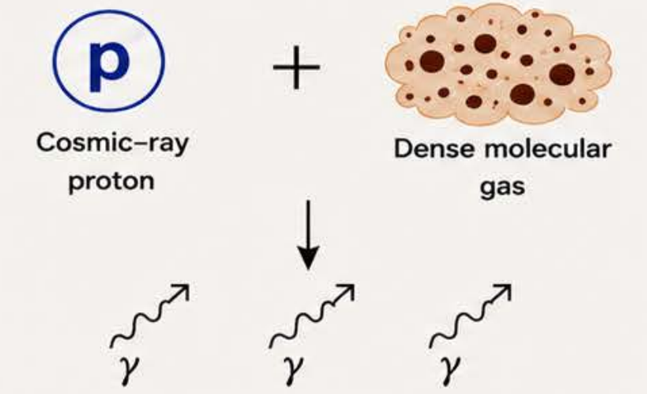
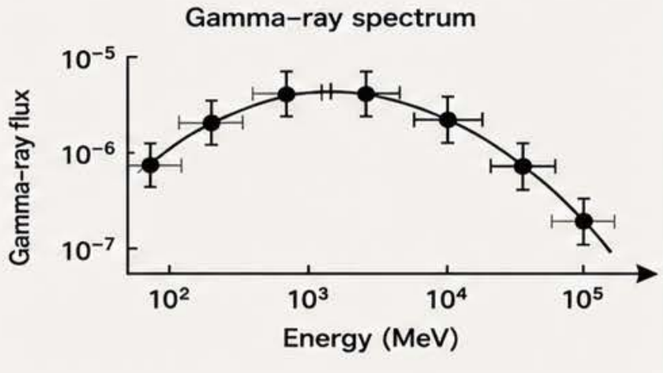
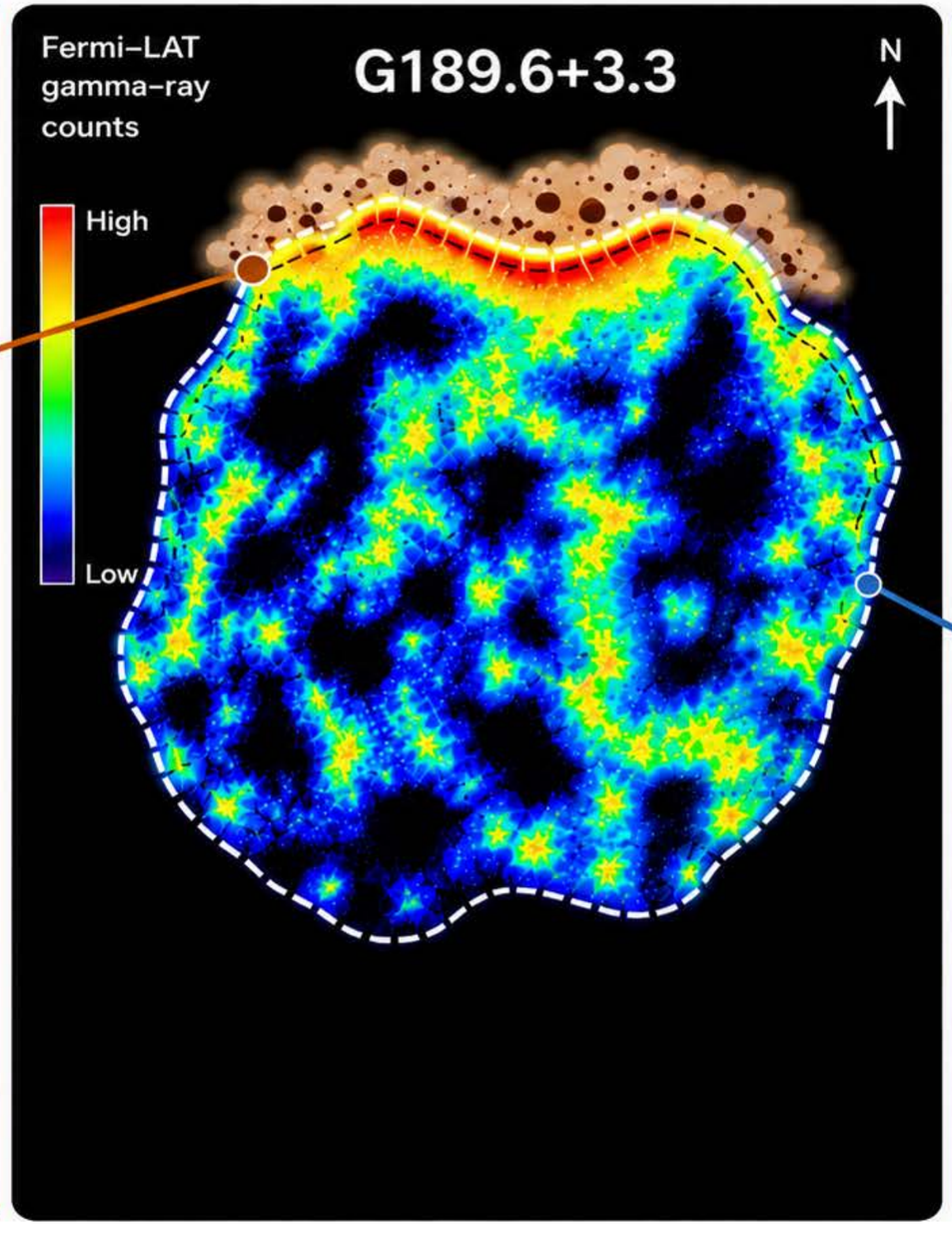
Two Cosmic-Ray Factories in One Remnant

NORTHERN BOUNDARY (FILAMENT + CLOUD)

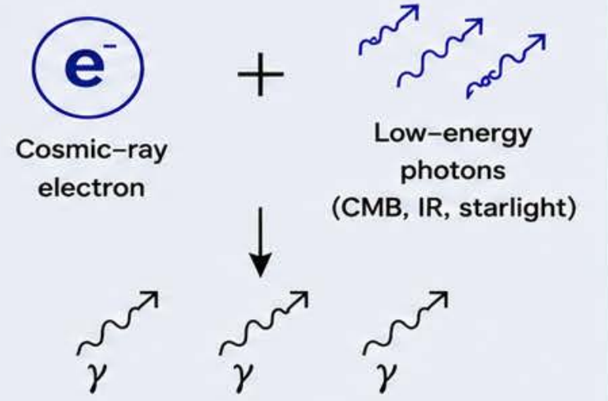


Dense molecular clouds and the adjacent filament at the northern boundary provide abundant targets for proton–proton interactions.

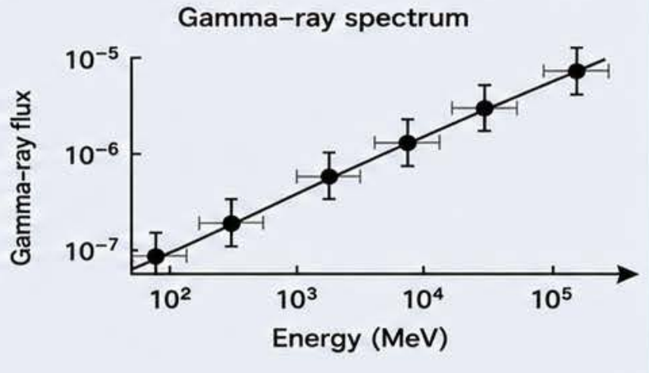




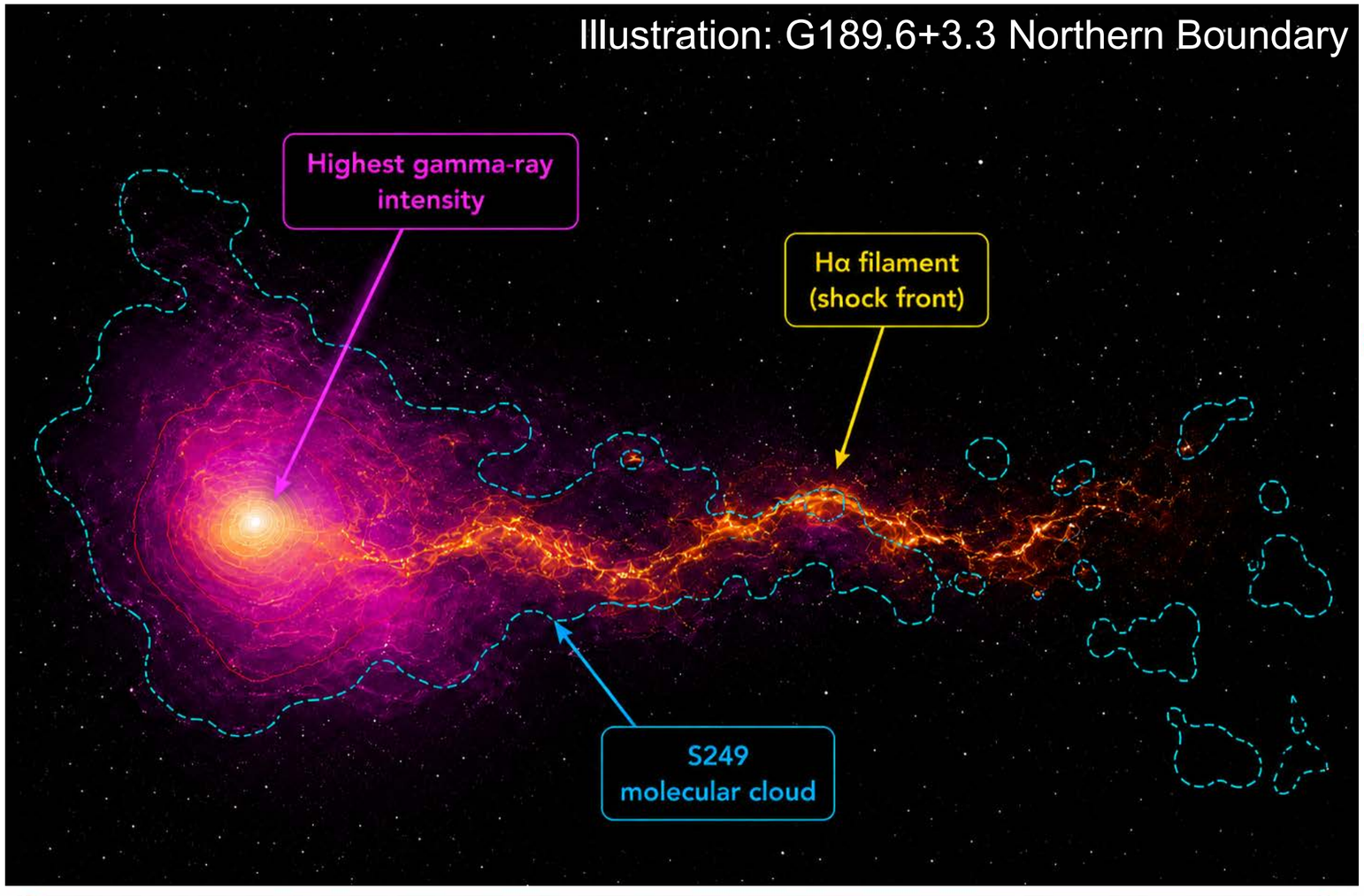
REST OF THE REMNANT

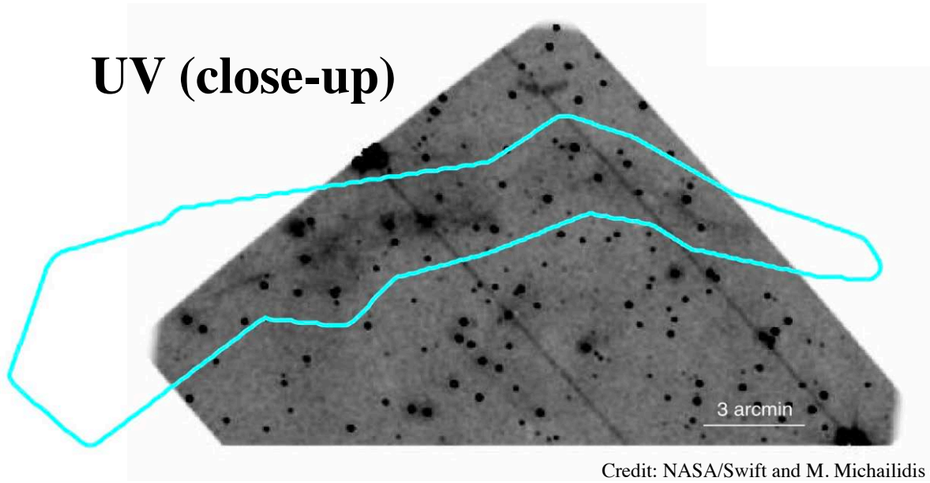


Lower gas density in the interior makes electron inverse Compton scattering the dominant process.

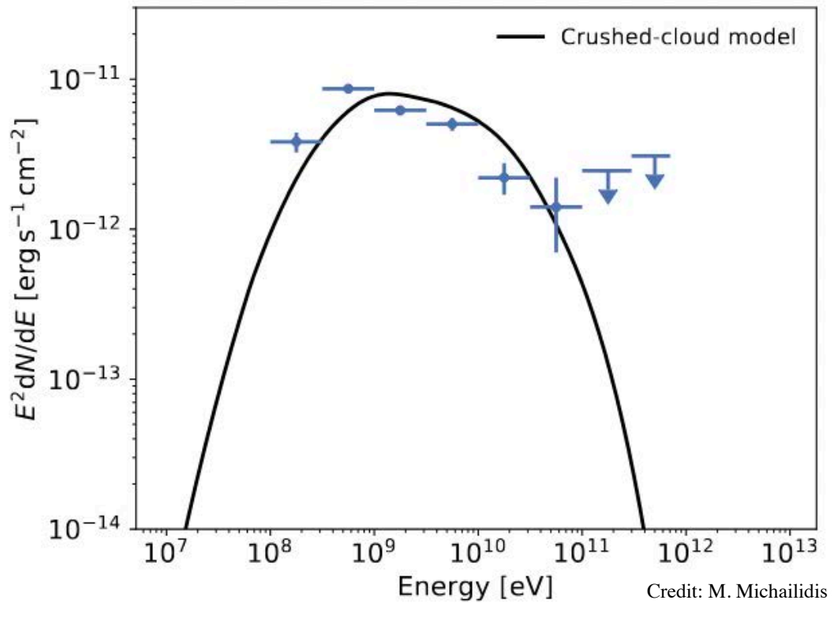


A Shocked Cloud Lights Up the Northern Boundary





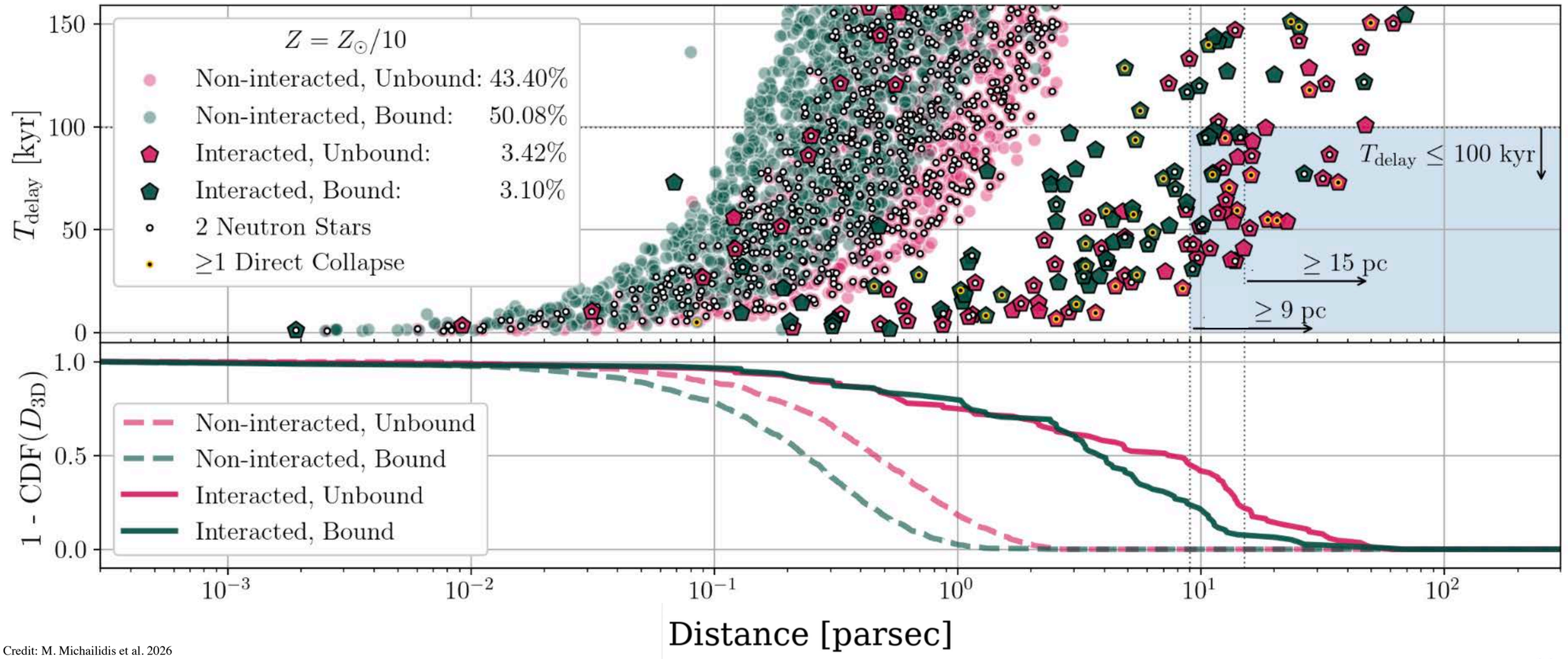
Credit: NASA/Swift and M. Michailidis et al. 2026



Credit: M. Michailidis et al. 2026

→ The highest-energy gamma-ray photons **come from a well-localized filament** coincident with the shock front interacting with dense gas.

From a Shared Environment to a Shared Origin



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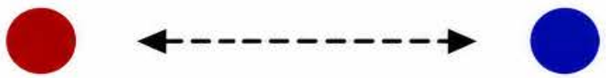
From a Shared Environment to a Shared Origin

1) CLOSE EXPLOSION CENTERS

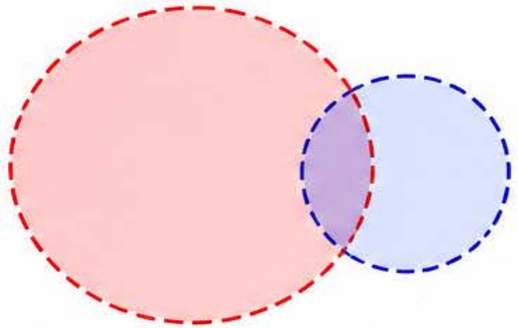
How likely are two unrelated remnants to appear this close together on the sky?



Probability: ~0.1%

2) OVERLAPPING SHELLS

How likely are two unrelated remnants to overlap this strongly?



Probability: ~0.1–1%

INPUTS USED IN BOTH ESTIMATES

- Galactic SNR surface density ($|b| \leq 5°$)
- **Distance compatibility** (~1.7–2.0 kpc; ~5,500–6,500 light-years)

TAKEAWAY

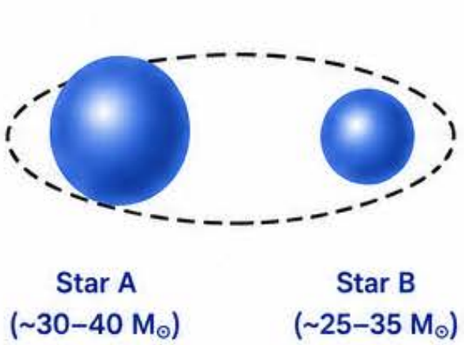
Both independent estimates indicate that the observed configuration is unlikely to occur by chance.

Chance alignment is unlikely.

A Binary Origin for IC 443 and G189.6+3.3

1 Massive binary system

Two massive stars orbit each other

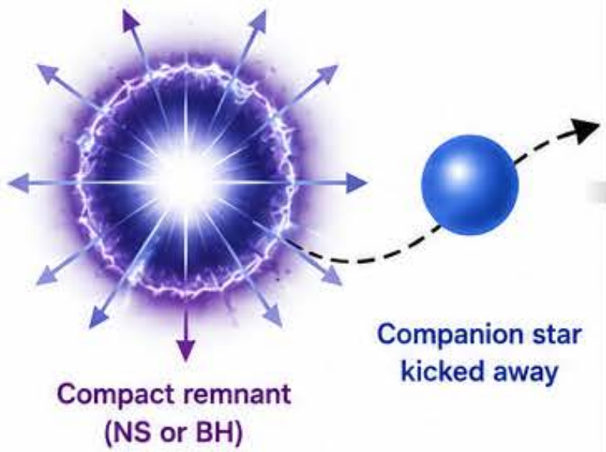


Bound binary

(before explosions)

2 First supernova

Star A explodes

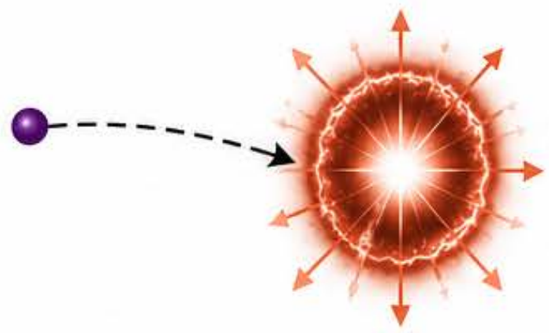


Binary disrupted

~0 years

3 Companion evolves and explodes

After tens of thousands of years, the companion becomes a supernova

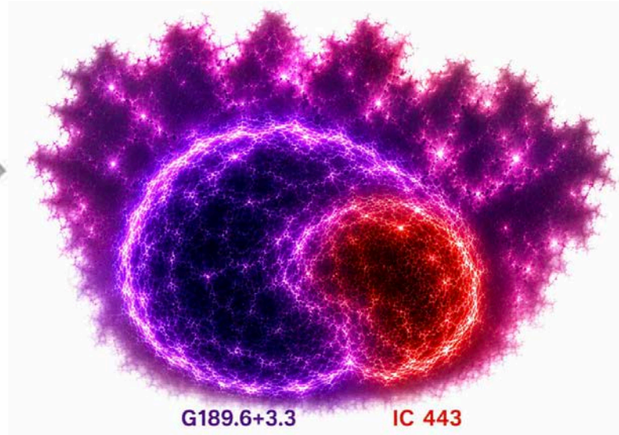


Two supernovae

~20,000–100,000 years

4 Today

We observe two supernova remnants in the same region of space



Two SNRs overlap

Today

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