

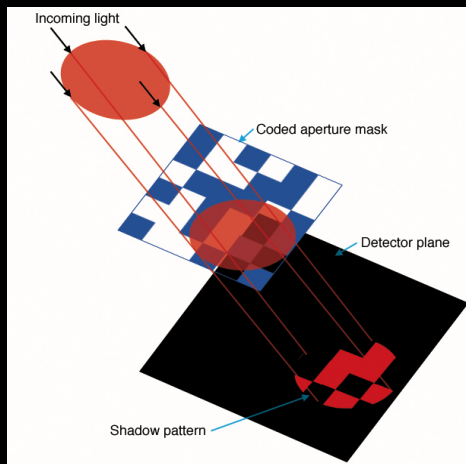
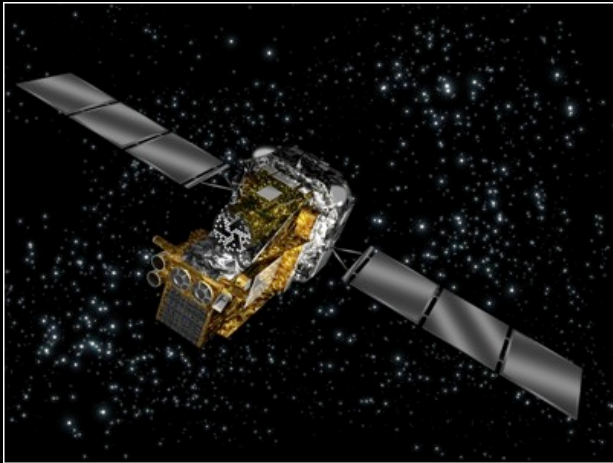
NuSTAR Observations of Non-thermal Emission from
Young Supernova Remnants

Fiona Harrison

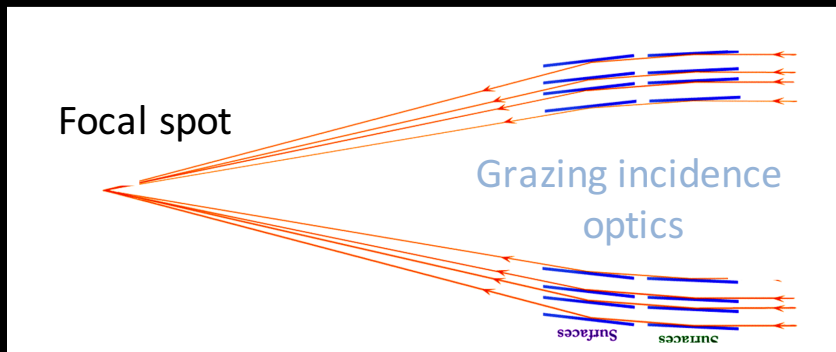
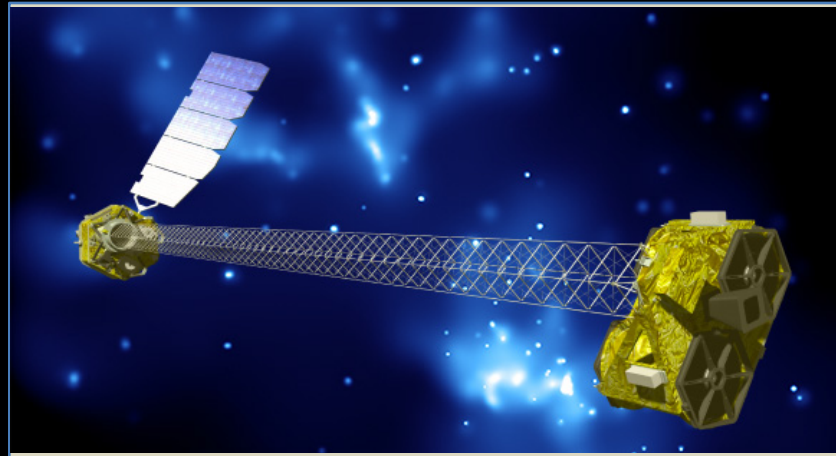
Caltech

TeVPA 2017

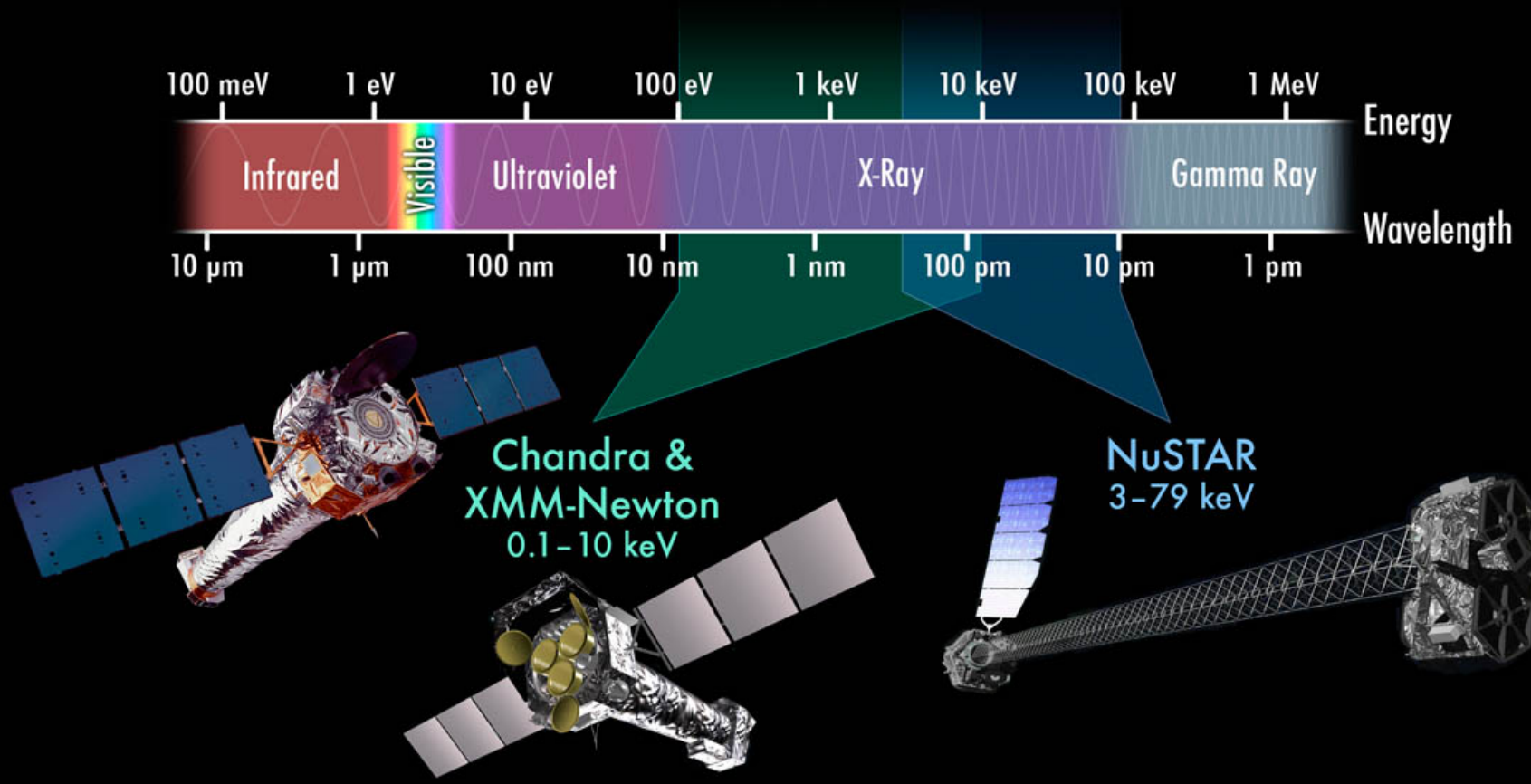
INTEGRAL, Swift BAT



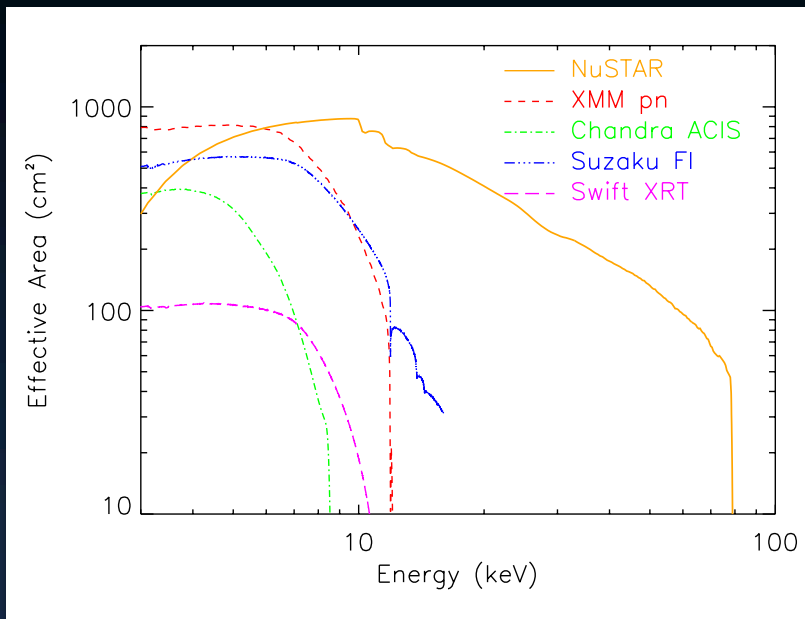
NuSTAR



X-Ray Telescopes & the Electromagnetic Spectrum



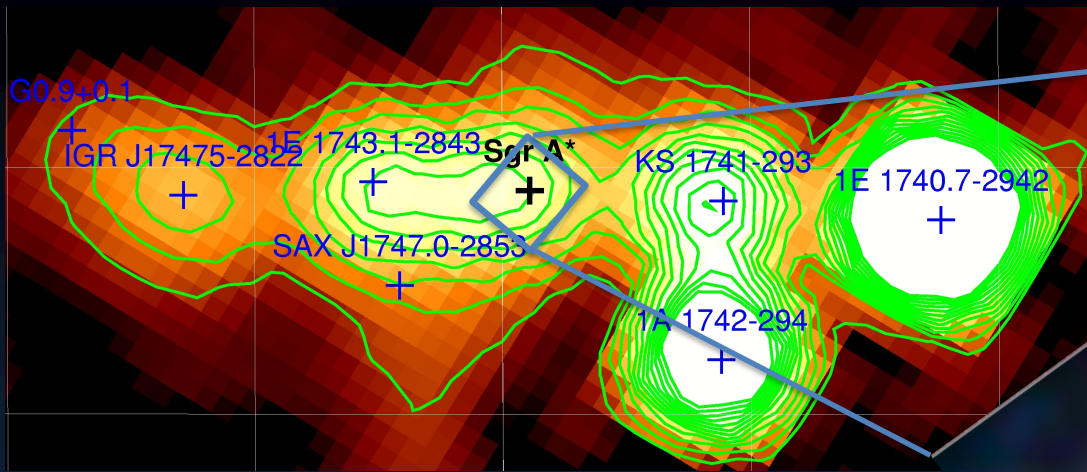
Sensitivity



NuSTAR two-telescope total collecting area

Satellite (instrument)	Sensitivity
INTEGRAL (ISGRI)	~0.5 mCrab (20-100 keV) with >Ms exposures
Swift (BAT)	~0.8 mCrab (15-150 keV) with >Ms exposures
NuSTAR	1 μ Crab (10-40 keV) in 1 Ms

Sensitivity comparison



NuSTAR E > 10 keV

*Previous high-energy X-ray view of
the heart of the Milky Way*

*Extended Hard X-ray Emission in the Inner Parsecs
of the Galaxy, Perez et al. Nature 2015*

SPUTNIK

Did NASA's NuSTAR Capture 'Screams' of Zombie Stars?

© NASA/JPL-Caltech

NEWS 02:46 05.05.2015 (updated 08:58 05.05.2015) [Get short URL](#)

799 4 1

New images captured by NASA of a mysterious glow at the center of our galaxy may have been produced by the "howls" of dead stars feeding off their live companions.

NEWS

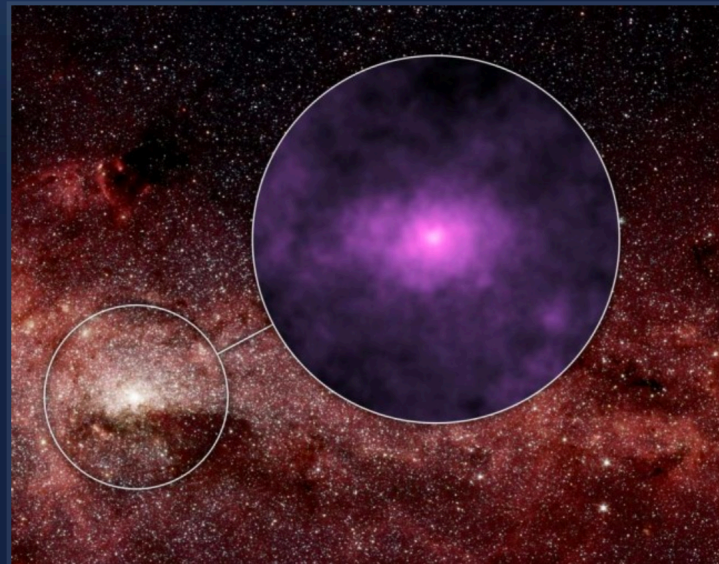
LATEST

MOST READ

02:15 US Breaches Human Rights Promises by Not Bringing CIA Torturers to Justice

LATEST NEWS

CAUGHT IN THE ACT: NUSTAR SHOWS 'ZOMBIE' STARS MAY HOWL AS THEY FEED



NuSTAR data reveals 'zombie' stars may scream as they devour their companions. Photo Credit: NASA/JPL-Caltech

MAY 4TH, 2015

AMY THOMPSON

NASA's Nuclear Spectroscopic Telescope Array (NuSTAR) has been peering deep into the heart of our galaxy, the Milky Way. In doing so, NuSTAR has created an incredible view of high-energy events...

AMAZING CHANNELS • PREDICTIONS • FEATURES \$5.95 US
7.95 CAN

SEDONA

Journal of EMERGENCE!

PEACE TO ALL BEINGS

MARCH 2013

AMAZING CHANNELS:

Almine

Hannah Beaconsfield

Lee Carroll

Judith Coates

Ronna Herman

Elliott Jackson

Kathlyn Kingdon

David Lowell

Jeff Michaels

David Miller

Miriandra Rota

Steve Rother

Robert Shapiro

Kahu Fred Sterling

James Tyberonn

Catherine Bean Weser

and many more!

This new view of the historical supernova remnant Cassiopeia A, located 11,000 light-years away, was taken by NASA. Inside, Cassiopeia speaks through Robert Shapiro

INSPIRED INFORMATION

from beyond the focus of Earth to guide, teach, and help you now as you emerge into your natural self and your natural talents and abilities.



Evolved star/Fe core



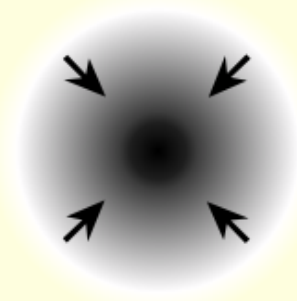
a Bounce, outward shock

Chandrasekhar mass
-> collapse

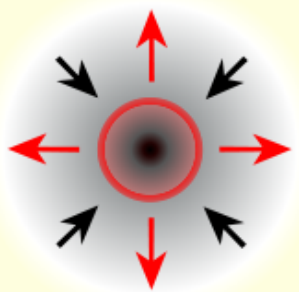


b Shock stalls

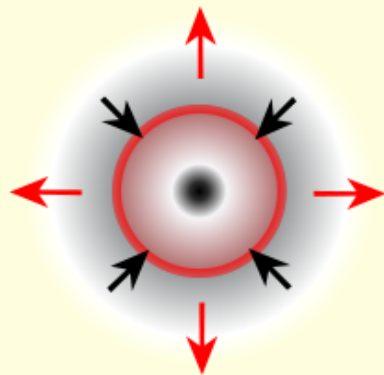
Inner part compressed
to neutrons



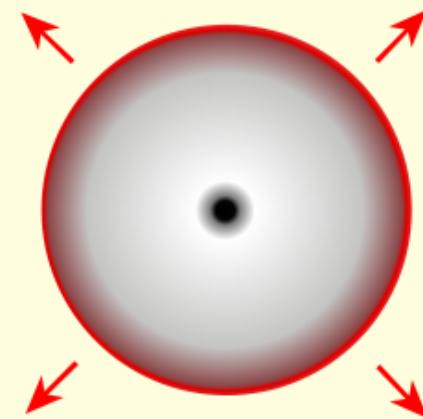
c Shock reinvigorated [how?]



d

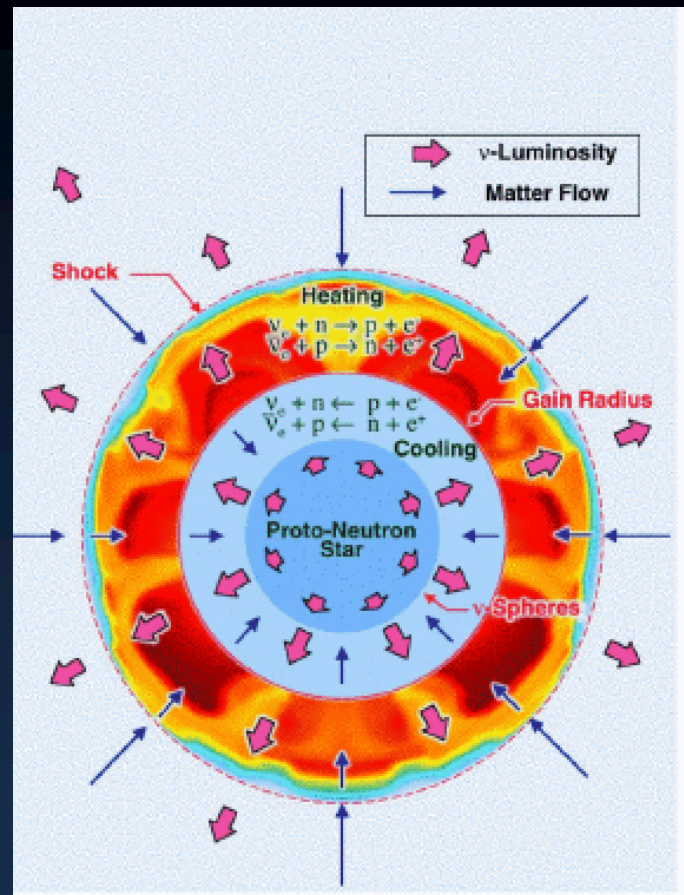


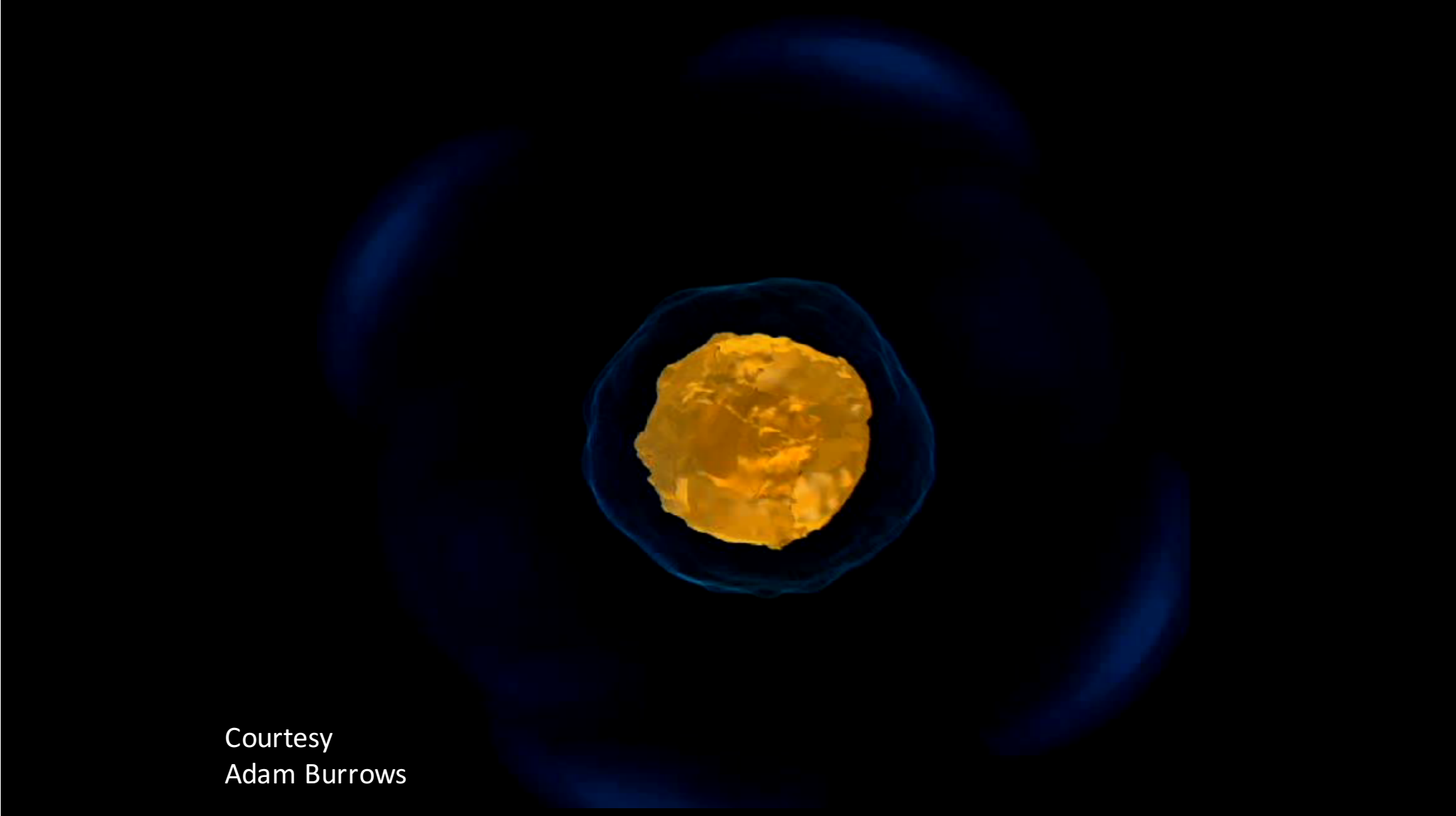
e



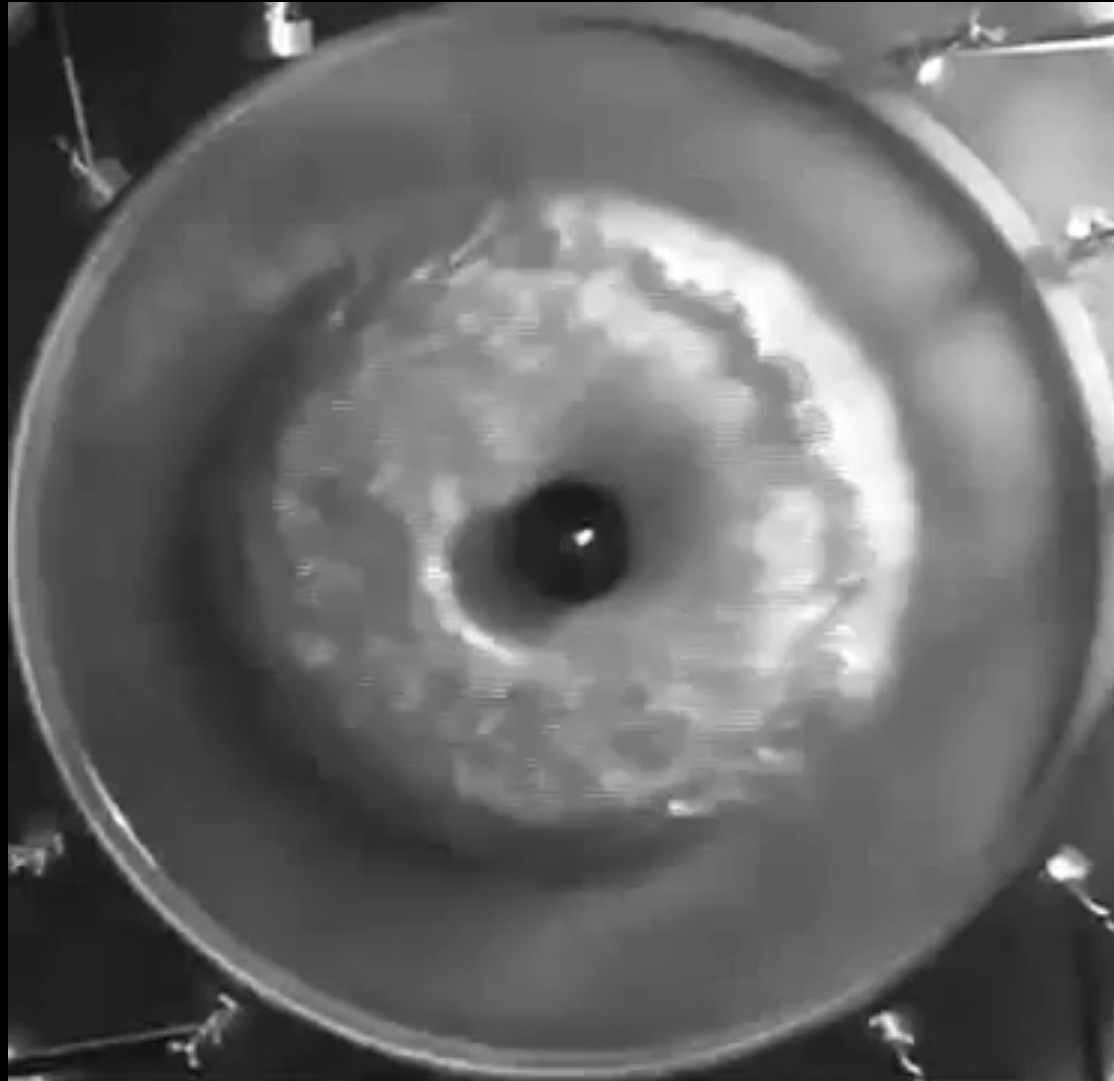
f

Neutrino Heating



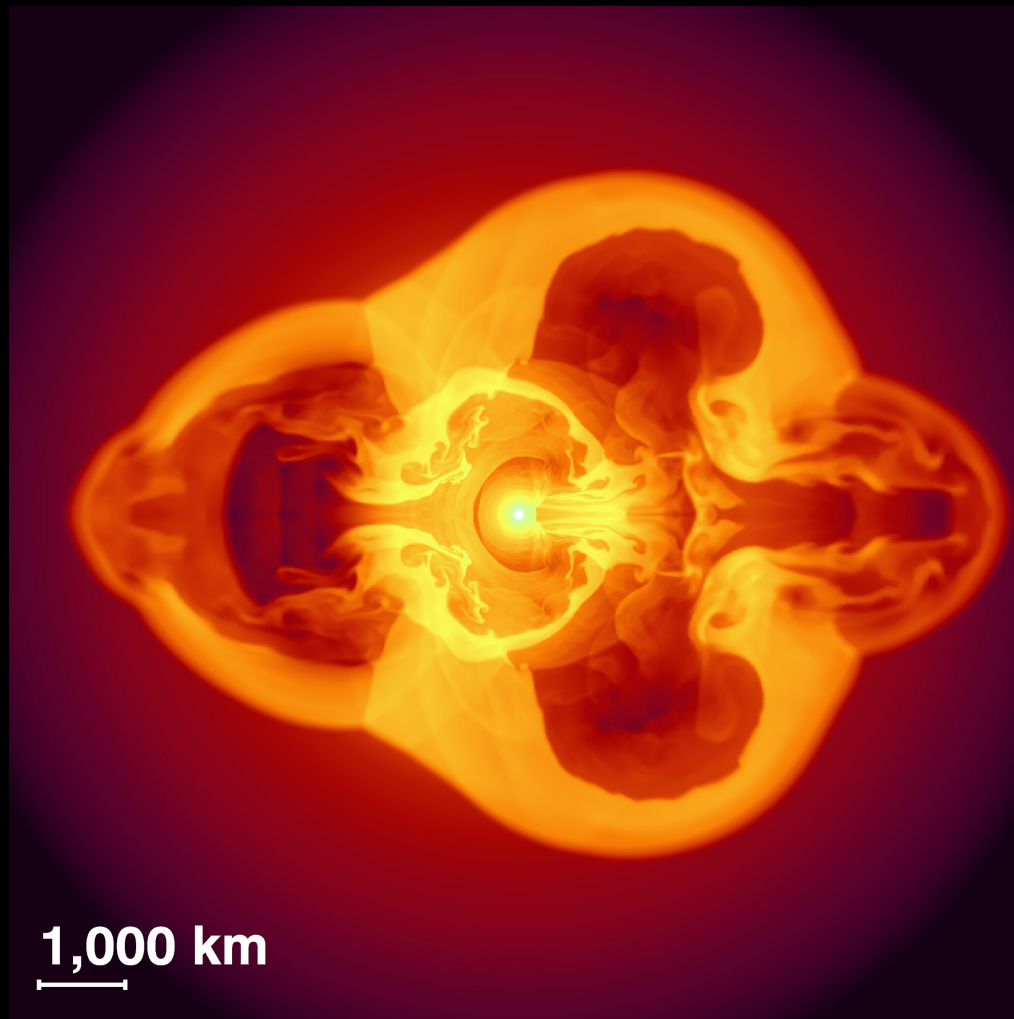
A 3D visualization of a cell. The nucleus is a bright yellow, textured sphere in the center. The cytoplasm is a translucent blue, irregularly shaped volume surrounding the nucleus. The background is solid black. The cell is centered in the frame.

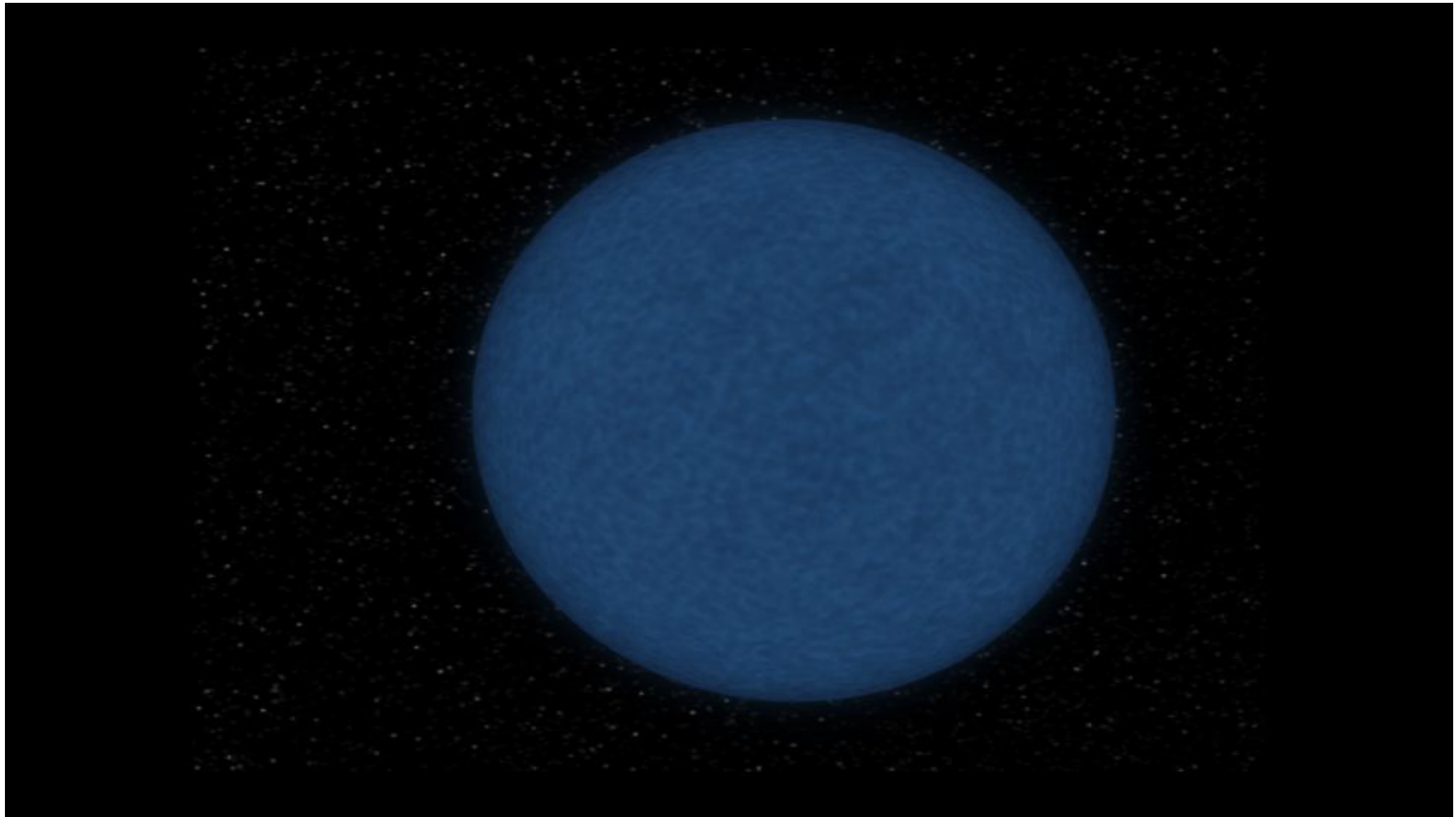
Courtesy
Adam Burrows



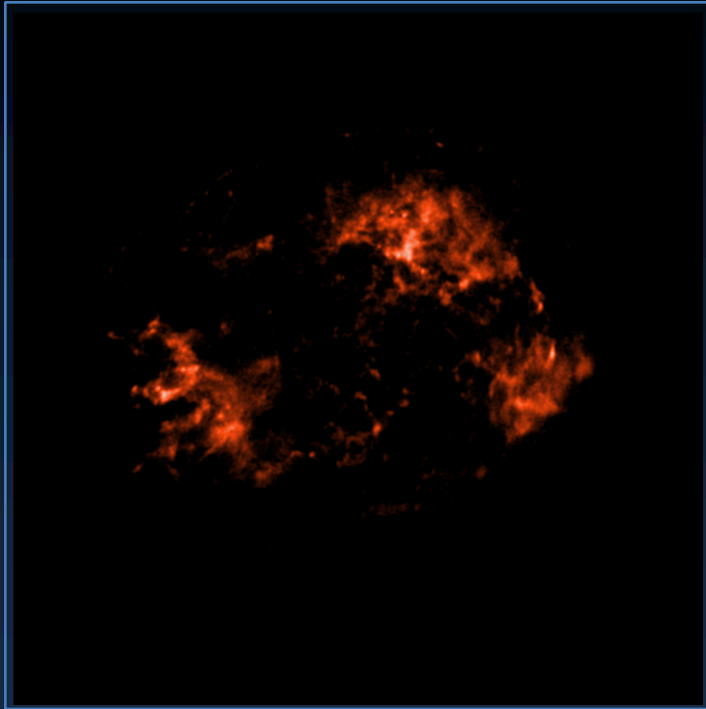
Foglizzo+, 2011

Courtesy T. Janka

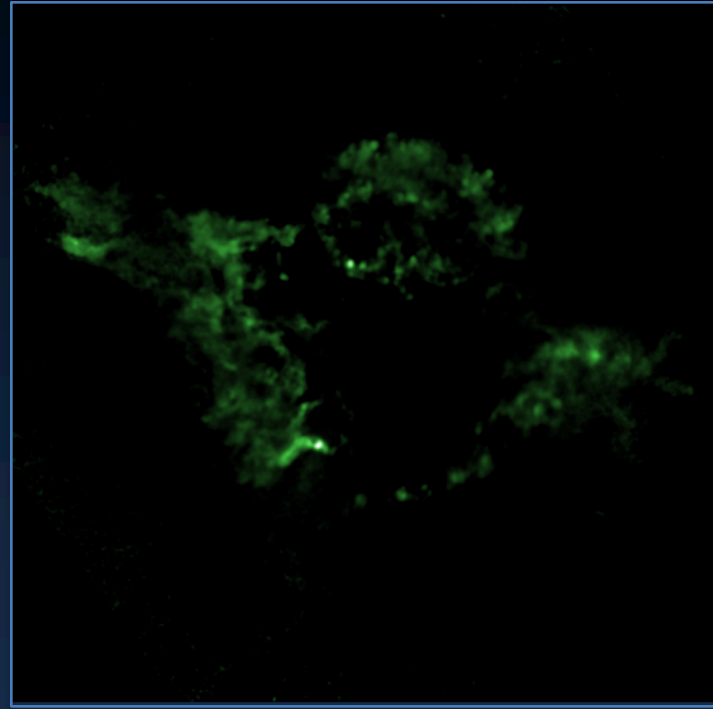




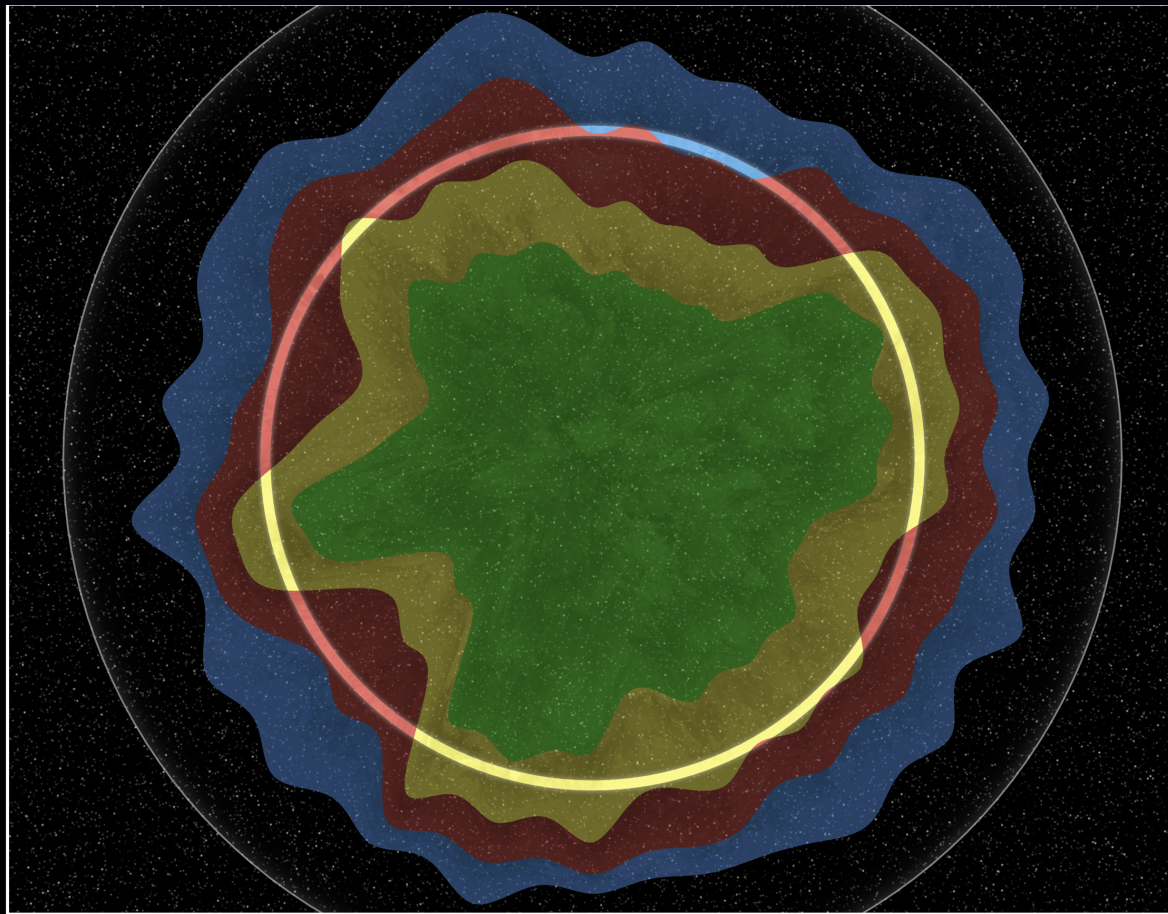
Cassiopeia A



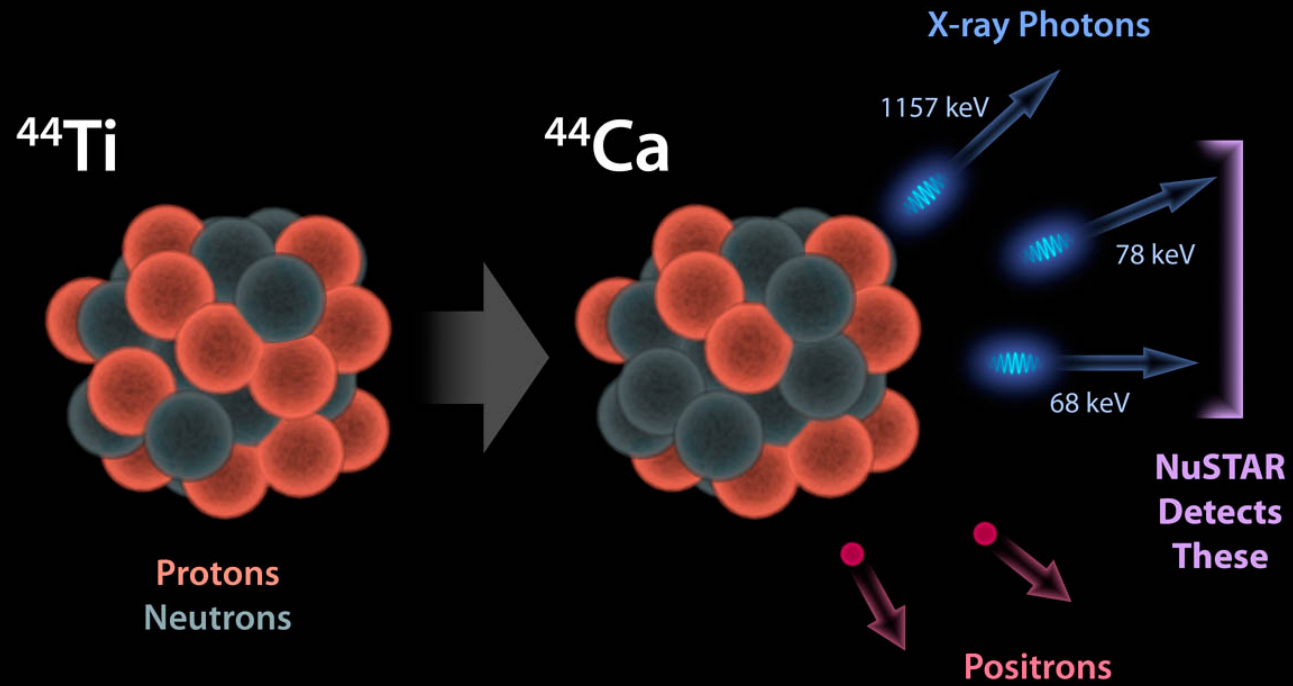
Iron



Silicon/Magnesium



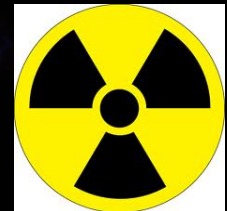
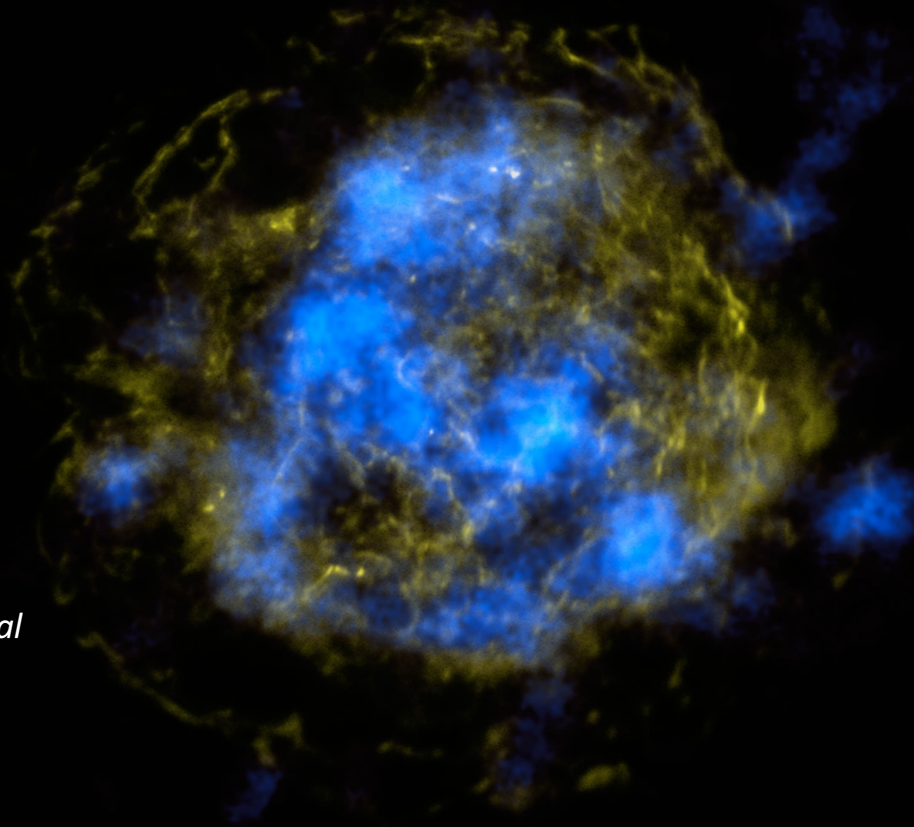
Radioactive ^{44}Ti



Cas A in Radioactivity



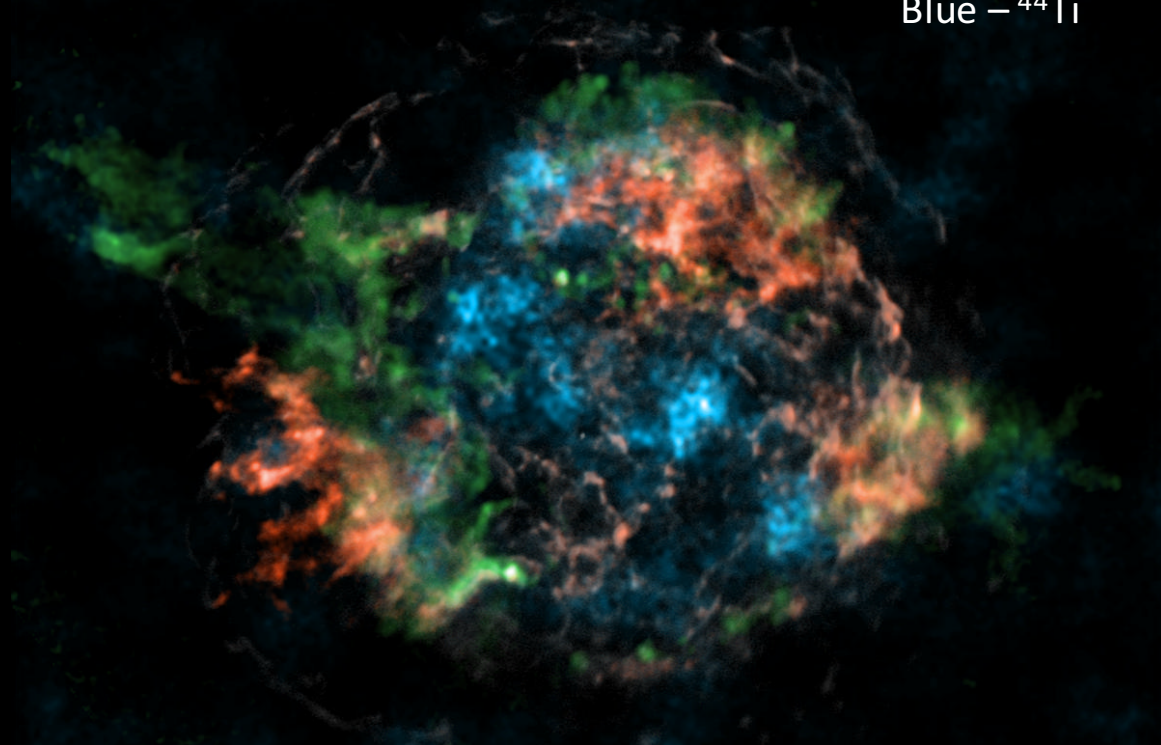
Grefenstette, FH et al
Nature 2014

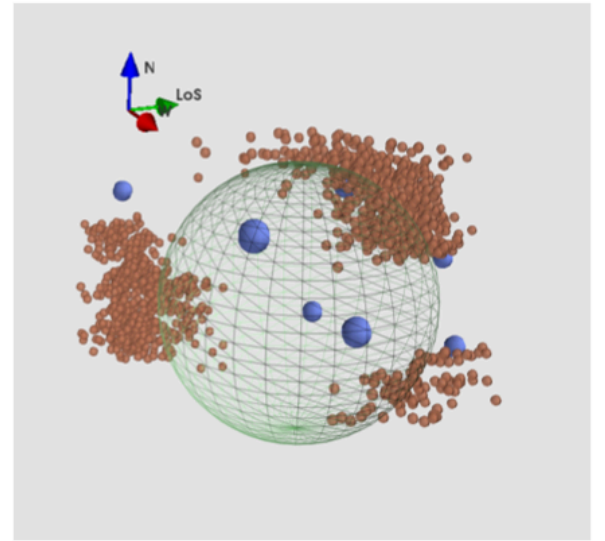
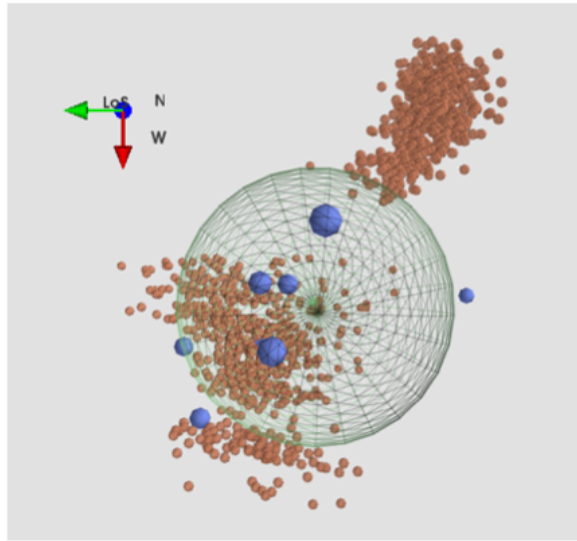
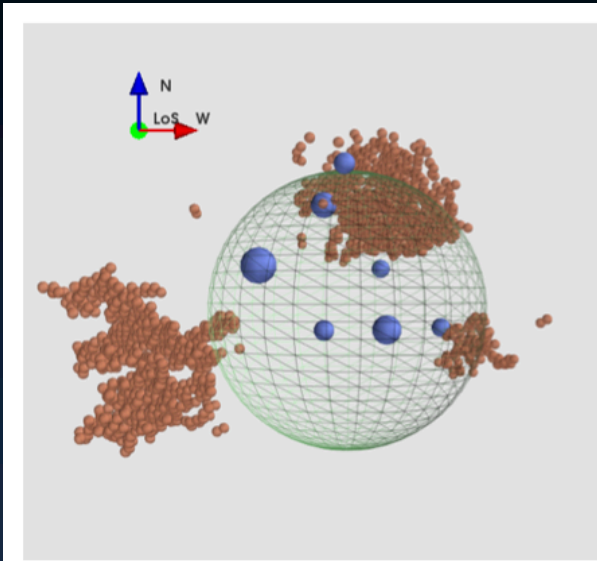


Green – Si/Mg

Red – Fe

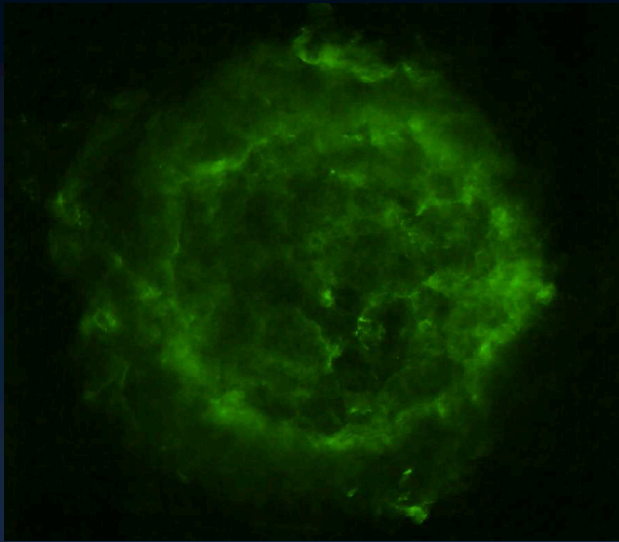
Blue – ^{44}Ti



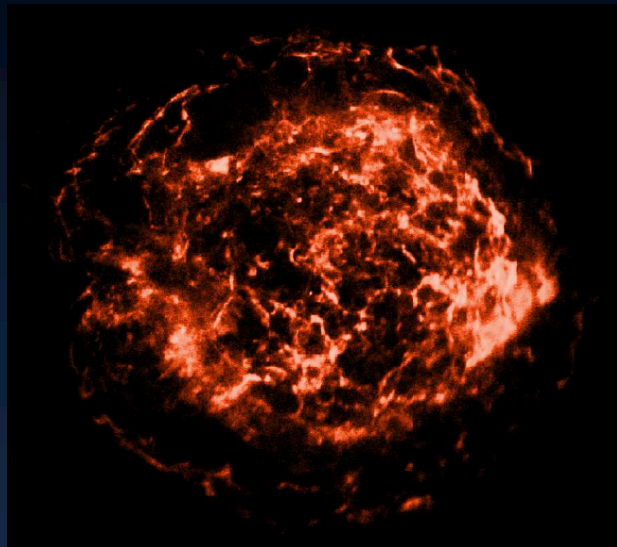


Grefenstette et al 2016

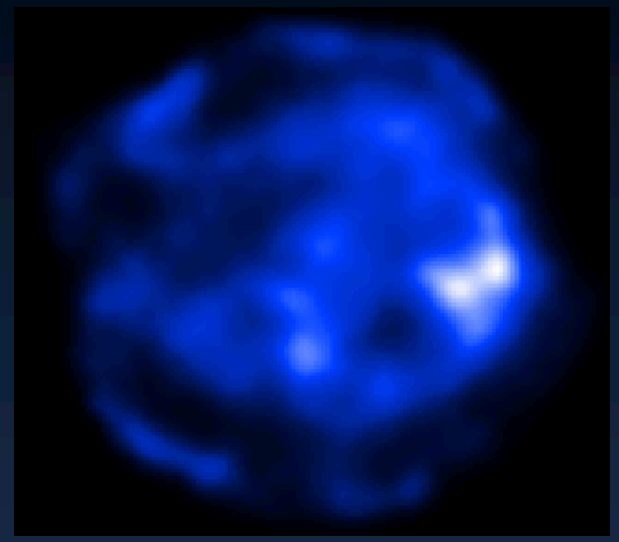
Locating the Most Energetic Electrons



6 cm radio

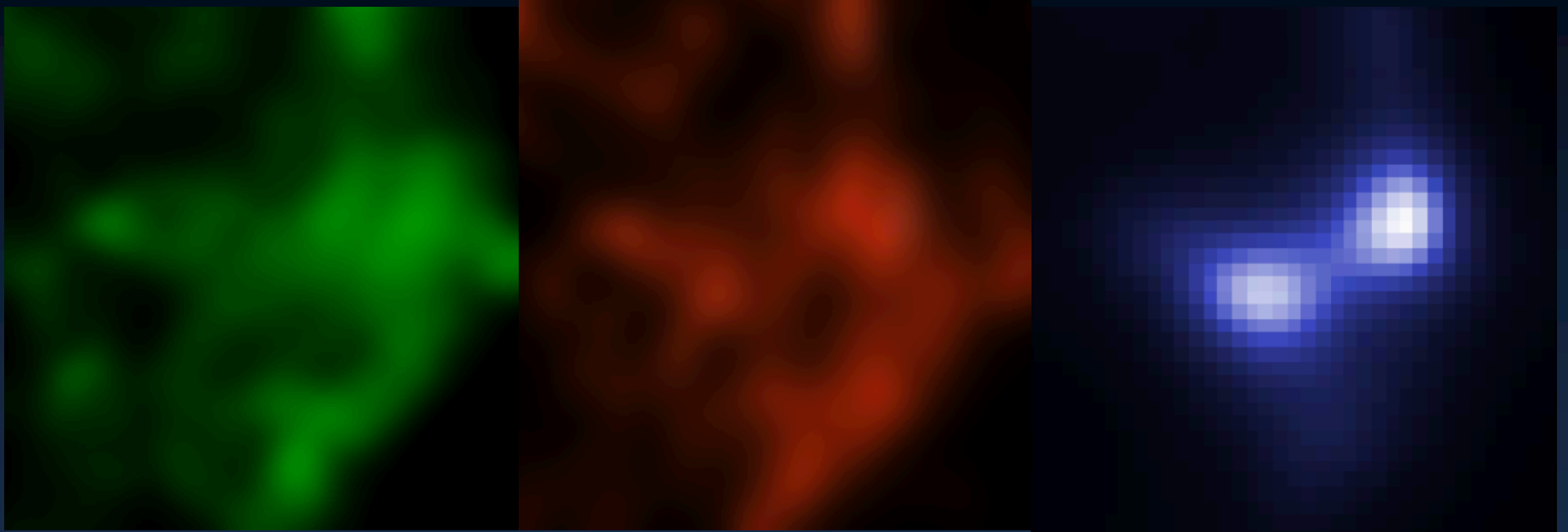


Chandra 5-6 keV

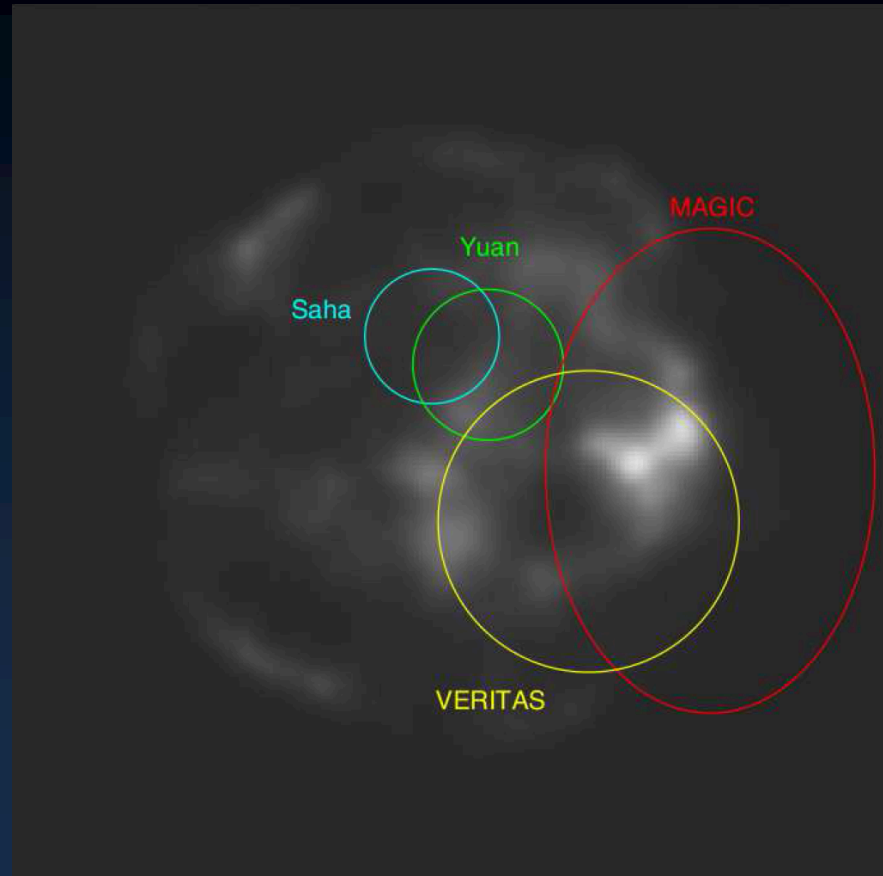


NuSTAR 10-20 keV

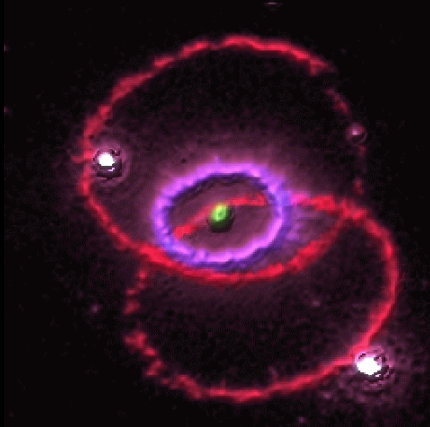
Zoom In on Interior Knots



GeV and TeV Emission

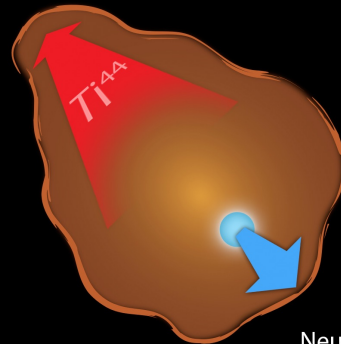


Another Famous Young Remnant— SN 1987A

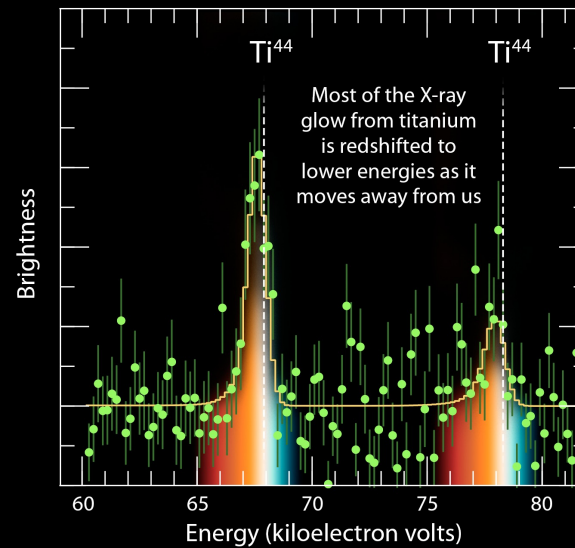


Boggs, FH et al Science, 2015

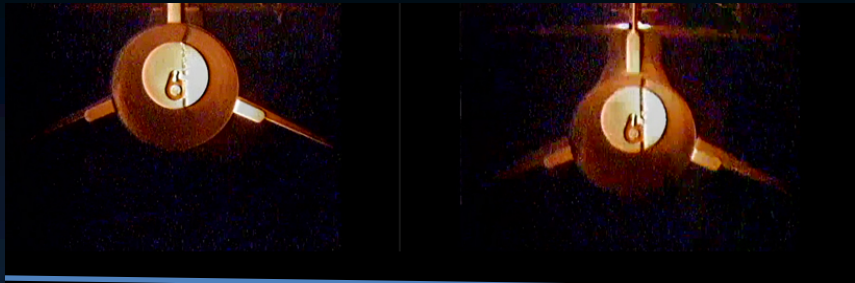
Asymmetric cloud of supernova debris
mostly thrown away from us



Neutron star
(not seen) kicked toward us



June 13 2012



June 13 2014



NuSTAR Legacy Surveys

NuSTAR GO Program: A0-3

25% NuSTAR time dedicated to Legacy Surveys

Program to observe HAWC, HESS, VERITAS sources

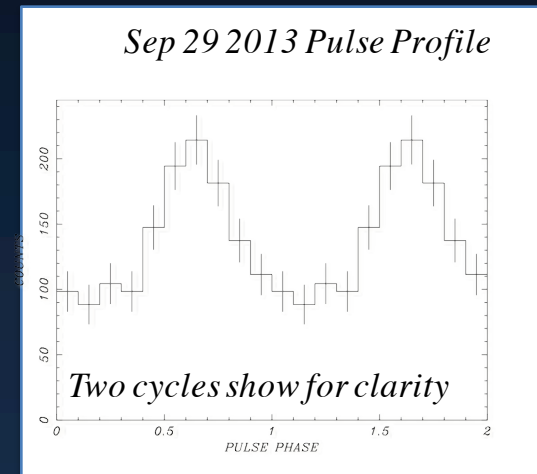
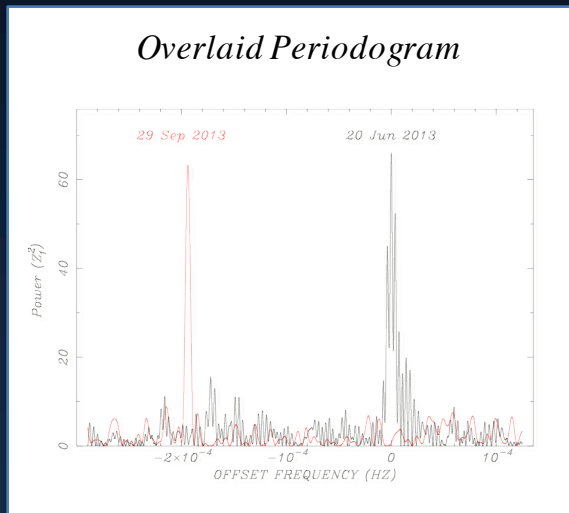
NuSTAR Observations of HESS J1640-465

Powered by a young pulsar

- Hard X-ray source discovered in Norma Survey
- Highly obscured – very faint in Chandra/XMM

PSR J1640-4631 confirmed with a significant frequency shift due to spin-down of pulsar

Young, energetic pulsar - 206 ms spin-down age, $\tau \sim 3$ kyr and energy, $\dot{E} \sim 5 \times 10^{36}$



PSR J1640-4631: pulsar powering HESS J1640-465, (Gotthelf et al. 2014)



HESS J1640-465

“HESS Source of the Month” twice - different interpretations!

Mar 2007: HESS J1640-465 – “A Pulsar Wind Nebula?”

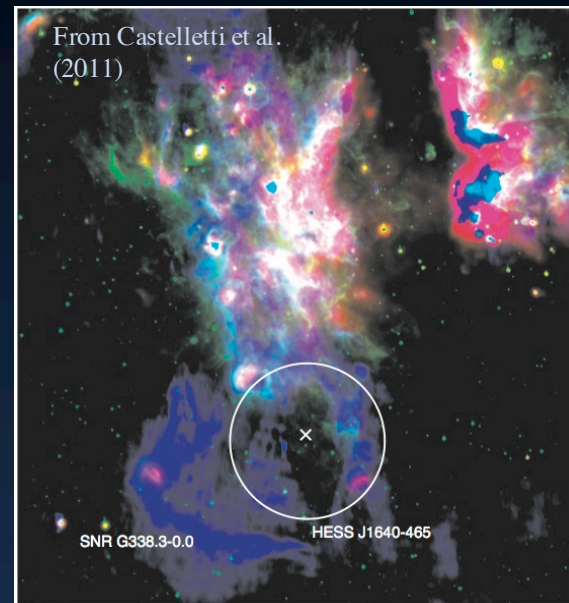
Sep 2013: HESS J1640-465 – “An Exceptionally Luminous TeV Γ -ray Supernova Remnant”

- Luminous, extended HESS TeV src., origin highly uncertain
- Coincident with radio SNR G338.3-0.0,
- Neighboring HII region due north - hadronic?
- Funk 2007: Extended XMM source - leptonic?
- Lumiere 2009: Chandra pt. src. + diff. emission.
- Slane 2010: Associated Fermi GeV source?

“Given the now available multi-wavelength data, it turns out that the hypothesis of a pulsar-wind origin of the gamma-ray emission is difficult to maintain; size and spectra (Fig. 2) of the source favor emission caused by interaction of supernova-accelerated cosmic rays with the dense ambient gas, in particular in the northern section of the remnant.”

Reference: H.E.S.S. Collaboration, A. Abramowski et al., "HESS J1640-465 – an exceptionally luminous TeV gamma-ray SNR", to be submitted.

Radio (blue), IR (8 μm green; 24 μm red), X-ray src (cross)



HESS J1640-465

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