


Thermal Emission from Supernova Remnants with Suzaku ⇣

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Supernova Remnants

Explosion by core-collapse of massive stars (II, Ib/c) or thermonuclear instability in accreting C+O white dwarf (Ia)

~10^{51} ergs kinetic energy released per explosion

Forward shock heats and compresses interstellar medium, accelerates particles (next talk)

Reverse shock heats ejecta starting from outermost layer inward as ejecta expand

Low gas densities, short ages of 100-10^4 yr
ionizing plasma: ionization timescale = $n_{electron}$ x t_{shock}

Remnants of Type Ia Supernovae

Type Ia supernovae: explosion of CO white dwarf due to thermonuclear instability triggered by accretion

Important standard candles for cosmology

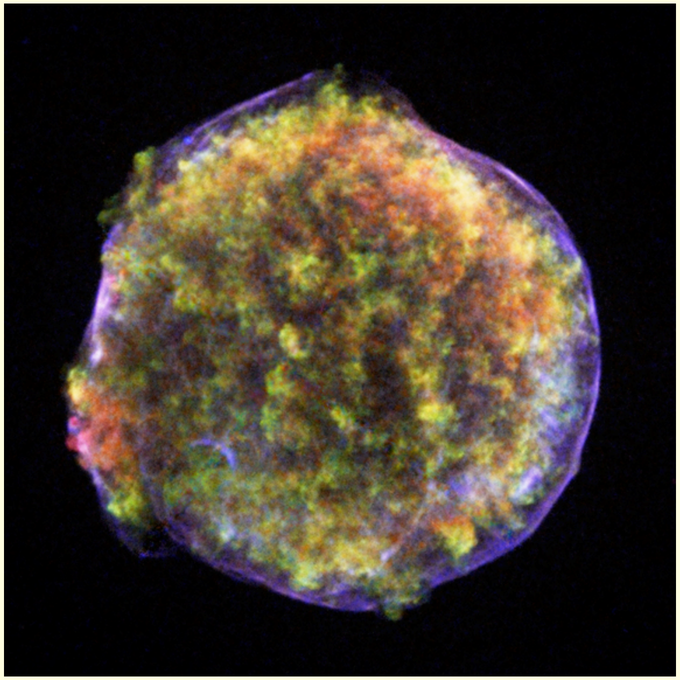
Exact progenitors and explosion mechanisms are not known, Type Ia may not be universally uniform

• G-type star the apparent companion for Tycho's SN (Ruiz-Lapuente+2005)

• more massive systems are also possible

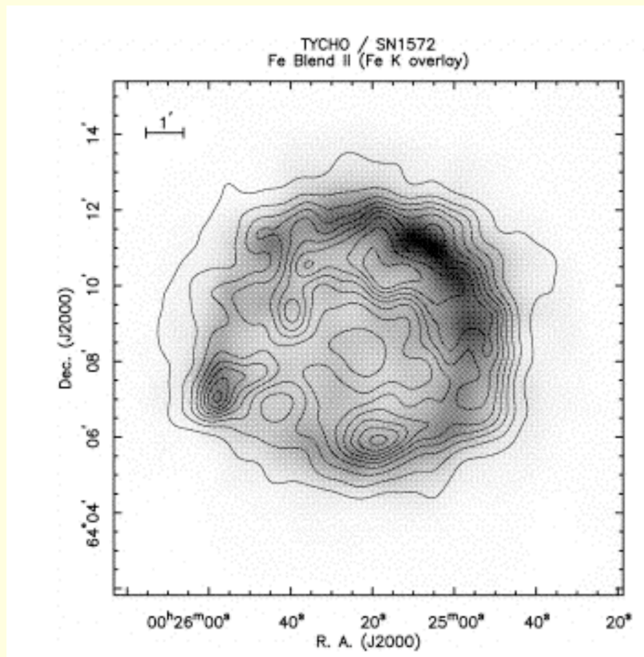
• proposed mechanisms include deflagration, (pulsating) delayed detonation, et cetera….

Tycho's SNR (SN 1572)



Chandra image
Warren+2006

Prototype Ia remnant
Ejecta emit only in X-rays
Fe hotter and less ionized than Si
Fe stratified interior to Si

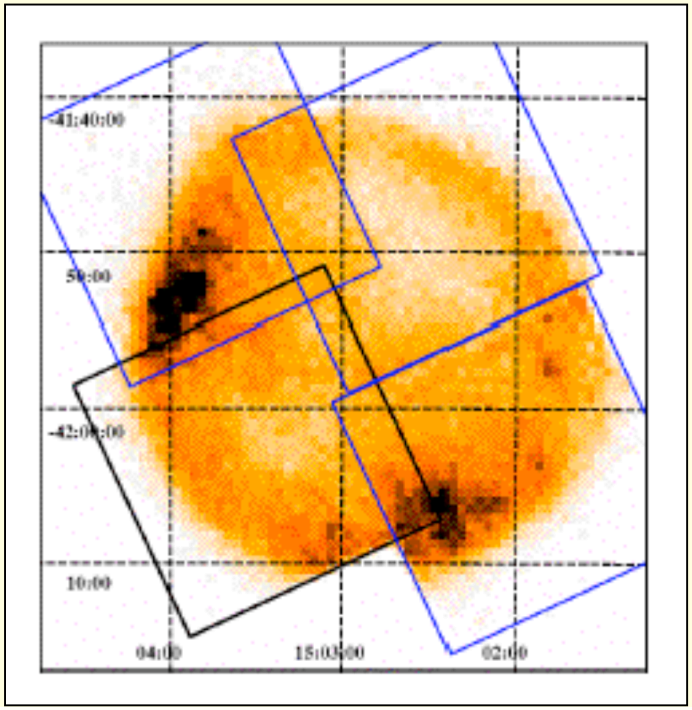


Fe L image
(matches Si)
Fe K contours

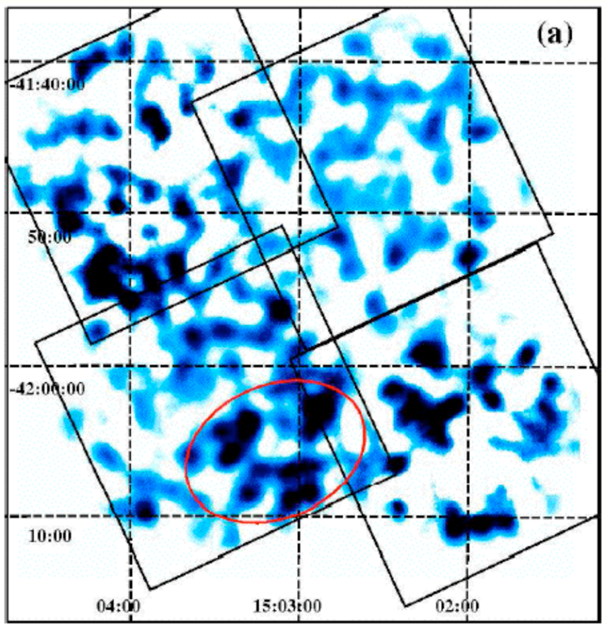
ASCA Hwang & Gotthelf 1997

SN 1006

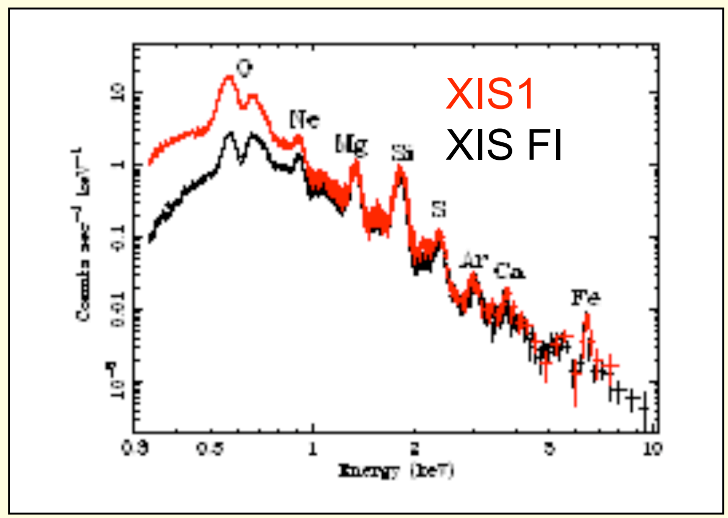
Yamaguchi+2008, PASJ in press
(Nonthermal emission: next talk, A. Bamba)



Remnant of SN Type Ia
Cold Fe ejecta observed previously in UV absorption
First detection of Fe K by Suzaku

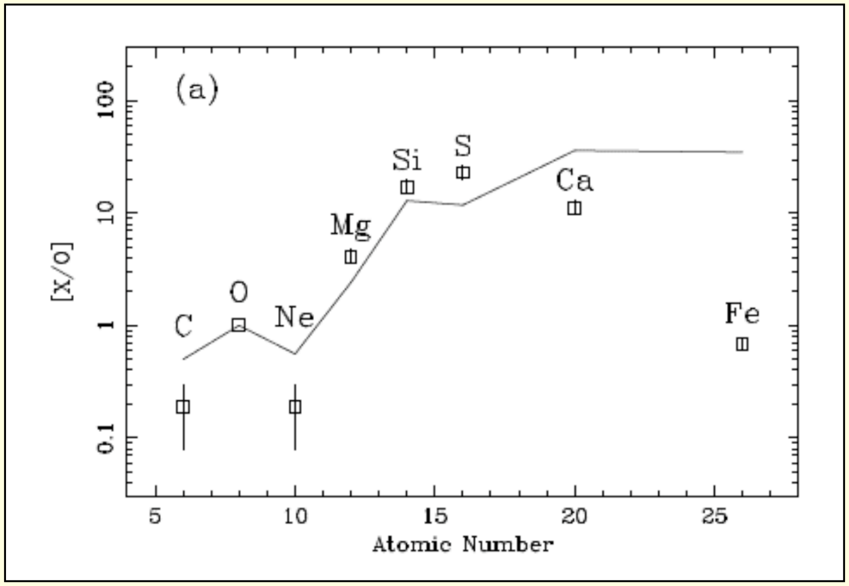


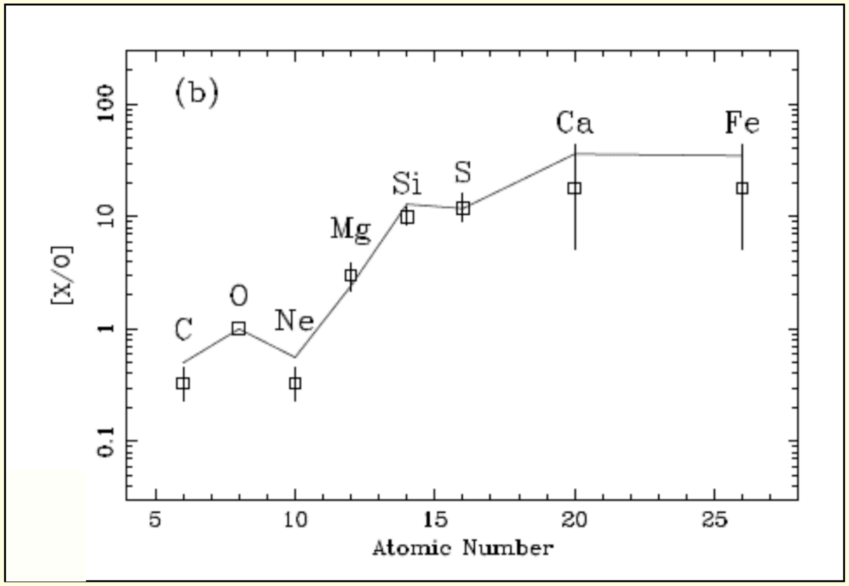
Fe K image



SN 1006

Two ejecta components to fit the spectrum
Hotter, less ionized component associated with Fe (below right)

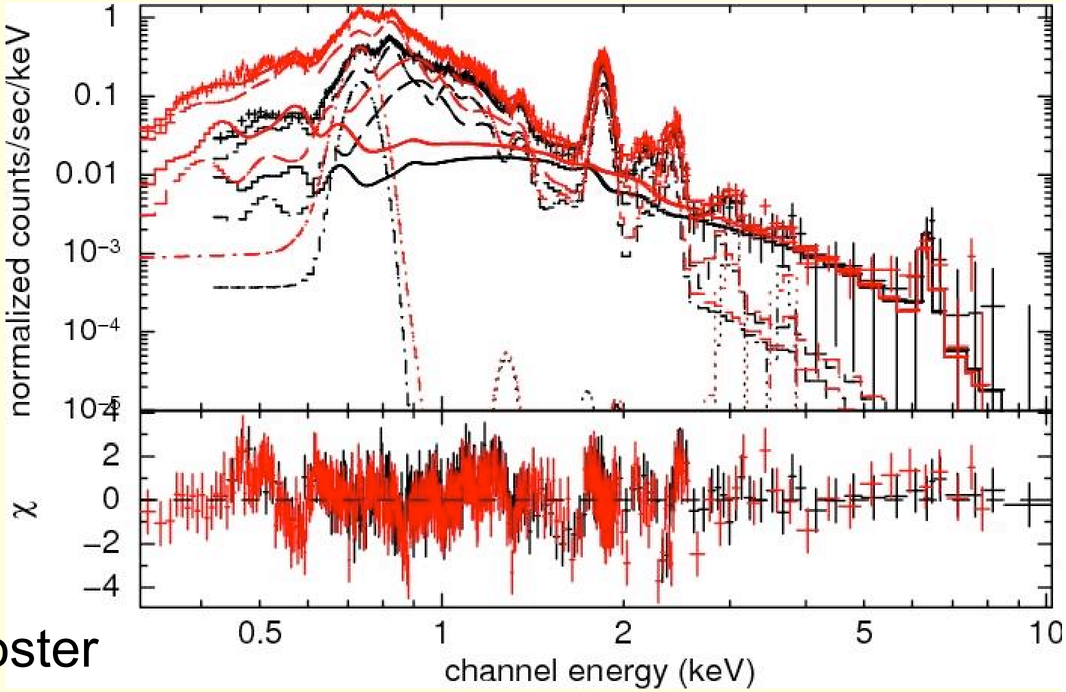




Fitted abundances of each component compared to W7 model

LMC SNR 0509-67

400 yr old Type Ia remnant
(Hughes+1994, Warren&Hughes 2003)
Suzaku detects hot, underionized
Fe ejecta
Possible line broadening



Nakajima poster

RCW 86
(possibly SN 185)

Southwest region (Ueno+2007)

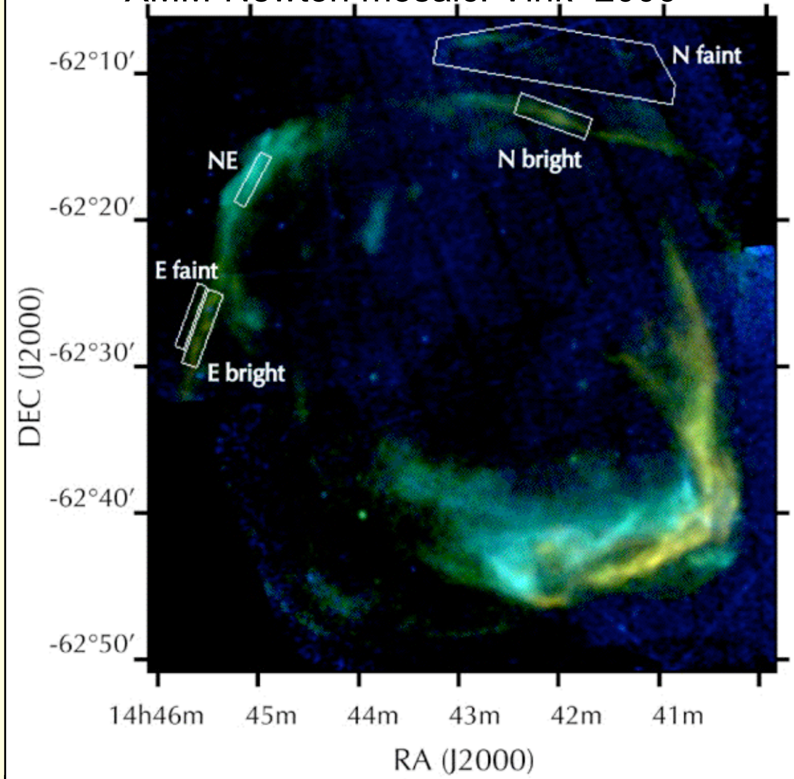
Fe K emission previously detected but not localized, E~6.4 keV (Vink+1997, Bamba+2000,Borkowski+2001,Rho+2002)

Suzaku localizes Fe K interior to forward shock

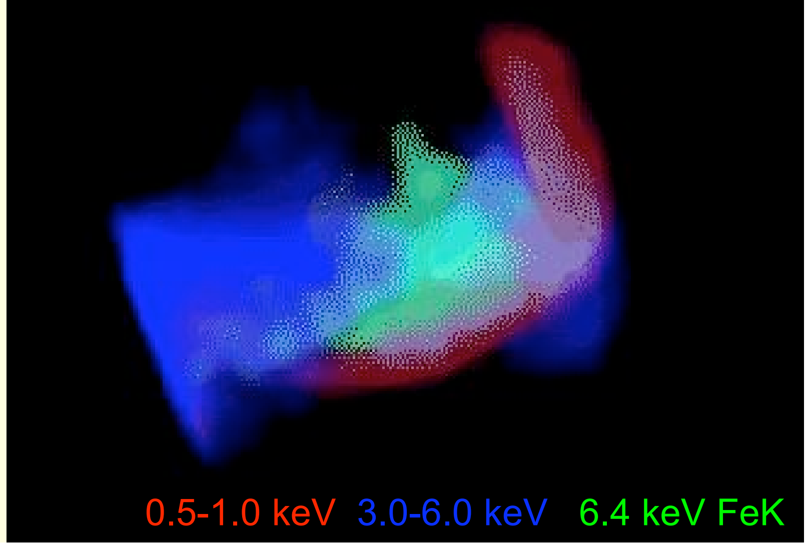
Fe K comes from the ejecta
Hot and in low ionization state
$n_e t < 10^9 \text{ cm}^{-3}$ s

Hard continuum is synchrotron

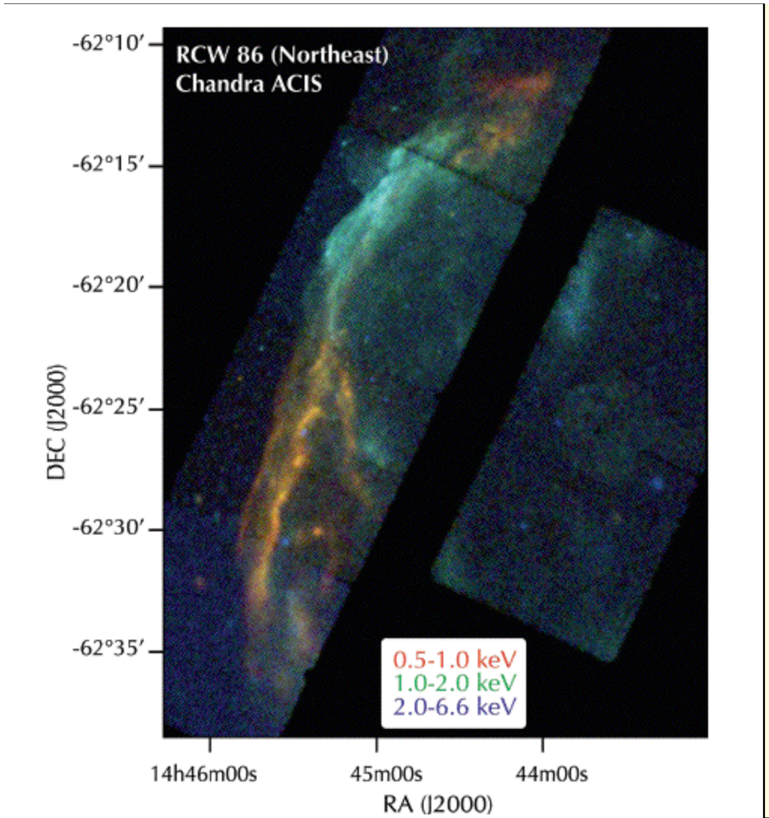
XMM-Newton mosaic: Vink+2006



Suazku: Ueno+2007 PASJ

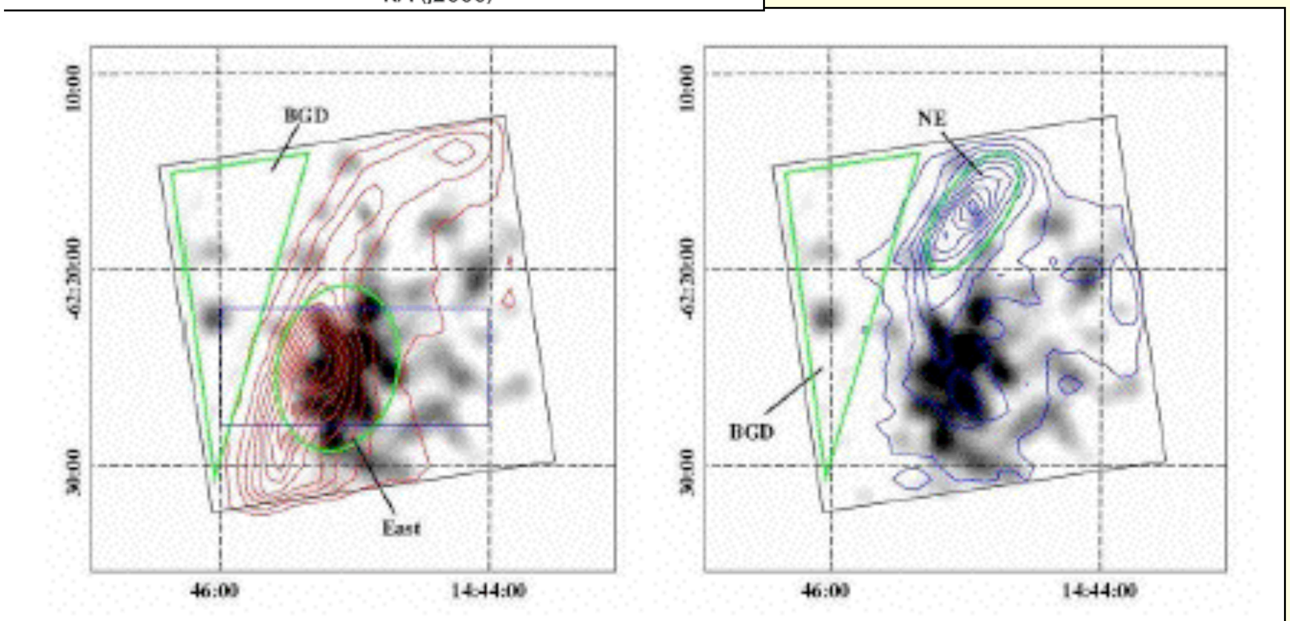


NE Region RCW 86



Fe K emission is detected and localized to the interior
Associated with hot and underionized ejecta

Chandra
Vink+2006 ApJL



Fe K greyscale
Contours:
(left) 0.5-1.0 keV
(right) 3.0-6.0 keV

Suzaku

Yamaguchi+2008 PASJ, in press

SNR G93.3+6.9 (aka DA530)

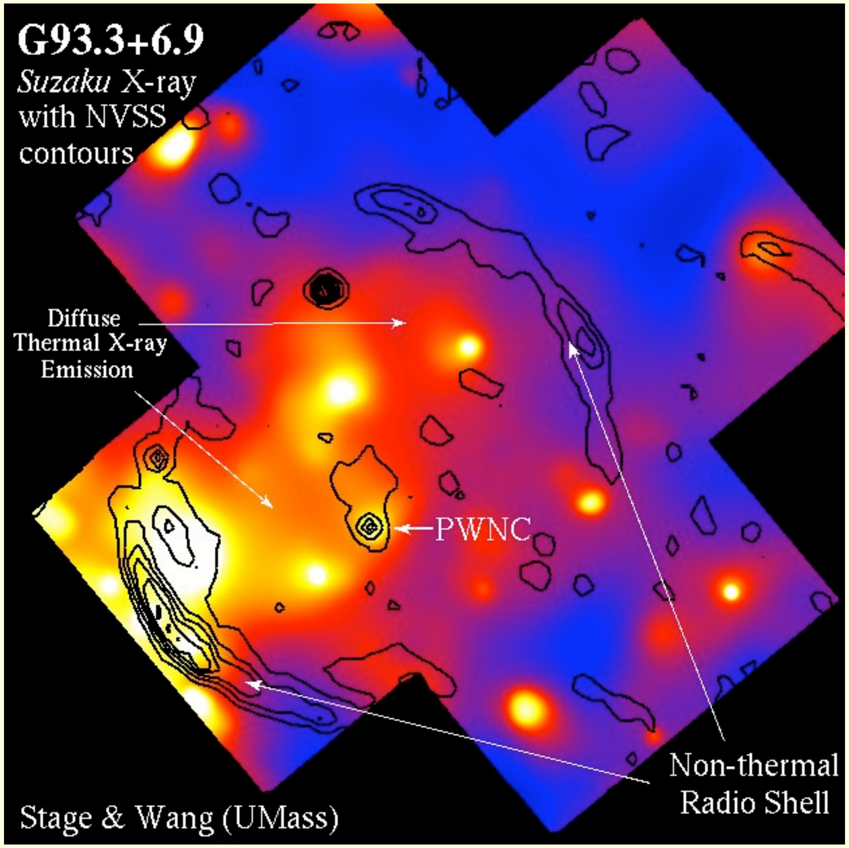
Poster by Stage

Mixed-morphology remnant with radio shell and weak centrally filled X-ray emission

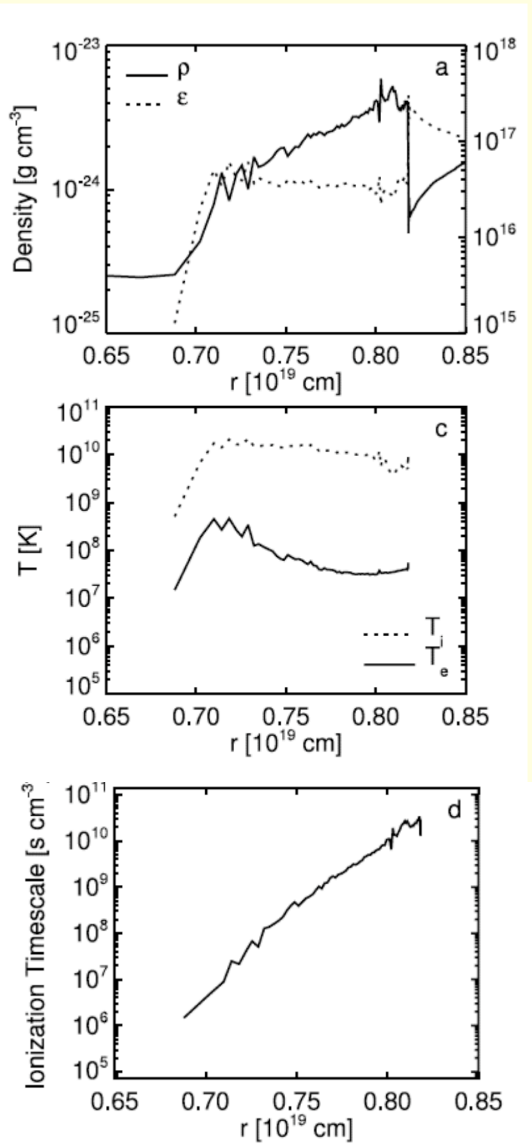
Apparently thermal diffuse emission requiring enhanced Si and Fe abundances

Pulsar wind nebula candidate?

Abundances suggest Ia in spite of PWN candidate



Tycho's SNR

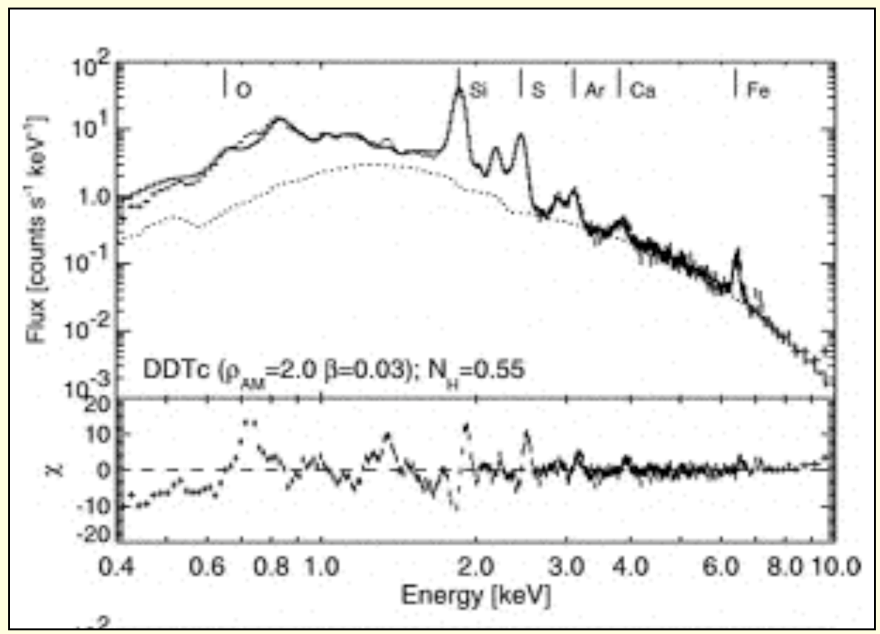


Badenes+2006, 2003

XMM-Newton spectra compared to 1-D hydro models of explosion evolved to age of remnant in constant density environment

Free parameters: explosion model, age, ambient density (not a "fit")

Delayed detonation is strongly favored



Delayed detonation predicts Fe stratified interior to Si

Hot underionized Fe indicates collisionless heating at the reverse shock

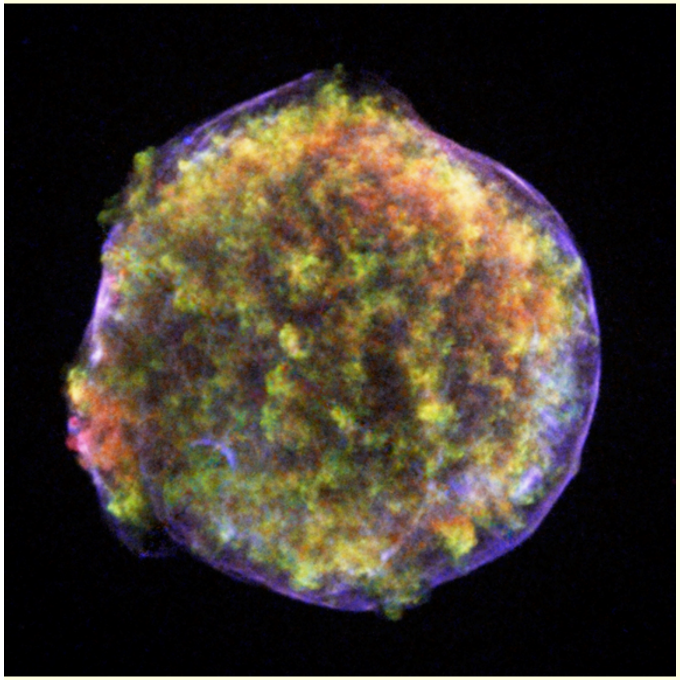
TYPE Ia SUPERNOVA REMNANTS: IONIZATION TIMESCALES IN THE SHOCKED EJECTA

	$\log(\langle n_e t \rangle)$ (cm^{-3} s)		
REMNANT NAME	Si	Fe	
Kepler	10.08–10.24	9.85–9.92	
Tycho	10.23–10.99	9.72–9.78	
SN 1006	9.49–9.60	~8.9	Suzaku
0509–67.5	9.80–9.82	<9.7	
0519–69.0	10.50–11.62	9.90–9.95	
N103B	10.64–11.94	10.62–10.69	

Badenes+2007

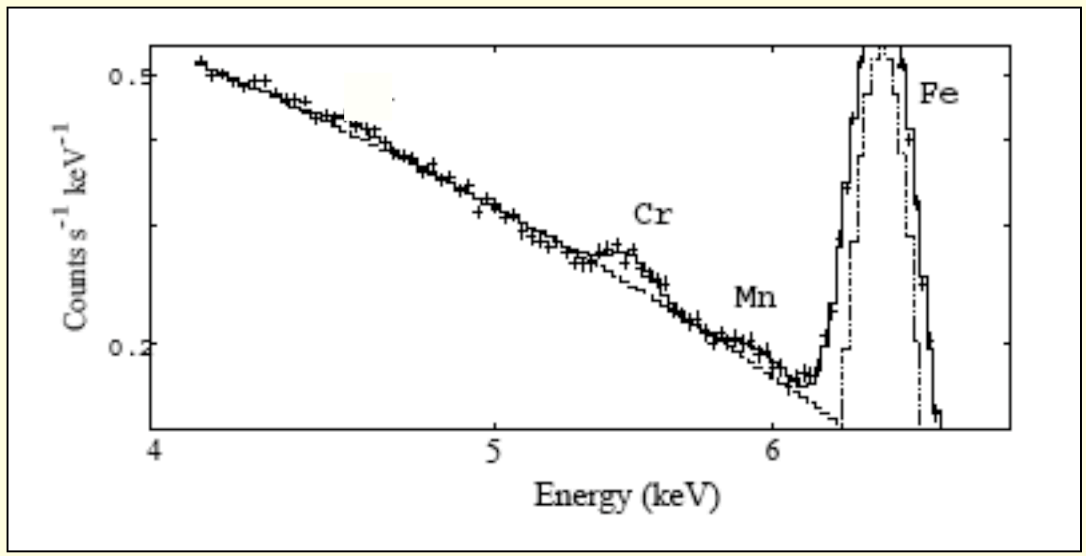
Tycho's SNR (SN 1572)

Posters by Tamagawa, Hayato



Chandra image
Warren+2006

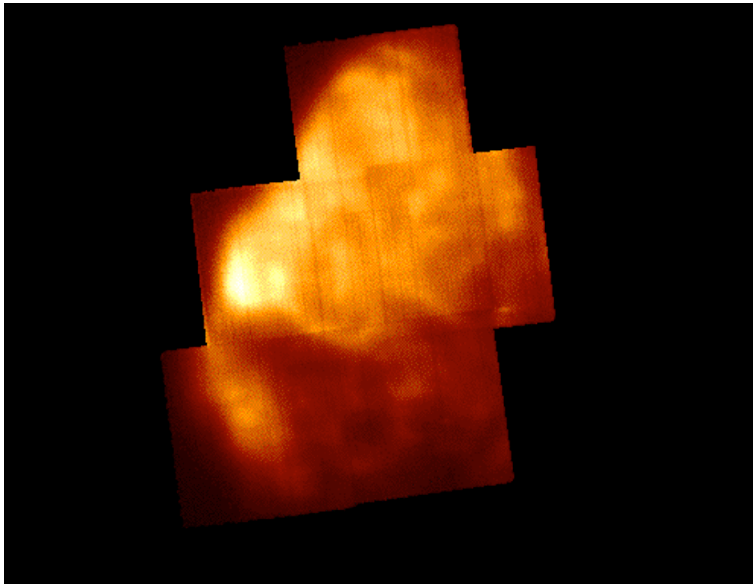
Newly discovered Cr and Mn emission lines
Abundances slightly high for Ia deflagration, delayed detonation models of Iwamoto+1999



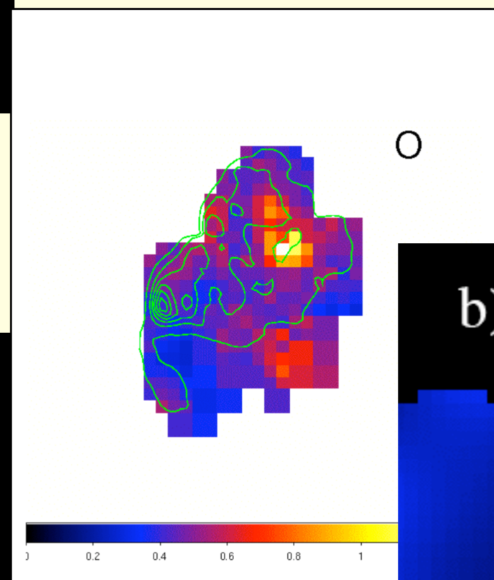
XIS spectrum

Puppis A

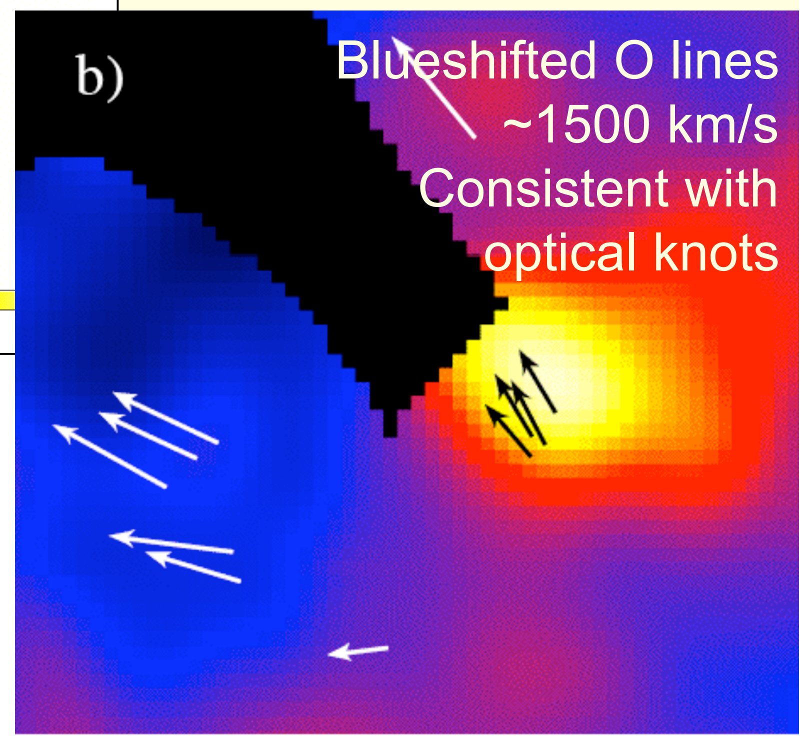
4000 year old remnant of
core-collapse SN
Optical O ejecta

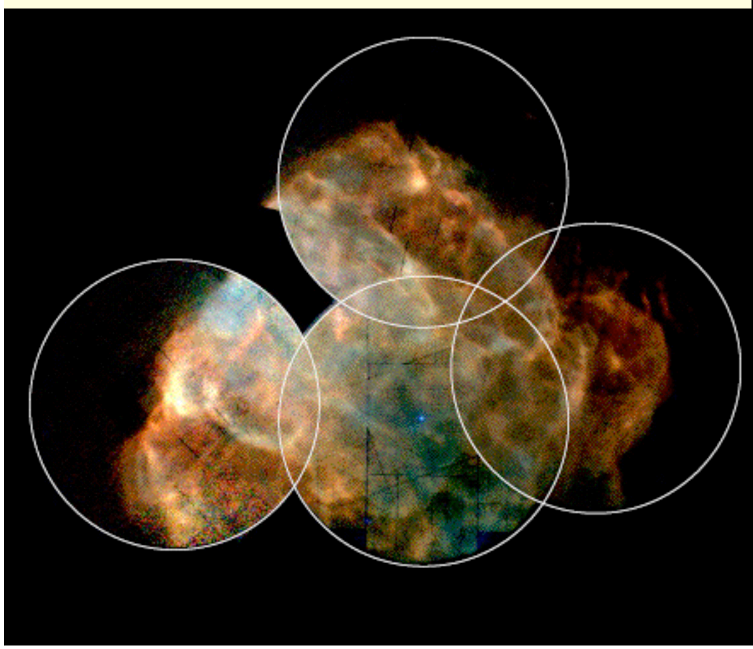


Suzaku
Hwang+2008



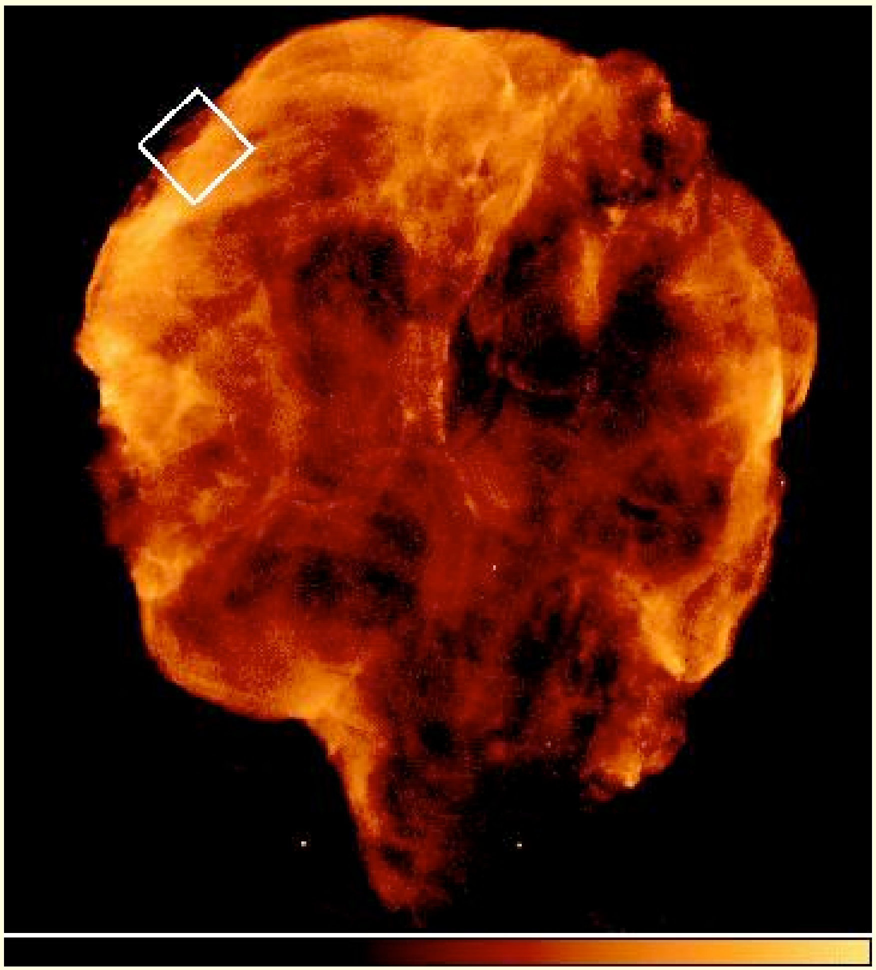
O ejecta





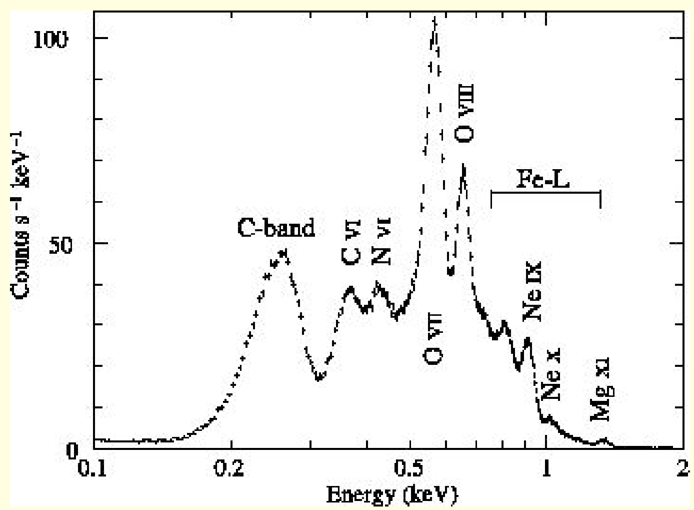
XMM-Newton
Katsuda+2008
Poster

Cygnus Loop

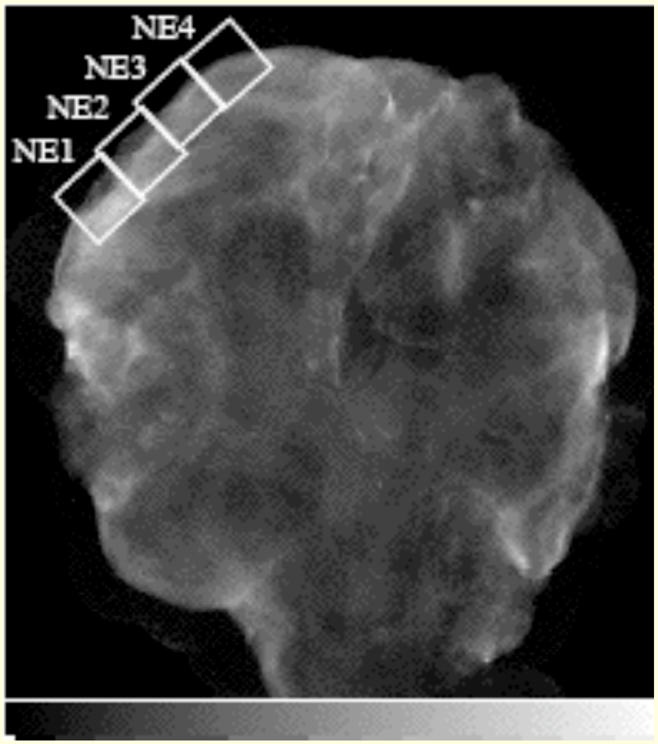


10,000 year old remnant
Interacting with cavity wall

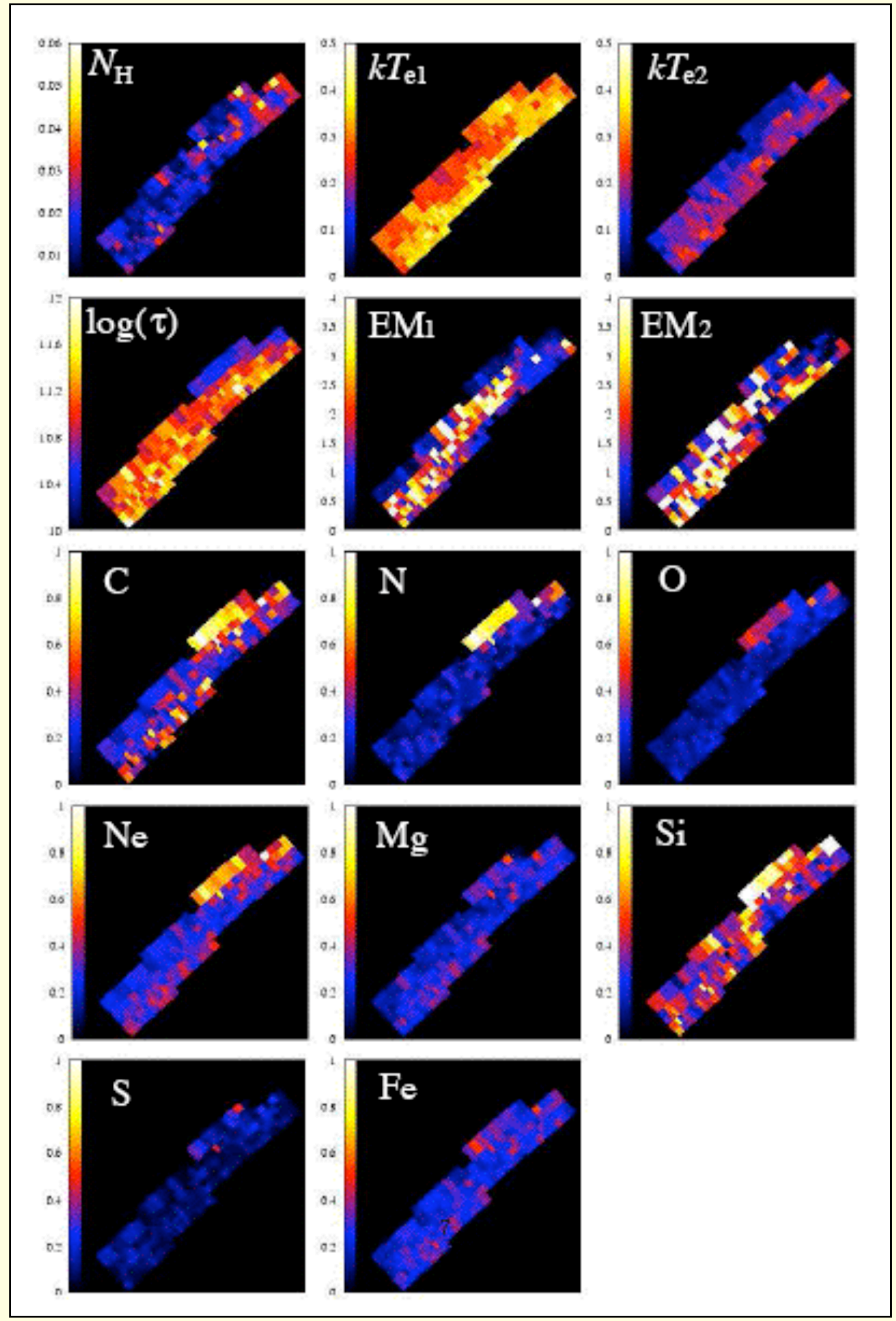
NE region: element abundances are depleted
Miyata+2007 PASJ



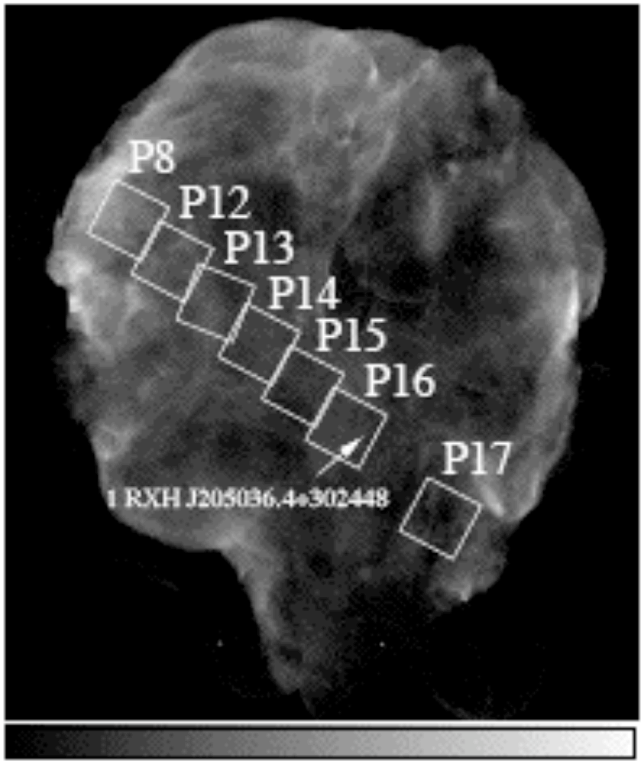
Localized region in NE with C and N abundance enhancement: circumstellar mass loss



Katsuda+2008a
PASJ



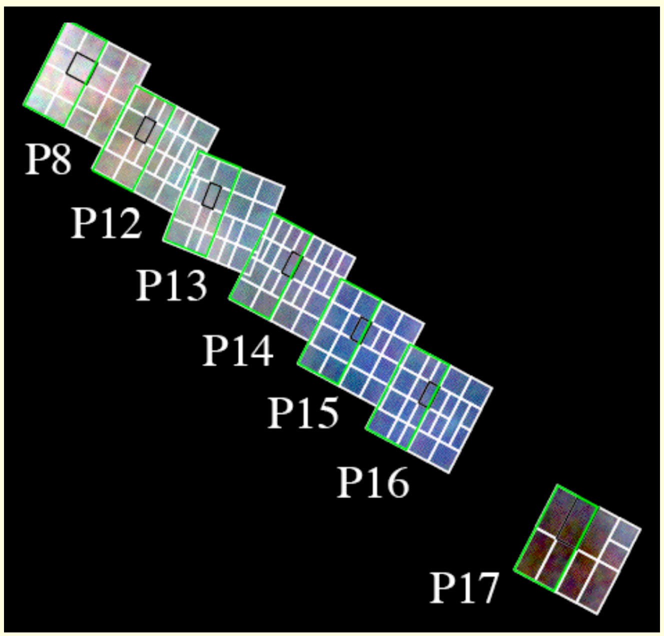
Ejecta in Cygnus Loop



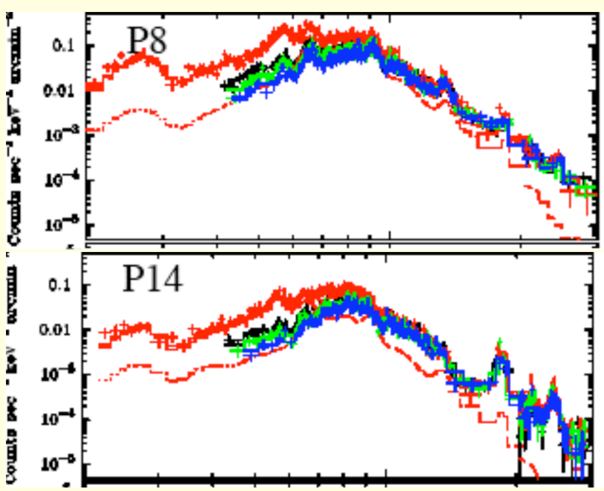
Element abundances and temperature increase toward the center

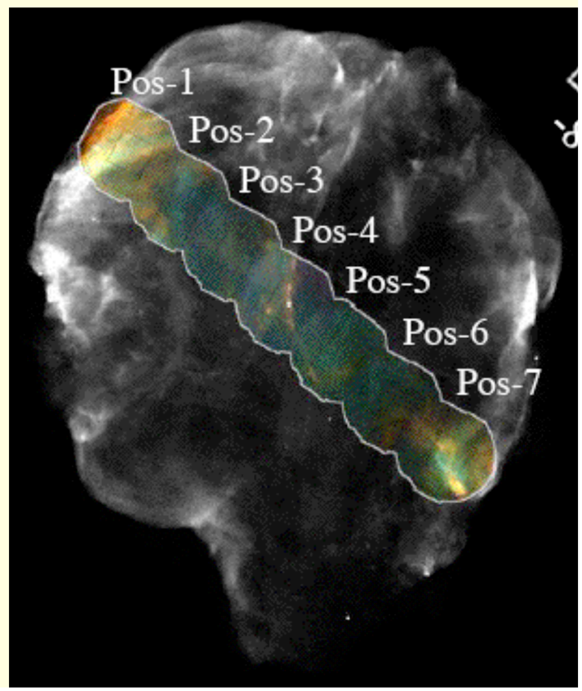
Ejecta are found in interior (ASCA: Miyata+1998)

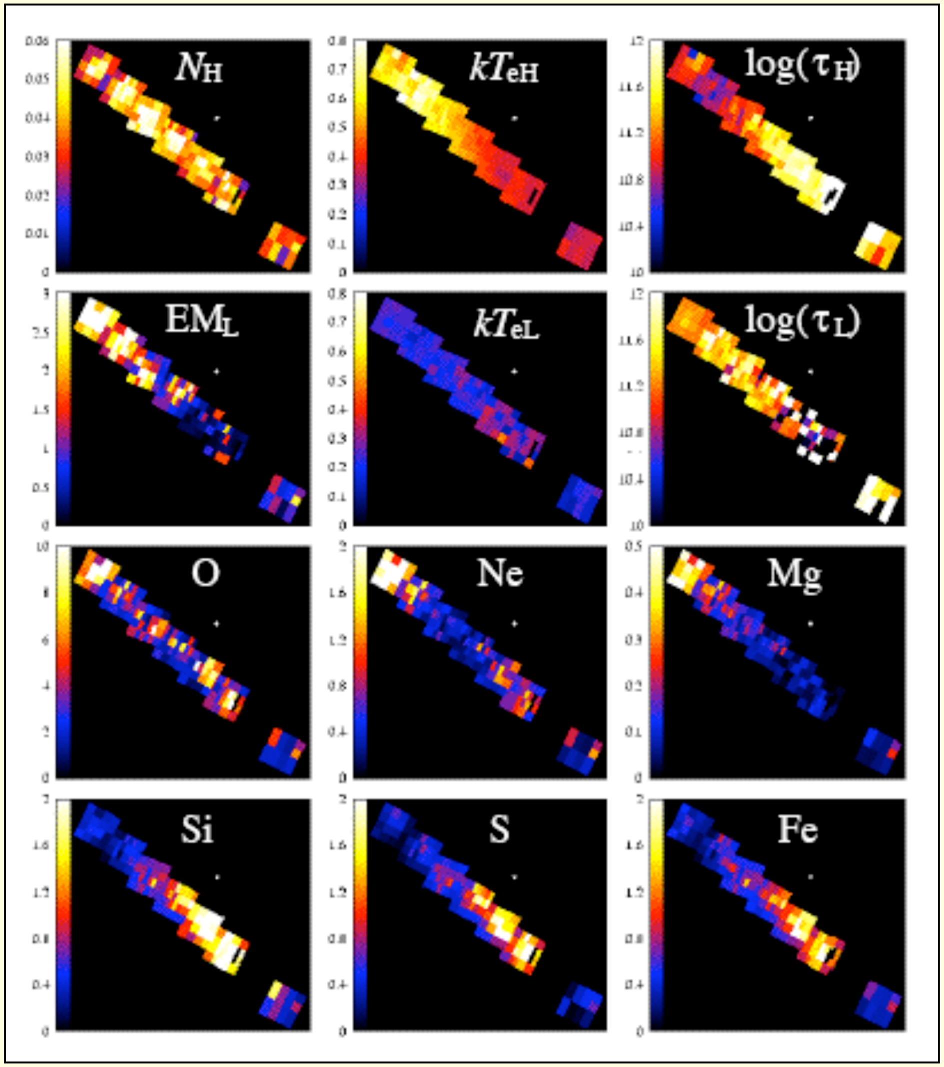
XMM-Newton Tsunemi+2007



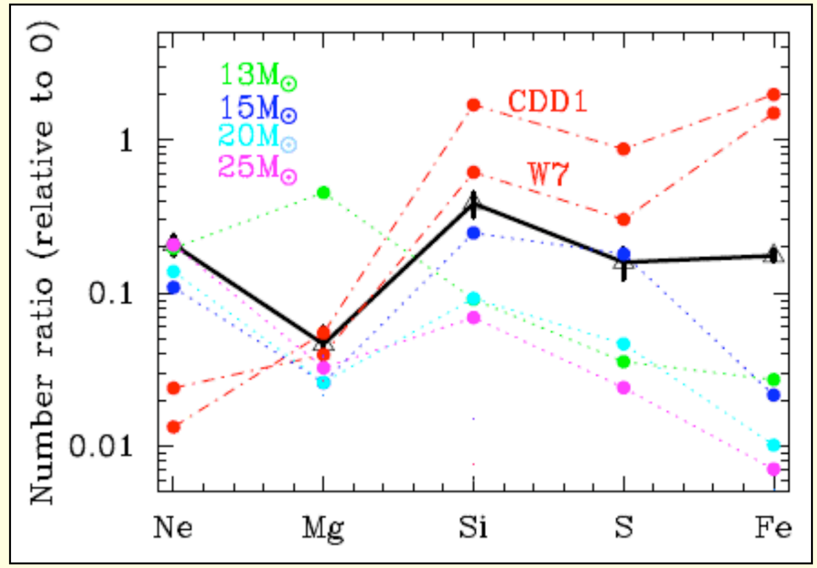
Katsuda+2008b PASJ







Katsuda+2008b



Tsunemi+2007

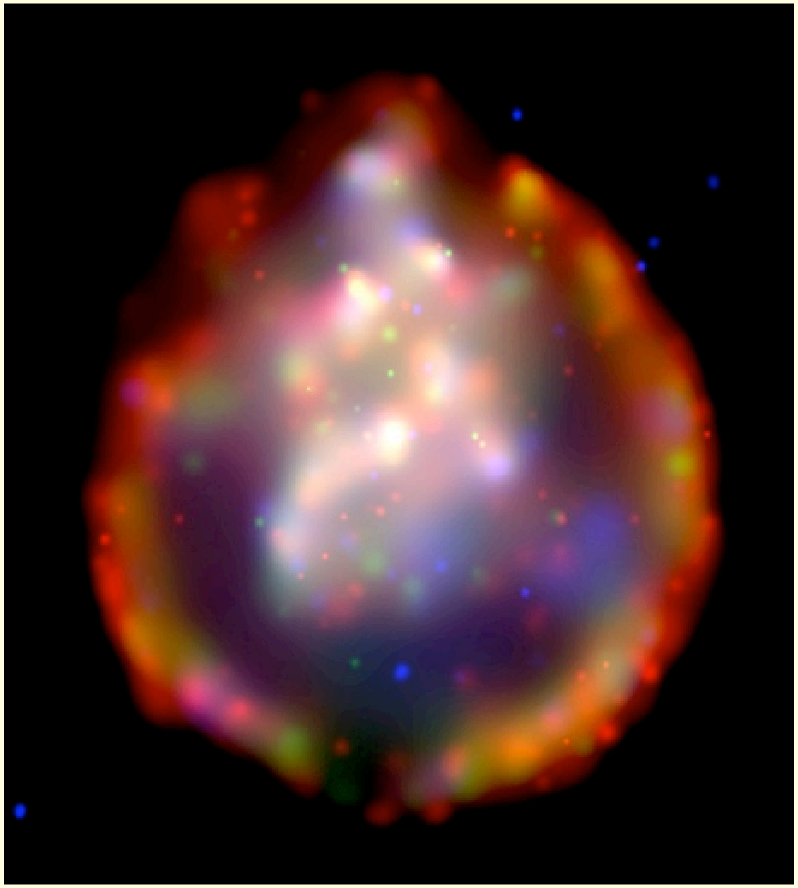
Clear (2x) asymmetry in the ejecta:

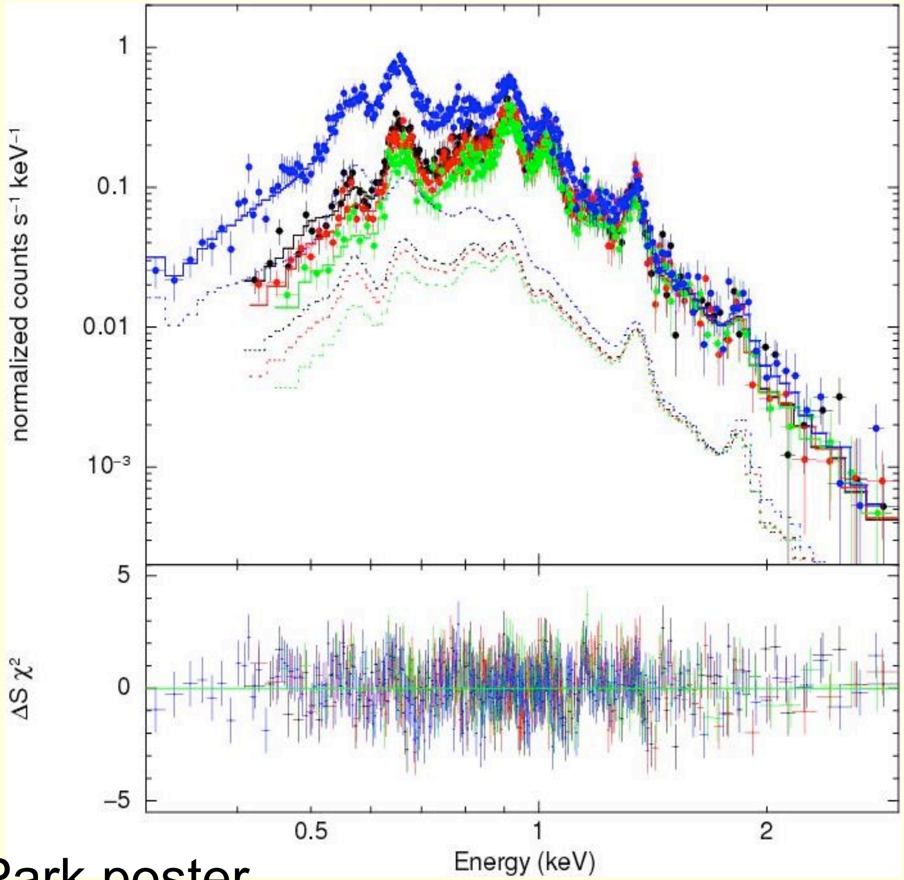
- More O and Ne towards NE
- More Si towards S/SW

Relative abundances consistent with 15 M_{sun} progenitor

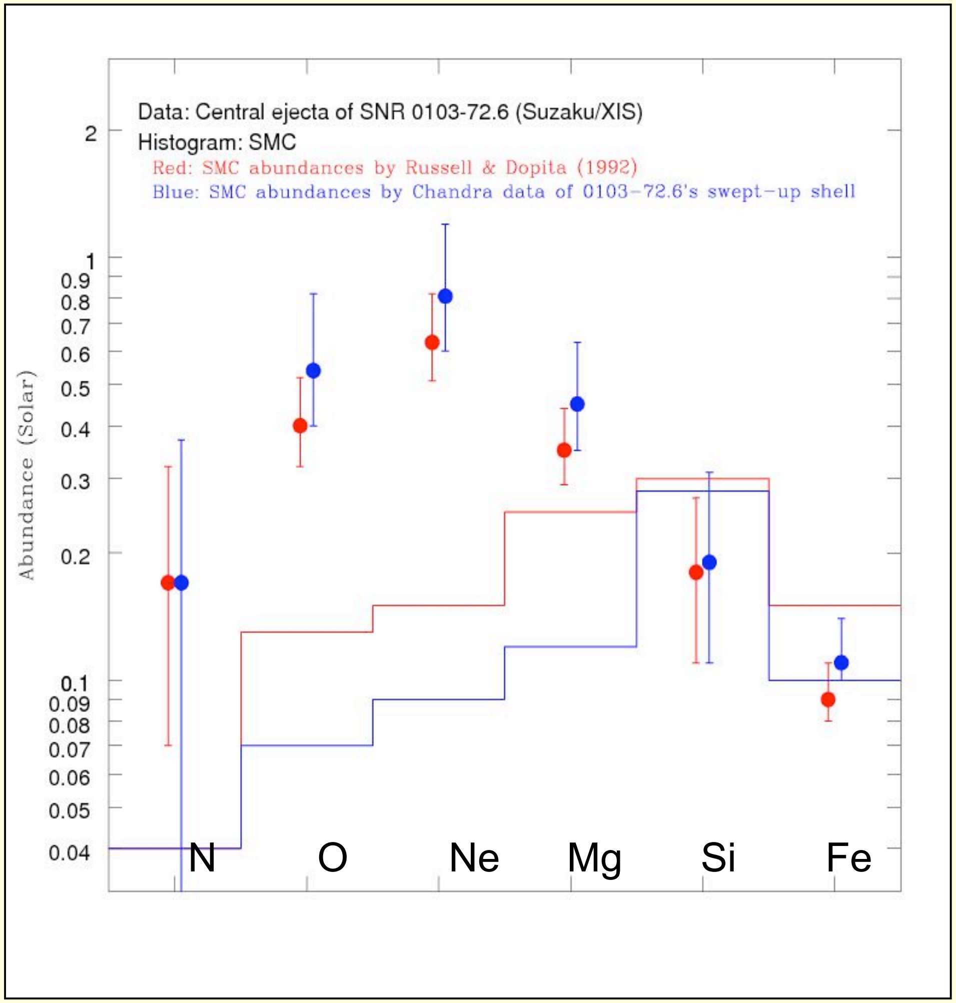
SMC E0103-72.6

Mature remnant, Sedov age ~18000 yr
Ejecta enrichment in the remnant center
(Chandra: Park+2003)





Park poster



Park poster

ISM component constrained from Chandra analysis

Clear enhancement of O and Ne relative to SMC abundances

Likely progenitor mass is 15-20 M_{sun}

Summary and Prospects

Detect Fe K emission in Ia remnants
Detect low-abundance nucleosynthesis species

- Increase sample of Ia remnants
- Spectra should be compared to more realistic models that include hydrodynamic structure and evolution
- Constraints on Type Ia mechanism and progenitors

Detect thermal emission in older remnants, remnants dominated by PWN, nonthermal emission

- Increase the sample of remnants with identified ejecta (SN class)
- Characterize abundance distributions
- Constrain evolutionary state of remnant, ambient density, properties of shocked ISM (posters by Nakamura, Ozawa)