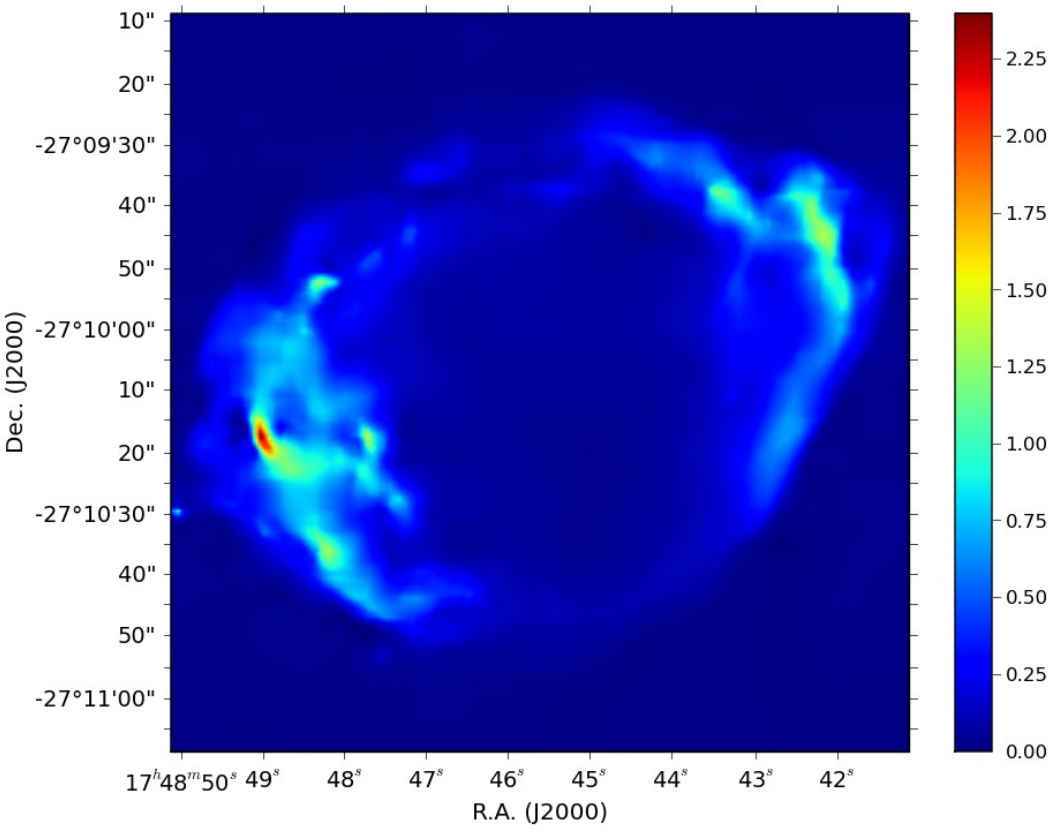
New Deep X-ray and Radio Observations of G1.9+0.3

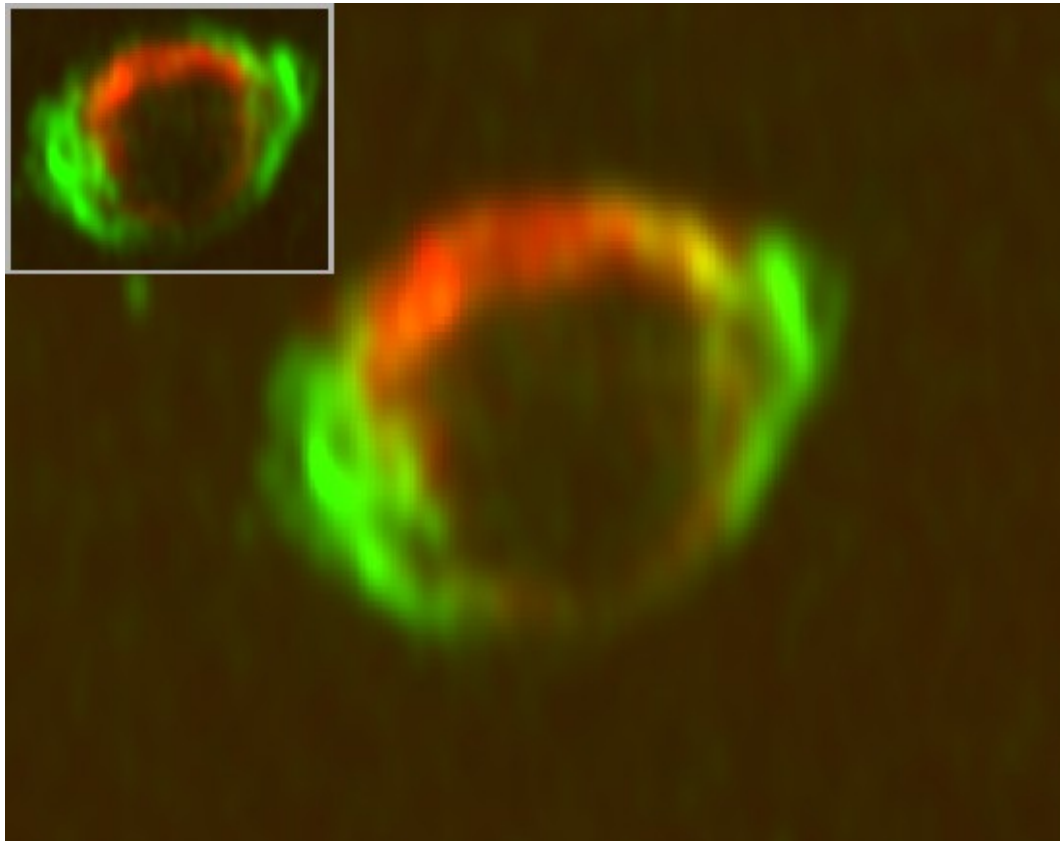
Kazimierz Borkowski, Stephen Reynolds (NCSU), David Green (Cambridge), Una Hwang, Ilana Harrus, Robert Petre (NASA/GSFC)

2007 Chandra Image of G1.9+0.3



- Discovered in radio by Green & Gull (1985)
- Observed by Chandra in early 2007 for 50 ks (Reynolds et al. 2008)
- About 8000 counts in this image, plus about 20% more in the dust-scattered halo
- Image smoothed with platelets (Willett 2007)
- Scale in counts per ACIS S3 pixel

2007 Chandra vs. 1985 VLA images



2007 Chandra – green

1985 VLA – red (inset)

1985 VLA expanded by 16% - red (main)

Expansion age of 140 yrs

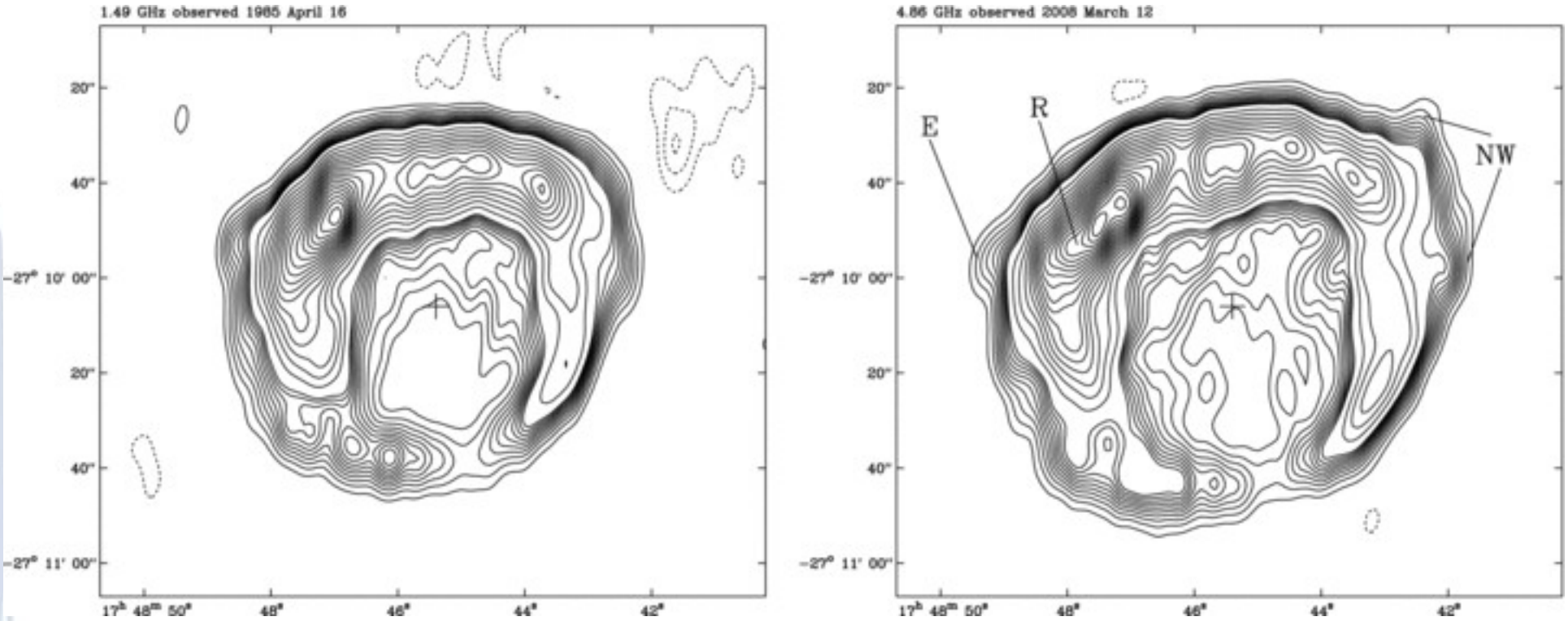
True age is about 100 yrs

because of deceleration

The youngest known SNR in the Milky Way

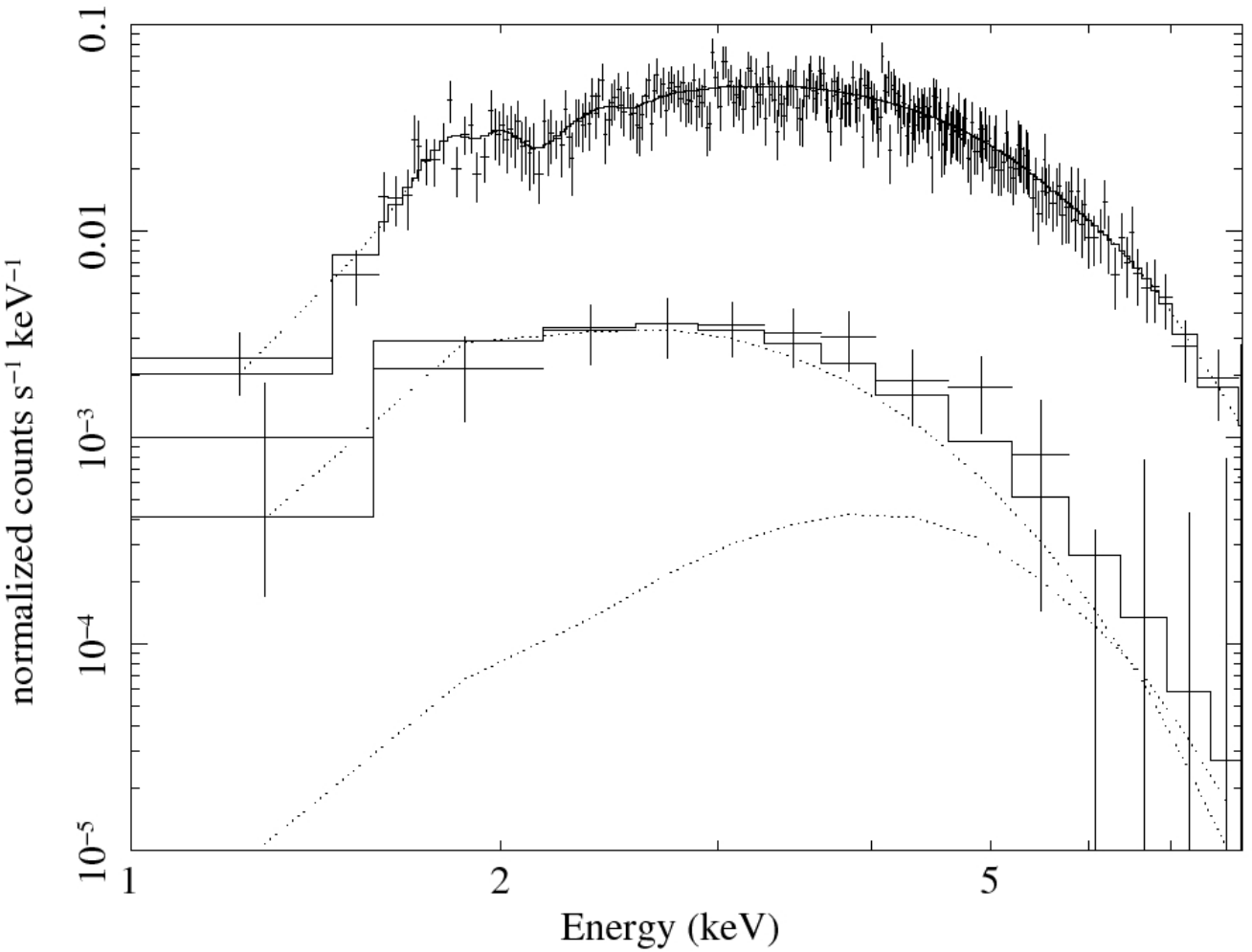
Strikingly different X-ray and radio morphologies

1985 vs. 2008 VLA Images



15% expansion rate between 1985 and 2008 (Green et al. 2008)

2007 Chandra X-ray Spectrum

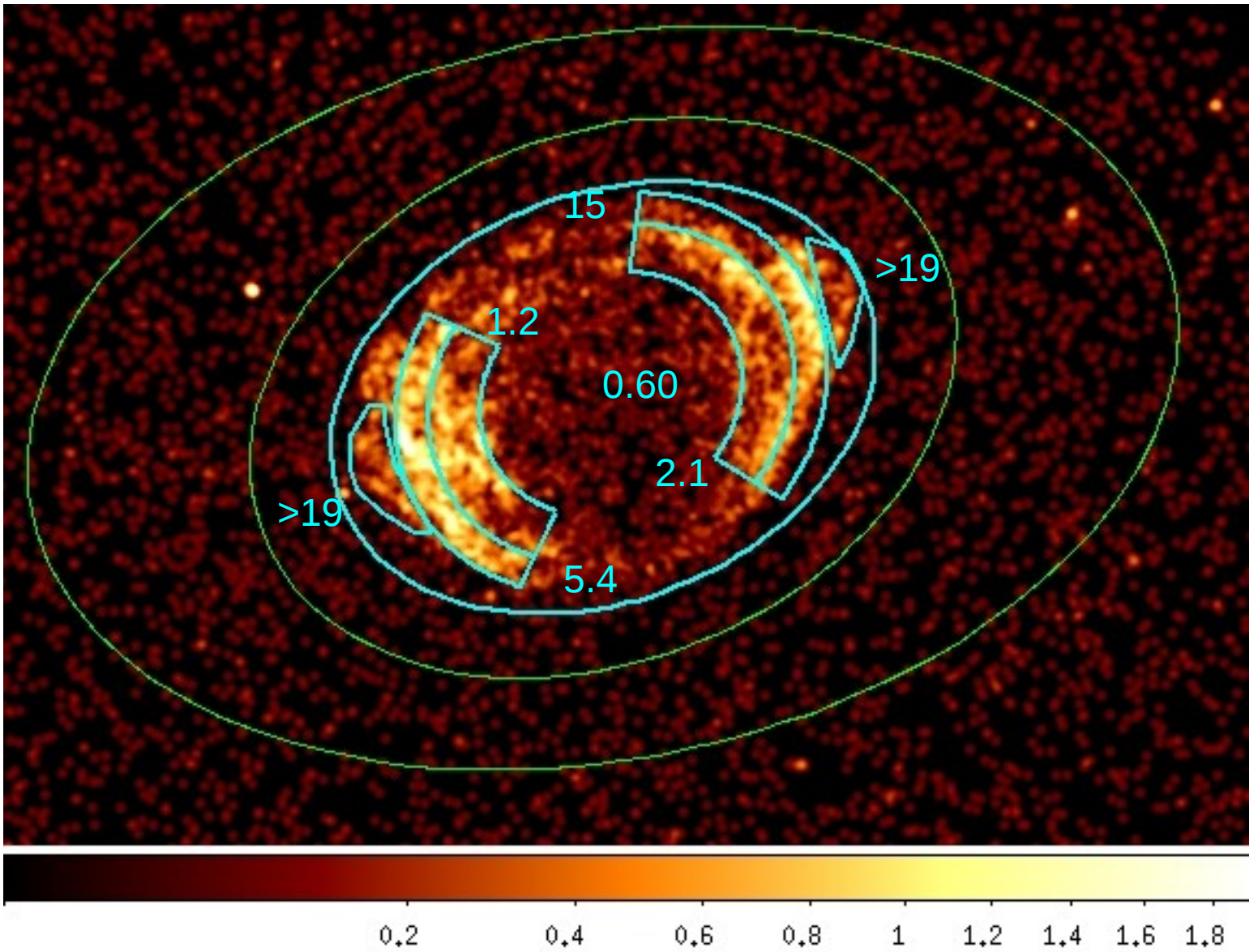


Synchrotron X-rays modeled with the “srcut” model, scattering by dust included (Reynolds et al. 2009): N_H(abs,scat) = 5.1 (3.5) x 10^{22} cm^{-2}, radio index 0.634, break frequency 2.2 keV.

Distance, Velocities, Time Variability

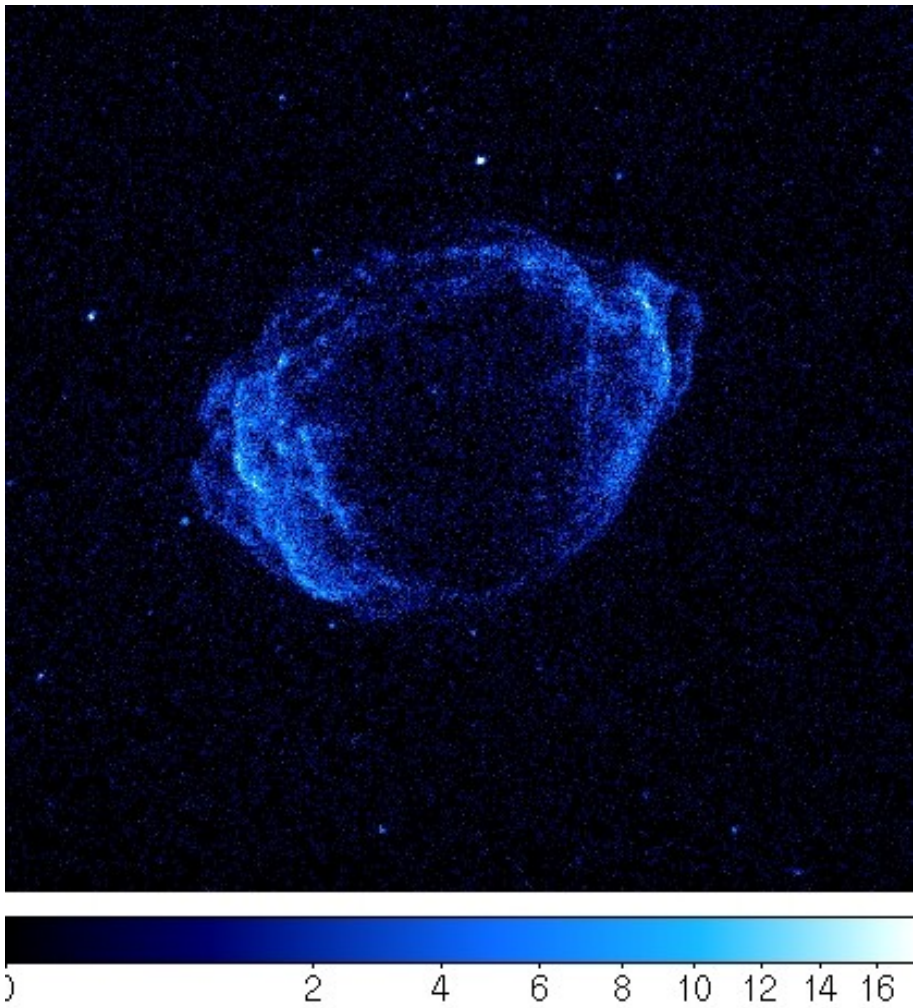
- Extremely high absorption and location near the Galactic Center (300 pc away in projection) suggest 8.5 kpc distance (but larger distances not excluded).
- Blast wave speed of 14,000 km/s from X-rays
- Expansion rate of 12,000 km/s from radio
- Radio flux increasing with time: 2% per yr (Green et al. 2008), 1.2% per yr (Murphy et al. 2008)
- Radio morphology changed significantly between 1985 and 2008, implying strong departures from homologous expansion

X-ray Spectral Variations



Break frequency increases outward along the bipolar X-ray axis

2009 July Chandra Image



- 237 ks observation with ACIS S3 chip
- Image in the 1-7 keV range
- About 40,000 counts, much better S/N ratio than in 2007 Chandra observations
- X-ray morphologies appear different in the north than in the bright bipolar lobes.

Smoothed 2009 Chandra Image

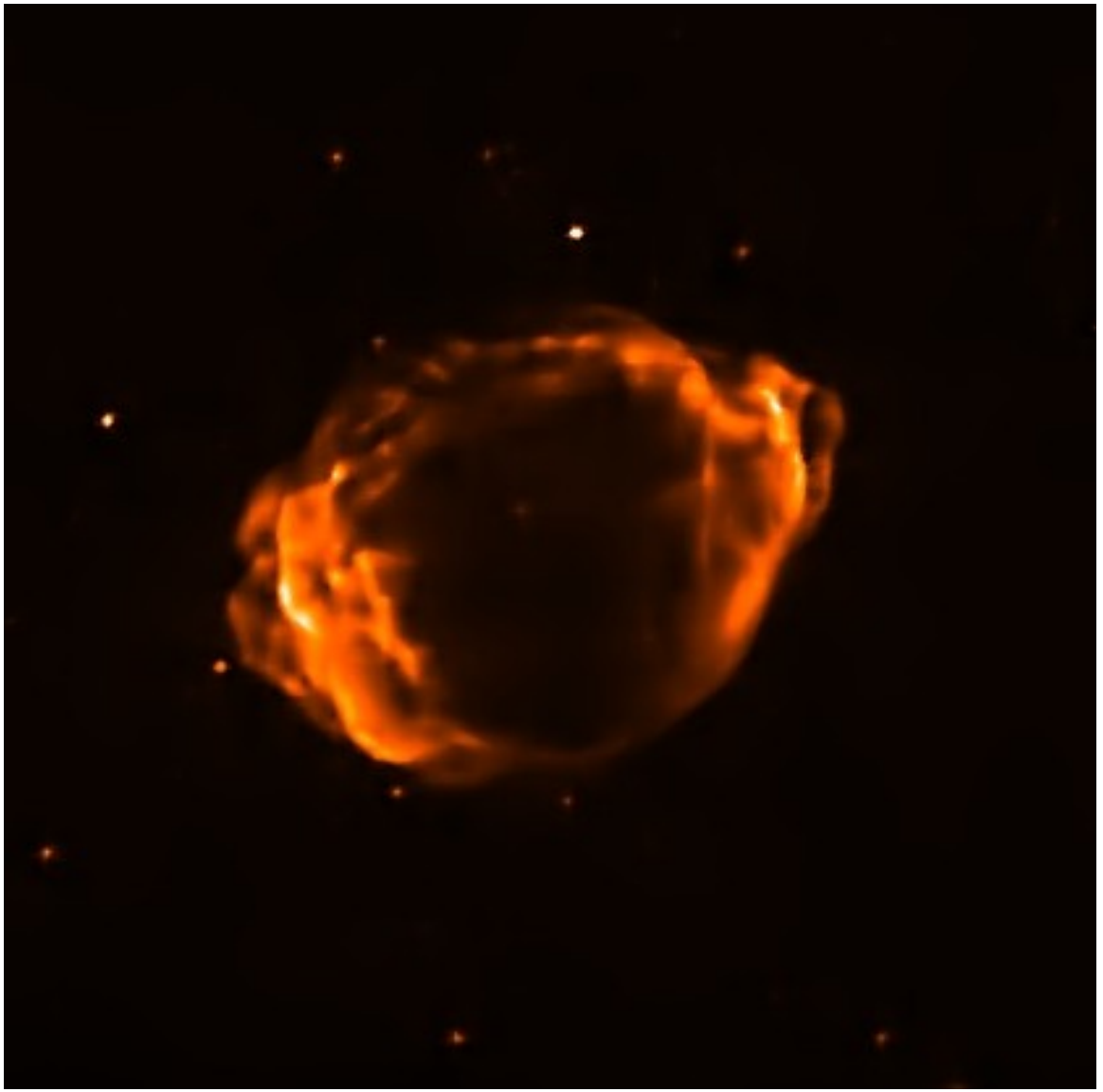
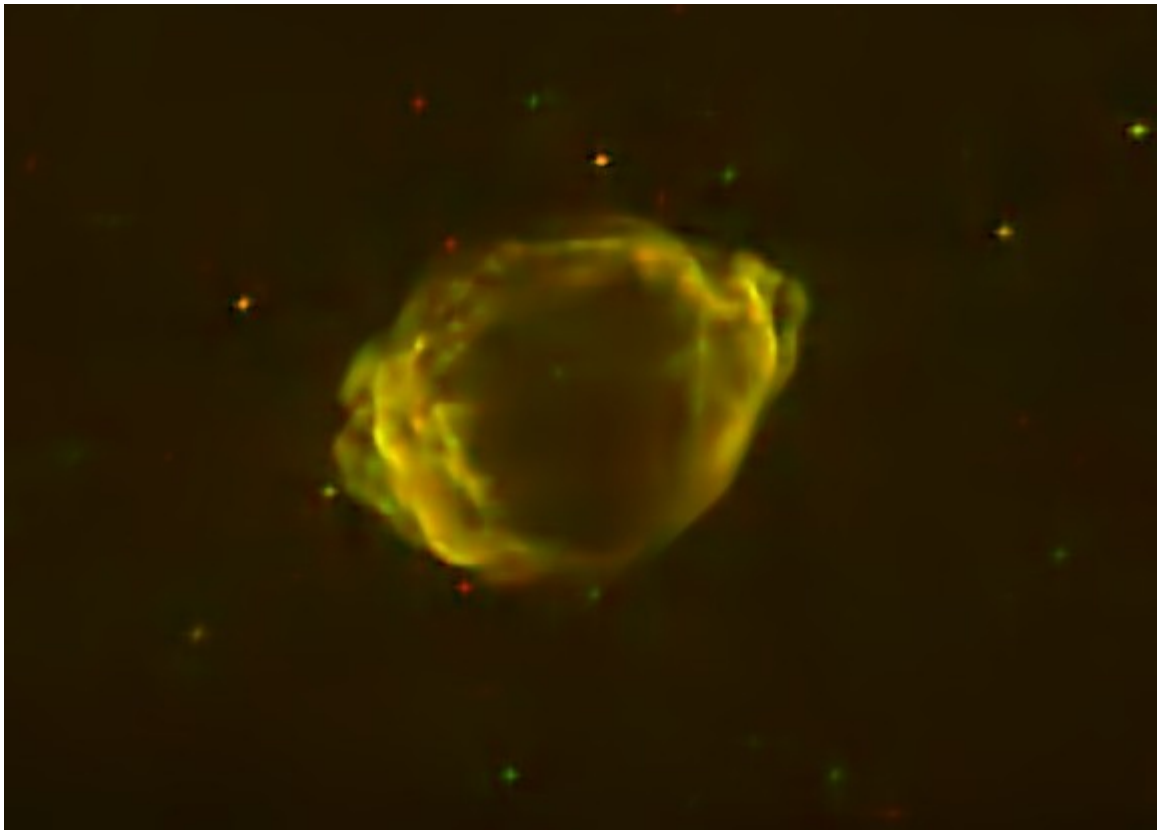


Image smoothed with platelets (Willett 2007)

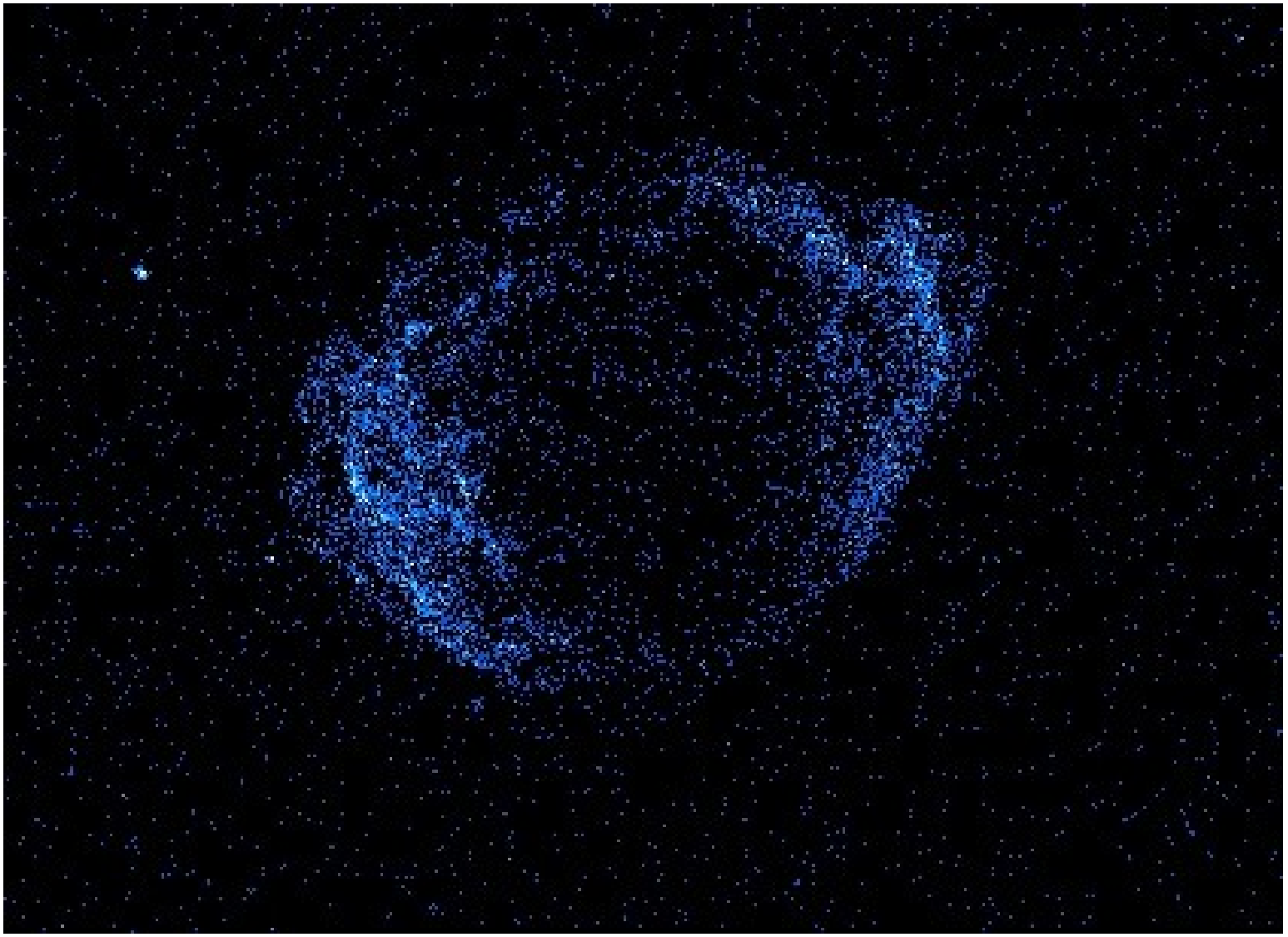
Two-color 2009 Chandra Image



Red: 1-3.5 keV, Green: 3.5-7 keV

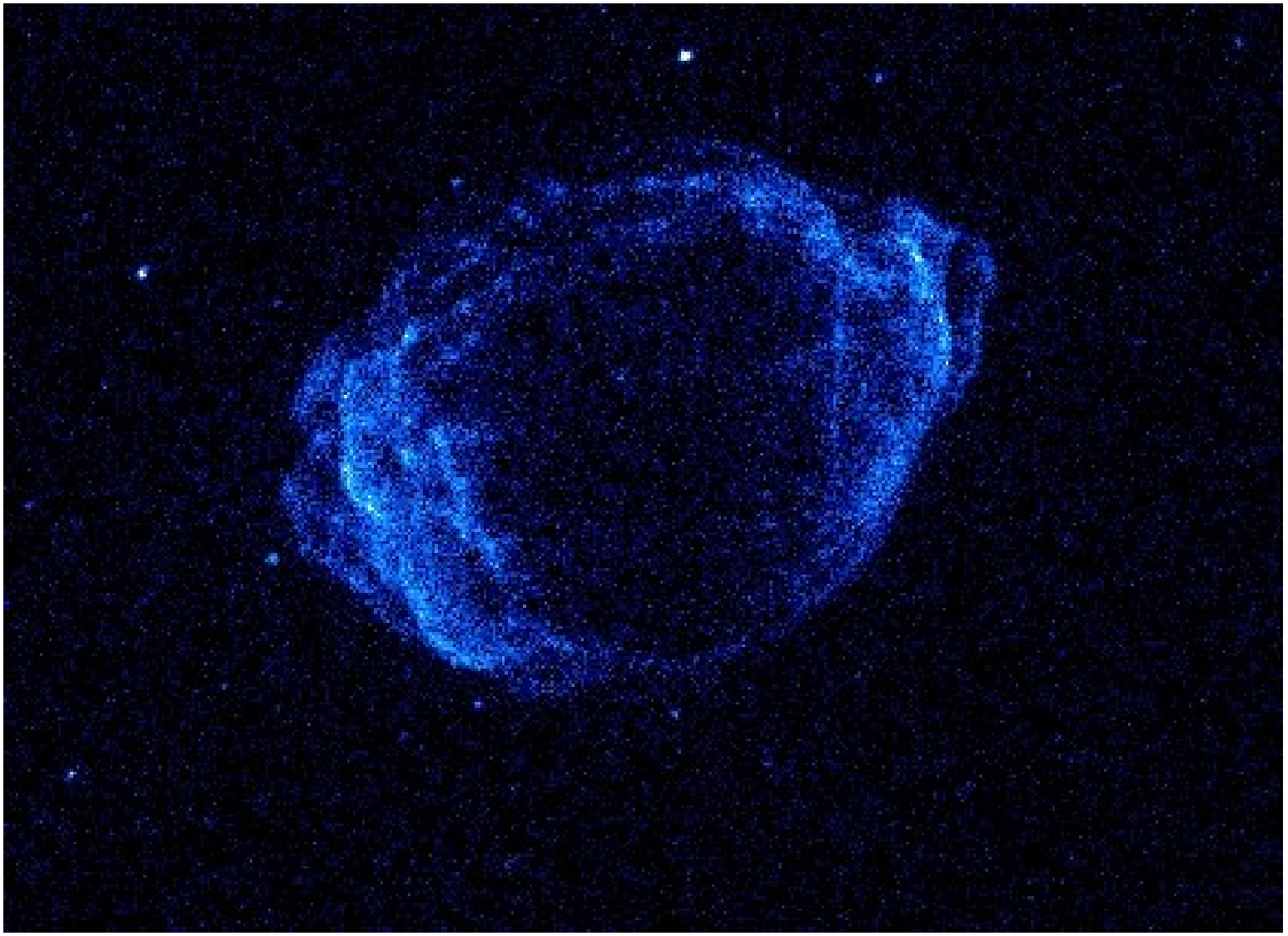
Spectral variations are apparent

2007



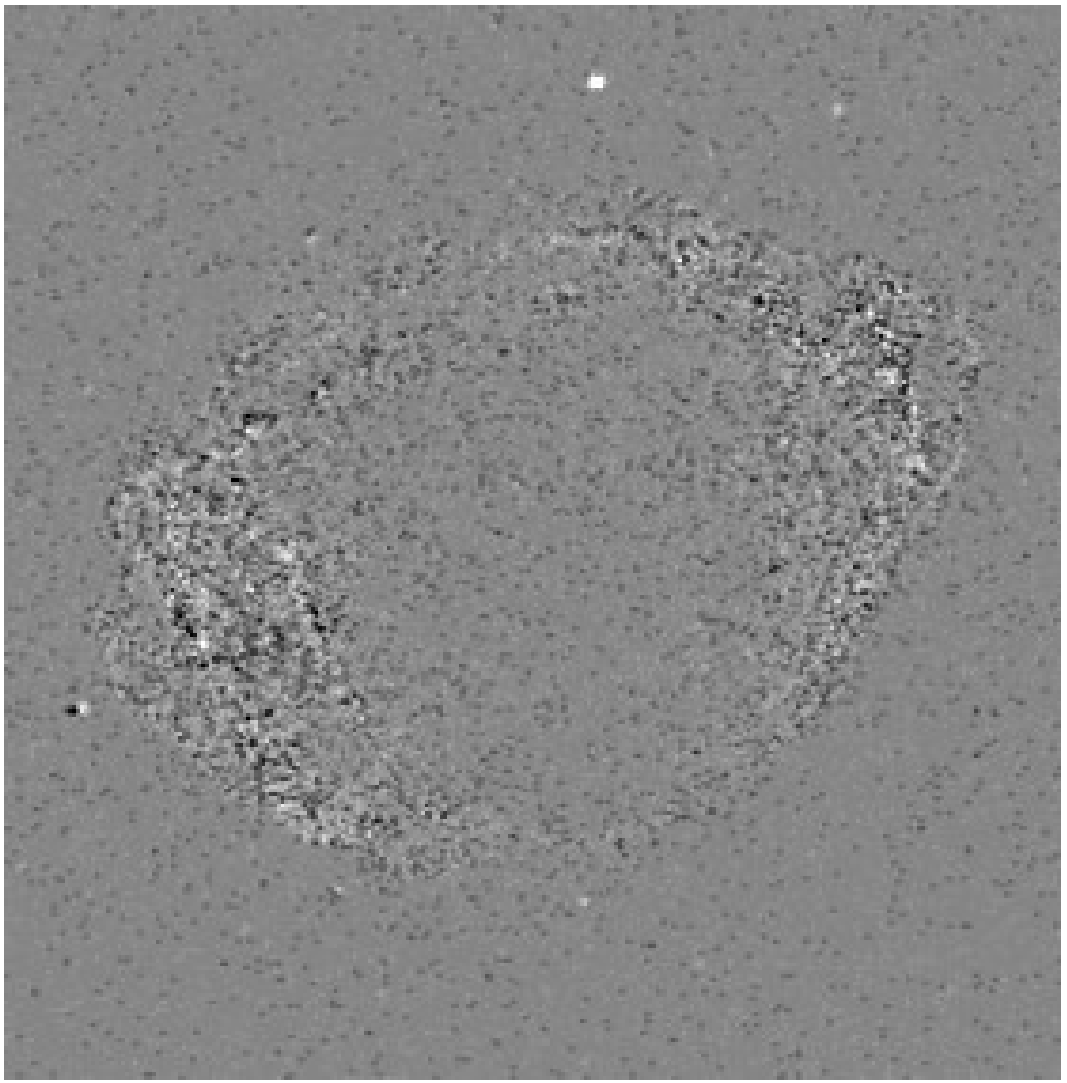
smaller

2009



bigger

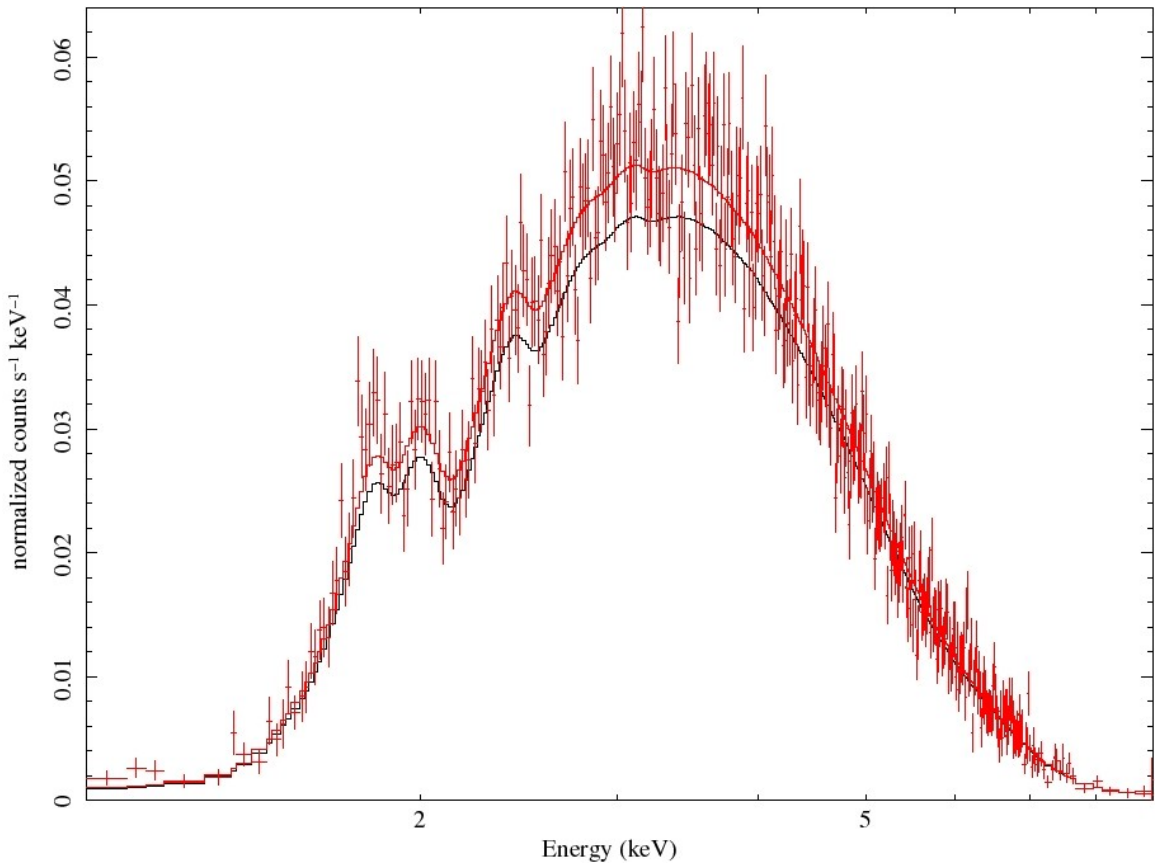
2009-2007 Difference Image



Difference image, after 16% (2007-1985) scaling and flux adjustment.

Expansion in the north appears slower than average.

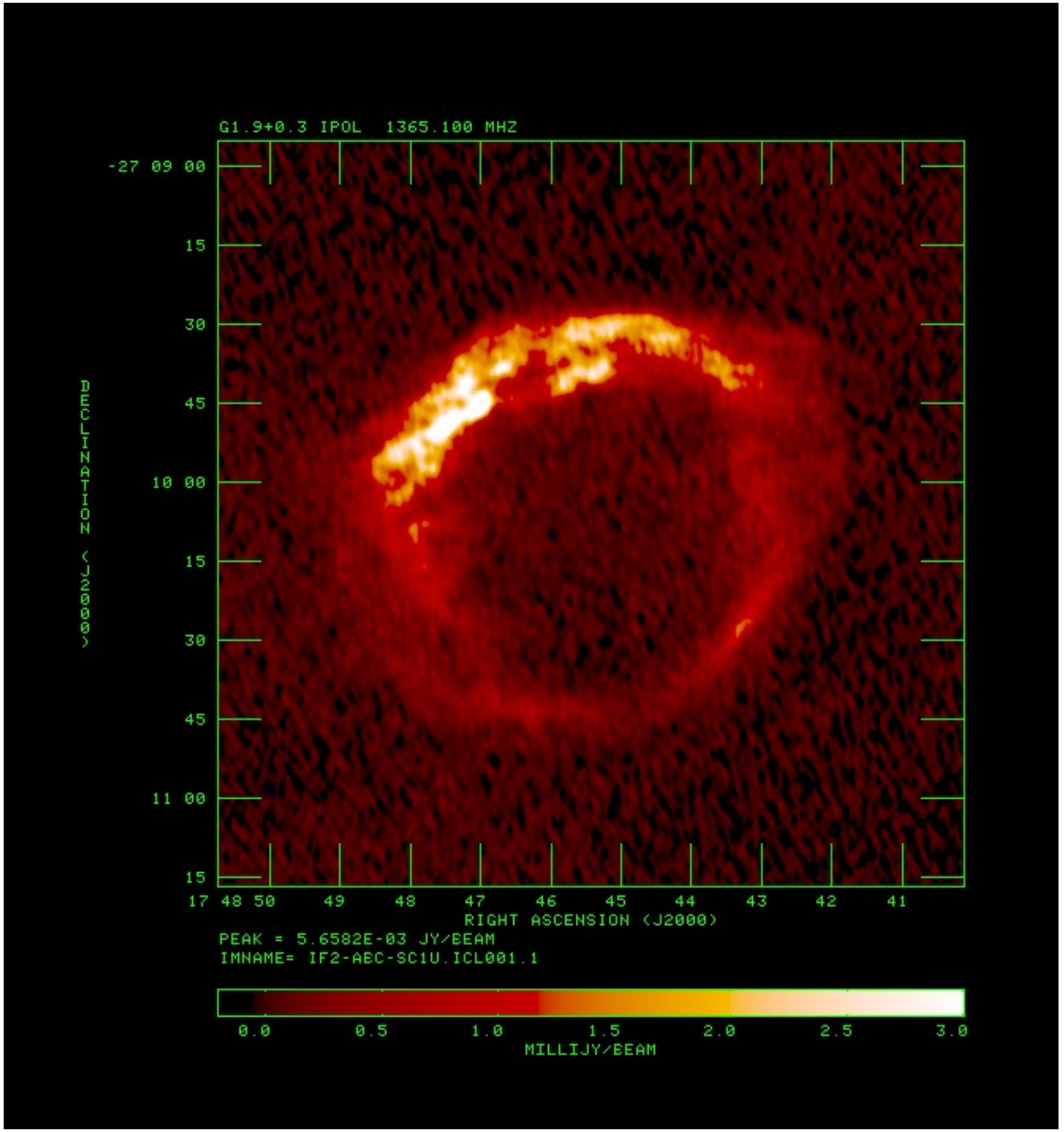
2009 X-ray Spectrum



Red line – current model, black line – old model

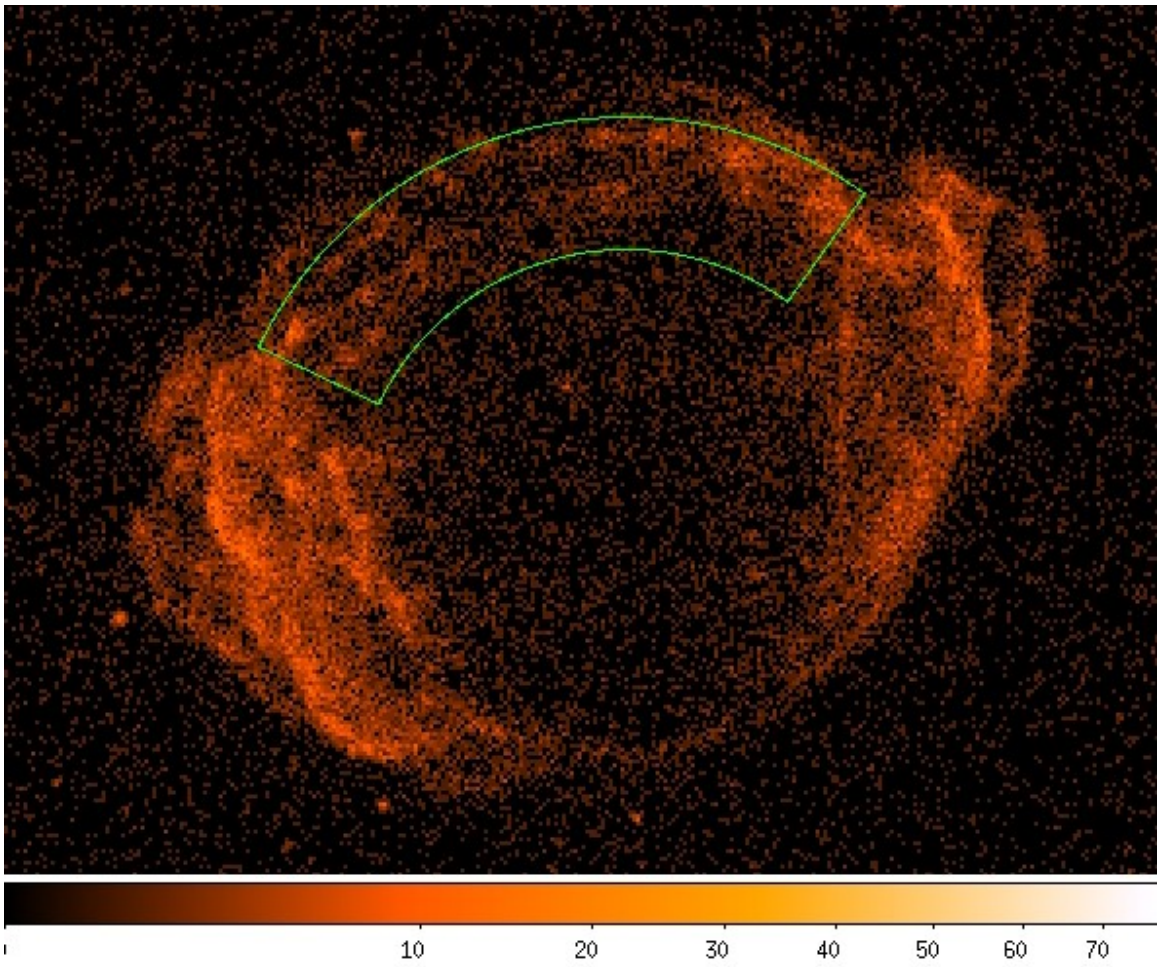
7% (?) increase in X-ray flux

2009 VLA Observations

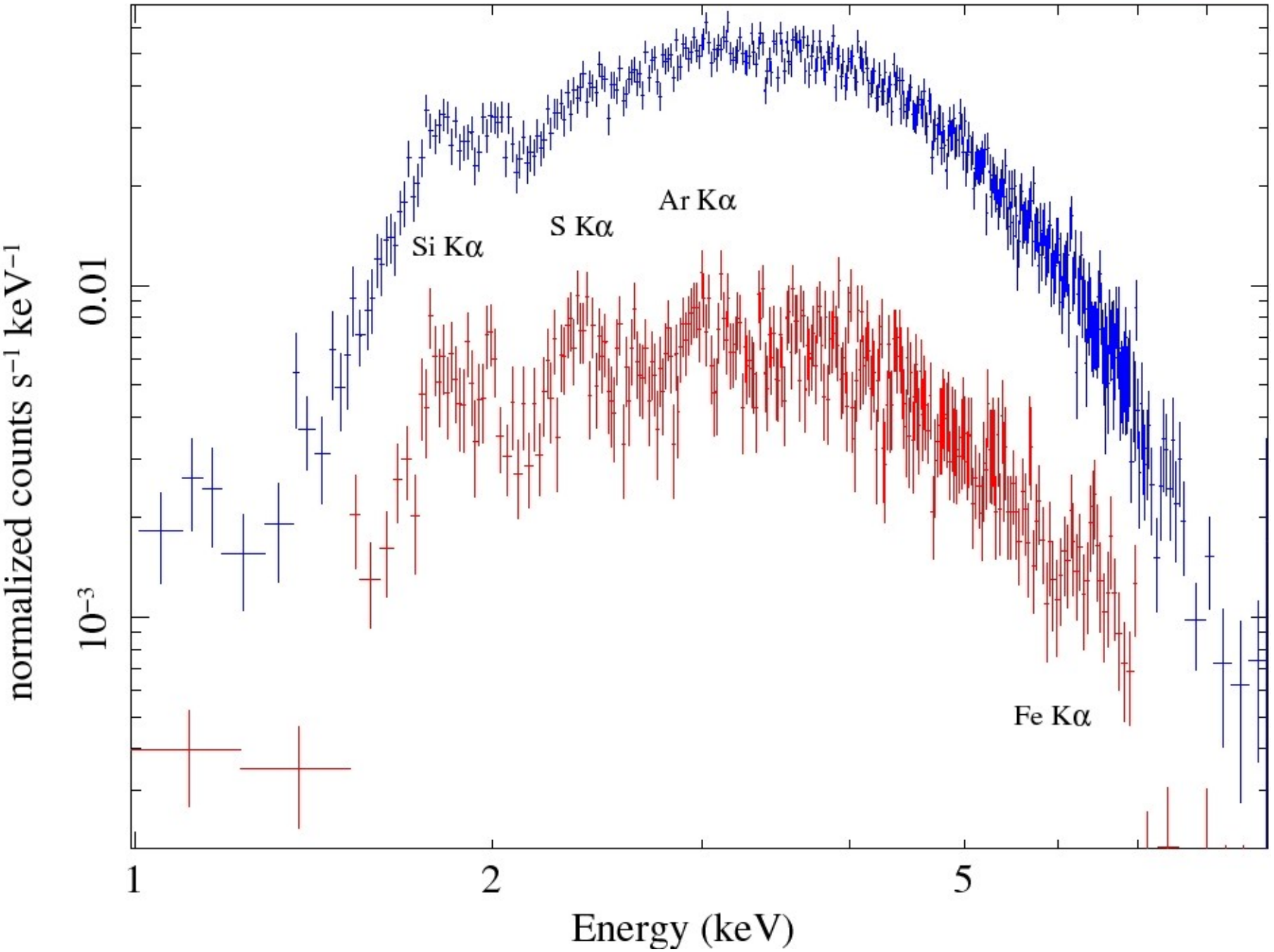


West “ear” finally visible

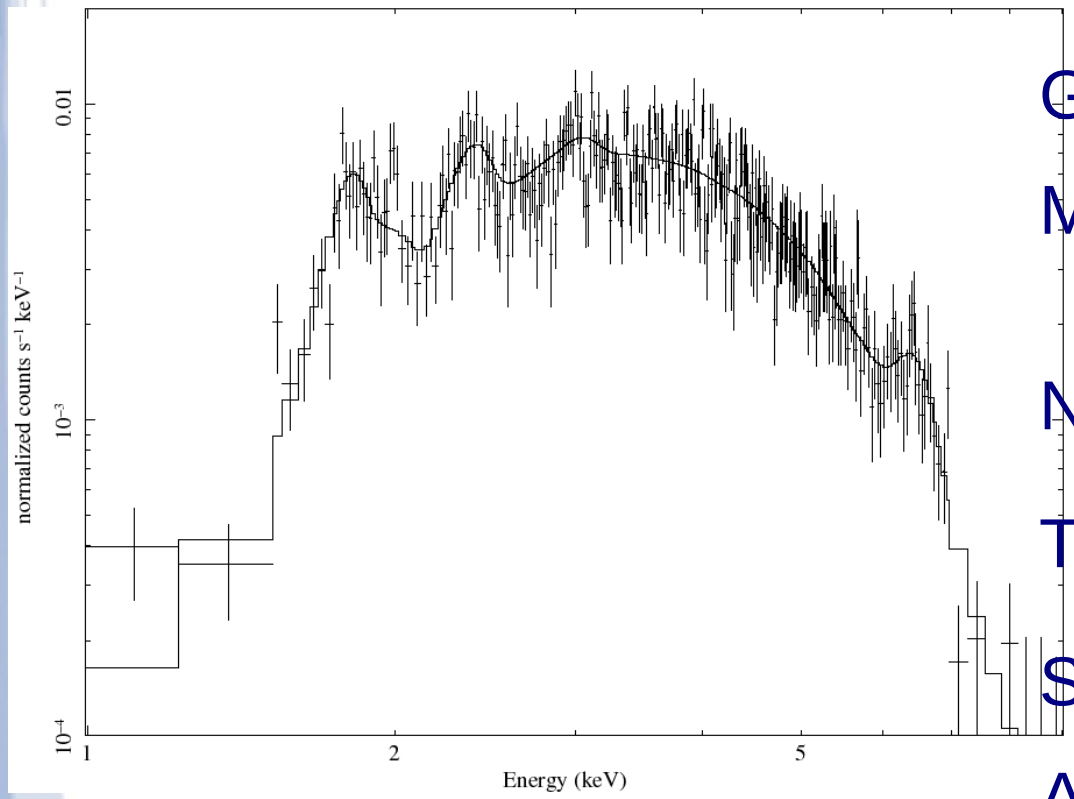
Spatially-resolved Spectroscopy



Radio bright but X-ray faint area


normalized counts s^{-1} keV^{-1}
0.01
10^{-3}
Si Kα
S Kα
Ar Kα
Fe Kα
1
2
5
Energy (keV)

Thermal model



Plane-shock NEI model from XSPEC without dust

Gaussian line broadening

MCMC simulations used (PyMC package in Python)

N_H=6.72 (6.88,6.72) x 10^{22} cm^{-2}

T_e=3.6 (3.2.4,0) keV,

Si=S=3.4 (2.0,4.6)

Ar=17(2.8,37),Fe=4.1(2,4,5.7)

τ=1.4 (0.78,3.1) x 10^9 cm^{-3} s

V_r = -4300 (-7600,-1300) km/s

FWHM=26500 (17600,34600) km/s

Doppler-shifted and Doppler-broadened lines produced by supernova ejecta, Type Ia explosion preferred

G1.9+0.3: Conclusions

Line emission from fast-moving SN ejecta detected

Broad lines preclude distances much less than 8 kpc

X-ray expansion consistent with previous expansion estimates, slower than average expansion in the north

Bright radio coincides with line emission - strongly asymmetric ambient medium implied

Type Ia explosion preferred because of strong Fe line emission

Asymmetric CSM around Type Ia SN has been predicted in several Type Ia SN progenitor scenarios

X-ray synchrotron emission probes particle acceleration in very fast collisionless shocks