The non-thermal X-ray emission from mixed-morphology SNR G346.6-0.2

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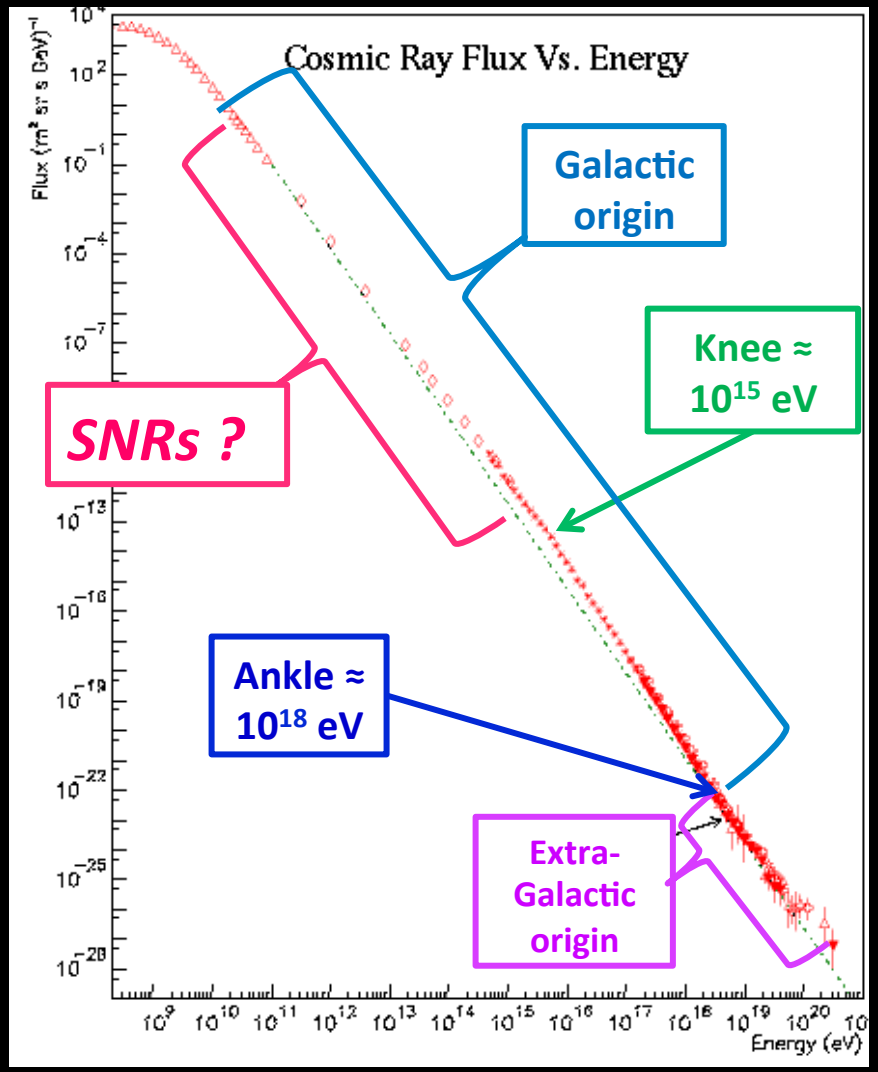
Auchettl et al. (2016), in prep.

Supernova remnants & Cosmic Rays

- *Below E_{knee}, there is evidence in favour of SNRs being the origin of cosmic rays (CRs).*

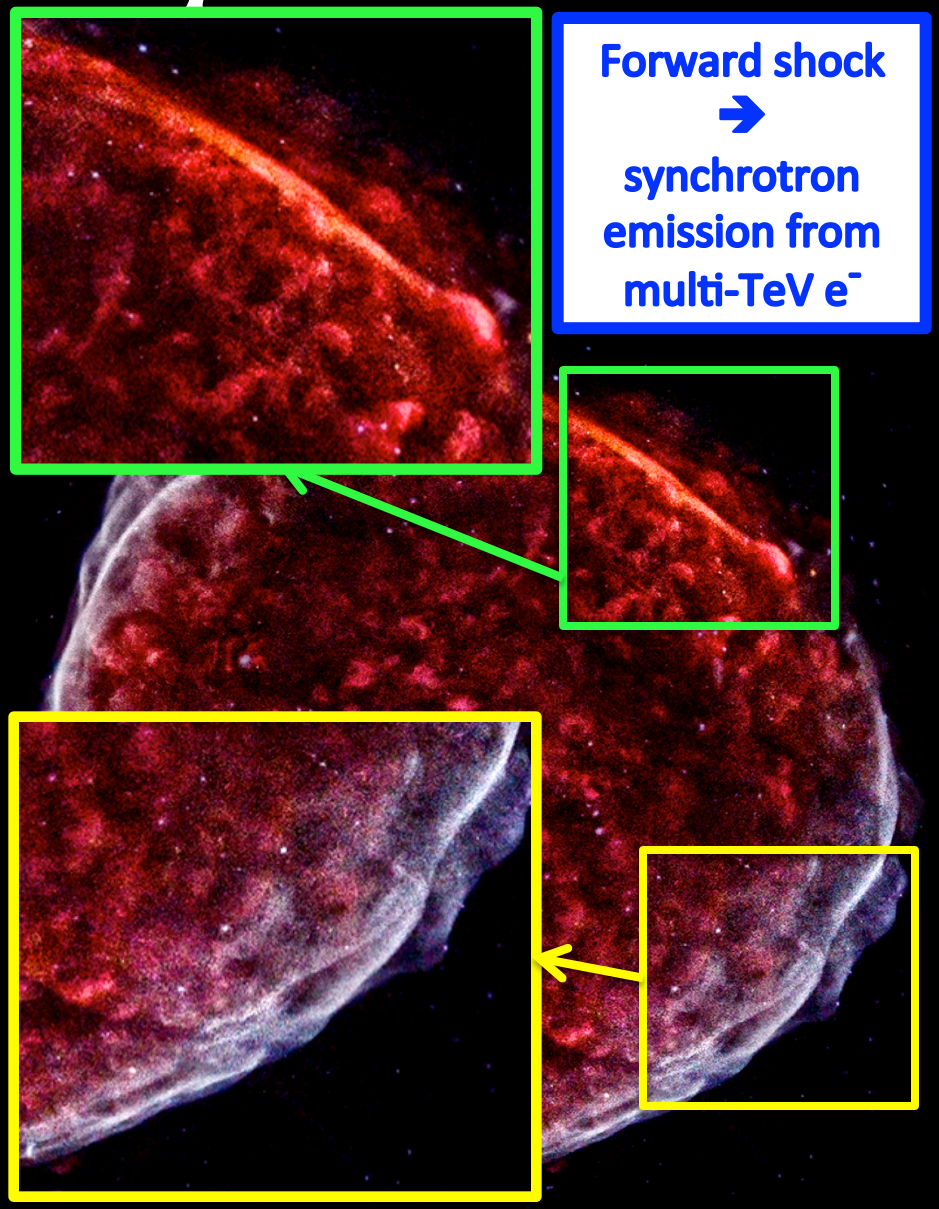
  1. *CR energy density ~ 1 eV cm^{-3}*
     - *SNRs can explain this.*
  2. *Spectral index of CR spectrum at Earth ≈ 2.*
     - *Consistent with spectral index of derived by diffusive shock acceleration.*



SNRs accelerate particles

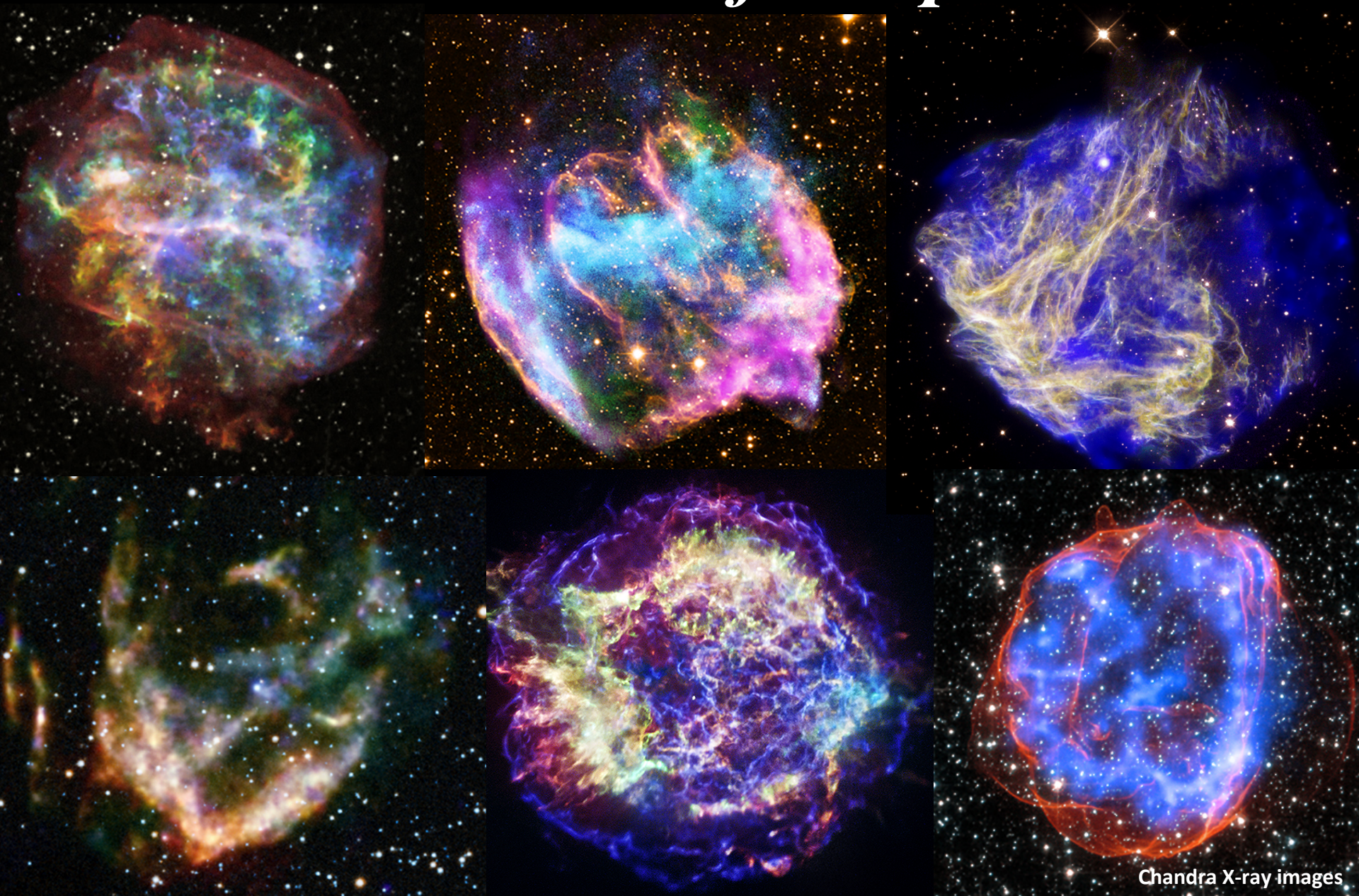
- *Forward shock (& reverse shock?) of a SNR can <u>accelerate</u> particles*
  - *eg. SN1006*
- *Lagage & Cesarsky (1983) applied diffusive shock acceleration to young shell-type SNRs and concluded that:*
  - *Particles in SNRs can be accelerated up to 10 -100 TeV.*

➔ *SNRs can accelerate cosmic rays!*



Chandra X-ray image(NASA/CXC/Middlebury College/F.Winkler)

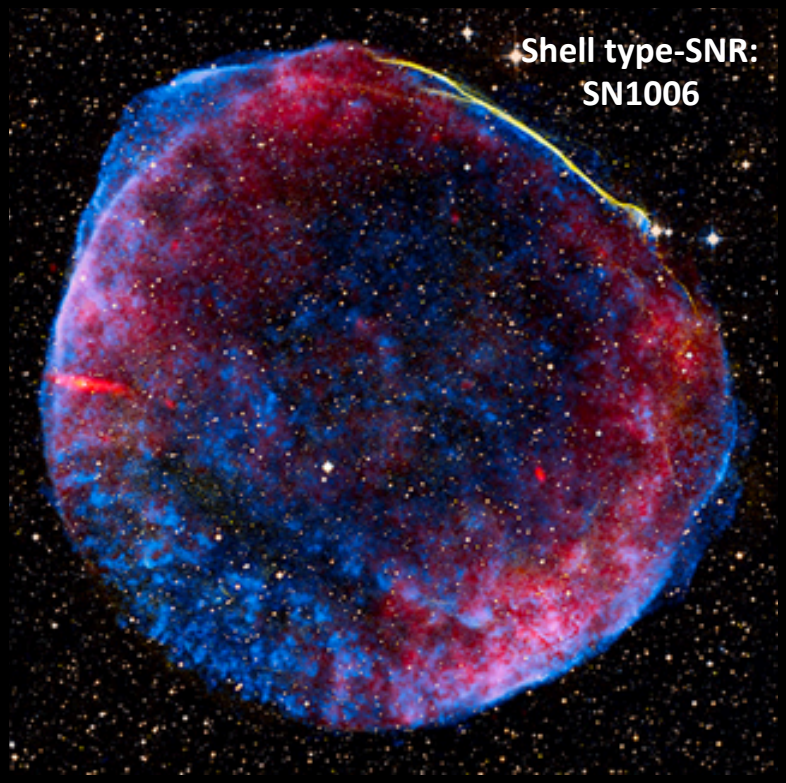
The remnants of a supernova



The remnants of a supernova

A dense environment has a profound effect on the morphology and properties of SNRs.

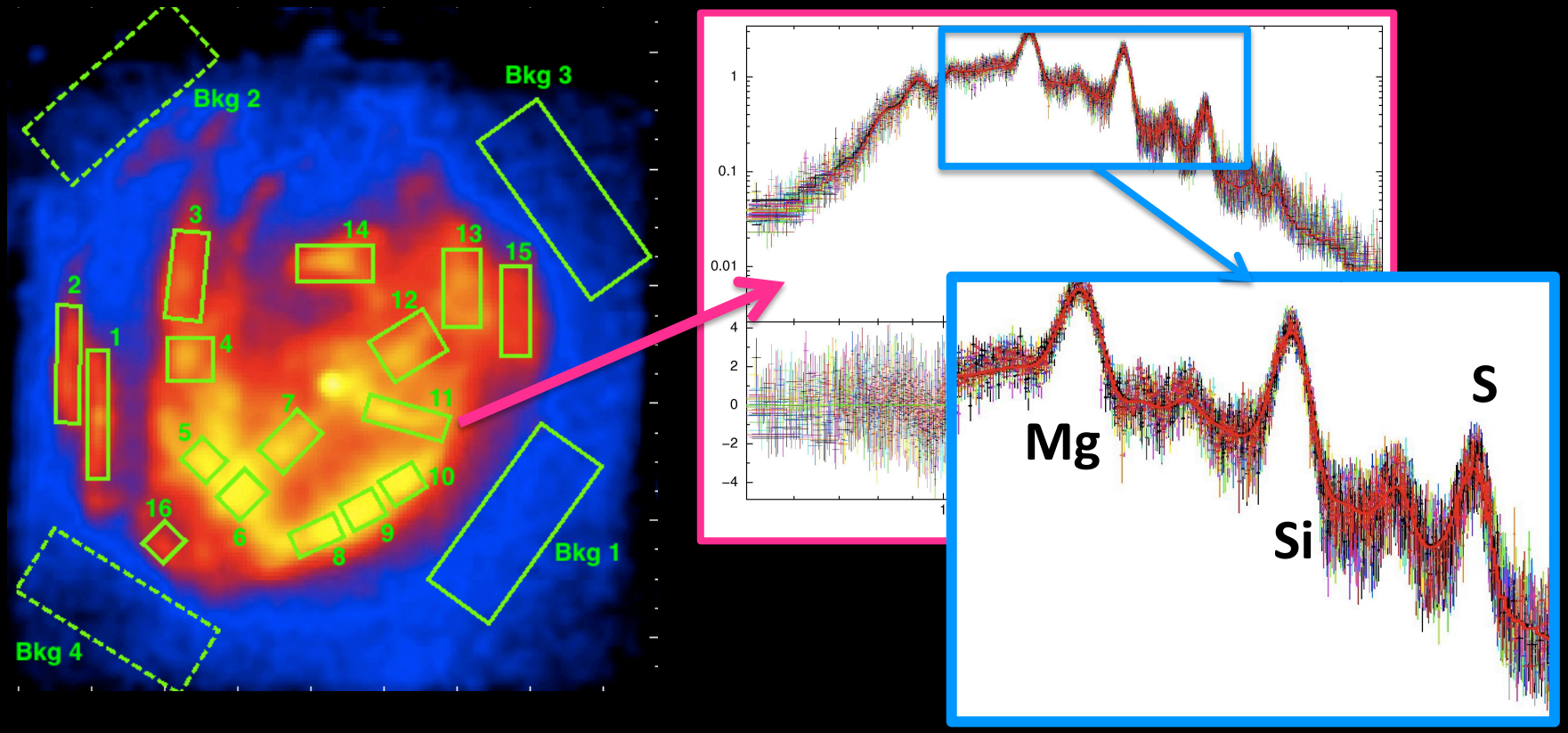
Centrally peaked X-ray morphology



- *Centrally peaked X-ray morphology which arises from a collisional hot plasma (Lazendic et al. 2006).*

Enhanced abundances

- *Strong X-ray lines imply super solar abundances of different elements.*
- *Indicates that some of the X-ray emission we are observing arises from stellar ejecta.*
- *Expect to see ejecta in young SNRs, not MM SNRs which are middle aged.*

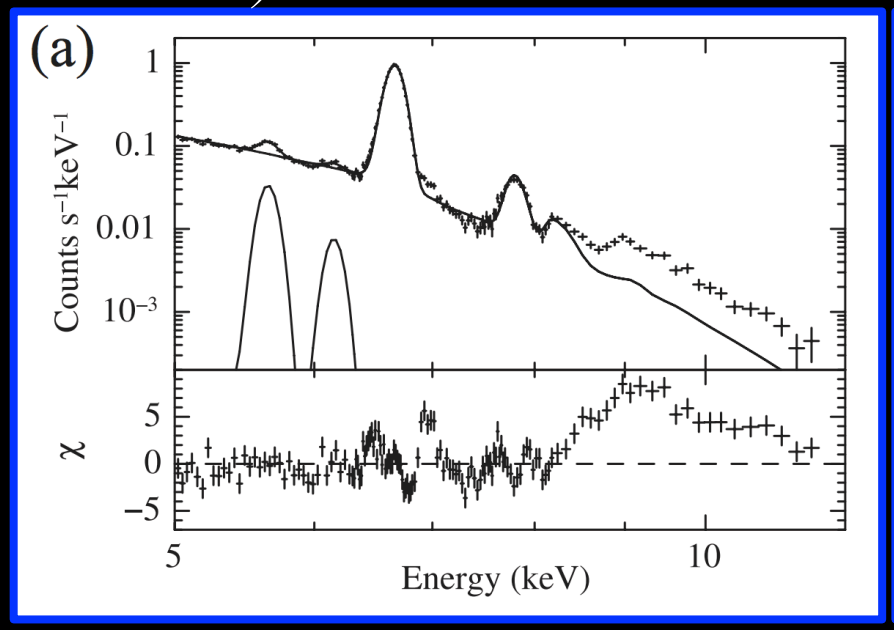


Kes 79 - Auchettl et al. 2014

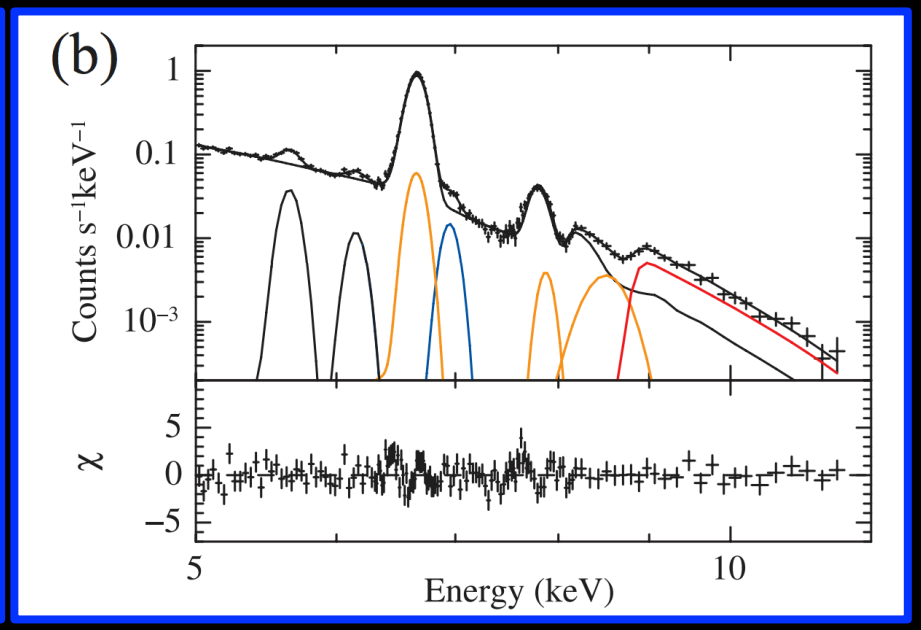
Overionised plasma

- *Overionised plasma is detected in the form of radiative recombination continuum (RRC).*
- *Indicates rapid electron cooling.*
- *Only found in SNRs interacting with molecular material (MM SNRs).*

Ozawa et al. 2009



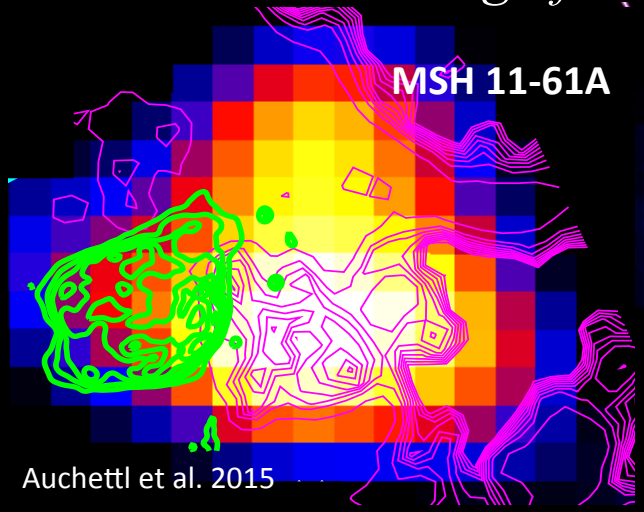
Fitting X-ray spectrum of W49B without recombination

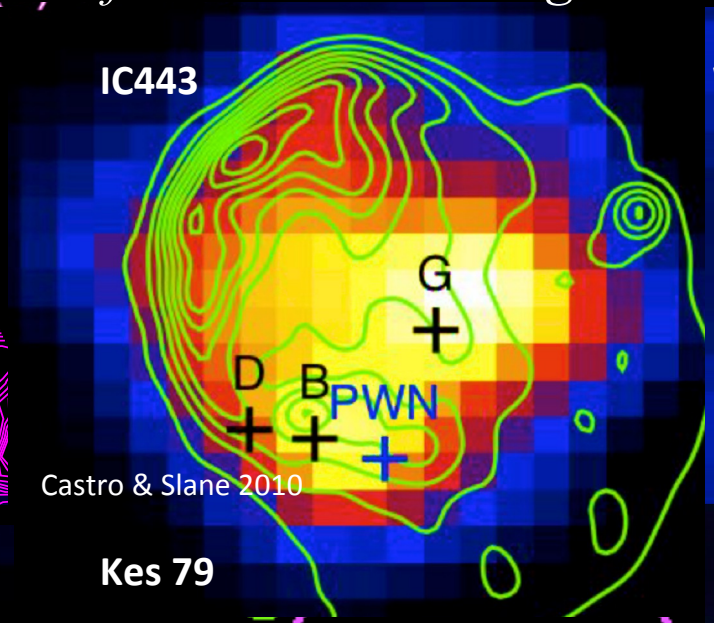


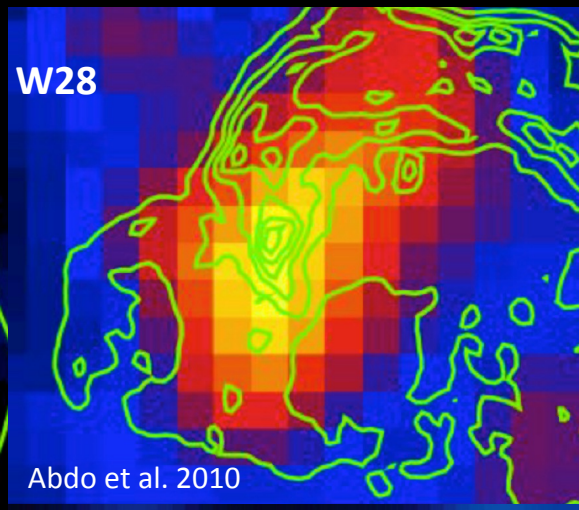
RRC seen in red + recombination lines seen in orange and blue added to fit.

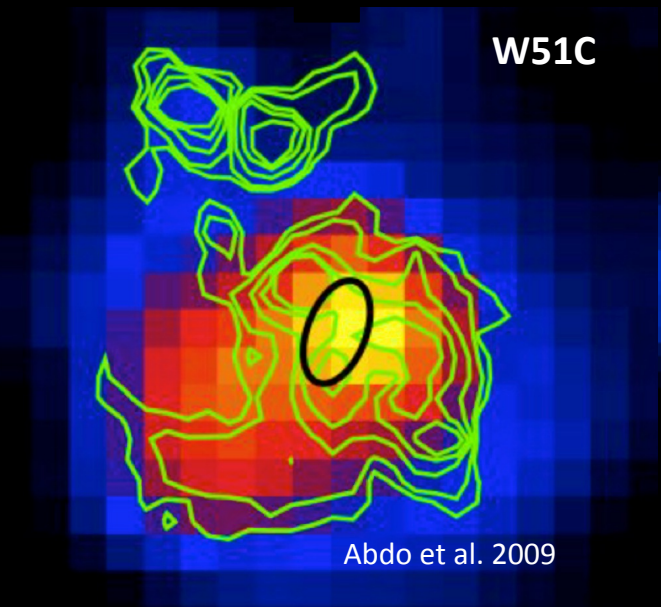
Sources of hadronic gamma-rays

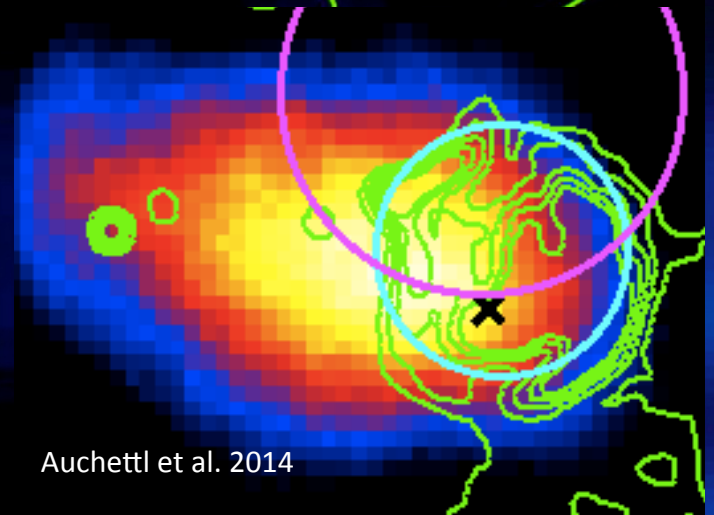
Surprising as MM SNRs are thought to have too slow of shocks but a significant of these a interacting with MCs.

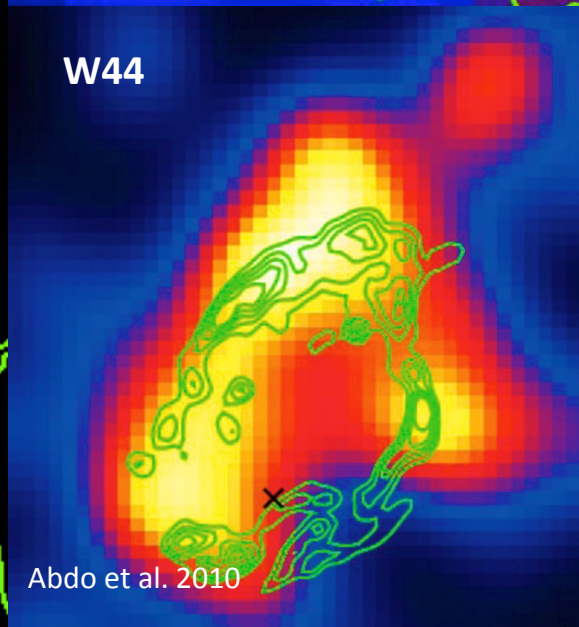












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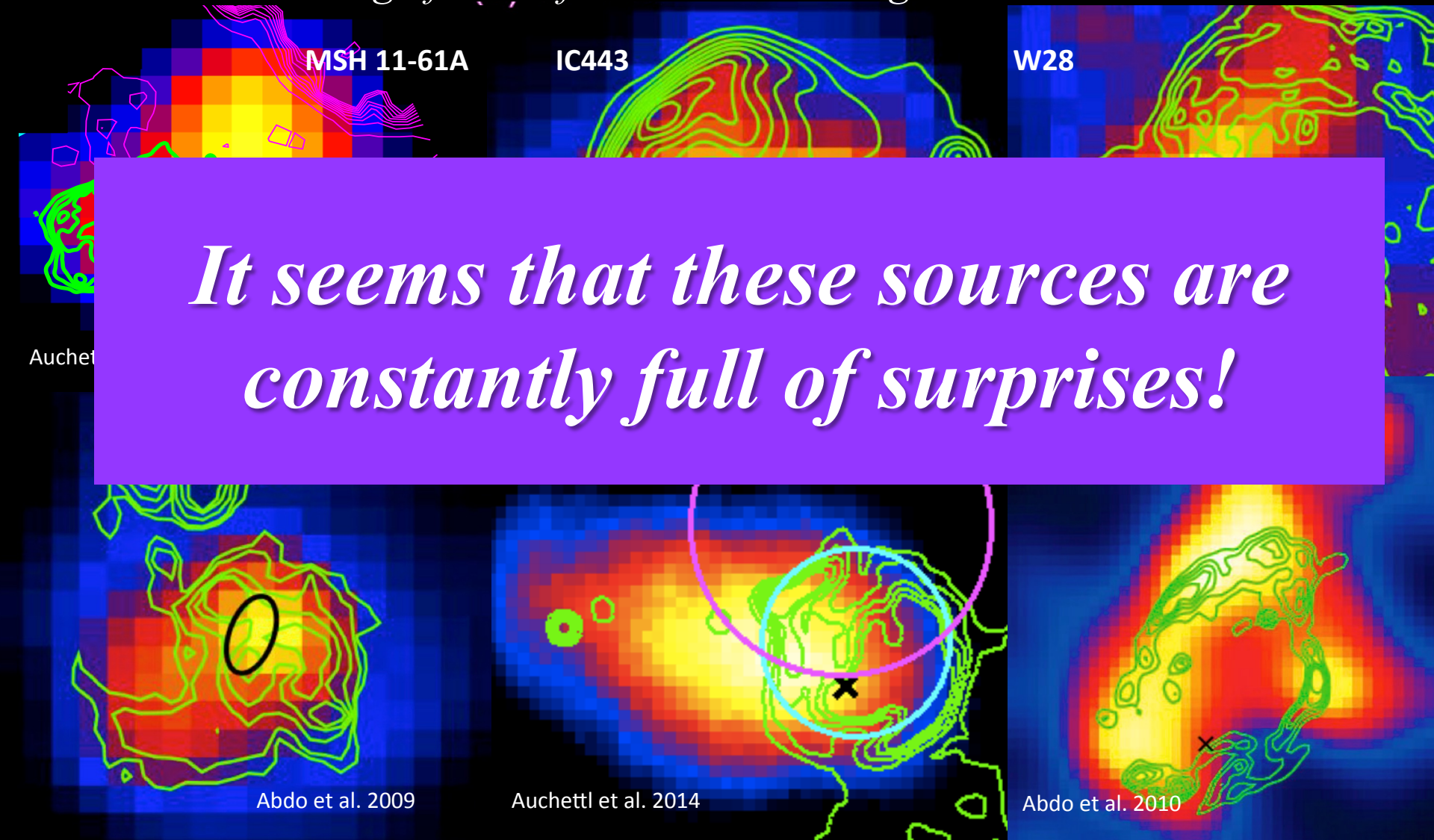
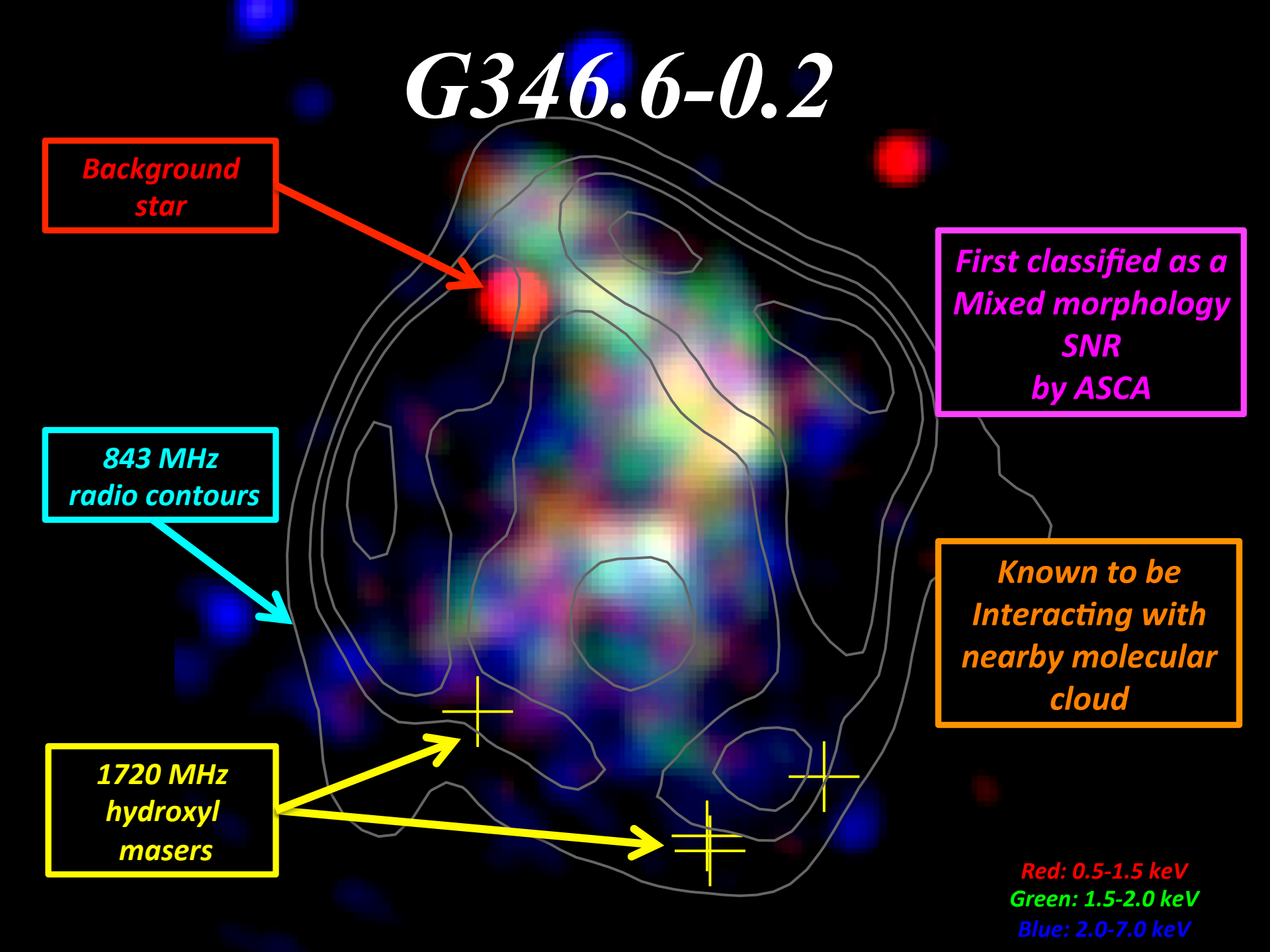


It seems that these sources are constantly full of surprises!

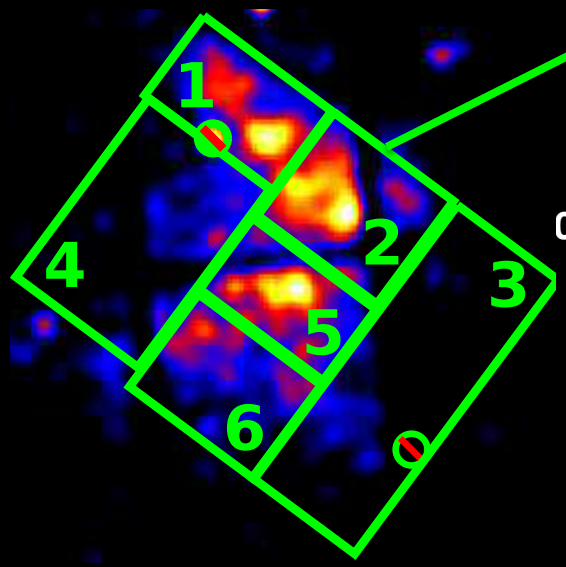
G346.6-0.2

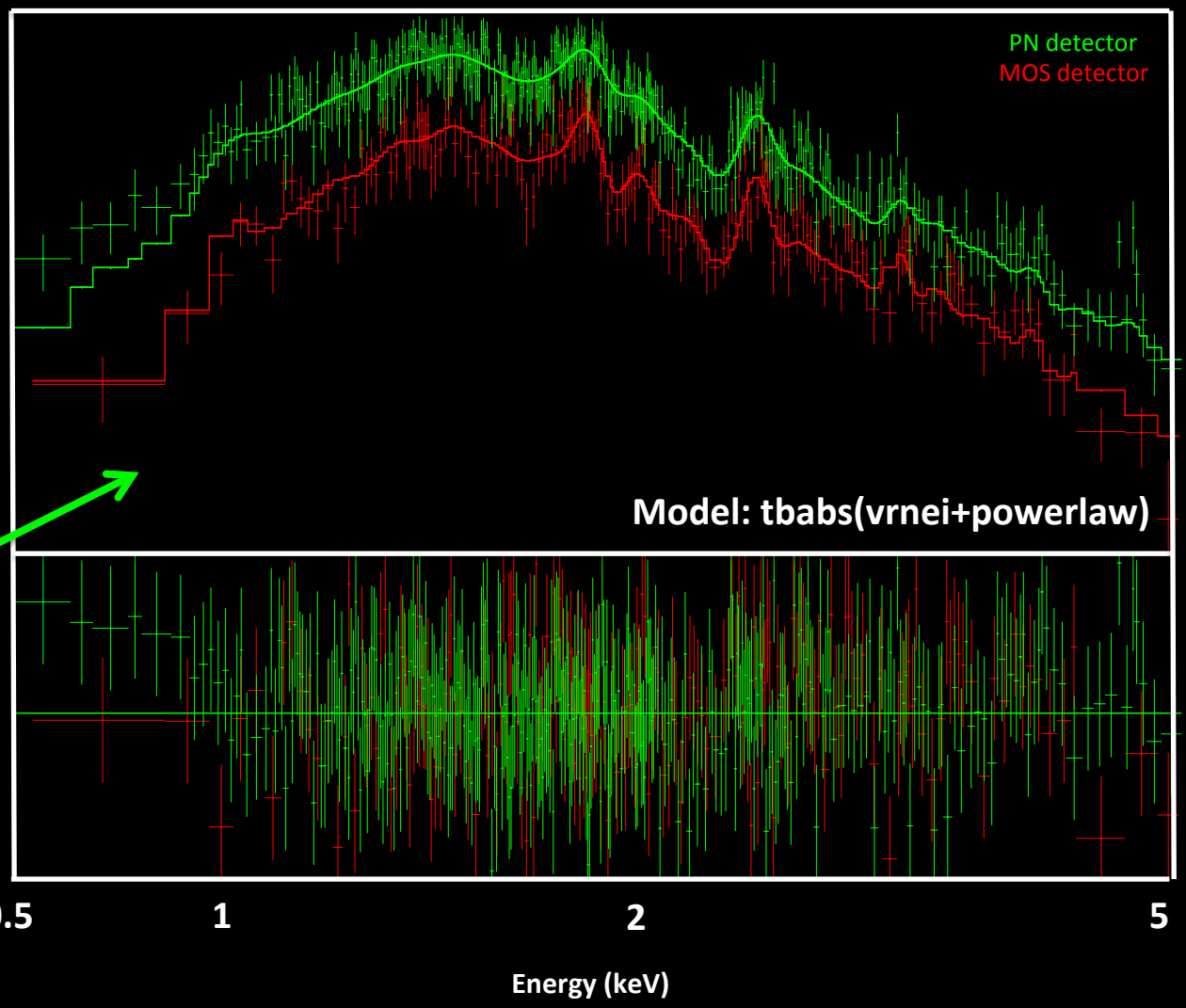

Background star
First classified as a Mixed morphology SNR by ASCA
843 MHz radio contours
Known to be Interacting with nearby molecular cloud
1720 MHz hydroxyl masers
Red: 0.5-1.5 keV
Green: 1.5-2.0 keV
Blue: 2.0-7.0 keV

X-ray analysis of G346

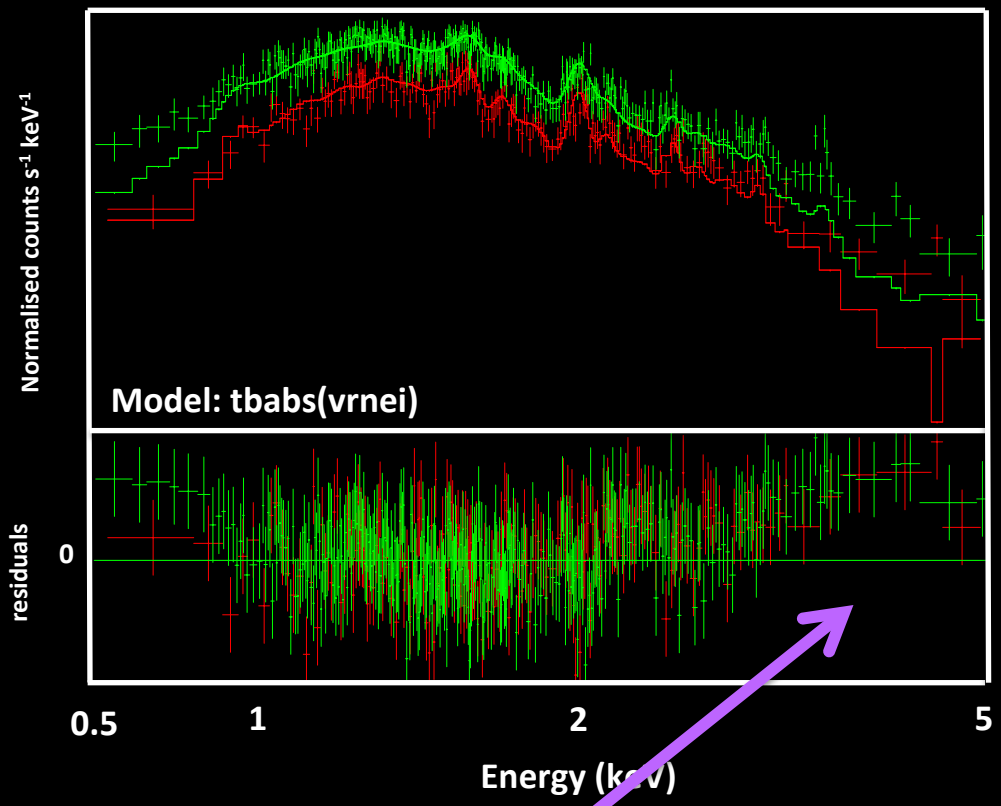
30 ks XMM-Newton Observation

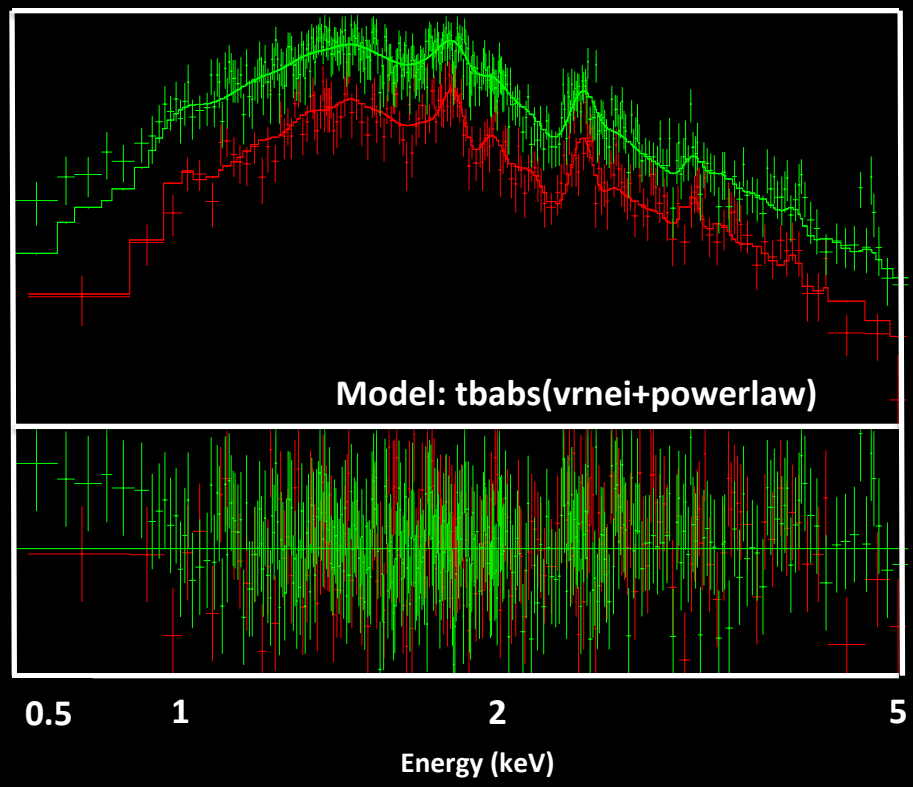
Extract global and individual regions to derive the local and global properties of the remnant.





Powerlaw component



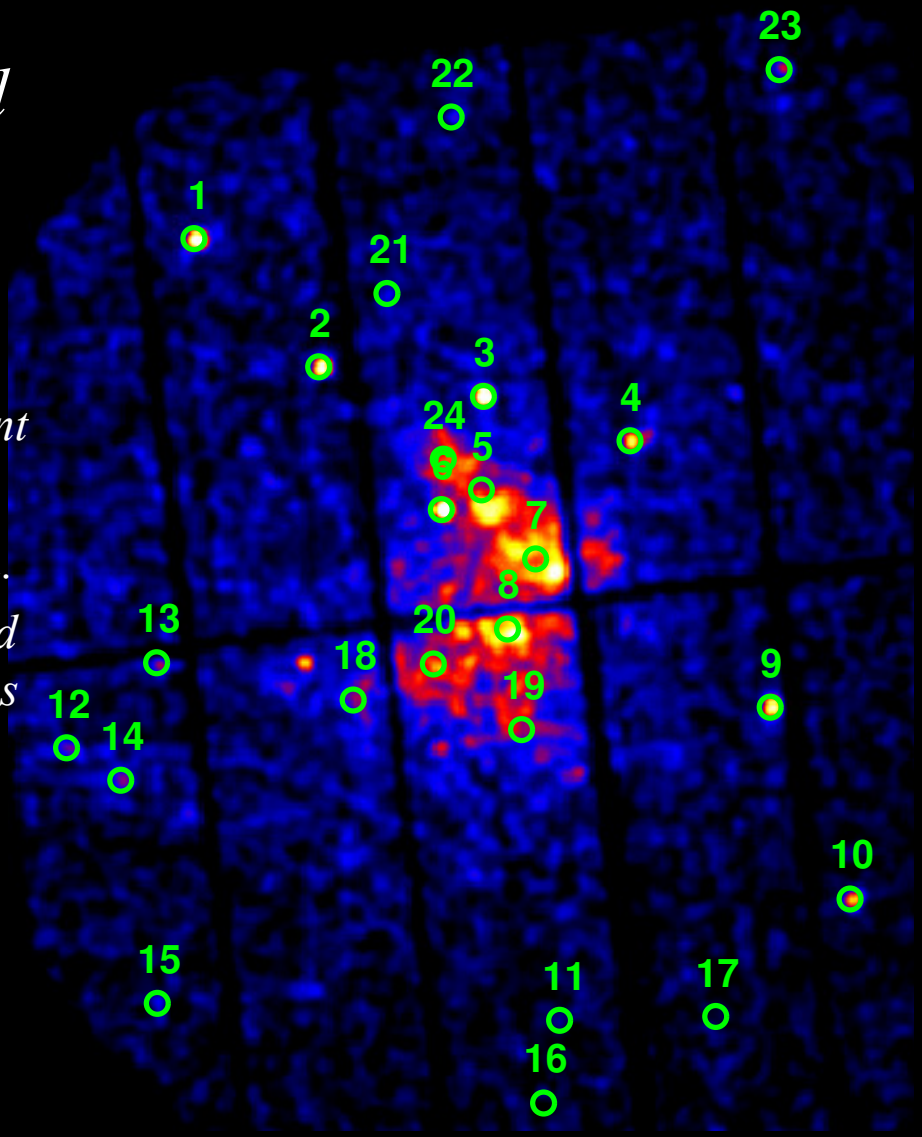


A single thermal model struggles to fit the data above > 4 keV

Thermal model + a Power law component with
Γ ≈2.3(global spectra)
Γ≈1.0-2.6(individual spectra)

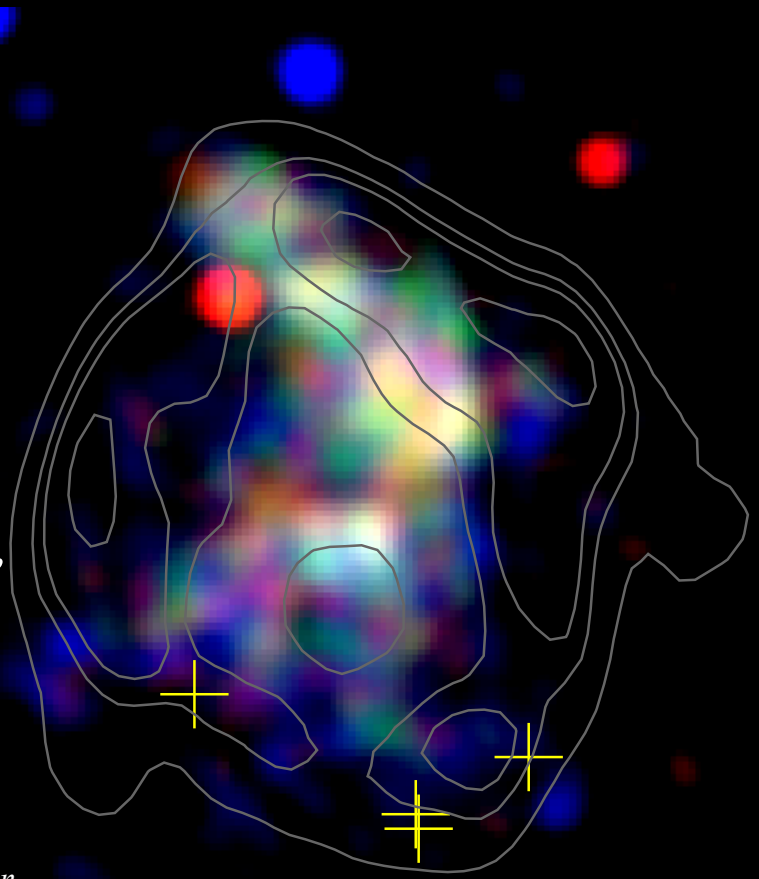
Origin of this powerlaw component?

- *Undetected pulsar/pulsar wind nebula?*
  - *Γ similar to that for a PWN.*
  - *Look for source:*
    - *Within the radio contours of remnant*
    - *Has no optical/IR counterpart*
    - *Predominantly hard X-ray emission.*
    - *Derived velocity assuming produced in same event that produced G346 is reasonable.*
  - *None of the sources within the field of view fulfill this.*
  - *Powerlaw component is found across the whole remnant not localised.*



Origin of this powerlaw component?

- *Synchrotron X-ray emission*
  - *Detected in young (<1kyr) shell type SNRs with v_s >2000 km/s and B=50-250 μG.*
    - ➢ *Electron E_{max}>1 TeV*
  - *MM SNRs v_s~100 km/s, too slow to accelerate electrons to these energies, assuming B=10-100 μG.*
  - *For G346:*
    - *v_s~1300 km/s*
      - *Assuming White & Long (1999) model of SNR evolution in a dense environment.*
    - *B = 1.7mG based on Zeeman splitting.*
      - ➢ *Electron E_{max} = 3 TeV*



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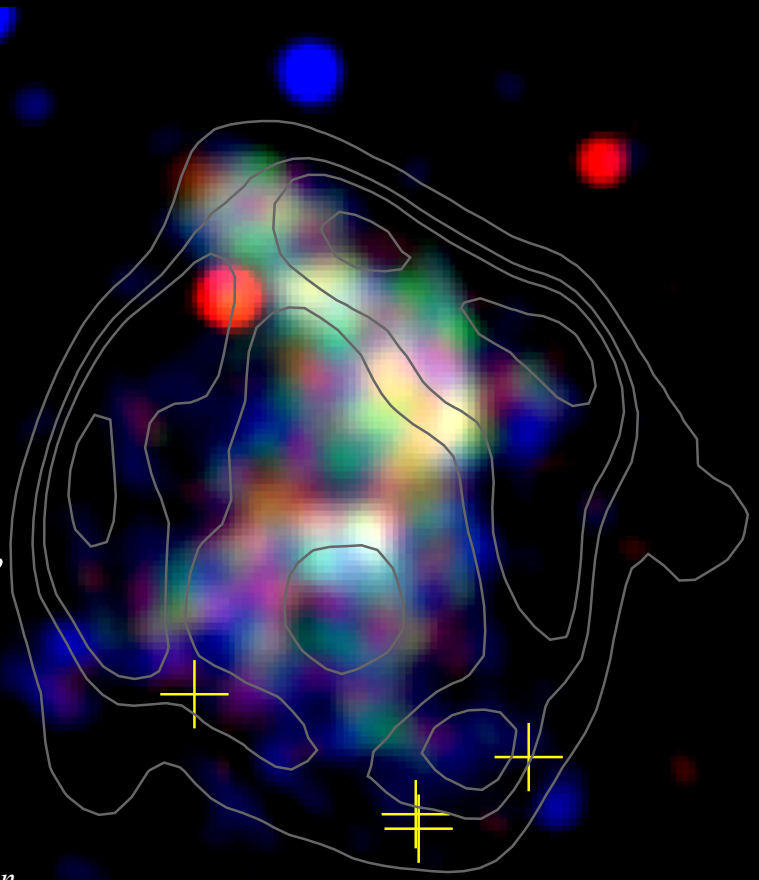
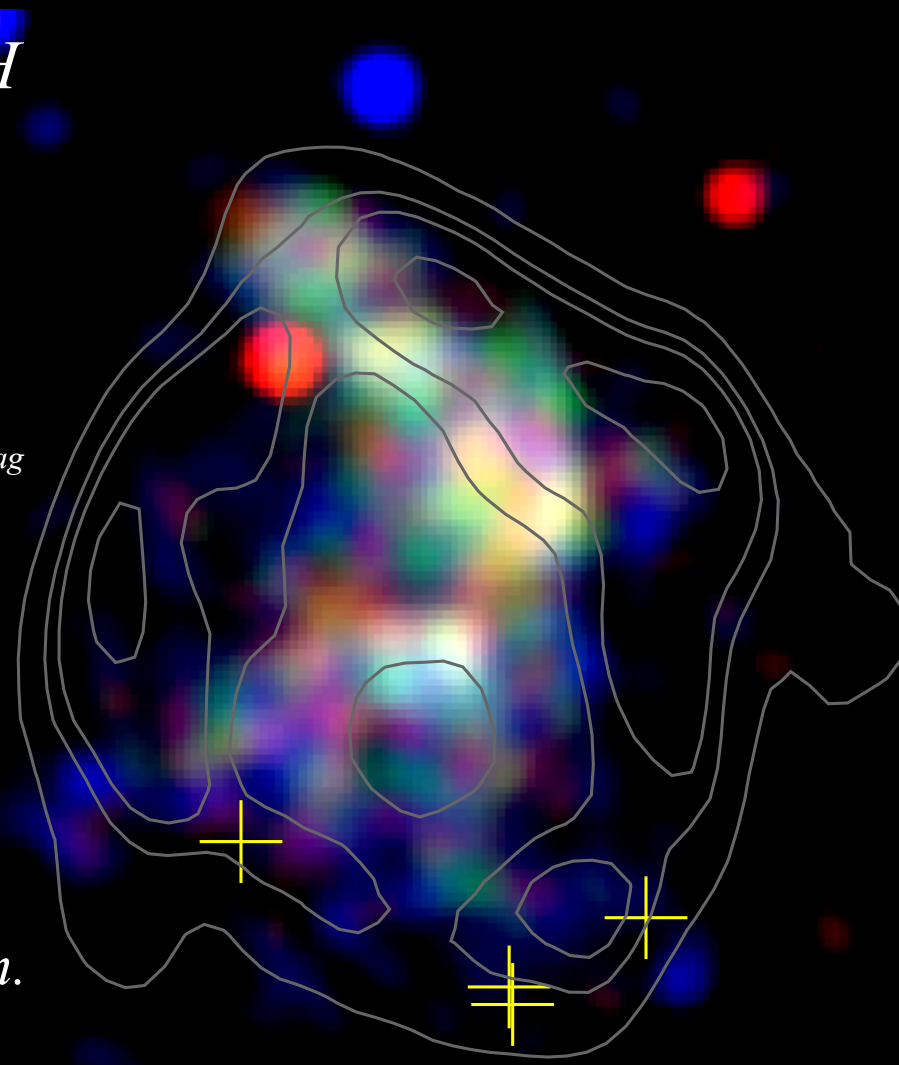


Not unreasonable that this powerlaw component could arise from synchrotron X-ray emission.

Things still to work out…

- *B_{mag} will be higher closer to OH masers.*
  - *Is it valid to assume this for the whole remnant?*
    - *Detection of X-ray filaments with Chandra would help constrain the B_{mag}*
- *kT_e ~0.23 keV is too low for v_s~1300 km/s!*
  - *kT propto V_s^2 => 2 keV*
  - *Shock front could have broken through dense material and is now expanding in a low density medium.*
    - *Currently investigating…*



Summary

- *Dense environments dramatically affect the properties of SNRs.*
- *Mixed Morphology SNR G346.6-0.2 shows evidence of X-ray synchrotron emission.*
  - *Most likely not a PWN.*
  - *Could arise from particles accelerated at the shock front.*
    - *Possibly the first MM SNR with this type of emission.*
  - *However is it valid to assume B field derived from OH masers for whole SNRs?*
  - *Temperature too low for shock velocity.*
- *Up coming XMM-Newton and NuSTAR observations will hopefully shed light on this interesting component.*