COOL STARS IN REALLY HOT PLACES

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The Origin of Diffuse X-rays

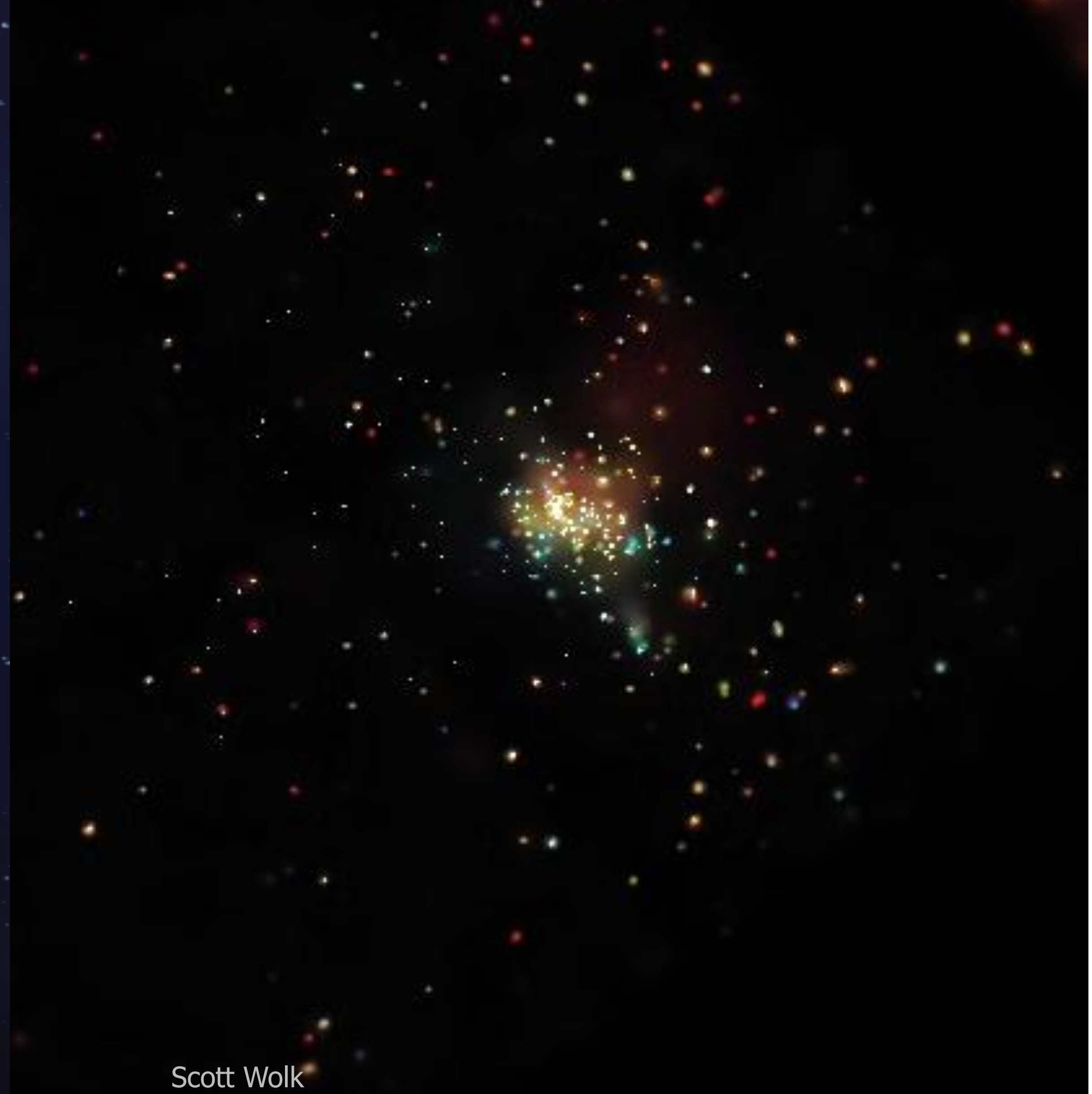
- Hard X-rays could come from compact object powered B fields.
- Soft X-rays are the result of massive star winds clearing material around them.
  - Per OB star:
    - ★L_{bol}~10^{38-39} L_w~10^{36-37} $L_X=\eta L_w$~10^{32-33}
    - ★η~10^{-4}
    - ★Low surface brightness
    - ★But high spatial resolution allows good cleaning of point sources.
- Diffuse emission has now been reported in about a dozen regions of massive star formation.

Key Questions

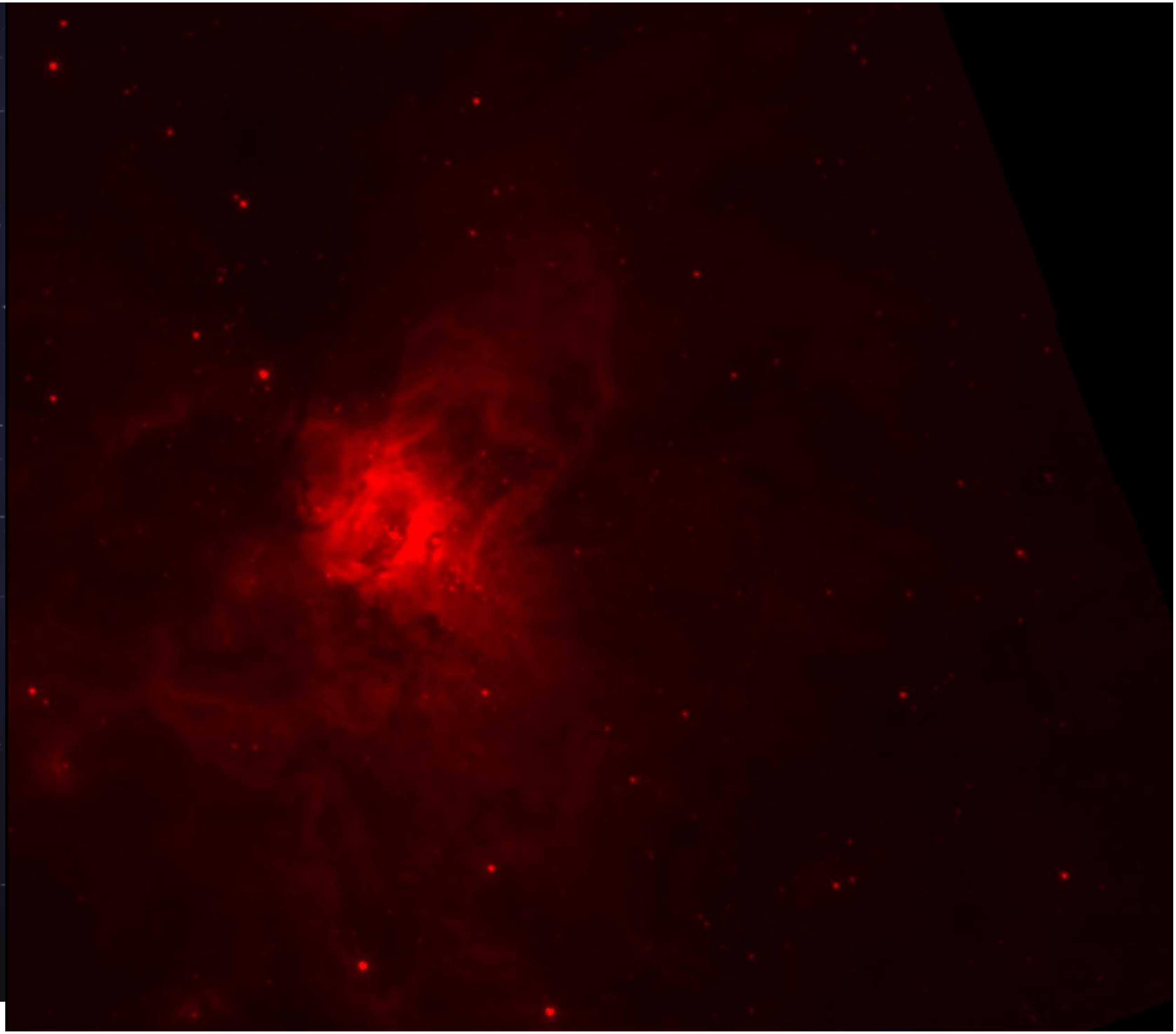
- What produces X-ray super bubbles.
  - If it is supernovae - What kinds?
  - If it is winds - What types of stars and interactions are required?
- Does diffuse X-ray emission interact with the rest of the star forming region?
  - Does it trigger charge exchange?
  - Do other non-thermal processes occur?
- Why do massive star forming GMCs look so similar?
- What is the substructure and content of extragalactic and IR super star clusters

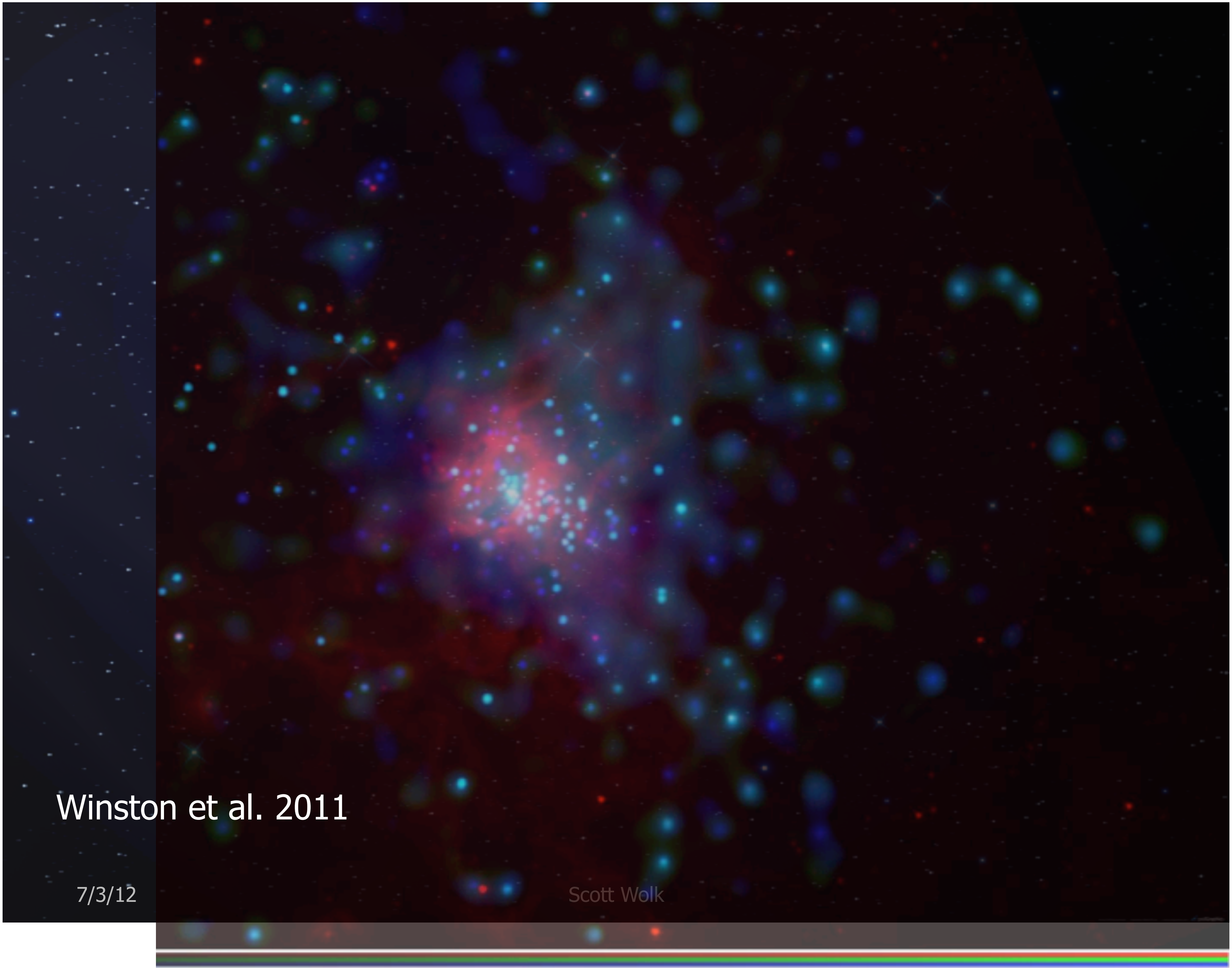
RCW 38

- D~1.7 kpc
- 10’~4.7 pc
- A face on version of the ONC with the molecular cap in place

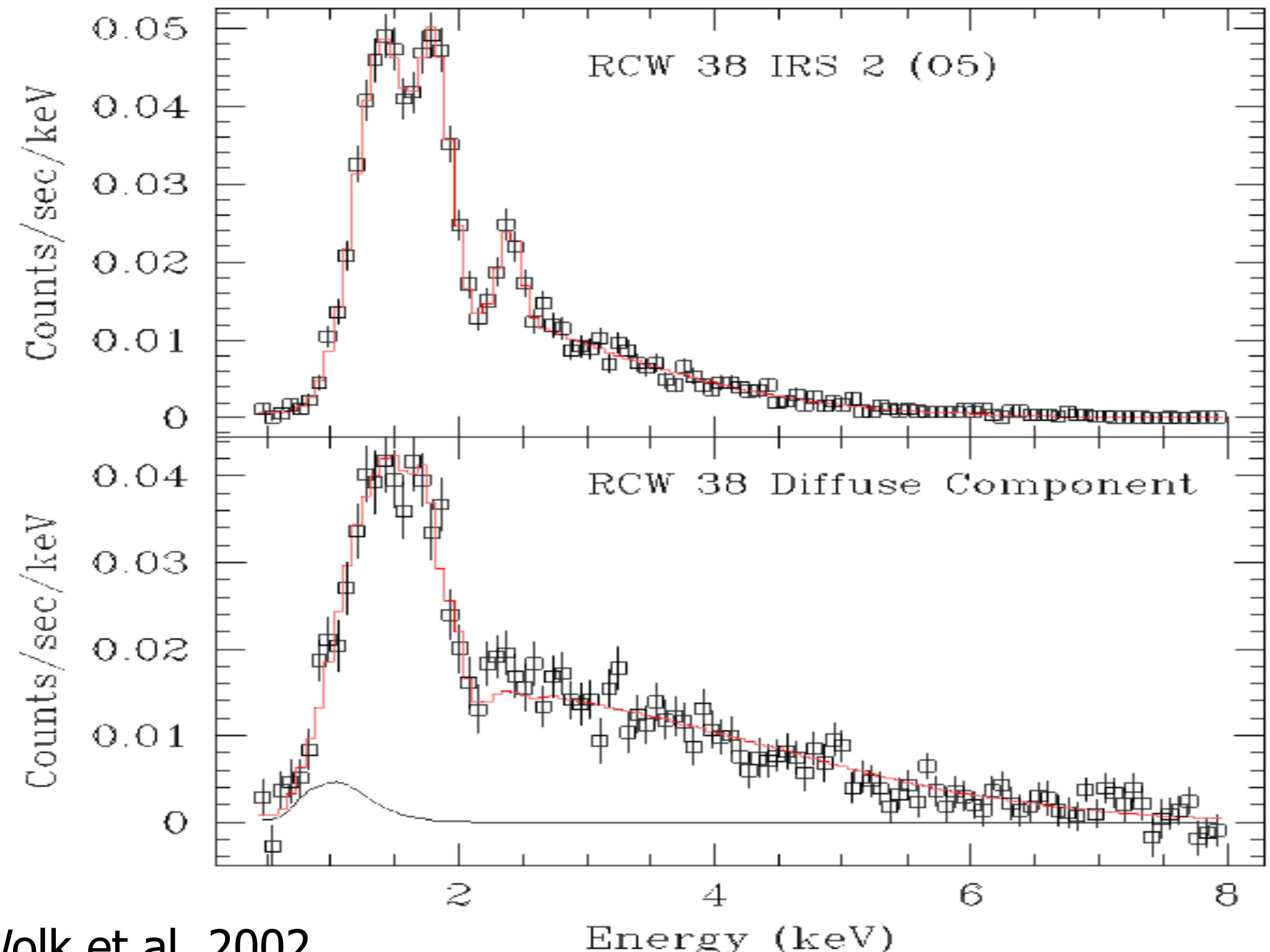


Wolk et al. 2002





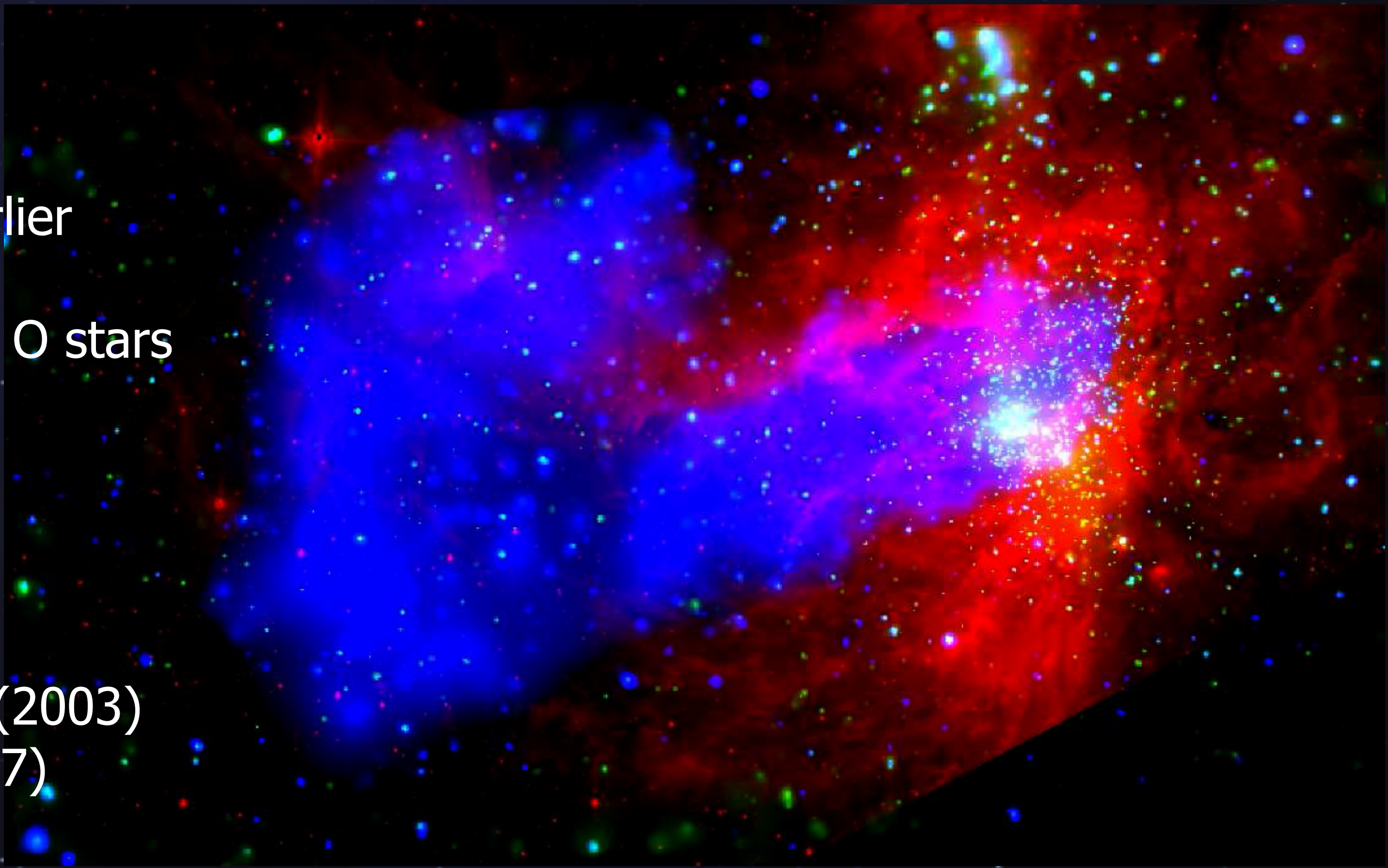
Winston et al. 2011



Wolk et al. 2002

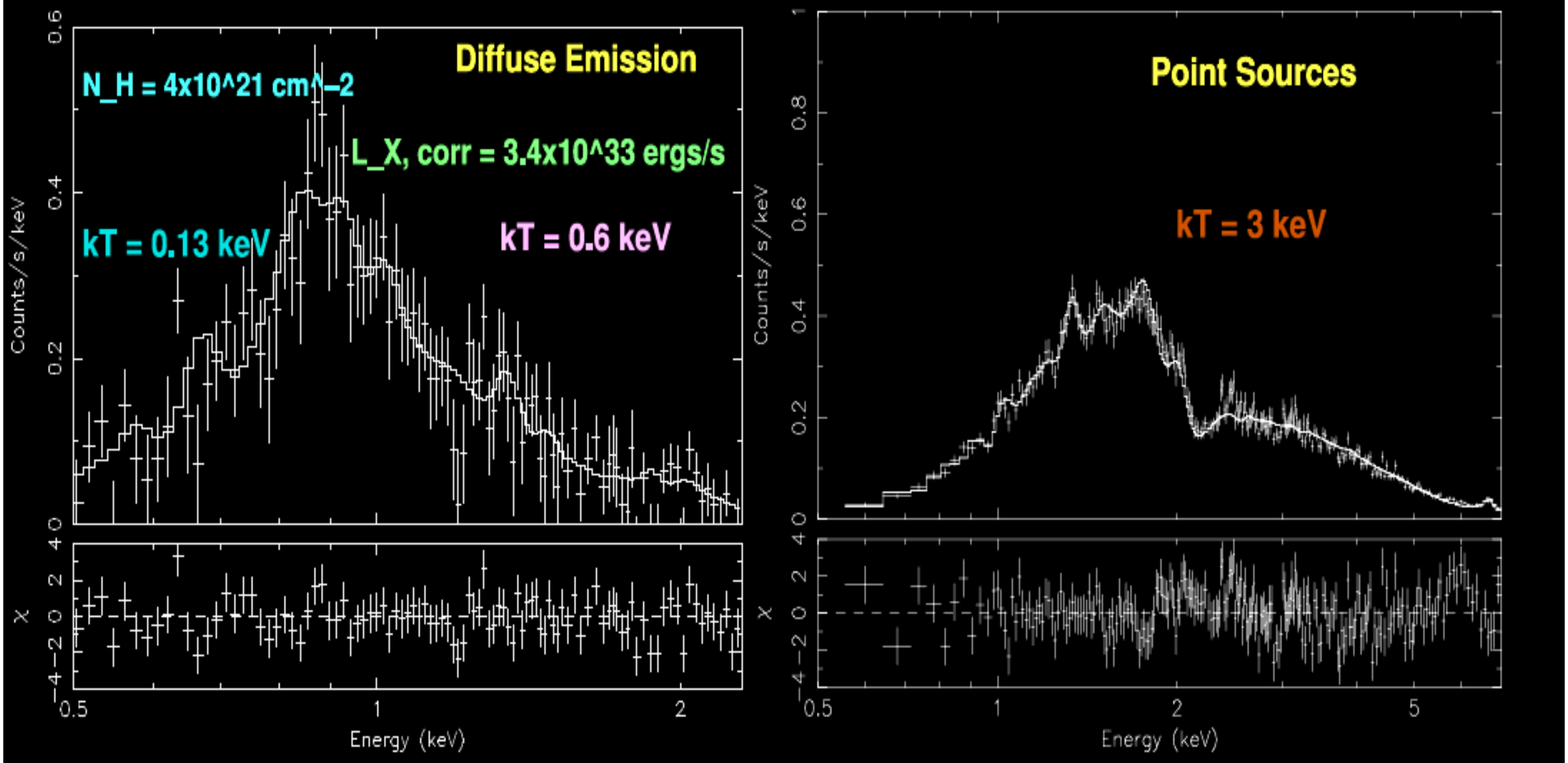
M17- a side view?

- D~1.6
- Age ~1
- 100 stars earlier than B9
- A 1′ "ring" of O stars



Townsley et al. (2003)
Broos et al. (2007)

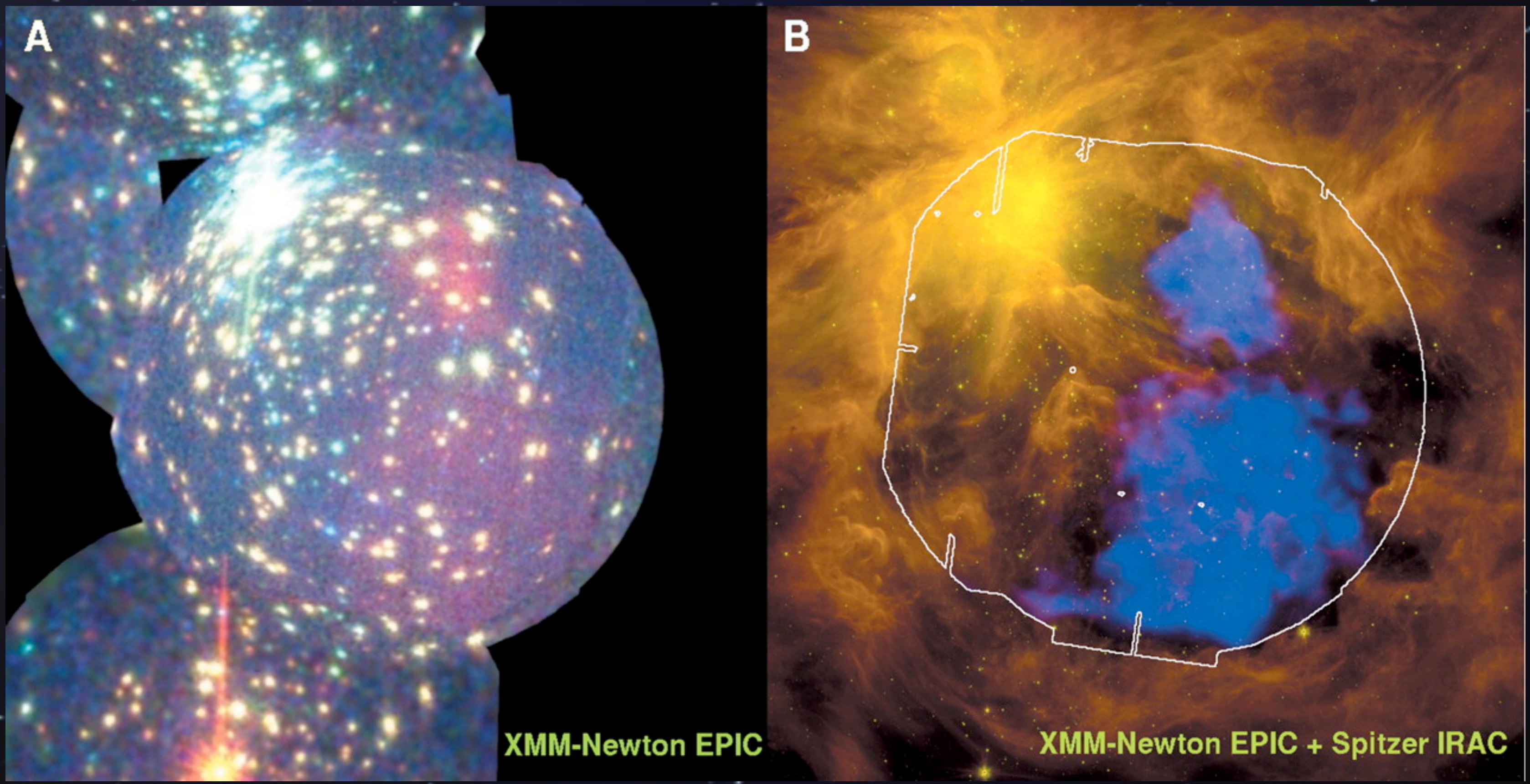
M17 Spectra



Diffuse Emission
N_H = 4x10^21 cm^-2
L_X, corr = 3.4x10^33 ergs/s
kT = 0.13 keV
kT = 0.6 keV
Point Sources
kT = 3 keV
Counts/s/keV
χ
Energy (keV)

Extended Orion Nebula

Güdel et al. 2008



η Carina

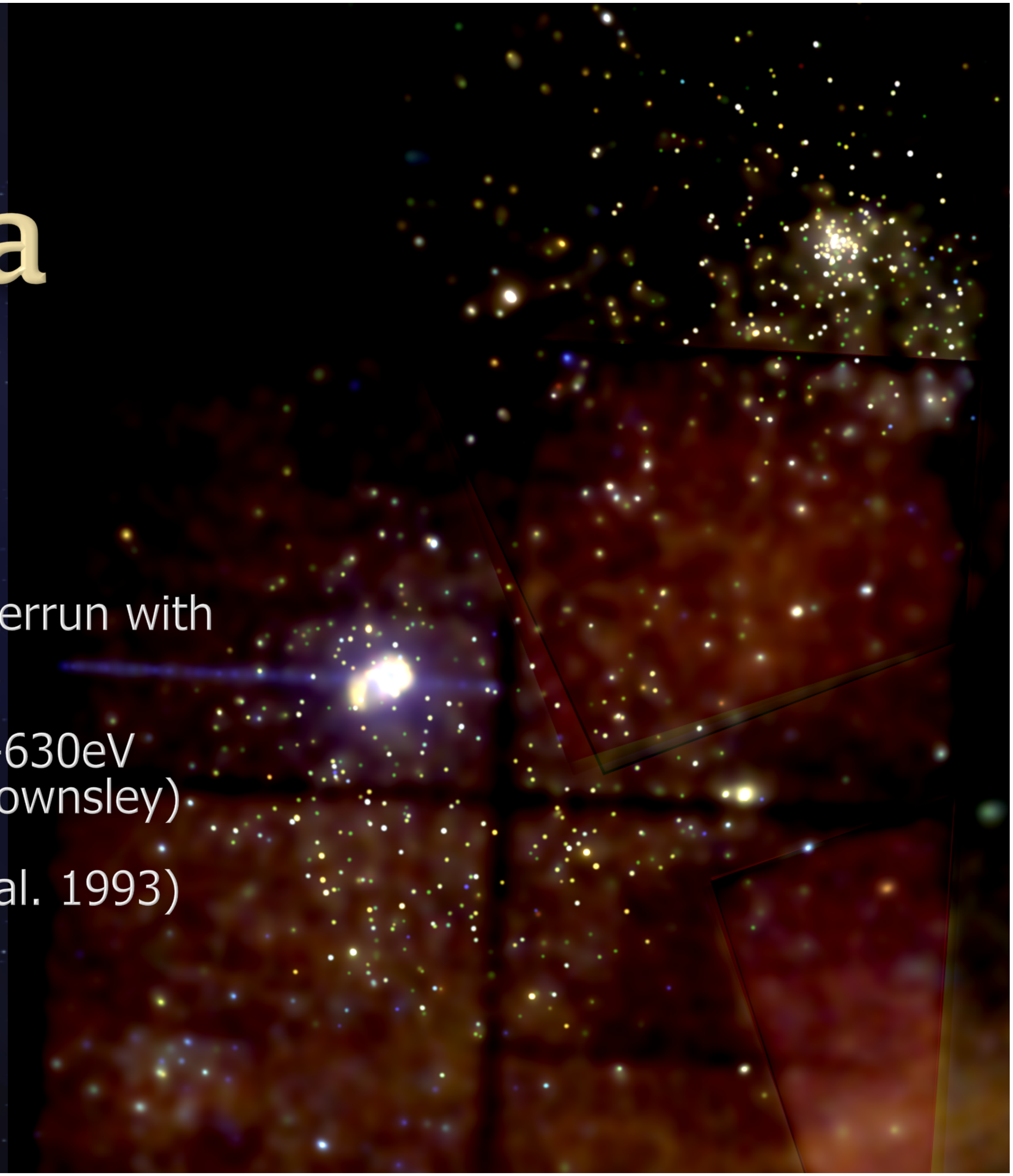
D~2.3 kpc
Age <1 Myr

10′=8.1pc

Whole TR 16 region overrun with soft emission

TR 14 Fitted with 260-630eV plasma with high Fe (Townsley)

"Cavity SNR?" (Chu et al. 1993)

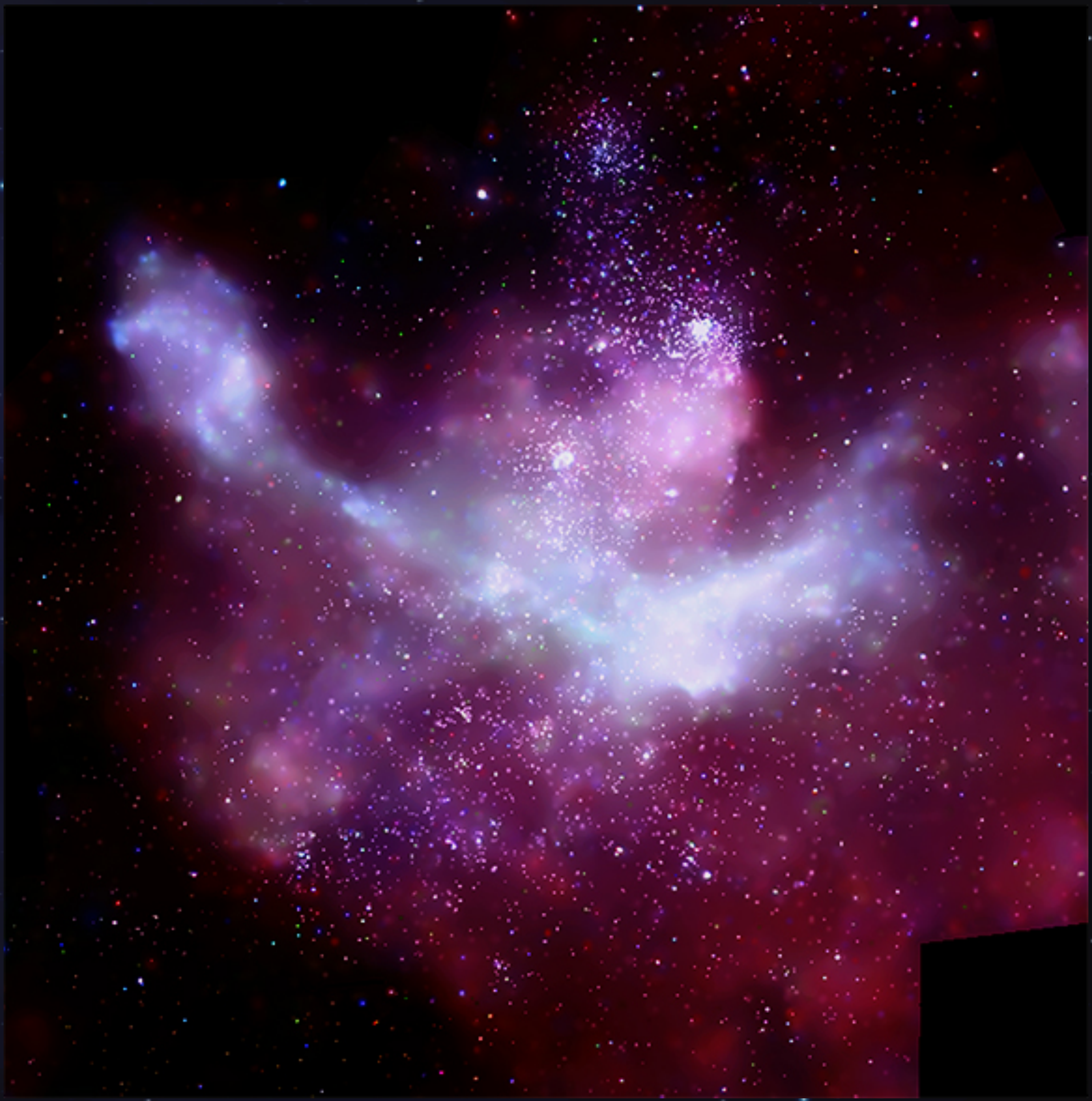


Carina

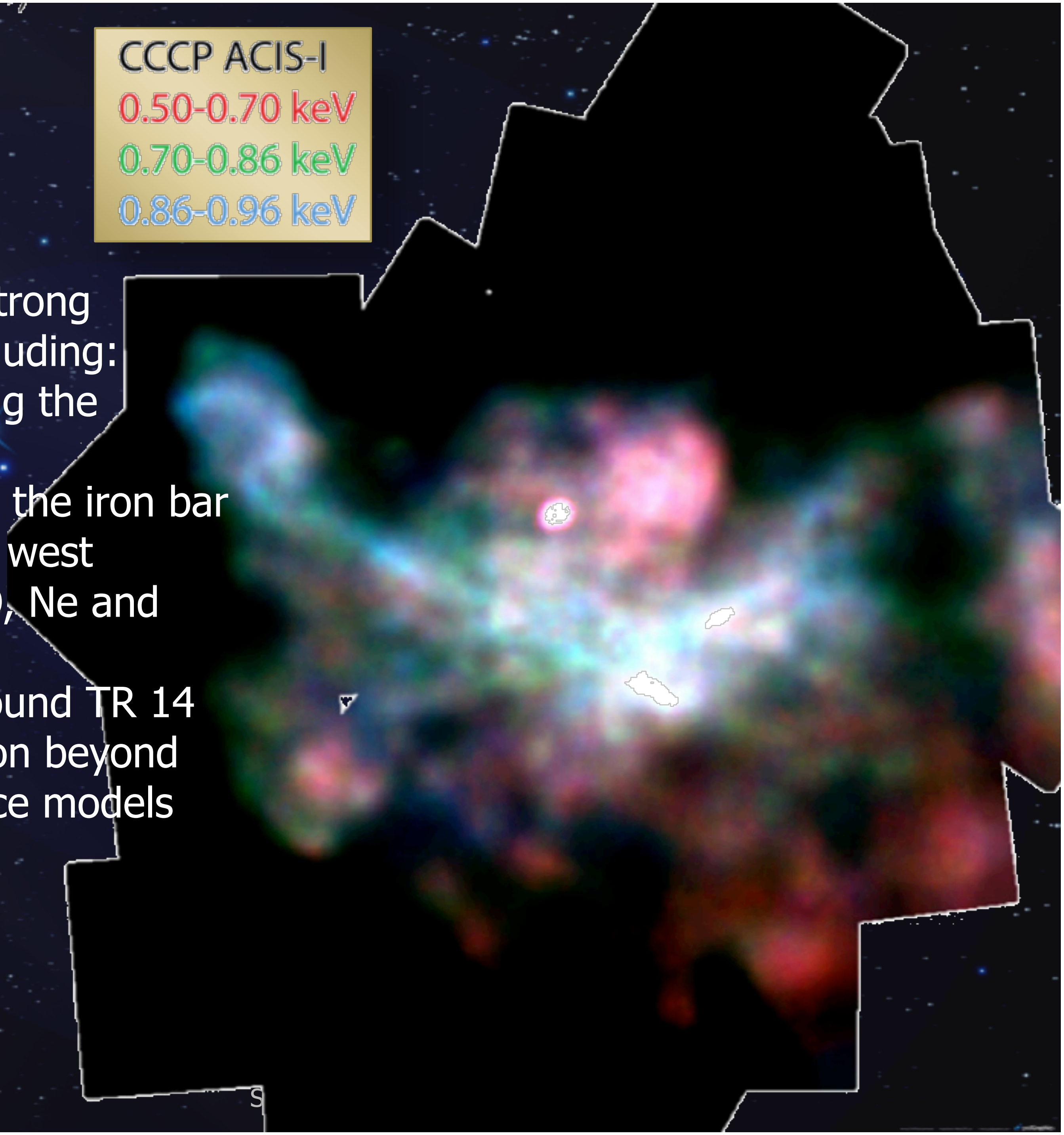
D~2.3 kpc

Several WR stars imply possible SN
1º ~ 42 pc

Townsley et al. 2011



Carina



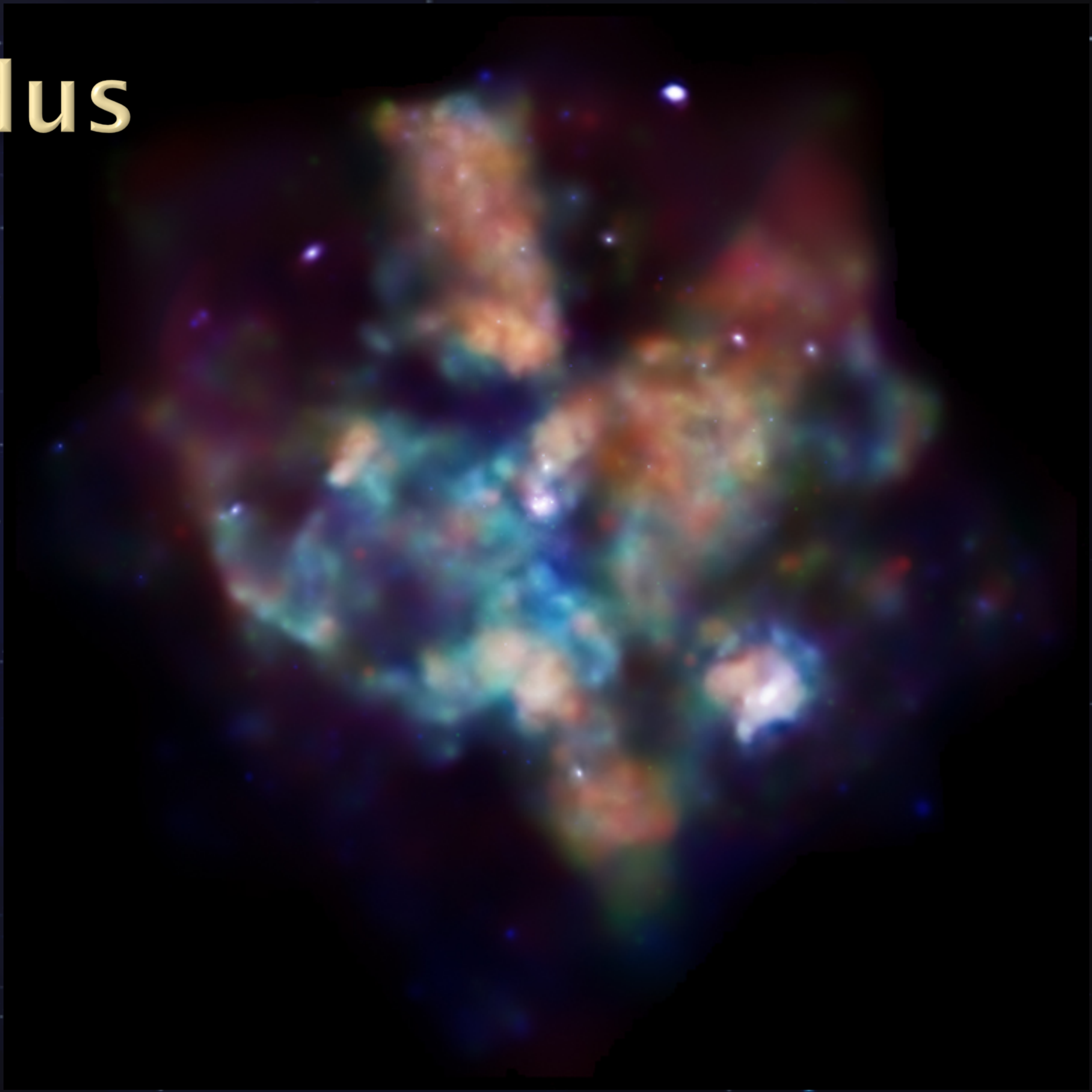
The plasma shows strong differentiation including:

1. An "iron bar" along the middle.
2. Sulfur surrounding the iron bar
3. Si strongest in the west
4. Small pockets of O, Ne and Mg.
5. Mostly thermal around TR 14
6. Excess line emission beyond variable abundance models

Townsley et al. 2011

30 Dorodus

D~ 50 pc
Age (R136)~1myr
SN filled bubbles



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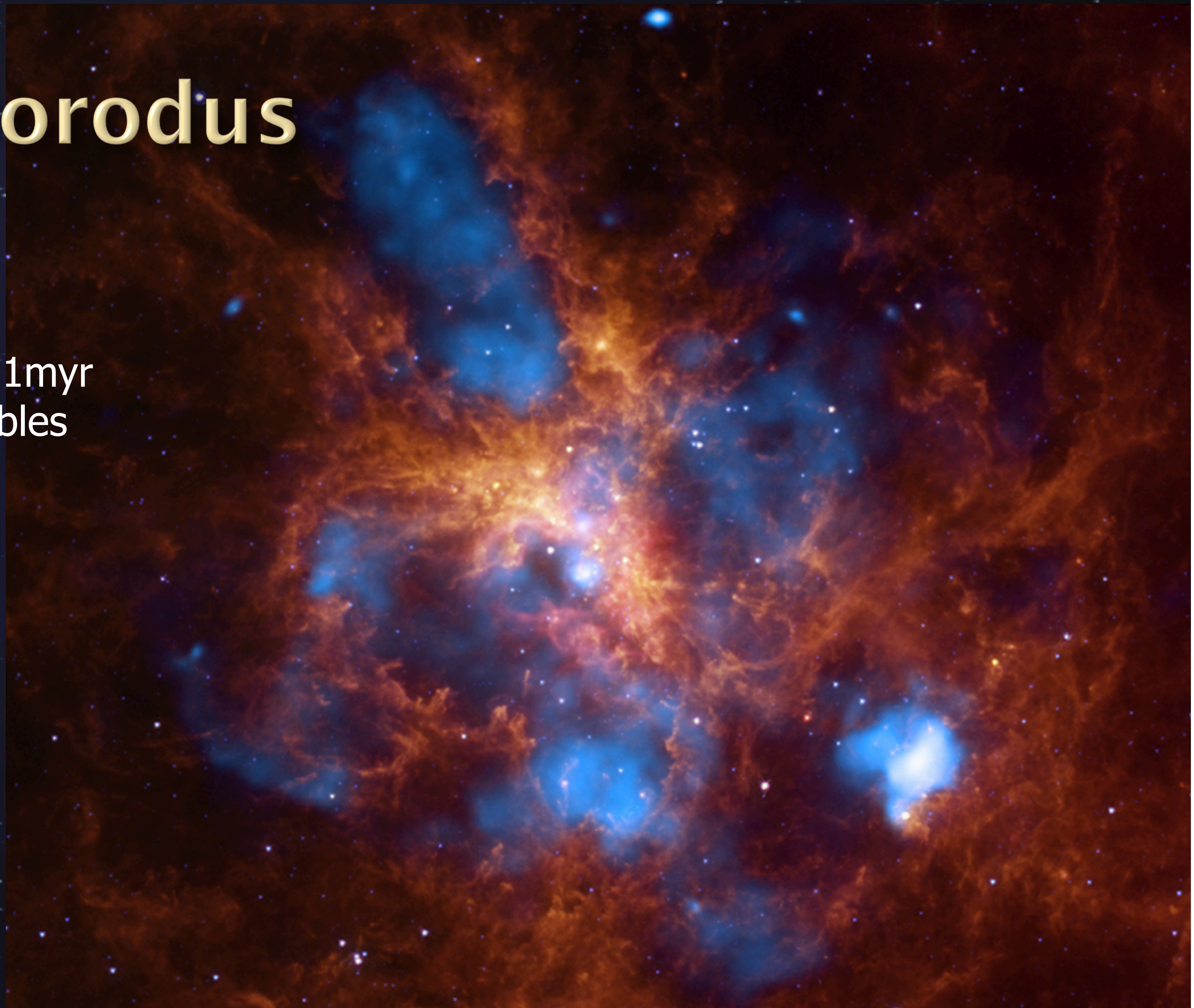
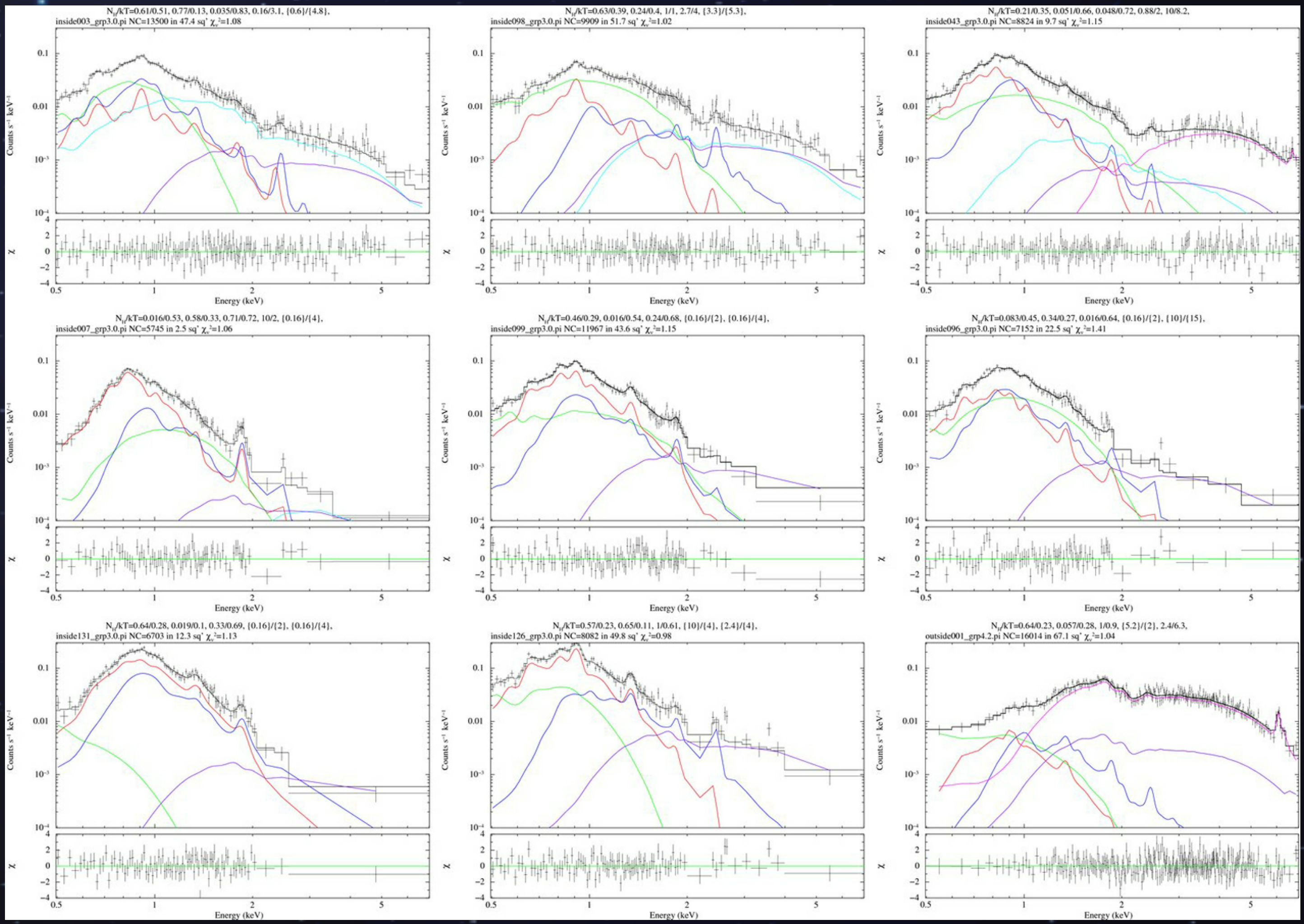


Spectral fits

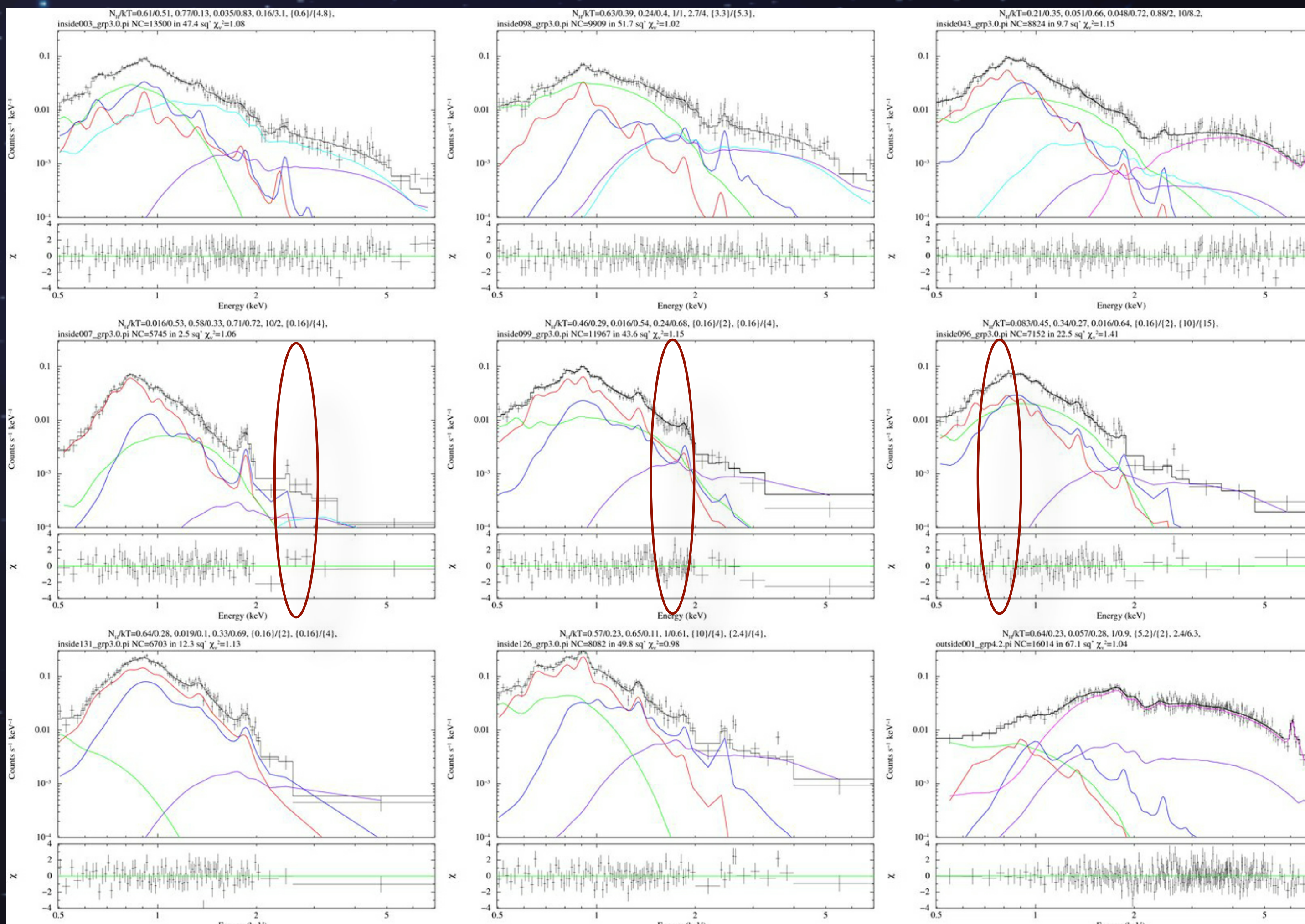
- 2002-2010:
  - Absorbed 1-2 temperature or power-law plasma
- Townsley et al 2011 with more flux in Carina:
  - *TBabs1*vpshock1 + TBabs2*vpshock2 + TBabs3*vpshock3 + TBabs4*apec4 + TBabs5*apec5 + TBabs6*apec6*
  - The first three components allow for soft, medium and hard components of the plasma,
    - ★the fourth is unresolved stars,
    - ★the fifth background galaxies,
    - ★the sixth the galactic ridge.

Spectral fits – Carina



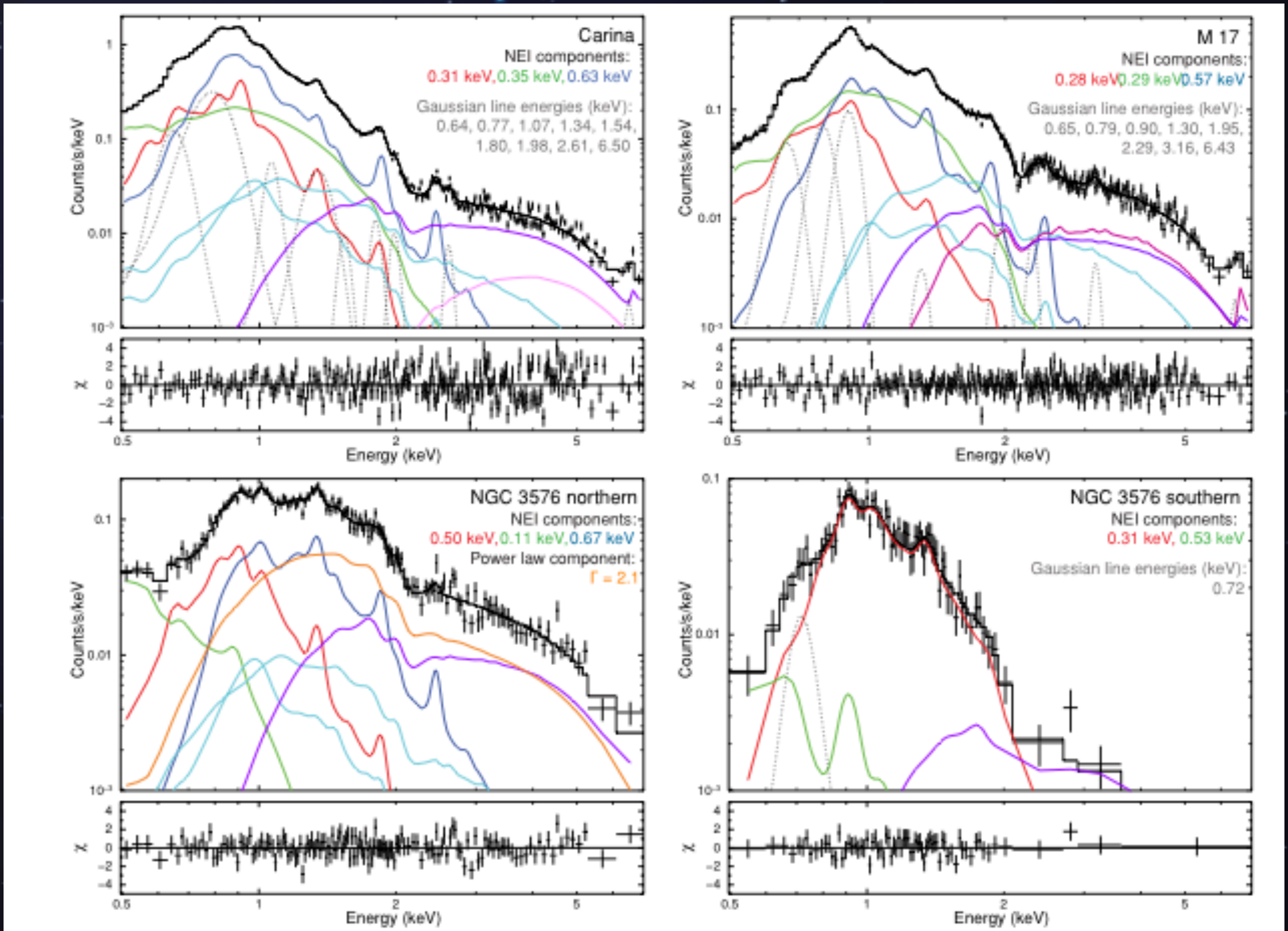
Townsley et al. 2011

Spectral fits – Carina



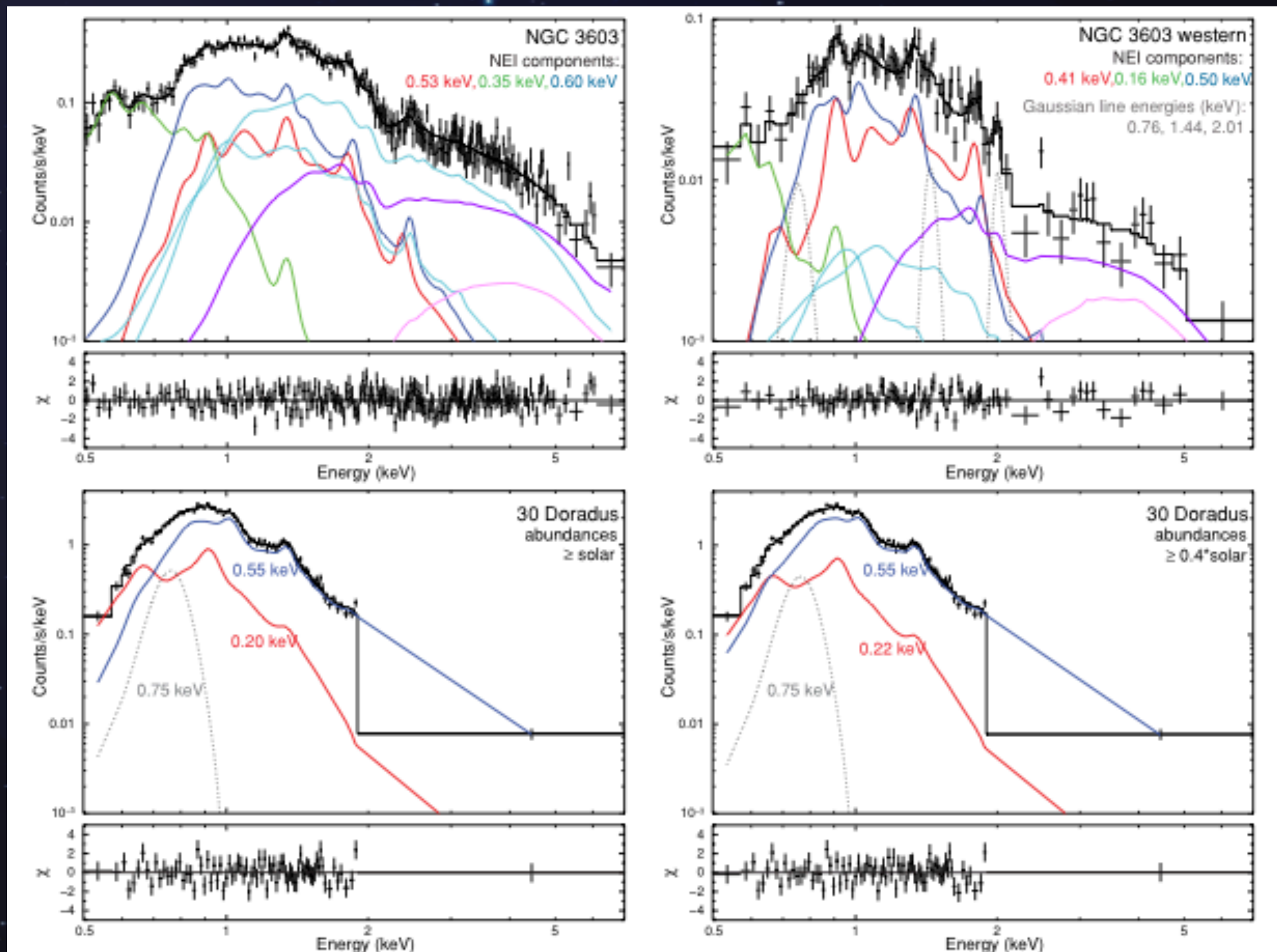
Townsley et al. 2011

Spectral fits



Townsley et al. 2011

Spectral fits



Townsley et al. 2011

What is the Diffuse Emission?

Diffuse emission has now been reported in about a dozen regions of massive star formation

- Some are thermal emission.
  - Wind driven models of diffuse emission tend have cool & thermal emission profiles.
    - ★ a softer component with kT ~ 0.1-0.6 keV
    - ★ a harder component with kT ~ 0.5-1.0 keV.
  - Seem to need an O6 or earlier star.
  - Pressure would be high leading to shocks.
  - Lines seen – are not well fitted by current thermal models
    - ★ Deficits seen ~ 0.65, 0.7, 0.9, 1.3, 1.9, 2.3 keV etc.
    - ★ Might be attributed to charge exchange.
- A couple appear to be dominated by power-law emission.
  - NGC 3576 and RCW 38
  - Synchrotron implies a B field to excite electrons
  - Common in SNR but lack of lines implies a shell type SNR, not consistent with the morphology.
- Hybrids - supernova with a massive O star wind filling the cavity.

NGC 281

~2.5 Kpc

O6 max

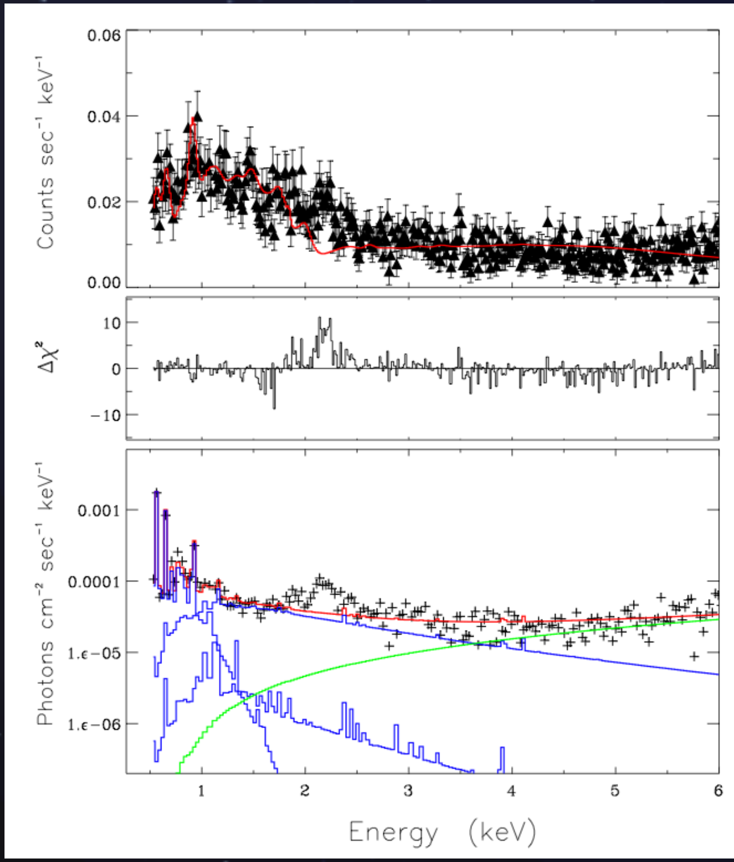
No differentiation in the plasma

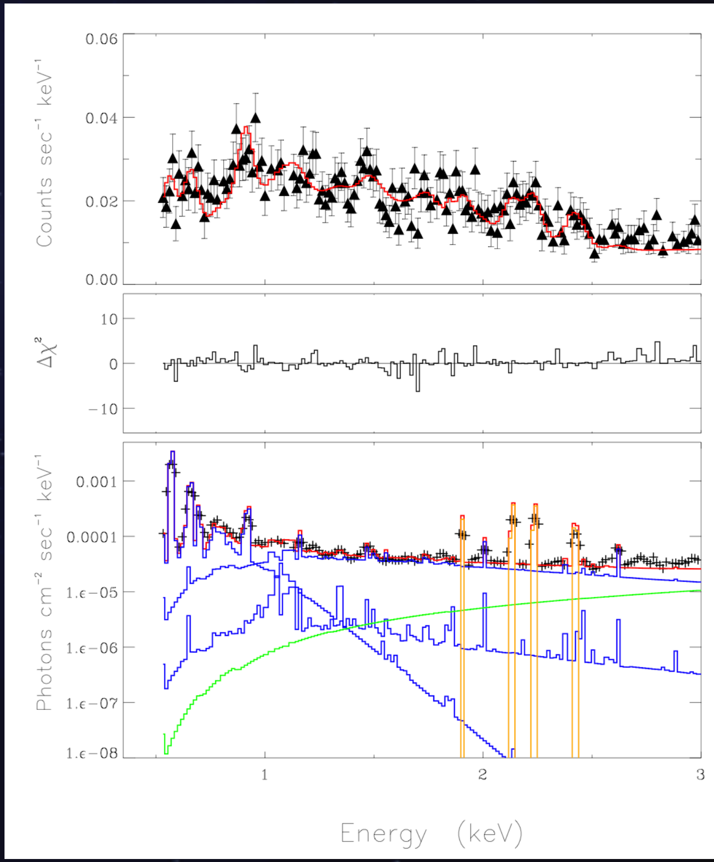
2 interacting star forming regions

Wolk et al. 2012

NGC 281

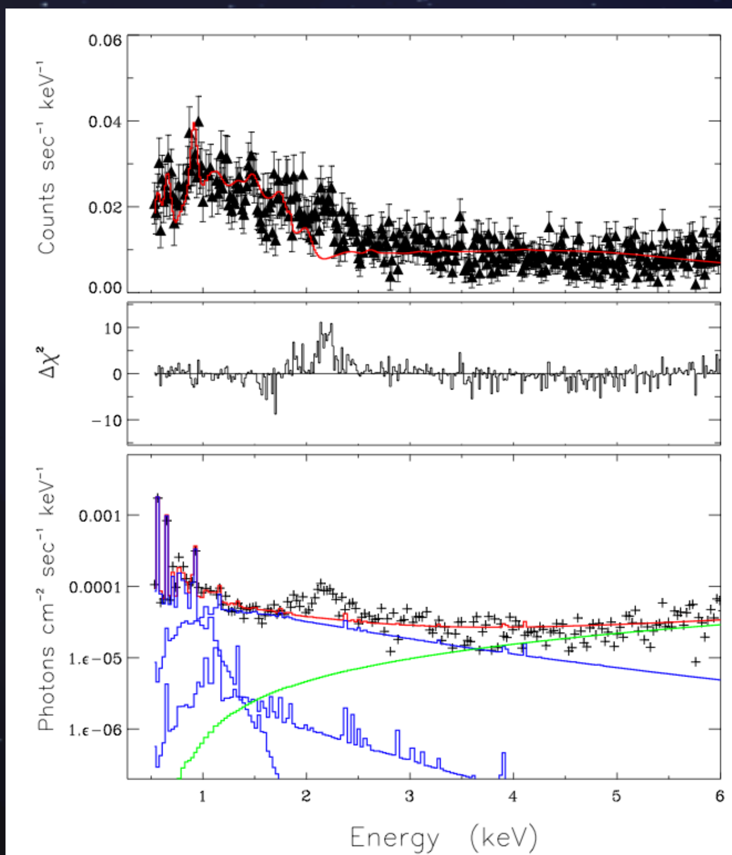
Spectra indicate excess line emission

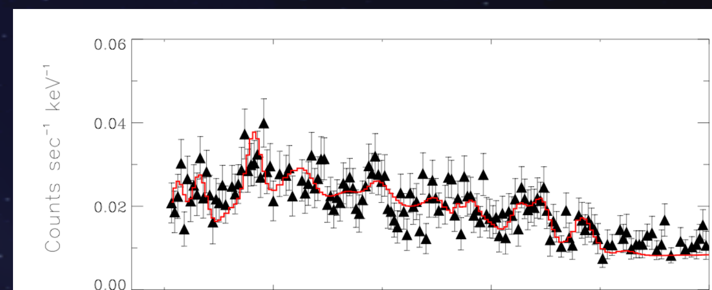


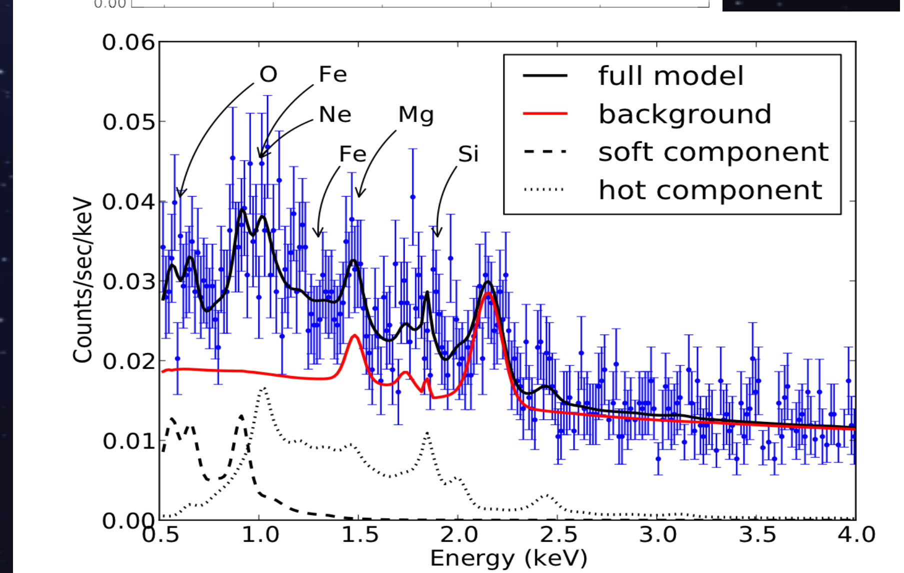


NGC 281

Or do they? Variable abundances fit as well







Discussion

- Some but not all diffuse emission shows lines excesses.
  - But what is the source of the excess?
- CXE has been clearly seen in Cygnus loop Katsuda et al. 2011
  - measured the $K\alpha$ to $K(\gamma\delta\varepsilon)$ and
  - noted the unusual emission is confined to the rim.
- Excess emissions are not seen to brighten near the edges of M17 NGC 281 or 30 Dor.
- Radiative recombination Has also been identified in SNR:
  - Requires a central hot (kT ~ 1.0 keV) region surrounded by a cool (kT ~ 0.2 keV) region
  - Give rise to some harder species Mg (2.0 keV), Si (2.7 keV) and S (3.5 keV)
- The ACIS background is spatially and temporally variable at levels that matter for this work
- The atomic data bases are very incomplete above 1 keV and these features may simply be lines which are not included in the models yet.
- μcalorimeters should be decisive here.