X-ray Observations of Massive Star Formation and Feedback

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X-rays from Massive Stars

Minishocks in fast winds
(Lucy & White 1980) ➔
soft, constant X-rays (<1 keV).

Then these powerful winds encounter the ISM...

Historically, these diffuse X-rays were not seen.
The problem: limited spatial resolution confuses any diffuse X-ray emission with the point source population in a young cluster; also $L_x < \text{theory.}$
M17, The Omega Nebula: A Fire-breathing Dragon

- $D \sim 2.2 \text{ kpc}; 10' \sim 6.4 \text{ pc}$.
- Closest giant HII region.
- Main cluster age $\sim 0.5 \text{ Myr}$.

2MASS JHK atlas image, $15' \times 15'$

ROSAT PSPC image, $\sim 35' \times 35'$. Point sources or diffuse emission?
The dragon’s breath: Chandra clearly detects diffuse X-ray emission and separates it from the stellar population.

A combined Spitzer/Chandra view of M17.

Townsley et al. 2003: diffuse emission has $kT = 0.6 \text{ keV}$, $L_x = 3 \times 10^{33} \text{ ergs/s}$. 

ACIS-I
0.5-2 keV
2-7 keV
GLIMPSE
IRAC 5.8μm

17´x30´, 320+92 ksec,
~2700 X-ray sources.
M17’s O4-O4 Binary: The Eyes of the Dragon

M17 core, 30″ × 30″

\[ N_H = 2.2 \times 10^{22} \]

\[ Z = 0.5Z_{\text{sol}} \]

\[ L_x = 3 \times 10^{33} \text{ ergs/s} \]

\[ N_H = 1.9 \times 10^{22} \]

\[ Z = 0.5Z_{\text{sol}} \]

\[ L_x = 2 \times 10^{33} \text{ ergs/s} \]

\[ \text{Counts/s/keV} \]

\[ \text{residuals} \]

\[ \text{Energy (keV)} \]

\[ \text{photons/ks/cm}^2 \]

\[ \text{TIME (ks)} \]

\[ \text{counts/s/keV} \]

\[ \text{residuals} \]

\[ \text{Energy (keV)} \]
New from Chandra: Hard X-rays from Massive Stars

Magnetically-channeled wind shocks (Babel & Montmerle 1997) \(\Rightarrow\) medium X-rays (~1-4 keV).

Colliding winds in close binaries \(\Rightarrow\) really hard X-rays (~6 keV), sometimes variable. Hoffmeister et al. 2008 find M17 O4 stars (both) to be spectroscopic binaries!

Corcoran et al. 2004

\[ kT=0.6 \text{ keV} \]

\[ kT=9.7 \text{ keV} \]

The kicker: these hard X-rays are gone by ~2 Myr! Perhaps fossil B fields die away or binaries are disrupted.
W3: A Cluster of Clusters

D = 2.0 kpc; 10′ ~ 5.8 pc.

Feigelson & Townsley 2008
X-rays trace massive stars that ionize young HII regions.

A new O star ionizing a HCHIIR: IRS5 NIR1 $N_H \rightarrow A_V = 150$.

W3(OH) is similar.
NGC 3576: X-rays Give Strong Evidence for Triggering

- $D \sim 2.8$ kpc; $10' \sim 8.1$ pc.
- Age $<1$ Myr.
- Second closest giant HII region, still forming stars.
- Two massive stars sit in a dust cavity north of GMC.
The embedded cluster: due to hard X-rays, ACIS finds the ionizing sources!

X-ray surprises:
* PSR J1112-6103 has a pulsar wind nebula.
* There is a large young stellar cluster in the dust cavity.
* Diffuse emission fills the cavity (note shadowing), hard X-rays may be signature of a cavity SNR.
* Southern outflow looks like M17's.
Hard O star emission allows Chandra to access massive star formation, giant HII regions across the Galaxy.

W51A is a giant HII region complex at ~7 kpc.

W51 IRS2 complex, 8” x 12”

IRS2E is also likely to be a massive binary!
Chandra 1.2 Ms survey: 22 ACIS-I pointings covering ~1 square degree; all but one observed.

Current tally ~14,000 point sources with 0.2″--0.4″ positions.

Field covers ~50 known O,WR stars.
MSX 8μm
0.5--2 keV
2--7 keV
Soft diffuse X-rays:

- 500--700 eV
- 700--860 eV
- 860--960 eV

Brightness
(total $L_x \sim 10^{35}$ ergs/s),
spectra, and complexity
may indicate a cavity SNR.
Blowhards and Windbags: A Summary

Some of your favorite ALMA targets are immersed in 10-100 MK X-ray plasmas!

* O star - ISM interactions lead to parsec-scale soft X-ray emission; this may pervade the Galactic plane but is hard to detect.

* The $10^4$K Strömgren Sphere is really a Strömgren shell filled with $10^7$K plasma in many cases; Chandra sometimes sees X-ray outflows in edge-on blister HII regions.

* Wind-wind interactions and/or B fields lead to harder X-rays close to star(s) -- this may be a way to determine close binarity or detect embedded massive clusters.

* This unexpected emission is gone by 2 Myr -- binary evolution or decaying fossil fields?

* BRIGHT diffuse soft X-rays are usually due to cavity SNRs.
Carina as a microcosm of starburst astrophysics: the Chandra Carina mosaic in context.

Plans for 2009

0.5-2 keV ACIS-I
MCELS H-alpha
(You-Hua Chu)
Spitzer 8 μm
(Bernhard Brandl)

30 Doradus