Remarkable X-ray Emission from the Young O4-O4 Binary in M17

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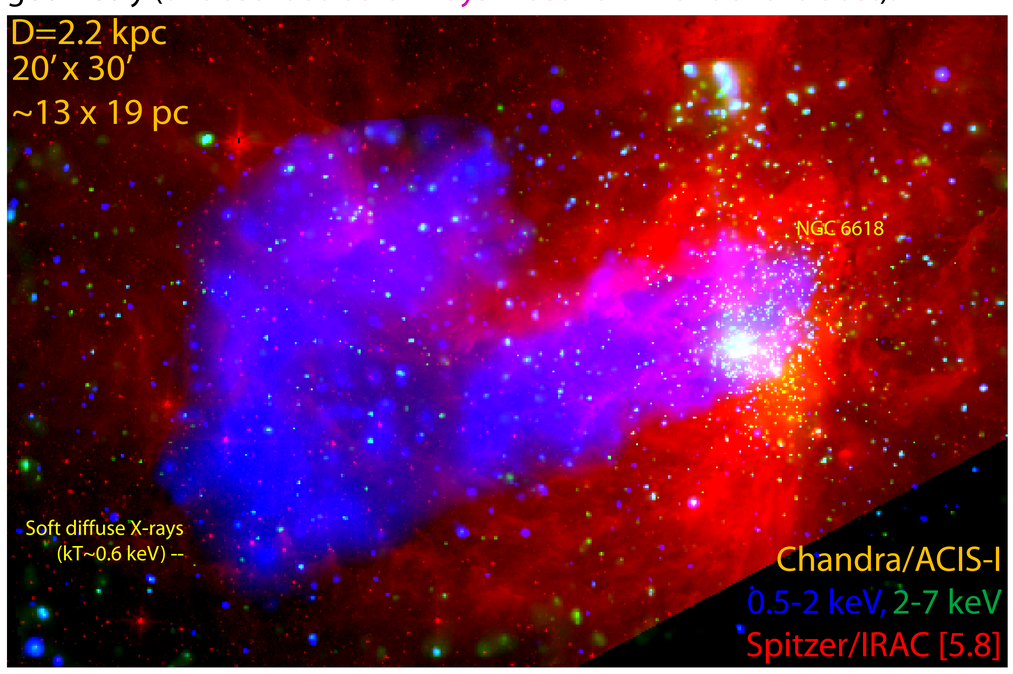
The Chandra X-ray Observatory, with its imaging CCD camera ACIS-I, is revealing that very young massive stars are often hard X-ray emitters. These unexpected hard X-rays may come from magnetically-channeled wind shocks around magnetic O stars, but in some cases there is compelling evidence that colliding winds from binary O stars are the cause. To add to the mystery, Chandra shows that these hard X-rays are not present in cluster O stars aged more than about 2 million years -- do fossil B fields die away, or are massive binary systems somehow disrupted early on? Whatever the cause, these hard X-rays can reveal early stages of massive star formation behind 150 magnitudes of visual extinction and from half-way across the Galaxy.

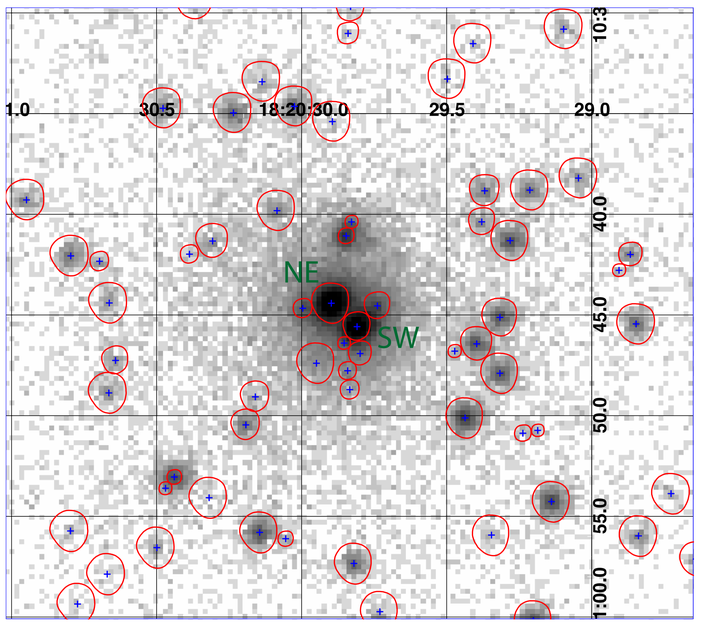
M17, The Omega Nebula

M17 is the closest giant HII region (D=2.2 kpc, Hoffmeister et al. 2008); it hosts the very young (~0.5 Myr, Hanson et al. 1997) massive cluster NGC 6618. This Chandra/ACIS-I mosaic (92 ks eastern cavity + 230 ks NGC 6618), finds 2729 X-ray point sources (mainly low-mass pre-main sequence stars plus all known O stars; Broos et al. 2007) and extensive diffuse emission (kT ~ 0.6 keV or 7 MK). Spitzer traces heated dust in the photoionization fronts. Soft X-ray shadowing reveals the cavity's geometry (unabsorbed soft X-rays must lie in front of the dust).



A FIRE-BREATHING DRAGON: hot plasma generated by O star winds emanates from a fissure in this edge-on blister HII region then billows into a cavity to the east, outlined and sometimes absorbed by heated dust traced by Spitzer. This is our best example of diffuse X-rays from a wind-blown bubble (Townsley et al. 2003).

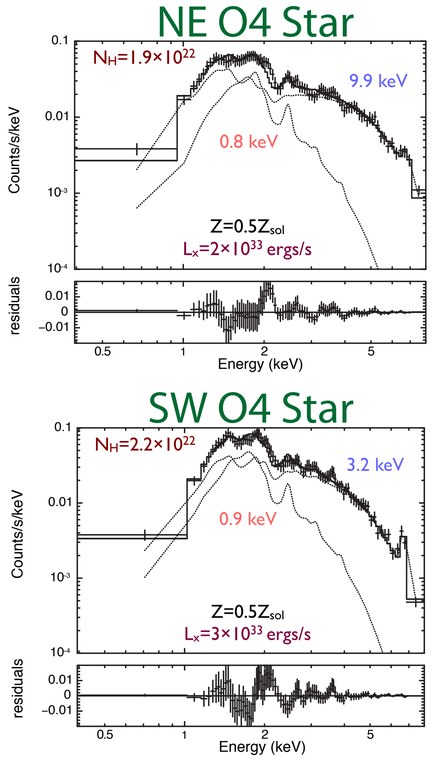
M17's O4-O4 Binary: The Eyes of the Dragon

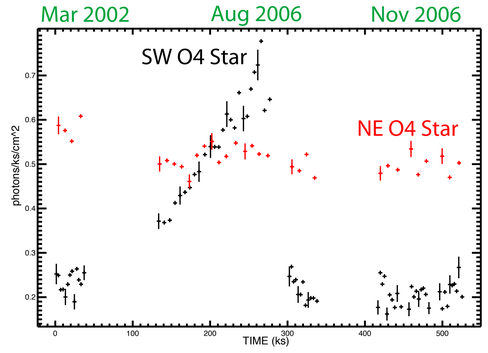


AN ACIS-I ON-AXIS IMAGE of the M17/NGC 6618 core, 30″ x 30″. Source positions are shown with +'s; red polygons show 90% PSF extraction regions (smaller for crowded sources). The two brightest sources are the O4-O4 binary, separated by 1.8″.

THE EXTREMELY HARD X-RAY SPECTRUM OF THE NE O4 STAR AND THE VARIABLE LIGHTCURVE OF THE SW O4 STAR LEAD US TO CONCLUDE THAT BOTH ARE LIKELY COLLIDING-WIND BINARIES. BOTH STARS WERE RECENTLY FOUND TO BE BINARY VIA VISUAL SPECTROSCOPY (HOFFMEISTER ET AL. 2008), SO NGC 6618'S CORE CONTAINS AT LEAST FOUR O4 STARS.

X-RAY SPECTRA of the O4 stars. Both stars show unusually hard spectral components in addition to the soft components expected from minishocks in the individual stellar winds (Lucy & White 1980).



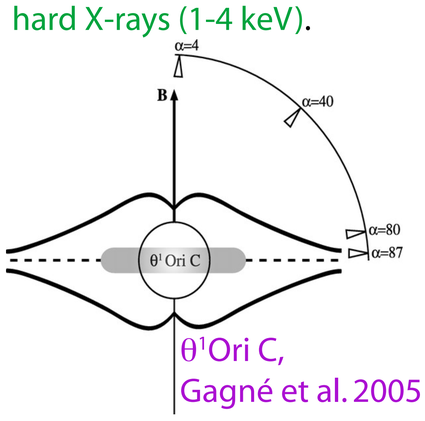


X-RAY LIGHTCURVES show only modest flux changes in the NE O4 star, but the SW O4 star brightens by a factor of ~3 in <2 days, then turns over and has returned to its quiescent level 3 days later.

This behavior is not predicted by normal wind minishocks or magnetically-channeled wind shocks.

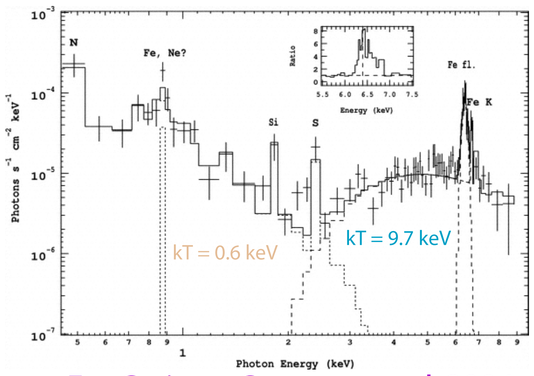
New from Chandra: Hard X-rays from Massive Stars

Magnetically-channeled wind shocks (Babel & Montmerle 1997) can produce medium-hard X-rays (1-4 keV).



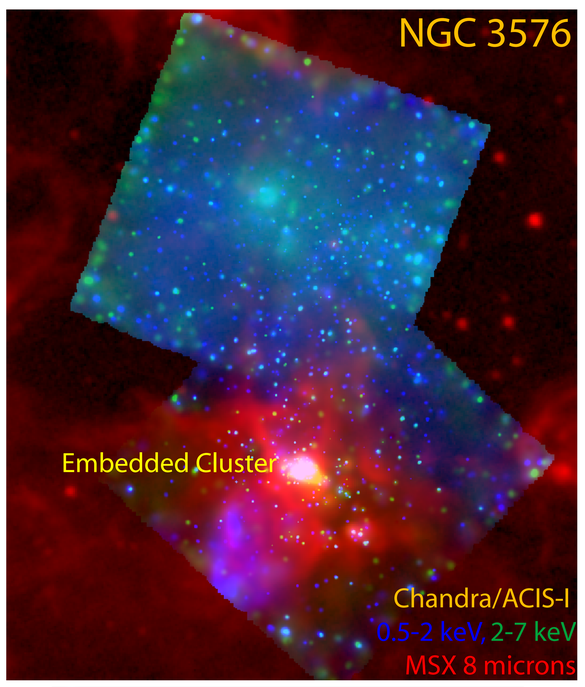
θ1Ori C, Gagné et al. 2005

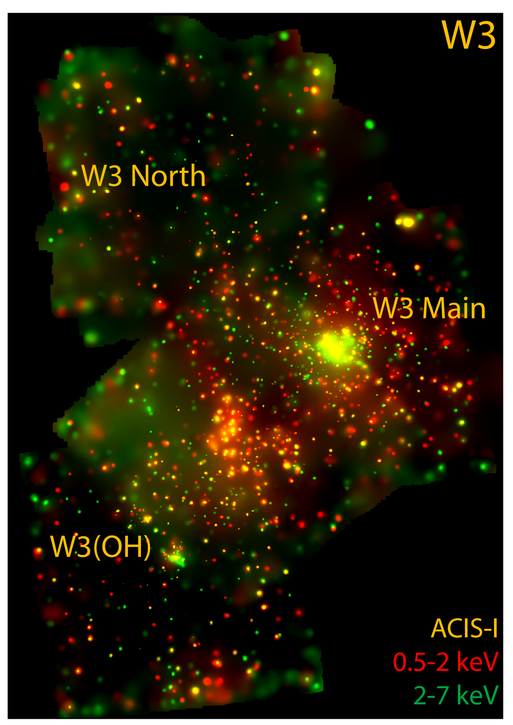
Colliding winds in close binaries can produce really hard X-rays (>6 keV) that are sometimes variable.

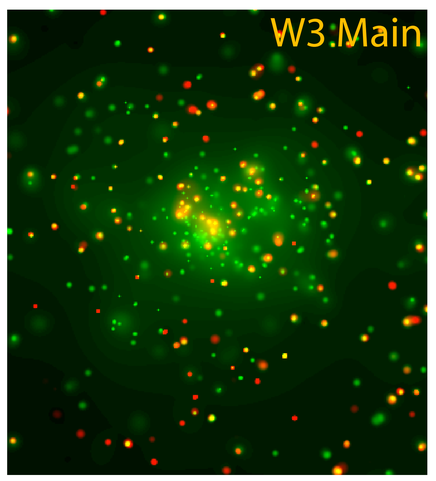


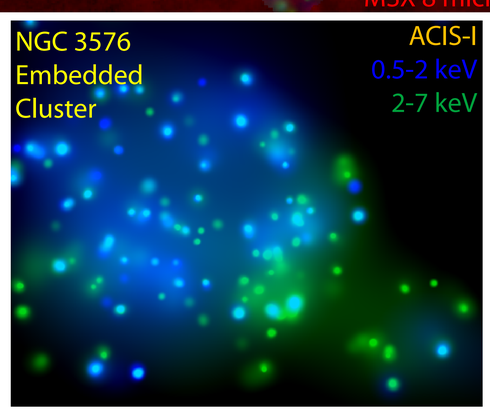
Eta Carinae, Corcoran et al. 2004

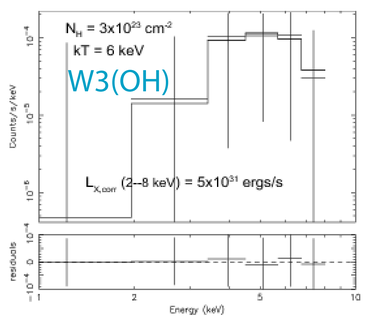
Other Examples of Hard X-rays from Embedded O Stars

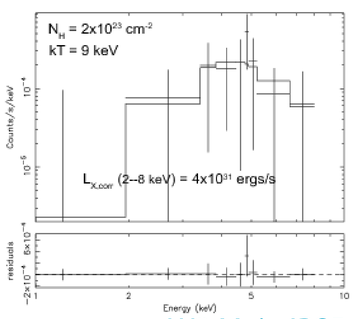










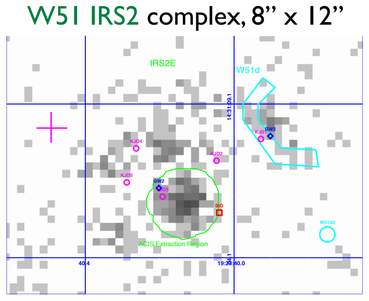


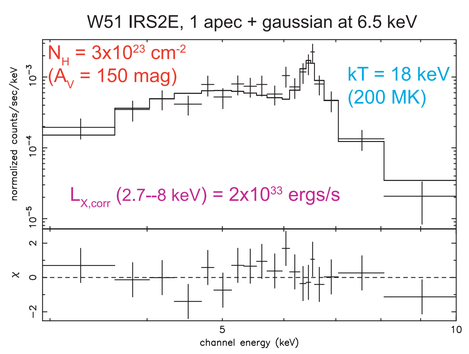
W3 Main IRS5

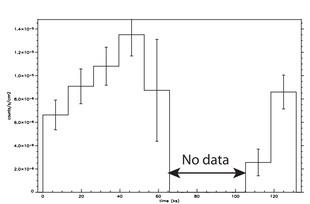
Hard O star emission allows Chandra to access massive star formation, giant HII regions across the Galaxy.

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!

DUE TO THEIR ANOMALOUS HARD X-RAY EMISSION, ACIS FINDS THE IONIZING SOURCES IN W51 IRS2E, NGC 3576'S EMBEDDED CLUSTER, THE PROTOTYPICAL ULTRACOMPACT HII REGION W3(OH), AND THE HYPERCOMPACT HII REGION W3 MAIN IRS5 NIR1.