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The Eagle Nebula: Pillars of Creation, EGGs, and PMS Stars in NGC 6611

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Abstract. We report on *Chandra* ACIS-I observations of the Eagle Nebula containing the young Galactic cluster NGC 6611 and the dark columns called the "Pillars of Creation.". We find that NGC 6611 contains a rich collection of young X-ray emitting stars, but the EGGs at the edge of the pillars are not detected at levels below the Orion young stellar objects.

1. Introduction

The Eagle Nebula star forming region (also called M16) contains the young (about 2 Myr) Galactic cluster NGC 6611 and the dark columns of dust and cold molecular gas known as the "Pillars of Creation." The optical image of the pillars obtained by Hester et al. (1996) is arguably the most famous image obtained by the *Hubble Space Telescope* (HST). On 2001 July 30–31, we obtained a 78 ks exposure of the Eagle Nebula with the ACIS-I instrument on the *Chandra X-ray Observatory* to study the X-ray emission from the young cluster stars and to search for X-rays from the evaporative gaseous globules (EGGs) at the edges of the pillars first identified by Hester et al. (1996). Figure 1 shows the locations of the optical, X-ray, and infrared fields of view. We summarize here some of the results from this study, but a series of papers beginning with Linsky et al. (2006) will describe the data reduction and results in detail.

Chandra detected 1101 X-ray sources in the ACIS-I $17' \times 17'$ field of view. Fewer than 100 are foreground or background sources and most are intermediate to low mass premain sequence (PMS) stars. Our detection threshold of 6 counts corresponds to $\log L_X \approx 29.8$ at the 1.8 kpc distance of the cluster. Figure 2

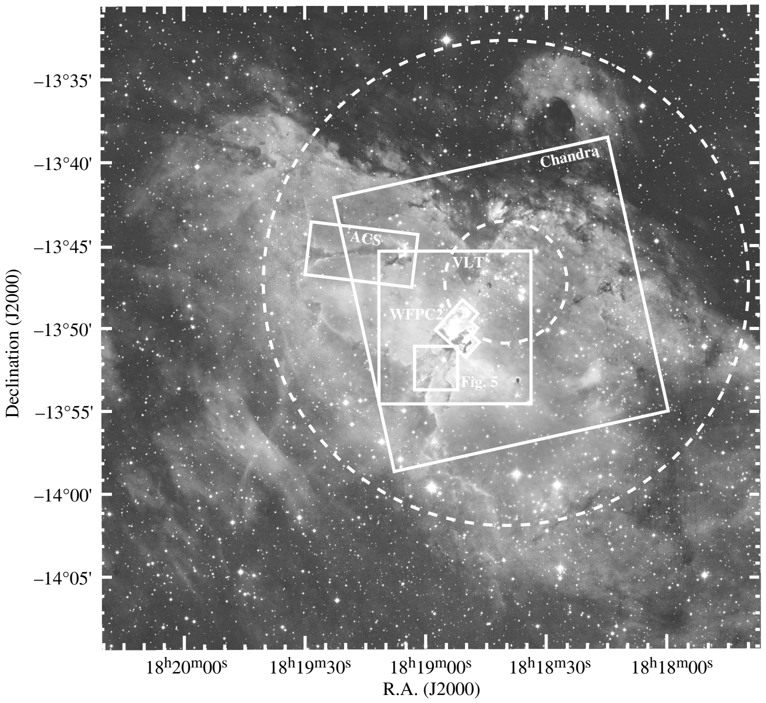

Figure 1. Optical image of the NGC 6611 region showing the emission nebula, the optically bright hot stars, and the molecular clouds surrounding the cluster core. The inner and outer dashed circles are the 3σ core and corona of NGC 6611. The O stars responsible for the photoevaporation of the pillars are located near the center of NGC 6611. Superimposed on the optical image are the boundaries of the *Chandra* ACIS-I field, the European Southern Observatory Very Large Telescope (VLT) ISAAC mosaic of pillars 1–4, the *HST* WFPC2 image of pillars 1–3, and the *HST* ACS mosaic of pillar 5.

shows the optical image with X-ray detections (circles) identified by the size of the 3σ uncertainty circles. Figure 3 shows the same field with infrared sources (McCaughrean & Andersen 2002). Nearly all of the X-ray detections have a corresponding infrared source but few have a corresponding optical source.

The 73 EGGs at the edges of the pillars identified by Hester et al. (1996) in their WFPC2 Hα image are marked in Figures 2 and 3. They argued that the molecular cloud is being evaporated by the UV radiation from a few O stars in NGC 6611, gradually revealing pre-existing embedded condensations that may contain PMS stars. In the near-IR image of this region (Figure 3), McCaughrean & Andersen (2002) found that 11 of the EGGs contain point sources ranging in mass from 1 $M_{\odot}$ to substellar. We find that none of the EGGs are coincident with a *Chandra* X-ray source down to our detection threshold of $\log L_X \approx 29.8$. This is significant because it indicates that the EGGs are less X-ray luminous than the Orion Nebular Cluster (ONC) PMS stars of similar mass. Table 1

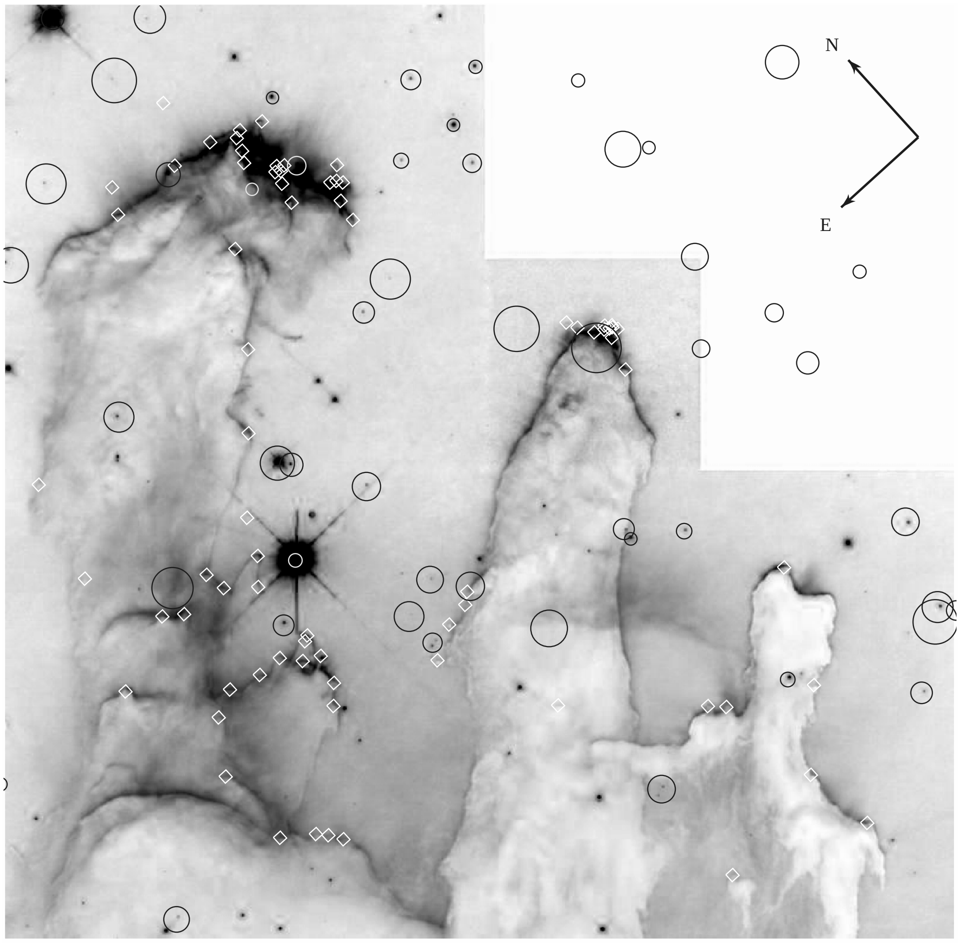

Figure 2. 1995 *HST* WFPC2 image of the $2'.5 \times 2'.5$ region centered on (*from left to right*) pillars 1–3. The 3σ X-ray position uncertainty circles indicate *Chandra* detections, and the diamonds indicate the locations of the 73 EGGs identified by Hester et al. (1996).

compares the X-ray luminosity upper limits of the four highest mass EGGs with the fraction (frac)of ONC stars of similar mass that have larger $L_{\rm X}$. The number of expected detections is the sum of the fractions: 2.28. The likelihood of detecting none of the four EGGs is only 1.5%, a 2.4σ result. Since none of the other EGGs were detected, we conclude that either (1) the EGGs do not form stars, or more likely that (2) the PMS stars in the EGGs are younger than the ONC PMS stars and have not yet become X-ray active.

NGC 6611 is a very rich cluster of YSOs. As shown in Figure 4, we predict that 1929 X-ray sources more luminous than $\log L_{\rm X} = 27.0$ are located within the ACIS-I field and about 4000 X-ray sources are in the cluster. The most remarkable source in the ACIS-I field is M16 ES-1, the very hard source at the head of pillar 1. Thompson et al. (2002) estimate that $L_{\rm bol} \approx 200 L_{\odot}$, indicating either a zero age main sequence B star, a massive PMS star, or a

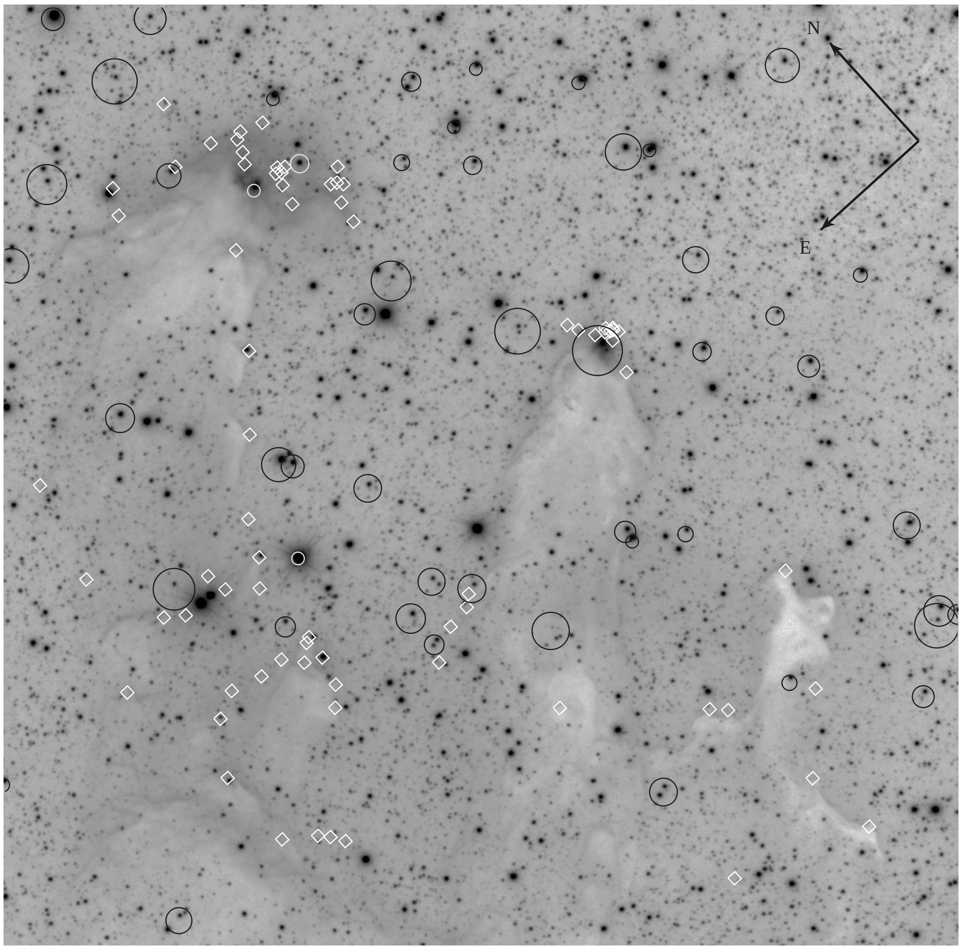

Figure 3. 2001 VLT ISAAC K_s, H, J_s image (McCaughrean & Andersen 2002) of the same field as Figure 2 with 3σ X-ray position uncertainty circles and location of EGGs (*diamonds*) superimposed. M16 ES-1 is the strong X-ray source (*small error circle*) at the head of pillar 1, and M16 ES-2 is the weak X-ray source (*large error circle*) at the head of pillar 2.

small cluster of PMS stars. The high plasma temperature (about 2.2 keV) and $L_{\rm X}/L_{\rm bol} \approx 2.1 \times 10^{-4}$ suggest magnetic confinement, perhaps along the lines of the magnetically confined wind shock model of Gagné et al. (2005).

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Table 1. Comparison of M16 EGGs to ONC YSOs

EGG Number	Mass ($M_\odot$)	A_V (mag)	N_H (10^{22} cm^{-2})	f_X (10^{-16} cgs)	f_X^{corr} (10^{-16} cgs)	$\log L_X$	frac
E25	0.50	9	1.4	7.6	19.9	30.00	0.68
E31	0.35	10	1.6	7.8	29.6	30.15	0.30
E35	0.95	22	3.5	8.1	52.4	30.40	0.41
E42	1.00	4	0.6	5.9	13.4	29.80	0.89
						Sum =	2.28

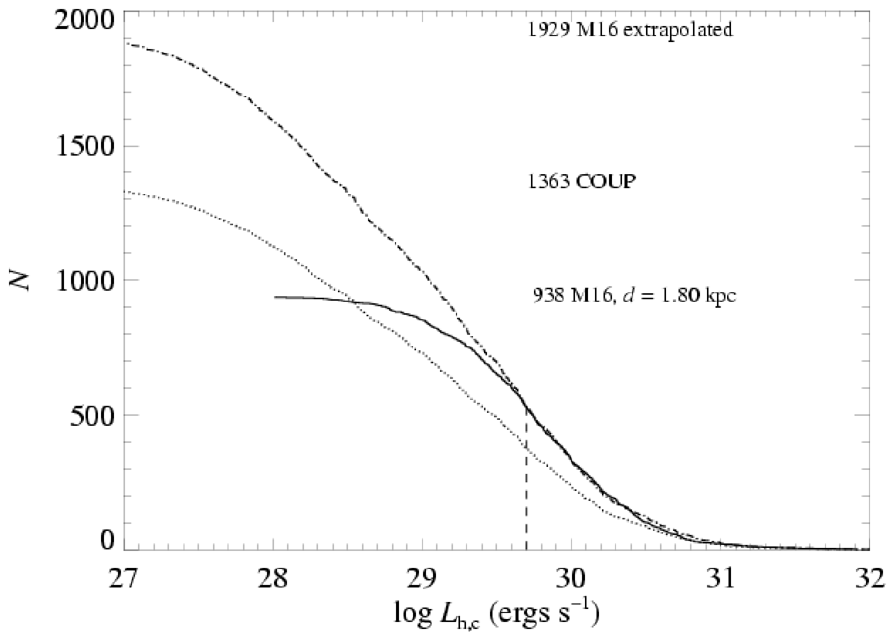

Figure 4. The X-ray luminosity function (XLF) for M16 in the ACIS-I field of view (*solid line*) and an extrapolation of the M16 X-ray luminosity function (XLF) (*dash-dot line*) assuming the same shape as the ONC XLF (*dotted line*). The extrapolated M16 XLF predicts 1929 X-ray sources more luminous than $\log L_X = 27.0$ in the ACIS-I field of view and about 4000 sources in the extended M16 halo. The detected fraction of M16 X-ray sources is 49.4%, including 11/11 O stars and 18/20 B0–B2 stars.

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