

# The Starburst and AGN of NGC 7130

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## ABSTRACT

Observations of the Seyfert 2 and starburst galaxy NGC 7130 with the *Chandra X-ray Observatory* illustrate that both of these phenomena contribute significantly to the galaxy's detectable X-ray emission. The active galactic nucleus (AGN) is strongly obscured, buried beneath column density  $N_H > 10^{24} \text{ cm}^{-2}$ , and it is most evident in a prominent Fe K $\alpha$  emission line with equivalent width greater than 1 keV. The AGN accounts for most (70%) of the X-rays at energy  $E > 4 \text{ keV}$ , with the remainder due to spatially extended star formation. The soft X-ray emission is predominantly thermal, on both small and large scales. We attribute the thermal emission to stellar processes, which include a large-scale galactic wind. In total, the AGN is responsible for only half of the observed X-ray luminosity of  $3 \times 10^{41} \text{ erg s}^{-1}$  of this galaxy. Buried AGN like NGC 7130 are truly common, and similar examples may contribute significantly to the cosmic X-ray background while remaining hidden at most other wavelengths.

## 1. NGC 7130

Approximately half of all Seyfert 2s contain circumnuclear starbursts (Cid Fernandes et al. 1998; González Delgado et al. 1998). These starburst/AGN composite galaxies are also preferentially more obscured than their “pure” counterparts, which lack starbursts (Levenson et al. 2001; Risaliti et al. 1999). NGC 7130 is an example of a composite galaxy. Classified on the basis of optical emission line ratios, it is a normal Seyfert 2 (Phillips et al. 1983). This galaxy also contains a powerful compact (90 pc) circumnuclear starburst (Figure 1), evident in both its vacuum ultraviolet spectrum, which shows absorption features formed in the winds and photospheres of massive stars, and in the optical spectrum, where the high-order Balmer series and He I lines are observed in absorption (González Delgado et al. 1998). We illustrate here that both the starburst and the AGN are energetically important, even in the X-ray regime. For  $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$ , the distance to NGC 7130 is 69 Mpc, and  $1'' \equiv 330 \text{ pc}$ .

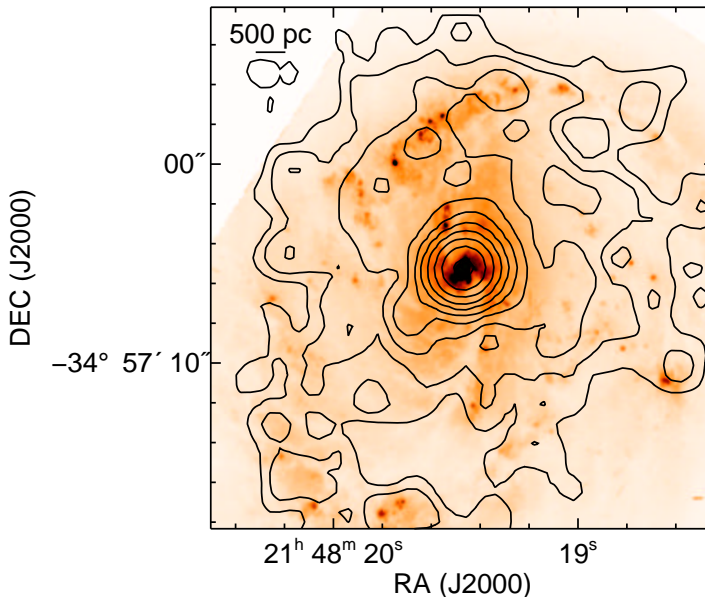


Fig. 1.— Optical (V) image of NGC 7130 obtained with the Wide-Field and Planetary Camera on the *Hubble Space Telescope*, with *Chandra*-ACIS X-ray contours overlaid. The high-resolution optical image shows concentrated yet extended stellar emission, in addition to the unresolved AGN, on the smallest scales that *Chandra* can resolve. The optical image is scaled linearly and the X-ray contours are in logarithmic intervals, from 6 standard deviations above the background level.

## 2. Spectral Models

The X-ray images (Figure 2) show the broad-band spectral differences between the concentrated, harder nucleus and the very extended softer emission. We extracted spectra from these two distinct regions. The nuclear aperture has a radius of  $1''.5$ . On this physical scale (500 pc), the nuclear spectral region encompasses the compact starburst, as well. Thus, the spectral models we consider here begin with typical AGN contributions—a power law and Fe  $K\alpha$  fluorescence line—and soft thermal emission, as observed in starburst galaxies.

Because *Chandra*'s sensitivity rapidly diminishes above 7 keV, in order to measure any significant emission above the Fe  $K\alpha$  line (and therefore measure both the line and continuum accurately), we initially model the unbinned nuclear data in the 4.0–8.0 keV energy range (Levenson et al. 2002). We then use these high-energy results to constrain the broad-band models. In addition to the high-energy power law and emission line of the AGN, the full nuclear spectrum shows multi-temperature thermal emission and an emission line at 2.3

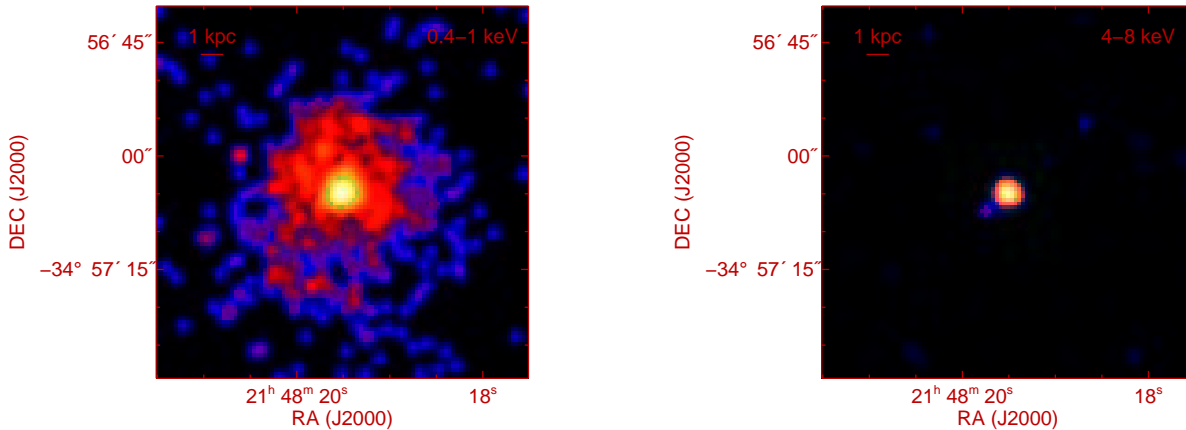


Fig. 2.— Images of NGC 7130 obtained in a 39 ks *Chandra* observation. Both the soft (0.4–1 keV) and hard (4–8 keV) images have been smoothed by a Gaussian of FWHM =  $1.5''$  and are scaled logarithmically. The very extended soft emission is thermal, heated by stellar processes. The harder emission is very concentrated, primarily due to the AGN.

keV, which is likely sulfur fluorescence. The extended emission region excludes the central  $3''$ , and is primarily, though not exclusively, thermal. The extended non-thermal emission is due to unresolved point sources, which are common in starburst galaxies and can collectively produce a very soft spectrum (Zezas et al. 2002). Figure 3 shows the spectra and model fits.

### 3. The Hidden AGN

The large Fe  $K\alpha$  equivalent width ( $EW = 1.2$  keV) confirms that the AGN is completely buried, beneath  $N_H > 10^{24}$  cm $^{-2}$ . Although the AGN still produces most of the observed hard X-ray luminosity (listed in Table 1), the intrinsic AGN is more powerful, with  $L_{AGN,intrinsic} \approx 10^{43}$  erg s $^{-1}$ . In total, however, the stellar emission dominates, emerging at longer wavelengths. The far-infrared spectral shape is typical of starbursts, and the far-infrared luminosity  $L_{FIR} = 5 \times 10^{44}$  erg s $^{-1}$ .

### 4. Conclusions

These *Chandra* data demonstrate that both the AGN and starburst in NGC 7130 are energetically important, even in X-rays. The buried AGN accounts for most of the emergent emission above 4 keV. Unresolved sources of the concentrated and extended starburst make

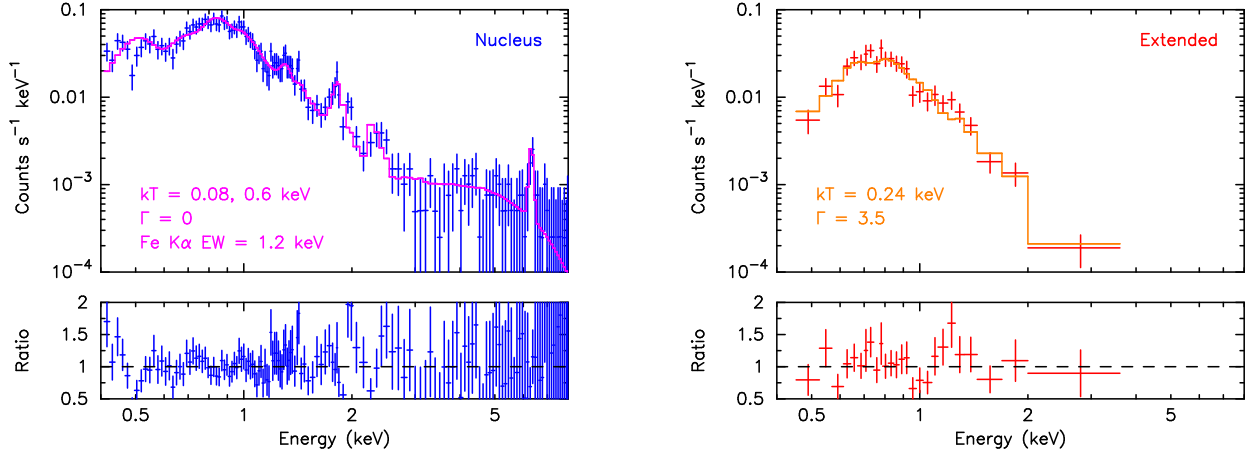


Fig. 3.— Spectra and model fits of the nuclear (left) and extended (right) emission of NGC 7130.

up the remainder of the hard X-ray emission. The majority of of the soft X-ray emission is due to the concentrated circumnuclear starburst. The mechanical energy of supernovae and stellar winds drives an outflowing wind, which likely extends several kpc along the line of sight.

**Table 1.** Observed Luminosities

| Region             | $L_{0.5-2}$<br>( $10^{40} \text{ erg s}^{-1}$ ) | $L_{2-10}$<br>( $10^{40} \text{ erg s}^{-1}$ ) |
|--------------------|---|--|
| NGC 7130 (total)   | 12  | 17   |
| AGN                | 0.2   | 13   |
| Central starburst  | 9.1   | 1.1  |
| Extended starburst | 1.2   | 1.7  |

Observed luminosity of various emission regions, in soft (0.5–2 keV) and hard (2–10 keV) X-ray bands, uncorrected for absorption.

like NGC 7130, serve as the building blocks of these more complex systems and demonstrate the limitations on accurately measuring the physical properties of distant cases.

These physically distinct components would not be identified in a spatially integrated spectrum. Although the luminosity alone could suggest the presence of an AGN, it would not be measured accurately at low resolution. The total X-ray spectral energy distribution is flat and does not reveal the hidden, luminous AGN. Starbursts and AGN together are likely important in ultraluminous infrared galaxies and in producing the cosmic X-ray background. Nearby examples that can be analyzed in detail,

## REFERENCES

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